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A STORAGE RING INTERACTION STATION FOR MEASURING PROTON PROTON ELASTIC SCATTERING IN THE VERTICAL PLANE

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This is a suggestion to build an interaction station for the measurement of proton proton elastic scattering in the vertical rather than horizontal plane. The advantage of going into this plane is that the magnet which then separates the scattered and unscattered protons is far superior to the septum magnet which serves this function in the horizontal plane.

The major problem in studying elastic scattering at storage rings is separating the scattered protons from the unscattered protons especially for small angle scattering. In this proposed layout we solve this problem by the use of special magnets which deflect the unscattered protons in the horizontal plane. This magnet has a special V-shaped notch which lets the vertically scattered protons pass thru undeflected as shown in Fig. 1.

In Fig. 2 which shows the horizontal layout, one can see that both of the unscattered protons are deflected from the storage rings into the interaction region and then back into the storage rings by four of these special deflection magnets. The deflection in each magnet is about 25 mrad. However the vertically scattered protons go above and below these magnets, passing thru the V-shaped field free slits, and are not deflected.

Thus the scattered and unscattered protons are cleanly separated in the horizontal plane by about 25 mrad. About 20 meters downstream there is ample room (50 cm) to put a substantial magnet to analyze the scattered protons in the vertical plane. Once the scattered proton has entered this magnet it is easy to get it away from the storage rings and many types of spectrometers could be used for further analysis. Below we suggest one type which may or may not be the best.

The vertical layout of the spectrometer is shown in Fig. 3. It consists of the two steering magnets S_1 and S_2. The magnet S_1 is the vertical deflection magnet mentioned above and its function is to steer protons scattered at different angles towards the S_2 magnet. The S_2 magnet is then set so that the protons always emerge from S_2 exactly on the central axis of the spectrometer, and going exactly in the horizontal plane. (Note that angle and position are two conditions and there are two magnets.) This technique has been used in accelerator experiments.[1] Once the protons are back in the horizontal plane they can be momentum analyzed by a deflecting magnet (D) in the horizontal plane with high $\int B \cdot dl$ and a very small aperture, because the protons have all been steered along the spectrometer axis. These magnets never have to be moved and the different scattering angles are measured by resetting the currents in S_1, S_2 and D.

In summary the principal ideas of the experiment are:

1. A special magnet with a V-shaped notch to separate the unscattered protons from the vertically scattered protons.

2. A spectrometer with a pair of steering magnets to bring protons scattered at all angles from 1 → 25 mrad back on the spectrometer axis.

I now believe that this system is superior to the one I discussed at the October meeting on storage rings at NAL. This earlier system used septum magnets to deflect the unscattered protons in the horizontal plane and had three problems:

a) It would be difficult to build the necessary septums.

b) The poor field shape of the septums would make operation of the storage rings difficult.

c) The system would require two non-cross-over points and would thus require an undesirable change in the overall geometry of the storage rings.

I would like to thank Dr. L. C. Teng for suggesting some of the ideas contained in this note.

