ELECTRON BEAM DIAGNOSTIC USING BREMSSTRAHLUNG AT ELECTRON-PROTON COLLIDER

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Abstract

At an electron-proton collider electromagnetic interaction of electrons with counter protons produces bremsstrahlung. Now this radiation is widely used for collider luminosity measurement. Bremsstrahlung photons distribution can be used also for measurement of electron beam divergence at interaction point. Comparison of bremsstrahlung angular distribution and electron beam angular spread is given for energy range typical for the electron-proton collider HERA. The counter proton beam is a strongly inhomogeneous target. It makes possible determination of relative position of electron and proton bunches at the interaction point in the transverse plane. Experimental data for the photon and the electron hodoscopes of the luminosity monitor of the H1 Detector at the electron-proton collider HERA were used for electron beam parameter extraction.

1 INTRODUCTION

In the electron-proton storage ring HERA at DESY laboratory in Hamburg 27.5 GeV electrons collide with 820 GeV protons [1]. One of the fundamental characteristics of a beam circulating in a storage ring is its transverse emittance $\varepsilon_{x,y}$. The beam transverse sizes modulation along the circular accelerator orbit is described by β-function which takes maximum values at the interaction points. Operation with positron beam in contrast to electron beam provides significantly larger beam life time.

For a measurement of a luminosity of electron proton collisions by bremsstrahlung process at the H1 detector of the electron-proton collider HERA the luminosity monitor is used [2].

1.1 Bremsstrahlung properties

Characteristic angle of the bremsstrahlung is $\sim \gamma^{-1} = m_e/E_e$, where m_e is the electron rest mass and E_e is the energy of the radiating electron. For $E_e = 27.5\,GeV$ this angle is equal to $0.18 \cdot 10^{-4}\,rad$.

2 THE EXPERIMENTAL SETUP

2.1 The luminosity monitor of the H1 Detector at HERA

The photon detector together with the electron tagger are used for the luminosity measurement by using the bremsstrahlung of circulating electrons on contrary protons [2]. By means of two total absorption cherenkov hodoscopes simultaneous detection of bremsstrahlung photons and scattered electrons is brought off.

Photon detector (PD) and electron tagger (ET) consist respectively of 25 and 49 separated modules with KRS-15 crystal as the radiator and FEU-147 photomultiplier as the viewer assembled in the square matrixes. Radiation length of KRS-15 crystal $X_0 = 0.92\,cm$, Moliere radius $R_m = 2.1\,cm$. Longitudinal radiator size ($l = 200\,mm, l > 20X_0$) provides nearly total absorption of electromagnetic shower in the detector. The transverse radiator sizes are $20 \times 20\,mm^2$ for PD and $22 \times 22\,mm^2$ [3].

2.2 Experimental technique

Photons distribution in the transverse plane of the photon detector carries out an information about geometric parameters of electron beam at interaction point such as angular spread, position and orientation of the beam axis.

3 DATA PROCESSING

For the positron beam parameters determination the data sample recorded by the luminosity monitor of the H1 detector at collider HERA at the end of 1995 year with positron beam was used. Preliminary events with summary positron and photon energy $E_e + E_\gamma$ deviating from mean value no more then $\pm 3\,GeV$ were selected. For the particle energy determination and finding of particle impact point at detector the algorithm developed in [4] was used. During reconstruction the iteration procedure was continued until displacement of reconstruction input particle point position with respect to obtained on previous step became less then $\varepsilon = 0.2$ mm or iteration number N was not exceeding $N_{max} = 20$. The energy and spatial distributions for photons and electrons entering PD and ET were constructed. Our results are in an agreement with the data presented in [5].

