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Abstract

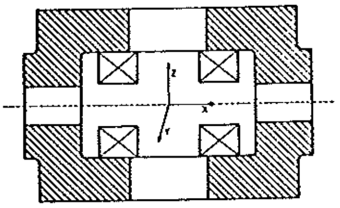
This report describes a streamer chamber which is used at DESY since 1968. The general properties of the chamber are discussed in terms of construction details, running conditions, measuring accuracy as well as its limits for physics applications.

The use of a streamer chamber for experiments at the 300 GeV machine (SPS) is suggested.

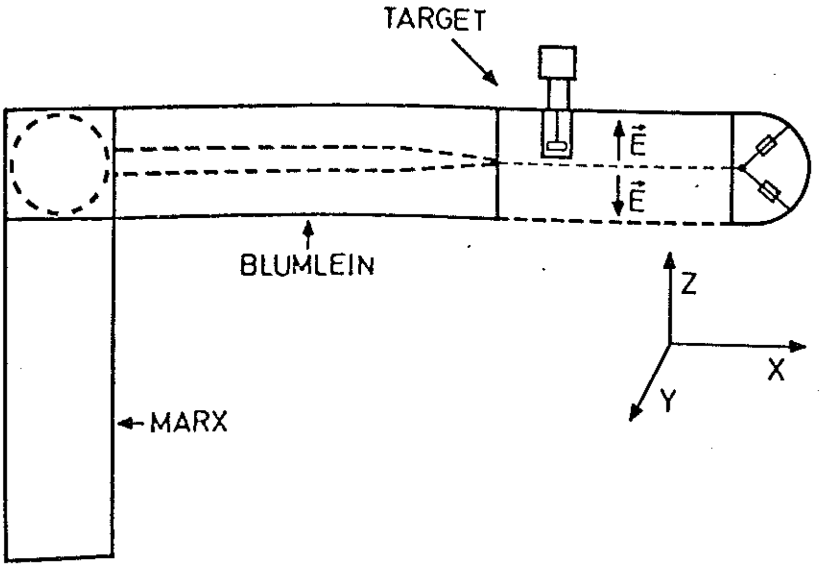
1. CONSTRUCTION OF THE CHAMBER

The geometry of the chamber is mainly determined by two conditions, the magnetic field configuration available and the requirements for an electric field of 25 kV/cm, which has to be very uniform over the sensitive volume of the chamber (Ref. 1, 2).

In our case the magnet is of bubble chamber type, this means two coils in "Helmholtz" geometry, fixed on to two movable u-shaped iron jokes for flux return. It has openings on all six sides, which provides great flexibility for use in experiments. The field is B = 18 kG with an useful volume ($\frac{\Delta B}{B} < \pm 5\ \%$) of $100 \times 60 \times 50\ \text{cm}^3$ (x, y, z).



The chamber is a lucite box $100 \times 60 \times 48\ \text{cm}^3$ in size, surrounded by a ground electrode with the high voltage plane in the middle. The high voltage electrode as well as the ground electrode on the camera



side are made out of wire meesh with 76 % transparency each. The rear ground electrode is fiber glass epoxy with a layer of copper (0.2 mm). In this configuration the electric field lines $\vec{E}$ are parallel to the main magnetic field component B_z, but pointing from the middle electrode to both ground electrodes in opposite directions. The electrodes are extended away from the sensitive volume by approximately the gap width to prevent edge sparking and to give uniform electric field inside the lucite box.

The high voltage pulse is produced by a Marx generator with 10 stages of ±35 kV at 8 nF capacity per stage. The Marx output pulse is shaped to 3 nsec rise and fall time and 10 nsec FWHM with a coaxial Blumlein system, which geometrically matches the Marx output to the cross section of the chamber. The chambers impedance is ~27 Ω.

The sensitive volume is given by filling the lucite box with He (30 %) Ne (70 %) at atmospheric pressure. With purely this gas mixture, the memory time would be >200 μsec, very small amounts (10^{-7} parts per volume) of SF_6 reduces it to any number from 0.5 μsec upwards.

Inside the rear half of the chamber a liquid hydrogen target is build in. The cell, made of H-foil, with 25 μ wall thickness and 12 μ for the beam windows, is 15 mm in diameter and 90 mm long. Separation from the chamber gas is provided by a cylindrical vacuum tube made of "Rohacell" (which is a perspex foam) of 10 mm wall thickness (0.06 g/cm^3). This tube extends from the rear ground electrode to the middle high voltage electrode thus avoiding spark breakedown along the target walls. A small (5 W) liquifier connected to the outside of the rear ground electrode filles the hydrogen target.

