Photodetection in the LHC experiment

Attempt of a review after two decades of R&D, construction and optimization

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Outline

- Reminder: The state-of-the art during the LEP/SLC era
- The LHC challenges (in photodetection)
- A selection of LHC specific photodetector developments, incl. upgrade plans
  - APD and VPT for CMS ECAL
  - HPD for CMS HCAL
  - HPD for LHCb RICH
  - CsI for ALICE HMPID
- Some other large scale applications of photodetectors
  - ATLAS TileCal
  - ATLAS ALFA
- Conclusions

Disclaimer

A review talk about photodetection in the LHC experiments can't be complete.
Please accept my excuses in case my selection appears imbalanced, subjective, arbitrary, ...

Acknowledgements

I'm very grateful to the following people for providing me material, information and advice

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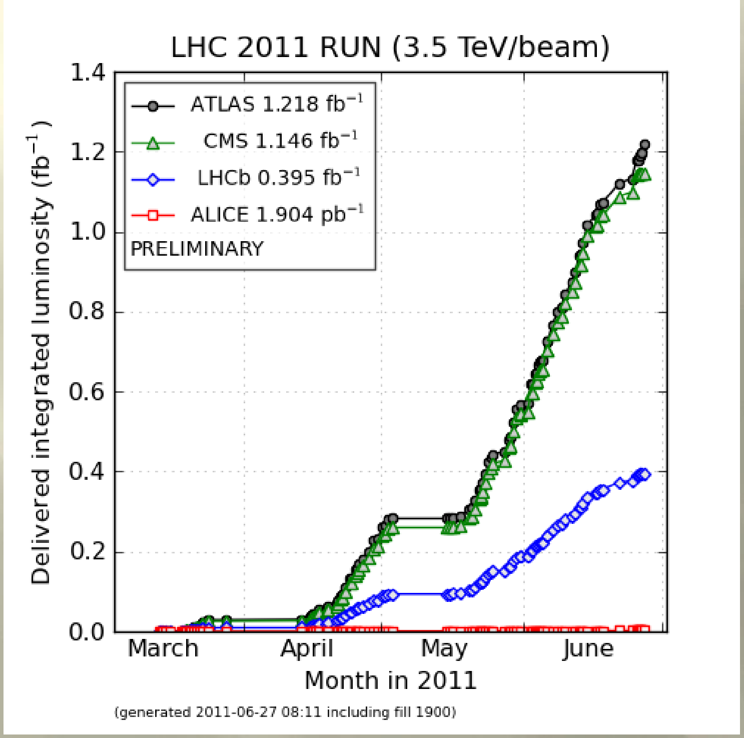
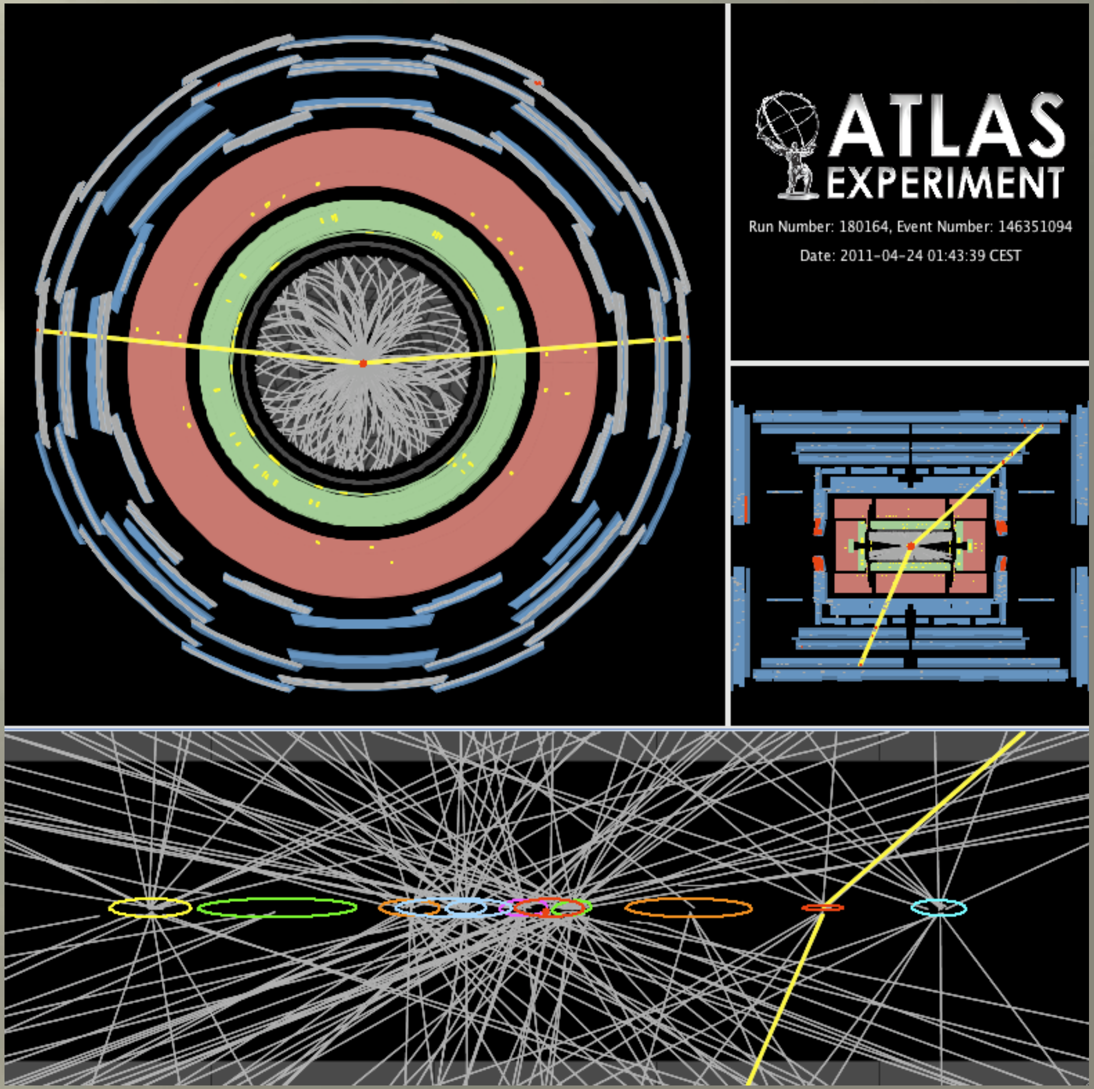
The LHC and the experiments are doing very well !

- LHC runs with E = 3.5 TeV/beam
- Currently 1380 bunches
- Bunch spacing 50 ns
- Luminosity record (until 27/6): $1.27 \cdot 10^{33}\ cm^{-2}s^{-1} = 1270\ \mu b^{-1}/s$
- 1 good fill now ~ 2010 full year
- 2011 goal of $1 fb^{-1}$ already exceeded





https://twiki.cern.ch/twiki/bin/view/AtlasPublic/EventDisplayPublicResults#Events_from_2011_Collisions

Photodetection in High Energy Physics

The classical domains of application

- Calorimetry
  - Readout of organic and inorganic scintillators, lead glass, scint. or quartz fibres → Blue/VIS, usually 10s – 10000s of photons

- Particle Identification
  - Detection of Cherenkov light → UV/blue → single photons
  - Time Of Flight → Usually readout of organic scintillators (not competitive at high momenta)
  - Transition radiation (X-rays, not covered in this talk)

- Tracking
  - Readout of scintillating fibres blue/VIS, few photons

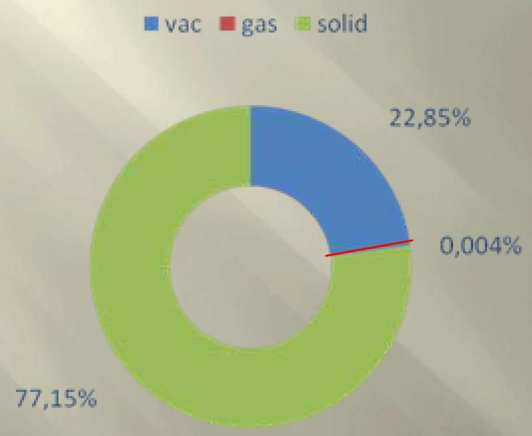
A few (rounded) numbers for the LHC experiments

- Total number of photodetectors installed: 158,000
- Total number of readout channels: 4,447,000

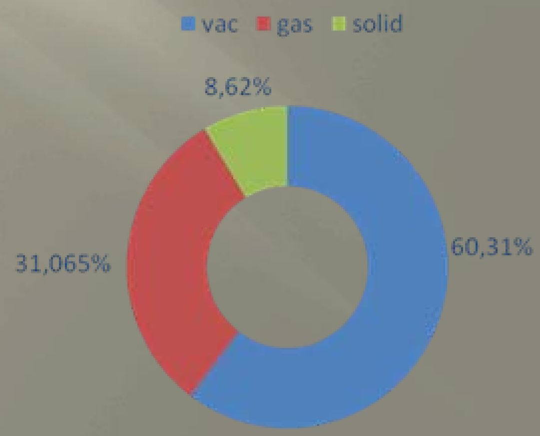
  → There are quite a few multi-channel devices, e.g. Pixel HPD in LHCb

- Total photosensitive area: 35,377,120 mm^2 = 35.4 m^2
- Estimated photocathode volume: 4364 mm^3 (only vacuum and gas devices)
  4.4 cm^3 (most of it is CsI). Just a few grams!

Percentages by device numbers



Percentages by surfaces



Let’s go 25 years back in time ....

The state-of-the art during the LEP/SLC era

- ‘Slow’ TMAE based RICH detectors (DELPHI at LEP / SLD at SLC)
- PIN diode readout for crystal calorimeters
- ‘Classical’ PMTs for TOF, trigger, scintillators

The DELPHI RICH detectors

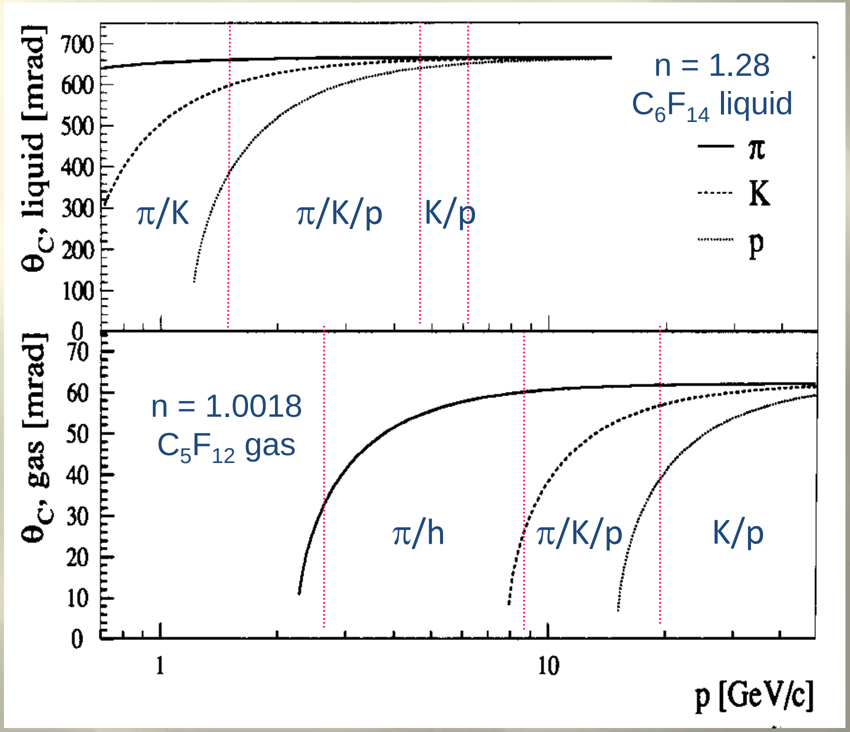
NDIP

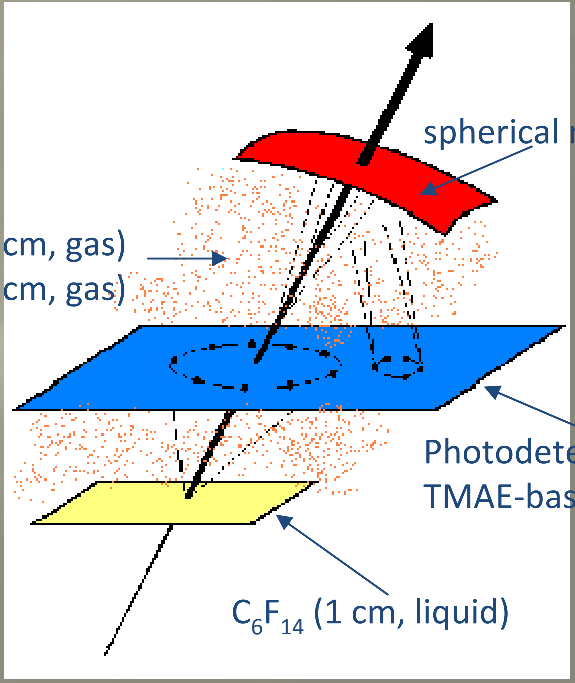
Particle Identification in DELPHI at LEP

E. Albrecht et al., DELPHI RICH collaboration, NIM A 433, (1999), 47-58

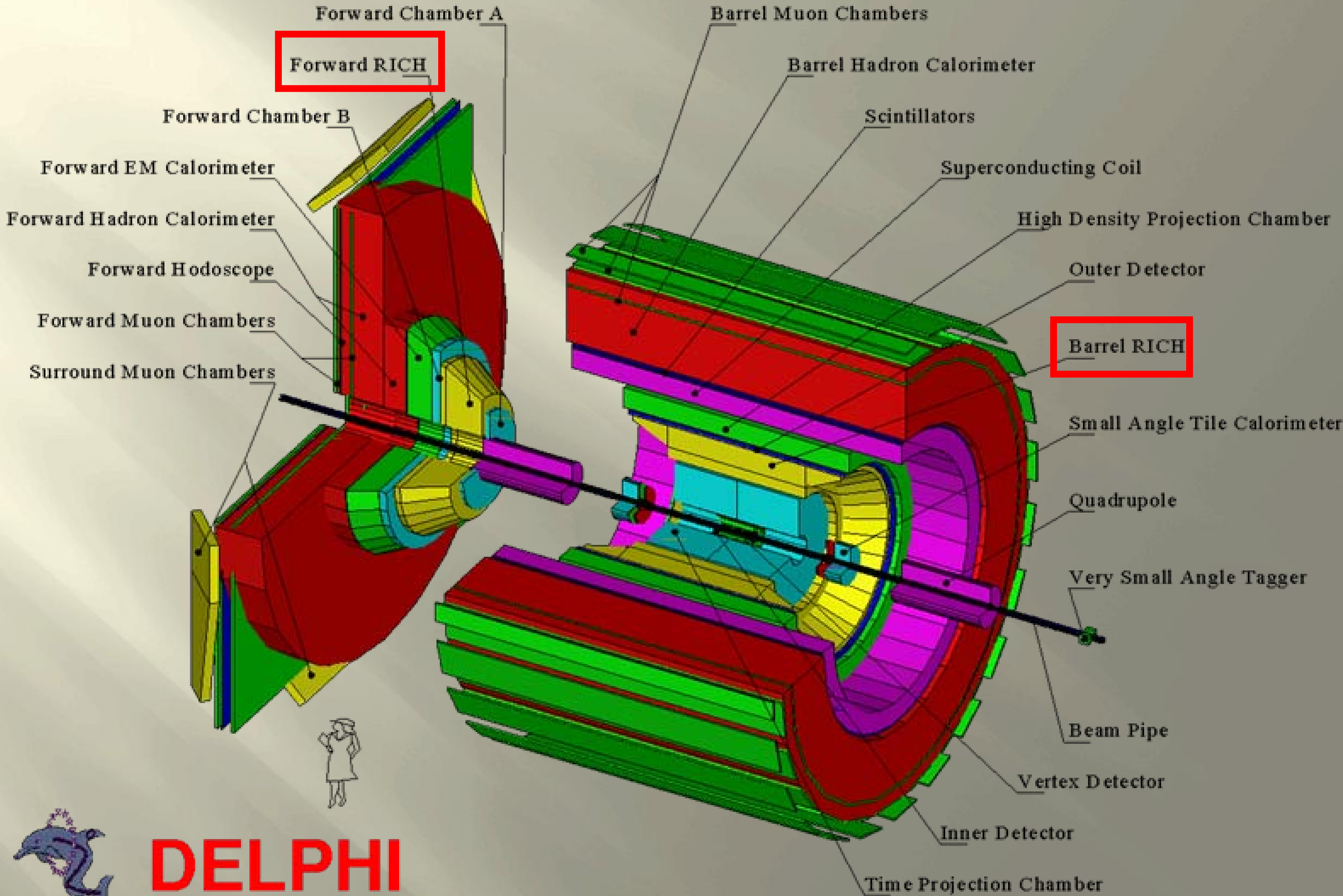
- $0.7 \leq p \leq 45$ GeV/c → gaseous + liquid radiators
- $15° \leq \theta \leq 165°$ → barrel + endcap RICHes

2 radiators + 1 photodetector



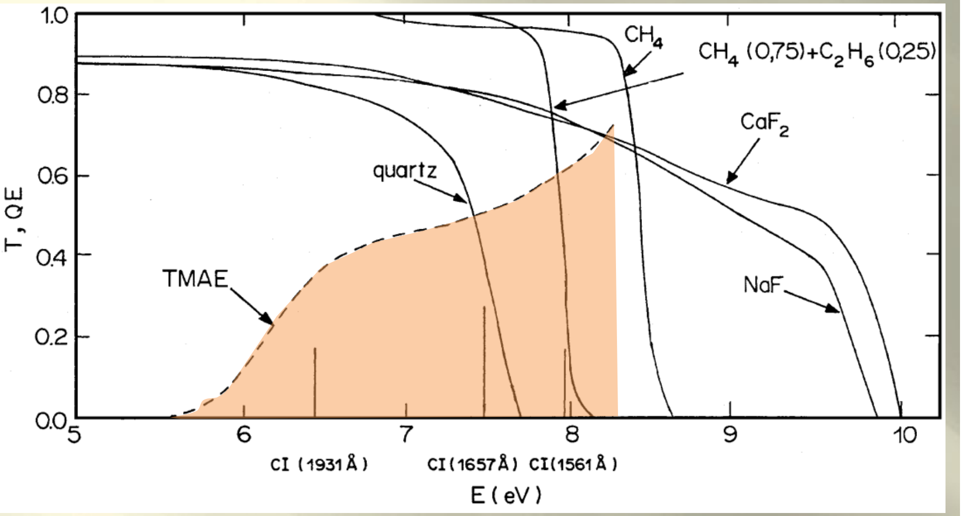


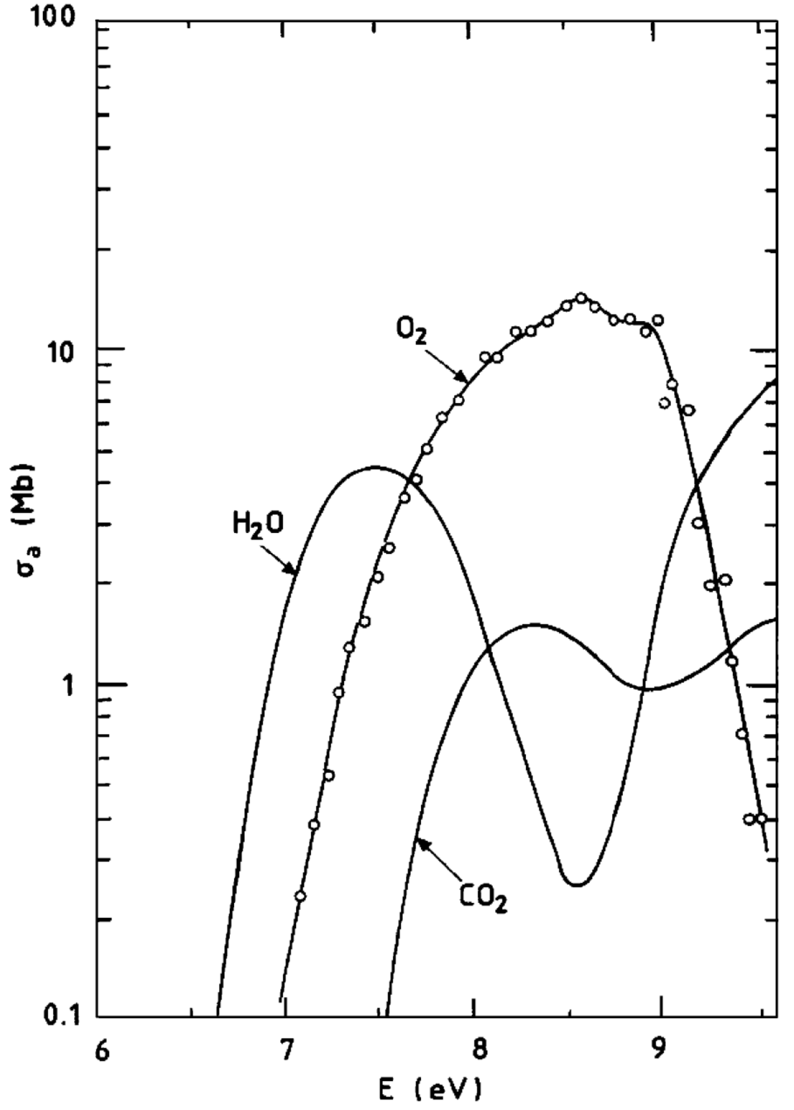
Technologically, one of the most challenging detectors ever built!


Forward Chamber A
Forward RICH
Forward Chamber B
Forward EM Calorimeter
Forward Hadron Calorimeter
Forward Hodoscope
Forward Muon Chambers
Surround Muon Chambers
Barrel Muon Chambers
Barrel Hadron Calorimeter
Scintillators
Superconducting Coil
High Density Projection Chamber
Outer Detector
Barrel RICH
Small Angle Tile Calorimeter
Quadrupole
Very Small Angle Tagger
Beam Pipe
Vertex Detector
Inner Detector
Time Projection Chamber

DELPHI

The TMAE challenge



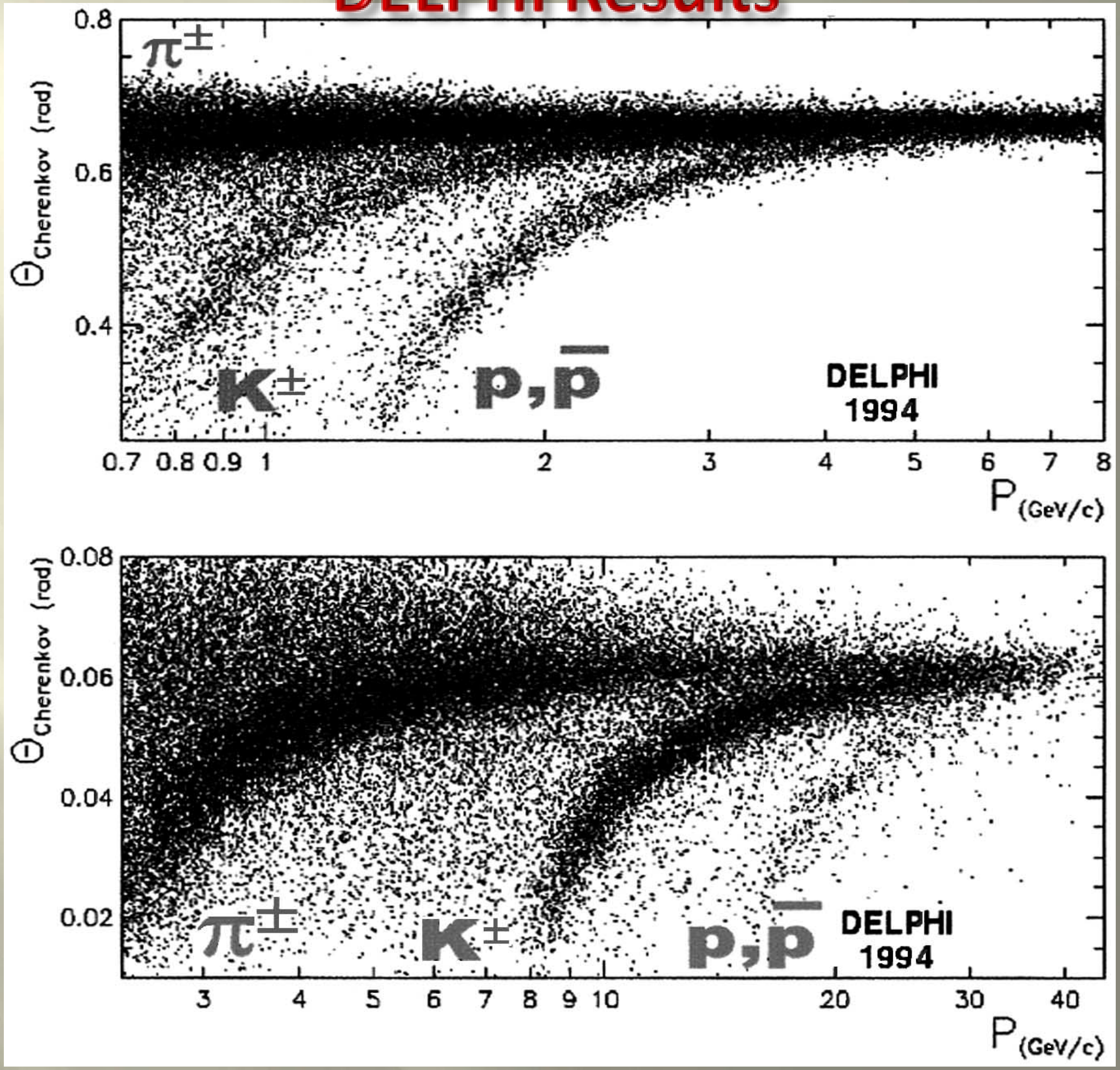


- Threshold around 220 nm → deep UV
- Use of quartz windows (cut-off ~ 165 nm)
- Very careful cleaning of radiator and chamber gases
- Temperature and absolute pressure stabilization of whole detector (avoid TMAE condensation, avoid quartz breaking)

