Methods of Particle Detection

Aaron White

Today

- Review Standard Model
- Particle detection methods slides
- Visit mPandaX

Review the Standard Model

Particles of the Standard Model

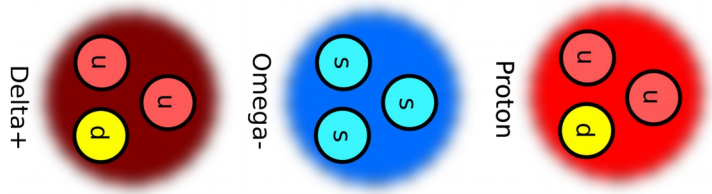
Up	Strange	Top	Electron	Muon	Tau	Photon	Gluon
Down	Charm	Bottom	Electron Neutrino	Muon Neutrino	Tau Neutrino	W±, Z	Higgs

Quarks:
Three makes a **baryon**
Two makes a **meson**

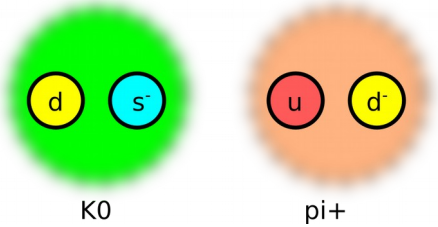
Leptons
Top three are **charged**
Neutrinos are **neutral**

Bosons
The Gauge bosons carry force
The Higgs boson gives some particles mass

Baryons:



Mesons:



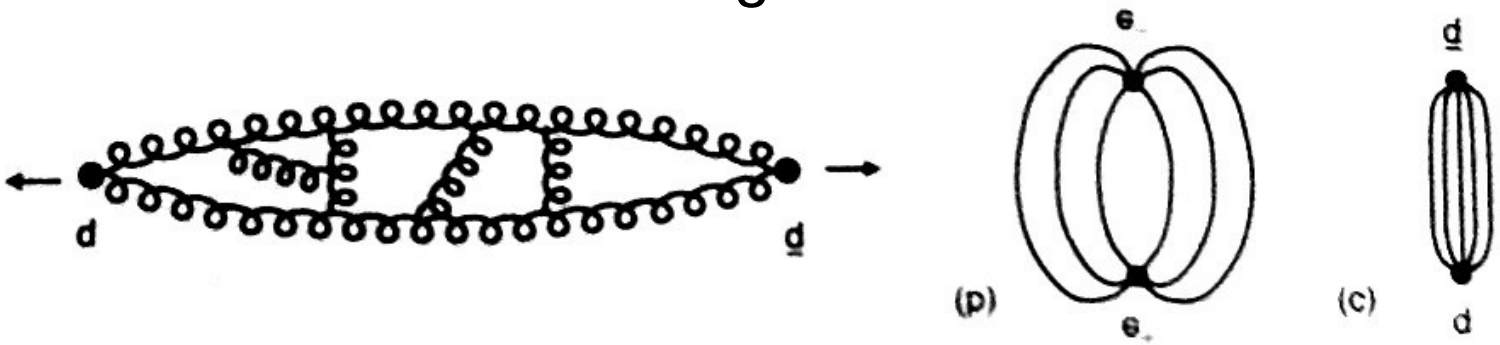
Strong Force and Gluons

$V=k*r^2$

- Attractive between all quarks
- Confinement:
  - Quarks interact w/ each other
  - Unlike photons carrying electric field
  - Field lines don't spread out
  - **Constant** force over long distance

$V=k*r^{-1}$

$V=k*r$



Modern Particle Physics, Mark Tomson

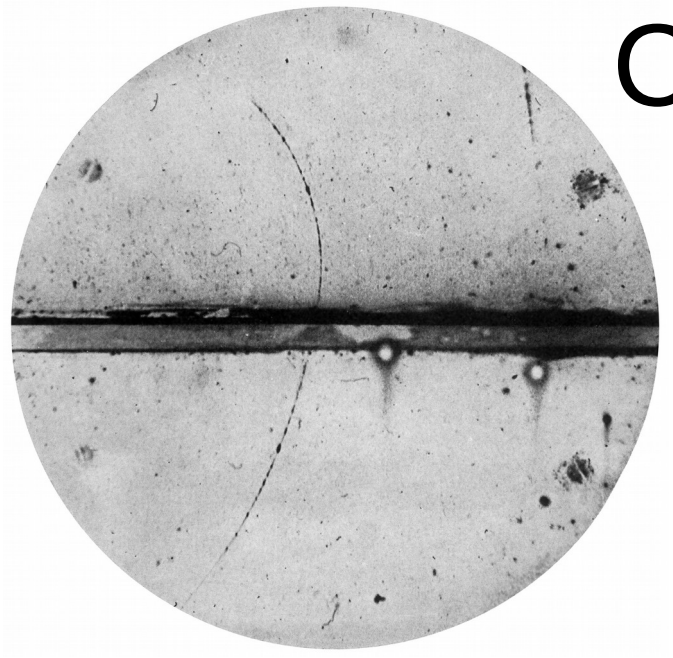
So how do we see them?

(You know one method already)

