Detector Technologies Group PH-DT

The mandate of the PH-DT group comprises development, construction, operation and maintenance of particle detectors for the experiments at CERN. The group clusters common services and infrastructure, which are available to all experiments at CERN, e.g. gas system support, thin film lab, silicon facility with bond lab, irradiation facilities, magnet operations support, B-field mapping, instrumentation and controls.

The group is organized in 5 sections (see also on the figure on the following page):

- DT/PO Project Office
- DT/DI Detector Infrastructure
- DT/TP Technology and Physics
- DT/EM1 Engineering and Mechanics 1
- DT/EM2 Engineering and Mechanics 2

As a consequence of retiring staff not compensated by new recruitments, the group head count decreased to about 75 staff plus 20 fellows and students. We collaborate with two Field Support Units (FSU) in the gas systems and controls activities. Most of the group activities are carried out by teams composed of physicists, engineers and technicians from several sections. It is therefore mainly the projects and services which define the working relations within the group.

In 2010 the group's activities were concentrated in four areas:

1. Completion and consolidation of the ongoing LHC projects (ATLAS ALFA, TOTEM RP);
2. Maintenance and operation: 'on-call' services, shutdown and preventive maintenance, repairs for detector systems and infrastructure;
3. New detector projects: participation in new developments (LHC upgrade, non-LHC experiments);
4. R&D: participation in common R&D activities in strategic fields.

While the structure and mandate of the group were identical to the previous year, we observe a further and natural move of resources from LHC activities (now at 40%; this includes projects (25%) and services to LHC experiments (15%)) to other areas. The fraction of the non-LHC experiments (CLOUD, Aegis, NA62, CAST) remained at about 15%. Services to non-LHC experiments and R&D represent about a third of our activities. About 10% of the resources are needed for general service tasks (workshop supervision, safety and management).

A comprehensive and anonymous survey among all DT staff and fellows was conducted with the goal to identify areas where improvements and corrections were needed. The survey addressed the areas group management, sections, projects and individual roles. The survey can be considered as representative, as 74% of the 88 distributed questionnaires were returned. The overall result (3.04 on a scale from 1 to 4) was satisfactory however there were significant differences when comparing different job categories (technicians, technical engineers, engineers and physicists). The results were presented and discussed in a dedicated group meeting and followed up in section meetings.

The following diagram lists the current DT staff members, fellows and doctoral students.

PH-DT-PO
BAULT, Christophe
CATINACCIO, Andrea
DAVID, Eric
GODLEWSKI, Jan
HATCH, Mark
JAMET, Olivier
LENOIR, Philippe
ONNELA, Antti
PETAGNA, Paolo
TROPEA, Paola
WERTELAERS, Piet

PH-DT-DI
BERGSMA, Felix
BLANC, Pascal
BOURGEOIS, Nicolas
BRAEM, Andre
CAPEANS GARRIDO, Mar
CARRIE, Patrick
D'AURIA, Andrea
DAVID, Claude
DE MENEZES, Louis-Philippe
DERONT, Laurent
FORTIN, Richard
GLASER, Maurice
GUIDA, Roberto
HAIDER, Stefan
MAIRE, Gilles
MCGILL, Ian
MERLET, Frederic
OLESEN, Gert
PAVIS, Steven
PONS, Xavier
RAVAT, Sylvain
SCHNEIDER, Thomas
VAN STENIS, Miranda
WASEM, Albin

PH-DT-TP
DAVENPORT, Martyn
GYS, Thierry
HAHN, Ferdinand
HONMA, Alan
JORAM, Christian
KLEMPT, Wolfgang
MARTINENGO, Paolo
MOLL, Michael
ROPELEWSKI, Leszek
SCHMIDT, Burkhard
TAUREG, Hans

PH-DT-EM1
ANSTETT, Didier
BOUVIER, Philippe
CANTIN, Bernard
DENARIE, Charles-Henri
DUMPS, Raphael
FRAISSARD, Daniel
IJZERMANS, Pieter
KOTTELAT, Luc
KRISTIC, Robert
LESENECHAL, Yannick
LOOS, Robert
PERINI, Diego
PIEDIGROSSI, Didier
VAN BEELEN, Jacob

PH-DT-EM2
BENDOTTI, Jerome
BODE, Alain
BRUNEL, Bernard
CHARRA, Patrick
DANIELSSON, Hans
DIXON, Neil
FOLLEY, Adrian
GARNIER, François
GIUDICI, Pierre-Ange
GONCALVES, Antonio
NOEL, Jerome
PEREZ GOMEZ, Francisco

FELLOWS, DOCT. STUDENTS, TECH. STUDENTS, PROJ. ASSOCIATE
BELTRAME, Paolo ; CASTILLO GARCIA, Lucia ; DAGUIN, Jerome ; DOLENC, Irena ; DROZD, Adam ; GABRYSCH, Markus ; HELLER, Matthieu ; LA ROSA, Alessandro ; MAPELLI, Alessandro ; MARTOIU, Victor ; MARTOS, Vasileios ; MAURISSET, Aurelie ; MOLNAR, Levente ; PACIFICO, Nicola; ROUWETTE, Sander; RUZ ARMENDARIZ, Jaime ; SCHINDLER, Heinrich ; SERGI, Antonino ; VAFEIADIS, Theodoros ; VILLA, Marco ; VEENHOF, Robert ; XYDOU, Anastasia ; ZWALINSKI, Lukasz

In the following we present the group activities in the areas Detector Projects, Services, R&D Activities and Other Activities.

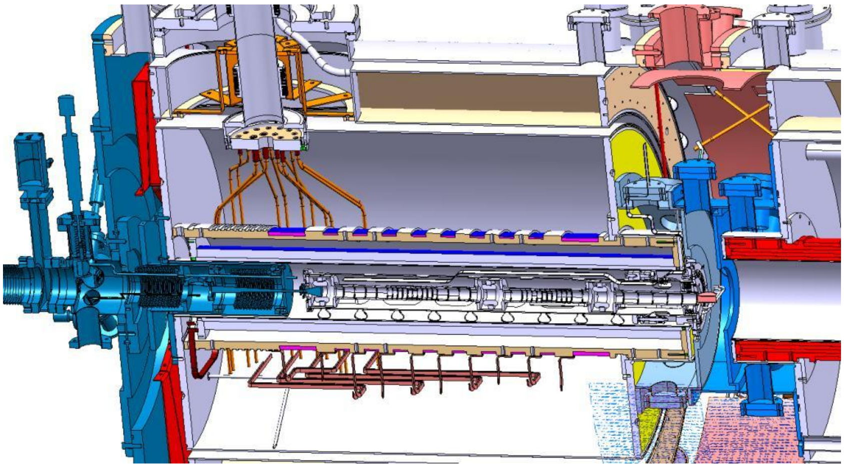
Detector Projects

AEGIS

During the past year we worked on the design of AEgIS infrastructures and we started the production of the first components.

DT technicians manufactured the superconducting solenoids. Both the main coils and the correction coils were wound in the work shop in building 164.

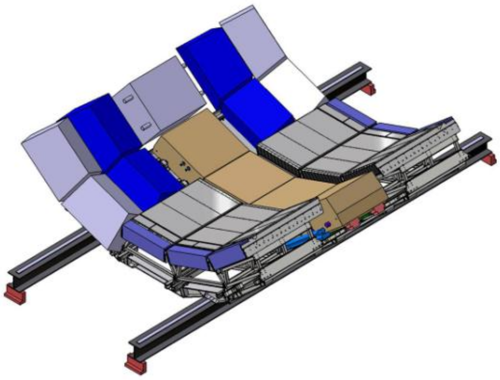
The detailed design of the main components of the experiment is almost completed and the integration of is well advanced. Call for tenders for the different components are launched and the goal is to test the solenoids and install the first elements in the experimental area during summer 2011.



Cross section of the catching region of the experiment. Antiprotons arriving from AD (coming from the right side in the picture) are prepared in bunches inside the traps (in grey in the picture) and then sent in the recombination region (on the left side of the picture and only partially visible) to produce the anti-hydrogen. The traps are at 4.2 K temperature and are inside a 5 T superconducting solenoid. The cryostat and the current leads are shown as well.

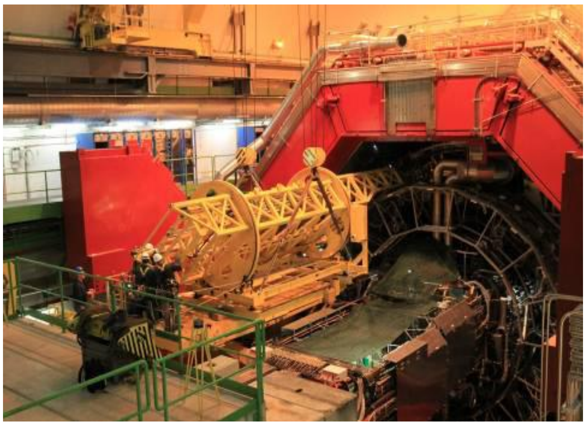
ALICE

In 2010 the DT group provided technical support to the ALICE experiment in several different fields, from the maintenance and operation of the gas systems at P2 to the operation of the experimental magnets. The involvement of the group in the maintenance and operation of the TPC and HMPID detectors continued while the group started contributing to the preparation of the experiment upgrade, namely the DCAL, ITS and VHMPID projects. The complete redesign of the support structure at the bottom of the ALICE solenoid (including re-routing of services), was completed in order to accommodate the newly proposed VHMPID and DCAL detectors and the already present PHOS calorimeter (see Figure).

