Study of the anomalous coupling between photon and the W/Z boson and the ATLAS Forward Physics (AFP) project.

Diffraction and Elastic scattering

Qui Nhon – Vietnam. Monday, December 19 2011.

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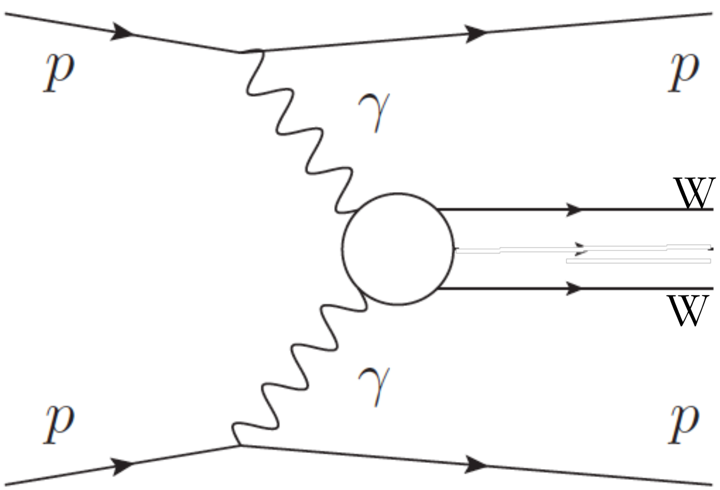
WW and ZZ photon induced processes

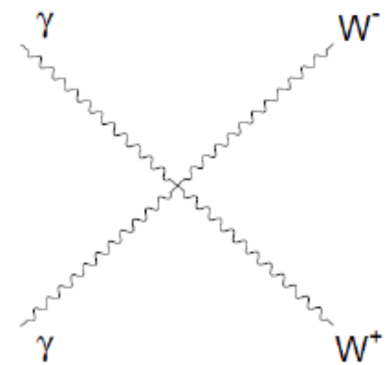
- Study of $pp \rightarrow pWWp$
  - Very clean process: W pair in central detector, intact protons in forward detector.
  - Cross section high and perfectly known (95.6fb QED).
- If $W > 1$TeV (cross. sec. = 5.9fb), still high, so it is possible to probe new physics.



WW and ZZ quartic anomalous photon induced processes.

$$\mathcal{L}_6^0 \sim \frac{-e^2}{8}\frac{a_0^W}{\Lambda^2}F_{\mu\nu}F^{\mu\nu}W^{+\alpha}W^-_\alpha - \frac{e^2}{16\cos^2(\theta_W)}\frac{a_0^Z}{\Lambda^2}F_{\mu\nu}F^{\mu\nu}Z^\alpha Z_\alpha$$

$$\mathcal{L}_6^C \sim \frac{-e^2}{16}\frac{a_C^W}{\Lambda^2}F_{\mu\alpha}F^{\mu\beta}(W^{+\alpha}W^-_\beta + W^{-\alpha}W^+_\beta) - \frac{e^2}{16\cos^2(\theta_W)}\frac{a_C^Z}{\Lambda^2}F_{\mu\alpha}F^{\mu\beta}Z^\alpha Z_\beta$$



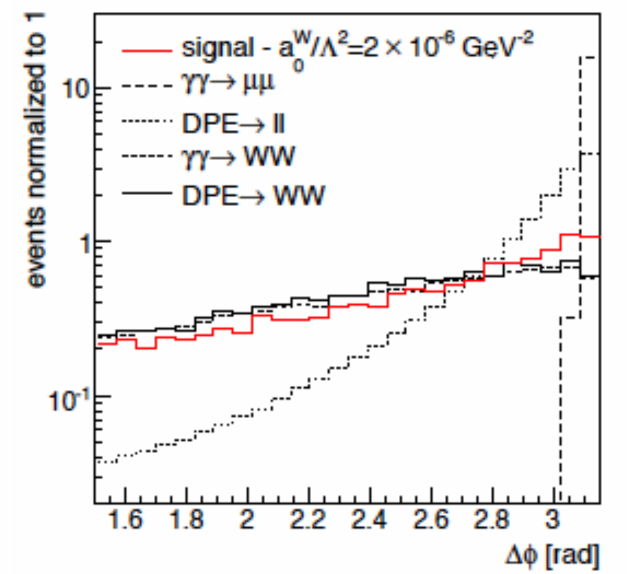
- In addition to standard model measurement, study of anomalous photon coupling [Phys. Rev. D81:074003, 2010 E. Chapon, O. Kepka, C. Royon].
- Anomalous quartic $WW\gamma\gamma$ and $ZZ\gamma\gamma$ coupling are not present in the standard model.
  - They are parameterized by 4 variables a_0^W, a_C^W, a_0^Z, a_C^Z.
  - Present limit on couplings from LEP ~2.10^{-2}.
- Anomalous coupling terms predicted by beyond SM theories: Higgless, extra-dimension. Expected values: few 10^{-6}.

