European Organization for Nuclear Research
Organisation européenne pour la recherche nucléaire

Detector Technologies Group PH-DT

2013

This report gives a summary of the mandate, structure and activities of the PH-DT group during the year 2013.

ANNUAL REPORT

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1. DT Mandate and Organization

The mandate of the PH-DT group covers development, construction, operation and maintenance of particle detectors for the experiments at CERN. The group is engaged in several detector projects for LHC and non-LHC experiments – ranging from detector construction, maintenance & operation to consolidation and upgrades –, operates services open to all CERN users for detector operation, research & development, and is involved in R&D projects on new detector technologies and related infrastructures.
The main PH-DT activities are listed below:

Services	R&D Projects	Joint Projects
Infrastructure for experiments: • Gas systems • Detector cooling systems • Magnet control and support • Instrumentation and controls • B-field mapping Infrastructure for Detector R&D: • Thin film & glass Lab • Silicon facility • Wire-bonding & QART Lab • Micro-Pattern Technologies • Irradiation facilities • Specialized labs (optics, gluing…) • Scintillator production	• Radiation tolerant silicon detectors • Gaseous detectors • Scintillating fibre detectors • Novel on-detector cooling • Micro-systems engineering	• M&O and Upgrades of the LHC experiments • AEgIS, CAST, CLOUD, NA62 • R&D for Linear Collider Detectors

Expertise in many different domains crucial for advanced detector-systems is available, among these are detector research development and system support, fine mechanics, engineering, micro-fabrication, thin film coatings, optics, silicon facility with wire-bonding lab, irradiation facilities, magnet support, B-field mapping, instrumentation and controls, gas and cooling systems for particle detectors. DT runs several mechanical workshops with conventional and CNC machines and equipment for specialised machining for scintillators, glass and ceramics.

Since the beginning of 2014, the CERN PCB workshop located in Bldg. 102 and part of the Technology (TE) Department till that date, has been integrated in PH-DT. The facility develops and produces mainly ceramic hybrids, low-mass circuits, fine-pitch readout boards, PCBs (FR4, kapton, flex-rigid) and detector components. The workshop is playing in particular a key role in the development of components for micro-pattern gas detectors (MPGD) and MPGD assembly techniques, an activity that has been growing very significantly in the last few years.

DT comprises about 89 active staff, 20 fellows and students fully or partially funded by DT, and hosts two Field Support Units (FSU PH-02 and PH-40) of 14 and 12 members respectively. DT staff is grouped in 6 sections (Detector Infrastructure, Detector Development, Technology and Physics, Engineering Office, and Engineering and Mechanics 1 & 2). Work is however carried out in project or service teams formed for a limited time, often with people from several sections and led by a DT project leader. Such teams include fellows, students and scientists associated to DT. This strategy offers flexibility, efficiency and a fast reaction time for new requests and activity/load variations.

Beyond the specific detector activities above, about 5% of the group's resources are engaged in general service tasks that include workshop supervision, safety, participation to CERN-wide committees and leadership of R&D collaborations and EU co-funded projects, and the management of the group.

Further information about the DT group is available at http://ph-dep-dt.web.cern.ch/ph-dep-dt/

The following diagram lists the DT staff members, fellows and doctoral students as of March 2014.

PH-DT Detector Technology

Group leader: Mar Capeans
Deputy: Andrea Catinaccio

Secretariat: Veronique Wedlake

Detector Infrastructures (DT-DI)

Mar CAPEANS

Measurements and Controls
BERGSMA Felix
BLANC Pascal
BOURGEOIS Nicolas
DERONT Laurent
MAIRE Gilles
PONS Xavier
RAVAT Sylvain

Gas
GUIDA Roberto
D'AURIA Andrea
DE MENEZES Louis-Philippe
CARRIE Patrick
MERLET Frederic
WASEM Albin
PAVIS Steven

Cooling
PETAGNA Paolo
GODLEWSKI Jan
TROPEA Paola
DAGUIN Jerome
ZWALINSKI Lukasz

BERRUTI Gaia (DOCT)
MARINHO Luis (ADM STD)
FEIGL Simon (MC FELL)
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REGANO Ernesto (TTE)

Detector Development (DT-DD)

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VAN STENIS Miranda
DAVID Claude

Silicon Detectors
HONMA Alan
MCGILL Ian
MANOLESCU Florentina

Gas Detectors
ROPELEWSKI Leszek

Irradiation Facilities
RAVOTTI Federico
GLASER Maurice
FORTIN Richard G
JAEKEL Martin

Micro-Pattern Technologies
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FERRY Serge
GRIS Alexandra
PIZZIRUSSO Olivier
RANCHIN David
RODRIGUES Alexis
TEIXEIRA Antonio
VERON Julie

FRANCHINO Silvia (FELL)
GALLRAPP Christian (FELL)
GKOTSE Blerina (TECH)
NEUGEBAUER Hannes (DOCT)
OLIVERI Eraldo (FELL)
RESNATI Filippo (FELL)
THUINER Patrik (DOCT)

Technology and Physics (DT-TP)

Burkhard SCHMIDT

DAVENPORT Martyn
GYS Thierry
HAHN Ferdinand
HAIDER Stefan
JORAM Christian
KLEMPT Wolfgang
MARTINENGO Paolo

CASTILLO GARCIA Lucia (DOCT)
KRUGER Andreas (TECH)
LOHFINK Elisa K (TECH)
UYTTENHOVE Simon A (TECH)
VAFEIADIS Theodoros (FELL)

Engineering Office (DT-EO)

Andrea CATINACCIO

ALVAREZ Diego
BATISTA Joao Carlos
BAULT Christophe Daniel
DEGRANGE Jordan
DUARTE Fernando
GARGIULO Corrado
JAMET Olivier
LENOIR Philippe
LOSASSO Marcello
MAPELLI Alessandro
MIGNE Julien
WERTELAERS Piet

NUIRY Francois-Xavier (FEL)
MAODDI Pietro (DOCT)
ROMAGNOLI Giulia (DOCT)

Engineering & Mechanics 1 (DT-EM1)

Antti ONNELA/
deputy Raphael DUMPS

ANSTETT Didier Henri
BOUVIER Philippe Jacques
CANTIN Bernard
IJZERMANS Pieter
KOTTELAT Luc-Joseph
KRISTIC Robert
LESENECHAL Yannick
LOOS Robert
PIEDIGROSSI Didier
VAN BEELEN Jacob Bastiaan

CICHY Kamil (TECH)
DZIURDZIA Piotr (TECH)
FERNANDEZ Ruben (TTE)
LIMA Pedro (TTE)
RZONCA Marcin (TECH)

Engineering & Mechanics 2 (DT-EM2)

Hans DANIELSSON/
deputy Pierre-Ange GIUDICI

BENDOTTI Jerome
BODE Alain
BRENDLEN Romain
BRUNEL Bernard
DIXON Neil David
GARNIER Francois
G. M. DE OLIVEIRA Antonio
NOEL Jerome
PEREZ GOMEZ Francisco
VERGAIN Maurice

2. PH-DT Highlights in 2013

M.Capeans (PH-DT-DI)

The current long shutdown (LS1) offers a first opportunity for prolonged access in all LHC experiments, and the DT group is engaged in an extensive program supporting the consolidation and maintenance work for LHC detectors and their experimental infrastructures. Contributions to non-LHC experiments, where DT staff plays important coordination roles, have also been an important part of the work. The table below summarizes the projects with DT involvement, details can be found in the corresponding sections of this report.

LHC Experiments

Experiment	Operational Support	LS1 Deliverables	Developments for LS2, LS3
ALICE	• General mechanical support: structures, movements, assembly areas, system support (TPC, HMPID, …) • Engineering (Project engineer & design support)		• New ITS
ATLAS	• ID cooling coordination and expert support • Mechanical support • ATLAS-ALFA	• IBL and Pixel nSQP • CO_2 and thermo-siphon cooling plants • ID opening, TRT leaks	• NSW m-megas for muon system • TK: Engineering
CMS	• Cooling coordination and expert support • Ecal cooling controls • Preshower detector support	• Pixel Luminosity telescope • CO_2 plants for TIF and Pixel • Tracker drier & colder	• TK: Module design, integration, support structures
LHCb	• Engineering, design support • VELO support, test beams • RICH operation, HPD repairs	• Shielding behind muon system • Detector movements • Mechanical support	• Sci-Fi studies • RICH, TORCH studies
TOTEM	• Mechanics of RP (Si-det), controls RP movement & secondary vacuum • Support for T2 stations (GEM)	• Dismantling RP at 147m and 220m RP extension • Control systems	

Non-LHC Experiments

Experiment	Activities
NA62	• Technical Coordination & technical support (mechanics, infrastructure, beam pipe…) • Straw tracker construction • RICH vessel design • GTK module micro-cooling and integration
AEGIS	• Technical Coordination & Mechanical support • Control/safety systems 1- 5 T magnets
CLOUD	• Technical Coordination & Mechanical support
CAST	• Technical Coordination & Electro-mechanical support
LCD	• Tungsten HCAL, Tungsten/Scintillator ECAL • Test beam support • Pixel detector

PH-DT Services

Service	LS1 Deliverables
Gas systems project	Consolidation of all gas systems in the LHC experiments New systems (e.g. ALICE MTR close-loop, ATLAS IBL, CMS GEM, LHCb RICH2 CF4-recup)
Magnet Control Project	Consolidation of the Control and Safety systems for LHC experimental magnets Development new MSS2 (Safety systems for M1, Compass)
Cooling Project (CO2 plants)	CO2 Plants for CMS Pix and ATLAS IBL
Magnet support B-field measurements	B-field measurement of MICE, NA62, LHCb magnets
Thin film/Glass Lab	NA62 RICH and CEDAR
Bond Lab, DSF and QART Lab	ATLAS IBL, CMS Pix and several R&D projects
Irradiation Facilities	Operation of the GIF (B.190) Construction GIF++ in the North Area Upgrade of PS Irradiation facilities in the East Hall

Infrastructures & Outreach

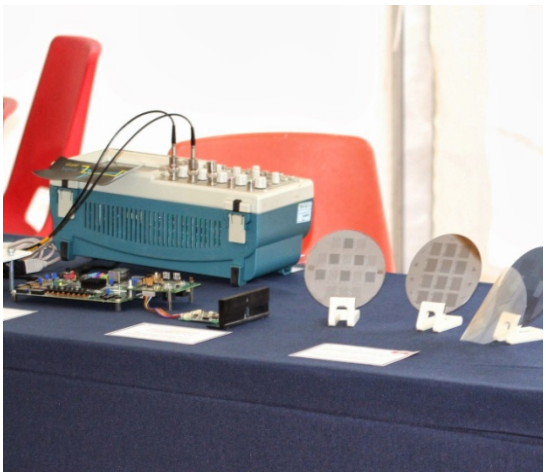
In terms of main equipment investments, PH-DT has acquired a Devoltec wire bonding machine for the Bond Lab, a 3D printing machine, specialized engineering software, diverse safety equipment for labs and workshops, high-tech instruments (e.g. high resolution infrared camera), a new pipe orbital-welding station for the gas workshop, to name but a few.

Several spaces have been upgraded or adapted to new activities, such as the installation of a soldering hut for the electro-mechanical workshop in B.21, enlarged the lab for LHCb RICH activities in B.16, extended the gas detectors R&D lab in B.154, set up a new controls lab in B.21, mounted a new lab in B.16 dedicated to LCD Vertex development. A large effort of machine conformity in PH-DT mechanical workshops was also started.

PH-DT has organized a visit point during the CERN Open days in September 2013. Visitors got a preview of a large straw chamber being constructed for the NA62 tracking system. They had the chance to talk to experts about the different stages of particle detector construction: engineering, design, testing, manufacture and operation. The visit point proposed also an exhibition of gaseous detectors, from the early stages of proportional detectors, through the Nobel Prize winning Multi-wire Proportional Chamber, scintillating fibres, medical imaging, to the most recent prototypes for the LHC's experiments and spin-off applications.

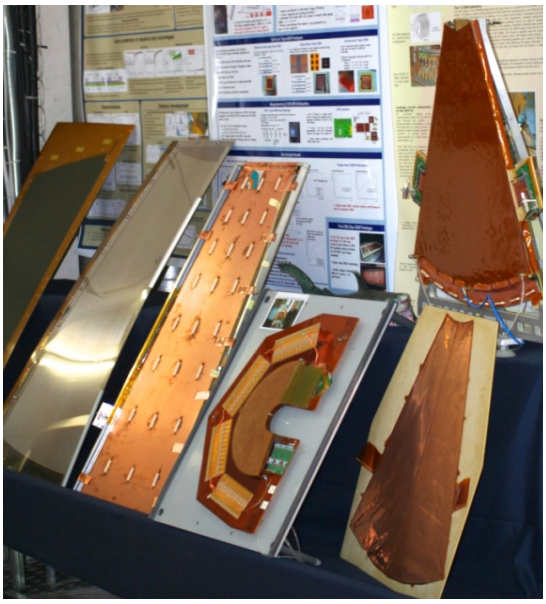
Open Days September 2013

View of the DT visit point.

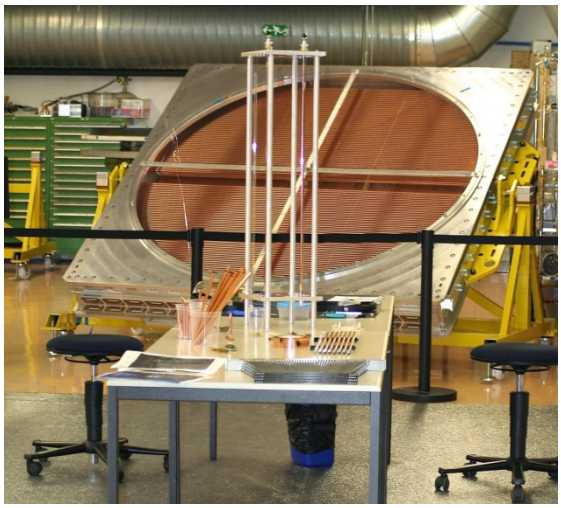


Stand of the PH-DT Engineering office, showing micro-fabricated developments.

Group of visitors in the Scintillating Fibres stand.



Micro-pattern gas detectors.



NA62 Straw chamber with examples of detector components.

DT Staff explains the NA62 Straw tracker construction details.

3. Collaborations with LHC Experiments

3.1. ALICE

C.Gargiulo (PH-DT-EM1)

3.1.1. Long Shutdown 1 activities

In 2013 the DT group has provided technical support to the ALICE experiment in integration, installation and maintenance of the detector and infrastructure, mostly for the activities foreseen for LS1.

At the beginning of the year, after the proton-lead run, the shielding has been removed and the doors of the L3 magnet opened to give full access to the different sub-detectors and the consolidation and maintenance work started. The DT team coordinated the removal of the old PHOS cradle at the bottom of the magnet and its replacement with the new one, which will host both the new DCAL calorimeter and PHOS (40ton). The new cradle required the installation inside the L3 Magnet of two new large beams, 10m in length and 4 ton in weight. The team also took the responsibility in the design of the installation jigs, their validation through structural analysis, test and the development of a detailed installation procedure as well the coordination and supervision of the installation in L3 magnet.

The PH-DT team, after an extensive qualification test campaign on surface, has coordinated and actively participated in the installation of the first 5 modules of the new DCAL detector inside L3. In particular, the insertion of two of these modules required the development by of a dedicated hydraulic system, able to displace and lift into the final position the heavy detector inside L3. The installation of the reworked PHOS modules and the remaining DCAL will be completed in 2014.

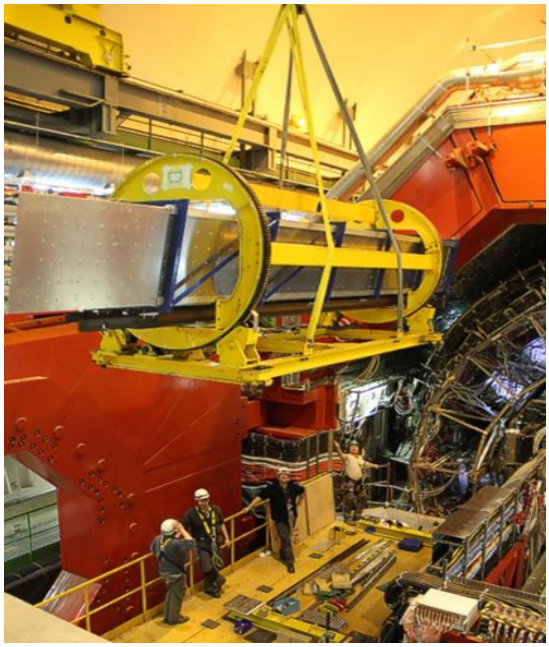
Installation of the main structural elements inside L3 to provide support to the new DCAL detector.

