Results on Total and Elastic Cross Sections in Proton-Proton Collisions at √s = 200 GeV Obtained with the STAR Detector at RHIC

For the STAR Collaboration

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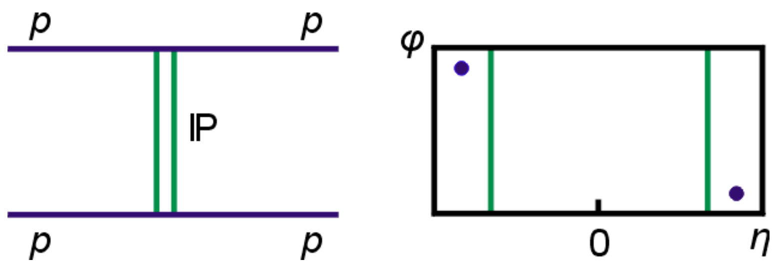
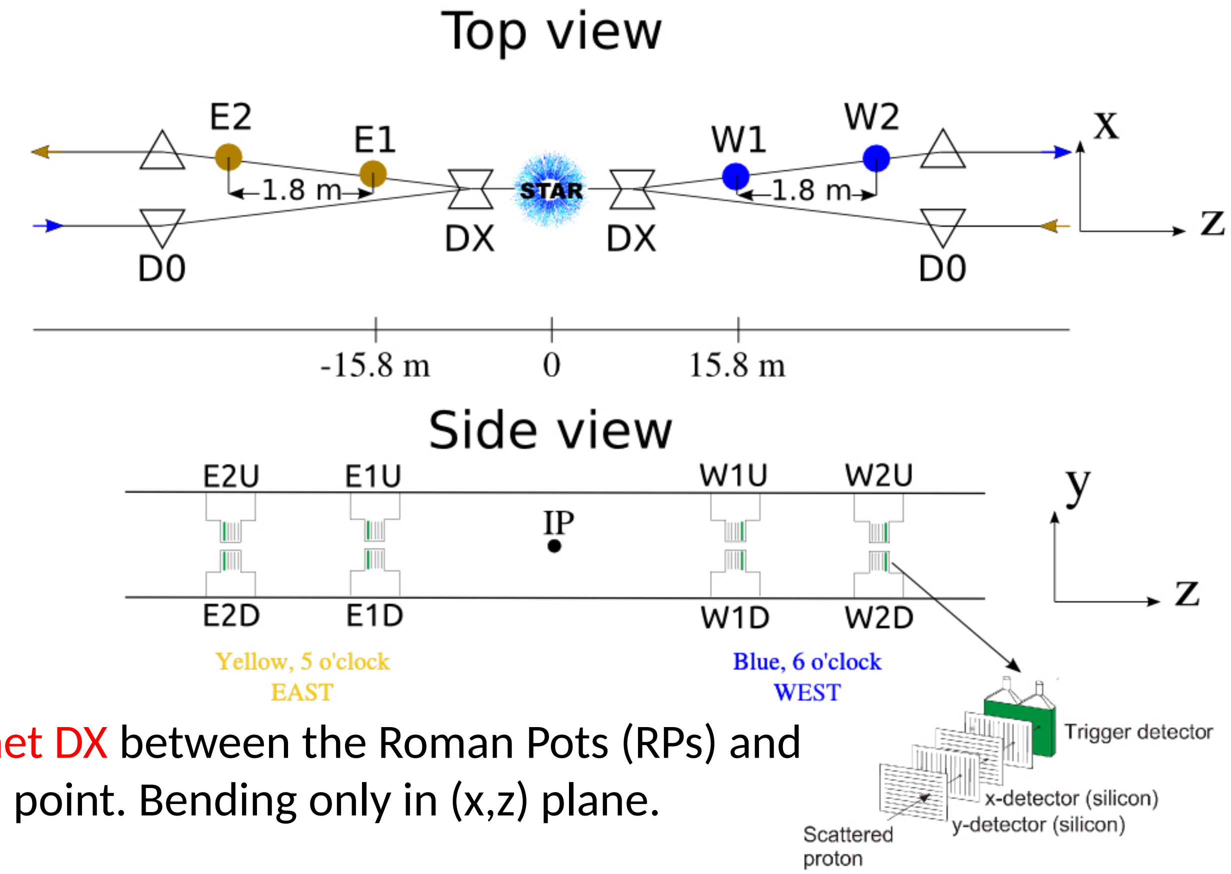


