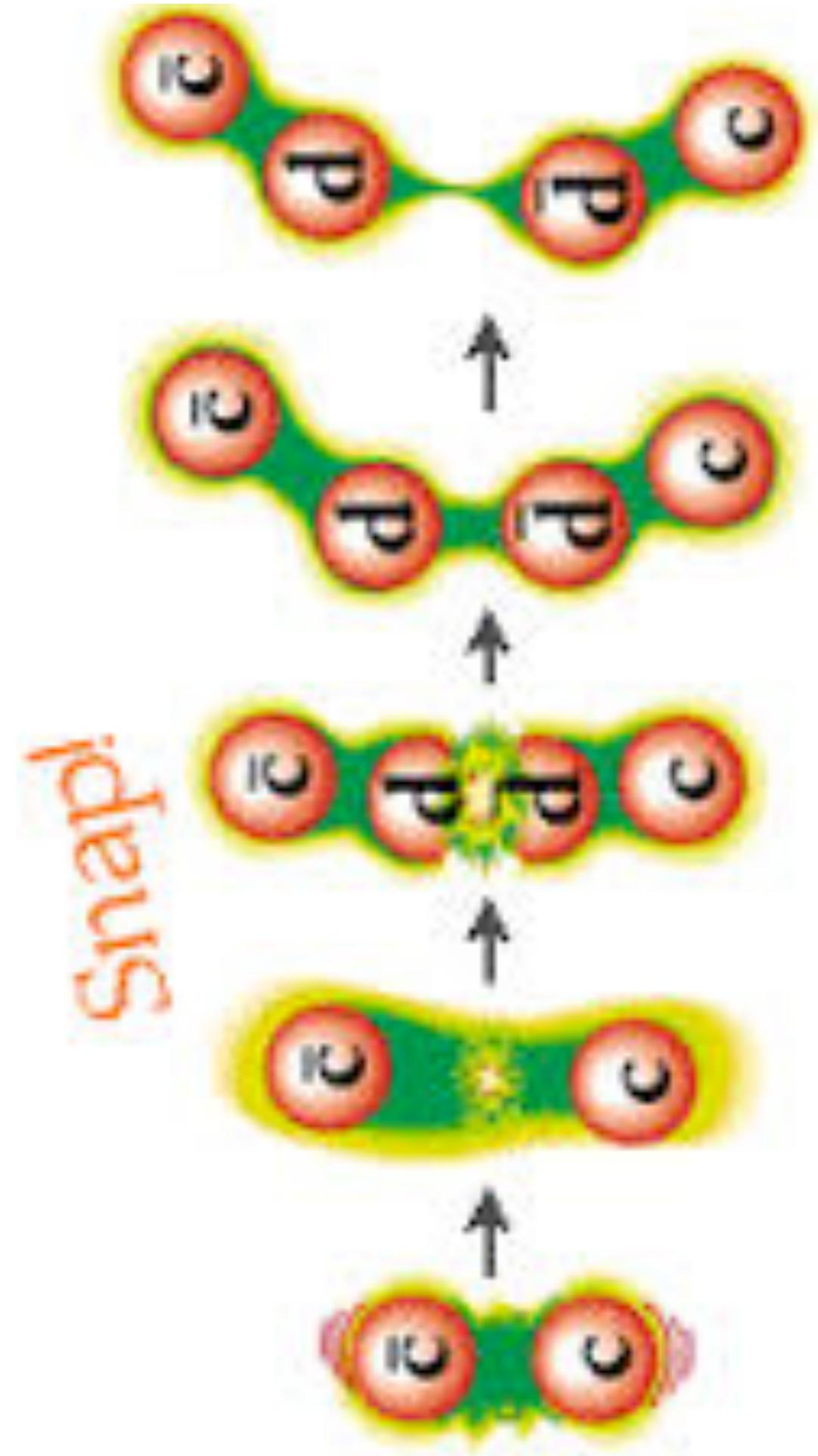
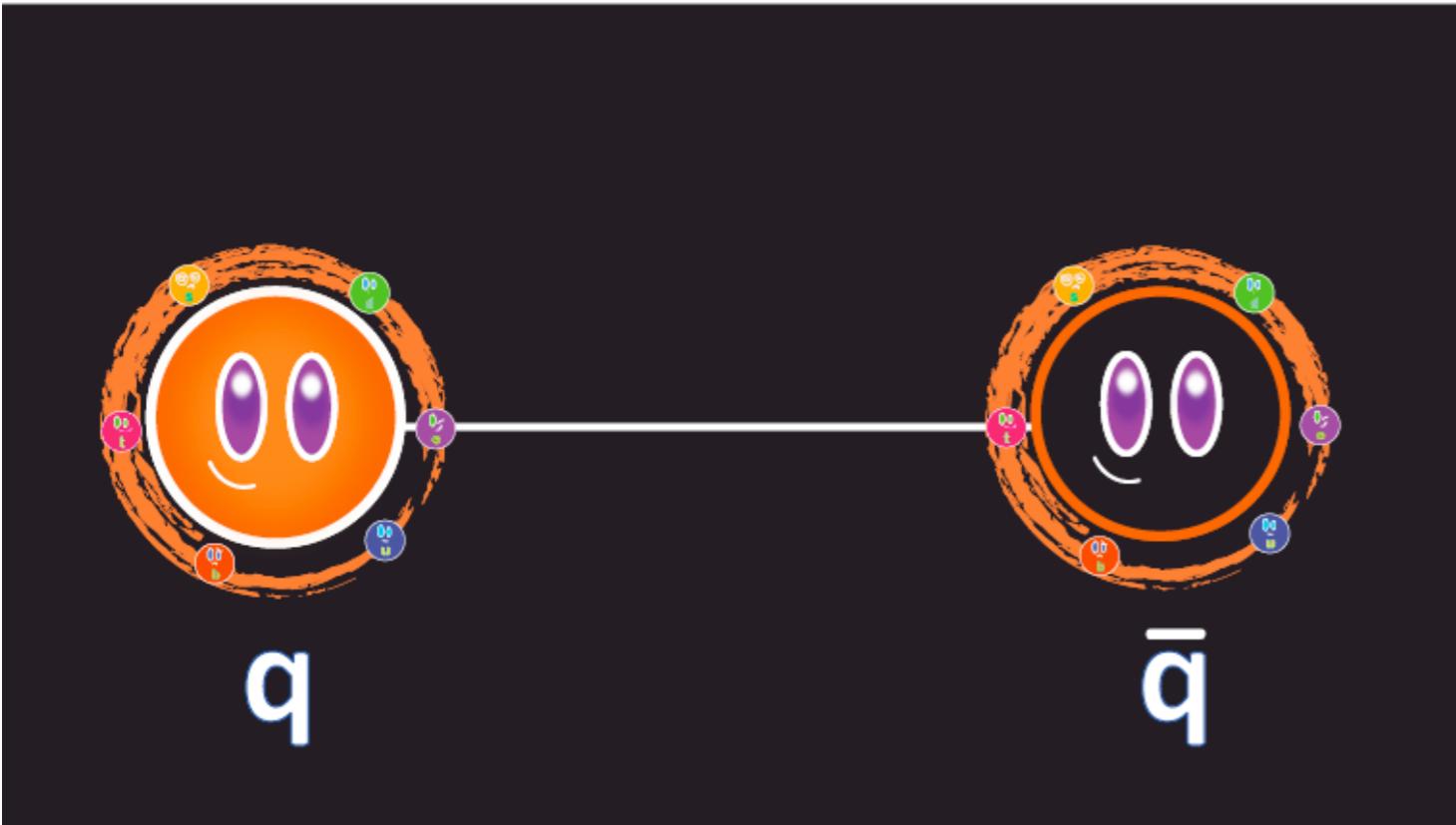


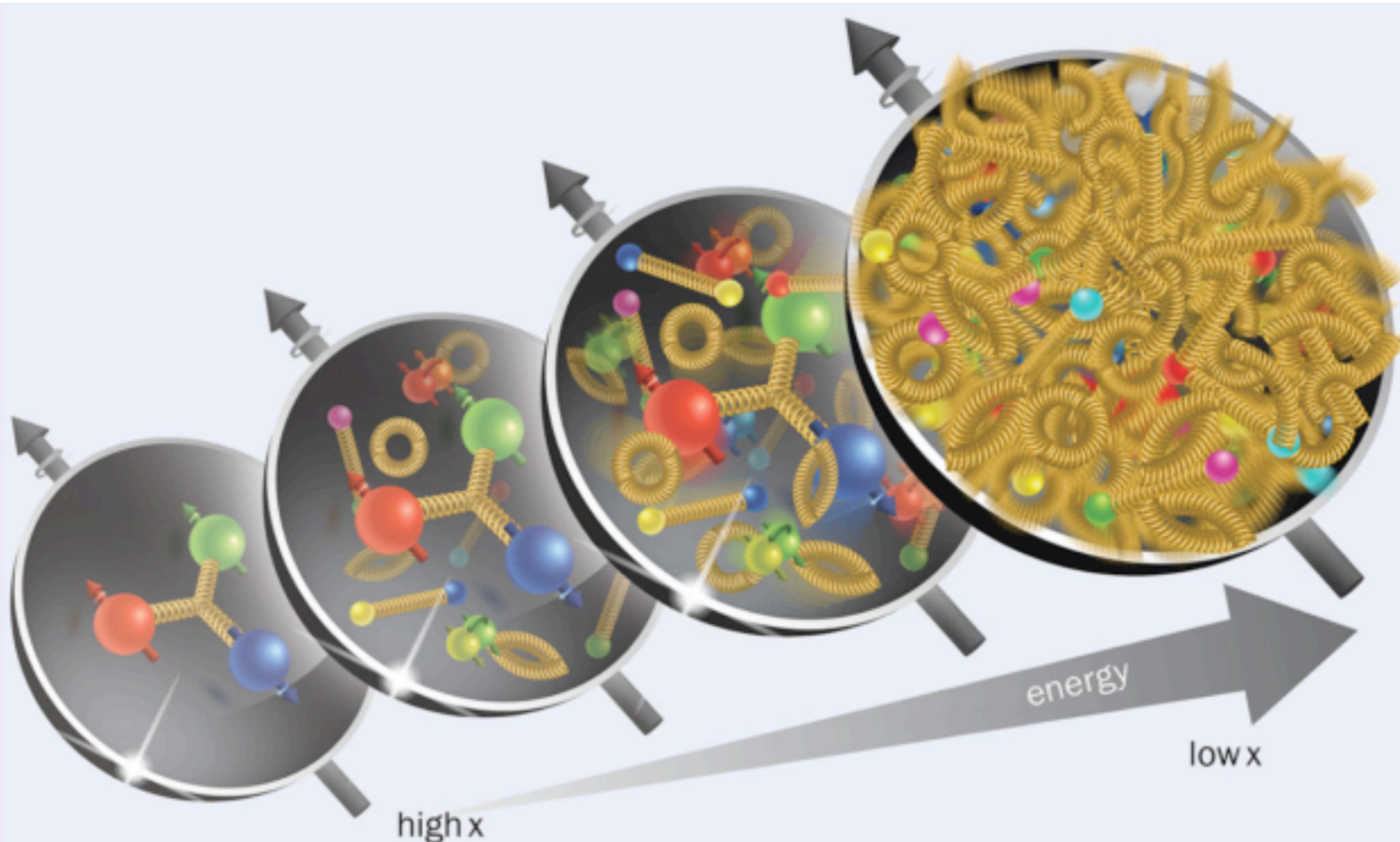
Let's Smash The Proton!

Raghav Kunnawalkam Elayavalli
(they/them)

School of Science and Math at Vanderbilt
Summer 2023

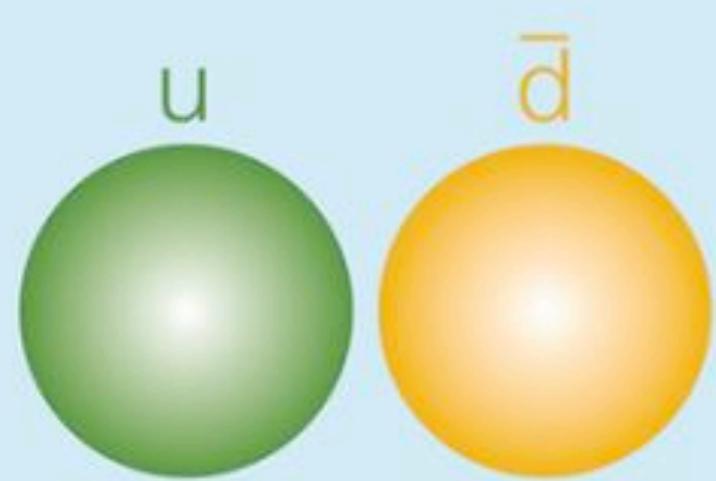
Day 4 - Whats inside the proton and how to measure it?





