Multiwire proportional drift chambers

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- What are they and what are they good for?
- Basics of construction and gas properties (charge, drift)
- Two examples from ALICE@LHC:
  - Time Projection Chamber (TPC)
  - Transition Radiation Detector (TRD)

Basics

A bit of history

Invented: 1968, Georges Charpak (NIM 62 (1968) 202)

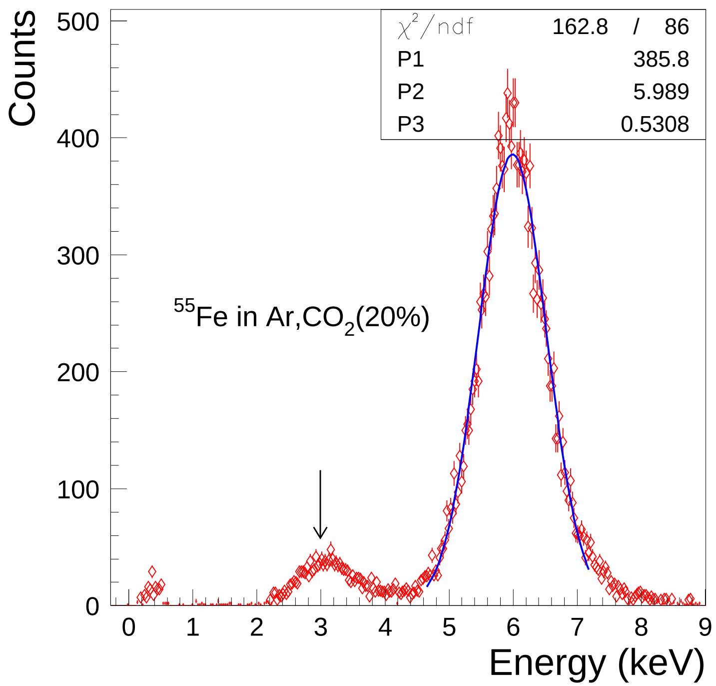
Nobel prize in physics, 1992

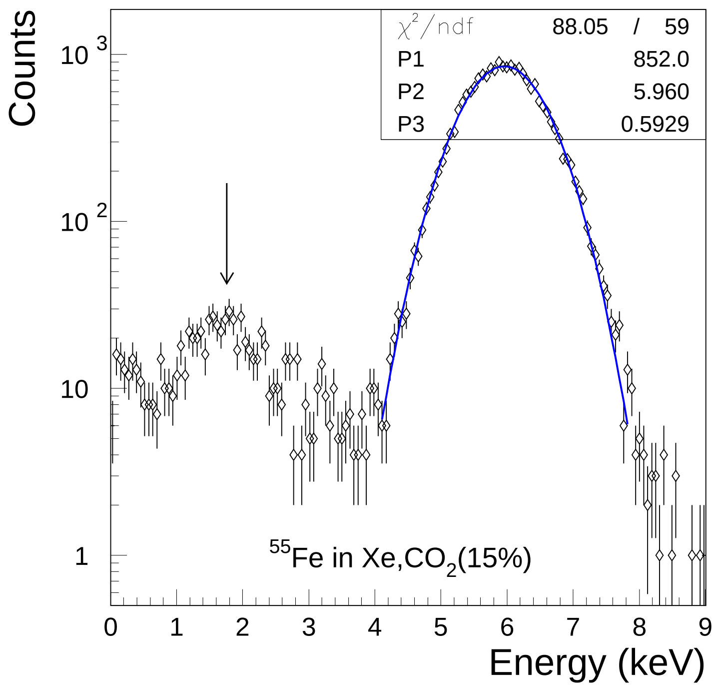
Allow:

- Particle identification (dE/dx) and tracking
- Large area coverage (with high granularity), low cost
- High rate counting (10^5 Hz)
- Applications: imaging
  - biomedicine (low dose)
  - industrial (large area)

Basics of construction (the devil is in the details)

- Frames, wires (anode: Au-W, 20μm; cathode: Cu-Be, 75μm), foils (Al-mylar)
- Glue (Araldite), stretch wires, solder, check (non)conductivities
- Gas: inert (He,Ne,Ar,Kr,Xe) + quencher (molecular: CH_4,CO_2..., $\sim$5-50%)
- Apply voltages (kV), read currents (nA), see signals (after amplifier)
- Check energy resolution, must get $\sigma \simeq$10% for ^{55}Fe (5.96 keV)





Basics of optimization

Choice of gas:

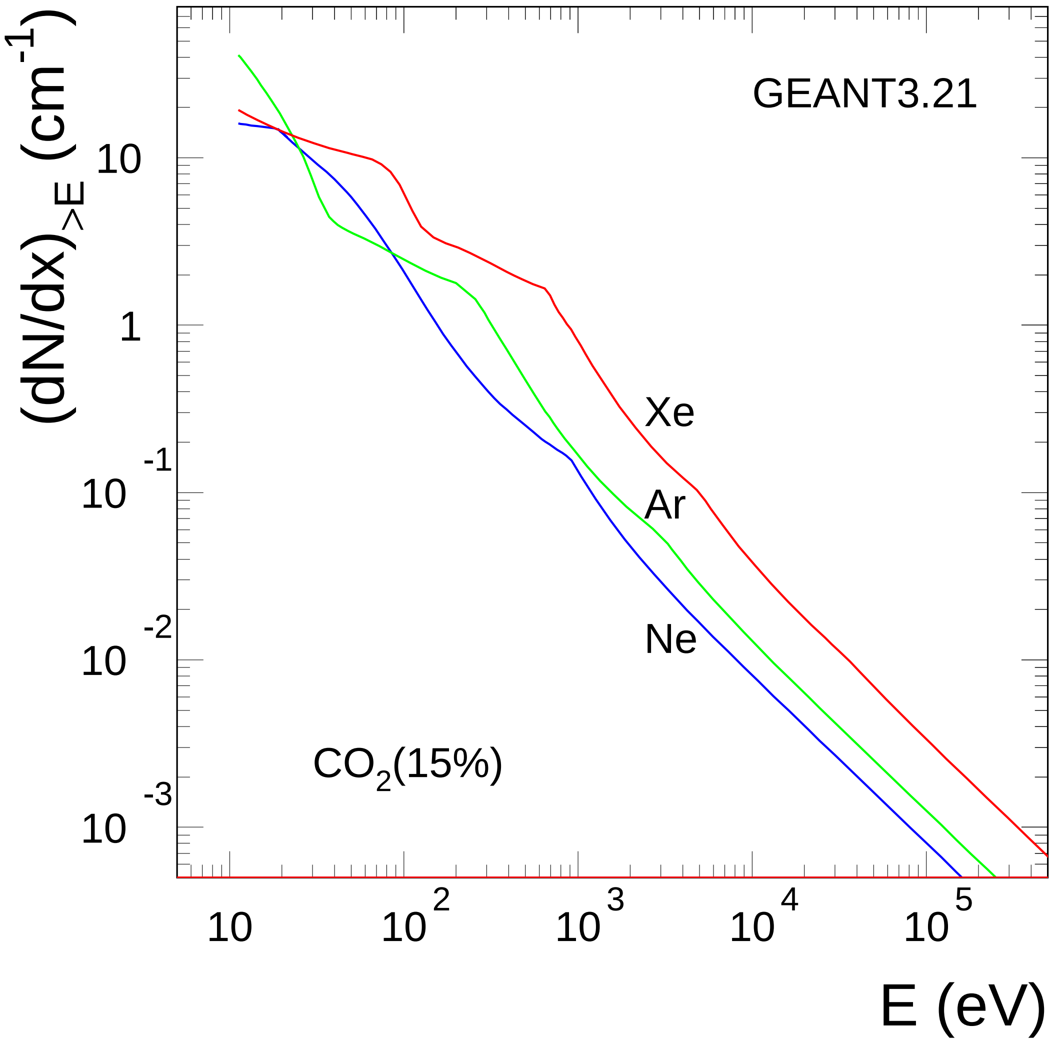
- Tracking: light gas (Ne) to minimize multiple scattering
- Photon detection (imaging): heavy gas (Xe) to maximize absorption

Gas and detector thickness:

- Signal amplitude and signal-to-noise ratio (in relation to FEE)
- Collection time and digitization scheme
- Energy resolution, space point resolution
- Granularity (detection cell, number of readout channels)

Creation of primary signal: ionization (dE/dx) basics

spectrum of electrons released in primary inelastic collisions (clusters)

