TOTEM Status Report

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on behalf of the TOTEM collaboration

LHCC Open Session, 13 June, 2012
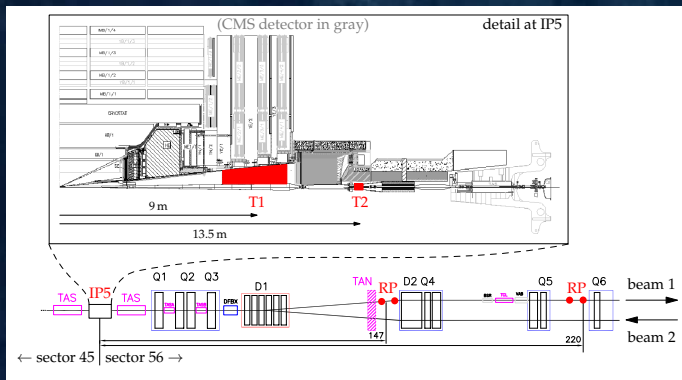
The TOTEM experiment

programme
- elastic scattering measurement in a wide t-range
- total cross-section measurement and
- a study of soft and hard diffraction

detectors

← forward telescopes T1 and T2 charged particles from inelastic collisions

← 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

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

EPL **98** (2012) 31002

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

$\downarrow$ $\downarrow$

Roman Pot data: data from T2 and T1
elastic cross-section   inelastic cross-section
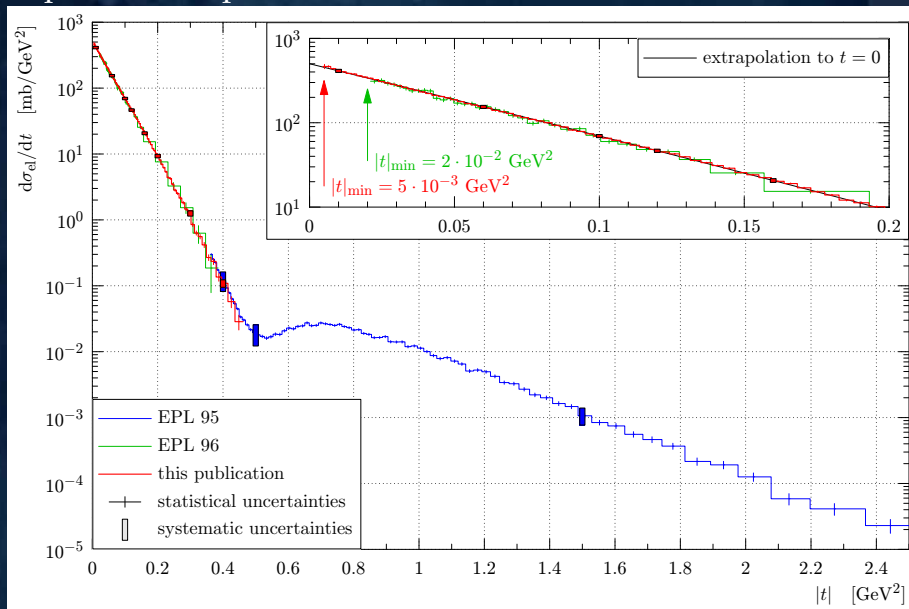
$\searrow$ $\swarrow$

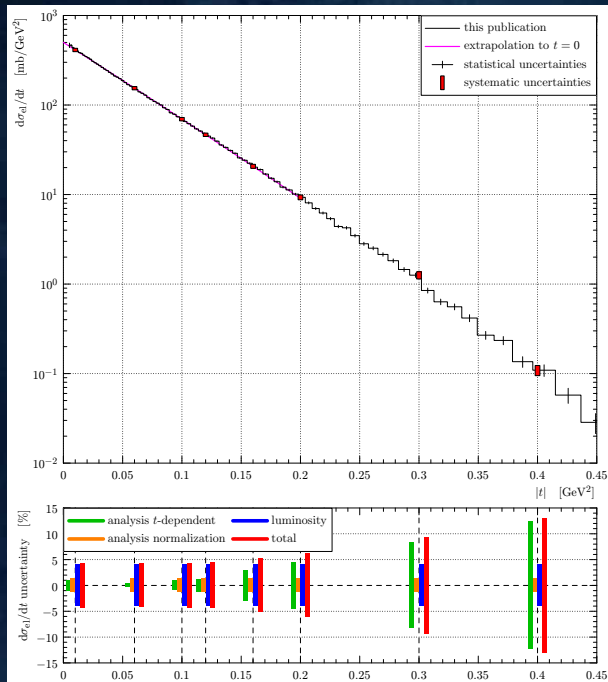total cross-section, luminosity, ϱ parameter, ...

