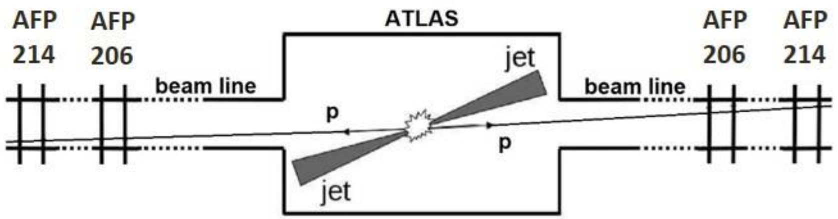
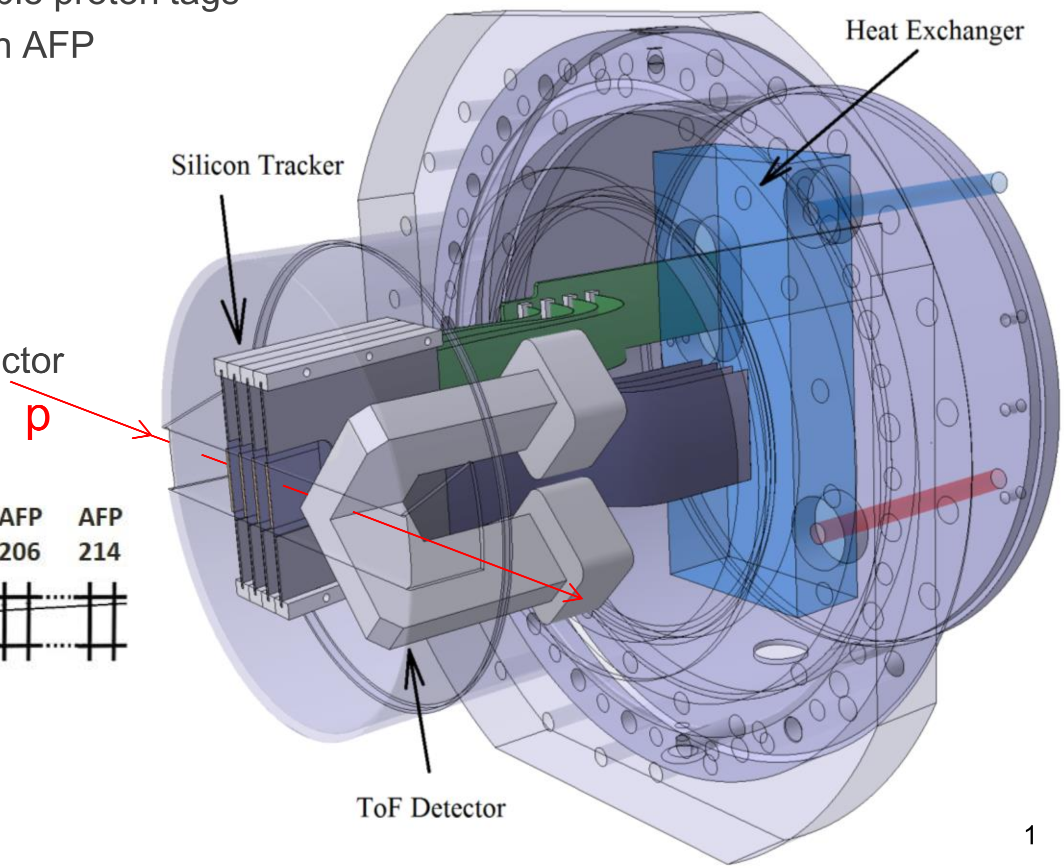
ATLAS Forward Proton Detectors

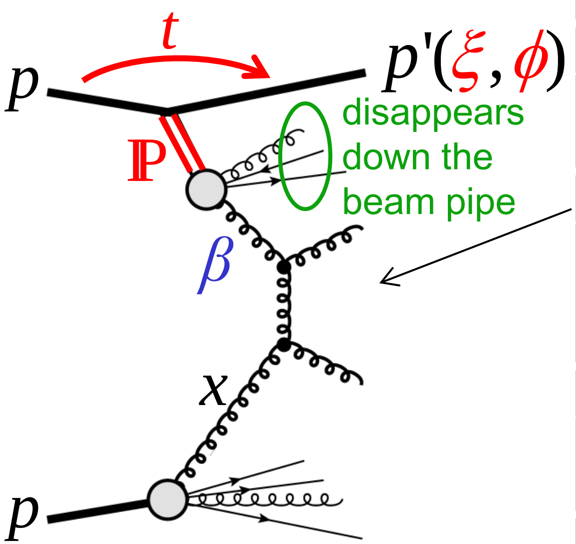
Michael Rijssenbeek
for the ATLAS Collaboration

- Physics summary:
  - Physics withSingle and Double proton tags
  - Benchmark study: DPEjj with AFP
- Installation & Run plans
- Roman pots
  - Pots, Stations, Services
- Detectors
  - Silicon Tracker, Timing Detector
- Run 2 and beyond





Summary of Single p-Tag Processes



Single Diffractive Production

$$t \equiv (p' - p)^2$$

$$\xi \equiv 1 - E'/E$$

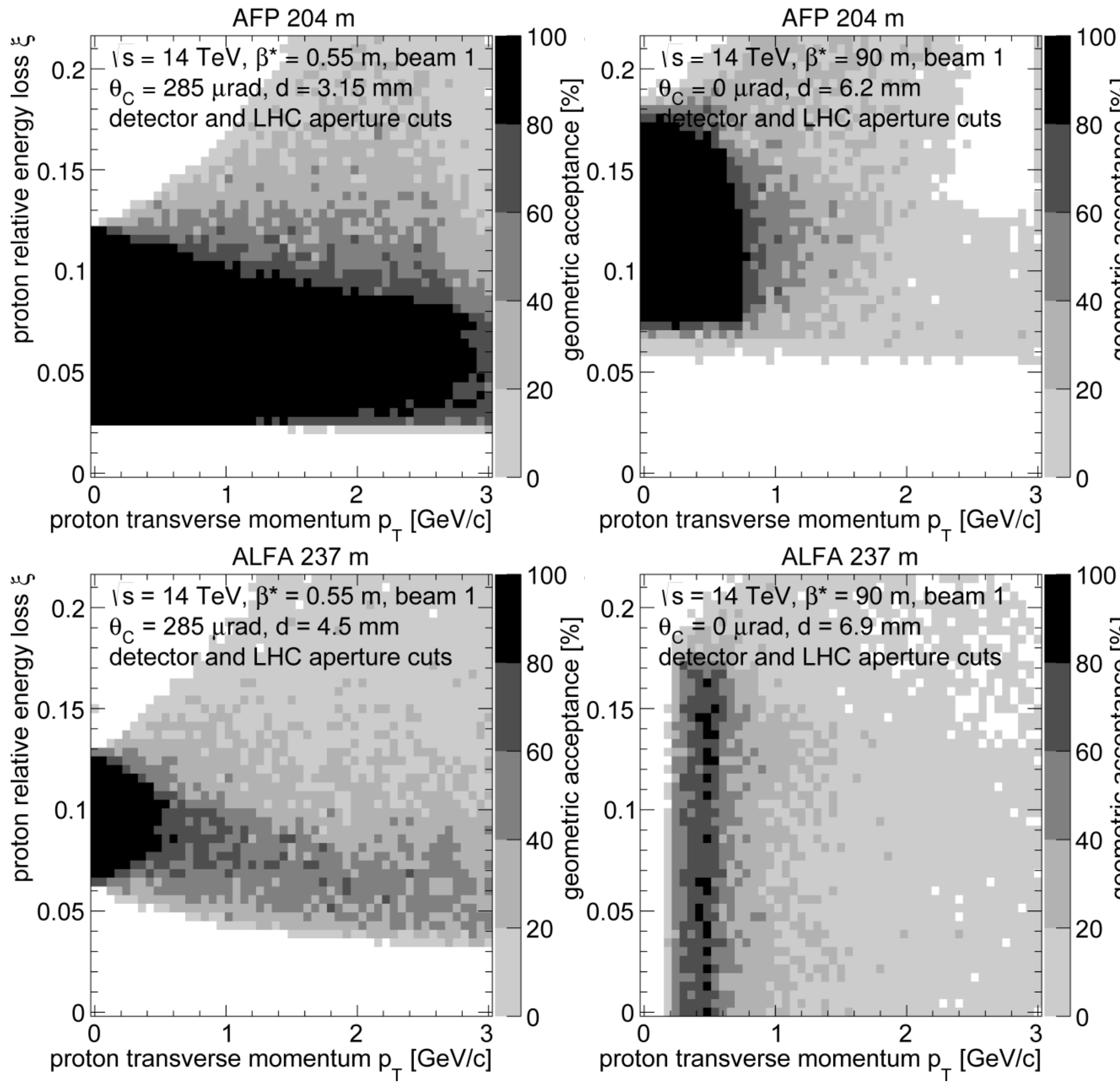
$$\beta \equiv x_{\mathbb{P}}$$

Analysis	**Motivation**	$\int L dt$ [pb^{-1}]	**Optimal μ**
Soft Single Diffraction with AFP0+2			
$d\sigma/dt$, $d\sigma/d\xi$, t-Slope vs. ξ, $dN^{\pm}/dp_T$ vs. t and ξ	Saturation, MC tuning, Cosmic Ray physics	1	$\mu \sim 0.01$
Single Diffractive jet Production [21]			
σ, rapidity gap, Jet structure and p_T, event shape (MPI [21]); vs. t, ξ, and β	gap survival probability, Pomeron structure	$10 - 100$	$\mu \sim 1$
Single Diffractive jet-gap-jet Production [22, 23, 24]			
σ, central gap distribution, Jet p_T; vs. t, ξ, and β	observation of a new process, test of BFKL dynamics	$1 - 100$	$\mu \sim 1$
Single Diffractive Production of γ + jet [25]			
σ, rapidity gap, Jet structure and p_T, Photon p_T, event shape (MPI); vs. t, ξ, and β	observation of a new process, mechanism of hard diffraction, gap survival probability, Pomeron structure	$10 - 100$	$\mu \sim 1$
Single Diffractive Z Production			
σ, rapidity gap, charge-asymmetry; vs. t, ξ, and β	gap survival probability, Pomeron structure	$10 - 100$	$\mu \sim 1$
Single Diffractive W Production			
σ, rapidity gap; vs. t, ξ, and β	gap survival probability, Pomeron structure and flavor composition	$10 - 100$	$\mu \sim 1$