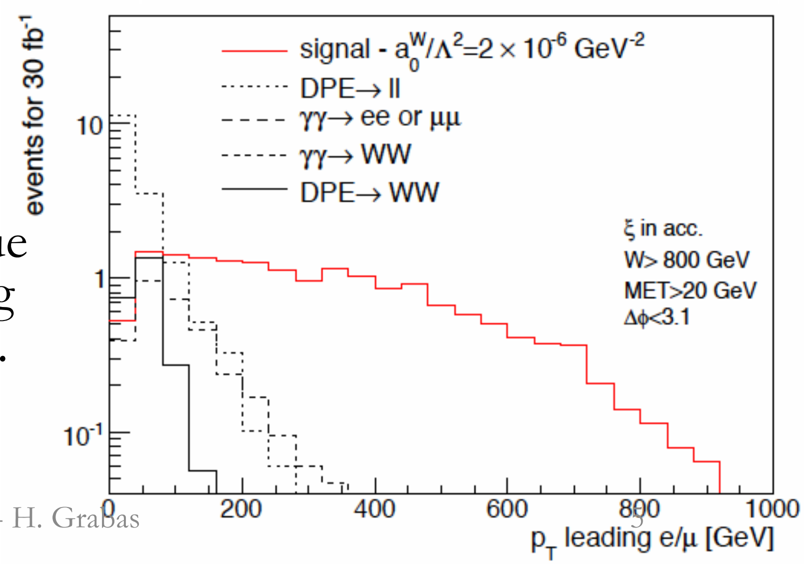
Forward Physics Monte Carlo (FPMC)

- Monte Carlo that implements all diffractive/photon induced processes.
  - Two photon exchange
  - Single diffraction
  - Double pomeron exchange
  - Central exclusive production
- Manual: see M. Boonekamp, A. Dechambre, O. Kepka, V. Juranek, C. Royon, R. Staszewski, M. Rangel, ArXiv: 1102.2531, code to be public soon.
- For this study the output of FPMC generator interfaced with the fast simulation of ATLAS detector in the standalone ATLFast++ package.
- Only leptonic decays of WW pair are considered (to avoid high jet backgrounds).

$WW\gamma\gamma$ production

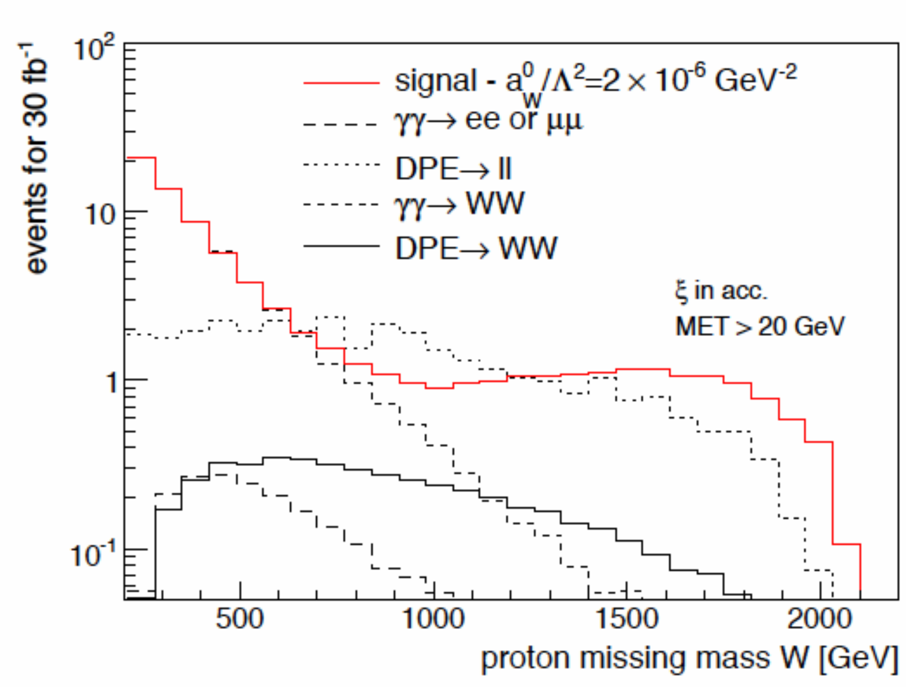
- Signal (red):
  - WW decay in the central detector, protons leave intact at small angles.
- Background (black):
  - SM WW pair production via photon exchange. Removed by cut on high mass.
  - Non diffractive WW production: large energy flow in the forward region. Removed by requesting tagged protons.
  - Dilepton production via photon exchange. Back-to-back leptons. Small cross section for high p_t leptons.
  - Lepton production via double pomeron exchange: activity in the forward region due to pomeron remnants. Removed by missing Et cut and small cross section at high mass.
  - WW via double pomeron exchange: removed by cut on high diffractive mass.





