The ATLAS Forward Physics Project (AFP)

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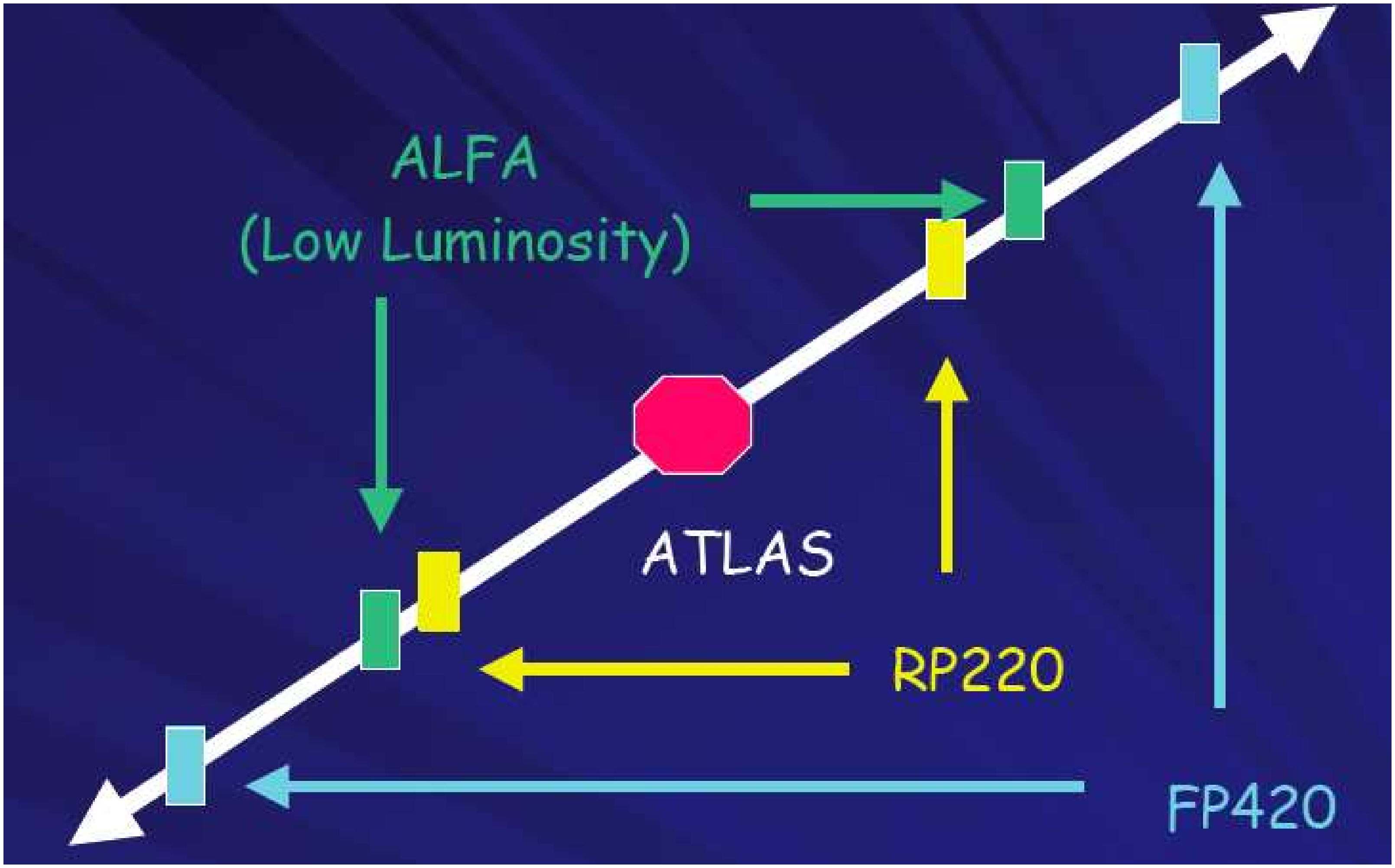
Contents:

- Physics: anomalous couplings and QCD topics
- Movable beam pipe
- Si detectors
- Timing detector
- Timescale

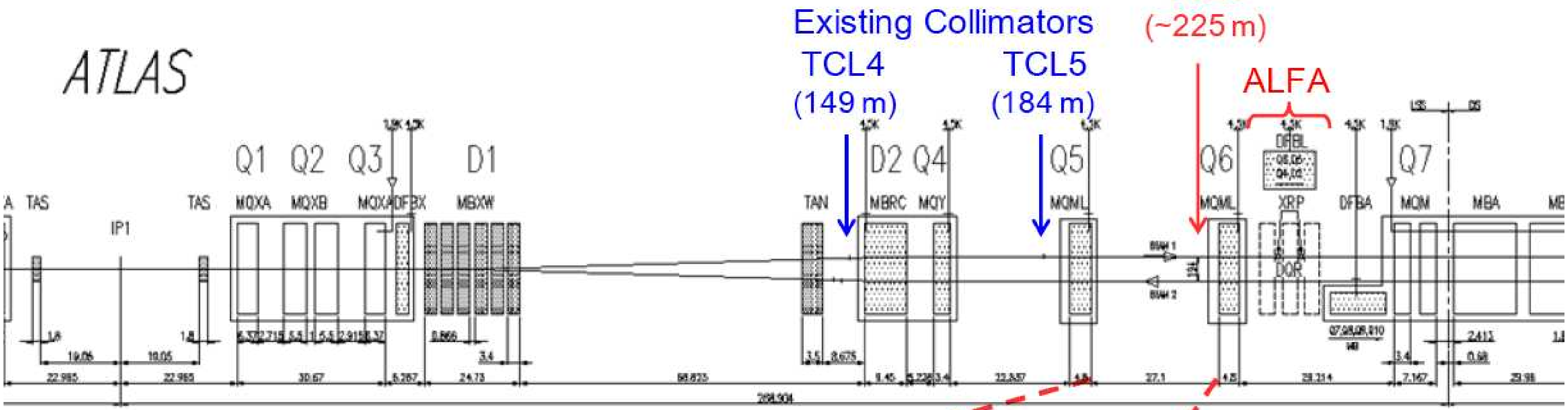
The AFP project

- Install forward proton detectors on both sides of ATLAS to detect intact protons: working at high luminosity
- what is needed? Good position and good timing measurements
- 220 m: movable beam pipes, phase 0
- 420 m: movable beam pipe, possible future upgrade if motivated by physics (discovery of Higgs boson at low masses for instance)
- Focus on physics topics which cannot be performed without AFP



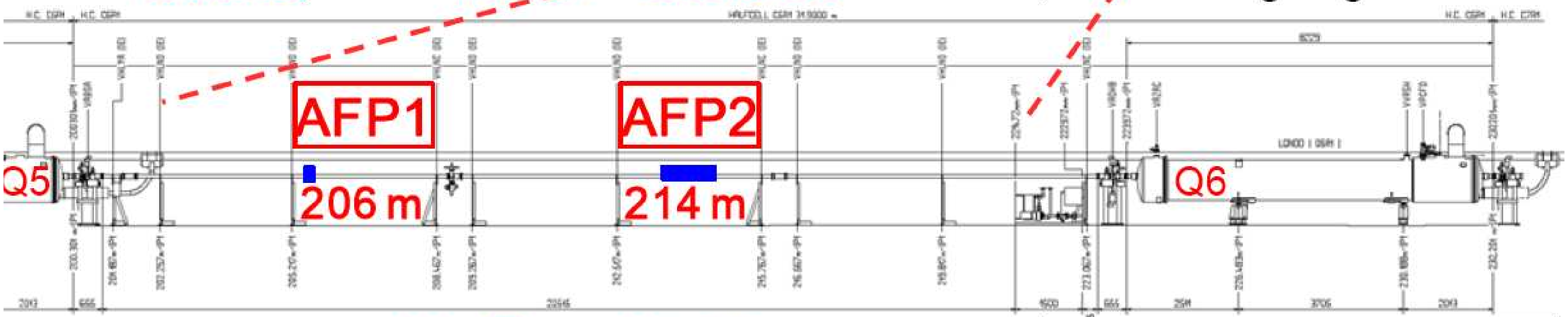
Location of AFP detectors

Locations at z =206 m and 214 m



– TCL5 limits AFP acceptance!

