The Wilson Chamber

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In 1954-55, I built a Wilson chamber. It was a super-compressed chamber, sort of a turbo chamber, which was able to operate at a few expansions per second.
The regular Wilson chamber operates more like at one cycle per minute, with a sensitive time of maybe 0.1 s. That was not a limitation in Cosmic Ray physics, after the introduction of the trigger idea, which is another unique advantage that the Wilson chamber had.

The chamber I built, mostly with my own hands – and those of another young colleague, was supposed to be used at the new 1 GeV Italian electron synchrotron. Those machines had an acceleration cycle of 1/50 s and it would have been a pity to waste 2999 out of every 3000 machine cycle.

The whole idea with accelerators was to make rare happenings very frequent – trigger does not help anymore if there is one event per cycle.

By the time, 1959, the synchrotron was operating, the Wilson chamber was superseded by the bubble chamber and in fact I had a 10 expansion/s bubble chamber running.

Wilson (C.T.R. – Wilson is a very common name and you must be careful with it – there is a J.G. Wilson who also was very involved with the chamber) invented the Wilson- or cloud-chamber (1911) while studying cloud formation. One day he saw a track in his chamber simulating super-saturated vapor condition as presumably responsible for clouds and rain.

You know that a gas mixture in which vapor is present, with a partial pressure greater, not too much, than the saturated vapor pressure does not condense to the liquid phase until "seeded".

It turns out that ions are very effective seeds. Thus the ion trail of a charged particle can be revealed by droplets of some liquid condensing on the ions.

Dangerous demonstrations of metastability around phase transitions:

1. A soda bottle in the freezer

2. A glass beaker of clean water in a microwave oven

A favorite liquid for the Wilson chamber is a mixture of water and pure ethylic alcohol, this being the source of uncountable jokes.

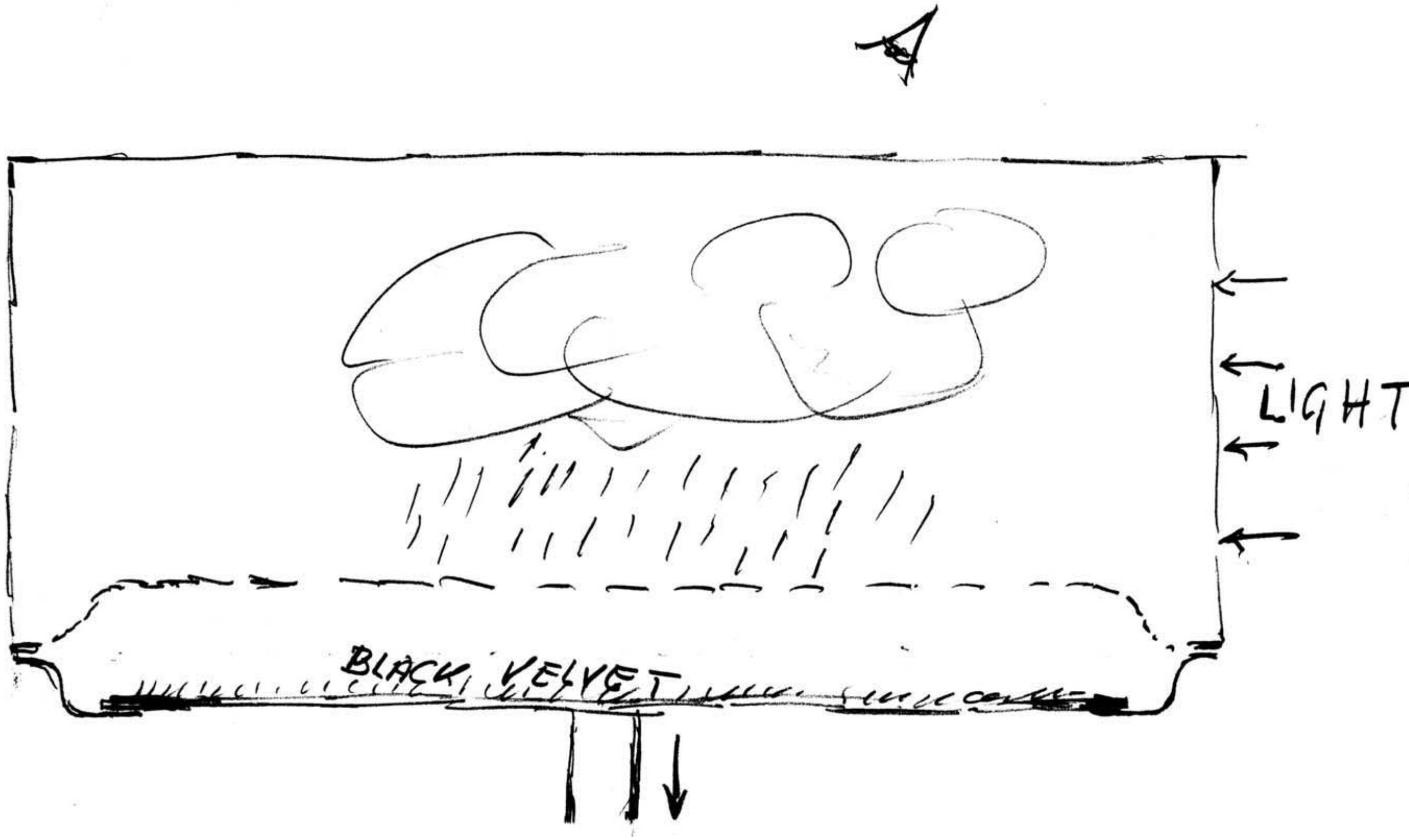
Sketch of a cloud chamber.

