Status of the AFP Project in ATLAS

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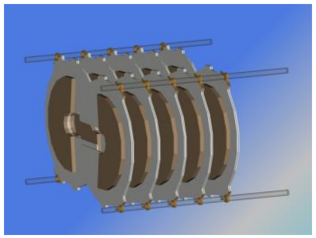
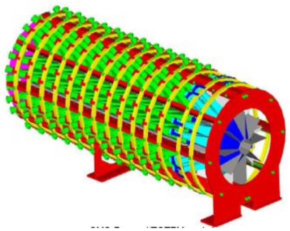
(on behalf of the AFP Collaboration)

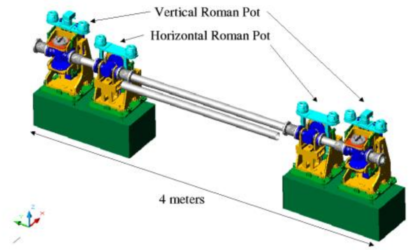
Low-x workshop 2014, Kyoto, Japan - 18/06 2014

1. Status
2. Concept
3. Physics program

Forward detectors around ATLAS and CMS

TOTEM -T2 CASTOR FSC ZDC TOTEM(now) PPS240 PPS420?

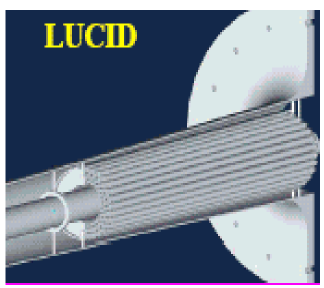



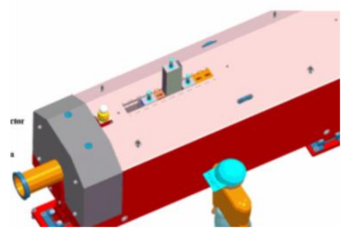
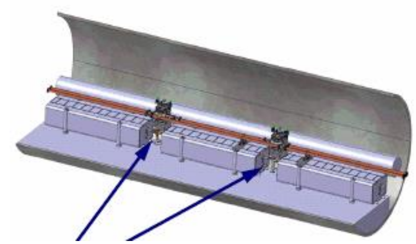
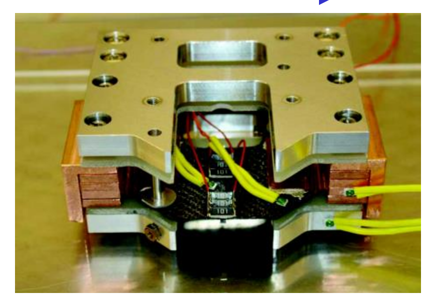


IP5

14 m 16 m 140 m 147m - 220 m 420 m

IP1

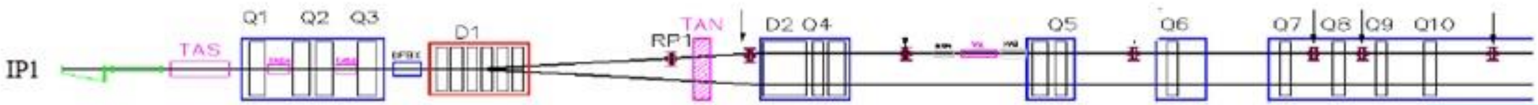


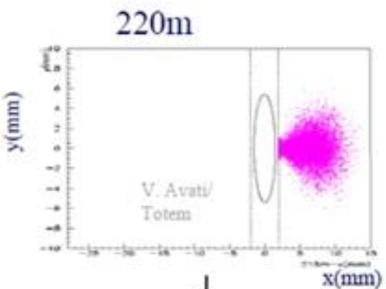




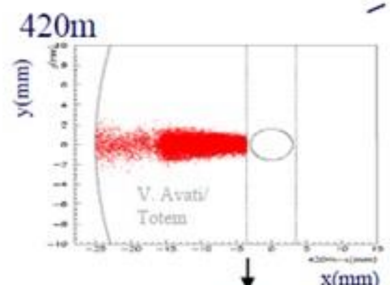
LUCID ZDC ALFA(now) AFP220 AFP420?

AFP = ATLAS Forward Proton

Proton leaves the interaction intact, travels through LHC optics and is detected at ~220 m





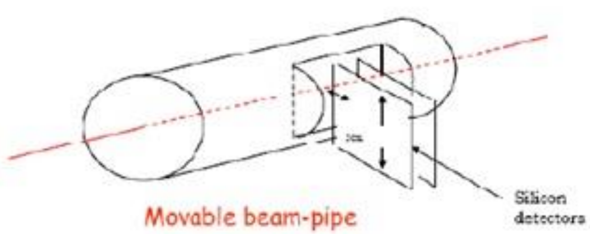


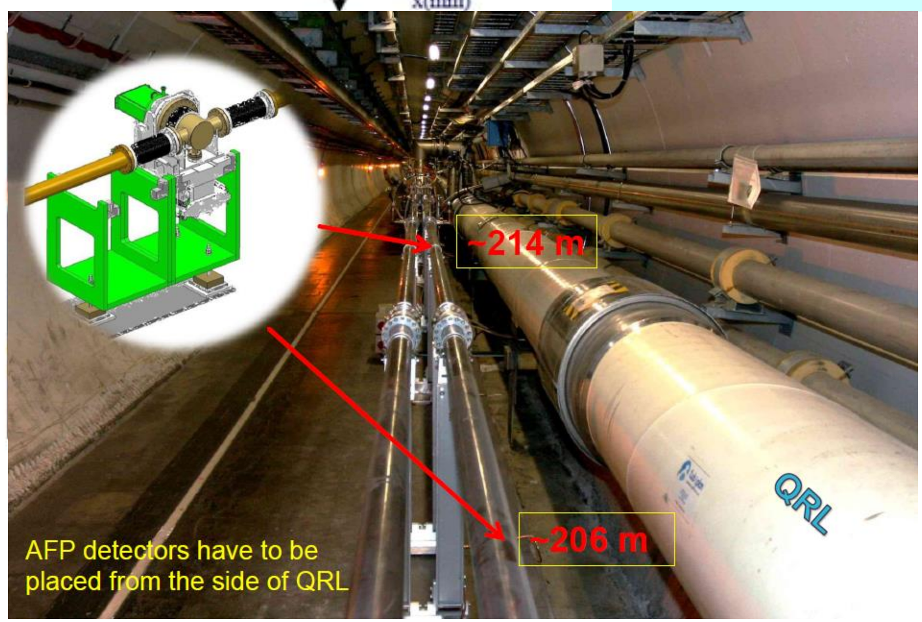
What is AFP?

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**

Horizontal detectors in a movable beam-pipe at 216 and 224 m on each arm.

Detectors as close as possible to the beam: 10σ = 1mm



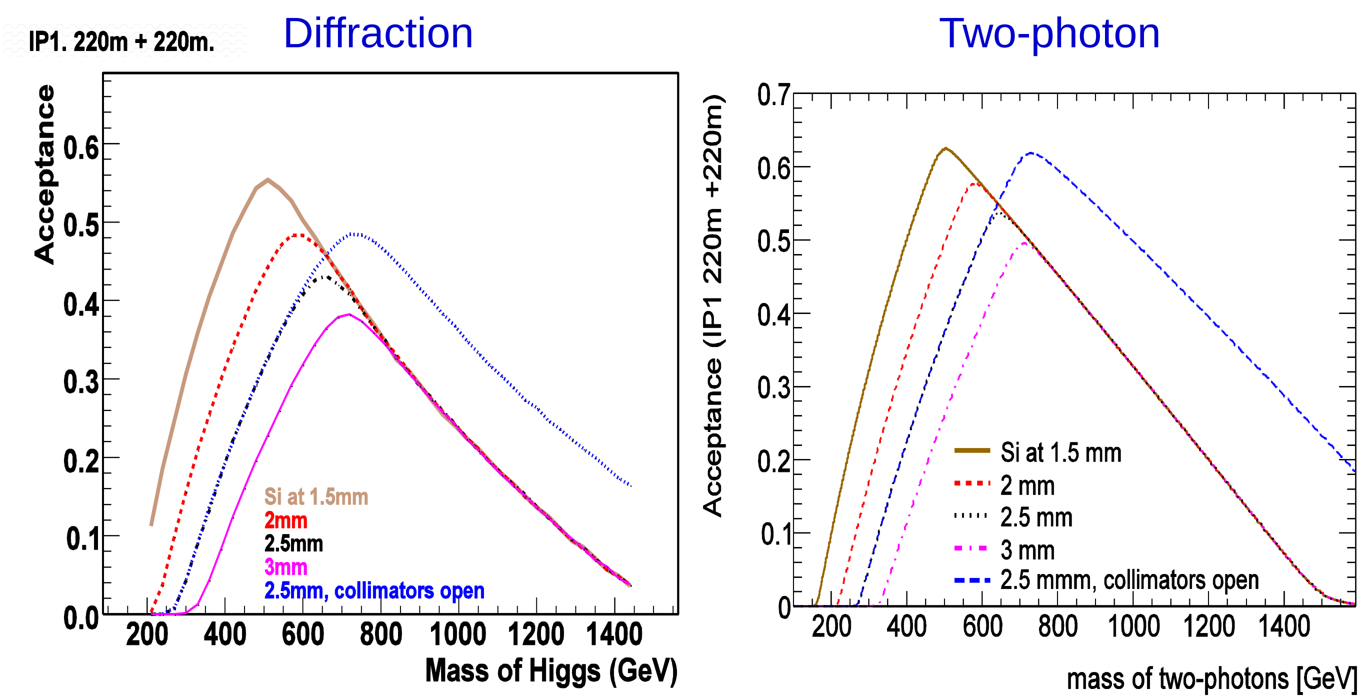


AFP: 2 stations on each side of IP with tracking and timing detectors at ~ 220m

200-220m, ATLAS side

What does AFP Provide?

