Lund Activities in ATLAS

- **Transition Radiation Tracker**

  (P. Eerola, B. Lundberg, U. Mjörnmark, T. Åkesson, O. Smirnova, N. Boelaert)

- **Luminosity (LUCID & ALFA)**

  (V. Hedberg, B. Lundberg, U. Mjörnmark, J. Groth-Jensen)

- **B-physics**

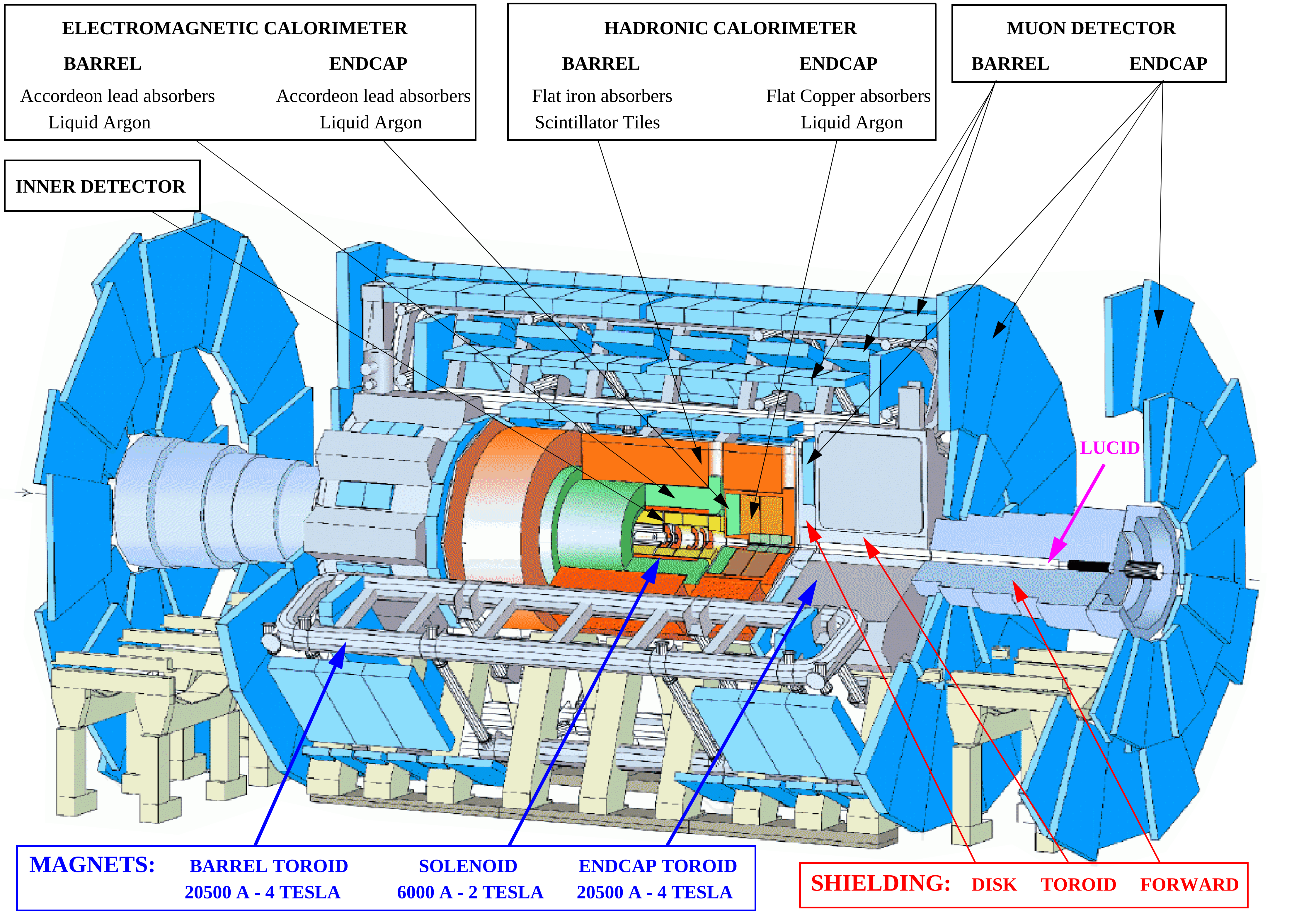
  (P. Eerola, W. Ji, C. Laaksometsä, S. Seidel)

- **Technical coordination**
  (Background radiation, Shielding, Radioprotection)

  (V. Hedberg)

- **GRID**

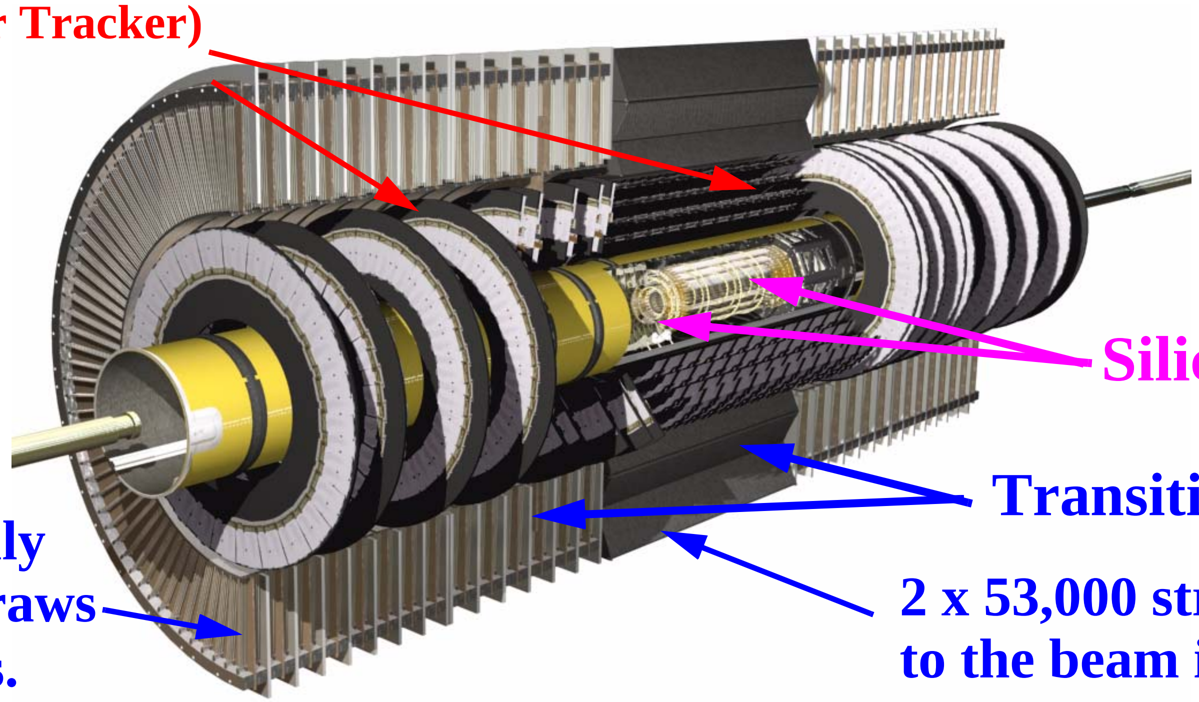
  (O. Smirnova, B. Konya)


ELECTROMAGNETIC CALORIMETER
BARREL
Accordeon lead absorbers
Liquid Argon
ENDCAP
Accordeon lead absorbers
Liquid Argon
HADRONIC CALORIMETER
BARREL
Flat iron absorbers
Scintillator Tiles
ENDCAP
Flat Copper absorbers
Liquid Argon
MUON DETECTOR
BARREL
ENDCAP
INNER DETECTOR
LUCID
MAGNETS:
BARREL TOROID
20500 A - 4 TESLA
SOLENOID
6000 A - 2 TESLA
ENDCAP TOROID
20500 A - 4 TESLA
SHIELDING:
DISK
TOROID
FORWARD

The Transition Radiation Tracker

ATLAS

Silicon Strip Detector
(The SemiConductor Tracker)



Silicon Pixel Detector

Transition Radiation Tracker

420,000 radially distributed straws in the endcaps.

2 x 53,000 straws parallel to the beam in the barrel.

The 4 mm diameter straws are made of kapton with a conductive coating and filled with a Xenon gas.

In the middle of each straw is a 30 μm gold-plated tungsten wire at 1.78 kV and the straws act as small cylindrical proportional chambers.

15 polypropylene radiators between the straws makes it possible to use the straws both as drift tubes for tracking and for electron identification.

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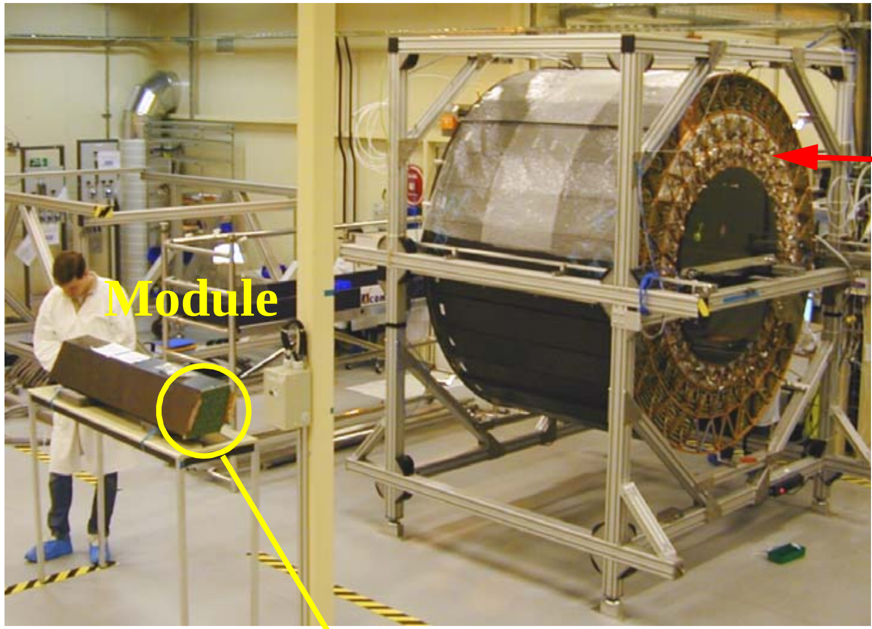
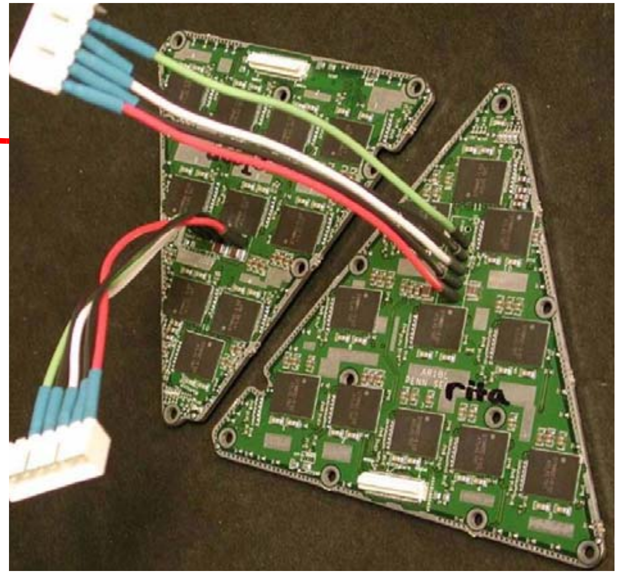
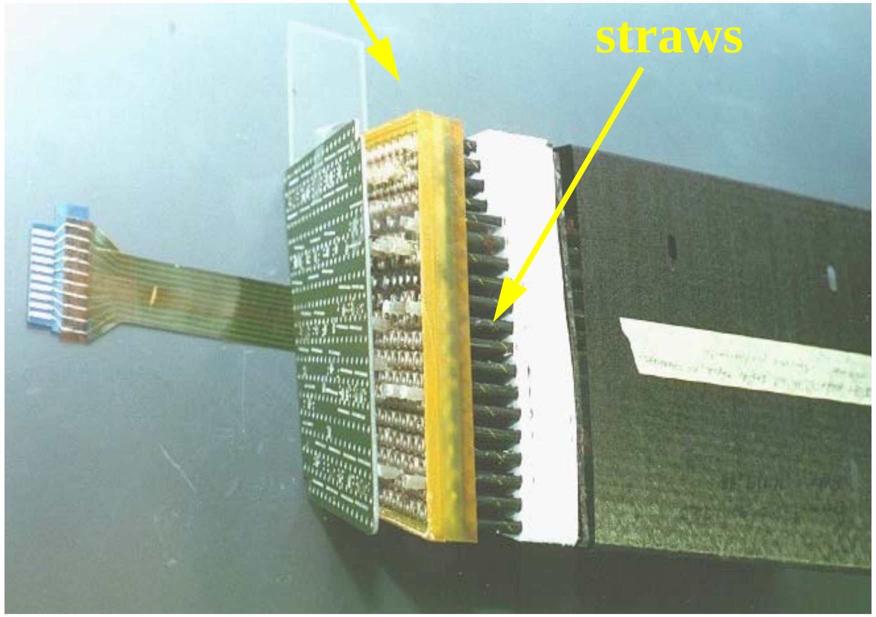
The Transition Radiation Tracker

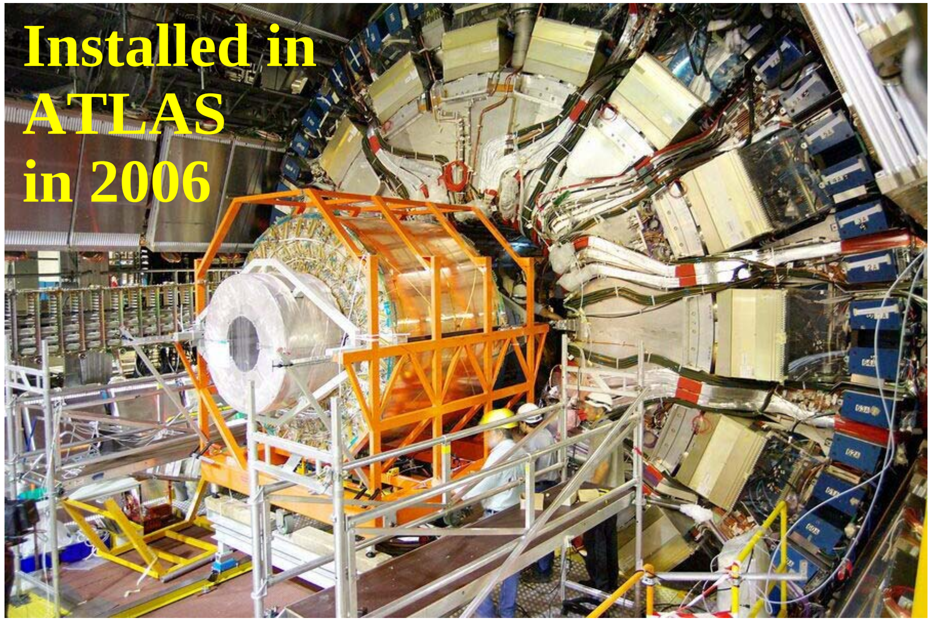
ATLAS





Front-end electronics built by Lund



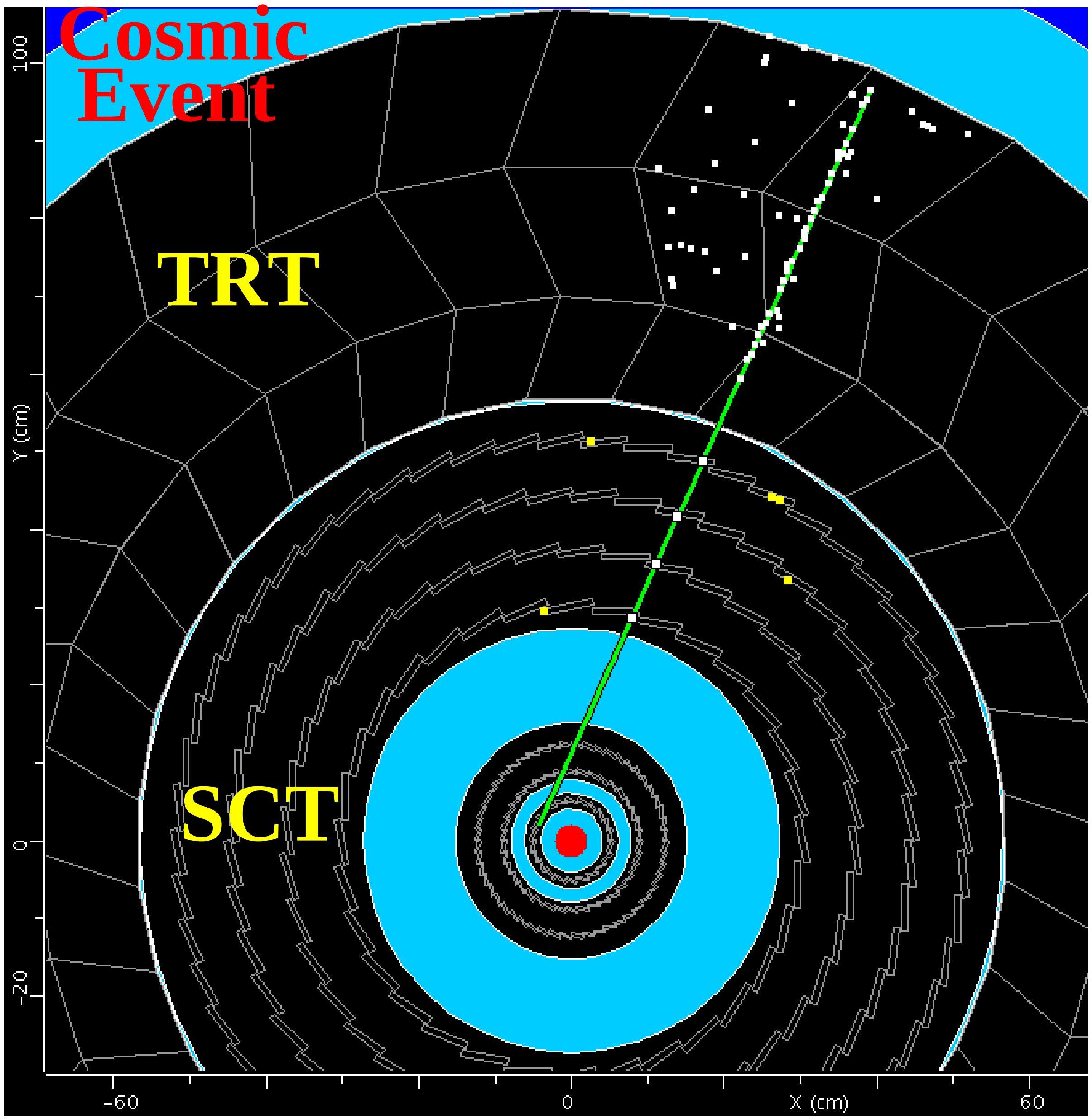


The Transition Radiation Tracker

ATLAS

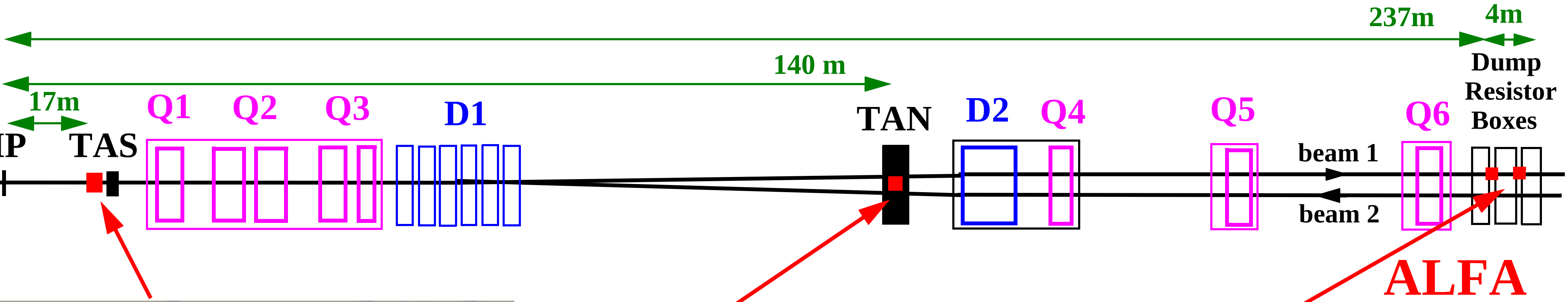
The detector project is now in the commissioning phase.

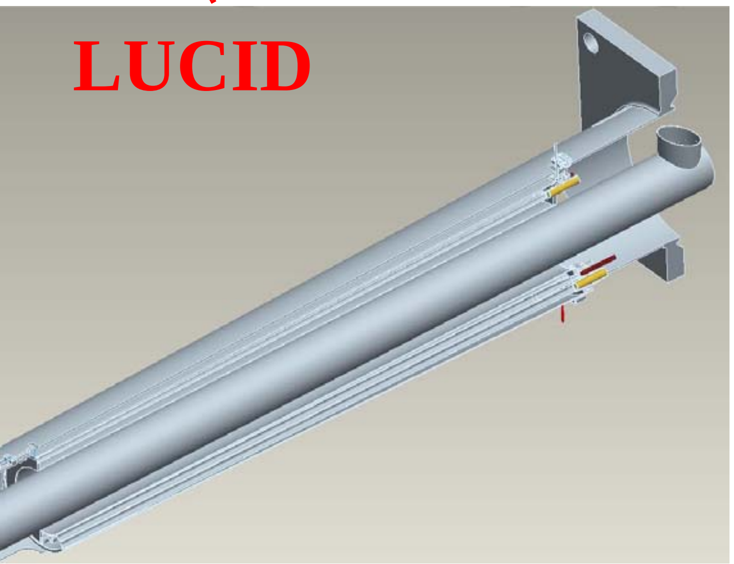
Lund will get involved in monitoring and data taking.



Forward Luminosity Detectors

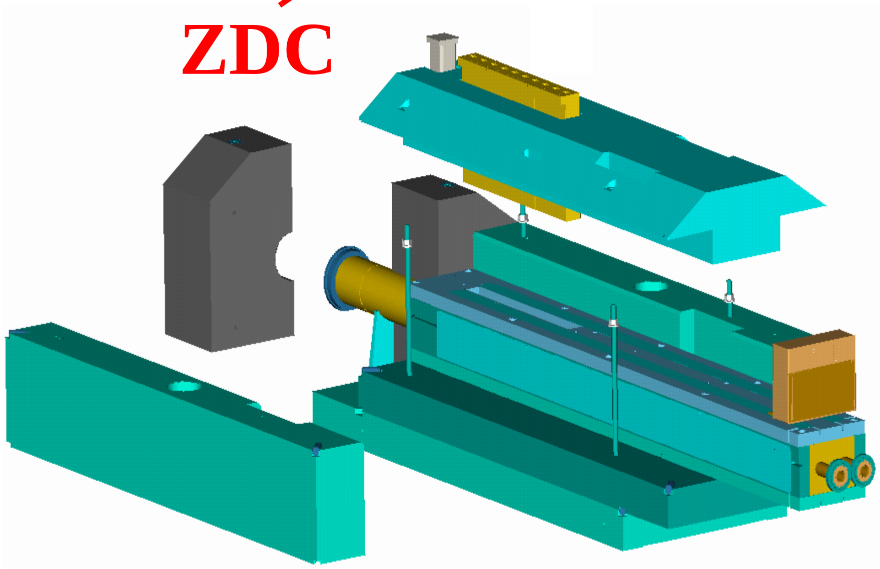
ATLAS





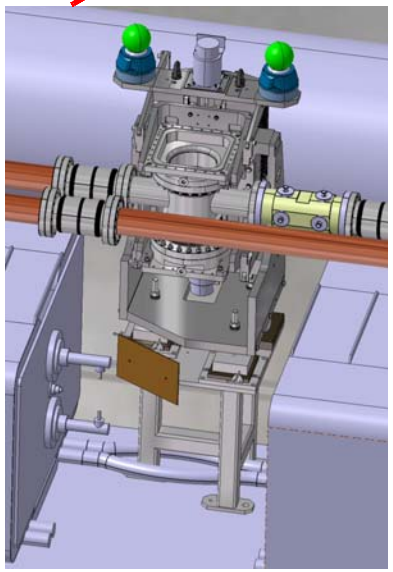
Cerenkov tubes

Relative luminosity monitoring.



Tungsten/quartz calorimeter

Forward physics in both pp and heavy ion collisions.



Scintillating fibres in Roman pots

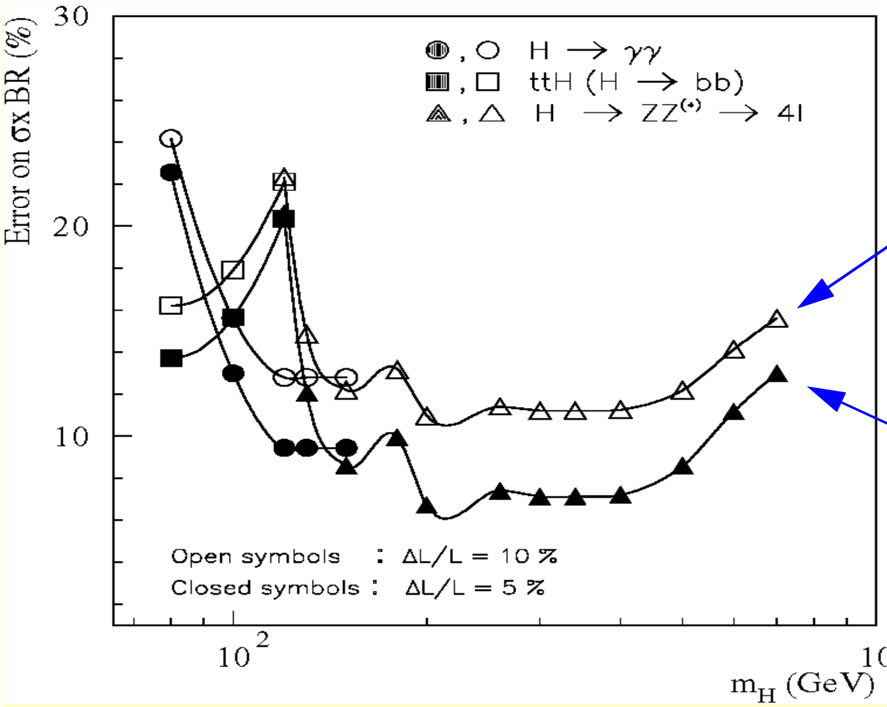
Absolute luminosity in dedicated LHC runs with special optics and low lumi.

Luminosity determination

Higgs coupling

WHY ?

Example →



$\frac{\Delta L}{L} = 10\%$

$\frac{\Delta L}{L} = 5\%$

STRATEGY ?

Measure elastic scattering at low luminosity
Measure rates of well-calculable processes e.g. QED, QCD
Measure relative luminosity with luminosity monitors

GOAL ?

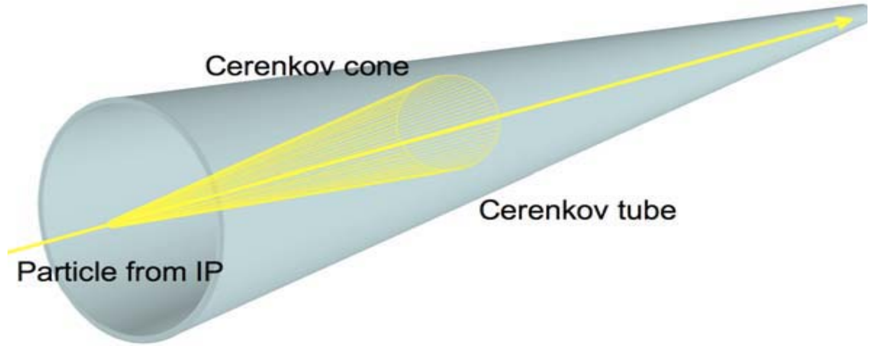
Measure the luminosity with 2-3% accuracy

LUCID: The basic concept

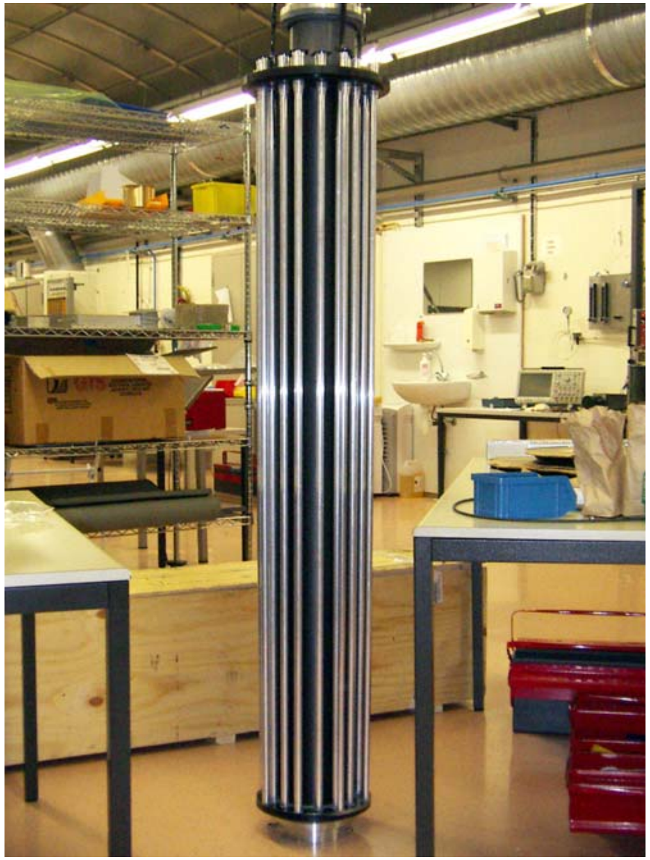
ATLAS

LUCID: LUminosity measurement using a Cerenkov Integrating Detector

An array of aluminum tubes filled with C_4F_{10} gas acts as Cerenkov counters.



The Cerenkov light is produced with a 3^o angle and makes typically 3 reflections while passing down the tube.



The Cerenkov threshold (10 MeV for elec. and 2.8 GeV for pions) and the pointing of the tubes surpresses background.

No Landau fluctuations makes it easier to determine if several particles have gone through the same tube.

A good time resolution makes it possible to study individual beam crossings.