$WW\gamma\gamma$ proton missing mass

- Signal appears at high mass
- Anomalous coupling value chosen is 2.10^{-6}



Signal and background for 30fb^{-1}

Background events for 30 fb^{-1}

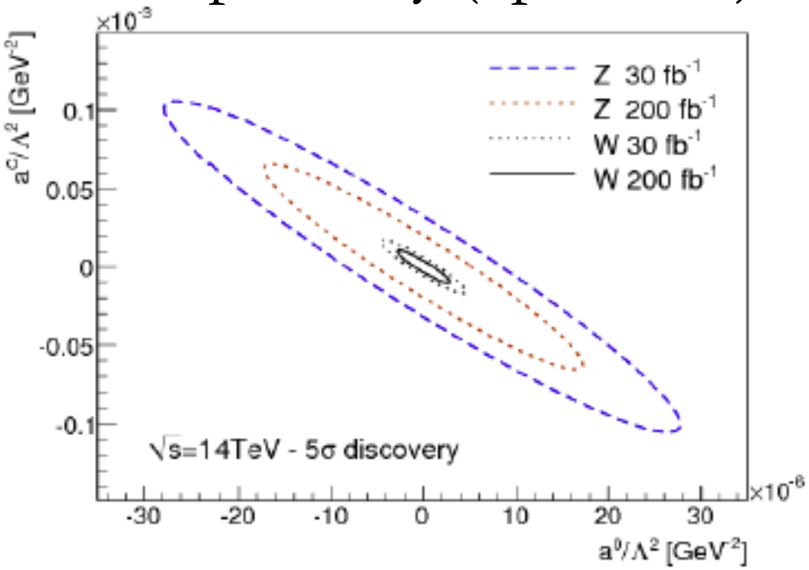
cut / process	$\gamma\gamma \to ll$	$\gamma\gamma \to WW$	DPE$\to ll$	DPE$\to WW$
$p_T^{lep1,2} > 10$ GeV	50619	99	18464	8.8
$0.0015 < \xi < 0.15$	21058	89	11712	6.0
$\not{E}_T > 20$ GeV	14.9	77	36	4.7
$W > 800$ GeV	0.42	3.2	16	2.5
$M_{ll} \notin <80, 100>$	0.42	3.2	13	2.5
$\Delta\phi < 3.13$	0.10	3.2	12	2.5
$p_T^{lep1} > 160$ GeV	0	0.69	0.20	0.024

Signal events for 30 fb^{-1}

cut / couplings (with f.f.)	$a_0^W/\Lambda^2 = 5.4 \cdot 10^{-6}$	$a_C^W/\Lambda^2 = 20 \cdot 10^{-6}$
$p_T^{lep1,2} > 10$ GeV	202	200
$0.0015 < \xi < 0.15$	116	119
$\not{E}_T > 20$ GeV	104	107
$W > 800$ GeV	24	23
$M_{ll} \notin <80, 100>$	24	23
$\Delta\phi < 3.13$	24	22
$p_T^{lep1} > 160$ GeV	17	16

Reach at LHC

- The anomalous coupling terms can be measured very precisely (up to 10^{-6}) using forward detectors.