Types of matter particles made with quarks

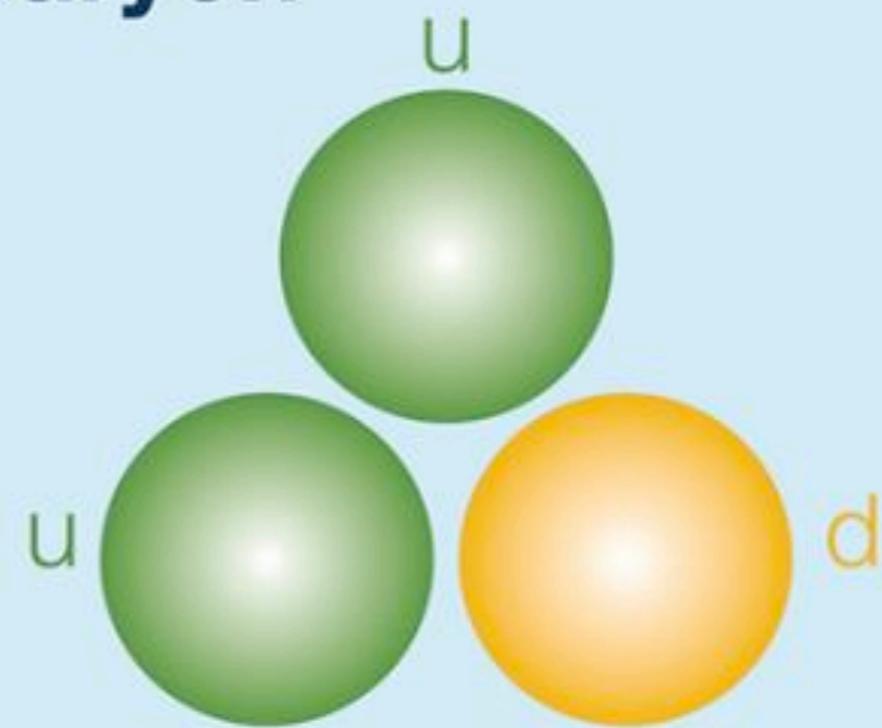
meson



Mesons are made of a quark and anti-quark

Shown here is a pion, made of an up and a down quark.

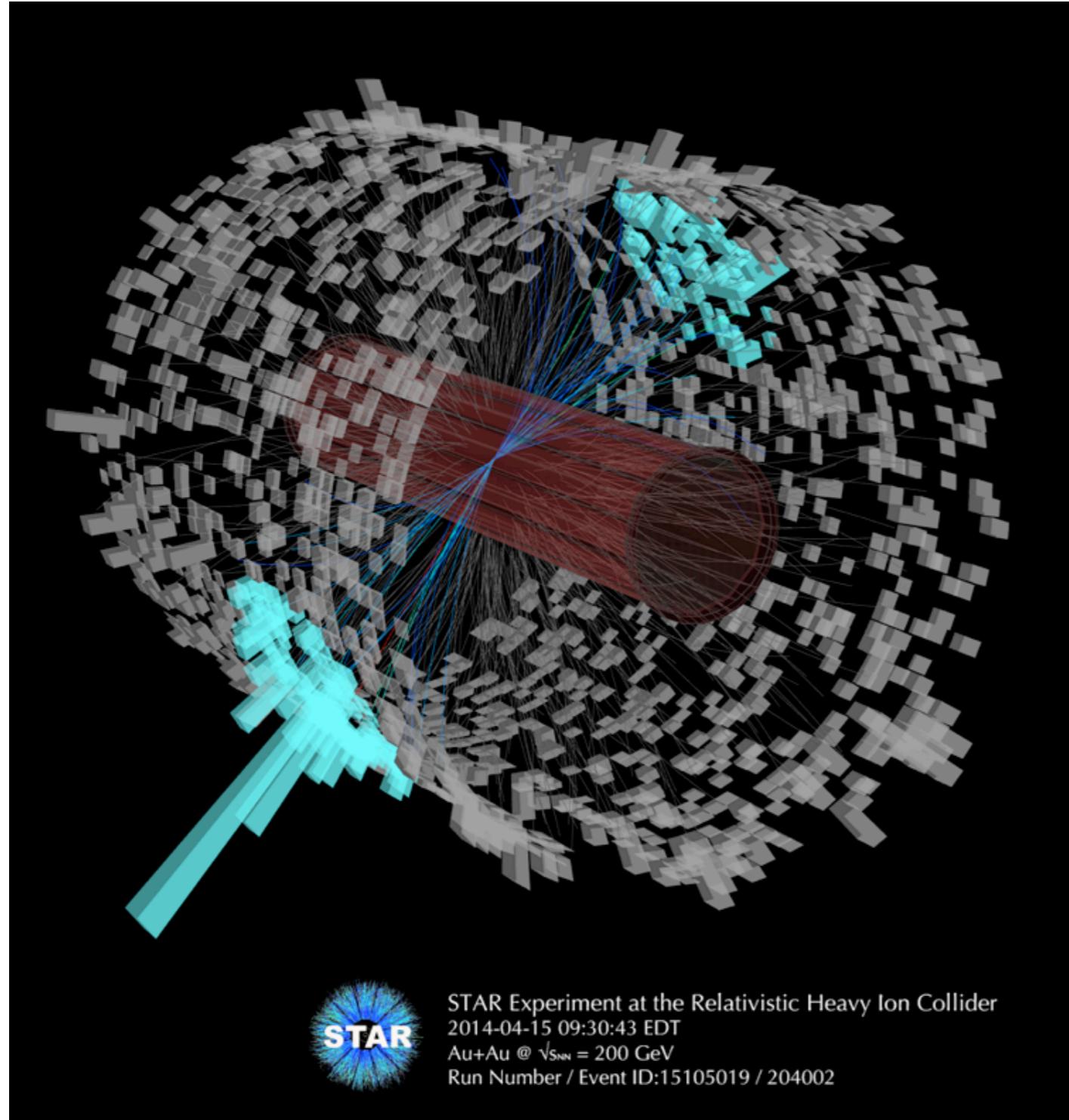
baryon



Baryons are made of three quarks

Shown here is a proton, made of two ups and a down.

Topic of the day!



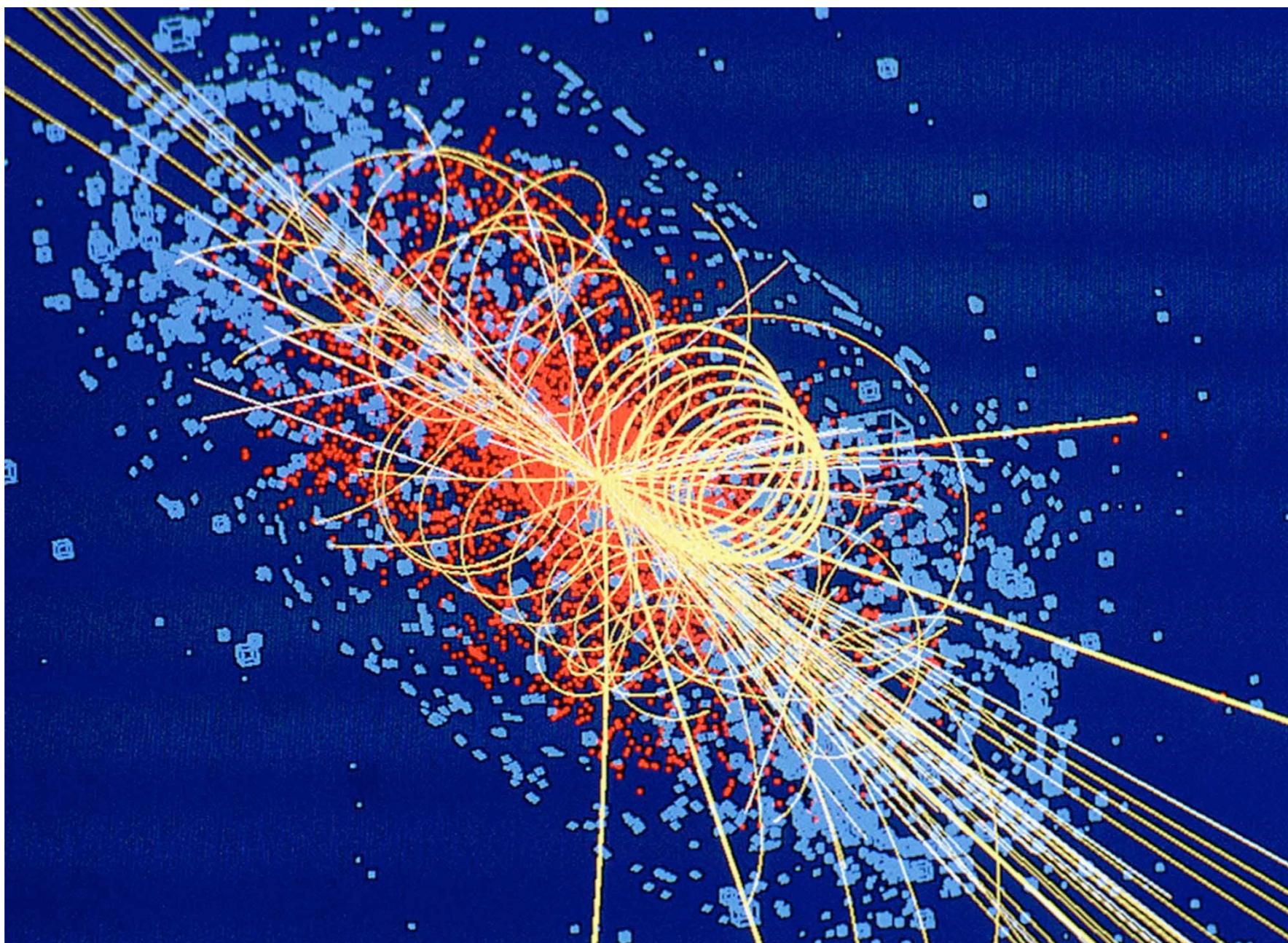
STAR Experiment at the Relativistic Heavy Ion Collider
2014-04-15 09:30:43 EDT
Au+Au @ $\sqrt{s_{NN}} = 200$ GeV
Run Number / Event ID:15105019 / 204002

How do we
measure the
particles?

