Measurement of Diffractive and Exclusive Processes with the ATLAS Detector

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on behalf of the ATLAS Collaboration

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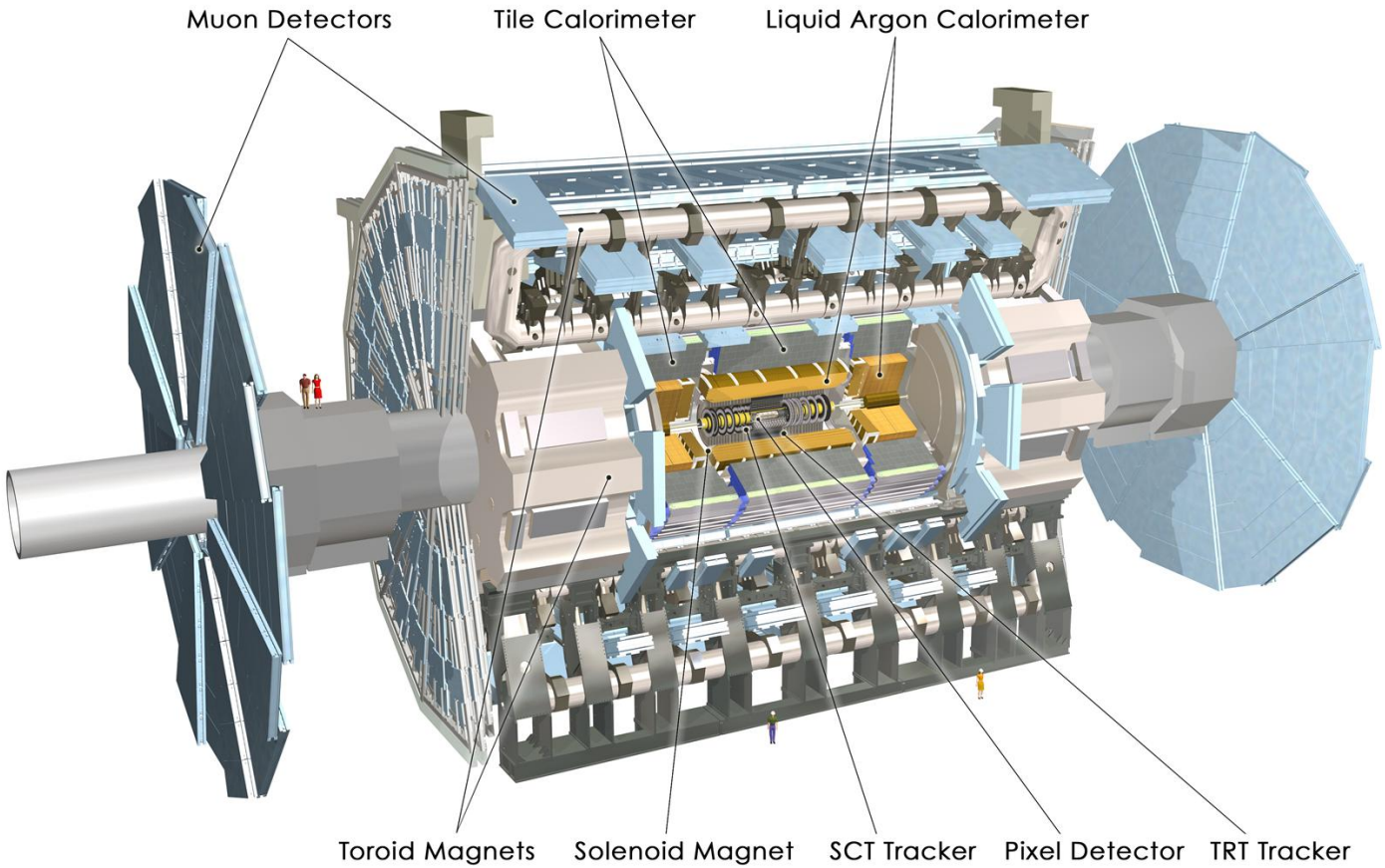
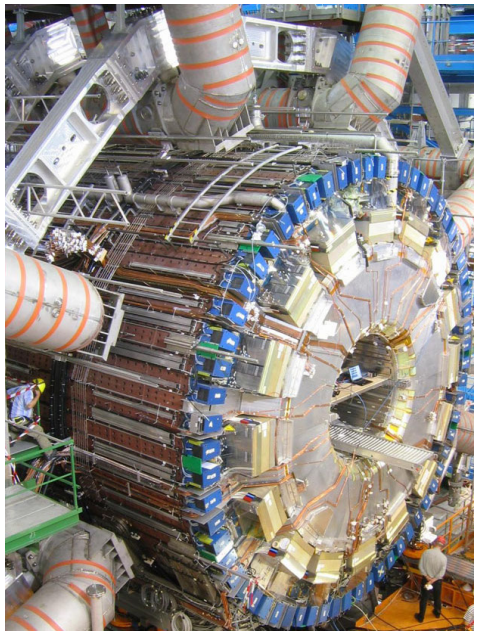
on Multiparticle Dynamics

