ATLAS Roman Pot Detectors: Absolute Luminosity For ATLAS

- The Measurement of Luminosity in ATLAS
- Roman Pots and the Scintillating Fiber Detectors
- Plans for Installation, Commissioning, First Run…

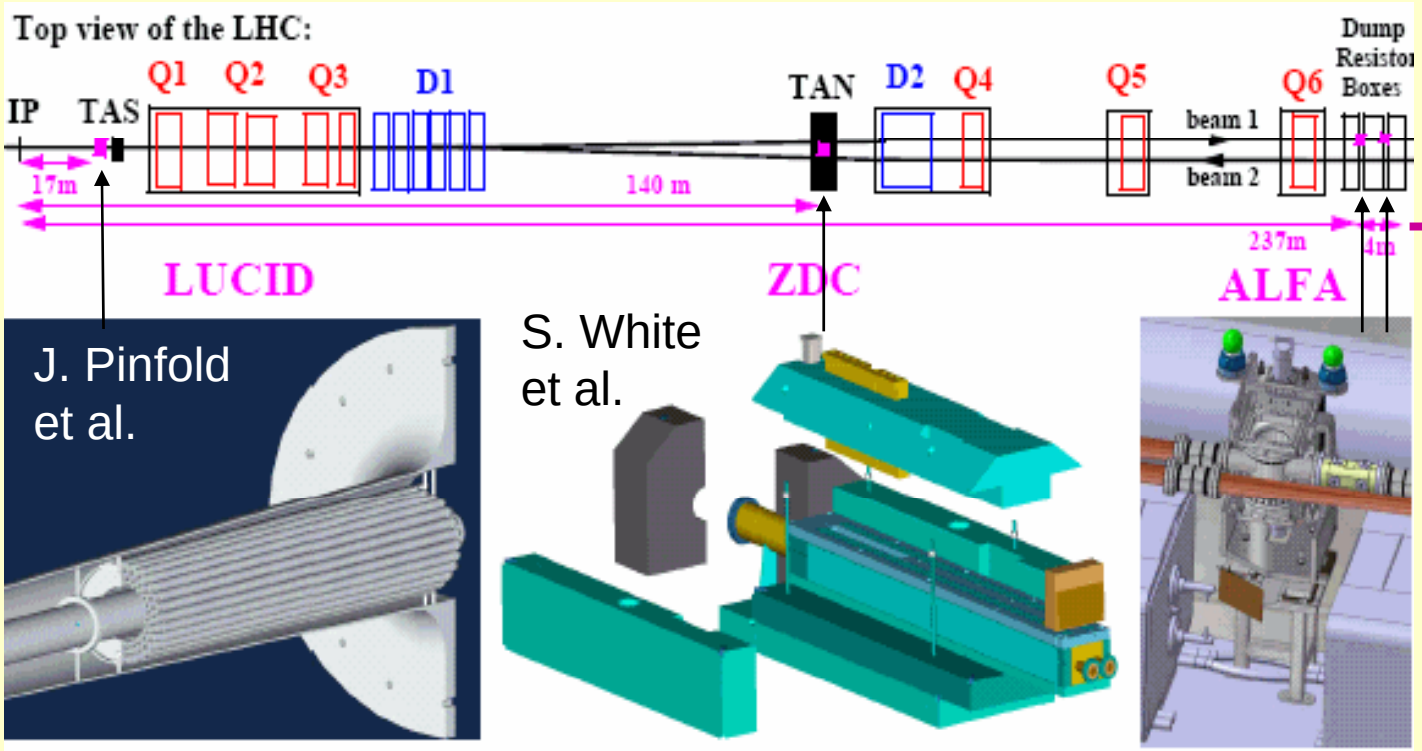
Absolute Luminosity Measurement

- LHC Machine parameters (10% - 5%)
  - Use ZDC in pp and heavy ion runs to understand machine parameters
- Rates of well-calculable processes (5% - 3%):
  - QED: muon-pair production via double-photon
  - QCD: W and Z production
- Luminosity from Coulomb Scattering (~2%):
- Optical theorem: forward elastic rate + total inelastic rate:
  - needs ~full $|\eta|$ coverage - ATLAS coverage limited !
  - Use σ_{tot} measured by others (TOTEM)
  - Combine machine luminosity with optical theorem

Roman Pots

We will pursue all options

ATLAS Forward Detectors

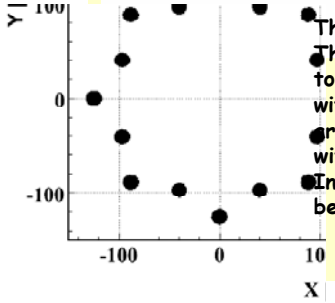


Very Forward Detectors

J. Pinfold et al.

Cherenkov tubes

Relative luminosity monitoring.

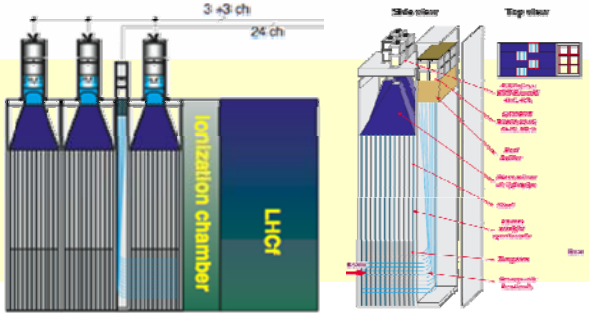


The Phase 1 detector: The present proposal is to build two detectors with 16 tubes each that are read out directly with photomultipliers. In addition, 4 tubes will be read out by fibres.

S. White et al.

Tungsten/Quartz calorimeter

Forward physics in both pp and heavy ion collisions.

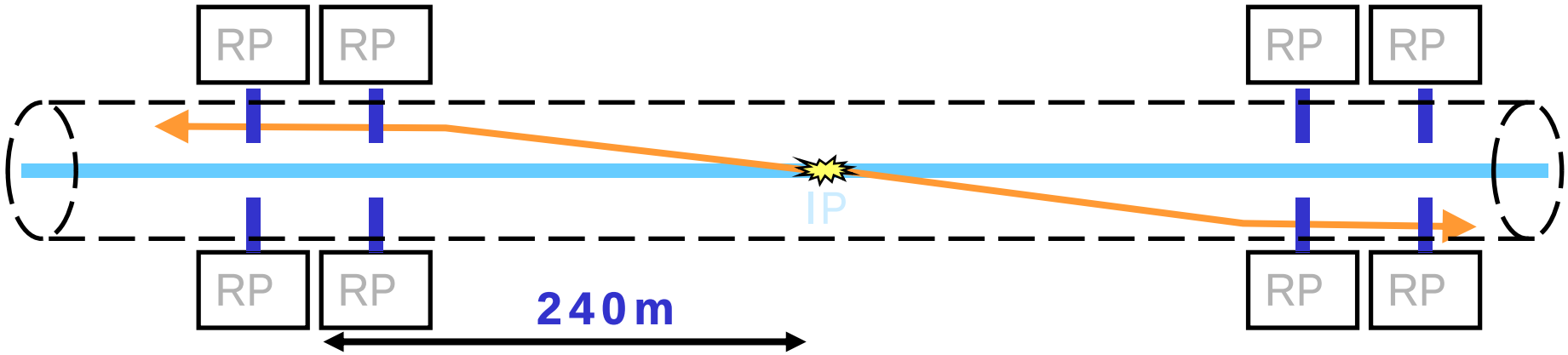


Scintillating fibres in Roman Pots

Absolute luminosity in dedicated LHC runs with

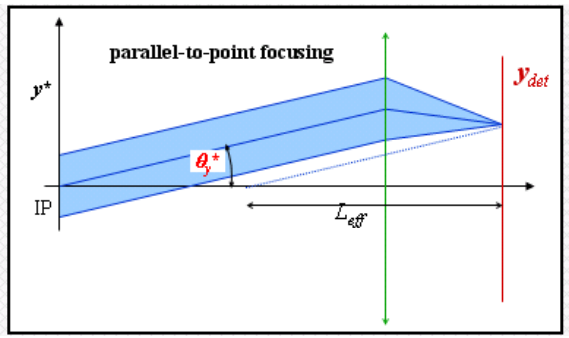
Absolute L from Coulomb Scattering

- Goal: Determine absolute luminosity at IP1 (2-3% precision)
- Measure elastic rate dN/dt in the Coulomb interference region (à la UA4). $|t|$~0.00065 GeV^2 or θ~3.5 μrad.