4 RESULTS OF THE MEASUREMENTS

Energy range of detected electrons determined by the ET acceptance extends from 6 to 21 GeV. Secondary electron energy distribution has a maximum at 15.5 GeV. Fig. 1 shows the spatial photons distribution for 1292 events, recorded by the photon detector. The cross-section of the photon beam by the transverse plane of the detector has elliptical form. The ellipse center is displaced with respect to the monitor center on - 10 mm in horizontal direction and on - 2 mm in vertical direction.

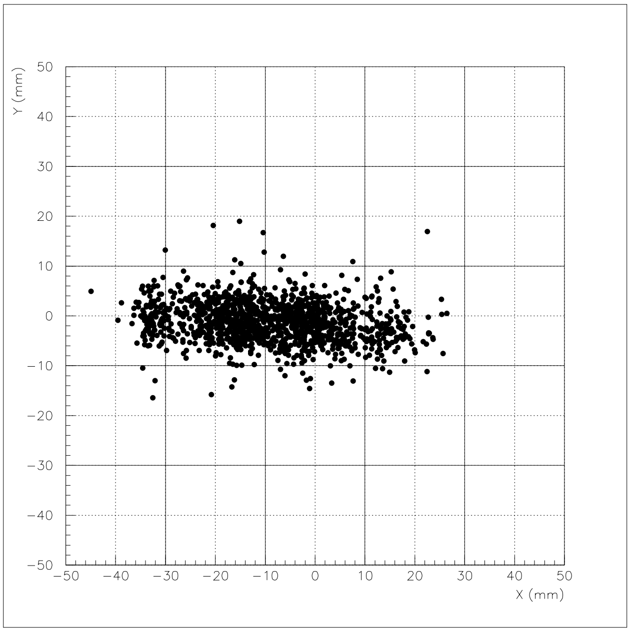

Figure 1: Spatial distribution of the photons at the photon detector

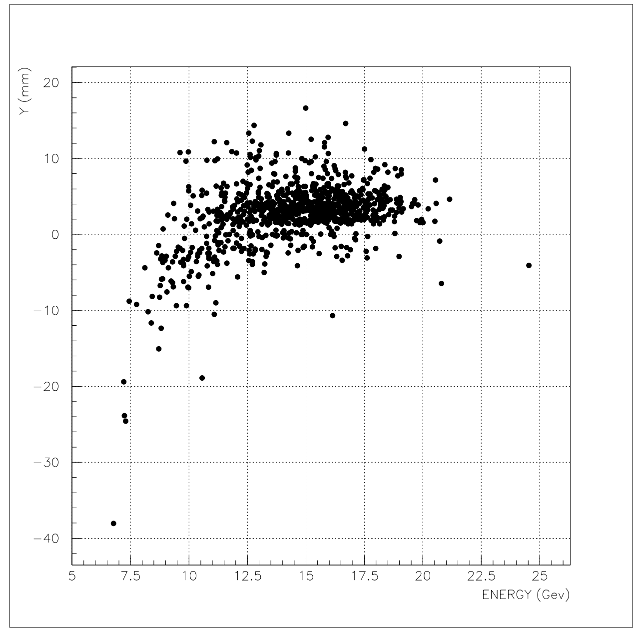

Figure 2: Dependence of electron vertical displacement at electron tagger plane on electron energy

4.1 Beams characteristics at interaction point

Photon distribution at the front PD plane can be fitted by Gaussians. As a result one can find for horizontal and vertical spread respectively $\sigma_{x'} = 1.23 \cdot 10^{-4}\, rad$, $\sigma_{y'} = 0.34 \cdot 10^{-4}\, rad$. The ratio of axes of the angular ellipse is equal to $\sigma_{x'}/\sigma_{y'} = 3.62$. These values are in good agreement with values given for design parameters of collider HERA. [6]: $\sigma_{x'} = 1.40 \cdot 10^{-4} rad$, $\sigma_{y'} = 0.40 \cdot 10^{-4} rad$, $\sigma_{x'}/\sigma_{y'} = 3.48$.