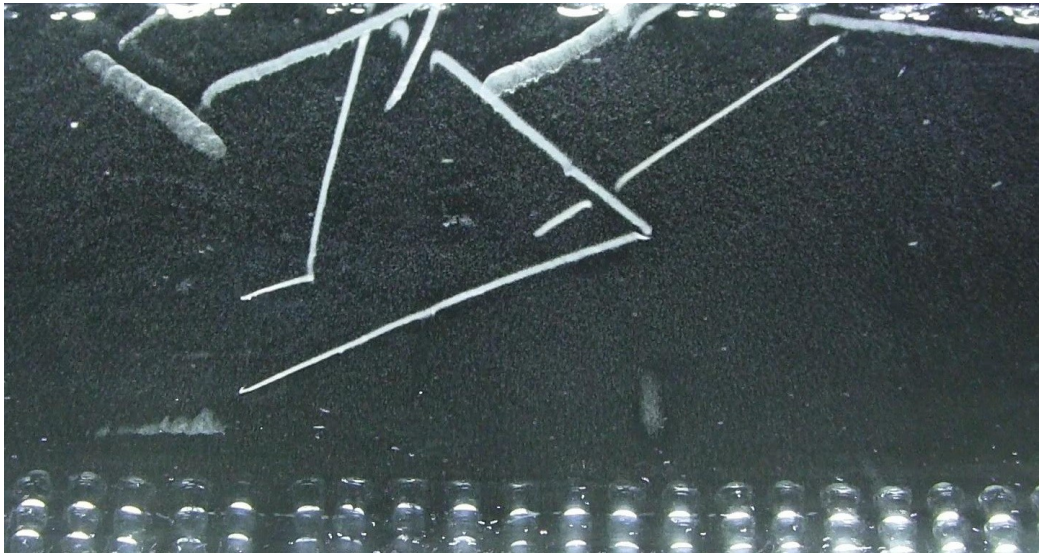
Cloud Chamber

- Super saturated vapor (water, alcohol)
- Charged particle ionizes atoms in path, vapor condenses, creates track
- Portable, experiments carried out in balloons and on mountains
- Magnetic field can allow momentum, charge analysis
- Place lead bar in middle, watch particles interact
- Can ID particles based on track: thickness, etc
- Can see decays
- Discovered: e+, muon, K0, lambda0, sigma-, pion

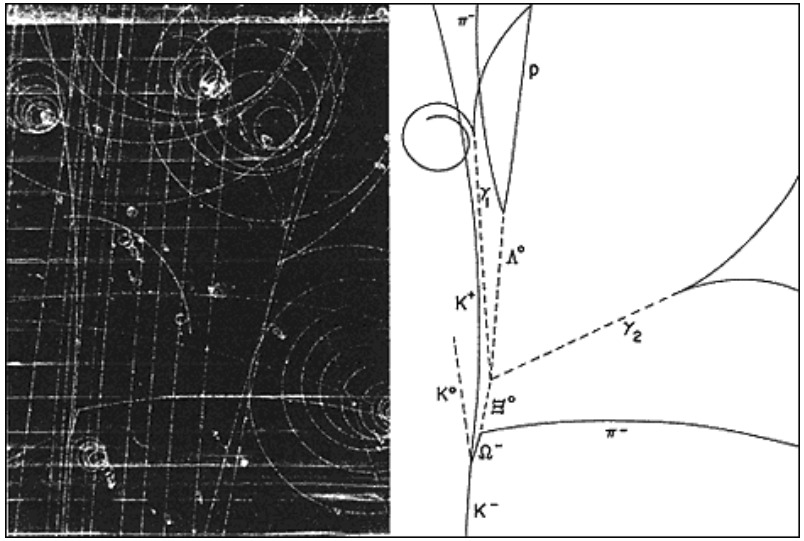
Cloud Chamber



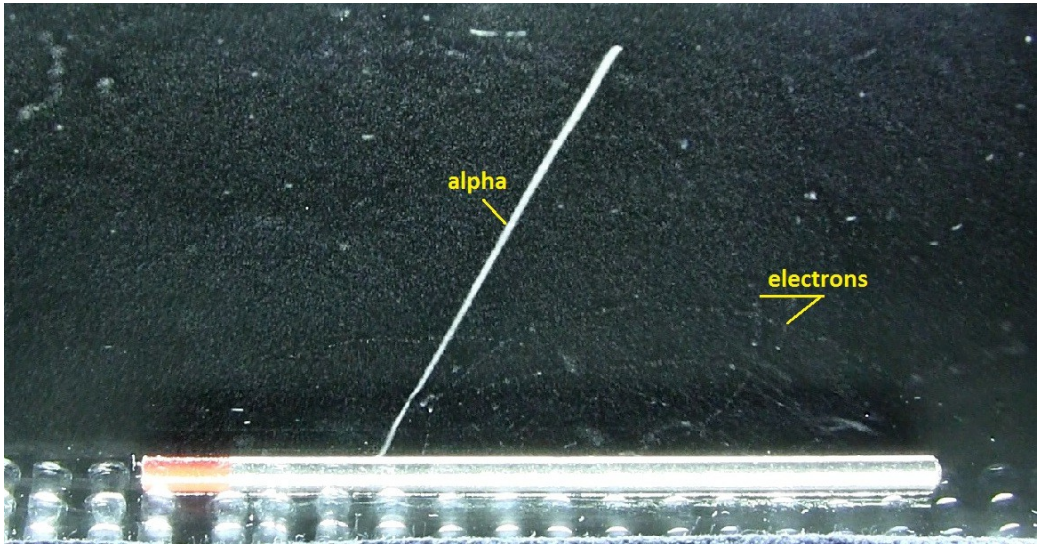
http://upload.wikimedia.org/wikipedia/commons/6/69/PositronDiscovery.jpg



http://upload.wikimedia.org/wikipedia/commons/2/2a/Radon220_decay_in_a_cloud_chamber.jpg



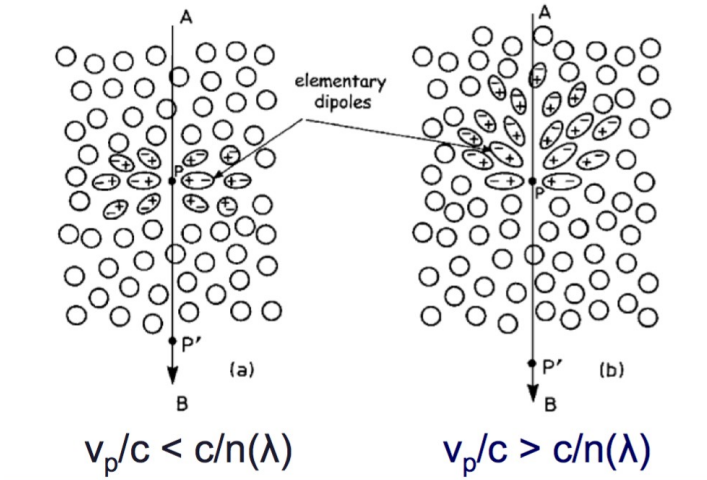
http://www.pd.infn.it/~dorigo/omega-dia-w.gif



http://upload.wikimedia.org/wikipedia/commons/a/ac/Alpha_particle_and_electrons_from_a_thorium_rod_in_a_cloud_chamber.jpg

