**Totem experimental setup**

**Roman Pots:** measure elastic & diffractive protons close to outgoing beam

**Inelastic telescopes:** charged particle & vertex reconstruction in inelastic events

- T1: $3.1 < \eta < 4.7$
- T2: $5.3 < \eta < 6.5$

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Vertical Pots

Horizontal Pot

Vertical Pots

Package of 10 “edgeless” Si-detectors

RP 147

T1 (CSCs)

Vertical Pot

Vertical Pot

Vertical Pot

T2 (GEMs)
2011 publications

• Proton-proton elastic scattering at the LHC energy of $\sqrt{s} = 7$ TeV.
  2011 EPL 95 41001
• First measurement of the total proton-proton cross-section at the LHC energy of $\sqrt{s} = 7$ TeV.
  2011 EPL 96 21002

2012 publications

• Measurement of the forward charged particle pseudorapidity density in pp collisions at $\sqrt{s} = 7$ TeV with the TOTEM experiment.
  2012 EPL 98 31002
• Measurement of proton-proton elastic scattering and total cross-section at $\sqrt{s} = 7$ TeV
  CERN-PH-EP-2012-239
• Measurement of proton-proton inelastic scattering cross-section at $\sqrt{s} = 7$ TeV
  CERN-PH-EP-2012-352
• Luminosity-independent measurements of total, elastic and inelastic cross-sections at $\sqrt{s} = 7$ TeV
  CERN-PH-EP-2012-353
• A luminosity-independent measurement of the proton-proton total cross-section at $\sqrt{s} = 8$ TeV
  CERN-PH-EP-2012-354
7TeV Cross Section Measurements
6 TeV Cross Section measurement

\[ \sigma_{tot} = \frac{16\pi}{1 + \rho} \left( \frac{1}{L} \frac{dN_{el}}{dt} \right) \mid_0 \quad (\rho = 0.14 \text{ [COMPETE]}) \]

June 2011 (EPL96): \( \sigma_{tot} = (98.3 \pm 2.8) \text{ mb} \)

Oct. 2011 (PH pre.): \( \sigma_{tot} = (98.6 \pm 2.2) \text{ mb} \)

\[ \sigma_{tot} \]

\[ \sigma_{tot} = \frac{1}{L} (N_{el} + N_{inel}) \]

\( \sigma_{tot} = (99.1 \pm 4.3) \text{ mb} \)

\[ \sigma_{tot} \]

\[ \sigma_{tot} = \frac{16\pi}{1 + \rho} \frac{dN_{el}/dt}{N_{el} + N_{inel}} \]

\( \sigma_{tot} = (98.0 \pm 2.5) \text{ mb} \)

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7 TeV elastic differential cross section

\[ d\sigma_{el} / dt = A e^{-B|t|} \]

\[
\begin{align*}
A &= 506 \pm 22.7^{\text{syst}} \pm 1.0^{\text{stat}} \text{ mb/GeV}^2 \\
503 \pm 26.7^{\text{syst}} \pm 1.5^{\text{stat}} \text{ mb/GeV}^2 \\
B &= 19.9 \pm 0.26^{\text{syst}} \pm 0.04^{\text{stat}} \text{ GeV}^{-2}
\end{align*}
\]

|t|_{dip} = 0.53 GeV^2

|t|_{min} = 2 \cdot 10^{-2} \text{ GeV}^2

|t|_{min} = 5 \cdot 10^{-3} \text{ GeV}^2

|t| \sim 7.8
8TeV Cross Section Measurements
The analysis has been performed on two datasets Ds2 and Ds3
Elastic scattering analysis

