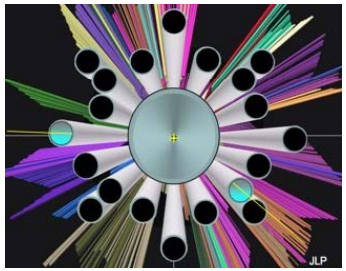
LUminosity measurement with a **C**herenkov **I**ntegrating **D**etector



LUCID

A Cherenkov Tube Based Detector for Monitoring the ATLAS Experiment Luminosity

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On behalf of the ATLAS Luminosity and Forward Physics working group

2007 Nuclear Science Symposium and Medical Imaging Conference

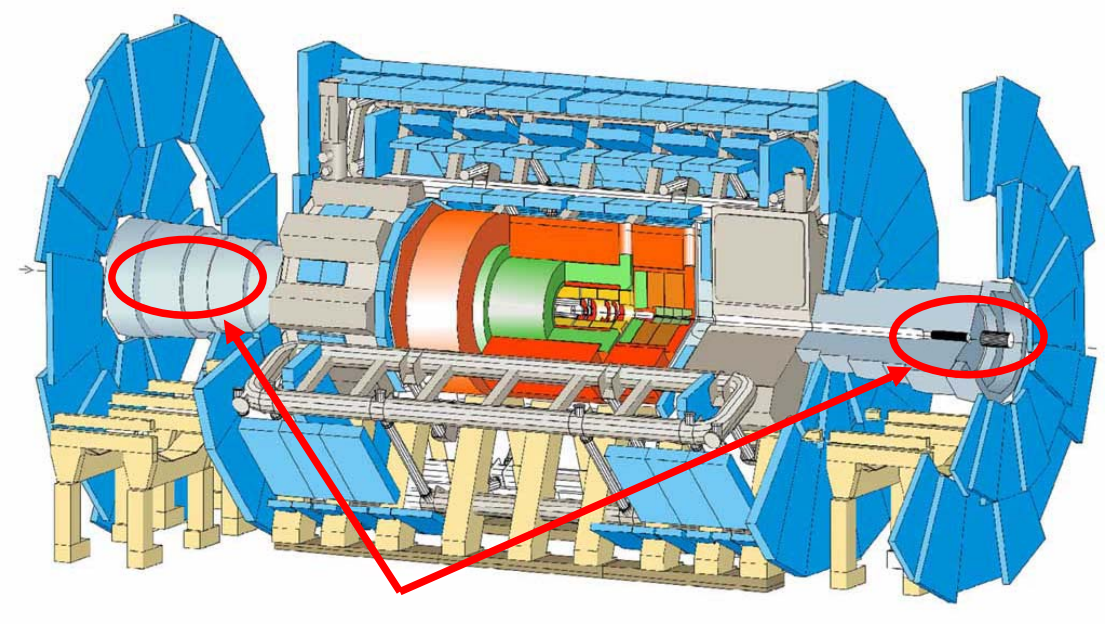
October 27 – Nov. 3, 2007 · Honolulu, Hawaii

IEEE NUCLEAR & PLASMA SCIENCES SOCIETY

Outline

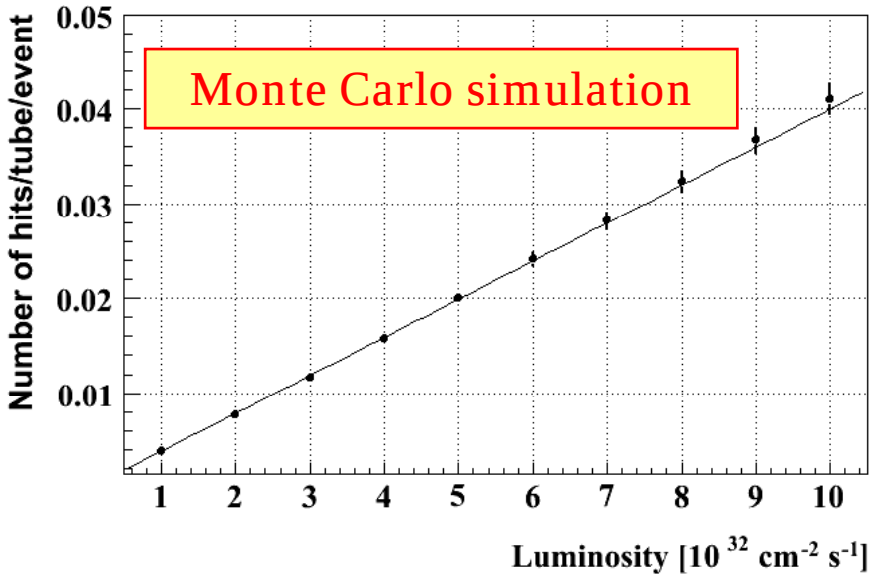
- LUCID in ATLAS
- Phase I and II detectors
- Test beam results
- Radiation hardness
- Conclusions

LUCID in ATLAS

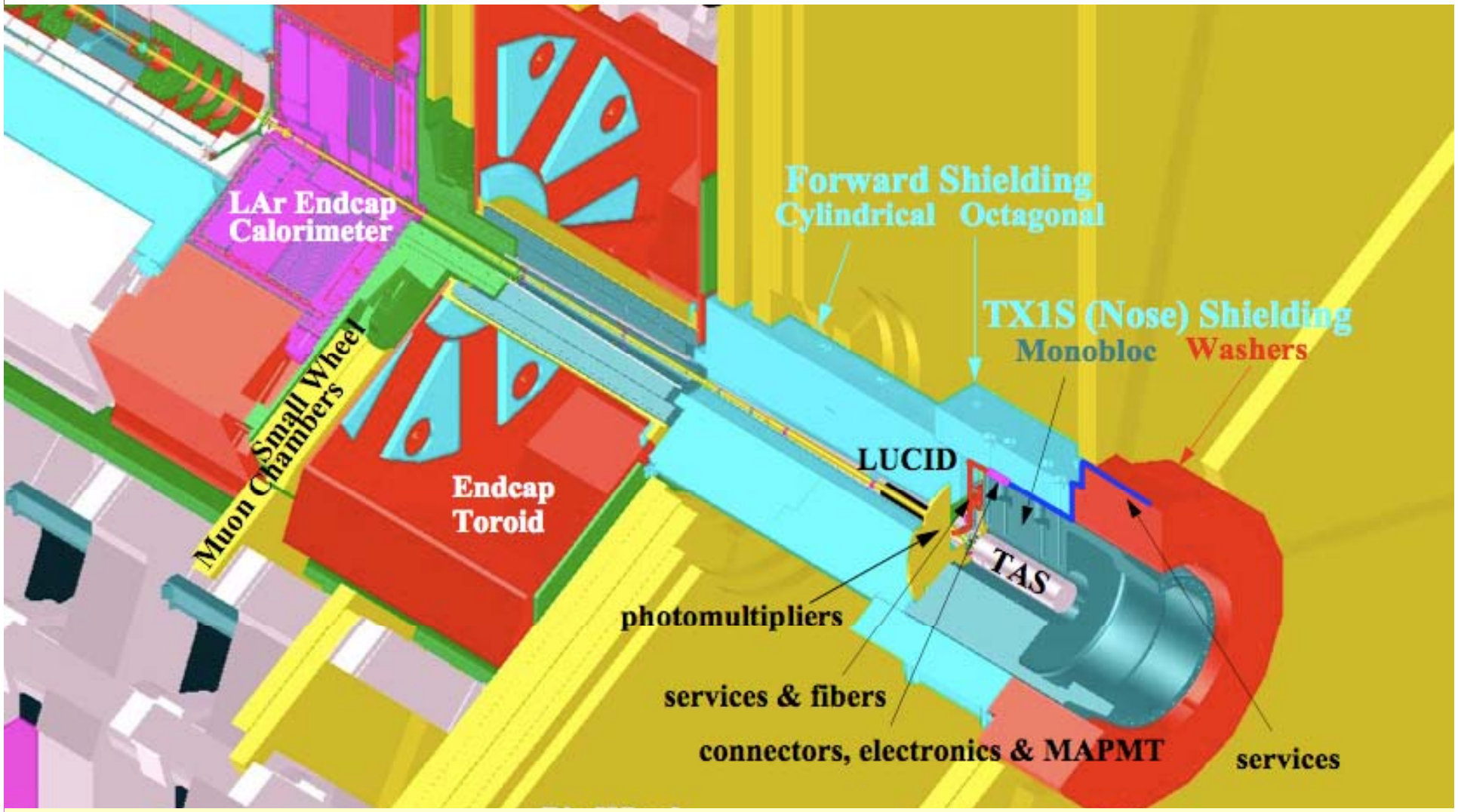


Two symmetrical arms at
17 m from the *pp* interaction region.

