Forward physics results of the ATLAS experiment

Rafał Staszewski

Henryk Niewodniczański
Institute of Nuclear Physics
Polish Academy of Sciences

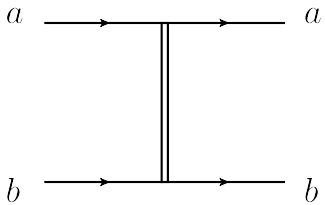
Various Faces of QCD

3rd Symposium of the Division for Physics of Fundamental Interactions of the Polish Physical Society

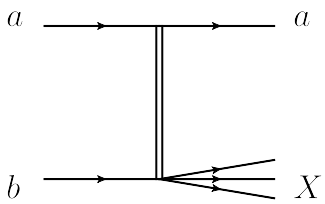
Świerk, 8 – 9 October 2016

Diffractive processes

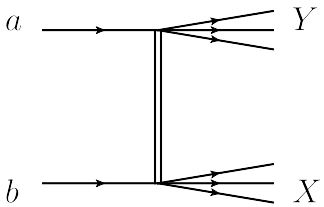
elastic scattering



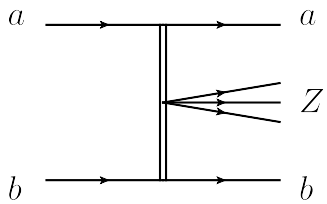
single diffraction



double diffraction



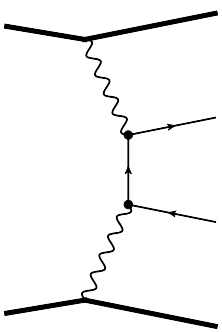
central diffraction

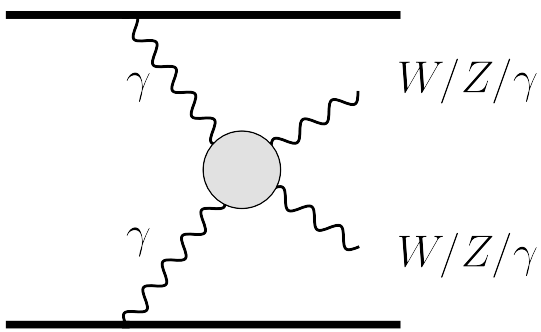


Experimental signatures:

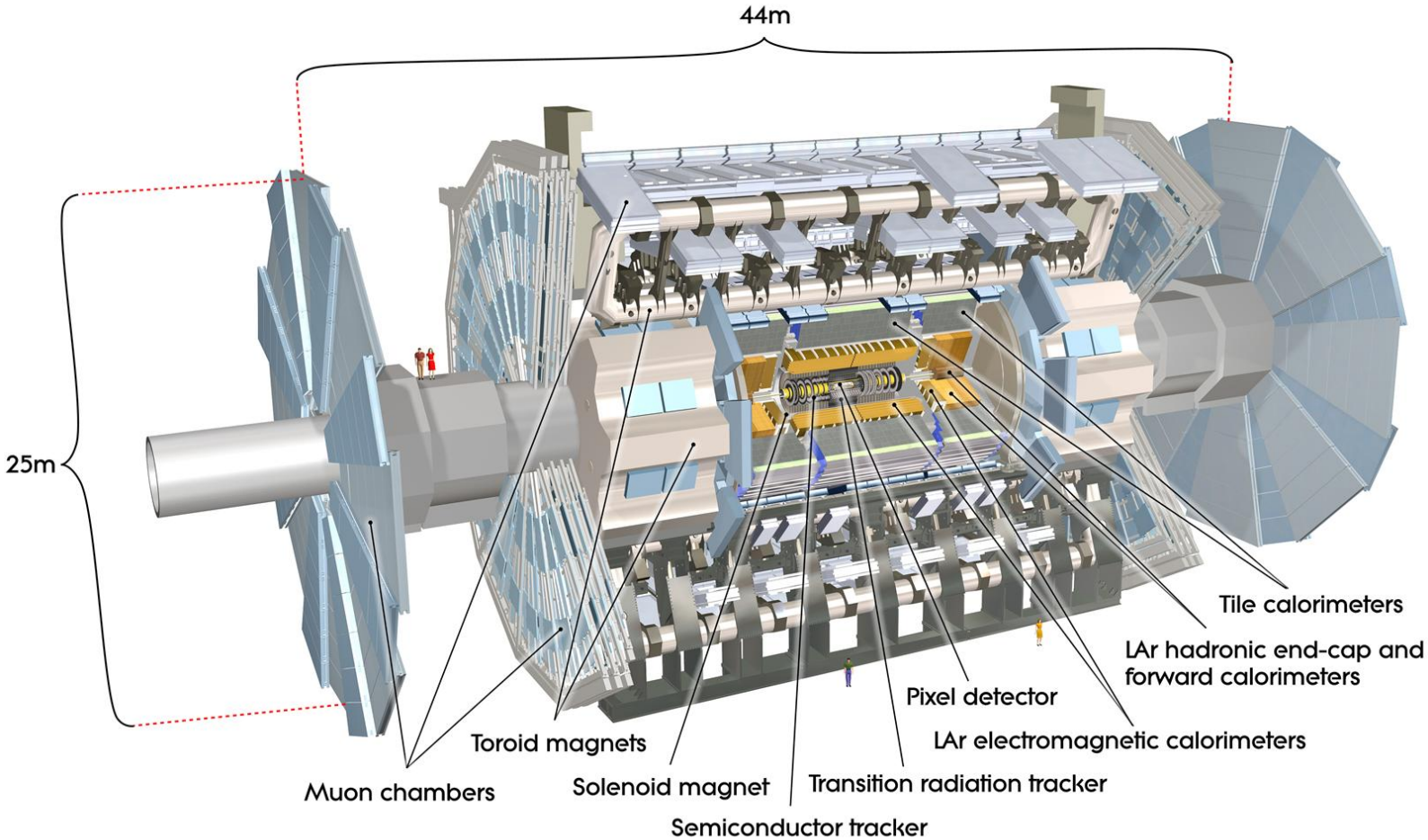
- large rapidity gaps
- forward protons

Two-photon processes:





ATLAS Detector



...but also forward detectors providing measurements of forward intact protons: **ALFA** and **AFP**