DT supported a large rework activity on several TRD modules that have been extracted from L3, reworked and installed back. In parallel the preparation for the installation and the insertion in the space frame of the last 5 modules of the TRD started and will continue till fall 2014.

As planned the TOF nominal support configuration inside the space frame was restored thanks to the development and installation of new mechanics developed by DT permitting the full transfer of the detector weight on the space frame.

Consolidation work, based on a completely new routing of all the low voltage cables inside L3 was also completed by the group.

Finally the drilling of the clogged filters of the present SPD cooling system was completed. The detector cooling recovered > 99% functionality, a very important result in view of the start of RUN2.



Installation of one TRD module.

3.1.2. ALICE Detector Upgrade

The large effort preparing the upgrade of the Inner Tracking System (ITS) for the 2018 long shutdown also continued in 2013. The main mission of the PH-DT group is to design and construct the lightest possible mechanical support that will maintain the silicon sensors in a very accurate position while removing at the same time the heat dissipated by the front-end electronics. In view of the submission of the TDR, the results obtained in the past years were consolidated and baseline solutions for the support mechanics, integration, installation and cooling were fully worked-out. DT has proposed a work plan for the production of the detector carbon composite fibre structure and has managed the construction of a clean room in CERN building 167 that will be devoted to this production.

DT also provided support, both managerial and technical, to the test beam activities of the project that, after the delivery of the first dedicated pixel chip prototypes, entered in full swing.

The TDR of the ITS upgrade has been issued in September and has been endorsed by the LHCC and approved by the SPC committees.

As a new detector project, the Muon Forward Tracking (MFT), was endorsed by the ALICE Collaboration and its LOI well received by the LHCC, DT started looking in all aspects of the integration and installation of this new detector in the very crowded and difficult to access region around to the muon absorber. The possible interference with the installation and access to the new ITS was also considered and studied in details. This activity will continue in 2014 as the MFT project will consolidated its design.

3.2. ATLAS

3.2.1. Cooling Coordination

J.Godlewski (PH-DT-DI)

In 2013 PH-DT group has been involved in several cooling projects in ATLAS.

The cooling system of the Insertable B-Layer (IBL) is a CO_2-based system that will be installed during LS1. The DT group is involved in the coordination of the R&D for this system, with other partners such as NIKHEF (Amsterdam). In 2013, the focus of the PH-DT team has been:
Installation:

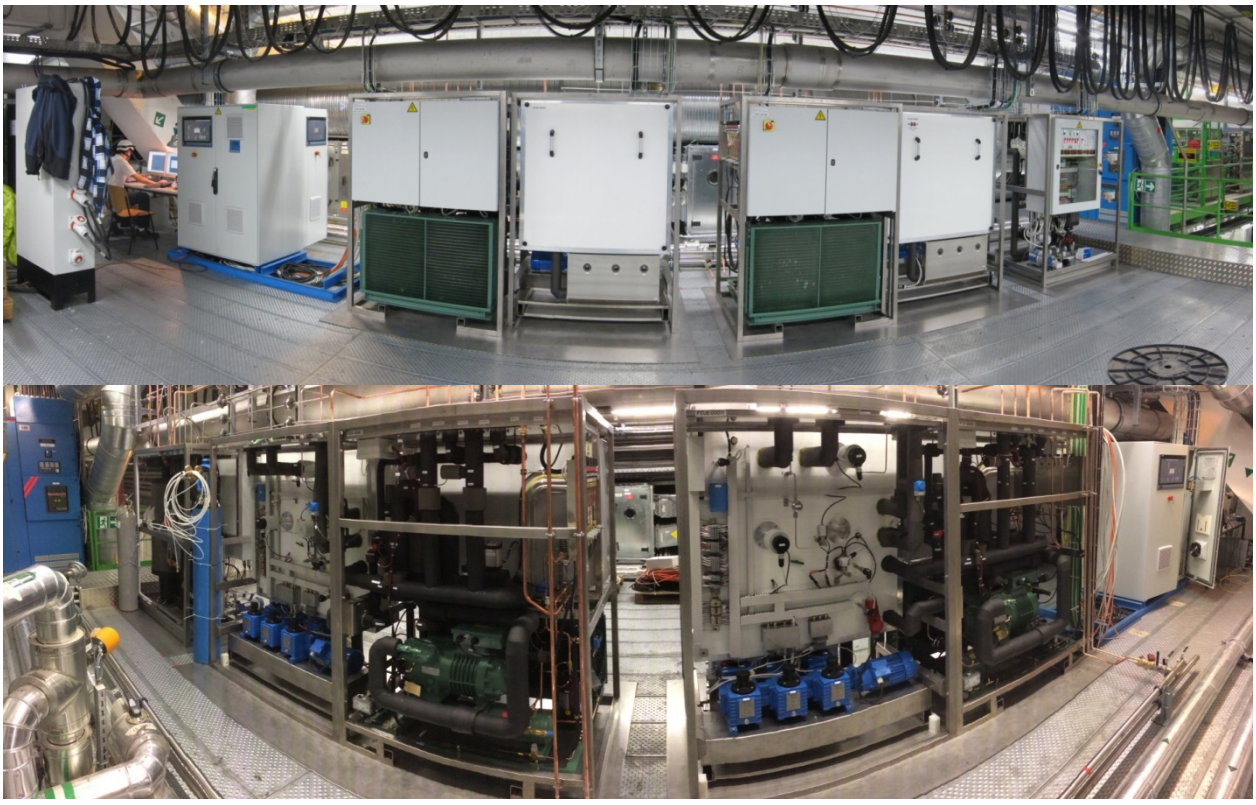
- Cooling units in USA15
- Transfer line from USA15 level 3 to Muon Barrel sector 5 z=0 (92 meters long)
- Pressure and leak-tight tests
- Vacuum system with all instrumentation installed in UX15
- Control cabinets for the cooling systems A&B installed in the final positions
- Control and power cables between USA15 and UX15 pulled and connected for cooling plant A&B

Commissioning:

- I/O check-out for cooling station A completed
- PLC and SCADA software developed and deployed

Flexible transfer lines R&D:

- Full scale prototype manufacturing
- Insulation quality tests (passed with very good results)
- CO_2 tests on CORA test stand (fully confirmed the expectations)



IBL CO_2 cooling station in USA15.

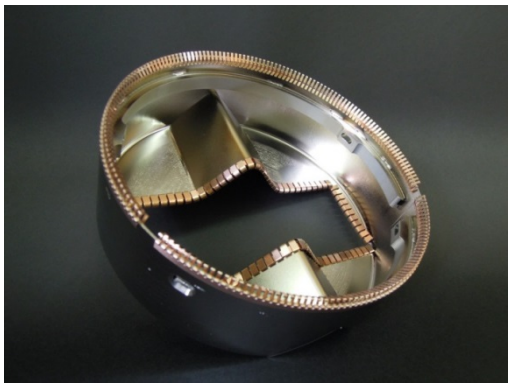
Other cooling activities related to LS1 have been:

- Second (redundant) pump for cooling systems in ATLAS cavern – six cooling systems have been equipped with the second pump circulating cooling liquid through the detector
- Additional pressure sensors in cooling lines of calorimeters end-caps (TileCal and LAr) – pressure sensors for calorimeters individual cooling lines (12 in total) are installed on the calorimeter and are not accessible in the closed position. Therefore on each position the redundant pressure sensor has been installed and will be cabled up to control racks in USA15
- New flushing lines for Inner Detector – IBL detector will required very dry atmosphere and will be flushed with dry nitrogen. New pipes have been installed between gas room in USA15 and IBL CO2 system distribution area in sector 5 of Muon Barrel
- Additional cooling lines for New Small Wheel (NSW) – NSW will be installed during phase-II ATLAS upgrade. It is already known that NSW will require more cooling then current Small Wheel. Profiting from LS1 time, new pipes with bigger diameter have been installed between Muon cooling stations A and C and flexible chains of Small Wheels.
- Additional interlock system based on Siemens PLC for TRACI IBL test stand in SR1 designed constructed and deployed.
- Additional hardware/electrical interlock system for LAr test stand in SR1 designed, constructed and deployed
- Extended operator trainings sessions for ATLAS SR1 CO2 cooling unit
- ELMB based CORA CO2 test stand control extension, fully integrated in PVSS and Siemens PLC based control system, for different detector test applications designed, constructed and deployed

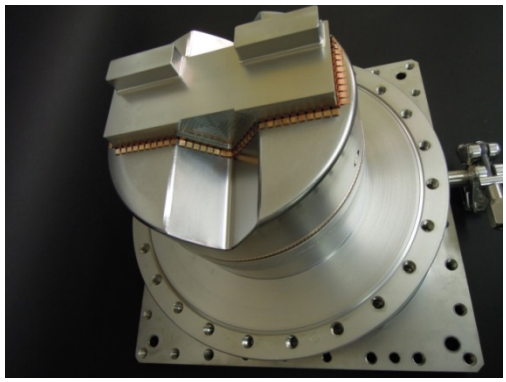
3.2.2. ATLAS ALFA

T.Schneider (PH-DT-DD)

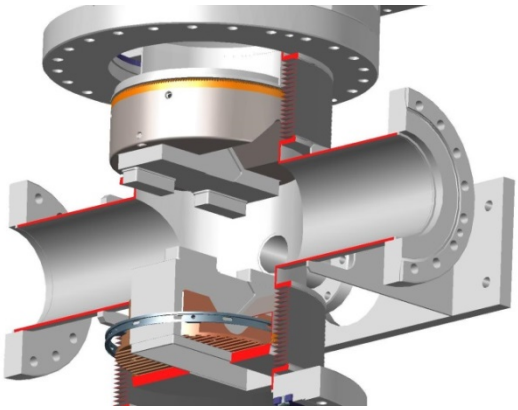
PH-DT is in charge of the maintenance of the mechanics and infrastructure (cooling /vacuum) of the ATLAS ALFA detector. Beam RF losses in the cavity of the Roman Pots (RP) create a critical heat deposit for the plastic fibre detectors. Based on the investigations of 2012 (detector heat cycling, heat monitoring system of the 4 stations and RF simulations from BE-ABP) it became clear that to cope with the beam conditions after LS1 some serious measures had to be taken to avoid deformation and degradation of the ATLAS ALFA fibre detectors. In 2013 the 4 ALFA stations were moved from the tunnel to the DT assembly hall 187. Detectors have been taken out and the RP and vacuum crosses been disassembled. To face the Beam RF induced heating problem several approaches have been worked out in the ALFA collaboration. Goal was on one hand to reduce the Beam RF losses and on the other hand to better remove the remaining heat. DT was strongly involved in the design and construction of a so called “RP-Filler“. In this approach a titanium cover, with appropriate shape, fills up the cavity and is fixed directly to the RP. Special RF Cu-Be fingers guarantee a good electrical contact and fill up the space between the RP-Filler and the RP ensuring no RF wave propagation to the inside of the filler. In addition the configuration of the ferrite was also modified.



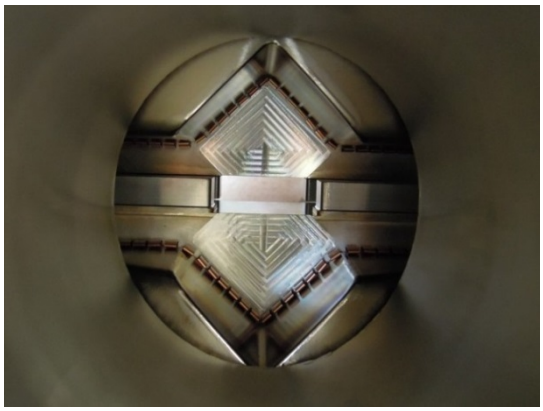
Titanium cover with RF fingers of RP-Filler.



RP-filler mounted on ALFA RP.



3D cut of the RP-Filler in the ALFA stations.



View along beam axis with RP system closed.

Instead of 2 ferrites close to the sensitive detectors a full ring of segmented ferrites was positioned far from the detectors, in good position to catch the RF losses and close to the massive vacuum flange to provide the best possible heat transfer to the outside. A full set of prototype ferrites has been machined in the glass workshop of PH-DT. RF simulations and RF test measurements on a RP-filler prototype validated this approach. The ALFA collaboration endorsed this solution and PH-DT followed up the production of 12 RP-Fillers to equip the complete ALFA detector. In close collaboration with the experts from the CERN main workshop all components were produced and delivered end of 2013.

PH-DT was also involved in evaluating the performance of the system. The group made major contributions to the alignment and coordination of data analysis. In addition, the motor control system software for moving ALFA RPs close to the beam was upgraded to make sequential movements in small steps significantly faster. A new test stand has been set up for validating the complete movement system.

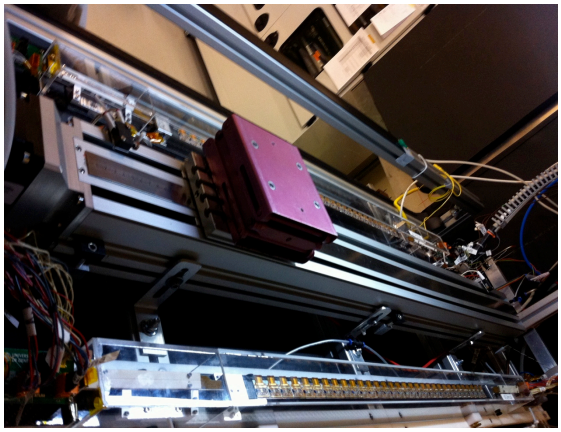
3.2.3. Long Shutdown 1 Activities

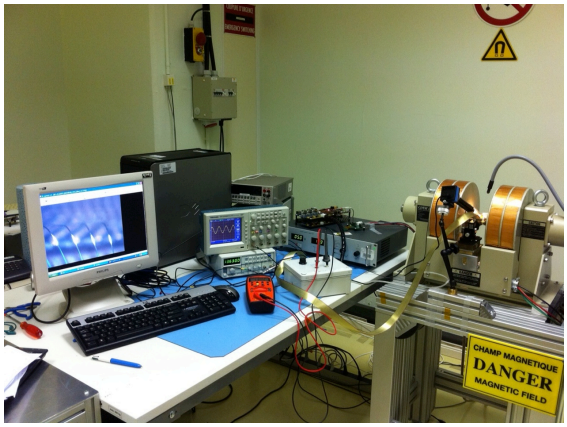
A.Catinaccio (PH-DT-EO), B.Mandelli (PH-DT-DI)

The DT Engineering Office (EO) has participated in the tracker opening with the IDEP disassembly, and with the TRT leak repair interventions.

On the ATLAS Insertable B-Layer (IBL) project, the group has contributed to the detector assembly in SR1, bonding all flexes on staves, developing a tool for positioning the rings on IPT, participating to the services installation and developing several parts and tools. The loading of staves and services type 1 is on-going, and the IBL package will be inserted on May 2014. In parallel, DT-EO continued to validate different options of thermal insulation by means of a thermal mockup built at the beginning of the project.

PH-DT has also been actively involved in the Quality Assurance (QA) and Quality Control (QC) of the 20 production staves for the IBL. Support for the preparation of infrastructure for the SR1 set-up stands was also provided. The IBL staves went through a QA process consisting of different steps for the final characterization of the production staves in terms of sensor quality and front-end functionality. In particular, leakage current, pixel defects and overall performance of all modules were considered for the final selection of the best staves. On average, each stave has less than 0.2% of pixel defects and the general detector quality is really good. Fourteen out of 20 staves have been selected and integrated around the new ATLAS beam-pipe for the completion of the IBL Detector. In parallel to the QA of the IBL staves, PH-DT contributed to the investigation of IBL wire bonds corrosion. The behavior of IBL-like wire bonds in presence of a 2 T magnetic field was studied to understand at which conditions wire bonds could break under oscillation. Different solutions of wire bonds protection were tested: encapsulation of the wire feet and coating of the wire bonds. Limits have been provided for the IBL detector safe operation.





