Paper Proposal on Total and Elastic Cross Section in pp at √s = 200 GeV

- **Title:**

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

- **PAs:**

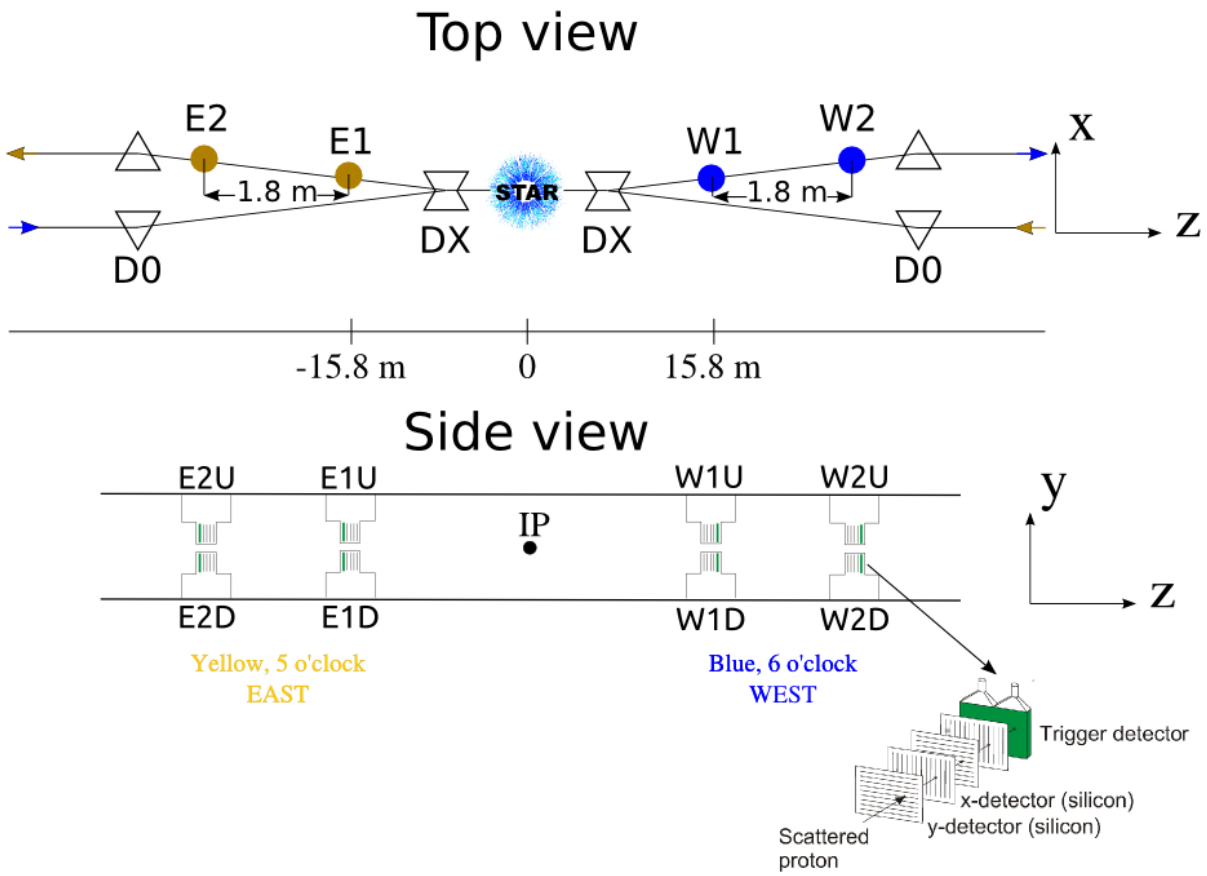
Leszek Adamczyk, Lukasz Fulek, Wlodek Guryn, Bogdan Pawlik,
Mariusz Przybycien, Rafal Sikora

- **Proposed Target Journal:**
Physics Letters B

Abstract:

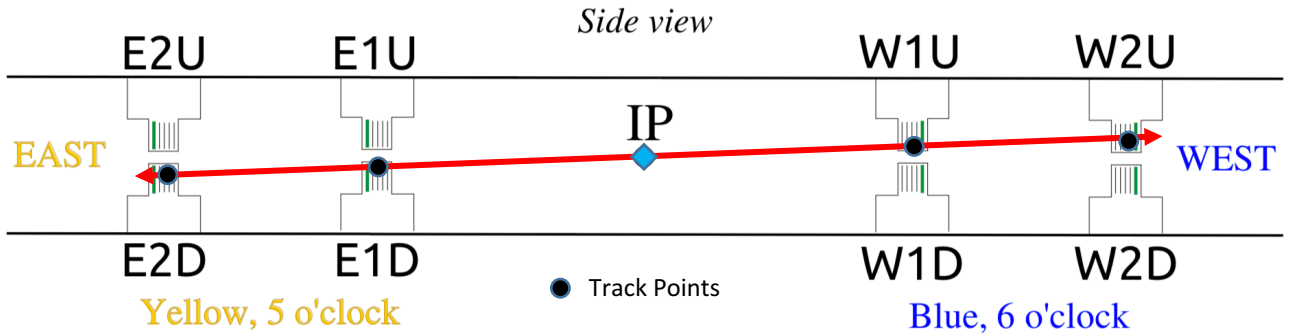
We report the results on the total and elastic cross sections in proton-proton col- lisions at the Relativistic Heavy Ion Collider (RHIC) at $\sqrt{s} = 200$ GeV . The results were obtained with the Roman Pot setup of the STAR experiment at the Relativistic Heavy Ion Collider (RHIC). The setup was used to measure elastic differential cross section in the four–momentum transfer squared (t) range $0.045 \leq -t \leq 0.14$ $(GeV/c)^2$. Elastic scattering was detected in the Roman Pot system, which was operated during standard data collection at STAR at the distance of about $8\sigma_y$ from the beam, where σ_y is the beam Gaussian width in the vertical coordinate. The results include the value of the exponential slope parameter B of the elastic differential cross section $d\sigma/dt$ in the measured small $-t$ range and the total cross section σ_{tot} obtained from the ex- trapolation of the $d\sigma/dt$ to the optical point at $-t = 0$ $(GeV/c)^2$. We also present the value of elastic cross section σ_{el}. All results are compared with the world data.

Fig. 1 Experimental Setup



Caption: The layout of the RPs with the STAR detector (not to scale). The Roman Pot setup at STAR for measuring forward protons. Two sets of RPs are positioned between DX and D0 magnets, at 15.8 m and 17.6 m from the IP. Top and side view are shown.

Data Analysis



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

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

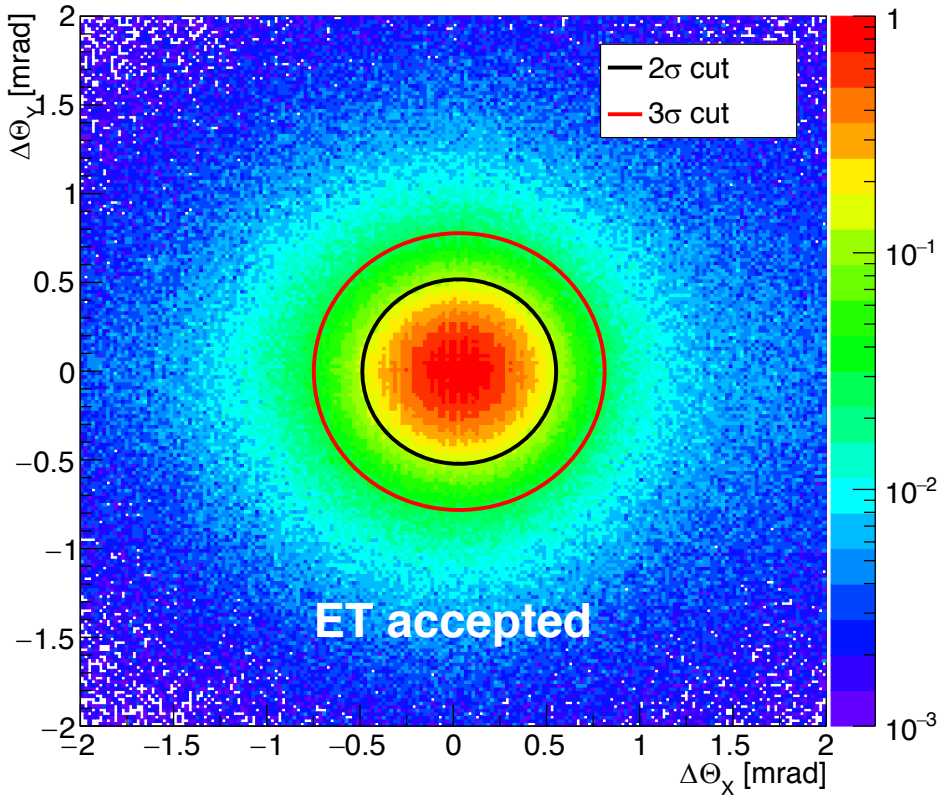
- Need to minimize background and maximize efficiency.
- To reduce background need angle reconstruction => two RPs on each side in up – down combination.