220+220 at IP1



Acceptance >40% for wide range of resonance mass

- Mass and rapidity of centrally produced system

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

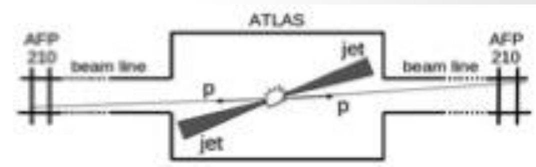
$$y = \frac{1}{2}\ln(\xi_1 / \xi_2)$$

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

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

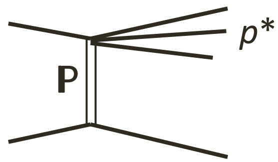
Primary goals of AFP

(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

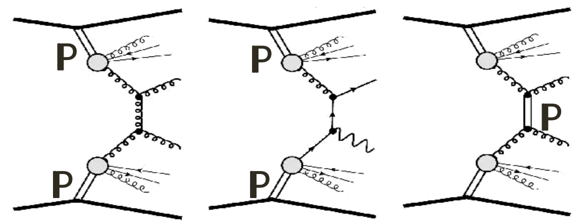


- Jets, W, Z: Soft survival prob. S^2
- Particle spectra, Gap spectra: SD vs. DD

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

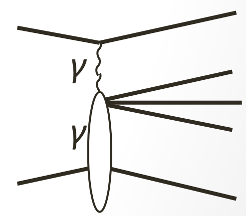
Double-tag: Double-Pomeron Exchange

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



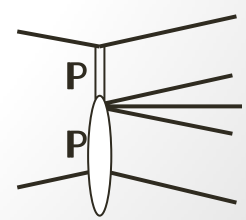
Double-Photon Exchange

- 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 & PPS

2003
Manchester Forward Physics Meetings

2005
FP420 Joint ATLAS & CMS Collaboration

2008
FP420 R&D Report

2008
Add FP220

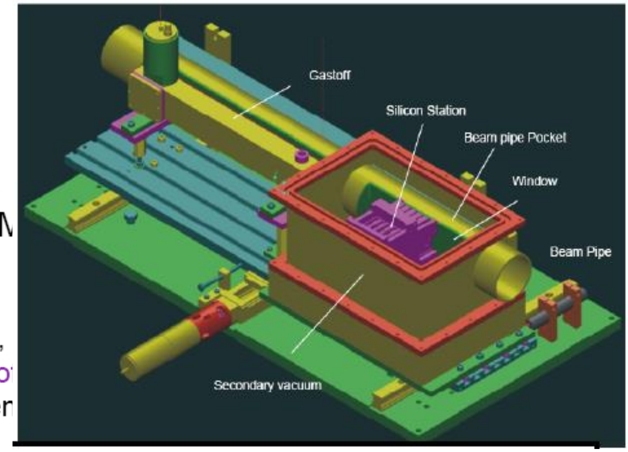
2009
Under review

2010-2014
Aim for Upgrade project

FP420 R&D Collaboration

- Spokes : Brian Cox (Manchester, ATLAS) and Albert DeRoeck (CERN,CMS)
- 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 of Texas at Arlington, The University of Glasgow, University of Calabria and INFN-Cosenza, 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 Nebraska, Institute of Physics, Academy of Sciences of the Czech Republic, Brookhaven National Laboratory, University College London, Cambridge University




The FP420 R&D Project at the LHC

FP420 R&D Report
JINST 4 (2009) T10001

+ FP220/240

ATLAS AFP R&D → **Upgrade Project**

CMS PPS R&D → **Upgrade Project**

2 Reviews of AFP in 2014

2014 = crucial year: both the Physics review and the Technical review passed

Outcome of the Physics review (Jan 24)

1) Recommended only 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**

2) Running scenarios to be discussed with Totem and ALFA

3) Collect data and study all sorts of backgrounds

4) Review the high-lumi program once bgr at nominal beta* studied and if physics wanted

5) Strengthen the collaboration and promote collaboration with ALFA

Outcome of the Technical review (March 25-26)

1) Robust alignment strategy: several methods available. Low-mu program gets by ~200 um precision, with enough data much better precision can be achieved.

2) Improvements in ToF: MCP R&D; tapering of bars; rad. hardness of HPTDC

3) Prepare combined test beam of the full system in November

4) Strengthen the collaboration and provide sufficient financial sources

5) Approve at CB and write TDR asap

AFP milestones in 2014

Difficulties due to US budget cuts: - R&D of Quartic ToF
- Manpower and funding situation in AFP

End June: conditional EB approval -> only if AFP secures sufficient funding & manpower

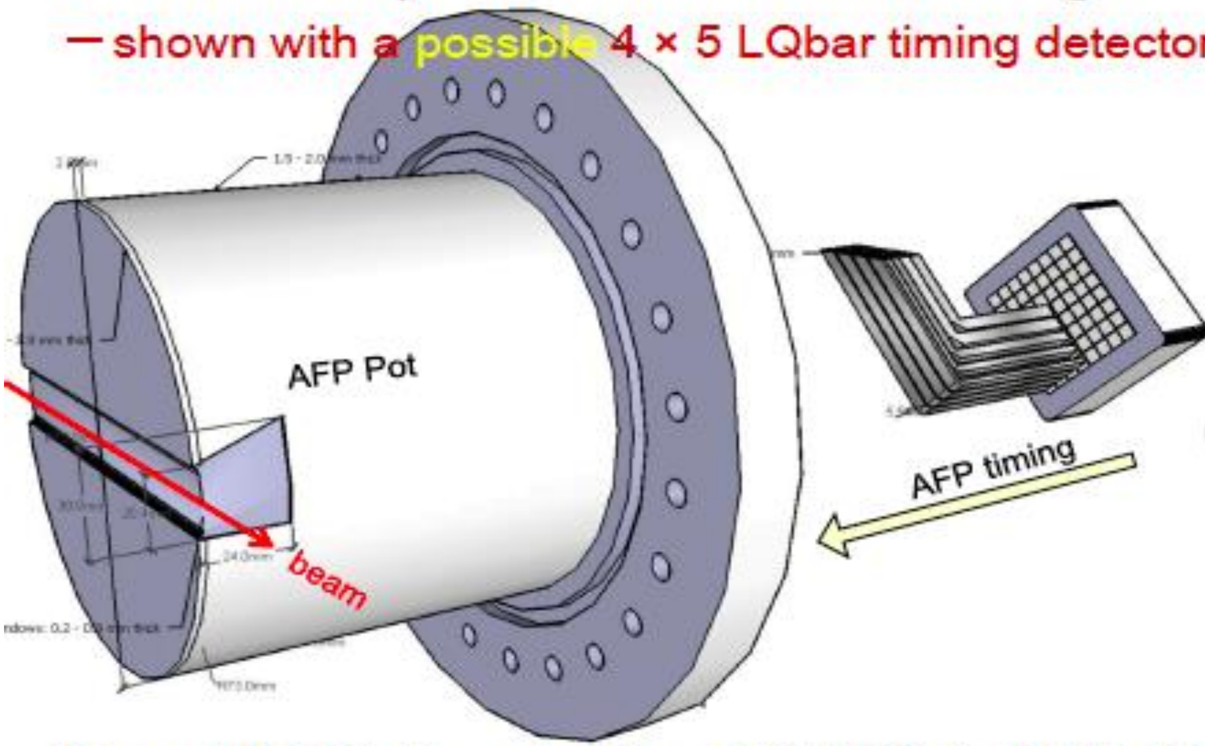
AFP activities:

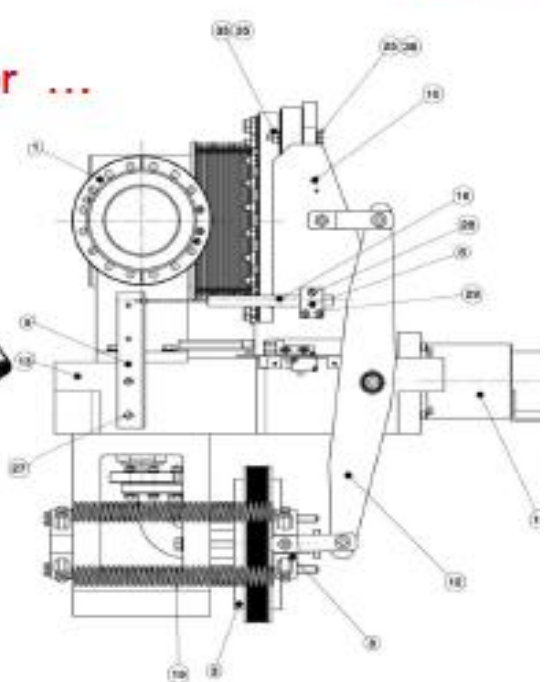
1) **R&D of Quartic ToF and also alternative ToF: diamond**
2) **R&D of Sampic** (Read-out chip for ToF)
3) **AFP and ALFA approaching:**
- Combined effort in simulation
- Combined optics studies
- AFP willing to participate in analyzing ALFA data
4) **Preparing for Test beams at CERN in November**
- DESY January TB: SiD sensors: efficiencies as functions of distance and inhom. irradiation (to be publ.)
- FNAL May-June TB: ToF: Final design of LQbar, p.e. yield, resolution, cross-talk. Results including PMT lifetime, rates and previous Qbar TB to be published
5) **Discussing running scenarios with Totem and ALFA**
6) **Writing TDR** (existing Technical Proposal as a basis)

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)

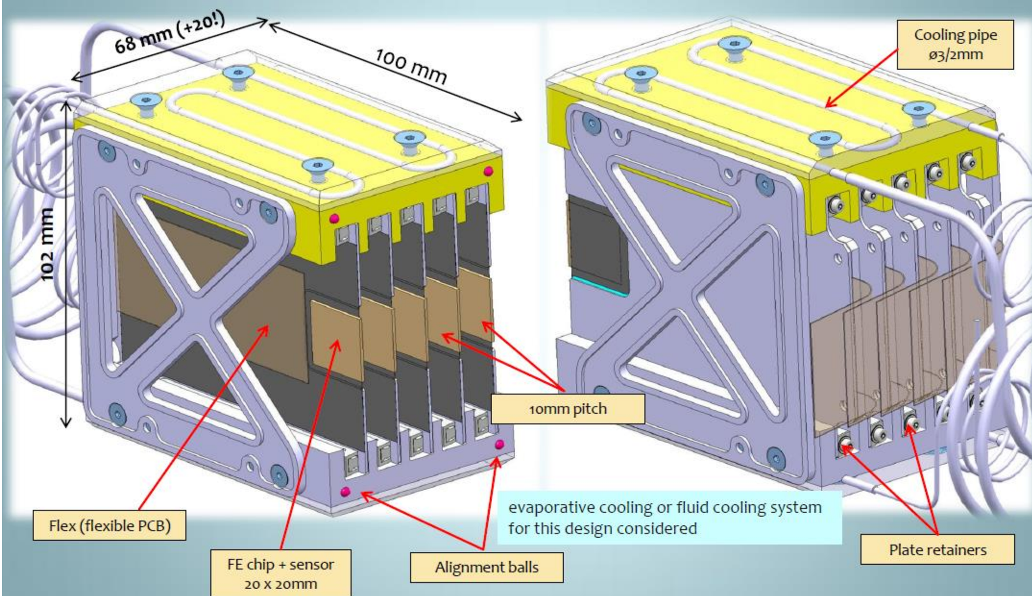
Copy RP Station design of ALFA & TOTEM:

– Ample operational experience

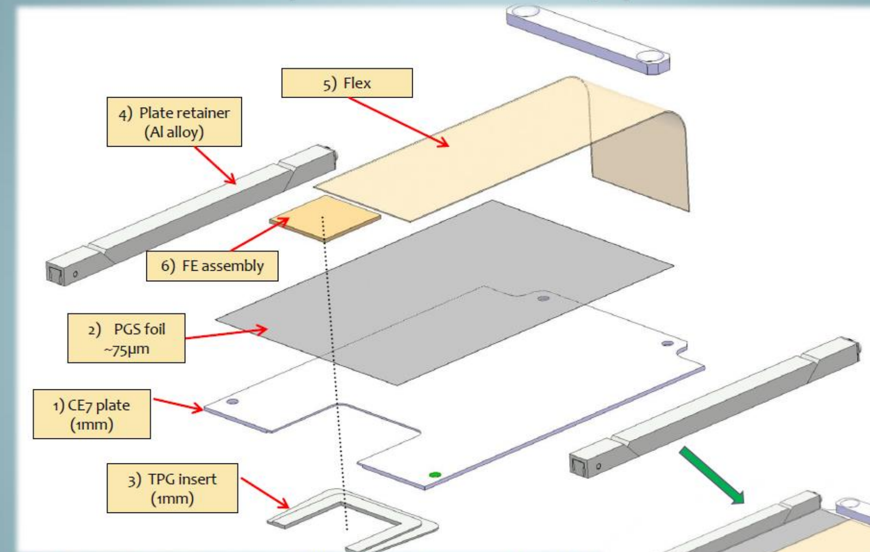
– Known cost and construction & installation procedures

