Interlude

Charged particle in magnetic field

Charged particle in magnetic field

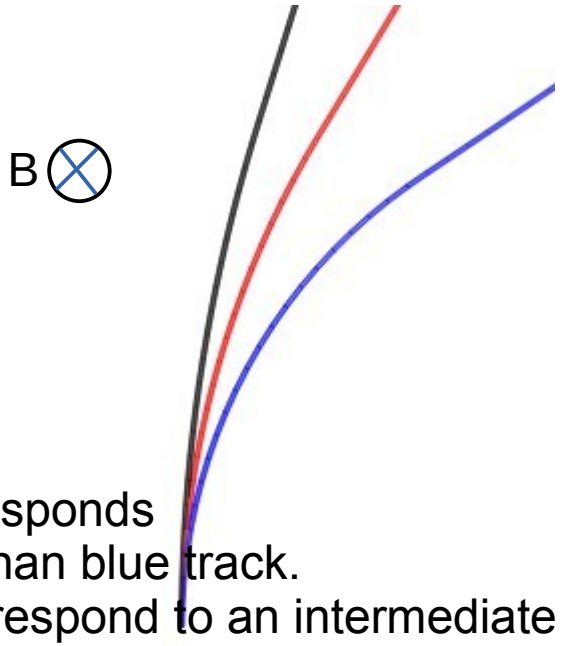
Phys. Rev. 51 (1937) 884

The experimental fact that penetrating particles occur both with positive and negative charges suggests that they might be created in pairs by photons, and that they might be represented as higher mass states of ordinary electrons.

Independent evidence indicating the existence of particles of a new type has already been found, based on range, curvature and ionization relations; for example, Figs. 12 and 13 of our previous publication.[1] In particular the strongly ionizing particle of Fig. 13 cannot readily be explained except in terms of a particle of e/m greater than that of a proton. The large value of e/m apparently is not due to an e greater than the electronic charge since above the plate the particle ionizes imperceptibly differently from a fast electron, whereas below the plate its ionization definitely exceeds that of an electron of the same curvature in the magnetic field; the effects, however, are understandable on the assumption that the particle's mass is greater than that of a free electron. We should like to suggest, merely as a possibility, that the strongly ionizing particles of the type of Fig. 13, although they occur predominantly with positive charge, may be related with the penetrating group above.

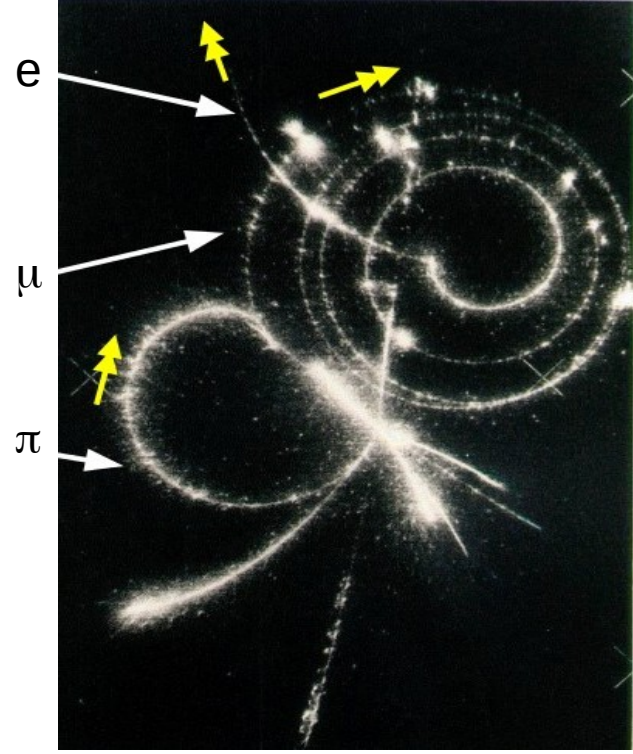
Carl David Anderson
(1905-1991)

Observation



For a given B and P
the black track corresponds
to a heavier object than blue track.
So the red track correspond to an intermediate mass object

Charged particle in magnetic field

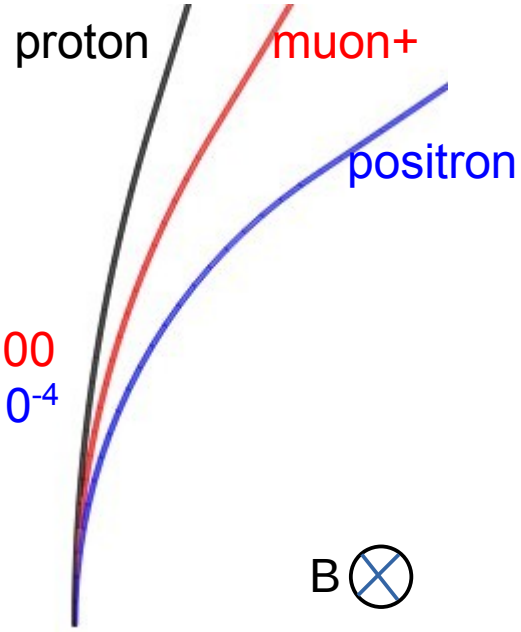


Lorentz force:

$$\vec{F} = q\vec{v} \times \vec{B}$$

$$P \sim 0.3 \cdot R \cdot B$$

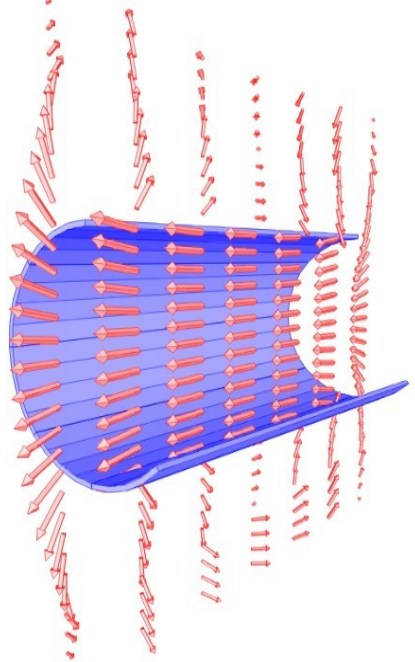
P: momentum (GeV)
R: curvature (m)
B: Magnetic field (Tesla)



Proton mass: ~1
Muon mass: ~0.100
Electron mass: ~5.10^{-4}

Remark: the curvature in this example does not correspond to the relative curvature between proton, muon & electron

Charged particle in magnetic field



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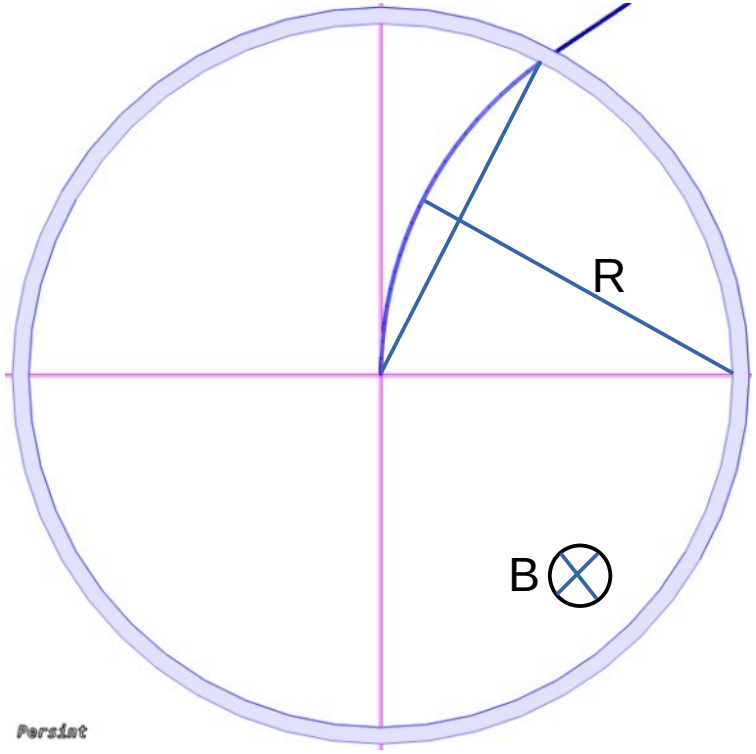
Solenoid (CMS,ATLAS,Delphi...)