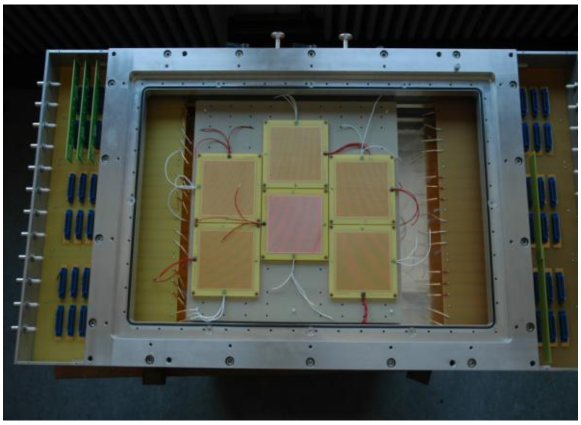


View of the new support structure to hold the VHMPID (upper left), PHOS (center, in tan) and DCAL detectors at the bottom of ALICE

The group was finally strongly involved in the preparation, supervision and execution of the work during the technical stop at the end of year, during which the EMCAL installation was completed and 3 additional TRD modules put in place while several maintenance interventions took place in order to guarantee optimal detectors performance in 2011. The preparatory work in view of the long shutdown foreseen in 2013 also started with the design and construction of the support structures and tools for the installation, access and maintenance of the detectors.



Installation of one EMCAL super-module



View of the TGEM prototype

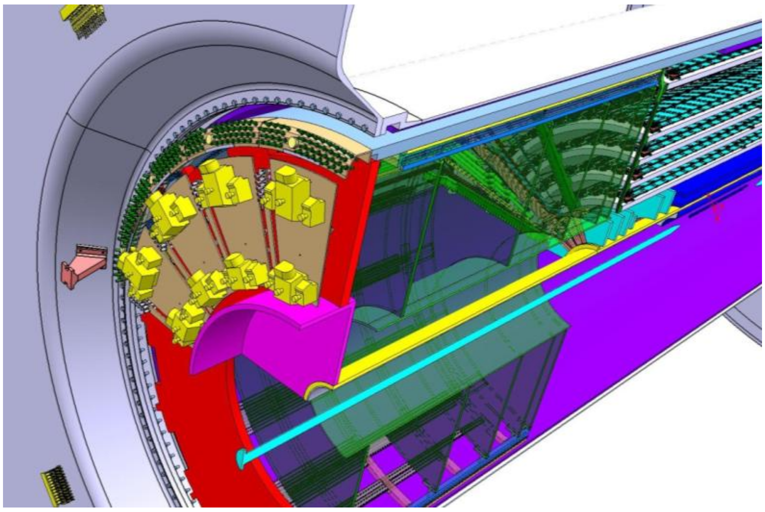
In the framework of the VHMPID project a prototype of a RICH detector based on the TGEMs (Thick GEM) coated with CsI technology was developed and successfully tested with beam of charged particles in the T10 experimental area.

ATLAS

As every year, the team has been involved in the shutdown activities driven by ATLAS technical coordination.

ATLAS upgrade

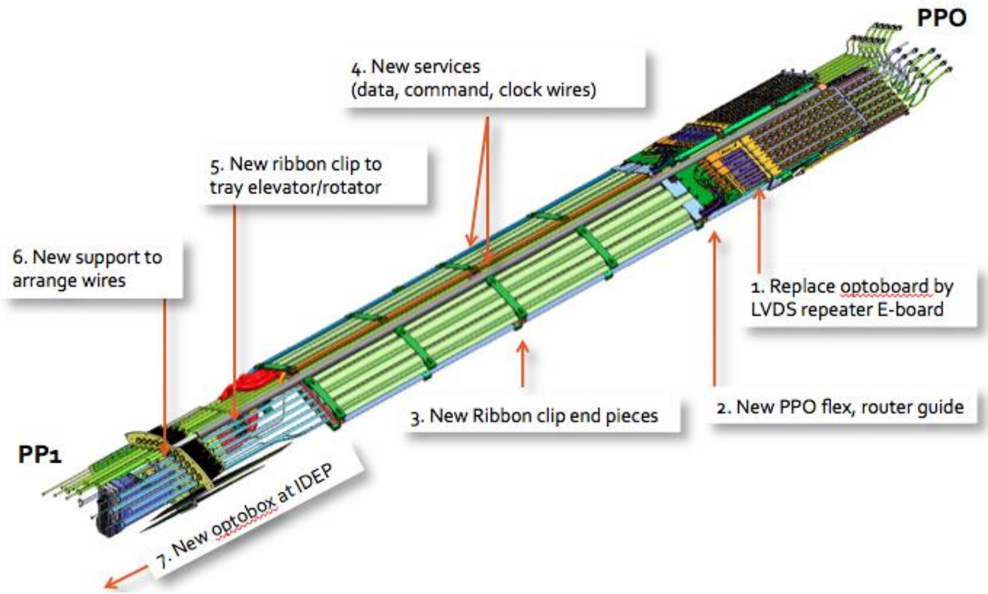
Collaborations for upgrade projects include the main coordination role in the engineering design and integration for the Tracker upgrade, together with the participation in the Insertable B-Layer (IBL) project and the New Services Quarter Panel (nSQP) project for the Pixel detector.



Developed 3D model for the fully integrated new tracker.

Specific activities for the High Luminosity LHC Tracker upgrade project include new conceptual studies and scenarios for future access and in situ maintenance and repair.
The IBL is a fourth layer added to the present Pixel detector between a new beam pipe and the current inner Pixel layer (B-layer). DT contributes to the overall IBL design and is in charge of constructing a real size, active IBL prototype for the full validation of the detector concept.

The Pixel nSQP project was launched by ATLAS in autumn 2010, motivated by the concern that on-detector optical transmitters (VCSELs) may be subject to failures. As these components are embedded in the non-accessible, existing SQPs, a new set of nSQPs where the optical readout is replaced by electrical readout, will be manufactured and possibly installed in Pixel detector during the next long shutdown. The coordination role, mechanical support and quality assurance are project aspects where DT staff is involved.

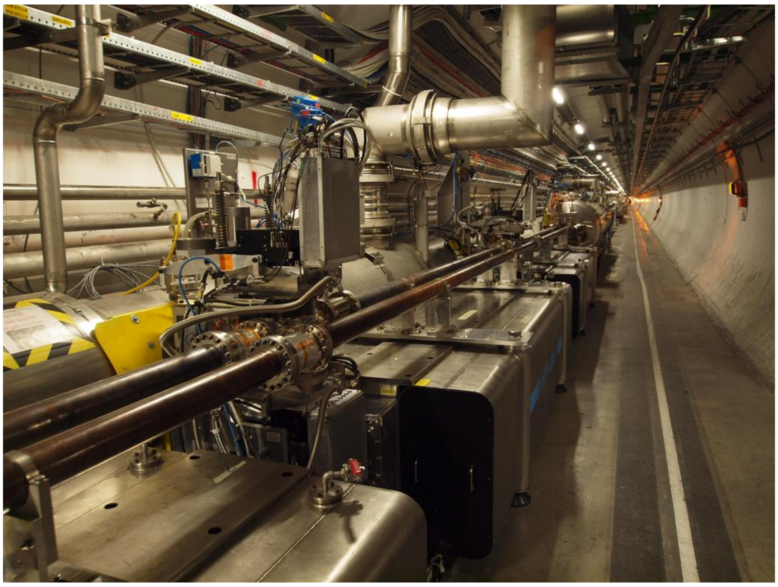


3 m long, new Service Quarter Panel for the Pixel detector. The main changes related to the replacement of the optical by an electrical readout are shown.

ATLAS ALFA Roman Pots

ALFA consists of four so-called Roman-Pot Stations containing tracking detectors positioned in the LHC tunnel on both sides of the ATLAS detector, at a distance 240 m. The Roman Pots can be moved

remotely thus allowing the detectors to be positioned to within 1.5 millimetre of the LHC beam after the beam has been injected and accelerated.
2010 was a crucial year for the ALFA project and for the DT team. The production of all components was completed and integrated by us and colleagues from the ESE group to full detector modules. Complete metrology of all 8 detectors has been carried out on our 3D TESA measurement device. All Roman Pot stations including all detectors and front-end electronics sets were extensively checked in a beam test in H6. The typical efficiency of a fibre layer was found to be 94%, close to the theoretical maximum of 96%. The expected resolution of between 25µm at the centre and 35µm at the inner edge of the detector was confirmed. In December 2010, all 4 ALFA stations were installed in the LHC tunnel, the 8 detectors inserted and the positions were surveyed and calibrated with a laser tracking device to a precision of 5µm. The full system was checked before the LHC tunnel was closed for the 2011 run, the read-out was synchronized to the LHC clock and the remote ALFA motor control was integrated into the LHC control and interlock system. While the ALFA team waits eagerly for the first data from LHC runs, the major part of the DT mission, which involved about 10 people, is now successfully completed. We will of course also play a major role in the foreseen M&O work, including the regular removals and installations of the ALFA detectors.



