Betriebsmoden von Gasdetektoren je nach E-Feld

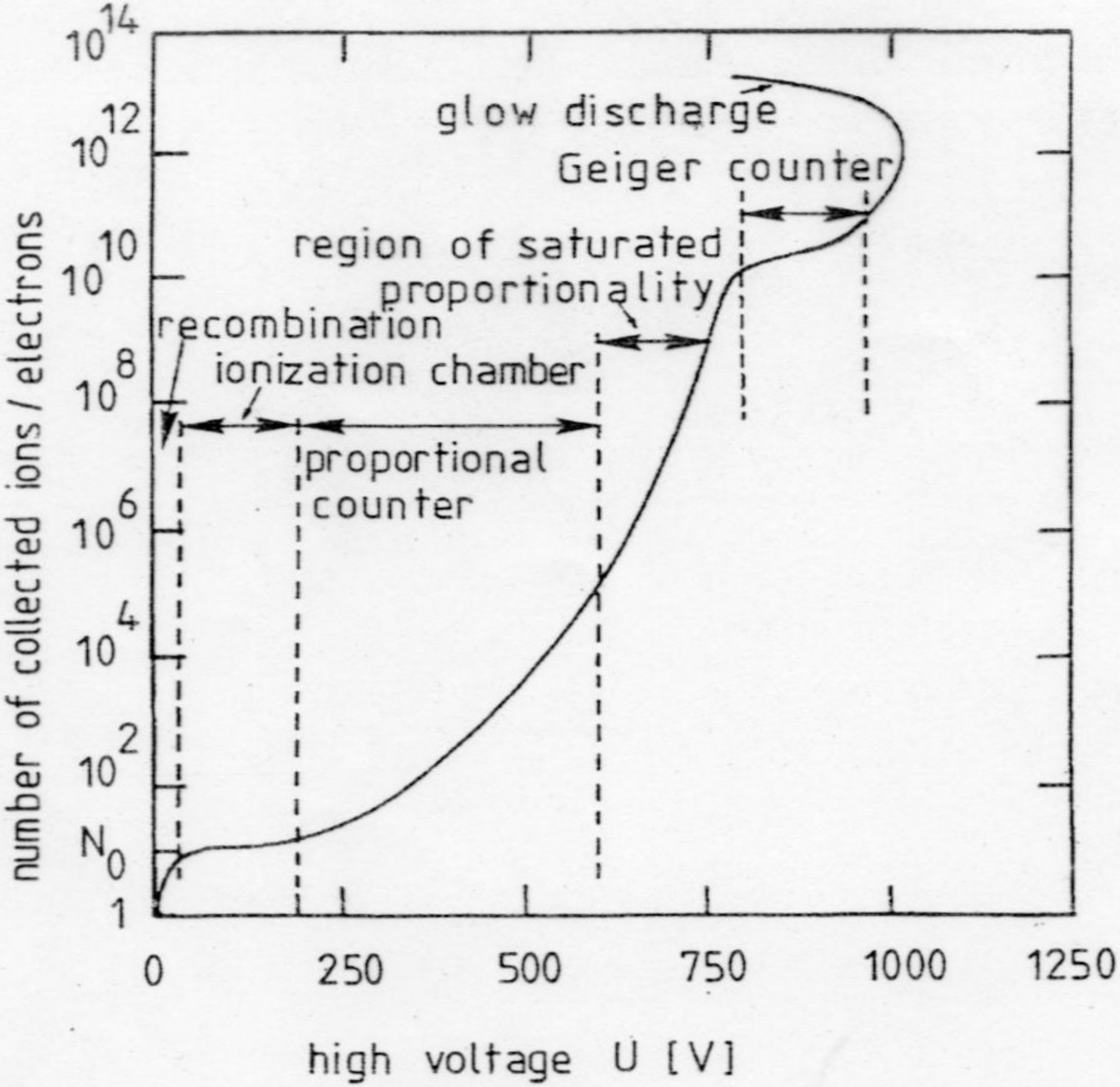


Fig. 4.21. Characterization of the modes of operation of cylindrical gas detectors (after [51]).

Ionisationskammer

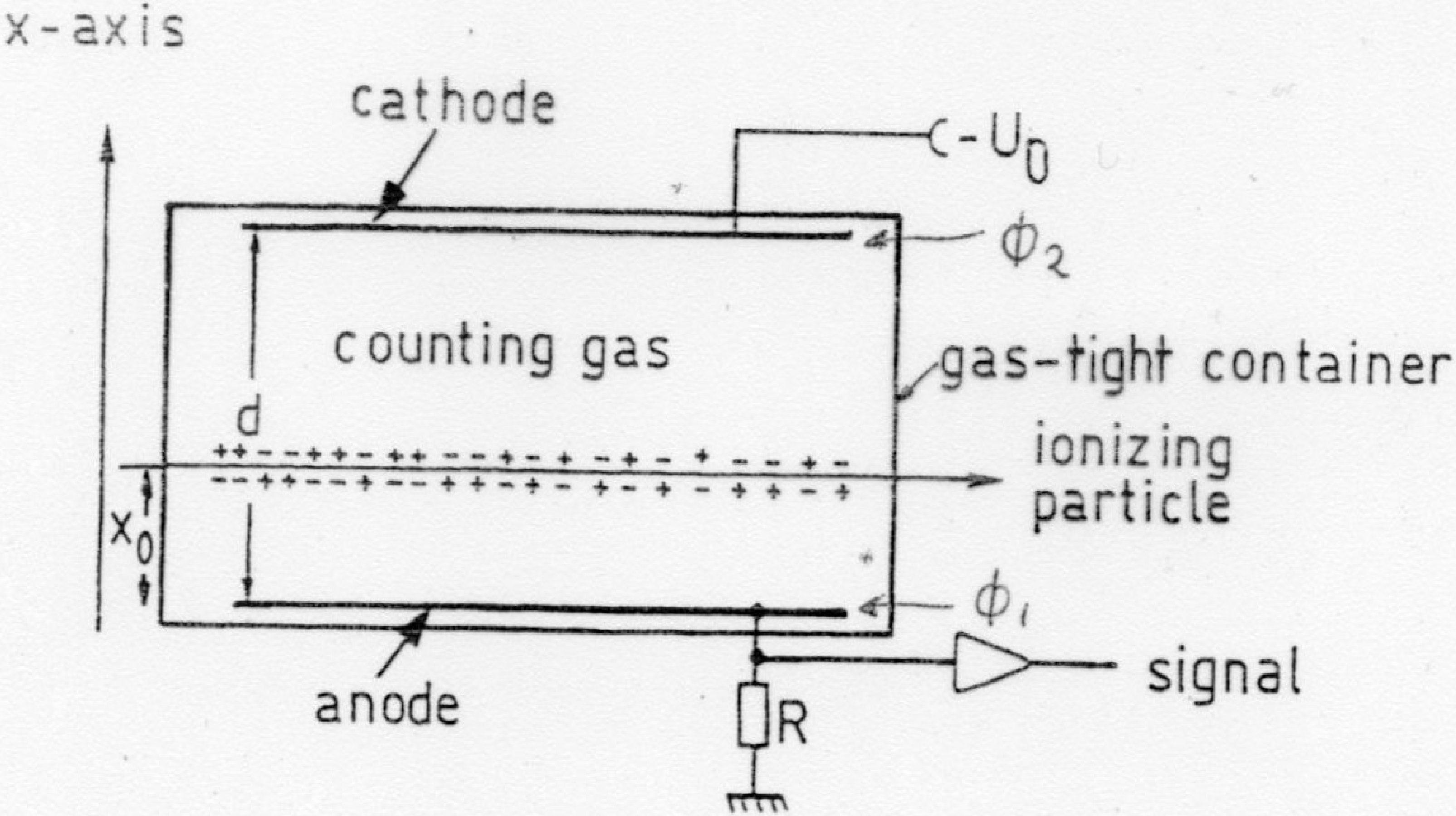


Fig. 4.1. Principle of operation of a planar ionization chamber.

Gasverstärkung in der Nähe eines Anodendrahtes:

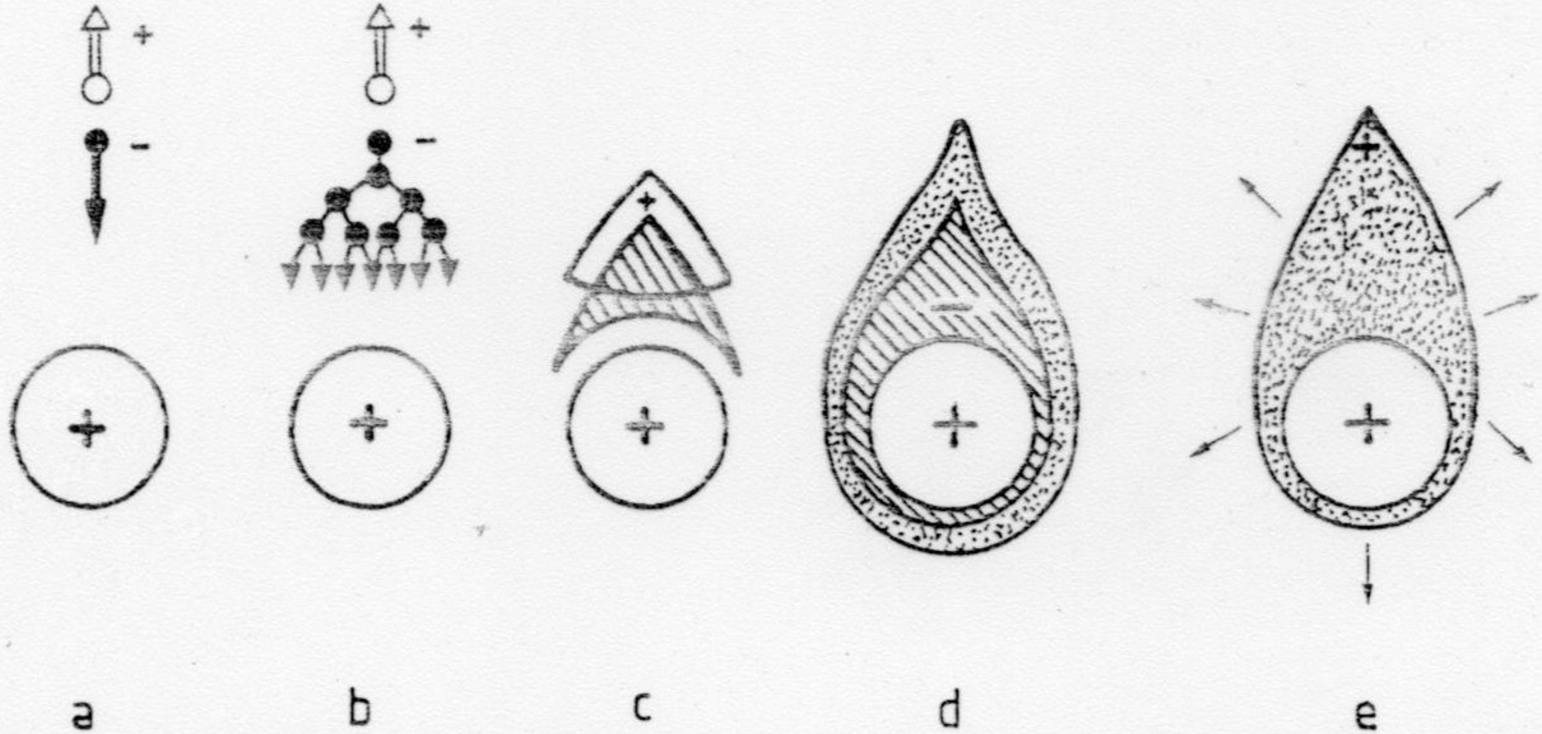


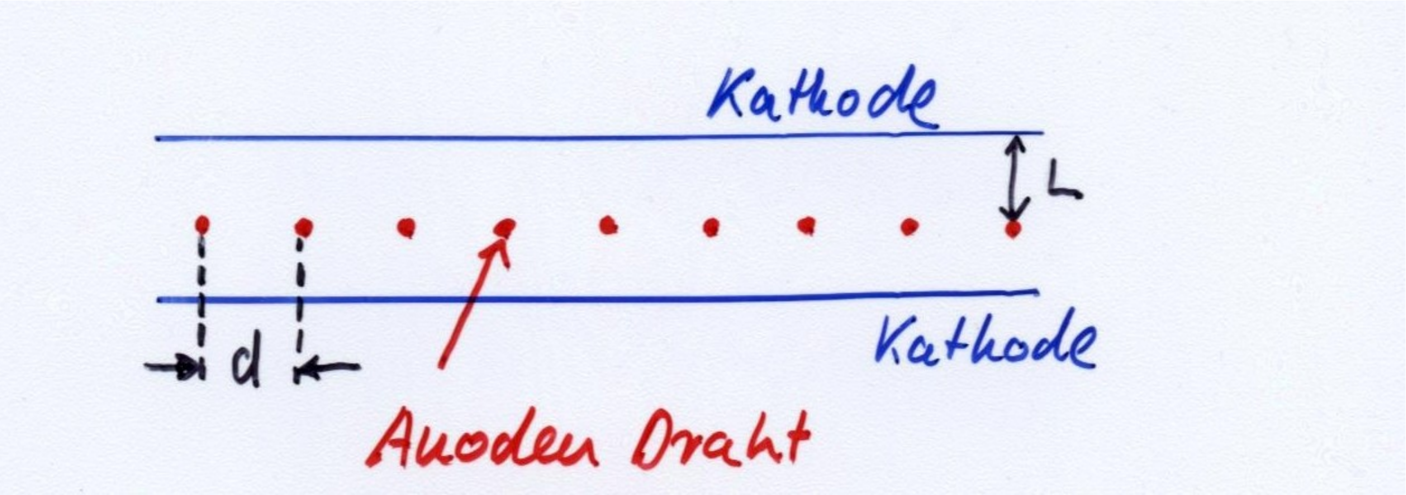
Fig. 4.27. Temporal and spatial development of an electron avalanche [51, 186].