Pictures are taken with 3 cameras at 18° stereo angle. The demagnification is 38 with a 35 mm optic (Zeiss Distagon) in 155 cm distance. We run at a f-number of 2.0 and take the pictures on Kodak Tri-X Aerographic film SO 265. The 6 fiducials on the rear ground electrode are illuminated by electroluminicence lamps, two fiducials on the front side are of the same type.
Arrays of gallium arsenid diodes with associated electronics are used for film and picture number.

2. RUNNING CONDITIONS

A chamber of this type - slightly modified in this earlier version - has been used for a photoproduction experiment. We have taken from June 69 to February 70 870 k Pictures in a tagged photon beam which gave ~200 k hadronic events and 40 k coming from the hydrogen target. (Most events came in that special case from the vacuum tube which was a scintillator of 5 mm wall thickness which provided the trigger counter).

The streamer quality is mainly determined by the high voltage pulse stability which was in general ±2 % in amplitude. At time intervals of ~100 k pulses the main spark gap at Blumlein entrance had to be cleaned, besides this the whole system was very stable during the run. The size of the streamers is typically ~10 mm in the direction of $\vec{E}$ and ~1 mm in diameter perpendicular to the electric field.

The deadtime was ~0.5 sec given by camera transport, and the time needed to recharge the Marx generator. The repetition time was typically 1/sec. The memory time of the chamber was chosen around 2 μsec by appropriate SF_6 admixture and is presently kept constant to ~10 % by an automatic regulation system (Ref. 3). A reduction of streamer quality due to SF_6 admixture has not been observed.

Presently the chamber is used in an electroprodcution experiment. The incident beam has an intensity of $\sim 2 \cdot 10^6$ e^-/sec with 5 % duty cycle and a diameter of 2.5 mm at 1/100 height. This beam intensity gives 50-80 electrons per memory time, which appear due to the smallness of the beam as one single bright beam track. The memory time of 2 μsec used now, is determined by trigger delay (~0.6 μsec) and delay in the high voltage pulse (~0.6 μsec) giving a total delay of 1.2 μsec for the high voltage pulse after the event particles passed the chamber. The repetition time is ~10 sec given by the event trigger.

3. MEASUREMENT ACCURACY

The film was measured mainly on hand-measuring tables (Vanguard type), part of the film was measured on SMP, and a trial run has been made on a HPD. The setting error σ (Thresh residual) defined by $\sigma^2 = \sum_i d_i^2/(n-5)$ (n - number of measured points, d_i - deviation of single points perpendicular to the fitted curve) in the film plane is ~6.5 μ which gives 250 μ in space.

For a run on the HPD the setting error improved to 3.5 μ. Multiple scattering and ionization loss in the chamber gas are negligible. therefore perpendicular to a uniform magnetic field the particle tracks are circles.
The vertex is not seen, but its reconstruction presents no difficulties, the accuracy achieved is Δy = Δx = ±0.5 mm, Δz = ±2.0 mm.

The measuring accuracy can be summarized by writing down the expression for the dependence of momentum and angle errors following from the Thresh reconstruction procedure

$$(\Delta p)^2 = \sigma^2 \cdot \left(p^2 \frac{\cos\lambda}{H3}\right)^2 \frac{720\ (n-1)^3}{L^4 n(n+1)(n^2-4)}$$

$$(\Delta\phi)^2 = \sigma^2 \cdot \frac{12\ (n-1)}{L^2 n(n+1)} \left(1 + \frac{15\ (n-1)^2}{n^2-4}\right)$$

$$(\Delta\lambda)^2 = \sigma^2 \cdot \cos^4\lambda \; (Q^2 + \tan^2\lambda) \cdot \frac{18\;(2n-3)}{L^2 n\;(2n+3)}$$

where p (GeV), ϕ (rad), λ (rad) are the momentum, azimuth and dip of the track, L (cm) is the measured projected length, n the number of points measured, σ (cm) the variance of the measurements in space, $Q = 1/\tan\alpha$ the mean stereo ratio and H3(kG) the magnetic field strength multiplied by $3 \cdot 10^{-4}$. These formulas are valid only near $\lambda = 0$. Otherwise one has to take into account the correlations between p and λ. Also the uncertainty of the magnetic field has to be added to Δp.

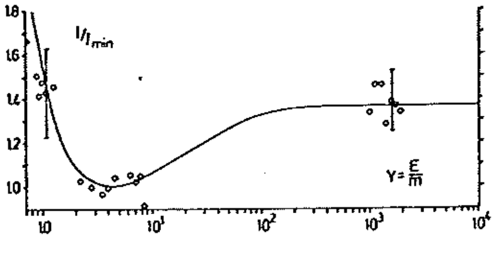
Tracks with $\lambda > 75^\circ$ are unmeasurable, with $75^\circ > \lambda > 65^\circ$ only the angles can be measured.

