Measurements of diffractive and exclusive processes with ATLAS

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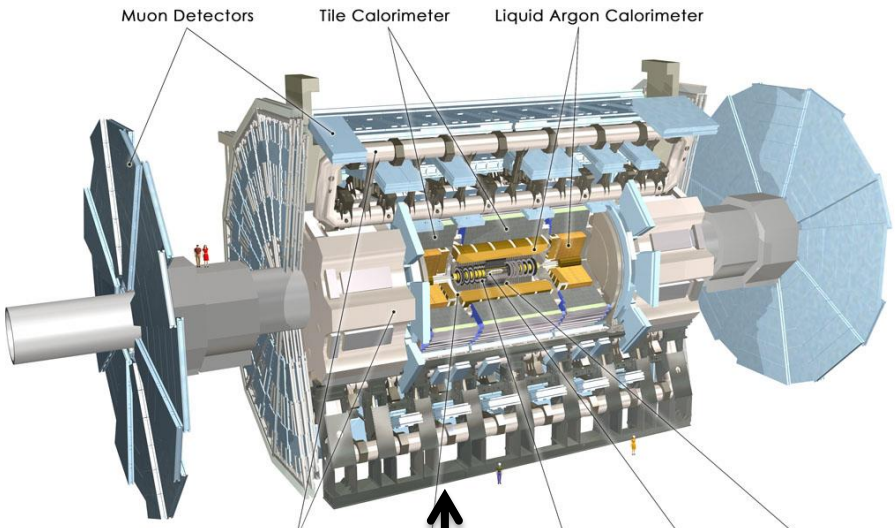
on behalf of the ATLAS Collaboration

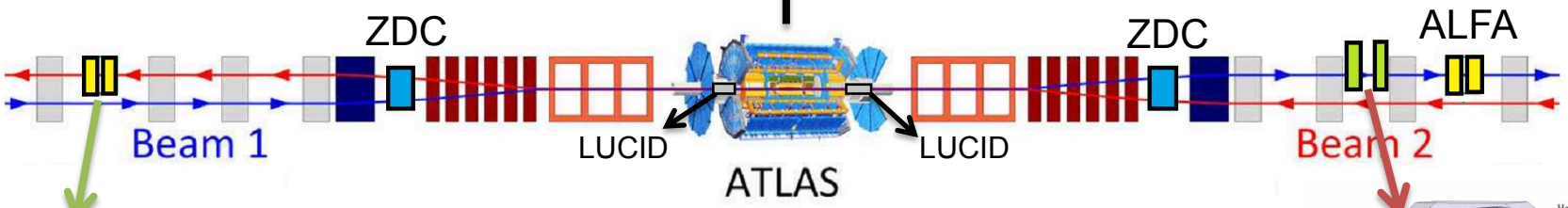
2-8 Sep 2016

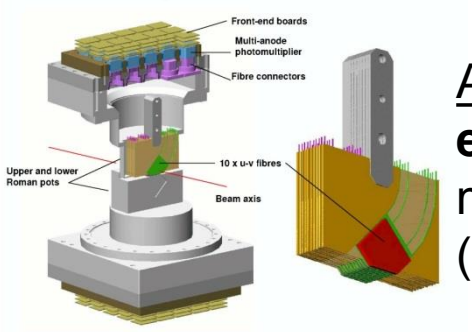
Outline

- Exclusive $\gamma\gamma \rightarrow \ell^+\ell^-$ Production at 7 TeV
- Exclusive $\gamma\gamma \rightarrow W^+W^-$ Production and Search for Exclusive Higgs Production at 8 TeV
- Diffractive Dijet Cross Sections at 7 TeV
- Feasibility Studies for Exclusive Jet Production with AFP

The ATLAS sub-detectors

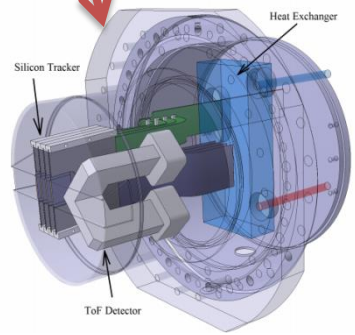






ALFA:
elastic protons measurement (see Hasko's talk)

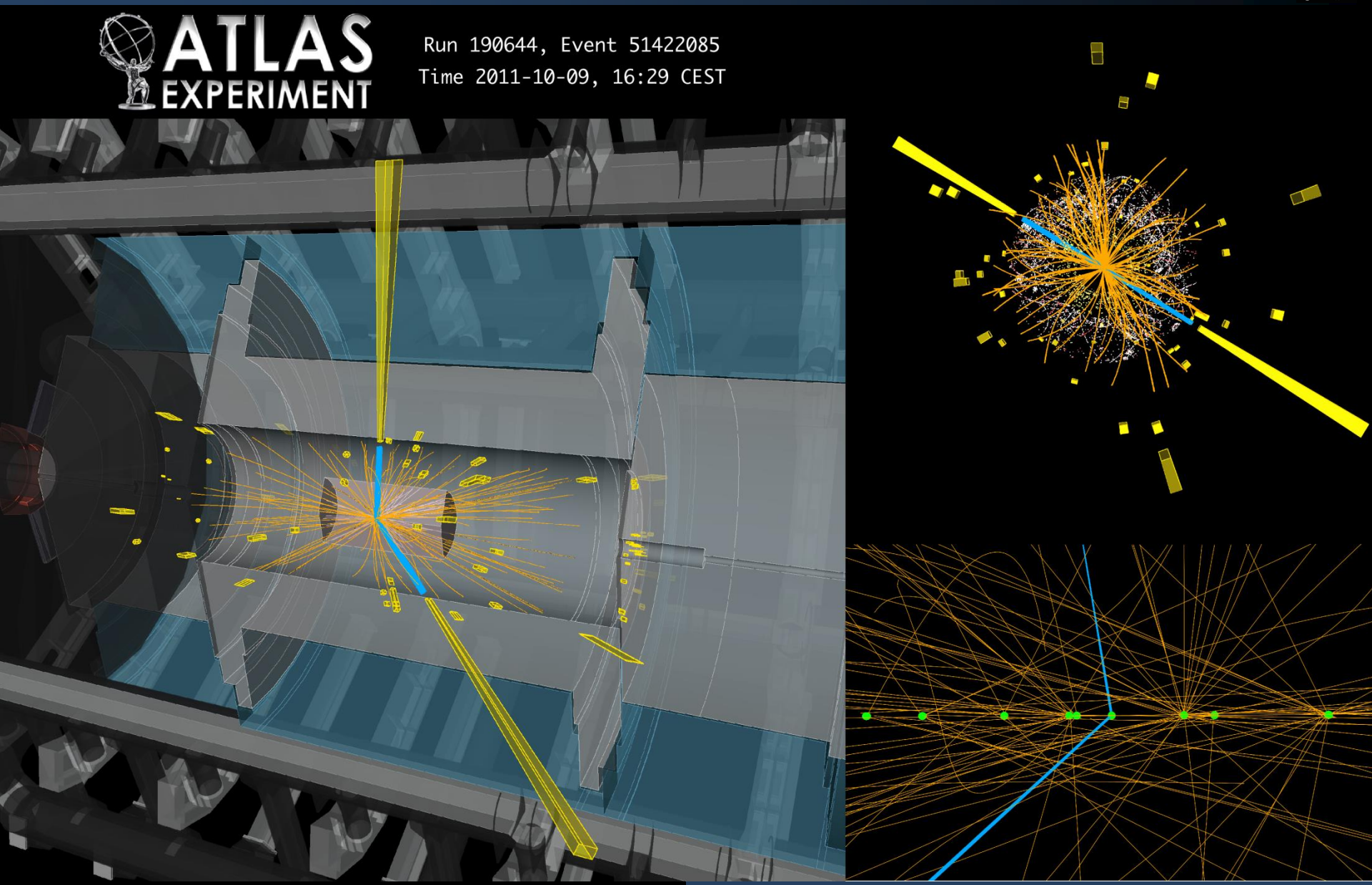
AFP:
diffractive protons measurement.
CERN-LHCC-2015-009
Single-arm installed, some diffractive data already taken!



