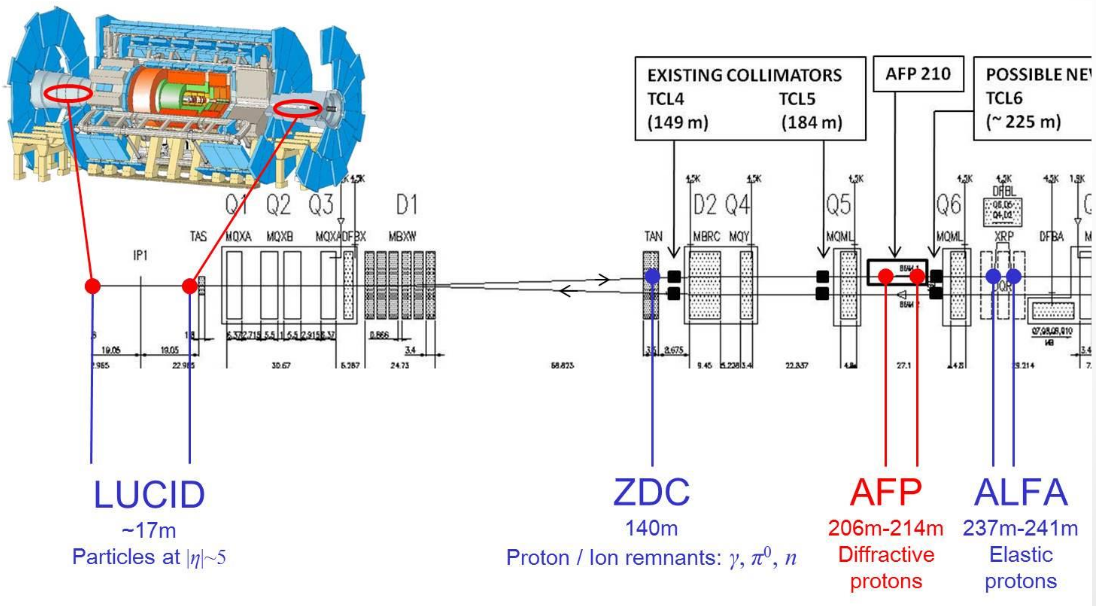
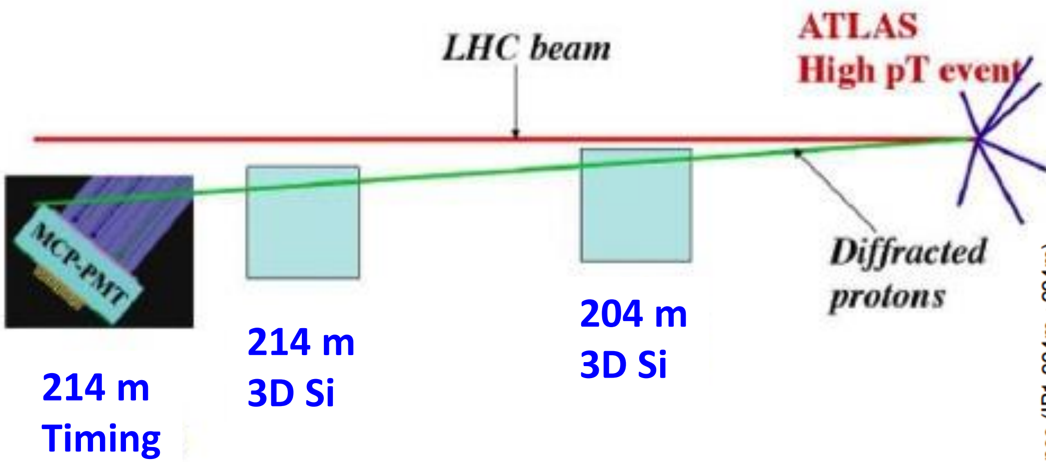
AFP status

- Detector
- Physics program
- Why AFP is necessary in addition to ALFA
- Detector status
- Test beam activities
- Summary
- Next Steps
- The collaboration

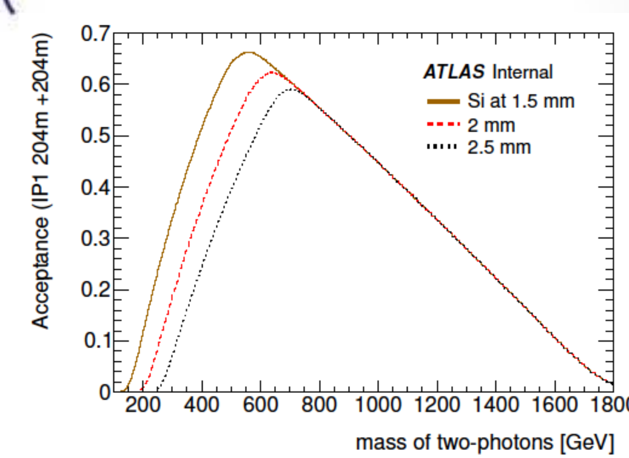


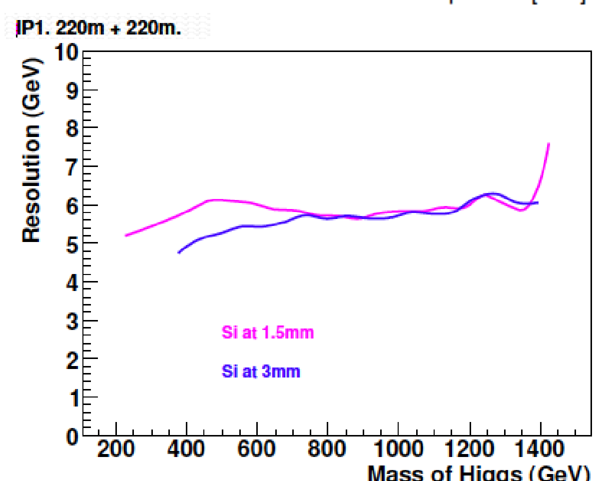
The AFP detectors



- Purpose:Tag and measure diffractive protons at 210 m (two arms)
- Precision MASS SPECTROMETER. In case of both p are tagged M=√($\xi_1\xi_2$s)
- Detectors
  - Radiation hard "edgeless" 3D Silicon detectors with ~μrad angular resolution for proton tracks reconstruction
  - High performing timing detectors

  (~ 10ps resolution, for proton pile-up background rejection **at high mu**)





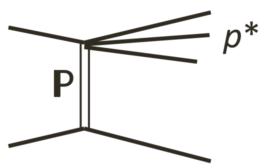
Forward Physics: any process where at least one particle goes forward

- At proton colliders, the protons typically interact inelastically, i.e. the collisions are between partons from protons
- While most of particles produced in these collisions are detected in the central detector, most of energy escapes undetected.

Interested in Forward Physics? → instrument the forward region

In a fraction of Forward Physics: one or both protons stay intact: measure them with AFP and provide ***ξ*** & ***t*** *(these make up around 20% of total pp x-section)*

Primary goals of AFP:

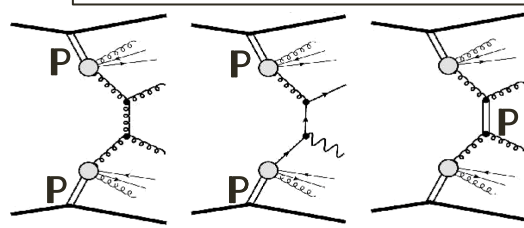


P:= 'Pomeron', a **color-less** object with *Q*-numbers of the vacuum

Single-tag: Single Diffraction

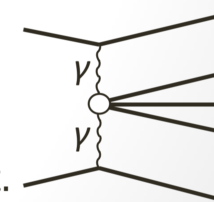
- Jets, W, Z: Soft survival prob. S^2

Double-tag: Double-Pomeron Exchange



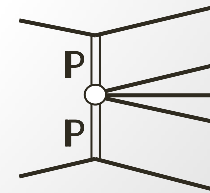
- Dijet: constrain gluon content of IP
- γ+Jet: constrain quark content of IP
- Jet-gap-jet: test BFKL IP

Double-Photon Exchange



- $\gamma\gamma \rightarrow$ **WW/ZZ**: Anomalous quartic couplings → sensitivity ~x100 wrt only central det.
- $\gamma\gamma \rightarrow$ **μμ:** calibration/alignment of AFP

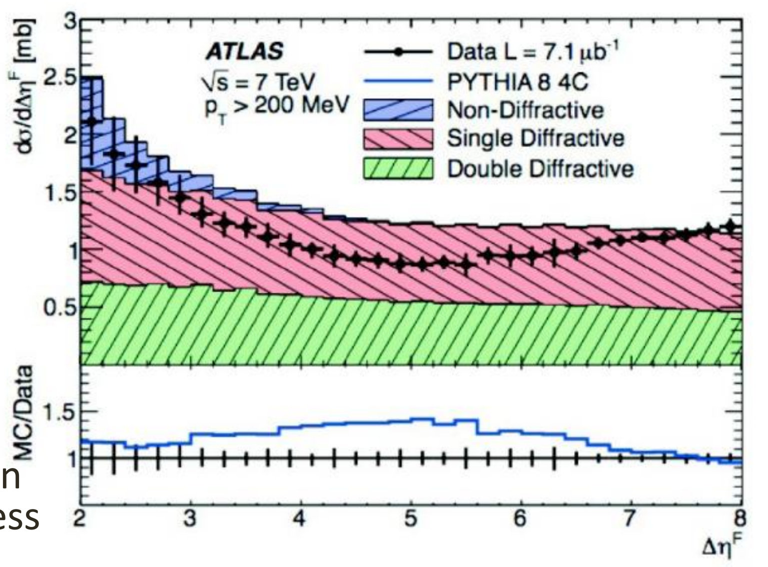
Central Exclusive Production



- Dijets, Trijets: constrain predictions to CEP of Higgs (S^2, Sudakov suppr., unintegr. f_g)

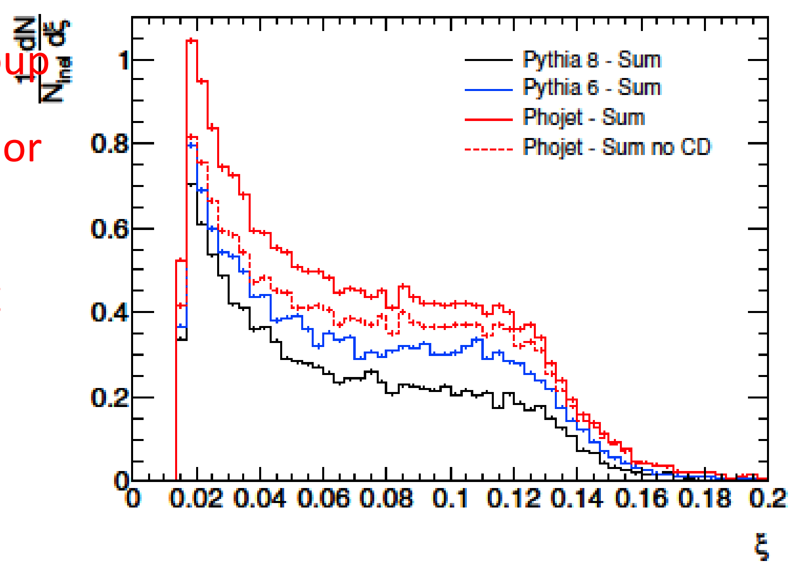
Soft diffraction program

- Measure $\frac{ds}{dxdt}$ as a function of ξ and t to test triple-Pomeron approach in the Regge Theory. Theoretical models differ factor of ~2



- High mass soft diffraction
  - charged particle distribution constrains particle production as a function of ξ
  - Since Pomerons are gluons dominated, production of strange particles in soft diffraction can lead to a better understanding of strangeness formation in hadronic processes

- Nearly all the analyses performed by sQCD group of SM, and that are mainly sensitive to non-diffractive events, could be repeated with one or two proton tags.



