Status & Prospects of the ALFA stations

LHC Lumi Days, January 13-14, 2010

K.Hiller, DESY on behalf of ATLAS

Outline:

1) Principle of the luminosity measurement with ALFA

2) Detector performance from test beam measurements

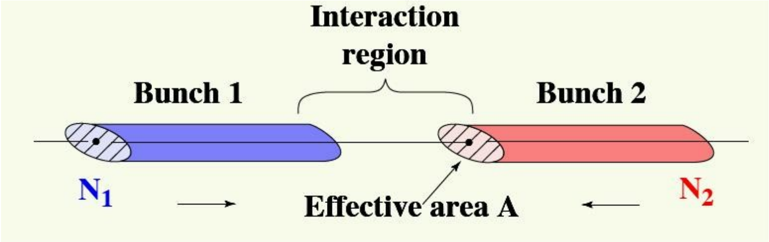
3) Status of the installation in the LHC tunnel

4) Prospects for data taking 2011 and beyond

The 2 ways of luminosity measurement

Direct from machine parameters

$$L = \frac{f \cdot N_1 \cdot N_2}{A}$$



Input:
- beam currents
- crossing area (e.g. from transverse beam scans)

Precision:
~ 10% at LHC startup,
~ 5 % with best systematics

Indirect from rates via *L = N / σ*

$$L = \frac{(N_{sig} - N_{bg})}{(\varepsilon \cdot acc \cdot \sigma)}$$

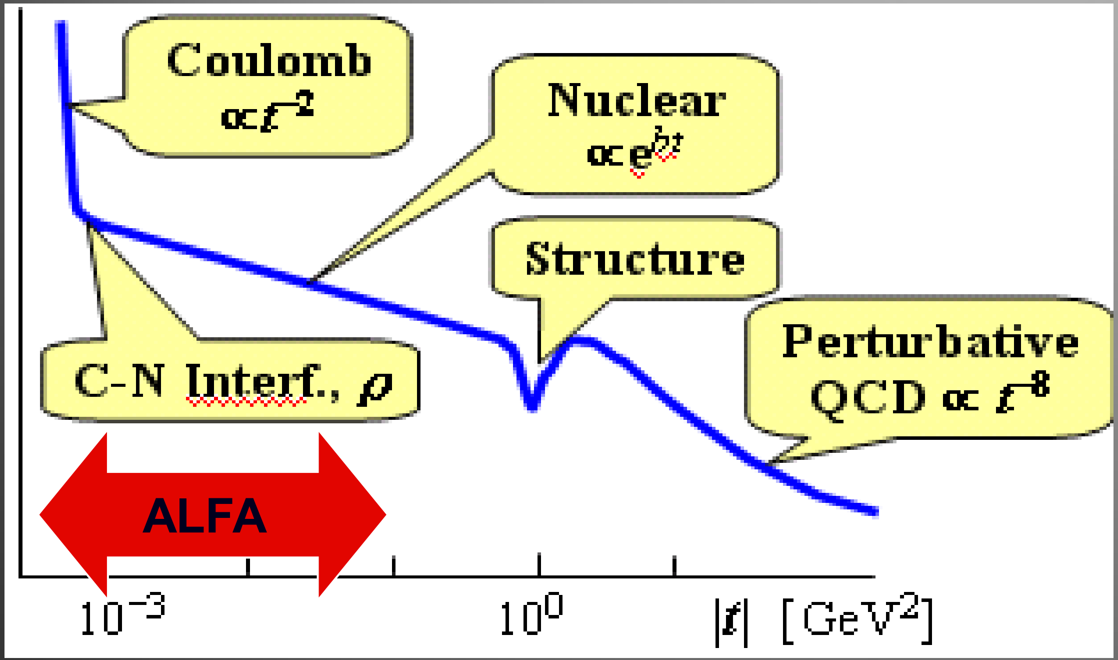
Input:
- cross sections e.g. W/Z from PDFs, or σ_{tot} via optical theorem
- efficiency, acceptance and backgrounds

ALFA concept to determine the luminosity from small angle proton scattering:

1) total + elastic rates + optical theorem limited due to ATLAS η range
2) elastic rate + σ_{tot}, e.g. TOTEM
3) elastic rate in the Coulomb-Nuclear Interference region

Concept of the ALFA measurement

Elastic scattering in the Coulomb-Nuclear interference region:



$$\frac{dN}{dt} \approx L\pi \left| -\frac{2\alpha}{|t|} + \frac{\sigma_{tot}}{4\pi}(i+\rho)\exp(-b|t|/2) \right|^2$$

L = luminosity , σ_{tot} = total cross section

$\rho = \mathrm{Re}\ f_{el} / \mathrm{Im}\ f_{el}(t=0)$, b = nuclear slope

Measurement program:

1) start from a well-known theoretical rate dependence

2) measure unbiased elastic rate

3) fit luminosity and 3 other free parameters to dN / dt

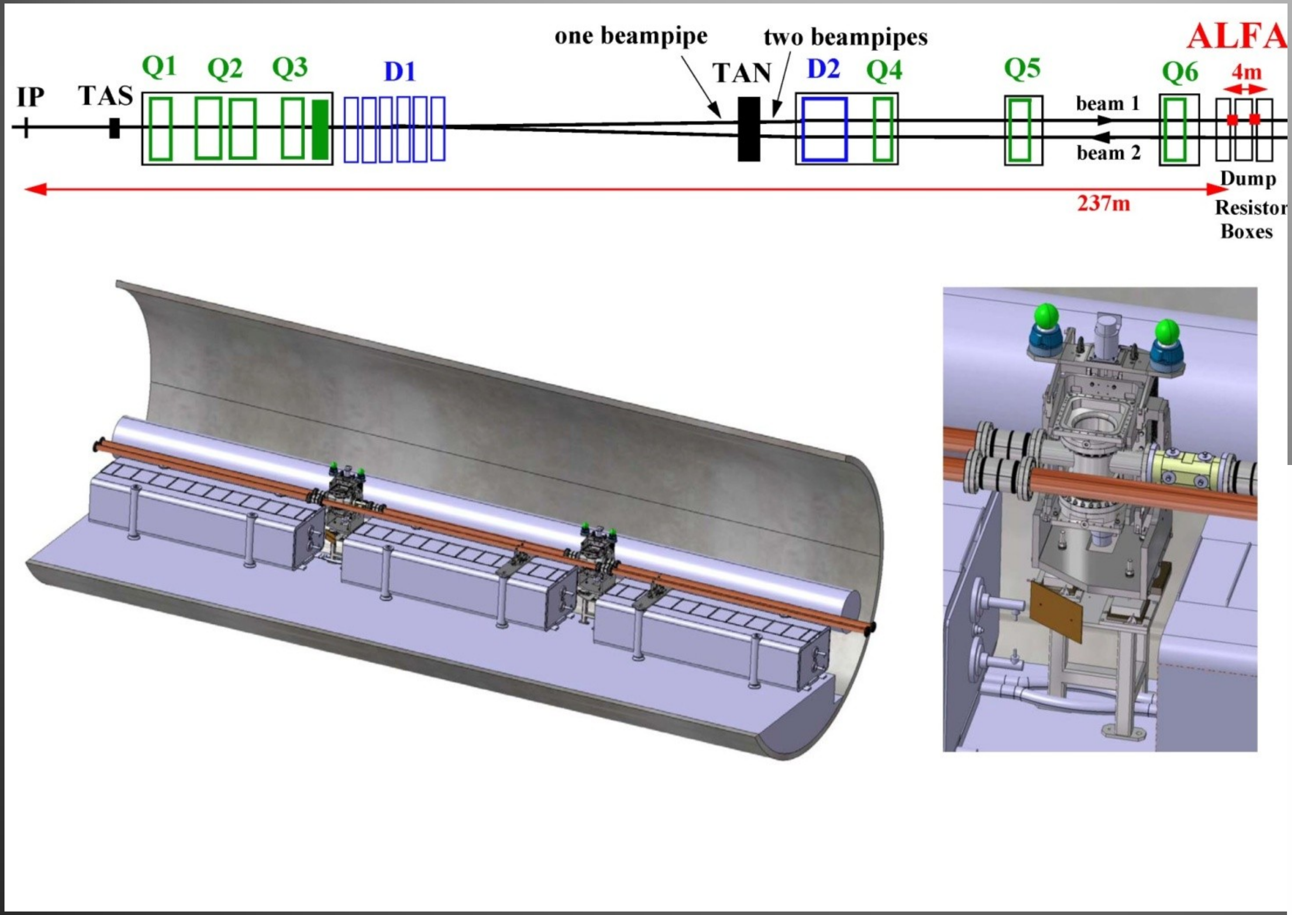
Main conditions to reach the Coulomb region $|t| < 10^{-3}$ GeV^2

→ Detector positions far from IP

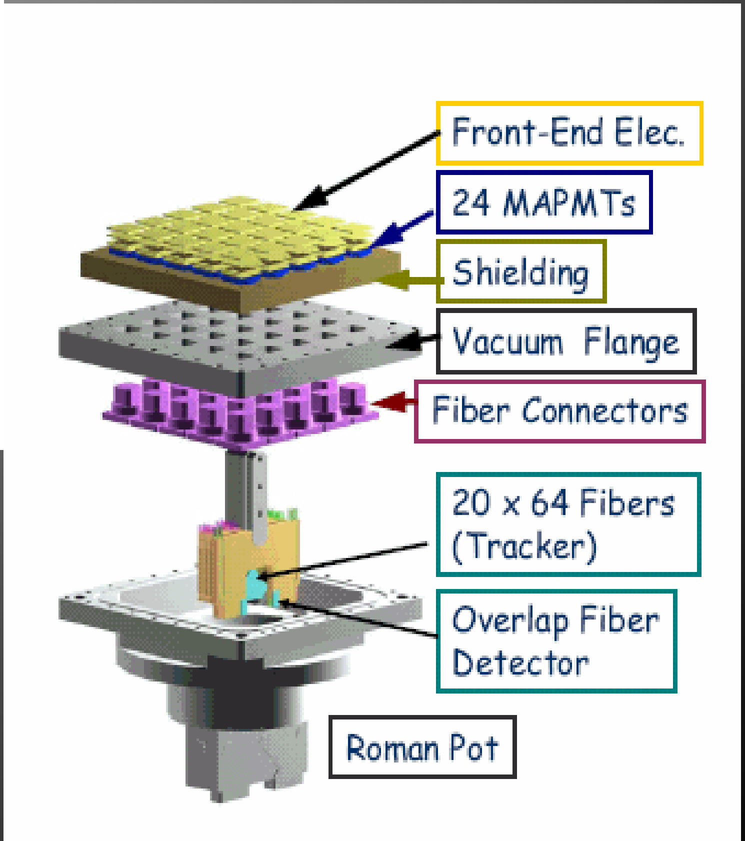
→ Special beam settings

→ Detectors close to beam

ALFA stations in the LHC tunnel



Multi-layer fiber detectors readout by Multi-Anode PMTs in Roman Pots



2 stations on both sides far from the IP approaching the beam in the vertical coordinate.