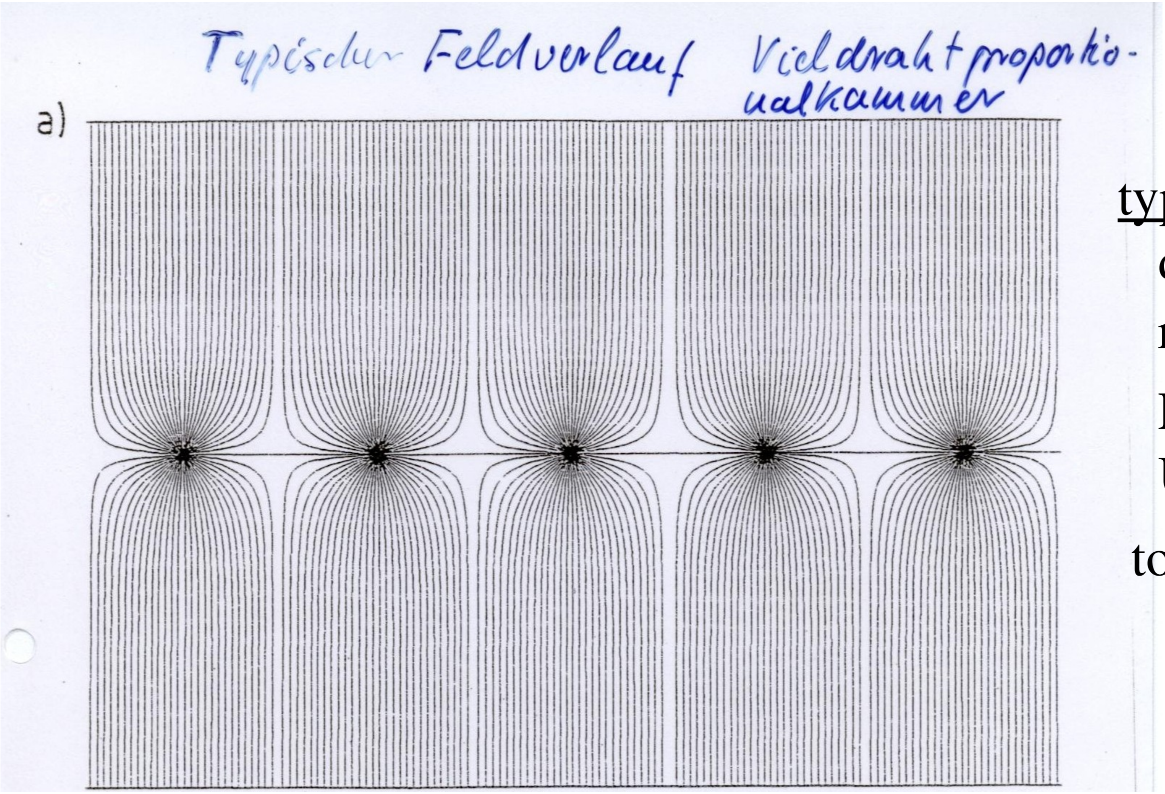
Elektronen der Lawine erzeugen sehr schnelles und kleines Signal
(kurze Driftstrecke)
induziertes Signal hauptsächlich durch langsame Ionendrift

Vieldrahtproportionalkammer

G. Charpak et al. NIM 62 (1968) 202   Nobelpreis 1992, Rev. Mod. Phys. 65 (1993) 591

planare Anordnung von
vielen Proportionalzählern
ohne Trennwände





<u>typische Parameter:</u>

$d = 2 – 4$ mm

$r_i = 20 – 25$ µm

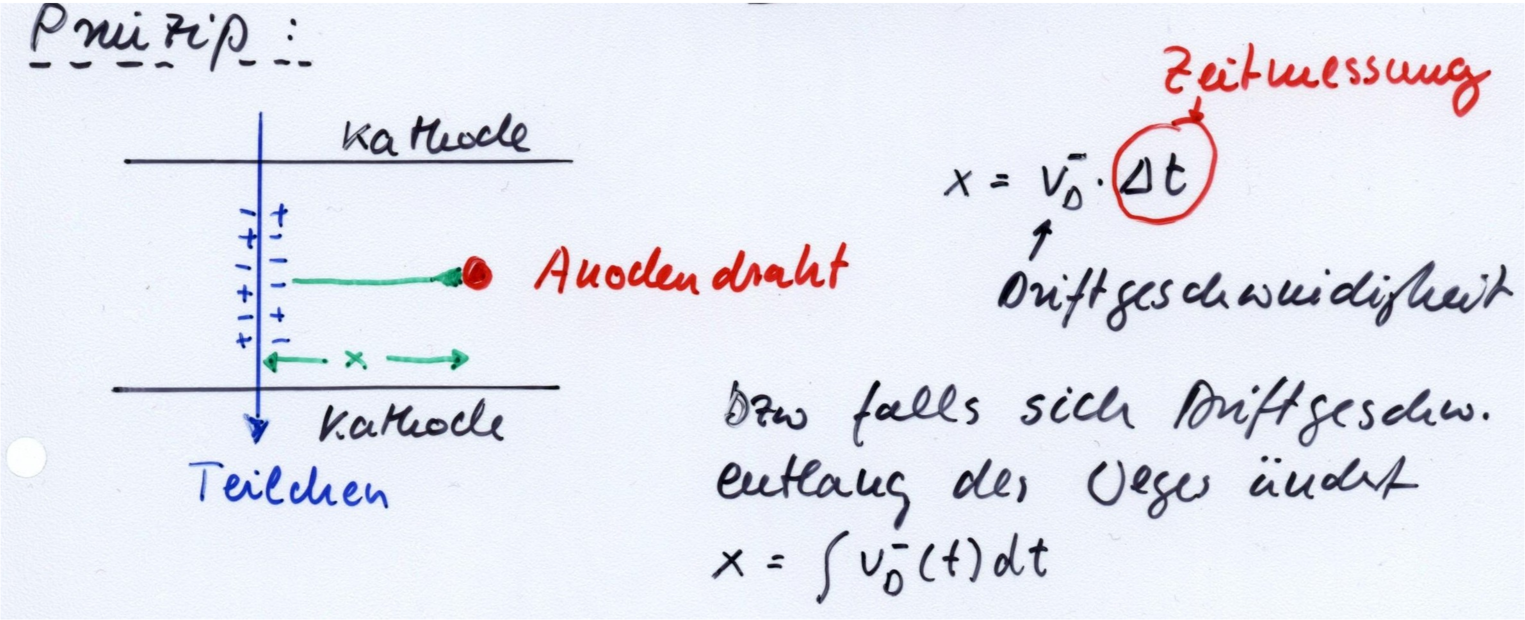
$L = 3 – 6$ mm

U_0 = several kV

totale Fläche: m^2

Driftkammer

A. Walenta, J. Heintze 1970 Phys. Inst. Univ. Heidelberg (NIM 92 (1971) 373)



Prinzip:

Zeitmessung

$$x = v_D^- \cdot \boxed{\Delta t}$$

Driftgeschwindigkeit

bzw falls sich Driftgeschw. entlang des Weges ändert

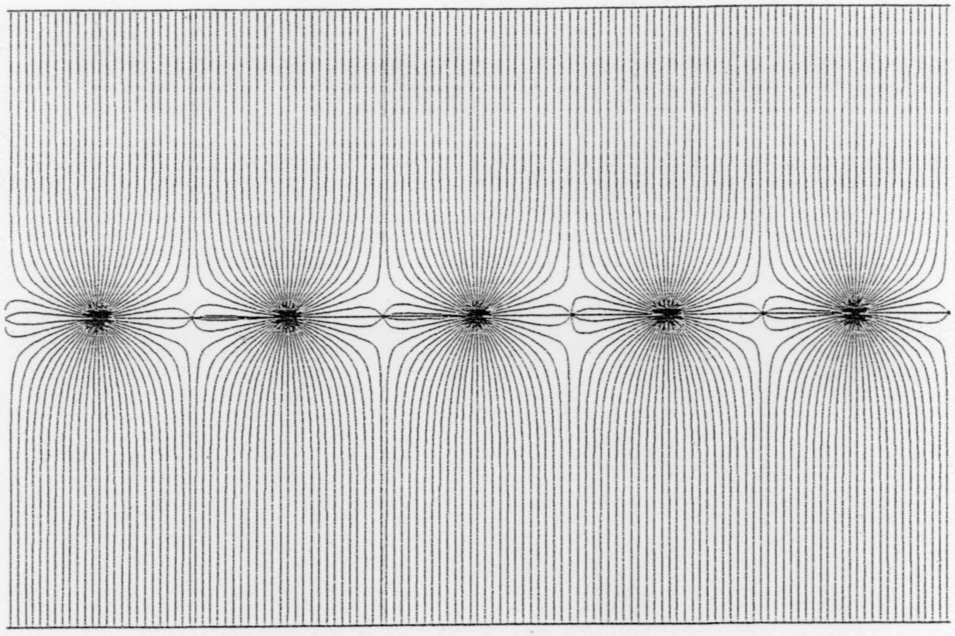
$$x = \int v_D^-(t)\,dt$$

in MWPC zwischen Anoden-Drähten
Regionen mit sehr niedrigem E-Feld

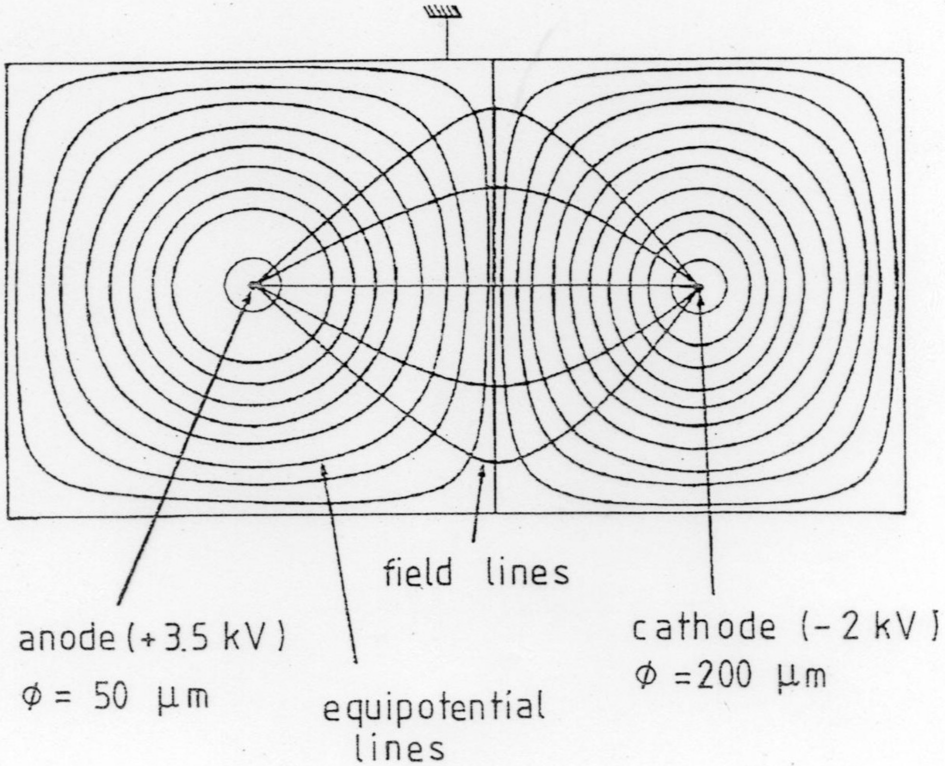
Einführung zusätzlicher Felddrähte
mit negativem Potential verbessert
Feldqualität dramatisch

essentiell für Driftkammer in der
Ortsauflösung bestimmt durch
Driftzeitvariationen und nicht durch
Struktur der segmentierten Elektrode

a)