- All these measurements are useful to tune MC generators

M. Bruschi, INFN Bologna (Italy) 20/02/2014

Hard Diffraction program

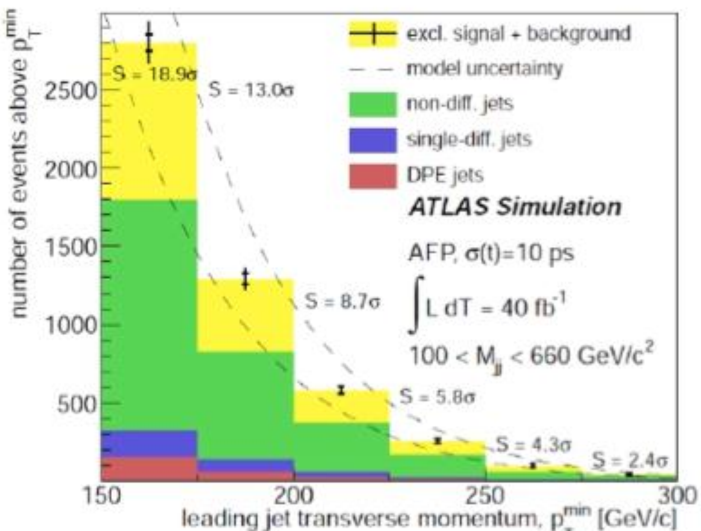
- Proton tagging at ATLAS will allow the study of hard diffraction, expanding and extending the investigations carried out at CERN by UA8, at HERA by H1 and ZEUS and at Fermilab by CDF and D0, and recently also by CMS
- From HERA and Tevatron measurements, a consistent picture emerged of Pomeron having a structure and dPDF governed by DGLAP evolution.
- There are however alternative theoretical developments where diffraction is a byproduct of a color rearrangement in the final state – Soft Colour Interaction (SCI)
- At LHC it will be possible to test the Pomeron model and search for deviations signaling other production mechanisms.

Hard Diffraction program

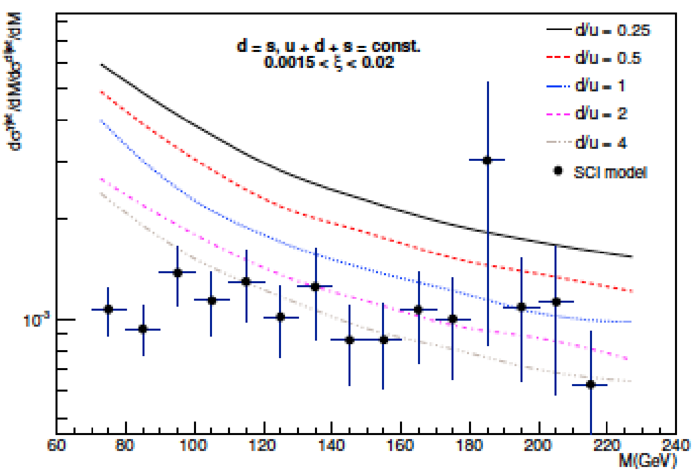
- Exclusive processes
- QED: γγ exchange
  - Anomalous couplings:

  Test of EW symmetry breaking (γγWW, γγZZ, γγγγ)
  - Search for Monopoles
- QCD: DPE
  - Exclusive Jet production: constrain

  diffractive Higgs production
  - Jet-gap-Jet to test BFKL dynamics
  - γ+jet production. Measurement of ratio of γ+jet over dijet cross sections will allow direct study of the quark content of the Pomeron



- SD W production (to be finalized)
- W charge asymmetry in single diffractive production is sensitive to the flavour structure of the Pomeron, in particular to u/d ratio
- HERA measurements cannot distinguish between different quark flavours, but AFP can!

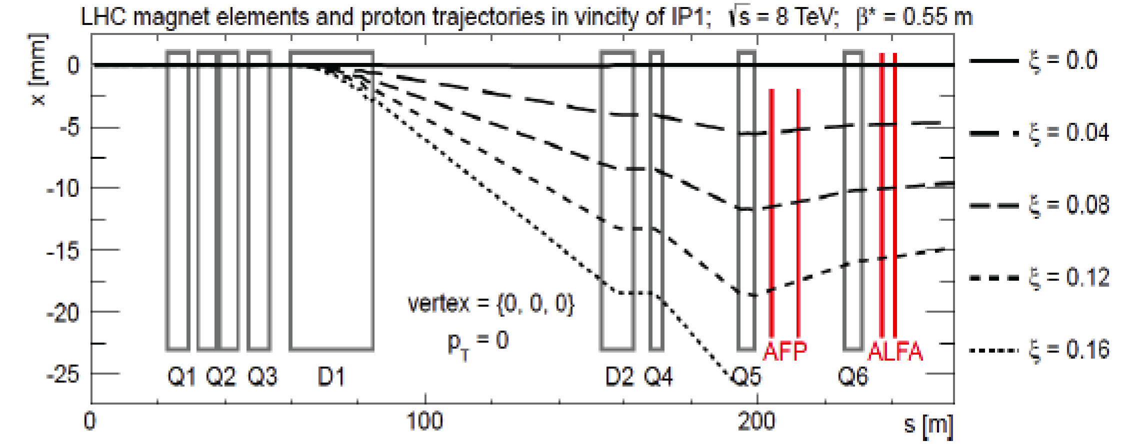


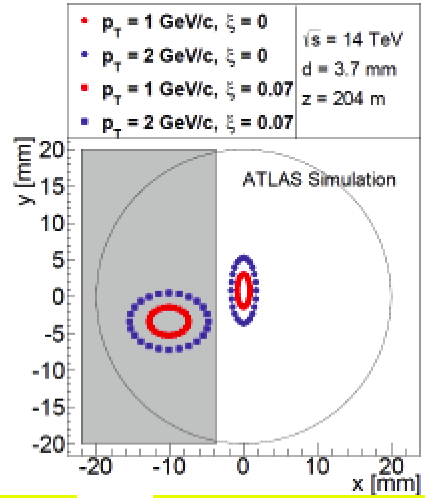
AFP Physics Program for RUN II

Analysis	Lumi req. [pb^{-1}]	Optimal μ range	β* scenario	L1 trigger
Particle spectra	1	< 0.05	90m(ALFA+AFP) 0.55m	AFP-ST AFP-DT
Gap spectra	1	< 0.05	90m(ALFA+AFP) 0.55m	AFP-ST AFP-DT
SD jj	10-100	0.01-1.0	90m **0.55m**	AFP-ST && Jet
DPE jj	10-100	0.5-5.0	90m **0.55m**	AFP-DT && Jet
SD W	10-100	0.1-1.0	90m **0.55m**	AFP-ST && Lepton (&& MET)
DPE γ+j/jj	> 200	1.0-2.0	0.55m	AFP-DT && Jet/Photon
DPE j-g-j	> 100	0.1-2.0	0.55m	AFP-DT && Jet

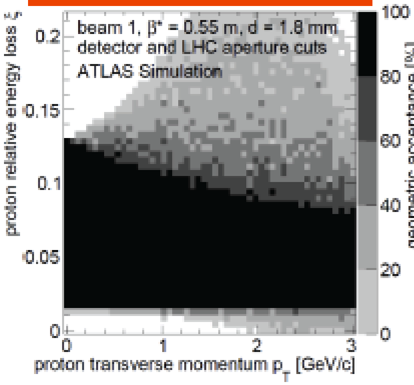
1 week of 100h:
μ = 0.1: ~10 pb^{-1}
μ = 1 : ~100 pb^{-1}

