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THE JETSET EXPERIMENT AT LEAR:

A STATUS REPORT TO THE PSCC
December 1989

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INTRODUCTION

As described in our previous report to the PSCC [1], the Jetset experiment (PS202) at LEAR will search for gluonic hadrons and other exotics in the interaction of in-flight antiprotons with protons at rest. We will study rare, "OZI-forbidden" formation reactions of the type $\bar{p}p \rightarrow M_1M_2$ in a region where these states are likely to be visible. We have divided our study into two phases. The focus of "Phase I" is to study in detail the production of $K^+K^-K^+K^-$, including ϕKK and most importantly $\phi\phi$. For the 4K reactions, the mass range to be covered extends from 1.96 to 2.43 GeV, corresponding to a LEAR momentum range of 0.647 to 2.0 GeV/c. In "Phase II" we intend to improve the detector in ways that will make possible the study of a much wider variety of related physics channels.

Our experiment uses a hydrogen cluster jet target which has been inserted in the LEAR ring and which will soon be surrounded by a general-purpose detector of advanced design. The "Phase I" detector is nearing completion, and most of its components will be at CERN early in 1990. They will be installed at LEAR in the spring and summer of 1990, followed by testing and data runs in the fall and winter of that year. Further runs after that time are also being planned.

The purpose of this report is to update the PSCC on the extensive progress made toward realizing the goals of our experiment. In what follows, we discuss the status of each of the major detector elements. Their descriptions were given in [1] and will not be repeated here except when necessary to note modifications and test results. The major modifications to the previous design are: (1) the inclusion of 60 "**pipe trigger scintillators**" which run longitudinally along the beam pipe, covering the full azimuthal angular range and polar angles from $15^o < \theta < 65^o$; (2) the doubling of the number of elements in the forward outer trigger system, giving an 8-fold increase in the number of coincidence cells; and (3) the reduction in thickness of the Cherenkov counters from 4 cm to 2 cm, and replacement (for the low momentum runs) of the freon radiator with water to reduce the density. The main purpose of these changes is to improve the acceptance at low momentum (see below).

THE "PHASE I" JETSET EXPERIMENT

The central feature of the Jetset apparatus is the **hydrogen cluster jet target**. The jet has an areal density of about 5×10^{13} atoms/cm^2, and provides a "massless" pure gaseous hydrogen cylindrical target of about 1 cm diameter. This target was used originally in the ISR experiment R704 and has been heavily modified for use in PS202 by the University of Genoa. It is shown in Fig. 1; it has recently (October 1989) been installed in the south straight section (SD2) of the LEAR ring. For the moment it is mounted using a temporary straight section for the LEAR vacuum pipe. In January, 1990 a **corrugated vacuum pipe** (see Fig. 2) will be installed; its purpose is to reduce the wall thickness and therefore the multiple scattering.

For a stored beam containing 4×10^{10} antiprotons moving with a circulation frequency of 3.2×10^{6} Hz, the peak luminosity will be $10^{31}/\mathrm{cm}^2/\mathrm{sec}$ in an interaction volume of about 1 cm^3. This offers the possibility of searching efficiently for rare physics channels such as $\bar{p}p \rightarrow \phi\phi$, which are present at the microbarn level. Such luminosities can provide rates of about 8×10^{5} events/μb/day, so that we will double the world's existing sample of $\phi\phi$ events in a very short running time. The event signature is $\bar{p}p \rightarrow \phi\phi \rightarrow K^+K^-K^+K^-$; the ϕ decays to K^+K^- with a 50% branch.

However, the desired signal is small compared to a number of physics backgrounds. The high luminosity of the jet target apparatus also means that the detector must be equipped to allow extraction of good events from a background rate of about 1 MHz. To do this we use the characteristics of the events we wish to study: they have (only) 4 charged prongs; they are forward of 90° in the lab frame; they each have a moderate β value. At least 3 of the 4 particles are almost always forward of 45° at all beam momenta. Thus we will apply cuts at the trigger level that focus on the multiplicity, the event geometry and the β values of the outgoing particles. This is discussed in more detail in [1] and below..

With a trigger based on the above ideas, the very large "purely pionic" background can be reduced to the level of the "good event" rate. Other, more troublesome, reactions are $\pi^+\pi^-K^+K^-$ and $\bar{p}p\pi^+\pi^-$; depending on beam energy, these provide signatures looking much more like good events. However, the "Phase I" detector is designed to distinguish these in both the on-line and off-line analysis [1].

A plan view of the "Phase I" detector is given in Fig. 2. The detector is a compact device ($\approx 1\mathrm{m}^3$) that surrounds the jet with about 75% of 4π solid angle. Although the LEAR beam pipe (an oval shape with major and minor half-axes 8.0 and 4.0 cm, resp.) limits the very forward acceptance (see Fig. 2), it will still be possible to measure the $\phi\phi$ production cross section near threshold, albeit with reduced efficiency (see below).

Significant problems that reduce the acceptance of our device are: (1) the detector geometry; (2) the amount of material in the detector components (giving rise to multiple scattering and secondary interaction effects); and (3) the natural decay of the outgoing kaons, especially near the reaction threshold. The ways we are countering these problems are discussed below.

STATUS OF DETECTOR COMPONENTS

The **pipe trigger scintillators** are shown in Figs. 2 and 3. They are arranged in two layers, each of which consists of scintillator strips 2 mm thick: the first set (40 scintillators, each 10 mm wide) covers the θ range from 15° to 45°. Because of the oval shape of the beam pipe the length of these strips varies (as shown in Fig. 3) in order to keep fixed the angular range covered by each strip. A second set of 20 scintillators (each 20 mm wide) covers the θ range from 45° to 65°.

The purpose of these scintillators is to provide a fast multiplicity and time-zero trigger, in conjunction with the forward outer trigger counters. These have the advantage of being close to the interaction region, so that they will be less affected by kaon decay, secondary interactions, or multiple scattering. At low momentum (near threshold), where these effects are large, they play a major role in keeping the acceptance at a reasonable level (see below). This is done by exploiting the fact that at low momentum the four outgoing kaons are mostly forward of 45°, whereas the contaminant pion reactions are more uniformly spread out in θ.

HYDROGEN CLUSTER JET TARGET

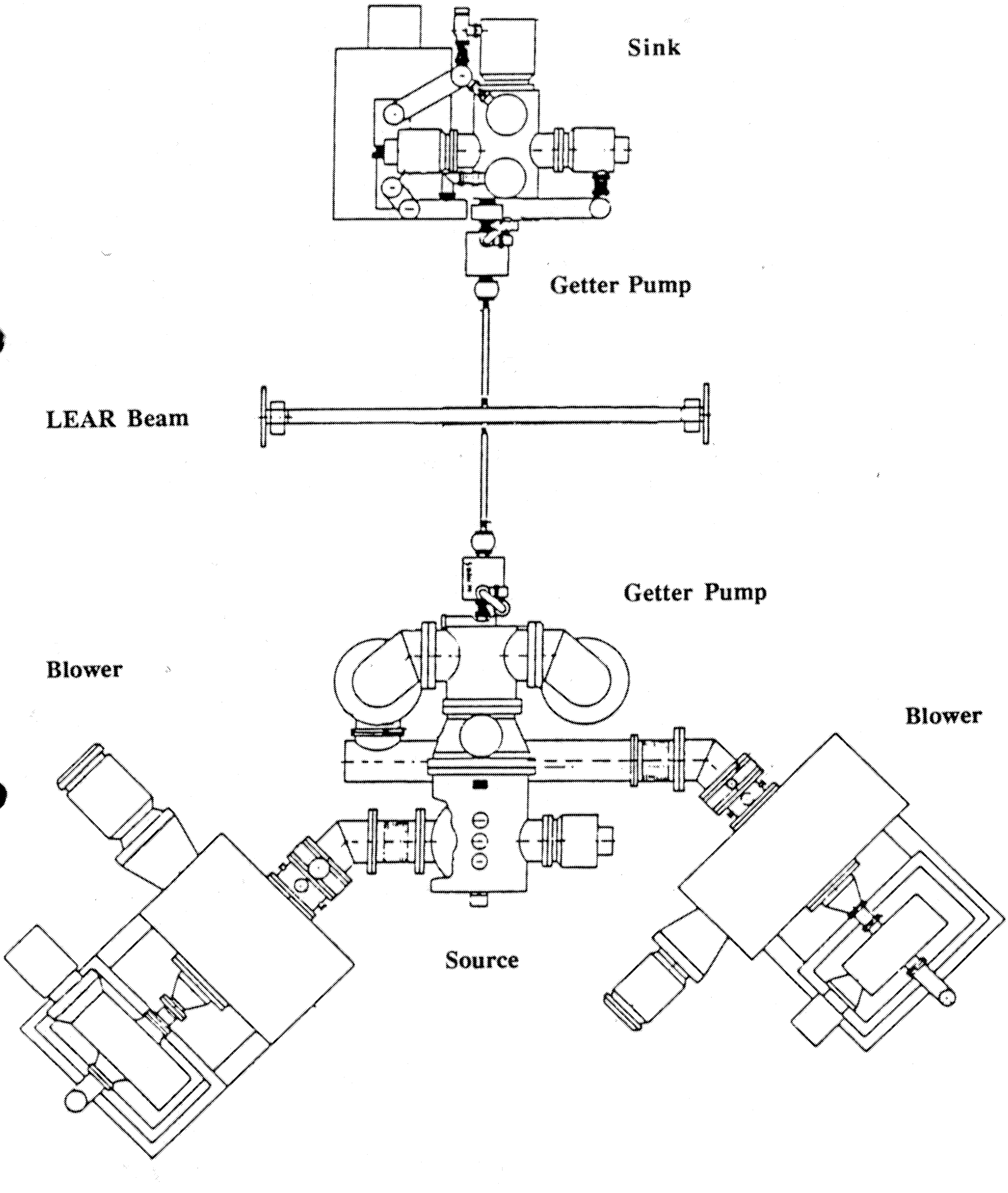
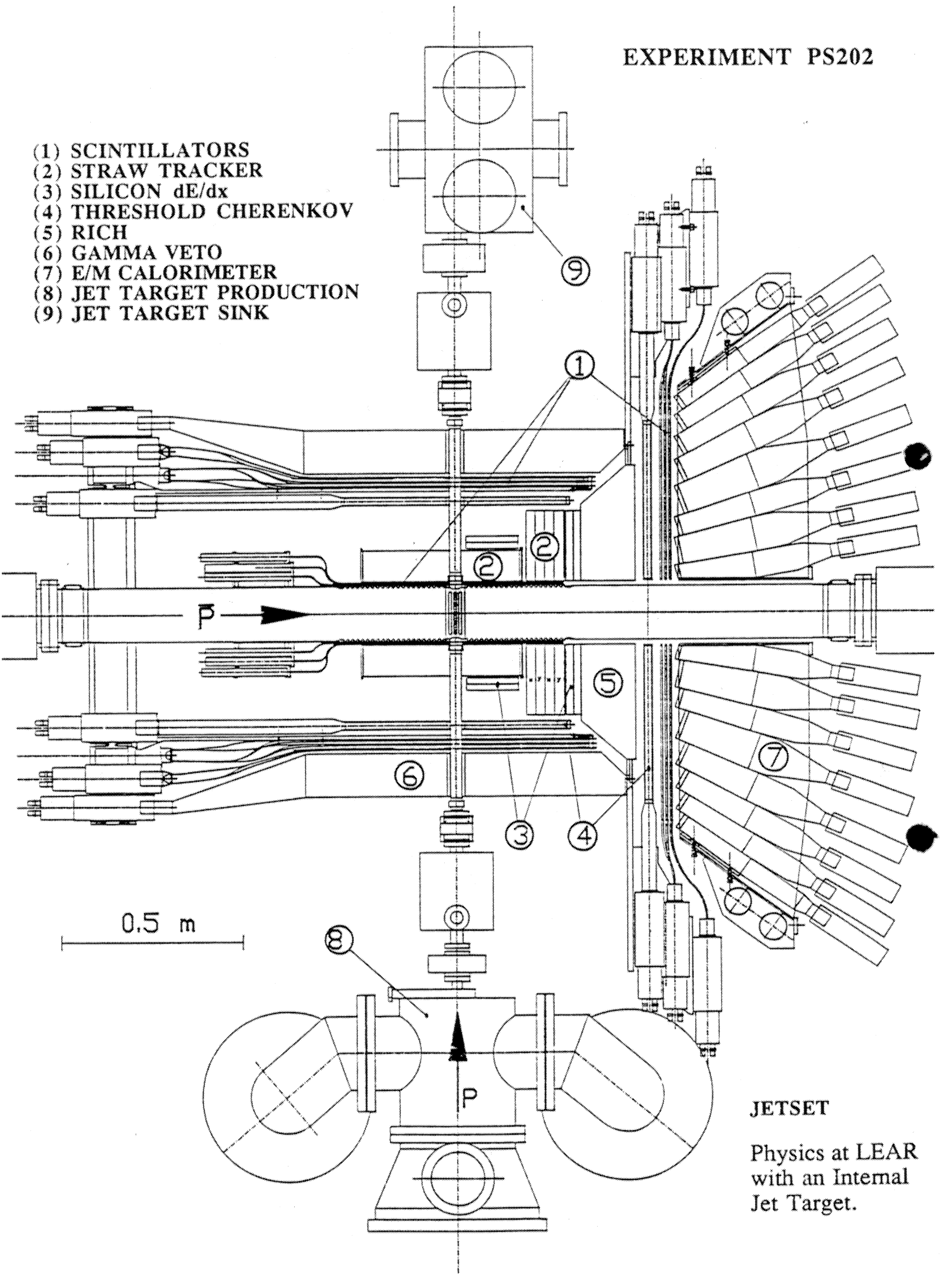


Fig. 1. Plan view of the hydrogen cluster jet target, now installed on the LEAR facility.

