ISR-BT/BdeR/EEK 12th November 1970

ISR RUNNING-IN

Runs 3, 4, 5 on November 6, and 9 1970

Results of some injection studies and measurement of $Q_V = Q_V$ (r)

1. Injection onto different orbits

The average radial position of the injection orbit as derived from the measured revolution frequency during the previous runs, was <r> =-15.9 mm. The aim of this experiment was firstly to inject onto an orbit close to the nominal injection orbit given in the ISR parameter list and secondly to inject onto the central orbit.

When we aimed at the nominal injection orbit of the parameter list, the frequency measurement gave the result <r> =-34.8 mm.

When we aimed at the central orbit, the frequency measurement gave the result <r> = + 2.6 mm. Two more measurements were made in the vicinity of the central orbit. The results are summarized in Table I below. The first column of this table lists the parameter p (B_o) which is the value of p displayed on the CRT of the field display and which corresponds to the momentum of a proton circulating on the central orbit of the ISR, as computed from the magnetic field measurements.

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Table I, Radial position of injection orbit using the wrong proton velocity

$p(B_o)$	<r>
15. 343 GeV/c	- 35.2 mm
15.175 GeV/c	- 15.9 mm
15.061 GeV/c	- 1.2 mm
15.041 GeV/c	+ 2.6 mm
15.020 GeV/c	+ 3.8 mm

This table suggests that one would inject onto the central orbit when $p(B_o) = 15.055$ GeV/c. However, this fact implies at the same time that the Table is wrong, since the computer printout used in making this table assumed that the proton velocity was that of protons with p = 15.000 GeV/c. The proton velocity changes with the momentum through the relation

$$\Delta\beta = \frac{1}{\gamma^2} \frac{\Delta p}{p}$$

For an increase in momentum $\Delta p/p = 0.055/\ 15 \approx 3.6 \times 10^{-3}$ and with j = 16.1 one finds $\Delta\beta \approx 1.4 \times 10^{-5}$, corresponding to an error in average radius of 2.1 mm. We nevertheless have given first the wrong results of Table I, to enable other people, who have used the same uncorrected data, to make an easy comparision with Table II, which gives the correct radial positions, calculated by K. Hübner, assuming that the value of $p(B_o)$ is correct and using the actual velocity of the protons from the PS, which are now believed to have a true momentum of 15.08 GeV/c. It can be seen that actual value of <r> is always 3 mm larger than the one read by Hansen in his printout for 15.000 GeV/c protons.

Table II. Radial position of injection orbits using the correct proton velocity

$p(B_o)$	< r >	r (715)	HV of inflector	Q_H	Q_V
15.343 GeV/c	- 31.8 mm	-38.5 mm	26.5 kV	8.813	8.659
15.175	- 13.2	-16.0	33.5 kV	8.810	8.659
15.061	1.7	2.1			
15.041	6.1	7.4	40.4 kV	8.810	8.660
15.020	6.7	8.1			

The data of Table II are also shown in Fig. 1.

The average value of the momentum compation function around the ISR is α_p (av) $\simeq$ 1.865 m. The maximum value is 2.28 m and occurs in ss 733, but at that place β_H = 18 m. The maximum aperture requirement occurs at the upstream end of unit F 715, where β_H has the maximum value of 41 m and where α_p = 2.25 m. Therefore, in addition to the values of <r> we have also given the values of the parameter

$$r\ (715) \simeq 1.21\ \langle r \rangle$$

The injection angle, as derived from the difference in horizontal beam position at LS 351 and LS 352 scaled in the manner that would be expected for different values of <r>. The same is true for the HV on the pfn of the inflector which is given in the 4th column of Table II. It can be seen, that we can inject just a bit beyond the central orbit if we do not want to exceed the design voltage of 40 kV.

At three radial positions of the injection orbit the values of Q_H and Q_V were measured by S. Hansen. The results are given in the last two columns of Table II.