Elastic: p + p → p + p

1. Experimental setup of STAR
2. Data set
3. Analysis
4. Distributions of physics variables (-t, ϕ)
5. Simulations and efficiency, acceptance corrections
6. Results: $d\sigma/dt$, B-slope, σ_{tot}, σ_{el}

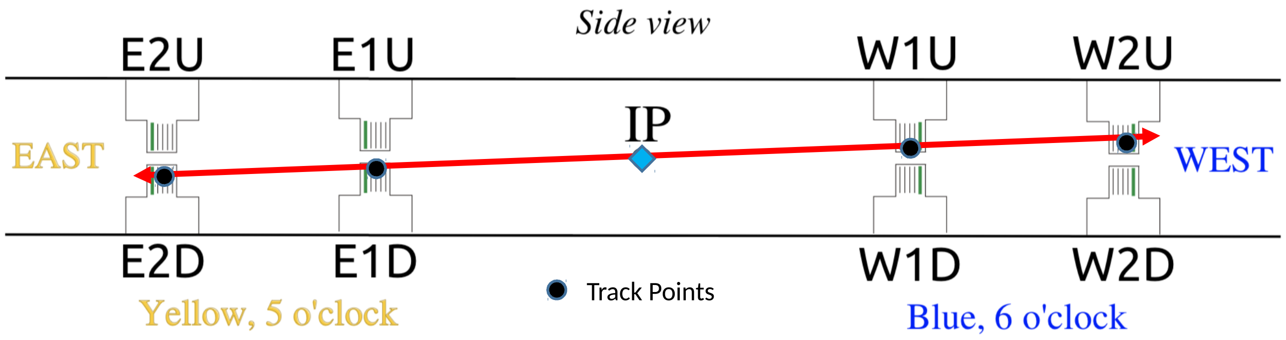
Experimental Setup



Only a dipole magnet DX between the Roman Pots (RPs) and the collision point. Bending only in (x,z) plane.

In this configuration, RP program at STAR was able to acquire large data samples without special running conditions – mostly for CEP, SDD and CP analyses .

Data Analysis



- Trigger was very inclusive: it required only a signal in at least one RP on each side.

$$\mathbf{RP\_ET} = (\mathbf{E1U} \vee \mathbf{E2U} \vee \mathbf{E1D} \vee \mathbf{E2D}) \wedge (\mathbf{W1U} \vee \mathbf{W2U} \vee \mathbf{W1D} \vee \mathbf{W2D})$$

- Need to minimize background and maximize efficiency.
- To reduce background, one needs angle reconstruction => two RPs on each side in up – down combination.

$$\mathbf{EU} = (\mathbf{E1U} \wedge \mathbf{E2U})\ ;\ \mathbf{ED} = (\mathbf{E1D} \wedge \mathbf{E2D})$$
$$\mathbf{WU} = (\mathbf{W1U} \wedge \mathbf{W2U})\ ;\ \mathbf{WD} = (\mathbf{W1D} \wedge \mathbf{W2D})$$
$$\mathbf{ET1} = (\mathbf{EU} \wedge \mathbf{WD})$$
$$\mathbf{ET2} = (\mathbf{ED} \wedge \mathbf{WU})$$

- Use events with four track points – one track point per Roman Pot.
- Finally, choose fiducial region away from the apertures of DX magnet and beam pipe in front of the RPs.