This requires:

- special beam optics, special runs
- detectors sensitive to ~1.5 mm from LHC beam axis
  - ➔ thin window next to beam
- detectors with minimal inactive edge (< 100 μm)
- detector resolution well below 100 μm (goal 30 μm)
- detectors operating in a secondary vacuum of a Roman Pot



Simulation of Elastic Scattering

hit pattern for 10 M elastic events simulated with PYTHIA + MADX for the beam transport

***t* reconstruction:**

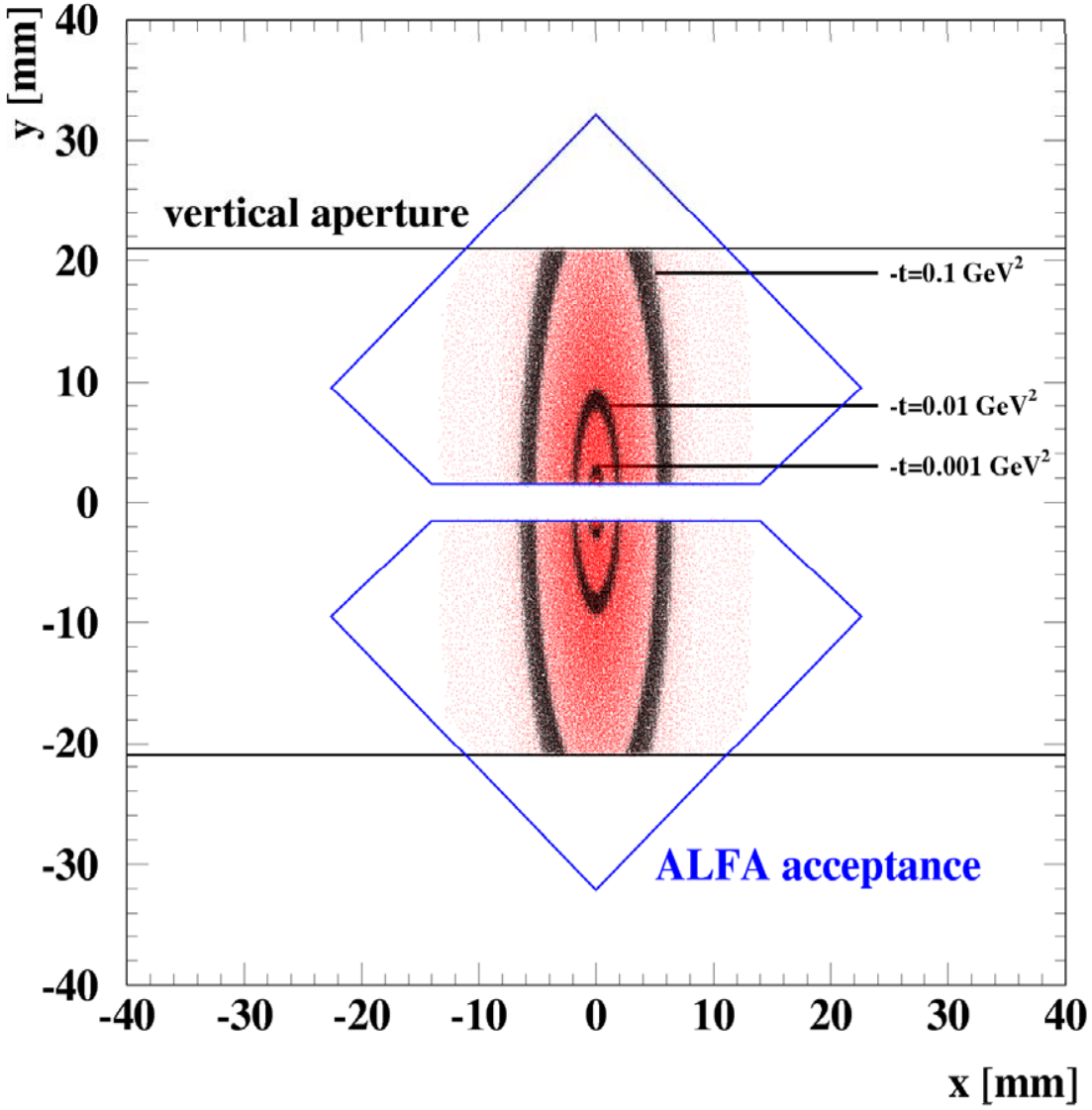
$$-t = \left(p\theta^*\right)^2 = p^2\left(\bar{\theta}_x^2 + \bar{\theta}_y^2\right)$$

$$= p^2\left(\left(\frac{\bar{x}}{L_{eff,x}}\right)^2 + \left(\frac{\bar{y}}{L_{eff,y}}\right)^2\right)$$

- special optics
- parallel-to-point focusing
- very high β*

$$L_{eff} = \sqrt{\beta\beta^*} \cdot \sin\Psi$$

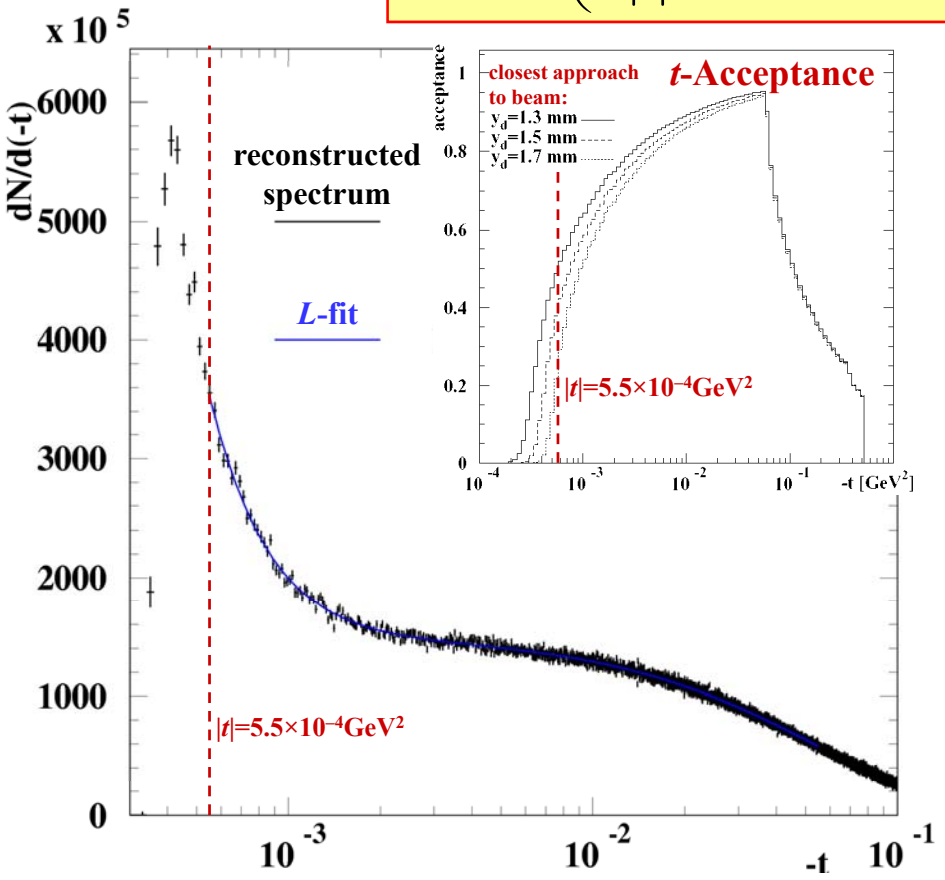
$$\Psi_y \approx \frac{\pi}{2}$$



L from Fit to the t-Spectrum

$$\frac{dN}{dt} = L\pi\left|F_C + F_N\right|^2$$

$$= L\left(\frac{4\pi\alpha^2}{|t|^2} - \frac{\alpha\rho\sigma_{tot}e^{-B|t|/2}}{|t|} + \frac{\sigma_{tot}^2\left(1+\rho^2\right)e^{-B|t|}}{16\pi}\right)$$



Simulated 10 M events (equivalent run time: 100 hrs)
fit range: 0.00055-0.055 GeV²

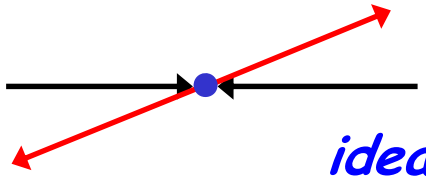
	input	fit	error	corre-lation
L	8.10×10^{26}	8.151×10^{26}	1.77 %	
σ_{tot}	101.5 mb	101.14 mb	0.9%	-99%
B	18 GeV^{-2}	17.93 GeV^2	0.3%	57%
ρ	0.15	0.143	4.3%	89%

large correlation between L and other parameters!

t-Resolution

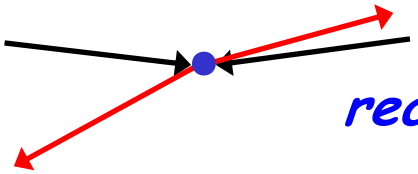
The t-resolution is dominated by the divergence of the incoming beams.

