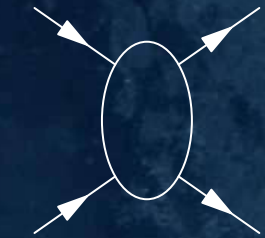
Total, elastic and diffractive cross-sections with TOTEM

Jan Kašpar
on behalf of the TOTEM collaboration

MPI@LHC 2012, CERN, 4 December, 2012

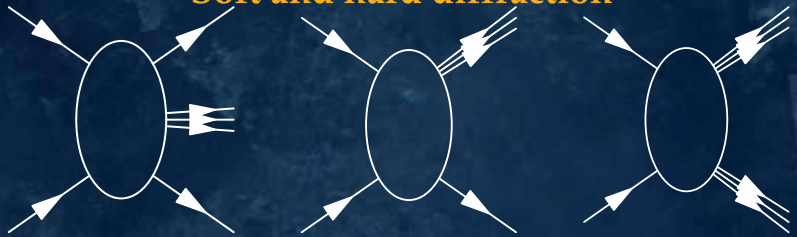
TOTEM physics programme

Elastic scattering



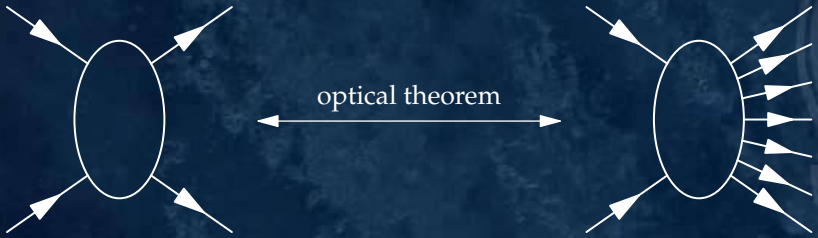
Total cross-section

Soft and hard diffraction

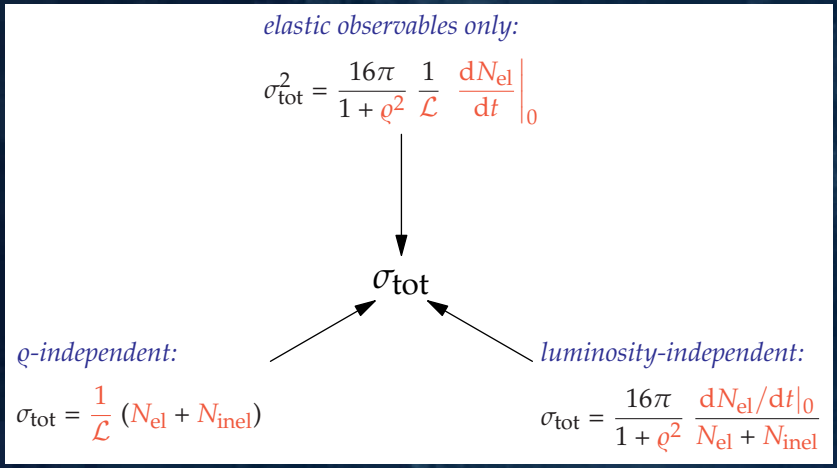


part I

Elastic scattering and Total cross-section



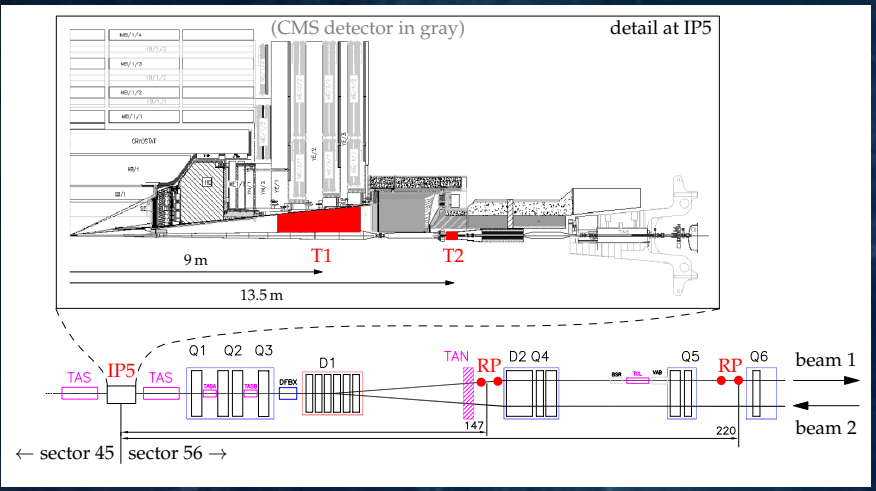
Three methods for total cross-section



ingredients

- elastic rate
  $\Rightarrow$ Roman Pot detectors
- inelastic rate
  $\Rightarrow$ telescopes T1 and T2
- luminosity
  $\Rightarrow$ provided by CMS
- $\varrho \equiv \left.\frac{\mathrm{Re}\,\mathcal{A}_{\rm el}}{\mathrm{Im}\,\mathcal{A}_{\rm el}}\right|_{t=0}$
  $\Rightarrow$ from COMPETE extrapolation