- Measure the LHC luminosity.
- Count the number of charged particles per BX, pointing to the primary *pp* interactions.

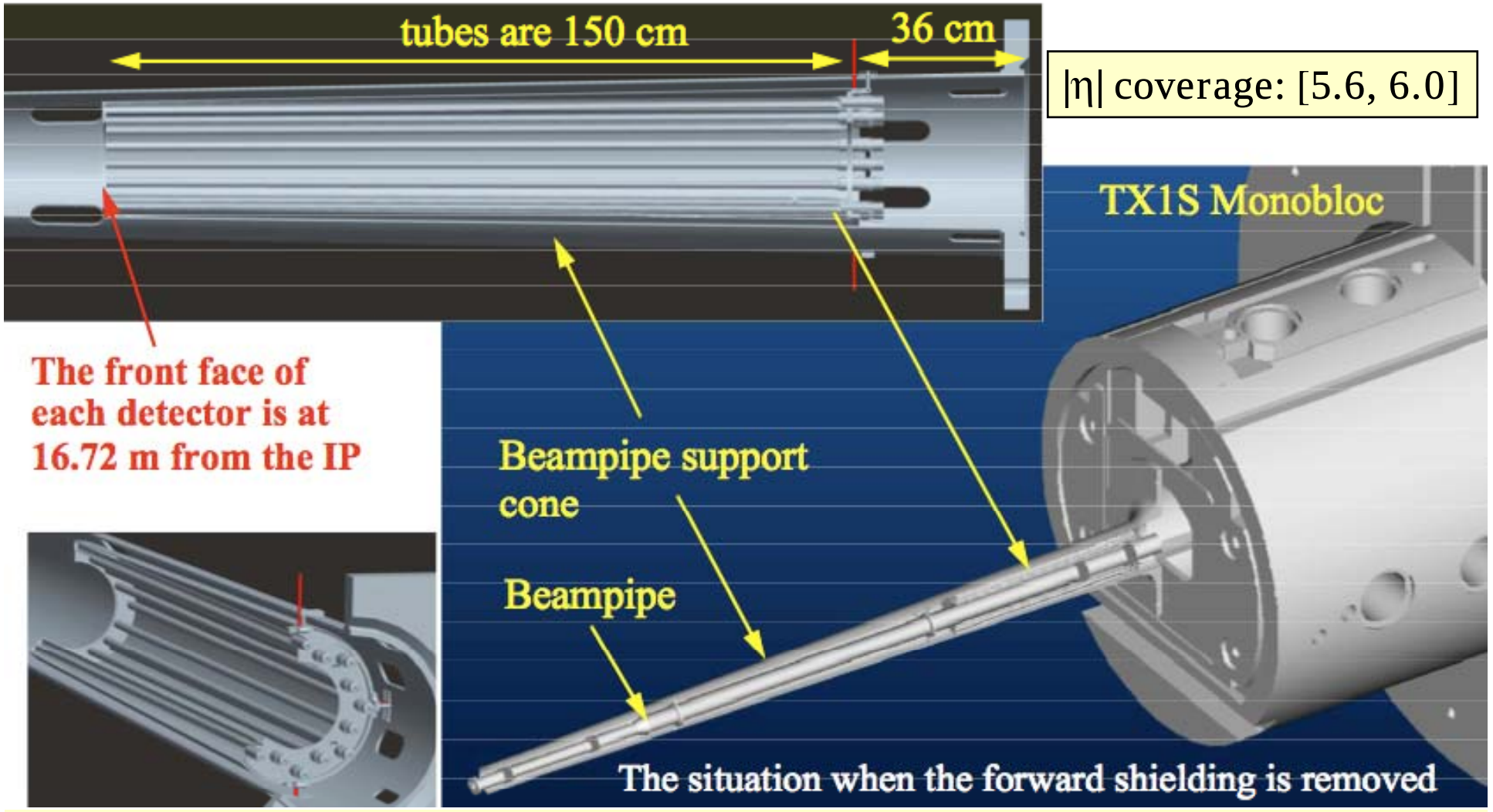


LUCID location



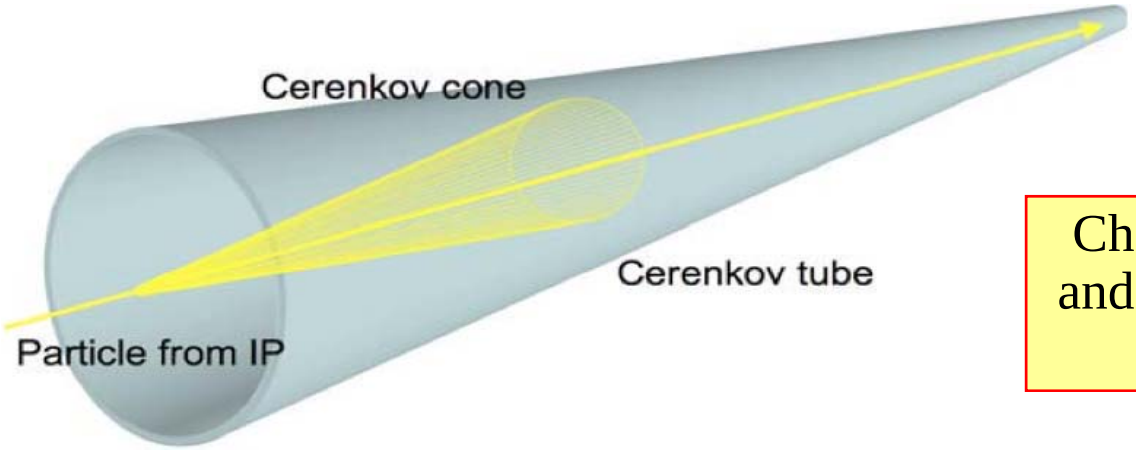
Expected dose: 7 Mrad/year @ higest luminosity (10^{34} $cm^{-2}s^{-1}$)

LUCID detector



Array of mechanically polished Aluminum tubes in a Cherenkov gas (C_4F_{10}).
C_4F_{10} pressure mantained at 1.25/1.5 bar (Leak <10 mbar/day).

