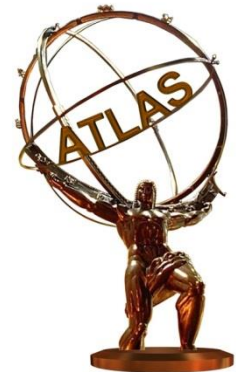
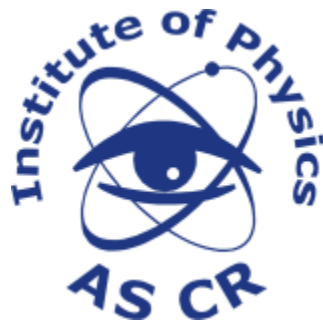


Status of the AFP Project in ATLAS



Marek Taševský

Institute of Physics, Academy of Sciences, Prague

(on behalf of the AFP Collaboration)

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

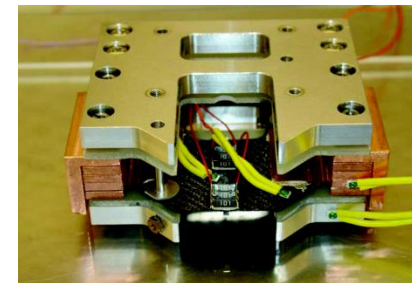
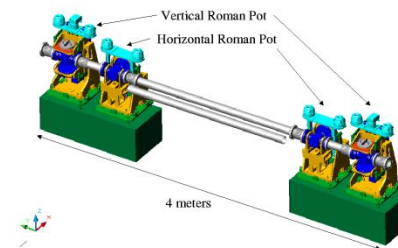
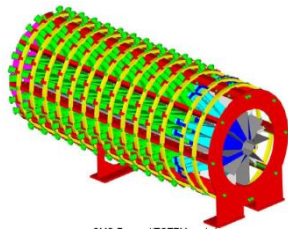
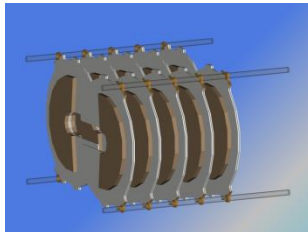
1. Status
2. Concept
3. Physics program

Forward detectors around ATLAS and CMS

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



IP5



14 m

16 m

140 m

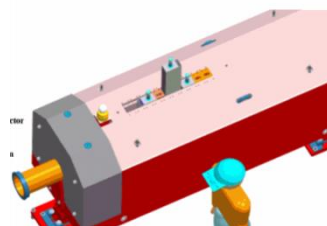
147m - 220 m

420 m

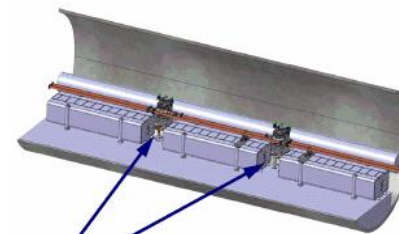
IP1



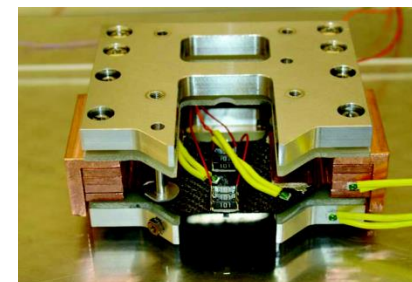
LUCID



ZDC



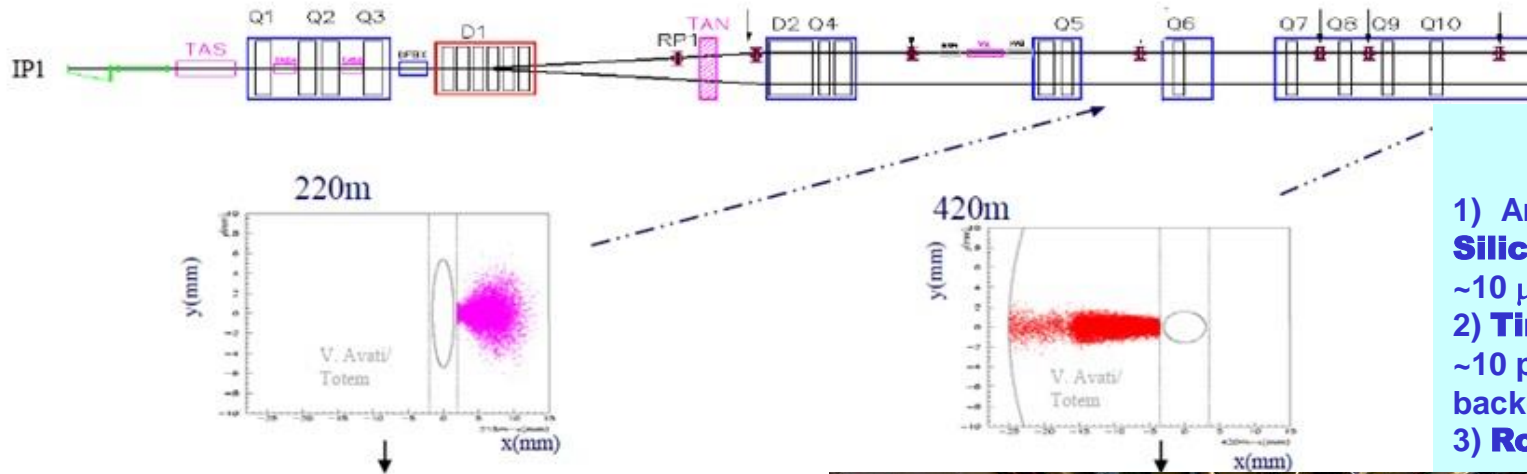
ALFA(now) AFP220



AFP420?

AFP = ATLAS Forward Proton

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

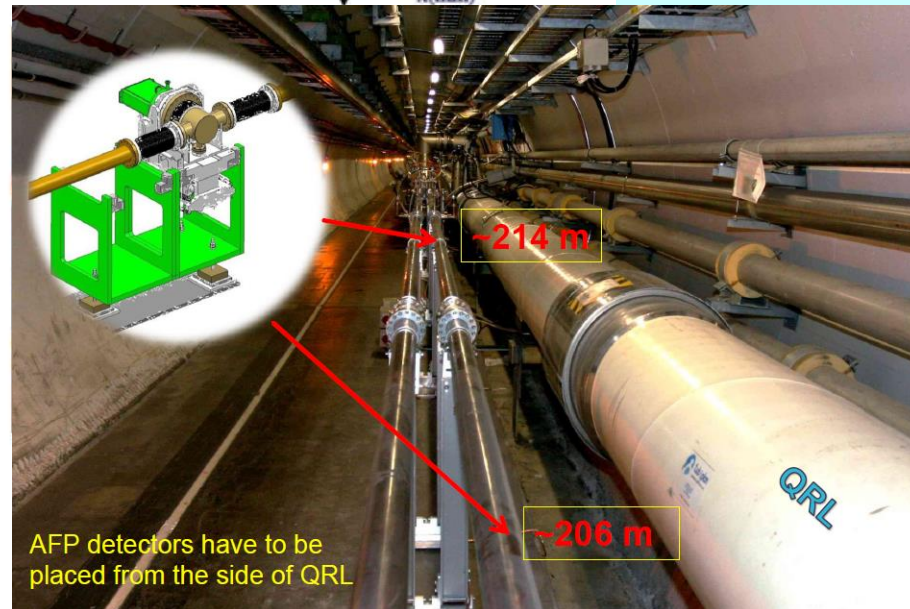
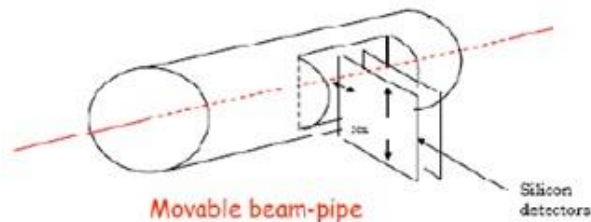


What is AFP?

- 1) Array of radiation-hard near-beam **Silicon detectors** with resolution $\sim 10 \mu\text{m}$, $1 \mu\text{rad}$
- 2) **Timing detectors** with up to $\sim 10 \text{ ps}$ 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:
 $10\sigma = 1\text{mm}$



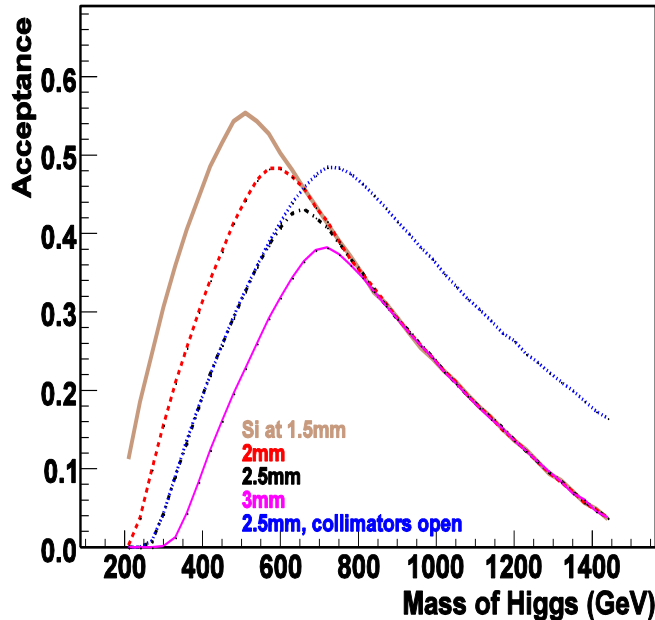
AFP: 2 stations on each side of IP with tracking and timing detectors at ~ 220m 200-220m, ATLAS side

What does AFP Provide?

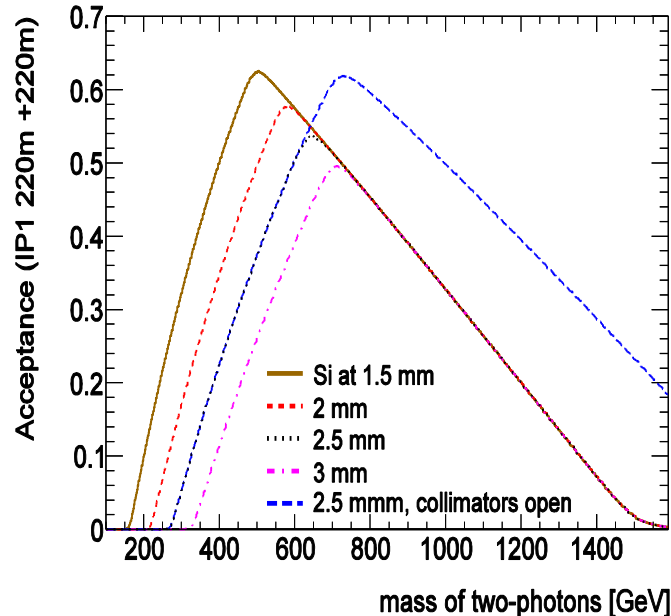
220+220 at IP1

IP1. 220m + 220m.

