TOTEM Status Report

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on behalf of the TOTEM collaboration

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**The TOTEM experiment**

**programme**
- elastic scattering measurement in a wide $t$-range
- total cross-section measurement and
- a study of soft and hard diffractive processes

**detectors**

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(CMS detector in gray)
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(left) forward telescopes T1 and T2 charged particles from inelastic collisions

(left) Roman Pots in the LHC elastic+diffractive protons

- all detectors fully operational
- T1 and T2 ready for data-taking
- Roman Pots waiting for beam-based alignment
Recently published results

Measurement of the forward charged particle pseudorapidity density in pp collisions at $\sqrt{s} = 7$ TeV with the TOTEM experiment

EPL 98 (2012) 31002
Three publications in preparation

$\beta^* = 90 \text{ m run, October 2011, RPs as close as } 4.8\sigma_{\text{beam}}$

$\Downarrow$

Roman Pot data:
- elastic cross-section

$\Downarrow$

data from T2 and T1
- inelastic cross-section

$\Downarrow$

total cross-section, luminosity, $\varrho$ parameter, ...
Elastic differential cross-section

- well compatible with previous results

- compared to our previous publication EPL96
  - $15 \times$ higher statistics
  - $|t|_{\min} \approx 5 \cdot 10^{-3}$ GeV$^2 \Rightarrow 91\%$ of cross-section observed (only 67\% before)
Elastic cross-section – Uncertainty assessment

- **analysis \(t\)-dependent** (green)
  - misalignments
  - optics imperfections
  - energy offset
  - acceptance correction
  - unsmearing correction

- **analysis normalization** (orange)
  - event tagging
  - background subtraction
  - detector efficiency
  - reconstruction efficiency
  - trigger efficiency
  - “pile-up” correction

- **luminosity** (blue)

⇒ reliable uncertainty estimates including correlations
1) most inelastic events hit T2 ⇒ counting events with T2 trigger ⇒ $\sigma_{\text{inel,raw}}$

2) $\sigma_{\text{inel,raw}} \rightarrow \sigma_{\text{inel,T2visible}}$: “detector corrections” = trigger and tracking efficiency, beam-gas background, pile-up

$$\sigma_{\text{inel,T2visible}} = (69.7 \pm 0.1^{\text{stat}} \pm 0.7^{\text{syst}} \pm 2.8^{\text{lumi}}) \text{ mb}$$

3) $\sigma_{\text{inel,T2visible}} \rightarrow \sigma_{\text{inel,}\eta<6.5}$

$$\sigma_{\text{inel,}\eta<6.5} = (71.0 \pm 0.1^{\text{stat}} \pm 0.7^{\text{syst}} \pm 2.8^{\text{lumi}}) \text{ mb}$$
4) $\sigma_{\text{inel}, \eta < 6.5} \rightarrow \sigma_{\text{inel}, \text{full}}$: mainly low-mass single diffraction ($M < 3.4$ GeV)

- considered range of Monte Carlos – QGSJET-II-4 found most reliable
- still large uncertainty: correction = $(3.7 \pm 2.0)\%$

$\sigma_{\text{inel, full}} = (73.7 \pm 0.1^{\text{stat}} \pm 1.7^{\text{syst}} \pm 2.9^{\text{lumi}}) \text{ mb}$

**BUT:** TOTEM can constrain the contribution of low-mass diffraction – see slide
Elastic + Inelastic $\rightarrow$ Total cross-section

elastic observables only:

$$\sigma_{\text{tot}}^2 = \frac{16\pi}{1 + \varrho^2} \frac{1}{\mathcal{L}} \left. \frac{dN_{\text{el}}}{dt} \right|_0$$

June (EPL96): $\sigma_{\text{tot}} = (98.3 \pm 2.0) \text{ mb}$
October: $\sigma_{\text{tot}} = (98.6 \pm 2.3) \text{ mb}$

$q$ independent:

$$\sigma_{\text{tot}} = \frac{1}{\mathcal{L}} (N_{\text{el}} + N_{\text{inel}})$$

$\sigma_{\text{tot}} = (99.1 \pm 4.4) \text{ mb}$

luminosity independent:

$$\sigma_{\text{tot}} = \frac{16\pi}{1 + \varrho^2} \left. \frac{dN_{\text{el}}/dt}{N_{\text{el}} + N_{\text{inel}}} \right|_0$$

$\sigma_{\text{tot}} = (98.1 \pm 2.4) \text{ mb}$
Four cross-section measurements

perfect consistency among all 4 cross-section determinations

low uncertainty ⇒ important for extrapolations
Elastic + Inelastic \rightarrow \ldots