ALFA vs. AFP for β*= 0.55m

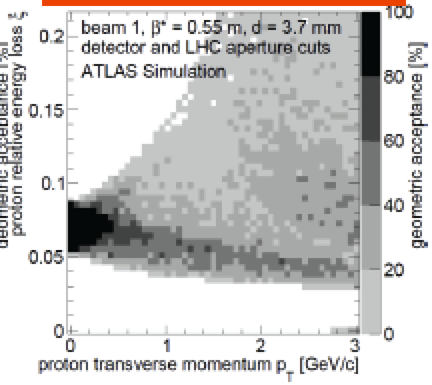




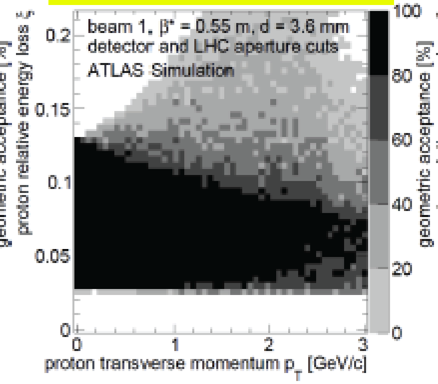
AFP 204m: 10σ = 1.8mm



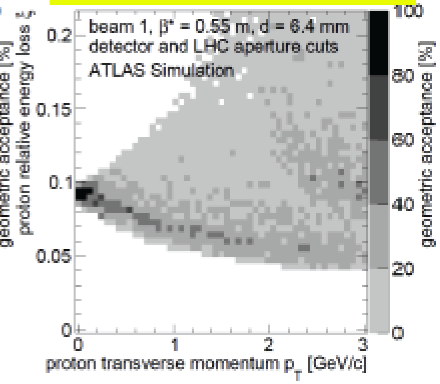
ALFA 237m: 10σ = 3.7mm



AFP 204m: 20σ = 3.6mm

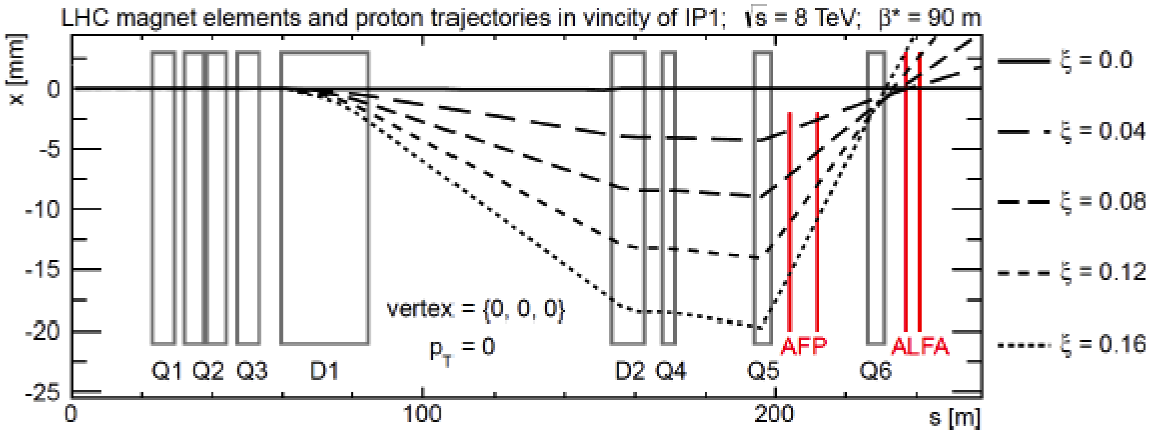


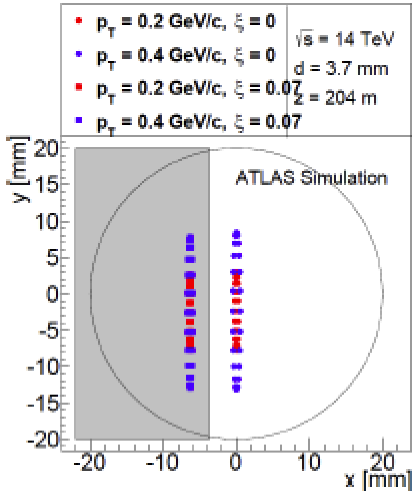
ALFA 237m: 20σ = 7.4mm

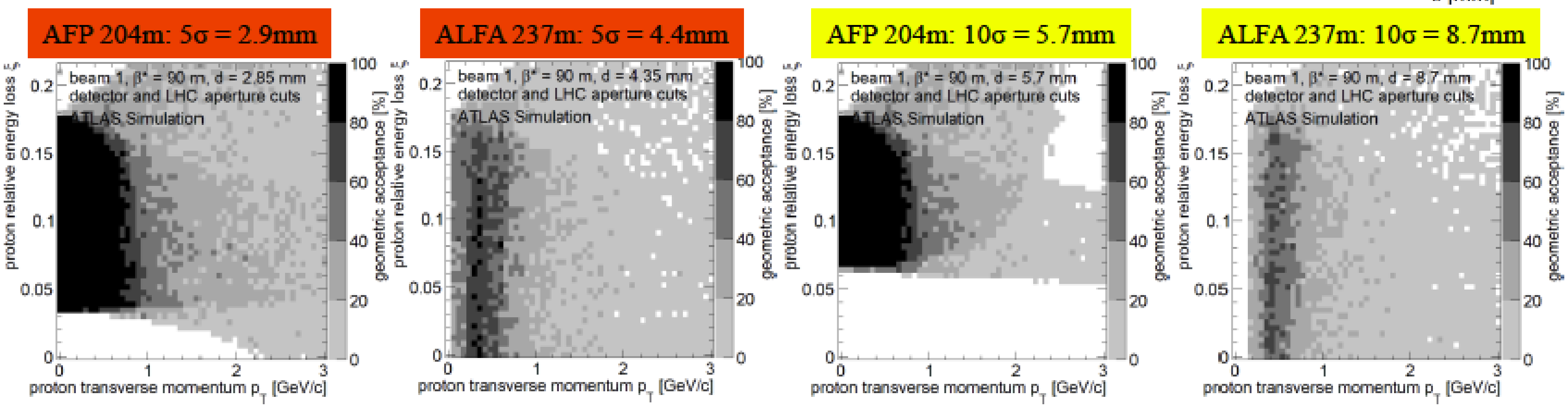


- ALFA (vertical pots only) covers ~1% of AFP (ξ, t)-acceptance. **At LHC with β*= 0.55m: diffraction is horizontal**
- **High inst. Lumi:** ALFA would need to replace sensors and to reduce dead time.

ALFA vs. AFP for β*= 90m





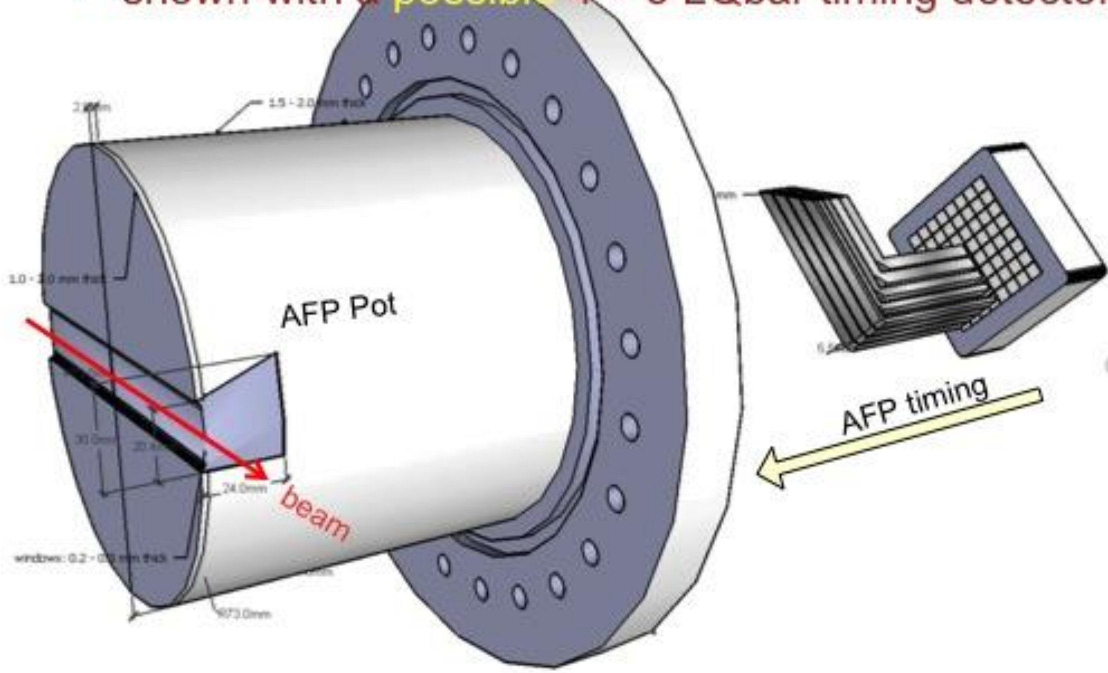


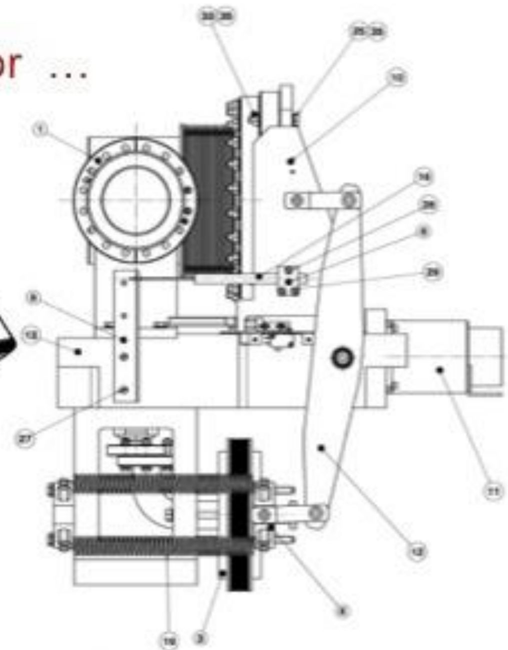
AFP concentrated around higher xi, while ALFA gives access to very low xi – common data taking would be best!
ALFA upgrades its dead time, radhardness and trigger. BUT: 1) Still there will be some dead time and 2) no timing det.
3) In the overlap regions, the ALFA acceptance is 10% of the AFP acceptance ;4) Below xi<10-3 resolution bad

AFP RP & STATION

AFP Pot adaptation from TOTEM design

– shown with a possible 4 × 5 LQbar timing detector …





TOTEM horizontal RP station (beam view)

Copy RP Station design of ALFA & TOTEM:

– Ample operational experience

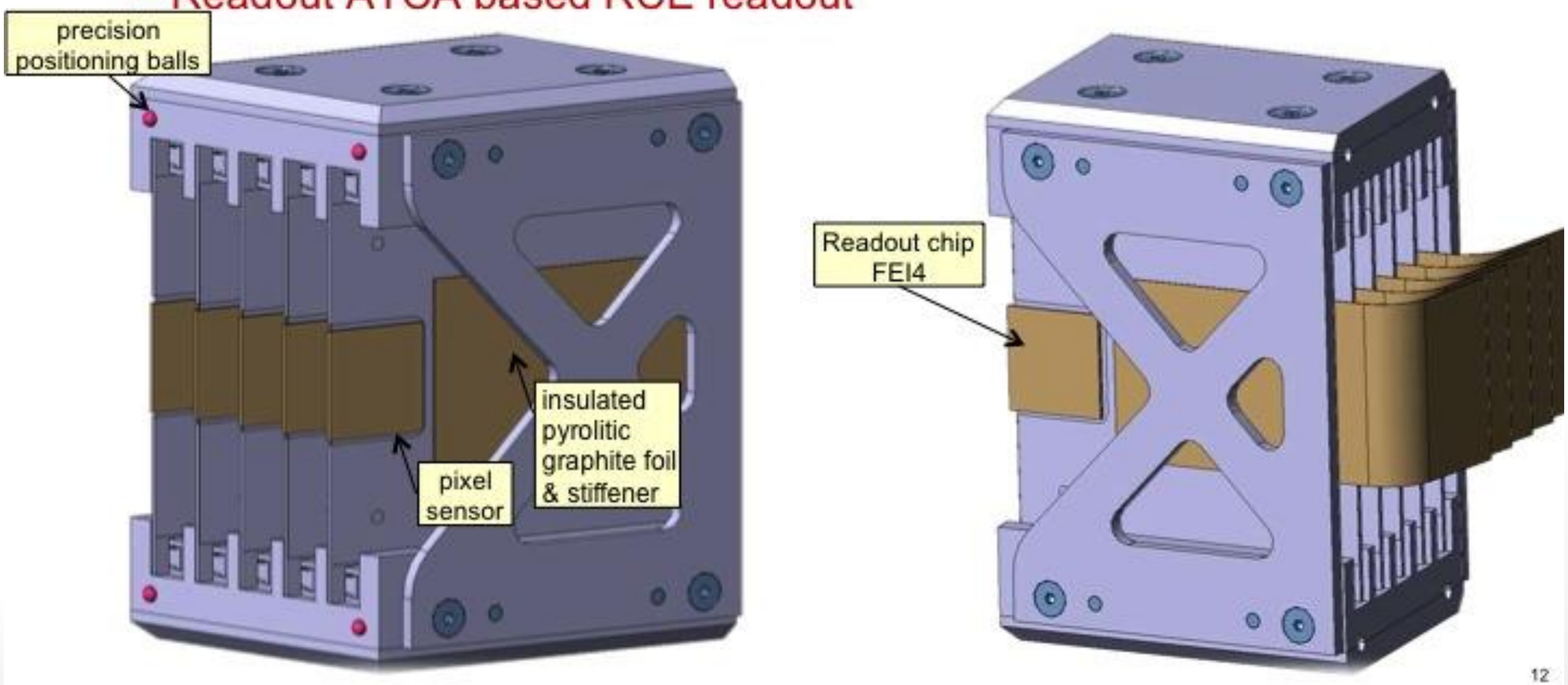
– Known cost and construction & installation procedures

Simulations (+test beam) show that ~20/(10) ps res. can be achieved in a shared/(dedicated) RP