LUCID detector principle



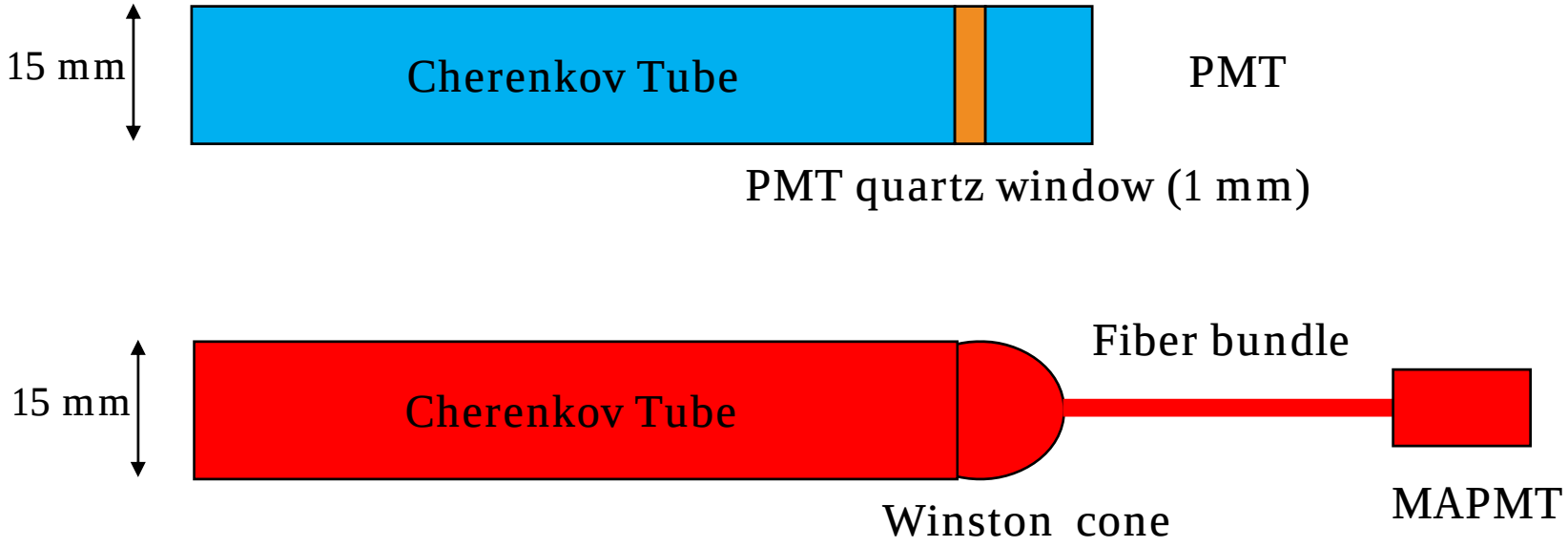
Cherenkov light is emitted at 3^{o} and is read-out after 3 reflections on the inner tube walls.

- Background suppression:
  - Cherenkov threshold in the gas (10 MeV for e^{-} and 2.8 GeV for p)
  - Tubes are pointing to the pp interaction region.

- The fast response (few ns) allows for single bunch crossing detection.

Read-Out scheme

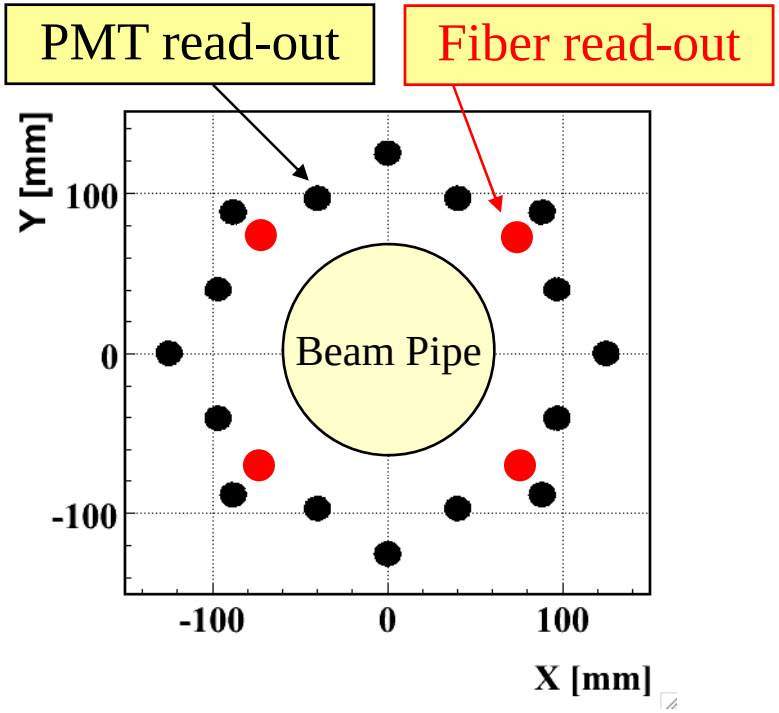
Direct coupling to Photo-Multiplier Tubes (PMT, Hamamatsu R762).
PMT must be radiation hard.

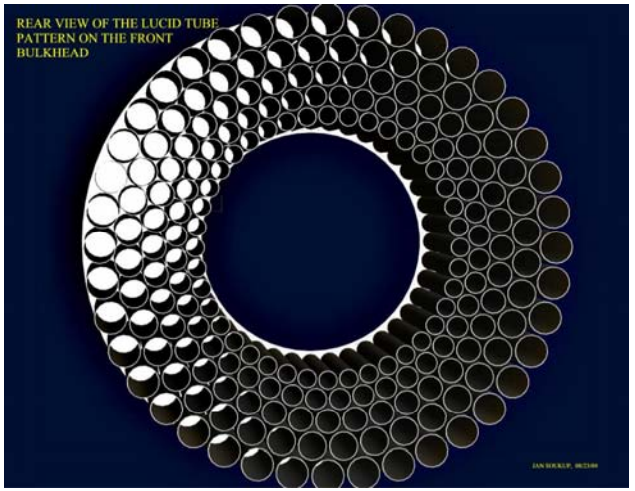


Optical fibers (PUV700) via Winston Cone to multi-anode PMT (Hamamatsu H7546B).
Better for high luminosity runs (MAPMT not exposed to high radiation doses).

Phase I and II detectors

PHASE 1 - Low luminosity	PHASE 2 - High luminosity
$L < 10^{33}$ cm^{-2} s^{-1} [end 2009]	$L = 10^{34}$ cm^{-2} s^{-1} [after 2009]
Goal: σ_{sys}~4-5% + σ_{pp} [CDF:~4%]	Goal: σ_{sys}~2-3% + σ_{pp}





LUCID under construction

LUCID vessel

Cherenkov tubes

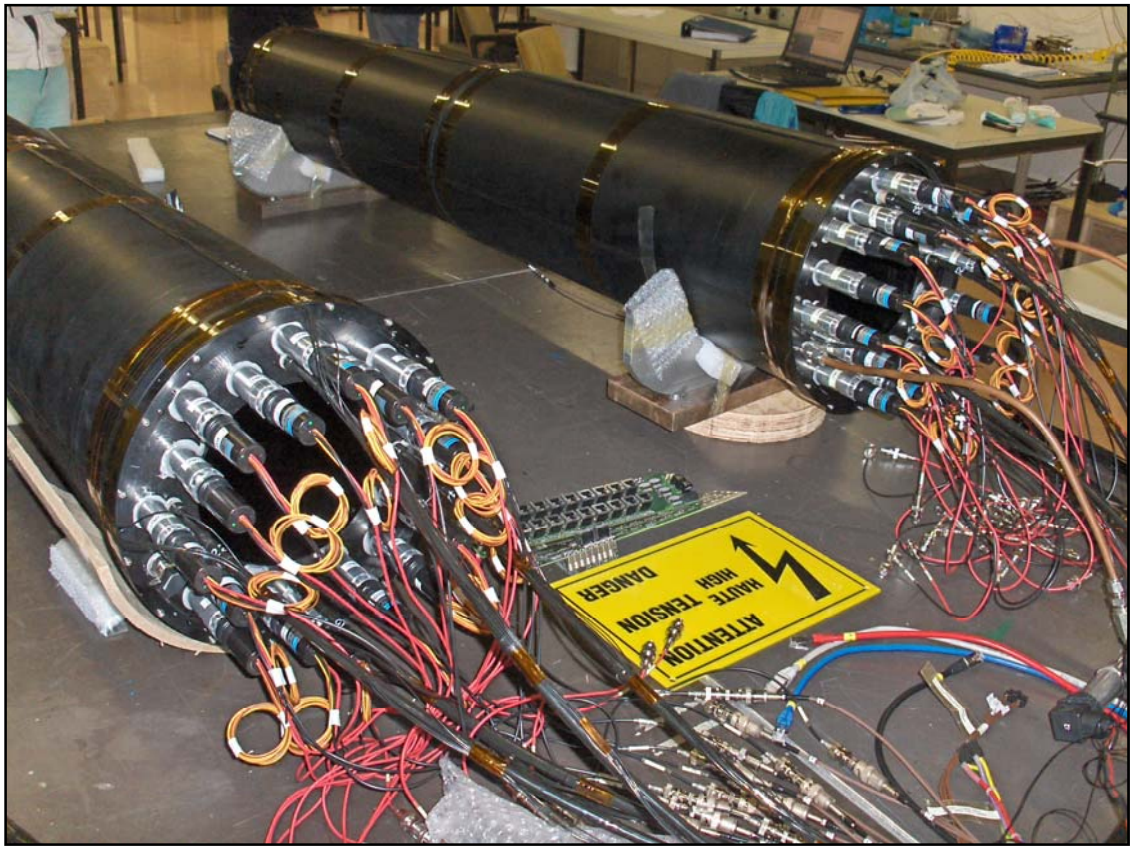
PMT (Hamamatsu R762)