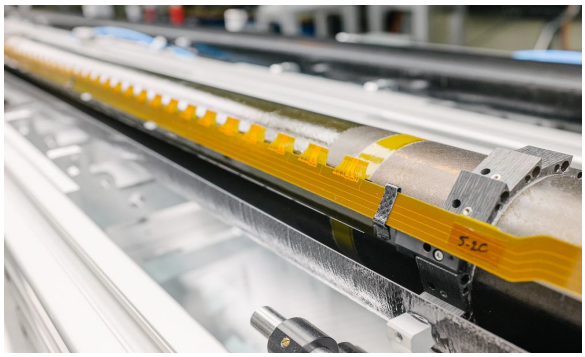
Left, picture of the IBL QA setup; Right, set-up for the wire bonds oscillation study in a B-field at PH-DT DSF lab. On the right the electromagnet with a test-board installed are shown, a CCD camera is positioned next to the electromagnet and is connected to the computer for the wire bonds monitoring. A pulse generator sends different type of pulse signals to the wires.

3.2.4. ATLAS Detector Upgrade Projects

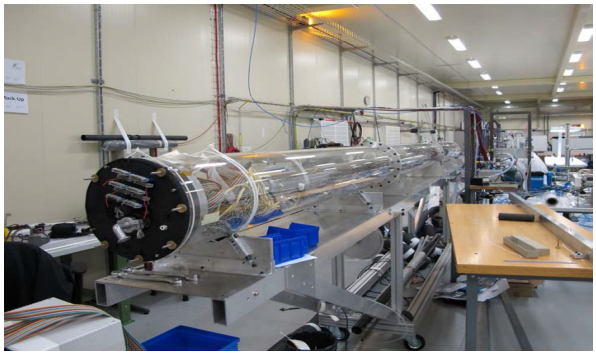
A.Catinaccio (PH-DT-EO), H.Danielsson (PH-DT-EM2)

For the ATLAS Micro-Megas phase-I upgrade, different solutions for manufacturing very flat composite panels were designed and tested on small-scale prototypes. R&D work on soft data connectors was also done and tested on dummy PCB. These connectors should be used all around Micro-megas panels.

On the ATLAS Tracker upgrade phase-II, the section maintains key engineering responsibilities with the coordination of the overall tracker mechanics and of the WG6 contributing, specifically on the engineering for the overall support structures, integrated models, envelope definition and control.



Stave loaded on IBL package.



IBL thermal mockup.

3.3. CMS

3.3.1. Cooling Coordination

P.Tropea (PH-DT-DI)

The LS1 activities on cooling at CMS have started at the very beginning of the year with an intense program on both water and fluorocarbon circuits. On the first, the major achievements have been the replacement of almost 200 faulty quick connectors and the repair of about 300 bad threaded connector couplings. On the yoke circuit, stress corrosion had been observed on a number of brass quick connectors during the previous year and all of them have been replaced with stainless steel ones. On the Muon circuit, all the connectors for the almost 300 flow restrictors used to balance the flow have been replaced by correct threaded ones and leak tested before assembly. On top of these activities, the full maintenance program has been successfully executed and the whole circuits restarted with no issues in June 2013. One technician from PH-DT has joint the CMS cooling team for these activities.

On fluorocarbon circuits, a huge refurbishment program has been performed by the team of EN/CV, with the collaboration of a technician from PH-DT. The heat exchangers of the Silicon Strip Tracker cooling plant have been replaced with new ones, as well as the evaporators of the main chiller: the integration of these new components has been prepared on a 3D model by two students supervised by PH-DT staff. Moreover, one engineer and one student of PH-DT have designed, purchased and followed up the installation of the new insulated cabinets for all the fluorocarbon cooling plants.

Preparation works for the installation of the new CO_2 cooling system for the phase-I Pixel upgrade have started in 2013, with the design and installation of the tri-axial transfer lines connecting the future detector to the manifold. This activity has been supervised by the cooling coordinator and has seen the contribution of a PH-DT cooling engineer for the leak tightness qualification of all the transfer lines.

3.3.2. CMS Tracker activities in LS1

A.Onnela (PH-DT-EM1)

The main target of the Tracker LS1 activities is to enable lowering the operation temperature of the silicon sensors to -10°C, thus reducing the radiation damage and stretching the detector's life-time up to LS3. The DT group is involved in all of the work-areas needed to reach the above target: condensation prevention in the Tracker Bulkheads and service channels, increase of dry gas injection capacity, improvements to the cooling stations and humidity measurement instrumentation. In addition to DT engineers carrying responsibilities in these activities, also the DT cooling and gas teams provide very significant contributions.

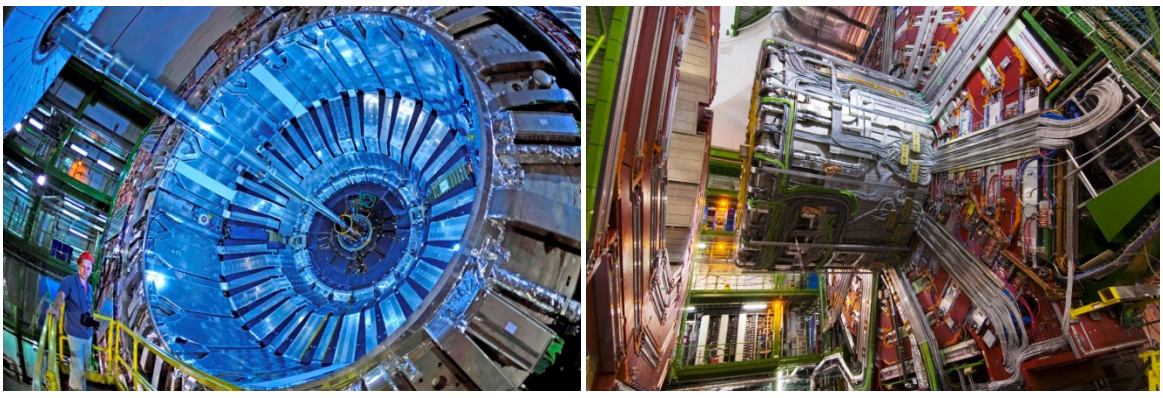
3.3.3. CMS Detector Upgrade Projects

R.Loos, A.Onnela (PH-DT-EM1), A.Honma (PH-DT-DD)

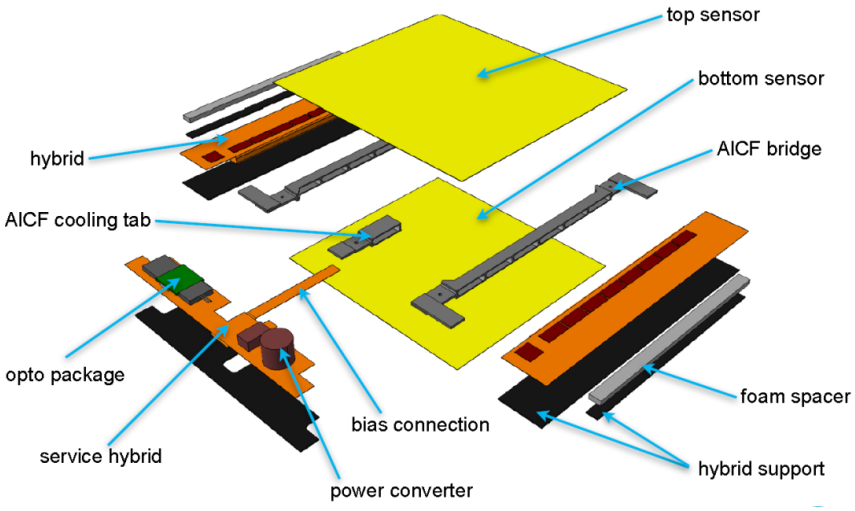
CMS Tracker Upgrades

DT is closely involved in the design and development of the CMS Tracking detectors upgrades. For the phase-I Pixel Upgrade, DT is in charge of the construction, commissioning and operation of the CO_2 cooling systems (see 6.2.2), for which a full scale prototype has been built in 2013 and the final systems will be delivered to CMS in 2014.

For the phase-II Tracker Upgrade the focus of the work in 2013 has been the design of the novel type of detector modules, the 2S (2 strip sensors) and the PS (pixel and strip sensors), as well as the conceptual design of the support structures. In these modules one read-out electronics unit is connected to back-to-back mounted sensors, thus enabling to filter off low momentum particle tracks. These highly performing modules require the development of sophisticated interconnection hybrids, as well as solving aspects related to the thermo-mechanical design and assembly procedures. A DT physicist and a DT engineer are leading the module development and mechanical design of the phase-II Tracker Upgrade.



Improvements done during LS1 enable reaching below -30C dew point in the Tracker service channels, allowing coolant temperatures down to the required level of -20 °C.



The novel 2S type modules consist of two superposed silicon strip sensors and include the electrical circuits for the read-out, powering and optical data links. Spacers made in Aluminum/Carbon-fiber composite provide for support and heat removal towards the cooling circuits.

3.4. LHCb

B.Schmidt, T.Gys, C.Joram (PH-DT-TP)

3.4.1. Long Shutdown 1 activities

The DT group has carried out maintenance activities for various LHCb sub-systems, in particular on the spectrometer magnet and the RICH, Calorimeter and Muon detectors. For the dipole magnet the support structures and clamps which keep the two 25 tons coils in their position had to be opened with large tooling equipment to exchange the protection between support and coil. Some of these clamps are difficult to access. The whole intervention relied heavily on the expertise of the DT-EO and EM2 sections.
LS1 work involved also many detector movements, in particular for the Calorimeter and Muon systems, and an overhaul of the power supplies and the rack turbines. The removal and re-installation and commissioning of the equipment was carried out by DT members.

Repair intervention in LHCb.

RICH detectors

The maintenance activities carried out by members of the DT group for the RICH detectors focused on two aspects:

- HV system: The last 10 unstable HV supply units have been removed and replaced with 10 repaired units. This completed the in-situ refurbishment. These unstable units were sent to the supplier for refurbishment. In addition, a few interventions have been required due to specific issues.
- Pixel Hybrid Photon Detectors (HPDs). HPD manufacturing process changes, in particular the implementation of getter strips, have been successful and resulted in much improved tube lifetime after reprocessing. The first tubes re-processed are now stable since 18 months. A total of 35 HPDs have been reprocessed. They are available for re-installation in the RICH detectors. During LS1, HPDs are kept under high voltage and laser illumination. For the vast majority of the tubes, this results in a limited vacuum degradation.

Muon system

In order to mitigate back-splash of shower particles from a small compensator magnet downstream of the Muon system into the last Muon station (M5), about 5 tons of additional shielding has been installed in the Winter Shutdown 2011/2012. Detailed simulation studies carried out in view of the LHCb upgrade showed that operating the detector at luminosities of 2 x 10^{33} /cm^2/s (about 5x times higher than during LHC Run I) requires further improvements of the shielding. Therefore, during LS1 additional 25 tons of iron shielding has been installed (see photo). The simulations and design studies for the shielding, including the drawings and calculations for the implementation of a support structure has been carried out by member of the DT group.

In view of the LHCb upgrade simulations have also been carried out for additional shielding behind the LHCb HCAL. This allows for a better absorption of shower particles and therefore to reduce the particle flux in the innermost part of Muon station M2 by about 30%. Studies on the implementation are ongoing

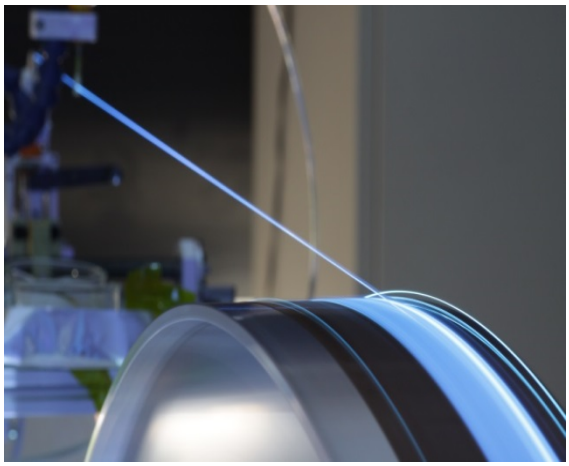
3.4.2. LHCb Detector Upgrade Projects

VELO upgrade

Important progress has been made in 2013 on the design of the upgraded VELO detector with significant contributions of the DT group. The work culminated in the submission and approval of the VELO upgrade TDR. A member of the group designed the new VELO pixel module with micro-channel cooling, which has been chosen as technology for the VELO upgrade. The L-shape design of the VELO pixel module has a symmetric cooling connector capable of withstanding up to 700bar of pressure, well above the requirement of 70bar. A proposal has also been made for an insulating tertiary vacuum safety box for the upgrade cooling installation, to account for the new cooling technology and integration into LHCb.

LHCb SciFi

LHCb prepares for a major upgrade of the detector to be operational after LS2 (2020). A key element is the replacement of the Inner (silicon) and Outer Tracker (gas straws) by a large scintillating fibre tracker, consisting of 12 planes of 30m2 surface each. 10'000 km of 0.25 mm diameter fibres will be readout by SiPM photo detectors (600'000 readout channels). The group participates in fibre R&D including radiation testing, photo detector studies and several other prototyping activities.



Winding of 0.25 mm Ø fibre on a structured coverlay substrate. The fibre was excited with UV light.

The analysis of the fibre irradiation campaign performed in late 2012 showed that the SciFi technology was viable in the LHCb environment, but with relatively little margin. In 2013, a further irradiation at KIT Karlsruhe confirmed this result. To maximize light yield, the non-read fibre end will be mirror coated. Together with the TFG service in DT systematic studies of mirroring technologies were performed which showed up to 80% yield increase.

A set-up to measure Photon Detection Efficiency (PDE) was adapted to characterize newly developed SiPMs from two different suppliers. It helps to optimize the matching with the fibre emission spectrum, which changes significantly due to radiation damage. Together with the CERN PCB workshop (since beginning of 2014 part of the DT group), a new technology for winding fibres on a kapton substrate, which is structured with a so-called coverlay, was developed and successfully tested (see photo).

TORCH

Within the framework of the European Research Council TORCH project, laboratory activities have been on-going with the tests of various Micro Channel Plates (MCP) with single- and multi-channel readout electronics. The tests were first carried out with the small TORCH beam test prototype (already used in

2012). Subsequently, a dedicated set-up was built and optimized for that purpose. MCP prototypes with extended lifetime have been manufactured by the TORCH industrial partner and are being tested at CERN.

RICH upgrade
The proof-of-concept of an HPD with external readout electronics (photon detector backup solution) has been demonstrated. Single photon signals were recorded with 25ns peaking time and the observed noise levels were as expected from the specifications of the front-end electronics (Beetle ASICs). These results have been reported in an annex of the LHCb Particle Identification upgrade TDR.

3.5. TOTEM

X.Pons (PH-DT-DI)

PH-DT is deeply involved in the Totem Roman Pot LS1 consolidation program requiring major support effort from the group in different domains. All the Roman Pot stations have been moved from the tunnel to the TIF workshop for mechanical corrections and modifications.

In parallel, the stations located at 147 meters from IP5 have been displaced to 210 meters requiring the deployment of all detector services to the new location. DT has also prepared a new rugged design of the secondary vacuum production system already installed in the tunnel.

DT is also producing the new software allowing for placing the detectors in a safe position inside the LHC beam pipe and collaborating with EN/ICE and BE/OP for the user interface detector control operation.

RP detector packages and stations ready for service work by PH-DT staff.