Charged particle in magnetic field

Lorentz force:

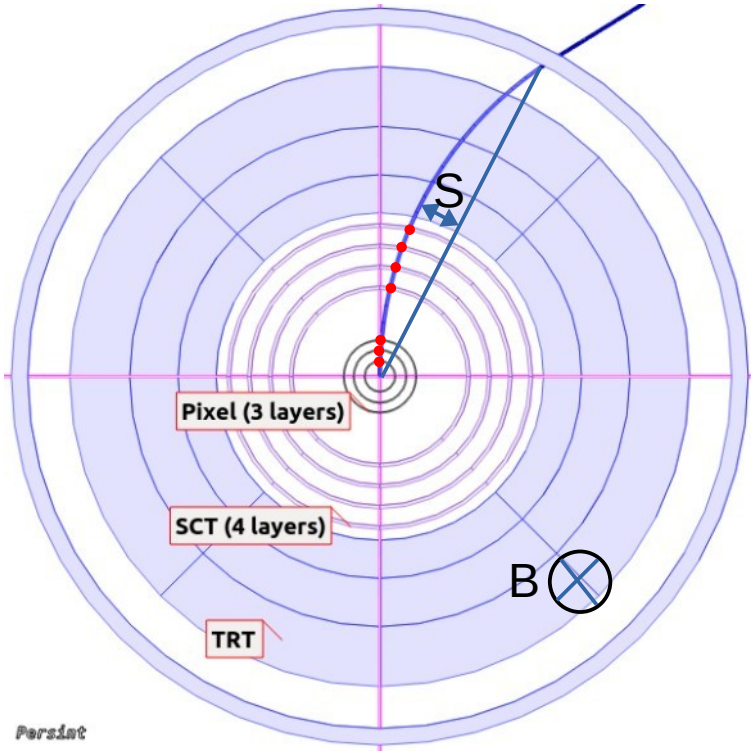
$$\vec{F} = q\vec{v} \times \vec{B}$$

$$P \sim 0.3 \cdot R \cdot B \qquad R \to \frac{1}{S}$$

P: momentum (GeV)
R: curvature (m)
B: Magnetic field (Tesla)

Charged track => signal in detectors
=> reconstruction program
=> Sagitta (=1/R) determination

Solenoid (ATLAS Inner Tracker)



Charged particle in magnetic field

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Charged track => signal in detectors
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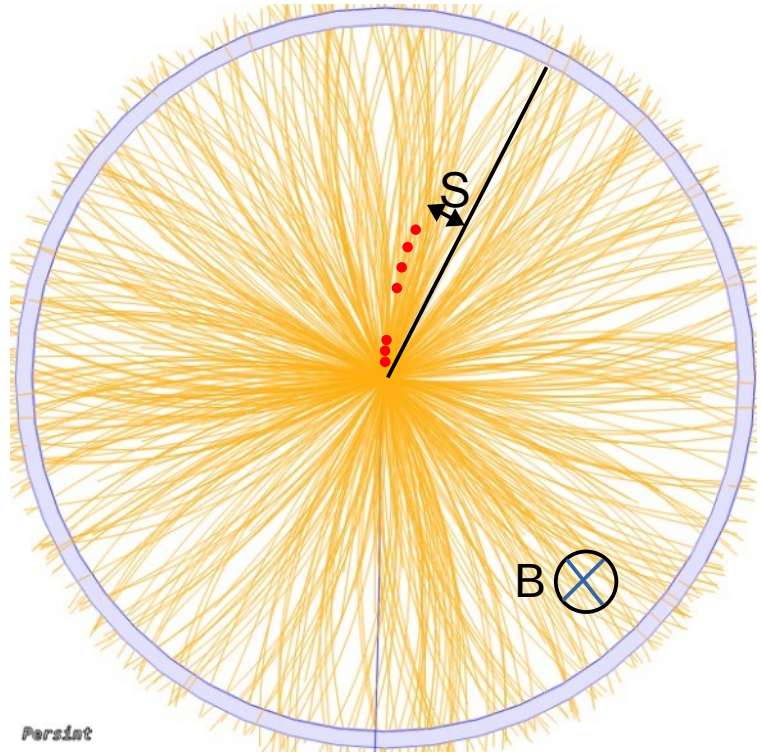
Reconstruction can be complicated

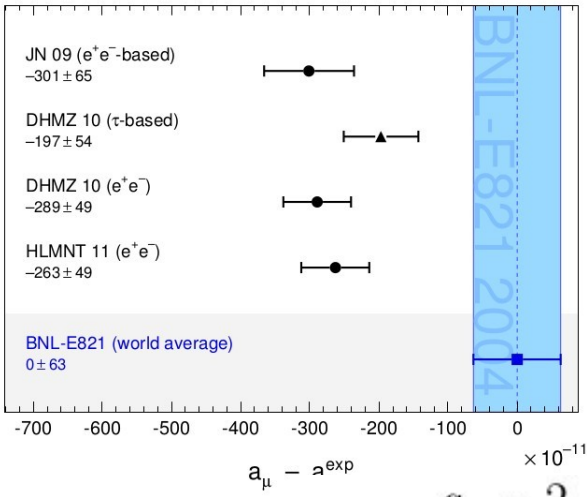
Solenoid (ATLAS Inner Tracker)



Muon Detection

Why Muon Detection?

- Determine intrinsic properties of this elementary particle
  - Constraint on the Standard Model (SM) ex: $g_\mu - 2$
- Very clean probe for many physic domains
  - Astroparticle: proton(cosmic rays) + atm $\rightarrow$ π $\rightarrow$ μ
  - Particle physics: Higgs $\rightarrow$ 4 μ
  - Neutrino signature for both domain
- As a tool:
  - Trigger
  - Veto
  - Detector calibration: MIP
  - Muo-graphy
- How?
  - Detection mechanism:
    - Ionisation, Scintillation, Cherenkov radiation
  - Identification:
    - Tag after “walls”, dE/dx, Cherenkov
  - + Magnetic Field => momentum measurment



$$a_\mu \equiv \frac{g_\mu - 2}{2}$$

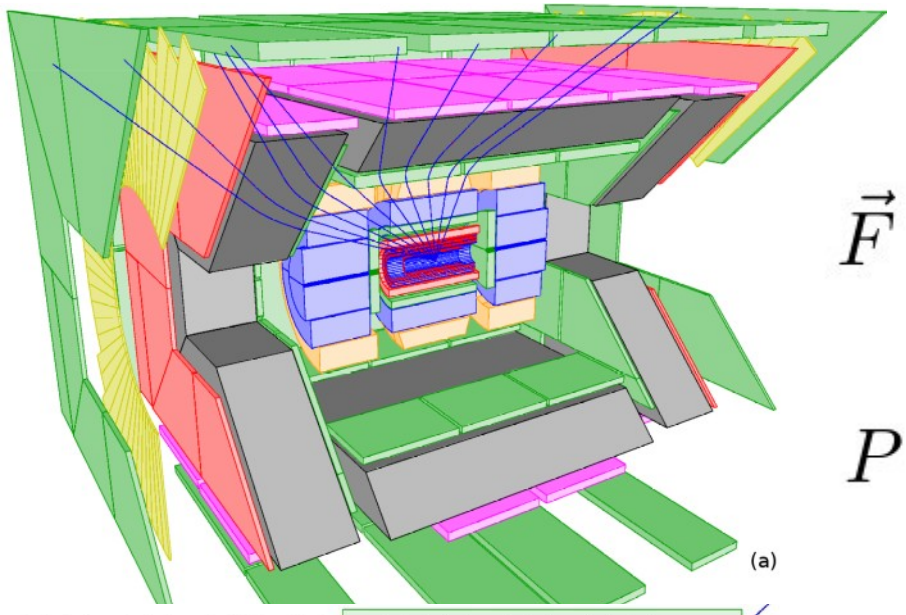
Search for Hidden Chambers in the Pyramids

The structure of the Second Pyramid of Giza is determined by cosmic-ray absorption.

