### Abstract

Elastic $pp$ (or $p\bar{p}$) scattering at microradian angles provides an absolute luminosity calibration as well as a measurement of the total $pp$ (or $p\bar{p}$) cross section, the slope of the elastic scattering cross section with $t$ (the square of the momentum transfer) and the ratio of real to imaginary scattering amplitudes. A detector is proposed which, given favourable beam design, can measure, at LHC/SSC energies, elastic scattering and small angle processes which are usually missed by a typical $4\pi$ detector. The proposed detector is made out of a scintillating fibers bundle. Light from these fibers is transported via fiber optics and read out with 2 Image Intensifiers and a Charge - Coupled Device (CCD). The active part of the detector is placed directly in the vacuum of the beam pipe and is moved by a high precision mechanism. Two couples of such detectors (symmetric in the horizontal or vertical plane) would be located along the beam pipe at symmetric positions respect to the interaction point.

### 1 The Detector

The proposed detector is shown schematically in Fig.1. The scattered particle travels $\sim 60\, mm$ lengthwise along a bundle of 100 $\mu m$ diameter scintillating fibers with 9 $mm$ radius semi-circular cross section. Each fibre has an hexagonal cross section. The core of the fibers is a polystyrene based plastic scintillator with p-terphenyl as primary fluor and with 2000 part per million of 3HF (3-Hydroxy-Flavone, a yellow-green emitting waveshifter), surrounded by 12 $mm$ PMMA cladding. 3HF is characterized by good radiation resistance (above 10 $M\text{Rad}$), fast decay time (around $5 - 10\, n\text{sec}$), and a large Stokes shift (poor self absorption and good attenuation length), properties which compensate for its poor scintillation efficiency ($\sim 36\%$). The front face of the fibers is Aluminum plated to enhance the light output, while the back face is glued to the light pipe. The entire bundle is sputtered with a heavy metal to slow outgassing (the same thing is done to the counter). The bundle is glued into a metal cradle with high vacuum grade epoxy and no material is foreseen on the front or bottom faces. The fibers are rotated at 1 degree from the beam axis to provide full efficiency and improve resolution by the method of center of gravity. Light from these fibers is transported by a bundle of non scintillating glass fibers to the readout system. The bundle is made out of 20 $\mu m$ diameter glass fibers and has a 10 $mm$ radius circular cross section. This
bundle traverses the flange between vacuum and air. The glass bundle vacuum seal is mounted on bellows and this allows the bottom of the bundle to be aligned parallel to beam by means of a set of three screws. Only half of the glass fibre bundle is used for piping the image coming from the active bundle to the read out chain. We take advantage of the remaining half to read out a backup scintillating counter which is housed behind the scintillating fibers bundle and covers the same solid angle (Fig.2). The counter is a 20x10x10 mm scintillating plate with horns. The shape is such that it can fit with the counter located in the detector below to provide a position calibration.

2 Readout System

The readout chain is mounted directly on the conflat flange. It consists of two proximity-focused micro channel plate Image Intensifiers followed by a CCD. The Image Intensifiers are gated XX 1450 MCP intensifiers with S20 photocathode and P46 phosphore screen (DEP). The optical gain of each one is about 1000 ph/ph. The first Image Intensifier is used as a gate. Only at the moment of bunch crossing the potential of the input face of the MCP is raised to the operational value, allowing the free passage of photoelectrons through it. The second Image Intensifier can be used as a trigger: the charge collected in the phosphor screen can be extracted and this pulse can be used as a trigger for the data acquisition of the CCD. From the second II the light is transferred to the CCD by a taper. If the level trigger is satisfied, the event initially stored in the image zone is transfered on the memory zone and digitized. Otherwise, a fast clear (1 μsec) of the image zone is performed using the antiblooming electrodes [1].

3 Requirement on Machine Design

\(pp\) total cross section is expected to be about 110 mb at \(\sqrt{s} = 16 \text{TeV}\) [2]. According to this value, in order to measure the \(\rho\) value and to use the coulomb amplitude for normalization of \(d\sigma/dt\) it is necessary to get to scattering angles smaller than 3 μrad. The possibility of reaching this value does not depend only on the detector but primarily on the accelerator lattice. The machine parameters must be such that beam divergence at the scattering point be less than the minimum scattering angle to be measured. The values of the \(\beta\) function at the interaction point and at the detector position are the limiting factors and should be foreseen and studied at the stage of machine design. Assuming some values for the machine parameters and for the expected total cross section, it is possible to do some easy calculation that give an idea of these requirements.

We set our goal at reaching an angle \(\Theta_{\text{min}} = 2.5 \mu\text{rad}\), where the coulomb cross section would be \(\sim 4\) times the nuclear cross section. We take the design normalized beam emittance of LHC of \(3.8 \text{mm mrad}\) [3] \((\epsilon^* = \gamma \sigma^*/\beta^*, \beta^* \text{ being the beta value at the interaction point and } \gamma \text{ the energy in proton rest mass units})\). Our value of \(\Theta_{\text{min}}\) it's smaller than the typical angular divergence of the beam at normal \(\beta\) values. We require a beam divergence \(\Delta \Theta = 0.14 \Theta_{\text{min}}\), which is 0.35 μrad. These assumption give for \(\beta\) at the interaction point \(\beta^* = 3.9 \text{km}\). Then,
assuming our detector can go as close as 1 mm from the beam axis, an effective length $L_{eff} = 400 \, m$ is required, implying at the detector the value $\beta_{det} = 40 \, m$. These values would give also a beam spot size $\Delta x = 138 \, \mu m$, corresponding to a detector active zone at 7 $\sigma$ from the beam axis.

These calculations have been done assuming no beam scraping. Since our measurement will be done on a dedicated run, we can assume we will use a reduced emittance beam from SPS. The same calculations will then relax the beam specifications to $\beta^* = 1900 \, m$, $\beta_{det} = 85 \, m$ with a spot size $\Delta x = 140 \, \mu m$.

4 Future Operation

For easy testing, the prototype of this detector has been designed to fit the dimensions of already existing "Roman Pots", that have been used at Fermilab by the E710 collaboration. Experiment E710 has been the last experiment to measure elastic and total cross sections [4]. The experimental apparatus was located in one of the long straight sections at the Tevatron Collider and consisted of small drift chambers in "Roman Pots". Our detector will replace the "pot" and will be mounted on its support with the conflat flange. The support is provided with a high precision moving mechanism that can bring the bundle close to the circulating beam with a repositioning accuracy of $\sim 5 \, \mu m$ and a absolute location accuracy of $\sim 20 \, \mu m$. Both the pots and the experimental area are still available at Fermilab and a full chain of 4 detectors can be tested at Tevatron during next collider run (1992).

References


detector below to provide a position calibration. The shape of the counter is such that it can fit with the counter located in the fibres bundle and is read out with half of the glass fibers bundle. b) The scintillating counter is housed behind the scintillating fibres bundle and is read out with half of the glass fibers bundle. b) The shape of the counter is such that it can fit with the counter located in the detector below to provide a position calibration.