Vol. 29 (1998) *ACTA PHYSICA POLONICA B* No 11

BEAM ENERGY CALIBRATION WITH MESON PRODUCTION*

B. Razen

Institut für Strahlen- und Kernphysik, Universität Bonn

for the GEM Collaboration

M.G. Betigeri [i], J. Bojowald [a], A. Budzanowski [d], A. Chatterjee [i] M. Drochner [b], J. Ernst [g], S. Förtsch [j], L. Freindl [d], D. Frekers [h] W. Garske [h], K. Grewer [h], A. Hamacher [a], M. Hawash [a†], S. Igel [a] I. Ilieva [e], R. Jahn [g], L. Jarczyk [c], G. Kemmerling [b], K. Kilian [a] S. Kliczewski [d], W. Klimala [c], D. Kolev [f], T. Kutsarova [e], B.J. Lieb [k] G. Lippert [a], H. Machner [a], A. Magiera [c], R. Maier [a], H. Nann [l] H.S. Plendl [m], D. Protic [a], B. Razen [g], P. von Rossen [a], B. Roy [i] R. Siudak [d], J. Smyrski [c], A. Strzałkowski [c], R. Tsenov [f] P.A. Żołnierczuk [‡], K. Zwoll [b]

[a] Institut für Kernphysik, Forschungszentrum Jülich, Jülich, Germany
[b] Zentrallabor für Elektronik, Forschungszentrum Jülich, Jülich, Germany
[c] Institute of Physics, Jagellonian University, Kraków, Poland
[d] Institute of Nuclear Physics, Kraków, Poland
[e] Institute of Nuclear Physics and Nuclear Energy, Sofia, Bulgaria
[f] Physics Faculty, University of Sofia, Sofia, Bulgaria
[g] Institut für Strahlen- und Kernphysik der Universität Bonn, Bonn, Germany
[h] Institut für Kernphysik, Universität Münster, Münster, Germany
[i] Nuclear Physics Division, BARC, Bombay, India
[j] National Accelerator Center, Faure, South Africa
[k] Department of Physics and Astronomy, University Fairfax, Virginia, USA
[l] IUCF, Bloomington, Indiana, USA
[m] Physics Department, Florida State University, Tallahassee, USA

(Received July 21, 1998)

The magnetic spectrometer BIG KARL is used to get energy calibration fix-points for the external beam of COSY-Jülich. These fixpoints were obtained by measuring the meson-production reaction $pp \to d\pi^+$ close to

---

* Presented at the Meson'98 and Conference on the Structure of Meson, Baryon and Nuclei, Cracow, Poland, May 26–June 2, 1998.

† On leave of absence from Nuclear Research Center, A. E. A., Cairo, Egypt.

‡ Now at Dept. of Physics and Astronomy, University of Kentucky, Lexington, USA.

threshold and at the beam momentum, where the forward pions and the backward deuterons have the same momentum.

PACS numbers: 13.60.Le, 25.40.Qa, 29.30.Aj

1. Introduction

To measure reactions with a high precision, especially close to threshold, one needs to know very accurately the momentum of the particles, namely the incident beam. As the circumference of the particle orbit of a synchrotron is not exactly known, measuring calibration reactions is a good tool to deduce the true beam-momentum. This is valid especially for the extracted beam, which has some additional uncertainties in the momentum.

2. Experiment

The experiments were performed at COSY (COoler SYnchrotron) Jülich at two sets of different proton beam momenta around 793 MeV/c and 1920 MeV/c, respectively. The proton beams were focused onto the target point of the BIG-KARL spectrometer, a 3Q2DQ magnetic system [1]. Acceptances of the spectrometer are ± 25 mrad in the horizontal or x-direction and ± 100 mrad in the vertical or y-direction and $\pm 4.5\%$ with regard to the central value of the chosen momentum bite. The target was a cell [2] containing liquid hydrogen, with 6 mm in diameter and a thickness of 4.4 ± 0.2 mm for the 1920 MeV/c runs and 2.4 ± 0.2 mm for the runs at 793 MeV/c. Windows were of 2μm thick Mylar each. The deuteron tracks were measured in the focal plane of the spectrometer with two stacks of multi-wire drift chambers (MWDC) which allow position measurements both in the horizontal and vertical direction. A track resolution of 0.2 mm was achieved. The MWDC stacks were followed by a timing detector consisting of four layers of scintillator paddles for trigger purposes and to reduce background.

