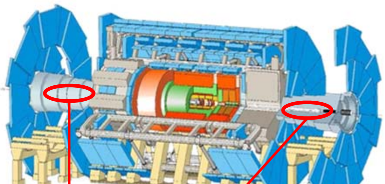
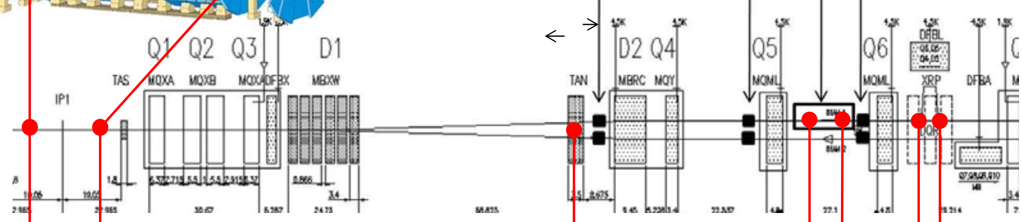
# LHCP2014 Columbia University, June 2-7

# The ATLAS Forward Proton Project






## LUCID ~17m
Proton remnants, low $p_T$ particles

## ZDC
140m
Proton/Ion remnants: $\gamma$, $\pi^0$, $n$

## AFP
206 m-214 m
Diffractive protons

## ALFA
237 m-241 m
Elastic protons

## AFP Physics:

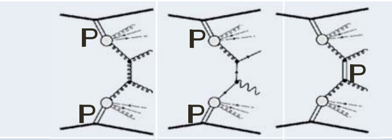
### Low Luminosity Program (μ≈1):

1 week≈100 hrs at μ≈1 ➔ ~100 pb$^{-1}$

**Conditionally approved by ATLAS**

**Single Diffraction**
- Jets, W, Z: Soft survival probability

**Double-Pomeron Exchange (DPE)**
- Dijet: constrain gluon content of P
- γ+Jet: constrain quark content of P
- Jet-gap-Jet: test BFKL P

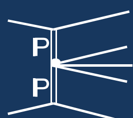
| Low-μ analysis | Luminosity [pb$^{-1}$] | Optimal μ | Optics β* [m] | L1 Trigger |
|---|---|---|---|---|
| Particle Spectra in diffraction | 1 | <0.05 | 90 (ALFA/AFP) 0.55 | AFP-Single Tag AFP-Double Tag |
| Rapidity Gap Spectra | 1 | <0.05 | 90 (ALFA/AFP) 0.55 | AFP-ST AFP-DT |
| SD jj | 0.1 – 1 | 0.01 – 1 | 90 – 0.55 | AFP-ST && Jet |
| SD W | 10 – 100 | 0.1 – 1 | 90 – 0.55 | AFP-ST && Lepton && MET |
| DPE jj | 1 – 10 | 0.5 – 5 | 90 – 0.55 | AFP-DT && Jet |
|  | | | | |
| DPE γj/γjj | >200 | 1 – 2 | 90 – 0.55 | AFP-DT && Jet/Photon |
| DPE j-gap-j | >100 | 0.1 – 2 | 90 – 0.55 | AFP-DT && Jet |

### High Luminosity Program (μ≳50):

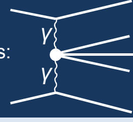
1 week≈100 hrs at μ≈50 ➔ ~5 fb$^{-1}$

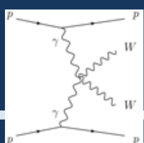
**Not approved; to be reviewed after successful running at Low Luminosity …**

**Central Exclusive Production**
- Dijets, Trijets: constrain predictions for CEP Higgs production
- S$^2$, Sudakov suppression, unintegrated $f_g$



**Double-Photon Exchange**
- γγ→WW/ZZ/γγ: Anomalous quartic couplings: sensitivity ~100× larger with AFP
- γγ→μμ: calibration/alignment of AFP



