# Luminosity estimation in $a0$ January 2001 beam time

**S. Dymov, V. Komarov, A. Petrus, Yu. Uzikov**

**Abstract**

Luminosity during $a0$ January 2001 beam time is estimated using $pp$ elastic scattering reaction with one proton registed in the ANKE forward detector. The value found is $L = 1.4 - 1.9 \times 10^{31}$ sec$^{-1}$cm$^{-2}$.

## 1 Method

The data used were obtained with $H_2$ cluster target, at 2.65 GeV proton beam energy (run 3350). The estimation was done using $pp$ elastic scattering reaction. We selected events belonging to $pp \to pp$ among the data taken with forward detector (FD) alone trigger and calculated luminosity using data on differential cross section of this reaction. Acceptance of FD for $pp \to pp$ elastic reaction, registration efficiency and DAQ efficiency were considered.

## 2 Differential cross section and acceptance calculation

The cross section of $pp$ elastic scattering at this beam energy was calculated by Yu. Uzikov with SAID program. It shows a good agreement with existing experimental data.

Acceptance was calculated by a GEANT-based simulation program, that includes a realistic description of D2 dipole and FD. Measured magnetic field map was used together with the calculated one. The program showed a good coincidence of simulation results with experimental data taken during April00, September00 and January00 beam times. 1.500.000 events of $pp$ elastic kinematics were generated and traced through the setup, with $\theta$ LAB of the forward emitted proton taken evenly in the range $(0 - 15^0)$, and $\phi$ LAB evenly in the range $(0 - 2\pi)$.

The criteria for accepting an event during the simulation were:

- A particle emitted does not hit D2 constructional elements (particularly the poles)
- It crossed the forward exit window of D2.
- It crosses sensitive region of forward MWPC1 ad MWPC2, that is, the number of wire hit calculated by the track crossing point coordinate is in the valid range.
- It crossed the first plane of FD hodoscope, what corresponds to the hardware trigger condition.

In result we obtained dependency of acceptance on $\theta$ LAB, showed in figure 1. The limit values of $\theta$ coincide well with experimental data.

# 3 Selection of $pp$ elastic events in experimental data

Because this reaction has a very big cross section and is not suppressed much by the setup acceptance, it is easily observable on momentum (see figure 2), missing mass and acceptance experimental spectra and as easily selectable.

Although momentum reconstruction shows good results for these data, there is a certain deviation of reconstructed values from the reaction kinematics increasing with $\theta$. For this reason we did not select events belonging to the reaction by missing mass value but built momentum distributions for different ranges of $\theta$ and chose the correspondent cuts on the momentum value. One of these distributions is shown on figure 3.

According to the acceptance angular dependency we took the region of $\theta = (5.5 - 9^0)$ where acceptance changes smoothly, and divided it into sectors $\Delta\theta = 0.5$ degree wide. Then the elastic peak region on momentum spectra was fitted by sum of gauss distribution with inclined line, and events were selected within $2\sigma$ from the fitted average momentum value.

# 4 Estimation of detector registration and track reconstruction inefficiency

The track search algorithm used required timing information from neibouring counters of two FD hodoscope planes ( at least one counter from each plane) and wire hits on FD MWPC1 and MWPC2 wire sensitive planes.

Run 3350 contains 917711 event with FD trigger. 803578, or 87.6% of them fulfill the requirement on timing presence. The rest was considered as background that does not pass the second hodoscope plane (hardware trigger used only the first one).

From these 803578 events only 235281 event has required hits on sensitive planes. Here we must consider estimation of MWPC registration efficiency. At the moment two estimates exist: one of them was obtained for a certain region of the MWPC sensitive area (approximately in the middle), for another we considered only correlation between hits presence on different SP's without requiring any geometrical criteria.

The first method has been implemented by A. Petrus and yields the following efficiencies of SP during this run: Eff. X1W= 84.5%, Eff. Y1W= 76.7%, Eff. X2W= 86%, Eff. Y2W= 98%, what gives 54.6% in product.