PMT holders

Fiber bundles

Gas pressure test

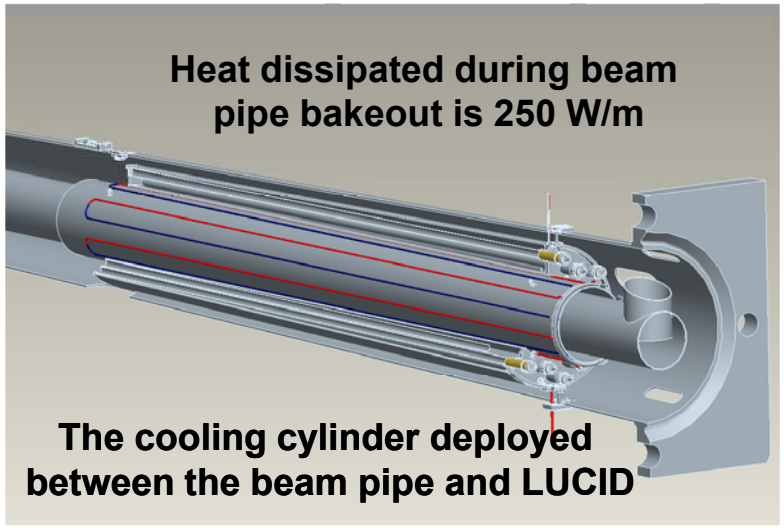
LUCID assembly



LUCID assembled at CERN by the Alberta, Bologna, LUND, CERN team.

LUCID cooling system

During beam pipe bake-out LUCID could reach ~250 ºC.
The temperature must be well below 50ºC (PMT specs.).



Aluminum cylinder with 6 copper cooling loops (20 litres/hr each).
Assuming perfect connection between cooling pipes and Aluminum: T ~20ºC.

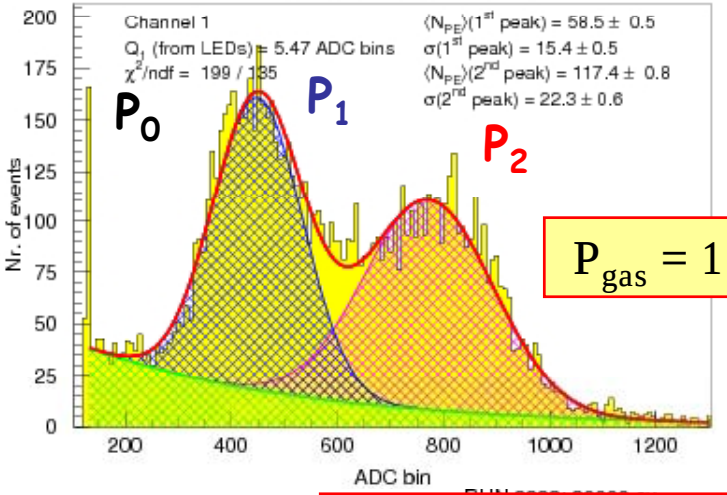
Test Beam results: PMT read-out

P_0 Particles not crossing the tube

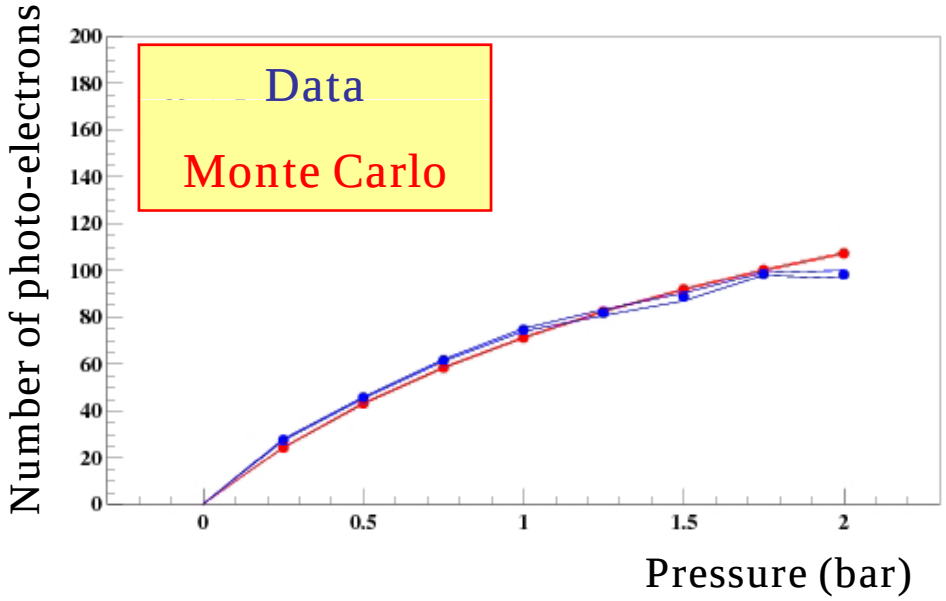
P_1 Photo-electrons in gas (70)

P_2 Photo-electrons in gas and PMT (120)

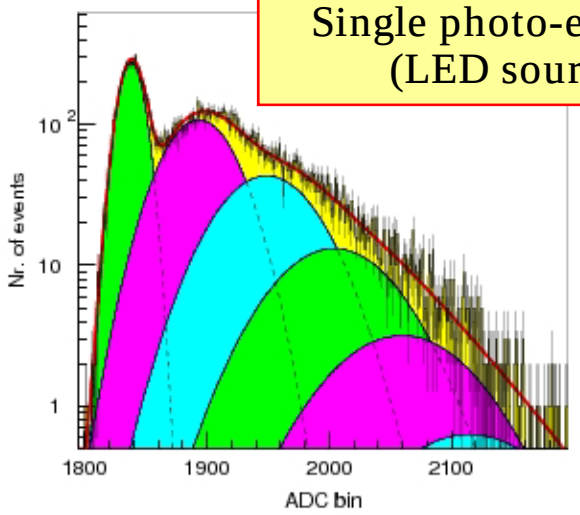
The signal from the PMT quartz window is at lower level.