Contents

Measurements w/o forward proton tagging

Proton tagging: ALFA detectors

Proton tagging: AFP detectors

Summary

1 Measurements w/o forward proton tagging

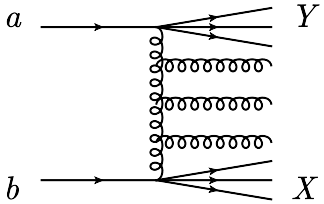
2 Proton tagging: ALFA detectors

3 Proton tagging: AFP detectors

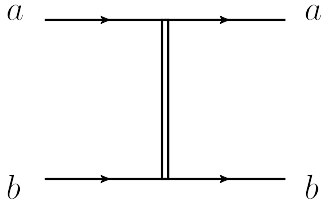
4 Summary

Soft diffraction

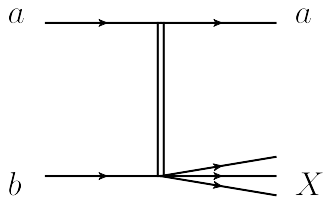
non-diffractive interaction



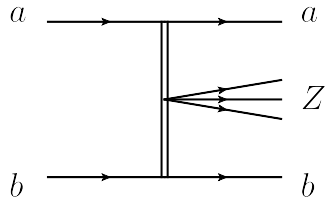
elastic scattering



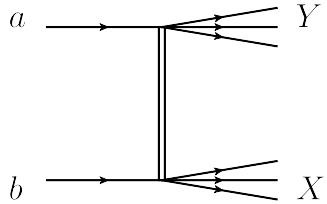
single diffraction

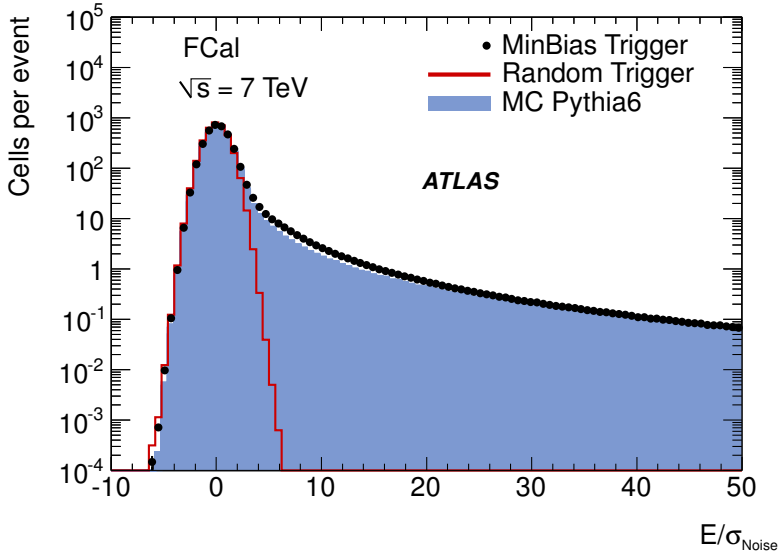


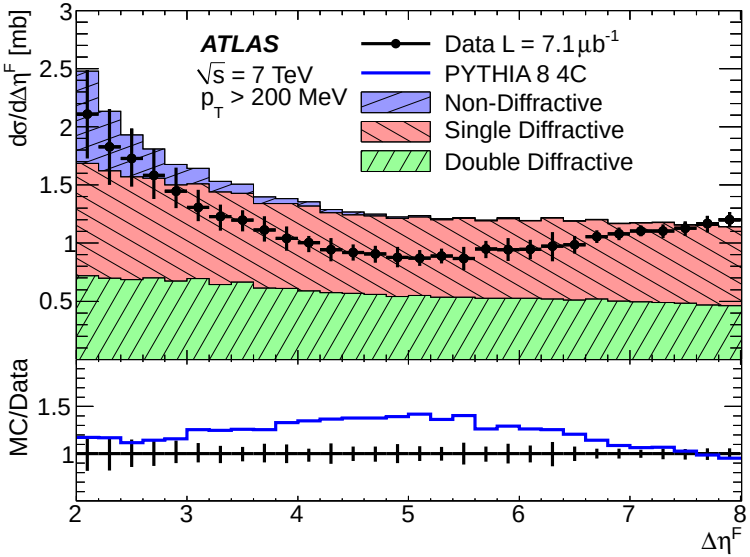
central diffraction



double diffraction



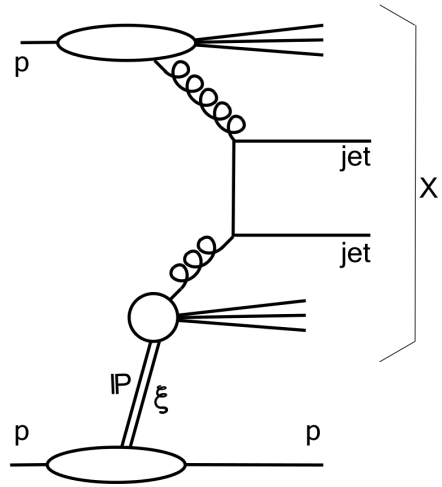




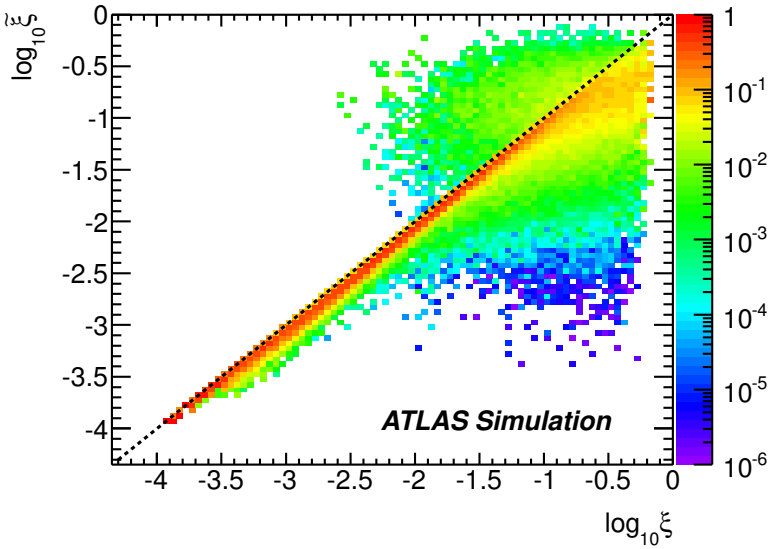
- Calorimeter used to measure rapidity gaps
- Separation of diffractive processes from non-diffractive processes
- Full separation of single and double diffraction not possible

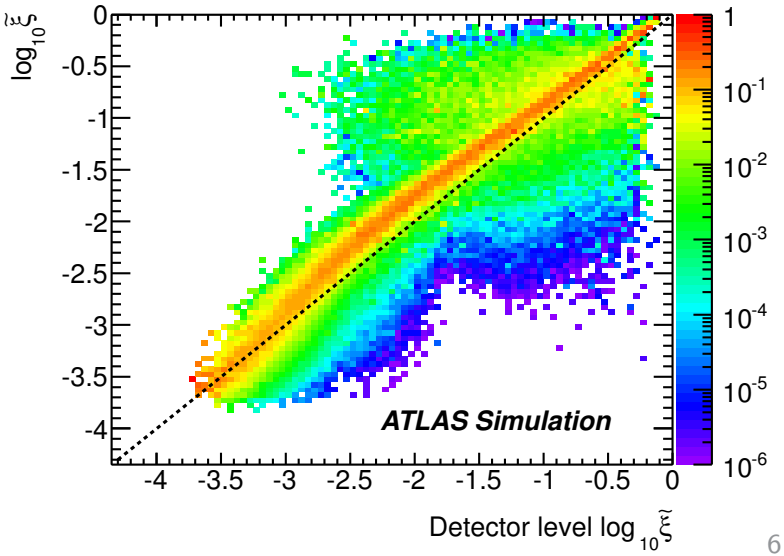
Diffractive jets

- Low pile-up data from 2010 ($\sqrt{s} = 7$ TeV)
- Rapidity gap based on
  - tracks ($|\eta| < 2.5$, pT > 200 MeV)
  - calorimeter cells ($|\eta| < 4.8$)
- Proton energy loss and diffractive mass

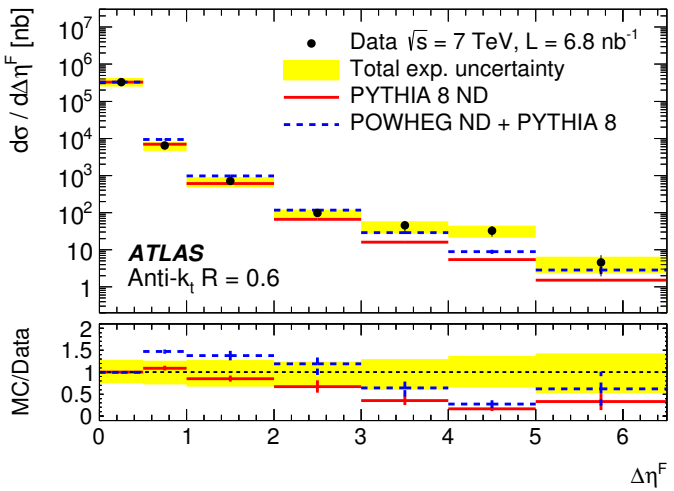


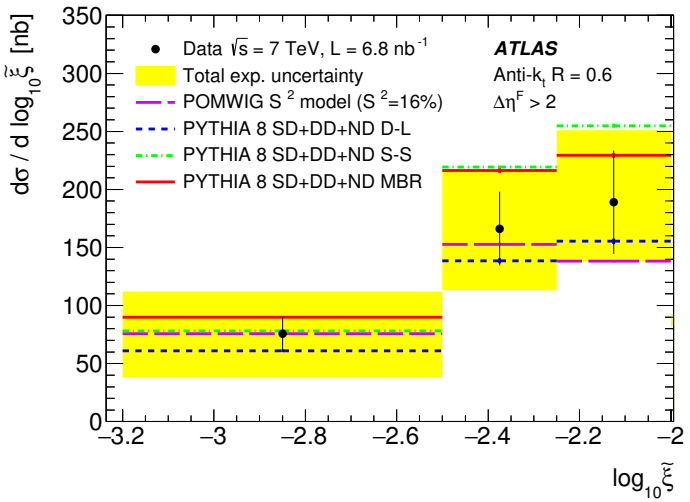
$$\xi = M_X^2/s \qquad \tilde{\xi} = \frac{\sum p_T e^{\pm\eta}}{\sqrt{s}}$$