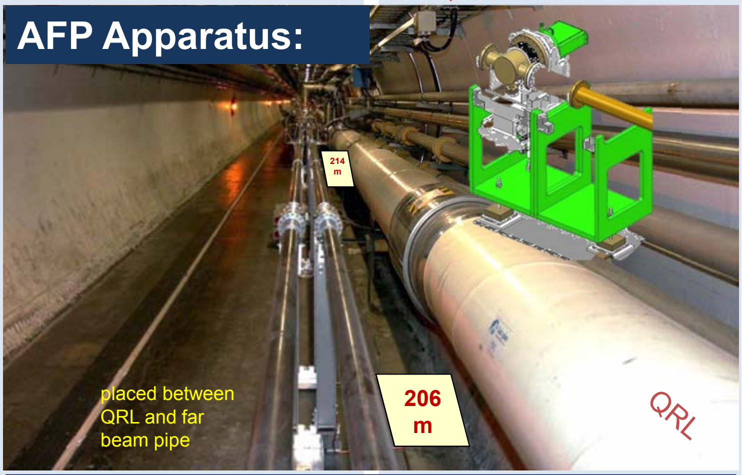


Example: γγ→WW anomalous quartic γγWW coupling:
- Best limits from LEP(OPAL): ~0.02–0.04 GeV$^{-2}$ (PRD 70 (2004) 032005)
- Predicted sensitivities at the LHC a few 10$^{-4}$GeV$^{-2}$ (P.J. Bell; ArXiv:0907.5299)
- Recent papers from DØ and CMS for γγWW: ~10$^{-4}$ GeV$^{-2}$ (100×better than LEP) (CMS-PAS-FSQ-12-010)
- Sensitivity predicted with AFP: 100× better
  - e.g. for 30 events per fb (1 yr run in 2016):

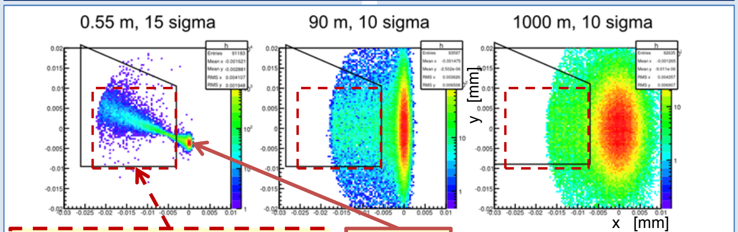
*C. Royon and O. Kepka*; PRD 78 (2008)
*E. Chapon, C. Royon, O. Kepka*; PRD 81 (2010)

| | form factor | $\lvert a_0^W/\Lambda^2\rvert$ | $\lvert a_C^W/\Lambda^2\rvert$ | $\lvert a_0^Z/\Lambda^2\rvert$ | $\lvert a_C^Z/\Lambda^2\rvert$ |
|---|---|---|---|---|---|
| | | limits $[10^{-6}\,\mathrm{GeV}^{-2}]$ | | | |
| 95% c.l. | $\Lambda_{cut}=\infty$ | 1.2 | 4.2 | 2.8 | 10 |
| | $\Lambda_{cut}=2\,\mathrm{TeV}$ | 2.6 | 9.4 | 6.4 | 24 |
| 3σ evidence | $\Lambda_{cut}=\infty$ | 1.6 | 5.8 | 4.0 | 14 |
| | $\Lambda_{cut}=2\,\mathrm{TeV}$ | 3.6 | 13 | 9.0 | 34 |
| 5σ discovery | $\Lambda_{cut}=\infty$ | 2.3 | 9.7 | 6.2 | 23 |
| | $\Lambda_{cut}=2\,\mathrm{TeV}$ | 5.4 | 20 | 14 | 52 |

## AFP Apparatus:




### AFP y-x hit patterns for β*=0.55 m, 90 m, 1000 m:

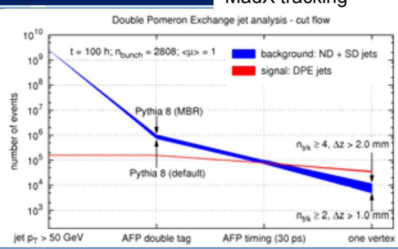



Stand-alone AFP simulations using MadX tracking

### The need for Picosecond Timing

Example: DPE jj Full Simulation
- at high μ≥1, protons from single-diffraction pile-up events begin to dominate the two-proton sample
- accurate proton time-of-arrival measurements can reject the pile-up background:

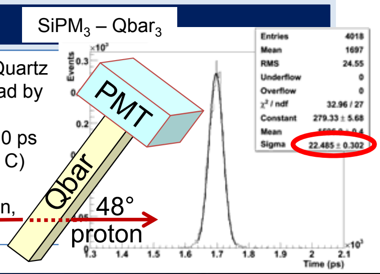
$z_{vtx}=(t_{Right}-t_{Left})/(2c)$
➔ if $\sigma_t$=10 ps, then $\sigma_z$=2.1 mm




### Fermilab beam test results (2012):

SiPM$_3$ – Qbar$_3$

2 mm wide × 6 mm deep (in beam direction) Quartz bar positioned at the 48° Cherenkov angle, read by 10 μm pore MCP-MAPMT:
- single bar: $\sigma_t \simeq$ 20 ps ➔ 4 Qbars at 48° ~10 ps
- rad hard PMT (no degradation seen up to 7 C)
- PMT out of the direct beam !
- Multiple measurements = 'tunable' resolution, size, and radiation/interaction length …

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