The ATLAS Forward Physics Project (AFP)

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Workshop on exclusive and diffractive processes
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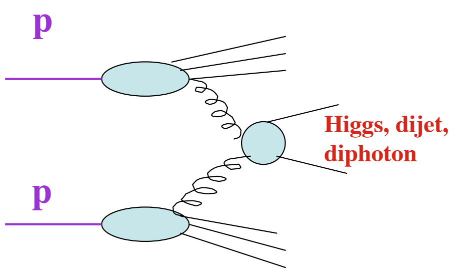
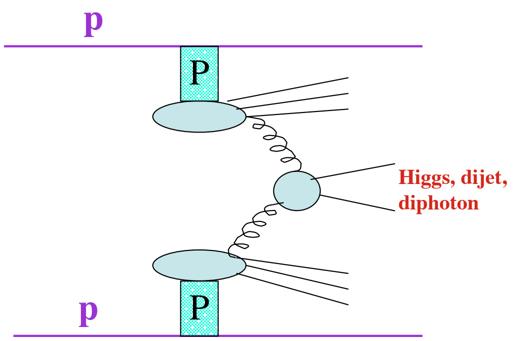
Contents:

- Physics motivation
- AFP detector location
- Movable beam pipe
- Si detector
- Timing detectors

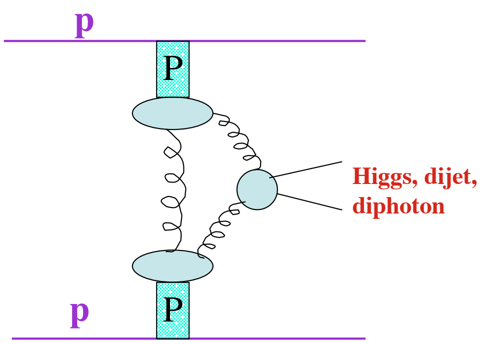
“Exclusive models” in diffraction



Inclusive non diffractive (1)



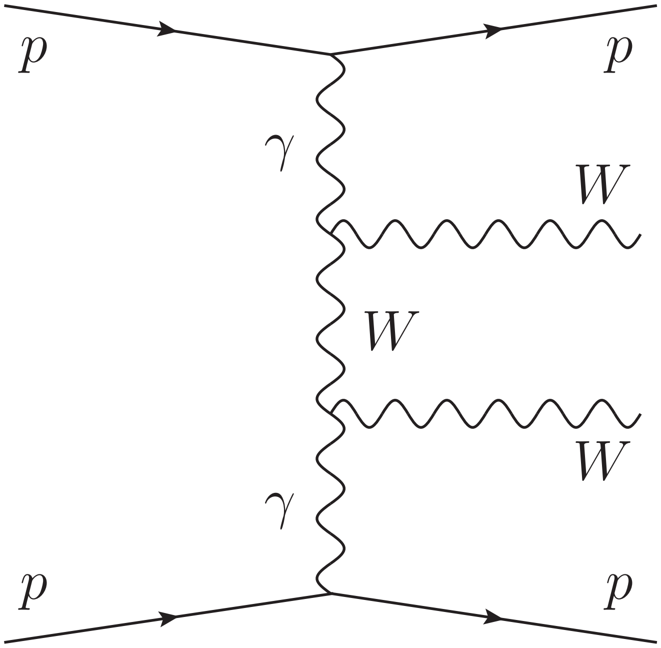
Inclusive Diffractive (2)



Exclusive Diffractive (3)

- All the energy is used to produce the Higgs (or the dijets, WW...), namely $xG \sim \delta$
- Possibility to reconstruct the properties of the produced object from the tagged proton: system completely constrained
- Process which can be used for any particle production (SUSY, resonance, WW, Higgs, jets...)
- See talk by Marek for more information about exclusive Higgs production cross section

WW production at the LHC



- Study of the process: $pp \rightarrow ppWW$
- Clean process: W in central detector and nothing else, intact protons in final state which can be detected far away from interaction point
- Exclusive production of W pairs via photon exchange: QED process, cross section perfectly known
- Two steps: SM observation of WW events, anomalous coupling study
- $\sigma_{WW} = 95.6$ fb, $\sigma_{WW}(W > 1TeV) = 5.9$ fb
- Rich $\gamma\gamma$ physics at LHC: see E. Chapon, O. Kepka, C. Royon, Phys. Rev. D78 (2008) 073005; Phys. Rev. D81 (2010) 074003; T J. De Favereau et al., arXiv:0908.2020; Nicolas Schul, Trento 2010, http://diff2010-lhc.physi.uni-heidelberg.de/Talks/, and arXiv:0910.0202