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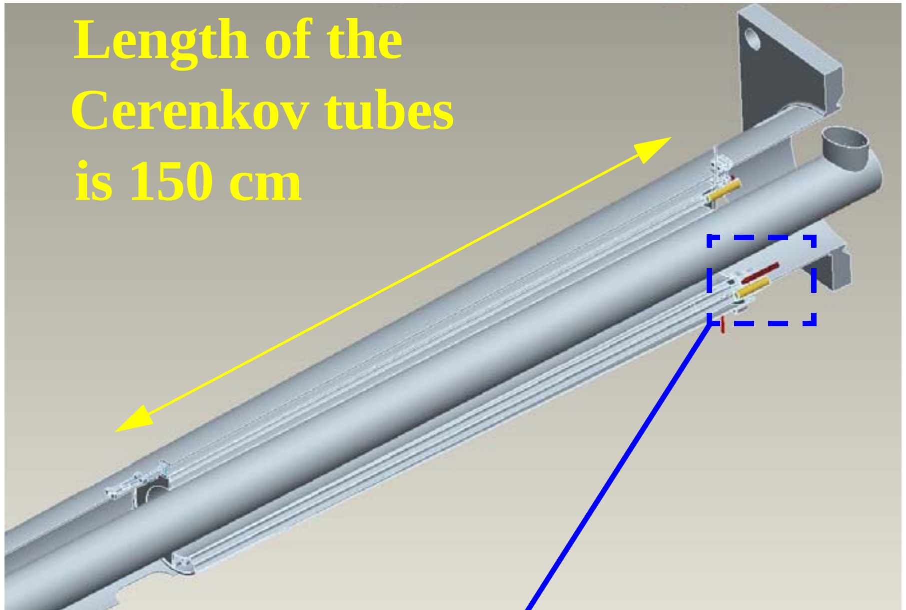
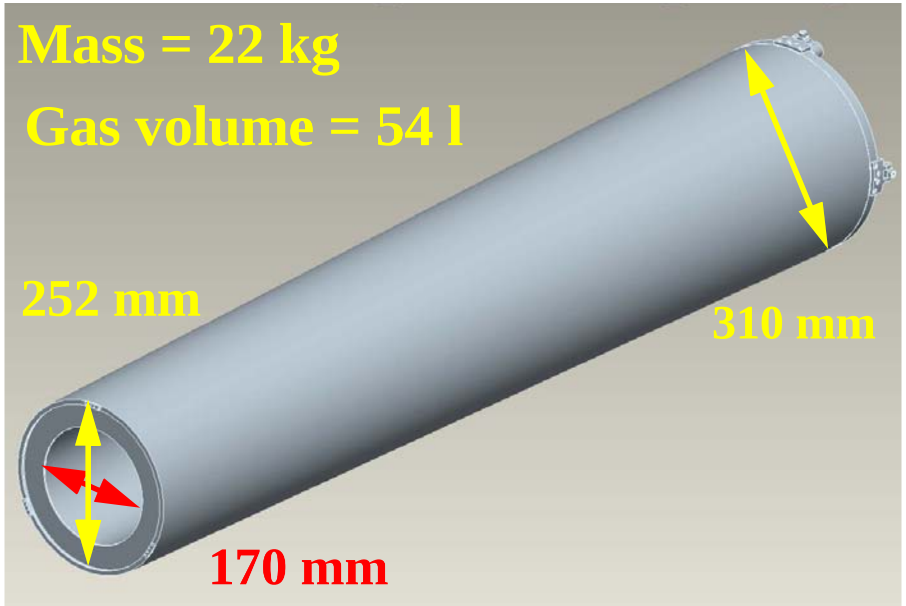
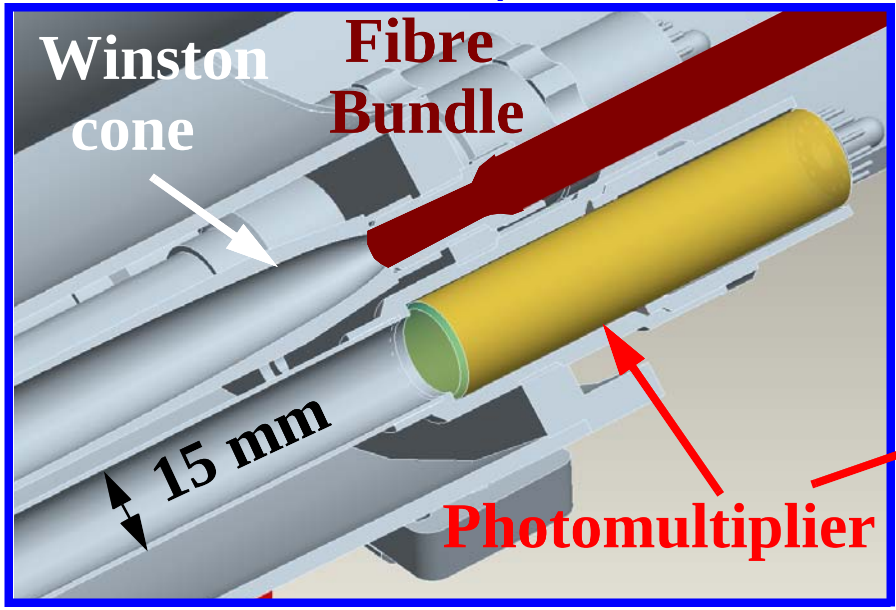
LUCID: The design

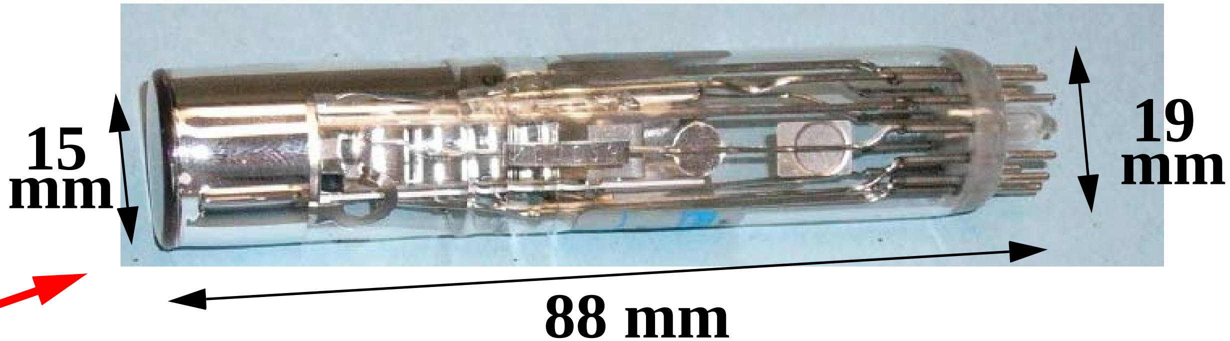
ATLAS







Hamamatsu R762



The quartz window thickness is 0.8 mm

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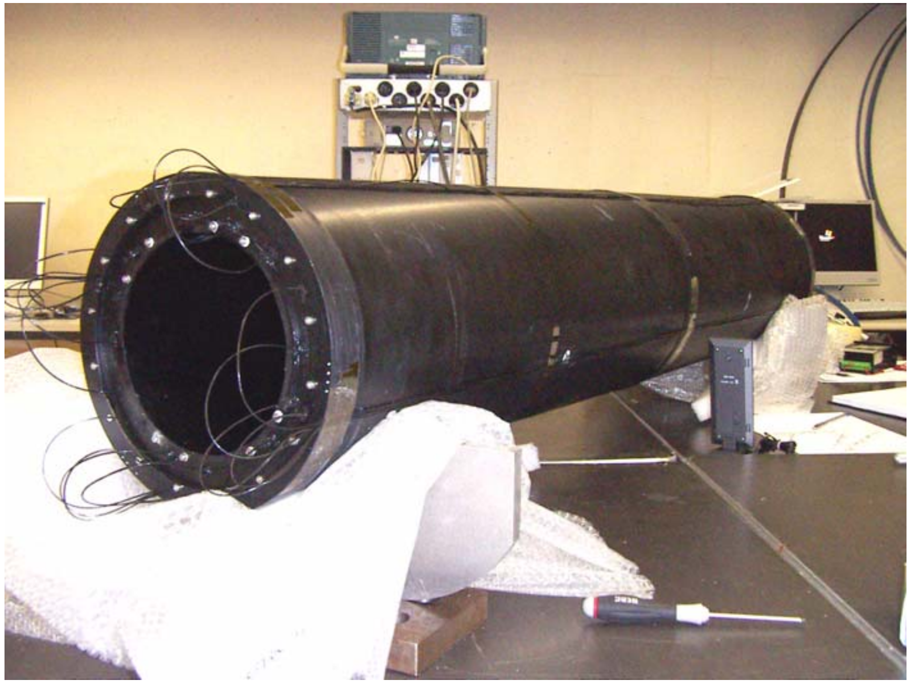
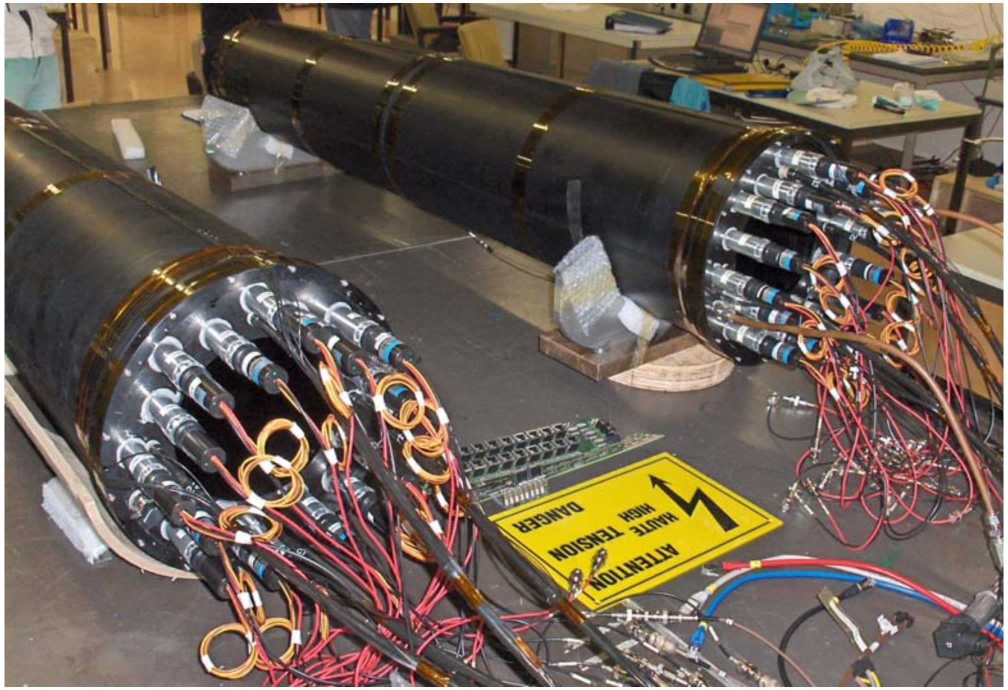
LUCID: Status of the detector

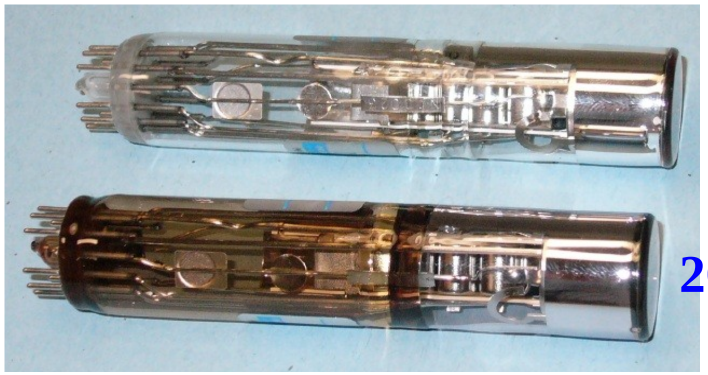
ATLAS





Three detectors have been built (one spare) and they are now being tested with LEDs. They will be tested fully in a testbeam at CERN in October. Installation in ATLAS in March. Lund is providing electronics.

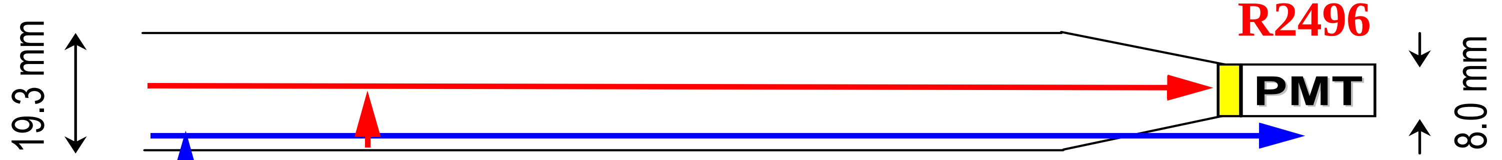
The radiation hardness of the read-out is crucial. Tests have shown that the photomultipliers can survive 3-5 years at 10^{34} $cm^{-2}s^{-1}$.



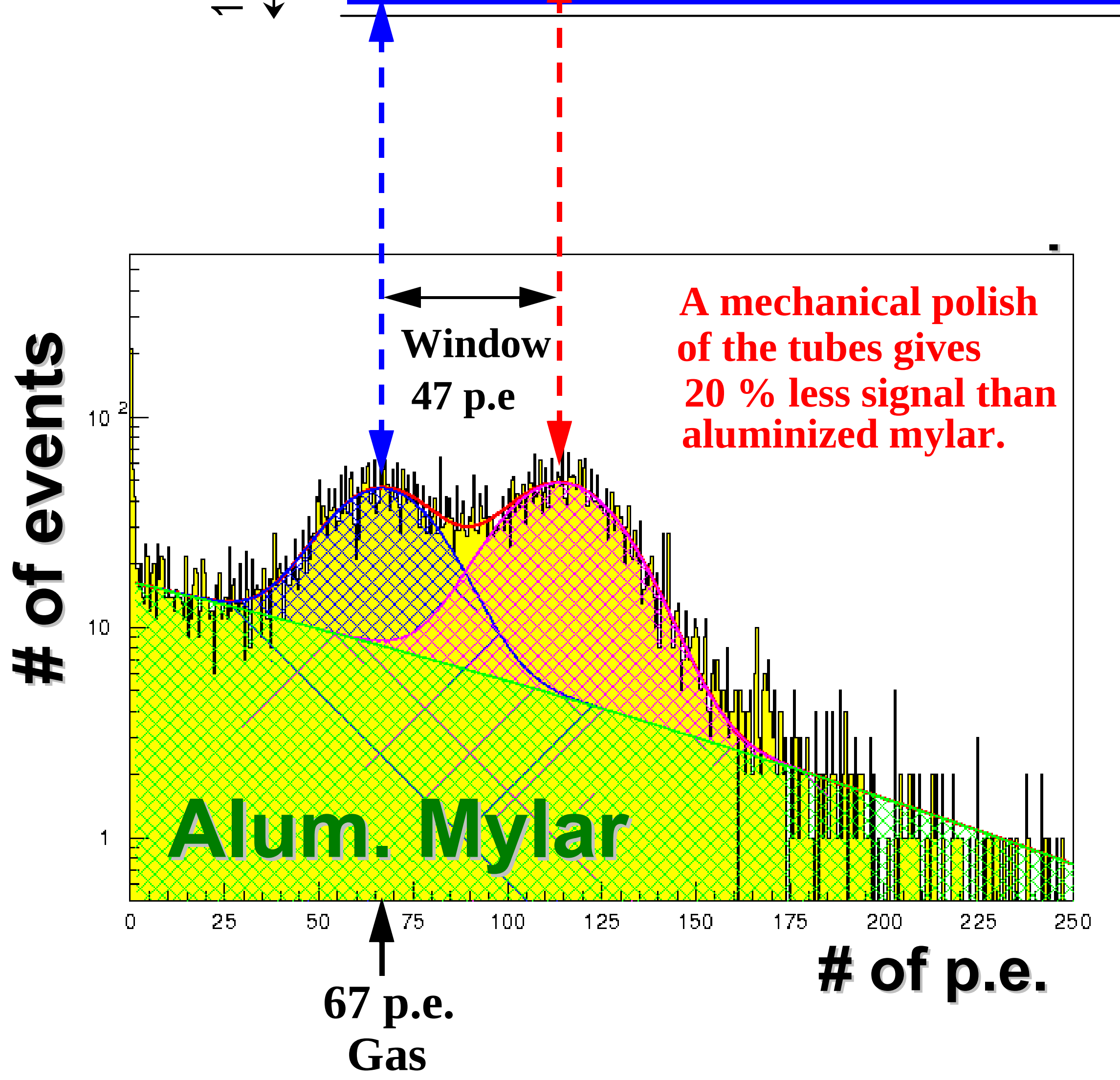
0 MRad

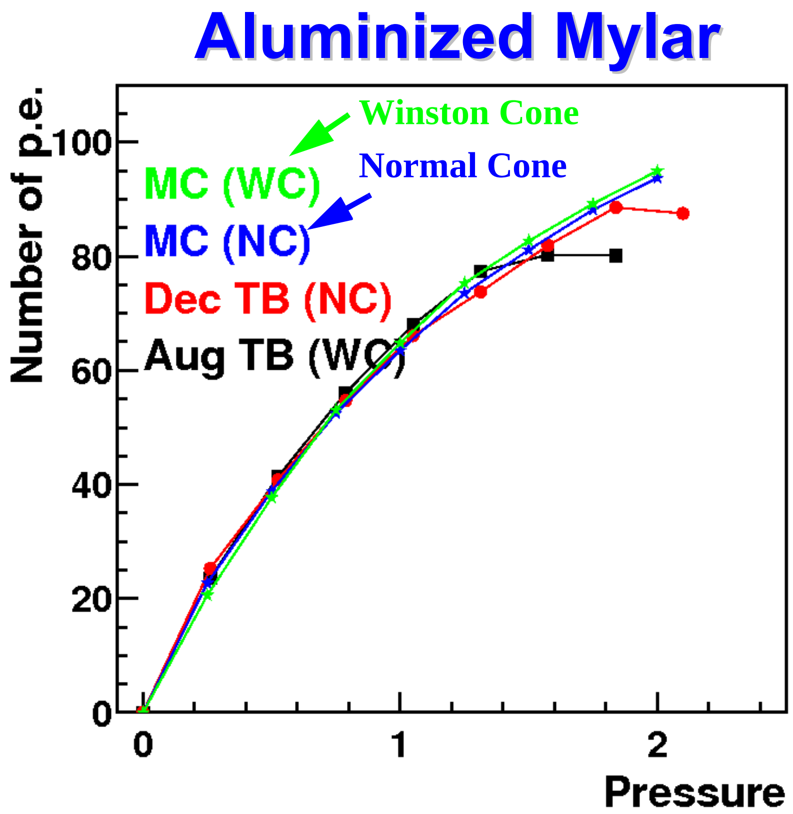
20 MRad

LUCID: Testbeam measurements



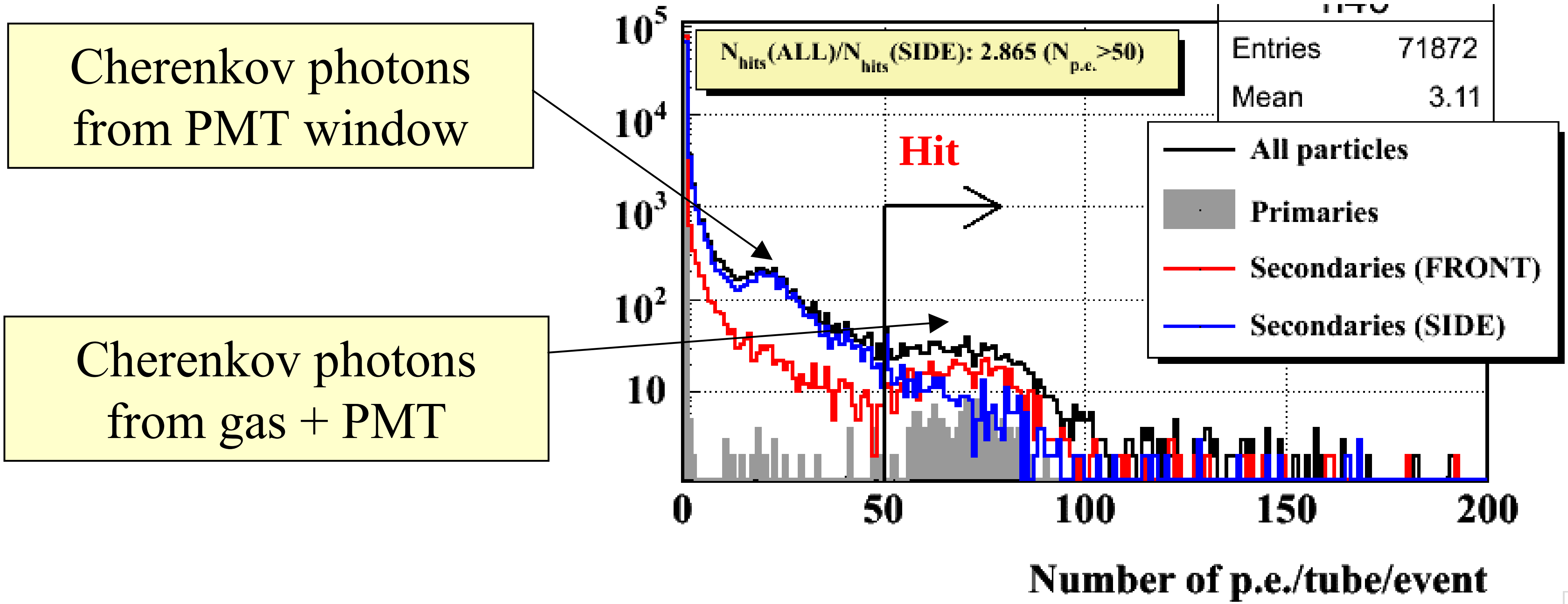
Concave quartz window with 0.8-2 mm thickness.





LUCID: Simulations

ATLAS

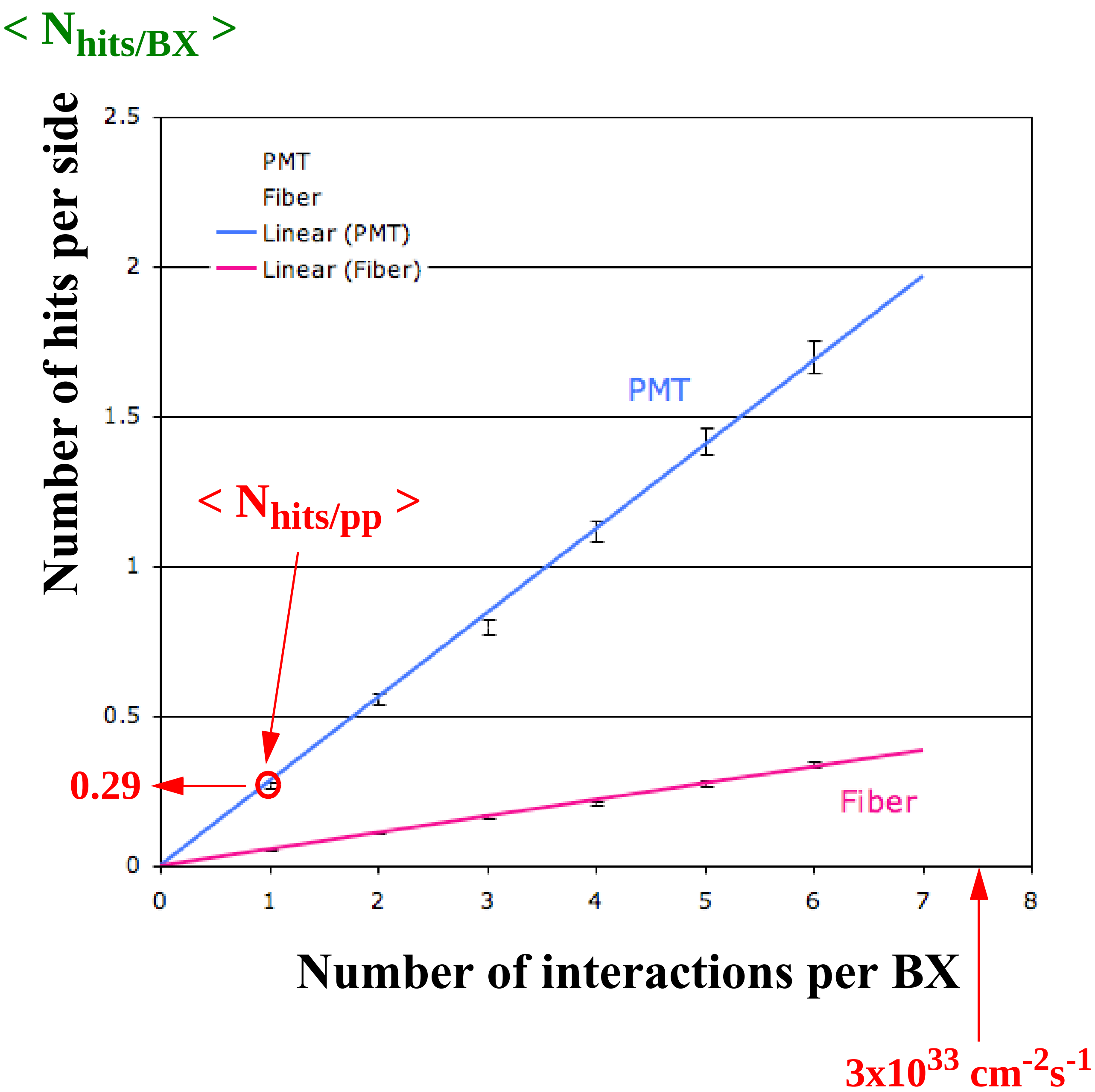


Hit counting: Count the number of tubes with signal > 50 photoelectrons

Particle counting: Count the number of tubes with signal > 50, 100, 150 p.e.

1, 2, 3 particles

LUCID: Simulations



2% of the tubes have a hit if there is one interaction.

21% of the events have at least one hit in LUCID if there is one interaction.

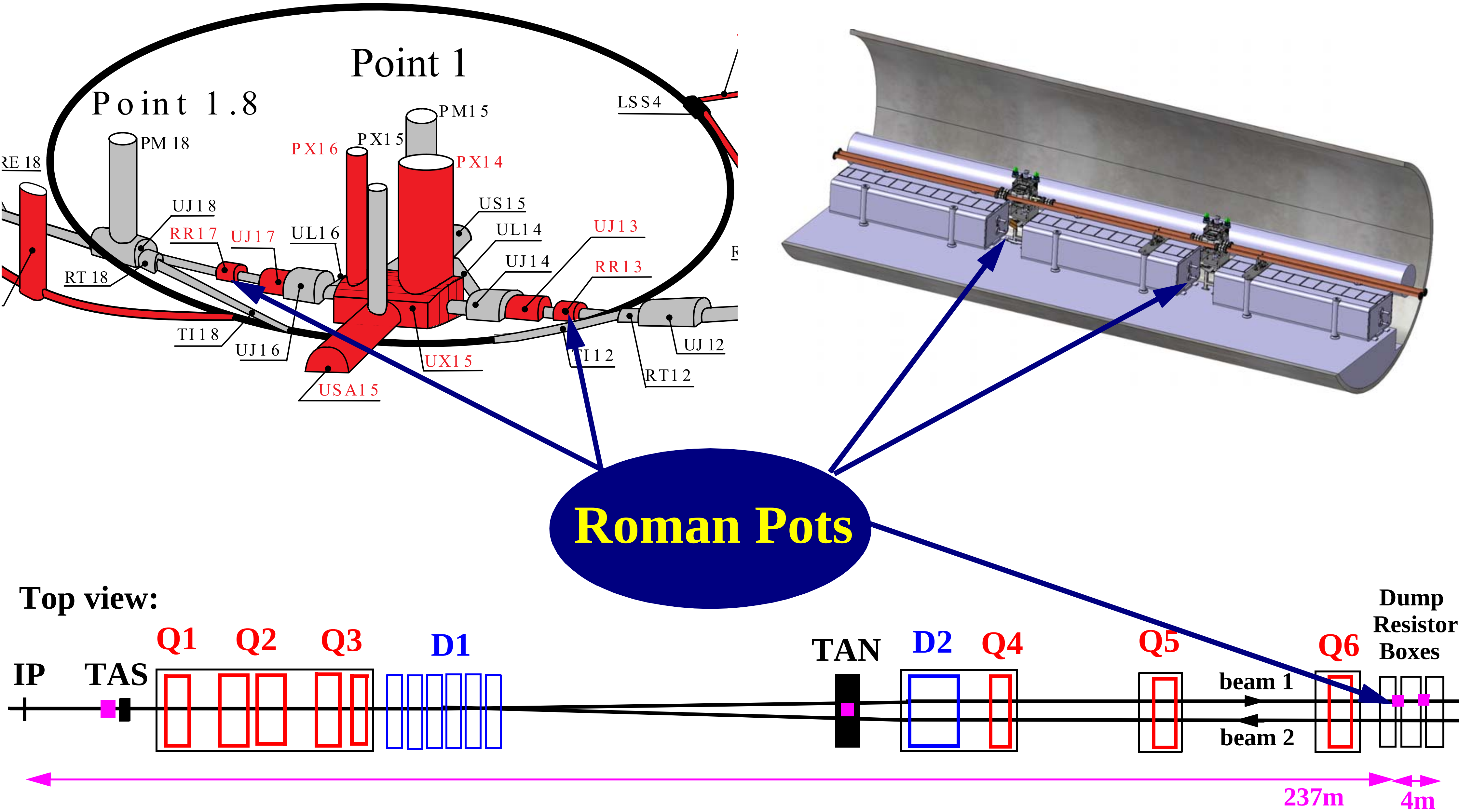
Bunch crossing rate

$$L = \frac{f_{BX}}{\sigma_{pp} \cdot \varepsilon_{LUCID}} \frac{\langle N_{hits/BX} \rangle}{\langle N_{hits/pp} \rangle}$$

Calibration constant from ALFA or W/Z & μμ/ee

ALFA: Location

ALFA: Asolute Luminosity For Atlas



ALFA: Elastic scattering

$$\left.\frac{dN}{dt}\right|_{t\approx 0} = L\pi\left|f_C + f_N\right|^2 \approx L\pi\left|-\frac{2\alpha_{EM}}{|t|} + \frac{\sigma_{tot}}{4\pi}(i+\rho)\,e^{-b|t|/2}\right|^2$$

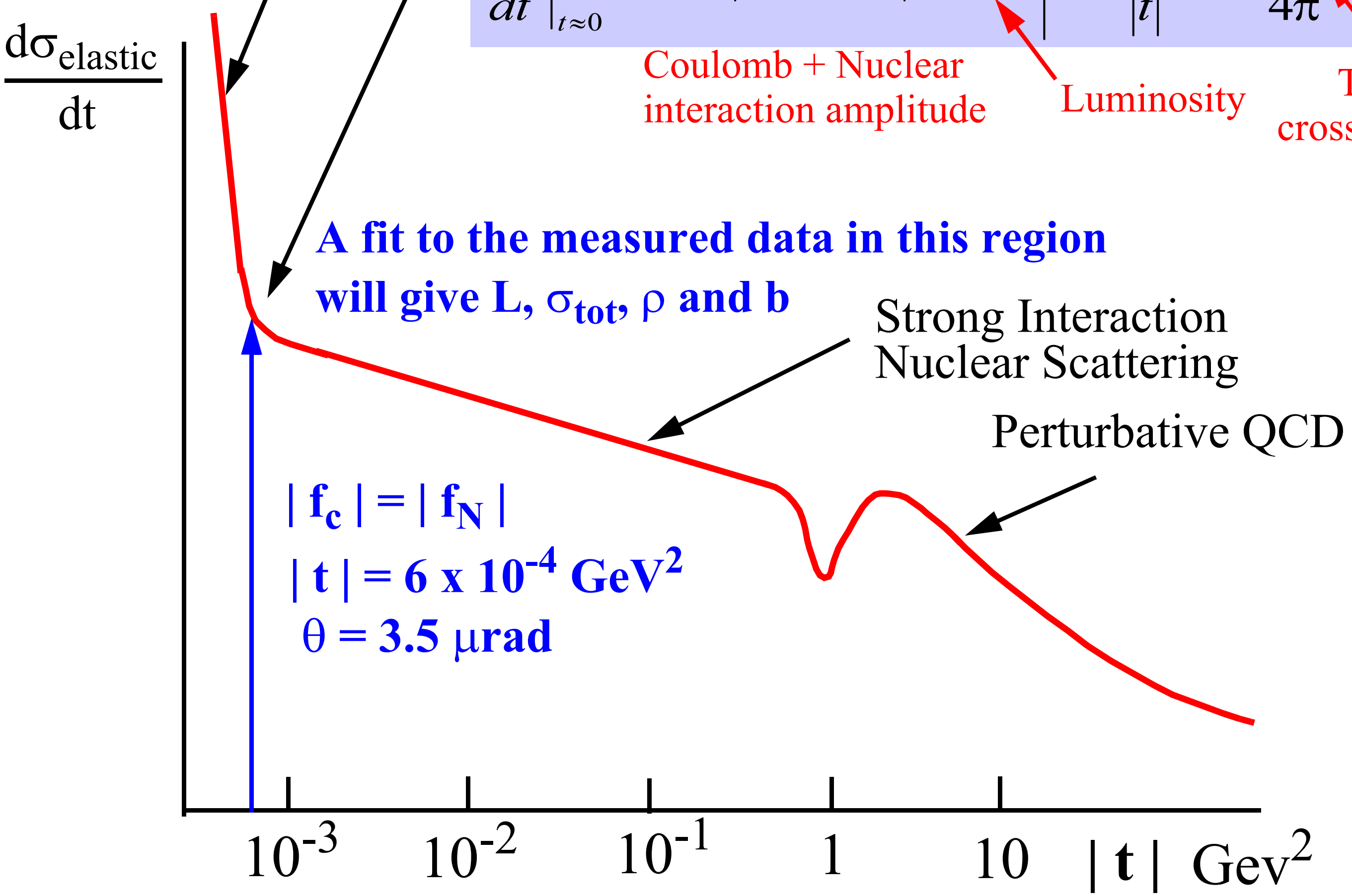
Ratio of real to imaginary part of the elastic scattering amplitude

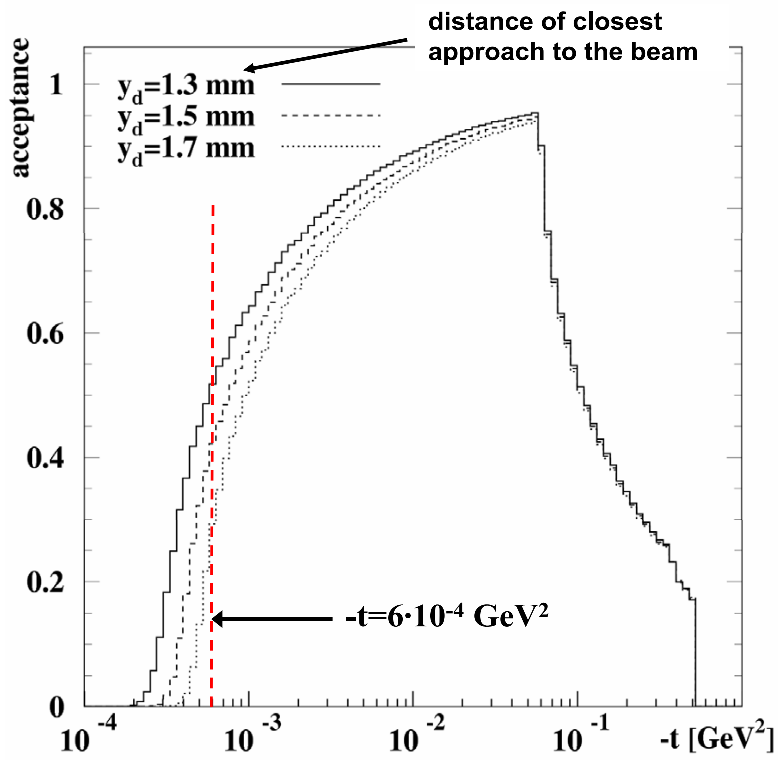
Coulomb + Nuclear interaction amplitude

Luminosity

Total cross section

Slope parameter





Special LHC optics is needed to reach the Coulomb region i.e. special dedicated LHC runs are required.

