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# Construction of a Large Drift Chamber and Test Measurements

by

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## Contents

## I. Introduction

To investigate scattering of charged leptons on nucleons at the highest energies available in the next years, a spectrometer is being built to be used with the 300 GeV muon beam at the CERN SPS. This spectrometer is shown in Fig. 1. It consists basicly of a large aperture magnet with lever arms to determine momentum and angle of secondary particles and a section where hadrons are absorbed and muons will be identified. The high momenta of the secondary particles and the high rate of the muon beam with its halo and the high rate of interactions in the target lead to drift chambers to measure the trajectories of the particles. Drift chambers combine high spatial resolution with small resolving time.

The measuring planes $W_1$ to $W_7$ in fig. 1 are packages of drift chambers of different sizes and geometries. DESY has undertaken the construction of the chambers $W_4$ and $W_5$, which are with an effective area of 250 x 510 $cm^2$ the largest ones in the project. These two packages together shall consist of 16 measuring planes with vertical, horizontal and 60° (to the horizontal) orientation of the sense wires. From reasons of multiplicity of particles per event and of economy the drift space for these chambers was determined to be 2 cm (distance between signal and potential wires). The required combined spatial resolution at the position of these chambers within the spectrometer is 0.6 mm FWHM. A further constraint for these chambers is a rather dense packaging in the longitudinal direction of the spectrometer to leave sufficient space for other parts of the spectrometer such as the Cerenkov counter $C_2$ and the calorimeter $H_2$.
Since there was practically no experience with chambers of this size it was necessary to built a full size prototype first. For simplicity of construction it was hoped to be able to use nongraded cathode planes. There was only a limited amount of information[1,2] that this might be possible with a drift space of 2 cm. Therefore also a small chamber of the size 30 x 30 $cm^2$ with drift spaces of 2 cm was built.
It is the purpose of this paper to show how these chambers are constructed and what the results are of a long series of test measurements.

## II. Construction of the Chambers

### 1.) The 30 x 30 $cm^2$ Chamber

To determine the properties of a drift chamber with 2 cm drift space and nongraded cathode planes a chamber with a sensitive area of 30 x 30 $cm^2$ with two signalwire planes was built. The cross section of this chamber is shown in Fig. 2. The signal wires in the two planes are displaced by one drift space to be able to solve the left right ambiguity. Otherwise the purpose of having two planes is to determine the position of particles in one plane as a reference for the other plane to measure the spatial resolution.

The two planes are separated by one cathode plane and have a common gas volume. The cathode planes are wire planes with 2 mm wire distance. Wire material and diameters are given in fig. 2. The frame material of all planes was epoxy with glass fibers and printed circuits for electrical connections. The signal wires in this small chamber were on ground potential, the cathode planes and potential wires therefore on negative high voltage.

The distance between cathode planes and signalwire planes could be varied by inserting empty frames of different thicknesses. Most of the measurements were made finally with 1 cm distance between the wire planes, thus having a cell size of 2 x 2 $cm^2$. An increase to 1,2 cm distance did not change the properties of the chamber significantly.

### 2.) The 250 x 510 $cm^2$ Chamber

The full size prototype chamber consisted of two signalwire planes and three cathode planes. The orientation of wires in the different planes is shown in Fig. 3. The cathode planes (frame No.1,3,5) are as in the case of the small chamber built with wires stretched along the smaller dimension of the frames. It was felt, that in this way the dimensions of the drift cells could be maintained more uniformly acrosss the chamber than by using for example very thin metallized foils. For reasons of multiple scattering and secon-

dary reactions it was also important to keep the amount of material small since the final chambers will be placed into the part of the spectrometer in front of the hadron absorber, where full accuracy for all charged particles must be maintained. The small angle of $5^{o}$ between the orientation of the cathode wires and the vertical direction was introduced to prevent that wires in the outer cathode planes see the full attractive force arising from the difference in the electrical potential between cathode and signal or potential wires.

To get experience with all three signalwire orientations one plane (frame no. 4) was built with two different orientations as shown in Fig. 3. Frame no. 2 contains the longest wires, which have a free length of 510 cm. They are supported by two threads to prevent too much saging through.

The frames are built such that each frame can stand the mechanical forces arising from the wires, especially from the cathode wires, with unimportant deformations. In this way the overall thickness of the chamber could be kept as small as possible. A cross section through the frames of the complete package in a stereoskopic view is shown in Fig. 4. The frame itself of each plane consists of Al MgSi, 1 x 30 $cm^2$ in cross section. The wires are mounted on small printed boards, which are glued with epoxy against the aluminum frame. The electrical connections from the signal wires to the electronic devices outside the chambers are made by short thin coaxial cables (Lemosa 732o3), which are inserted into channels going through the frame and passing underneath the O-rings necessary to make the package gas tight. At the inner end the channel with the cable inserted is made gas tight with epoxy. The cables can stand 3 kV high voltage.

The cathode planes have been wired by using a machine, where the wires are placed with the proper distance on a rotating cylinder. Then a whole section of wires is placed on the frame, while this frame is mounted on a special support frame to keep it plain. Here the proper tension is brought to this section of wires and the wires are soldered on three lines to the printed board (see fig. 4).

Each signal- and potentialwire was brought into its place individually. Their position with respect to eachother and to reference holes at the corners of the frames was optically controlled with an accuracy of the order of 10 μm. Also these wires are soldered. During the time of operation of this chamber for about 9 months no wire breaking or loosening was observed, when the chamber was closed.

The following table I gives wire materials, thicknesses and tensions:

Table I: Wires used in the chambers

| Type | Material | Diameter | Tension |
|---|---|---|---|
| Cathode | Cu-Be | 50 μm | 110 g |
| Potential | Cu Be | 100 μm | 400 g |
| Signal | Au plated W | 20 μm | 50 g |
| Support thread | braided "DRACON" | 350 μm | 1500 g |

The package of drift chambers is closed by two Hostaphanfoils of 100 μm thickness. One is glued against the outside of the cathode frame no. 1, the other against an additional frame no. 6 (see fig. 4). Gas inlets resp. outlets are in the signalwire planes on the lower resp. upper beams of the frame with connections to a manifold. Only one frame however was used at a time for gas flow during all test measurements. In the final version of the chambers inlets and outlets will be in the special foil frame no. 6 only, thus avoiding more than two types of frames.

The whole finished prototype is shown in a photograph in Fig. 5. For transportation the package of six frames is mounted on a support frame with beams of a cross section of 15 x 15 $cm^2$ as can be seen in this picture. However the package can hang without the support frame without any significant deformation.

## 3.) Cleaning of the Chambers

After carefully cleaning the frames with aceton and alcohol the wiring was done in a clean room. Filtered air flew continuously through this room of about 120 $m^2$ and 4,5 m hight with a rate of approximately one exchange per three hours. The wires were cleaned with a mixture of aceton, alcohol and frigen before being winded or stretched. During the soldering the wires were protected against splashes of the solder material. The foils were cleaned with alcohol before gluing them against the frames. Also the cathode plane no. 1 had to be cleaned first with alcohol on that side, where the foil is to be attached. Then this frame was lifted in the horizontal position by the crane with the foil on the upper side. Accordingly the foil was cleaned from dust with a stream of ionized nitrogen from underneath and the wires were cleaned with alcohol from underneath too. Then one wire plane after the other was cleaned on the upper side with alcohol (wires and frame), connected to the frames already hanging at the crane and cleaned again with alcohol from underneath. Finally the second foil was made free of dust in the same way as the first one on its upper side and with it the chamber was closed.

## 4.) Mechanical and electrical stability

It was calculated that the long beams of the cathode-frames would move together by 2,5 mm on either side due to the total force of the wires of 28o5 kg. About that before wiring the frame was preloaded by using the support frame. When the frame was disconnected from the support after wiring, no movement of the long beams of the frame and no change of wire tension within a few percent was observed.

When the whole package of six frames was screwed together it turned out to be rigid enough without a support frame to hang in the vertical position without any significant deformation. The lower long beam sag through because of its weight by 0.2 mm. The same applies to the upper beams, if the chamber is standing or connected to any lifiting device at its far corners. In all cases the long horizontal wires are pulled down by about 0.1 mm by the support threads, which are connected to the upper and lower beam. But without support threads these wires sag through by their own weight by 0.5 mm.

Before connecting the chamber to high voltage it was filled with Argon only over a period of a few days to have clean gas conditions inside. Then the chamber could stand about + 1,2 kV on the signal- and potential wires without drawing current. Above this voltage only a steady current was drawn, but no discharges occurred in the chamber.

With the operating gas mixture (see below) the voltage was increased to +2 kV at the signalwires and to -1 kV at the potentialwires. The wires were observed for movements perpendicular and parallel to the planes. Beyond the accuracy of observation of about ±50 μm no movement was observed.

## III. Measurements with a Test Beam

### 1.) Experimental Setup at the Beam

With radioactive sources it was only possible to get some qualitative information about the operation of the chambers, mainly because of too much multiple scattering in trigger counters or the chamber itself. All measurements reported here were made therefore with an high energy electron beam of several GeV from the DESY Synchrotron and with an intensity variable between $10^2$ and $10^5$ $e^-$/sec in 50 pulses per second of 5 msec length. The beam was spread over a few cm horizontally and a few mm till two cm vertically depending on the energy of the synchrotron. Collimators were used to make the cross section of the beam even smaller if necessary.

The experimental setup at the beam is shown in Fig. 6a. The beam particles were defined by a coincidence between four scintillation trigger counters which were spread along the beam over about 8 m.

The first measurements on the small 30x30 $cm^2$ chamber with a drift space of 2 cm were made by using a second chamber of the same size but with 1 cm drift space for comparison and particle definition. All measurements on the large chamber were made by using the small chamber with 2 cm drift space as a reference for one coordinate of the trajectory of the particle.

### 2.) Electronic Circuit

As was indicated already above the small chamber was operated with the signalwires on ground potential. In the large chamber however the cathode planes are on ground potential. The reason for this was to have the signal wires better shielded against signals induced from the outside. Therefore the two chambers have different connections between the signalwire and the amplifier / discriminator as shown in Fig. 6b. The threshold of the amplifier / discriminator (VD, CERN-Verweij type) was set to 0,5 mV on 50 Ohms. The next discriminator served to shape the pulse before it went into the long cable to the controlroom. Ordinary time to digital converters with a resolution of 1 nsec were used to measure the drifttime with respect to the trigger signal. The PDP 8/I computer with its connection to the IBM 360 allowed us to see the individual time spectra of the wires as well as the time correlation between two wires online. The test output of the VD amplifiers was used to register the pulse height of the wire signals in correlation to their time.

Pulses from the wires behind the 470 Ω resistor on 50 Ω, using a $Fe^{55}$ source, are shown in Fig. 7 for three different lengths of wires and at different positions of the source on the long wires. The operating voltage was about the same in all cases (2,05 kV on signal- or cathodewires, 0,9 kV or 2,95 kV on potentialwires), the gas mixture was Argon/Methan/Isobutan = 36/8/0,9 liters/hour.

In the small chamber (Fig. 7a) the rise time is 10 nsec and the pulse height about 12 mV. On the long wires the pulses are much more spread out because of the larger capacitance of the chamber. The rise time is between 10 and 20 nsec depending on the position of the source along the wire. Pictures b) and e) are at the excit or near end, c) and f) in the middle and d) and g) at the far end of the wires. The wires act as delay lines with a rather large damping because of the 1,8 Ω/cm resistance of the tungsten wire. Therefore the delay line was kept open at the far end; in this way the reflection compensates to some extent in pulse height.

As can be seen from Fig. 7 there is not much pulse height variation along the wire, even for the 510 cm wire. However some distortion occurs by the reflection at the far end, when the particles are at the near end.

### 3.) Control of Gas Flow

The proper gas mixture was made by measuring each component with a rotameter. Then the different components went into a long common hose leading to the chamber. For a certain part of the measurements a measured fraction of the argon component was lead through methylal, which was cooled by ice. Whereas the rotameters for argon and isobutan were very stable without any additional means, it was necessary to stabilize the flow of methan. This was done with fotocells at the rotameter acting on a valve. The two chambers were in the same gas stream normally, the small chamber in front of the large one.

## IV. Results of the Measurements

### 1.) Comparison of Argon/Isobutan and Argon/Methan/Isobutan Gas Mixtures

Argon/isobutan gas mixtures are used quite extensively for driftchambers with a graded field at the cathode planes[3]. Our small test chamber with 1 cm drift space and nongraded cathode planes also worked successfully with this gas mixture, i.e. with an efficiency of better than 99 % over the full drift space, a resolution of 0.21 mm FWHM per wire and a good linearity.

The small chamber with 2 cm drift space was also tested with this gas mixture. Here it was found, that one has to go to rather high potentials in order to achieve an efficiency above 95 % averaged over the drift space. Typical values were -2,6 kV at the cathode plane and -3,8 kV at the potential wire. At these voltages the chamber was almost completely operating in the Geiger mode, which means the pulses were about half a microsecond long and in height at the order of 100 mV on 50 Ohms. Drift times were very long and resolution very poor. This is shown in Fig. 8, where the drift time of one wire in the 2 cm chamber is plotted versus the time of a wire in the 1 cm chamber, displaced by 2 cm with respect to the first one. The measurement was done with the high energy electron beam as shown in section III.1 and as valid for all further measurements described in this report. The correspondence between the two times is very nonlinear. The resolution can be estimated from fig. 8 and is only about 40 nsec FWHM. After some time of operation deposits on the potential wires appeared and the chamber started to draw current. It was not possible, to improve the behaviour of the chamber by a small admixture of methylal (~ 2 %).

Therefore the small chamber with 2 cm drift space was tested with a mixture of Argon/Methan, which also has been used before[1,4]. Here the results were much better. For comparison Fig. 9 shows in its left part again the drift time of one wire against the time of a wire displaced by one drift space. The linearity is very good. The resolution, obtained by the sum of the drift time of both wires across the full drift space, as shown in the right part of fig. 9, is down to 8 nsec FWHM. The operating voltages are 2,1 kV/3,1 kV only, sufficient to give an efficiency of 99 %. Pulse height and length were similar to those in fig. 7. The small admixture of isobutan (~ 2 %) was found to increase the length of the high voltage plateau (see below fig. 11) without changing the properties of the chamber otherwise.

Fig. 10 shows similar graphs as fig. 9 but with a smaller fraction of methan. The resolution here is only 12 nsec FWHM, indicating that it depends somewhat critically on the admixture of methan.

From the comparison of the two gas mixtures it is clear that the drift velocity has a much weaker dependence on the electrical field strength for the Argon/Methan mixture than for Argon/Isobutan. In the plane of the signal- and potentialwires the electrical field strength varies by a factor of 4,5 between x = 2,0 mm and the minimum of field strength at x = 12,5 mm (x = 0 at the signalwire).

### 2.) Efficiency

Typical curves for the efficiency as a function of the high voltage at the cathode planes are shown in Fig. 11 for the small chamber. The efficiency is obtained from the rate of one or two wires in the same plane divided by the rate of the displaced wire in the second plane. With particles close to the potentialwire the efficiency plateau is reached more slowly with increasing voltage and for 99 % a higher voltage is needed than in the middle of the drift space. At the potentialwire, the number of primary electrons, which move towards the signalwire is smaller and therefore a higher gas amplification is necessary than for the remaining part of the drift space.

The efficiency as a function of the drift time of the reference wire is shown in Figs. 12 and 13 for the different wire orientations and different beam positions in the large prototype chamber. The reference wire, which is a wire of the small chamber with 2 cm drift space, was displaced by some mm with respect to the large chamber. A dip in efficiency appears at the position of the potential wire of the large chamber. Outside this dip the efficiency is between 99 and 100%. The efficiency averaged over the total drift space including the potential wire is between 98.0 and 99.4 %.

A more detailed measurement of the efficiency at the potentialwire for 250 cm length is shown in Fig. 14. The response of the two neighboured signalwires is plotted separately. The region, where the efficiency of one wire drops down and goes to zero, is 1.5 mm in width with half of this section lying on the opposite side of the potential wire. A similar behaviour has been reported in other measurements[1].

The wires with different orientations and different lengths show no significant differences in efficiencies. This is also demonstrated in the Figs. 15-17, where the pulse height spectra as taken with an ADC and integrated over the drift space are shown. Taking into account the slightly different gainfactors of the amplifier used in front of the ADC there is no important difference between the distributions visible. Fig. 15 also shows the pulse height versus drift time. For the latest times coming from particles at the potentialwire, a decrease of the pulse height is seen.

### 3.) Linearity of Drifttime versus Driftspace

To determine the dependence of the drifttime on the space coordinate between the signalwire and the potentialwire one chamber was moved with respect to the other one perpendicular to the wires in measured steps. At first the small chamber was moved in steps of 2,oo mm with respect to the large chamber. A small beam was selected by selecting a small time interval in the center of a drift space in the large chamber. The result of this measurement is shown in Fig. 18, where the drifttime for two wires is plotted versus the space coordinate. Between 2 and 18 mm the linearity is very good. Deviations from the straight line are less than 2 nsec. The drifttime is 16,4 nsec/mm. At the signalwires the driftvelocity seems to decrease. However this is most likely due to the fact, that for particles passing the chamber close to a signalwire the relative difference between the average path length of the drifting electrons and the perpendicular distance between the signalwire and the particle track is very large.

Also the electrons started by particles close to the potentialwire need more than the average drifttime to reach the signalwire. Here the reason is not as clear. There are two effects pointing in this direction. The first one is, that the electrons have to traverse the full range of low electrical field. The second one, that the number of primary electrons is small and that there may be none, moving along the shortest field line to the signalwire. However in both cases one would expect a more steady increase of the deviation from the straight line beyond 14 mm.

To measure the linearity of the large chamber, the linear part of the drift space of the small chamber was used to determine the time space relation. The large chamber was therefore moved only in two defined steps. The result is shown in Fig. 19 for a 250 cm wire and in Fig. 20 for a $60^o$ wire. In both cases we also have good linearity. The maximum deviations from the best straight line drawn by an eye fit are 10 nsec for the 250 cm wire and 8 nsec for the $60^\circ$ wire. The average drifttime is however with 2o,6 nsec/mm and 19,8 nsec/mm larger than for the small chamber. It is especially the driftspace below 12 mm towards the potentialwire where more drifttime is needed.

It must be noted here, that this linearity in the large chamber was achieved only after replacement of the inlet gas manifold by a new one. Before this replacement was made, the linearity was not as good and the total drifttime was yet larger by about 40 nsec. Impurities of the first manifold apparently changed the properties of the gas. This was in addition demonstrated, when the small chamber, which was normally in the gas stream in front of the large chamber, was placed behind it. Then also the total drifttime in this chamber was larger than 400 nsec. Therefore we believe, that the remaining difference in linearity and total drifttime between the small and the large chamber is caused by some impurities, which have been carried into the large chamber.

### 4.) Resolution versus Driftspace

The accuracy of the drifttime determination was measured by adding the drifttime of two wires on opposite sides of the beam for different positions of the beam particles within the driftspace. The results are shown in the Figs. 21-25 for the different types of wires. One of the two wires is always a 30 cm wire in the small chamber. This chamber was alined parallel to the wires of the large chamber with wire behind wire. It was put as close as possible to the large chamber to minimize the influence of beam divergence on the measurements. The results show a minimum of the resolution in the middle of the driftspace with an increase towards the signalwire/potentialwire position. Fig. 23 shows contrary to the others the difference between two drifttimes, since a signalwire was placed behind a signalwire. Therefore this figure gives the superposition of the resolution in similar parts of the drift space. Starting from this curve it was possible to do an unfolding in order to obtain the resolution for a single wire. The results of this unfolding procedure are given in Figs. 26-29. The best resolution is 4 nsec FWHM in the central region of the driftspace of the small chamber. For the longest wires it increases up to 9 nsec FWHM. Towards the potential wire there is always an increase up to about 14 nsec FWHM. This is due to the very small number of electrons, which have a chance to get to the signalwire and therefore initial strokes with gas molecules are not averaged out. Also towards the signal wire an increase of the resolution is seen. Here the different electrons produced by the ionization through the primary charged particle have different times of arrival in the gas amplification zone around the signalwire. This again may lead to statistical fluctuations in time larger than for the central part of the drift space.