Diffraction



Two-photon



Acceptance >40% for wide range of resonance mass

- Mass and rapidity of centrally produced system

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

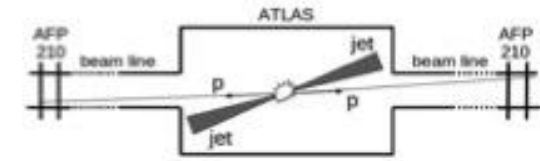
$$y = \frac{1}{2} \ln(\xi_1 / \xi_2)$$

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

Allows ATLAS/CMS to use LHC as a tunable \sqrt{s} gluon-gluon or $\gamma\gamma$ collider while simultaneously pursuing standard physics program

Primary goals of AFP

(for low-mu and high-mu program)



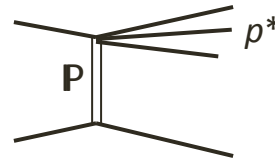
28 Aug 13

[5]

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

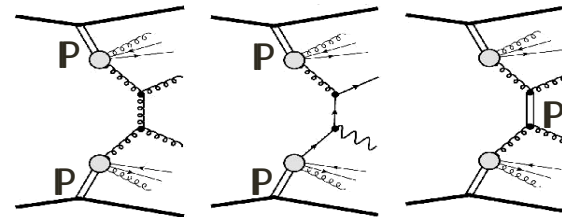
- Jets, W, Z: Soft survival prob. S^2
- Particle spectra, Gap spectra: SD vs. DD



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

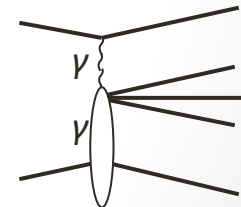
Double-tag: Double-Pomeron Exchange

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



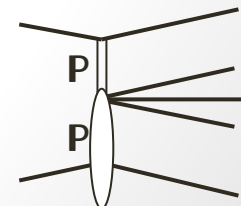
Double-Photon Exchange

- $\gamma\gamma \rightarrow WW/ZZ/\gamma\gamma$: Anomalous quartic couplings \rightarrow sens. $\sim \times 100$ wrt only central det.
- $\gamma\gamma \rightarrow \mu\mu$: 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

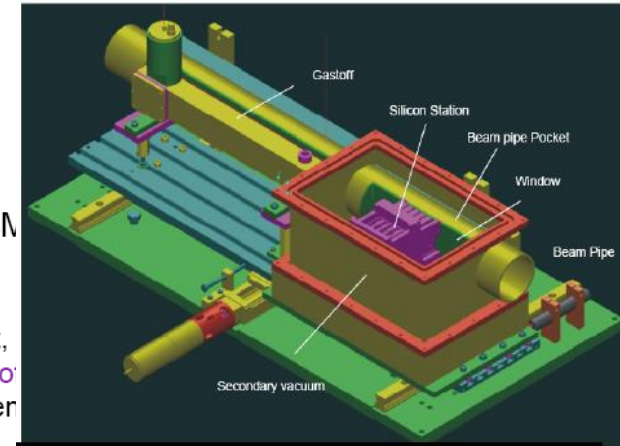
2003

Manchester
Forward
Physics
Meetings

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-Cosme, 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



2005

FP420
Joint ATLAS
& CMS
Collaboration



The FP420 R&D Project at the LHC

FP420 R&D Collaboration
1. FNAL, 2. The University of Manchester, 3. University of Eastern Piedmont, Novara and INFN-Turin, 4. The Cockcroft Institute, 5. University of Antwerpen, 6. University of Texas at Arlington, 7. The University of Glasgow, 8. University of Calabria and INFN-Cosme, 9. INFN-Turin, 10. Lawrence Livermore National Laboratory, 11. CERN, 12. University of Turin and INFN-Turin, 13. University of Lund, 14. Rutherford Appleton Laboratory, 15. Molecular Biology Consortium, 16. Institute for Particle Physics Phenomenology, Durham University, 17. DESY, 18. Helsinki Institute of Physics and University of Helsinki, 19. UC Louvain, 20. University of Hawaii, 21. LAL Orsay, 22. University of Alberta, 23. Stony Brook University, 24. Boston University, 25. University of Nebraska, 26. Institute of Physics, Academy of Sciences of the Czech Republic, 27. Brookhaven National Laboratory, 28. University College London, 29. Cambridge University

2008

FP420
R&D Report

2008

Add FP220

2009

Under review

2010-2014

Aim for
Upgrade project

+
FP220/240

ATLAS AFP R&D

CMS PPS R&D

Upgrade Project

Upgrade Project

FP420 R&D Report
JINST 4 (2009) T10001

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

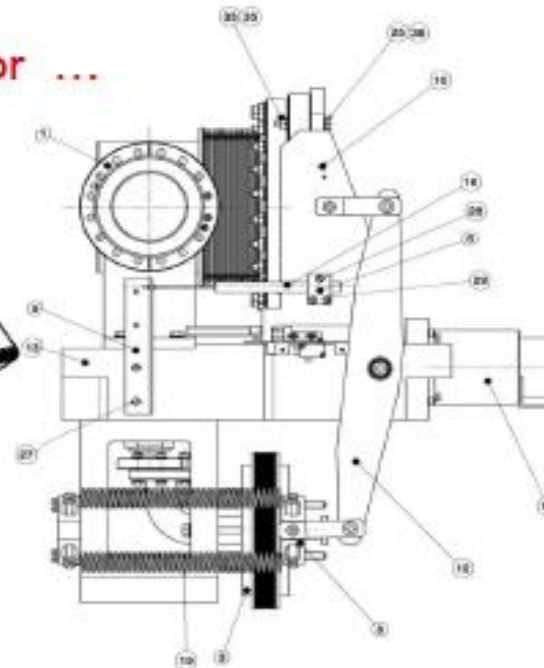
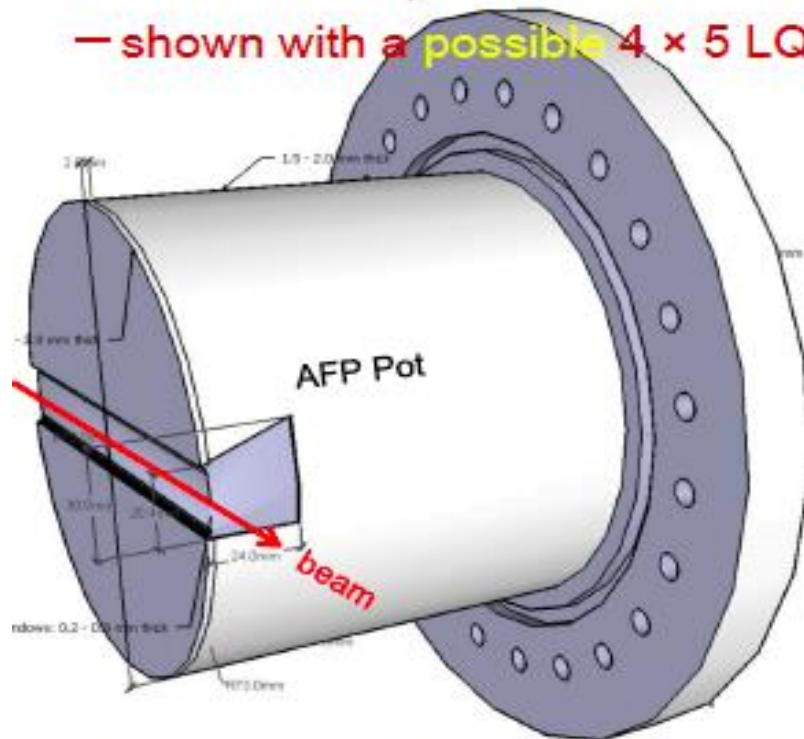
AFP activities:

- 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 ...



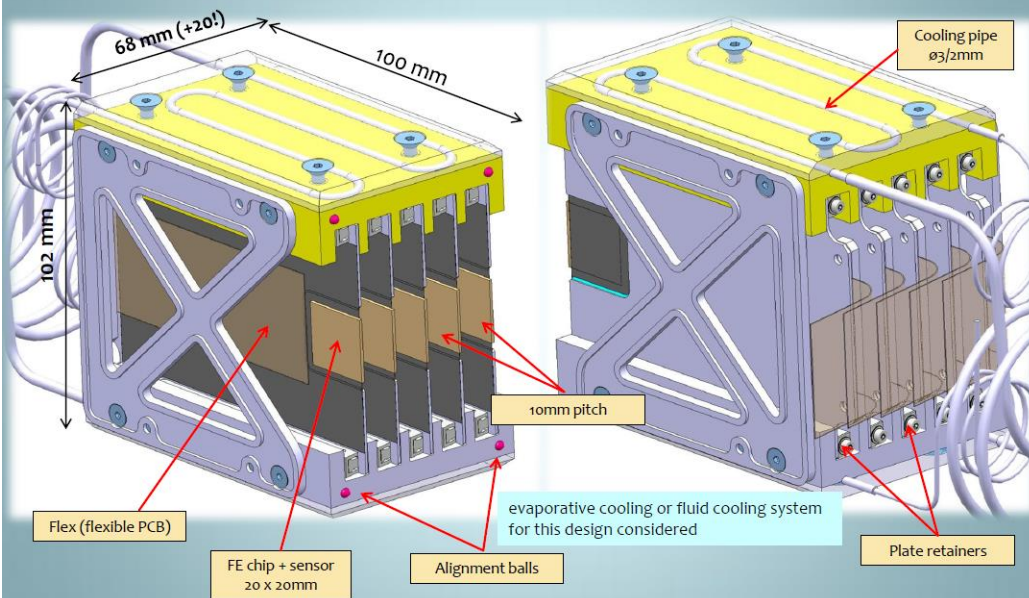
TOTEM horizontal
RP station
(beam view)

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)