Collinearity

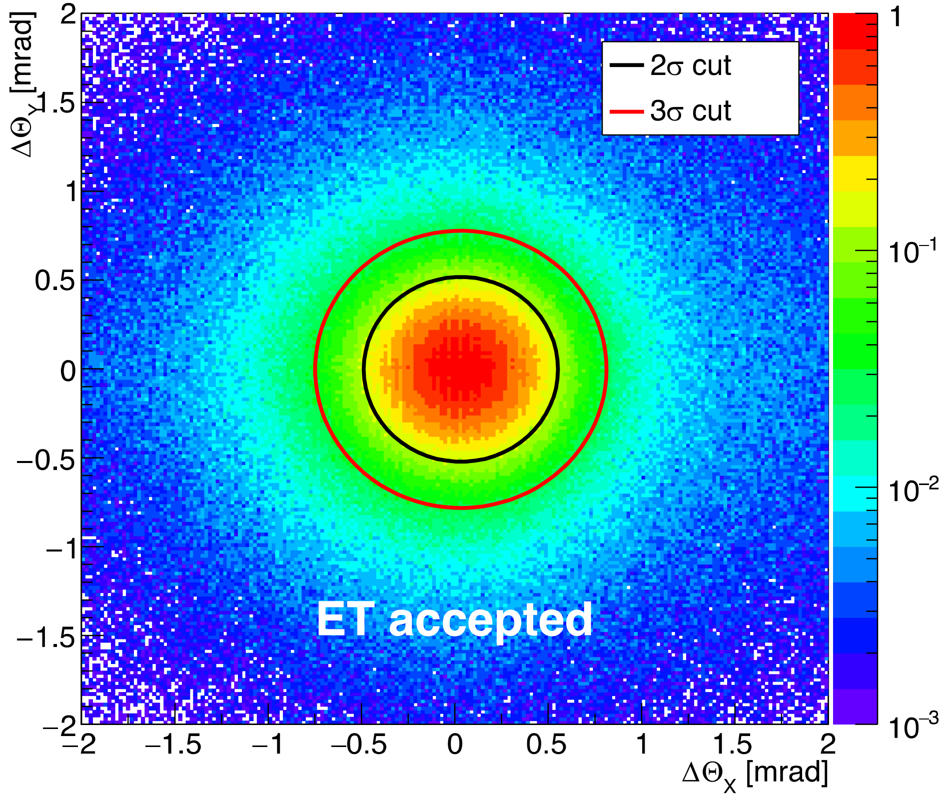
$$\vec{p_1} = -\vec{p_2} \Rightarrow (\Theta_{x1}, \Theta_{y1}) = (-\Theta_{x2}, -\Theta_{y2}) \Rightarrow \Delta\Theta_x = \Delta\Theta_y = 0$$

Since the elastic events must satisfy collinearity condition within 2σ.

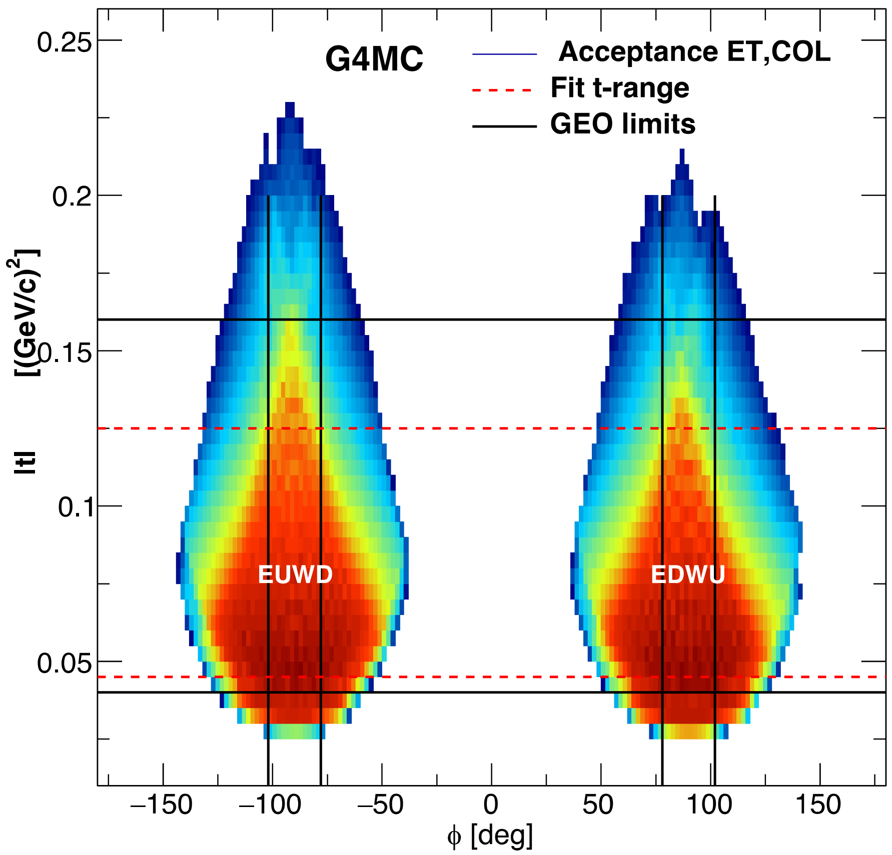
$$|\theta_{West} - \theta_{East}| < 2\sigma_\theta,$$