ALFA Roman Pot station installed in LHC tunnel.

CAST

The group gives support to the CAST experiment in the areas of technical coordination, operation of the ^3He system, operation of a Micromegas (MM) detector, mechanical and electrical components of the magnet movement system, cold windows, slow controls and vacuum interlocks.

In 2010 the mechanical support designed and installed a cable support to relieve stresses causing aging in the 13kA water cooled cables for the CAST magnet.

The Controls group added humidity sensing wires to give early warning of leak. This group also installed environmental monitoring probes (temperature, humidity and radon) in the CAST experimental zone and connected them to the CAST Slow Control. Further safety interlocks were added to the magnet movement system and load pins. The EMC protection of the frequency inverters controlling the magnet movement motors was improved to eliminate intermittent noise pick-up seen in some detectors.

The ^{3}He gas system safety was reviewed in 2010 in view of the CAST pressure scan moving into the range of highest pressures. An expert committee from PH-DT & TE-CRG made recommendations which were implemented by PH-DT and TE-CRG. The precision ^{3}He system ran safely and smoothly throughout the 2010 scan reaching a final ^{3}He pressure in the cold bore of 82.5 mbar at 1.8K corresponding to an axion rest mass of 1.01 eV/c^{2}. CAST has now penetrated well inside the theoretically-favored region for the axion and beyond the KSVZ(E/N=0) line for the first time at these high masses.

The extreme conditions inside the cold bore give rise to large Van der Walls effects. A PH-DT Fellow has been leading a CAST team advised by experts in EN-CV to make and analyze simulations using Computational Fluid Dynamics(CFD) and compare this with measurements on the CAST magnet itself. The aim is to understand the gas dynamics and density distributions of the ^{3}He along the cold bore which are essential inputs for the axion conversion physics. A very important advance in our understanding was made this year.

A PH-DT doctoral student has been responsible for the day-to-day operation and calibration of a MM detector (IRFU-Saclay) on the Sunrise side of the CAST magnet. In parallel a test lab is being set up within the group to calibrate detectors using a variable energy x-ray beam line.

CLOUD

Two beam runs were successfully completed by CLOUD in 2010: June-July and October-November, and a paper was recently submitted to Nature on the results obtained. DT contributes to the experiment by an engineer acting as the Technical coordinator and GLIMOS, and a technician providing support to the experiment's construction and maintenance activities. The DT thin film workshop made coatings on many components needed for CLOUD's UV-light systems.

As the main technical changes the CLOUD experiment's thermal and humidity sealing was substantially improved in spring 2010 and allowed operation down to -30^{o}C. Another essential new part was a set of 4 thermally insulated racks that were constructed and installed around the CLOUD aerosol chamber. These racks allow cooling down measurement instruments, to follow the operating temperature of the aerosol chamber. The thermal system improvements have been done in close collaboration with EN-CV and a visiting CLOUD technician.

CLOUD experiment ready for beam in the PS East Hall.

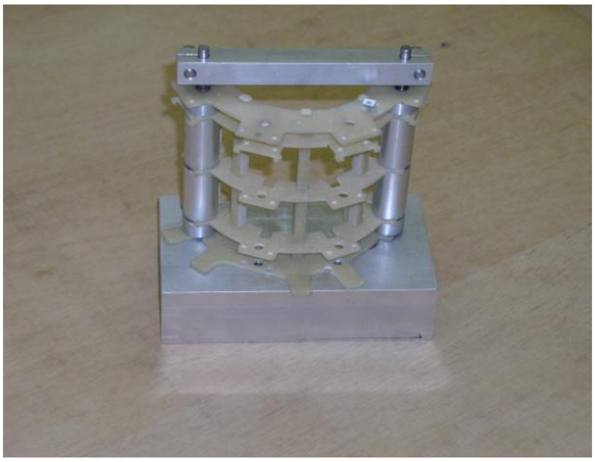
CMS

Detector operation

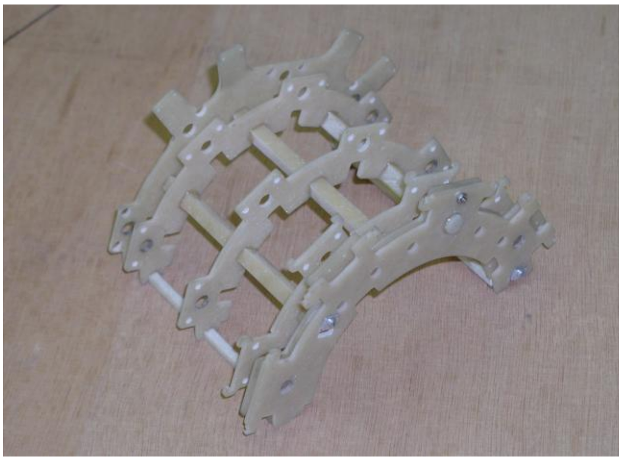
During the otherwise very successful operation of the CMS detector 1 of the 7 cold-temperature C6F14 cooling plants (SS2 plant of the Silicon strip tracker) showed again increasing leak problems. Several members of the DT group participated together with their EN-CV and CMS colleagues in the cooling leak-search, system improvement and maintenance activities. A dedicated Leaks Task Force was established in November 2010 and coordinated the activities through the Christmas 2010-2011 stop.

Engineers from DT act as the CMS Cooling coordinator and as the Tracker Upgrade Mechanics and Thermal system coordinator.

DT is also providing support to the design and integration of the new Pixel Luminosity Telescope (PLT), a part of the ambitious Beam Radiation Monitoring (BRM) program at CMS. In 2010 DT participated to the design of the new support structure of the PLT, including its servicing, integration and alignment philosophy. The new PLT design was fully endorsed at the EDR, and a first mock-up was constructed and successfully tested.



New structure for the PLT in the gluing jig



The very light structure itself

CMS Upgrade

In the frame of the phase I upgrade of CMS, DT has accepted to take the responsibility for the design and construction of the new CO2 cooling plant for the upgraded PIX detector. The first activities launched in2010 have been an experimental support to the definition of the on-detector cooling parameters of the new PIX, and the re-qualification of the PIX pipes presently installed in CMS for the higher pressures involved by a CO2 cooling.

Several of the DT R&D lines launched on cooling for the experiments are closely followed by CMS.

LHCb

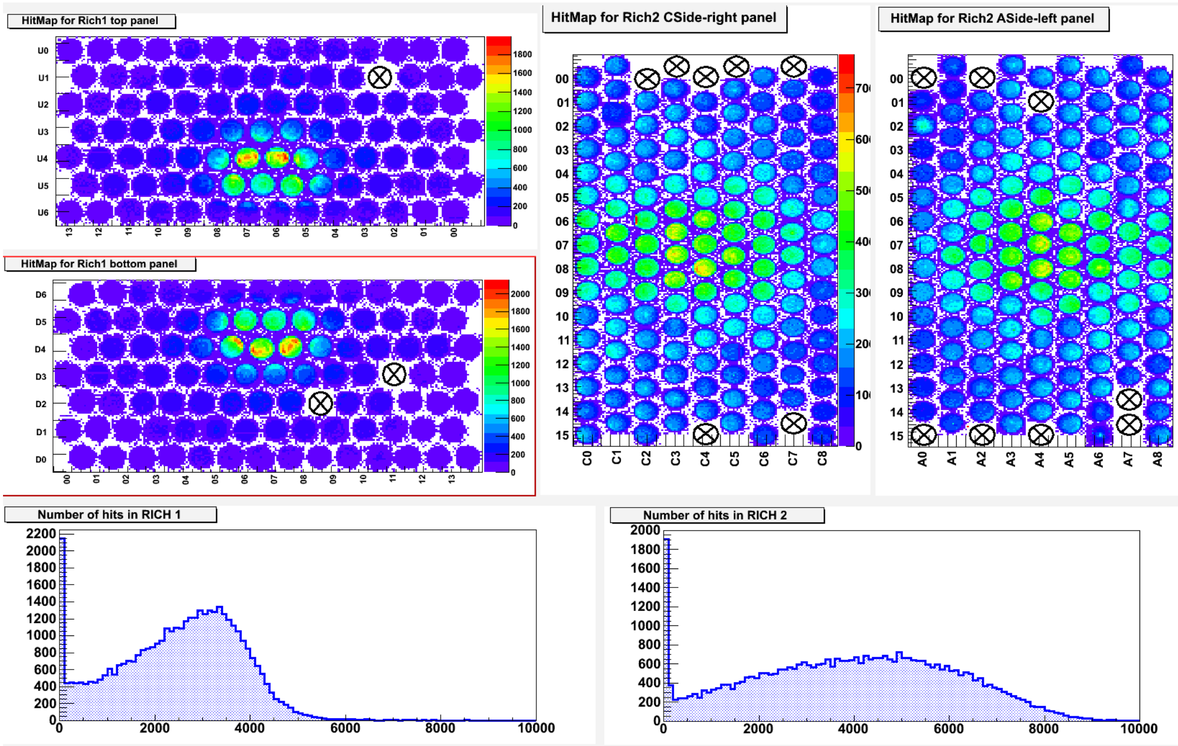
Detector Operation

The DT group has carried out operation and maintenance activities for various LHCb sub-systems, in particular VELO, RICH and Muon detectors. Also the winter shutdown activities have been successfully completed by early February 2011 and the LHCb detector is in excellent shape for the 2011 LHC proton physics run.