As for the applications of this drift chamber in the spectrometer the particles traverse several planes it is meaningfull to give the values for the resolution averaged over the total drift space. These values are summarized in the following table II:

Table II: Averaged resolution for the different wires

| Type of wire | Averaged resolution FWHM | |
|---|---|---|
| | nsec | mm |
| 30 cm | 6,5 | 0.40 |
| 250 cm | 7,5 | 0.37 |
| 290 cm | 8,5 | 0.43 |
| 510 cm | 10,0 | 0.50 |

### 5.) Influence of Beam Intensity

It was observed during the various measurements that efficiency and resolution depended on the beam intensity. In Fig. 30 efficiency/high voltage curves are shown for different trigger rates. The rates as given in this figure are rates during the spill. The beam was spread out approximately across one driftspace and only a few millimeters wide in height (parallel to the wire). Already for 40 Kc the efficiency is down to 95 %. For horizontal wires and the same cross section of the beam the loss of efficiency was much less. Also the resolution depends on the intensity of the beam as shown in Fig. 31. Here the overall resolution is only 11 nsec FWHM for 40 Kc, which must be compared with the 8 nsec in fig. 9. A summary of the inensity dependence for the 250 cm wires is given in Fig. 32.

### 6.) Miscellaneous

The large chamber showed a considerable amount of cross talk from one wire to other wires in the same plane, when the 470 Ω resistors (Fig. 6) in series with the amplifier input were not yet in place. The cross talk signals looked like the original signals differentiated with negative and positive parts and with 10 % in amplitude. The damping resistor brings this signal below the threshold with only a small change for the main signals. With the resistor the cross talk is less than 1 %, if the high voltage on the signalwire is set at the lower part of the efficiency plateau.

The small chamber has been turned with respect to the beam by 30° for additional measurements in order to study some properties of the chamber for inclined particle trajectories. The efficiency stayed at the normal value of 99 %. The spread in time (resolution) for two wires was 6 nsec in the middle of the driftspace and 9 nsec towards the potentialwires and therefore not different from the case, where the trajectory is perpendicular to the driftchamber planes. The linearity has not been measured, but the correlation of drifttime between two neighboured wires shows a change in the middle of the driftspace (Fig. 33).

Also in the small chamber the distortion of the efficiency and the drifttime close to the frame has been measured. Depending on the last wire being a signal- or a potentialwire at the frames parallel to the wires at most 1 1/2 drift spaces are distorted. In the other dimension a region of only about 1 cm cannot be used.

The efficieny around the support thread on the 510 cm wires was found to be almost zero for approximately 10 mm and recovers rapidly on both sides over 2-3 mm.

## V. Conclusions

It has been shown, that a drift chamber with 2 cm drift space between signal- and potentialwire operates well with nongraded cathode planes, if a gas mixture of Argon/Methan = 38/9ℓ/h with a small fraction of Isobutan (~ 2 %) is used. A prototype with a sensitive area of 250x510 $cm^2$ was built with the longest signalwires being 510 cm. The efficiency is larger than 98 %. The space time relation is linear with 20 nsec/mm and with the largest deviation from the straight line being 10 nsec. The resolution averaged over the drift space is 0.4 mm FWHM. The desired resolution for the spectrometer at the position of these chambers is 0.6 mm FWHM. This can be obtained, if corrections are made for nonlinearity, for deviations of the particle trajectories from the normal to the drift chamber planes and for signal delay due to the length of the wires.

## References:

1. H.J. von Eyß et al., Interner Bericht DESY F12-75/01

2. D.C. Cheng et al., Nucl. Instr. and Meth. 117 (1974), 157

3. Breskin et al., Nucl. Instr. and Meth. 124 (1975), 189

4. A.H. Walenta et al., Nucl. Instr. and Meth. 92 (1971), 373

## Figure Captions:

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Fig. 19 and 20: The same as fig. 18 but for the large chamber.

Figs. 21 - 25: Resolution (sum or difference of the time of two wires seing the same particles) as a function of the coordinate between signal- and potentialwire.
One wire is always the same wire in the small chamber with 2 cm drift space.

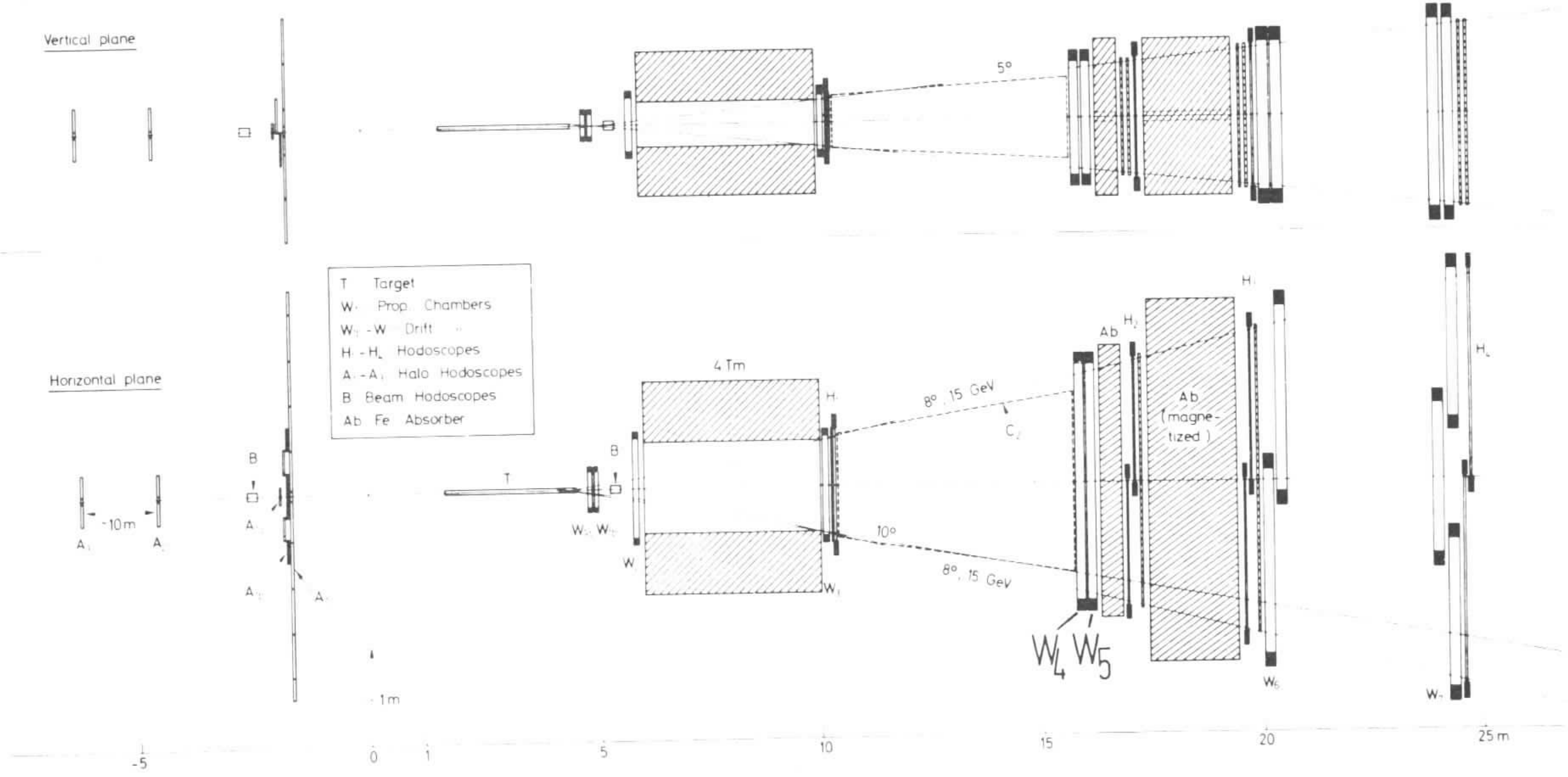
Figs. 26 - 29: The resolution of figs. 21-25 but unfolded for only one wire.

Fig. 30: Efficiency in the large chamber for different trigger rates. The beam was spread across the total drift space but only a few millimeters wide parallel to the wires.

Fig. 31: The same as fig. 9 but for a high trigger rate.

Fig. 32: Efficiency and resolution as a function of trigger rate.

Fig. 33: Drifttime of one wire versus the drifttime of a displaced wire for particles with 30° against the normal on the wire planes.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Horizontal plane
T Target
W Prop. Chambers
W - W Drift "
H - H Hodoscopes
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Fig. 1

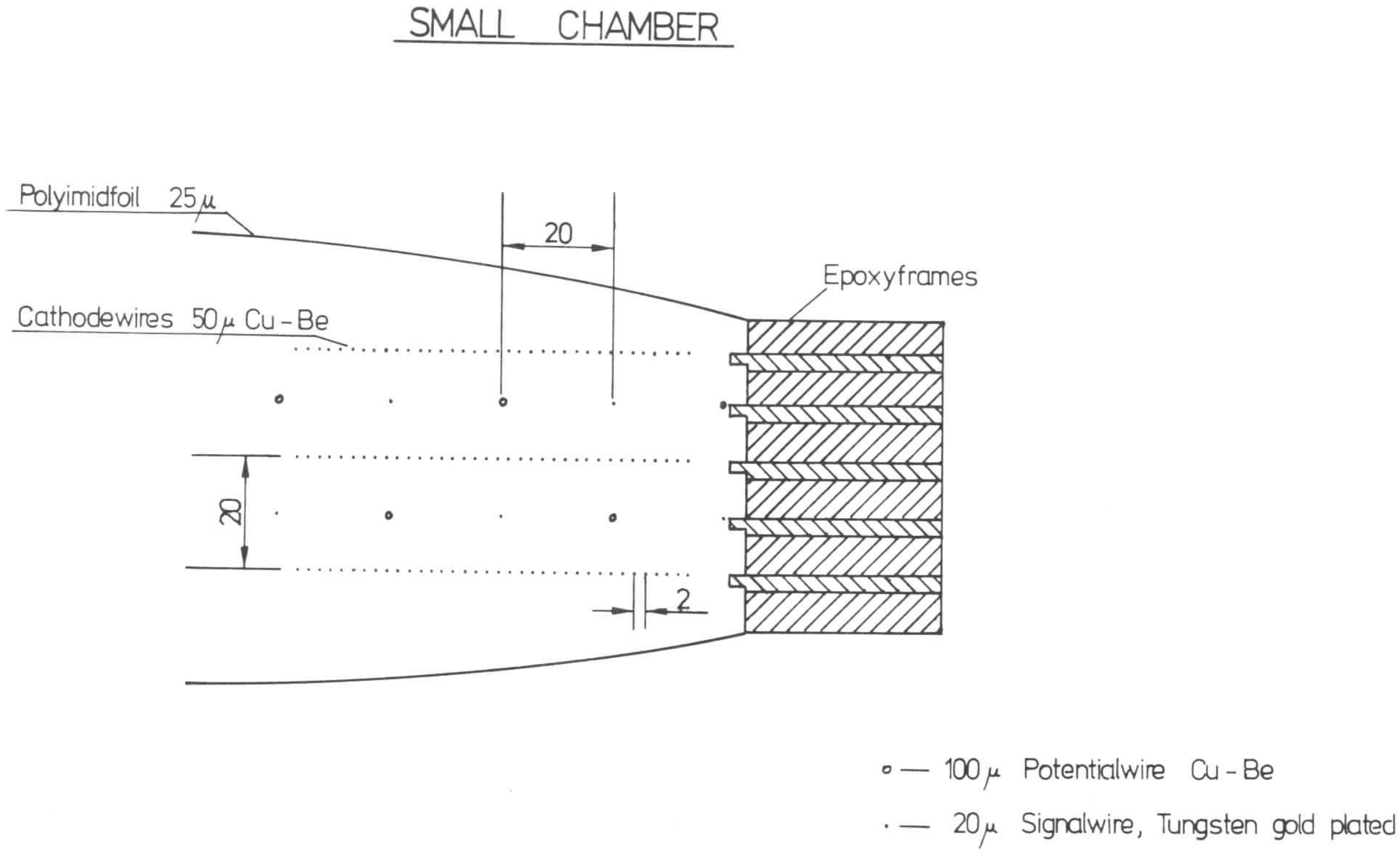
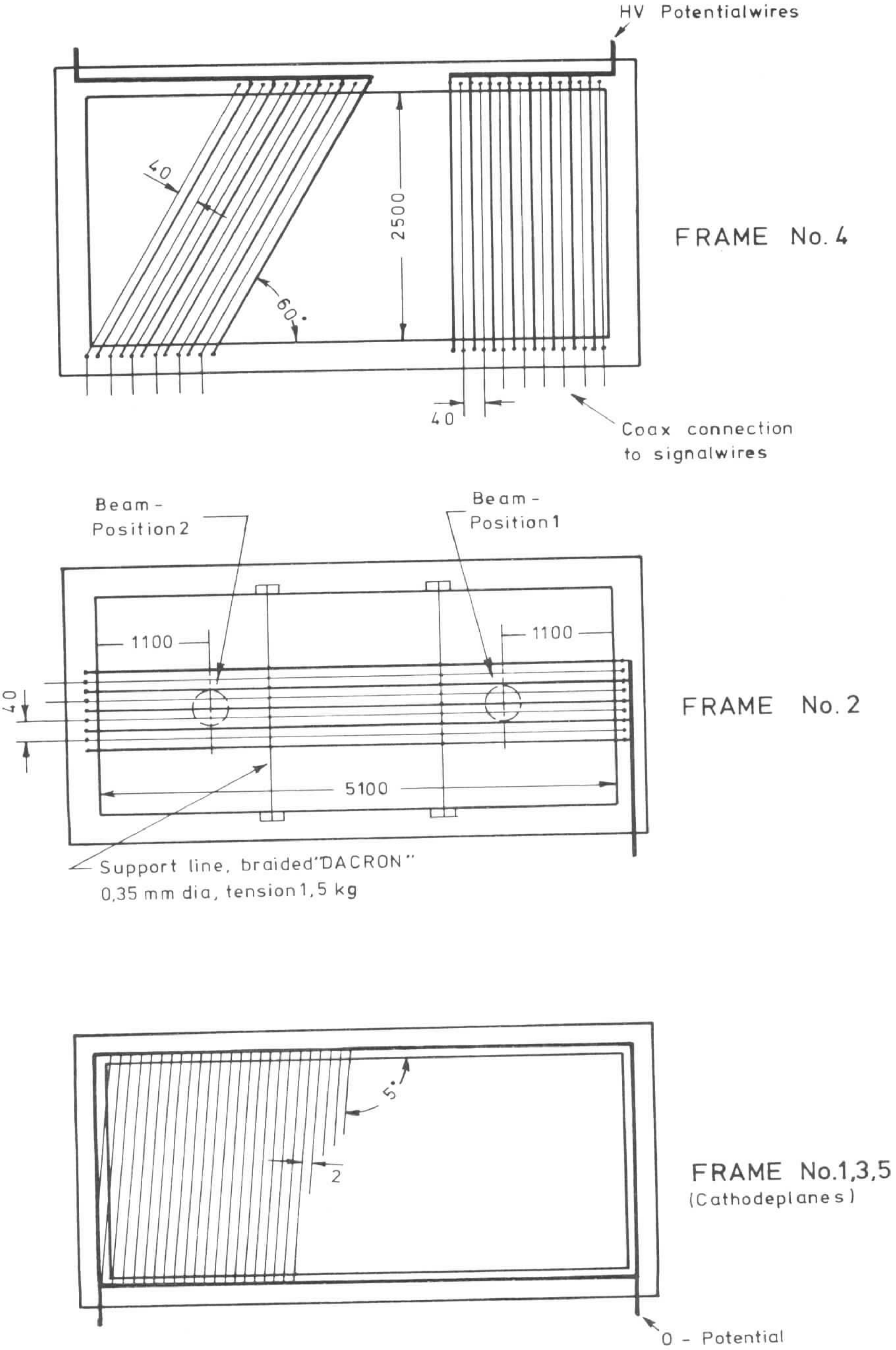

SMALL CHAMBER

Fig. 2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2500
60°
40
Coax connection
to signalwires
FRAME No. 4
Beam -
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Position 1
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1100
40
5100
Support line, braided "DACRON"
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2
FRAME No.1,3,5
(Cathodeplanes)
0 - Potential

Fig. 3

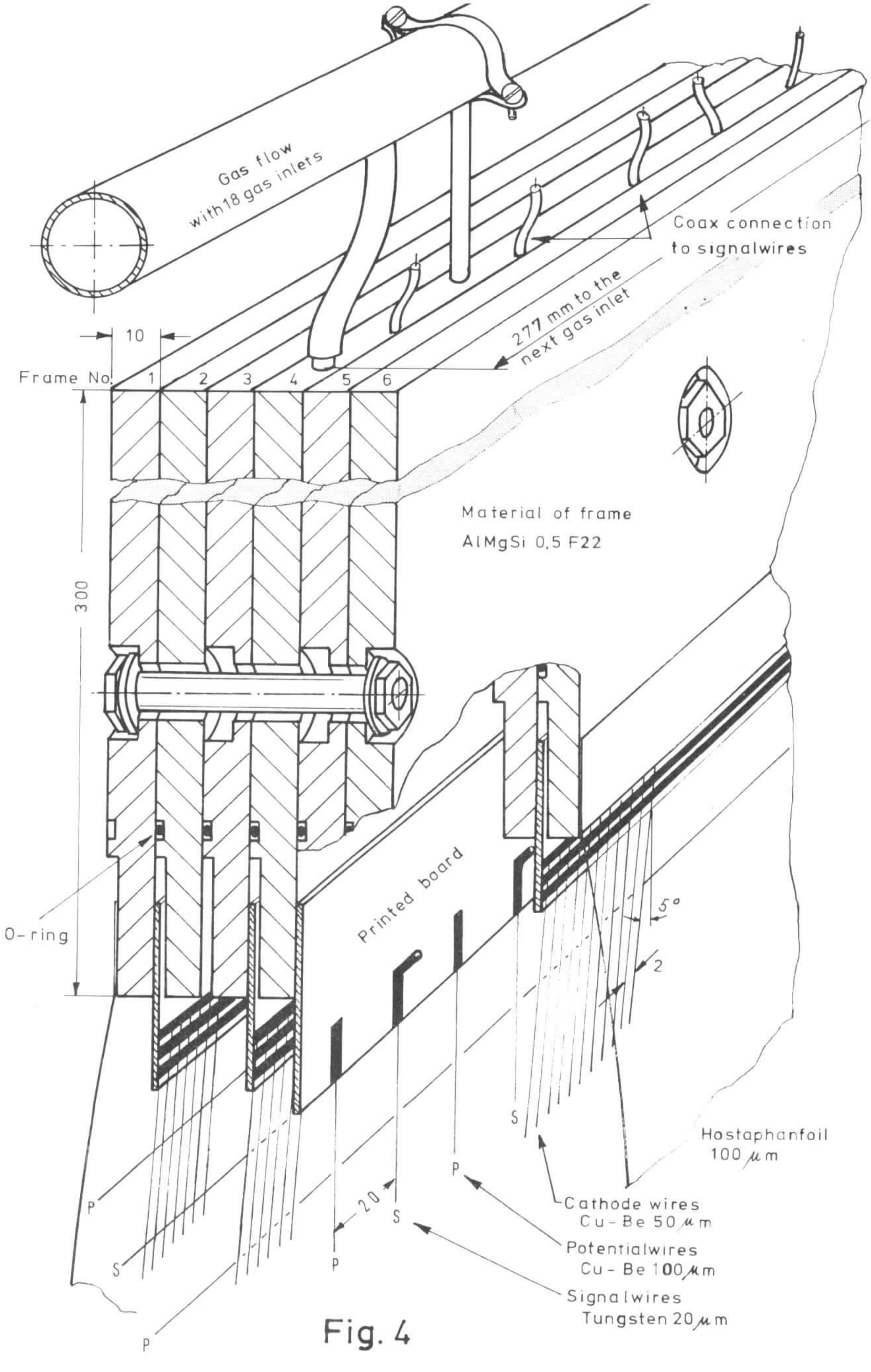

Gas flow
with 18 gas inlets
Coax connection
to signalwires
277 mm to the
next gas inlet
10
Frame No.
1
2
3
4
5
6
300
Material of frame
AlMgSi 0,5 F22
O-ring
Printed board
5°
2
20
S
P
P
S
P
S
P
S
P
Hostaphanfoil
100 μm
Cathode wires
Cu-Be 50 μm
Potentialwires
Cu-Be 100 μm
Signalwires
Tungsten 20 μm