where $=$ 255 μrad, is required.

Events are well centered within 2σ and 3σ contours.



Geometrical Acceptance GEANT4 MC: I



Choice of geometrical acceptance (t,ϕ) plane

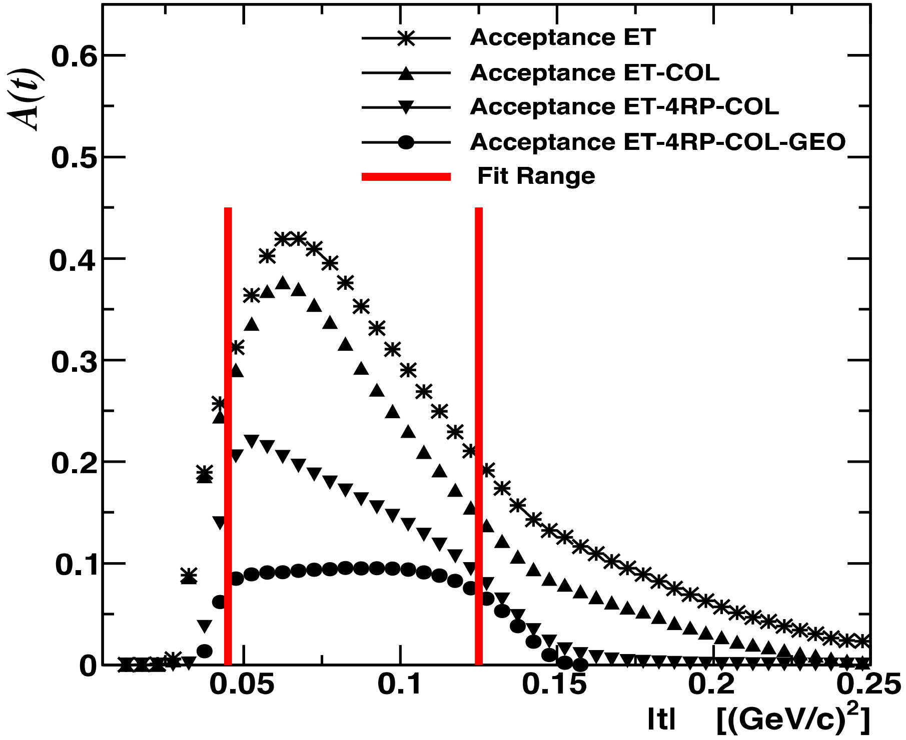
$$0.04 \leq |t| \leq 0.16[(GeV/c)^2]$$

$$79.5 \leq |\phi| \leq 101.5[deg]$$

$$2.00 \leq \theta \leq 4.00[mrad]$$

Fit range is chosen:
- to stay far away from edges where geometrical acceptance rapidly varies – drops
- for GEO filter acceptance is to a good approximation flat (see fig. on next slide)

