Forward Proton Measurements with ATLAS

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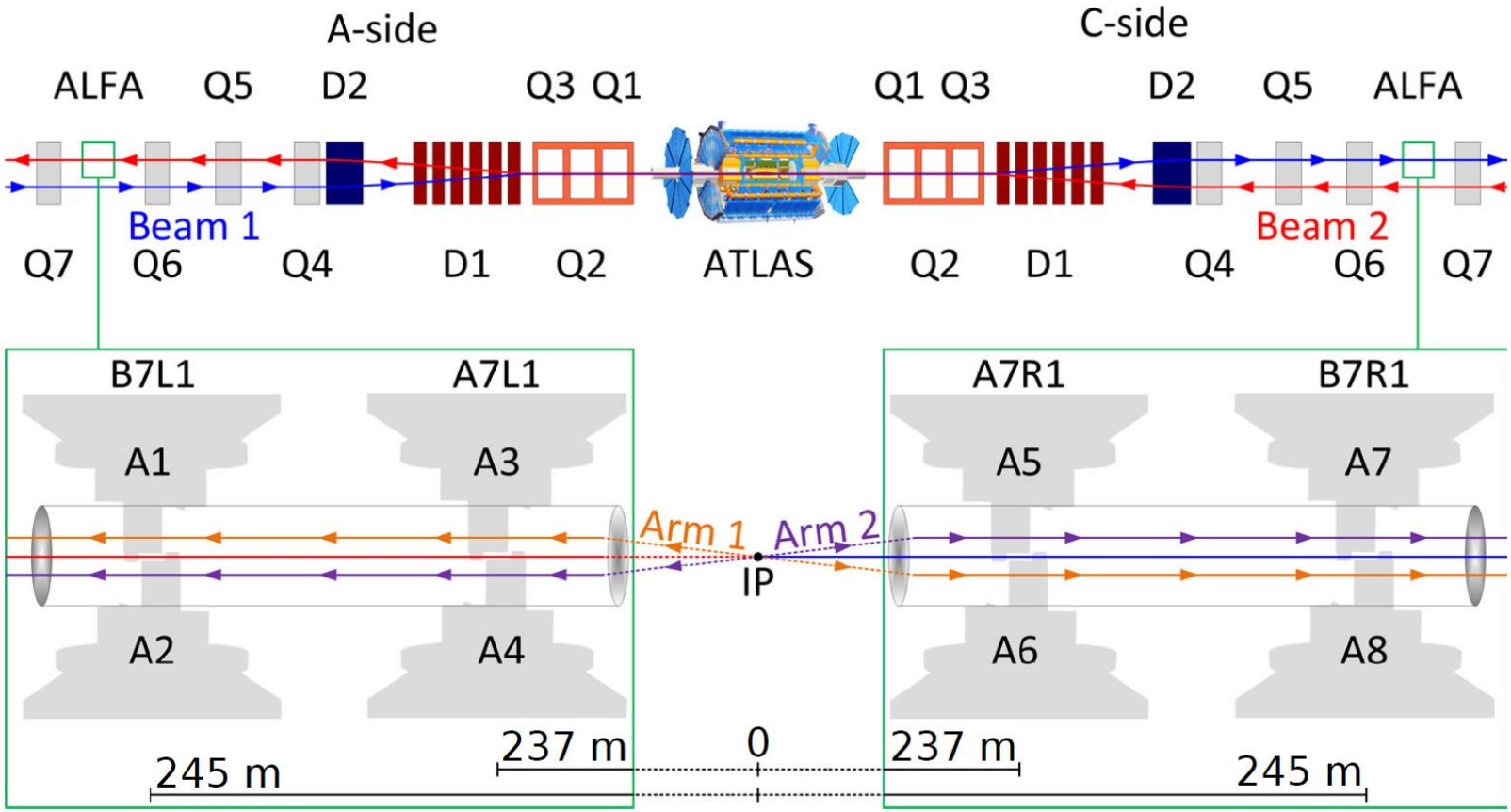
ALFA Detector

- 4 Roman Pot (RP) stations 237 m & 245 m from IP (A- & C-side) for measuring elastic *pp*-scattering
- Objective: total cross-section & various physics parameters
- High $\beta^\star$ runs (small scattering angles): $\beta^\star = 2.5\,\mathrm{km}$ @13 TeV