Fig. 4

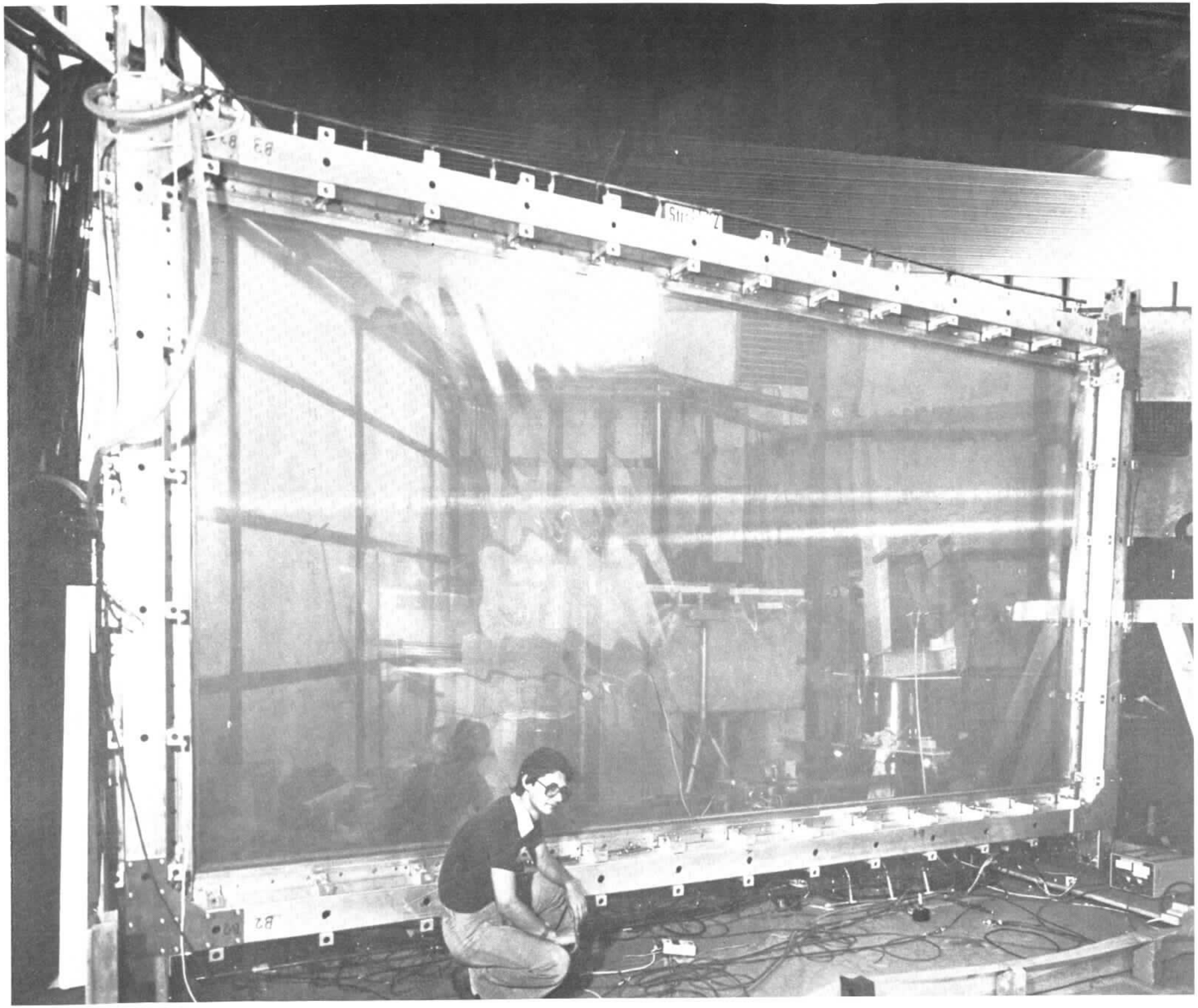


Fig. 5

Fig. 6

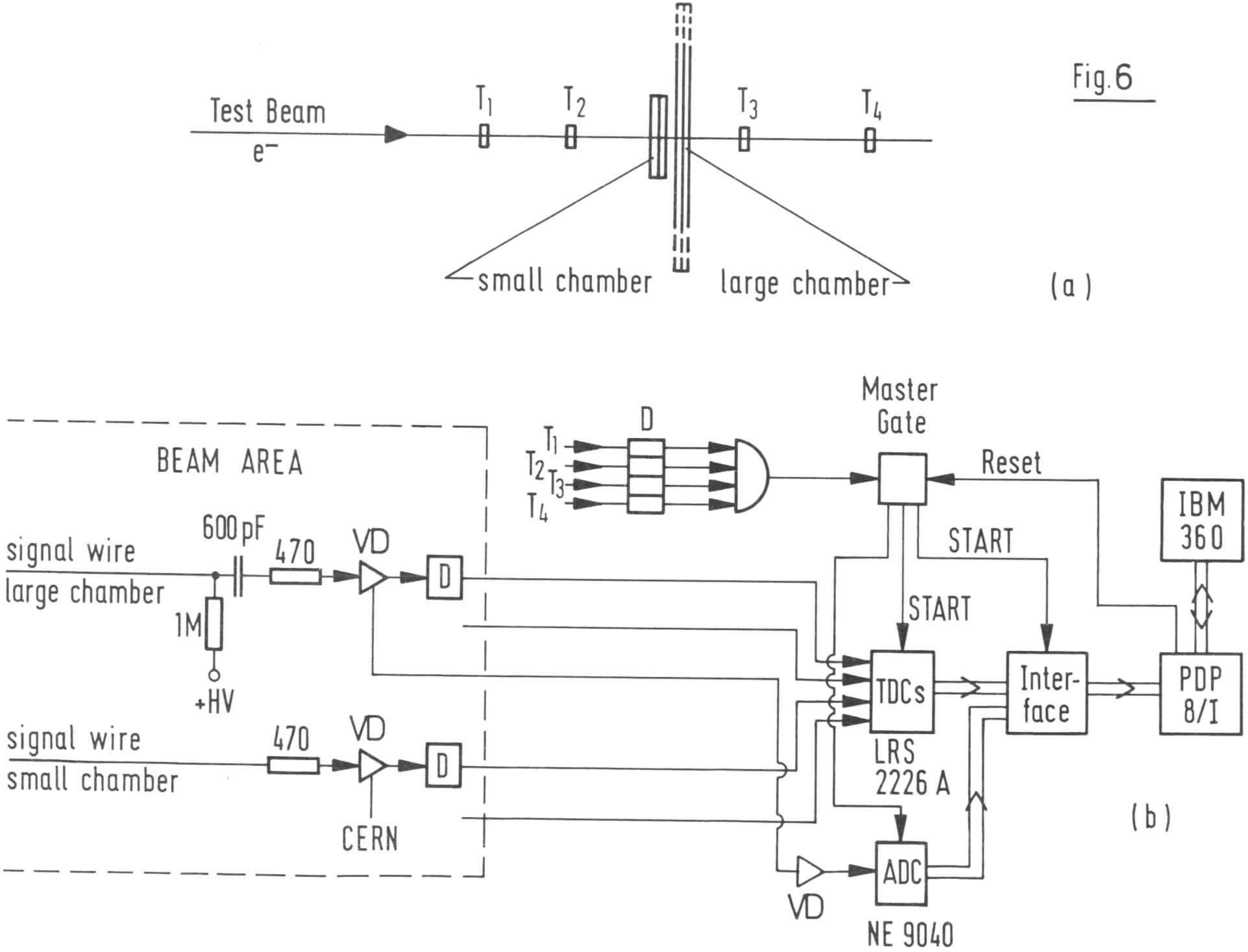
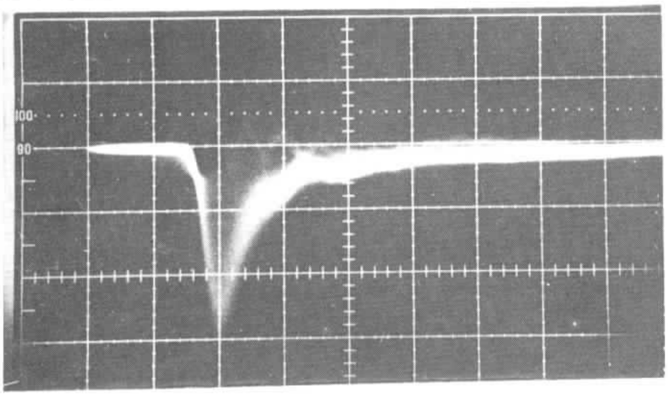

Test Beam
e⁻
T1
T2
T3
T4
small chamber
large chamber
(a)
BEAM AREA
signal wire
large chamber
600 pF
470
VD
D
1M
+HV
signal wire
small chamber
470
VD
D
CERN
T1
T2
T3
T4
D
Master Gate
Reset
START
START
IBM 360
TDCs
LRS 2226 A
Inter-face
PDP 8/I
VD
ADC
NE 9040
(b)

Fig. 7

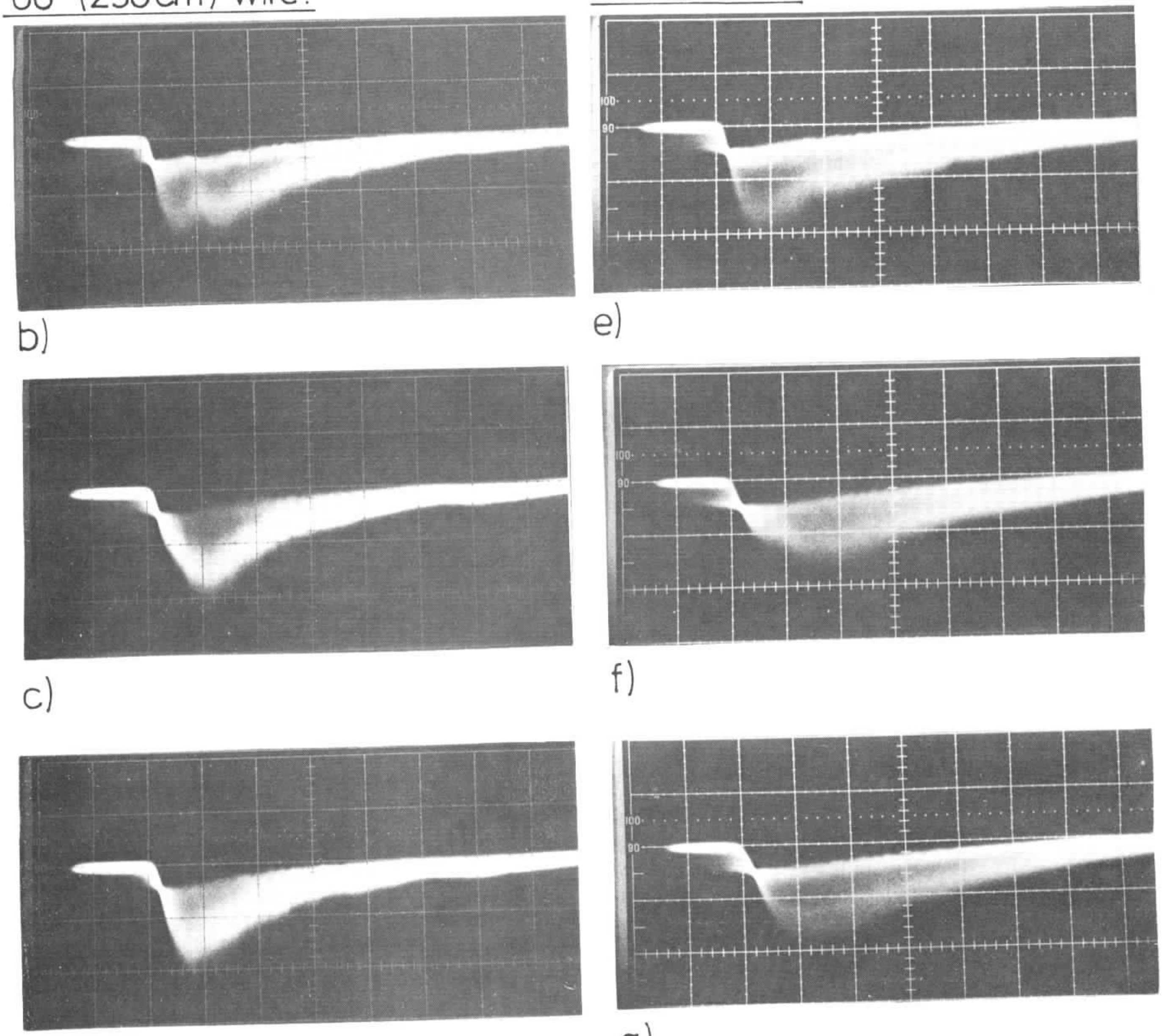
30 cm wire:



a) 5 mV/cm ; 20 nsec / cm

60° (290 cm) wire:

510 cm wire



b)

e)

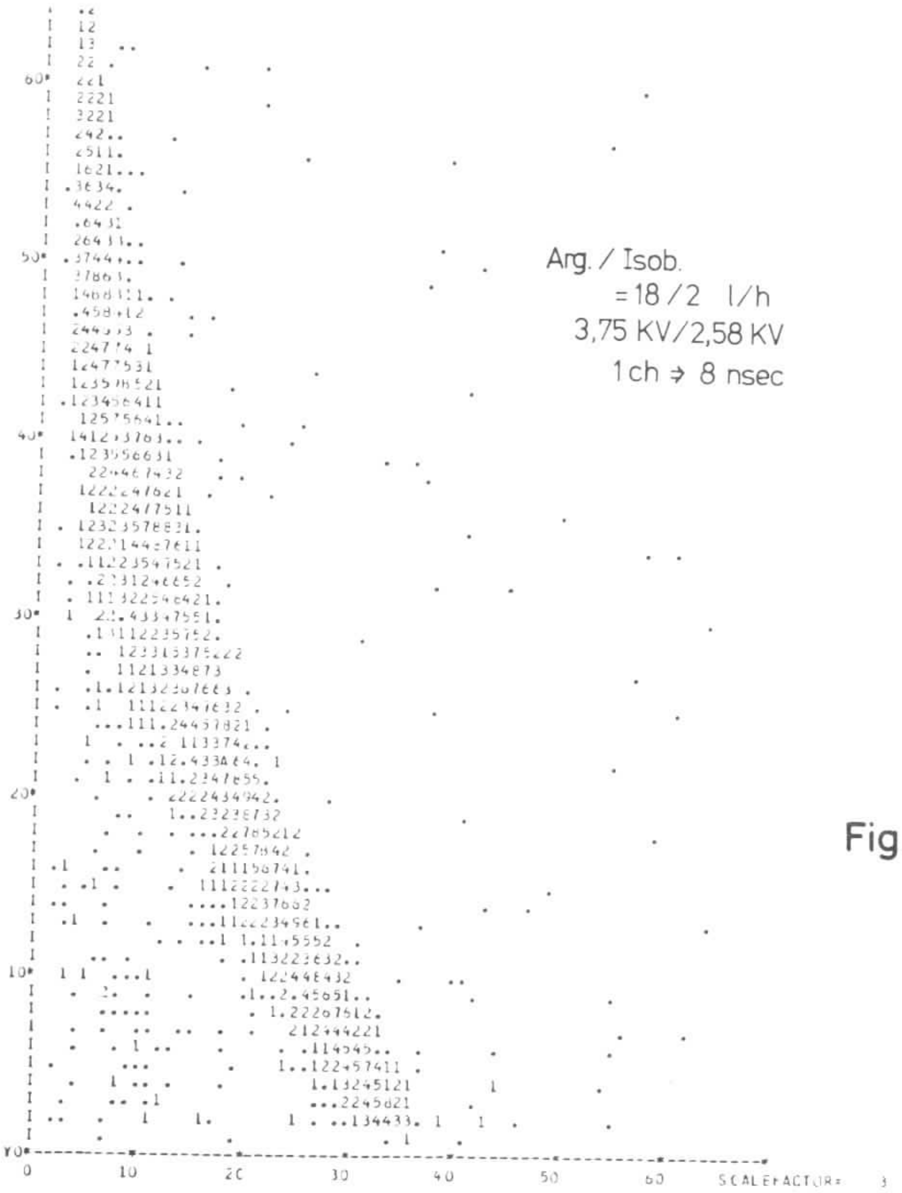
c)

f)

d)

g)