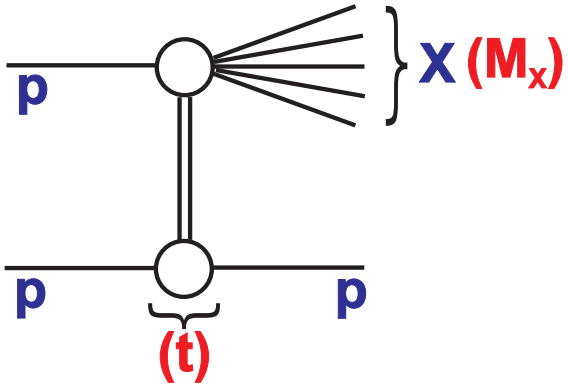
ATLAS



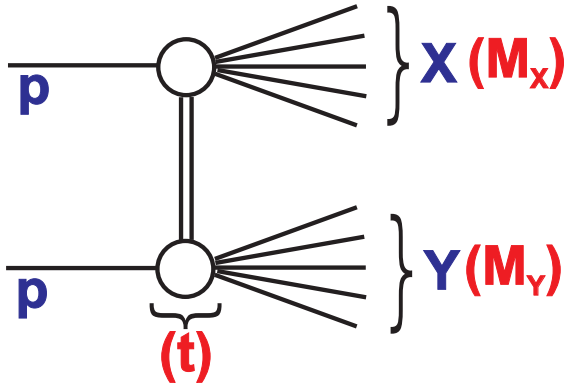


- Calorimeters $|\eta| < 4.9$
- Trackers $|\eta| < 2.5$

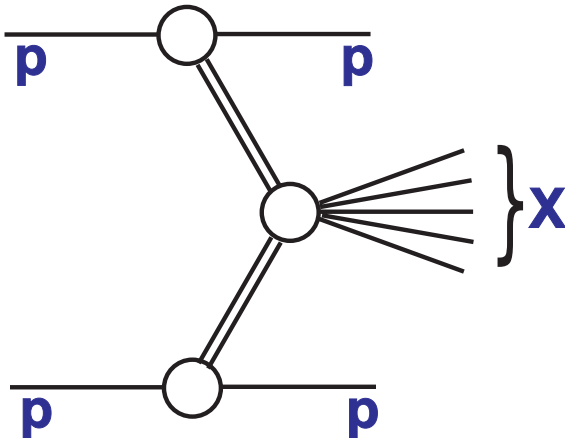
Diffraction at ATLAS



Single Diffractive Dissociation



Double Diffractive Dissociation

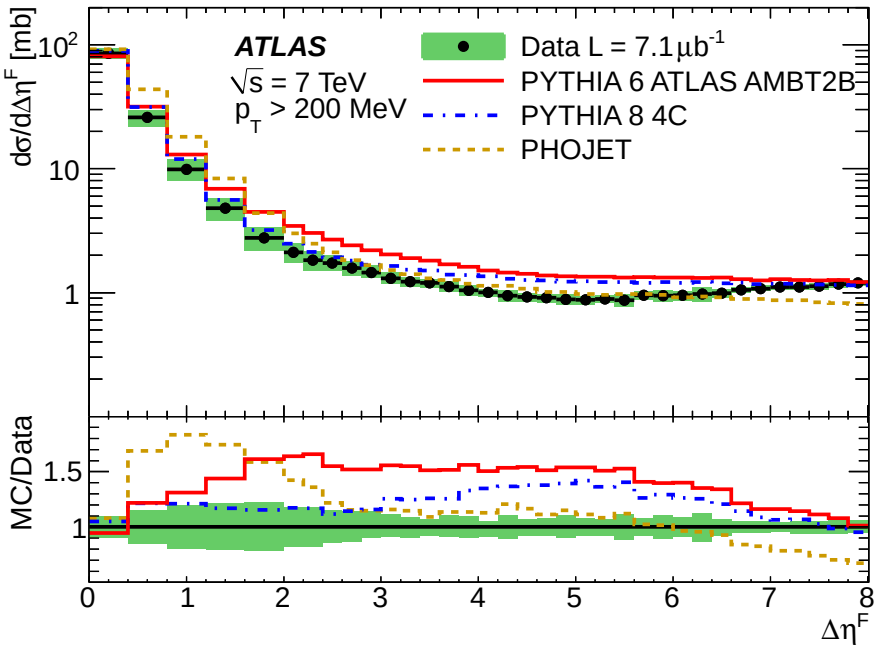


Central Diffraction

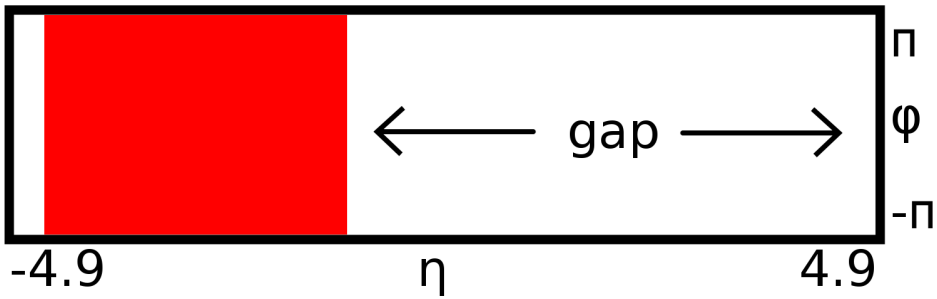
- Quantum numbers of respective initial and final states are the same in diffractive interaction (colour singlet or Pomeron exchange)
- Diffractive processes can be identified by the presence of rapidity gap i.e. space devoid of particles and/or by detecting intact forward protons