The second method gives Eff. X1W= 87.4%, Eff. Y1W= 69.2%, Eff. X2W= 71.7%, Eff. Y2W= 97.3%, and 42.2% in product.

In future the MWPC efficiency will be studied in a more detailed way, but currently the difference of this numbers gives us uncertainty in luminosity value that is probably comparable with uncertainty caused by other factors.

One can notice that the loss of events from 803578 to 235281 can not be explained only by MWPC inefficiency, some at least 30% of triggers are lost due to a different reason. Comparison of count rates of hodoscope and the trigger chamber (that has a stable high registration efficiency), positioned between the D2 exit window and MWPC1, shows roughly the same 30% difference. That means that most of those events are not coming from the exit window.

Next, the track geometrical criteria were applied, that resulted in fall from 235281 events to 147531, or 37% reduction. Those criteria are:

- Horizontal and vertical limitation on track coordinate on the D2 exit window. We required track to cross the window within the window or not more than 2 cm beyond. The horizontal limitation cuts off $\approx 5\%$ events, the vertical one $< 1\%$. Although the exit window edges are not seen clearly on correspondent track coordinate distributions (see figure 4), correlation between the horizontal track coordinate region and $Y'Y$ (see below) distribution shows correctness of these cuts.

- Vertical cut on the target ($Y'Y$ distribution). This distribution is a scatter plot of vertical track coordinate (on the exit window) and projection of the track angle with Z axis onto YZ plane (see figure 5). The region populated by events coming from the target is clearly seen on this picture, the cuts applied are shown as lines. This criterion rejects $\approx 30\%$ of tracks with very few of useful ones.

- Horizontal and vertical limitation on track coordinate on the counter fired surface. This criterion uses coordinate calibration of counter time Up and Low signal difference, obtained on data. In horizontal plane a track is permitted to miss counter not more than 1 cm, and $3\sigma$ cut is applied on the vertical coordinate. The distributions of the points of track crossing with the counter fired show that the counters are seen shifted not more than 0.5 cm from the expected position. This criteria reject only $\approx 1-2\%$ of events.

Concluding, we can say that the loss of useful events because of the track geometrical cuts can be estimated as less then $1-2\%$ and is neglectable.

# 5 Estimation of DAQ inefficiency, correction on beam cycle intervals

To do these corrections we used scaler information on FD trigger in and scaler events time stamp together with counting the number of FD trigger out. In figure 6 distribution of FD trigger in (reduced by 999) and FD trigger out is shown versus time (the values are averaged in 10 sec intervals). For every second we considered the number of FD triggers out, demanding it to be greater then 100. In this case we summed this second (second as well as microsecond timing information was used), number of triggers in, number of triggers out and number of accepted *pp* elastic events that happened during this time, to the correspondent accumulators.

In result, for run 3350, that lasted during 2 h and 32 min, useful time interval was $\Delta T = 8027.71$ sec $\approx$ 2 h 14 min, what coincides well with cycle intervals fraction ($\approx$ 40 sec of 300 sec).

During these 8027.71 sec $1.736 \times 10^6$ pre-scaled FD triggers in was found, that is $1.734 \times 10^9$ triggers in totally, and 916676 FD triggers out. This gives ratio (Trigger in)/(Trigger out) = 1891.6. At the same time 27409 elastic events were selected with $\theta = (5.5 - 9^0)$ within $2\sigma$ momentum cut, that is, 28719 elastic events reconstructed in this angular region.

# 6 Luminosity calculation

If we neglect all the detection inefficiencies except the MPWC inefficiency and (Trigger in)/(Trigger out) ratio we get the rate of $pp$ elastic ejectile protons emitted in FD acceptance $n = \frac{28719 \times 1891.6}{0.422 \times 8027.71} \approx 16035.7$ sec$^{-1}$ (taking MWPC efficiency 42.2%).