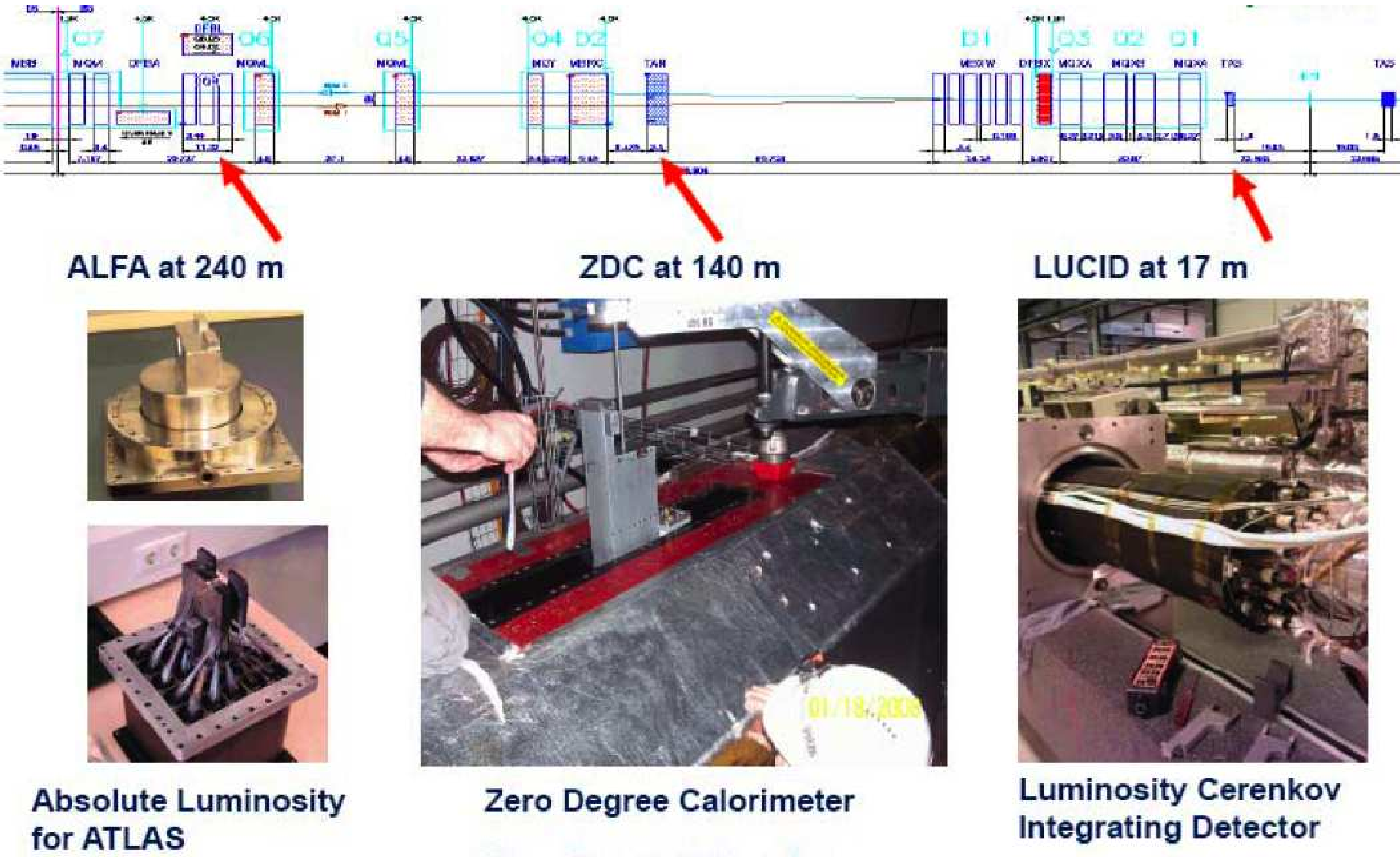
Reach at LHC

Reach at high luminosity on quartic anomalous coupling

Couplings	OPAL limits [GeV^{-2}]	Sensitivity @ $\mathcal{L} = 30$ (200) fb^{-1} 5σ	95% CL
a_0^W/Λ^2	[-0.020, 0.020]	5.4 10^{-6} (2.7 10^{-6})	2.6 10^{-6} (1.4 10^{-6})
a_C^W/Λ^2	[-0.052, 0.037]	2.0 10^{-5} (9.6 10^{-6})	9.4 10^{-6} (5.2 10^{-6})
a_0^Z/Λ^2	[-0.007, 0.023]	1.4 10^{-5} (5.5 10^{-6})	6.4 10^{-6} (2.5 10^{-6})
a_C^Z/Λ^2	[-0.029, 0.029]	5.2 10^{-5} (2.0 10^{-5})	2.4 10^{-5} (9.2 10^{-6})

- Improvement of LEP sensitivity by more than 4 orders of magnitude with 30/200 fb^{-1} at LHC!!!
- Reaches the values predicted by Higgsless/extradimension models