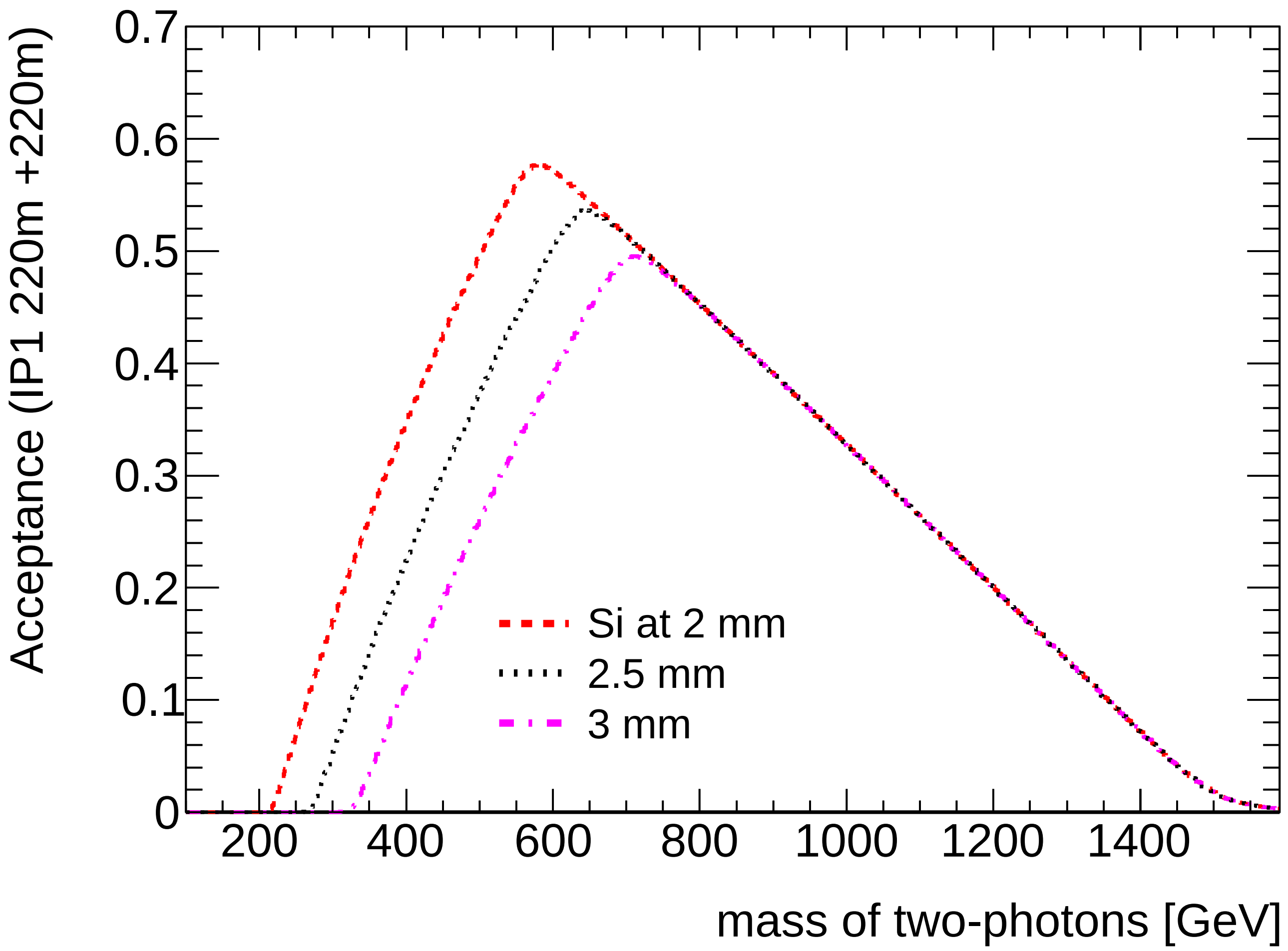
– relocate, or add new TCL before Q6 – feasible; studies ongoing …



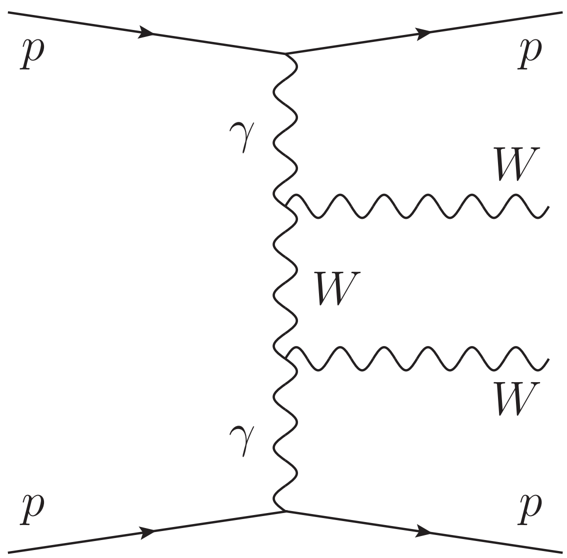
R. Appleby, D. Macina, et al.

Detector acceptance

- Mass computed using forward proton detectors: $M = \sqrt{\xi_1 \xi_2 S}$ where ξ is the fraction of the proton momentum carried by the exchanged colorless object, for instance the photon
- Good mass acceptance at high mass (220 m detectors only)



What can AFP bring to ATLAS Physics: anomalous couplings



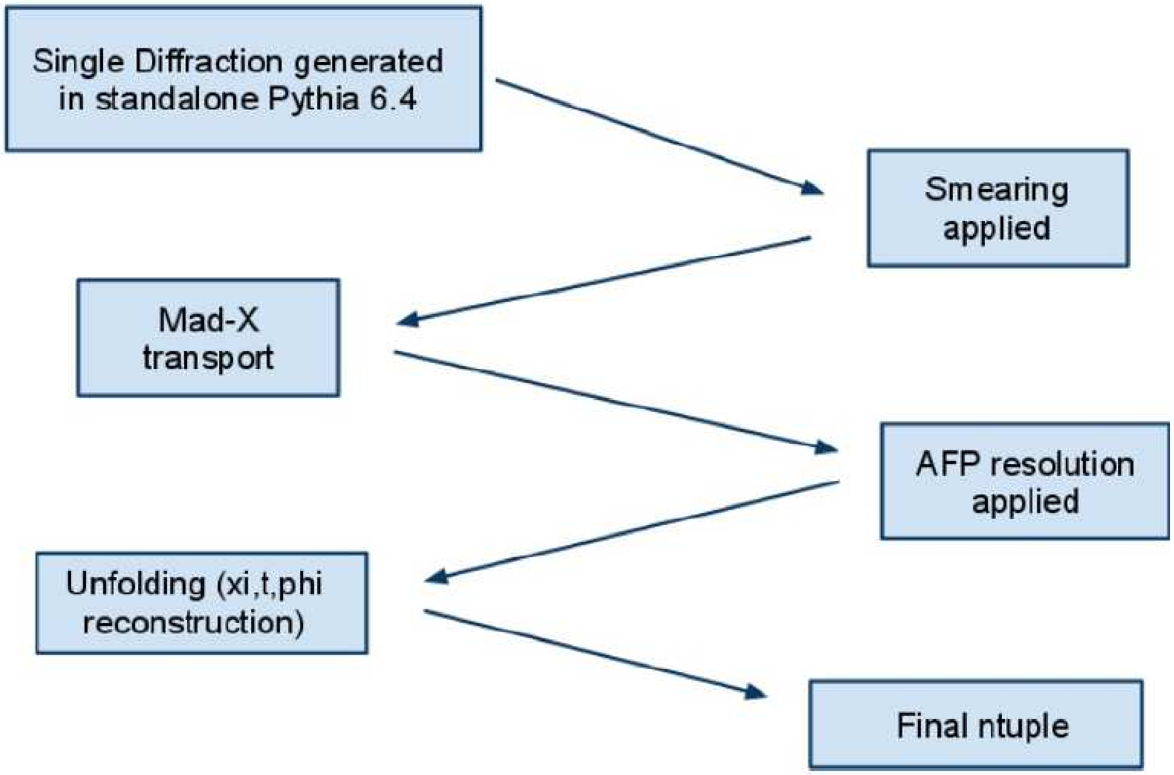
- W pair production via photon exchanges (QED processes): sensitivity to anomalous couplings between γ and W/Z boson
- Anomalous couplings (WW/ZZ production): A paper is being finalised by Christophe Grojean, Rick Gupta, James Wells, "Probing Quartic Neutral Gauge Boson Couplings using diffractive photon fusion at the LHC", showing the possibility to probe higgsless and extradimension models by proton tagging of diffractive events
- See: Anomalous quartic $WW\gamma\gamma$, $ZZ\gamma\gamma$, and trilinear $WW\gamma$ couplings in two-photon processes at high luminosity at the LHC. E. Chapon, C. Royon, O. Kepka. Phys.Rev. D81 (2010) 074003