Diffractive jets

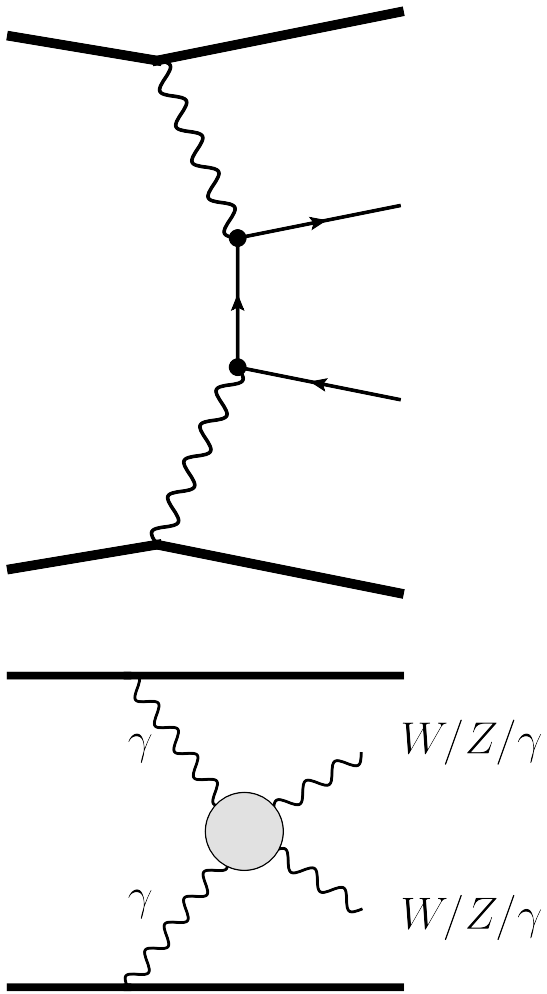




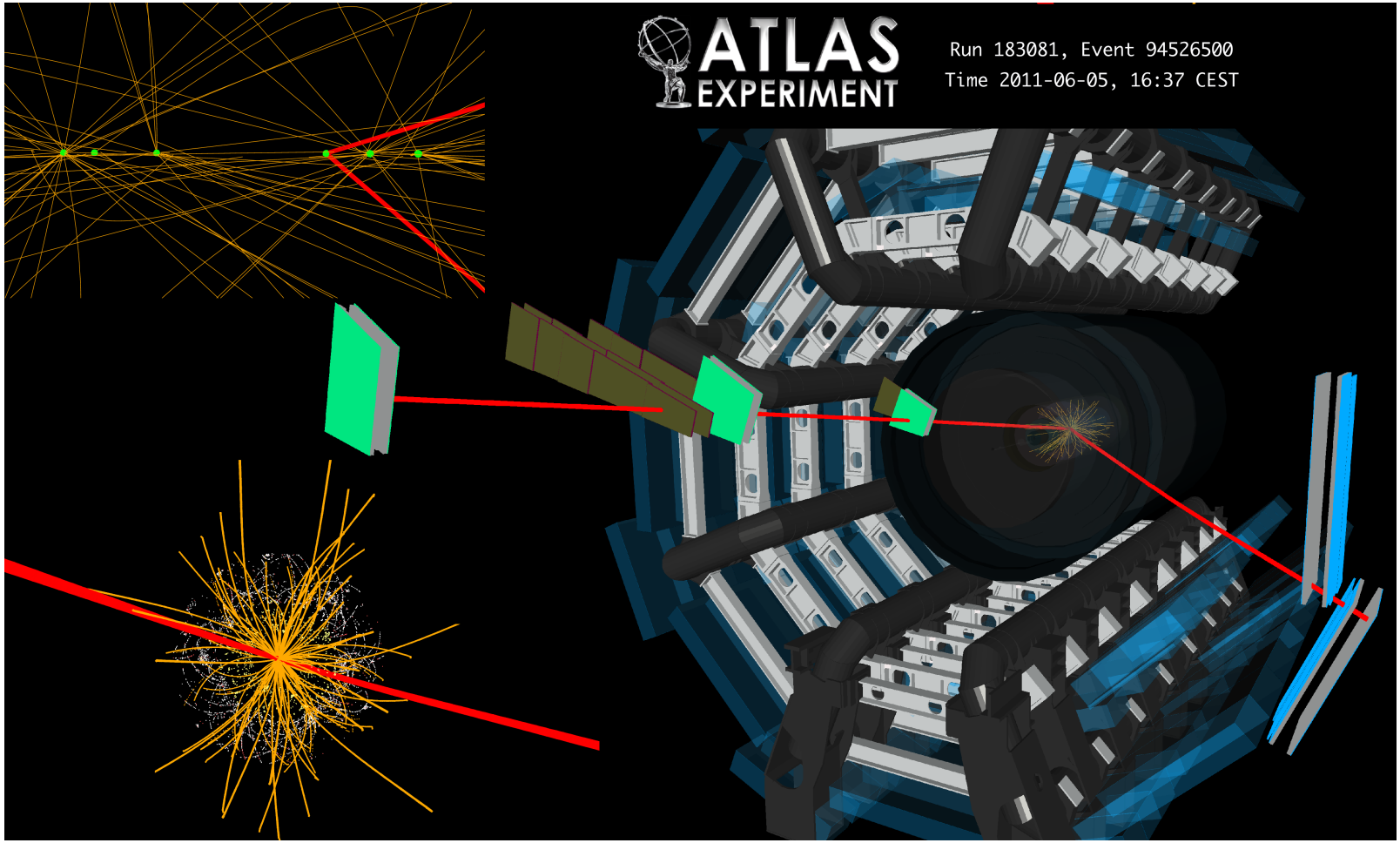
- Evidence of diffractive component
- Good description by Pythia8
- Gap survival probability: 0.16 ± 0.04 (stat) ± 0.08 (exp. syst.)

Two-photon processes

- Two-photon processes can be computed within QED
- Exclusive $\gamma\gamma \to ll$
  - Standard candle for photon-induced physics
  - Non-negligible background to Drell-Yan like reactions
- Test of SM γWW and $\gamma\gamma WW$ couplings
- Searches for new physics
- QCD:
  - absorptive corrections
  - dissociation