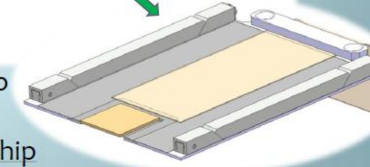
Tracker mechanics – first design version

April 2013–that time considered for integration with HBP (no serious space constraints)



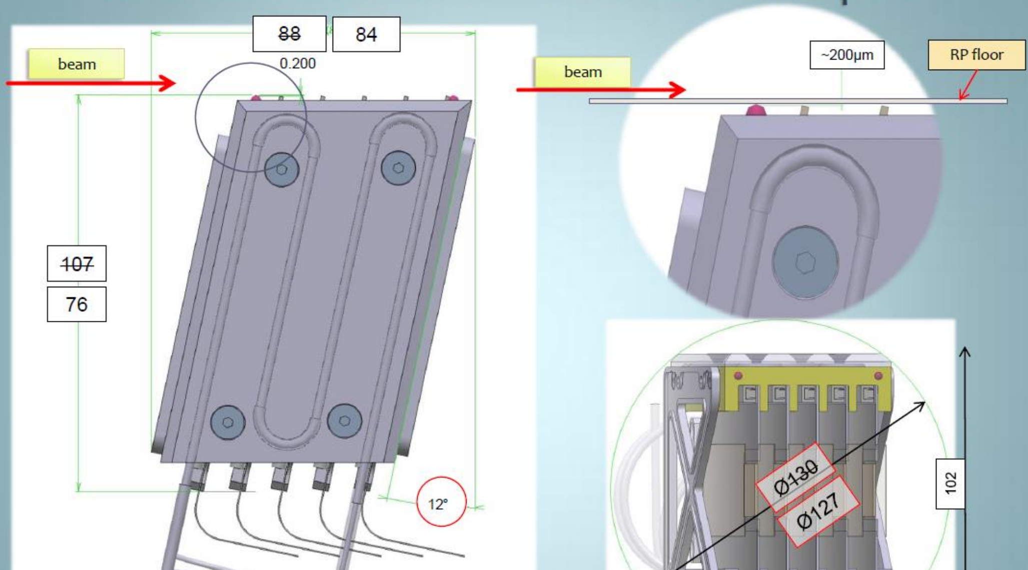
Tracker plate – assembly procedure





- TPG insert improves rigidity in region of FE chip boundary (considered as option)
- There is just 75µm of extra material under FE chip

How does the tracker fit inside roman pot?



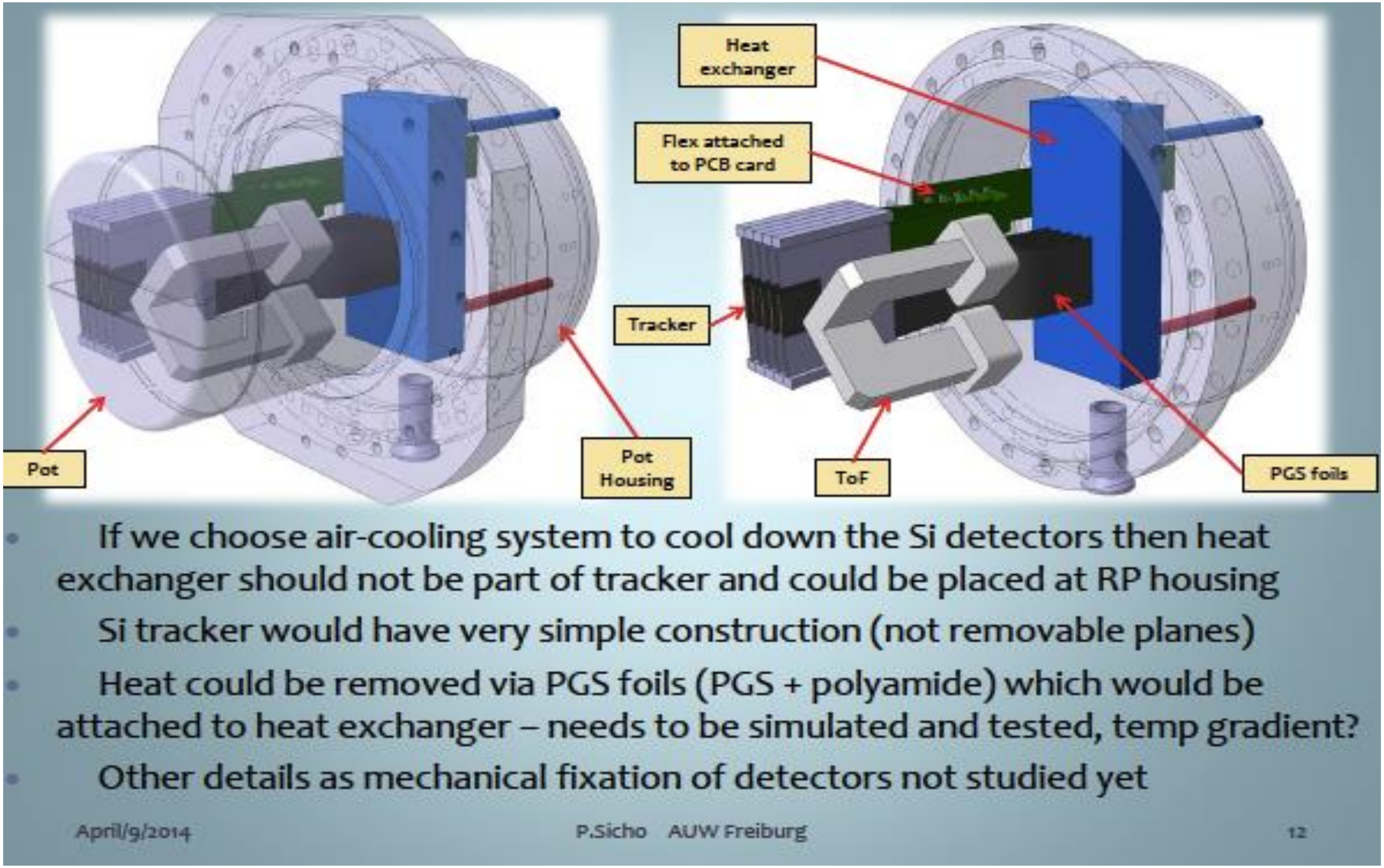
➢ Reduction of detector depth (107 to 76 mm) helps

RCE readout system

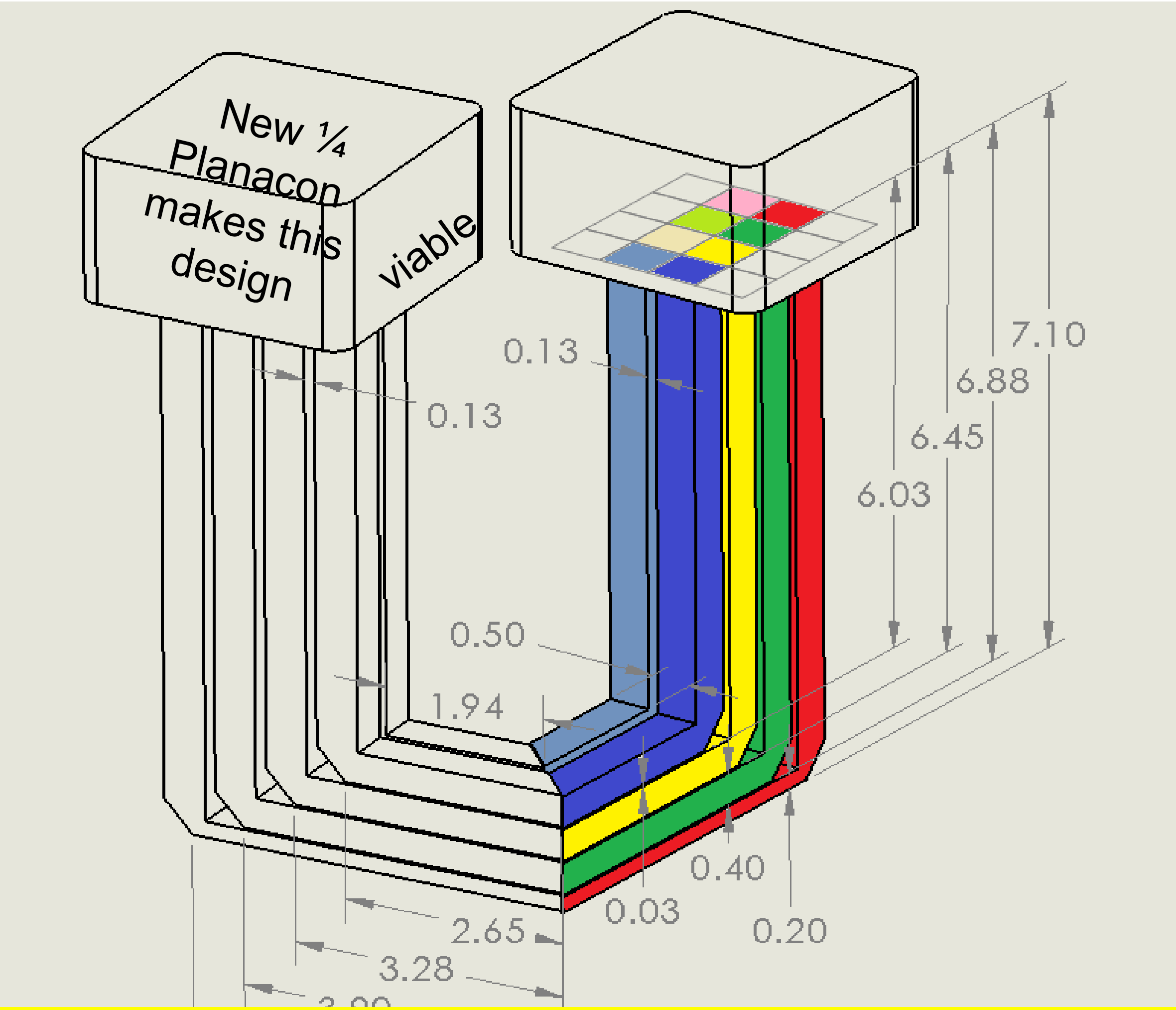
- DAQ system developed at SLAC
- ATCA standard, 10 Gb/s ethernet. Based on System-on-chip technology.
- Linux PC controls RCE via ethernet. RCE runs scans.
- Since AFP uses FEI4 frontend chips it would be straightforward to use the RCE system for readout.
- ToF detector readout could be added to the system.