Exclusive photon-induced processes: **Motivation**

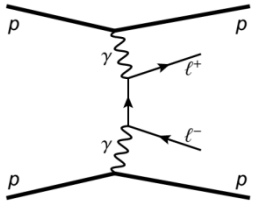
- Exclusive $\gamma\gamma \rightarrow X$ production can be computed in QED+EWK with relatively small uncertainty (EPA)
  - True if we neglect proton absorptive corrections…
- Exclusive $\gamma\gamma \rightarrow \ell^+\ell^-$ production
  - Standard candle for photon-induced physics
  - Non-negligible background to Drell-Yan like reactions
  - Possible to use $pp(\gamma\gamma) \rightarrow pp\,\ell^+\ell^-$ for luminosity calibration at the LHC?
- Exclusive W^+W^-
  - Test of SM $\gamma\gamma WW$ quartic gauge coupling
  - Probe of anomalous quartic gauge couplings (aQGCs)
- Exclusive (CEP) $gg \rightarrow$ Higgs $\rightarrow W^+W^-$
  - Similar final state as in exclusive $\gamma\gamma \rightarrow W^+W^-$ studies
  - Can be used for Higgs properties studies (low systematics due to the clean production environment)

Exclusive $\gamma\gamma \rightarrow \ell^+\ell^-$ production at 7 TeV, PLB 749 (2015) 242-261

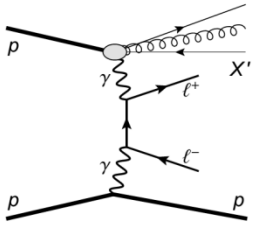


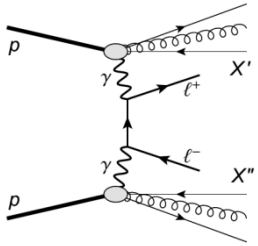
Exclusive $\gamma\gamma \rightarrow \ell^+\ell^-$ production at 7 TeV, PLB 749 (2015) 242-261

- Photon-induced processes: cross-section dominated by so-called **single-** and **double-proton dissociative** reactions. Non-negligible background for many analyses (low, high-mass DY, $\phi^*/p_T(Z)$ measurement, …)

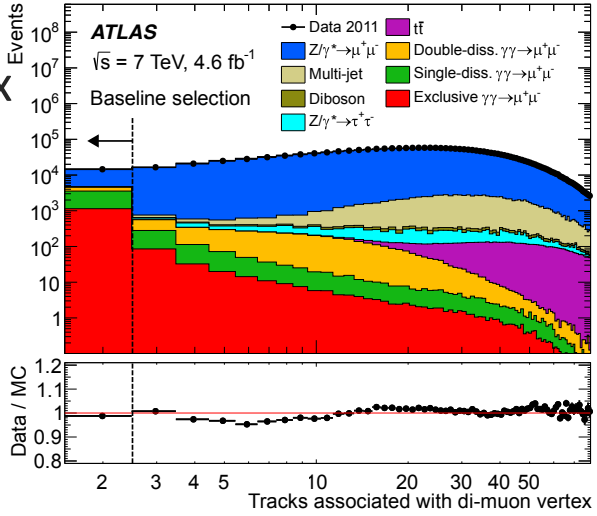


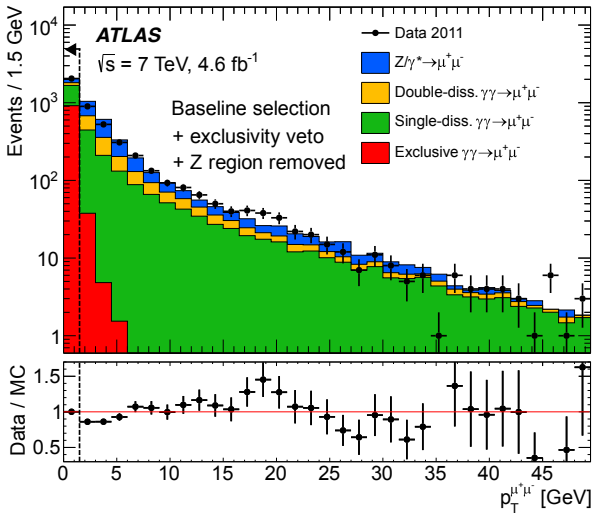
- Preselection:
  - **p_T^{μ}>10 GeV**, $|\eta_\mu|$<2.4, $M_{\mu+\mu-}$>20 GeV
  - **p_T^{e}>12 GeV**, $|\eta_e|$<2.4, M_{e+e-}>24 GeV





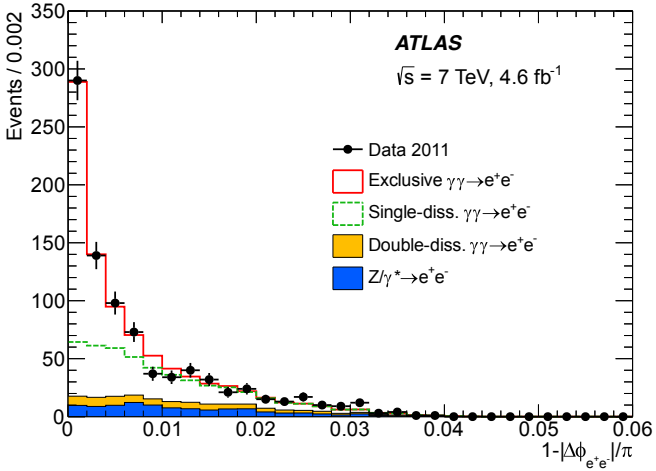
- **Exclusive selection**:
  - **3 mm** dilepton-vertex longitudinal isolation **efficiency = 74%**
  - **p_T** of the dilepton system **< 1.5 GeV**

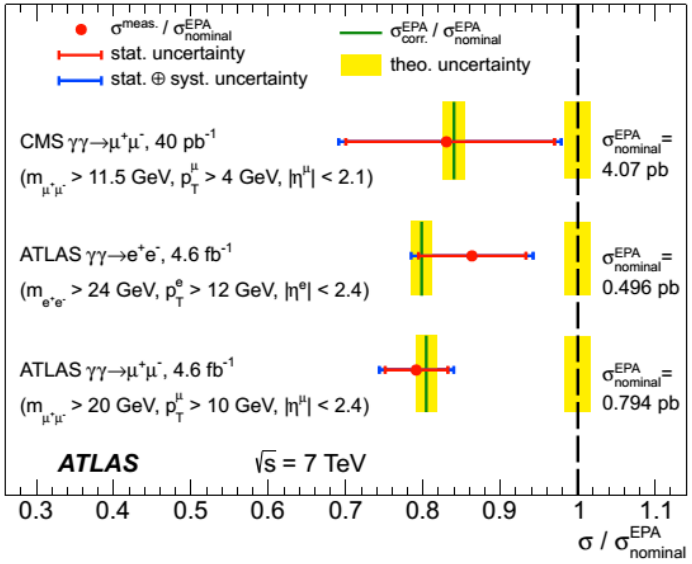




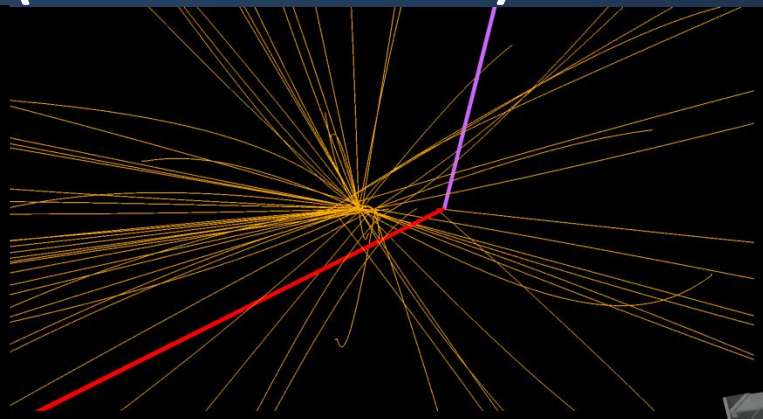
Exclusive $\gamma\gamma \rightarrow \ell^+\ell^-$ production at 7 TeV, PLB 749 (2015) 242-261

