Status of the AFP Project in ATLAS

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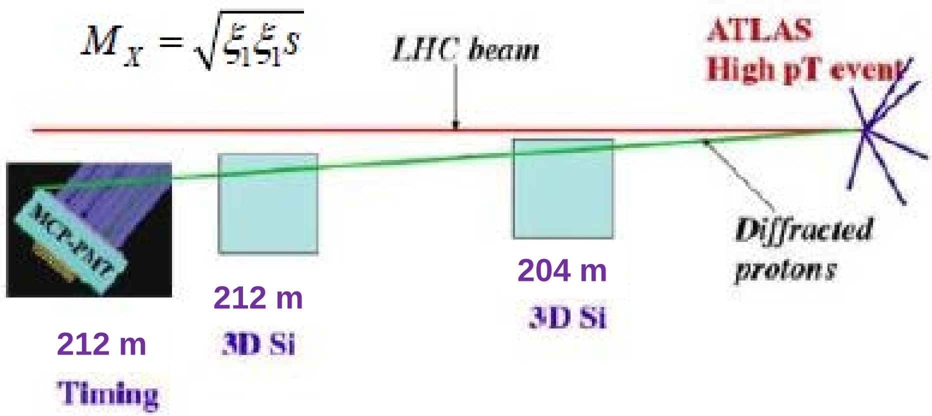
On behalf of the ATLAS collaboration

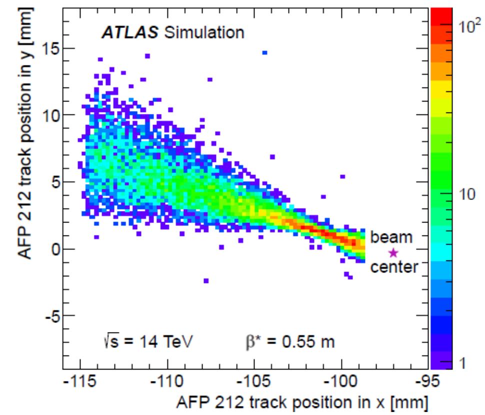
Diffraction 2014, Primošten, Croatia - Sept 10-16 2014

1) Concept
2) Status
3) Physics program

AFP = ATLAS Forward Proton

Proton leaves the interaction intact, travels through LHC optics and is detected at ~210 m





Pythia 8 diffraction processes

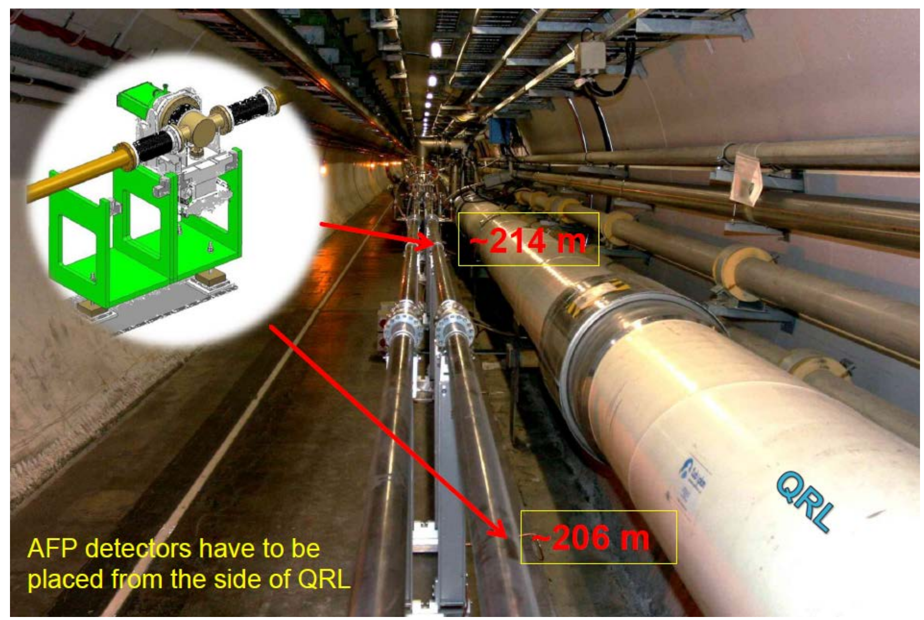
AFP: 2 stations on each side of Inter.Point with tracking detectors at 204 and 212m and timing detectors at 212m

What is AFP?

1) Array of radiation-hard near-beam Silicon detectors **with resolution ~10 μm, 1μrad**

2) Timing detectors **with up to ~10 ps resolution for overlap background rejection (SD+JJ+SD)**

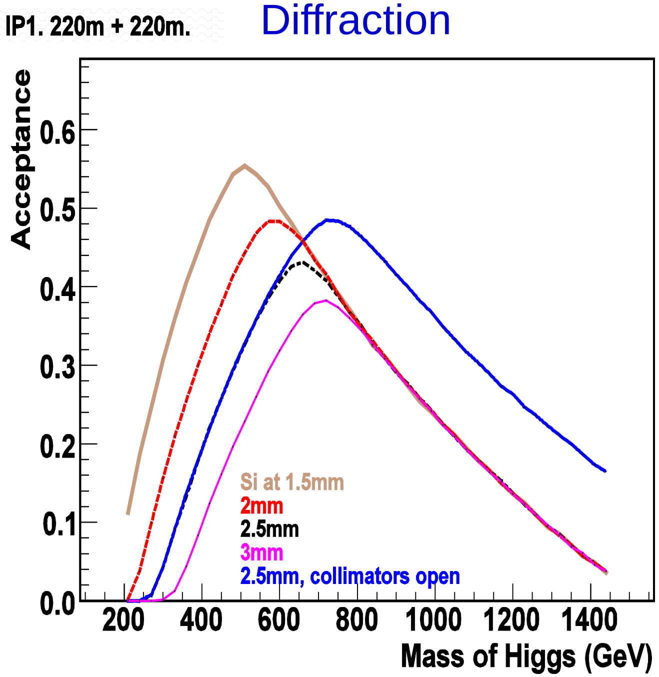
3) Roman Pots



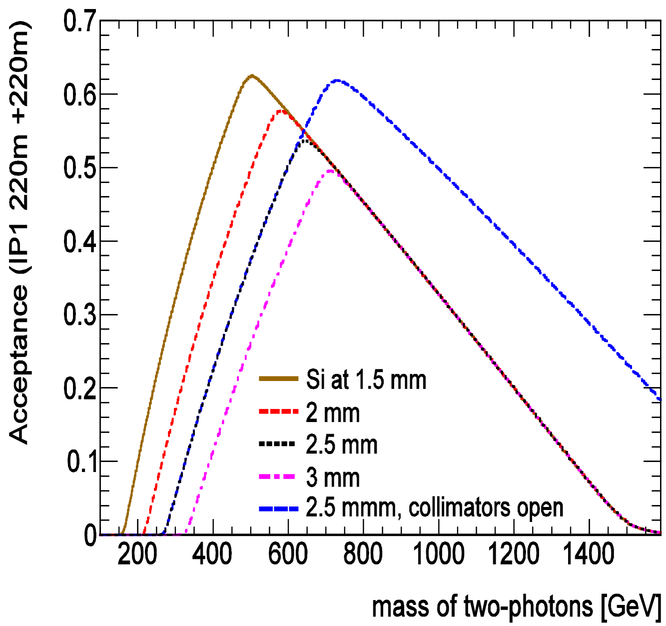
What does AFP Provide?

210+210 at IP 1

Diffraction



Two-photon



Acceptance >40% for wide range of resonance mass

- Mass and rapidity of centrally produced system

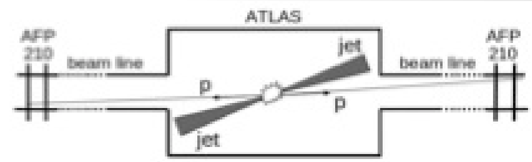
$$M = \sqrt{\xi_1 \xi_2} * \sqrt{s}$$

$$y = \frac{1}{2} \ln(\xi_1 / \xi_2)$$

- where $\xi_{1,2}$ are the fractional momentum loss of the protons
- Mass resolution of 3-5 GeV ***per event***

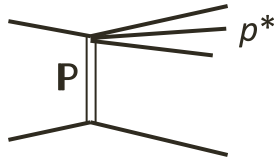
Allows ATLAS to use LHC as a tunable √s gluon-gluon or γγ collider while simultaneously pursuing standard physics program

Primary goals of AFP
(for low-mu and high-mu program)



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)*

Single-tag: Single Diffraction

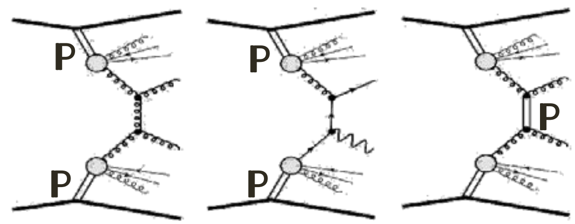


P:= 'Pomeron', a **color-less** object with *Q*-numbers of the vacuum

- Jets, W, Z: Soft survival prob. S^2
- Particle spectra, Gap spectra: SD vs. DD

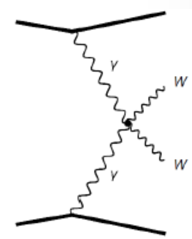
Double-tag: Double-Pomeron Exchange

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



Double-Photon Exchange

- γγ→ **WW/ZZ/γγ**: Anomalous quartic couplings → sens. ~x100 wrt only central det.
- γγ→ **μμ:** calibration/alignment of AFP



Central Exclusive Production

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

History: FP420+FP220 → AFP & CT-PPS

2003
Manchester Forward Physics Meetings

2005
FP420 Joint ATLAS & CMS Collaboratio

2008
FP420 R&D Report

2008
Add FP220

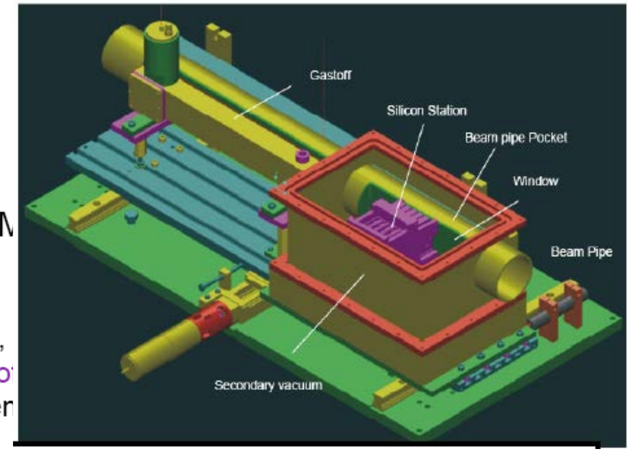
2009
Under review

2010-2014
Aim for Upgrade project

FP420 R&D Collaboration

- Spokes : Brian Cox (Manchester, ATLAS) and Albert DeRoeck (CERN,CM
- Technical Co-ordinator : Cinzia DaVia (Manchester)

Collaboration : FNAL, The University of Manchester, University of Eastern Piedmont, Novara and INFN-Turin, The Cockcroft Institute, University of Antwerpen, University o Texas at Arlington, The University of Glasgow, University of Calabria and INFN-Coser CERN, Lawrence Livermore National Laboratory, University of Turin and INFN-Turin, University of Lund, Rutherford Appleton Laboratory, Molecular Biology Consortium, Institute for Particle Physics Phenomenology, Durham University, DESY, Helsinki Institute of Physics and University of Helsinki, UC Louvain, University of Hawaii, LAL Orsay, University of Alberta, Stony Brook University, Boston University, University of Nebrask Institute of Physics, Academy of Sciences of the Czech Republic, Brookhaven Nationa Laboratory, University College London, Cambridge University




The FP420 R&D Project at the LHC

FP420 R&D Collaboration

FP420 R&D Report
JINST 4 (2009) T10001

+ FP210/240

ATLAS AFP R&D → **Upgrade Project**

CMS CT-PPS R&D → **Upgrade Project**

AFP milestones in 2014

2014 = crucial year: **ATLAS decides to focus on a Run-2 programme based on special runs with low mu (following the experience of Totem and ALFA) which means:**