DELPHI Results

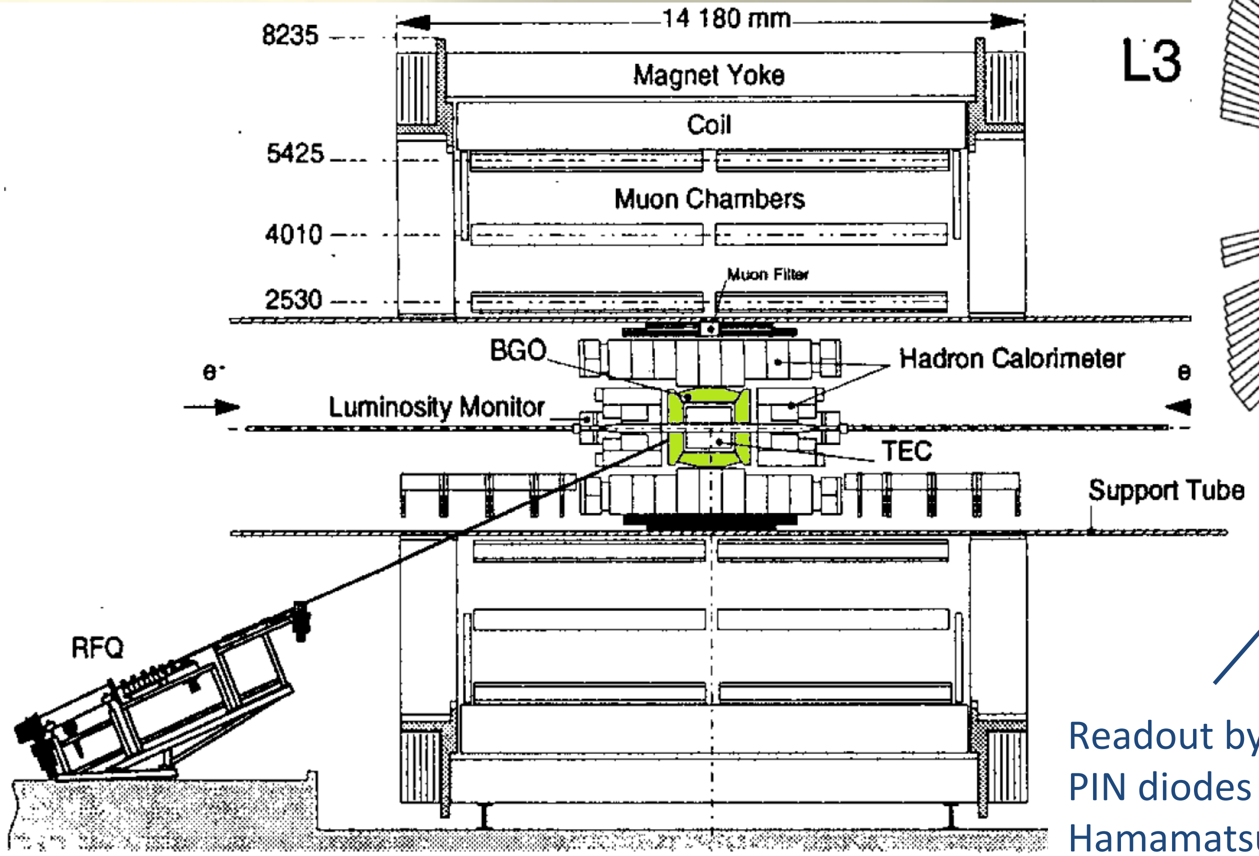
liquid radiator

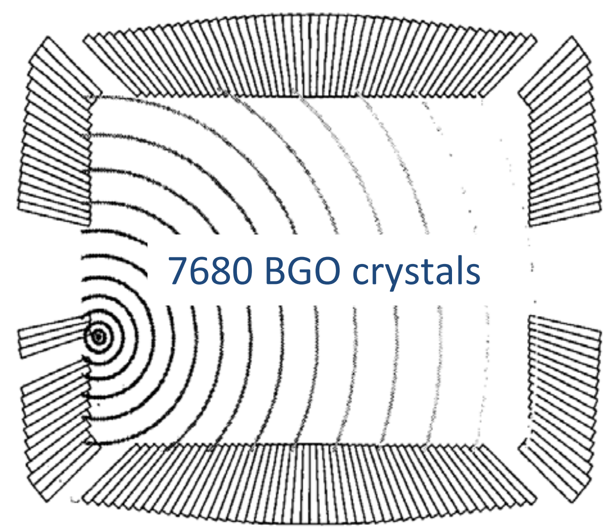
gaseous radiator

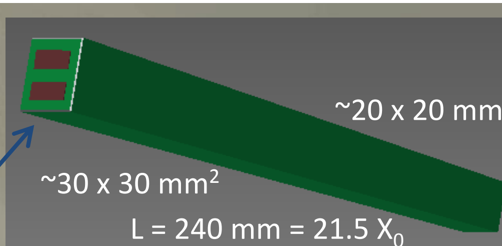


Sorry, there were no colour plots in 1994 ☹

PIN diode based calorimeter readout (L3)







Readout by 2 PIN diodes Hamamatsu S2662 (20 x 7.5 mm2)

BGO	
ρ (g/cm3)	7.3
X_0 (cm)	1.12
LY (ph/MeV)	~8000
λ_{max} (nm)	480
τ (ns)	300
d(LY)/dT	-1.55 %/K

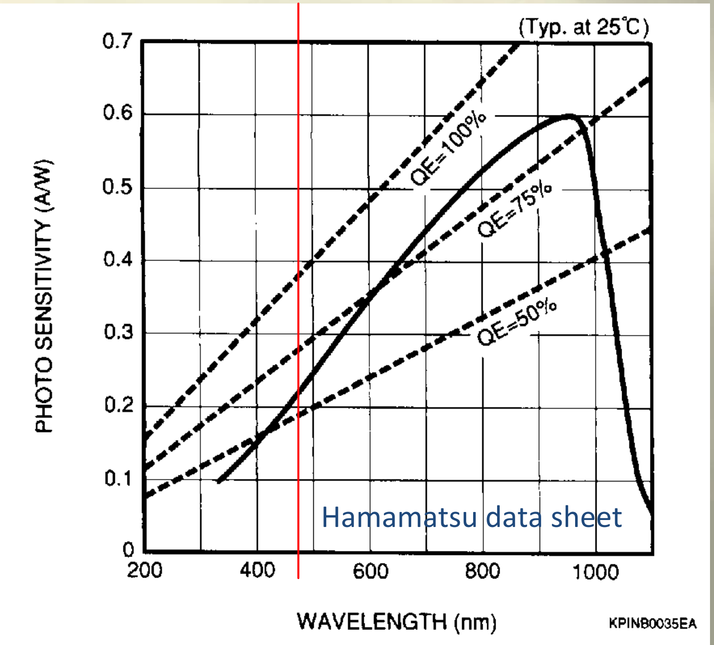
RFQ acclerator: 1.85 MeV p

→ $p + {}^7_3\mathrm{Li} \rightarrow {}^8_4\mathrm{Be} + \gamma$

→ 17.6 MeV γ for crystal calibration

L3 results

Photodiode: Hamamatsu S2662



$\langle S \rangle_{BGO}$ = 0.26 A/W → <QE> ~ 0.67

PIN photodiode → Gain = 1

Still, high light yield of BGO leads to 0.2 fC = 1200 e^- / MeV deposited in BGO

Calorimeter resolution (prototype and test beam)

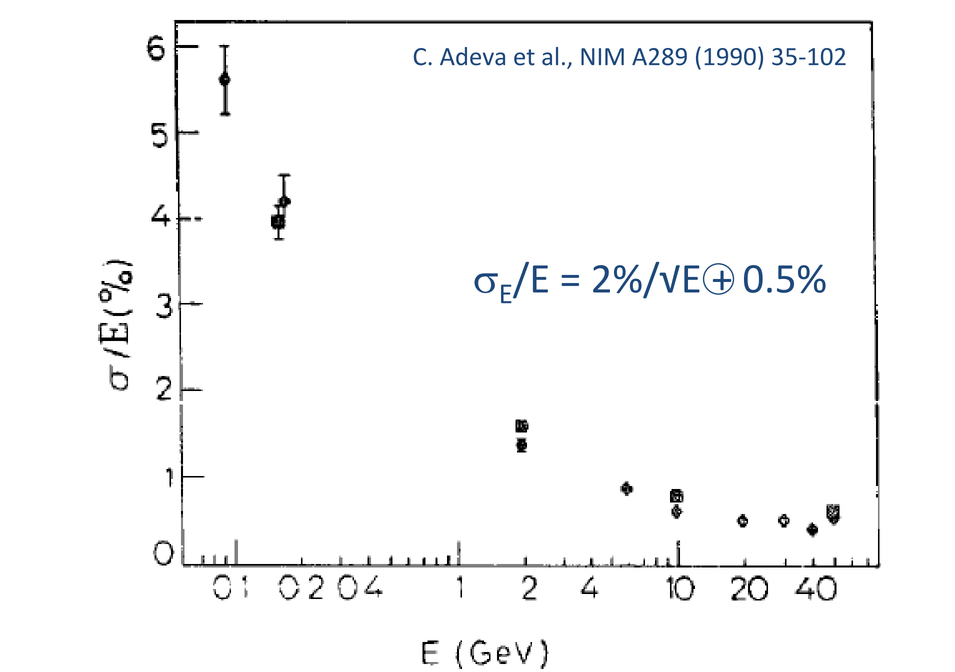


Fig. 96. Energy resolution. Diamonds: prototype 1985; squares: barrel 1988.

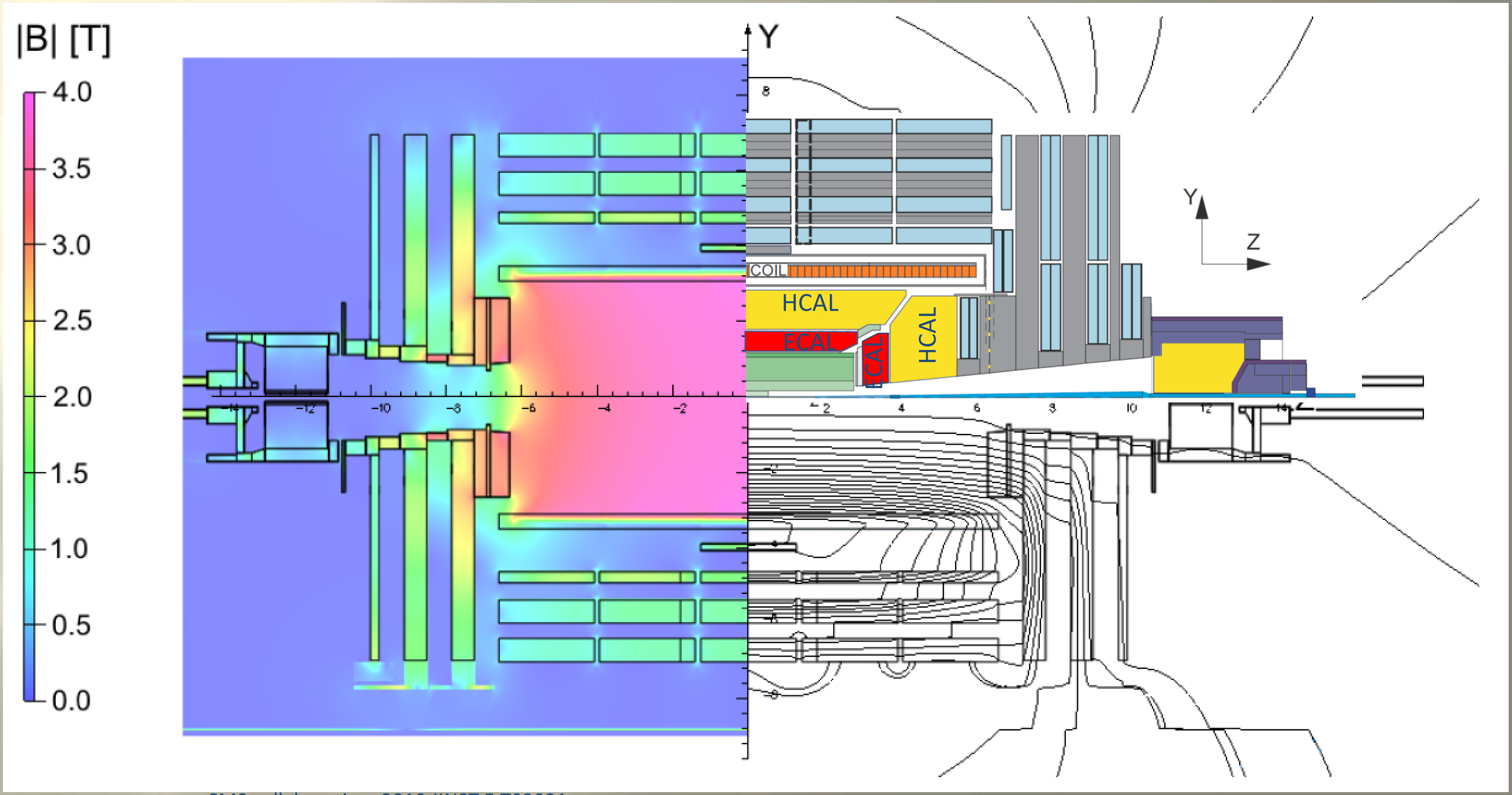
Constant term was kept below 1% during 12 years of LEP operation

The LHC environment for photon detectors

- Event rate up to 40 MHz with high multiplicity → high occupancy → high granularity → fast readout
- Strong magnetic fields (up to 4T)
- High radiation levels (NIEL and ionizing particles)
- Restricted accessibility and maintainability → reliability
- Very large channel counts → cost effectiveness → high level of integration → sophisticated calibration

Magnetic fields

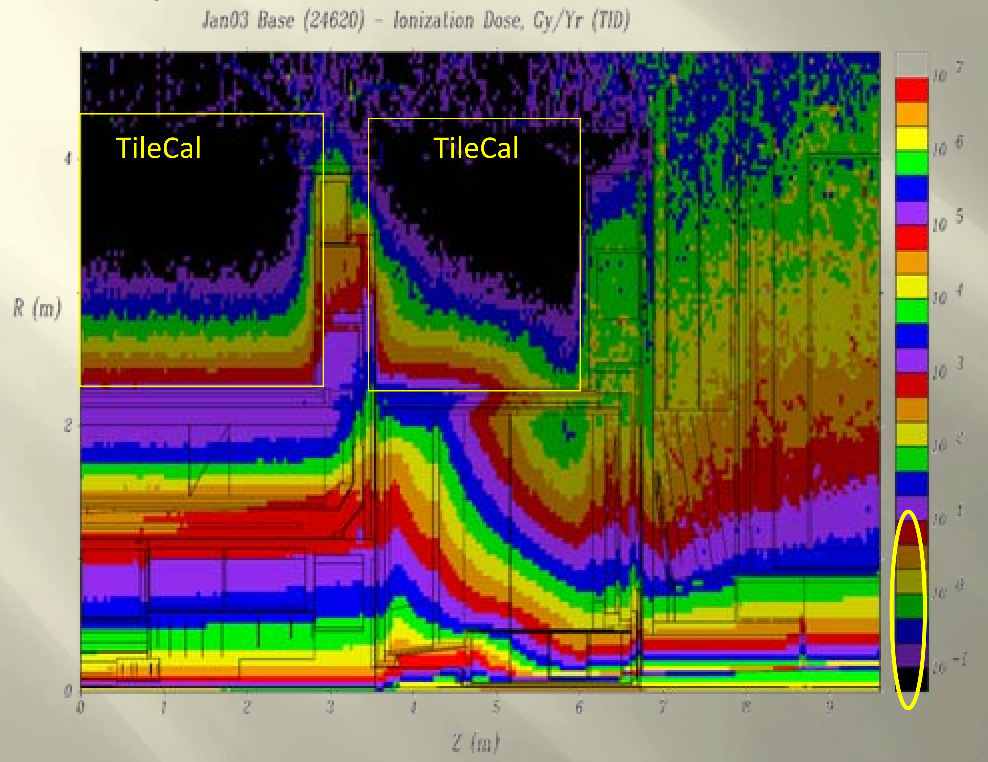
Example: magnetic field map of CMS



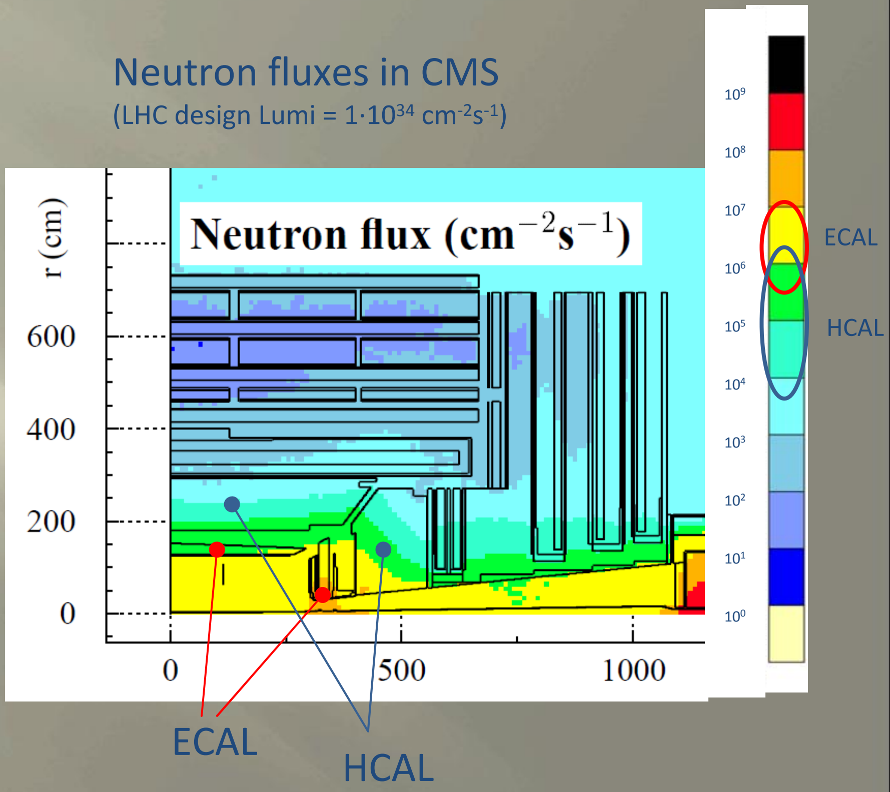
CMS collaboration, 2010 JINST 5 T03021

Radiation fields

Total Ionization dose in the calorimeter region of ATLAS
(LHC design Lumi = $1\cdot10^{34}$ $cm^{-2}s^{-1}$)



Neutron fluxes in CMS
(LHC design Lumi = $1\cdot10^{34}$ $cm^{-2}s^{-1}$)



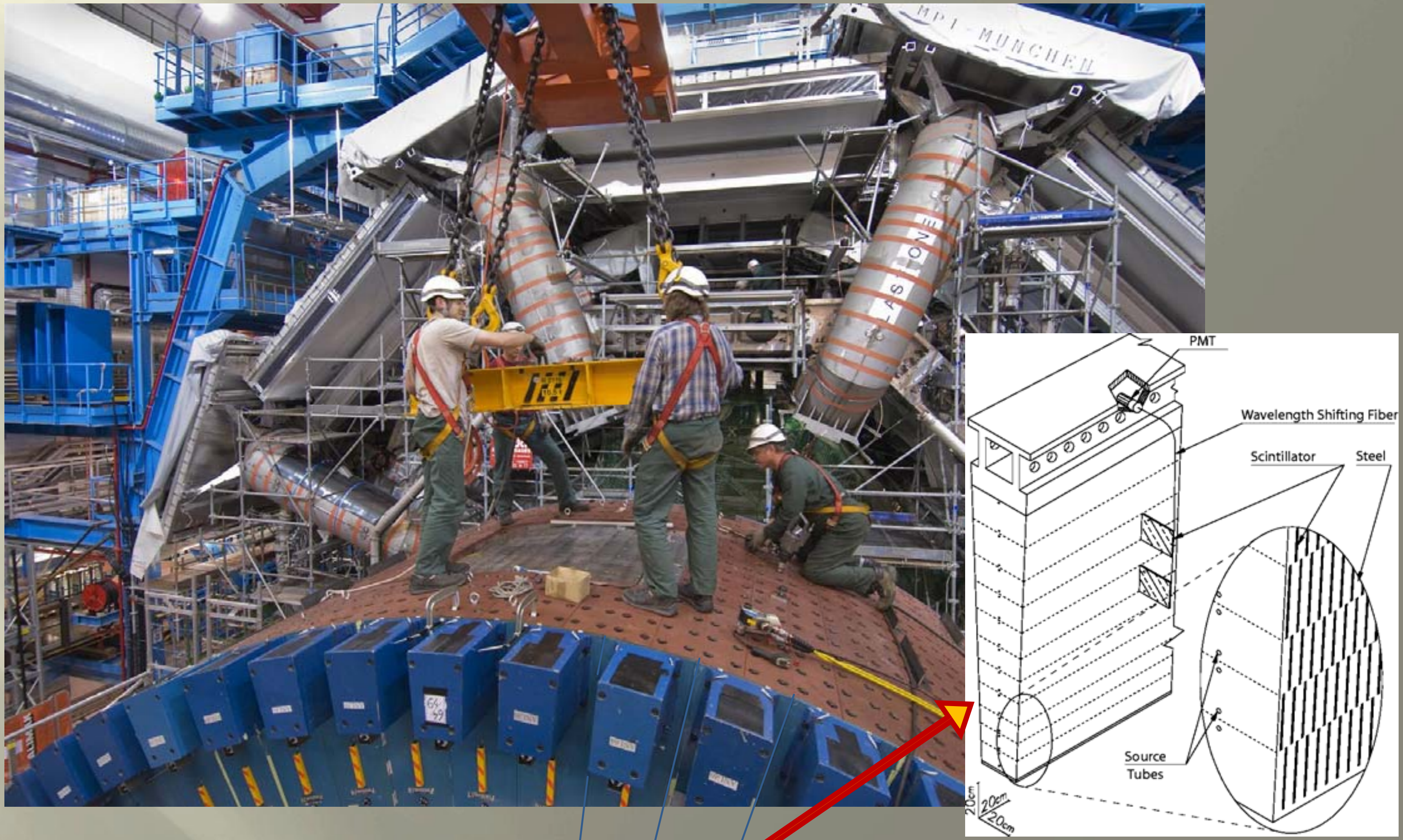
Restricted access

A snapshot during the installation of the ATLAS Tile Calorimeter

This huge steel structure hides a total of ~10000 PMTs (Hamamatsu R 7877)

Maintenance, repair or replacement ?

