Detector Technologies Group PH-DT

In the course of the PH restructuring process in view of the transition from LHC construction to maintenance and operation, the group PH-DT was created in May 2008 by merging the former DT1 and DT2 groups into a single unit.

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.

- 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

In 2008 the group's activities were concentrated in four areas:

1. Completion and consolidation of the ongoing LHC projects;
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.

About 80% of the resources were (directly or indirectly) allocated to the LHC activities of the first two items.

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.

Detector Projects:

ALICE

During the first months of the year PH-DT was involved in the installation of the last TOF detector elements and a few TRD detector elements and it was responsible for the modification of the services (cables and pipes) trays in the solenoid "chicane". Then the group participated in the installation of the mini space frame carrying all the services of the central detectors. Finally the shielding was assembled and the experiment infrastructure was ready for the first machine run.

The group was then in charge of the re-alignment of the baby space-frame (BF), the support structure holding the services for the whole experiment, and of the space-frame (SF), the support structure holding the detectors, w.r.t. the beam line, an operation which required the lifting up by 4 mm of both structures.

In close collaboration with the TPC technical coordinator, the group gave support to the preparation and commissioning of the detector. This activity included the modification of the so called transfer rails, required to move the TPC in and outside the experiment, the realization of the services (cables, optical fibers, pipes) trays on the C side of the detector and the modification of its gas system. The group gave also support to the modification of the patch panels for the LV distribution and to several interventions on the read-out chambers. The design of a new support structure to replace the so called “Delphi frame” also started, this new structure will hold the TPC while outside the SF.

Following the new planning after the machine accident it was decided to remove the shielding and the mini space frame in order to give access again to the central part of the experiment. In this way during the last months of the year the group helped installing some further TRD detector elements. During the period in which the mini space frame was back on the surface part of the services was re-routed in order to leave more space to access the TPC service support wheel during future maintenance. PH-DT prepared as well the structures to install some PHOS elements before the next machine run.

The mini space frame during the installation.

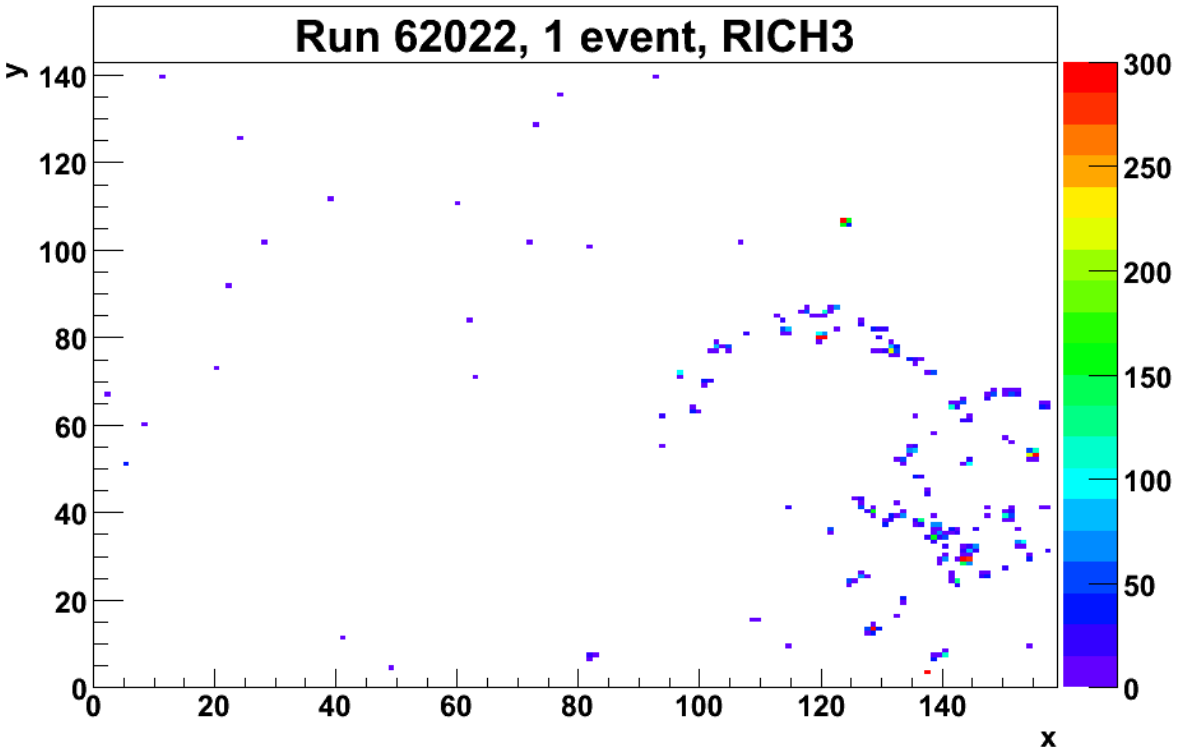
The group completed, as planned, the installation of the services for the ALICE HMPID with the move to Point 2 of the C_6F_{14} circulation system after tests in the laboratory.