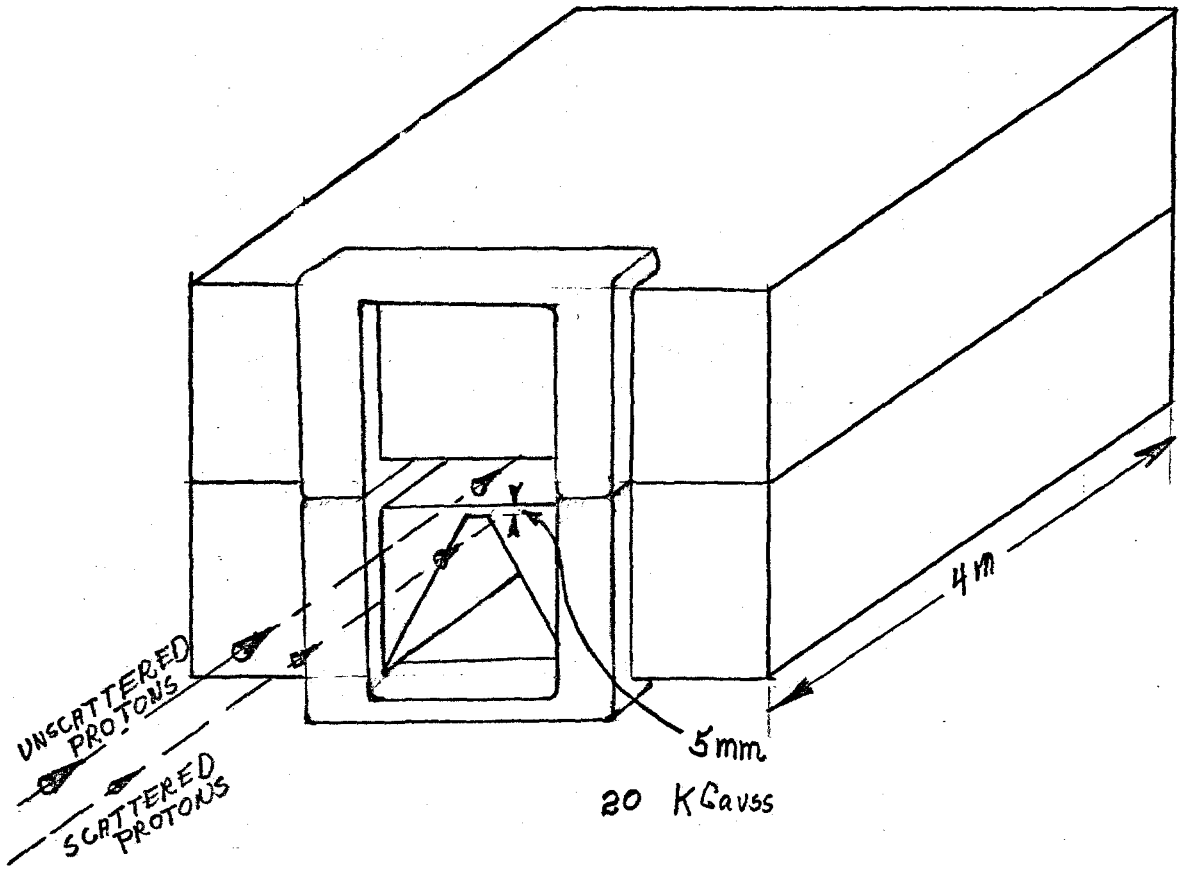

Fig 1 Special Magnet with V-Shaped Notch

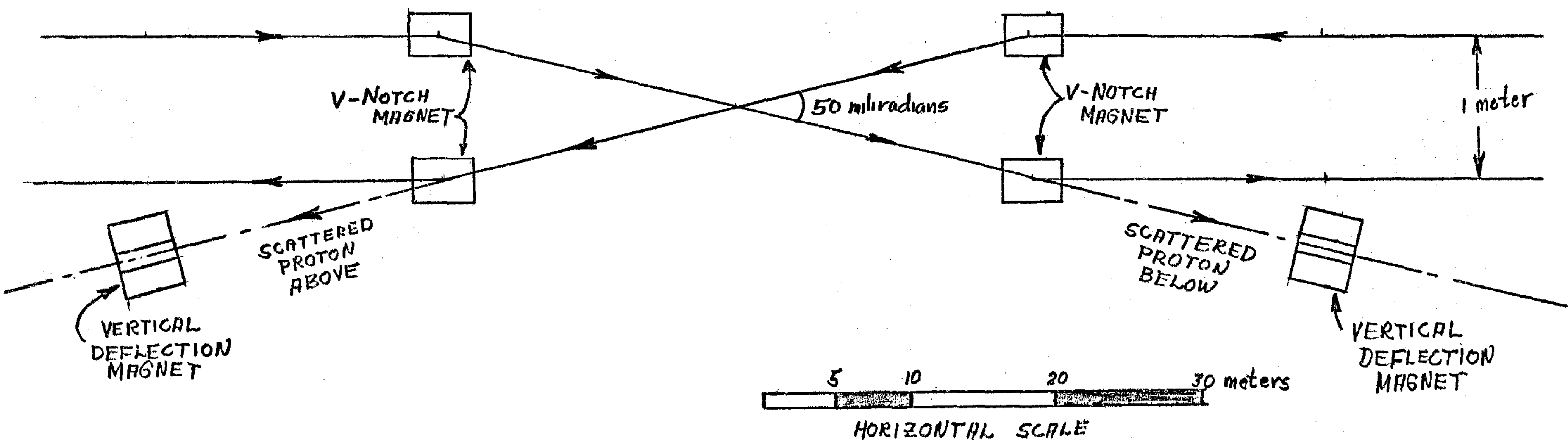