- The RCE system is a versatile DAQ system used in a number of applications.
- RCE system is used for IBL stave testing. Software for FEI4 calibration is in place.
- RCE system is going to be be firstly used in ATLAS by CSC Muon group

Current conceptual design of arrangement in RP



Two-Arm ToF Detector



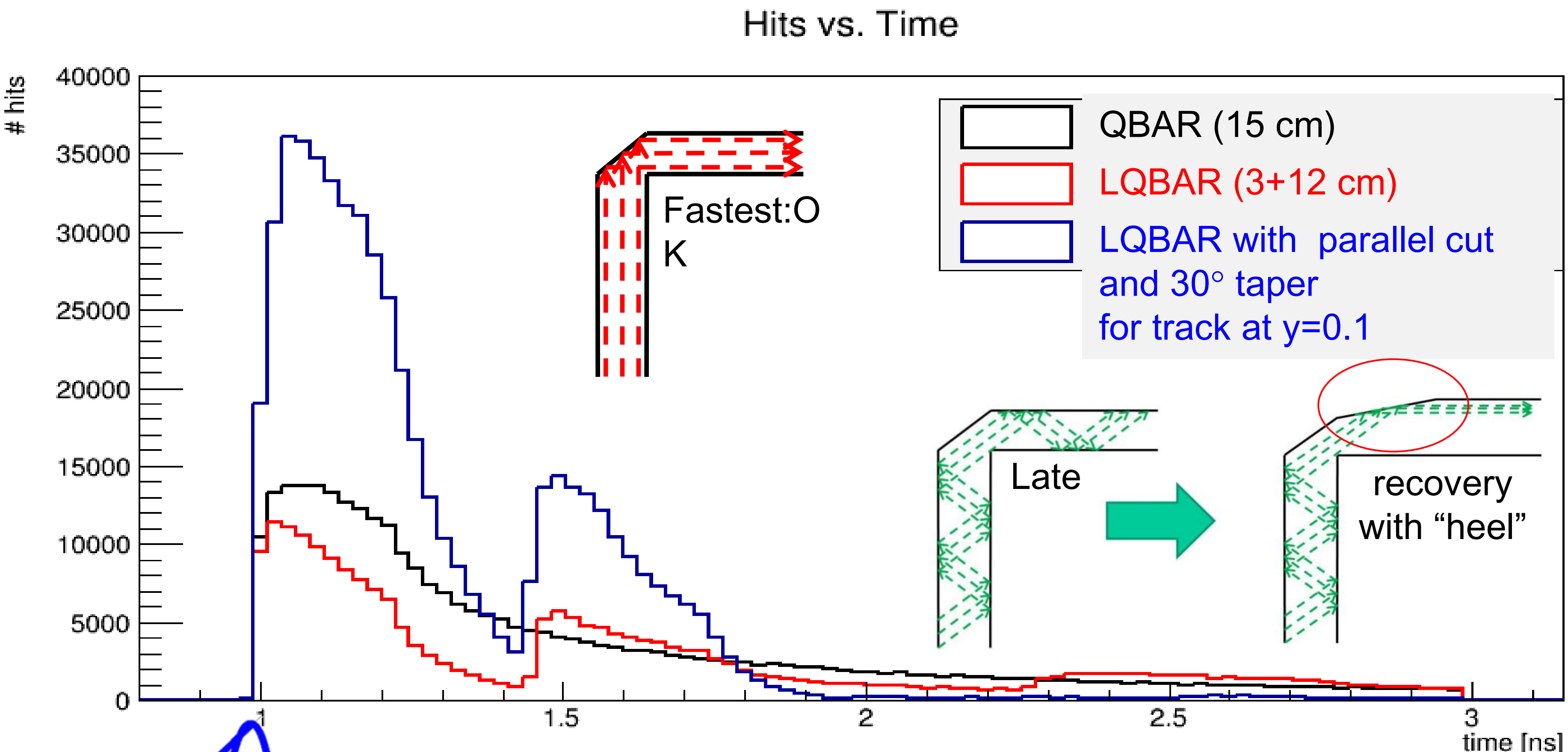
16 ch/side, 4 layers (depths in x)
2 rows (depths in z)
2 y measures (+/-) [the 2 arms]

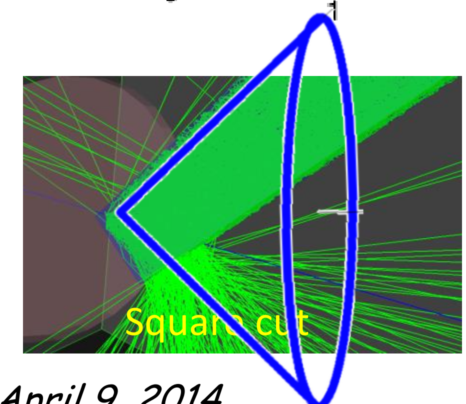
Main features:

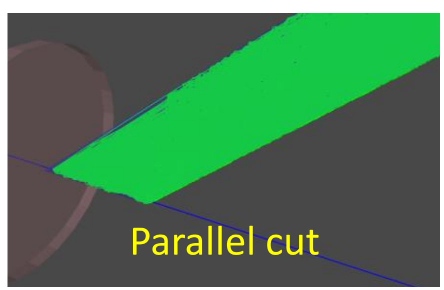
- Takes advantage of parallel cut (lots of light)
- Very compact 5×9 cm
- Segmentation of 8, so this detector can serve as low-lum detector but can also be used for high-lum tests
- Only two very accurate measurements per proton
- Easily upgradeable to 32 channels (see next slide)
- Could have 6 mm ×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

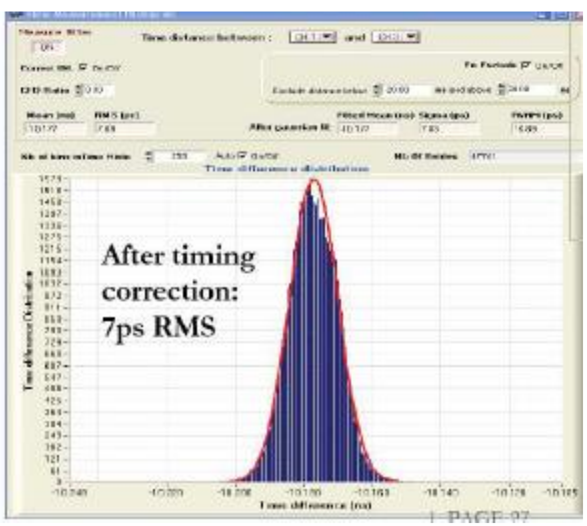
SAMPIC = Sampler for Picosecond time pick-off

- Test chip: Prototype of future chip to be used in AFP in high pile up /high luminosity environment
- R&D funded to IRFU-Saclay and LAL-Orsay by "P2IO" (frontier research) grant, not by experiment
- Goals for the prototype:
  - Evaluation of AMS 0.18 μm technology
  - Evaluate new design options (DLL...)
  - Evaluate simultaneous Read and Write
  - Multichannel chip usuable in real environment (with detector and real DAQ)

- Tests:
  - Electronics tests performed (see this talk)
  - Tests with real detectors (test stand and beam tests) started between April and October in collaboration with CMS/TOTEM
  - If successfull, SAMPIC installed in CMS/TOTEM and ATLAS to take real data at the LHC (readout of Si and/or diamond timing detectors)

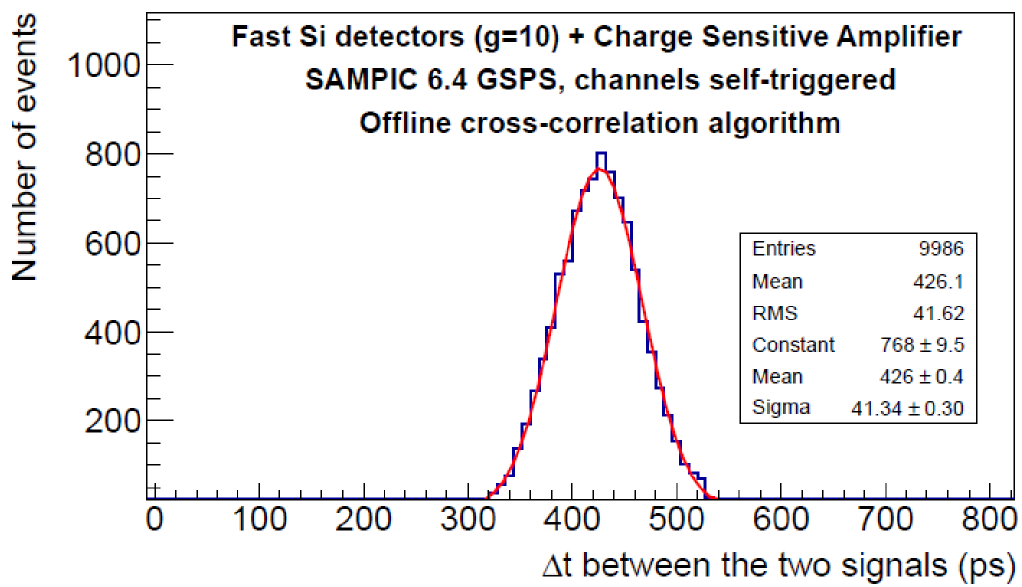
Sampic: sigma~4ps/channel

TIMING RESOLUTION
(PEDESTAL CORRECTED ONLY)



Sampic + Si det: sigma ~ 30ps/channel

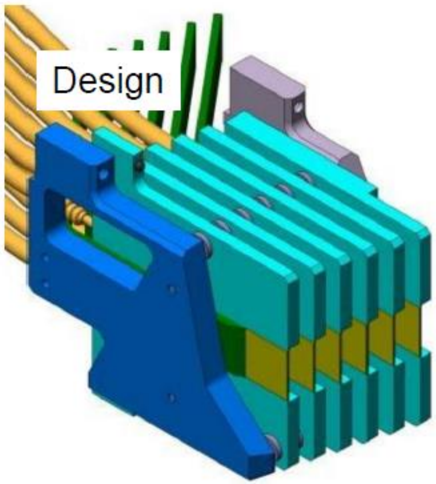
- Time resolution using sampic and Si detectors: measure the time difference between two channels
- Time reolution: (dominated by detector): $\sim$ 35 ps

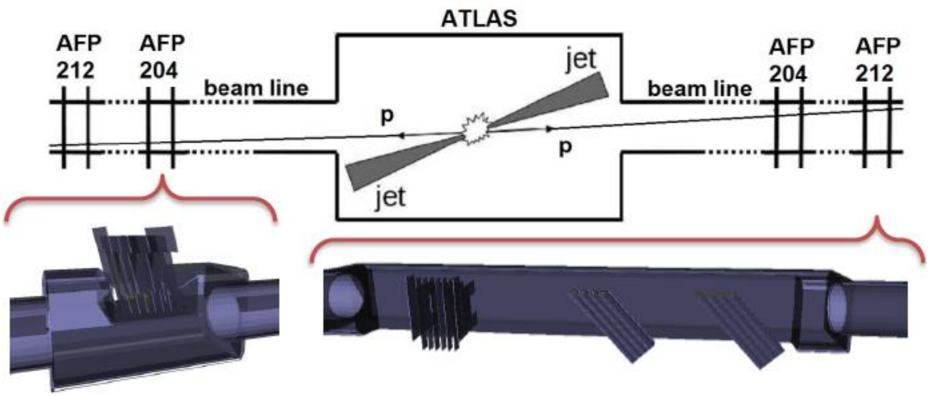


AFP in ATLAS simulation (2): SiD hits

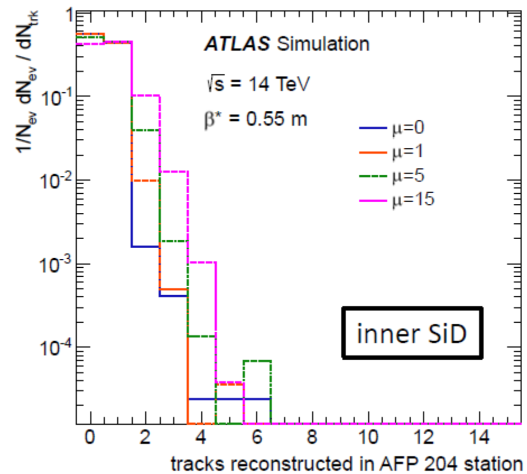
- Actual SiD setup:
  - 2 AFP stations with Si detectors per ATLAS side (**SiD 0 - 1 <– IP –> SiD 2 - 3**)
  - 6 Si layers/station separated by 10 mm (13 deg tilt in the x-z plane)
  - No staggering of the layers (yet)
  - 336 x 80 array of **50 x 250** μm^2 pixels per layer
  - **Kalman filter** is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