b) - a) : 2 mV/cm ; 20 nsec / cm

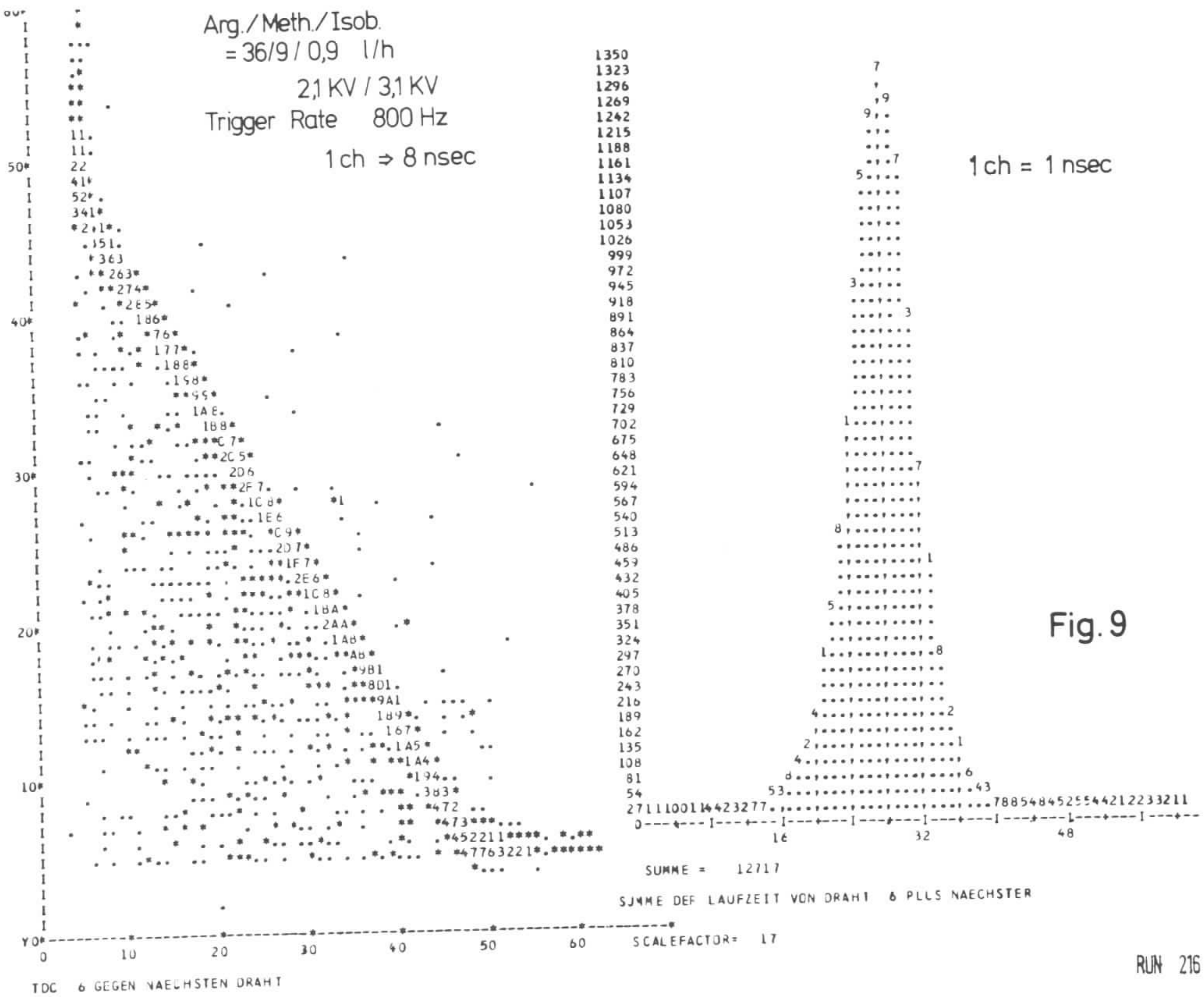


Arg. / Isob.
= 18 / 2 l/h
3,75 KV/2,58 KV
1 ch ⇏ 8 nsec

TDC 1 GEGEN NAECHSTEN DRAHT

Fig. 8

RUN 134



Arg./Meth./Isob.
= 36/9 / 0,9 l/h

2,1 KV / 3,1 KV

Trigger Rate 800 Hz

1 ch ⇒ 8 nsec

1 ch = 1 nsec

```
TDC   6 GEGEN NAECHSTEN DRAHT
```

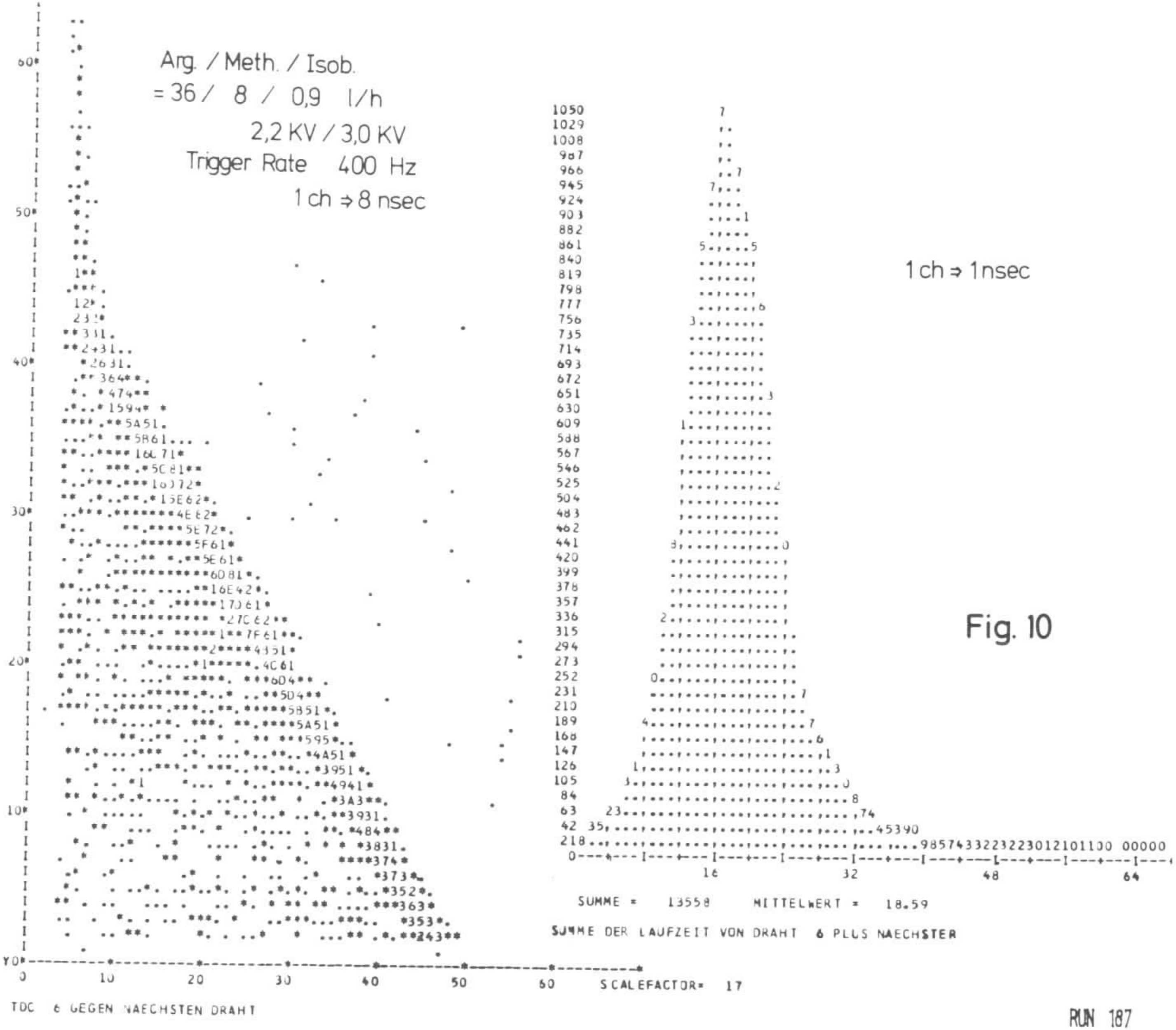
```
SUMME =     12717

SUMME DER LAUFZEIT VON DRAHT  6 PLUS NAECHSTER

SCALEFACTOR=  17
```

Fig. 9

RUN 216



```
SUMME =    13558     MITTELWERT =    18.59

SUMME DER LAUFZEIT VON DRAHT  6 PLUS NAECHSTER

SCALEFACTOR=  17

TDC  6 GEGEN NAECHSTEN DRAHT
```

Fig. 10

RUN 187

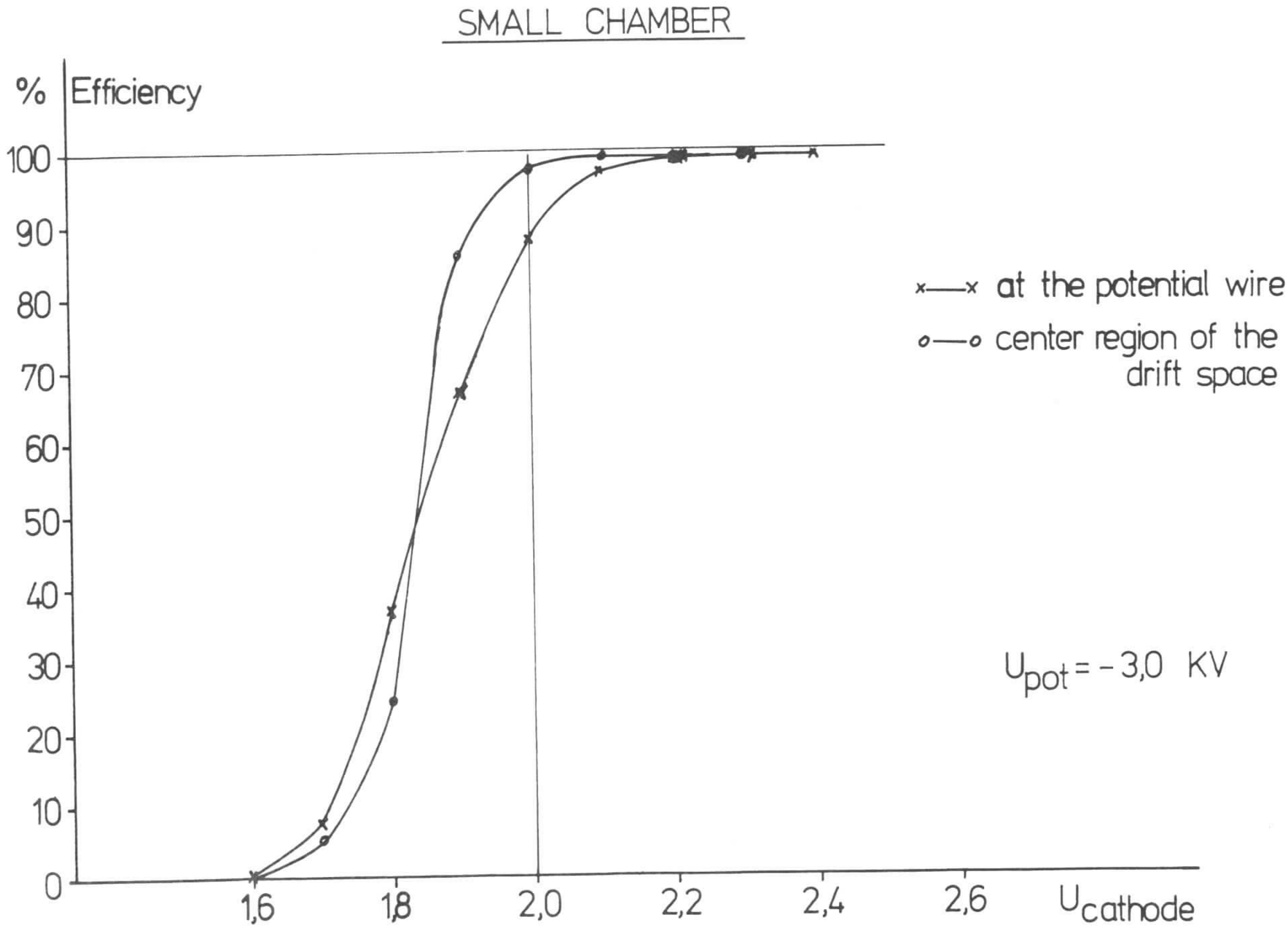
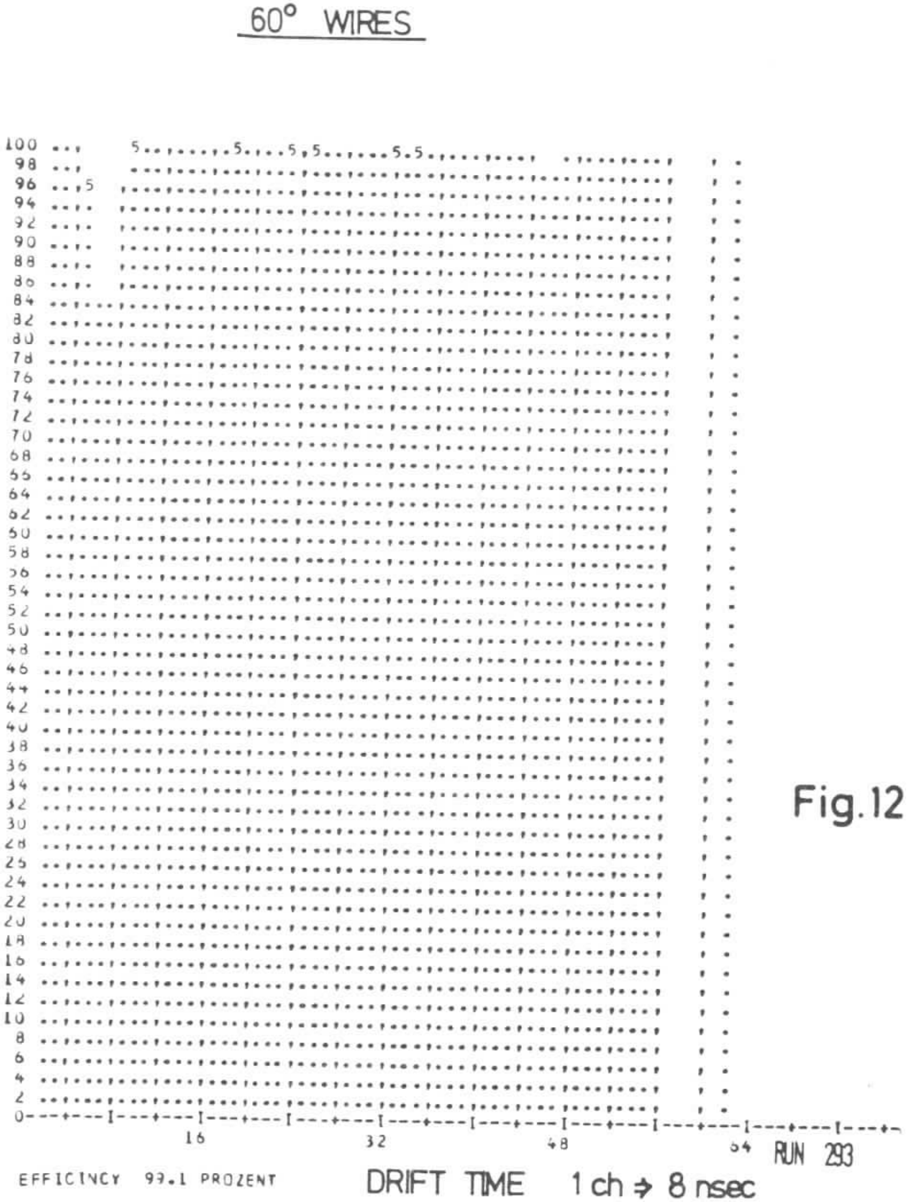

SMALL CHAMBER
% Efficiency
100
90
80
70
60
50
40
30
20
10
0
1,6
1,8
2,0
2,2
2,4
2,6
$U_{cathode}$
×—× at the potential wire
o—o center region of the drift space
$U_{pot} = -3,0$ KV

