3-dimensionale Messung: Time Projection Chamber (TPC)
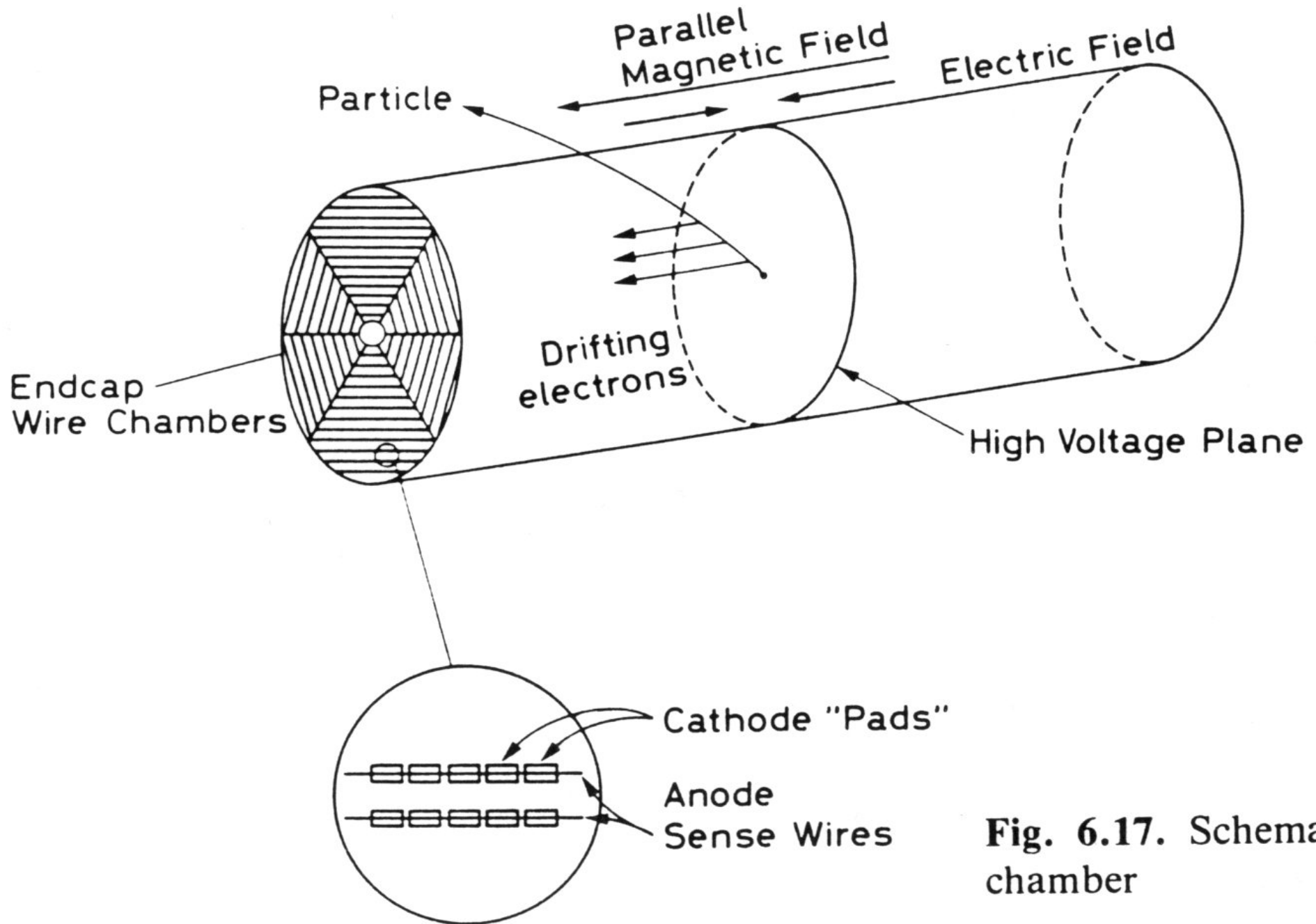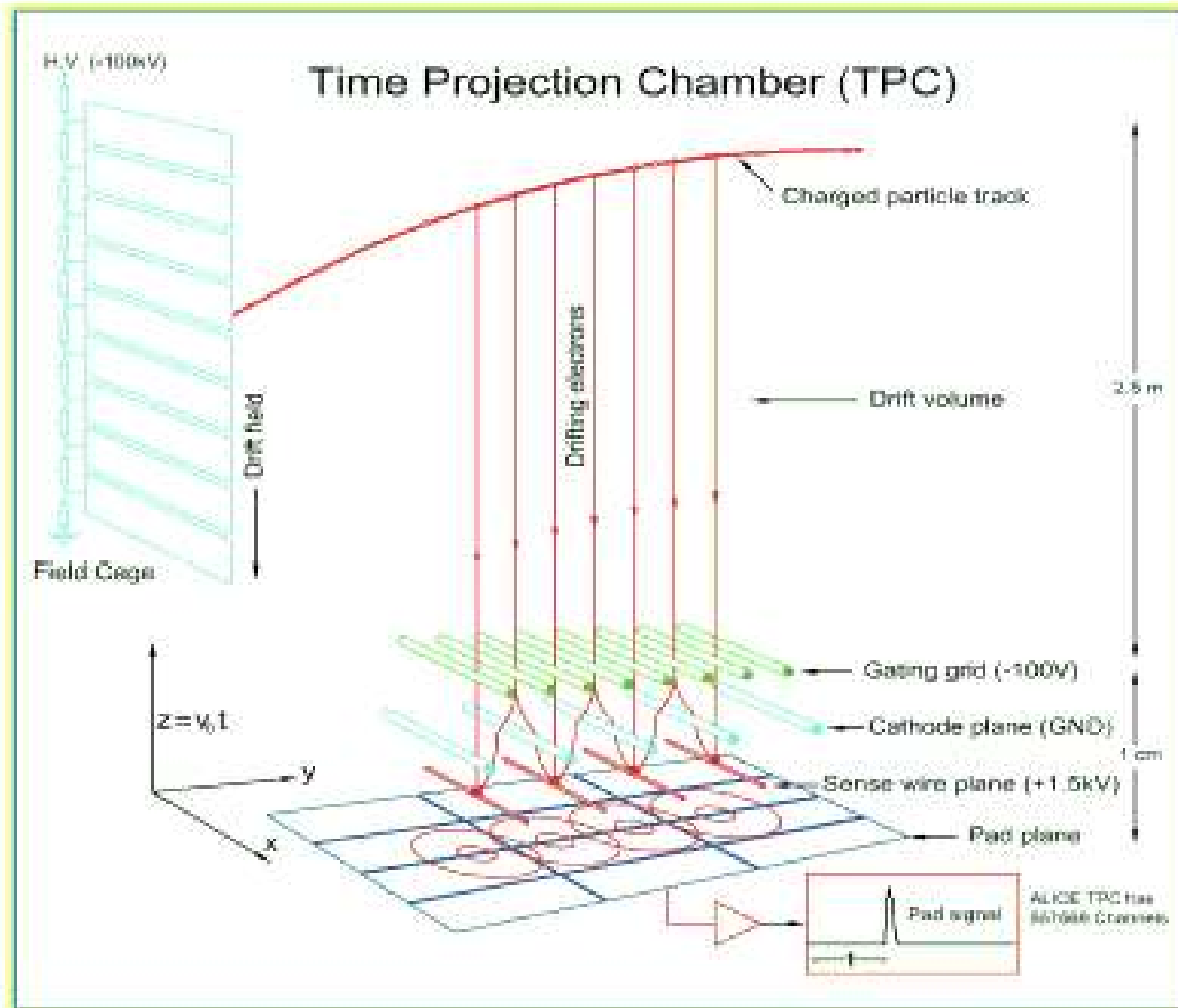

