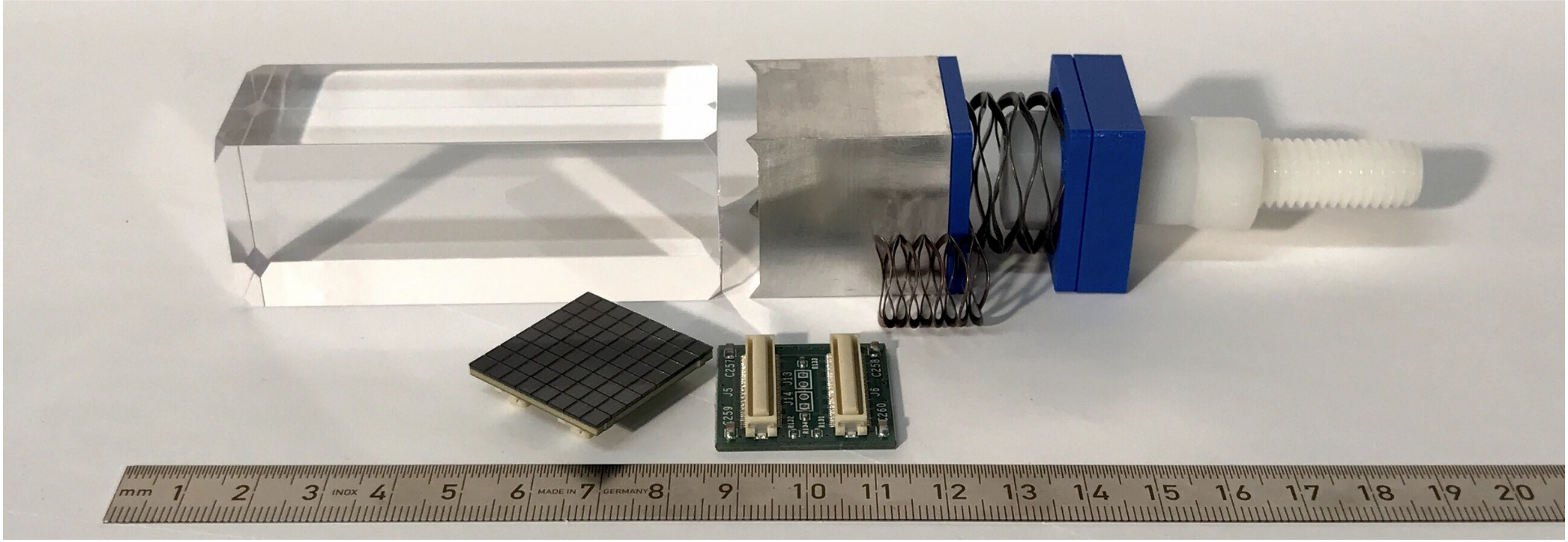


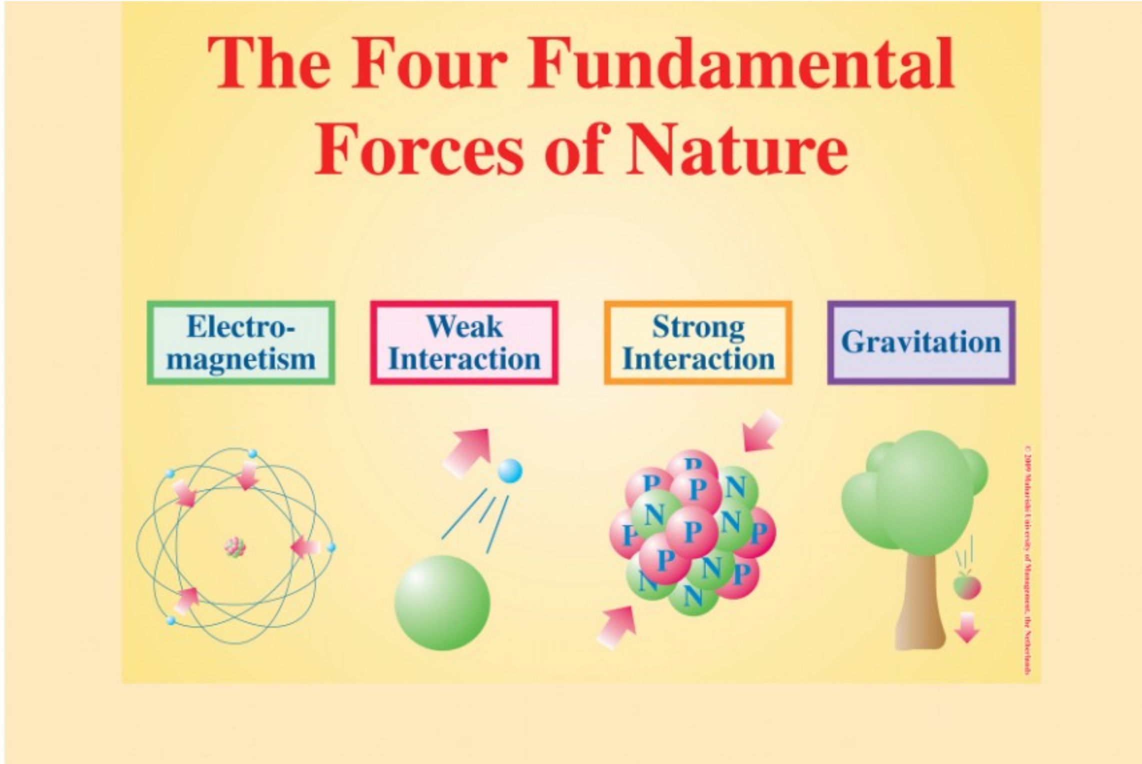
PARTICLE DETECTORS

Particle Physics 2020

IRAKLI KESHELASHVILI – I.KESHELASHVILI@FZ-JUELICH.DE

JÜLICH Forschungszentrum

Which forces can we use for acceleration



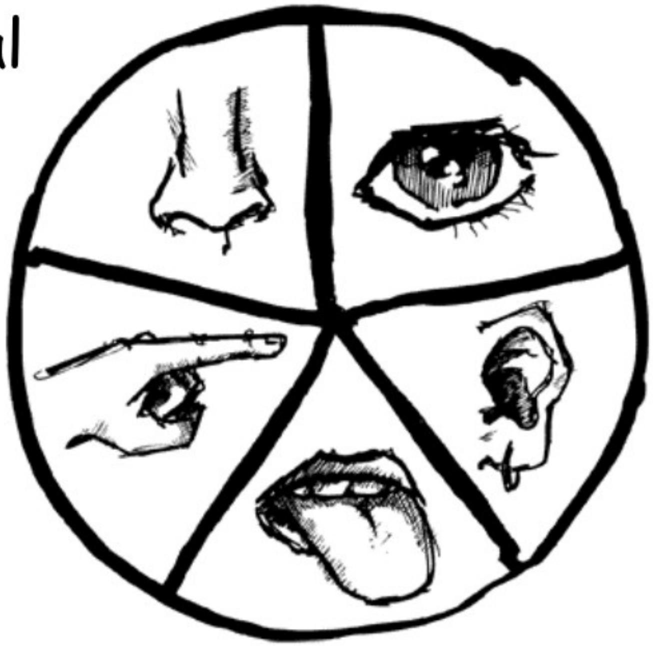
PROPERTIES OF THE INTERACTIONS

Property \ Interaction	Gravitational	Weak (Electroweak)	Electromagnetic (Electroweak)	Strong: Fundamental	Strong: Residual
Acts on:	Mass – Energy	Flavor	Electric Charge	Color Charge	See Residual Strong Interaction Note
Particles experiencing:	All	Quarks, Leptons	Electrically charged	Quarks, Gluons	Hadrons
Particles mediating:	Graviton (not yet observed)	W^+ W^- Z^0	γ	Gluons	Mesons
Strength relative to electromag for two u quarks at: 10^{-18} m	10^{-41}	0.8	1	25	Not applicable to quarks
Strength relative to electromag for two u quarks at: 3×10^{-17} m	10^{-41}	10^{-4}	1	60	
for two protons in nucleus	10^{-36}	10^{-7}	1	Not applicable to hadrons	20

Why we need particle detectors?

Charged & Neutral

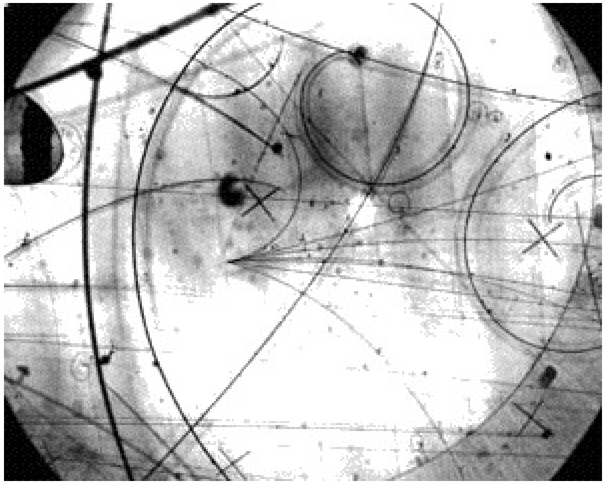
Smaller than the visible photons

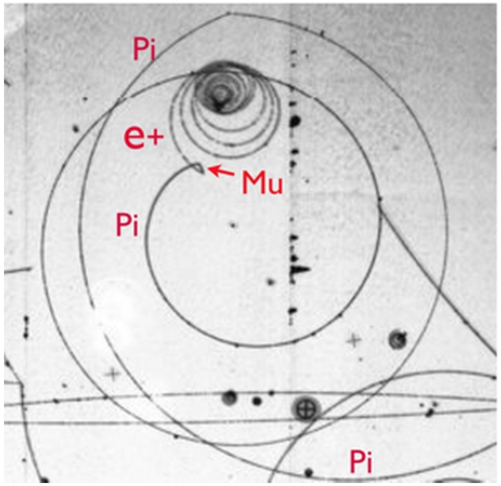


Too Small for the nerves

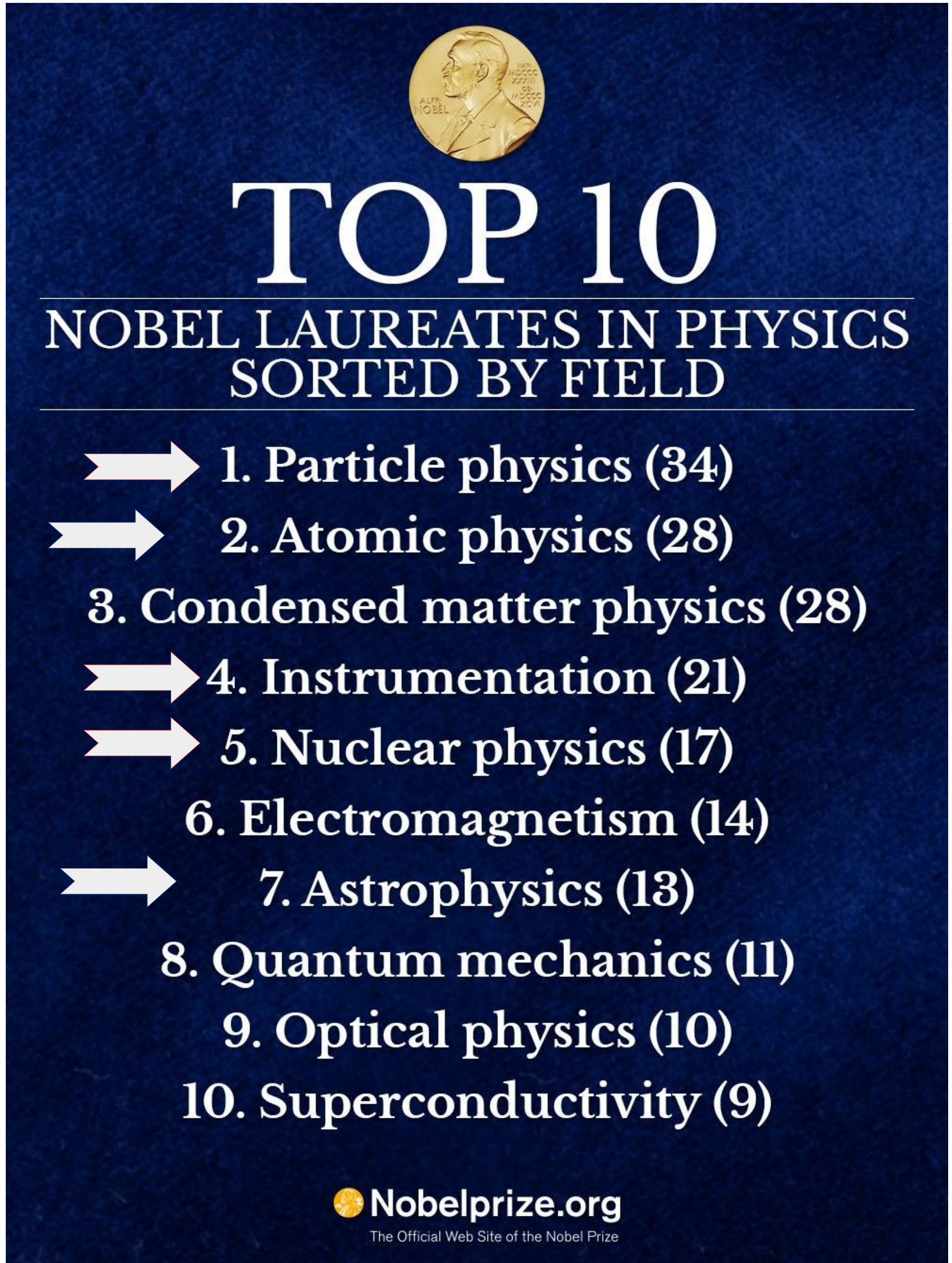
This we always do :)