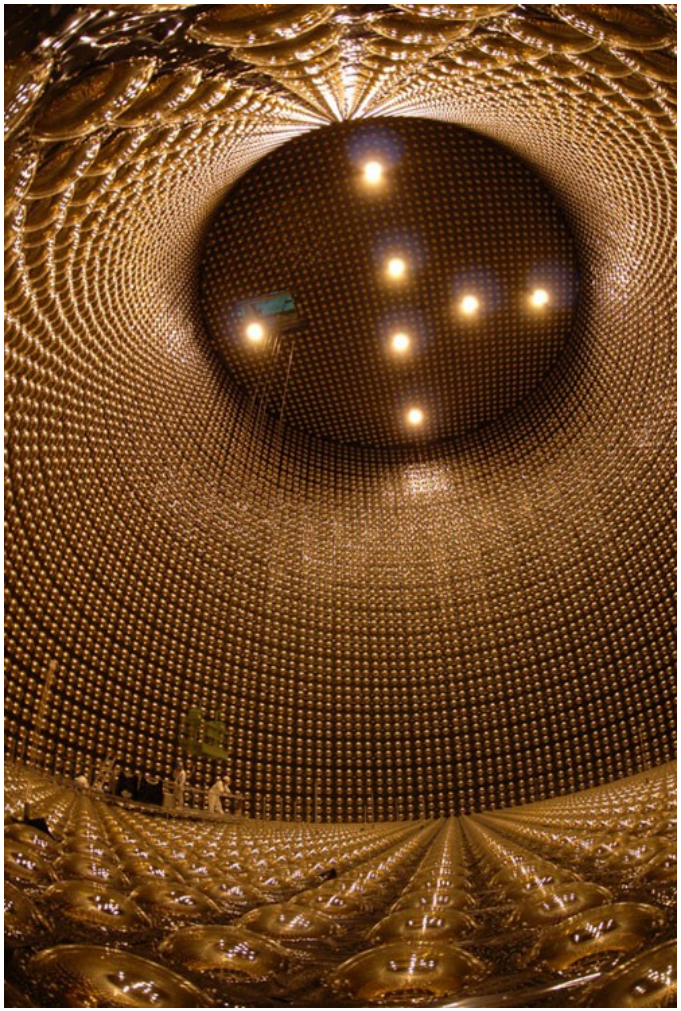
Cherenkov Radiation

- When charged particle passes through medium ***faster than the speed of light in that medium***
- Kind of a sonic boom for light
- The particle ***polarizes*** the media
- Oscillating dipoles radiate (usually visible) light
- Good materials:
  - Transparent
  - Dielectric
  - Lead glass, aerogel, water, etc
- Detect the light (Super Kam)

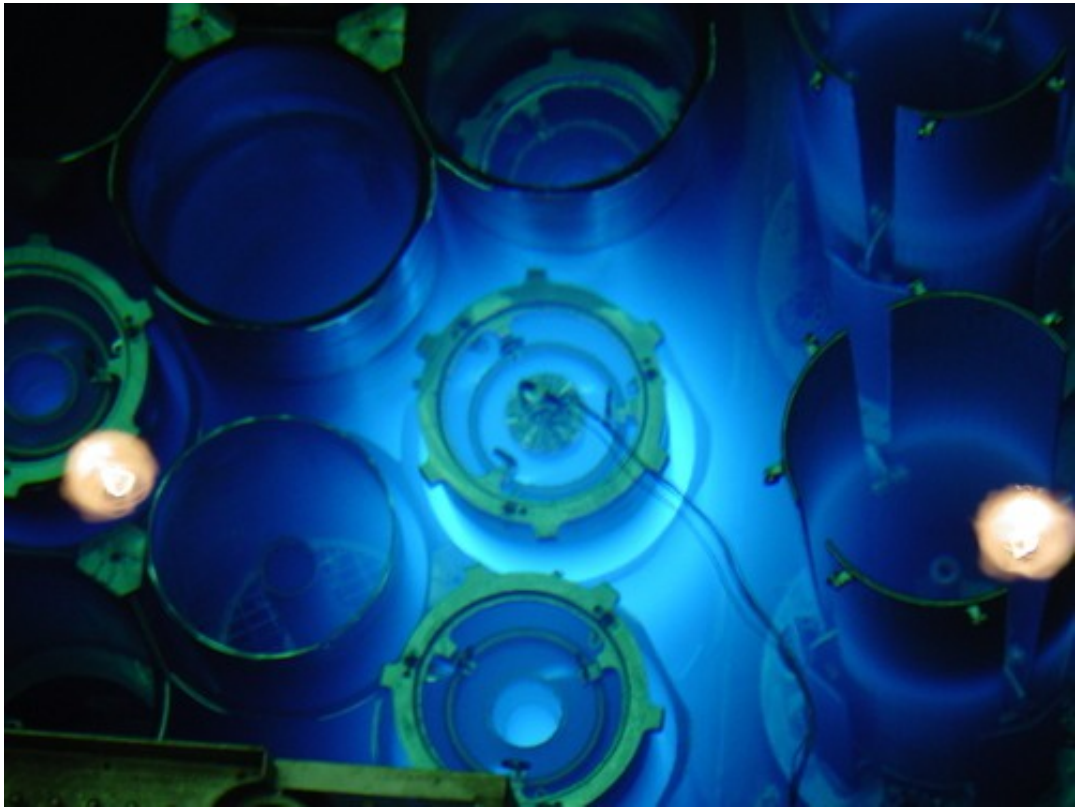


https://indico.cern.ch/event/318429/material/slides/0.pdf

Cherenkov Radiation



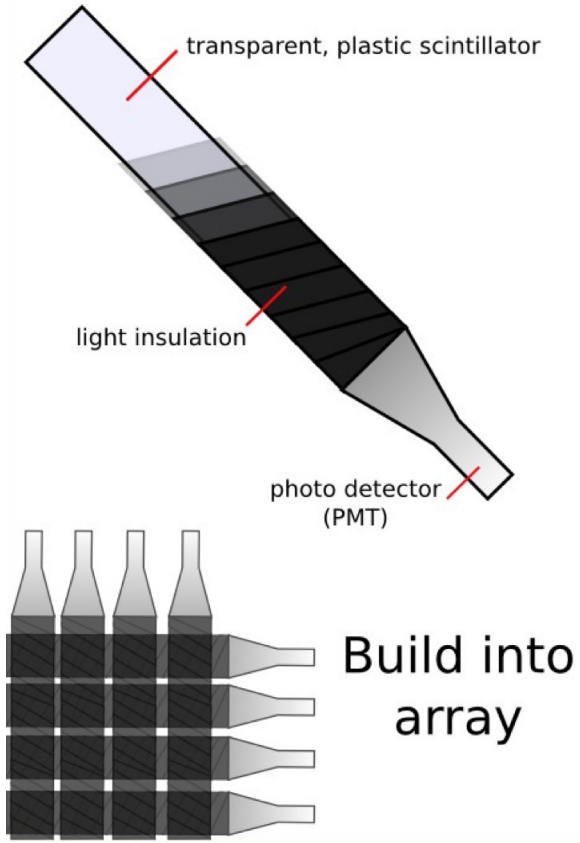
http://www.planetdamage.com/wp-content/uploads/2009/09/cherenkov-01.jpg