4. Collaborations with non-LHC experiments

4.1. AEgIS

S. Haider (PH-DT-TP)

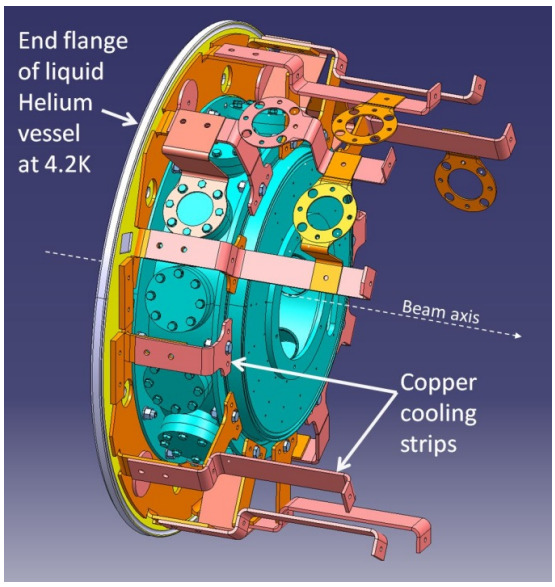
The beam-free period of 2013 was used to consolidate and improve the experiment as well as the experimental zone. Despite no beam, the experiment was at fully operational running conditions for more than 5 months.

Due to the extreme space shortage in the AEgIS zone, several facilities needed to be installed to improve the working conditions in the zone. An elevated platform, for example, to support dewars for cryogens needed for the cooling of the experiment. Up to this point, when dewars were in the zone, most other activities needed to be suspended due to space shortage. Now, the dewars are at 2.5 m height and do therefore not inconvenience ongoing activities any longer.
Similarly, the installation of a second laser table had to find space in vertical direction rather than just next to the existing table. Most of the future installation in the zone will need to follow these examples and "climb-up" surrounding walls.

A rather large step forward was also the installation of a new test equipment for the characterization of the excitation process for positronium. The tests commenced late in 2013 and will guide us towards the final implementations needed for the production of anti-Hydrogen atoms.

In the late 2012 physics run, we saw that the cooling in the most inner part of the experiment, the Penning-traps, was not efficient enough. The minimum temperature reached was only about 24 Kelvin, whereas the required minimum for the present setup is around 6 Kelvin. With the help of cryogenics experts, we were able to improve the present design, by introducing a large set of copper strips and plates that conduct the cold to the Penning-traps. See Fig. 1. The final minimum temperature reached was around 6 to 7 Kelvin. In order to decrease further to temperatures below 1 Kelvin, we need to construct additional means of cooling for the run in 2015.

In the fall of 2013, we started the discussions of the implementation issues needed for the down-stream module, named the "Gravity module", with which we will attempt to measure the gravitational acceleration g on anti-Hydrogen atoms. This process is an ongoing activity and will most certainly be an iterative process of design and experimental verification.



Part of the AEgIS central region between 5-Tesla and 1-Tesla magnets. Shown are copper cooling strips that connect thermally the end flange of the 5T Liquid Helium vessel (4.2 K) with the inner parts of the experiment (not shown) that need to be cooled.

4.2. CAST

M. Davenport (PH-DT-TP)

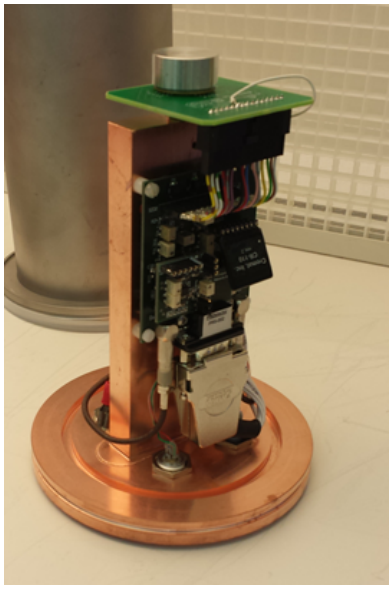
The group gives support to the CAST experiment in the areas of technical coordination, mechanical and electrical components of the magnet movement system, slow controls and vacuum interlocks. It operates an X-ray test beam lab for detector calibration and is involved in the development of sub-keV detectors.

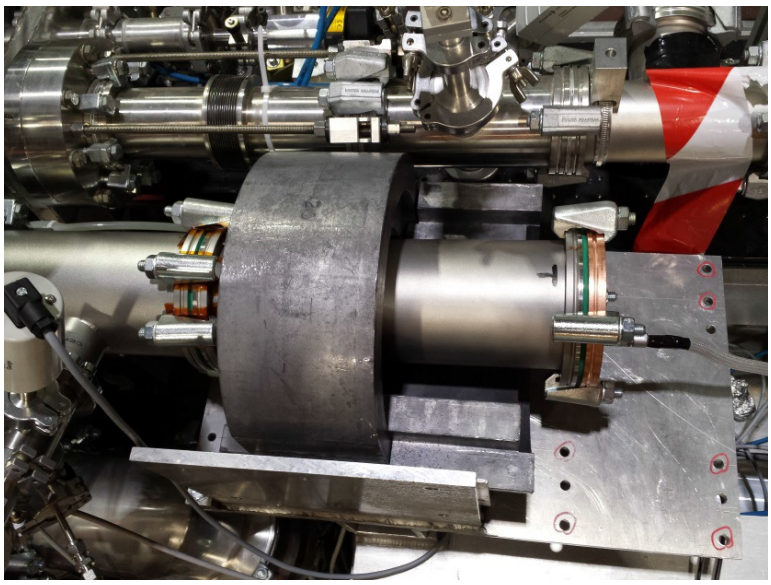
In 2013, there was a long shutdown where the CAST magnet was warmed-up and the cryostat opened. The X-ray cold windows on the cold bores of the magnet were removed and the 3He gas lines to the cold bores were disconnected so as to convert CAST back to a 'vacuum running' configuration for the years 2013-2015. During this period, CAST will make new higher sensitivity measurements in the range 1-7 keV searching for low mass solar axions. Improving the low-noise background of the detectors entailed accommodating extra lead shielding on CAST which required heavy welding work to strengthen the support of the sunrise telescope platform.

In the X-ray test lab, the X-ray test beam upgrades were completed and a number of detectors were calibrated prior to the 2013 data taking run. The vacuum configuration allows signals in the sub-keV energy range to arrive at the detectors. Hypothetical dark-energy chameleon particles with energies peaked in the sub-keV range can be produced in the sun and then be transformed back to X-rays in the CAST magnet and so be detected.

The group prepared a small-area (17mm2) commercial Silicon Drift Detector (SDD) to take a 'first look' at this energy region on CAST. In parallel, a project was launched to develop an upgraded system using a windowless research grade larger-area (93mm2) SDD detector (bSDD). The bSDD was incorporated into a vacuum vessel with an integrated cooling system and copper and lead shielding. The mechanical design was made by a Technical Student, the electrical system by the PH-DT Controls Group and the DAQ, cooling control and analysis by a Fellow and a Trainee.

Both detectors worked well on CAST and data was taken over the full 2.5 months available. Analyses of these data are underway and we are confident that the analyses will provide a world-class limit on the existence of the chameleon particle.





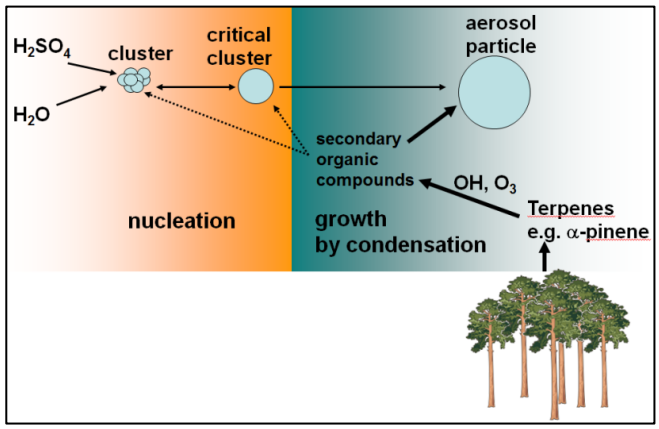
Left, SDD preamplifier card mounted on the copper heat exchanger and vacuum flange. The SDD is connected to the heat exchanger and to the small printed circuit board at the top. Right, vacuum pipe with SDD installed onto a vacuum port, lead shielding partially completed.

4.3. CLOUD

A.Onnela (PH-DT-EM1)

In October-December 2013 CLOUD had one run, CLOUD8. Despite missing the beam due the on-going LS1, CLOUD was able to take data in 'neutral' conditions (all cosmic-ray induced ions removed by HV field) and in natural cosmic ray conditions. The measurements focused on studying aerosol nucleation with organic species, and on diverse formation mechanisms of ice particles. Many of these measurements required using optical methods, new at CLOUD.

DT contributed to the experiment by an engineer acting as the Technical coordinator, GLIMOS and Resources coordinator, and a technician providing support to the experiment's construction and maintenance activities. A lot of work was done by the DT gas workshop to adapt the gas system for the experimental needs of the CLOUD8 run. The main upgrades of the CLOUD facility involved adding optical windows to the aerosol chamber for laser and camera systems, completion of the fast expansion system, and improved thermal control of gas feeds. A new door system was constructed at the bottom of the CLOUD Thermal housing for faster and safer access.

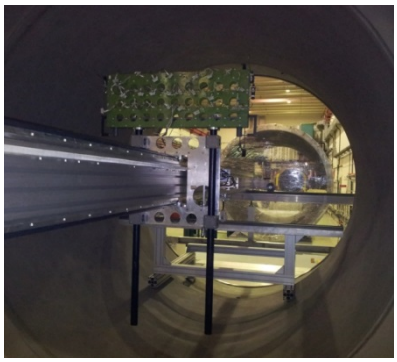


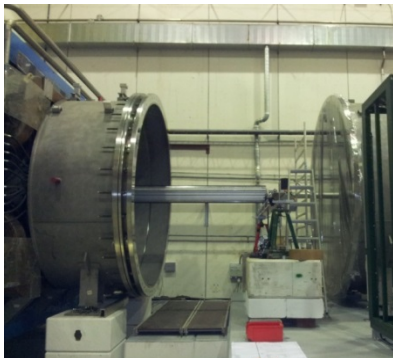
Growth of freshly nucleated aerosols is known to be often dominated by secondary (oxidesed) organic compounds. CLOUD measurements done in 2013 revealed that secondary organics can have a significant role also in the aerosol nucleation.

4.4. NA62

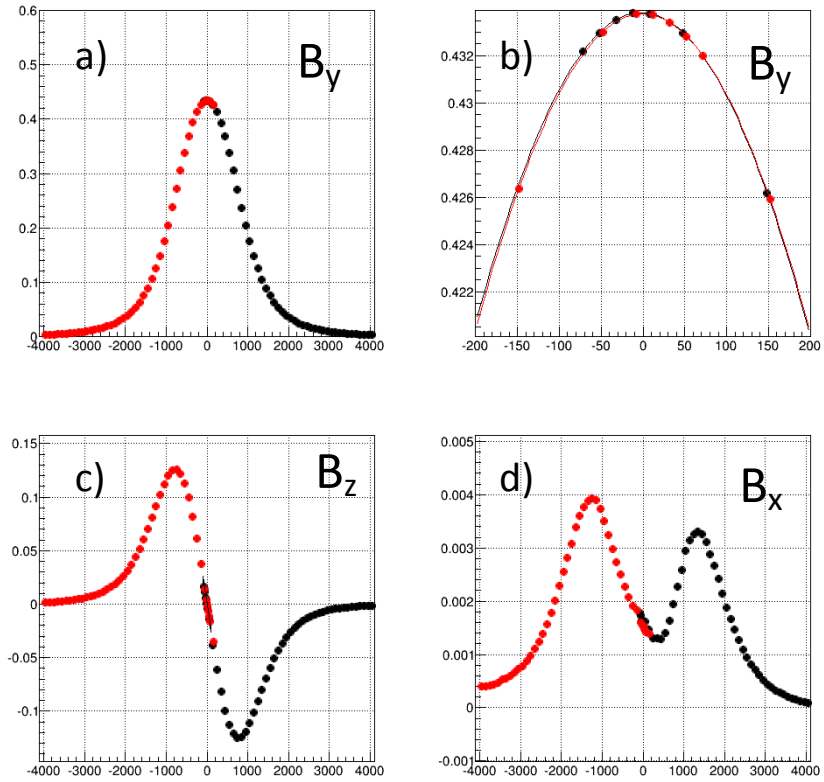
F.Hahn (DT-PH-TP), H.Danielsson (PH-DT-EM2)

Last summer the PH-DT magnet team has worked on precise B-field measurements of the spectrometer magnet and the residual B-field along the vacuum tank. A custom measurement bench was introduced into MNP33 to take about 100'000 data points in a region of up to ±4 m in Z and on a diameter of about 2m in X and Y, covering thus, the central field region and the fringe fields at the periphery of the magnet. The aim of this measurement was to establish a B-field map with an accuracy $\frac{\Delta B}{B} < 0.1\ \%$, allowing to fully exploit the performance of the pion spectrometer.





FB-field measurement bench as it was introduced in MNP33.



Example from the B-field measurements. (a) B_y (X=28cm, Y=44cm) versus Z, (b) same as a with zoomed scales, (c) B_z (X=28cm, Y=44cm) versus Z, (d) B_x (X=28cm, Y=44cm) versus Z. Note: Z=0 is in the centre of the magnet.

Preparation for the first Physics Run in October 2014

The construction and installation of the NA62 experiment is entering the final straight before its first physics data taking this autumn. At this moment all groups are in full swing to complete the construction and to install the detectors in time for the commissioning. The progress over the last 12 months has been at the level of our expectation, and we are confident that the few delays which have occurred for some deliverables (e.g. RICH vessel and vacuum tubes 26+28) can be caught up before the run. The activities with DT participation are the following:

- **GTK**: The detector assembly with the micro-channel cooling plates has been tested using dummy components. The outstanding work remains on a tight time plan, but the most difficult technical issues have been mastered and we believe that it is feasible to install a first version of the full size detectors for the run in October 2014.
- **Straw Tracker:** the module assembly is completed at CERN (4/4 modules completed) and coming to the end at JINR (3/4 modules completed, the last module will be finished by June). The total FE electronics was produced and successfully tested. The "dressing of the chambers", i.e. connecting all services (HV, LV and gas patch panels) to the chambers is in full swing. The SRB (back-end electronics) development is coming to the end and the production of a pre-series is expected to start in May 2014.
- **RICH:** the 17m long vessel (see Figure 3) has been installed and leak tested. The aluminisation of the mirrors is ongoing at CERN (≈60% completed) and will be finished in time for the installation.
- The **Aluminum Beam Pipe** (20m long) was designed in PH-DT and is now fabricated in the CERN work-shop; the machining of the pieces is completed, the welding work is on schedule (≈55% completed). The installation is foreseen during the summer.
- **Gas System:** The CEDAR gas system is already installed and operational. The Straw and RICH gas systems have been fabricated and installed this spring.

Unloading of 3rd RICH Vessel in EHN1.

5. R&D Projects

5.1. Radiation Tolerant Silicon Detectors

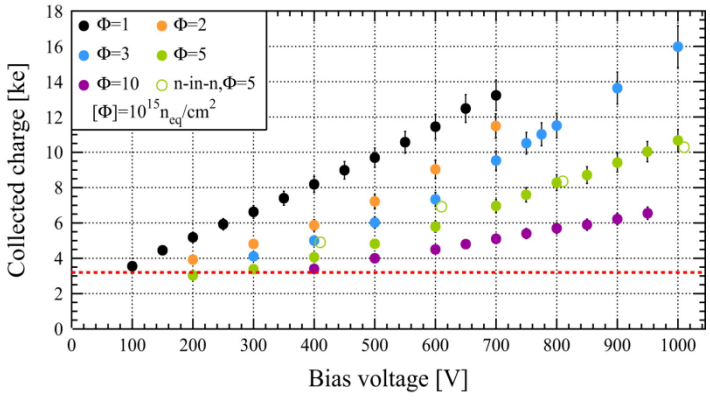
M.Moll (PH-DT-DD)

The PH-DT group participated in the framework of the RD50 collaboration and the CMS phase-II Tracker Upgrade in R&D activities related to silicon sensor developments.

