PROPOSAL FOR A TEST AND SURVEY
EXPERIMENT AT THE ISR.

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1. INTRODUCTION

In 1971 the CERN Intersecting Storage Rings will start operating, and in 1972 a large experimental magnet will be installed at the intersect 4. The above group, formed of CERN staff and visitors at CERN, will provide the necessary experimental equipment, as far as it is standard and can be used for several experiments. This equipment includes a set of large multi-wire proportional chambers with the corresponding electronics, on-line computers and a basic analysis program chain.

The final configuration will be available for experiments at the end of 1972. We suggest, however, that parts of the apparatus should operate at an earlier date and then gradually build up to the final complete system. Furthermore, the physicists involved in the construction intend to gain experience during the first phase of ISR operation.

We therefore propose a test and survey experiment which serves a triple purpose:

i) to test the proportional chambers, the special electronics connected to them, the on-line operation with the computers, and a preliminary analysis chain;

ii) to gain experience in the specific environment at the ISR, investigating background, trigger conditions for beam-beam interactions, and luminosity and calibration questions;

iii) to perform some simple survey measurements on relatively abundant processes, such as multiparticle production (section 3), and a search for diffraction
This proposal updates and completes the program given already to the ISRC in October 1969\textsuperscript{3).}
2. DETECTION SYSTEM

The detector to be operated in the SFM has to fulfill several conditions: It should
- be insensitive to magnetic field;
- have high spatial resolution in order to make best use of the field;
- be flexible enough to be adapted to different experiments;
- be movable to be adapted to the magnet on-off condition, and to allow baking of the vacuum chambers;
- be reliable to be operated in an inaccessible experimental area.

To satisfy the above criteria we have chosen a detector consisting essentially of multiwire proportional chambers\(^2\). A prototype of a first standard chamber has been constructed, based on the experience gained so far in our and other groups\(^4\)\(^5\), and is being tested now.

2.1. Proportional Chambers

The geometrical configuration of the prototype is shown in Fig. 1. Nonmagnetic materials, such as Vetronite, and aluminum, have been used to construct modular frame units of 7mm thickness and outside dimensions of 54x185 cm. Electrodes, i.e. either HV or wire planes, are separated by one module. Several modules can be assembled together in order to give a chamber with a desired number of planes. The chamber is mechanically stiffened by an aluminum frame attached on one side of it. The special cut-out on one side of the chamber will allow to extend the sensitive area of the chamber as near as 50mm from the beam axis, assuming an elliptical vacuum pipe of 60mm height. The prototype consists of three independent wire planes, one horizontal, and two at ± 60°. The wire distance
is 2mm, and the prototype has about 1200 wires. One preamplifier per wire is attached on the chamber frame, and twisted-pair ribbon cables then transport the signal to the control-room outside the experimental area. This separation is useful since it reduces the electronics volume in the magnet gap and brings the major part of the electronics to an accessible environment.

2.2. Electronics

The diagram of the wire electronics is shown in Fig. 2a. The wire is connected to a differential preamplifier PA, after which the signal is transferred over ~30m through flat, 32 twisted-pair cables to the control-room. There the pulse is processed by a receiver and shaper R, a delay D, a memory gate MG and a memory M. The delay, achieved by a monostable with a mean pulse length of 250 nsec., allows for logical decision to be taken before accepting the event in the memory. By changing a reference voltage, it is possible to cover the delay range between 220 and 300 nsec for the whole system. The decision logics incorporates the self-triggering facility of the chambers; it is initiated by the front edge of the delay pulse, and timing or logical decisions can be based on signals from groups of 32 wires. The instant logics (Fig. 2b) permits these decisions to be taken within the intrinsic time resolution of the proportional chambers, less then 50 nsec in our case.

After this special circuitry a second slow level of decision (DC logics) is followed by a readout device, leading to the on-line computer (EMR 6130, 16 bit, 0.780 μsec). This small computer will be later linked to a CII 10070 (Omega main computer). The computer will read the proportional chambers, and it will control the run (on-off-reset) and check parameters such as gas pressures
and high voltages. Finally it will control an automatic test facility for the chambers. We imagine a test procedure which:

(i) searches discharges or oscillations by looking for fixed bits appearing in consecutive random triggers;

(ii) searches for empty bits when exposing all wires of one chamber to a small pulse on the HV mesh synchronized with a strobe on all memory gates of this chamber.