The group participated also in the test beam activities for the VELO upgrade project and improved a beam telescope, providing rotations around all axes. The setup is capable of handling the new

RELAXD readout boards and testing irradiated devices at stable temperatures and stable mechanical conditions including a remote controlled movement. This involved the integration of an intricate Peltier cooling system together with high thermal conductivity cooling tapes integrated in the sample supports.
In addition, a laser stand for the evaluation of Timepix chip has been prepared, enabling time over threshold versus time of arrival calibrations to be performed in vary stable conditions. The set up has been copied for other labs as well.

As responsible for LHCb-RICH pixel hybrid photon detectors (HPDs), the group has conducted the replacement of 40 vacuum-degraded HPDs. It has been deeply involved in the detector performance optimization and in laboratory investigations of aerogel performance degradation induced by fluorocarbon gas contamination. Moreover, the repair and further optimization of the HPD high voltage system has been carried out.
The LHCb-RICH detectors have been operating optimally and successfully in 2010 (see Figure below). Particle identification performance was excellent, as are showing the physics results from the LHCb collaboration.



LHCb-RICH HPD hit maps. The 3 "missing HPDs" in RICH1 (left) are caused by dead VCSELs that do not transmit data (the corresponding HPDs are fine). Two VCSELs are dead too in RICH2 (the corresponding HPDs are fine), the peripheral HPDs are replaced by anodes.

The group continued also to participate in the operation of the Muon system. After optimizing the electronics thresholds in 2009, the HV settings have been further optimized during 2010 in order to minimize detector aging effects. Problems which appeared on some chambers during the 2010 proton physics run were due to insufficient conditioning of these chambers prior to their installation and could be overcome by an in-situ conditioning procedure. The overall performance of the Muon system has been very good during the first LHC physics run, which is also reflected by the fact that most of the published analysis of LHCb use the muon trigger and have muons in the final state. The number of dead readout channels was at the 0.5% level.

LHCb Upgrade

Within the framework of the LHCb-RICH upgrade and in particular the TORCH project, the timing and gain performance of commercial Micro Channel Plate Photon Detectors with segmented anode are being investigated in the laboratory.

NA62

In December 2010 the NA62 collaboration completed a Technical Design (TD) document describing the design layouts and the expected performance of the experimental set-up in detail.
It contains a description of:

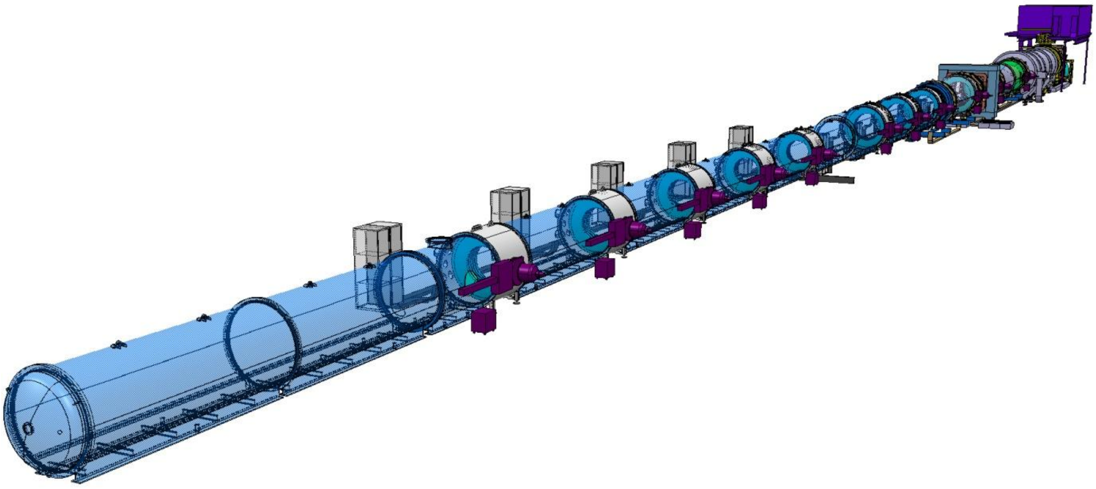
- The high intensity K^+ beam line and the beam defining detectors (CEDAR, GTK and CHANTI)
- The downstream detectors (Photon Veto, Straw Tracker, RICH, CHOD and MUV)
- The Readout and data handling

The participation of PH-DT in the experiment is twofold:

1. Technical Coordination and detector integration
2. The construction of the Straw Tracker, which is done in collaboration with JINR.

Technical Coordination

To make room for the future experiment, the year 2010 started with the dismantling of the former NA48 beam line and detectors, i.e. beam magnets, Hadron Calorimeter, Muon Counters, AKL's and Wire Chambers. Several of the dismantled detectors were discarded, but some are refurbished and will be re-used in NA62 or in other experiments. For example, the NA48 Wire-Chambers were delivered to JINR (Dubna) where they will serve the MPD experiment. The Magnet "MNP33" was dismantled, refurbished and re-assembled in the new NA62 position (30 m upstream with respect to the former location). The nineteen decay vacuum tank elements that will be re-employed in the future have been cleaned and refurbished. Studies have been launched for the necessary upgrades of the infrastructure, both in the TCC8 and ECN3 caverns and in the surface buildings. Correspondingly a budget has been prepared.

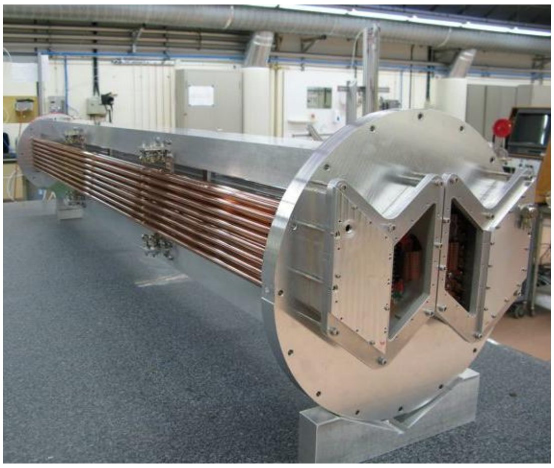


Important progress was made on the 3D CAD modeling of the new experiment. All relevant sub-detectors have been represented in CATIA and these models are used for installation and integration studies. In the next months the models will be extended to the auxiliaries and services.
The spatial coordinates of several fiducial points in the experimental area have been re-measured, in order to establish reference coordinates for the future axis of the experiment. This reference axis has been defined as a straight line between the T10 target (located 15m from the beginning of TCC8)

and the exit of the LKR calorimeter (located 240m further downstream)). Further fiducial marks along the experiment axis will then be used to position the beam elements and the sub-detectors.

The Straw Tracker

The purpose of the Straw Tracker is to measure with good accuracy the direction and the momentum of secondary charged particles originating from the decay region. The spectrometer consists of four chambers intercepted in the middle by a high aperture dipole magnet providing a vertical B-field of 0.36T. Each chamber is equipped with 1'792 straw tubes (two modules) in order to provide full efficiency, remove left-right ambiguity and provide at least one space point for the tracks. The main element of the detector is an ultra-light straw tube, which is 2.1m long, and 9.8 mm in diameter. The tubes are manufactured from 36 μm thin PET[1] foils, coated –on the inside of the tube- with two thin metal layers (0.05 μm of Cu and 0.02 μm of Au) to provide electrical conductance on the cathode. The anode wire (Ø=30 μm) is gold-plated tungsten.
A prototype to host 64 2.1 m long straws was designed, built and tested in 2010. The assembly of the first module (996 straws) is planned to start in the spring 2011.



