

Total Cross Section Measurement with TOTEM at the LHC

Spaatind 2012 – Nordic Conference on Particle Physics
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Contributed talk on behalf of the TOTEM collaboration



Outline



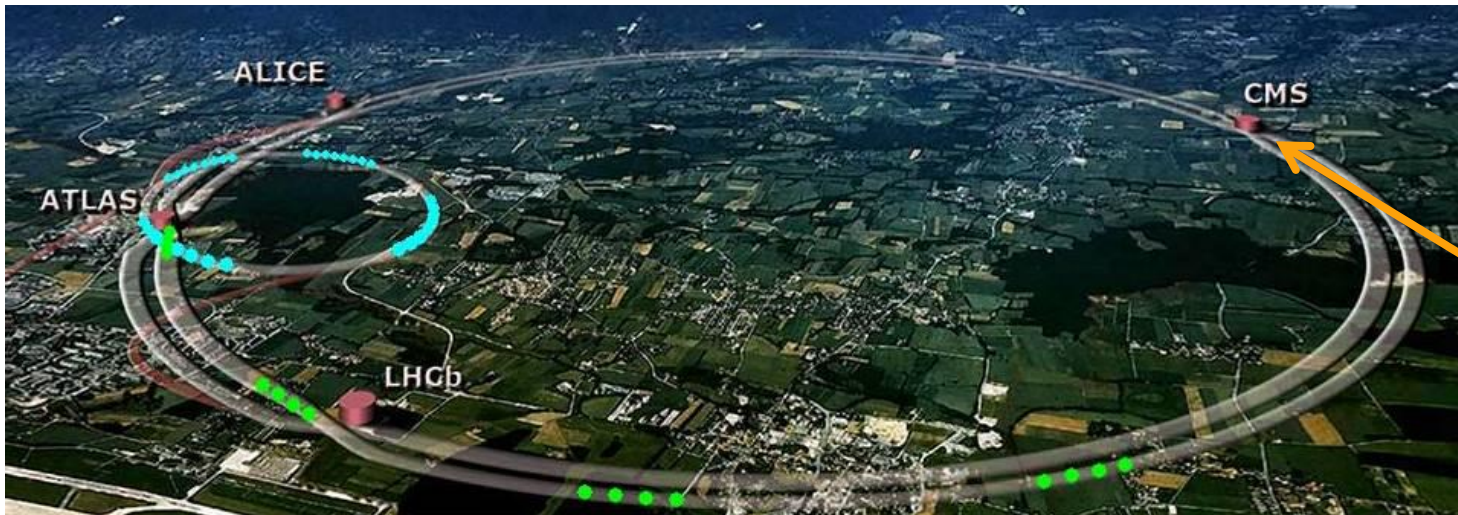
- What is TOTEM?
 - Goals
 - Experimental setup
- Cross section measurement
 - First results
 - Inelastic rate measurement for the luminosity independent cross section measurement



What is TOTEM?



- TOTAL, Elastic and diffractive cross section Measurement
- A small experiment at the Large Hadron Collider (LHC)
- Located at IP5 together with CMS
- Focus on forward physics