EXPERIMENT PS202



(1) SCINTILLATORS
(2) STRAW TRACKER
(3) SILICON dE/dx
(4) THRESHOLD CHERENKOV
(5) RICH
(6) GAMMA VETO
(7) E/M CALORIMETER
(8) JET TARGET PRODUCTION
(9) JET TARGET SINK

JETSET

Physics at LEAR
with an Internal
Jet Target.

Fig. 2. Plan view of Jetset.

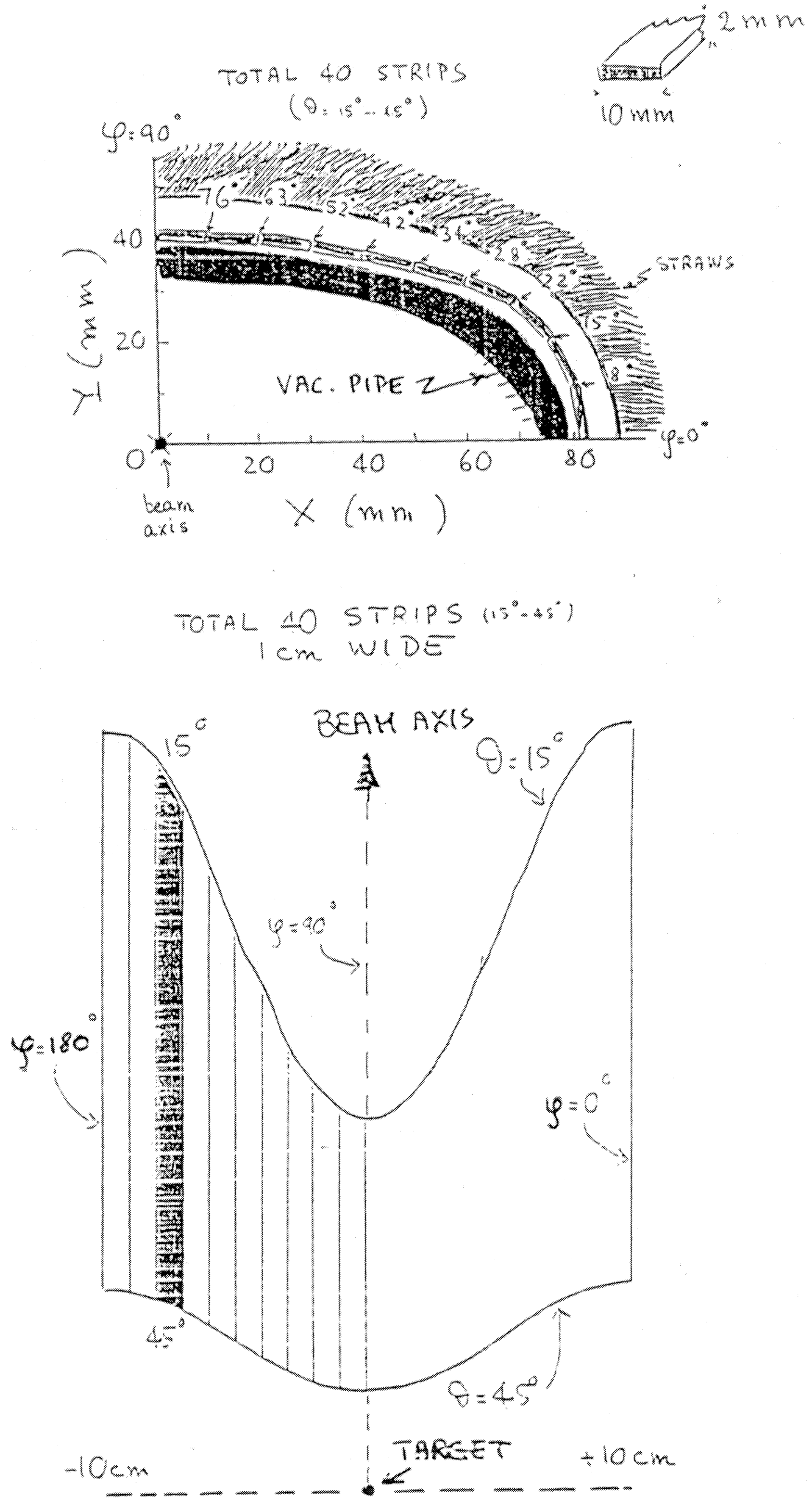


Fig. 3. (Top) One-quarter cross section of the LEAR beam pipe surrounded by the pipe trigger scintillators and the barrel straw tracker. (Bottom) Because of the oval shape for the beam pipe, the pipe scintillators have lengths depending on their azimuthal position.

The CERN group has assumed responsibility for building these detectors. The construction is complete and the units will be tested in the November, 1989 PS185 run. At a later time they may be augmented by silicon pads mounted on the beam pipe.

The precision barrel tracker provides an unambiguous measure of (r,θ,ϕ) information for off-line analysis of the charged tracks in the barrel region ($\theta > 45^o$). It will consist of about 1500 individual drift-tube counters ("straws") running parallel to the beam direction and glued together into a self-supporting unit (Fig. 4 top). The "straws" fill about 85% of the available volume. Such a construction reduces the amount of supporting material needed in the forward direction and thus minimizes multiple scattering. For this reason all the connections to gas supply, high voltage and readout systems are made at the barrel rear endplate.

In order to disassemble the tracker easily the entire unit is split along its horizontal midplane into two halves. Fig. 4 shows that the "straws" in the horizontal mid-plane region are split to allow for the entry of the jet. Those "straws" (about 500 out of 1500) will not be mounted in the first installation.

Each "straw" consists of a tube that is 8 mm in diameter and 436 mm in length with a resistive anode wire (30 µm diameter stainless steel, $R \approx 1k\Omega/m$) running down its center at a tension of about 80 g. Tests of various prototypes are described in [2]. We had planned to use Al tubes of 60 µm wall thickness that were to be etched down to a thickness of 30 µm; however, it proved difficult to etch the tubes uniformly. We concluded [3] that leaving the tubes unetched at their nominal 60 µm thickness had little effect on the multiple scattering of the outgoing kaons. Since the last PSCC report, the Delrin endpieces supporting the wires have been redesigned to insure for good wire positioning precision and gas-tight drift tubes.

Tests have been carried out [2] on various arrays of straw tubes of different length to determine a suitable gas mixture for optimum operation; a 50/50% mixture of Ar/CO_2 is a good candidate. Using a high voltage of 2.15 kV the drift-time measurement yields a spatial resolution averaging about 160 µm, although it varies as one expects as the track approaches the central wire (Fig. 5). Charge division is used to measure the longitudinal coordinate of the particle along the resistive wire; in our tests the measured resolutions were about 1% of the wire length. The efficiency of the units tested was above 95%. These results are quite competitive with what has been achieved elsewhere.

The effects of space charge on the resolutions and efficiencies can be dramatic. While our tests (Fig. 5) show little effect when the charged particle rate is below 5 kHz/cm, the effects are quite strong when the rate is above 10 kHz/cm. As we expect the rate to be of order 3 kHz/cm when the experiment is taking data, there appears to be an adequate safety margin.

In order to reduce the amount of material in the forward region of the barrel tracker (important for particles that will enter the forward tracker), all the wire readout is done from the rear end of the assembly. Each wire is equipped separately with drift-time readout in order to measure the radial distance of impact. In order to measure the longitudinal coordinate by means of charge division, two wires are connected to each other using resistors (in SMD technology) that are located at the forward end of the assembly. The combined information from TDC's (drift time) and ADC's (charge division) will provide unambiguous three-dimensional information for off-line track finding and fitting.

Construction of the tracker is in progress based on a Freiburg/EP-TAG design. LN Industries (Switzerland) is supplying the tubes for the barrel, while the precision aluminum endplates have been produced in Freiburg. The tracker is being assembled at CERN under EP/TAG supervision but supported financially by the University of Freiburg. Mechanical construction is expected to be finished by the end of January, 1990. Cabling, testing and calibration will take place until mid-summer, at which time the device will be installed in the detector.

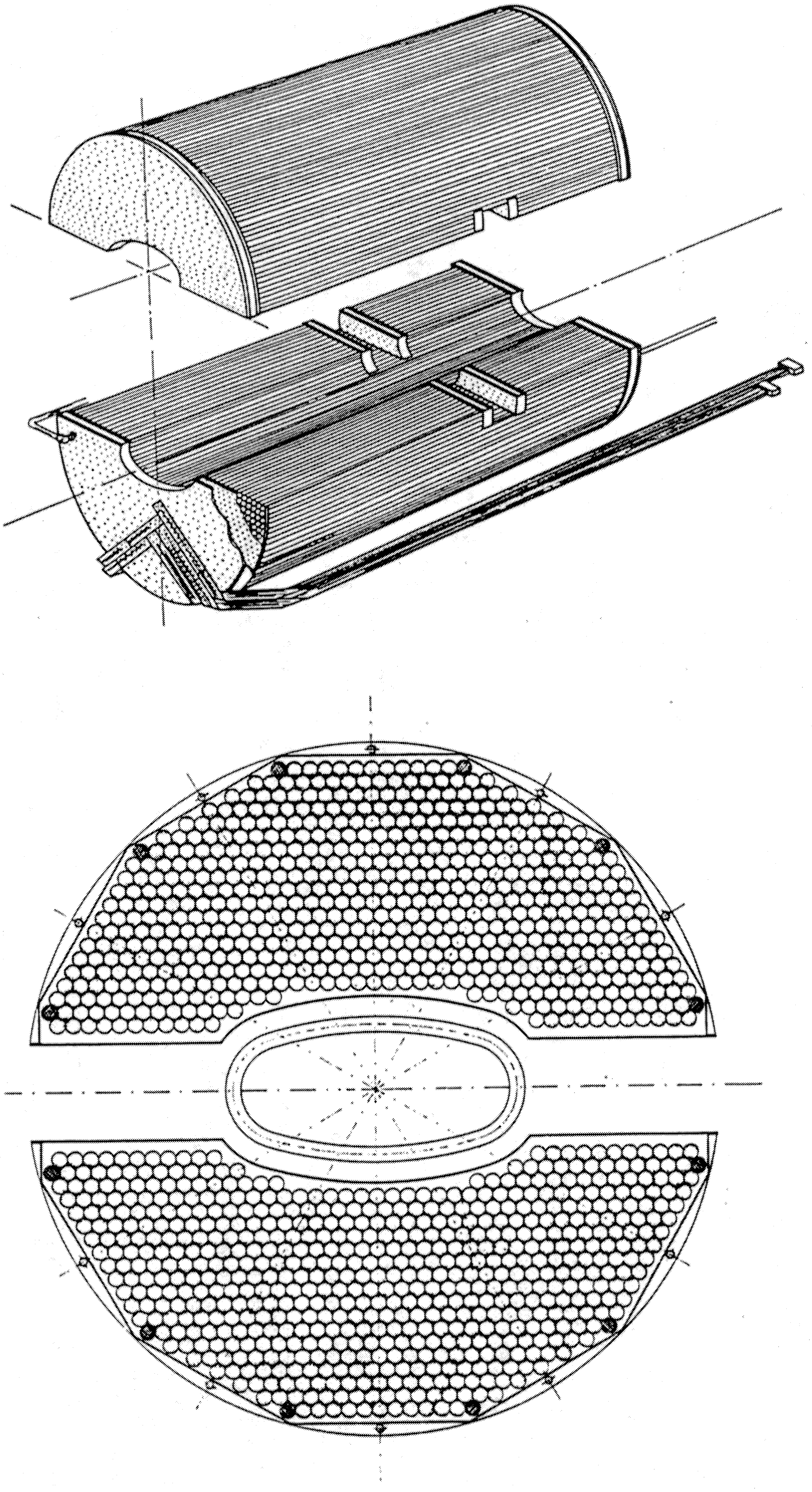


Fig. 4. (Top) Exploded view of the barrel "straw" tracker. Note the rear entry of the gas and electronics connections, and the side entry of the jet. (Bottom) End view of the tracker showing the cutout for the jet. This region will not be instrumented in Phase I.