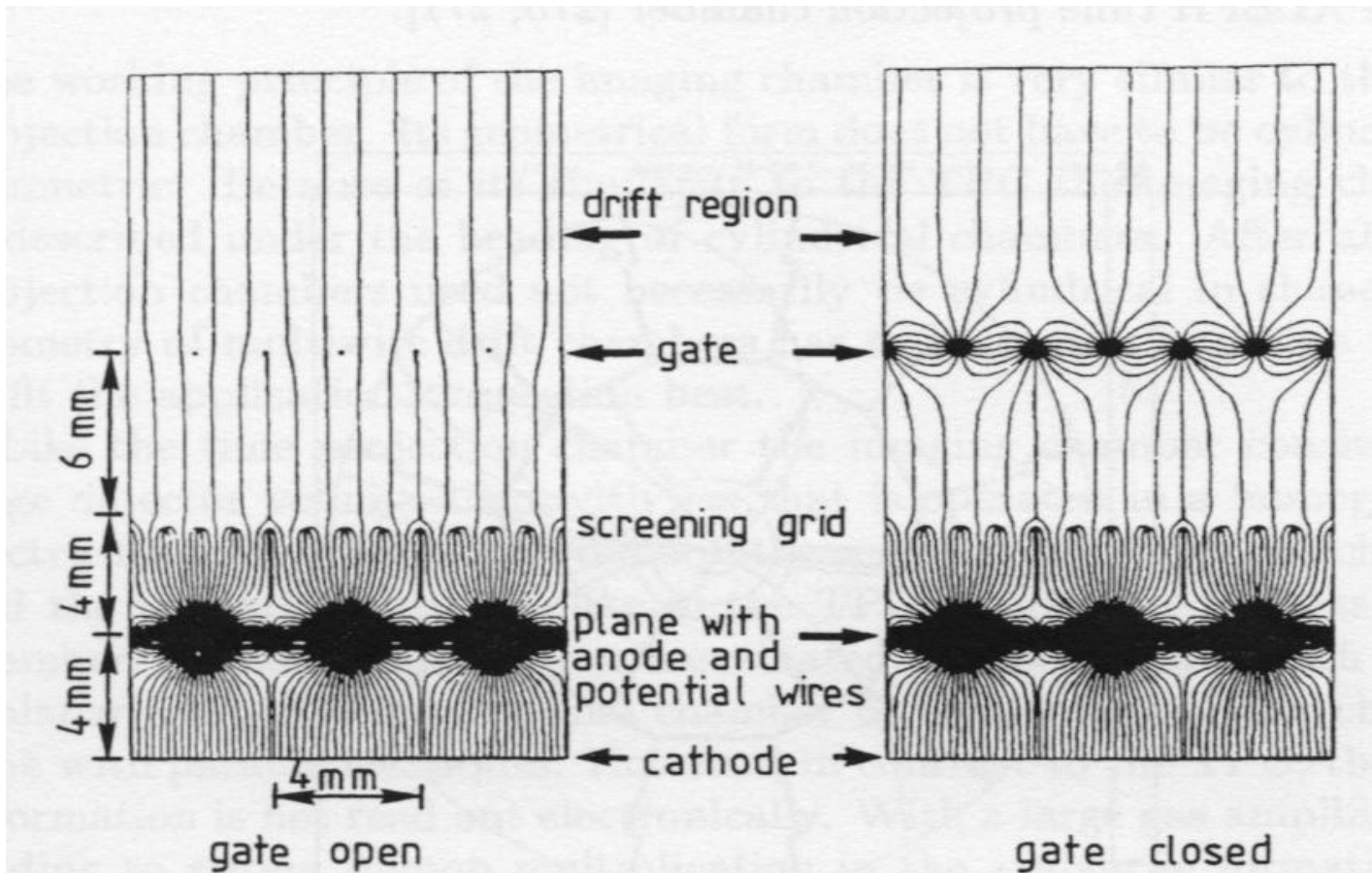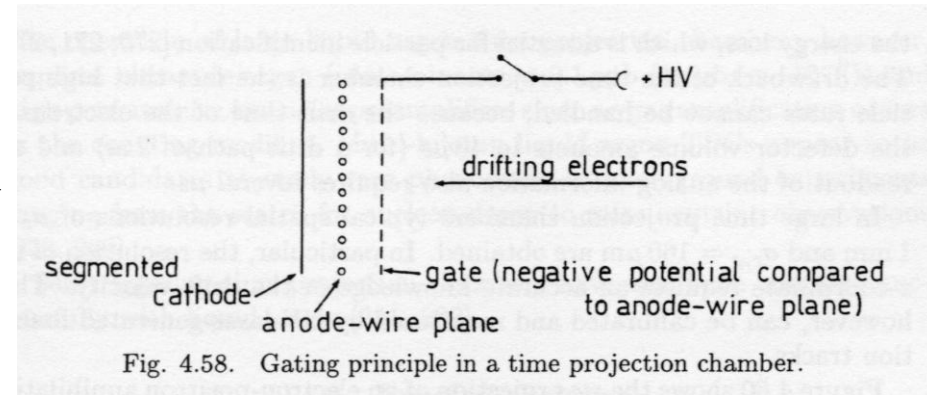**Fig. 6.17.** Schematic chamber

3-dimensionale Messung: Time Projection Chamber (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

drifting electrons

segmented cathode

gate (negative potential compared to anode-wire plane)

anode-wire plane

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

drift region

gate

screening grid

plane with anode and potential wires

cathode

6 mm

4 mm

4 mm

4 mm

gate open

gate closed

die **ALICE TPC** (CERN LHC)
mit **95 m³** groesste je gebaute TPC
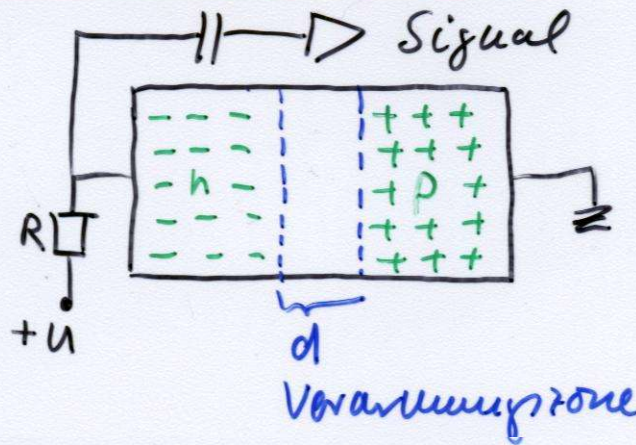**560 Millionen Auslesepixel!**

Halbleiter:

E

/ / / ⏟ E_c } Bandlücke E_{gap}

‾‾‾‾‾ E_v

Si   1.1 eV
Ge   0.7 eV
GaAs 4.3 eV
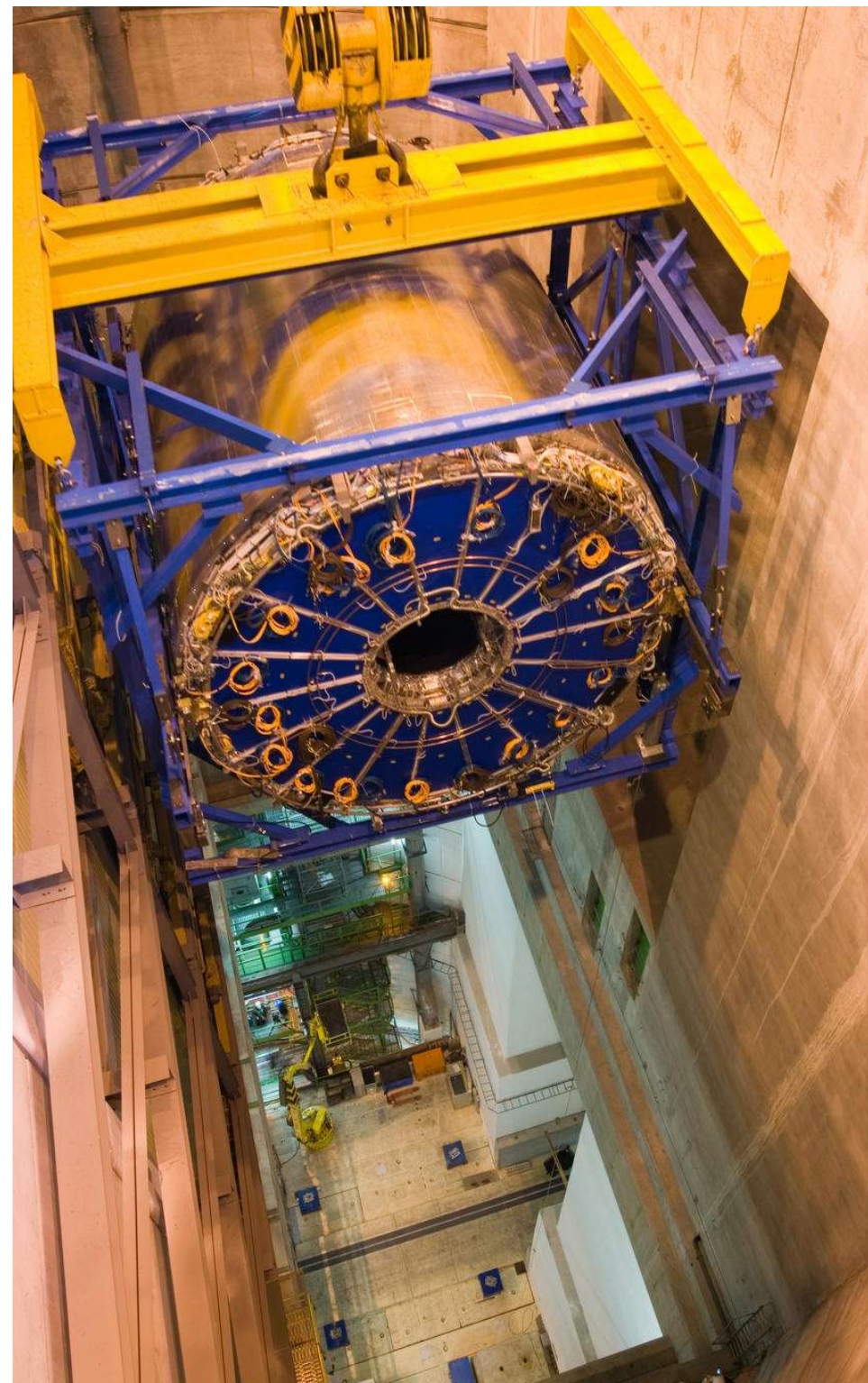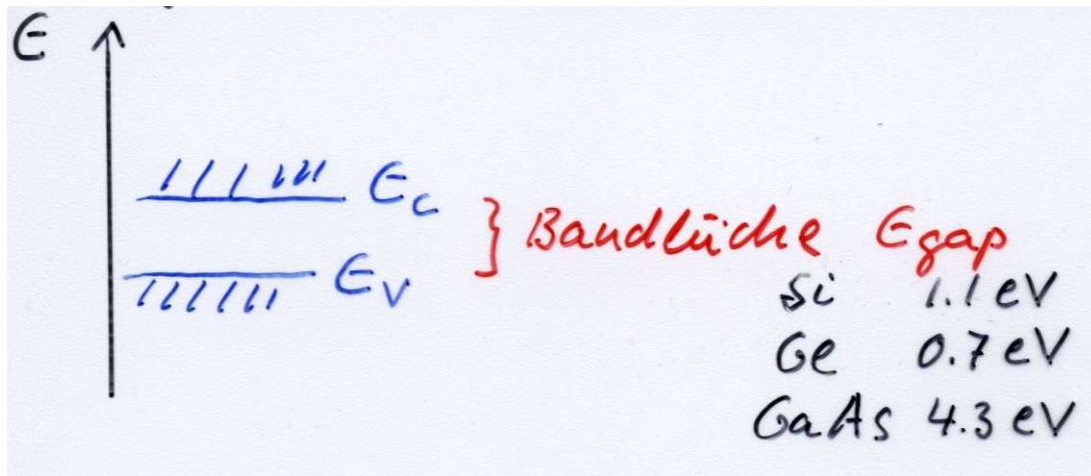
Dotierung mit 5- bzw. 3-wertigem Element -> n- bzw. p-Typ Halbleiter

n

Sb   P   As
————————————————————————— E_c
.039 eV   .044 eV
          .049 eV

– – – – – – – – – – – – – – – E_F reines Si

.045 eV   .067 eV   .085 eV

p
————————————————————————— E_v
B   Al   Ga

1.1 eV
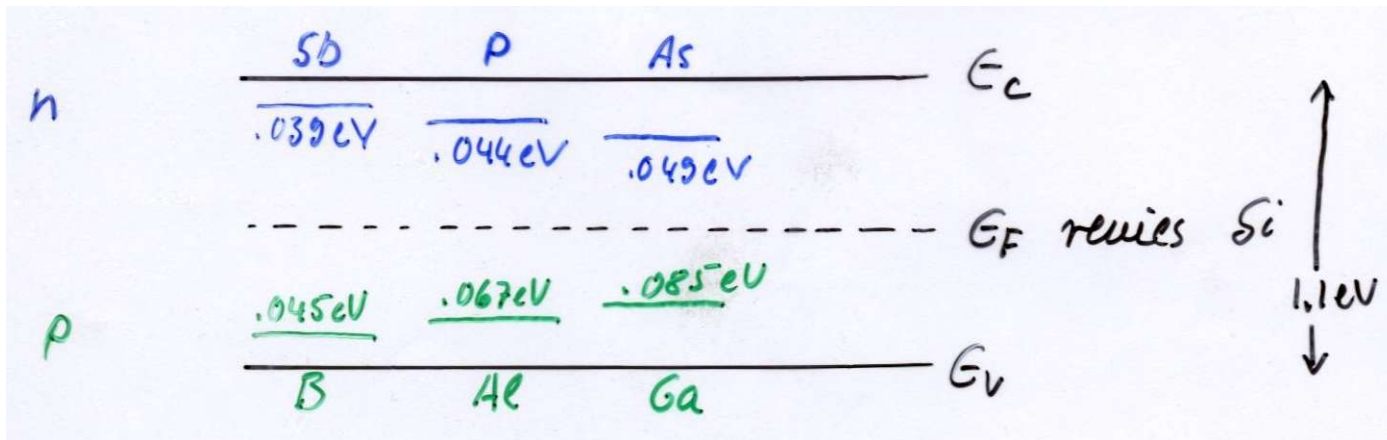
Prinzip Halbleiterdetektor:

p–n   Halbleiterzähler

→▷ Signal

$+++$: "freie Ladungsträger"
$---$

d
Verarmungszone

$\rho \approx 10^4 \, \Omega \, cm$

P

n_A

$n+$ p^+
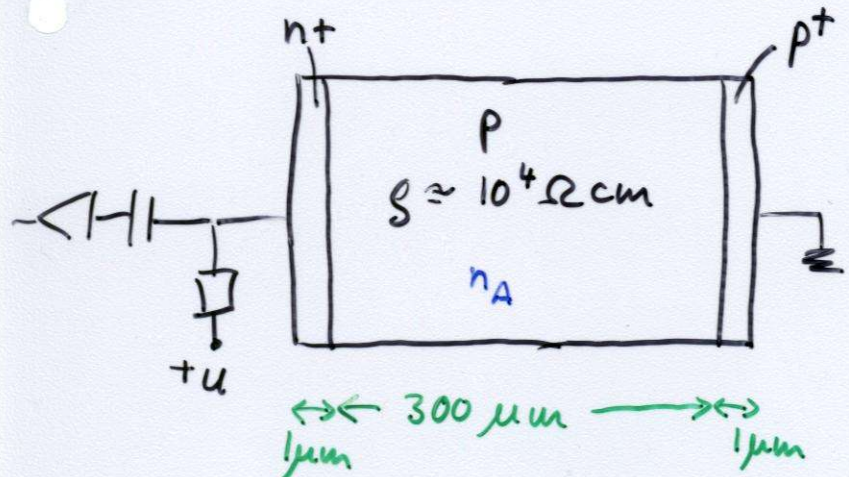
p^+, n^+ : sehr hoch
dotiert, gut
leitend