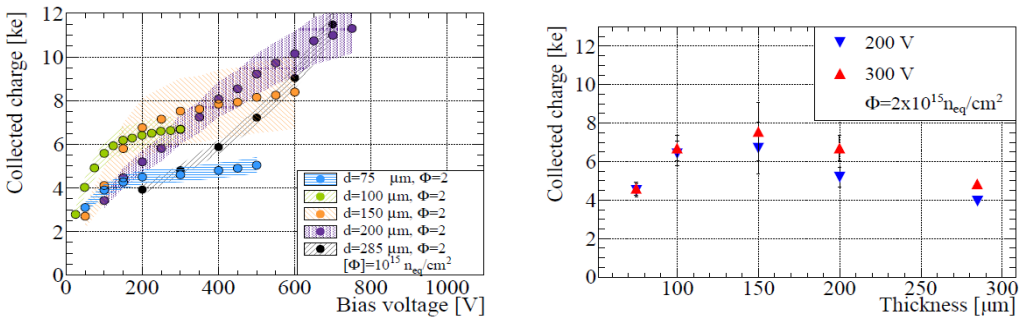
In the framework of the RD50 collaboration (49 Institutions, 272 members) the PH-DT group participated in the research on radiation tolerant silicon sensors for vertex and tracking detectors for the luminosity upgrade of the LHC. The coordination of the RD50 collaboration was supported and steered by PH-DT by providing a co-spokesperson, administrative support, the budget holder and the co-ordination of several RD50 common projects.

Significant progress was obtained in many RD50 research areas like microscopic defects, device simulations, sensors with intrinsic gain (low gain avalanche detectors), edgeless and 3D sensors and in particular on the development of p-type silicon sensors. For the outer tracking detectors (strip sensors) n-in-p silicon sensors have become the baseline solution for the HL-LHC Trackers of ATLAS and CMS. For the pixel sensors n-in-p sensors are on their way to become a very reasonable solution for at least the outer pixel detector layers in the HL-LHC.

Contrary to the presently used n-in-n pixel sensor technology (n-in-n: n-type implants form the segmented front electrodes in n-type silicon) the n-in-p sensor technology offers several advantages. The production process is much easier (and less expensive) since a double-sided processing is not needed. Furthermore, the homogeneous backside of the n-in-p sensors is less problematic to handle, allows for easier mounting of the sensors and enables easier wafer thinning methods. The latter are used to reduce the mass of the sensor and therefore the multiple scattering of particle in the inner tracking volume. The only potential drawback of this technology is the fact that spark protection has to be assured between the low potential of the readout chip and the edges of the sensor. However, feasible solutions have now been developed and demonstrated to offer good protection up to more than 1000V. Prototypes of p-type pixel sensors have been produced, irradiated and successfully tested. As for n-in-n pixel sensors, it has been shown that even after the highest expected HL-LHC radiation levels, enough charge is collected at the sensor electrode to produce a signal to noise ratio that allows for efficient particle tracking, provide a sufficiently high voltage is applied. The figure below gives an example of signal measurements as function of applied voltage. The dotted red line indicates the threshold for detection in this specific test run. P-type sensors are thus well suited to become a cost-effective sensor option for future radiation tolerant pixel detectors.



Collected Charge (MPV – Most Probable Value) for neutron irradiated n-in-p planar pixel sensors of 285 micrometer thickness. The measurements were performed with a beta-source (^{90}Sr) as function of the applied bias voltage. The dotted red line indicates the tuned threshold of the sensors, 3200 electrons [NIMA 730 (2013) 44-49].



Comparison of collected charge as measured with a Sr90 source on irradiated p-type pixel sensors with different thickness bump-bonded to ATLAS FEI4 readout chips. [Figure: S.Terzo, 23rd RD50 Workshop, CERN, Nov.2013].

A question under study is the optimal thickness of the sensors, which impacts on one hand on the material budget, but on the other hand also on the collected charge (signal) of the sensor. Surprisingly, recent measurements have shown that after high levels of radiation thin detectors can deliver even higher signals than thick sensors. This is demonstrated in the figure above for n-in-p-type pixel sensors with different thickness. It can be seen that for sensors exposed to $2x10^{15}$ n_{eq}/cm^2 the optimal thickness is 150 micrometer if 200-300 V are applied to the sensor.

This striking result is originating from the fact that charge collection after extreme particle fluencies is impacted by very strong charge trapping (charge loss) which reduces the advantage of thick sensors. Furthermore, thin sensors profit from the higher electric field strength at same voltage.

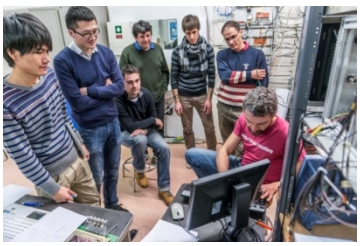
5.2. Micro-Pattern Gaseous Detectors

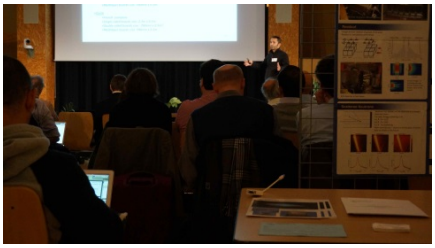
L.Ropelewski (PH-DT-DD)

DT group plays a major role in the coordination of the RD51 Collaboration focused on the promotion and development of the Micro-Pattern Gaseous Detector technologies.

Following years of successful activities witnessing major technological breakthroughs leading to applications of the MPGDs in high-energy physics experiments, RD51 Collaboration was approved for the next 5 years by LHCC and Research Board. RD51 will continue to support CMS and ATLAS muon system and ALICE TPC end cap readout upgrades, which adopted single mask GEM and resistive anode MicroMegas technologies developed within Collaboration. As in previous years emphasis will be placed on the industrialization and quality assurance of the detector components fabrication and on the simplification of the detector assembly allowing for low cost, large volume production. At the same time Collaboration will continue efforts on the extension of the versatile Scalable Readout System, electronics laboratory instrumentation, and maintenance of the simulation tools for gaseous detectors. Collaboration will also draw more attention on the applications of the MPGD technologies outside high-energy physics and training. In collaboration with HEPTech RD51 organized specialized workshop on detection neutrons with MPGDs. DT Gas Detector Development lab hosted also RD51 electronics school.

DT GDD team serves as a center of expertise and maintains extended laboratory and test beam facilities used by Collaboration. This includes necessary detector services, lab instrumentation, trackers with data acquisition systems and reconstruction software. Generic R&D of the GDD team was focused last year on the application of GEM detectors for neutron detection (in collaboration with ESS), development of the sealed clean detectors based on the glass GEM (in collaboration with Tokyo University), and application of the nanotechnologies for development of the efficient, ultrafast gaseous detectors (in collaboration with London Centre of Nanotechnologies).





Left, Electronics training session by Eraldo Oliveri. Center, RD51 electronics school teachers and students in front of the extended DT GDD lab. Right, Rui de Oliveira presenting current MPGD techniques during 'Detecting Neutrons with MPGDs Academia-Industry Matching Event'.

5.3. On-detector Cooling R&D

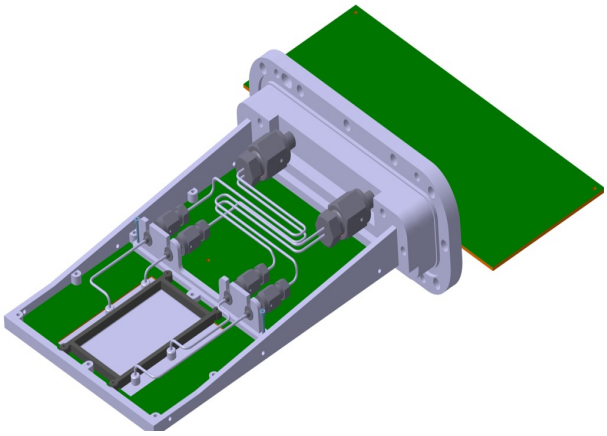
P.Petagna (PH-DT-DI)

Silicon micro-channel cooling (NA62 GTK)

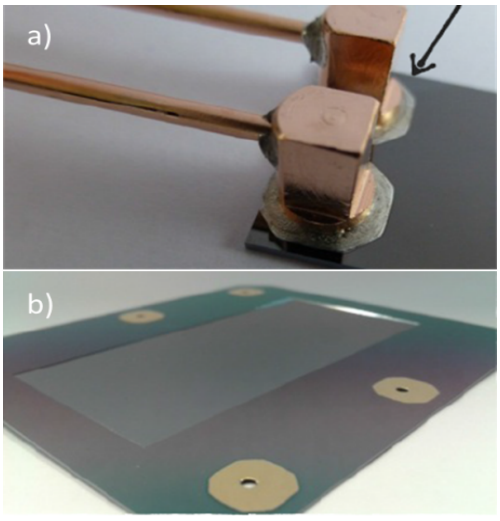
2013 has marked the passage of the group involvement in the NA62 GTK cooling and integration from a phase of applied R&D to a phase of service to the experiment. The activity has been focused on the definition of the whole procedure aiming at the first integration of an operational tracking detector with an active silicon micro-channel cooling device. All aspects related to reliability, handling, alignment precision, wire-bonding to the GTK PCB and integration in the GTK vacuum vessel have been tackled.

In collaboration with PH-ESE, the PH-DT team has brought to definition the details of the assembly sequence and the tools required for the production of the assembled GTK module. Through a combination of CAD modelling and physical mock-ups, including the use of the new PH-DT 3D printer for fast prototyping of complex shapes, different procedures and fixtures have been evaluated until satisfaction of the stringent requirements.

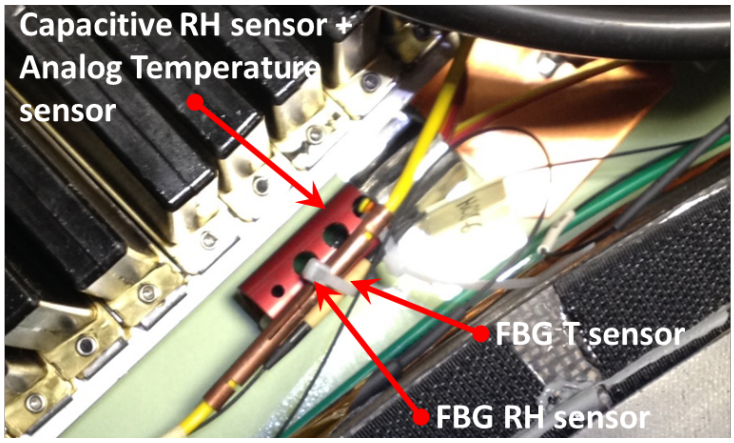
One fundamental breakthrough has been the achievement of very reliable hydraulic miniaturized connections resistant to high pressure: an ad-hoc soldering process of custom mini-connectors machined in Kovar, an iron-nickel-cobalt alloy with a coefficient of thermal expansion similar to that of borosilicate glass and crystalline silicon, on the silicon cooling device has been developed in collaboration with PH-ESE and EN-MME and successfully tested on several prototypes. The work proceeds now steadily towards the completion of the first set of fully integrated modules in due time for the 2014 physics run of NA62. Other generic developments and progress in this activity are reported in section 5.4.



CAD model of one fully integrated GTK module.



(a) Custom made Kovar mini-connectors mounted on a test plate, and (b) metal soldering pad deposited on a GTK cooling device ready for connectors.



An FBG RH+T sensor couple, forming a FOS hygrometer, installed in a critical are of the CMS Tracker end-flange close to electrical connectors. Beside it, standard RH+T sensors in their protection casing.

Relative Humidity Optical Fibre Sensors

A full network of 72 optical fibre sensors for hygrometric measurement, each one formed by an FBG Temperature sensor and one FBG Relative Humidity sensor has been installed in the critical area of the CMS Tracker end-flange for constant distributed humidity monitoring. Pre-irradiated at ionizing radiation dose of 210 kGy, the FBG's are expected to have a lifetime spanning over many years in the hostile environment typical of the inner detectors of CMS. The pre-irradiation level has been carefully selected as the one guaranteeing a negligible radiation-induced signal shift until LS2, when it will be possible to re-calibrate *in-situ* the sensors. The second year of LS1 will be used to gain confidence on the read-out of this finely distributed network, in particular at low humidity levels, in view of the re-start of the CMS operation.

In parallel, the work on the new generation of optical fibre-based Relative Humidity sensors, partially supported by CERN KT funds, has also shown progresses: the good potentiality of LPG gratings in connection with oxide coating has been confirmed and optimal coating material and thickness have been defined. Thorough characterizations have been conducted to put in evidence a very satisfactory behavior even at low temperature and good characteristics of reproducibility of the sensor. A first step of irradiation with gamma, up to 10 kGy, has shown a very good behavior. The program of next year will focus on tests under strong irradiations of gamma and neutrons, as well as on the prototyping of an optimized casing for the first on-field applications.

5.4. Micro-systems Engineering

A.Mapelli (PH-DT-EO)

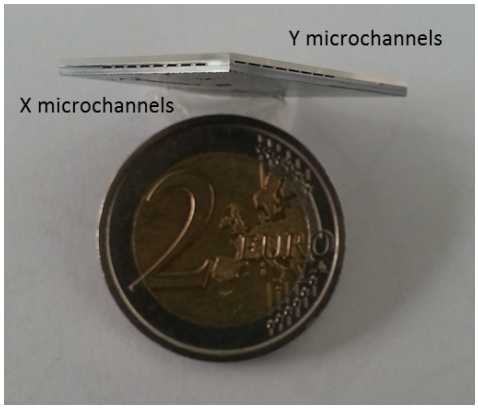
In 2013, the PH-DT Engineering Office has started investigating micro-technologies for the development of novel types of detectors and alternative approaches to on-detector services, such as cooling. The fabrication of microsystems is performed by PH-DT in the class 100 MEMS cleanroom at the EPFL Center of MicroNanoTechnology[1] in close collaboration with the EPFL Microsystems Laboratory[2].

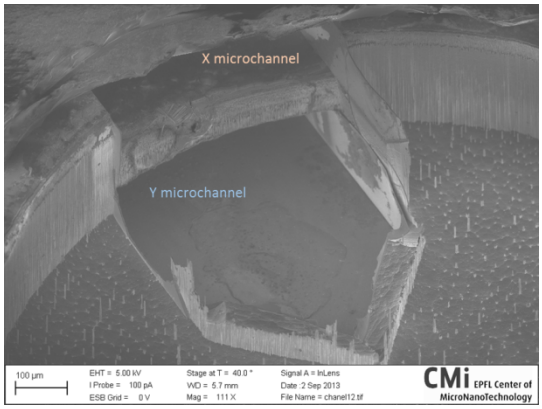
Structural Analysis of Thin Silicon Membranes

The microsystems under development by PH-DT mainly consist of microfluidic devices. Complex microchannel networks are etched in silicon substrates to contain and circulate liquid scintillators (microScint) or cooling fluids (microCool). In order to meet the material budget requirements of HEP experiments, thin silicon membranes, of the order of 50 µm or less, are used to close the microchannels.

[1] cmi.epfl.ch

[2] lmis4.epfl.ch





(left) Picture of a silicon bi-layer microfluidic scintillation detector. (right) Scanning Electron Microscope picture of the single inlet of the detector used to distribute liquid scintillator in the X and Y layers simultaneously.

The fracture mechanics of thin silicon layers is not well understood and it is currently being studied within the Engineering Office through experimental testing and Finite Element Analysis (FEA).

microScint
Recently, a new type of scintillation detector based on microfluidics has been demonstrated. It is being considered as potential candidate for particle tracking and beam monitoring devices in HEP and medical applications. In the summer of 2013, the first bi-layer (XY) microfluidic scintillation detector was fabricated at EPFL and characterized at CERN demonstrating the reconstruction of the two coordinates of a particle in a plane with a single microfluidic channel following the approach patented in 2012 with the support of FP-KT (patent WO 2013/167151 A1).

microCool
A similar microfluidic approach has been adopted to develop ultra-thin silicon on-detector active cooling systems. Such systems have been selected in 2013 for the thermal management of the NA62 GigaTracKer pixel detectors (see Section 5.3) and for the 2018 major upgrade of the LHCb Velo. They are also considered in the context of the upgrade of the most inner layers of the ALICE ITS.

In these projects, PH-DT manufactures the prototype devices at EPFL and characterizes them at CERN in close collaboration with the experiments and PH-ESE. PH-DT then takes care of the tendering and follow-up of the fabrication of the microsystems by external partners.