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

- 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.

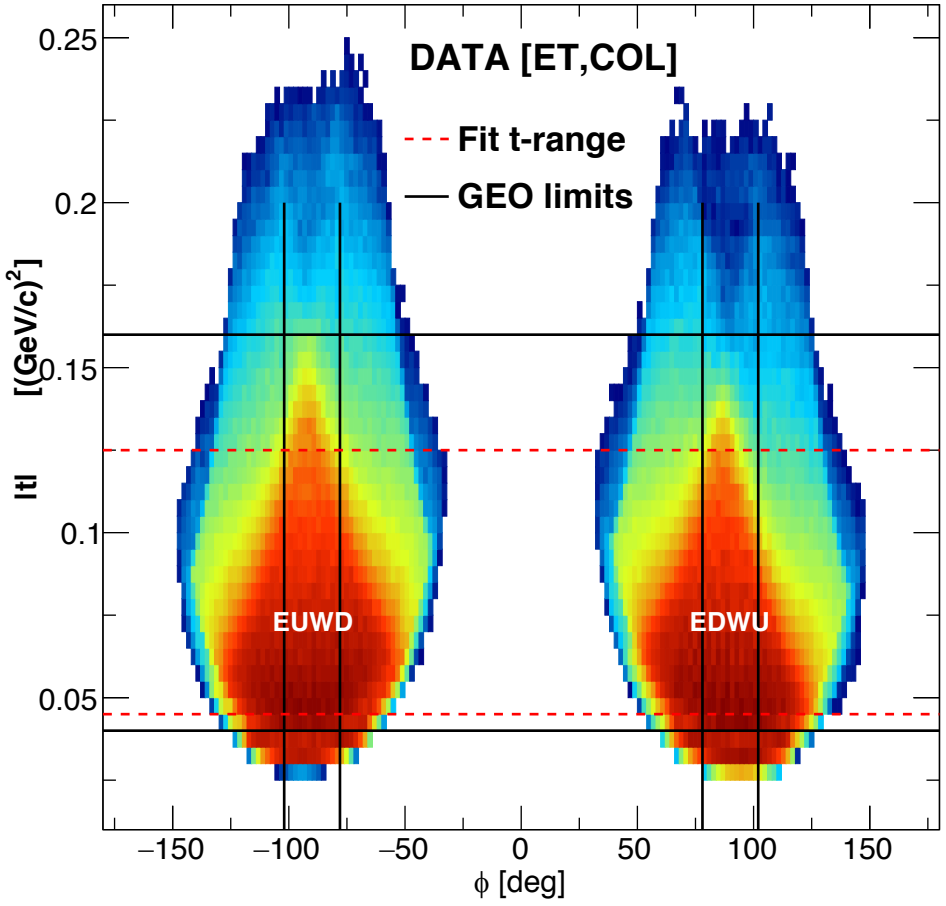
Fig. 2: Collinearity

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



Caption: ΔΘy vs ΔΘx with the contours of 2σ and 3σ.