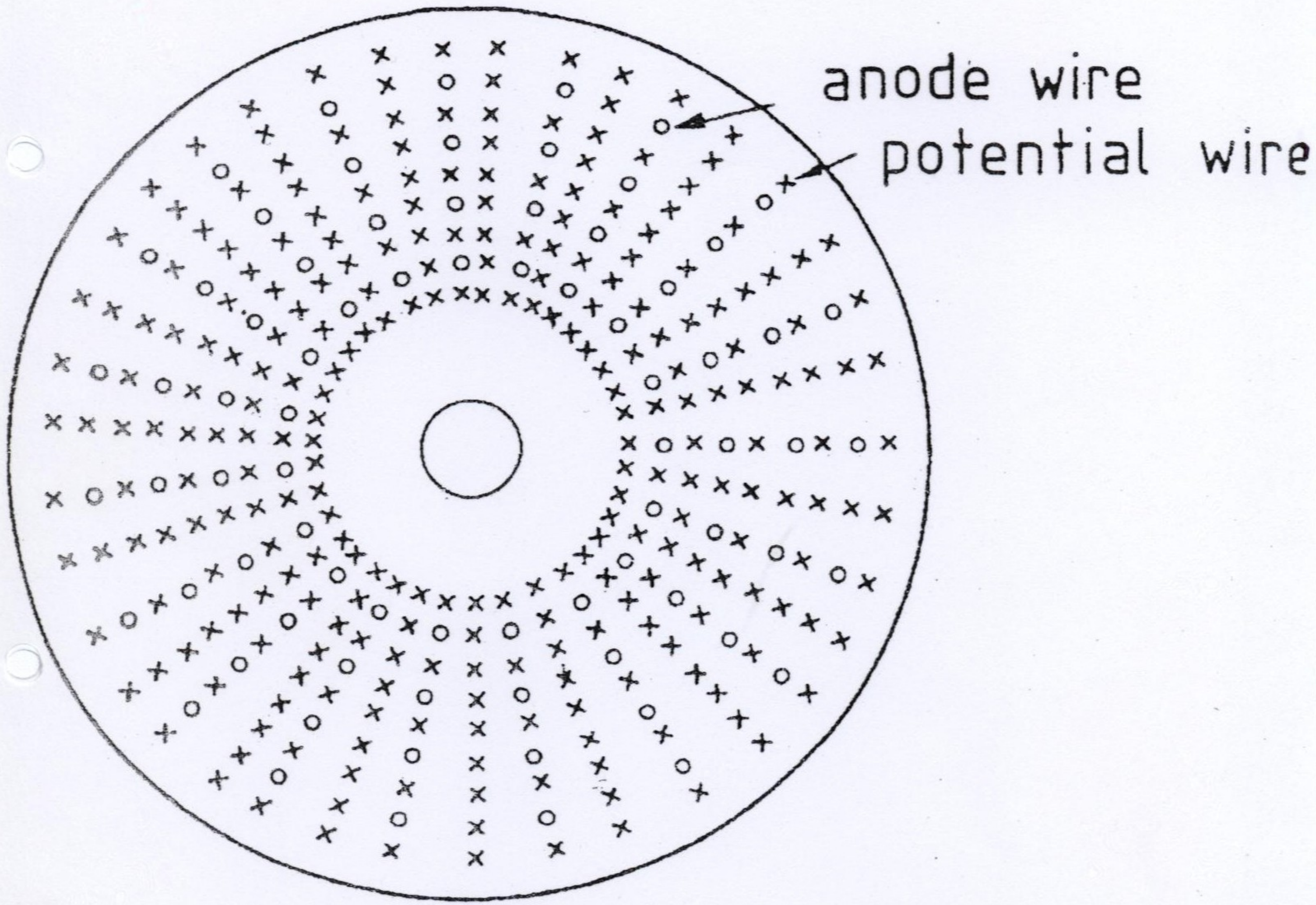
b)



Zylindrische Kammern im Magnetfeld betrieben → Messung des Krümmungsradius einer Teilchenspur → Impulsmessung (innerhalb eines einzigen Detektors)

$$p\,(\mathrm{GeV}/c) = 0.3 \cdot B\,(\mathrm{T}) \cdot \rho\,(\mathrm{m})$$

Prinpip einer zylindrischen Driftkammer: Drähte in axiale Richtung (parallel zu kollidierenden Teilchen und dem Magnetfeld)



alternierende Anoden- u
Felddrähte

- je ein Felddraht zwisch
  2 Anodendrähten
- zylindrische Lagen vo
  Felddrähten zwischen
  Lagen von
  Anodendrähten

-> gut geformte
Driftzellen

3-dimensionale Messung: Time Projection Chamber (TPC)

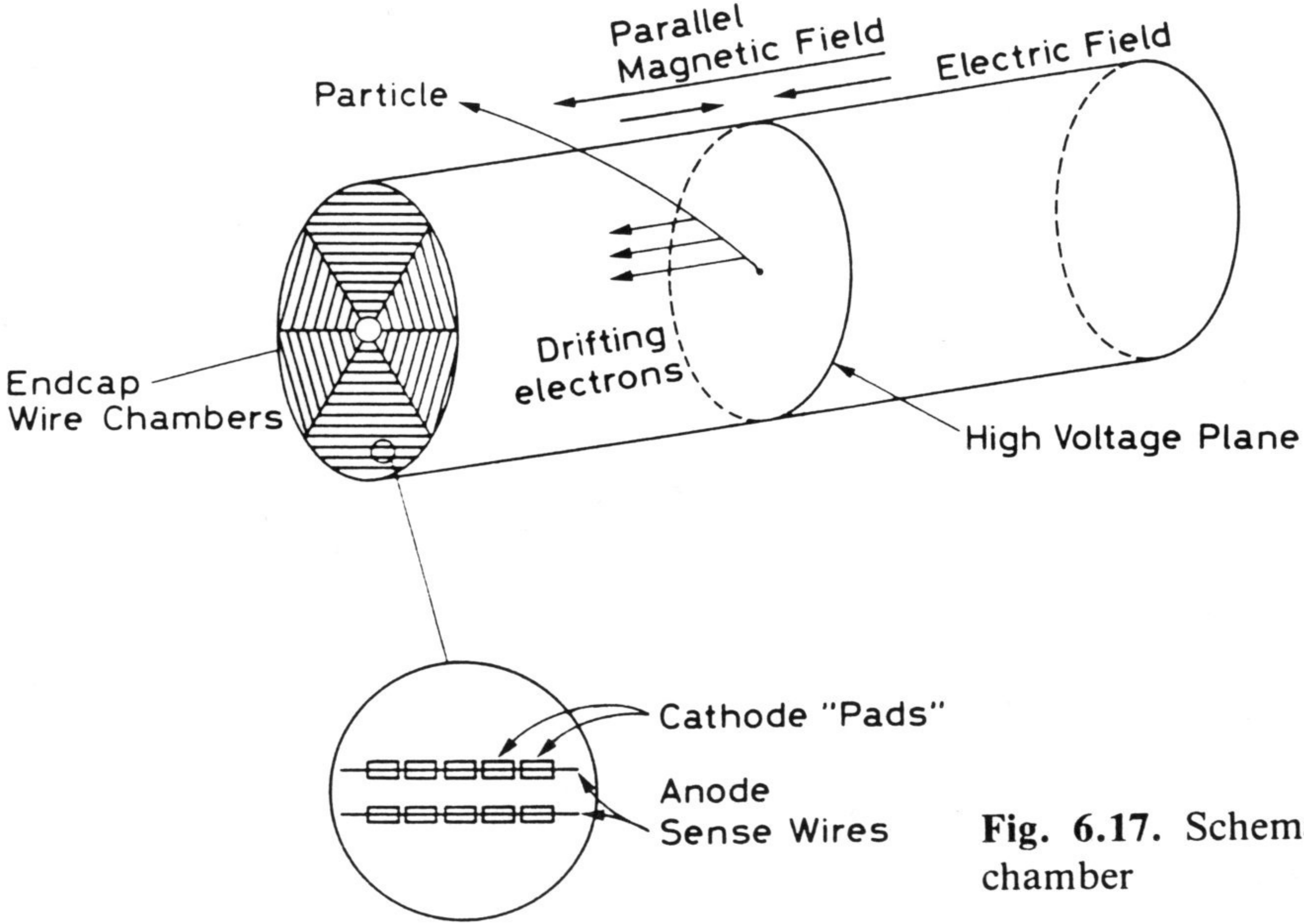
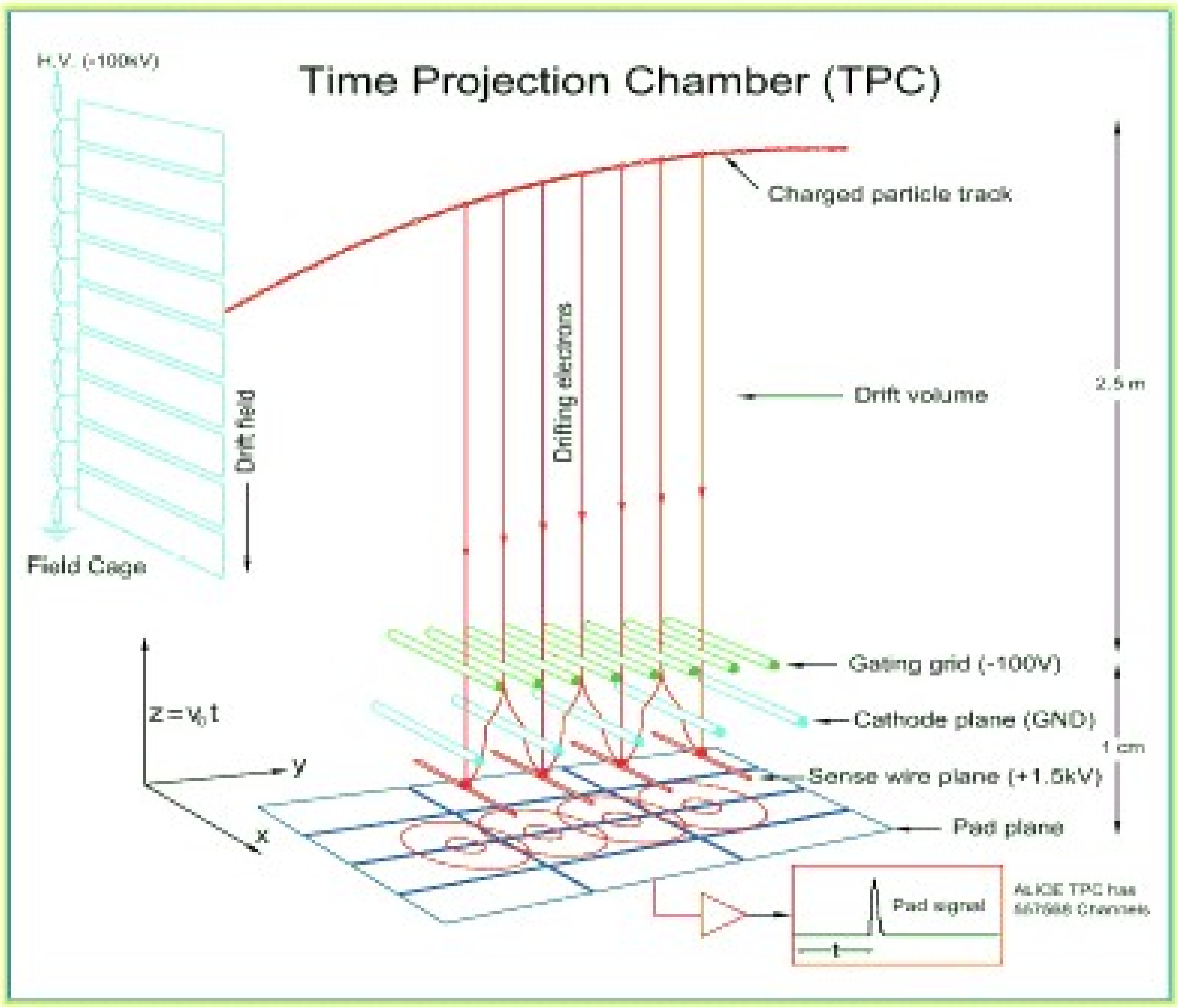
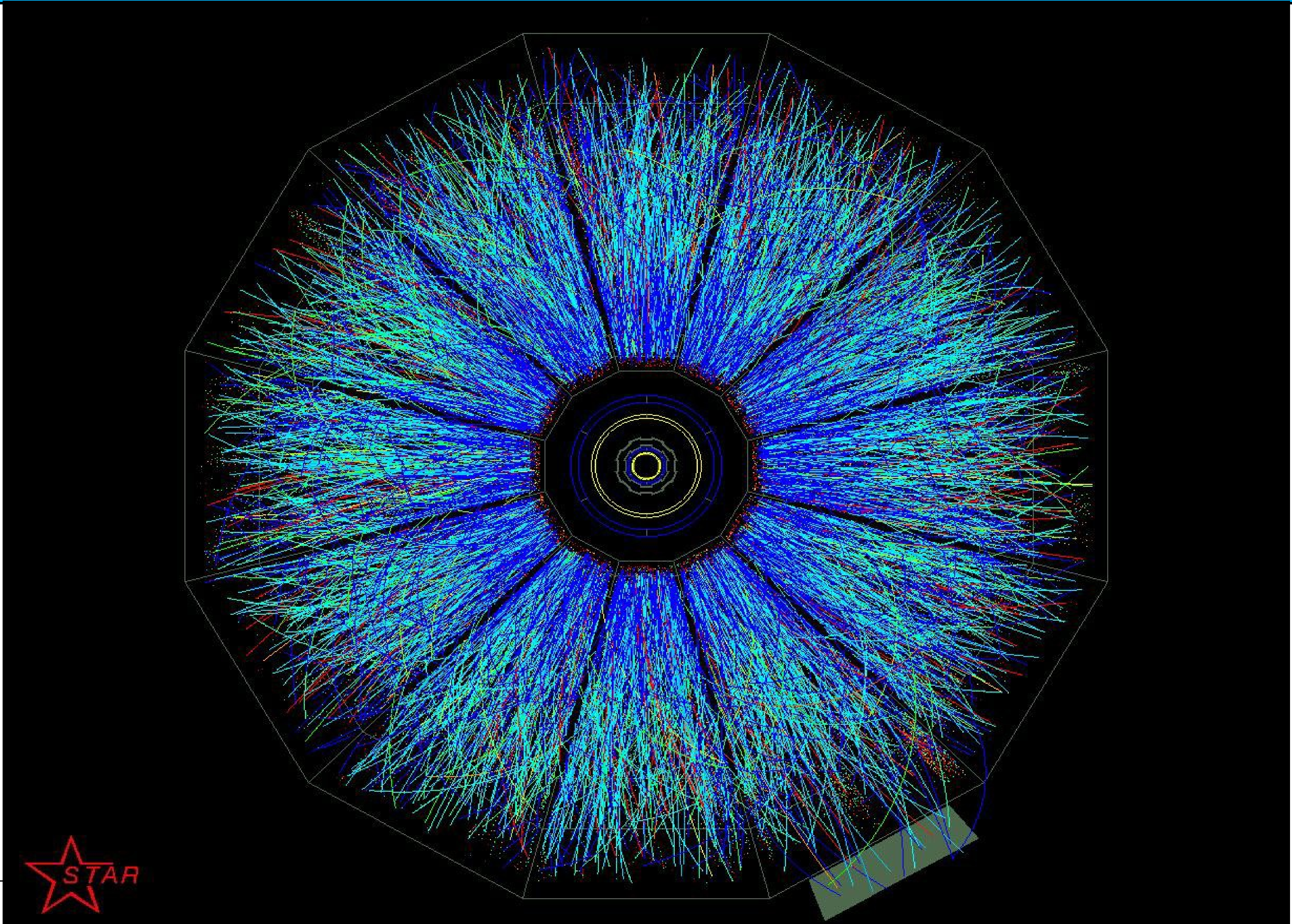