Geometrical Acceptance and Event Yields



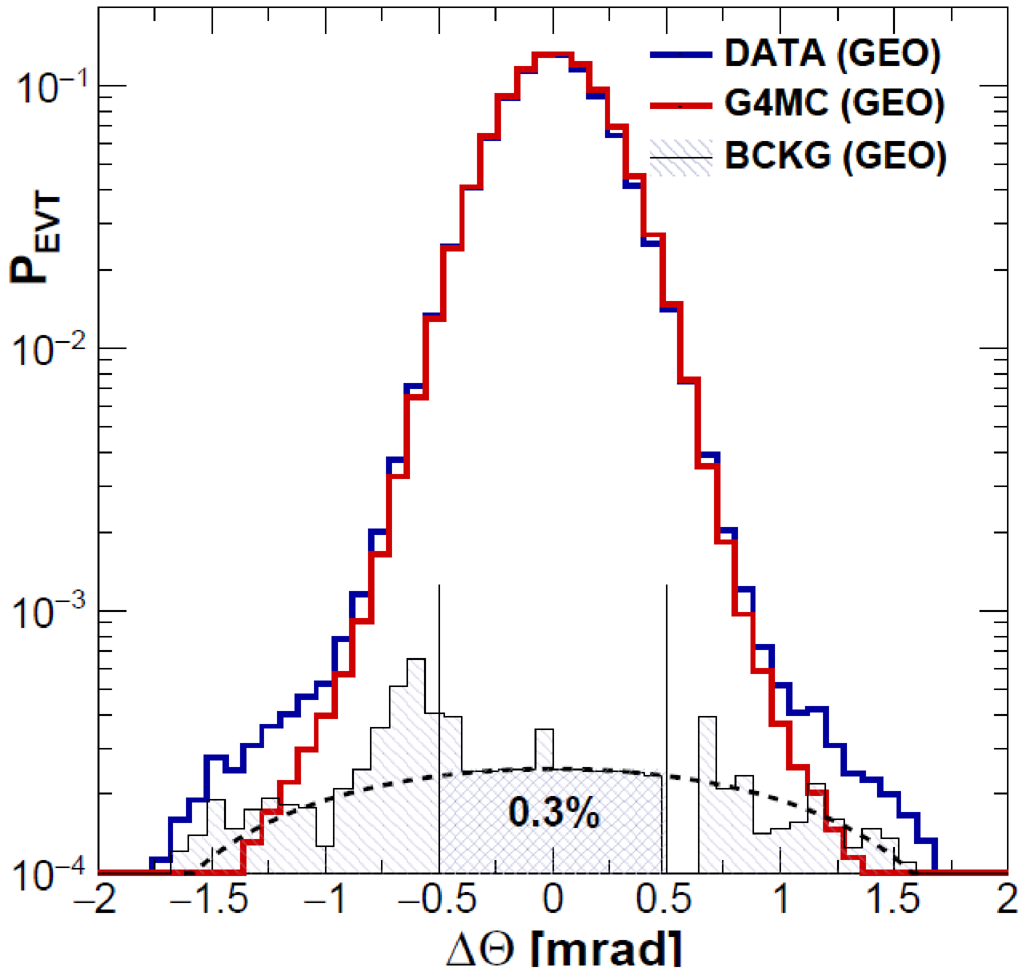
Choose fit range away from steep variation and edges of acceptance

Condition	# events
ET triggered	6.607M
ET accepted	3.974M
Collinear	2.696M
4 PT Collinear	1.100M
4 PT Collinear Geom.	0.667M

667K events used for the final analysis

GEANT4 MC: Background Study

1. Each distribution is normalized to 1 independently
2. MC is normalized to Data in the peak region
3. Background mostly due to the re-scattered protons in the beam pipe and the DX magnet
4. Background is small – 0.3%, after 2ΔΘ cut and after geometrical acceptance cut