Fig. 3 Geometrical Acceptance (choice of fiducial volume)



Choice of geometrical acceptance (t,ϕ) plane

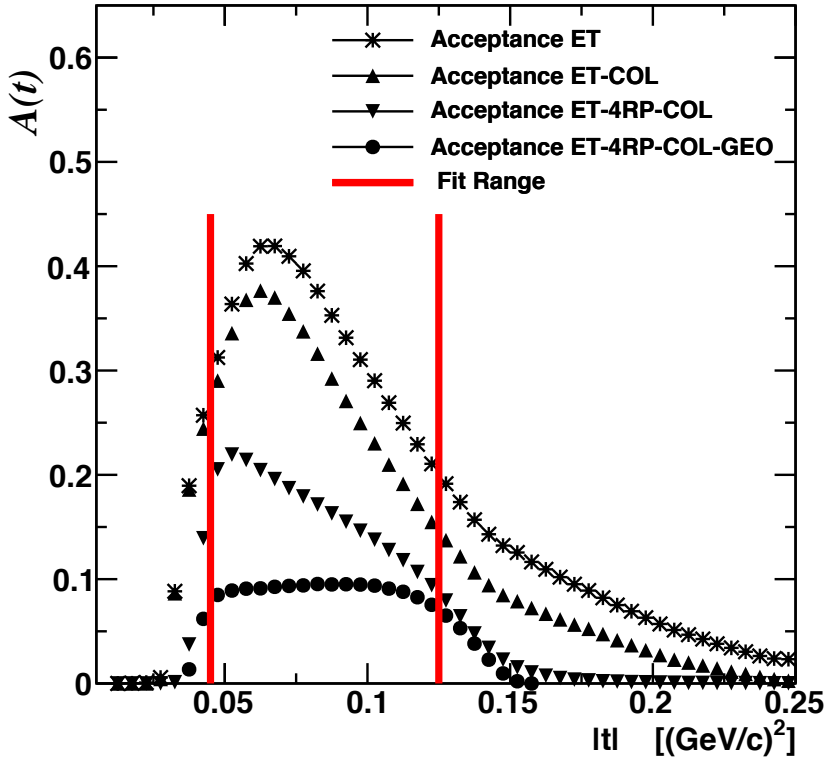
$$0.04 \leq |t| \leq 0.16[(GeV/c)^2]$$

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

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

Caption: |t| vs ϕ distributions for data for 4PT collinear events. The boundaries for geometrical acceptance cuts are shown.