What can AFP bring to ATLAS Physics: anomalous couplings

Couplings	Sensitivity @ $\mathcal{L} = 30$ (200) fb^{-1}	
	5σ	95% CL
a_0^W/Λ^2	5.4 10^{-6} (2.7 10^{-6})	2.6 10^{-6} (1.4 10^{-6})
a_C^W/Λ^2	2.0 10^{-5} (9.6 10^{-6})	9.4 10^{-6} (5.2 10^{-6})

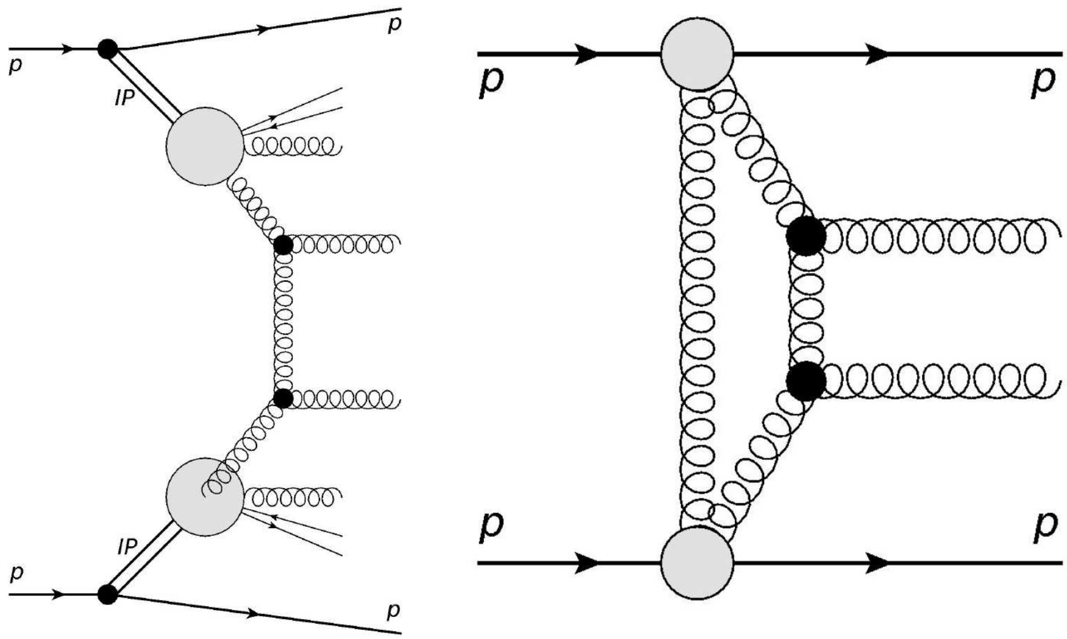
- Results shown above: Analysis using leptonic decays of W/Z, and fast ATLAS simulation ATLFAST
- Improvement of "standard" LHC methods by studying $pp \to l^\pm \nu \gamma \gamma$ (see P. J. Bell, ArXiV:0907.5299) by more than 2 orders of magnitude with 30/300 fb^{-1} at LHC!!!
- Reaches the values expected for higgsless models (C. Grojean, J. Wells) and extradim models
- ATLAS full simulation in progress: assume 25 (from 2014) or 46 (from 2017) pile up events per crossing; double tagged events in AFP; integrated luminosity of 10-30 fb^{-1} (from 2014) and 300 fb^{-1} (from 2017)
- Trigger: ATLAS triggers on high p_T jets, leptons and W pairs

Full MC simulation and background rejection



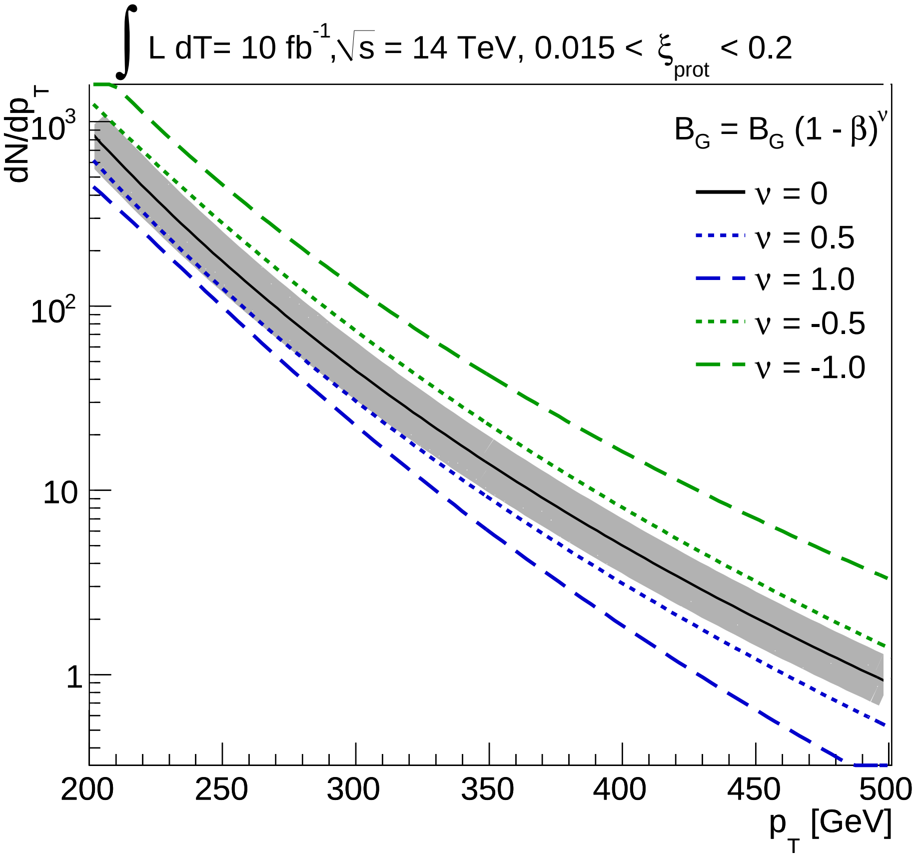
- Full simulation of all signal and background events: for anomalous coupling studies for instance, we consider same processes considered for background as standard WW analysis requesting high p_T leptons ($p_T > 120$ GeV)
- Considered backgrounds: Double pomeron exchange (shows some uncertainties due to gluon in pomeron, small though), production of dileptons by photon exchanges, non diffractive WW and pile up, $t\bar{t}$ and Wt, other dibosons (WZ, ZZ, $W\gamma$)...
- Use proton database to add intact protons from pile up