A procedure, together with tools, to access the electronics while keeping the detector inside the solenoid has been worked out and successfully applied in order to repair a problem with two readout control boards.

Beam induced events have been recorded during the LHC commissioning as well as cosmic ray events, exploiting the TOF trigger facility.

Offline analysis shows the detector is qualitatively performing as expected although, due to the low statistics available (Cherenkov light is emitted only by particles traveling from the interaction point), it is not possible to assess quantitatively its performance in terms of gas gain or photo-cathodes quantum efficiency. Nevertheless, a few Cherenkov rings have been recorded.

The matching between tracks reconstructed in the TPC and entering the HMPID, for which few hundreds tracks are available, has been studied and shows a distance between the extrapolated and measured impact points of less than 1 cm, without alignment corrections. The noise level is measured, as expected, at less than 1000 electrons on average.



Cherenkov rings in the ALICE HMPID

ATLAS

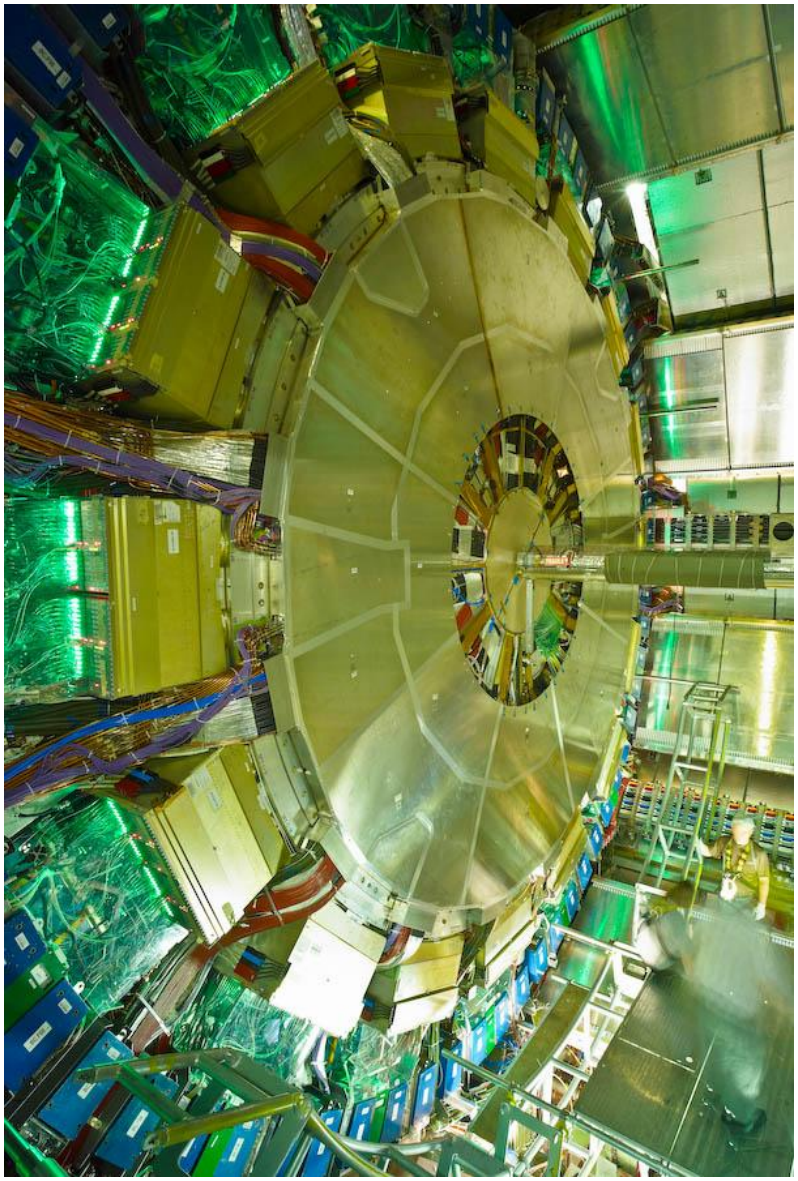
In 2008 the PH-DT group continued its Project Engineering responsibilities for the ATLAS Inner Detector (ID). The group has completed the assembly and installation of the ID End Plate sealing the tracker and allowing the full commissioning under dry environmental gas. The mono-phase cooling system was completed and additional detectors, like BLM's and Medipix, have been integrated into the ID.

The complete Inner Detector was made ready for the first successful data taking during the September run.

During the year the group also focused on updating and extending the documentation for the ID and its sub-systems, like the conversion and assembly of 3D models, updating of drawings and procedures and the full analysis of the ID alignment survey data.

