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PROPOSAL FOR 12 METER STREAMER CHAMBER

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Introduction

The observation and measurement of reactions at very high energies requires a detector which can be used at the high multiplicities common at these energies, including the cascading decays of high strangeness particles. The hydrogen bubble chamber becomes impractical at these very high energies because the final state particles interact before an accurate momentum or angular measurement is made. Experience shows that visual detectors are indispensable for high multiplicity and cascading strange-particle decay events. Simultaneous with the observation and accurate measurement of charged particles, the detection and measurement of π^o γ rays and of recoil neutrons is necessary at these energies because of the dwindling percentage of only charged-particle final states.

The streamer chamber appears to fit the needed requirements of a high-energy detector.

General Properties of the Streamer Chamber

The low density of the Ne gas in the streamer chamber insures that the multiple coulomb scattering, the nuclear diffraction scattering, and the interaction of the outgoing tracks are all negligible (a radiation length is 300 m and a collision length is 850 m in the Ne gas at 1 atm).

Hydrogen targets can be used in the streamer chamber as a target for interactions (this can be changed to D_2, He, etc. for other experiments). Two classes of targets can be used: gaseous or liquid. A gas target with very thin walls (0.001 in. mylar) can hold over two atmospheres of pressure and see recoil protons down to 50 MeV/c. A 0.004 in. mylar wall tube can hold 10 atmospheres and see proton recoils down to 72 MeV/c. A 10-atmosphere, 6-meter long H_2 gas target has 0.54 gms/cm^2 of H_2 equivalent to 8 cm of liquid hydrogen.

The observation of the event in one set of stereo cameras facilitates the standard techniques of scanning and measuring; a hybrid system has problems in tying the various tracks in the different parts together. This is partly due to the surveying problem in tying together the fiducials in the different parts of the hybrid system and partly due to the difficulty in mapping the magnetic field through the various fringe fields of the composite system.

The possibility of triggering the streamer chamber (with a memory of about 10 μsec) allows one to have clean pictures (only one event and no background tracks) suitable for automatic measurement. The use of a highly selective trigger then allows one to raise the beam intensity up to a maximum of 10^6/pulse and hence with a 6-meter 10-atmosphere

H_2 gas target one reaches a cross section of 3 μb/beam pulse.* The chamber can be triggered at least 10 times per second.

There are many possible types of triggers from the simplest to the very complicated. For example, a very simple trigger would be to trigger the chamber if a specified particle comes into the chamber, as signified by some counters upstream of the chamber, and does not come out, as signified by a set of counters downstream of the chamber.

A more complicated trigger would be achieved by surrounding the target with a counter in anticoincidence, providing triggers for (π^-, K^-, $\bar{p}$ + p → all neutrals). Other's could be Ω^-, Ξ^-, Σ^- + p → neutrals.

Other triggering bases could be the number of particles in the final state, the presence or absence of γ rays, and possibly a mass trigger, using decision-making spark chambers plus a hard-wired computer.

The use of peripheral devices is necessary for the detection of π^0 γ rays and neutrons.** Other useful apparatus are a Cerenkov counter at the input to tag the incoming particles and downstream spark chambers for additional position and angle information.

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*A rapid-cycling (10 pps) bubble chamber with 1 meter of liquid H_2 and 20 tracks/expansion has a data rate of 1.2 mb/machine pulse.

**The streamer chamber is perfectly compatible with such detectors. The outer shell of the electrical structure can be made as thin as 10^{-2} radiation lengths.

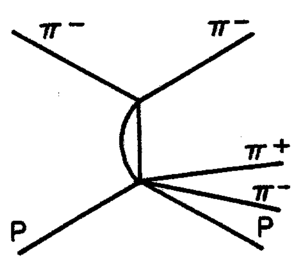
Design Parameters of Magnet and Chamber

Using several reactions as guides, we have tentatively fixed the dimensions of the chamber as 12 meter length, 4 meter width and 1.5 meter depth. The desired field is as high as possible but a 20-kG field would be satisfactory in production experiments. Cascading decays of 150 BeV/c Ω^-'s require fields as high as possible, but even with 20 kG many of the p decay modes can be studied. The problem with going to higher fields is that the force between the coils increases as B^2, requiring many posts to keep the coils apart. This results in difficulties for the use of peripheral equipment outside the magnet. Detailed design of the magnet is necessary to determine what is the maximum practical field.

The reactions which determined the parameters listed above were the following:

$$\pi^- + p \to \pi^- + \pi^+ + \pi^- + p, \text{ 100 GeV/c } \pi^- \text{ incident.}$$

A FAKE program produced events with a t distribution to the inelastically scattered π^- of $e^{-81\,t}$ and a mass distribution of the lower vertex $\pi^+\pi^-$



uniform between 1.4 GeV to 14 GeV, decaying uniformly in the cm system. We feel that, independently of the validity of the FAKE model, the events provide a severe test of the chamber. In the FAKE program we used a uniform magnetic field of 16 kG, a target two meters long centered two meters from the beginning of the chamber. The setting error in the film plane was chosen as 8μ with a demagnification of 70 corresponding to $\pm 560\mu$ in space.