- **Processes with reasonably high x-sections**
- **No strong demands on the precision of the ToF detector and on alignment**

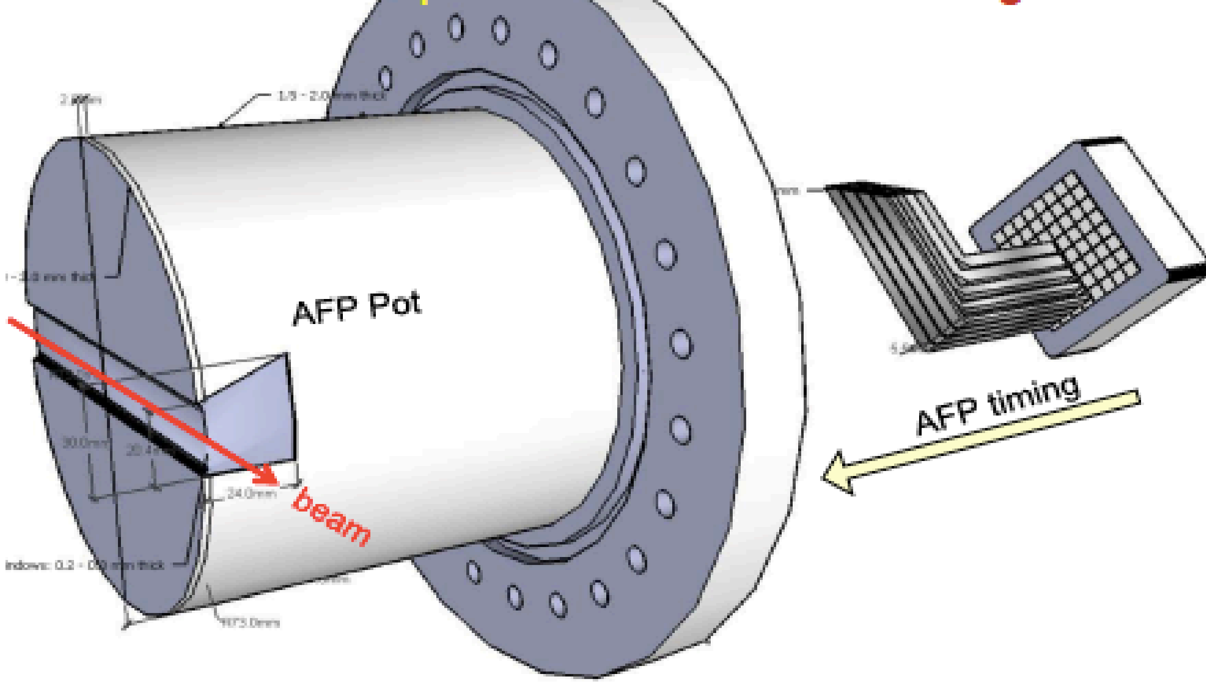
AFP activities:

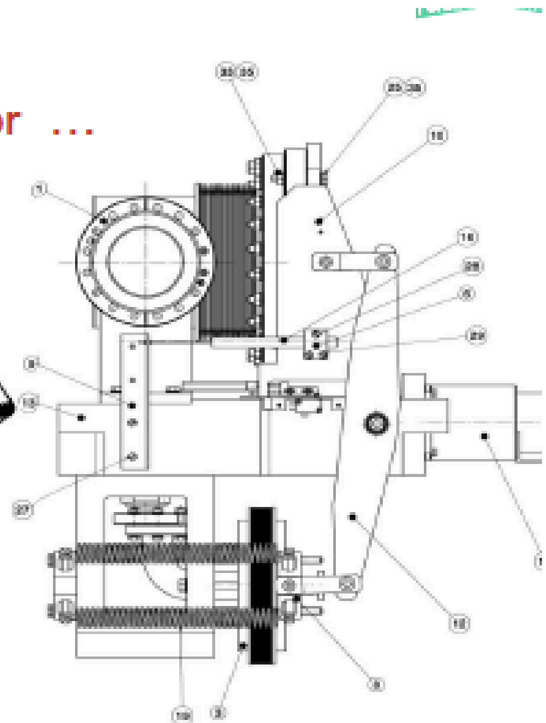
1) **R&D of Quartic ToF and also alternative ToF: Fast Si or Diamond**
2) **R&D of Sampic** (Read-out chip for ToF)
3) **AFP and ALFA approaching:**
   - Combined effort in simulation
   - Combined optics studies
   - AFP participation in ALFA data analysis
4) **Preparing for Test beams at CERN in November**
   - DESY January TB: SiD sensors: efficiencies as functions of distance and inhom. irradiation (to be publ.)
   - FNAL August TB: ToF: Final design of LQbar, p.e. yield, resolution, cross-talk. Results including PMT lifetime, rates and previous Qbar TB to be published
   - Sampic + Fast Si: several TBs during 2014 organized by CMS/Totem, October: Sampic+AFP
5) **Discussing running scenarios with Totem and ALFA**

AFP Roman Pot and Station

AFP Pot adaptation from TOTEM design

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



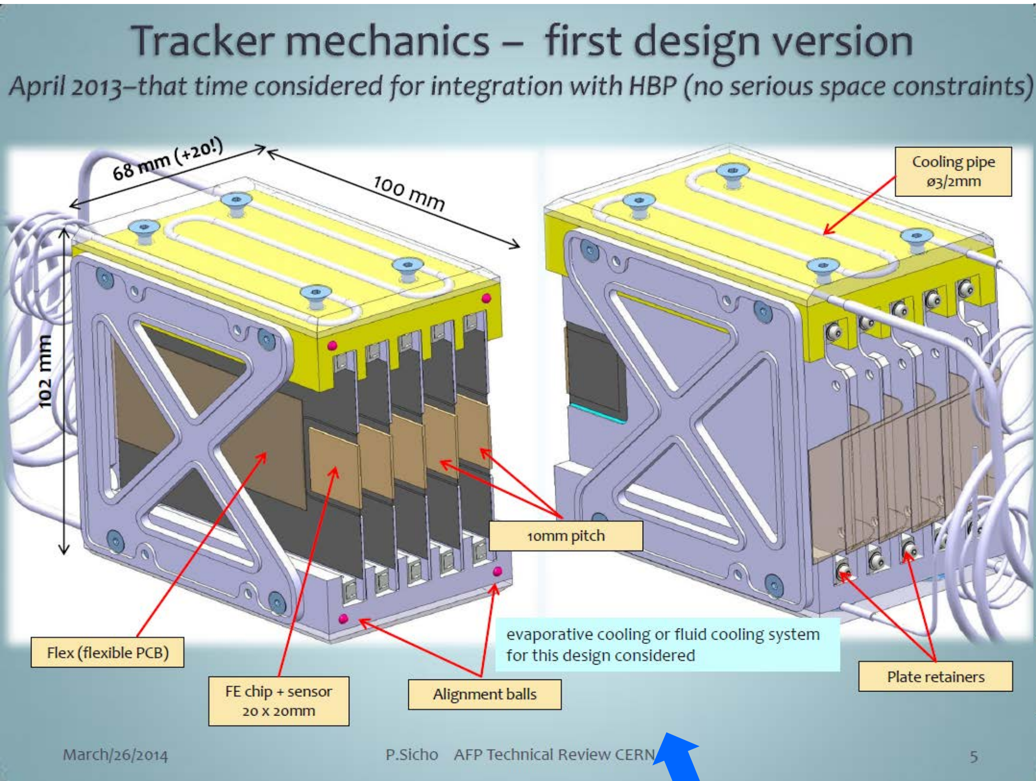


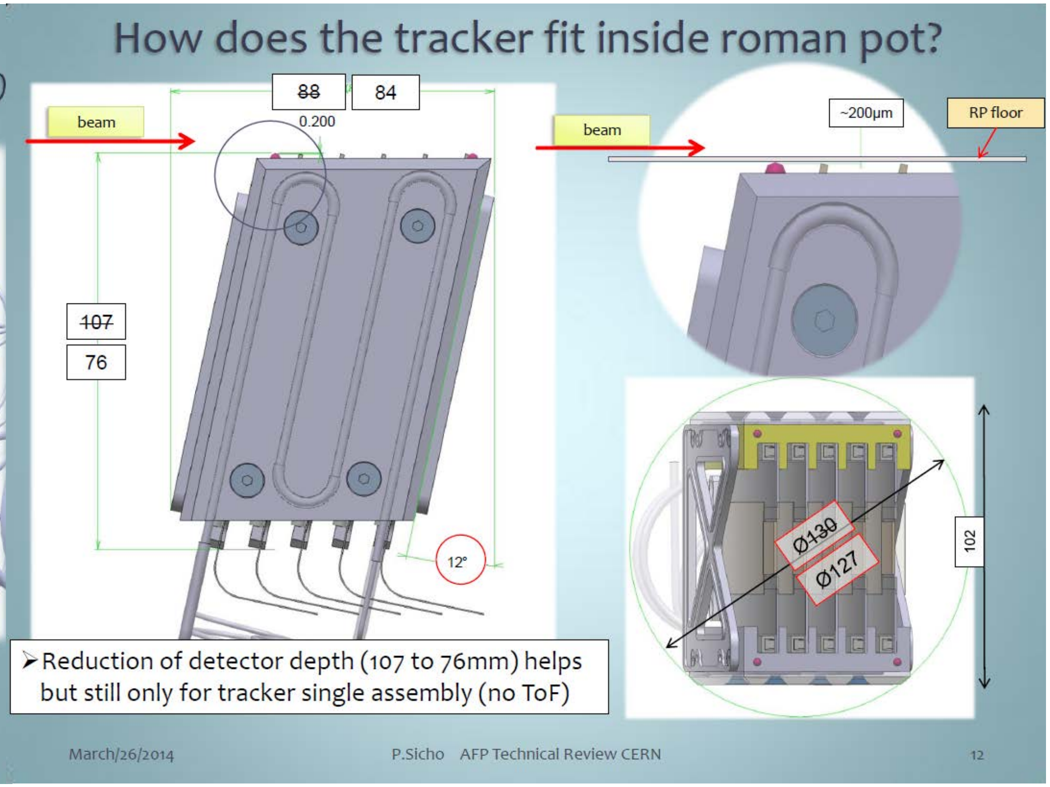
TOTEM horizontal RP station (beam view)

Copy RP Station design of ALFA & TOTEM:

– Ample operational experience
– Known cost and construction & installation procedures