2. Measurements of Q_V across the aperture

To measure Q_V in the region r > o, which cannot be reached by the injection system, the beam was injected with the display set to $p(B_o) = 15.061$ GeV/c and then accelerated by the RFsystem until the desired radial position was reached. The frequency of the RF system was then kept constant, so that the bunched beam continued to circulate on this orbit. Subsequently the beam was given a vertical kick by pulsing one of the four dump magnets at the reduced voltage of 5 kV. The Q-value was then obtained by taking a photograph of the resulting coherent oscillations and by measuring the frequency with the Q-meter. These measurements were made respectively by Rochepeau and Hansen. The maximum difference between these two methods, found in 5 measurements at different <r>, was 0.004, the values given by Rochepeau always being lower. During these measurements the intensity of the injected beam was always 4 bunches and it is promising that by then the Q-meter had been adjusted already so well that it could do single shot measurements with 4 bunches, which corresponds to about 15 mA circulating beam as read on the PIDC. The results of the Q_V - measurements, that is the average of Rochepeau's and Hansen's measurements, are shown in Fig. 2, which also includes the data obtained when injecting onto orbits at r < o. The values of <r> were calculated by Hübner, using the correct proton velocity.

3. Vertical closed orbit position in the inflector

During run 5 a measurement was made of the vertical c.o. position and the available vertical aperture in the inflector FK. This was done by displacing the FK vertically, parallel to iself,with repetitive injection and by measuring on the PIDC the number of protons of each injected pulse which survived as a circulating beam. The results are shown in Fig. 3. Comparing the left and right hand side slope of the curve one sees that the vertical c.o. in the inflector is at $z = -0.5$ mm and this is the position that will be used in run 6 etc.

The loss in circulating beam current is 5% for $z = -5.0$ mm and $z = +4.3$ mm. The nominal vertical aperture of FK is 20 mm, but after subtracting shims and non-straightness the effective aperture is about 19 mm. The results therefore indicate a vertical beam size in FK of 19 - 9.3 = 9.7 mm, corresponding to an emittance $\hat{z}^2/\beta = (4.85)^2/14 = 1.7$ mm x mrad. On the other hand, the vertical emittance, as measured with the SEM G monitors in the Ring, on the first turn, with the beam stopper in, and which therefore does not contain vertical injection errors, is about 0.5 mm x mrad, corresponding to a half height $\hat{z} = \sqrt{E\beta} = \sqrt{0.5 \times 14} = 2.7$ mm in FK. Most of the difference can probably be explained by the injection errors which up to now it was never tried to adjust better than an amplitude of about 2 mm.

Fig. 4 shows the output voltage of the ionisation chamber near FK, as a function of z, which was measured by S. Turner. As can be seen, even for small values of z when Fig. 3 indicates practically no beam loss, the ionisation chamber already shows a substantial signal. This discrepancy will be studied further.

4. Measurement of heating of the septum magnet chambers by the beam

The aperture of the chamber in the gap of the downstream septum magnet S 302 is smaller than that of the upstream septum magnet S301,which in turn is smaller than that of the transfer channel. Therefore beam loss is likely to occur in the septum magnets and thermocouples have been brazed on the walls of these chambers to measure heating by the beam. An injection beam of 4 bunches was displaced parallel to itself towards the wall of the gap chambers on the septum side until the intensity of the surviving beam vanished. The maximum temperature increase occurred at the upstream end of S302 and was $4^{o}C$. This corresponds to about $25^{o}C$ for 2×10^{12} protons per pulse and $125^{o}C$ for 10^{13} protons/pulse. The measurements were made by printing out every 10 seconds the temperatures of all thermocouples as measured by the analogue scanner and stored in the memory of the ARGUS computer.

