Nuclear Instruments and Methods in Physics Research A 593 (2008) 203–231

Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research A

journal homepage: www.elsevier.com/locate/nima

The CERES/NA45 radial drift Time Projection Chamber

D. Adamová [a], G. Agakichiev [b], D. Antończyk [b], H. Appelshäuser [c], V. Belaga [d], J. Bielčíková [e], P. Braun-Munzinger [b], R. Campagnolo [f,h], A. Cherlin [g], S. Damjanović [h], T. Dietel [h], L. Dietrich [h], A. Drees [i], W. Dubitzky [h,*], S.I. Esumi [h], K. Filimonov [h], Z. Fraenkel [g], C. Garabatos [b], P. Glässel [h], G. Hering [b], J. Holeczek [b], V. Kushpil [a], A. Marín [b], J. Milošević [h], A. Milov [g], D. Miśkowiec [b], L. Musa [f], Y. Panebrattsev [d], O. Pechenova [d], V. Petráček [h], A. Pfeiffer [f], J. Rak [e], I. Ravinovich [g], M. Richter [h], H. Sako [b], E. Schäfer [h], W. Schmitz [h], J. Schukraft [f], W. Seipp [h], A. Sharma [f], S. Shimansky [d], J. Stachel [h], M. Šumbera [a], H. Tilsner [h], I. Tserruya [g], J.P. Wessels [j], T. Wienold [h], B. Windelband [h], J.P. Wurm [e], W. Xie [g], S. Yurevich [h], V. Yurevich [d]

[a] NPI/ASCR, Řež, Czech Republic
[b] Gesellschaft für Schwerionenforschung, Darmstadt, Germany
[c] University Frankfurt, Germany
[d] Joint Institute for Nuclear Research, Dubna, Russia
[e] Max-Planck-Institut für Kernphysik, Heidelberg, Germany
[f] CERN, Geneva, Switzerland
[g] Weizmann Institute, Rehovot, Israel
[h] University Heidelberg, Germany
[i] Department of Physics and Astronomy, SUNY Stony Brook, USA
[j] University Münster, Germany

ARTICLE INFO

Article history:
Received 3 February 2008
Received in revised form
26 March 2008
Accepted 21 April 2008
Available online 10 May 2008

Keywords:
Radial drift TPC
Field cage
Pad plane
Gating grid
Readout electronics
Pad response
Cooling system
Gas composition
Drift velocity
Calibration
Alignment
Field calculation
Pattern recognition
Tracking

ABSTRACT

The design, calibration, and performance of the first radial drift Time Projection Chamber (TPC) are presented. The TPC was built and installed at the CERES/NA45 experiment at the CERN SPS in the late nineties, with the objective to improve the momentum resolution of the spectrometer. The upgraded experiment took data twice, in 1999 and in 2000. After a detailed study of residual distortions a spatial resolution of 340 μm in the azimuthal and 640 μm in the radial direction was achieved, corresponding to a momentum resolution of $\Delta p/p = \sqrt{(1\% \cdot p/\mathrm{GeV})^2 + (2\%)^2}$.

1. Introduction

Heavy-ion collisions at ultra-relativistic energies offer the possibility to study the behavior of nuclear matter at high density and/or temperature where one expects the formation of the Quark Gluon Plasma (QGP). A valuable tool to explore the early stage of heavy-ion collisions are electromagnetic probes. They are not subject to the strong interaction and can freely escape the surrounding hadronic medium.

CERES/NA45 (Cherenkov Ring Electron Spectrometer) is the only experiment at the CERN Super Proton Synchrotron (SPS) dedicated to the study of e^+e^--pairs produced in p–A and A–A

* Corresponding author. Tel.: +49 177 2387396.
E-mail address: wilrid@dubitzky.de (W. Dubitzky).

0168-9002/$ - see front matter
doi:10.1016/j.nima.2008.04.056

collisions in the low mass range of $0.1\,\mathrm{GeV}/c^2 < m_{ee} < 1.2\,\mathrm{GeV}/c^2$. It was installed in 1990 at the H8 beam line of the SPS North Area and started its operation in 1991. Systematic studies have been done using S–Au interactions in 1992 and proton-induced reactions p-Be and p-Au in 1993. An energy scan of Pb–Au interactions has been performed in beam times from 1995 to 2000. One of the main achievements of the CERES experiment is the measurement of an enhanced dilepton yield in S–Au and Pb–Au collisions as compared to expected contributions from vacuum decays of hadrons [1–5].

In 1998 the experiment was upgraded with a radial drift Time Projection Chamber (TPC) [6,7] in order to significantly improve the mass resolution in the range of the ϕ-meson from $\Delta m/m = 7\%$ [5] to 3.8% [8,9]. The additional information from the differential energy loss $\mathrm{d}E/\mathrm{d}x$ in the TPC further improved the pion/electron separation capability. At an electron efficiency of 0.68 the pion misidentification rate dropped from 5×10^{-4} to 2.5×10^{-5} at a particle momentum of $1\,\mathrm{GeV}/c$ [10,11]. The dilepton invariant mass spectra measured after the experimental upgrade with the TPC allowed for the first time to discriminate between different theoretical approaches [10,12]. Finally, the TPC also opened the possibility to study hadronic channels. Since then many interesting topics have been addressed like particle multiplicities, elliptic flow, event-by-event fluctuations, particle correlations, and strangeness analyses (see for example Ref. [9]).

