# The ATLAS Forward Physics Project (AFP)

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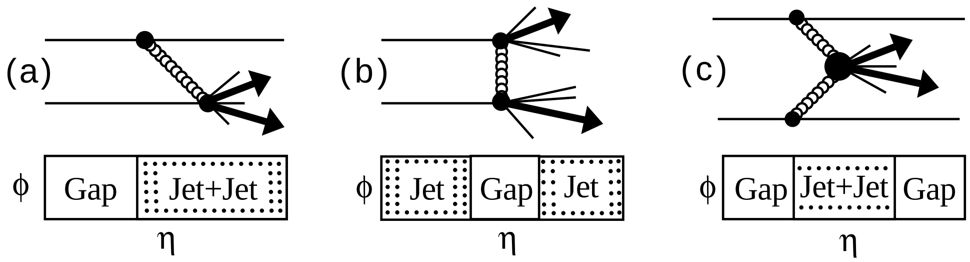
**QCD and diffraction at the LHC,**
**Cracow, Poland, November 29 2011**

Contents:

- Hard diffraction at the LHC
- Diffractive Higgs production at the LHC
- Anomalous $W\gamma$ couplings at the LHC
- ATLAS Forward Physics (AFP) project

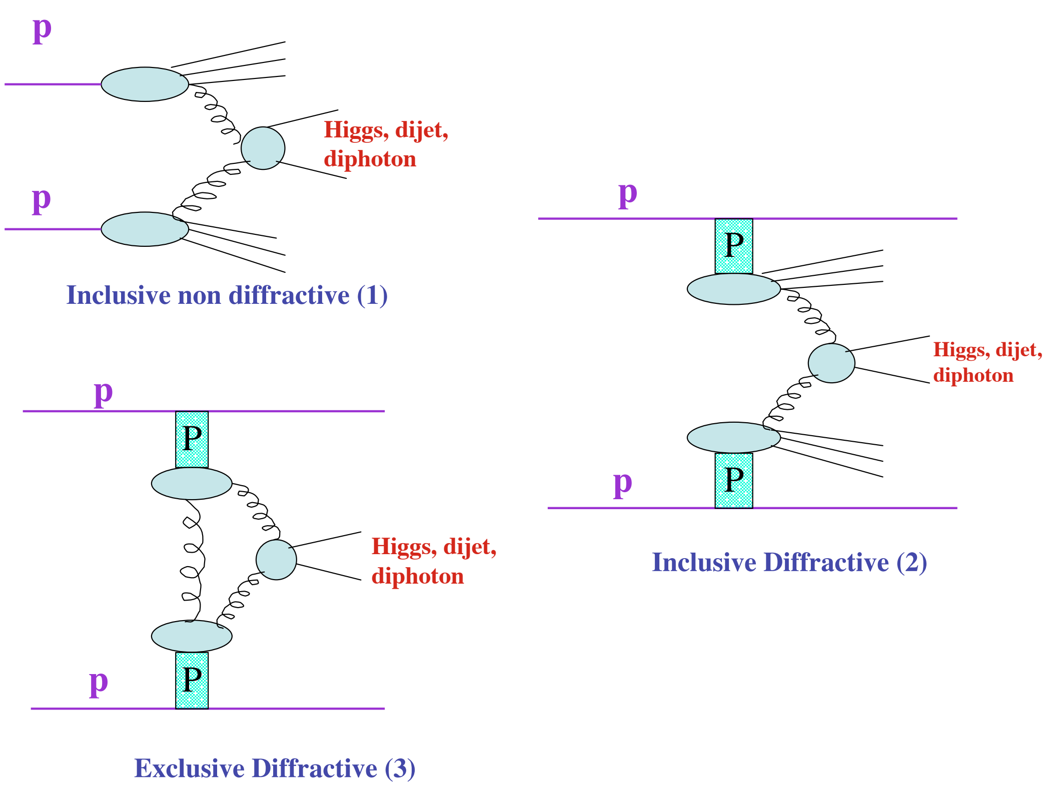
# Diffraction at Tevatron/LHC




## Kinematic variables

- $t$: 4-momentum transfer squared
- $\xi_1, \xi_2$: proton fractional momentum loss (momentum fraction of the proton carried by the pomeron)
- $\beta_{1,2} = x_{Bj,1,2}/\xi_{1,2}$: Bjorken-x of parton inside the pomeron
- $M^2 = s\xi_1\xi_2$: diffractive mass produced
- $\Delta y_{1,2} \sim \Delta\eta \sim \log 1/\xi_{1,2}$: rapidity gap

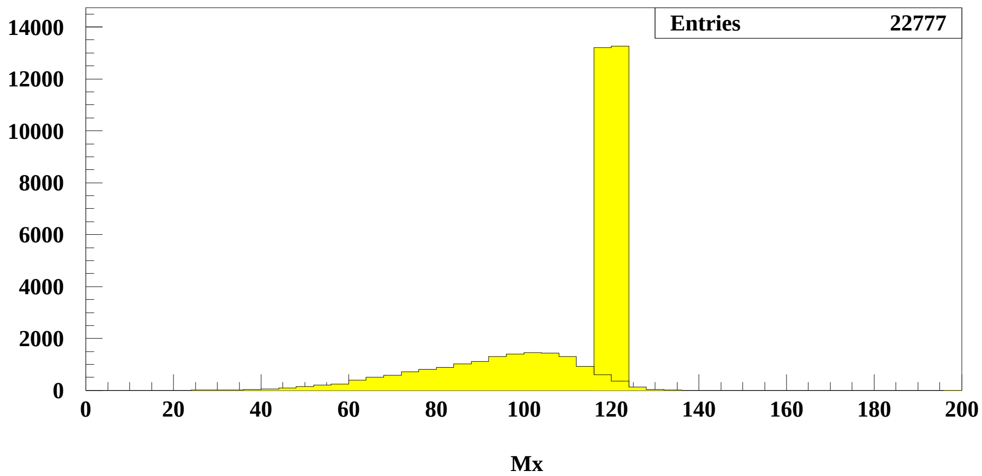
# “Exclusive models” in diffraction

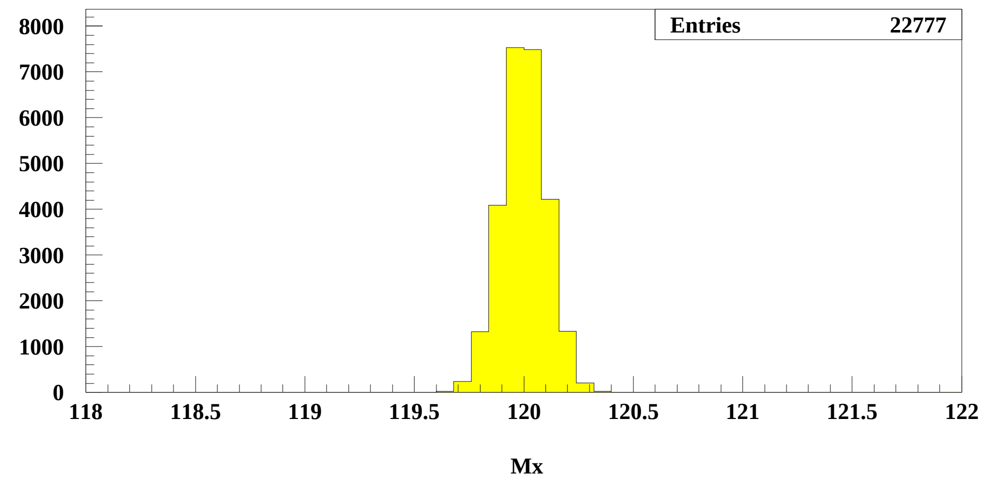



- All the energy is used to produce the Higgs (or the dijets), namely $xG \sim \delta$
- Possibility to reconstruct the Higgs boson properties from the tagged proton: system completely constrained
- See papers by Khoze, Martin, Ryskin; Boonekamp, Peschanski, Royon; Sczurek, Pasechnik; Dechambre, Cudell, Ivanov...