Physics Motivation

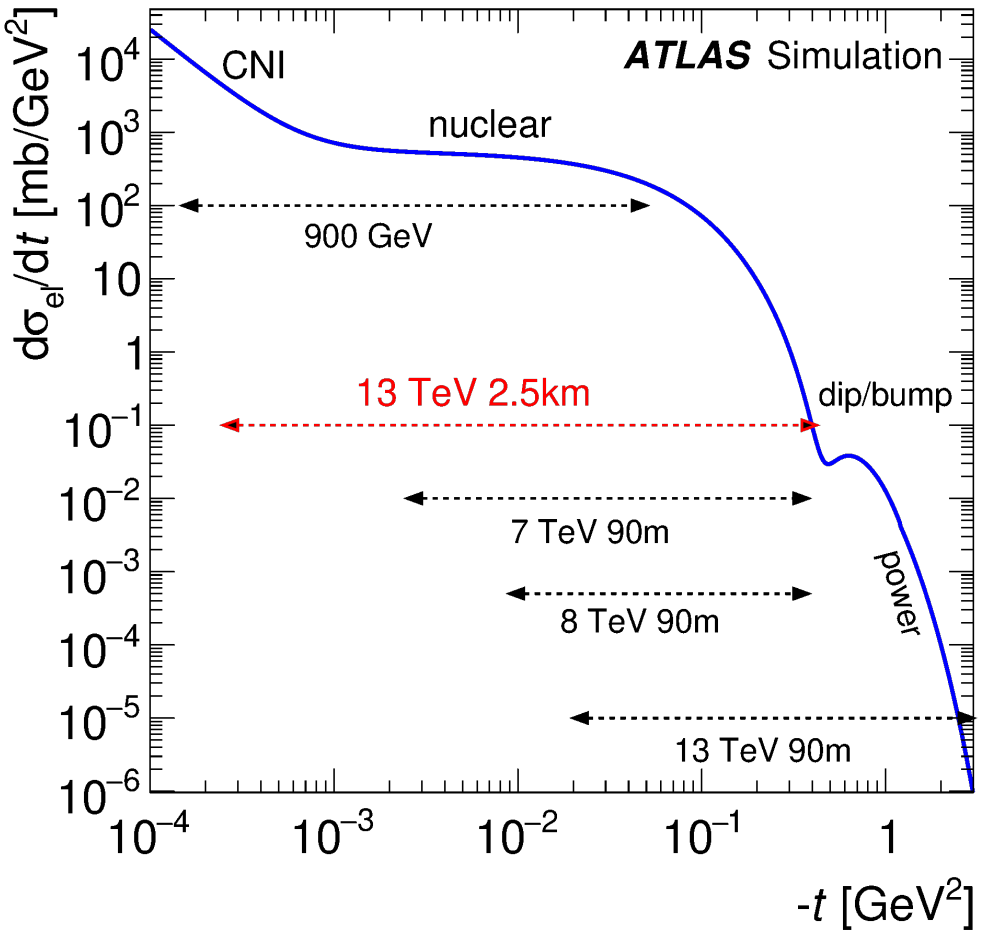
- Accessing unprecedented low values of t:

$$t \approx (p\theta)^2$$

- Sensitive to Coulomb-nuclear interference region
- Important for probing ρ-parameter:

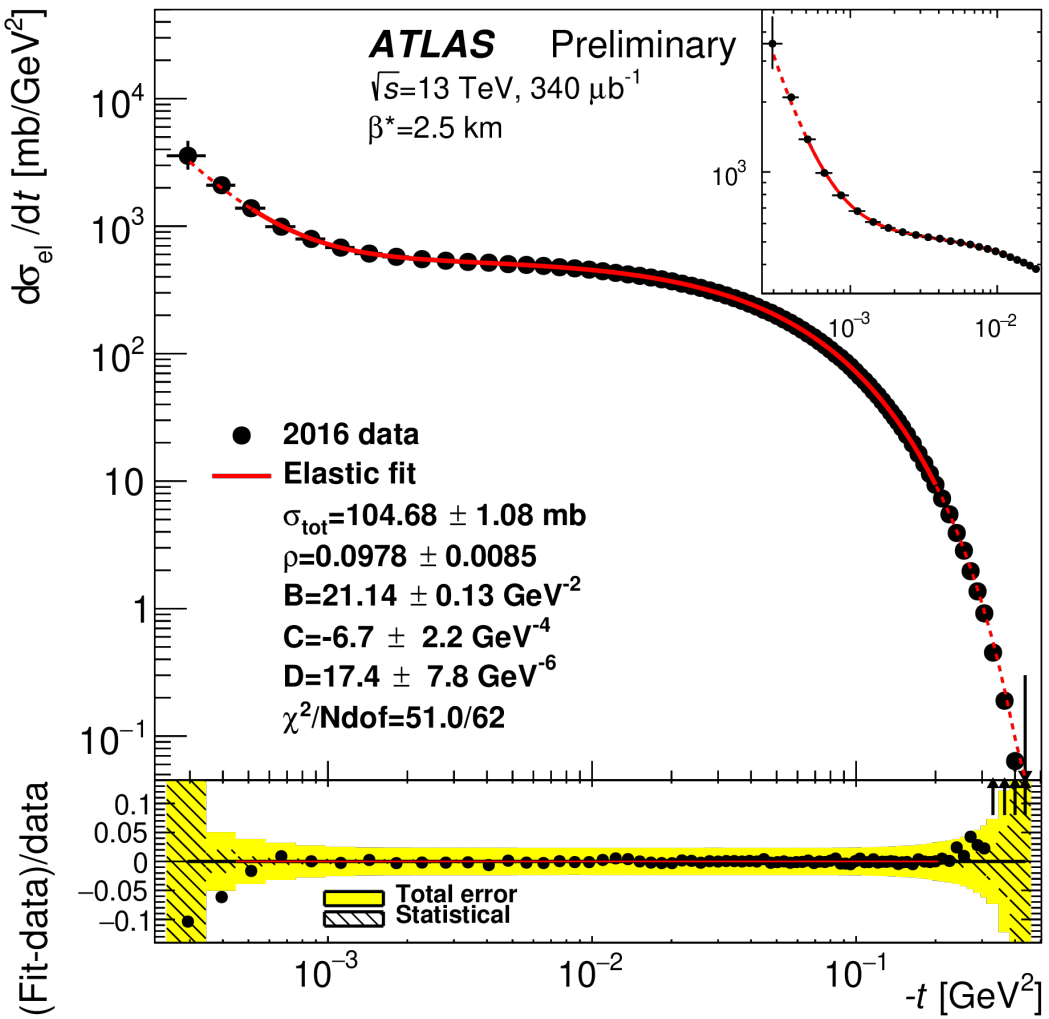
$$\rho = \frac{\mathrm{Re}f(0)}{\mathrm{Im}f(0)}$$

- Unique & important probes of non-perturbative QCD



Methadology: Rafal's talk on Tuesday & my poster

Analysis Results



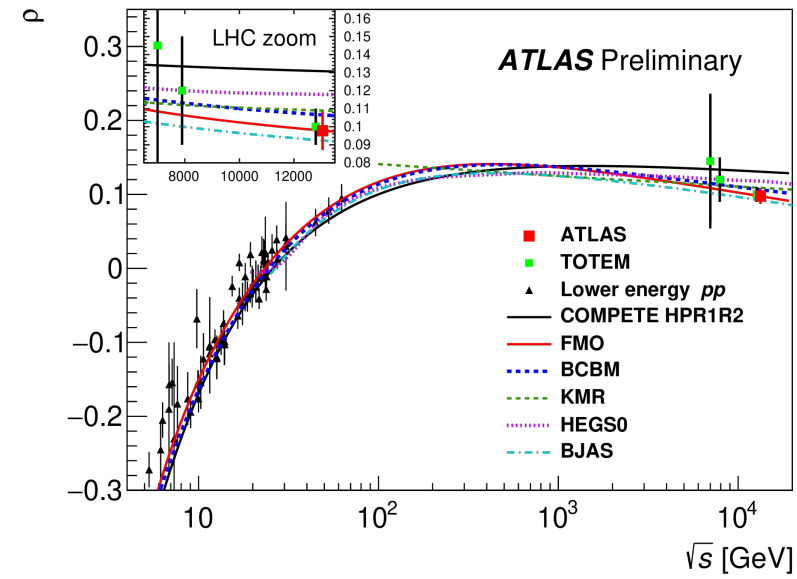
- Red line: fit to elastic data points
- σ_{tot}: total elastic cross-section:

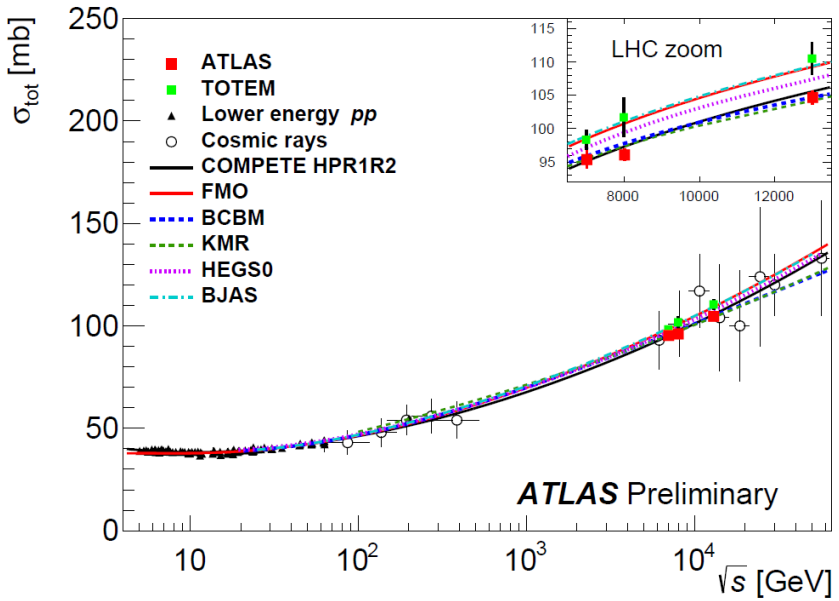
$$\sigma_{\text{tot}}^2 = \frac{16\pi}{1+\varrho^2} \cdot \left.\frac{\mathrm{d}\sigma_{\text{el}}}{\mathrm{d}t}\right|_{t\to 0}$$

- ρ: Real-to-imaginary ratio
- B, C, D: nuclear slope parameters
- Remarkable precision:
  - ρ with 1%
  - σ_{tot} with 11%

Interpretation

- ATLAS & TOTEM: Canonical evolution model COMPETE clearly disfavoured (predicted $\rho \approx 0.13$)
- Difference in σ_{tot} about 2.2σ between ALFA and TOTEM
- Similar trend observed in 7 & 8 TeV measurements
- Model including odderon (3-gluon state) tuned to TOTEM data $\Rightarrow$ not in good agreement with ALFA σ_{tot}
- Conclusion: BCBM damped amplitude model (alternative to odderon) best agreement with data





Thank you very much!

Backup Slides

Elastic Scattering

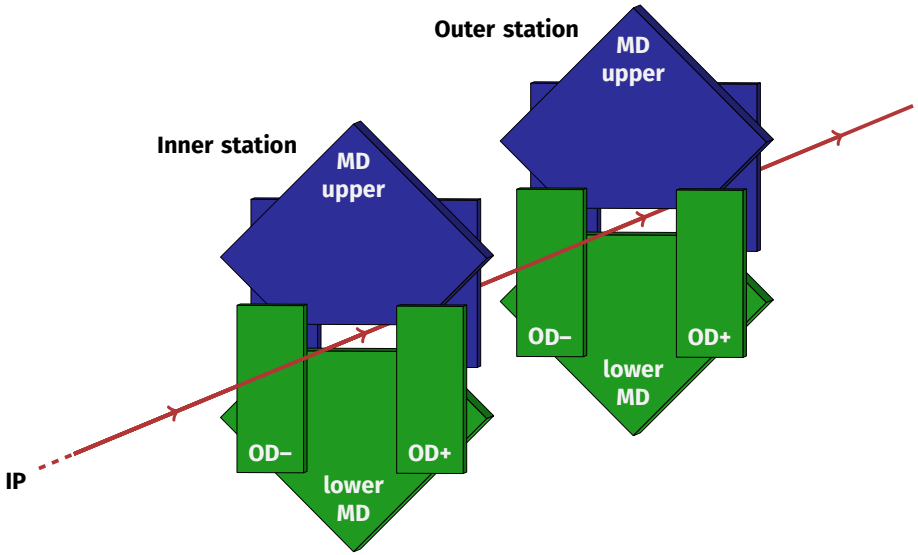
- Elastic pp scattering kinematics:
  p_1 & p_2 incoming momenta
  p_3 & p_4 outgoing momenta
- Simple kinematics to calculate momentum transfer t:

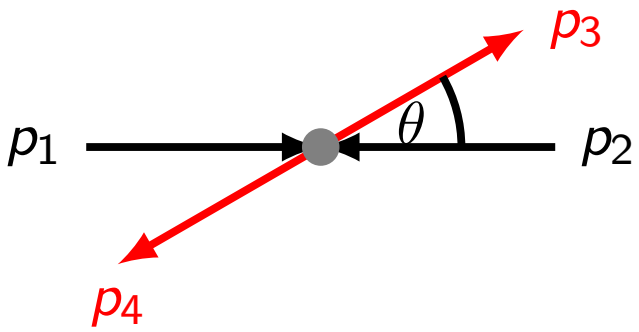
$$t = (p_1 - p_3)^2 = -4p^2 \sin^2 \frac{\theta}{2}$$

