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TARGET MONITORING SYSTEM FOR HERA-B EXPERIMENT. MULTI-TARGET OPERATION

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By using developed Target Monitoring System (TMS) the multiple wire mode operation has been investigated for four and eight targets. The HERA-B internal target consists out of eight target ribbons arranged around the beam. Each target can be moved in radial direction independently in sub-micron steps allowing to compensate relative beam shifts and to steer for the desired interaction rate. The experimental constraints require a stable interaction rate equally distributed over all inserted targets. The actual equalisation is based on a measurement of charge originated from the beam-target interaction. The TMS automatically controls a total interaction rate (IR) and performs an equal sharing among target wires by moving the target with respect to the beam. The system shows a good linearity with the interaction rate and allows a reasonable distribution of the interaction rate among several wires. To cross check the performance of the multiple wire mode steering the reconstructed tracks and primary vertices in the silicon vertex detector have been used.

Introduction

HERA-B is a fixed target experiment [1] with the primary goal to study CP violation in the decays of B-mesons [2] into the "gold plated" mode $B^0 \rightarrow J/\psi + K^0_S$ (Fig. 1) The B-mesons are produced in interactions of the 920 GeV protons of the HERA storage ring with an internal target operating in the beam halo close to the beam core at typical distances of a few beam sigma. Due to the small cross section for b-quark production, small branching ratios and limited detector efficiency an interaction rate of 40 MHz is required to achieve a significant CP violation signal within one year of data taking.

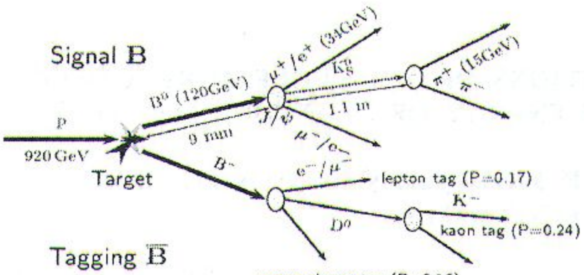

Fig. 1. The "gold plated" mode of B-mesons decay $B^0 \rightarrow J/\psi + K^0_S$.

The HERA-B target is placed inside the vertex detector vessel (Fig. 2). Each target wire can be moved in radial direction independently in sub-micron steps allowing to compensate relative beam shifts and to steer for the desired interaction rate. The experimental constraints require a stable interaction rate equally distributed over all inserted targets at progressively or occasionally varying parameters of the proton beam. Several suggestions have been discussed and tested to provide a feedback for the multiple wire mode steering. The Target Monitoring System (TMS) was developed in Kiev for a control of the total interaction rate (IR) and performs an equal sharing among target wires by moving the targets with respect to the beam. The actual system is mainly based on a measurement of charge, which is created in the target ribbons. The intentions of the present paper are to test the linearity with the interaction rate and obtain a reasonable distribution of the interaction rate among several wires. One used reconstructed tracks in the silicon vertex detector to cross check the performance of the multiple wire modes steering.

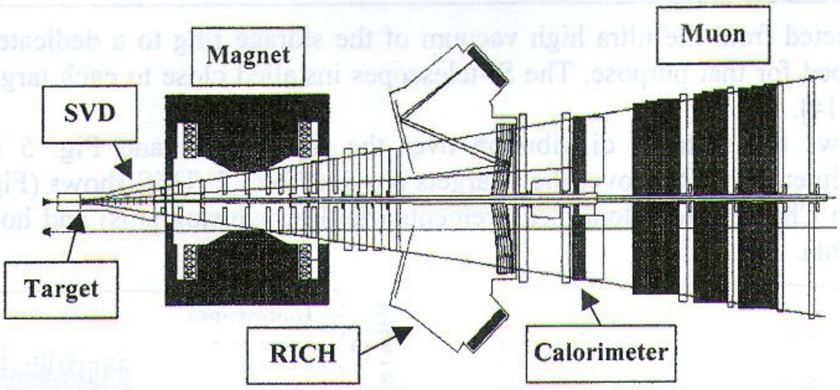

Fig. 2. Schematic view of HERA-B detector. SVD – silicon vertex detector tank. RICH – ring imaging Cherenkov detector. Targets are placed inside of SVD vessel.

Target Set-up and operation

The internal HERA-B target consists out of eight target ribbons arranged around the beam (Fig. 3) with a typical dimension of 500 μm along the beam axis and 50 μm in radial direction. This configuration has the advantage that it is mechanically simple and stable, easy to operate and that the various interactions per bunch crossing (4 – 5 typically) are separated among well-localised main vertices on different wires.