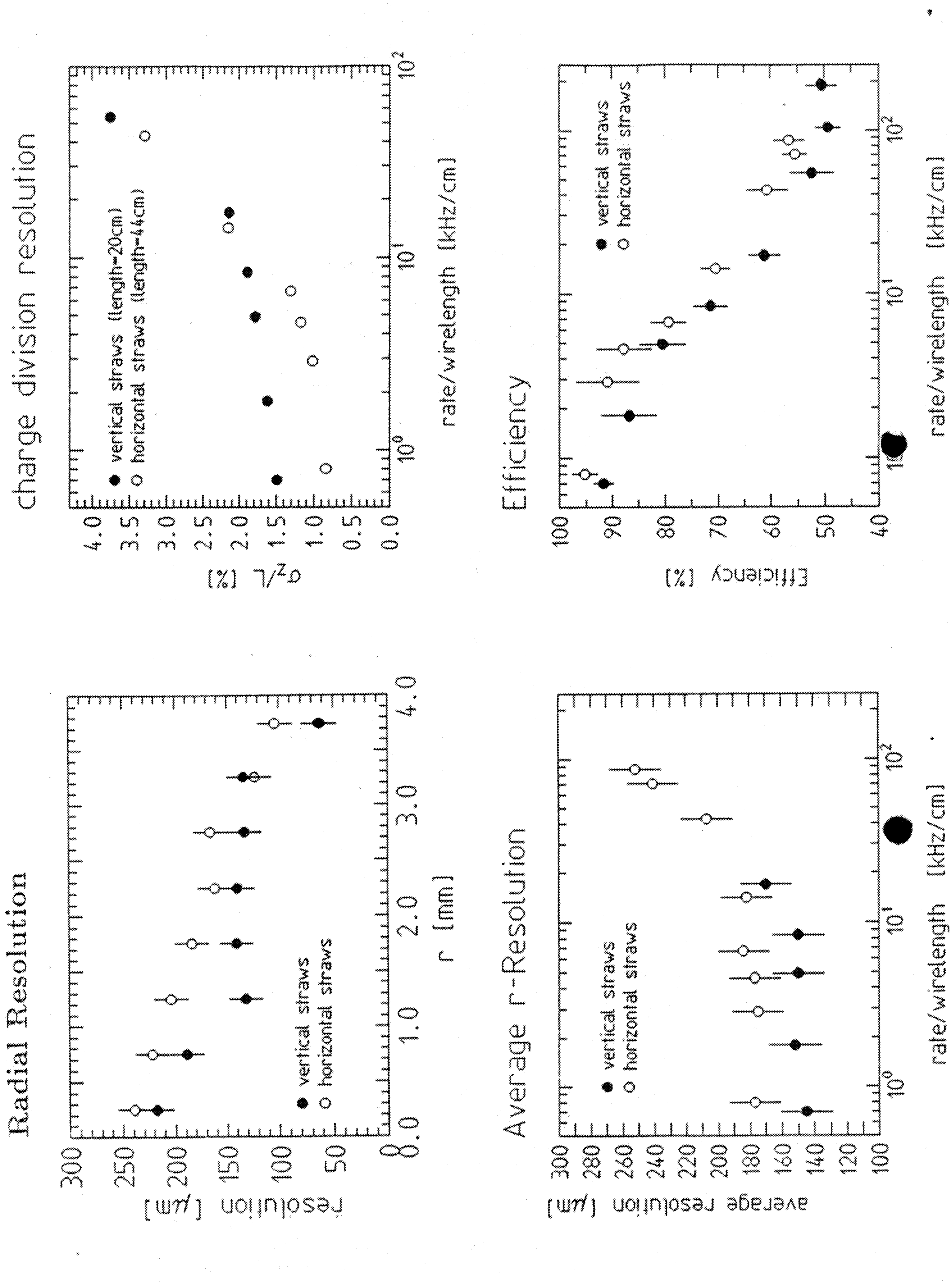


Fig. 5. Test results using the T11 beam for straws of length of 44 cm (horizontal) and 20 cm (vertical).

Freiburg has also assumed responsibility (with partial financial support from the University of Uppsala) for the design and construction of the front-end electronics for the barrel and forward trackers. A monolithic preamplifier (Fujitsu MB 43468) is used for the drift tubes. The preamplifier and high voltage distribution system for the barrel and the forward trackers, consisting of 160 cards with 16 channels each, is under construction. The preamplified signals are then fed into a receiver card which contains a differential amplifier (µA 733), analog drivers for the connection to the ADC's, and fast discriminators (LeCroy MVL 407) for the connection to the TDC's. This system, comprising 2560 channels because it serves both the barrel and forward trackers, is also under construction and will be completed on the same timescale as the detector.

The precision forward tracker provides tracking information for the forward-going ($\theta < 45^\circ$) charged particles. It is constructed using the same drift tube "straws" and electronics as described above, although the geometric configuration and endplate assemblies are completely different [4].

These counters are mounted in 12 layers perpendicular to the beam axis, with alternating x- and y-modules: (3x)(3y)(3x)(3y). The x- and y-modules are not identical because of the oval beam pipe (see Fig. 6). They contain 270 and 240 straws, respectively, for a total of 1020 straws. All tubes are equipped for drift time and charge division readout; the preamplifiers will be placed outside the detector. We have achieved [4] essentially the same resolution figures as mentioned above for the barrel. As is the case with the barrel tracker, the independence of each straw insures that there will be no track ambiguities from this source in the off-line analysis.

Construction is underway, with completion expected in January, 1990. CERN and the University of Uppsala are constructing this device. The electronics chain is the same as will be used for the barrel "straw" detector.

The silicon dE/dx forward counters measure the beta of the charged particles and thus greatly help to distinguish 4K events from the $\bar{p}p\pi^+\pi^-$ reaction (and other) backgrounds. The silicon counter is a natural complement to the threshold Cherenkov and RICH counters, as it measures β best at low energies. At present this system is designed for the off-line analysis. Cuts on dE/dx, when used in conjunction with the trackers, will reduce the backgrounds to a fraction of a percent without loss of the desired signal.

The forward silicon will be mounted in two planar arrays arranged to yield an (x,y) measurement (See Figs. 2 and 7). These will thus provide two energy loss measurements as well as geometric information about the particle track. The silicon planes consist of units 1.95 x 2.40 cm^2 in area, each made up of four pads, and each 280 µm thick. There are 924 such detectors in the forward counter covering an area of 0.43 m^2. The amount of material at normal incidence is estimated to be $\approx$ 3.5% of a radiation length with the silicon itself representing about 0.6%. The silicon is supplied by SI/AME, Norway.

The electronics will be mounted on the same printed circuit board as the detector. The front-end VLSI electronics (see [5] and [6]) will be based on the Amplex chip developed at CERN/EF Division for UA2. An elaborate multiplexing scheme [6] will be used to read out the 3696 pads in the forward region.

Tests have been made [7] at the T_{11} test beam which clearly show (Fig. 8) the ability to measure dE/dx adequately for our purposes; based on them, the forward counters are under construction at the University of Genoa in collaboration with the CERN/EF Division and the University of Oslo. They will be mounted in the detector in mid-summer, 1990.

The silicon dE/dx barrel counters will provide two energy loss measurements in the barrel. We use the same silicon pads as in the forward counter, in this case arranging them in a cylindrical geometry. Here 1152 detectors (4608 pads), covering 0.54 m^2, will be mounted. The barrel Si counters extend to $\theta = 78^\circ$,

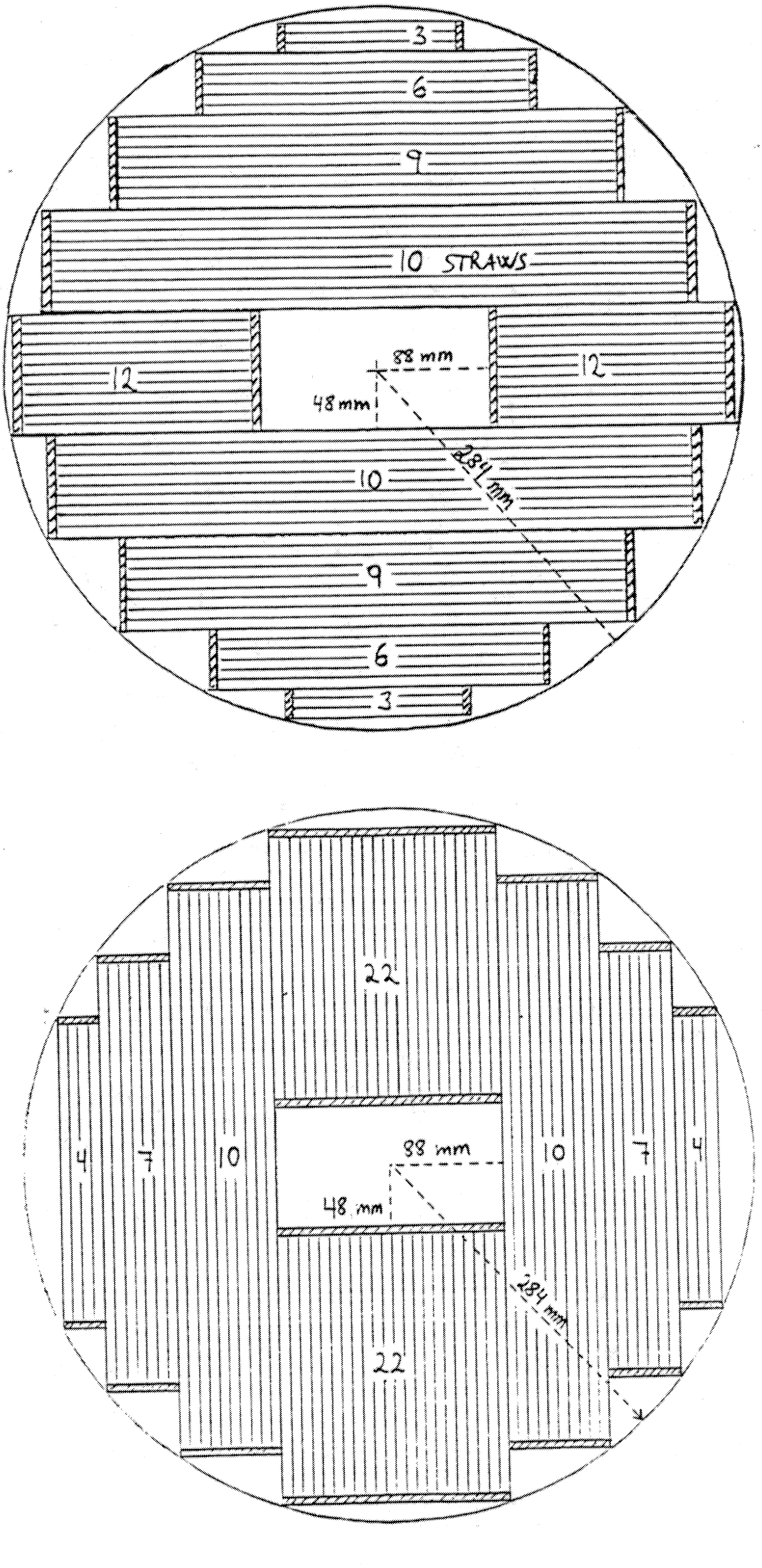


Fig. 6. Plan view of single forward tracker planes for y (top) and x (bottom) trajectory measurements.