What can AFP bring to ATLAS Physics program: QCD processes



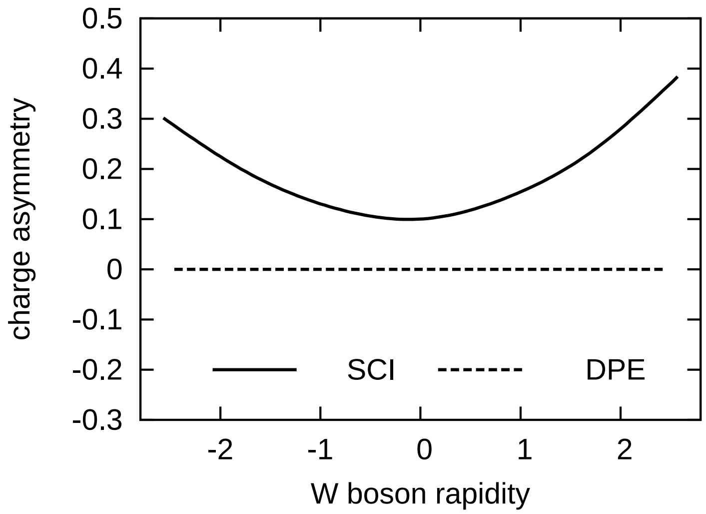
- Probe QCD and diffraction in a completely new kinematical domain: left: DPE, right: exclusive diffraction
- Jet production in double pomeron exchange events: study sensitivity on gluon density in pomeron in double tagged events (luminosity of 10 fb^{-1})
- Exclusive diffractive jet production: measure dijet mass fraction (as in CDF) and look for exclusive events at high dijet mass fraction in double tagged events (luminosity of 10 fb^{-1})
- Inclusive DPE W production: sensitive to quark density in Pomeron, measure W asymmetries

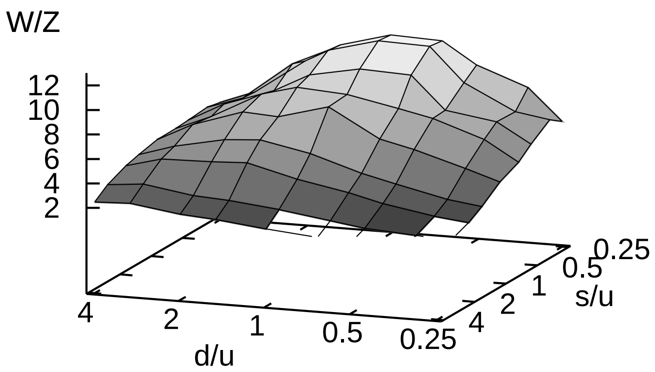
What can AFP bring to ATLAS Physics program: Jet measurements



- Jet cross sections sensitive to gluon content in Pomeron
- Multiply the gluon density in the pomeron by $(1-\beta)^\nu$ with ν=-1, -0.5, 0, 0.5, 1. to show the effect of the gluon uncertainty at high β
- ATLAS data with 10 fb^{-1} will allow to probe QCD an a completely new kinematical domain (test DGLAP evolution, determination of gluon density in Pomeron)

What can AFP bring to ATLAS Physics: new ideas in W/Z

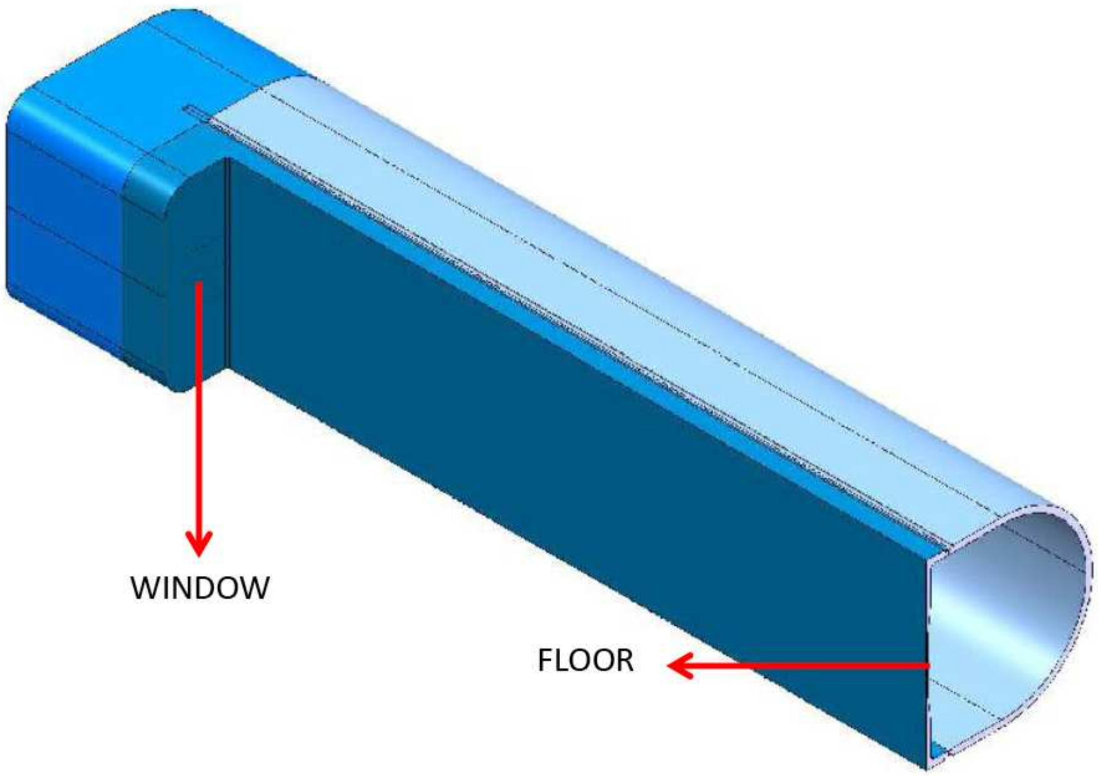




- New simple idea to probe QCD: K. Golec-Biernat, C. Royon, L. Schoeffel, R, Staszewski, arXiv:1110.1825
- Measure W/Z DPE cross sections: constrain quark densities in Pomeron
- Measure W asymmetry: should be 0 if diffraction due to Pomeron exchanges (made of quark and gluons, since $u = \bar{u}$, $d = \bar{d}$), non-zero if due to soft colour exchanges (diffraction explained through soft colour exchanges at the hadronisation phase, same asymmetries expected as for the proton)
- If aymmetry is 0, measure u/d quark density ratio in the Pomeron: first possible measurement ever, important to test QCD evolution which assumes $u = d = \bar{u} = \bar{d}$