64-straw prototype

Module frame in Aluminium (996 straws)

TOTEM

The group was active mainly in the Roman Pots (RP) project and supported the installation of the T1 detector inside CMS. In the second half of the year, a DT physicist took over the Technical Coordination of the whole TOTEM experiment and subsequently changed group affiliation to PH-TOT.
The DT group participated in the production, testing and installation of the RP detectors with full responsibility for all mechanical, the assembly of the silicon modules, their integration with the cooling circuits, the secondary vacuum and the movement control of the pots. The 12 RP detectors installed during the previous shutdown (at 220 m), proved to work reliably and produced already first physics results. During the shutdown 2010/11, the second batch of 12 RP detectors was installed and fully commissioned, completing the full RP system. The RP motor systems which allow moving the RPs within the LHC beam pipes were calibrated and tested in close collaboration with LHC. The vacuum equipment for the secondary vacuum in the RP envelopes was installed and tested. As in the ATLAS ALFA, the group will continue to provide support for M&O activities during operations and shutdowns.

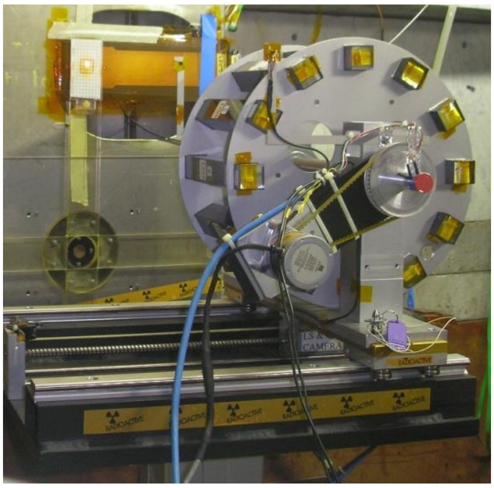
[1] PET = polyethylene terephthalate

Totem near station at 220m

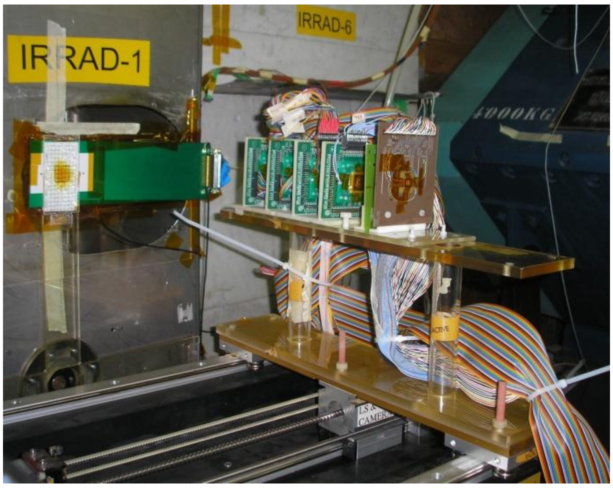
SERVICES

Irradiation Facilities

In 2010 the PS proton irradiation facilities were operated throughout 175 days. In total 557 objects were irradiated and 1003 dosimeters were analyzed in order to provide the facility users with a precise and reliable particle fluence measurement for their respective individual object under test. As in previous years the facilities served a wide international user community with main focus on activities related to the upgrade of the LHC. Irradiation experiments were performed for ATLAS, CMS, LHCb, RD42, RD50, NA62, LHC-Magnets, RADMON, PH-ESE, CERN RP and other groups and projects. In addition to the irradiations at CERN a pion irradiation campaign was organized and performed by PH-DT and a PSI team in which 160 objects were irradiated with 300 MeV/c pions for ATLAS, CMS and RD50.



Rotating support structure for irradiation of 12 scintillating crystals mounted on a y-z table (constructed in collaboration with PH-CMX)



Irradiation test of prototype chips for the ATLAS Pixel upgrade (FEC4 in 130nm CMOS technology). In the background a new beam profile monitor is visible.

The Gamma Irradiation Facility (GIF) in bldg. 190 was maintained and made available to several users. The "Facilities and Component Analysis for Detector R&D" working group (PH-R&D project WP7) was the main user. In view of the limitations of the present facilities and the increasing demands in terms of particle fluence and complexity of the irradiation experiments, an upgrade of the facilities is under consideration. Within the interdepartmental "Working group on future irradiation facilities at CERN" the need for future facilities has been evaluated and corresponding conclusions were presented to the management, the LHCC and the SPSC. First steps towards new facilities were taken by designing a new GIF++ facility and successfully including the PS facilities upgrade planning and the GIF++ user infrastructure into the FFP7 AIDA project.

Radiation Monitoring

In the framework of the PH RADMON project further RADMON boards and dosimeters were provided to the LHC Experiments. In total about 80 RADMON boards and 60 sensor packages are now installed in ALICE, ATLAS, LHCb and TOTEM and working according to their specifications. The continued interest of the LHC experiments in the delivered devices was expressed in further requests for RADMON devices for 2011.

Solid State Detector Lab

The infrastructure of the solid state detector laboratory in bldg.28 was extended with a new Edge-TCT (Transient Charge Technique) system. It allows characterizing the electric field depth profile inside a semiconductor strip detector by means of a pulsed infrared laser focused on the side (edge) of the sensor. Furthermore, a second ALIBAVA system for charge collection efficiency measurements of structured sensors and a cold chuck system were installed. Part of the laboratory equipment was made available to colleagues from CMS, Le-Pix, PH-ESE, TOTEM, RD39 and RD50.

Bondlab

The main effort concerned finishing Totem Roman Pot modules and spares, Medipix bonding (Mpx2, Mpx3, Timepix), ATLAS pixel R&D (sensors and read-out chips) as well as CMS silicon sensor upgrade studies. Other jobs included: PH/ESE (many different chips on test PCBs), RD50, RD51, NA62, ATLAS (ALFA, LUCID), ILC detector (tracker, ECAL), LHC beam condition monitors and numerous other small jobs. The Bondlab is busier than ever given the loss of a part-time technician whom we hope can be replaced in 2011. In addition to the standard gluing and wire bonding activities, a significant amount of time was spent giving advice and aid for detector construction and connectivity issues to several projects.

Quality Assurance and Reliability Testing (QART)

This new lab founded in 2008 was still a WP6 activity in 2010 but it became part of PH/DT at the end of the year. Based around a high-end environmental chamber and powerful vibration test system, in 2010 the lab procured a small aperture high field (2T) electromagnet for testing of small devices in magnetic fields similar in magnitude to those in the LHC experiments. The lab equipment has been used by many of the LHC experiments (ATLAS, CMS, ALICE, TOTEM) for understanding the existing detectors as well as doing testing on prototypes for the upgrades. In addition, many non-LHC experiments and projects have benefitted from the resources of this new lab: Medipix, NA62, CERN radioprotection, CLIC R&D. Research in progress being pursued by the two QART lab scientists include studies of bond wire damage from resonant vibration in magnetic fields, tests of reliability of new metallizations of PCBs, and studies of risk to silicon detector modules from vibration and shock encountered during transport and handling. Another continuing activity is the building a library of QA and reliability testing documentation, procedures, and standards.

A QA workshop is planned for 2011 to try to learn from the LHC experiments silicon detector construction experience so as to better prepare for the next generation of silicon detectors.

DSF (Departmental Silicon Facility)

Alice pixel, CMS silicon tracker upgrade and occasionally Medipix are still active in DSF clean room. A meeting with all 4 main LHC experiments and other users took place in 2010 to discuss usage of clean and non clean room for the future. The conclusion was that no clear picture for the near future could be determined until the future LHC schedule was decided (some key decisions were expected for end of January 2011). Thus discussions concerning longer term usage of the facilities was postponed until it was more clear what would be the revised planning of the LHC experiments given the expected delay in the long shutdown(s) of the machine. Until then the DSF is open to short-term smaller scale projects needing clean room facilities.

Thin Film and Glass Lab (TFG)

In 2010 the Thin Film and Glass lab continued to provide support in term of thin films coatings and glass/ceramics machining to different experiments. The main activities were: CNC machining of different glass quartz pieces, production of CsI photo-cathodes and VUV mirrors for the upgrade of the ALICE/RICH, metallization of quartz fibers and development of transparent/conductive coatings for the CLOUD environmental chamber. In the framework of the ATLAS/ALFA collaboration, the mass production of about 30.000 aluminum coated scintillating fibers was completed in 2010. A major upgrade of our VUV reflectometer and e-gun deposition devices has been launched in order to face the reflective coatings foreseen to take place in 2011 toward the RICH detectors of ALICE and NA62. Another special application in the TFG lab is the coating of wave length shifting materials (TPB/p-Terphenyl/CSI).

Nowadays the glass part of the lab is focused on machining of hard materials with specific diamond tooling. Prototypes or small series out of standard floating glass, quartz, ceramics as well as sapphire can be machined. For example, pieces out of sapphire for the AEGIS experiment and different approaches out of Pyrex used as end-plugs of micro channel cooling for NA62 have been successfully produced.

Gluing service

In the gluing service we provide expertise in gluing techniques and adequate surface preparation. A major job in 2010 was the preparation of 30 tungsten absorbers for the Linear Collider Detector (LCD) calorimeter test. The tungsten sheeted were glued on steel supports and framed in an Aluminium structure. The service got also involved in gas detector gluing and composite work. The control software of the large volume (7.9 m^3) oven is being upgraded to allow better controlled curing cycles.