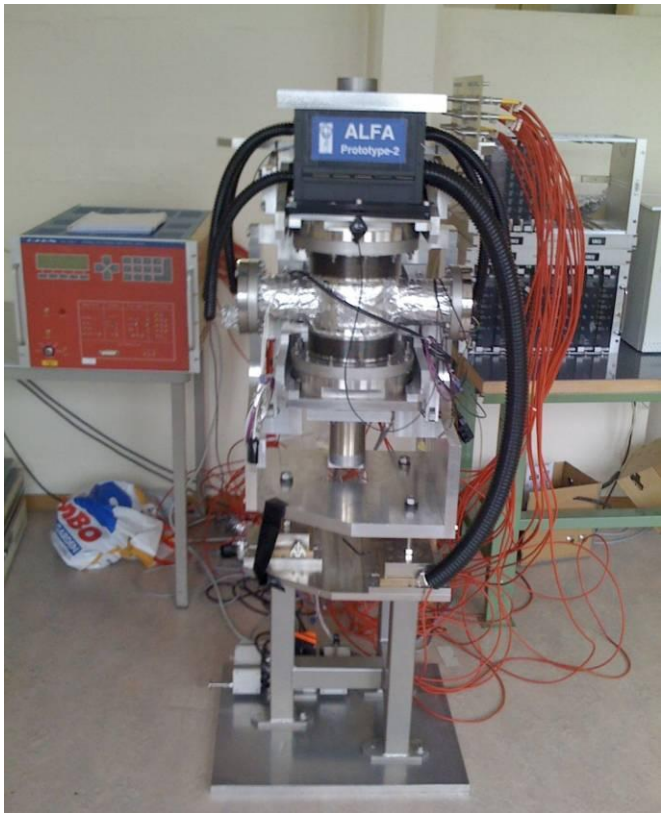
The decommissioning and classification of all ID tooling has been completed and the group has prepared the access to the detector during the winter shutdown for interventions of consolidation.

Parallel activities have spanned from the Atlas Tracker Upgrade, with a main coordination role in the engineering design and integration, to the participation in the B-layer replacement project (Insertable B-Layer). The later included studies and prototyping of the beam pipe replacement tool, the additional services and 3D imaging by laser survey techniques to model the “as built” environment.



ALFA (Absolute Luminosity for ATLAS) is a forward detector based on scintillating fibre technology, intended to measure the absolute luminosity at IP1 by detecting scattered protons at micro radian angles. The designs of the body and components for the full ALFA module were completed. A full size prototype was equipped, inserted in a roman pot and tested in a proton beam (SPS H8). The results indicate still deficiencies on the readout electronics but also on the detector precision side, which are to be corrected in 2009.

The mechanical design of the Roman Pot mechanics was revised to optimize rigidity and hence positioning precision. The first of the 4 final pot stations were assembled and tested. Work continued on the instrumentation (motors, switches, measuring devices, cabling, control software) and the integration of the stations. Installation in the LHC tunnel is foreseen for spring 09.



ALFA RP set-up before transport to H8 test beam zone.

CMS

The two ECAL end caps (ECAL EE) were the last CMS detector components, which were installed before the first LHC beam in 2008.

The PH-DT group participated in the coordination, assembly, transport and installation of the ECAL EE at Point 5 of LHC. Each of the two ECAL end caps is composed of two elements called DEE. A single DEE houses 3662 $PbWO_4$ crystals grouped in 156 'Super Crystals' and pointing to the CMS interaction region. The associated electronics with the optical fibre system are mounted on the back side of each DEE. A complex water cooling system stabilizes the temperature to better than 0.1° C. As the total weight of single DEE is about 9 tons, a very rigid support structure was used during assembly, transport and installation of an individual DEE.

About 50 technicians, engineers and physicists from different departments of CERN and collaborating institutes have been working on the project. Finally all 4 DEEs have been successfully integrated in the CMS experiment by August 2008 and are now ready for the first LHC collisions.

Lifting of DEE 2 on the mounting platform at CMS. DEE 1 is already attached to the HE.

For the CMS Preshower, 2008 was the year of global assembly. PH-DT was particularly involved in the production, partly in-house, finishing, and testing of major mechanics' components and assemblies and on-detector cooling equipment. Furthermore, the fibre-optic harnesses, tailored to the specific needs through "splicing", were produced. Sub-detector final assembly and cabling was nearly completed for both end caps by the end of 2008. The group, since long involved herein, initiated and constantly supervised this activity. Installation of the Preshower is planned for 2009.

Cabling of the Preshower detector

PH-DT also performed various small interventions on the CMS building site, concerning works on transport, handling and installation of final Preshower assemblies.

An engineer from PH-DT organized and supervised the installation and quality control of 500 cooling pipes connecting the CMS Tracker into the supply pipe system. This project was done under a very high schedule pressure in February-March 2008 in the CMS pit, to allow for a timely closing of the experiment. The work was executed by a team of 10 technicians, of which 2 came from PH-DT. The team worked in shifts with other teams that installed other services in the same congested area inside the CMS magnet cryostat.

Soldering tracker cooling pipe connections inside the CMS magnet cryostat

LHCb

Eight members of the PH-DT group are involved in the LHCb experiment. In the year 2008 the activities focused on the completion of the installation and the commissioning of the experiment.

The PH-DT group is responsible for the pixel hybrid photon detectors (HPDs) of the LHCb RICH detectors. Following the installation in 2007 of 288 HPDs in the RICH2 detector, another 196 HPD tubes have been successfully installed and operated in the RICH1 detector. The overall RICH system is now fully equipped.