High-β* optics for ALFA runs

- Use of standard collision optics impossible due to beam divergence at IP:

$$\sigma(y') = \sqrt{\varepsilon / \beta^*} \text{ , with emittance } \varepsilon \text{ and } \beta^* \text{ at IP}$$

- Distance of scattered proton from nominal beam line depends on y* and Θ*:

$$y = \sqrt{\beta / \beta^*}\left(\cos\Psi + \alpha^* \sin\Psi\right) y^* + \sqrt{\beta\beta^*} \sin\Psi\, \theta_y^*$$

In the left-right difference of y-coordinates the unknown vertex offset cancels

$$(y_L - y_R) = 2\Theta^* \sqrt{\beta\beta^*} \sin(\Psi)$$

- For phase advance ψ = 90° parallel-to-point focusing possible: protons with same angles at IP focus to same position y in ALFA

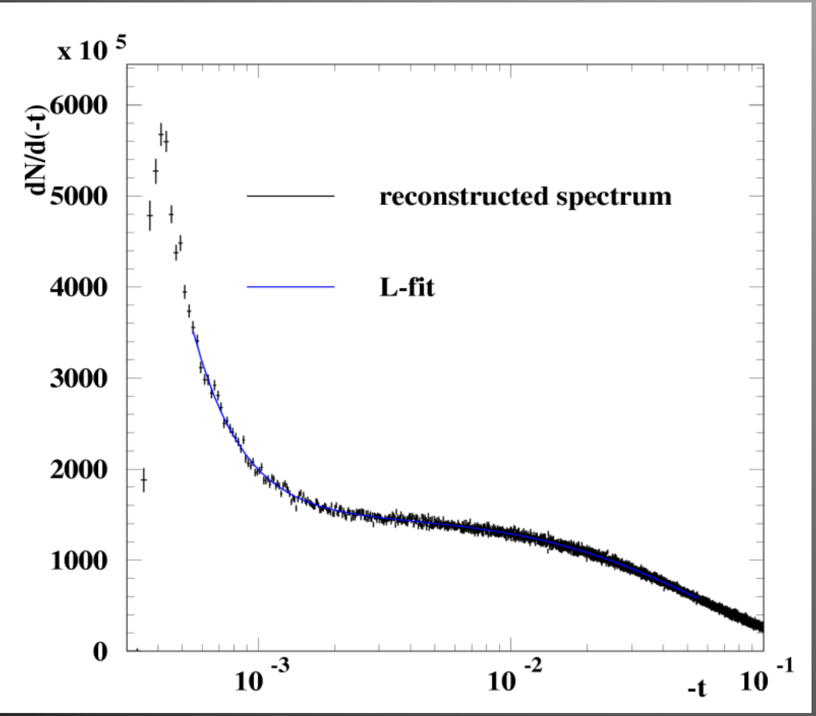
Special runs for ALFA with:

- Small beam divergence at IP by β* = 2625m, ε = 1μm rad,
- Vertical phase advance ψ = 90°
- 0-crossing that scattered protons hit the detectors
- Moderate number of bunches

All this implies running at low luminosity L ~ 10^{-27-28} $cm^{-2}s^{-1}$

Estimate of luminosity precision

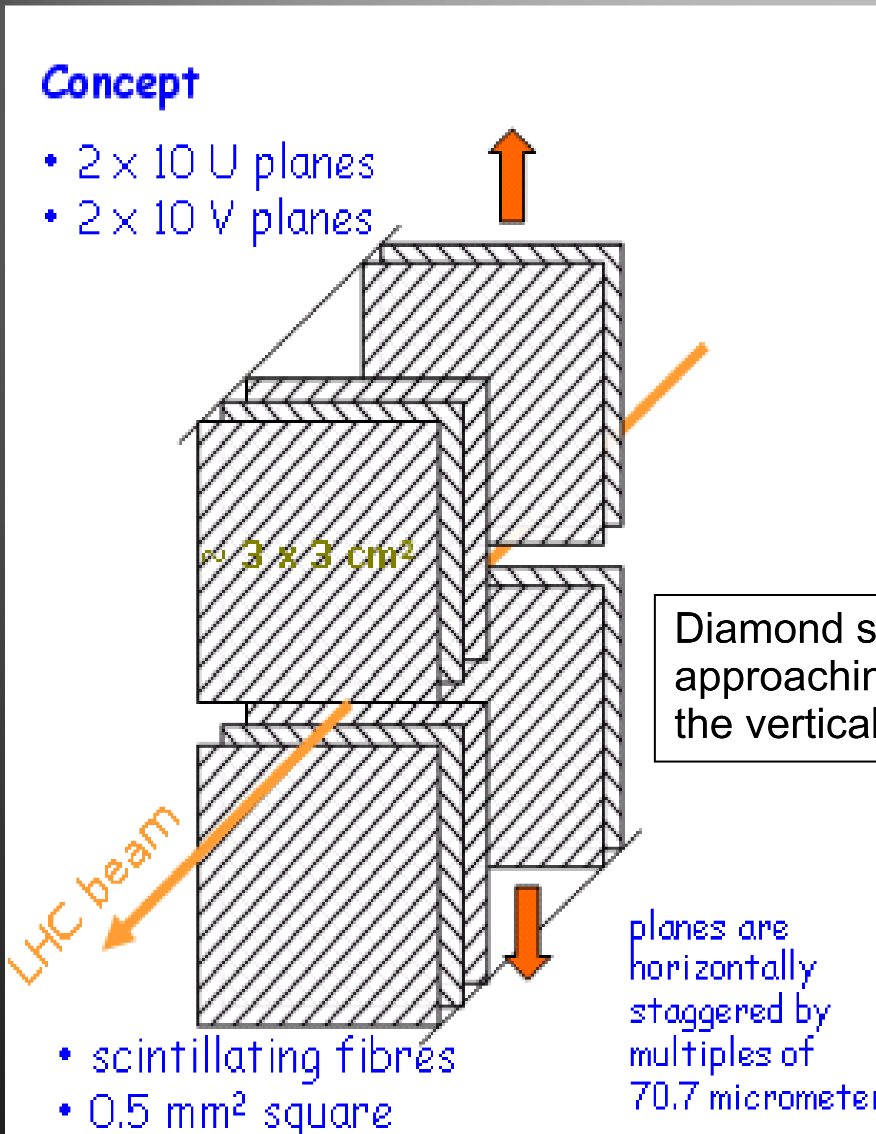
Simulation of elastic protons including beam optics and detector effects and detectors in a distance of 12σ = 1.5 mm to the beam.

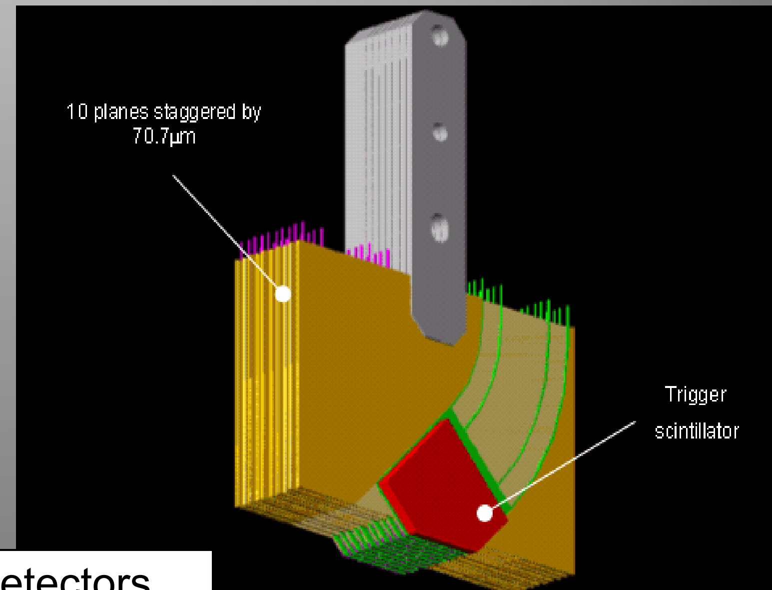


Variable	Input	Uncertainty %
Statistics	6.6 million, 1.5mm	1.77
Beam divergence	+-10%	0.31
Crossing angle	+- 0.2 μrad	0.18
Optical functions	β* 1%, β 2%	0.59
Phase advance	+- 0.5 degree	1.0
Detector alignment	+- 10 μm	1.3
Acceptance	+- 10 μm	0.52
Resolution	30 μm	0.35
Backgrounds		1.1
Total uncertainty		2.82