P_{gas} = 1 bar

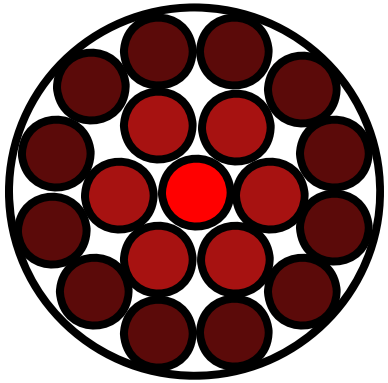


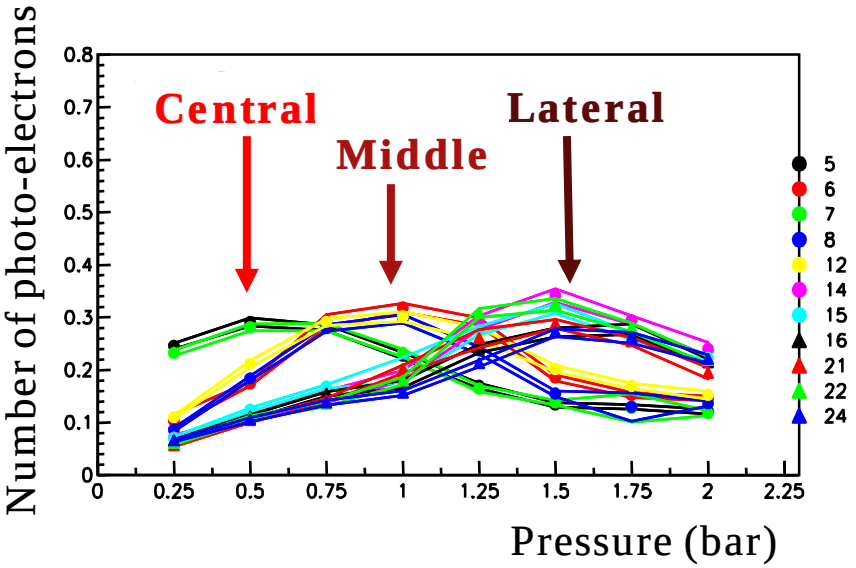
Single photo-electron (LED source)



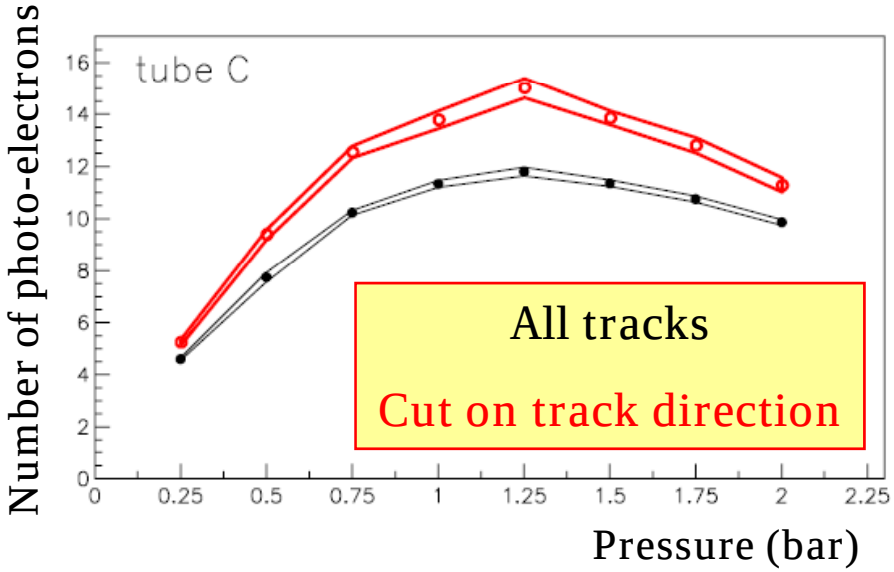
Test Beam results: Fiber read-out

Fiber Bundle





Maximum N_{pe} per tube = 12-15



Fiber read-out less efficient than PMT.

Radiation hardness test

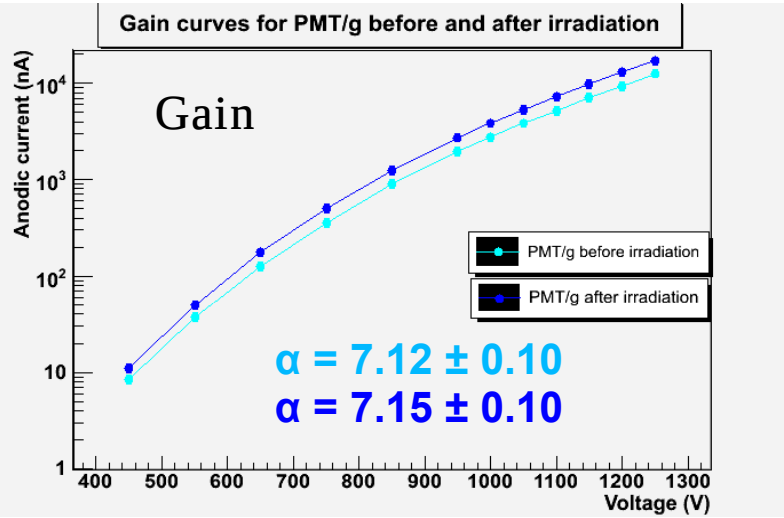
γ: ^{60}Co, $E = 1.22$ MeV Dose = 20 ± 1 Mrad 30 years of LHC in phase I	n: ENEA-Casaccia reactor E = 100 KeV Dose = 10 years of LHC in phase I

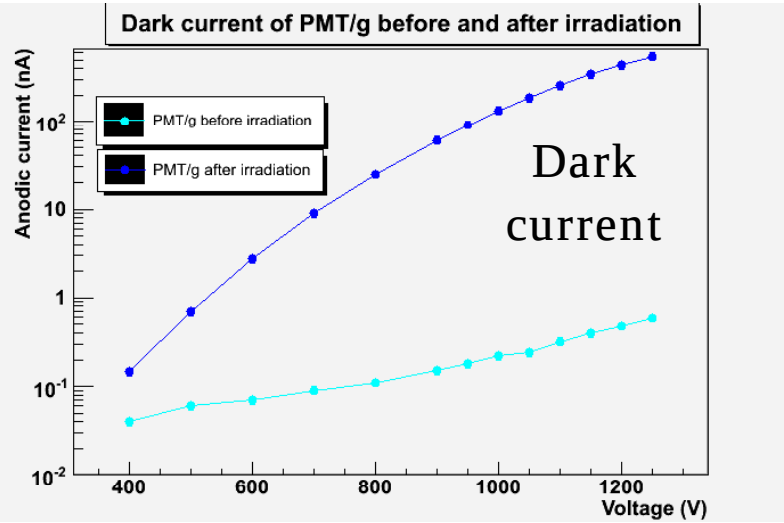
Before

After

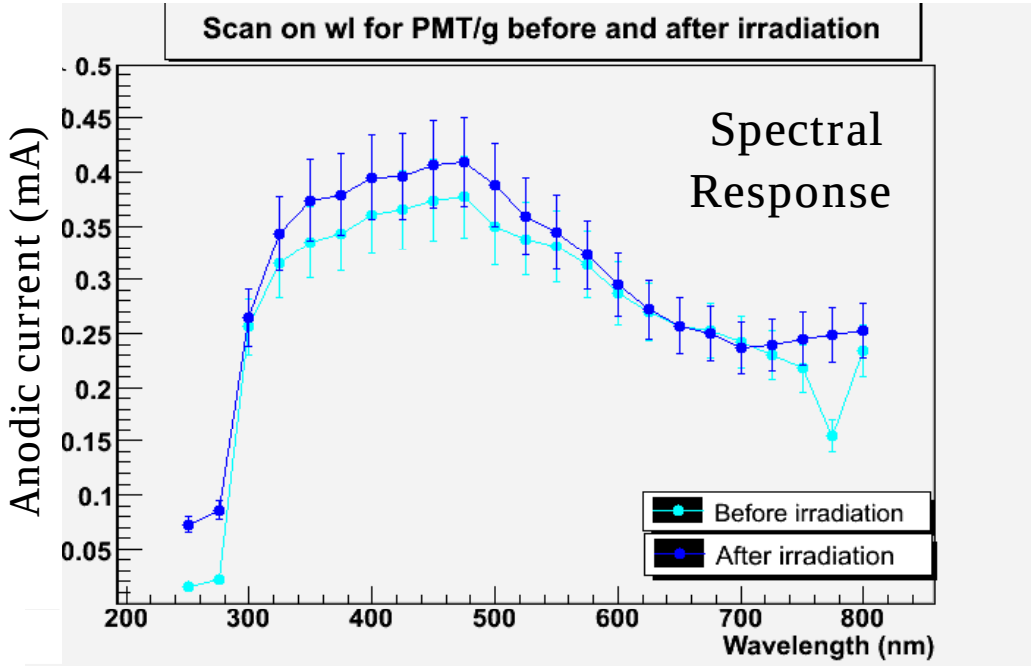
No visible damage to metal and quartz. Glass opacity increased.	No visile damage to matal, glass and quartz