AFP and ALFA: Complementarity

AFP – Horizontal Pots:

- large t acceptance
- ξ range shifts with optics
- high β^* and low β^*=0.5 m

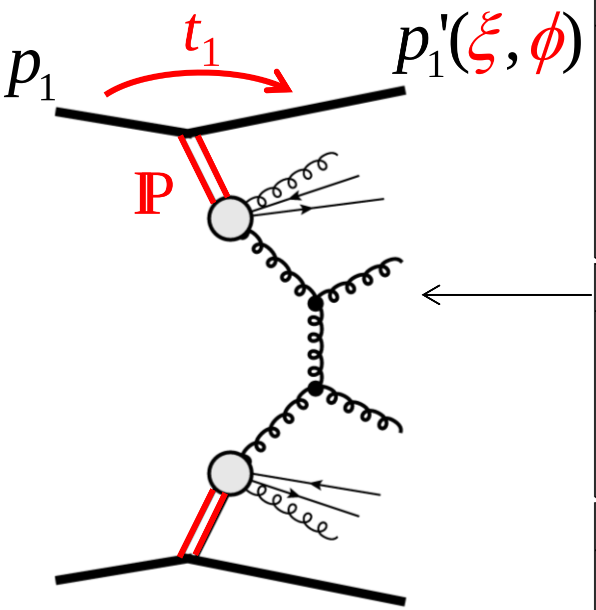


ALFA – Vertical Pots:

- limited t acceptance
- ξ=0 acceptance for β^*≥90, elastics
- only low-Luminosity, high β^* runs

Summary of Double p-Tag Processes

DPE jet-jet



$$t_i \equiv (p_i' - p_i)^2$$

$$\xi_i \equiv 1 - E_i'/E_B$$

$$\beta_i \equiv x_{\mathbb{P},i}$$

$$M_{jj} \le M_{pp} = \sqrt{s\xi_1\xi_2}$$

Analysis	**Motivation**	$\int Ldt$ [pb^{-1}]	**Optimal μ**
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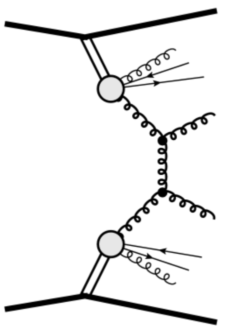
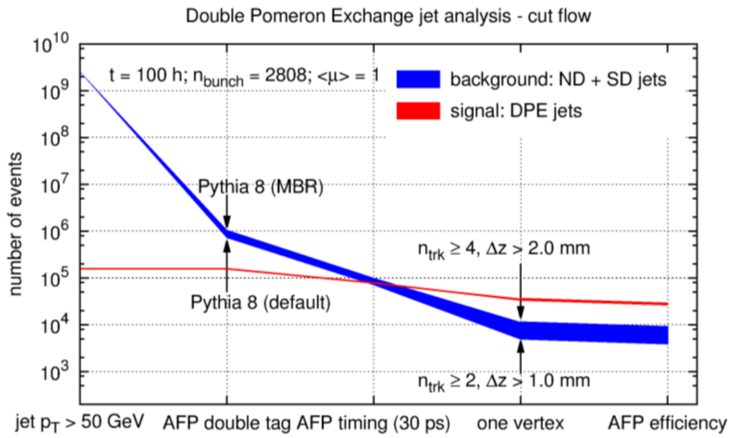
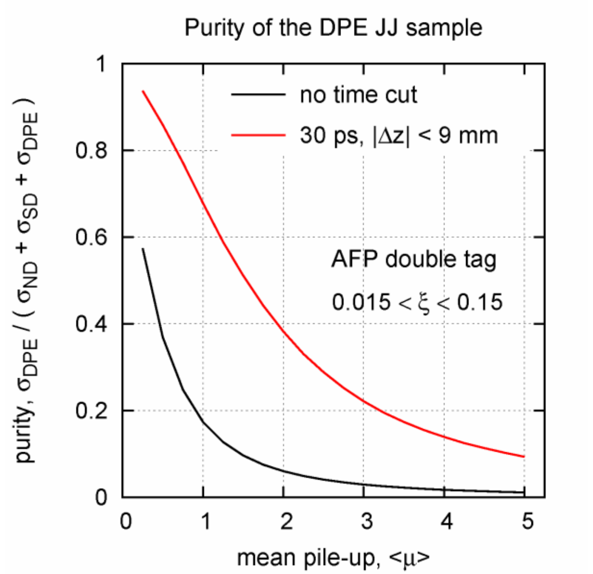
$d\sigma/dt_{1,2}$, $d\sigma/d\xi_{1,2}$, t-Slope vs. ξ, Mass M and y of the central diffractive system, ϕ_1 vs. ϕ_2, $dN^{\pm}/dp_T$; vs. $t_{1,2}$, $\xi_{1,2}$, M.	general understanding of DPE processes	1	$\mu \sim 0.1$
Central Diffractive jet Production (DPEjj) [28]; see also Sect. A			
$d\sigma/dt_{1,2}$, $d\sigma/d\xi_{1,2}$, t-Slope vs. ξ, $d\sigma/dp_T^{jet}$, Mass M and y of the central dijet system, ϕ_1 vs. ϕ_2	gap survival probability for DPE processes, Pomeron structure, general understanding of DPE processes	10 – 100	$\mu \sim 1$
Jet-gap-jet Production [22, 24]			
$d\sigma/dt_{1,2}$, $d\sigma/d\xi_{1,2}$, $d\sigma/dM_{jj}$, central gap distribution, $d\sigma/dp_T^{jet}$, ϕ_1 vs. ϕ_2	observation of a new process, test of BFKL dynamics	10 – 100	$\mu \sim 1$
γ + jet Production			
σ, rapidity gap(s), Jet structure and p_T, Photon p_T; vs. $t_{1,2}$, $\xi_{1,2}$, and M_{jj}	observation of a new process, mechanism of hard diffraction, gap survival probability, Pomeron structure	10 – 100	$\mu \sim 1$

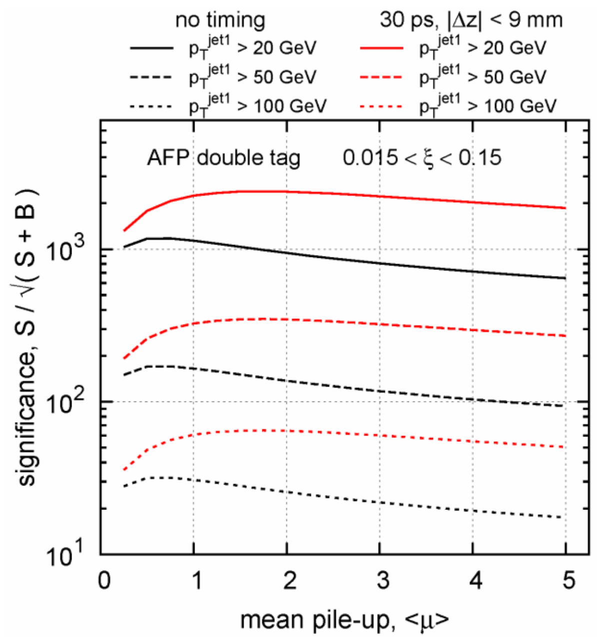
Benchmark: DPEjj Processes

- Fast & Full simulation of AFP + ATLAS, including pile-up
  - generator: PYTHIA 8.165 with POMFLUX = 1, 5(MBR)
  - 100 h (1 wk); 2808 bunches, μ=1
- Event Selections:
  - p_T(jet)> 20, 50, 100 GeV
  - double proton tag in AFP
  - *matching* with AFP vertex from timing (σ_t = 30 ps)
  - *single* vertex in ATLAS









Installation: AFP 0+2 → AFP 2+2

Single Arm, 2 Roman Pot Stations (204 m, 212 m)

- Earliest opportunity to install: Winter 2015-16 SSD
  - AFP Beam Pipe section ~9 m
  - RP Stations + BPM
  - Cables
  - Vacuum, Cooling

a VERY large job in VERY little time !

- Tracking detectors (SiT)
  - 4 planes of 3-D Silicon Pixels; edgeless (150 um)
  - provide L1 Trigger from FE-I4 HitOR outputs (e.g. 3 planes out of 4)
  - SiT can be installed during a short (6 hr) access
- **NO** Time-of-Flight (ToF) for AFP0+2
  - ToF not needed/useful for 1-arm physics …
    - only for study of time structure of backgrounds …

  → install only if the rest is done !

