COSY–11 threshold measurements with a slowly increasing beam momentum

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For the extraction of excitation functions measurements at different momenta are needed. This can be performed by separate momentum settings or with continuous momentum variation and measuring during the acceleration, which was used extensively at the EDDA[?] experiment. A similar operation modus was used for measurements at COSY–11.
COSY–11, an internal cluster target experiment, is installed in an arc section of the COSY ring, which complicates the beam preparation compared to experiments in the straight section.
At COSY–11 threshold measurements are performed, i.e. a momentum range of some 10 MeV/c is analyzed. For measurements with a continuous momentum variation, a COSY operation modus was worked out with an additional slow acceleration during a long "flat top" after the usual fast acceleration to a certain momentum.
Within this "slow ramp" the momentum is increased by only $\approx 1\%$ linearly.
With this method the threshold region for the $p\,p \to p\,p\,\eta'$ and the $p\,p \to p\,p\,\eta$ reaction were scanned, whereby the total beam preperation time could be reduced.
In the η' measurement the beam momentum was increased in 300 seconds from 3200 MeV/c to 3224 MeV/c, in the beamtime for the η in 360 seconds from 1972 MeV/c to 2002 MeV/c.
The stability of the position of the COSY beam with respect to our target during the slow ramp was checked with the beam position monitors. At the target region the beam was fixed during the ramping within the uncertainty of the beam position monitors which amounts to $\approx \pm 1$ mm.
The collected events include the time difference to the cycle start. With this time information the value of the nominal absolute beam momentum for each event can be extracted from the momentum definition of the control system. Thus the cross section for each momentum point of the ramp can be determined.
The uncertainty of the momentum for each point in the ramp is given by the knowledge of the absolute beam momentum plus the beam momentum resolution.
The absolute beam momentum is known with an accuracy of $\pm 0.1\%$ concerning the uncertainty in the estimation of the proton orbit length.
The momentum resolution $\frac{\Delta p}{p}$ of the COSY beam was measured for the two different beamtimes mentioned above using the well known equation [?]:

$$\frac{\Delta f}{f} = \frac{1}{\gamma_{tr.}^2}\frac{\Delta B}{B} + \left(\frac{1}{\gamma^2} - \frac{1}{\gamma_{tr.}^2}\right)\frac{\Delta p}{p}, \qquad (1)$$

where Δf is the change of the revolution frequency f corresponding to the variation of the magnetic field B by ΔB, and $\gamma_{tr.}$ is the Lorentz factor γ at "transition energy". For the quantification of the beam resolution the value of Δf and the frequency resolution $\frac{\Delta \nu}{\nu_0}$ was determined with the amplitude of the driving frequency switched off.
The momentum resolution $\frac{\Delta p}{p}$ (FWHM) was determined to 7.3 $\times 10^{-4}$ for the η' momentum and 5.5×10^{-4}, for the η momentum, respectively. A decrease of the momentum resolution during the ramp due to the energy loss was not observed.
Thus the uncertainty of the absolute momentum represents the main contribution to the error in the beam momentum.
For the specification of a cross section near threshold the exact knowledge of the beam momentum is of enormous importance. The measurement in the threshold region of a reaction with many different beam momenta itself can be used for the determination of the absolute beam momentum by a comparison with Monte Carlo data. With this method described in [?] depending on the statistcs a decisively more exact value of the absolute beam momentum is obtained as gained from the relation between the revolution frequency and the estimated proton orbit length.
Therefore this slow ramping will be a strong tool to fix the absolute beam momentum with good accuracy of less than $\pm 0.05\%$ depending on the statistics of the measurement.

References:

[1] W. Scobel et al., Physica Scripta 48 (1993) 92 - 94

[2] C. Bovet et al., CERN/MPS-SI/INT. DL/70/4 (1970)

[3] P. Moskal, Method of the absolute beam momentum determination, this report