←← 300 μm →→
1μm   1μm

+u

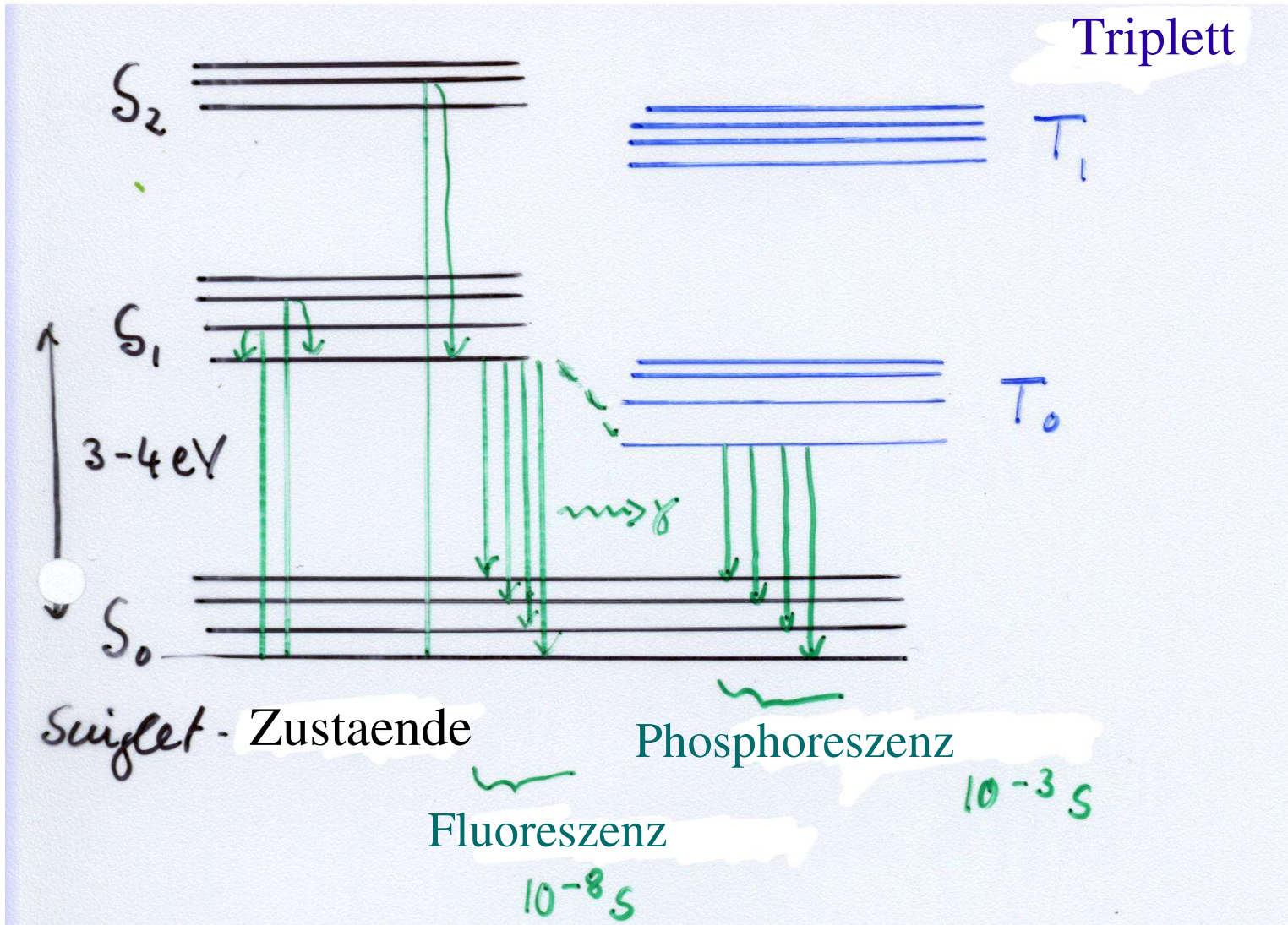# Ortsmessung mit Halbleiterzaehler: Streifen
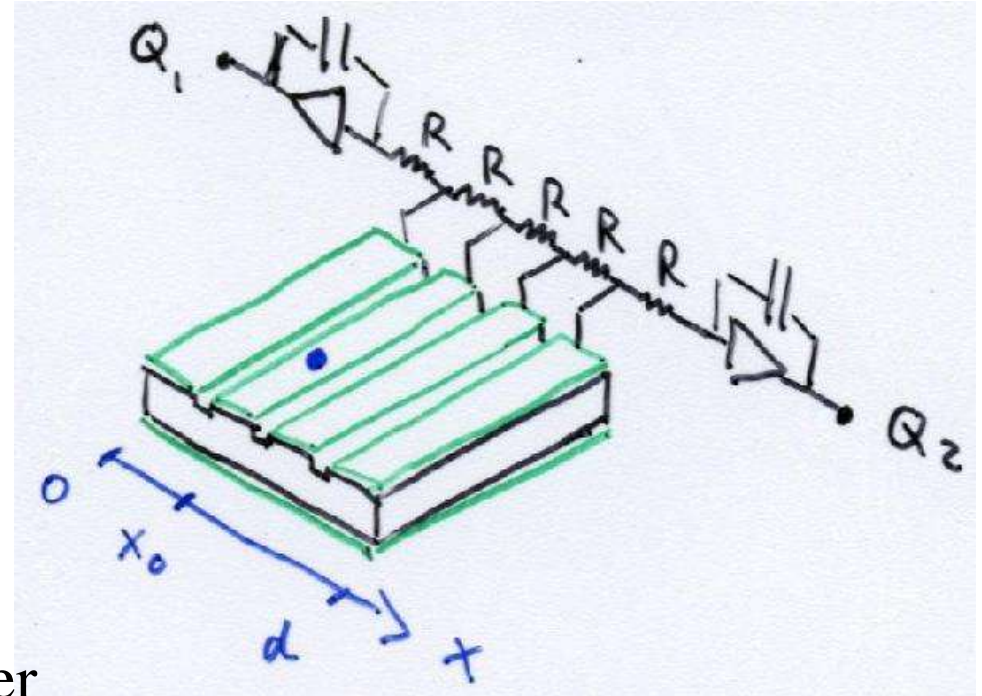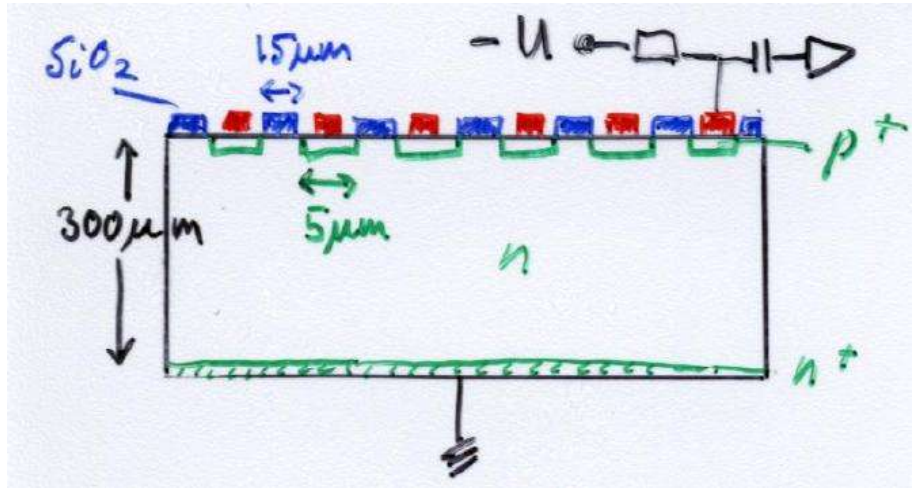
oder Pixel mit Elektronik direkt darueber
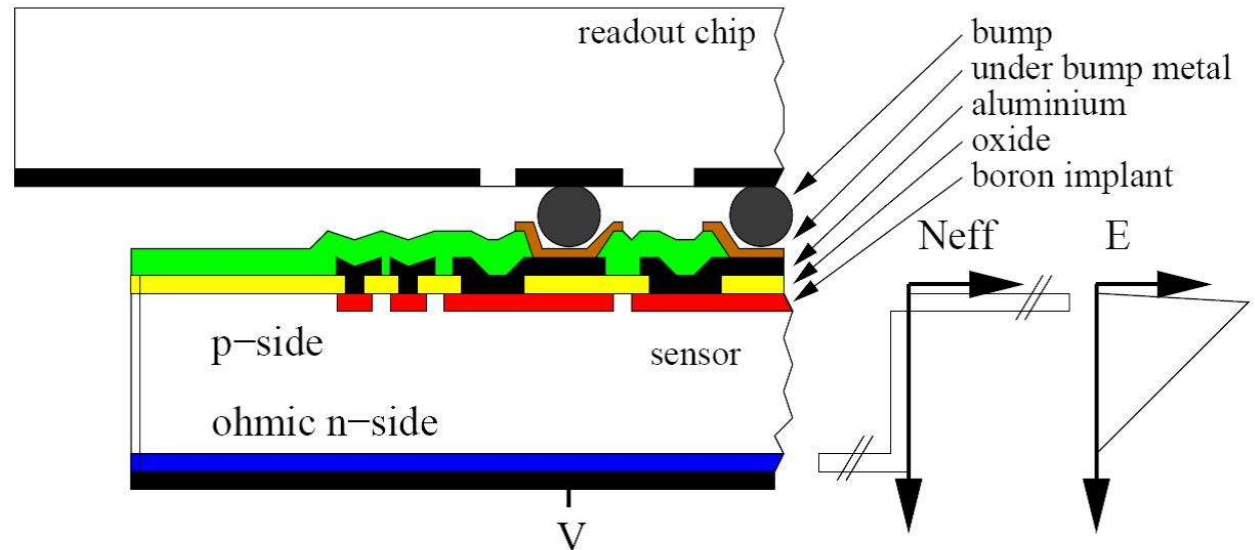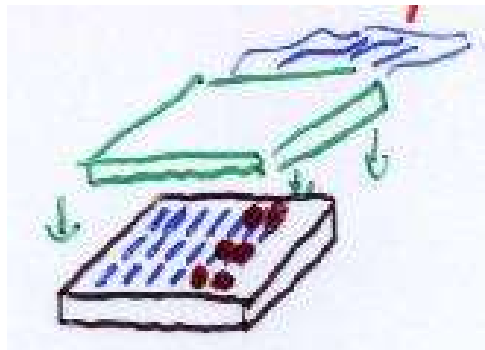
organische Szintillatoren:

Triplett

S_2

T_1

S_1

T_0

$3-4\,eV$
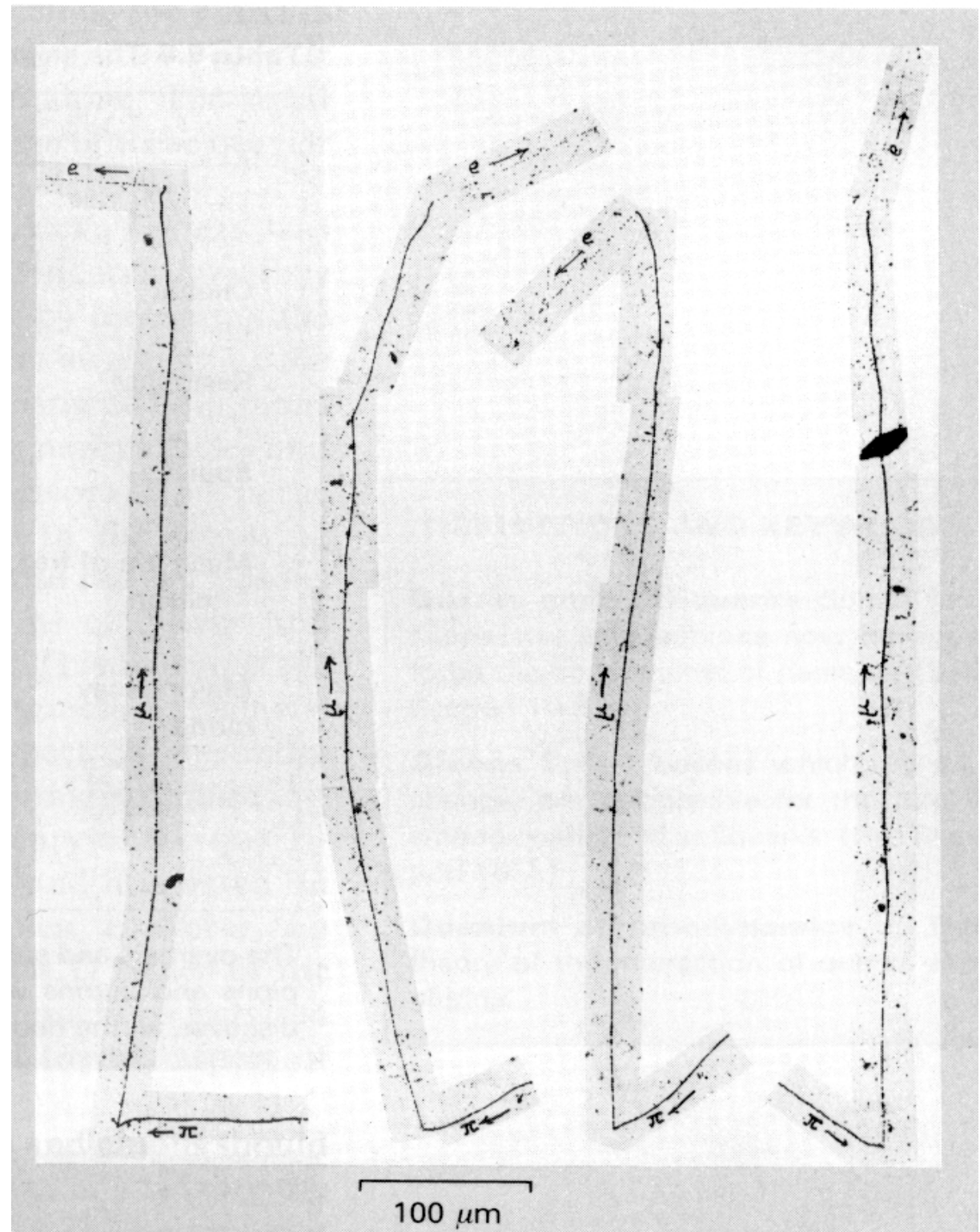
S_0

Singlet - Zustaende

Phosphoreszenz

$10^{-3}\,s$

Fluoreszenz

$10^{-8}\,s$

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

$\pi \rightarrow \mu \rightarrow e$

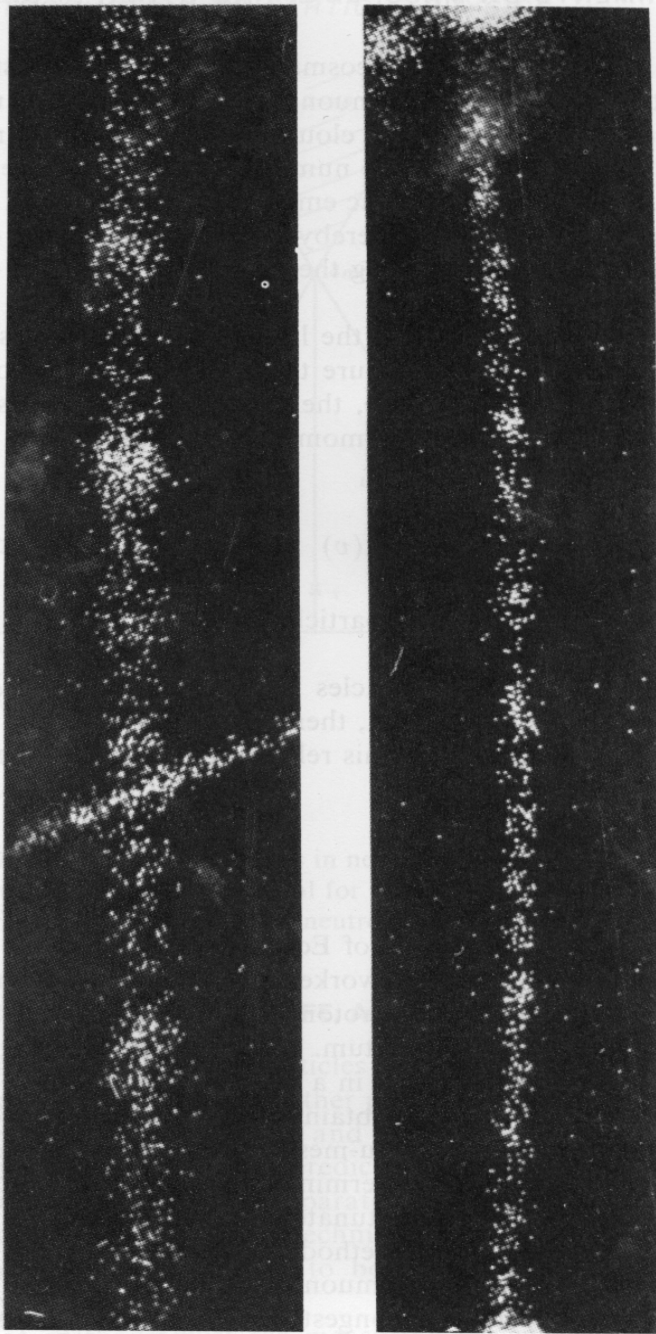
100 μm

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.]
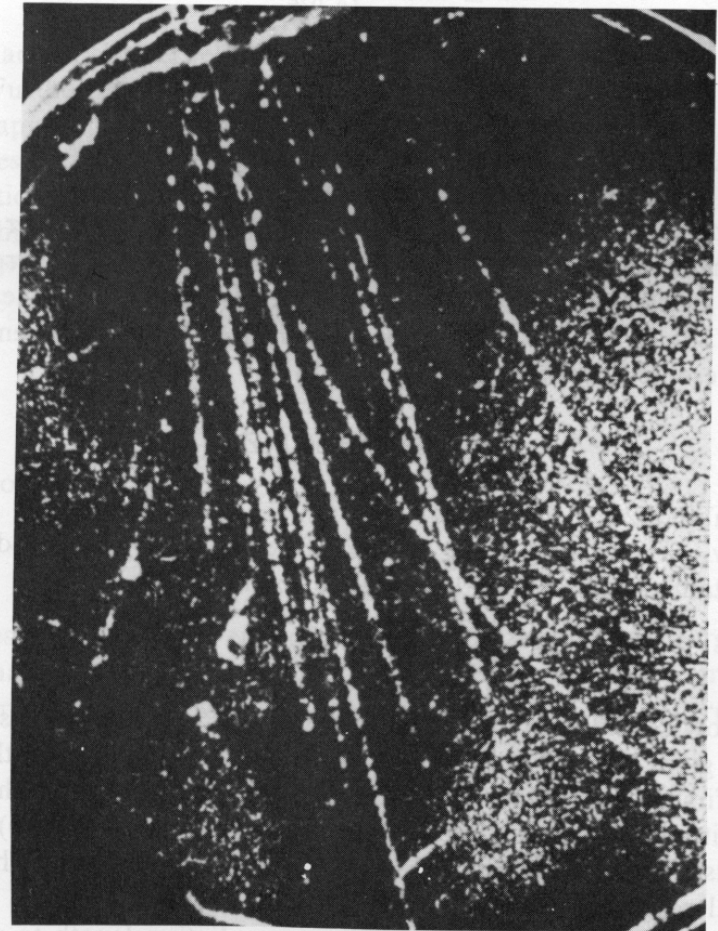