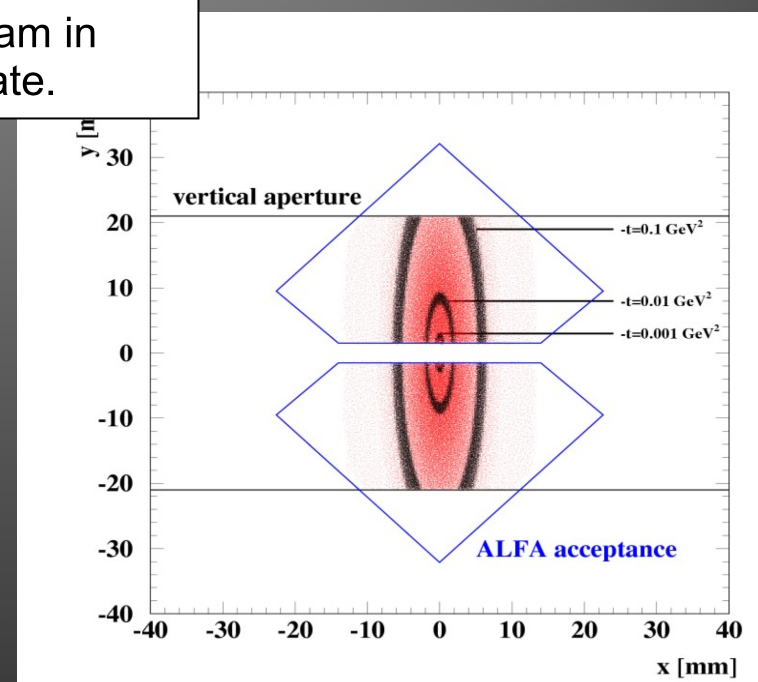
➔ Δ L / L ~ 3% seems to be possible

ALFA fiber trackers



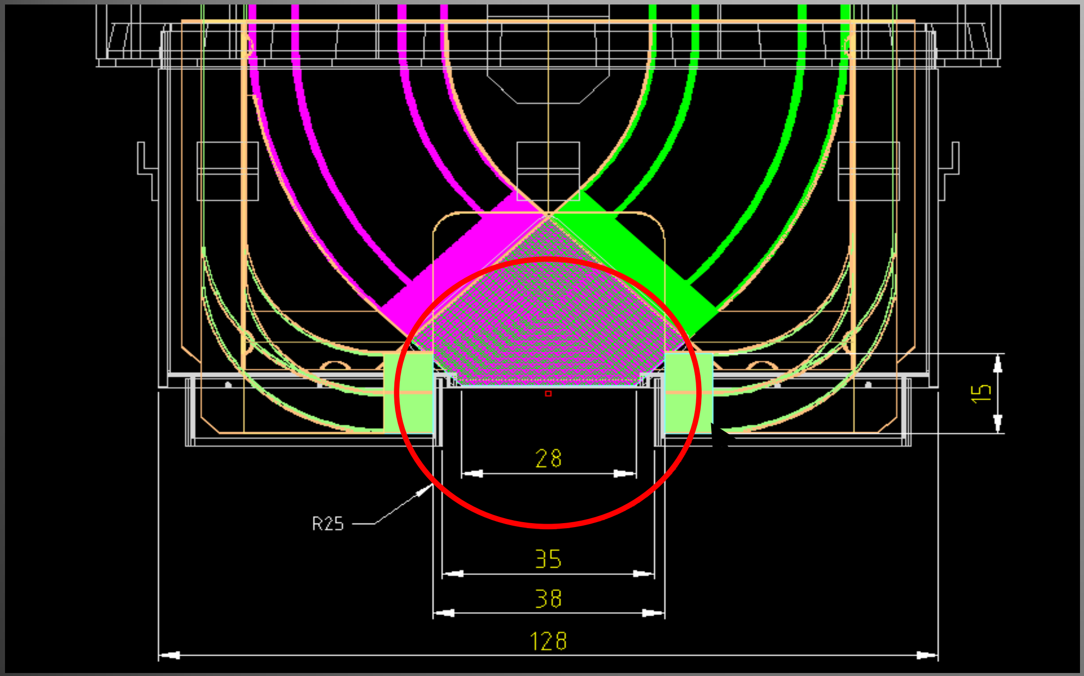


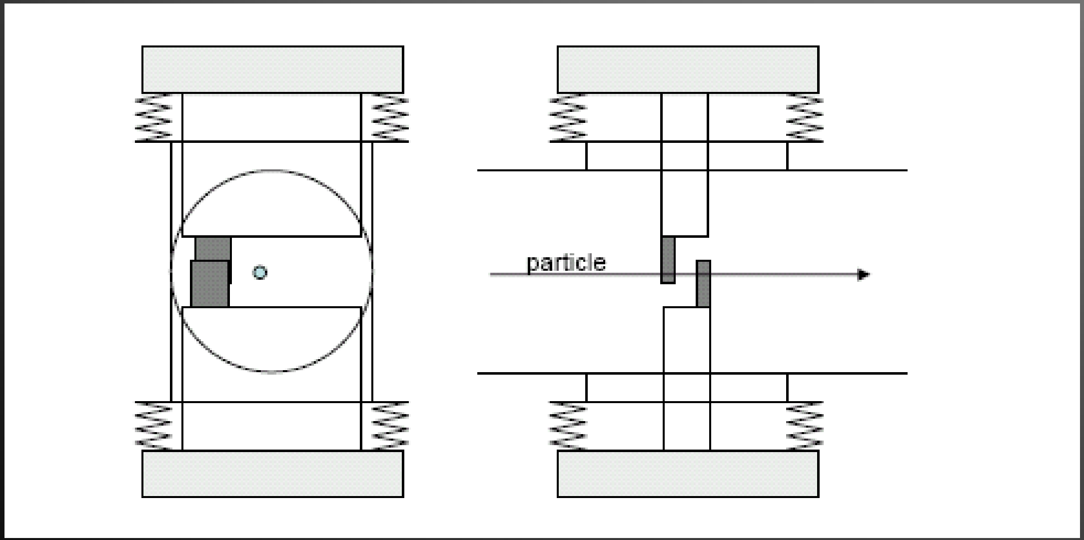
Diamond shaped detectors approaching the beam in the vertical coordinate.



Note:
fibers good for luminosity ~ $10^{-27\text{-}28}$ $cm^{-2}s^{-1}$,
but not radiation hard for collision runs .