Scintillator service

There is a relatively small but continuous demand for plastic scintillation counters, be it for test beams, cosmic set-ups, beam diagnostics or real physics experiments. The group provides a service to assist CERN users to design and build their detectors and equip it with appropriate photo-detectors. Often, users request just repairs, modifications, new wrappings or 'rejuvenation' of old but still functional detectors. We keep a small stock of scintillator raw material, which allows the clients to avoid the typical 8 weeks of delay when ordering from industrial suppliers.

Gas Systems

Next to the all-year covering piquet service, the LHC gas systems were largely optimized regarding operational up-time. As an example, the largest gas system of all LHC experiments, the ATLAS MDT, was turned off for only about half a day during the course of 2010,- despite upgrades, cooling water interruptions, power cuts and alike. Following the increasing demand of precision of gas sensors, we have organised and equipped a new gas calibration laboratory in Bldg. 256. Calibrations for digital Mass Flow Controllers, for channel flow meters (ELMB), for pressure sensors, and gas analysers

including gas chromatographs can now be carried out in one lab in well controlled conditions and gas qualities.
In collaboration with EN/MEF, our colleagues from the CERN gas supply team, we have installed monitoring and analysis systems for all LHC experiment, which is designed to give more information on the state of the gas supply system including availability and gas quality. This system was successfully integrated into the experiments gas control projects.
Toward the end of 2010, we started the construction of a CF_4 recovery system for the CMS CSC detector. When operational (foreseen 2011), this will substantially reduce running costs for this expensive gas.

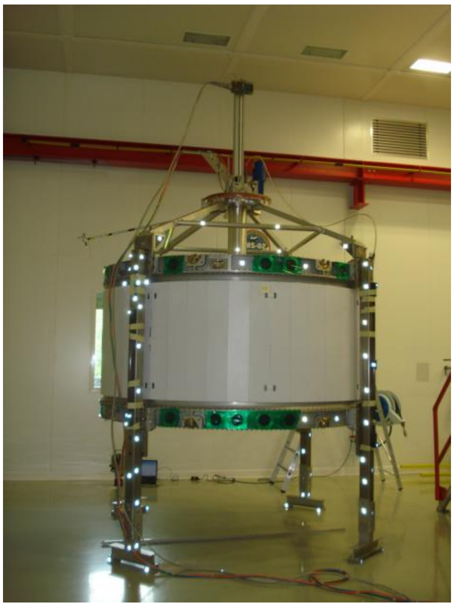
Instrumentation & Control

2010 marked the year where the *Magnet Control Project* - MCP, which controls and protects all 4 experiment magnets at the LHC, transformed into a *Maintenance aNd Operation* - MNO service. Thanks to the excellent work of the team in previous years, all systems are now showing the expected performance and maximum availability in all experiments, contributing greatly to the overall performance of the LHC itself. The team consolidates and maintains magnet control, safety and diagnostics systems in all LHC experiments, in total over 60 racks with individual configurations. A number of upgrade projects for these systems are under study in collaboration the experiments.
The year was marked by a change of rhythm induced by hectic technical stops and emphasis on alternative projects outside these. New control systems have been studied, proposed or implemented for experiments such as TOTEM, ALFA, ArDM, Aegis and CAST. With increasing support inside the DT group and also the department of the ¨Field Support Unit¨, attached to the MNO service, the unit also showed very good and versatile results throughout the year, becoming an integrated part of several department projects.
The members of the *Systems On-call Service* - SOS, who take care of common experiment magnet systems and also functions as a general service platform, showed great dedication to the experiment magnets, handling interventions on an efficient, complementary basis, thus also contributing to CERN's overall success.

Magnetic field measurements

Field mappings were done for AMS, LHCb and MICE.

- It was decided to use the permanent magnet for the final AMS mission and not the superconducting one, which was already mapped by us. The B-sensors were recalibrated for the lower field. The mapping of this permanent magnet was surveyed and successfully terminated in May 2010 .
- A short term request came to perform a check of the magnetic field close to the LHCb beam line. A measuring head carrying 6 B-sensors was designed and built. It is using the new mBATCAN read-out system with extended monitor software. Measurements are planned February 2011.
- A design has been made to map the MICE super conducting solenoids.


The permanent magnet of AMS with the mapping gear mounted on top of it.

The installation of a calibrator in the PT7 magnet is progressing. This magnet can produce a field of 2.5 Tesla (1.5 Tesla for the old MNP24 calibrator). For the temperature regulation the old Peltier controller was replaced by a forced air-flow system. Hot and cold air is mixed by two servo-valves. The average stabilization time went down from 20 min to 3 min.

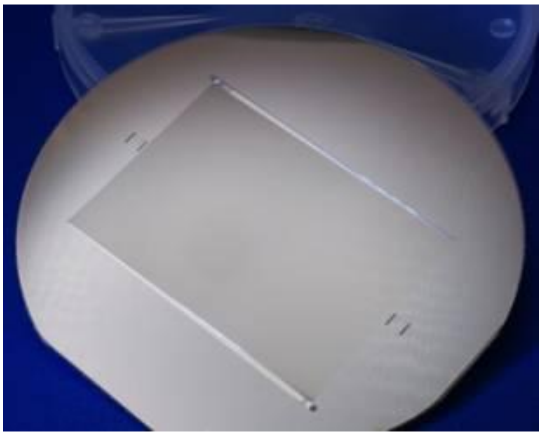
The new mBatCan module was produced and tested. One module was capable of reading out 128 B-sensors placed on 4 strings of 32. The length of the strings is about 3 m each.
Some promising candidates were found to replace the Siemens KSY44 Hall probe, which is no longer in production. Testing is continuing.

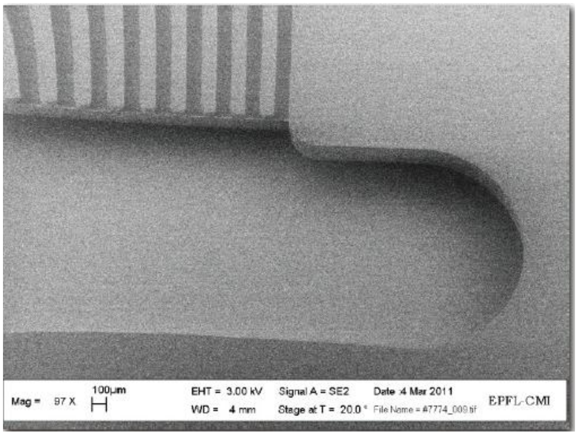
Many clients have made use of the magnetic test facility in 2010: Magnets MNP17 and VARIAN had 7 users and 55 days of occupation. Loan of material (Gauss meters): 9 users, 109 days of loan. The current switch between MMNP24 and PT7 is operational and upgrades to the water supplies have been made.

R&D on cooling systems for the Experiments

The main line of R&D on cooling is on the development on new CO_2 systems for laboratories and future detectors. The design of two new compact cooling units (one with 100W and one with 1kW cooling power @ -40 C) has been completed and the first prototypes of these units will be built in 2011. The one kW unit design permits to satisfy the cooling needs of a small detector – like the new ATLAS IBL – with minor modifications. DT also participates to the operation and constant evolution of the Prototype plant installed at the Cryo-lab.

New miniaturized cooling devices, based on micro-channels etched in thin silicon plates have been developed as an innovative solution for on-detector heat management in cases where the minimization of material budget is critical. The first case study has been the GTK module of NA62, for which a prototype cooling device in its final geometry is presently under test. More possible applications are under study, in particular for the upgrades of ALICE and LHCb.


Micro-channel cooling wafer for the NA62 GTK



Micro channels etched on silicon plates

Extremely promising results have been recently obtained on a new generation of Relative Humidity sensors based on Optical Fibres. Such sensors will allow for multi-point humidity and temperature sensing along one single fibre, thus providing EM noise-free distributed measurements of absolute and relative humidity inside a detector without any complex and space consuming wiring (just one fibre to be laid down).

Other ongoing activities focus on remote leak search in inaccessible pipes and remote leak repair (the latter at present limited to water circuits).

Mechanical workshops

The DT group has 8 mechanical workshops of which 3 are dedicated to support DT service activities like thin films and gas systems. The 5 other workshops include point 1 and 2 workshops and general purpose workshops for e.g. production of prototypes, complex assemblies, and quick fixes during detector assembly phases. These workshops provide work-space and tools also for project members of visiting teams. In 2010 the main investments were made to improve safety and working conditions, like machined part cleaning units and welding fume extraction systems.