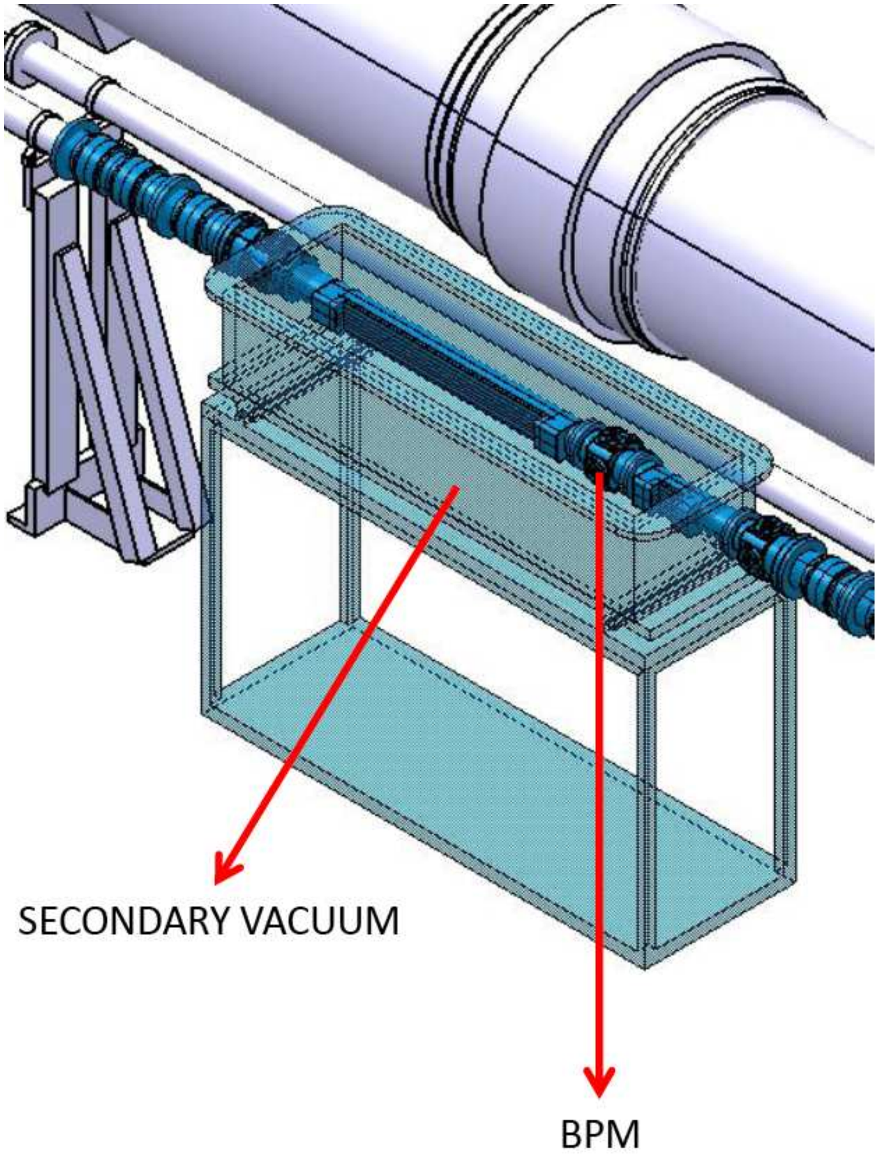
Movable beam pipe hosting the timing/Si detectors

- Movable beam pipe: simple idea to move the detectors close to the beam when beam is stable, to be treated like a collimator from the beam division point of view
- Thin windows needed between beam vacuum and secondary vacuum where detectors are located
- Movable beam pipes host Si and timing detectors
- Design being finalised: many thanks to Marzio Nessi/Giancarlo Spigo!



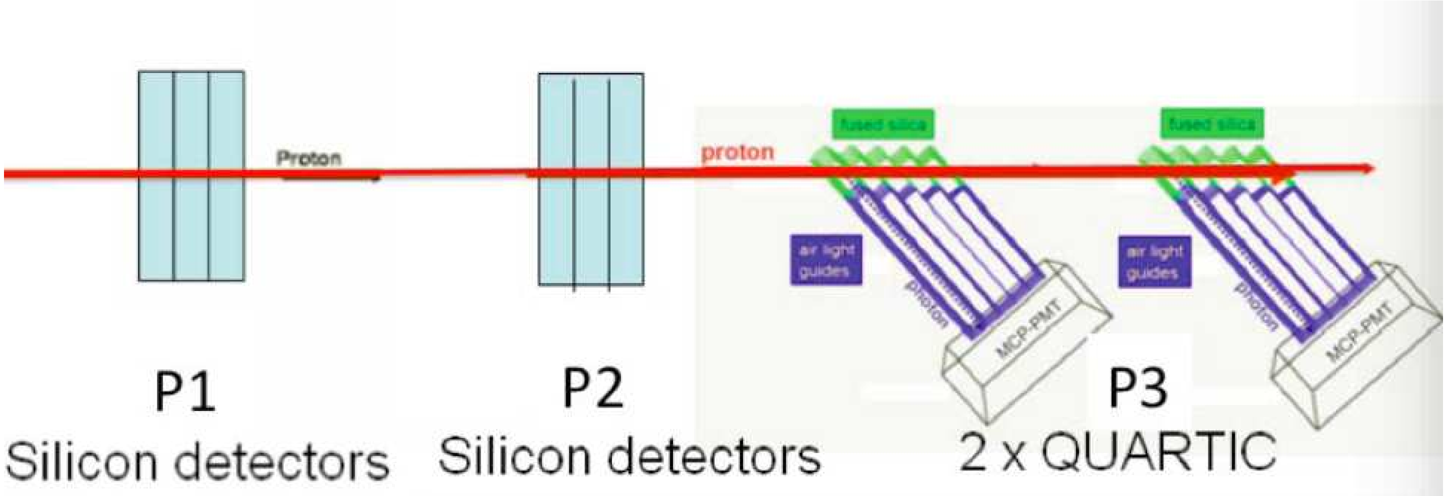
Movable beam pipe hosting the timing/Si detectors

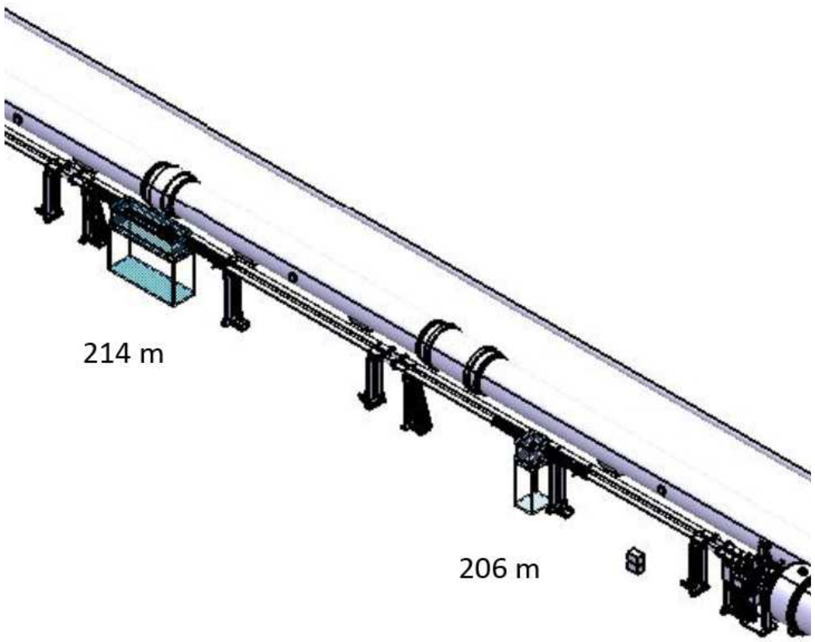
- Detectors located in pocket in secondary vacuum
- Beam Position Monitors: standard LHC equipment
- Same motors as for the LHC collimators



