JHEP PROCEEDINGS
International Europhysics Conference on HEP

Charged particle tracking at HERA-B

Torsten Zeuner[*] [†]
University of Siegen
E-mail: tzeuner@mail.desy.de

Abstract: The HERA-B experiment at DESY is a large acceptance spectrometer originally planned to detect B mesons produced in fixed target proton (920 GeV) nucleus interactions. The detector is designed to reconstruct 4 to 5 interactions per bunch crossing (96ns) with about 120 charged tracks using a silicon vertex detector, an inner MSGC-GEM detector and an outer large volume honeycomb drift chamber. The detectors are operated in an radition environment comparable to LHC conditions with particle fluxes of up to 10^7 (10^5) particles/sec/cm^2 for the inner and outer gaseous tracking detectors.

1. Introduction

HERA-B is a fixed target experiment at the HERA 920 GeV/c proton storage ring at DESY. The experiment has been designed with the primary goal of measuring CP violation in the neutral B system [1] using decays $B^0 \to J/\Psi K^0_s$. Proton-Nucleon reactions are produced by collisions of the protons with an internal wire target consisting of 8 wires of different materials (C, Al, Ti, W). The experiment is designed for 4-5 superimposed interactions per bunch crossing (96ns) demanded by the low signal to background ratio of the interesting physical reactions ($O(10^{-11})$). Due to the strongly forward oriented kinematics the detector is built as a forward magnet spectrometer covering polar angles varying from 10 to 220 mrad (see Figure 1).

One of the challenging components of this spectrometer is the tracking system. It has to cope with the extremely high particle fluxes (up to 10^7 charged particles per cm^{2}s^1) and high radiation doses facing a new area comparable to the experiments planned for the Large Hadron Collider (LHC) at CERN. The expected radiation load per year accumulates to

- up to 10 Mrad for the silicon vertex detector modules,

[*]Speaker.
[†]For the HERA-B collaboration

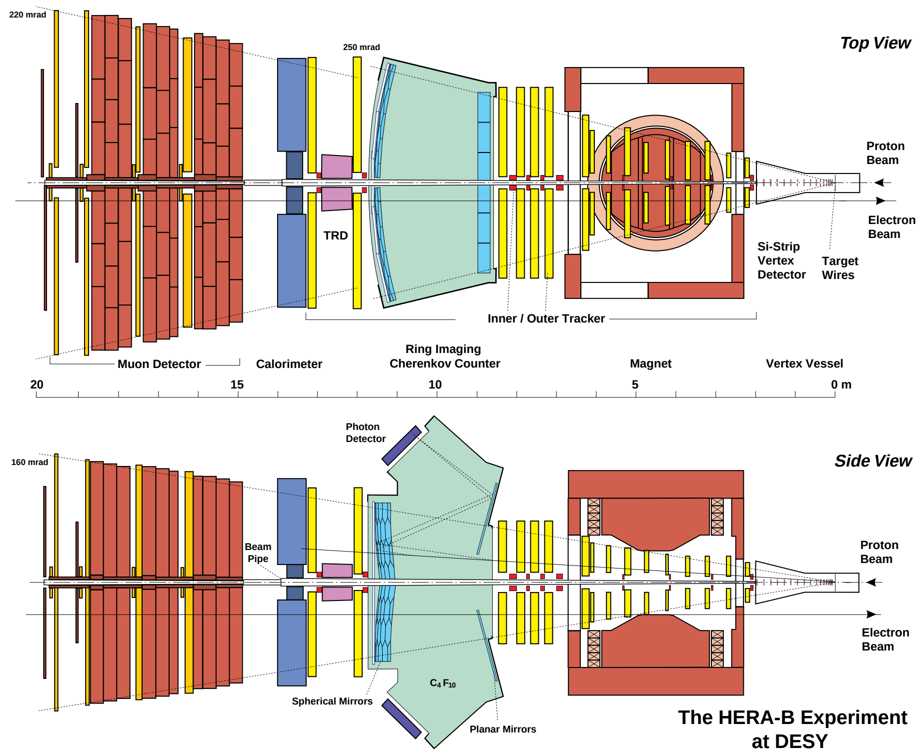

Figure 1: Overview of HERA-B detector.