Fig. 11


60° WIRES
100
0
16
32
48
64
RUN 293
EFFICINCY 99.1 PROZENT
DRIFT TIME 1 ch ⇒ 8 nsec

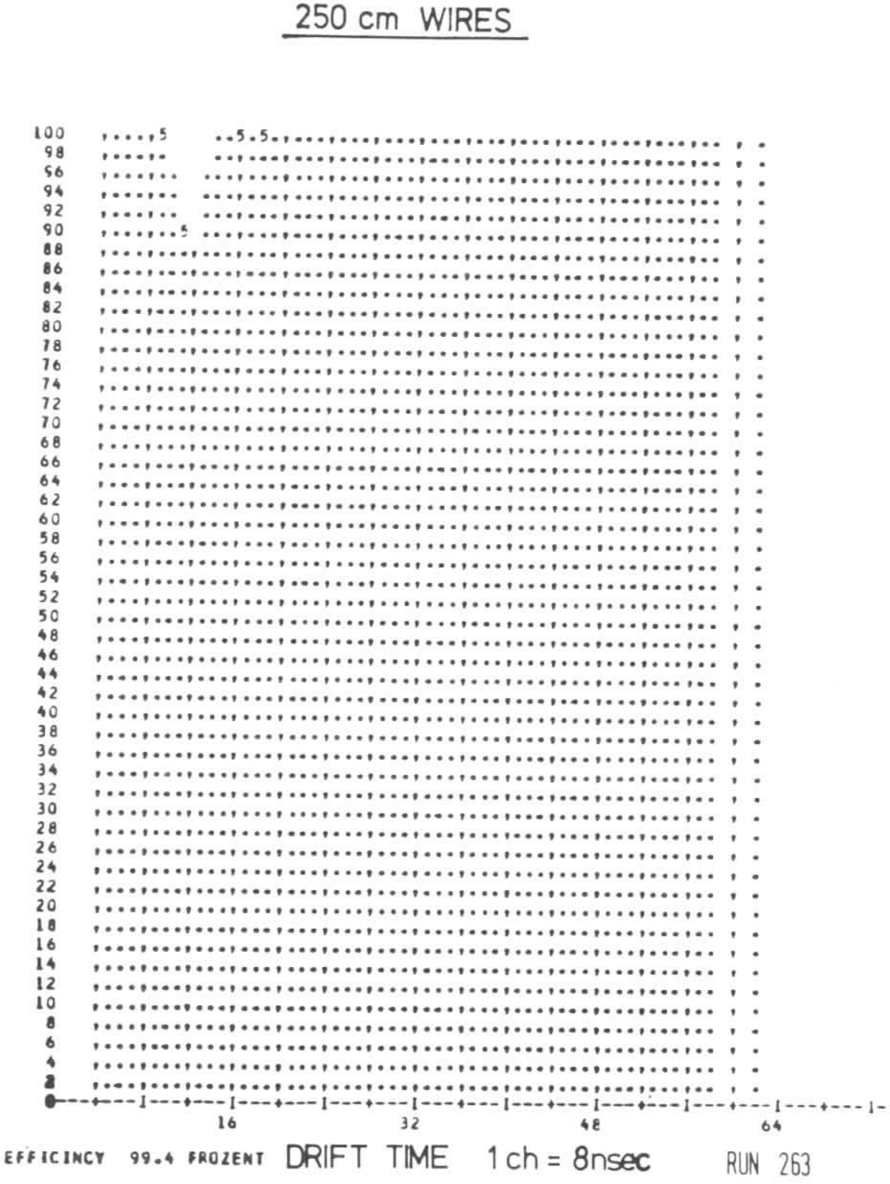

250 cm WIRES
100
0
16
32
48
64
EFFICINCY 99.4 PROZENT
DRIFT TIME 1 ch = 8nsec
RUN 263

Fig.12

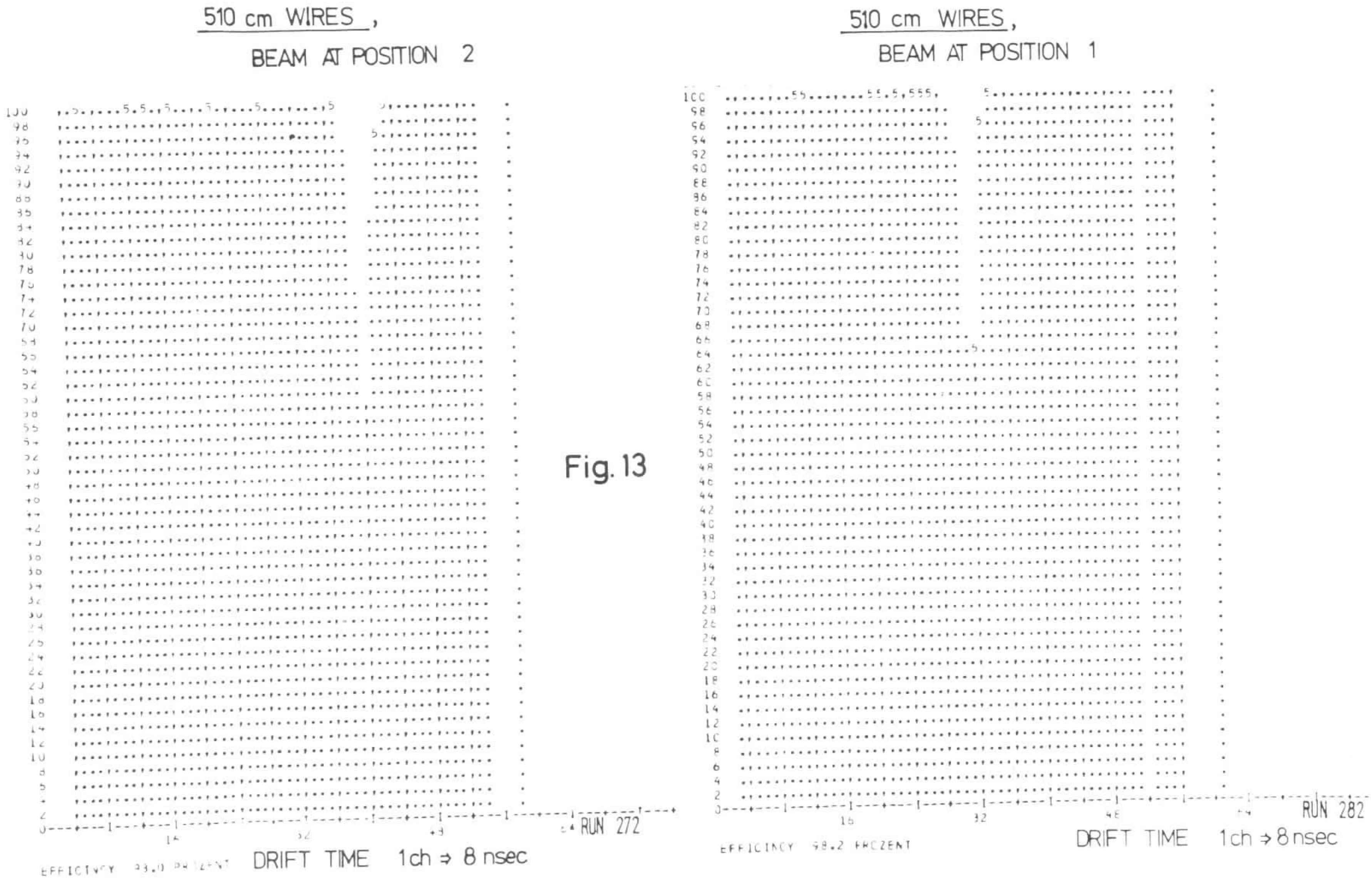
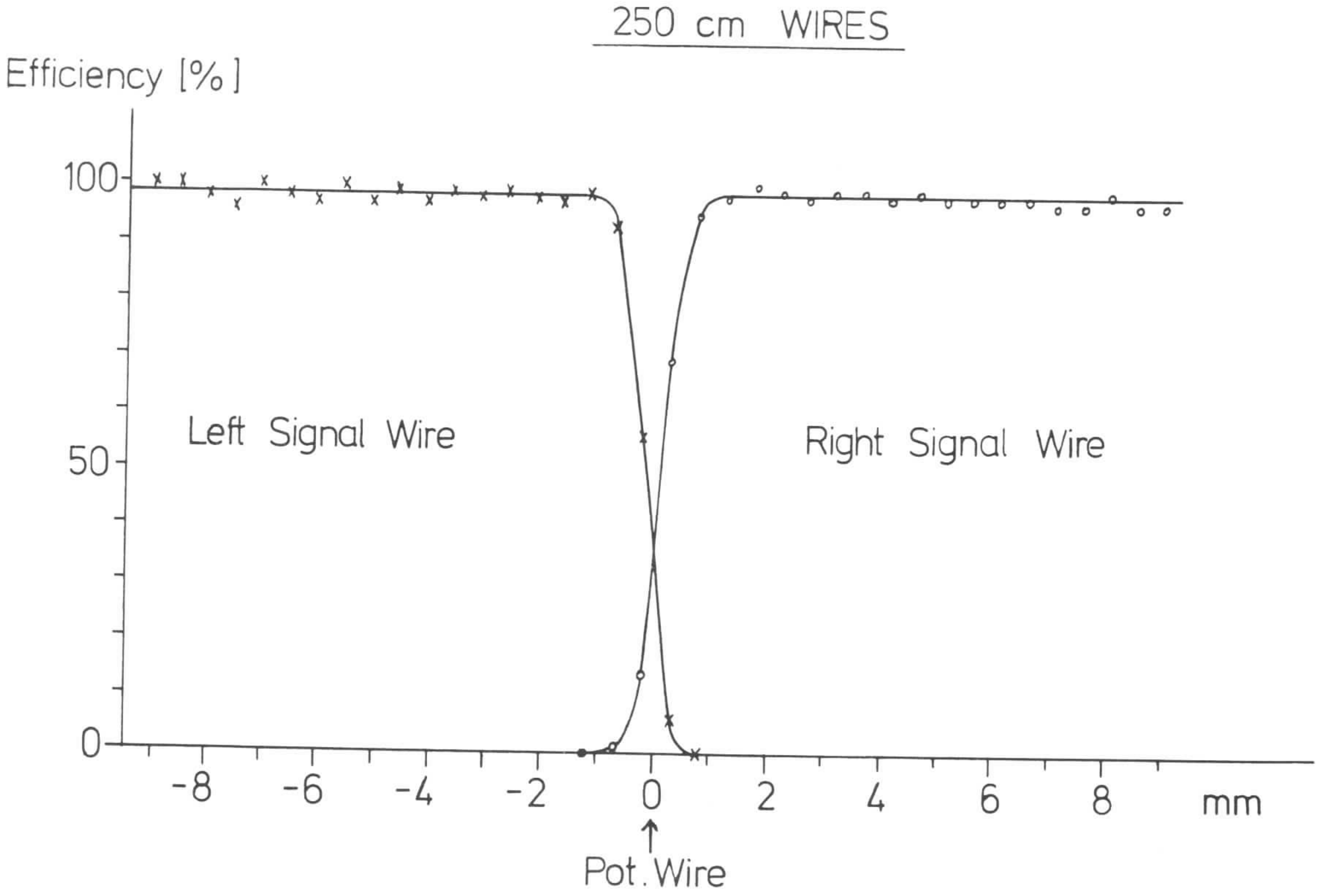

510 cm WIRES ,
BEAM AT POSITION 2
DRIFT TIME 1ch ⇒ 8 nsec
RUN 272
EFFICINCY 93.0 PROZENT
16
32
48
64
510 cm WIRES ,
BEAM AT POSITION 1
DRIFT TIME 1ch ⇒ 8 nsec
RUN 282
EFFICINCY 98.2 PROZENT
16
32
48
64

Fig. 13



RUN 268

Fig. 14

RUN 271

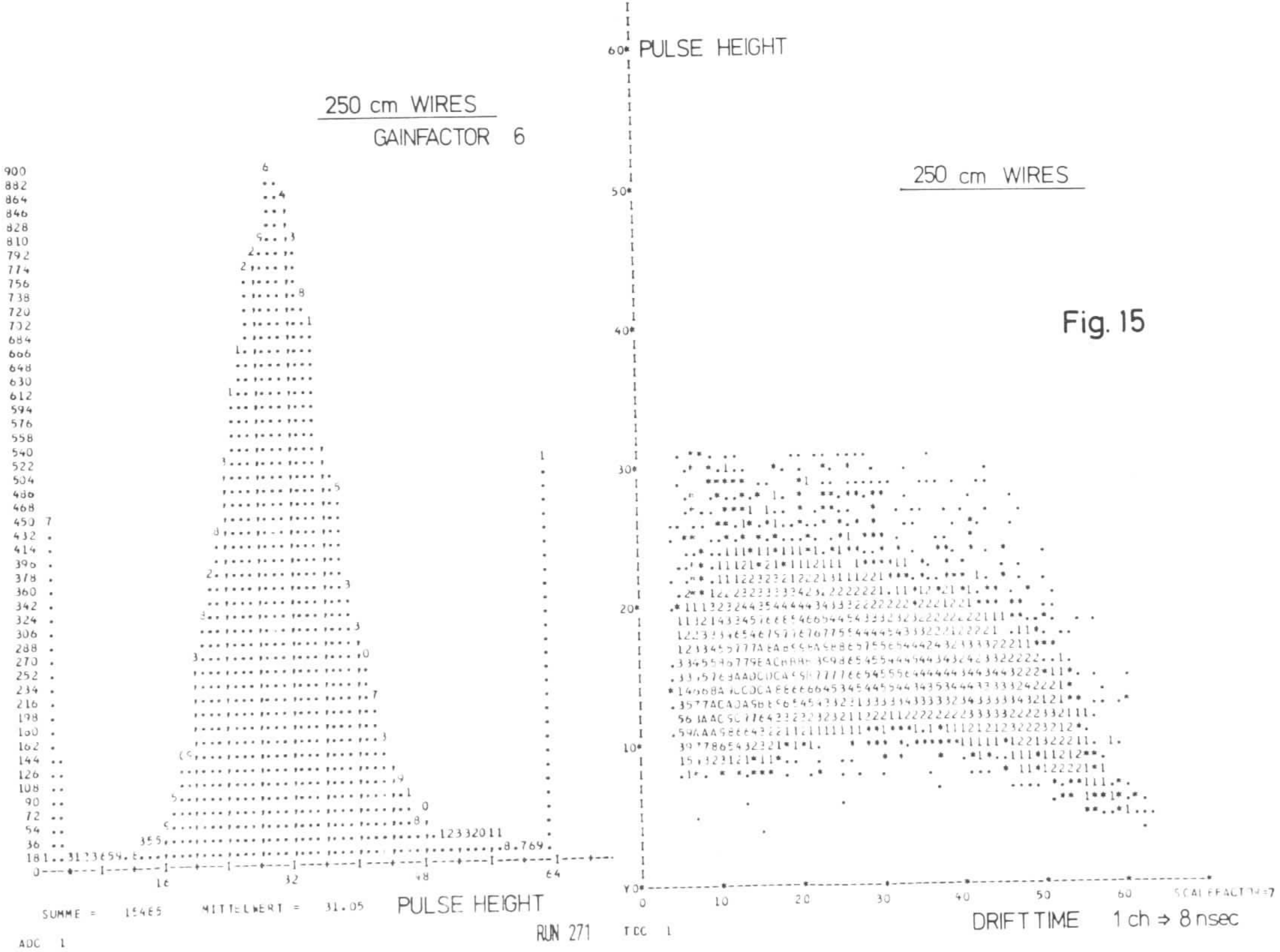
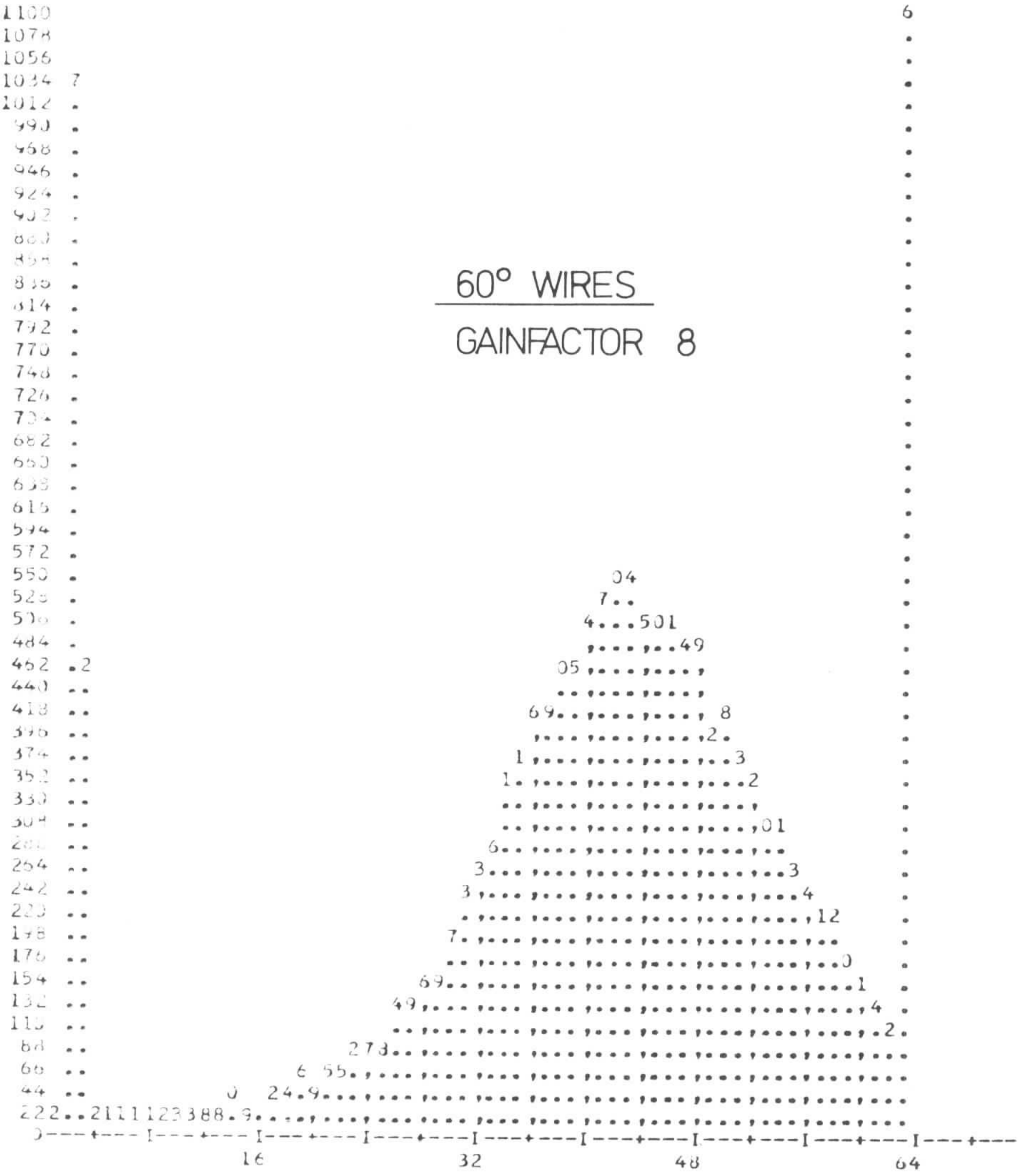


Fig. 15



```
SUMME =    15C86      MITTELWERT =    39.94
```

PULSE HEIGHT

```
ADC   1
```

Fig. 16

RUN 286

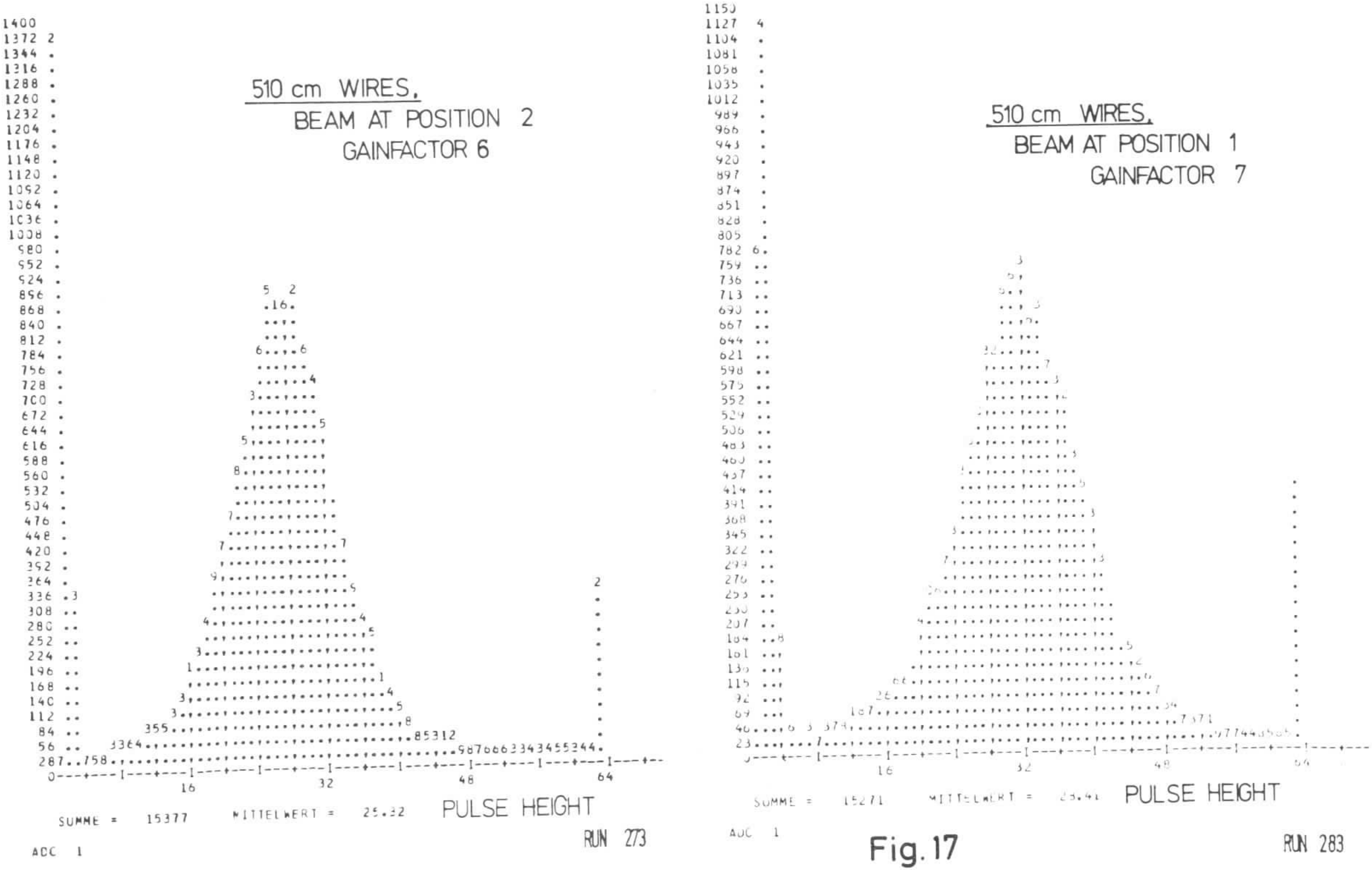

510 cm WIRES,
BEAM AT POSITION 2
GAINFACTOR 6
1400
0
16
32
48
64
SUMME = 15377
MITTELWERT = 25.32
PULSE HEIGHT
ADC 1
RUN 273
510 cm WIRES,
BEAM AT POSITION 1
GAINFACTOR 7
1150
0
16
32
48
64
SUMME = 15271
MITTELWERT = 25.41
PULSE HEIGHT
ADC 1
RUN 283