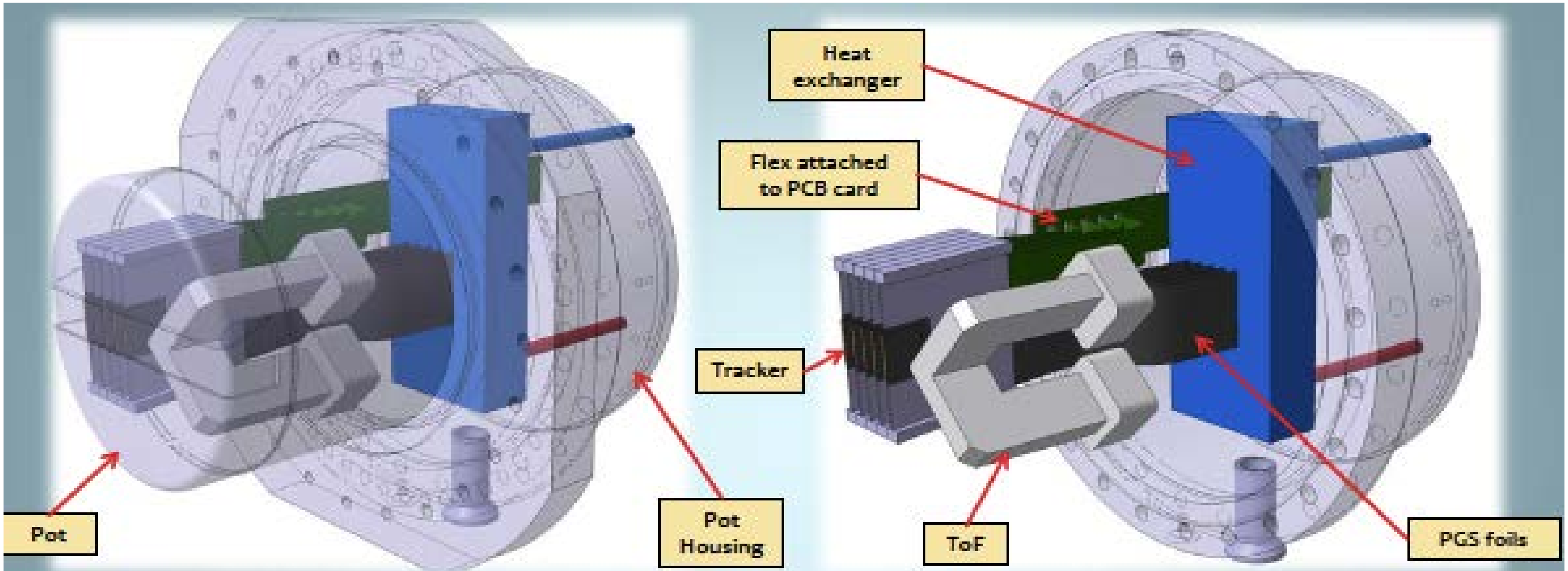
Silicon Detector mechanics





Design for Hamburg Beam Pipe.
Similar design can be used for Roman Pots – cooling system has to be changed.
Baseline = relatively cheap air-cooling system based on vortex tubes

Current conceptual design of arrangement in RP

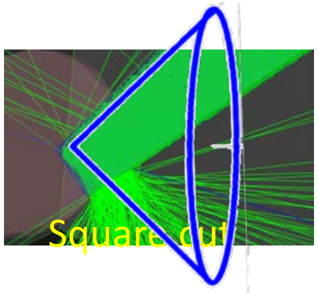


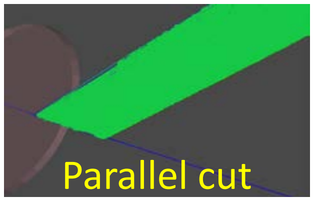
- If we choose air-cooling system to cool down the Si detectors then heat exchanger should not be part of tracker and could be placed at RP housing
- Si tracker would have very simple construction (not removable planes)
- Heat could be removed via PGS foils (PGS + polyamide) which would be attached to heat exchanger – needs to be simulated and tested, temp gradient?
- Other details as mechanical fixation of detectors not studied yet

April/9/2014 P.Sicho AUW Freiburg 12

ToF detector

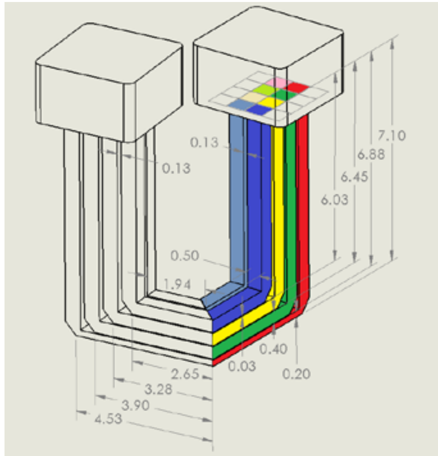
- **Quartic with LQ bars**: several years of R&D [UTA Texas, Stony Brook, Alberta] tests and improvements → most advanced and capable to provide 10 ps resolution needed for high-lumi running (not yet approved by ATLAS) - can be tested in Run II





16 ch/side, 4 layers (depths in x)
2 rows (depths in z)
2 y measures (+/-) [the 2 arms]

- Parallel cut (provides a lot of light)
- Easily upgradeable to 32 channels



- **R&D of other options ongoing: Diamond and Silicon read out by SAMPIC**
  For Run II a moderate resolution (~50ps) sufficient → still intensive R&D and tests necessary (fruitful collaboration with CMS/Totem already working)

- SAMPIC (SAMpler for PICosecond time pick-off) reached 4ps internal resolution [Saclay]

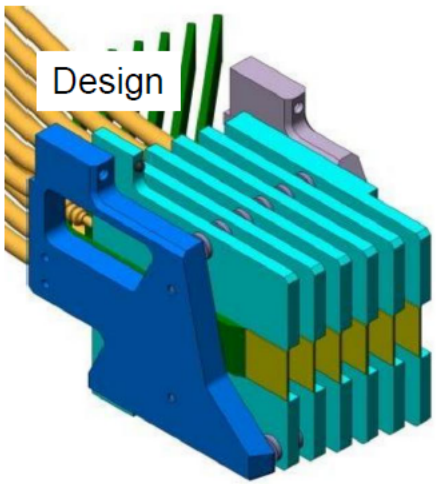
- SAMPIC + Fast Si [Torino,Barcelona]/Diamond[Lecce,Bologna,Roma]: currently ~40 ps resolution obtained. Working on improvement of:
  - time resolution (combination of amplifiers)
  - dead time (bits in ADC)
  - rate capacity (segmentation)
  - radiation hardness (depends on Sampic location: alcove vs. mezzanine)

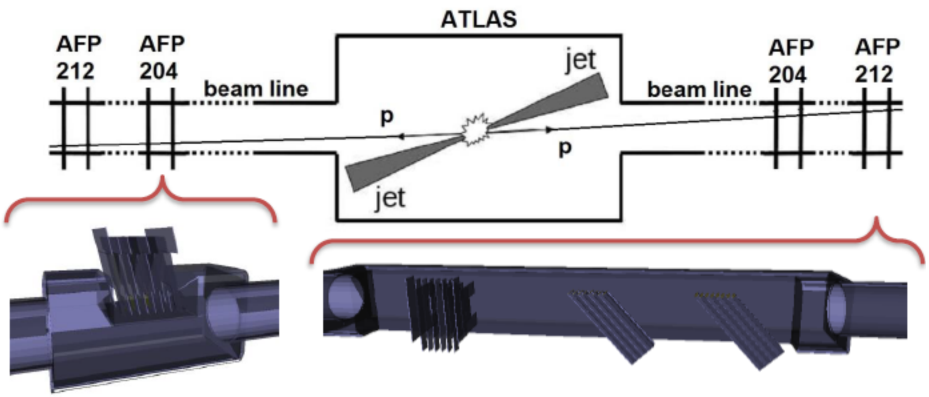
Frequent test beams in collaboration AFP+CMS+Totem during 2014

AFP in ATLAS simulation (1): SiD hits

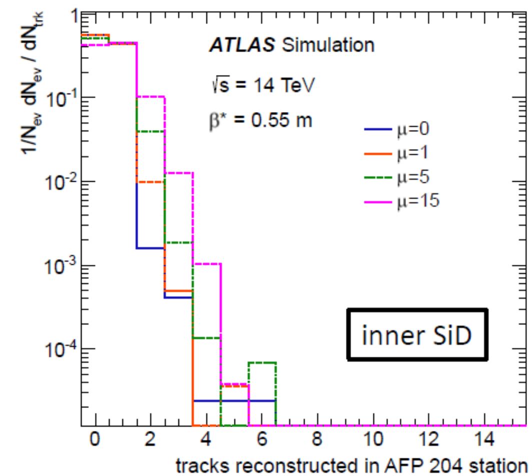
- Actual SiD setup:
  - 2 AFP stations with Si detectors per ATLAS side (**SiD 0 - 1 <– IP –> SiD 2 - 3**)
  - 6 Si layers/station separated by 10 mm (13 deg tilt in the x-z plane)
  - No staggering of the layers (yet)
  - 336 x 80 array of **50 x 250** μm^2 pixels per layer
  - **Kalman filter** is used for the tracking reconstruction

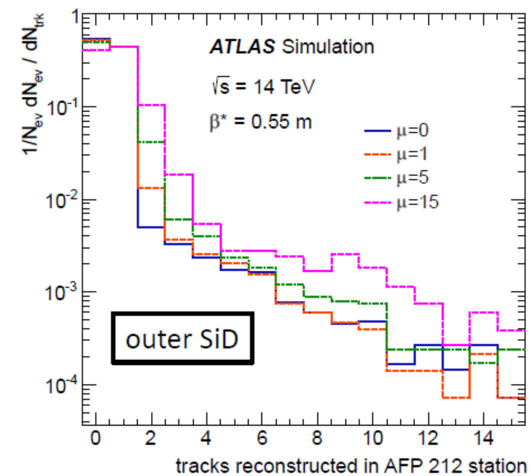
- Expected tracking resolution wrt 4 staggered layers: 8 μm in x, 20 μm in y





Geant4 AFP GeoModels

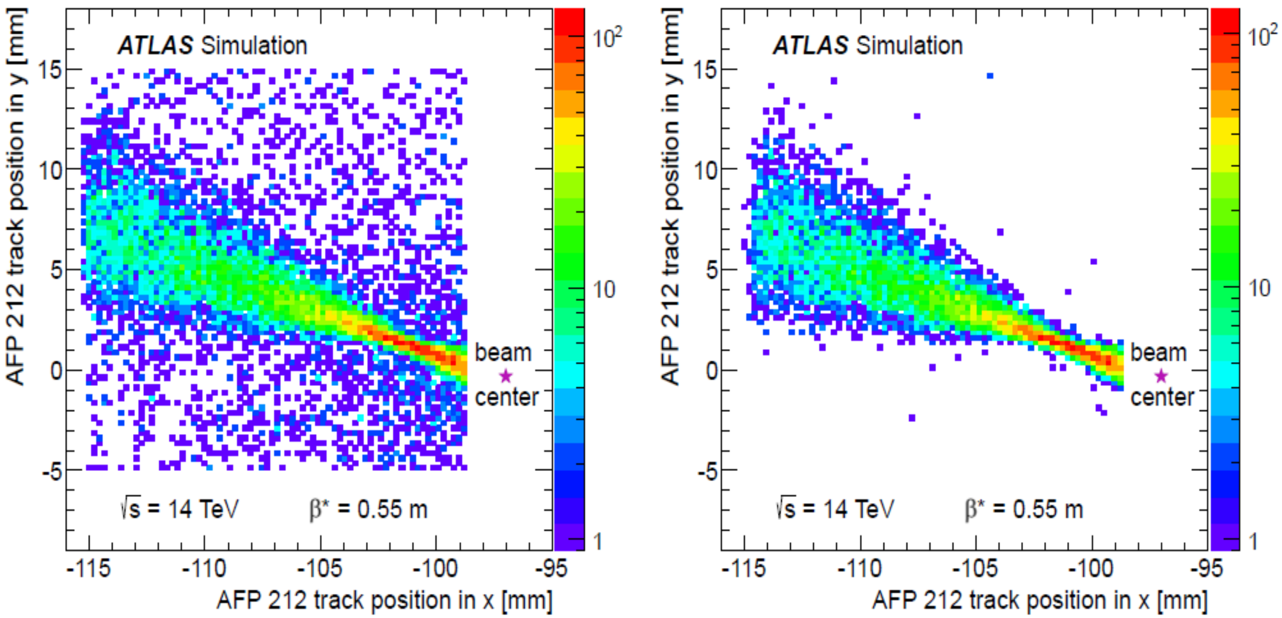


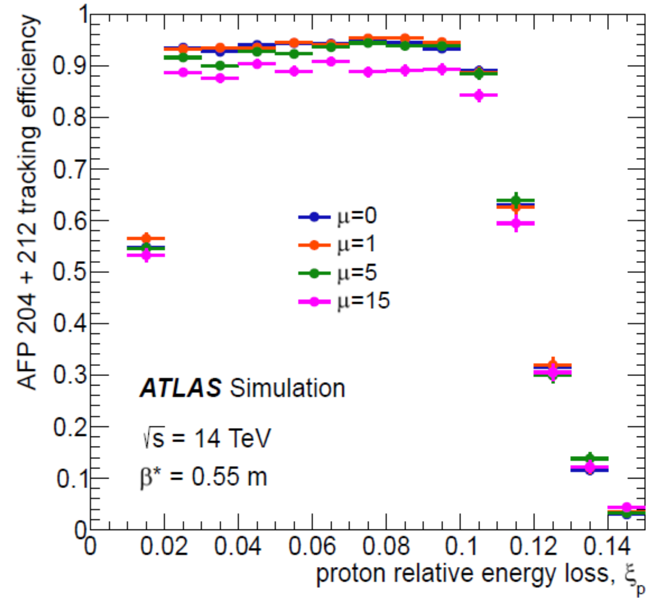


- **Reconstructed track multiplicity** with $|x_{slope}| < 0.003$ and $|y_{slope}| < 0.003$ cut (per station) to separate proton tracks from showers
- Events are generated without any cut on the proton kinematics (i.e. $\xi < 1$)
- Approximately **50%** of protons in the sample **do not enter** the AFP acceptance region (**$0.015 < \xi < 0.15$**) which results in no reconstructed tracks