Fig. 6.17. Schematic
chamber

3-dimensionale Messung: Time Projection Chamber (TPC)



central Au Au collision at RHIC recoreded by the STAR TPC



Schwierigkeit in TPC: Raumladung durch grosse Dimension und langsam driftende Ionen

Trick: Erfingung des 'gating grid'

nach Wechselwirkung schaltet Grid von 'geschlossen' nach 'offen', wenn alle Elektronen innerhalb sind, wieder auf 'geschlossen' -> Ionen aus Verstaerkung am Draht bleiben drin

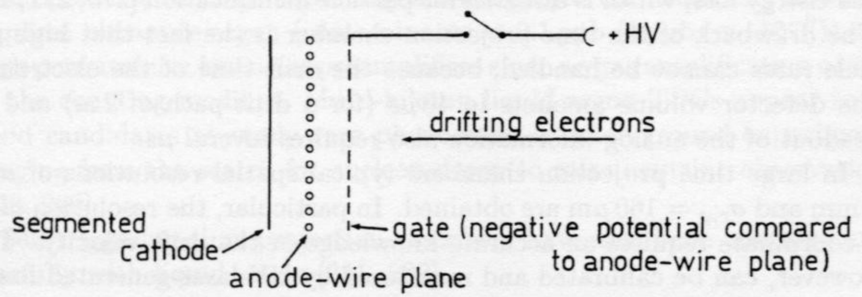
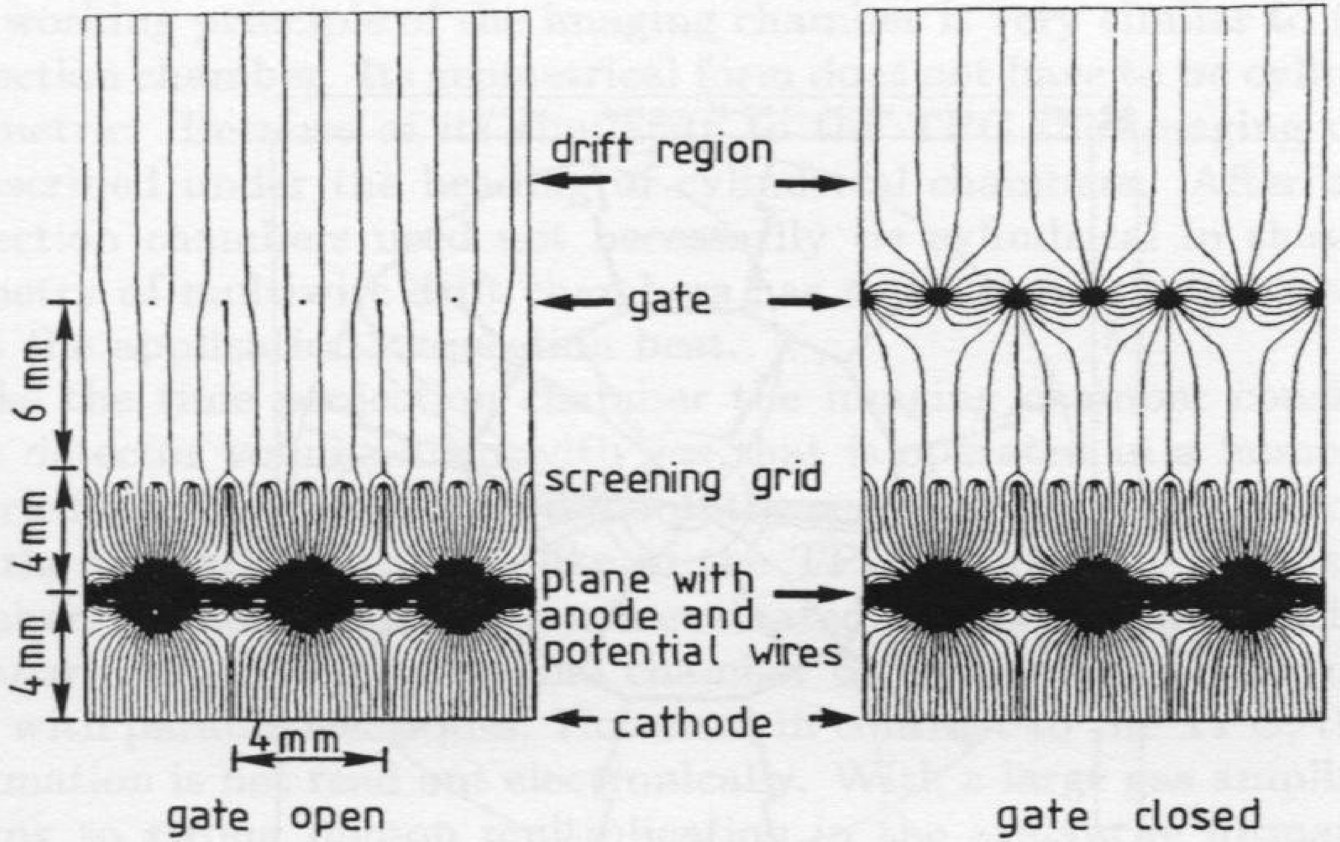
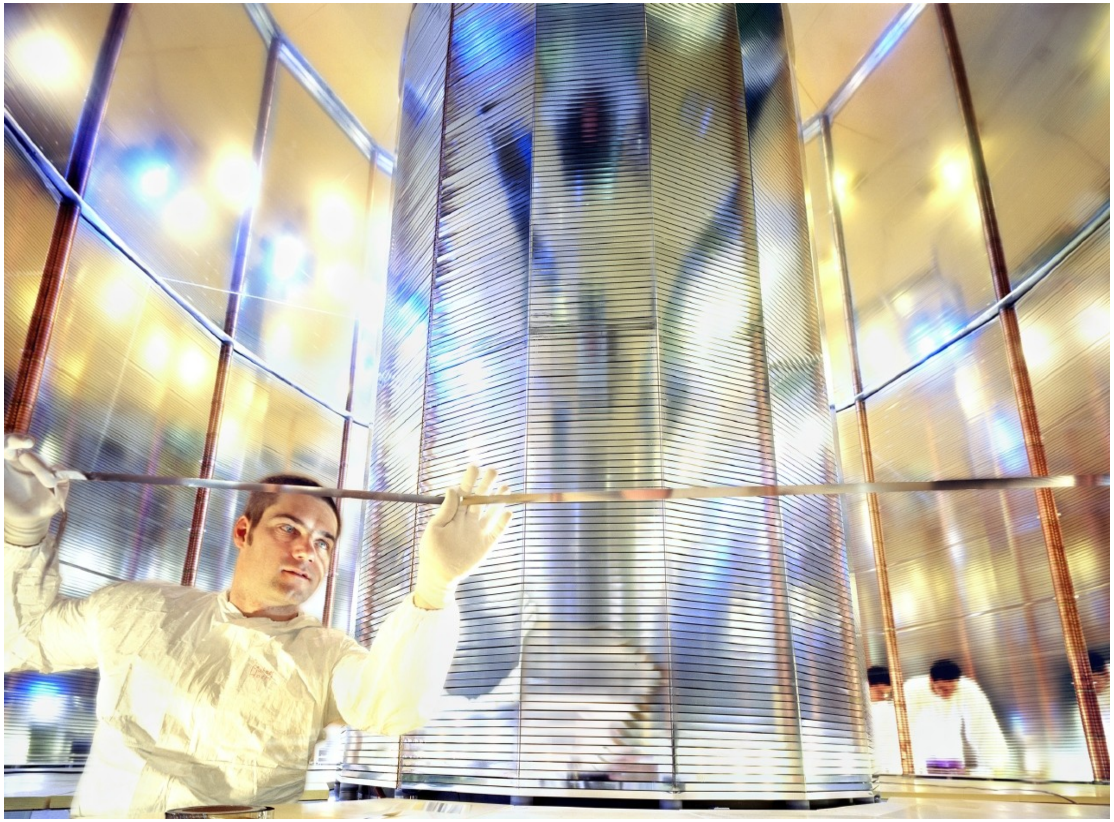


Fig. 4.58. Gating principle in a time projection chamber.



die ALICE TPC fuer LHC mit 95 m^3 die groesste TPC grosse Teile in Heidelberg und bei GSI entwickelt und gebaut

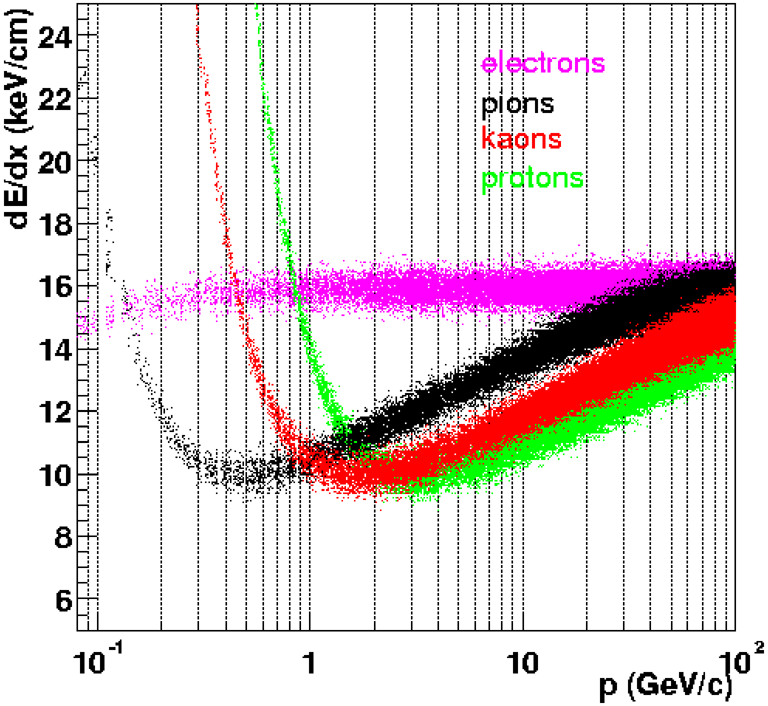


560 Millionen Auslesepixels!

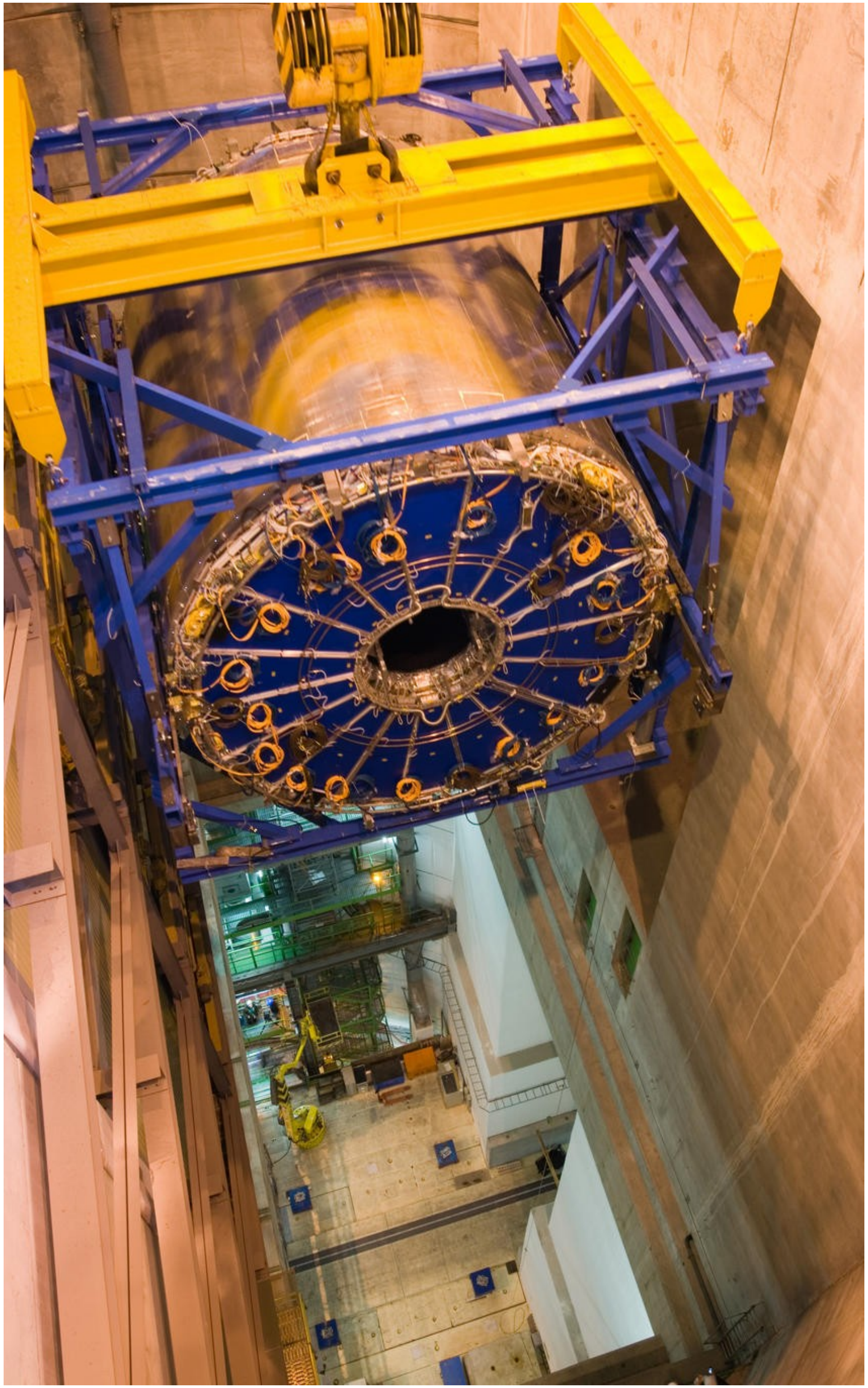
Aufloesung besser als 500 µm in allen 3 Dim.