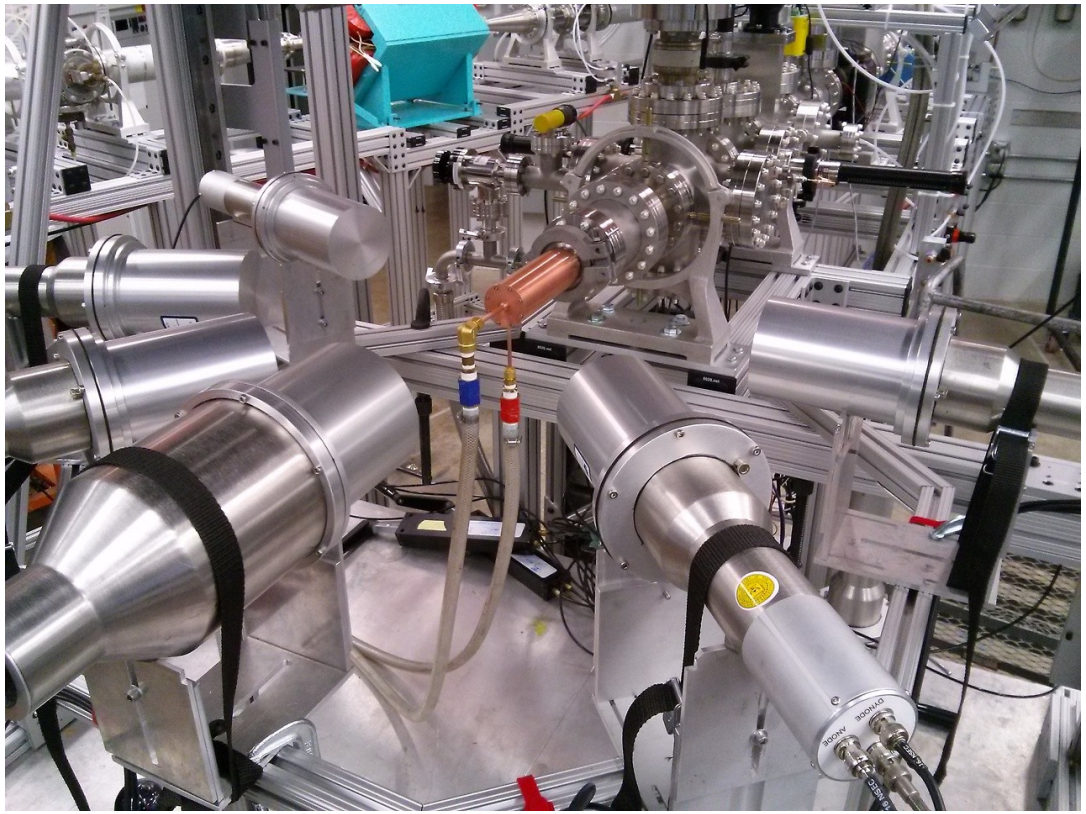
http://images.ookaboo.com/photo/m/HFIR_Gamma_Blue_Glow_m.jpg

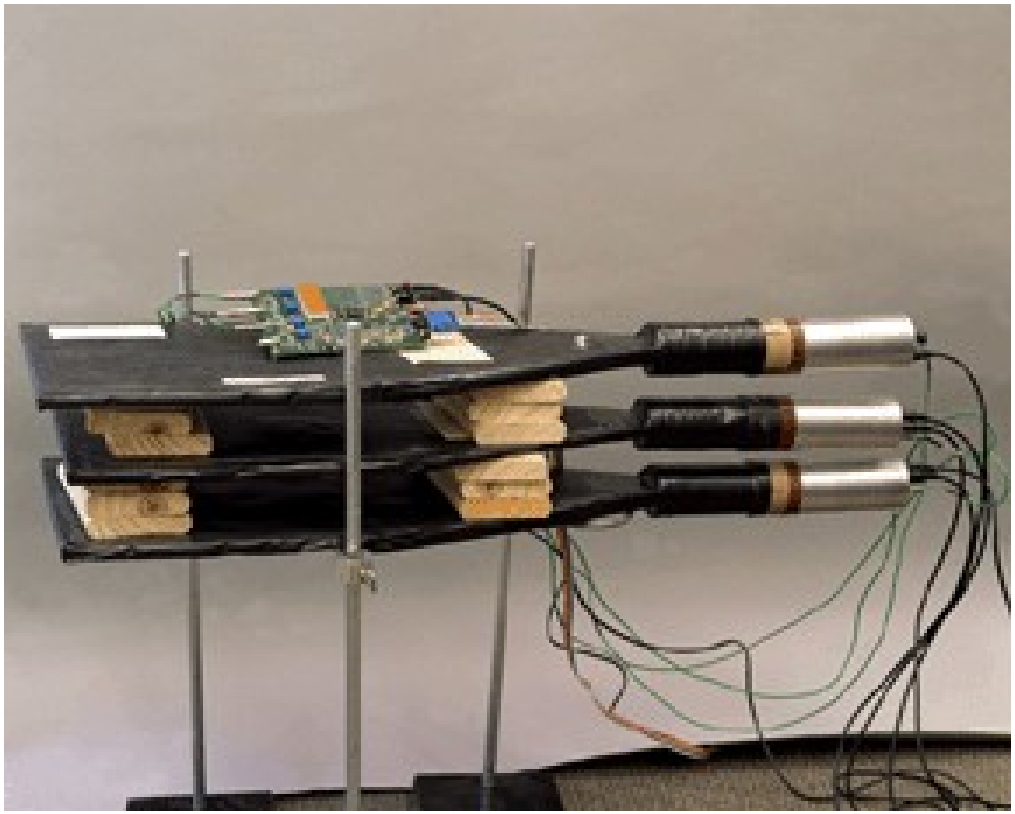
Scintillation

- Charged particle passes through medium
- Excites electrons in medium
- Detection transition radiation
- Photons are detected with photomultiplier tube (PMT)
- Use either
  - a large liquid mass
  - Strips of transparent ig plastic, glass, crystal
- Use to search for:
  - Dark matter – DM decays, produces ionizing radiation
  - Neutrinos – neutrino creates electron, which ionizes media