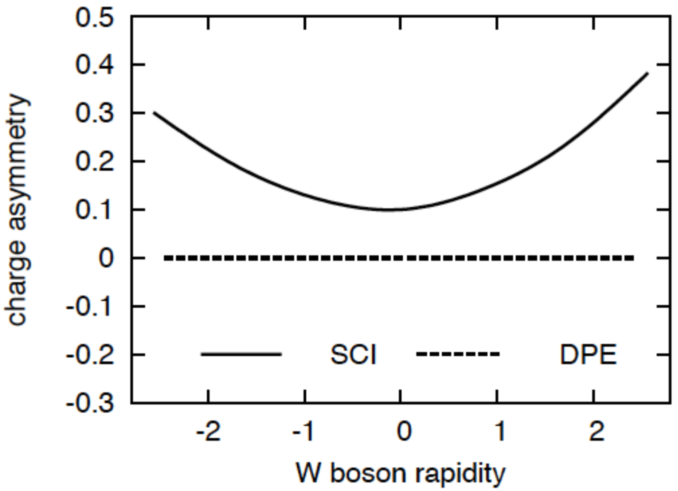


Couplings	OPAL limits [GeV^{-2}]	Sensitivity @ $\mathcal{L}$ = 30 (200) fb^{-1} 5σ	95% CL
a_0^W/Λ^2	[-0.020, 0.020]	5.4 10^{-6} (2.7 10^{-6})	2.6 10^{-6} (1.4 10^{-6})
a_C^W/Λ^2	[-0.052, 0.037]	2.0 10^{-5} (9.6 10^{-6})	9.4 10^{-6} (5.2 10^{-6})
a_0^Z/Λ^2	[-0.007, 0.023]	1.4 10^{-5} (5.5 10^{-6})	6.4 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 over previous LEP measurement by 4 orders of magnitude with 30/200fb^{-1} at LHC. And 2 orders of mag. better than standard studies at the LHC (methods by studying $pp \rightarrow l^{\pm} \nu \gamma\gamma$ [P. J. Bell, ArXiV:0907.5299]).
- Reaching the values in Higgsless and extra dimension models.

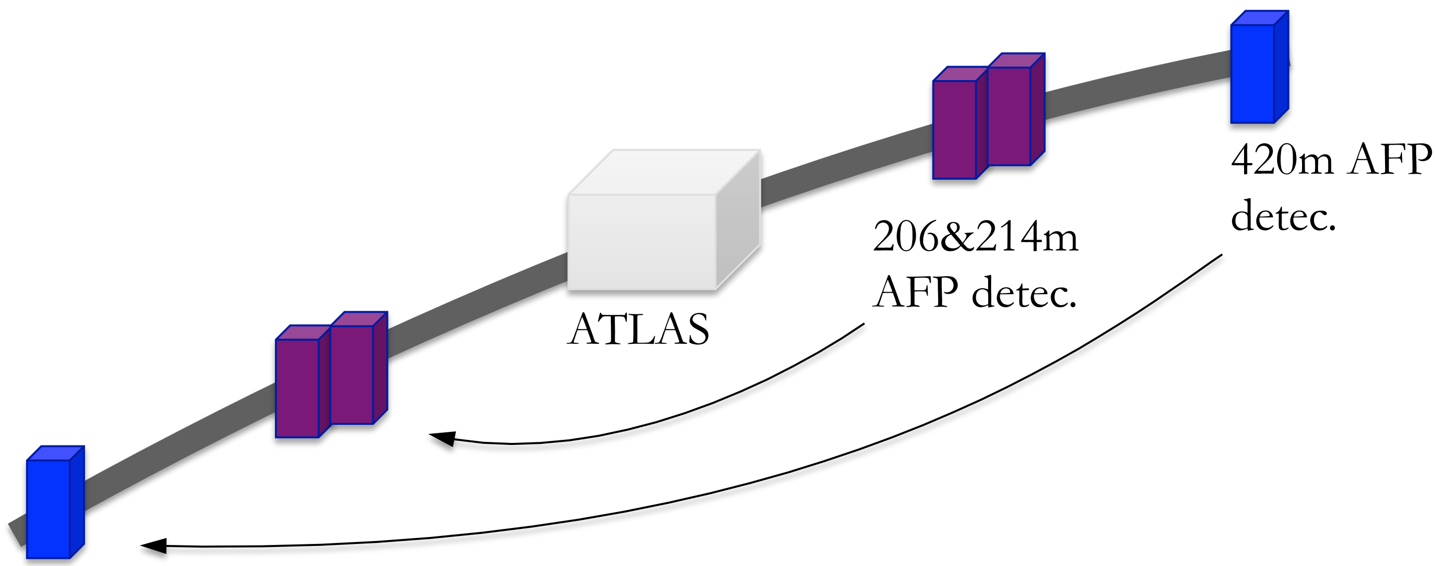
Additional physics using AFP

- Possible improvement of sensitivity including $WW \to l$ + jet.
- Anomalous $\gamma\gamma \to \gamma\gamma$ coupling study.
- W charge asymmetry. To probe the mechanism of diffraction (pomeron or soft color exchange) [arXiv:1110.1825. K. Golec-Biernat, C. Royon, L. Schoeffel, R, Staszewski in press in Phys. Rev. D.]