The differential cross section integral with acceptance function, calculated within $\theta = (5.5 - 9^0)$ is equal 0.862822 mb. This gives us luminosity equal to $L = 1.86 \times 10^{31}$ sec$^{-1}$cm$^{-2}$. Taking MWPC efficiency 54.6% we get $L = 1.43 \times 10^{31}$ sec$^{-1}$cm$^{-2}$.

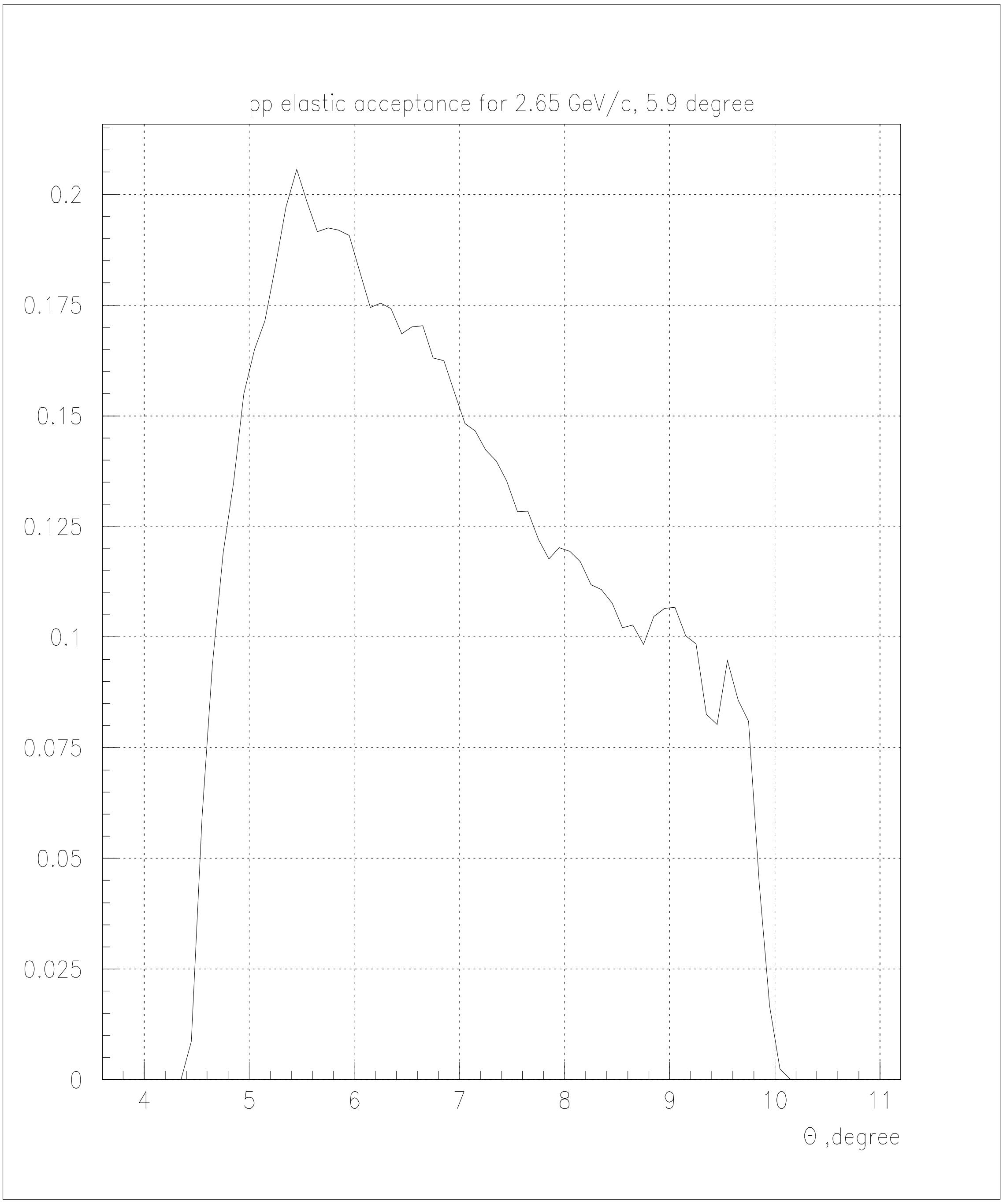


Figure 1: FD acceptance of $pp$ elastic