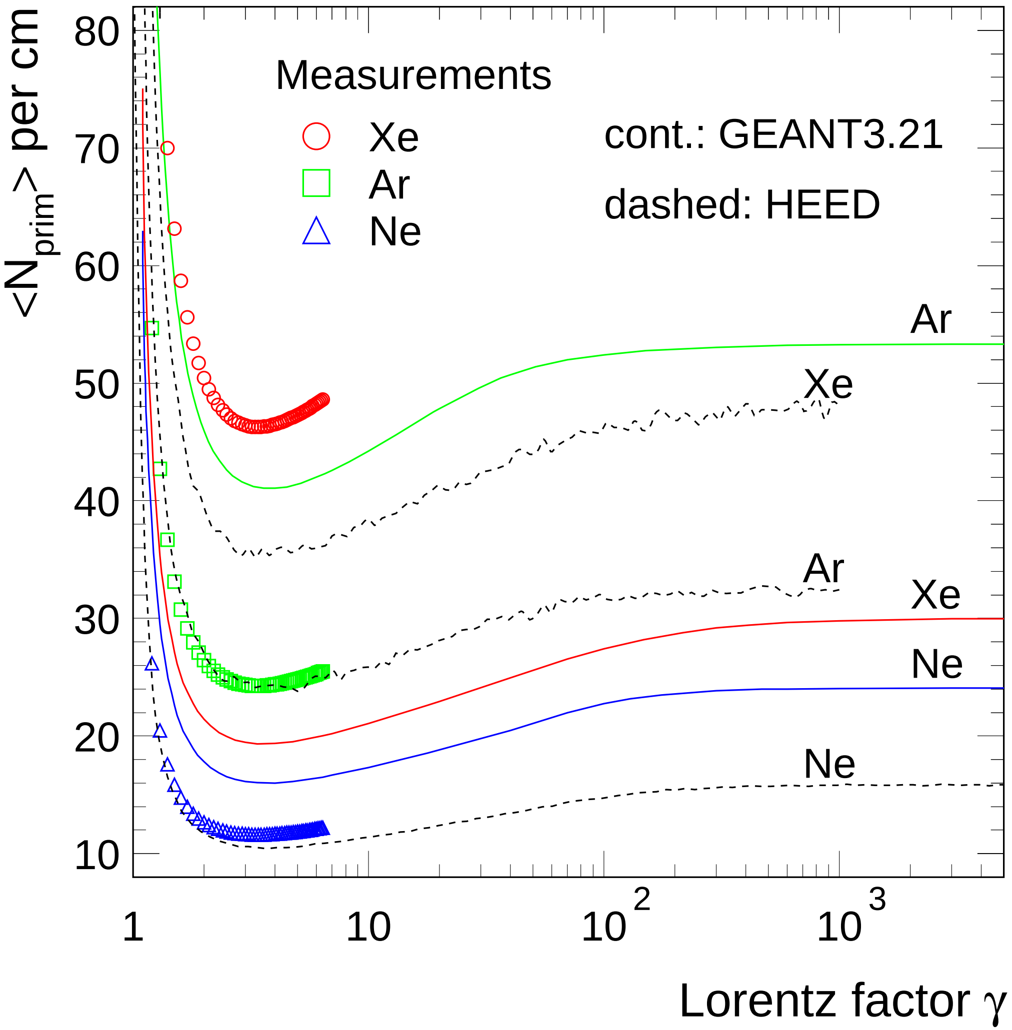


- integral spectrum (GEANT3.21)
- calculated with Photoabsorption and Ionization (PAI) model (input: X-ray abs. cross sections)
- details: atomic shell structure
- electrons per cluster: E/W

gas	Ne	Ar	Xe
W (eV)	36	26	22

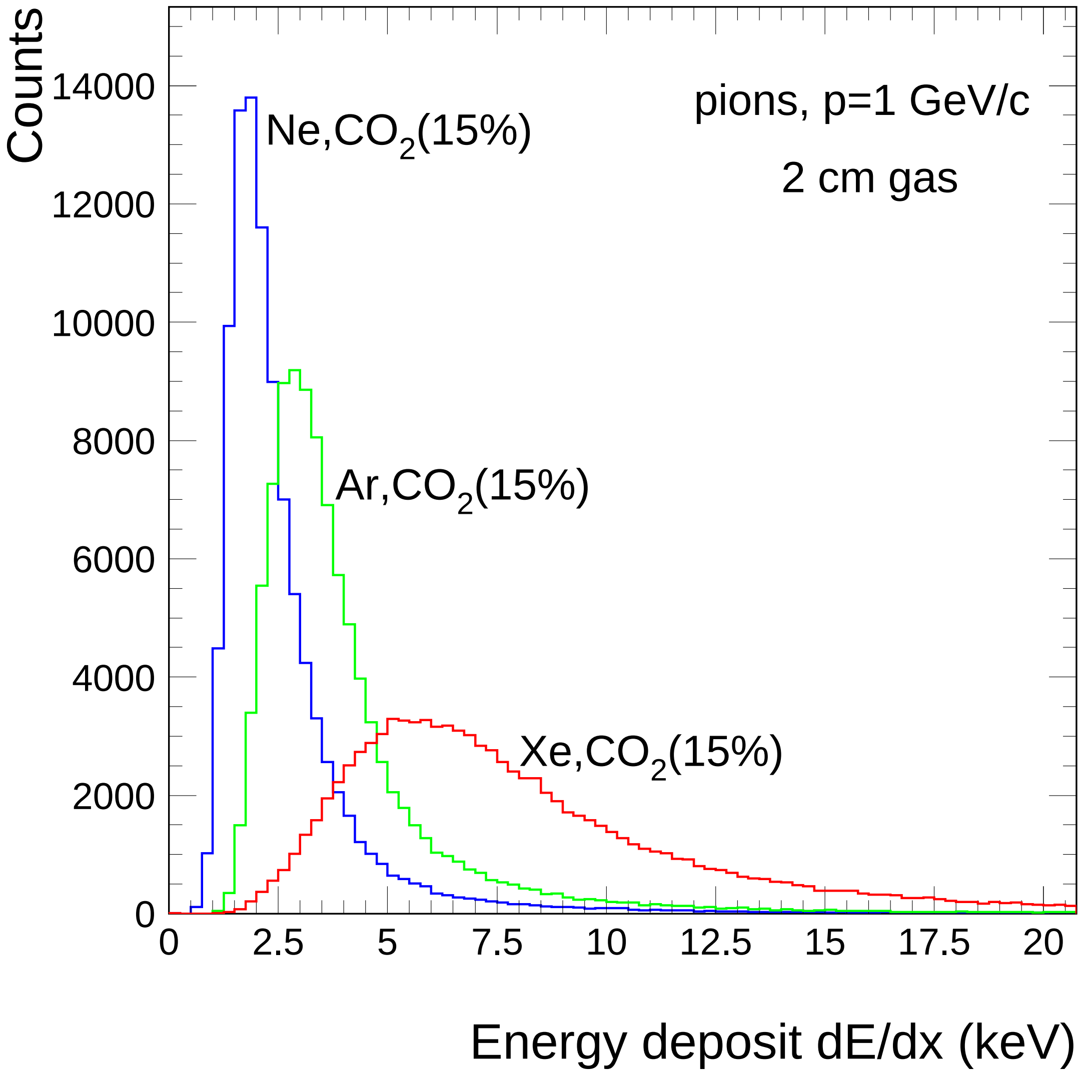
dE/dx: momentum dependence

average number of primary inelastic collisions (clusters)



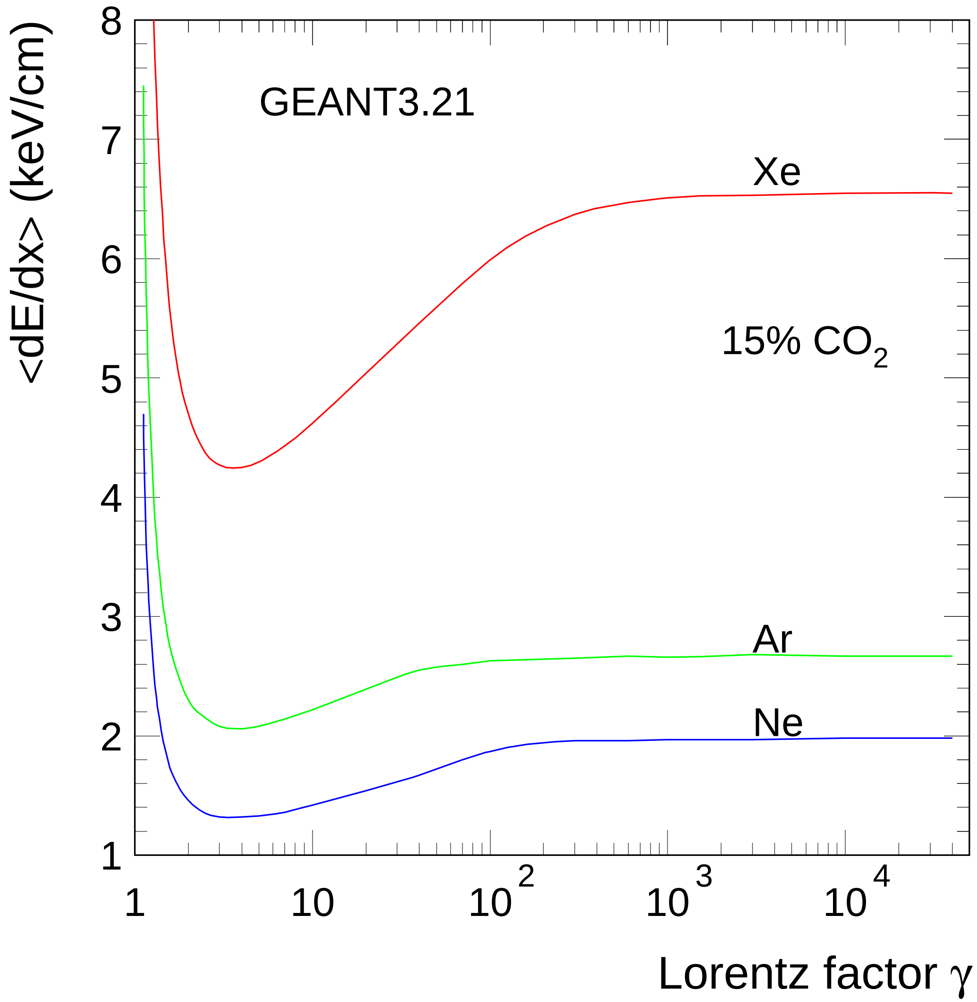
- Poisson fluctuations
- data and models do not always agree (calc.: strong dep. on X-ray cross sections at low E)