One HPD plane in the RICH1 detector (© R.Plackett from Imperial College London)

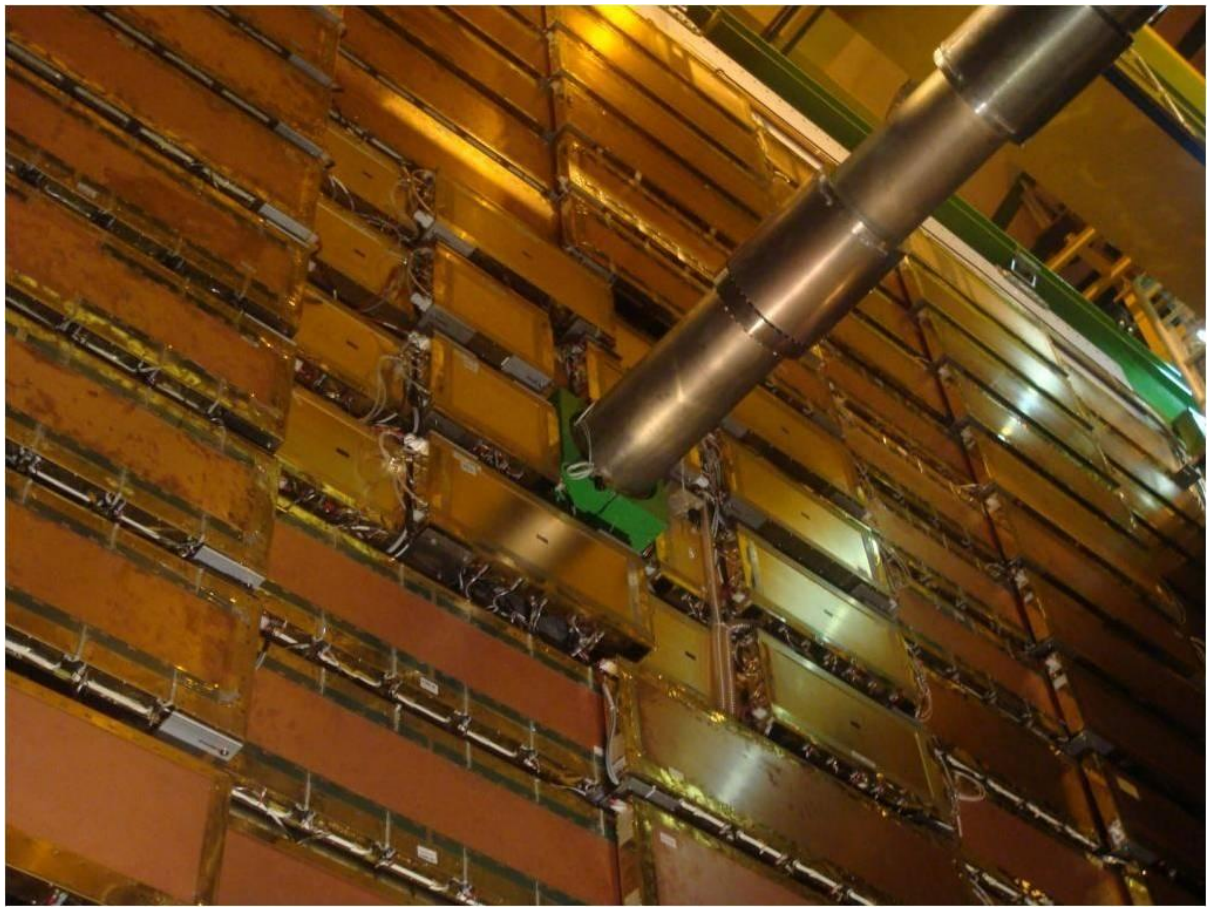
From a total of 484 tubes, a large majority is performing in an optimal way, as was demonstrated during the LHC commissioning phase. However, a 10% fraction of the tubes shows a strong degradation caused by an increase of the residual gas level in their vacuum envelope. Half of these degraded tubes have already been replaced by spare HPDs, and the removed, degraded tubes have been successfully re-processed by the HPD manufacturer. In parallel, detailed investigations have been carried out in order to understand the problem.

One member of the group, being the main responsible for movement system of the calorimeter, was frequently occupied with the displacement of the calorimeter before the closing of the LHCb cavern in summer 2008.

The group participated in the installation and commissioning of the so-called SMOG system used for the measurement of the luminosity at the LHCb interaction point.

Group members prepared a setup to study the behavior of VELO modules during exposure to high rates of charged particles under various HV/LV conditions in the PS irradiation facility.

The group coordinated the installation and integration of the Muon system. This included during 2008 in particular the final alignment of Muon stations M2-M5. A control system reading the information from end- and security-switches has been put in place to ensure safe opening and closing of the half-stations. The group participated also in the commissioning of the gas- and HV-systems of the Muon detector and contributed to the running of the LHCb experiment at the time of the LHC startup. In addition, significant support has been provided for the alignment of station M1, which will continue throughout the shutdown period.