$\sigma' = 0.23\ \mu\text{rad}$

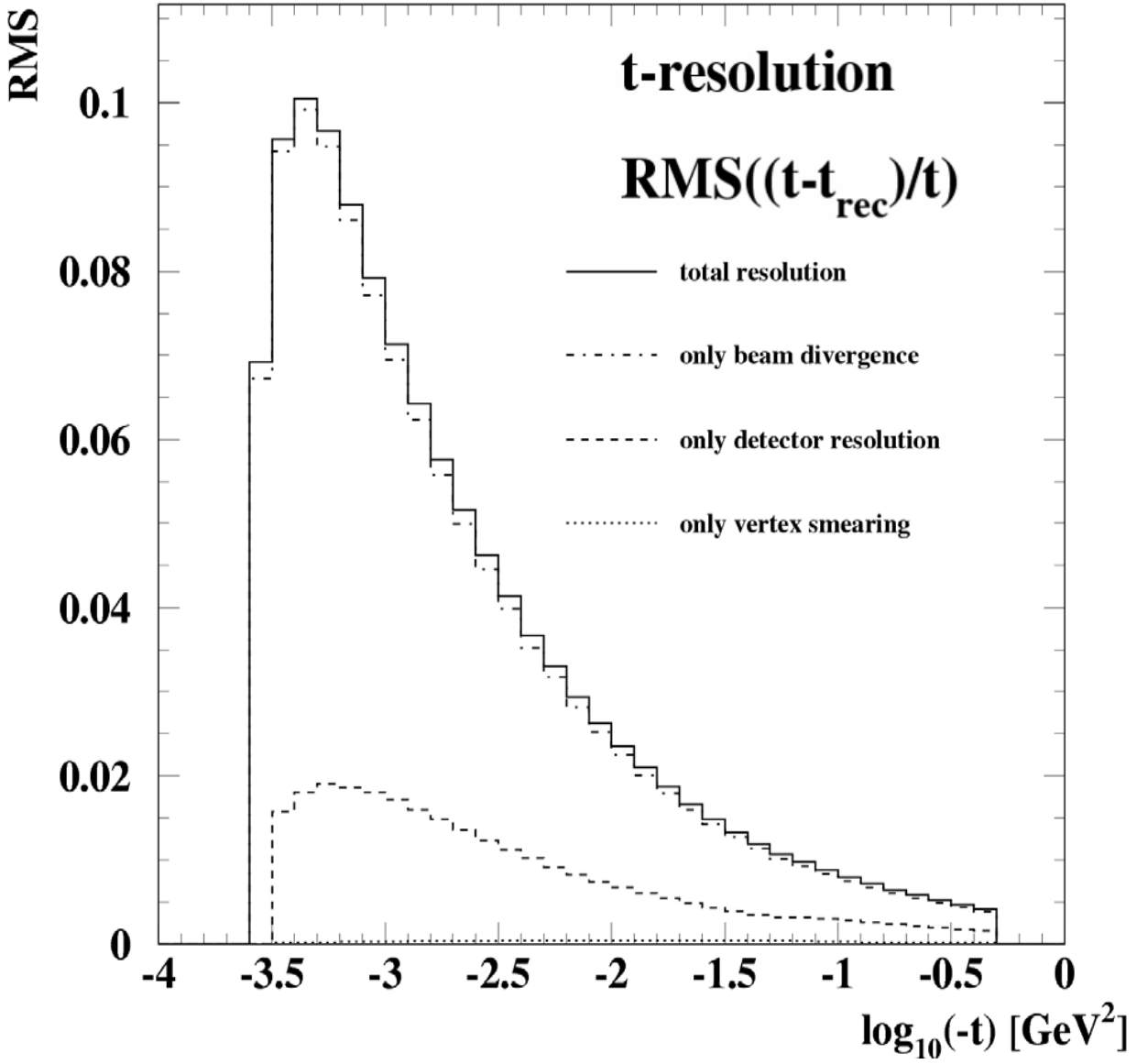


ideal case

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



real world



Systematic Uncertainties

From Technical Design Report:

	(%)
▪ beam divergence	0.31
▪ detector resolution	0.35
▪ detector alignment	1.30 (±10μm)
▪ acceptance	0.52
▪ beam optics	1.17 ($\Delta\Psi_{Hor}$)
▪ Background subtraction	1.10 (stat)

$$\Delta L/L \approx 1.8\%(\text{stat}) \oplus 2.2\%(\text{syst}) = 2.8\%$$

Further study is ongoing…

Luminosity Transfer $10^{27} \rightarrow 10^{34}$ $cm^{-2}s^{-1}$

- Bunches are resolved ⇒ consider luminosity/bunch
  ⇒ range: ~2 x10^{-4} to ~20 interactions/bunch

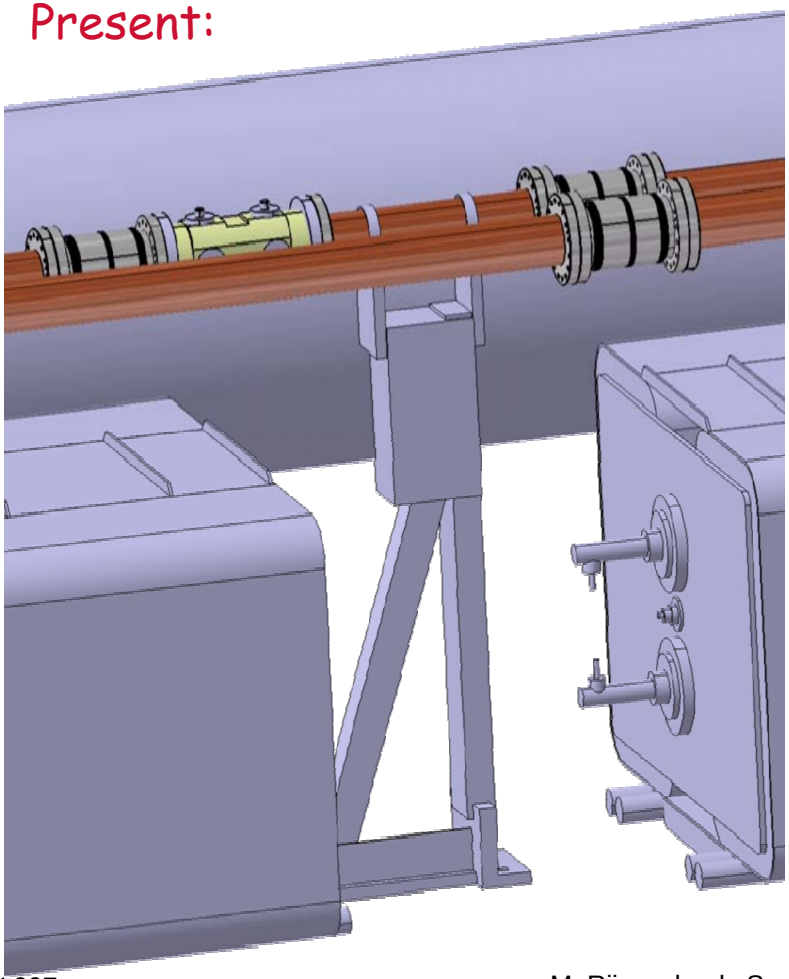
⇓

- Required dynamic range of the detector: ~20

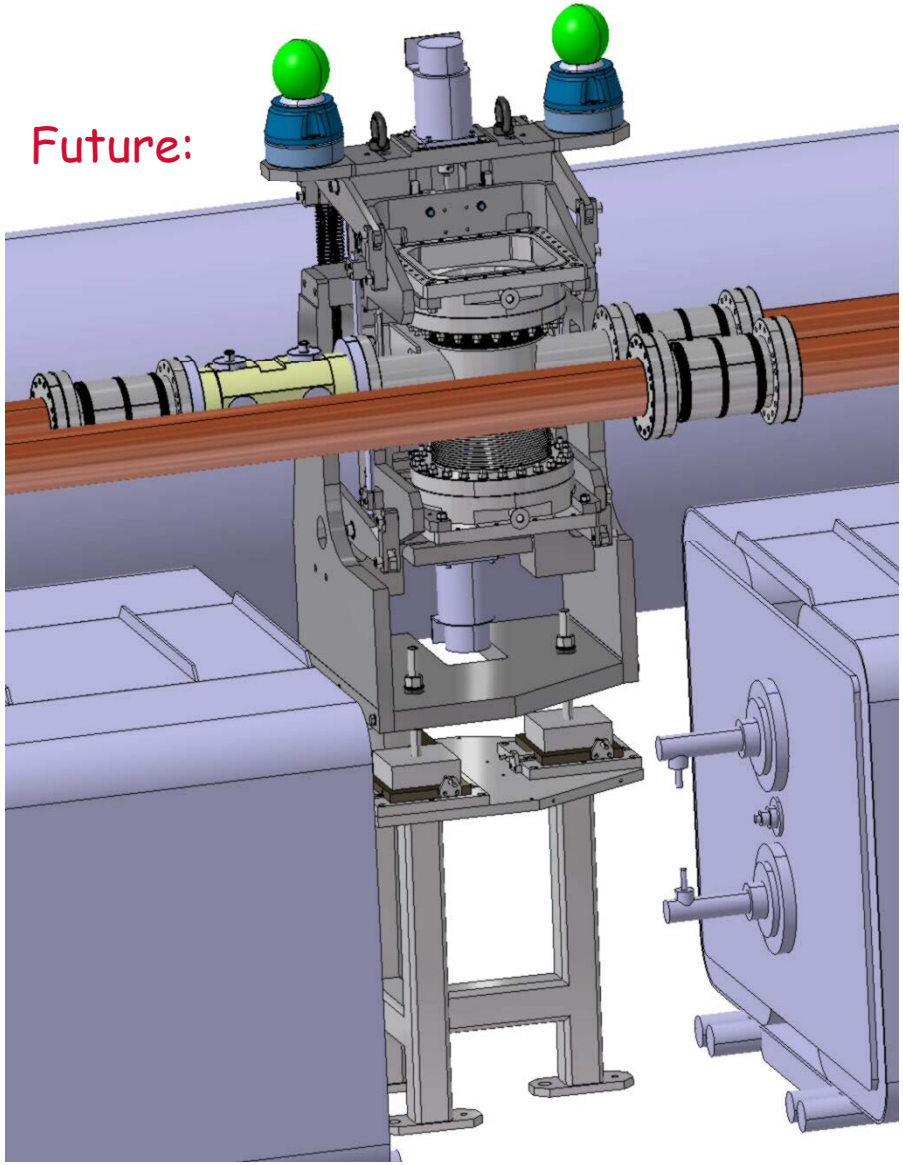
- Background: must be <<2 x10^{-4} interactions per bunch
  - main background is from beam-gas interactions
  - Dynamic vacuum difficult to estimate but at low luminosity we will be close to the static vacuum.
  - Static vacuum ⇒ beam gas ~10^{-7} interactions /bunch/m
  - We are in the process of performing MC calculation to see how much of this will affect LUCID