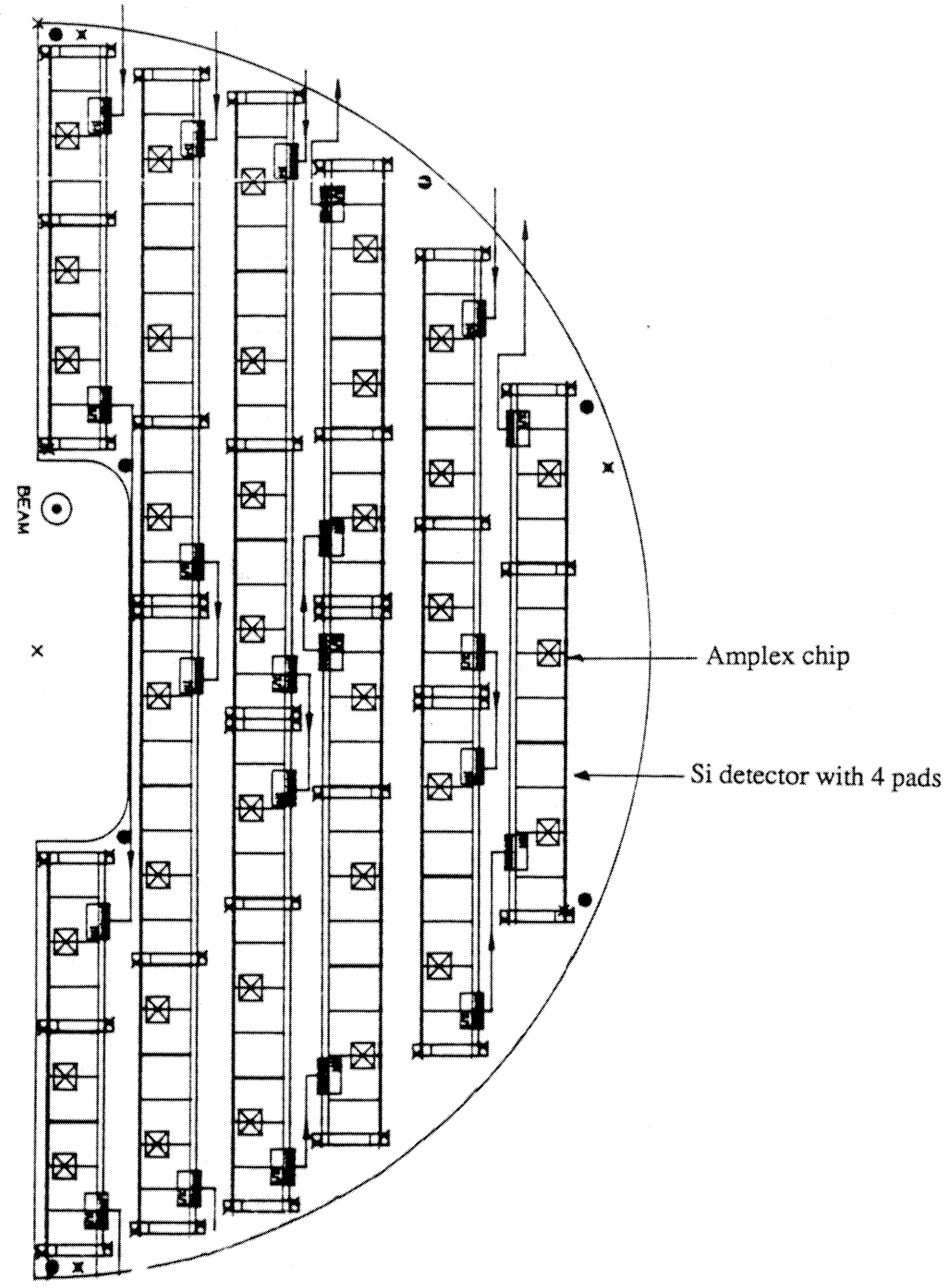


Fig. 7. Plan view of mounting for one of the four silicon half-planes for the silicon dE/dx forward counter. The vertical strips are rows of silicon detectors and associated Amplex electronics. Two half-planes have this orientation; the other two have the silicon running perpendicular to what is shown here. This arrangement gives full coverage for the dE/dx counter.

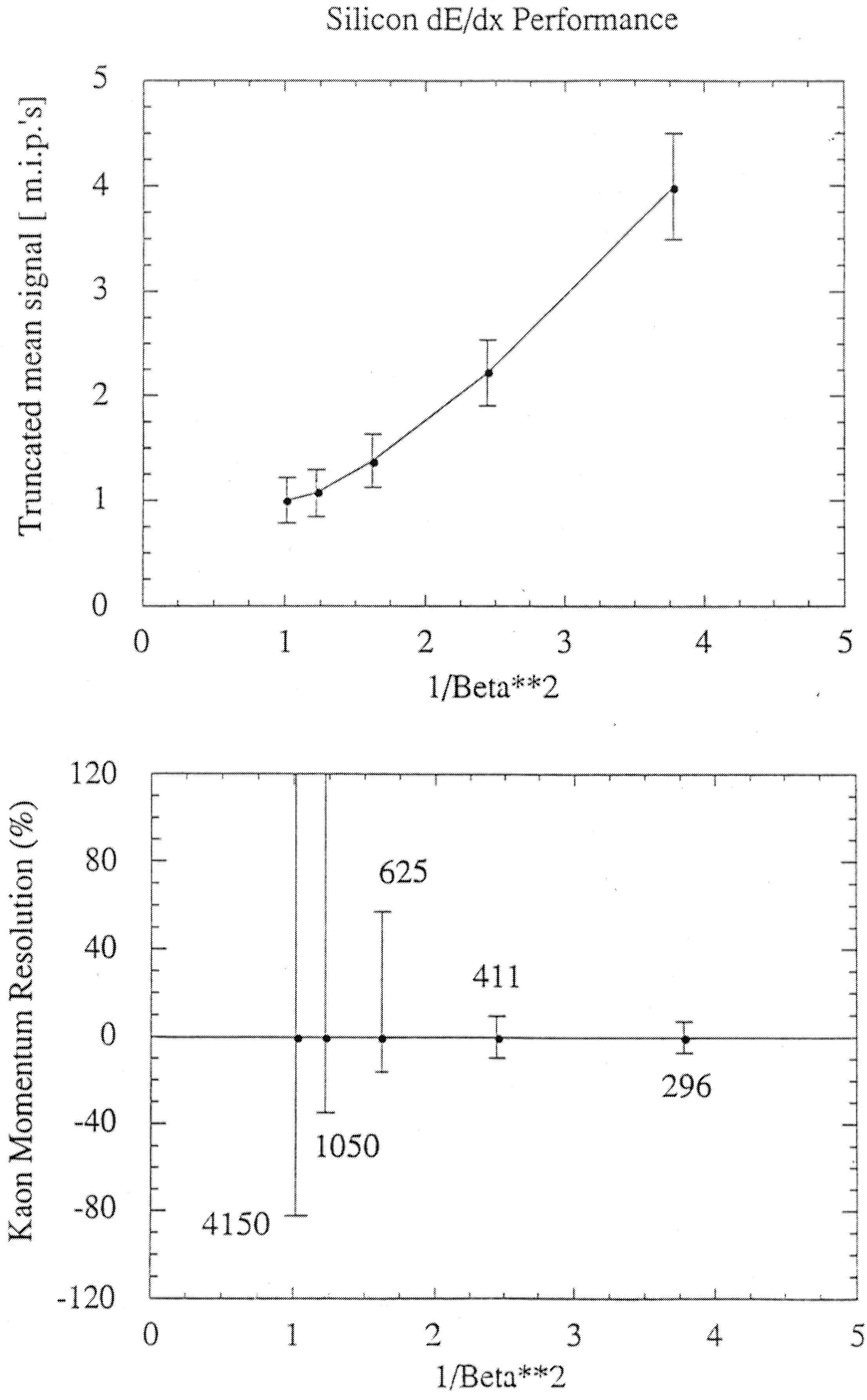


Fig. 8. Performance of our silicon prototype detectors mounted in a three-layered stack, allowing for three independent samplings of dE/dx. The top figure shows the truncated mean signal (i.e. the average of the two smallest signals among the three) versus $1/\beta^2$. The behaviour is nearly linear (as it should be) for β's below the minimum ionizing region. Error bars represent fluctuations in the energy loss in the silicon. The lower figure shows the corresponding kaon momentum resolution. The momentum (MeV/c) for each measurement is given near the error bar for each point.

corresponding to the maximum value of θ for the process $\bar{p}p \rightarrow \phi\phi \rightarrow K^+K^-K^+K^-$. Presently it is planned to install these counters in mid-1991.

The threshold Cherenkov counters are used to reject the fast charged pion background at the trigger level. The counters are basically the same now as described in [1] and [8]; the only changes are to reduce their thickness from 4 to 2 cm, and to use water as the active element for the low momentum runs. Both changes are intended to reduce the multiple scattering and absorption effects on the outgoing kaons. The detectors consist of "liquid freon" (C_6F_{14}) or H_2O filled plexiglass wedges (2 mm wall thickness) in the barrel and forward regions. The "liquid freon" material (3M Corporation FC-72) has an index of refraction $n = 1.26$, making the detector sensitive to particles of $\beta > 0.8$. For water ($n = 1.33$) the value is $\beta > 0.75$.

Tests [8] on the original 4 cm thick counters, using the RCA 8850 "Quantacon" 2-inch PMT, showed that more than 10 photoelectrons are typically produced by the light from the minimum ionizing particles. After optimizing the lightguides for best transmission a similar result was obtained for the 2 cm counter. This insures that there will be sufficient signal for a very effective pion veto.

The forward threshold Cherenkov counter is formed of 24 pie-shaped wedges of outer radius about 30 cm; the barrel consists of 24 straight counters, each 50 cm long (Fig. 9). The wedges will be read at the outside radial edges, the barrel "staves" at the rear. The segmentation of this device is made to match that of the outer trigger scintillators and the gamma calorimeter/veto. The barrel and forward counters are being constructed by CERN and will be finished by the beginning of 1990.

The Ring-Imaging Cherenkov (RICH) counter will provide additional (off line) information about the momentum of the charged tracks. This device is in the R&D stage. It is presently conceived to have a 1 cm thick CaF_2 or quartz ($n = 1.56$, $\beta_{threshold} = 0.64$) radiator and a 6 cm empty "drift space" whose purpose is to allow the Cherenkov light cone to broaden as much as is practical before detection. We estimate that for particles of $\beta > 0.64$, measurement of the cone under these conditions will yield β with about 10% uncertainty. This device therefore complements very well the measurements we will obtain from the Si layers.

Photons in the arc are converted into photoelectrons by striking TMAE gas carried in He-ethane at room temperature. This mixture is contained in a 2D "honeycomb" module consisting of 64 miniature wire chambers, each one of which operates independently. The module is 64 mm on a side, and each wire chamber cell has dimensions of 8 mm by 8 mm.* The pattern of struck cells provides the information necessary to determine the β value. The wires of the honeycomb are perpendicular to the radiator surface and are cloisonné.

The design of the final device is in the early stages. The work is being carried out at CERN in the EP/TAG group. Prototype tests of a 64-element wire chamber matrix have been very encouraging. We plan on having a functioning RICH available by mid-1991.

The forward electromagnetic calorimeter (FEMC) will measure the energy of γ rays coming from the decay of neutral mesons. This detector is a part of the full γ calorimeter which will be completed for "Phase II"; at present it will be used only as a part of the overall γ veto scheme and to provide additional information on the charged particle multiplicity. The forward calorimeter (Fig. 10) is segmented in such a way as to match the segmentation of the forward threshold Cherenkov counter and the outer trigger scintillators. It will contain 300 individual Pb/SciFi modules grouped in 8 rings of constant θ, with 12, 24 or 48 modules per ring in the ϕ direction. The particulars of its design, construction, and initial testing are described in [1] and [9].

In tests with electrons ranging in energy from 88 MeV (at the University of Illinois Microtron), to 110 MeV at Saskatchewan, to 1.5 GeV (at the T_{11} beam), to 5

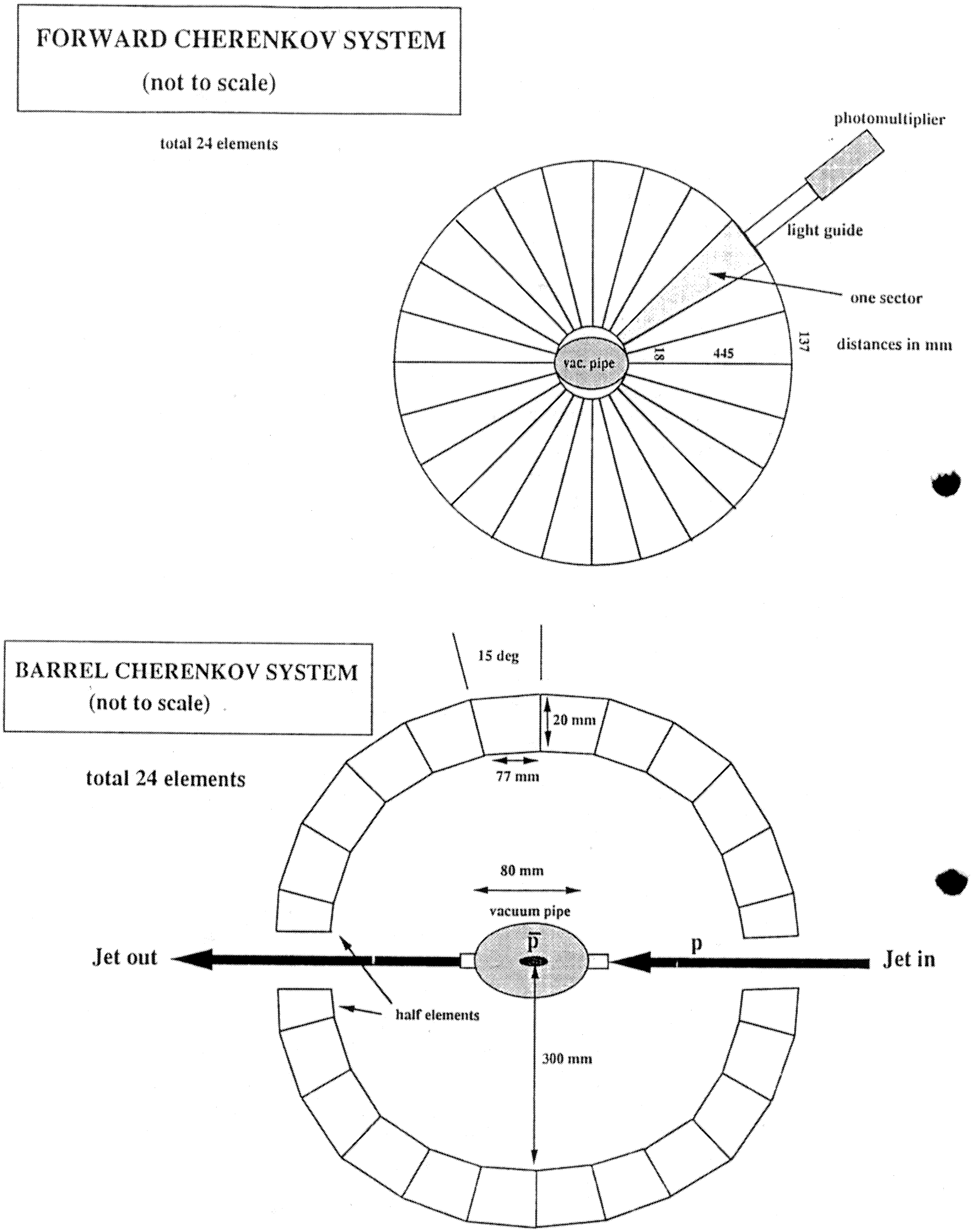


Fig. 9. (Top) Schematic view of the forward Cherenkov system. (Bottom) Cross section of the Cherenkov counters for the barrel region. There are 24 counters in each.