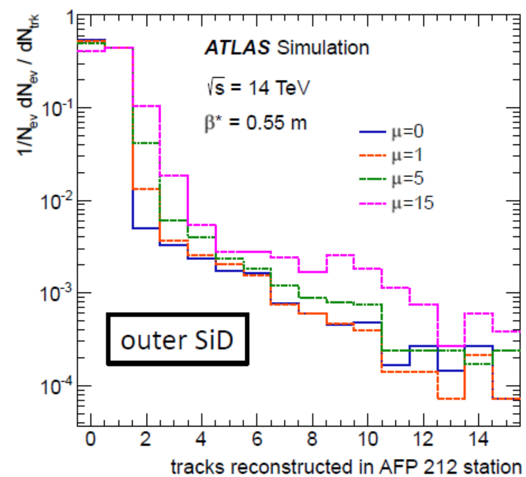
- Expected tracking resolution wrt 4 staggered layers: 8 μm in x, 20 μm in y





Geant4 AFP GeoModels

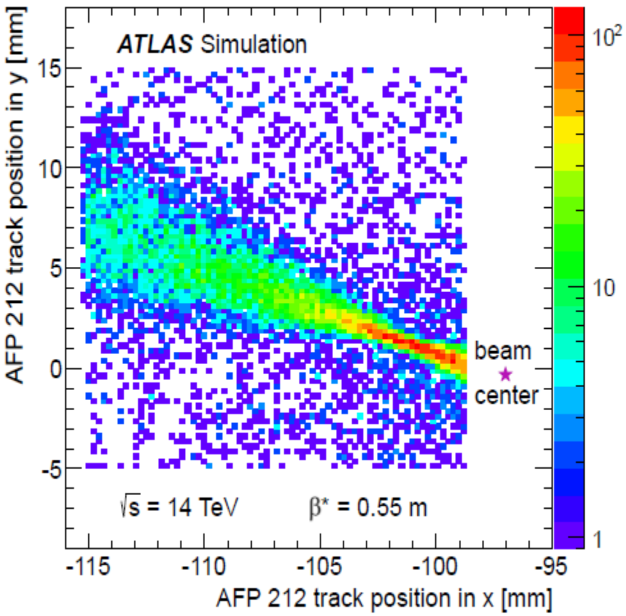


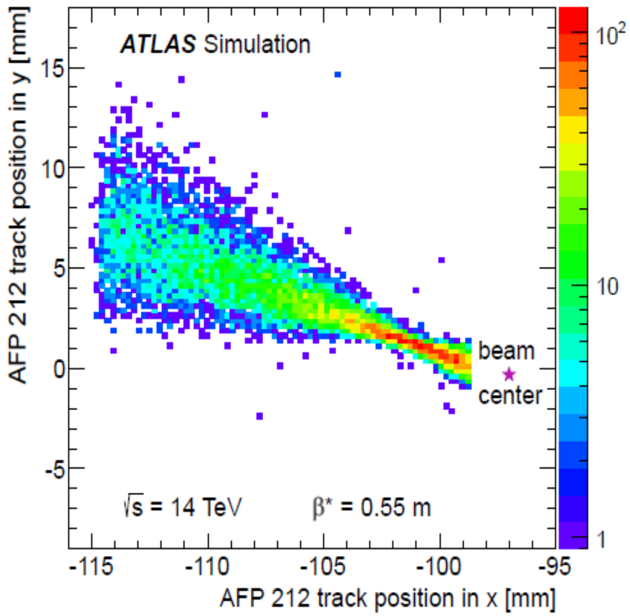


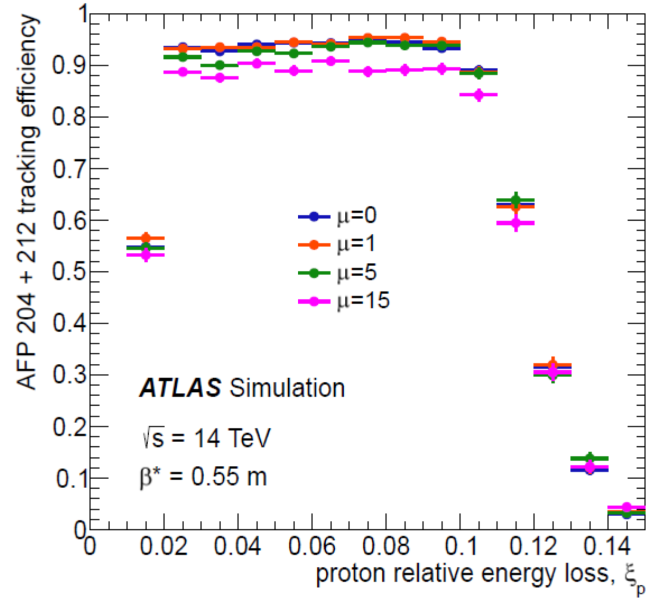
- **Reconstructed track multiplicity** with $|x_{slope}| < 0.003$ and $|y_{slope}| < 0.003$ cut (per station) to separate proton tracks from showers
- Events are generated without any cut on the proton kinematics (i.e. $\xi < 1$)
- Approximately **50%** of protons in the sample **do not enter** the AFP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

AFP in ATLAS simulation (3): 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

AFP part of LHC Forward Physics WG

Low luminosity WG (~1 pb^{-1}, $\mu<1$)

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]

AFP part of LHC Forward Physics WG

Medium luminosity WG (~10-100 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

- 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 AFP plays an important role (Christophe is a member of AFP)

AFP is well-established and well-represented in the LHC Forward Physics community

AFP also inspires numerous theorists

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]

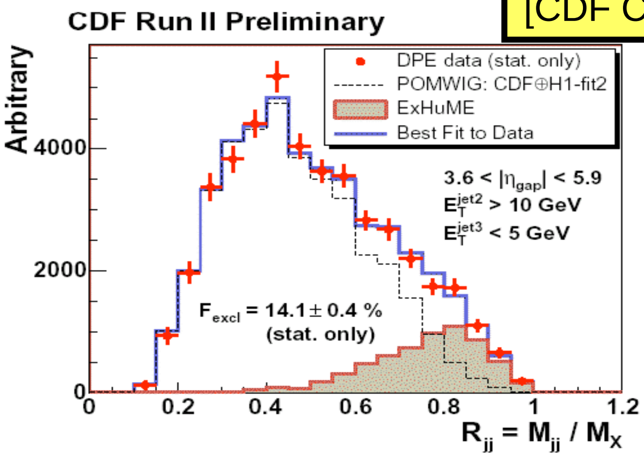
Physics with forward proton tagging at high lumi

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 $h \to WW^*$, $140 < M < 180$ GeV

[EPJC 45 (2006) 401]

MSSM $h \to bb$, $h \to \tau\tau$

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

[JHEP 0710:090,2008]

Photon-induced interactions

Excl. $\gamma\gamma \to ee, \mu\mu$ => calibration of FDs
Excl. $\gamma\gamma \to \gamma\gamma$
Excl. $\gamma\gamma \to \chi_c$, J/ψ
Excl. $\gamma\gamma \to WW/ZZ$ => anomalous triple and quartic gauge couplings => Higgsless and Extra-dimension models

$\gamma p \to jj$ Factorization breaking in hard diffraction

CDF: Observation of Exclusive Charmonium Prod. and $\gamma\gamma \to \mu\mu$ 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]

Possible running scenarios

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

Definition of Run Scenario

Totem upgrade approved by LHCC
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

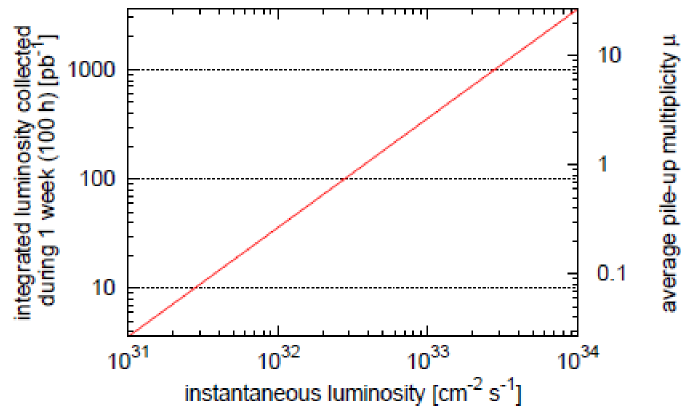
2) High beta, medium luminosity
   β^*=90m, $N_{bunch} \sim 1000$, $\mu \sim 0.5$, $\mathscr{L} \sim 10^{31}$ Hz/cm^2
   RP approach 10-15 σ

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

AFP concentrated on (all presented analyses based on):

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

Running conditions for scenario 4



$\mu = 0.1$: ~10 pb^{-1} in one week
$\mu = 1$: ~ 100 pb^{-1} in one week

Example from Physics program: Pomeron structure

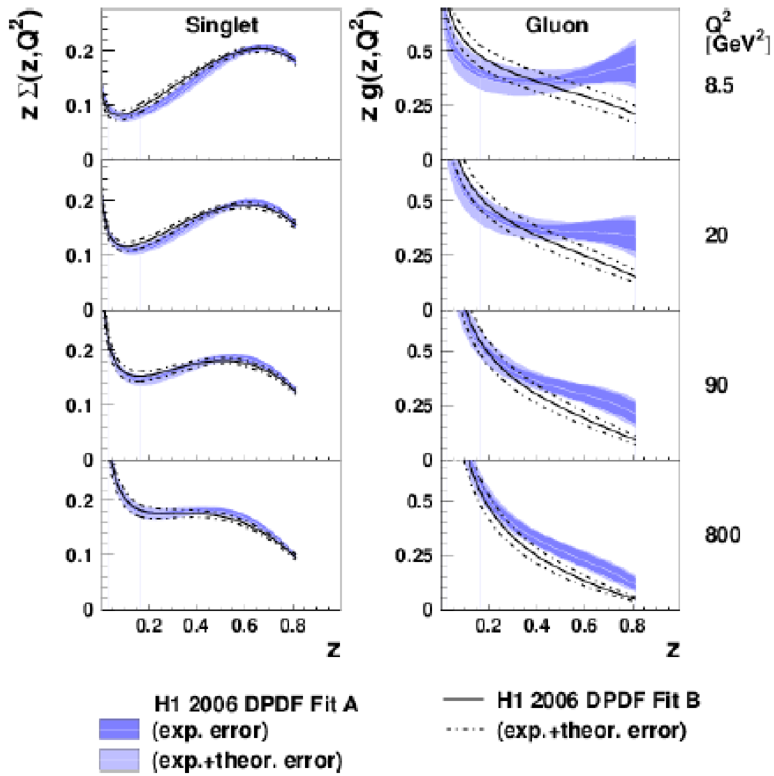
Pomeron structure (dPDFs) measured at HERA