Rapidity Gap Cross-Sections

Eur. Phys. J. C72 (2012) 1926

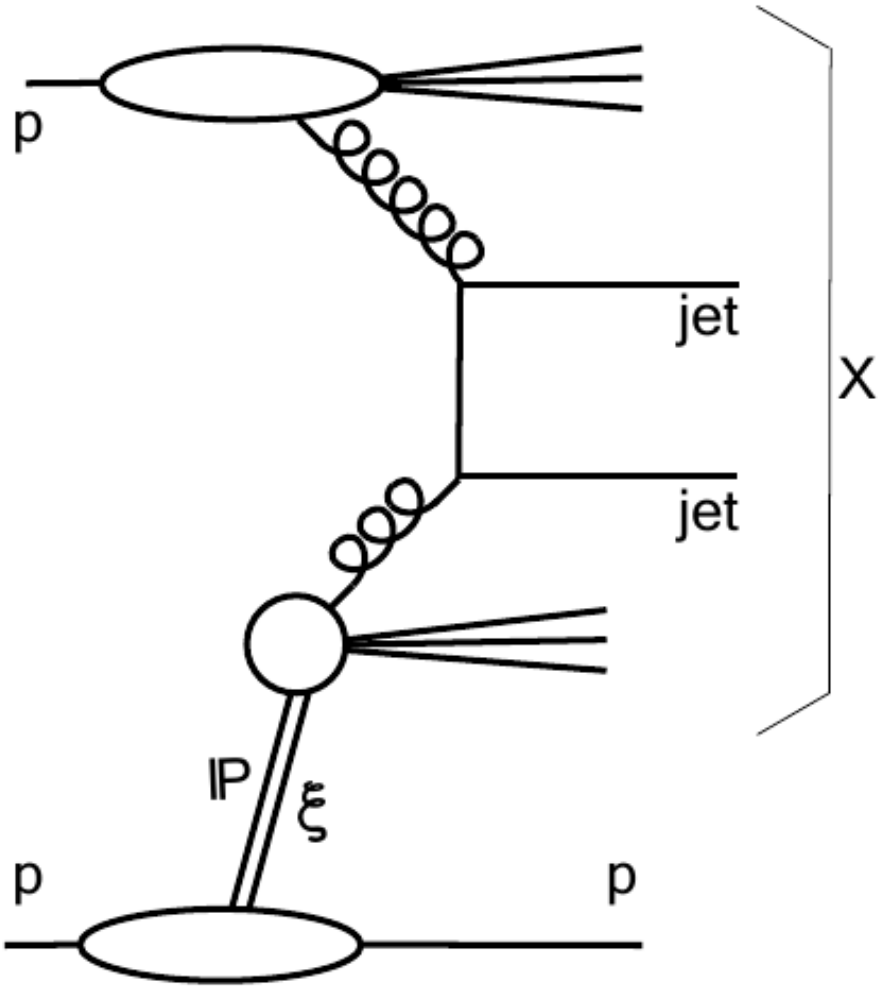


- $\mathcal{L} = 7.1\,\mu\mathrm{b}^{-1}$
- mean pile-up $\mu < 0.005$
- $\xi_X = M_X^2/s \gtrsim 10^{-5}$
- $p_t > 200\,\mathrm{MeV}$



- Exponential decrease of the cross-section at low $\Delta\eta^F$ is attributed to non-diffraction
- the plateau at large $\Delta\eta^F$ to diffractive processes

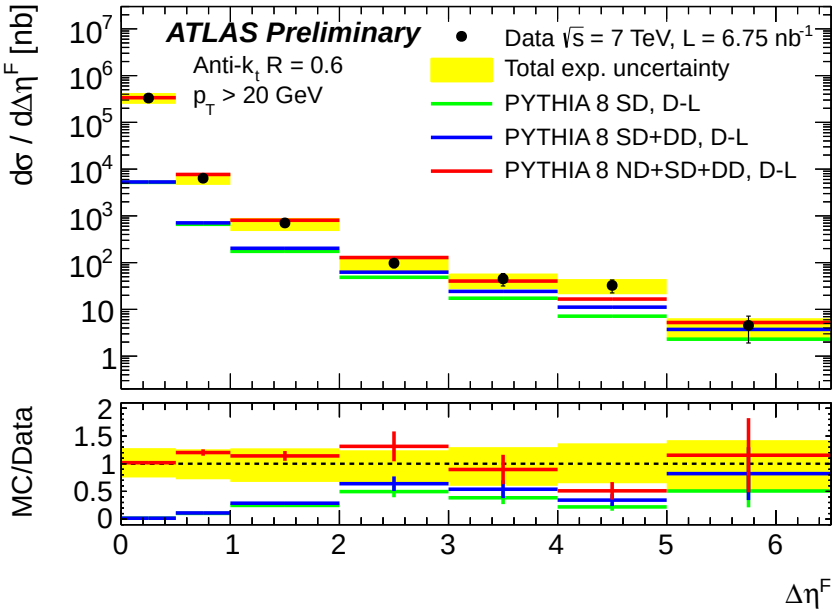
Dijet Production with Large Rapidity Gaps at $\sqrt{s} = 7\,\mathrm{TeV}$