Only possible during winter shutdowns, need ~ 7-9 weeks break, incl. calori-meters opening

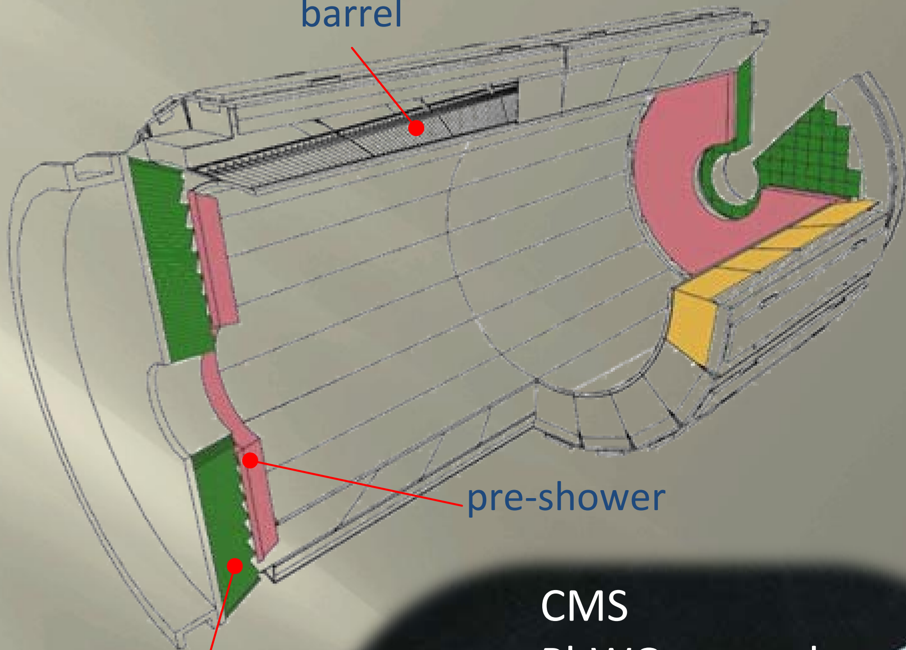


ATL-ATL-COM-TILECAL-2007-019

Readout of the CMS ECAL

The challenge: Read out a high precision crystal calorimeter based on 61200 (barrel) + 14648 (EC) crystals

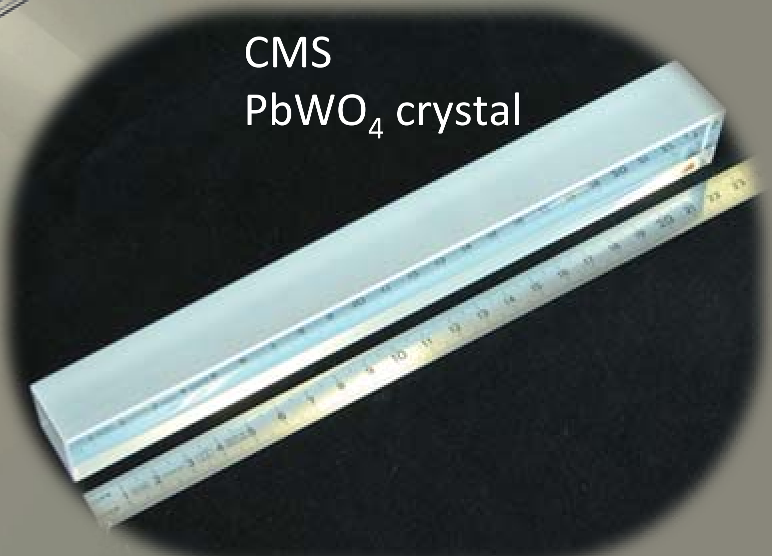
	BGO	$PbWO_4$
ρ (g/cm3)	7.3	8.28
X_0 (cm)	1.12	0.89
LY (ph/MeV)	~8000	~200
λ_{max} (nm)	480	~420-430
τ (ns)	300	~10
d(LY)/dT	-1.55 %/K	-2.0 %/K



Environment:

- B ~ 3.8T
- Dose rate: ~0.2 (barrel) – 5 (EC) Gy/hr
- Neutrons: O(10^{13} – 10^{14} cm^{-2}) in 10 yrs

$PbWO_4$ provides required speed and radiation hardness but produces very few photons/MeV

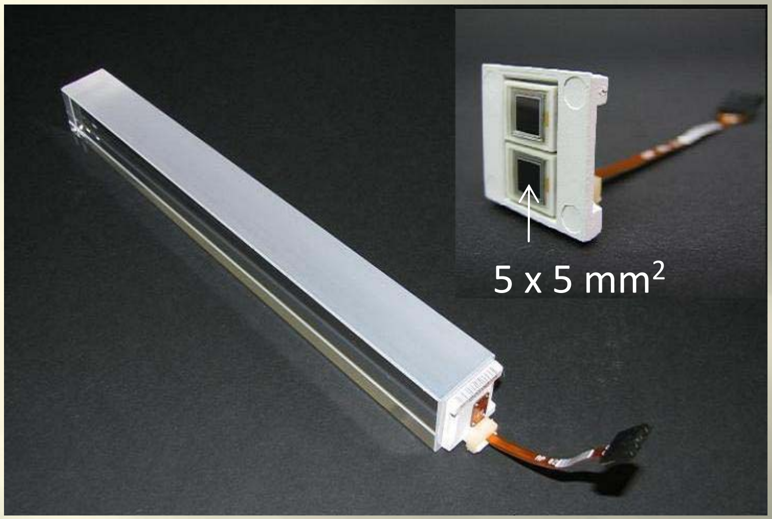


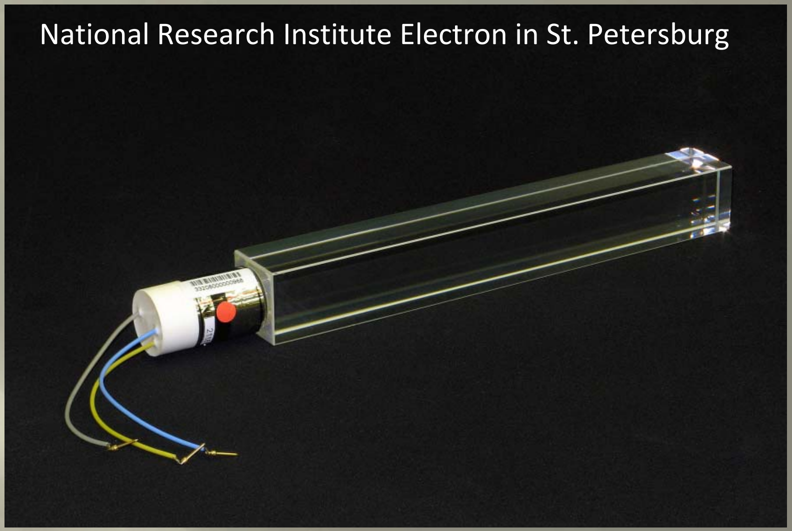
The CMS ECAL group. 2010 JINST 5 P03010

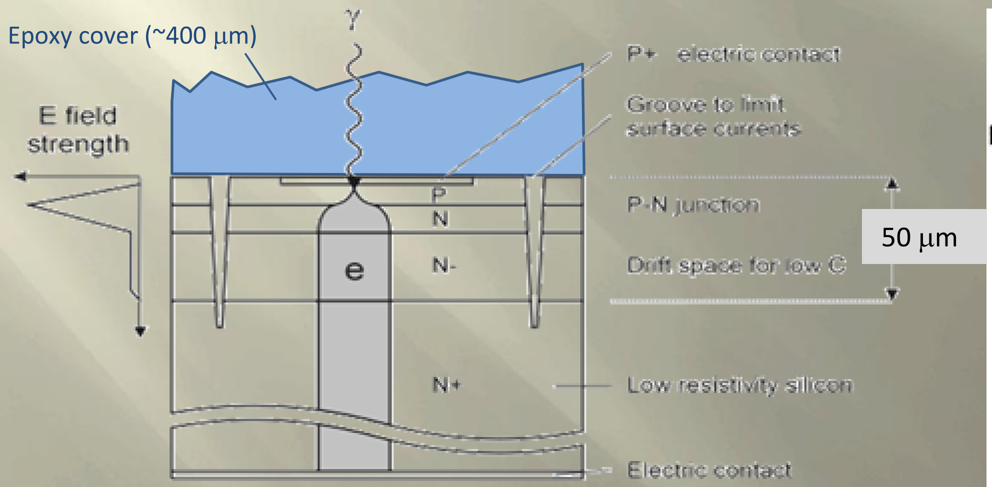
CMS specific photodetector developments

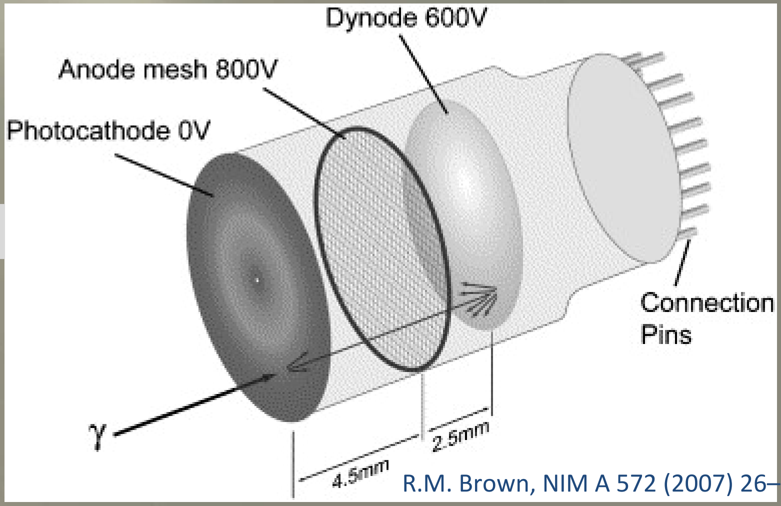
Barrel: 2 x APD, Hamamatsu S8148

EC: Vacuum PhotoTriodes (VPTs), PMT188









R.M. Brown, NIM A 572 (2007) 26–28

CMS ECAL photodectors

	APD	VPT
Area	25 mm^2	280 mm^2
QE	~0.75	0.2
V_{op}	340 – 430 V	800 / 600 V
G	50	10
1/G · dG/dV	3.1%/V	saturated
1/G · dG/dT	-2.4 %/K	negligible
ENF	2 (at G=50)	~1
PE yield / MeV	4.5	4.5

Requires precise (~10 mV) voltage stability

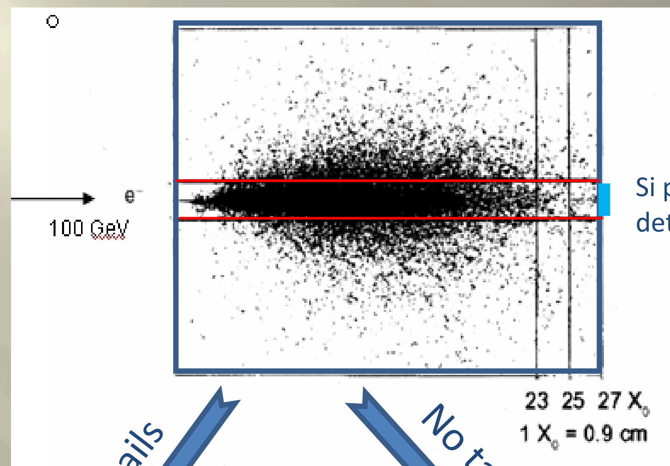
Effect amplifies d(LY)/dT of $PbWO_4$. Very precise T stabilization (~ 0.05 K) needed

300 x less than in L3 BGO calorimeter

Why APDs ?

Reminder: A rad hard PIN diode wouldn't have done the job
- Too little light from $PbWO_4$
- Nuclear Counter Effect

Geant simulation: 100 GeV e- in PbWO4. Each dot stands for an energy deposition of more than 10 keV



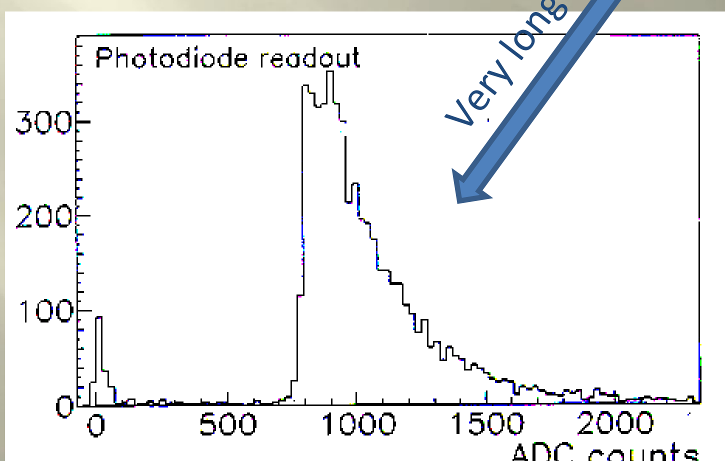
Even after 27 X_0, a small fraction of the shower leaks into the photodetector.

A single MIP produces ~22.000 e^- in 300 μm thick PIN diode.

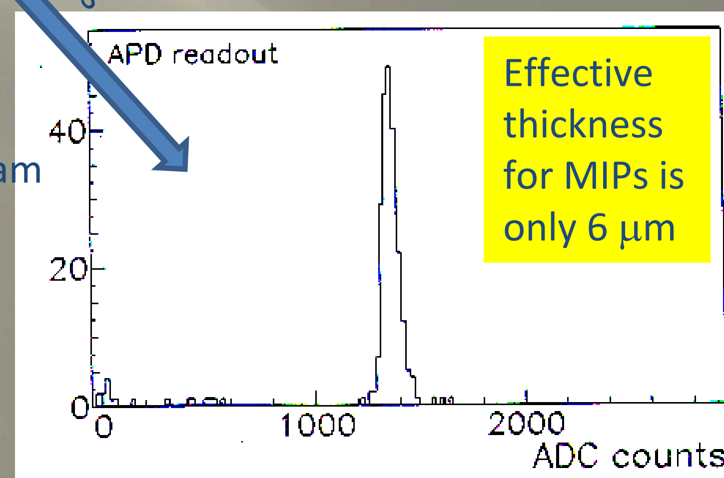
This is equivalent to a 7 GeV photon absorbed in the $PbWO_4$ crystal .

Very long tails

No tails



CMS test beam 1993 !

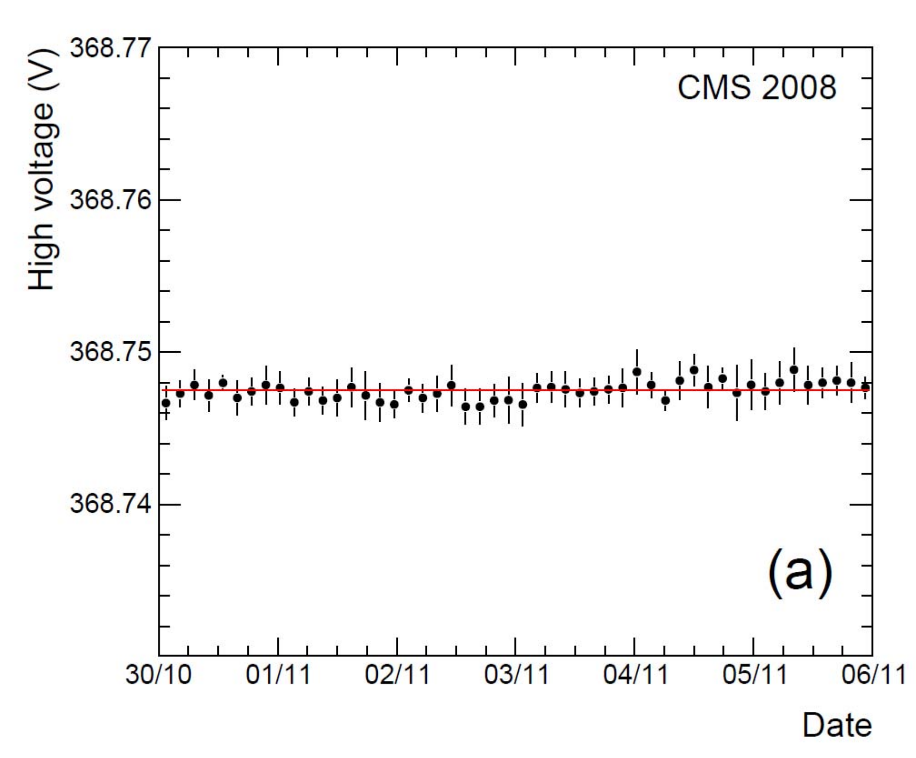


Effective thickness for MIPs is only 6 μm

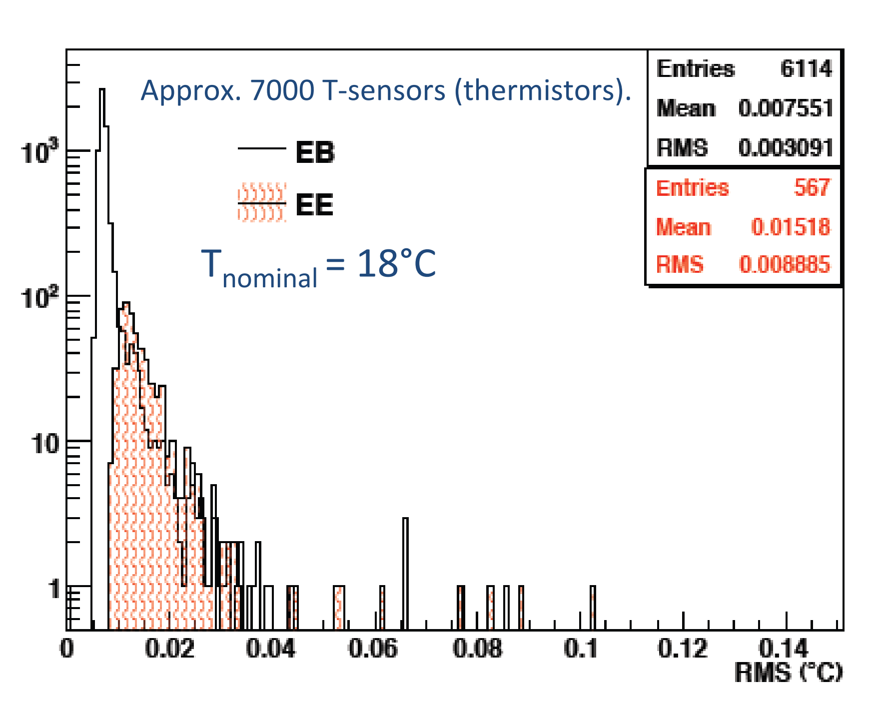
CMS ECAL Operation

Operational channels: 99.30% (Barrel) and 98.94% (Endcap).

Barrel : APD bias voltage stability



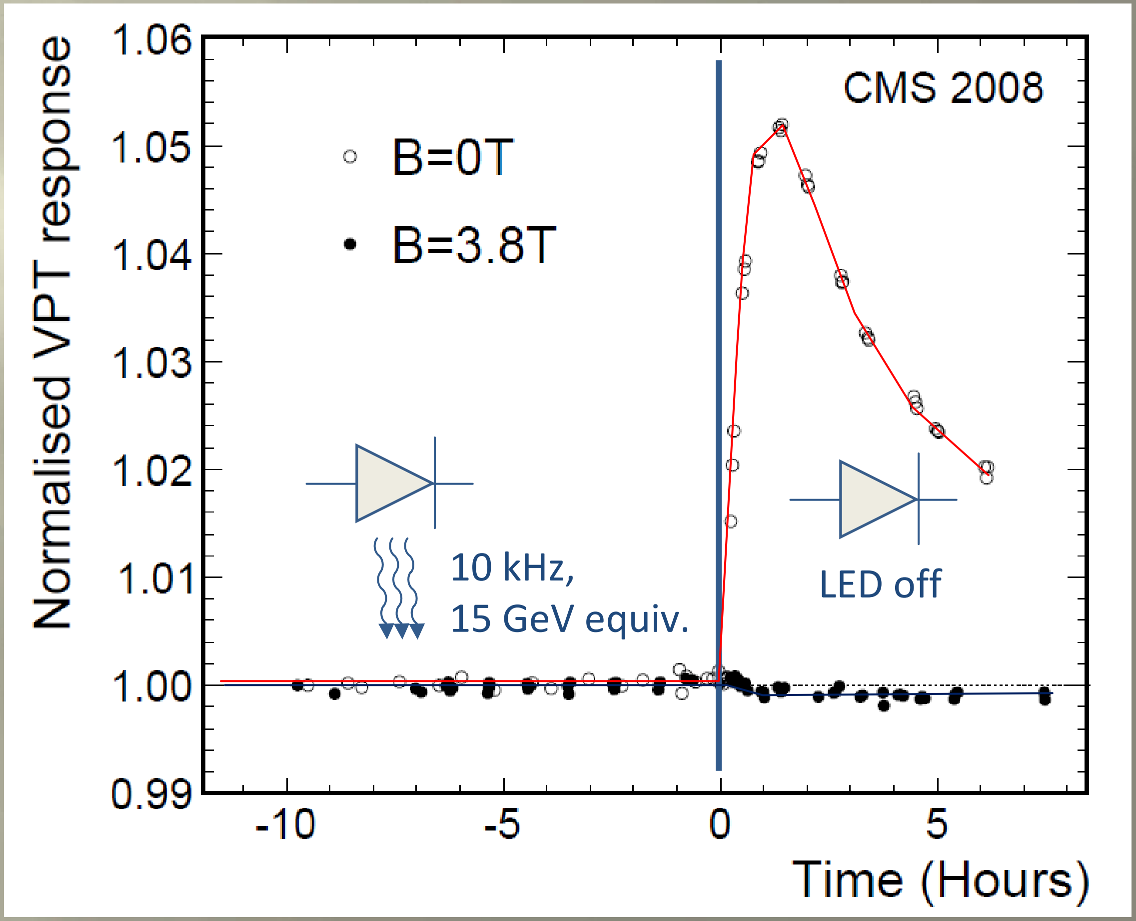
Barrel + end cap: Temperature stability (RMS) over 2 months.



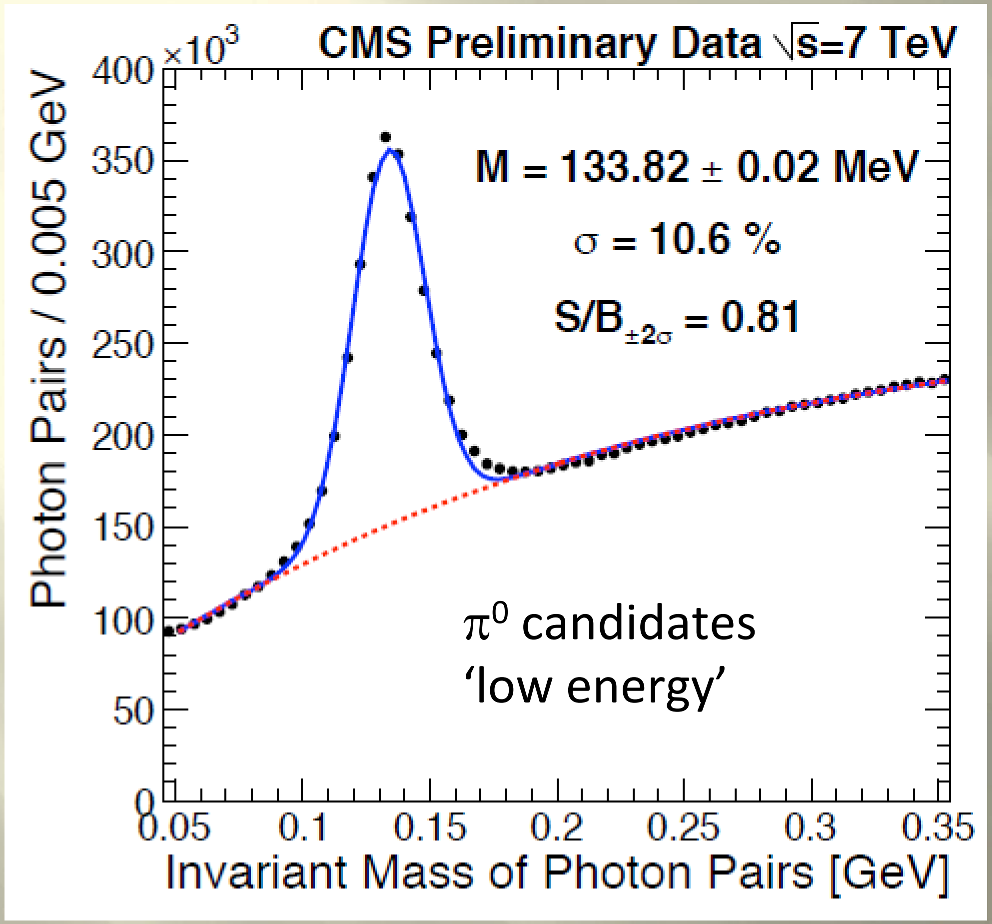
2010 JINST 5 T03010

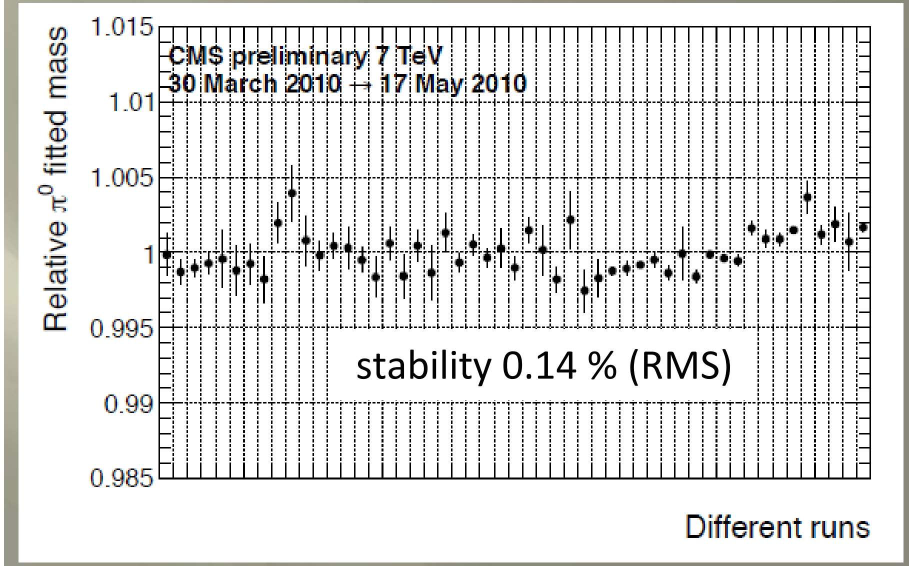
CMS ECAL (endcap)

- VPTs have no electrostatic focusing and are known to show peculiar rate effects.
- Magnetic field stabilizes their operation.
- 3.8 T eliminates the rate effect to less than 0.2%.
  → Well acceptable for ECAL operation.