Smaller than molecules





Importance of scientific instruments



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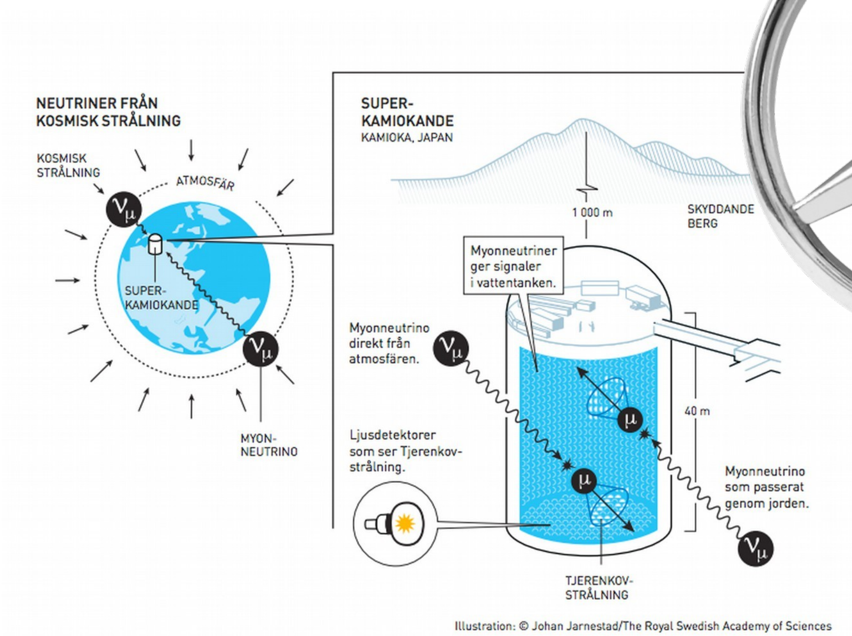
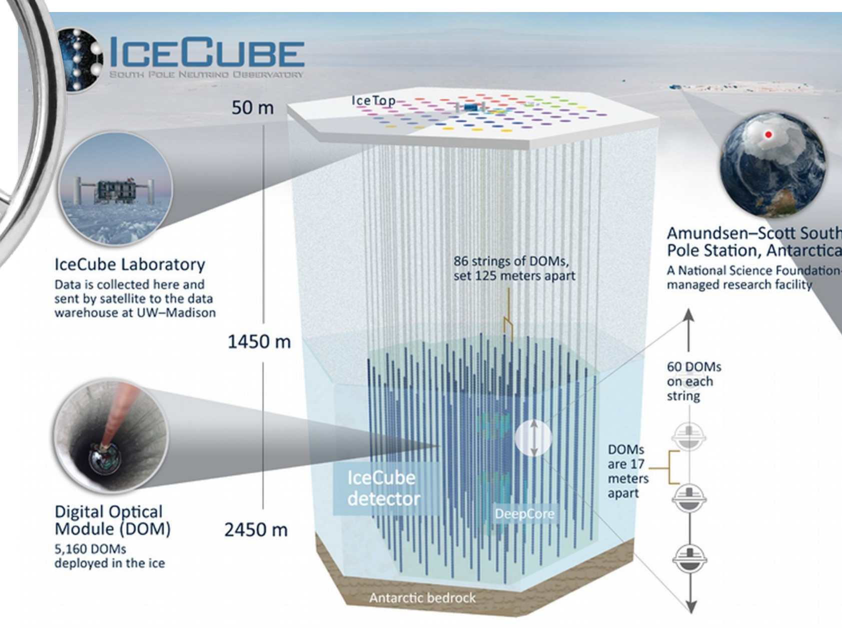
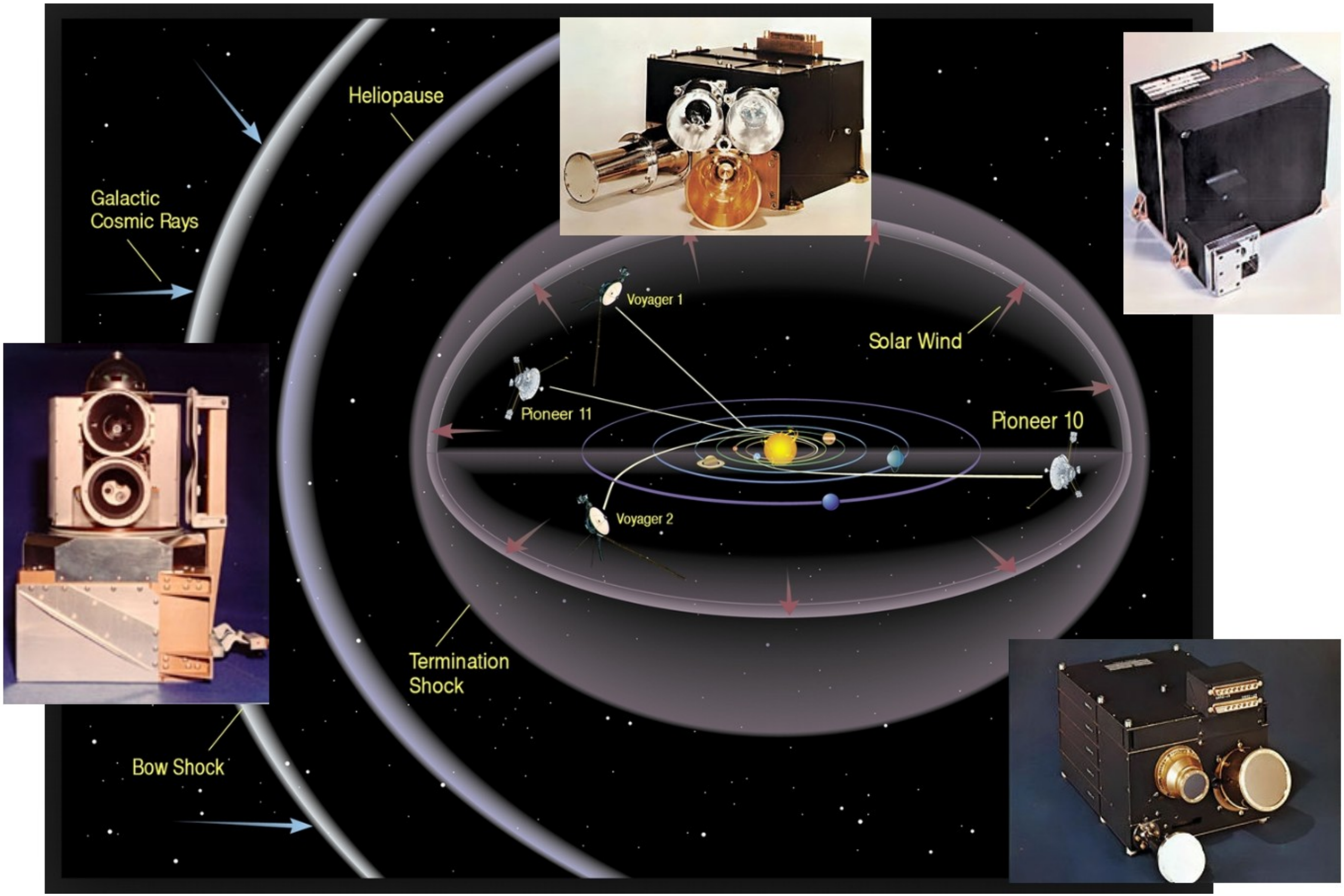
Detectors are everywhere





Voyager & Pioneer

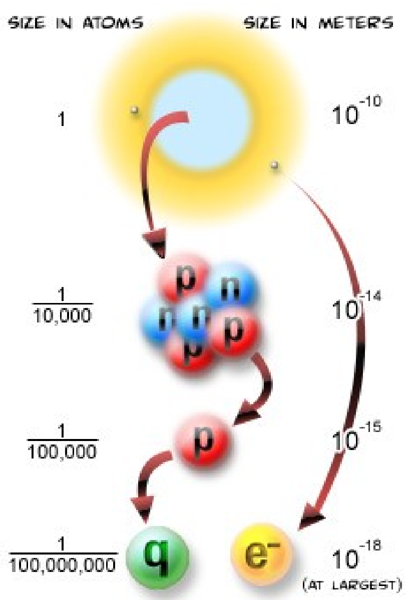


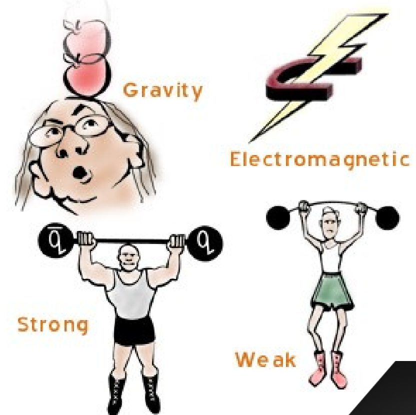
The Radiation Assessment Detector, or RAD

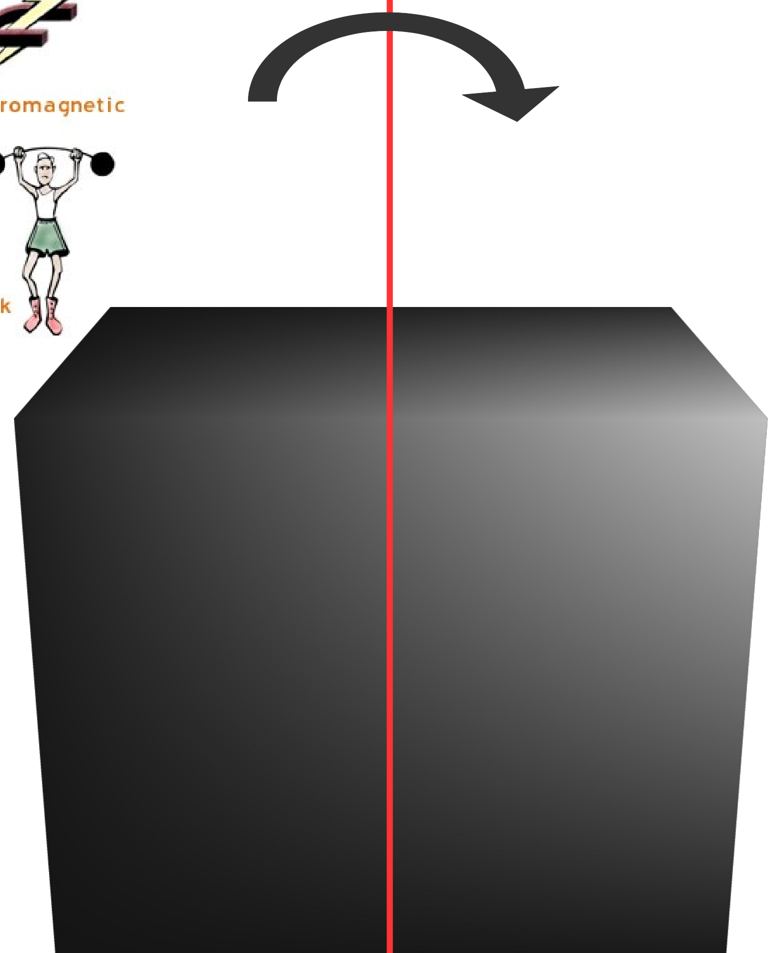
will monitor naturally occurring radiation that can be unhealthful if absorbed by living organisms. It will do so on the surface of Mars, where there has never before been such an instrument, as well as during the trip between Mars and Earth.