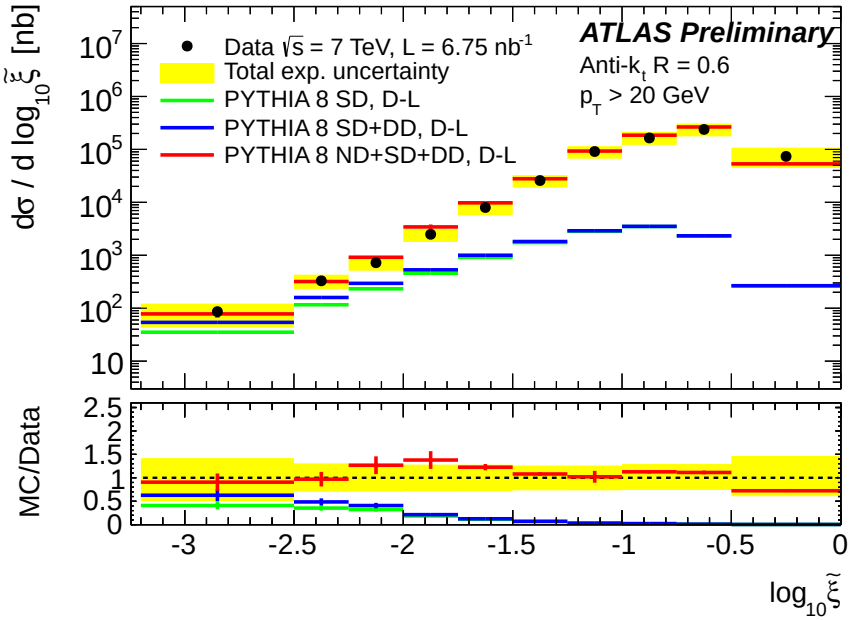


- Peak $\langle\mu\rangle \sim 0.04$–$0.14$
- Anti-k_t jets with $R = 0.6$ and $R = 0.4$ (not shown)
- $p_{t\ \mathrm{jet}} > 20\,\mathrm{GeV}$
- $|\eta_{\mathrm{jet}}| < 4.4$

- Diffractive process with hard scale for pQCD calculations
- Sensitivity to underlying parton dynamics and colour singlet exchange
- Sensitivity to soft survival probability S^2

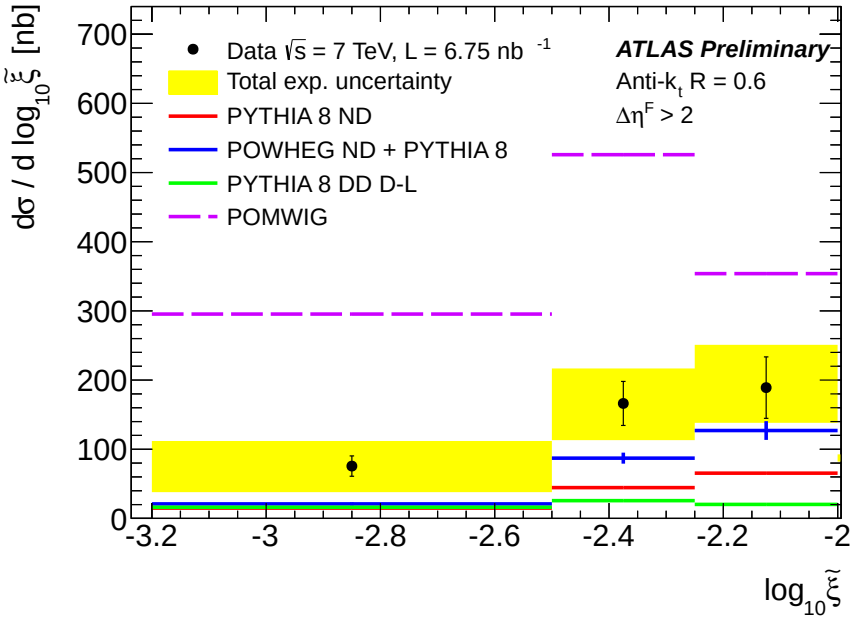
Dijet Production with Large Rapidity Gaps

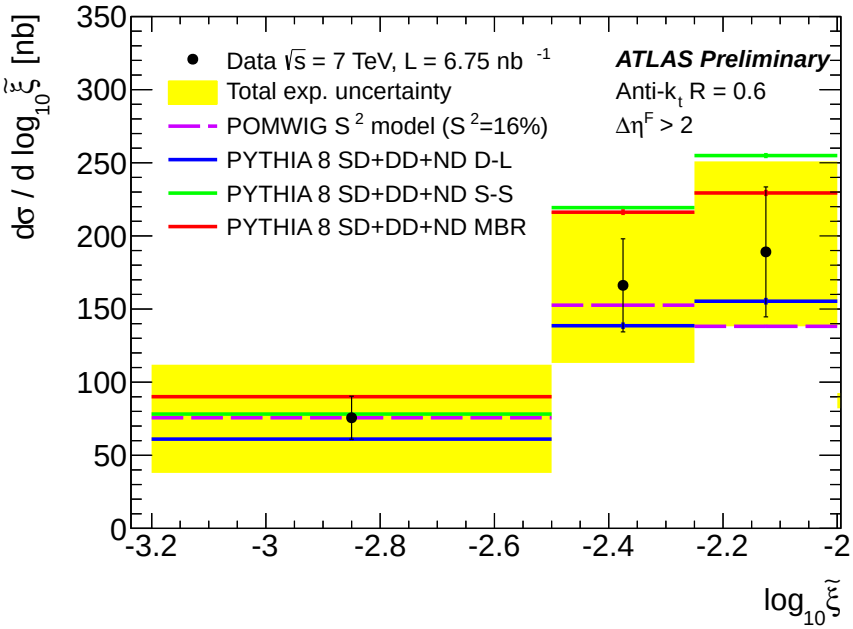




- Non-diffractive contribution scaled by 1/1.4 to match the data in the first gap bin
- No clear diffractive plateau, because of phase space reduction at large rapidity gaps
- Data are well described by Pythia8
- The larger the gap (the smaller the ξ) the more important diffractive component, at gap equal 3 $\sigma_{diff} \approx \sigma_{ND}$