# Advantage of exclusive Higgs production?

- Good Higgs mass reconstruction: fully constrained system, Higgs mass reconstructed using both tagged protons in the final state ($pp \to pHp$)
- No energy loss in pomeron "remnants"
- Mass resolution of the order of 2-3% after detector simulation



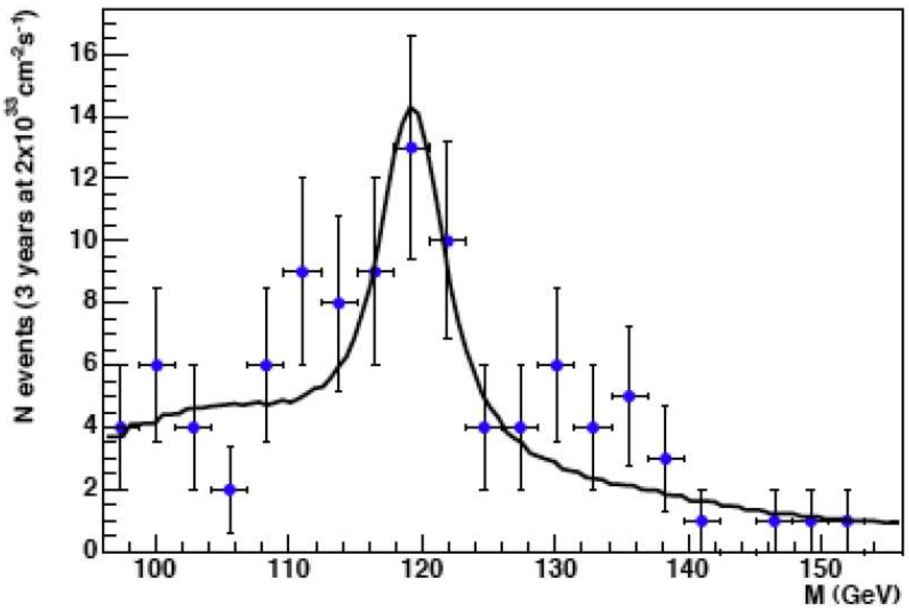



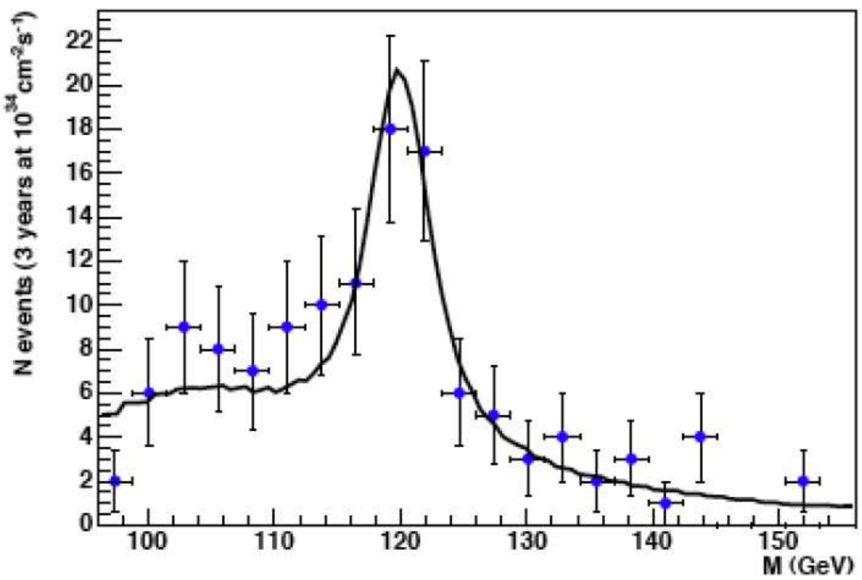
## Forward Physics Monte Carlo (FPMC)

- FPMC (Forward Physics Monte Carlo): implementation of all diffractive/photon induced processes
- List of processes
  - two-photon exchange
  - single diffraction
  - double pomeron exchange
  - central exclusive production
- Inclusive diffraction: Use of diffractive PDFs measured at HERA, with a survival probability of 0.03 applied for LHC
- Survival probability for photon exchange events: 0.9
- Central exclusive production: Higgs, jets... for Khoze Martin Ryskin and Dechambre Cudell models
- FPMC manual (see M. Boonekamp, A. Dechambre, O. Kepka, V. Juranek, C. Royon, R. Staszewski, M. Rangel, ArXiv:1102.2531)
- Output of FPMC generator interfaced with the fast simulation of the ATLAS detector in the standalone ATLFast++ package

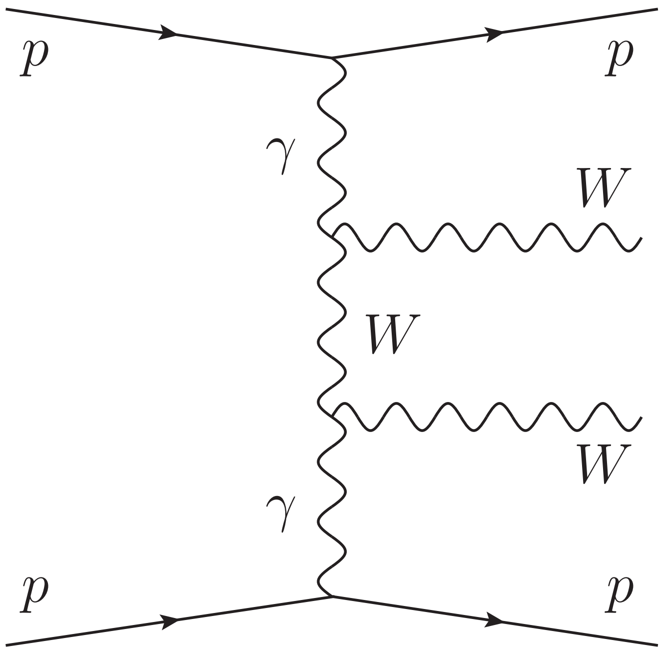
## SUSY Signal significance

- Signal and background full simulation, pile up effects taken into account: see B. Cox, F. Loebinger, A. Pilkington, JHEP 0710 (2007) 090 for $h$ production at $\tan\beta \sim 40$, 8 times higher cross section than SM
- Significance $> 3.5\sigma$ for 60 fb$^{-1}$ after detector acceptance
- Significance $> 5\sigma$ in 3 years at $10^{34}$ with timing detectors
- Diffractive Higgs boson production complementary to the standard search
- See talk by Valery



## $WW$ production at the LHC




- Study of the process: $pp \to ppWW$
- 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
- See talk by Hervé