Let $R = V_{fin.}/V_{in.}$.

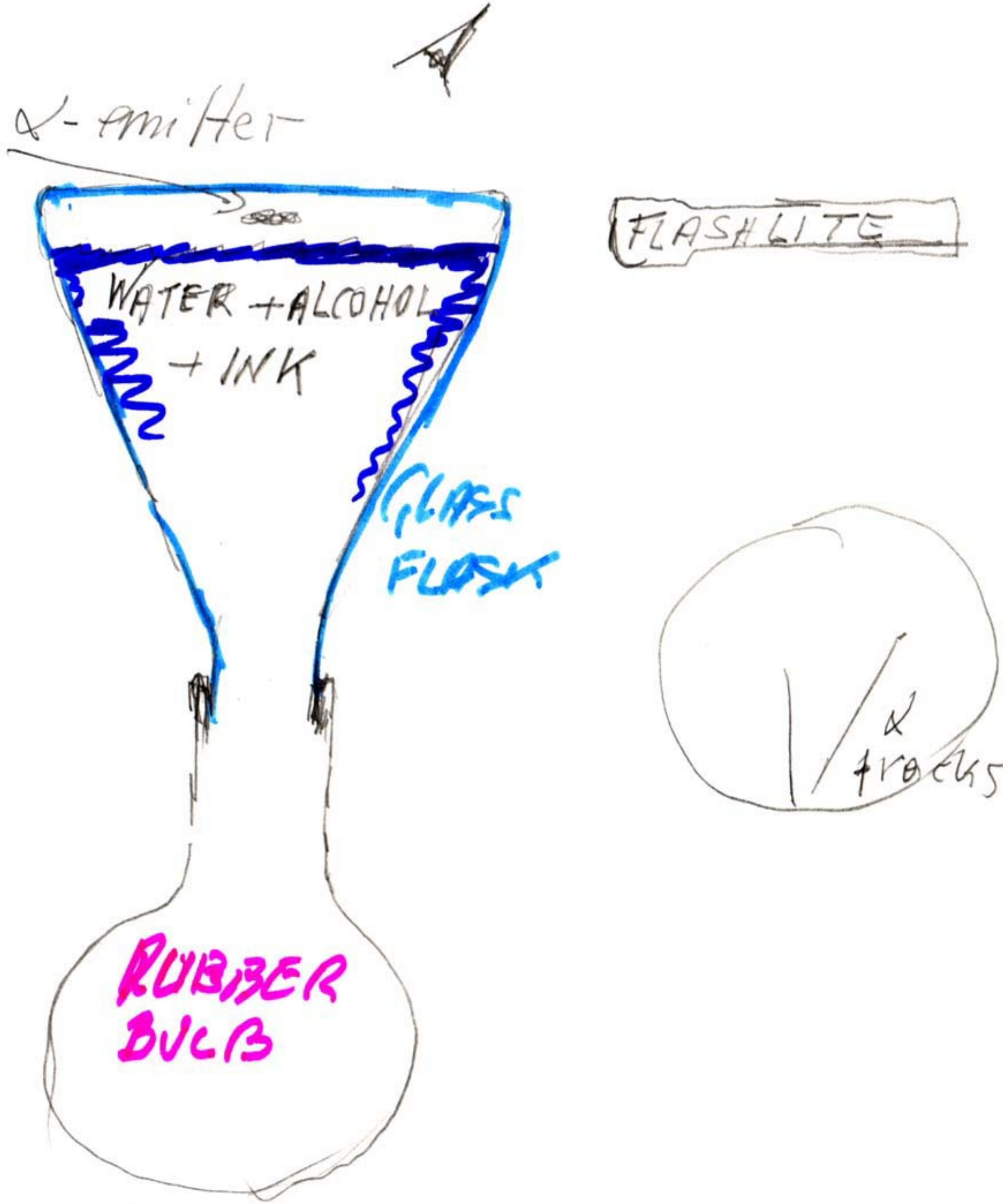
For 1< R <1.25 fog forms on dust.

For R >1.25 vapor condenses on negative ions.

For R >1.31 vapor condenses on positive ions.