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

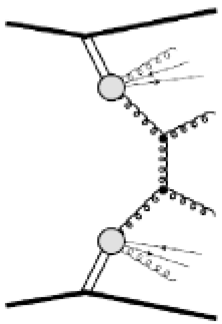
- Two degrees of freedom: R_{ud} = u/d, R_{sd} = s/d
  - u = q* 6 *R_{ud}/(1+R_{sd} + 4R_{ud})
  - s = q* 6 * R_{sd}/(1+R_{sd} + 4R_{ud})
  - d = q* 6 / (1+R_{sd} + 4R_{ud})
- Result: different Pomeron flavour structures consistent with HERA



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*

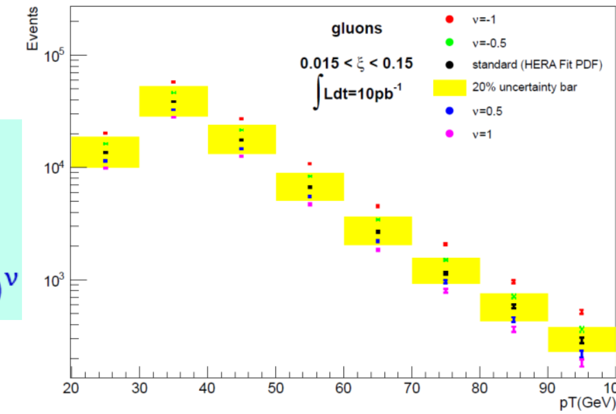
Pomeron structure: DPE dijet

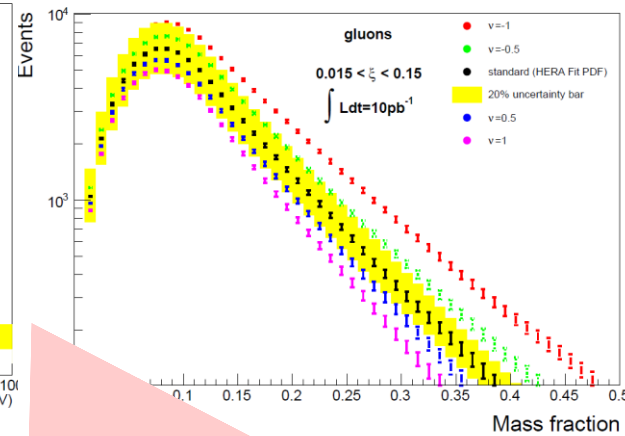


Cross-section after cuts ~ 10nb
- Dominantly g+g

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





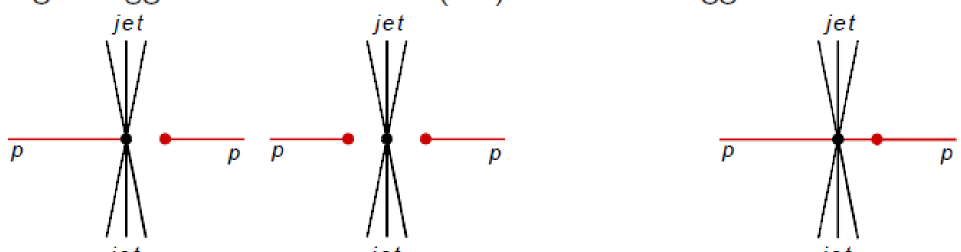
Already 10pb-1 (=10h with mu~1) provides a beautiful separation between various gluon dPDF (statistical uncertainties only)

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

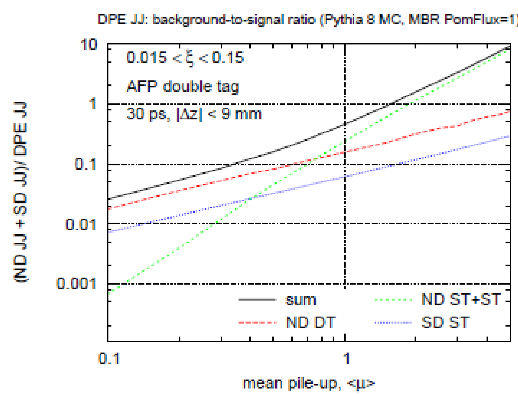


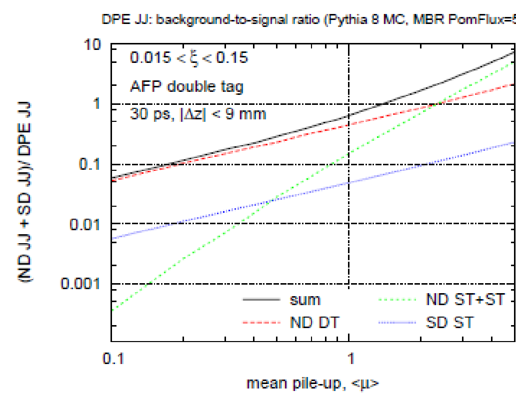
SD JJ + ST ND JJ + ST + ST ND JJ + DT

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

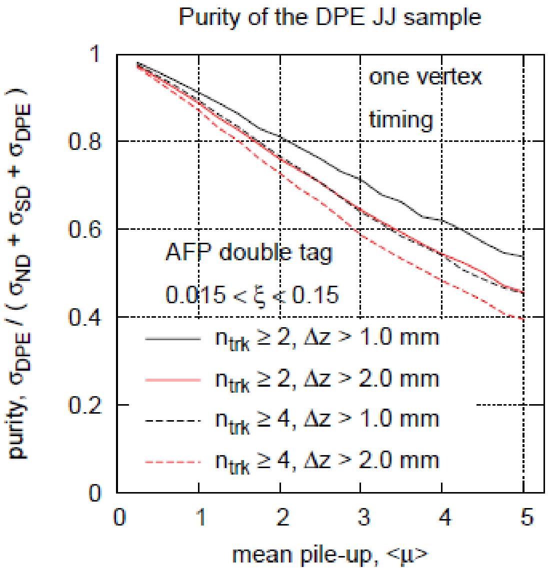
Double Tag (ST) Interactions				
probability $[10^{-3}]$				
default	0.47	0.37	–	0.014
MBR	0.31	0.36	26.0	0.012
cross section [μb]				
default	6.1	3.3	–	0.81
MBR	3.5	3.4	21	0.67
	SD	DD	CD	ND

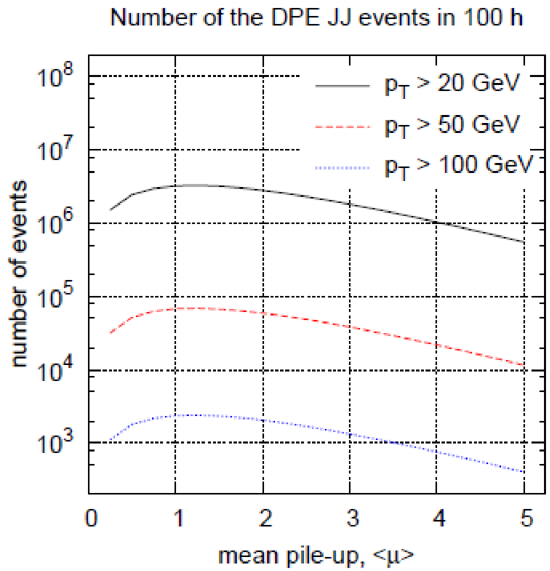
B/S ratio for Py8 default and Py8 MBR

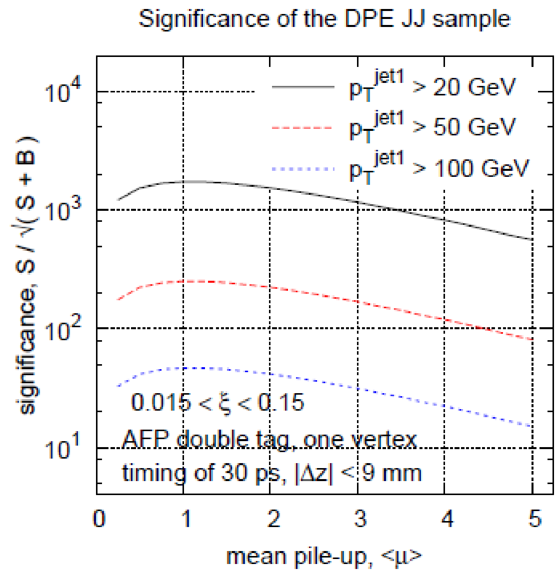




Pomeron structure: DPE dijets







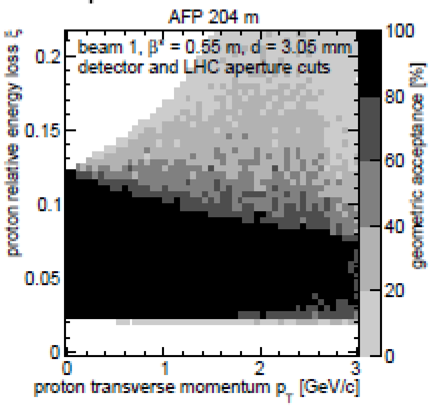
With moderate timing resolution 30ps and one-vertex requirement:
1) Excellent purity up to μ~3
2) Event yield and significance optimal at μ~1 but still manageable up to μ~5

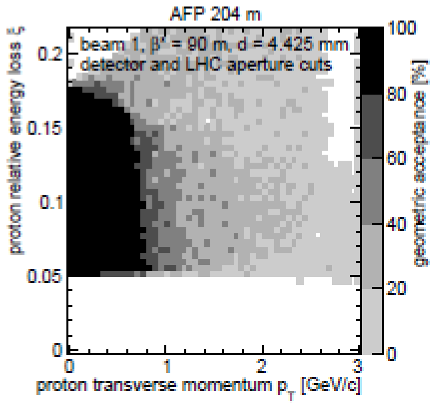
M. Trzebinski, PhD thesis, private simulation

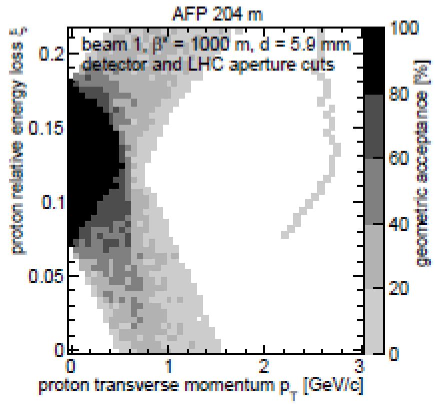
Running scenarios:
- Effective x-section ~ 10 nb -> medium lumi needed
- μ~1 optimal but μ up to 5 &&
  Etjet up to 100 GeV manageable
- Run of 100h with μ<5
- May be measured with both β*=0.55m and 90m (0.55m preferred due to larger statistics and larger AFP acceptance)
- Double-tag AFP210 + Jet trigger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

AFP in different running scenarios

- 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 $\beta^*=0.55$m and $\mu<3$, however, AFP closely watches the scenario proposals by Totem and is prepared for common discussions with Totem and ALFA.