ALFA overlap detectors

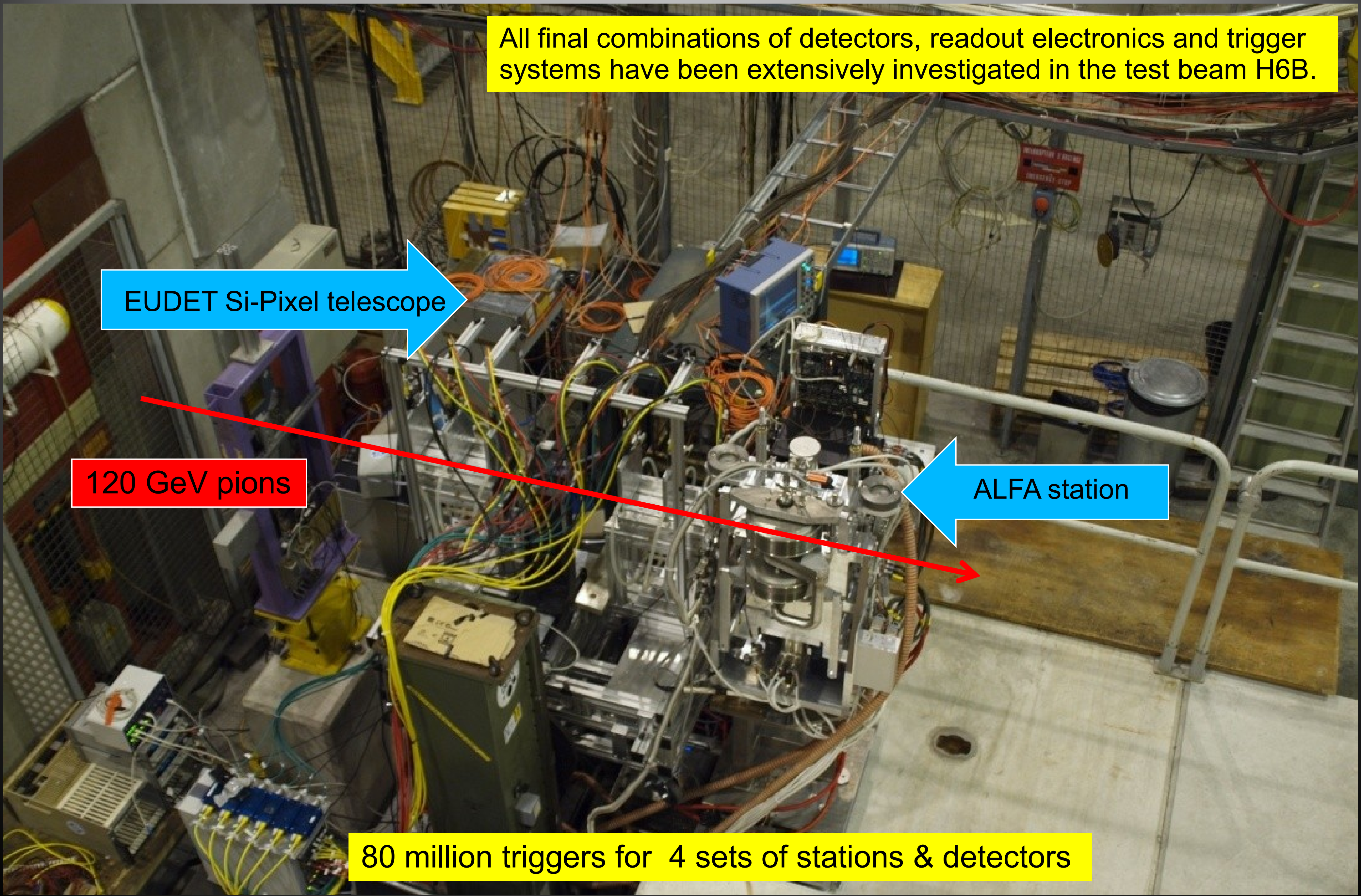




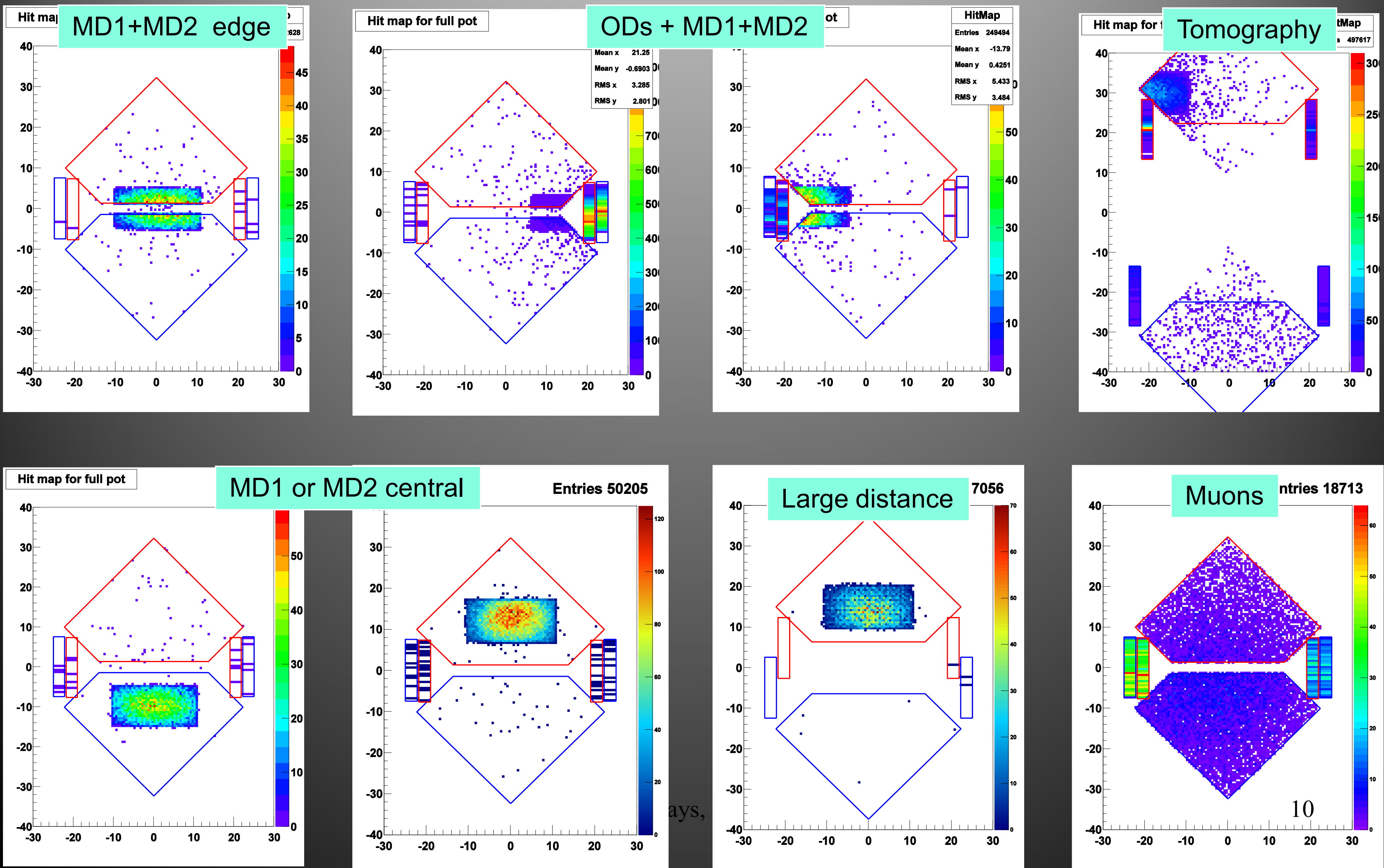
- To ensure precise pot positioning
- 3 layers of 60 fibers staggered by 166 μm
- Precision given by large number of halo proton tracks

First test beam result: $\sigma_{OD} < 10\ \mu m$,
final values coming from test beam 2010