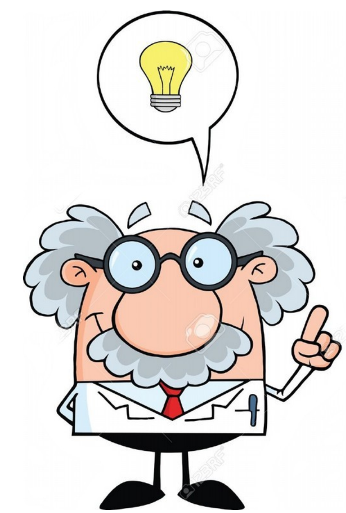
Not human readable world!

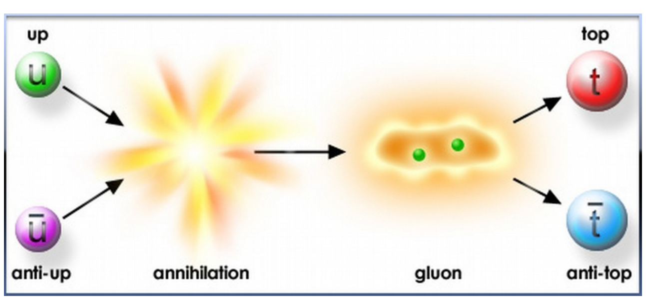
Human readable world!



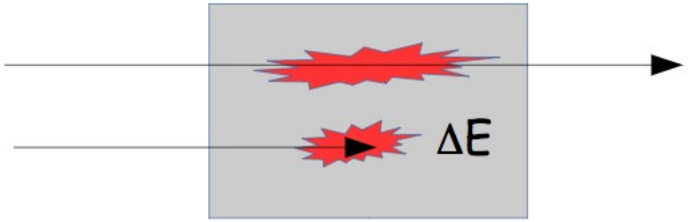








Only the result of an interaction with matter will be observed



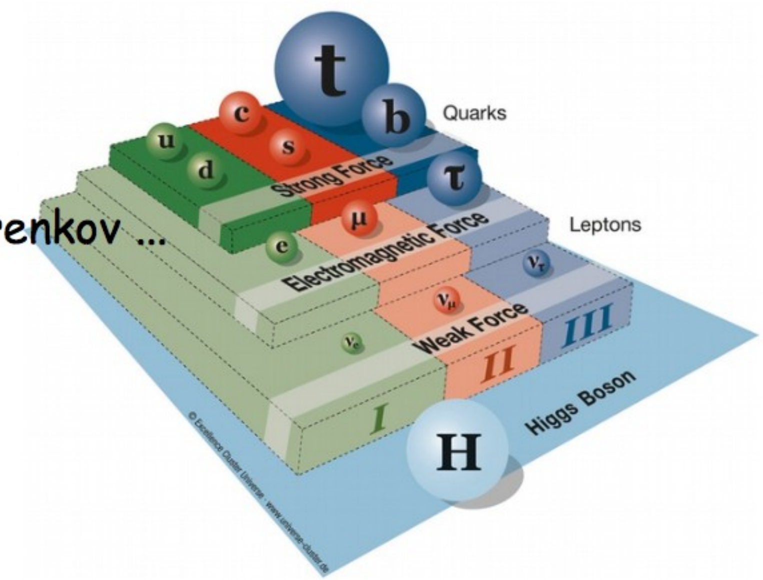
The detection of particles happens

via their ΔE in the material it traverses ...

Charged particles: Ionization, Bremsstrahlung, Cherenkov ...

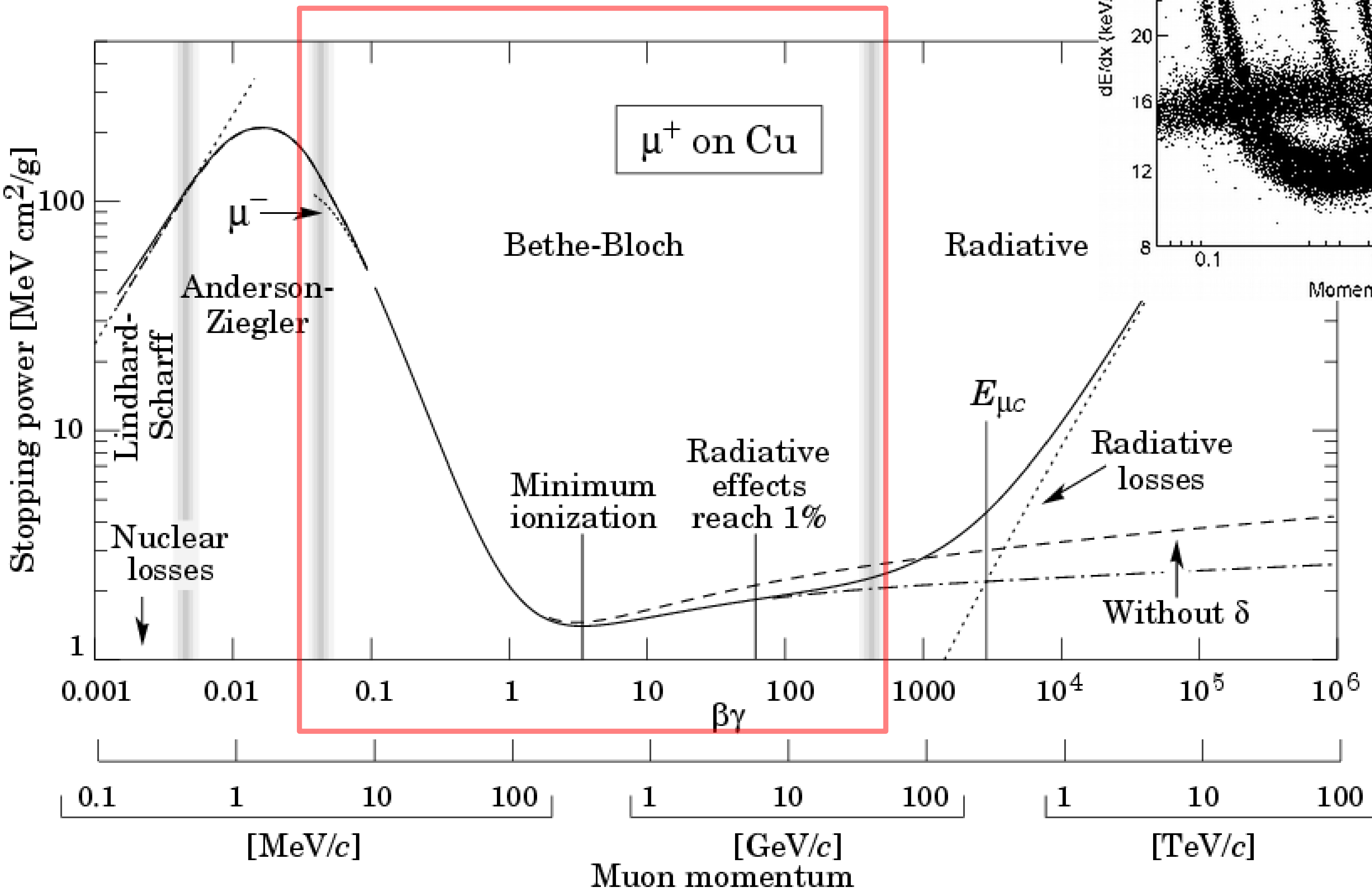
Photons: EM → Photo, Compton, pair production

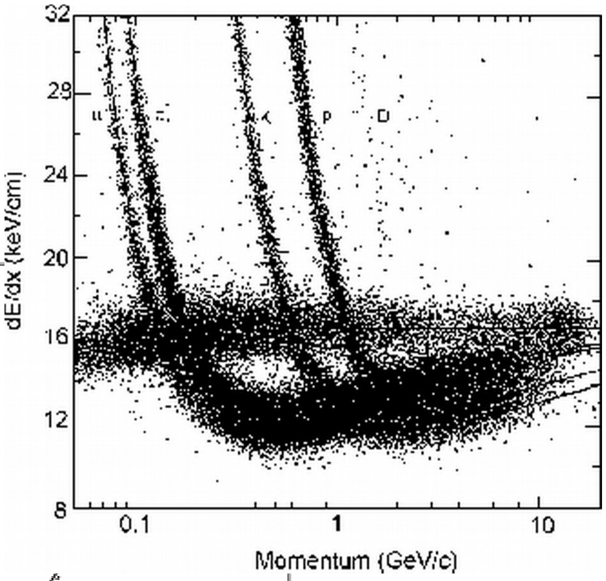
Hadrons: Strong, EM, Weak interactions



Bethe-Bloch stopping power

$$-\frac{dE}{dx} = K \cdot z^2 \cdot \frac{Z}{A} \cdot \frac{1}{\beta^2} \cdot \left[\frac{1}{2}\ln\frac{2m_ec^2\beta^2\gamma^2T_{\max}}{I^2} - \beta^2 - \delta/2\right]$$