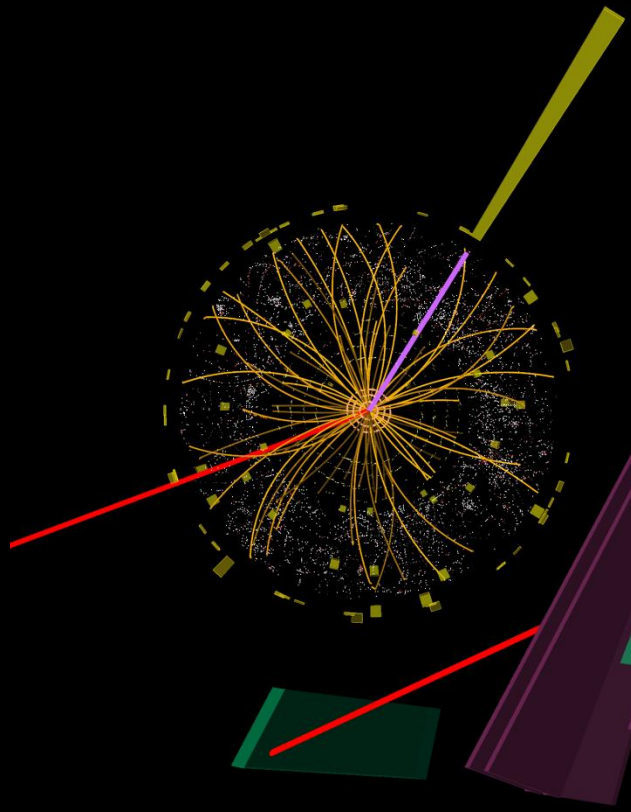
- **Signal extraction**: binned maximum-likelihood fit to the measured dilepton acoplanarity distribution
- Corresponding fiducial cross-sections:
  - $\sigma^{excl.}_{\gamma\gamma\rightarrow e+e-}$ = 0.428 ± 0.035(stat.) ± 0.018(syst.) pb
  - $\sigma^{excl.}_{\gamma\gamma\rightarrow \mu+\mu-}$ = 0.628 ± 0.032(stat.) ± 0.021(syst.) pb
- Theory predictions (QED-EPA), with absorptive corrections from PLB 741 (2015) 66-70 (**20% effect**)
  - $\sigma^{EPA,\,corr.}_{\gamma\gamma\rightarrow e+e-}$ = 0.398 ± 0.007(theo.) pb
  - $\sigma^{EPA,\,corr.}_{\gamma\gamma\rightarrow \mu+\mu-}$ = 0.638 ± 0.011(theo.) pb
- Agreement also with similar CMS measurement

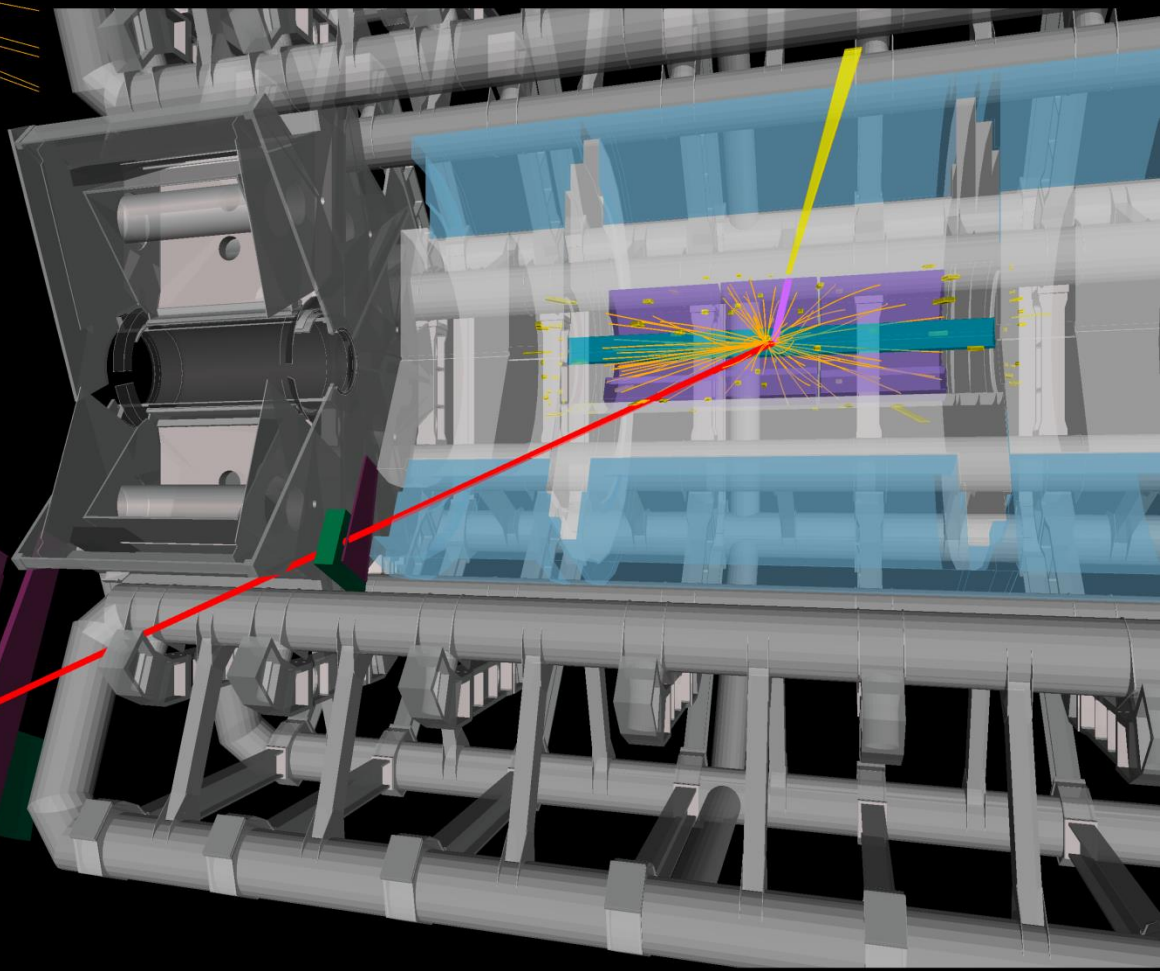




Exclusive γγ → W^+W^- and Search for Exclusive H at 8 TeV (arXiv:1607.03745) PRD 94 (2016) 032011

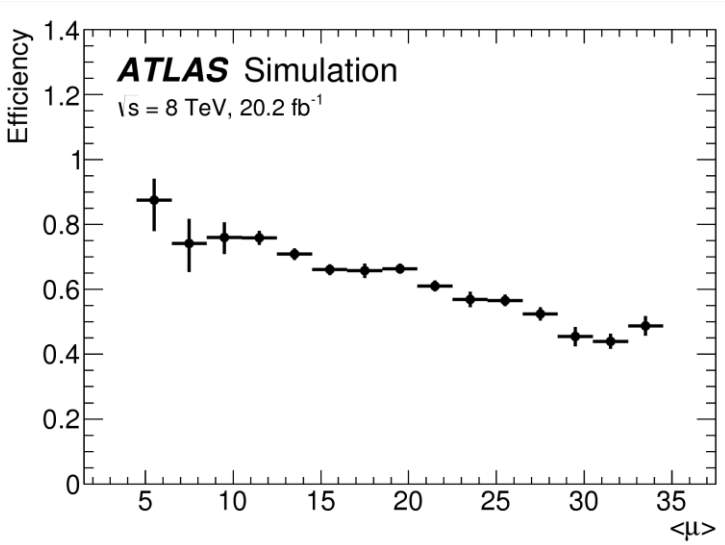






Exclusive γγ → W^+W^- and Search for Exclusive H at 8 TeV (arXiv:1607.03745)