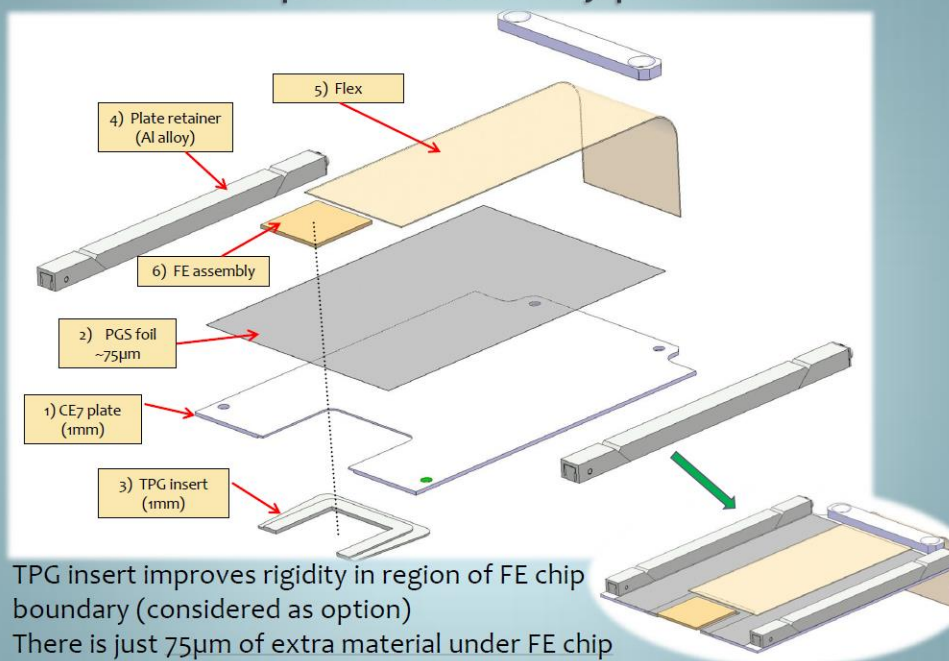


March/26/2014

P.Sicho AFP Technical Review CERN

5

Tracker plate – assembly procedure

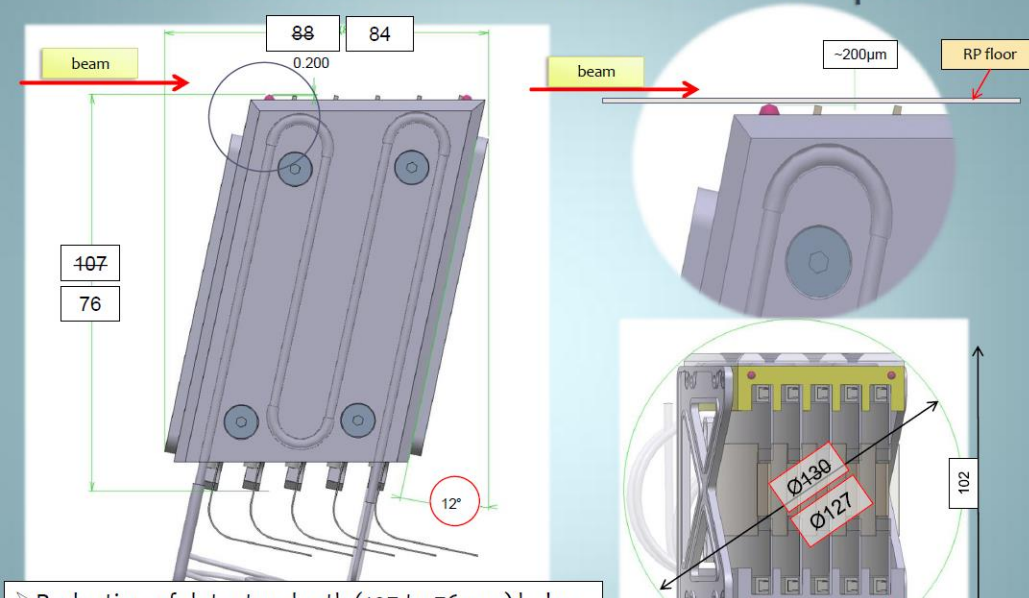


March/26/2014

P.Sicho AFP Technical Review CERN

9

How does the tracker fit inside roman pot?



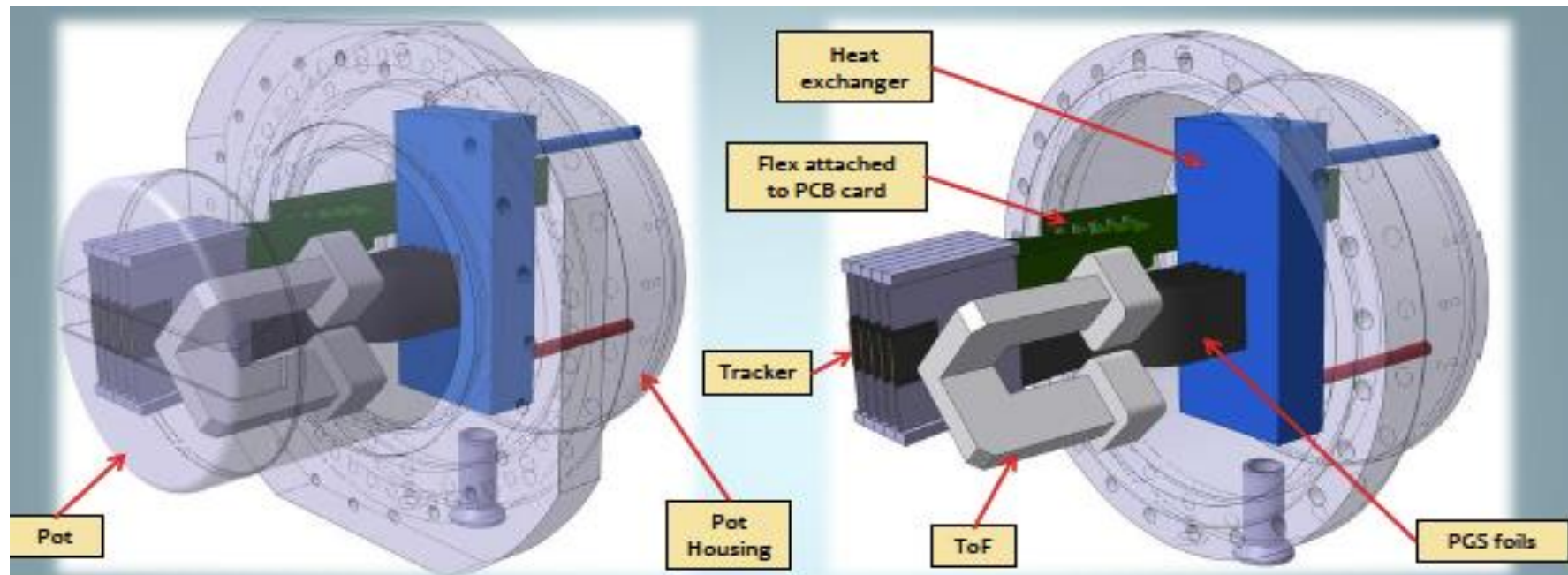
RCE readout system

- 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 first used in ATLAS by CSC Muon group

Current conceptual design of arrangement in RP



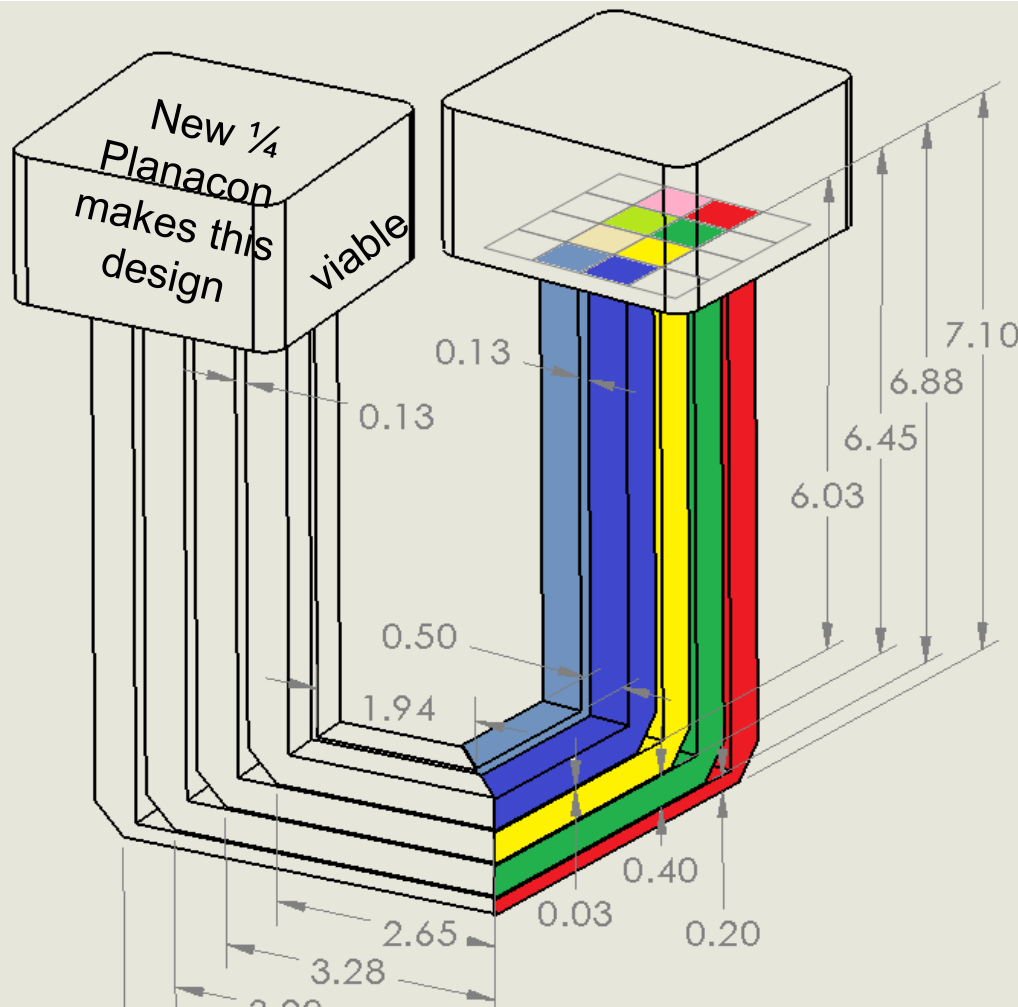
- If we choose air-cooling system to cool down the Si detectors then heat exchanger should not be part of tracker and could be placed at RP housing
- Si tracker would have very simple construction (not removable planes)
- Heat could be removed via PGS foils (PGS + polyamide) which would be attached to 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