2.3. Performance

Our standard chambers will have a 7.2 mm gap between HV and wire plane, a 2 mm wire distance and an A-CO₂ gas filling. For these conditions an intrinsic time jitter of 30 nsec has been measured \(^4\). Allowing for an additional jitter from electronics, a 60 nsec strobe will ensure full efficiency. The 60 nsec will be the time resolution of the system. The dead time on each wire is determined by the delay D and should be about 4 times the delay time, i.e. \(\sim 1\) μsec. Note that for \(10^6\) ten-prongs/sec, equally distributed over a 1000 wire plane the loss due to dead time is 1%. The spatial accuracy for 2 mm wire distance has been experimentally measured, and results in a standard deviation of \(\pm 0.57\) mm.

3. SURVEY ON MULTIPARTICLE PRODUCTION (1971)

The first period of ISR operation (2nd half of 1971) is largely determined by safe running-in conditions for the accelerator. For the experiments this means that only vacuum chambers with rather thick walls and no special windows or flares will be available. Hereby the
measurement of forward particles is greatly disturbed. We therefore
will concentrate during this time on the detection of large angle par-

ticles.

3.1. Physics

Lacking of any complete theory for "inelastic" processes, multi-
particle production has been described in a number of approaches,
such as the

- thermodynamical theory \(^6\);
- the two-fireball model \(^7\);
- the isobar pionization model \(^8\);

These different descriptions can be tested by the measurement of
overall properties, as there are

- production spectra of \(\pi, K, N\) etc., as function
  of momentum and angle;
- average multiplicity and multiplicity distribu-
  tion;
- correlations between particles produced.

Since no means of particle identification and momentum measure-
ment will be available in our case, we will concentrate on the
second of the above points.

We will measure:

i) the average multiplicity of secondary parti-
cles produced by the collision of two protons
colliding at \(E_{CM} = 50\) GeV;

ii) the multiplicity distribution of the seconda-
ries;

iii) the angular distribution of the secondaries;

(note, that the particle angles are measured
in the laboratory system, which moves with 
\( \beta_{\text{CM}} \approx 0.13 \) perpendicular to the intercept of 
the colliding beams with respect to the CM. 
Without knowledge of momenta the exact re-
transformation is not possible, but, in view 
of the small value of \( \beta_{\text{CM}} \), a correction 
should be possible with assumptions on the 
momentum distribution and on the isotropy 
of the angular distribution around the line 
of collision in the CM).

Essential byproducts will be the determination of the shape of 
the interaction diamond by reconstruction of the vertices and a 
measurement of the beam overlap distribution

\[
\int \rho_1(z)\rho_2(z)dz \propto h^{-1}_{\text{eff}}
\]

3.2. Experiment
The measurements described above require a detector arrangement 
of almost \( 4\pi \) acceptance. On the other hand, we will have to meet 
a number of restrictions due to the initial phase of operation 
of both the ISR and the detection system:

- a very simple, thick walled vacuum chamber limits 
  particle detection, due to interactions and multiple 
  scattering, to angles \( \leq 200 \text{ mrad} \);

- only a detector of limited size, probably < \( 10^4 \) wires 
  of proportional chambers, will be available at that time.

We intend to start with a simple arrangement of 7 proportional 
chambers of the standard size (Fig. 3a). Each chamber contains 
three wire planes. Double chambers on three sides allow vertex
reconstruction and measurements of the beam overlap distributions in both the vertical and horizontal planes. The precision of reconstruction should be of the order of ±1 mm for particles emerging at large angles with respect to the vacuum chamber.

In view of the maximum acceptance it is desirable to place 4 additional chambers in the forward-backward direction (Fig. 3b). With these chambers, however, one will encounter some background problems due to beam-gas interactions of the incoming beams, which have to be studied in more detail.

3.3. Acceptance Calculations

In order to obtain an estimate of the angular and multiplicity acceptances we performed a Monte Carlo-calculation, generating events with a mean multiplicity of about 12 and a reasonably flat multiplicity distribution (Fig. 4a).

The angular and momentum distributions of the secondaries were chosen to follow the predictions of the thermodynamical model, which, at the same time, yields the known $p_{\perp} \exp(-p_{\perp}/0.2)$ distribution of transverse momentum.