CMS ECAL performance





CMS NOTE -2010/012

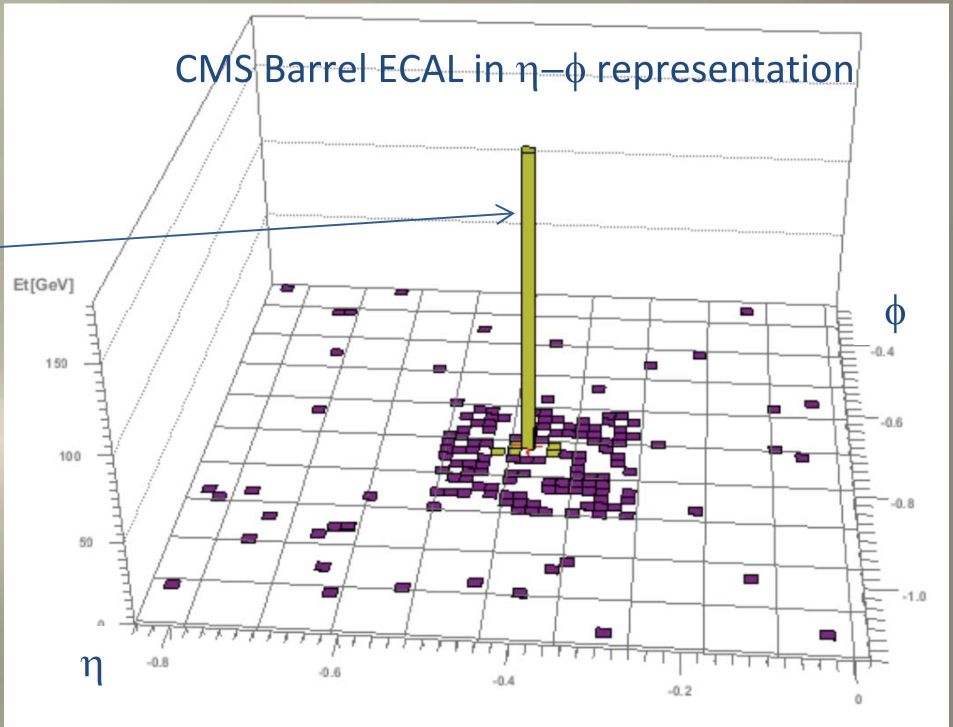
Anomalous signals in the ECAL Barrel

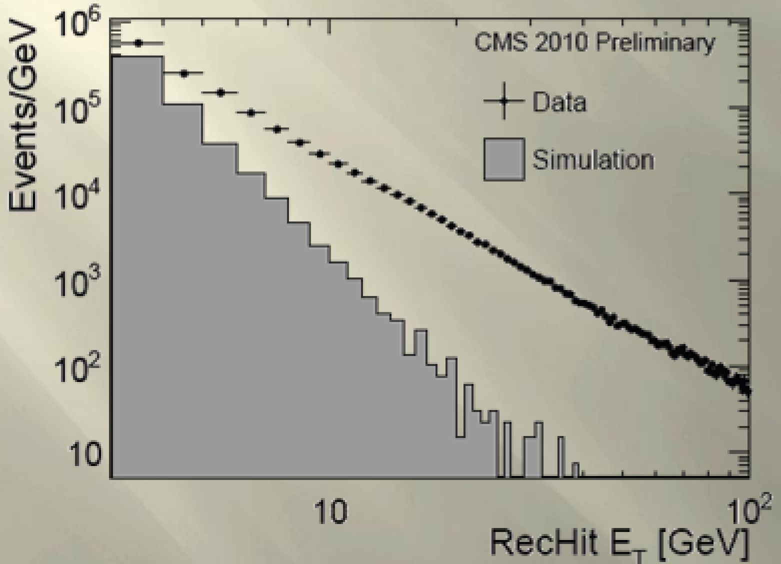
Interesting topic, currently under study:
Anomalous signals in the ECAL Barrel

(see poster of David Petyt in session PII for details)

Observation of *spikes* = Isolated, high energy deposits in single channels, inconsistent with e.m. showers, which normally involve 3x3 or 5x5 crystals.

CMS Barrel ECAL in $\eta-\phi$ representation





Spikes are mainly related to pp collisions. They are relatively rare: $O(10^{-3})$ spikes/minimum bias event.

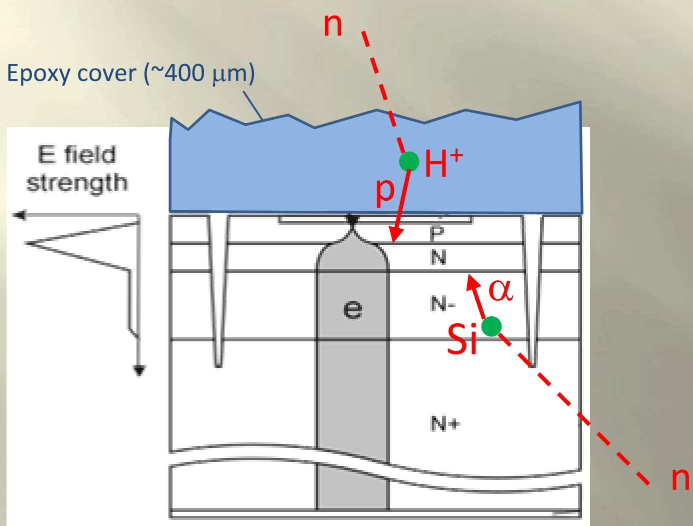
However they lead to an excess of high energy hits in the 'RecHit' distribution, completely dominating at high energies.

What is the cause ?

The full details in the talk by Q. Ingram, session 9.

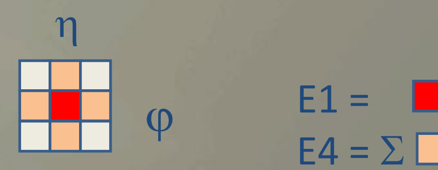
A set of detailed measurements (K. Deiters et al., CMS Note-2010/016) with an Am/Be source indicates that there are at least 2 main contributions:

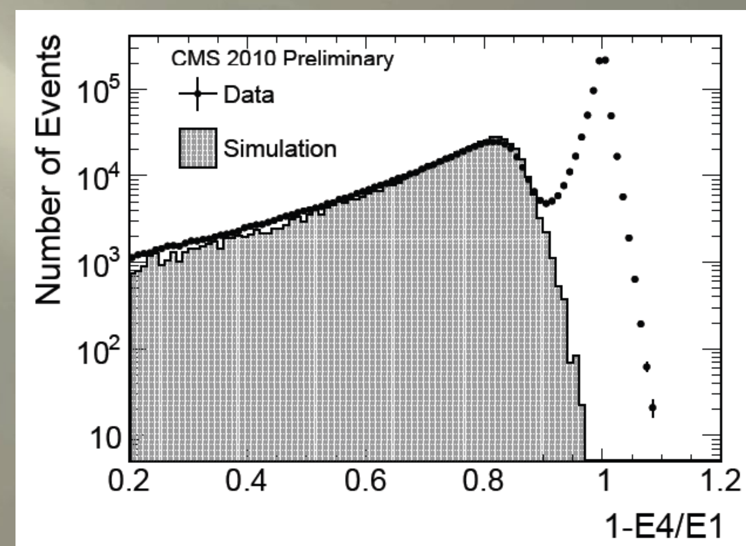
- neutron exchange reactions with the hydrogen (oxygen) in the epoxy cover layer (400 μm thick). σ(n-p) ~ 1 barn. → Signals equivalent to O(10 GeV) in CMS.



- neutron reactions with the silicon, e.g. elastic or n-α → Signals equivalent to *O*(50 GeV).
- Highest signals observed are equivalent to ~300 GeV in CMS.

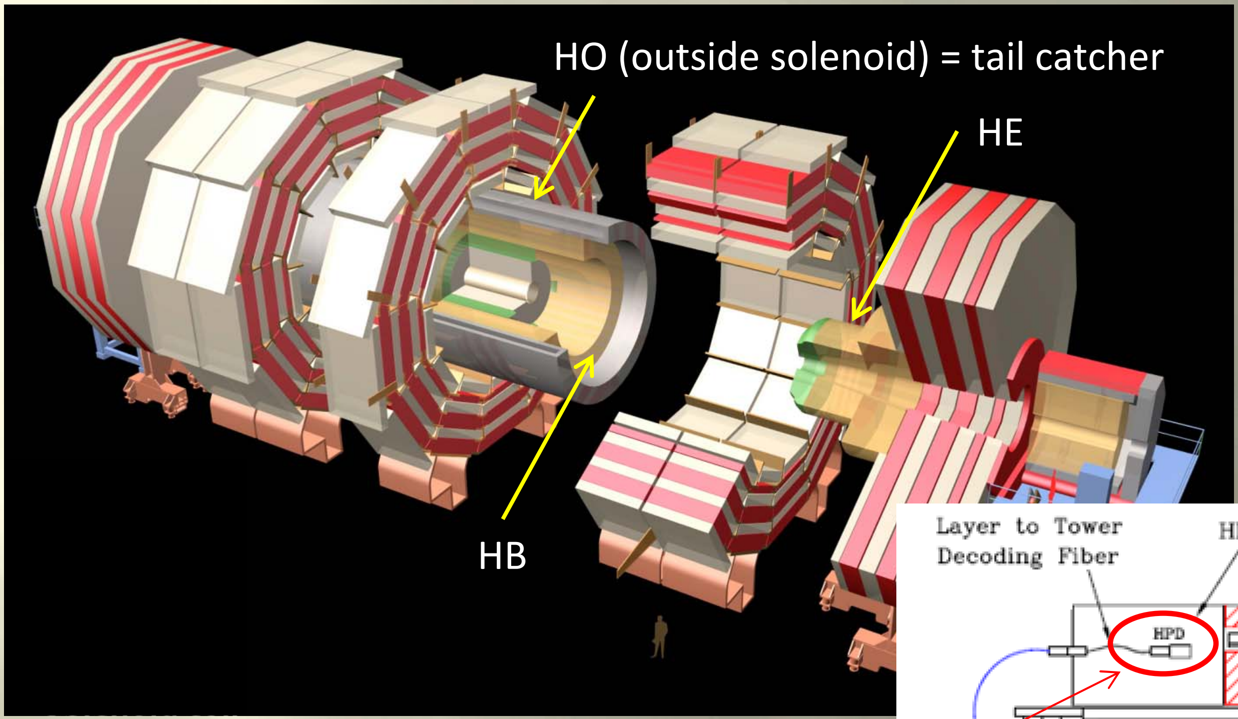
During CMS data taking, anomalous events can be fairly easily suppressed, e.g. by the topological 'Swiss Cross' variable (1—E4/E1)





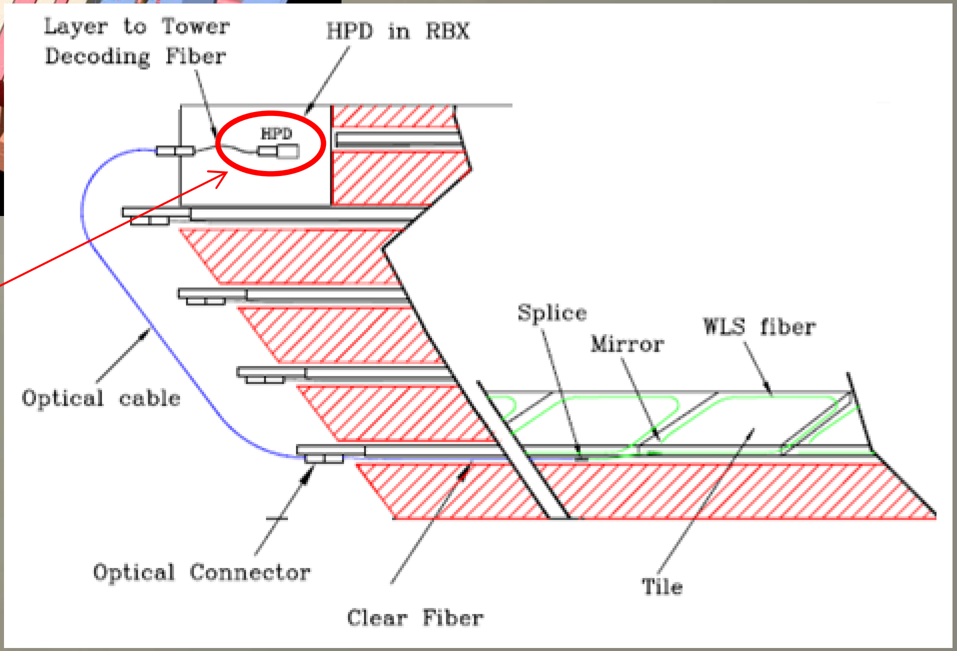
Also signal timing properties are slightly different, since anomalous signals are faster (no scintillation decay constant!)

Readout of the CMS Hadron Calorimeter



A Brass / plastic scintillator sampling calorimeter

Fibres are read out by ~500 multi-pixel proximity-focused HPDs, developed with DEP-Photonis, operated in B ~ 4T.

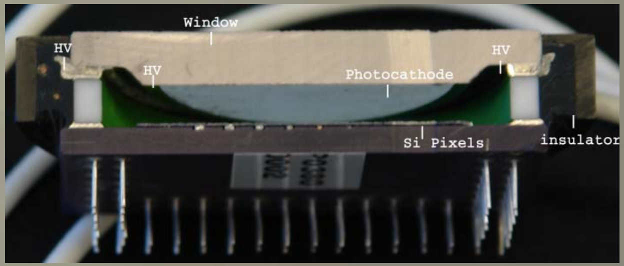


Proximity focused HPD for CMS HCAL

- B = 4T → proximity-focusing with 3.35mm gap and HV=10kV;
- 19(18) hexagonal pixels (20 mm^2).

(http://cmsinfo.cern.ch/Welcome.html/
CMSdetectorInfo/CMShcal.html)

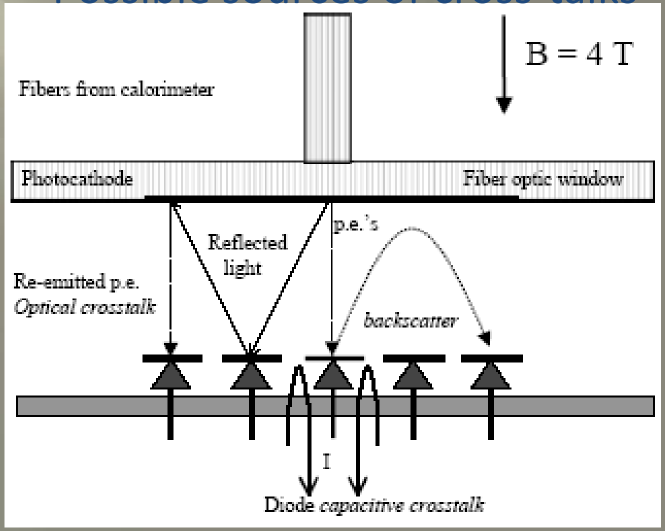
(P. Cushman et al.,
NIM A 504 (2003) 502)



2008 JINST 3 S08004

- Minimize cross-talks:
  - photo-electron back-scattering: align with B;
  - capacitive: Al layer coating;
  - internal light reflections: a-Si:H AR coating optimized @ λ = 520nm (WLS fibres);
- Results in linear response over a large dynamic range from minimum ionizing particles (muons) up to 3 TeV hadron showers;

Possible sources of cross-talks



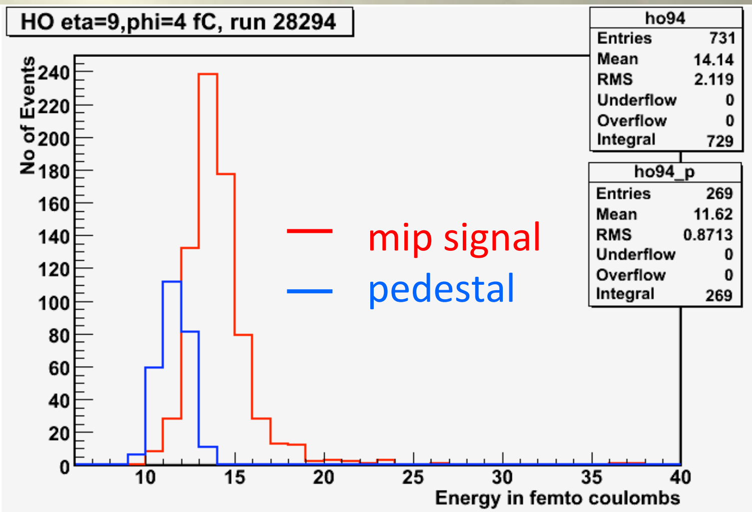
HCAL upgrade activities

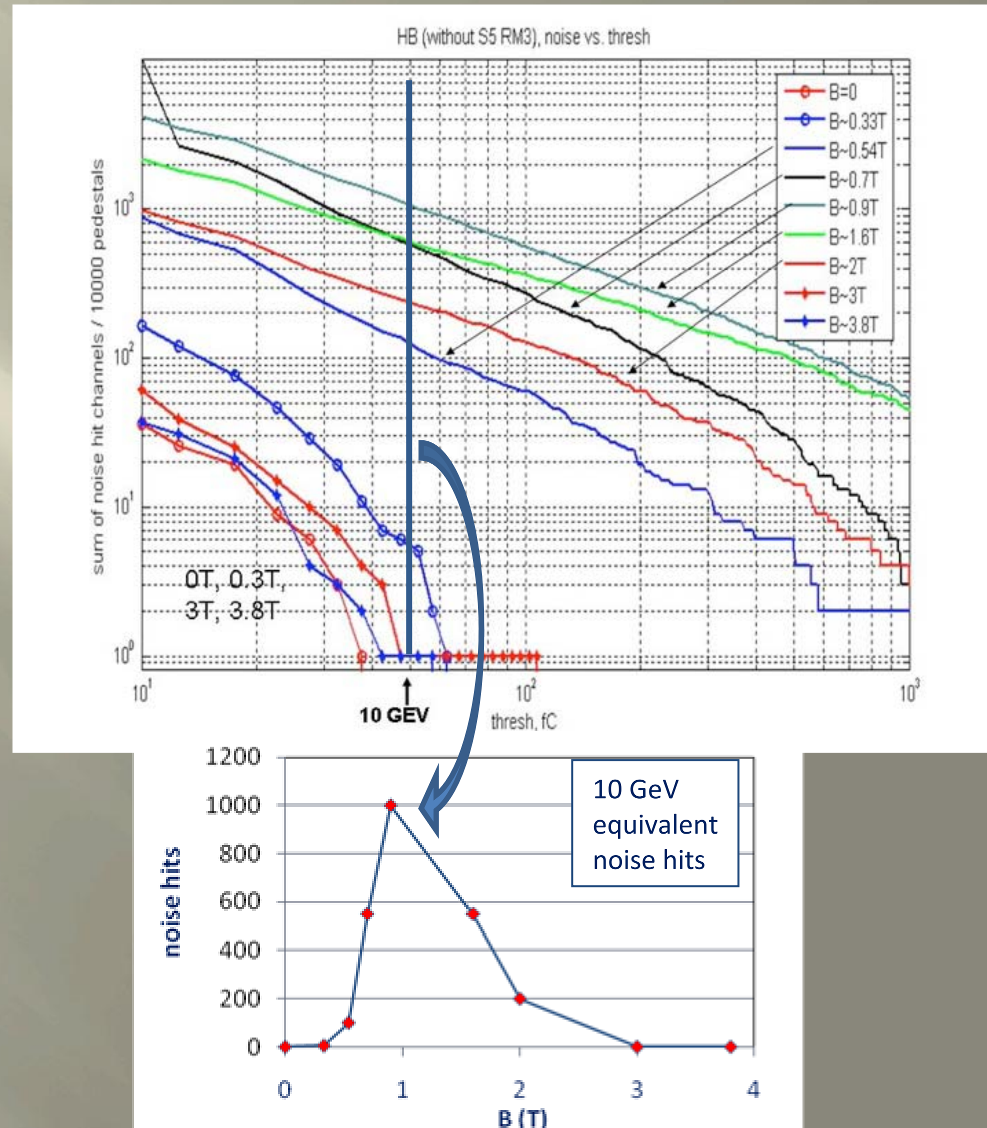
Two unwanted features:

- Noise activity inside HPD at intermediate B-field levels. Apparently some electron avalanches caused on tube walls.

  → Problematic in HO area, where B is inhomogeneous and << 4T.

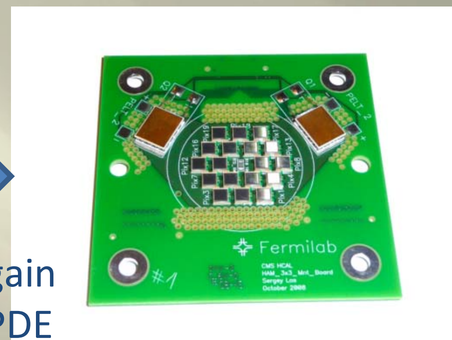
- Gain of HPDs (1500 @ 8 kV) is slightly marginal for HO area, where the signal comes only from a 5 mm thick scintillator tile.





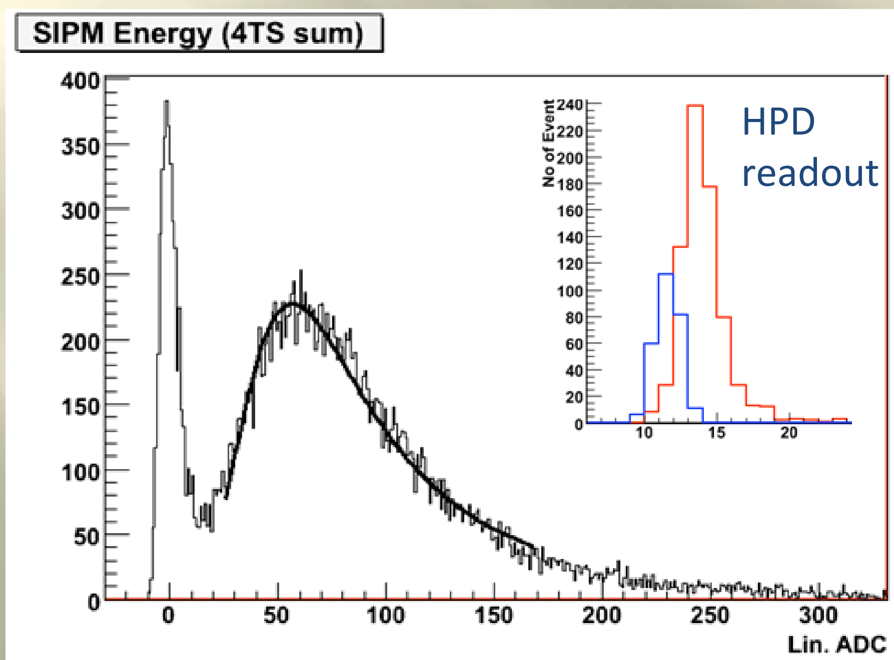
In April 2009: Replaced 8 HPDs in HO area by 144 G-APDs

More gain
More PDE



- 36 Zecotek 15K/mm^2, 3×3mm
- 108 Hamamatsu 400/mm^2, 3×3mm

Could also be an option for HB / HE readout → granularity could provide longitudinal tower segmentation.