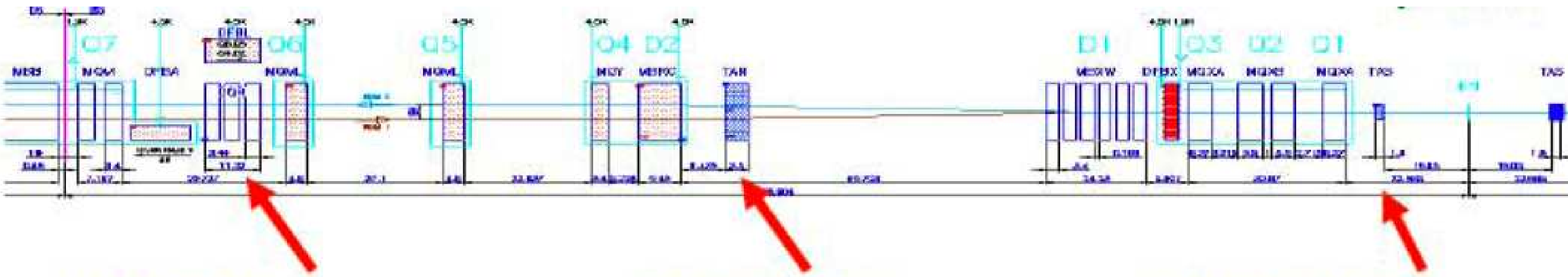
# Reach at LHC

Reach at high luminosity on quartic anomalous coupling

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

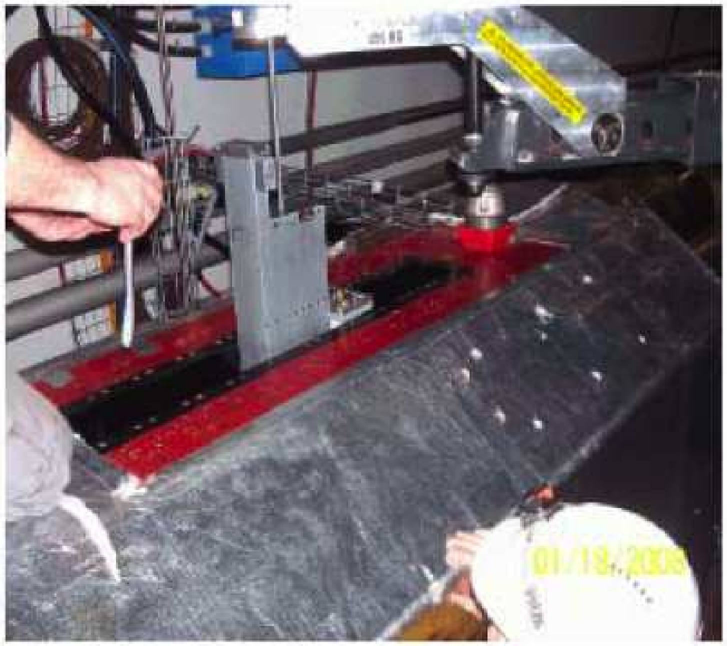
# Forward detectors in ATLAS




ALFA at 240 m

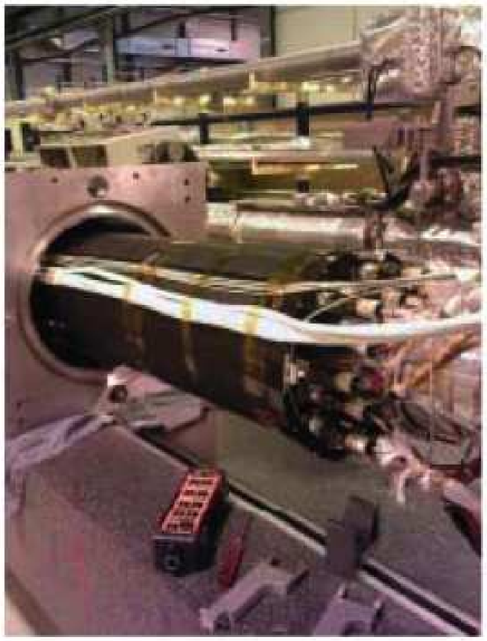
Absolute Luminosity for ATLAS

ZDC at 140 m



Zero Degree Calorimeter

LUCID at 17 m

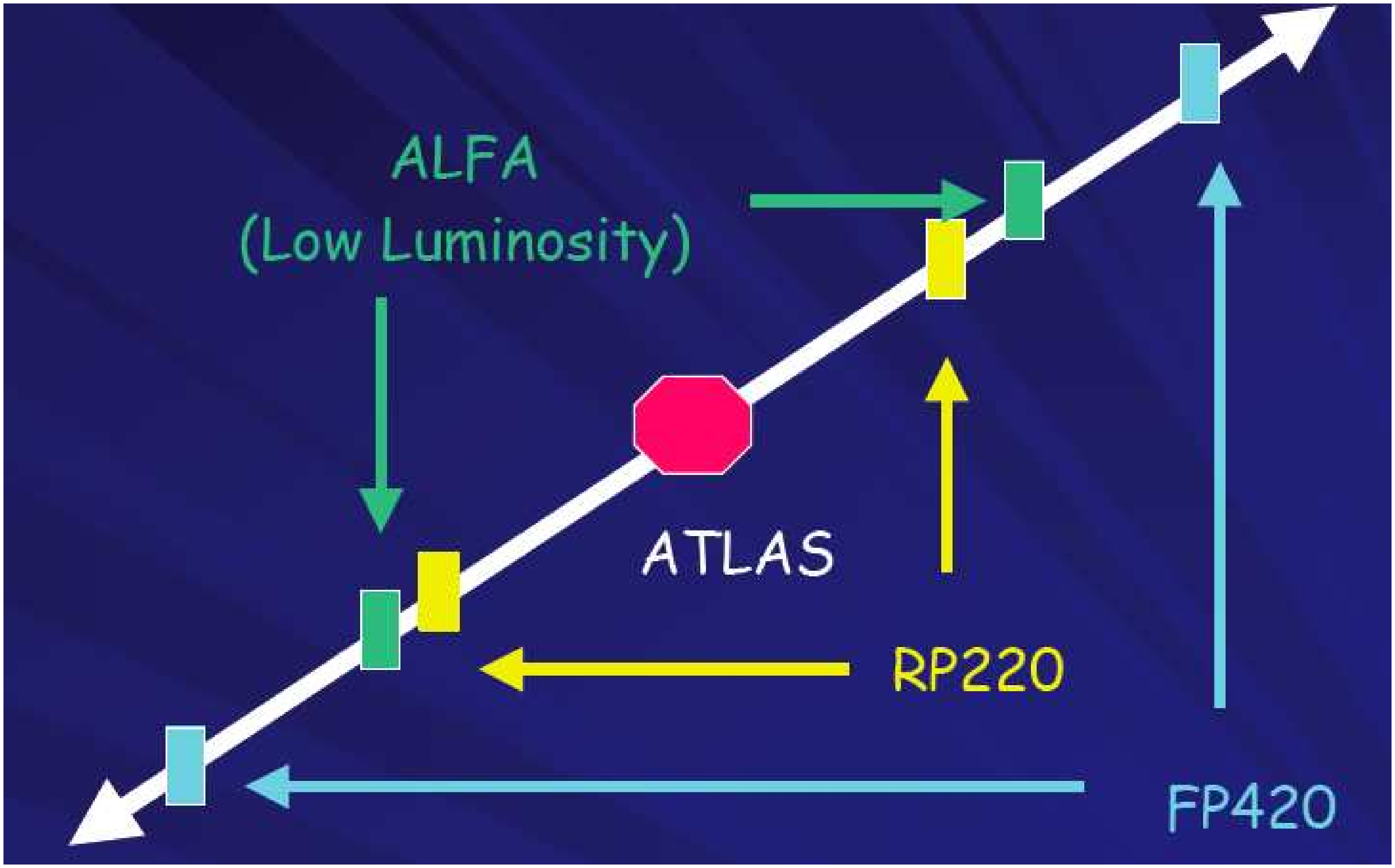


Luminosity Cerenkov Integrating Detector

- ALFA: TDR submitted, CERN/LHCC/2008-004, roman pots installed
- ZDC: Detector installed
- LUCID