- maximum 1 Mrad for the inner tracking MSGC-GEM detectors,
- and maximum 0.6 C/cm for the outer tracking honeycomb drift chambers.

The tracking system of HERA-B is subdivided in two parts, the vertex detector system and the main tracking system consisting of an inner and outer part. The main tracking system will be part of this article. A detailed description of the vertex detector system can be found in [2] [3].

1.1 The main tracking system of HERA-B

The main tracking system of HERA-B is distributed along the beam pipe in three main regions (compare Figure 1). Because of a strong radial dependence of the particle flux with the distance to the beam pipe ($\approx 1/\mathrm{R}^2$), different granularities for the tracking detectors are used to keep occupancies at a reasonable level ($\leq 20\%$). These different granularities are achieved by choosing different technologies for the inner and outer tracking region. MSGC-GEM detectors are used in the inner region (Inner Tracker - ITR) to cover the distance between 6 cm and 30 cm (10 mrad $\leq \theta \leq$ 100 mrad) around the beam pipe. The outer region (Outer Tracker - OTR) starting at a distance of 20 cm and covering the area up to the full coverage of $220 \cdot 160$ mrad^2 is equipped with honeycomb drift chambers.

The track reconstruction procedure starts with the pattern recognition process in the pattern region (the field free region behind the magnet and in front of the RICH). Three dimensional track candidates in this region are propagated to the trigger region and into the magnet. In a next step of the reconstruction algorithm track candidates produced by the main tracking system are matched with track segments of the standalone tracking of the vertex detector system and the particle identification systems of HERA-B. The track reconstruction is based on Kalman Filtering techniques [7].

In this article the setup of the inner and outer tracking system is described, and some of the main results of the detector development and commissioning phase will be presented. Finally the achieved detector performance during the run 2000 and the detector upgrade during the HERA luminosity upgrade will be shown.

2. The inner tracking system

The inner tracking system consists of 184 detectors with ≈140000 analog readout channels and is distributed to ten detector stations along the beam pipe. Each of them consists of several detector layers with four independent L-shaped detectors per layer. The detectors overlap in their sensitive regions in order to cover the full area. Some of the detector stations are located in the field of the spectrometer magnet ($B_{max} \approx 0.85$ T).

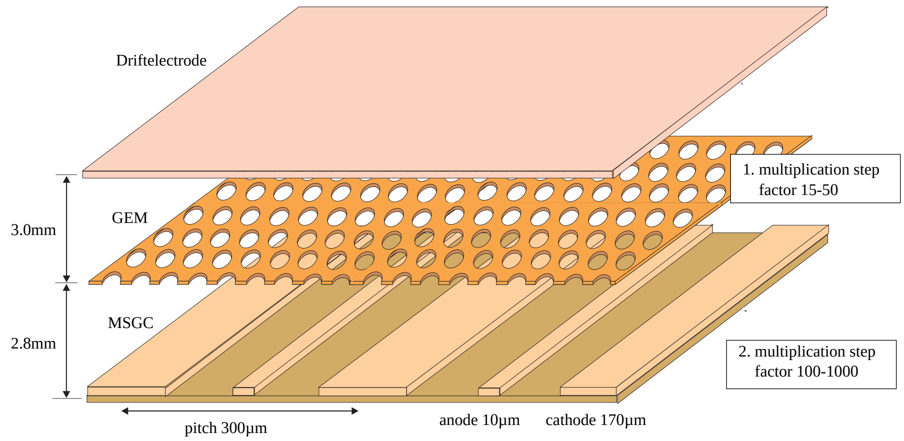

Figure 2: Sketch of a MSGC-GEM detector.