Radiation hardness



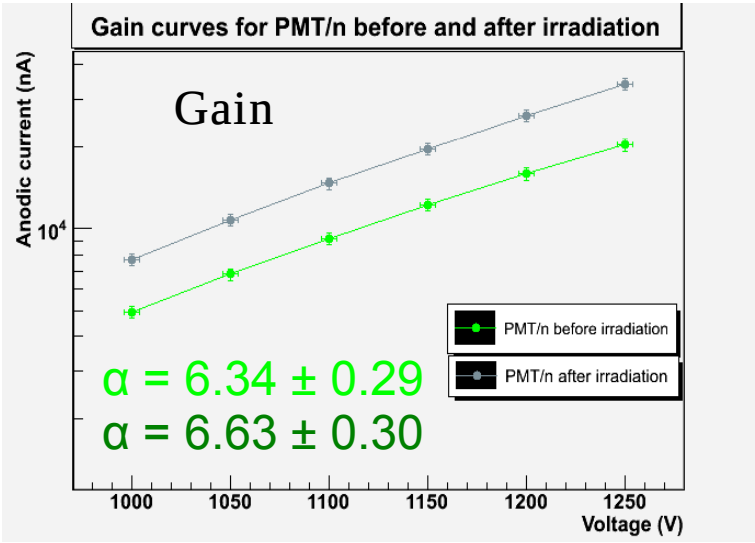


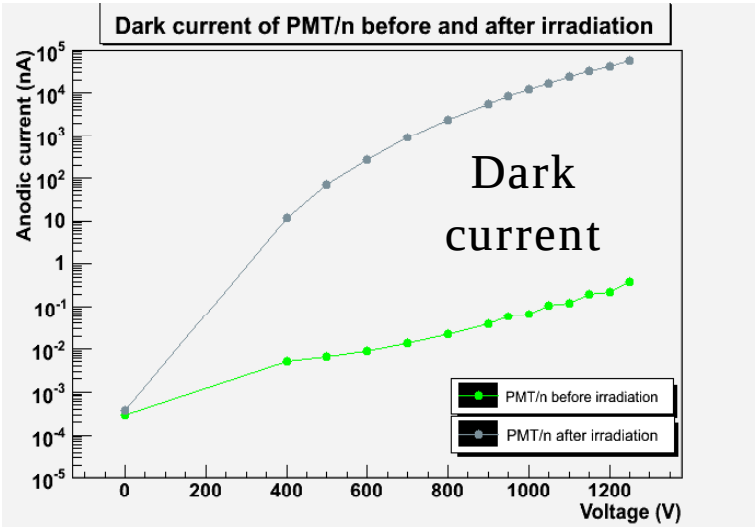
γ: ^{60}Co, E = 1.22 MeV
Dose = 20 ± 1 Mrad
30 years of LHC in phase I



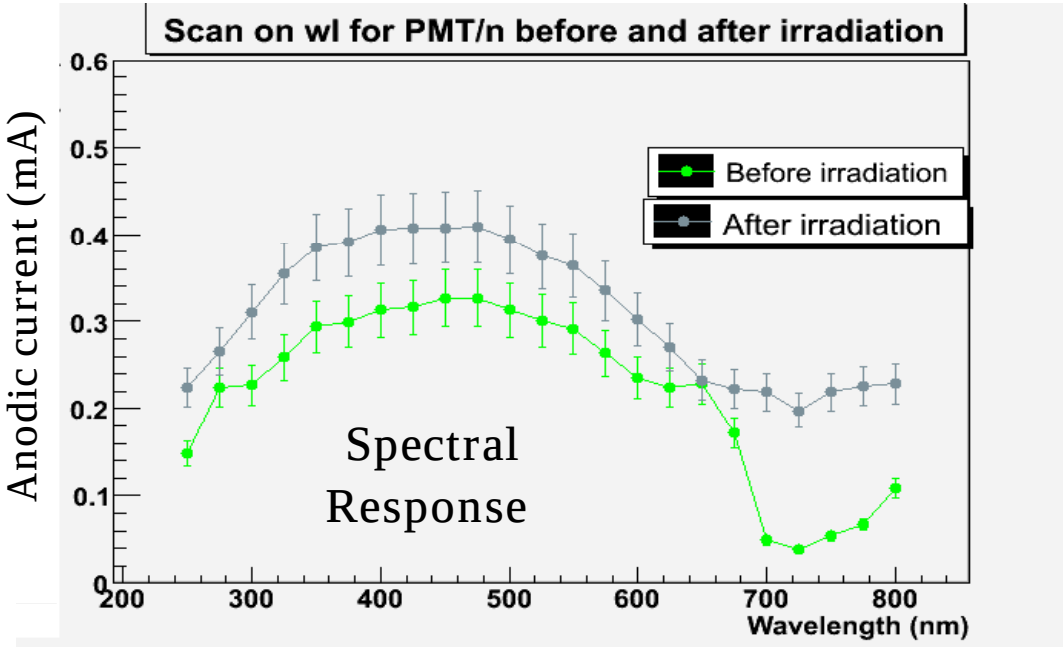
No relevant effects for phase I

Radiation hardness





n: ENEA-Casaccia reactor
E = 100 KeV
Dose = 10 years of LHC in phase I



No relevant effects for phase I

Conclusions

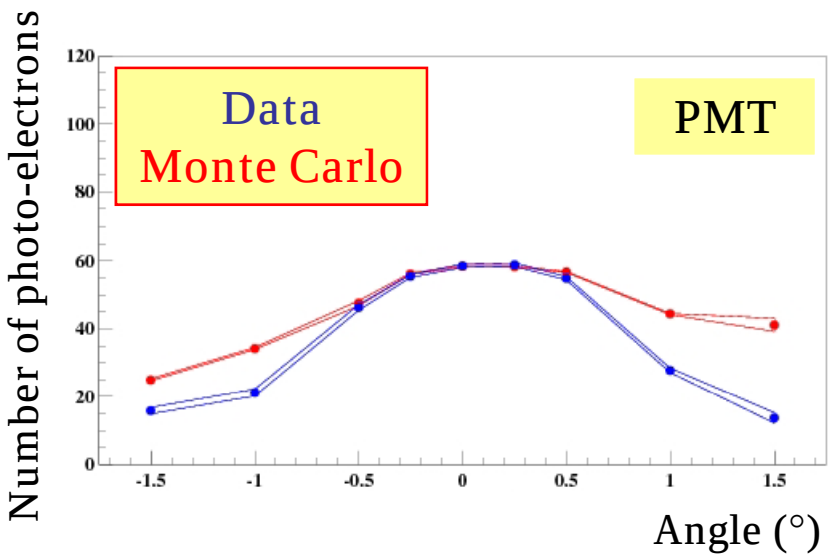
- LUCID was approved at the ATLAS review in 01/2007.
- LUCID has been successfully assembled in 07/2007.