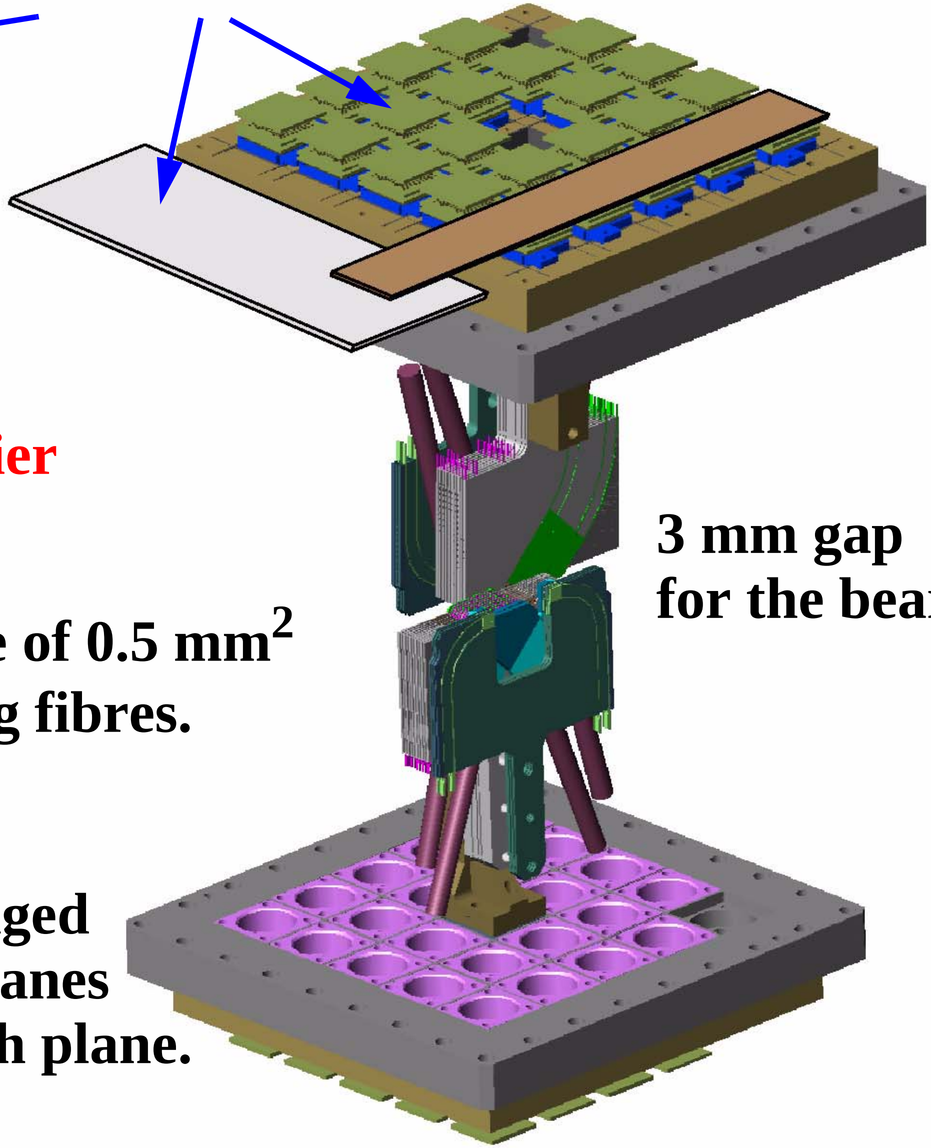
ALFA: The detector

ATLAS

39 mm

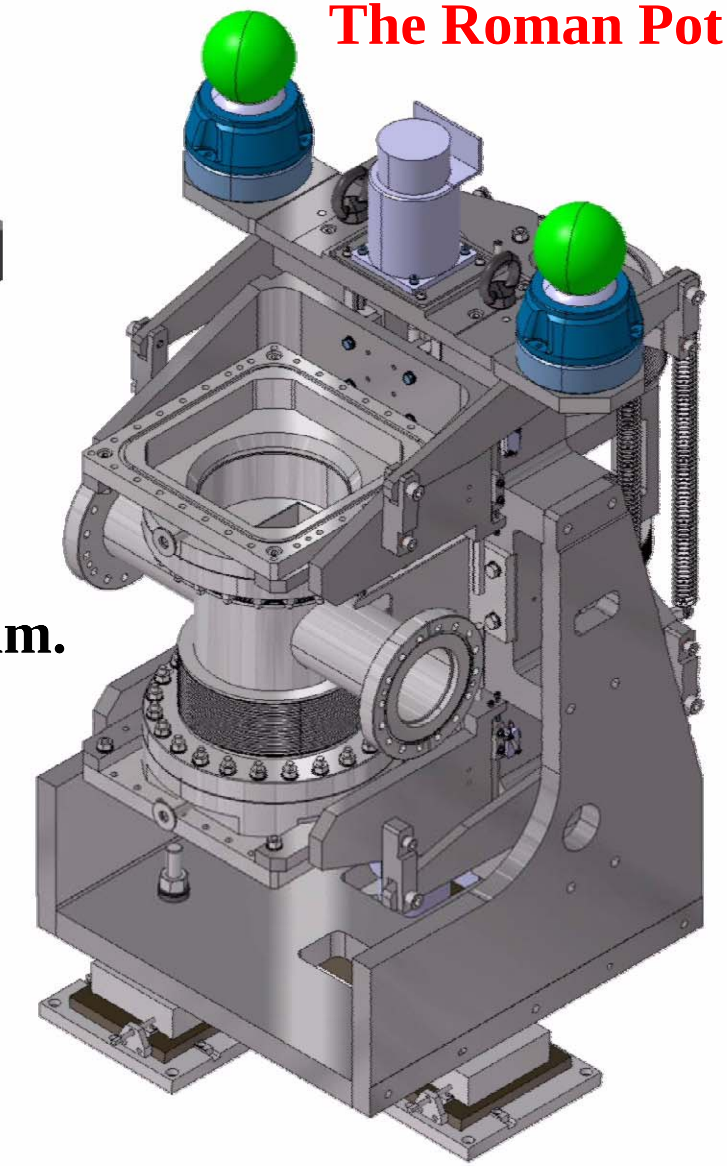
Multi-anode Photomultiplier

Front-end electronics (designed by Lund)



3 mm gap for the beam.

The Roman Pot



The tracker is made of 0.5 mm^2 square scintillating fibres.

The fibres are arranged in 10 U- and 10 V-planes with 64 fibres in each plane.

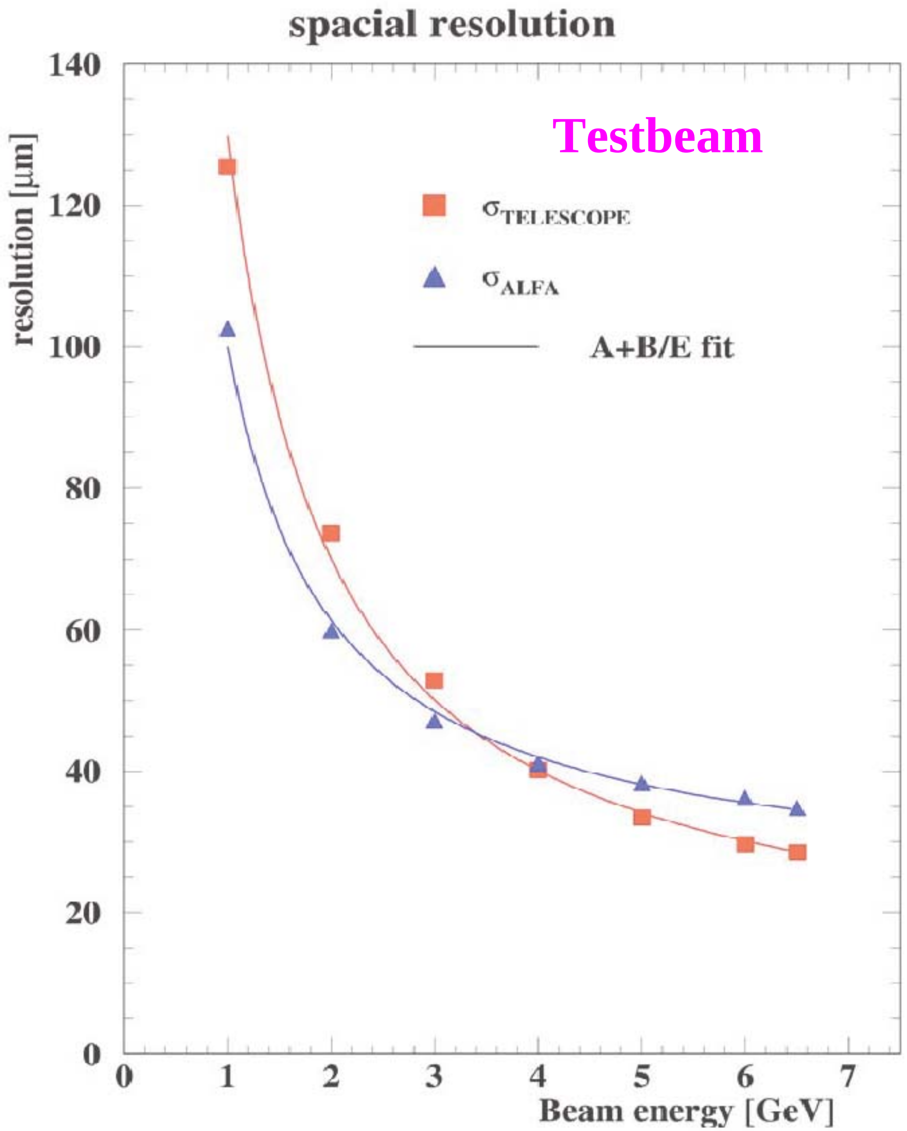
ALFA: Evaluation of prototype

Several testbeams have been made with prototype trackers.

Spatial resolution < 36 µm

Non-active edge region << 100 µm

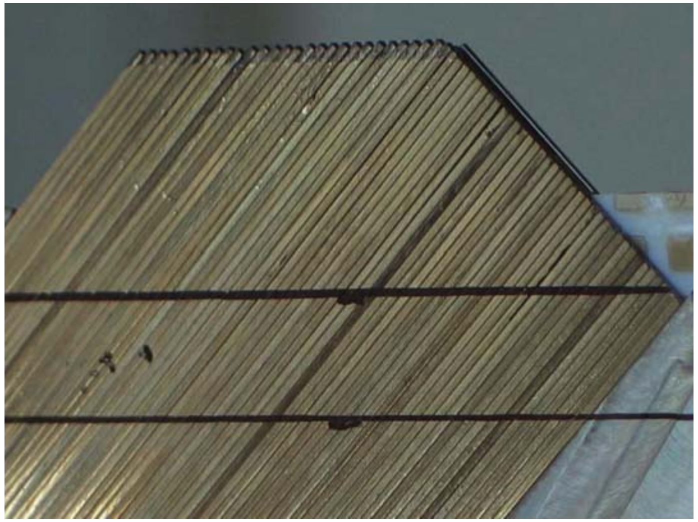
Light yield is 4.5 photoelectrons



ALFA: Status of the detector

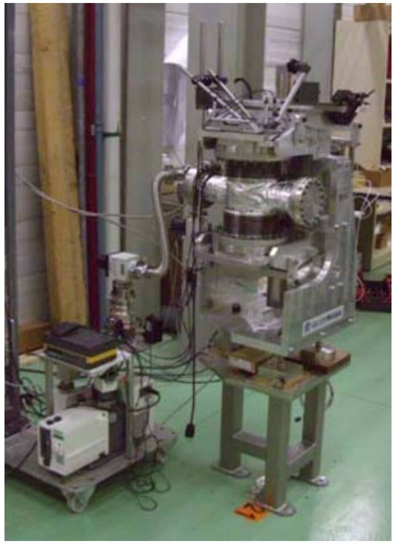
ATLAS



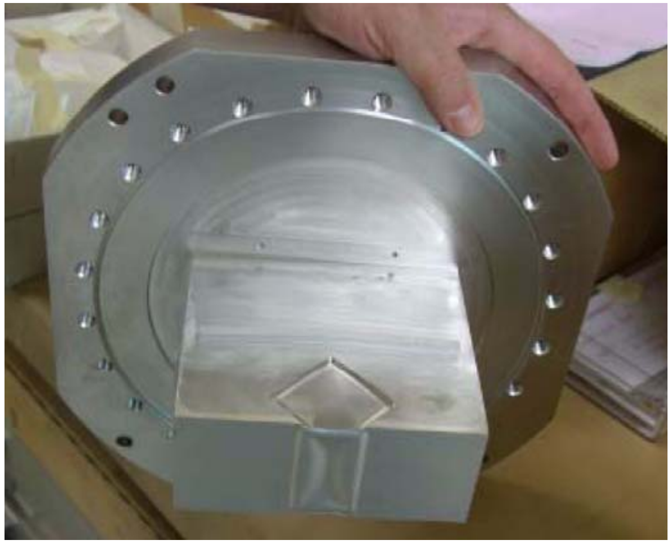


A full-scale fibre tracker module with 20 planes is being built.

A prototype Roman Pot Unit is being validated.



Two Roman Pots will be ready by next summer.



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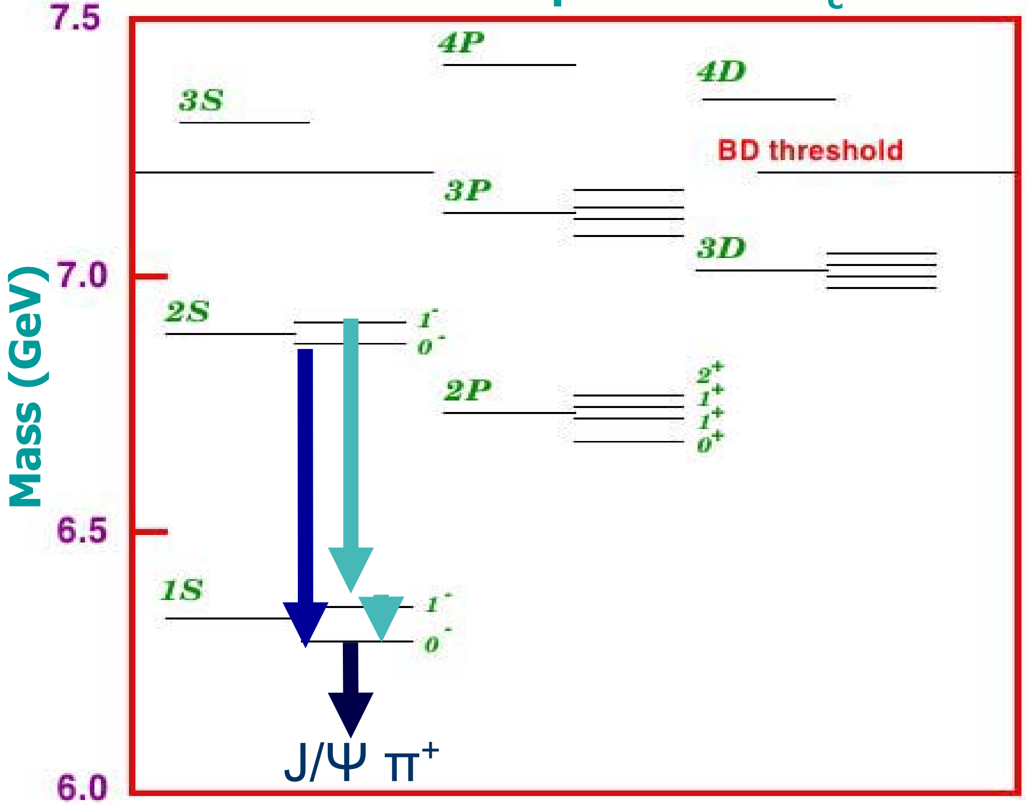
B-physics: Study of B_c states

The B_c ground state was first measured by CDF.

Predicted mass-spectrum of B_c states



- Possible decay modes:

$B^*_c(2^1S_0) \rightarrow B_c(1^1S_0)+\pi^+\pi^-$

$\downarrow$

$J/\Psi\ \pi^+$

Δm = 600 Mev
low P_T tracks down to 200 - 300 MeV

- $B^*_c(2^1S_1) \rightarrow B^*c(1^1S_1)+\pi^+\pi^-$

$\downarrow$

$B_c(1^1S_0)+\gamma$

$\downarrow$

$J/\Psi\ \pi^+$

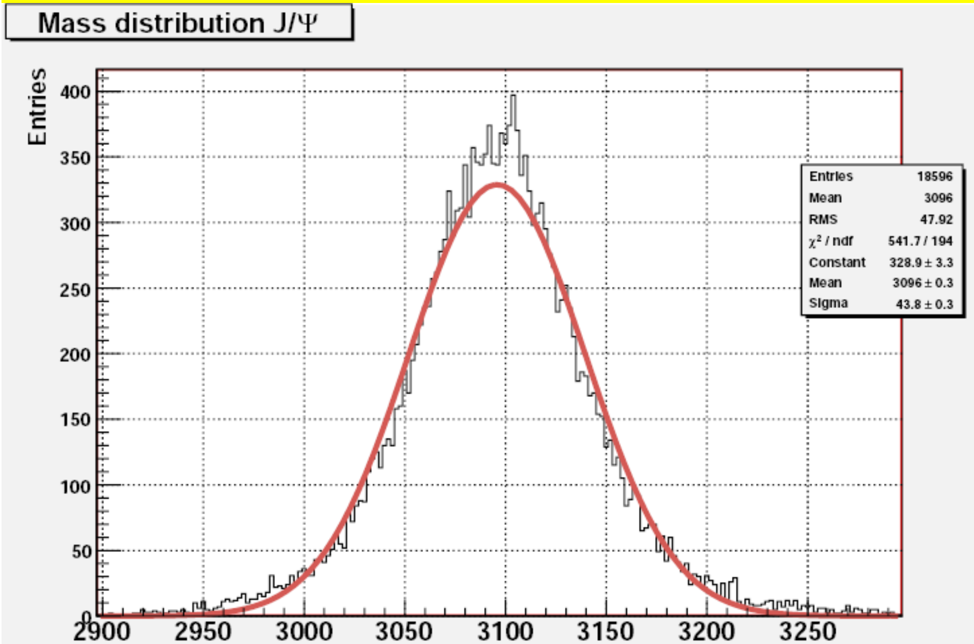
Eγ <70 keV

The Lund group is doing a study to see if B_c states can be seen by ATLAS.

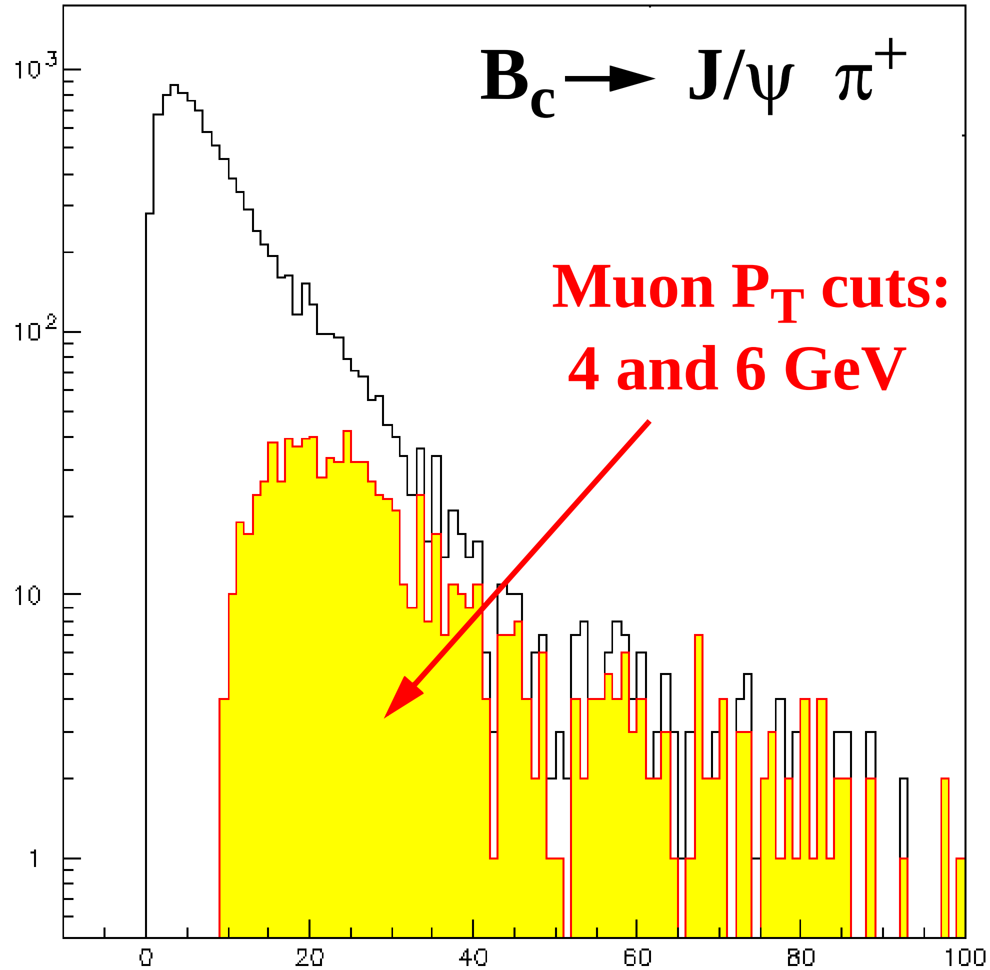
B-physics: Reconstruction

ATLAS

Reconstructed J/ψ mass: σ=43 MeV



Mass (MeV)

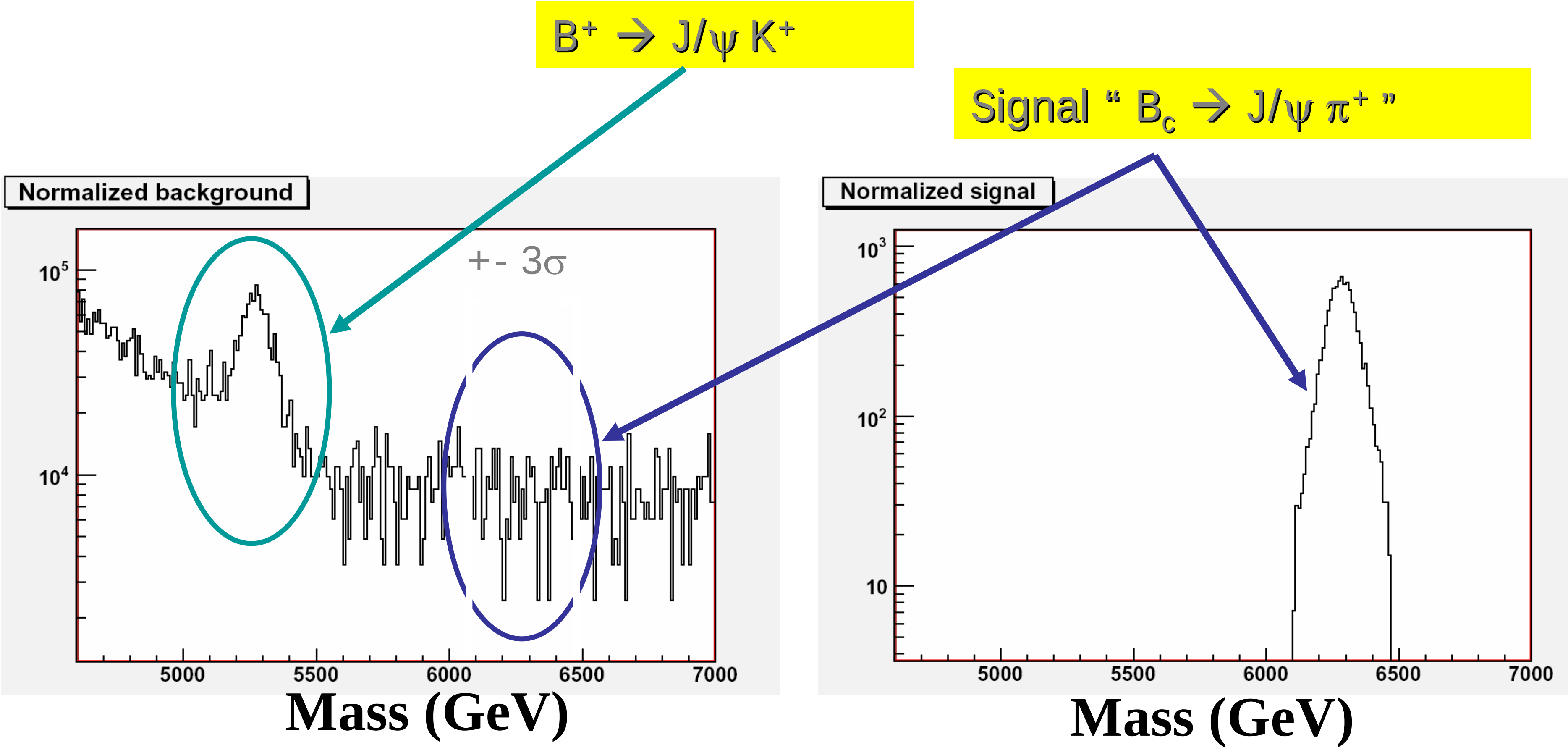


Muon P_T (GeV)

B-physics: Results

ATLAS

The presently available Monte Carlo sample corresponds to 0.02 fb^{-1} and is not sufficient to see a signal.



With 20 fb^{-1} the number of B_c in the sample should be 10,000 with a signal significance Signal / $\sqrt{\text{Background}}$ = 18 .

Technical coordination: Shielding

ATLAS is using 2825 tonnes of shielding (iron, steel, copper, polyethylene, lead and concrete) to protect the inner detector and the muon spectrometer from background radiation.

Physicist from 7 universities have been involved in the shielding design and the background calculations.

