Rho and total cross section measurements from TOTEM

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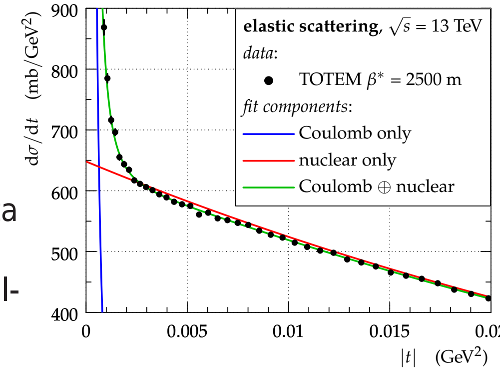
- several datasets at $\sqrt{s}$ = 13 TeV with different LHC optics (β^*)

- β^* = 90 m [CERN-EP-2017-321, arXiv:1712.06153]
  - first σ_{tot} determination at $\sqrt{s}$ = 13 TeV

- β^* = 2500 m [CERN-EP-2017-335 (v3), arXiv:1812.04732]
  - first ρ determination at $\sqrt{s}$ = 13 TeV
  - new: another σ_{tot} determination
    - completely independent of the 90 m result (data, method)
    - Coulomb-nuclear interference explicitly treated

- $\beta^* = 2500$ m $\Rightarrow$ access to very low $|t|$
  - both Coulomb (electromagnetic) and nuclear (strong) interactions relevant
$$\frac{dN}{dt} \propto \mathcal{L}\, |\mathcal{A}^C \oplus \mathcal{A}^N|^2$$
  - **if** $\mathcal{A}^N$ negligible $\Rightarrow$ normalisation (luminosity $\mathcal{L}$) can be determined from data ($\mathcal{A}^C$ known from QED)
  - luminosity determination important $\Rightarrow$ analyses of 90 and 2500 m data decoupled



- partial Coulomb normalisation: when $\mathcal{A}^N$ cannot be completely neglected
  - information about $\mathcal{A}^N$ "learned" from higher $|t|$
  - $\mathcal{L}$ as fit parameter
    - only few points with normalisation sensitivity $\Rightarrow$ care
    - technically: $\mathcal{L} = \mathcal{L}_{90} \cdot \eta$, thus η gives relative correction to normalisation from 90 m

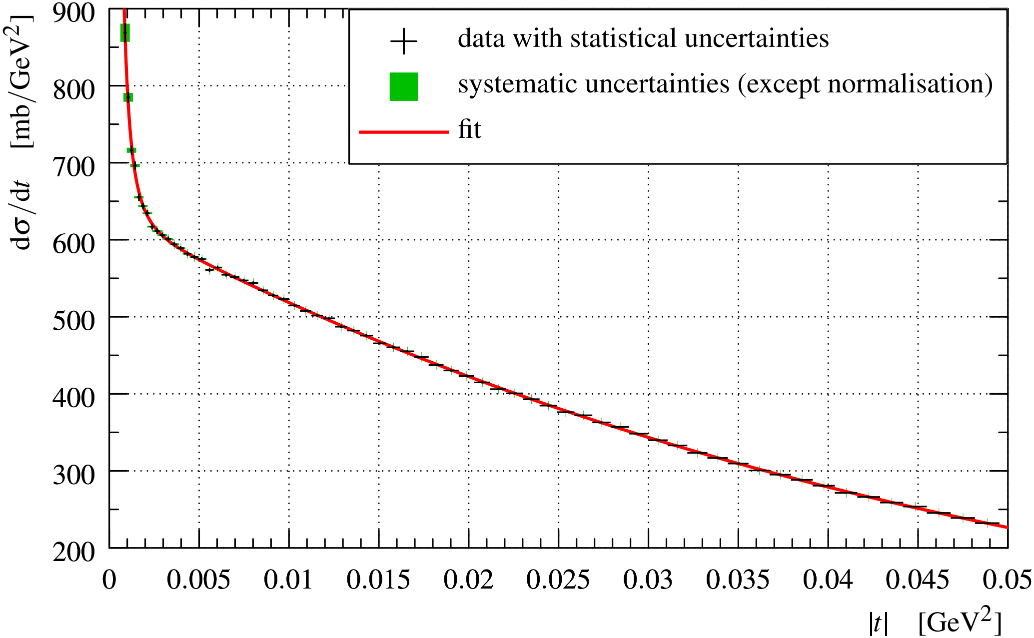
- exploit different approaches $\rightarrow$ consistency $\rightarrow$ confidence
  - *approach 1*: normalisation fixed from 90 m data
  - *approach 2*: normalisation variable but “attracted” to 90 m value
  - *approach 3*: normalisation free

Example – approach 3

$$\frac{\mathrm{d}\sigma}{\mathrm{d}t} = \eta \left| \mathcal{A}^C \oplus \mathcal{A}^N \right|^2 , \ \mathcal{A}^N = a e^{bt} \ldots$$