\textit{luminosity calibration}

\[
\mathcal{L}_{\text{int}} = \frac{1 + \varrho^2}{16\pi} \frac{(N_{\text{el}} + N_{\text{inel}})^2}{dN_{\text{el}}/dt|_0}
\]

October: \quad \mathcal{L}_{\text{int}} = (83.7 \pm 3.2) \, \mu b^{-1} \quad [\text{CMS: } (82.0 \pm 3.3) \, \mu b^{-1}]

June: \quad \mathcal{L}_{\text{int}} = (1.65 \pm 0.07) \, \mu b^{-1} \quad [\text{CMS: } (1.65 \pm 0.07) \, \mu b^{-1}]

\frac{\sigma_{\text{el}}}{\sigma_{\text{tot}}} \text{ independent of luminosity and } \varrho

\[
\frac{\sigma_{\text{el}}}{\sigma_{\text{tot}}} = 0.257 \pm 0.005
\]

\textit{\varrho determination}

\[
\varrho^2 = 16\pi \mathcal{L}_{\text{int}} \frac{dN_{\text{el}}/dt|_0}{(N_{\text{el}} + N_{\text{inel}})^2} - 1
\]

TOTEM: \quad |\varrho| = 0.14 \pm 0.09 \quad \text{COMPETE extrapolation } \varrho = 0.141 \pm 0.007

\textit{low-mass single diffraction}

M < 3.4 \text{ GeV} \Rightarrow \text{all particles more forward than } \eta = 6.5 = T2 acceptance limit

\[
\sigma_{\eta > 6.5} = \sigma_{\text{tot}} - \sigma_{\text{el}} - \sigma_{\eta < 6.5} = (2.3 \pm 2.2) \, \text{mb} \quad [\text{from MC: } \approx 2.6 \, \text{mb}]
\]
Data-taking with CMS: April

- engineering run (RP alignment)
- trigger: CMS jets $\rightarrow$ TOTEM
- CMS+TOTEM data synchronization:

![Graphs showing Orbit and Bunch number difference](image)
Data-taking with CMS: May

- low-pile-up run, 8M events collected, RPs not inserted
- exchange of triggers:
  TOTEM $\rightarrow$ CMS: trigger menu $\rightarrow$ TOTEM
  $\Rightarrow$ both experiments recorded the same events
- physics potential due to large coverage: CMS+T1+T2 = $-6.5 < \eta < +6.5$
  - $dN_{ch}/d\eta$ over the complete range with the same min. bias trigger
  - total inelastic cross-section
  - multiplicity distributions and correlations (forw./back., forw./cent.)
  - rapidity gap distributions, multi-gap and central-gap events
  - jets – underlying event studies extended to forward region
  - energy flow and multiplicity between central and forward jets
  …
Data-taking with CMS: including RPs

- triggering with RPs possible due to **electrical trigger**
  - transfers signals RP 220 ↔ CMS in time
  - recently installed and commissioned

- central, single diffraction
  - trigger – CMS: jets, TOTEM RPs: 1 or 2 protons

- example: exclusive di-jet production
Plans for 2012 runs

Special run at $\beta^* = 90\,\text{m}, \, 156$ bunches
- CMS + TOTEM T1, T2 and Roman Pots = very large acceptance
- proton acceptance: $|t| \gtrsim 0.02\,\text{GeV}^2$, any $\xi$
- soft and medium-hard diffraction, elastic and total cross-section
- expected early July

Standard runs at $\beta^* = 0.6\,\text{m}, \approx 1400$ bunches
- TOTEM Roman Pots + CMS
- proton acceptance: $\xi \gtrsim 2 - 3\%$, any $t$
- high luminosity $\Rightarrow$ high masses accessible

Special run at $\beta^* = 500\,\text{m}$, low luminosity
- low-|$t$| elastic scattering
- determination of $\varrho$
Conclusions

- TOTEM has published the forward charged particle pseudorapidity density in pp collisions at $\sqrt{s} = 7$ TeV

- TOTEM has measured total, elastic and inelastic cross-sections with several methods including the luminosity-independent one
  - soon to be published in 3 papers
  - soon to be repeated at $\sqrt{s} = 8$ TeV

- two successful data-takings with CMS, common data analysis in progress
  $\Rightarrow$ exciting measurement possibilities already for this year

- very low-$|t|$ elastic scattering measurement planned with $\beta^* = 500$ m
  $\Rightarrow$ possibility to determine the $\varrho$ parameter