It is to be emphasized that this setting error of 8μ on film or 560μ in space cannot be compared with the 200μ accuracy one normally hears about in conventional spark chambers. That result comes usually in fitting a series of measurements to a straight track perpendicular to the plates. For example, straight tracks in the streamer chamber going through the optic axis of a camera were fitted with an error of 3μ on film or 210μ in space. The value of 8μ is an experimental one gathered in the fitting of several thousand events at SLAC in the reactions $\gamma + p \rightarrow p + 2\pi\ (4\pi)\ (6\pi)\ (8\pi)$. This 8μ setting error contains the uncorrected errors in fitting the magnetic field, and the uncorrected terms in the lens distortions, and the uncorrected errors in the fiducial positions as well as the measuring error. We believe that from the success of DESY in putting wire meshes inside the neon that it will be possible to eliminate flares and distortions from streamer chambers.

The FAKE events with 15 points measured per track and a setting error of 8μ on film were put into the kinematics program TEUTA and fits were attempted for the following hypotheses:

1. $\pi^- + p \rightarrow \pi^- + \pi^+ + \pi^- + p$ (correct)
2. $\pi^- + p \rightarrow \pi^- + p + \pi^- + \pi^+$ } 3c fit × unknown mass
3. $\pi^- + p \rightarrow \pi^+ + \pi^- + x + p$ }

4. $\pi^- + p \rightarrow 0 + n^+ + \pi^- + p$
5. $\pi^- + p \rightarrow \pi^- + 0 + \pi^- + p$

(4 and 5: 1c fit, ^{0} not seen)

Two hundred sixty five FAKE events were fit and gave the following results:

(i) 1.1% of the events fit hypothesis (2) independent of probability comparing the probability of hypotheses (1) and (2) only 0.4% had similar probabilities.

(ii) The result of the 3c hypothesis (3) was an average mass of 170 MeV for the π.

(iii) No events fit either hypotheses (4) or (5).

The following table respresents the average errors in the events after fitting.

P_{track} (GeV/c)	% of tracks	Δp (MeV/c)	(dip angle error) mrad
0-5	40	7	1.7
5-20	25	30	0.5
20-100	35	42	0.17

These results make us confident that for reactions of the type

$$\text{Meson} + p \rightarrow n \ \text{Mesons} + p$$

and

$$\text{Baryon} + p \rightarrow n \ \text{Mesons} + 2\ p,$$

with incident momenta even above 100 GeV/c, the 12 m streamer chamber in a 20-kG field can resolve most ambiguities in reactions of hadrons. Furthermore, on discovering the surprisingly long decay lengths of strange particles at high energies we are convinced that the 12-meter length of the chamber becomes a necessity if one wishes to get decent momentum measurements on neutral strange particles. For charged hyperons, since the track length is short, as high a field as possible is desired to get good momentum measurements. For example in the leptonic decay of the Ω^-, $\Omega^- \rightarrow \Xi^- + \pi^+ + e^- + \nu$. (This reaction is of great interest for $\pi^-\Xi$ phase shifts) with 140 GeV/c Ω^-'s one gets an average Ξ^- energy 110 GeV, π^+ energy 14 GeV, e^- energy 4 GeV, and ν 3 GeV. The mean decay distance of the Ω^- is 2.8 meters, that of the Ξ^- is 4.3 m and that of the Λ 5.8 meters. The sum is 12.9 meters which is longer than the chamber but the average decay lengths are all smaller than the mean lengths. Furthermore, if lower momenta Ω^-'s were used, these distances would be shorter. Even at 140 BeV/c incident momenta many of the decay modes can be fit uniquely. Smaller but higher field magnets are no substitute for the types of physics discussed. However, we do believe that for different classes of experiments a three to four meter magnet with a streamer chamber inside and wire chambers outside would be of great value at NAL. This suggestion is not to be considered a substitute for the 12 meter magnet and chamber.

Cameras and Optics

Five 70-mm rapid-advance (10/sec) cameras will view the chamber with parallel axes in the configuration shown. If the demagnification is fixed at 80 at the median plane, then the film format will be 50 mm wide by 150 mm long. The lenses should be f/2.0, perhaps f/2.8 with 150 mm focal length, and capable of viewing out to a half angle of 26 ° without vignetting or excessive distortion or loss of resolution. This focal length would place the cameras 12 meters away.

Location

At present, the best location for the magnet and streamer chamber would be the detector building if no hydrogen bubble chambers were around.