Movable beam pipe hosting the timing/Si detectors

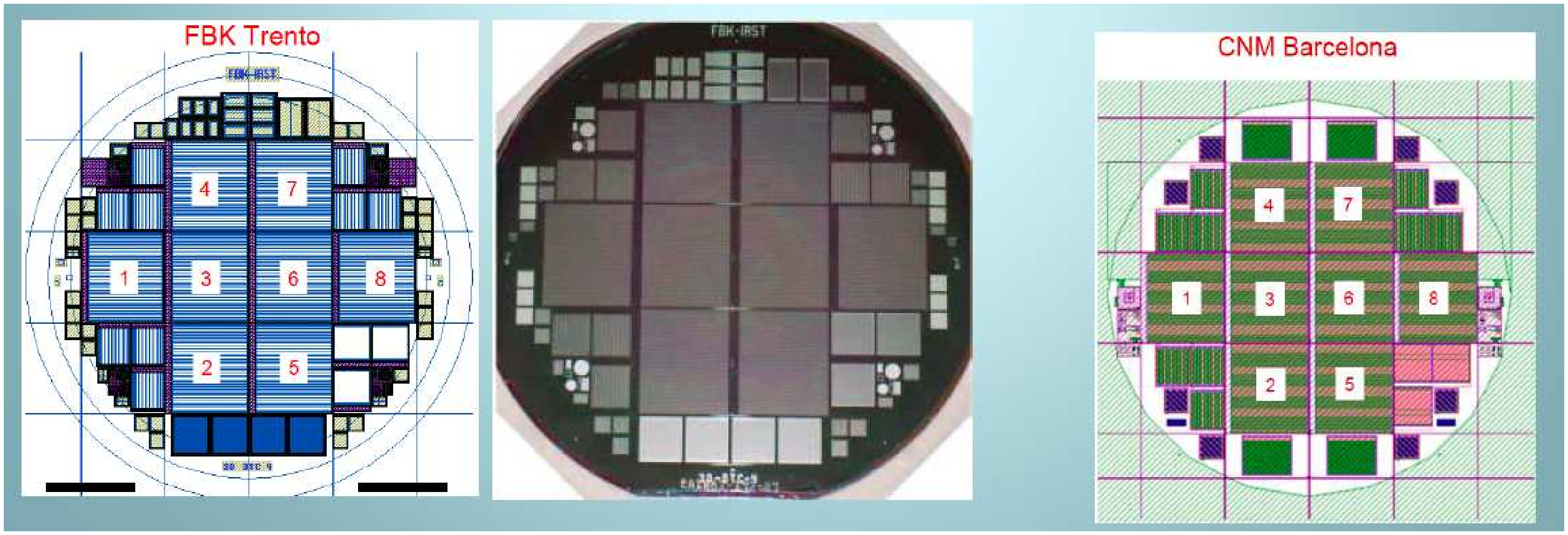
- 206 m: small pocket to host Si detector only
- 214 m: small pocket for Si and large pocket to host timing detector





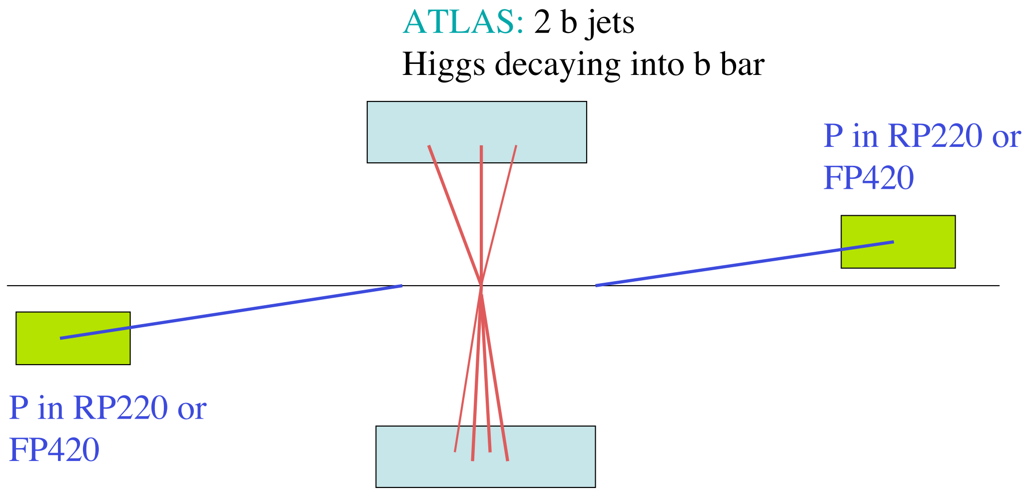
AFP position detectors: Si

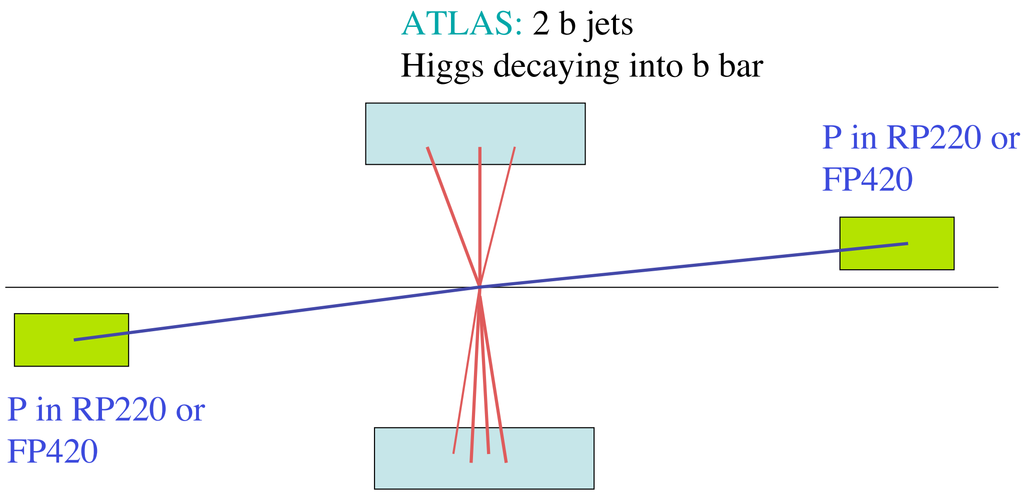
- We need to measure the proton position with a precision of $\sim 15\ \mu$m
- Use Si detectors developed for IBL: 3D Si is the favoured option since it allows to go closer to the beam and the needed power is smaller
- 3D sensors (IBL type): dead region of 200 μm
- 3D edgeless detectors: dead region of 50 μm, ideal for us
- Standard IBL readout chip: FE-I4



Why do we need timing detectors?

We want to find the events where the protons are related to the hard interaction and not to other soft events