FIG 2 HORIZONTAL LAYOUT

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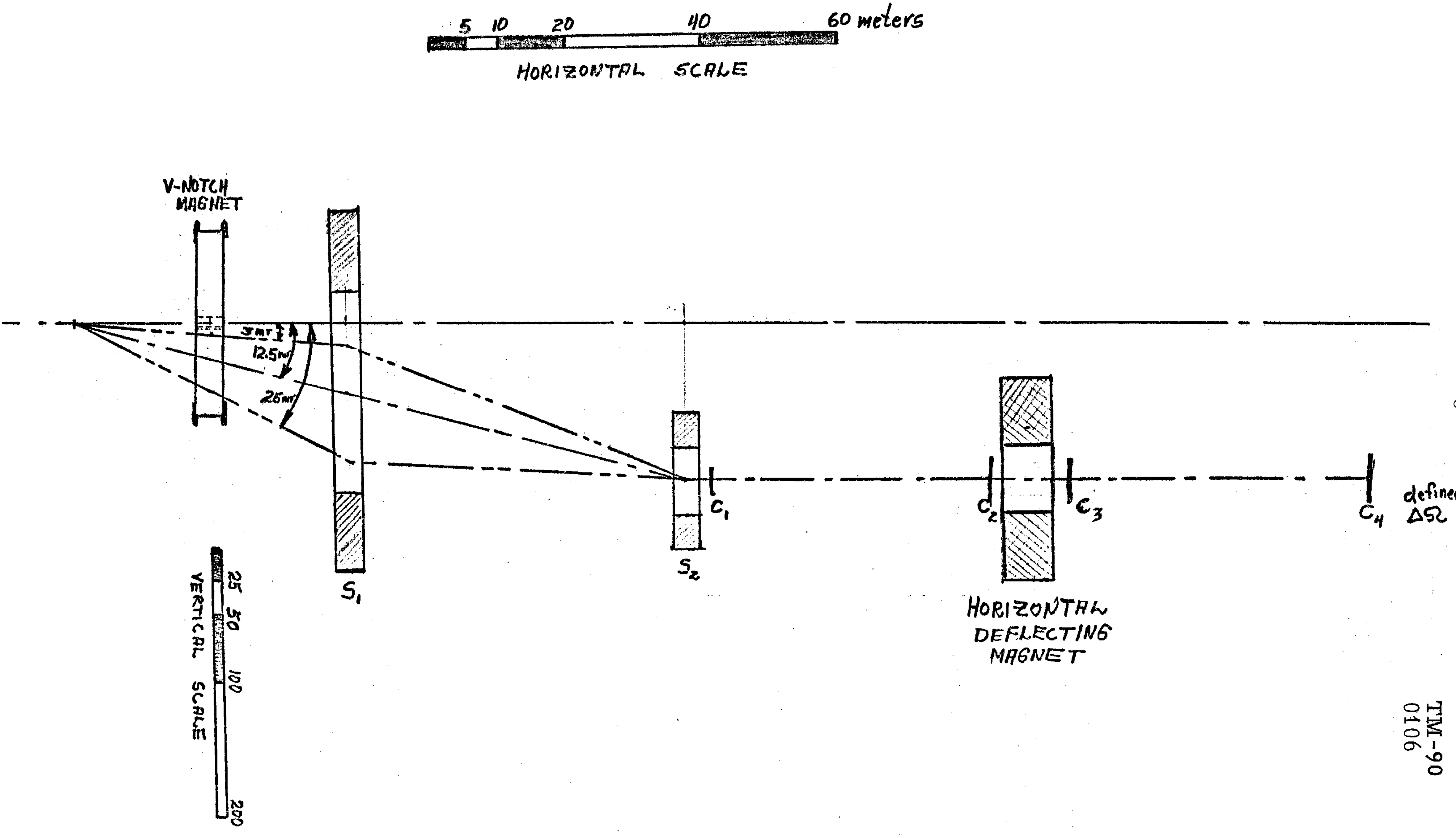