Scintillation





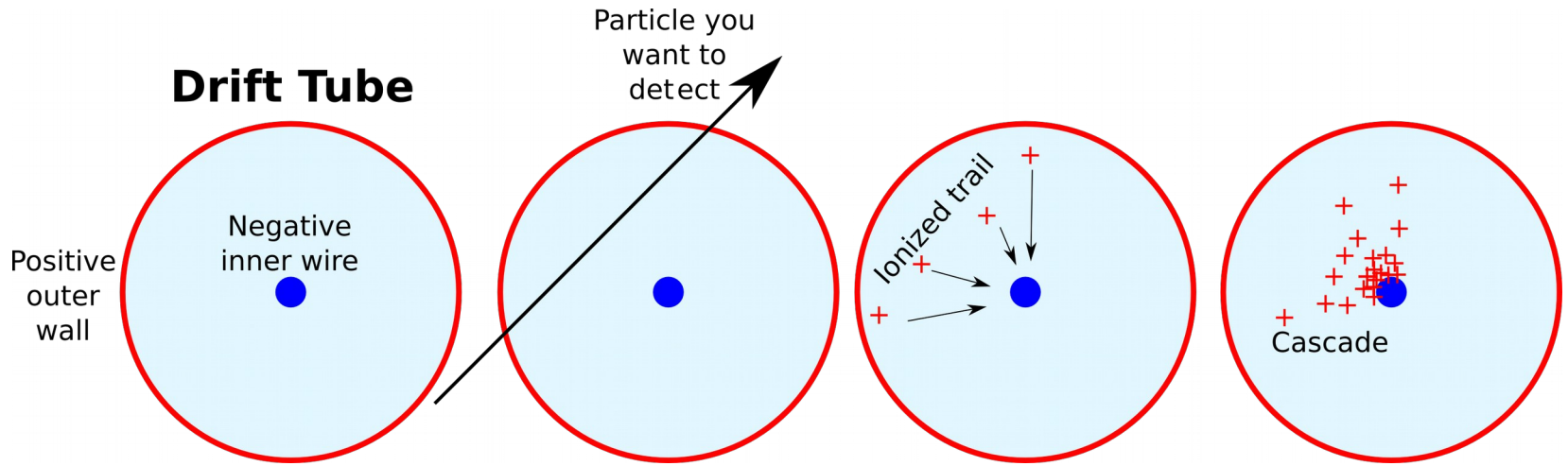
http://quarknet.fnal.gov/toolkits/new/graphics/muoncount.gif

Liquid Scintillators

Plastic Scintillators

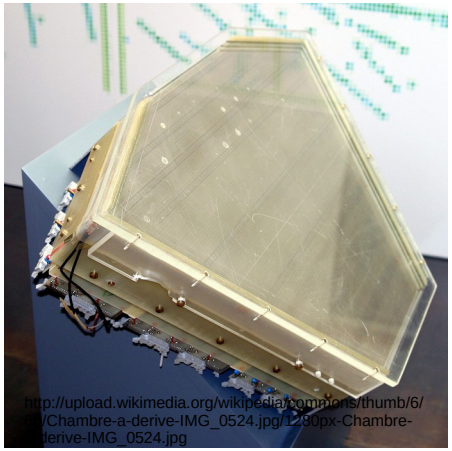
Drift Chamber

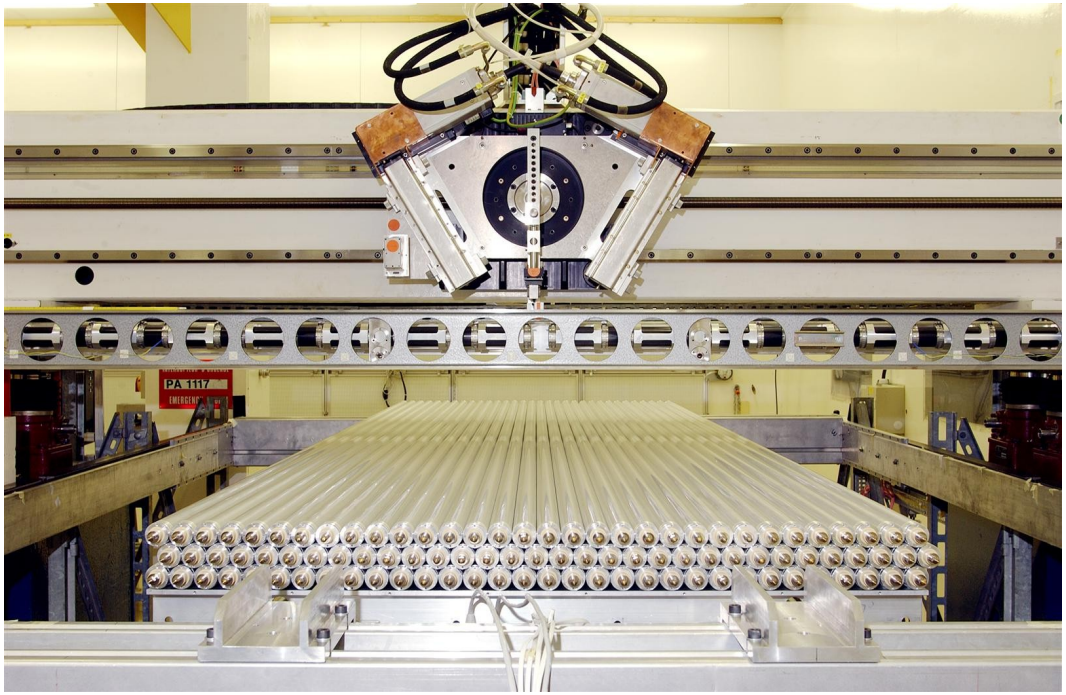
- Charged particles ionize gas in chamber
  - Remember ions are electrically **positive**
- Strong electrical field pulls ions towards a wire
- As ion moves towards wire, speeds up and ionizes more gas
- Ions hit wire, detected by electronics