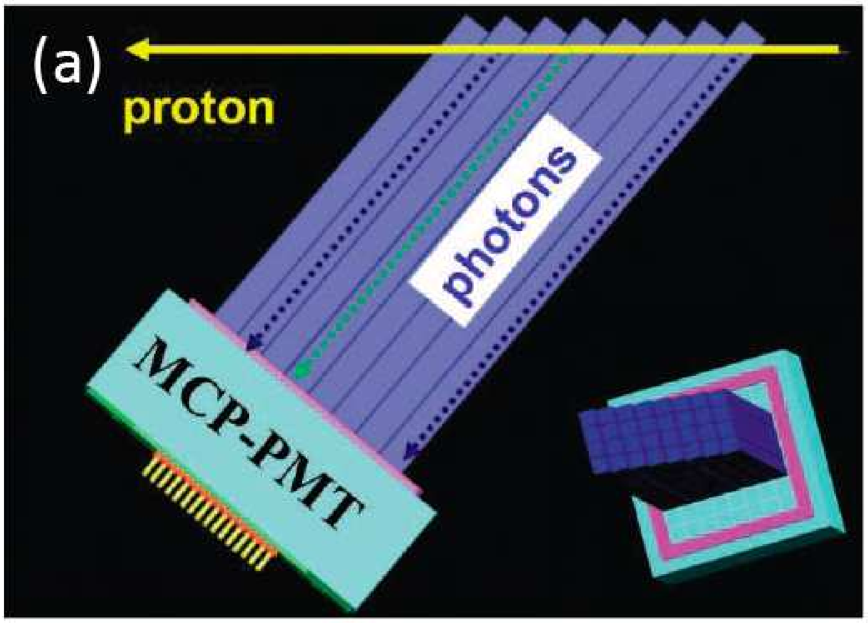


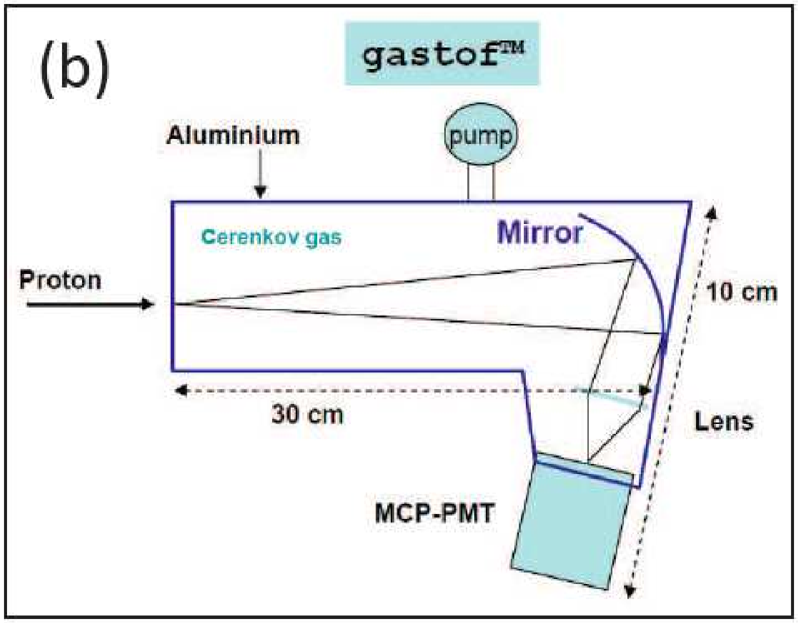
QUARTIC and GASTOF timing detectors

Requirements for timing detectors

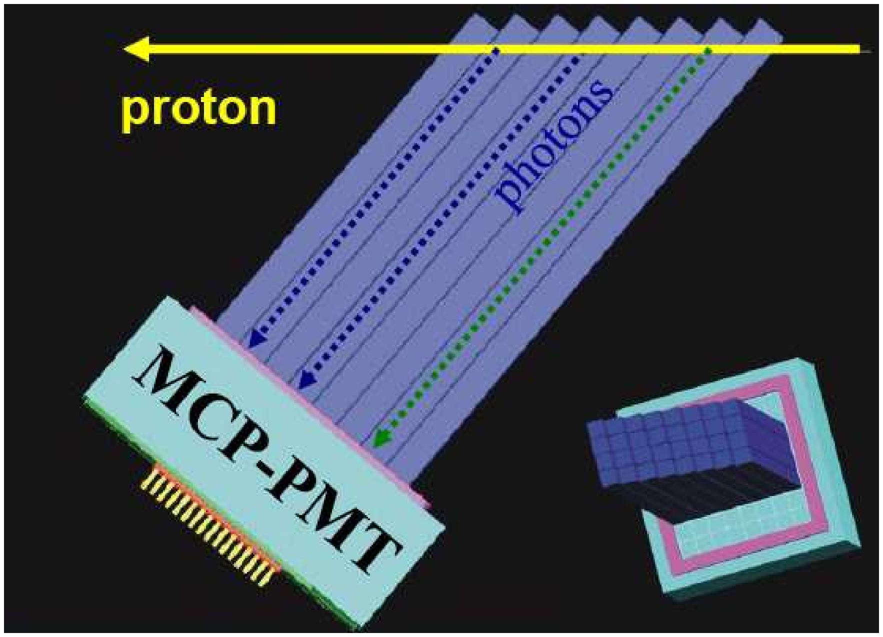
- 10 ps final precision (20-30 ps for phase 0) (GASTOF in Louvain, QUARTIC in UTA, Fermilab, Alberta)
- acceptance that fully cover the tracking detectos, efficiency close to 100%
- high rate capability
- segmentation for multi-proton timing (not critical for phase 0)
- level 1 trigger capability (not critical for phase 0)

Micro-channel plate PMT lifetime issue: critical at highest lumi (new developments in progress by Hamamatsu, common developments between UTA and Burle/Photonis)





QUARTIC is the primary AFP timing detector



- QUARTIC: each QUARTIC has 4×8 array of quartz bars
- Each proton passes through eight bars in one of the four rows
- Only need a 30-40 ps measurement/bar since one can do it 8 times
- Initial prototype had fixed bin sizes of 5×5 mm^2, optimisation of bin size in progress in order to equalise rate (smaller bin size close to the beam)
- Possible optimisation with quartz fibers instead of bars

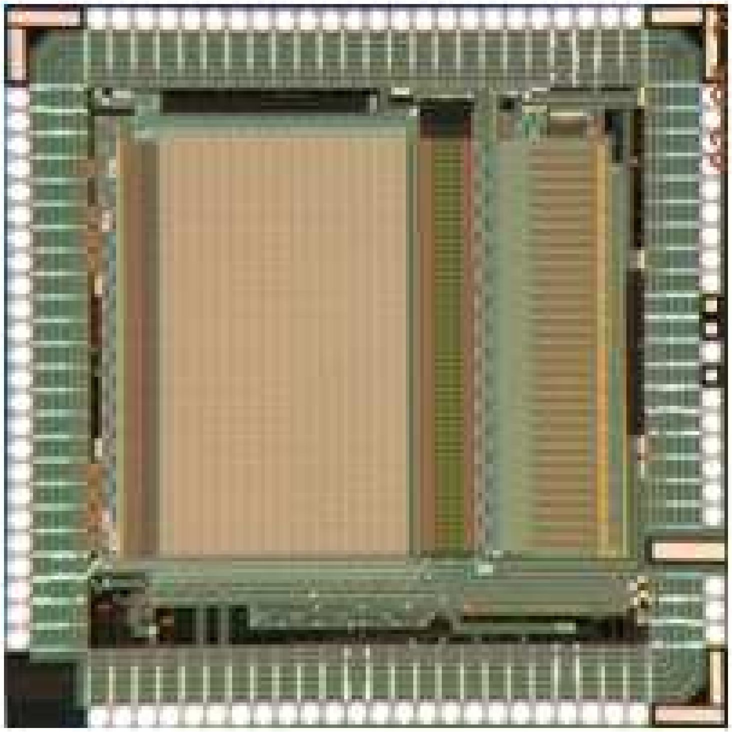
Requirements on timing detectors and electronics

- Timing resolution: 10-15 ps needed to suppress pile up background
- Event rate: at the highest luminosity, 1 event per BC, 40 MHz rate; depends on detector segmentation to reduce rate per channel
- ATLAS trigger (input to AFP): 100 kHz with 100 μs latency $\rightarrow$ buffer to keep events locally in AFP waiting for ATLAS trigger
- AFP trigger: Provides coincidence between different channels
- Starting point: SAM chip developped in Saclay/Orsay
- Case of anomalous coupling studies (fast simulation studies):

Resolution	μ	Signal	Background
none	25	3	1
20 ps	25	30	1
10 ps	25	120	1
10 ps	50	30	1
10 ps	180	2.3	1

Swift Analog Memory (SAM) chip for HESS2 experiment

- SAM chip was developpped in Saclay/Orsay for HESS 2 experiment in order to achieve high frequency sampling needed during the short time of cosmic rays
- Very good timing resolution observed on this chip (25 ps rms)



Going beyond the SAM chip

- Issues with SAM chip:
  - Bandwidth and sampling rate not large enough
  - Cannot sustain 40 MHz event rate
  - Other fast timing chips very expensive: 50k$ for 4 channels at 2 GHz)
- Development of a new chip in progress with higher sampling frequency and rate and analog bandwidth
- High event rate issue to be solved together with improving detector segmentation
- Advantages: only stores the region of interest (32 or 64 points) reducing the data flow, reduced cost (10$ per channel), patent originated in Saclay
- Many applications in particle physics, medicine, radiation detector, beam position detection...