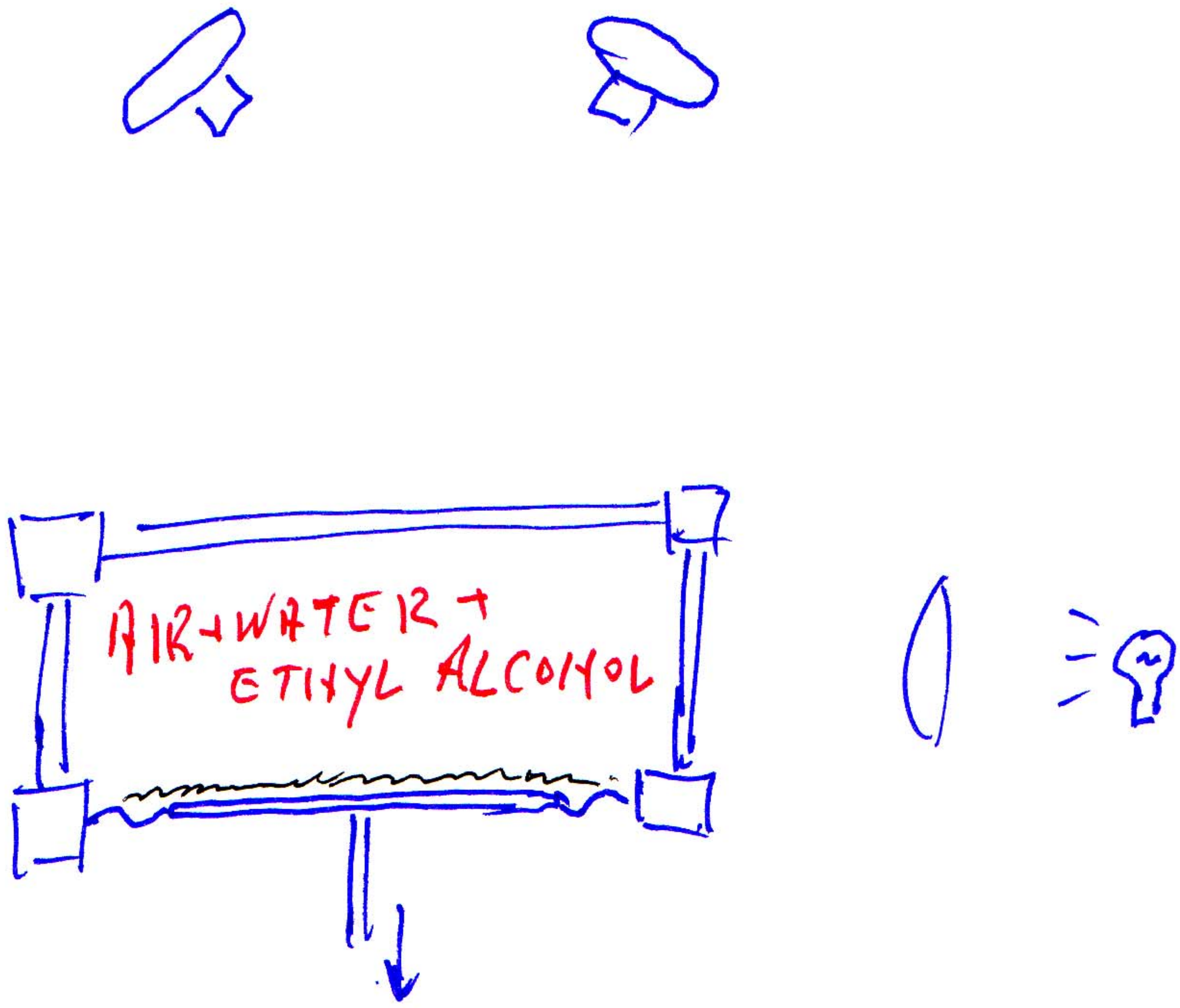
How to make your own. The hardest thing is finding a crumb of U or Th. . .

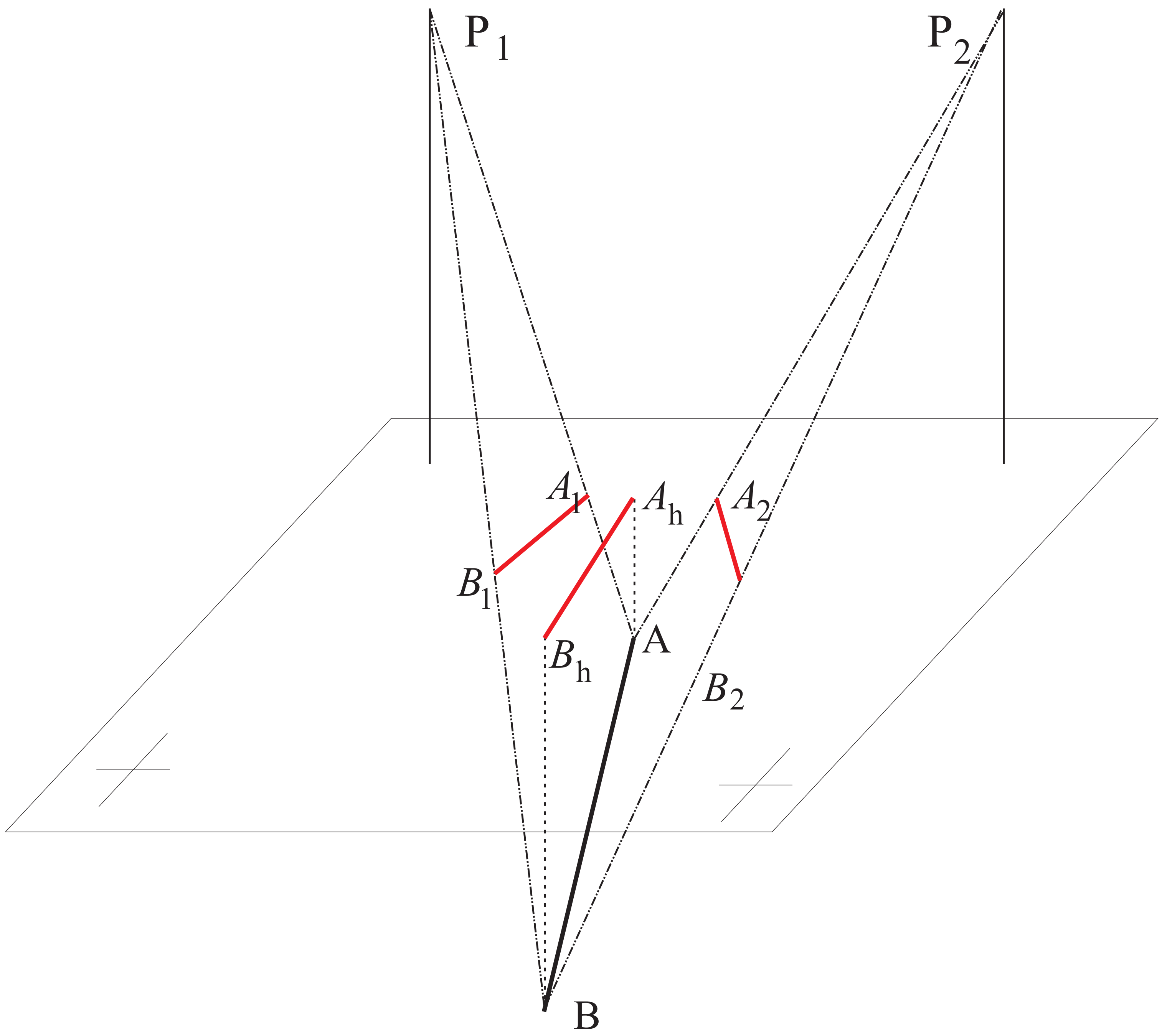


A cloud chamber cycle.

