ADDENDUM TO THE PROPOSAL ON

THE MEASUREMENT OF ELASTIC SCATTERING

AND OF THE TOTAL CROSS SECTION

AT THE CERN pp COLLIDER

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1. INTRODUCTION

Our SPS proposal P114 was discussed by the SPSC and by the Research Board and approved with the condition of being compatible with experiment UA2. In this Addendum we update our proposal [1], on the measurement of elastic scattering and total cross section at the pp collider, discussing the implications of the two following constraints:

(a) Installation in LSS4 of the additional quadrupoles for the low-\(\beta\) insertion.

(b) Installation in LSS4 of the apparatus of experiment UA2.

2. ELASTIC SCATTERING

2.1 Low \(t\) set-up

The installation foreseen for the elastic scattering telescopes ("Roman pots" with high accuracy drift chambers and counter hodoscopes) is sketched in fig. 1. The geometry is very similar to that given in our proposal. Our experimental equipment is compatible with the machine elements and other instrumentation of the presently designed low-\(\beta\) insertion [2].

The minimum detectable scattering angle is determined by the minimum distance of approach of the detectors to the beam axis. From the aperture needed at the injection we estimated \(\theta_{\text{min}} \approx 0.45\) mrad (\(-t_{\text{min}} \approx 1.5 \times 10^{-7}\) GeV\(^2\) at \(\sqrt{s} = 540\) GeV). The use of movable scrapers and dump blocks to remove the beam tails and shield the detectors will further reduce the value of \(\theta_{\text{min}}\) [3]. If the detectors could be approached to the beam axis at a distance equal to five times the beam radius, then \(\theta_{\text{min}} \approx 0.2\) mrad.

The maximum detectable scattering angle is determined on the left arm by the vertical aperture (162 mm) of the vacuum chamber inside the quadrupole QM 418, which implies \(\theta_{\text{max}} \approx 3.0\) mrad (\(-t_{\text{max}} \approx 0.65\) GeV\(^2\) at \(\sqrt{s} = 540\) GeV). In this range of \(t\) the collinearity requirement will be very powerful in selecting elastic events [4].
We believe that this low \( t \) set-up will give the required information on elastic scattering in the specified \( t \)-range.

2.2 Large \( t \) set-up

In the original proposal the maximum scattering angle was \( \theta_{\text{max}} = 4.5 \) mrad. Due to the insertion of the quadrupoles needed for the low-\( \beta \) crossing required by UA2, this maximum angle is now only 3.0 mrad. In order to recover this angular region and extend the range of elastic scattering to higher \( t \)-values, it is proposed to install telescopes of high accuracy drift chambers in front of the quadrupoles QF 418 and QD 419, at both extremes of the intersection region. The minimum vertical size of the vacuum chamber in this location is \( \pm 27 \) mm. If the detectors can start to measure at 30 mm from the beam axis at 11 m from the crossing point, the minimum detectable scattering angle will be \( \theta_{\text{min}} = 2.73 \) mrad (\( -t_{\text{min}} = 0.54 \) GeV\(^2\) at \( \sqrt{s} = 540 \) GeV).

The interest of this measurement is related to the possibility of exploring proton-antiproton elastic scattering in the region where a minimum of the diffraction pattern is expected if the \( \overline{p}p \) and \( pp \) systems behave similarly at very high energy.

The ISR data [5] show that, empirically, \( -t \sigma_{\text{dip}} \sigma_{\text{tot}} \propto \text{const} \approx 56 \) mb\cdot GeV\(^2\) which, at \( \sqrt{s} = 540 \) GeV, implies \( -t_{\text{dip}} = 0.86 \) GeV\(^2\) corresponding to \( \theta_{\text{dip}} = 3.4 \) mrad, if shrinking will continue at the same rate. On the other hand, geometrical scaling demands that at the second maximum the differential cross section \( \sigma_{\text{dip}}/\sigma_{\text{tot}} \) which at the ISR is of the order of \( 10^{-4} \) mb/GeV\(^2\), goes as \( \sigma_{\text{dip}}/\sigma_{\text{tot}} \).

Running in the low-\( \beta \) mode (\( L = 10^{16} \) cm\(^{-2}\) s\(^{-1}\) and \( \beta_v = 2 \) m) with telescopes covering \( \Delta \phi/2\pi = 1/3 \), one expects in a \( t \)-bin equal to 0.1 GeV\(^2\), about 300 events/day for \( \sigma_{\text{dip}}/\sigma_{\text{tot}} = 10^{-4} \) mb/GeV\(^2\). The \( t \)-resolution around \( -t = 1 \) GeV\(^2\) will be of about 0.05 GeV\(^2\).
The $t$-resolution expected in this measurement is inferior to that of the ISR experiments [6] performed in the same $t$-range ($\sim 0.02$ GeV$^2$), but should be sufficient to observe the diffractive minimum if it is there. The rejection against inelastic events is also inferior because momentum analysis, present in the experiments of ref. [6] is missing. However, in our set-up the very good collinearity check combined with vetoing of inelastic events provided by the vertex detector should allow a reasonable rejection of inelastic events. Lead sheets placed in front of the telescopes of the vertex detector will allow rejection of diffractive events accompanied by only neutral pions.