Forward detectors in ATLAS



ALFA at 240 m

ZDC at 140 m

LUCID at 17 m

Absolute Luminosity for ATLAS

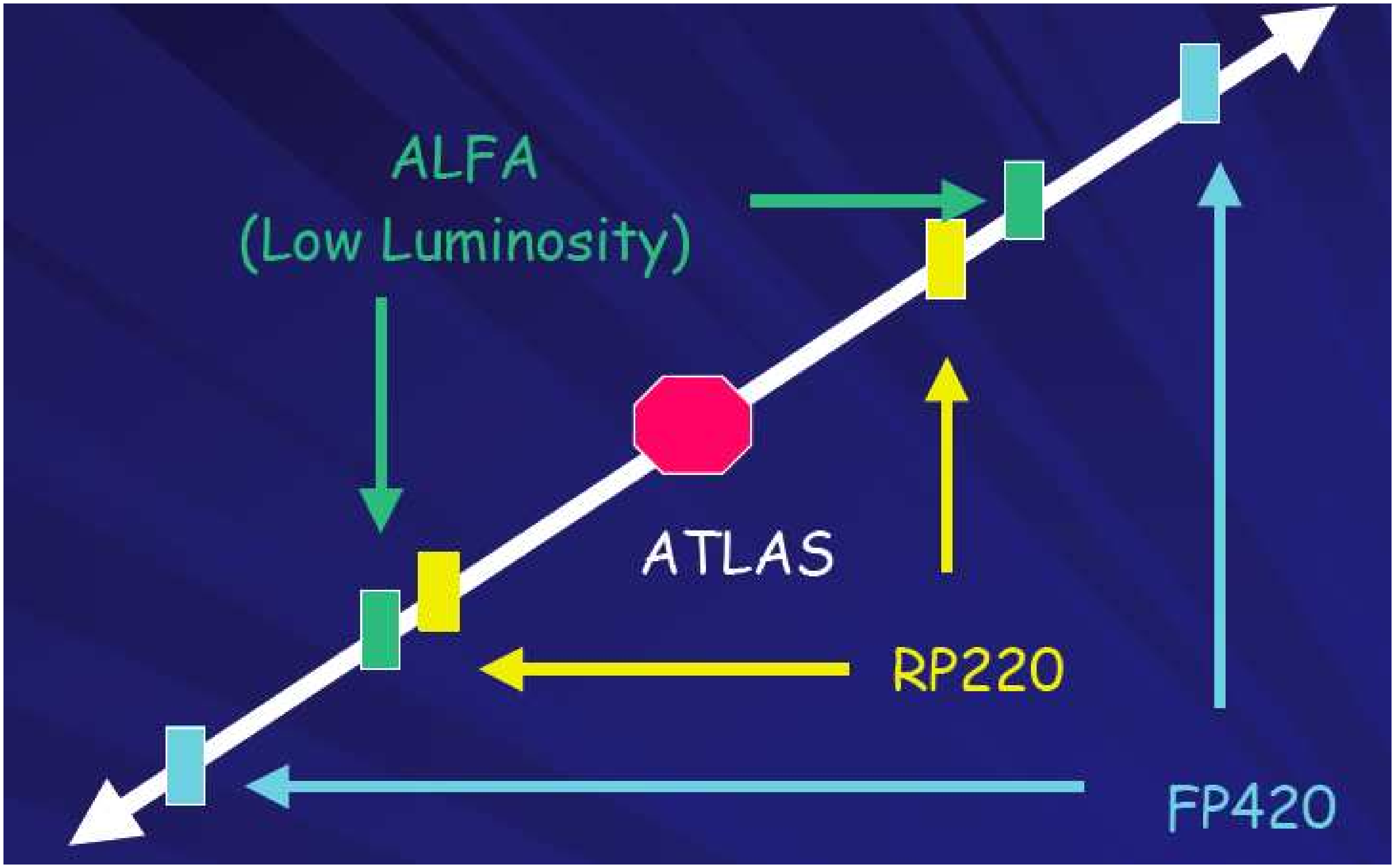
Zero Degree Calorimeter

Luminosity Cerenkov Integrating Detector

- ALFA
- ZDC
- LUCID

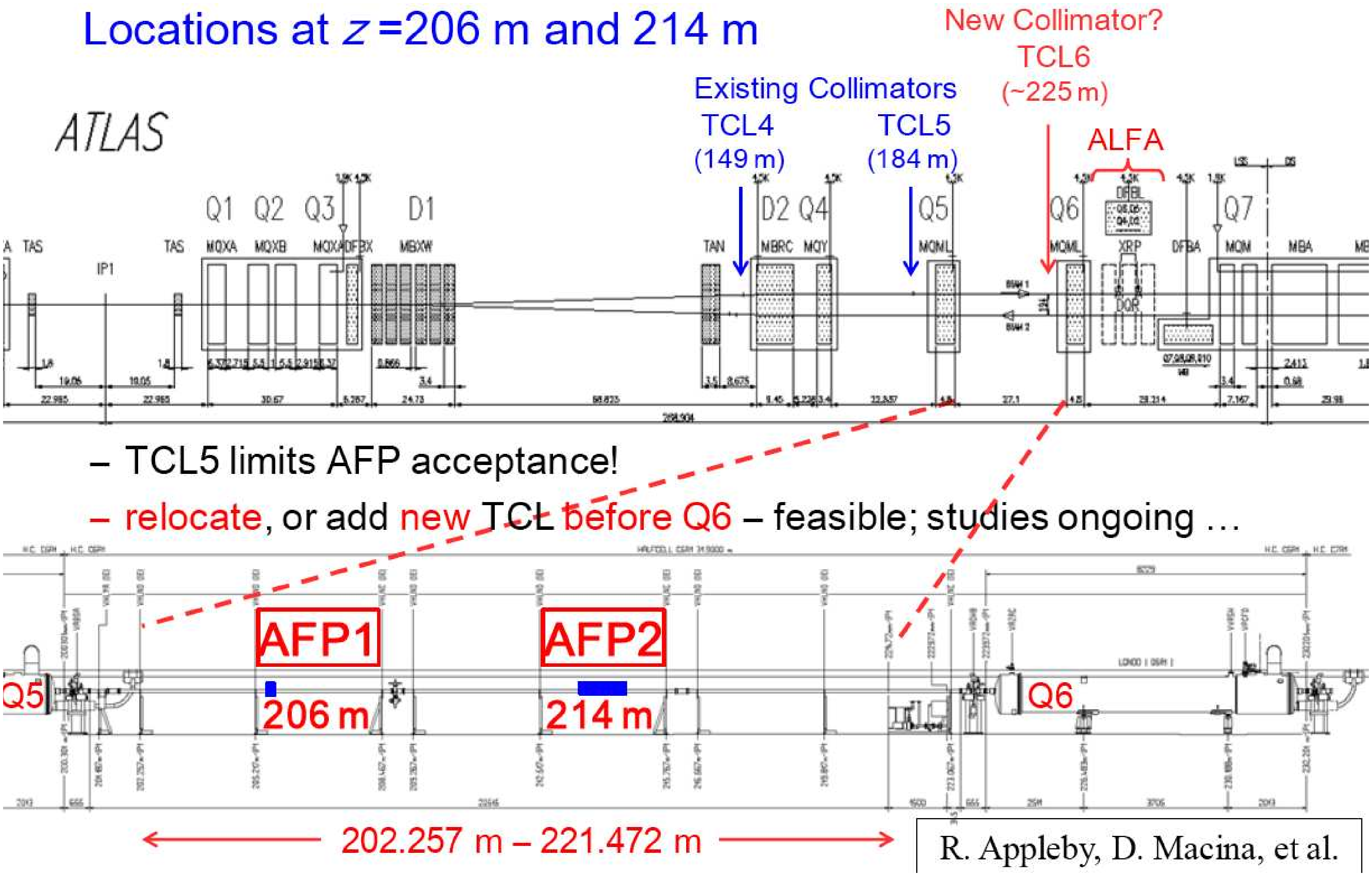
Detector location

- what is needed? Good position and good timing measurements
- 210 m: movable beam pipes - for phase 1, only 210 m forward detectors
- 420 m: movable beam pipe (roman pots impossible because of lack of space available and cold region of LHC) - phase 2 of project



Location of AFP detectors in phase 1

Locations at z =206 m and 214 m

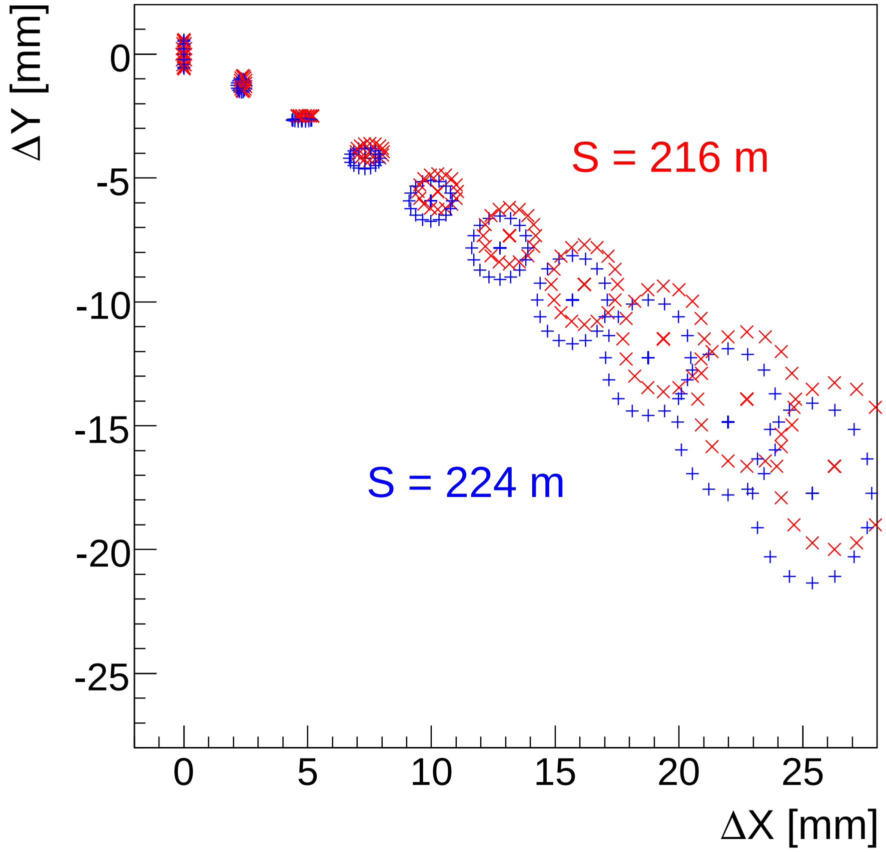


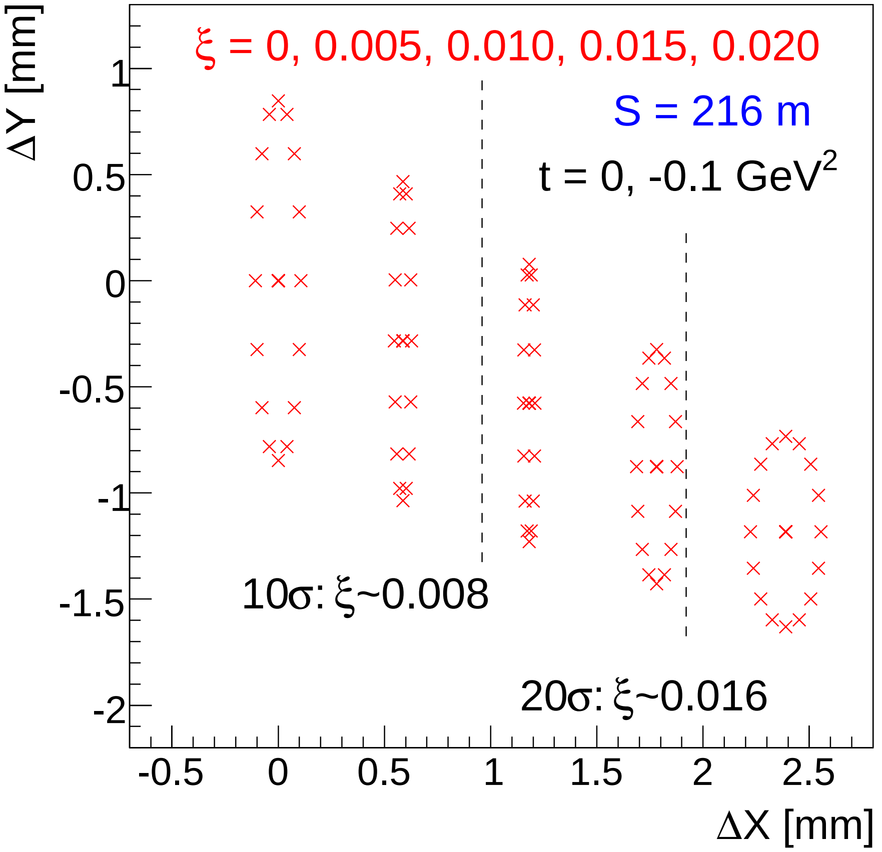
- TCL5 limits AFP acceptance!
- relocate, or add new TCL before Q6 – feasible; studies ongoing …