Two-Arm AFP2+2: in Winter 2016-2017 (19 wks)

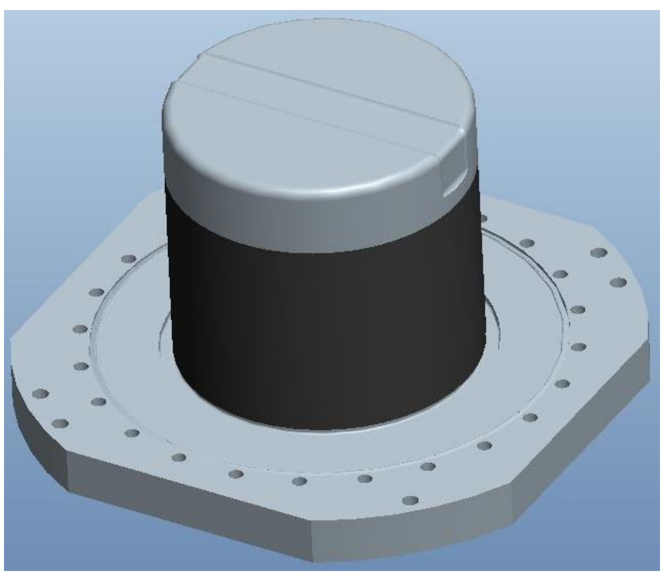
Closing in to the Beam: Roman Pot

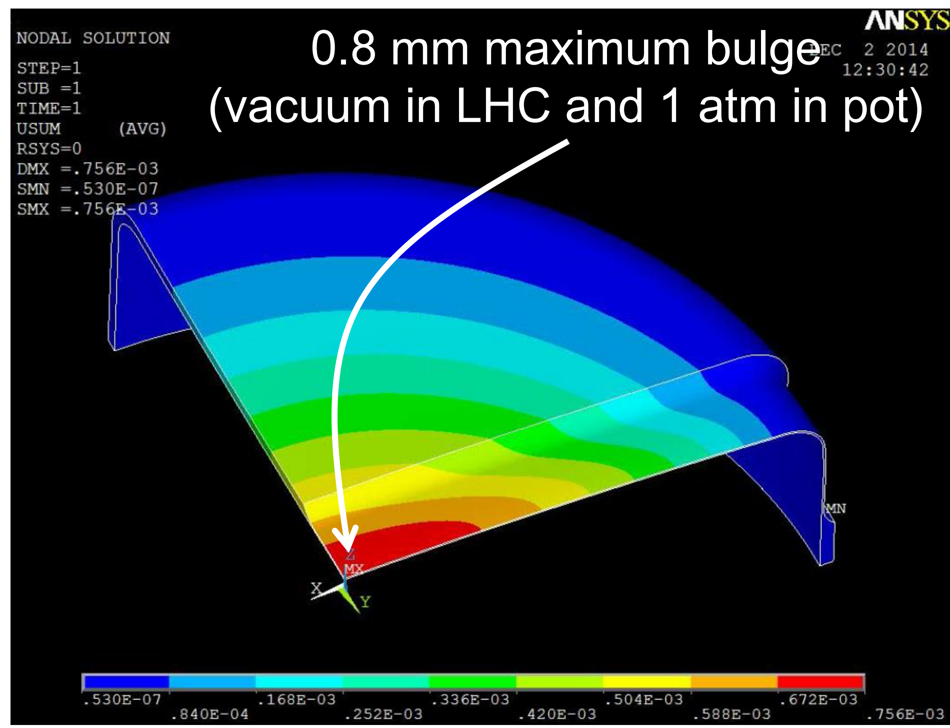
AFP pot very similar to TOTEM pot

- cylindrical: good RF behavior (≤1% of LHC impedance)

AFP detectors require a *flat inside bottom* in the pot

- thin window machined on the *beam* side –different from TOTEM pot
- design & simulations done
- prototype in 5-6 weeks





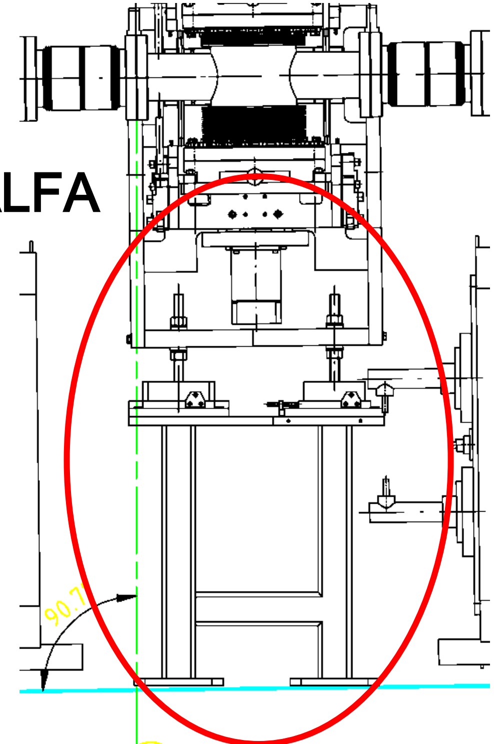
Roman Pot station

AFP Roman Pot station:

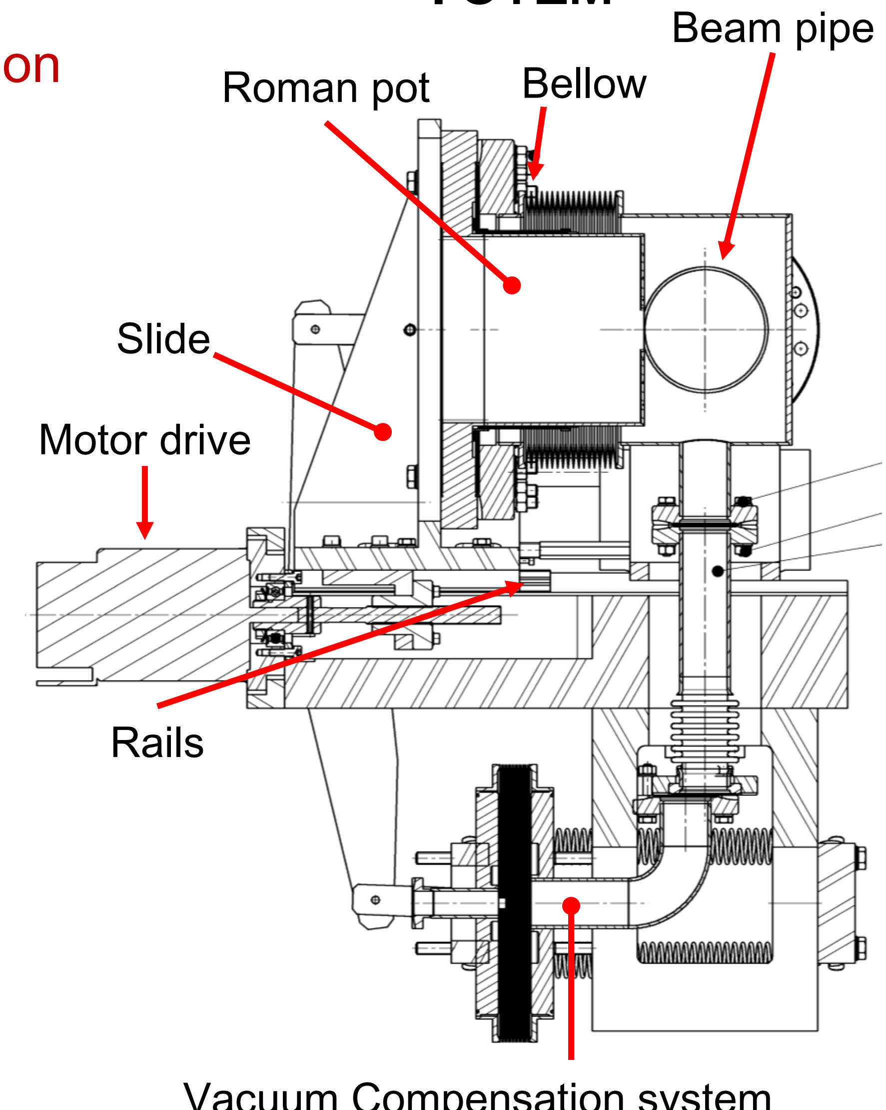
- Replicate TOTEM *horizontal* station
  - reliable and proven design
  - external manufacturer
- Interface to ALFA pedestal

➔ minimal extra design needed

ALFA



TOTEM



Infrastructure

AFP Beam Pipe:

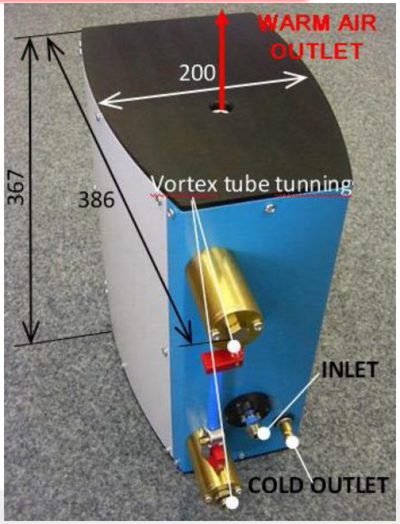
- beam pipe RP station placeholder sections
- BPM at 212 m station, beam Loss Monitors

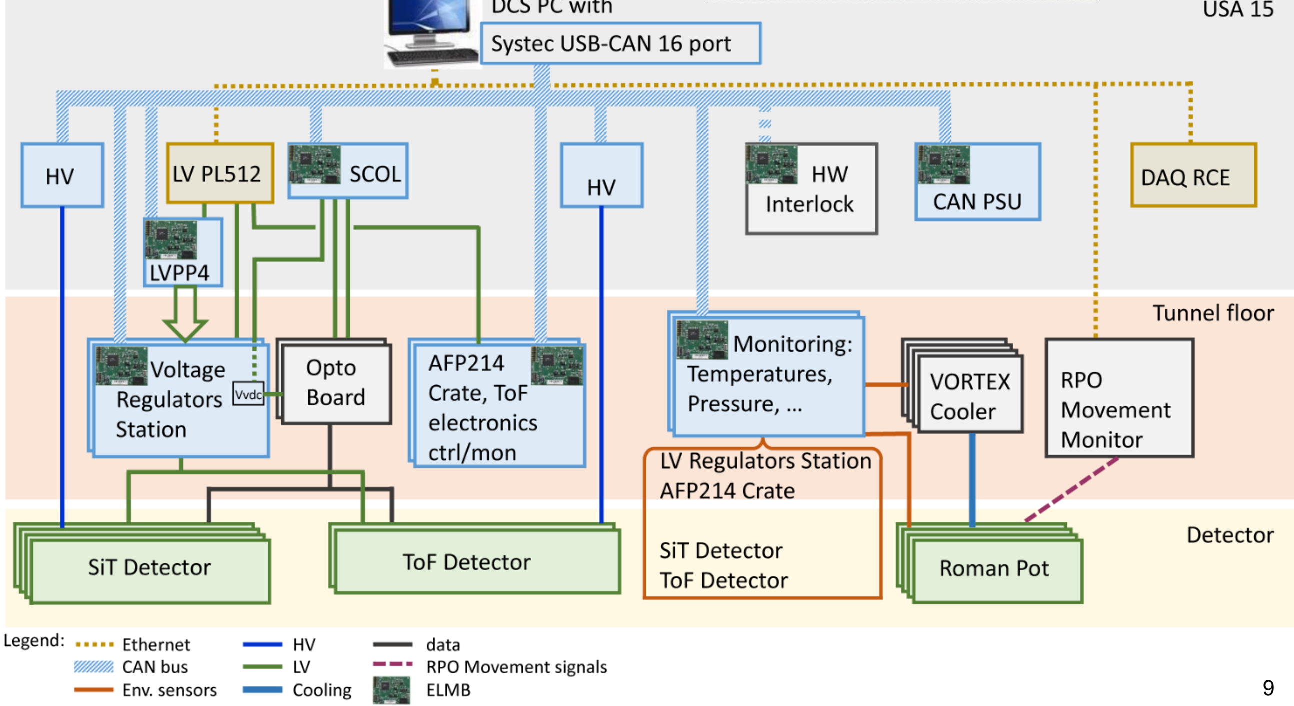
Services:

- Cooling for pots and detectors
- Secondary vacuum
- Cables:
  - fast foam-core cables for Trigger, Reference Clock
  - Optical fibers TDAQ
  - HV and LV cables
  - DCS CanBus cables

DCS:

- Secondary pressure
- cooling air pressure
- Temperatures
  - pots, detectors, air, crates, regulators
- Voltages and currents

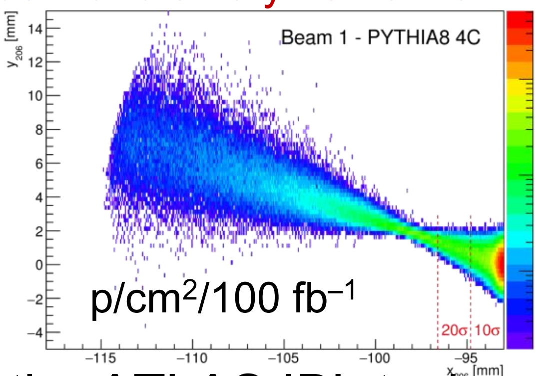




3-D Silicon Pixel Tracker

Requirements:

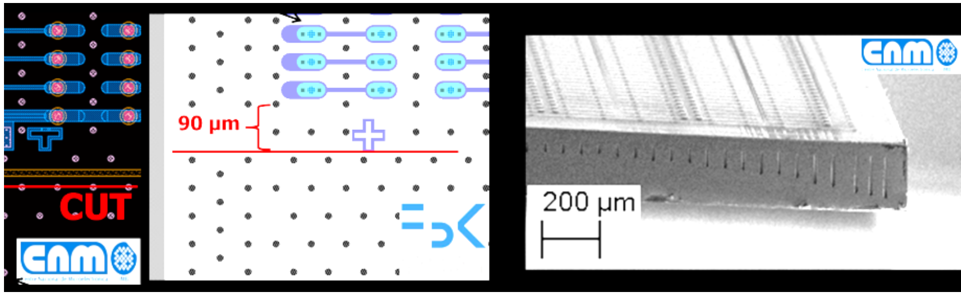
- Resolution: σ_x=10 µm, σ_y=30 µm
- Radiation hard: 5×10^{15} p/cm^2/100 fb^{-1}
- edgeless ≲200 µm
- must handle very non-uniform irradiation



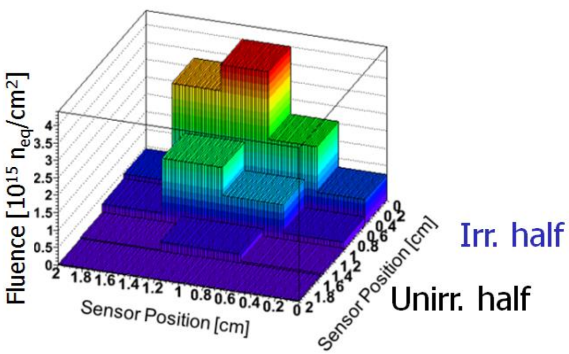
Use the ATLAS IBL technology:

- 3-D pixel sensors:
  - 336 × 80 of 50 µm (x) × 250 µm (y)
  - after cut: efficient to 100-150 µm
- FE-I4b readout ASIC
  - rad hard – tested up to 2.5 MGy and 5×10^{15} 1 MeV-eq n/cm^2
- non-uniform irradiation tests few×10^{15} p/cm^2 successful

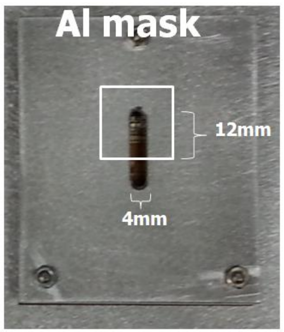
3-D CNM Pixel Sensor and Cut

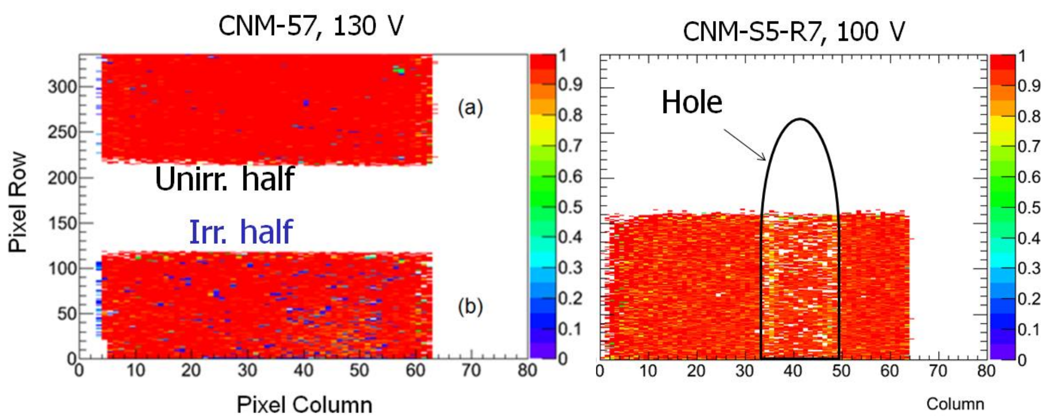


CERN-PS Focussed Beam



KIT Slit Hole





3-D Silicon Pixel Tracker

Trigger:

- AND of 3 planes (FE-I4 HitOR)

DAQ:

- RCE-based (AdvancedTCA)
- used for IBL stave testing
- worked **VERY** well in test beam!

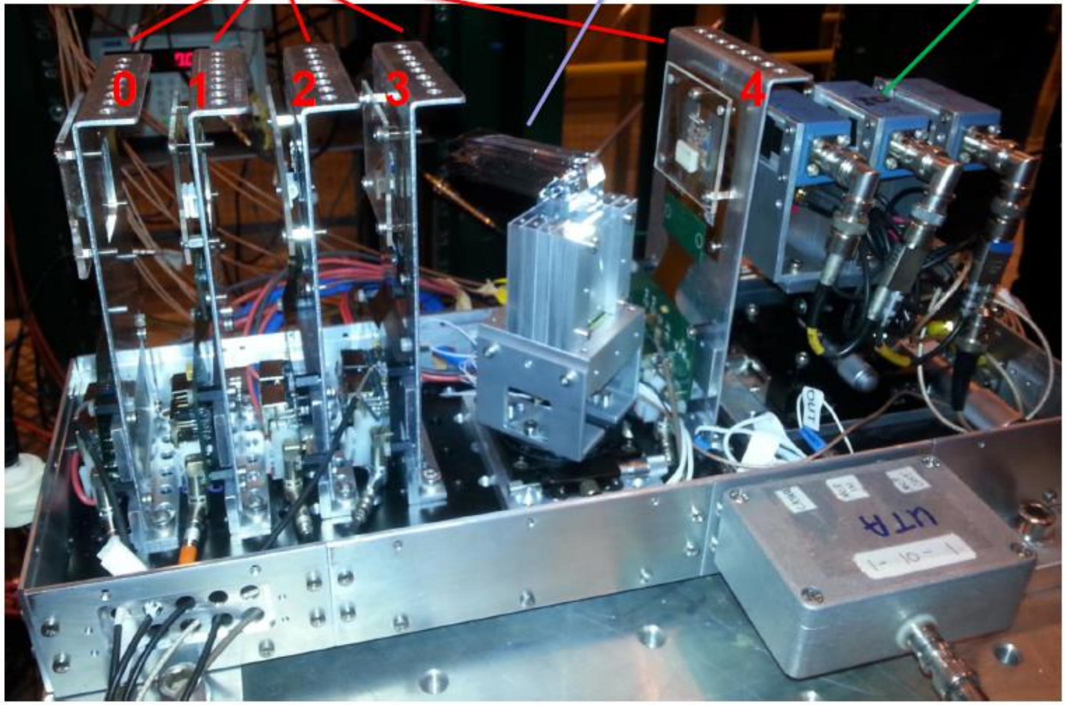
Performance:

- Efficiency ≥98%/plane (will be higher with 13° tilt)
- 98% single track events, 0.4% empty triggers
- Track CoG resolution: σ_x=7 μm, σ_y=36 μm

Production Status:

- Sensors cut, Under Bump Metallization done
- FE-I4 in house, to be sent for UBM
- Flexes to be designed 🡐 critical path
- Sensor card and holder: to be designed 🡐 critical path