Luis W. Alvarez, Jared A. Anderson, F. El Bedwei,

Charged particle in magnetic field

All detectors D0 to ATLAS,CMS,...until AMS are using Magnetic Field to measure the particle momentum.



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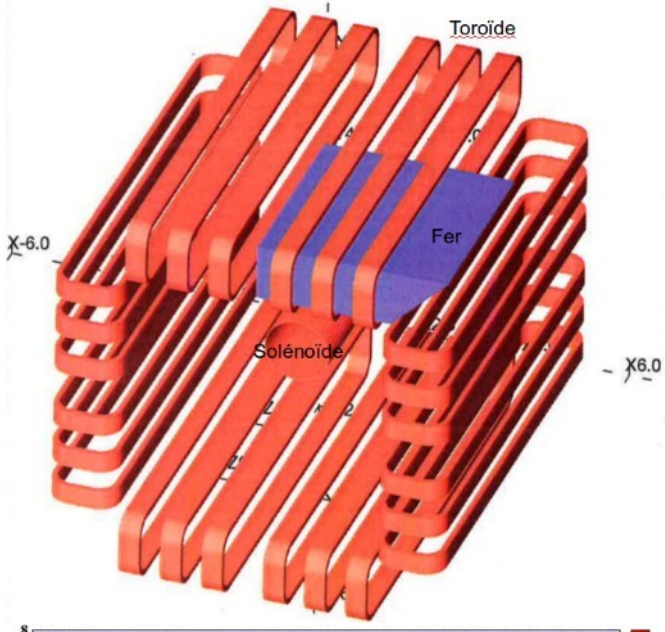
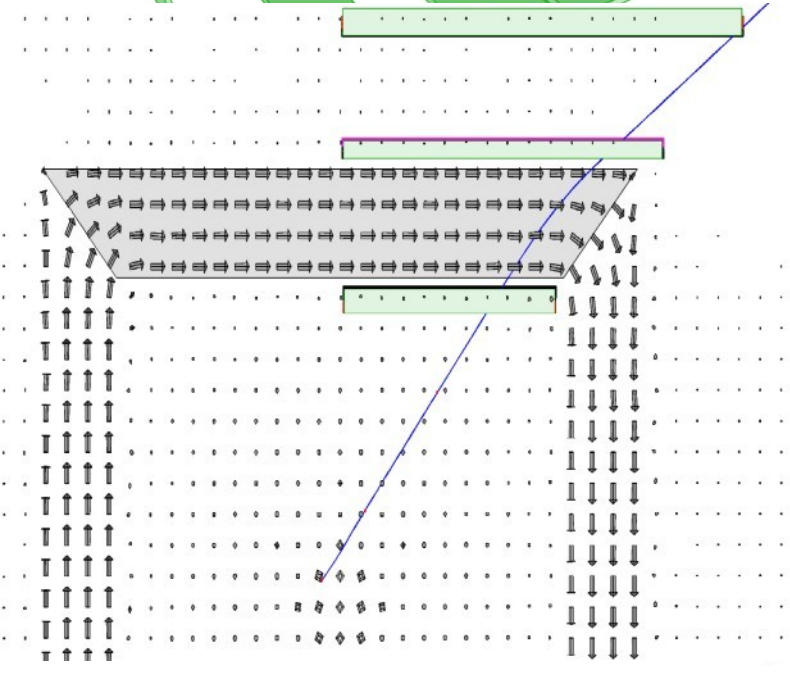
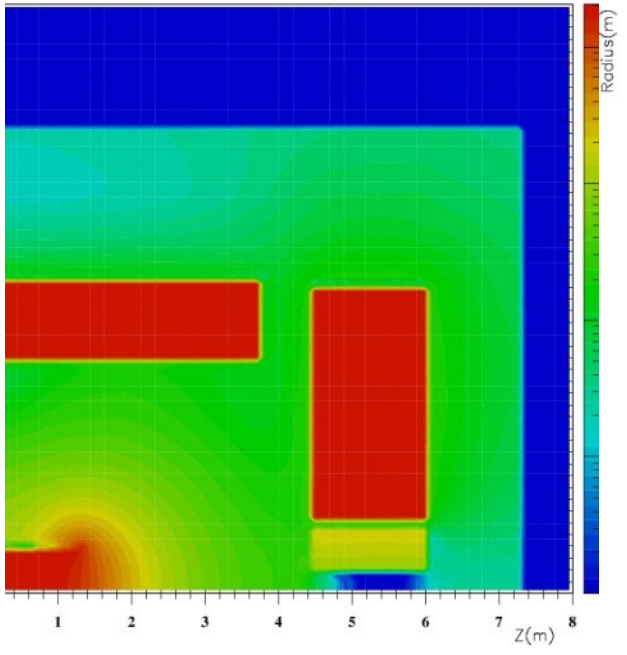
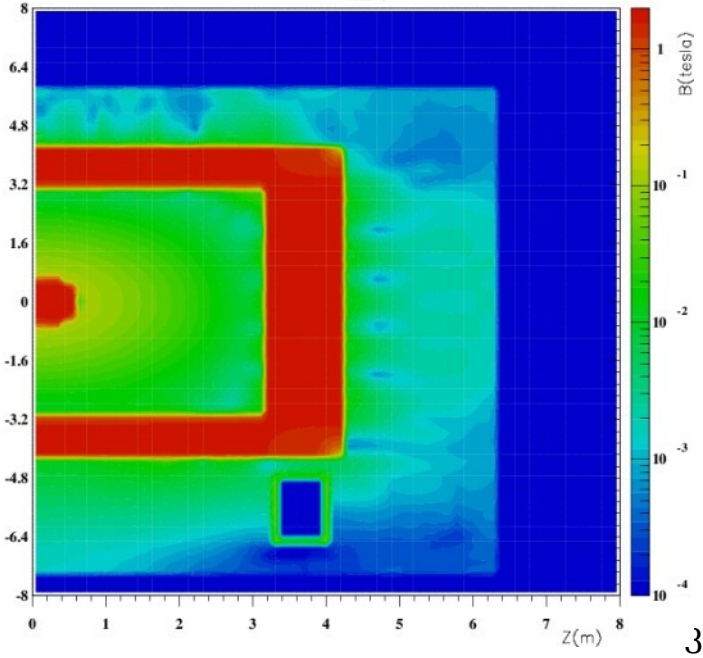
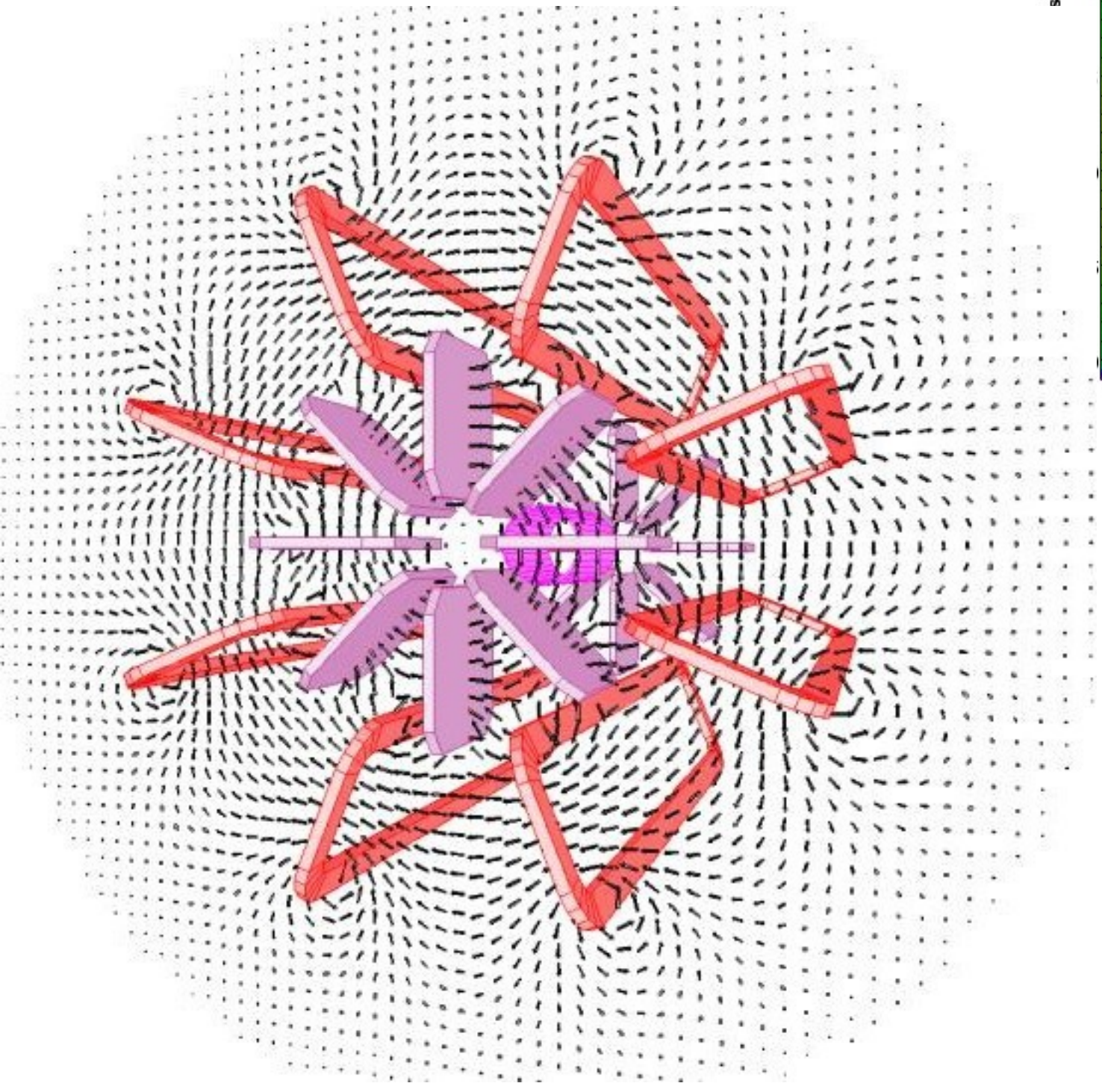