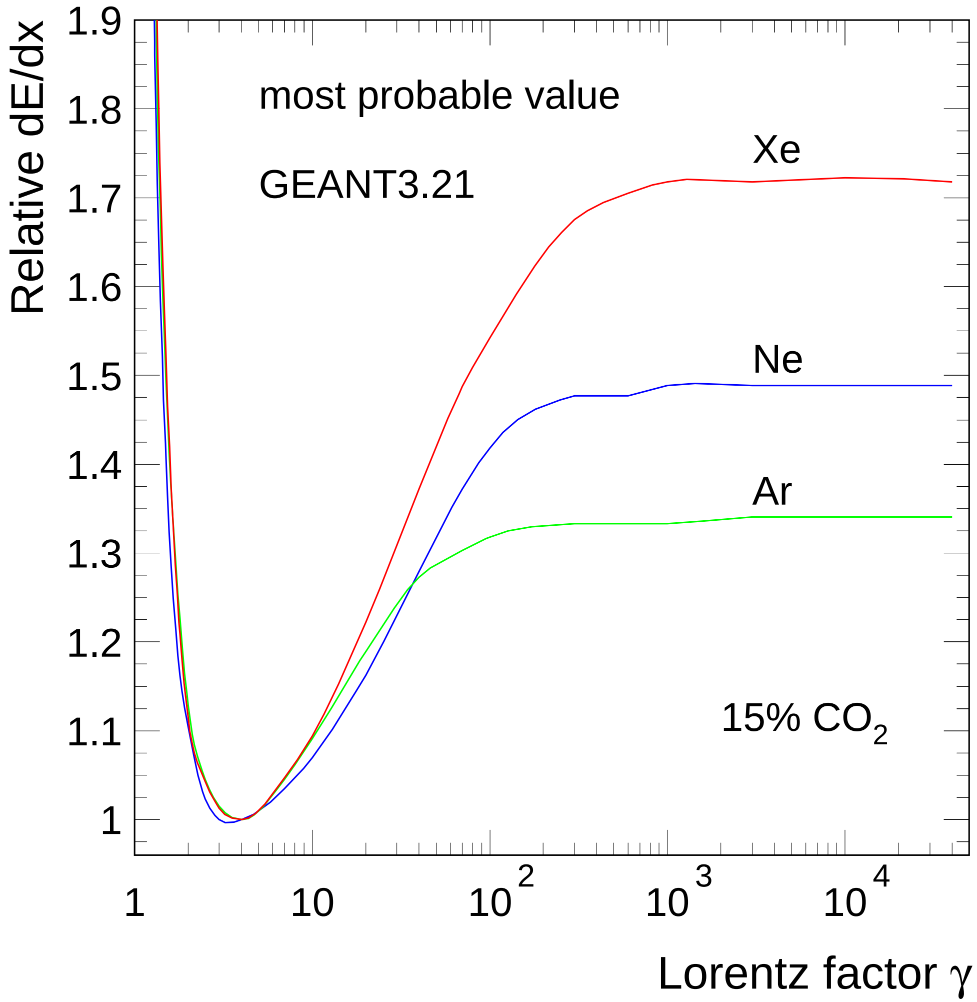
dE/dx "observable": charge spectra



- Landau distribution characterized by:
  - mean
  - most probable value
  - FWHM
- large tails (reduced by truncation, after sampling)

dE/dx "observable": grand summary

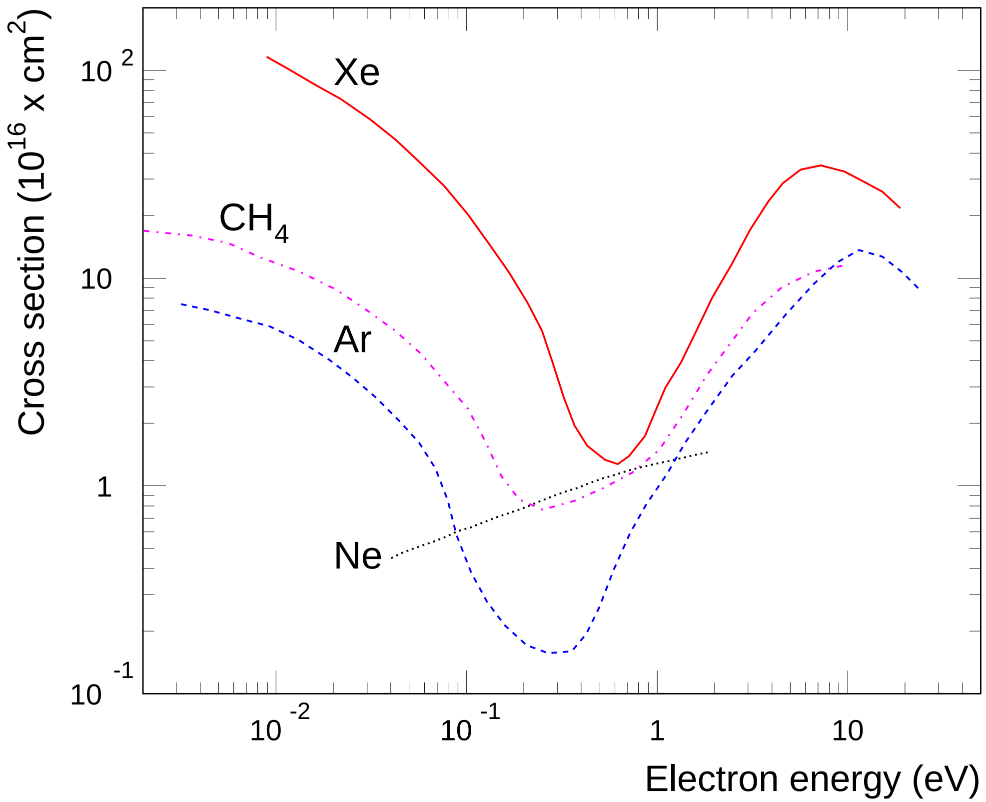




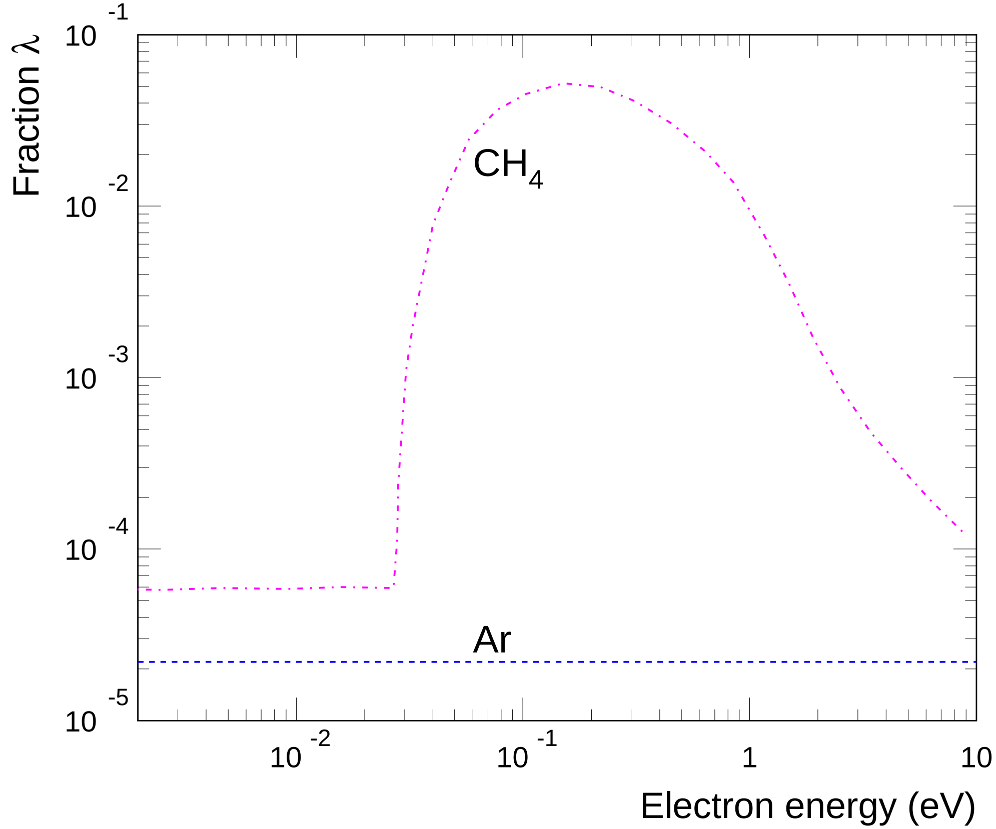
this is just GEANT 3 version!