- **Event selection**
- WW → evμv final states are considered
- 1 mm dilepton-vertex longitudinal isolation -> efficiency = 58 ± 6%
- Full event selection criteria:

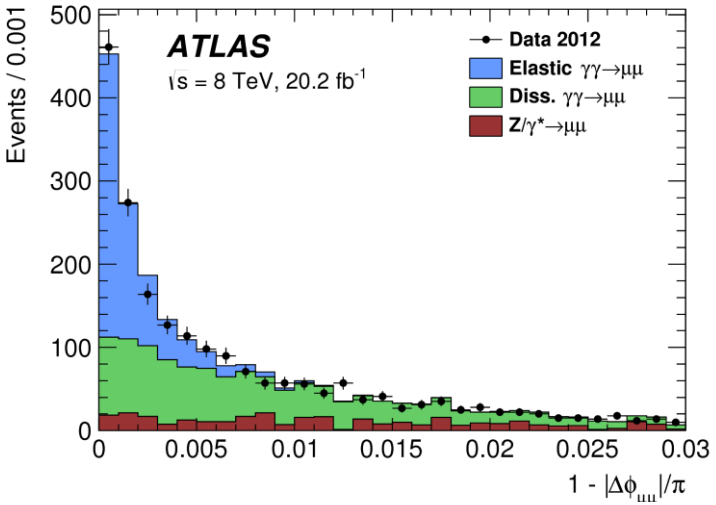


Variable	Excl W^+W^-	Excl Higgs
p_T^{lep}	$> 25, 20$ GeV	$> 25, 15$ GeV
$m_{e\mu}$	> 20 GeV	> 10 GeV
$p_T^{e\mu}$	> 30 GeV	> 30 GeV
Δz_0^{iso}	1mm	1mm
$p_T^{e\mu}$ (aQGC)	> 120 GeV	-
$m_{e\mu}$	-	< 55 GeV
$\Delta\phi_{e\mu}$	-	< 1.8
m_T	-	< 140 GeV

Higgs selection: lower pT / mass requirement (one W is off-shell)

Exclusive γγ → W^+W^- and Search for Exclusive H at 8 TeV (arXiv:1607.03745)

- ***γγ → $\ell^+\ell^-$* validation**



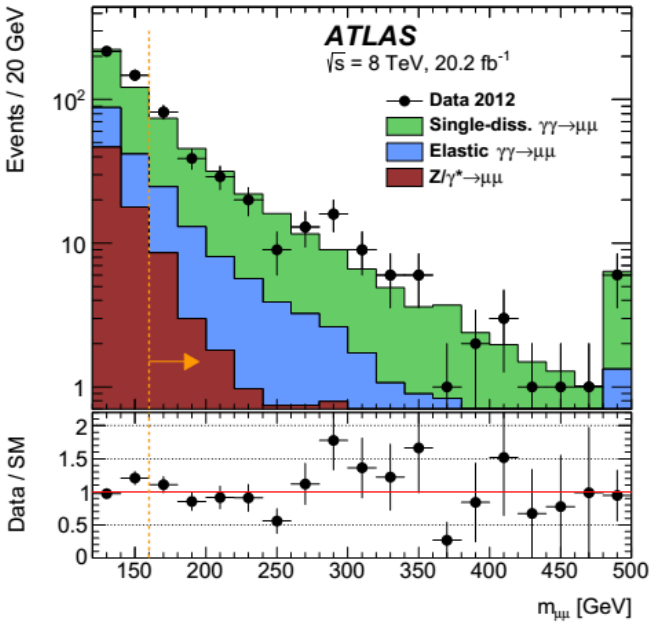
- Ratio of observed elastic ***γγ → $\ell^+\ell^-$*** to bare EPA prediction:

$$f_{\mathrm{EL}} = 0.76 \pm 0.04(\mathrm{stat.}) \pm 0.10(\mathrm{sys.})$$

-> Suppression is stronger due to larger invariant mass being probed

- No simulation available for SD and DD γγ → W^+W^- (and EL+SD+DD are mixed due to W decays): a correction factor is applied using ***γγ → $\ell^+\ell^-$*** for $m_{\ell^+\ell^-} > 160$ GeV:

$$f_\gamma = \left.\frac{N_{\mathrm{Data}} - N^{\mathrm{POWHEG}}_{\mathrm{Background}}}{N^{\mathrm{HERWIG++}}_{\mathrm{Elastic}}}\right|_{m_{\mu\mu}>160\ \mathrm{GeV}} = 3.30 \pm 0.22(\mathrm{stat.}) \pm 0.06(\mathrm{sys.})$$

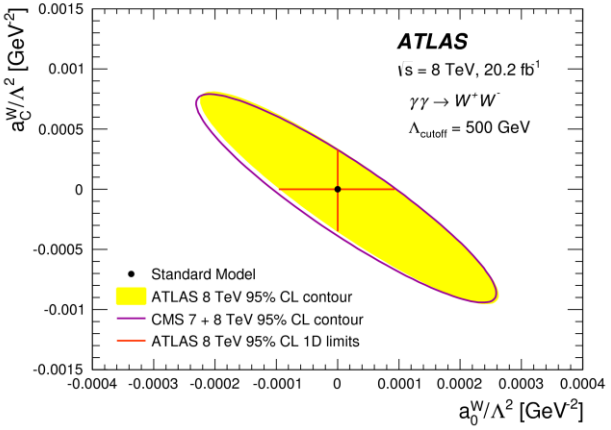


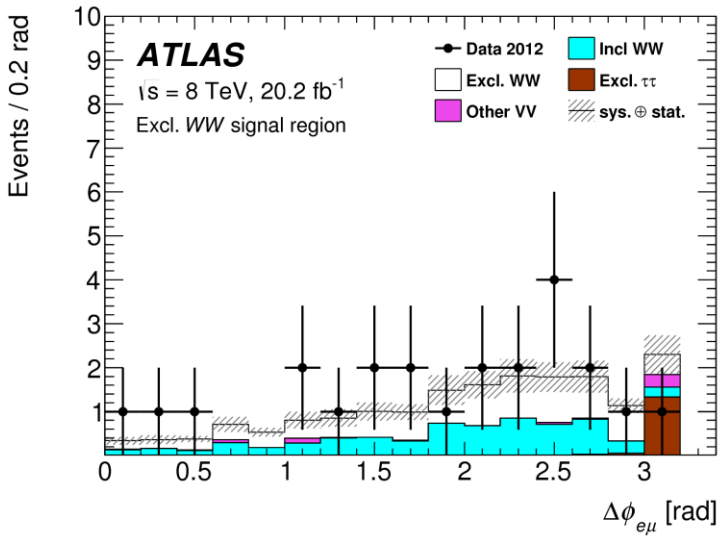
Exclusive γγ → W^+W^- and Search for Exclusive H at 8 TeV (arXiv:1607.03745)