Fig. 17

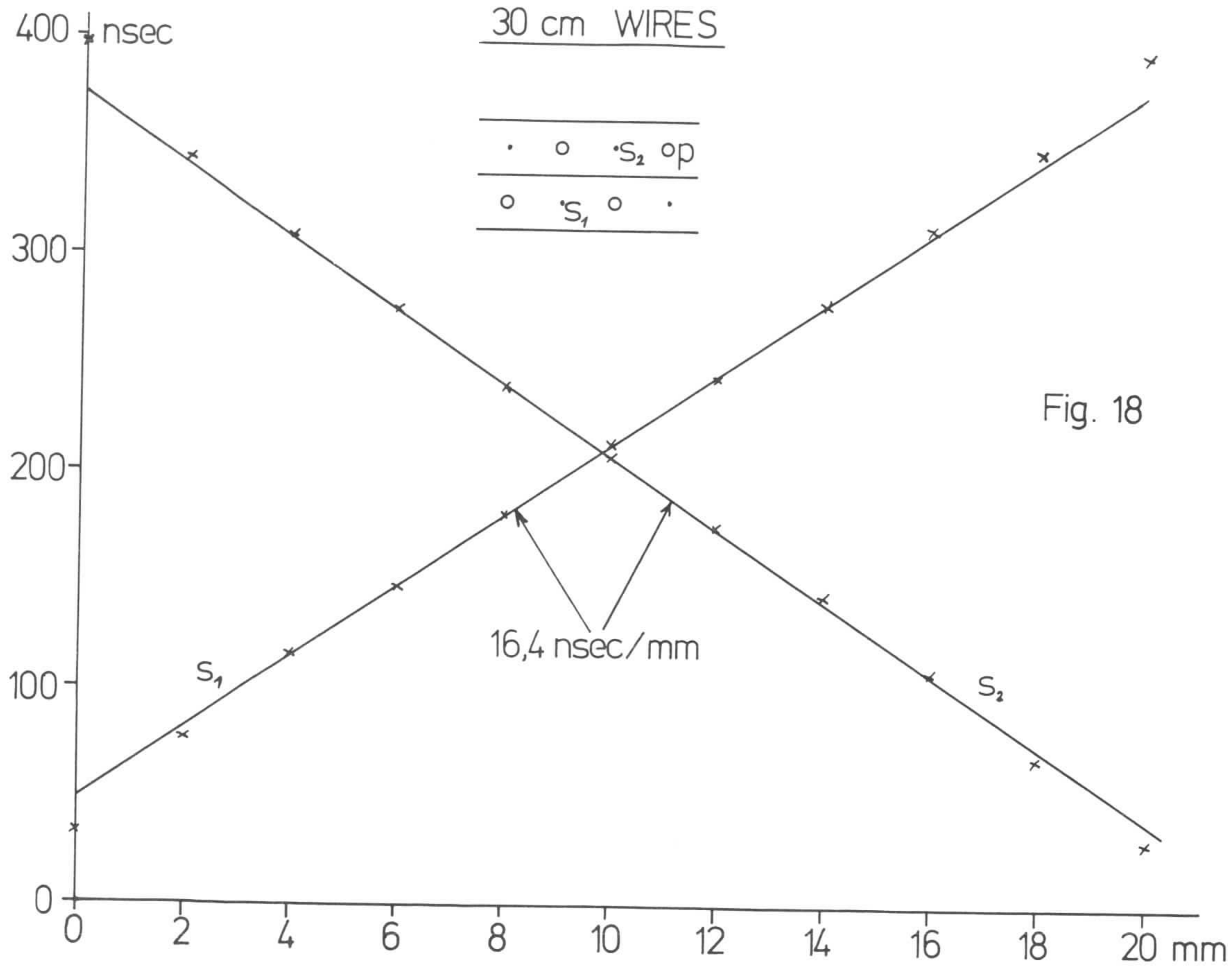


Fig. 18

RUN 238-248

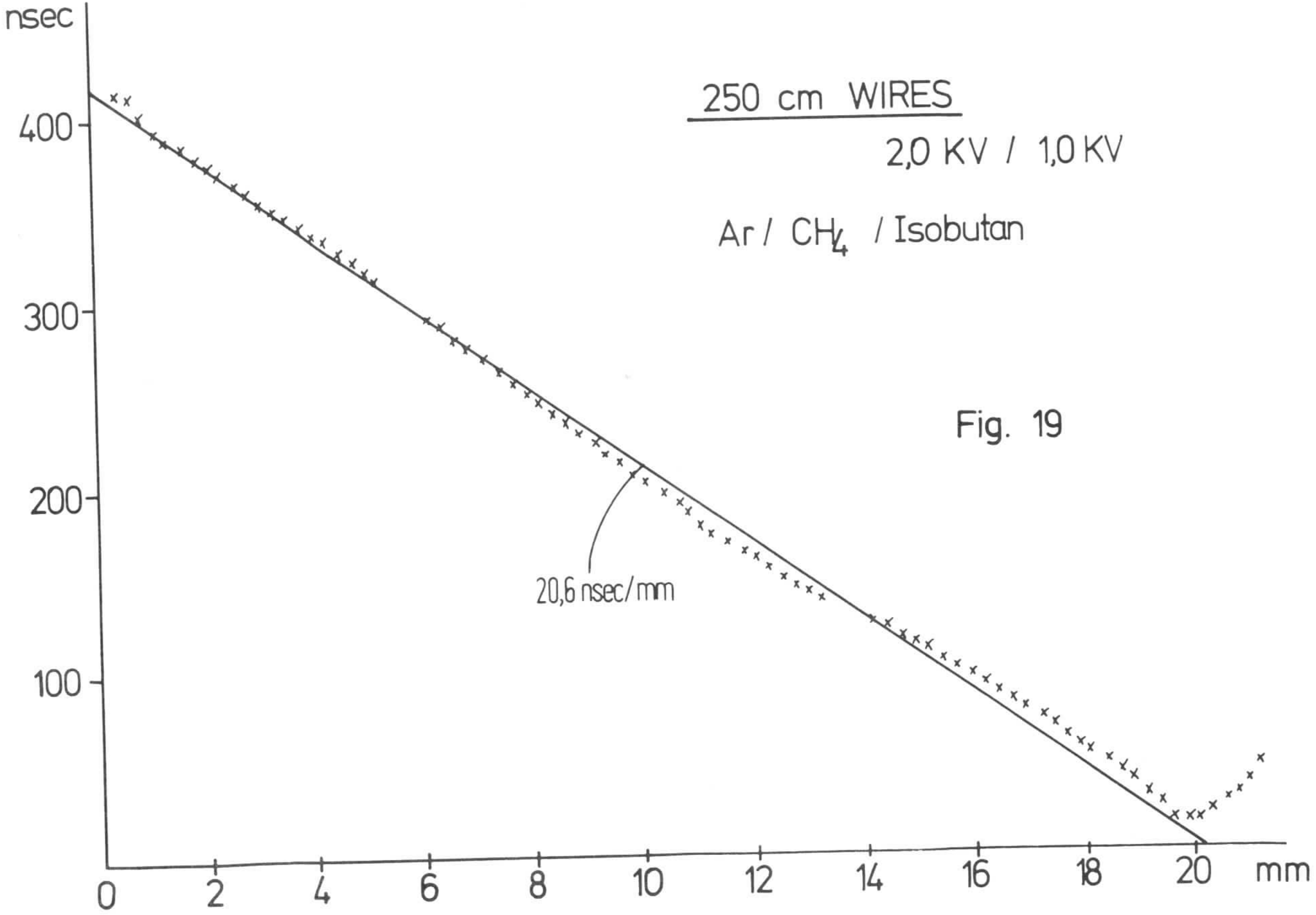


Fig. 19

RUN 268-270

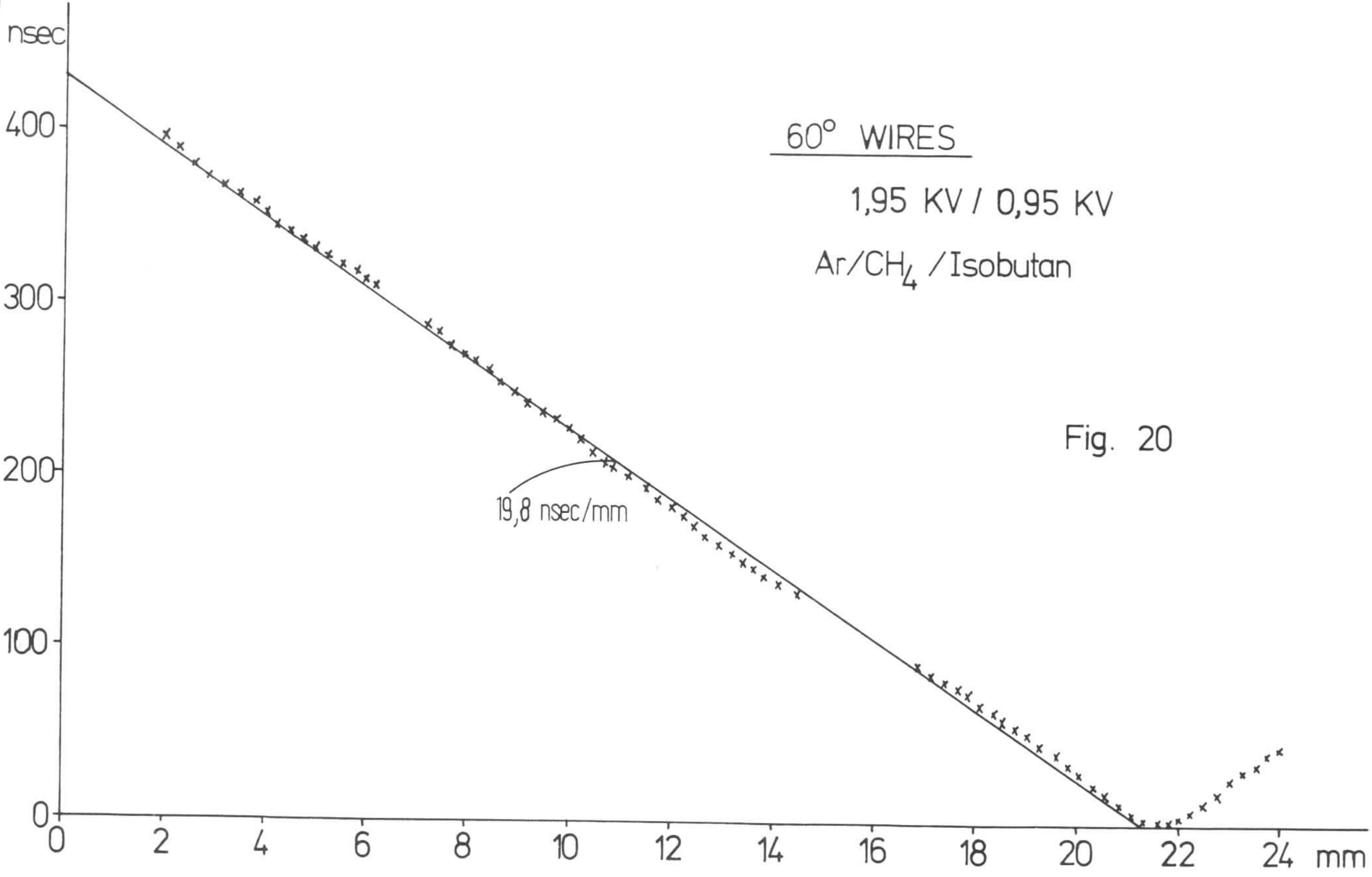


Fig. 20

RUN 290 - 292

## RESOLUTION VS. DRIFTSPACE, 30 cm WIRES

(2 wires)

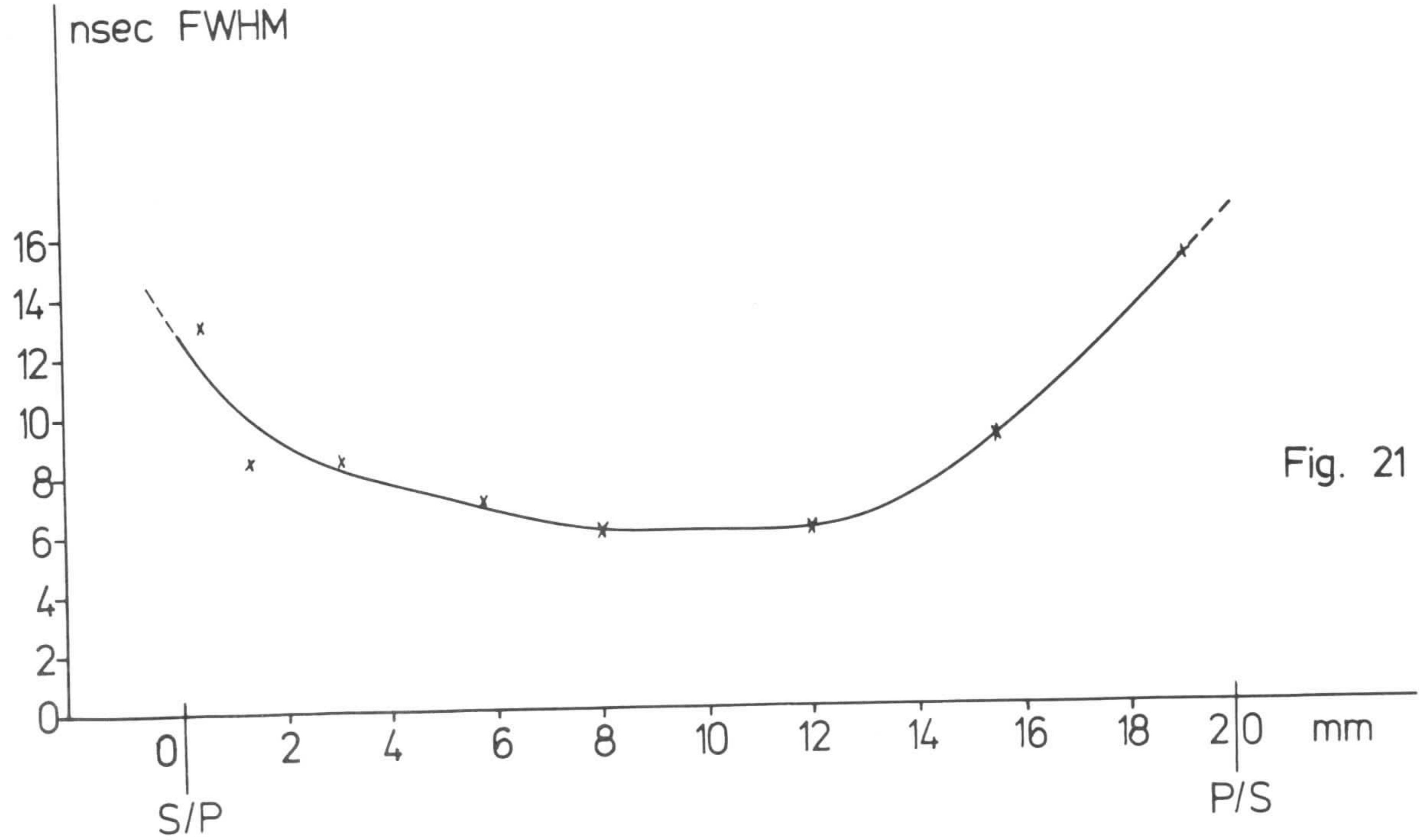


Fig. 21

RUN 270

RESOLUTION VS. DRIFTSPACE, 250 cm WIRES
( 2 wires )

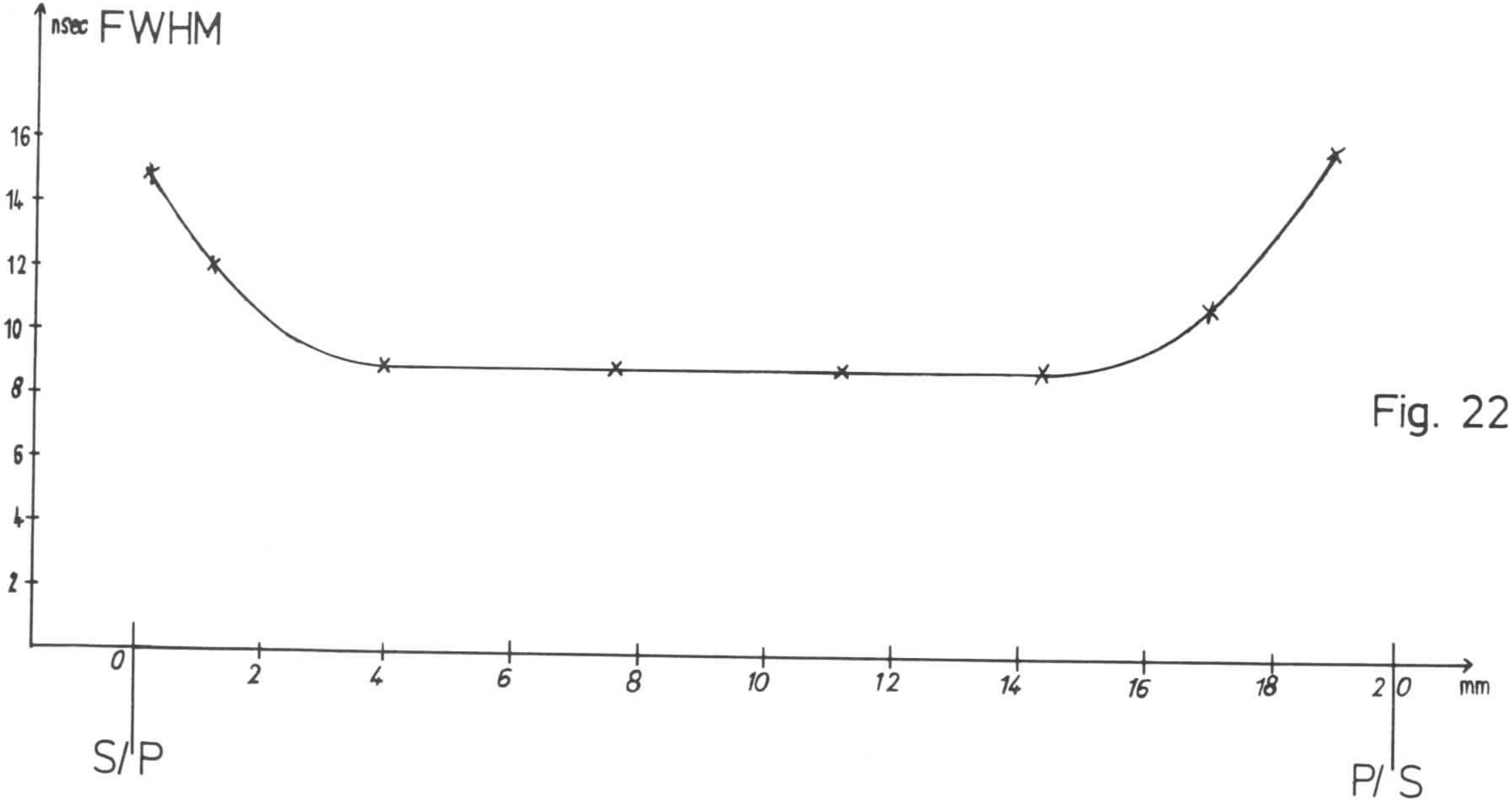


Fig. 22

RUN 270

RESOLUTION VS. DRIFTSPACE, 250 cm WIRES

(2 wires)

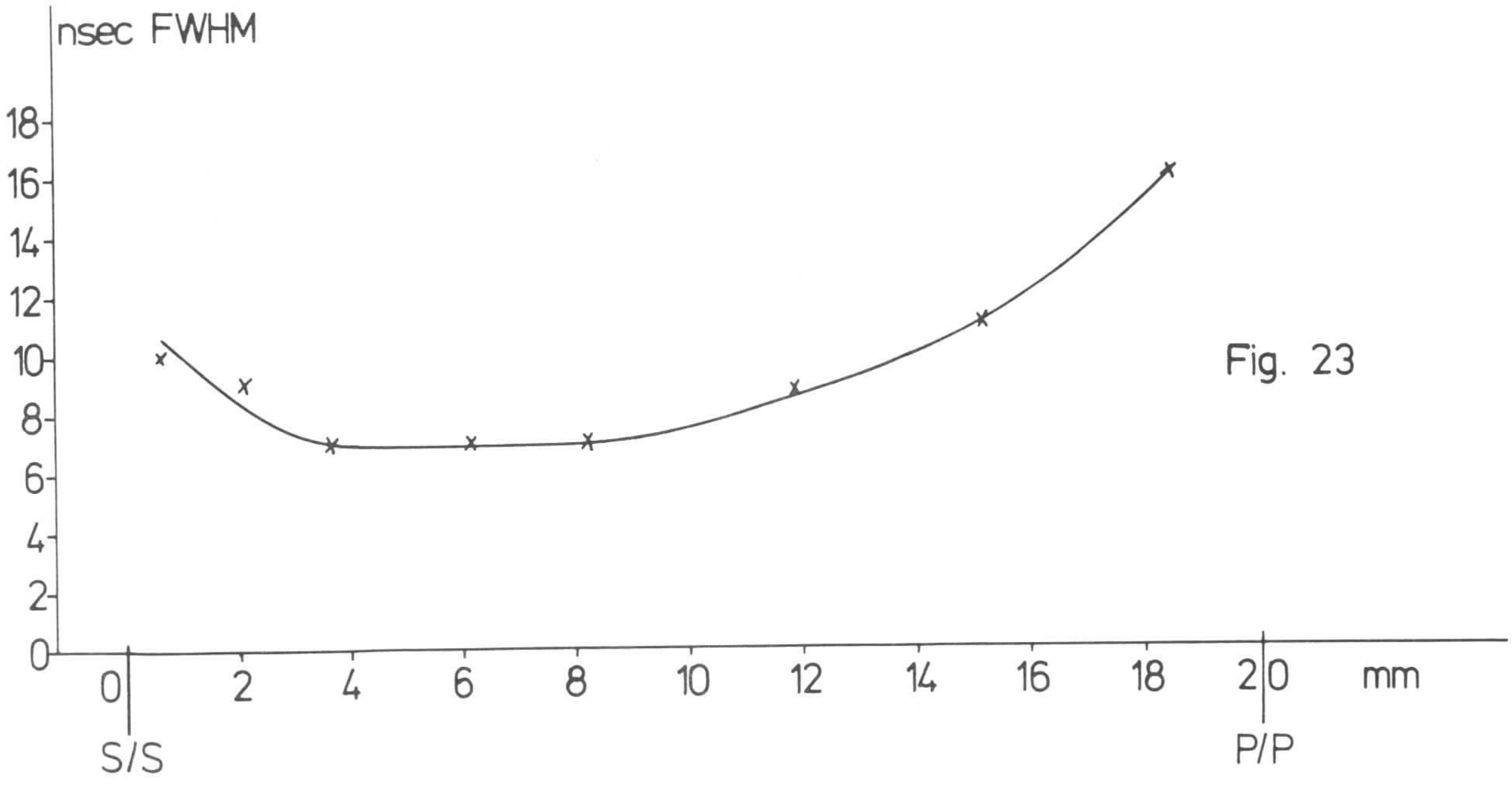


Fig. 23

RUN 270

RESOLUTION VS. DRIFTSPACE, 60° WIRES
(2 wires)