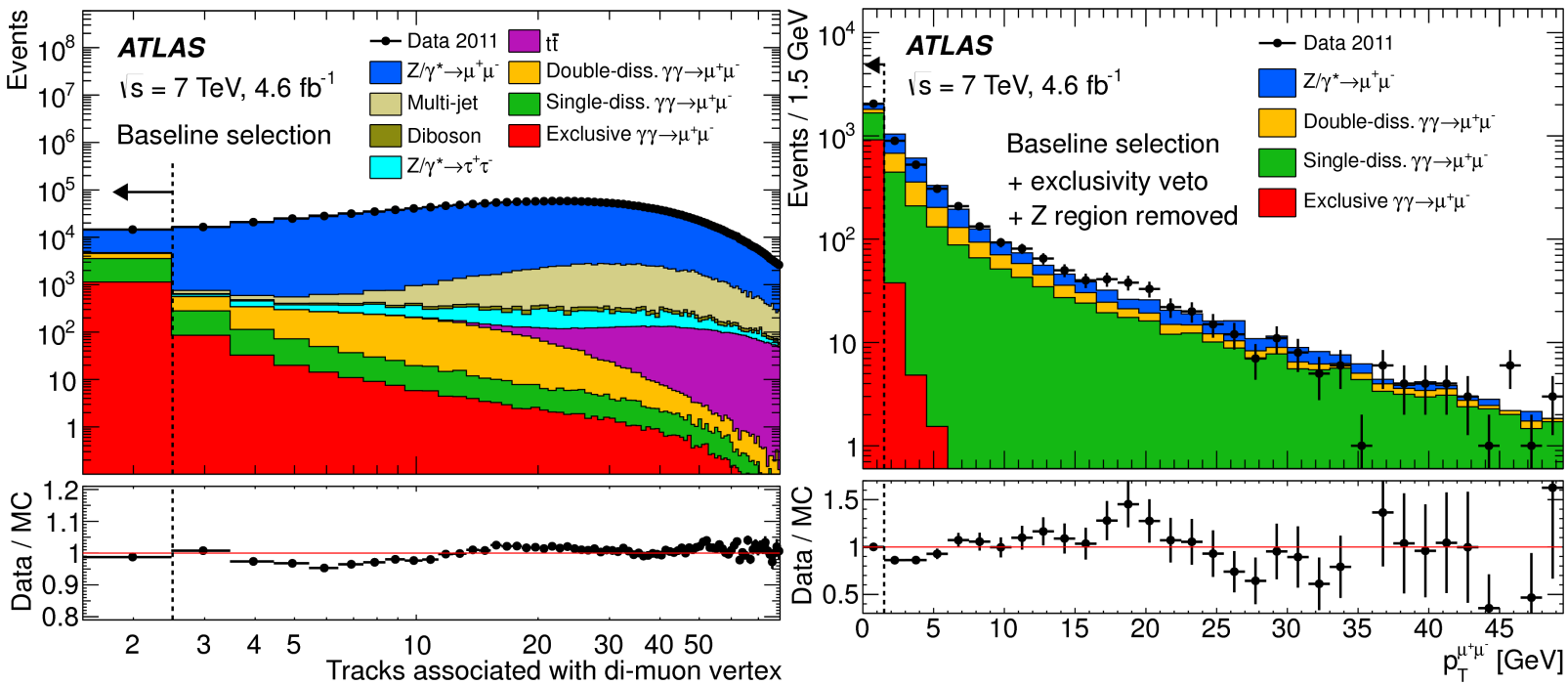


$\gamma\gamma \to \mu\mu$ in pp

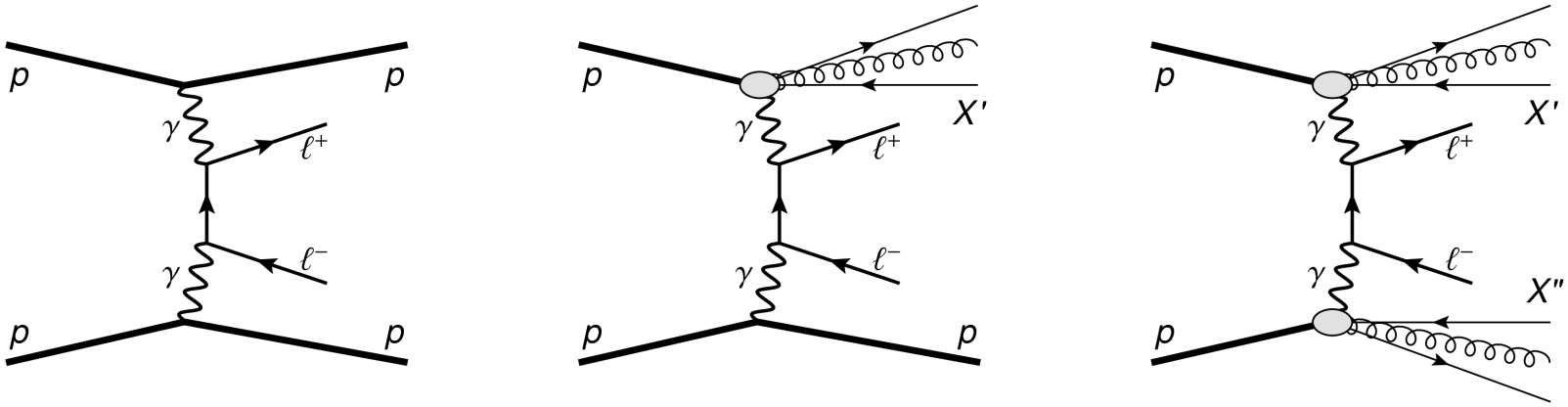


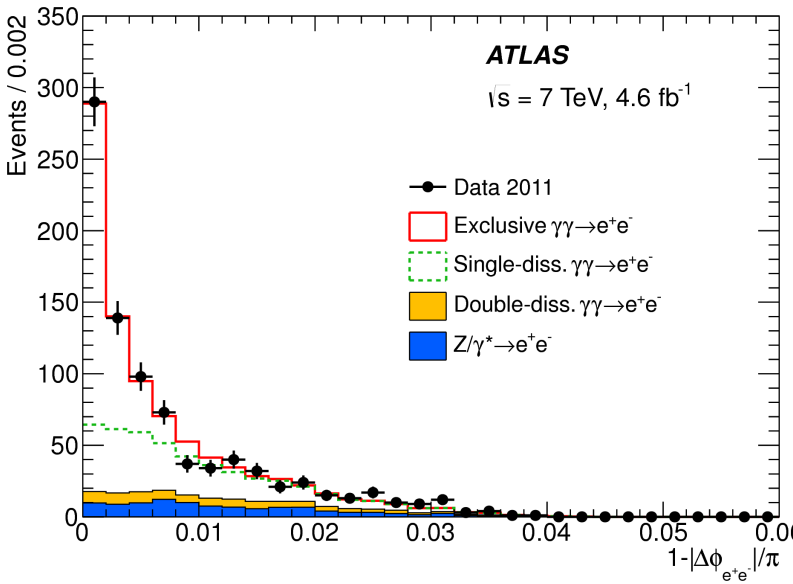
$\gamma\gamma \to \mu\mu$ in pp: event selection

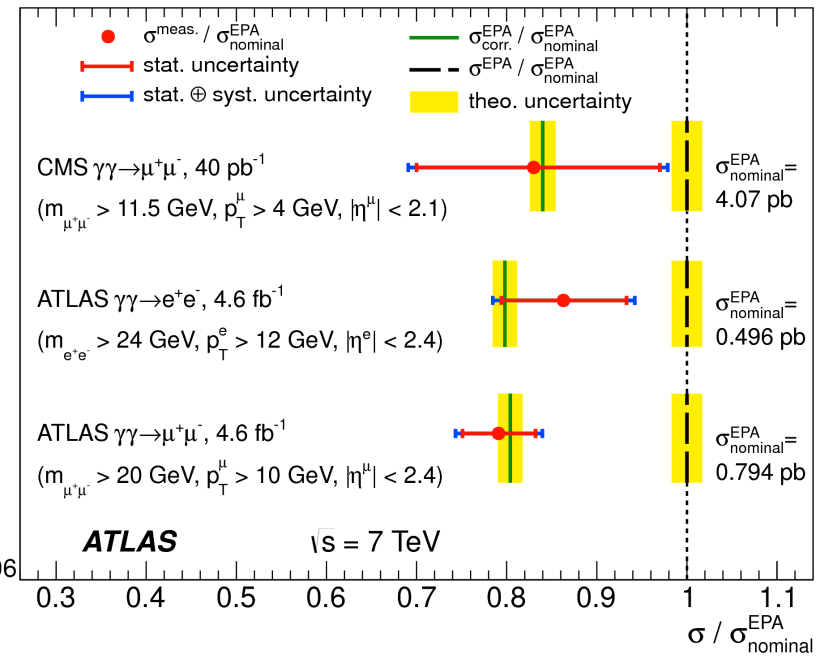
- Preselection:
  - muons: $p_T > 10$ GeV, $|\eta| < 2.4$, $M_{\mu\mu} > 20$ GeV
  - electrons: $p_T > 11$ GeV, $|\eta| < 2.4$, $M_{ee} > 24$ GeV
- Exclusive selection:
  - 3 mm vertex longitudinal isolation (efficiency = 74%)
  - p_T of the pair below 1.5 GeV



$\gamma\gamma \to \mu\mu$ in pp: results



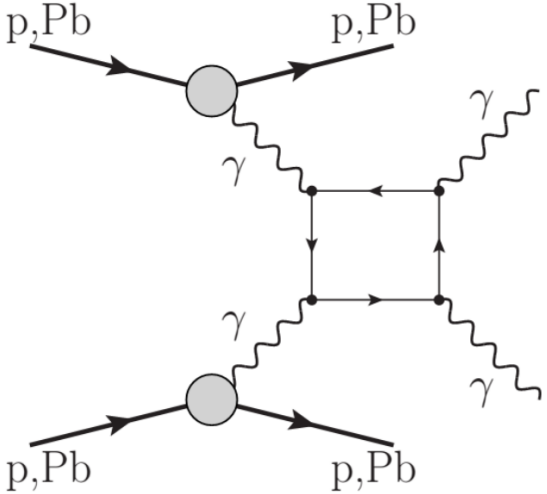


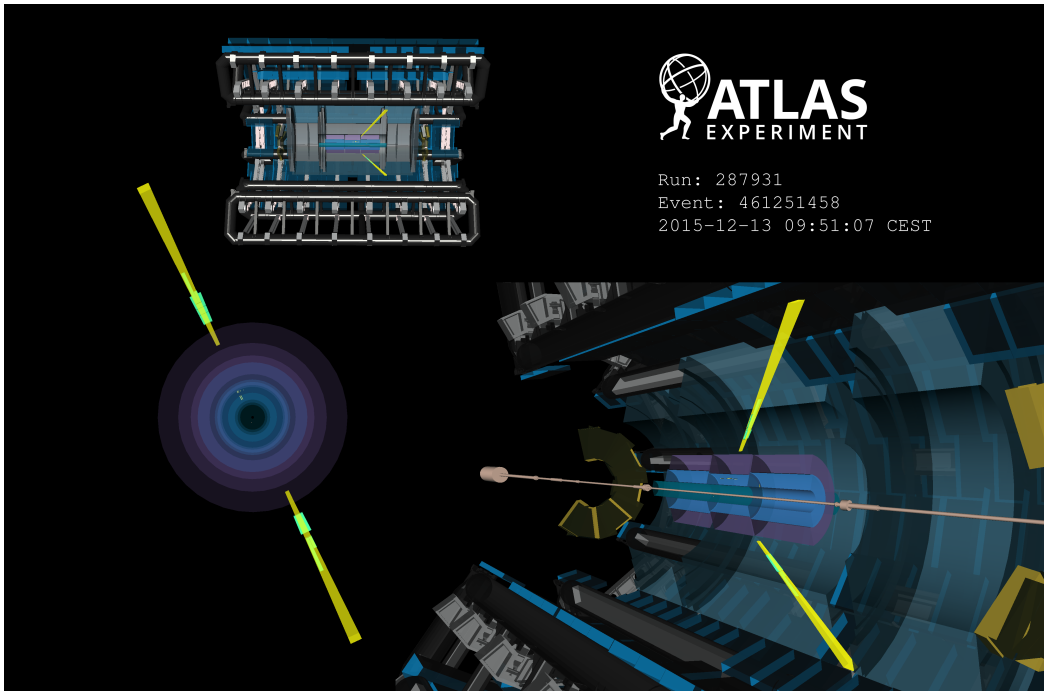


- Agreement with calculations (absorptive corrections are important)
- Agreement with CMS measurement