Geometrical Acceptance and Event Yields

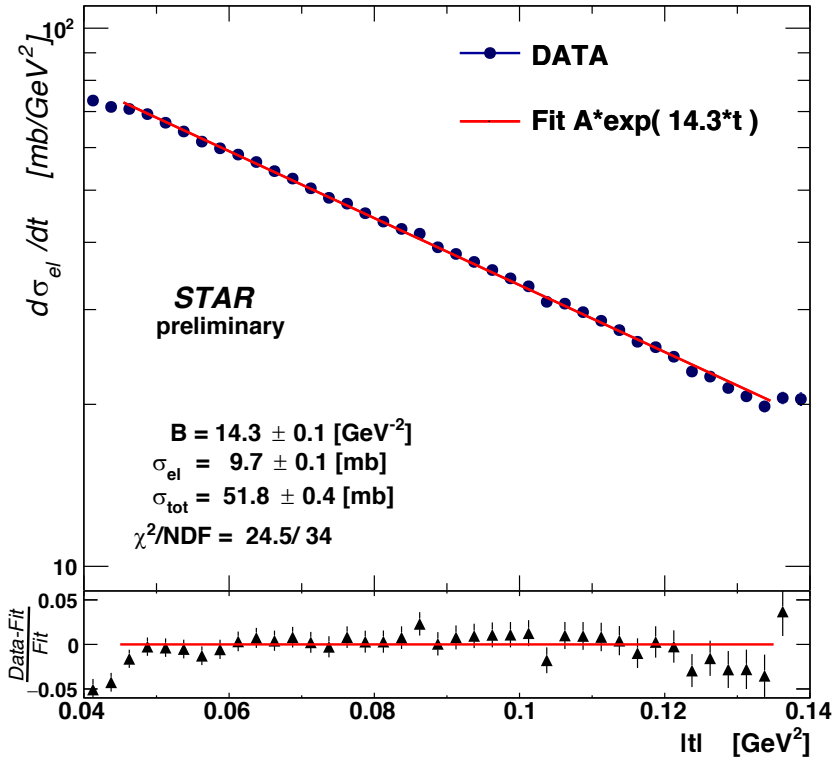


Choose region away from steep variation and edges of acceptance

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

New Fig. 4 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 ρ = 0.128 from COMPETE model was used*.

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

Caption: Corrected differential cross-section dN/dt fitted with exponential A · exp(−Bt). We do not observe nonlinear behavior of the exponential shape.