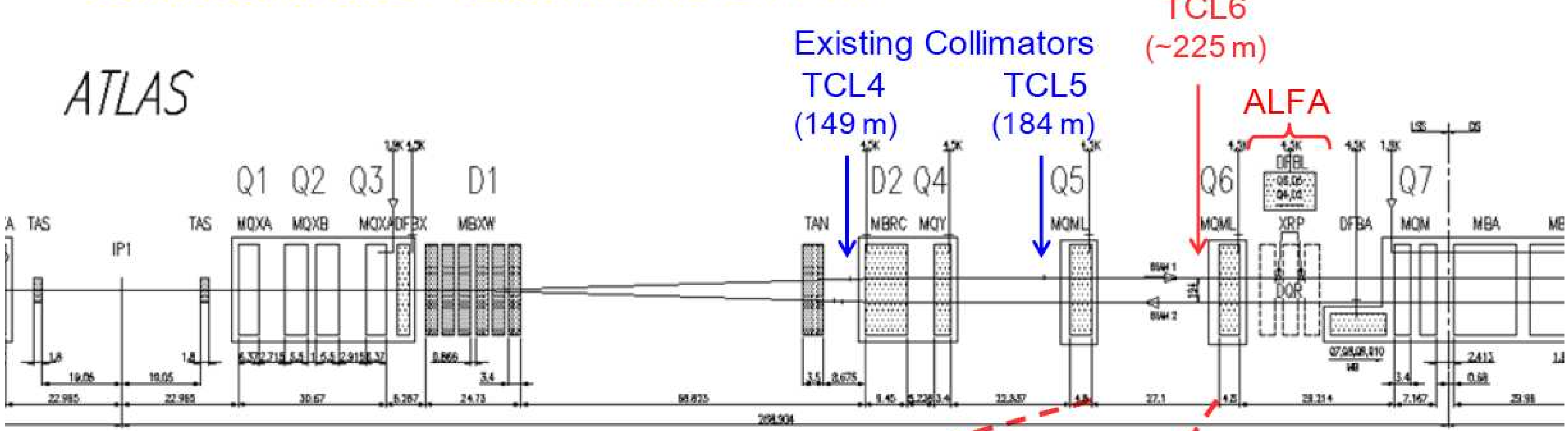
## Detector location

- what is needed? Good position and good timing measurements
- 220 m: movable beam pipes - for phase 1, only 220 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



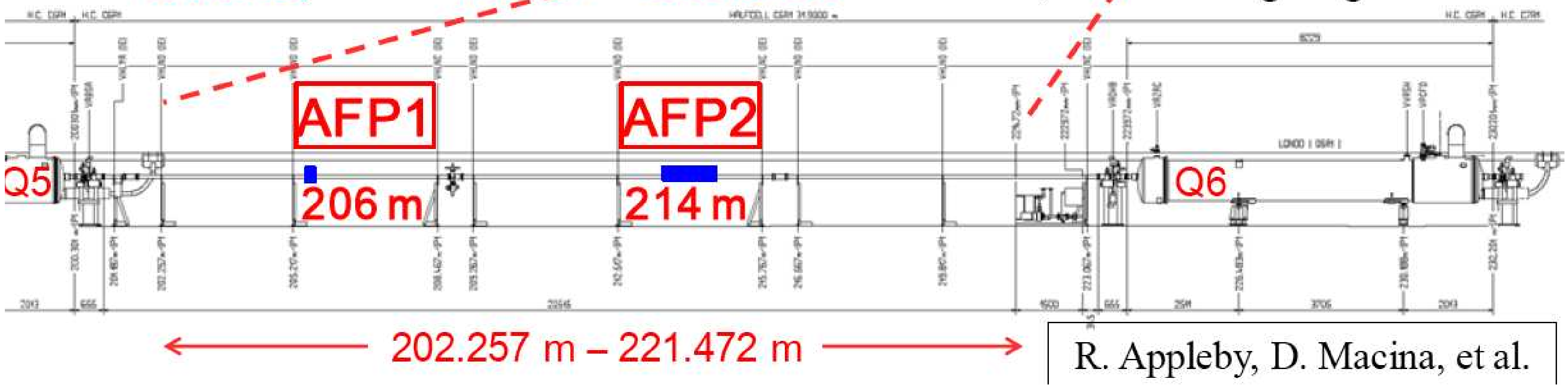
# Location of AFP detectors

## Locations at $z$ =206 m and 214 m



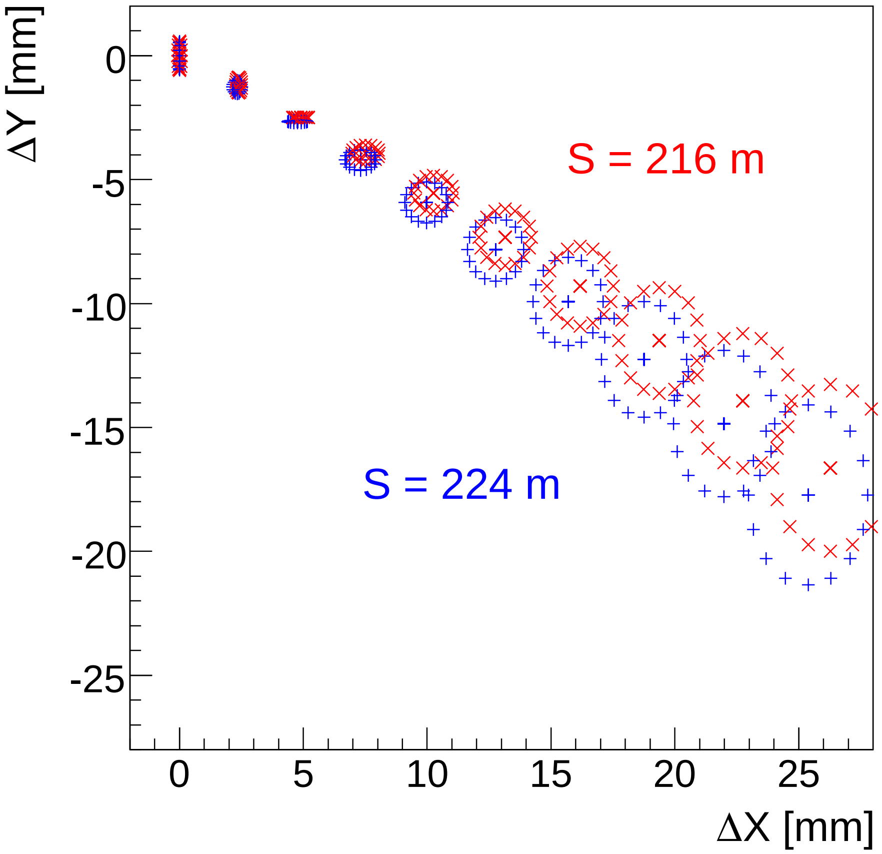

– TCL5 limits AFP acceptance!

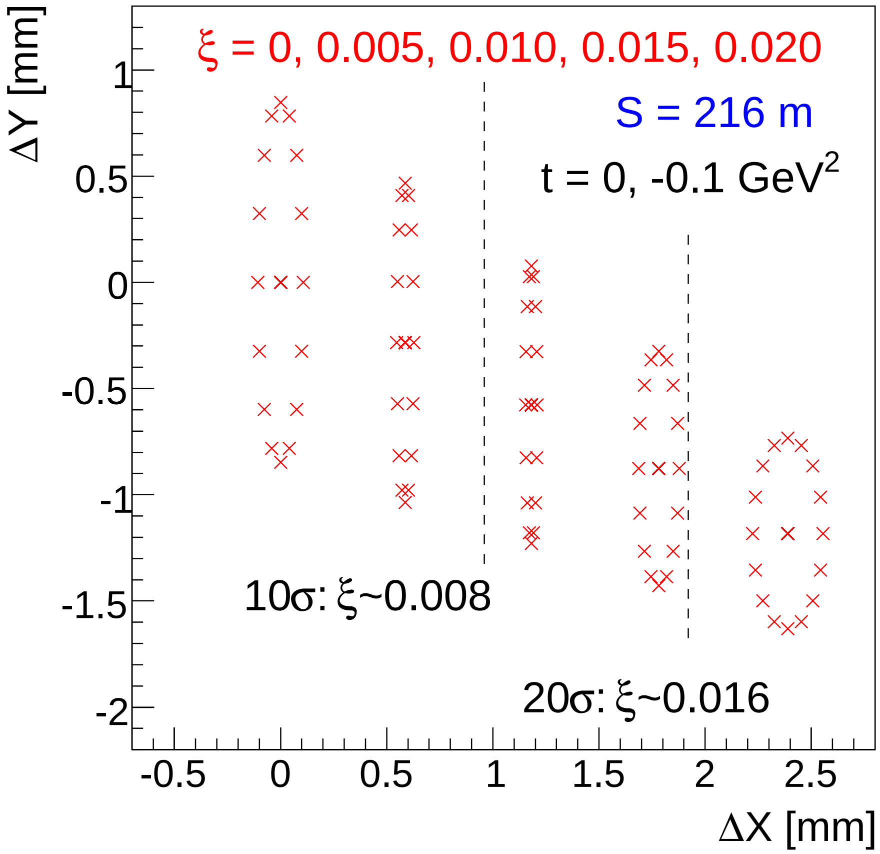
– relocate, or add new TCL before Q6 – feasible; studies ongoing …



