Measurement of Diffractive and Exclusive Processes with the ATLAS Detector

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on behalf of the ATLAS Collaboration

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Calorimeters $|\eta| < 4.9$

Trackers $|\eta| < 2.5$
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

\[ \frac{d\sigma}{d\Delta \eta} \]

\[ \text{MC/Data} \]

- \( L = 7.1 \mu b^{-1} \)
- mean pile-up \( \mu < 0.005 \)
- \( \xi_X = \frac{M_X^2}{s} \gtrsim 10^{-5} \)
- \( p_t > 200 \text{ MeV} \)

- Exponential decrease of the cross-section at low \( \Delta \eta^F \) is attributed to non-diffractive
- the plateau at large \( \Delta \eta^F \) to diffractive processes
Dijet Production with Large Rapidity Gaps at $\sqrt{s} = 7$ TeV

- Peak $\langle \mu \rangle \sim 0.04$–$0.14$
- Anti-$k_t$ jets with $R = 0.6$ and $R = 0.4$ (not shown)
- $p_t \text{jet} > 20$ GeV
- $|\eta_{\text{jet}}| < 4.4$
- Diffractive process with hard scale for pQCD calculations
- Sensitivity to underlying parton dynamics and colour singlet exchange
- Sensitivity to soft survival probability $S^2$
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 $\xi$) 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

ATL-PHYS-PUB-2015-003

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

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

Atlas Forward Proton

- Grzegorz Gach (AGH)

Diffraction at ATLAS 5 October 2015 8 / 16
Exclusive Dijet Production

- 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

**Signal/background** = 0.57

**Signal/background** = 0.16

ATLAS Simulation Preliminary

$\sqrt{s} = 14$ TeV, $L = 40$ fb$^{-1}$, $\mu = 23$

$200 < M_{jj} < 660$ GeV/c$^2$

ATLAS Simulation Preliminary

$\sqrt{s} = 14$ TeV, $L = 300$ fb$^{-1}$, $\mu = 46$

$200 < M_{jj} < 660$ GeV/c$^2$
Exclusive Dilepton Production

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

Selection
- no additional charged particles with $p_T > 400$ MeV
- $Z$ mass region removed
  - $70 < m_{ll}/\text{GeV} < 105$
- $p_T^{ll} < 1.5$ GeV
### Exclusive Dilepton Production


<table>
<thead>
<tr>
<th>electron collision</th>
<th>muon collision</th>
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</thead>
<tbody>
<tr>
<td>$p_T &gt; 12 \text{ GeV}$</td>
<td>$p_T &gt; 10 \text{ GeV}$</td>
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<td>$m_{ll} &gt; 24 \text{ GeV}$</td>
<td>$m_{ll} &gt; 20 \text{ GeV}$</td>
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<thead>
<tr>
<th>exclusive cross section ($\gamma\gamma \to e^+e^-$) [pb]</th>
<th>exclusive cross section ($\gamma\gamma \to \mu^+\mu^-$) [pb]</th>
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<tbody>
<tr>
<td>$0.428 \pm 0.035(\text{stat.}) \pm 0.018(\text{syst.})$</td>
<td>$0.628 \pm 0.032(\text{stat.}) \pm 0.021(\text{syst.})$</td>
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<tr>
<th>cross section with EPA correction ($\gamma\gamma \to e^+e^-$) [pb]</th>
<th>cross section with EPA correction ($\gamma\gamma \to \mu^+\mu^-$) [pb]</th>
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<tr>
<td>$0.398 \pm 0.007(\text{theor.})$</td>
<td>$0.638 \pm 0.011(\text{theor.})$</td>
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• Measured cross-sections are about 20% smaller than predicted by Equivalent Photon Approximation
• The observed suppression is in agreement with proton absorption contribution
LHCf is located at $z \approx -140$ m and detects neutral particles produced at $-\infty < \eta < -8.4$

First successful combination of ATLAS and LHCf data
Neutral hadron-like particle energy peak 3.5 TeV and scattering angle close to 0 suggest process
\[ p + \gamma \rightarrow \Delta^+ \rightarrow n + \pi^+ \]

Events with no measured tracks in ATLAS are dominated by Ultra-Peripheral-Collisions
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 $\sqrt{s_{NN}} = 5.02$ TeV runs; p+p at $\sqrt{s} = 13$ TeV data was collected this year
Thank you for your attention!