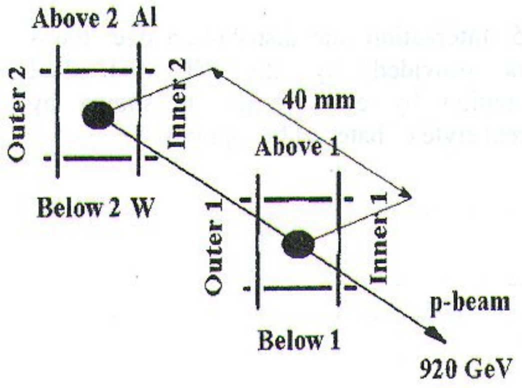

Fig. 3. The position of target ribbons in the beam halo.

HERA-B target is able to provide a stable interaction rate up to 40 MHz and even more during several hours of operation time. At 40 MHz the wires are very close to the beam: up to 4σ with a typical σ ≈ 400 μm. At this distance the interaction rate is very sensitive to the beam movements and the wires must react very quickly on any critical situation. As a damage to the p-beam would affect not only the operation of HERA-B, but also the operation of all experiments at the HERA-ring the operation of the target has to be extremely reliable. For this purpose the step-motors drive targets in automatically chosen steps (minimum 0.1 μm) under dynamically varying proton beam features (intensity, position, collimator setting, etc.). Under the nominal operation conditions movement of any target by 10 μm leads to the IR variation by factor of two.

Target Monitoring System

The main task for the Target Monitoring System is to monitor target-beam interactions and to provide data to the steering code for an equal distribution of the Interaction Rate (IR) over all 8 inserted targets while the absolute rate is fixed by the scintillation counters (hodoscopes) information.

TMS is supposed to run 10^7 s/year continuously, in a secure and reliable way. TMS steers targets every 0.1 s in accordance with the feedback data from scintillating hodoscopes (overall IR and charge integrators (CI) connected to each single target (partial contribution into the IR) [3]. One important part of the TMS are the Charge Integrators (CI). The beam-target-interaction born current (secondary-electrons are leaving the target) produces in the CI a frequency at the rate of 10 – 30 Hz per Interaction Rate of 1 MHz. To measure this current each target ribbon is mounted electrically isolated and connected from the ultra high vacuum of the storage ring to a dedicated electronics, which was developed for that purpose. The Si-telescopes installed close to each target ribbons are also used for TMS [4].

Fig. 4 shows the vertexes distribution over the four targets and Fig. 5 illustrates the distribution of the Interaction Rate over the 8 targets provided by CI. TMS shows (Fig. 6) a perfect agreement between Charge Integrators measurements (the lower histograms) and hodoscopes (the upper histogram) data.

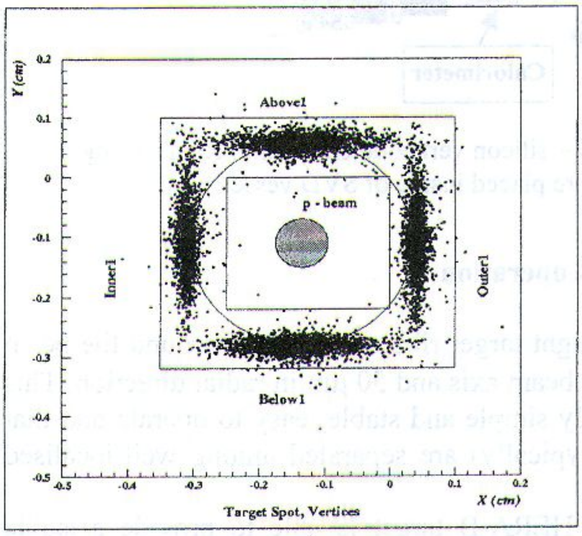

Fig. 4. Four targets operated in the beam-halo simultaneously. Vertices reconstructed by the SVD at 40 MHz. Solid line indicates range of expected target positions. Interaction Rate 40 MHz.

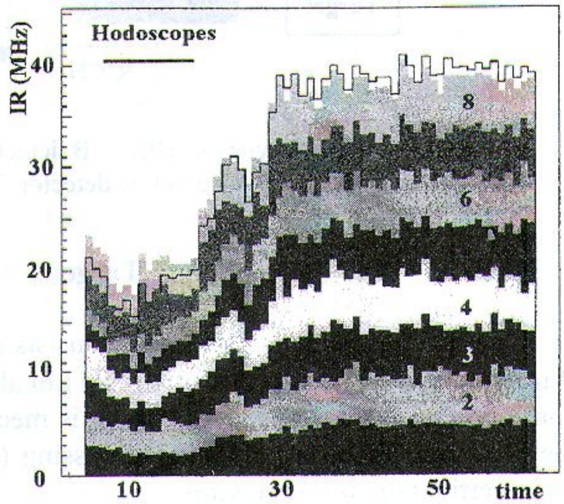

Fig. 5. Interaction rate distribution over the 8 targets provided by the CI. Individual contribution by every target is shown by different style of hatched histograms.