Positioning

Present:

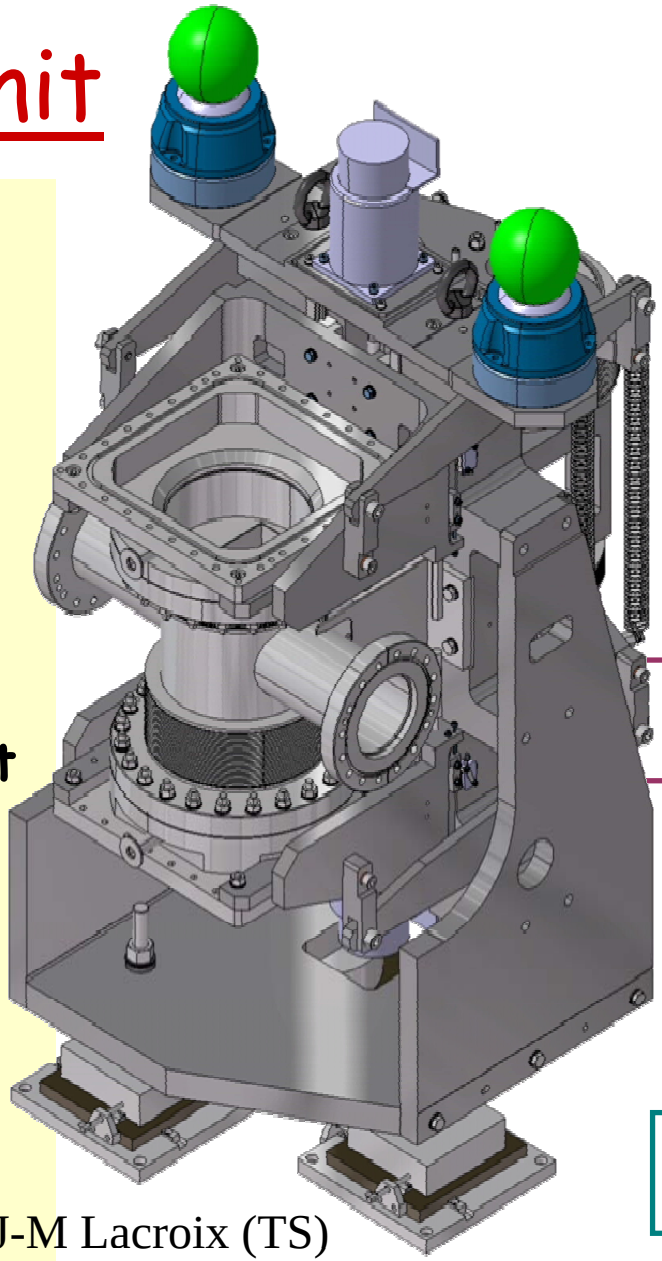


Future:



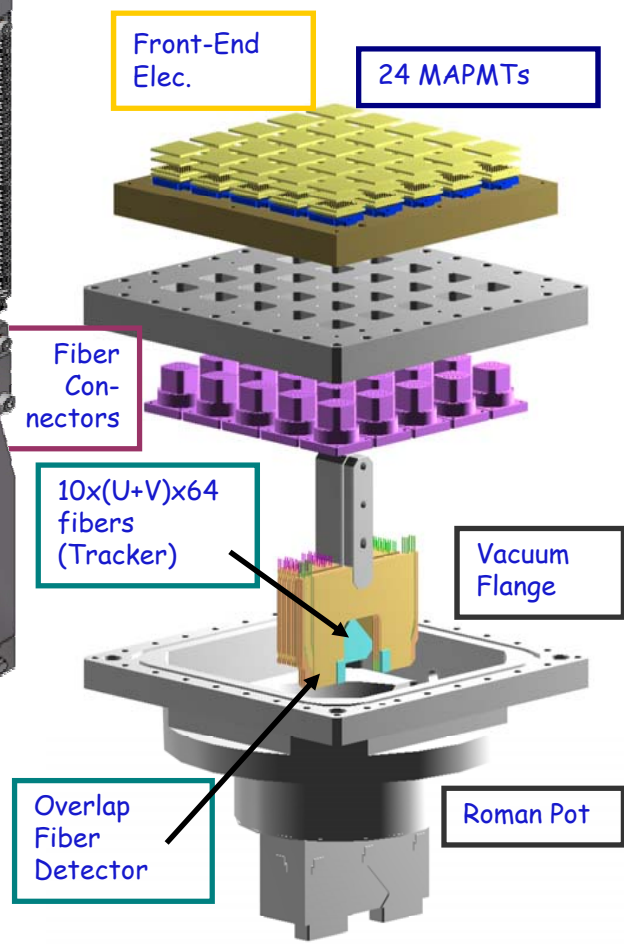
ATLAS RP Unit

- Based on TOTEM design
- Changes:
  - No horizontal pot
  - Different mounting of Pot on flanges
  - Modifications to respect beam height and to make the extraction of the bottom Pot easier…

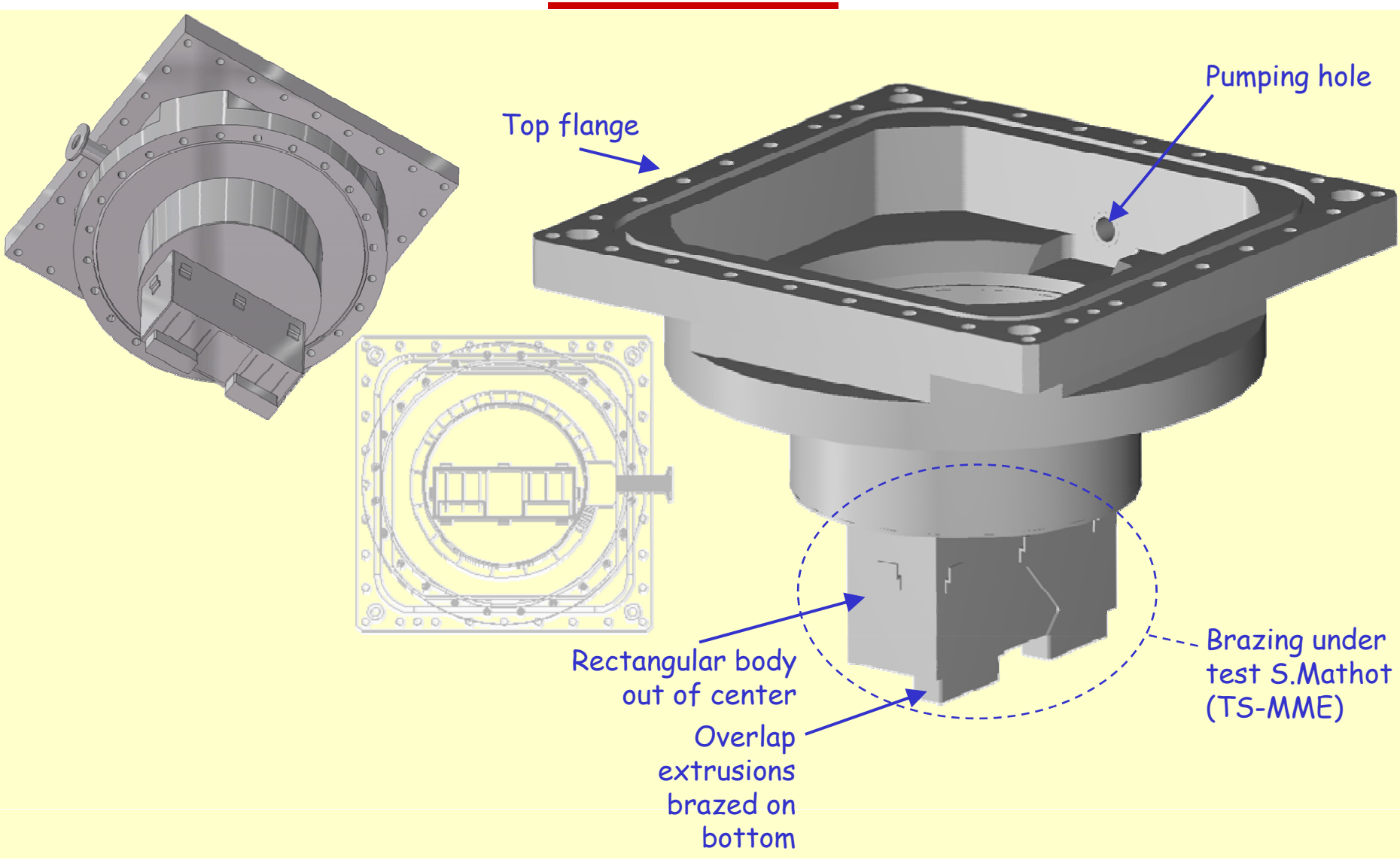


Designer: J-M Lacroix (TS)