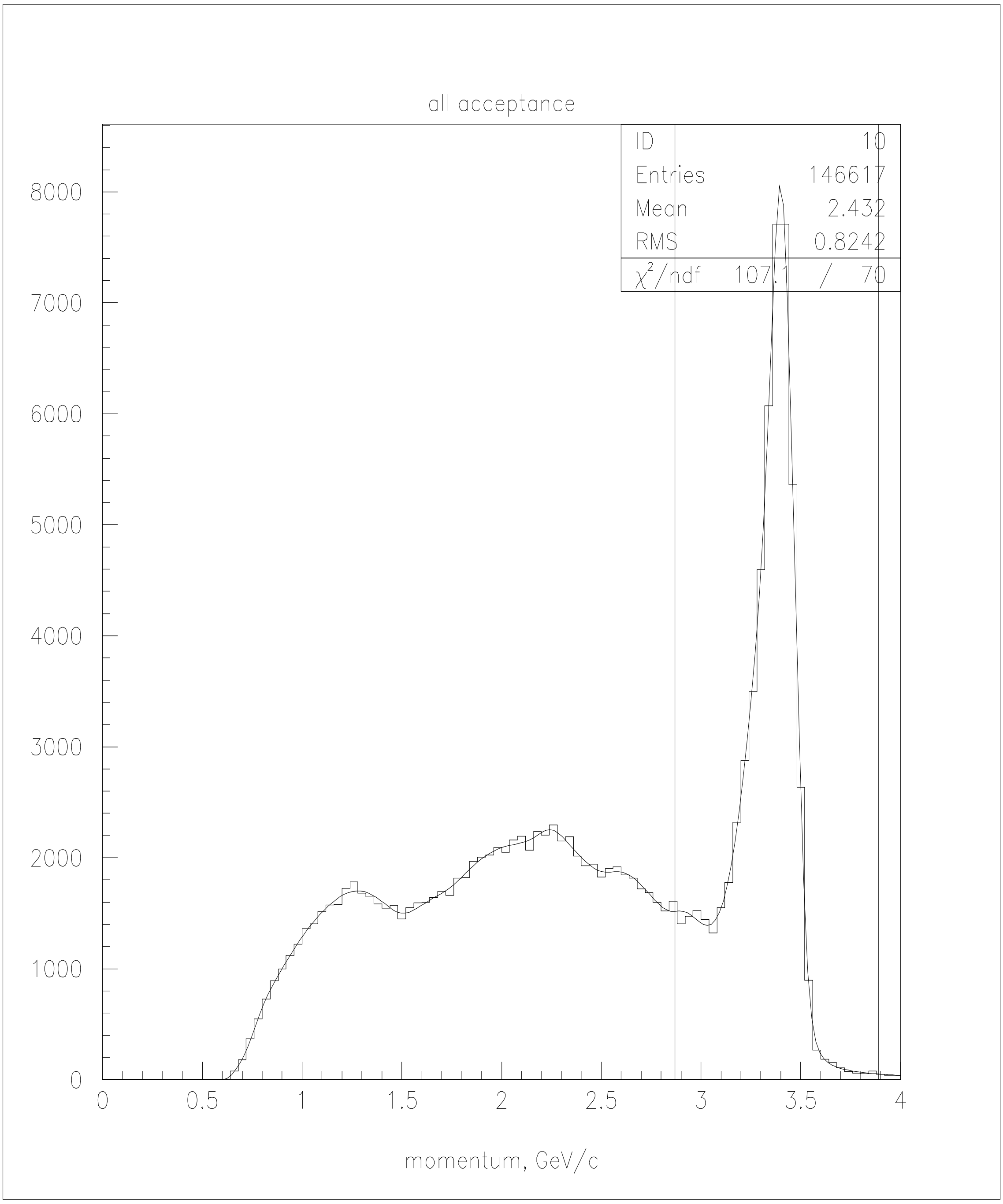


Figure 2: momentum distribution in FD

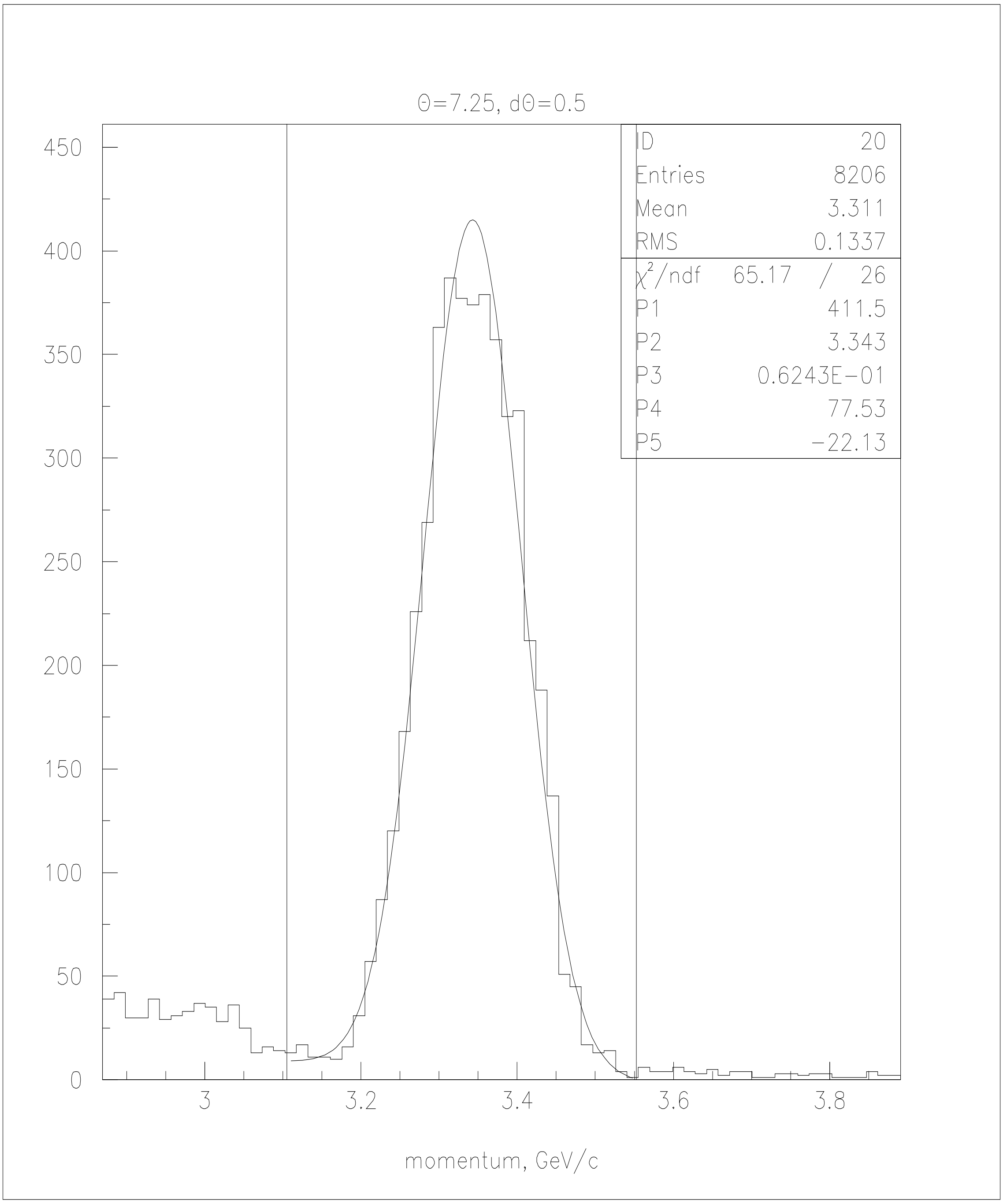


Figure 3: momentum distribution in FD, $\theta = (7 - 7.5^0)$, $pp$ elastic region

