national accelerator laboratory

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Section:

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Subject: PROTON-PROTON ELASTIC SCATTERING WITH 2x100 GeV COLLIDING BEAMS

We seek to answer the questions

1) Can a configuration be found to study pp elastic scattering in an "interesting" (e.g., most studied at existing energies) range of t values using Teng's parameters for 100x100 GeV pp colliding beams?

2) Can a septum magnet be used to separate the scattered from the on-going (circulating, unscattered) beams in the vertical plane?

3) What is the counting rate for some relatively large -t values (low $d\sigma/dt$)?

Orientation: Teng Parameter List

In the y-dimension in the intersection region (target to 45 m downstream) the beam is $\pm$ .73 mm / $\pm$ .49 mr at the target and $\pm$ 22 mm at the end of the straight section.

$d\sigma/dt$ ranges from $\sim 10^{-25}$ cm^2/(GeV/c)^2 at t=0 to 10^{-32} at $-t=4$ (GeV/c)^2

$-t = (p\theta)^2$	$p = 100$ GeV/c
$-t = .01$	$\theta = 1.0$ mr
$-t = 1.0$	$\theta = 10$ mr
$-t = 4.0$	$\theta = 20$ mr

$$\frac{d\sigma}{d\Omega} = \frac{d\sigma}{(2\pi\theta d\theta)} = \frac{d\sigma}{dt} \times \frac{p^2}{2\pi}$$

$$\frac{dt}{d\Omega} = \frac{p^2\theta d\theta}{d\Omega} = \frac{p^2}{2\pi}$$

$$\frac{d\sigma}{d\Omega} \cong 1.6 \times 10^3 \frac{d\sigma}{dt}$$

We are interested over the range of from 1.6×10^{-22} to 1.6×10^{-29} cm^2/sr in $d\sigma/d\Omega$.

The relevant parameters for the design of a septum bending magnet for 100 GeV/c protons are: $B\ell = 300\ \theta$, where B is in Tesla, ℓ in meters. Consider that a 1 cm septum can separate a 5000 gauss field from 0 field.

Proposal:

A 10 m long septum magnet would be placed about midway between the "target" (intersection region) and the nearest subsequent magnet 45 m downstream. This compromises access to smaller scattering angles (requiring a large distance from the "target" region) with minimal requirements on the septum magnet (requiring as large as possible spacing between the septum magnet and the closet magnet of the storage ring structure). The magnet would be placed 20 m from the target and would separate scattered particles in the vertical plane. The scattering experiment would of course require a septum magnet, etc., in each downstream leg of the storage ring pair, one to select protons scattered up, the other, down.

At 20 m from the target the beam is 1.0 cm half height. A 1.0 cm septum would permit minimum scattering angles of 1 mr corresponding to $-t = 0.01\ (GeV/c)^2$.

The magnet could have an aperture of 10 cm horizontally (along the field line) and 40 cm vertically. This would cover the range $0.01 < -t < 4$ $(\text{GeV/c})^2$, covering in turn 7 orders of magnitude in $d\sigma/dt$. A bending of 5 Tesla-meters (5000 gauss for 10 meters) would deflect the 100 GeV/c beam by 15 mr. 20 m downstream the particles would then be displaced by 30 cm vertically from the equilibrium orbit, sufficient to clear the next beam magnet comfortably. Beyond this point the scattered particles could be deflected horizontally and vertically according to the desire of the experimentalist. The essential problem is in clearing the first obstruction. (There are still some problems: the protons scattered down would lie under several ring magnets, and they would in turn require cantelevered or overhead supports to permit ready access to the scattered particles.)

The 5000 gauss field would require a septum carrying 8000 amp/cm^2 for a 1 cm thick conductor.

Resolution:

It can be assumed that spark chambers or equivalent detectors will be used with 1 mm resolution. The primary information might come from four x-y detector planes; one near the intersection region, one on either side of the septum magnet, and one 20 m beyond the magnet. Even assuming no further momentum analysis, this would permit a resolution $d\theta = 1/20$ mr or $dp/p = 0.3\%$ (300 MeV/c at 100 GeV/c). The spread in the storage ring is 0.1%.

The angular resolution of 1/20 mr would be much better than the ±0.35, ±0.5 mr angular spread in the beams. For small scattering angles, the signature of an event as elastic would come from momentum measurements rather than angular measurements. The beam would also presumably be clipped vertically where intensity permits.