# Example: Acceptance for 220 m detectors

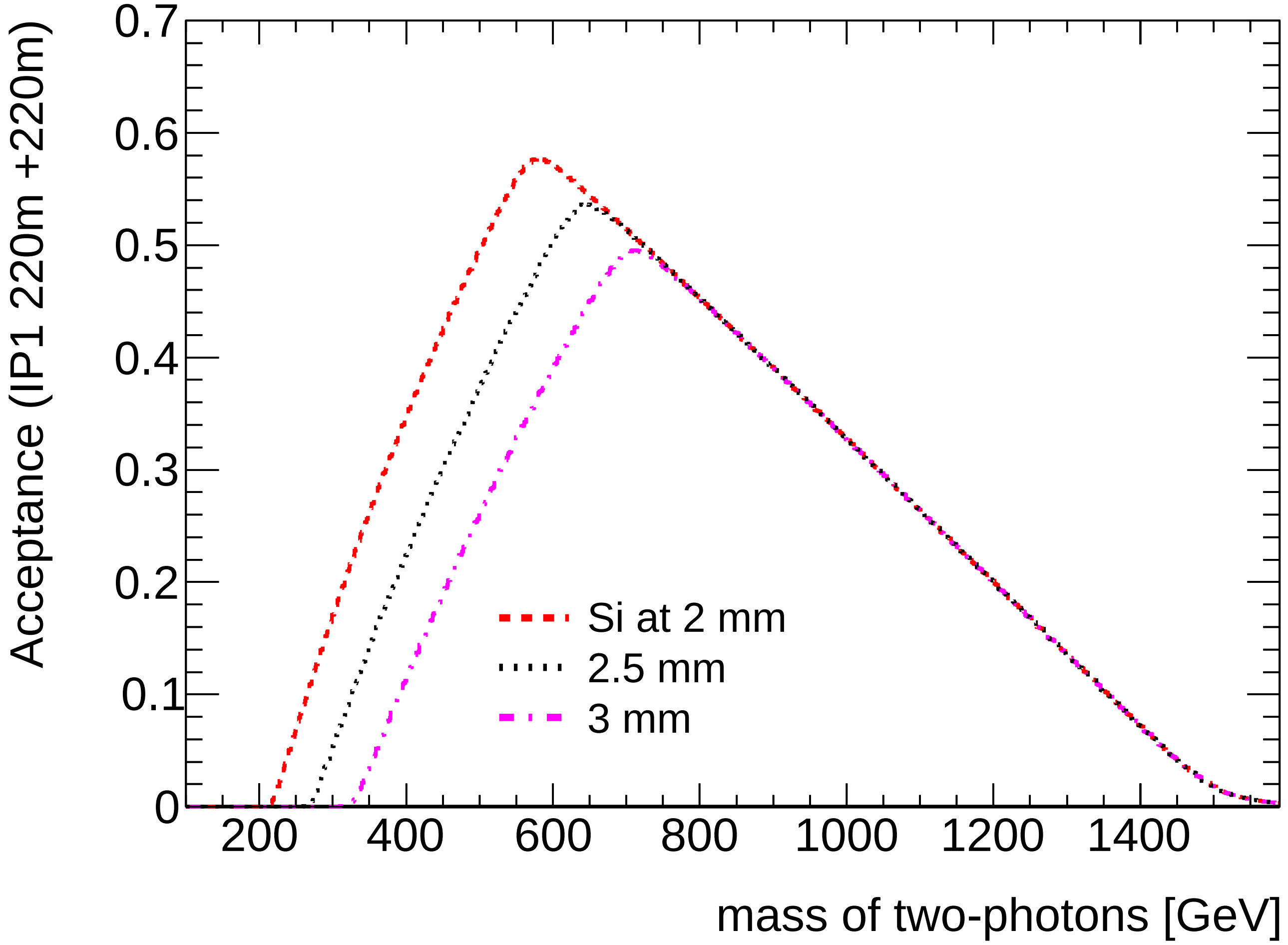
- Steps in $\xi$: 0.02 (left), 0.005 (right), $|t|$=0 or 0.05 GeV$^2$
- Detector of 2 cm $\times$ 2 cm will have an acceptance up to $\xi \sim 0.16$, down to 0.008 at 10 $\sigma$, 0.016 at 20 $\sigma$
- Estimate: possibility to insert the detectors up to $\sim 15\sigma$ from the beam routinely
- Detector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



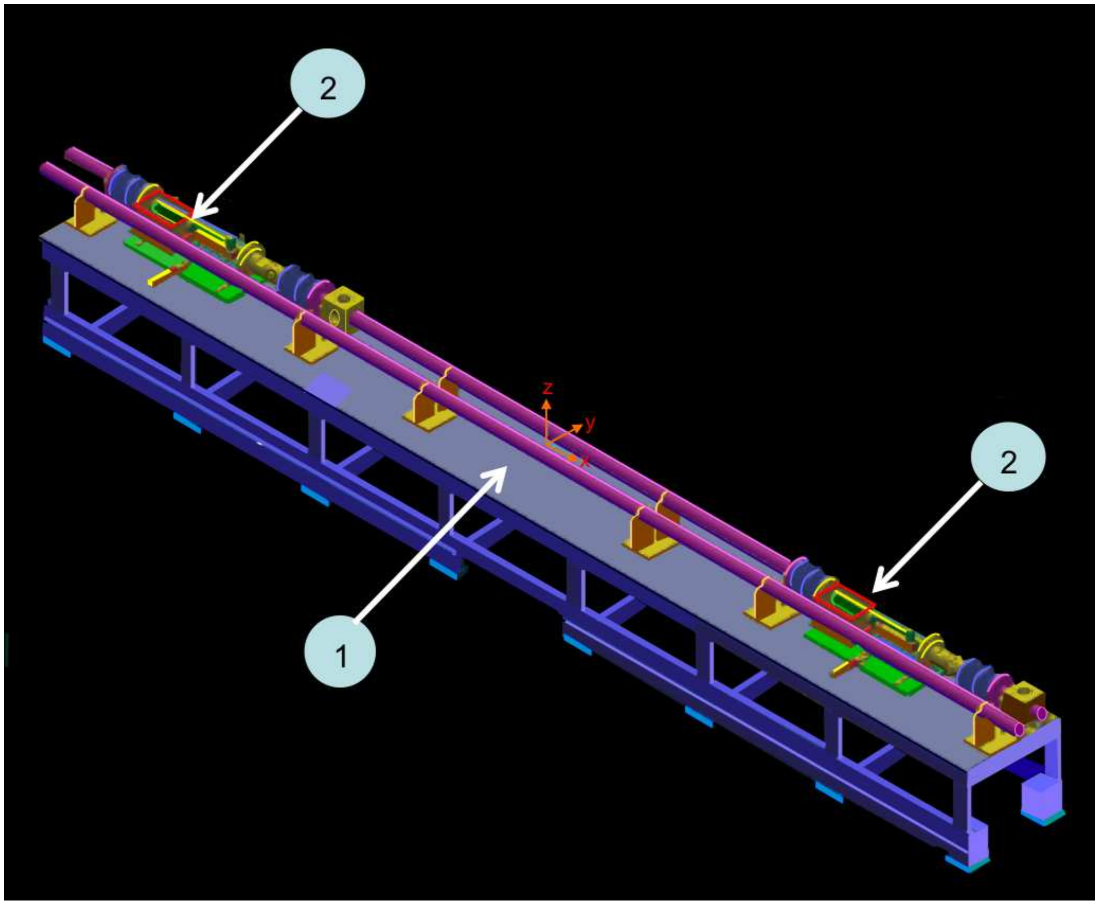
# Detector acceptance

- Mass computed using forward proton detectors: $M = \sqrt{\xi_1 \xi_2 S}$ where $\xi$ 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)