Tracking Detectors

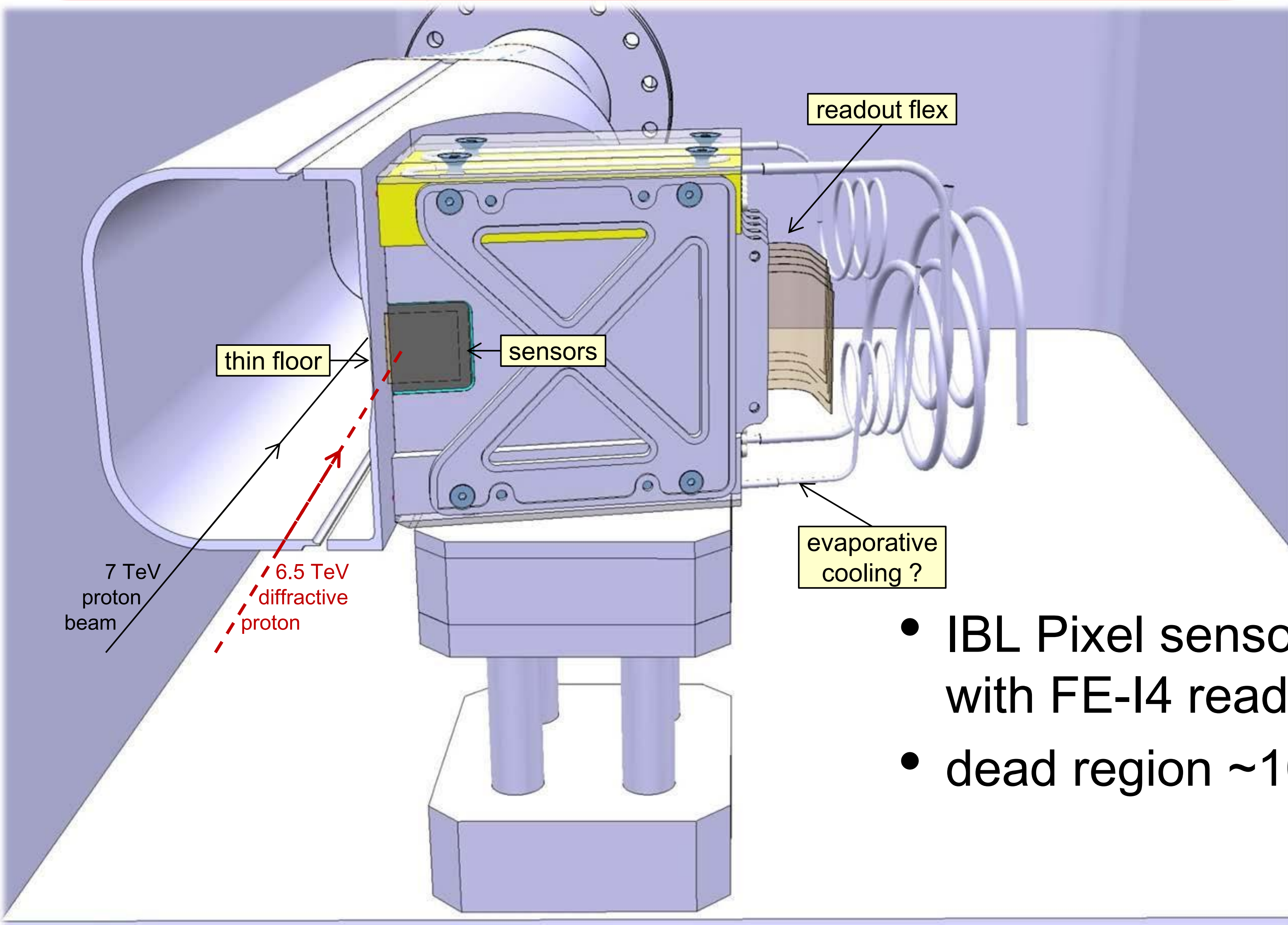
- AFP will use ATLAS IBL pixel sensors bonded with FE-I4 readout chips
  - 50 μm × 250 μm pixels size
  - future: edgeless 3-D pixel sensors ➔ closer to beam
  - Readout ATCA based RCE readout

AFP Detector R&D: P. Sicho et al.



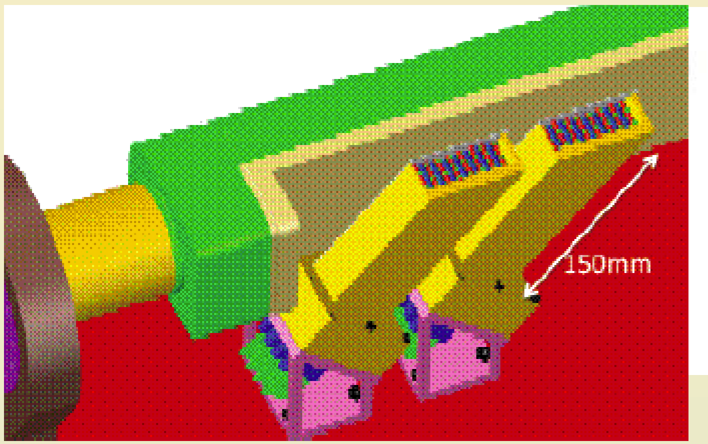
12

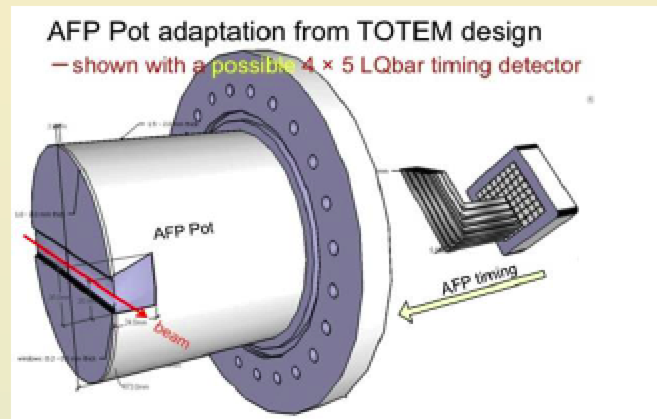
Si Tracker in Hamburg Beam Pipe

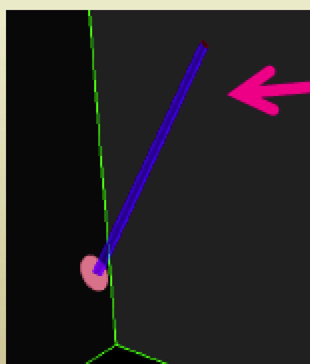


- IBL Pixel sensors with FE-I4 readout
- dead region ~100 μm

Challenge: Adapt Timing Detector to be compatible with Roman Pot instead of HBP

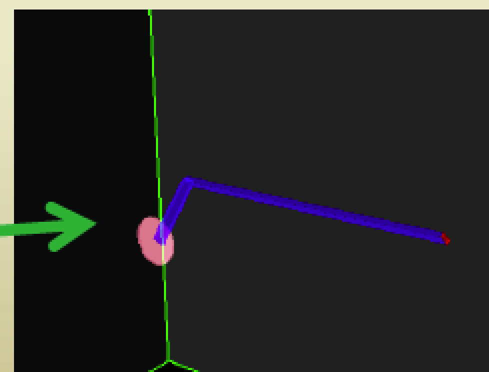




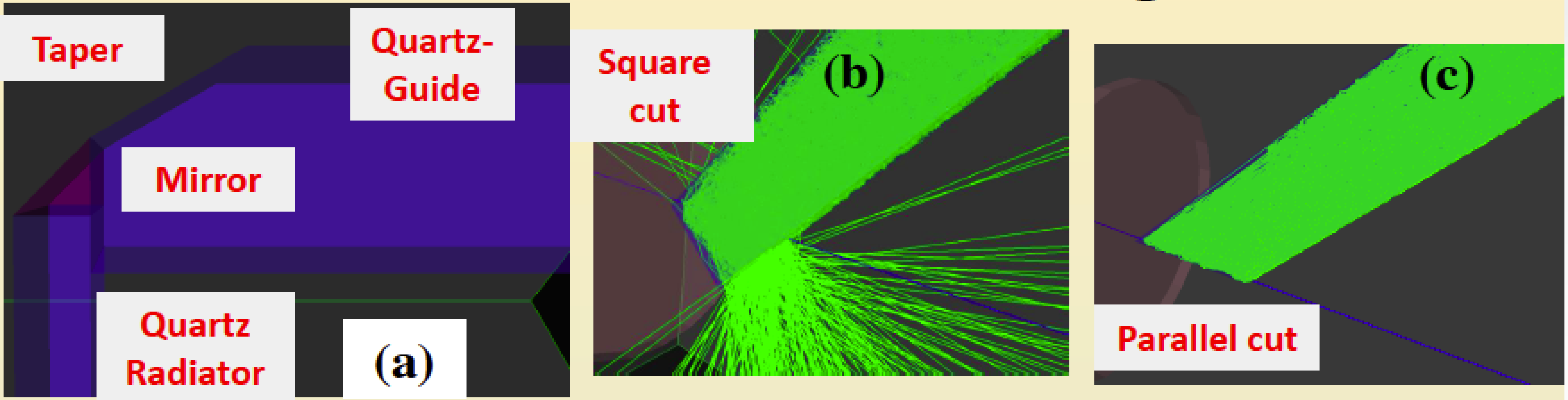


Straight bar at quartic angle

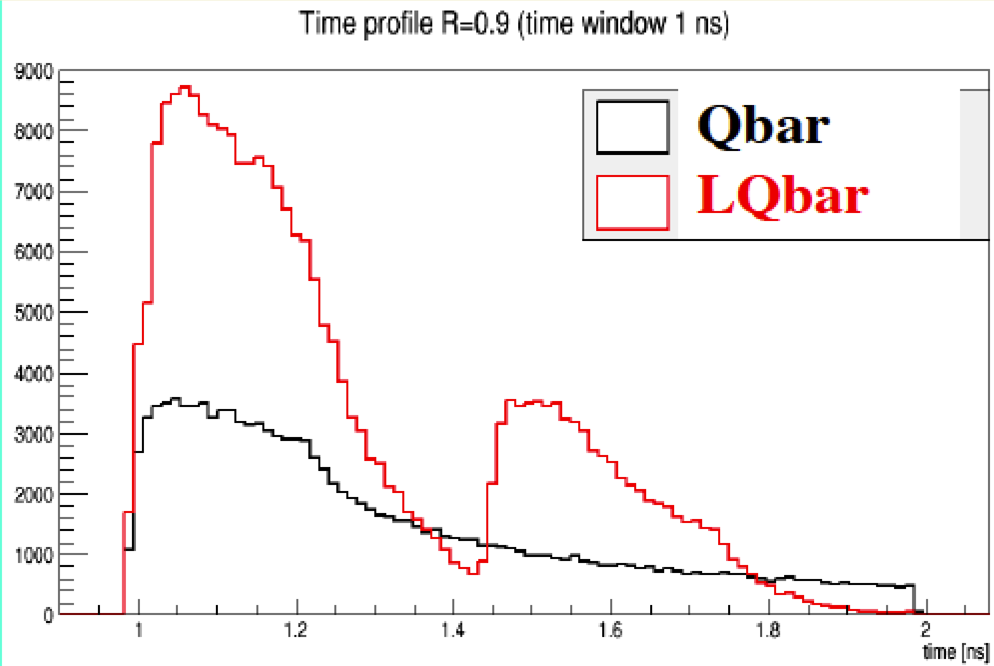
LQBar takes light out at 90 degrees



Baseline LQbar design



The expectation was that the LQbar would be inferior to the Qbar, due to light lost at the elbow, but a taper (a) to focus the slower wide angle light and replacing a square cut (b) with a parallel cut at the bottom end of the bar (c) actually gives an improved distribution (d) from which we can infer that the bent bar will actually have superior performance

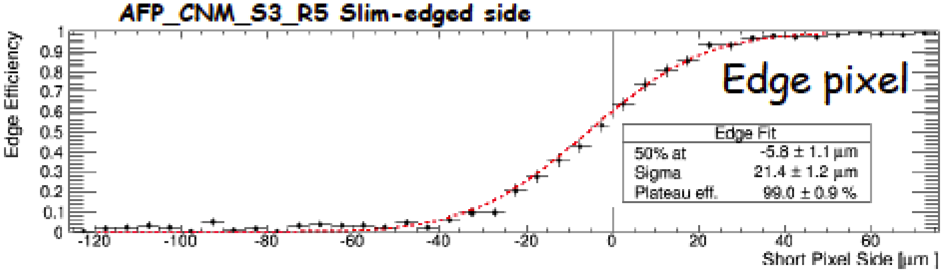


More on timing

- The basic readout scheme for quartic is MCP PMT+ Amplifier+CFD+HPTDC
- As an upgrade we are also considering to use SAMPIC instead of CFD+HPTDC
- Also a detector upgrade based on diamond sensor is being investigated as R&D

Test Beam Activities

- June 2013 test-beam at DESY:
  - Validation of devices with 100 μm dead region with diamond saw cut
  - Efficiency studies in edge region



- July 2013/January 2014 test-beams at DESY:
  - Studies of non-uniformly irradiated samples (up to 2 - 3E15 n_{eq}/cm^2)
  - *Missing: expected dose for AFP trackers in different realistic scenarios!*

These test-beams conclude the studies of the two critical issues for AFP pixel sensors
1) High efficiency in slimmed-edge sensors, also at edge (previous bug fixed)
2) High efficiency achievable after non-uniform irrad. (analysis of Jan. TB still ongoing)

See e.g. presentations at AFP Meetings (10.7.13, 6.11.13) :
https://indico.cern.ch/getFile.py/access?contribId=4&resId=0&materialId=slides&confId=261342
https://indico.cern.ch/getFile.py/access?contribId=10&resId=0&materialId=slides&confId=280846
Note in preparation.