Two-Arm ToF Detector



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

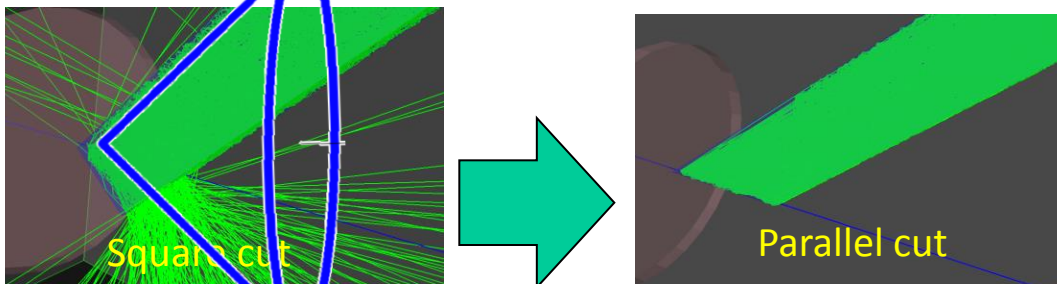
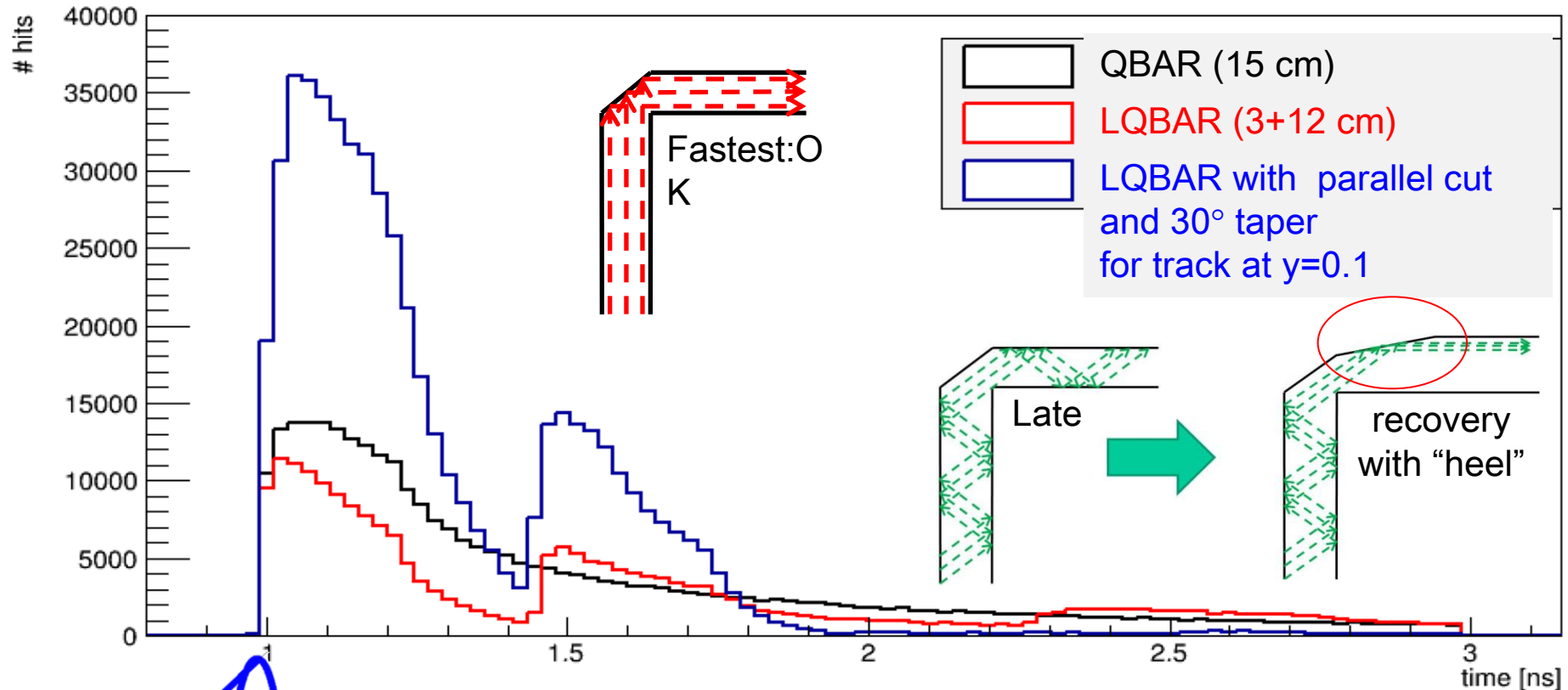
Main features:

- 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

Hits vs. Time



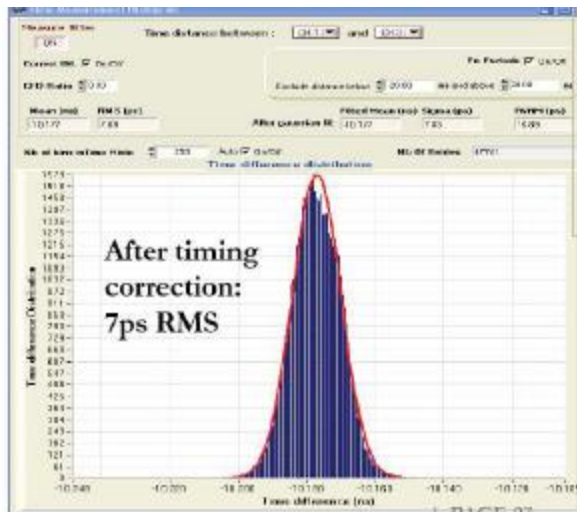
Simulation says the tuned LQbar detector is a vastly superior detector with 2-3 times more light in the same time window as the Qbar case! Will test this Summer

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 usable in real environment (with detector and real DAQ)

Sampic: sigma~4ps/channel

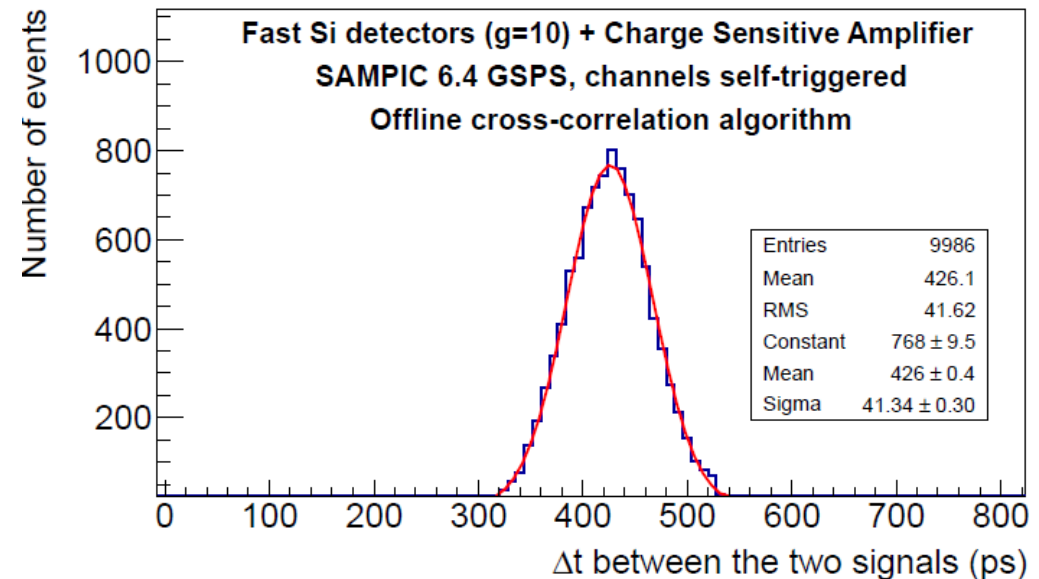
**TIMING RESOLUTION
(PEDESTAL CORRECTED ONLY)**



- 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 successful, SAMPIC installed in CMS/TOTEM and ATLAS to take real data at the LHC (readout of Si and/or diamond timing detectors)

Sampic + Si det: sigma ~ 30ps/channel

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

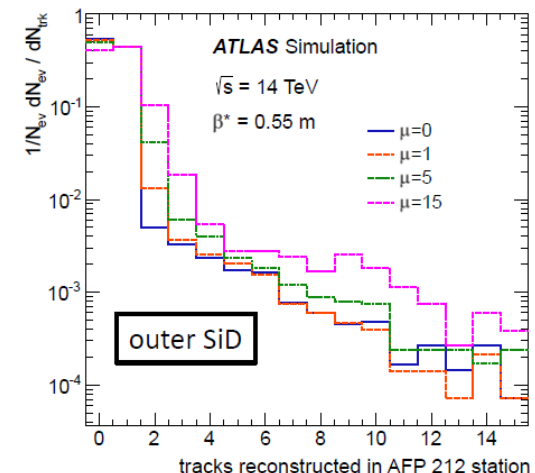
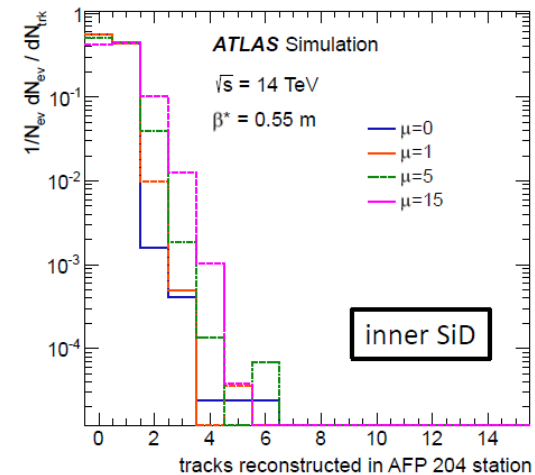
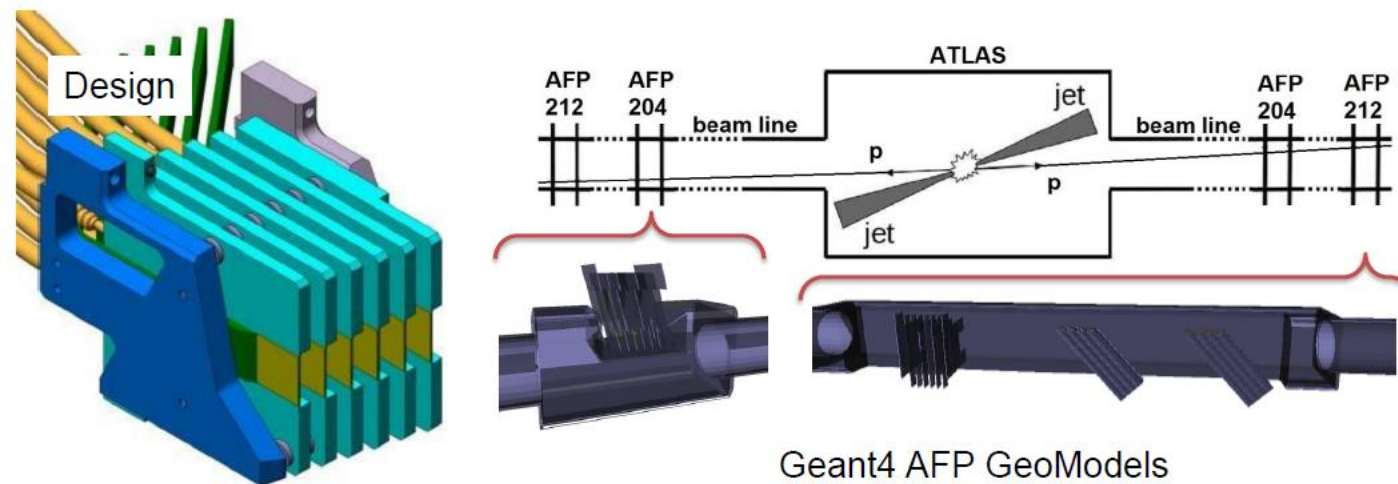