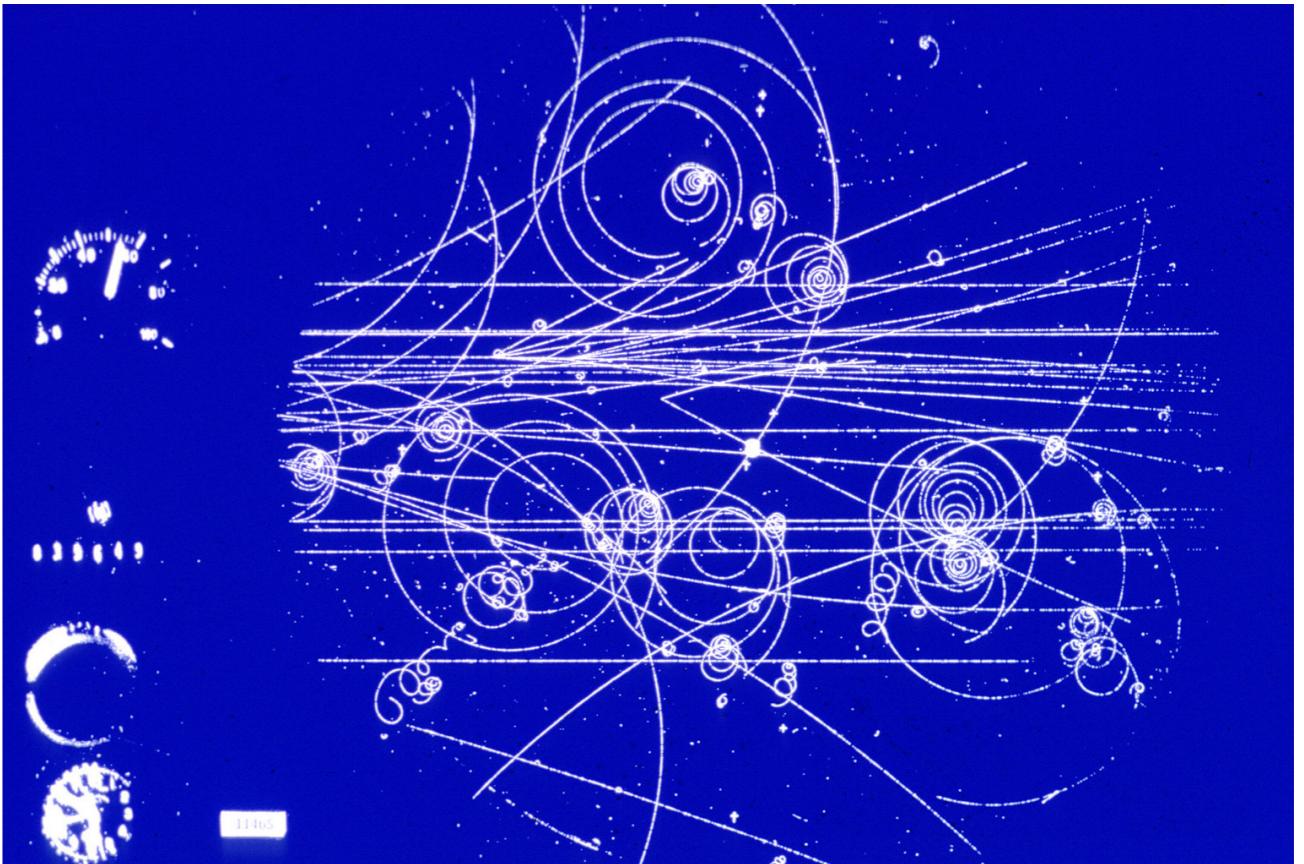
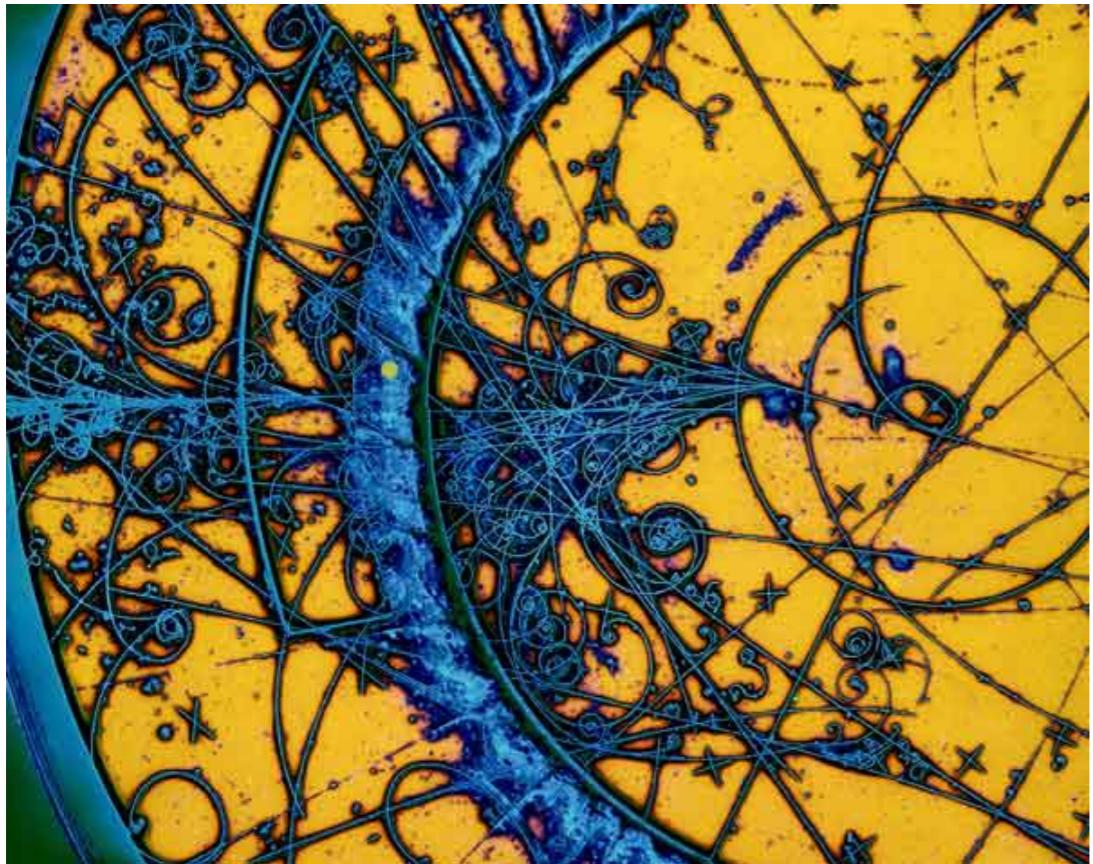
What are
detectors?

Particle Detectors

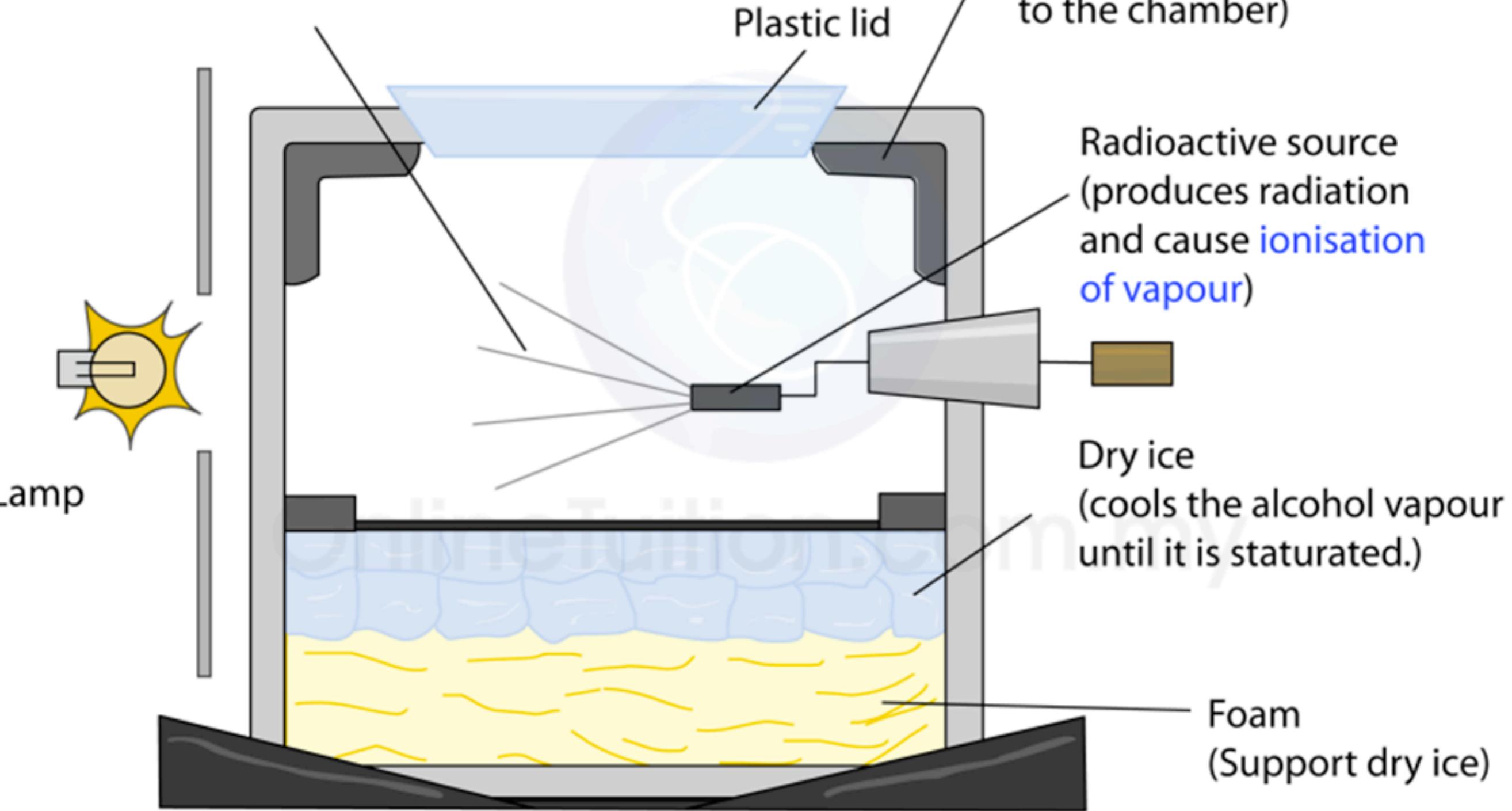
- They are essentially digital cameras that record information of particles which are produced in the collision
- We reconstruct the timeline based on the photos we take at the end



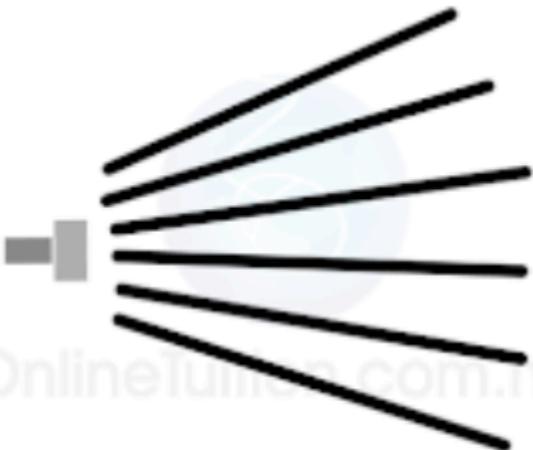
Historical particle detector - Cloud Chamber