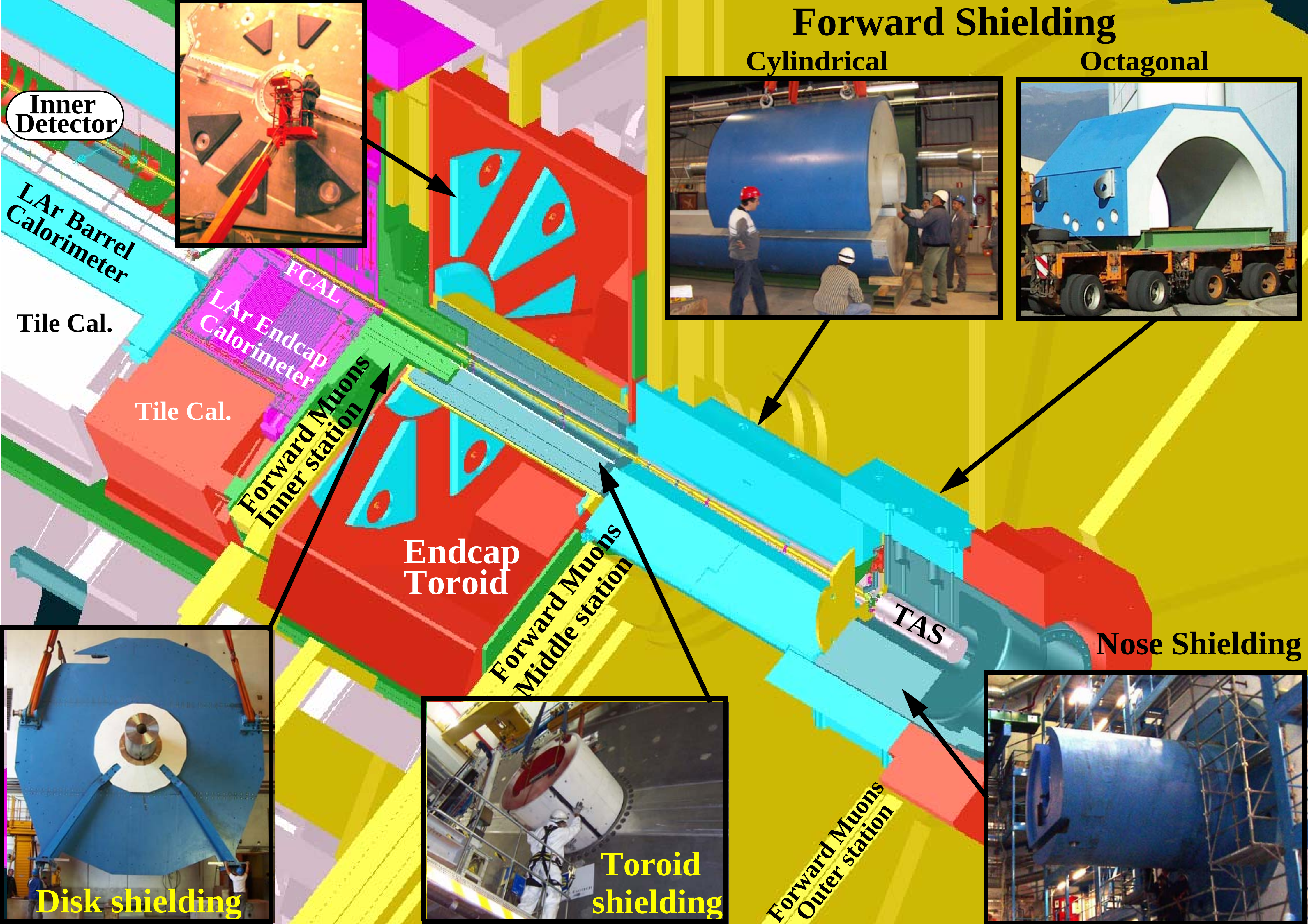
46 companies in 13 different countries have been used in the manufacturing.

Copper shielding is being cast in Armenia.

100 tonnes iron shielding pieces being cast in the Czech republic.

9 m diameter steel disk is assembled in Serbia.

Tooling made in Bulgaria.

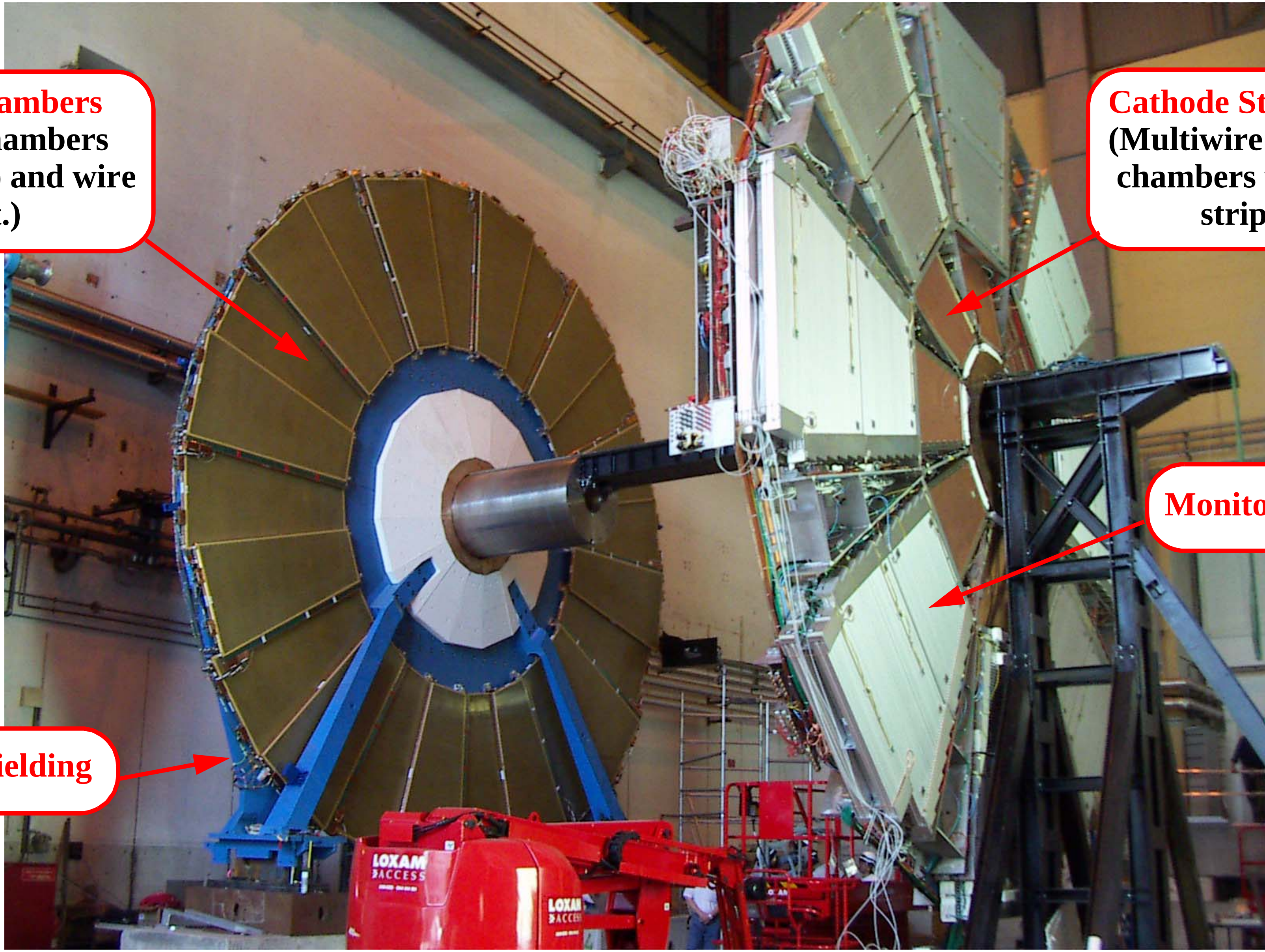


Forward Shielding
Cylindrical
Octagonal
Inner Detector
LAr Barrel Calorimeter
Tile Cal.
FCAL
LAr Endcap Calorimeter
Tile Cal.
Forward Muons Inner station
Endcap Toroid
Forward Muons Middle station
TAS
Nose Shielding
Forward Muons Outer station
Disk shielding
Toroid shielding

Lund University

Technical coordination: Shielding

ATLAS



Thin Gap Chambers
(Multiwire chambers with both strip and wire readout.)

Cathode Strip Chambers
(Multiwire proportional chambers with cathode strip readout)

Monitored Drift tubes

Disk shielding

Summary

- **Transition Radiation Tracker**

  The TRT is installed and in a commissioning phase.

- **Luminosity (LUCID & ALFA)**

  LUCID: Ready for installation

  ALFA: Prototypes tested. First LHC run in 2009.

- **B-physics**

  Analysis of B_c events in preparation.

- **Technical coordination**

  (Background radiation, Shielding, Radioprotection)

  The shielding/background project will finish next spring.

  Radioprotection will become a serious issue.

Surplus slides

Luminosity measurements

ATLAS

Luminosity using elastic scattering data

Lumi = 10^{27} cm^{-2}s^{-1}

Roman Pots equipped with scintillating fibre detectors will be used to measure the protons in elastic scattering events.

Luminosity using single W/Z production

Lumi > 10^{30} cm^{-2}s^{-1}

The rate of $W \rightarrow l\nu$ is expected to be 60 Hz at high luminosity

The uncertainty in the rate of W/Z events is currently about 4%

Luminosity using $\gamma\gamma \rightarrow \mu\mu$ data

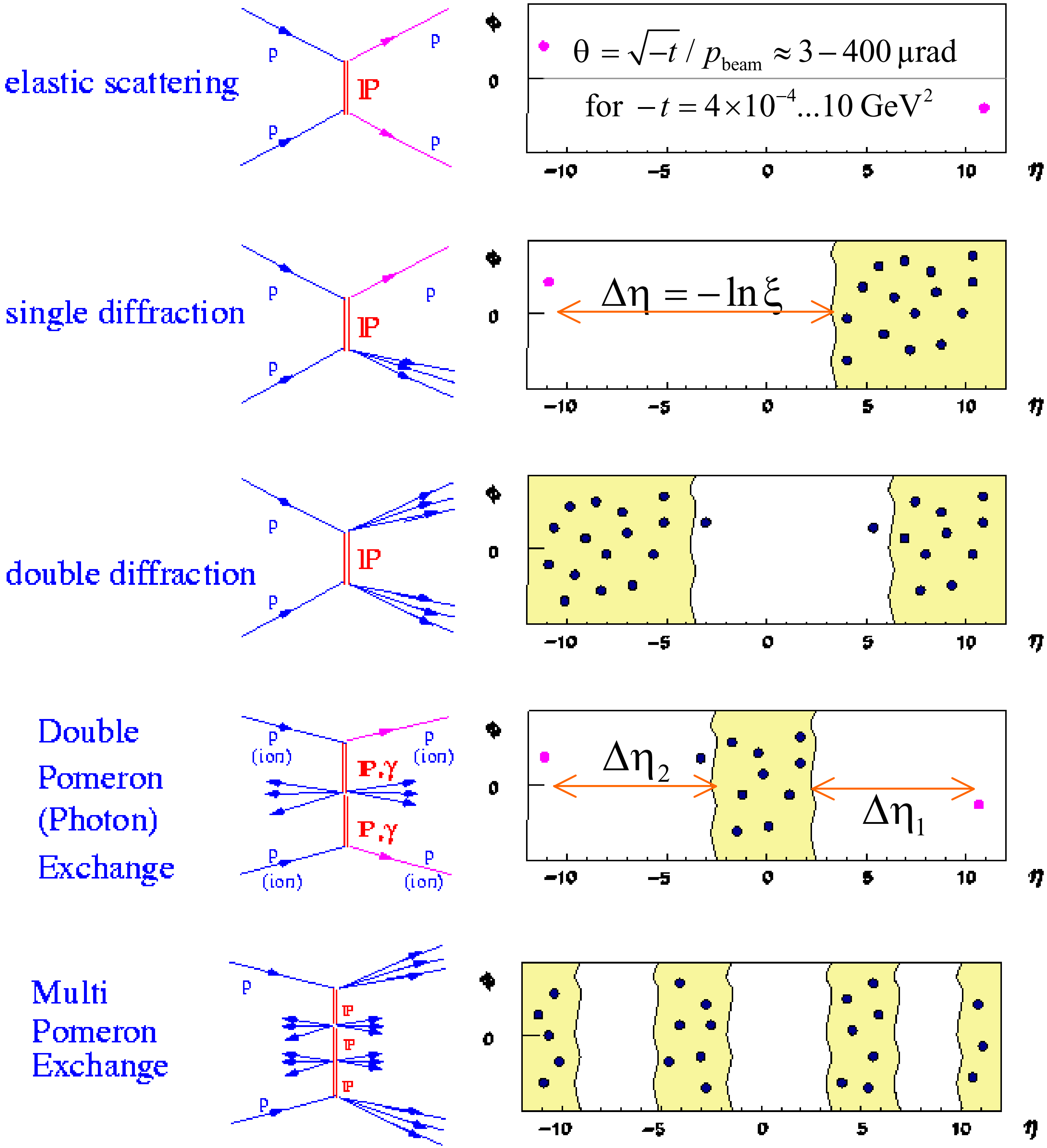
Lumi > 10^{30} cm^{-2}s^{-1}

QED process

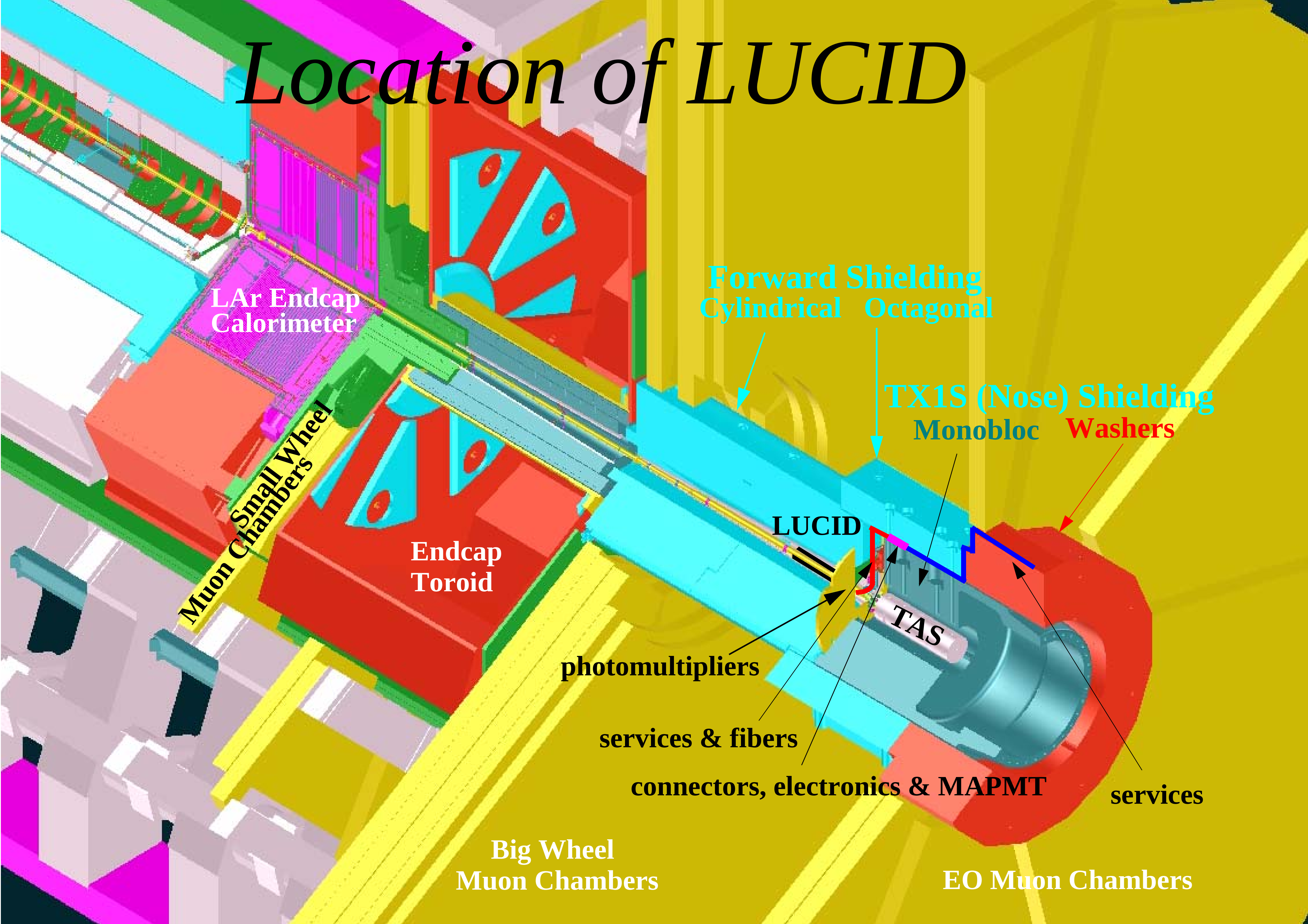
About 10k events/day at high lumi if P_T>3 GeV (1.5k if P_T>6 GeV)

Overall calibration of a Luminosity monitor

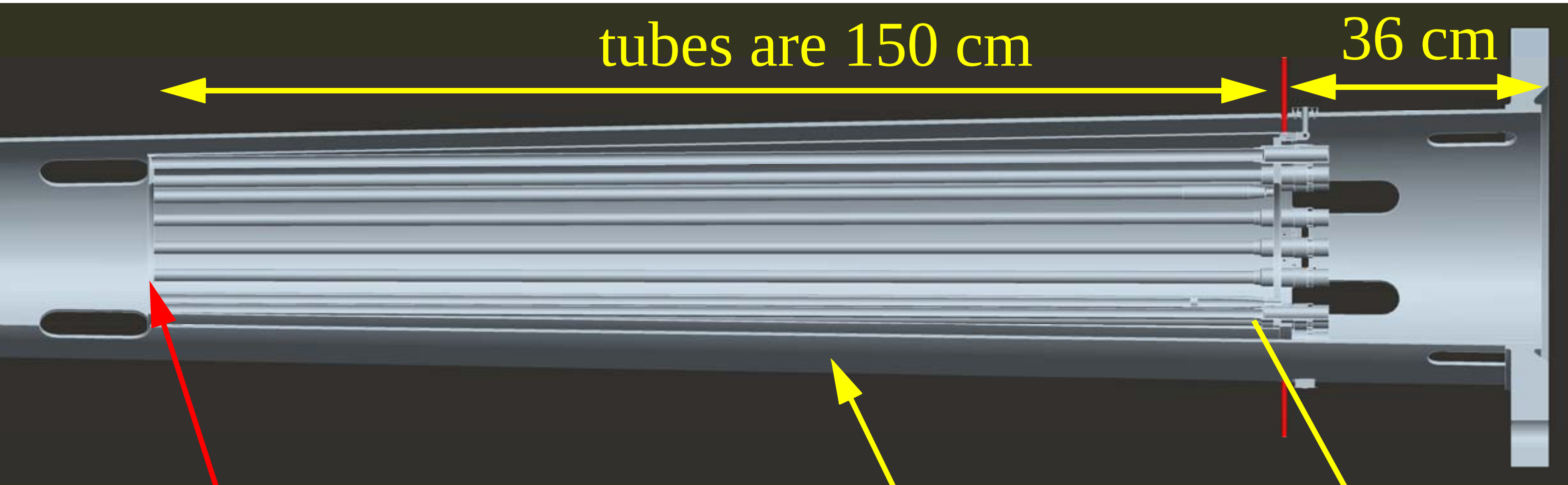
LUCID: A detector consisting of Cherenkov tubes that surrounds the beampipe. No absolute luminosity measurement !


elastic scattering
p
p
p
p
IP
φ
0
θ = √−t / p_beam ≈ 3 − 400 μrad
for −t = 4×10^−4 ...10 GeV^2
−10
−5
0
5
10
η
single diffraction
IP
Δη = −ln ξ
double diffraction
IP
Double
Pomeron
(Photon)
Exchange
p
(ion)
P,γ
Δη2
Δη1
Multi
Pomeron
Exchange
IP

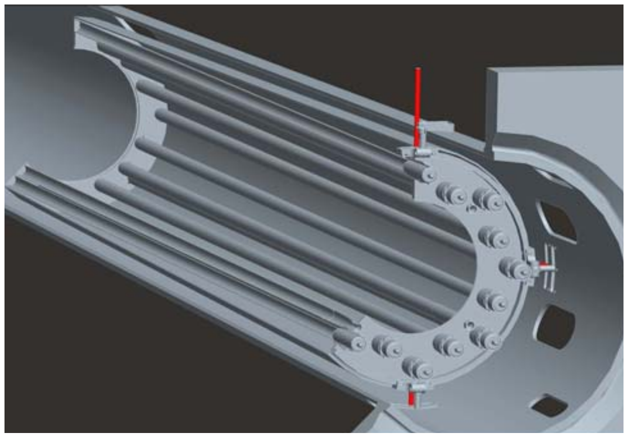
Location of LUCID

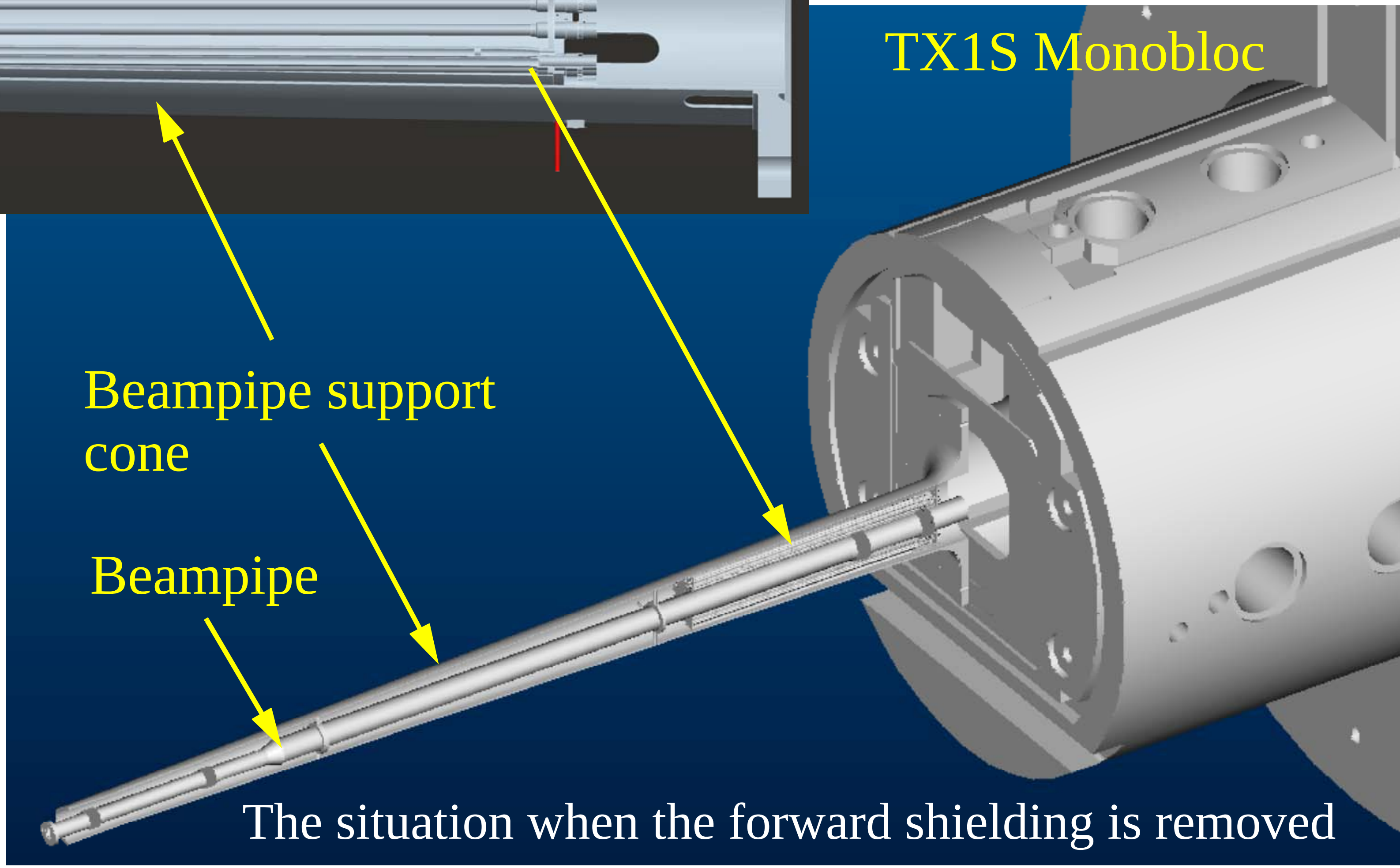


LUCID: Location of the detectors



The front face of each detector is at 16.72 m from the IP





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LUCID: Basic concept

ATLAS

The rate of the pp interactions (R_{pp}) seen by LUCID is proportional to the luminosity (L):

$$R_{pp} = \mu_{LUCID} \cdot f_{BX} = \sigma_{pp} \cdot \varepsilon_{LUCID} \cdot L$$

Bunch crossing rate = $\frac{2808}{3564}$ x 40 Mhz (2808: filled BX; 3564: total BX)

Number of pp interactions per bunch-crossing (BX) as measured by LUCID.

Efficiency (and acceptance) of LUCID to detect a pp interaction (~21% for single sided detection and ~5% for detection on both the A and C side).

Zero Counting

Count bunch crossings with no interactions:

$$\mu_{LUCID} = -\ln\left(\frac{N_{zeroBX}}{N_{totalBX}}\right)$$

Hit Counting

Count the number of tubes with a signal (hit):

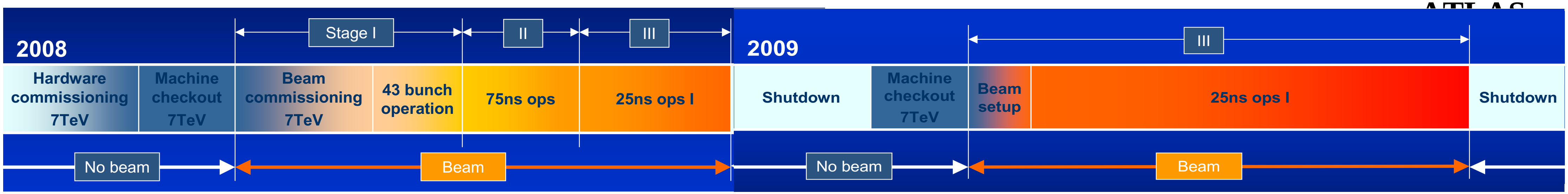
$$\mu_{LUCID} = \frac{\langle N_{hits/BX} \rangle}{\langle N_{hits/pp} \rangle}$$

Particle Counting

Count the number of particles in LUCID by doing several cuts on the pulseheight distributions:

$$\mu_{LUCID} = \frac{\langle N_{particles/BX} \rangle}{\langle N_{particles/pp} \rangle}$$

LUCID: upgrade

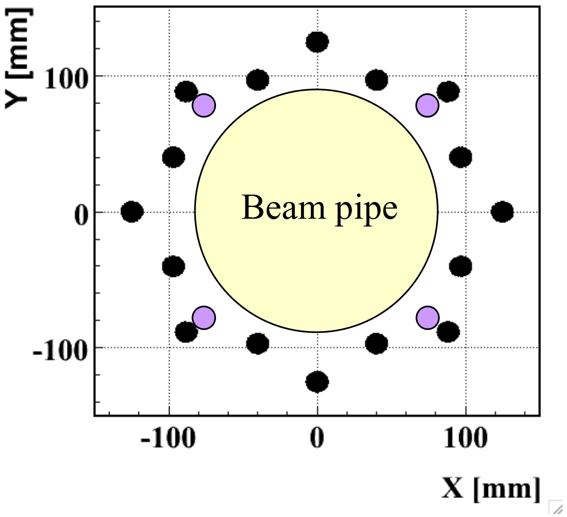


$< 1 \cdot 10^{33}$ cm^{-2}s^{-1}
< 7 int. / crossing

$< 2 \cdot 10^{33}$ cm^{-2}s^{-1}
< 4 int. / crossing

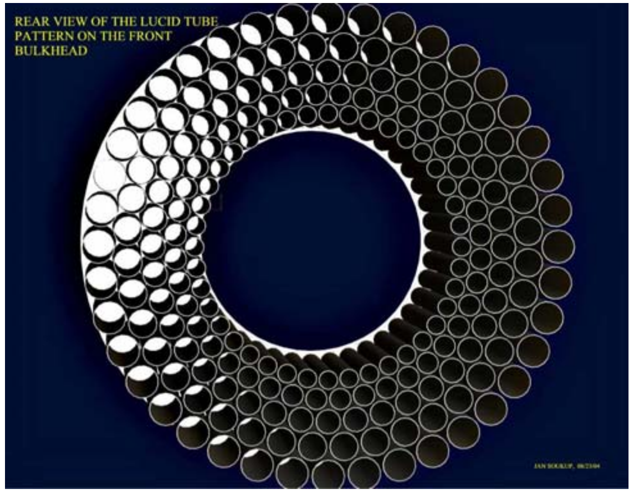
Long Shutdown for upgrade to LHC Phase 2

The Phase 1 detector



The present proposal is to build two detectors with 16 tubes each that are read-out directly with photomultipliers. In addition 4 tubes will be read-out by fibres.

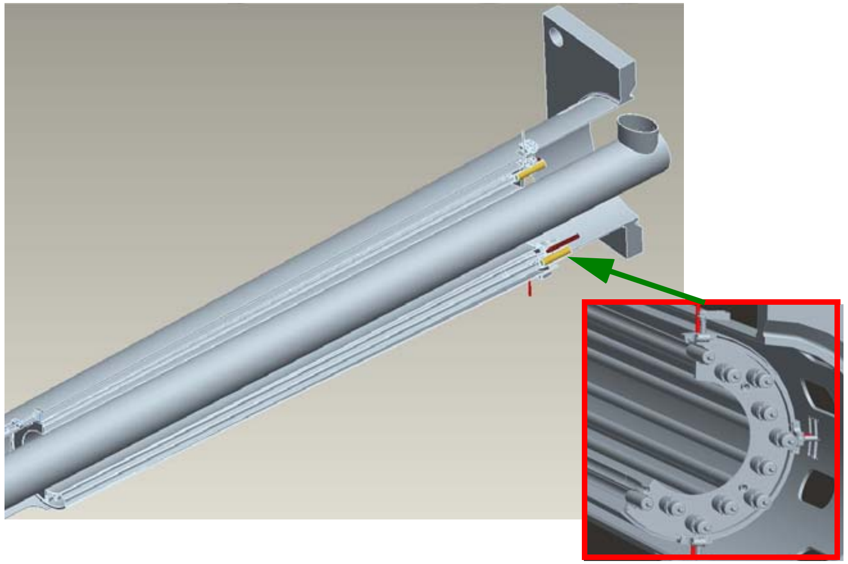
The Phase 2 detector



The original proposal was to build two detectors with 200 tubes read-out by 1400 optical quartz fibres. This design was later reduced to 168 tubes but the number of fibres was increased to 6216.

LUCID: upgrade

The Phase 1 detector

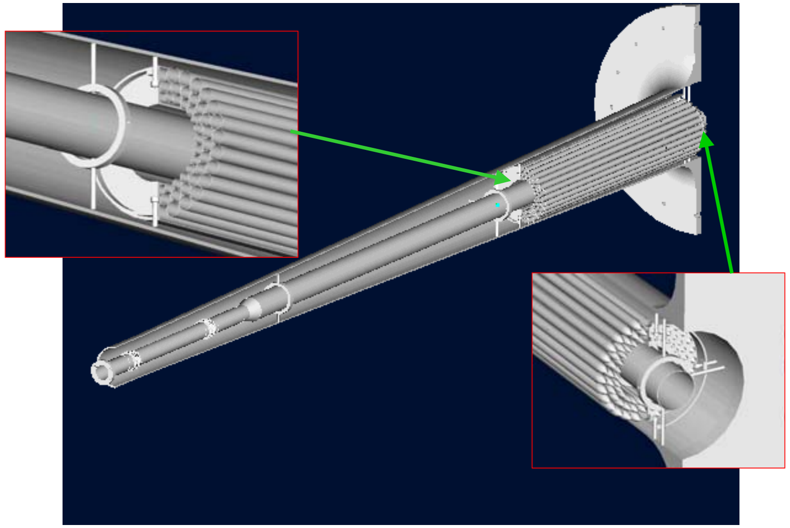


The main question is how long the pms can survive the radiation. Tests show that LHC phase 1 should not be a problem.