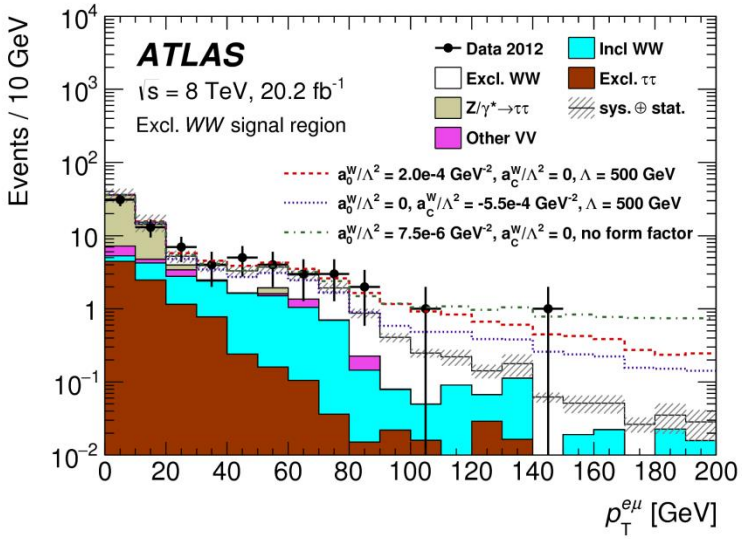
- **Results (γγ → W^+W^- and aQGCs)**

- Exclusive W^+W^- event yields: Data = 23, Background = 8.3 ± 2.6, Signal = 9.3 ± 1.2
  ->Measurement significance of 3σ

- aQGC event yields [pT(eμ) > 120 GeV]: Data = 1, Background = 0.37 ± 0.13, SM Signal = 0.37 ± 0.04
  -> new aQGC limits are set







Exclusive γγ → W^+W^- and Search for Exclusive H at 8 TeV (arXiv:1607.03745)

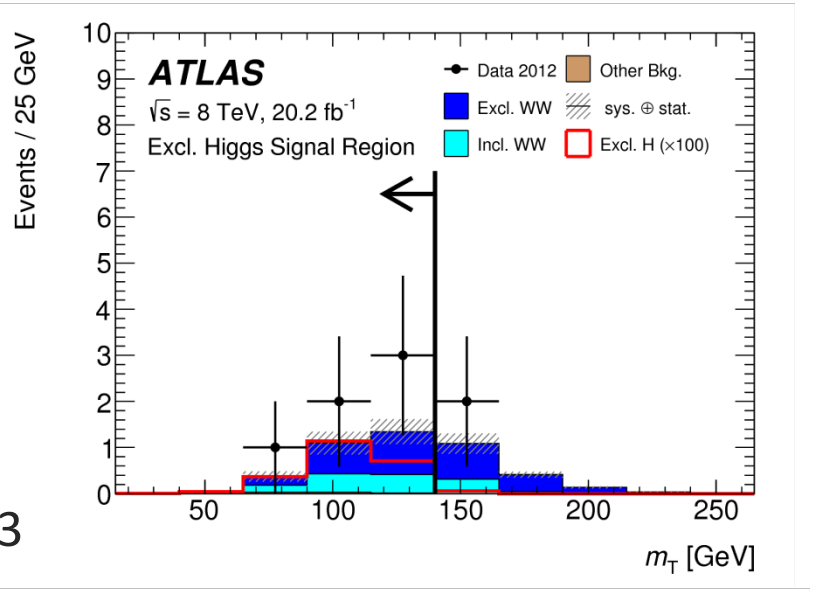
- **Results (exclusive Higgs)**

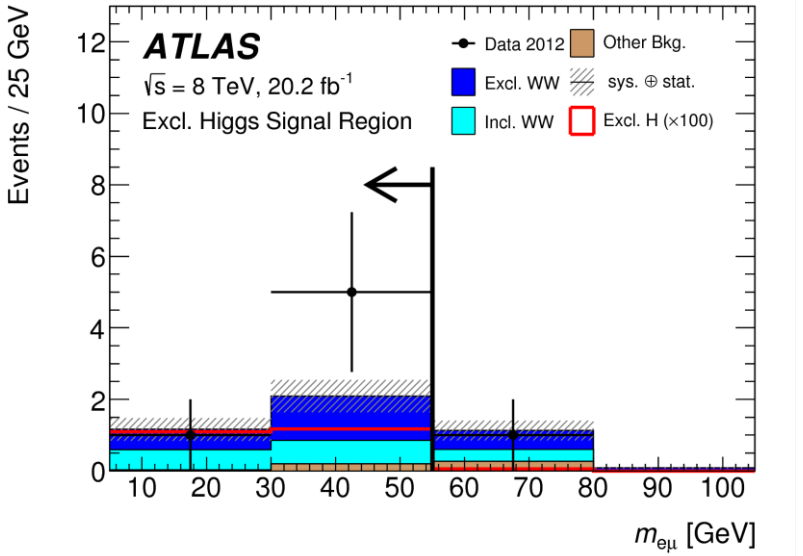
- Exclusive and inclusive W^+W^- are the dominant background

- Exclusive Higgs event yields: Data=6, Background = 3.0 ± 0.8, Signal = 0.023 ± 0.003

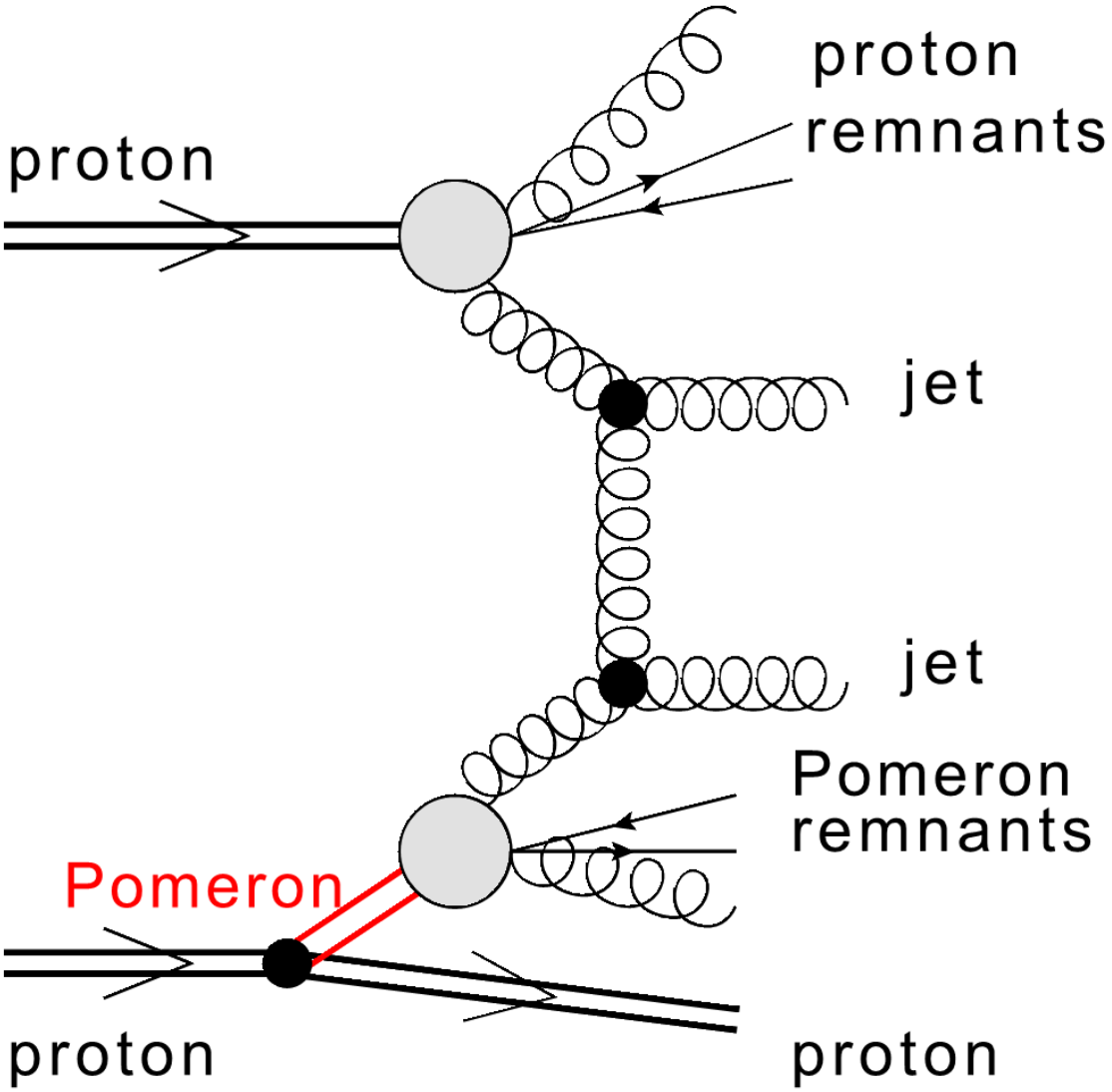
- Observed and expected limits:
  σ < 1.2 pb @ 95% CL (Observed)
  σ < 0.7 pb @ 95% CL (Expected)