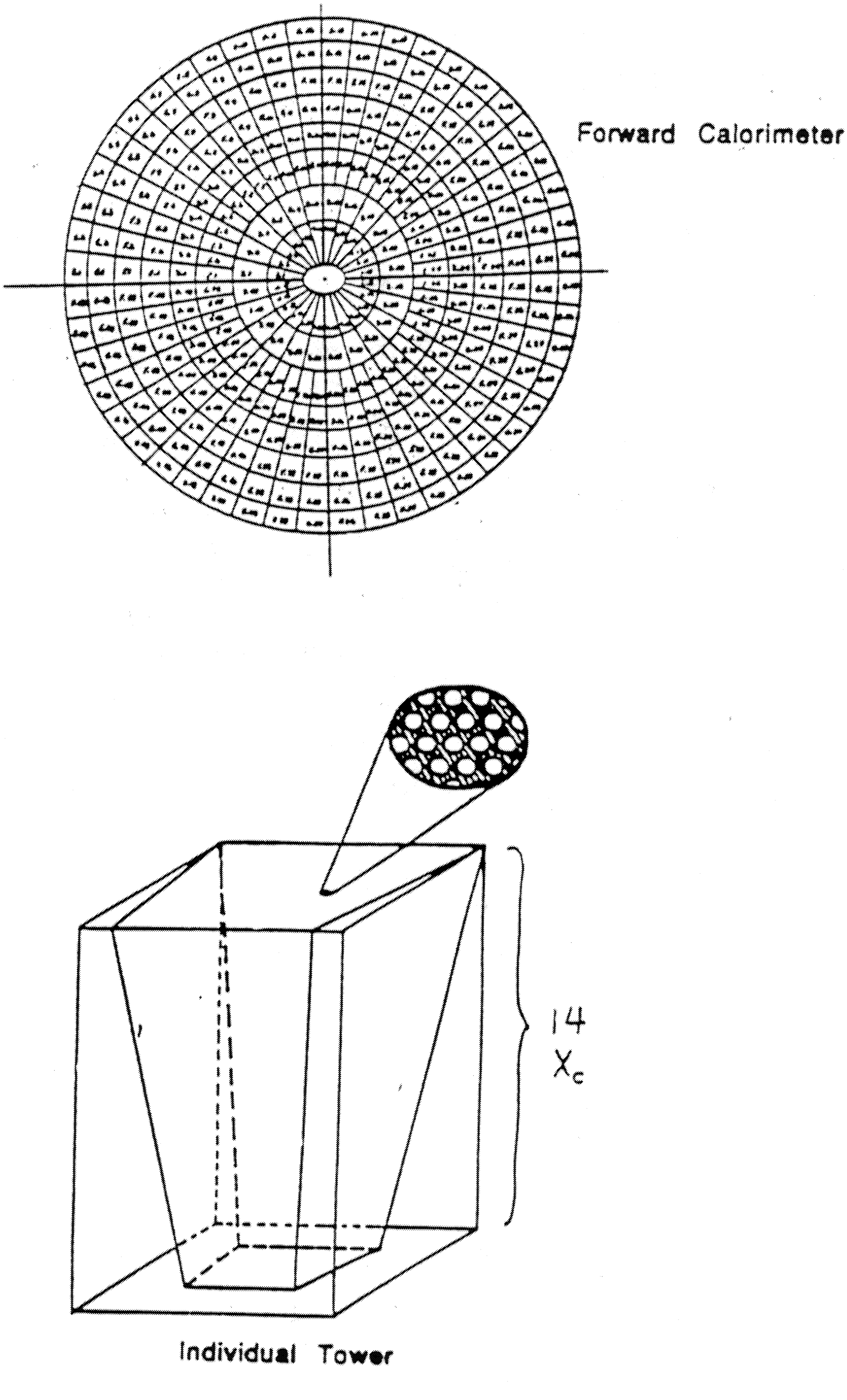
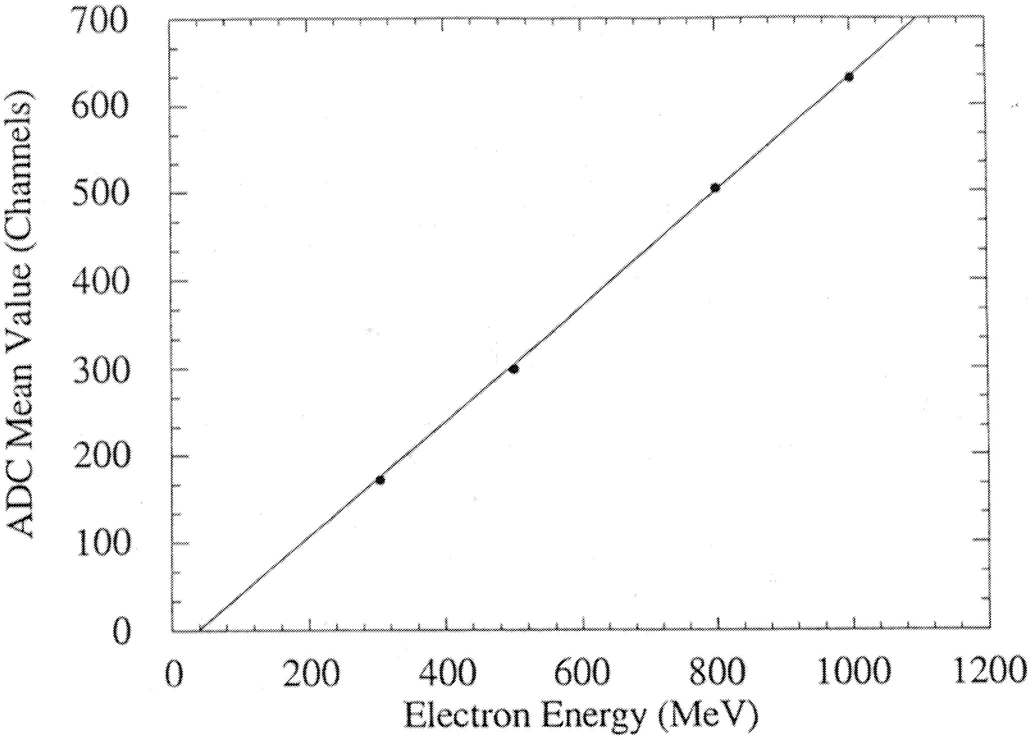


Fig. 10. (Top) Front view of the 300-element electromagnetic SciFi calorimeter. (Bottom) Schematic view of an individual element showing the Pb-scintillator fiber matrix. The element contains 50% Pb, 40% fiber, and 10% glue by volume.



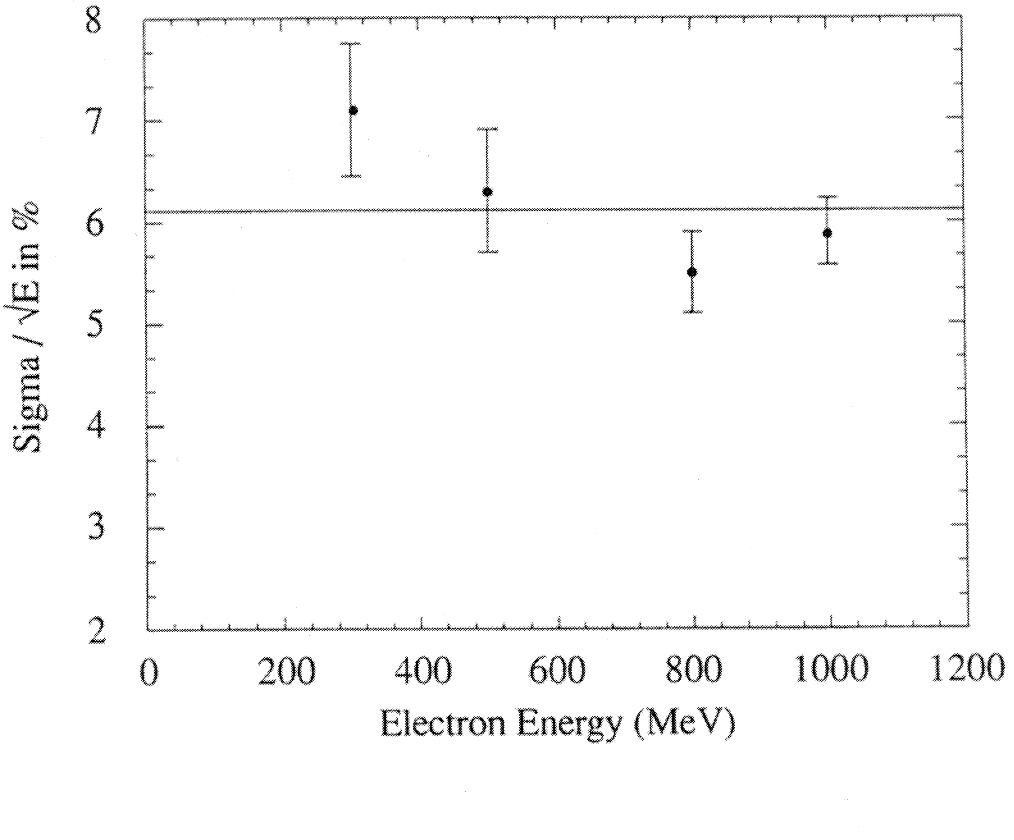


Fig. 11. Test results for a square (3x3) array of SciFi elements. (Top) Summing the output from the array when it is irradiated by photons over the energy range from 250 to 1000 MeV gives a linear result. (Bottom) The resolution (σ/E) over the same range has an average value of 6.1%/√E. These tests were carried out at the T_{11} beam.

GeV at DESY, energy resolutions (σ/E) of about 6%/√E (E in GeV) have been achieved in tests with prototypes.

In order to facilitate the construction of the 300 units, a sophisticated assembly-line apparatus has been developed. It has also been demonstrated that the basic "SciFi block" can be machined with tapered edges with no serious degradation in performance. To illustrate this, Fig. 11 shows the result of mounting 9 SciFi blocks together in a "mini array". The electromagnetic shower was summed by the 9 blocks; the resulting resolution is shown in Fig. 11. The FWHM is only slightly worse than found for one block alone when it contains the entire shower.

Tests have also determined that these elements are efficient for detecting charged particles. Further testing is in progress (at the PS185 run) to determine if the blocks can discriminate antiparticle annihilations from electromagnetic showers and from other charged particles. This latter property would be highly useful.

A major fraction (240/300 blocks) of the full FEMC is being used in the PS185 run. A laser calibration scheme has been developed and will be tested during that run in preparation for JETSET. The complete instrument will be at CERN at the beginning of 1990, and will be installed during the spring or summer. The device was constructed at the University of Illinois.