Pot and Detector Package



Final Pot

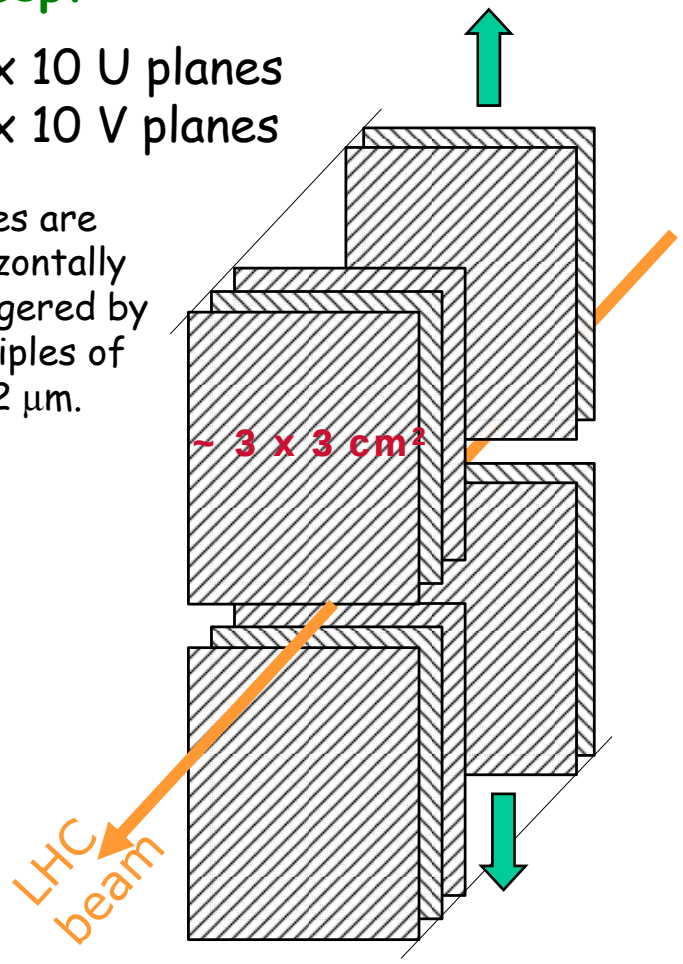

Pumping hole
Top flange
Rectangular body
out of center
Overlap
extrusions
brazed on
bottom
Brazing under
test S.Mathot
(TS-MME)

Scintillating Fiber Tracker

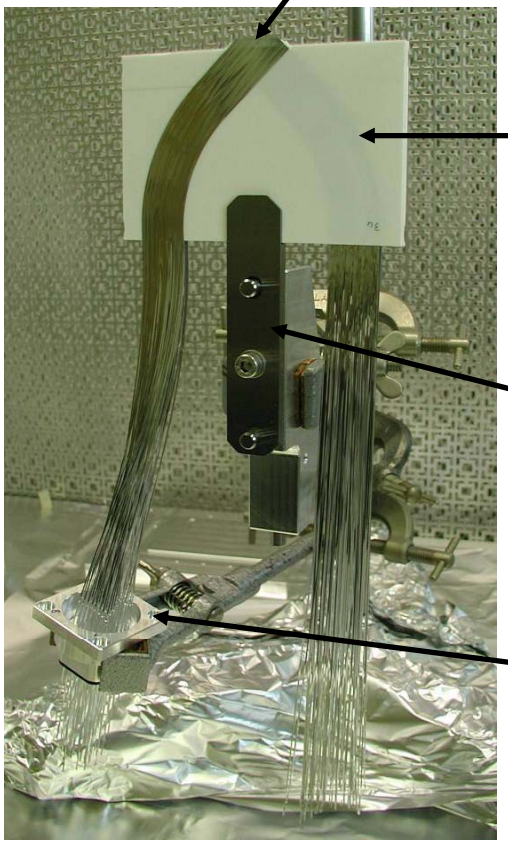
Concept:

- 2 x 10 U planes
- 2 x 10 V planes

planes are horizontally staggered by multiples of 50√2 μm.



- 64 scintillating fibers
- 0.5mmx0.5mm cross section



DESY Testbeam - November 2005

Detectors:

Two different types were built: measure light yield, efficiency, cross talk, edge sensitivity, resolution, etc.

Base line fiber:
SCSF-78, S-type
Kuraray 0.5mm-square
single-clad

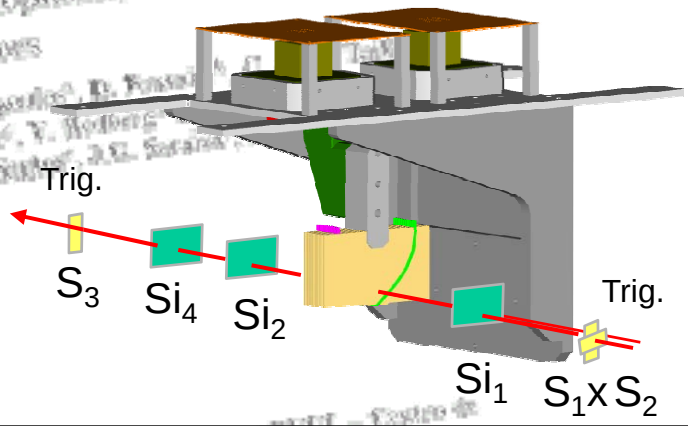
Beam:

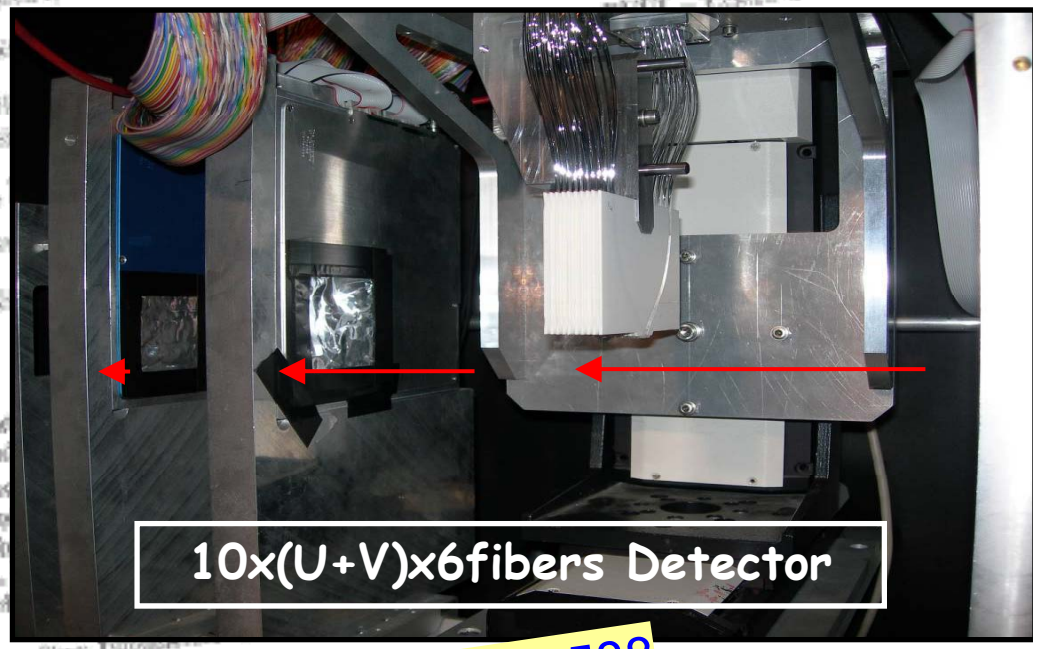
- 6 GeV electrons

Beam spot ~ 1 cm^2

Setup:

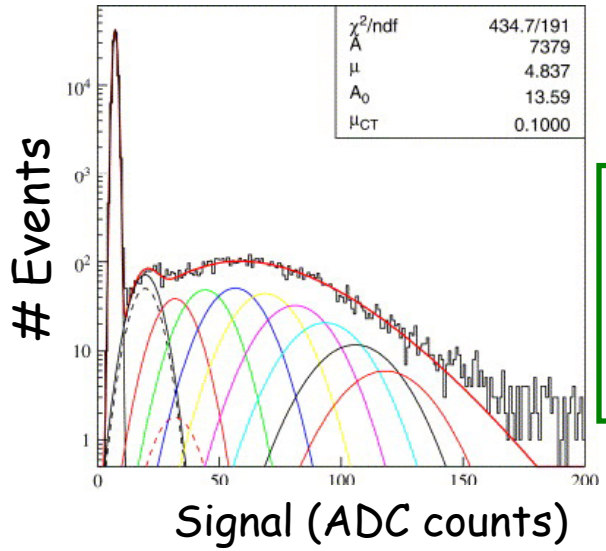
- Si telescope (~30 μm resolution)
- MAPMT – CAEN QDCs – PC