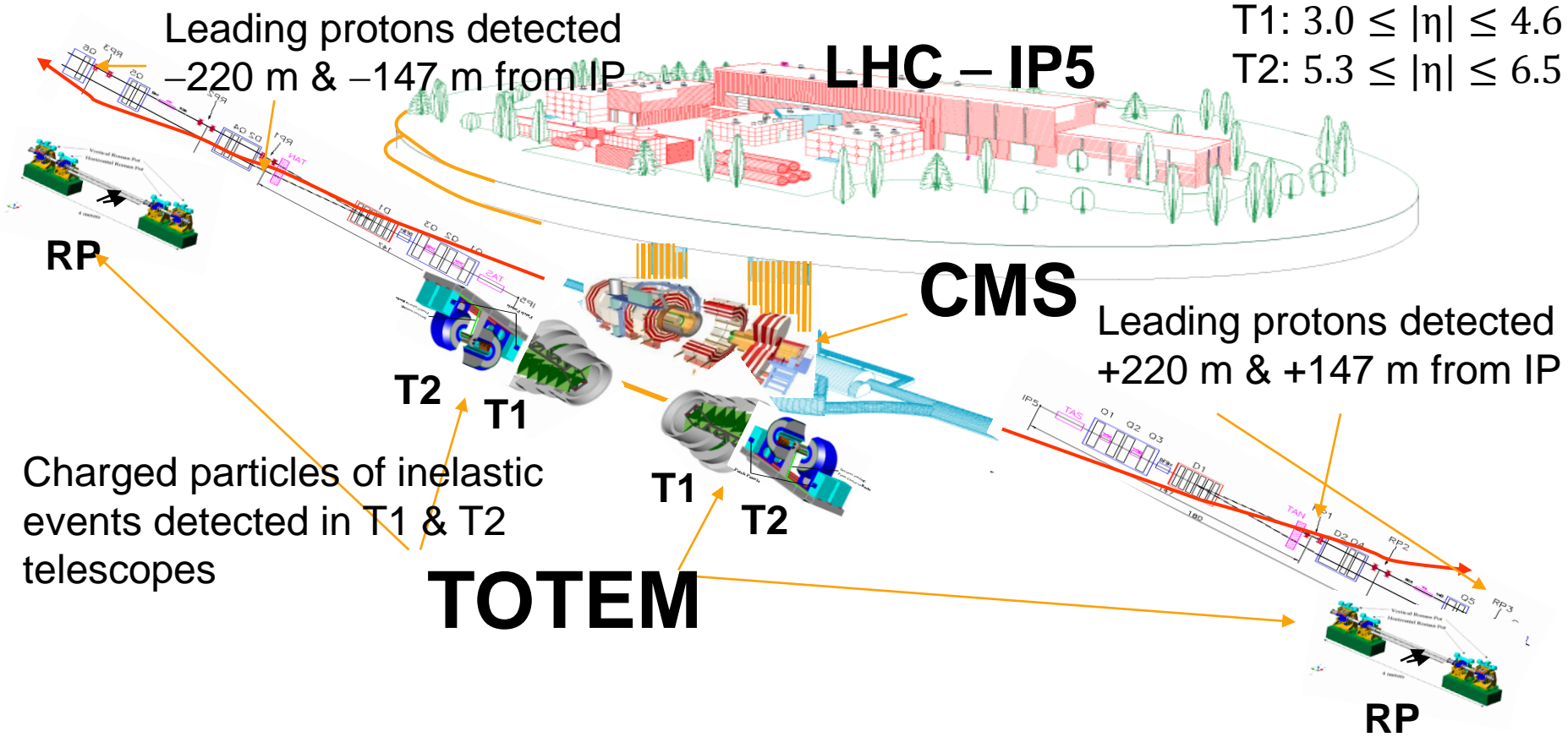
Physics goals



- Total pp cross section measurement with high precision
 - Luminosity (in)dependent method
- Elastic scattering and diffraction
 - Better understanding of the structure of the proton
 - Allows for improvement of models in non-perturbative region
- Forward charged particle production
 - Related to cosmic rays



Experimental setup





Methods for total cross section measurement



- Based on the optical theorem
 - Luminosity independent method

$$- \sigma_{tot} = \frac{16\pi \frac{dN_{el}}{dt} \Big|_{t=0}}{(1+\rho^2)(N_{el}+N_{inel})}$$