| Source                          | Effect on | \(|t| = 0.01\) GeV² | 0.1 GeV² | 0.2 GeV² |
|--------------------------------|-----------|---------------------|----------|----------|
| Alignment                      | \(t\)     | ±0.21%              | ±0.3%    | ±0.57%   |
| Kinematics Reconstruction      | \(t\)     | ±1.09%              | ±0.72%   | ±4.3%    |
| Optics, Beam Energy            | norm.     |                     |          |          |
| Selection                      |           | 0.5%                |          |          |
| Acceptance (corr. factor)      | \(dN/dt\) | 3.3 ± 0.024         | 1.2 ± 0.002 | 1.8 ± 0.004 |
| Resolution Unfolding           | \(t\)     | (0.5 ± 0.1)%        | (−0.2 ± 0.003)% | (−2.6 ± 0.1)% |
| Efficiency                     | norm.     | Uncorrelated ineff. |          |          |
|                               |           | (10 ± 0.6)%         |          |          |
|                               |           | Correlated ineff.   | (3 ± 1)%  |          |
|                               |           | Pile-up: (4.7 ± 0.4)%|          |          |
| Extrapolation/Fit              |           | \(dN_{el}/dt|_{t=0}\) |           |          |
|                               |           |                     | B        |          |
|                               |           | \((19.9 ± 0.3)\) GeV⁻² |          |          |

45 B – 56 T
mean = \(2.9 \times 10^{-7}\)
RMS = \(9.5 \times 10^{-6}\)

45 T – 56 B
mean = \(2.6 \times 10^{-10}\)
RMS = \(8.8 \times 10^{-9}\)

45 T – 56 B
mean = \(1 \times 10^{-7}\)
RMS = \(3.2 \times 10^{-6}\)
Comparison between the 3 different datasets, at different distance from the beam, and the two diagonals.
$\beta^* = 90\text{m} \ \text{hit distribution}$

Raw hit distribution

Elastic protons hit distribution
Inelastic rate

- The trigger required at least one track in T2.
- Non colliding bunches used to estimate the beam-gas event rate.
- No-bias trigger subsample used to estimate the trigger efficiency and central diffraction events getting in T1 and not in T2.
- Central diffraction rate outside Totem inelastic detectors acceptance estimated via MonteCarlo.

<table>
<thead>
<tr>
<th>Source</th>
<th>Correction</th>
<th>Uncertainty</th>
<th>Effect on</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam gas</td>
<td>0.45%</td>
<td>0.45%</td>
<td>all rates</td>
</tr>
<tr>
<td>Trigger Efficiency</td>
<td>1.2%</td>
<td>0.6%</td>
<td>all rates</td>
</tr>
<tr>
<td>Pile up</td>
<td>2.8%</td>
<td>0.6%</td>
<td>all rates</td>
</tr>
<tr>
<td>T2 reconstruction</td>
<td>0.35%</td>
<td>0.2%</td>
<td>(N_{T2vis})</td>
</tr>
<tr>
<td>“T1 only”</td>
<td>0.8%</td>
<td>0.4%</td>
<td>(N_{inel}, N_{</td>
</tr>
<tr>
<td>Internal Gap covering T2</td>
<td>1.2%</td>
<td>0.4%</td>
<td>(N_{inel}, N_{</td>
</tr>
<tr>
<td>Central diffraction</td>
<td>0.4%</td>
<td>0.2%</td>
<td>(N_{inel}, N_{</td>
</tr>
<tr>
<td>Low mass diffraction (seen)</td>
<td>0.4%</td>
<td>0.2%</td>
<td>(N_{</td>
</tr>
<tr>
<td>Low mass diffraction</td>
<td>4.8%</td>
<td>2.4%</td>
<td>(N_{inel})</td>
</tr>
</tbody>
</table>