AFP in ATLAS simulation (2): SiD efficiency

- **x-y track positions hitmap** for outer SiD station before (left) and after (right) track matching included for outer (AFP 212) station
- Tracks matched between inner and outer SiD stations are considered
- Positions are calculated in the ATLAS Coordinate System – beam center at x = -97mm





AFP proton track reconstruction efficiency for different pile-up conditions:

≈ 95% in **0.02 < ξ < 0.11** and **μ = 0/1**

- matching between tracks in inner and outer stations included
- cuts suppressing showers applied (ntr_inner <=2, ntr_outer <=5)
- improvement expected, subject of further cut optimization

Possible running scenarios

Running scenarios for LS1-LS2 period proposed by Totem
(V. Avati, Cracow Nov.2013):

TOTEM

Definition of Run Scenario

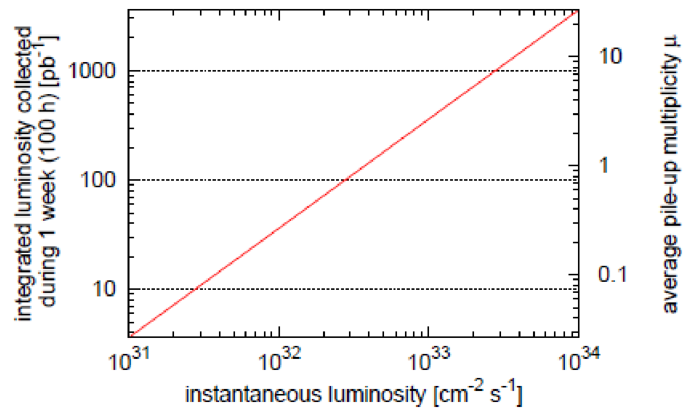
Totem upgrade approved by Research Board
CT-PPS approved by CMS

1) High beta, low luminosity
β^*=90m, $N_{bunch} \leq 100$, reduced bunch intensity, μ ~ few %, $\mathscr{L} \sim 10^{28} - 10^{30}$ Hz/cm^2
RP approach 5-10 σ

2) High beta, medium luminosity
β^*=90m, $N_{bunch} \sim 1000$, $\mu \sim 0.5$, $\mathscr{L} \sim 10^{31}$ Hz/cm^2
RP approach 10-15 σ

3) Low beta
β^*=0.6m, $N_{bunch} \sim 2800$, $\mu \sim 30$-50, $\mathscr{L} \sim 10^{33} - 10^{34}$ Hz/cm^2
RP approach 15 σ

Running conditions for scenario 4



AFP concentrated on (all presented analyses based on):

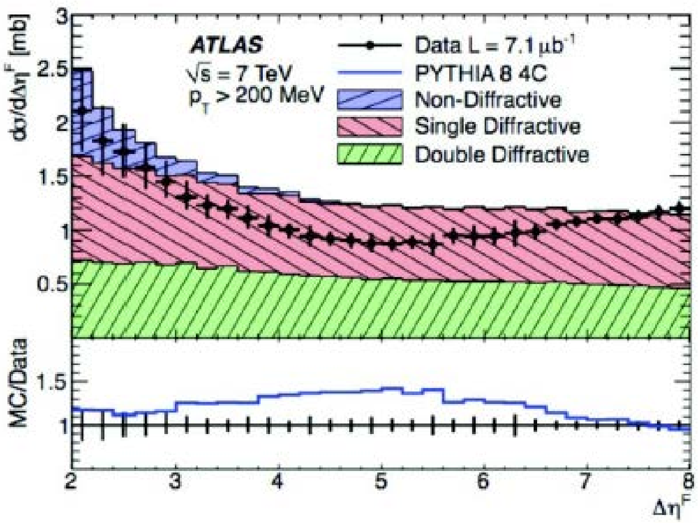
4) Low beta, medium luminosity
β^*=0.55m, $N_{bunch} \sim 2800$, $\mu \sim 0.1$-3, L ~ 10^{31} - 10^{33} Hz/cm2,
RP approach ~10σ

μ = 0.1: ~10 pb^{-1} in one week
μ = 1 : ~ 100 pb^{-1} in one week

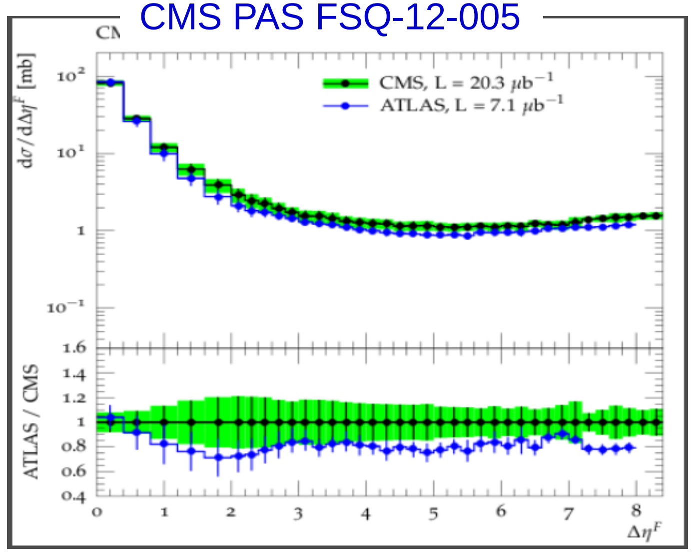
Example for low luminosity: Gap spectra

ATLAS and CMS measurements without proton tags:

ATLAS EPJ C72 (2012) 1926



CMS PAS FSQ-12-005



ATLAS and CMS agree within systematic uncertainties (hadron |eta|<4.7 vs. |eta|<4.9: 5% diff. model for unfolding: 10%)

1) CMS systematically above ATLAS !
2) Pythia8 predicts SD~DD !

Could proton-tagging shed light on 1) and 2) ?

- AFP: wide t-range, ξ-acceptance depends on beam optics
- ALFA: whole ξ-range, limited t-acceptance Suitable for high- β* optics
- AFP & ALFA complement each other

β*=0.55m, √s = 14TeV, d=3mm

- AFP210 provides limited range of gaps: $0 < \Delta\eta \sim -\ln\xi < 2.5$
- Gap on the side of the detected proton in AFP
- DD shows very different gap spectrum

Running scenarios:
- Statistics not a problem
- Very low μ necessary
- β *=90m: ALFA + AFP common run
- β *=0.55m: larger (xi,t)-acceptance with AFP
- Single-tag or Double-tag AFP Trigger

Example for medium luminosity: Pomeron structure

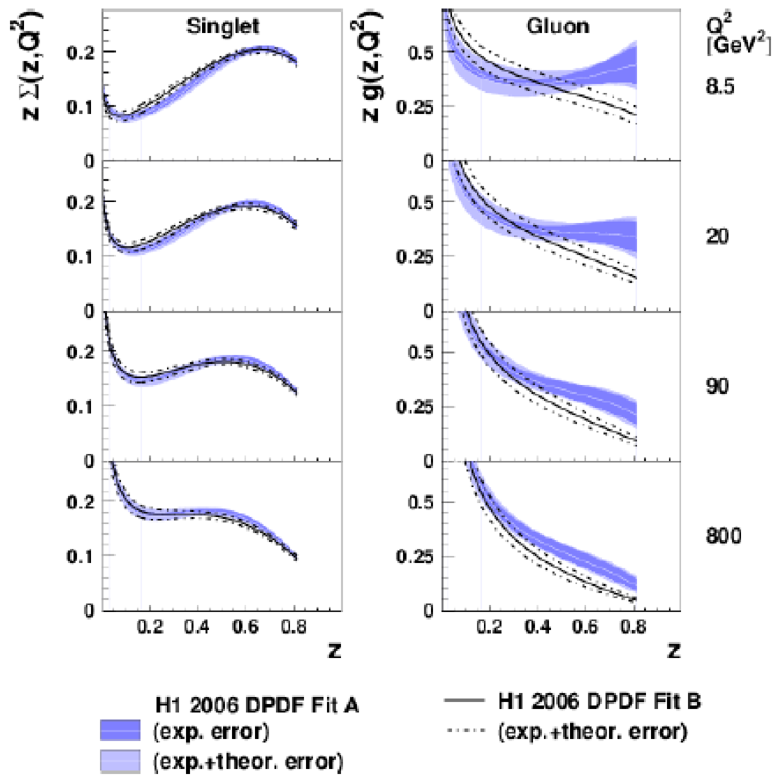
Pomeron structure (dPDFs) measured at HERA

1) Not well constrained at high β (= z = x_{Bj}/ξ)

2) Assumptions in H1Fit of dPDFs measured at HERA:

u=d=s=ubar=dbar=sbar -> F2D ~ 4/9u + 1/9d + 1/9s

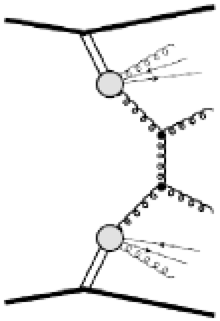
- Two degrees of freedom: R_{ud} = u/d, R_{sd} = s/d
  - u = q* 6 *R_{ud}/(1+R_{sd} + 4R_{ud})
  - s = q* 6 * R_{sd}/(1+R_{sd} + 4R_{ud})
  - d = q* 6 / (1+R_{sd} + 4R_{ud})
- Result: different Pomeron flavour structures consistent with HERA



AFP has potential to complement the HERA measurements

SD W production	- *Sensitive to quark content of dPDFs* - *Measure charge asymmetry*
DPE gamma+jet	- *Sensitive to quark content of dPDFs and to Soft Color Interaction model*
DPE dijet	- *Sensitive to gluon content of dPDFs and to Soft Color Interaction model*

Pomeron structure: DPE dijet



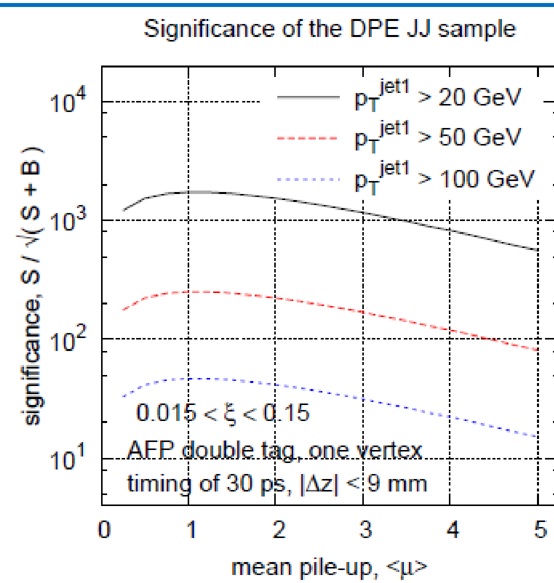
Cross-section after cuts ~ 10nb
- Dominantly g+g