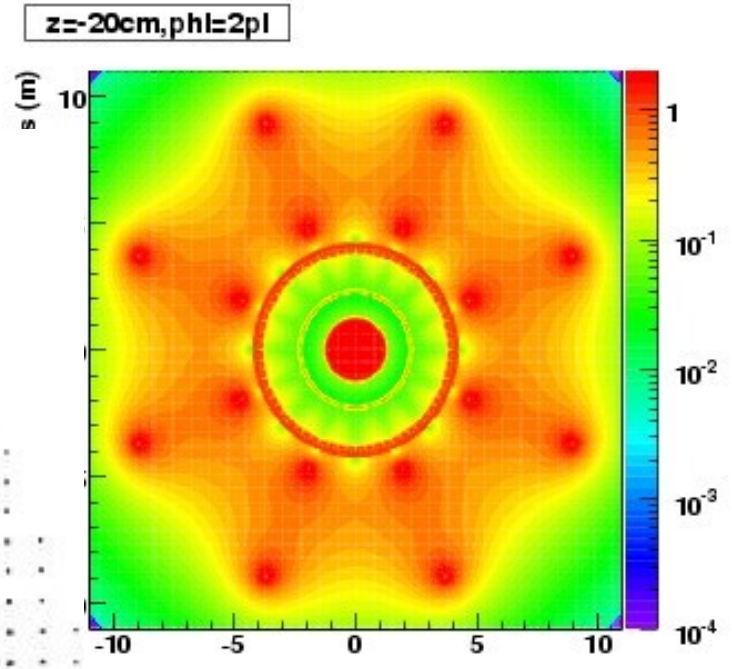






Charged particle in magnetic field



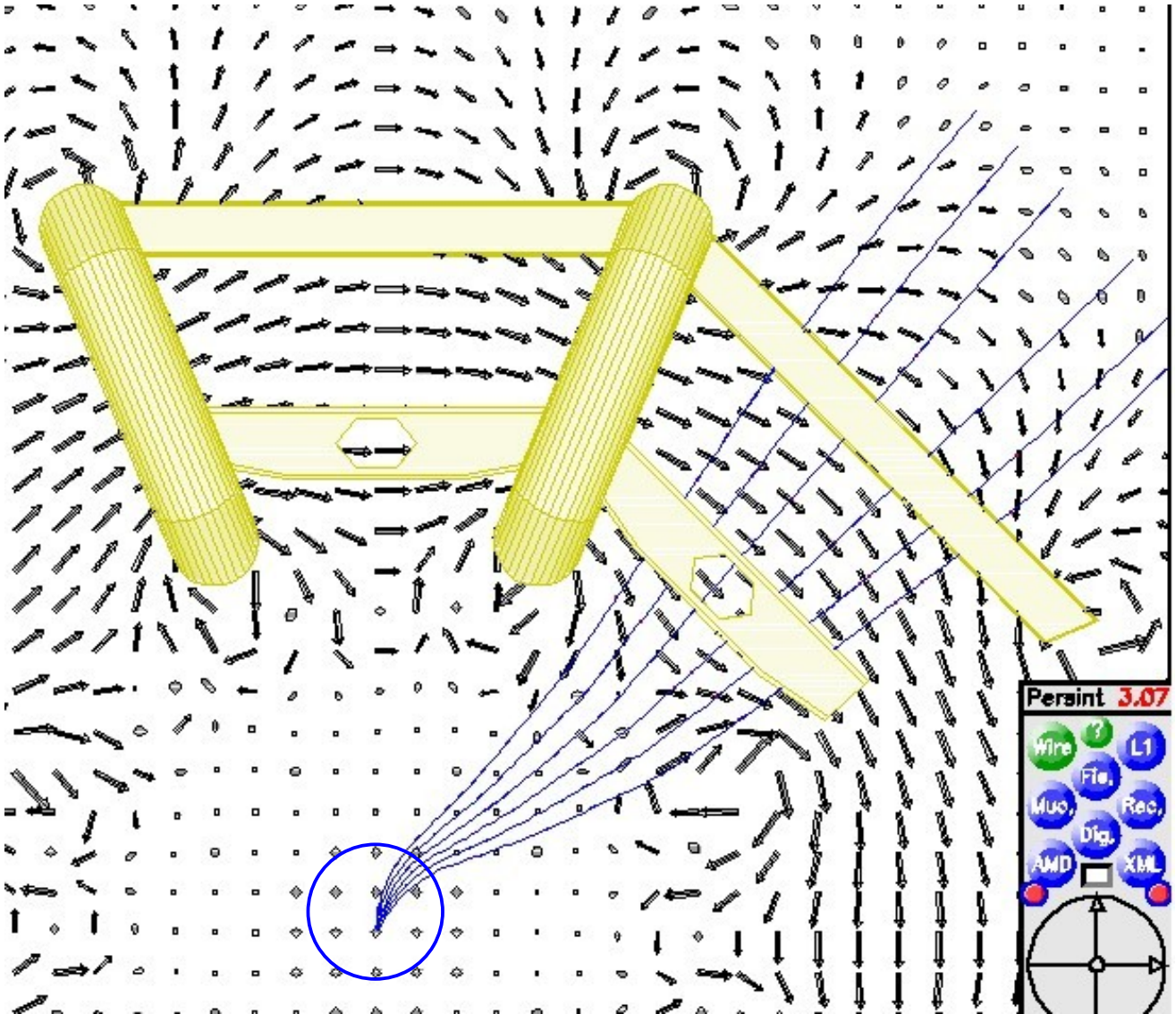


ATLAS magnetic field
1 solenoid
3 toroids

Charged particle in magnetic field

ATLAS magnetic field
1 solenoid
3 toroids

R-ϕ projection



Charged particle in magnetic field