Challenges:

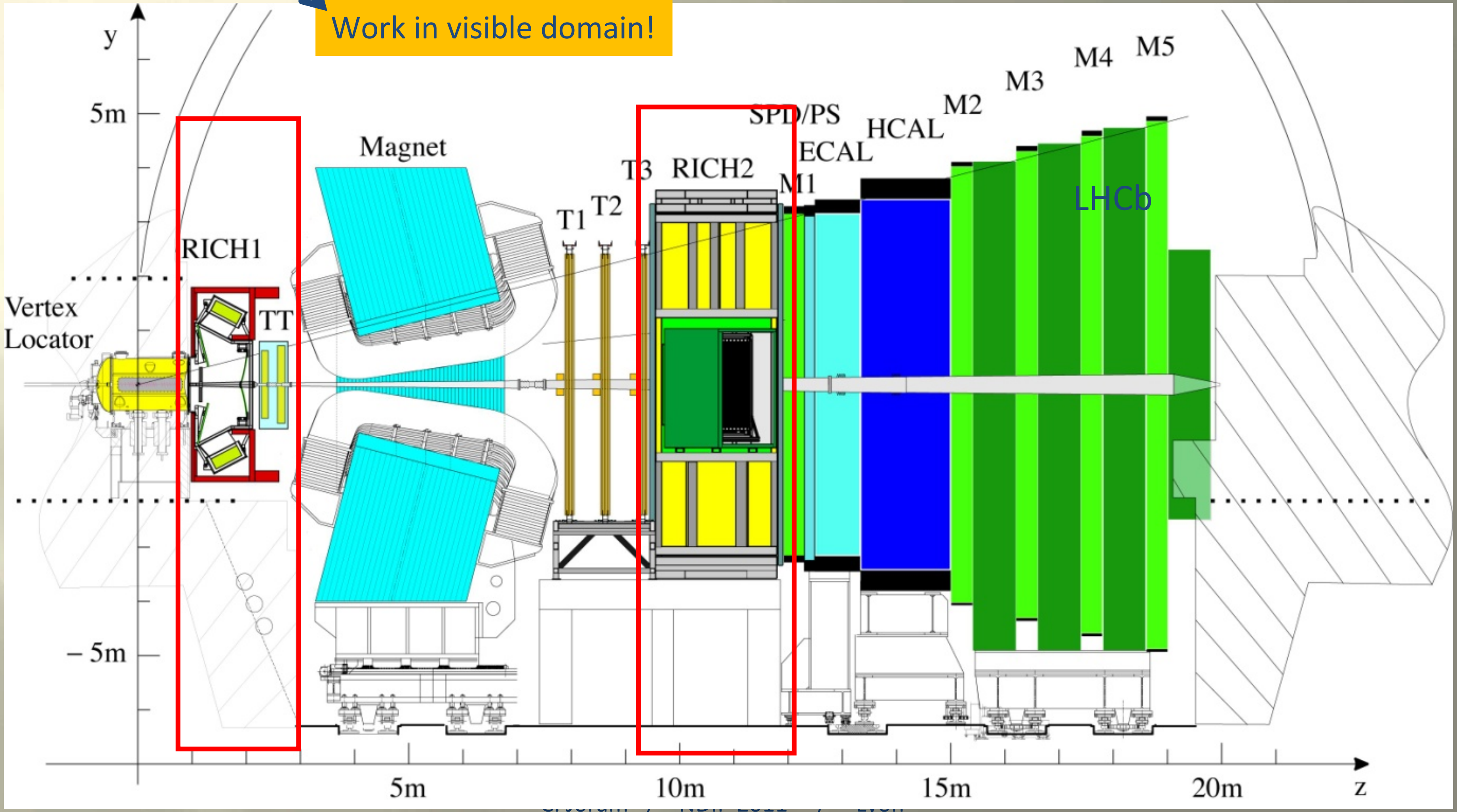
- Very large dynamic range (mip to O(100 GeV))
- High occupancy → fast recovery time
- Radiation levels : $3 \cdot 10^{12}$ cm^{-2} (1 MeV n_{eq}) for 3000 fb-1 (SLHC)

See also S17 SIPM HEP Yury MUSIENKO's talk in session S17
Studies of large dynamic range silicon photomultipliers for the CMS HCAL

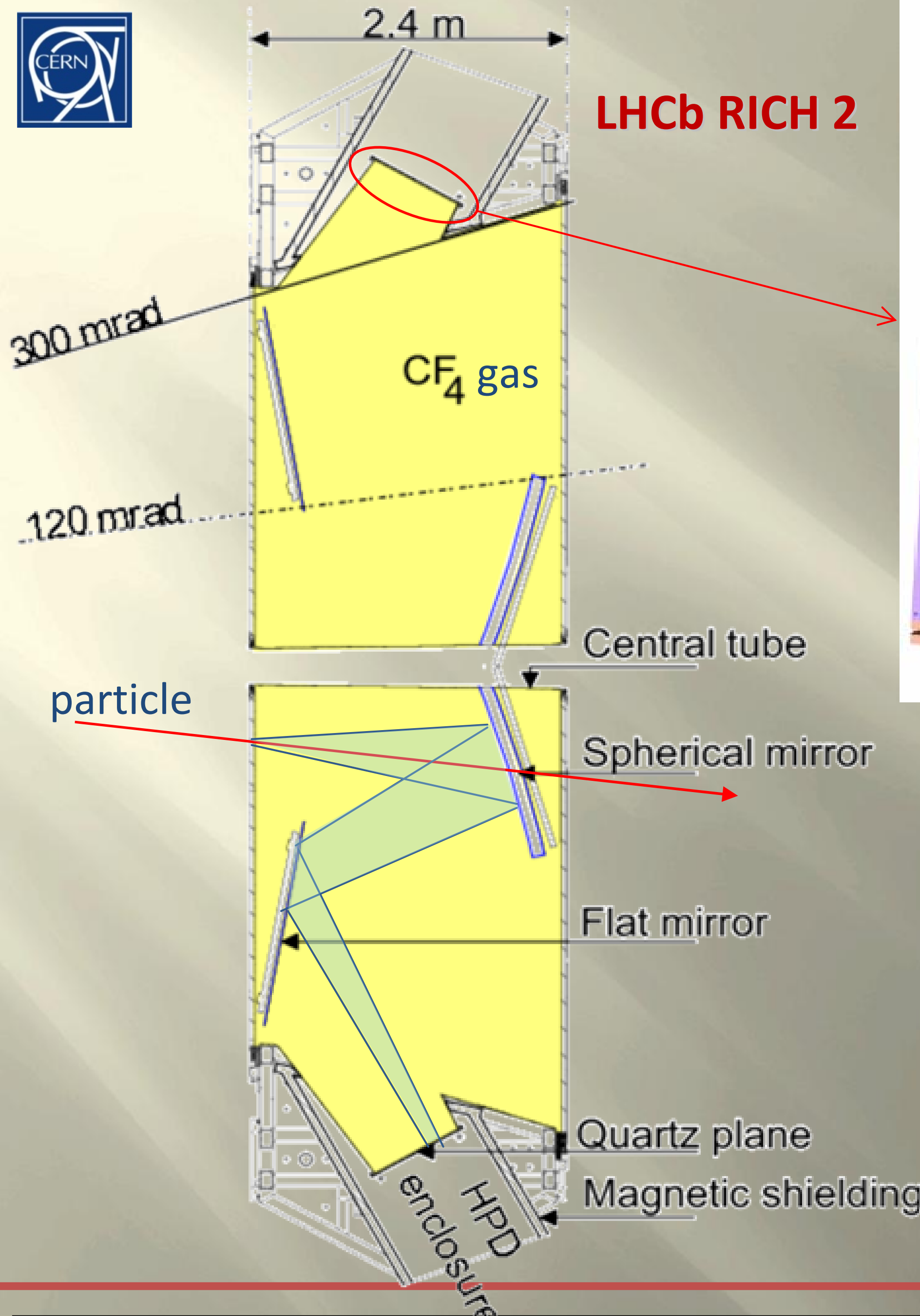
The Pixel HPD in the LHCb RICHes

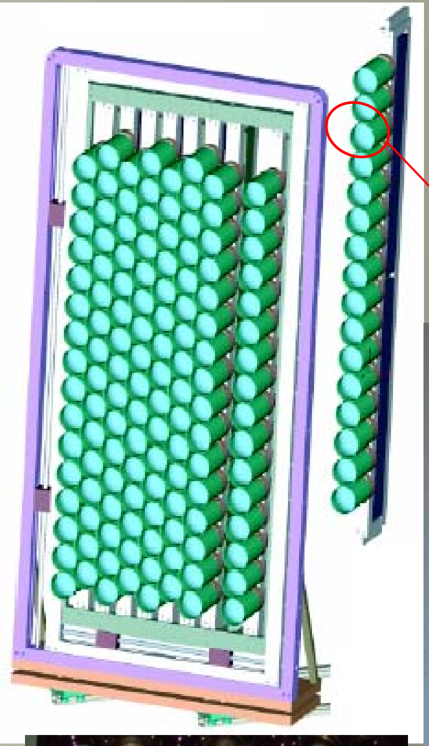
Two fast RICHes for π/K separation from 1 to ~100 GeV/c

Work in visible domain!



LHCb RICH 2

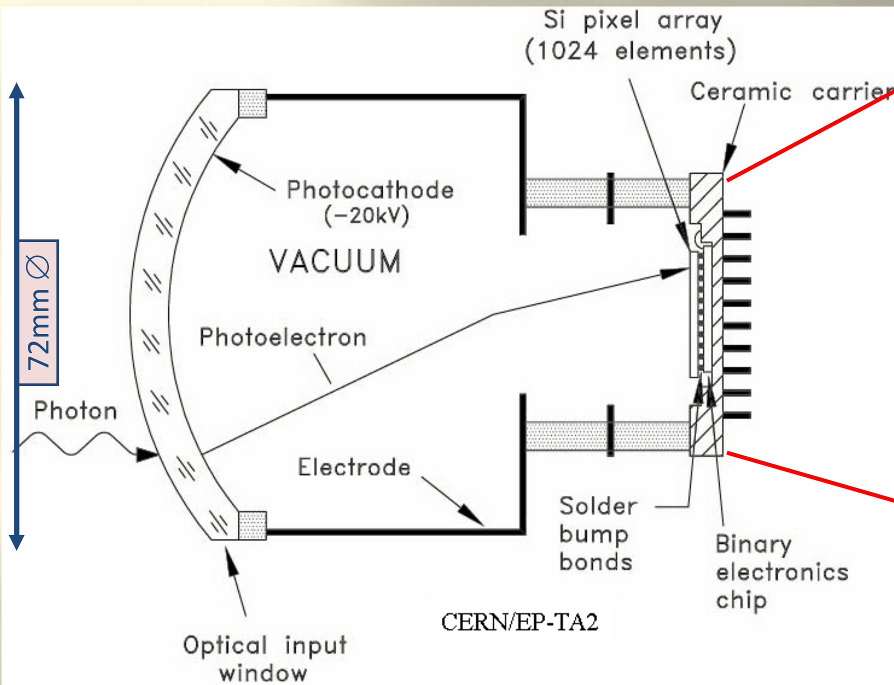




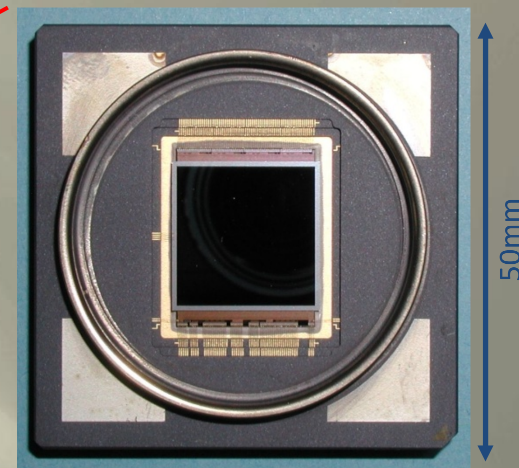
In total (RICH 1+2)
484 HPDs

Pixel HPD

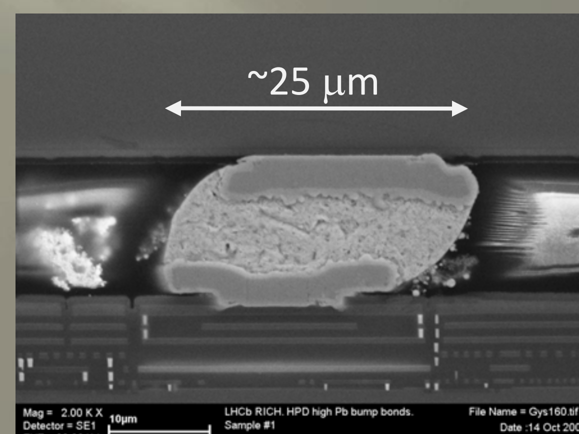
- Industry (Photonis-DEP) - LHCb development



(M. Moritz et al., IEEE TNS Vol. 51, No. 3, June 2004, 1060-1066)



Pixel-HPD anode

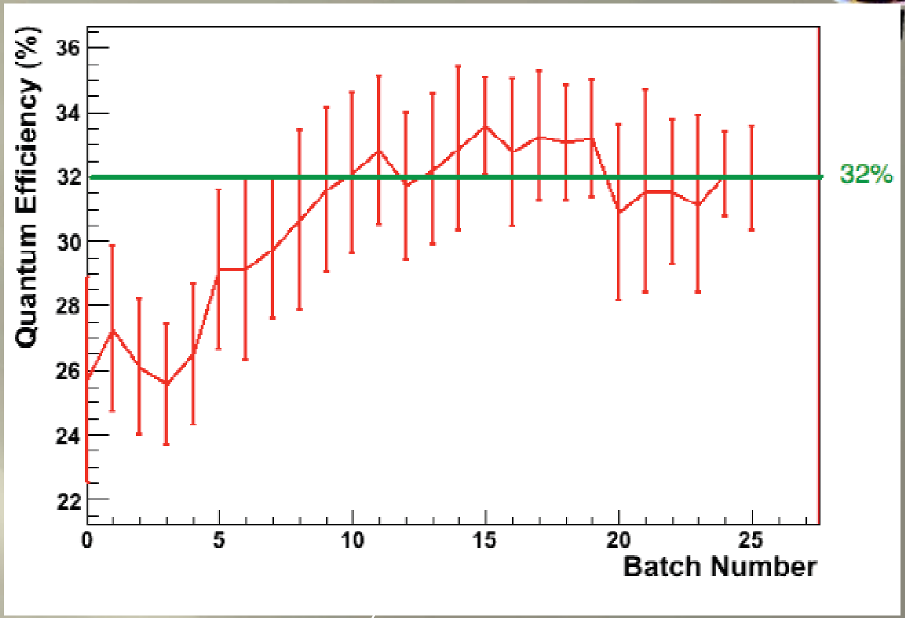


(K. Wyllie et al., NIMA 530 (2004) 82-86)

- LHCb-dedicated pixel array sensor bump-bonded to binary electronic chip (in close collaboration with ALICE-ITS), specially-developed high T° bump-bonding;
- Flip-chip assembly encapsulated inside vacuum tube using full-custom ceramic carrier;

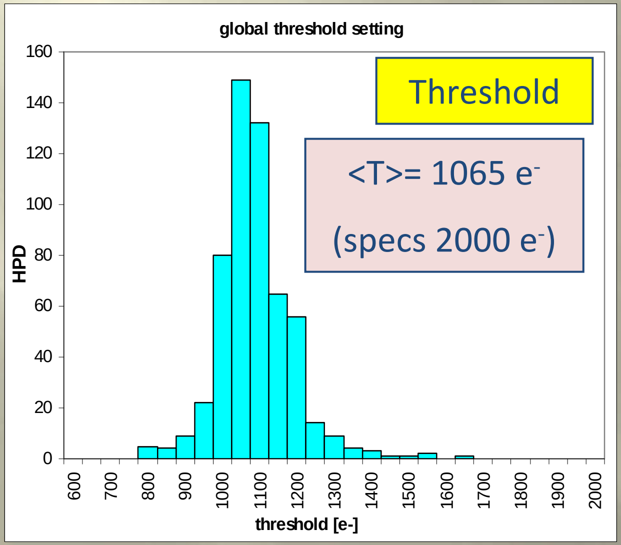
Pixel HPD

- Must cover 200-600nm wavelength range
- Multi-alkali S20 ($KCsSbNa_2$)
- Improved over production
- Resulted in a ∫QEdE increased by 27% wrt the original specifications

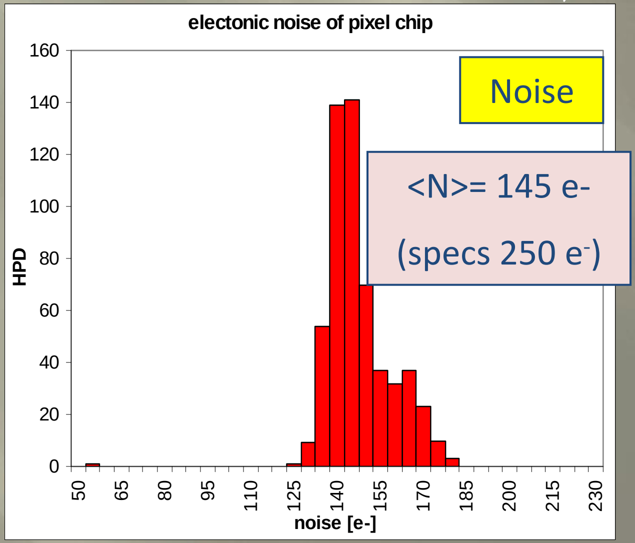


(R. Young, RICH 2010 conference)

(M Adinolfi et al., NIM A 603 (2009) 287–293)

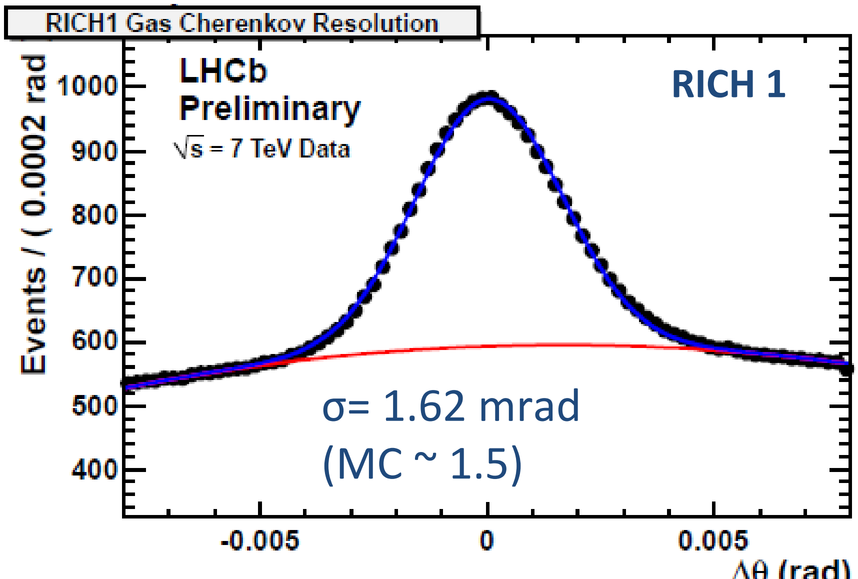


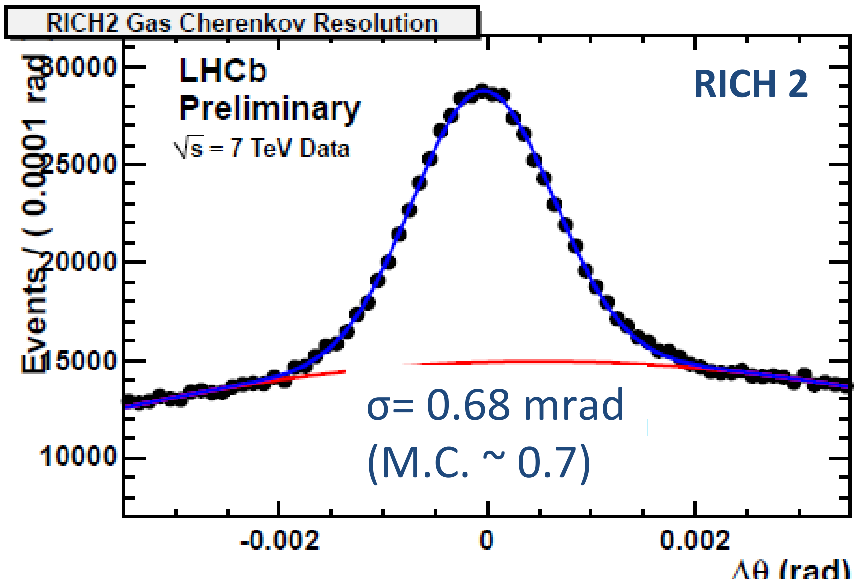
(S. Brisbane, A 595 (2008) 146–149)

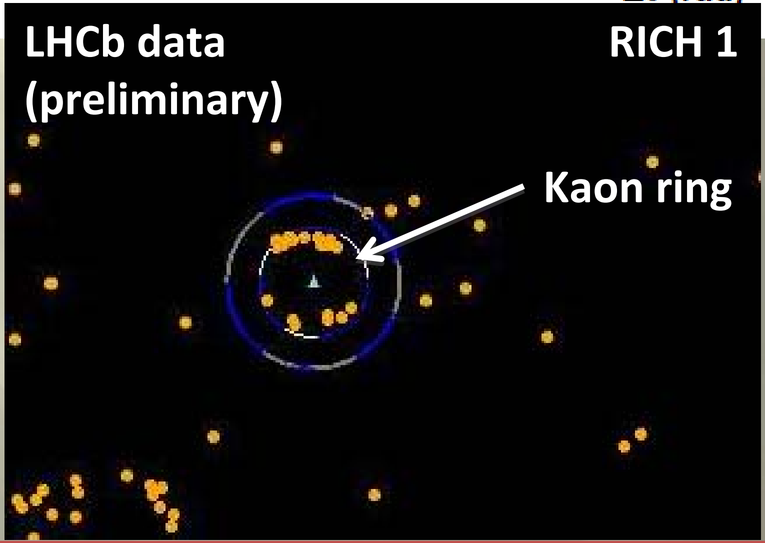


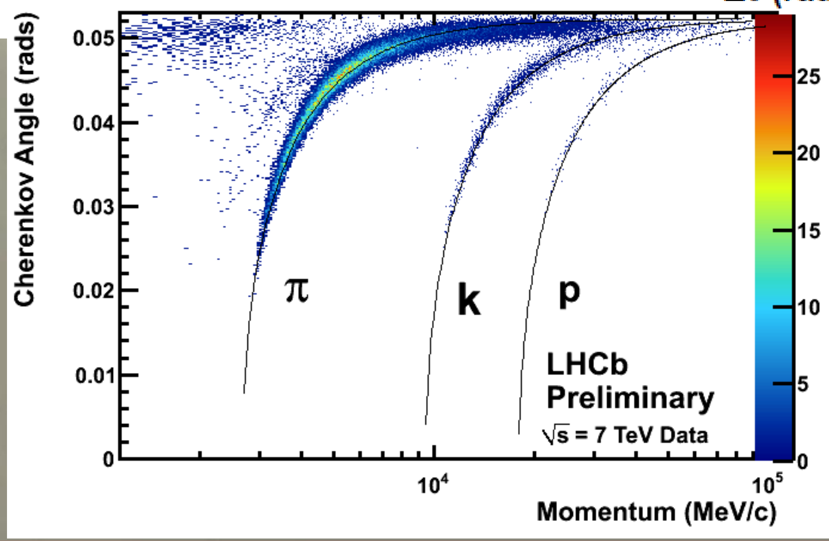
- Typical signal is 5000 e^-
- ε_{det} (1 p.e.) ~85% (for 25ns strobe)
- Residual inefficiency is dictated by photo-electron back-scattering (18% probability) and charge-sharing effects

Achieved resolution









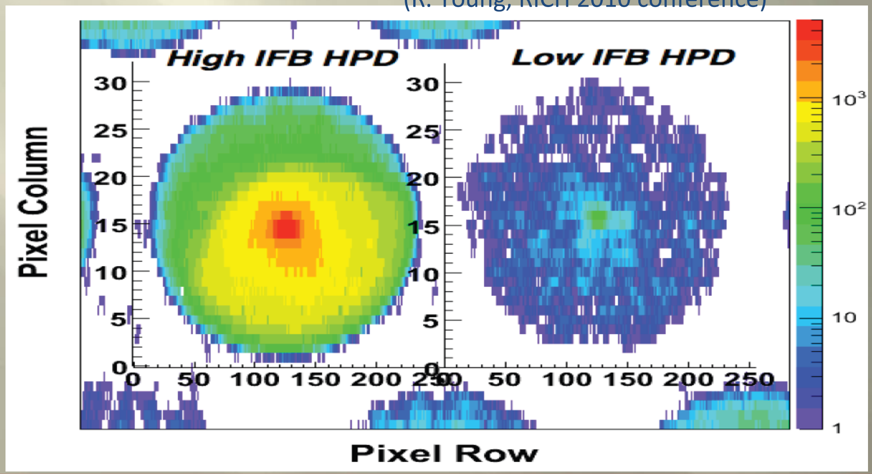
The ion feedback issue – present on a subset of the LHCb HPDs

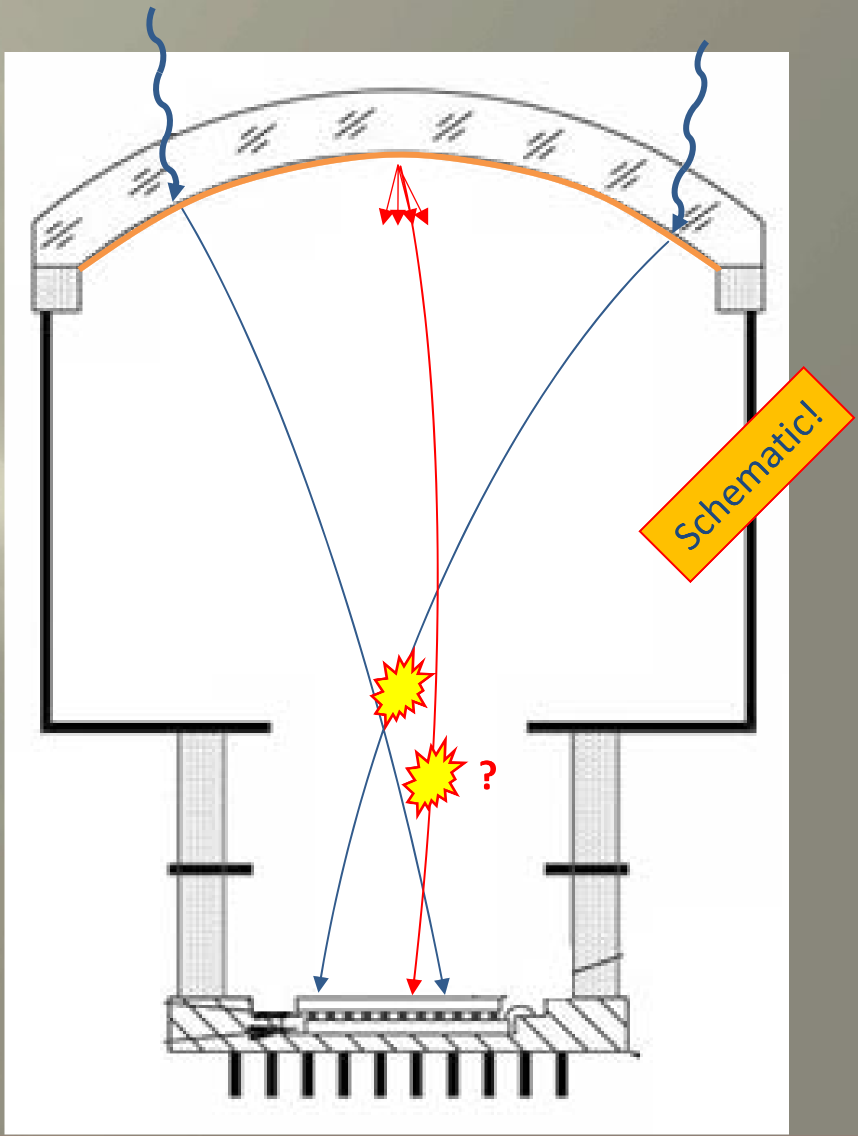
Diagnostics:
- Shower of secondary photoelectrons.
- Delayed by 200-300ns w.r.t. primary photoelectron.
- Hits concentrated at centre of photocathode.
- Detectable as large clusters of pixels.

Most likely cause: Ionisation of residual gas molecules.