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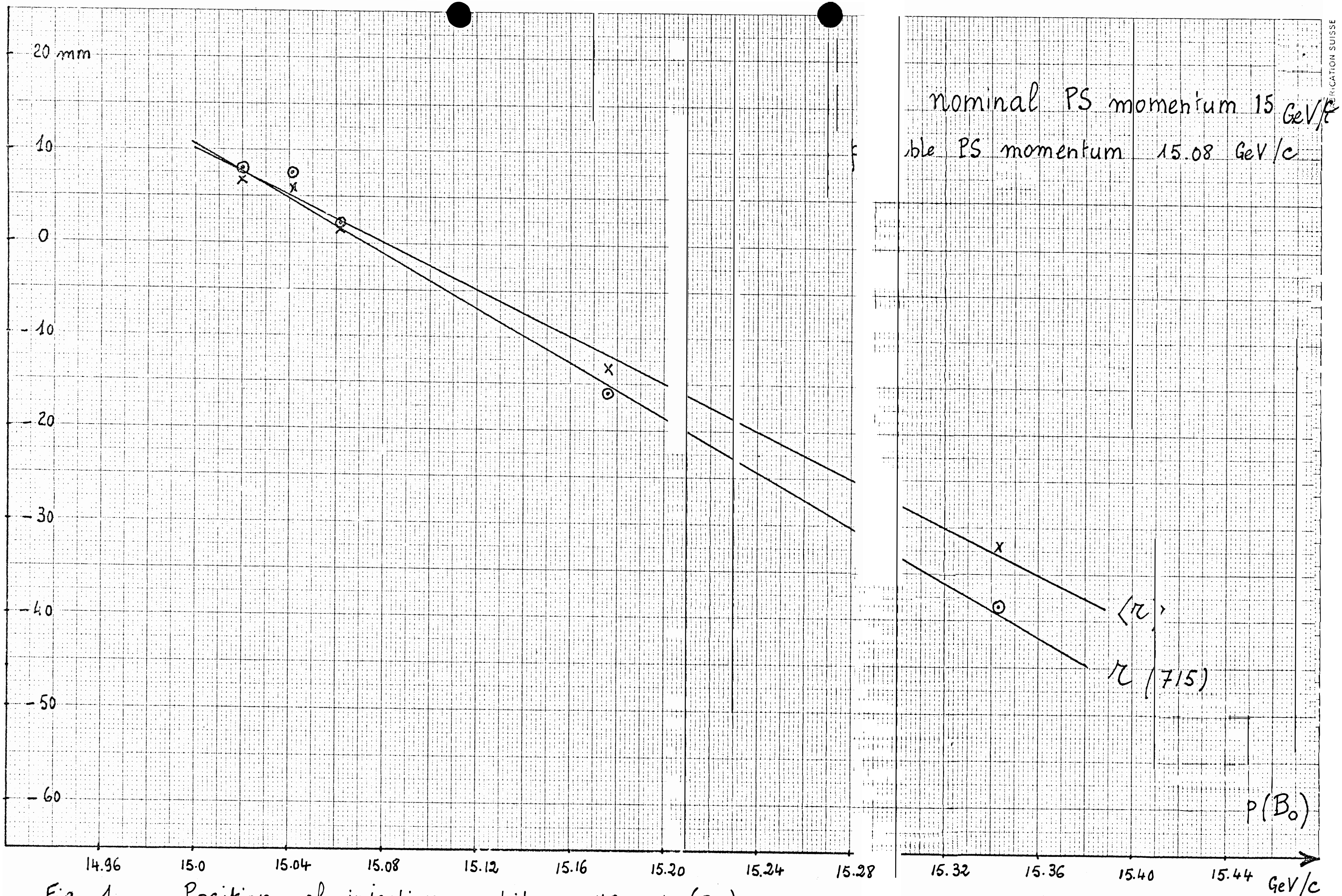
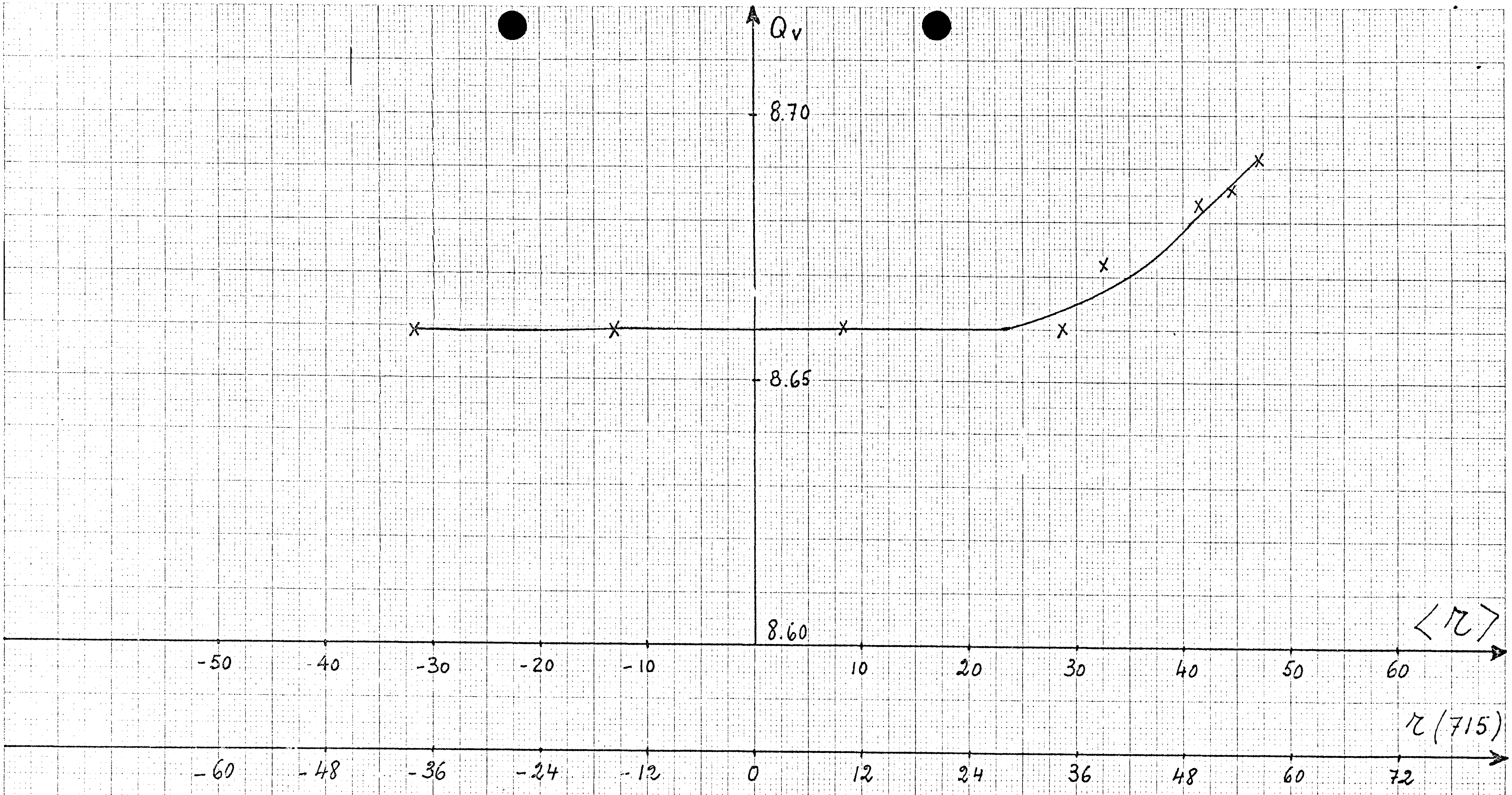