LHCb muon system

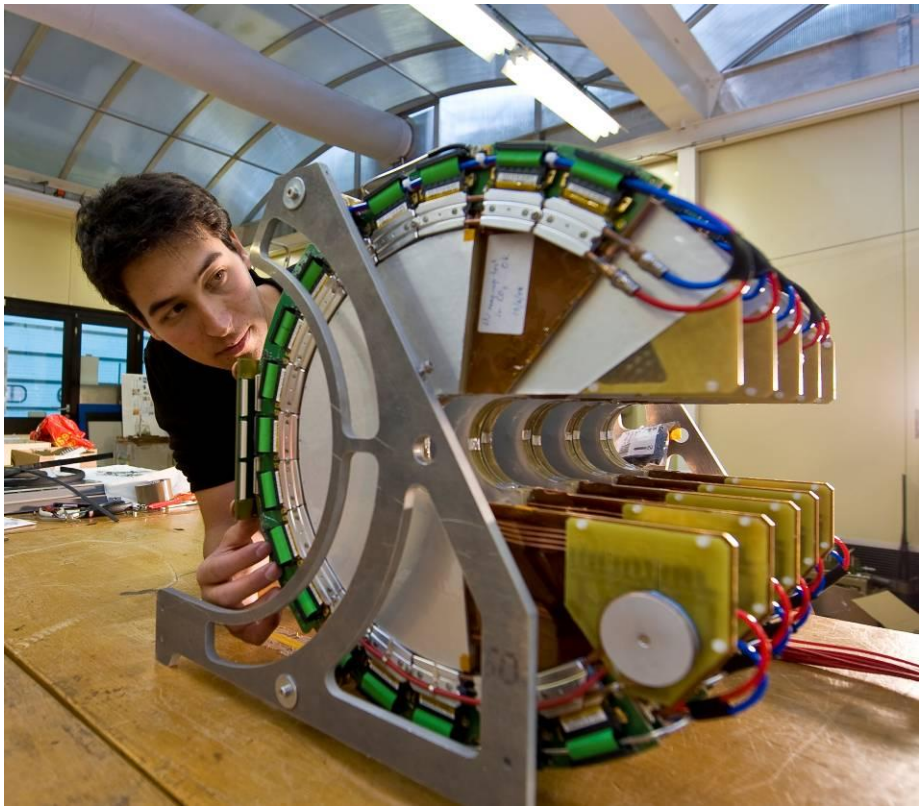
TOTEM

The group continued the technical support for the integration of the TOTEM detectors T1 and T2 into the forward arm of CMS. A provisional cooling system for the T1 and T2 detectors as well as the CASTOR detectors has been conceived and installed.

The mechanical mock-up for the T1 telescope has been finalized, which allowed to validate the integration procedure and to study the complex cabling scheme. However, the T1 telescope could not be installed before the LHC start due to the late delivery of the T1 chambers, the unforeseen necessity for re-aligning LHC elements and the consequent constraints in the installation schedule.

For the T2 detector a new mechanical support structure has been designed and the construction supervised. One half of the T2 telescope was successfully installed before LHC start up.

The group prepared and carried out the installation of 8 Roman Pot (RP) stations in the LHC tunnel at 147 and 220m from the interaction point 5 (CMS), including integration of auxiliary systems like vacuum pumps and cooling pipe work. The design of the RP silicon detector assemblies was completed and most of the mechanical components procured or produced at CERN. Two silicon modules (10-planes each) were assembled (precision +/-30 microns) and, after lab and beam tests, installed in the LHC tunnel. A set-up for cosmic ray testing was prepared, including scintillator trigger counters.