ATLAS magnetic field
1 solenoid
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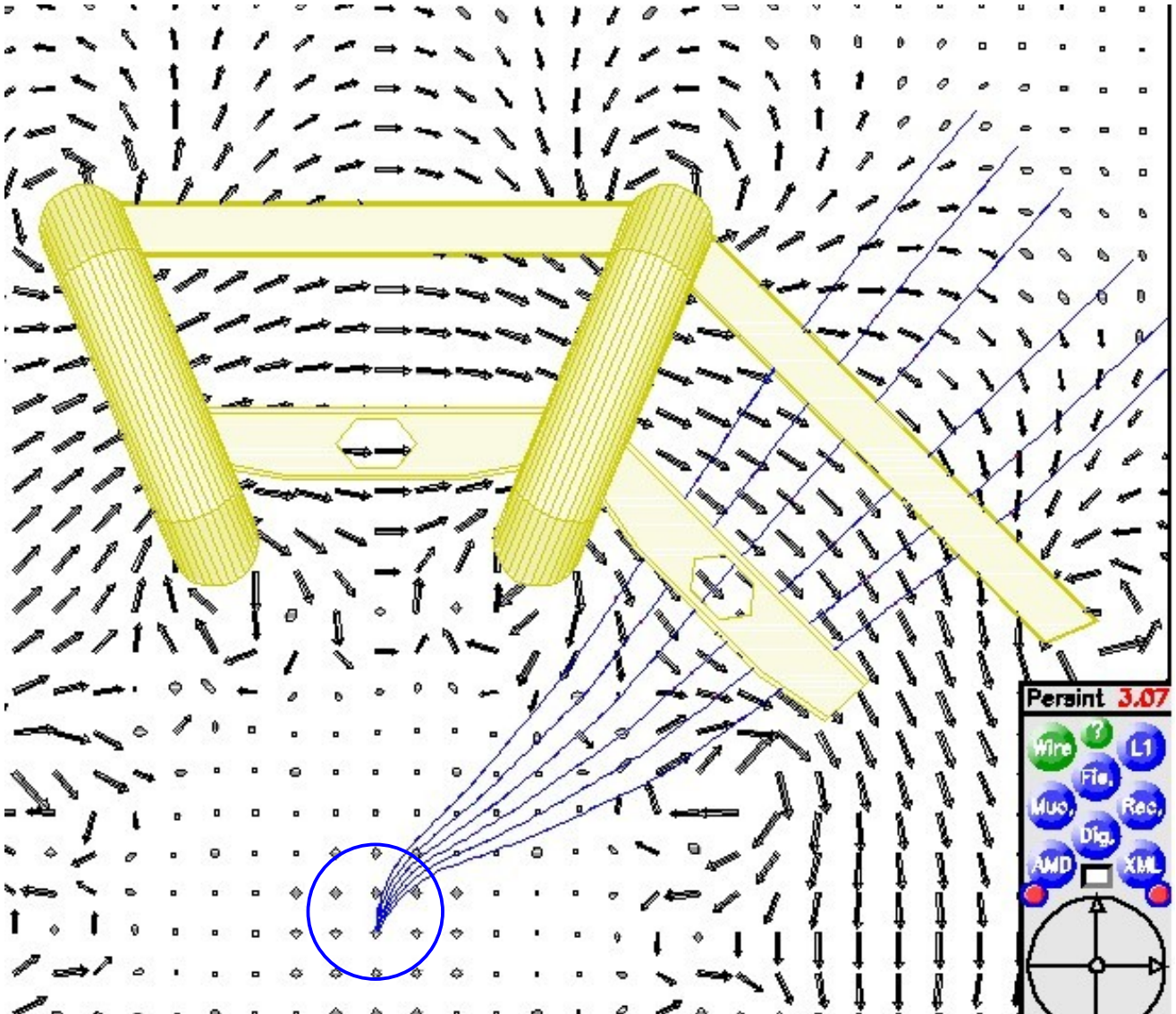
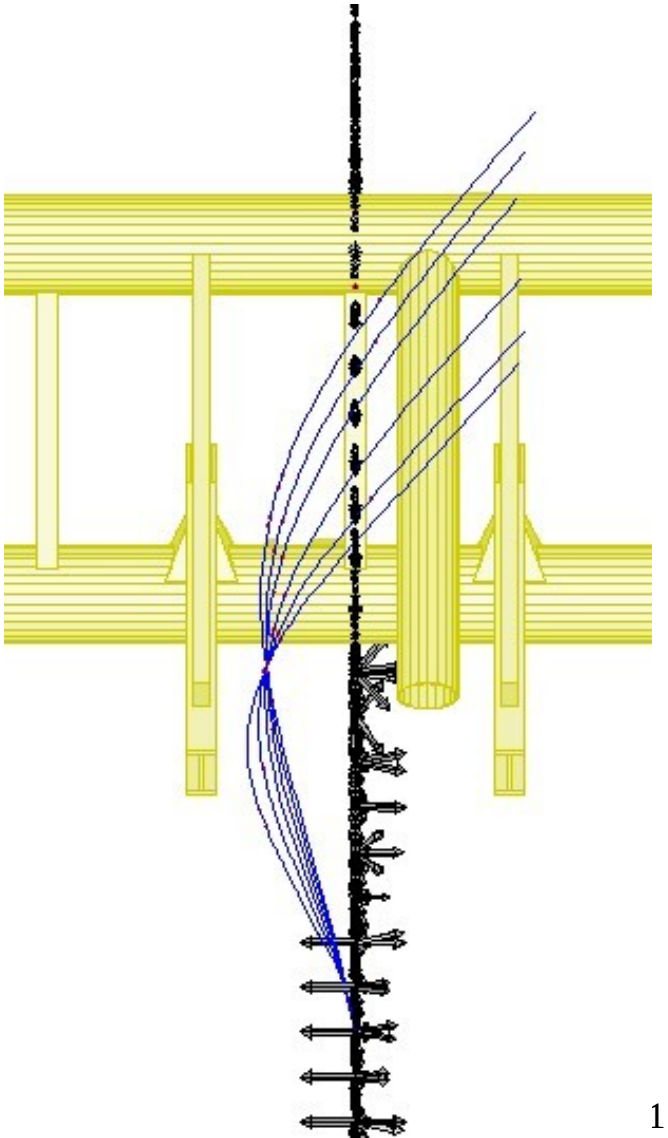


R-Z projection



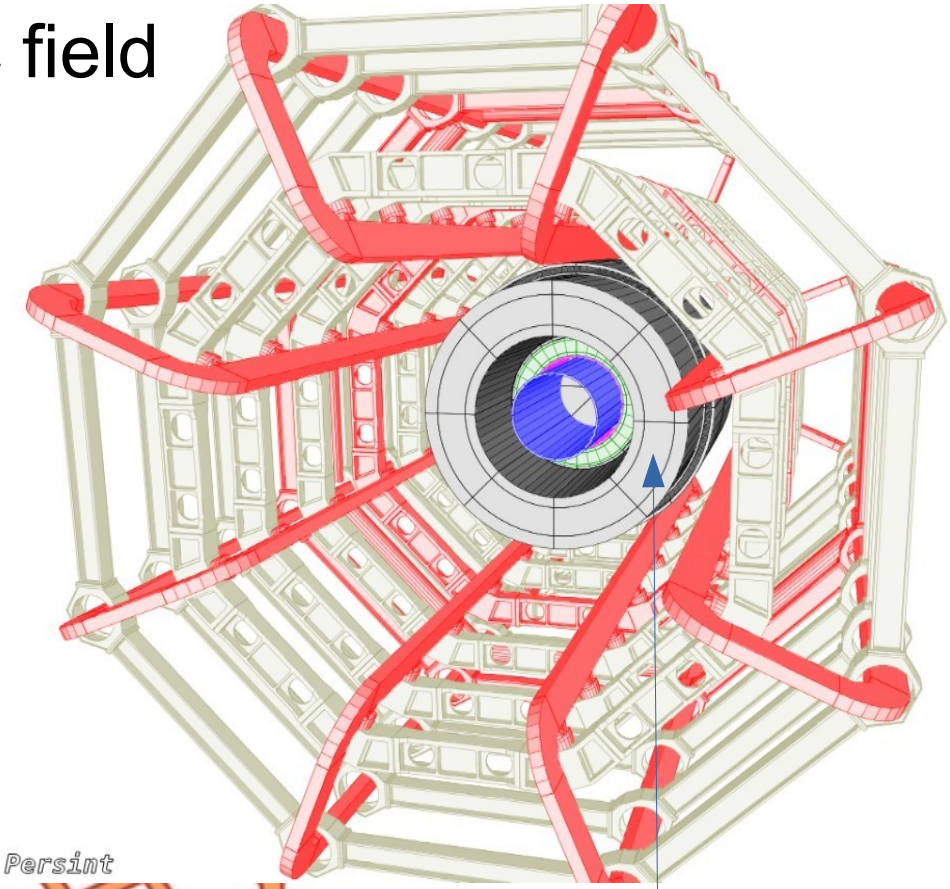
Charged particle in magnetic field

Order of Magnitude:

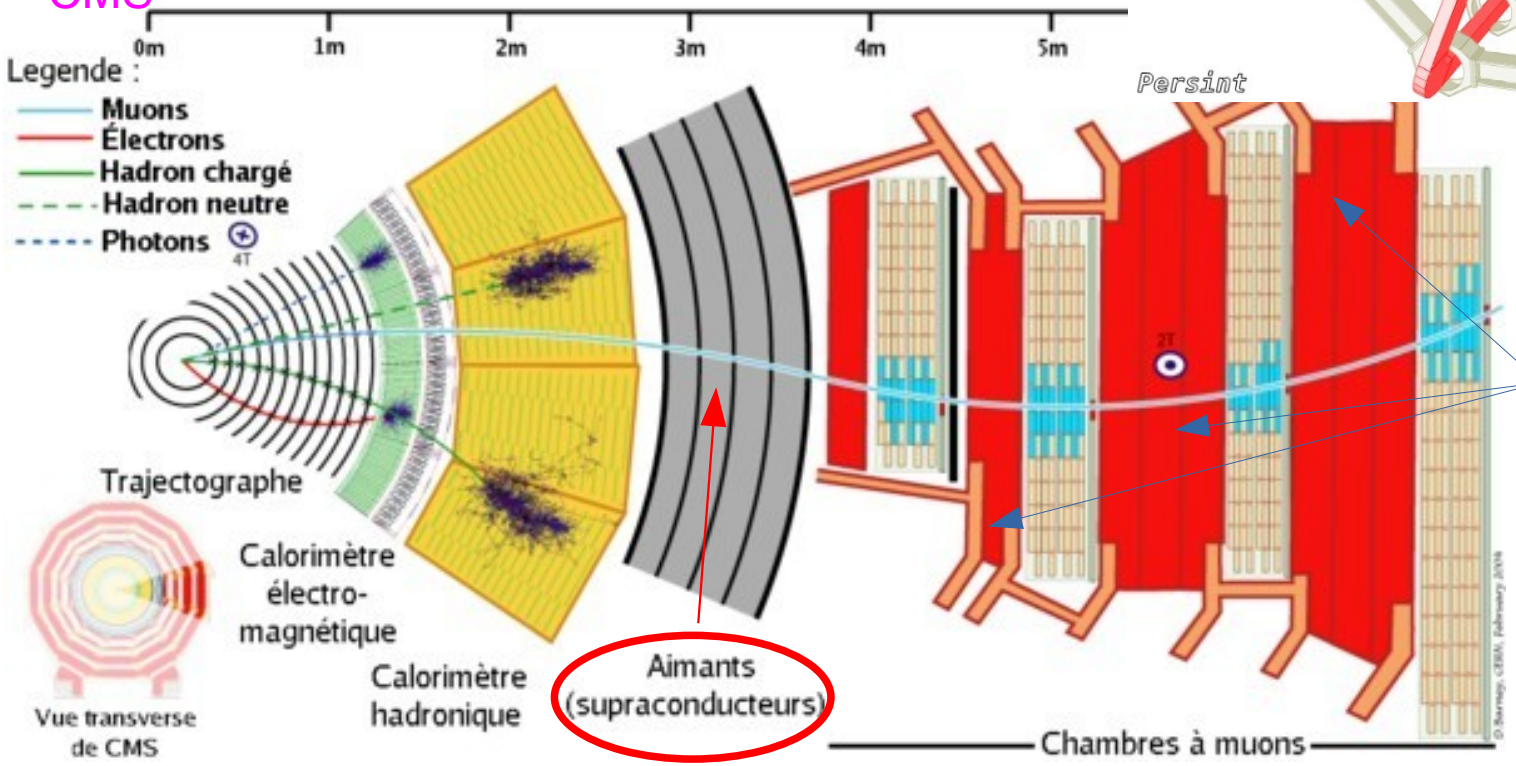
Toroid ATLAS: B~0.5 Tesla

Solenoid ATLAS (R=1m): B~2.0 Telsa

Solenoid CMS (R=3m): B~3.8 Telsa



CMS



Solenoid Return Yoke

Charged particle in magnetic field

Order of Magnitude:

Toroid ATLAS: B~0.5 Tesla
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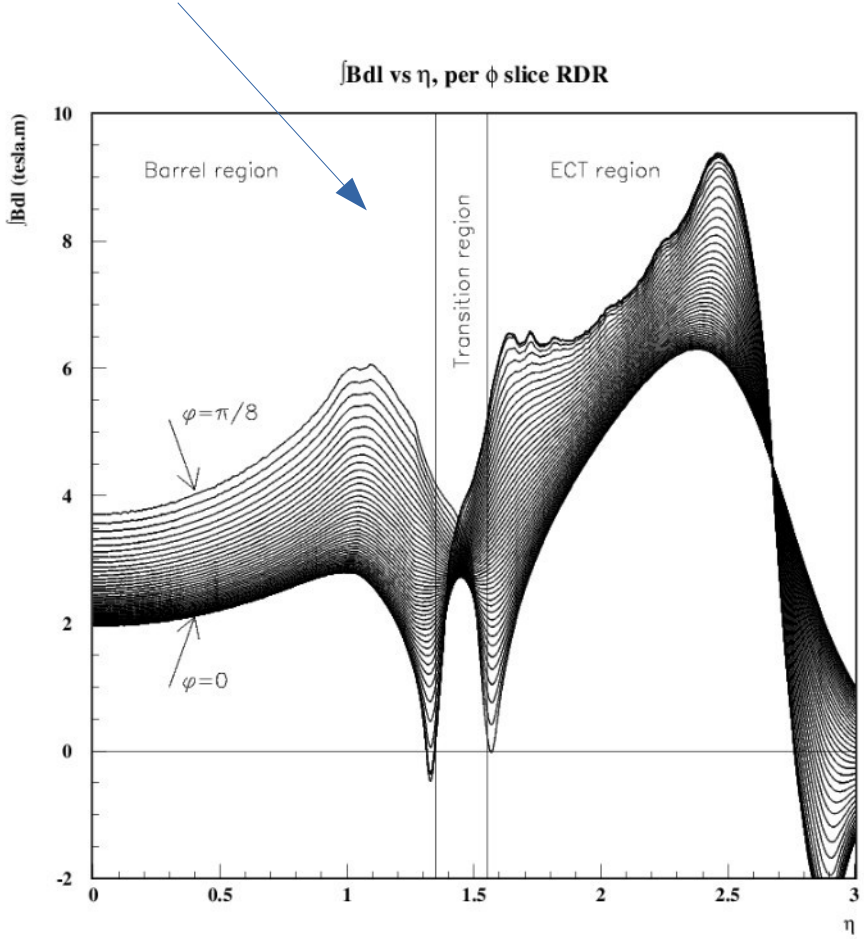
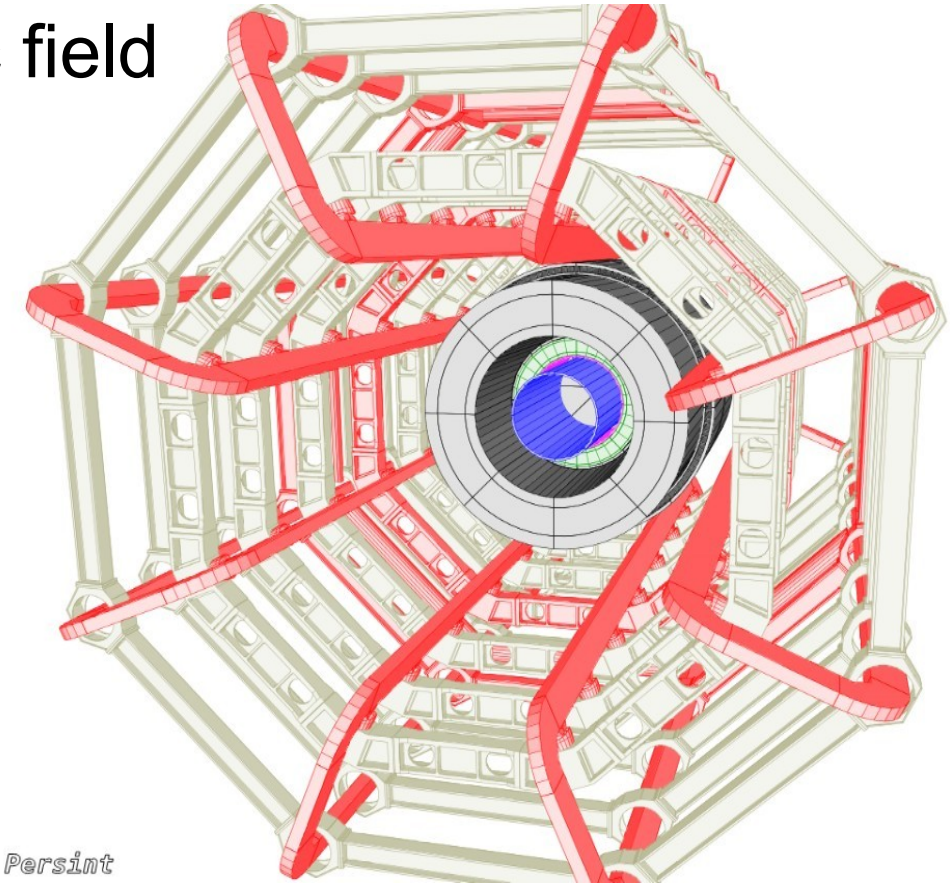
Int Bdl is the relevant parameter for a magnet