Results: Corrected dσ/dt and Fits

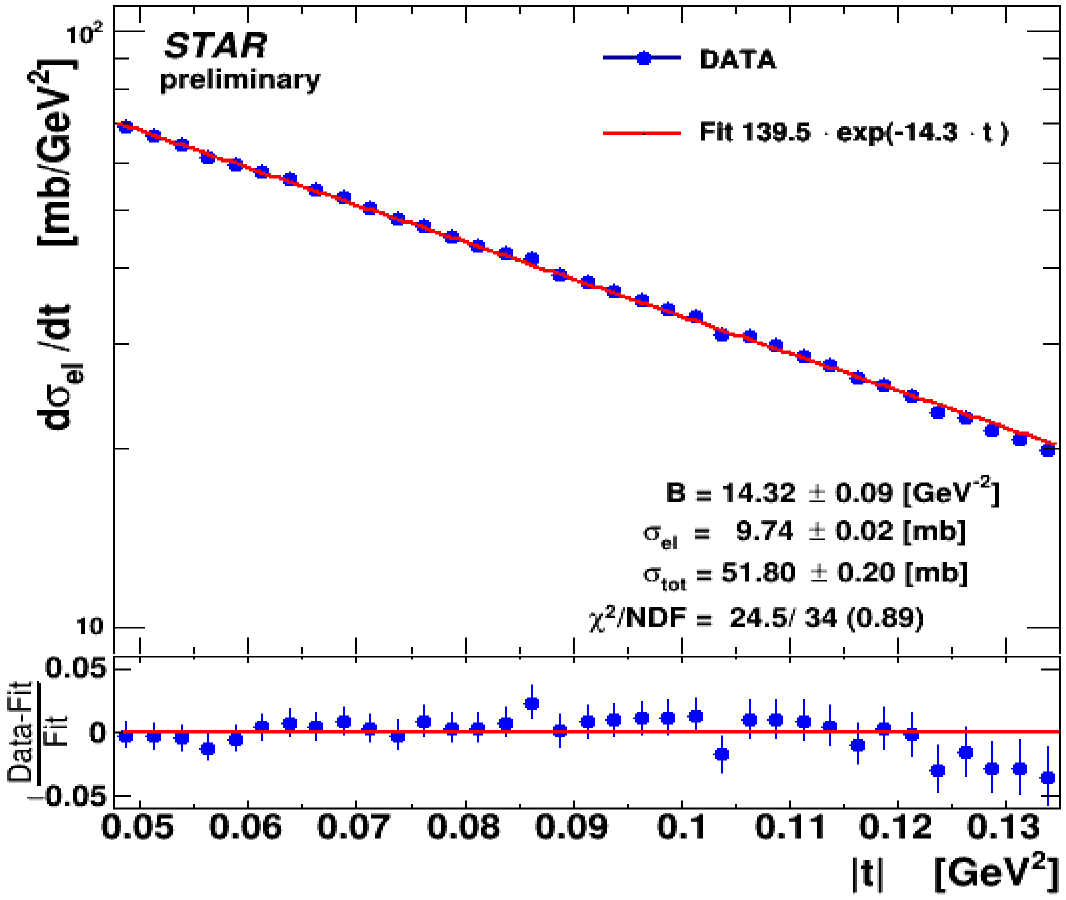
$$\frac{d\sigma_{el}}{dt} = \frac{1+\rho^2}{16\pi(\hbar c)^2} \cdot \sigma_{tot}^2 \cdot e^{-B\,|t|}$$

$$\sigma_{tot}^2 = \left(\frac{16\pi(\hbar c)^2}{1+\rho^2}\right) \left.\frac{d\sigma_{el}}{dt}\right|_{t=0}$$

$$\sigma_{el} = \int \frac{d\sigma_{el}}{dt} dt$$

The value of $\rho = 0.128$ from COMPETE model was used*.