Detector apparatus

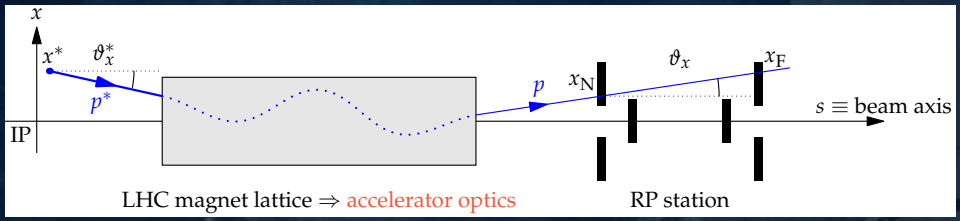


← telescopes T1 and T2
charged particles from inelastic collisions
T1: $3.1 < |\eta| < 4.7$
T2: $5.3 < |\eta| < 6.5$

← Roman Pots at the LHC
elastic and diffractive protons

- all detectors symmetrically on both sides of IP5
- all detectors trigger-capable

Proton measurement with Roman Pots

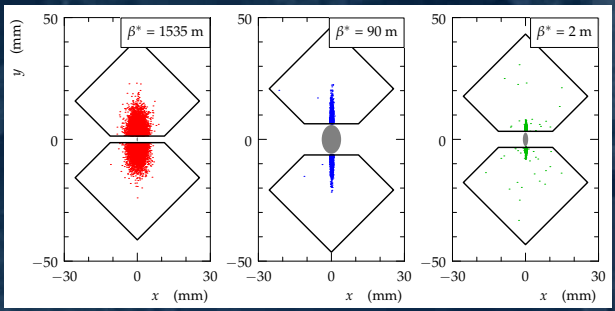


hit position at RP — optical functions — proton kinematics at IP

$$x(\mathrm{RP}) = (\text{effective length } L_x)\cdot(\text{scattering angle } \vartheta_x^*) + (\text{magnification } v_x)\cdot(\text{vertex } x^*) + (\text{dispersion } D_x)\cdot(\text{rel. momentum loss } \xi \equiv \frac{\Delta p}{p})$$

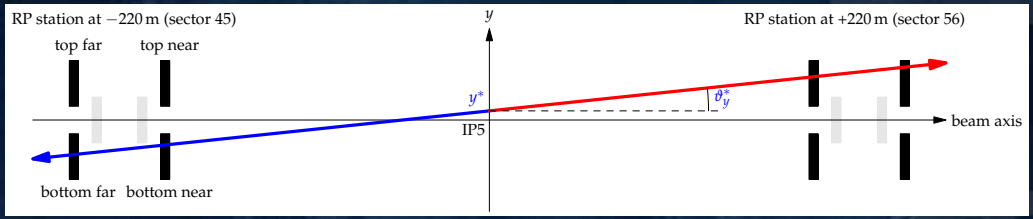
- optics defines what and how can be observed:

the same sample of elastic events seen with different optics:



- this presentation: optics $\beta^* = 90$ m used (almost) everywhere

Elastic scattering measurement

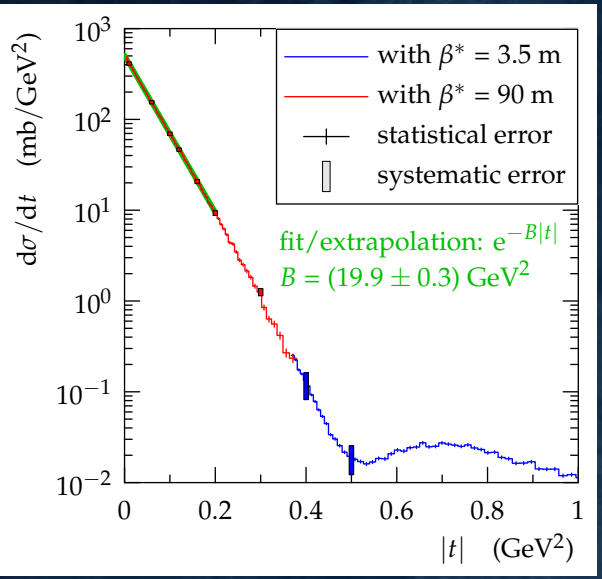


1. **Kinematics reconstruction**
   - proton tracks in RPs $\xrightarrow{\text{inverse optics}}$ proton kinematics at IP
2. **Elastic tagging**
   - elastic event = 2 anti-collinear protons from the same vertex $\Rightarrow$ compare left and right reconstructed protons
   - each proton $\xi \approx 0 \Rightarrow$ correlation hit position vs. track angle at RPs
3. **Acceptance corrections**
   - RP sensors have finite size, LHC apertures
   - azimuthal symmetry $\Rightarrow$ geometrical correction (+ smearing around edges)
4. **Unfolding of resolution effects**
   - angular resolution from data (compare left and right protons)
   - Monte Carlo $\Rightarrow$ impact on t-distribution
5. **Inefficiency corrections**
   - uncorrelated one-RP inefficiencies
   - near-far correlated RP inefficiencies
   - "pile-up" = elastic event + another track in a RP
6. **Luminosity**
   - from CMS (if available), uncertainty $\approx 4\%$

Elastic scattering results

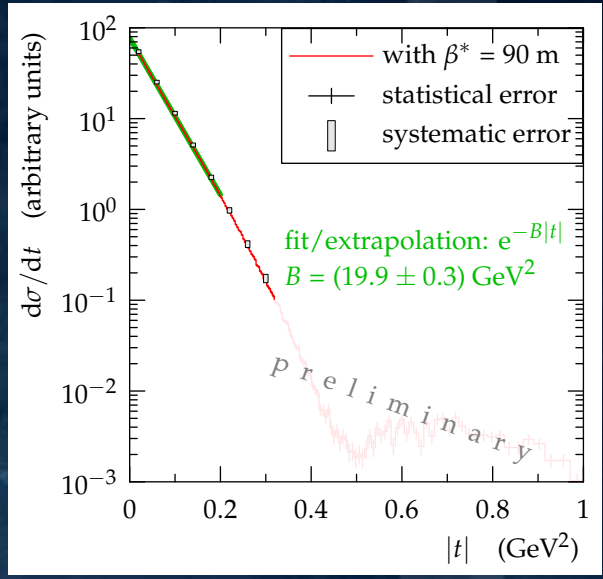
$\sqrt{s}$ = 7 TeV

[EPL 96 (2011) 21002, CERN-PH-EP-2012-239]