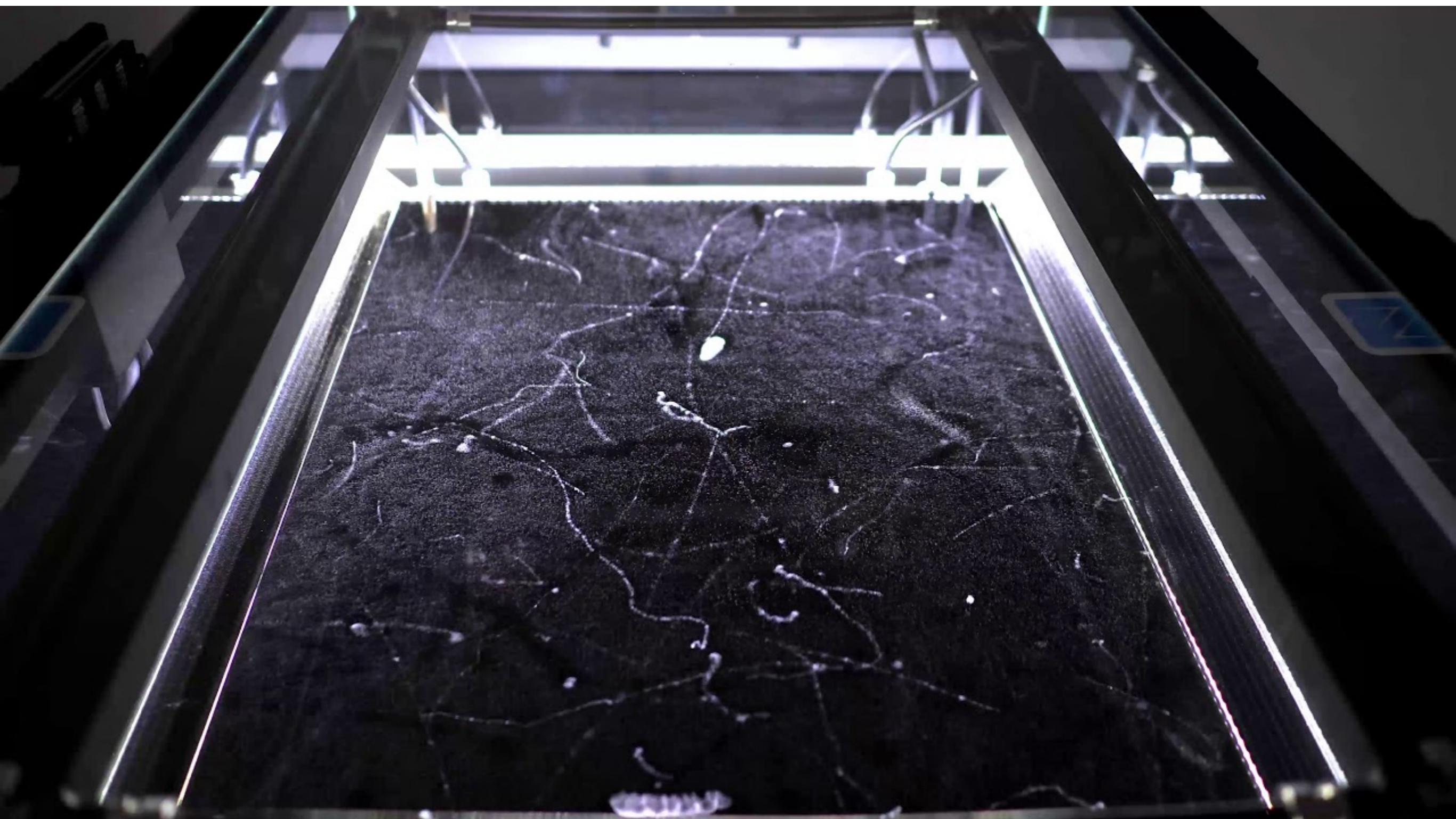


Alcohol vapour condense
to form liquid droplets
around the ionised molecule

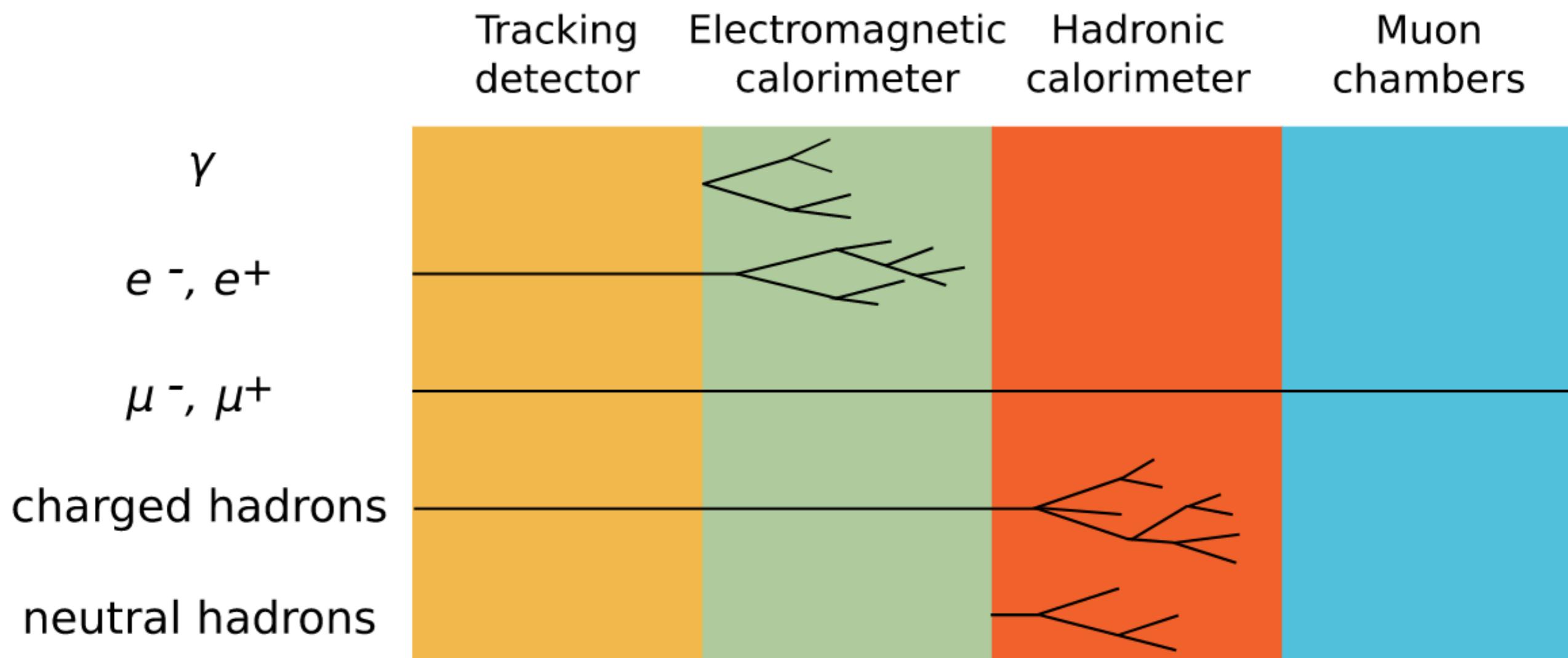


Signatures of particles

Alpha-particle tracks:	Beta-particle tracks:	Gamma-ray:
		
Thick and straight, with the occasional deflection if an alpha particle collides with an air molecule.	Thin and crooked. The particles cause much less ionization and, being light, are continually being pushed off; caused by air molecules nearby.	Don't produce tracks as such. The tracks seen are those caused by electrons which have absorbed energy from photons and have escaped from atoms.