It should be noted that the $\theta$-distribution (see Fig. 4b) is rather sharply peaked at small angles. Therefore we find an overall particle acceptance of only 39% for the experimental setup of Fig. 3a, whereas we see 63% of all particles with the additional chambers of Fig. 3b. All results quoted below have been obtained with the complete arrangement (Fig. 3a and b).

According to the limited acceptance, the "measured" mean multiplicity decreases to 7.8. Correcting for the percentage of lost particles one can get back the right mean value and multiplicity
distribution (Fig. 4a). Generally, however, this procedure is quite model-dependent and in the actual experiment one has to take account of the correlations between the angular distributions and the multiplicity.

The results shown in Fig. 4b indicate that we can obtain angular distributions for $\theta_{\text{lab}} \gg 200$ mr with reasonable accuracy. The kinematical transformation back to the center-of-mass system (already quoted above) does not seriously affect the $\theta$-distribution. On the other hand, the distribution of the azimuthal angle $\Phi$, which is isotropic in the CM-system, gets quite asymmetric in the lab (see Fig. 4c). In this case one can test suitable momentum distributions to get back isotropy in the CM-system.

The conversion of $\gamma$-rays in the vacuum chamber would be determined seperately to correct the measured charged multiplicity.

4. SURVEY OF DIFFRACTION REACTIONS (1972)

In this phase of ISR operation the use of special vacuum chambers is expected to be possible so that the measurement of small angle particles becomes feasible. We propose to perform during this phase an initial search for and a study of diffraction processes.

4.1. Physics

It is expected that those two-body or quasi-two-body final states which can be produced by diffraction (or Pomeron exchange) will dominate at high energies. The processes belonging to this class are:
(1) \[ pp \rightarrow pp \]
(2) \[ pp \rightarrow pN^X_{\pi^+n} \]
(2') \[ pp \rightarrow pN^X_{p\pi^-\pi^+} \]
(3) \[ pp \rightarrow N^X_{\pi^+n} \rightarrow N^X_{\pi^+n} \]

The \( N^X \) refers to the family of isobars with isospin \( \frac{1}{2} \) and parity \( (-1)^{\Delta J} \) where \( \Delta J \) is the isobar spin minus \( \frac{1}{2} \).

There is some knowledge on the behaviour of reaction (1) at higher energies \(^{11}\). Reaction (2) was studied up to 29 GeV \(^{12}\), reaction (3) has not been investigated at present accelerator energies.

It was discussed earlier \(^{13}, 14\) that the reconstruction of the above reactions is possible in a 2C, 1C, 0C, 0C fit, respectively, if the directions of all secondaries are measured. The elastic reaction is used as a monitor. Cross sections and rate estimates are given in table 1. Simultaneously the cross section (or, at least, an upper limit of it) for the exchange process

(4) \[ pp \rightarrow nN^{X+\pi^+}_{p\pi^-} \]

can be obtained.

4.2. Detector

The detector is shown schematically in Fig. 5. It is built up of SFM standard chambers (For neutron detector see also appendix). Anticounters (not shown) cover the solid angle not subtended by the detector.
4.3. **Acceptance and Resolution**

Acceptance calculations have been done for the reactions 1, 2 and 3 with the following conditions:

- a vacuum chamber, symmetrical in both directions, with a flare of 50cm radius at a distance of 5 meters from the intersect, and an elliptical tube continuing from there on;

- standard chambers perpendicular to the beam at distances of 5.1 meters and 7.35 meters. The chambers were assumed to be sensitive at 5cm distance from the beam axis;

- neutron chambers with the same geometry at a distance of 7.5 meters from the intersect.

The results of the Monte Carlo calculations for reactions (1) to (3) are given in Fig. 6 and 7, respectively. An isobar mass of 1470 MeV was used, and a variation of the differential cross section with $e^{10t}$ was assumed.

The resolution of the reconstruction was tested by

- generating events in a M.C. procedure;

- digitizing them with a precision of ±1mm for charged particles and ±8mm for neutrons;

- processing the digitizations by the SFM pattern recognition and reconstruction programs$^{15}$.

The result is shown in Fig. 8a by the effective mass distribution for a zero width isobar with a mass of 1470 MeV.