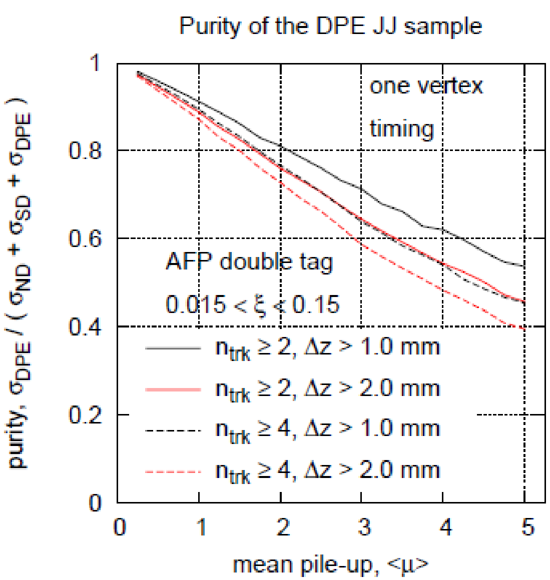
MAD-X + MC generator-level:
- 2 jets Et>20 GeV + AFP acceptance

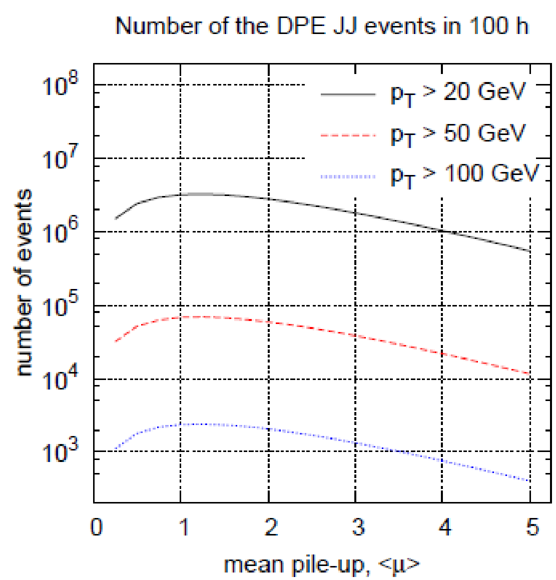
Effect of PU studied:
- Single-tag as well as double-tag
- Two models (Py8 default, Py8 MBR)
- Fast timing det. necessary

β^*=0.55m, $\sqrt{s}$ = 14TeV, d=3mm

Assuming conservatively resolution of only 30ps for Run II







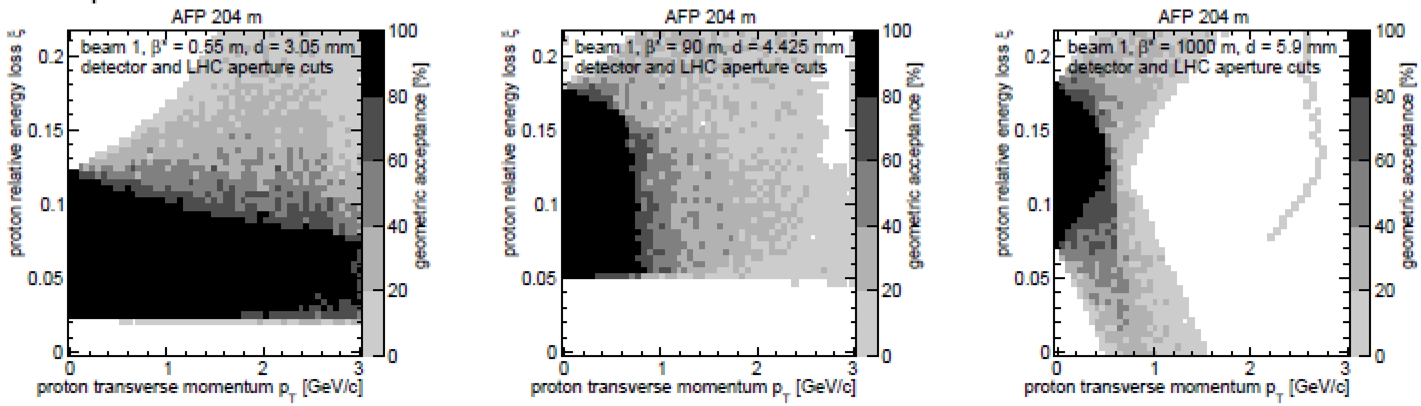
With moderate timing resolution 30ps and one-vertex requirement:
1) Excellent purity up to μ~3
2) Event yield and significance optimal at μ~1 but still manageable up to μ~5

Running scenarios:
- Effective x-section ~ 10 nb -> medium lumi needed
- μ~1 optimal but μ up to 5 && Etjet up to 100 GeV manageable
- Run of 100h with μ<5
- May be measured with both β^*=0.55m and 90m (0.55m preferred due to larger statistics and larger AFP acceptance)
- Double-tag AFP210 + Jet trigger gives sufficiently low rate

AFP in different running scenarios

MAD-X + particle gun

- Acceptance:



- Collimators are wide open. In the reality the upper ξ range could be the same for all optics (and of about 0.12 or less)! Do we know collimators position?
- Assuming **realistic** values of 15 / 7.5 / 7.5 σ distance for $\beta^* = 0.55$ / 90 / 1000 m one can conclude that:
  - background is on the same level for all optic settings for both ST and DT events,
  - – ST probability is $\sim 2\%$,
  - – DT probability is $\sim 0.02\%$.
- Amount of visible signal (hard diffraction) is comparable (factor of 2 in the worst case) for all optics.
- For 100 h of collecting data: thousands DPE jets with $p_T > 100$ GeV, hundreds Z/W.

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}

Summary

1) **AFP has a long tradition and plays an important role in the efforts and plans of the LHC Forward Physics Working Group**

2) AFP prepared a rich physics program for special runs in the Run II. This physics program is based on specific scenario with β^*=0.55m and $\mu<3$, however, AFP closely watches the scenario proposals by Totem and is prepared for common discussions with Totem and ALFA.

3) Big progress in ToF R&D: Quartic with LQ bars, SAMPIC readout chip

4) **A lot of software work has been done:**
   - ✓ Several alignment methods developed
   - ✓ Detailed simulation of SiD, TiD and some LHC elements
   - ✓ Detailed physics program including detailed sim for DPE dijets
   - ✓ Study of backgrounds using existing ALFA data + MC predictions
   - ✓ Study of running scenarios proposed by Totem

5) AFP made big steps forward in ATLAS approval in 2014

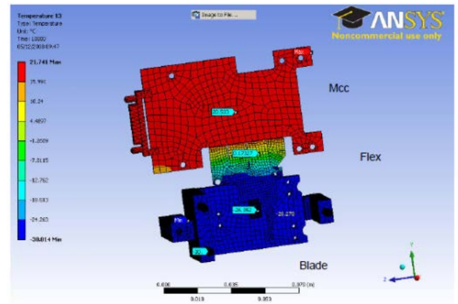
6) **AFP will welcome new collaborators**

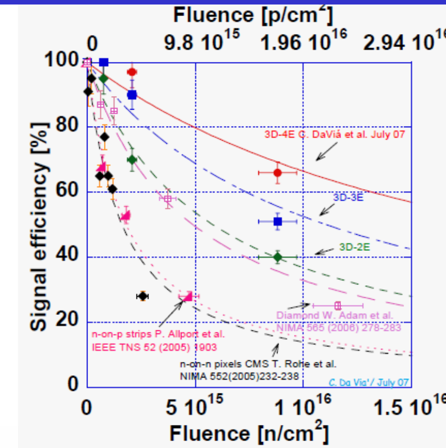
BACKUP SLIDES

History

During the R&D phase, a lot of things around tracking detector for FP420 (3D-Si oriented) have been done, investigated, proposed and worked out by UK and other institutes!

Detector layout, Module assembly, Mechanical support, Sensor design, Edge response, Irradiation tests, Power supplies, Noise studies, Off-sensor readout, External services, Optical links, Detector control system, Full thermal modeling/stress

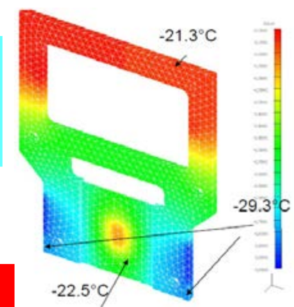


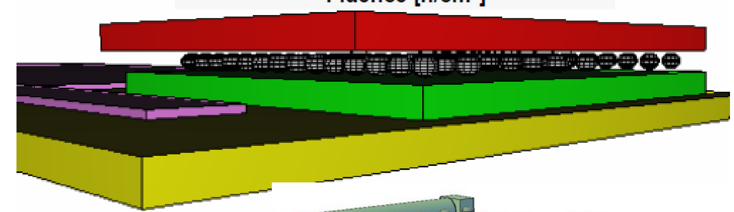



The FP420 R&D Project at the LHC

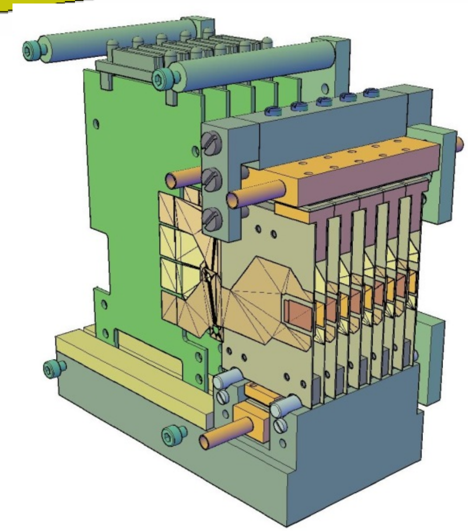
FP420 R&D Collaboration

FP420 R&D Report
JINST 4 (2009) T10001





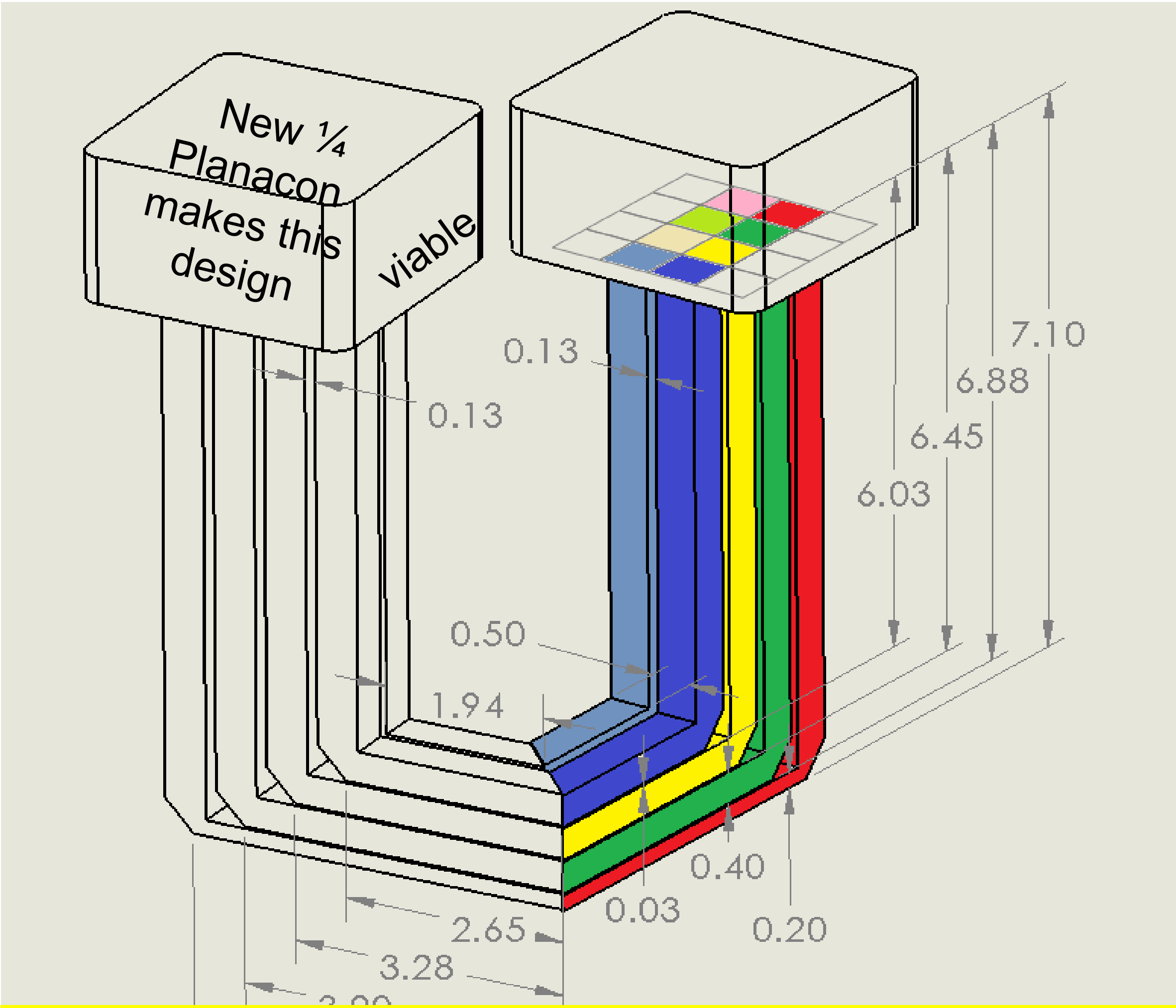
After the drastic budget cuts in UK, AFP/PPS face manpower problems.
Some solutions can be used for AFP220/PPS240.