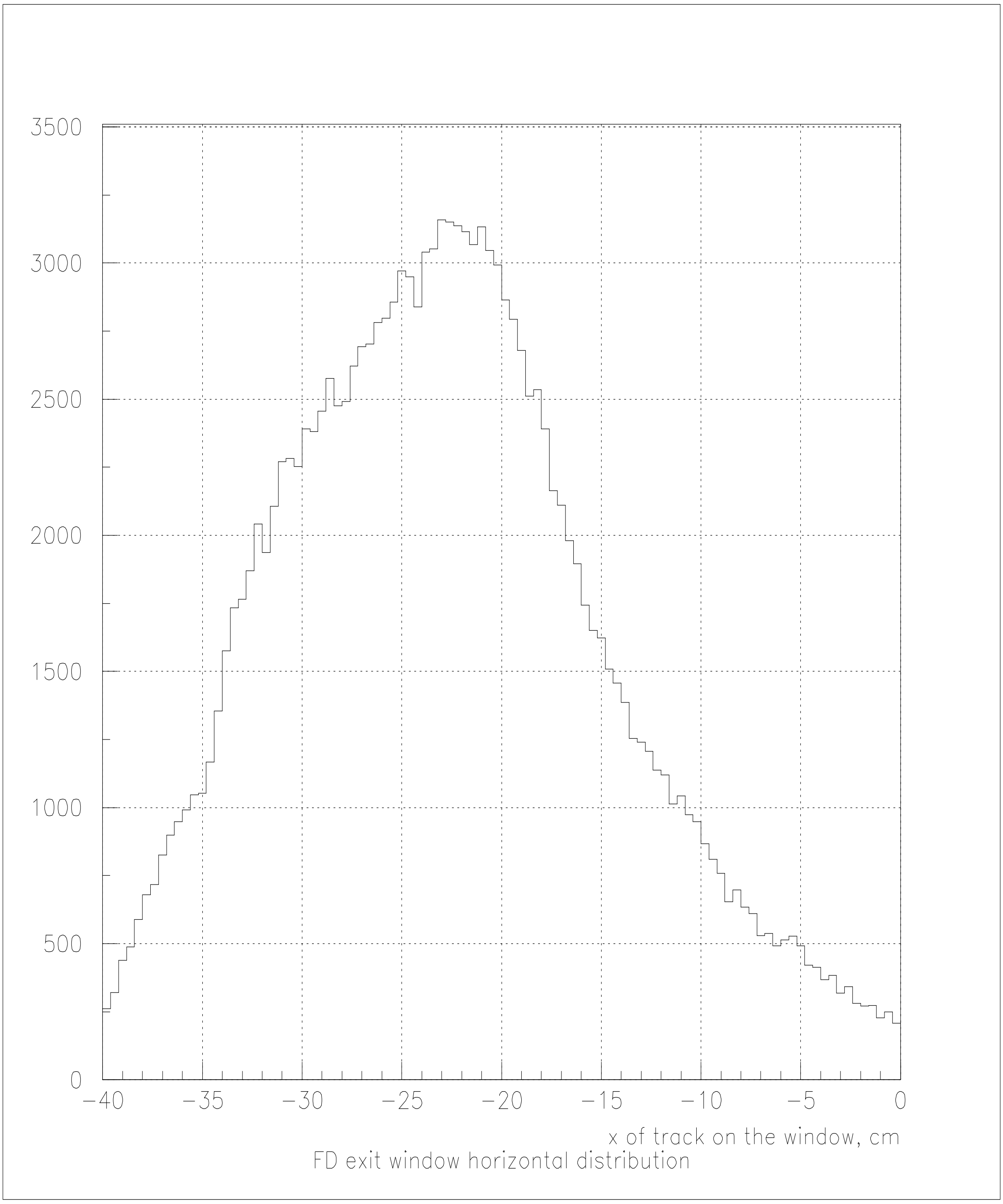


Figure 4: The window is positioned from -10 to -34 cm