Part of the TOTEM T2 detector

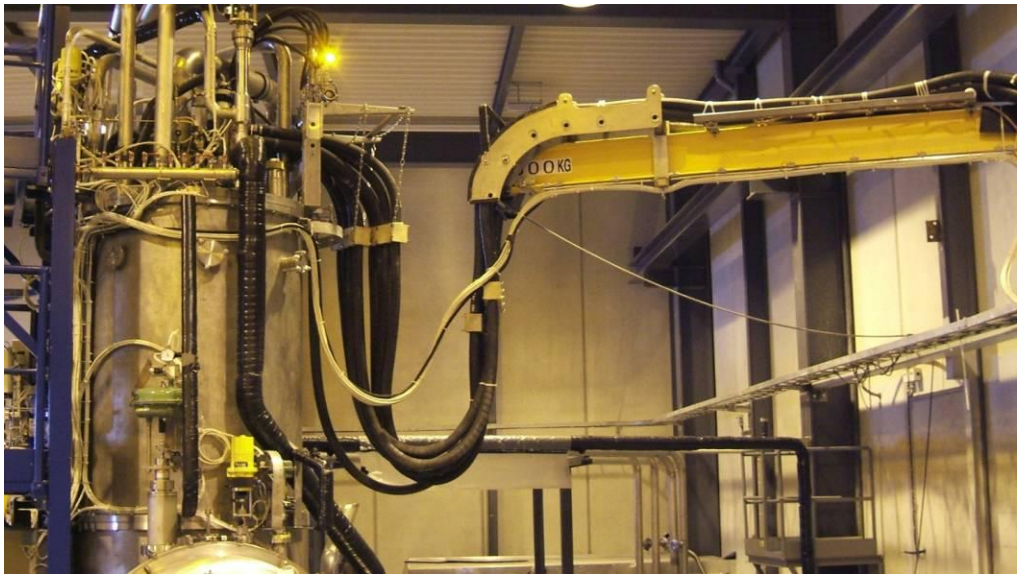
CAST

The group gives support to the CAST experiment in the areas of technical coordination, operation of the ^{3}He system, mechanical and electrical components of the magnet movement system, slow controls and vacuum interlocks.

The frequent movements of the magnet had caused aging, already observed in 2007, of the rubber sheaths of the water cooled, 13kA power cables for the magnet. In 2008 the group designed, together with TS-MME, and installed an elaborate, new cable support system significantly reducing the mechanical stress on the power cables.

The group built and commissioned a ^{3}He gas leak interlock for the vacuum system and upgraded the low voltage distribution of the acquisition cards for the slow control system. The power source of the slow control system was transferred to a UPS network.

The year 2008 saw the first use of ^{3}He as the buffer gas in the cold bore of the CAST magnet. The complex ^{3}He gas system enabled CAST to make small steps in the buffer gas density half-way through each solar tracking. A total of 252 new density steps were performed from 13.4 to 36.3 mbar @ 1.8K corresponding to an axion rest mass range of 0.39 to 0.64 eV/c^2. Thus the search for the hypothetical axion was extended well into the theoretical favoured region.



The new support for the magnet power cables

CLOUD

An engineer from PH-DT worked as the technical coordinator of the PS215-CLOUD experiment, with the target of completing the CLOUD facility for physics measurement in summer 2009. Other PH-DT personnel contributed in the design of the field cage to be installed inside the CLOUD aerosol chamber. The work was carried out in collaboration with a designer and technical support from the TS department, and with other CLOUD collaborating institutes, especially with PSI on the design and manufacture of the CLOUD aerosol chamber.

SERVICES

Thin film and glass

The former thin film and glass service (TFG) has been merged in 2008 into the new DT-DI section. The support in term of specific thin films and machining of hard materials has continued for the PH detectors and R&D activities.

The TFG service is deeply involved in the construction of ALFA fiber tracker, a detector for measuring elastic scattering and luminosity at ATLAS. A new setup for the mass production of aluminum coated scintillating fibers has been built and more than 15000 fibers were coated, fulfilling the needs for the 10 modules currently under construction.

Mechanical designs and aluminum coatings on LYSO crystals and wavelength shifter strips were successfully provided to the AX-PET collaboration, a demonstrator for an AXial PET camera with WLS strips and G-APD readout). The mechanical parts of two detector modules were built and the tools for the alignment and bonding of G-APD devices were realized. Two modules are being assembled.

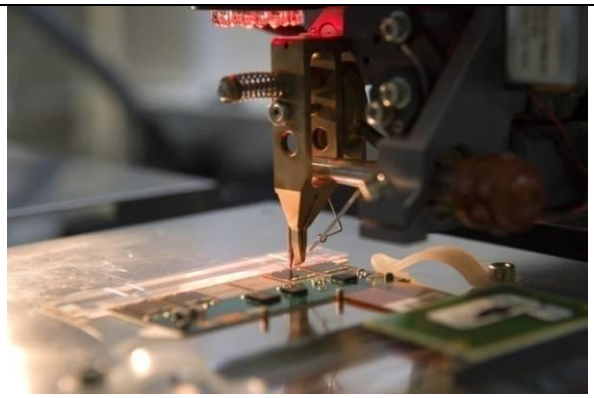
Bonding Lab

The main activity throughout 2008 in the Bond Lab of the Departmental Silicon Facility (DSF) was the production of CMS Preshower modules. With about 850 modules already produced in 2007 the production re-started in January. A total number of 4300 produced modules was reached in

September despite the partly very poor quality of the metallization on a fraction of the delivered silicon sensors and the consequently time intensive and delicate assembly process. This number was sufficient to fully populate the CMS Preshower detector. The project was finally concluded towards the end of the year with the production of spare modules.

Further important activities were the prototyping and production of modules for the TOTEM Roman Pot detectors, the assembly of MEDIPIX devices, ATLAS ALFA boards and ALICE Pixel modules. Several jobs were executed for the Crystal Clear collaboration, the Beam Condition Monitors of ALICE, ATLAS and CMS, the RADMON project, the RD39, RD42 and RD50 collaborations. Various projects were realized for the PH-ESE group including e.g. the assembly of TOTEM GEM hybrids. A wide range of smaller jobs including urgent repairs, test-assemblies and prototype production were performed for various CERN groups and users.