Setup in test beam Nov 2014 CERN SPS



Time-of-Flight Detector

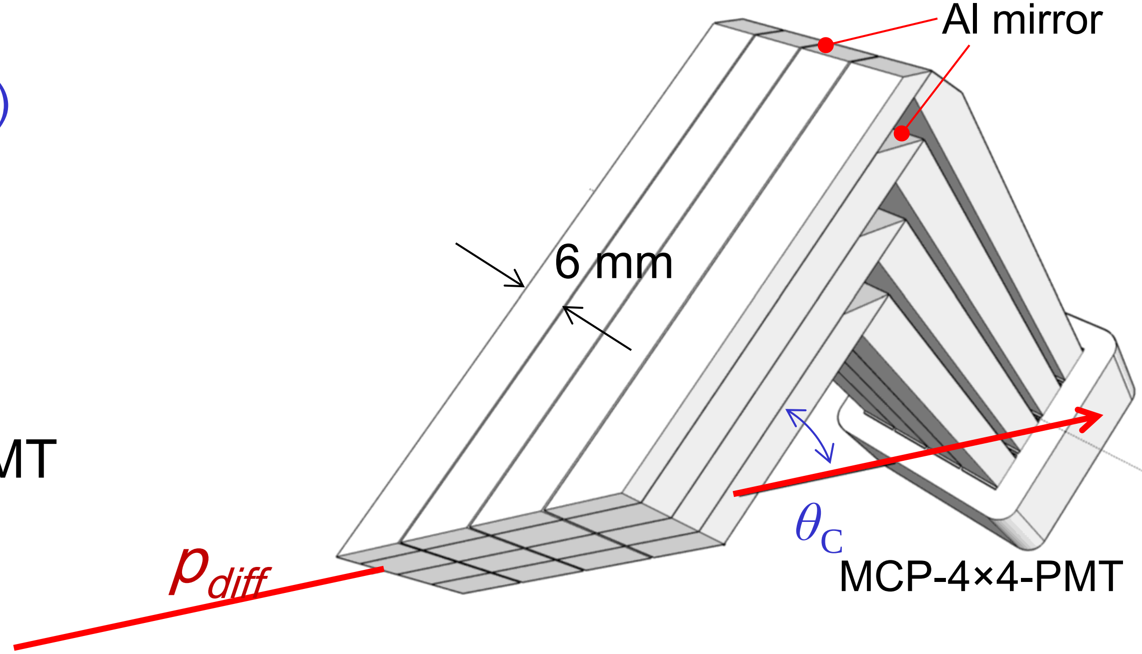
Requirements:

- high resolution: $\sigma_t \leq 10$ ps
- high rate: ≤5 MHz
- radiation hard (100-300 fb^{-1})
- long life PMT
- segmentation in x ($\sim\xi$)
- L1 Trigger capability
- low mass: 1.8%λ_{int}/bar

Long-life, high-rate MCP-PMT

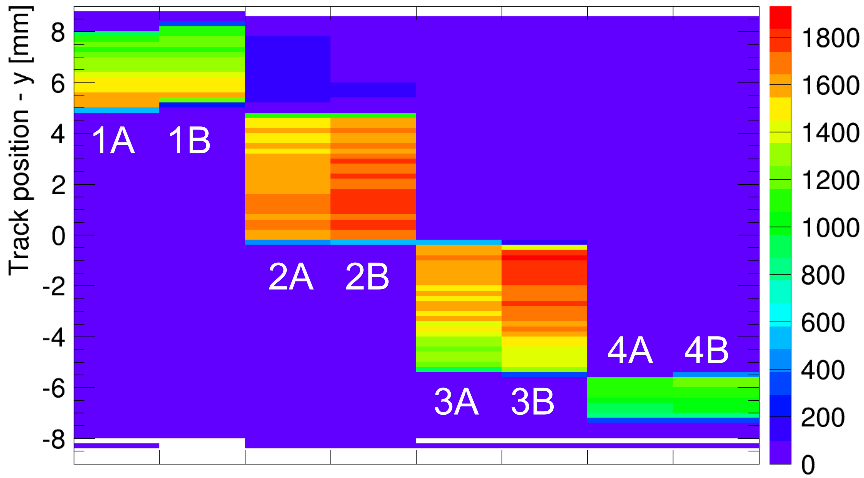
Design: "LQbar"

- each bar $\sigma_t \leq$ 30 ps
  - tests: 25-30 ps
- 4 independent bars: ≤15 ps

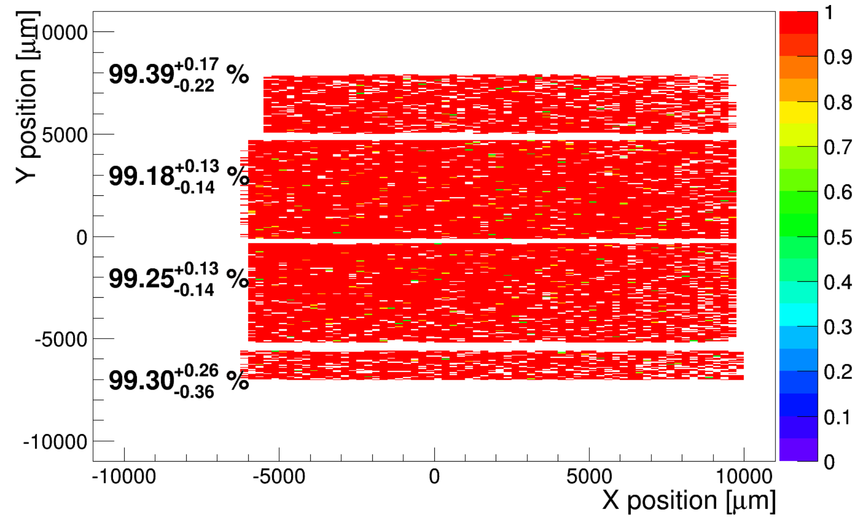


Beam Test: Time-of-Flight Detector

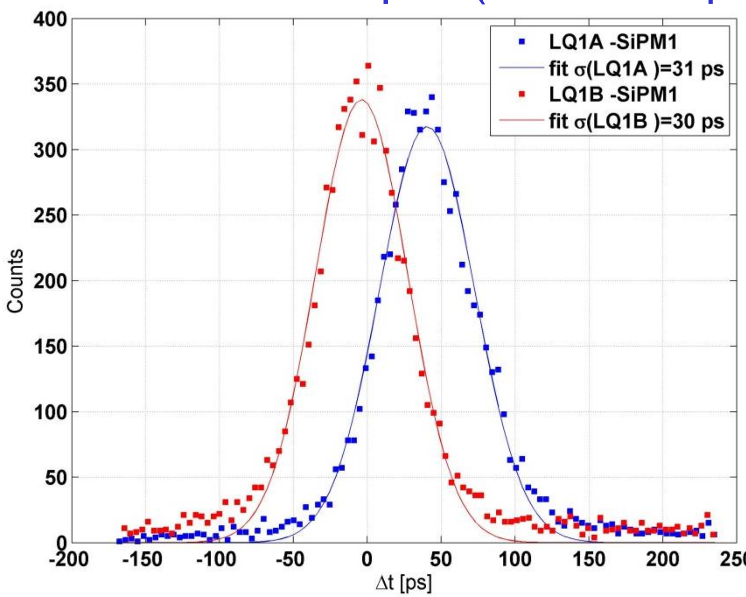
– Sit-ToF correllation: excellent (but some X-talk)

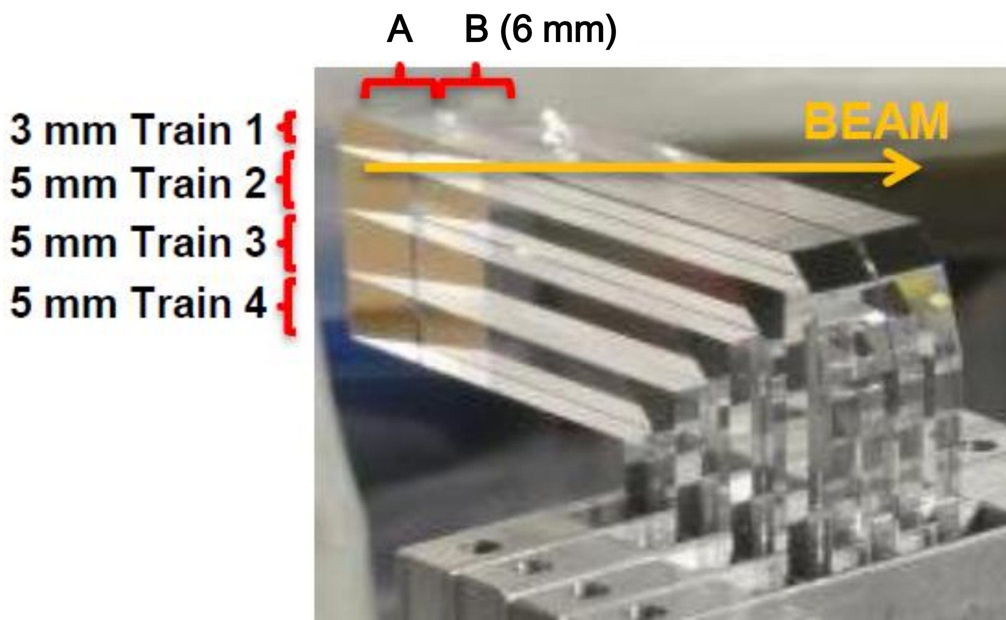


ToF efficiency: >99%



– Resolution: ~30 ps (Oscilloscope)