- Upper limit = 400 x predicted σ
  (predictions include just the elastic process)



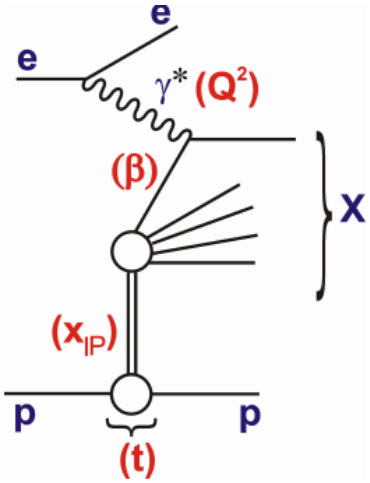


Diffractive Dijet Production at 7 TeV, PLB 754 (2016) 214-234

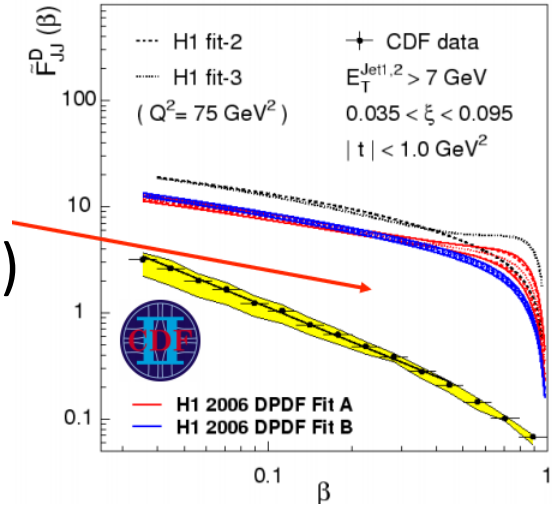


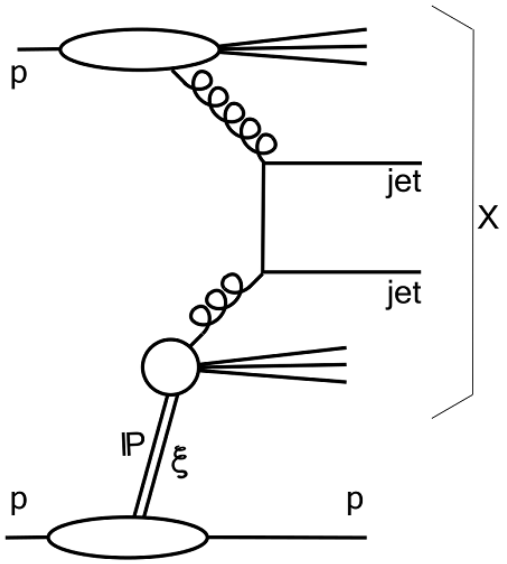
Diffractive Dijet Production at 7 TeV, PLB 754 (2016) 214-234

- **Motivation**



- Diffractive DIS at HERA: Diffractive parton densities dominated by gluon
- pp(pbar) collisions:
  Failure in comparison of Tevatron proton-tagged diffractive dijets with HERA DPDFs
  -> **'rapidity gap survival probability'** due to rescattering (absorptive corrections) breaks factorisation

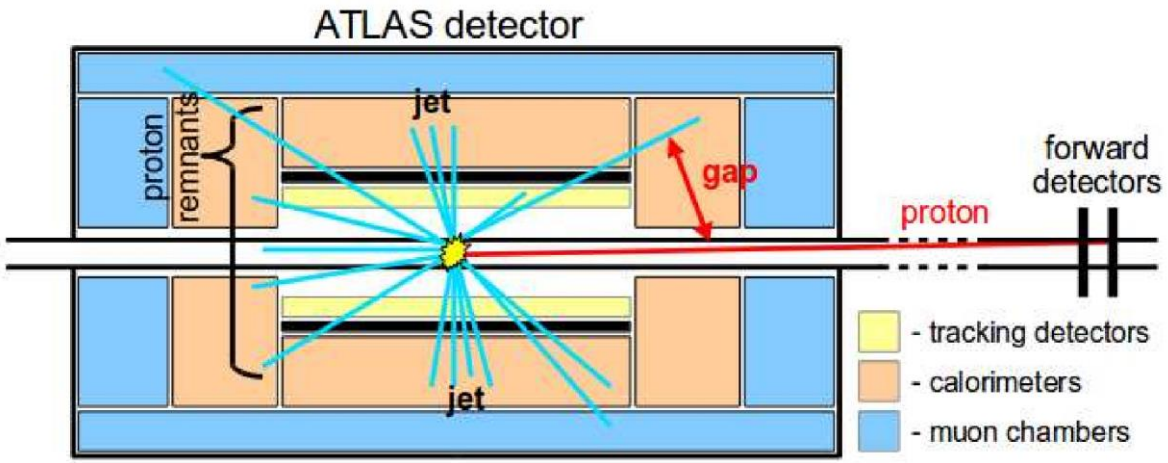




Diffractive Dijet Production at 7 TeV, PLB 754 (2016) 214-234

- **Kinematics and selection**

- Low pile-up data sample from 2010 with √s= 7 TeV and integrated luminosity of 6.8 nb
- Jets with anti-kT algorithm, pT > 20 GeV, |η| < 4.4, R=0.4, 0.6
- Gaps characterisedusing $\Delta\eta_F$, based on tracks (|η| < 2.5, pT > 200 MeV) and calocells (|η| < 4.8) that are >5σ out of noise distribution



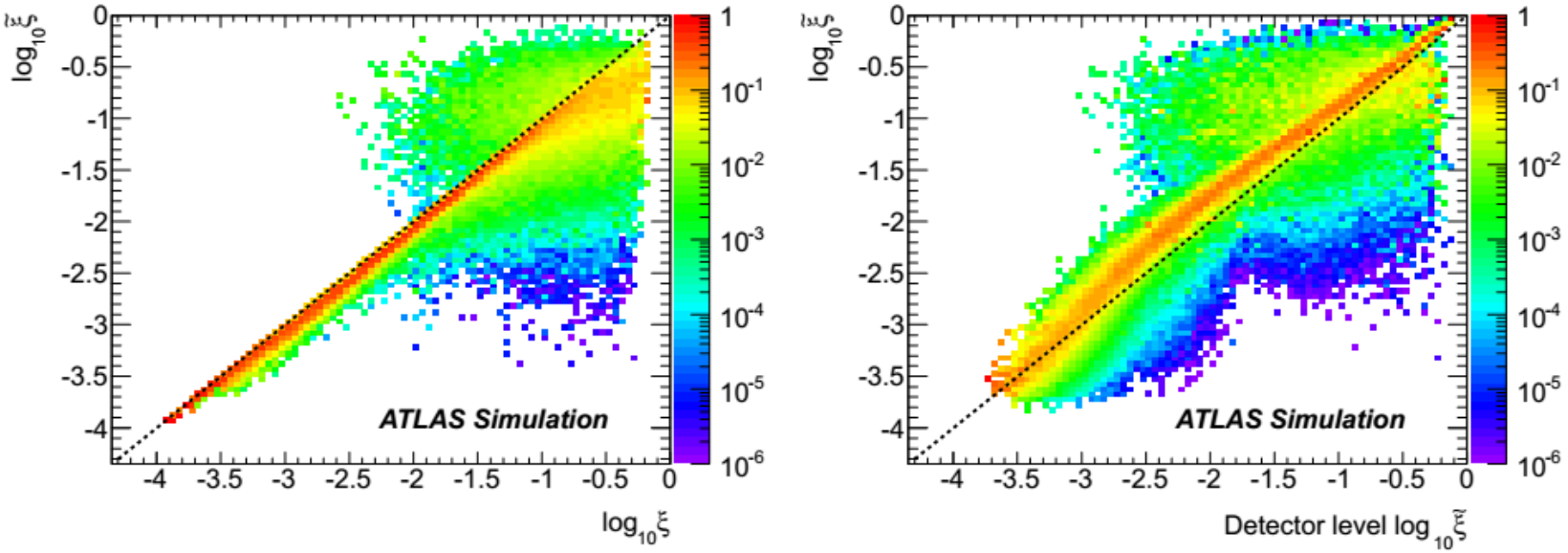
Diffractive Dijet Production at 7 TeV, PLB 754 (2016) 214-234

