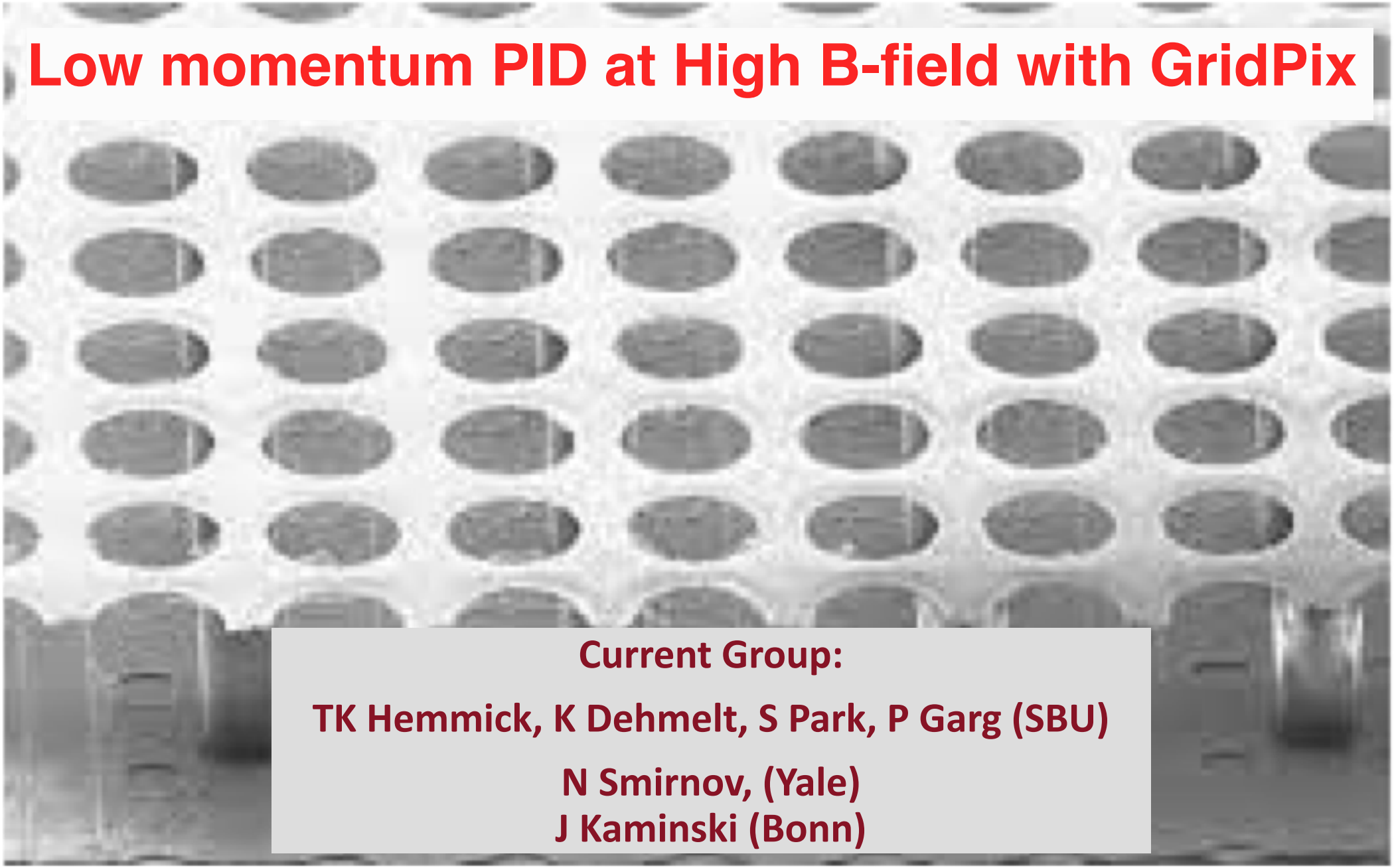
Low momentum PID at High B-field with GridPix