The DSF clean room space and infrastructure was maintained and served the ALICE Pixel, CMS Preshower, LHCb Tracker, LHCb VELO, LHCb RICH and MEDIPIX collaborations as clean assembly area. Naturally, with the LHC experiments being installed, the activity in the clean rooms decreased over the year and finally will allow in 2009 to accommodate new projects. First preparations to participate in R&D activities related to the LHC upgrade and future interconnect technologies were made as well as to accommodate a Quality Assurance Laboratory. As in the previous years, the DSF with its various installations has been a very attractive site for CERN visitors ranging from student groups over industry delegates to television crews.

	
Operator in front of one of the wire bonding machines.	Zoom on the bond head placing one of the 25 □m thick Al wires.

Irradiation Tests

The PS irradiation facilities were heavily utilized by many CERN groups and external users. In 150 days of beam time about 550 objects were irradiated and about 150 dosimetry measurements were performed. Clients were coming from the ATLAS, CMS, LHCb and TOTEM experiments, the RD39, RD42 and RD50 collaborations and the RADMON project. The objects irradiated were mainly silicon sensors and detector systems for the LHC upgrade, but also optical link systems, calorimeter crystals, electronic components, dosimeters, radiation monitors and other types of components and materials. Compared to previous years an increase of the complexity of the irradiation experiments and an increase on the requested total particle fluence was observed. For example, irradiations of electronics and detectors were performed under operational conditions (e.g. at low temperature or powered and with data acquisition operating), exposed to fast extracted beams and irradiated up to several 10^{16} protons/cm^2.

In parallel to the irradiation experiments a prototype of a 16 channel beam profile monitor based on secondary particle emission from Aluminum Foils was produced and successfully tested. It can now

be used to obtain a faster alignment of the irradiation beam and to give a fast online response on unwanted beam position movements during the irradiation experiment.

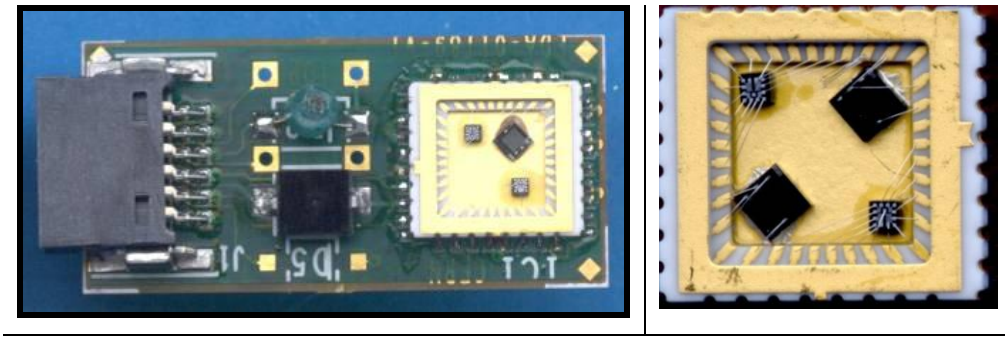
The Gamma Irradiation Facility (GIF) in bldg. 190 was made available to several users. In the first half of the year the facility was mainly used by colleagues working on the LHCb Multi-Wire Proportional Chambers (MWPC), ATLAS Monitored Drift Tubes (MDT chambers) and LHC Beam Loss Monitors while in the second half of the year aging tests on CMS Resistive Plate Chambers (RPCs) were performed in the framework of a PH R&D project (WP7 – Facilities and Component Analysis for Detector R&D).

In addition to the regular maintenance of the facility and the irradiation source several smaller activities aiming to improve the safety of the facility were performed including for example a new warning light indicator for ongoing irradiations, an in-depth cleaning of the facility and a thorough removal of unused items.

Finally, all personnel of the irradiation facilities participated very actively in the ongoing evaluation and planning for new or upgraded irradiation facilities at CERN.

Radiation Monitoring

In the framework of the RADMON project radiation sensors were provided to the LHC Experiments (ALICE, ATLAS, LHCb and TOTEM) and a low level of R&D focusing on low cost commercial and custom made silicon pin diodes was maintained. In total about 80 RADMON boards and 700 calibrated radiation sensors were provided through this activity in 2008. Furthermore, a detailed study on the impact of radiation sensor packaging on the sensor performance was conducted using the GEANT4 toolkit and resulting in improving the precision of the dose measurement with packaged RADMON devices in the LHC experiments.



Radmon board (left) with dimensions of 30 x15 mm carrying temperature and radiation monitoring diodes as well as a chip carrier (right) that can be equipped with different types of RadFET sensors according to the specific needs of the client.

Gas systems

In 2008, the LHC Gas project transformed from installation activities to nearly fully operational activities. Across the five LHC experiments, 20 gaseous detectors ready for operation were served with correct gas mixtures in time for their first data taking periods. Also the largest flammable gas system, the ATLAS TGC system, was successfully brought to operation featuring a purification and recuperation plant of the expensive n-Pentane gas. Even the most challenging systems in terms of operation, like RPC CMS, RPC Atlas, TRT Atlas, or TRD Alice, were supplied efficiently with stable and clean mixtures.