R. Appleby, D. Macina, et al.

Example: Acceptance for 210 m detectors

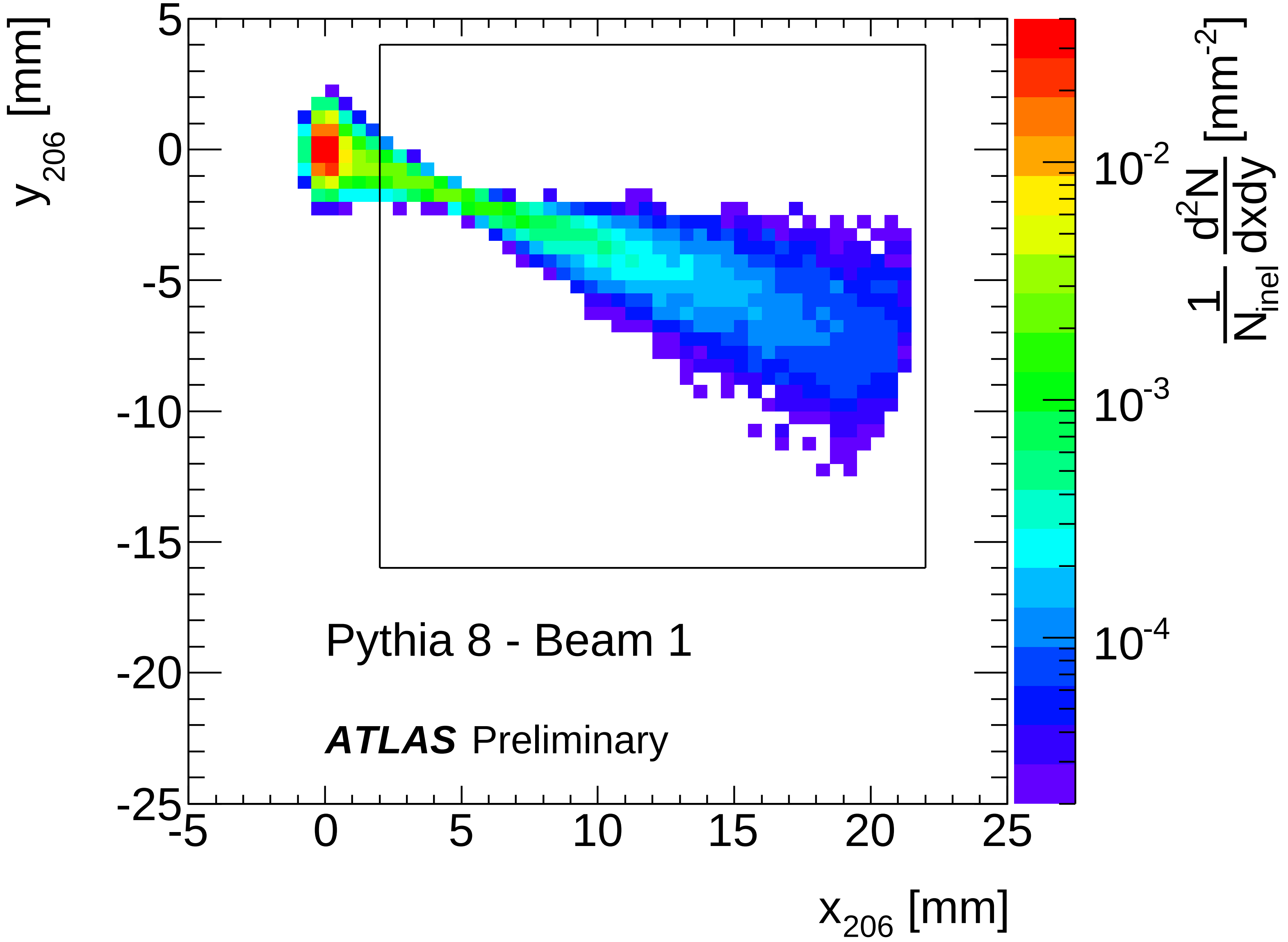
- Steps in ξ: 0.02 (left), 0.005 (right), $|t|$=0 or 0.05 GeV^2
- Detector of 2 cm × 2 cm will have an acceptance up to $\xi \sim 0.16$, down to 0.008 at 10 σ, 0.016 at 20 σ
- Estimate: possibility to insert the detectors up to $\sim 15\sigma$ from the beam routinely (10 σ will be possible after some experience)
- Detector coverage of 2 cm × 2 cm needed





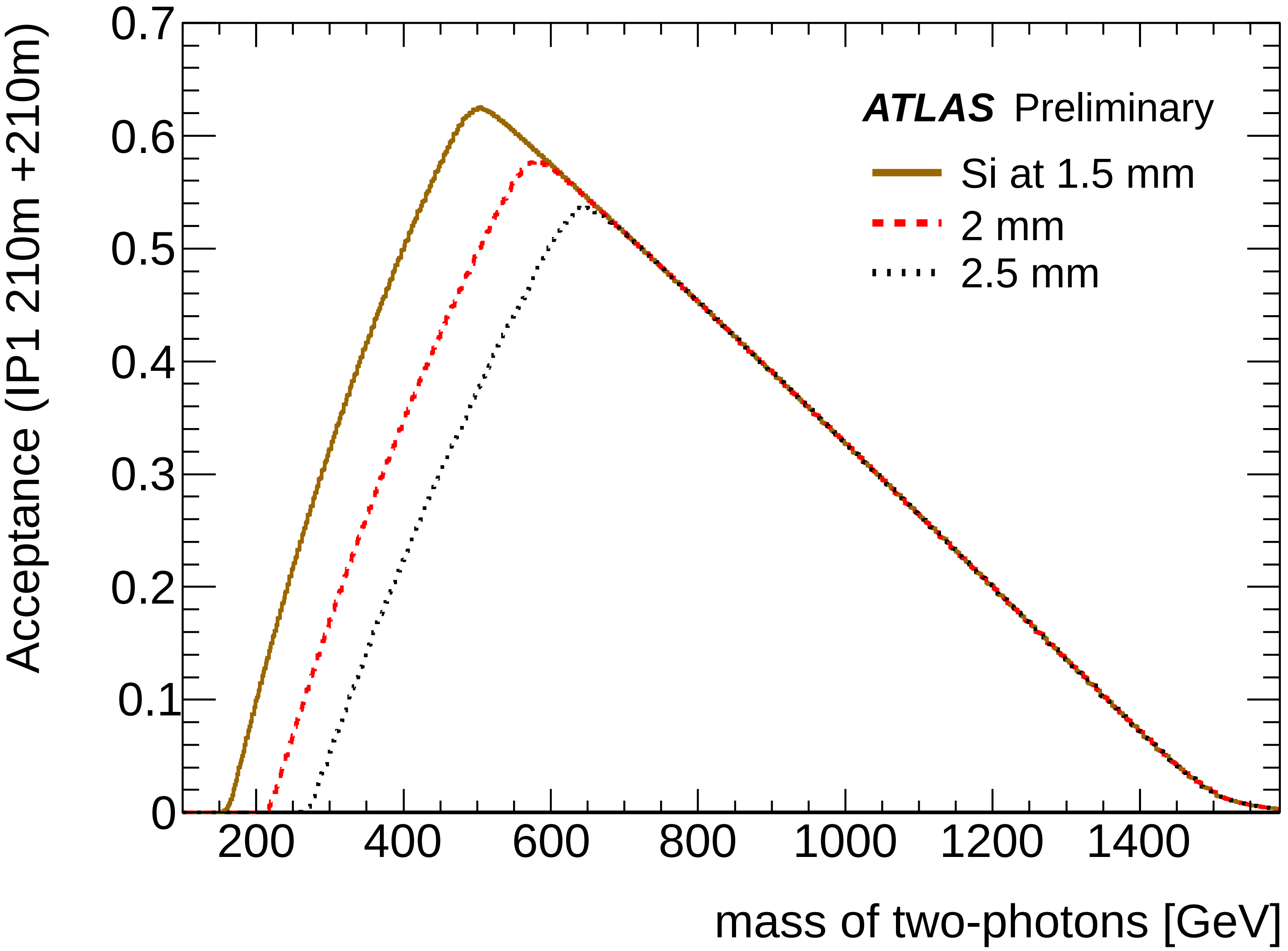
ATLAS Forward Physics detector acceptance