Another problem is Cherenkov light produced in the pm window. According to simulations this also will be on a manageable level.

The number of electronic channels is reduced in the Phase 1 detector to 32(PM)+80(MAPMT) from 3360 in the Phase 2 design.

The Phase 2 detector

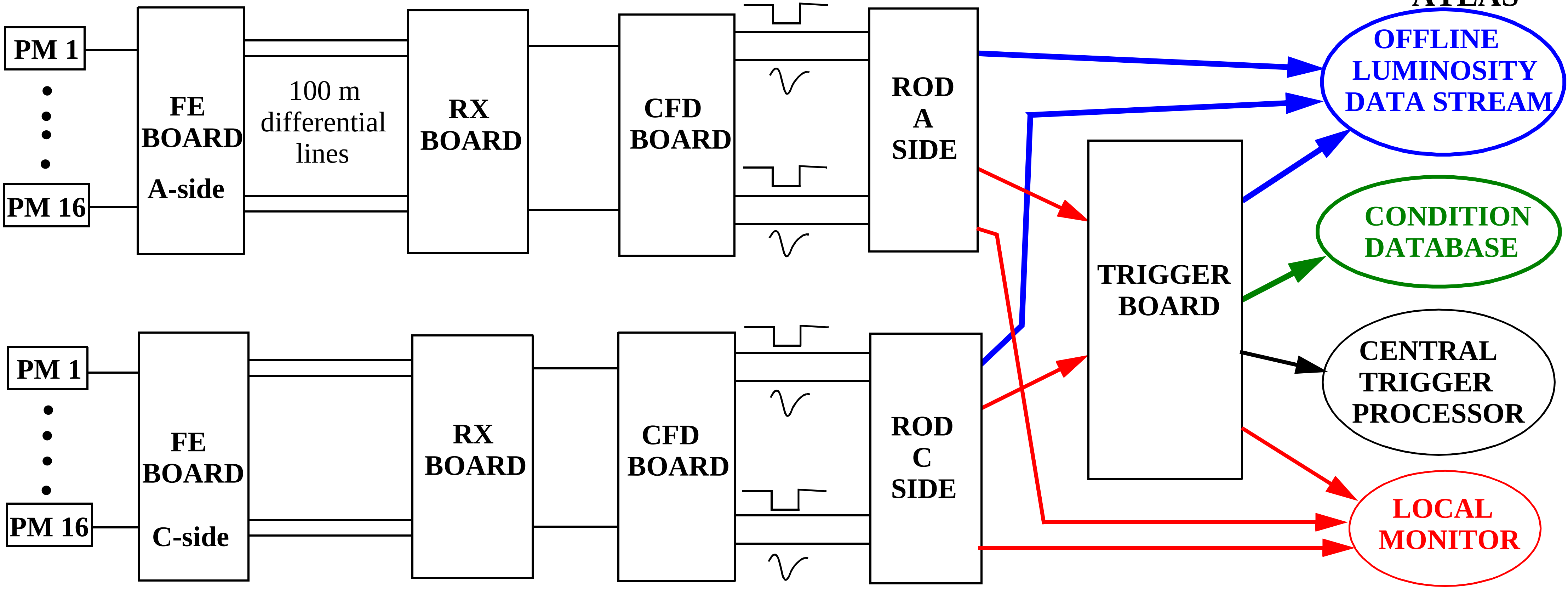


The fibre read-out results in a loss of light but for two-track separation at least 20 photo electrons are needed.

Cherenkov light will be produced in the fibres. This is difficult to simulate.

The detector will have a better coverage for forward physics than the Phase 1 detector (but for luminosity this is not needed).

LUCID: Electronics



Preamplifiers
Differential
Line drivers

Amplifiers
Pol zero
compensation

Constant
Fraction
Discriminators

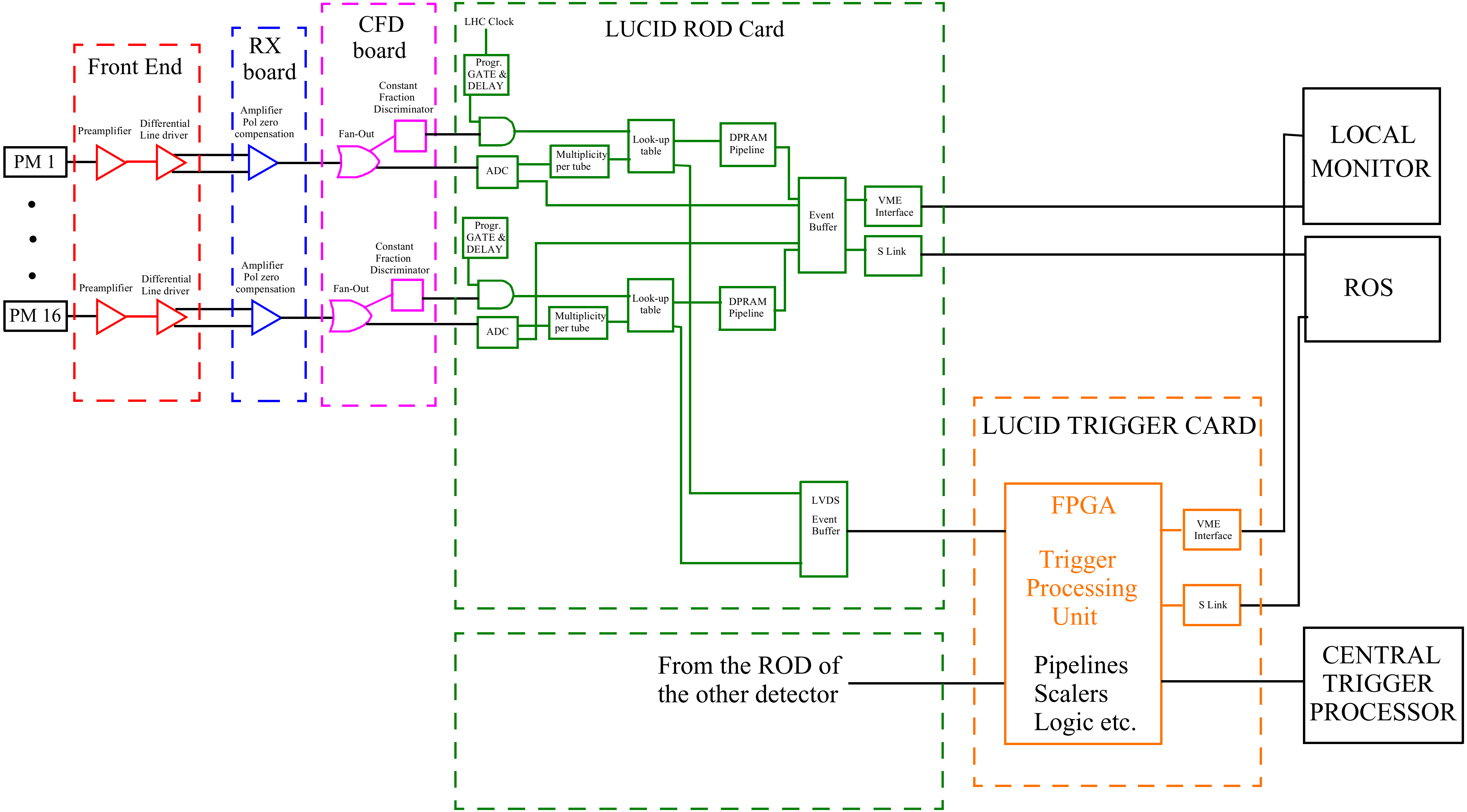
ADC
Pipelines
Tube
Multiplicity

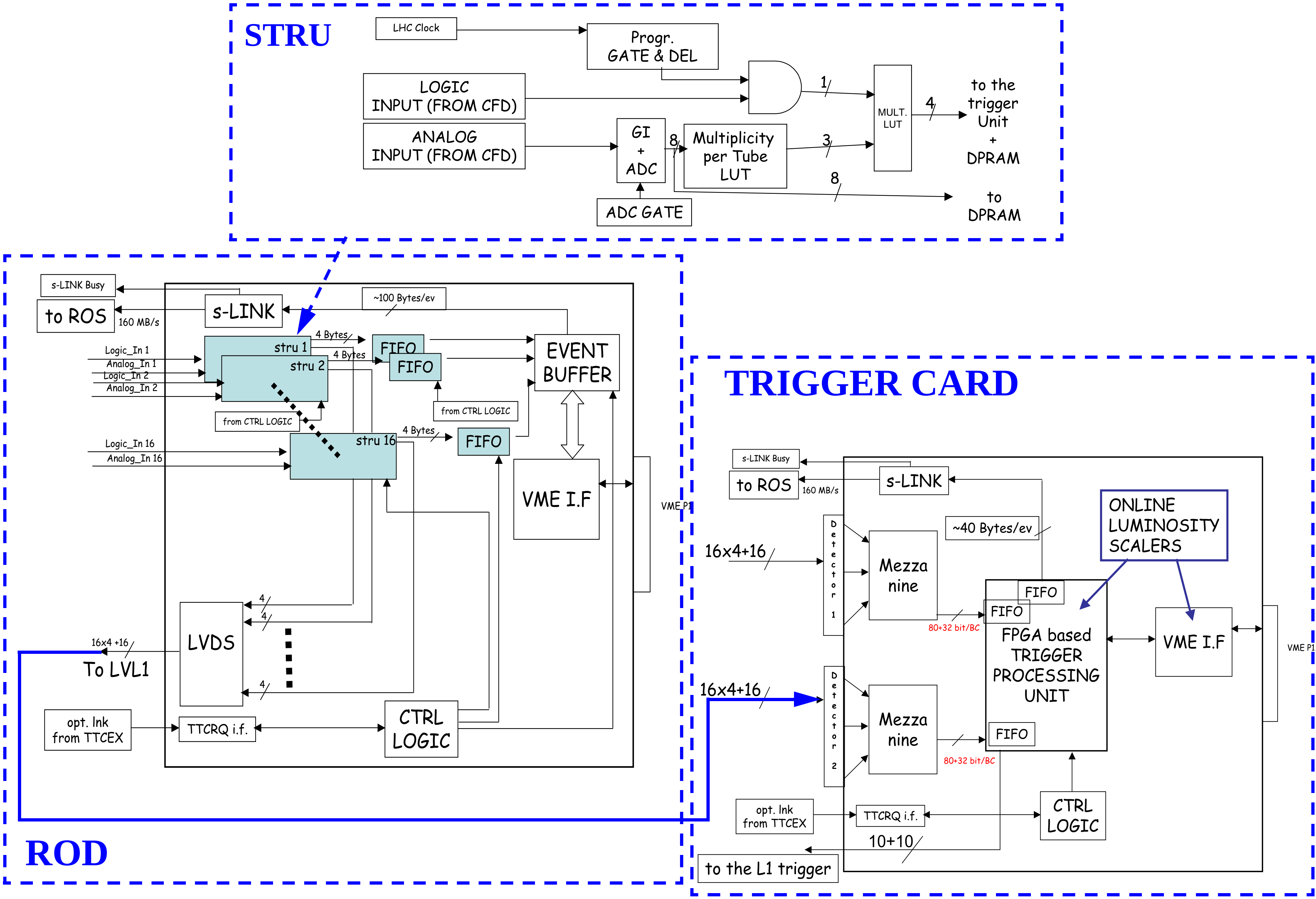
Trigger Logic
Pipelines
Scalers

OFFLINE: The ADC values are used to get the luminosity averaged over all bunch crossings.

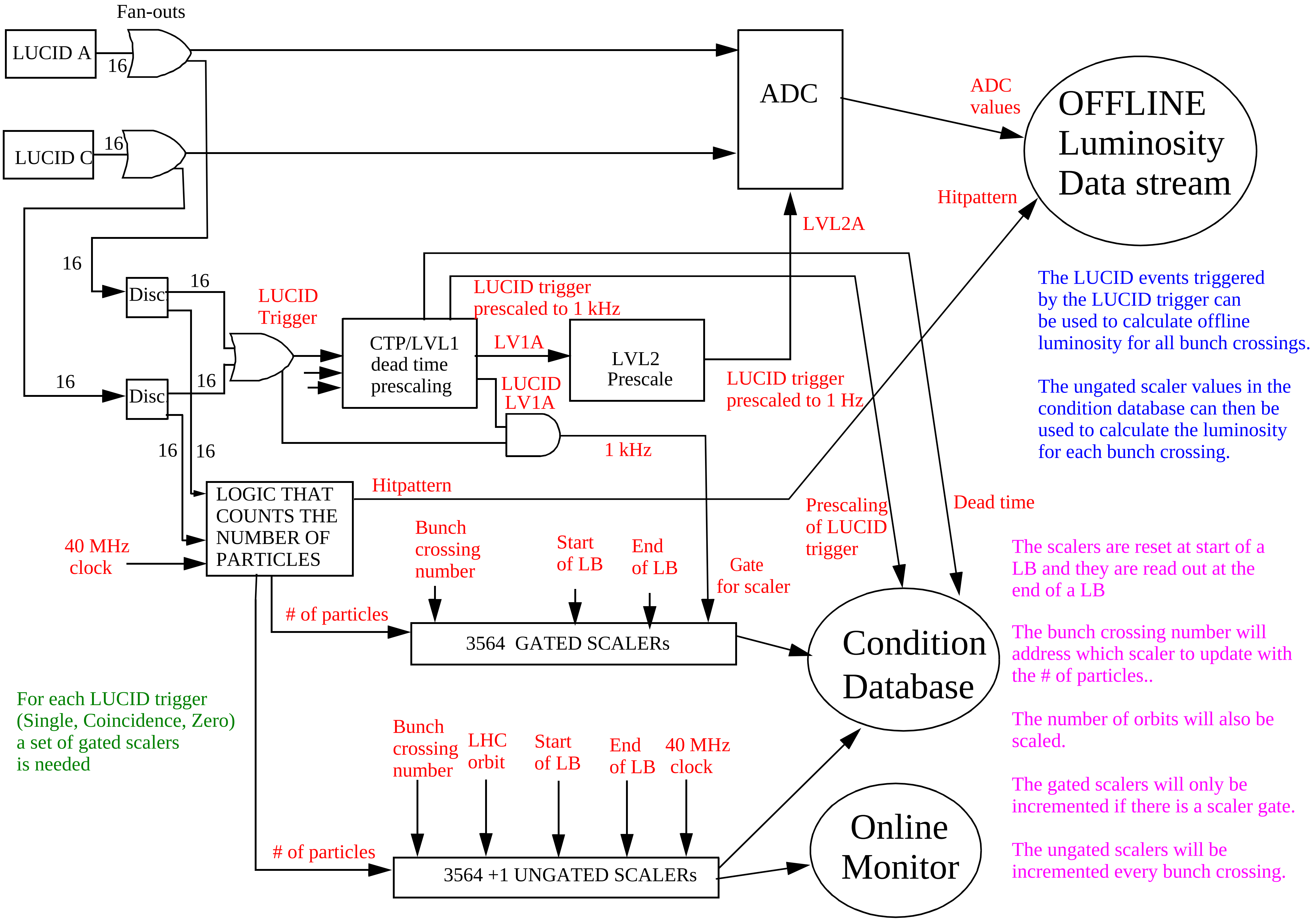
CONDITION DATABASE: Scaler values are stored for each luminosity block. From this the luminosity for each individual bunch crossing is calculated.

LUCID: Electronics



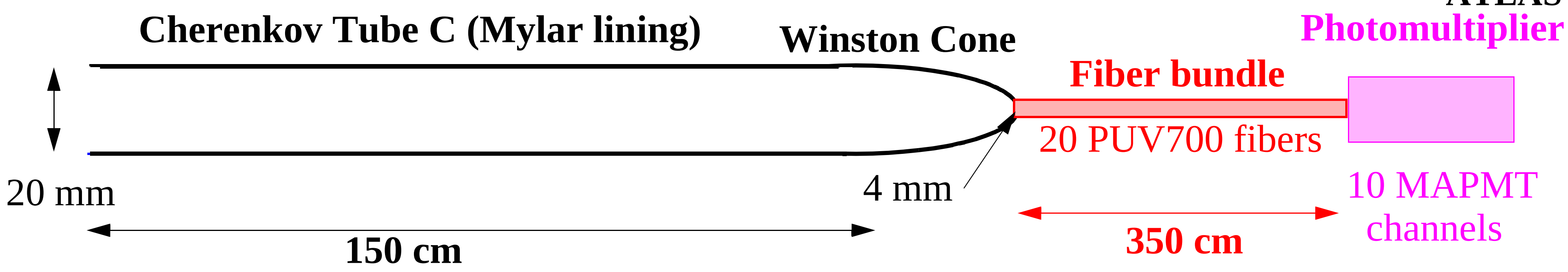


STRU
LHC Clock
Progr. GATE & DEL
LOGIC INPUT (FROM CFD)
ANALOG INPUT (FROM CFD)
GI + ADC
ADC GATE
Multiplicity per Tube LUT
MULT. LUT
to the trigger Unit + DPRAM
to DPRAM
ROD
s-LINK Busy
to ROS
160 MB/s
s-LINK
~100 Bytes/ev
4 Bytes
stru 1
stru 2
stru 16
FIFO
EVENT BUFFER
Logic_In 1
Analog_In 1
Logic_In 2
Analog_In 2
Logic_In 16
Analog_In 16
from CTRL LOGIC
VME I.F
VME P1
LVDS
16x4 +16
To LVL1
opt. lnk from TTCEX
TTCRQ i.f.
CTRL LOGIC
TRIGGER CARD
~40 Bytes/ev
ONLINE LUMINOSITY SCALERS
16x4+16
Detector 1
Detector 2
Mezza nine
80+32 bit/BC
FPGA based TRIGGER PROCESSING UNIT
10+10
to the L1 trigger


Fan-outs
LUCID A
16
LUCID C
16
ADC
ADC values
OFFLINE Luminosity Data stream
Hitpattern
LVL2A
16
Disc
16
LUCID Trigger
CTP/LVL1 dead time prescaling
LUCID trigger prescaled to 1 kHz
LV1A
LVL2 Prescale
LUCID trigger prescaled to 1 Hz
16
Disc
16
LUCID LV1A
1 kHz
16
16
LOGIC THAT COUNTS THE NUMBER OF PARTICLES
Hitpattern
40 MHz clock
Bunch crossing number
Start of LB
End of LB
Gate for scaler
Prescaling of LUCID trigger
Dead time
# of particles
3564 GATED SCALERs
Condition Database
The LUCID events triggered by the LUCID trigger can be used to calculate offline luminosity for all bunch crossings.
The ungated scaler values in the condition database can then be used to calculate the luminosity for each bunch crossing.
The scalers are reset at start of a LB and they are read out at the end of a LB
The bunch crossing number will address which scaler to update with the # of particles..
The number of orbits will also be scaled.
The gated scalers will only be incremented if there is a scaler gate.
The ungated scalers will be incremented every bunch crossing.
For each LUCID trigger (Single, Coincidence, Zero) a set of gated scalers is needed
Bunch crossing number
LHC orbit
Start of LB
End of LB
40 MHz clock
# of particles
3564 +1 UNGATED SCALERs
Online Monitor

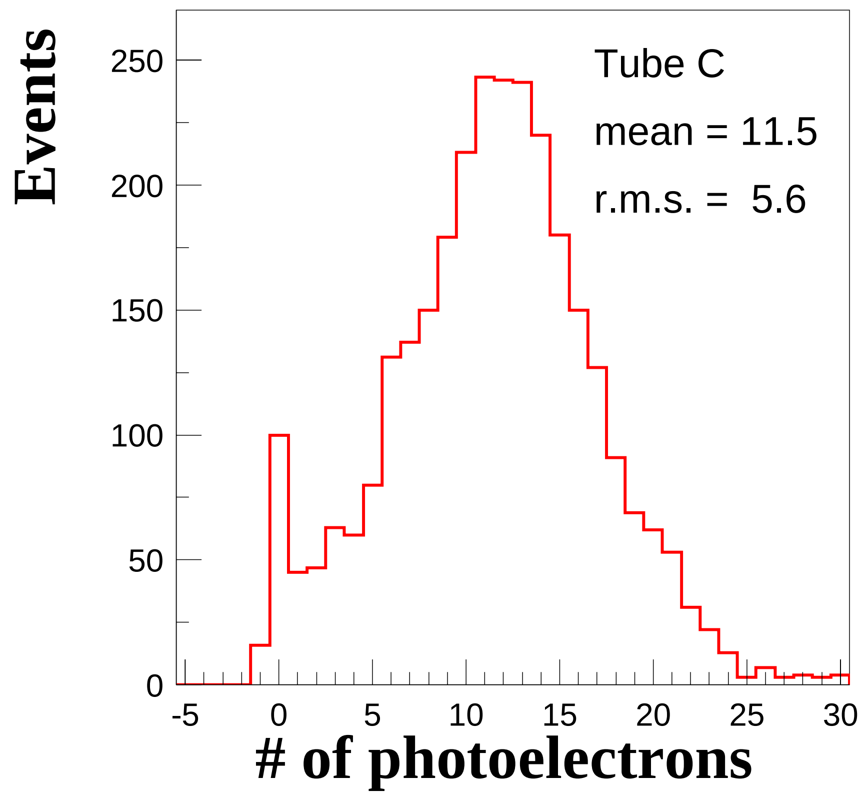
LUCID: Testbeam of fibre read-out

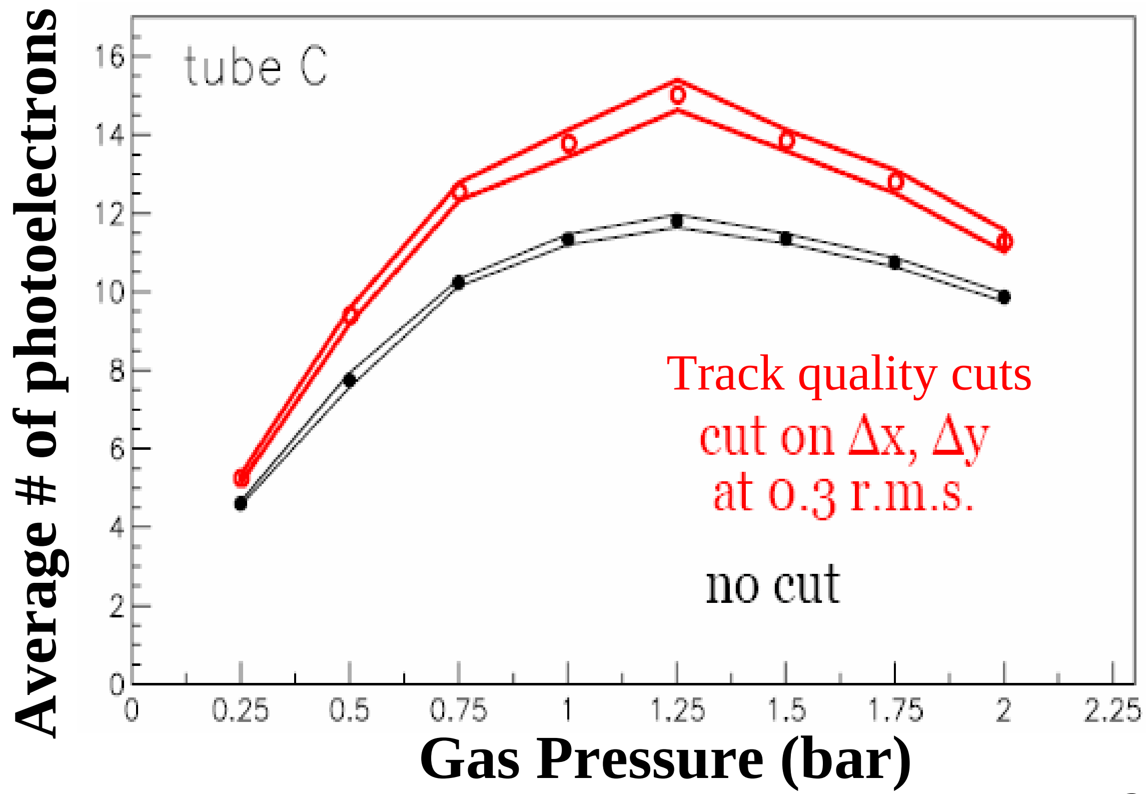
Lund University — ATLAS



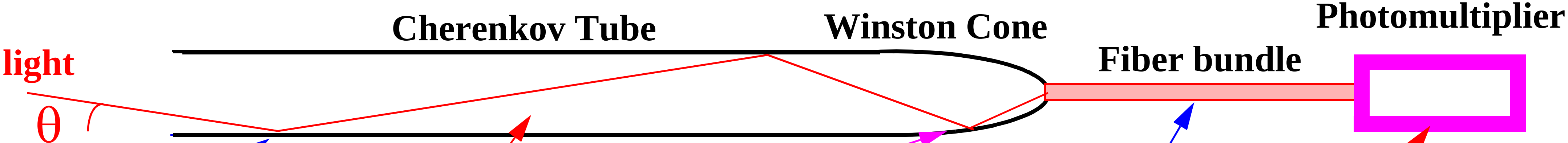
The number of p.e. are not enough to do two-track separation

Simulations predict an increase by a factor 2 for a 6 mm Winston cone.





LUCID: Factors that influence the number of p.e.



Tube:
Reflectivity &
Diffusion in the walls

Winston cone:
Is optimized for a specific Cherenkov angle i.e. pressure.

Photomultiplier:
i) Window
ii) Quantum efficiency

Gas:
The number of photons increase linearly with pressure but the Cherenkov angle change and this change the number of captured photons.
Isobutan absorption.

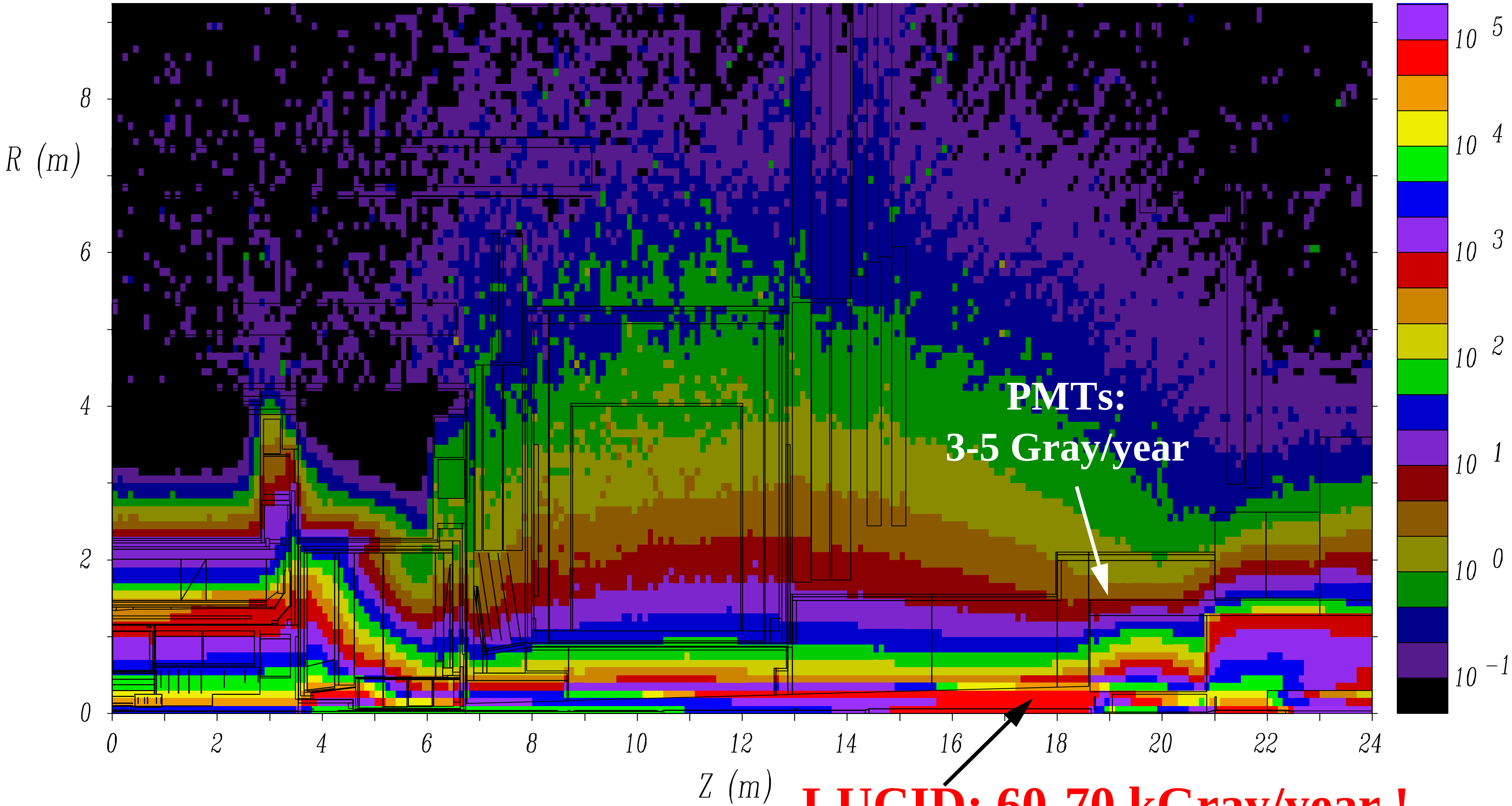
Fibers:
i) Transmission efficiency
ii) Geometry (number of fibers)
iii) Numerical aperture
iv) Fiber-ends (polishing etc)
v) Attenuation

$$N_{pe} = 370 \cdot L \cdot \langle \sin^2 \theta_c \rangle \cdot \varepsilon_T \cdot \varepsilon_I^{abs} \cdot \varepsilon_F^{att} \cdot \varepsilon_{C+F} \int \varepsilon_{PMT}(E) \cdot \varepsilon_F(E) dE$$

LUCID: Radiation levels

ATLAS

Total Ionizing Dose (Gray/year) at a luminosity of 10^{34} $cm^{-2}s^{-1}$



LUCID: 60-70 kGray/year !