3. The spectrometer

The fields of the spectrometer were set in a way, that it allows ray tracing of the tracks in the focal plane to the target position. In the vertical direction the spectrometer worked in a point-to-parallel mode, in the horizontal direction in a point-to-point mode. The description of such a magnet-optical system can be done with a set of transfer matrices: $x_i^f = R_{ij} x_j^t$ which can be extended to higher orders by means of tensor description: $x_i^f = R_{ij} x_j^t + T_{ijk} x_j^t x_k^t$. Several measurements close to threshold provided us with the full kinematics of the $pp \to d\pi^+$ reaction. Comparison of these data with the expectation from the matrix-description showed, that mainly chromatic terms contribute to the second order corrections [3]. A second test to proof whether the matrix-description of the spectrometer works, was done by measuring the dispersion. The primary beam was transported into the focal plane with different settings for the central momentum of the spectrometer. From the expectation from the matrix we found good agreement of the measured data points at different central momenta of the spectrometer. Hence, the optical behavior of the spectrometer is known and it can be used as a tool to calibrate the primary beam.

4. Calibration with threshold reactions

Close to the pion-production threshold the outgoing deuterons have only small transverse momenta and can be fully detected in the spectrometer. As the center-of-mass momentum of the deuterons varies strongly with the beam-momentum close to threshold, the edge of the full momentum-ellipsoid can be used to determine the beam momentum (Fig. 1 left part). The circles in the picture show the kinematical loci for beam momenta of 792.7 and 793.1 MeV/c, which are either too large or too small compared to the data. In addition the mass of the missing pion can be calculated and is a second tool to determine the right beam-momentum. For the nominal beam-momentum of 793 MeV/c we found, the real momentum to be 0.1 MeV/c smaller.

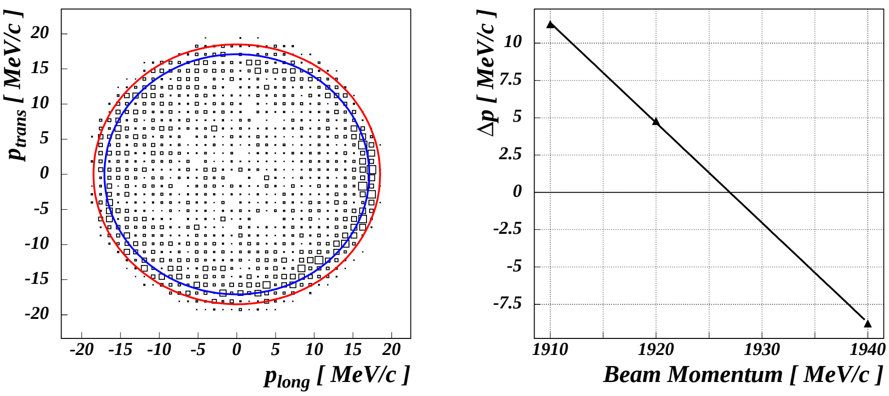

Fig. 1. Left — calculated kinematical loci for beam momenta of 792.7 and 793.1 MeV/c are shown (full circles) in comparison with data (squares). Right — a fit to the measured distances of the pions and deuterons in momentum space. The point $\Delta p = 0$ corresponds to a beam momentum of 1930.54 MeV/c.

5. Calibration with kinematical coincidence

For the reaction $pp \rightarrow d\pi^+$ the backward deuterons (in CMS) and the corresponding forward pions have exactly the same mometa. Therefore a magnetic system can detect them both simultaneously. This measurement provides two independend possiblities to determine the beam-momentum. As the total momentum of both reaction products is measured, one can recover the momentum of the incident beam. This leads to a beam-momentum of 1911.7 ± 0.8 MeV$/c$, which is 1.84 MeV$/c$ higher than the nominal value. The second possibility deals with the distance between the deuterons and pions in momentum-space. This distance can be measured at several incident momenta and is plotted as a function of the beam-energy in Fig. 1 (right part). A linear fit to the data yields 1928.02 MeV$/c$ for $\Delta p = 0$. Including the energyloss in the target this corresponds to a deviation of $+2.03 \pm 0.10$ MeV$/c$ between the real and the nominal beam momentum.

6. Summary

It was shown that the spectrometer BIG KARL is a good tool to measure the beam momentum of the extracted beam at COSY. For two different energy ranges we could deduce the difference between the nominal and the real value of the beam momentum. Normally it is possible to extrapolate the deviation between the nominal and real value of the beam momentum to other beam energies. But this difference depends on the extraction method, which was changed between the two experiments. A new measurement whereby the extraction method is kept the same is highly desirable.

REFERENCES

[1] S. Martin *et al.*, *Nucl. Instrum. Methods,* **214**, 281 (1983).
[2] V. Jaeckle *et al.*, *Nucl. Instrum. Methods,* **A349**, 15 (1994).
[3] B. Razen, Ph.D thesis, Univ. Bonn, Berichte des FZ Jülich, Jül 3488.