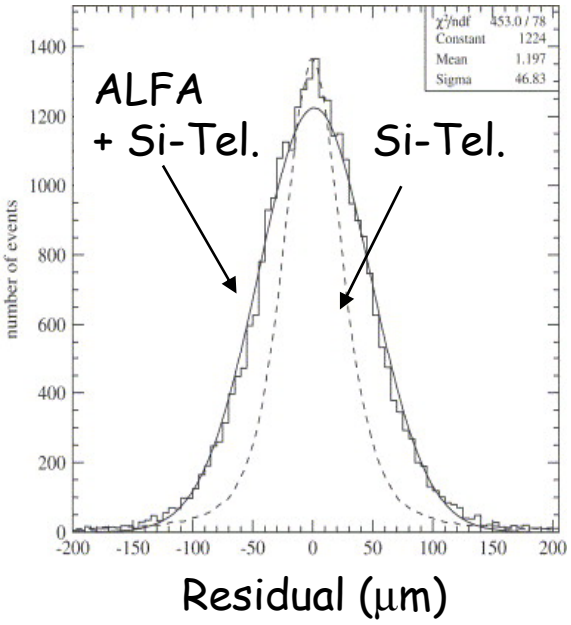


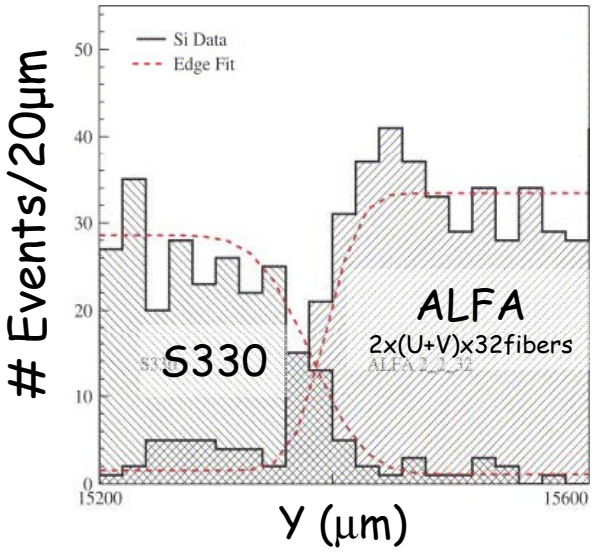
Published NIM **A** 568 (2006) 588

DESY Testbeam published results



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



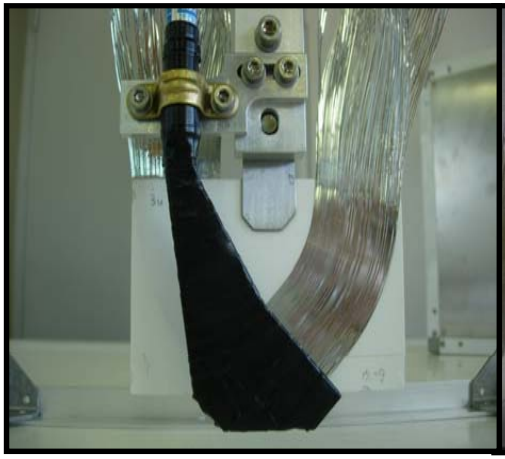


Inactive Edge:
<<100 μm

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

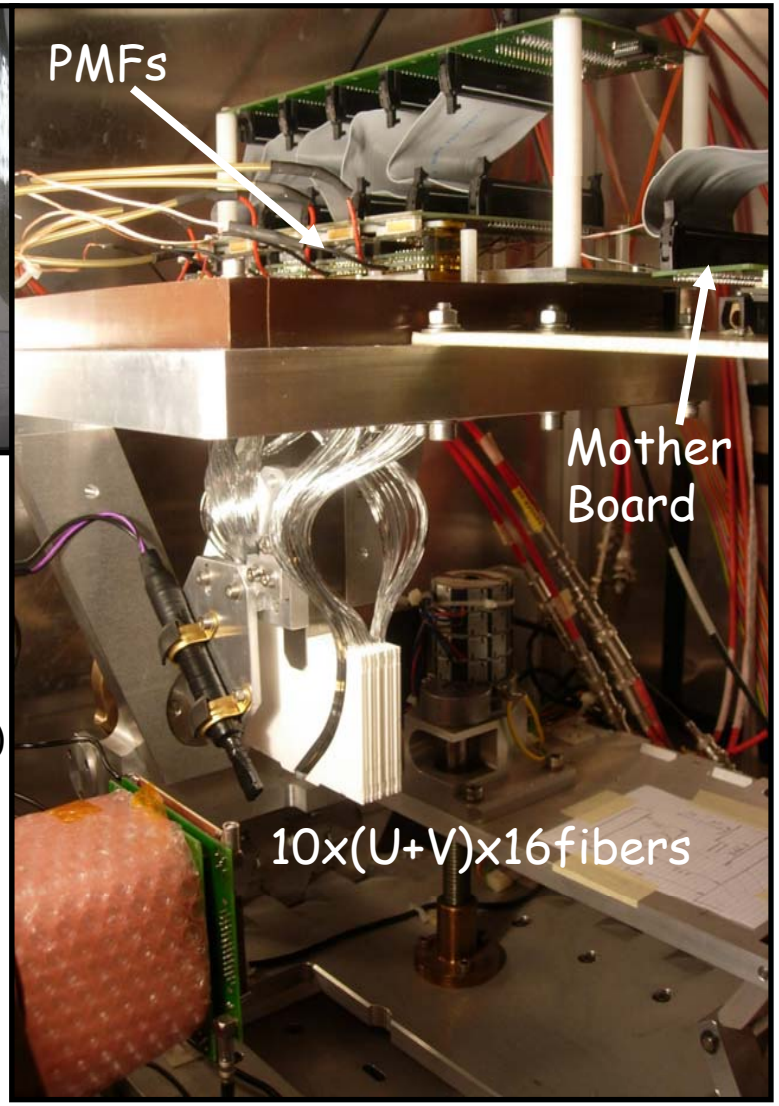
(Possibly increased by multiple scattering of the relatively low energy 6 GeV electron beam)

CERN Testbeam - October 2006



2x(U+V)x64fibers
+ Final Trig.

Overlap Detectors



Detectors

- Two ALFA trackers (larger than at DESY TB)
- Overlap Detectors

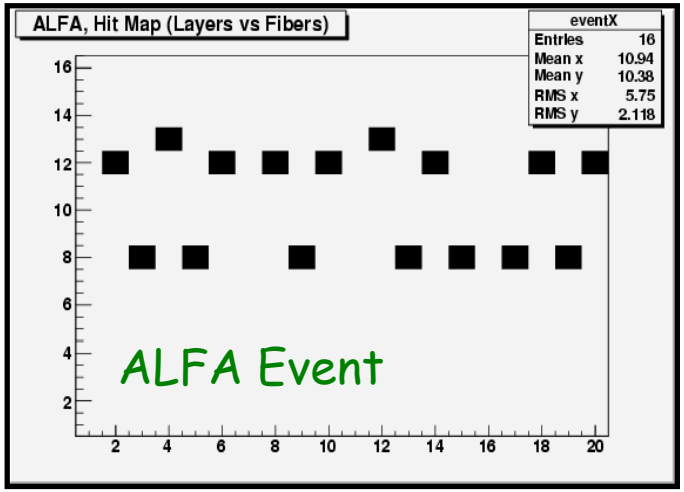
Beam

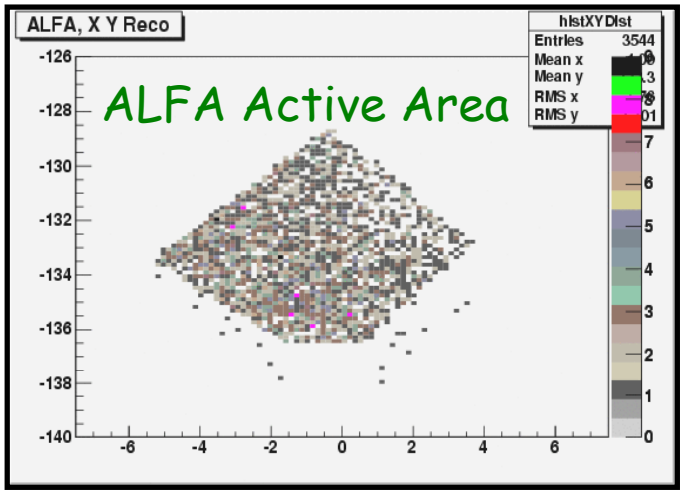
- 230 GeV protons ($\pi^{+/-}$)