Counting Rate:

There is no problem at smaller t. Look at rates near $-t = 4\ (\mathrm{GeV}/c)^2$.

Consider a 10 cm aperture 40 cm from beam. $\Delta\varphi \cong 1/25$. For $\Delta t = 0.1$ at $4\ (\mathrm{GeV}/c)^2$,

$$dt = 2p^2 \theta d\theta; \quad d\theta = .25 \text{ mr}; \quad dr\ (20\text{ m}) = 0.5 \text{ cm}.$$

So the last .5 cm of $d\theta$ gives the last 0.1 in t.

$$\Delta t = 0.1 = 2 \times 10^4\ \theta d\theta, \quad \theta d\theta = 5 \times 10^{-6}$$

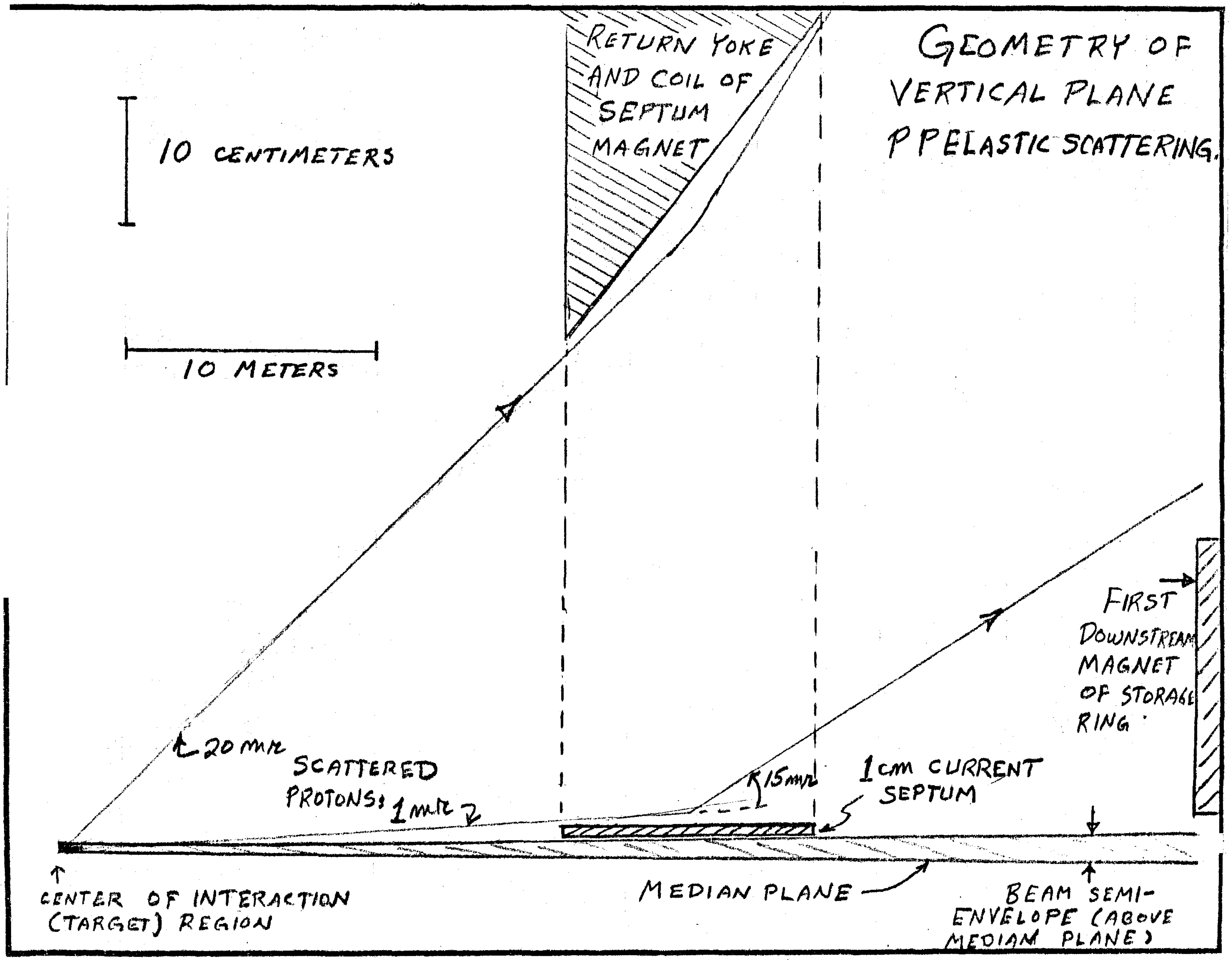
$$\text{Rate} = 1.6 \times 10^{-29} \times 10^{32} \times \frac{1}{25} \times 5 \times 10^{-6}$$

Rate $= 3 \times 10^{-4}$ or $\sim$1 per hour in last bin.