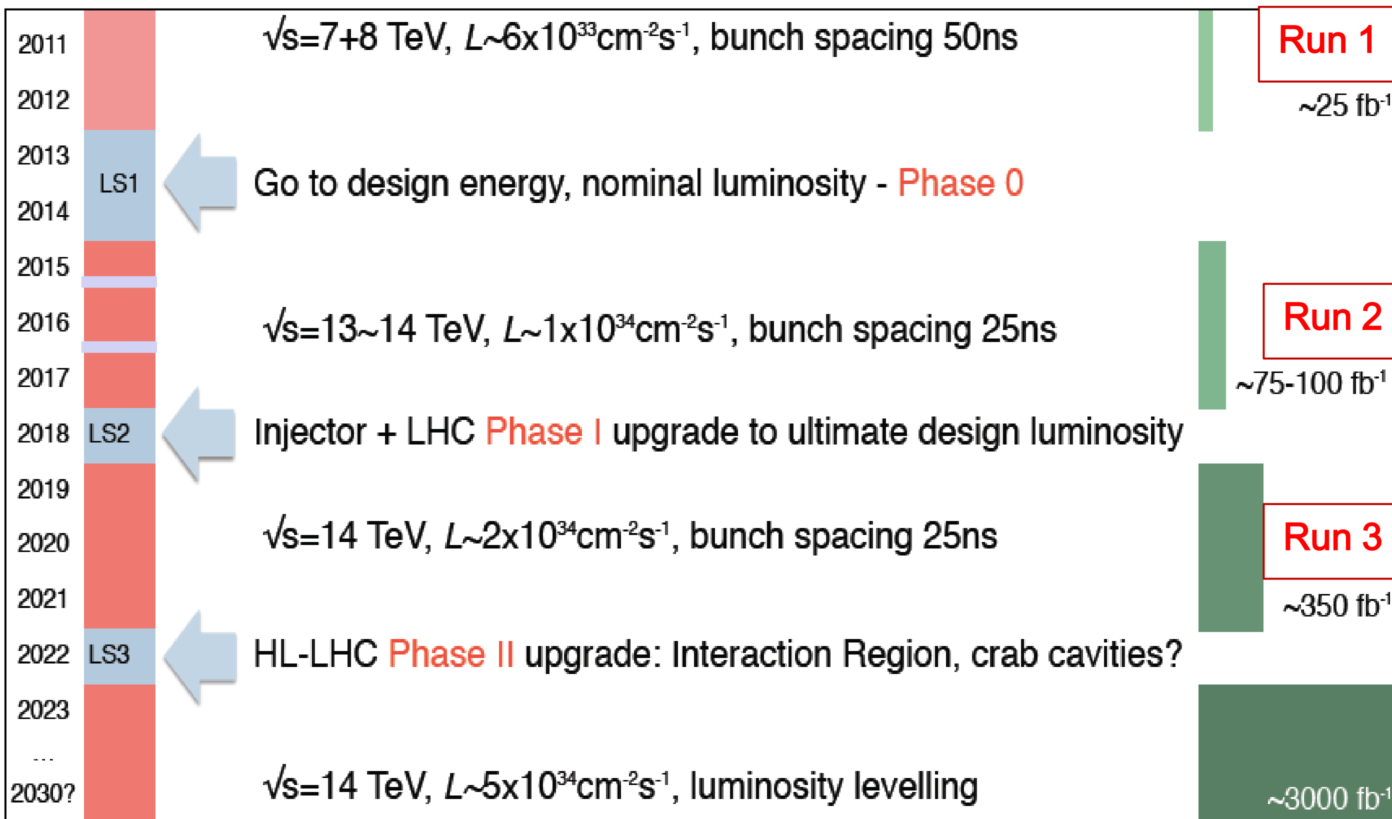
Run 2 and Beyond

Plans for Run 2:

- **AFP0+2** in 2015/16 SSD (?); **AFP2+2** in 2016/17
- Special high β^* runs in 2016-2017
- Standard optics runs to measure environment

Participate in Run 3 if:

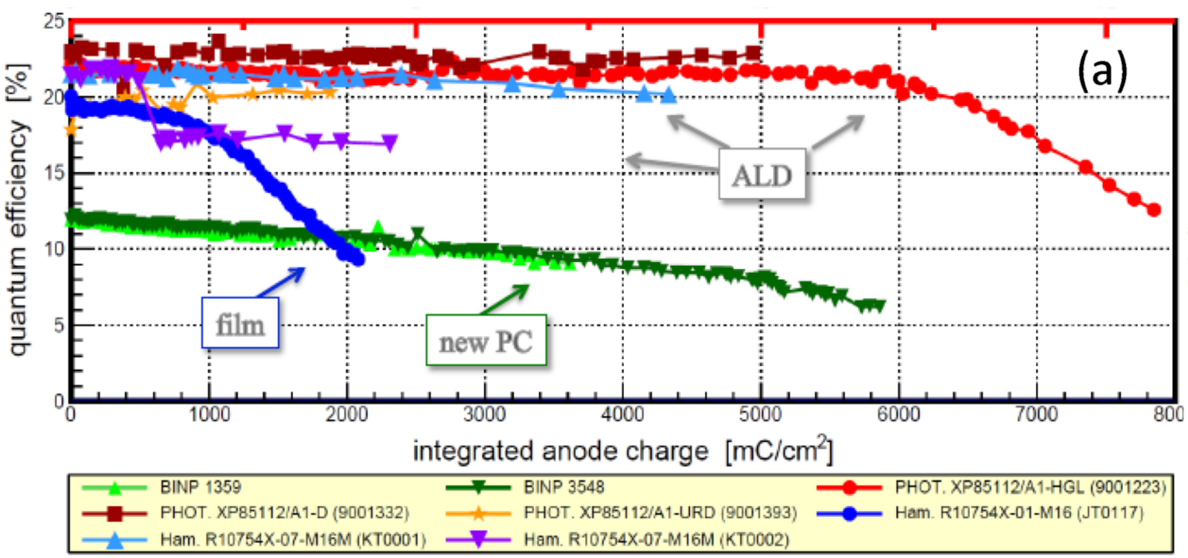
- standard optics works for AFP (review)
- High Lumi AFP program is approved (review)

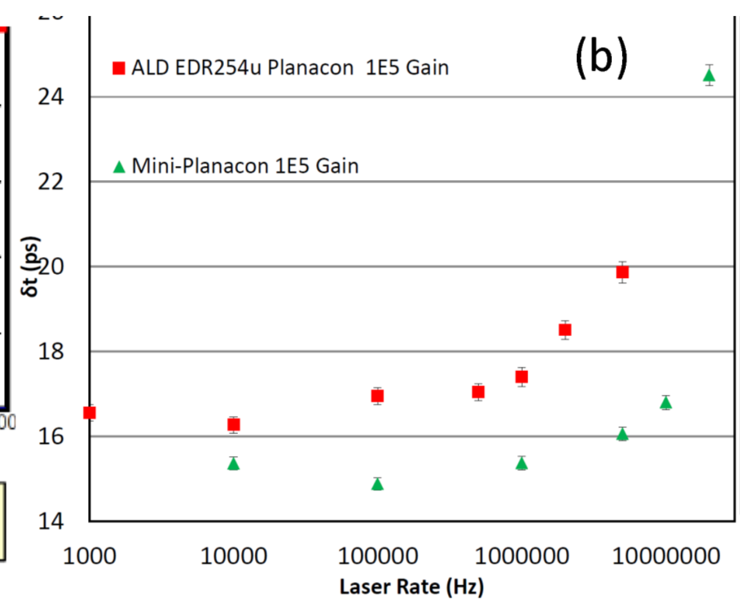


Backup Material

Backup – ToF MCP-PMT

- MCP-PMT Life Time and Rate





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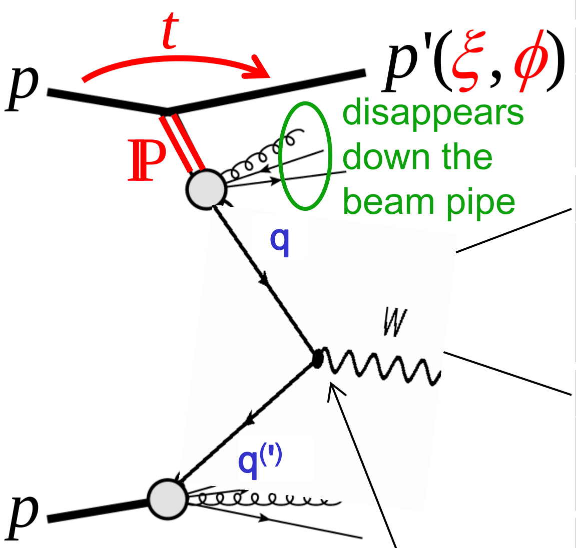

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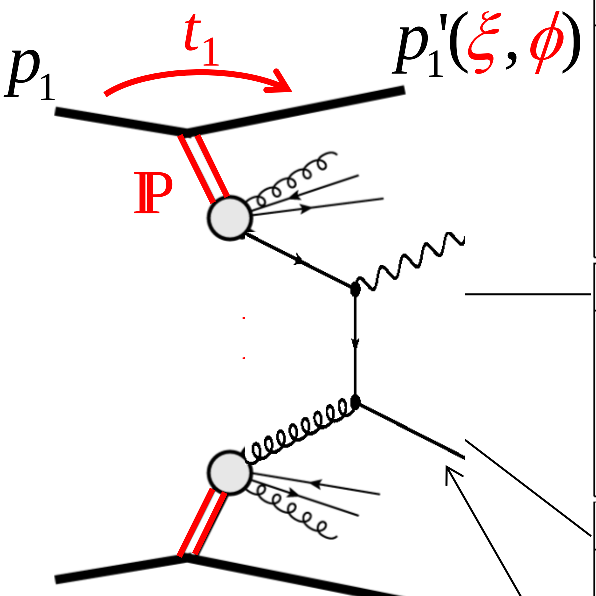