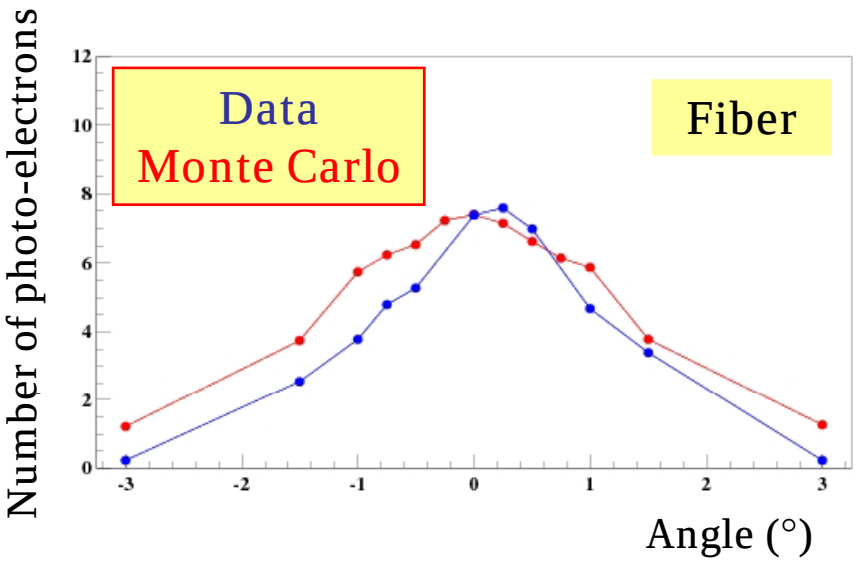
- Beam tests have shown that the behavior of phase I detector is satisfactory and under control.
- The PMT R762 is radiation hard [at least for phase I].
- The cooling system and the alignment system have been designed and are being assembled.

- A phase II detector is being studied.

Back-up slides

Angular scan

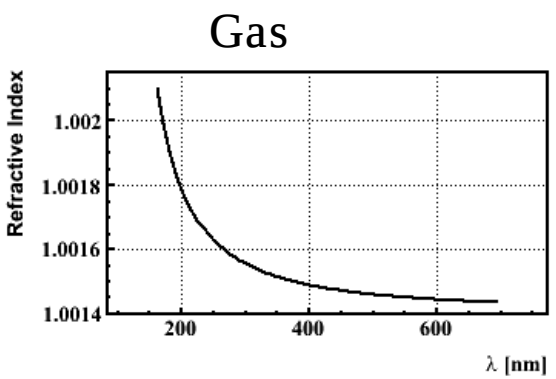


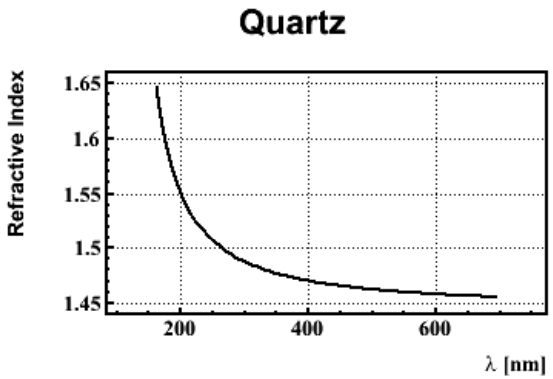


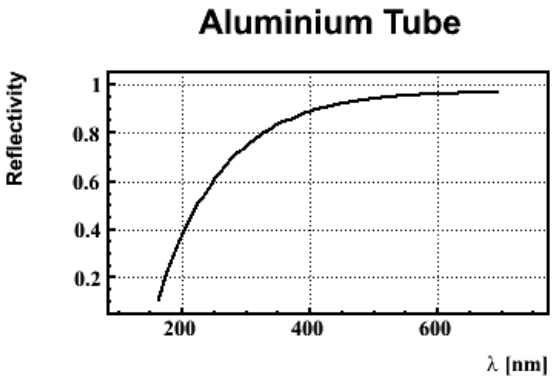
Asymmetry is due to rotation around the vessel, rather than the tube.

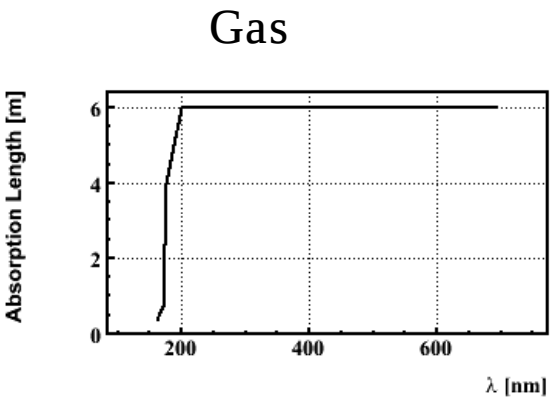
Higher selectivity on track direction with fiber read-out (better IP pointing).