- Exclusive diffractive jet cross section meas. and comparison with the Khoze Martin Ryskin model, allows to further constrain the model [A. Dechambre, O. Kepka, C. Royon, R. Staszewski Phys. Rev. D83(2011) 054013]
- Diffractive Higgs measurement [V.A. Khoze, A.D. Martin, M.G. Ryskin Eur. Phys. J C23 (2002) 311-327] [R. Maciula, R. Pasechnik, A Szczurek Phys. Rev. D83 (2011) 114034], etc…
- Etc…

AFP installation project at LHC

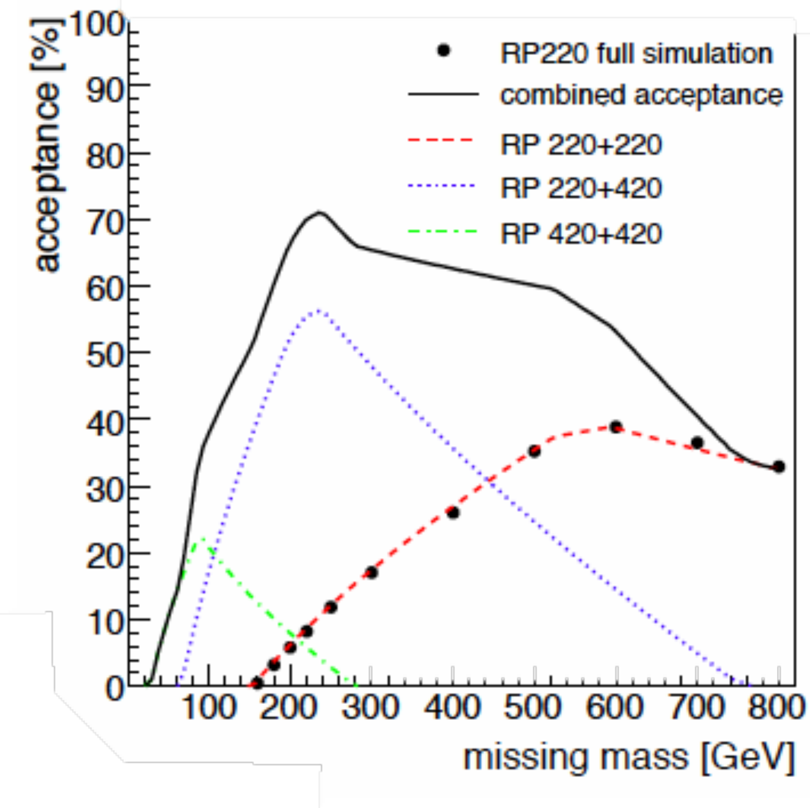


- Project under evaluation by ATLAS.
- Phase 0. 2014, installation of the 206 – 214m station. Timing and position detectors.
- Phase 1. If motivated by physics (discovery of H boson) adding 2 stations at 420m. Sensitive to lower mass.

Tagging intact protons in ATLAS

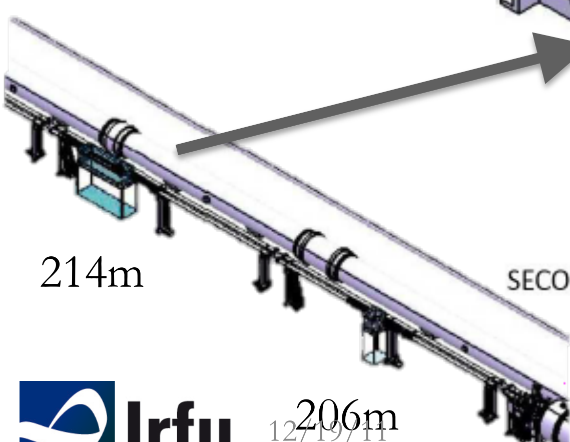
- Tagging done at 210m, 420m or both.
- High ξ proton cut by LHC magnets.
- 210m detector provides high mass acceptance necessary for anomalous coupling.