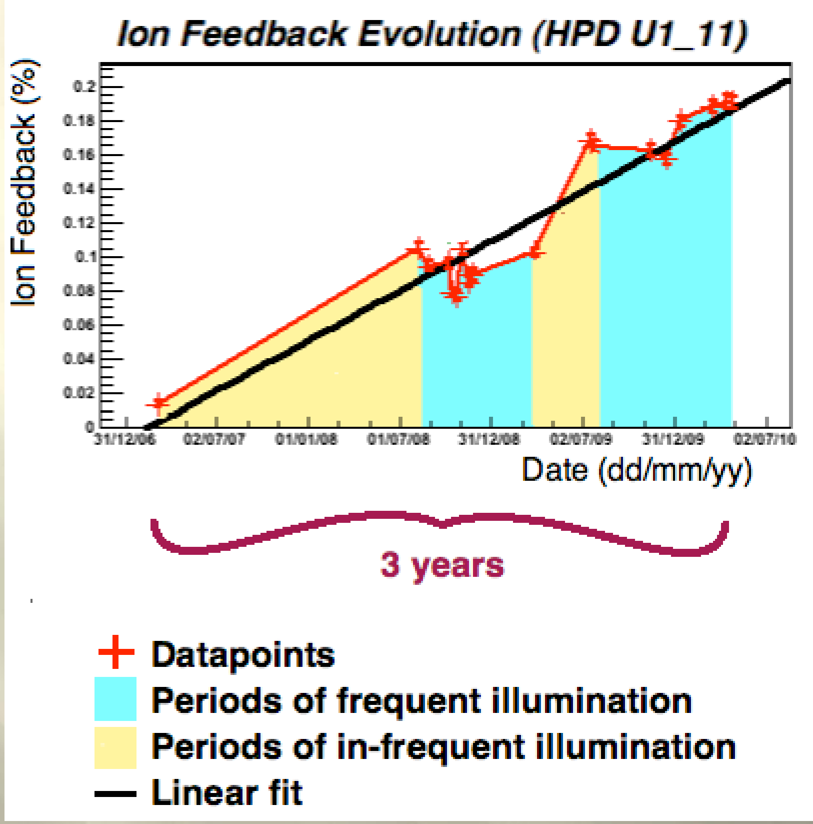
Residual gas ionisation may become self-sustaining for HPDs with large ion feedback: Probability gas ionisation x Electron Multiplicity > 1

(R. Young, RICH 2010 conference)





Ion feedback phenomenon evolves with time, slowly and about linearly



→ Time of failure (5% ion feedback rate) reasonable predictable.

LHCb RICH had so far to replace 20% of the HPDs. They are re-processed by Photonis and afterwards reinstalled in the detector.

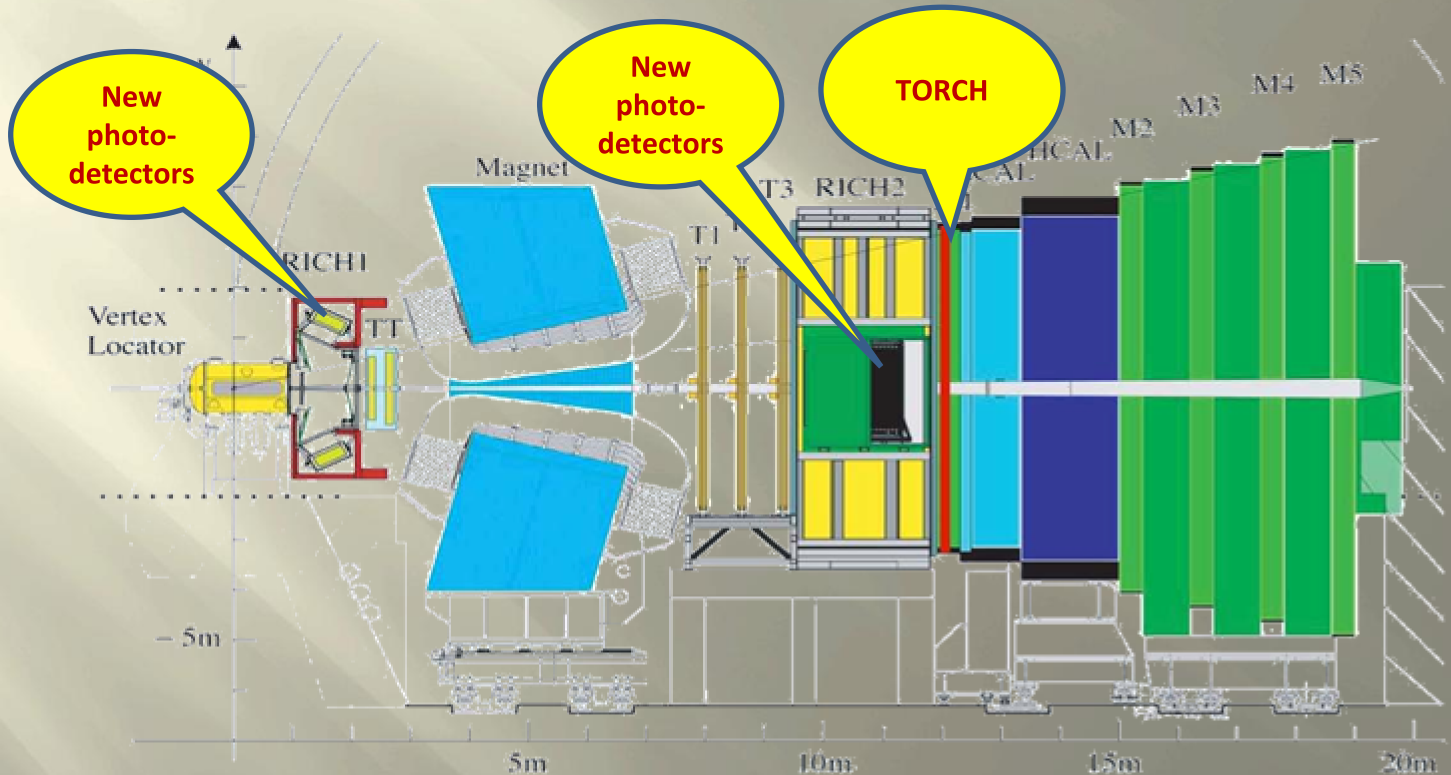
Not a disaster, but lots of extra work!

LHCb RICH - Upgrade ideas

Two areas in the focus

o Pixel-HPD electronics has a readout rate of 1 MHz → will become a bottleneck for LHCb high luminosity (around $2{\cdot}10^{33}$ $cm^{-2}s^{-1}$) operation.

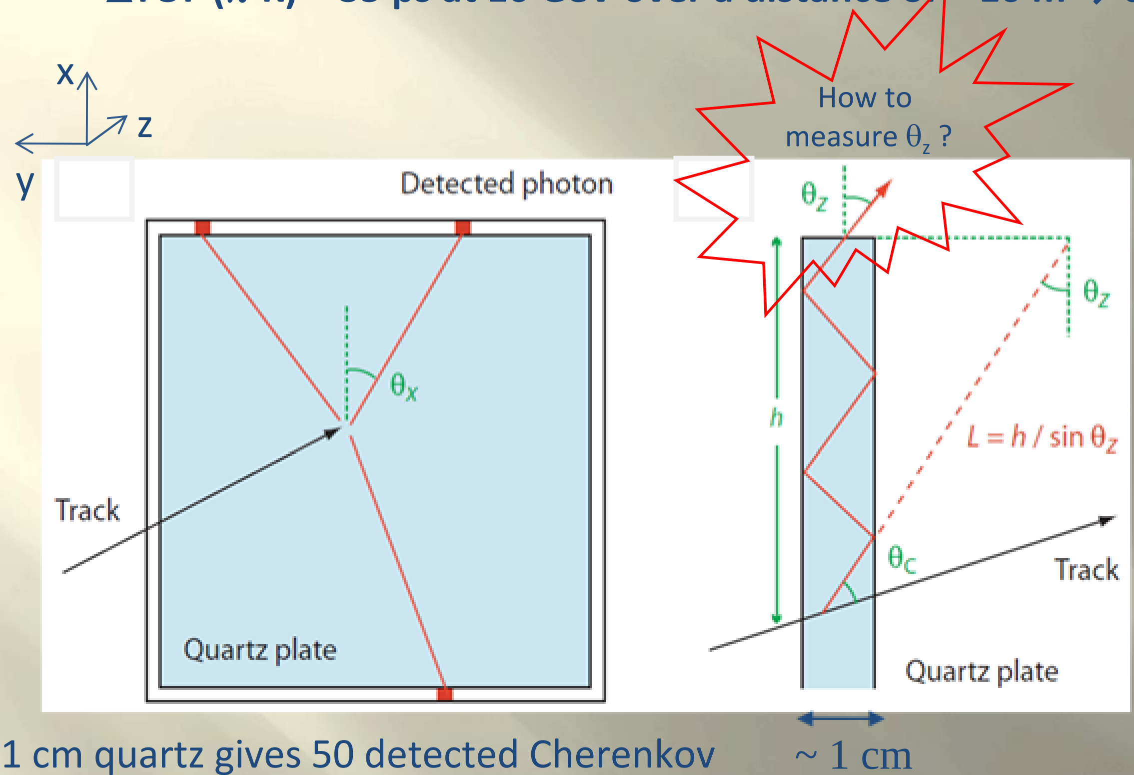
o Electronics is encapsulated inside the HPD. → Photodetector replacement. MAPMT and Flatpanels under consideration (external electronics).

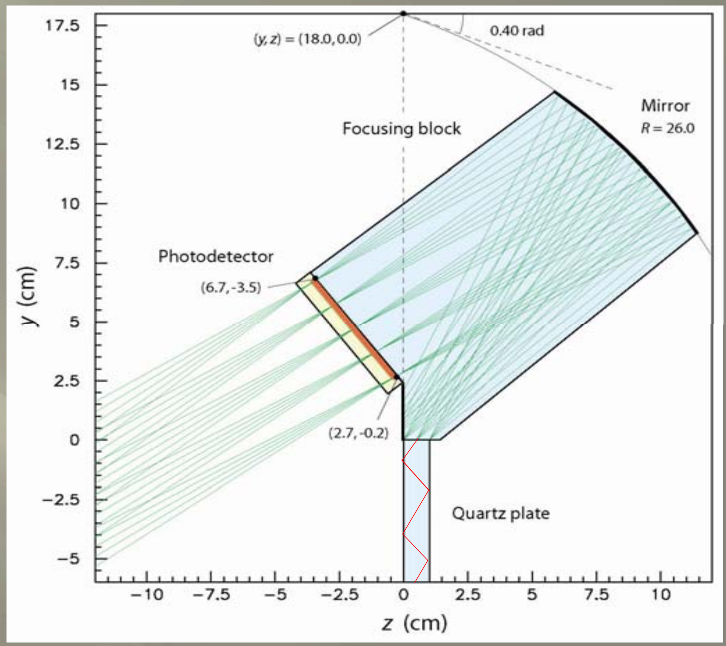


o Aerogel radiator of RICH-1 gets also in trouble at higher luminosities (too high occupancy for too low photon yield). → LHCb considers a DIRC-type TOF detector, called TORCH (Time Of internally Reflected CHerenkov light), installed behind RICH-2.

TORCH principle

ΔTOF (π-K) = 35 ps at 10 GeV over a distance of ~ 10 m → aim for 15 ps resolution per track





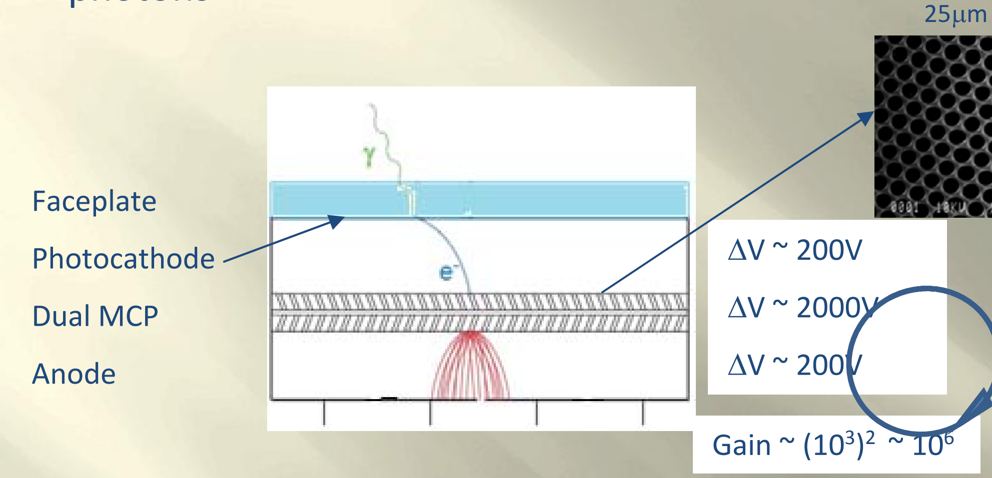
1 cm quartz gives 50 detected Cherenkov photons per track, however path lengths of photons need to be known → Need to know track and measure θ_x and θ_z with a precision of few mrad.

Θ_x is pretty simple because of long lever arms *O*(m). → need *O*(cm) resolution in x.

A quartz box with curved reflecting surface converts angles to positions. → need *O*(mm) resolution in transverse direction.

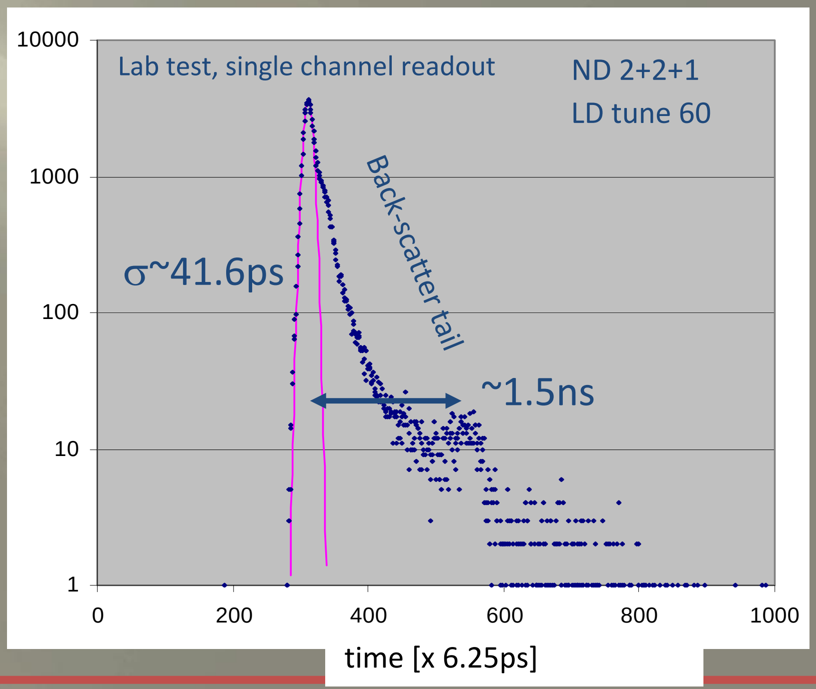
TORCH photodetector candidate

Micro-channel plate (MCP) photodetectors are currently the best choice for fast timing of single photons



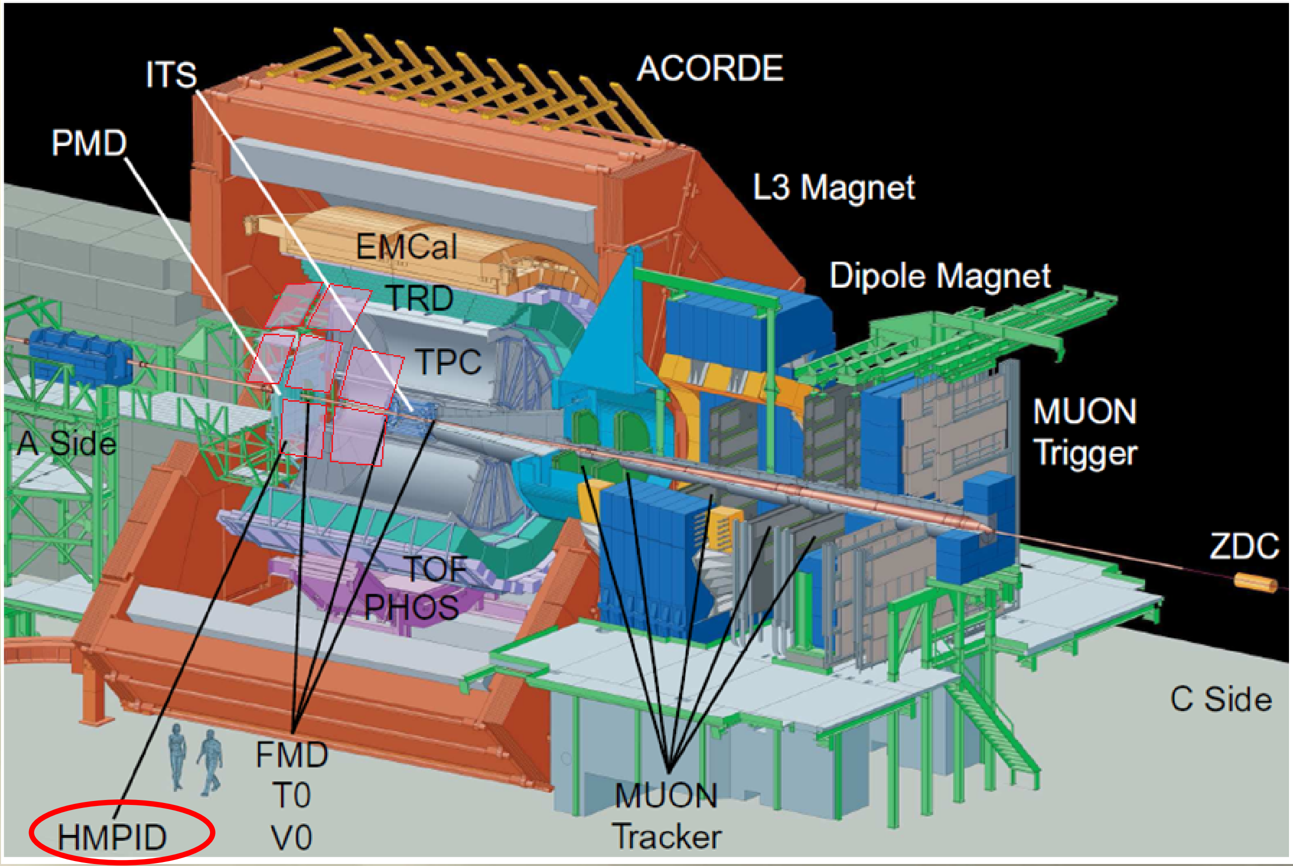
See the poster no. 121
By Lucía CASTILLO GARCíA

Planacon MCP-tube + Pilas blue Laser Diode



- Anode pad structure can in principle be segmented according to need (coarse in x, fine in transverse direction)
- Smearing of photon propagation time due to photodetector granularity ~40 ps
- Assuming an intrinsic arrival time measurement resolution per p.e. of 50 ps, the total resolution per detected p.e. is 40 ⊕ 50 ~ 70 ps, as required

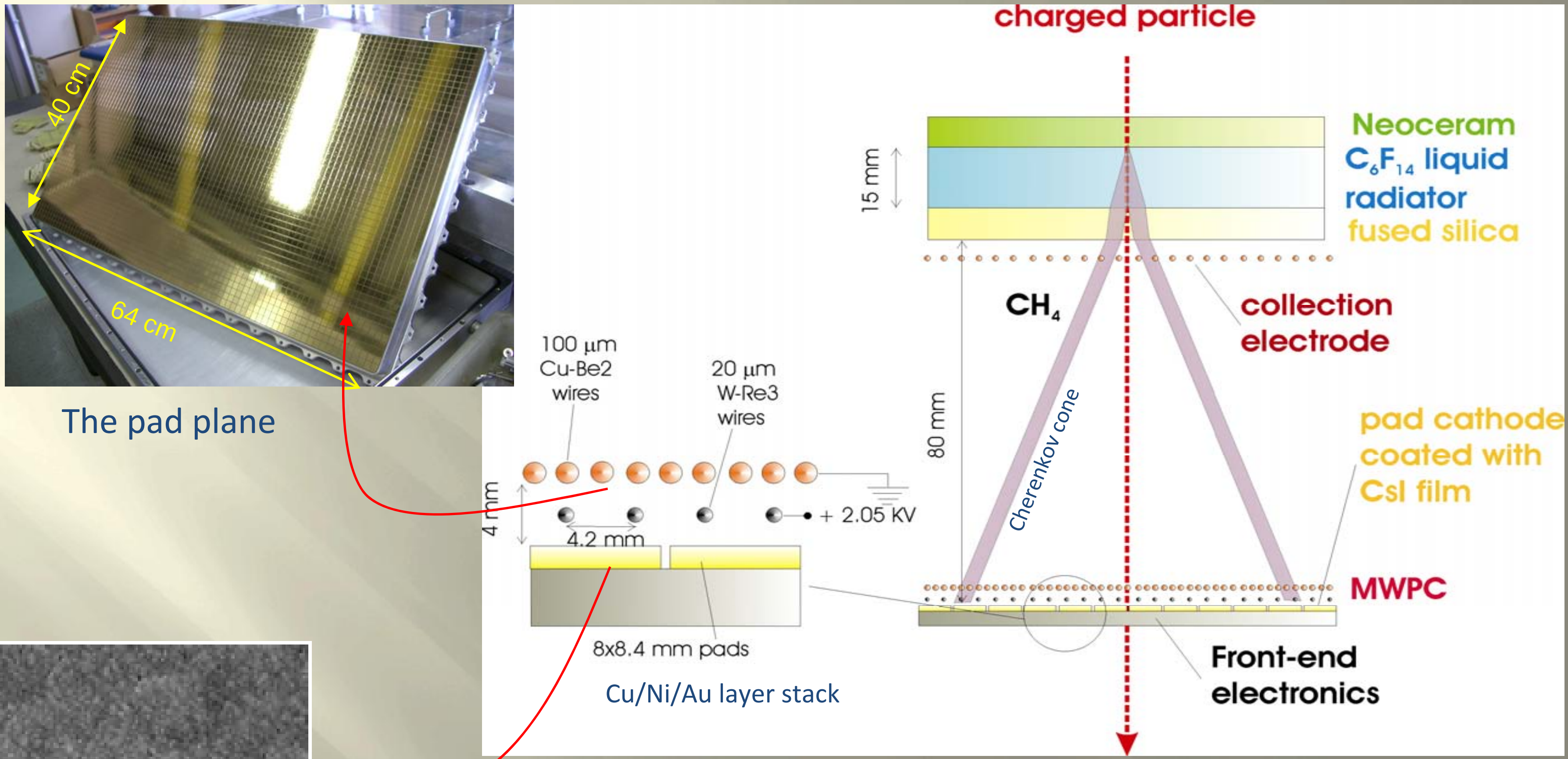
CsI in the ALICE HMPID RICH detector



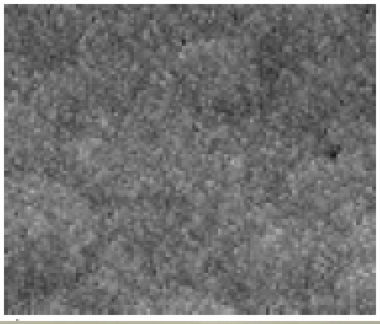
High Momentum Particle ID: π/K ($p < 3$ GeV/c) and K/p ($p < 5$ GeV/c), track-by-track

- 7 proximity focused' RICH modules of 1.4x1.3 m^2 → 11 m^2 of photosensitive area.
- 6 CsI photocathodes/module

Principle of the HMPID



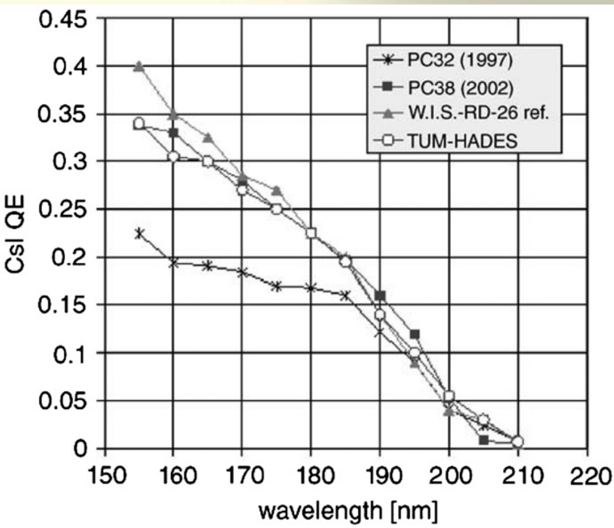
The pad plane



300 nm CsI, vacuum evaporated

- The detector is in principle fast, because the conversion point is fixed (contrary to TMAE gas).
- To allow robust operation, a relatively low gain ($5\cdot10^4$) combined with a relatively slow Gassiplex FE chip τ_{peak} = 1.2 µs is chosen (ALICE event rates allow such a choice).