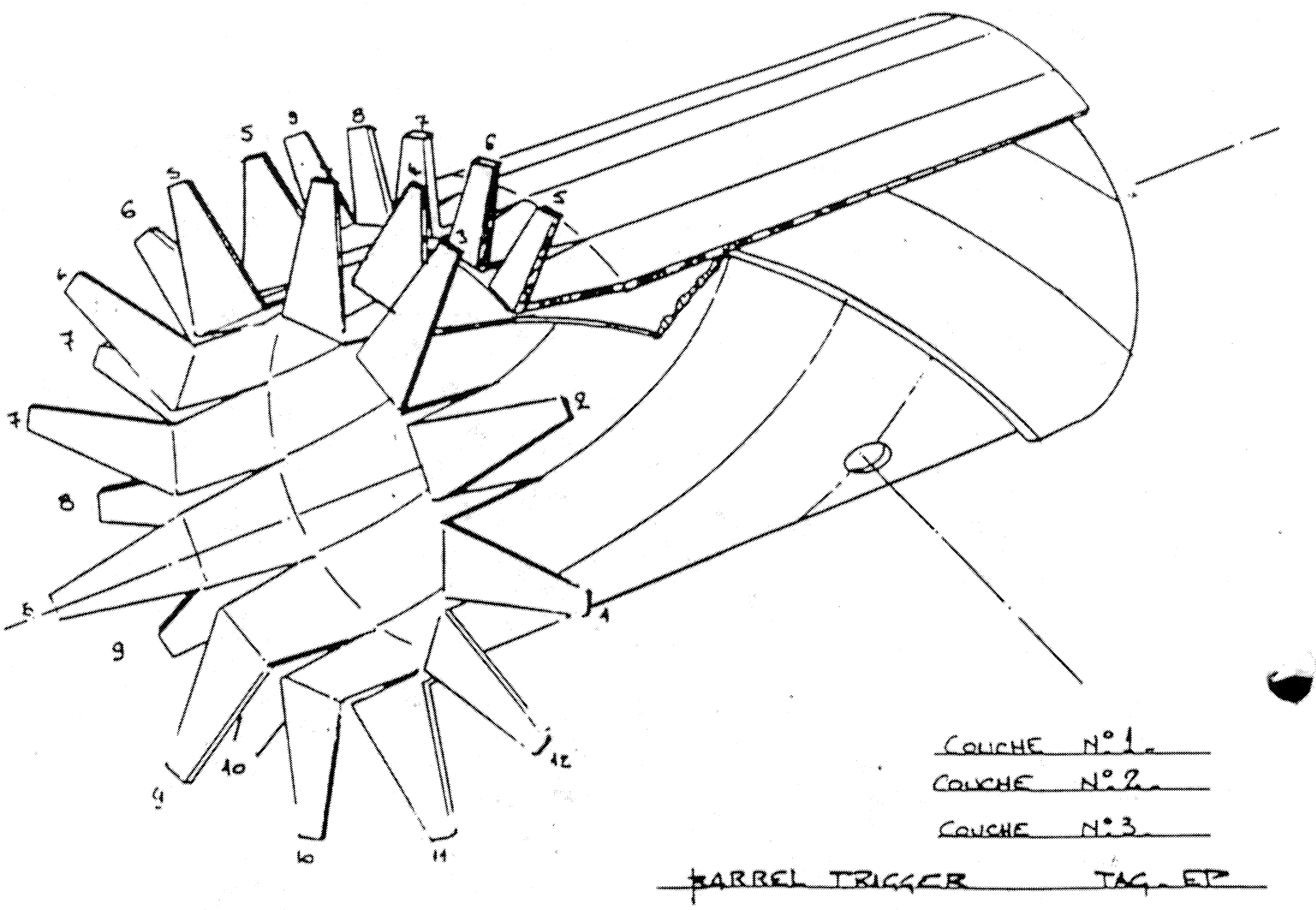
The γ veto counter in the barrel region is intended to detect the γ rays from the decay of neutral mesons possibly produced in $\bar{p}p$ collisions, and then veto those events [1]. The geometry of this counter will be similar to that of the barrel Cherenkov counter; it is wedge-shaped and segmented into 24 elements in the azimuthal direction. It will be constructed using the Pb/SciFi technology described above, but with the scintillating fibers running parallel to the beam pipe. Construction of a prototype is now in progress at Illinois. It is intended to "fill the gap" in the barrel region for the "Phase I" program while the full barrel calorimeter is under construction. This detector will be constructed at Illinois and will be ready at CERN by the summer of 1990.

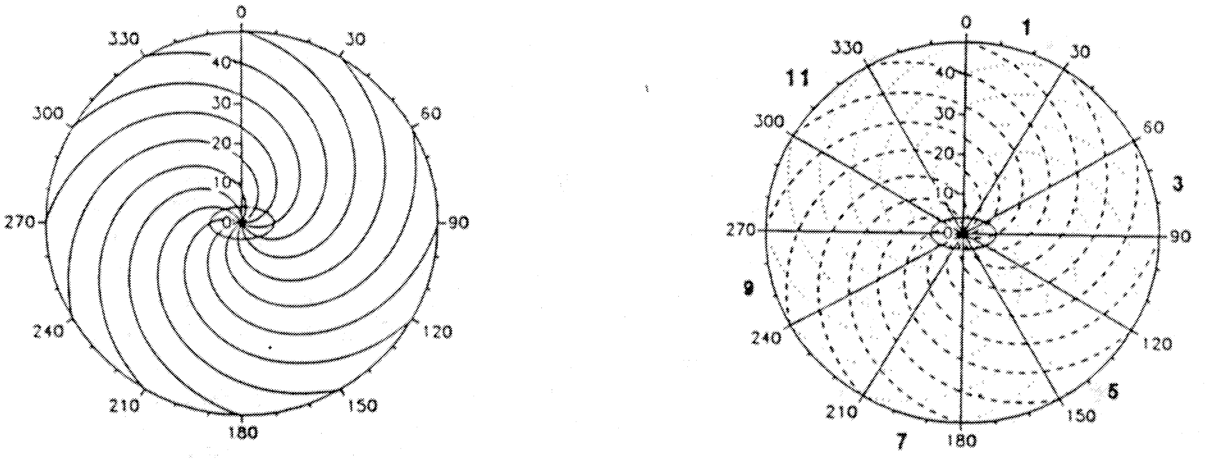
The fast outer trigger counters in the barrel and forward regions perform several functions. In conjunction with the "pipe trigger scintillators", these counters will define the time reference for the trackers and will measure the event multiplicity. In addition, they will provide: a charged particle veto shield for the forward and barrel gamma detectors; crude first-level kinematic filters (e.g. rudimentary momentum balance); additional dE/dx information (especially for the non-annihilation background in the forward region); and fast θ–ϕ coordinates for possible use in the next level trigger, where additional constraints characteristic of true 4K events can be applied.

The construction of these three counter arrays is described in [1] and illustrated in Fig. 12. Together they measure the multiplicity with very high reliability (>99%). In order to make the possible θ–ϕ measurement freer of ambiguities, and in response to suggestions made at our last PSCC presentation, we have doubled the number of wedges (now 48) and curved segments (now 24 in each direction) in the forward region. This gives an 8-fold increase in the number of coincidence cells, reducing potential ambiguities substantially.

These detectors have been constructed at the KFA-Jülich and at the CERN scintillator workshop. The forward wedge counters will be at CERN for use with the FEMC during the November PS185 run, and the complete assembly will be available from January, 1990.

The data acquisition computer array is based on the CERN Valet-Plus (VME-based) system with a fast Transputer interconnect (see Fig. 13). Seven Valets will be used to control the experiment: one for the dE/dx silicon counters; one for the barrel and forward straw trackers; one for the γ calorimeter and γ veto; one for the outer trigger scintillators; one for the pipe scintillators and threshold Cherenkovs; and one for the slow controls. The results from this first-level processing will then be assembled by the Transputer event builder in the last Valet into an "event" that can be further analyzed





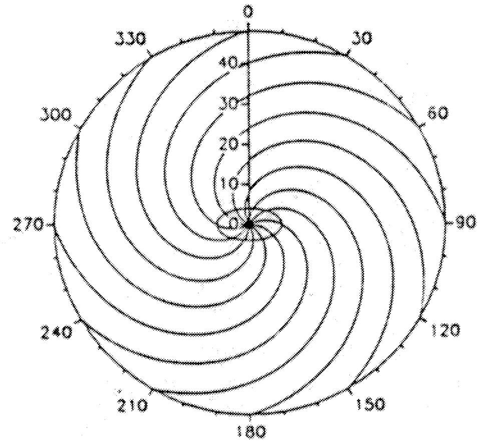


Fig. 12. (Top) Schematic drawing of the fast scintillator outer counters in the barrel region. There are 24 straight sections and 12 (each) left and right going twists. (Bottom) End views of the front fast outer counters. There are 48 wedges and 24 (each) for the left and right going twists. The number of counters has been doubled to reduce possible ambiguities.

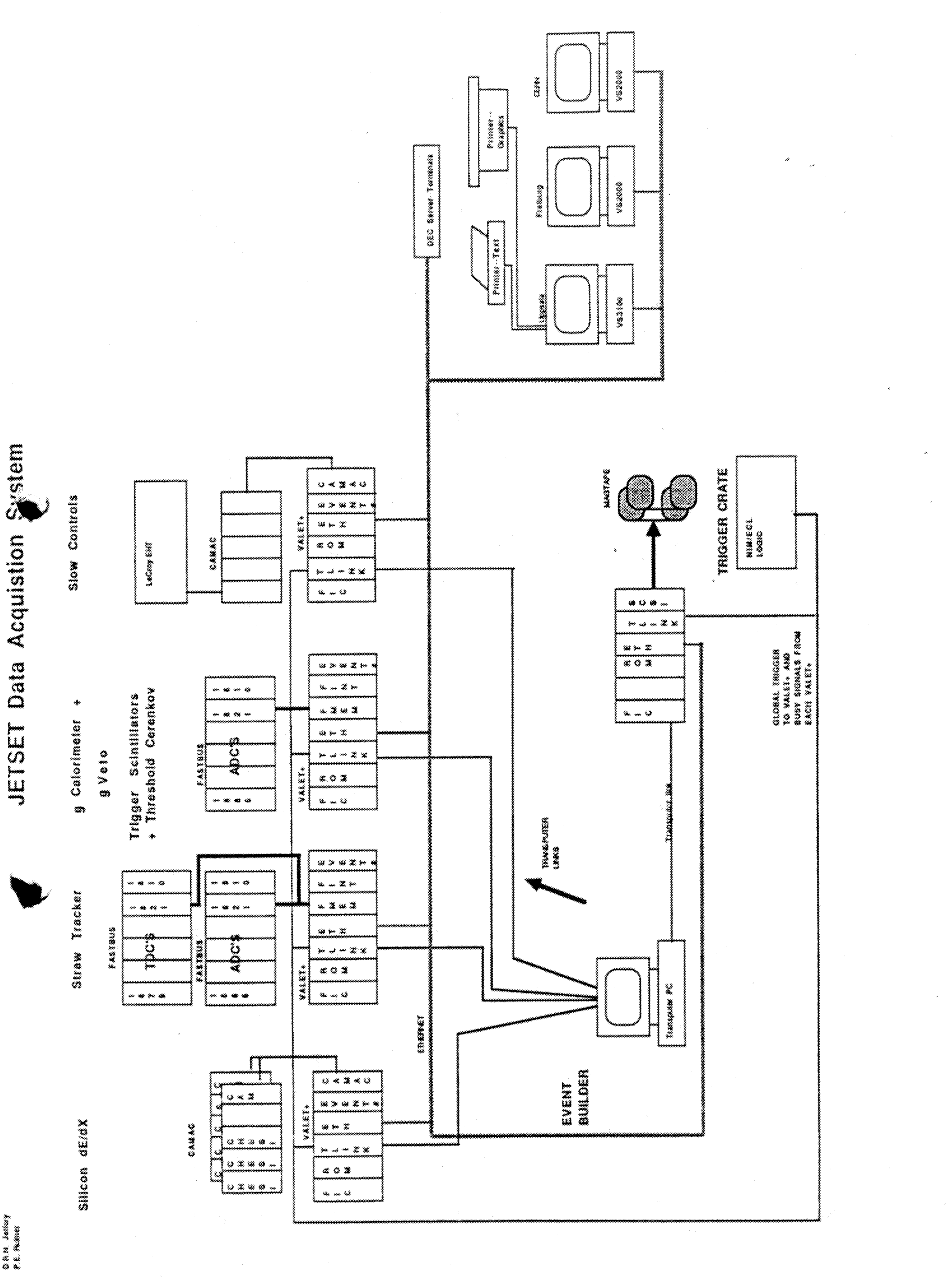


Fig. 13. Schematic of the Valet data acquisition computer system for Jetset.

and written to tape. The analysis takes place in a system of μVAX computers, which also monitor various aspects of the experiment.

Some of the detectors (drift tubes, scintillators, and γ detectors) will be equipped with TDC's and/or ADC's. The University of Freiburg has developed VME boards to act as interfaces between Fastbus and the Valet-Plus. They consist of a VME I/O module for which a list processing mode is foreseen, and a high-speed (> 64 MByte/sec) dual-port VME memory. Prototypes of both modules exist and are operating in the Valet-Plus environment.

At present, each of the groups working on one of the sub-detectors is using its own Valet-Plus to carry out normal prototype tests; this means that the development of the online readout schemes is presently being developed on a subsystem level by the appropriate responsible detector group. The development of the overall coordination, run control and event builder software is being done by CERN and Illinois.

In view of the large number of scintillators in this experiment, we have enlisted the help of the CERN/EF division in building a specialized 16-channel fast CAMAC discriminator unit equipped with a latch and a multiplicity (current sum) output. The cost of these units was quite modest. They will be used throughout the electronics logic.

The mechanical design of the overall assembly is being undertaken by the EP/TAG group at CERN. They have coordinated and defined the various detector envelopes with special attention to the unique problems that our experiment poses due to its installation as part of the LEAR facility itself. The detector must be capable of rapid assembly and disassembly for maintenance of the sub-detectors or the accelerator.

The mechanical support system for the detector is shown in Figs. 14-16. The assembly is divided into 6 parts, not all of which are shown: (1) support for the forward calorimeter; (2) support for the forward outer trigger and Cherenkov counters; (3) support for the barrel Cherenkov and barrel trigger counters; (4) support for the barrel straws, Si counters, and forward straws; (5) support for the "pipe trigger scintillators"; and (6) support for the barrel γ veto. Most of these units will be ready by January, 1990; item (4) will be completed by spring, and item (6) will be ready by the summer of 1990.

The EP/TAG group has also helped the individual Institutes with the design of the sub-detectors and has assumed responsibility for the construction of the RICH counter.

As indicated at the November, 1988 PSCC meeting, we expect to have mounted the full "Phase I" detector by mid-1990 in preparation for physics runs in the same and following years.