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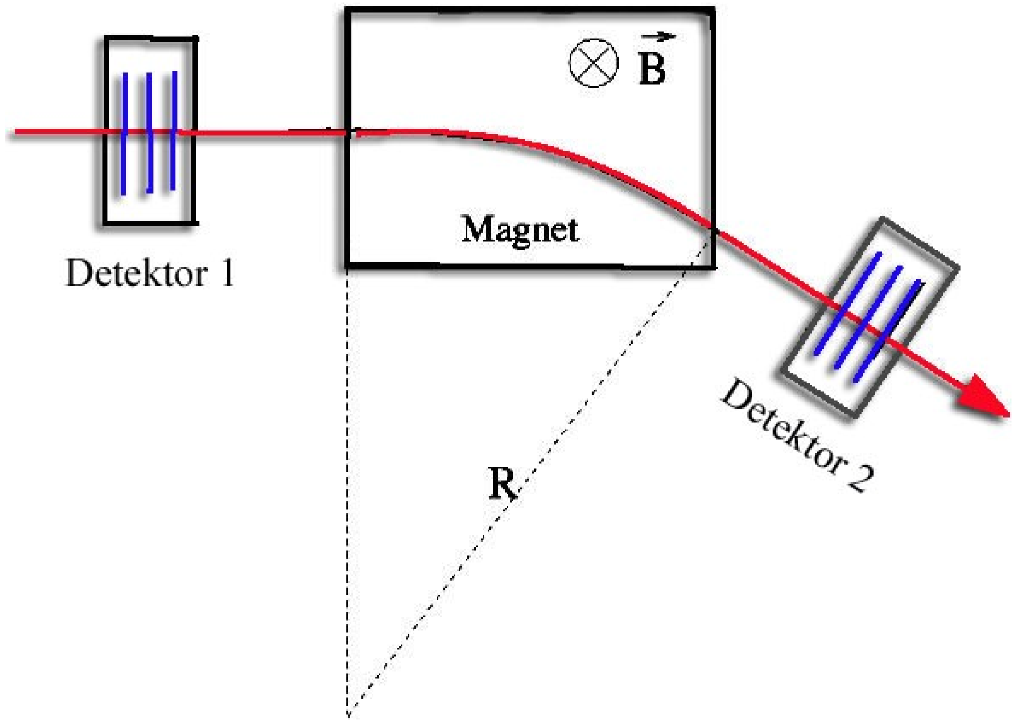
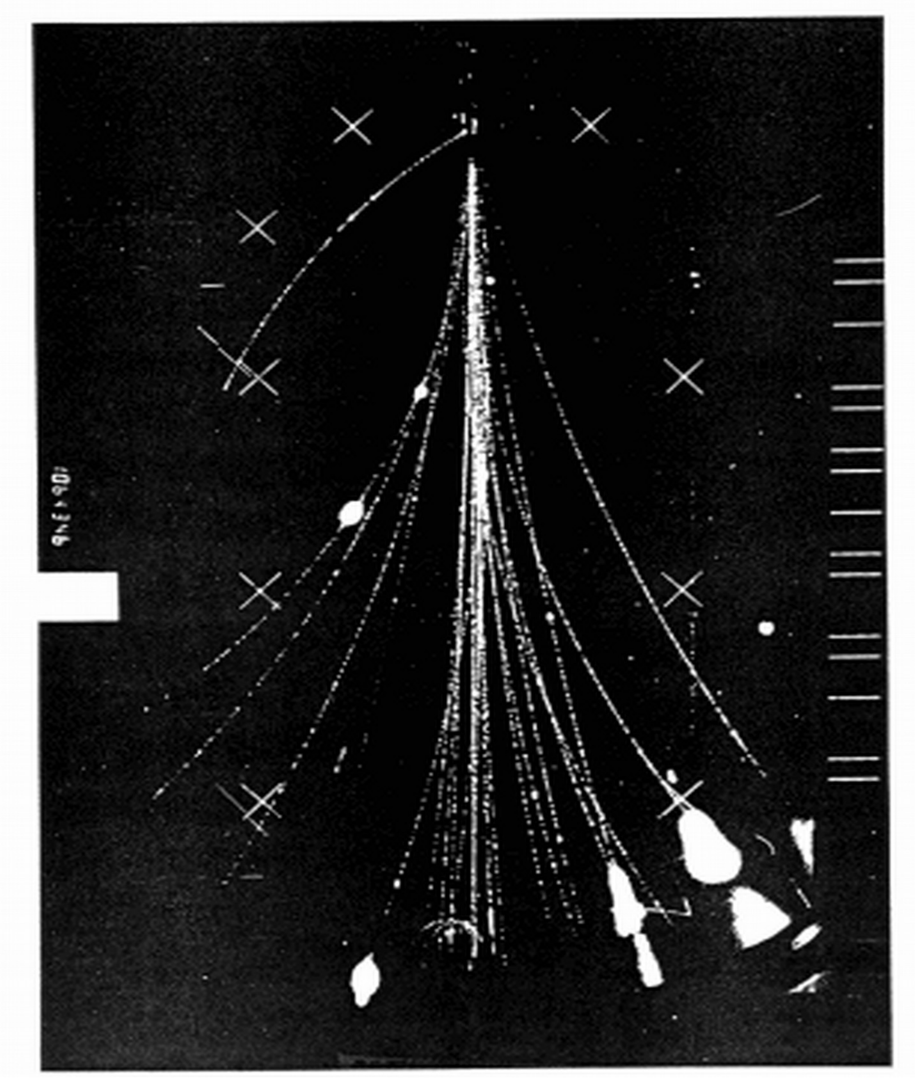
Momentum measurement



$$F = q \cdot (v \times B)$$

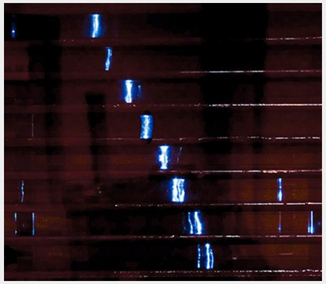


Classification

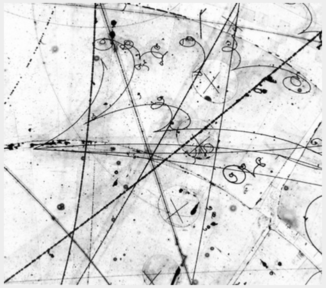
Track visualization

- Cloud/Wilson chamber (supersaturated vapor) 1911; Nobel 1927

- Spark chamber 1930 tracking



- Bubble chamber (superheated liquid) 1952; Nobel 1960



Direct e-charge signal

Gaseous

- Geiger–Müller tube: *1908; radiation*
- Ionization chamber
  flux measurement
- MWPC Multi-wire proportional chamber: *1968, energy, tracking*
- Straw tubes: *energy, tracking*
- Drift chamber: *energy, tracking*
- GEM & micromegas
- TPC Time projection chamber
  3D, energy, traking
- TRD Transition radiation detector
- RPC Resistive plate chamber
  Very precise time measurement

Semiconductor

- Silicon detectors
  vertex reconstruction strip, drift, pixel, ...
- Germanium detectors
  energy measurement
- Diamond detectors
  luminosity detectors
- ? MCP micro-channel plate ?

Photon signal → electric signal

Scintillation

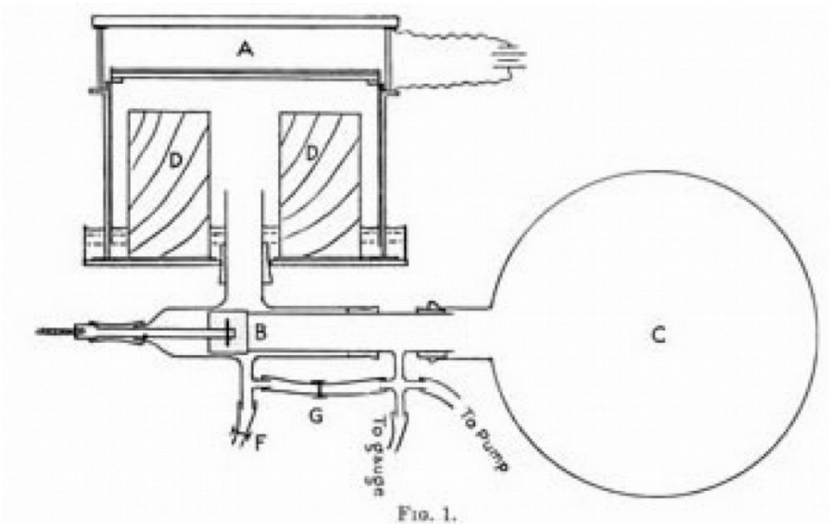
- Organic Plastic
  energy, position, TOF, tracking, fast triggers, dE/E,…
- Liquid: *energy, position, tracking, dE/E, neutron, ...*
- **Inorganic**
  precise energy measurement in very large scale

Cherenkov

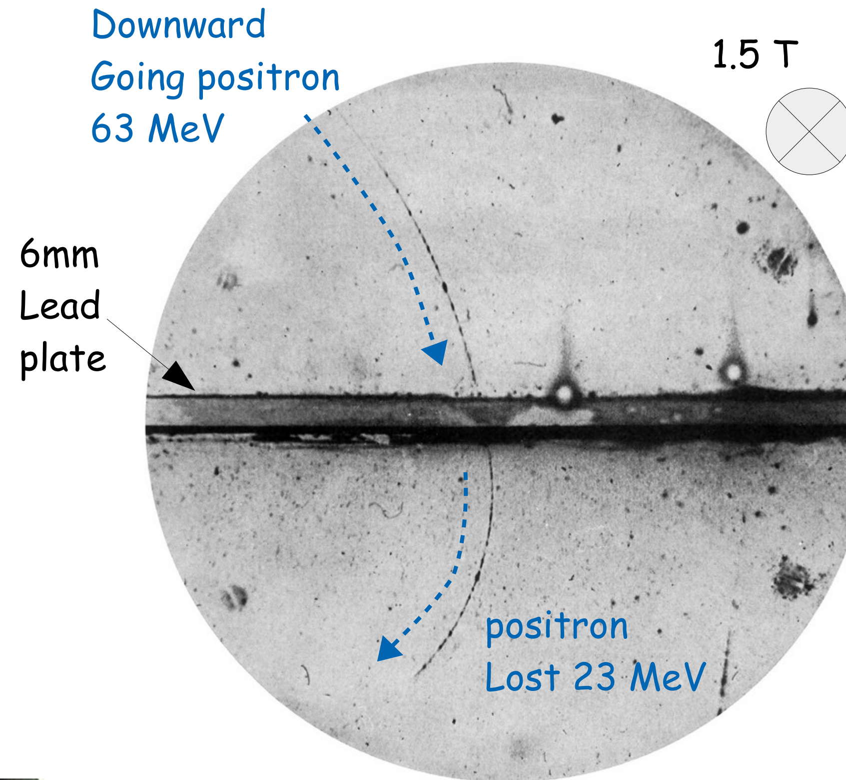
- Gaseous, Aerogel
  relativistic particles
- Liquid, solid; *medium energy*
- RICH – ring image Cherenkov
  momentum, charge, direction
- DIRC – Detection of Internally Reflected Chrenkov light

Cloud / Wilson chamber

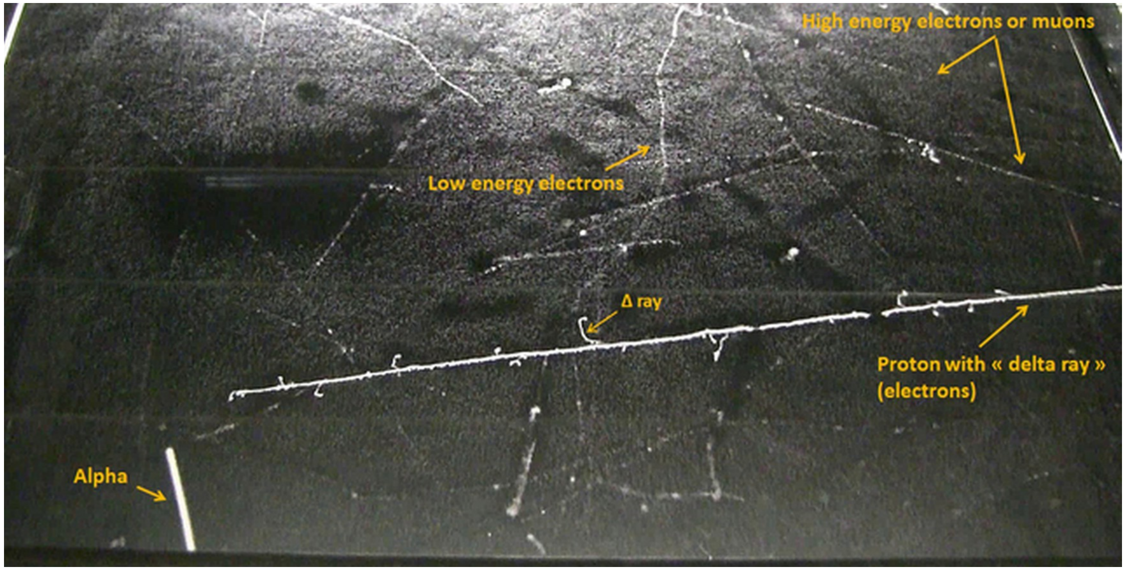
- supersaturated vapor 1911; Nobel prize 1927



A diagram of Wilson's apparatus. The cylindrical cloud chamber ('A') is 16.5cm across by 3.4cm deep.