- Luminosity dependent method

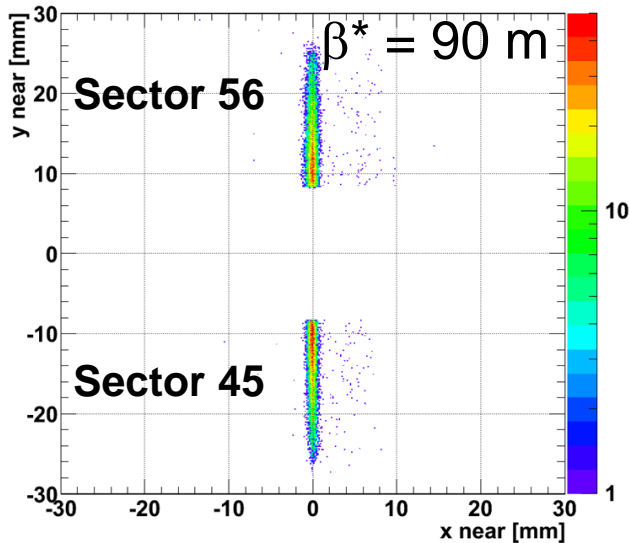
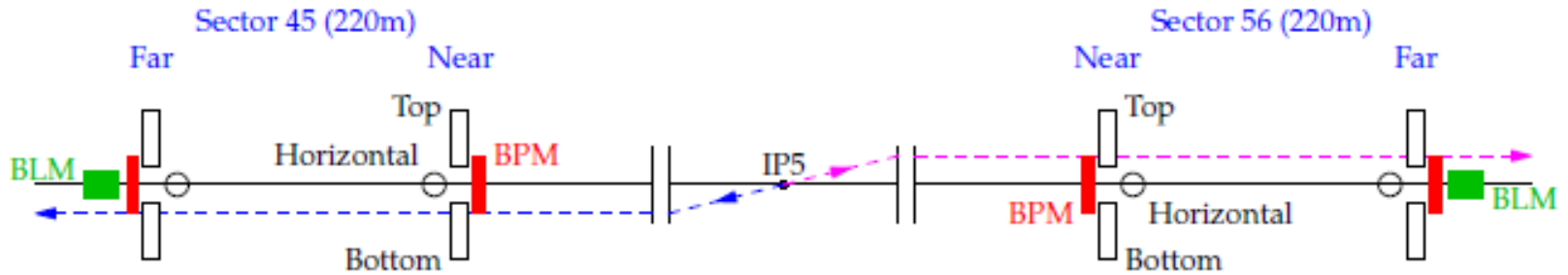
$$- \sigma_{tot} = \sqrt{\frac{16\pi}{1+\rho^2} \frac{d\sigma_{el}}{dt} \Big|_{t=0}}$$

- Luminosity measurement from CMS

- $\rho \sim 0.14$ (at 7 TeV) from theoretical predictions



Elastic scattering



$$t = -p^2 \theta^2$$

$$\zeta = \Delta p/p$$

Topology: track in near & far units in diagonal configuration w.r.t. IP

Low $|\xi|$ selection (3σ): $|x_{RP}| < 3\sigma_x @ L_x = 0$ & corr. $y_{RP, near} \leftrightarrow y_{RP, far}$

Elastic collinearity (3σ): $\theta^*_{x,45} \leftrightarrow \theta^*_{x,56}$ & $\theta^*_{y,45} \leftrightarrow \theta^*_{y,56}$