ATLAS Technical Proposal:
AFP: A Proposal to install Proton Detectors at 220 m around ATLAS to Complement the ATLAS High Luminosity Physics Program
(April 2011)

CMS Upgrade R&D Proposal:
R&D of the Detector Systems for Stage One of the High Precision Spectrometer Project
(June 2010)

Two-Arm ToF Detector



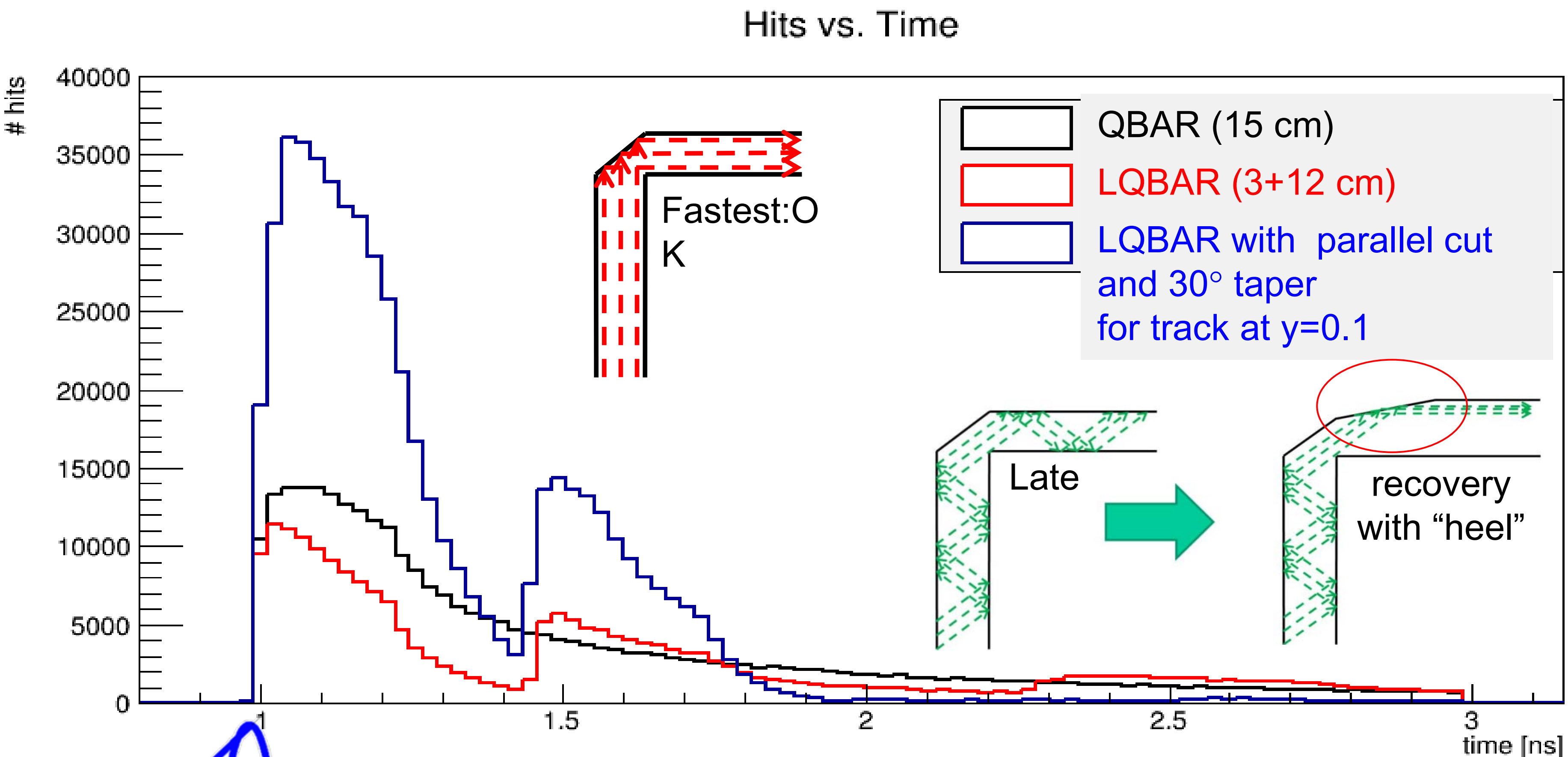
16 ch/side, 4 layers (depths in x)
2 rows (depths in z)
2 y measures (+/-) [the 2 arms]

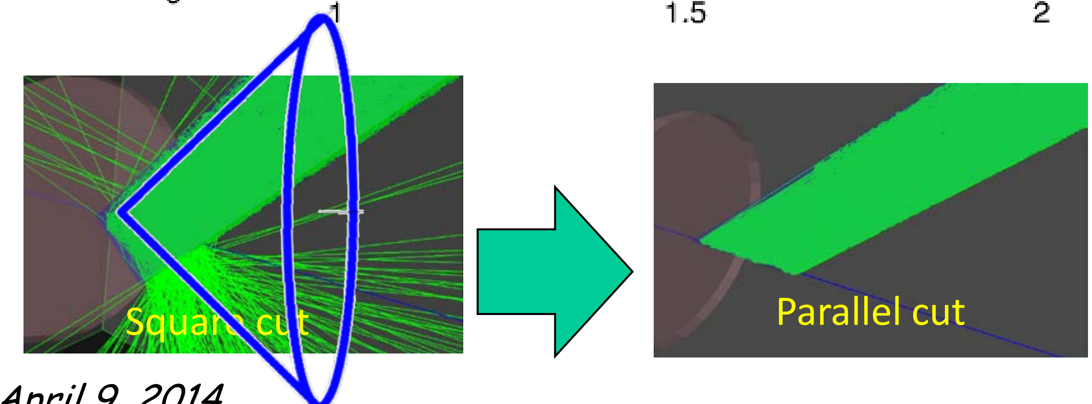
Main features:

- Takes advantage of parallel cut (lots of light)
- Very compact 5×9 cm
- Segmentation of 8, so this detector can serve as low-lum detector but can also be used for high-lum tests
- Only two very accurate measurements per proton
- Easily upgradeable to 32 channels (see next slide)
- Could have 6 mm × 4 mm light guide bars to further improve cross talk

Plan to have a 20 ps detector suitable for sharing a Roman pot in 2014
no known technical obstacles to a 10 ps high lum ToF system in 2016

AFP in ATLAS simulation (1): LQbar Photon

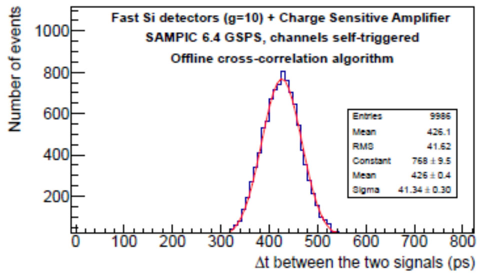




Simulation says the tuned LQbar detector is a vastly superior detector with 2-3 times **more light** in the same time window as the Qbar case! Will test this Summer

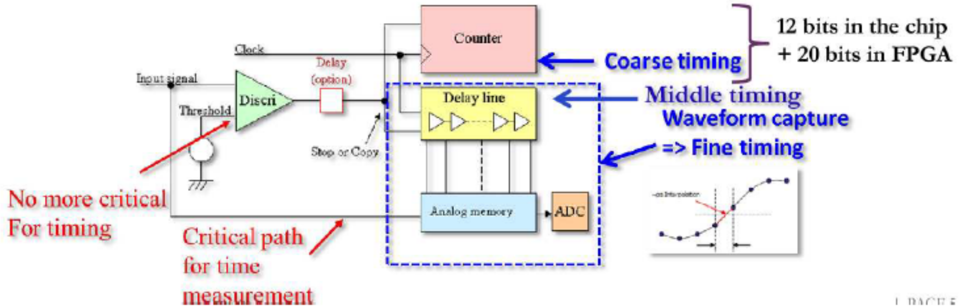
SAMPIC

SAMpler for **PIC**osecond time pick-off : A read-out chip for the timing detectors



- Application-Specific Integrated Circuit **(ASIC)** for picosecond timing measurement, acquiring the **all waveform shape** of a detector signal
- **16 (50 Ω terminated) channels** with **embedded ADC** and independant deadtime. Each is **self-triggerable** (External triggering is also available)
- **3 working prototypes available now, 3 more being made.** SAMPIC is integrated on a mezzanine board. The motherboard can hold 2 mezzanines → possibility to have a 32 channel box
- **4 ps RMS reached** on the Δt between 2 signals from pulse generators and **40 ps RMS reached** on the Δt between 2 signals from Laser + Fast Si detectors
- Analysis of beam tests with SAMPIC + Fast Si/Diamond in progress *collaboration with CMS/TOTEM*

Timing measurement with SAMPIC



- **Timing measurement is performed in 3 steps**
  - **TimeStamp Gray counter** (≃ 6 ns step) sampling the external (or internal) reference clock
  - **DLL** (≃ 150 ps step) defining a region of interest
  - **Waveform shape** (few ps RMS after interpolation) acquired on a 64-step analog memory
- **The discriminator is used only for triggering**, not for timing → no jitter
- **The drawback is an important deadtime per triggered channel**
  - Many improvements will be implemented in the next version in order to reach < 100 ns deadtime/detector channel
  - An adequate segmentation of the detector will be required in order to handle LHC rates

AFP part of LHC Forward Physics WG

Medium luminosity WG (~10-100 pb^{-1}, μ~1)

[Convenors: N. Cartaglia, C. Royon]

Repeat analyses already done without forward proton detectors!

Proton tagging: - guarantees the exclusivity
- enables proton azim.angle measurement → info about S2 and spin of produced resonance

CEP

- Dijets, trijets: testing ground for CEP x-section calculation [AFP+ATLAS, CMS+Totem, KMR]
- Diphotons [CMS+Totem]
- Chi-b, Chi-c, eta-b, eta-c [LHCb]
- Pipi [ALFA+ATLAS]
- Meson pair production (K+K-, rho+rho-, eta+eta-, eta+'eta-') [Totem, Szczurek, DIME MC]

In all subgroups (Low-lumi, Medium-lumi, High-lumi, Detectors) AFP plays an important role
(C. Royon is a member of AFP)

Diffraction

- SD dijets [AFP+ATLAS, CMS+Totem]
- DPE dijets [AFP+ATLAS, CMS+Totem]
- DPE gamma+jet/dijets [AFP+ATLAS]
- SD W/Z [AFP+ATLAS, CMS+Totem]

Low-x BFKL

- Mueller-Navelet jets [AFP+ATLAS CMS+Totem, Vera, Murdaca, Ducloue]
- Jet-gap-jet [AFP+ATLAS Marquet]
- Jet veto [AFP+ATLAS Werder, Marquet]
- Double J/Psi [LHCb]
- MPI [Strikman, Jung]

Low-x Saturation

- Forward Drell-Yan [LHCb, Del-Ducati, De Olivieira, Lewandowska]
- Forward photons in pA [Peitzmann]
- Forward jets in pp, pA [Kutak, Kotko]
- Exclusive Vector Mesons in UPC [Contreras, Tapa, Takaki]

AFP part of LHC Forward Physics WG

Low luminosity WG (~1 pb^{-1}, μ<1)

Repeat analyses already done without forward proton detectors!