The upgraded CERES spectrometer, as it was used during the heavy-ion runs in 1999 and 2000, is shown in Fig. 1. The main components of the experiment are two Silicon Drift Detectors (SDD1, SDD2) for vertex reconstruction, two Ring Imaging Cherenkov Counters (RICH1, RICH2) for electron identification, and a radial drift TPC for the measurement of the particle momentum and particle identification. All detector components of the spectrometer cover full azimuth at polar angles $8^\circ < \theta < 14^\circ$, corresponding to a pseudorapidity range of $2.10 < \eta < 2.65$.

2. TPC design considerations

The aim of an improved mass resolution required the addition of a charged particle spectrometer to the existing CERES experiment, consisting of a magnet system and a large volume electron tracking device [13,14]. The TPC technology has been successfully applied for this task in heavy-ion experiments, combining high resolution tracking with large acceptance, low material budget, and reasonable cost.

The new spectrometer system had to preserve the polar angle acceptance and the azimuthal symmetry of the existing experiment. This led to a radial electric field configuration resulting in the first radial drift TPC ever to be operated. In addition, a magnetic field configuration with two new magnet coils around the TPC has been adopted providing a strong radial component for momentum determination (cf. Fig. 1 and Section 5). With a momentum dependent curvature in the r–ϕ plane the ionization electrons drift almost radially outwards to the readout chambers which are installed on the outer circumference of the TPC.

For significant parts of the drift volume this design implies crossing electric and magnetic field lines leading to a finite variable Lorentz angle of the drifting electrons. The drift gas mixture Ne/CO_2 (80%/20%) has been found as an optimum with regard to small diffusion coefficients and Lorentz angle, sufficient primary ionization, long radiation length, and detector stability. In addition, the maximum drift time should be kept low in order not to compromise the trigger rate without requiring excessively high drift fields.

3. Mechanical layout

The TPC was installed downstream of the existing spectrometer, at a distance of 3.8 m from the target system. A cross-section of the TPC is shown in Fig. 2. The mechanical stability of the TPC is provided by a massive backplate and an outer cylinder,

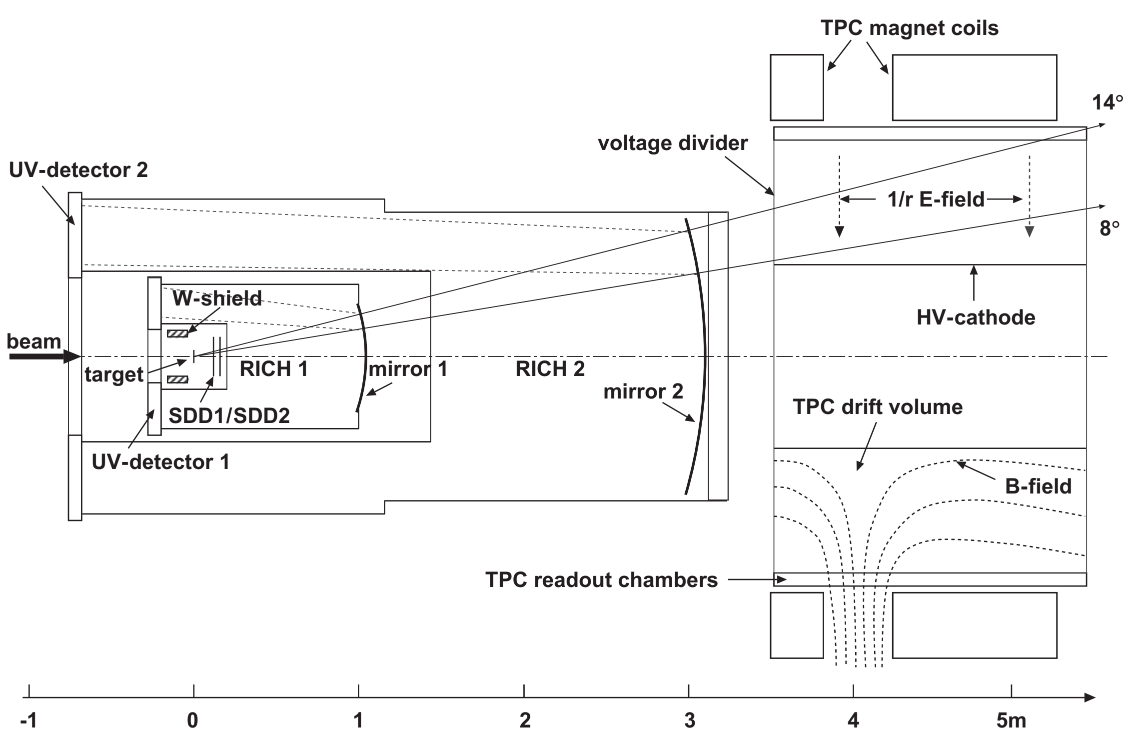

Fig. 1. Schematic view of the CERES/NA45 spectrometer. The TPC is operated inside an inhomogeneous magnetic field generated by two opposite polarity coils. The electric field inside the TPC is radial, pointing from the readout chambers to the high voltage cylinder.