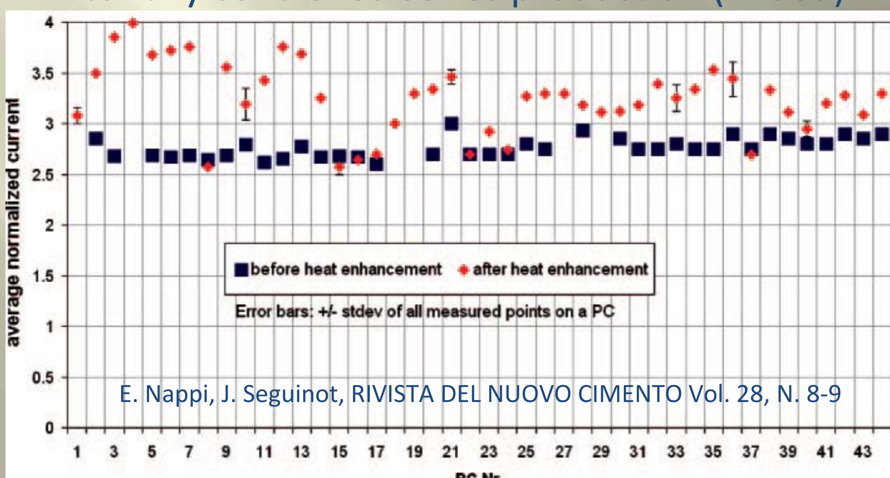
Coating and Quality Control plant at CERN



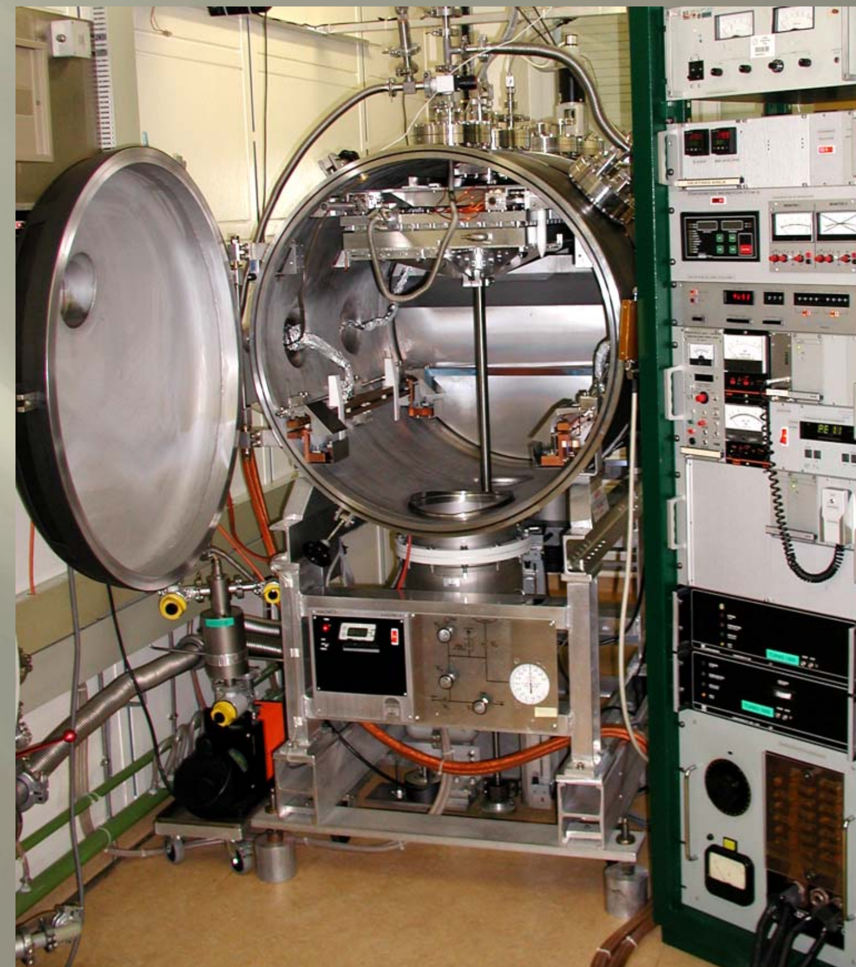
S. Dalla Torre NIM A 639 (2011) 111–116

From R&D (1990s) by RD26 collab. + many other groups)

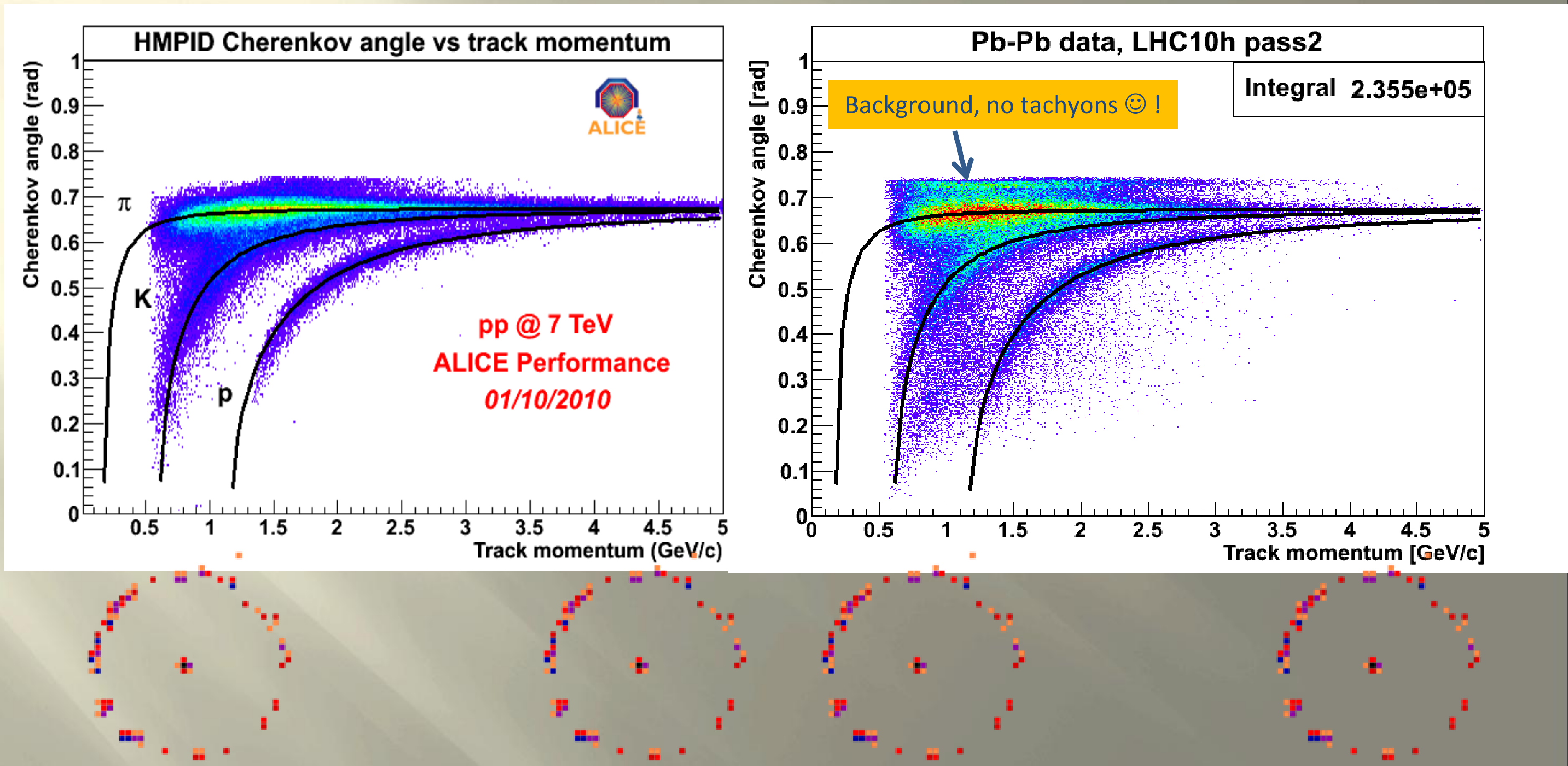
... to fully controlled series production (~2005)



E. Nappi, J. Seguinot, RIVISTA DEL NUOVO CIMENTO Vol. 28, N. 8-9

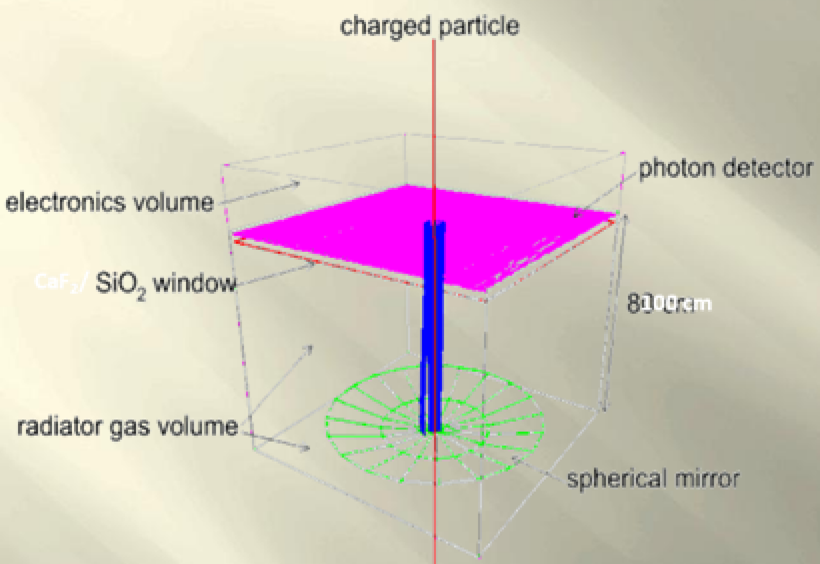


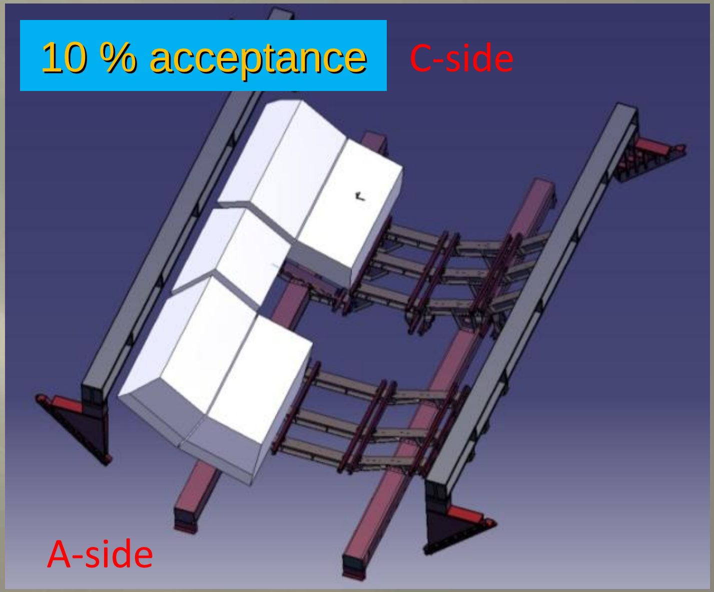
Particle separation in p-p and Pb-Pb runs



HMPID upgrade plans → VHMPID

Baryon/Meson puzzle discovered at RHIC, transposed to LHC energies, requires PID well beyond HMPID reach → track-by-track PID in the momentum range of 10 – 30 GeV/c

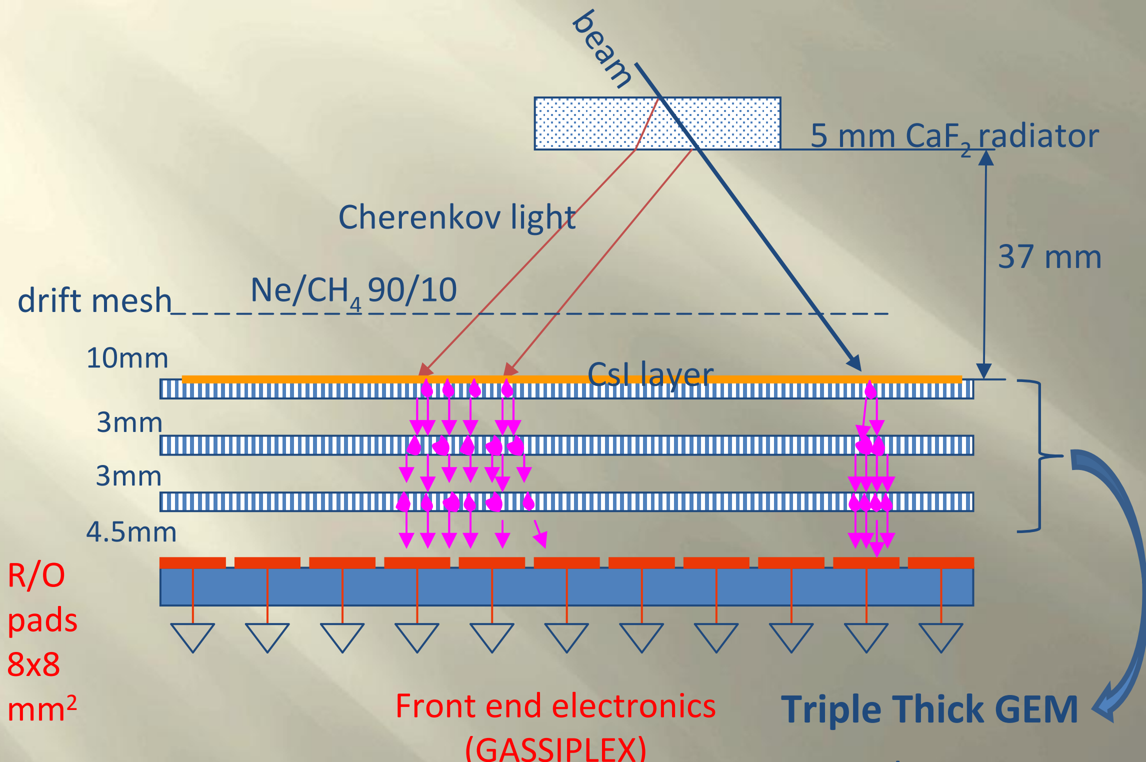




- Focusing RICH with spherical (or parabolic) mirrors
- C_4F_{10} gaseous radiator L ~100 cm
- Photon detector baseline layout: MWPC with CsI photocathode, operated with CH_4
- HMPID FE electronics (Gassiplex)
- More aggressive concepts (like Thick GEM, SiPM) are also being studied.

Principle of a 3-TGEM chamber

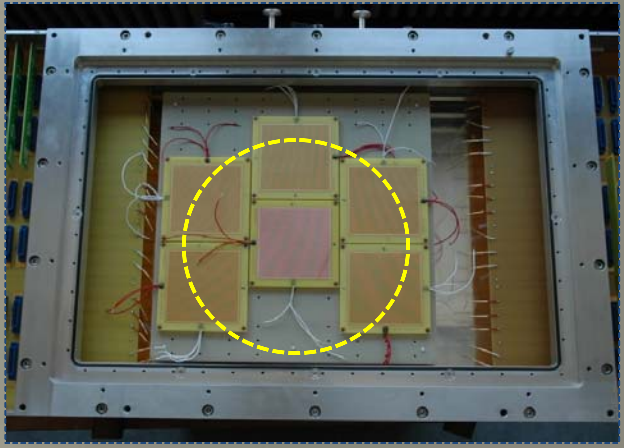
R&D on CsI-TTGEM option, to achieve better spatial resolution and exploit intrinsically faster signal

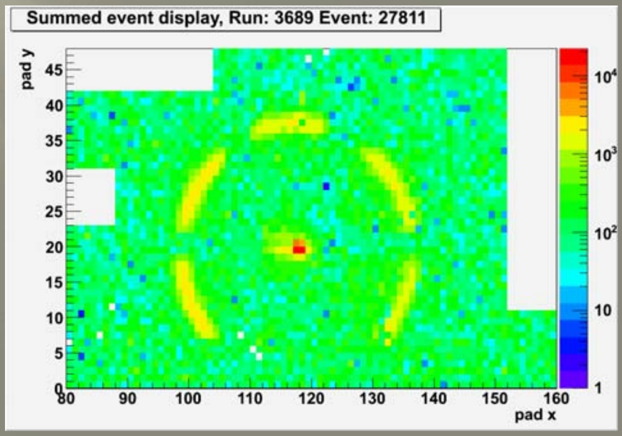


GEM characteristics
•thickness 0.45 mm
•hole diam: 0.4 mm
•pitch: 0.8 mm

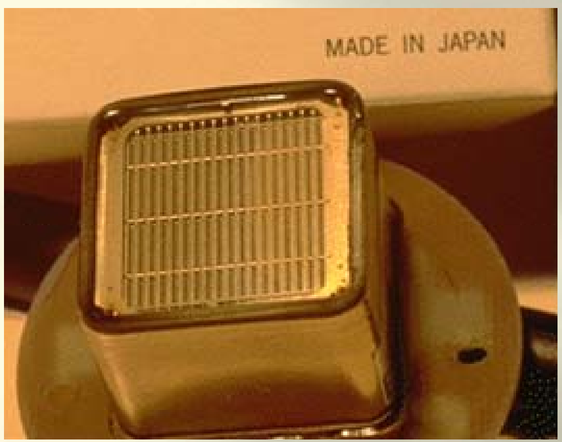
See talk by Vladimir PESKOV, in session S11 Gaseous

CERN PS/T10 testbeam (May 2011)

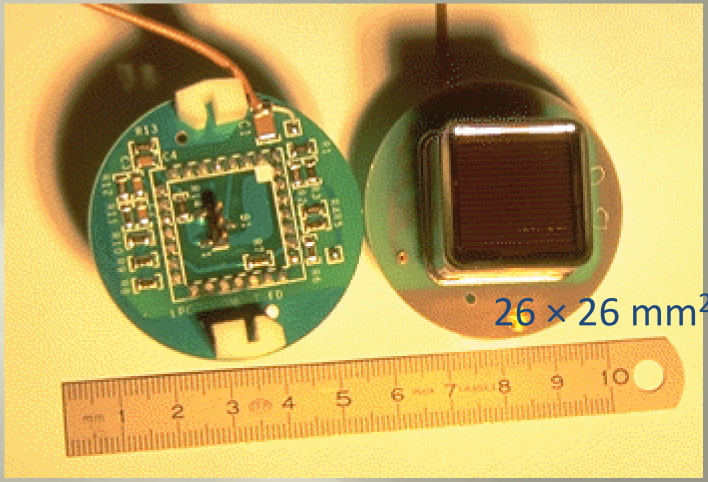




Readout of the ATLAS TileCal



10,000 Hamamatsu R7877
Metal package
Metal channel dynodes



Custom made voltage divider

8 stages, 700 V, $G = 10^5$

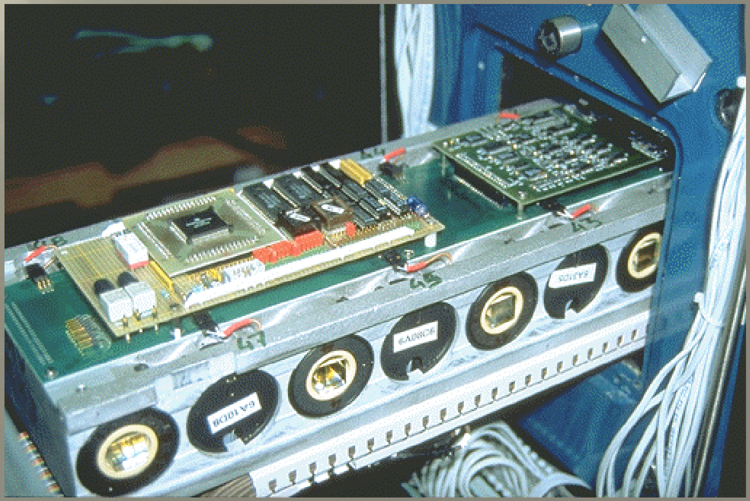
Dynamic range: 16 bits, up to 50 kpe ~ 800 pC (20 MeV – 1.5 TeV)

Linearity: within ~2% for pulses up to I_A = 50 mA

Very robust, reliable and fail safe.

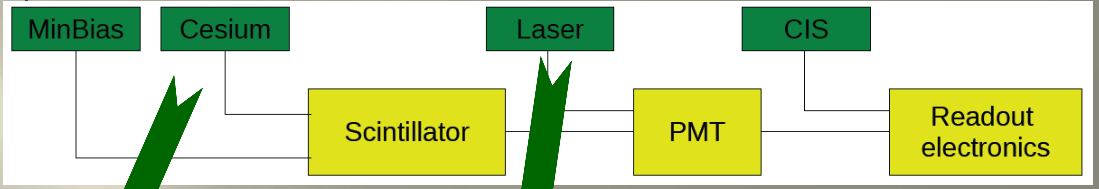
http://cdsweb.cern.ch/record/683595/files/tilecal-97-129.pdf

PMTs + μ-metal shields + electronics are mounted on a drawer which can be slided in from the side of the tiles

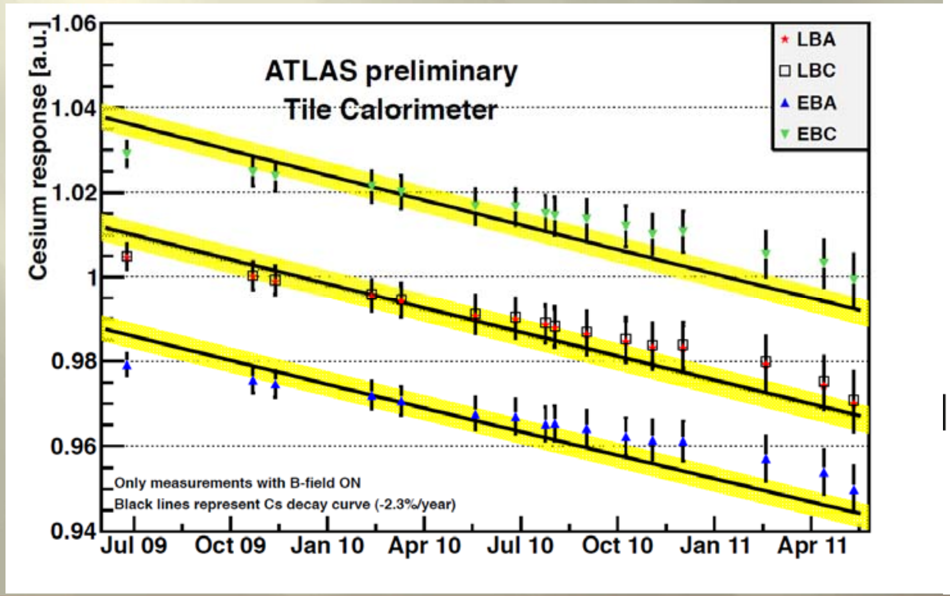


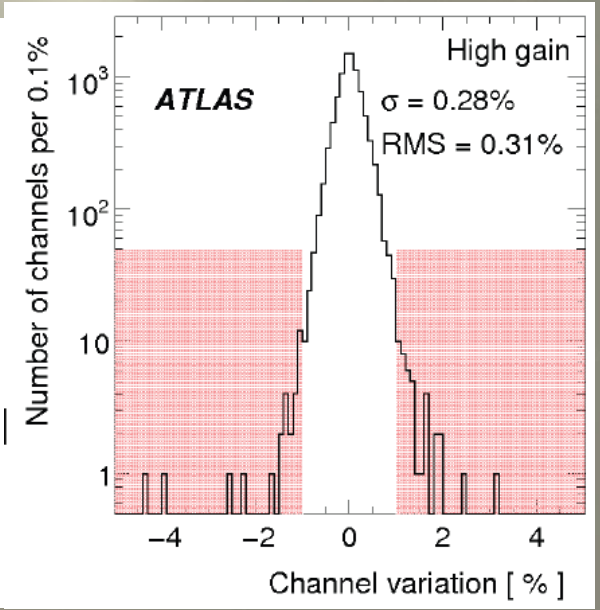
Very important for an overall calibration and monitoring of the calorimeter energy scale to <1% ...

A sophisticated calibration system, including ...



Cesium run takes 7 h (10 km path)

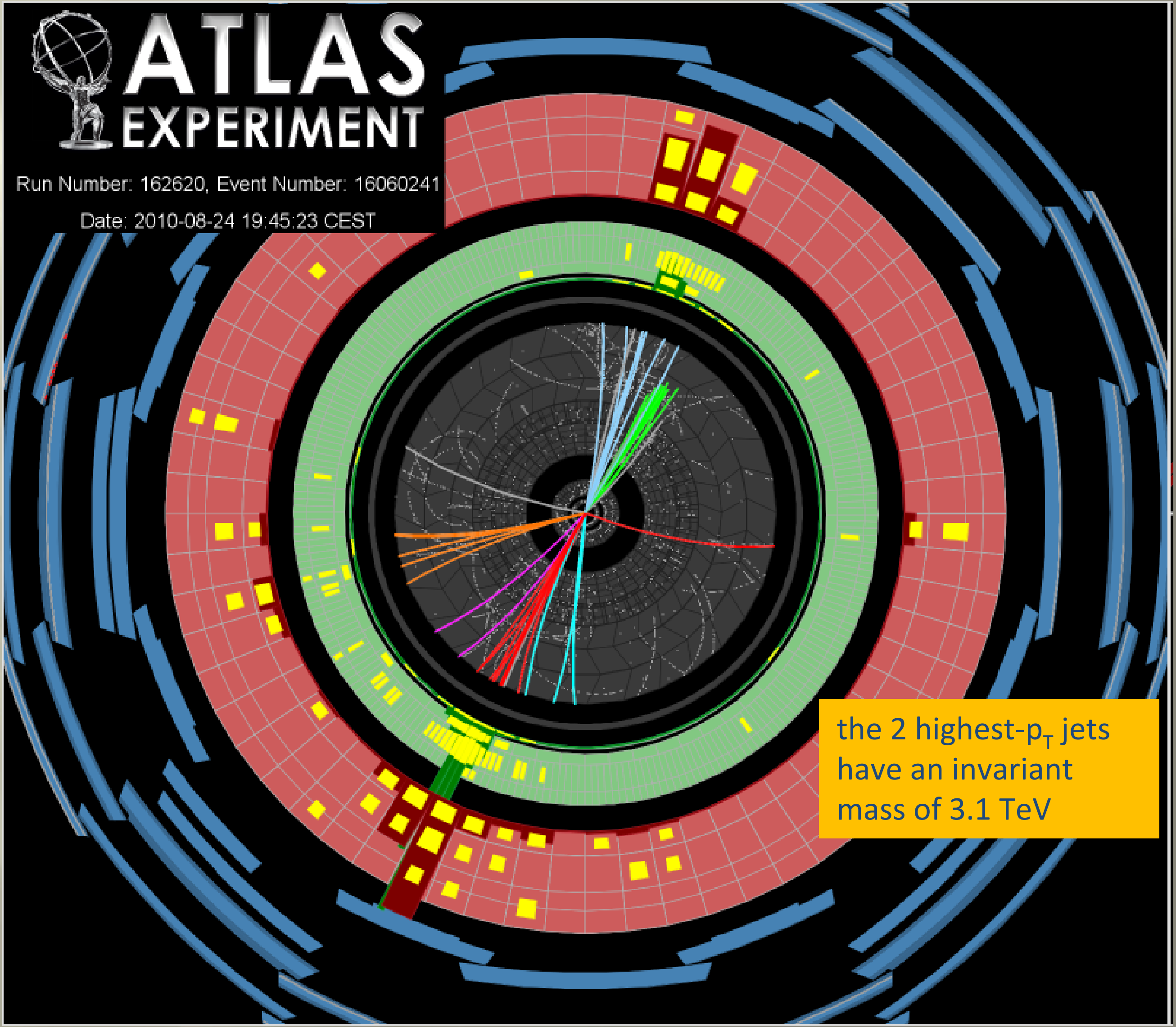




LASER monitoring (in between Cs runs)

Allows to precisely follow time variation of PMT response.