Drift properties: the key ingredients

'momentum transfer' cross section

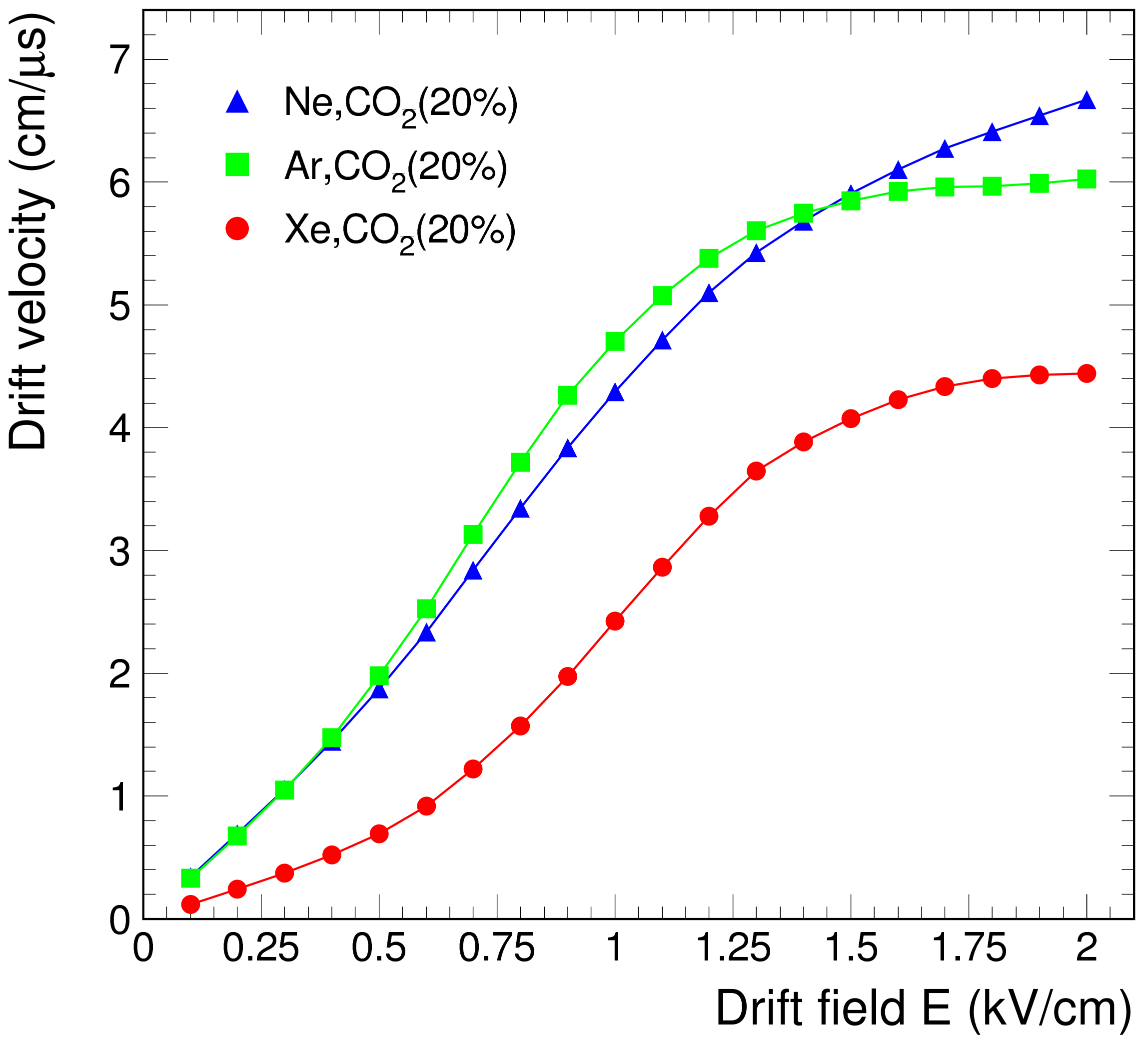


fraction of energy loss per collision



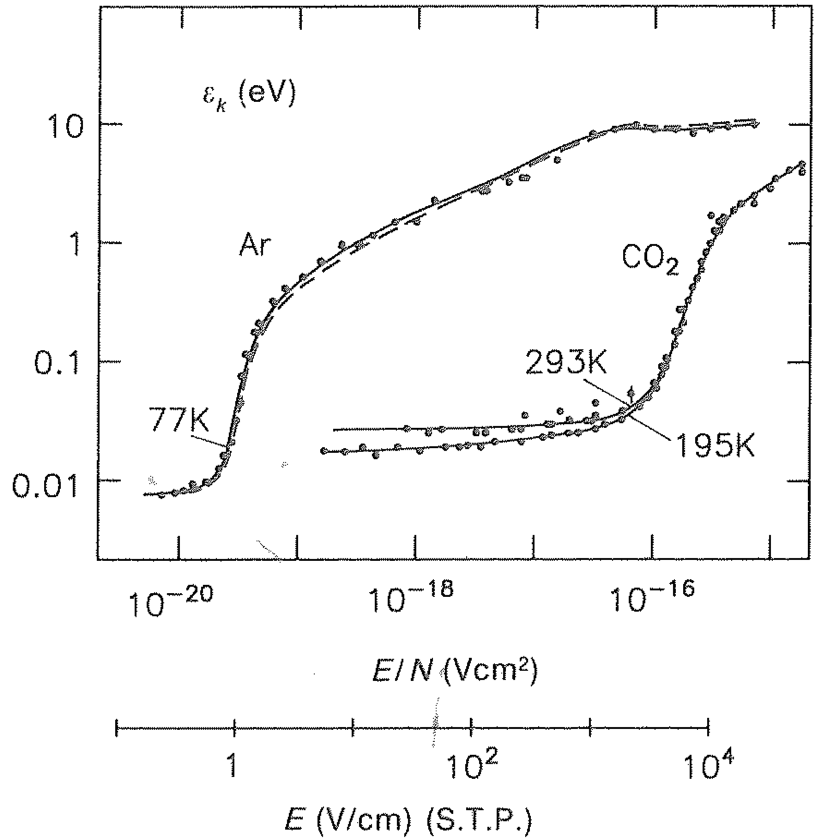
drift velocity: $v_d = \frac{eE}{mN\sigma}\sqrt{\frac{\lambda}{2}}$ $\longrightarrow$ quencher plays an essential role