4.4. **Background**

Extensive background calculations have been done for reactions (1) and (2) only. The background for reaction (1) consists of inelastic
events which produce two accidentally collinear (in the CM)
charged particles and no other charged particles traversing the
chambers (the existence of the anticounters was ignored in this
consideration). These are:

\[ \begin{align*}
    pp & \rightarrow (\text{everything}) + \pi^+ + \pi^- \\
    pp & \rightarrow pN^X \rightarrow pp (\pi^-) \\
    pp & \rightarrow N^XN^X \rightarrow \pi^+(n)\pi^+(n) \\
    pp & \rightarrow N^XN^X \rightarrow p (\pi^-) p (\pi^-)
\end{align*} \]

The following production ratios were used:
all inelastic: \( pp : pN^X : N^XN^X = 3 : 1 : 0.1 : 0.01 \)

The first reaction was generated according to a CKP formula\(^{16}\),
the others in the standard way using a \( t \)-dependence of \( e^{10t} \), as
it was also used for the elastic reaction. Fig. 6 shows the \( t \)
distribution for events defined as collinear by a cut at \( \pm 2 \) mrad.
The figure does not indicate any background problem up to
\( t = -0.5 \) (GeV/c\(^2\))\(^2\).

The background of reaction (2) was investigated for the following
processes

\[ \begin{align*}
    \text{i)} & \quad pp \rightarrow p + N^X \rightarrow p + n \pi^+ (\pi^-) \\
    \text{ii)} & \quad pp \rightarrow N^XN^X \rightarrow (n)\pi^+ + n\pi^+ \\
    \text{iii)} & \quad pp \rightarrow N^XN^X \rightarrow p (\pi^-) + n\pi^+
\end{align*} \]

The background events were simulated and then processed like
genuine events. The number of the accepted background events and
of those having passed the fit are displayed in table 2. Fig. 8a
shows the \( (nn) \)-invariant mass distribution of the successfully
fitted events from reaction i). Fig. 8b shows the \( t \)-distribution
of these events. The contribution of reactions ii) and iii) to the
distributions of Fig. 8a and 8b were deliberately omitted since
their \((nn)\)-invariant mass distributions are flat over a wide energy range, their production cross section is small and the rejection rate of the fit very high.

The experimental result will be the sum of the histograms in Fig.8a (widened by the intrinsic width of the \(N^X\)), assuming equal yields for both processes. We conclude, that a separation by purely kinematical methods is difficult. Therefore three sets of anticounters, one around the intersect, and two shielding the downstream region not covered by the main detector, will be inserted. The anticounters, consisting of lead-scintillator sandwiches, will be effective for charged particles and \(\gamma\)-rays. Fig. 8b shows the expected background reduction for the background reaction discussed above, assuming a detection efficiency of 95\%.
Table 1: pp → pp

<table>
<thead>
<tr>
<th>θ [mrad]</th>
<th>t [GeV²/c]</th>
<th>( \frac{d\sigma}{dt} \left[ \text{cm}^2/\text{GeV}^2\text{c} \right] )</th>
<th>( \frac{d\sigma}{d\Omega} \left[ \text{cm}^2/\text{sterad} \right] )</th>
<th>counts/sec.mrad</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.</td>
<td>( \text{80.5 \cdot 10}^{-27} )</td>
<td>( \text{16.0 \cdot 10}^{-24} )</td>
<td>------</td>
</tr>
<tr>
<td>10</td>
<td>0.0625</td>
<td>43.1</td>
<td>8.56</td>
<td>41</td>
</tr>
<tr>
<td>15</td>
<td>0.141</td>
<td>19.6</td>
<td>3.90</td>
<td>390</td>
</tr>
<tr>
<td>20</td>
<td>0.250</td>
<td>6.6</td>
<td>1.31</td>
<td>250</td>
</tr>
<tr>
<td>25</td>
<td>0.391</td>
<td>1.61</td>
<td>0.32</td>
<td>76</td>
</tr>
<tr>
<td>30</td>
<td>0.563</td>
<td>0.29</td>
<td>( \text{57.6 \cdot 10}^{-27} )</td>
<td>17</td>
</tr>
<tr>
<td>40</td>
<td>1.000</td>
<td>( \text{3.62 \cdot 10}^{-30} )</td>
<td>0.72</td>
<td>0.3</td>
</tr>
<tr>
<td>50</td>
<td>1.563</td>
<td>0.013</td>
<td>( \text{2.59 \cdot 10}^{-30} )</td>
<td>0.001</td>
</tr>
</tbody>
</table>