We believe that this large $t$ set-up could give information on elastic scattering for $-t \gtrsim 0.5$ GeV$^2$. While the effectiveness of this simple set-up in rejecting inelastic events is not clear at present, we believe that its installation in LSS4 is justified by the very limited effort required, the compatibility with all other equipment and the physics interest. To avoid reducing the maximum angle of the low $t$ set-up, we think of performing this large $t$ measurement in a second stage after careful understanding of the background problems.

3. VERTEX DETECTOR FOR THE INTERACTION RATE

For the measurement of the total rate of inelastic interactions, which is needed in conjunction with elastic scattering to obtain the total cross section, we proposed to use the existing inner detector of the ISR experiment R209.

In order to ensure the compatibility with UA2 in LSS4, we have been requested to make use of the central detector of experiment UA2. This central detector is cylindrical with various layers of proportional and drift chambers having cathode strip read-out. It has full azimuthal coverage and polar angle coverage from $90^\circ$ to $20^\circ$. We propose to complete this detector, toward a near $4\pi$ coverage, by adding telescopes of drift chambers and scintillators counters in the forward cones, between $\sim 10^\circ$. 
and 0.5°. The angular region between 8.5° and 20° is occupied by the electronics and cables of the central detector [7].

This angular gap corresponds to a rapidity gap of about one unit out of a total of 6.4 at $\sqrt{s} = 540$ GeV. According to Monte Carlo calculations, such a gap would imply a loss of less than 2% of the events. From the observed angular distribution of the events we will derive a correction which would be known at the 20-30% level.

A sketch of the overall vertex detector is shown in fig. 2. The exact position and geometry of the telescope $D_i$ will depend on the final design of the toroids and of their current leads, which is in progress.

As discussed in our proposal, the drift chambers of the forward telescopes measure the x-y coordinates of the track by combining drift and delay line. This simplifies the pattern recognition. The central detector of UA2, in spite of its greater complexity and better spatial resolution, measure the $\theta$ and $\phi$ coordinates of a track with different chamber planes. We would like to implement this facility by introducing charge division in some of the wire planes and we are discussing this possibility with the authors of UA2. Similarly, discussions have started on several other issues as the way our data acquisition system can have access to the CAMAC crates of UA2 and on establishing a method of making an interaction trigger.

4. COMPUTER TIME FOR OFF-LINE ANALYSIS

On the basis of our previous experience on event reconstruction for the inner detector of the ISR experiment R209, we had sent a request of 250 hours of 7600 CP time in CERN. We thought that we could use 200 hours of 7600 CP equivalent time outside CERN, distributed among Amsterdam (CDC 6400), Bologna (CDC 7600) and Pisa (IBM 370).
This request assumed a total number of processed events of 4 millions (one million at each of four different energies).

The COCOTIME Committee accepted as reasonable usage 200 CDC 7600 CP hours at CERN (CERN/COCO/78/206, COCO 35, 29.11.1978). In the new configuration of the experiment, this request can represent a rough estimate of our needs.

5. RUNNING OF THE EXPERIMENT

In the low-\beta mode the angular acceptance of the low t telescopes is restricted to a very limited range around 1.5 mrad. The angular resolution will be about five times worse than that calculated in our proposal for the normal \beta mode, due to the larger angular spread of the beams. Therefore, only setting up of the detectors could be done during the normal operation of the collider at \( \sqrt{s} = 540 \text{ GeV} \) with low-\beta mode in LSS4.

Data taking will require special runs, of two or three days each, at four different energies with normal \beta mode in LSS4.
REFERENCES

ELASTIC SCATTERING SETUP

\[ p \rightarrow \text{QD417} \rightarrow \text{QLL1} \rightarrow \text{QLL2} \rightarrow \text{QM418} \rightarrow \text{QF418} \rightarrow \text{UA2} \rightarrow \text{QD419} \rightarrow \text{QLL3} \rightarrow \text{QLL4} \rightarrow \text{QF420} \rightarrow \bar{p} \]

- Machine quadrupoles
- Additional quadrupoles for low $\beta$

LEFT ARM

\[ QWL2 \rightarrow \text{BPC} \rightarrow \text{PODH} \rightarrow \text{QM418} \rightarrow \text{QF418} \rightarrow \bar{p} \]

\[ \sim 2.5 \text{ m} \]

RIGHT ARM

\[ BPL \rightarrow \text{PODY} \rightarrow \text{BPC} \rightarrow \text{POPHI} \rightarrow \text{QF420} \]

\[ \sim 3.0 \text{ m}, \sim 3.8 \text{ m} \]

FIG. 1
THE 4π DETECTOR

ANGULAR COVERAGE

D: drift chambers
T: trigger hodoscope
Q: quadrupole

D3 | 0.47° - 1.10°
D2 | 1.10° - 4.0°
D1 | 4.0° - 10.1°
UA2 | 20° - 90°

THE VACUUM CHAMBER

Small angle telescopes
UA2 Central detector

FIG. 2