Types of particle signatures

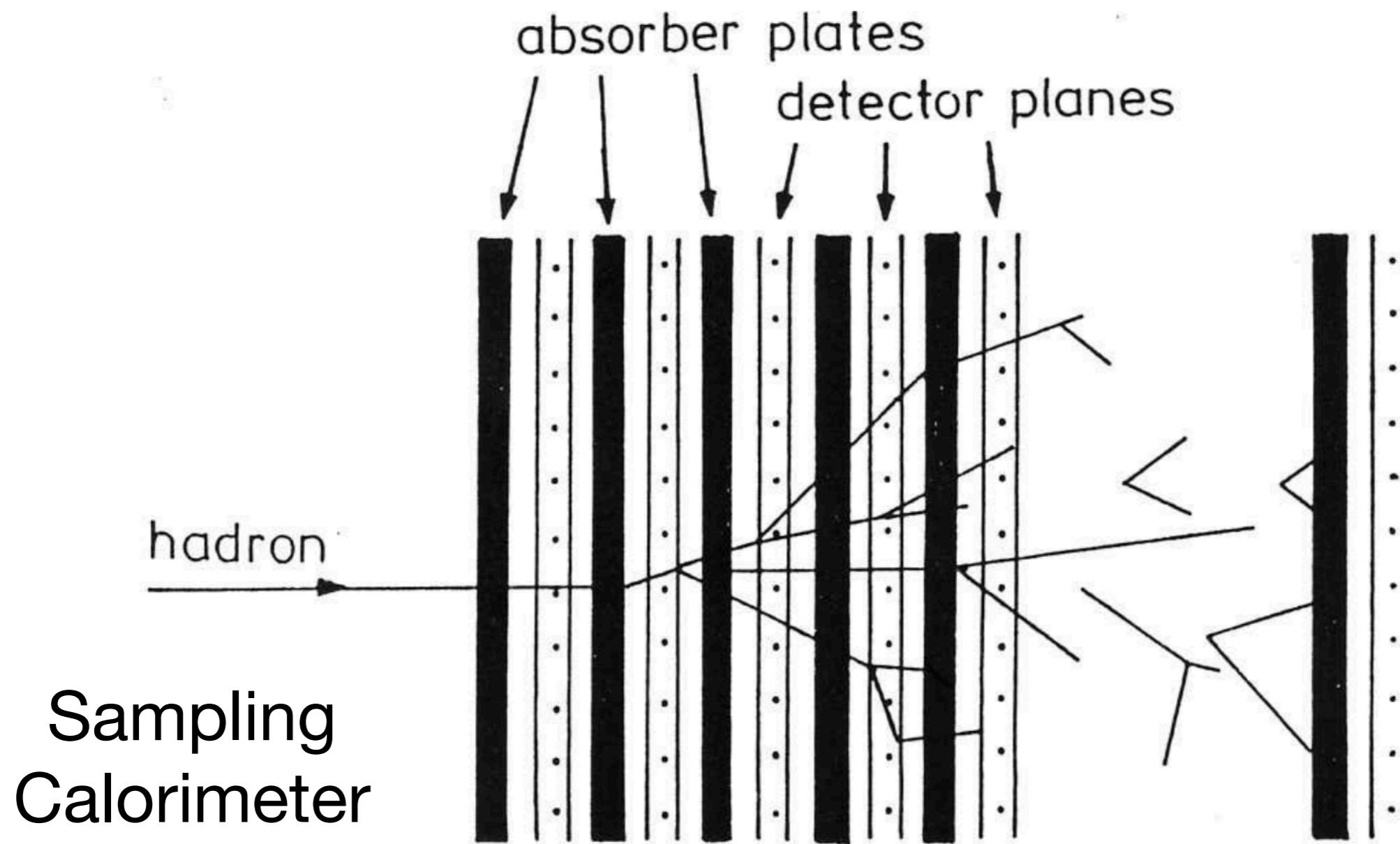


Energy deposition

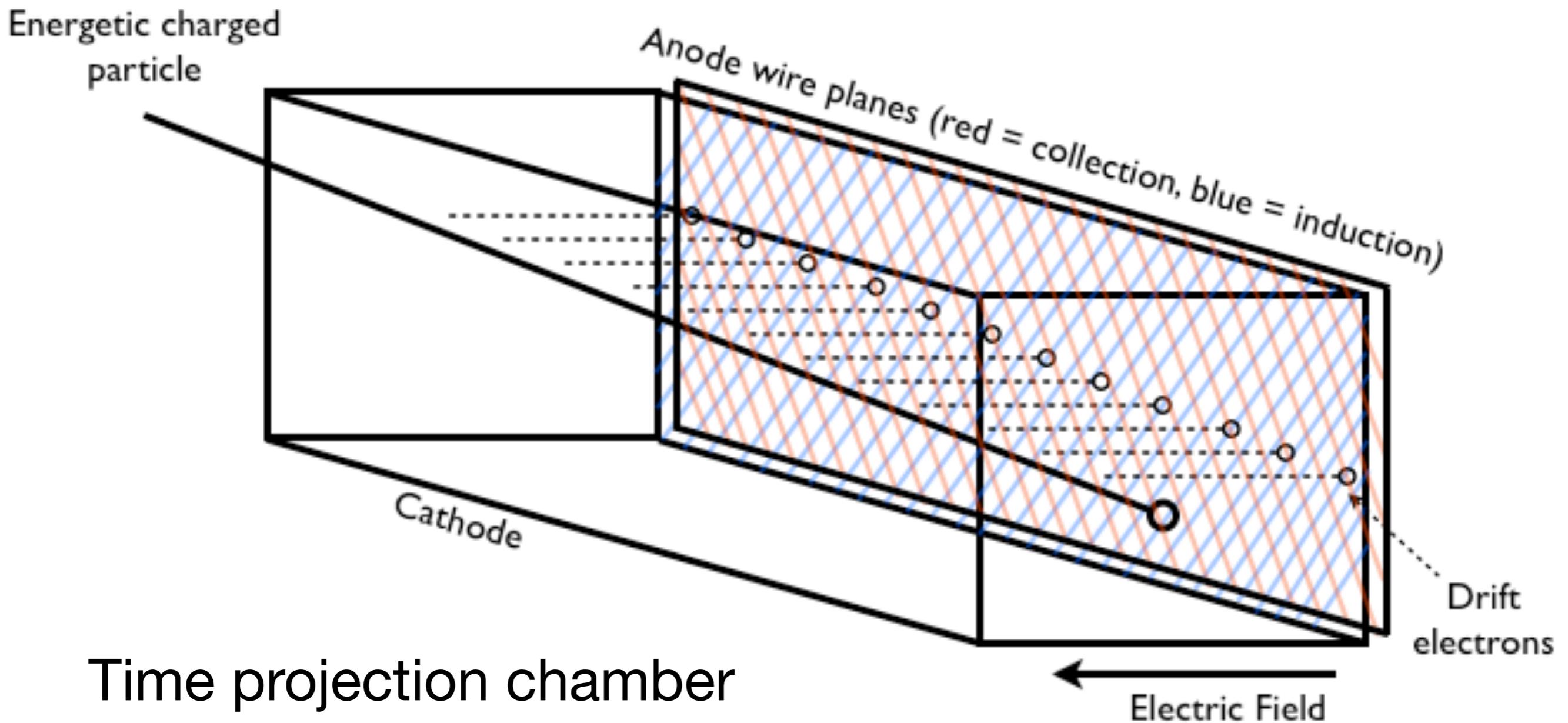
Particle momentum

Particle identification

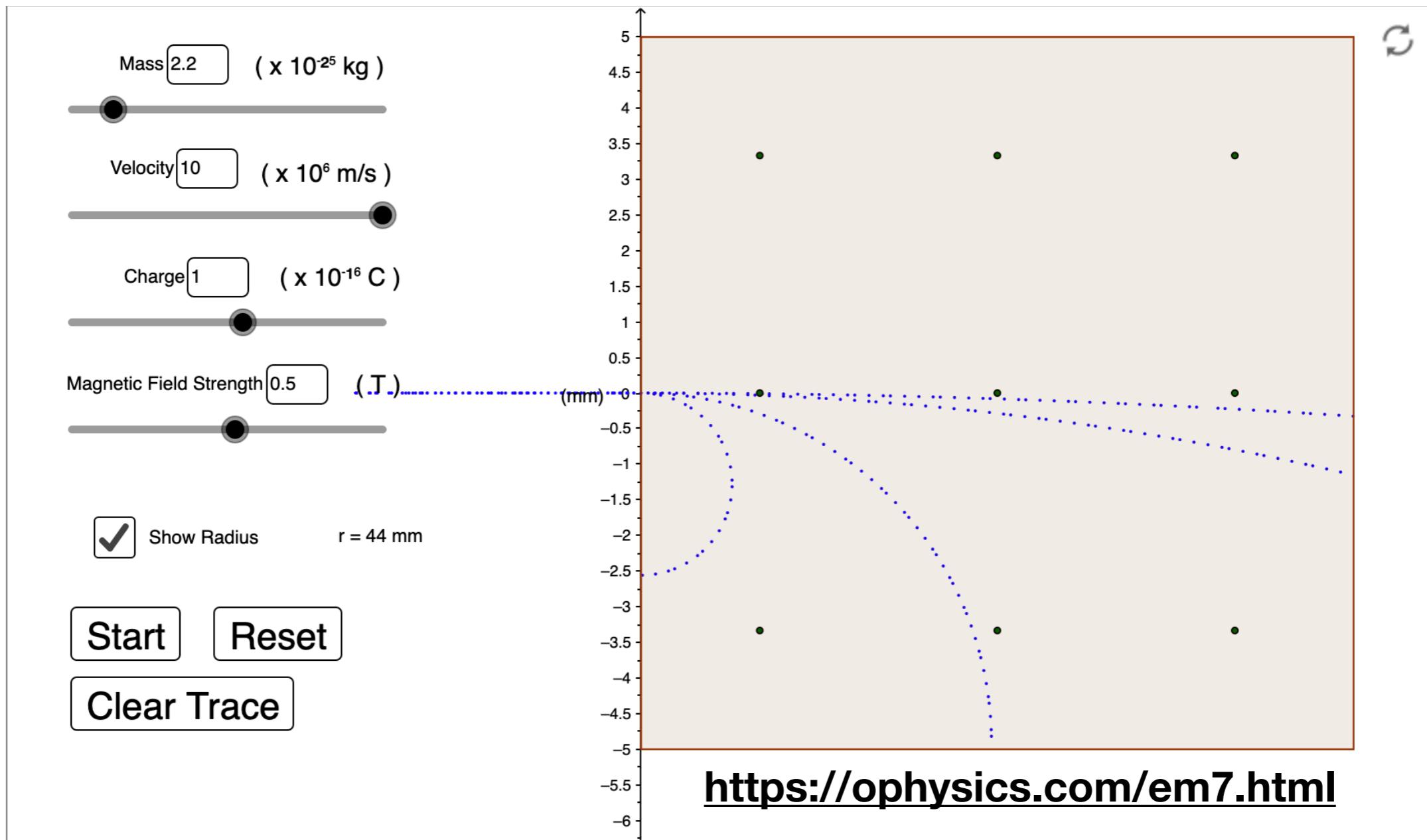
Measuring energy - Calorimeters



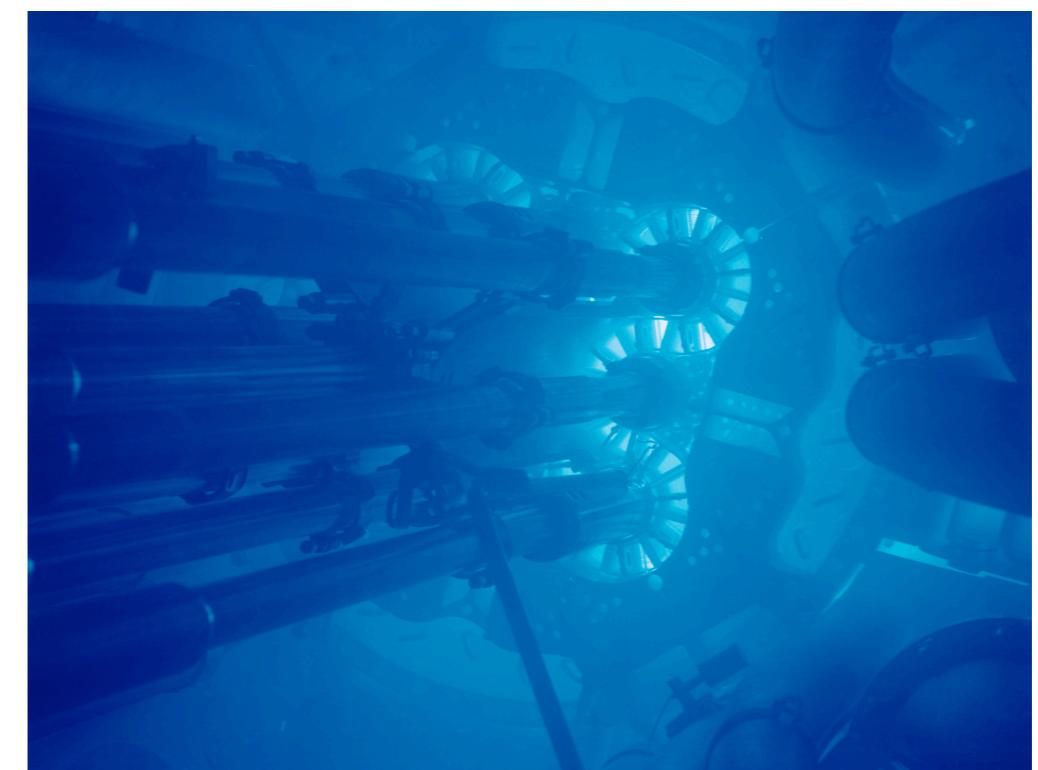
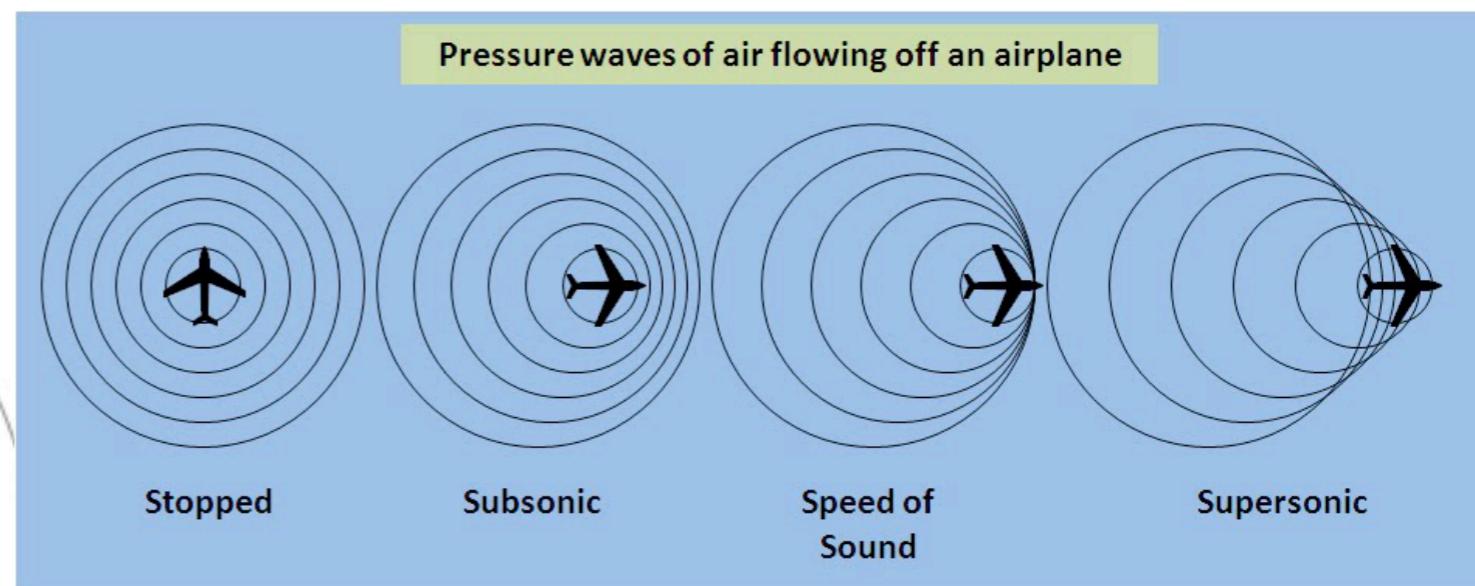
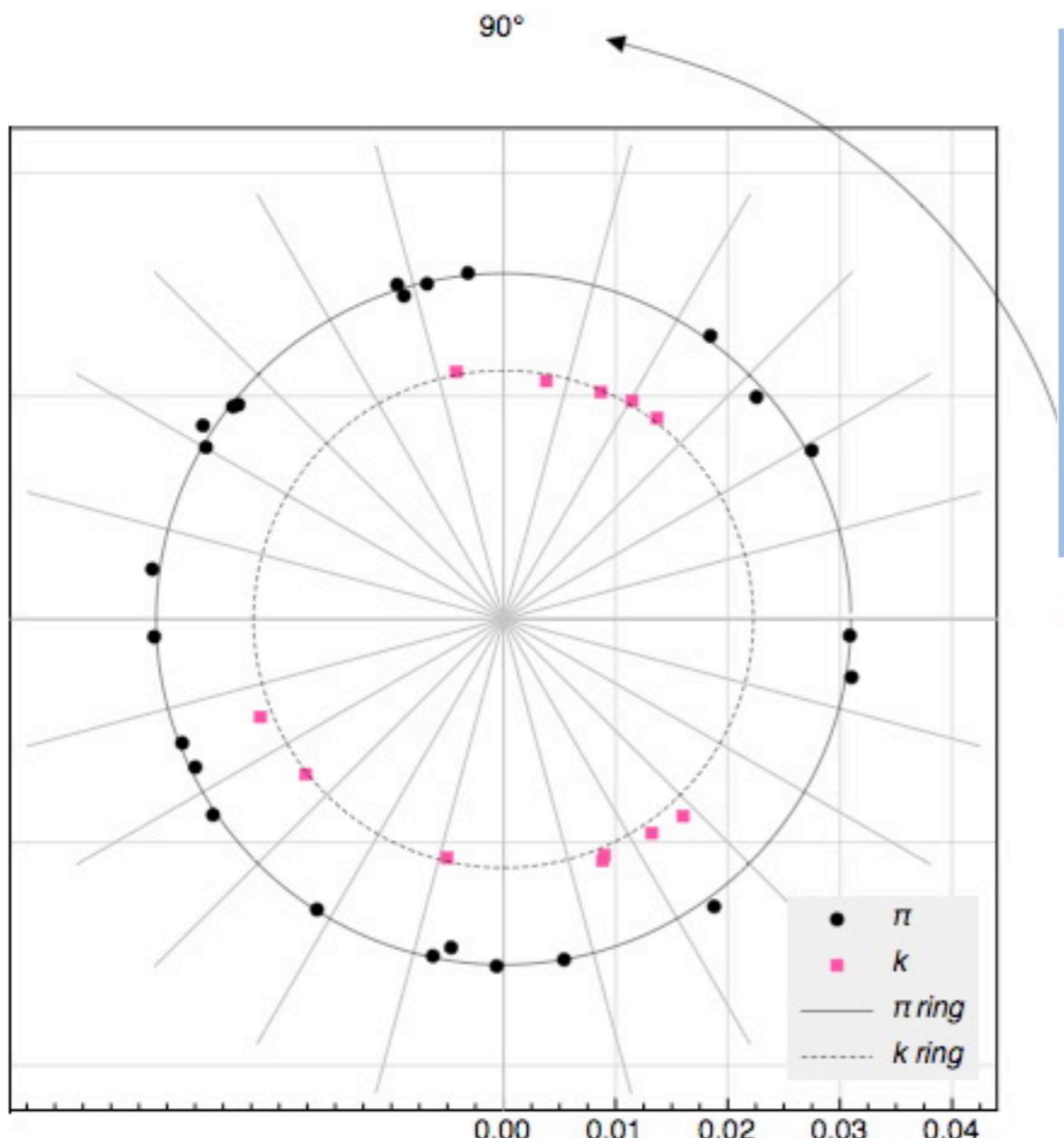
Measuring momentum - Trackers