**NOTE:**

1) The cross section is computed on the basis of

\[
\frac{d\sigma}{dt} = \frac{\sigma^{2\text{tot}}}{16\pi} e^{bt} = \frac{t}{k^2} \frac{d\sigma}{d\Omega}
\]

\(\sigma^{\text{tot}} = \text{40 millibarn}, \quad b = 10 \left[ \text{GeV/c} \right]^{-2},\)

\(k = \text{proton CM momentum};\)

2) rates were calculated using the acceptance calculations from Fig. 6 and the nominal luminosity of \(4.10^{30} \left[ \text{cm}^{-2}\text{sec}^{-1} \right]\).
Table 2:

<table>
<thead>
<tr>
<th>Reaction</th>
<th>Generated Events</th>
<th>Accepted Events</th>
<th>Fitted Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>$p p \rightarrow p N^X$</td>
<td>45000</td>
<td>778</td>
<td>666</td>
</tr>
<tr>
<td>$\rightarrow p n\pi^+$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$p p \rightarrow p N^X$</td>
<td>45000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\rightarrow p n\pi^+\pi^0$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>i) $\pi^0$ undetected</td>
<td></td>
<td>991</td>
<td>317</td>
</tr>
<tr>
<td>ii) $n$ undetected and $\gamma$ simulates neutron</td>
<td></td>
<td>392</td>
<td>49</td>
</tr>
<tr>
<td>$p p \rightarrow N^X N^X$</td>
<td>45000</td>
<td>1267</td>
<td>64</td>
</tr>
<tr>
<td>$\rightarrow n\pi^+ n\pi^+$ (one $n$ undetected)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$p p \rightarrow N^X N^X$</td>
<td>45000</td>
<td>1133</td>
<td>147</td>
</tr>
<tr>
<td>$\rightarrow p\pi^0 n\pi^+$ (\pi^0 undetected)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
NEUTRON DETECTOR

The detection of the neutron in the $N^*$ decay is essential to reconstruct the reaction $pp \rightarrow pn\pi^+$ in an experiment without the magnet, and gives an obvious advantage in mass resolution with the split field magnet\(^\text{17}\).

Considering the kinematics of $N^*$ production and decay, we are faced with the problem of detecting neutrons in the momentum range $5 - 25$ GeV/c, and emitted in the laboratory between $0^\circ$ and $5^\circ$ with respect to the $N^*$ direction (at first approximation we can consider this direction as that of the I.S.R. circulating proton). We want to measure the neutron direction with an uncertainty of the order of $\pm 1$ mrad.

Neutrons will be detected by observing the charged particles produced in nuclear reactions. The exact calculation of all the various interaction mechanisms is difficult. To study a possible detector, we have therefore used experimental results instead of trying a long and difficult Monte Carlo calculation\(^\text{18}\). For that purpose, we have scanned about 500 pictures taken by the Karlsruhe group in an elastic $n$-$p$ scattering experiment\(^\text{19}\) performed in a neutron beam having a momentum range of $3 - 20$ GeV/c, and a maximum intensity around 9 GeV/c. An optical spark chamber arrangement with thin (1.5 and 3 mm) iron plates in between served to detect the scattered neutrons.

The scanning shows several features:

a) The mean multiplicity at the vertex (without counting the slow backwards particles) is 2.8; this number decreases slowly with an increasing amount of iron after the vertex:
<table>
<thead>
<tr>
<th>cm of iron behind the vertex</th>
<th>mean multiplicity</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2.8</td>
</tr>
<tr>
<td>5</td>
<td>2.6</td>
</tr>
<tr>
<td>10</td>
<td>2.2</td>
</tr>
<tr>
<td>15</td>
<td>1.6</td>
</tr>
</tbody>
</table>

This fact indicates that we can consider using thick converters, thus decreasing the number of detectors and the price.

b) The mean maximum angle of the secondaries is $32^\circ$.

c) In about 37% of the events, we have one or several backwards tracks able to cross about 0.5 cm of iron.

d) We have deduced from the density of the events along the detector, a "detectable" collision length $\lambda_D = 15.5$ cm, related to the usual collision length $\lambda_{col}$ by the proportion:

$$\lambda_D = 1.2 \times \lambda_{col}$$

So we can use the following efficiency formula:

$$\varepsilon = 1 - \exp \left( -L/\lambda_D \right)$$

For example, $\varepsilon \approx 0.5$ for 10 cm of iron.