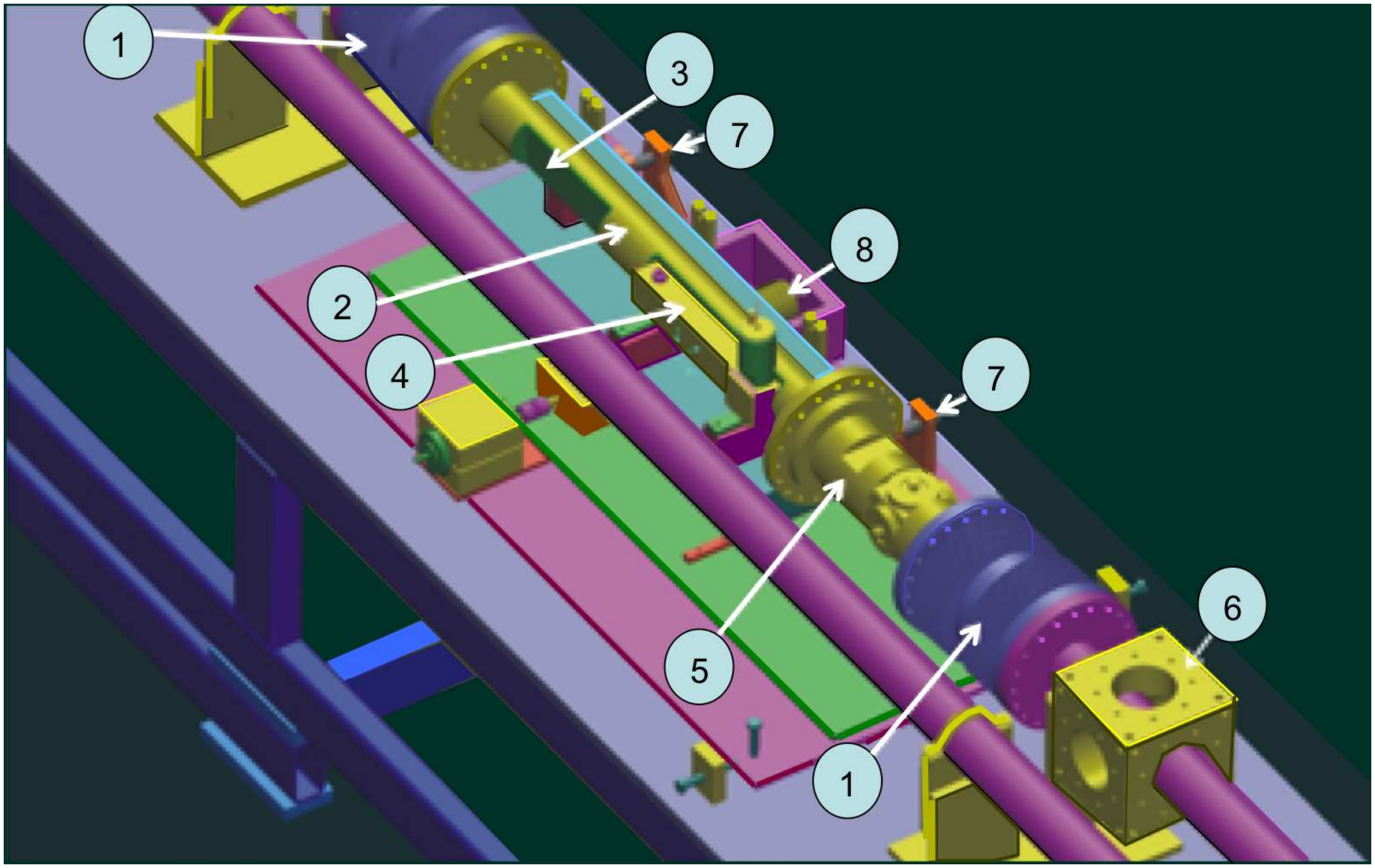
## Movable beam pipes

- allow precise and repeatable movement of detectors close to the beam by $\sim$ 25 mm (HERA, Louvain)
- 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