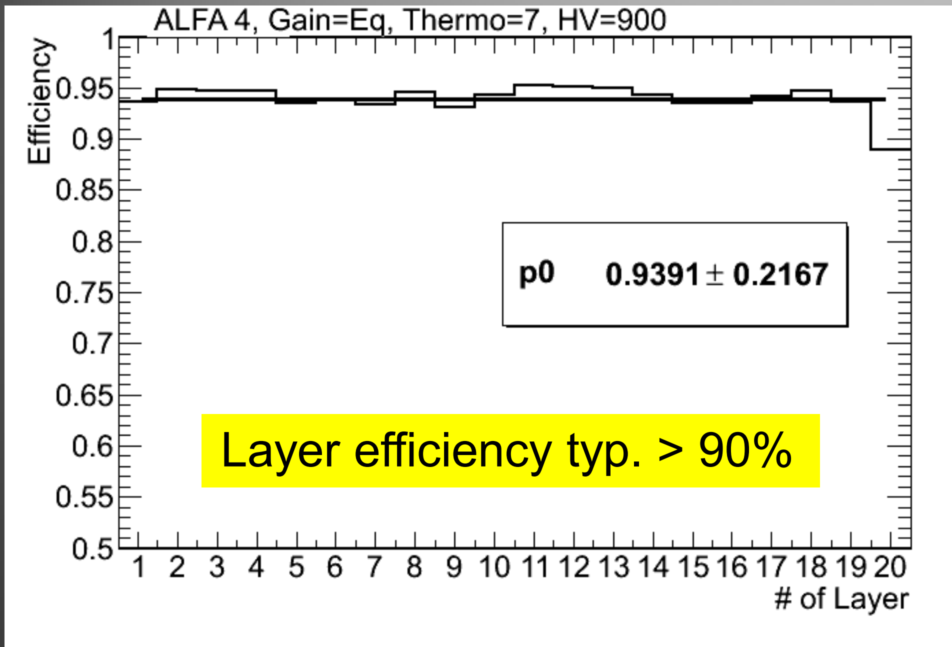
Test beam campaign 2010

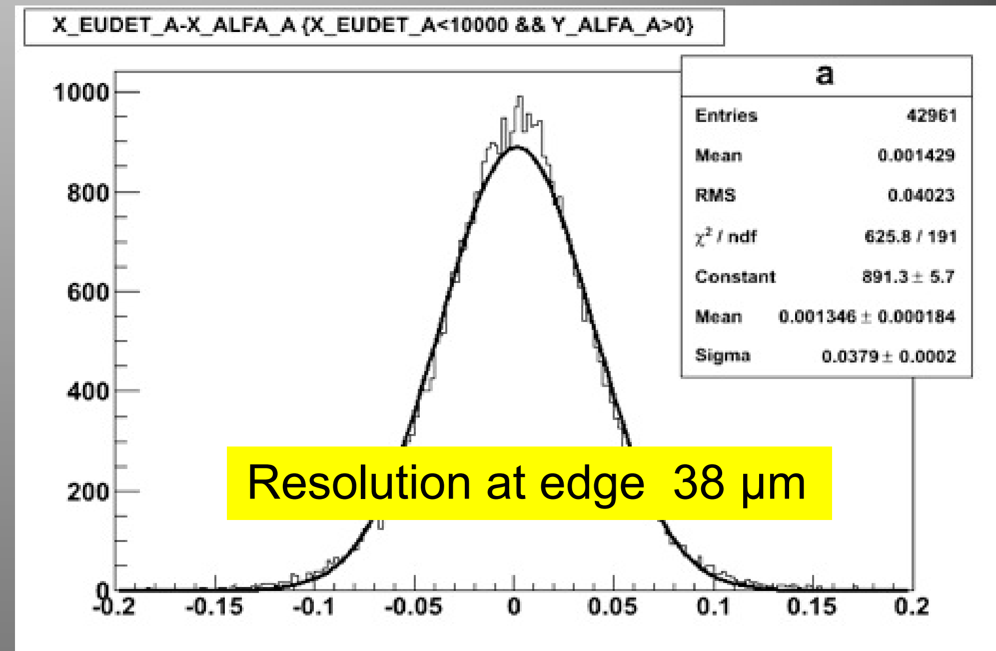


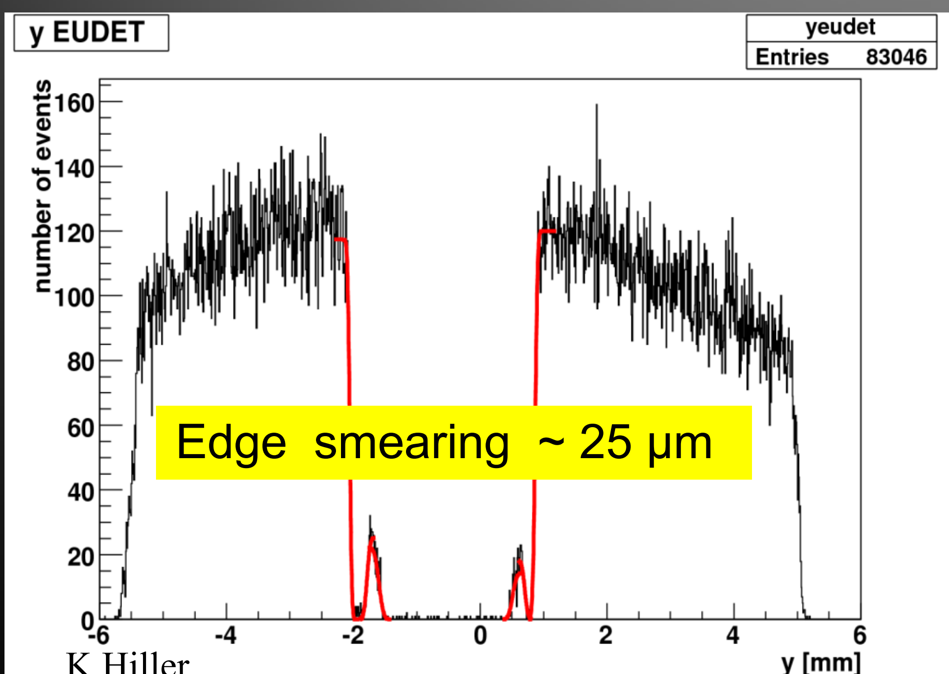
Overview measurement program

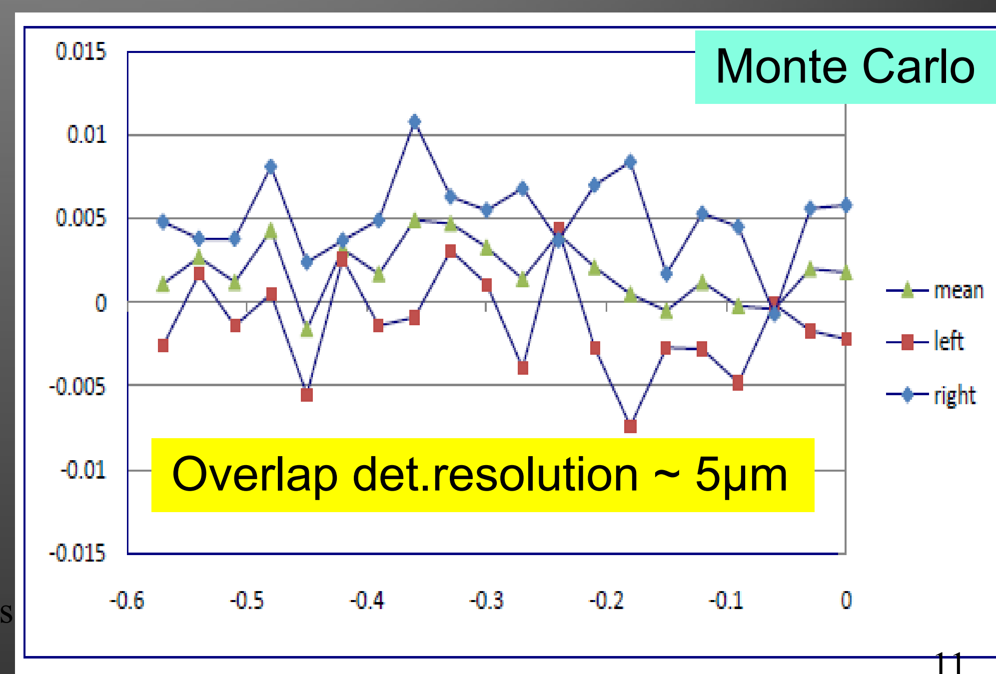


Preliminary TB10 results





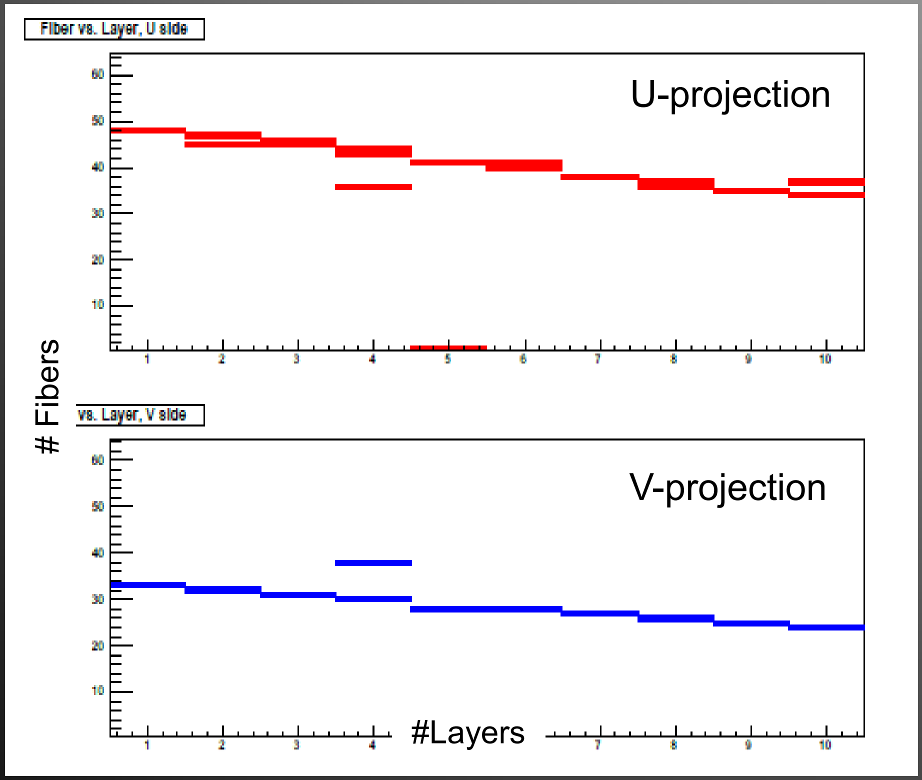


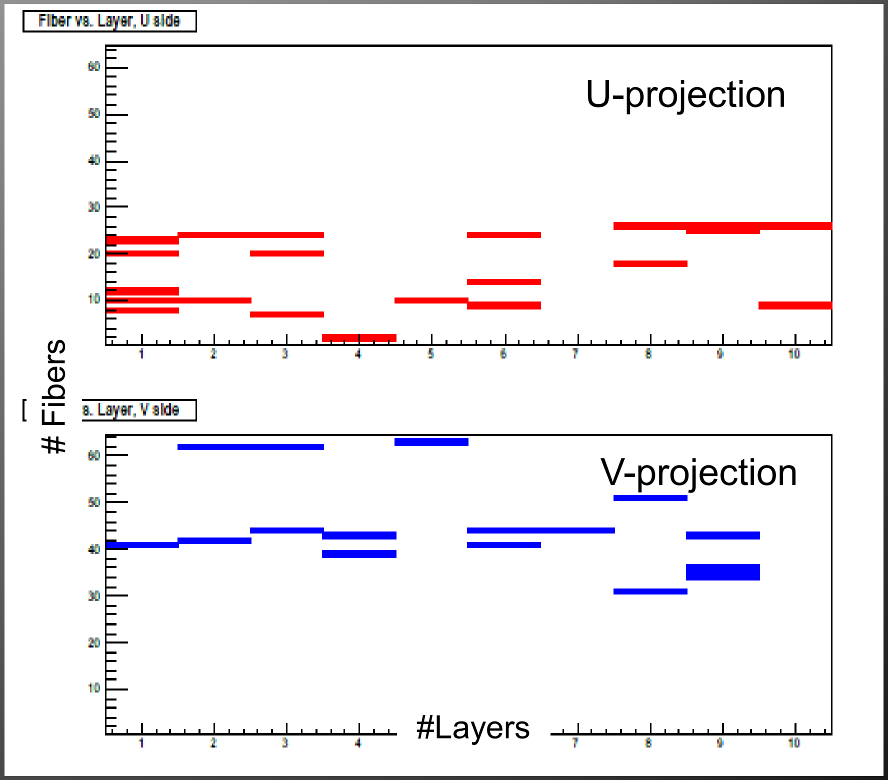


First tracks from the tunnel

- Station B7L1 with the upper detector ALFA2 in parking position installed 2009/10
- Not triggered by ALFA - parasitic running in spy mode with ATLAS L1A triggers
- 2nd attempt with proper TDAC configuration: HI run 170406 December 4

→ tracks, showers and many empty triggers





Main installation activities in the LHC tunnel

December 2010:

- removal of detector ALFA2 in station B7L1 (installed 2009/10)
- breaking of Roman Pot and LHC vacuum
- removal of ALFA2 Roman Pot
- installation of 2nd station A7L1 in sector 8-1
- installation of both stations in sector 1-2
- reinstallation of ALFA2 Roman Pot with new ferrites
- station alignment in LHC coordinate system
- restoring of Roman Pot and LHC vacua
- bake out of stations and close by beam pipes

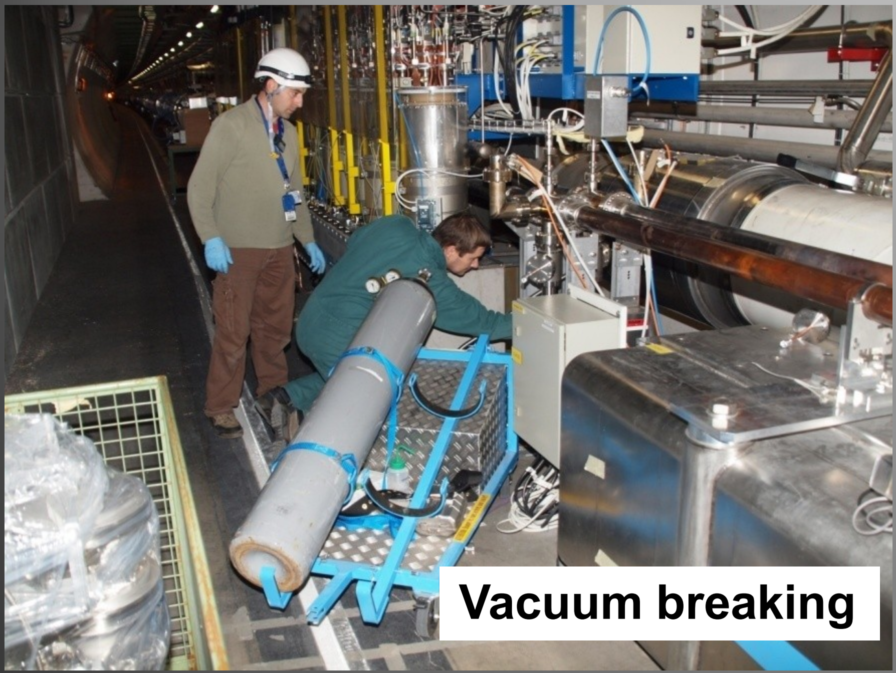
All stations including Roman Pots were installed. Stations aligned to LHC system, bake out done.