➢ Future combined (tracker + timing) test-beam at CERN:
Requested beam time for the Nov-Dec 2014 schedule (very tight)

Test Beam

May28 2014 FNAL with Mike Albrow:

I. Single Bar Optimization Studies for LQBAR

- Measure LQbar response as fct of radiator length and width, light guide length and width, Cherenkov angle, height in the bar, type of glue, etc.
- Use band pass filters to optimize wavelength range
- Multi-bar test?

II. 6 Channel Studies (for completeness)

- Single row (6 channel) QUARTIC tests through HPTDC
- Use clock as well if possible
- Use detector to measure speed of light
- Put material in front of detector to simulate effect of vacuum windows multiple scattering, nuclear interaction.
- Use tracking to measure efficiency and multi proton effects

AFP Status summary

- The AFP community did impressive progress in the last months
  - Analysis
    - Full simulation study: DPE jj (see Maciej's talk)
    - Alignment (see Rafal's talk)
    - Soft diffraction (see Tim's and Vlasta 's talk)
    - $\gamma\gamma\gamma\gamma$ anomalous coupling (Christophe, Matthias)
    - Detector efficiency study using full simulated forward region (Antonello, Leszek, Matheus)
  - Detector
    - Test beam results on 3D slim edge
    - LQBar design
- The AFP physics review (organized by ATLAS) held its final meeting on Friday 24th January
  - The above mentioned impressive recent progress in several areas (physics case and simulation) noted by panel
  - Unique diffractive and QCD physics programme achievable with a few days dedicated running during Run-2 at low luminosity
  - Developing close collaboration with ALFA is positive and should continue
  - Detailed recommendations are being written; next steps are resources and technical reviews
  - Run-3 program for high luminosity will be revisited in 2016, when experimental data on background and running experience will be available

AFP next steps

- The ATLAS technical review will take place in the week from March 24th to 28th

- If successfully passed, the next foreseen steps are:
  - Approval from the ATLAS CB in June 2013 (go ahead to TDR)
  - Approval from LHCC in fall 2014

- The writing of the available parts of the TDR will start shortly after the technical review
- Final TDR to be submitted to LHCC ready in september 2014
- Final validation test beam (RP+Tracking+LQBar Timing) at CERN in November 2014 (tough, but it will be tried)
- Detector construction in 2015
- Detector installation during Christmas shutdown 2015/2016

The AFP collaboration

- Canada: Alberta, Toronto
- Czech: Olomouc, Prague AS, Prague CTU
- France: Saclay
- Italy: Bologna, Genova, Milano, Roma2, Trento
- Norway: Bergen, Oslo
- Poland: Cracow AGH UST, Cracow AFJ PAN
- Portugal: Lisbon
- Spain: Barcelona
- Switzerland: Bern, Geneva
- USA: Arlington (Texas), New Mexico, Oklahoma, Stony Brook

- Presently: 20 people involved at >50%

Future potential:23 Institutes, 80 people (30 FTE) !

- AFP MUST now pass the Technical review
  at the end of March if we want to realize it

- Institutional/National commitments for AFP are time-critical
  - Timing (USA): only R&D funds available now
  - Tracking: needs institutional commitments for manpower
- Things are expected to change positively this spring, at some point after the Technical Review

NEW COLLABORATORS ARE NEEDED: YOU ARE INVITED TO PARTICIPATE !

Last … but not least

- An important role in the recent success of the AFP plans is played by the existence of this **LHC Working Group on Forward Physics and Diffraction**

- We look forward to a fruitful collaboration with the other LHC experiments representatives to push for an excellent and exhaustive forward physics program at LHC

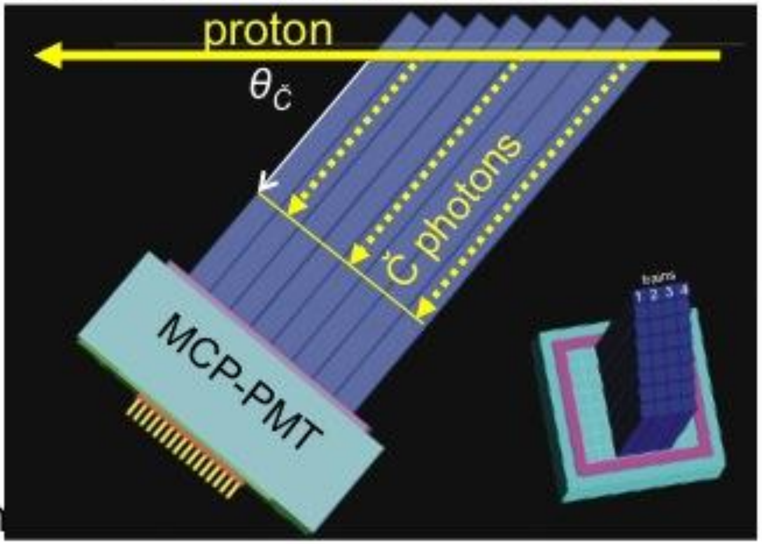
The union makes us strong !

Backup

AFP Fast ToF

QUARTIC concept: M. Albrow et al. (FP420 R & D Collab.), JINST 4 (2009).

- Initial design:
  4 trains of 8 Q bars: 6mm × 6mm ×100mm
- mounted at Cherenkov angle $\theta_{\check{C}} \simeq 48°$
- Isochronous – Cherenkov light reaches tube at ~same time for each bar in a train
- arrival time of proton is multiply measured: bar + readout resolution less stringent!
  - e.g 30 ps / bar → 11 ps for train of 8 bars



2011 DOE Advanced Detector
Research award for electronics developm

8-Channel Preamplifier (PA-a)

PA-b Programmable Gain Amp

CFD Daughter Board

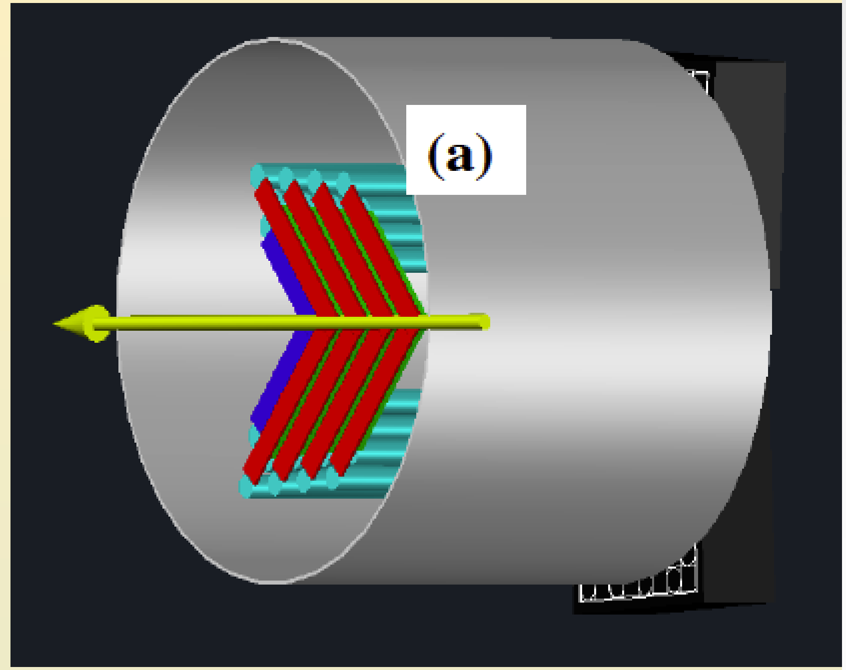
HPTDC Board

Detector & PMT: U Texas at Arlington (A. Brandt et al.);
Electronics: Stony Brook (M.Rijssenbeek et al.), U Alberta (J. Pinfold et al.)

AFP Progress report : Section 9.3

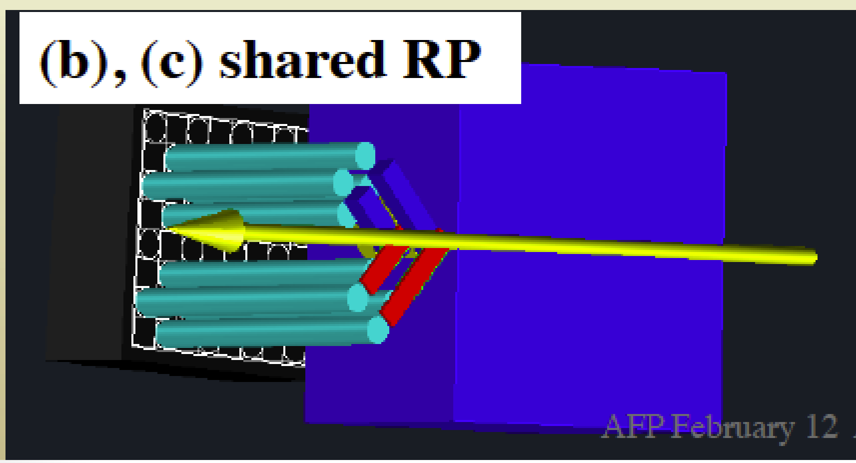
UPTOP: Concepts

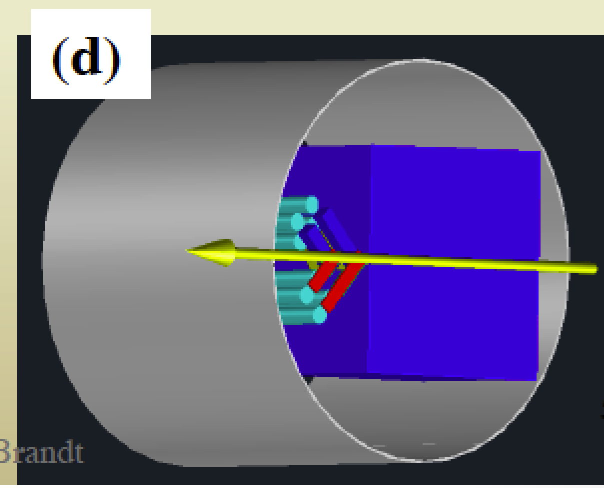
(a) RP detector dedicated



Baseline:
16 ch/side
4 layers in x
2 layer in y (+/-)
2 meas. each

Takes less space in front





Timing System Summary

Component	δt(ps) Current (HBP)	δt(ps) Projected (HBP)	δt(ps) ESTIMATED (shared RP 2016)	δt(ps) Projected (dedicated RP OR 2*RP 2019?)
Radiator/MCP-PMT (~10 /20 pe's w/ 10 μ /6μ)	19	14	14	10
CFD	5	5	5	5
HPTDC/(Sampic or HPTDC')	15	5	15	5
Reference Clock	5	5	5	5
Total/bar	25	16	22	13
Total # bars (in row)/ # channels	6/96	6/96	4/32	8/128
Resolution	10	7	16	7

16 ch/side
4 layers in x
2 layer in y (+/-)
2 measurements each

7

ToF Resolution: Test beam 2012 FNAL

30 mm long Quartz bar // beam read by SiPM: $\sigma_t \simeq 10$ ps for a SiPM (CFD only!)