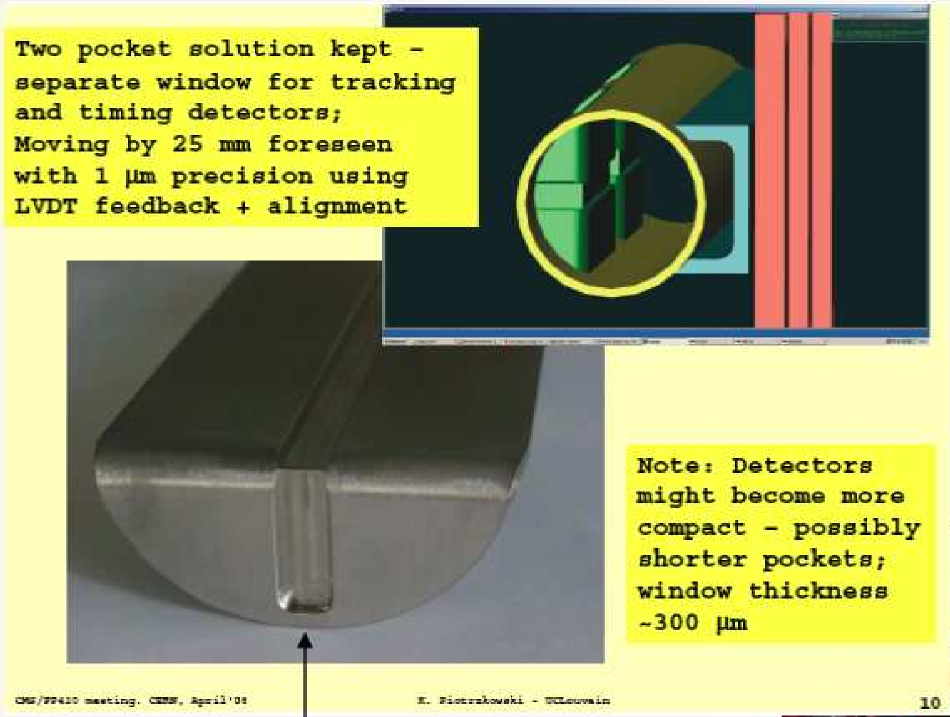


# Movable beam pipes

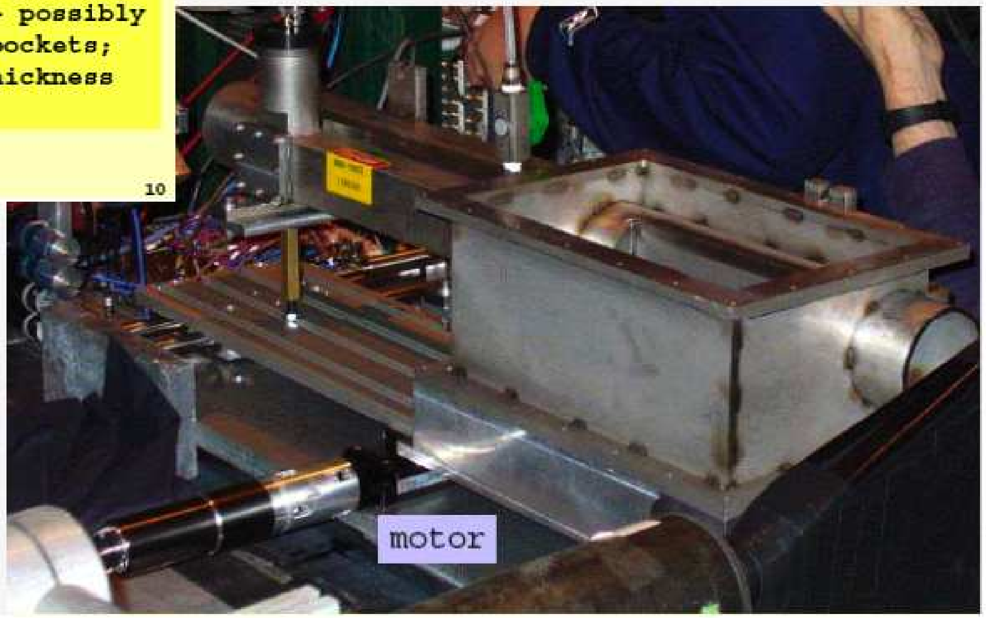
- Different elements of movable beam pipes: (1) bellows, (2) movable beam pipe, (3) Si pocket, (4) timing detector pocket, (5) moving beam position monitors (BPM), (6) fixed BPM, (7) LVDT
- For 2013-14 shutdown: restrict to 220 m detectors
- 2 pockets for Si/timing detector 216 m: Si, GASTOF; 224 m: Si, QUARTIC



# Movable beam pipes and pockets




Details of the movable Beam-pipe during the 2007 test beam

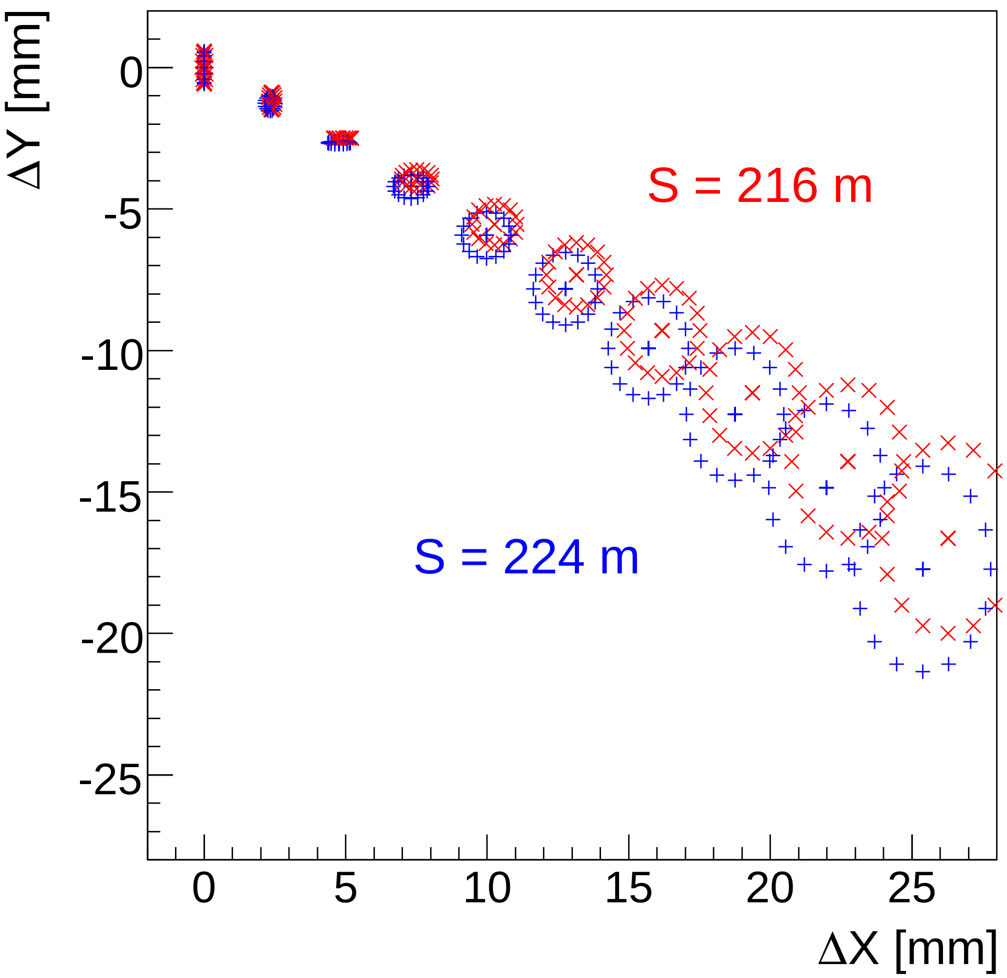



300 µm window
Louvain

## Si tracking detector

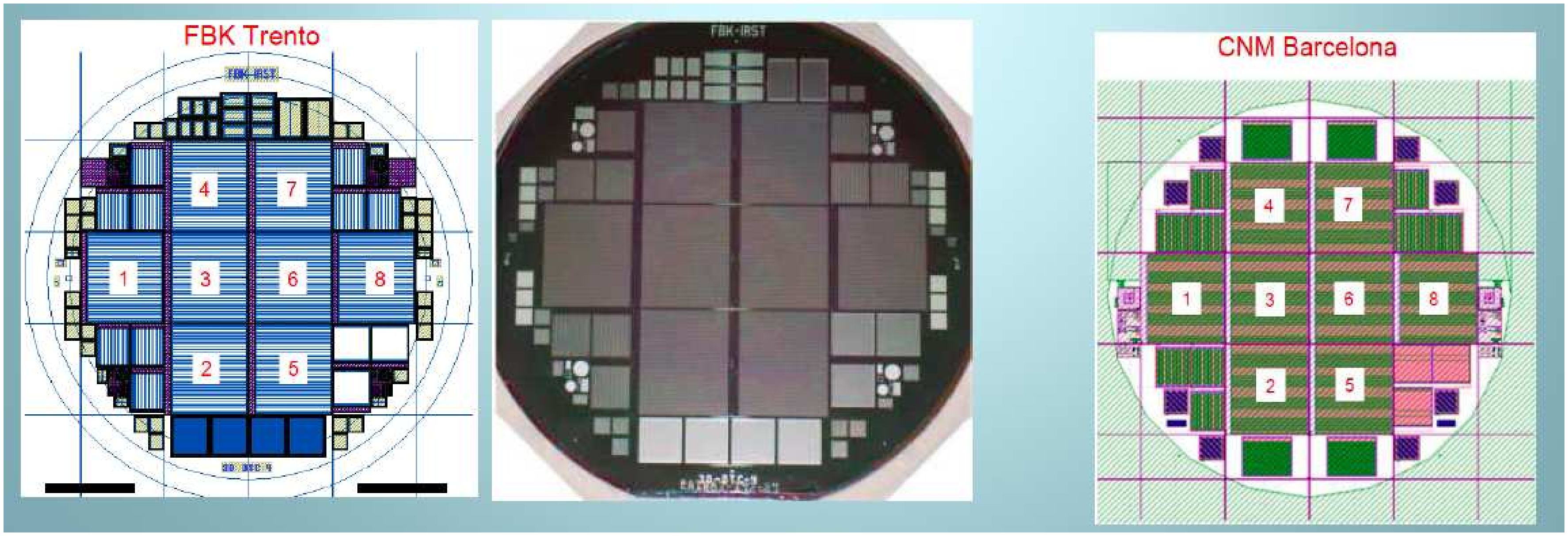
Key requirements for the Si detector

- Spatial resolution of 10 (30) $\mu$m in $x$ ($y$) direction
- Angular resolution of about 1 $\mu$rad
- High efficiency over 20 mm $\times$ 20 mm
- minimal dead space at the edge
- Sufficient radiation hardness