Setup

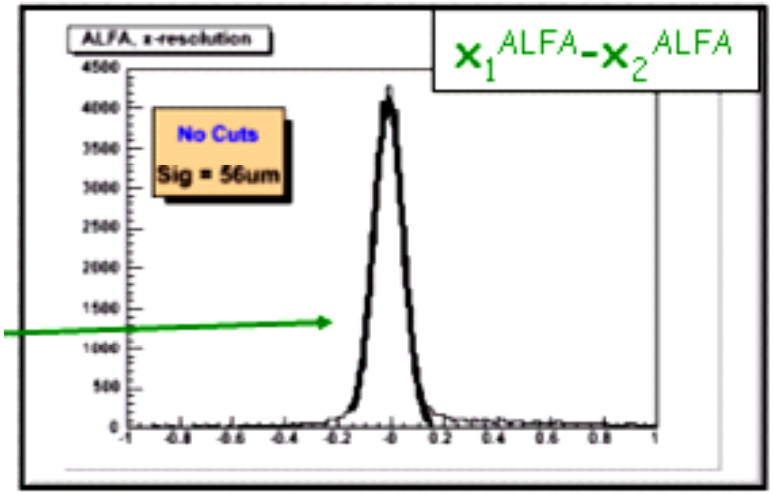
- 5 x MAPMT – 5 x PMF - Motherboard – PC

CERN'07 Testbeam: very preliminary





σ =56μm



(Reconstructed using 2 x half of ALFA)

σ_{half}=40μm (MC ideal Geom: σ_{half}=30μm)

"Online" Results !

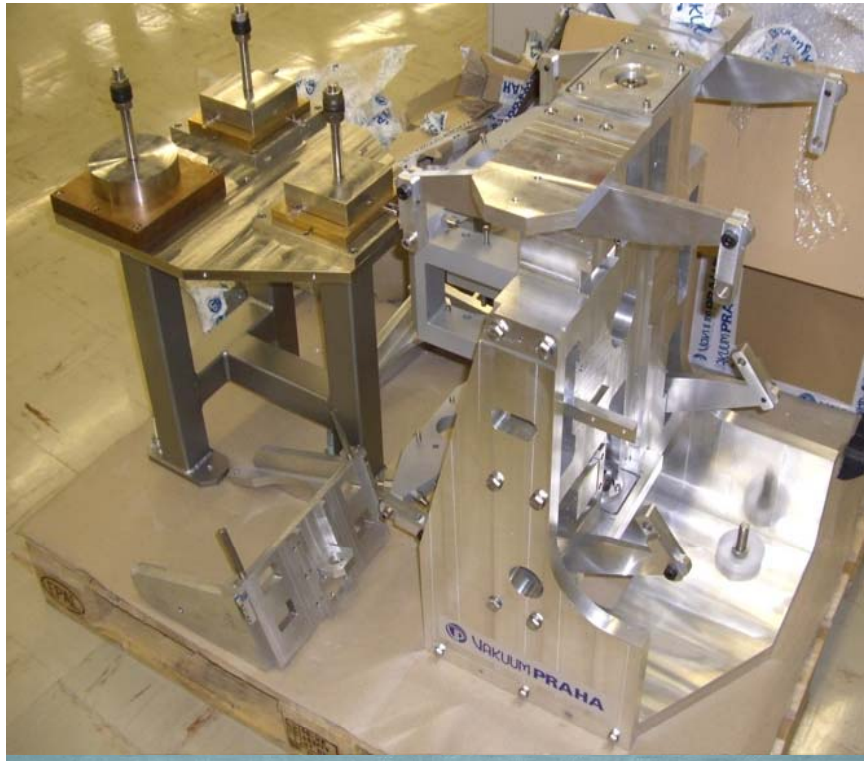
Offline analysis ongoing

Status of the Mechanics

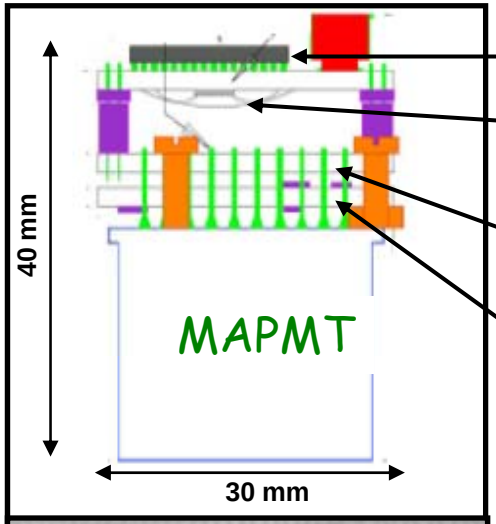
- Received pre-series Roman Pot Unit at CERN
  - Assembled and being tested by PH/DT1 team
  - Will be a fully operational Roman Pot Unit
    Will be used to develop the control system and the cable routing and patch panels
  - Investigate the precision of the Pot movement:
    Verification of deformations under vacuum
    Assessment of the achievable precision and reproducibility
  - Foreseen to use in 2007 testbeam setup

- We will start the final procurement after pre-series sign-off
  - 4 Roman Pot Units

Prague Roman Pot Unit



Final front-end electronics



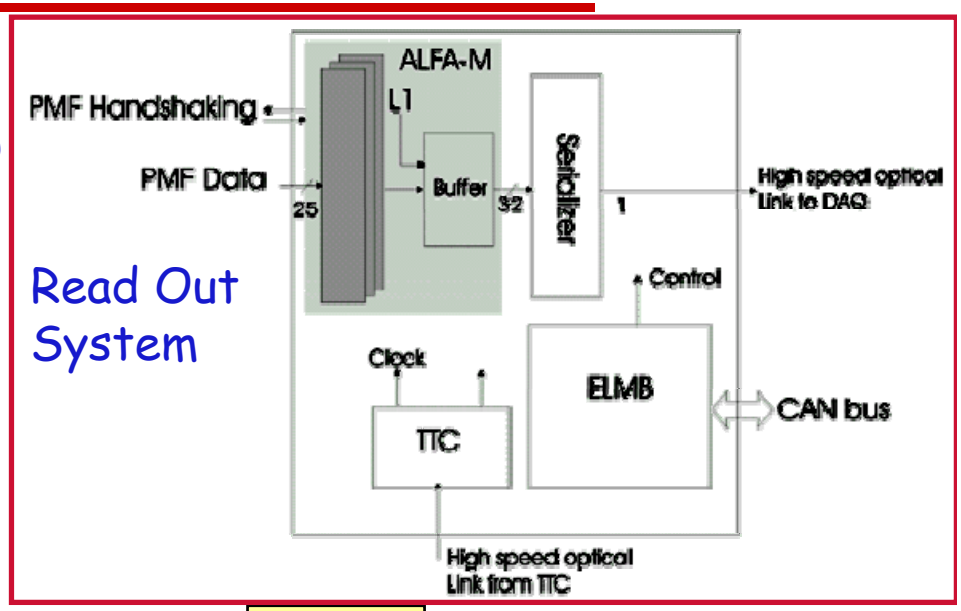
R/O FPGA

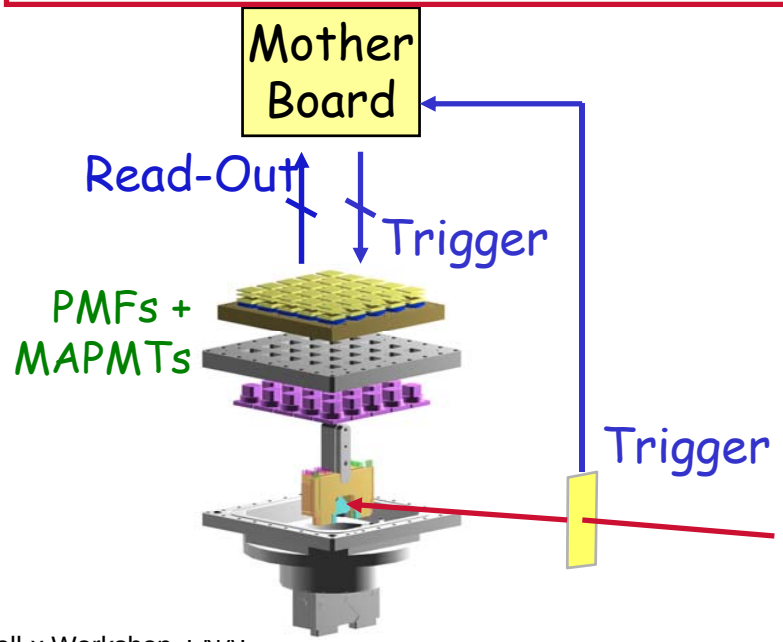
MAROC R/O chip
(64 x Amp. + Disc.)