Dijet Production with $\Delta\eta^F > 2$ and $\log(\tilde{\xi}) < -2$





- Application of a cut $\Delta\eta^F > 2$ significantly reduces non-diffractive background
- The lowest $\log(\tilde{\xi})$ bin gives model-dependent estimate

$$S^2 = 16 \pm 4(\text{stat.}) \pm 8(\text{syst.})\,\%$$

- No additional rapidity gap survival probability needed for Pythia8 (ATLAS AU2-CT10)
- All 3 tested Pomeron fluxes agree with data

Exclusive Dijet Production

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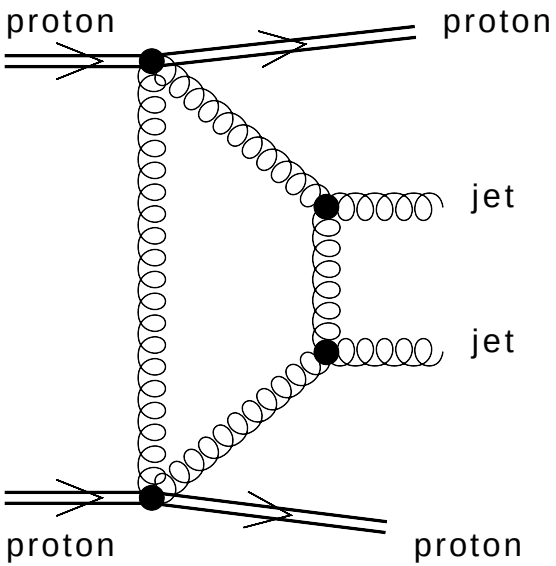
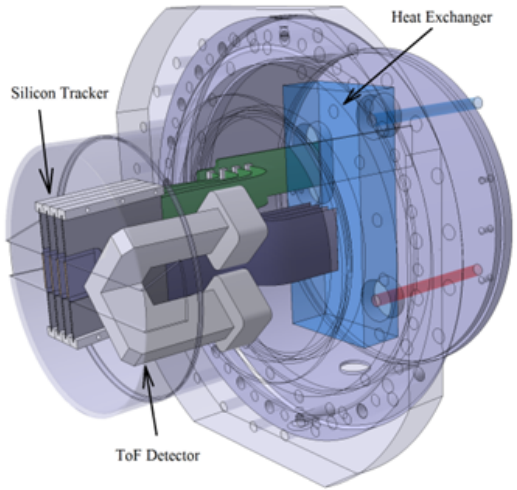


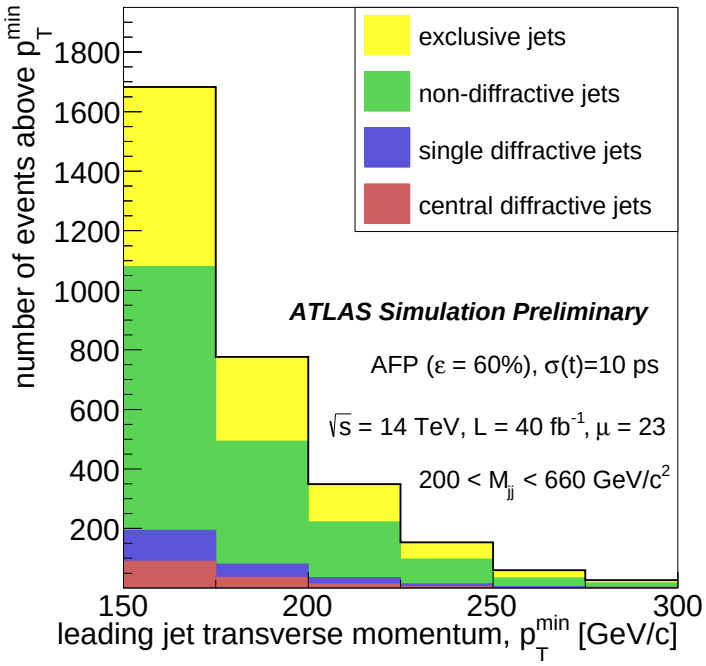
- Provides access to gluon distribution in proton
- Small cross-section 0.5 pb