To further exhibit the accuracy of the chamber as described above, we quote some values for mass resolutions (FWHM) in our photoproduction experiments at 5 GeV.

$K^0 \to \pi^+\pi^-$	$\Delta M_{K^0} = 13$ MeV
$\gamma p \to p\omega \to p\pi^+\pi^-\pi^0$	$\Delta M_\omega = 35$ MeV
$\gamma p \to n\pi^+\pi^+\pi^-$	$\Delta M_n = 220$ MeV
$\gamma p \to \pi^+\pi^-(p)$ ↳unmeasured	$\Delta M_p = 240$ MeV

4. IONISATION

The dependence on specific ionization loss, as expected from theory is shown in Fig. 3 (for He)



It has been verified to some extend, by measuring the gap length distribution of streamers, or just by streamer counting. Note the relativistic rise to approximately $1.3 \cdot I_{min}$.

In our actual photoproduction experiment, for not too steep tracks ($\lambda < 35^\circ$) ionization information is used for momenta $p < 1$ GeV/c where a discrimination between p and π is possible.

5. SOME LIMITS AND FUTURE DEVELOPMENTS

a) Chamber size

The measuring accuracy of the chamber is among other's factors determined by the track length available.

If a larger magnetic field is available, the chamber can easily be made longer. A limit is given by the number of cameras, that can be used without to much troubles. To enlarge the depth of the chamber the high voltage had to be increased more than proportional, to get brighter streamers, because a larger f-number (now 2.0) is required to get enough resolution over a larger chamber depth.

b) Streamer size

Having smaller streamers would improve the resolution of course. It would also give better ionization information, which is limited by a robbing effect of nearby streamers and by spark development for too large dip angles. The size of the streamers is determined by the light output needed, to get it photographed with the high speed film. If image intensifiers of sufficient resolution were available this would be a natural solution. An improvement in the same direction may be a larger high voltage pulse with steeper rise and fall times. It would at the same time reduce a systematic streamer shift along the electric field lines, away from the middel electrode which is caused by a move of primary electron avalanches before the streamer formation. Streamer size is also affected by diffusion, but in directions perpendicular to the magnetic field, diffusion is strongly suppressed. (Ref.4).

c) Event rates

Sensitivity to small cross sections is mainly determined by the memory time, which has to be chosen around 2.5 μsec, because of the high voltage pulse delay. Some improvements are possible, but not below 0.7 μsec. Assume, one could tolerate 100 beam tracks inside 1 μsec memory time, then with 25 % duty cycle a beam intensity of $2.5 \cdot 10^7$/sec could be taken, which gives for 20 mb and 10 cm liquid hydrogen $2 \cdot 10^5$ event/sec. With the further assumption that 10 pictures/sec can be taken the intensity of $2.5 \cdot 10^7$/sec is useful only if a trigger level of 1 in $2 \cdot 10^4$ can be achieved. The sensitivity would be, 10^4 events/h for 1 $\mu b/\Delta\Omega$ where $\Delta\Omega$ is the trigger acceptance.

d) Repetition rate and track storage

The repetition rate is limited by camera advance, usually of order 10/sec. An ultimate limit is the memory of the chamber for tracks that have been made visible by a previous high voltage pulse. This time is around 10-100 msec.

Because the first pulse can be chosen so as not to produce visible streamers a second pulse after ~1-5 msec would produce visible streamers, providing a track storage mode of the chamber (Ref. 4). This leaves sufficient time to make complicated trigger decisions. Tests have shown no measurable track distortion during this time.

6. SUMMARY OF PROPERTIES

A streamer chamber seems to be well suited for use at 300 GeV in applications where one wants

1) excellent multitrack efficiency
2) good momentum and angle measurements
3) low mass around the target, to avoid multiple scattering and secondary interactions
4) to see low energy protons (p > 140 MeV/c) and discrimination $p - \pi^+$ (up to 1 GeV/c)
5) good time resolution (~ 1 μsec)
6) to measure low cross sections with complicated final states (incident flux > 10^6/sec possible)
7) only 1 event/picture coming from a fixed target region, and no confusion from other tracks, (for automatic measurements)
8) to work in a high background level with 4π acceptance (hyperon beam, unseparated beams)
9) a 4π instrument together with outside detectors, like a forward spectrometer, neutron-counters, Cerenkov-counters, or photon detectors.

* * *

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