Adaptor Board

HV Board

PMF
(PM Front-End)





Scheduling

- **Tunnel:**
  - LHC-IP1-Q4 Manual Polarity switches in place
  - Cables in place, ancillary elements being procured
  - RPU Patch panels being prepared
  - Movable vacuum equipment to be procured

- **Roman Pot Units**
  - 4 Units to be procured - after sign off on pre-series
  - Procurement of motors, screws, rails and misc. has started
    Currently foreseen delivery: Spring-Summer 2007
  - Installation in May 2007 seems difficult, not yet impossible
    We would only install the mechanics, with pots or covers. All locked in safe position.
    Otherwise, will wait for the 2007/2008 shutdown.
- **Pots**
  - First prototype being prepared
    Will be tested under vacuum
    One or two will be used for the future test beam
  - Simulation of RF compatibility ongoing and tests to be done
  - Final production in sync with Roman Pot Units production - All material procured
- **Detectors and electronics:**
  - Concepts tested and proven suitable for our application
    Improving various details
    plan another beam test in 2007
  - Aiming for installation during 2008/09 shutdown

Commissioning: Shutdown 2008/09

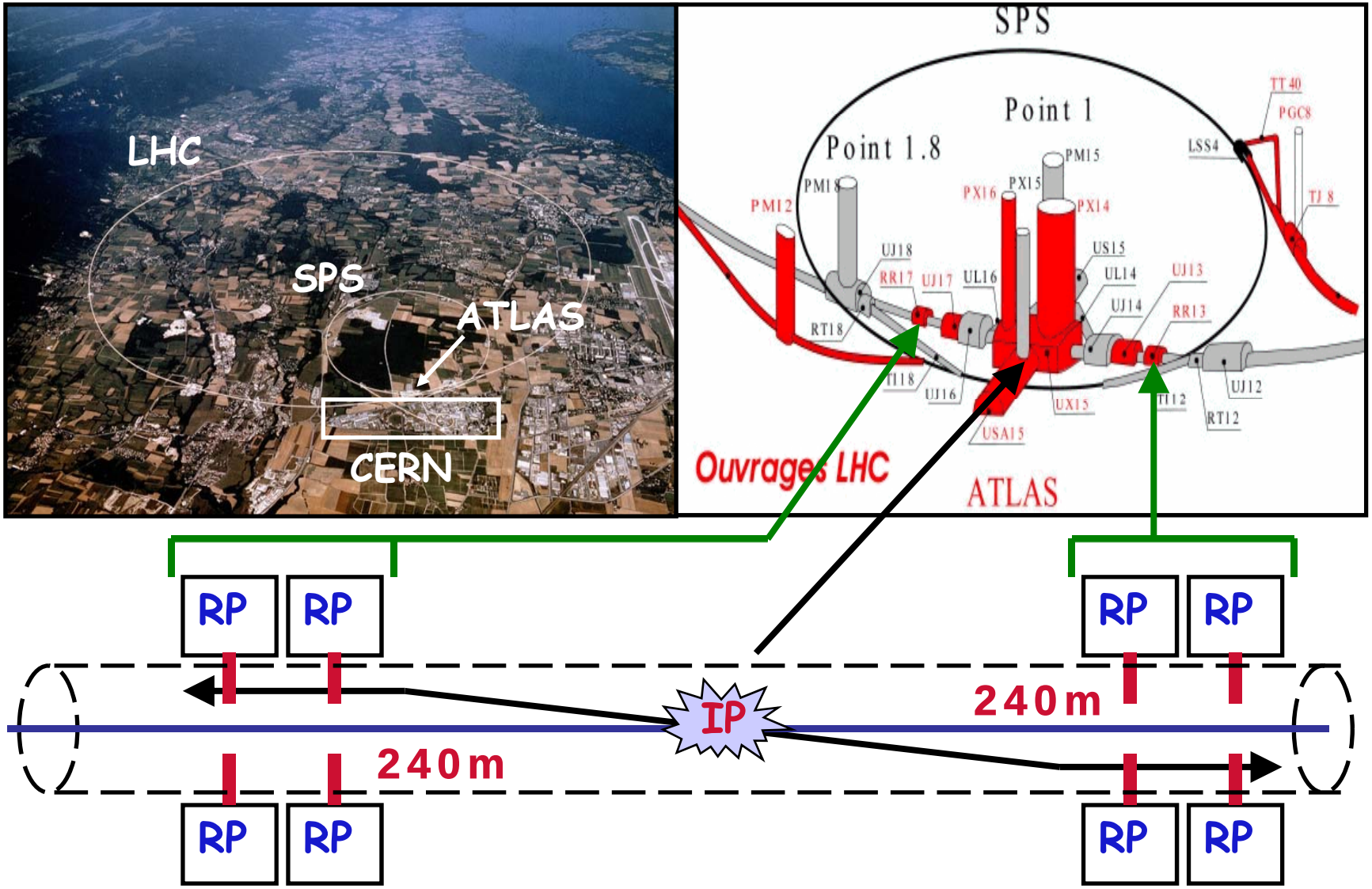
- **Commissioning during shutdown:**
  - **Movements and controls**
  - **Access procedures**
  - **Safety procedures**
  - **Vacuum system**
  - **Interlocks**
  - **Simulation of normal and alarm conditions**

First Operations: 2009 run

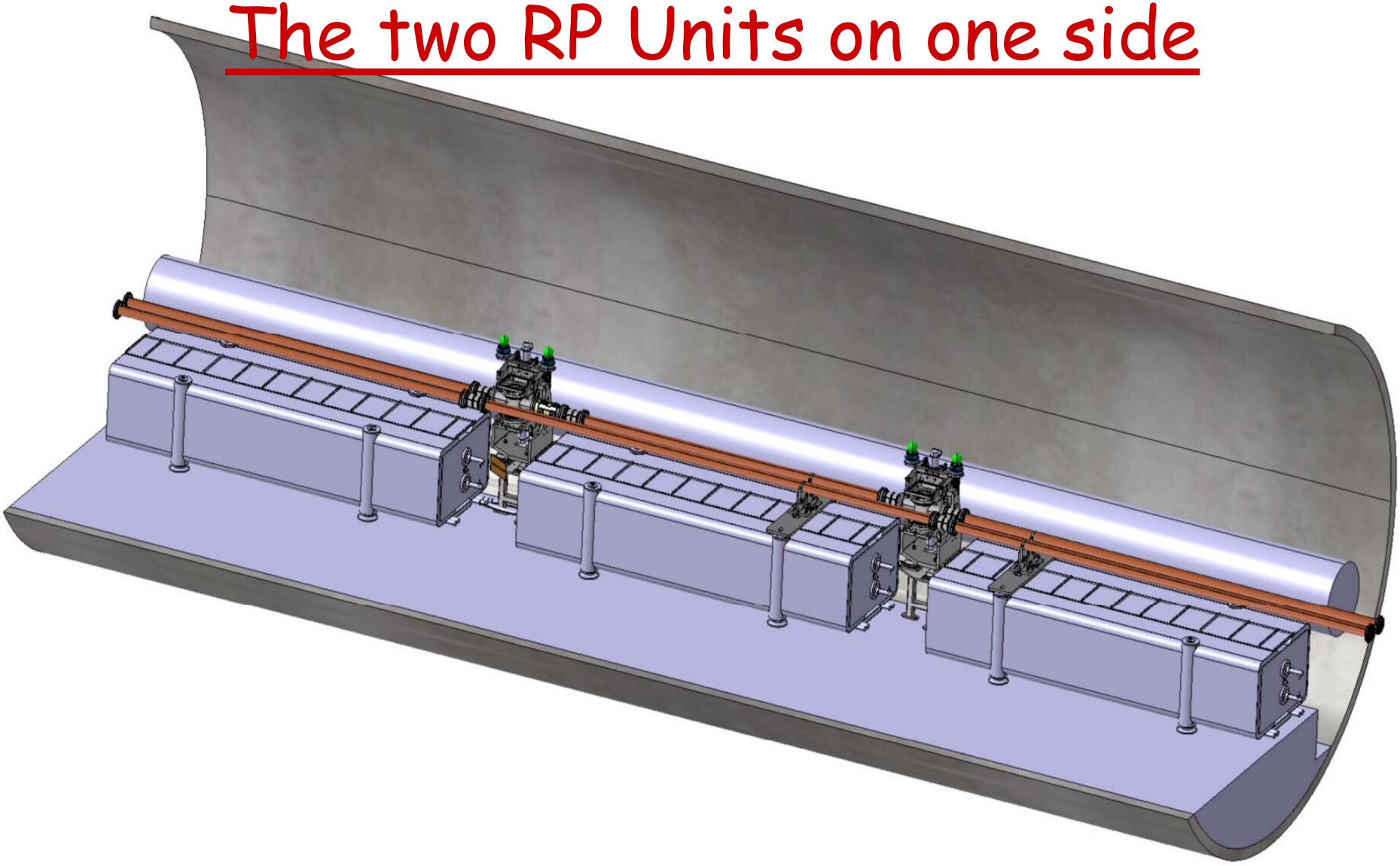
- **With standard low-β optics, at moderate luminosity:**
  - **In "park" position**
    - **Detector commissioning with halo particles**
    - **Background studies**
- **With high-β optics:**
  - **Approach to the beam**
  - **Detector commissioning (1st time)**
  - **Test on overlap detectors**
  - **Normal running**

Backup Slides

ATLAS Roman Pot locations



The two RP Units on one side



Top view of the detector in the pot