The microstrip gas detector consists of a glass plate coated by a chemical vapor deposition method[1] with an amorphous carbon coating (‘diamond like coating’, a-Si-C:H:N). The surface resistivity of this coating lies in the range of 10^{14}-$10^{15}\Omega/\Box$ and has a thickness of 60 nm. On the coated glass plate a strip pattern is produced by a lift-off technique[2]. This structure consists of 10 μm wide anodes and 170 μm wide cathode strips with a gap of 60 μm in between, resulting in a pitch of 300 μm. The MSGC is combined with a Gas Electron Multiplier foil which is located between the microstrip structure and the drift electrode (see Figure 2). The distances between the MSGC, the GEM and the drift electrode are kept by hollow G10 frames. They are also used for the gas distribution. The GEM itself consists of a Kapton foil (thickness 50 μm) which is copper clad on both sides (thickness 7 μm). It has a regular hole pattern (round holes with a diameter of 90 μm in the copper and 50-60

[1] Engineering and Thin Films, Braunschweig, Germany
[2] IMT: Industrielle Masken und Teilungen, Greifensee, Switzerland.

μm in the Kapton with a pitch of 140 μm). One MSGC-GEM detector represents a total radiation length of $7.8 \cdot 10^{-3}$ in its active area.

3. The outer tracking system

The outer tracking system is built out of honeycomb drift-chamber modules. A schematic sketch of the construction is presented in Figure 3. The whole system consists of about 1000 individual modules.

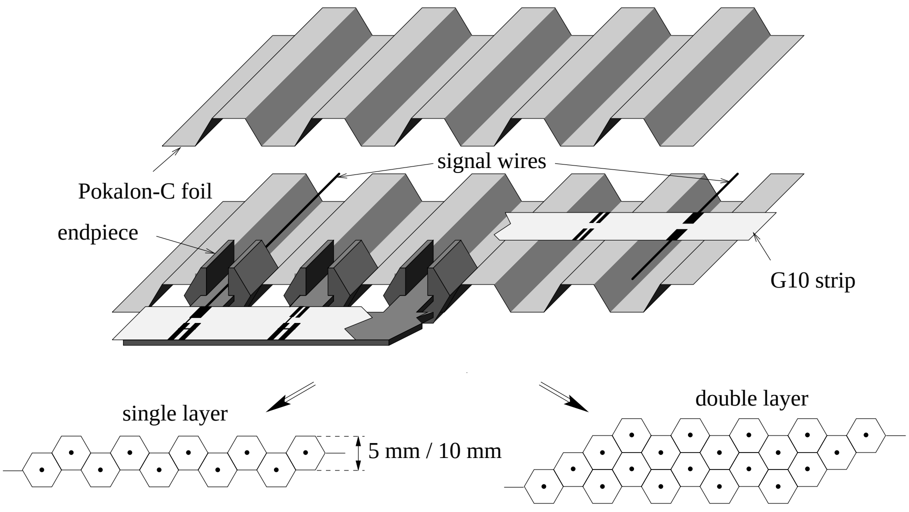

Figure 3: The OTR honeycomb technology.

The hexagonal structure from which the honeycomb cells are formed is produced of 75 μm thick carbon loaded poly-carbonate foil (Pokalon-C) coated with copper (40 nm) and gold (40 nm). Precise FR4 (G10) strips are glued onto the foils as wire support. The anode wire is made out of gold-plated tungsten and has a diameter of 25 μm. Cell diameters of 5 mm for the modules of the inner detector area and 10 mm for the modules of the outer part of the covered area are used. To avoid pile-up especially in the 10 mm cells a fast drift gas, $Ar/CF_4/CO_2$ (65:30:5), is used. The modules reach a maximum length of 4.6 m. The maximum sensitive area covered by one chamber is 4.6 m $\cdot$ 6.5 m. The outer tracker consists of a total of 115000 readout channels.

4. Detector development

The development of tracking detectors for HERA-B was driven by the requirements of radiation hardness, low radiation length, mass producibility and the capability of high rate operation. These requirements led to the choice of MSGC-GEM detectors for the inner tracking system. The technology was never applied for similar environements and for detectors of this size. Similarly honeycomb drift chambers for the outer tracking region have not been used before under comparable conditions.

The development phase took place from 1994 till 1999. During this period several critical problems had to be solved [4] [6].

The experience gained during the development phase of the tracking detectors showed that for operation under HERA-B or LHC conditions it is essential

- to test prototypes in high intensity hadronic beams,
- to perform large area irradiation of full-size prototypes to guarantee several years of lifetime,
- to careful choose materials and gases.