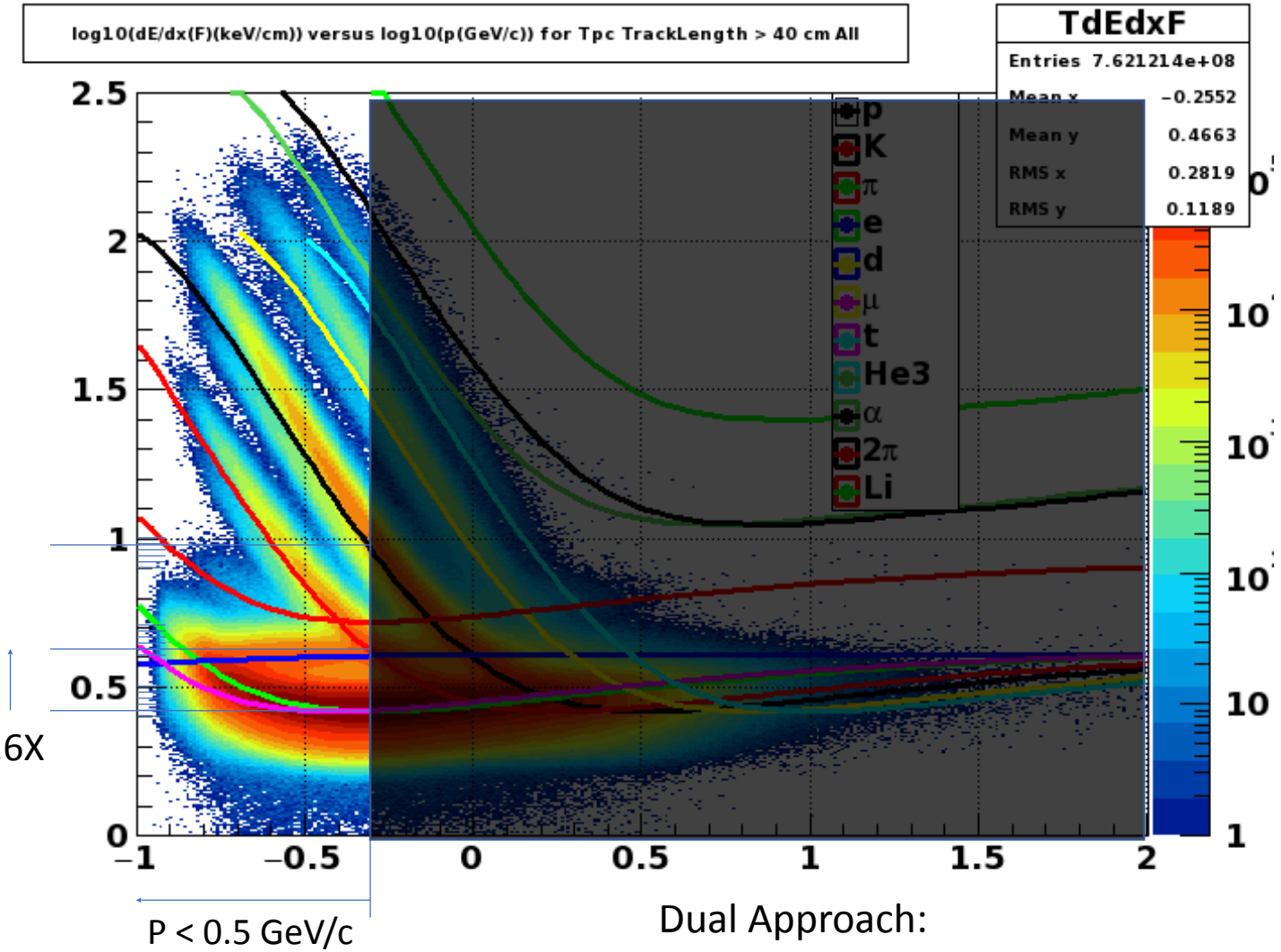


Current Group:

TK Hemmick, K Dehmelt, S Park, P Garg (SBU)

N Smirnov, (Yale)
J Kaminski (Bonn)