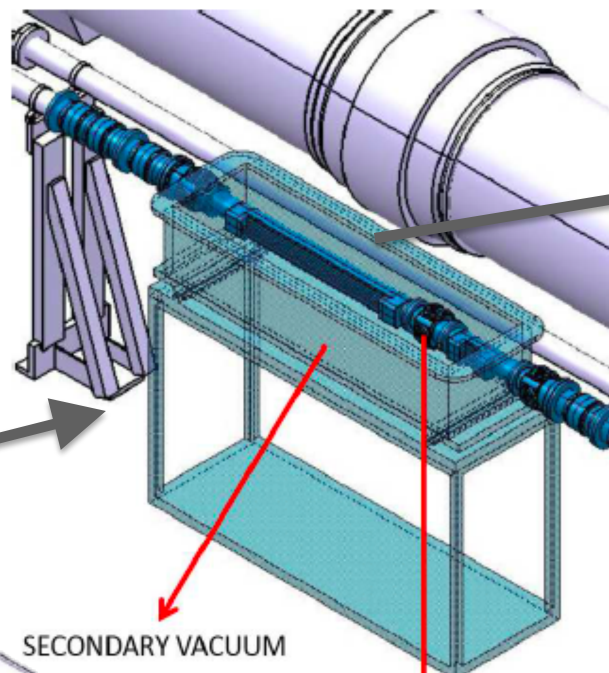
Missing mass $M = \sqrt{\xi_1 \xi_2 s}$

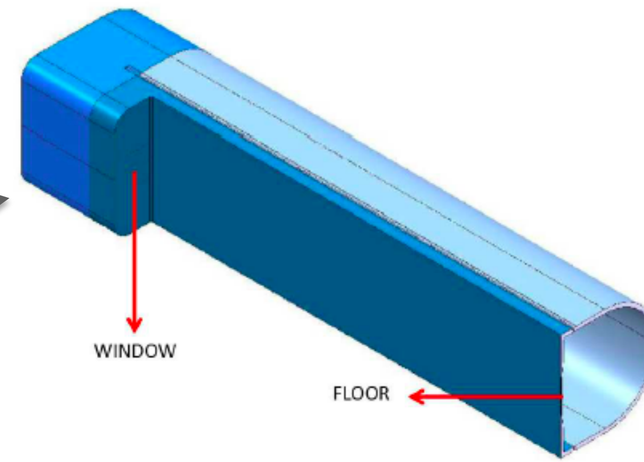


210m AFP detector

- 2 movable beam pipes at 206 & 214m from ATLAS interaction point.
  - Detector far from the beam during proton injection.
  - Don't have to work against vacuum.
  - Big pocket size for detector installation (70 cm for timing0
- Beam pipes pockets contains both timing and position detectors.



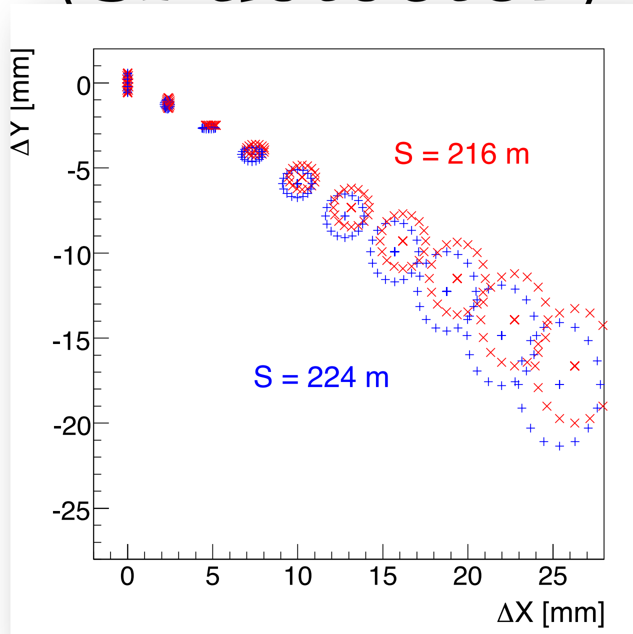


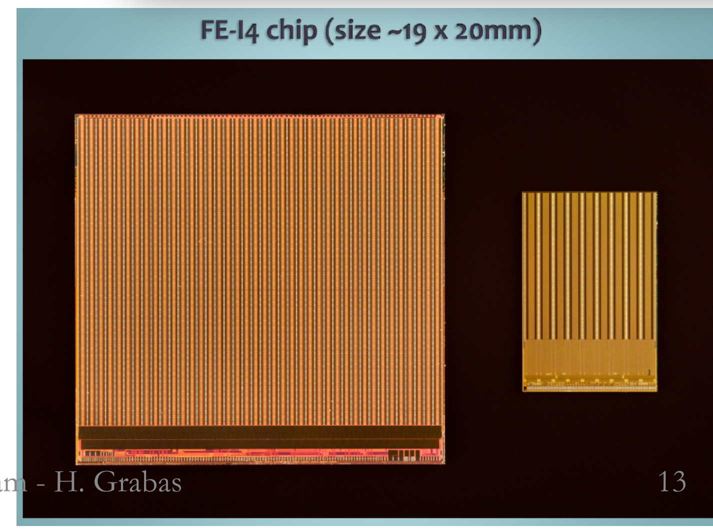


- 206m : 1 position detector
- 214m : 1 position detector & 1 timing detector

AFP position detector (Si detector)