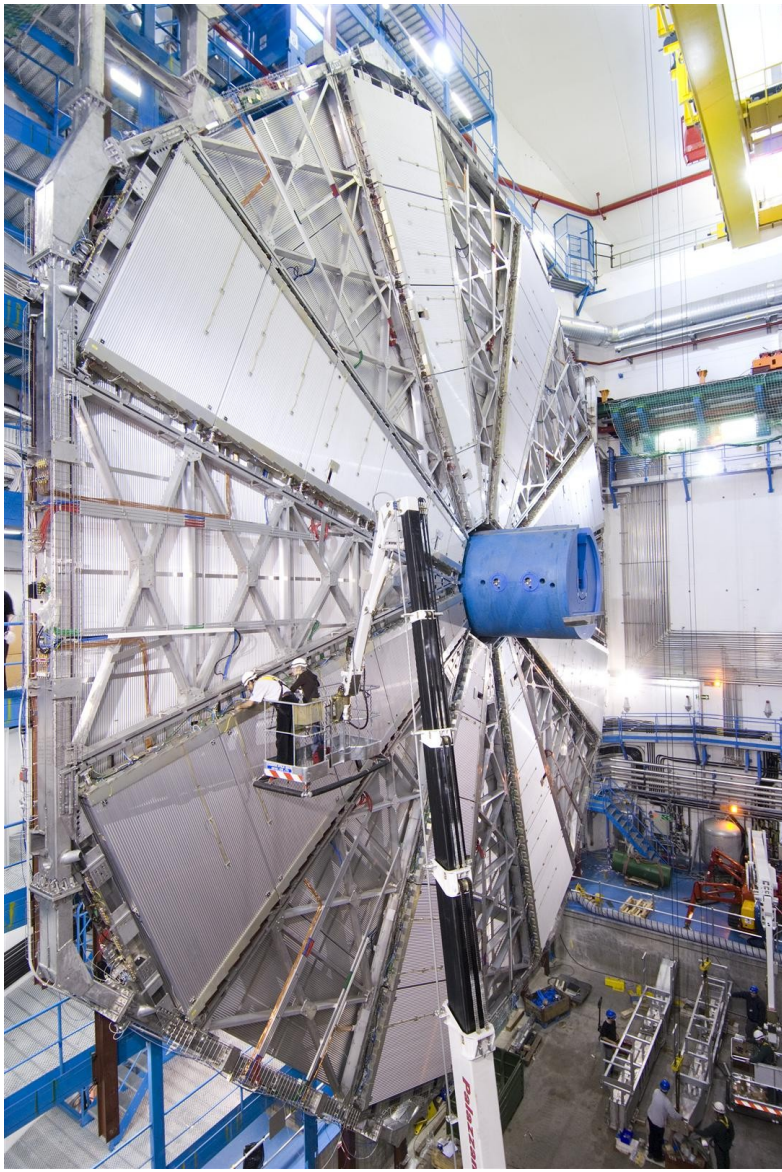


Drift Chamber

- Many configurations of same principle
  - Box with many cross-hatched wires
  - Tubes with a single wire
  - Plates – resistive pad chambers