Light-by-light scattering in $PbPb$

- Elastic scattering of two photons
- Quantum effect: not present in classical theory
- Very small cross section
- No direct observation so far
- Possible channel to study new physics

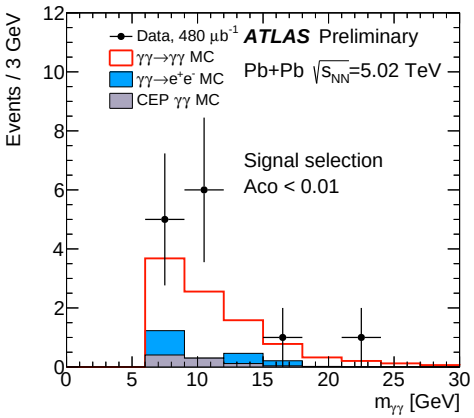


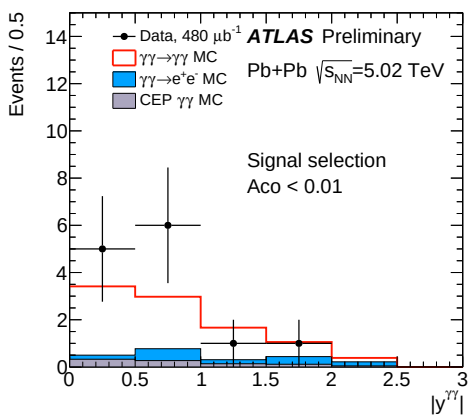


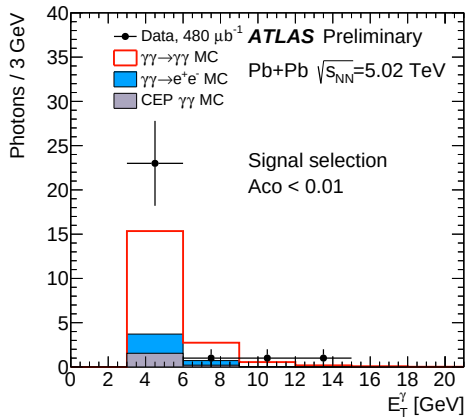
$\gamma\gamma \to \gamma\gamma$ in $PbPb$: results

- First direct observation of the light-by-light signal
- Excess in the data consistent with predictions
  (M. Kłusek-Gawenda *et al.*, Phys.Rev. C93 (2016) no.4, 044907)

$$\sigma_{\text{fid}}^{\text{meas}} = 70 \pm 20(\text{stat}) \pm 17(\text{syst}) \text{ nb} \qquad \sigma_{\text{fid}}^{\text{th}} = 49 \pm 10 \text{ nb}$$







- Observed significance: 4.4σ (expected: 3.8σ)
- Signal strength: $\mu = 1.6 \pm 0.6$

Contents

Measurements w/o forward proton tagging

Proton tagging: ALFA detectors

Proton tagging: AFP detectors

Summary

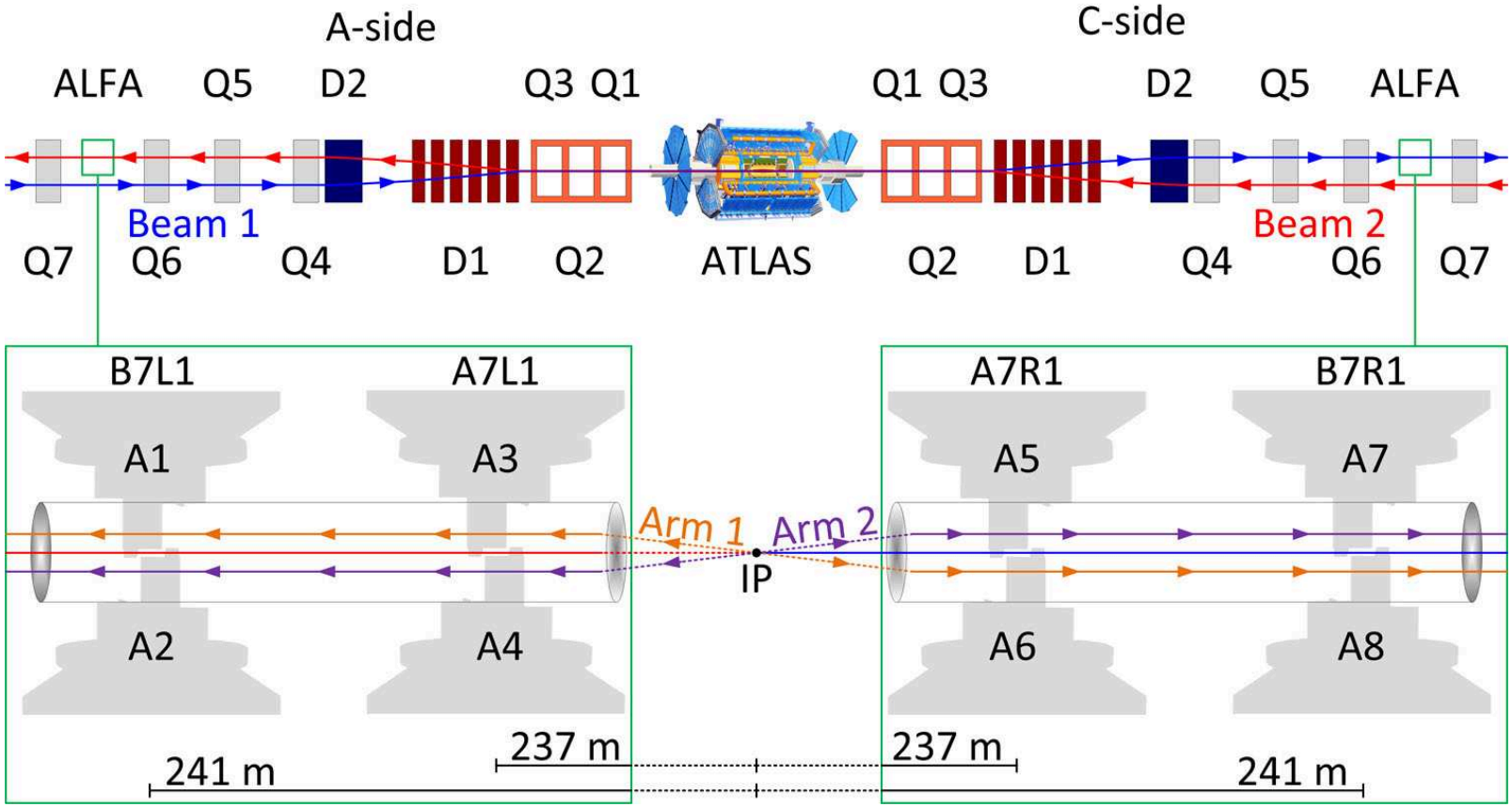
1 Measurements w/o forward proton tagging