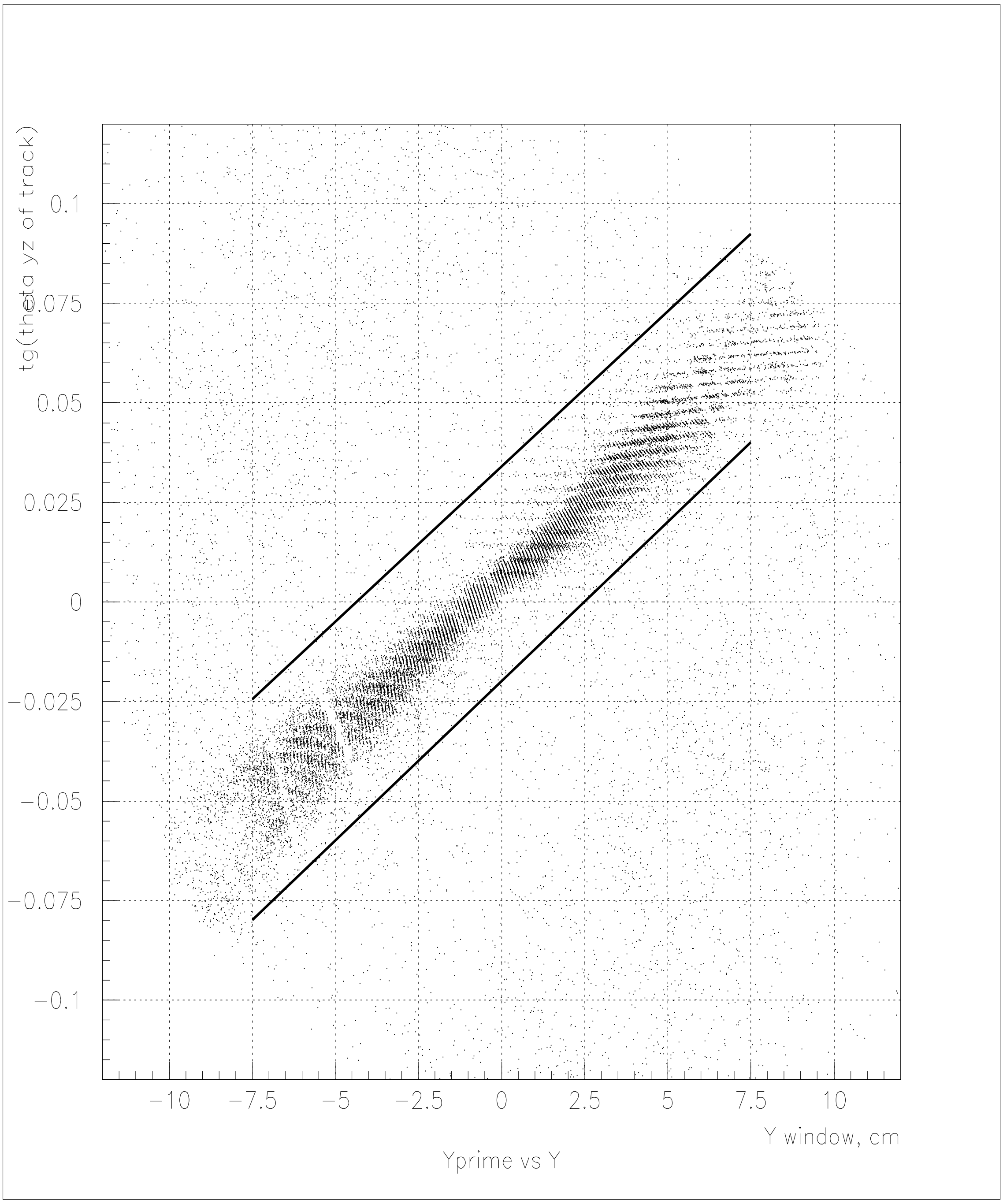


Figure 5: Vertical cut on the target

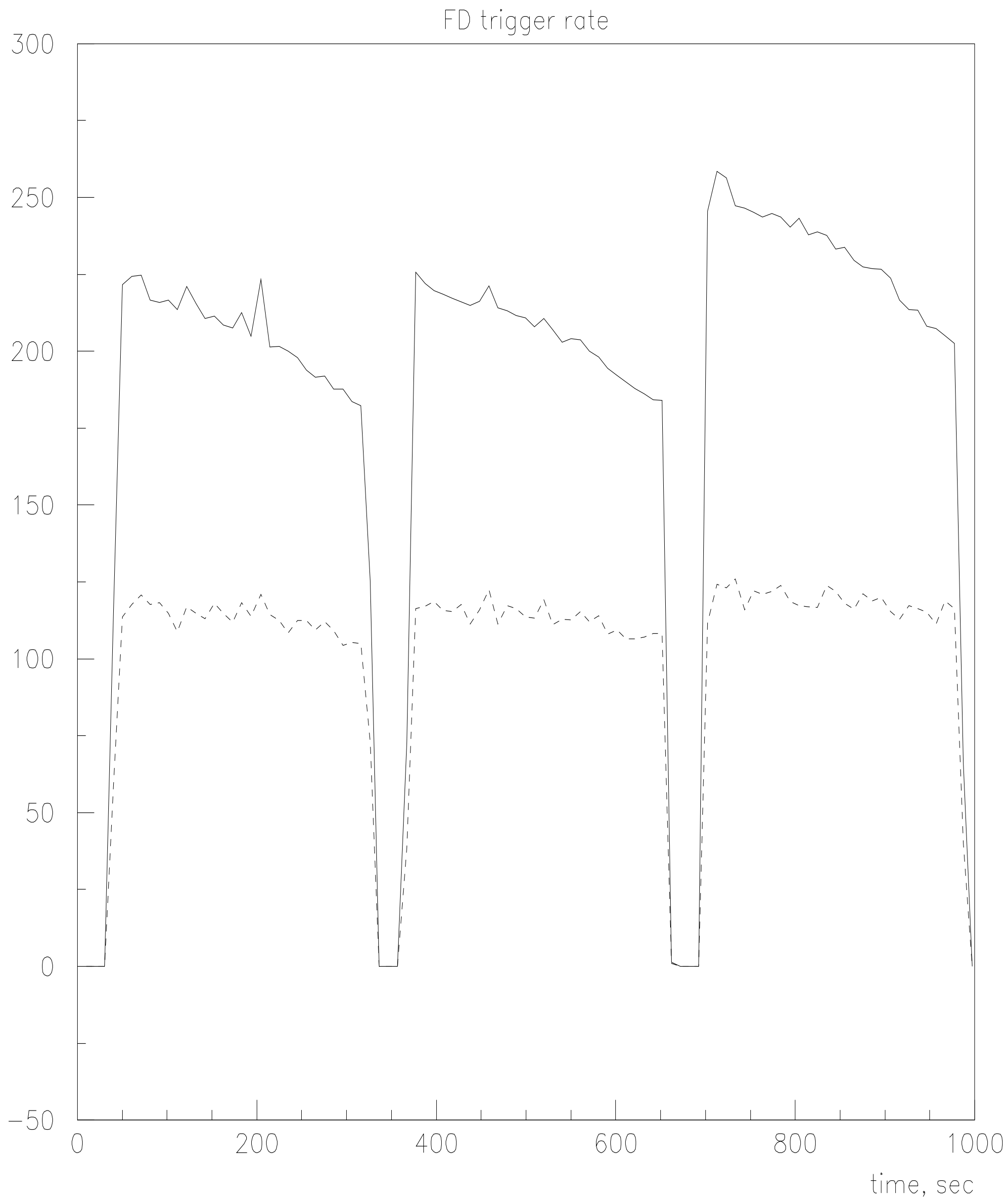


Figure 6: FD trigger out (/999, solid line) and trigger in (dashed line) rates