1. A particle leaves a trail of ions. The chamber gas is saturated.
2. Within a short time, say $<$0.01 s, expand the chamber. The adiabatic expansion cools the gas which becomes supersaturated.
3. Let the droplets grow to a convenient size, $\sim$0.01 s
4. Take a (stereo-pair) picture
5. Restore the initial conditions, about 1 minute to reach equilibrium, turbulence included.
6. Ready to try again

Stereo Photography





P 1
P 2
A1
Ah
A2
B1
Bh
A
B2
B

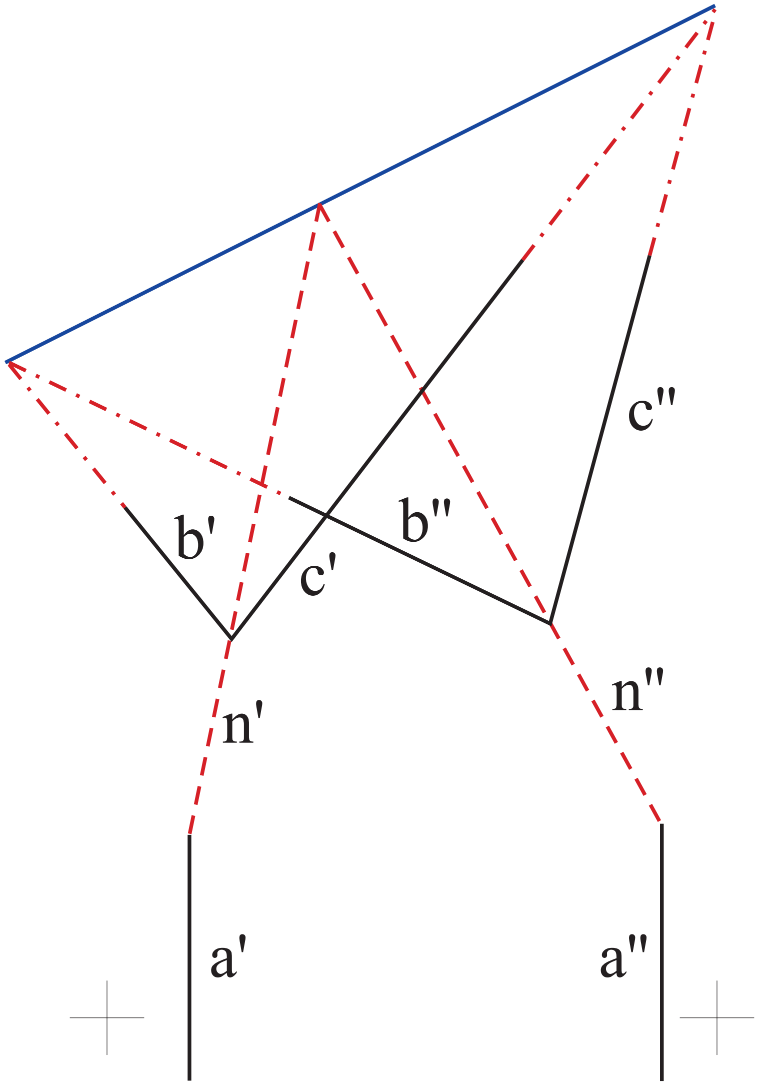
a+T→n

n→b+c

′ is view 1

″ is view 2

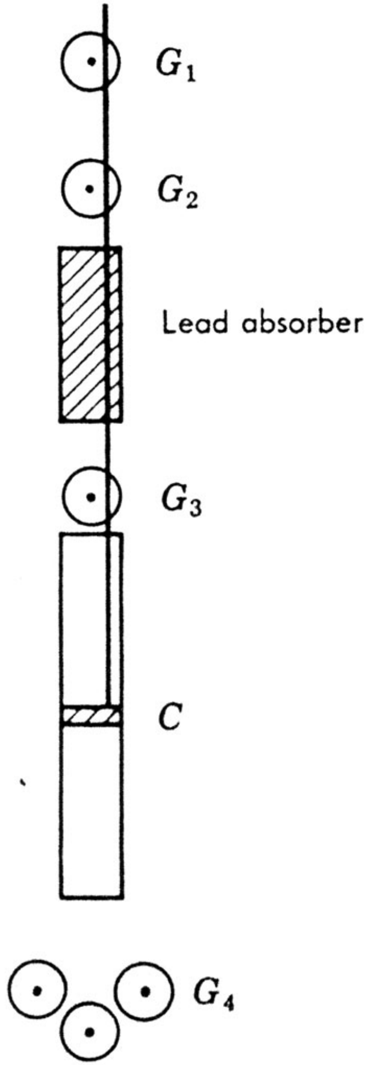
Want to check coplanarity of n, b, c



The golden era of the Wilson chamber

Wilson Chamber is synonym to Cosmic Rays - and new particle discovery. The Wilson chamber main drawback is the short sensitive time in a cycle. This can be overcome because it is possible to expand the chamber after something happened.