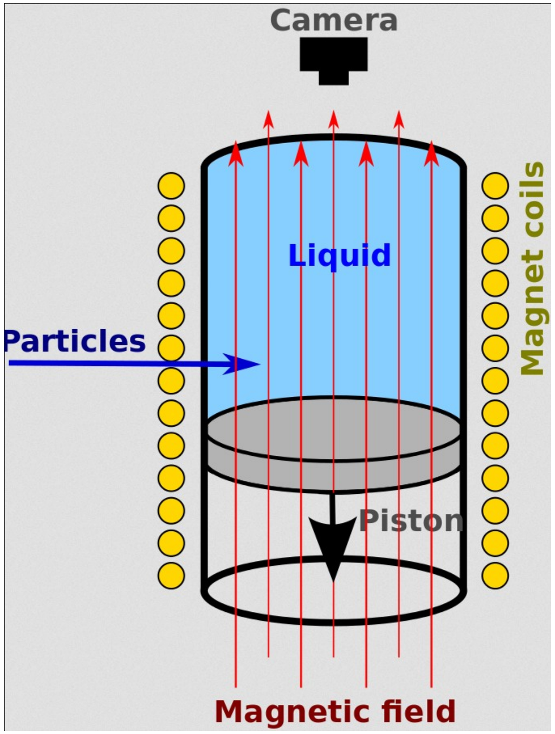
Smaller radius defines the track direction

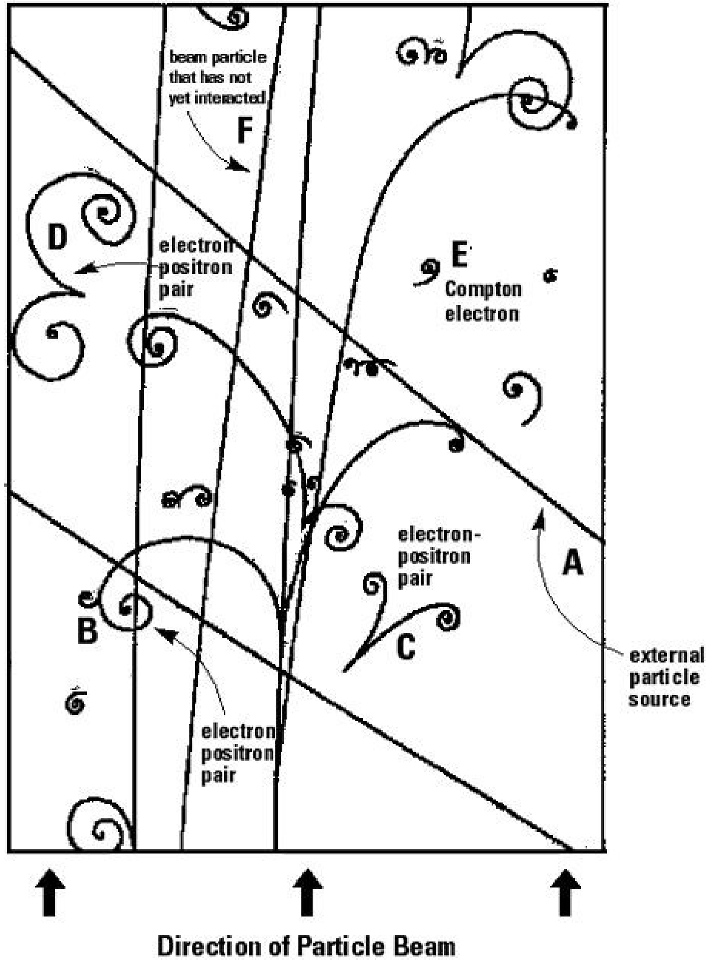


Bubble chamber

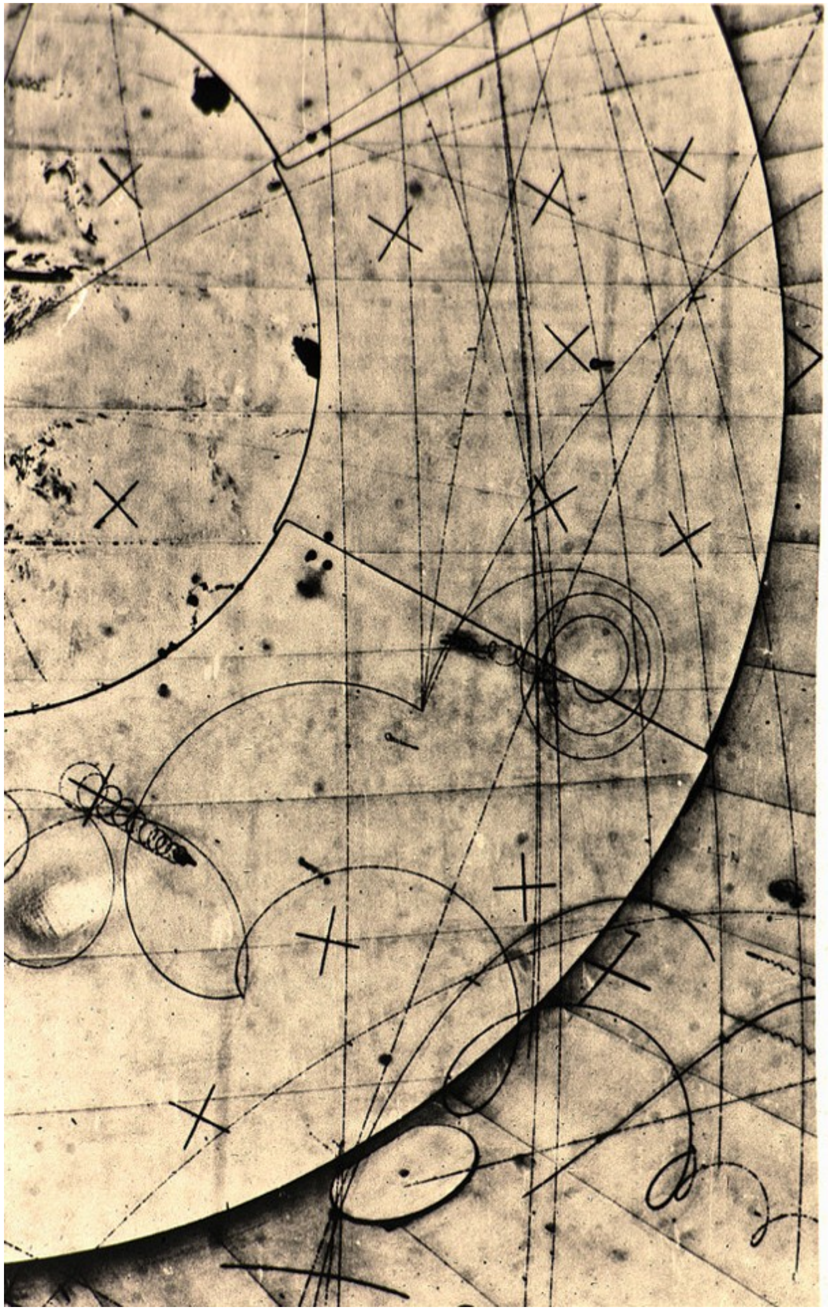
A bubble chamber is a vessel filled with a **superheated transparent liquid** (most often liquid hydrogen) used to detect charged particles moving through it.

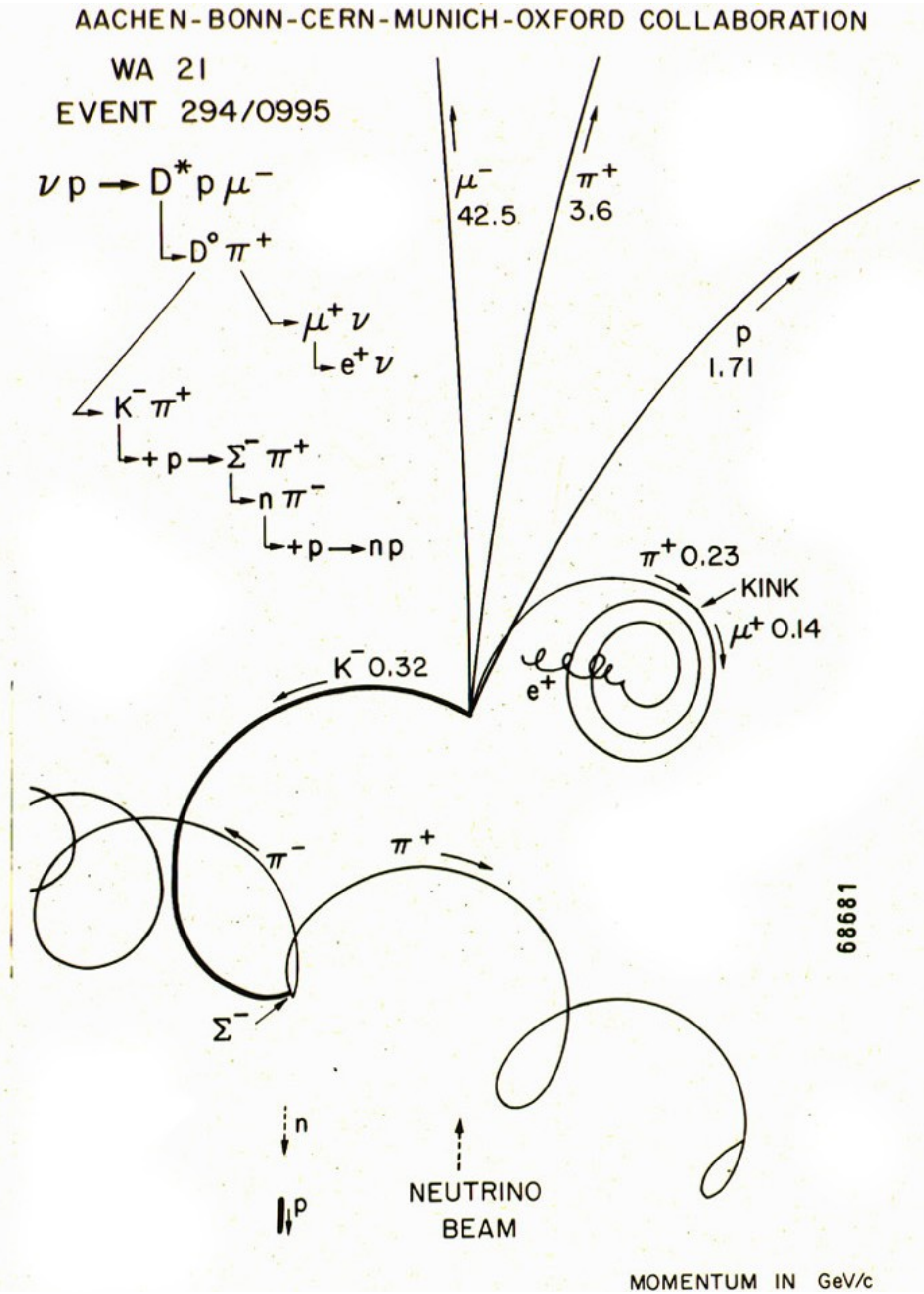
It was invented in 1952 by Donald A. Glaser, for which he was awarded the 1960 Nobel Prize in Physics.