4.2 Electron beam focusing at electron tagger

A description of the HERA straight section magnetic optics is presented in [7]. Electron beam in the HERA storage ring close to the ET position has simultaneously a vertical and a horizontal crossover. At the crossover the horizontal beam size has maximum value and on the contrary vertical one has a minimum. The dispersion function at the same point has a local maximum. For the secondary electrons having due to breamsstrahlung photon emission lower energy compare with the primary electrons the crossover position is shifted in the direction of the interaction point. And under certain conditions it can coincide with the front plane of the ET. It was found through the computer simulation by means of the TRANSPORT code that at the given ET position effect of the maximum vertical focusing will take place for electrons falling into the 12.0 - 13.0 GeV energy range.

Low energy electrons ($E_e < 12\, GeV$) a rather sensitive to a machine misalignment and to effects of coherent interaction with electromagnetic fields of own electron bunch and with colliding proton bunch field. Fig. 2 shows a dependence of electron vertical displacement at electron tagger plane on electron energy. Deflection of low energy electrons from collider middle plane is clear seen.

4.3 Connection between electron and photon beams angular characteristics

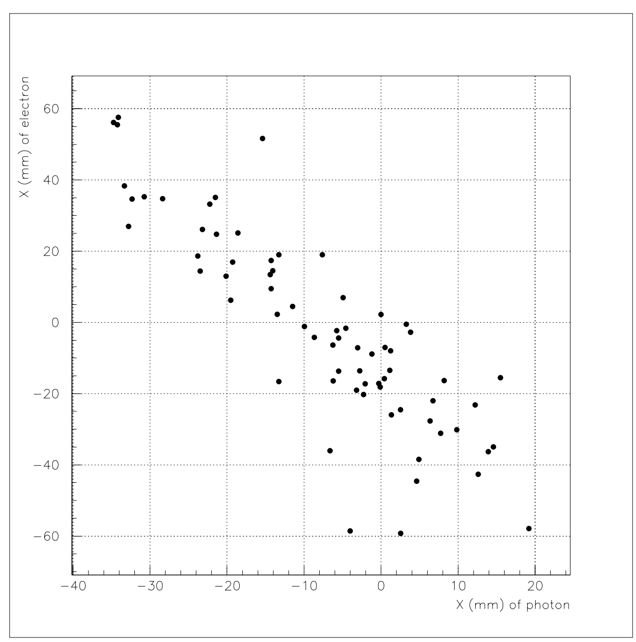

Figure 3: Scatter plot of the horizontal displacement of the bremsstrahlung photons at PD vs the horizontal displacement of the secondary electrons at ET

The horizontal electron angular spread $\sigma_{x'}$ at the interaction point is much bigger than the characteristic angle of the bremsstrahlung $\sim \gamma^{-1}$ The correlation between horizontal displacements of electrons and photons at ET and PD detectors is shown at Fig. 3. The electron energy takes a value in the interval 12.1GeV $< E_e < 12.9$ Gev. An attraction of the points to a straight line is clearly seen.

5 CONCLUSIONS

5.1 Proton beam as a target

It should be noted that the contrary proton beam represents a highly inhomogeneous in vertical direction target. A displacement of the electron beam axis in this direction relative to the proton beam axis results in partial beams overlapping a therefore can make a vertical breamsstrahlung photons distribution narrower.

5.2 Pilot bunch electron breamsstrahlung

Information on relative electron and proton beams axes position at the interaction point can be received from comparison of form and position of the photon beam radiated on relativistics protons with the photon beam emitted by pilot bunch electrons on residual gas atoms.

5.3 Spin effects

Another interesting manifestation of difference beam-beam interaction for colliding and pilot bunches could be essential difference of polarization degree for these two types bunches. It is clear that for high polarization degree achievement careful storage ring magnetic structure tuning is required, however the tune rather difficult to make simultaneously for colliding and pilot bunches.

6 ACKNOWLEDGEMENTS

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