Positions of proton detected by AFP and rates observed in the detectors



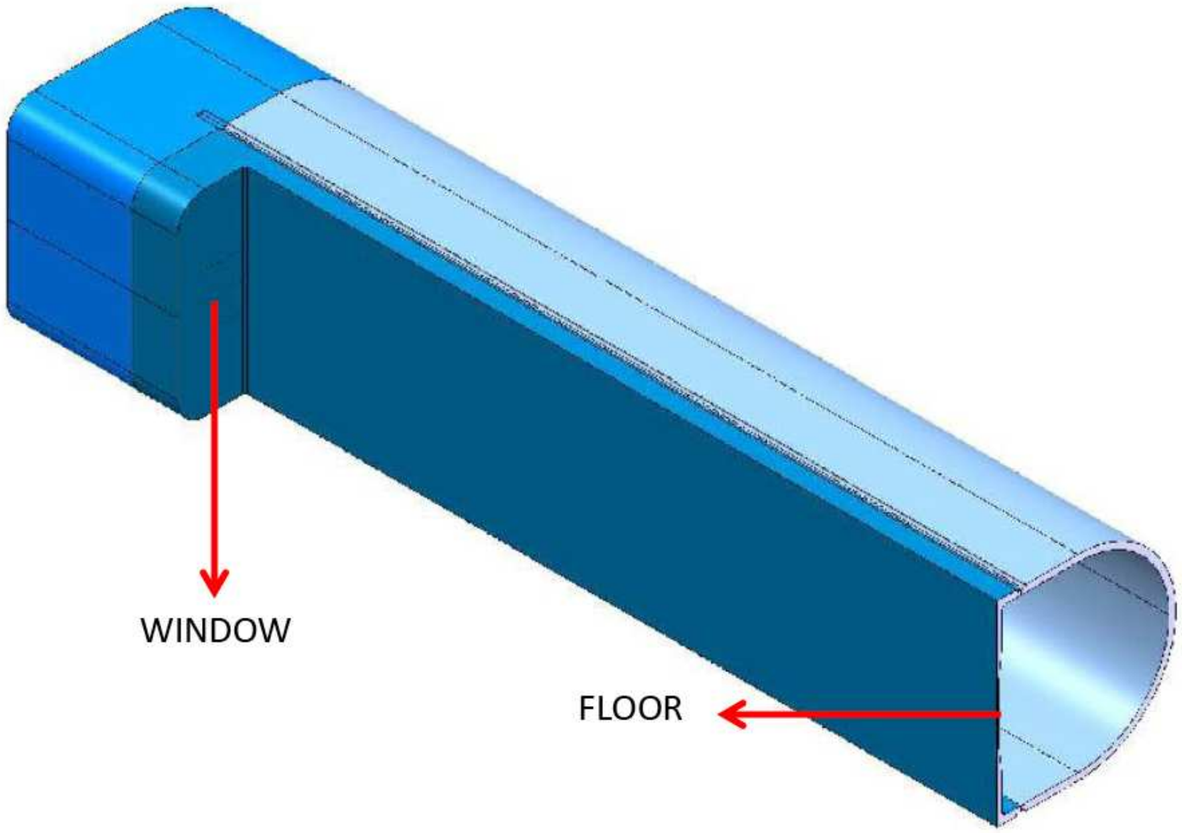
ATLAS Forward Physics detector acceptance

Acceptance in mass for the 210 m detectors



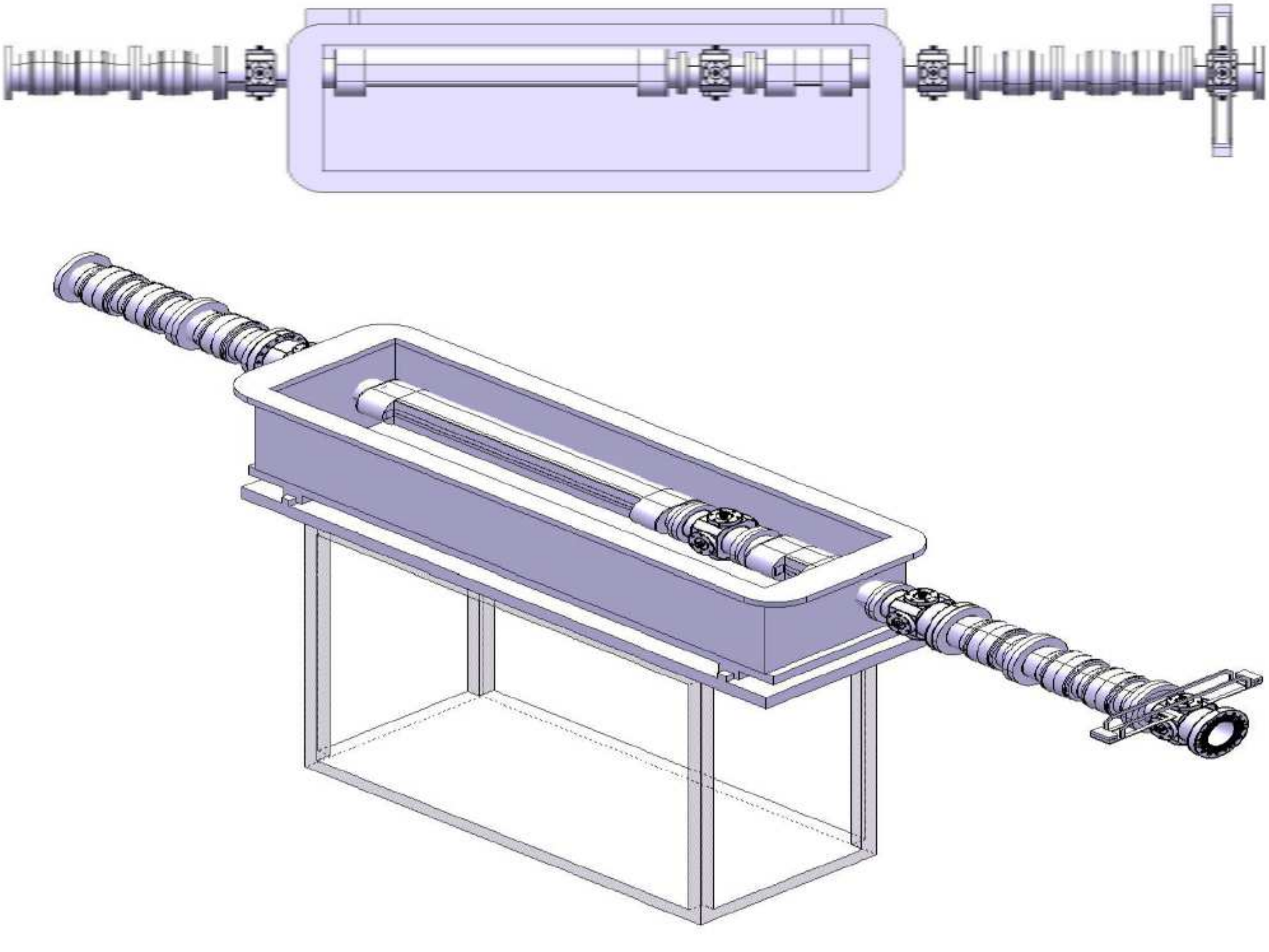
Movable beam pipes

- allow precise and repeatable movement of detectors close to the beam by $\sim$ 25 mm (HERA, Louvain, CERN)
- minimum deformation, thin vacuum window (detector a few mm from the beam), small RF impact
- use standard LHC components (bellows...)
- Choose movable beam pipe technique: less mechanical stress than roman pots since a fixed vacuum volume is maintained
- The movable beam pipe is treated as an instrumented collimator from the LHC point of view which does not go as close to the beam as the collimator, uses same motors