3) AFP successfully passed two important reviews (Physics and Technical) and is working towards the approval by the ATLAS collaboration in 2014.

4) **AFP is preparing for test beams in November with a full system (RP+tracking+timing)**

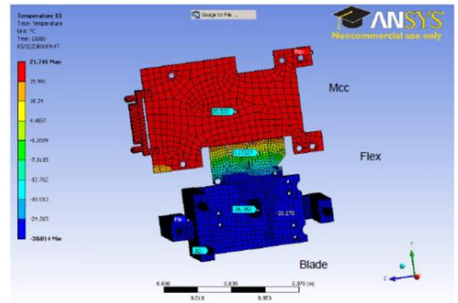
5) If approved by ATLAS, if funding secured and November test beam successful, AFP will submit TDR for the LHCC approval this year.

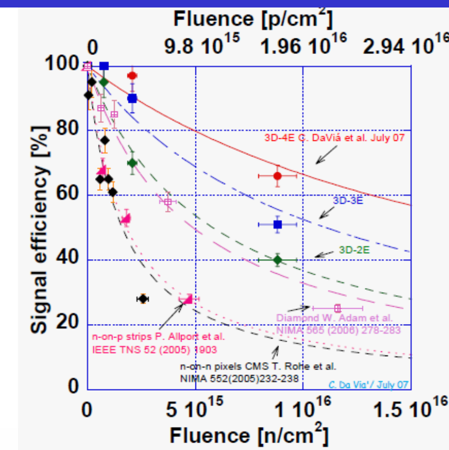
BACKUP SLIDES

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

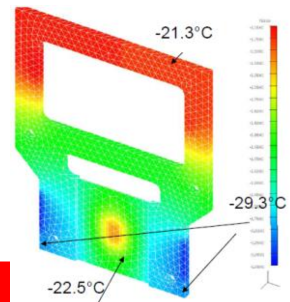


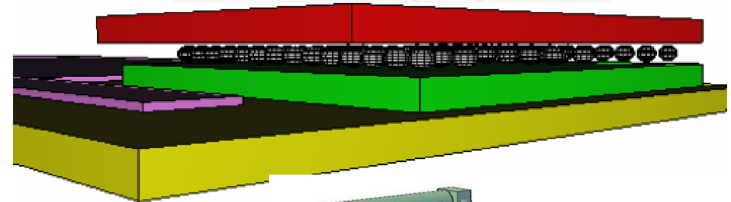



The FP420 R&D Project at the LHC

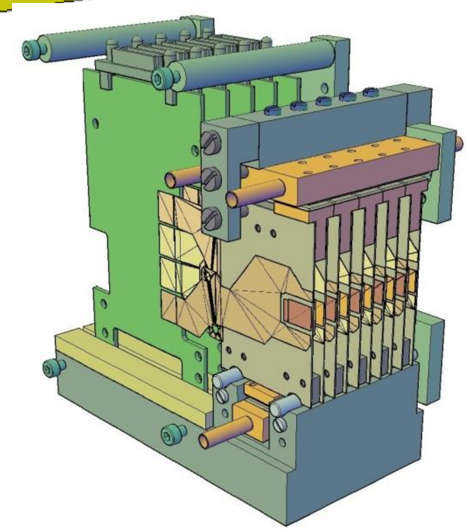
FP420 R&D Collaboration

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:

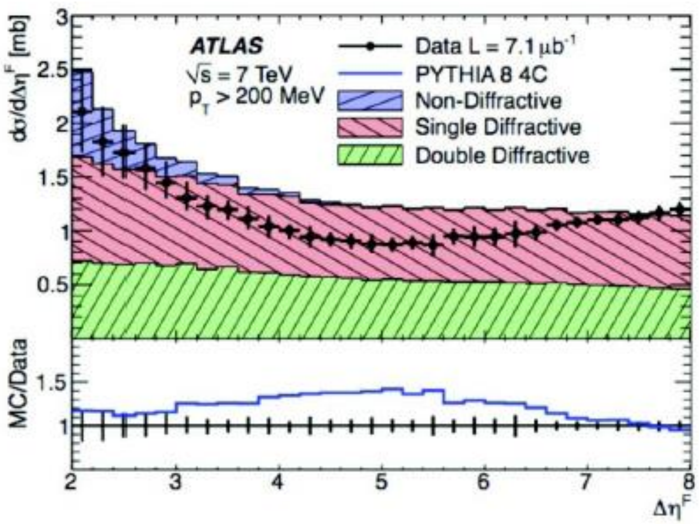
R&D of the Detector Systems for Stage One of the High Precision Spectrometer Project

(June 2010)

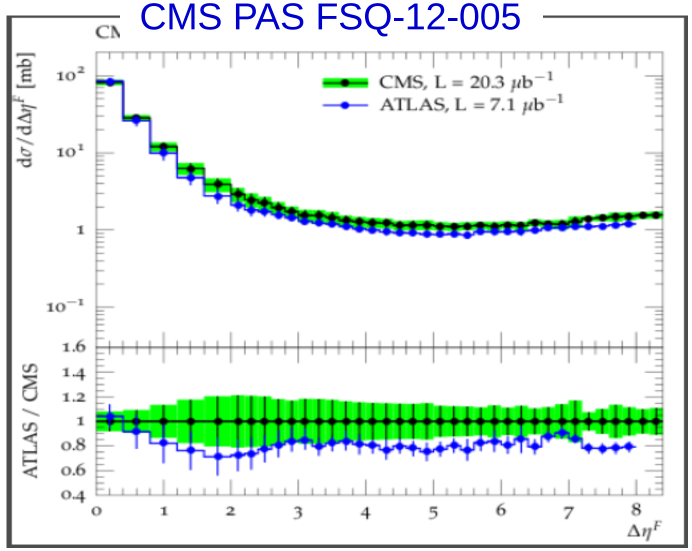
Gap spectra

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) ?

β^*=0.55m, $\sqrt{s}$ = 14TeV, d=3mm

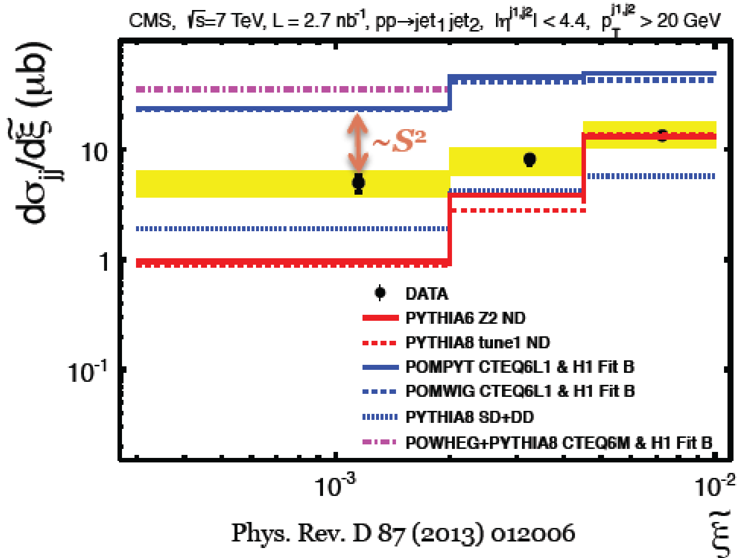
- AFP210 provides limited range of gaps: 0 < $\Delta\eta \sim -\ln\xi$ < 2.5
- Gap on the side of the detected proton in AFP
- DD shows very different gap spectrum

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

SD dijets

ATLAS and CMS measurements without proton tags:

ATLAS (ongoing)



Phys. Rev. D 87 (2013) 012006

Taking proton dissociation
Into account:

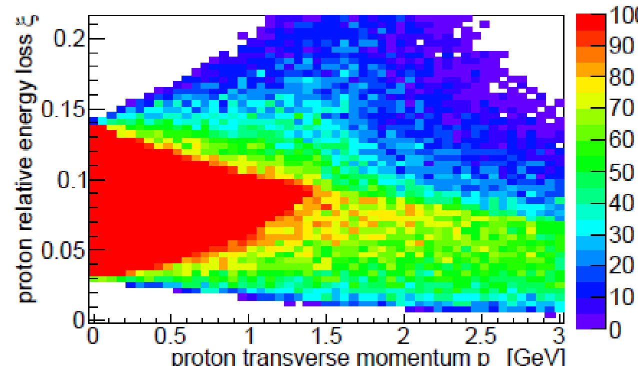
$S^2_{data/MC} = 0.12 \pm 0.05$ (LO MC)
$S^2_{data/MC} = 0.08 \pm 0.04$ (NLO MC)

Challenging measurement since

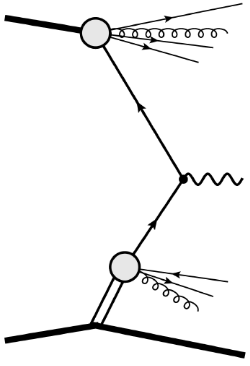
1) eta coverage is limited (|eta|<5)
2) Based on gaps or xi (sensitive to det. noise)
3) Fake gaps from hadronization
4) Low statistics due to requiring jets and low PU
5) No MC tuned for this process

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

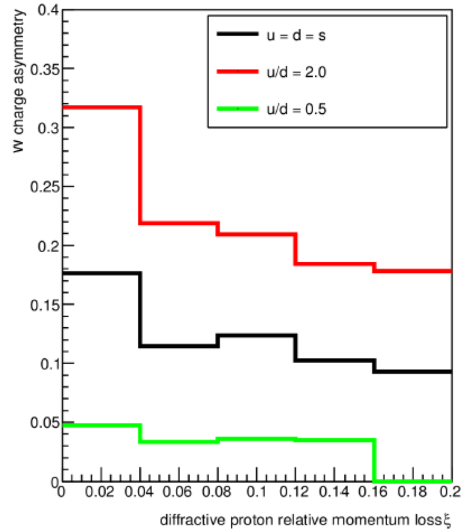
β*=0.55m, √s = 14TeV, d=3mm

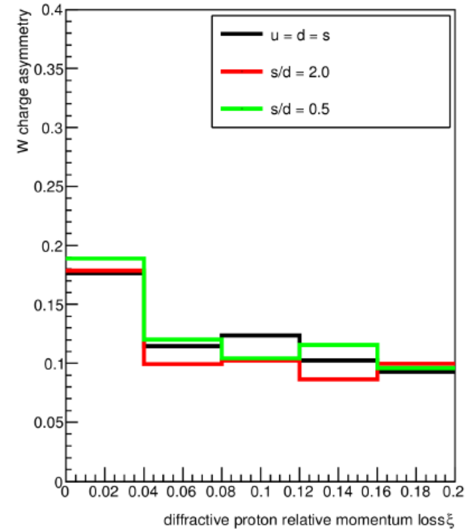


Pomeron structure (1): SD W



- Dominantly quark from Proton, antiquark from Pomeron
- x-section(AFP210)~2 x-section(AFP420)
- Measure charge asymmetry **A = $(N_+ - N_-)/(N_+ + N_-)$**
- sensitive to u/d, not to s/d