Restate the Problem

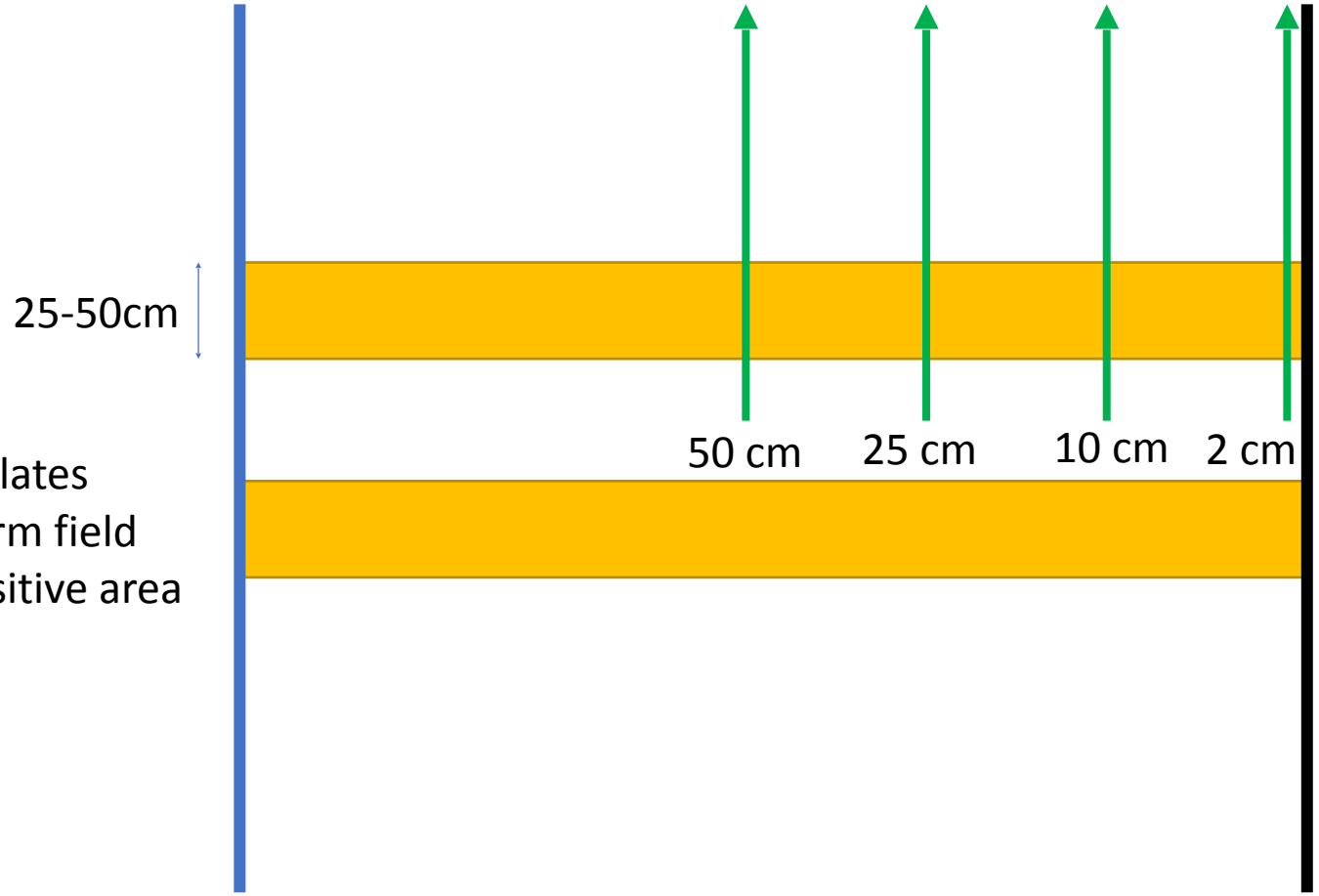


- DIRC has low-p limitations:
  - Curl Up (0.45 GeV/c)
  - Kaon threshold (0.47 GeV/c)
- Rather than lower the field:
  - PID at low radius.
  - dE/dx separations huge!
    - 1.6X pi-K
    - 2.25X K-p
  - GridPIX
    - Established
    - Robust
    - Excellent tracking

Dual Approach:

- Standalone Garfield (optimize detector)
- GEANT (integrate into full simulation)