First total cross section

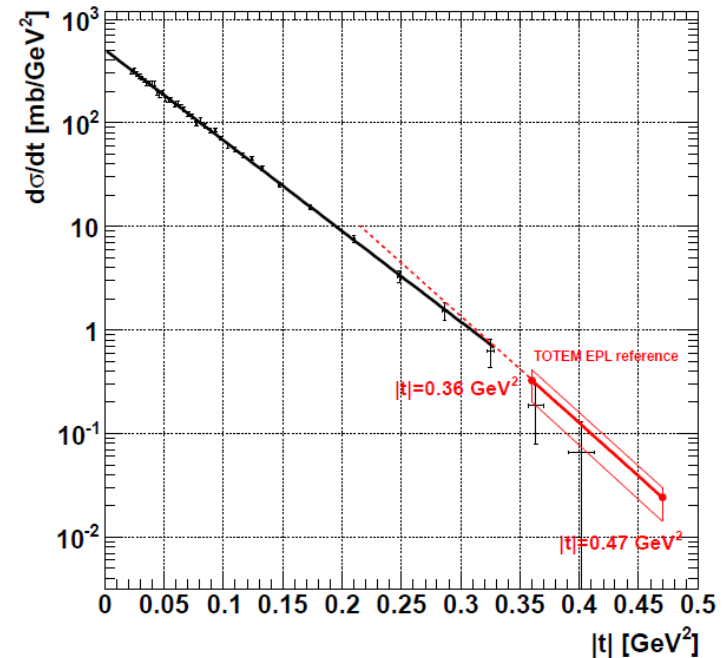


- Based on $\beta^* = 90$ m run from June 2011 with $\mathcal{L} = 0.002 \text{ nb}^{-1}$
- Optical point $\frac{d\sigma_{el}}{dt}|_{t=0} = 503.7 \pm 1.5(stat) \pm 26.7(syst) \text{ mb/GeV}^2$
- Elastic proton-proton cross section (integrated) $\sigma_{el} = 24.8 \pm 0.2(stat) \pm 0.3(syst) \text{ mb}$
- Total proton-proton cross section $\sigma_{tot} = 98.3 \pm 0.2(stat) \pm 2.8(syst) \text{ mb}$
- Inelastic proton-proton cross section

$$\sigma_{inel} = \sigma_{tot} - \sigma_{el} =$$

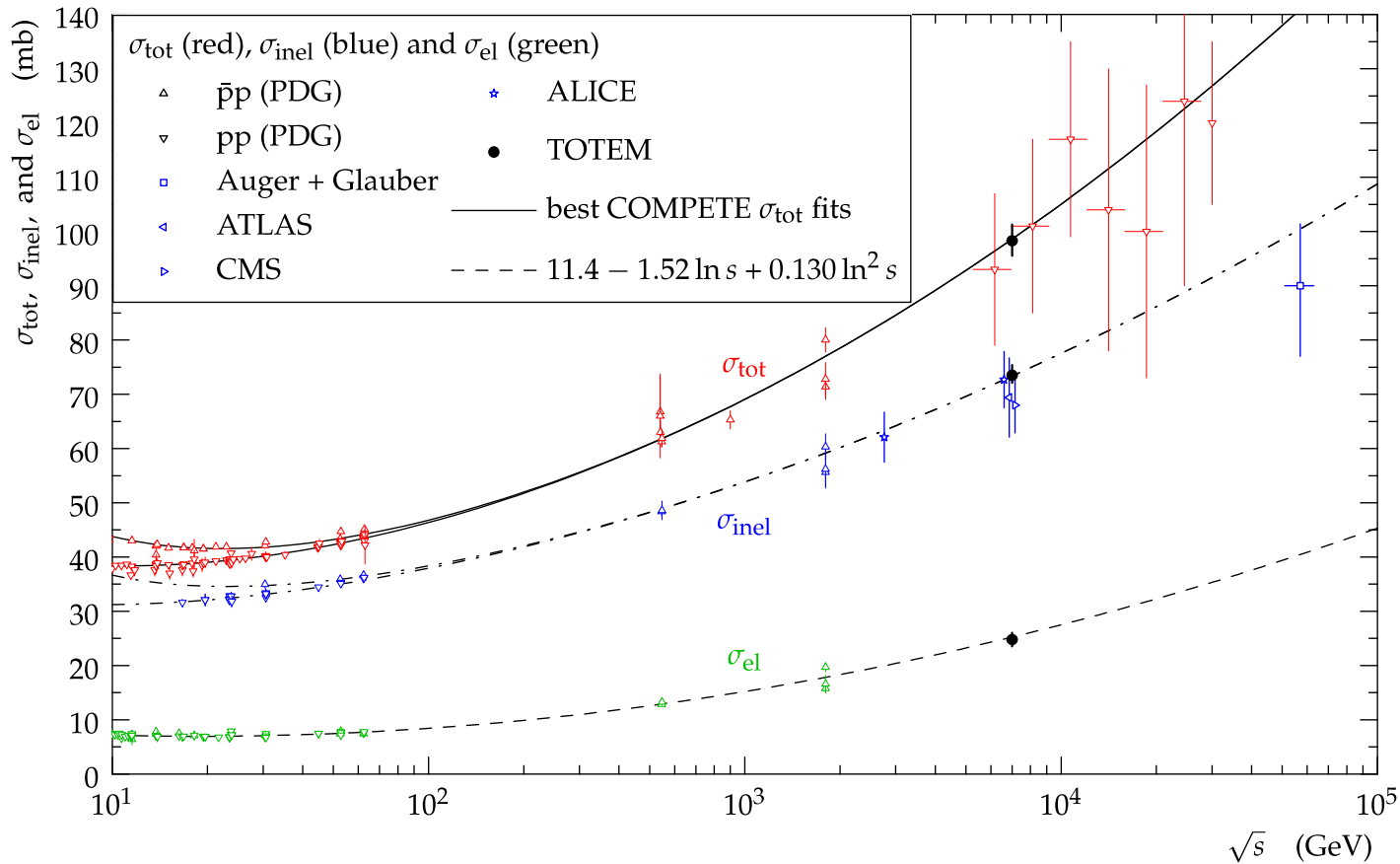
$$73.5 \pm 0.6(stat)_{-1.3}^{+1.8}(syst) \text{ mb}$$