Proton tagging: - guarantees the exclusivity
- enables proton azim.angle measurement → info about S2 and spin of produced resonance

CEP

- Diphotons [CMS+Totem]
- Chi-b, Chi-c, eta-c, eta-b [LHCb]
- Pipi [ALFA+ATLAS Totem]
- Meson pair production (K+K-, rho+rho-, eta+eta-, eta+'eta-') [Totem, Szczurek, DIME MC]
- Glueball searches – Pt filtering with tagged protons [Totem+CMS]
- Invisible searches – missing mass with tagged protons [Totem+CMS]

Particle spectra

Charged and neutral particle multiplicities; E, Pt, eta spectra; Correlations; Forward E-flow; Identified particles [ALFA+ATLAS AFP+ATLAS , CMS+Totem, LHCb]

Diffraction

- Soft diffraction: gap spectra [AFP+ATLAS , CMS+Totem]
- SD J/Psi [Totem]
- SD dijets [AFP+ATLAS , CMS+Totem]

Sigma_tot, Elastics

[Totem, ALFA]

Cosmic Rays

- Multiplicity and E-flow of forward n, photons
- Special p-O2 runs to further tune MCs [LHCf]

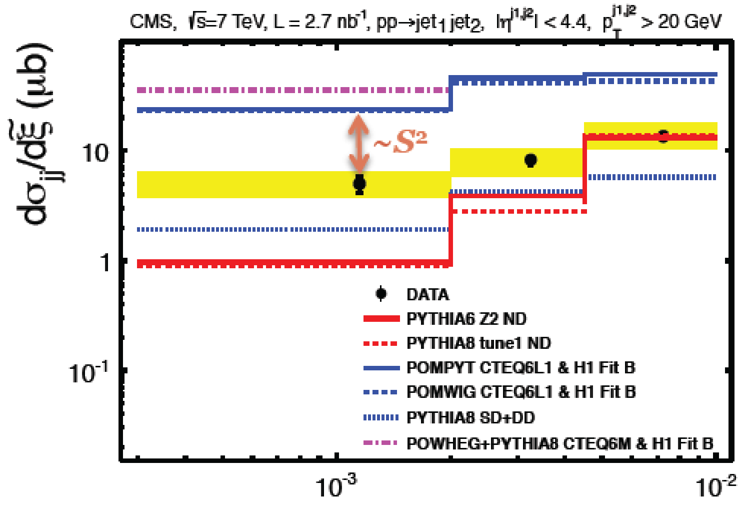
p-Pb

[LHCb, ALICE]

SD dijets

ATLAS (ongoing)

ATLAS and CMS measurements without proton tags:



Phys. Rev. D 87 (2013) 012006

Taking proton dissociation
Into account:

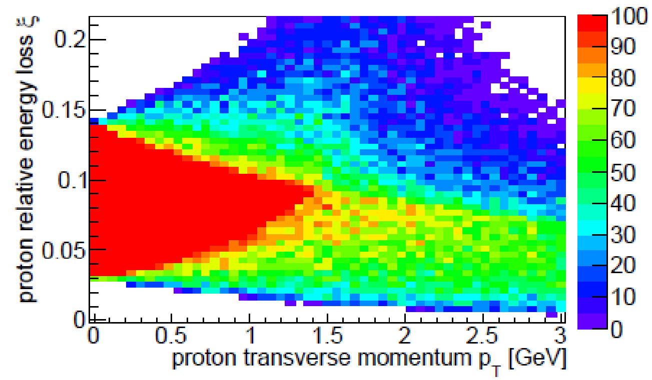
$S^2_{data/MC} = 0.12 \pm 0.05$ (LO MC)
$S^2_{data/MC} = 0.08 \pm 0.04$ (NLO MC)

Challenging measurement since

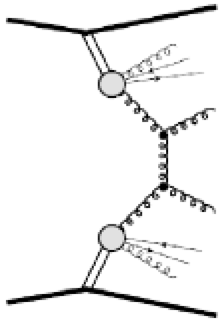
1) eta coverage is limited (|eta|<5)
2) Based on gaps or xi (sensitive to det. noise)
3) Fake gaps from hadronization
4) Low statistics due to requiring jets and low PU
5) No MC tuned for this process

- Limited statistics only allows S2 measurement.
- Measuring dPDFs needs more statistics and proton-tagging

β^*=0.55m, $\sqrt{s}$ = 14TeV, d=3mm



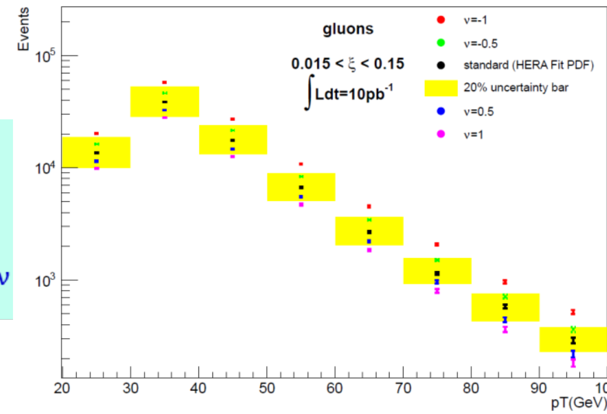
Pomeron structure: DPE dijet

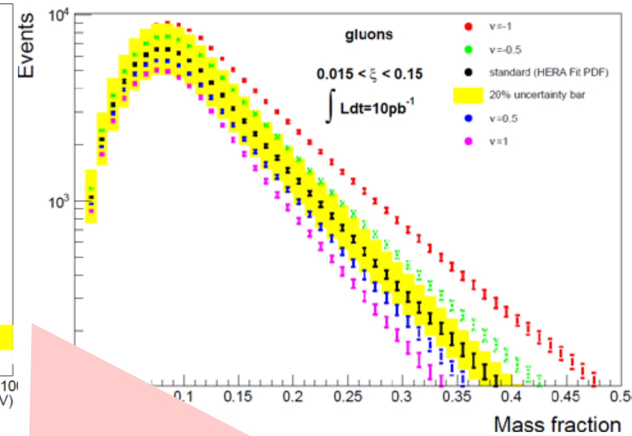


Cross-section after cuts ~ 10nb
- Dominantly g+g

Truth level: 2 jets E_T >20 GeV
+ AFP acceptance
- Sensitivity to high-β tail in gluon dPDF by varying ν in $(1-\beta)^{\nu}$

β*=0.55m, √s = 14TeV, d=3mm





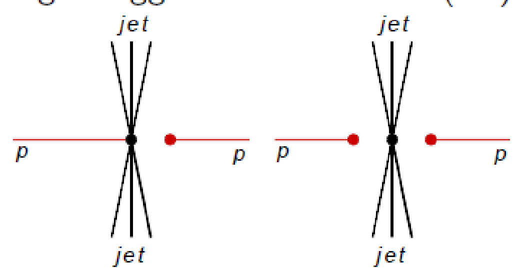
Already 10pb-1 (=10h with mu~1) provides a beautiful separation between various gluon dPDF (statistical uncertainties only)

Detailed sim. of ATLAS and AFP:
- 2 jets Et>20 GeV + AFP acceptance

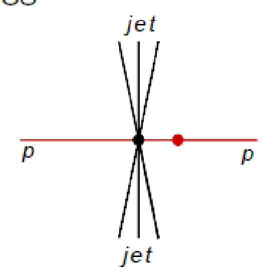
Effect of PU studied in great detail!
- Single-tag as well as double-tag
- Two models (Py8 default, Py8 MBR)
- Fast timing det. necessary

Assuming conservatively resolution of only 30ps for period between LS1 and LS2

Single Tagged Soft Interaction(ST) Double Tagged Soft Interaction(DT



SD JJ + ST ND JJ + ST + ST

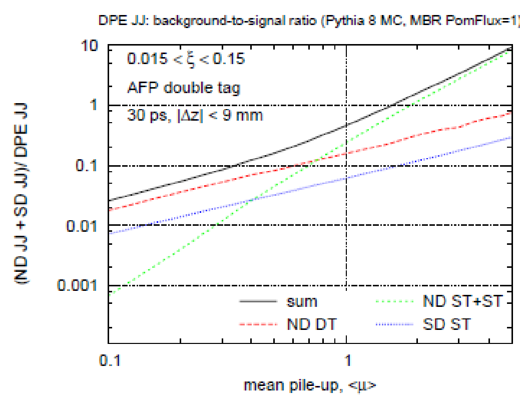


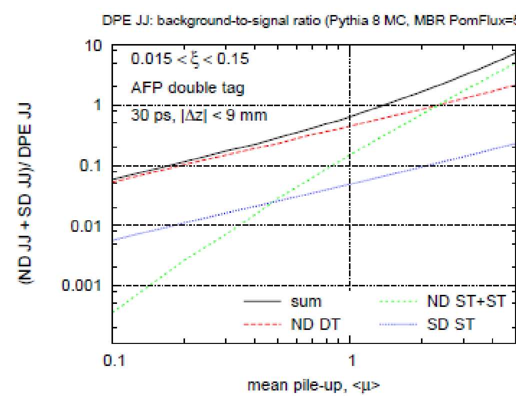
ND JJ + DT

Single Tag (ST) Interactions					
probability					
default	0.18	0.045	–	0.0055	0.038
MBR	0.12	0.040	0.42	0.0054	0.030
cross section [mb]					
default	2.3	0.40	–	0.32	3.0
MBR	1.3	0.38	0.34	0.30	2.3
	SD	DD	CD	ND	MB

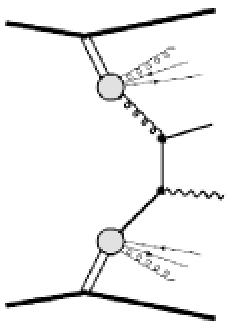
Double Tag (ST) Interactions				
probability $[10^{-3}]$				
default	0.47	0.37	–	0.014
MBR	0.31	0.36	26.0	0.012
cross section [μb]				
default	6.1	3.3	–	0.81
MBR	3.5	3.4	21	0.67
	SD	DD	CD	ND

B/S ratio for Py8 default and Py8 MBR





Pomeron structure (3): DPE gamma+j/jj

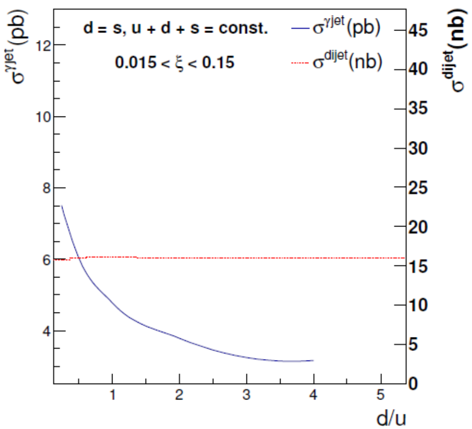


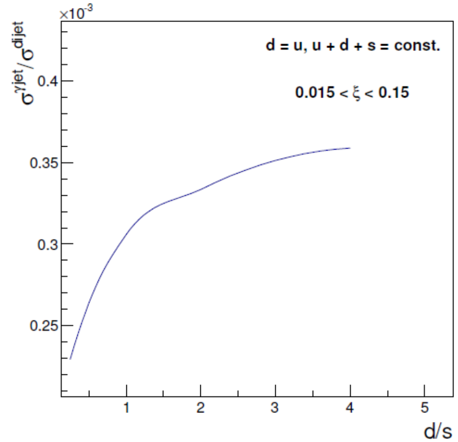
Gamma+j Cross-section after cuts ~ 1pb
- Dominantly q+g -> Sensitivity to quark dPDFs
- Make ratio with DPE jj to suppress systematics
- DPE jj studied in great detail in a separate analysis