Conclusions

We would like to emphasize the preliminary nature of this proposal. Streamer-chamber technology is certainly far from having reached the ultimate accuracy, and there are many areas where the system could be improved. First, there is no reason to believe that 560μ in space is a streamer-chamber limit. The diffusion-limited accuracy (in 20 kG field) is 90μ. If all other errors could be kept half of the present errors in the SLAC streamer chamber, for instance, 0.25% error in the magnetic field, instead of 0.5%, a reasonable estimate of the overall setting error is 320μ. For constant accuracy the magnetic field size will go down to 7 meters instead of 12 m. Furthermore, we have not taken into account improvements in the accuracy given by the peripheral spark chambers; again this improvement should reduce the magnetic field necessary.

Our present plans are to study different reactions ($\bar{\pi}$, k, p, $\bar{p}$ on protons as initial states) using the same technique we used for π^- events, and introducing the peripheral gear, to minimize the size of the magnet. Further technical development is expected from the 2m SLAC streamer chamber and from elsewhere.

Costs Estimate

The major cost of the apparatus is the magnet. If one scales the 2.7 million dollar cost of 25-foot bubble-chamber magnet according to the formula Volume $\times$ B then one arrives at a cost of 3.6 million dollars. The refrigeration and iron for reducing stray unwanted fields are not calculated.

	Millions of $'s
Magnet less refrigeration, power supply and iron	3.6
Cameras plus spares	0.3
Pulser plus streamer chamber	0.1
Building plus services @ $ 50/sq ft	0.5
Wire Chambers, counters, electronics	0.5
Computer	0.5
	$ 5.5