Figure 2-32 First shower observed by Blackett and Occhialini in a cloud chamber triggered by counters in coincidence above and below the chamber. [*Proc. Roy. Soc.* (*London*), **139**, 699 (1933).]
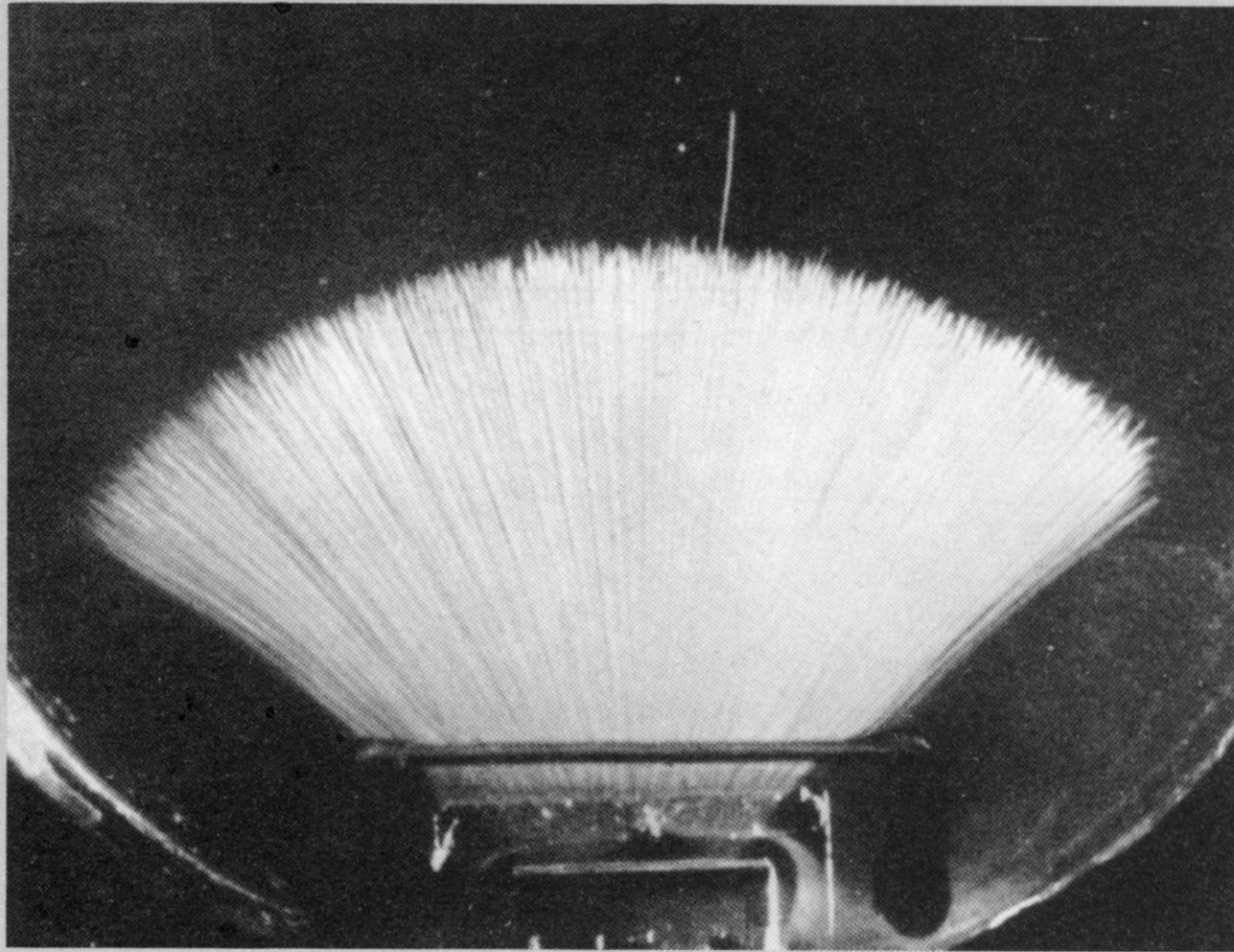
Fig. 6.6 A cloud chamber photograph of α-particles from the decay of $^{214}_{83}$Bi. The almost constant range of particles of 7.69 MeV from the decay of the ground state of $^{214}_{84}$Po is clear (see Section 11.3 and Fig. 11.4). The outstanding particle is the product of the