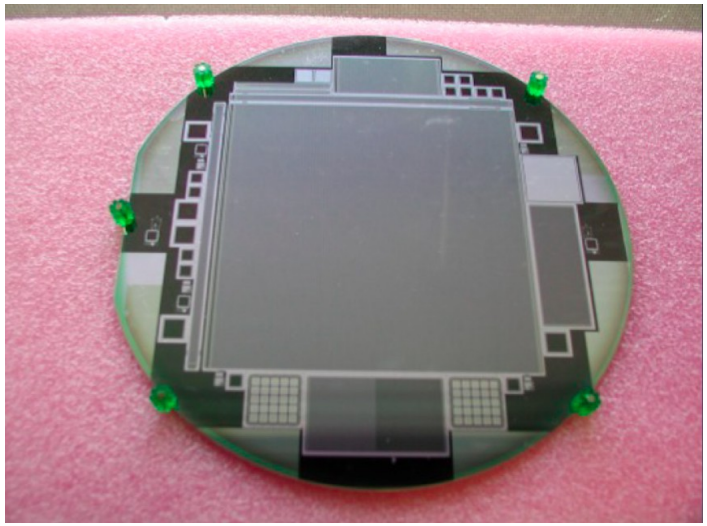


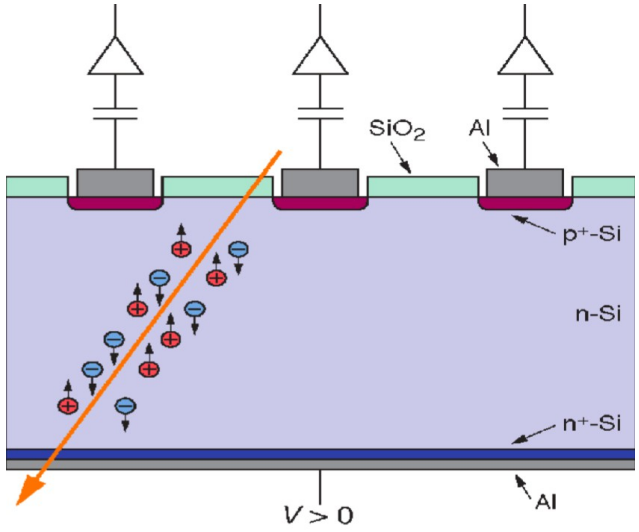




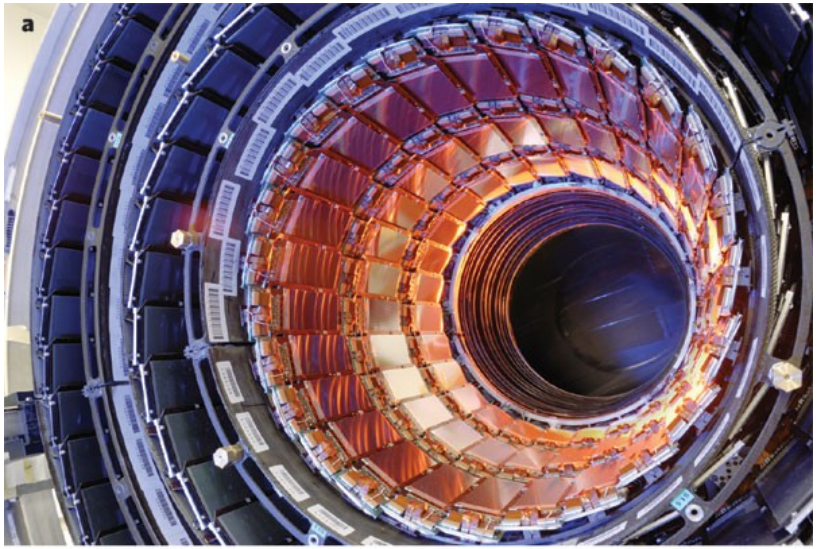
Silicon

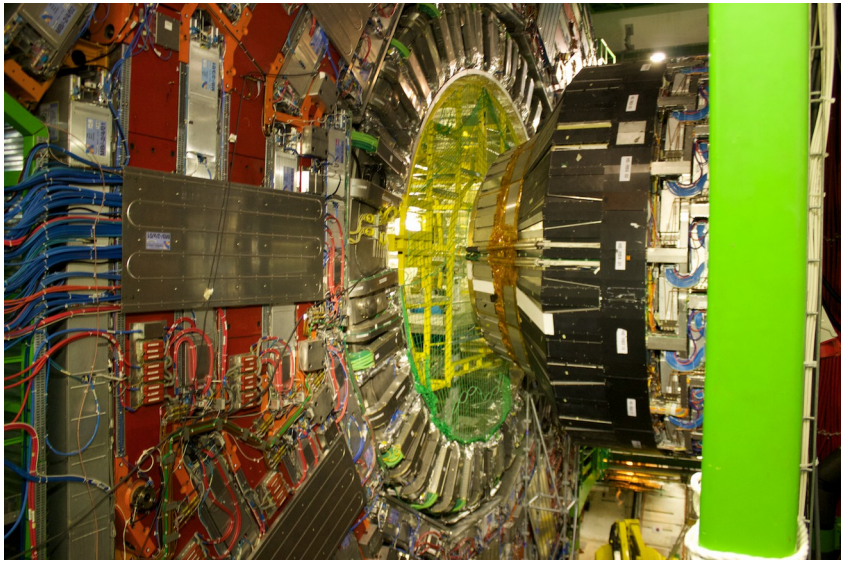
- “We have all these computer chips, can we use them to detect particles?
  - ***Yes***
- Silicon detectors use the same manufacturing used make a CPU to make microscopic particle detectors
- Very good for precise, high resolution particle tracks

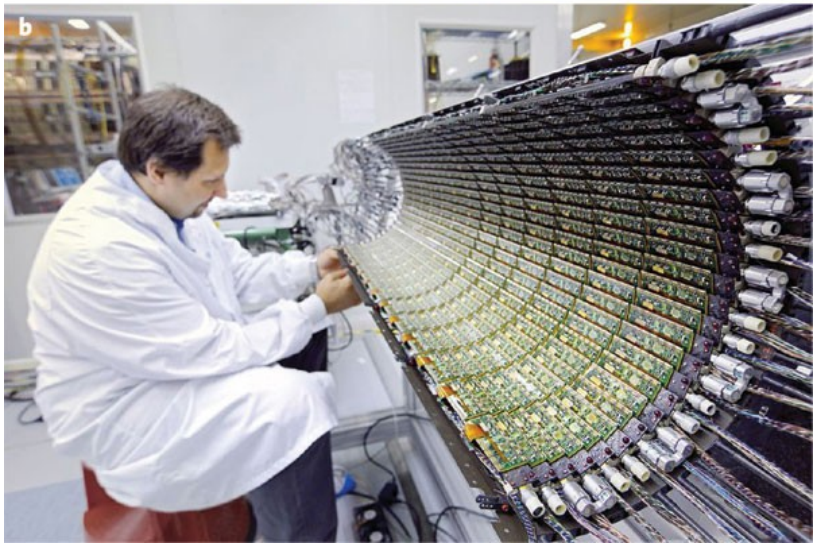




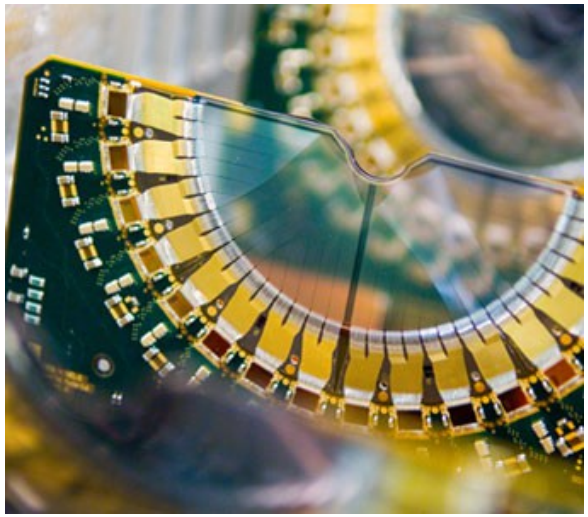
Silicon







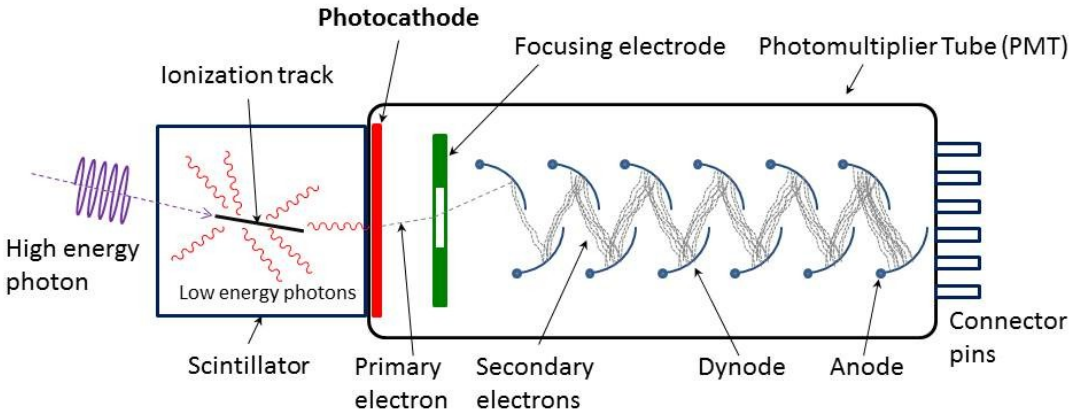
http://www.nature.com/nature/journal/v448/n7151/images/nature06078-f2.2.jpg