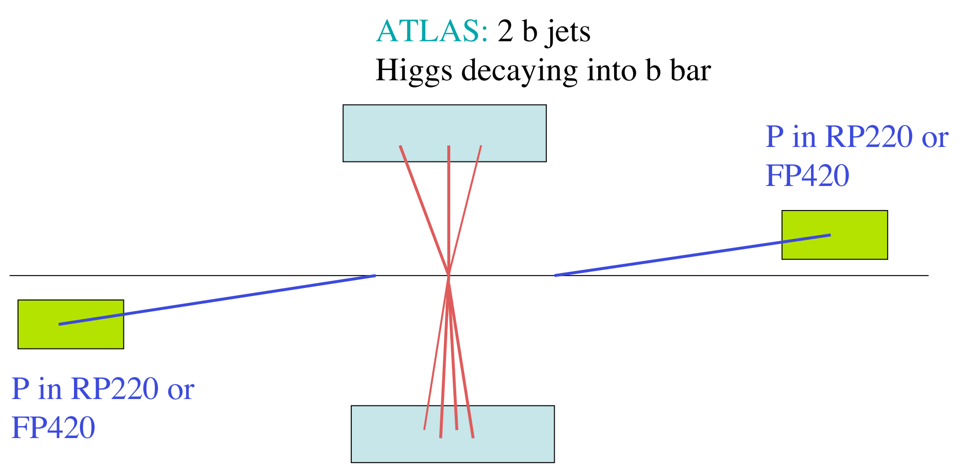
## Si detector: sensors

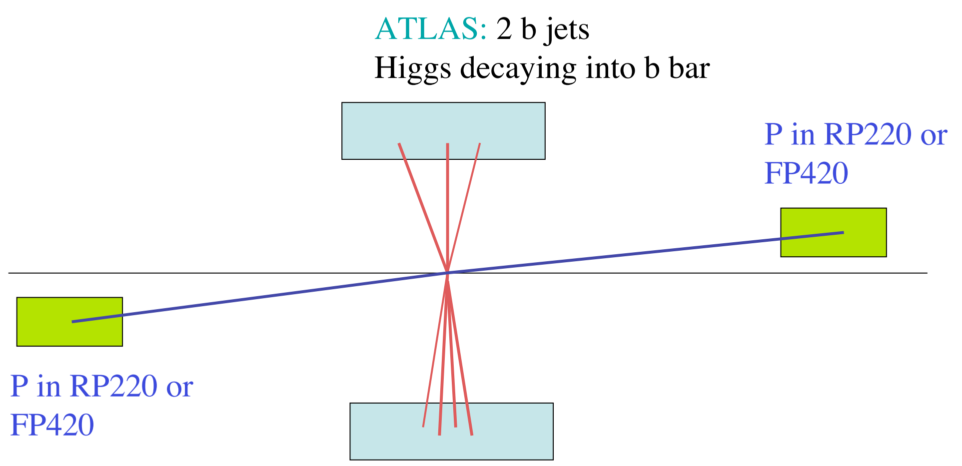
- Different options prossible for Si sensors (we benefit and follow the ATLAS IBL project)
- 3D sensors: Double sided 3D sensors or single sided full 3D with active edges
- Readout chip: FEI4, 1 chip needed per silicon layer, New FEI4 chip: radiation hard
- Cooling: under study, thermosiphon or vortex-based 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!!!!)



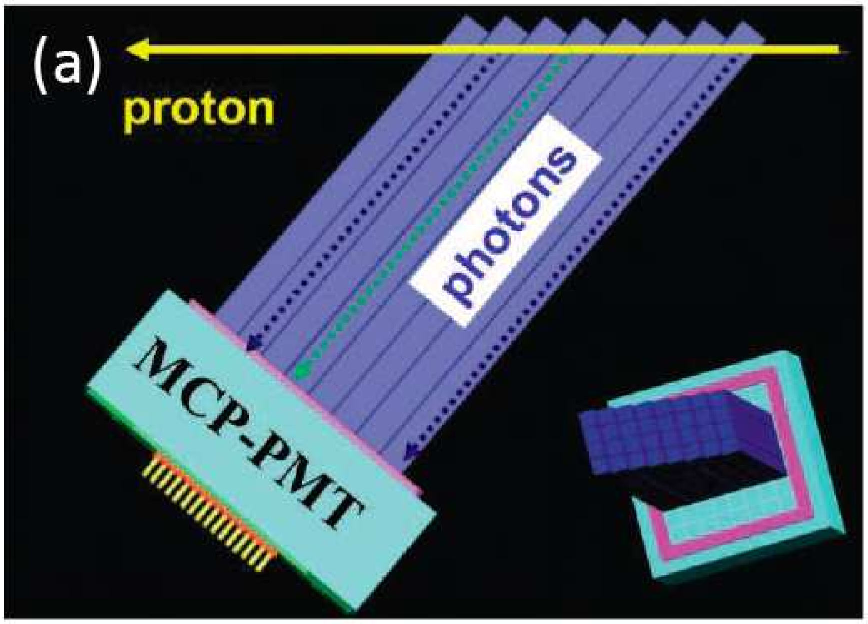



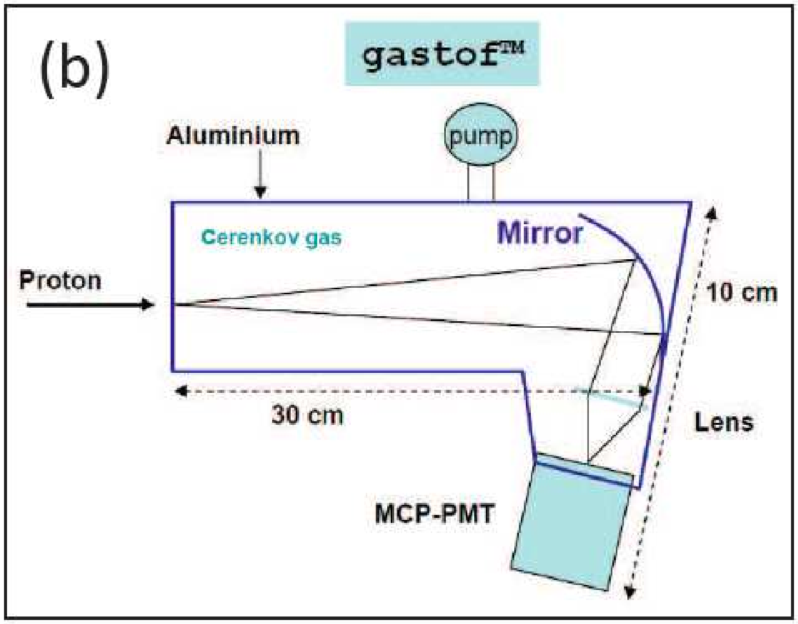
# QUARTIC and GASTOF timing detectors

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 (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)



## Conclusion and timescale

- Diffractive physics at the LHC: QCD, Higgs, $WW$, anomalous coupling...(see talks by Hervé, Maciej, Rafal)
- AFP project: movable beam pipes needed at 220/420 m - 2 phases: 220 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)
- Timescale: technical proposal submitted to ATLAS in February for first phase ; timing detectors approved as an R&D project; approval as an upgrade project under discussion; many groups involved: France (Saclay), Poland (Cracow), Czech Republic (Prague), Italy (Bologna, Milano, Genova), Spain (Barcelona), USA (Texas Arlington, Stony Brook, New Mexico, SLAC, Oklahoma), Canada (Alberta), Germany (Giessen, Wuppertal), Portugal (Lisbon)
- 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