TRIGGERING AND EVENT RECOGNITION IN "PHASE I"

The triggering for Jetset must be capable of bringing a 1 MHz rate for all events (the vast majority of which are due to unwanted interactions) down to a rate of about 100 Hz that can be handled by the data acquisition system with tolerable deadtimes. In doing this, as few good events as possible should be sacrificed.

The fast trigger will be produced for each event within 200 ns by the pipe trigger scintillators (PS), the outer trigger scintillators (OS), the electromagnetic calorimeter (EC) and γ veto (GV), and the threshold Cherenkov counters (TC). At this level events with the wrong charged/neutral multiplicity are discarded, and some decisions based on β are made.

At this time the readout system ADC's will be latched and TDC's will be stopped, beginning the various event digitizations. For the ϕϕ (4 K) events of Phase I, this involves the following rather stringent and simple conditions: (1) a multiplicity of 4 charged particles, not more than 1 backward of 45^o; (2) no gammas; (3) not more than 1 of these charged particles with $\beta > 0.8$ (the threshold of the fast Cherenkov

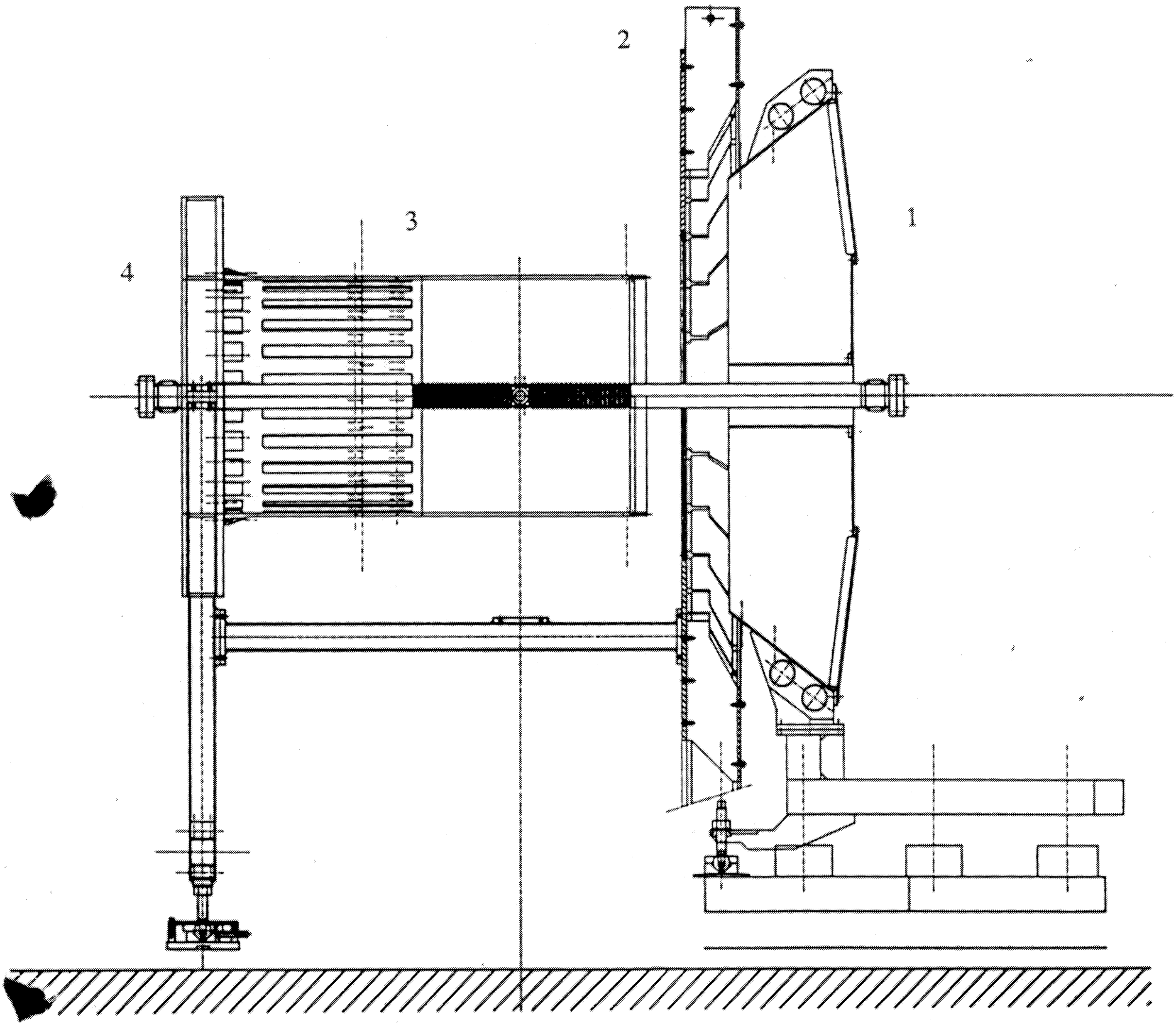


Fig. 14. Side view of the assembled mechanical support structures for the (1) forward calorimeter, (2) the forward Cherenkov and trigger counters, (3) the barrel Cherenkov and trigger counters, and (4) the rear support for the barrel Cherenkov and trigger counter phototubes. Not shown are the supports for the barrel and forward tracker or the silicon, the support for the pipe scintillators, and the support for the barrel gamma veto array.

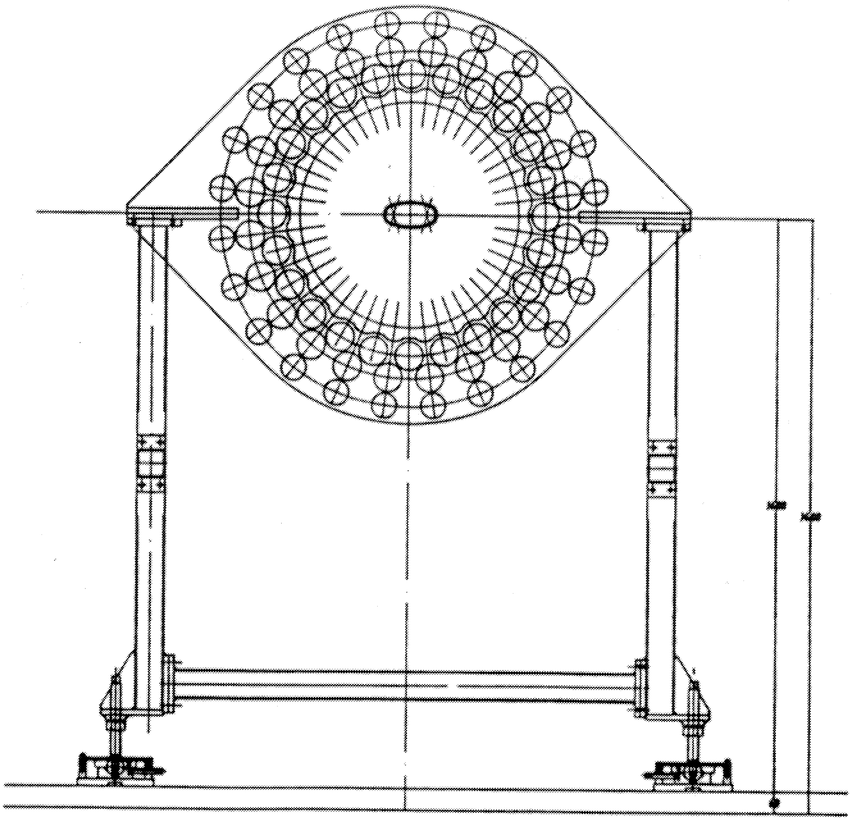


Fig. 15. Upstream end view of the support for the barrel scintillator phototubes.

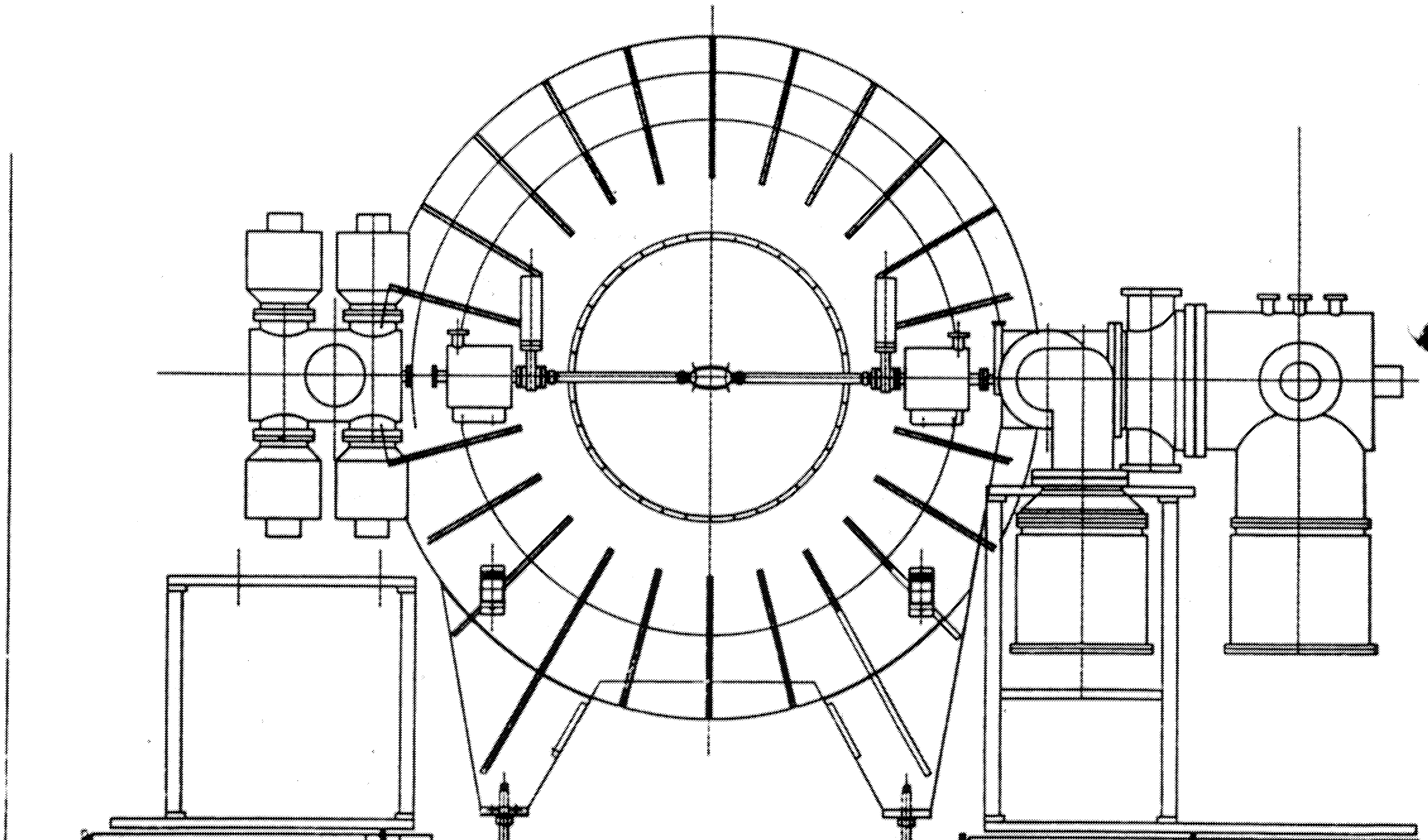


Fig. 16. Downstream end view of the forward Cherenkov and trigger counter support and the gas jet.

counter). A crude test of momentum conservation ("balance") can be applied by simply checking that not all tracks emerge on one side of the detector. At this level the potentially troublesome $\bar{p}p\pi^+\pi^-$ reaction can be substantially reduced by its topology and possibly by the detection of the antiproton in the EC.

The multiplicity is determined by the PS (60 strips), the segmented OS systems (total of 72 elements), and the forward EC (300 elements). Each of these subsytems will therefore be required to provide only a "range" of multiplicity, for example from 3 to 5 charged particles (since it must be an even number).

The pipe trigger scintillators could be used with the outer trigger scintillators and the calorimeter elements to establish hit correlations. Ideally, this could clean up the trigger sample significantly, leaving for further processing in a second level trigger four (θ,ϕ) prongs pointing to the vertex.

Neutrals are rejected by the EC and GV layers; this is important because these processes are quite prominent (eg, $\sigma(\bar{p}p \rightarrow 4\pi^{\pm} + n\,\pi^{\circ}) > 20\,\mathrm{mb}$). The GV efficiency has been studied for the proposed detectors, including all known effects such as construction cracks, thresholds, and charged particle "blinding" (from true charged particles entering the same ϕ segment as a potential gamma). It is found to be essentially 95% effective for events where a single π^0 accompanies 4 charged particles.

Since the threshold Cherenkov counters give a reasonable signal for charged fast pions, we do not expect any problems in keeping the event sample which passes these first-level trigger quite pure. Thus the level-one trigger will be a series of "yes" signals from all of the detector subsystems and can be thought of as a number of loose cuts on the event sample.

We hope to reduce the initial 1 MHz rate to less than one kHz after the first level without allowing the deadtime to exceed 20%. Further planning is in progress to define a second level trigger.