- **Event characteristics**

- Diffractive proton energy loss (ξ) is extracted from energy deposits:

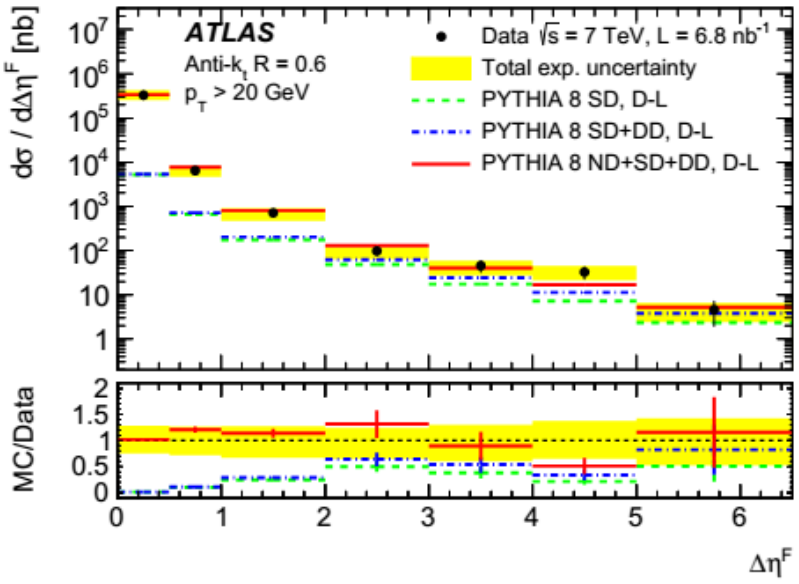
$$\tilde{\xi} \simeq M_X^2/s = \sum p_T e^{\pm\eta}/\sqrt{s}$$

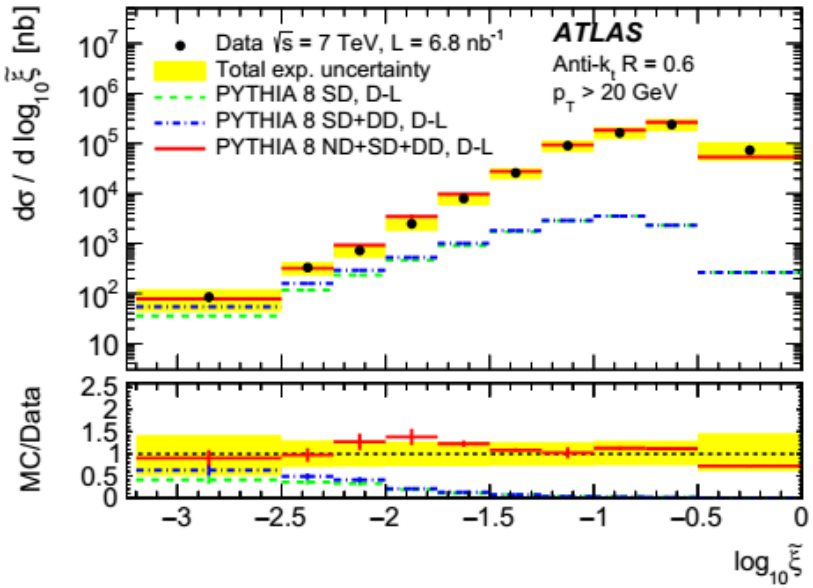
- Experimental resolution on log(ξ) is approximately 10%



Diffractive Dijet Production at 7 TeV, PLB 754 (2016) 214-234

- **Results**

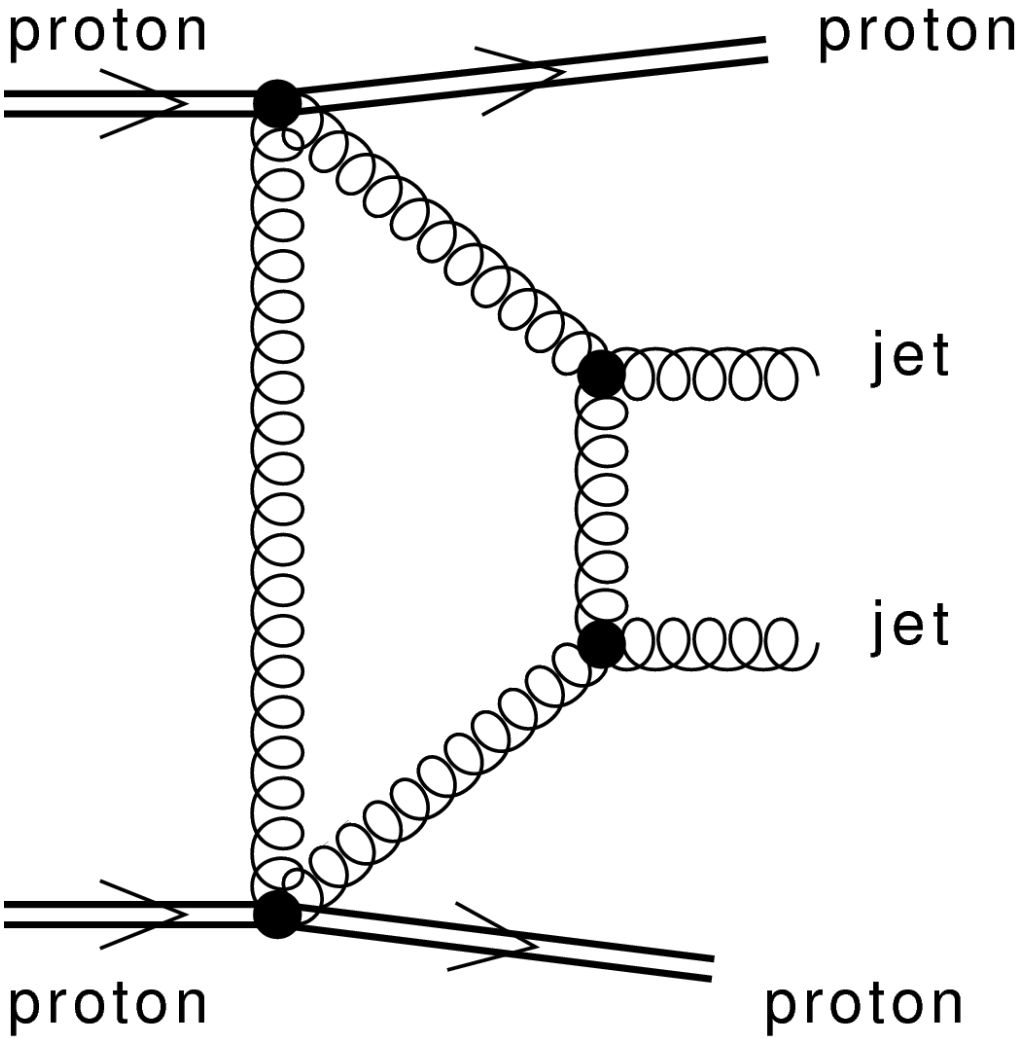




- Diffractive component is required for more complete description of data
- Pythia8 gives a good description of shape and normalization
- Rapidity gap survival factor is extracted in the context of POMWIG (and H1 2006 Fit B DPDFs):