Movable beam pipes

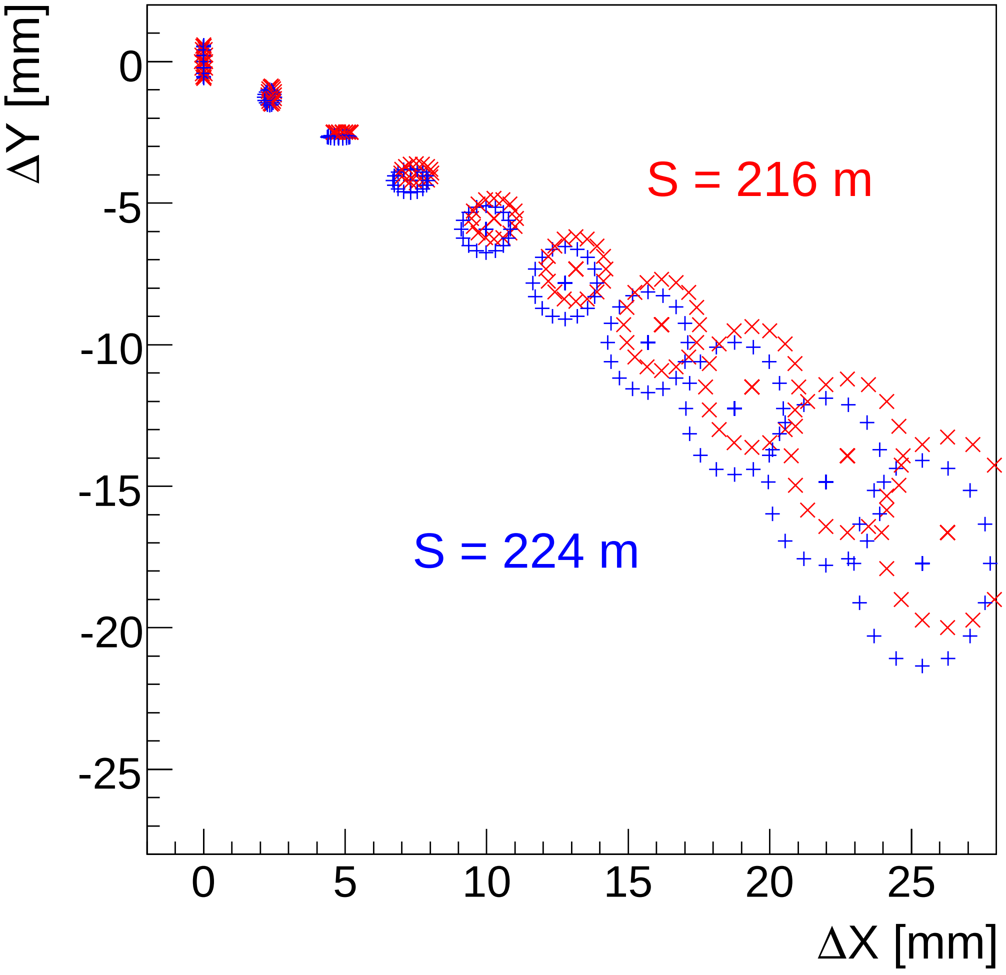
- Different elements of movable beam pipes: bellows, movable beam pipe, Si pocket, timing detector pocket, moving and fixed beam position monitors (BPM)
- For 2013-14 shutdown: restrict to 210 m detectors
- 2 pockets for Si/timing detector 206 m: Si; 214 m: Si, QUARTIC



Si tracking detector

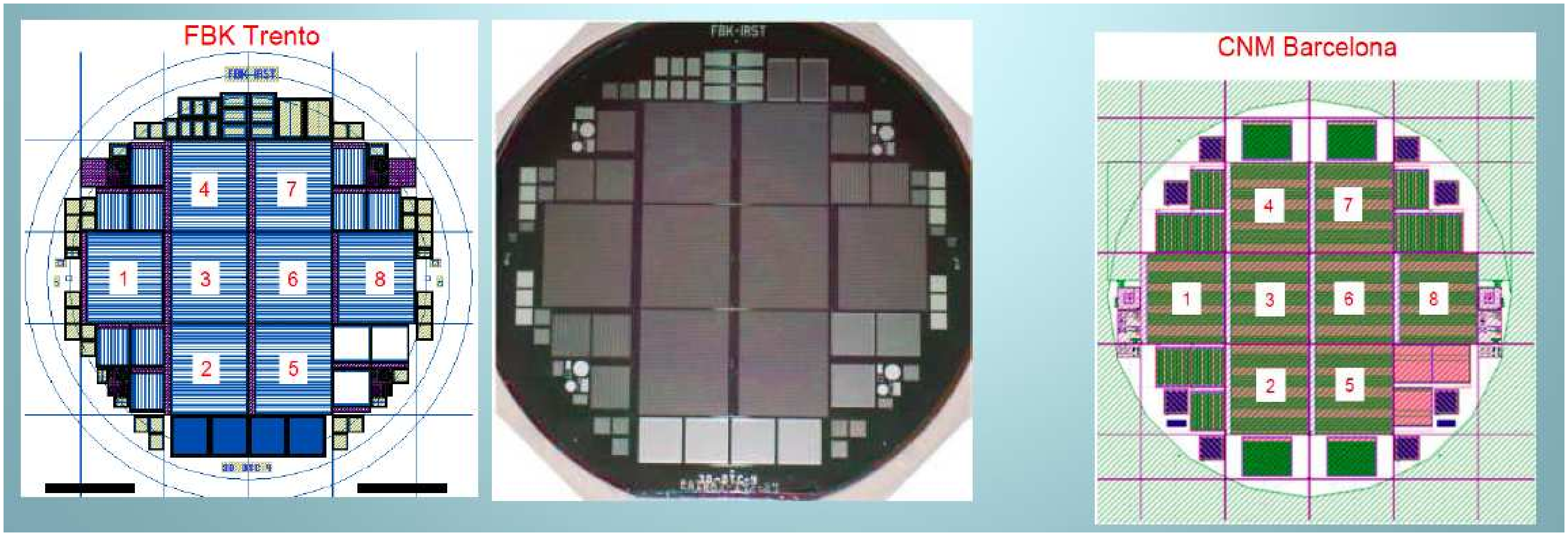
Key requirements for the Si detector

- Spatial resolution of 10 (30) μm in x (y) direction
- Angular resolution of about 1 μrad
- High efficiency over 20 mm × 20 mm
- minimal dead space at the edge
- Sufficient radiation hardness



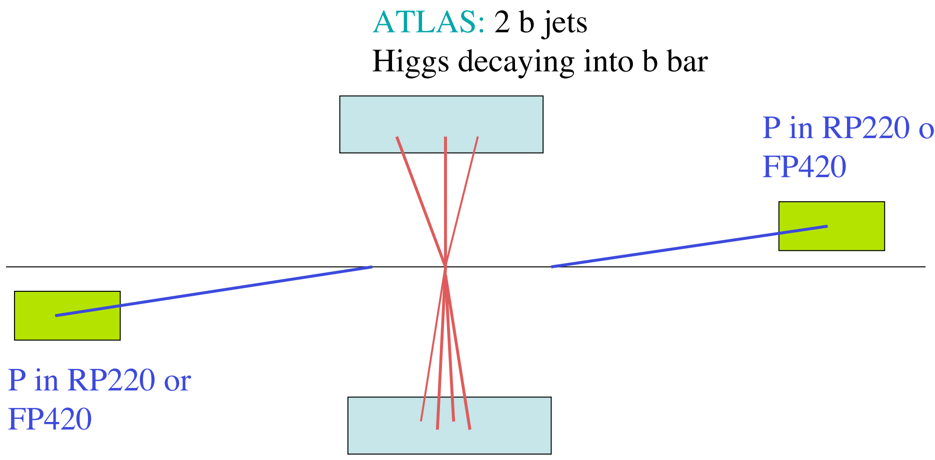
Si detector: sensors

- Different options prossible for Si sensors (we benefit and follow the ATLAS IBL project)
- 3D sensors: Double sided 3D sensors or single sided full 3D with active edges
- Readout chip: FEI4, 1 chip needed per silicon layer, New FEI4 chip: radiation hard
- Cooling: under study, thermosiphon or vortex-based dry air cooling (local station enough to cool down Si, only compressed air needed)



Why do we need timing detectors?