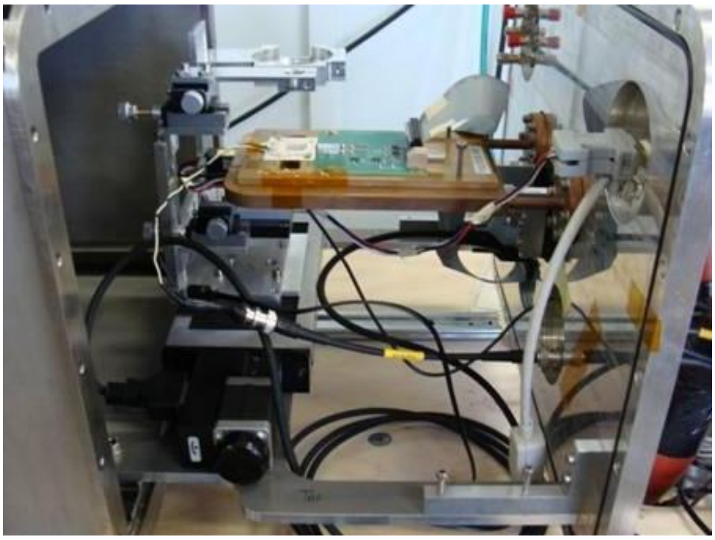
Research and Development

The major part of the R&D work within the PH-DT group is funded through the ‘White Paper’ scheme and described in a separate chapter of the PH Annual Report. In addition, two small activities are described, which do not fall in this category.

R&D on Radiation Tolerant Silicon Sensors

The PH-DT group participated in the framework of the ‘White Paper’ Work Package 4 “Radiation Hard Silicon Sensors”, the CMS Tracker Upgrade and the RD50 collaboration in R&D activities related to silicon sensor developments. The coordination of the White Paper WP4 project was handled by PH-DT and the overall work of the RD50 collaboration (48 Institutes, 255 members) was supported and steered by providing a co-spokesperson, administrative support, the budget holder and the co-ordination of several RD50 common projects.

The PH-DT research program focused strongly on the evaluation of p-type silicon strip sensors being presently the most promising sensor type for the tracking detector upgrade. In parallel, some work was performed on MCZ silicon sensors and the fundamental understanding of the movement of primary irradiation induced defects in silicon. In the framework of the CMS Tracker Upgrade, the group participated very actively in the initiation, preparation and set-up of a large silicon sensor evaluation program on a series of Hamamatsu Phontonics K.K. (HIPK) sensors. The characterization of the irradiated sensors within this project will be the main activity in 2011.



Setup to measure the Charge Collection Efficiency of silicon sensors, constructed by students and fellows of group. The setup can be operated at -20^{o}C.

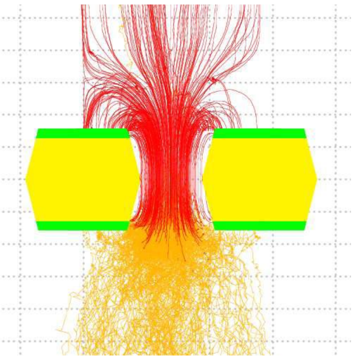
Micro-Pattern Gas Detector developments

PH DT group initiated the RD51 Collaboration for development of MPGD technologies. Its goal is to bundle and coordinate detector development and simulation work, which is currently being performed in numerous groups at universities and research institutes. The collaboration allows to

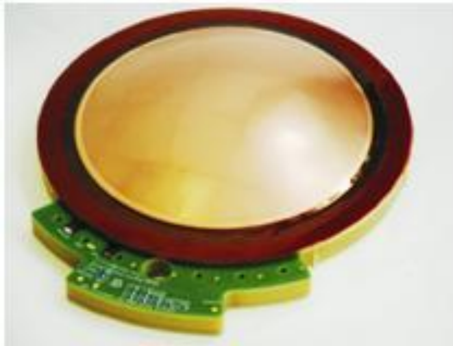
- structure, coordinate and focus ongoing R&D efforts;
- share knowledge, experience and infrastructure, agree on common test and quality standards;
- coordinate widespread simulation efforts towards setting-up a common maintainable software package for gas detector simulations and share investment of common projects.

Specific development work on MPGD (mostly GEM and MicroMegas) was carried out by PH-DT Gas Detector Development (GDD) laboratory. Main emphasis was put on the development of large size planar detectors. A new single mask GEM foil production technology was developed and evaluated. The new technology was adopted by CMS High Eta Project and a full size prototype (0.5 x 1 m^2) was constructed and successfully tested in the RD51 beam facility.

The GDD is also involved in the software tools development for MPGD simulations like GARFIELD model refinements for electron transport and field calculation, the implementation of the microscopic electron tracking, the interface to GEANT4 and ROOT and the simulation comparison with experimental data.
PH DT participates in the coordination effort for the RD51 beam facility maintenance and contributes to its infrastructure (gas system, trigger, and tracker). In 2010 RD51 conducted three 2 weeks beam test campaigns with over 10 participating institutes. Gas detector lab was equipped with the new test stations, flammable gas system and made available to the RD51 participants. Currently it is hosting SLHC upgrade groups from both ATLAS and CMS experiments.
Finally the group coordinates the effort of the upgrade of the MPGD production facility (TE-MPE) for the large volume, large area MPGD detectors production, and collaborations with industrial partners with the support from KTT group. One of the examples of the successful technology transfer was development of the spherical GEM detector for X-ray diffraction applications.



Simulation of microscopic electron tracking with in GEM foils

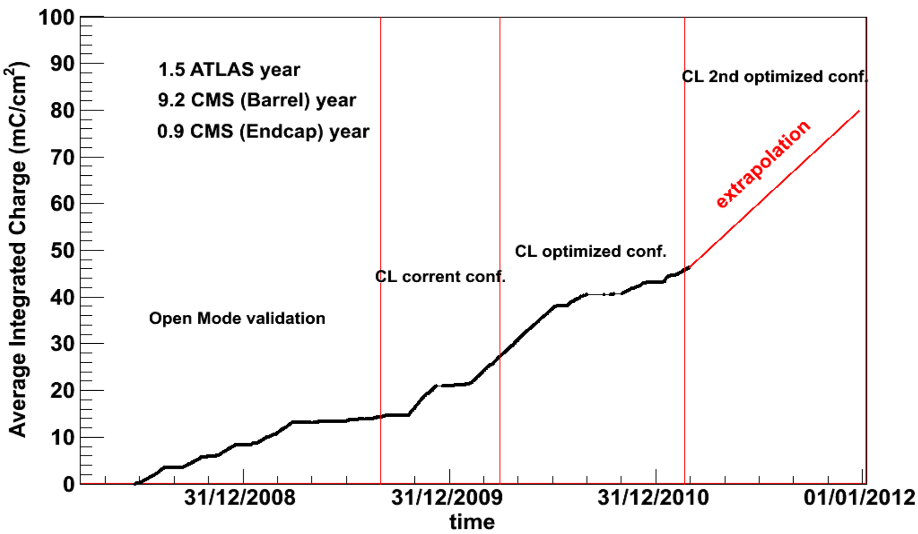


A spherical GEM detector for X-ray diffraction applications

Optimization of the operation of RPC muon systems in the LHC experiments

Most RPC systems at LHC are operated in a mixture of $C_2H_2F_4$-iC_4H_{10}-SF_6-H_2O. In the high radiation environment expected at LHC many different, chemically reactive impurities are created in the gas, which are potentially dangerous for the detector materials, the gas system and ultimately will degrade the detector performance. Based on economical grounds and related to the large chamber size, RPC systems are operated in re-circulating gas systems where these impurities are somehow filtered by purifiers. However, at higher luminosities the impurity concentration will increase and furthermore, chemical reactions between the purifiers and the impurities can degrade the absorber materials themselves or release new pollutants into the gas.

This study focuses on the gas system aspects and investigates in particular the impurities produced in heavily irradiated RPC chambers and the properties of possible absorbers to be used at LHC in order to keep the gas purity near the level of the fresh gas quality.
The experimental setup consists of a set of RPCs irradiated at the CERN Gamma Irradiation Facility, GIF (590 GBq ^{137}Cs source). Chambers are connected to a versatile closed-loop gas system and gas analyzers where purifiers can be studied in detail, at the same time that chambers behavior is regularly monitored.



