Access to low x PDFs at LHC

Tara Shears,
On behalf of the LHC collaborations
• Introduction
• The LHC experiments
• Measurements sensitive to low x
• Conclusions
1. Introduction
2. LHC experiments
3. Low x measurements
4. Conclusions

Overview

LHC kinematic region
Probing low x

LHC: pp collisions at $\sqrt{s} = 14$ TeV

pp interactions access $x$, $Q^2$ region beyond previous experiments
PDFs must be evolved to describe LHC data

Measurements at LHC
- test DGLAP evolution
- test BFKL evolution

Low x measurements sensitive to saturation effects
This talk: concentrate on how we can make measurements sensitive to low $x$:

1. Within central region
   
   \((-2.5 < \eta < 2.5)\)
1. Production of low mass $(Q^2 \sim 100)$ objects in central regions of LHC experiments

- Experiments fully instrumented, can reduce backgrounds
1. Production of low mass ($Q^2 \sim 100$) objects in central regions of LHC experiments

- Experiments fully instrumented, can reduce backgrounds

Sensitive to $x \sim 10^{-3} \rightarrow 10^{-5}$
2. Measurements taken at high rapidity (forward particle production - eg. $1.8 < \eta < 4.9$), and high $Q^2$ (eg. Z, W)

- Z, W backgrounds low, cross-section reasonable.

Sensitive to $x \sim 10^{-3} \rightarrow 10^{-5}$
3. Measure production of low mass objects at high rapidity (forward production)

- Lowest $x$ range
- Not all experiments have full detection facilities (hence backgrounds may be higher)

Sensitive to $x \sim 10^{-4} \rightarrow 10^{-6}$
<table>
<thead>
<tr>
<th>1. Introduction</th>
<th>ATLAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. LHC experiments</td>
<td>CMS</td>
</tr>
<tr>
<td>3. Low x measurements</td>
<td>LHCb</td>
</tr>
<tr>
<td>4. Conclusions</td>
<td>ALICE</td>
</tr>
</tbody>
</table>
Possible: low mass DY (|η|<2.5, or forward w.o. tracking)
Forward jet production (|η|<4.5)

<table>
<thead>
<tr>
<th>η:</th>
<th>8</th>
<th>6</th>
<th>4</th>
<th>2</th>
<th>0</th>
<th>2</th>
<th>4</th>
<th>6</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tracking</td>
<td>-2.5 &lt; η &lt; 2.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Counters (lumi)</td>
<td>5 &lt; η &lt; 6.1, -6.1 &lt; η &lt; 5,</td>
<td>η</td>
<td>&gt; 8.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ECAL, HCAL</td>
<td>-4.5 &lt; η &lt; 4.5,</td>
<td>η</td>
<td>&gt; 8.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Muon</td>
<td>-2.7 &lt; η &lt; 2.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trigger at low (high) lumi</td>
<td>Pt(μ) &gt; 4 GeV, (10 GeV), Pt(e) &gt; 5 GeV, (12 GeV)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
2008: complete and installed apart from;
ALFA: $|\eta|>8.1$ under construction (installation 2009)
Roman pots at ± 220 m and ± 420 m (proposal stage)
Possible: low mass DY (|η|<2.5, or forward with limited tracking)
Forward jet production (|η|<6.5)

<table>
<thead>
<tr>
<th>Tracking</th>
<th>-2.5 &lt; η &lt; 2.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECAL, HCAL</td>
<td>±3.1 &lt; η &lt; ±4.7, ±5.2 &lt; η &lt; ±6.5</td>
</tr>
<tr>
<td>Muon</td>
<td>-6.5 &lt; η &lt; 6.5</td>
</tr>
<tr>
<td>Trigger</td>
<td>Pt(μ)&gt;3.5 GeV, Pt(calor)&gt;4 GeV, + fwd. triggers</td>
</tr>
</tbody>
</table>
2008: complete and installed apart from:

Castor: half installed (rest 2009)

Totem: half installed (same side as Castor). 220 m roman pots partially equipped.

Roman pots at ± 420 m (proposal)
Possible: low mass forward DY ($1.8 < \eta < 4.9$)
Forward Z/W production ($1.8 < \eta < 4.9$)
Forward jet production ($1.8 < \eta < 4.9$)

<table>
<thead>
<tr>
<th>Tracking</th>
<th>$1.8 &lt; \eta &lt; 4.9$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particle ID</td>
<td>$1.8 &lt; \eta &lt; 4.9$</td>
</tr>
<tr>
<td>ECAL, HCAL</td>
<td>$1.8 &lt; \eta &lt; 4.9$</td>
</tr>
<tr>
<td>Muon</td>
<td>$1.8 &lt; \eta &lt; 4.9$</td>
</tr>
<tr>
<td>Trigger</td>
<td>$\text{Pt}(\mu) &gt; 1 \text{ GeV}$, $\text{Pt}(\text{had}) &gt; 2.5 \text{ GeV}$</td>
</tr>
</tbody>
</table>
2008: complete and installed.
Possible: low mass DY ($|\eta| < 0.9$)
Forward particle (muon) production ($-4 < \eta < -2.5$)