Atlas **F**orward **P**roton

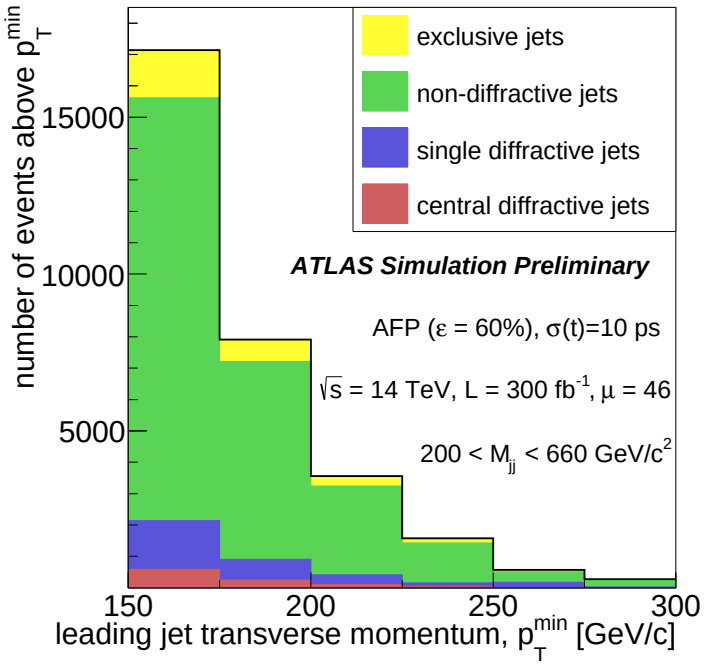


- 2015: Research Board Approval
- Detectors ≈ 220 m away from the nominal interaction point
- Timing detectors are crucial in high pile-up conditions

Exclusive Dijet Production



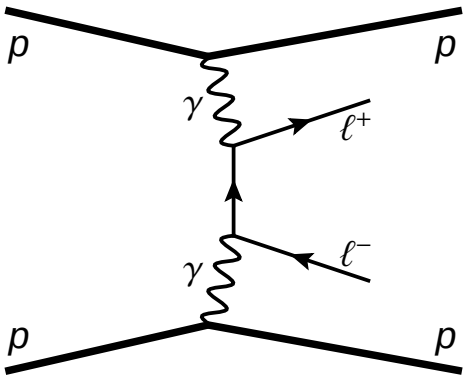
signal/background = 0.57

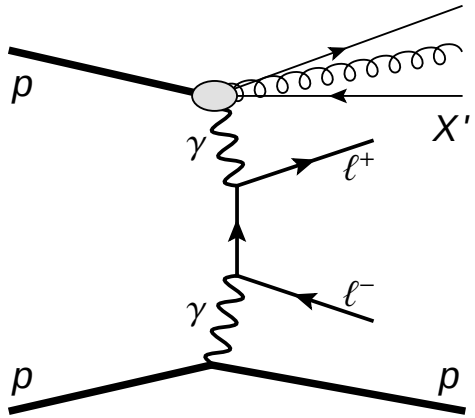


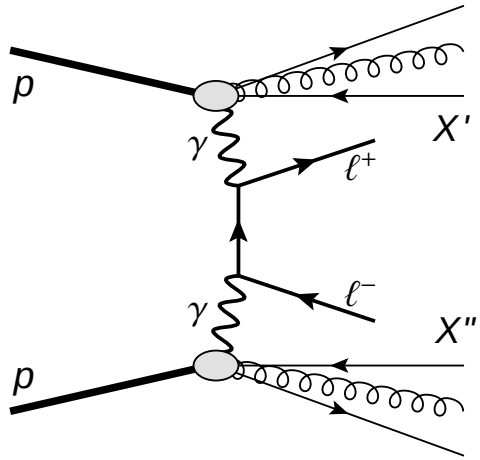
signal/background = 0.16

- Largest uncertainties come from background estimation
- Require double proton tags
- Measurement feasible with $\mu \approx 23$, but for larger pile-up better background understanding is needed

Exclusive Dilepton Production







Data

- 2011 p+p data
- $\mathcal{L} = 4.6\,\mathrm{fb}^{-1}$
- $\sqrt{s} = 7\,\mathrm{TeV}$
- $\langle\mu\rangle \approx 6.3$–$11.6$

Selection

- no additional charged particles with $p_T > 400\,\mathrm{MeV}$
- Z mass region removed $70 < m_{ll}/\mathrm{GeV} < 105$
- $p_T^{ll} < 1.5\,\mathrm{GeV}$

Exclusive Dilepton Production

Physics Letters B 749 (2015) 242-261

Electron

- $p_T > 12\,\mathrm{GeV}$
- $|\eta_T| < 2.4$
- $m_{ll} > 24\,\mathrm{GeV}$

Muon

- $p_T > 10\,\mathrm{GeV}$
- $|\eta_T| < 2.4$
- $m_{ll} > 20\,\mathrm{GeV}$

$\sigma^{\mathrm{excl.}}_{\gamma\gamma\to e^+e^-}$ [pb]

$0.428 \pm 0.035(\mathrm{stat.}) \pm 0.018(\mathrm{syst.})$

$\sigma^{\mathrm{excl.}}_{\gamma\gamma\to \mu^+\mu^-}$ [pb]

$0.628 \pm 0.032(\mathrm{stat.}) \pm 0.021(\mathrm{syst.})$

$\sigma^{\mathrm{EPA,corr.}}_{\gamma\gamma\to e^+e^-}$ [pb]

$0.398 \pm 0.007(\mathrm{theor.})$

$\sigma^{\mathrm{EPA,corr.}}_{\gamma\gamma\to \mu^+\mu^-}$ [pb]