- ***NA62-GTK*** - In 2013, the NA62 collaboration and PH-DT selected CEA-Leti for the fabrication of the GTK microchannel cooling plates. The first devices should be delivered at CERN mid-2014 to be implemented in the experiment before the end of the year.
- ***LHCb Velo Upgrade*** – In 2013, the LHCb collaboration selected silicon microchannel cooling as the baseline for the thermal management of the Velo detector in view of the 2018 major upgrade. The microchannels will operate with evaporative CO_2.
- Before launching the fabrication of the cooling plates, a thorough study of brazed metallic connectors to thin silicon is being performed to guarantee reliable operation.
- ***ALICE ITS Upgrade*** – In parallel to the fabrication of silicon microchannel frames in the EPFL cleanroom and their characterization in the DSF Facility with evaporative C_4F_{10}, a partnership has started with the Thai Microelectronics Center (TMEC) for the supply of microcooling frames fabricated in 6" wafers. PH-DT and ALICE have also started working on 6" wafers at EPFL to fabricate dummy frames to study integration aspects with carbon fibre support structures in stave configurations.

microHeII
A third application aims at studying the heat transfer of superfluid Helium II in a network of microchannels embedded in a glass substrate in view of an improved insulation for the LHC supraconducting magnets. In this project, PH-DT provides microchannel networks embedded in insulating substrates to be characterized at CEA-Saclay.

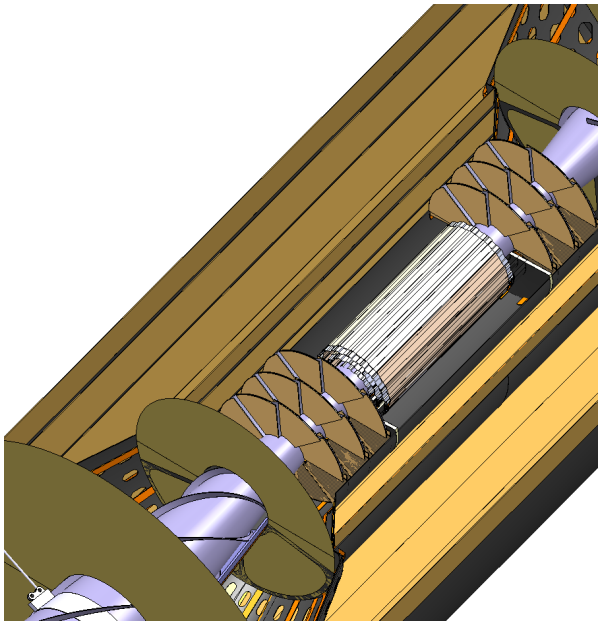
5.5. Studies for the CLIC vertex detector

W.Klempt (PH-DT-TP)

The group has been involved in CLIC (Compact Linear Collider) vertex detectors studies. The activity consists of testing and simulating the mechanical infrastructure and the cooling of the vertex detector of the CLIC_ILD detector concept.

The vertex detector contains a barrel and an end-cap section, with both being composed of three double layers of silicon pixel detectors. The design has to be extremely light; the material budget of each layer has to be as low as 0.2% X0. This requirement can only be achieved by using dry air as cooling medium.

To meet these specifications the group has engaged an investigation to conceive and build light-weight carbon fibre composite ladders and test their stiffness using 3-point bending tests. The results have been compared with finite element calculations. Also a small-scale wind tunnel has been designed and built to validate the air-cooling. Real size ladders have been equipped with electrical heaters and cooled with wind speeds of 3 – 10 m/sec. Temperature measurements have been compared to results from fluid dynamic finite element calculations. Also vibration studies of the ladders in the cooling air flow have been performed. First comparisons between measurements and calculations are promising and indicate the soundness of the design.



Drawing of CLIC Vertex detector.

6. Services Provided by DT

6.1. Infrastructure for Detector R&D

6.1.1. Irradiation Facilities

R.Guida (PH-DT-DI), M. Jaekel, F. Ravotti (PH-DT-DD)

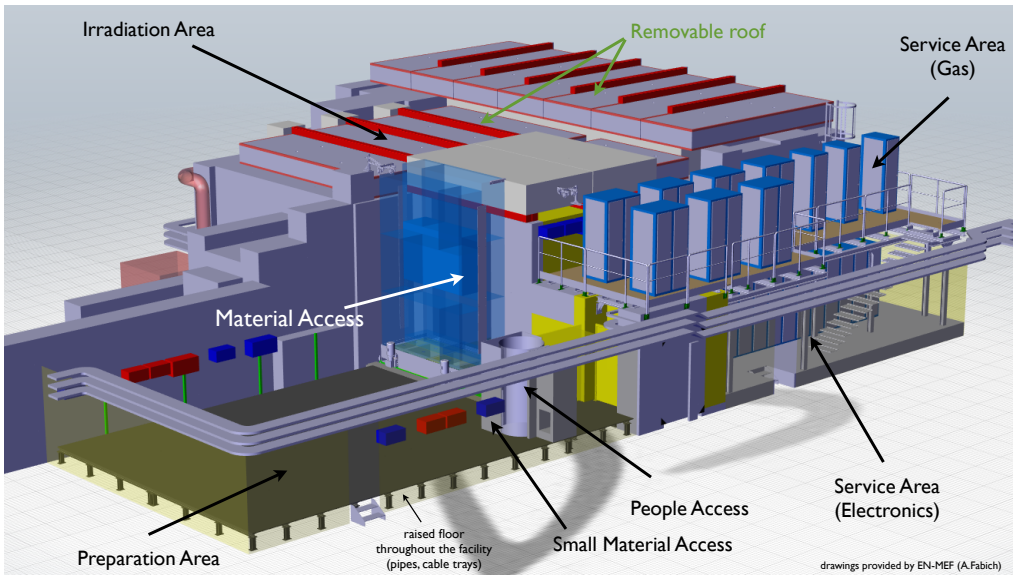
Gamma Irradiation Facilities – GIF & GIF^{++}

The current CERN-Gamma Irradiation Facility (GIF) has been intensively used to expose detectors to the photons from a 0.5 TBq ^{137}Cesium source throughout the year by several groups. In particular the ATLAS-RPC group tested a new RPC with modified front-end electronics for possible application in the future ATLAS upgrade. The CMS-GEM collaboration continued a long term ageing test on a large GEM. Several types of Beam Loss Monitors were validated, as well as radiation monitors for the future gamma irradiation facility. The operation of the GIF facility is currently foreseen to end in August 2014.

In July 2013, a new 14 TBq^{137}Cesium source has been acquired and will be delivered to CERN in September 2014. The construction of the new irradiation bunker in the SPS North area has started in late 2013. Located at the H4 beam line in EHN1, the GIF^{++} will be a unique place where high energy charged particle beams (mainly muon beams with momentum up to 100 GeV/c) are combined with a background field 30 times higher than in the previous facility. This increased luminosity will allow to cumulate radiation doses equivalent to High Luminosity - LHC experimental conditions in a reasonable time.

In collaboration with the EN department, during 2013, the layout of the facility has been significantly improved. Two large radiation fields (±37degdrees horizontally and vertically) with individual radiation attenuator systems will allow for the simultaneous testing of a wide range of small detector prototypes, electronic components, radiation monitors and dosimeters under a strong photon flux as well as the characterization and understanding of the long-term behavior of large particle detectors. The facility will be equipped with a dedicated control system, recording all relevant parameters from beam- & irradiator status to environmental conditions and gas supply status.

Several user infrastructures proposed in the framework of the WP8-AIDA project have been included in the design of the facility, and will be installed in the coming months, including a common Detector Control System, radiation monitoring (RADMONs), as well as beam- and cosmic-trigger chambers.



The improved layout of the GIF^{++}, with a dedicated preparation zone, a large material access gate and a removable roof to accept full size detector elements of several m^2.

Radiation Monitoring (RADMON) sensors

In the framework of the PH RADMON project, the PH/DT group supplied further new integrated sensor boards (23 units) and new samples of dosimeter devices (RadFETs, p-i-n diodes, radio chromic films) to various experiments and groups within CERN but also for irradiation tests in external facilities. These include the ALICE, CMS and LHCb experiments at CERN and irradiation tests at CERN-GIF, BNL and ESS (for the RD51 collaboration) among others. These new 23 integrated sensor carriers and the tens of single dosimeters delivered during 2013 add up to the ones already operational in the LHC Experiments. The requests received during 2013 confirm the success and the continuous interest of the experimental community in the PH RADMON sensors made available by DT.

Proton (IRRAD) & mixed-field (CHARM) irradiation facilities at CERN-PS

In a joint effort by the CERN PH and EN departments and in the framework of the AIDA project, a proposal for the upgrade of the East Area Irradiation Facilities (EA-IRRAD) was developed. The proposal, approved in 2012, consisted in moving the old T7 proton facility to the T8 beam line and exploiting the area previously occupied by the DIRAC experiment (that completed its data-taking period at the end of the same year) to build a new combined proton/mixed-field facility based on the slow-extracted 24 GeV/c proton beam from the PS. After developing a detailed facility concept and a facility design, the construction project started in November 2013. The new proton irradiation area (IRRAD) is being installed at the former location of the DIRAC target, while the new mixed-field area (CHARM) is being constructed downstream of the IRRAD facility.

The PH/DT AIDA team is focusing its work on the proton IRRAD facility area: here a new shuttle system, cloned from the previous IRRAD1 and IRRAD2 has been built during 2013.

The rest of the year 2013 was mainly devoted to the following activities:

1. The dismantling of the old PH facility infrastructures, including the intervention for the removal of the radioactive IRRAD2 target previously used by PH/DT for mixed-field irradiations;
2. The finalization of the design of the new proton area, which included among others, work with the Radiation Protection group for the optimization of the radiation shielding (using FLUKA simulations), the definition of the requirements for the ventilation system, the beam specifications, the beam instrumentation, the access system, the cabling network and the peripheral infrastructure (storage, counting rooms, etc.);
3. The preparation of some of the new IRRAD facility equipment, including the new beam profile monitor (BPM) display, the shuttle control system as well as the required safety documentation;
4. The integration inside IRRAD of the cryogenic infrastructure (together with the BE and TE departments) which will enable the possibility to perform proton irradiations down to 1.8K inside a cryostat fed with liquid Helium.

The EN team is instead focusing its work on the CHARM mixed-field area. Here, the particles coming from the upstream proton area interact with a 50cm long Al/Cu target, generating a particle field optimized to reproduce the radiation environment found in the LHC tunnel, in other CERN accelerators as well as the radiation field encountered close to the interaction points within the experiments. A series of remote-controlled systems, currently under design, will allow for moving the equipment under test inside the area (power converters, magnet components, etc.). The installation of the new irradiation equipment inside the IRRAD and CHARM areas will take place during 2014 with the goal of starting the exploitation of the new irradiation facility at the end of the same year.

PS East Experimental area (bld. 157) taken during the first weeks of 2014. The construction of the IRRAD and CHARM irradiation facilities has started. First concrete and iron shielding blocks, defining the footprint of the irradiation bunker, have been already posed on the ground.

New proton IRRAD shuttle system. The loading bay is visible on the right-hand side of the figure. On the left-hand side the (open) conduit shows the rail along which the remote-controlled shuttle convey the samples to be irradiated in the proton beam.

6.1.2. Solid State Detector Lab, Bond Lab, QART Lab and DSF

M.Moll, A.Honma (PH-DT-DD)

The hardware infrastructure of the solid-state detector laboratory (SSD) in bldgs.28 and 186 was maintained and enhanced. A new test set-up combining a Transient Current Technique (TCT) and edge-TCT (e-TCT) system in an electromagnetic shielded box was designed and build (see figure). The LASER system of the previous TCT set-up was reconfigured and developed into a Photo Induced Current Transient Spectroscopy (PICTS) measurement system. Further available systems in the lab are set-ups for Capacitance-Voltage (CV), Current-Voltage (IV) and Charge Collection Efficiency (CCE) measurements. The (Sr-90 beta source) CCE measurements are based on the Alibava readout system (LHCb Beetle chip) and can be performed in a dry air atmosphere down to about -30°C. The CV/IV system can be cooled down to about -40°C for the measurement of highly irradiated samples. Part of the equipment was made available to external groups: colleagues from ATLAS, CMS, LHCb, RD39, RD50 and BE-BI performed measurements for their individual solid-state sensor projects in the laboratory.

The primary projects for the Bond lab in 2013 concerned ATLAS (IBL – see below, DBM, pixel upgrade), ALICE (ITS upgrade), CALICE (16 chip modules), CMS (pixel and strip upgrades), Medipix bonding (Mpx2, Mpx3, Timepix), and PH/ESE (DC-DC converters). As usual there were a large number of smaller jobs from a large variety of clients: AEGIS, Cristal Clear, CLIC, RADMON, LHCb, NASA, etc. A significant amount of time was spent giving advice and aid for detector construction and connectivity issues to a variety of projects, most notably ATLAS IBL. The Bond lab usage remains at a high level.

An unexpected emergency occurred in September 2013 that implicated large fraction of the bonding lab's resources and all three of the lab's personnel. This was a condensation problem with the ATLAS IBL pixel upgrade detector, where more than half of the total number of staves (stave = ladders of pixel modules) to be produced (20 produced, 14 needed) were found to have severe corrosion attack on their wire bonds. A crash program of failure analysis followed by a major repair program was undertaken. The lab was asked to become the repair centre for IBL staves and from November 2013 through January 2014 this became the primary work in the lab. This job required an understanding of the corrosion problem, extensive visual inspections, wire bond pull testing, removal of attacked wires, PCB and silicon chip cleaning, and wire bonding to replace removed wires. In addition, a number of studies of the IBL problem involved use of the QART lab equipment. At this writing in February 2014, the repair program was completed on time and 11 damaged staves were repaired successfully.

Quality Assurance and Reliability Testing (QART) Lab

The QART lab, based on a high-end environmental chambers, a powerful vibration test system, a small aperture high field (2T) electromagnet, and numerous smaller specialized test equipment, continued to have increased usage from a variety of users. Some of the notable jobs included LHCb tracker upgrade (vibration study), POLAR (space detector, thermal cycling), ATLAS IBL (wire vibration in magnetic field), PH/ESE DC-DC converters (climatic chamber), and LCD (linear collider detector R&D, climatic chamber). Both the large LHC experiments (ATLAS and CMS) had numerous upgrade projects which used the QART lab facilities and advice. Both of our fast temperature cycling environmental chambers were in frequent use and 2013 saw much user interest in our high field electromagnet as well.

DSF (Departmental Silicon Facility)

ALICE ITS, CMS tracker upgrade, and Medipix were active users of DSF clean room in 2013. As LHC experiment upgrade plans are becoming better defined, a meeting of the DSF users was called to plan the usage over the next 5 years. This resulted in a well-defined new request for significant space from ALICE and requests to retain existing space from CMS and LHCb. No other large requests were made but nearly all floor space was already accounted for, so in order to gain a bit more margin, it was decided to replace the little needed large double doors with an accordion-style door between the DSF and Bond Lab, thus gaining almost 10m2 in usable floor space for the DSF. This has been done and the DSF is slowly being rearranged to the new floor plan as agreed.

New lab space in bldg. 186 with a PICT (Photo Induced Current Transient) system (in the back) and a TCT/e-TCT (Transient Current Technique) set-up in a RF shielded box (right, in the front).