$$\boxed{\Delta t = \frac{\Delta u}{U} \cdot \frac{1}{\sqrt{3 f_s \cdot f_{3dB}}}}$$

	U (dynamic)	Δu (noise)	f_s (sampling freq)	f_{3db} (cutoff frequency)	Δt (timing resolution)
Actual chips (SAM...)	100 mV	1 mV	2 GSPS	300 MHz	~10 ps
	1 V	1 mV	2 GSPS	300 MHz	1 ps
	100 mV	1 mV	20 GSPS	3 GHz	0.7 ps
Targeted chip	1V	1 mV	10 GSPS	1 GHz	0.5 ps

Timescale and Management

- Forward group leader: Marco Bruschi, Forward IB Chair: Hasko Stenzel
- Current management: Christophe Royon, Si: Petr Sicho, Cinzia Da Via, Timing detectors: Andrew Brandt, movable beam pipes: Giancarlo Spigo, Physics: Oldřich Kepka
- Timescale
  - Beam tests in January 2012 (timing detectors), June 2012 (Si and timing), Autumn 2012 (fully integrated system including movable beam pipes)
  - Installation of movable beam pipes and 1 Si (3D, IBL type) and 1 timing detector on both sides by the 2013-14 shutdown
  - 2015: installation of second Si detector during the Christmas shutdown
  - 2017: installation of upgraded Si (3D edgeless) and timing detectors
  - Realistic schedule and budget agreed with Upgrade ATLAS management, detailed schedule under progress
- Timing AFP was approved as an ATLAS Upgrade R&D project last August
- AFP is part of the Upgrade LOI which is being finalised
- AFP is well on track to take data in 2014!

Budget

Total cost: 2.5 million Euros

Forward Physics (AFP)				last update:	10/11/11		contacts:	M.Bruschi				
Fill in	Fill in	Fill in	calculated	Fill in	calculated	Fill in	Fill in	Fill in	Fill in	Fill in	Fill in	Fill in
Deliverables		CORE COST (MCHF)		possibel error		2012	2013	2014	2015	2016	2017	2018
Si detector, mechanics			0.243		0.000							
	Sensors	0.017				0.002	0.004	0.003	0.004	0.004		
	FE-I4b	0.017				0.002	0.004	0.003	0.004	0.004		
	Bump-bonding, tests	0.110				0.011	0.022	0.022	0.028	0.028		
	Mechanics, local support	0.052				0.006	0.013	0.007	0.013	0.013		
	Assembly	0.048				0.005	0.011	0.008	0.012	0.012		
Off Si detector, integration			0.323		0.000							
	R/O electronics	0.110				0.025	0.050	0.010	0.025			
	Power chain	0.064				0.013	0.026	0.010	0.015			
	Cooling	0.098				0.023	0.045	0.010	0.020			
	Integration	0.052				0.010	0.019	0.008	0.015			
Movable beam pipe		0.944	0.944		0.000	0.235	0.414	0.295	0.000	0.000	0.000	0.000
TCL6		0.100	0.100		0.000	0.020	0.040	0.040				
Timing Detectors			0.323		0.000							
	Detector/PMT R&D	0.072				0.060	0.012					
	Full Protype QUARTIC Detector	0.050					0.050					
	Final Quartic Detectors (4+2)	0.201							0.101	0.101		
Timing Electronics			0.337		0.000							
	Timing Electronics R&D	0.018				0.018						
	Full Prototype Electronics System	0.093					0.093					
	Timing Electronics (amps/ADC/ CFD/HPTDC) (16+2)*8 channel boards	0.161							0.080	0.080		
	Timing Trigger Electronics (2+1)	0.008							0.004	0.004		
	Pulser System (2+1)	0.012							0.006	0.006		
	Reference Clock	0.045							0.022	0.022		
Infrastructure			0.189		0.000							
	Cables	0.100					0.050	0.050				
	HV, LV, Readout	0.089					0.045	0.045				
Total			2.458		0.000	0.429	0.896	0.510	0.349	0.274	0.000	0.000

Current and new collaborators

AFP Collaborators:

University of Alberta

Charles University, Prague

Institute of Physics of ASCR, Prague

IRFU-SPP, CEA Saclay, Paris

Justus-Liebig Universität, Giessen

Institute of Nuclear Physics, Cracow

Glasgow University

University of Texas at Arlington

Stony Brook University

New/Renewed/Expanded Interest from:

Barcelona

Bologna

Manchester

SLAC

Stony Brook

University of New Mexico

Oklahoma State University

University of Oklahoma

University of Wuppertal

and as yet unconfirmed others ..

Tasks to be performed in Saclay: fast electronics

Task: Concept and realisation of a picosecond timing system

- Present achievement: development in IRFU/LAL of the SAM Chip for HESS-2 (timing circuits based on analog memories)
- Task 1.1 - Concept and realisation of a numerisation high frequency chip: starting from the SAM chip, to be optimised for high event frequency (40 MHz), sampling frequency of 10 GS per second
- Task 1.2 - Realisation of a test bench for the circuit and performance check: test bench built in collaboration with LAL
- Task 1.3 - Characterisations and tests of the timing detector and electronics: laser test bench, beam tests (SLAC or CERN)
- Financial and manpower requests: 25 kEuros for the chip, 3 kEuros for trips (beam tests), Hervé Grabas (PhD student, 2 years), Eric Delagnes

Tasks to be performed in Saclay: Mechanics

Mechanics, assembly of the Si detectors in the movable beam pipe pockets

- Task 2.1 - mechanical study of the arrangement of the Si layers in the movable beam pipes: 6 layers per detectors, 1 layer shifted by 25 microns with respect to the other (sensor size: 50 μm)
- Task 2.2 - Alignment methods of the Si layers: 5 to 10 microns precision
- Task 2.3 - Mechanic and thermal study of the complete detector: interface with outside, cable feed-through, detector in vacuum
- Task 2.4: Alignment study of the full detector (with respect to BPM...)
- Manpower and resources needed: Mechanical engineer (mechanical and thermal studies): 3 months, CAO technician (Catia): 4 months

Manpower and resources in Saclay

- Manpower available:
  - SPP: L. Schoeffel, C. Royon, (M. Boonekamp), students: E.. Chapon (starting 01/2012), R. Staszewski, M. Trzebinski (coleadership with Cracow), M. Zeman (coleadership with Prague)
  - SEDI: E. Delagnes, student: H. Grabas (advisor: Eric and Christophe)
  - SIS: P. Ponsot (help needed from one engineer/ one technician)
- Resources:
  - Resources requested for timing chips: 25 kEuros, 3 kEuros for travel
  - P2IO project to be submitted (E. Delagnes) together with Orsay
  - ERC synergy proposal: about AFP, Si and timing detectors, under discussion with Cinzia Da Via (Manchester), Marzio Nessi (CERN), discusisons with Prague, Bologna, Barcelona

Conclusion

- AFP project: well started
- Physics topics in progress using full simulation: focuses on WW anomalous coupling studies and some QCD processes at medium lumi (inclusive and exclusive diffractive jets, DPE diffractive W production) This physics cannot be presently done elsewhere at the LHC
- Possibility to test easily models of diffraction (W asymmetries), and measurement of u/d in pomeron
- Final design of movable beam pipe: in progress, approval procedure with LHC beam division management in progress, (first meeting 10 days ago organised by Marzio, Daniela, Christophe, people involved from beam division identified)
- Timing detectors: possibilities to achieve 10 ps with R&D proposal
- Si detectors: Follow detector and readout chip developped for IBL
- All pieces at hand to achieve phase 0 : detector solution to perform QCD program and to achieve unprecedented sensitivities to anomalous couplings at 30 fb^{-1} already available
- Saclay: mechanical studies for Si detector - fast timing electronics