Final Conclusion:

Elastic scattering over this range can be done using 2 septum magnets, one midway from the target region to each downstream magnet and vertically over (and under) the beam. This would be combined with an "array" of spark chambers and counters.

After clearing the next magnet further magnets could be used.


GEOMETRY OF
VERTICAL PLANE
P P ELASTIC SCATTERING.
RETURN YOKE
AND COIL OF
SEPTUM
MAGNET
10 CENTIMETERS
10 METERS
20 mr
SCATTERED
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1 cm CURRENT
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OF STORAGE
RING
CENTER OF INTERACTION
(TARGET) REGION
MEDIAN PLANE
BEAM SEMI-
ENVELOPE (ABOVE
MEDIAN PLANE)

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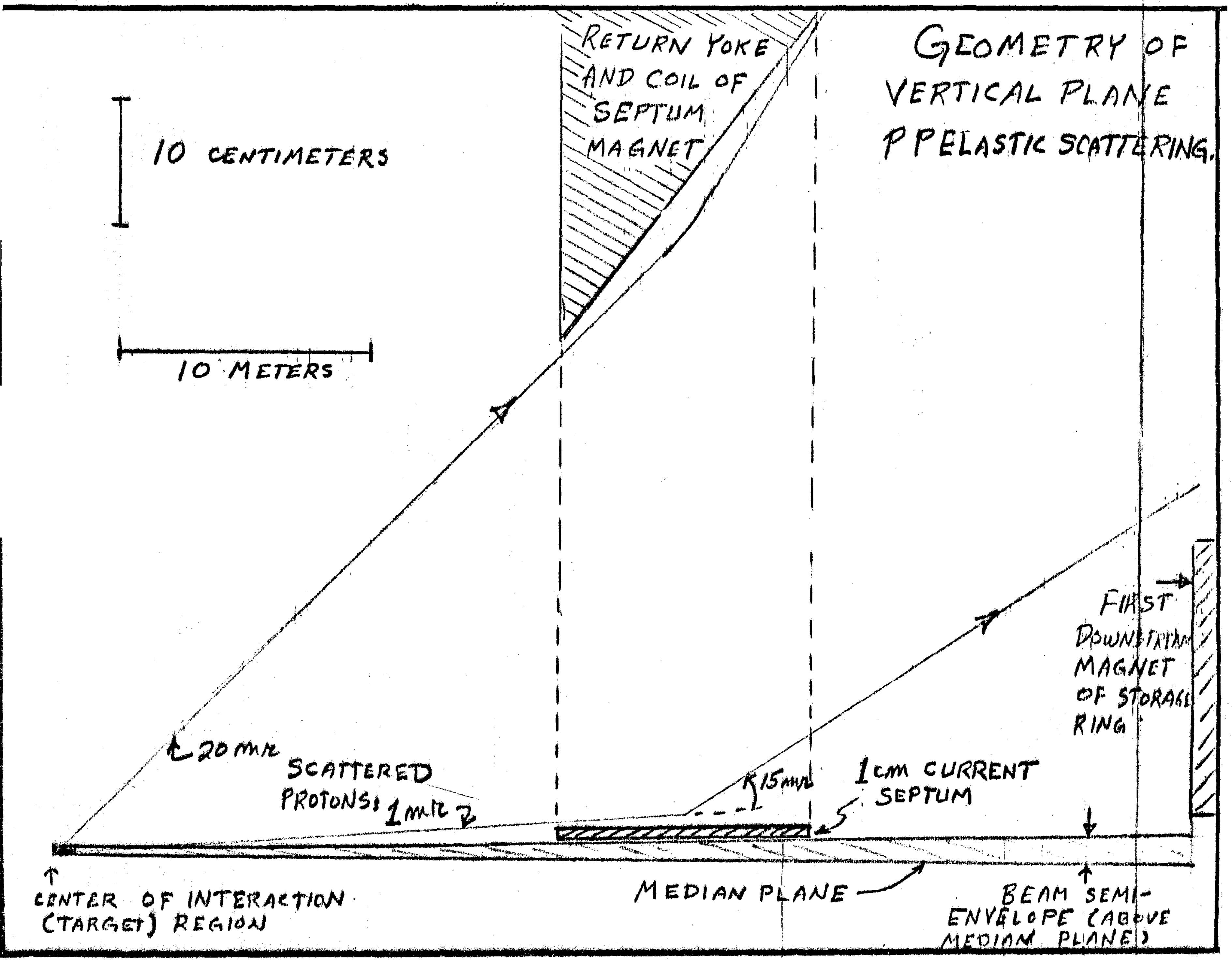