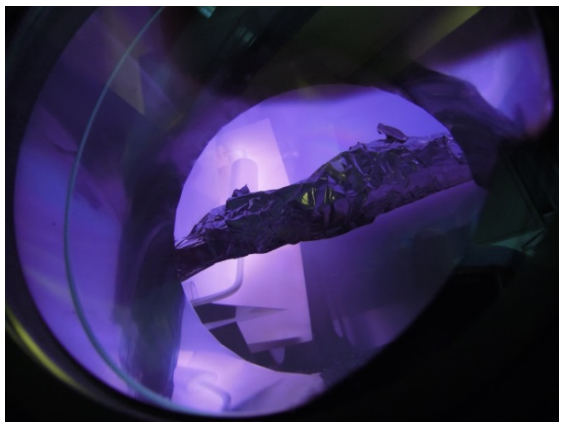
6.1.3. Thin Film and Glass

T.Schneider (PH-DT-DD)

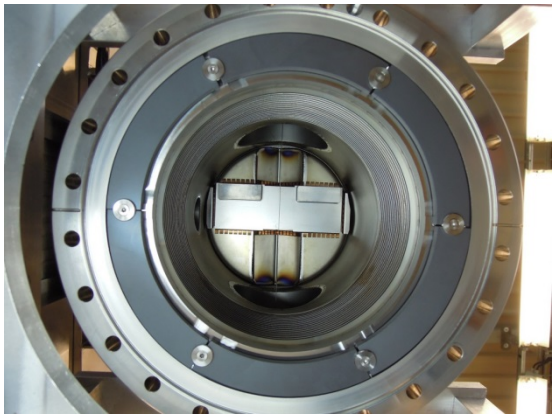
The mandate of the Thin Film and Glass (TFG) section in PH-DT is to give support to the different CERN experiments in terms of thin film coating as well as glass and ceramic machining. The activity in the Thin Film service covers the large field of Physical Vapour Deposition (PVD) based coatings. Different metals, dielectrics and also organic materials have been evaporated. Most layers produced in 2013 were for optical use like fibre-end coatings for LHCb SciFi upgrade project, TPB coating for PM windows of ArDM and NA62 CEDAR lens coatings. In addition also functional layers have been requested. In 2013 a major upgrade of the E-gun HV system for the lab's biggest evaporator has been successfully accomplished. Subsequently the device has been re-adjusted to perform the UV enhanced mirror coatings for the NA62 RICH detector scheduled for the beginning of 2014. In the Optical Quality Control lab of TFG we are equipped with several microscopes and spectrometers to qualify the outcome of our work. Several experiments and CERN users could profit in 2013 of this infrastructure.

The TFG Glass Workshop is equipped with several dedicated diamond tools for hard material machining. We offer a unique service at CERN for the machining of specific materials such as glass, Pyrex, quartz, sapphire, ferrites and other ceramics. In 2013 several prototypes and small series have been machined for ATLAS ALFA, CMS, ISOLDE, CLIC, Ax-PET, MAX4, LINAC 4, AEgIS and the µ-channel cooling activities in PH-DT.

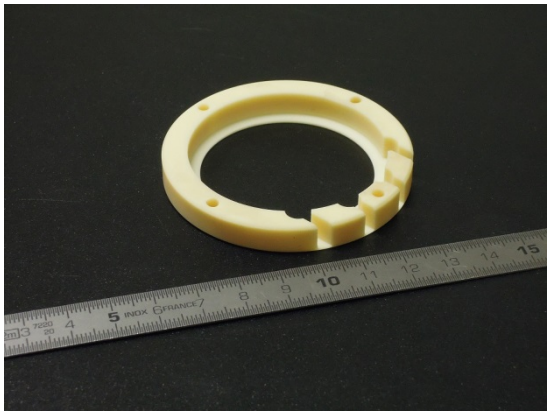
Big evaporator with HV supply rack in the back.



Substrate cleaning cycle with ion bombardment.



Set of machined Ferrite segments for ATLA ALFA.



Ceramic machining for AEgIS.

6.2. Infrastructure for experiments

6.2.1. Gas Systems

R.Guida (PH-DT-DI)

During 2013 the activity of the PH-DT-gas service team was mainly driven by the intense program of consolidation and upgrade of the gas systems for the LHC experiments.
The relatively long duration of LS1 gave a great opportunity to review existing detectors and related infrastructures. The consolidation program elaborated for the gas systems is articulated around three main points: the reduction of down time due to periodic maintenance, the required upgrade in functionalities needed to cope with the increase of the LHC performances and the reduction of operational costs as well as the impact on the environment. An example of upgrade related to new requirements is the construction of new dry gas distribution units for the CMS inner detector flushing system that will allow operating the CMS Tracker at lower temperature.

In order to facilitate the detectors maintenance, several additional systems have been prepared to supply gas mixture during LS1 in conditions different from standard ones. Some examples are related to RPCs (ATLAS and CMS), CMS-DT, ATLAS-TRT, TOTEM, CMS-SX5 Pixel lab, CMS-SX5 DT and CSC gas distribution, CMS-904 facility.
The TIF laboratory has been equipped with new gas distribution systems for GEM detectors and for the validation run of the first CMS-CO_2 cooling plant. The latter was successfully built in the PH-DT gas workshop in collaboration with the PH-DT cooling team.

The gas team supported the challenging detectors gas leak search campaigns carried out by the experiments. This contribution is complemented by the strategy of converting open gas systems to re-circulation (like for example in the case of ALICE-MTR). The two activities aim in a reduction of the gas consumptions for containing operational costs and emission of greenhouse gases.

The DT-gas team is involved also in non-LHC projects, which represent about 20% of the total activities. The main contributions are related to the support for operation and development of the CLOUD and NA62 gas systems.
During 2013 the collaboration for the development of the gas source for the new LINAC4 accelerator continued with the construction of the final gas injection unit. As part of the accelerator, this unit is now undergoing a long validation run and from 2018 it will become the new source of protons for the CERN accelerator complex.

Competencies and expertise of the team contributed in many other small projects. An example is the support to ISOLDE facility for the upgrade of the gas injection in the REX-TRAP and the study of H_2 production in correlation with release of water on warm Tantalum rod.

Analysis unit for automatic monitoring of humidity in the CMS TK volume, and new dry gas distribution racks.

Students from the ESIPAP School and the PH-DT gas team around the set-up prepared for the hands-on session.

Finally, the PH-DT gas laboratory hosted a detector hands-on session of the ESIPAP School: a set-up based on RPC detectors was used to show how the gas mixture composition can affect detector performances and the possible instruments used for monitoring.

6.2.2. Development and construction of CO_2 cooling plants

The main achievement in 2013 of the PH-DT Cooling Team on CO_2 has been the successful completion of the construction of the prototype cooling plant for the phase-I upgrade of the CMS PIX detector and of its main commissioning. With its 15 kW refrigeration power at -20 °C and its maximum mass flow rate of 150 g/s, this is the largest plant ever built using the 2PACL principle. Based on the experience gained with the construction and testing of this prototypes, including a long phase of detailed commissioning to explore the whole operational envelope of the unit in 2014, two identical units will be built and installed in CMS before the end of LS1.

Prototype of the new CMS PIX 15 kW cooling plant assembled in the CMS Tracker Integration Facility in Bldg. 186.

The end of 2013 has also marked the delivery to ATLAS of the control system for the brand new CO_2 cooling plant for the IBL detector. For this plant, the realization of the mechanics and of the high pressure circuits has been entrusted by the experiment to NIKHEF. The IBL cooling plant controls fully conform to the hardware/software standard approach defined for all plants developed in PH-DT: the control architecture relies on an industrial Ethernet IP field network and on highly reliable industrial hardware. The user interface is based on the Siemens WinCC Open Architecture SCADA and the control software conforms to the UNICOS CPC6 framework of CERN. This approach simplifies the maintenance and operation activities both for the system experts and for the operators. Also, the use of state-of-the-art industrial technology allows for a long lifetime perspective of the adopted standard. Following the long track of positive collaboration between NIKHEF and PH-DT, this split-responsibility project has been characterized by a very positive spirit of cooperation. The two twin IBL cooling plants have been fully completed and are presently under commissioning in Point 1.

On its side, MARCO (Moving Apparatus for Research on CO_2), the plant developed in collaboration with MPI as a common prototype for the cooling of both the ATLAS IBL and the BELLE-II SVD/PXD detectors, has been faithful to its name: after completion of the full commissioning down to an operation temperature of -40°C, the plant has been moved to DESY for test beam cooling. After completion of the test beam activity, it has been moved to MPI, where it will be used during 2014 for testing of SVD/PXD detector portions, prior to come back to CERN at the end of this year.

As planned, during the past year the third generation of TRACI units (the 100W portable machine for laboratory use) has been conceived: more compact control cabinet with PLC-based logic, touch screen with on-line status monitoring features, optimised hydraulic design are some of the features introduced. In parallel, a new test bench for CO_2 pumps have been assembled and is actively used to select good candidate for this application. The production of few prototypes of this third generation of TRACI units is planned for 2014.

6.2.3. Instrumentation and Controls

S.Ravat, X.Pons (PH-DT-DI)

In 2013 the team provided technical support to the LHC experiment magnets and auxiliary systems in integration, installation, maintenance of the magnet infrastructure during the LS1. For CMS, LHCb, and ALICE solenoid and Dipole magnets, the reinforcement of the UPS electrical power supply has been done, including also the DSS. DT is designing a new electronic temperature monitoring system with 1500 measurement points for the Solenoid magnet connected to PLC read-out system with Oracle database archiving.

For the ATLAS magnet, the team has designed, engineered and built a 1MW redundant electrical distribution circuit for the magnet vessel safety heaters. This power will be distributed in heat form in order to avoid condensation in the toroid magnet vessels in case of failure of the vacuum conditions. The team has designed a redundant vacuum system based on large turbo-pumps directly connected in the Toroids and EndCaps magnet vessels. This system will provide safety vacuum condition to the ATLAS magnet in case of major services failure in the pit. Due to an integration conflict between the ATLAS magnet equipment and the new Muon chamber detectors to be installed in ATLAS the team made a long and hard intervention in the cavern changing and modifying electrical and mechanical equipment; this work will continue in 2014 because new Muon chamber have been approved for installation in the magnet feet.

The PH-DT Electromechanical Workshop also provided support to different projects. Some examples are DSS racks assembled for ALICE and LHCb, NA62, CMS CO_2 cooling control racks, electronic PCB assembly and electromechanical crate assembly for new Magnet Safety System, TOTEM and ALFA position control test rack, COMPASS and M1 magnets electromechanical support, PH-DT tooling machine conformity acceptance, TE/VSC support for the VT retractable table based on stepper motor of the ATLAS beam pipe.

Left, 1MW redundant power distribution rack being assembled in the electromechanical workshop for the ATLAS magnet safety heaters. Right, parallel connection of DN250 turbo-pump and diffusion pump in the coil 2 of ATLAS magnet.

PH-DT-DI has taken the responsibility of refurbishing the Control and Safety systems of the COMPASS polarized target magnets. This project was an opportunity to implement a new safety system (MSS2) that has been developed by the team, and to technically validate the system on an operational superconductive magnet. MSS2 uses National Instruments CompactRIO devices, a reconfigurable embedded system containing a processor running a real-time operating system (RTOS), FPGA, and interchangeable industrial I/O modules. The new system offers a significant reduction of analogue electronics with respect to the current magnet safety systems (MSS) installed in the LHC experiments, facilitates system maintenance and in opposite to the custom-made MSS, MSS2 is made of industrial components.

By the end of 2013, the control system MCS and the safety system MSS2 were built and connected to magnets instrumentation. To power the magnets, PH/DT and TE/EPC-LPC worked in collaboration to design the electrical circuit composed of two power supplies of TE/EPC-LPC and a magnet discharge system. In March 2014, the full system chain (MCS, MSS2, discharge system, power supplies) was successfully tested, validated and ready to be installed in the COMPASS area. This first successful deployment of the new MSS2 system is an important step forwards a possible application of the systems to the LHC experimental magnets.

6.2.4. B-Field mapping

F.Bergsma (PH-DT-DI)

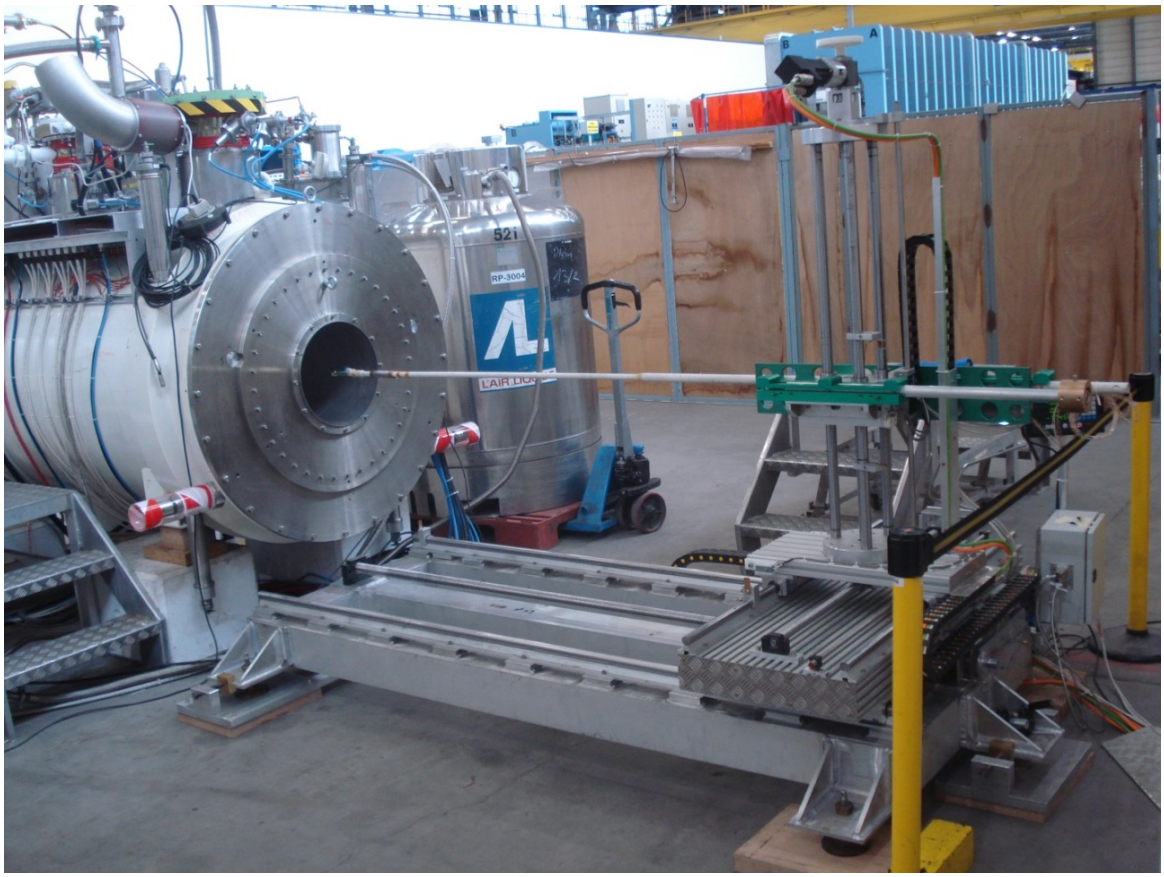
In 2013, the following measurements have been carried out:

- **MICE:** The first MICE 4 Tesla superconducting spectrometer solenoid was mapped at Wang, Livermore CA, during 2 weeks. The electro-pneumatic bench, especially build for MICE by DT, operated well, the calibration of the B-sensors was checked and found to be stable within 0.5 $\cdot 10^{-4}$ after 6 years. A file with correction factors was produced to bring back the precision to 1.0 $\cdot 10^{-4}$. An operation manual for the bench was written and provided to the team, who can from now on take the lead to perform new measurements.
- **NA62**: the NA62 mapping has been completed successfully. A board carrying 60 B-sensors was moved on a 5 m long rail through the MNP33 magnet. The new DAQ software and hardware were tested and used. The newly developed handheld B-monitor was found to be precise within 0.1 Gauss at a level below 10 Gauss, after calibration with a Helmholtz coil built also in DT.

- **COMPASS:** The new 3D-bench was prepared for the mapping of the refurbished COMPASS solenoid. **BE Department**: BE is heavily using an old 3D bench developed and manufactured in DT. Several interventions were necessary to keep the system working.

Development activities of the service were:

B-sensor production: 70 B-sensors + BATCAN-interface produced, calibrated and delivered to CMS.
B-sensor calibration: the new B-sensor calibration station has been completed. Among many improvements related to the mechanics and software, a correction was found for the non-homogeneity of the field. The coils are used as reference, temporarily checked against NMR. Taking into account lab tests that confirmed the effect of high temperature in the Hall Probes, a new system to mount the probes was found using wire wrap technique at cold. The B-sensor calibration station was successfully used to calibrate 70 sensors at 2.5 Tesla for the CMS experiment.
B-sensor DAQ system: the new software of the modular magnetic field monitoring system was tested during the NA62 mapping and showed good performance.
Hall probe station: a systematic lab test is run to check the long term performance of Hall probes. It has been found that GAs Hall probes change sensitivity after exposure to heat (~150 Deg. C). This change disappears after a period of time at room temperature varying from a month to more than a year. On the practical side, this means that Hall probes should not be exposed to heat sources at any stage. For this reason a special soldering process with cooling clamps was developed and seems to work very well on prototypes. The effectiveness and reliability of this procedure will be tested with the new 3D-bench being used in early 2014 to map the COMPASS solenoid. Another approach was tested by development of a mini wire wrap device for 0.05 mm copper wires, which makes soldering unnecessary. A test showed that the wrapped Hall probes didn't show sensitivity changes after 6 months.



