Accuracy of the Absolute Beam Momentum Determination by Means of the COSY - 11 Detection System

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The COSY - 11 experiment studies the close to threshold meson or meson pair production in the proton-proton collision up to proton beam momenta of about 3.5 GeV/c. Near the kinematical threshold the total cross section for such reactions grows rapidly with increasing beam momentum. Thus, in view of the theoretical description, the determination of the absolute beam momentum is as important as the accuracy of the cross section values.

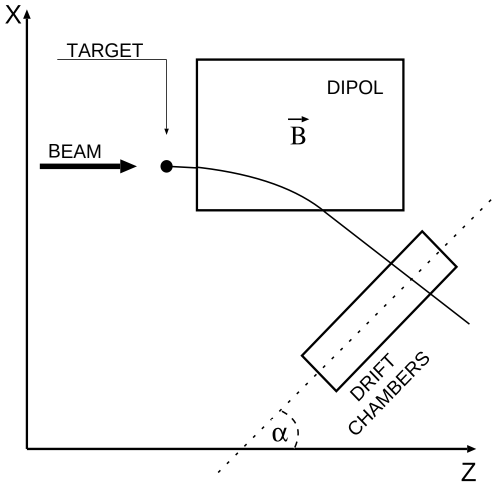

Figure 1: Schematic view of the relative settings for the target, the dipole magnet and the drift chamber stack at the COSY - 11 detection system [1] .

In case of the $pp \to pp\eta$ or $pp \to pp\eta'$ reactions the produced meson is identified via the missing mass method, which requires the knowledge of the beam momentum and of the two four-momentum vectors of the registered protons. The deviation of the experimental missing mass from the real meson mass reflects directly the offset between the real beam momentum and the one used in the analyses. An error of this offset is influenced by the accuracy of the four-momentum vectors of both protons. The protons are identified by measuring their momenta and velocities [1]. After the unique identification the proton mass is taken from the Particle Data Booklet. Thus the accuracy of the beam momentum determination from a missing mass spectrum is defined by the accuracy of the measured proton momenta, which are derived from the numerical reconstruction of the track between the target and the drift chambers (see figure 1) through the magnetic field in the dipol. The crucial parameters for the proton momentum determination and hence for the meson mass calculations are the target position, the magnetic field in the dipol and the settings of the drift chambers. Figures 2, 3, 4 and 5 depict how the error of these parameters influences the determination of the missing mass in the case of the $pp \to pp\eta\prime$ reaction. This study was performed by simulating a sample of events with the Monte-Carlo method and then analysing them the same way as the experimental data. In the simulation the target dimensions, the beam spread in space and momentum, as well as the drift chamber resolution were taken into account. All mentioned parameters were established from the experimental data. The target is a cylindrical hydrogen beam with a diameter of 9 mm. The proton beam has the Gauss distribution in horizontal and vertical direction with $\sigma \sim 4$ mm. The beam momentum spread amounted to 1.1 MeV/c, and the spatial resolution of one drift chamber plane is 0.3 mm, where 14 planes were used.

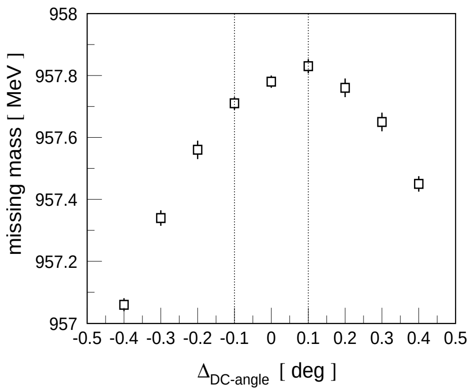

Figure 2: Missing mass of the η' meson as a function of the error of establishing the drift chamber angle. This angle is known with the accuracy better than $\pm 0.1^o$ where the missing mass changes by less than 0.12 MeV.