$\sqrt{s}$ = 8 TeV

[CERN-PH-EP-2012-354]



(CMS luminosity unavailable)

Total cross-section results

inelastic rate measurement: see Giuseppe Latino's talk (on Monday)

$\sqrt{s}$ = 7 TeV

[CERN-PH-EP-2012-353]

elastic observables only:

$$\sigma_{\text{tot}}^2 = \frac{16\pi}{1+\varrho^2}\,\frac{1}{\mathcal{L}}\,\frac{\mathrm{d}N_{\text{el}}}{\mathrm{d}t}\bigg|_0$$

$\sigma_{\text{tot}} = (98.6 \pm 2.3)$ 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:

$$\sigma_{\text{tot}} = \frac{16\pi}{1+\varrho^2}\,\frac{\mathrm{d}N_{\text{el}}/\mathrm{d}t|_0}{N_{\text{el}} + N_{\text{inel}}}$$

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

$\sqrt{s}$ = 8 TeV

[CERN-PH-EP-2012-354]

elastic observables only:

$$\sigma_{\text{tot}}^2 = \frac{16\pi}{1+\varrho^2}\,\frac{1}{\mathcal{L}}\,\frac{\mathrm{d}N_{\text{el}}}{\mathrm{d}t}\bigg|_0$$

σ_{tot}

ϱ-independent:

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

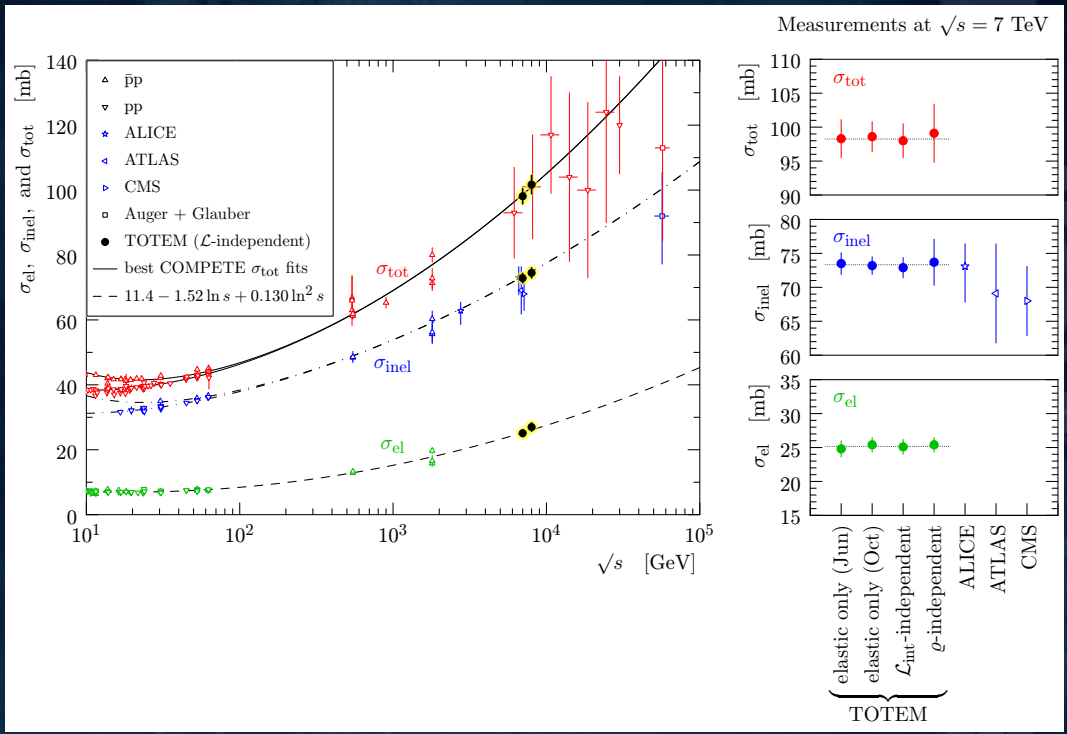
luminosity-independent:

$$\sigma_{\text{tot}} = \frac{16\pi}{1+\varrho^2}\,\frac{\mathrm{d}N_{\text{el}}/\mathrm{d}t|_0}{N_{\text{el}} + N_{\text{inel}}}$$