Reverse engineering the momentum knowing the curvature and the magnetic field

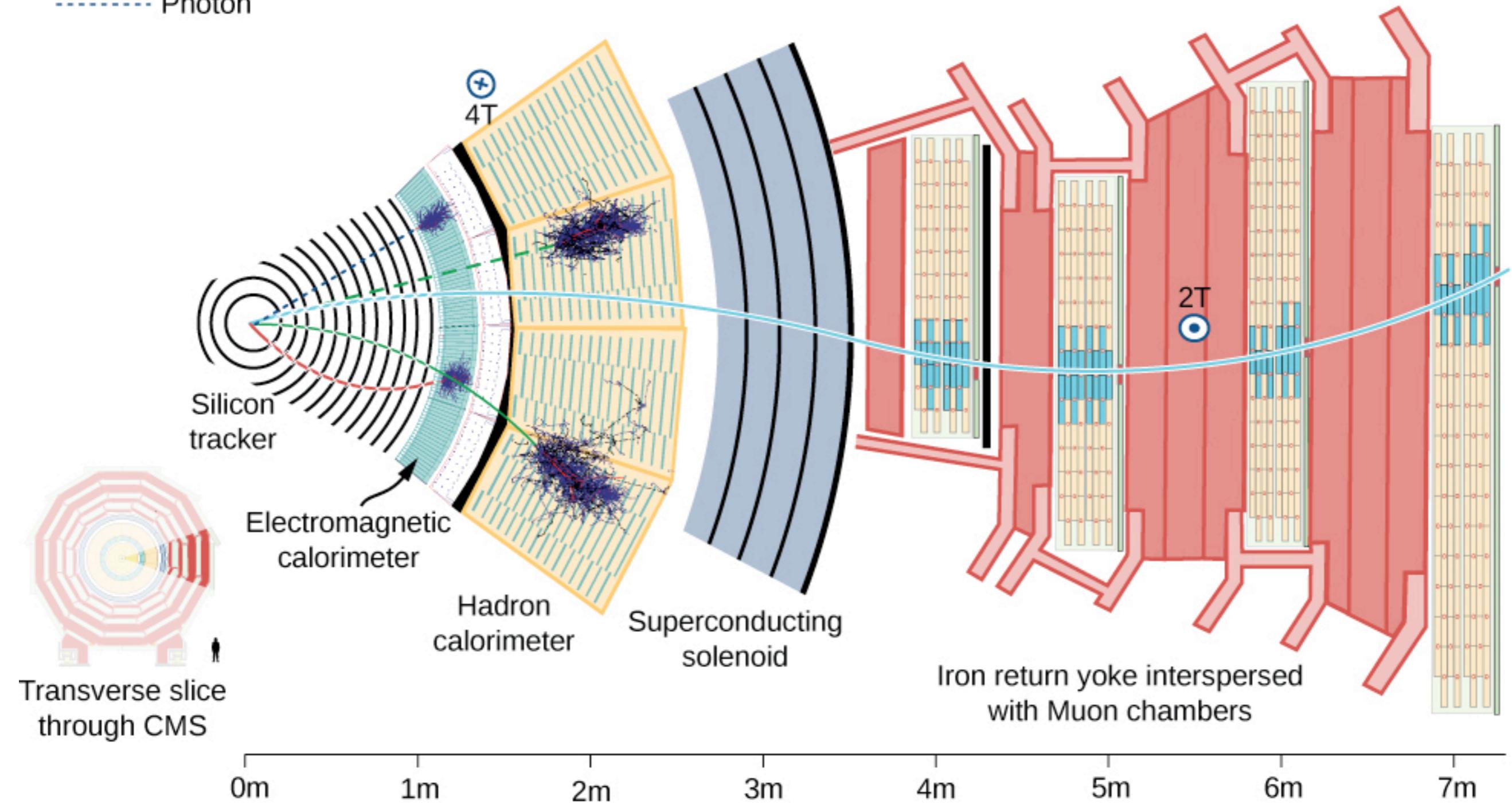


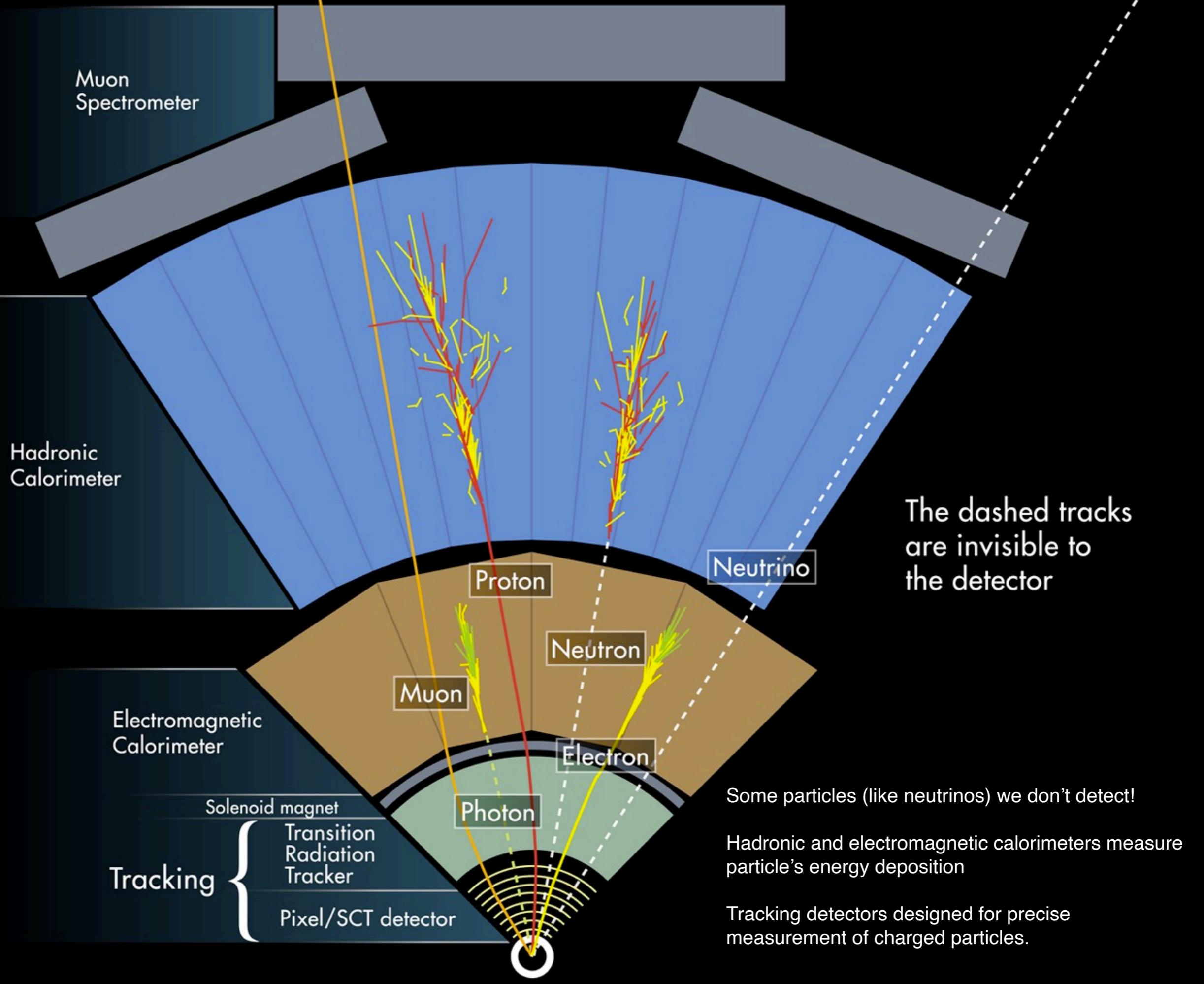
Measuring the particle identification - Cherenkov detectors



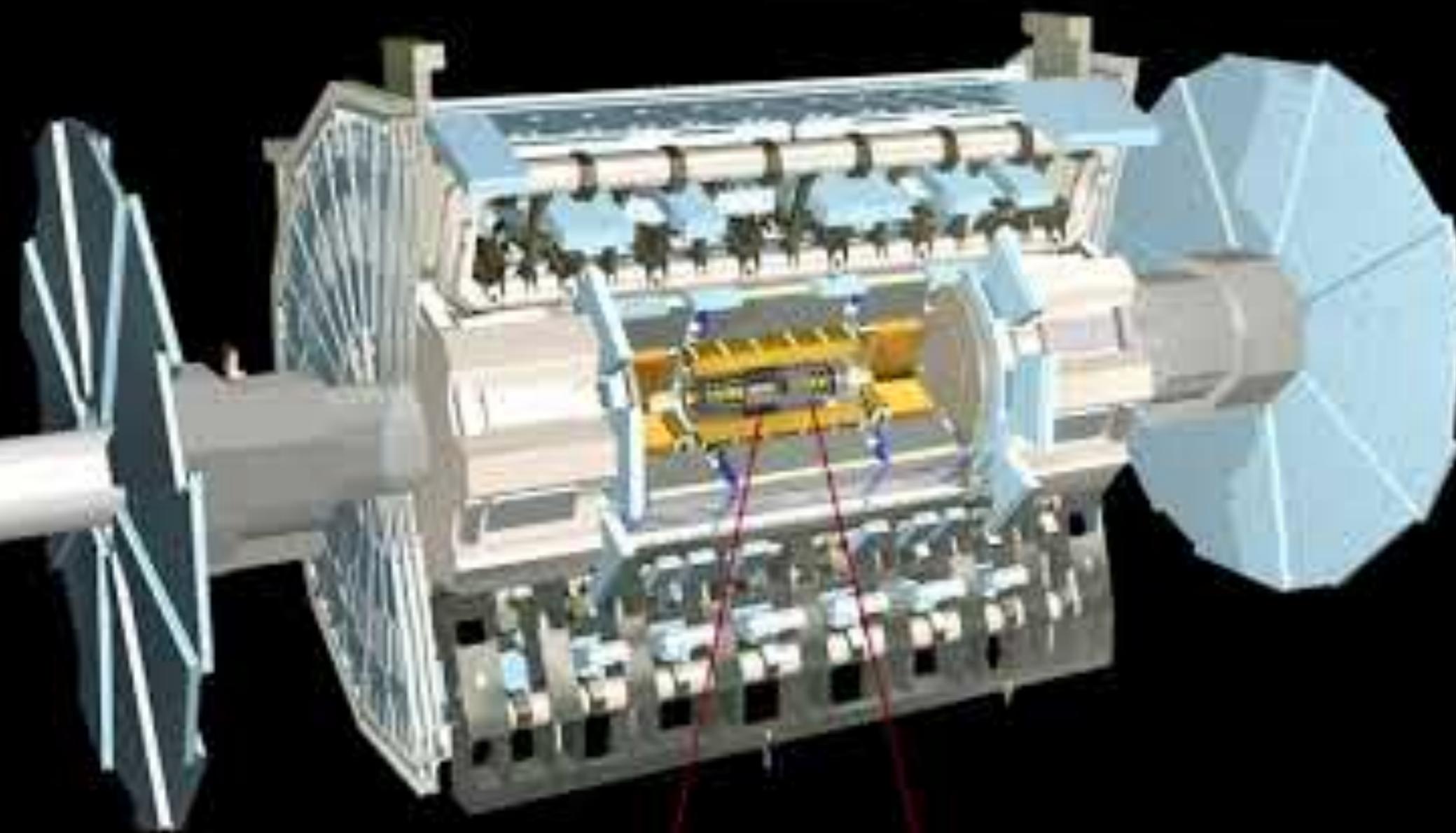
Key:

- Muon
- Electron
- Charged Hadron (e.g. Pion)
- Neutral Hadron (e.g. Neutron)
- Photon





