# Experiment to Measure Total Cross Sections, Differential Cross Sections and Polarization Effects in $pp$ Elastic Scattering at RHIC

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Abstract

We are describing an experiment to study proton-proton ($pp$) elastic scattering experiment at the Relativistic Heavy Ion Collider (RHIC.) Using both polarized and unpolarized beams, the experiment will study $pp$ elastic scattering from $\sqrt{s} = 50$ GeV to $\sqrt{s} = 500$ GeV in two kinematical regions. In the Coulomb Nuclear Interference (CNI) region, $0.0005 < |t| < 0.12$ $(\mathrm{GeV}/c)^2$, we will measure and study the $s$ dependence of the total and elastic cross sections, $\sigma_{tot}$ and $\sigma_{el}$; the ratio of the real to the imaginary part of the forward elastic scattering amplitude, $\rho$; and the nuclear slope parameter of the $pp$ elastic scattering, $b$. In the medium $|t|$-region, $|t| \leq 1.5$ $(\mathrm{GeV}/c)^2$, we plan to study the evolution of the dip structure with $s$, as observed at ISR in the differential elastic cross section, $d\sigma_{el}/dt$, and the $s$ and $|t|$ dependence of $b$. With the polarized beams the following can be measured: the difference in the total cross sections as function of initial transverse spin states $\Delta\sigma_T$, the analyzing power, $A_N$, and the transverse spin correlation parameter $A_{NN}$. The behavior of the analyzing power $A_N$ at RHIC energies in the dip region of $d\sigma_{el}/dt$, where a pronounced structure was found at fixed-target experiments will be studied. The relation of $pp$ elastic sacttering to the beam polarization measurement at RHIC is also discussed.

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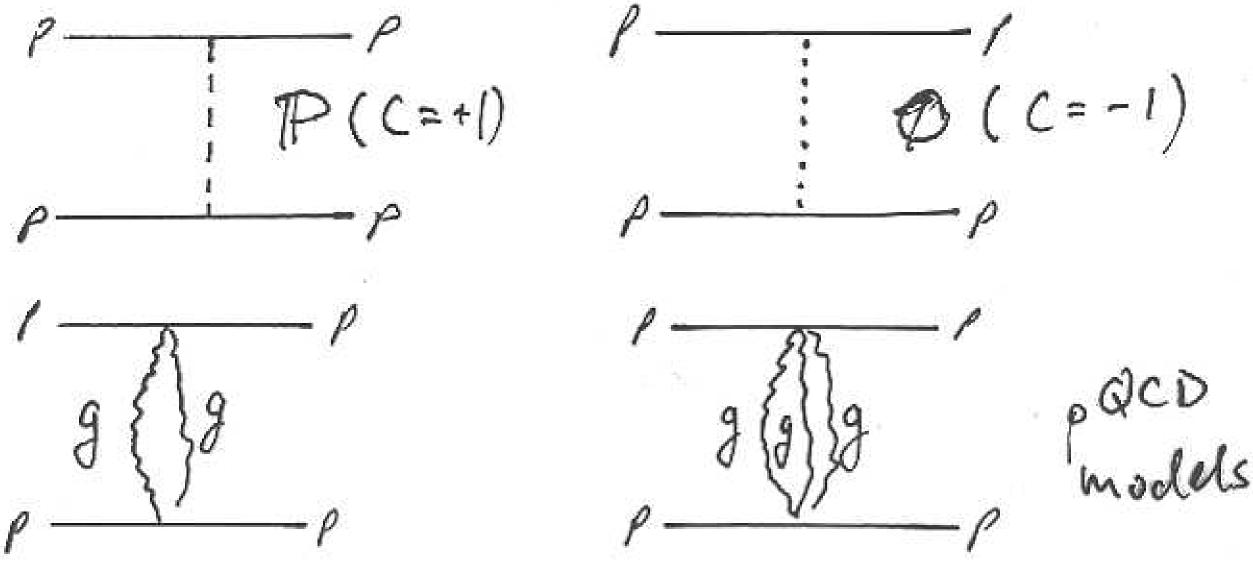
Studying total and elastic cross sections played a crucial role in particle and nuclear physics, in particular, $pp$ and $p\bar{p}$ experiments extend to the highest $s$. **Elastic scattering has been measured at every accelerator**, for every cms energy available.

Spin related cross sections have been measured at fixed target energies up to $p_{lab} = 300\ GeV/c$.

Elastic scattering at high energies is dominated by exchange of **Pomeron** and **Odderon**, the Pomeron's partner with negative C-parity.

The properties of the **Pomeron**, vacuum quantum numbers, are quite well known but more studies are needed to determine it's structure, especially it's unknown **spin properties.**

Even-though there are very strong theoretical reasons for it, the existence of the Odderon has not been established experimentally.



The information gained in elastic scattering tests two areas of particle interactions:

1. **In the region of small four momentum transferred - |t|,** one tests in a model independent way, general analytical properties of scattering amplitudes: analyticity, unitarity and crossing symmetry, $\sigma_{tot}$, $\rho$.