During the commissioning of Jetset the luminosity will be lower than the design figure, and the trigger will at first be somewhat loose in order to be as bias-free as possible. Multiplicities will be "windowed" around the desired 4 charged particle value, and at least 1 gamma will be allowed in the event. We will run above and below the $\bar{p}p\pi^+\pi^-$ threshold to test the effects of that unwanted interaction on our event sample. As always, we must accumulate "luminosity" events in order to measure not only the total number of $\bar{p}p$ interactions (to normalize the data), but also to determine the performance of our detector and thus to develop more stringent on-line triggers based on hardware cuts.

OFF-LINE PROGRAMMING AND SIMULATIONS

A subgroup of our collaboration (from CERN, Genoa, Oslo, and Uppsala) has been developing the necessary analysis programs, based on the detector described above, to model the acceptance of the detector and to investigate how we will reconstruct $\phi\phi$ events from a sea of possible 4-charged particle backgrounds. It is comforting to note that we can safely reconstruct the $\phi\phi$ events from the 4K background, and moreover, that we can easily distinguish these events from other 4-charged particle backgrounds that may have leaked through our hardware selection process.

Our studies of the detector acceptance are shown in Figs. 17 and 18, both of which plot the integrated acceptance of the detector for **good $\phi\phi$ events only** as a function of the incident beam momentum.

The top curve of Fig. 17 shows the result assuming a massless detector with full efficiency everywhere except forward of $\theta = 15^{\circ}$, where there is no detection because of the LEAR beam tube. Also, there is no kaon decay. The four remaining curves indicate how that acceptance is reduced by including kaon decays, nuclear interactions in the detector materials, and the limited coverage of the pipe trigger scintillator detector

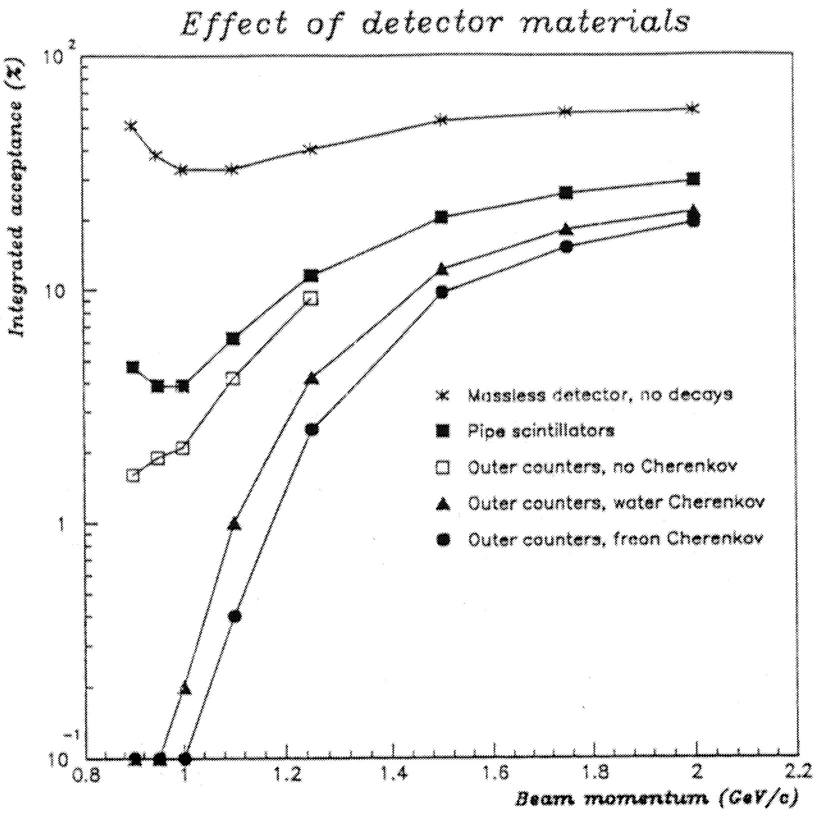


Fig. 17. Curves showing the effect of the detector materials and kaon decays on the acceptance of the Jetset detector. The geometry of the detector in these calculations is completely sealed, except for the region forward of θ = 15°.

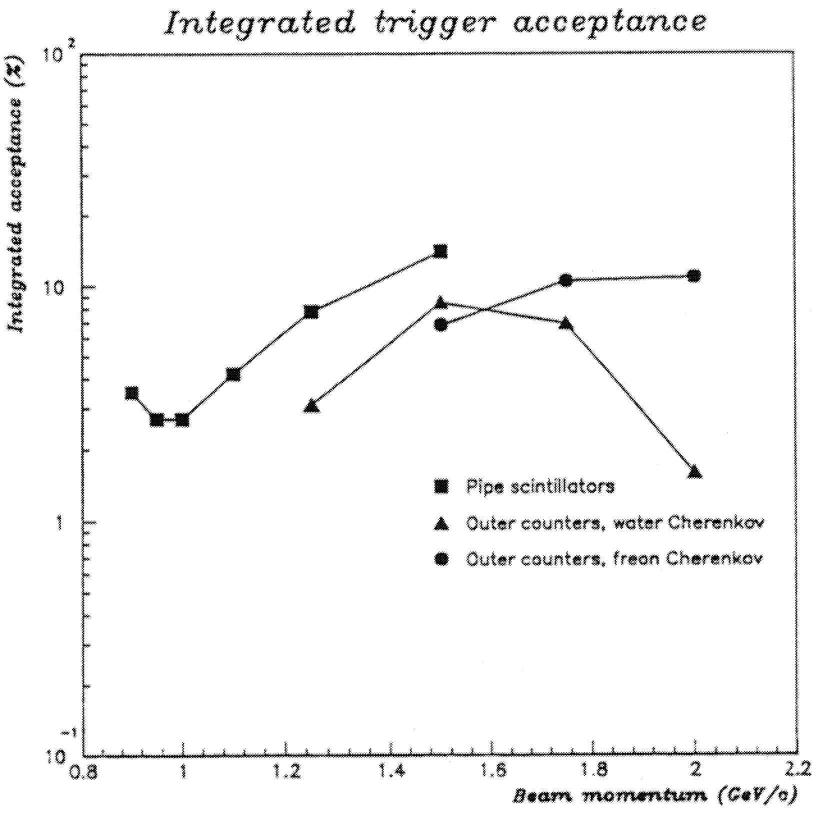


Fig. 18. Curves showing the integrated acceptance of the Jetset detector after including materials, decays, and the realistic target geometry. Triggers are discussed in the text.

(although this effect is small). We show results using the inner pipe trigger scintillators or the outer trigger scintillators as the event trigger. Note the effect of decays, and interactions in the Cherenkov counter, the silicon and the tracker, on the acceptance when using the outer counters as the trigger. In these calculations, the Cherenkov counters are not in the trigger.

The dramatic drop for the outer counter trigger at low momentum indicates conclusively that we should use only the pipe trigger scintillators as the trigger in the low momentum region. We exploit the fact that at low momentum the four outgoing kaons are mostly forward of 45°, whereas the contaminant pion reactions are more uniformly spread out in θ. We thus require that at most one particle appear in the 45° to 65° range.

We are thus led to define two possible triggers: one, useful at low momenta, consists of using only the pipe scintillators and takes advantage of the kinematics mentioned in the last paragraph. The second consists of using the outer trigger counters and the Cherenkovs, and is appropriate for higher momenta.

Fig. 18 shows the overall detector integrated acceptance for 4K events, taking into account the effects of actual sub-detector geometrical acceptances and expected efficiences, and the triggers mentioned above. The pipe scintillator curve is not continued past 1.6 GeV/c because the kinematic signature that is so useful at lower momenta is no longer distinctive. Thus we would use the outer fast scintillators and Cherenkov counters as the trigger beginning at about that momentum. However, it is clear also that the use of water as a radiator (with its sensitivity to lower β) will begin to cut out kaons as their average momentum rises. Thus, above about 1.6 GeV we will use the freon radiator.

TIMETABLE

We intend to test apparatus at LEAR as soon as possible in the spring and to begin taking data in Jetset by the fall of 1990. In the time before then, the detector components need to be completed, tested off-line, and installed. A possible schedule is shown in Fig. 19.

The central element, the hydrogen cluster jet, is presently installed on the LEAR ring. Vacuum and gas leak tests are in progress; they will continue into the winter of 1989/90. At that time the corrugated vacuum pipe will be installed and the final check-out can begin. This will allow ample time for testing the impact of the jet on LEAR operations, and will also provide a way for us to test the other detector components under realistic conditions as they are completed.

The vertical steering magnets necessary for bringing the beam squarely onto the gas target have been designed by the LEAR accelerator staff, and they will be installed also in the winter of 1990.

As has been described above, most of the detector elements are nearing completion. The pipe trigger scintillators, the Cherenkov counters, the outer trigger scintillators, and the gamma calorimeter will be completed and at CERN by the beginning of 1990. Indeed, the calorimeter, parts of the forward outer counter, and the pipe trigger scintillators will be tested in PS185 in November of 1989. The forward and barrel trackers will be assembled by the end of January and February, respectively, and tested and calibrated during the early spring. They will be installed during the summer schedule shown in Fig. 19 along with the silicon dE/dx counters.

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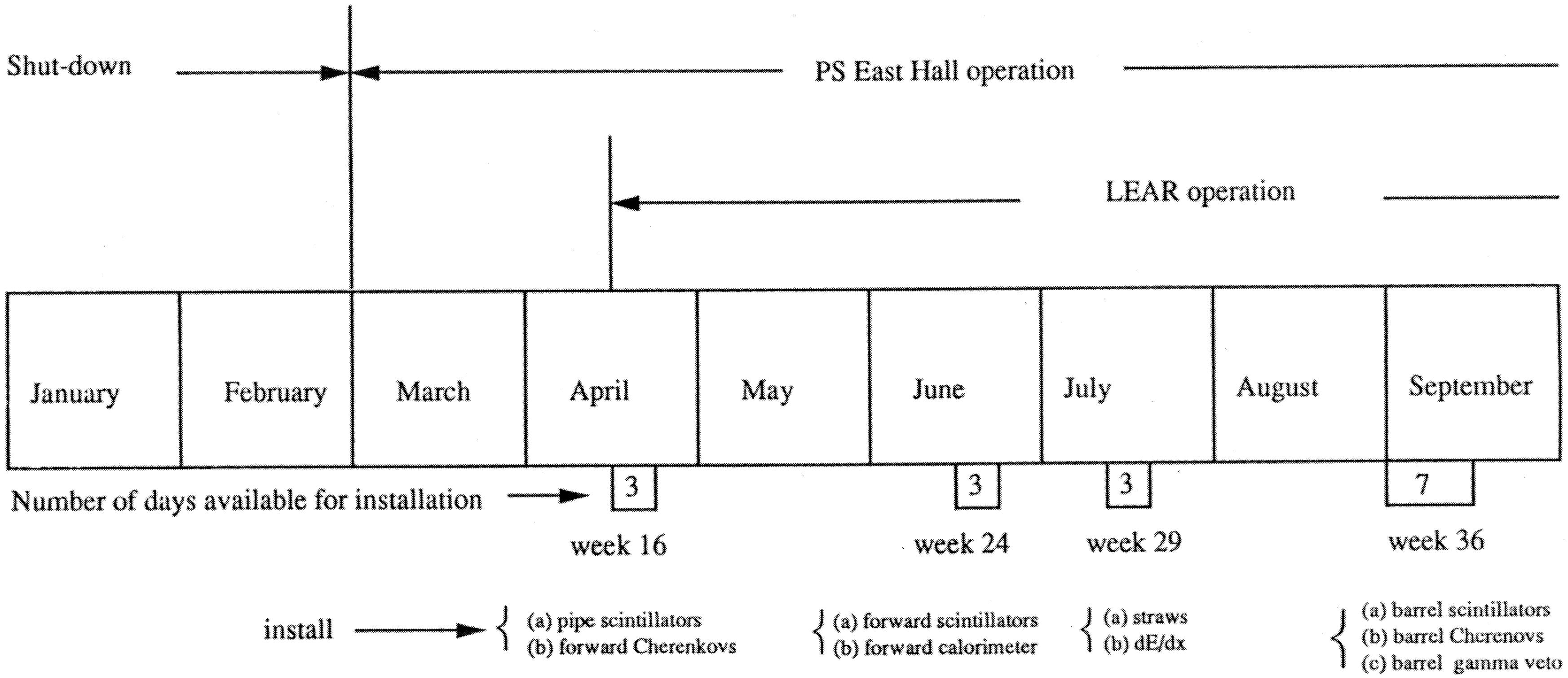

Based on tentative accelerator schedule for 1990. MACHINE STOP periods are used for installation. Each period to be followed by 1 day JETSET-dedicated operation. Installation of the straws and dE/dx counters may require more than three days. The exact ordering of the installations will depend on existing circumstance; what appears here is a reasonable, but not certain, scenario.

IN ADDITION to what is shown here, we request 3 weeks of running time for JETSET physics. One week should be roughly in October, followed by two weeks in December.

Fig. 19. Suggested schedule for the 1990 calendar year.

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