Bubble chamber: D meson production and decay





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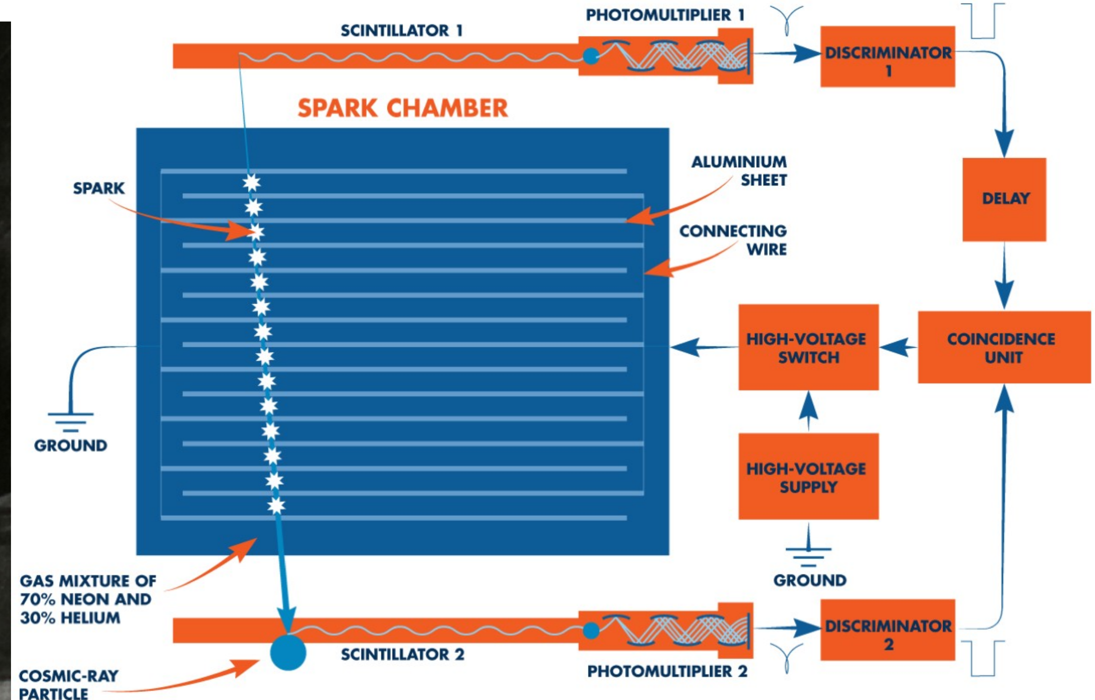
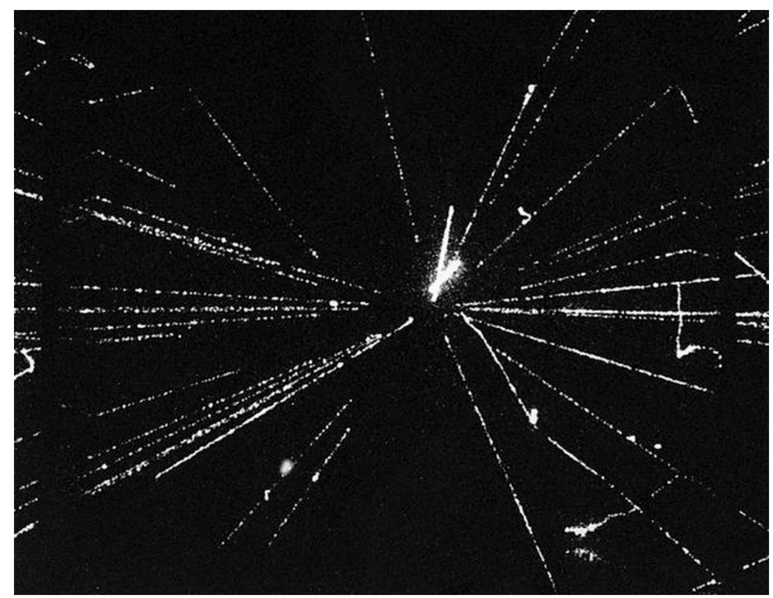
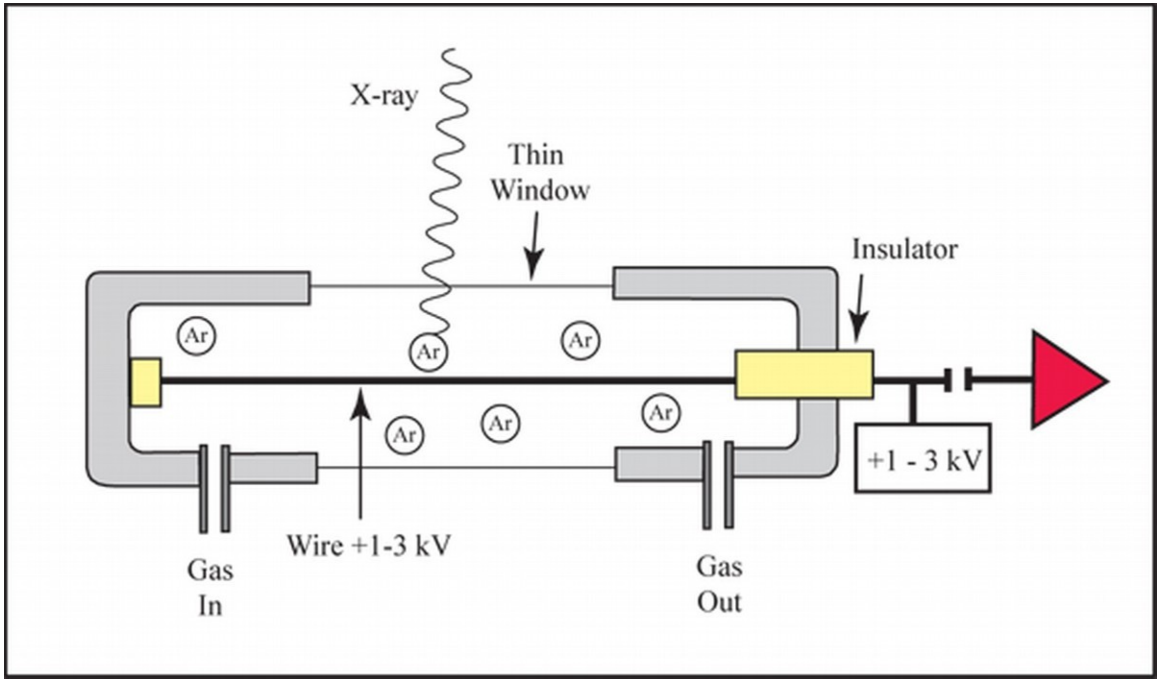
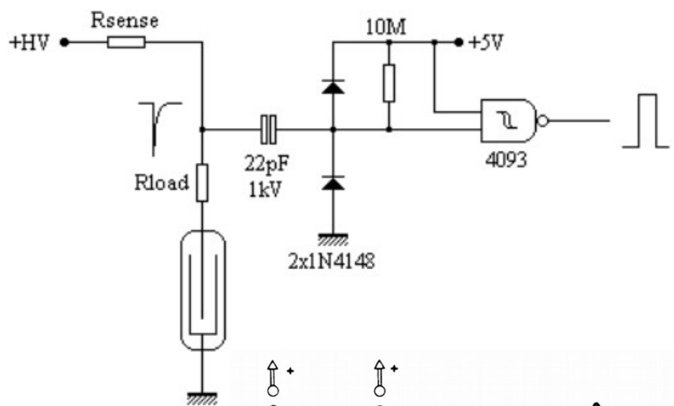

SCINTILLATOR 1
PHOTOMULTIPLIER 1
DISCRIMINATOR 1
SPARK CHAMBER
SPARK
ALUMINIUM SHEET
CONNECTING WIRE
DELAY
GROUND
HIGH-VOLTAGE SWITCH
COINCIDENCE UNIT
HIGH-VOLTAGE SUPPLY
GROUND
GAS MIXTURE OF 70% NEON AND 30% HELIUM
DISCRIMINATOR 2
SCINTILLATOR 2
PHOTOMULTIPLIER 2
COSMIC-RAY PARTICLE