ATLAS Detectors



Pixel detectors and
Semiconductor tracker

Transition radiation tracker



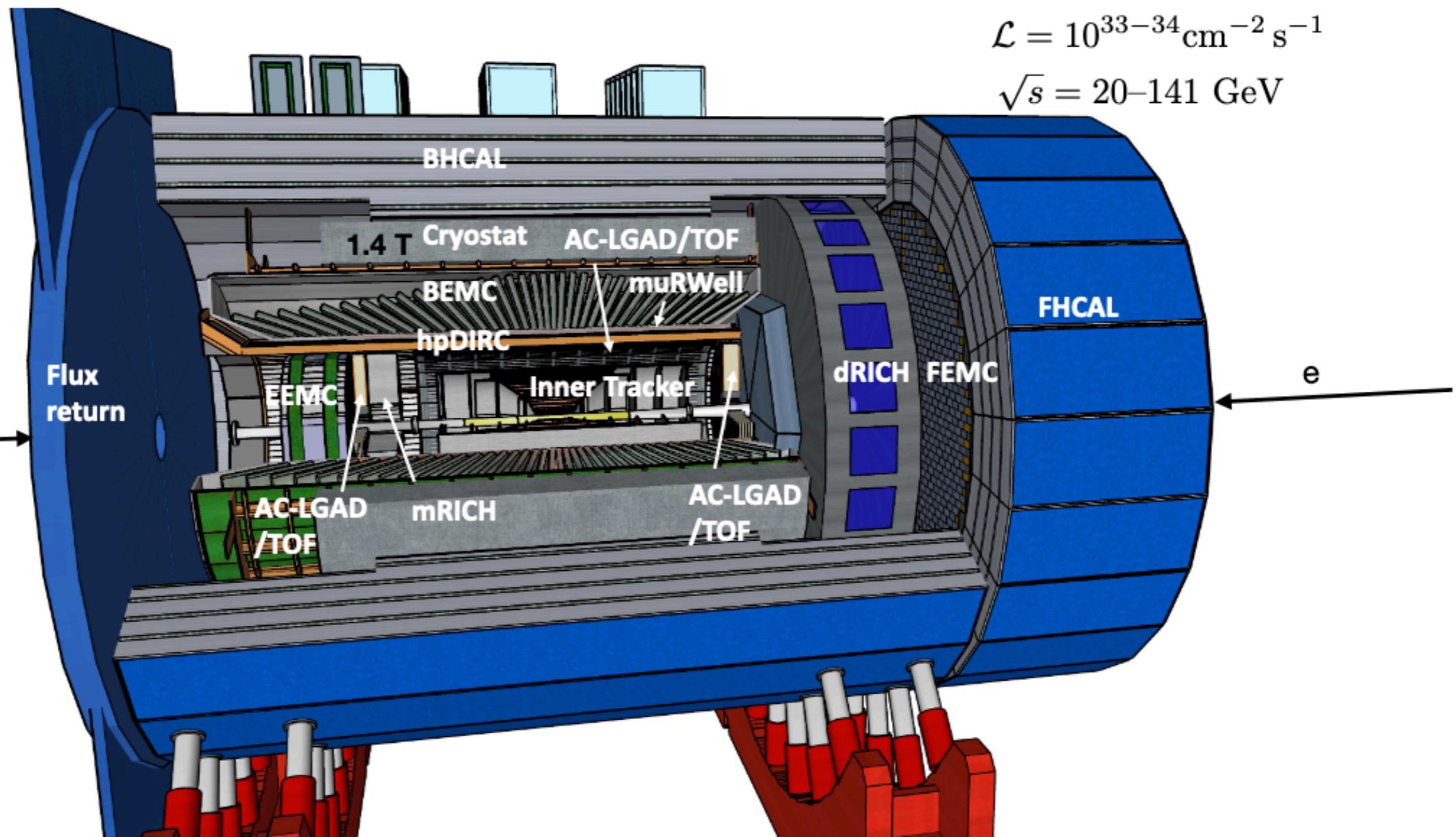
Transition radiation tracker

ECCE – EIC Comprehensive Chromodynamics Experiment

$e + p/A$, with A=D, ..., Au, Pb

$\mathcal{L} = 10^{33-34} \text{ cm}^{-2} \text{ s}^{-1}$

$\sqrt{s} = 20-141 \text{ GeV}$

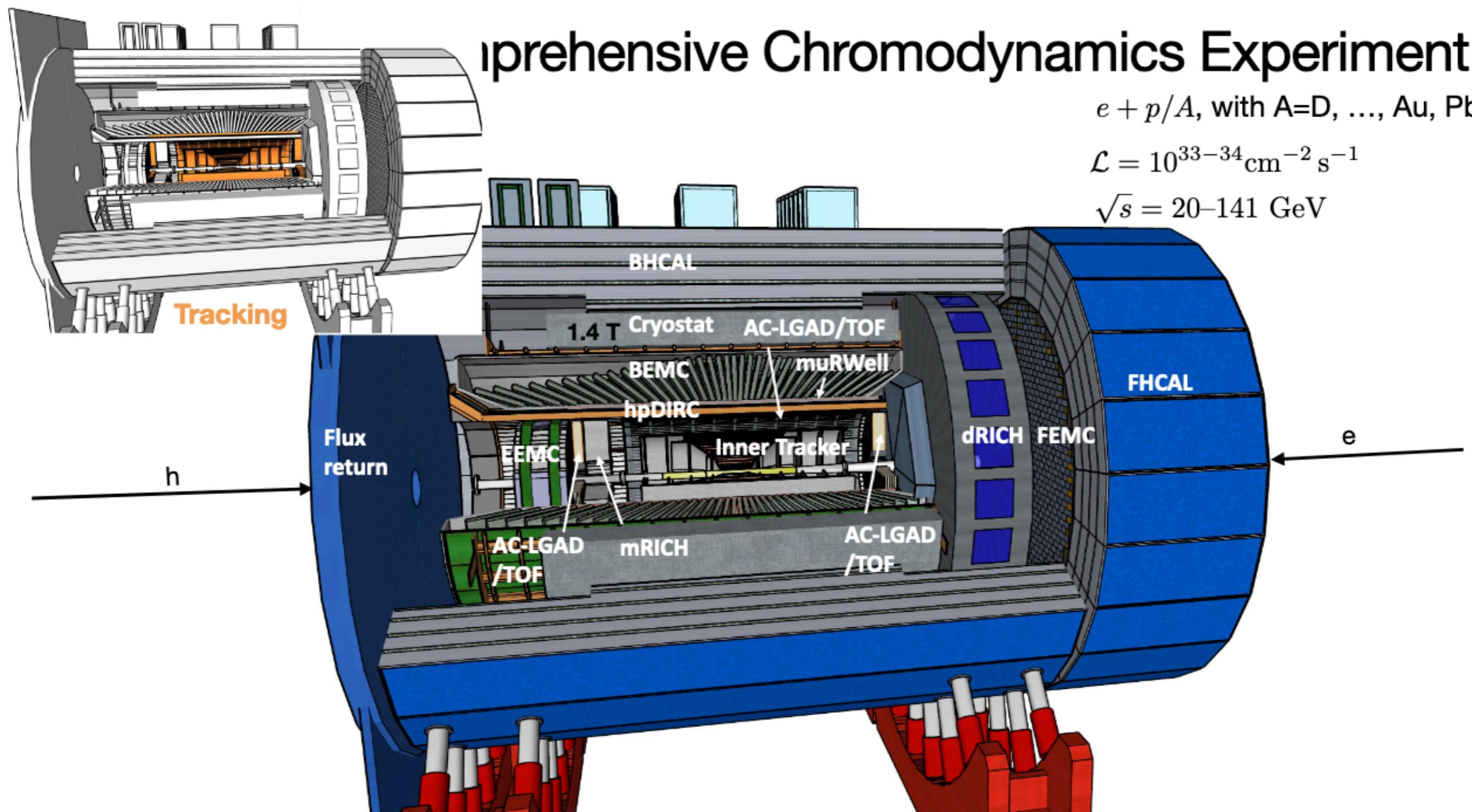


Comprehensive Chromodynamics Experiment

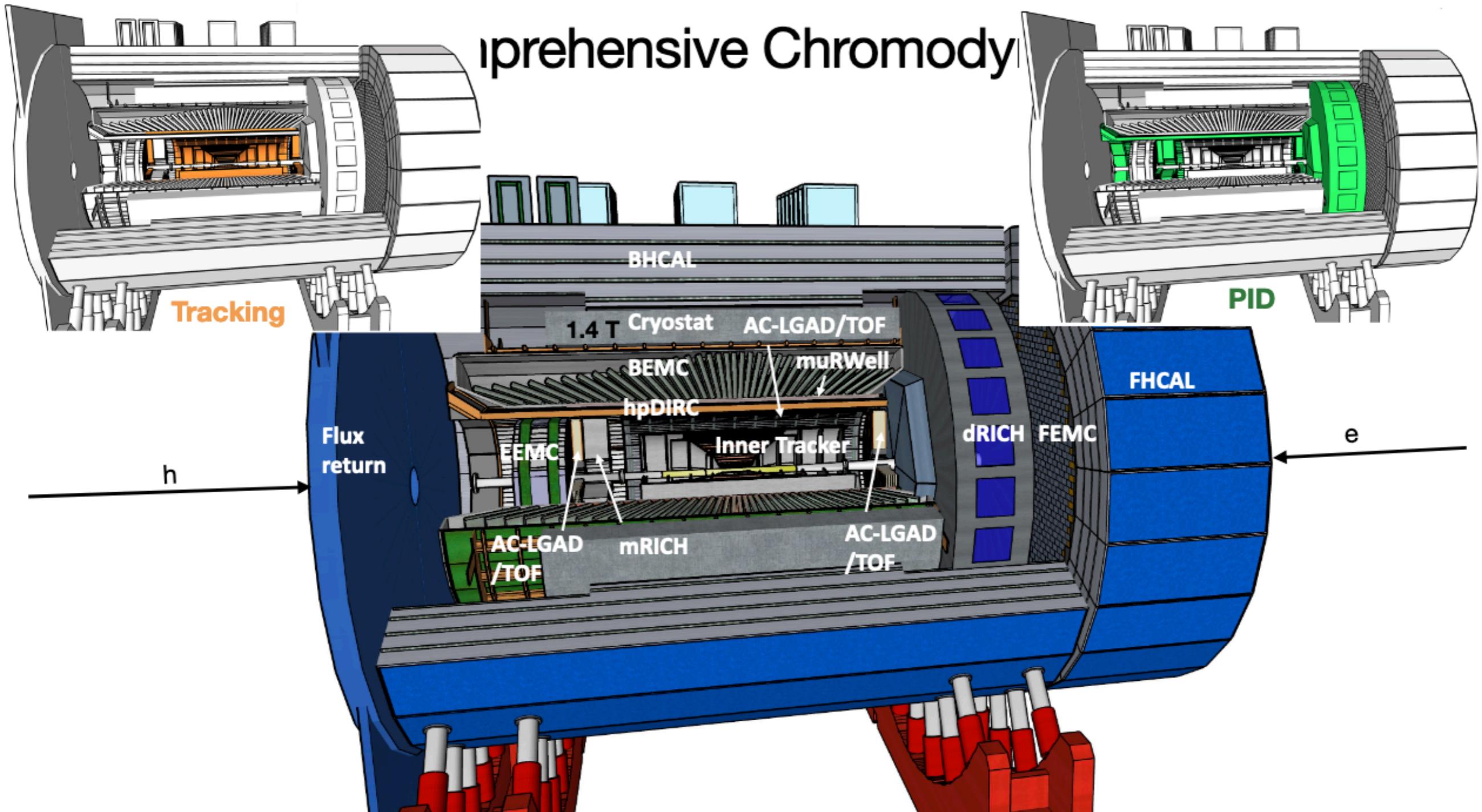
$e + p/A$, with $A=D, \dots, Au, Pb$

$\mathcal{L} = 10^{33-34} \text{ cm}^{-2} \text{ s}^{-1}$