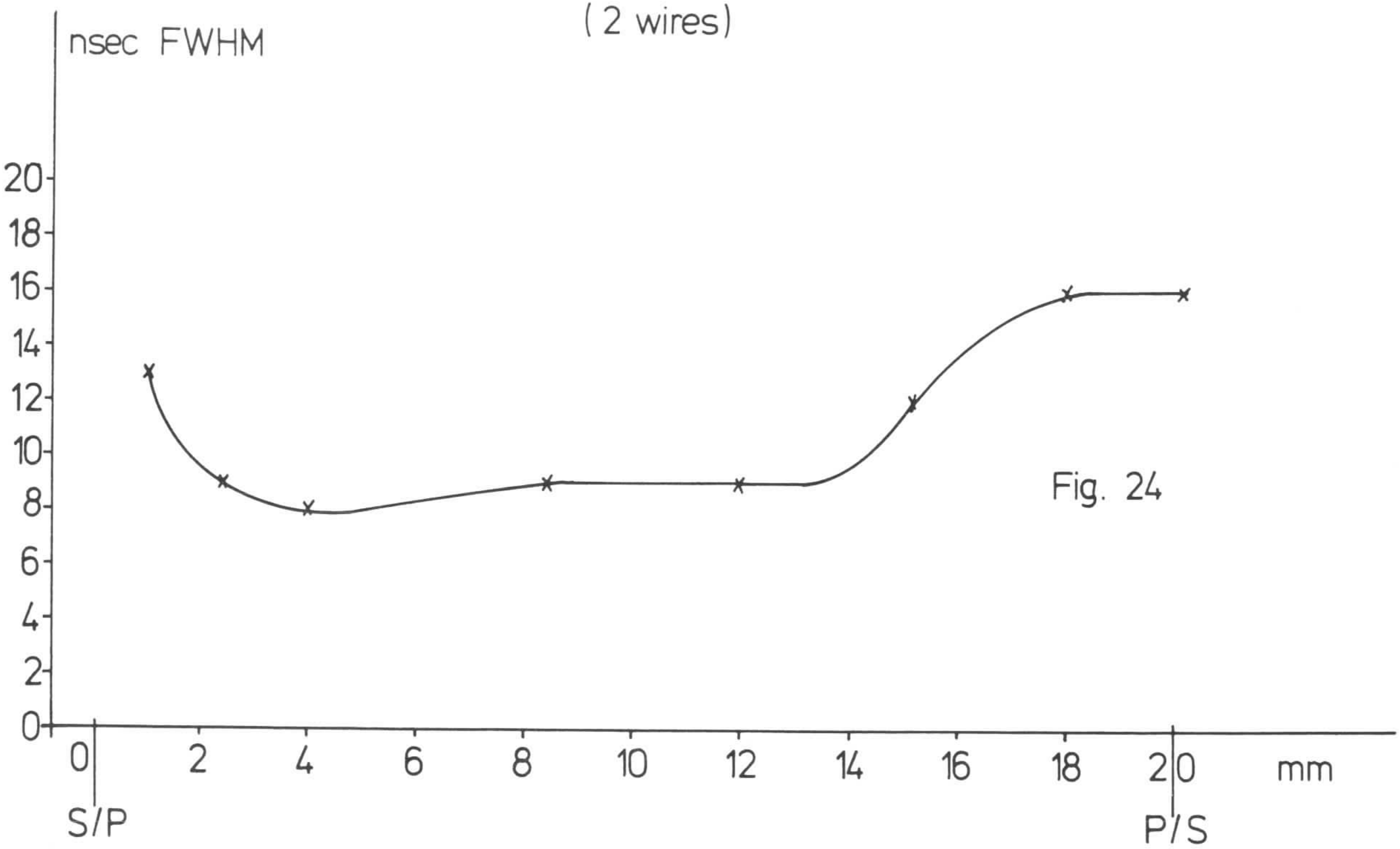


Fig. 24

RUN 285

RESOLUTION VS. DRIFTSPACE, 510 cm WIRES

BEAM AT POSITION 1
(2 wires)

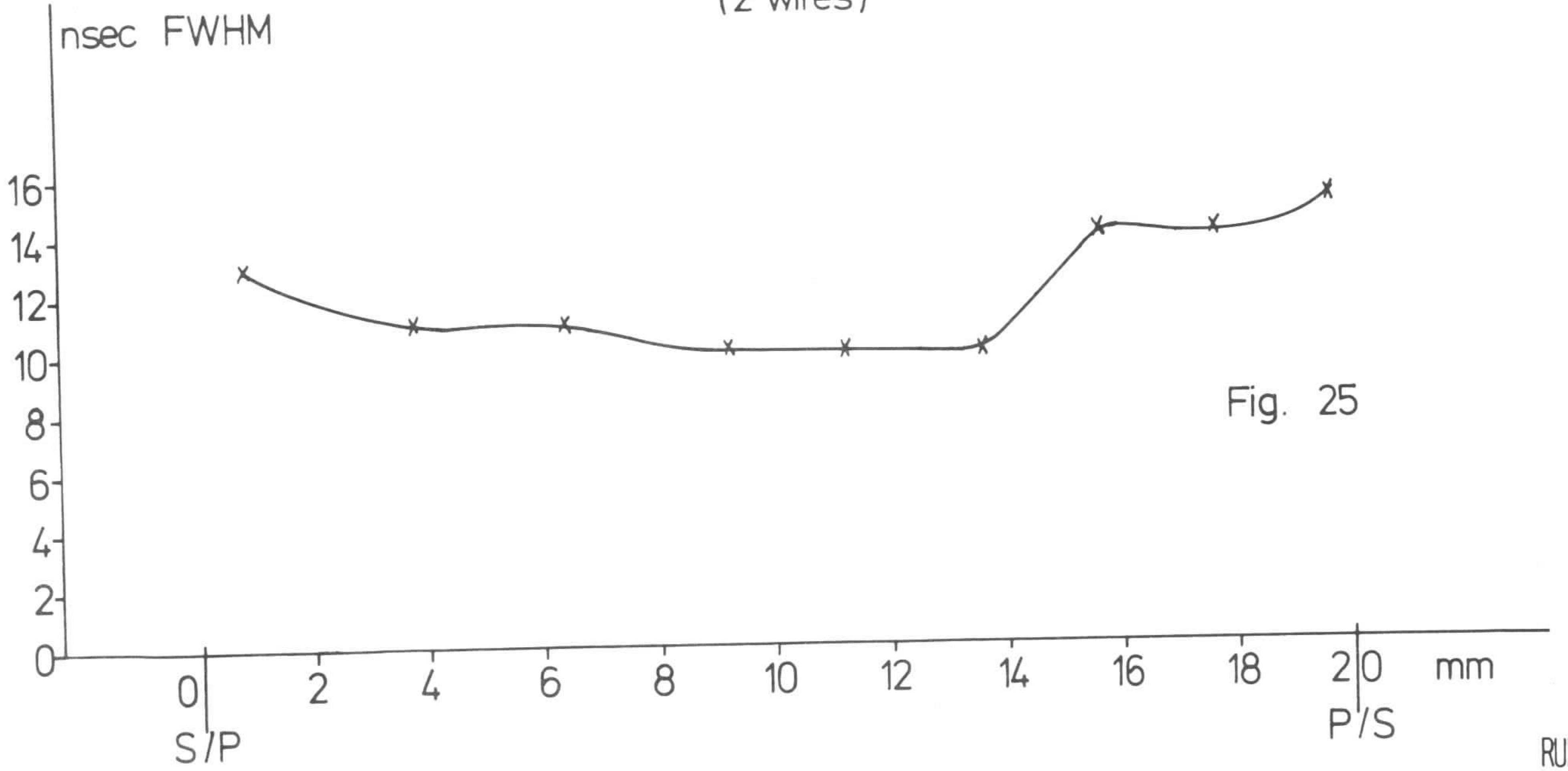


Fig. 25

RUN 282

SINGLE WIRE, 30 cm

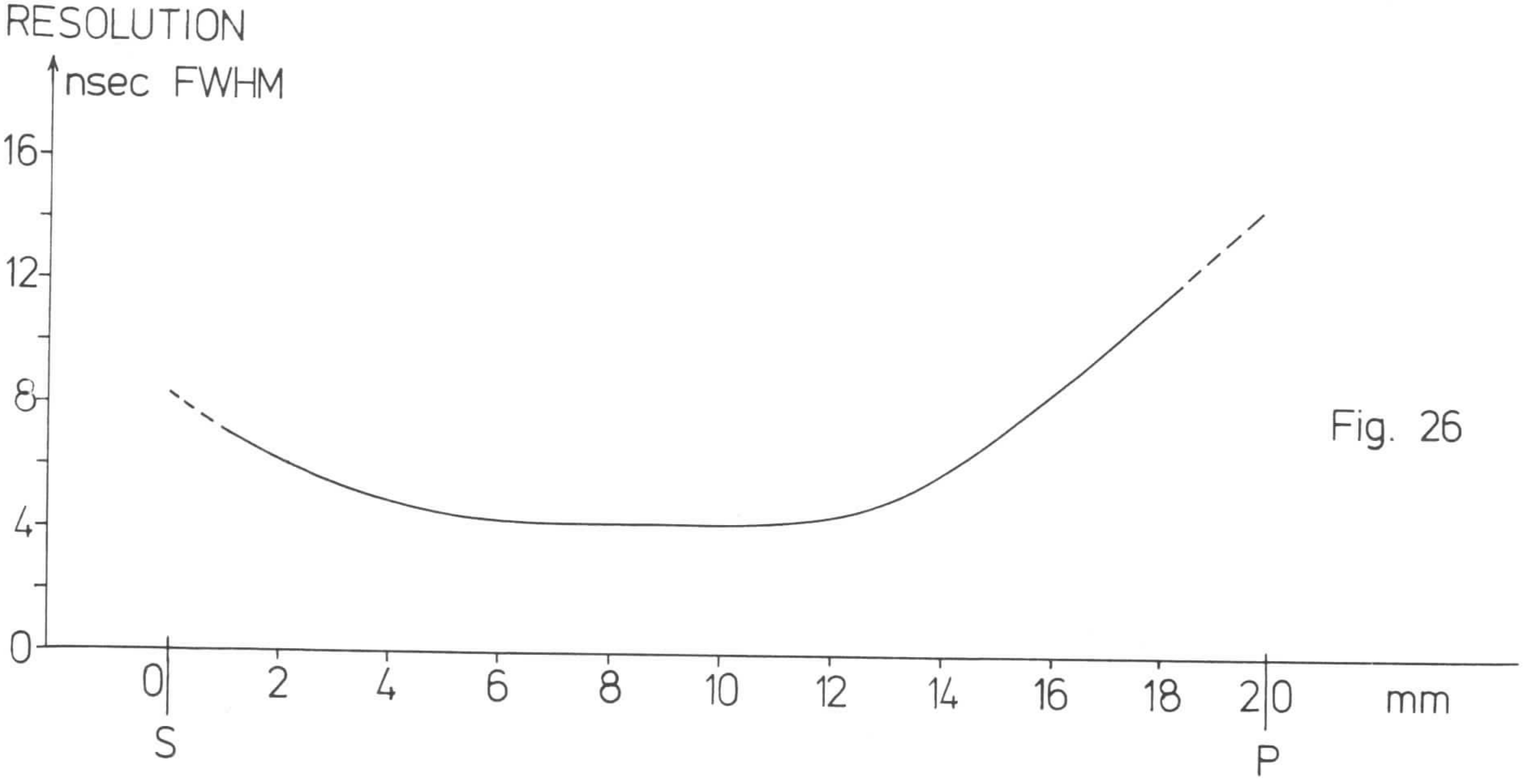


Fig. 26

RUN 270

SINGLE WIRE, 250 cm

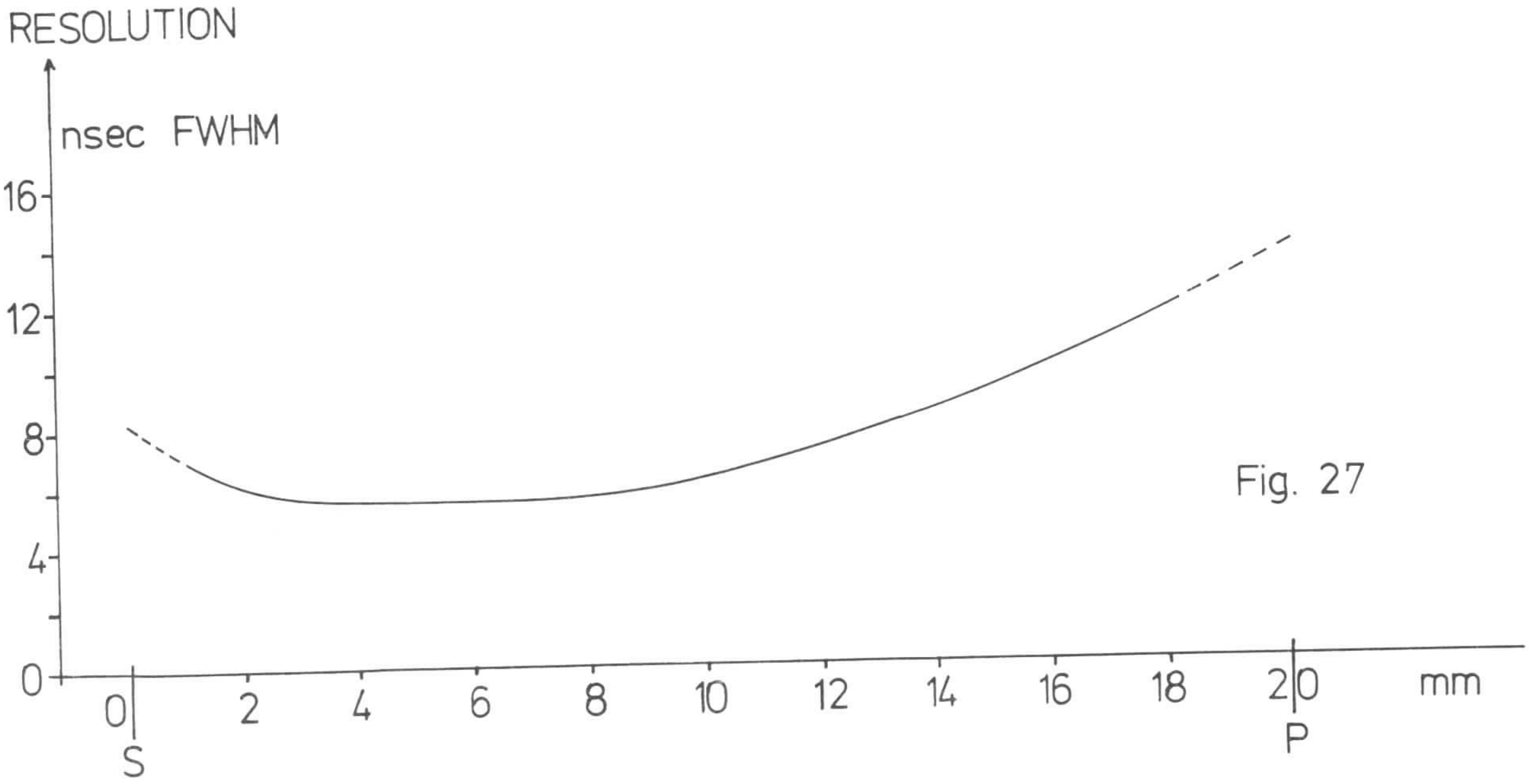


Fig. 27

RUN 270

SINGLE WIRE , 60° [ 290 cm ]