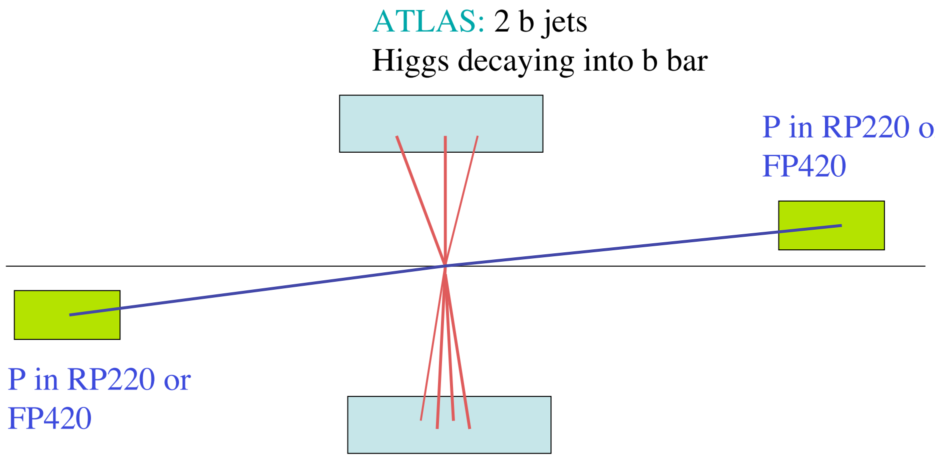
We want to find the events where the protons are related to Higgs production and not to another soft event (up to 35 events occuring at the same time at the LHC!!!!)



ATLAS: 2 b jets
Higgs decaying into b bar

P in RP220 or
FP420

P in RP220 or
FP420



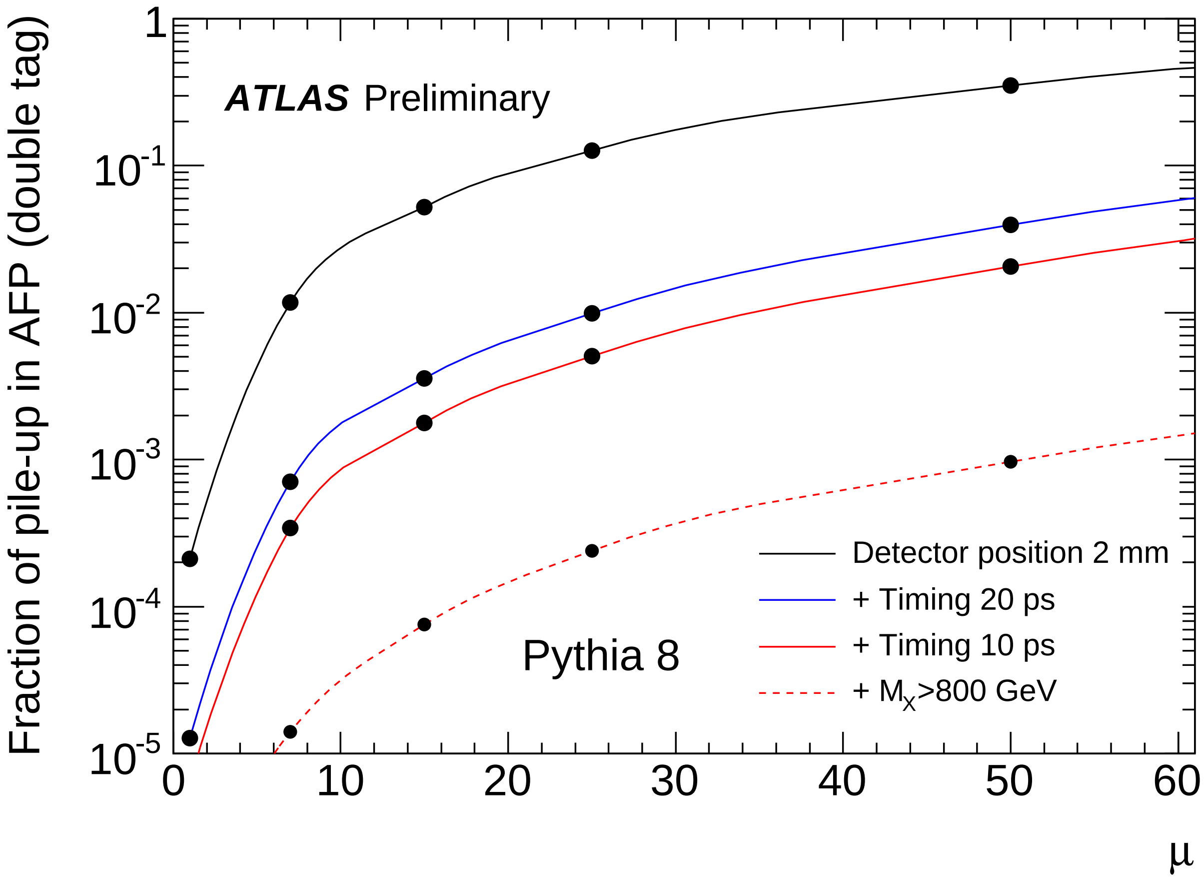
ATLAS: 2 b jets
Higgs decaying into b bar

P in RP220 or
FP420

P in RP220 or
FP420

Why do we need timing detectors?

- Fraction of pile up events seen in AFP as a function of the number of interactions
- Effect of 10/20 ps resolution timing detectors
- Effect of requesting high mass object to be centrally produced: pile up events produced mainly at low ξ close to the beam in AFP whereas high mass events are produced further away from the beam