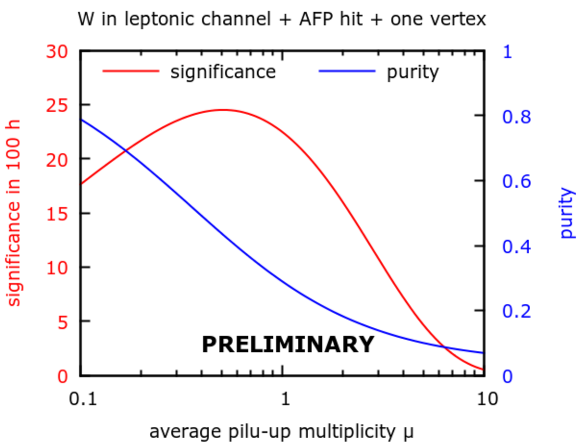


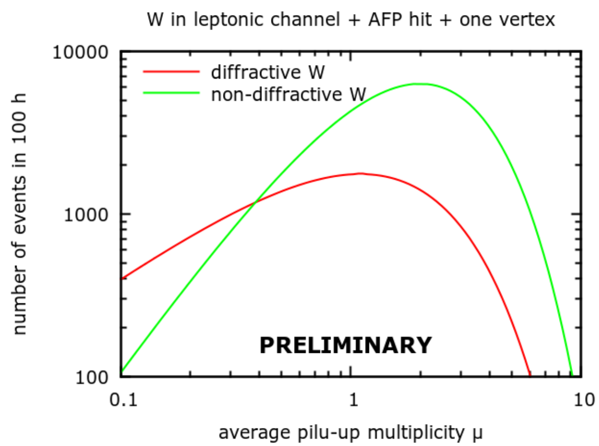
FPMC generator:
enu+munu W-decays (Pt inclusive) + one vertex

+ AFP acceptance

β*=0.55m, √s = 14TeV, d=3mm

- Without Calo information: low PU necessary: mu~0.2 -> 700 W per 1 week, purity ~60% and significance ~ 20





With Calo information: higher PU possible

CMS measurement: EPJ C72 (2012) 1839:

Fraction of W/Z events with a forward gap:

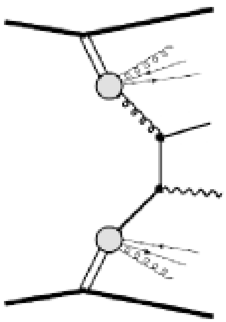
W→lν: 1.46 ± 0.09(stat.) ± 0.38(syst.) %

Z →ll: 1.60 ± 0.25(stat.) ± 0.42(syst.) %

- Observed Asymmetry between signed lepton and gap side

Running scenarios:
- Effective x-section ~ 40pb -> medium lumi needed
- Low mu preferable but μ~1 manageable
- May be measured with both β =0.55m and 90m (0.55m preferred due to larger statistics and larger AFP acceptance)
- Single-tag AFP210 + Lepton trigger (+MET) gives sufficiently low rate

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

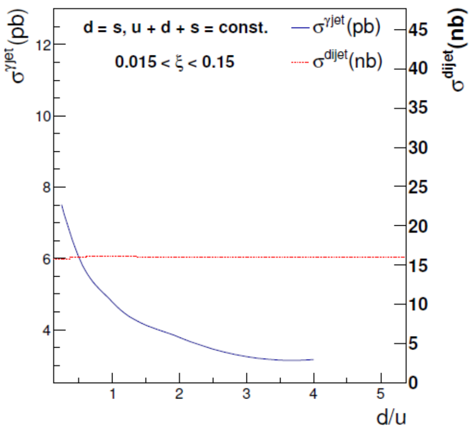


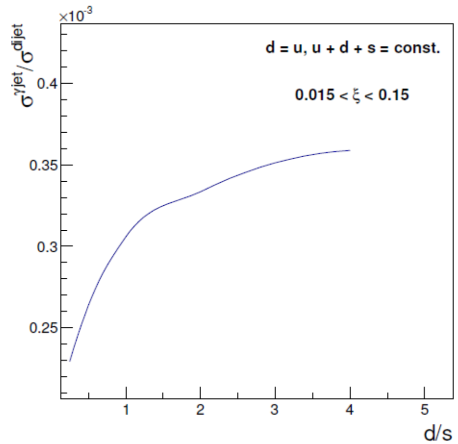
Gamma+j Cross-section after cuts ~ 1pb

- 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, √s = 14TeV, d=3mm

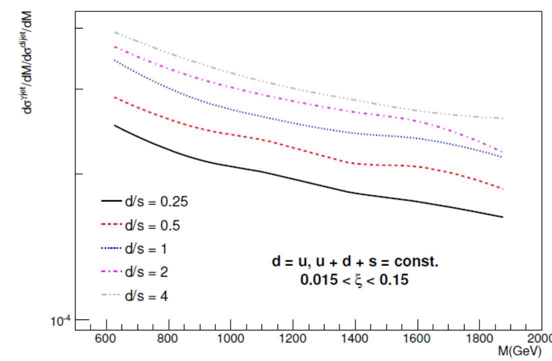
C. Marquet et al., PRD 88 (2013) 074029



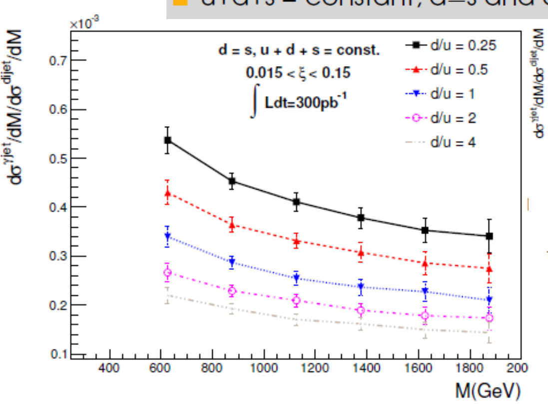


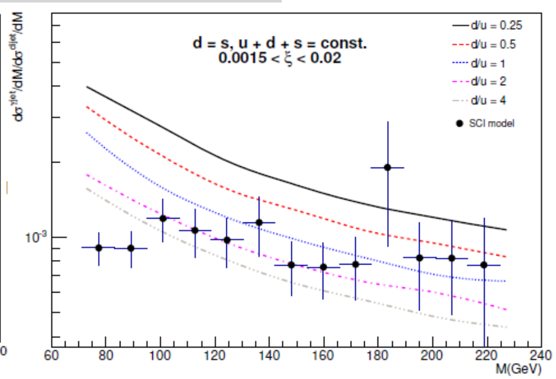
Truth level: AFP acceptance
+ jets: Et > 20 GeV
+ photons: Et > 20 GeV, |eta| < 2.5
- Assuming Lumi=300pb-1 at mu=1

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



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



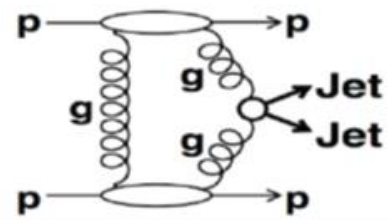


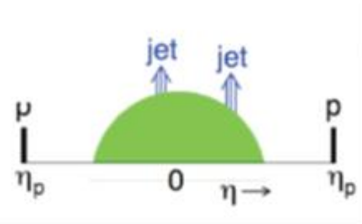
Running scenarios:

- 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

- 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

CEP dijets with one proton-tag (1)

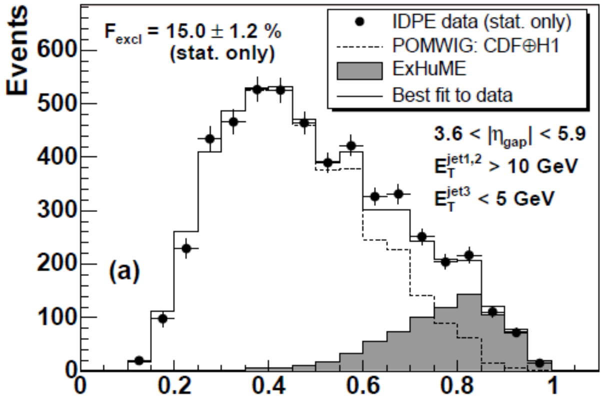




Very fruitfull process: combined effect of all basic ingredients to CEP:

- 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

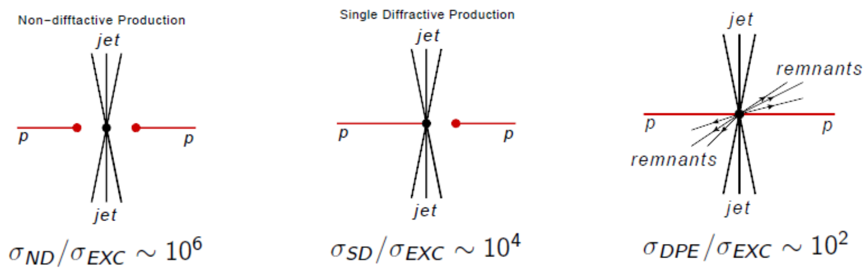
Effect of PU studied in great detail!

- 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)

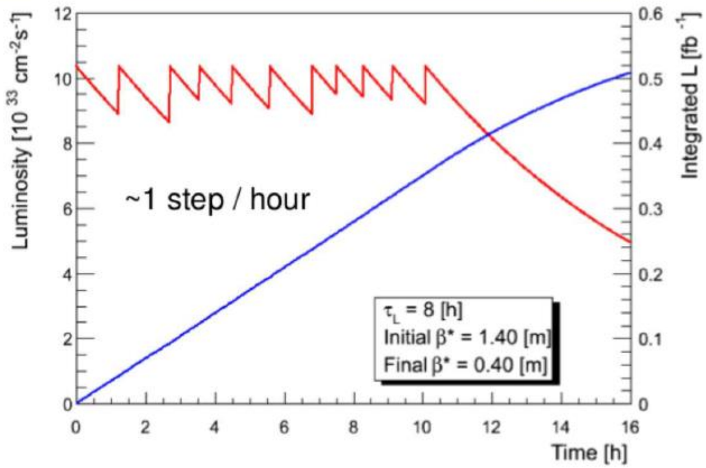
c) Forward energy flow



Single Tag (ST) Interactions					
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

Luminosity leveling

Leveling Scheme*



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

Step: 0.1 m every 1 hour.

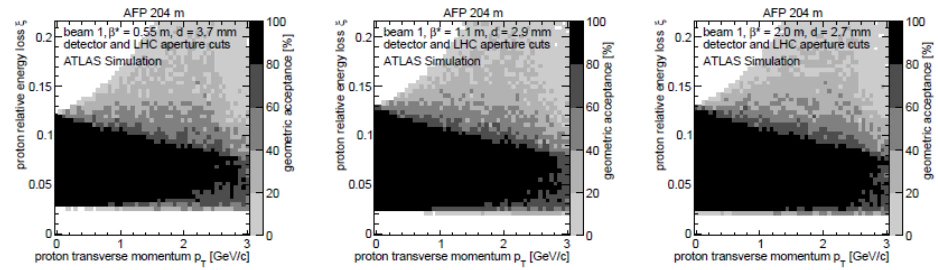
- Sould AFP detectors move from the beam during the change of β^*?
- If yes – how far?

* – 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.**