$0.638 \pm 0.011(\mathrm{theor.})$

Exclusive Dilepton Production

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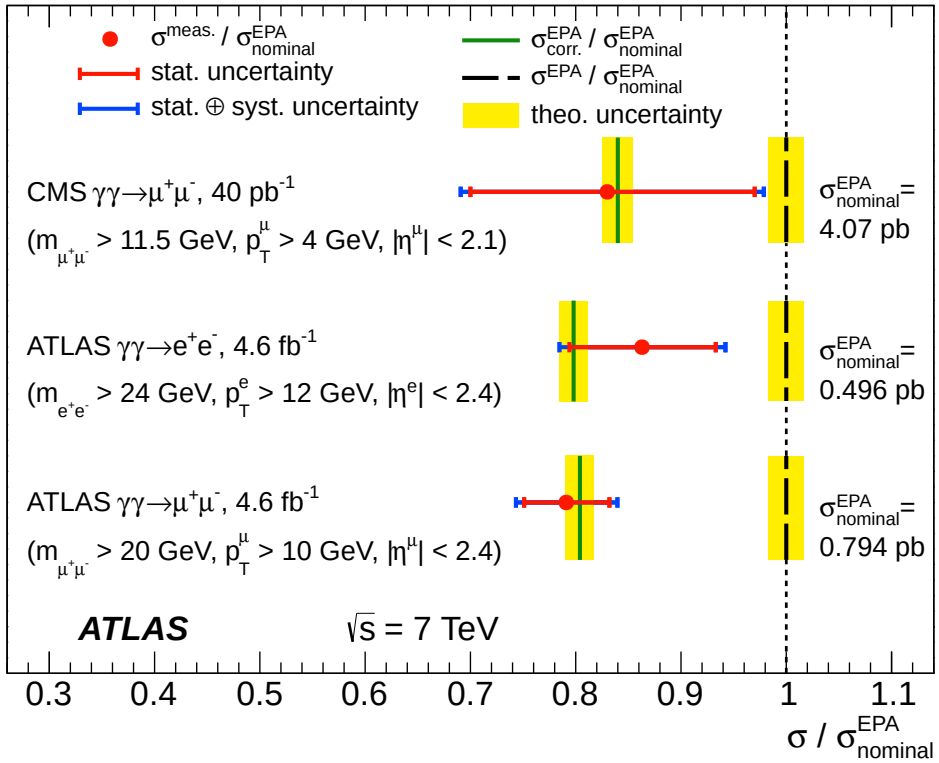

- Measered cross-sections are about 20 % smaller than predicted by Equivalent Photon Approximation
- The observed suppression is in agreement with proton absorption contribution

ATLAS–LHCf p+Pb at $\sqrt{s_{NN}} = 5.02\,\mathrm{TeV}$

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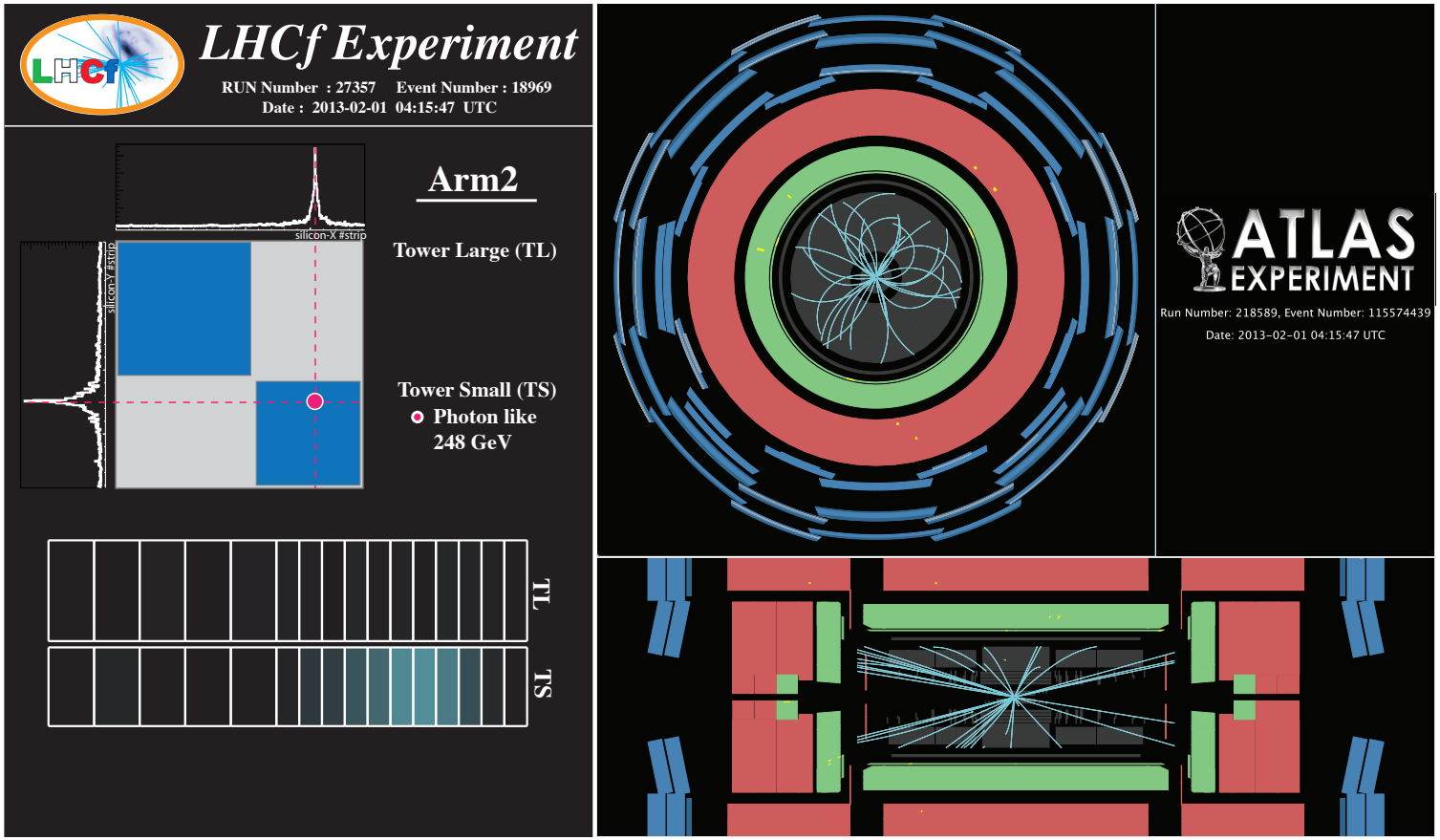