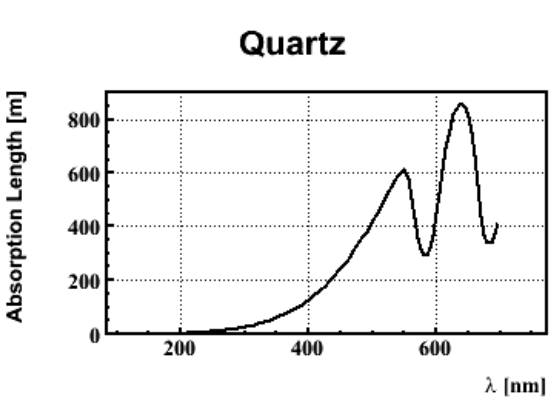
Wavelength parameterisation

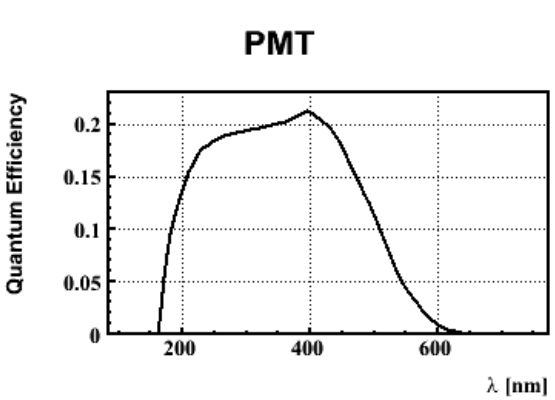






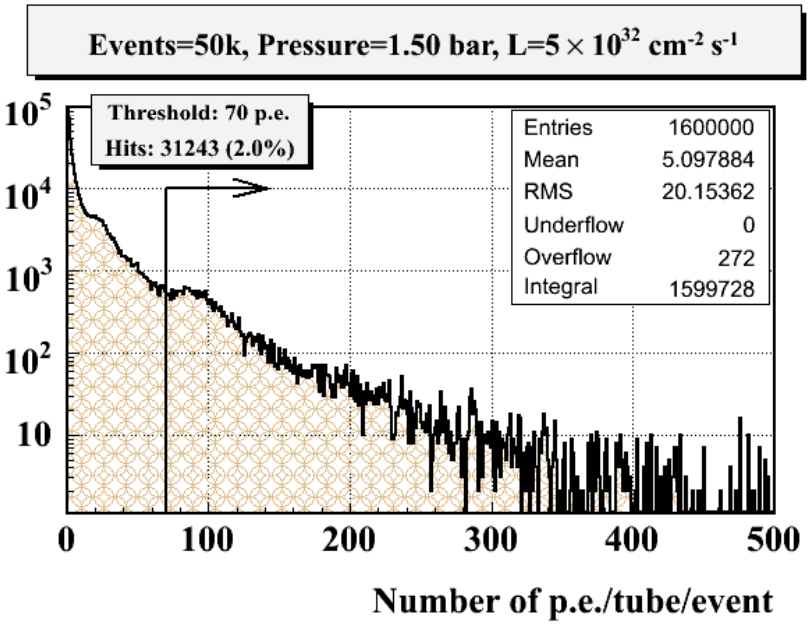


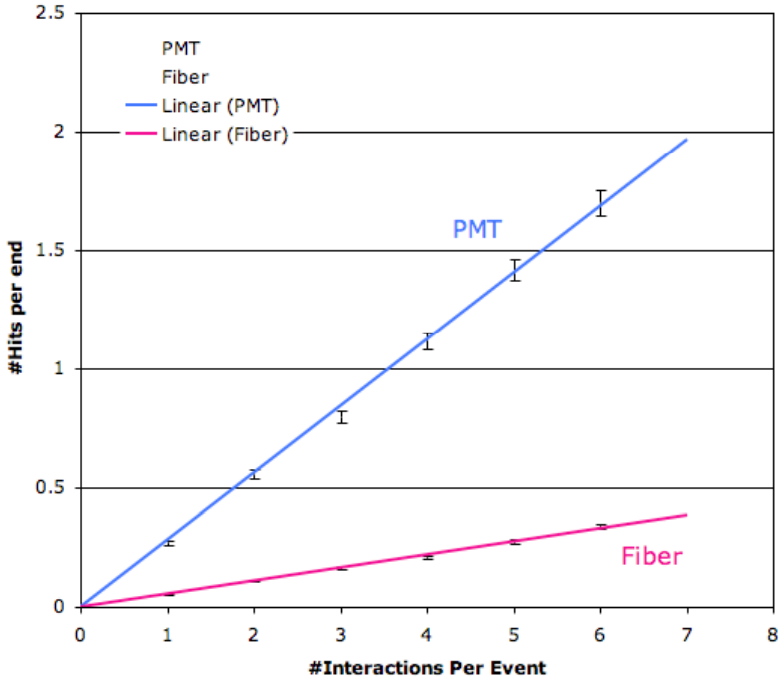




The wavelength of read-out photo-electrons is [160, 650] nm.

LUCID simulation





Luminosity with LUCID

The Monte Carlo simulation is used for cross-check (via ε and $\sigma_{inelastic}$).

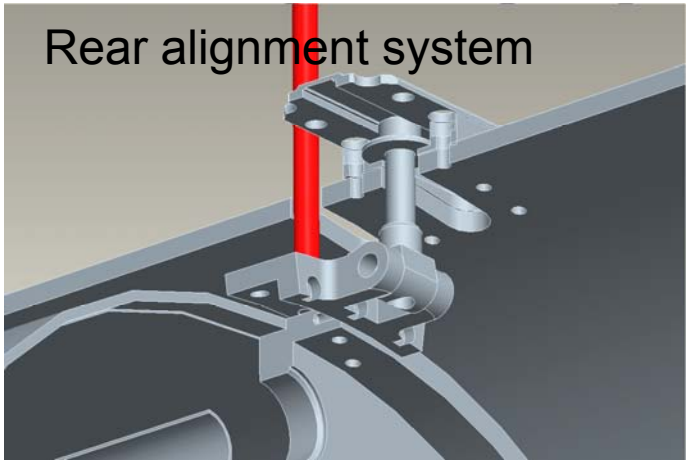
$$L = \frac{N_{LUCID}}{\varepsilon_{LUCID}\sigma_{inelastic}}$$

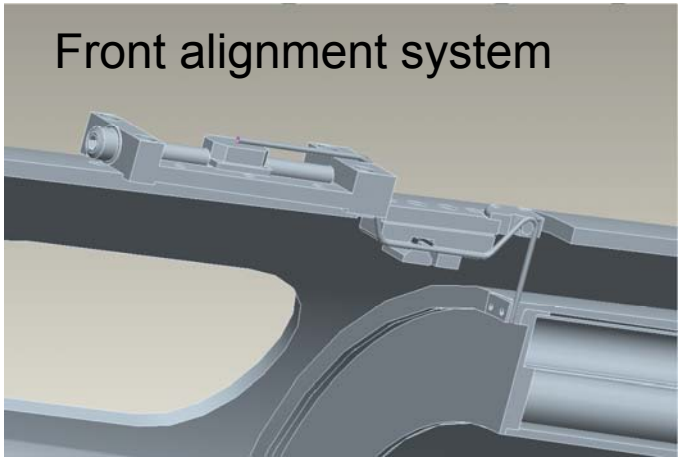
Being calibrated on the absolute luminosity provided by the ALFA detector (via k_{ALFA}), LUCID is only partially based on the Monte Carlo simulation.

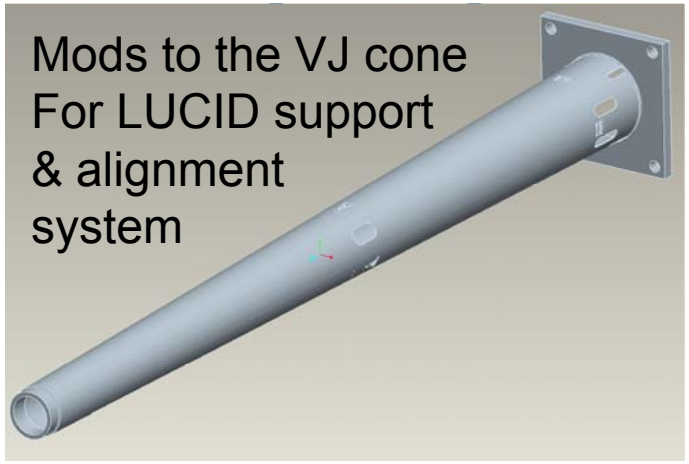
$$L = k_{ALFA} N_{LUCID}$$

Still, MC important for showing the work of principle (linearity).

The Alignment system

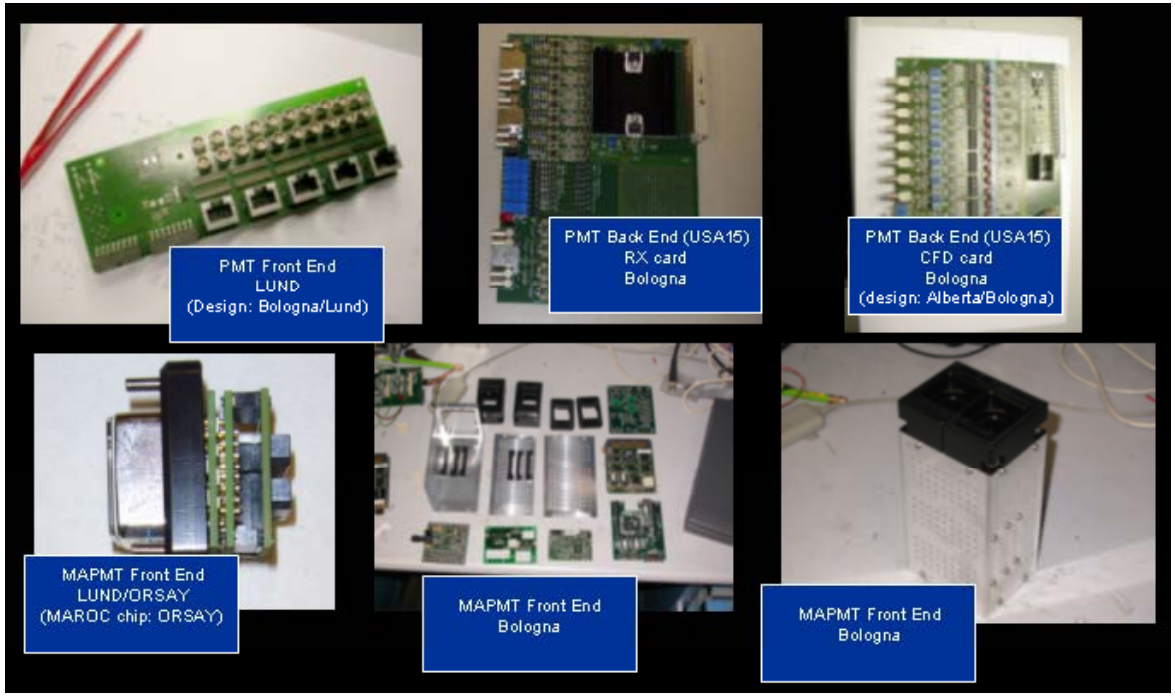






Alignment to a fraction of a degree to the beam axis is required.

LUCID electronics



- The PMT readout is produced tested and installed (upper photos).
- The MAPMT readout (lower photos) is in a advanced state of readiness. Final commissioning will start as soon as the MAROC3 chip is available next spring
- The LUCID processor VME card (LUMAT) (trigger, data output, on-line luminosity measurement) is in an advanced state of design (ready next spring).