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Total Cross Section, Elastic Scattering and Diffraction Dissociation at LHC

The **TOTEM** Collaboration

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In this note we wish to present our evaluation of the high-β insertion designed by S.Weisz (SL Note 94-09 AP) and discussed at the LHCC meeting of 27-28 January 1994. We first recall very briefly our main goals as discussed in our TOTEM document LHCC 93-47.

1) *Measurement of* σ_{tot} by extrapolation of the elastic rate to the optical point and detection of the inelastic interactions in a "forward vertex detector"

$$|t_{min}| \simeq 10^{-2} \text{ GeV}^2, \text{ which implies } \beta^* \simeq 1500 \text{ m.}$$

2) *Absolute normalization with Coulomb scattering and measurement of the parameter* ρ (ratio of the real to the imaginary part of the forward hadronic amplitude)

$$|t_{min}| \simeq 5 * 10^{-4} \text{ GeV}^2, \text{ which implies } \beta^* \simeq 30000 \text{ m .}$$

3) *Measurement of elastic scattering in the large momentum transfer region, up to at least* $10\ GeV^2$ .This requires a medium-β optics ($\beta^* \sim 10$ m) which can be obtained by designing the high-β insertion for "item 1" with a tunable β^* .

For technical reasons the minimum distance y_d of the inner edge of the detectors (placed inside the "Roman pots") from the machine axis should not be too small. A reasonable value is $y_d = 2$ mm. *This implies a condition on the effective distance* L_{eff} *of the "Roman pots" from the crossing which should not be too small* ($L_{eff} \geq 200$ m, for "item 1"). In terms of the β function at the detector, β_d, the condition on y_d is equivalent to $\beta_d \geq 25$ m. We remind that $L_{eff} = \sqrt{\beta^* \beta_d}$ at $\sin \Delta\psi = 1$.

The design of the high-β insertion proposed by S.Weisz for "item 1" is a good improvement with respect to the preliminary study made at the time of the Aachen Workshop which had $\beta^* = 750$ m and $L_{eff} \simeq 35$ m.

The relevant features of this design are

1) There is a free space of about 80 m on both sides of the crossing. This allows the installation of the *"forward vertex detector"* at the end of the free field region.

2) The β-value at the crossing, β^*= 3000 m is large enough.

3) The β-value at the "Roman pots" is quite small, $\beta_d \simeq 1.5$ m. As a consequence the effective distance is too short, $L_{eff} \simeq 65$ m.

4) The maximum accepted value of t, as determined by the aperture (3.1 cm radius) of the quadrupole Q4, is $|t_{max}| \simeq 0.7$ GeV^2. This allows a large enough range of t to be explored for the extrapolation to the optical point.

5) The angular divergence of the beam at the crossing has a r.m.s. value of 0.43μrad. The corresponding spot size at the "Roman pots" is 28μm which implies for the detectors a spatial resolution of about 25μm which is certainly attainable with present techniques for detectors of small size. The "ultimate" momentum transfer resolution, as determined by the beam angular divergence, $\Delta t = 0.0042\sqrt{|t|}$, is adequate.

Some of these features are good and fulfill our requirements. We wish, however, to point out two serious problems.

- **The design value of β_d (and therefore of L_{eff}) is too small.** "Theoretically" the minimum value of t that could be reached is small enough, i.e. $|t_{min}| \simeq 0.5*10^{-2}$ GeV^2, but this would be obtained with $y_d = 0.5$ mm which is exceedingly low. With $y_d = 2$ mm the minimum momentum transfer is $|t_{min}| \simeq 0.1$ GeV^2 which is not satisfactory.

  In this respect we remark that a too small value of y_d poses two problems.

  i) Technical difficulty in the realization of a detector which should be efficient at a distance $y = 0.5$ mm from the beam axis.

  ii) Safety risk in case of beam instability.

  The advantage of having a larger value of β_d (and therefore greater L_{eff}) is obvious.

  In the present design there is a free space of about 150 m between the separating dipoles used for the crossing and those of the dispersion suppressor, while the effective distance L_{eff} is only 65 m. Perhaps, using quadrupole triplets instead of equally spaced quadrupoles (arranged in a way which essentially extends the machine lattice into the straight section) the present design might be optimized. A value of L_{eff} of about 100 m does not seem to be completely unrealistic. This would of course be at the expenses of greater complexity and of additional cost for more quadrupoles.

- **The extension of the accepted interval of momentum transfer above $|t| =$ 0.7 GeV^2 and up to at least 10 GeV^2 is crucial for our physics program.** Therefore, the compatibility of the high-β insertion with a medium-β optics, obtained by only changing the current of the quadrupoles, in order to allow extension of the accepted t range above 0.7 GeV^2 should also be assessed (see Fig.1 of LHCC 93-47).

Concerning **"item 2"**, we realize that $\beta^* \simeq 30000$ m with $L_{eff} \simeq 800$ m is a requirement which seems to be unrealistic. Nevertheless, **because of the intrinsic interest of the measurement, we believe that this option should not be completely ignored**. We suggest that the possibility of installing the "Roman pots" further away (430 m from the crossing in the space available between the dispersion suppressor and the arc), of using quadrupole triplets very close to the crossing and separating dipoles arranged to produce head-on collisions as for the low-β insertions, could be examined before discarding the measurement under "item 2" irrevocably.