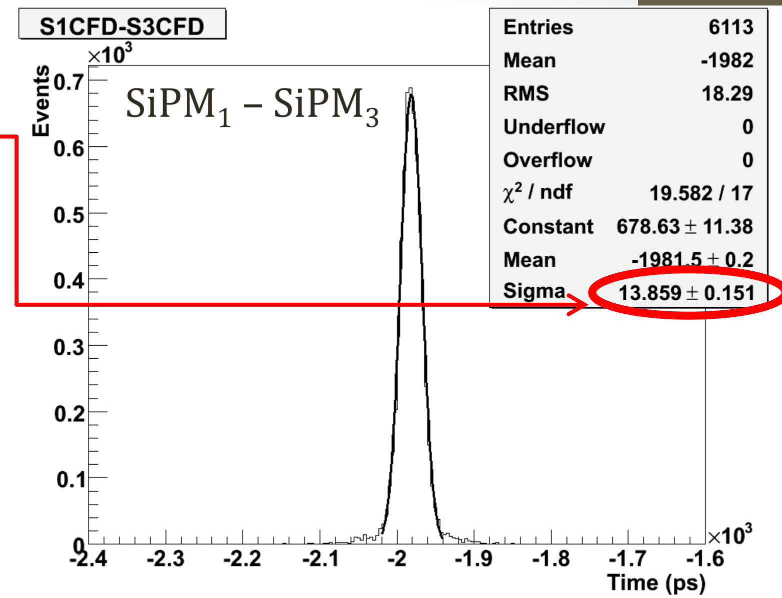
- excellent resolution! ☺
- not very radiation hard ☹

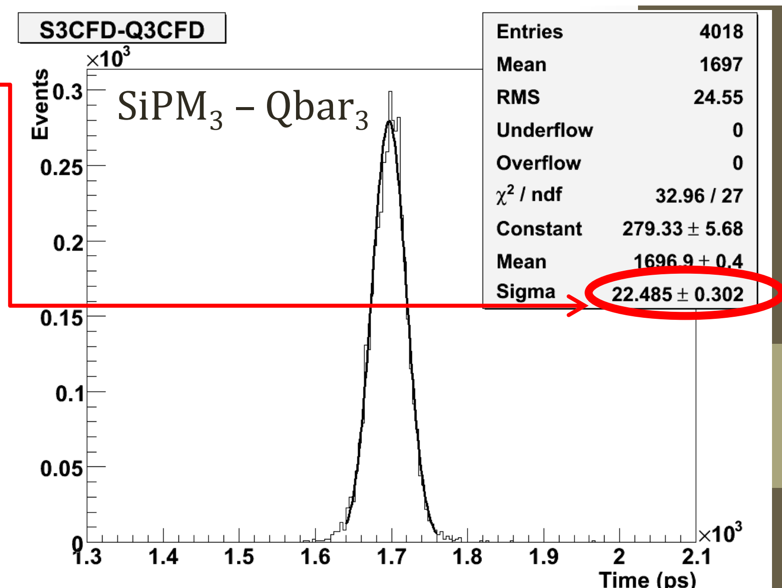
2 mm wide × 6 mm deep (in beam direction) Quartz bar positioned at 48° with beam (Cherenkov angle), read by 10 µm pore MCP-MAPMT

- single bar: $\sigma_t \simeq 20$ ps (CFD only!)
  - 4 bars at 48° (~32 mm): expect ~10 ps ☺
- single bar with 17 ps HPTDC: $\sigma_t \simeq 26$ ps
  - 6 bar train measurement (Test Beam): ~11 ps
- rad hard tube (no degradation seen yet up to 5 C)

Multiple measurements ➔

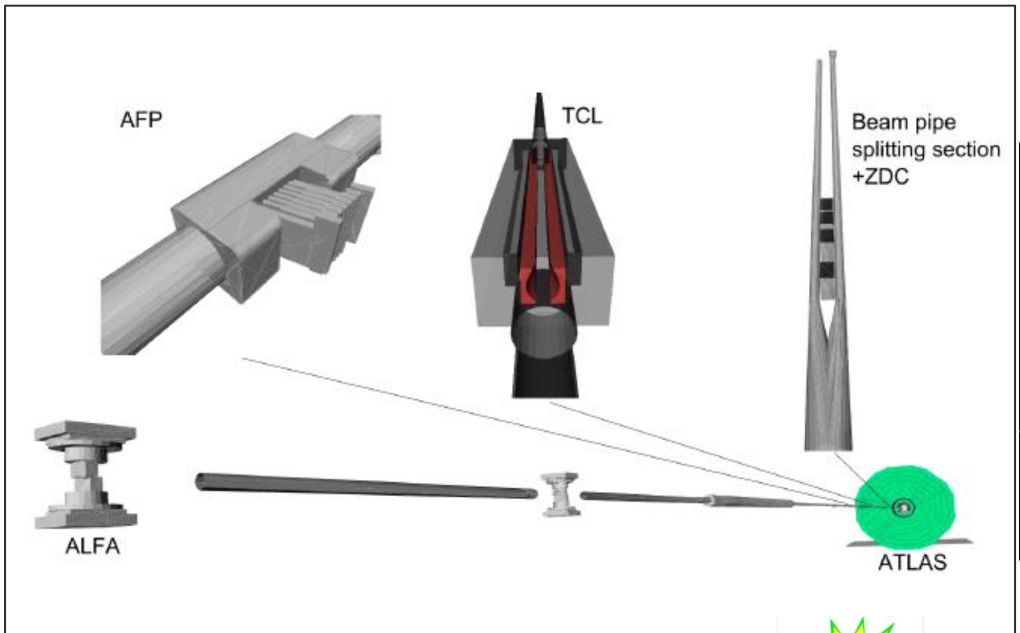
Modular system: 'tunable' resolution, size, and interaction length …

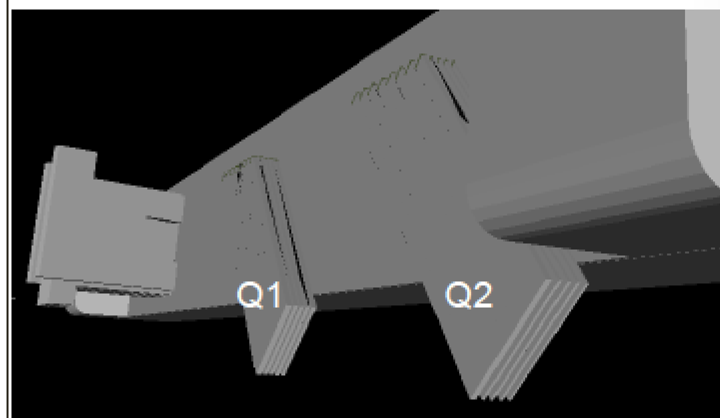




Forward region full simulation

Decisive improvements for
- Detector studies
- Physics analysis
- Beam background studies





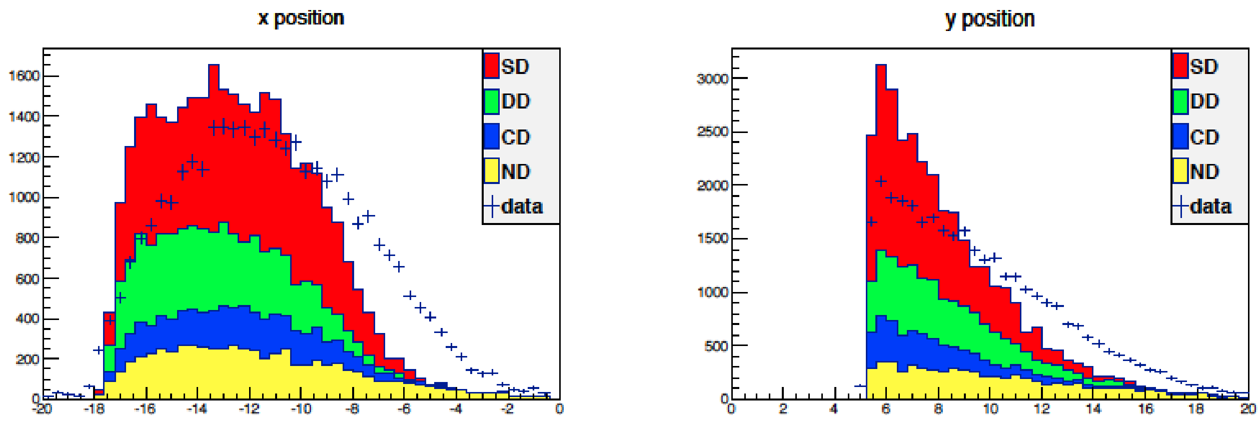
Recently ADDED:
- Roman Pot (RP) simulation for AFP (also timing in RP)
- Reconstruction for tracking

Full Integration in ATHENA:
a few details missing (dump D3PD)

AFP Progress report : Section 3

Background studies

Position Distributions



- MC normalised to data
- Important contributions from non-SD processes
- Qualitative agreement of the distributions
- Possible reasons of differences:
  - Underestimated contributions from ND
  - Backgrounds
  - Different beam position
  - Detector misalignment