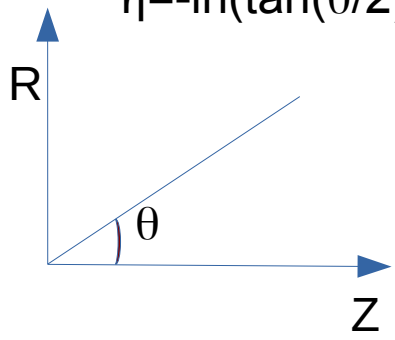




Solenoid: IntBdl → η

Toroid: IntBdl → with η

η=-ln(tan(θ/2))



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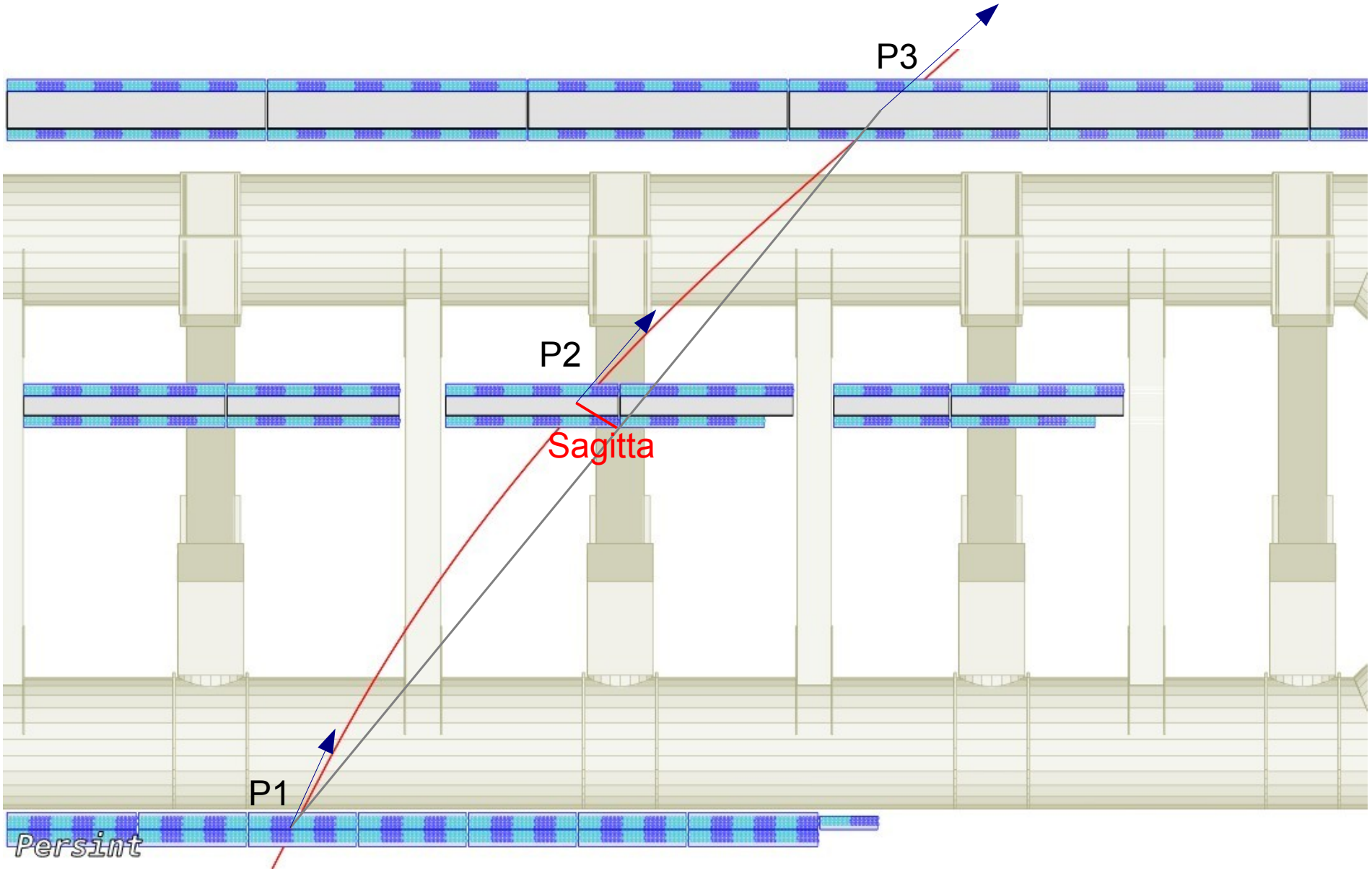

3 measurement points (p1,p2,p3): d(p1,p3) straight line
Sagitta: distance between d(p1,p3) & p2