We first considered a sandwich detector compound of 4 cm thick blocks of brass separated by XY proportional wire chambers, using the barycentres of the jets seen in the chambers to obtain the neutron impact point. As an alternative, we studied the following detector, which for the same price gives a space resolution three times better.

It consists (Fig. 9) of two identical modules, each compound of a 10x150x50 cm$^3$ brass converter, followed by two XY proportional wire
chambers at 10 and 30 cm distance. These can be of the "standard" type, with 2 mm wire spacing, but in clustering 3 or 4 wires to the same amplifier. So we get two points for each outgoing track and we can reconstruct the vertex inside the converter. The accuracy obtained with the events of the film for the coordinate perpendicular to the axis of the detector is.

\[ \sigma_x = 0.4 \text{cm} \ (\pm 0.5 \text{ mrad at 8 meters}) \]

to compare with \( \sigma_x = 1.2 \text{ cm} \) in the barycentre method. The efficiency for a two modules' detector will be better than 0.64.

\[ \varepsilon \geq 0.64 \]

(it is lower than \( \varepsilon \) given by the formula since some events have no tracks able to cross all the converter, and others are rejected by the vertex program).

Considerations of accuracy (bound to the length of the converter), magnetic field and price have determined our choice for brass as converting material. We choose proportional chambers essentially for their time resolution, needed by the "hot" region where the neutron detector will operate.

A \( \gamma \) detector consisting of a standard lead-scintillator sandwich will be placed in anticoincidence before the neutron detector. In having a loss in neutron efficiency in the range of 15% off, we can have a \( \gamma \) efficiency of 0.95 with 2 cm of total lead thickness. The 5% of remaining \( \gamma \) can be in part eliminated by selections on the events configuration.

The final efficiency can be 60%. It will have to be measured before the experiment.
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15. We want to acknowledge the important contribution of Dr. H. Grote to the development of the analysis programs.


FIGURE CAPTIONS

Fig. 1  SFM standard proportional wire chamber.

Fig. 2  a) Wire electronics
        b) Block diagram of the proportional chamber electronics.

Fig. 3  Chamber setup for the initial experimentation at the ISR
        a) large angle chambers;
        b) small angle chambers.

Fig. 4  a) Multiplicity distributions
        upper part: input distribution of Monte Carlo calculation;
        lower part: distribution accepted by the apparatus (shaded) and distribution corrected for
                    particle losses;
        b) Distributions of the polar angle $\theta_{lab}$;
        c) Distributions of the azimuthal angle $\phi_{lab}$.

Fig. 5  Detector for diffraction reactions.

Fig. 6  $t-$ distribution of accepted genuine and background events for the process $pp\rightarrow pp$.

Fig. 7  $t-$ distributions of generated and accepted events of the processes $pp\rightarrow pN^X$ and $pp\rightarrow N^XN^X$. 
Figure Captions cont'd

Fig. 8 Resolution and background rejection for the process

\( pp + p_{\bar{X}} \rightarrow p_\pi^+ n \).

a) resolution curve for a zero width resonance and
effective \((\pi^+)\) mass distribution for the back-
ground decay \( p_{\bar{X}} \rightarrow n\pi^+ \pi^- \).

b) \( t\)-distribution of genuine and background events.

Fig. 9 Neutron detector consisting of anticounter, two converters
and two proportional chambers per converter.
fig. 2a  GROUP ELECTRONICS ORGANIZATION

fig. 2b  DETECTOR AND READOUT BLOCK DIAGRAM
fig. 4
fig. 6
\[ \text{fig. 7} \]
Fig. 8

(b) $p\pi^+n$ fitted (666 events)

$P\pi^+n$ fitted from $p\pi^+n\pi^0$ (312 events)

$P\pi^+n$ fitted from $p\pi^+n\pi^0$ with anticounter (24 events)

$\sqrt{M_{\pi^+\pi^-\pi^0}} = 1.469$ GeV

$\sigma_* = 0.026$ GeV (4 ev cut)
fig. 9

x, y chambers

brass plates

anti-counter

10 cm