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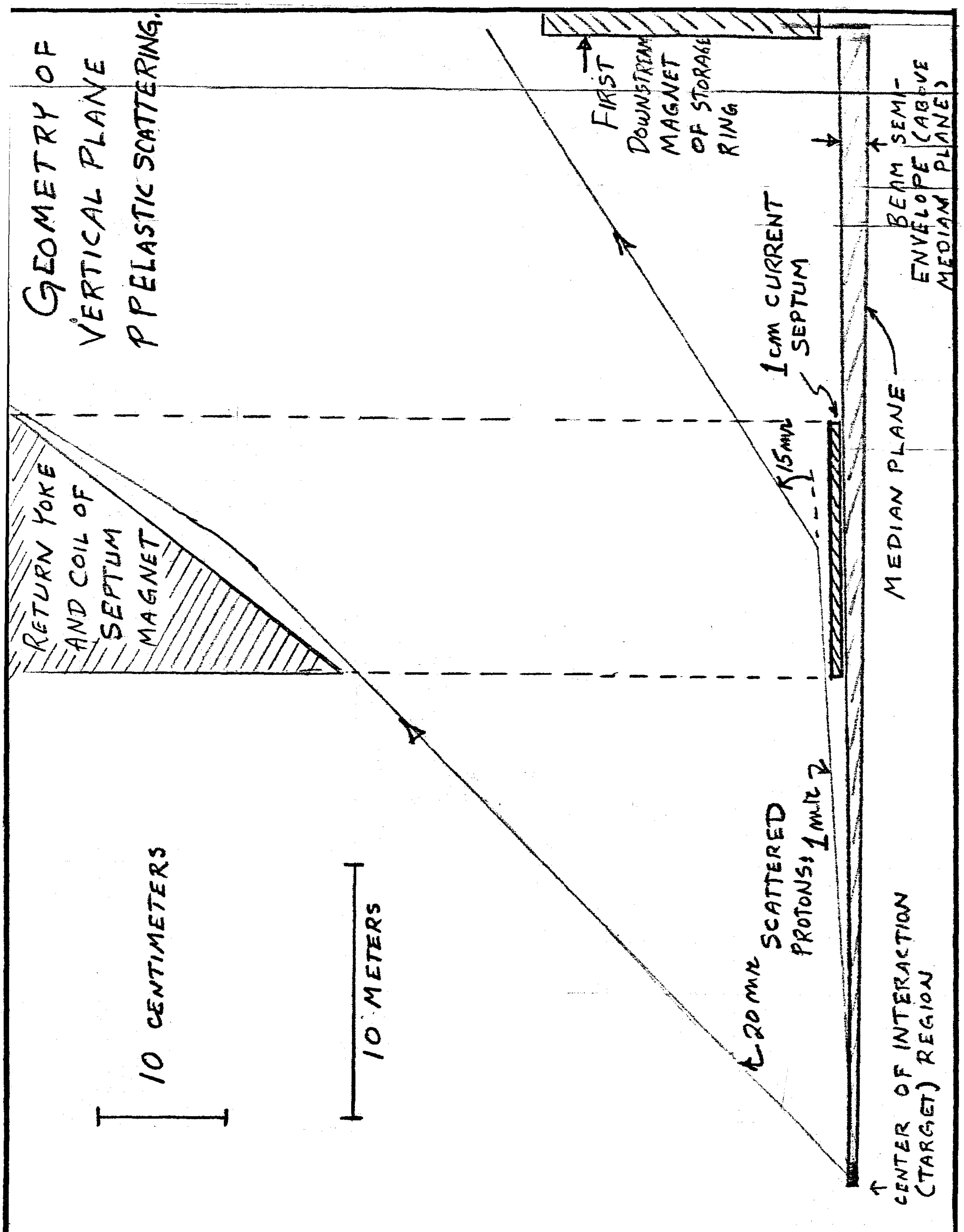