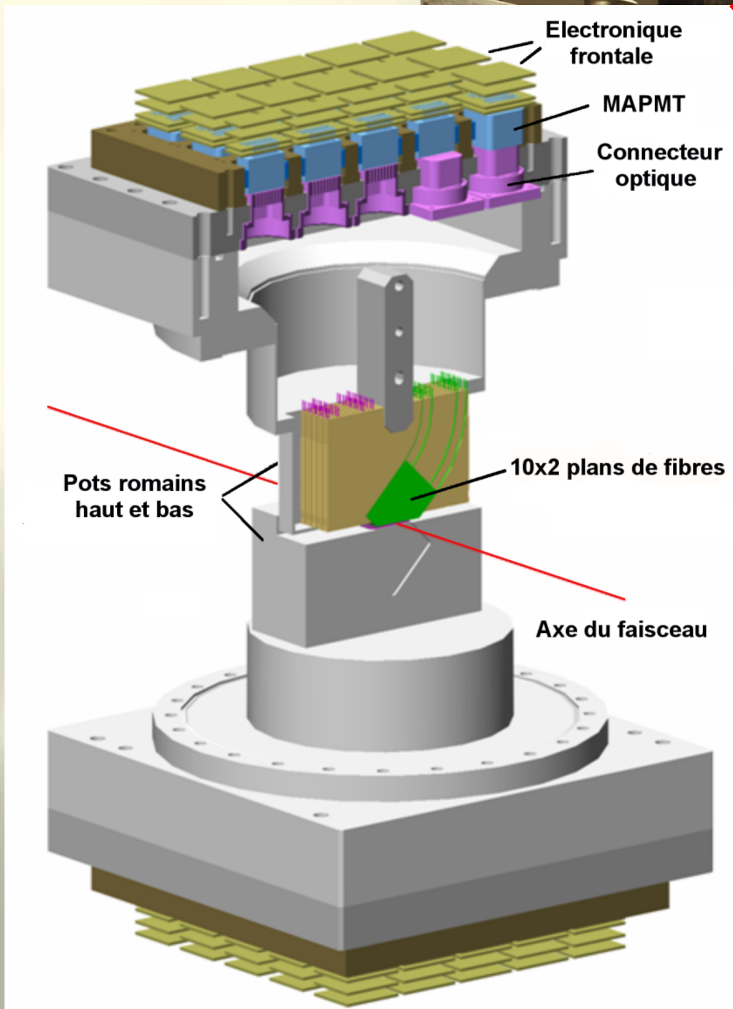
TileCal in action...

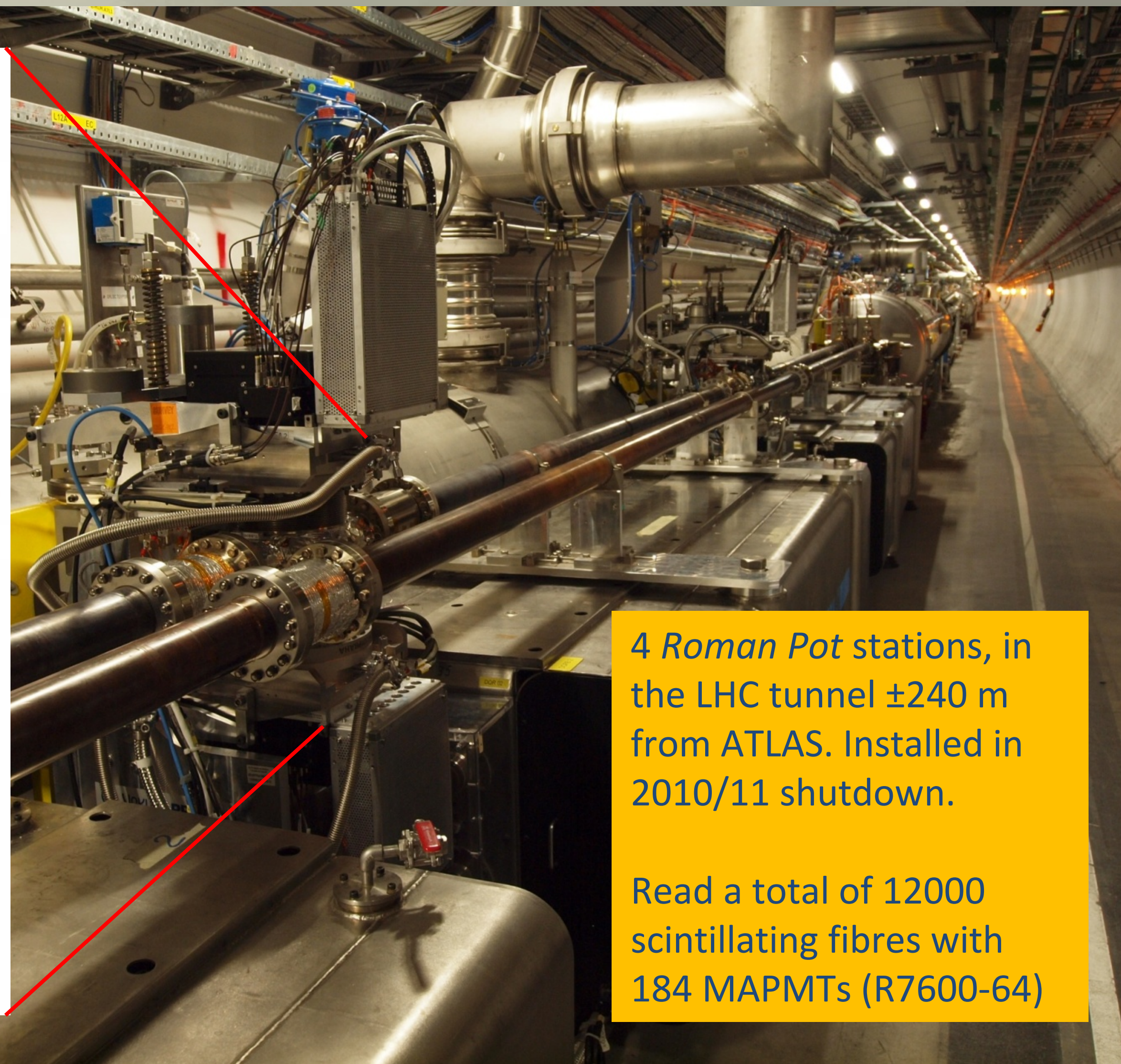


the 2 highest-p_T jets have an invariant mass of 3.1 TeV

Currently there are no upgrades of the optical system foreseen.

ALFA = Absolute Luminosity for ATLAS





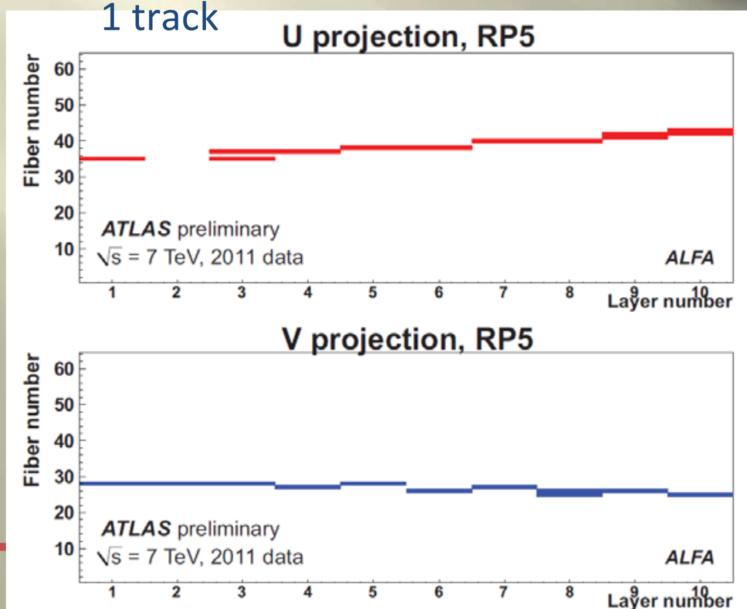
4 *Roman Pot* stations, in the LHC tunnel ±240 m from ATLAS. Installed in 2010/11 shutdown.

Read a total of 12000 scintillating fibres with 184 MAPMTs (R7600-64)

Integration of 64 channel MAPMT (HPK R7600) with voltage divider and MAROC front-end

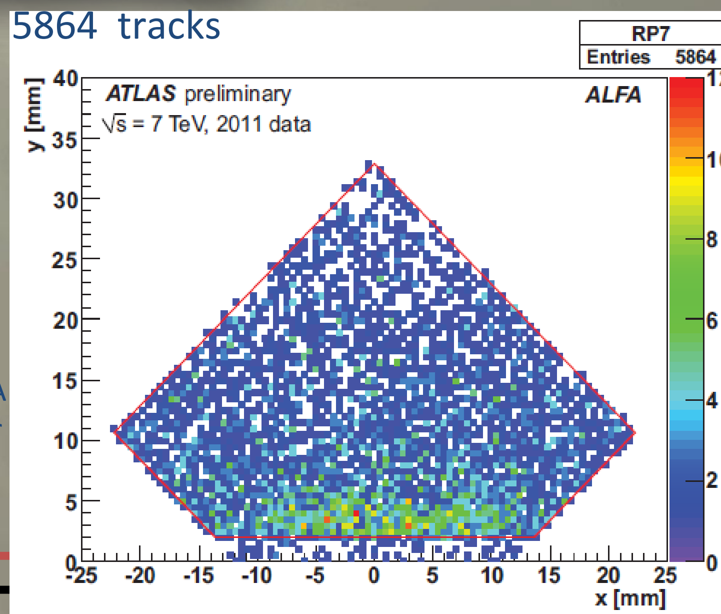
See the poster by Sune Jakobsen on the ATLAS ALFA detector, currently being commissioned. Session PIII, id 82.

1 track



3.5 TeV protons crossing the ALFA detector

5864 tracks



Conclusions (1)

- The LHC and the experiments run remarkably well. The machine and the detectors are still in a learning process but have very quickly achieved a performance which allowed them to do physics.
- A huge number of photodetectors (APD, (MA-)PMT, VPT, HPD, CsI) contribute to this success.
- Sophisticated calibration and monitoring systems allow to follow and tune their performance.
- Some devices start to show some weaknesses. Consolidation and upgrade efforts are already under way.
- LHC luminosity is approaching its design value. Detector appear to cope with it. Radiation damage becomes an issue. We'll hear more in NDIP 2014.

Conclusions (2)

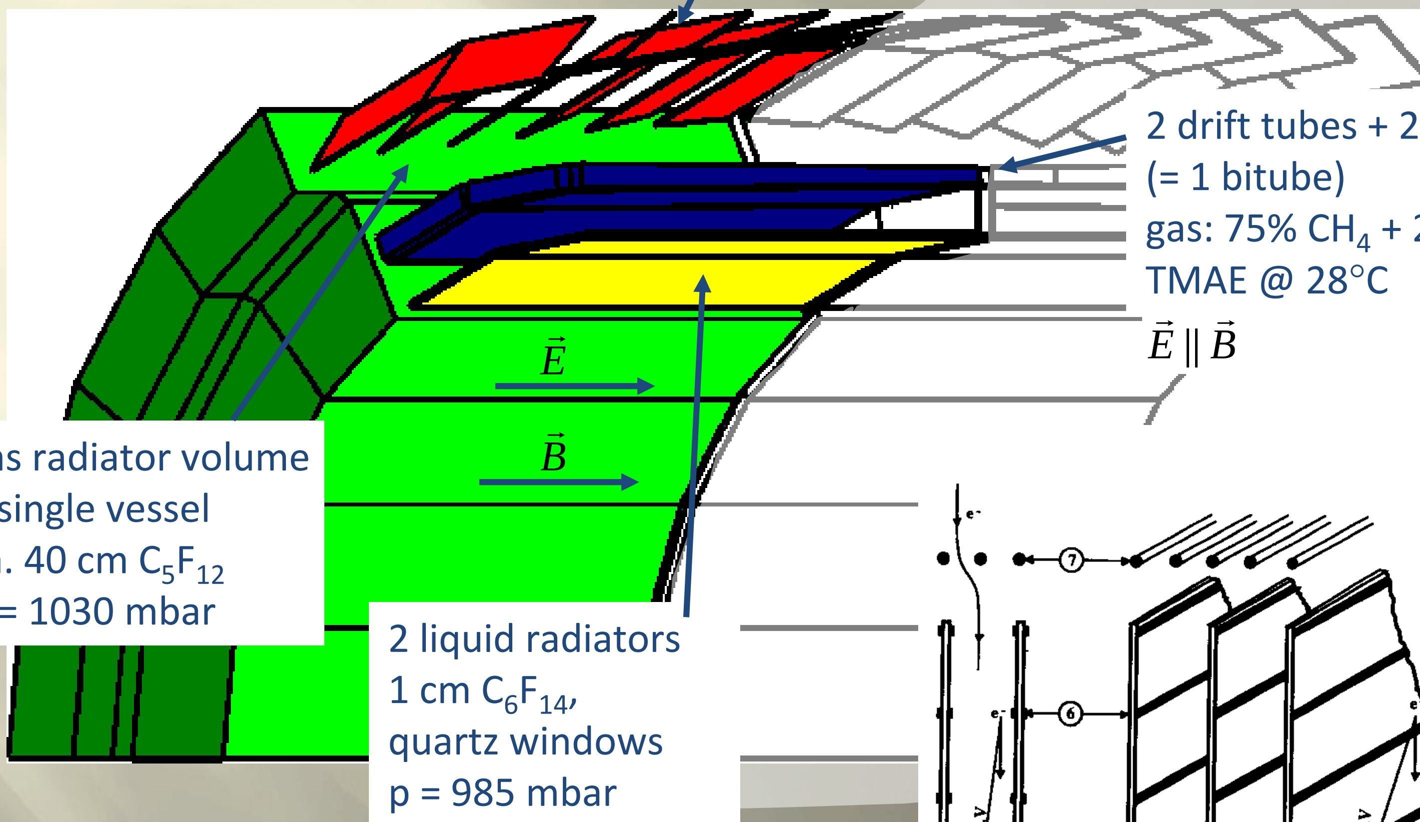
- There were developments which were made mainly ‘in-house’ and others which involved intense collaborations with industrial partners.
- Reliable and competent industrial partners are the key to success when one talks about 1000’s or 100000’s of sensors. However, they can not and should not replace in-house competence.
- The LHC requirements led to the development of some new types of photodetectors, but even more effort was spent adaptation, optimization, integration, reliability, radiation hardness, etc. of known types.
- All 3 species (vacuum, gas, solid state) have still their raison d’être and stay active fields of research.
- The industrial availability of G-APD / SiPM came too late for large scale use in LHC. We will soon see more of them in upgrade efforts.

back-up slides

Complete detector heated at 40 ± 0.3 °C !

DELPHI Barrel RICH

1 of 2×12 sectors

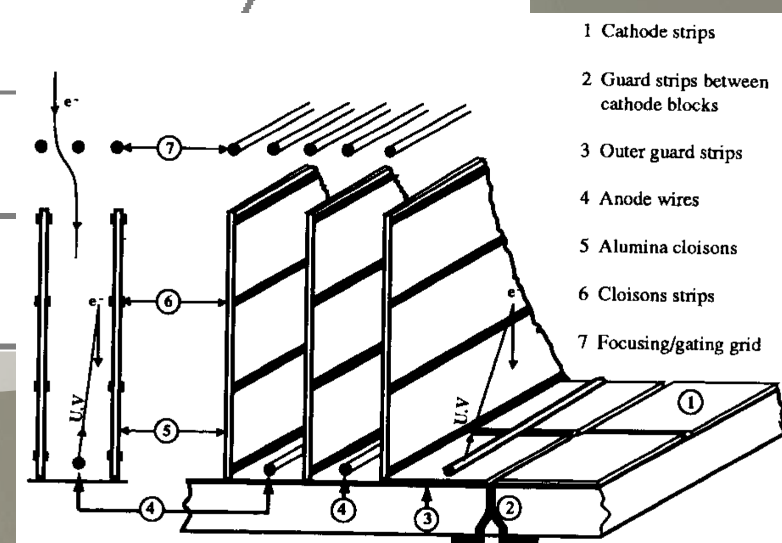


2 × 6 parabolic mirrors

2 drift tubes + 2 MWPC
(= 1 bitube)
gas: 75% CH_4 + 25% C_2H_6,
TMAE @ 28°C
$\vec{E} \parallel \vec{B}$

gas radiator volume
1 single vessel
ca. 40 cm C_5F_{12}
p = 1030 mbar

2 liquid radiators
1 cm C_6F_{14},
quartz windows
p = 985 mbar

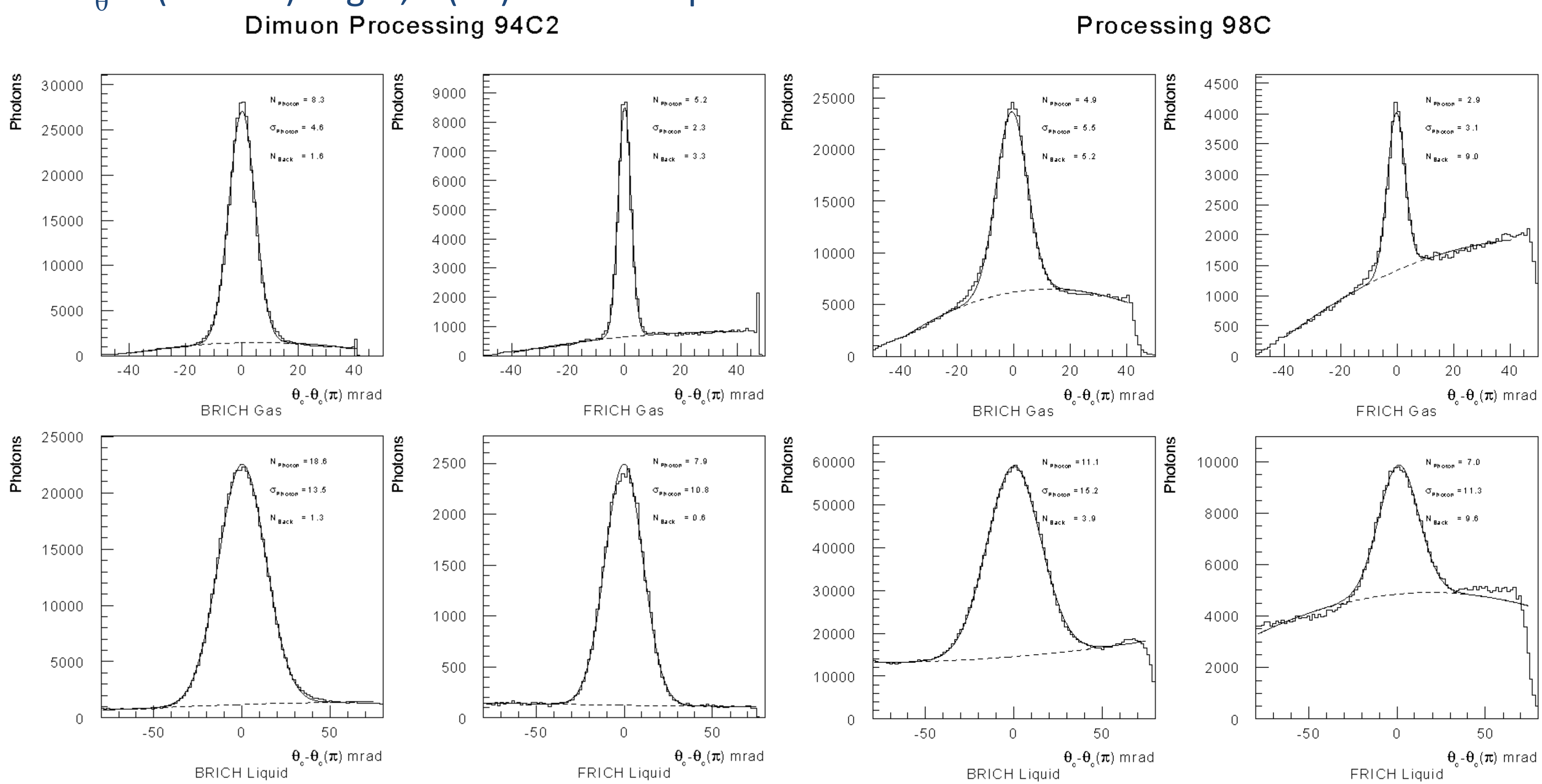


DELPHI Results

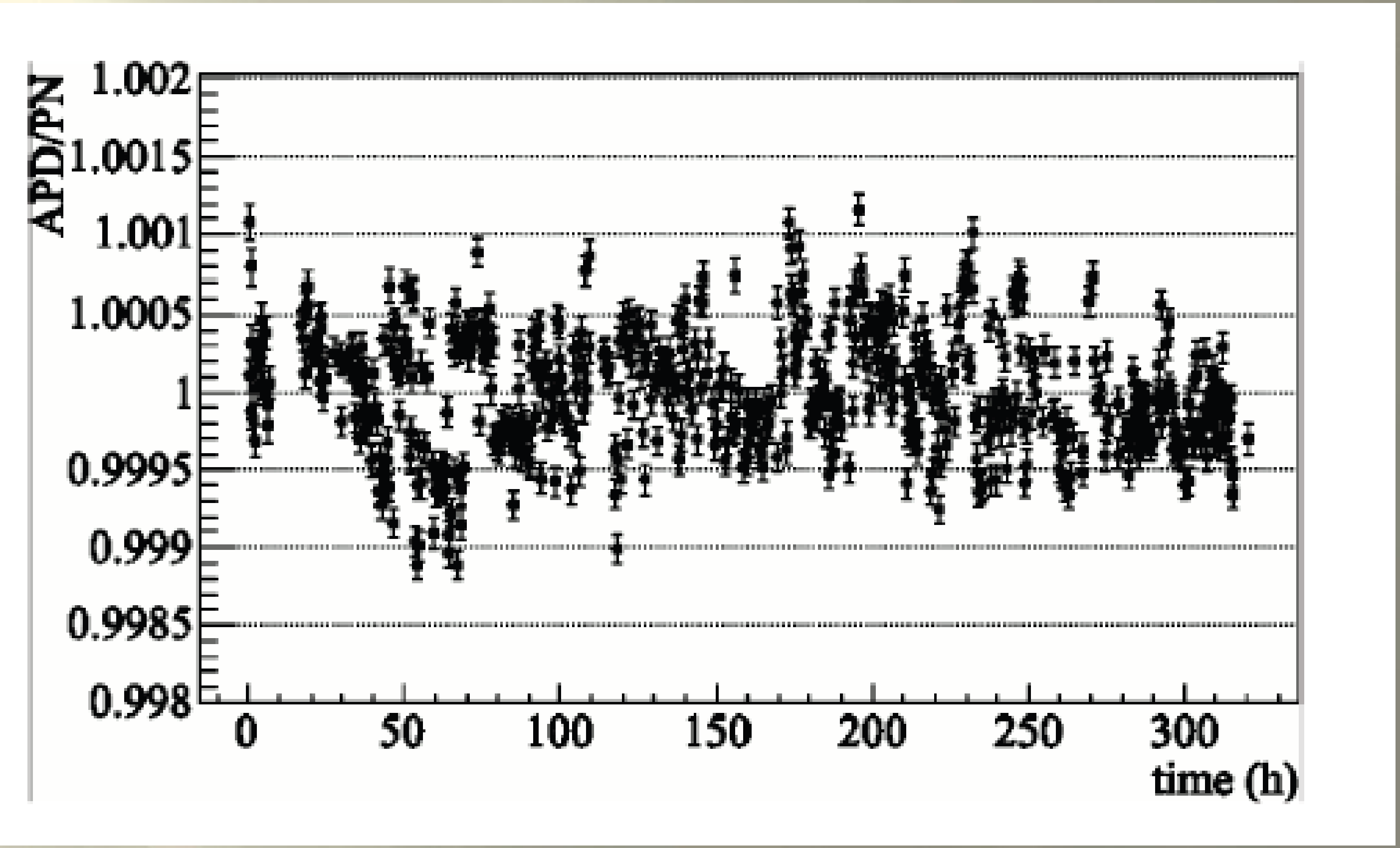
Some examples of the achieved performance…

Npe: O(10) p.e. per ring

σ_θ: O(5 mrad) in gas, O(15) mrad in liquid



CMS ECAL (Barrel)



Stability (incl. that of the monitoring system) over two weeks, represented by the ratio of signals from the APD and the PN diode when illuminated by the blue laser → extremely good stability.

CMS NOTE -2010/012

ALICE HMPID. Estimation of contributions to detected Cherenkov photons