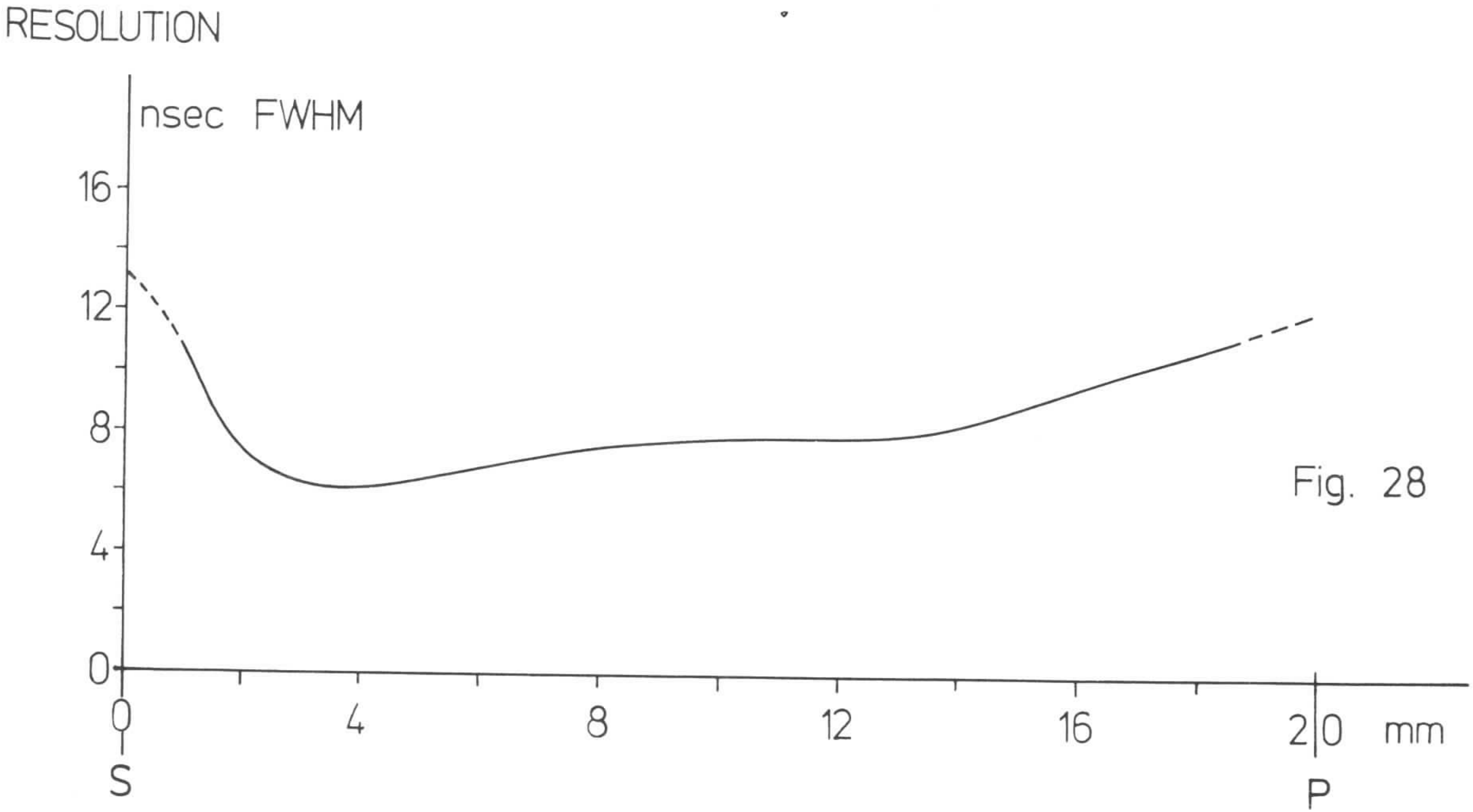


Fig. 28

RUN 285

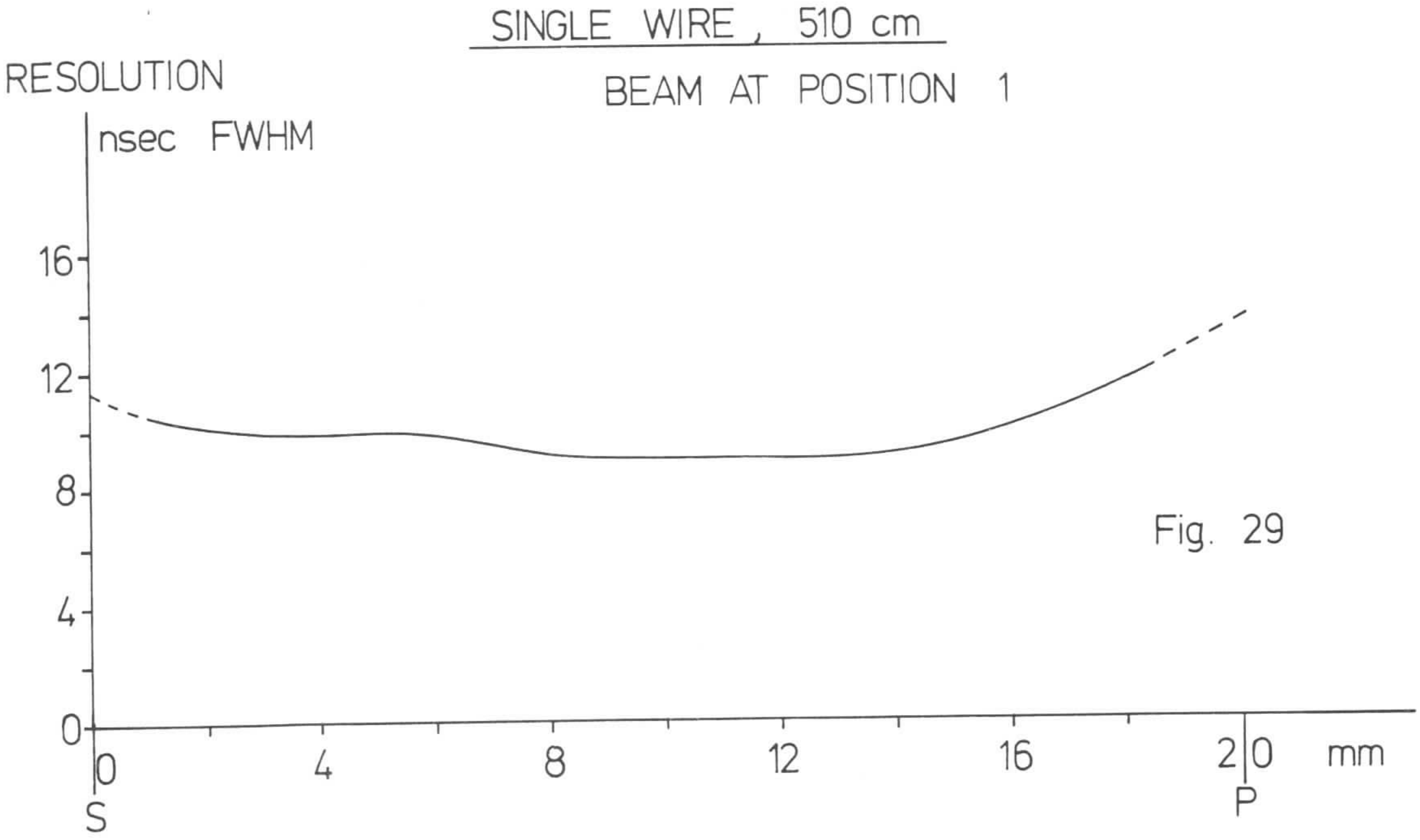


Fig. 29

RUN 282

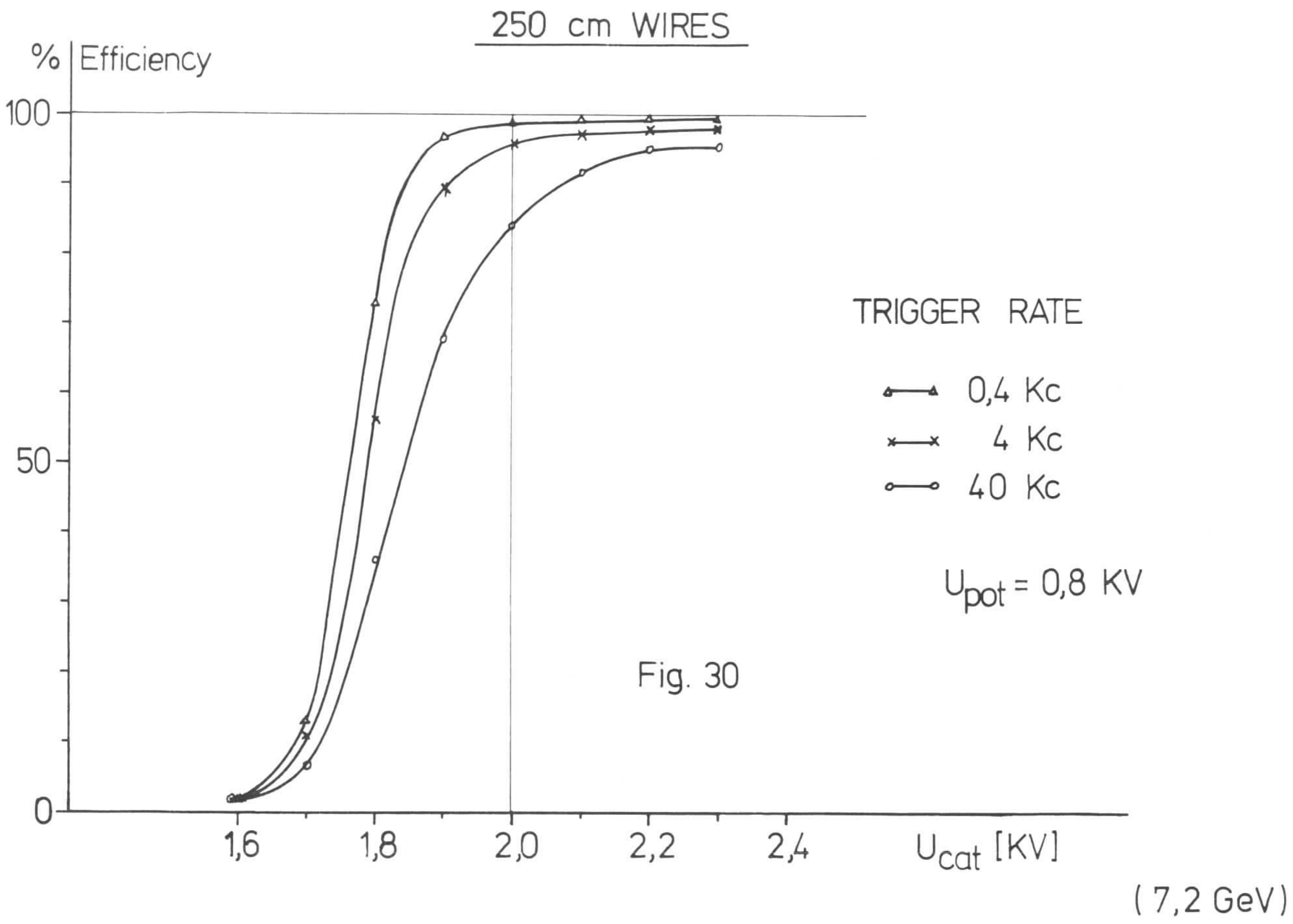
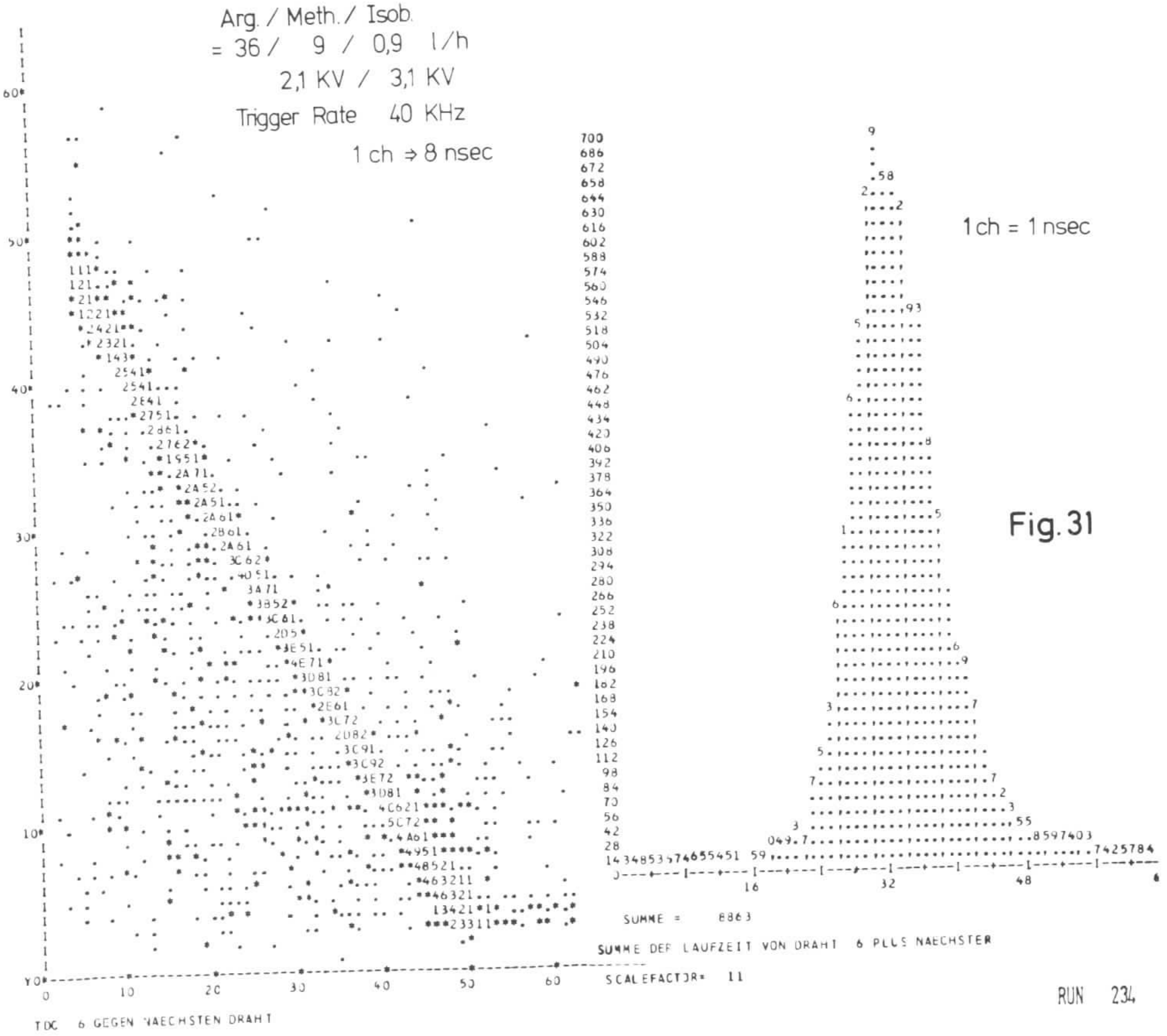

250 cm WIRES
% Efficiency
100
50
0
1,6
1,8
2,0
2,2
2,4
U_cat [KV]
TRIGGER RATE
0,4 Kc
4 Kc
40 Kc
U_pot = 0,8 KV
( 7,2 GeV)

Fig. 30



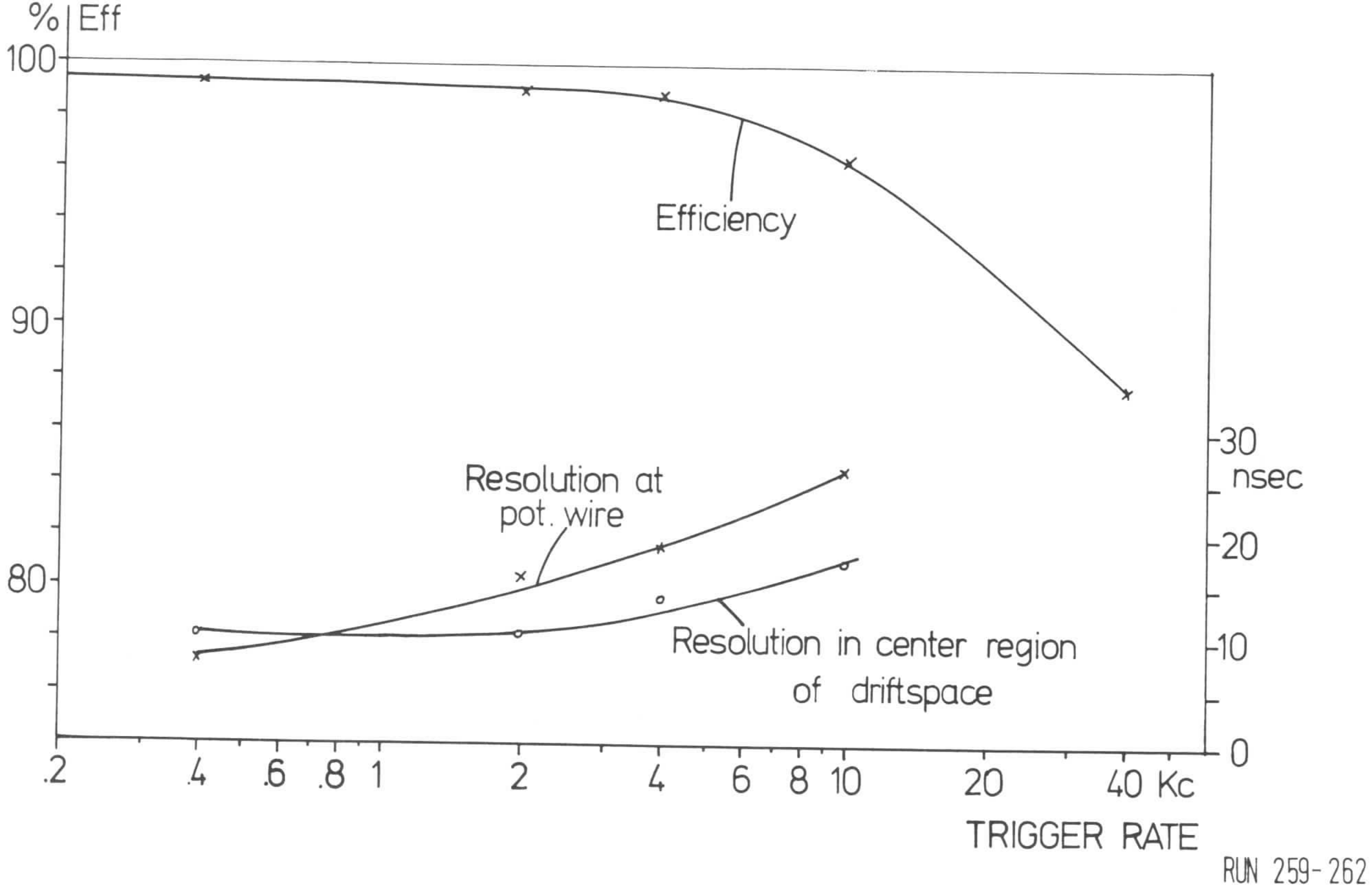
Arg. / Meth. / Isob.
= 36 / 9 / 0,9 l/h
2,1 KV / 3,1 KV
Trigger Rate 40 KHz
1 ch ⇒ 8 nsec

1 ch = 1 nsec

Fig. 31

RUN 234

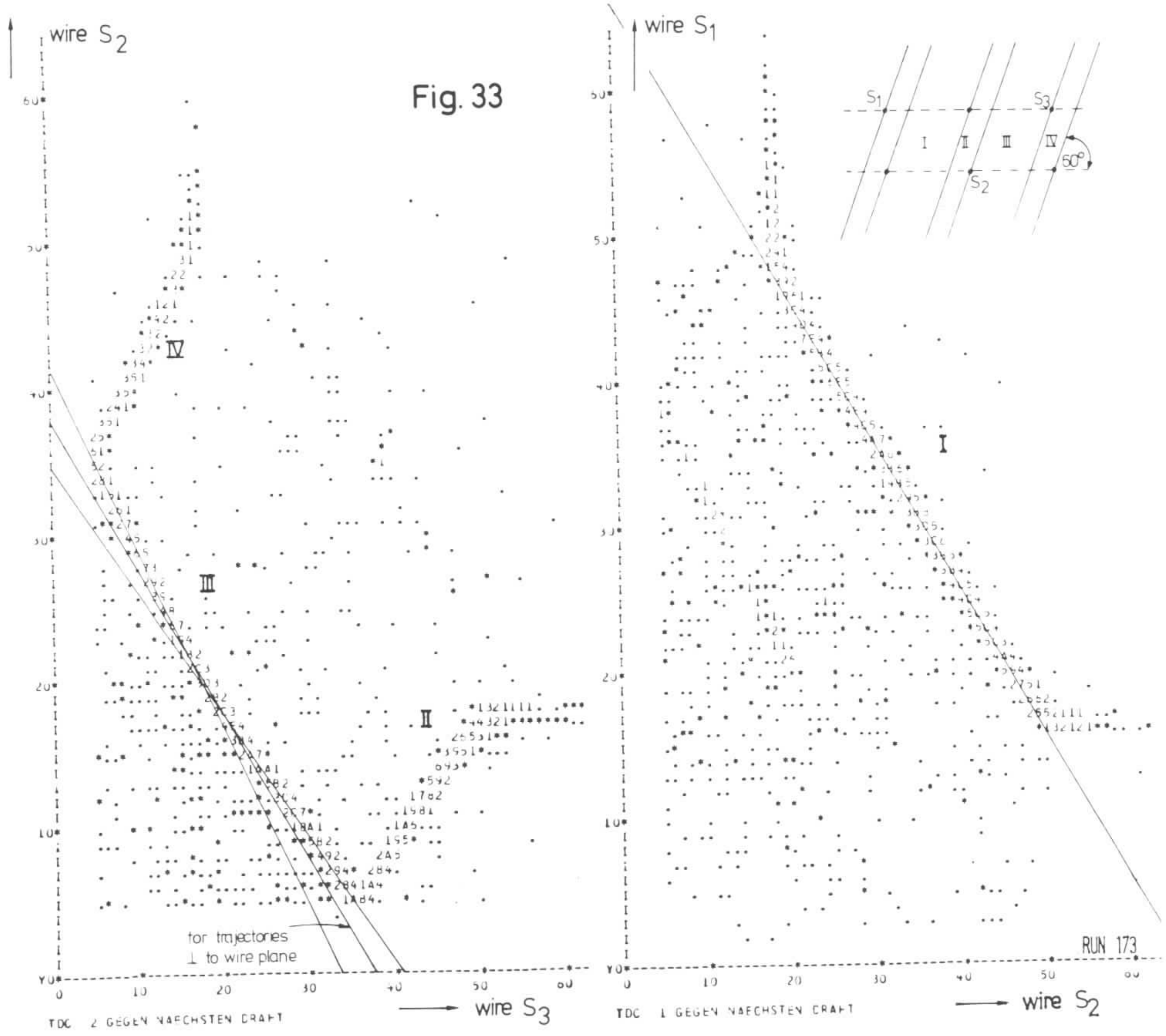
Fig. 32



250 cm WIRE

2,0 KV / 1,0 KV

Fig. 33


wire S2
60
50
40
30
20
10
Y0
0
10
20
30
40
50
60
wire S3
IV
III
II
for trajectories
⊥ to wire plane
TDC 2 GEGEN NAECHSTEN DRAHT
wire S1
S1
S3
I
II
III
IV
60°
S2
I
RUN 173
wire S2
TDC 1 GEGEN NAECHSTEN DRAHT