Drift velocity



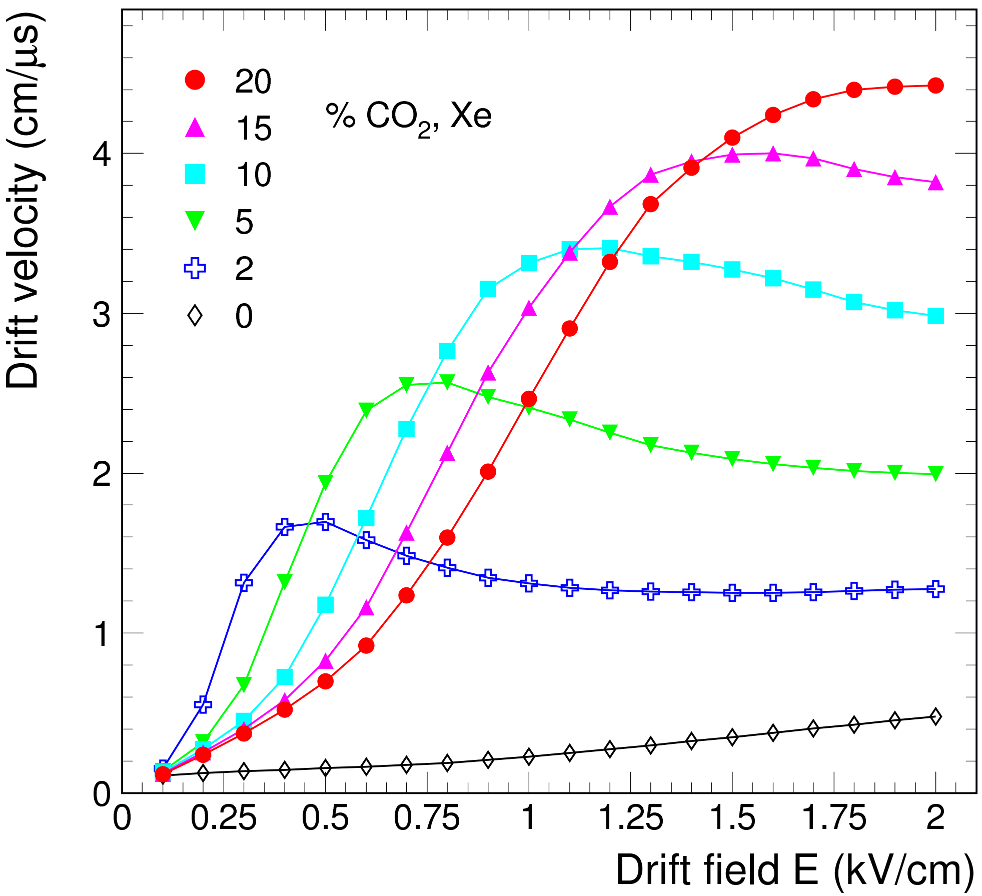
characteristic electron energy

$\varepsilon \sim E$

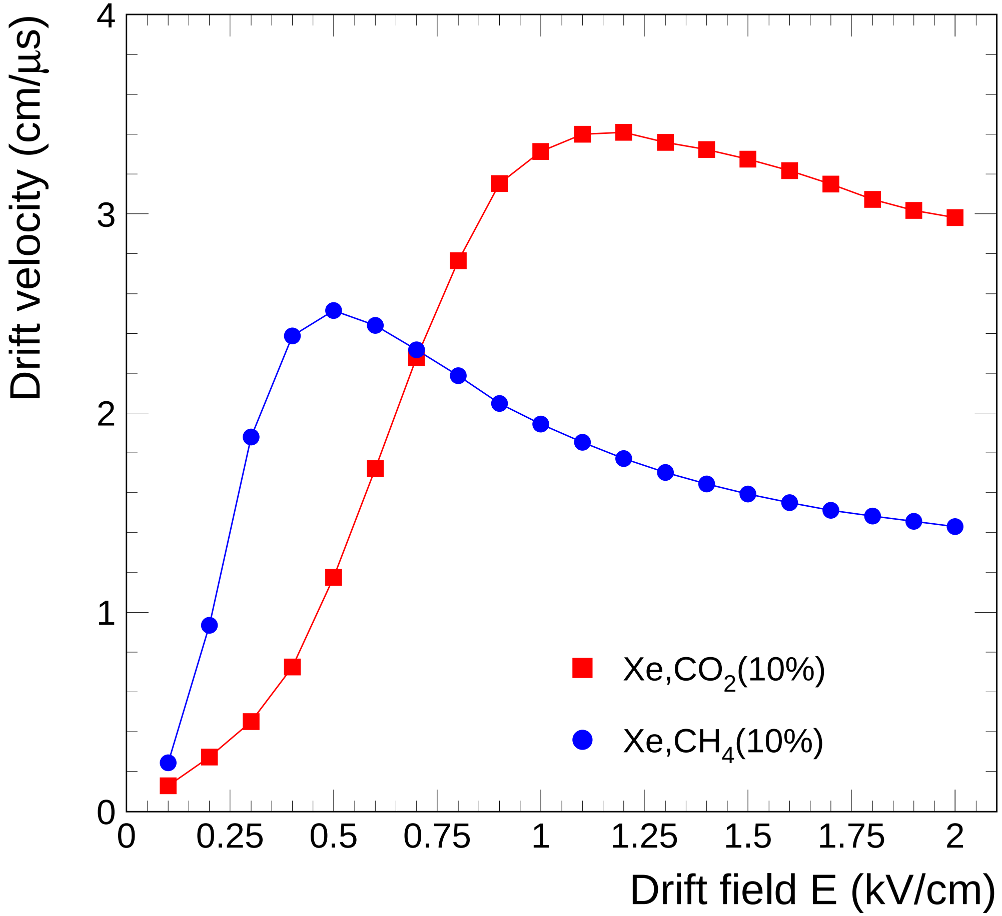


Drift velocity: quencher dependence

concentration



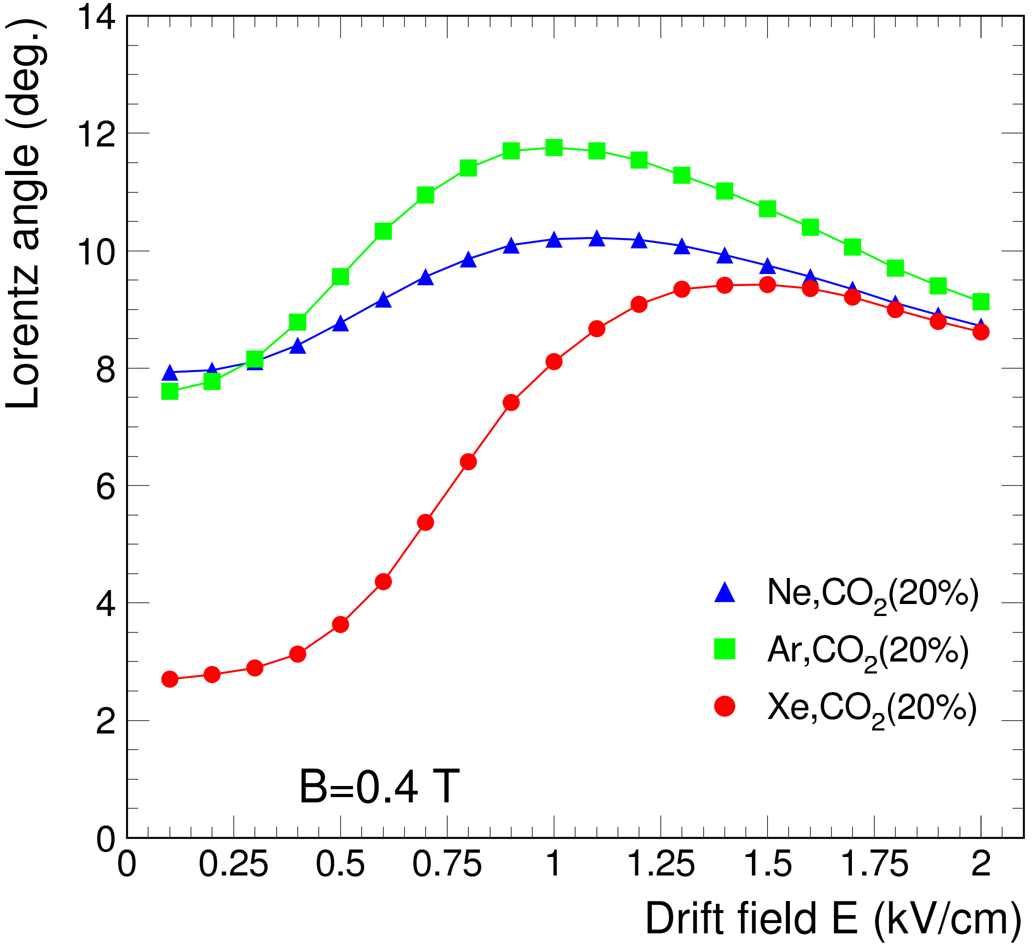
type

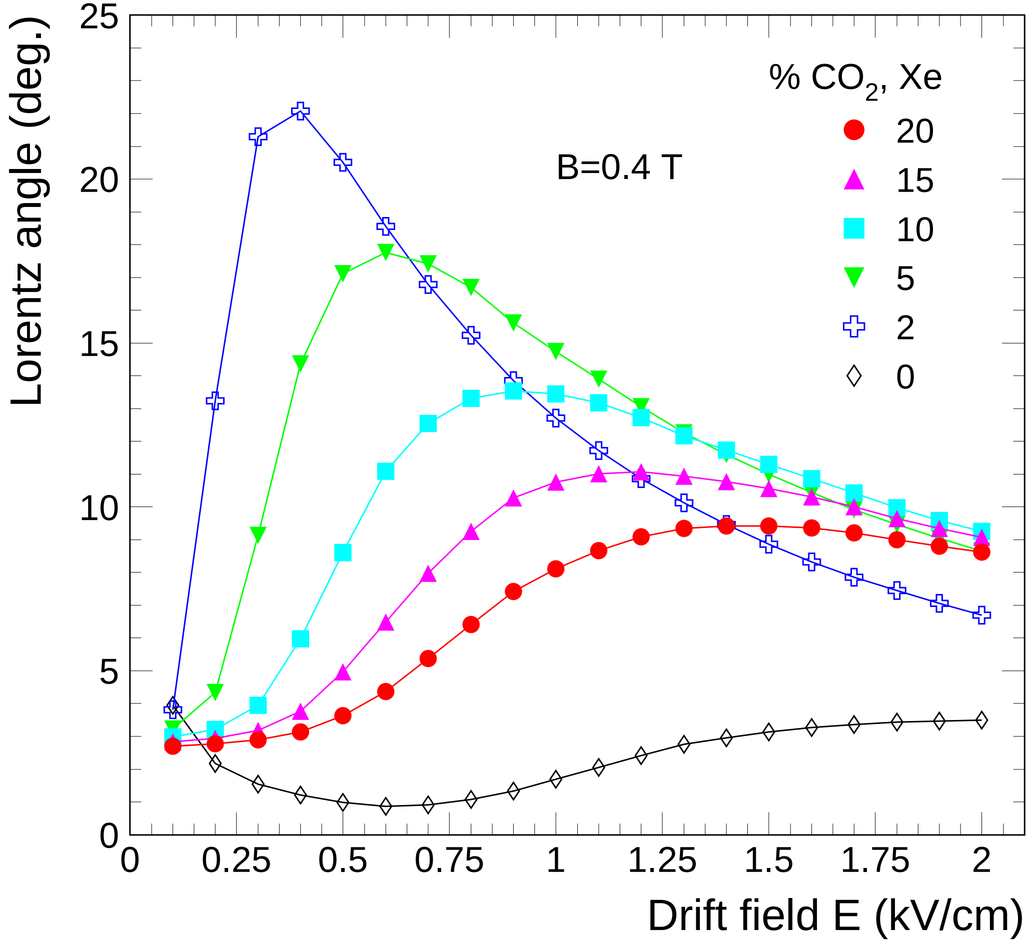


CH_4 is bad for aging; flammable, not allowed in underground exp. (LHC)

Lorentz angle

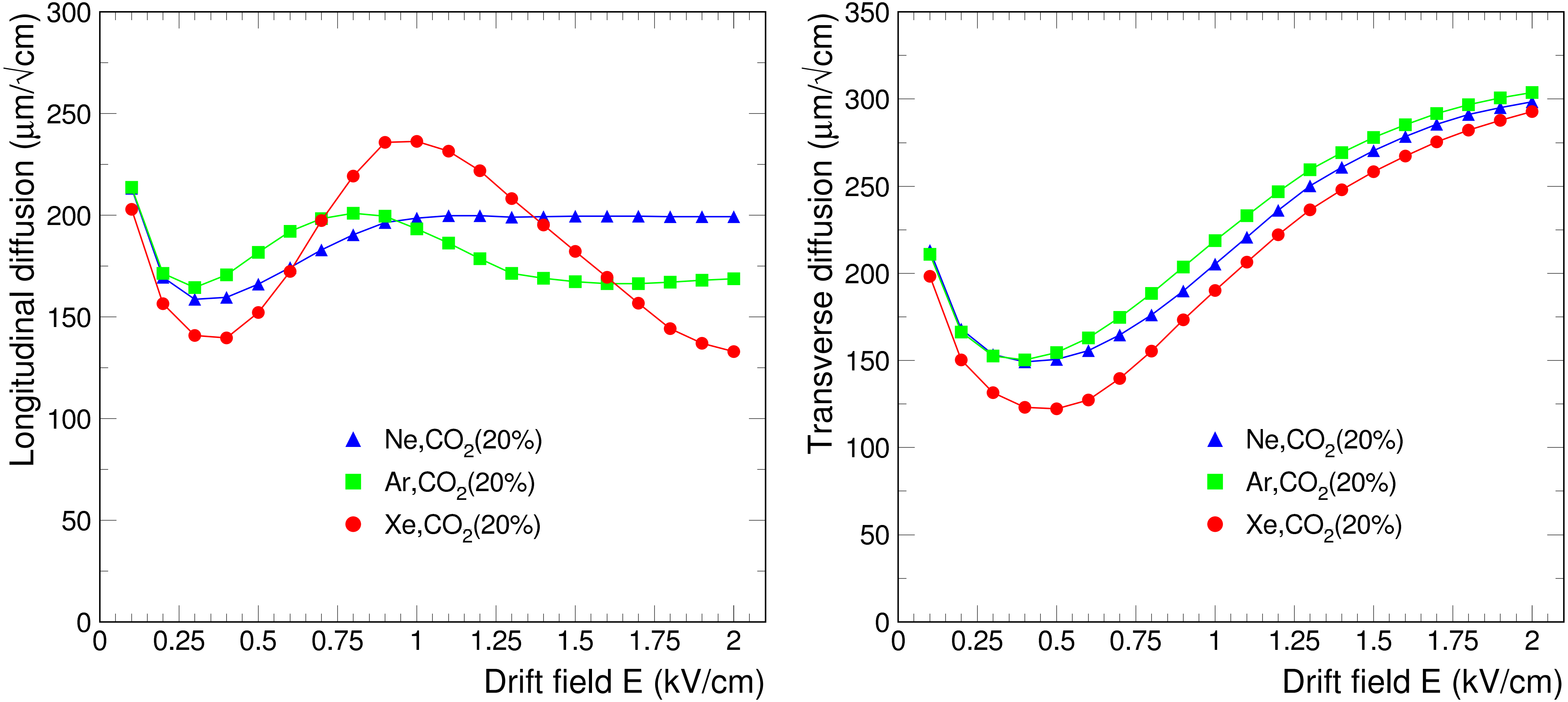
drift in magnetic field: angle between drift velocity and electric field