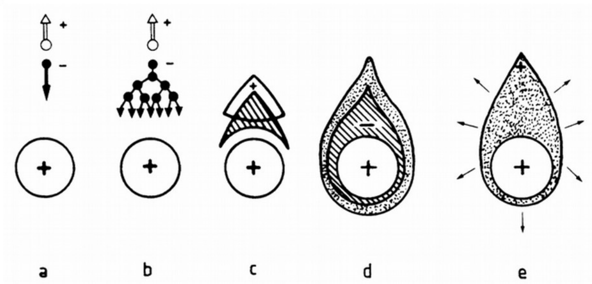


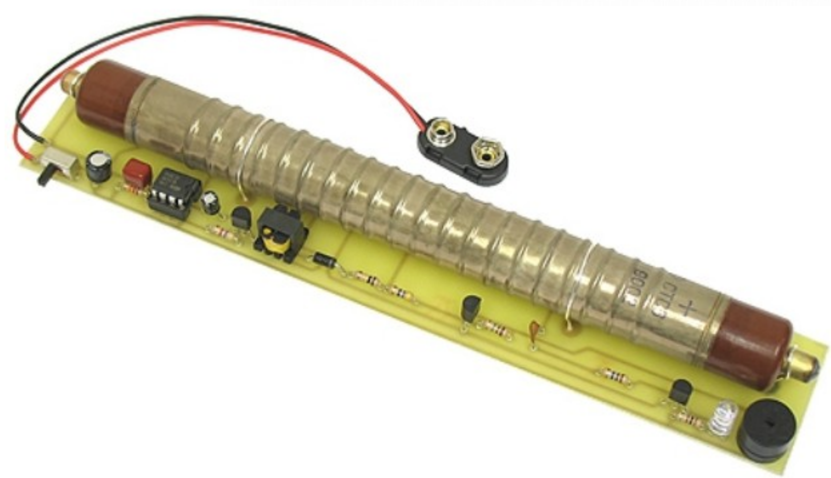
Gaseous Counters

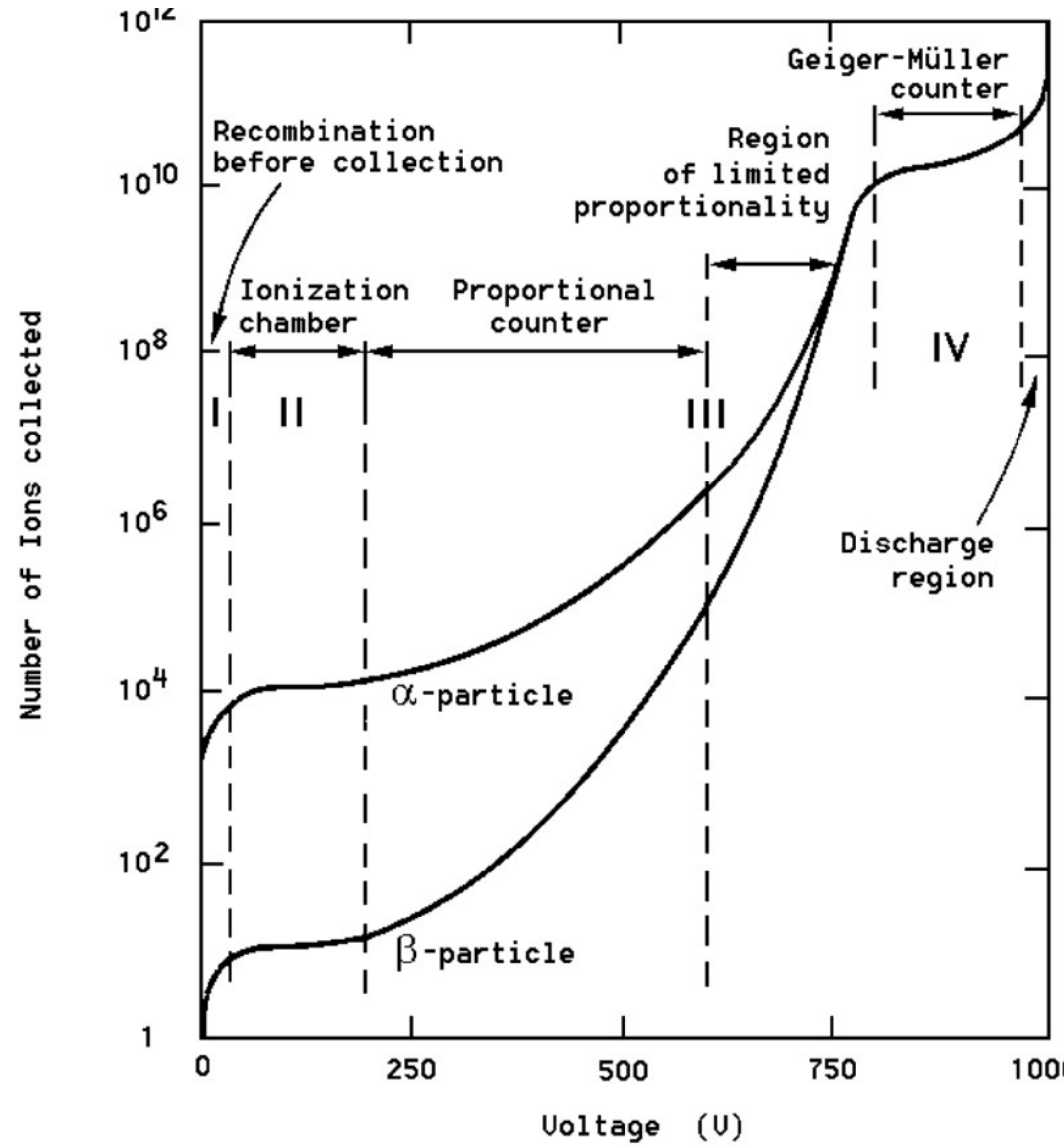


Gaseous detectors

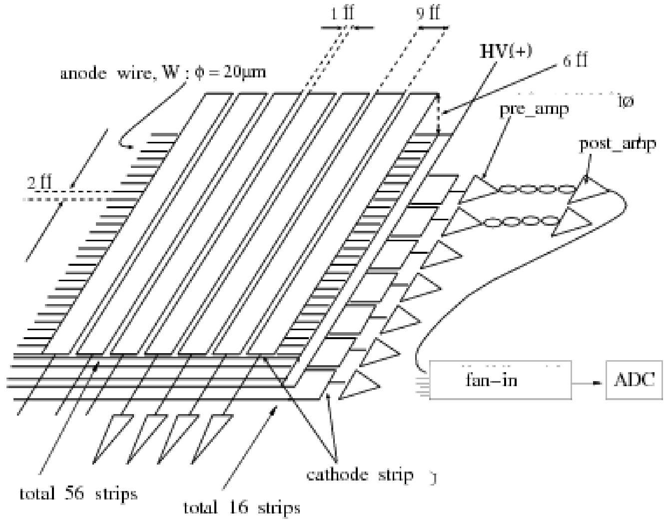


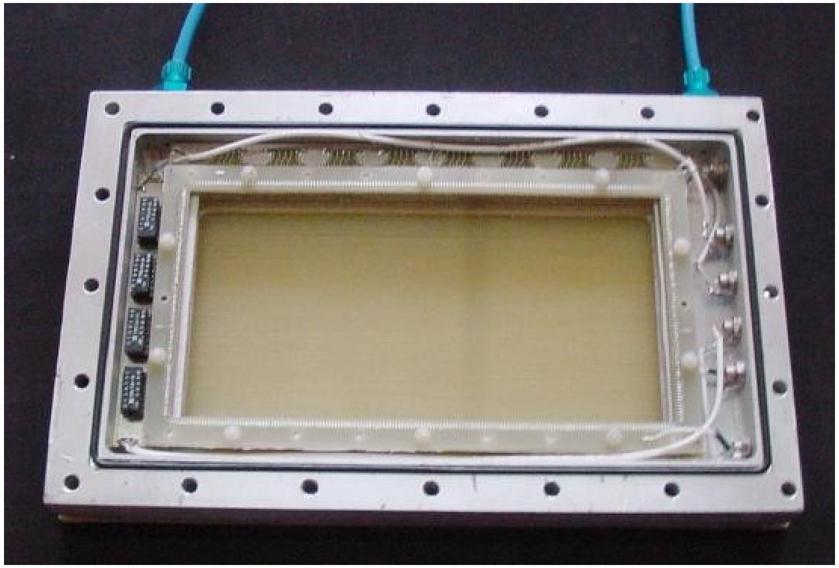


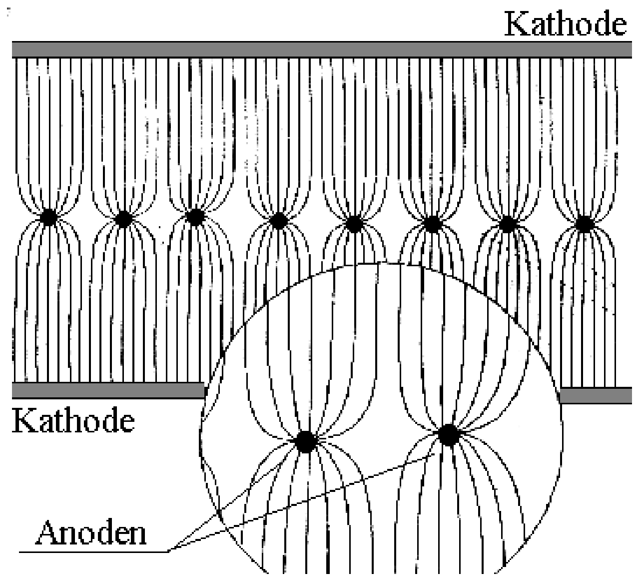


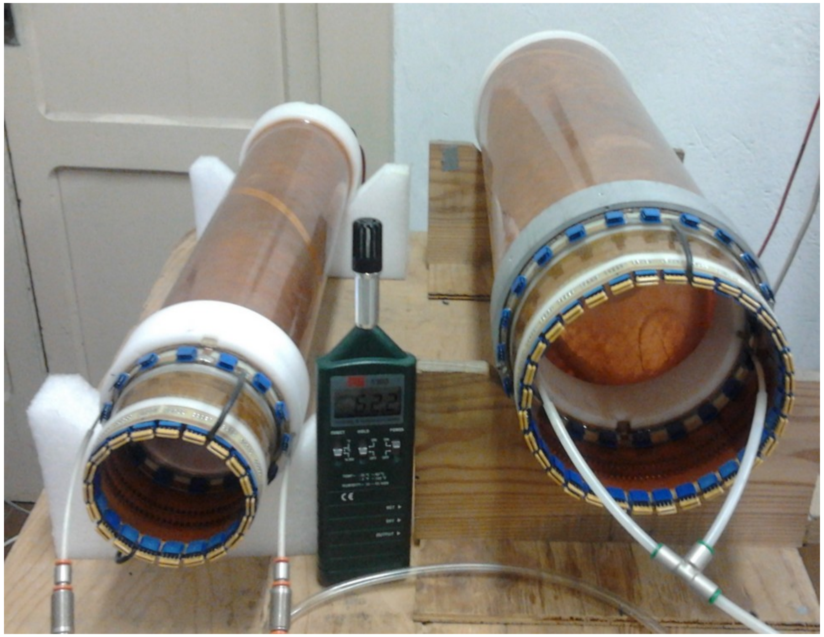


MWPC—multi wire proportional chamber

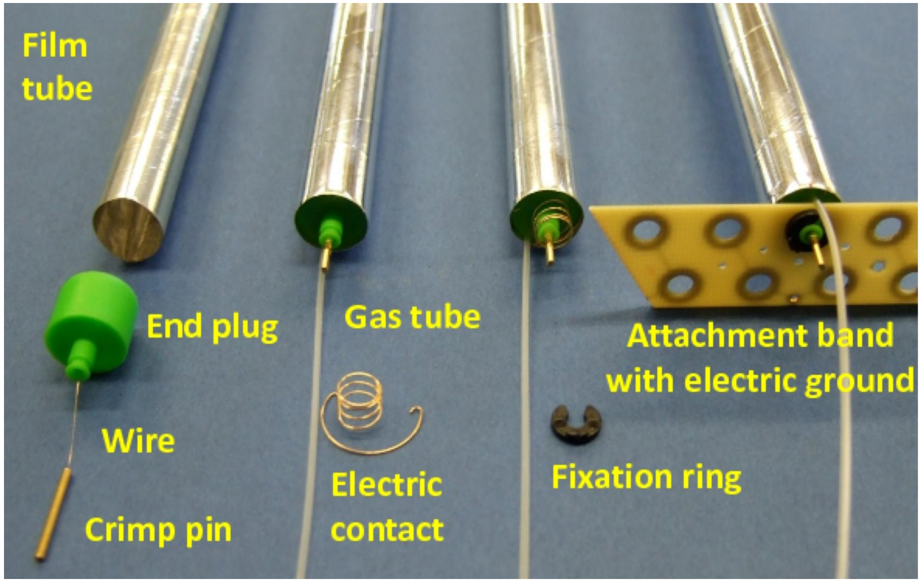


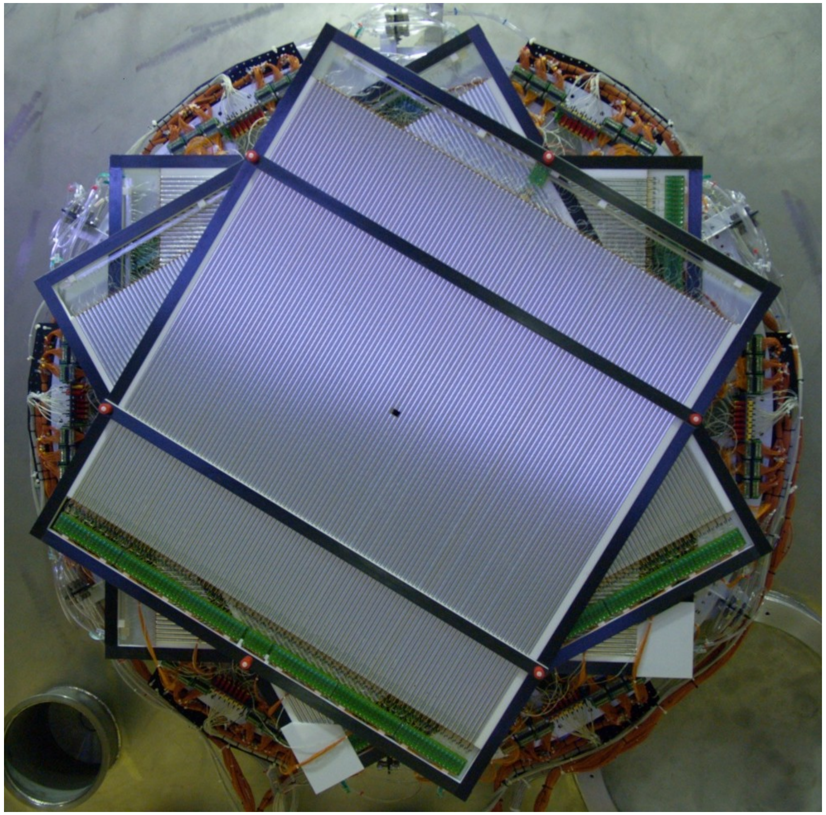


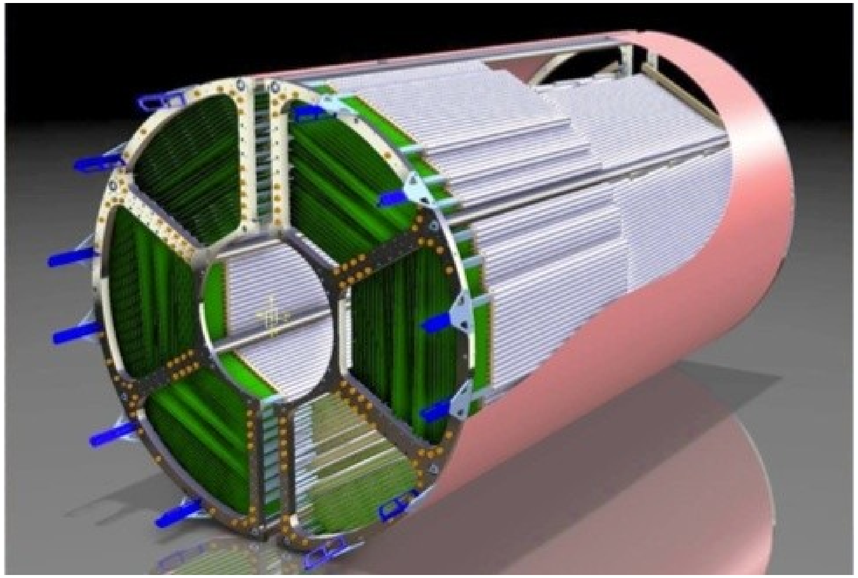


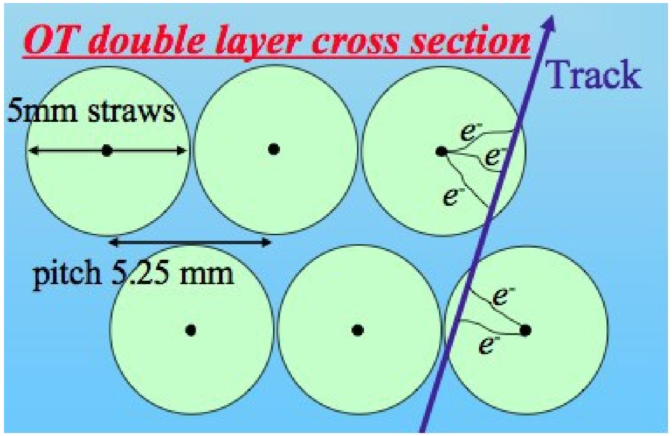


Straw tubes

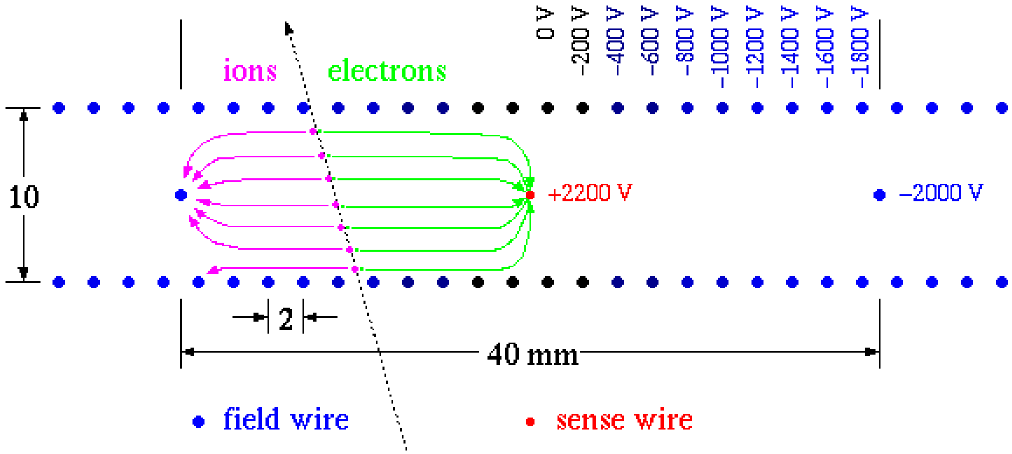

Film
tube
End plug
Gas tube