The T2 acceptance edge at \(|\eta| = 6.5\) corresponds approximately to diffractive masses of 3.6GeV (at 50% efficiency). The contribution of events with all final state particles at \(|\eta| > 6.5\) is estimated with QGSJET-II-03 after tuning the MonteCarlo prediction with the observed fraction of “1h” events.
8TeV cross sections

\[ \sigma_{tot} = \frac{16\pi}{1 + \rho^2} \frac{dN_{el}}{dt}\bigg|_0 \frac{dN_{el}}{dN_{el} + dN_{inel}} \]

\[ \sigma_{tot} = (101.7 \pm 2.9) \text{mb} \]

\[ \frac{\sigma_{el}}{\sigma_{inel}} = 0.362 \pm 0.011 \]

\[ \sigma_{inel} = (74.7 \pm 1.7) \text{mb} \]

\[ \sigma_{el} = (27.1 \pm 1.4) \text{mb} \]
8TeV cross sections

σ_{el} (green), σ_{inel} (blue) and σ_{tot} (red) [mb]

√s [GeV]

σ_{tot} fits

11.4 − 1.52 \ln s + 0.130 \ln^2 s

Nicola Turini 5° Dec 2012
Measurement of $\rho$ by studying the Coulomb – Nuclear interference region down to $|t| \sim 6 \times 10^{-4}$ GeV$^2$

Reachable with $\beta^* \sim 1000$ m!
Reaching the Coulomb-Nuclear Interference Region

In October the beam was unsqueezed to reach the $\beta^* = 1\text{Km}$ Totem could approach one vertical diagonal (Top – Bottom) up to $3\sigma$ from the beam axis. The other diagonal had to be put to $10\sigma$ due to safety (anti-collision) switches blocking the contemporary approach of top-bottom telescopes.
β* = 1km preliminary plots

One diagonal (vertical top – vertical bottom) was close to the beam, 3σ from beam axis (blue dots) while the other (red dots) had to be put at 10σ from the beam axis due to safety (anti-collision) switches.
Joint Data Taking with CMS
Joint Data Taking with CMS

May 2012: low pileup run: $\beta^* = 0.6$ m, $\sqrt{s} = 8$ TeV, T1 & T2 & CMS read out

<table>
<thead>
<tr>
<th>Date</th>
<th>Trigger</th>
<th>Inelastic events</th>
<th>RP position</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 1</td>
<td>T2</td>
<td></td>
<td>BX</td>
</tr>
</tbody>
</table>

July 2012: $\beta^* = 90$ m, $\sqrt{s} = 8$ TeV, RP & T1 & T2 & CMS read out

<table>
<thead>
<tr>
<th>Date, Set</th>
<th>Trigger</th>
<th>Inelastic events</th>
<th>RP position</th>
</tr>
</thead>
<tbody>
<tr>
<td>July 7, DS 2</td>
<td>T2</td>
<td></td>
<td>RP$_{2\text{arms}}$</td>
</tr>
<tr>
<td>July 12-13, DS 3a</td>
<td>T2</td>
<td></td>
<td>RP$_{2\text{arms}}$</td>
</tr>
<tr>
<td>July 12-13, DS 3b</td>
<td>T2</td>
<td></td>
<td>RP$_{2\text{arms}}$</td>
</tr>
</tbody>
</table>

- Combined $dN_{ch}/d\eta$ and multiplicity correlations
- Soft and hard diffraction: $p$ + dijets (90m runs)
- $M_{jj}/M_{\zeta\zeta}$ correlation and search for exclusive dijet production (90m runs)
Joint Data Taking with CMS pA run

- The common trigger rules have been addressed
  - T2 (Minimum bias)
  - T2(low multiplicity) & Castor Electromagnetic (ultraperipheral interactions)
  - T2(low multiplicity) & Castor total energy
  - T2- & vetoT2+ for diffraction events
  - RP (proton side) & T2 veto for quasielastic events search.
Conclusions

- Totem has finalized the proton proton cross-section measurements for both 7TeV and 8TeV datasets, the results are available in CDS.
- The run with $\beta^*=1000\text{m}$ looks promising although the statistics is quite low.
- The CMS-Totem joint analysis on the data taken in July is under way.
- The CMS and Totem have already setup their apparatus for a joint data taking in the next pA run.