3D-bench at Hall 180 COMPASS solenoid.

New 3D bench: It has been completed to the point that it can be used to characterize magnets in experiments. The last months of 2013 were crucial to finalize several aspects. Six different speeds and five measuring intervals can be chosen for the measurements. The device has been moved to Hall B180 where it will be used to map the repaired COMPASS solenoid in early 2014.
Hand-held B-monitor: two prototypes of the hand-held 3D B-monitor were produced. One of them has been intensely used by the NA62 experiment team to measure the stray field in the vacuum tunnel and improvements resulting for this operation have now been incorporated to the construction of the 3rd unit.
Magnetic facility area: it has had 8 users for a total of 17 sessions. Total occupation time 45 days.

6.3. Engineering office

A.Catinaccio (PH-DT-EO)

During 2013, the DT Engineering Section has increased its effectives with the arrival of two new staff, allowing the team to be able to cover a large number of projects planned for next years, such as the upgrades for the LHC experiments and CLIC. The most relevant projects for the EO section this year, covering different aspects related to design, calculation, production follow-up and installation, are listed below.

NA62: large size elements as the Rich Vessels and the Straw Link Interfaces were successfully produced, tested and delivered by the manufacturer. The large hydro-formed Rich Aluminium membrane was manufactured in house by DT. Services for NA62 straw chambers were fully designed and mounted on the first straw chamber. The installation scenarios, support and access structure are in progress. For NA62 Giga tracker, EO section has provided design support to manufacture tooling for handling and accurate positioning bonding of the sensor, cooling system, PCB and the global Giga tracker integration.

CLIC vertex detector: the section participated in the development, optimization and prototyping of carbon fibre structures for the future CLIC vertex detector. In order to measure the efficiency of heat dissipation and the vibration induced by the air flow (cooling) on the staves, a specific test bench was designed and assembled. This test bench will be used and upgraded all along the future project phases.

AIDA: the test beam calorimeter was fully assembled, surveyed by EN/MME, and improved to achieve the physics requirements in terms of 10 microns flatness for the tungsten plates with their positioning distance better than 1mm +/- 50 microns. The device has been delivered and is ready for the 1st test beam at DESY (Hamburg). A new preliminary design has been started for a phase-II device able to decrease the distance between each silicon or tungsten element.

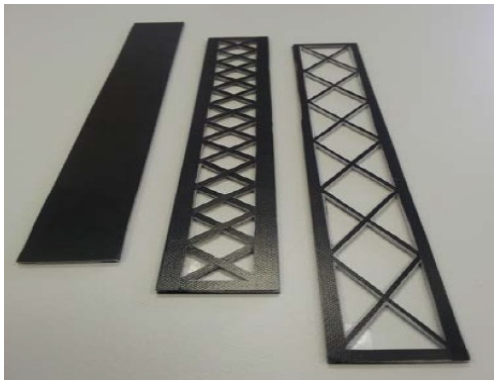
ATLAS: the section has contributed to several projects, as metioned in section 3.2.4.

LHCb consolidation activities during LS1, the section studied and supervised the manufacturing of the HCAL-ECAL extension platform for calorimeter upgrade, and a new visit platform

Micro-systems engineering activities, see section 5.4.

In collaboration with **DT cooling** team, the EO section participated in the improvements of the cooling plant prototype and in launching in production for CMS experiment.

In the support activities to **PH-ESE**, the section has completed the design and supervised the fabrication of versatile transceiver latches and of a DCDC converter holder in order to allow fast assembly.



CLIC vertex Carbon fibre stave prototype.

CLIC vertex Air cooling test bench.

7. EU projects, representation in committees and working groups

The AIDA[3] project addresses the upgrade, improvement and integration of key research infrastructures in Europe, developing advanced detector technologies for future particle accelerators, as well as transnational access to test beams and irradiations facilities. M.Moll (PH-DT-DD) leads AIDA WP8 'Improvement and equipment of irradiation and test beam lines' and coordinates WP8.3 'Irradiation Facilities upgrade'. P.Petagna (PH-DT-DI) is Task leader of AIDA sub-task 9.3C 'Precision Pixel Detector Infrastructure'. He also leads WP13 'Detectors & DAQ: CO_2 cooling' in the Research Infrastructures project CRISP[4] 'Cluster of Research Infrastructures for Synergies in Physics'.

TALENT[5] is an ITN that aims at career development of young researchers in the field of instrumentation for radiation detection. The project focuses on piloting new state-of-the-art technologies on the new precision pixel detector ATLAS Insertable B-Layer detector and for future precision tracking detectors. The project research evolves on advanced radiation sensors, fast and low power consumption read-out and data acquisition electronics, new cooling technologies and ultra light mechanical support structures. M.Capeans (PH-DT-DI) is involved in the overall network coordination as deputy network coordinator. DT hosts one Marie-Curie fellow working on the ATLAS IBL system integration, detector services and infrastructure activities, complemented with R&D on HV-CMOS sensors as a promising technology for future tracker detectors.

Staff from the DT Engineering office hold key roles in the following PH- and CERN-wide engineering committees and working groups: Computer-Aided Engineering Committee (CAEC), Groupe d'Utilisateurs Catia-SmarTeam (GUCS), CAD Use in Experiments (CADEX), and Computational Structural Analysis Committee (CoSAC). DT control engineers represent PH in inter-departmental working groups such as CNIC, GUAPI, Fieldbus, PXI, FESA.

The Indo Swiss Joint Research Program (ISJRP) promotes bilateral research cooperation between Switzerland and India. The project "Radiation Tolerant Silicon Detectors" started in September 2012 for 24 months and covers the exchange of scientists and students between the Delhi University and PH-DT-DD & RD50. The project combines the strengths of the two participating partners: at CERN an in-depth experimental characterization of the silicon sensors is performed while at the University of Delhi complex device simulations using commercial TCAD (Technology Computer Aided Design) software are conducted. During the recent exchange visits a TCT system was setup at the Delhi University and a TCAD simulation program was setup at CERN. Contact: M.Moll

[3] http://cern.ch/aida
[4] http://www.crisp-fp7.eu/
[5] http://cern.ch/TALENT

8. Safety in PH-DT

A.Catinaccio (PH-DT-EO)

During 2013 the group has invested considerable efforts in the conformity for workshops and machine tools. Along the year, thanks to group resources dedicated to this task and the collaboration with the conformity team of EN-MME, almost 150 machines have been put in full conformity. The three main DT workshops, namely 108, 162 and 166 have been equipped with a TRAKA control system to authorize and monitor the use of the machines. Conformity work has also covered the other DT workshops, such as 164, 21, 21, 3, and some rationalization has started by merging the machines of WS25 into WS155 to potentiate the latter. Workshop supervisors have completed the risk assessment for each machine and have equipped them with hazard warning panels as required by HSE. The implementation of the complete WS safety documentation is in progress and includes safety forms, machines manuals, machine conformity database, access control and authorization, safety signs, WS conformity interventions (i.e. fire prevention, noise, layout, evacuation, chemicals, etc.) in collaboration with HSE safety inspectors.

The evaluation of the work needed in matters of safety and conformity for DT labs, research infrastructures and assembly facilities has been launched with a view into defining consolidation and transformation of infrastructures at group level. This includes for instance plans for the upgrade of composite/gluing lab in B153.

9. Secretariat

V.Wedlake (PH-AGS-SE)

In 2013 the DT secretariat continued to provide administrative and secretarial support to the group and to the following collaborations: NA62, RD50, RD51, CLOUD.

10. Selected Publications and Contributions to Conferences Involving DT Members

Detector Development

L.Ropelewski, M.Titov, Micro-Pattern Gaseous Detector Technologies and RD51 Collaboration; Modern Physics Letters A, Vol.28, No. 13 (2013) 1340022

M.Moll, Development of Radiation Tolerant Silicon Sensors - A Status Report of the RD50 Collaboration, PoS (Vertex2013)026 (2013)

R.Dalal, A.Bhardwaj, K.Ranjan, M.Moll, A.Elliott-Peisert, Combined effect of bulk and surface damage on strip insulation properties of proton irradiated n^{+}-p^{-} silicon strip sensors; accepted for publication in JINST.

C.Casella, M. Heller, C. Joram, T. Schneider, A high resolution TOF-PET concept with axial geometry and digital SiPM readout, Nucl. Instr, Meth. A736, Pages 161–168

C.Joram, Imaging results and TOF studies with axial PET detectors, Nucl. Instr, Meth. A732, pages 586–590

Joram, C.; Schneider, T.; Shatalov, P., Measurements and radiation tests on scintillating fibres for the LHCb SciFi project CERN-LHCb-PUB-2014-021

C.Joram, T.Schneider, Mirroring of fibre ends for the LHCb SciFi project , CERN-LHCb-PUB-2014-020

C.Joram, E.Gushchin, Comparative Measurements of the Photon Detection Efficiency of KETEK SiPM Detectors for the LHCb SciFi Upgrade Project, CERN-LHCb-PUB-2014-018

A.Mapelli, Microstructured Devices for HEP and Particle Therapy, 13th Vienna Conference on Instrumentation VCI 2013, Vienna, Austria, 2013

P.Maoddi et al, Scintillation detectors based on silicon microfluidic channels, IPRD13, Siena, Italy

A.Honma, A.Onnela, et al., Detector Module R&D for the Future CMS Tracker, Forum on Tracking Detector Mechanics 2013, Oxford 19-21 June 2013

A.Honma, A.Onnela, et al., Concept for Tracker Inner Barrel with Tilted Modules, Forum on Tracking Detector Mechanics 2013, Oxford 19-21 June 2013

A.Honma, A.Onnela, et al., CMS Tracker services, Forum on Tracking Detector Mechanics 2013, Oxford 19-21 June 2013

H.Danielsson, Design, Construction and Testing of the Straw Tracker for the NA62 Experiment, 2013 IEEE NSS/MIC conference, October 27-November 2, Seoul, South Korea

The ALICE Collaboration, Upgrade of the ALICE Inner Tracking System: https://cds.cern.ch/record/1625842?ln=en

Gas Systems

R.Guida et al., The gas systems for the LHC experiments; IEEE-NSS conference record 2013 N10-6

R.Guida et al., Development of the gas system for the CLOUD experiment at CERN; IEEE-NSS conference record 2013 NPO1-130

R.Guida et al., The new gas injection system for the LINAC4 accelerator at CERN; IEEE-NSS conference record 2013 NPO2-96

M.Capeans, R.Guida, F.Hahn, S.Haider, B.Mandelli, RPC performances and gas quality in a closed loop gas system for the new purifiers configuration at LHC experiments, JINST 8 (2013) T08003

R.Guida et al., Linac4 low energy beam measurements with negative hydrogen ions, Proceedings of the 15th International Conference on Ion Sources (2013), Review of Scientific Instruments 85, 02B122 (2014)

On-detector Cooling and Cooling Systems

A.Mapelli et al., *Low Mass Integrated Cooling,* PoS(Vertex 2013) 046

A.Nomerotski et al., Evaporative CO_2 cooling using microchannels etched in silicon for the future LHCb vertex detector, JINST 8 P04004, 2013

A. Francescon, A. Mapelli, G. Nuessle, P. Petagna, A. Pezous, P. Renaud, G. Romagnoli, Application of Micro-channel Cooling to the Local Thermal Management of Detectors Electronics for Particle Physics, Microelectronics Journal, Volume 44, Issue 7, July 2013, Pages 612-618

G. Berruti, M. Consales, M. Giordano, L. Sansone, P. Petagna, S. Buontempo, G. Breglio, A. Cusano, Radiation Hard humidity Sensors for High Energy Physics Applications Using Polyimide-coated Fiber Bragg Gratings Sensors (Sensors and Actuators B: Chemical, Volume 177, February 2013, Pages 94-102

J.Godlweski, L.Zwalinsli et al., Simultaneous on-line ultrasonic flowmetery and binary gas mixture analysis for the ATLAS silicon tracker cooling control system, ICALPCS 2013, San Francisco CA

L.Zwalinski, J.Daguin, J.Godlewski, J.Noite, M.Ostrega, S.Pavis ; P.Petagna, P.Tropea, B.Verlaat, The control system for the CO2 cooling plants for physics experiments, ICALEPCS 2013, San Francisco CA

A.Mapelli, *Microfabricated on-detector cooling systems*, presented at TWEPP, Perugia, Italy, 2013

G.Nuessle, NA62 GigaTracKer cooling with Silicon Microchannels, ICATPP, Como, Italy, 2013

P.Petagna, Past Experiences and Future Trends on Vertex Detector Cooling at LHC, VERTEX 2013

A.Mapelli, O.A.De Aguiar Francisco, J. Buytaert, A.Catinaccio, J.Degrange, R.Dumps, A.Francescon, C.Gargiulo, K.Howell, M.John, M.Morel, J.Noel, A.Nomerotski, G.Nuessle, P.Petagna, G.Romagnoli, P.Renaud, M.VanStenis, B.Verlaat, Low Mass Integrated Cooling, Proceedings of Science (Vertex 2013) 046

A.Francescon, Thermal management of the ALICE ITS detector at CERN with ultra-thin silicon micro-channel devices, Presented at the 8th World Conference on Experimental Heat Transfer, Fluid Mechanics, and Thermodynamics, Lisbon, Portugal, 2013

The Thermosiphon cooling system of the CERN ATLAS Experiment Inner Detector, 8th World Conference on Experimental Heat Transfer, Fluid Mechanics, and Thermodynamics June 16-20, 2013, Lisbon, Portugal

Control systems

S.Ravat, L.Deront, A.Kehrli, X.Pons, A Safety System for Experimental Magnets Based on CompactRIO, Proceedings of ICALEPCS2013, San Francisco, CA, USA

G.Maire, A.Kehrli, S.Ravat, H.Coppier, The detector safety system of the NA62 experiment, Proceedings of ICALEPCS2013, San Francisco, CA, USA

G.Maire, A.Kehrli, M.Pezzetti, S.Ravat, B.Charnier, H.Coppier, Evaluation and implementation of advanced process control with the CopmactRio material from National instruments, Proceedings of ICALEPCS2013, San Francisco, CA, USA

X.Pons, S.Ravat, F.Ravotti et al., A Movement Control System for Roman Pots at the LHC, Proceedings of ICALEPCS2013, San Francisco, CA, USA

L.Zwalinksi et al., Experimental infrastructure control systems development; HEPTech Academia - Industry Matching Event on Technology of Controls for Accelerators and Detectors in Athens 2013

Experiments

R.Oldeman, R.Paluch, B.Schmidt, *Additional shielding behind the LHCb Muon detector,* LHCb-PUB-2013-021

J.Almeida, A.Onnela et al., Molecular understanding of amine-sulphuric acid particle nucleation in the atmosphere, Nature, Volume 502, 17 October 2013, 359-363 [doi:10.1038/nature12663]

R.Schnitzhofer, A.Onnela et al., Characterisation of Organic Contaminants in the CLOUD Chamber at CERN, AMT Atmospheric Measurement Techniques, amt-2013-177, 2013

Outreach

Available at the PH newsletters, CERN Physics Department, http://ph-news.web.cern.ch/supporting-groups/dt

- P.Petagna, Using CO2 for detector cooling - an innovative approach
- F.Ravotti, M.Glaser, The new proton & mixed-field Irradiation facility at CERN PS
- M.Moll, The RD50 Collaboration - Radiation tolerant silicon detectors
- M.Capeans, RD50 and RD51 research projects on silicon and gaseous detector developments
- M.Capeans, PH-DT activities in 2012
- L.Ropelewski, M.Titov, The RD51 Collaboration: Development of Micro-Pattern Gas Detectors Technologies
- C.Joram, Axial PET: Applying novel ideas in PET geometry
- M.Moll, Towards radiation tolerant silicon sensors – News from RD50

Editors: M.Capeans and P.Martinengo for PH-DT

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