AFP Progress report : Section 8

http://cds.cern.ch/record/1595300

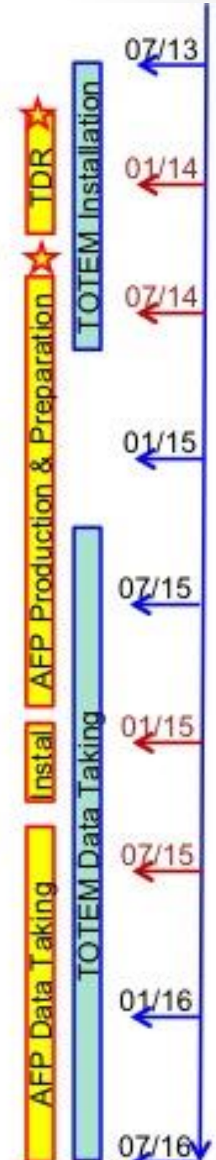
AFP Progress Report

Contents

Updated version posted on CDS on September 28th

AFP staged approach

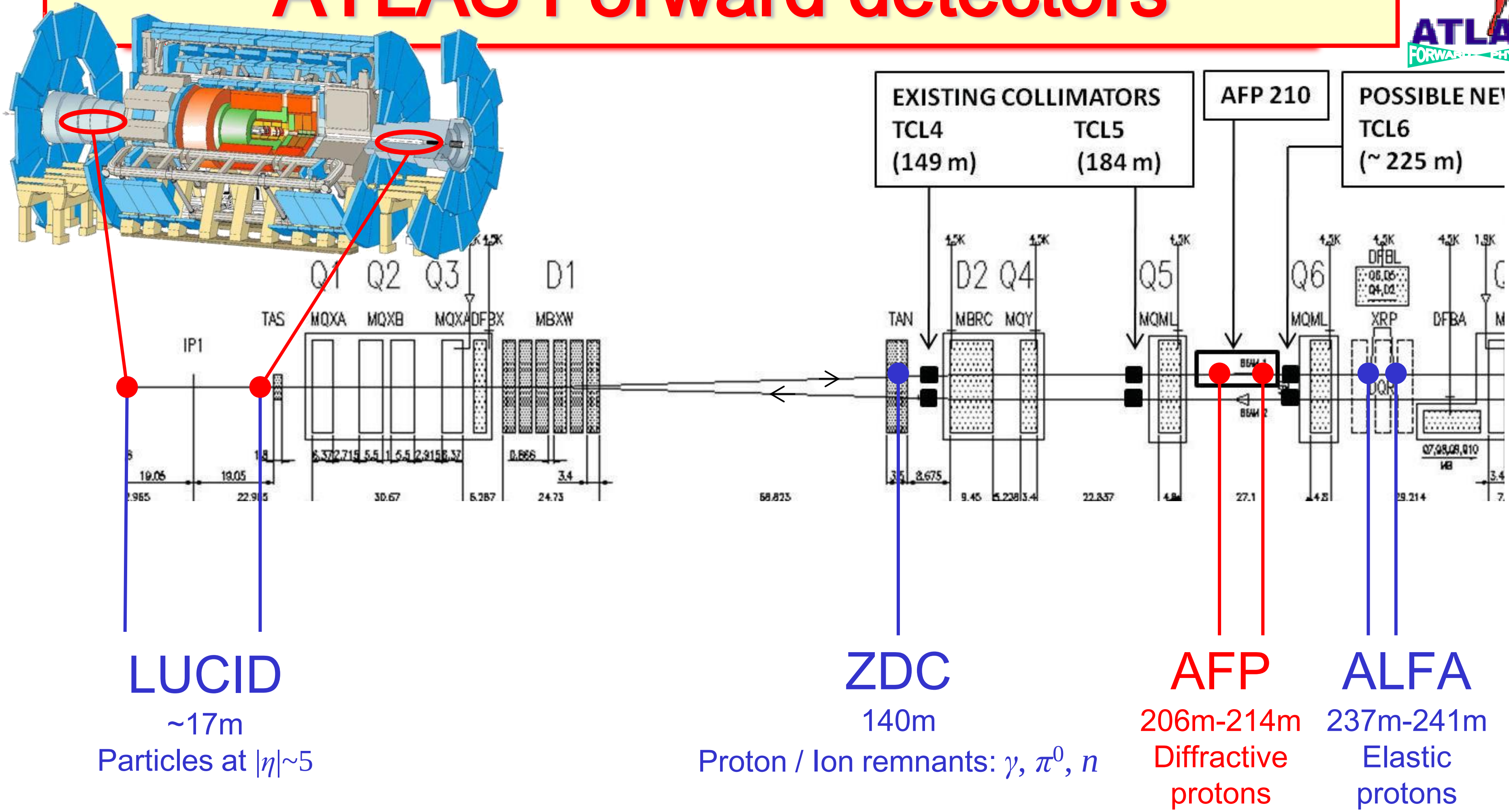
- 2013-2015:
  - Sep-Oct 2013: AFP approval, start TDR
  - <u>Jun 2014:</u> AFP TDR approval; final go-ahead for AFP
    - start order/construction of RPs
  - – TOTEM: insertion of 1+1 Horizontal RPs
    - September 2013: CMS-PPS Approval
  - 2015: Measure & evaluate backgrounds at P5
  - – 2014-15: prep work for AFP installation
  - – Xmas 2015: Install 2+2 Horizontal RPs in ATLAS
    - RP 206m: tracking; RP 214m: tracking + (modest) timing
- 2016-2017 (Phase 0 – AFP0)
  - 2016: Measure & evaluate backgrounds at ATLAS
  - 2016-17: Low-μ Physics
  - <u>Mid-2017: Decision point:</u> HBP or Timing in 3rd RP ?
  - <u>Mid-2017: Decision point:</u> AFP420 ?
- 2018-2021 (Phase 1 – AFP1)
  - – 2018 (LS2): Final AFP installation
  - – 2019-21: AFP Data taking



AFP Progress report : Section 9.1

28 Aug 13

ATLAS Forward detectors

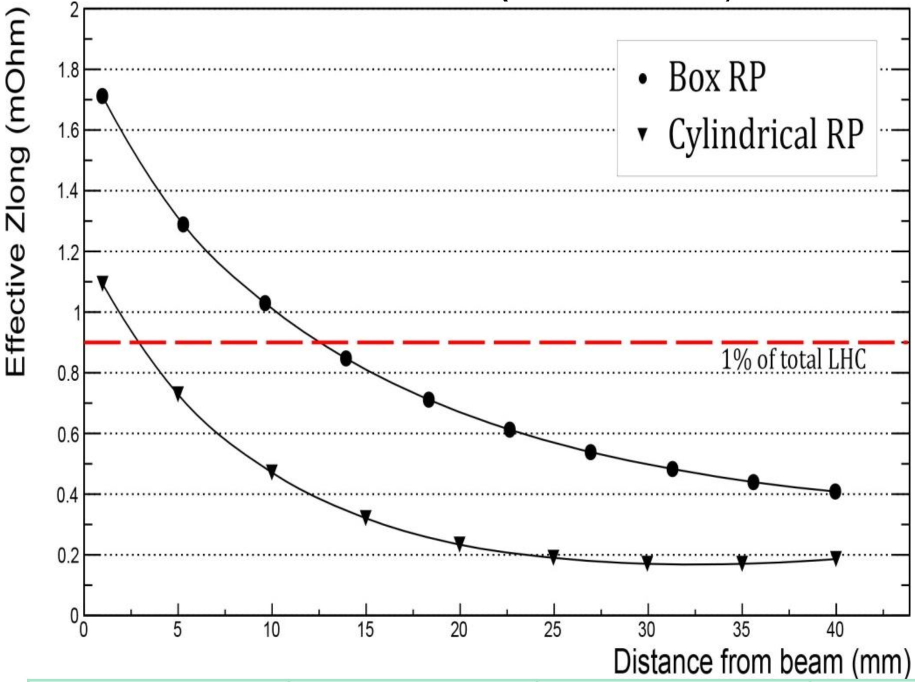


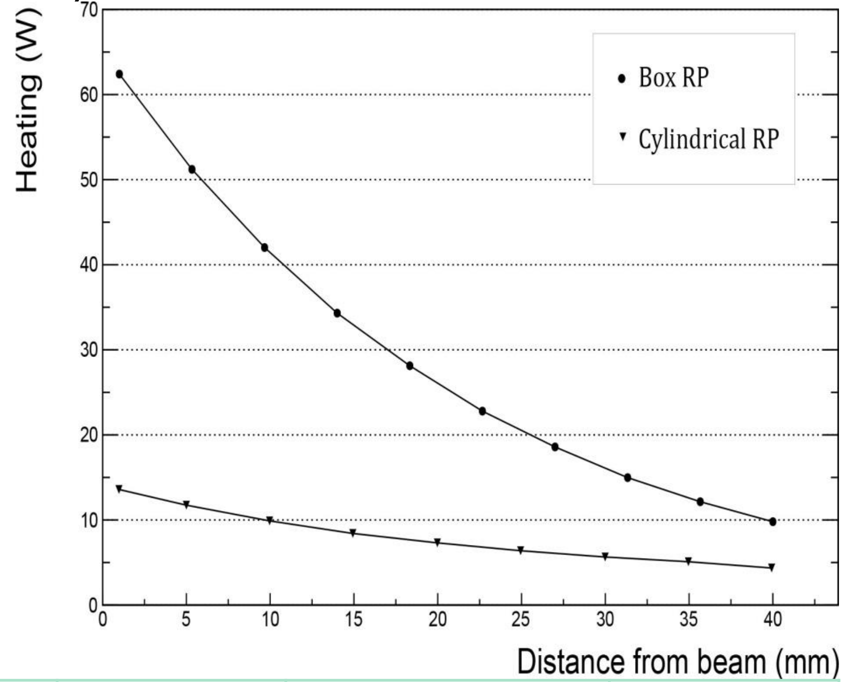
The 40 m long central ATLAS detector detects/identifies/measures most interaction products, except those going down the beam pipe!

➔ ATLAS Forward Detectors

Simulations: Impedance and Heating

TOTEM simulations (N.Minafra, B.Salvant, et al.)





	Distance to beam (mm)	Z^{Eff}_{Long} (mΩ)	cfr. LHC: 90 mΩ (%)	Z^{Eff}_{Trans} (kΩ/m)	cfr. LHC: 25 MΩ/m (%)	Power Loss (W)
Cylindrical RP	1 5 40	1.1 0.73 0.18	1.2 % 0.81 % 0.20 %	60	0.2 %	13 11 4

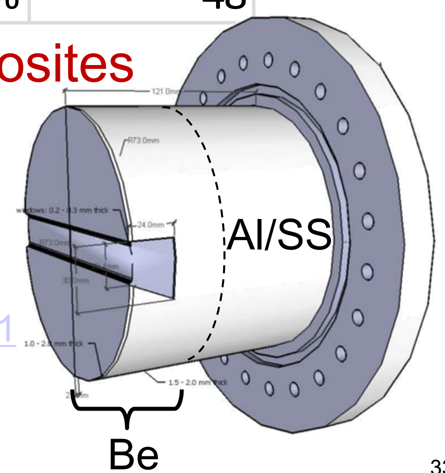
TOTEM Upgrade TDR – June 2013

Pot and Window Materials

- Al pot with Be window and floor?
  - Started discussion with BNL RP physicist & engineer