- step by step fit – physics-motived fit configurations for each parameter
  - step a: determine parameters of nuclear amplitude
    - $|t| > 0.0071\ \mathrm{GeV}^2$: CNI effects small $\Rightarrow$ can be ignored $\Rightarrow$ model indep.
    - $|t| < 0.026\ \mathrm{GeV}^2$: single-exponential parametrisation sufficient
    - determines b and product ηa^2
  - step b: determine normalisation
    - $|t| < 0.0023\ \mathrm{GeV}^2$, b and ηa^2 fixed from step a
    - η determined, thus also a determined
  - step c: determine ρ
    - $|t| < 0.0071\ \mathrm{GeV}^2$, b fixed from step a, η and a from step b
- single fit (potentially fragile)

Fit example : *Approach 3, single fit*



- fit
  - good quality (p-value 0.7)
  - $\eta = 1.05$, i.e. less than a sigma from the 90 m normalisation

- total cross-section derived

$$\sigma_{\text{tot}}^2 = \frac{16\pi(\hbar c)^2}{1+\rho^2} a$$

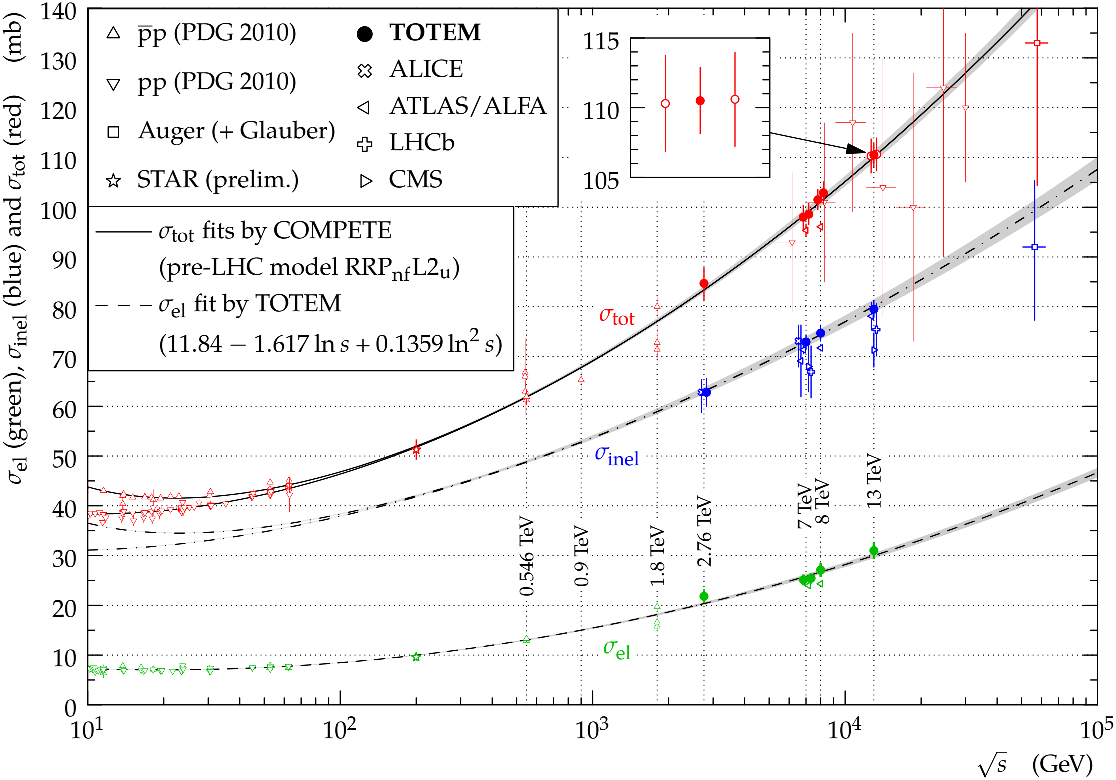
Table 6: Summary of ρ and total cross-section results.

data	method	ρ	σ_{tot} [mb]
$\beta^* = 90\,\text{m}$	Ref. [6]	-	110.6 ± 3.4
$\beta^* = 2500\,\text{m}$	approach 1	0.09 ± 0.01	111.8 ± 3.2
	approach 2	0.09 ± 0.01	111.3 ± 3.2
	approach 3	$0.08(5) \pm 0.01$	110.3 ± 3.5
	approach 3 (single fit)	0.10 ± 0.01	109.3 ± 3.5
$\beta^* = 90$ and $2500\,\text{m}$	Ref. [6] $\oplus$ approach 3		110.5 ± 2.4

- results consistent between all approaches
- η never further than a sigma from the 90 m normalisation
- results from 90 m and 2500 m (approach 3) *completely independent*
  $\Rightarrow$ weighted average $\Rightarrow$ *uncertainty reduction* (2.2 % relative)

$$\sigma_{\text{tot}} = (110.5 \pm 2.4)\ \text{mb}$$

Result summary



Conclusions

- $\beta^* = 2500$ m data
  - first use of Coulomb normalisation at LHC
  - another and independent $\sigma_{\rm tot}$ determination at $\sqrt{s} = 13$ TeV
- $\beta^* = 2500$ m + 90 m data
  - combined result: $\sigma_{\rm tot} = (110.5 \pm 2.4)$ mb