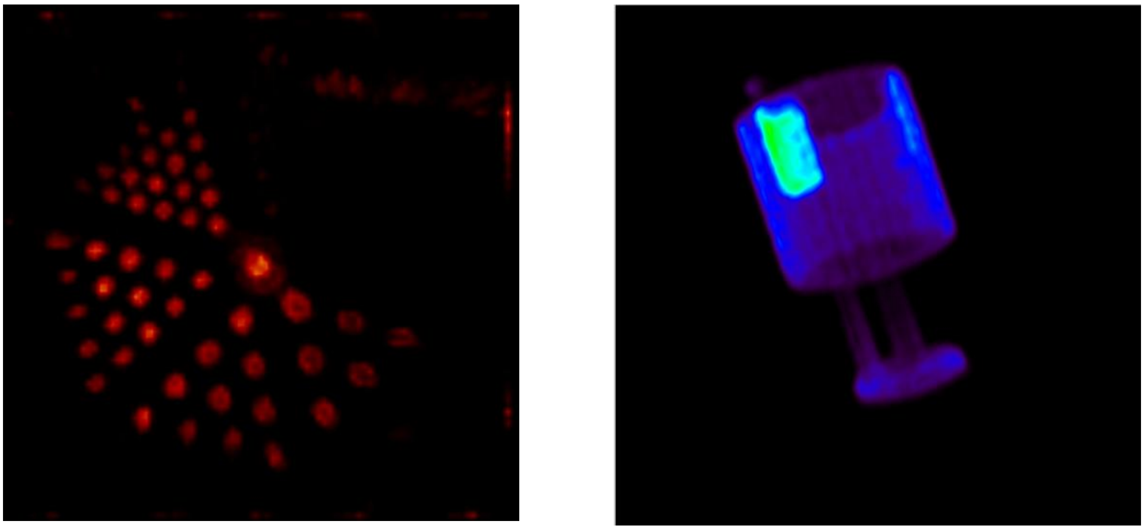
Integrated charge accumulated by the RPC gaps during the long-term irradiation test at the GIF, from mid 2008 to beginning 2011. The chambers have been operated with the gas system in four distinct conditions: i) open loop, ii) closed-loop with a set of purifiers as currently used in the LHC gas systems, and iii) and iv) closed-loop *with an optimized, efficient set of purifiers. In red, the extrapolated amount of charge that will be accumulated in 2011 is shown.*

The performance of a large number of purifiers has been understood. On that basis, an optimal filter configuration consisting of Molecular Sieve (MS) of 5Å and 4Å, and Ni-Al_2O_3 catalyst is being validated at long-term. Fig. 1 shows the average integrated charge in the RPCs, from the beginning of this study: shown are four different periods corresponding to different purifier configurations. The chosen optimal configuration (the 2nd) optimizes the filtering capacity for H_2O, O_2, freon-like molecules and other RPC typical impurities. An important feature is the increase of the cycle duration for each purifier that results in better system stability, reduced system downtime and, if needed, it permits to increase comfortably the gas flow in the detectors during the high luminosity running periods at LHC. This filtering configuration will now be implemented in the LHC RPC gas systems.

AX-PET

The AX-PET collaboration (9 member institutes from Europe and US) completed the construction of a demonstrator module of a novel Positron Emission Tomography (PET) camera principle, based on a matrix of long axially oriented crystals interleaved with plastic wavelength shifting strips for the reconstruction of the longitudinal coordinate.

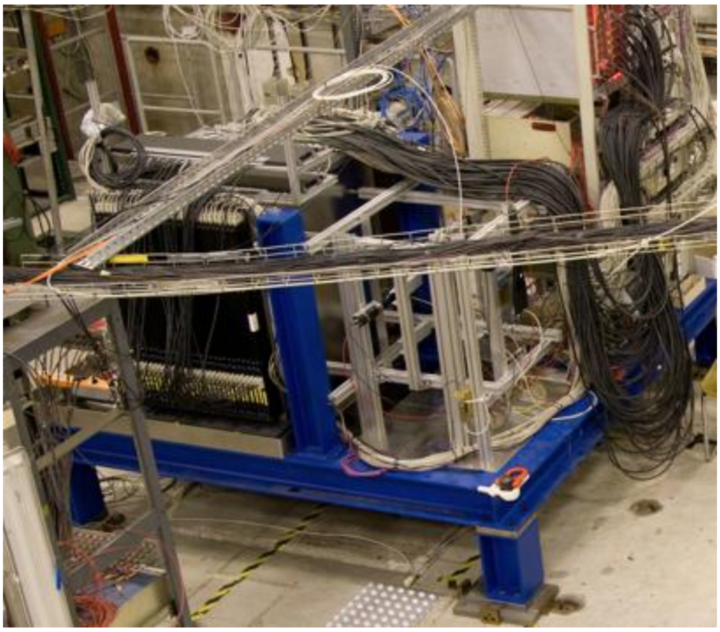
After having demonstrated the expected performance with point sources in the lab, two successful measurement campaigns were performed with phantoms filled with PET radiotracers (FDG, based on F-18), one at the ETH Zurich and one at the company AAA in Saint Genis. The preliminary results, obtained with AX-PET specific reconstruction software, indicate very good and uniform resolution. The commercialization efforts through a Finnish consortium of companies and institutes made some progress but have not yet led to a clear road map.



Examples of reconstructed phantoms. Left: 2D-slice of a multi-channel phantom, produced in the DT workshop. Right: Reconstruction of a commercial NEMA phantom.

CLIC W-HCAL

The group participated in the effort to validate Tungsten as a possible absorber material for a high granularity hadron calorimeter aiming for a compact design for a future CLIC detector. In the framework of the CALICE collaboration, a physics prototype of 30 layers of W absorber with a total absorption length 3 L has been constructed. As detector elements the resulting sandwich structure the fine-segmented scintillator tiles (3 x 3 cm^2 in the core region) from the CALICE AHCAL prototype have been used. First test of the prototype have been successfully carried out in the PS experimental area with particles of up to 10 GeV momentum. The analysis of the data is ongoing, preliminary results are promising and allow the determination of resolution and shower sizes. For 2011 the prototype will be equipped with 10 additional layers and test beams at the SPS are planned to measure the performance with energies of up to 400 GeV.



The WHCAL prototype in the PS test beam T9

Other activities

MC-PAD

MC-PAD is an EU funded Marie Curie Initial Training Network (ITN) with 22 positions for doctoral and post-doctoral researchers. Four of the positions (CERN fellows) are located in the DT group. Founded in November 2008, the network has a total volume of 4.7 M EUR. In 2010, two training events with an overall participation of 80 students were organized at the University of Hamburg and the Jozef-Stefan Institute in Ljubljana. The network passed successfully its midterm review with representatives of the European Commission. A member of the group is in charge of the network coordination.

EIROforum

The instrumentation working group of EIROforum (CERN, EMBL, ESA, ESO, ESRF EFDA/JET, ILL and since 2010 XFEL) organized a 3-days workshop on Radiation Hardness Measurement, Testing and Materials, to which several DT physicists and engineers participated. The Marie Curie ITN proposal, submitted end of 2009, didn’t achieve high enough scores to be funded. Towards the end of 2010, the proposal was completely rewritten and re-submitted. If approved, it would bring to the group 4 fully financed PhD positions (12 man years). The next large event is the 2nd EIROforum School of Instrumentation, planned for May 2011 at Grenoble. Several DT physicists will contribute as lecturers.

Summer Student Workshops

The DT group organized a part of the 2010 Summer Student Workshops which offer the chance to gather hands-on experience on beam line and particle detector elements as well as data analysis tools. In total 6 groups of students were trained by PH-DT in 2 courses. The course "Measurements with scintillating fibers" focused on the study of the scintillation emission spectrum, light absorption length, reflective coating properties and photo detectors. The course "Silicon sensors" taught the basic working principles of silicon detectors and gave an introduction to performance degradations arising from radiation damage. Finally interconnect techniques were explained and demonstrated in the PH-DT bonding laboratory.

Representation in CERN working groups/committees

Interaction with CERN engineering activities

The DT design office in building 25 underwent in 2010 a major renovation work allowing staff and visiting designers to work in an open office area consisting of 8 work posts, and neighboring meeting and printing facilities. In addition to their daily project involvements the DT Project Office staff had 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).

Selection of publications involving DT members

- J.Mekki, M.Moll, M.Fahrer, M.Glaser, L.Dusseau,Prediction of the Response of the Commercial BPW34FS Silicon p-i-n Diode Used as Radiation Monitoring Sensors up to Very High Fluences, IEEE Transactions on Nuclear Science. IEEE TNS, Vol.57, No.4, August 2010, 2066-2073
- M.Moll, Recent advances in the development of radiation tolerant Silicon Detectors for the Super-LHC, World Scientific on "Astroparticle, Particle, Space Physics, Radiation Interaction, Detectors and Medical Physics Applications - Vol.5"(ISBN: 978-981-4307-51-2/3), April 2010, World Scientific, pp 101-110.
- J. Duplissy et al., The CLOUD experiment at CERN, International Aerosol Conference, IAC2010, Helsinki, 29 August – 3 September 2010.
- L. Gruber, W. Riegler, B.Schmidt: *Time resolution limits of the MWPCs for the LHCb Muon system*, published in NIM A 632 (2011) 69-74.
- E. Bolle et. al, The AX-PET project: *Demonstration of a high resolution axial 3D PET*, Nucl. Instr. Meth. A617 (2010) 214-216
- C. Joram et al., *Proof of principle of G-APD based hybrid photodetectors*, Nucl. Instr. Meth. A621 (2010) 171-176
- Serge Duarte Pinto et al., *First results of spherical GEMs,* paper presented at the IEEE NSS at Knoxville, October 30 – November 6, 2010
- S. Colafranceschi et al., *Construction of the first full-size GEM-based prototype for the CMS high-η muon system,* paper presented at the IEEE NSS at Knoxville, October 30 – November 6, 2010
- M. Capeans, I. Glushkov, R. Guida, S. Haider, F. Hahn, A. Lehan, S. Rouwette, *Optimal Gas System for the Operation of Resistive Plate Chambers at the Large Hadron Collider Experiments*, paper presented at the IEEE NSS at Knoxville, October 30 – November 6, 2010.