$$S^2 = 0.16 \pm 0.04\ (\text{stat.}) \pm 0.08\ (\text{exp. syst.})$$

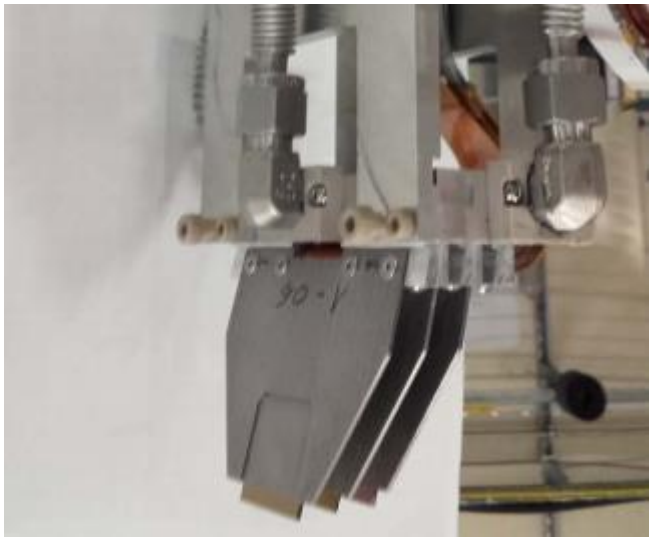
Feasibility Studies for Exclusive Jet Production with AFP, ATL-PHYS-PUB-2015-003

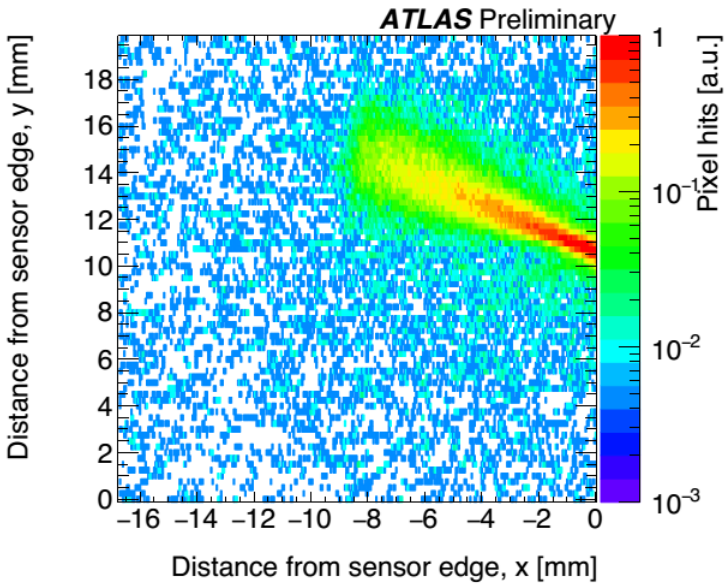


Feasibility Studies for Exclusive Jet Production with AFP, ATL-PHYS-PUB-2015-003

- **AFP detector status** (see Marek's talk)

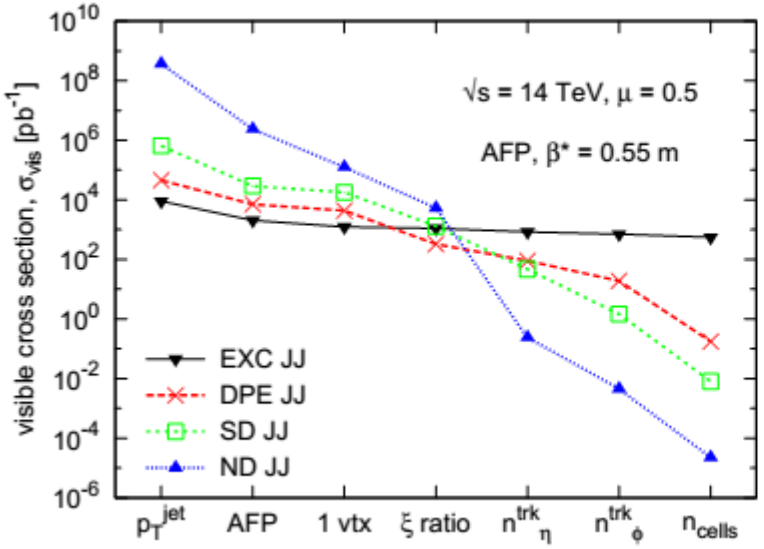
- Single-arm with **3** 3D pixel detector layers (near station) and **4** layers (far station) fully integrated with ATLAS
- 300 b fill #4906 (10th of May 2016), AFP readout (20σ from the beam) but triggered by ATLAS ($\mu \lesssim 26$, 2:16 hrs)
- Low-μ run with dedicated AFP-based triggers is also recently recorded ($\approx 0.04\ pb^{-1}$)

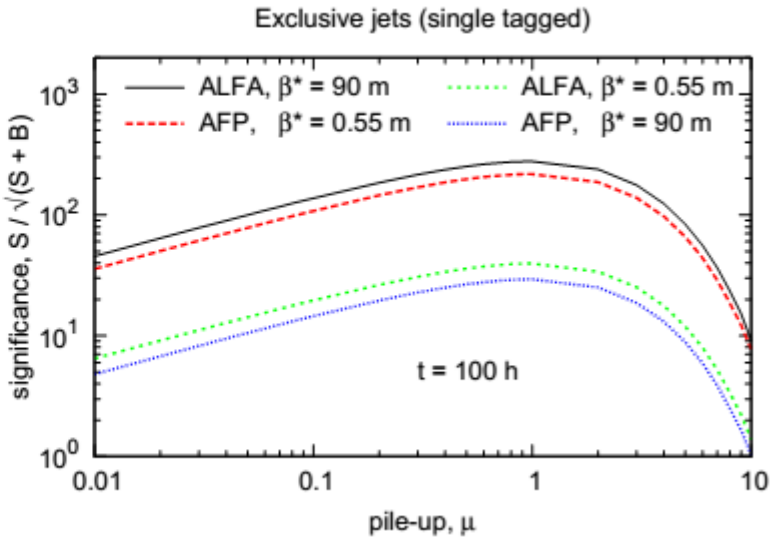




Feasibility Studies for Exclusive Jet Production with AFP, ATL-PHYS-PUB-2015-003

- **Motivation and feasibility results**
- Constrains other exclusive productions (e.g. Higgs)
- Cross section measurement is possible, even with single-tag configuration:
  - S/B = 10^4 after applying all the selection requirements
  - ~400 events expected with 1pb^{-1} of data
  - See also EPJC 75 (2015) 320





Summary

- Exclusive (photon-induced) processes
  - Cross sections of the exclusive $\gamma\gamma \rightarrow \ell^+\ell^-$ production have been measured
    -> Observation is consistent with the suppression (20%) expected due to proton absorption contributions
  - Evidence of SM exclusive $\gamma\gamma \rightarrow W^+W^-$ production (significance of 3σ)
    -> No evidence for an excess in the kinematic region targetting aQGC
    -> Limits on exclusive Higgs production cross section are also set

- Diffractive Dijets
  - Evidence for diffractive contribution in 7 TeV data
  - Detailed understanding heavily limited by poorly known non-diffractive contribution
  - Future prospects with dedicated proton spectrometers (AFP) are very promising