Fig. 1 Position of injection orbit vs $p\ (B_0)$



$\langle r \rangle$ = average radial position, derived from revolution frequency

$r(715) = 1.21 \langle r \rangle$ = radial position at upstream end of unit 715

Fig. 2. Q_V of Ring 1 at 15 GeV/c

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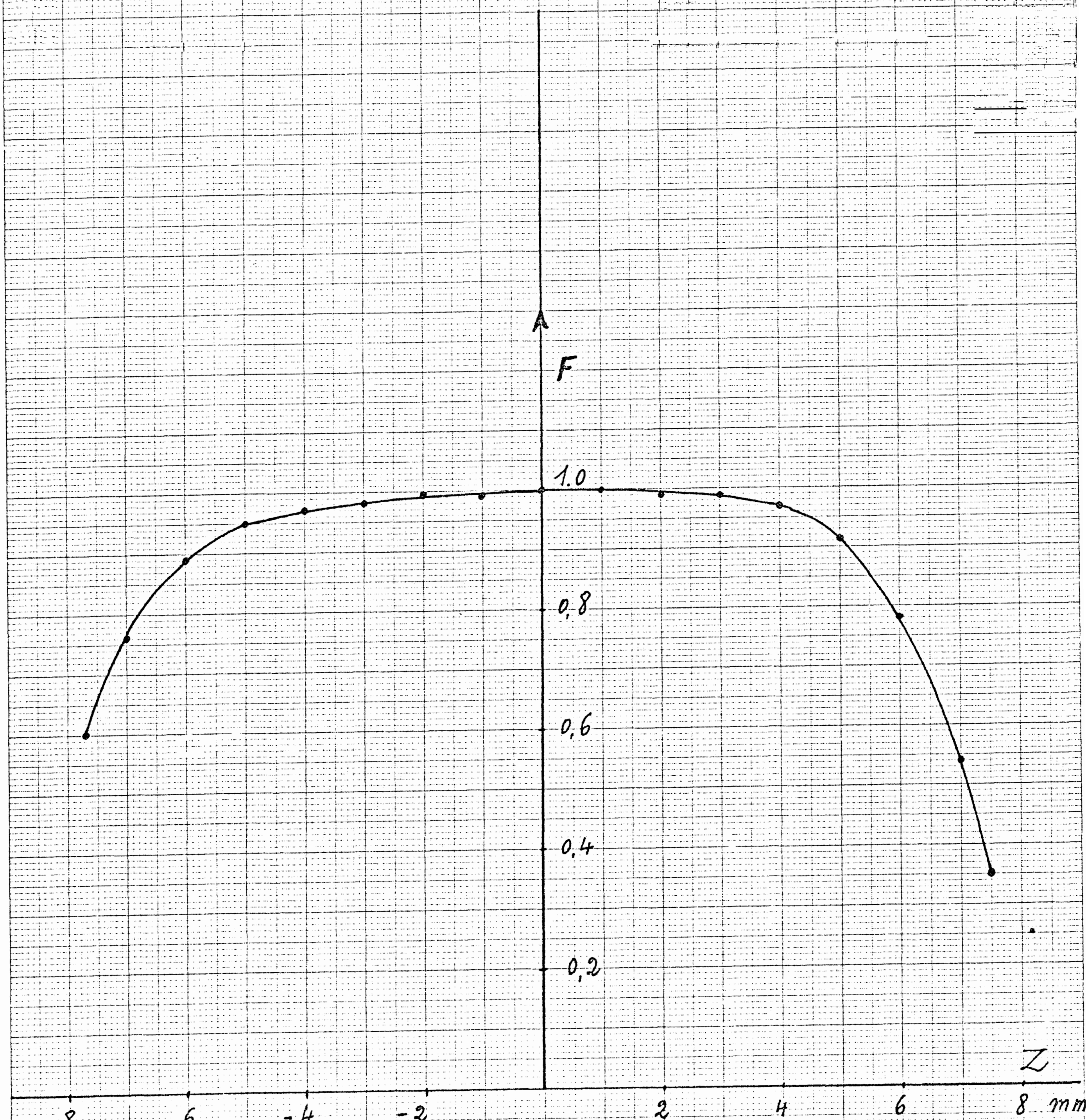