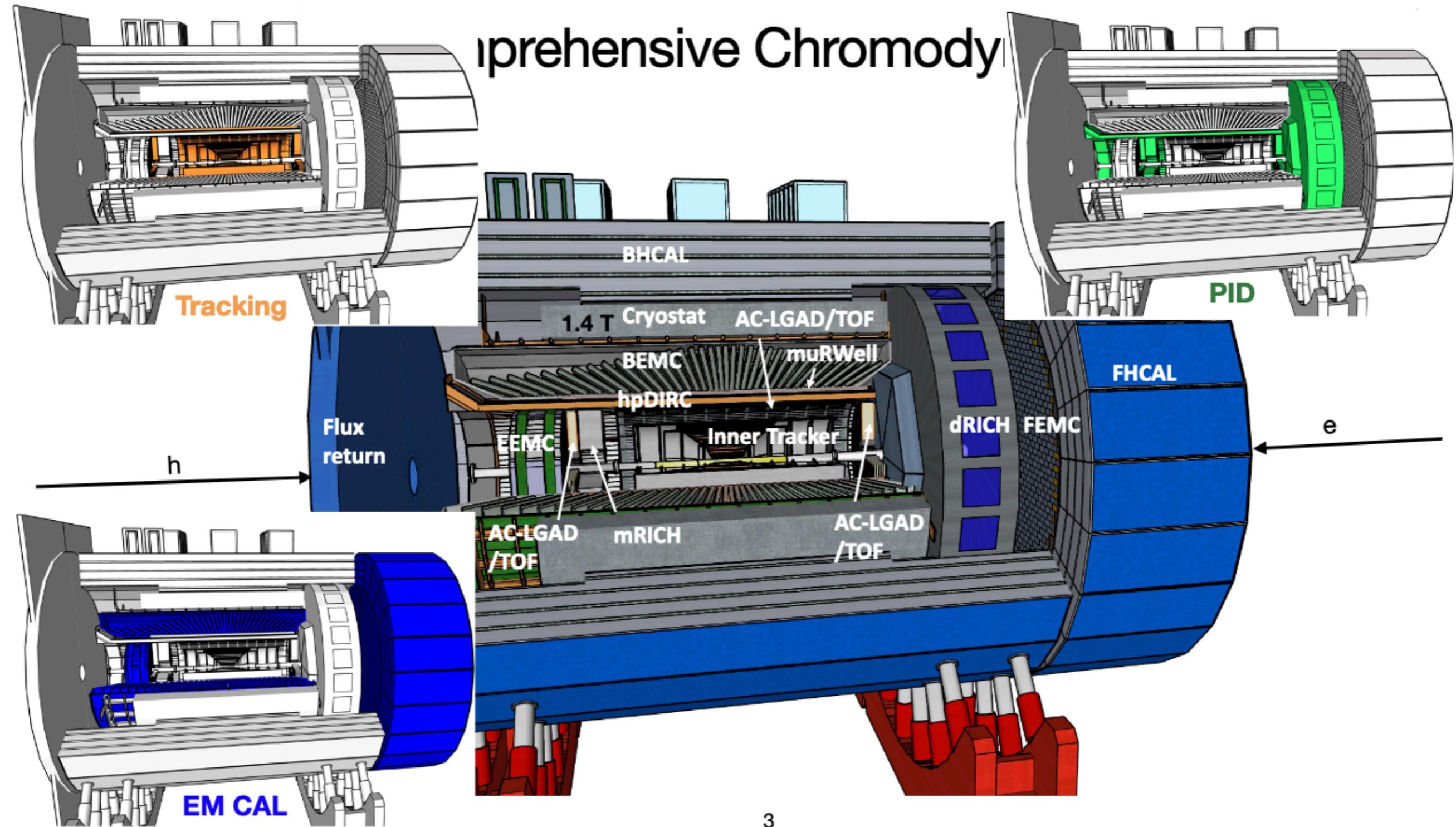
$\sqrt{s} = 20-141 \text{ GeV}$



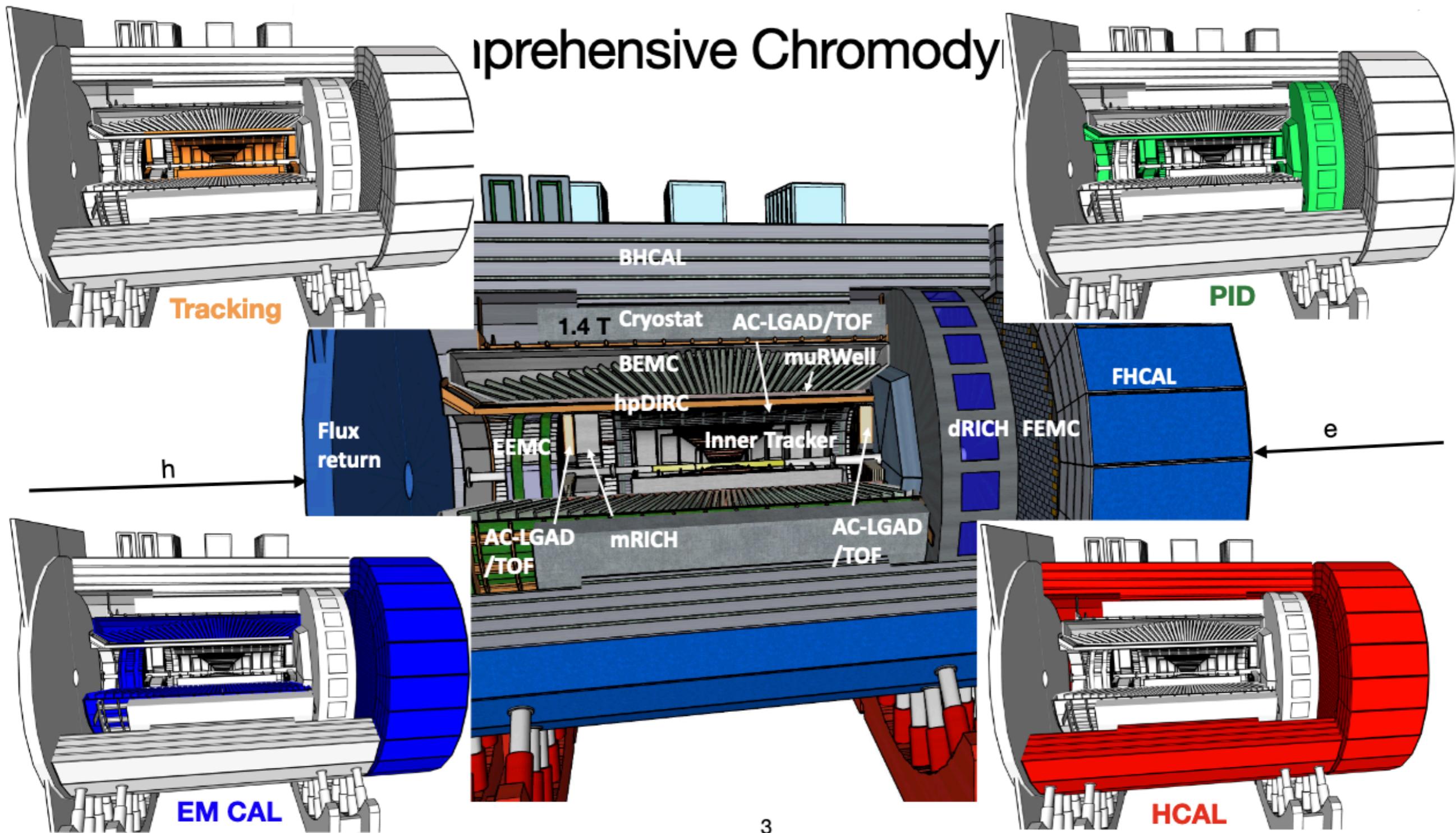
Comprehensive Chromody



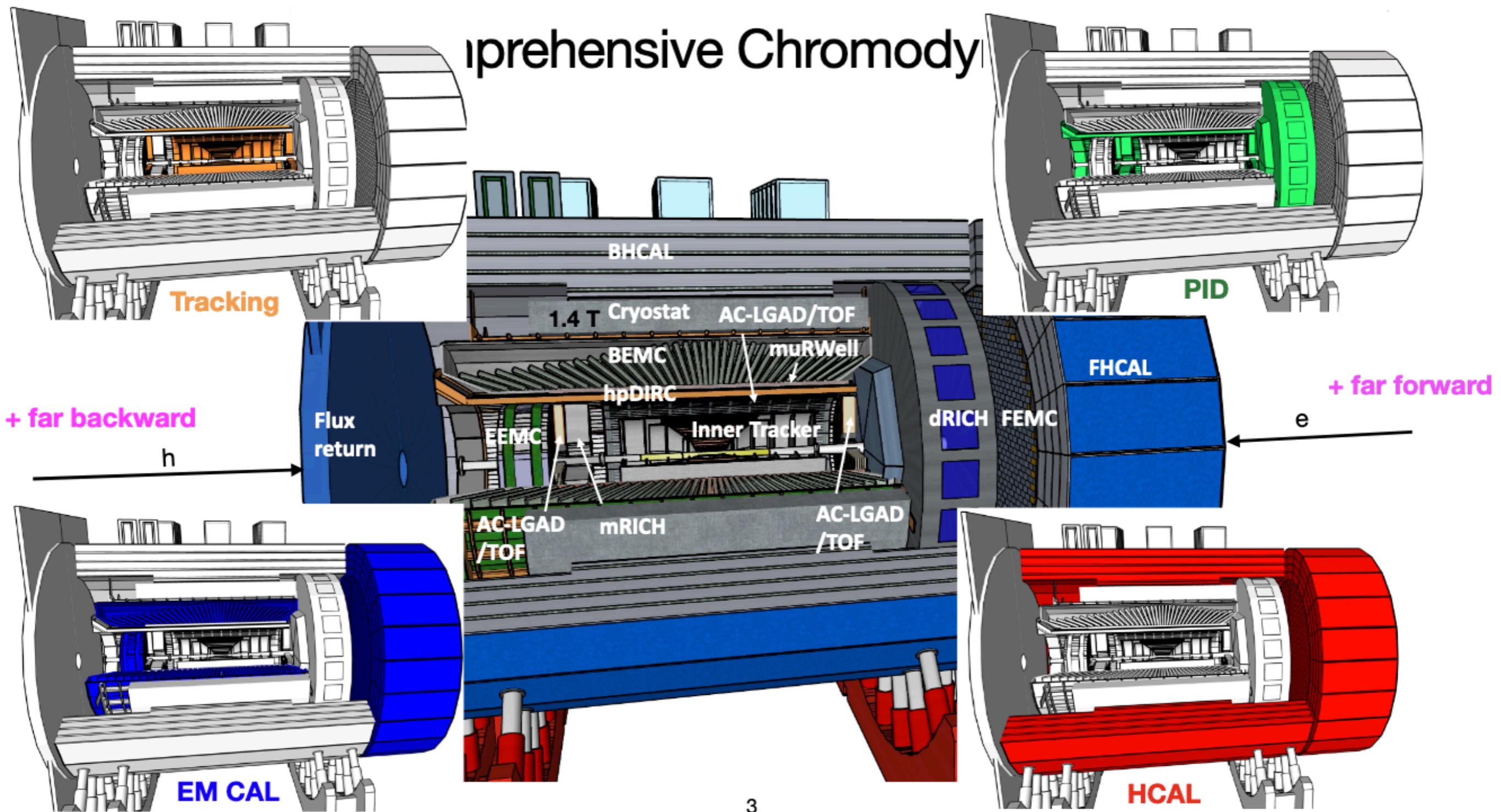
Comprehensive Chromodynamics

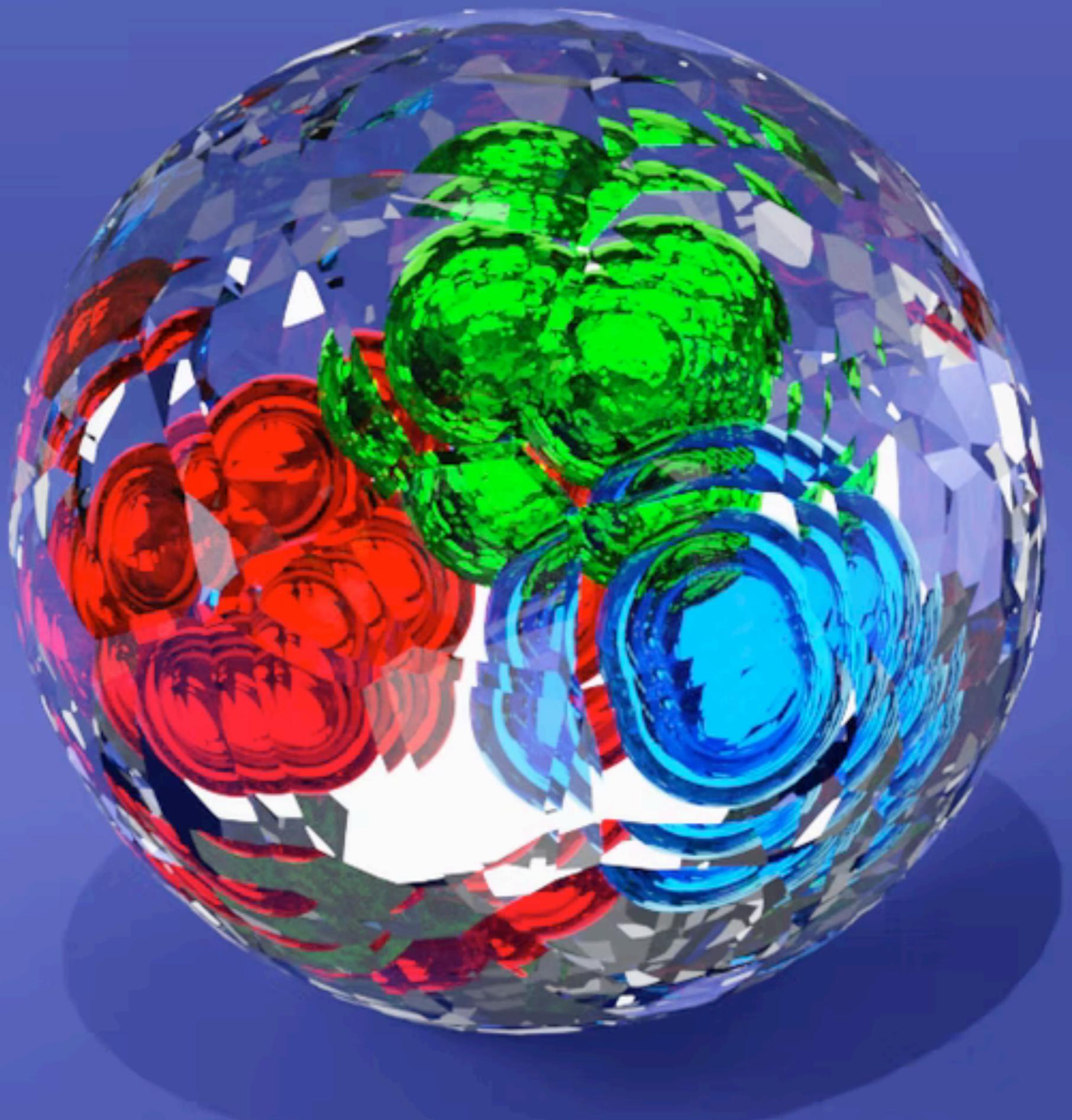


Comprehensive Chromody



Comprehensive Chromody





Different energies at the EIC

	Electron energy (GeV)	Proton energy (GeV)
Group 1	200	920
Group 2	100	940
Group 3	50	250

	Electron energy (GeV)	Proton energy (GeV)
Group 4	25	100
Group 5	50	100
Group 6	50	50
Group 7	20	20