β^*=0.55m, $\sqrt{s}$ = 14TeV, d=3mm

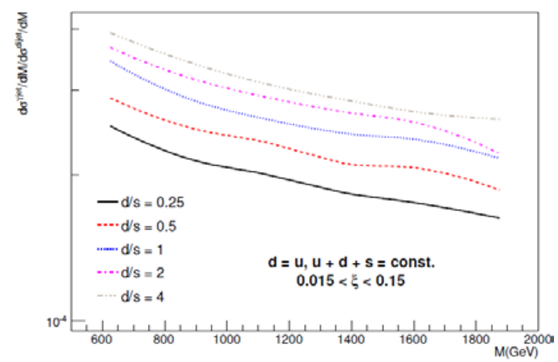
C. Marquet et al., PRD 88 (2013) 074029

Truth level: AFP acceptance
+ jets: Et > 20 GeV
+ photons: Et > 20 GeV, |eta| < 2.5
- Assuming Lumi=300pb-1 at mu=1





u+d+s = constant, d=u and d/s ∈ {0.25,0.5,1,2,4}



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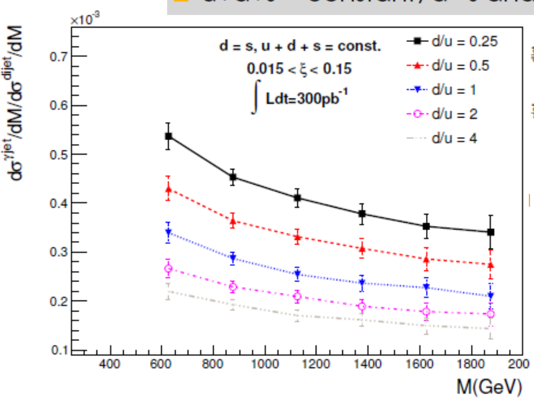
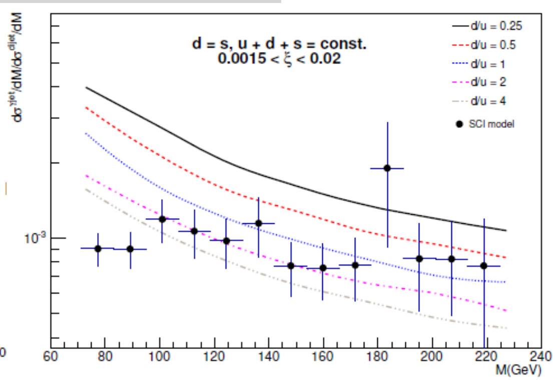
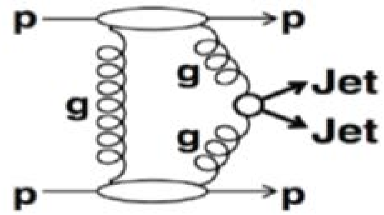


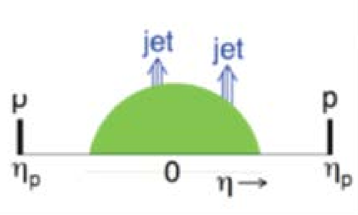


- Cross-section ratios vary by a factor 1.5
- M = $\sqrt{\xi_1 \xi_2 s}$ (AFP measurement), systematics largely cancel
- Some rejection power for all: u/d, s/d and SCI

Running scenarios:
- Statistics is an issue for gamma+jet (L>200 pb-1 needed) -> medium lumi (μ~1-3) needed
- need for statistics prefers β^*=0.55m
- Run of 200h with μ~1.5
- Double-tag AFP210 + Jet/Photon Triggers

CEP dijets with one proton-tag (1)

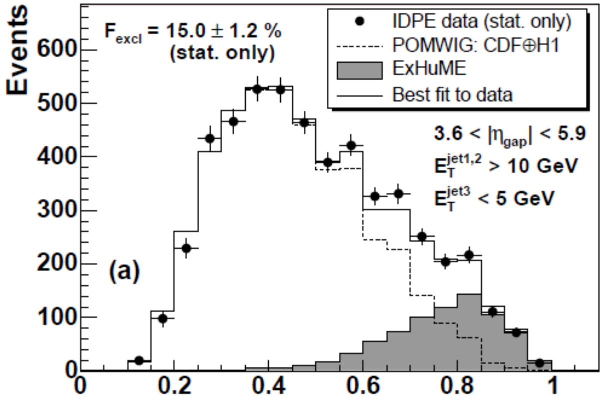




Very fruitfull process: combined effect of all basic ingredients to CEP:

- Soft survival S^2
- Sudakov suppression
- Unintegrated f_g
- enhanced absorption

KMR, EPJC 55 (2008) 363



Observed by CDF and D0.
In good agreement with KMR but still big uncertainties

Motivation:

- Reduce the factor 3 of uncertainty in calculations of x-section at LHC (KMR)
- Measure R_{jj} distribution and constrain existing models and unintegrated f_g

β^*=0.55m, $\sqrt{s}$ = 14TeV, d=3mm

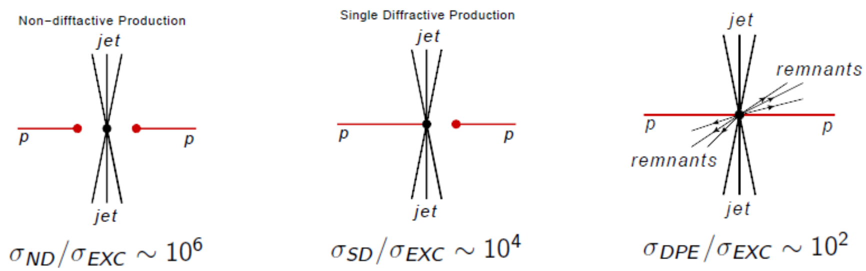
Detailed sim. of ATLAS and AFP:

- 2 jets Et>20 GeV + AFP acceptance

Effect of PU studied in great detail!

- Two models (Py8 default, Py8 MBR)
- Fast timing det. cannot be used
- Exclusivity cuts:

a) number of tracks outside jets
b) Xi(AFP) vs. xi(jets)
c) Forward energy flow



Single Tag (ST) Interactions

	SD	DD	CD	ND	MB
probability					
default	0.18	0.045	–	0.0055	0.038
MBR	0.12	0.040	0.42	0.0054	0.030
cross section [mb]					
default	2.3	0.40	–	0.32	3.0
MBR	1.3	0.38	0.34	0.30	2.3

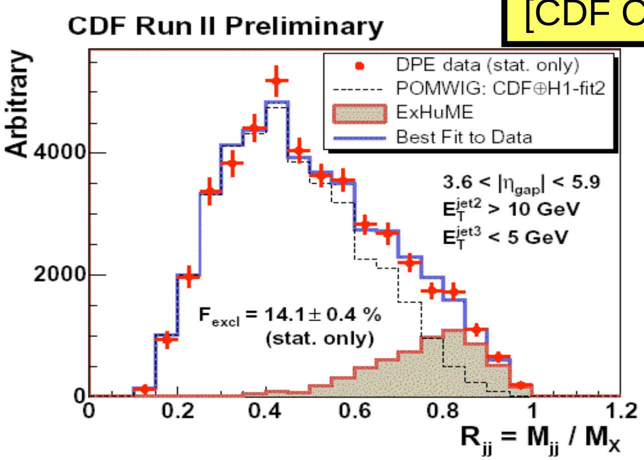
Physics with forward proton tagging at high lumi

Diffraction

Hard SD/DPE/CED (dijets, diphoton, W/Z, …)
Gap Survival / Underlying event
High precision calibration for the Jet Energy Scale

Central Exclusive Production of dijets:

[CDF Coll, arXiv:0712.0604]



Evidence for CEP

Central Exclusive Production of Higgs

- BSM not excluded entirely, but concentrate on SM

SM h→WW*, 140 < M < 180 GeV [EPJC 45 (2006) 401]

MSSM h→bb, h→ττ

[EPJC 53 (2008) 231
EPJC 71 (2011) 1649
EPJC 73 (2013) 2672]

[JHEP 0710:090,2008]

Photon-induced interactions

Excl. γγ→ee, μμ => calibration of FDs
Excl. γγ→ γγ
Excl. γγ→ χ_c, J/ψ
Excl. γγ→ WW/ZZ => anomalous triple and quartic gauge couplings => Higgsless and Extra-dimension models

γp→jj Factorization breaking in hard diffraction

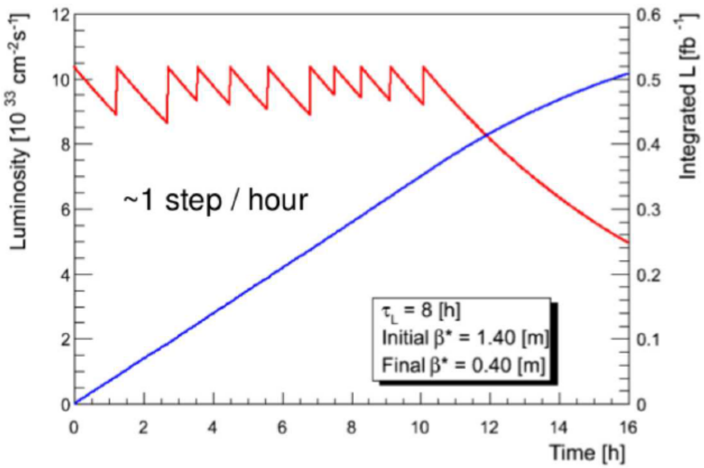
CDF: Observation of Exclusive Charmonium Prod. and γγ→μμ in pp collisions at 1.96 TeV [arXiv:0902.1271]

- Quartic Gauge Couplings – testing BSM models
- Reaching limits predicted by string theory and grand unification models ($10^{-14} - 10^{-13}$ for $\gamma\gamma\gamma\gamma$)
- Exc. jets – verification of QCD production models, unintegrated gluon PDFs

[PRD 78 (2008) 073005
PRD 81 (2010) 074003]

Luminosity leveling

Leveling Scheme*



Initial $\beta^* = 1.4$ m. Final $\beta^* = 0.4$ m.

Step: 0.1 m every 1 hour.

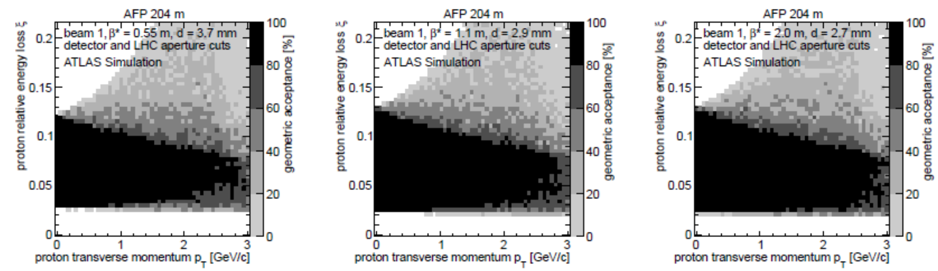
- Sould AFP detectors move from the beam during the change of $\beta*$?
- If yes – how far?

* – from Jorg Wenninger presentation: ,,*ATLAS – post LS1 options*", 02.07.2013

Geometric Acceptance

In all cases detectors are 20σ far from the beam.

$\beta^* = 0.55\ m$ $\beta^* = 1.10\ m$ $\beta^* = 2.00\ m$



Detector acceptance is not affected.

Summary

- It is certainly easier to operate with fixed optics (constant β^*).
- Luminosity leveling – difficulties:
  - optics changes,
  - detector operation.
- **It is not impossible to take data with luminosity leveling.**
- **Geometric acceptance is not affected.**
- Leveling step: 0.1 m every 1 hour.
- **With automated movement detectors should be re-positioned within few minutes.**