January 2011:

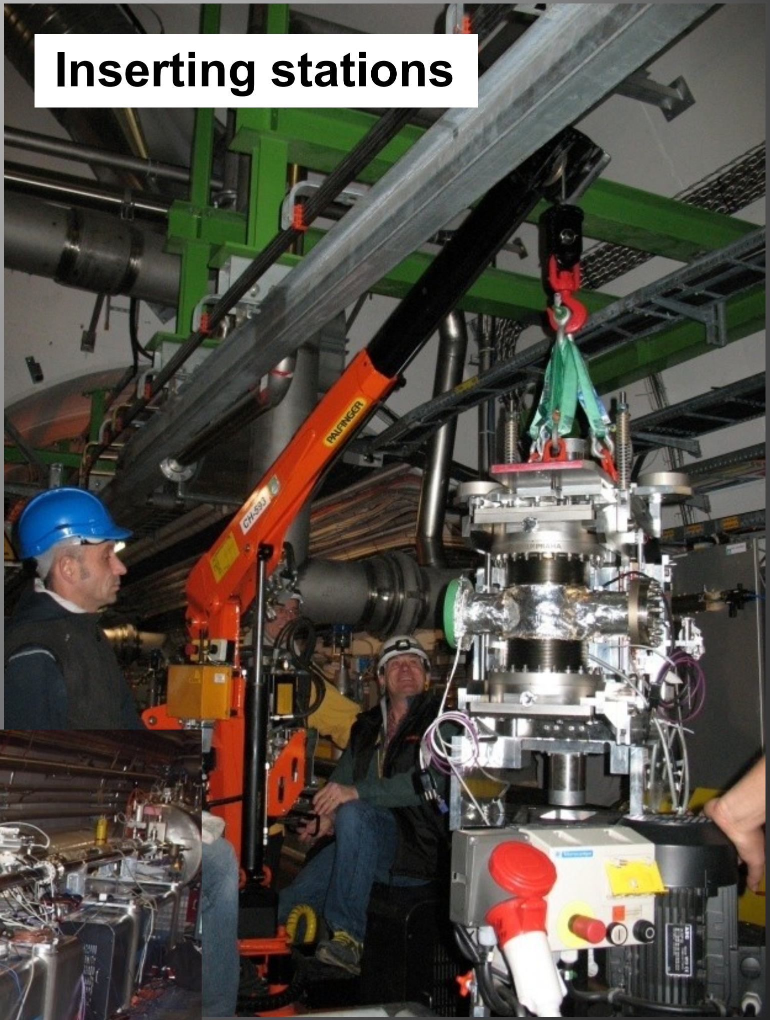
- replacement and adjustment of new springs for auto-retraction
- insertion of the fiber detectors
- installation of the electronics and cabling
- commissioning of the station movement systems
- survey and final LVDT calibration for detector positioning
- commissioning of the data readout by LED signals

End of January all 4 stations on both sides should be ready for movement and data taking.

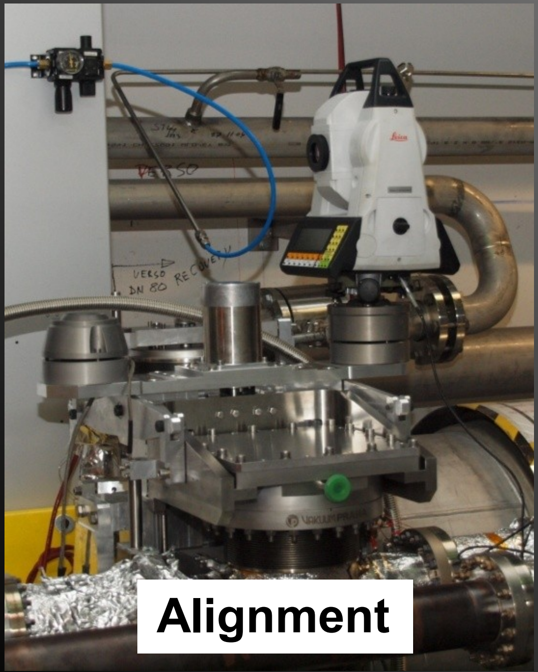
Installation in the tunnel



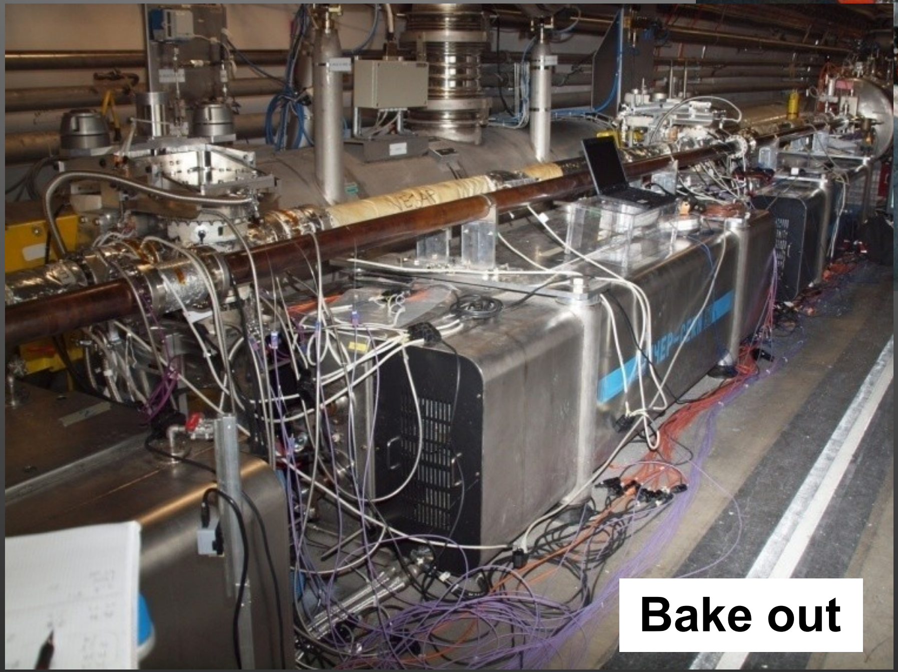
Vacuum breaking



Inserting stations



Alignment



Bake out

Road map 2011 and beyond

1) Parasitic runs with collision optics and detectors in garage positions:
Commissioning of individual detectors and readout with shower fragments.

2) Parasitic runs with collision optics and detectors outside garage positions:
Commissioning of the twin stations in both sectors 1-2 and 8-1 with halo particles. Detectors are outside of garage positions but still very far from the beam, e.g. 20mm.

3) Special run with β*=90m and detectors close to the beam:
Extrapolating the elastic rate to t = 0 GeV2 can be used to determine the total cross section with a precision in the range from 5-7%. Luminosity cannot be measured – needed as input from VdM scan or elsewhere.

Note: The feasibility of the un-squeeze to 90m with external tune compensation and parallel running of TOTEM and ALFA has to be demonstrated by machine studies.

4) Intermediate high-β* optics 1500m
TOTEM baseline optics, with some additional hardware interventions (more details explained LHC note 431, May 2010)
Not sufficient to reach Coulomb-Nuclear Interference region**.** But smaller t by higher β* improves the extrapolation to 0 GeV2. With additional input for missing factors luminosity and/or total cross section can be determined.

5) **ATLAS high-β* optics 2600m**
The ultimate optics to reach the Coulomb Nuclear Interference region with most stringent requirements (aperture of injection line, small emittance, phase advance).

A note about commissioning of high-β* optics for ALFA is in preparation.

Time line

1) Commissioning in garage position can happen very soon.

2) Move out of garage position for commissioning with halo particles seems very likely as the next step.

3) β^*=90m needs machine studies, also for parallel running of TOTEM and ALFA
It is a necessary step to very high-β^* and would be very good if it happens 2011.