Especially in case of the microstrip gaseous detectors it was shown that testing the detectors in X-ray beams is not sufficient for an adequate test for operation in high intensity hadronic beams. Sparking thresholds are significantly reduced in presence of high ionizing particles. Different results for gas ageing have been observed using irradiated spot sizes of 113 mm^2 and 900 mm^2. With the smaller spot size neither ageing nor deposits were visible while with the large area irradiation obvious damage was observed.

5. Commissioning achievements

The installation was nearly finished at the end of 1999. The commissioning of the MSGC-GEM detectors started with a careful detector training under stable beam operation. The chamber high voltages are increased in several steps with intermediate operation till the final settings are reached. It has been shown that a stable detector operation can be achieved after a careful training while chambers without training show frequent over-currents. During the whole run period 2000 (about 1000 operation hours per chamber) around 1 % of dead channels were accumulated, mostly at the begin of the chamber operation due to imperfections in the chamber. After the detector training typically about 1 spark per chamber and day was observed.

Large gain variations between different detectors at the same high voltage settings were measured. These variations could be traced back to slight misalignments between the masks for the upper and lower sides during the GEM production. By individual gain adjustments of the GEM voltages these variations could be corrected.

The OTR was completely installed begin of 2000. During 2000 the system was routinely operated and used in data taking. However, the high voltage had to be reduced by about 4 % compared to test beam results due to HV problems. A continuous loss of around 1 HV channel per 5 hours was observed. This problem was quite serious due to a grouping of the HV by 16 channels, in total a loss of $\approx$ 10 % of all HV channels was observed. The problem was traced back to soldering remains for a specific HV capacitor on the HV distribution boards.

Due to a noise problem from the TDC trigger connection the amplifier threshold had to be raised from 2.5 fC to 4 fC. Both the reduced HV settings and the increased threshold reduced the achieved detector efficiency. Modifications to solve these problems were applied during the shutdown 2000/2001 (see section 7).

6. Detector performance

As pointed out in the last section, the inner and outer tracking system could not be operated at the design voltages. Consequently the efficiencies lay between only 85 and 98 % while in the design values larger than 95 % are assumed. The hit resolution of the inner tracking system corresponded to the design value ($\approx 100\ \mu$m), the outer tracking system reached a hit resolution of $\approx 350\ \mu$m (design 200 μm). Since the detector performance was lower than expected, the reconstruction software had to be optimized to cope with reduced efficiencies, worse resolution and dead regions. A satisfactory tracking efficiency in the main tracking region of ≥ 95 % for reference tracks could be reached.

7. Detector improvement

Since August 2000 the HERA accelerator is stopped for a luminosity upgrade. This long shutdown period was used by HERA-B to improve the tracking detectors and to solve the problems observed during the detector commissioning. The inner tracking system has repaired all problematic chambers. The HV problem of the outer tracking system was solved by removing the faulty capacitors, in addition bad modules are replaced and due to a more rigorous module testing the re-installed modules show a failure rate reduced by one order of magnitude at twice the gas gain. By a modification of the TDC trigger link the noise problem could be solved which allowed to reduce the threshold to the value of 2.5 fC.

8. Conclusion

It has been shown that detector operation under HERA-B conditions (high particle flux, high radiation load) and track reconstruction are possible. The largest MSGC-GEM system and drift chamber system for high rate application has been built.

The experience gained in 2000 was used during the HERA luminosity upgrade to improve the HERA-B tracking system. This modification and improvement work is finished by now. The restart of the detector is planned for winter 2001/2002.

References

[1] E.Hartouni et al., HERA-B Design Report, DESY-PRC 95/01 (1995)

[2] C.Bauer et al., Nucl. Instr. Meth A418 (1998) 65

[3] C.Bauer et al., Nucl.Instr. Meth. A453 (2000) 103

[4] T.Zeuner, Nucl. Instr. Meth. A446 (2000) 324

[5] HERA-B Inner Tracker Collaboration, Development of MSGC and GEM detectors for the Inner Tracking system of HERA-B, in preparation

[6] M.Capeans, Nucl. Instr. Meth. A446 (2000) 317

[7] R.Mankel, Nucl. Instr. Meth. A395 (1997) 169