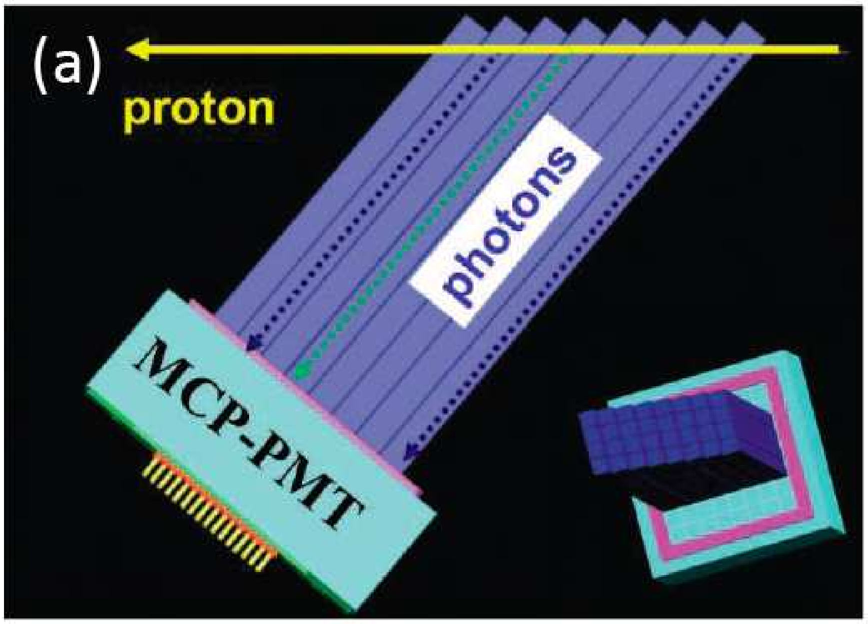


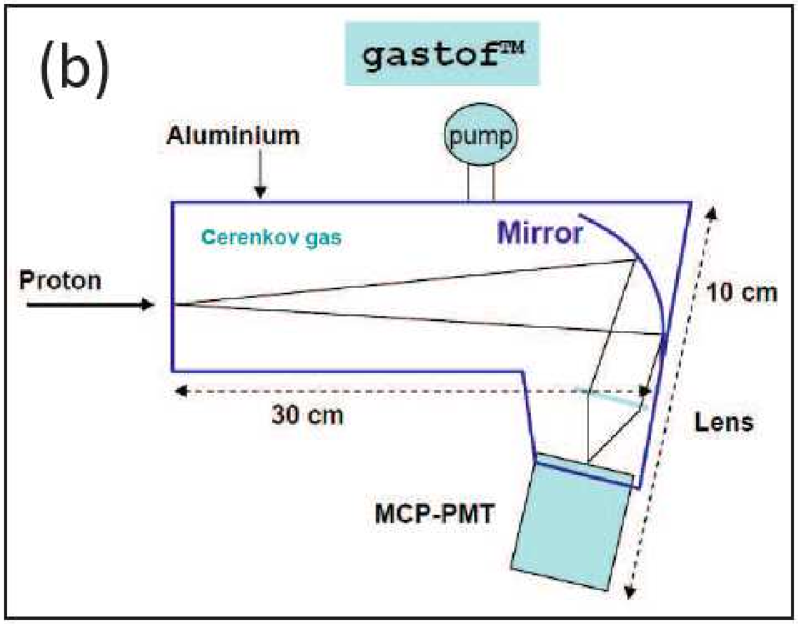
QUARTIC and GASTOF timing detectors

Requirements for timing detectors

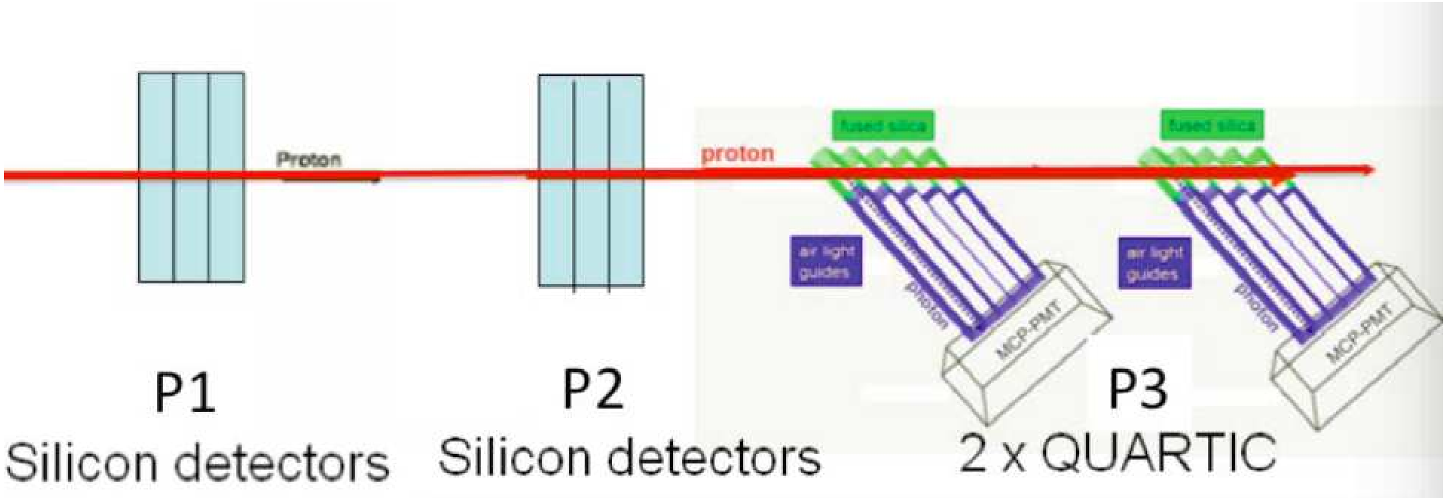
- 10 ps final precision (15-20 ps for phase 0) (GASTOF, QUARTIC)
- acceptance that fully cover the tracking detectos, efficiency close to 100%
- high rate capability
- segmentation for multi-proton timing
- level 1 trigger capability

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

How to achieve 10-20 ps timing resolution?

- Present achievement: ∼14 ps with one QUARTIC (8 times the same measurement with 8 bars)
- Future achievement (minor modifications) ∼ 7 ps with two QUARTICS
- Longer term achievements: 1 ps for readout Chip, better spatial resolution (∼ 1 mm^2)

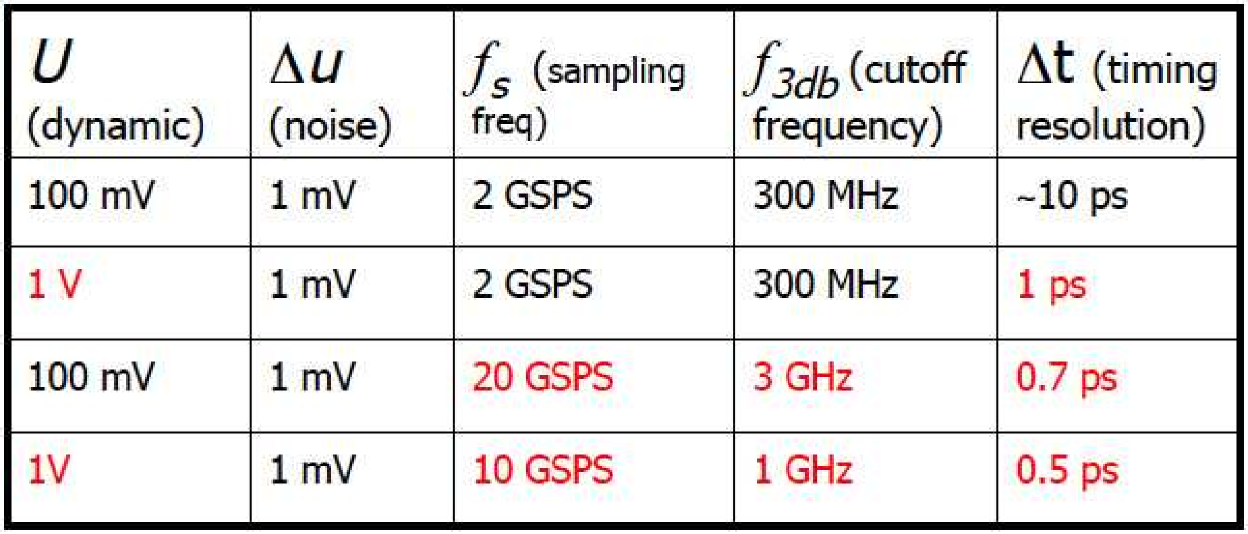
Component	Time resolution (ps)
Radiator (quartz bar) 10-15 pe's	22 (15)
MCP-PMT (64 channel 25 μm Planacon)	20 (16)
CFD	5
Total	30
Cable dispersion	15%
Total	34.5
HPTDC	20 (12)
Reference clock	5
Total per bar	40 (30)
Total for 8 channel quartic	14
Total for 2 QUARTIC	10 (7)

Possibility of using cheaper new chips to be built in Saclay with a preicison of about 1 ps

Saclay: Going beyond the present chip

- Issues with present usual chips (SAM for instance):
  - Bandwidth and sampling rate not large enough
  - Cannot sustain 40 MHz event rate
  - 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 and pipeline
- 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

Conclusion and timescale

- Diffractive physics at the LHC: QCD, Higgs, WW, anomalous coupling, SUSY, resonances...
- AFP project: movable beam pipes needed at 210/420 m - 2 phases: 210 m detectors only to be installed in 2013, 420 m additional detectors to be installed if physics motivates it later
- Position detectors to be used: 3D Silicon
- Timing detectors: High precision needed especially for high luminosity at the LHC ($\sim$ 10-15 picoseconds), QUARTIC
- Timescale: Letter of Intent approved by ATLAS, under review by LHCC; many groups involved: France (Saclay), Poland (Cracow), Czech Republic (Prague), Italy (Bologna, Milano), Spain (Barcelona), Portugal (Lisbon), USA (Texas Arlington, Stony Brook, New Mexico, SLAC, Oklahoma), Canada (Alberta), Germany (Giessen, Wuppertal), others joining
- Management structure in progress: Christophe Royon, ATLAS Forward Physics Project Coordinator
- Many developments performed/in progress for the project and extremly useful for the future in particle physics or medical applications: 3D Si, timing detectors