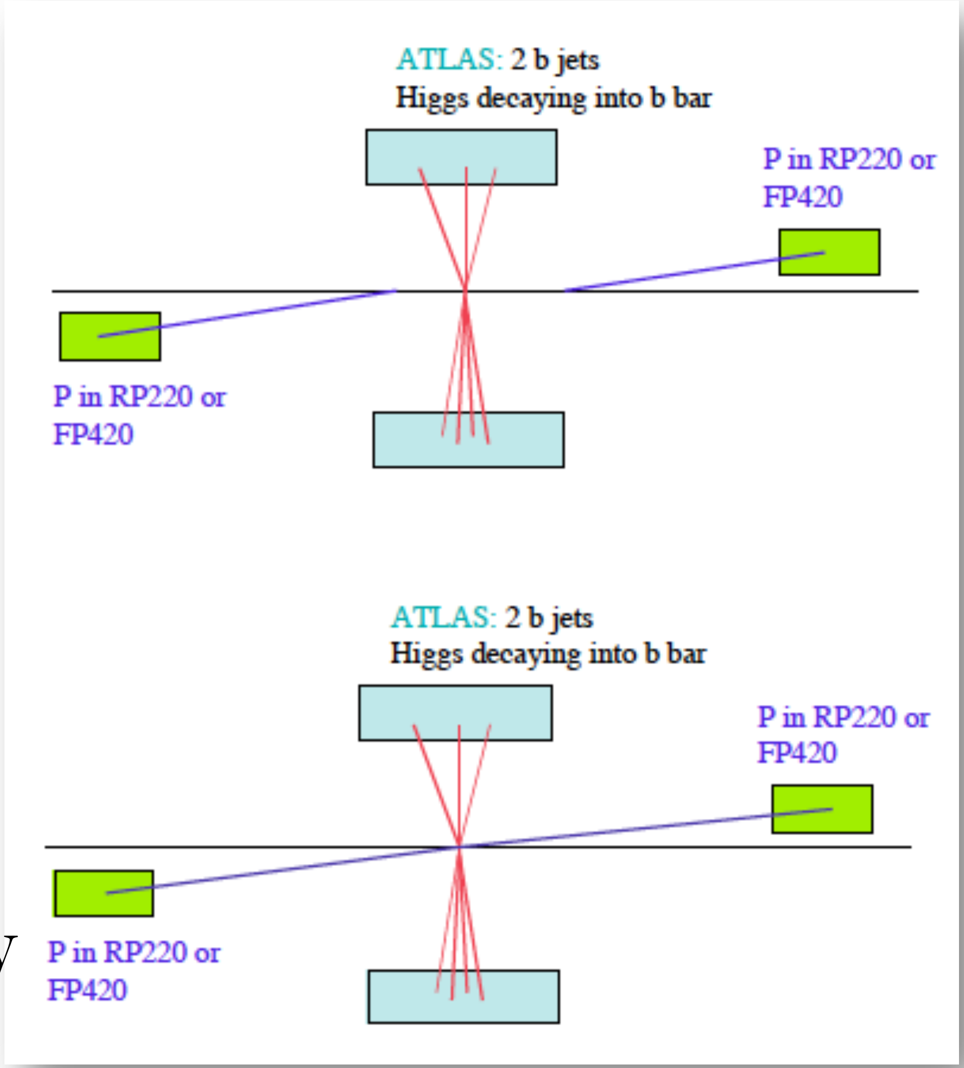
- Proton position required to be measured with a precision of ~15µm.
- Consist of 6 layers of silicon 3D detector (edgeless).
- Plan on using of IBL (ATLAS Insertable B Layer upgrade)
  - Pixel size 50*250µm.
  - IBL sensor covers perfectly AFP acceptance 19*20mm.
- Design benefiting from all IBL institutes involved.