AFP in ATLAS simulation (2): SiD hits

Actual SiD setup:

- 2 AFP stations with Si detectors per ATLAS side (**SiD 0 - 1** \leftarrow IP \rightarrow **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

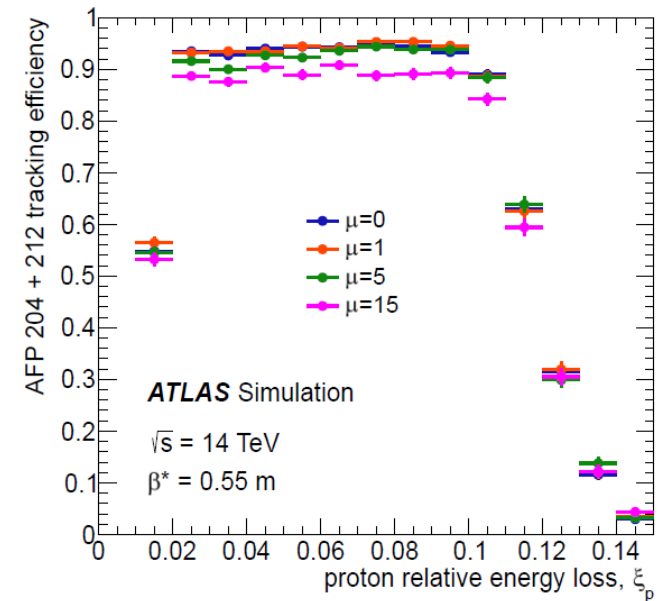
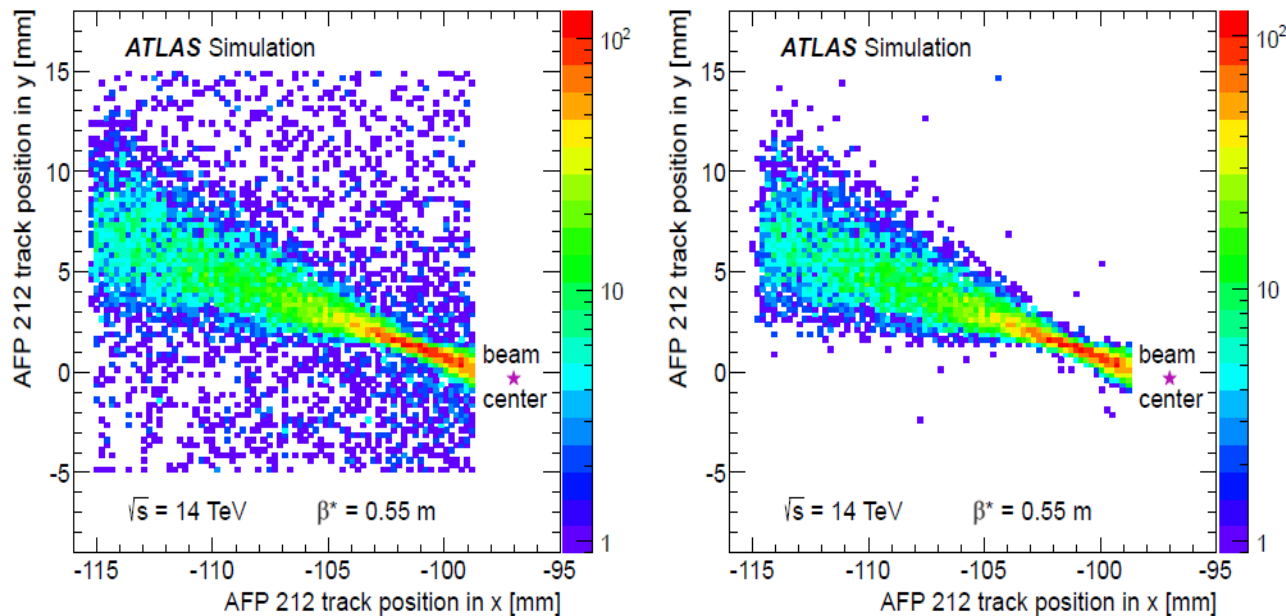
- Expected tracking resolution wrt 4 staggered layers:
8 μm in x, 20 μm in y



- Reconstructed track multiplicity** with $|x_{\text{slope}}| < 0.003$ and $|y_{\text{slope}}| < 0.003$ 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 $x = -97\text{mm}$



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

$\approx 95\%$ in $0.02 < \xi < 0.11$ and $\mu = 0/1$

- matching between tracks in inner and outer stations included
- cuts suppressing showers applied ($n_{tr_inner} \leq 2$, $n_{tr_outer} \leq 5$)
- improvement expected, subject of further cut optimization

AFP part of LHC Forward Physics WG

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

Repeat analyses already done without forward proton detectors!

Proton tagging: - guarantees the exclusivity
- enables proton azimuthal angle measurement \rightarrow info about S2 and spin of produced resonance

CEP

- Diphotons [CMS+Totem]
- χ -b, χ -c, η -c, η -b [LHCb]
- $\pi\pi$ [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, η 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 ($\sim 10\text{-}100\text{ pb}^{-1}$, $\mu \sim 1$)

Repeat analyses already done without forward proton detectors!

Proton tagging: - guarantees the exclusivity
- enables proton azimuthal angle measurement \rightarrow 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]
- χ -b, χ -c, η -b, η -c [LHCb]
- Pion [ALFA+ATLAS ,]
- Meson pair production (K^+K^- , $\rho^+\rho^-$, $\eta+\eta^-$, $\eta+\eta'$) [Totem, Szczurek, DIME MC]

Diffraction

- SD dijets [AFP+ATLAS , CMS+Totem]
- DPE dijets [AFP+ATLAS , CMS+Totem]
- DPE γ +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 , Wverder, Marquet]
- Double J/ Ψ [LHCb]
- MPI [Strikman, Jung]

Low-x Saturation

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

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

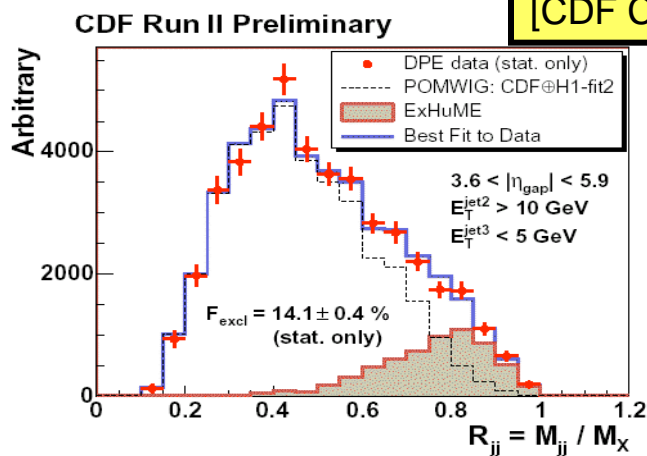
AFP also inspires numerous theorists

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 $h \rightarrow WW^*$, $140 < M < 180 \text{ GeV}$

[EPJC 45 (2006) 401]

MSSM $h \rightarrow bb$, $h \rightarrow \tau\tau$

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

[JHEP 0710:090,2008]

Photon-induced interactions

Excl. $\gamma\gamma \rightarrow ee, \mu\mu \Rightarrow$ calibration of FDs
Excl. $\gamma\gamma \rightarrow \gamma\gamma$
Excl. $\gamma\gamma \rightarrow \chi_c, J/\psi$
Excl. $\gamma\gamma \rightarrow WW/ZZ \Rightarrow$ anomalous triple
and quartic gauge couplings \Rightarrow
Higgsless and Extra-dimension models

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

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

$\beta^*=90\text{m}$, $N_{\text{bunch}} \leq 100$, reduced bunch intensity, $\mu \sim \text{few } \%$, $\mathcal{L} \sim 10^{28} - 10^{30} \text{ Hz/cm}^2$

RP approach 5-10 σ

2) High beta, medium luminosity

$\beta^*=90\text{m}$, $N_{\text{bunch}} \sim 1000$, $\mu \sim 0.5$, $\mathcal{L} \sim 10^{31} \text{ Hz/cm}^2$

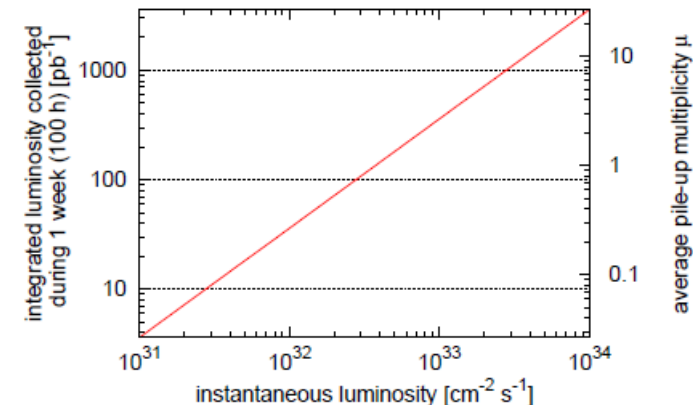
RP approach 10-15 σ

3) Low beta

$\beta^*=0.6\text{m}$, $N_{\text{bunch}} \sim 2800$, $\mu \sim 30-50$, $\mathcal{L} \sim 10^{33} - 10^{34} \text{ Hz/cm}^2$

RP approach 15 σ

Running conditions for scenario 4



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

$\mu = 1$: $\sim 100 \text{ pb}^{-1}$ in one week

AFP concentrated on (all presented analyses based on):

4) Low beta, medium luminosity

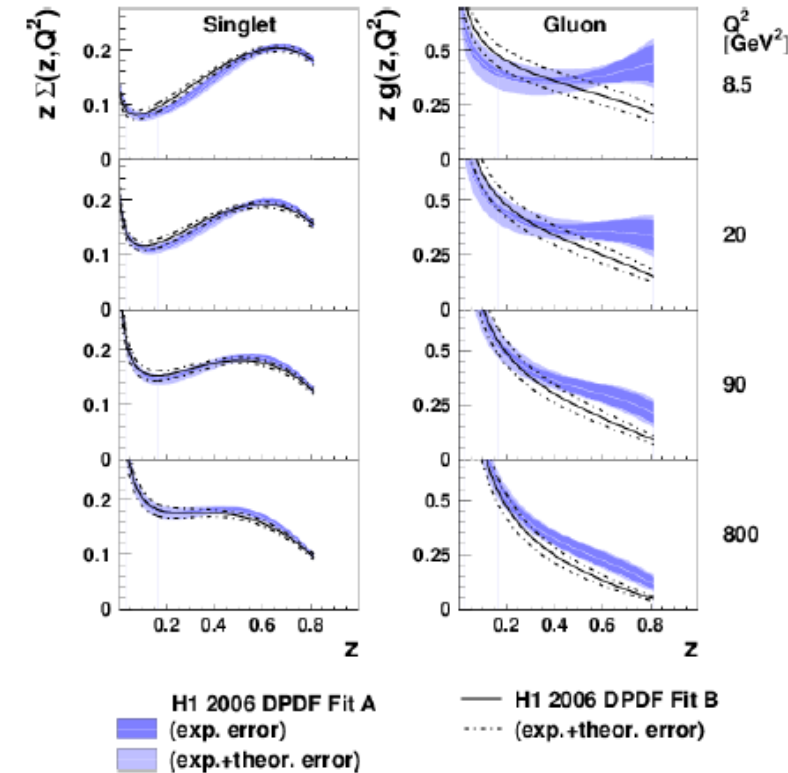
$\beta^*=0.55\text{m}$, $N_{\text{bunch}} \sim 2800$, $\mu \sim 0.1-3$, $\mathcal{L} \sim 10^{31} - 10^{33} \text{ Hz/cm}^2$,