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)

- **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)

$\Rightarrow$ reliable uncertainty estimates including correlations

Inelastic cross-section I

1) most inelastic events hit T2 $\Rightarrow$ counting events with T2 trigger $\Rightarrow \sigma_{\text{inel,raw}}$
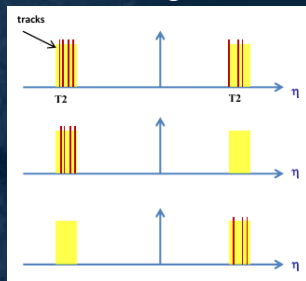
2) $\sigma_{\text{inel,raw}} \longrightarrow \sigma_{\text{inel,T2visible}}$: "detector corrections" = trigger and tracking efficiency, beam-gas background, pile-up

$$\sigma_{\text{inel,T2visible}} = (69.7 \pm 0.1^{\text{stat}} \pm 0.7^{\text{syst}} \pm 2.8^{\text{lumi}}) \text{ mb}$$
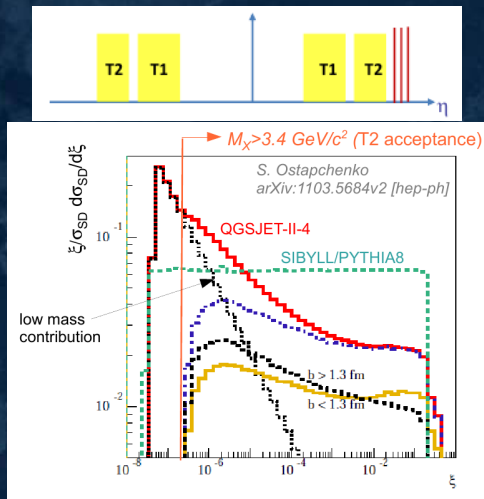
3) $\sigma_{\text{inel,T2visible}} \longrightarrow \sigma_{\text{inel},\eta<6.5}$

$$\sigma_{\text{inel},\eta<6.5} = (71.0 \pm 0.1^{\text{stat}} \pm 0.7^{\text{syst}} \pm 2.8^{\text{lumi}}) \text{ mb}$$

4) $\sigma_{\text{inel},\eta<6.5} \longrightarrow \sigma_{\text{inel,full}}$: 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 → 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): $\sigma_{\text{tot}} = (98.3 \pm 2.0)$ mb
October: $\sigma_{\text{tot}} = (98.6 \pm 2.3)$ mb

σ_{tot}

ϱ independent:

$$\sigma_{\text{tot}} = \frac{1}{\mathcal{L}}\ (N_{\text{el}} + N_{\text{inel}})$$
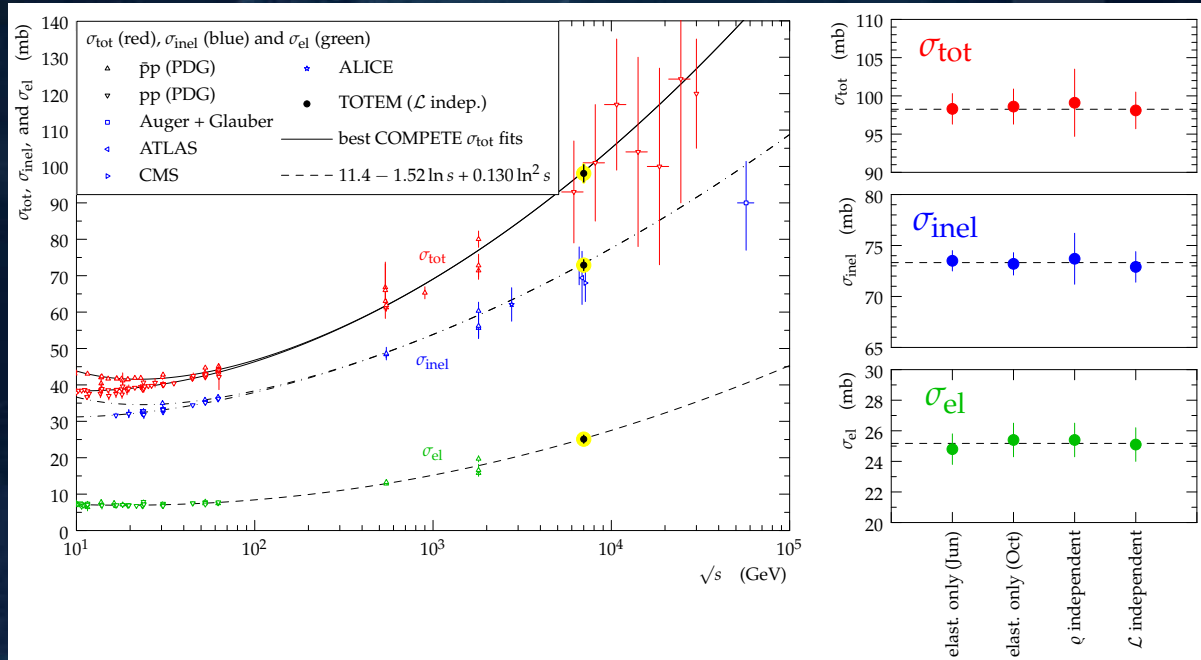
$\sigma_{\text{tot}} = (99.1 \pm 4.4)$ mb

luminosity independent:

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

$\sigma_{\text{tot}} = (98.1 \pm 2.4)$ mb

perfect consistency among all 4 cross-section determinations

low uncertainty ⇒ important for extrapolations

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

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

$\sigma_{\text{el}}/\sigma_{\text{tot}}$ *independent of luminosity and ϱ*

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

ϱ *determination*

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

TOTEM: $|\varrho| = 0.14 \pm 0.09$ COMPETE extrapolation $\varrho = 0.141 \pm 0.007$
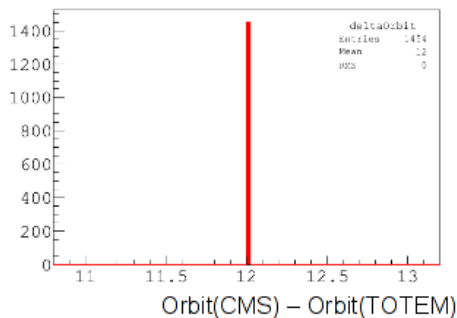
low-mass single diffraction

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

$\sigma_{\text{inel}}^{\eta > 6.5} = \sigma_{\text{tot}} - \sigma_{\text{el}} - \sigma_{\text{inel}}^{\eta < 6.5} = (2.3 \pm 2.2)\,\text{mb}$ [from MC: $\approx 2.6\,\text{mb}$]
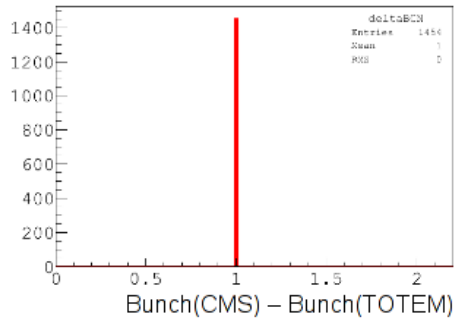
- engineering run (RP alignment)
- trigger: CMS jets → TOTEM
- **CMS+TOTEM data synchronization**:

- low-pile-up run, 8M events collected, RPs not inserted

- exchange of triggers:

$$\text{TOTEM} \longrightarrow \text{CMS: trigger menu} \longrightarrow \text{TOTEM}$$

  $\Rightarrow$ 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
  $\cdots$

- triggering with RPs possible due to **electrical trigger**
  - transfers signals RP 220 $\leftrightarrow$ 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
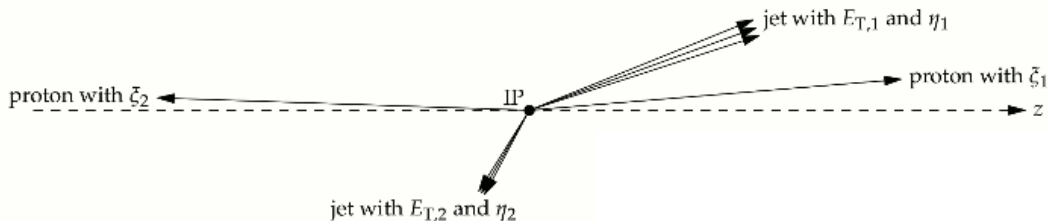
Special run at $\beta^* = 90$ m, 156 bunches

- CMS + TOTEM T1, T2 and Roman Pots = very large acceptance
- proton acceptance: $|t| \gtrsim 0.02 \, \text{GeV}^2$, any ξ
- soft and medium-hard diffraction, elastic and total cross-section
- expected early July

Standard runs at $\beta^* = 0.6$ m, ≈ 1400 bunches

- TOTEM Roman Pots + CMS
- proton acceptance: $\xi \gtrsim 2 - 3\%$, any t
- high luminosity $\Rightarrow$ high masses accessible

Special run at $\beta^* = 500$ m, low luminosity

- low-$|t|$ elastic scattering
- determination of ϱ

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
  ⇒ exciting measurement possibilities already for this year

- very low-$|t|$ elastic scattering measurement planned with β^* = 500 m
  ⇒ possibility to determine the ϱ parameter