Interlude: Detectors conception

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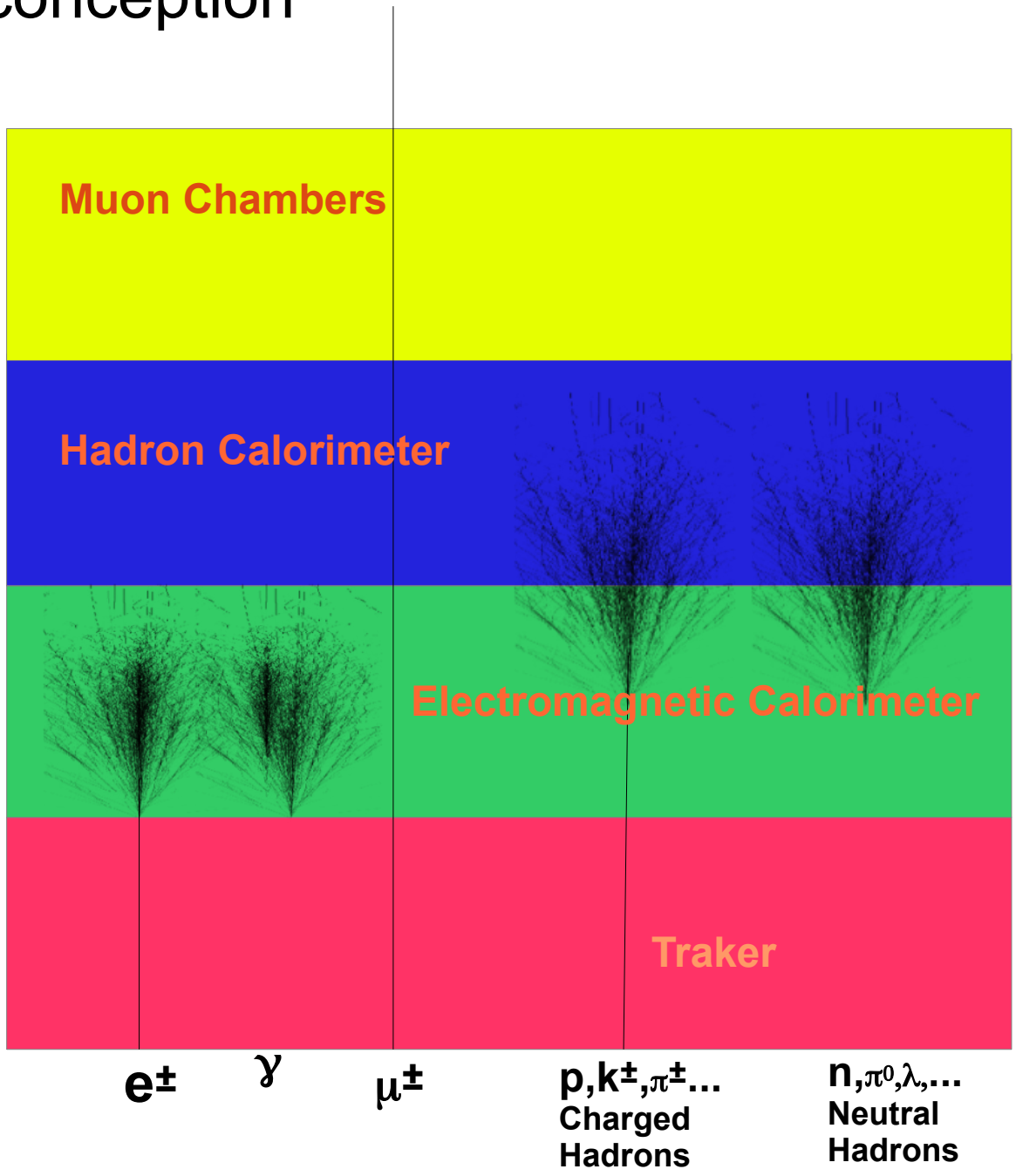
Principle

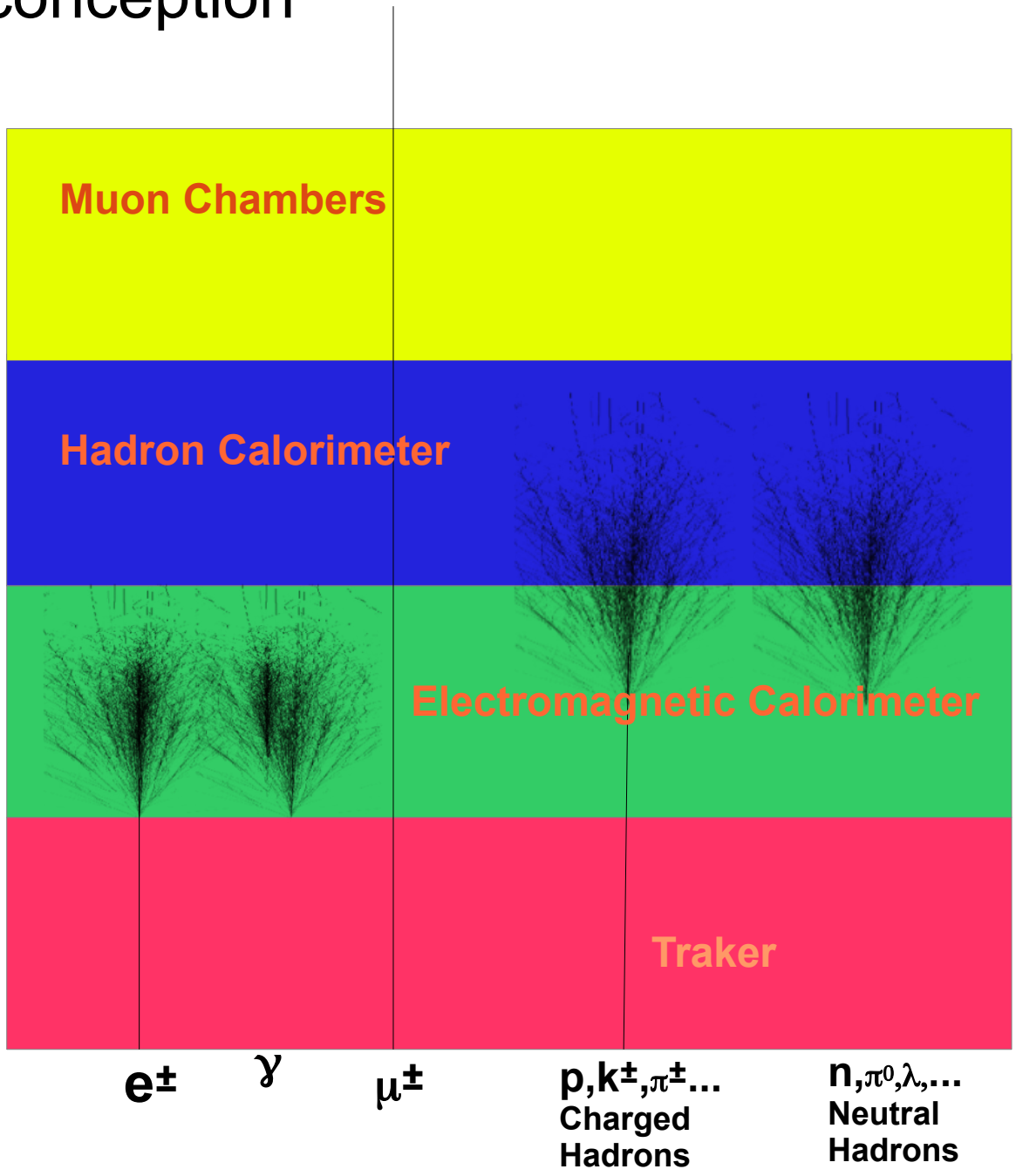
- Muon detection:
  - Tracker (charged particle)
  - MIP in calorimeter
  - Tracks in Muon chambers



Interlude: Detectors conception

Principle

- Muon as Tool
  - Trigger
  - Veto
    - Ice Cube
    - Double Chose
  - Calibration MIP
    - LHC
    - Hess (Telescope)

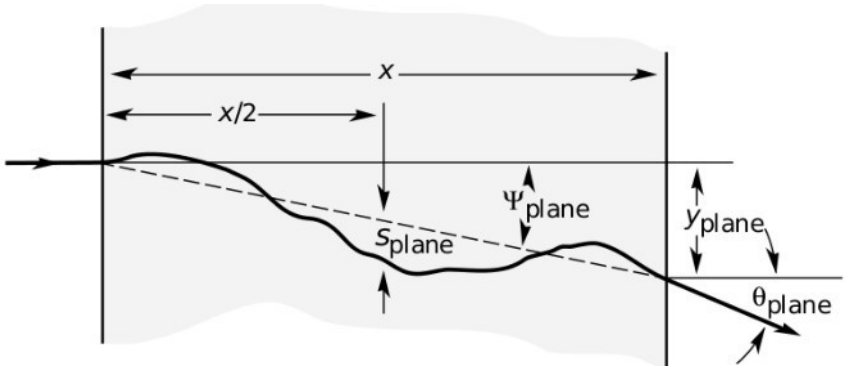


Interlude: Detectors conception

Coulomb scattering

- Multiple scattering : perturbation (degradation)
  - Deflection
  - => minimize matter ex: Muon spectrometer (ATLAS)

$$\theta_0 = \frac{13.6\ \text{MeV}}{\beta c p}\, z\, \sqrt{x/X_0}\left[1 + 0.038 \ln(x/X_0)\right]$$



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CMS