FIG 3 VERTICAL LAYOUT

APPENDIX

COUNTING RATE FOR ELASTIC SCATTERING AT $P_{cm} = 100$ GeV/c STORAGE RINGS

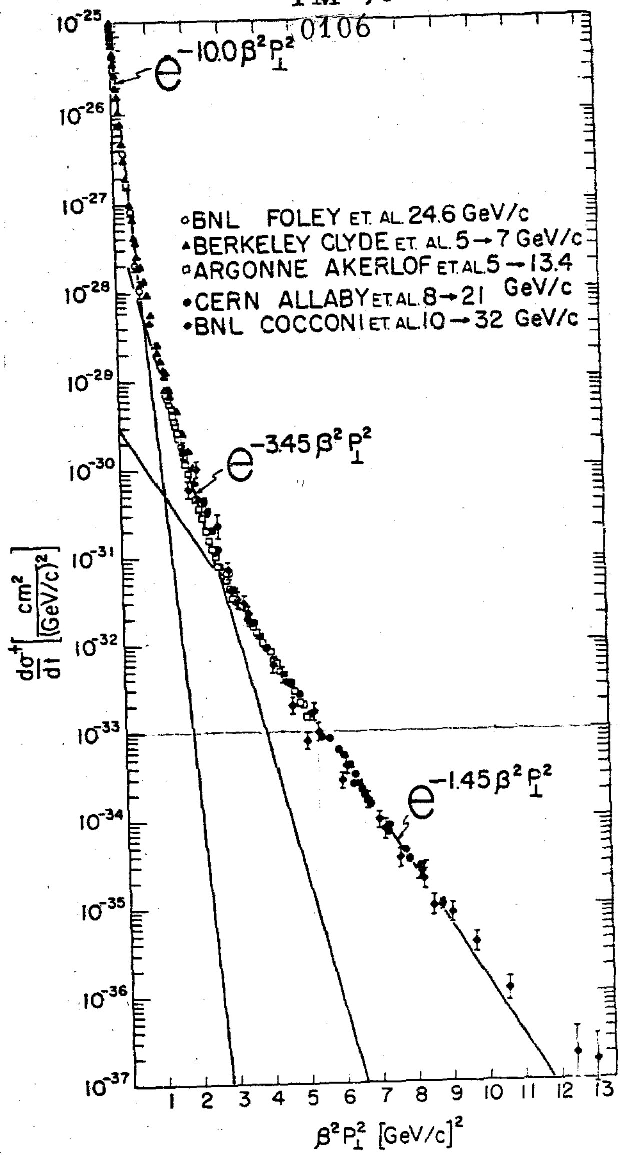

FIG. 4. Plot of $d\sigma^\dagger/dt$ vs $\beta^2P_\perp{}^2$ for all high-energy proton-proton elastic-scattering data (Refs. 1-5). Not all small-angle data (Refs. 1 and 2) are shown on this plot to avoid crowding. (All small-angle data are shown in detail in Fig. 2 of Ref. 10, where $d\sigma/dt$, which is identical to $d\sigma^\dagger/dt$ for small angles, is plotted against $\beta^2P_\perp{}^2$.) The lines drawn are straight-line fits to the data.

$$\text{Events/hour} = L\ \sigma_{elas}$$

Now $L = 2\ 10^{32}\ cm^{-2}\ sec^{-1}\ [3600\ sec/hr]$

$$\boxed{L = 7\ 10^{35}\ cm^{-2}\ hr^{-1}}$$

$$\sigma_{el} = \left.\frac{d\sigma}{d\Omega}\right)_{cm} \Delta\Omega_{cm}$$

Now $\Delta\Omega = \Delta\theta\ \Delta\phi \sin\theta$

Now if we choose $\Delta\theta = 0.5$ milirad

Then $\Delta P_\perp^2 = 2P_{cm}^2 \sin\theta \cos\theta\Delta\theta \approx 2P_{cm}^2\theta\Delta\theta$

$$= 2(100)^2(.0002)\theta$$
$$= 10\ \theta$$

So that

$P_\perp^2$ $(GeV/c)^2$	θ radians	$\Delta P_\perp^2$
.01	.001	.01
.25	.005	.05
1.00	.010	.10
6.25	.025	.25

Let $\Delta\phi \sin\theta = 2$ miliradian

Then $\boxed{\Delta\Omega_{cm} = 10^{-6}\ sterad}$

Next note that

$$\left.\frac{d\sigma}{d\Omega}\right)_{cm} = \frac{P^2}{\pi}\frac{d\sigma}{dt} = \frac{P^2}{\pi}\left.\frac{d\sigma}{dt}\right)_{\theta=0} X \quad \text{where } X \equiv \frac{d\sigma/dt}{\left.d\sigma/dt\right)_{\theta=0}}$$

Thus we have

$$\text{Events/hr} = L \left.\frac{d\sigma}{d\Omega}\right)_{cm}\Delta\Omega_{cm} = L\frac{P^2}{\pi}\left.\frac{d\sigma}{dt}\right)_{\theta=0} X\ \Delta\Omega_{cm}$$

$$= 7\ 10^{35}\ \frac{(100)^2}{\pi}\left[10^{-25}\ \frac{cm^2}{GeV/c^2}\right] X\ 10^{-6}$$

so that

$$\boxed{\text{Events/hr} = 2\ 10^8\ X}$$

Thus we can follow the cross section over about 8 decades or out to about $P_\perp^2 \approx 5.5\ (GeV/c)^2$ as seen from Fig 4

Note at 200 meters a counter to subtend .5 mr × 2 mr is 10 cm × 40 cm