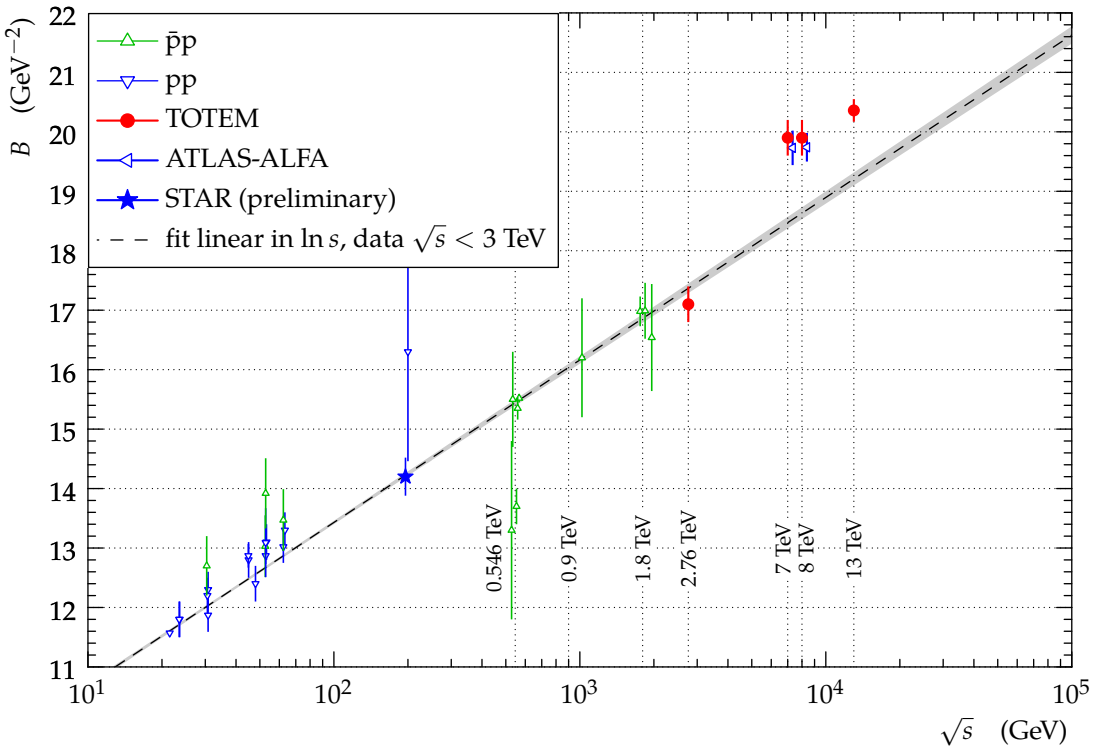
Result Summary

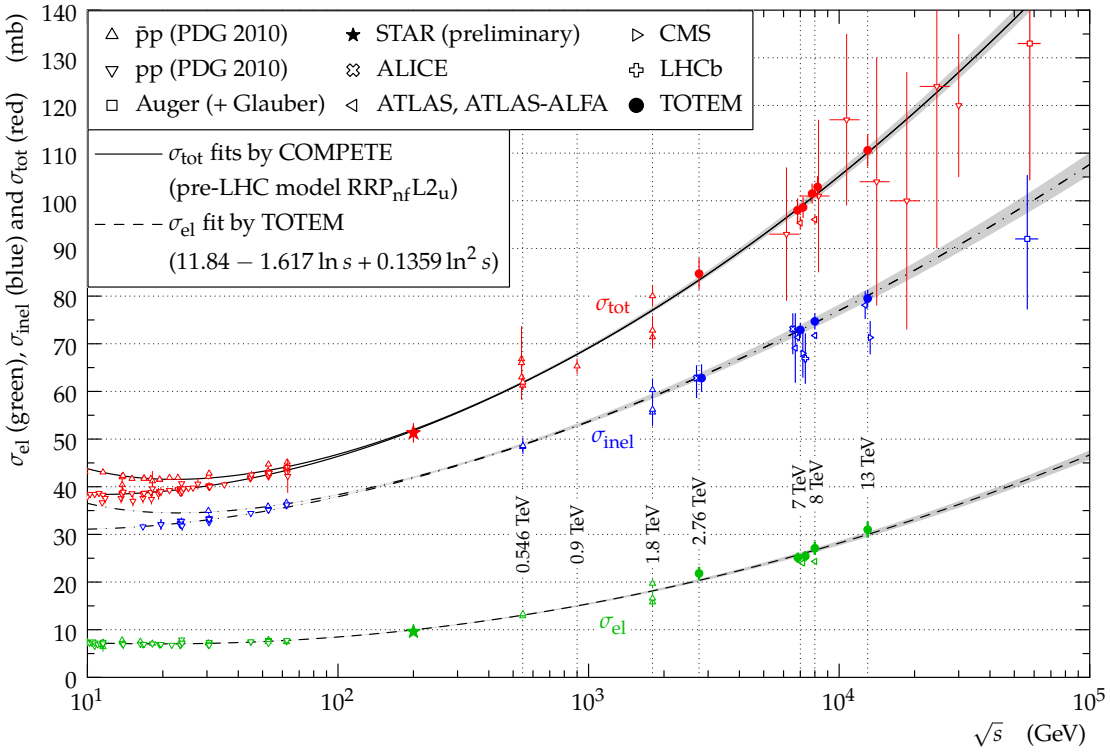
The new normalization syst. uncertainty is due the efficiency correction factor obtained by including Si efficiency in the MC. This correction also gives the new value of the σ_{tot} and σ_{el}.

Table 1: Result summary with systematic uncertainties contributions.

Quantity			Statistical	Systematic uncertainties				
name	units	Value	uncertainty	$\|t\| - dep$	norm	lumi	ρ	full
$d\sigma_{el}/dt_{t=0}$	[mb/ GeV^2]	137.1	± 1.1	2.4	0.6	$^{+10.2}_{-8.9}$	n/a	$^{+10.5}_{-9.3}$
B	$[GeV^{-2}]$	14.3	± 0.1	0.3	n/a	n/a	n/a	± 0.3
σ_{el}	[mb]	9.7	± 0.1	0.1	0.04	$^{+0.7}_{-0.6}$	n/a	± 0.7
σ_{tot}	[mb]	51.8	± 0.4	0.5	0.5	$^{+1.9}_{-1.7}$	$^{+0.2}_{-0.4}$	$^{+2.1}_{-1.9}$

Fig. 5: Comparison with the World Data





Caption: Comparison of world data for B-slope and elastic and total cross section.

Summary

Summary

At the RHIC energy of $\sqrt{s}$ = 200 GeV the STAR experiment has measured differential cross-section for elastic proton-proton scattering as a function of the four-momentum transfer t in the range $0.045 < -t < 0.135$ GeV^2. Differential elastic cross-section is well described by exponential fit with the slope B = 14.3 ± 0.1(±0.3) GeV^{-2}, in brackets systematic uncertainty is quoted. Extrapolation of measured differential elastic cross- section over non-detected (≈ 40%) low t region allowed to determine elastic cross- section to be 9.7 ± 0.1(±0.7) syst. mb, and using optical theorem total pp cross-section was found to be 51.8 ± 0.4 stat (+ 2.1 - 1.9) 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.