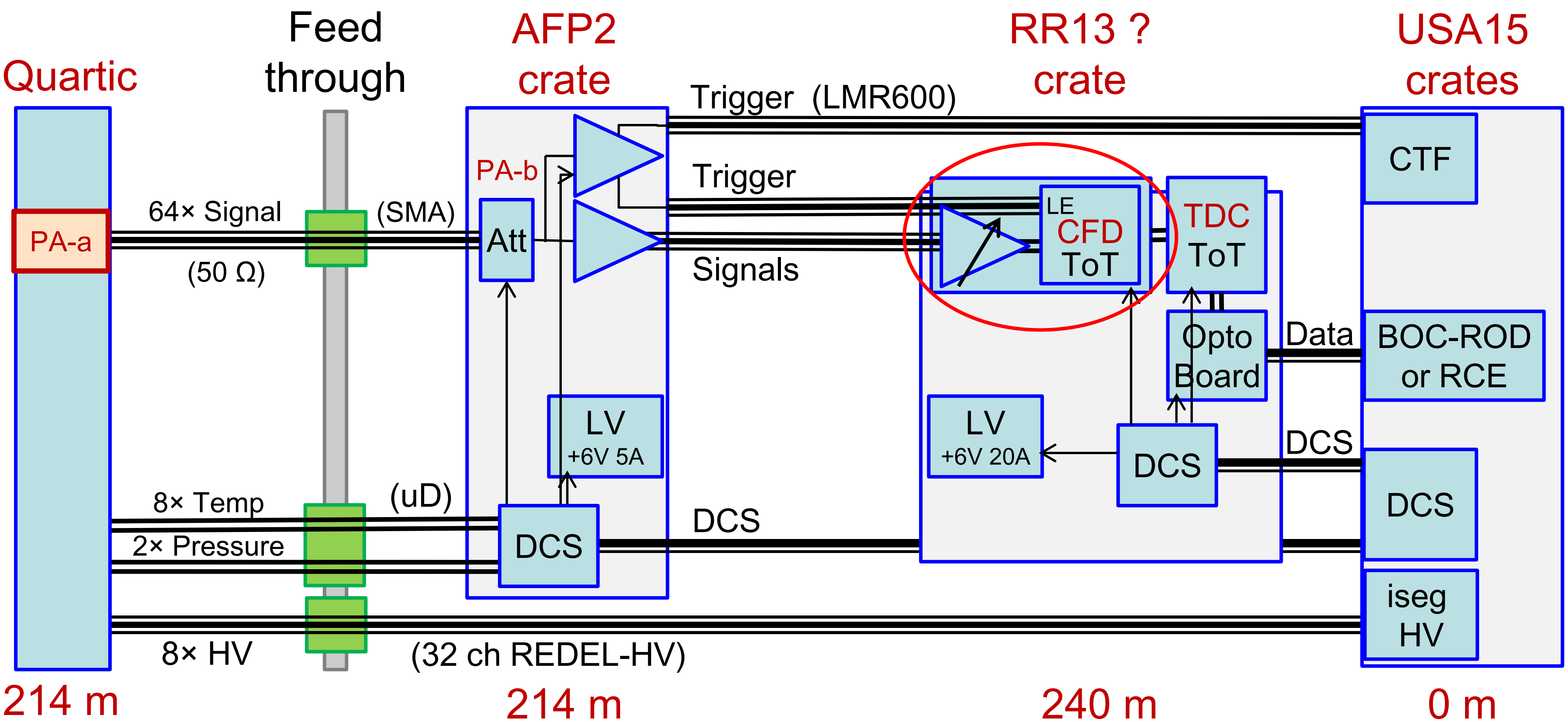
Material	Thickness	θ_0	P_{Coll}	P_{Int}	Yield Stress
	(cm)	(μrad)	(%)	(%)	(MPa)
→ Be	0.03	0.041461597	0.10%	0.07%	240
→ Al	0.04	0.103524078	0.15%	0.10%	214
Inconel 718R	0.02	0.184210737	0.19%	0.12%	740-1100
SS 316L	0.03	0.217801393	0.29%	0.18%	280
→ Ti	0.02	0.116958447	0.12%	0.07%	1100
Si	0.15	0.207211619	0.47%	0.31%	0
SiO2	5.38	1.246033178	16.63%	11.42%	48

  - Discussing with Materion Corp. re Beryllium & Composites
    - Be window with 2 mm SS pot (incl. conflat): ~18 k$
    - Materion makes Be beam pipes for LHC experiments and Be supports, X-ray windows
      - see e.g. https://indico.cern.ch/conferenceDisplay.py?confId=245511



Electronics Layout Phase 0

AFP1 Baseline: 5 trains of 4-6 channels/side:



- if the CFD is sufficiently radiation-hard, it can be located at 214 m
- if the HPTDC is sufficiently radiation-tolerant, it can be located at 214 m
  - active irradiation tests Sep, Dec 2013

Some Highlights of Timing R&D

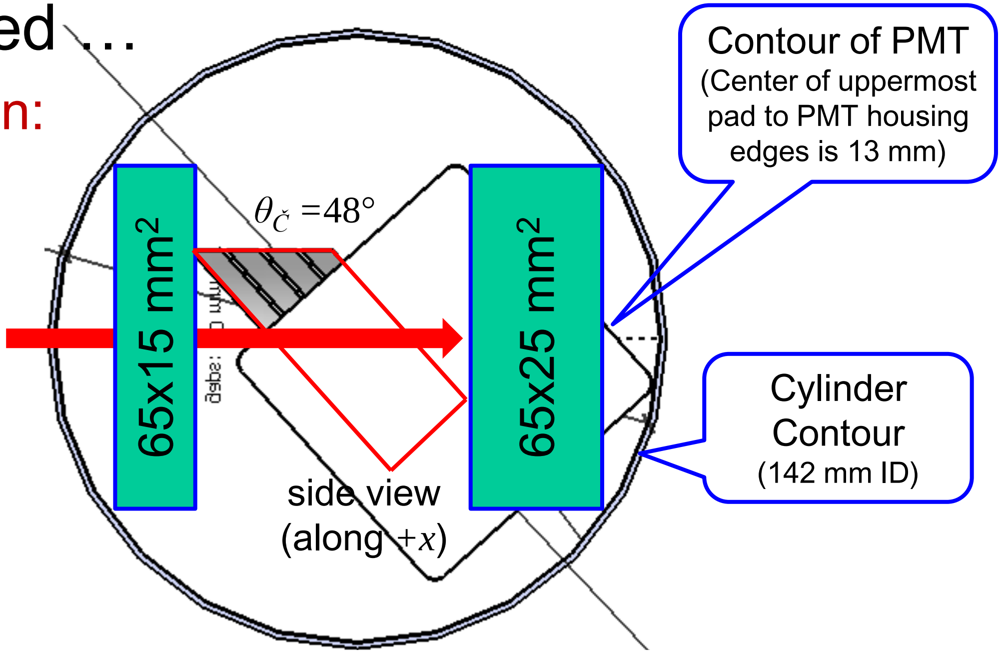
- Using test beam and laser tests we have demonstrated a prototype timing system for a Hamburg Beampipe capable of 11 ps resolution including electronics
- Developed with background group new simulation and visualization techniques that allow us to conclude that we can achieve <10 ps in a dedicated Roman pot, and <20 ps in a shared Roman pot
- We have developed with Arradiance+Photonis a special phototube capable of sustained proton rates in the 5-10 MHz /pixel range, with a lifetime estimated to >100 fb^{-1}

Plan to have a 20 ps detector suitable for sharing a Roman pot in 2014
With funding and a dedicated RP, no known obstacles to a 10 ps high lum ToF system in 2015

Tracking + Quartic ToF Detector in RP?

Sketch only: to be designed …

- If only 4 LQbars in z-direction:
  - material reduced by ½
  - σ_t increased by √2
  - room for tracking planes?
- Make-up the reduction in σ_t by improved MCP-PMT (pore-size) and electronics



- Not doubt, diamond ToF could be fitted together with tracking, but σ_t for diamonds is not yet competitive …

AFP POT Modifications

- AFP needs changes in the POT design:
  - the TOTEM design has a **different thin window size**, not optimally matched to our acceptance
  - the TOTEM floor is a **groove** in the pot bottom:
    - requires a bump-out of the tracking sensor,
    - making it difficult to insert a Quartic detector close to the beam …
- We have more time than TOTEM ➔ use to investigate improvements
  - We should make the AFP pot a bit larger (to ~144 mm) by reducing the 2.5 mm gap between the bellows and the pot itself to ~1 mm.
    - Making it even larger than that requires a different ‘Tee’ design and RF calculations will have to be repeated to validate a larger cylinder. Unless absolutely necessary, I would prefer to keep the pot to 144 mm ID.
  - We should investigate alternative pot and window materials, coatings, etc.
    - e.g., a Be window of 200-400 μm thickness welded to an Al pot (cfr. Daniela) would be a huge improvement over the current TOTEM pot in terms of conductivity, radiation length (MS), and interaction length.
- Need our own feedthrough plate with the services as we require them, adapting the plate as designed for TOTEM to AFP needs.
    - Possibly the plate for the ‘timing’ will be different from the plate for the ‘tracking’

420m

- Very useful information from the WG4

- Potential for new discovery: presently not foreseen
- Several processes studied:
  - MSSM exclusive Higgs production (7 recently proposed benchmark scenarios tried out): the only viable is LowMH scenario which needs ~1000 fb-1 and only 420+420 configuration
  - Exclusive chargino production: low S/B, Pile-up issue
  - NMSSM Charged Higgs: rather low x-section
- Experimental challenges:
  - 420 can hardly be put into L1 trigger
  - 420 can only be put after LS2 -> very high pile-up

- Potential for improving 210m physics program: VERY HIGH
  - Acceptance is extended to low mass region
  - A better understanding of background for high mass search is provided

→ CONCLUSION: The AFP collaboration will reconsider 420m installation after year 2016, depending on the following:
  - experience gained after one year of running the 210m stations
  - experience gained from TOTEM/CMS
  - strength of the collaboration

Visible cross section: 0.55 m vs 90 m

AFP Physics Programme for Low and Medium Luminosity

R. Staszewski

- Comparison at 10σ distance:
  0.55 m $\leftrightarrow$ $0.015 < \xi < 0.12$
  90 m $\leftrightarrow$ $0.07 < \xi < 0.18$
- Cross section of the same order

90 m optics:

- Acceptance at higher ξ values, but slightly larger ξ span
- Different kinematic phase-space
- Different sensitivity to Pomeron structure
- Greater effects from Reggeon
- Should be studied in more details

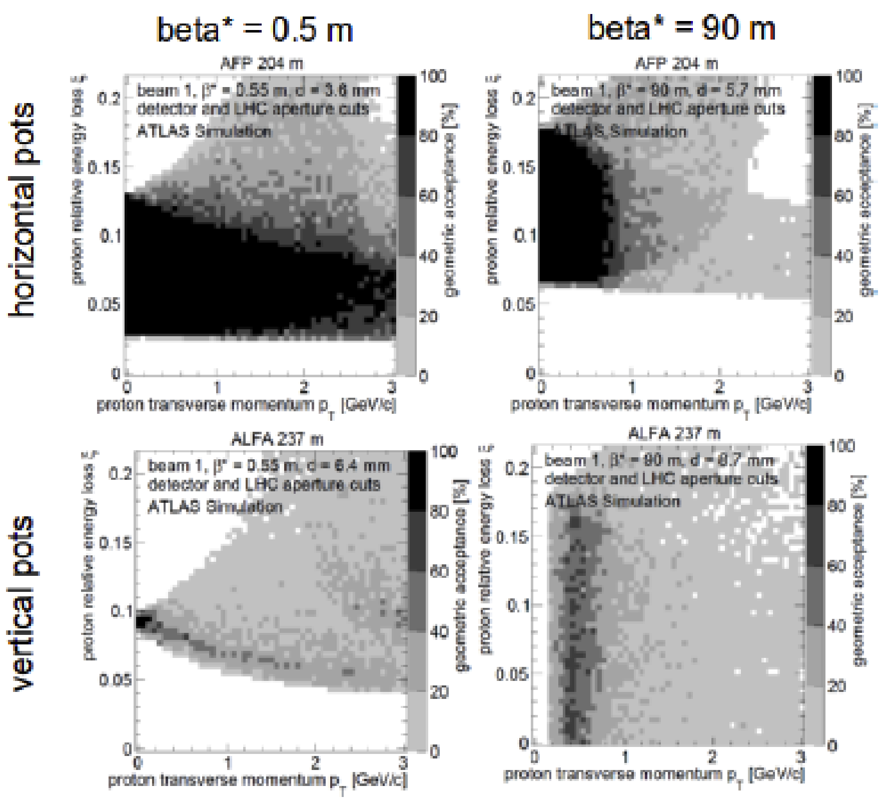
p_T thres.	0.55 m	90 m
SD Jets		
20 GeV	29 mb	33 mb
50 GeV	770 nb	940 nb
100 GeV	25 nb	50 nb
200 GeV	1.2 nb	1.9 nb
DPE Jets		
20 GeV	41 nb	26 mb
50 GeV	710 pb	530 pb
100 GeV	18 pb	15 pb

Table : Cross sections within AFP acceptance (generator level)

Optics comparison: 0.55 m vs 90 m

AFP Physics Programme for Low and Medium Luminosity

R. Staszewski



TOTEM prefers 90 m due to:

- Much better acceptance for vertical pots
- More and better experience
- Less background (for TOTEM)

Difference for AFP:

- Higher ξ
- Worse ξ resolution
- Better t resolution