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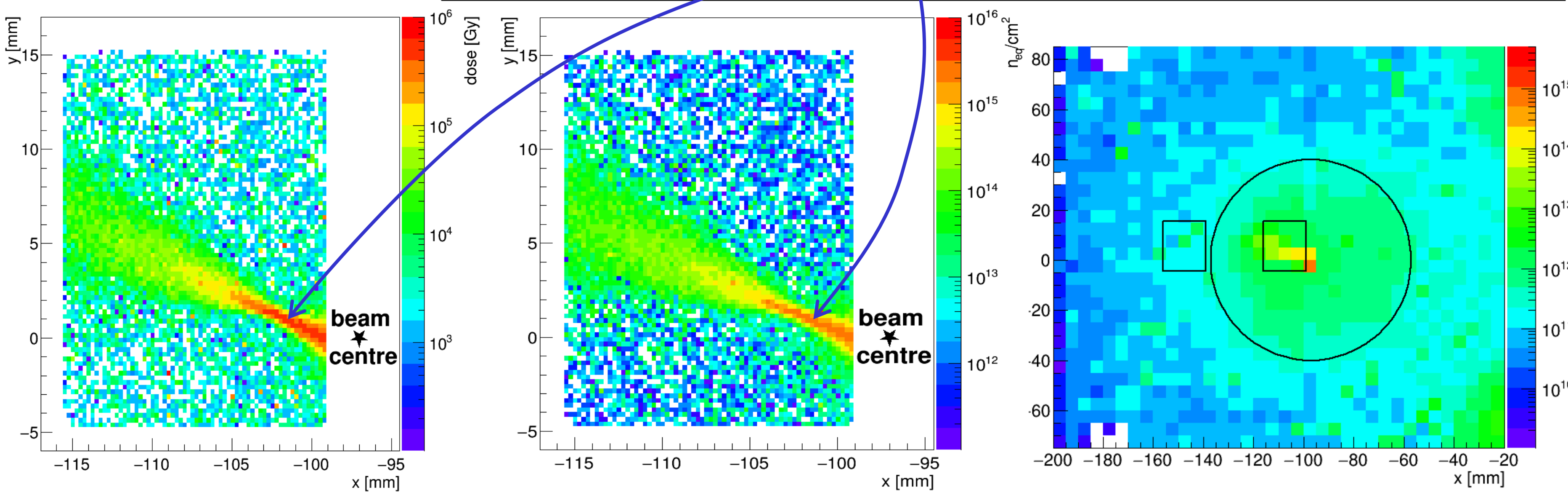
Backup – Radiation Levels

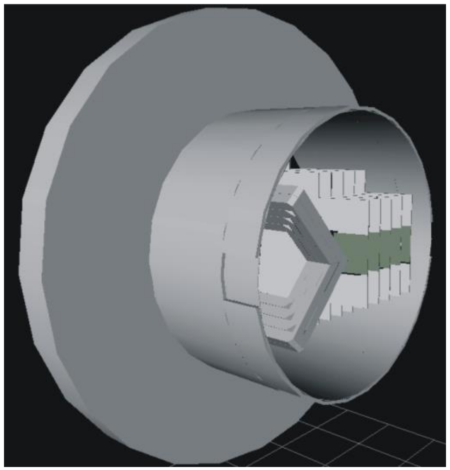
Radiation levels for **100 fb^{-1}**

- inputs: ALFA and TOTEM measurements
- AFP Full simulations in minbias events (below)
- early FLUKA calculations (A Mereghetti, 2009)

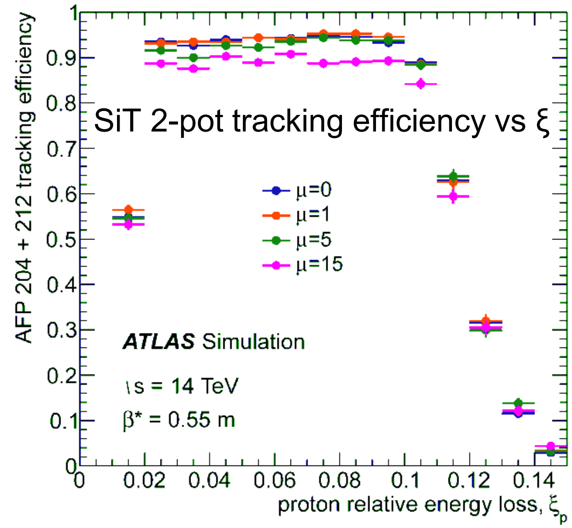
Position	5 mm from beam	5 cm from beam	Tunnel Floor
Electronics type	3-D sensor & FE-I4	PA-a	PA-b, Trigger, CFD, HPTDC
High-energy hadrons	$< 5 \times 10^{15}/\text{cm}^2$	$5 \times 10^{12}/\text{cm}^2$	$1 \times 10^{11}/\text{cm}^2$
n_{eq}	$< 3 \times 10^{15}/\text{cm}^2$	$3 \times 10^{12}/\text{cm}^2$	$5 \times 10^{10}/\text{cm}^2$
Dose	< 700 kGy	200 Gy	50 Gy



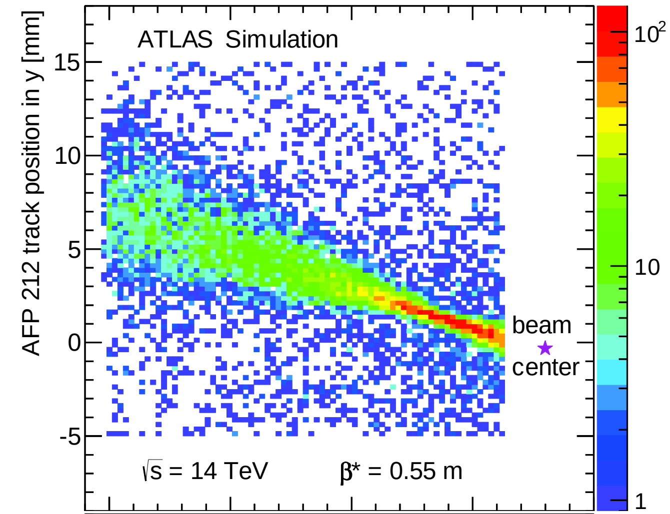
Backup - Simulations

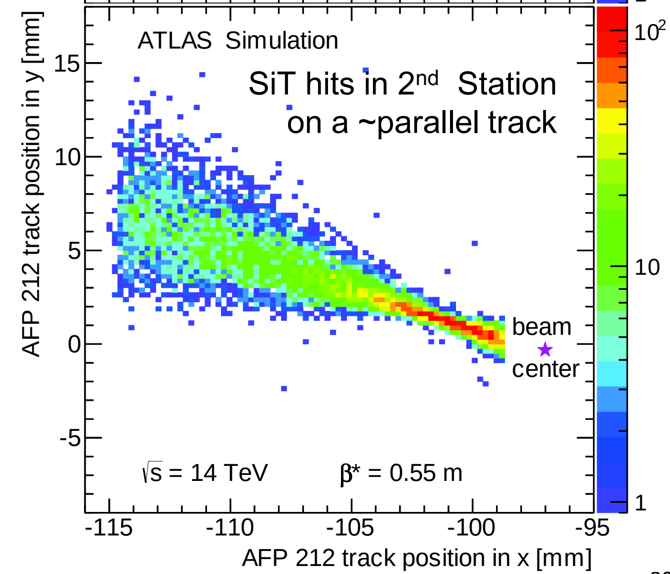


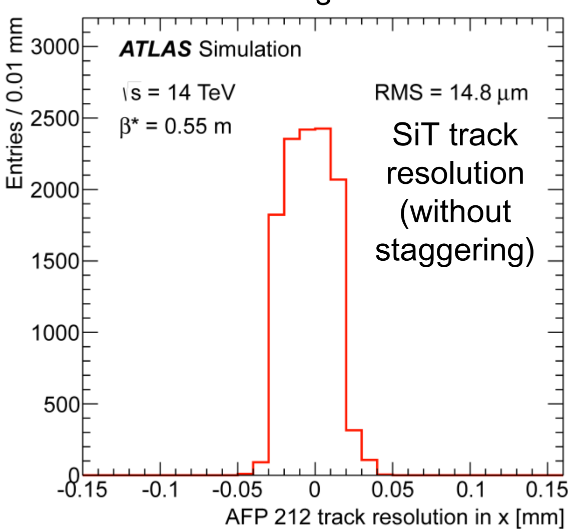
GEANT4 model of Roman pot with Si Tracker and Timing detectors