Attachment band
with electric ground
Wire
Electric
contact
Fixation ring
Crimp pin

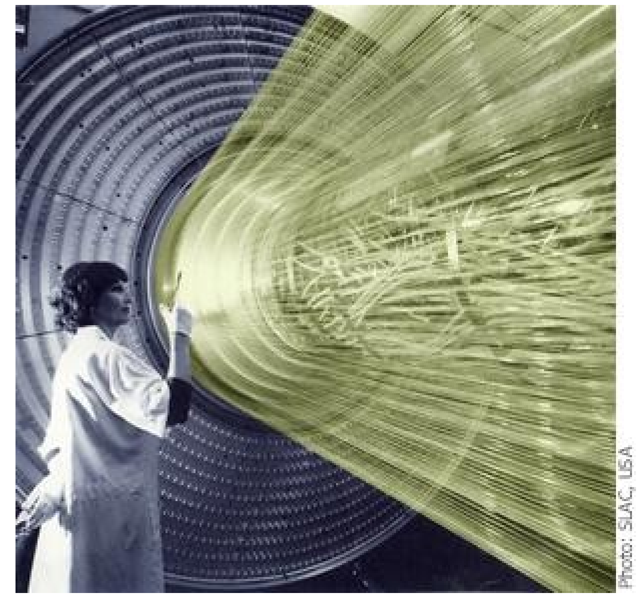


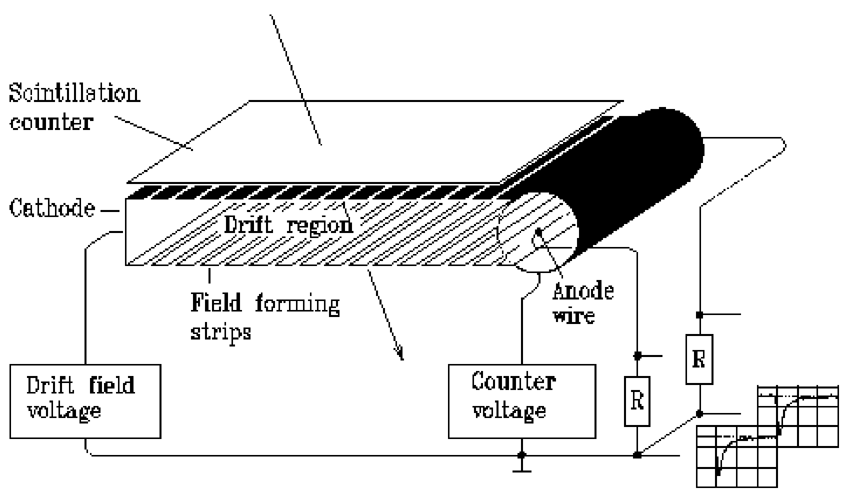


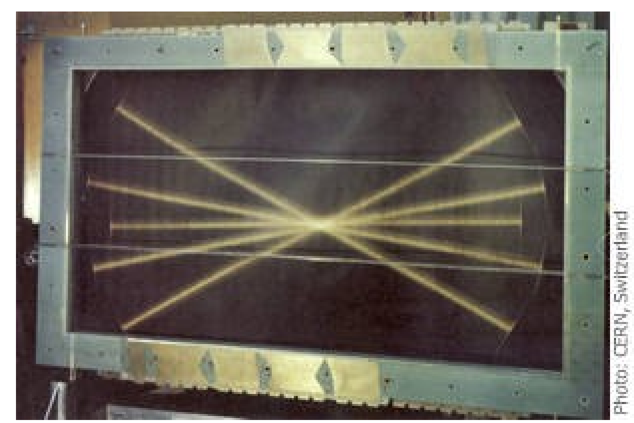

OT double layer cross section
Track
5mm straws
pitch 5.25 mm

MWDC—multi wire drift chamber

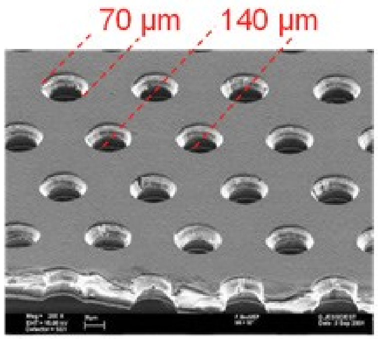


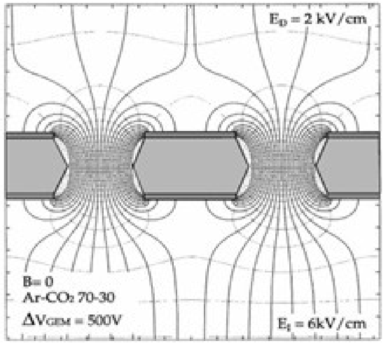


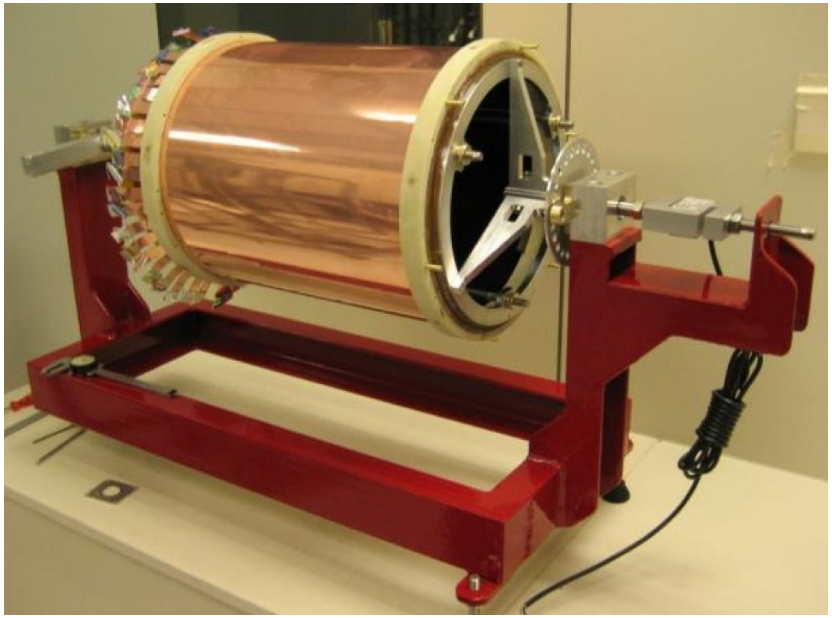


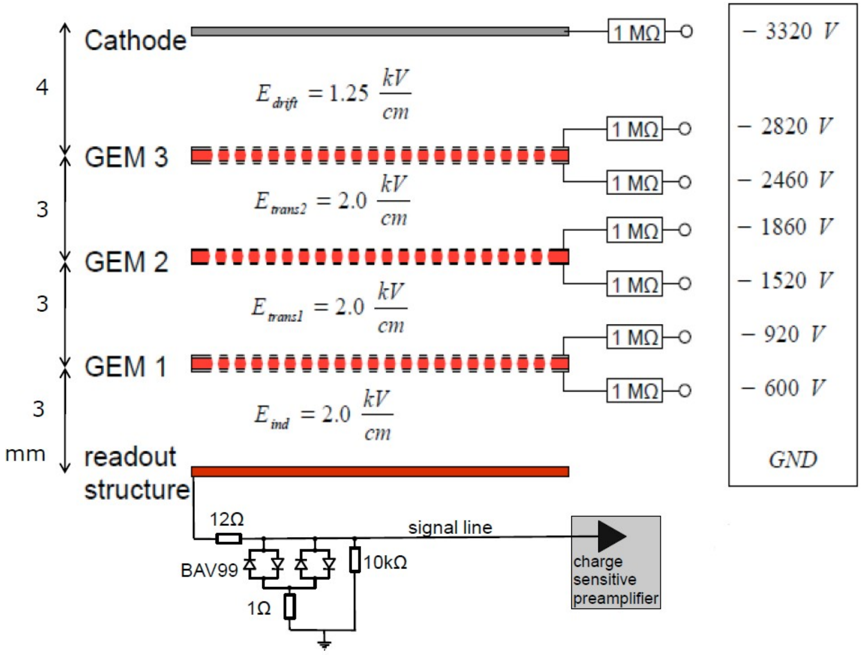


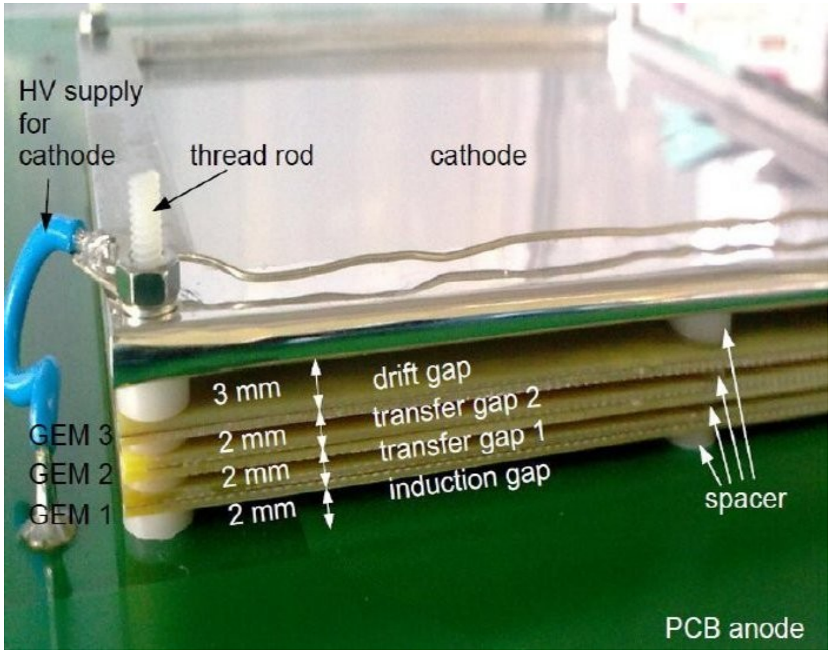
GEM—gas electron multiplier











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TPC—time projection chamber