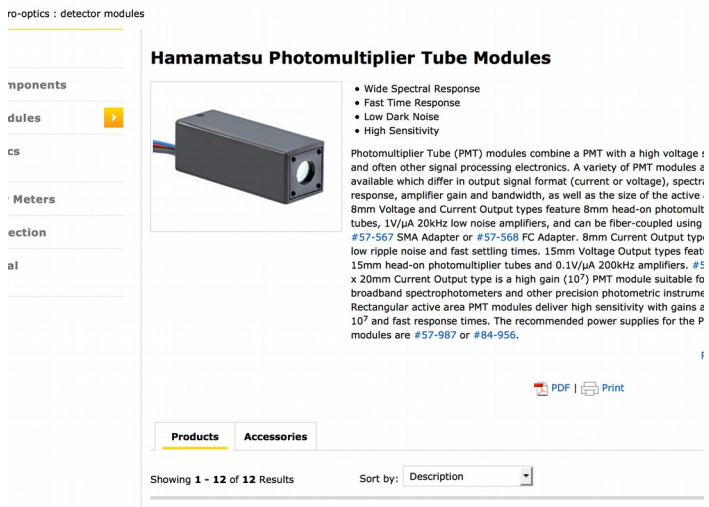
http://www.liv.ac.uk/particle-physics/Velo-340x300.jpg

Photomultiplier

- Detects individual photons



http://upload.wikimedia.org/wikipedia/commons/5/5f/PhotoMultiplierTubeAndScintillator.jpg



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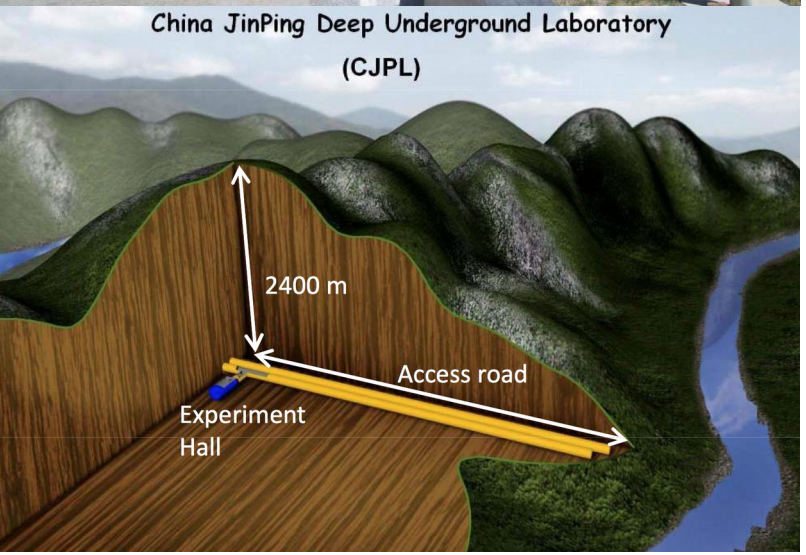
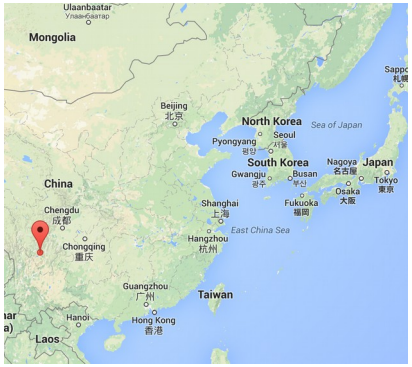
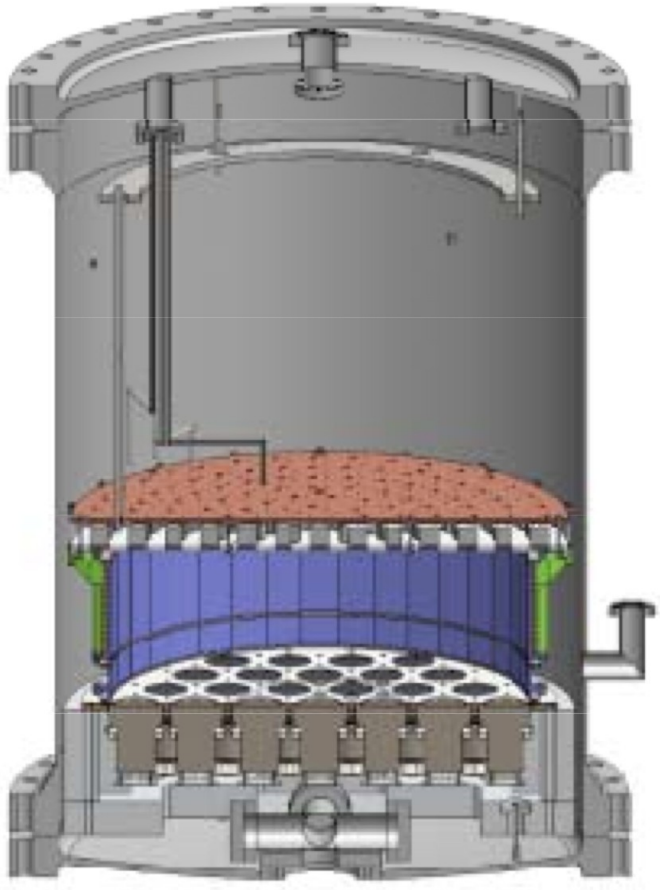




PANDA X



Guillaume Plante Columbia University – LIDINE2013
on behalf of the XENON Collaboration