2 Proton tagging: ALFA detectors

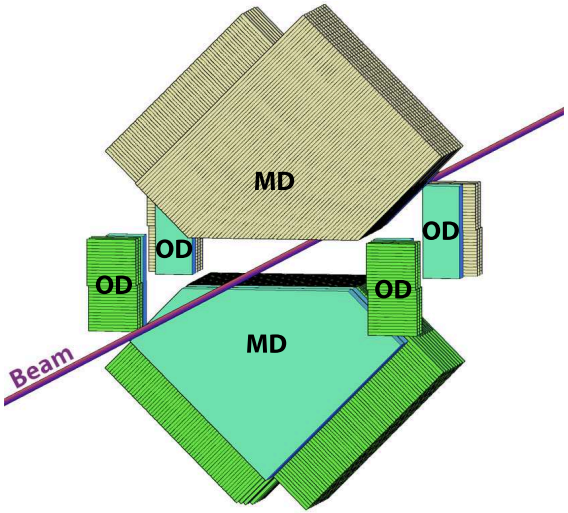
3 Proton tagging: AFP detectors

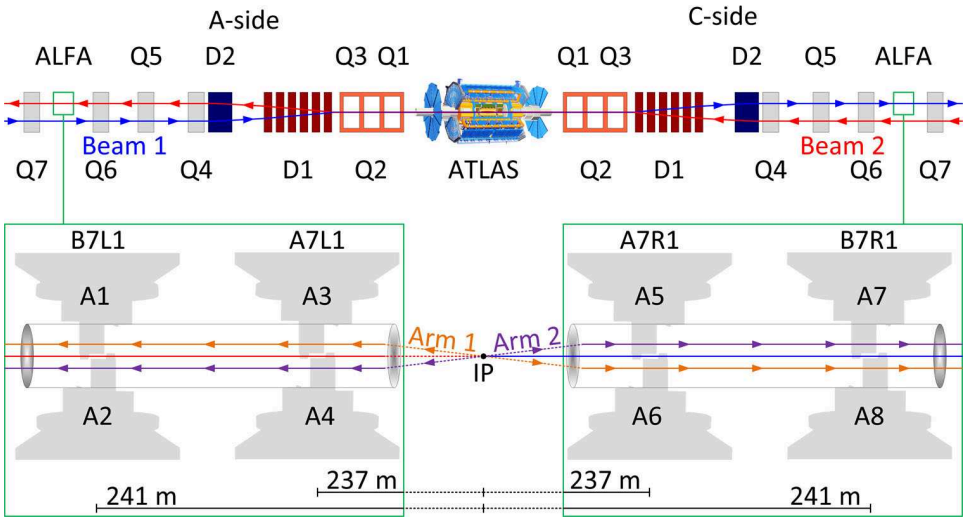
4 Summary

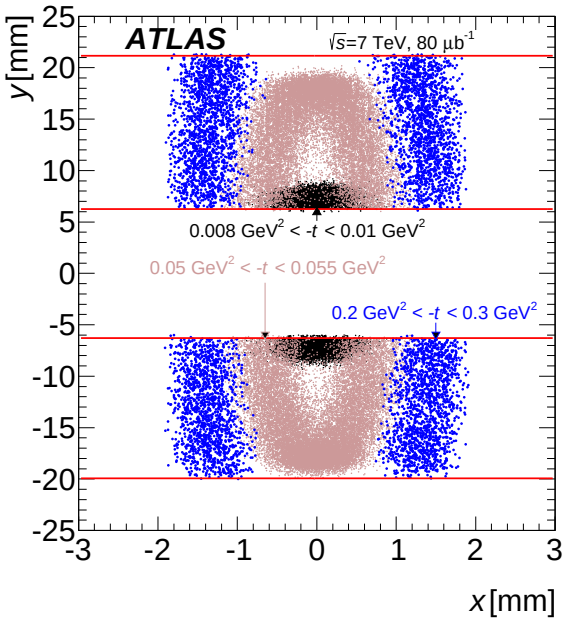
ALFA (Absolute Luminosity For ATLAS) detectors