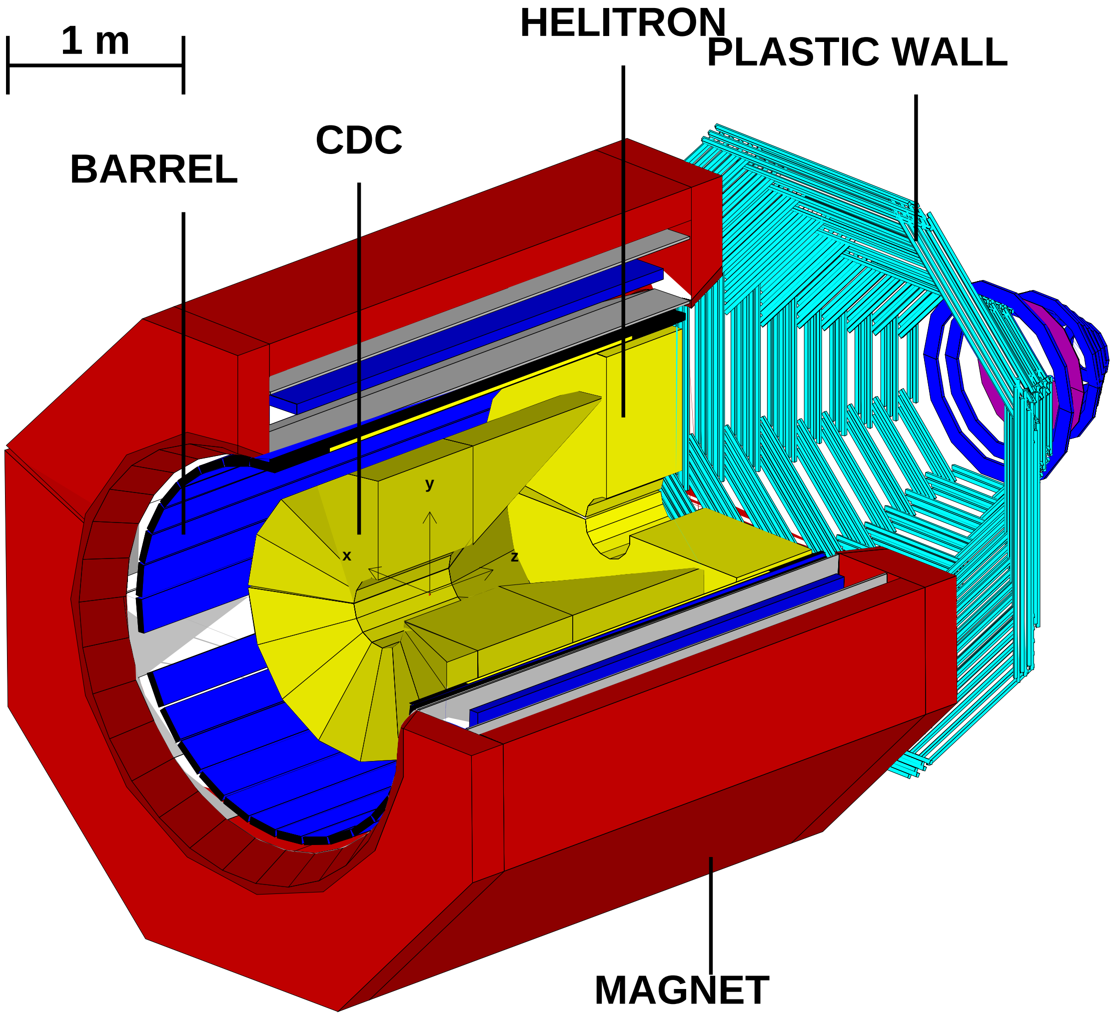
Diffusion

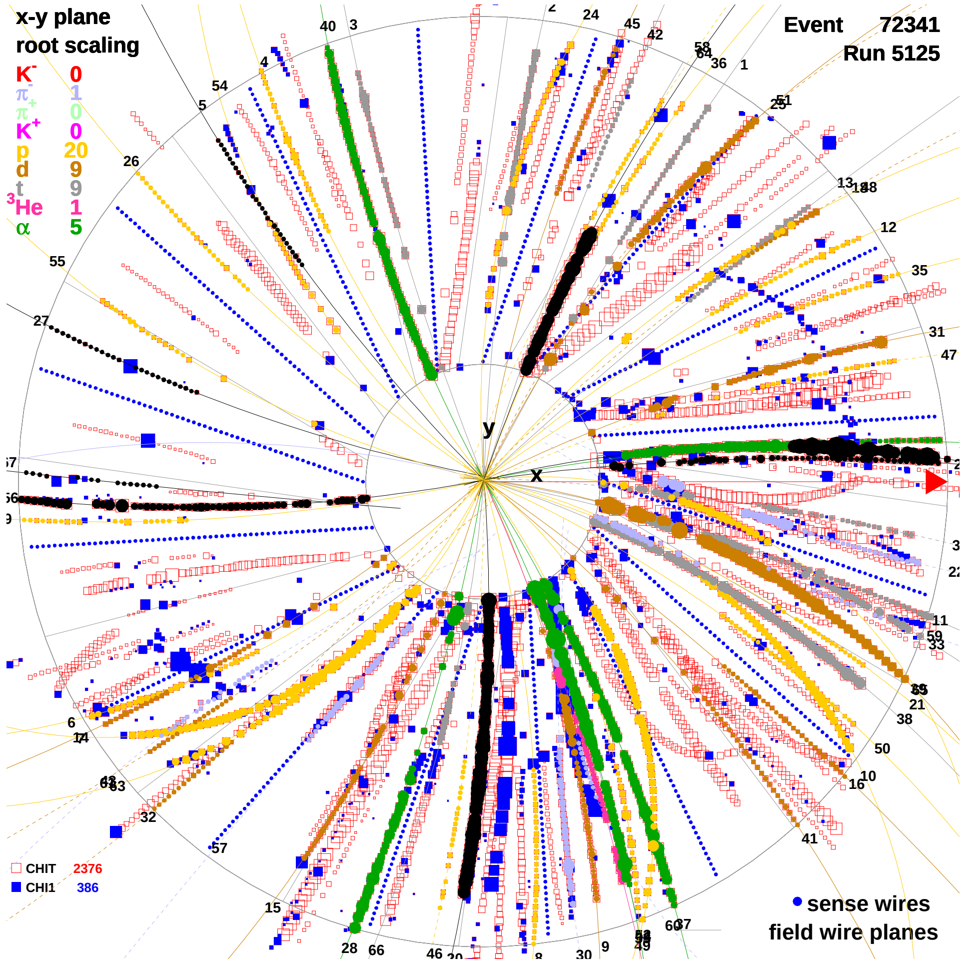
longitudinal **transverse**



spread of a point-like electron cloud after distance L: $\sigma^2 = 4\varepsilon L/3eE$

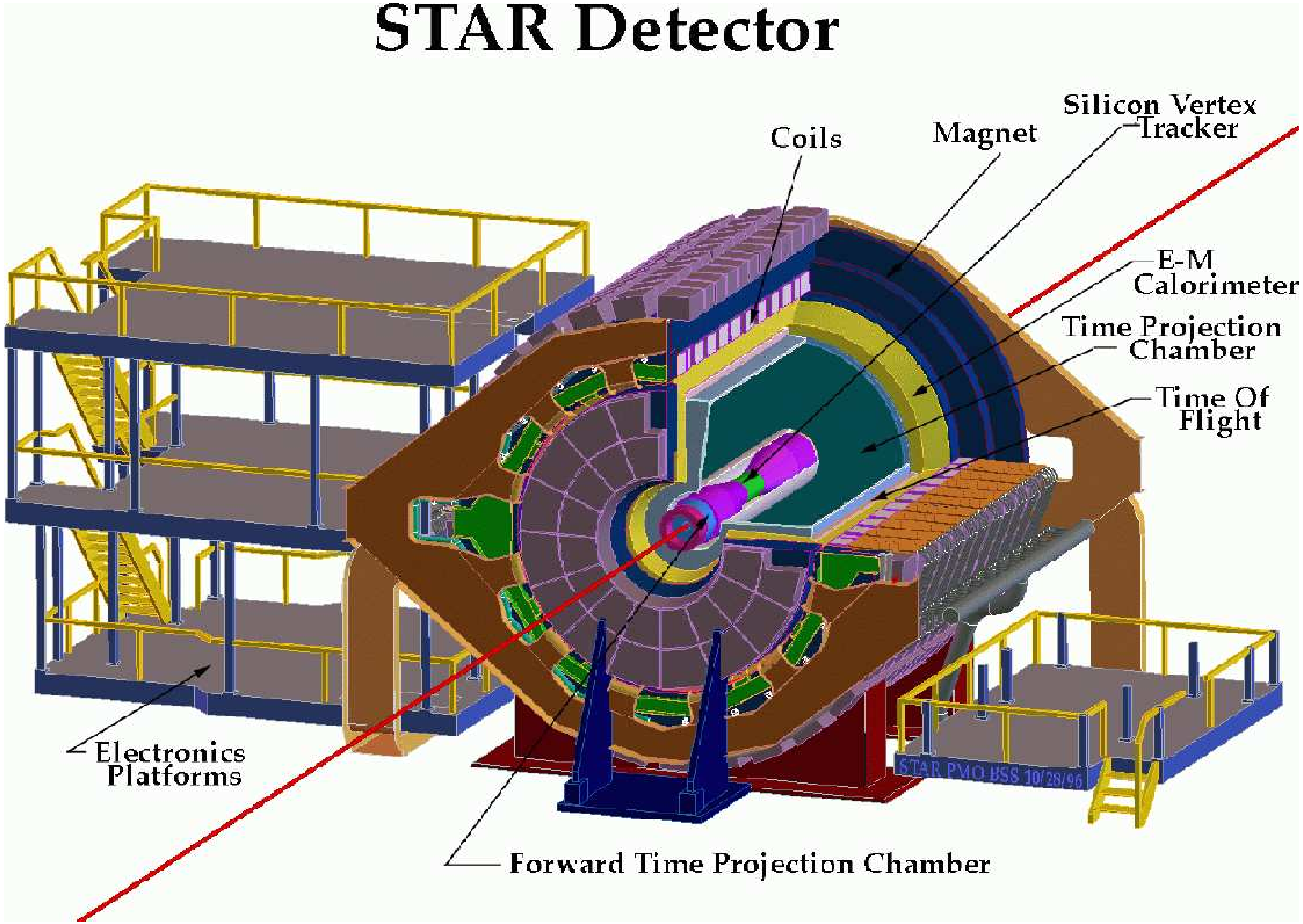
FOPI detector @ GSI: E_{beam}=0.1–2 AGeV