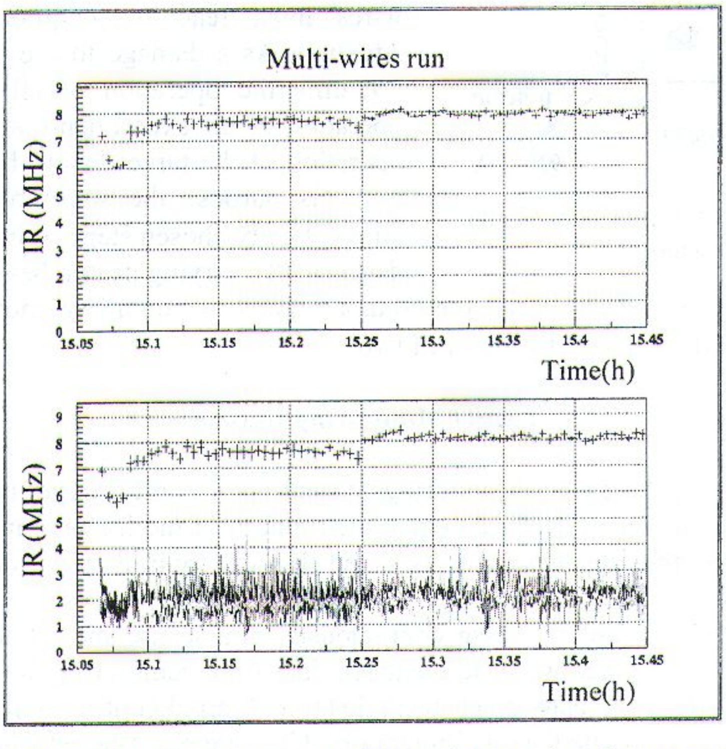

Fig. 6. Upper part of figure: the time dependence of IR hodoscope data. Lower part: the individual IR for Inner1, Below1, Above1 and Outer2 targets (lowest histograms) reconstructed from CI output frequencies. The sum of these individual IRs is shown my markers "+".

In order to keep the interaction rate constant both targets are moving towards to the beam core with time (Fig. 7). The sensitivity of an individual wire to the interaction rate production is approximately a factor of 2 per 10 μm movement.

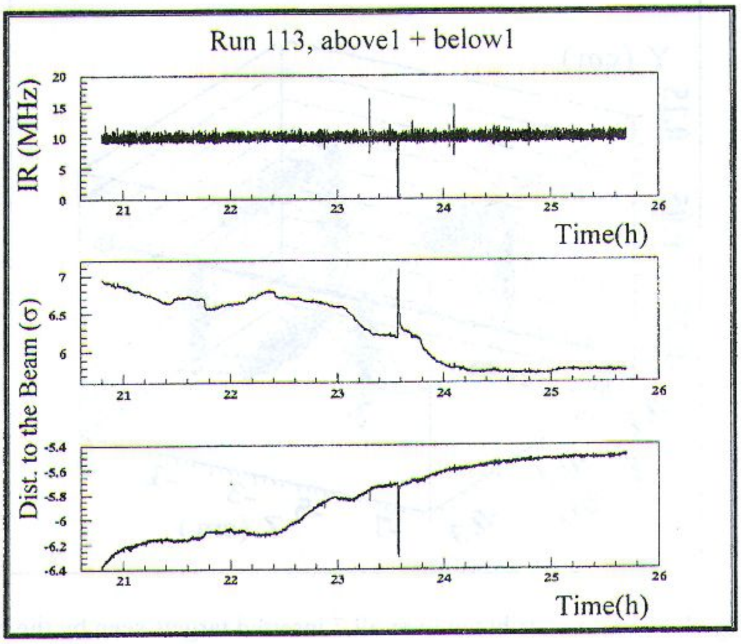

Fig. 7. The interaction rate (IR) and the distances to the beam core versus time for Above1 and Below1 target ribbons. The wire is moving in radial direction to the proton beam core.

The automatic Target Monitoring System is faster and more accurate than any human control. To achieve a nearly continuous operation of 10^7 sec/year the target steering has to be very secure, reliable, fast and easy to be operated. The main part of the TMS contains the automatic routines for controlling the wires without help of the user side. Every 0.1 s the interaction rates are read out, the decision if wires have to be moved is made and executed.

Vertex Detector Reconstruction

Nevertheless, the most relevant data about the performance of the target set-up emerge from HERA-B sub-detectors. Silicon Vertex Detector (SVD) data (reconstructed tracks and vertices) are used for the target alignment as well as for the evaluation of the beam-halo profile. SVD allows also controlling the contributions of each target separately. Per time interval equal number of tracks are shared by different wires.