180 Raum- und Energieverlustpunkte pro Spur

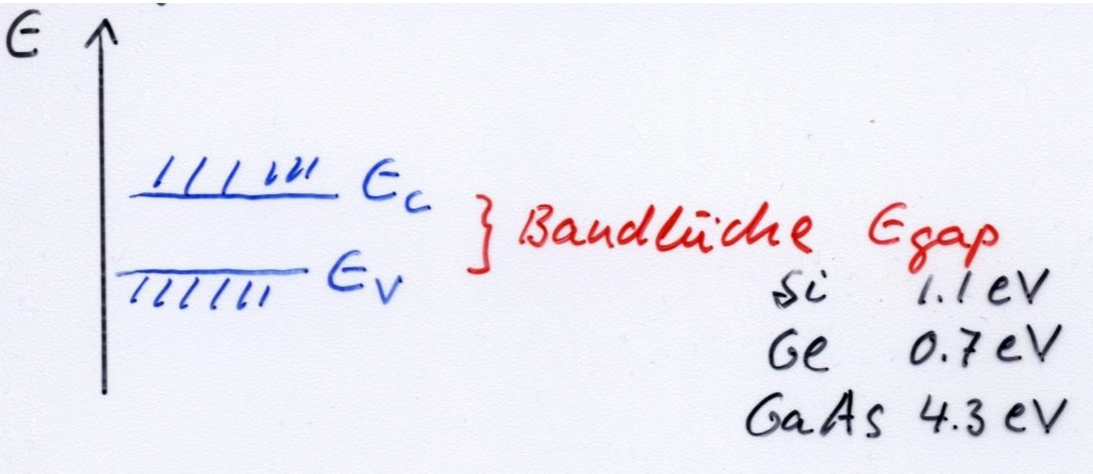
Teilchenidentifikation durch Messung von dE/dx (180 mal und Mittelung)



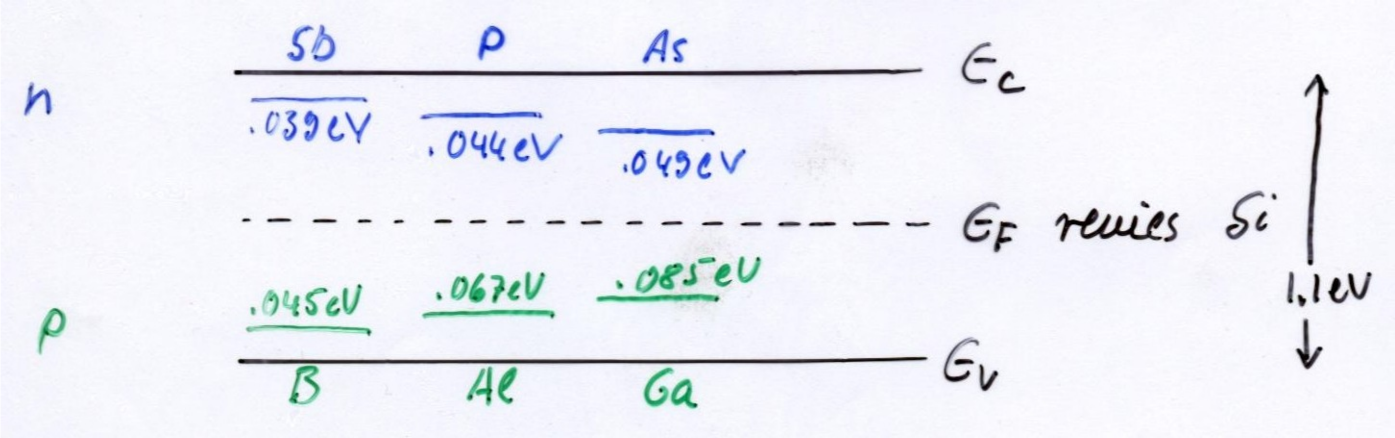
die **ALICE TPC** (CERN LHC)
mit **95 m^3** groesste je gebaute TPC
560 Millionen Auslesepixel!



Halbleiter:

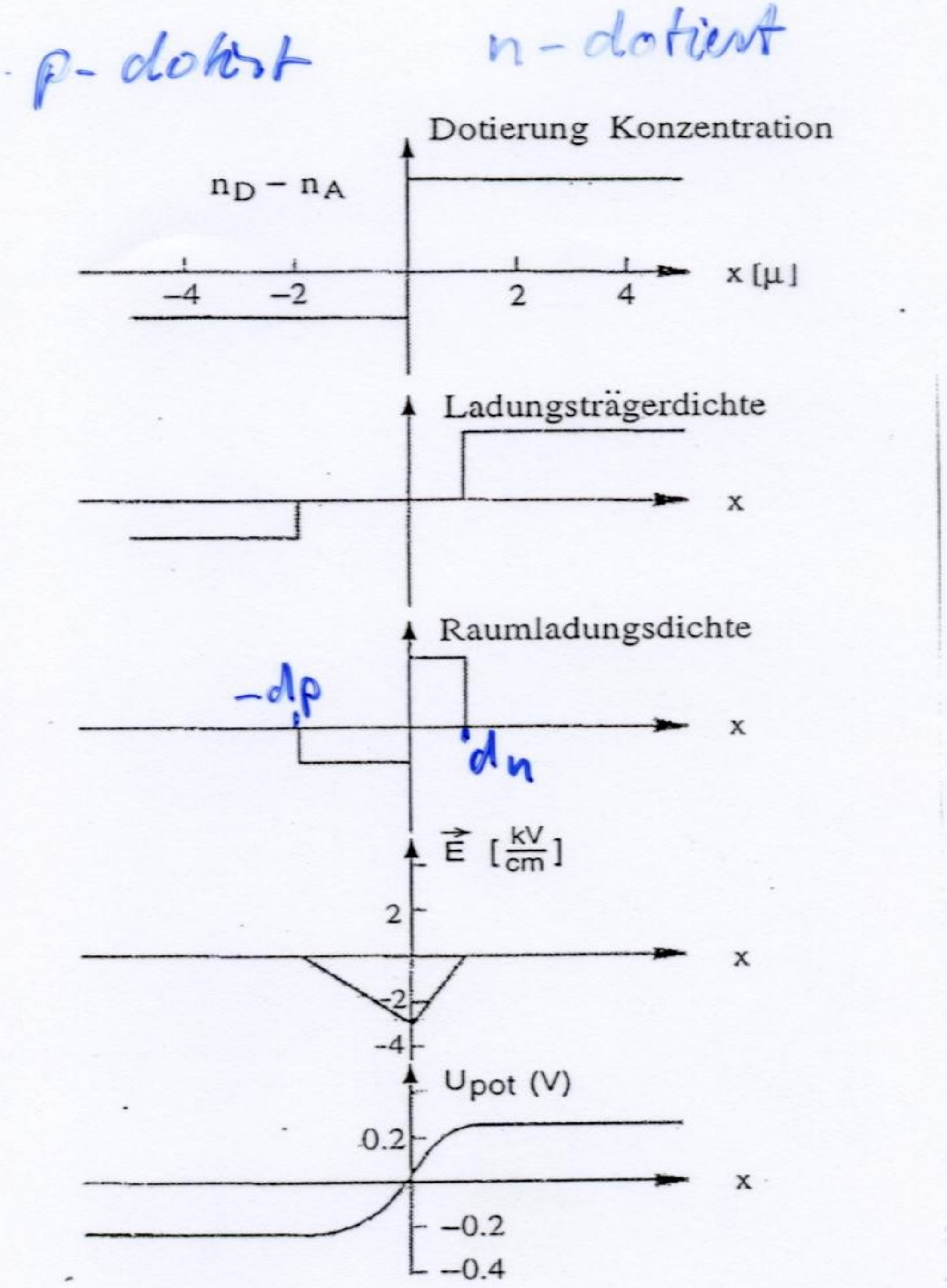


Dotierung mit 5- bzw. 3-wertigem Element -> n- bzw. p-Typ Halbleiter



Prinzip Halbleiterdetektor:

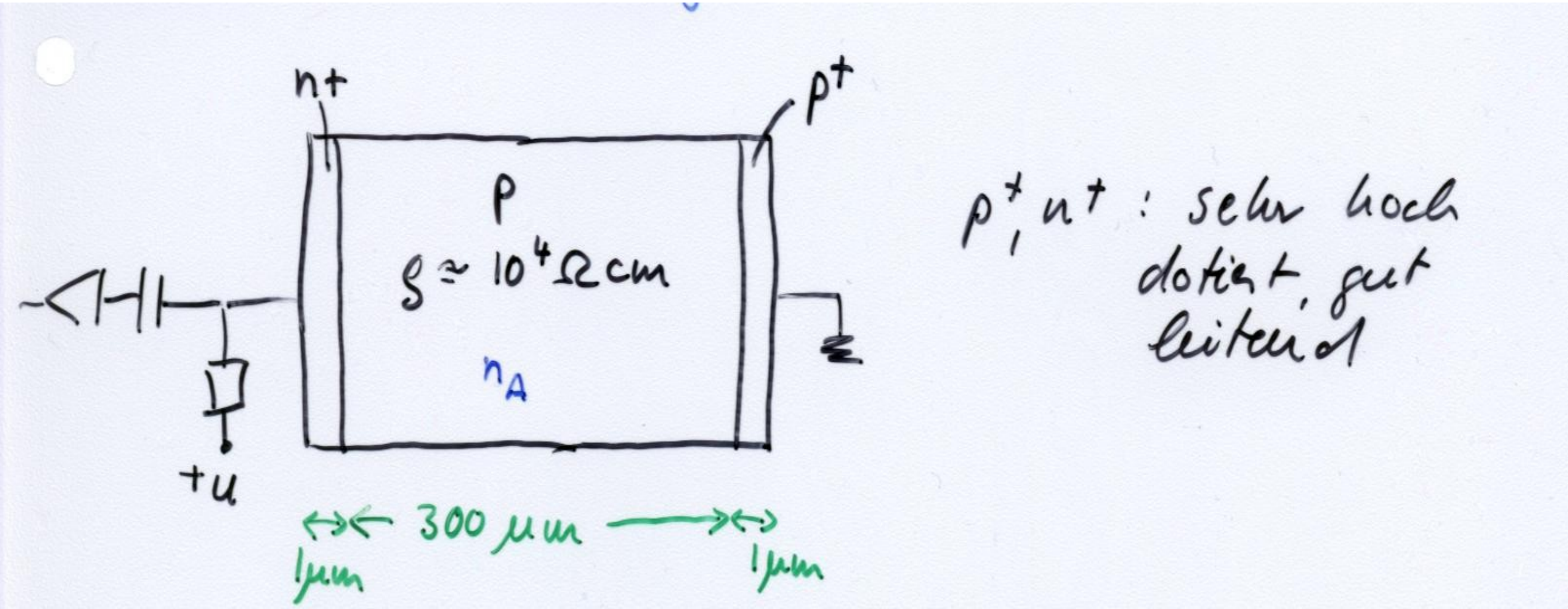
bringe p und n Halbleiter in Kontakt
Elektronen driften von n -> p
es entsteht eine Zone, die frei von beweglichen Ladungstraegern ist
“Verarmungszone” von -dp bis dn
enthaelt feste Raumladungstraeger
positiv auf n-Seite
negativ auf p-Seite
-> erzeugen E-Feld



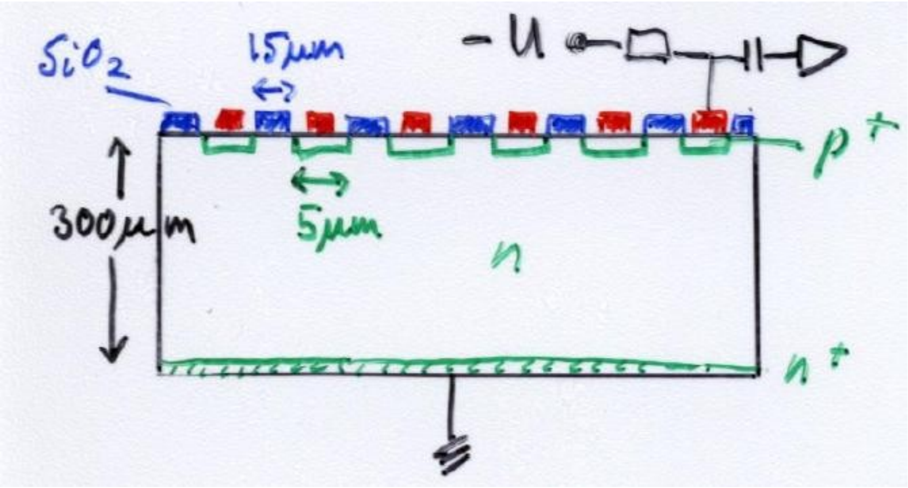
Realisierung Halbleiterdetektor:

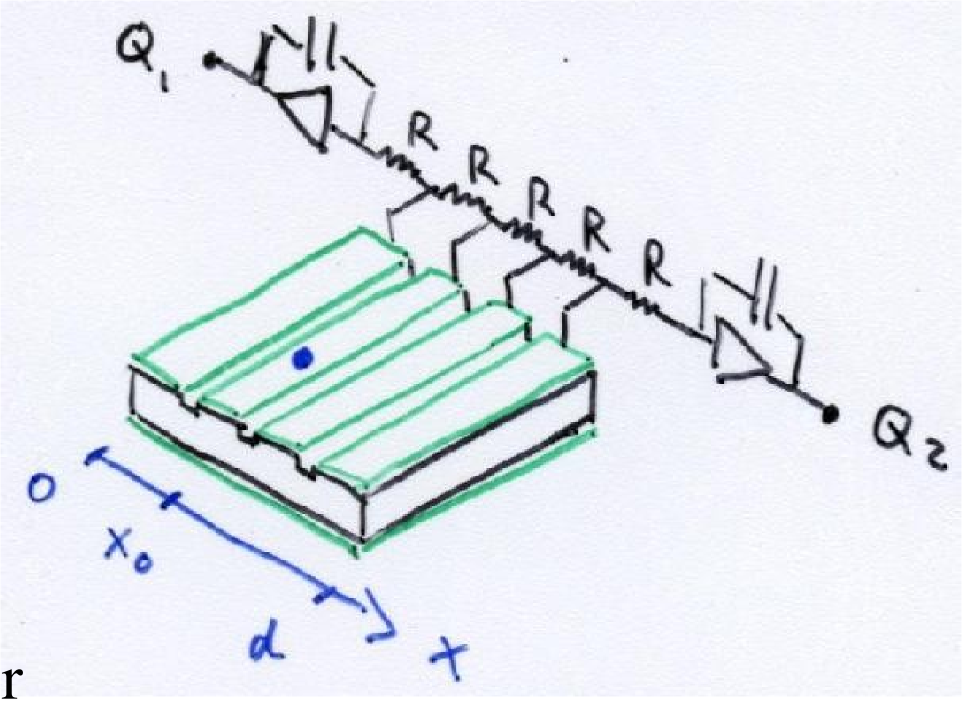
Anlegen einer positiven Spannung an die n-Seite verbreitert Verarmungszone

Oberflaechen koennen durch sehr hohe Dotierung leitend gemacht werden

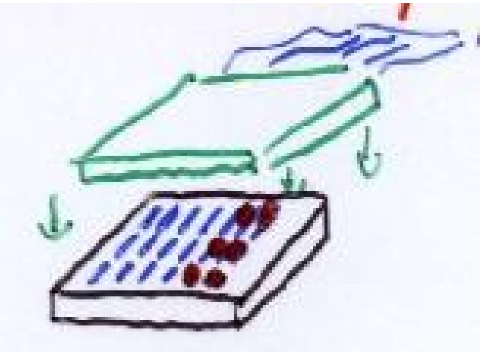


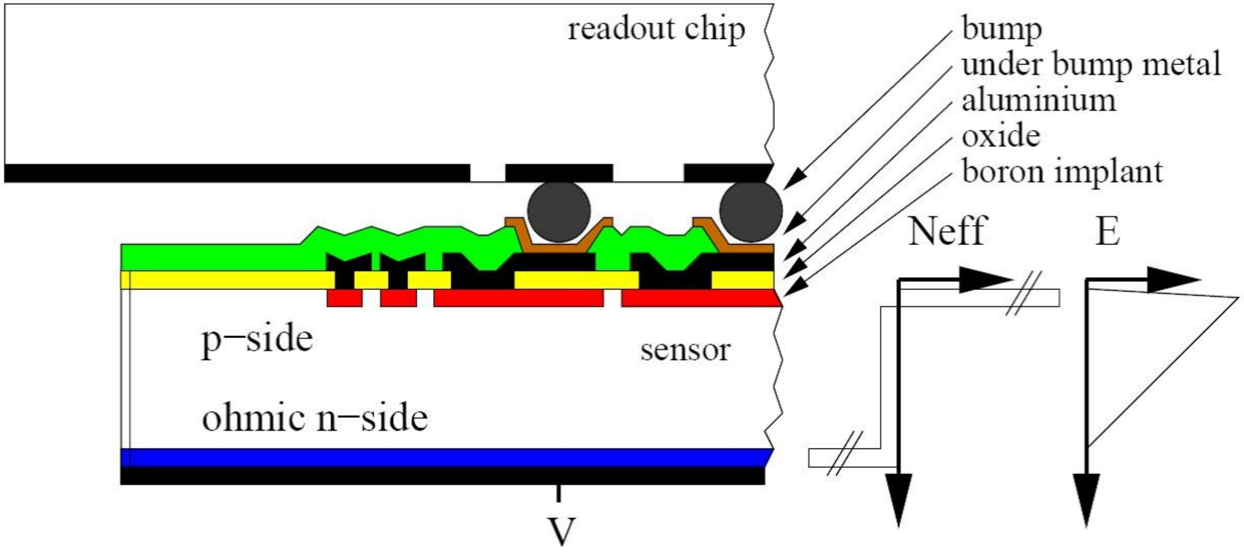
Ortsmessung mit Halbleiterzaehler: Streifen



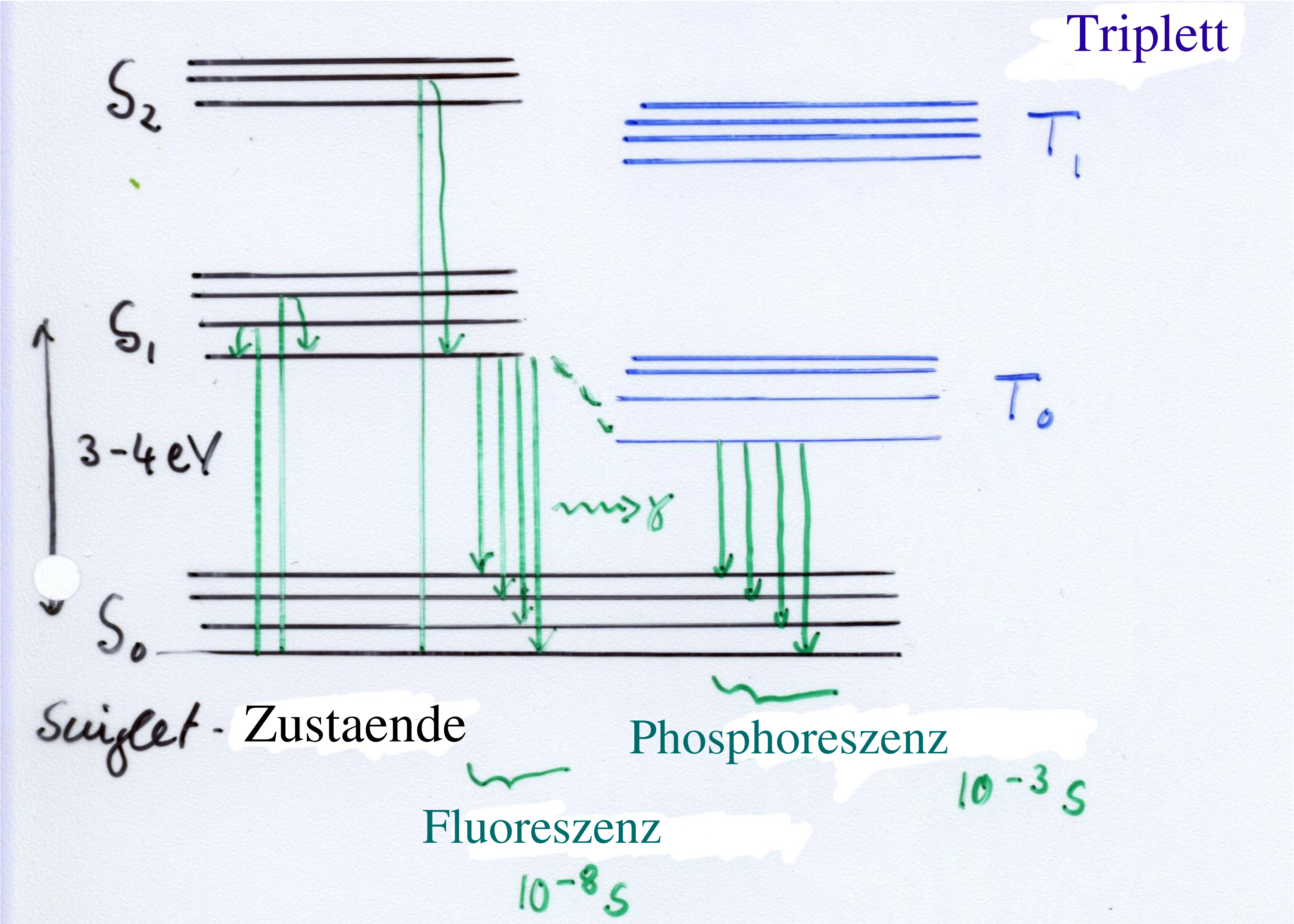


oder Pixel mit Elektronik direkt darueber





organische Szintillatoren:



Triplett

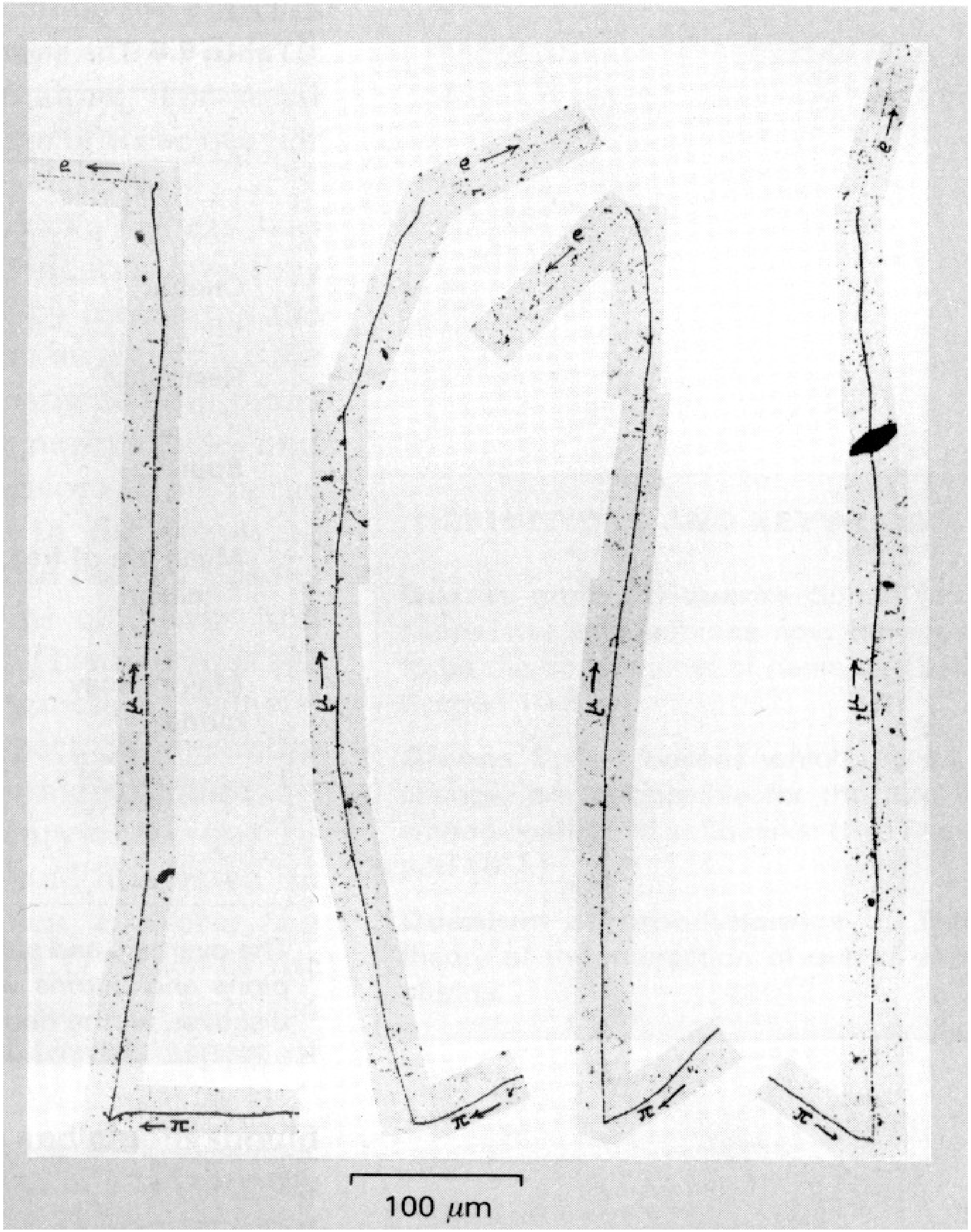
Zustaende

Phosphoreszenz

Fluoreszenz

photographische Emulsion:
Entdeckung des Yukawa Pions
durch Powell und Co. (1950)