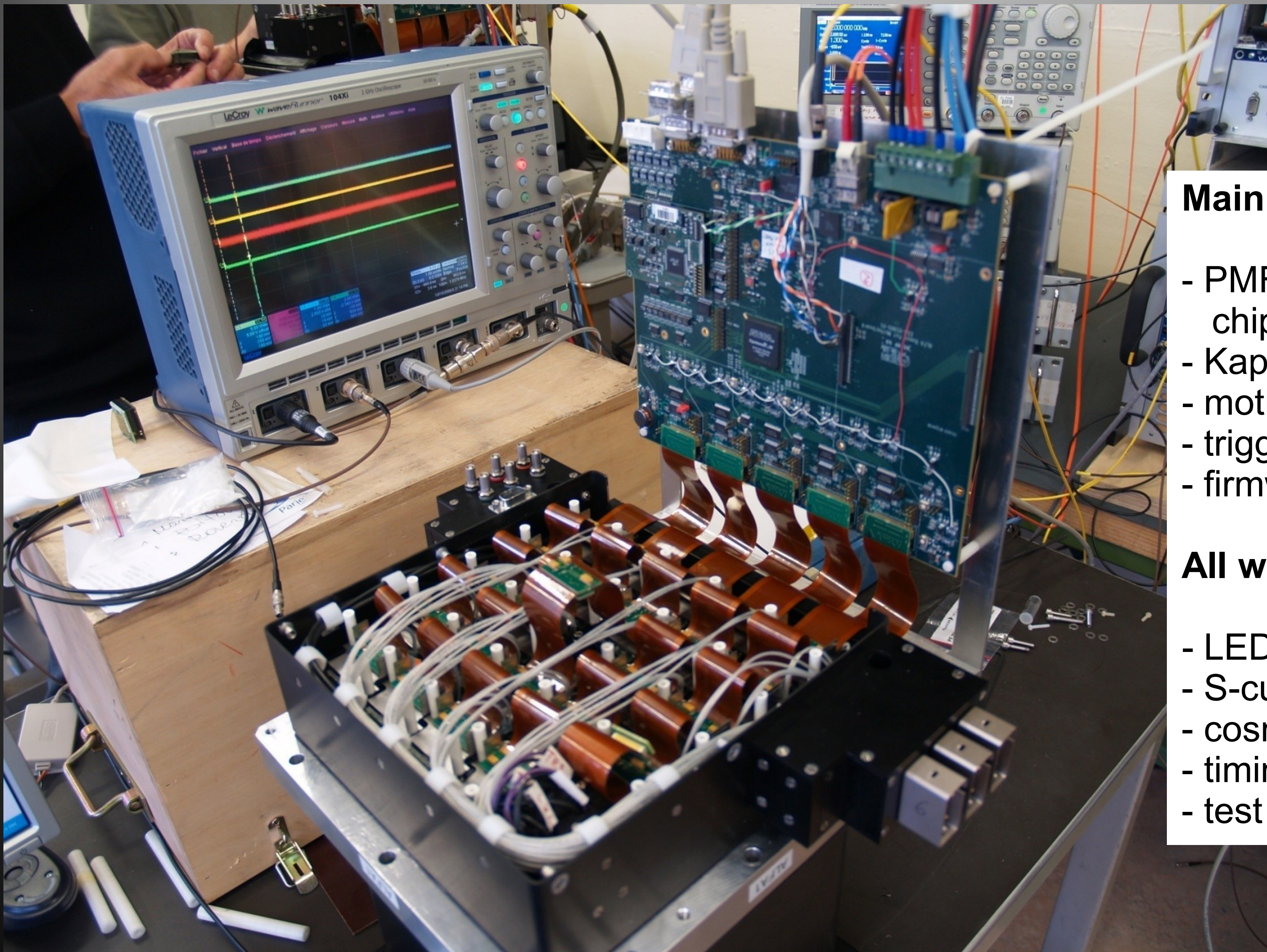
4) Intermediate β^*=1500m:
Due to hardware intervention realistic only after next long shut-down.

5) Very high β^*=2600m:
As for 4) dedicated machine studies needed. Time scale depend certainly on decision about β^* = 1500m.

Schedule for items 4), 5) depend on experience and results achieved at 1) – 3).
Dedicated machine studies are needed to prepare β^* = 1500 , 2600m runs.

Thanks for Attention

Front-End Electronics



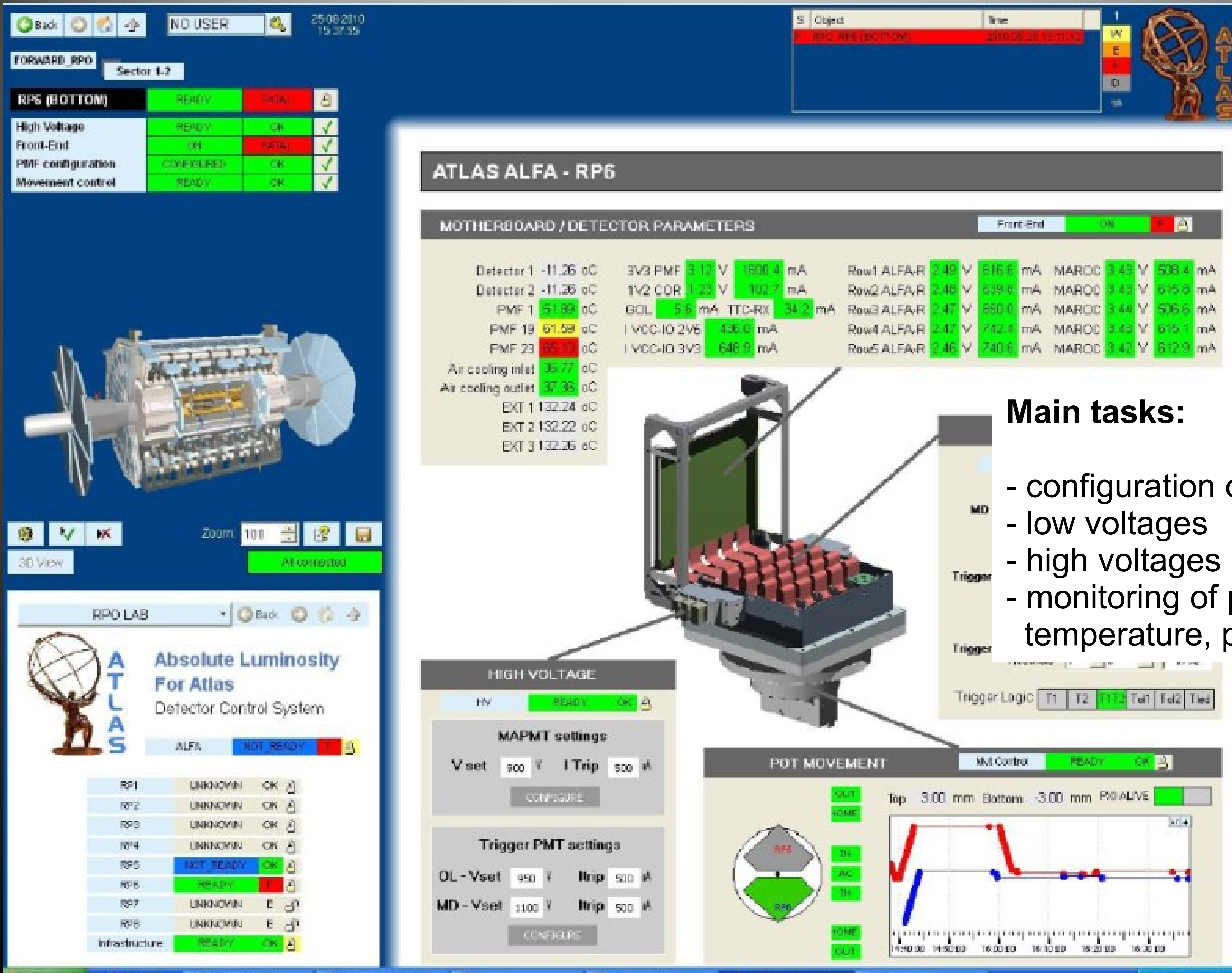
Main components:

- PMFs with MAROC chips on MAPMTs
- Kapton cables
- motherboards
- trigger mezzanines
- firmware

All well-tested by:

- LED signals
- S-curves
- cosmic runs
- timing by source
- test beam

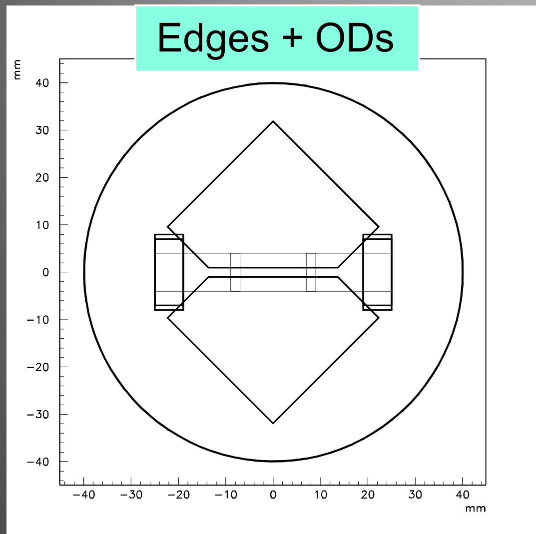
Detector Slow Control

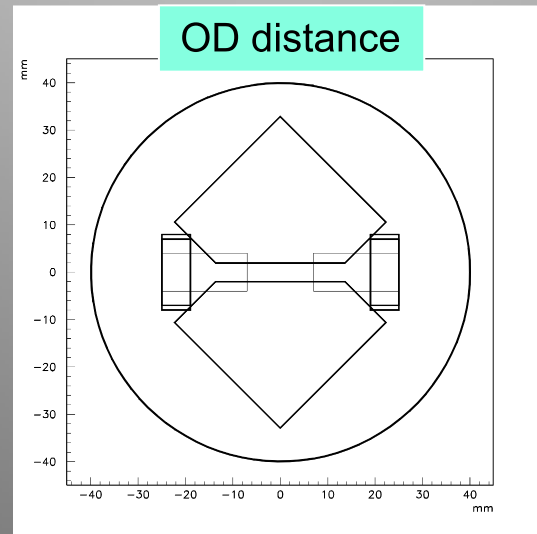


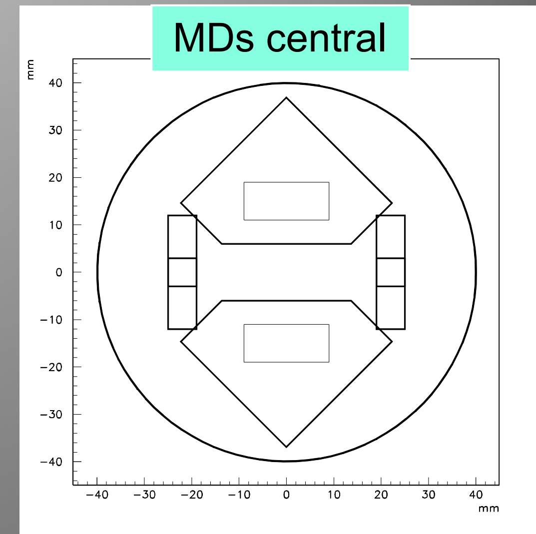
Main tasks:

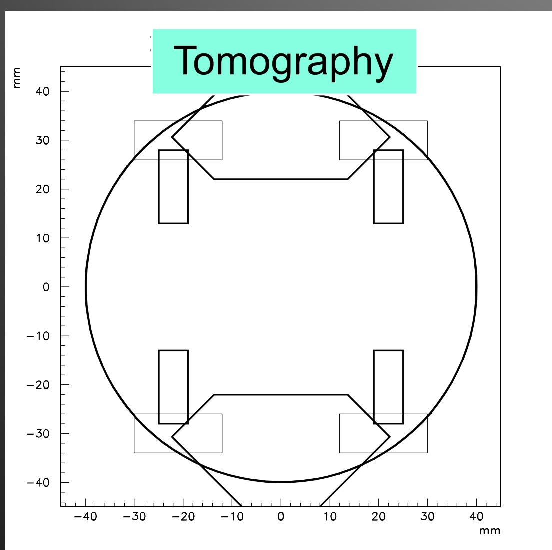
- configuration of R/O
- low voltages
- high voltages
- monitoring of positions, temperature, pressure,..

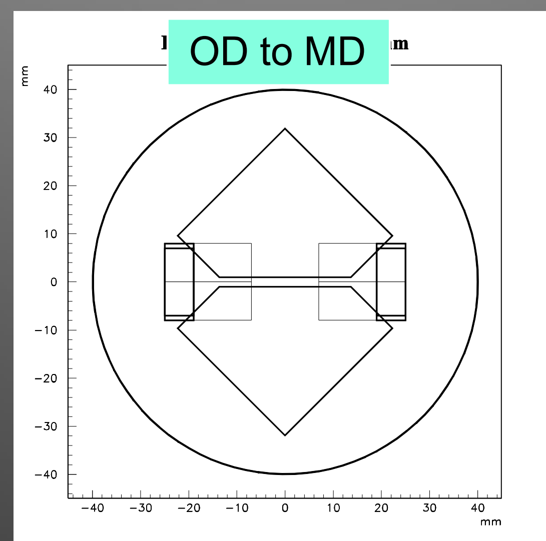
Measurement Program

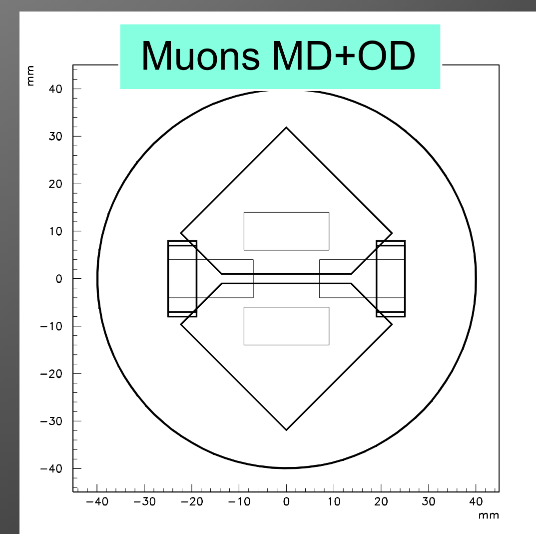








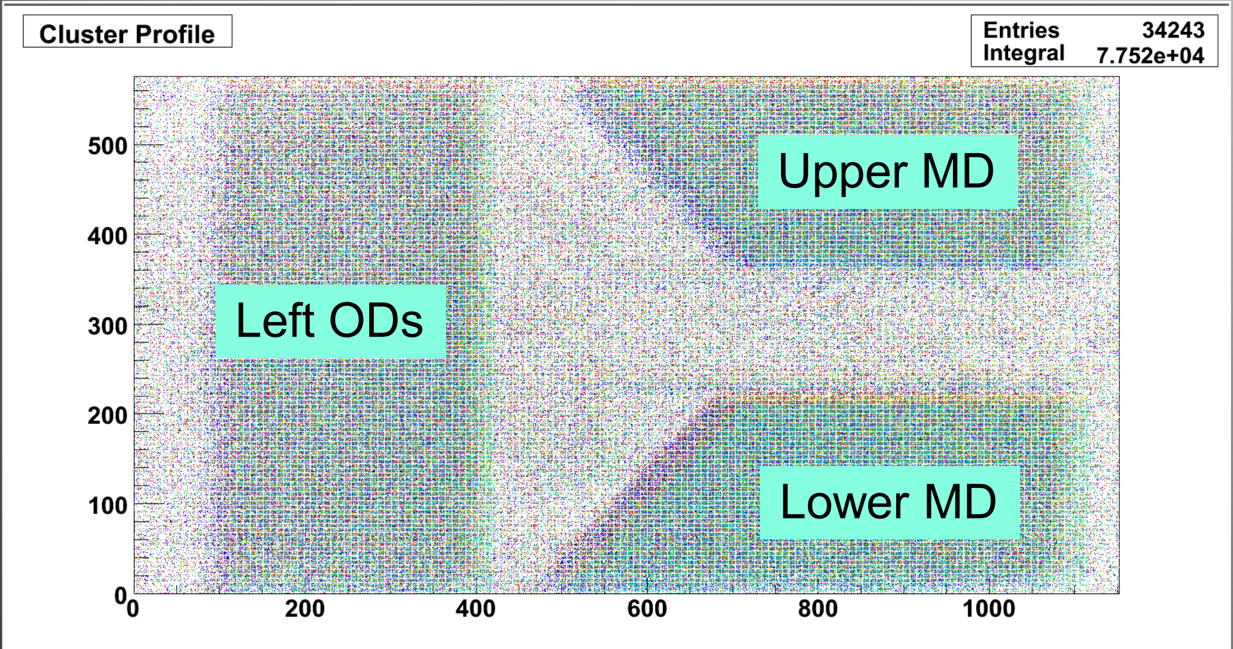


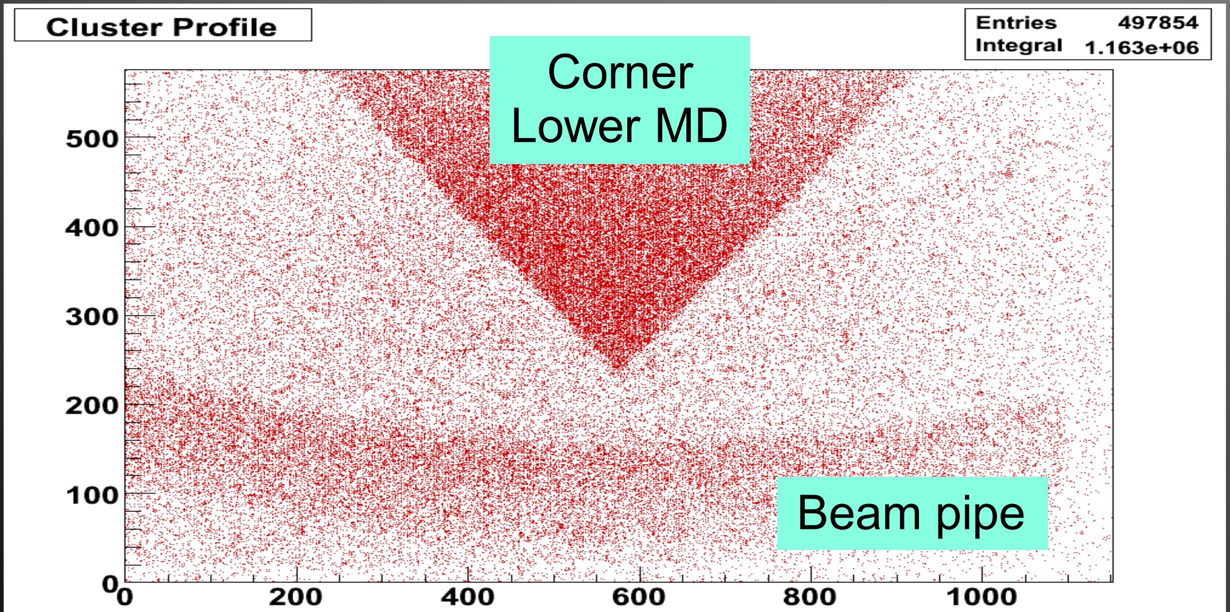


Standard Settings:

- ❑ HV(MAPMT) = 900V, HV(Trigger) = 950V / 1100V (Bialkali/SBA)
- ❑ THERMO = 7, GAIN = Equalized
- ❑ Trigger = EUDET ⊗ ALFA ⊗ Veto

TB10 Tomography with EUDET Clusters





Many useful cross checks:

- distance of MDs
- position of ODs to MDs
- detector position to 0-beam

… will be much better later with EUDET tracks