The vertex distribution along the wire gives an important information about the beam and beam-halo shape. Fig. 8 shows the distribution of the vertices over 7 targets. Number of vertices at each target is in a good agreement with the IR distribution provided by the CI. It is possible to calculate the absolute beam and target positions using SVD reconstructed tracks information.

Number of SVD-tracks per one MHz interaction rate are in agreement with the hodoscopes measurements. This kind of SVD-data could be used on-line at the Second or Third Level Trigger [1] in order to equalize the number of tracks per wire.

Conclusions

Since 3 years now HERA-B Target Monitoring System is in continuous operation. The multi-target operation was successful. The set-up including the steering works very reliable. Interaction rate is almost equally shared among eight target wires. The charge integrator measurements are in a very good agreement with the hodoscopes. Developed Target Monitoring

System appear to be a powerful tool for the interaction rate monitoring and target steering for different experiments with fixed target at storage rings.

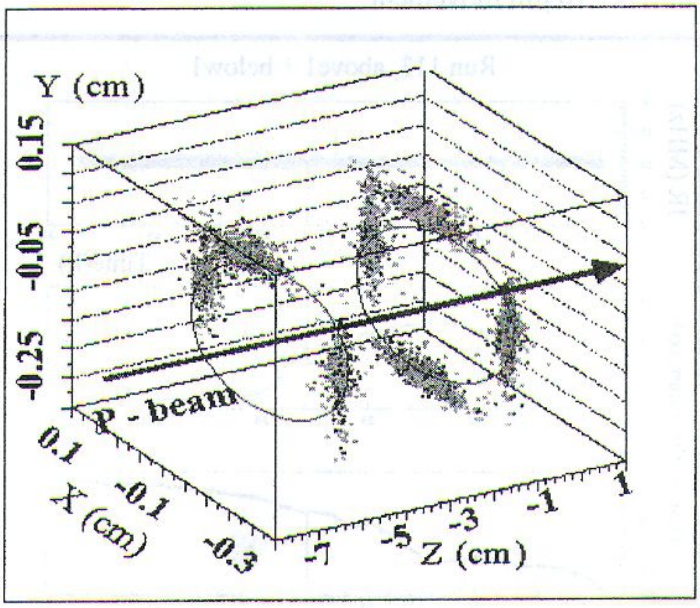

Fig. 8. Vertices distributed over all 7 inserted targets seen by the SVD.

Acknowledgments

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СИСТЕМА МОНІТОРУВАННЯ МІШЕНІ В ЕКСПЕРИМЕНТІ HERA-B. УПРАВЛІННЯ БАГАТЬМА МІШЕНЯМИ

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Досліджувалась работа восьми мішеней у режимі одночасної роботи, використовуючи розроблену систему моніторування мішені. Внутрішня HERA-B мішень складається з восьми мішенних стрічок, встановлених навколо пучка. Кожна мішень може незалежно рухатись у радіальному напрямку з субмікронним кроком, щоб компенсувати просторову нестабільність пучка з метою підтримки бажаної частоти взаємодії. Умовою проведення експерименту є стабільність частоти взаємодії та її рівномірний розподіл серед усіх введених мішеней. Це забезпечується шляхом вимірювання заряду, що генерується при взаємодії пучка з мішенями. Створена система показує хорошу лінійність з частотою взаємодії й дозволяє здійснювати прийнятний її розподіл серед декількох мішеней. Для перевірки функціонування системи управління мішенями на основі даних вершинного детектора проведено реконструювання треків та початкових вершин.

СИСТЕМА МОНИТОРИРОВАНИЯ МИШЕНИ В ЭКСПЕРИМЕНТЕ HERA-B. УПРАВЛЕНИЕ МНОГИМИ МИШЕНЯМИ

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Исследовалась работа восьми мишеней в режиме одновременной работы, используя разработанную систему мониторирования мишени. Внутренняя HERA-B мишень состоит из восьми мишенных полос, установленных вокруг пучка. Каждая мишень может независимо двигаться в радиальном направлении с субмикронным шагом, чтобы компенсировать пространственную нестабильность пучка с целью поддержки требуемой частоты взаимодействия. Стабильность частоты взаимодействия и ее равномерное распределение между всеми введенными мишенями является одним из условий проведения эксперимента. Это обеспечивается путем измерения заряда, генерируемого при взаимодействии пучка с мишенями. Созданная система показывает хорошую линейность с частотой взаимодействия и позволяет осуществлять приемлемое ее распределение между несколькими мишенями. Для контроля функционирования системы управления мишенями на основе данных вершинного детектора проведена реконструкция треков и начальных вершин.