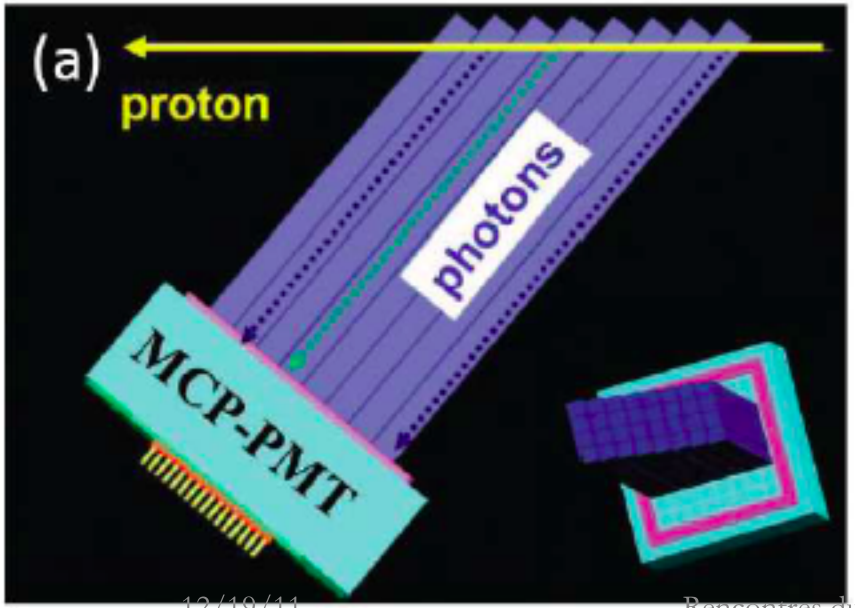
AFP timing requirements

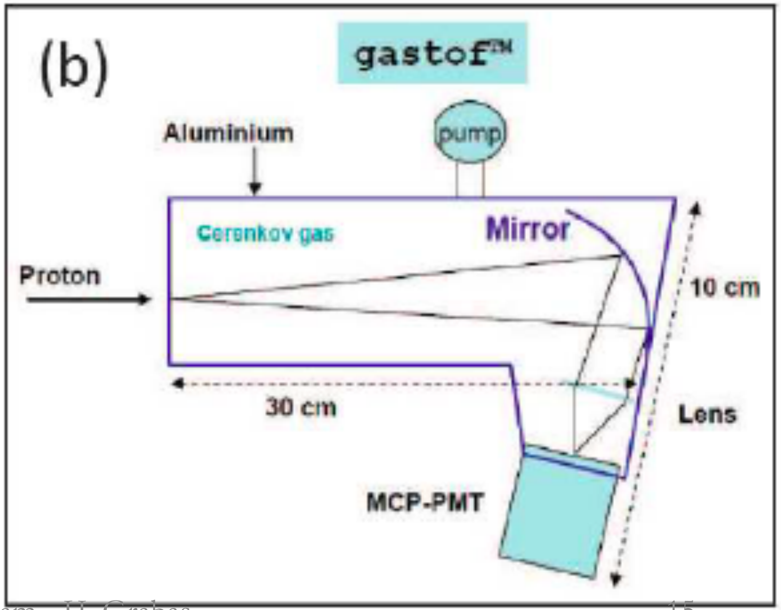
- 23 pile-up events at LHC in 2014 and 46 in 2017.
- Pile-up background suppression done by matching protons back to the primary vertex.
- Protons: use of timing detector, ie.10ps gives 2.1mm resolution.
- Background rejection by a factor 30.



AFP timing detector

- Intact protons create Cerenkov light cone detected in the very fast photo-multiplier detector.
- Timing resolution objectives:
  - 20ps by 2013
  - 10ps or better by 2017





Timing detector picosecond resol. R&D

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

Strong R&D research project started in Chicago and continued in CEA Saclay to built picosecond timing electronics for timing detector readout.

U (dynamic)	Δu (noise)	f_s (sampling freq)	f_{3db} (cutoff frequency)	Δt (timing resolution)
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
1V	1 mV	10 GSPS	1 GHz	0.5 ps

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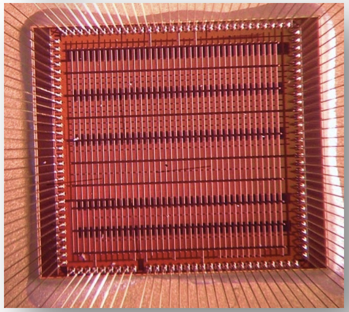

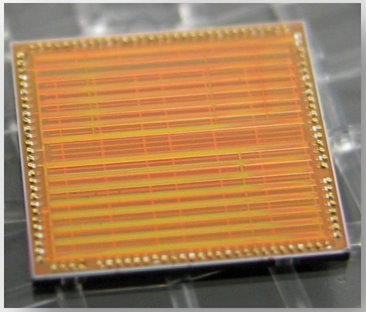

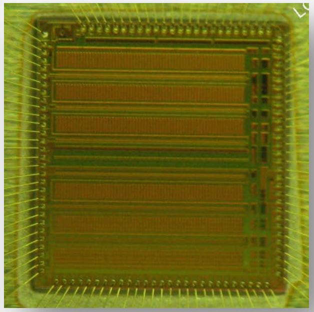

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Collaborator list

Spokesperson : C. Royon (management structure in progress).

AFP Collaborators:

- University of Alberta
- Charles University, Prague
- Institute of Physics of ASCR, Prague
- IRFU, CEA Saclay
- Justus-Liebig Universität, Giessen
- PAN & AGH, Cracow
- Glasgow University
- University of Texas at Arlington
- Milano
- Lisbon
- Barcelona
- Bologna
- Manchester
- SLAC
- Stony Brook
- University of New Mexico
- Oklahoma State University
- University of Oklahoma
- University of Wuppertal

Conclusion

- Gain 4 orders of magnitude in quartic anomalous coupling, reaching values predicted by Higgsless, extra-dimension models.
- Analysis redone in ATLAS using full simulation of signal, background and pileup (Diboson, single top, ttbar, W+jet, etc). Sensitivity found to be similar to ATLFast studies shown in this talk.
- Movable beam pipes needed at 206 and 214m at LHC (phase 0).
- Two types of detector: timing and position (Silicium)
- Many other technical applications: edgeless Si tracking detector for space applications, PET TOF, …)