- LHCf is located at $z \approx -140\,\mathrm{m}$ and detects neutral particles produced at $-\infty < \eta < -8.4$
- First successful combination of ATLAS and LHCf data

ATLAS–LHCf p+Pb at $\sqrt{s_{NN}} = 5.02\,\mathrm{TeV}$

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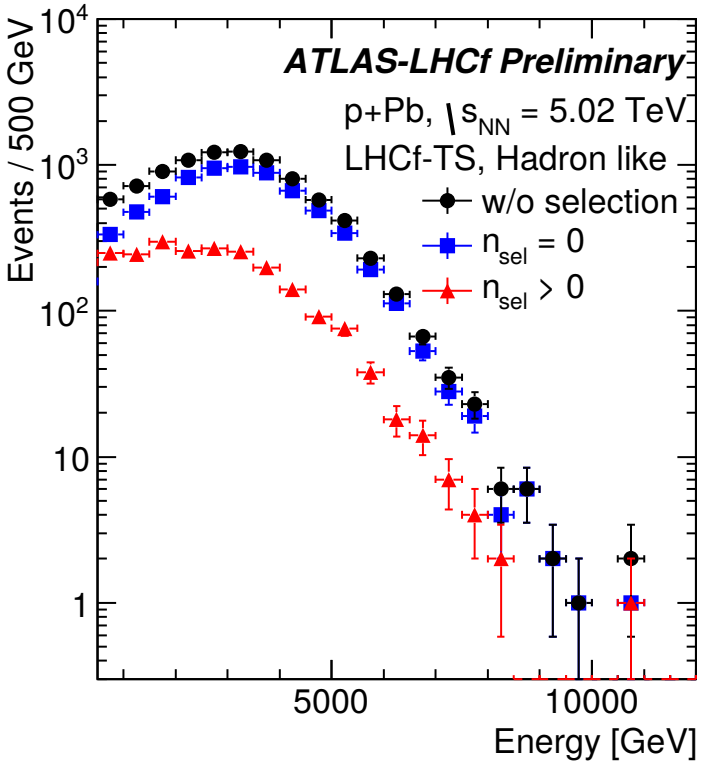

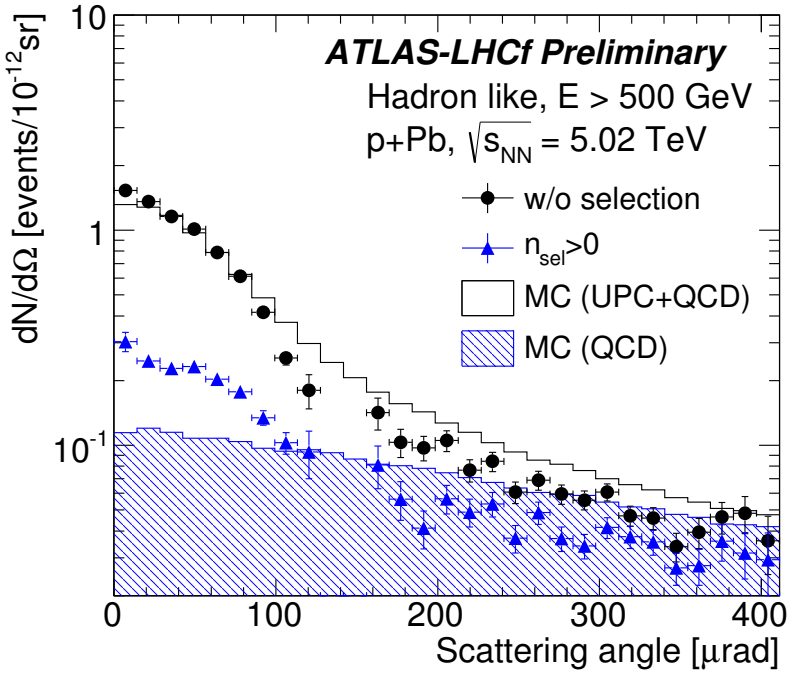

- Neutral hadron-like particle energy peak 3.5 TeV and scattering angle close to 0 suggest process $p + \gamma \to \Delta^+ \to n + \pi^+$
- Events with no measured tracks in ATLAS are dominated by Ultra-Peripheral-Collisions

Summary

- Rapidity gap cross-section measurement extended with dijet analysis
- Pythia8 describes the diffractive dijet data without the need for additional gap survival probability
- In order to measure exclusive dijet production AFP with good timing detectors is required
- Measured exclusive dilepton production cross-section is in agreement with Equivalent Photon Approximation corrected for proton absorption
- ATLAS and LHCf data were successfully combined for $\sqrt{s_{NN}} = 5.02\,\text{TeV}$ runs; p+p at $\sqrt{s} = 13\,\text{TeV}$ data was collected this year

Thank you for your attention!