Requires special optics to have access to very small t





First total cross section



σ_{inel} (CMS) =
 $68.0 \pm 2.0^{\text{(syst)}}$
 $\pm 2.4^{\text{(lumi)}}$
 $\pm 4.0^{\text{(extrap)}} \text{ mb}$

σ_{inel} (ATLAS) =
 $69.4 \pm 2.4^{\text{(exp)}}$
 $\pm 6.9^{\text{(extrap)}} \text{ mb}$

σ_{inel} (ALICE) =
 $72.7 \pm 1.1^{\text{(model)}}$
 $\pm 5.1^{\text{(lumi)}} \text{ mb}$



Inelastic rate measurement at $\beta^* = 90$ m



- T1 and T2 telescopes used as inelastic event counters
- T2 telescope used for triggering
- Visible inelastic rate obtained from measured one correcting for:
 - Trigger inefficiency (few percent)
 - Trigger efficiency as function of charged particle multiplicity determined from data with bunch crossing trigger
 - Beam gas background (few permille)
 - Estimated from events triggered for non-colliding bunches
 - Events with tracks only in T1 (few percent)
 - Fraction calculated from data with bunch crossing trigger
 - Pileup (~1.5 percent)
 - Estimated from relative trigger rate in data with bunch crossing trigger



Inelastic rate measurement at $\beta^* = 90$ m



- Invisible inelastic rate
 - Some events have all their final state particles outside the acceptance of T1 and T2
 - Mainly low mass single diffractive
 - Correction based on diffractive mass distribution
 - Calculation of diffractive mass distribution based on rapidity gaps
 - Unfolding
 - Polynomial fit of diffractive mass distribution in region of good efficiency
 - Extrapolation to low diffractive mass
 - Cross-check using events with only proton and no tracks in T1 and T2
- Sum of extrapolated and visible number of events give the inelastic rate → used for total cross section measurement



Summary



- Luminosity dependent cross section measurement based on elastic scattering published (EPL **96** (2011) 21002)
- Luminosity independent cross section measurement
 - Visible inelastic rate measurement requires several corrections
 - Invisible inelastic rate can be measured by extrapolating diffractive mass distribution/counting proton only events
 - dN_{el}/dt measurement
- Thank you for your attention!



References



- G. Antchev et al.: “First measurement of the total proton-proton cross section at the LHC energy of $\sqrt{s} = 7$ TeV”, EPL, 96 (2011) 21002
- The TOTEM Experiment at the CERN Large Hadron Collider, <http://www.iop.org/EJ/abstract/1748-0221/3/08/S08007>
- J.R. Cudell et al.: “Benchmarks for the forward observables at RHIC, the Tevatron-Run II, and the LHC”, Phys. Rev. Lett. 89 (2002) 201801.