Most of the famous physics with the cloud chamber comes from high altitude observatories, were chambers were “triggered” by a system of Geiger-Müller counters, making smart choices.



Anderson and Neddermeyer

The Wilson chamber provides two pieces of information:
Trajectory
Specific ionization

Embedding the chamber in a field B allows measuring momenta (need to know the charge, but. . .) and the sign of the charge - important.

$$p_\perp = 300Br$$
$$r = \frac{l^2}{8s}$$

$1/r$ or $1/p$ is gaussian.

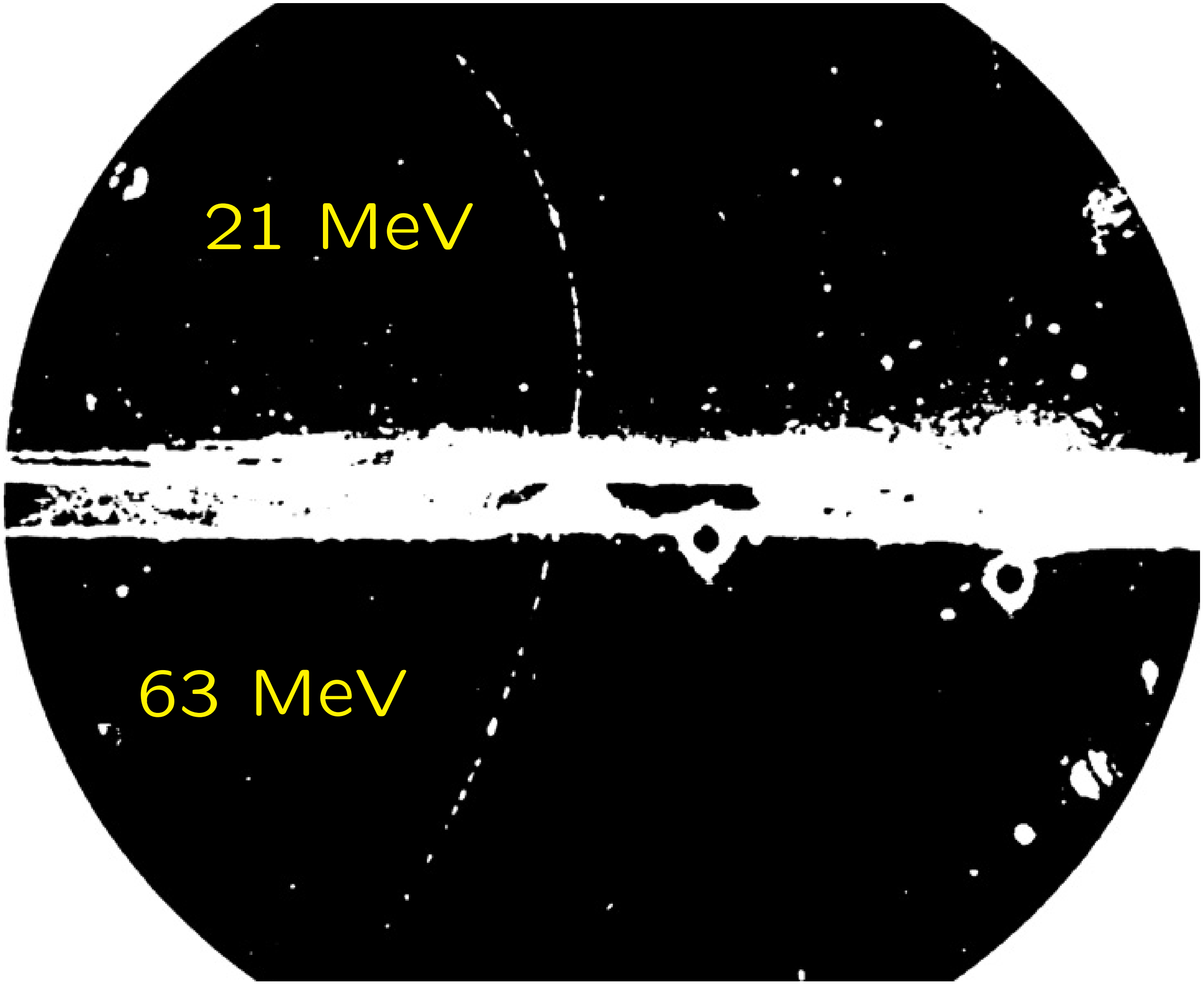
Together with kinematics we have all the tools necessary to make discoveries.

The energy lost in 6 mm Pb is larger than ionization loss, ∼7 MeV.

First direct observation of radiation loss.

Also discovery of positron.

New tool for discovery.