- Approximation of t: product of momentum & scattering:

$$t \approx -(p\theta)^2$$

- scattering angles obtained from hit position $\Rightarrow$ t-spectrum



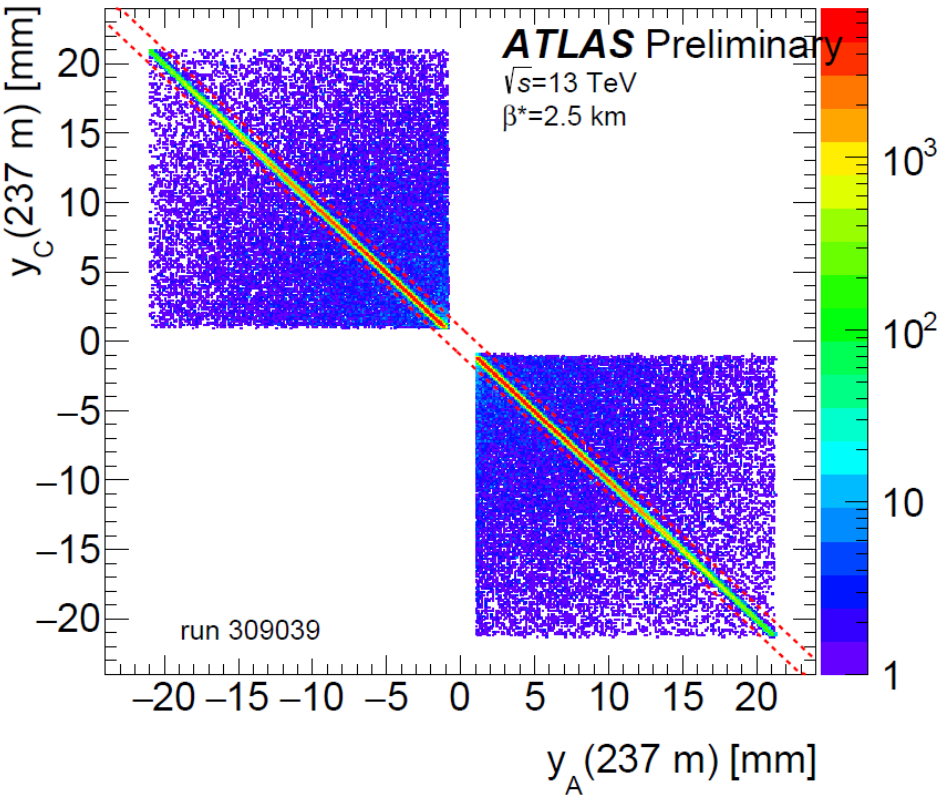


Reconstruction Method

- **Subtraction Method** for reconstructing θ:

$$\theta^* = \frac{\{x, y\}_A - \{x, y\}_C}{M_{12,A} + M_{12,C}}$$

- Full analysis contains steps:
  - Selection of elastic events
  - Background subtraction
  - Acceptance & unfolding corrections
  - Normalization by luminosity



- Special optics with a long focal length $\beta^\star = 2.5\,\text{km}$ required for measuring ρ at small t (small scattering angles)
- Total cross-section $\sigma_{\text{tot}} = \sigma_{\text{inel}} + \sigma_{\text{el}}$

Results

- Fit functions from theoretical model:

$$\frac{\mathrm{d}\sigma_{\mathrm{el}}}{\mathrm{d}t} = \frac{1}{16\pi}\left|f_N(t) + f_C(t)e^{i\alpha\phi(t)}\right|^2$$

$$f_C(t) = -8\pi\alpha\hbar c\frac{G^2(t)}{|t|}$$

$$f_N(t) = (\varrho + i)\frac{\sigma_{\mathrm{tot}}}{\hbar c}e^{\frac{-B|t|-Ct^2-D|t|^3}{2}}$$

f_N: nuclear amplitude

f_C: Coulomb amplitude

Results for physics parameters

	$\sigma_{\mathrm{tot}}[\mathrm{mb}]$	ρ	$B[\ GeV^{-2}]$	$C[GeV^{-4}]$	$D[GeV^{-6}]$
Central value	104.68	0.0978	21.14	−6.7	17.4
Statistical error	0.22	0.0043	0.07	1.1	3.8
Experimental error	1.06	0.0073	0.11	1.9	6.8
Theoretical error	0.12	0.0064	0.01	0.04	0.15
Total error	1.09	0.0106	0.13	2.3	7.8