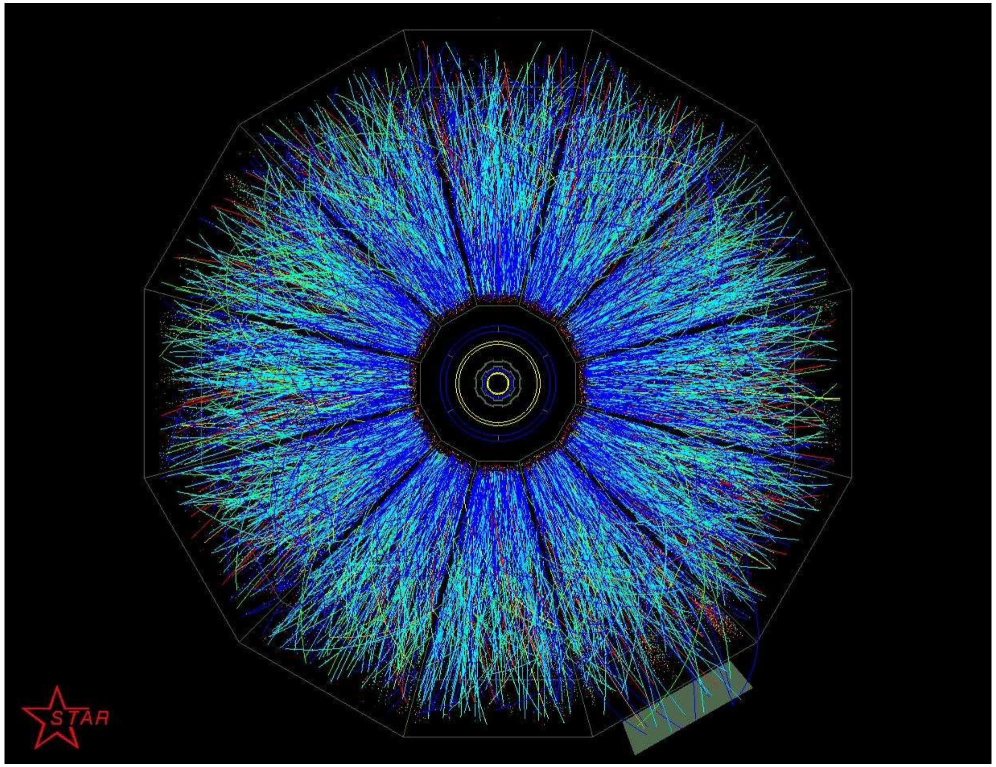


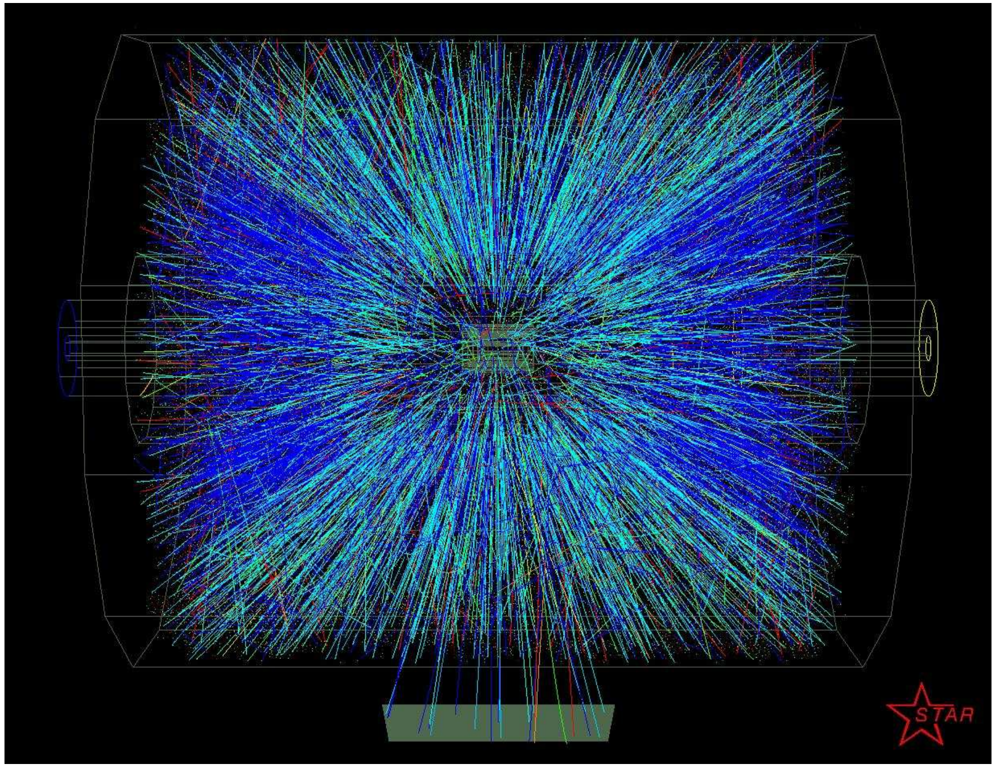
STAR detector @ RHIC: $\sqrt{s_{NN}}$=20-200 GeV