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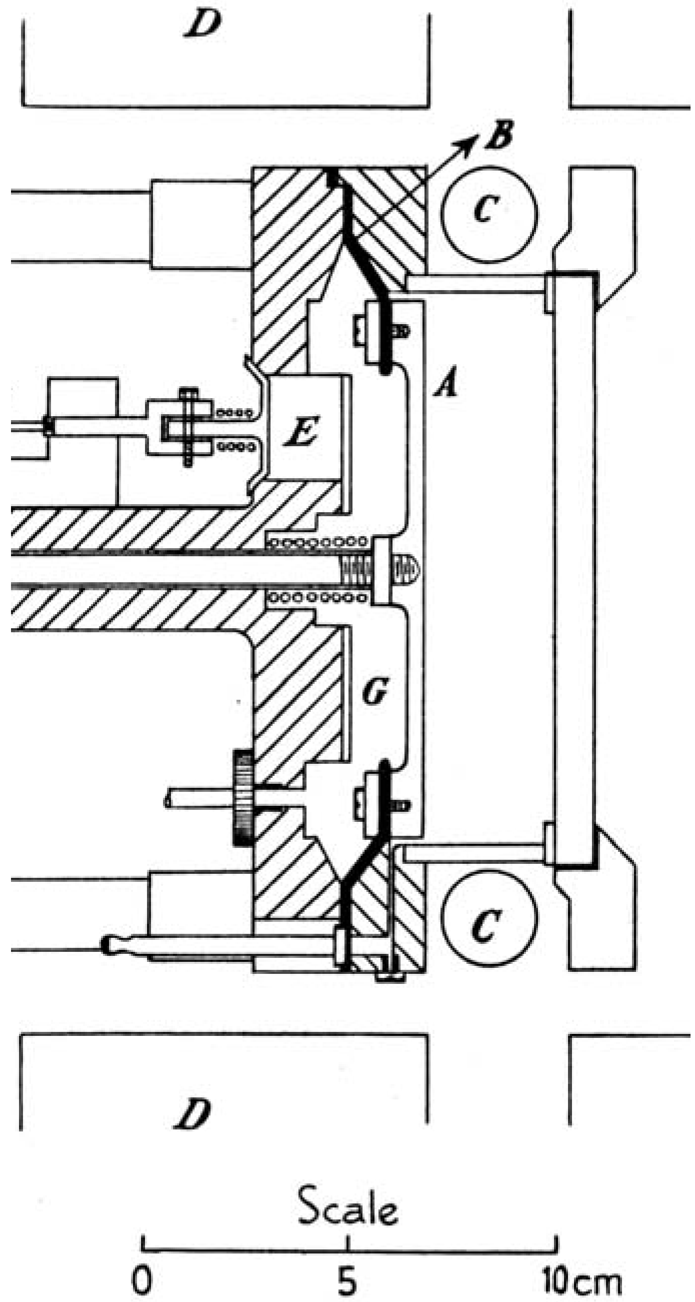
There was not much confidence in the Bethe Heitler calculations of pair production and radiation. By the end of the 30's the Wilson chamber had confirmed their validity and discovered the muon.

Anderson and Neddermeyer, 1937, used 1 cm platinum (ΔE(min) =20 MeV, t=3.3X_0) in their chamber, clearly recognizing a class of tracks for which the energy loss was almost independent of energy – muons – and another where the energy loss was very large and proportional to the energy.

The observation was widely confirmed, Street and Stevenson - 1937, and the muon mass estimated from dE/dx and p.

That the muon was assumed to be the Yukawa mesotron is history and was not Wilson's chamber's fault.

Blacket and Occhialini further improved on the triggered cloud chamber and provided a good magnetic field for measurements up to 1 GeV and even 10 GeV.
They especially pioneered the high altitude observatory.