RP approach $\sim 10\sigma$

Example from Physics program: Pomeron structure

Pomeron structure (dPDFs) measured at HERA

- 1) Not well constrained at high β ($= z = x_{Bj}/\xi$)
- 2) Assumptions in H1Fit of dPDFs measured at HERA:
 - $u=d=s=\bar{u}=\bar{d}=\bar{s} \rightarrow F_2D \sim 4/9u + 1/9d + 1/9s$
 - 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 $\sim 10\text{nb}$
- Dominantly g+g

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

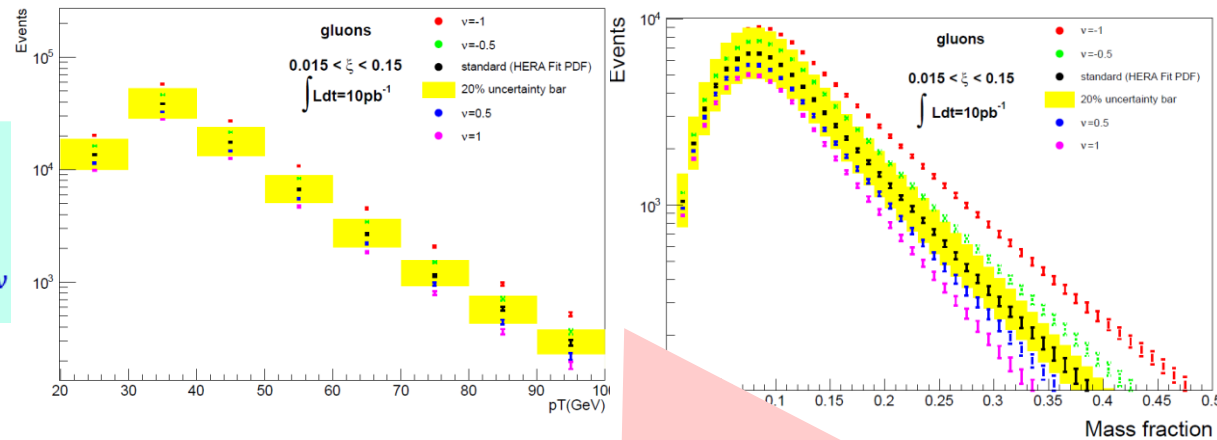
$$\beta^* = 0.55\text{m}, \sqrt{s} = 14\text{TeV}, d = 3\text{mm}$$

Detailed sim. of ATLAS and AFP:

- 2 jets $E_T > 20\text{ GeV}$ + AFP acceptance

Effect of PU studied in great detail!

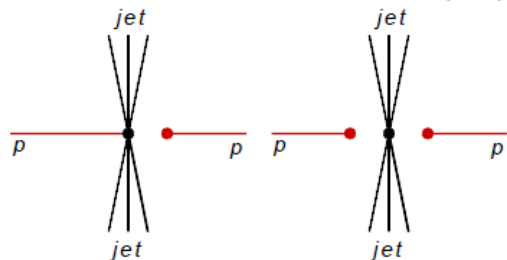
- Single-tag as well as double-tag
- Two models (Py8 default, Py8 MBR)
- Fast timing det. necessary



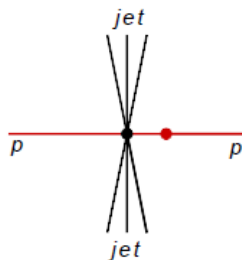
Already 10pb^{-1} ($=10\text{h}$ with $\mu \sim 1$) provides a beautiful separation between various gluon dPDF (statistical uncertainties only)

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

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



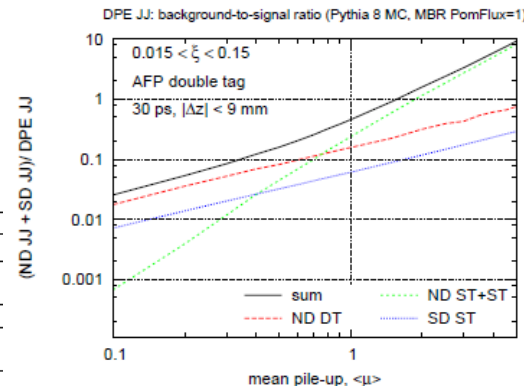
SD JJ + ST ND JJ + ST + ST



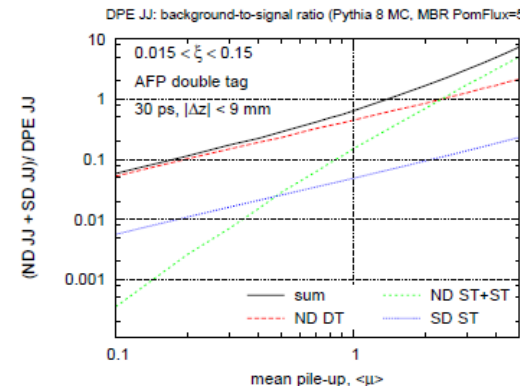
ND JJ + DT

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	

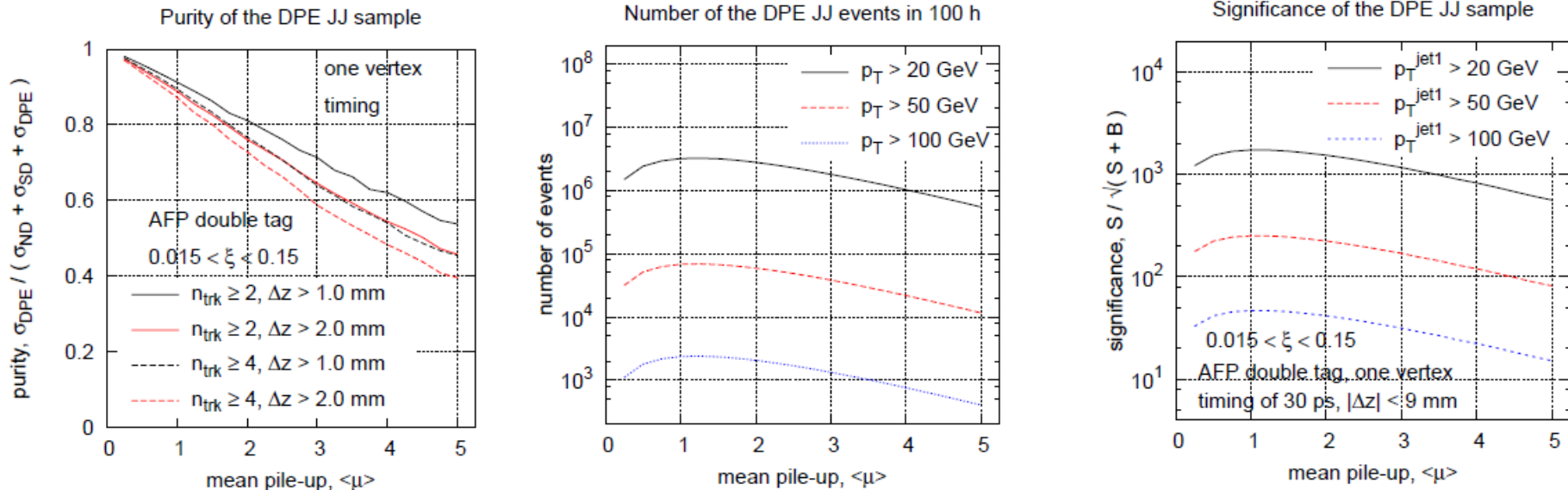
Double Tag (ST) Interactions				
probability [10^{-3}]				
default	0.47	0.37	-	0.014
MBR	0.31	0.36	26.0	0.012
cross section [μb]				
default	6.1	3.3	-	0.81
MBR	3.5	3.4	21	0.67
SD	DD	CD	ND	



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 $\mu \sim 3$
- 2) Event yield and significance optimal at $\mu \sim 1$ but still manageable up to $\mu \sim 5$

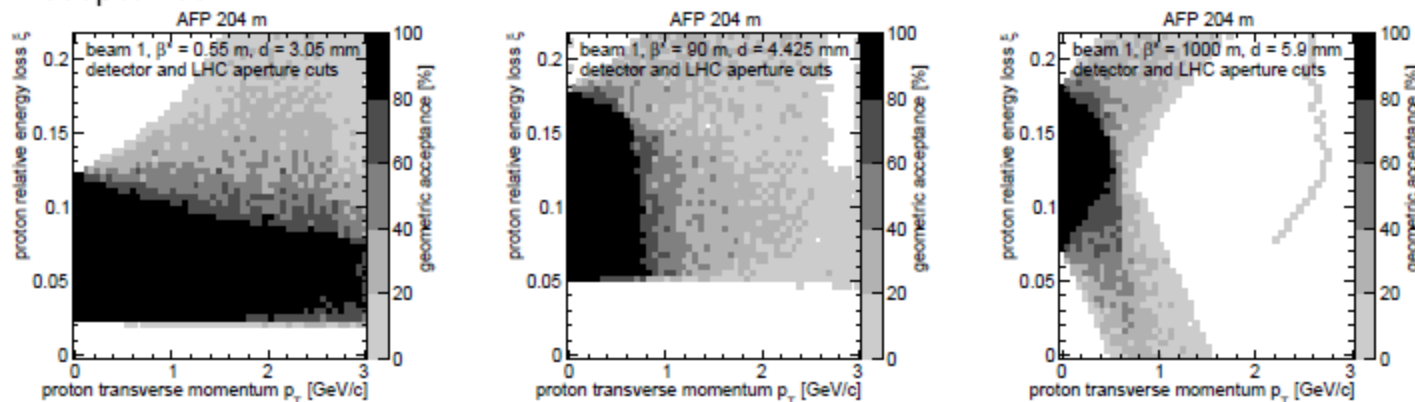
M. Trzebinski, PhD thesis, private simulation