LUCID: Radiation hardness

LUND UNIVERSITY

ATLAS

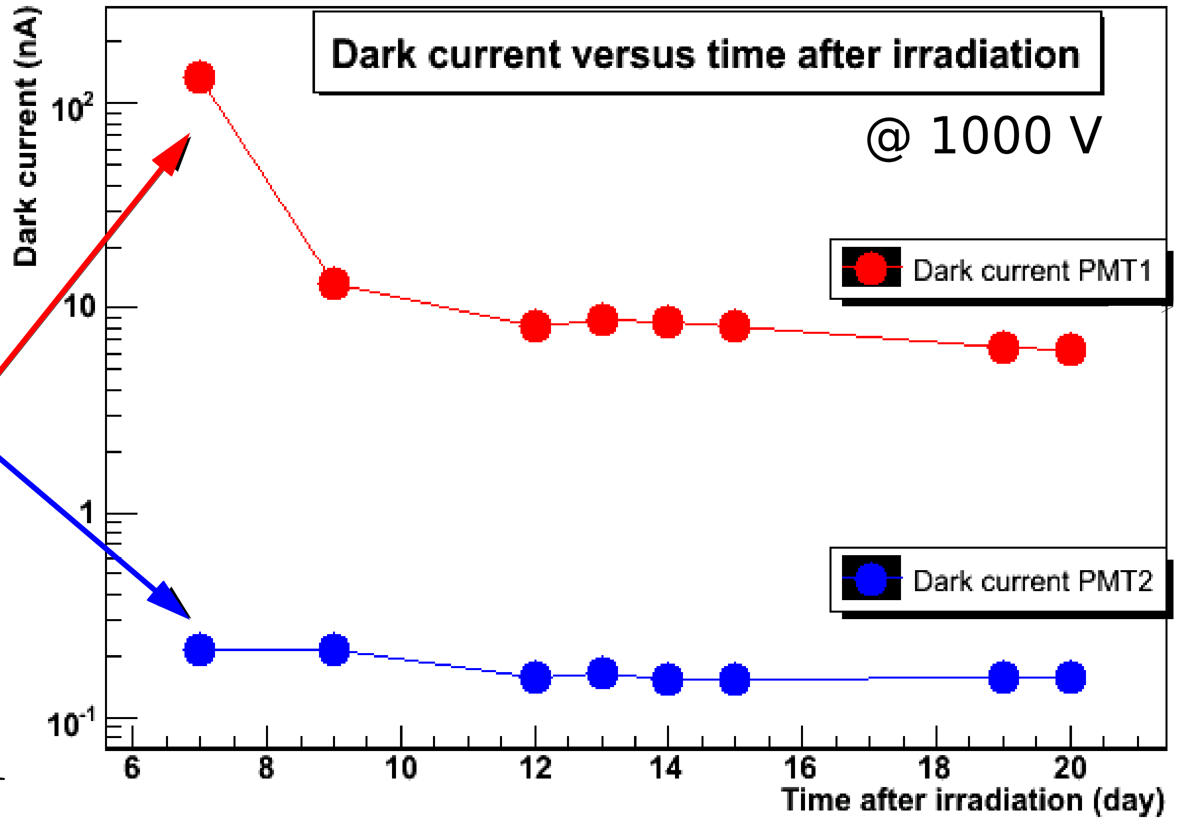
A Hamamatsu R762 photomultiplier has been irradiated with a ^{60}Co source and the dark current and gain has been studied.

PMT 2: No irradiation

PMT 1: 20 MRad in 18 hours

Equivalent to 15 years at 2x10^{33} cm^{-2}s^{-1}

Equivalent to 3 years at 1x10^{34} cm^{-2}s^{-1}



The increase of the dark current is not a concern for the PMT lifetime !

LUCID: Radiation hardness

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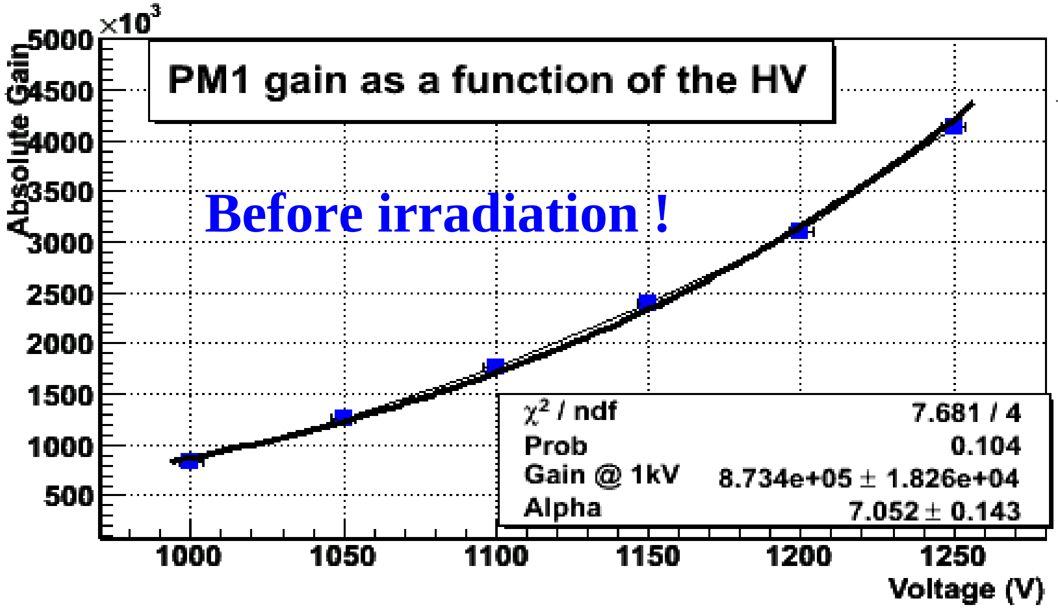
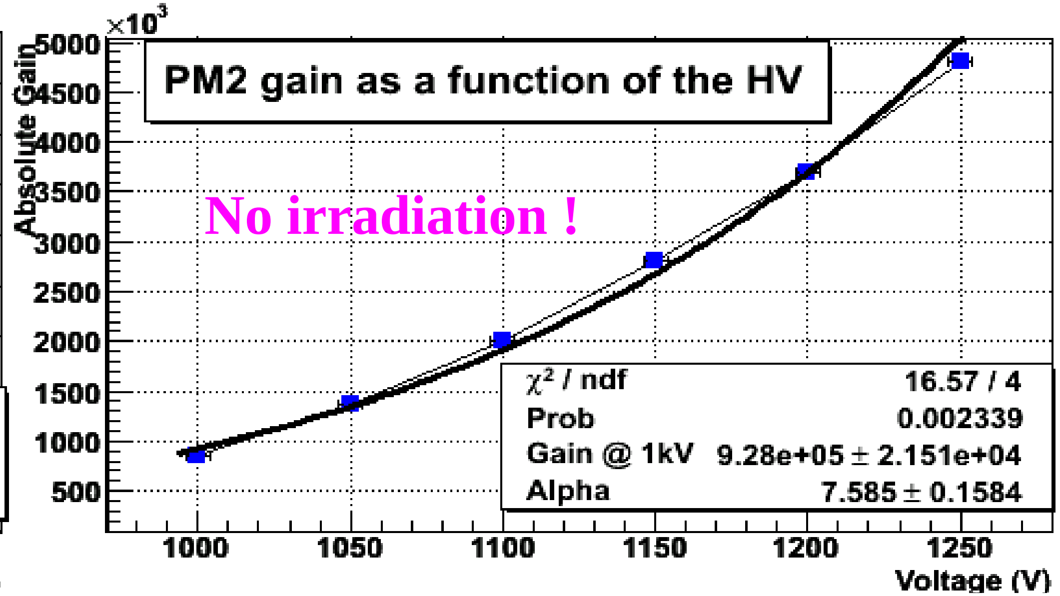
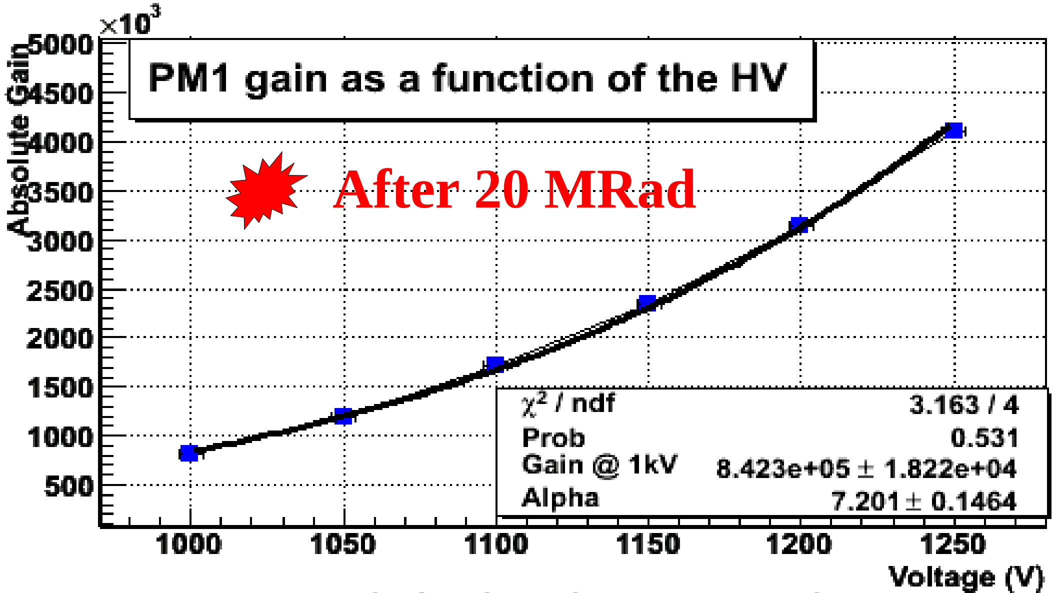
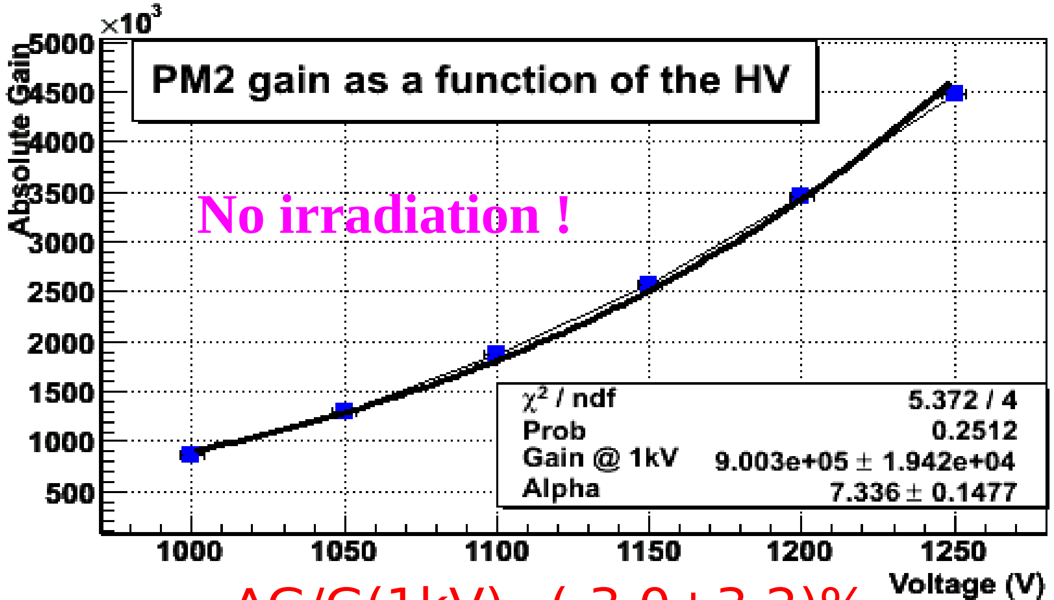
ATLAS







$\Delta G/G(1kV) = (-3.6 \pm 3.0)\%$



$\Delta G/G(1kV) = (-3.0 \pm 3.2)\%$

LUCID: Simulations

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ATLAS

EVENT GENERATOR

Simulation
of hard and soft
pp interactions

PHOJET 1.12

ATLAS

Simulation of the whole
detector, except for
an empty volume
to be filled with LUCID

GCALOR

LUCID

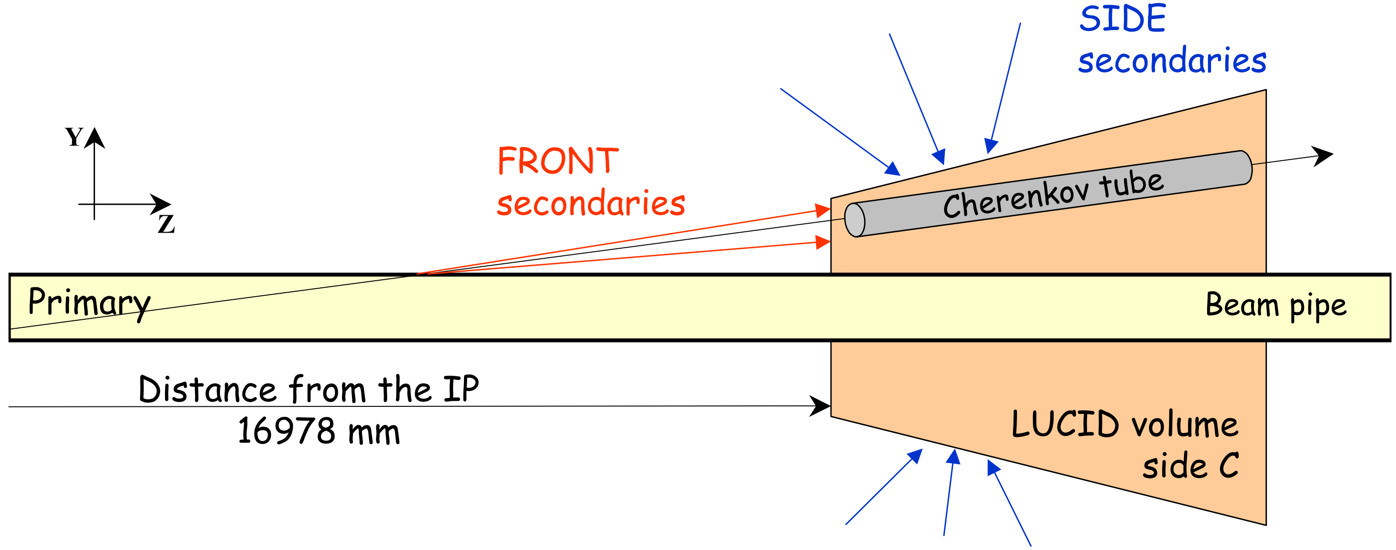
Simulation
of the LUCID detector
in the available
volume

GEANT 4.7.1

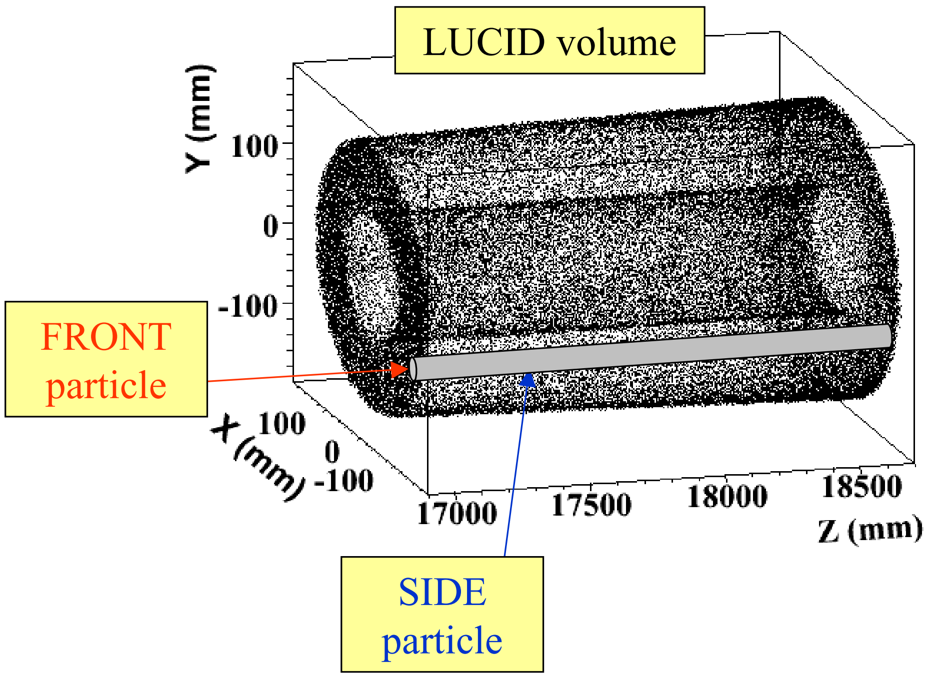
LUCID: Simulations

Primaries are mostly charged pions.

Secondaries are mostly electrons.



The output of the GCALOR program is 4-vectors of particles entering the LUCID volume.



LUCID: Simulations

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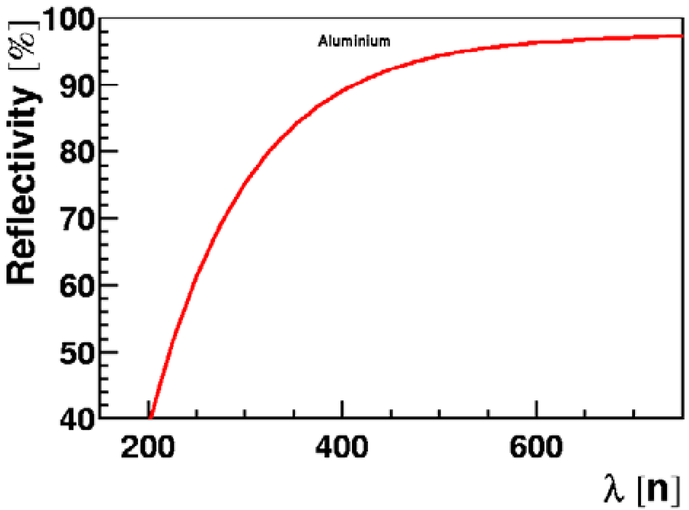
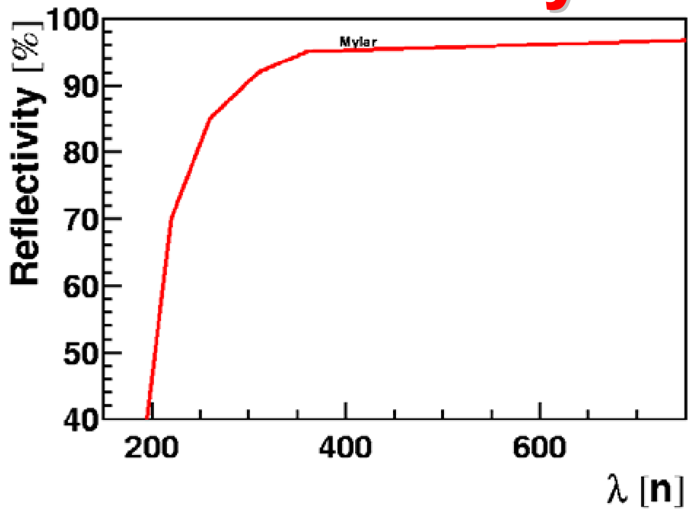
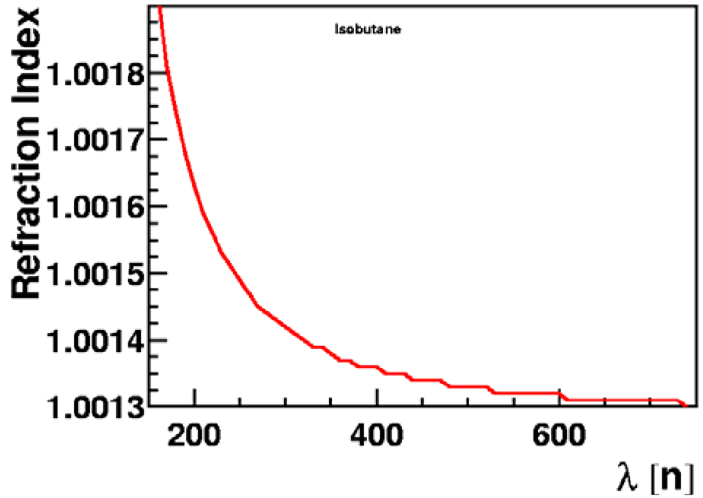
Aluminium



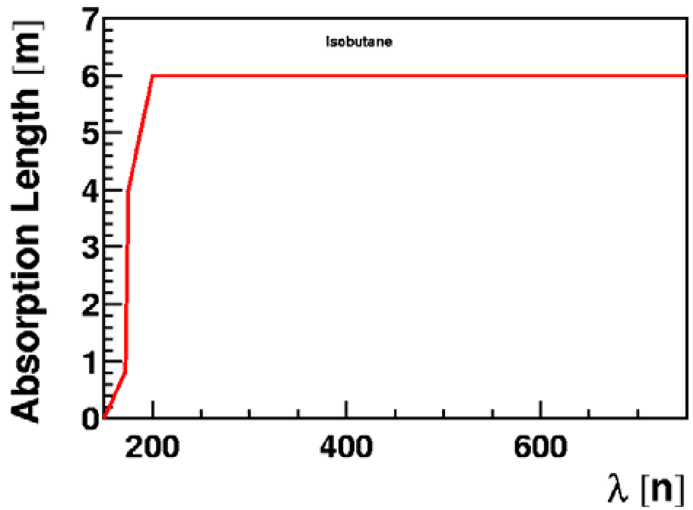
Aluminized Mylar



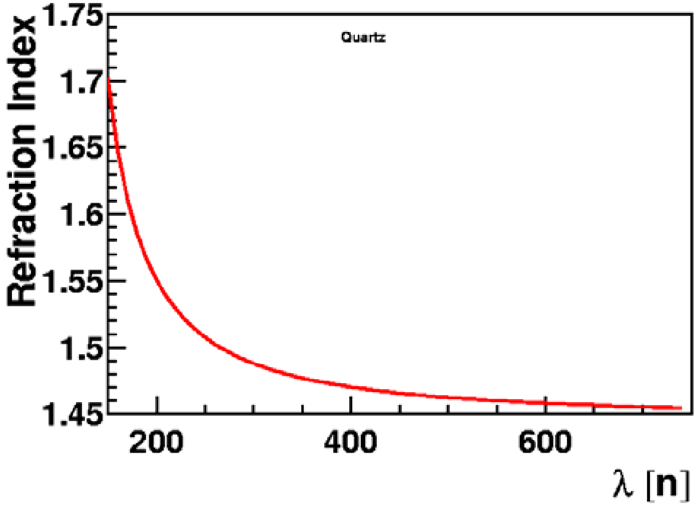
Isobutane



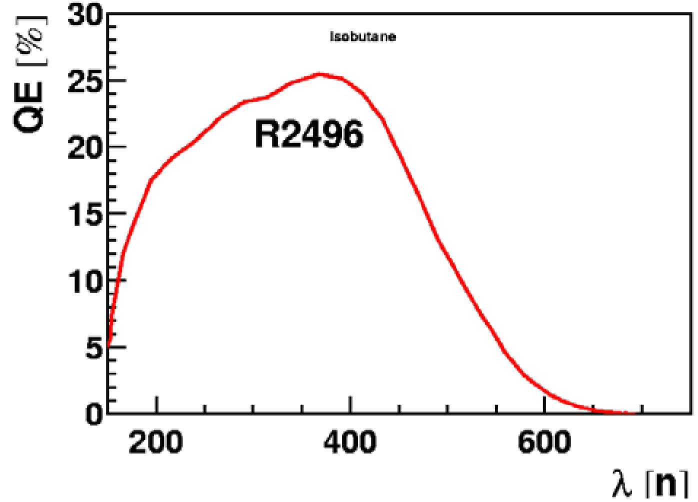
Isobutane



Quartz



PMT



LUCID: Machine background

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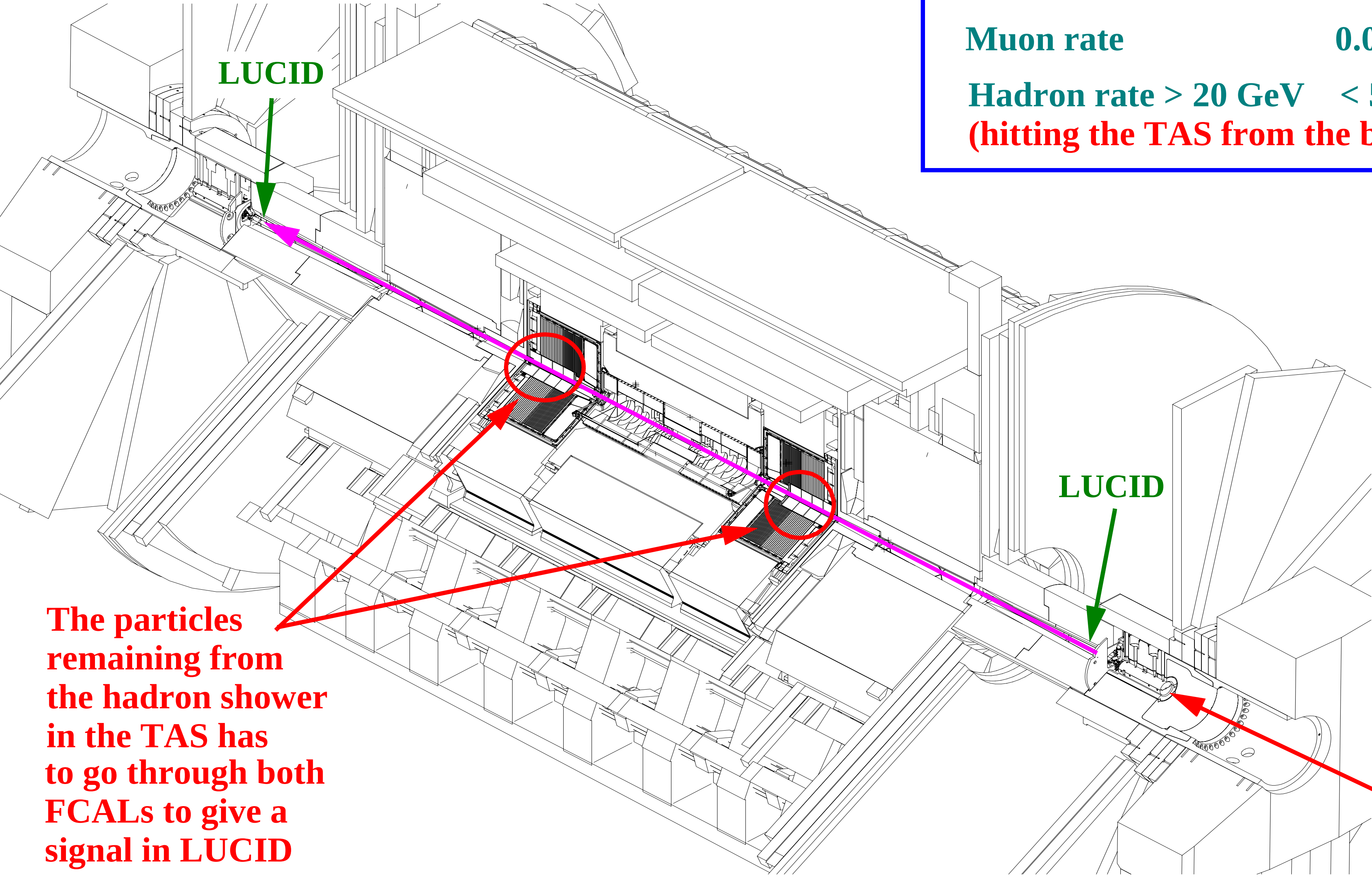
ATLAS

Luminosity:	10^{27}	10^{34} $cm^{-2}s^{-1}$
LUCID signal rate:	16 Hz	32 MHz
Muon rate	0.06 Hz	40 Hz
Hadron rate > 20 GeV (hitting the TAS from the back)	< 50 Hz	< 31 kHz



From a calculation by V. Talanov that gives beam gas background entering the ATLAS cavern.

It is assumed that only hadrons with E > 20 GeV can penetrate the TAS

The particles remaining from the hadron shower in the TAS has to go through both FCALs to give a signal in LUCID

LUCID: Activation considerations

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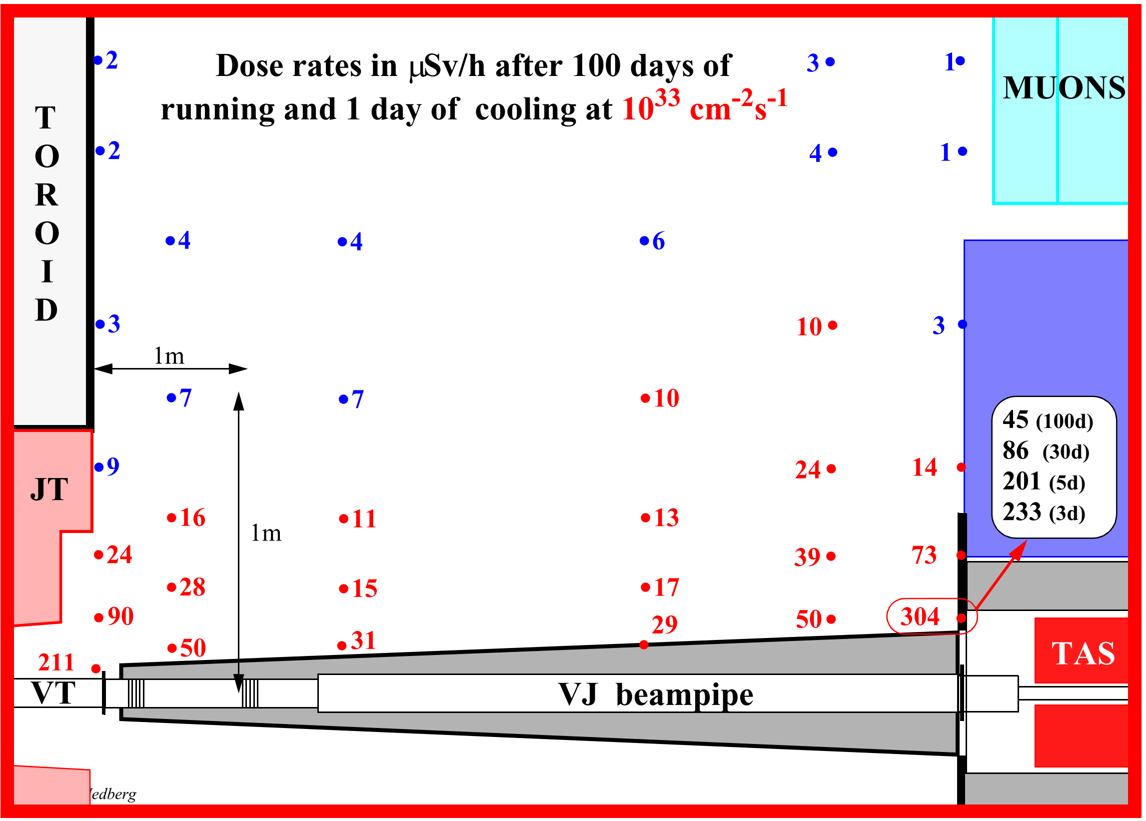
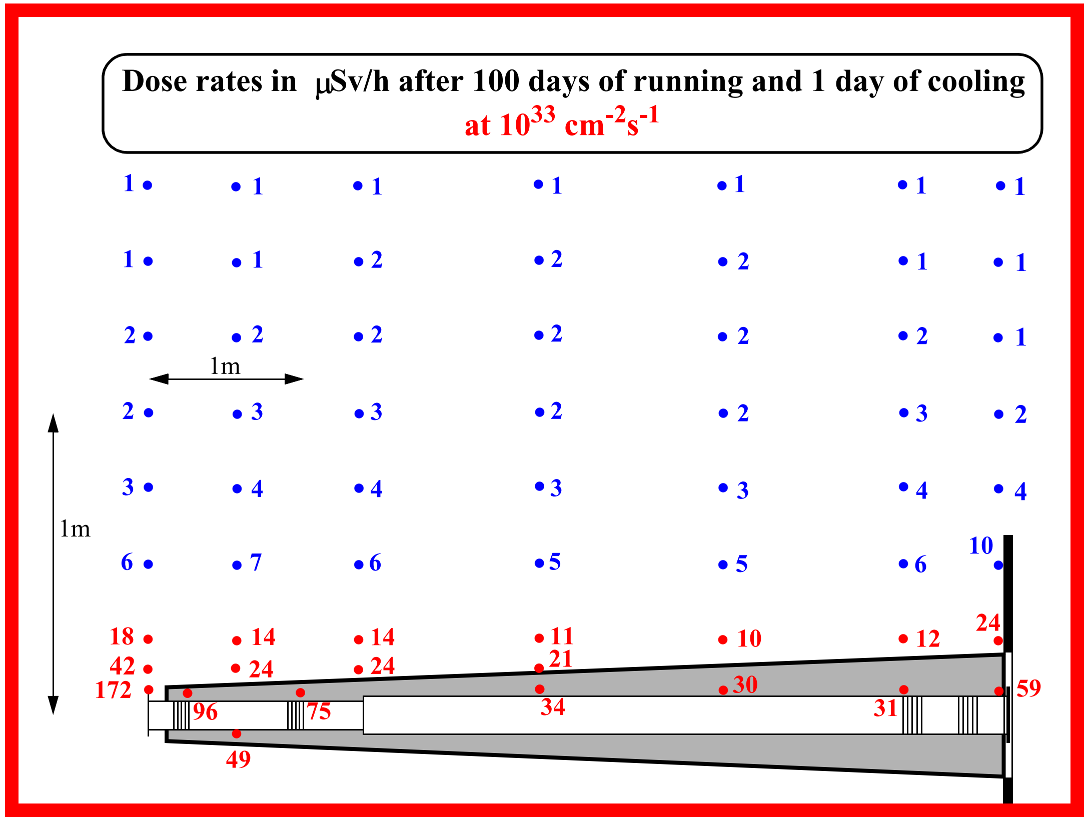
ATLAS

The activation of the detector and the beampipe will be an issue when the Phase 1 detector will be exchanged for the Phase 2 detector. Calculations show that one can expect fullbody dose rates of about 10 μSv/h, i.e., one can work on the detector for some 200 hours per year per person.