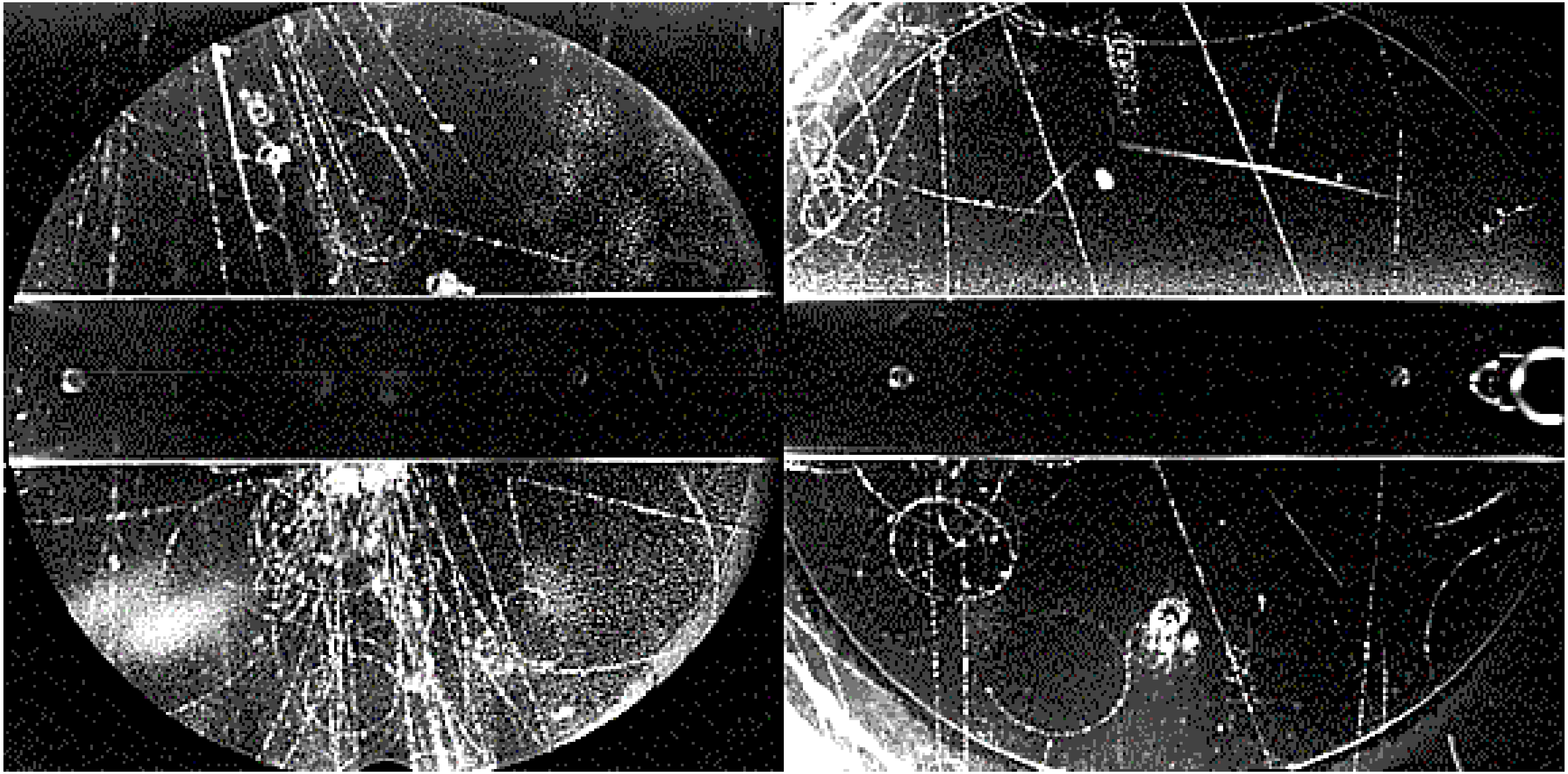


Just when the muon-pion riddle had been cleared – it took nuclear emulsions and G-M counters to really do it – the Wilson chamber produced evidence for the "V-particles".

There were V_1 and V_2, up to V_4 - neutral and charged, later they became θ, τ, Λ, Σ...

The masses were centered around two values: around 1/2 of the proton mass and larger than the proton mass.

Most strange, their abundant production was at odds with their slow decay. The production cross section was clearly $\sim$mb, the lifetimes 10^{-9}–10^{-10} s, c=30 cm/ns.



Rochester and Butler, 1947

There is an earlier claim by Leprince-Ringuet, 1943.

Strangeness

To resolve the strong production-slow decay conflict one can try to invoke a selection rule, after inventing a quantum number.

We know today of very many additive quantum numbers or charges but 50 years ago it appeared more natural to begin with a mutiplicative attribute, a sort of parity $\mathcal{Q}$, as Abraham Pais suggested.

Specifically all new particles had $\mathcal{Q}$ negative while the old particles have $\mathcal{Q}$ positive. For Pais production of a pair of any V is okay.

The right way was that of Gell-Mann, who assigns to the new particles an additive QN S, shown in the table in today's notation.

Particle	S
p, n, π	0
K^+, K^0	1
K^-, $\bar{K}^0$	-1
Λ, Σ	-1
$\bar{\Lambda}, \bar{\Sigma}$	1

This was initially resisted because it implies that a neutral particle, the K^0 is different from its antiparticle, the $\bar{K}^0$. We can experimentally prove that it is indeed so.

With the assignment goes the rule that S is conserved in strong interactions, while in weak interactions $|\Delta S| = 0, 1$

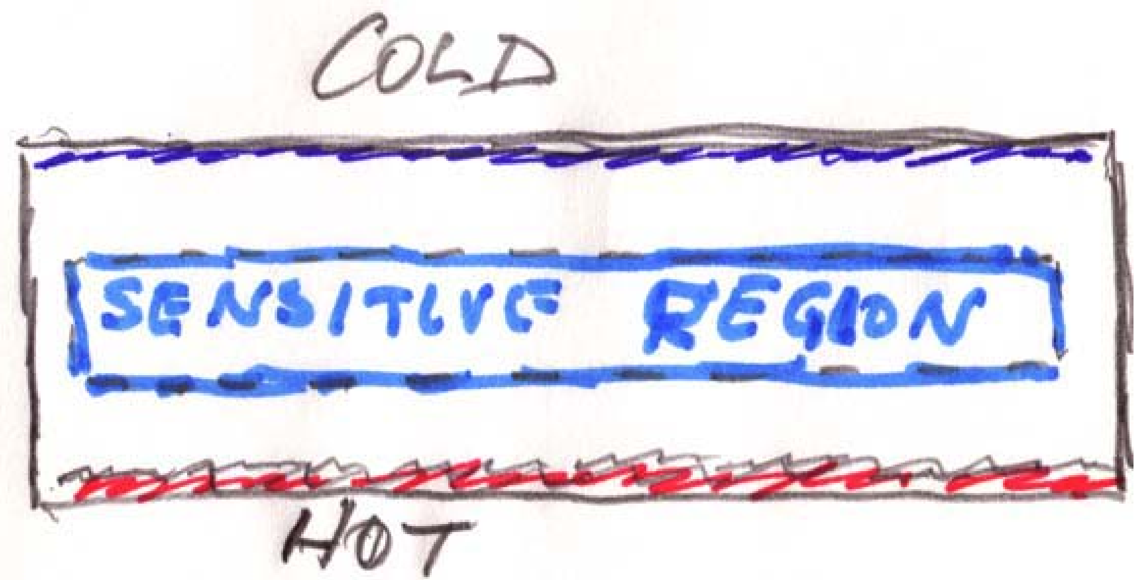
Strange particles are produced conserving S which leads to the idea of associated production: strange particles are always produced in pairs: $\Lambda + K$, $K^0 + \overline{K}^0 \ldots$. For instance