$\pi \rightarrow \mu \rightarrow e$



Nebelkammeraufnahmen

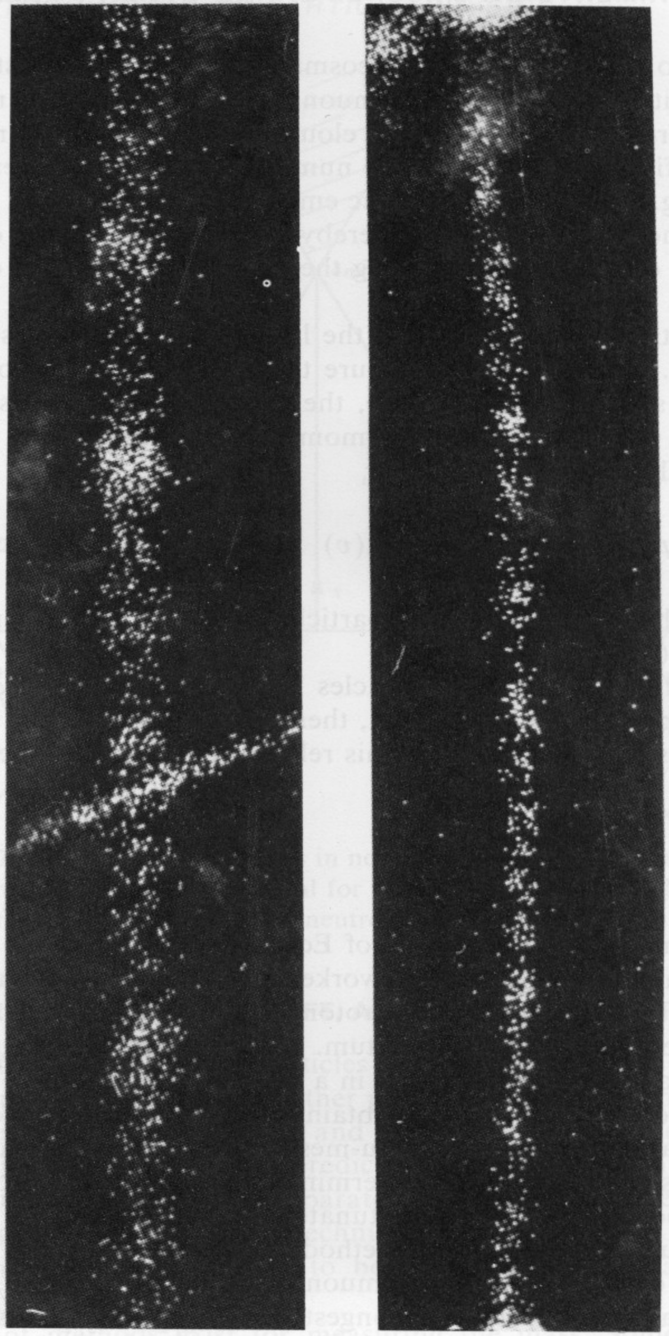


Figure 13-8 An early cloud chamber picture showing the velocity (from the ionization, i.e., the number of droplets per unit path length) and momentum (from the curvature) of a meson. Pressure in cloud chamber 1.5 atm of N_2. Magnetic field 800 G. Expansion occurred 0.5 sec after particle had crossed the chamber to give time to the ions to diffuse and make droplets countable. [Courtesy R. B. Brode and D. R. Corson.]

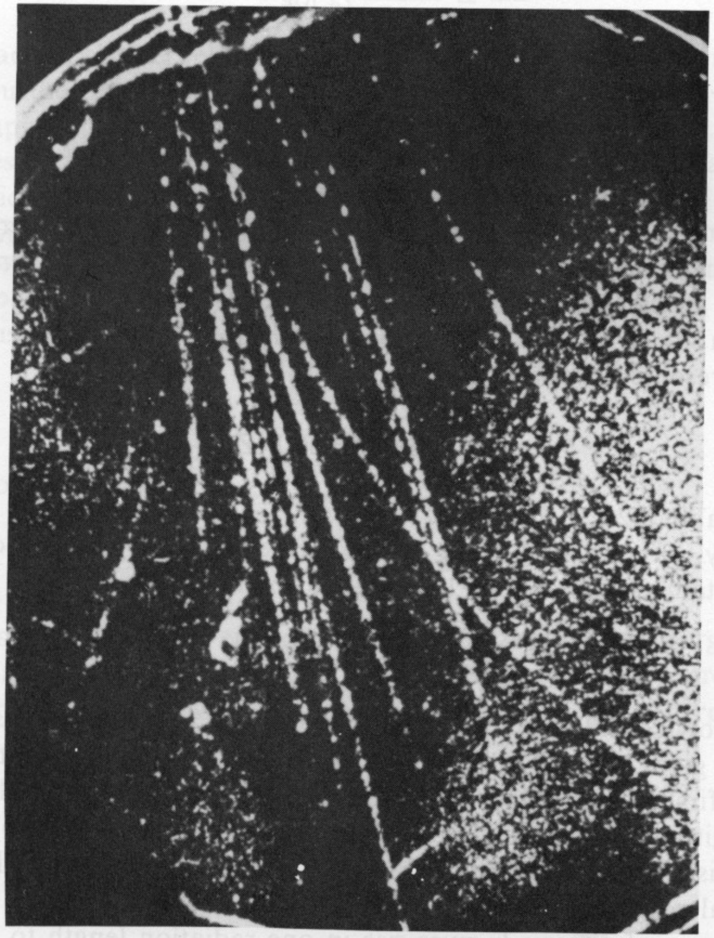


Figure 2-32 First shower observed by Blackett and Occhialini in a cloud chamber triggered by counters in coincidence above and below the chamber. [*Proc. Roy. Soc.* (*London*), **139**, 699 (1933).]

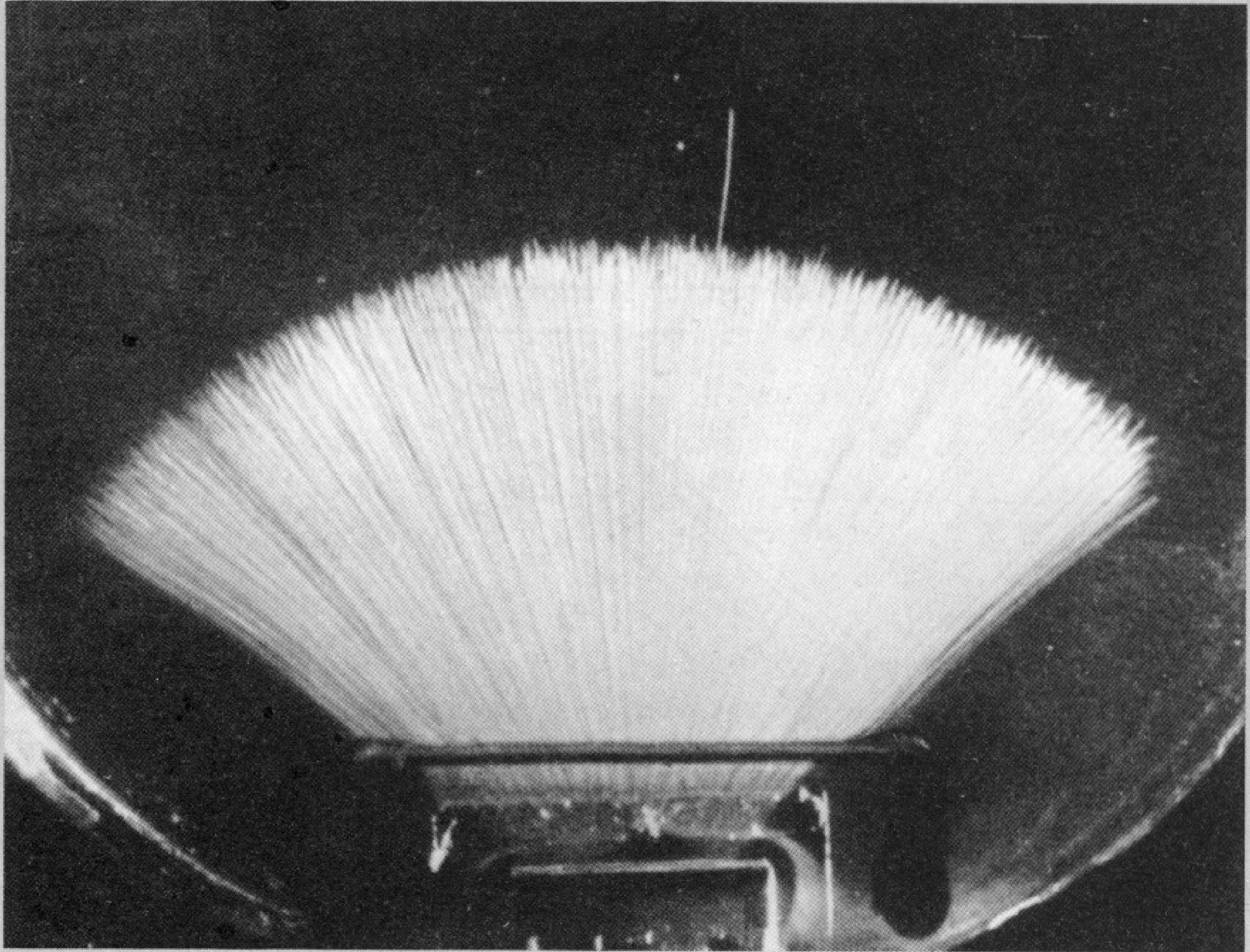


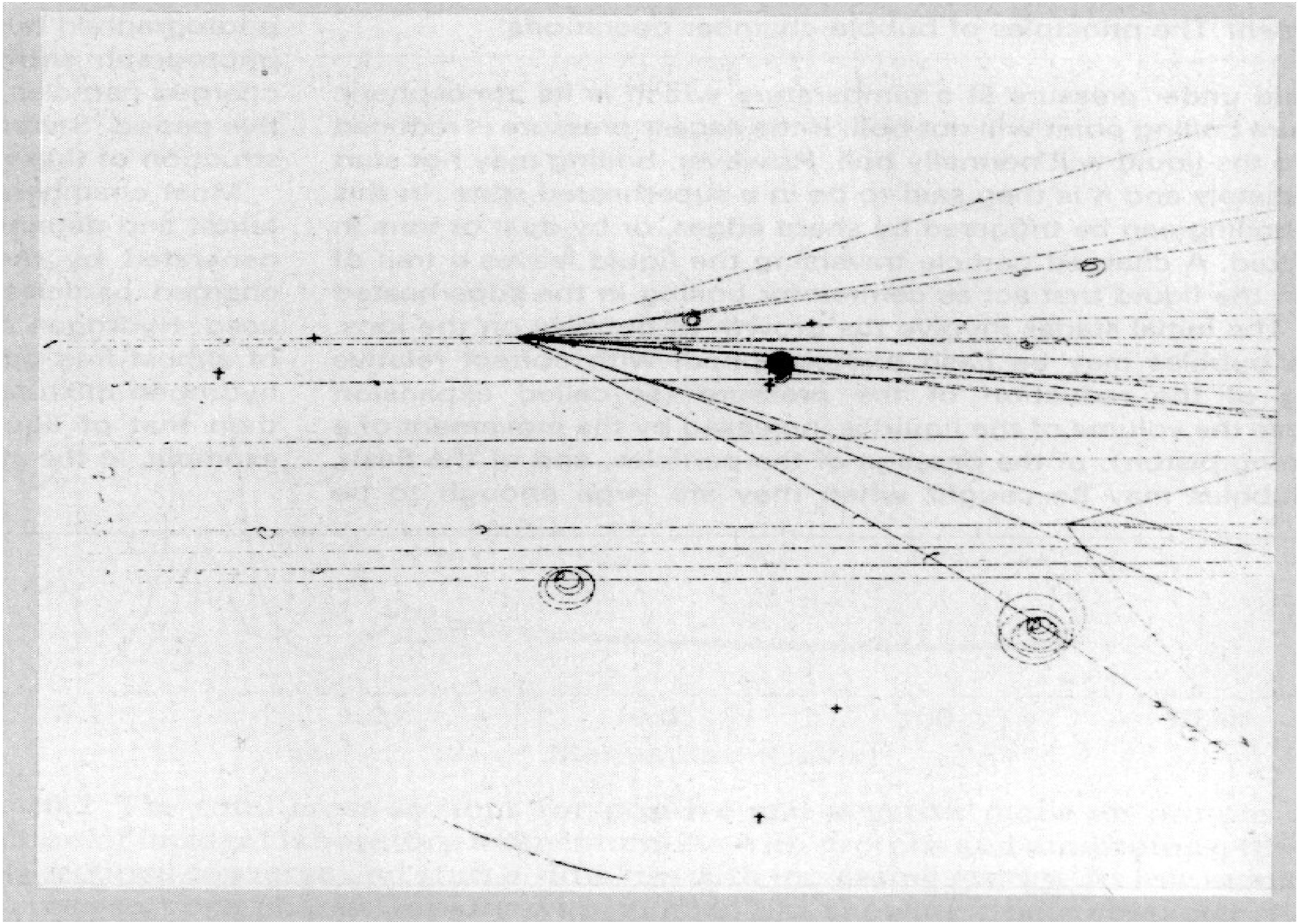
Fig. 6.6 A cloud chamber photograph of α-particles from the decay of ${}^{214}_{83}\text{Bi}$. The almost constant range of particles of 7.69 MeV from the decay of the ground state of ${}^{214}_{84}\text{Po}$ is clear (see Section 11.3 and Fig. 11.4). The outstanding particle is the product of the rare decay from an excited state of ${}^{214}_{84}\text{Po}$, as described in the text and in Fig. 6.5.

[What is a cloud chamber? A volume of gas saturated with a suitable vapour (e.g. ethyl alcohol) is enclosed in a cylinder. The gas is expanded adiabatically so as to become supersaturated and condensation of the vapour onto drops takes place: the first stage is condensation on charged ions so that small drops of liquid form along the trajectories of ionizing particles which have traversed the gas just previously to or immediately after the expansion. The tracks are illuminated through side windows and photographed through a window in the cylinder end. By careful timing of a flash photograph with respect to the expansion, the tracks may be recorded at their most visible and before general condensation occurs. In this example the radioactive source was fixed on an inside wall of the chamber and collimated to give a fan of visible tracks. The cloud chamber was invented by C. T. R. Wilson in 1911. Gentner *et al*. (1954) have published an atlas of cloud chamber photographs illustrating many nuclear particle processes. The above photo is in this atlas and was published originally by Philipp (1926).]