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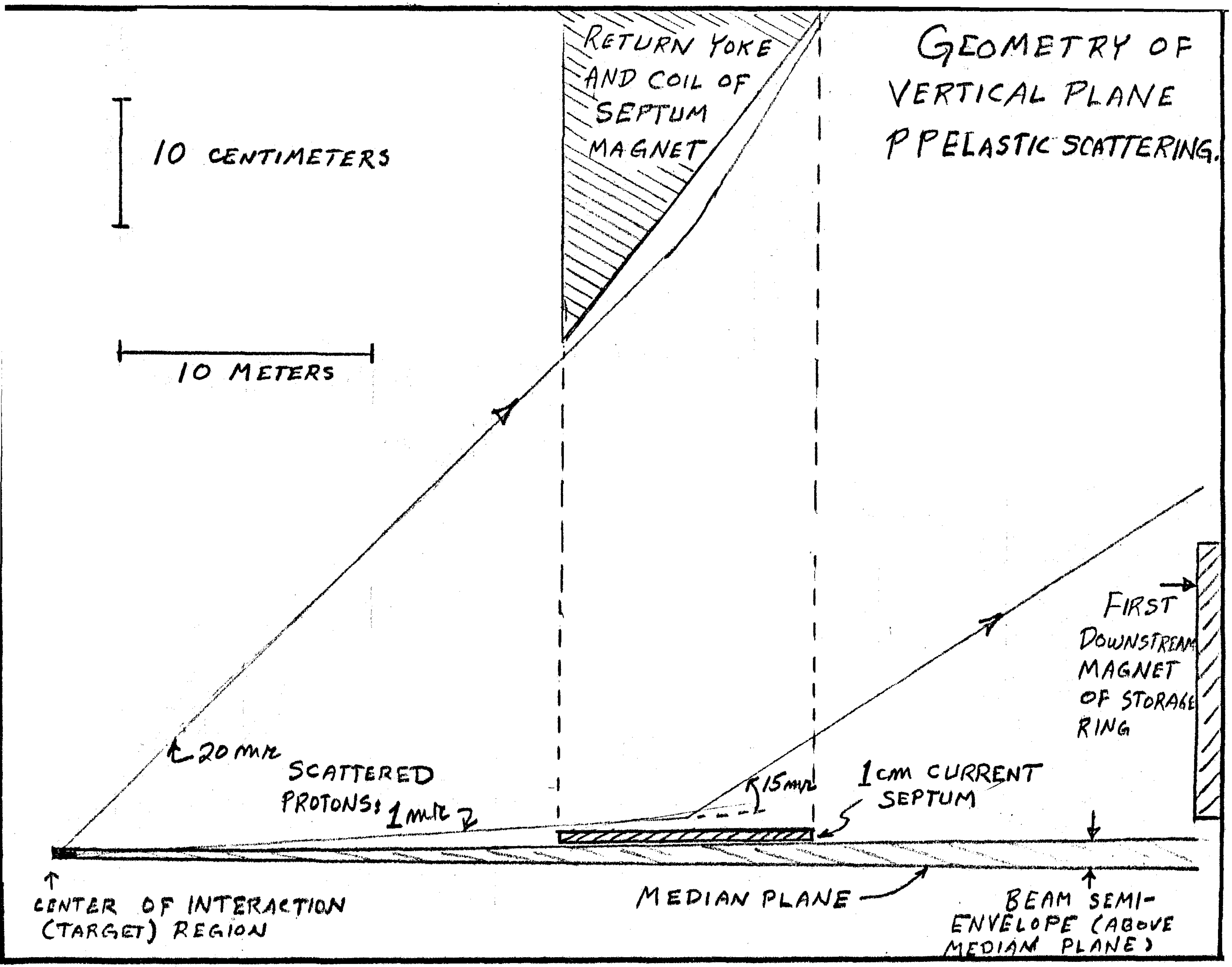
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