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

(CMS luminosity unavailable)

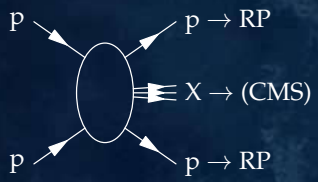
TOTEM results in context



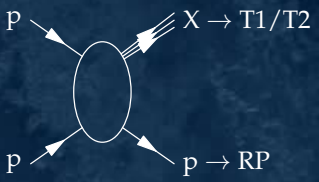
- outlook: successful data-taking with $\beta^* = 1000$ m optics – goal: ϱ determination

part II

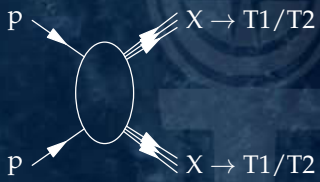
Diffraction



double-pomeron exchange (DPE)
(central production)



single diffraction (SD)



double diffraction (DD)

Optics for diffractive studies

$\beta^* = 90$ m

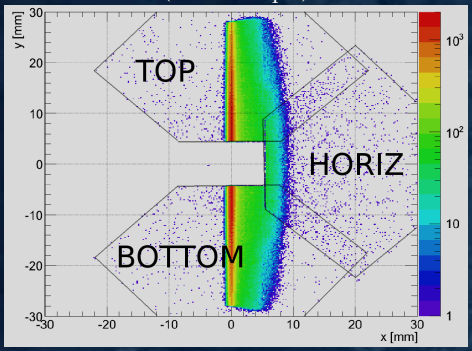
- optical functions at RP 220:

  $L_x \approx 0, \quad L_y \approx 260$ m, $\quad D_x \approx 4$ cm

  $\Downarrow$

  diffractive protons in vertical RPs

(a DPE sample)



- $|\xi|_{\min} = 0\% \Rightarrow$ low masses
- ξ-resolution
  - RPs only: (0.4 to 1)% (t-dependent)
  - with CMS vertex: $\approx 2\times$ better

used in 2012

low β^* (0.7 m here)

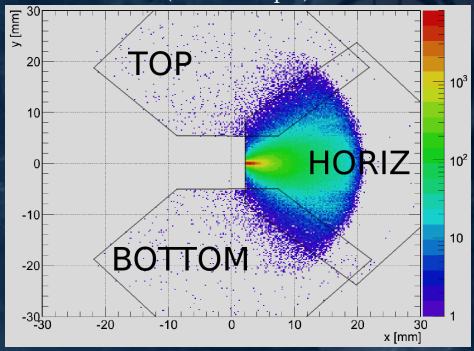
- optical functions at RP 220:

  $L_x \approx 1.7$ m, $\quad L_y \approx 14$ m, $\quad D_x \approx 8$ cm

  $\Downarrow$

  diffractive protons in horizontal RPs

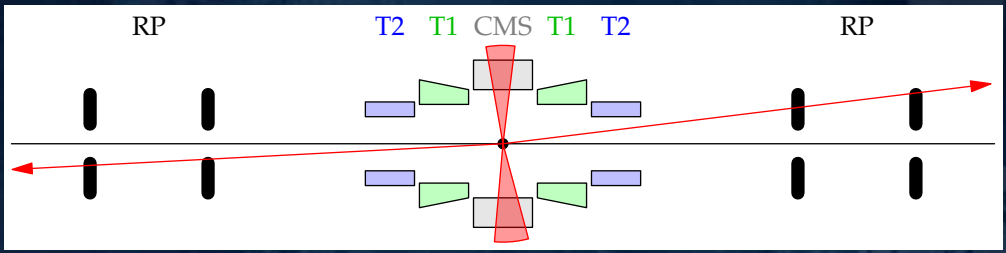
(a DPE sample)