Running scenarios:

- Effective x-section $\sim 10 \text{ nb}$ -> medium lumi needed
- $\mu \sim 1$ optimal but μ up to 5 && Etjet up to 100 GeV manageable
- Run of 100h with $\mu < 5$
- May be measured with both $\beta^* = 0.55 \text{ m}$ 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 $\gamma+j/jj$	> 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:
 $\mu = 0.1$: $\sim 10 pb^{-1}$
 $\mu = 1$: $\sim 100 pb^{-1}$

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 $\beta^*=0.55\text{m}$ 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

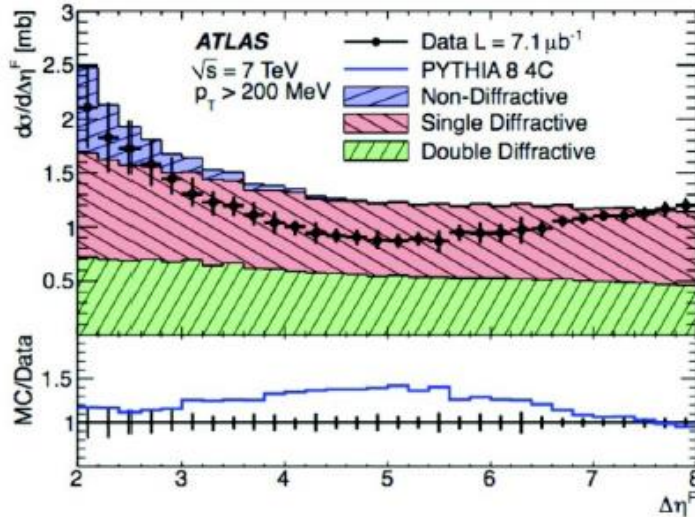
FP420 R&D Collaboration

1. FNAL 2. The University of Manchester 3. University of Toronto 4. University of New Brunswick 5. The University of Alberta 6. University of Guelph 7. The University of Regina 8. University of Colorado 9. INFN-CNAF 10. INFN-FR 11. INFN-NA 12. INFN-PD 13. INFN-SE 14. INFN-TN 15. INFN-VI 16. INFN-FC 17. INFN-GE 18. INFN-BO 19. INFN-CA 20. INFN-CL 21. INFN-FI 22. INFN-GR 23. INFN-NA 24. INFN-PA 25. INFN-PR 26. INFN-PS 27. INFN-RN 28. INFN-TO 29. INFN-TS 30. INFN-VA 31. INFN-VI 32. INFN-VE 33. INFN-VR 34. INFN-WS 35. INFN-ZN 36. INFN-AB 37. INFN-BO 38. INFN-CL 39. INFN-FI 40. INFN-GR 41. INFN-NA 42. INFN-PA 43. INFN-PR 44. INFN-PS 45. INFN-RN 46. INFN-TO 47. INFN-TS 48. INFN-VA 49. INFN-VE 50. INFN-VR 51. INFN-WS 52. INFN-ZN 53. INFN-AB 54. INFN-BO 55. INFN-CL 56. INFN-FI 57. INFN-GR 58. INFN-NA 59. INFN-PA 60. INFN-PR 61. INFN-PS 62. INFN-RN 63. INFN-TO 64. INFN-TS 65. INFN-VA 66. INFN-VE 67. INFN-VR 68. INFN-WS 69. INFN-ZN 70. INFN-AB 71. INFN-BO 72. INFN-CL 73. INFN-FI 74. INFN-GR 75. 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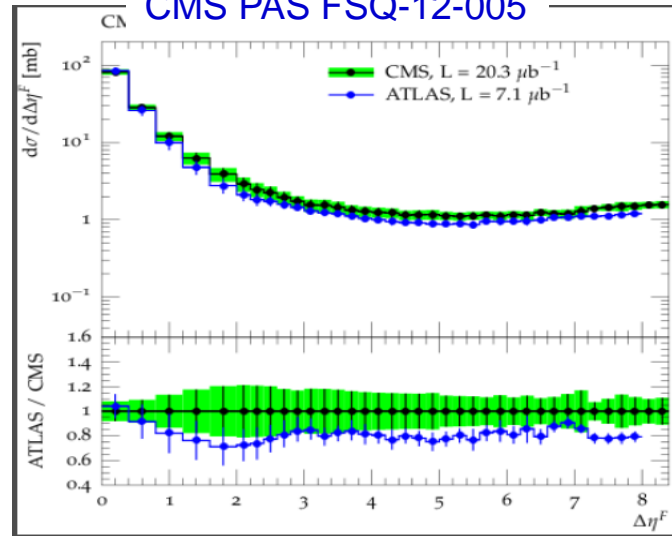
Gap spectra

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) ?

$\beta^* = 0.55\text{m}$, $\sqrt{s} = 14\text{TeV}$, $d = 3\text{mm}$

- 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

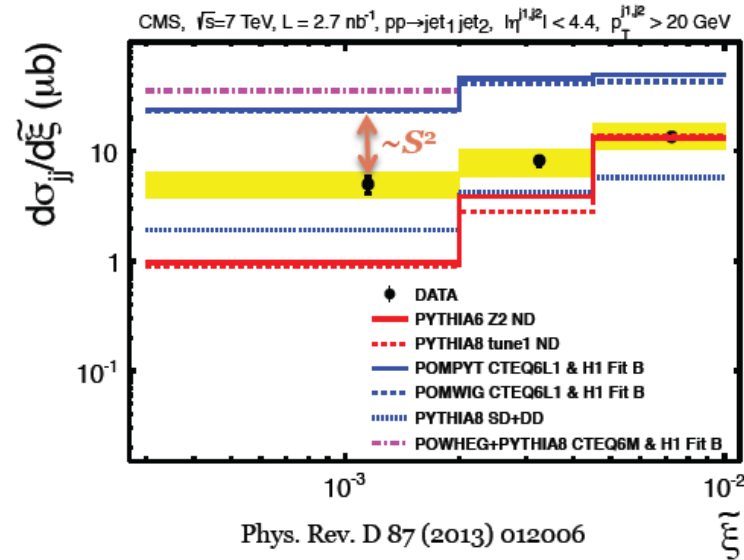
Running scenarios:

- Statistics not a problem
- Very low μ necessary
- $\beta^* = 90\text{m}$: ALFA + AFP common run
- $\beta^* = 0.55\text{m}$: larger (ξ, t) -acceptance with AFP
- Single-tag or Double-tag AFP Trigger

SD dijets

ATLAS (ongoing)

ATLAS and CMS measurements without proton tags:



Taking proton dissociation
Into account:

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

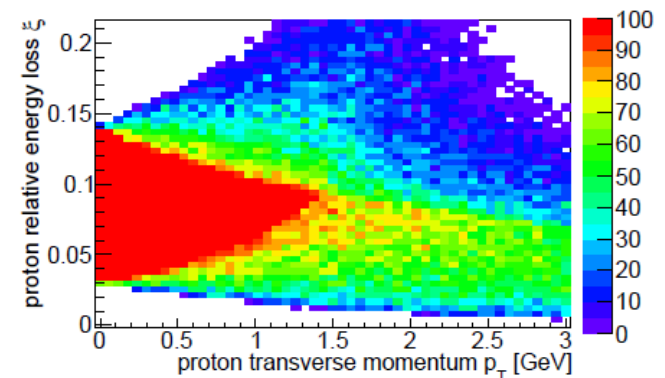
$$S^2_{\text{data/MC}} = 0.08 \pm 0.04 \text{ (NLO MC)}$$

Challenging measurement since

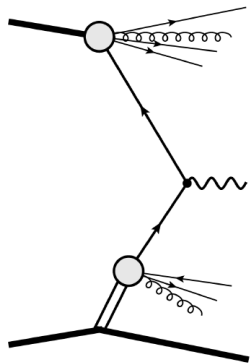
- 1) eta coverage is limited ($|\eta| < 5$)
- 2) Based on gaps or xi (sensitive to det. noise)
- 3) Fake gaps from hadronization
- 4) Low statistics due to requiring jets and low PU
- 5) No MC tuned for this process

- Limited statistics only allows S^2 measurement.
- Measuring dPDFs needs more statistics and proton-tagging

$\beta^* = 0.55 \text{ m}$, $\sqrt{s} = 14 \text{ TeV}$, $d = 3 \text{ mm}$



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:

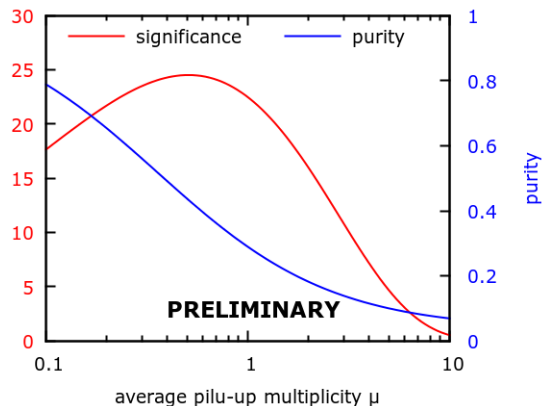
enu+munu W-decays (Pt inclusive) + one vertex

+ AFP acceptance

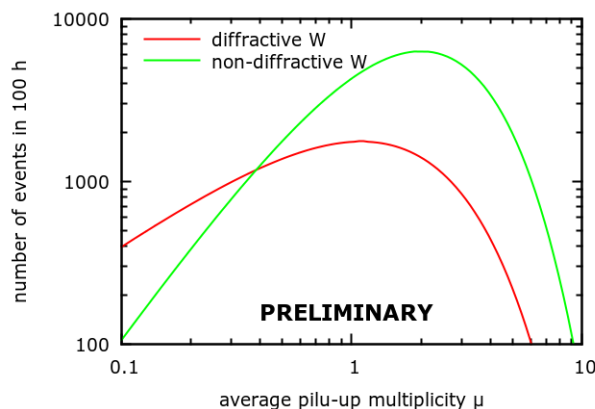
$$\beta^* = 0.55\text{m}, \sqrt{s} = 14\text{TeV}, d=3\text{mm}$$

- Without Calo information: low PU necessary: $\mu \sim 0.2 \rightarrow 700 \text{ W per 1 week}$, purity $\sim 60\%$ and significance ~ 20