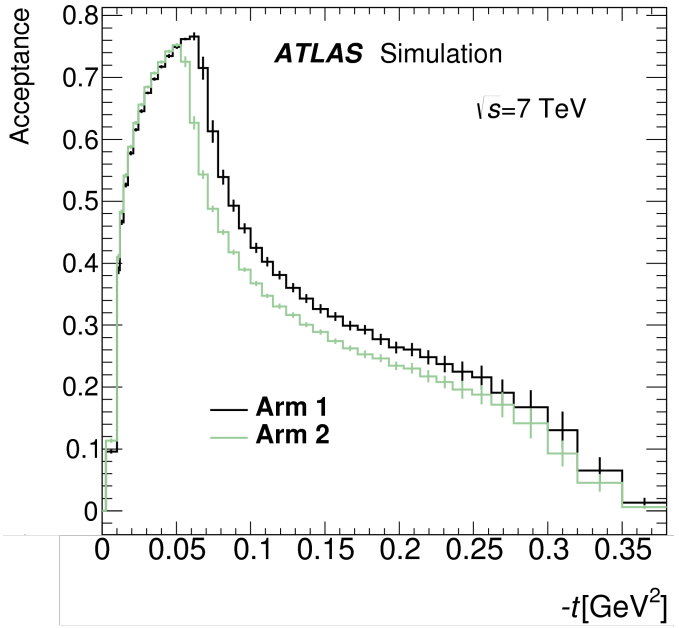


Elastic events in ALFA

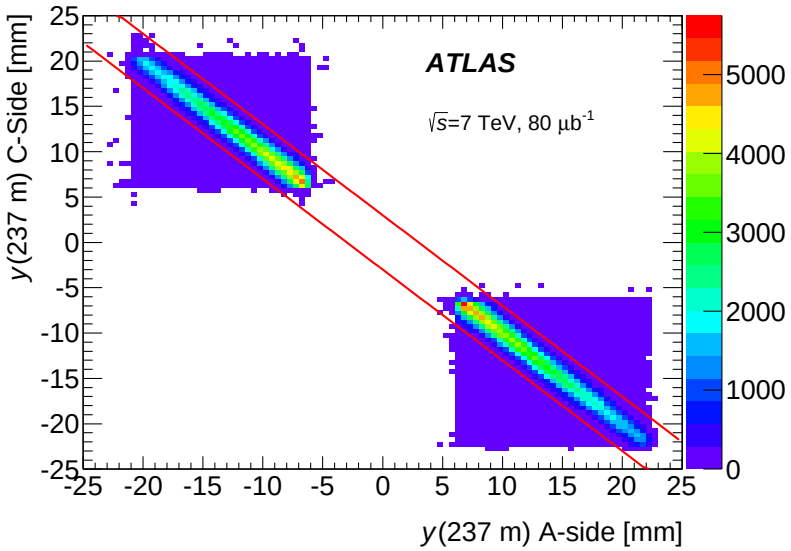


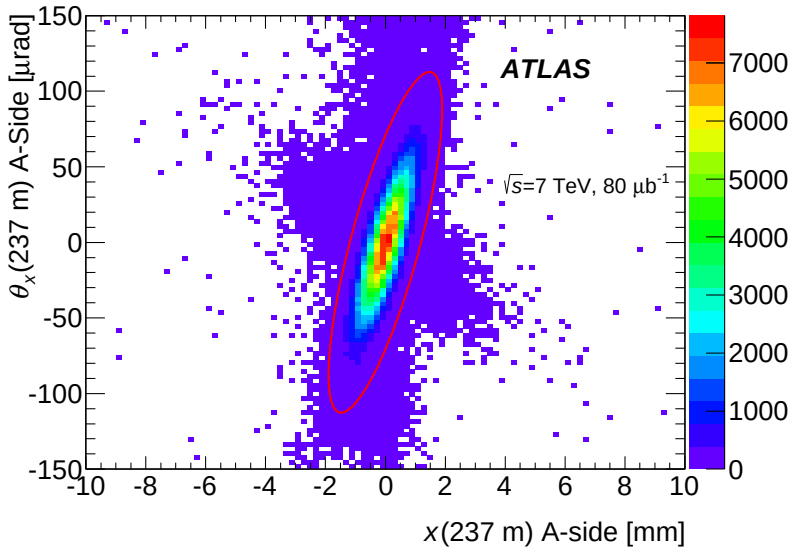


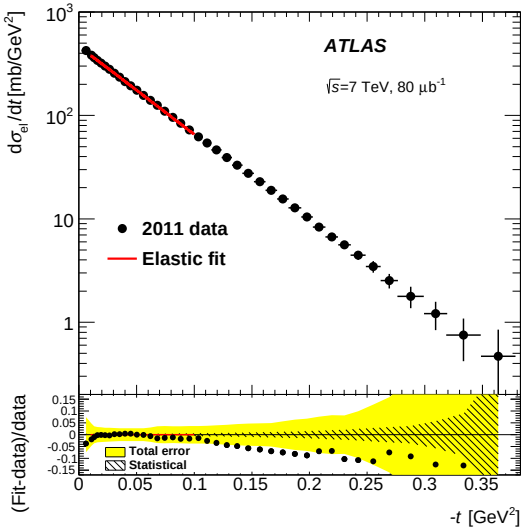


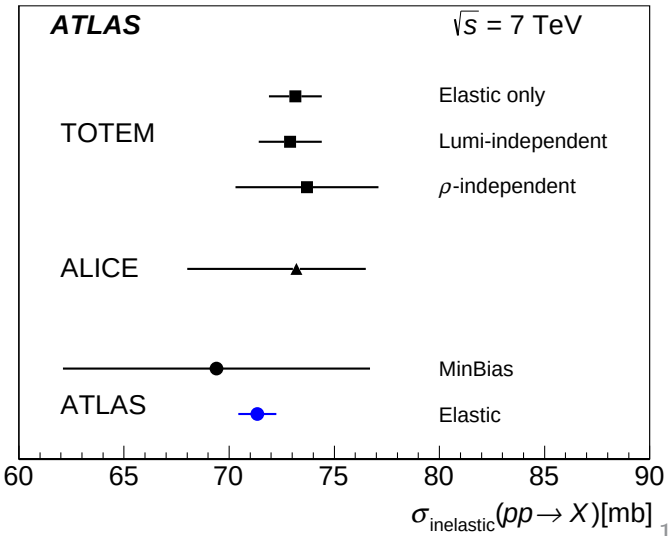


Elastic events in ALFA

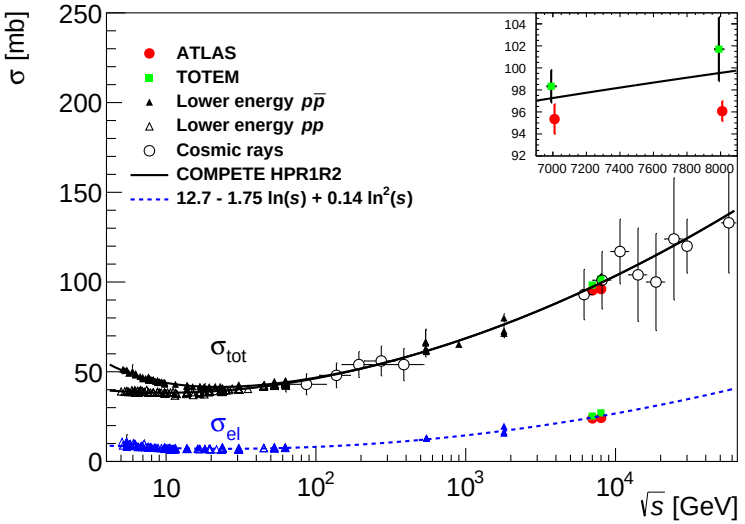




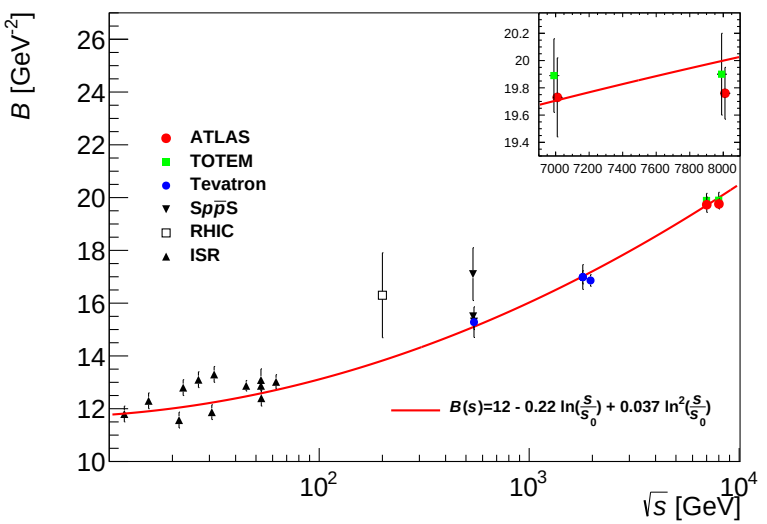




Total cross section end elastic slope

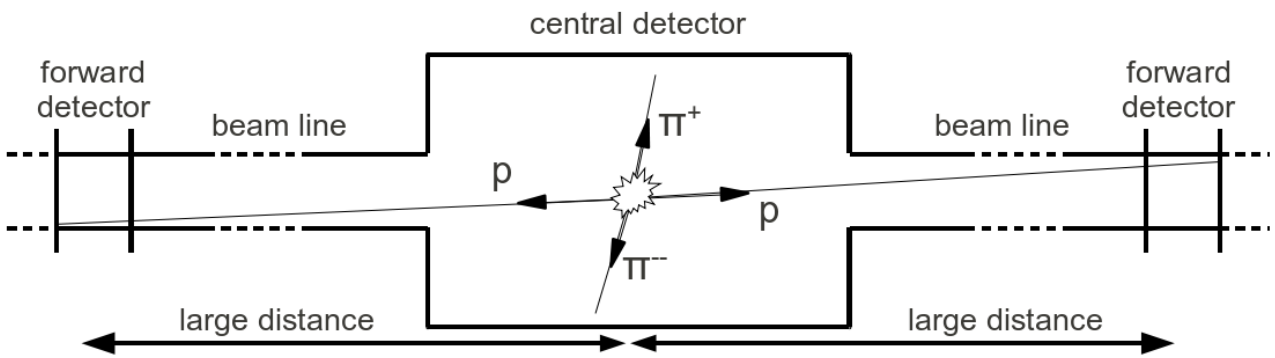


(a)



(b)

- Published measurements at 7 and 8 TeV
- Ongoing measurement of ρ at 8 TeV
- Data at 13 TeV collected
- Diffractive analyses ongoing



Contents

Measurements w/o forward proton tagging

Proton tagging: ALFA detectors

Proton tagging: AFP detectors

Summary

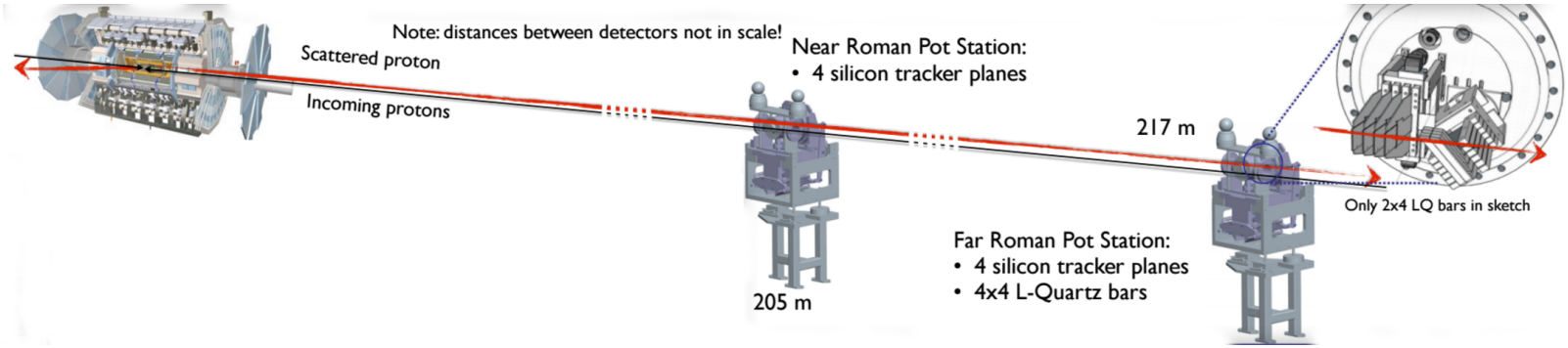
1 Measurements w/o forward proton tagging