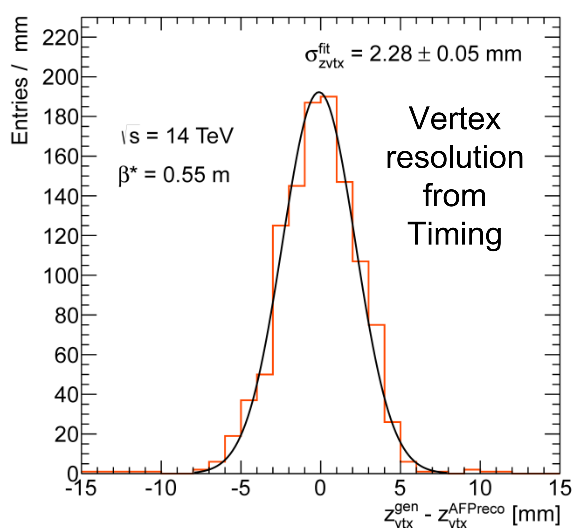


SiT hits in 2nd Station



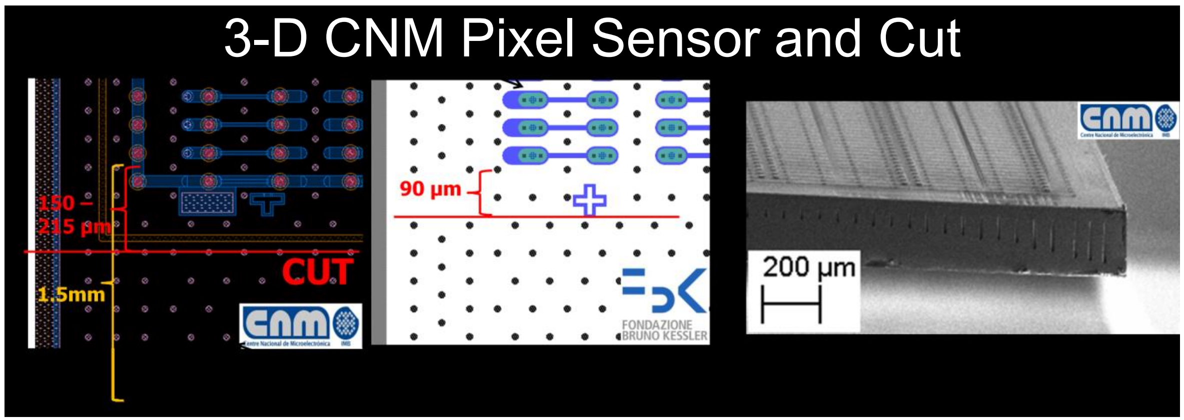


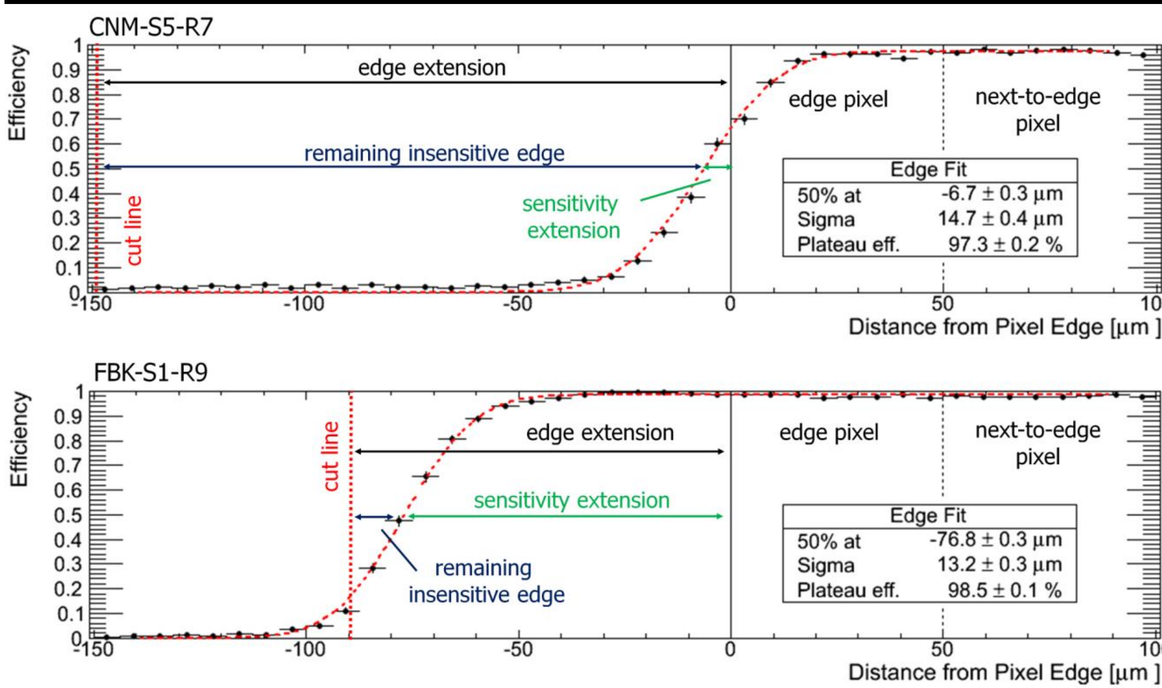




Backup - 3-D Silicon Sensor Cut

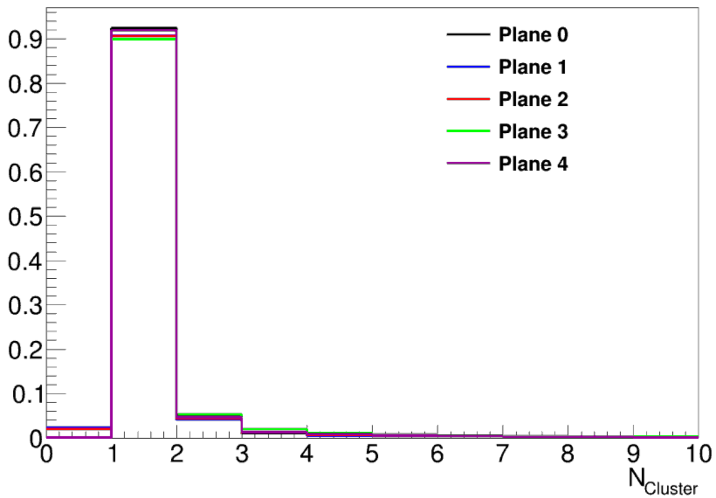
Edge cut by diamond saw (IFAE Barcelona)



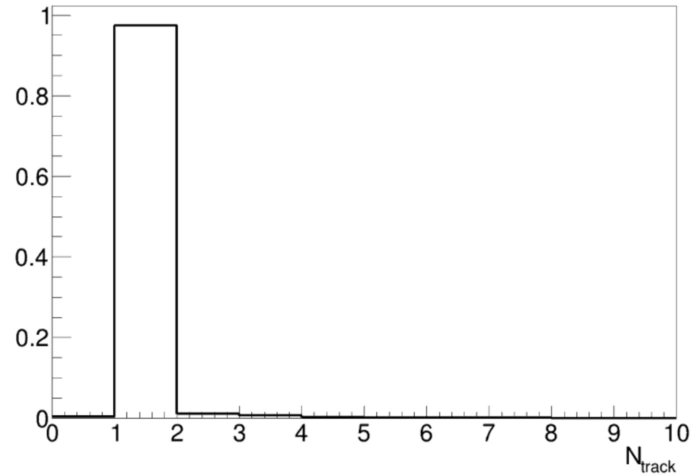


Backup – Test Beam – SiT

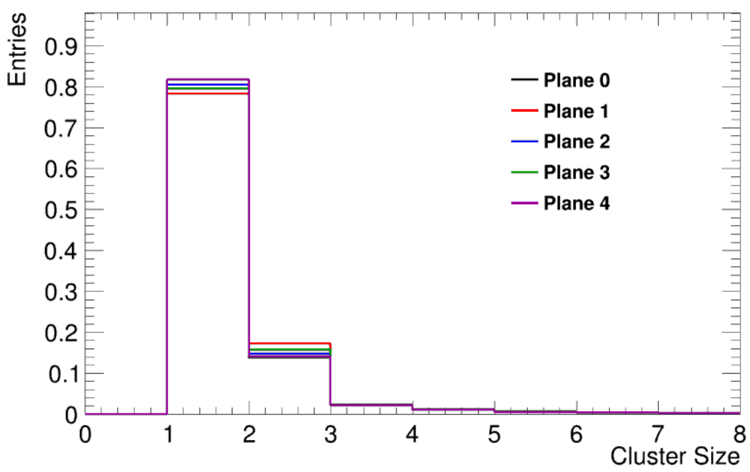
Cluster multiplicity



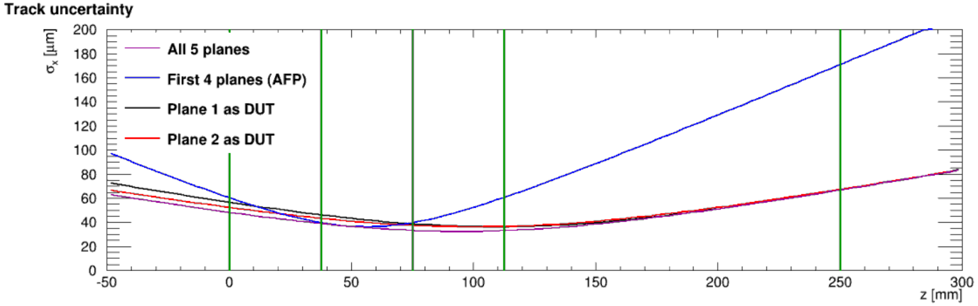
track multiplicity



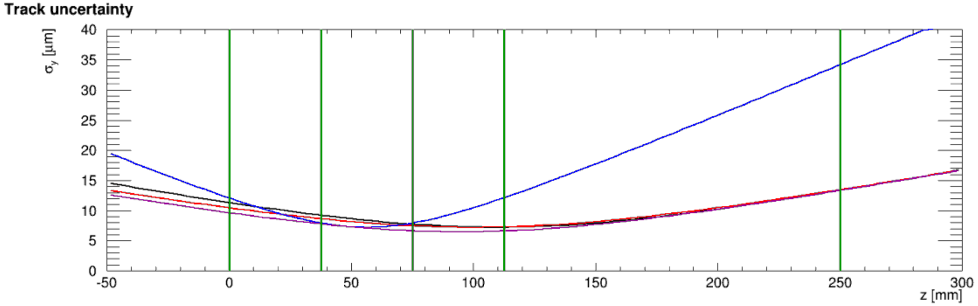
Cluster Size



Track uncertainty



Track uncertainty



Technical Manpower Needs 2015

- Urgent:
  - **1 FTE of onsite TC** (+ 1 FTE PL + 0.3 FTE RC)
    - probably OK
  - **0.5 FTE of onsite Project/Mechanical Engineer**: assistance with oversight of RP Station assembly, Detector integration, LHC integration, installation. To work closely also with ATLAS TC.
    - in the works …
  - **1.0 FTE of a good onsite Technician** with experience in UHV work and electrical work: RP Station assembly, Detector integration, installation (~50% from FD M&O B)
    - combination of 2 technicians?
  - **0.2 FTE of offsite Mechanical Engineer/Designer** for the Silicon Tracker
    - Oslo/Bergen !
- Not Urgent:
  - 0.2 FTE for 0.3 year of Mechanical Engineer/Designer for the Time-of-Flight (detector holder)
    - ??
- It would be advantageous to have a local (technical) contact in Prague to follow the RP Station production and Vortex Cooling at Vakuum Praha AS and at CTU …