Blasenkammer: 24 GeV Protonen auf fl. Wasserstoff

eines von 9 Protonen -> inelastische Kollision -> 14 geladene Teilchen

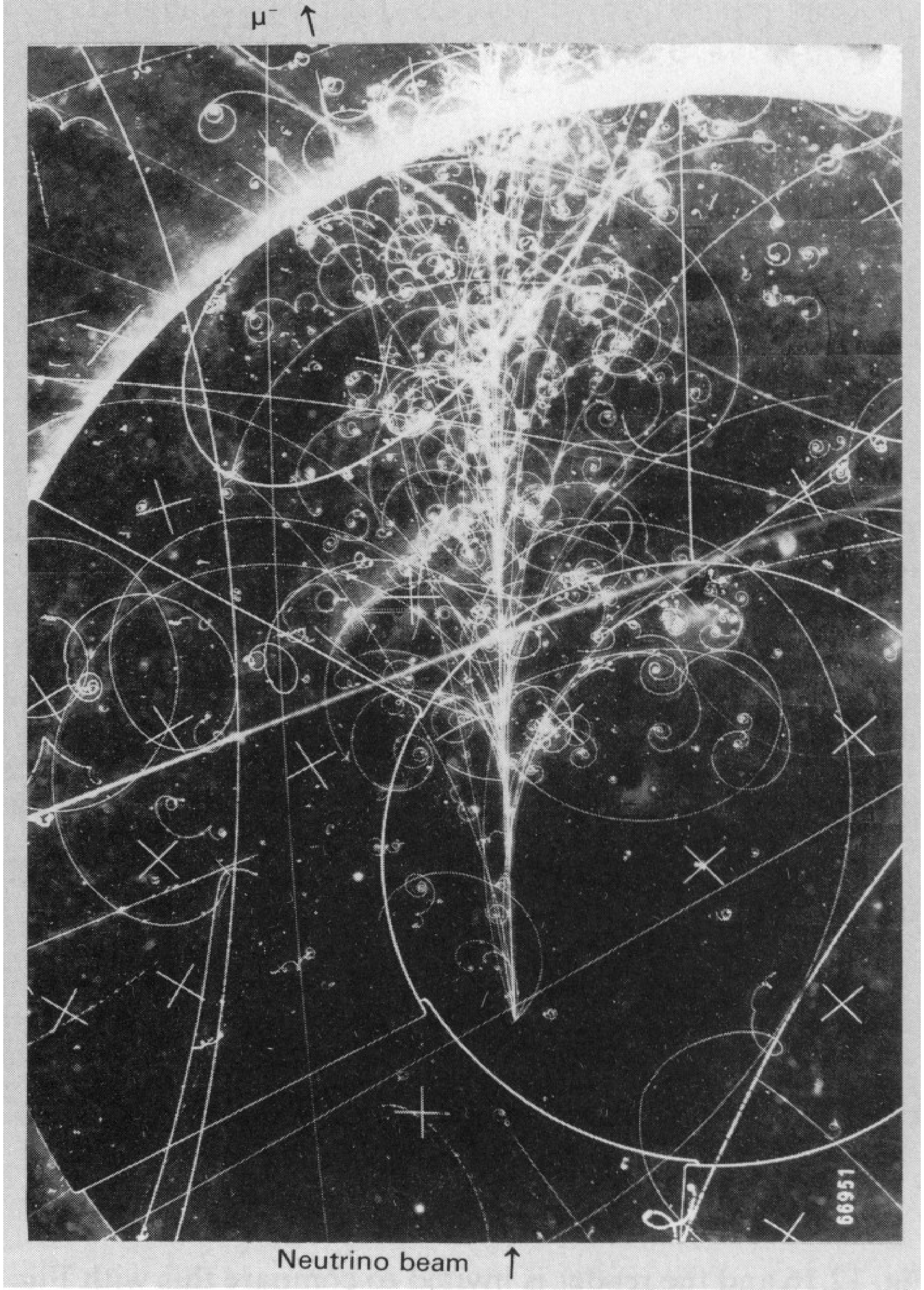
zylindrische Kammer mit 32 cm Durchmesser, B = 1.5 T entlang Achse



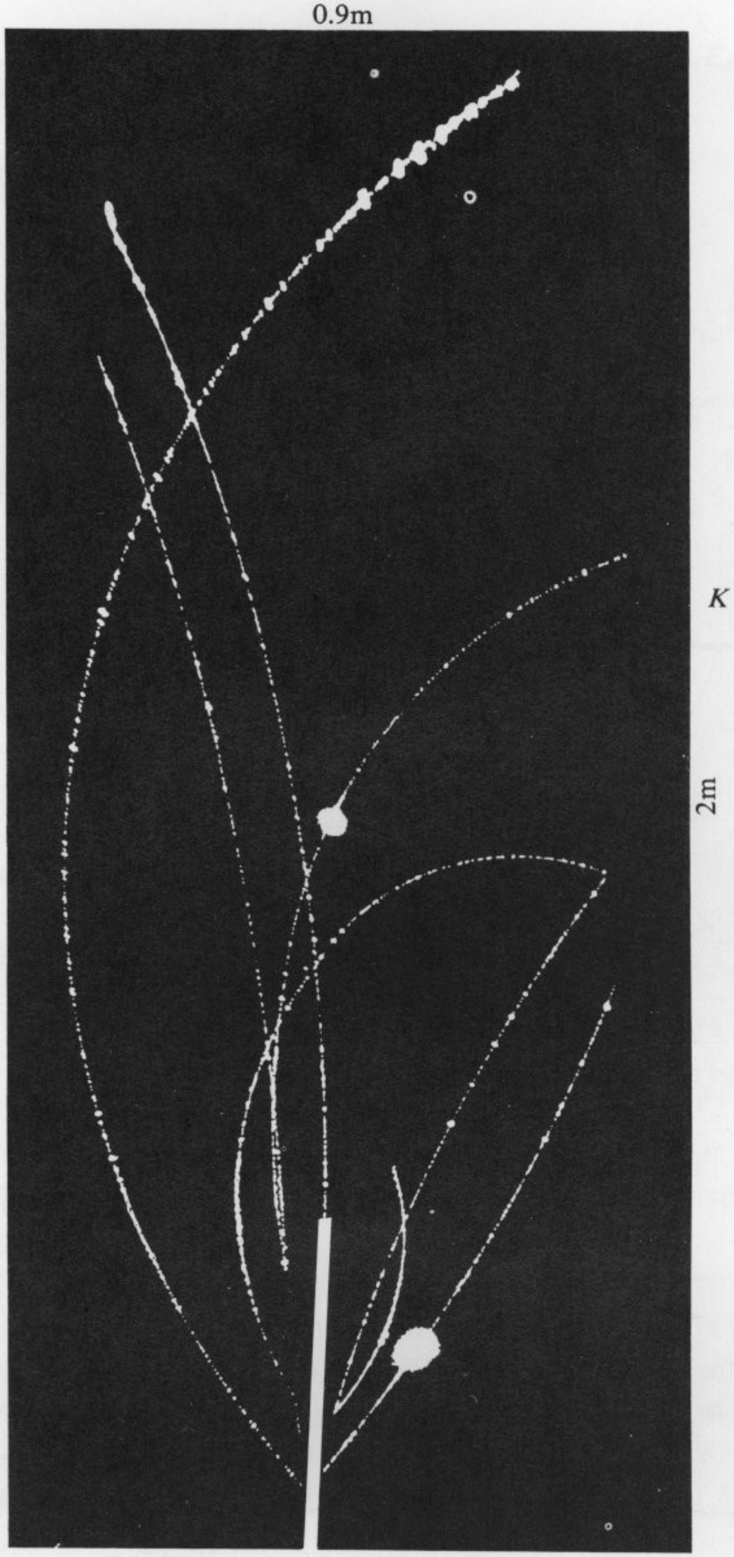
Blasenkammerphoto:
muon neutrino in Ne-H fluessig
-> muon + π°
-> γγ -> em Schauer

Dimensionen:
innerer Kreis r = 1.1m, B = 3.5 T

fuer viele Jahre das Werkzeug
der Teilchenphysik



Streamer-Kammer-Aufnahme:



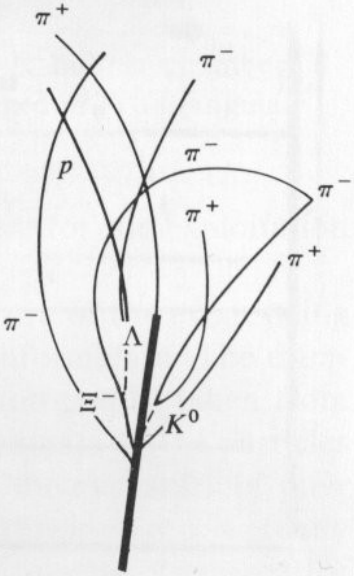
$$K^- + p \Rightarrow \Xi^- + K^0 + \pi^- + \pi^+ + \pi^+$$

$$K^0 \hookrightarrow \pi^- + \pi^+$$

$$\Xi^- \hookrightarrow \Lambda + \pi^-$$

$$\Lambda \hookrightarrow \pi^- + p$$

The "Cascade"



Funkenkammer:

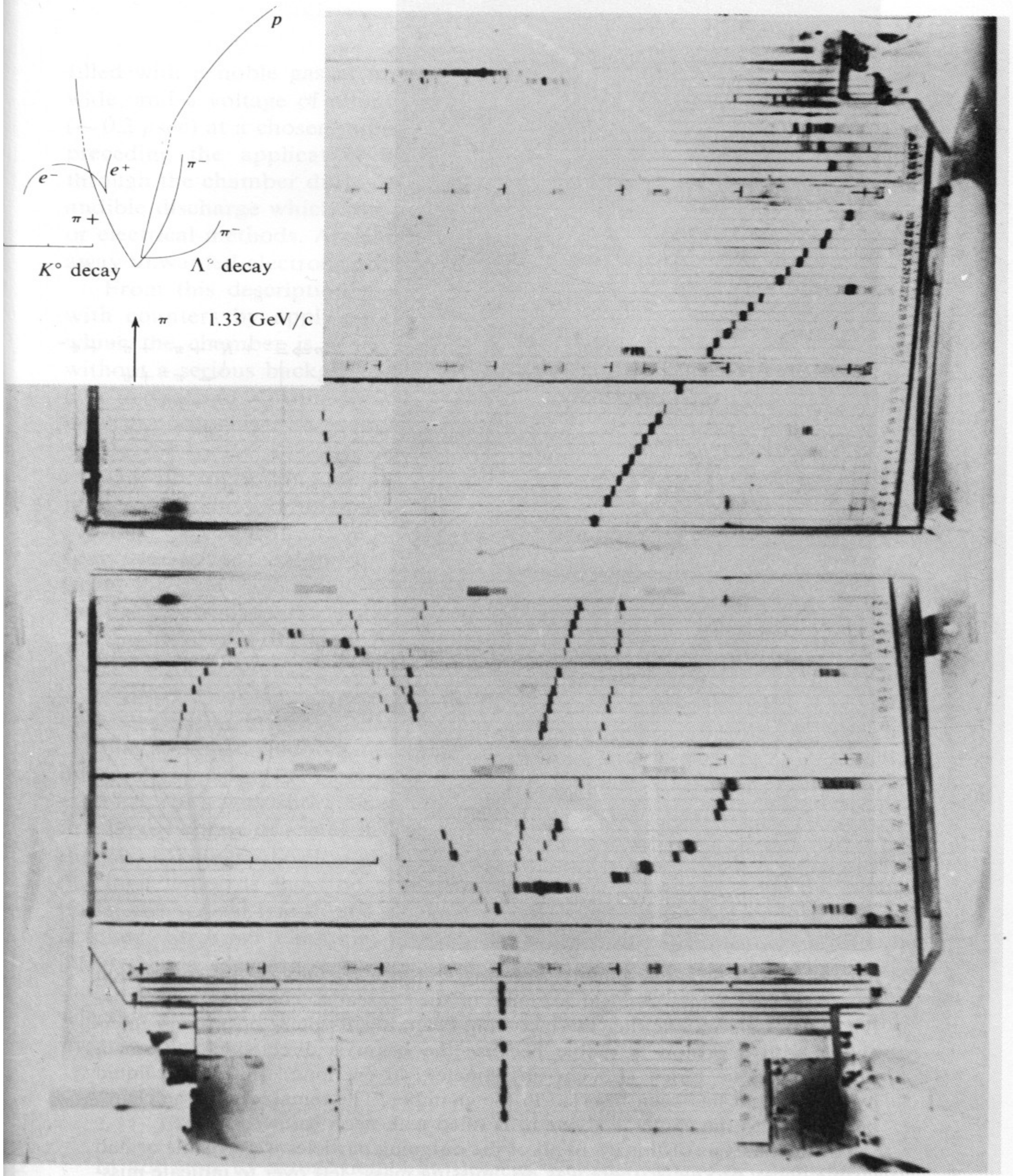


Figure 3-30 Spark-chamber picture of $\pi^- + p \rightarrow \Sigma^0 + K^0$ reaction and subsequent reactions $\Sigma^0 \rightarrow \Lambda^0 + \gamma$; $\Lambda^0 \rightarrow p^+ + \pi^-$; $\gamma \rightarrow e^+ + e^-$. The spark chamber is in a field of approximately 13.5 kG. [Courtesy A. Roberts.]

eine zentrale Au-Au Kollision bei RHIC
total 5000 geladene Teilchen
davon misst STAR TPC etwa 1500