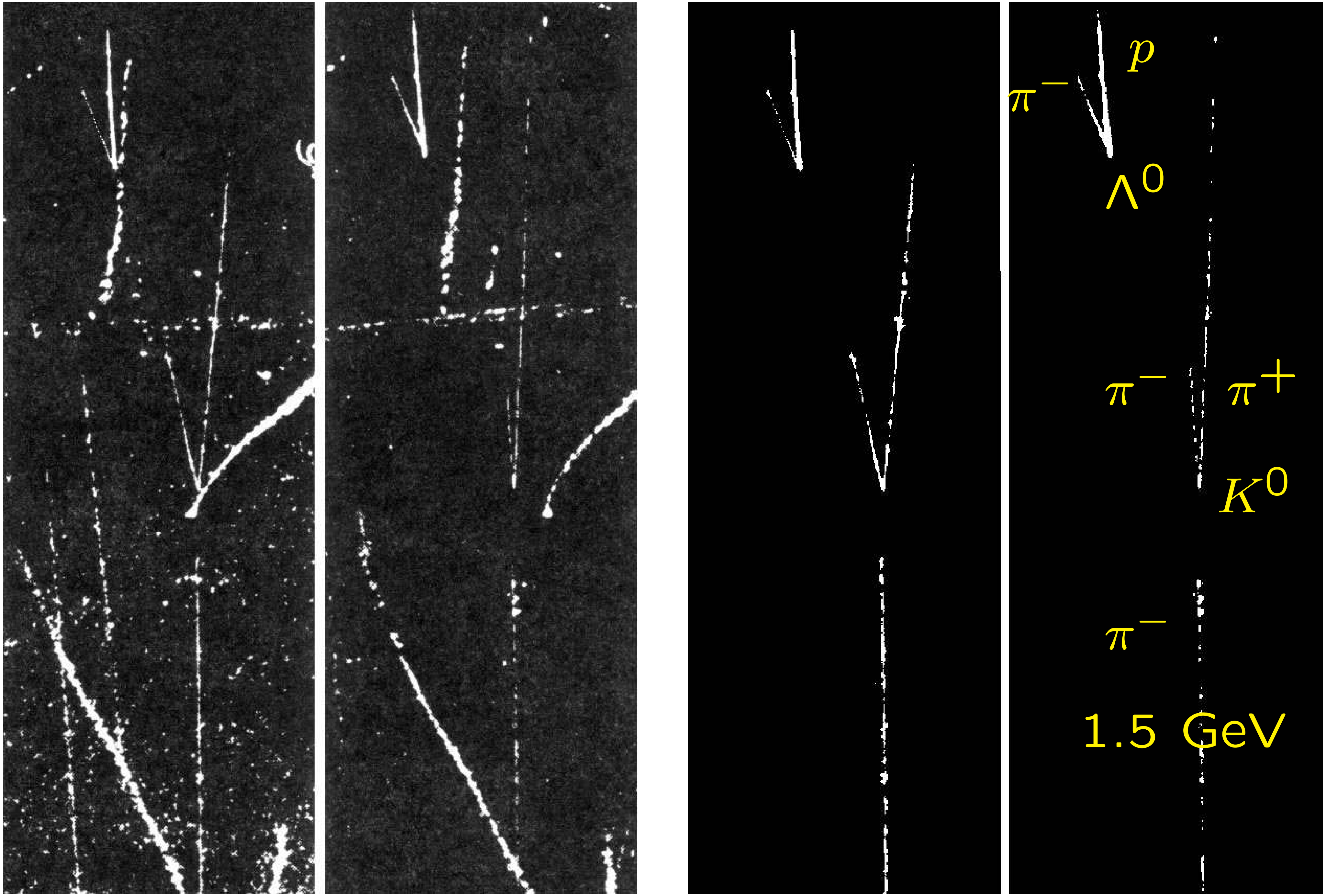
$$\begin{aligned} \pi^- + p &\to \Lambda^0 K^0 \\ &\to \Sigma^- K^+ \\ &\not\to \Sigma^+ K^- \\ &\not\to K^+ K^+ \pi^- \pi^- n \end{aligned}$$

It took the first proton synchrotron, the BNL Cosmotron, 3 GeV p and a diffusion chamber to verify the above.
The last two reactions are allowed by Pais.

In 1953 Fowler and Shutt exposed a H_2 diffusion chamber to a beam of negative pions of 1.5 BeV kinetic energy. Today we would say $p\sim 1.64$ GeV/c.

The diffusion chamber needs no expansion. A super-saturated region is constantly present in the middle of the chamber because of a temperature gradient. The chamber is hot at the bottom, where liquid is present, cold at the top.




p
π^-
Λ^0
π^-
π^+
K^0
π^-
1.5 GeV

$\sim$1/2 of Λ's have K^0 observed. All events – 6 – are consistent with a K^0 produced.

The way to study strange particles for the next two decades!

$$K^0, \overline{K^0}, K_1, K_2$$

Pais and Gell-Mann
$K^0 \Leftrightarrow \overline{K}^0$, C or CP eigenstates are K_1, K_2.

$$K_1 = \frac{K^0 + \overline{K}^0}{\sqrt{2}}$$
$$K_2 = \frac{K^0 - \overline{K}^0}{\sqrt{2}}$$

But $\Gamma(K_1) \gg \Gamma(K_2)$ since $K_2 \to \pi^+\pi^-$, $\pi^0\pi^0$ is forbidden.

Expect $\tau(K_2)\sim 1000\tau(K_1)$
In 1956 Chinowski, Lande and Lederman placed a diffusion chamber at a distance of 6 m from an internal target at the Cosmotron.

At a distance corresponding to $\sim 100\tau(\theta^0)$, CL&L conclusively observed 3 body decays of kaons, thus proving the existence of the K_2.

Many experiments have studied neutral kaons. In particular we know $\tau_1=0.89\times 10^{-10}$ $\tau_2=5.17\times 10^{-8}$

At this point the cloud chamber disappears from particle physics, replaced for a while by the bubble chamber.

RIP