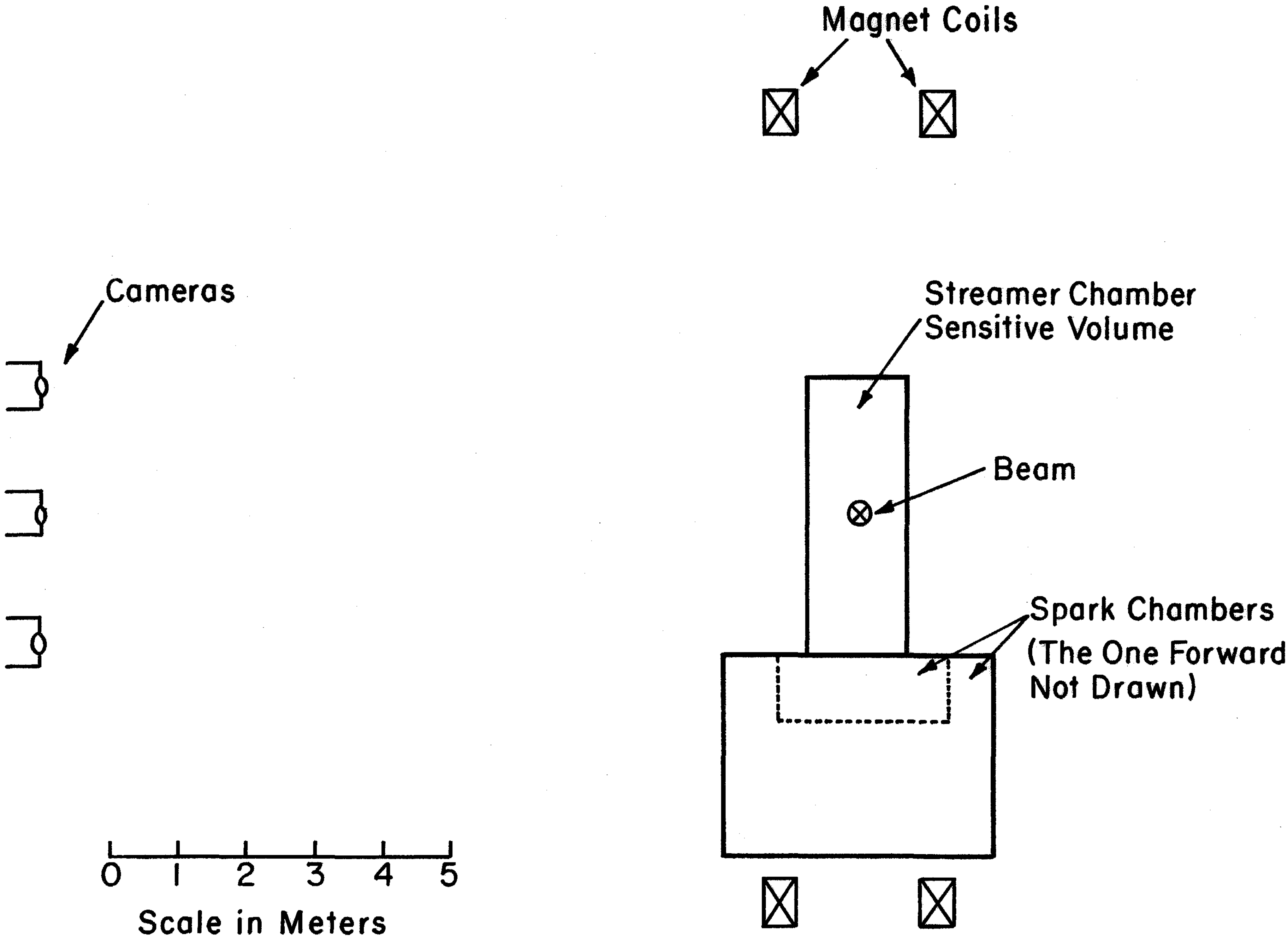


Fig. 1. Twelve-meter streamer-chamber system as seen looking downstream along the beam.

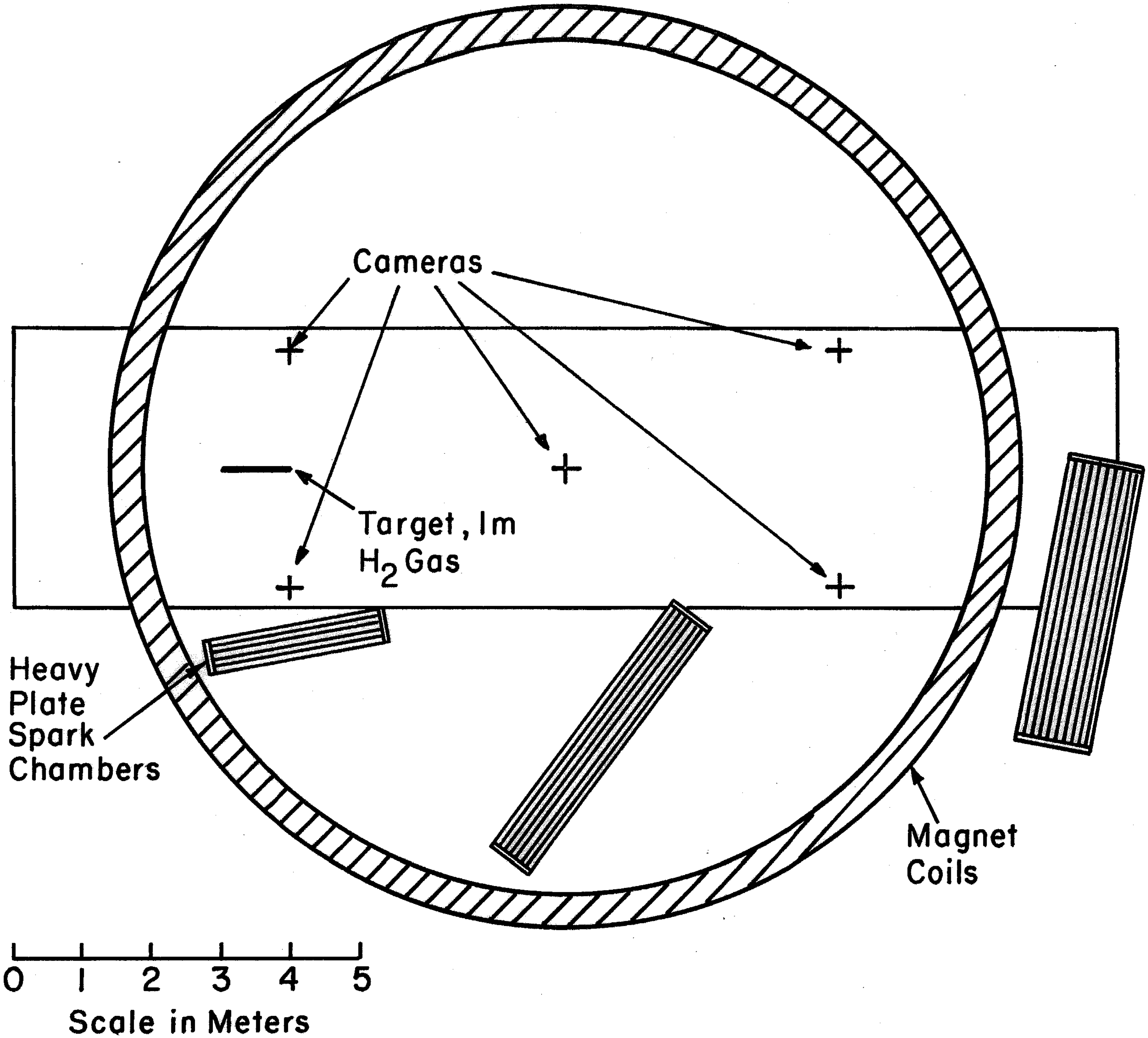


Fig. 2. System configuration looking parallel to magnetic field.