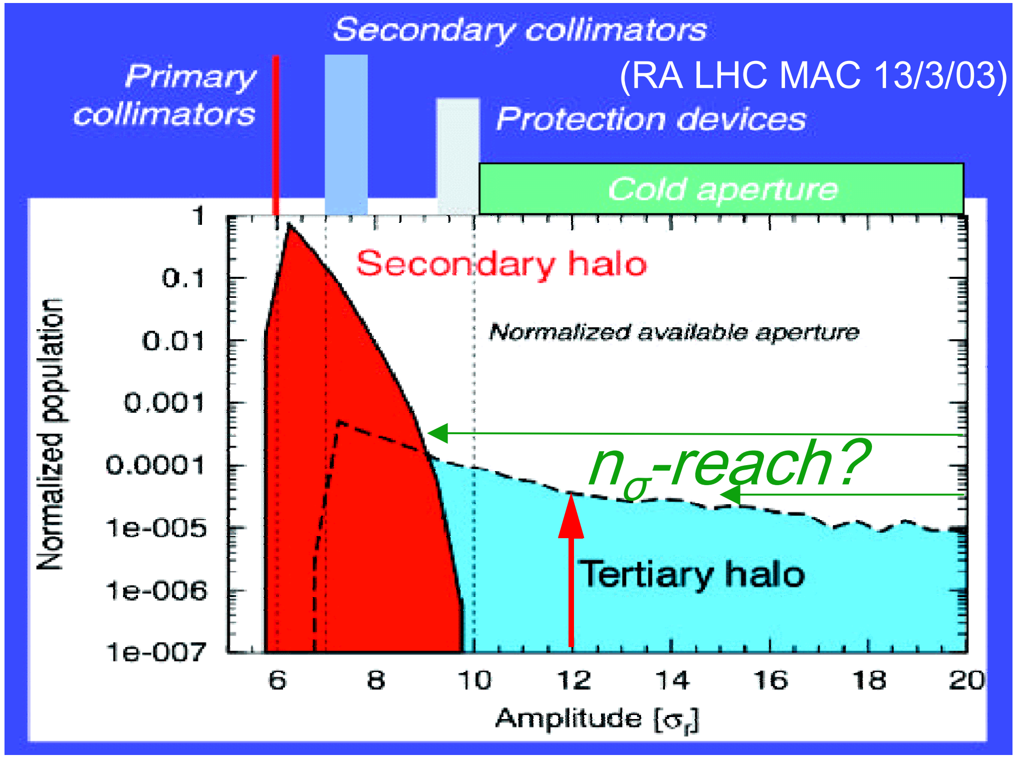


ALFA: Detector requirements

ATLAS

The measurement of elastic scattering in the Coulomb region at the LHC is very challenging and requires a detector with the following requirements:

- **The active area has to be very close to the beam (~1.5 mm)**
- **The detector has to be far away from the interaction point (240m)**
- **The dead space at the edge of the detector has to be small (< 100 μm)**
- **The detector resolution has to be about 30 μm**
- **The times resolution has to be about 1 ns.**



- **The detector should be insensitive to the electromagnetic pulse from the LHC beam.**

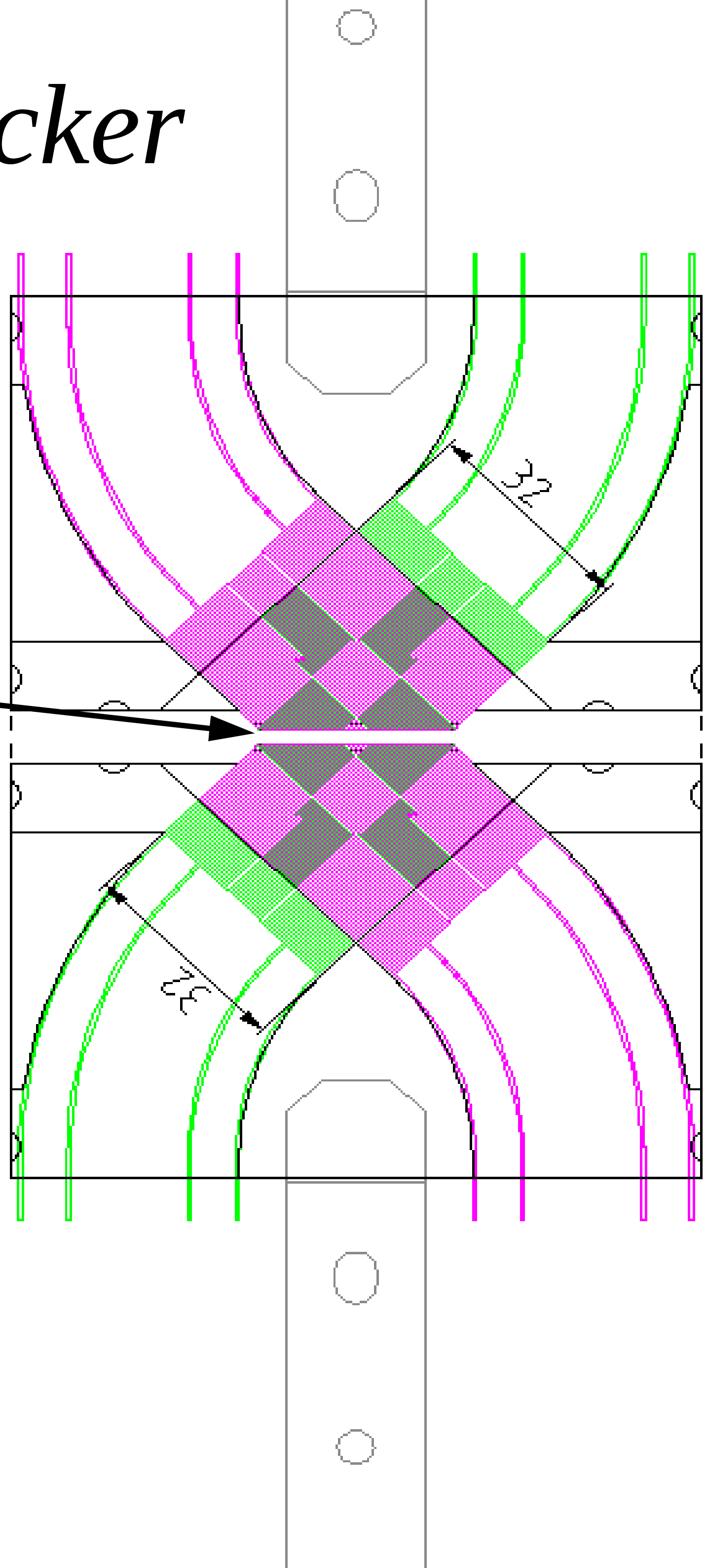
but this is not all..... a special LHC optics is also needed to reach the Coulomb region i.e. special dedicated LHC runs are needed.

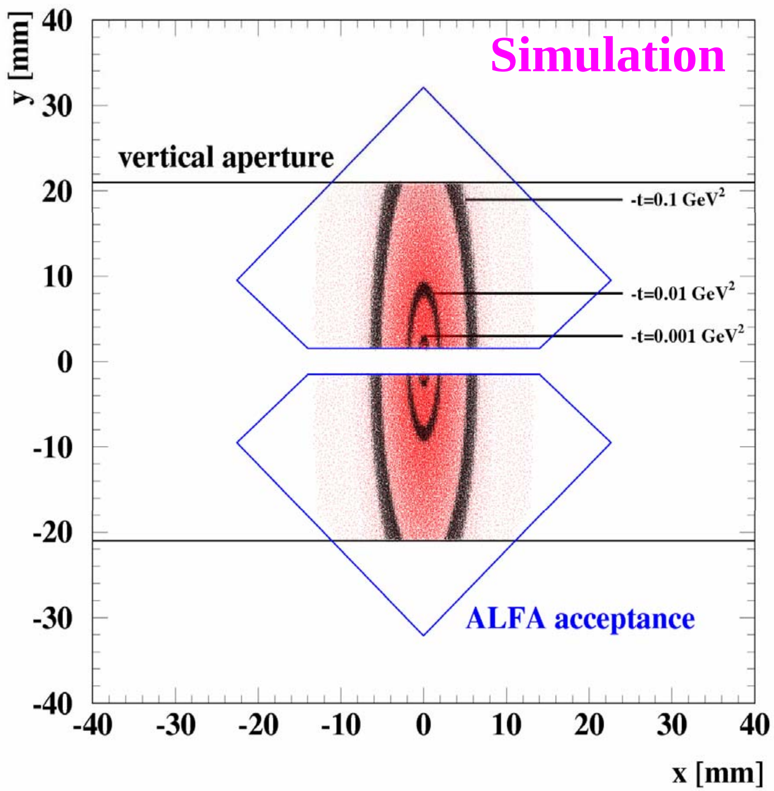
ALFA: The Fibre Tracker

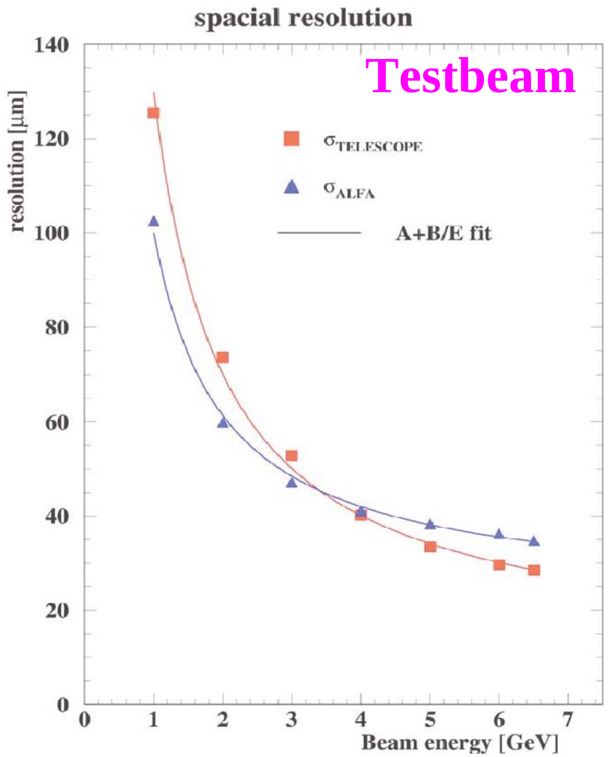
The tracker is made of 0.5 mm^2 square scintillating fibres.

These are arranged in 10 U- and 10 V-planes with 64 fibres in each plane.

The distance between the top and bottom detector is only about 3 mm during datataking.

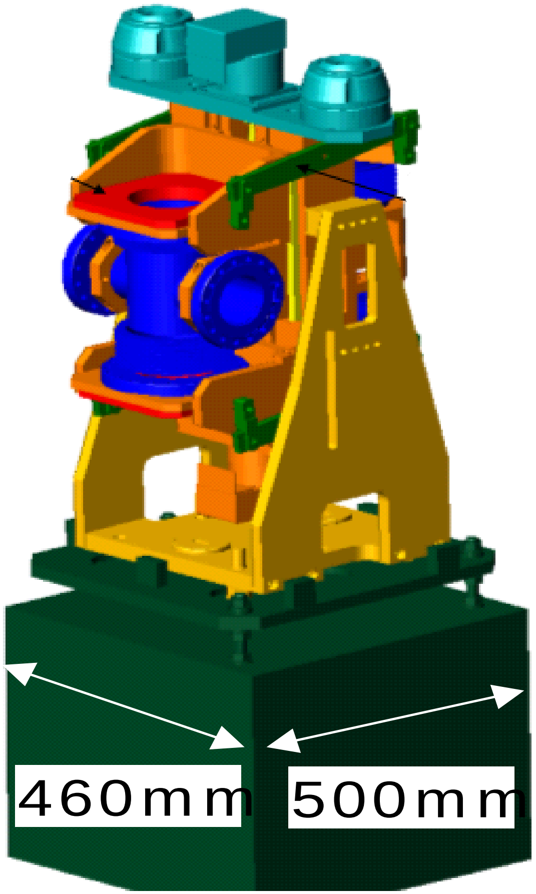


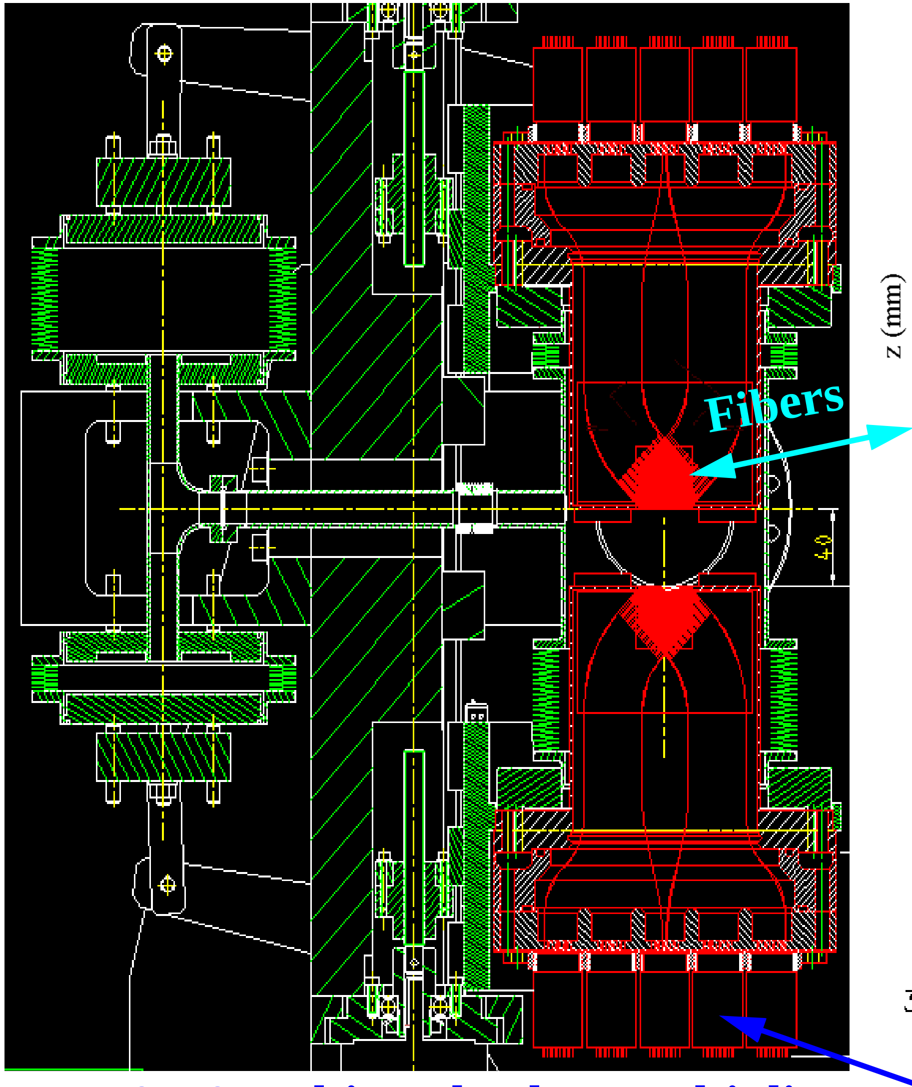


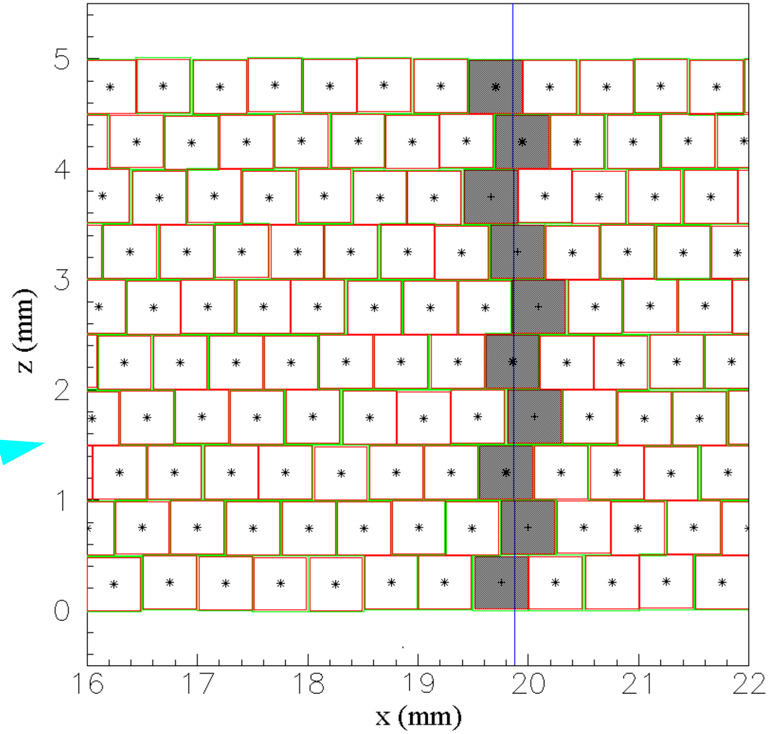


The Roman Pots are the devices which allows the detectors to get close to the beam.

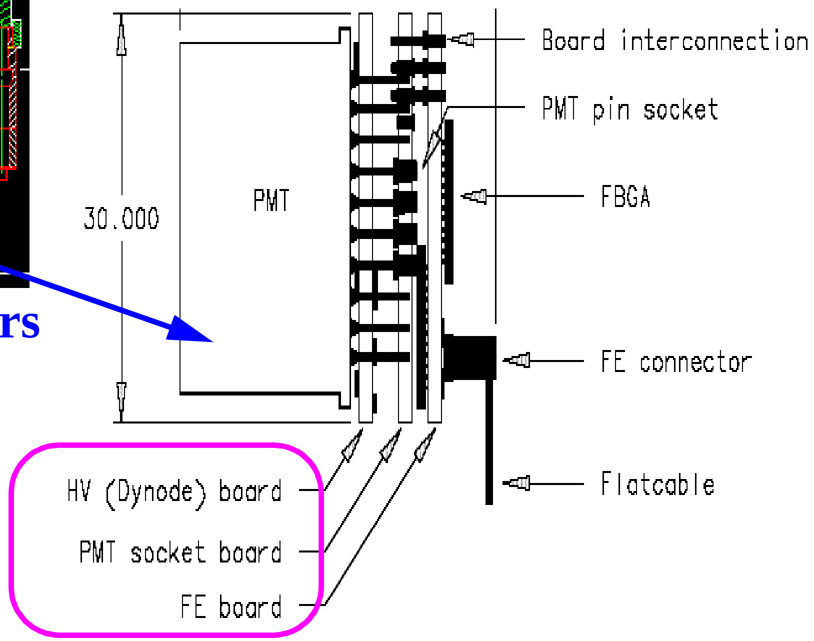
10 layers of square 0.5 x 0.5 mm scintillating fibers







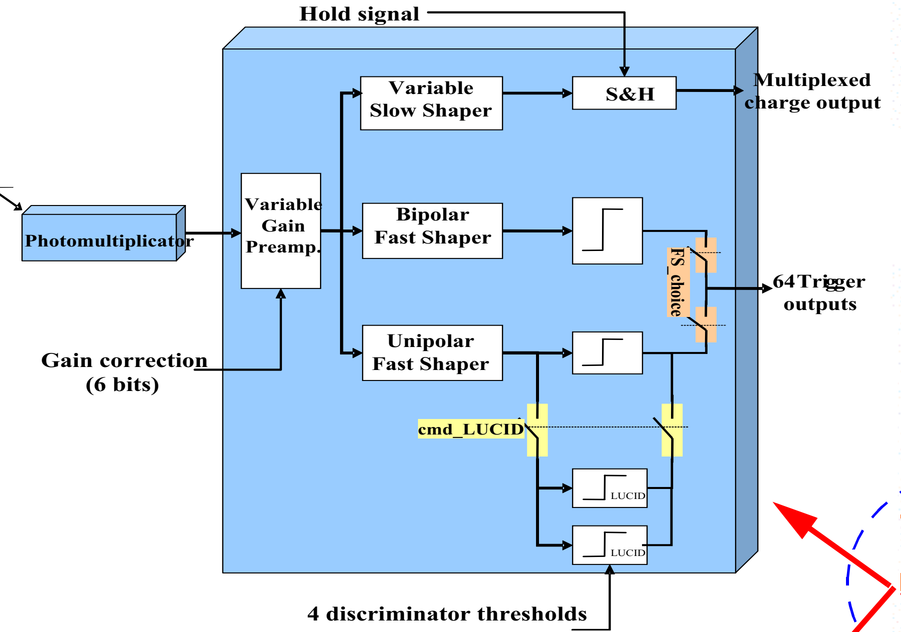
8 x 8 multianode photomultipliers



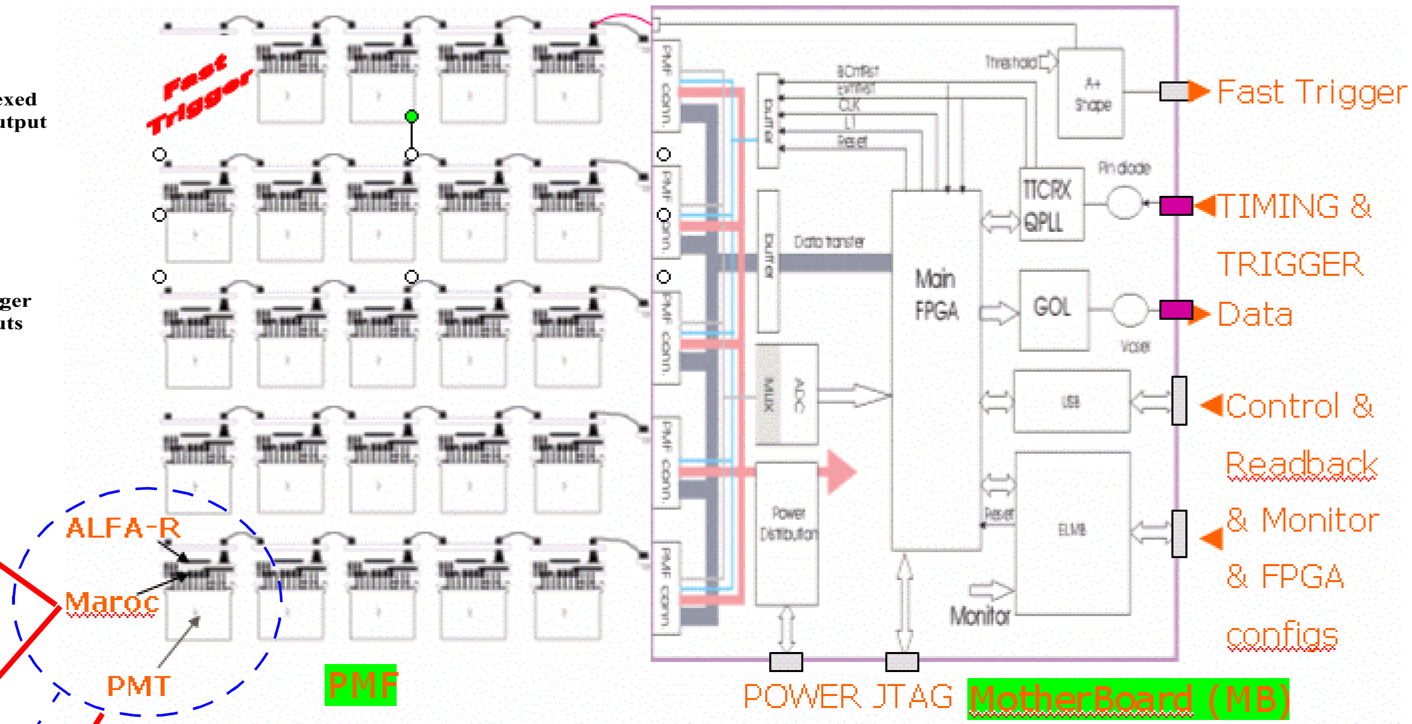
Lund is making the PC boards for the front-end electronics

ALFA: Electronics

Multi Anode Read Out Chip
in 0.35 mm SiGe technology
for read out of 64 channels



Electronic Box (one per Roman Pot)



MAROC board

Adapter board

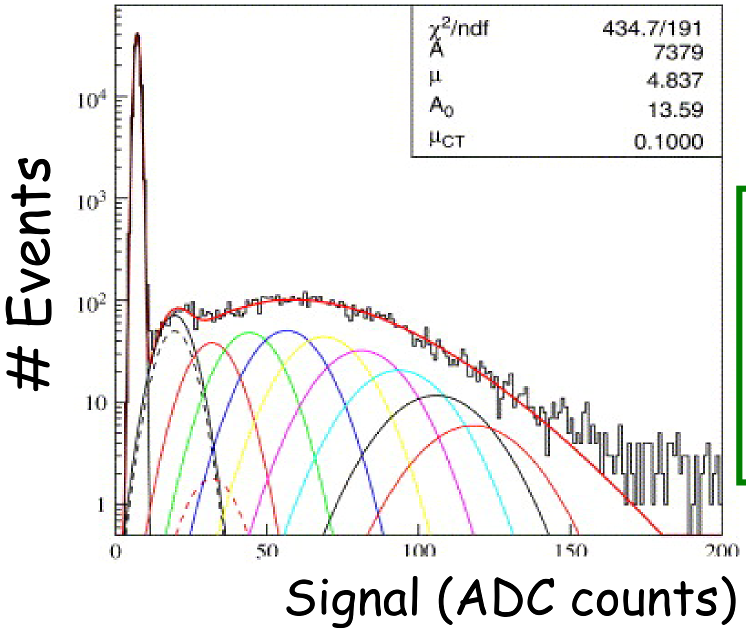
HV divider board

8 x 8 Multianode photomultiplier

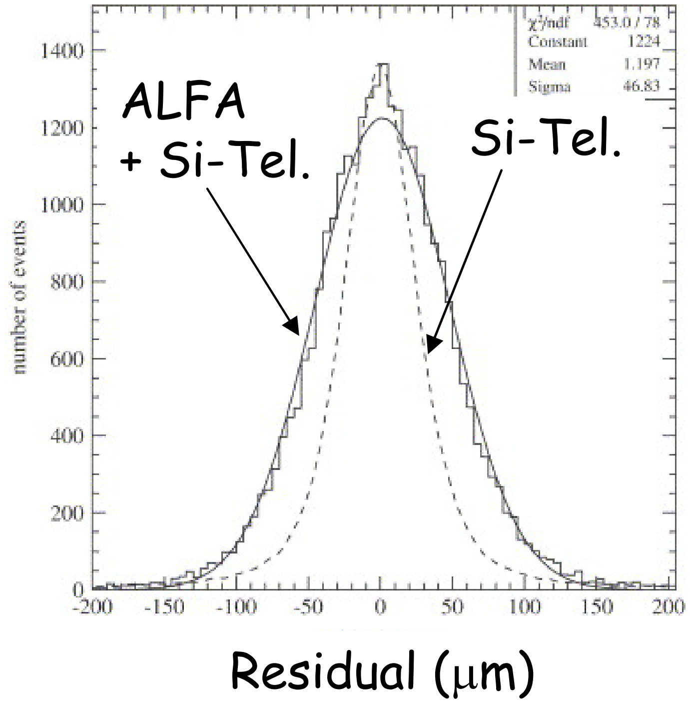
39 mm

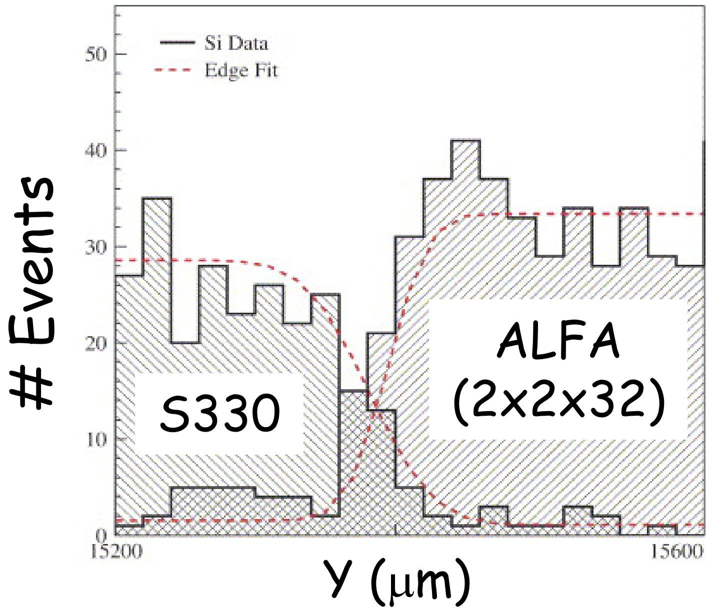
ALFA: Testbeam at DESY in 2005

ATLAS



Light yield:
45° cut → 3.9 p.e.
90° cut → 4.5 p.e.
Efficiency ~ 95%





Non-Active Edge
Region << 100μm

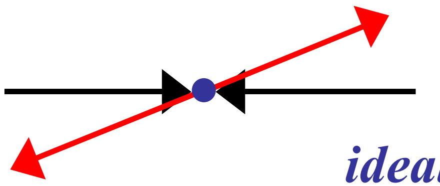
ALFA Resolution:
$\sigma_{x,y}$ ~ 36 μm

Potentially increased by multiple scattering of the relatively low energy electrons

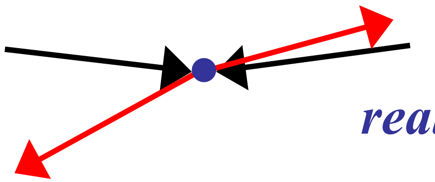
ALFA: t-resolution

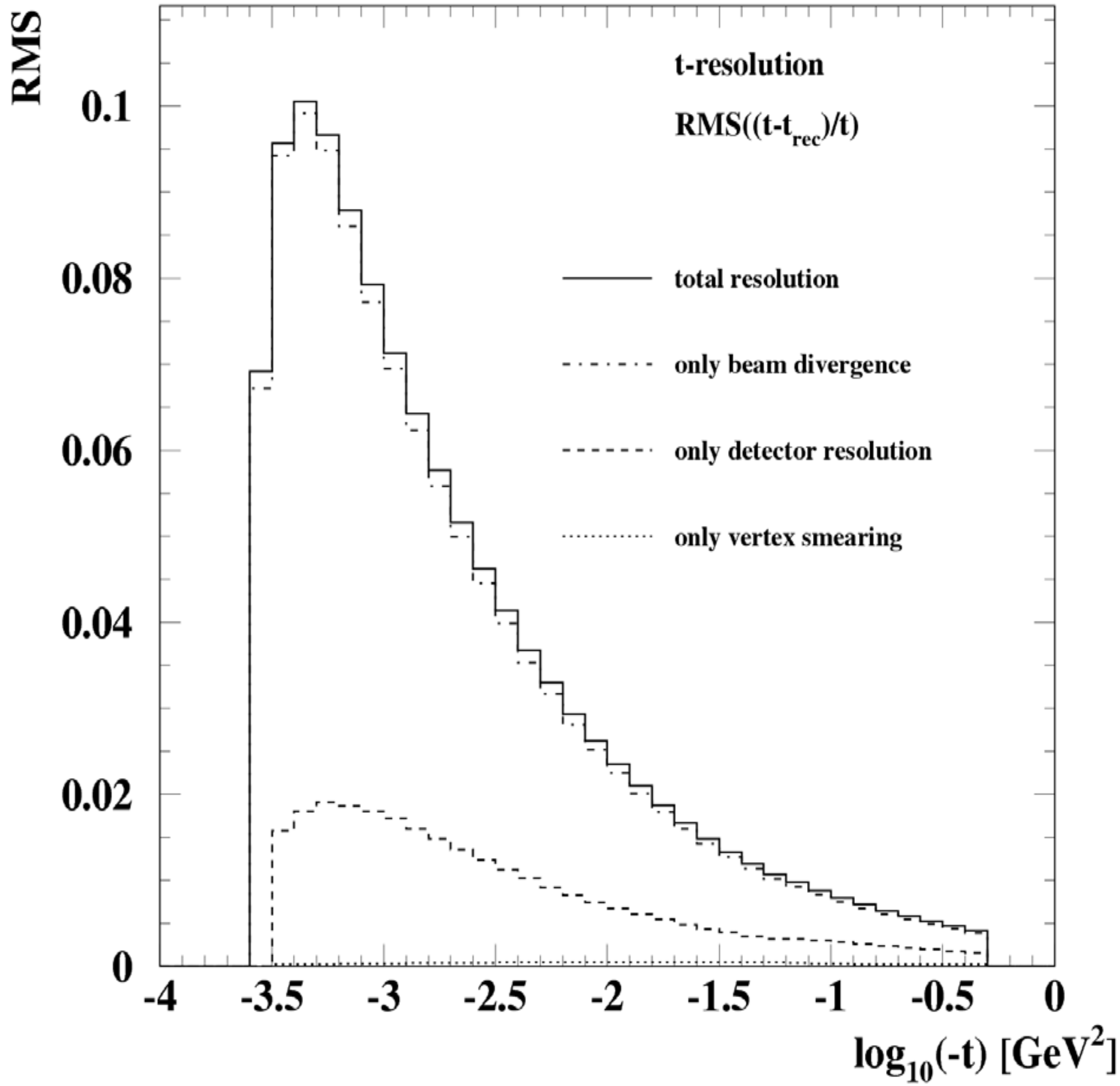
The *t*-resolution is dominated by the divergence of the incoming beams.