2. **In the diffractive region,** with four momenta transferred $|t|<1.5\text{GeV}^2$, one studies the dynamics of long range strong interactions. Hence, addressing one of the main, unsolved problems in particle physics: confinement and non-perturbative QCD. Namely, being able to derive from the QCD Lagrangian fundamental equations when the strong interaction $\alpha_s$ is large, and thus preventing a perturbative expansion.

In this "data-driven" field, having more experimental results is important. Additional observable like polarization, will give access to one more degree of freedom, spin.

## SPIN EFFECTS in ELASTIC SCATTERING

For the unpolarized beams, it is assumed real and imaginary parts have the same |t| dependence and that spin effects are negligible.

However, **it has been observed experimentally** that there is a correlation between the position of the dip and the single spin asymmetry $A_N$ crossing zero at the same |t| value. The spin-flip amplitude contributes to filling of the dip.

$$A_N = \frac{2\,\mathrm{Im}\, f_{++} f_{+-}^{*}}{|f_{++}|^2 + |f_{+-}|^2}$$

This experiment will test the Odderon hypothesis by:

1. Measuring the region of the first diffractive minimum and comparison with data from $S p\bar{p} S$ collider, UA4 experiment

2. Measuring spin asymmetries $A_N$, $A_{NN}$ and $A_{LL}$ at moderate values of |t|. *

** An interesting suggestion was made at this workshop by L. Trueman: Odderon could contribute to spin related asymmetries in pp elastic scattering.*

# RHIC Operation

- More then one $p_{beam}$. It is very likely that RHIC will have at least 100 GeV/c and 250 GeV/c proton beams, which will allow us to take data at two $\sqrt{s}$ points.

- 5000 evts/$10^{-4}$ $GeV^2/c^2$ bin $\Rightarrow \int L dt \approx 2\times10^{33} cm^{-2}$. The effective luminosity in our IR is $5\times10^{28}$ $cm^{-2}sec^{-1}$. Two short (few days) running periods separated by one year are preferable.

- In the **dip region** we can run with the standard tune and all data we need can be taken while other experiments are running. No dedicated run conditions are required. At luminosity $4\times10^{30}$ $cm^{-2}sec^{-1}$, 200 hrs data on tape to acquire 1000 evts/0.02 $GeV^2/c^2$ bin.

| **Tune** | **Roman pot position** | **Leff** | **-t range** (GeV/c)**2 | **Comment** |
|---|---|---|---|---|
| Standard | 20 m | -- | 0.02 - 1.5 | NO special hardware |
| Standard | 57 m | 20 m | 0.008 - 0.2 | NO special hardware |
| Special | 72 m | 37 m | 0.004 - 0.12 | PS NO warm-cold |
| Special | 144 m | 87 m | 0.0004 - 0.03 | PS Warm-Cold |

We shall study systematically ***pp*** elastic scattering in

$$50 < \sqrt{s} < 500 \text{ GeV}$$

with polarized and/or unpolarized beams in the four-momentum transferred **-t** sub-divided into two kinematic ranges:

1. **Day one of proton running,** in the diffractive region, **with no special running conditions required:**

$$0.006 < -t < 1.5 \ (\text{GeV}/c)^2$$

DAY ONE (STANDARD TUNE)

- evolution of dip structure observed at the ISR in $d\sigma_{el}/dt$;
- $s$ and **t** dependence of the nuclear slope, $b$;
- $s$ dependence of $\sigma_{tot}$.

2. Coulomb Nuclear Interference ( **CNI** ) region:

$$0.0004 < -t < 0.12 \ (\text{GeV}/c)^2$$

- $s$ dependence of $\sigma_{tot}$ and $d\sigma_{el}/dt$;
- ratio of real to imaginary part of the forward scattering amplitude, $\rho$;

**With well understood and straight-forward upgrades of the setup the following could be studied:**

1. Measurement of the elastic scattering in the **CNI region** will allow precise determination of $\rho$, $\sigma_{tot}$ and their spin dependence, $\phi_5$ spin flip hadronic amplitude. ( Machine modifications are required.)

2. Large -t region will test pQCD calculations. **Same detectors**, but a magnet in the IR for momentum measurement will be needed.

**With no modification to the setup the following can be studied:**

1. **Single diffraction dissociation**, can be studied by appropriate design of the veto system and a an additional trigger condition.

2. **Elastic scattering of pd,** $p^{\uparrow}$ **d, dd,** can be measured. Some of those measurements have been done at the ISR, with very nice results confirming extended Glauber model. **I think that understanding of those reactions might be very important to the HI program at RHIC.** Need to study dynamical range and trigger.

# Status and Plans

1. Experiment has scientific approval.
2. Since the approval time our work concentrated on:
   - Optimization of the experiment;
   - Interaction with the accelerator group;
   - Design of critical parts: Roman pots, detectors;
   - Design of inelastic veto is ongoing.
3. Our goal is to be ready in the spring of 2001 when the RHIC spin program is expected to run in full capacity.
4. We are working on the TDR with a goal of finishing it by the end of the summer.

In order to achieve these goals need to do R&D during the next twelve months.

Start building components of the experiment in FY 2000.

**We have a lot of work to do: MORE collaborators are welcome!**