rare decay from an excited state of $^{214}_{84}$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
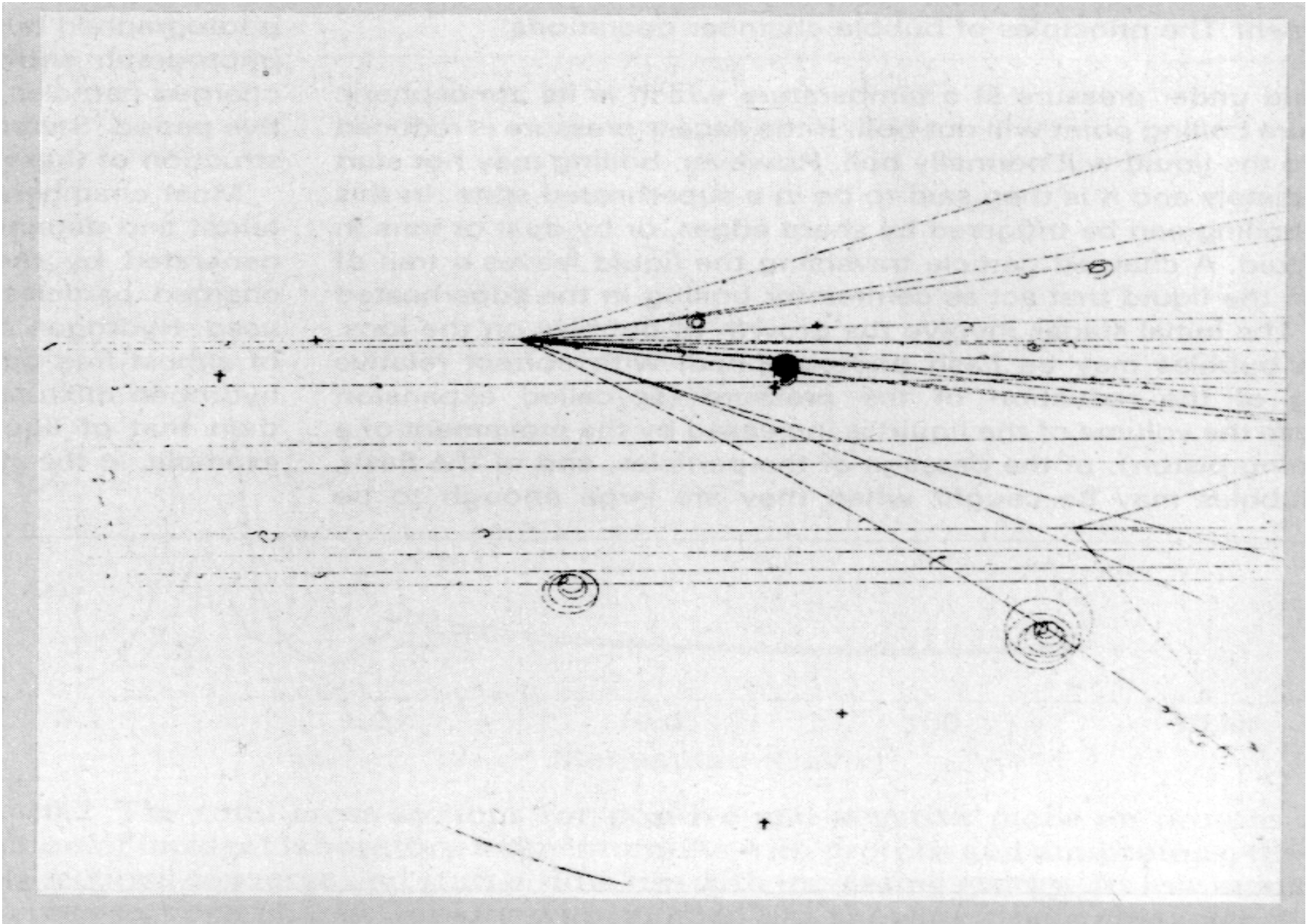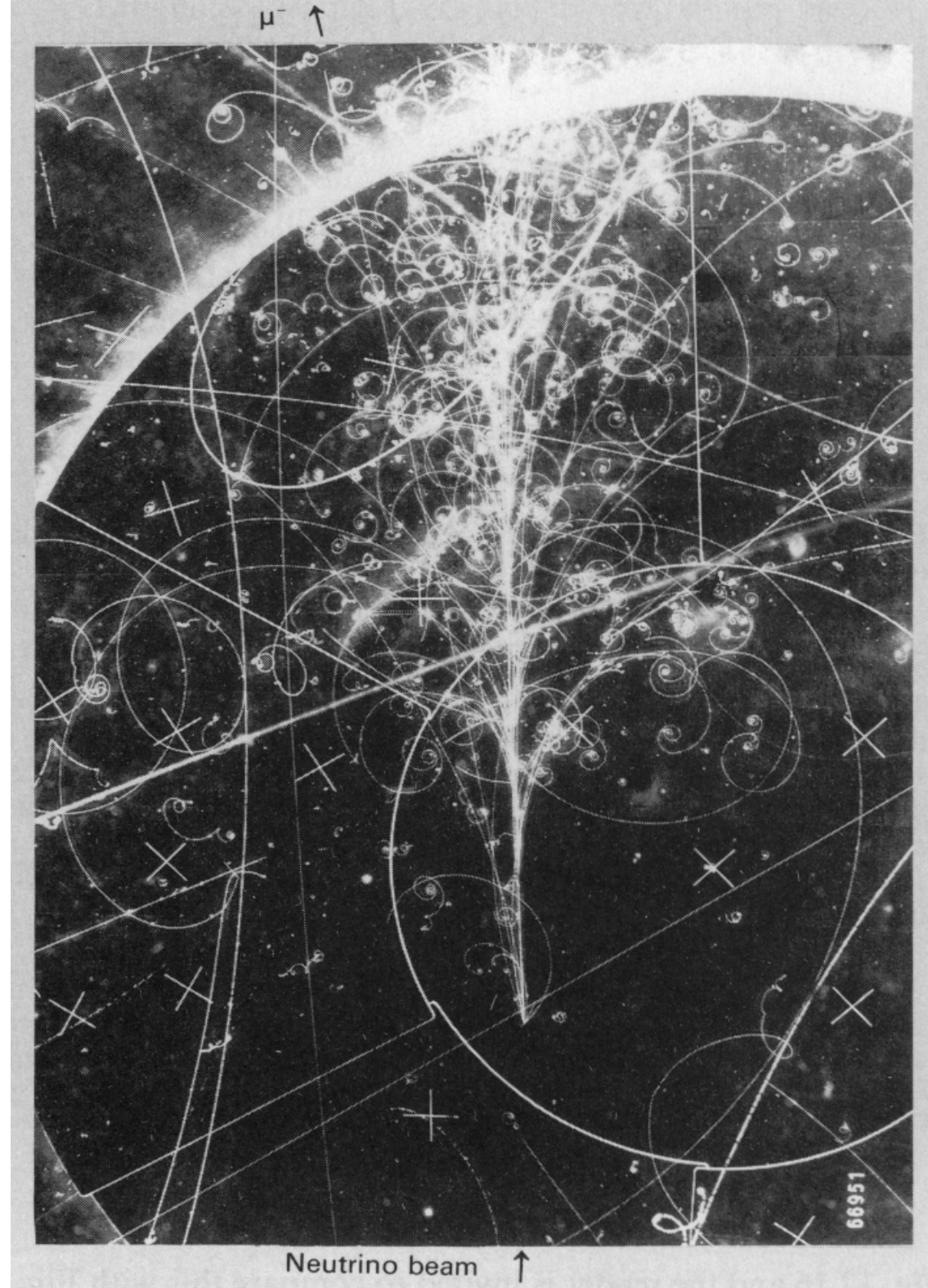
Blasenkammerphoto:
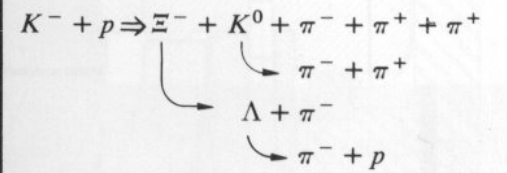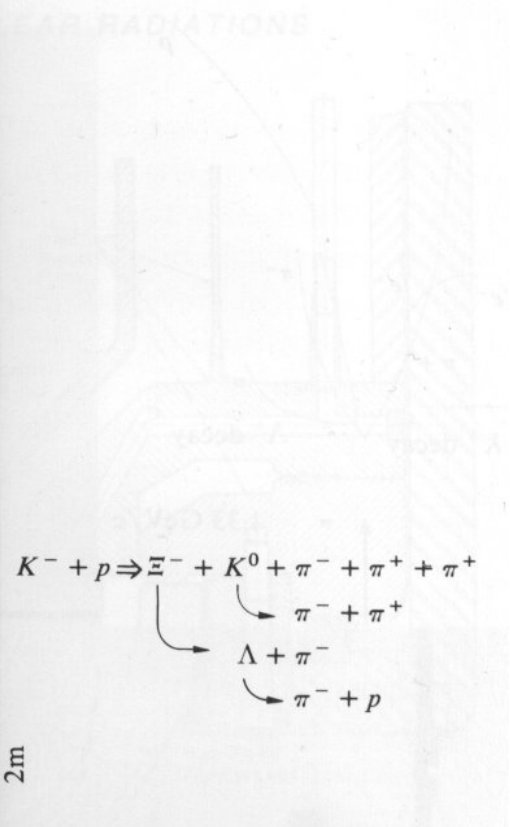muon neutrino in Ne-H fluessig
-> muon + π°

-> γγ -> em Schauer

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

fuer viele Jahre das Werkzeug
der Teilchenphysik
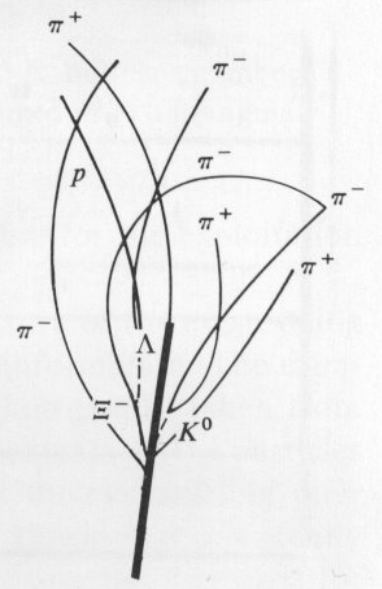
Streamer-Kammer-Aufnahme:

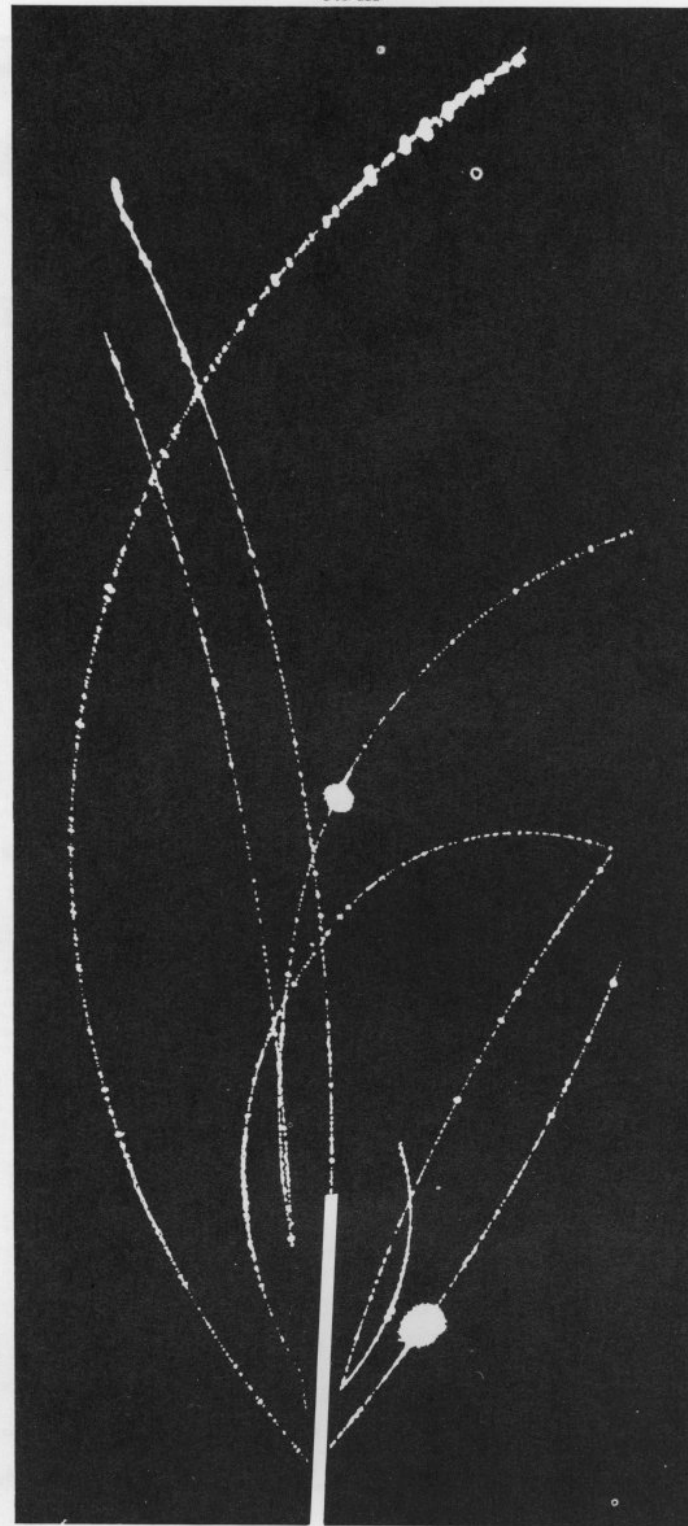

$$K^- + p \Rightarrow \Xi^- + K^0 + \pi^- + \pi^+ + \pi^+$$
$$\hookrightarrow \pi^- + \pi^+$$
$$\hookrightarrow \Lambda + \pi^-$$
$$\hookrightarrow \pi^- + p$$

The "Cascade"

Funkenkammer:

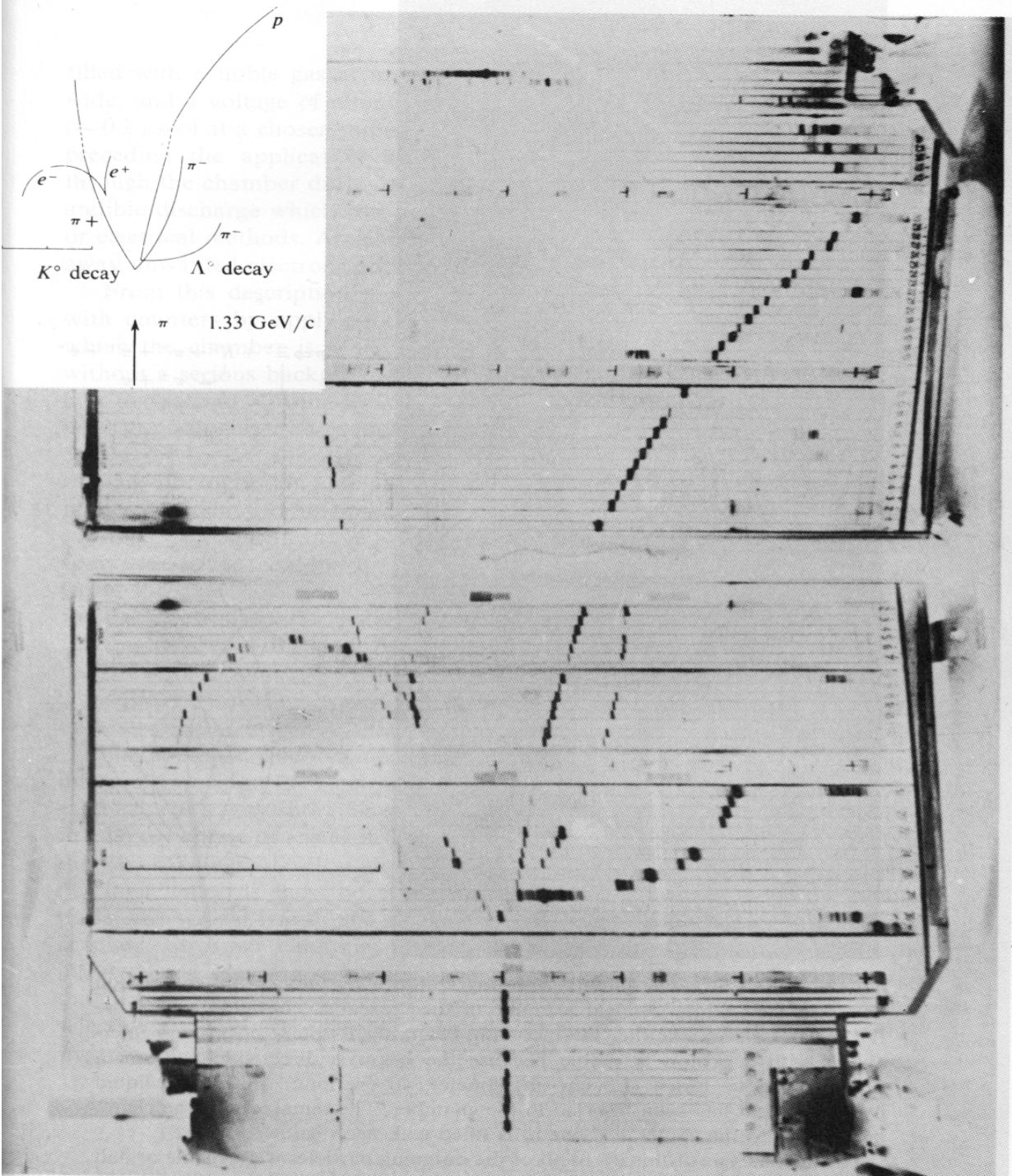**Figure 3-30** Spark-chamber picture of $\pi^- + p \to \Sigma^0 + K^0$ reaction and subsequent reactions $\Sigma^0 \to \Lambda^0 + \gamma$; $\Lambda^0 \to p^+ + \pi^-$; $\gamma \to e^+ + e^-$. The spark chamber is in a field of approximately 13.5 kG. [Courtesy A. Roberts.]

	stark	elektromagn.	schwach	Gravitation
Kopplungskonst.	$g_s^2/\hbar c \approx 15$ $\alpha_s \approx 1$	$e^2/\hbar c = 1/137$	$g^2/\hbar c = 4\cdot10^{-3}$	$\dfrac{G_N m^2}{\hbar c} = 6\cdot10^{-39}$
Austauschboson	Pion --- 139 MeV gluon 0 MeV	Photon 0 MeV	$W^{\pm}$ 84 GeV Z^0 92 GeV	Graviton ?
Stärke rel. zu starker WW bei 1 fm	$\equiv 1$	10^{-2}	10^{-13}	10^{-38}
typ. Zeitskala für Zerfälle	10^{-23} s	10^{-20} s	10^{-10} s	?
typ. Reichweite	$1.4\cdot10^{-15}$ m	∞	$2\cdot10^{-18}$ m	∞