The dashed lines on figures 2, 3, 4 and 5 indicate

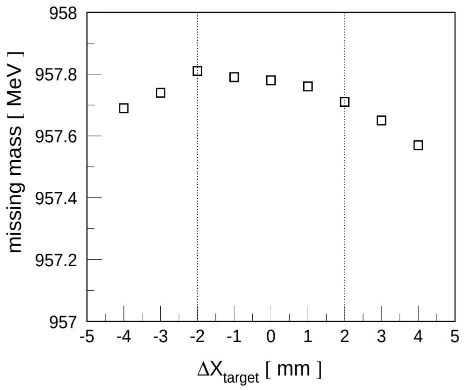

Figure 3: Missing mass of the η' meson versus the deviation of the target position in the horizontal direction perpendicular to the beam axis. The position of the target is known with an accuracy better than $\pm$ 2 mm which corresponds to the missing mass variation smaller than 0.1 MeV.

the maximum expected deviation in the determination of the considered parameters. The error of the target position and the drift chambers angle is smaller than 2 mm and 0.1^o, respectively. Specifically the 0.1^o corresponds to the inaccuracy of the drift chamber stack position of ~ 3 mm. The three components of the magnetic field were measured for few different dipol currents by means of the Hall probe with the accuracy of 0.1%[2]. However, because of the interpolation error the overall accuracy amounts to ∼0.25%[3].
Summing the deviation of the missing mass caused by the above listed uncertainties (see figures 2, 3, 4, 5) one obtains the overall systematic error to be smaller than 0.3 MeV, which transfers to beam momentum variation less than 0.9 MeV/c. This value is three times smaller than the estimation from the beam orbit lenght and the revolution frequency. Figure 6 shows the deviation of the missing mass caused by the error of the absolute beam momentum. One sees that here the relative dependence is much stronger than those resulting from figures 2, 3, 4 and 5.

References

[1] S. Brauksiepe et al., Nucl. Instr. & Meth. **A 376** (1996) 397

[2] M. Rook, Doctor Thesis, KFA Jülich, 1994

[3] COSY - 11 collaboration, Annual Report FZ Jülich, Jül-3365, p. 38

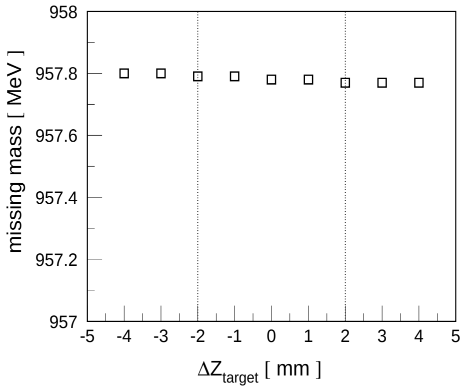

Figure 4: Missing mass of the η' meson versus the deviation of the target position along the beam direction. Since the position of the target is known better than $\pm$ 2 mm the missing mass variation caused by this parameter is less than 0.04 MeV

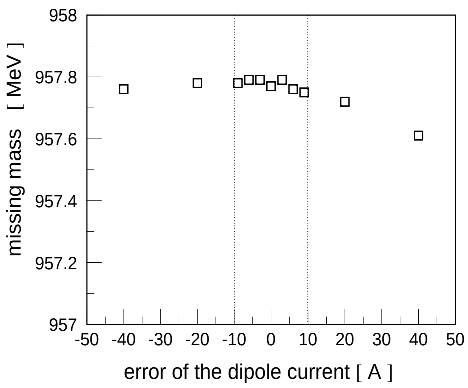

Figure 5: Missing mass of the η' meson versus changes of the dipol current. The absolute current value used in the mesurement of the $pp \to pp\eta'$ reaction was $\sim$ 3700 A which corresponds to the vertical magnetic field component of $\sim$ 1.5 T. The magnetic field is known with the accuracy better than 0.25 % which is equivalent to a missing mass variation of less than 0.04 MeV.

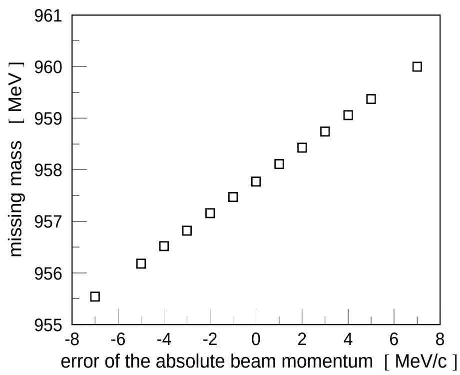

Figure 6: The uncertainty of the beam momentum transfers linearly to the the missing mass, namely as: $3 \cdot \Delta P[MeV/c] \sim= \Delta mm[MeV]$.