- $|\xi|_{\min} = 2.8\% \Rightarrow$ higher masses
- ξ-resolution
  - RPs only: $\approx 0.2\%$

planned after long shutdown

Double-pomeron exchange

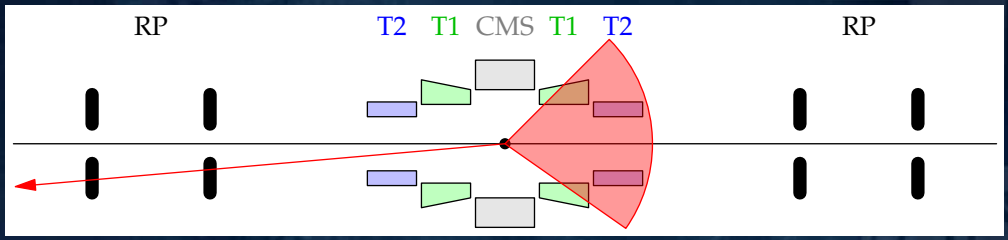


- available data
  - $\sqrt{s}$ = 7 TeV, β^* = 90 m, TOTEM alone: analysis ongoing
  - $\sqrt{s}$ = 8 TeV, β^* = 90 m, TOTEM+CMS: analysis ongoing
    (CMS trigger: di-jets with $p_T > 20$ GeV)

- measurement with RPs only
  - integrate over all $\xi \Rightarrow$ determine $|t|$-distribution
  - extrapolate t-distribution $\Rightarrow$ integrated DPE cross-section

- measurement with CMS
  - double determination of diffractive-system mass: RPs (both sides!) and CMS
  - goals: cross-sections and exceptional-event search

Single diffraction

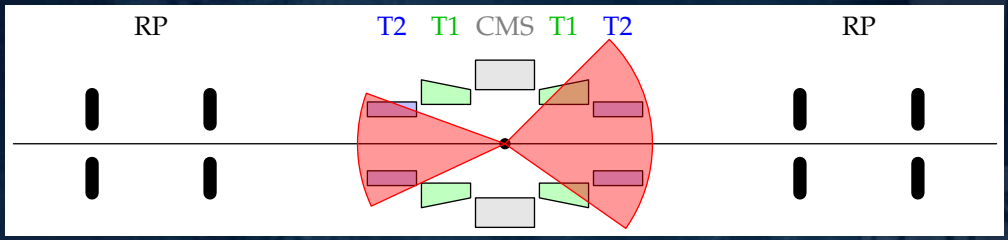


- available data
  - $\sqrt{s}$ = 7 TeV, β^* = 90 m: analysis ongoing
  - $\sqrt{s}$ = 8 TeV, β^* = 90 m (TOTEM + CMS)
- event topologies $\Rightarrow$ mass classes

mass	ξ region	proton side	opposite side
low mass	$\xi < 10^{-6}$	nothing	T2 only
medium mass	$10^{-6} < \xi < 0.25\%$	nothing	T1 and T2
high mass	$0.25\% < \xi < 2.5\%$	T1 only	T1 and T2
very high mass	$\xi < 2.5\%$	T1 and T2	T1 and T2

- double measurement of ξ:
  - RPs + optics
  - rapidity gap in T1/T2
- goals: integrated and differential SD cross-sections

Double diffraction



- available data
  - $\sqrt{s}$ = 7 TeV, β^* = 90 m: analysis ongoing
  - $\sqrt{s}$ = 8 TeV, β^* = 90 m

- trigger types
  - T1 and T2: dominated by MB $\Rightarrow$ background estimation
  - T2 but not T1: sensitive to DD

- goals
  - integral cross-section
  - differential cross-section (as function of $\eta_{\min}$)