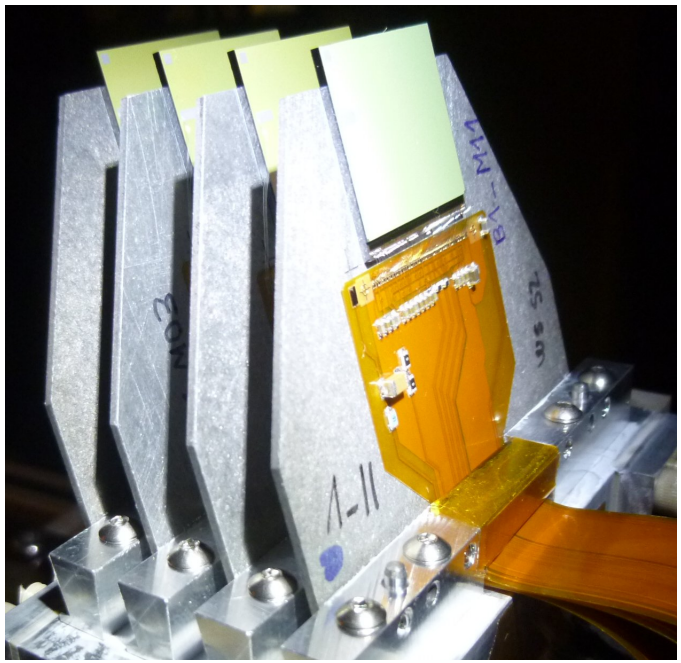
2 Proton tagging: ALFA detectors

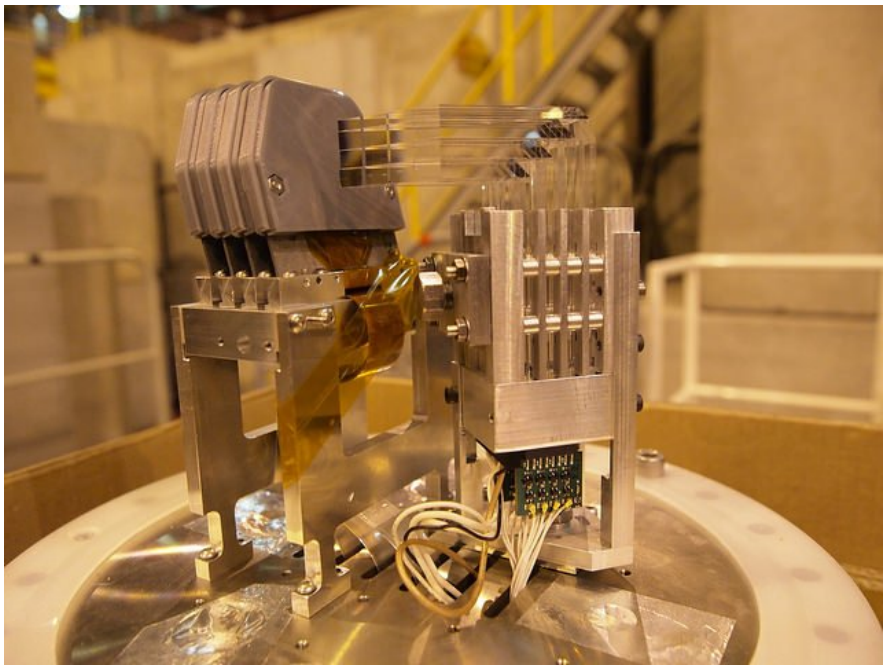
3 Proton tagging: AFP detectors

4 Summary

AFP (ATLAS Forward Proton) detectors

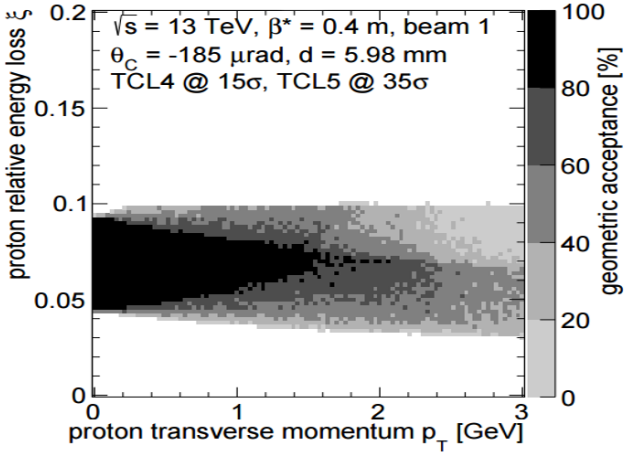


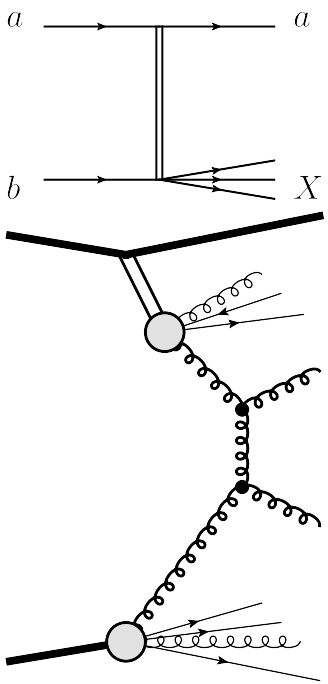


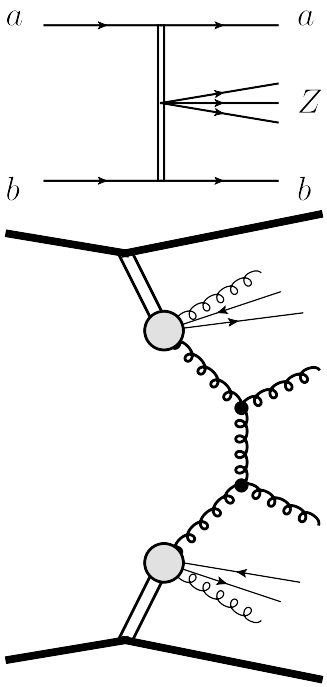


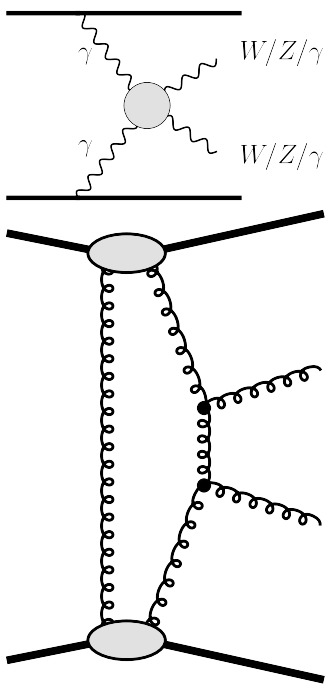
AFP physics

- soft diffraction
- hard diffraction
- exclusive diffraction
- two-photon processes
- new physics



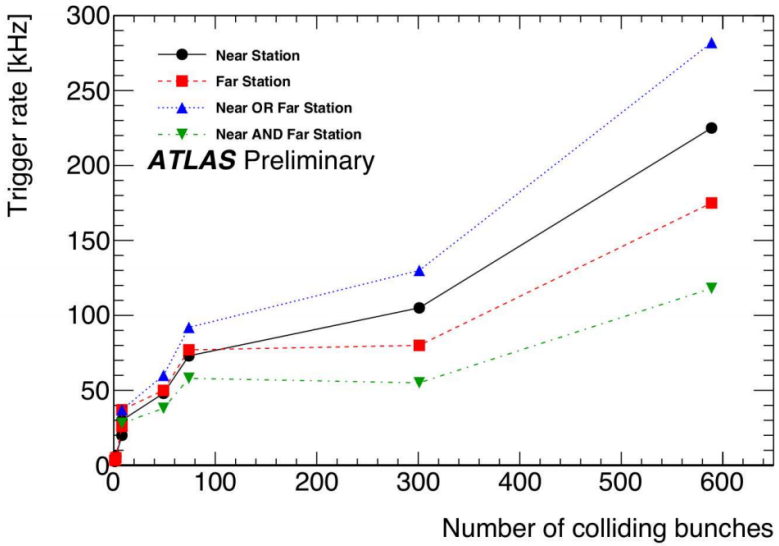


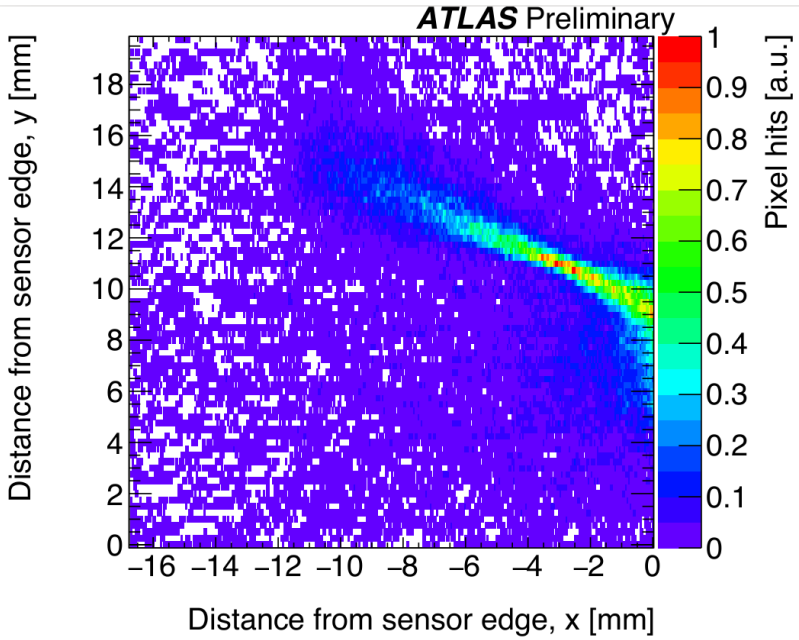


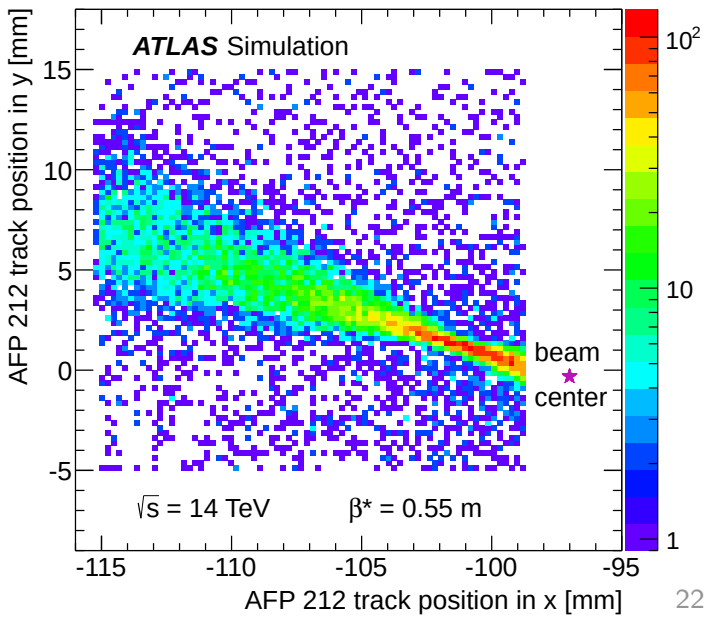


AFP data taking

- Several insertions with different beam conditions
- Beam based alignment and loss maps
- One dedicated physics run in August







Contents

Measurements w/o forward proton tagging

Proton tagging: ALFA detectors

Proton tagging: AFP detectors

Summary

1 Measurements w/o forward proton tagging

2 Proton tagging: ALFA detectors

3 Proton tagging: AFP detectors

4 Summary

Summary

- Measurements of diffraction with rapidity-gap method exploiting ATLAS central systems
  - soft diffraction
  - diffractive jets
- Two-photon physics
  - Absorptive corrections
  - Proton dissociation
  - Observation of light-by-light scattering
- Proton tagging
  - ALFA – elastic scattering, low-mass diffraction
  - AFP – high-mass diffraction, hard diffraction, exclusive diffraction, two-photon physics