* Phys. Rev. Lett. 89 (2002) 201801

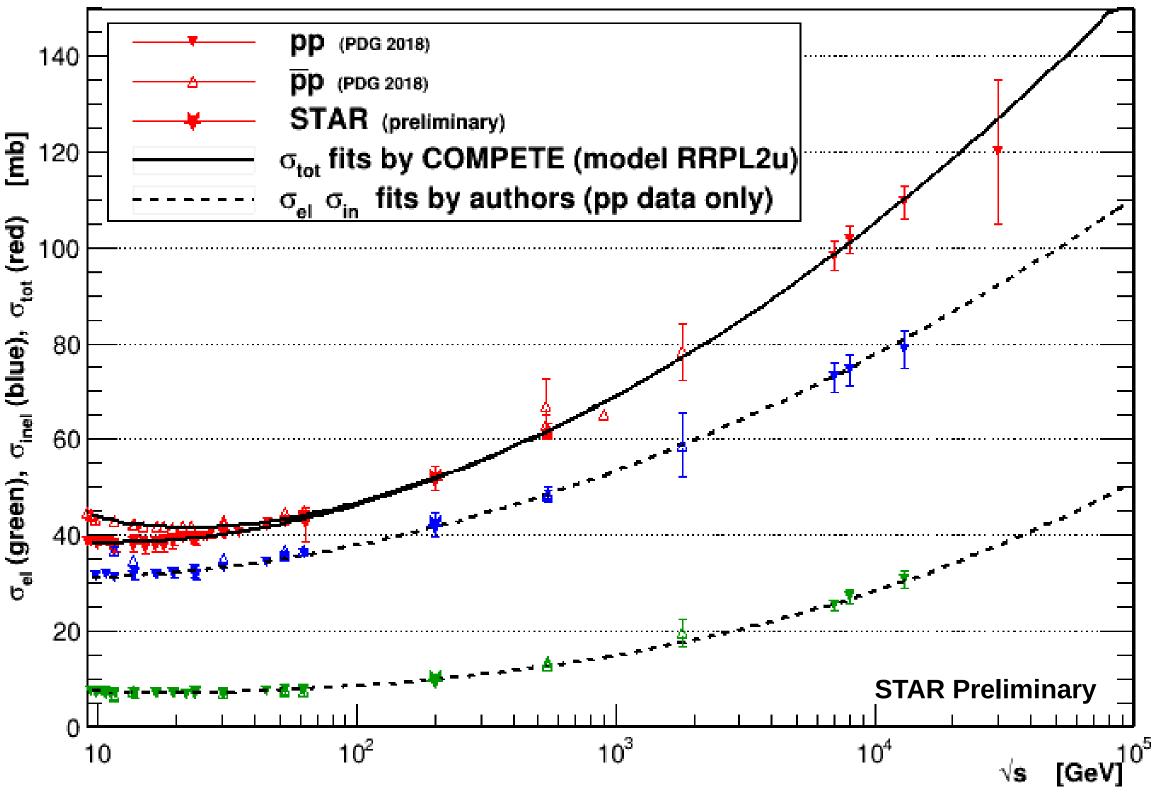


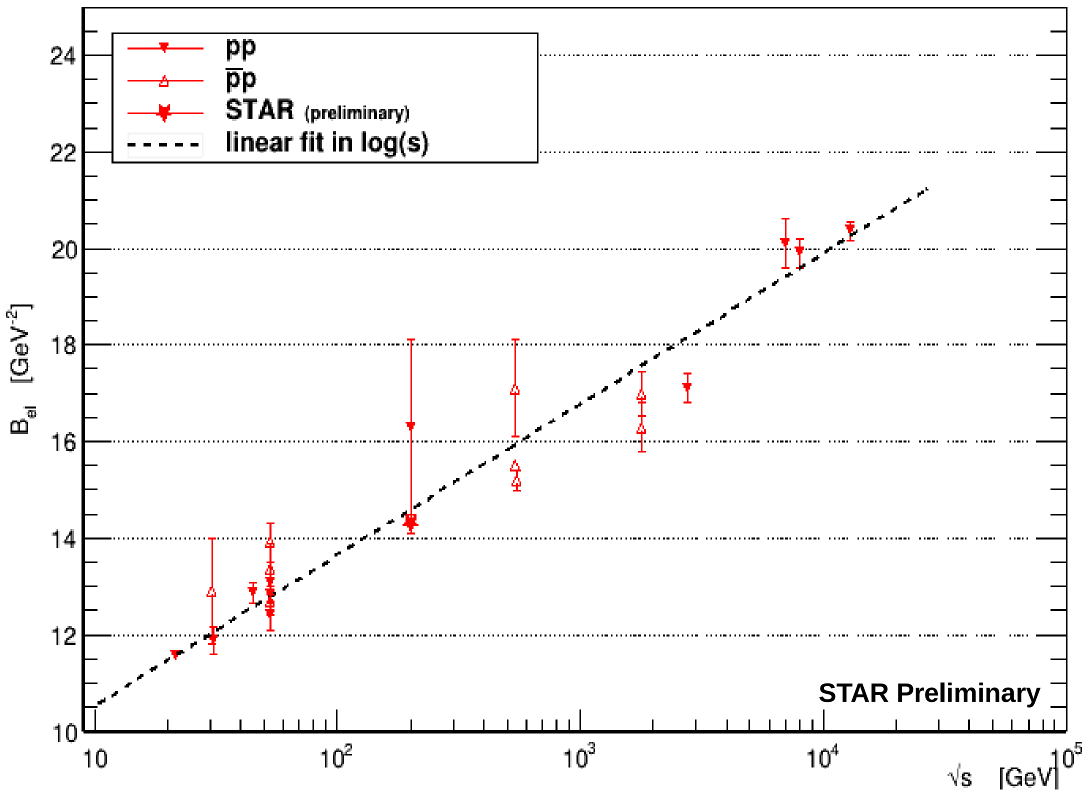
Results

Quantity			Statistical uncertainty	Systematic uncertainties			
name	units	Value		$\boldsymbol{b}$-tilt	lumi	ρ	full
$d\sigma_{el}/dt\|_{t=0}$	[mb/GeV^2]	139.53	± 1.06	$^{+1.07}_{-0.83}$	$^{+10.50}_{-10.07}$	n/a	$^{+10.61}_{-10.16}$
B	[GeV^{-2}]	14.32	± 0.09	$^{+0.18}_{-0.32}$	n/a	n/a	$^{+0.20}_{-0.33}$
σ_{el}	[mb]	9.74	± 0.02	$^{+0.06}_{-0.04}$	$^{+0.74}_{-0.60}$	n/a	$^{+0.74}_{-0.59}$
σ_{tot}	[mb]	51.81	± 0.20	$^{+0.19}_{-0.61}$	$^{+1.91}_{-1.90}$	$^{+0.2}_{-0.4}$	$^{+1.94}_{-2.05}$
σ_{inel}	[mb]	42.07	± 0.20	$^{+0.20}_{-0.61}$	$^{+2.05}_{-1.99}$	$^{+0.2}_{-0.4}$	$^{+2.08}_{-2.13}$

The main sources of systematic uncertainty are: luminosity measurement and beam tilt angle.

Comparison with the World Data





STAR results compare well with the world data and the COMPETE predictions

Summary

1. The STAR experiment at RHIC measured elastic differential cross sections in the |t|-range [0.045, 0.135] $(GeV/c)^2$ in p+p collisions at $\sqrt{s}$ = 200 GeV.

- The resulting values of B-slope, σ_{tot}, σ_{el} are:
  - Slope parameter B = 14.32± 0.09 (stat) $^{+0.20}_{-0.33}$ (syst) $(GeV/c)^{-2}$
  - The total cross section σ_{tot}= 51.81 ± 0.20 (stat) $^{+1.94}_{-2.05}$ (syst) (mb)
    COMPETE Predictor, Phys. Rev. Lett. 89 (2002) 201801 σ_{tot}= 51.76 ± 0.12 (stat) $^{+0.4}_{-0.2}$(syst) mb
  - The elastic cross section σ_{el} = 9.74 ± 0.02 (stat) $^{+0.74}_{-0.59}$ (syst) mb

At this point, the largest syst. uncertainties are: 1% due to the beam tilt angle and 7% due to the luminosity.
We expect the luminosity uncertainty to be about 3% after the careful calibration.