σ'=0.23 μrad



$$-\hat{t} = (p_1 - p_3)^2 \approx (p\theta^*)^2$$





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ALFA: Systematic Errors

ATLAS

Divergence + 10%	± 0.31%
Alignemnt ±10μm	± 1.3%
Acceptance ±10μm (edge)	± 0.52%
β ± 2 %	± 0.69%
Ψ ± 0.2 %	± 1.0%
Detector resolution	± 0.29%
Total exp.syst. error	± 1.9%

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The ATLAS Shielding Project

ATLAS

Original budget: 6.8 MCHF (40 MSEK) CERN manpower not included

Radiation calculations Shielding physics design — ***Mechanical design*** — ***Market surveys Tendering Contracts*** — ***Production*** — ***Transport*** — ***Assembly*** → ***Installation***

Radiation calculations / Shielding physics design:
~100 GCALOR simulations each taking 1 week of CPU time at the ATLAS BNL computer center

Mechanical design:
324 drawings

29 Technical Specifications

FE calculations

Reactor tests of radiation hardness

Tests of flammability

Market surveys / Tendering / Contracts:
3 MCHF (18 MSEK) in orders made

Production:
Czech republic (4 companies)
Serbia (2 companies)
Armenia (2 companies)
Poland (1 company)
Belgium (1 company)
Pakistan (2 companies)
Spain (1 company)
Italy (1 company)
France (1 company)
Germany (1 company)
Switzerland (1 company)

Transport:
Example:

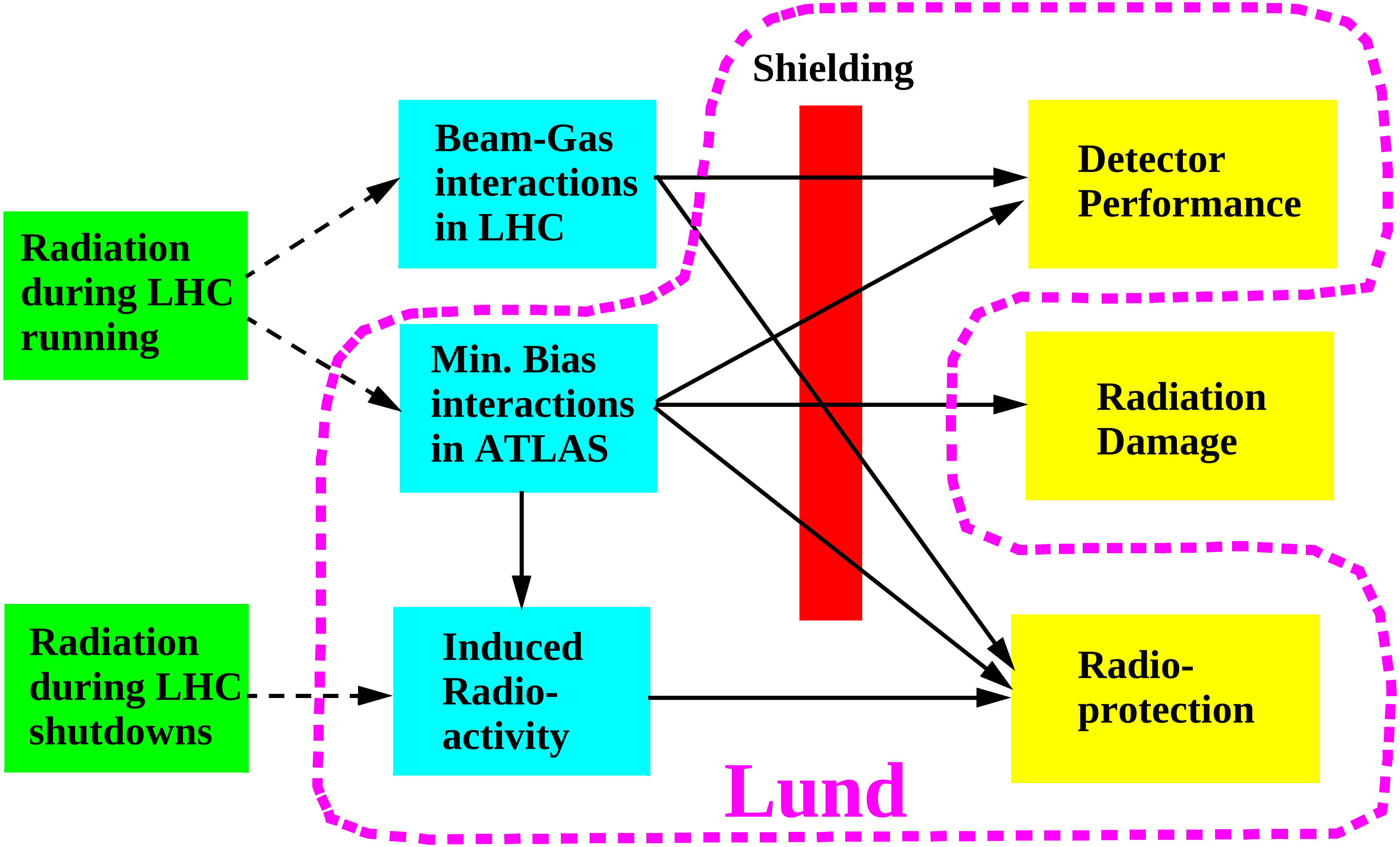
10 x 100 tons special transports Plzen-CERN

Assembly:
In the Czech republic and at CERN

Installation:
Scheduled for

2005
2006
2007

Radiation in ATLAS



Shielding Optimization

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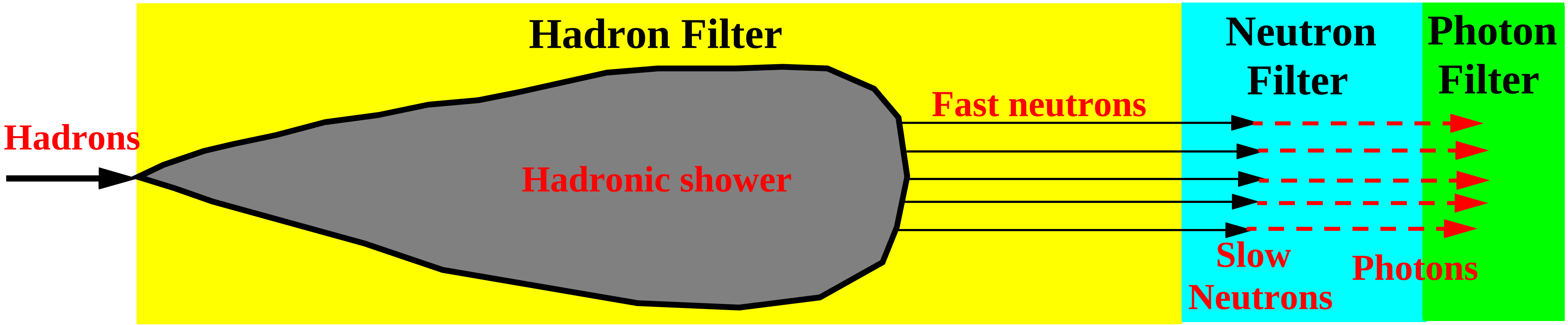
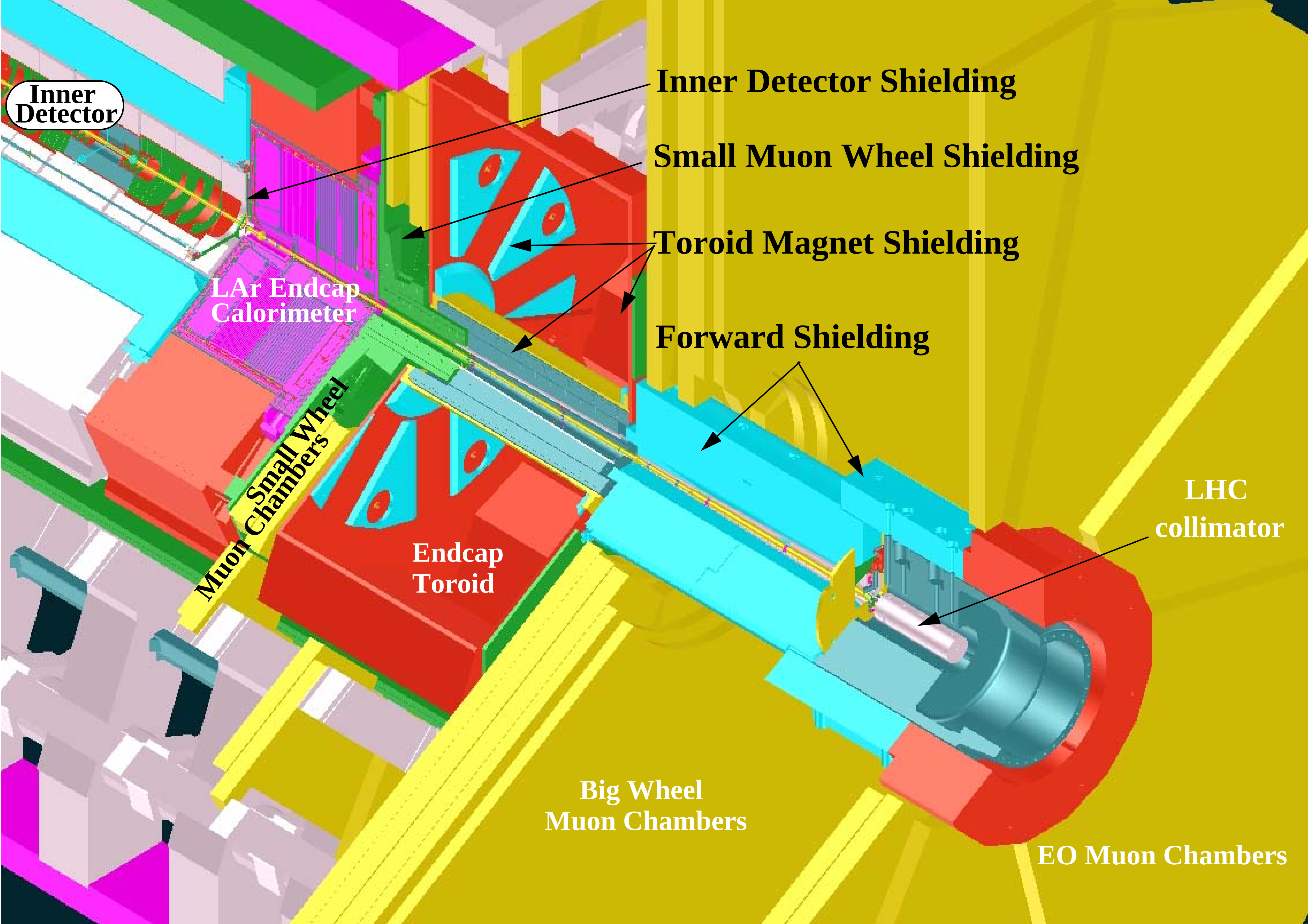
ATLAS

ATLAS is using a layered shielding design which requires a multi-parameter optimization:

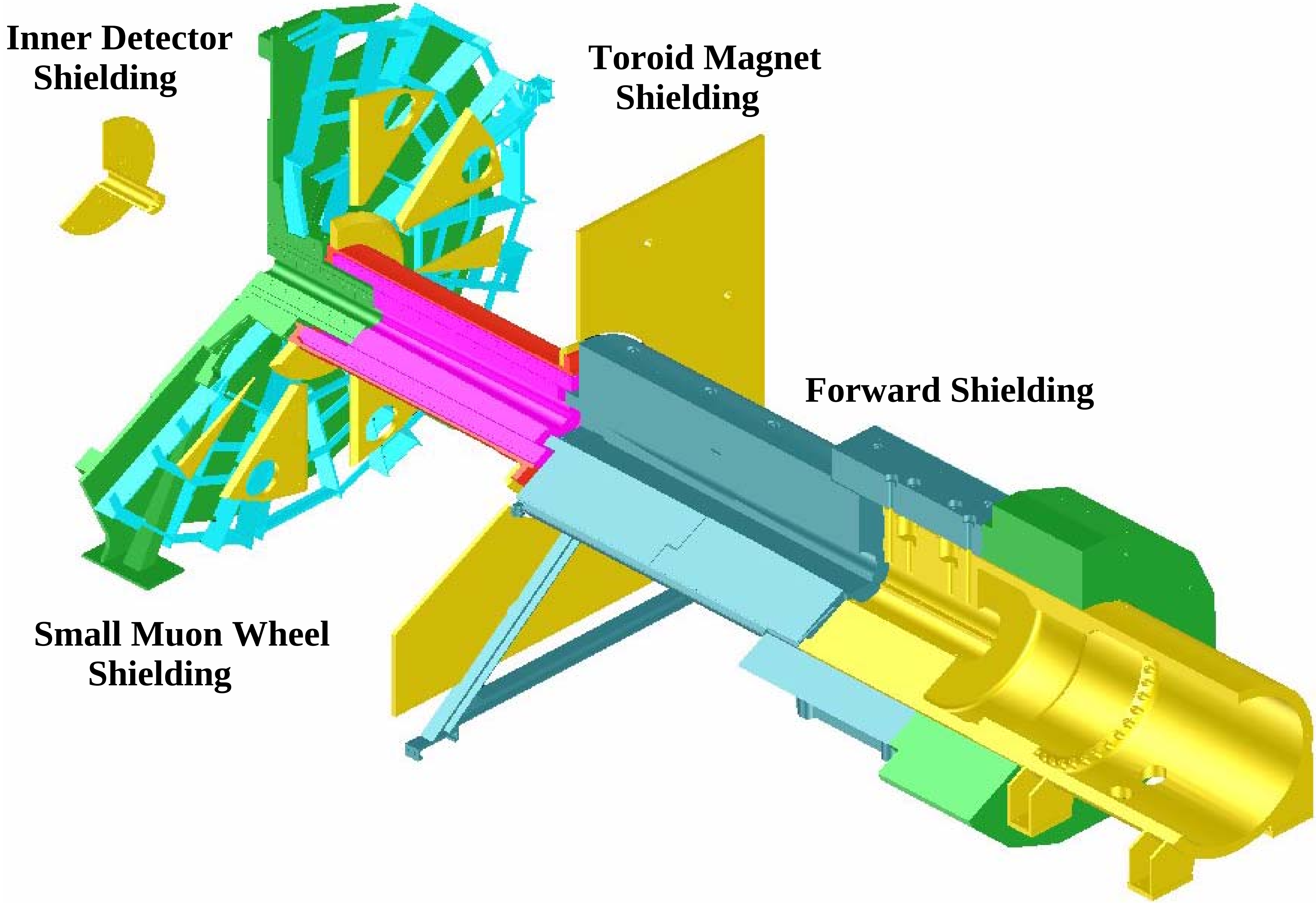


PARAMETERS

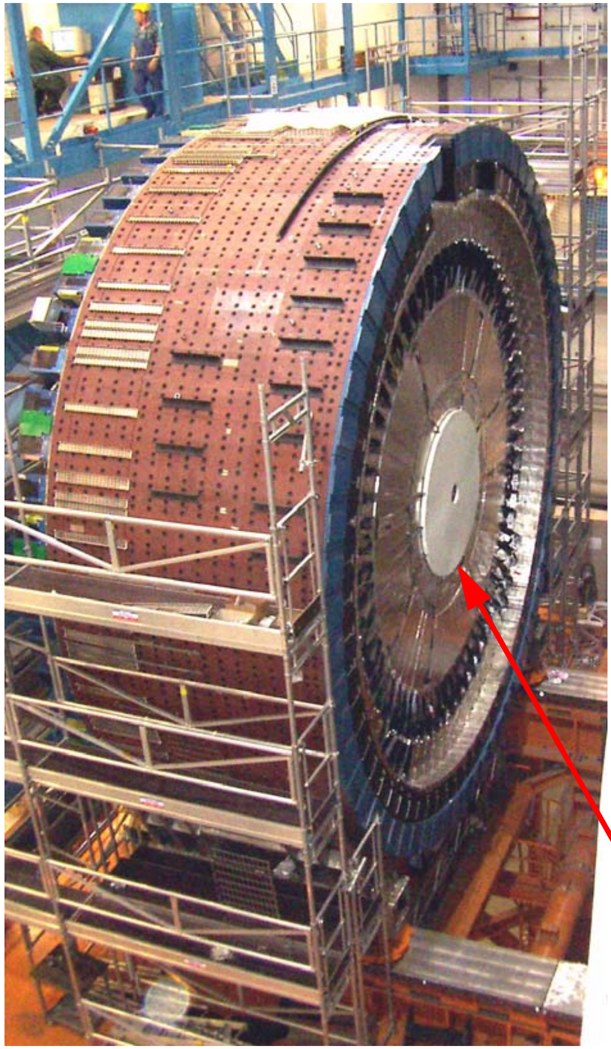
Materials:	**Ductile Iron, Stainless Steel, Bronze, Gray Steel**	**Polyethylene doped with B_4C, B_2O_3 H_3BO_3, LiF**	**Lead Steel**
Thickness:	**10-20 λ**	**5-8 cm**	**3 cm**
Properties:	**Mechanical characteristics**	**Flammability**	
	Magnetic properties	**Rad. hardness**	
Cost			

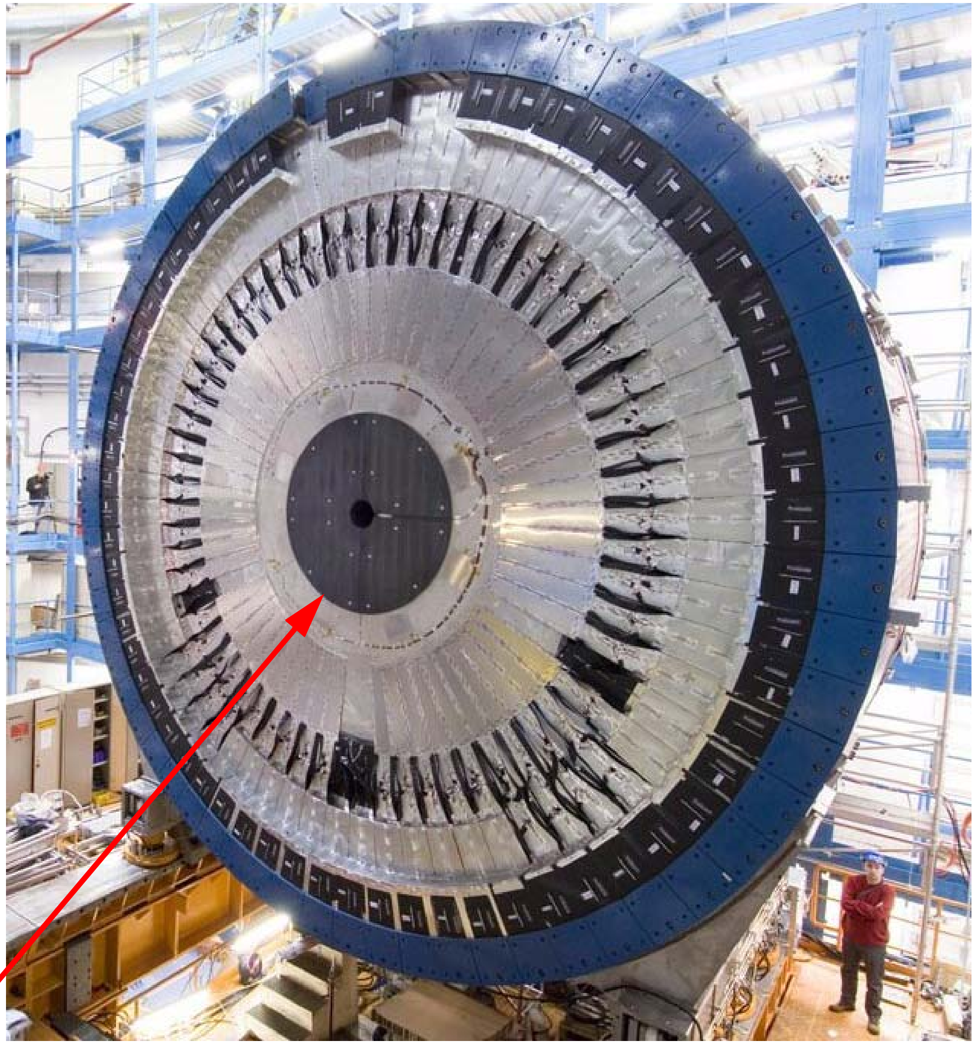


Inner Detector
Inner Detector Shielding
Small Muon Wheel Shielding
Toroid Magnet Shielding
LAr Endcap Calorimeter
Forward Shielding
Small Wheel Muon Chambers
LHC collimator
Endcap Toroid
Big Wheel Muon Chambers
EO Muon Chambers


Inner Detector Shielding
Toroid Magnet Shielding
Forward Shielding
Small Muon Wheel Shielding

Moderator shielding





The Moderator shielding is placed on the front face of the LAr calorimeter.

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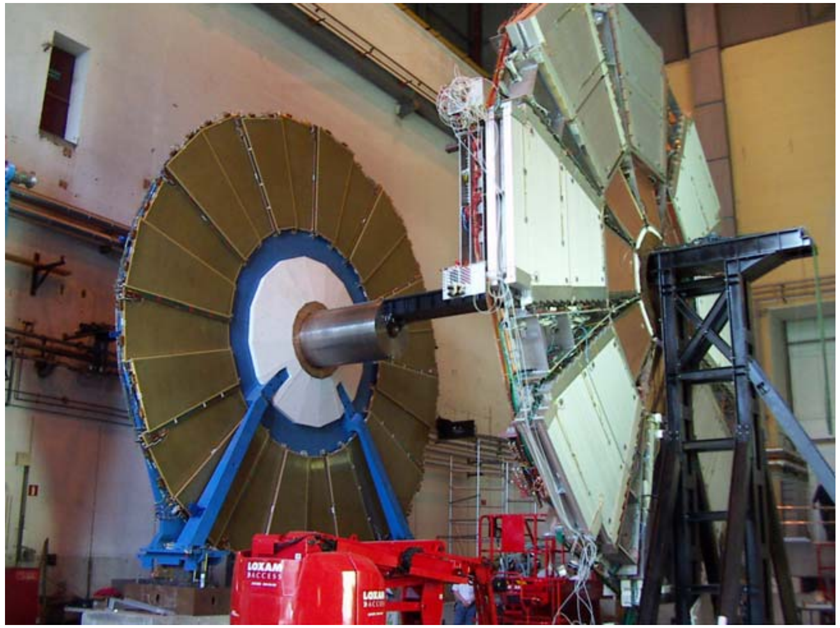
Disk shielding

ATLAS

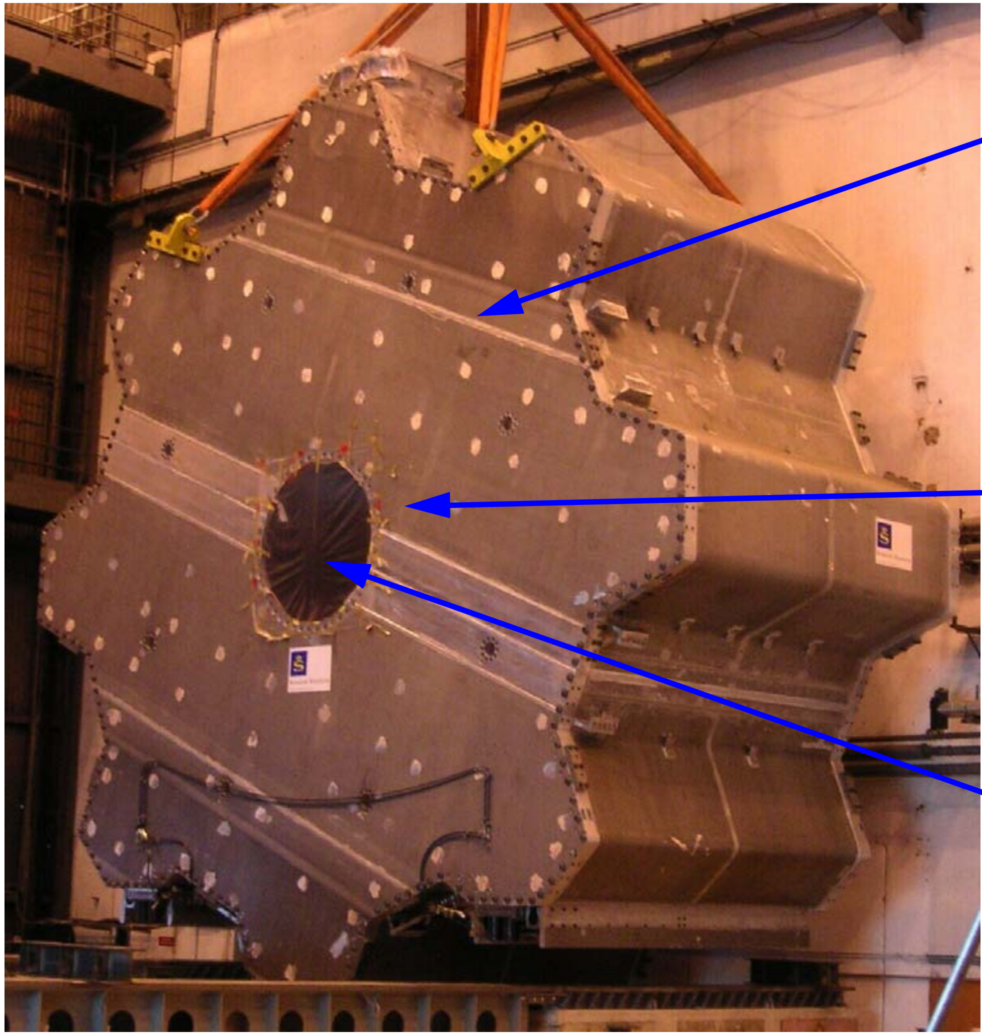


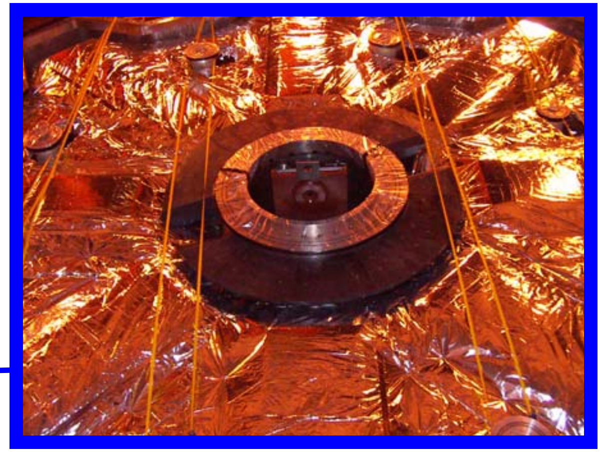






Toroid shielding





Forward shielding

Nose shielding