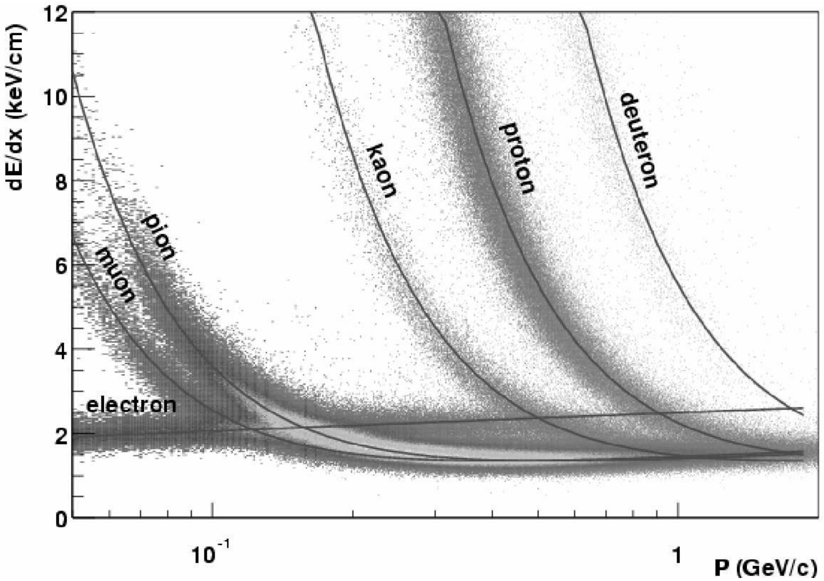
http://www.bnl.gov/rhic



STAR detector: Time Projection Chamber

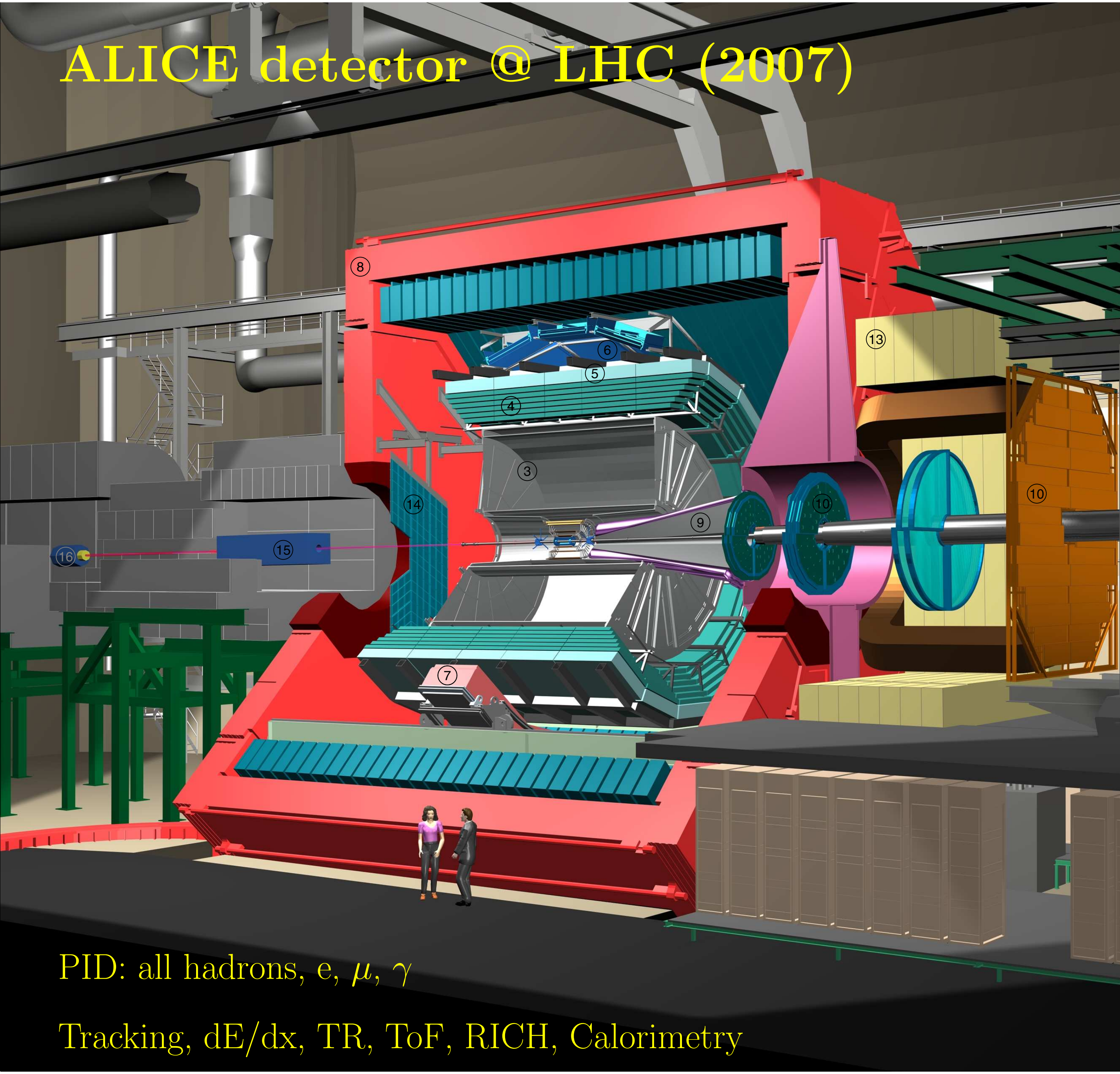


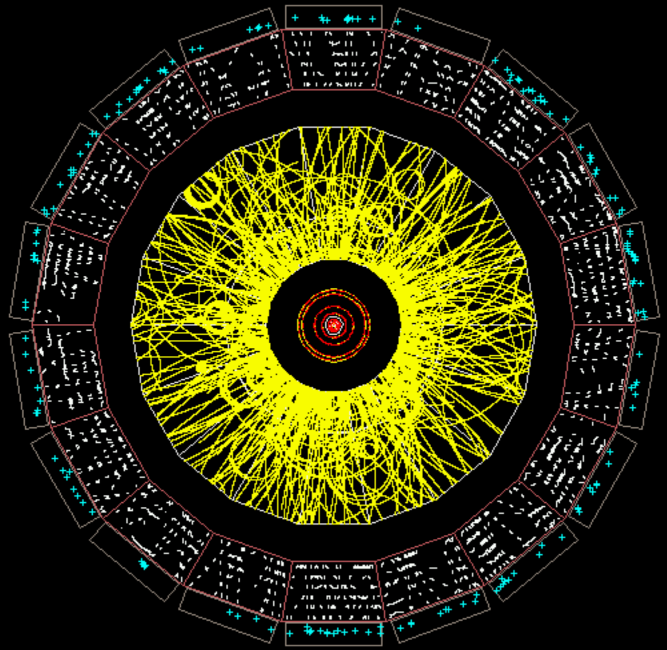




ALICE Collab.: 27 countries, 83 institutes, 1000 persons

ALICE detector @ LHC (2007)





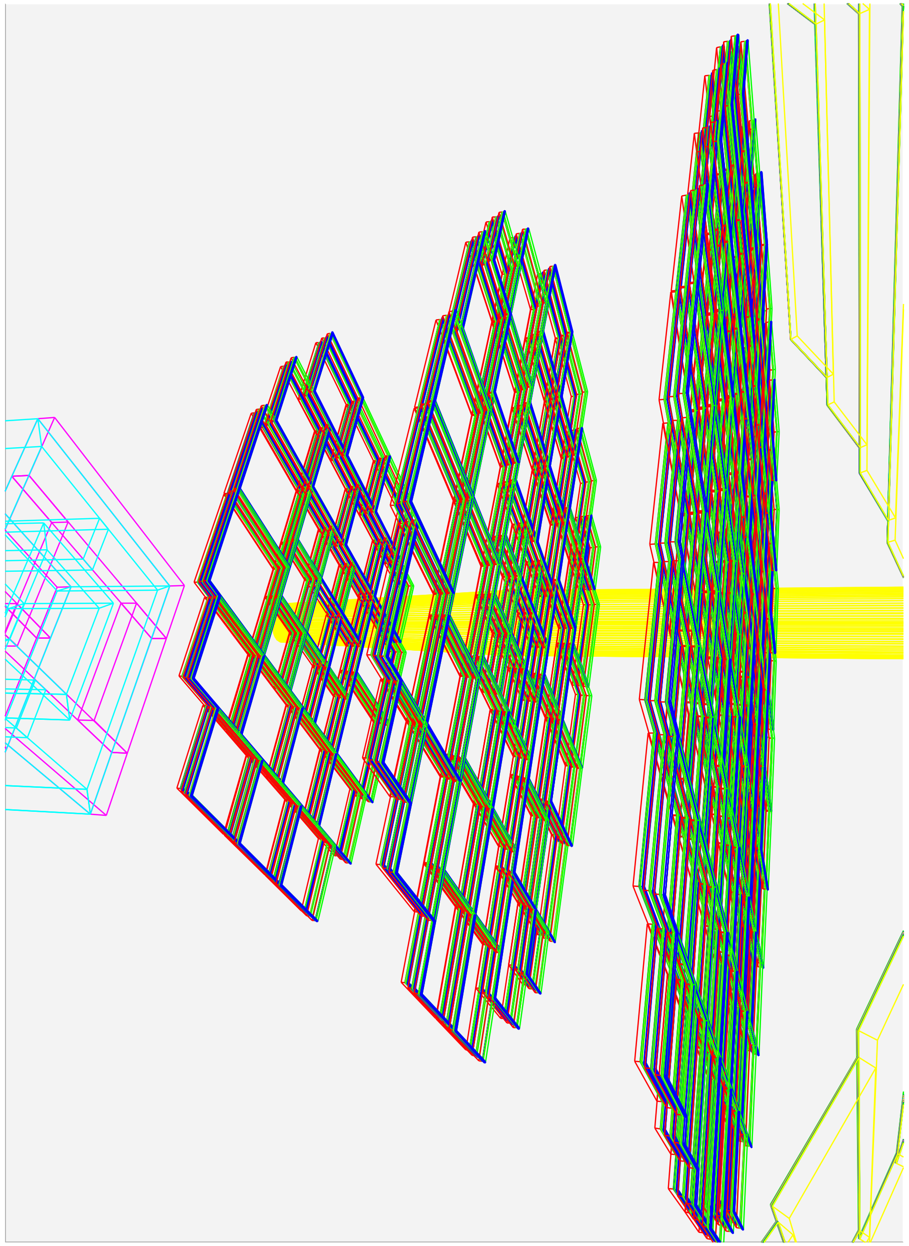
1% of a central Pb+Pb at LHC

01. I.T.S.
02. F.M.D.
03. T.P.C.
04. T.R.D.
05. T.O.F.
06. H.M.P.I.D.
07. P.H.O.S. C.P.V.
08. L3 MAGNET
09. ABSORBER
10. TRACKING CHAMBERS
11. MUON FILTER
12. TRIGGER CHAMBERS
13. DIPOLE MAGNET
14. P.M.D.
15. COMPENSATOR MAGNET
16. C.A.S.T.O.R.

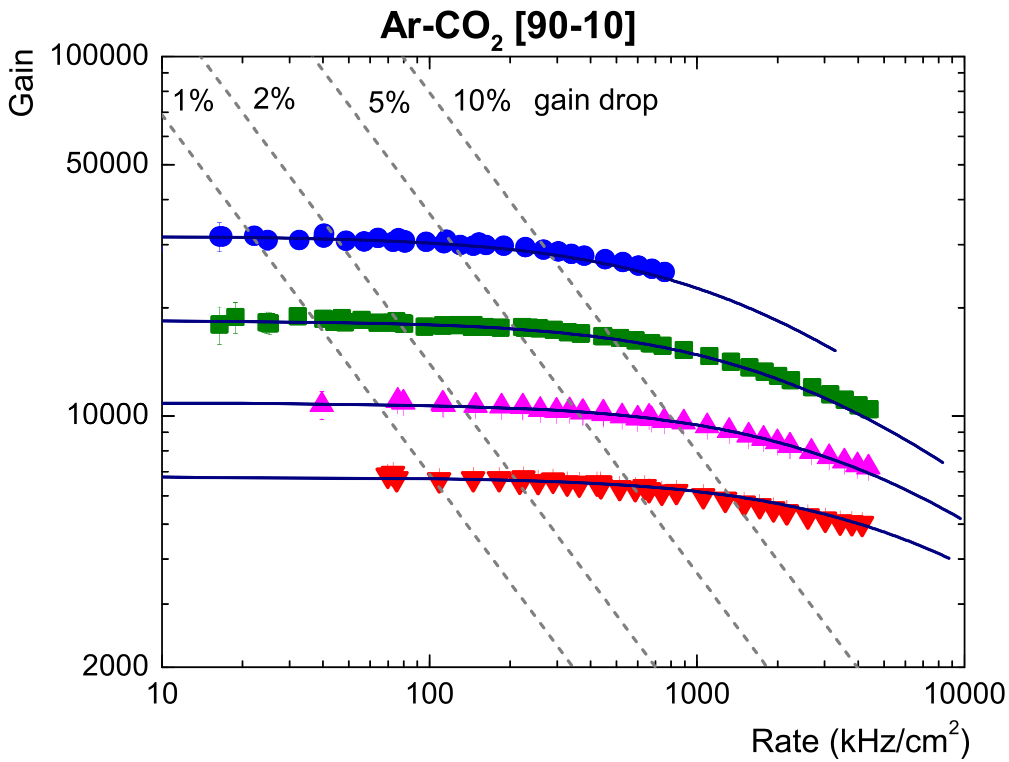
PID: all hadrons, e, μ, γ

Tracking, dE/dx, TR, ToF, RICH, Calorimetry

The last in line: CBM@FAIR/GSI (∼2014)



... pushing the rate capability



References

- W. Blum and L. Rolandi, Particle Detection with Drift Chambers, Springer-Verlag, 1994
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- S. Biagi, Magboltz Package, *http://consult.cern.ch/writeup/magboltz/*
- I. Smirnov, HEED Package, *http://consult.cern.ch/writeup/heed/*
- GEANT 3.21, *http://consult.cern.ch/writeup/geant/*