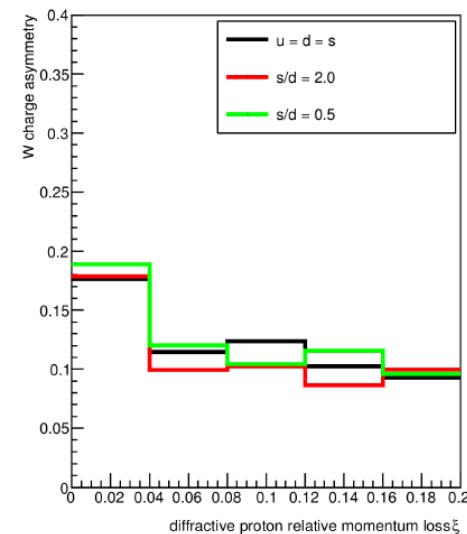
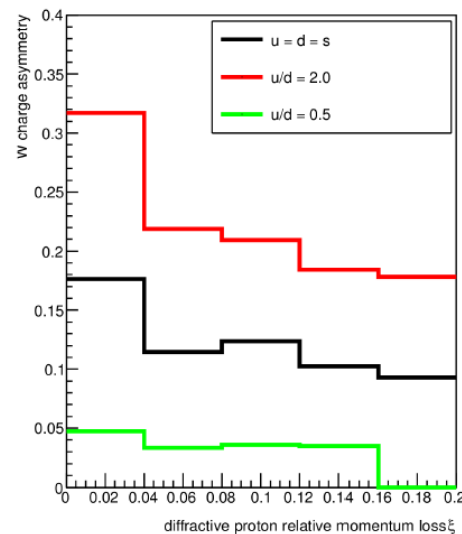
W in leptonic channel + AFP hit + one vertex



W in leptonic channel + AFP hit + one vertex



With Calo information: higher PU possible



CMS measurement: EPJ C72 (2012) 1839:

Fraction of W/Z events with a forward gap:

W \rightarrow lv: $1.46 \pm 0.09(\text{stat.}) \pm 0.38(\text{syst.}) \%$

Z \rightarrow ll: $1.60 \pm 0.25(\text{stat.}) \pm 0.42(\text{syst.}) \%$

- Observed Asymmetry between signed lepton and gap side

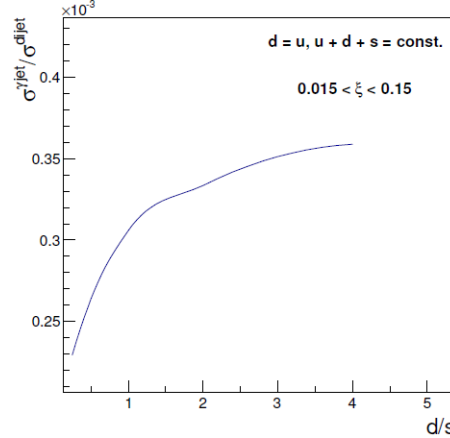
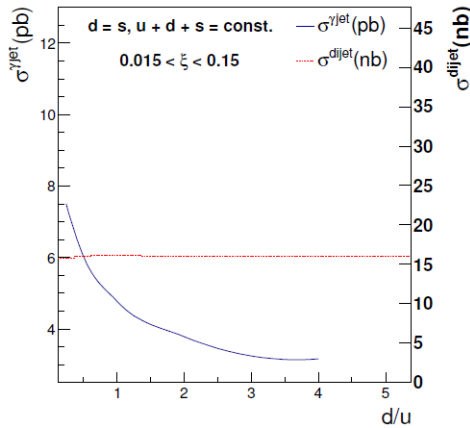
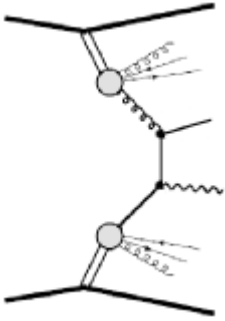
Running scenarios:

- Effective x-section $\sim 40\text{pb} \rightarrow$ medium lumi needed
- Low μ preferable but $\mu \sim 1$ manageable
- May be measured with both $\beta = 0.55\text{m}$ 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 $\sim 1\text{pb}$

- Dominantly $q+g \rightarrow$ Sensitivity to quark dPDFs
- Make ratio with DPE jj to suppress systematics
- DPE jj studied in great detail in a separate analysis

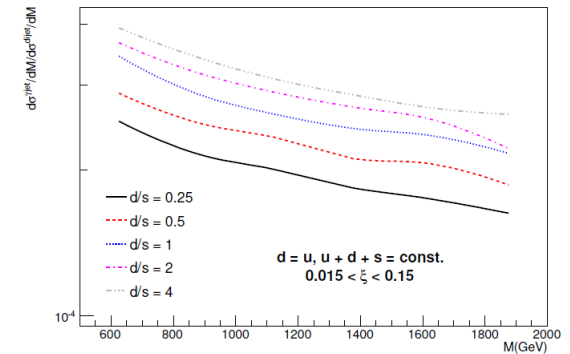
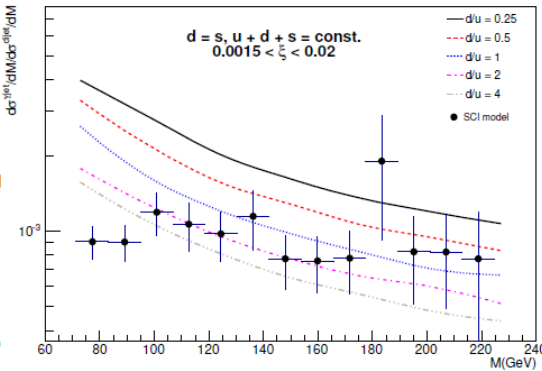
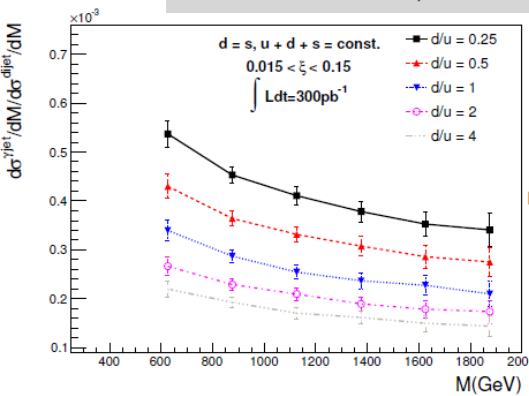


$$\beta^* = 0.55\text{m}, \sqrt{s} = 14\text{TeV}, d=3\text{mm}$$

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

Truth level: AFP acceptance
 + jets: $E_t > 20\text{ GeV}$
 + photons: $E_t > 20\text{ GeV}$, $|\eta| < 2.5$
 - Assuming Lumi=300pb-1 at $\mu=1$

■ $u+d+s = \text{constant}$, $d=u$ and $d/s \in \{0.25, 0.5, 1, 2, 4\}$

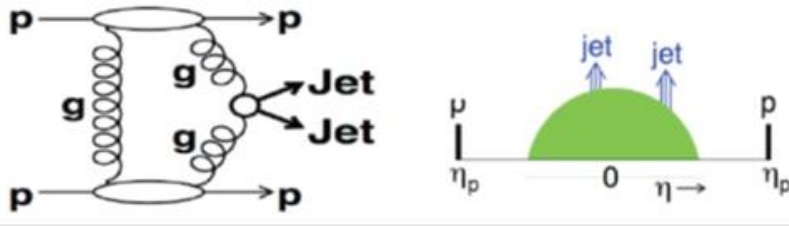


Running scenarios:

- Statistics is an issue for gamma+jet ($L > 200\text{ pb}^{-1}$ needed) \rightarrow medium lumi ($\mu \sim 1-3$) needed
- need for statistics prefers $\beta^* = 0.55\text{m}$
- Run of 200h with $\mu \sim 1.5$
- 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 fruitful 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

$\beta^* = 0.55\text{m}$, $\sqrt{s} = 14\text{TeV}$, $d=3\text{mm}$

Detailed sim. of ATLAS and AFP:

- 2 jets $E_t > 20\text{ GeV}$ + AFP acceptance

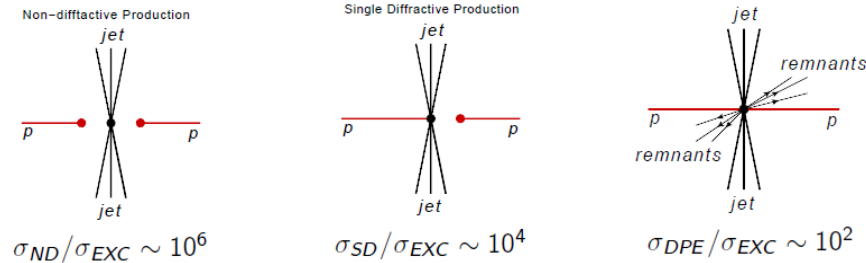
Effect of PU studied in great detail!

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

a) number of tracks outside jets

b) $\Xi(\text{AFP})$ vs. $\xi(\text{jets})$

c) Forward energy flow

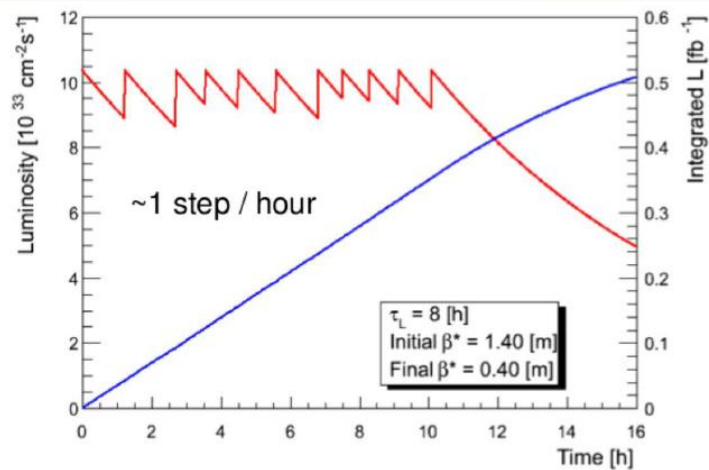


Single Tag (ST) Interactions

	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 $\beta^* = 1.4 \text{ m}$. Final $\beta^* = 0.4 \text{ m}$.
Step: 0.1 m every 1 hour.

- Should 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

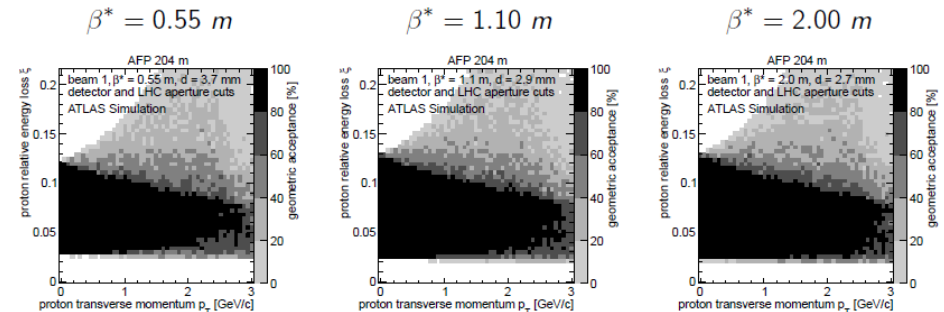
M. Trzebiński

Luminosity Leveling

5/12

Geometric Acceptance

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



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.