In CMS a large Nitrogen and dry air flushing system was given to the detector experts for supplying certain parts of the detector, eg the CMS Silicon tracker, with very dry gas.

In Atlas, the TRT forward gas cooling system, although originally built by an ATLAS team, was successfully taken over into the maintenance and operation schemes of the gas project. In particular the integration into the existing controls project was challenging as the underlying control hardware was different to the normally used. IT/CO, the sole end application provider to the gas project, dealt with this problem swiftly and efficiently and by beginning of December a full system integration test was successfully performed.

One of the most important changes the gas project faced in 2008 was the start of an around-the-clock piquet service. In this context, 31 weeks were covered with approximately one intervention per week outside normal working hours.

CMS RPC gas system in USC5

Magnetic field measurement

A pneumatic measuring bench for the T2K neutrino oscillation experiment in J-PARC, Tokai

has been designed and constructed. The device has 89 3D B-sensors which measure the field of 0.2 T in the former UA1 magnet with a precision of 0.1 mT and a spacial accuracy of 0.1 mm over a volume of about 6 x 2 x 2 m^3. The field measurements are planned for June 2009.

A device to map the field of the magnet for the Alpha Magnetic Spectrometer has been designed and constructed. The device has 15 3D B-sensors which measure the 1 T field with a precision of 0.1 mT. The volume to map is a cylinder of 1 m radius and 1 m length. The field mapping is foreseen in March 2009

Improvements of the 3D B-sensor were initiated in collaboration with NIKHEF.

New backplane is being designed with short range SPI-interface or long range CAN interface, both with robust connectors and ARM-based read-out.

*** We could add a few sentences about our mechanical workshops, including procurement of the new lathe → Antti

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R&D

A large part of the R&D work within the PH-DT group is funded through the 'White Paper' scheme and described in the section xxx.

X-HPD

Together with the industrial partner Photonis two X-HPD prototype tubes with LYSO crystal anodes were produced and tested in our labs at CERN. The results demonstrate the essential features of the concept e.g. the very large viewing angle (3 π), double cathode effect and good timing. Collaboration with a postdoc from ETH Zurich allowed simulating the processes in the LYSO crystal and the light collection with Geant4. The results were presented at two conferences and led to two NIM A papers.

AX-PET

The AX-PET collaboration (9 member institutes from Europe and US) pursued the demonstration of a novel 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. The readout of crystals and WLS is done with Geiger mode APDs (so-called MPPCs from Hamamatsu). During 2009 the collaboration developed, procured and validated all hardware components and, in parallel, prepared specific modelling and reconstruction software. The main contributions of the DT group are the mechanical design and assembly as well as the overall-coordination of the activity.

Other activities

MC-PAD

The funding of the Marie Curie Initial Training Network MC-PAD, which was approved at the end of 2007, was negotiated with the European Commission. 22 positions with a total funding volume of close to 4.7 M EUR were granted. The network started on 1st of November 2008. Three doctoral students and one postdoc were recruited for activities at CERN, integrated in ongoing research like radiation hard silicon studies, micro pattern gas and photo detectors. A member of the group is in charge of the network coordination.

EIROforum

The instrumentation working group of EIROforum proposed to organize a 2-yearly school on instrumentation, jointly organized by the 7 EIRO organizations (CERN, EMBL, ESA, ESO, ESRF EFDA/JET and ILL). Following approval by the EIRO DGs, the first school will be held from 11th to 15th of May 2009 at CERN. Members of DT participate in the school organization committee and are also foreseen as lecturers.

Selection of publications involving DT members

- The ALICE experiment at the CERN LHC, The ALICE Collaboration, K Aamodt et al, 2008 JINST 3 S08002
- The CMS experiment at the CERN LHC, The CMS Collaboration, S Chatrchyan et al, 2008 JINST 3 S08004
- The LHCb Detector at the LHC, The LHCb Collaboration, A Augusto Alves Jr et al, 2008 JINST 3 S08005
- The ATLAS Experiment at the CERN Large Hadron Collider, The ATLAS Collaboration, G Aad et al, 2008 JINST 3 S08003
- The TOTEM Experiment at the CERN Large Hadron Collider, The TOTEM Collaboration, G Anelli et al, 2008 JINST 3 S08007
- Arnaud, M; Bardoux, J; Bergsma, F (CERN); et al., Commissioning of the magnetic field in the ATLAS muon spectrometer, Nucl. Phys. B, Proc. Suppl. 177-178 (2008) 265-266
- Braem et al., The X-HPD—A modern implementation of a SMART concept, NIM A, 2008
- Braem et al., Wavelength shifter strips and G-APD arrays for the read-out of the z-coordinate in axial PET modules, NIM A, 2008

- T. Gys, Status and perspectives of vacuum-based photon detectors for single photon detection, NIM A 595, 2008, 136-141
- D'Ambrosio, Commissioning of the LHCb RICH detectors, NIM A 595, 2008, 36-39
- Wiedner, E. Albrecht, F. Hahn, R. Lindner, L.P. de Menezes, The use of n-perflourcarbons as RICH radiators, NIM A 595, 2008, 216-219