Fig. 3. Surviving circulating beam vs vertical position of FK

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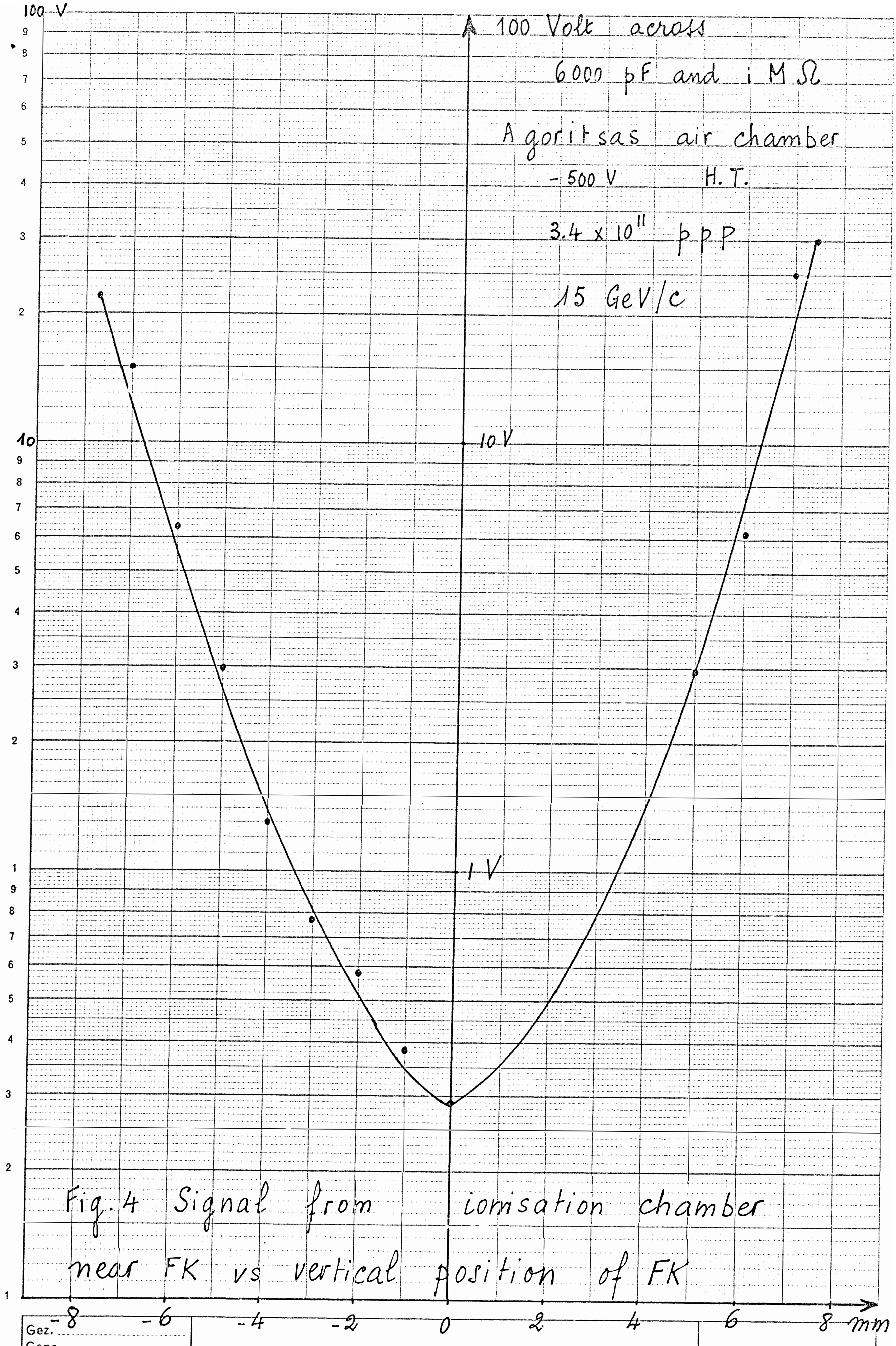

Fig. 4 Signal from ionisation chamber near FK vs vertical position of FK

Gez.
Gepr.
Ges.