<table>
<thead>
<tr>
<th>Tracking</th>
<th>Domain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particle ID</td>
<td>$-0.9 &lt; \eta &lt; 0.9$</td>
</tr>
<tr>
<td>ECAL (HCAL)</td>
<td>$-0.9 &lt; \eta &lt; 0.9$ ($</td>
</tr>
<tr>
<td>Muon</td>
<td>$-4 &lt; \eta &lt; -2.5$</td>
</tr>
<tr>
<td>Counters</td>
<td>$-3.4 &lt; \eta &lt; 5$</td>
</tr>
<tr>
<td>Trigger</td>
<td>Pt ($\mu$) &gt; 1 (2) GeV</td>
</tr>
</tbody>
</table>
2008: complete and installed apart from;
EMCAL: parts to be installed in 2009, 2010
Extra TRD, PHOS modules in 2009
• Low mass Drell-Yan
  – ATLAS
  – CMS
  – LHCb

• Forward jet production
  – CMS

• Forward particle production
  – ALICE

Not covered here:
LHCb Z,W production ($x \rightarrow 10^{-5}$): see LHCb DY reference
CMS exclusive upsilon production ($x \rightarrow 10^{-5}$): CMS PAS DIF-07-001
Trigger: $p_t(e) > 10$ GeV, $|\eta| < 2.5$ (low lumi)

Event selection:
- 2 oppositely charged electrons
- Both electrons: $p_t(e) > 10$ GeV, $|\eta| < 2.5$
- Missing $E_T < 30$ GeV

Eff. $= 1\%$ at $M(\text{ee}) = 8$ GeV

Backgrounds: dijets (largest), $\tau\tau$, $tt$, diboson

Systematic errors: acceptance correction (PDFs) largest, rest under investigation

$\Rightarrow$ stat. error $\sim 7\%$ $(M(\text{ee})=8\text{-}60\text{GeV})$ 50 pb$^{-1}$
**Trigger:** $E_{\text{em}} > 300$ GeV, 
$E_{\text{had}} < 5$ GeV, 
n.charged $\geq 1$  \(5.2 < \eta < 6.5\)  
(CASTOR + TOTEM)

**Event selection:** 
$M(\text{ee}) > 4$ GeV 
No background /full simulation yet.
No systematic study yet.

**Probes:** $x \to 10^{-6}$

Sensitive to saturation effects if $M(\text{ee}) \sim 4$ GeV possible (~30% difference).
**Trigger:** 2 muons $\Sigma Pt > 1.6$ GeV
Eff. > 70% for $M(\mu\mu) > 8$ GeV

**Event selection:**
- 2 muons, impact parameter consistent with primary vertex
- Momentum cuts to ensure isolated muons in empty event.

**Backgrounds:** misid. muons, b, c decays considered

Full **systematic** study ongoing.

Note shapes similar for different masses but normalisation varies.
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Drell-Yan production
Forward jet production
Forward particle production

Mass: 5→8 GeV
eff ~5%
pur~70%

Mass: 8→10 GeV
eff ~10%
pur~70%

Mass: 10→15 GeV
eff ~15%
pur~95%

Mass: 15→20 GeV
eff ~30%
pur~95%

Mass: 20→80 GeV
eff ~50%
pur~95%
Probes $x \rightarrow 10^{-6}$

Stat. error 1% in 100 pb$^{-1}$ data (independent of mass)

Sys. error studies ongoing

**Note:** all studies need lumi determination

$Z/W?$ (~5% error)

Theoretical error **much bigger**.
Trigger: Jet \( E_t > 10 \text{ GeV} \)\textsuperscript{*} \( 3 < |\eta| < 5 \) (HF calorimeter)

Event selection:
- Cone jets \( R=0.5 \), \( E_t > 20 \text{ GeV} \)

Expected systematics:
- Energy scale (3%)
- Luminosity (5%)
- Energy correction (UE, hadronisation) (? - 30%)

\textsuperscript{*}possible (L1 threshold)

Probes \( x \rightarrow 10^{-5} \)

Needs full and careful systematic study
ALICE: courtesy K. Safarik
Forward muon production
Probes $x \rightarrow 10^{-6}$
with $J/\Psi$ production
(no selection or systematic errors available)
LHC has started very successfully!

Experiments have detected first beam and are ready to take data

PDFs must be evolved to lower x and higher $Q^2$ to describe LHC data

Studies presented which probe low x:

  $x \sim 10^{-4}$ : low mass DY (ATLAS)

  $x \sim 10^{-5}$ : forward jets (CMS)

  $x \sim 10^{-6}$: forward DY (LHCb), forward DY (CMS)

  forward $J/\Psi$ (ALICE)
Extra
Totem

Inelastic Telescopes:
- T1: 3.1 < |η| < 4.7
- T2: 5.3 < |η| < 6.5
  - T1: Cathode strip chambers
  - T2: GEM detectors

Roman Pots: edgeless silicon

(from K. Eggert, CERN seminar 21/02/08)