Garfield Setup



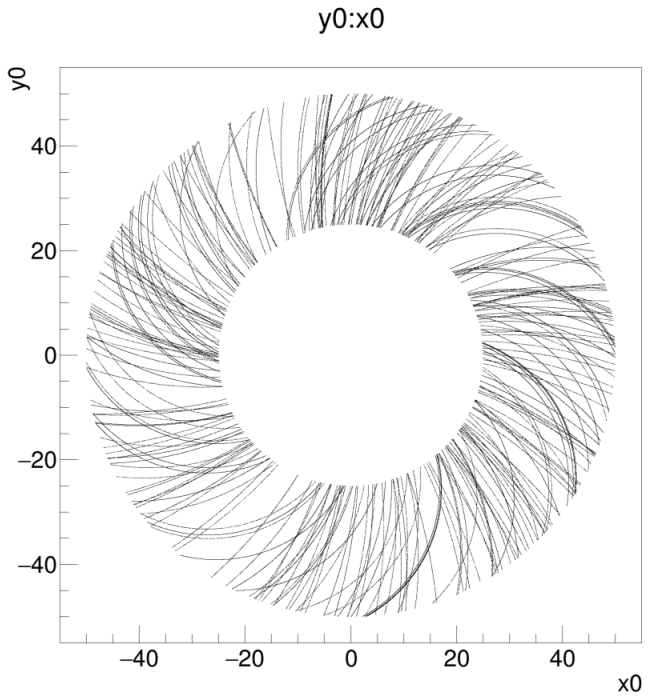
- Use HUGE plates to get uniform field
- Limited sensitive area

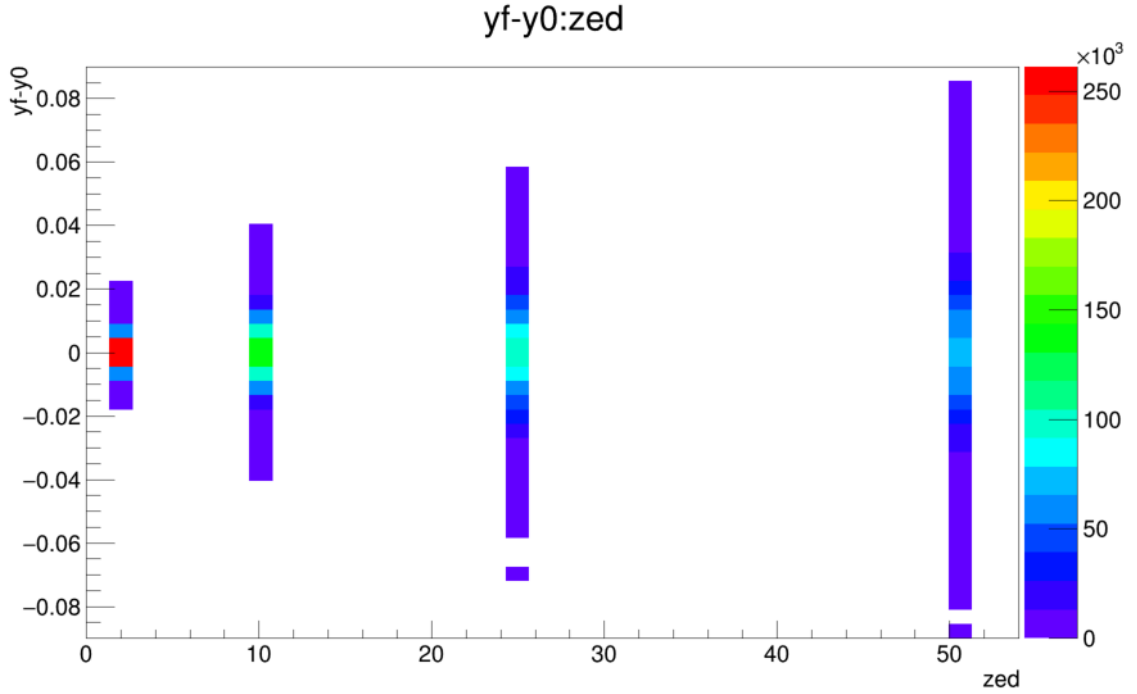
- Consider r=0.5 meter
- Defines p(max) = 0.8 GeV/c
- P(list)
  - 0.2 0.4 0.6 0.8
- Z(list)
  - 2 10 25 50
- ID(list)
  - Pi, K, p
- Conditions:
  - 4*4*3 = 48 conditions
- Gas(list)
  - T2K only (for now)
- B(list)
  - 3 T only (for now)
- E(list)
  - 130 V/cm

- Simple Ntuple (for now)
- Designed to not change as studies evolve
- Ntuple: q, mass, p, theta, phi, zed, gas, B, E, track #, cluster #, x0, y0, z0, t0, xf, yf, zf, tf

ID Kinematics Detector Electrons

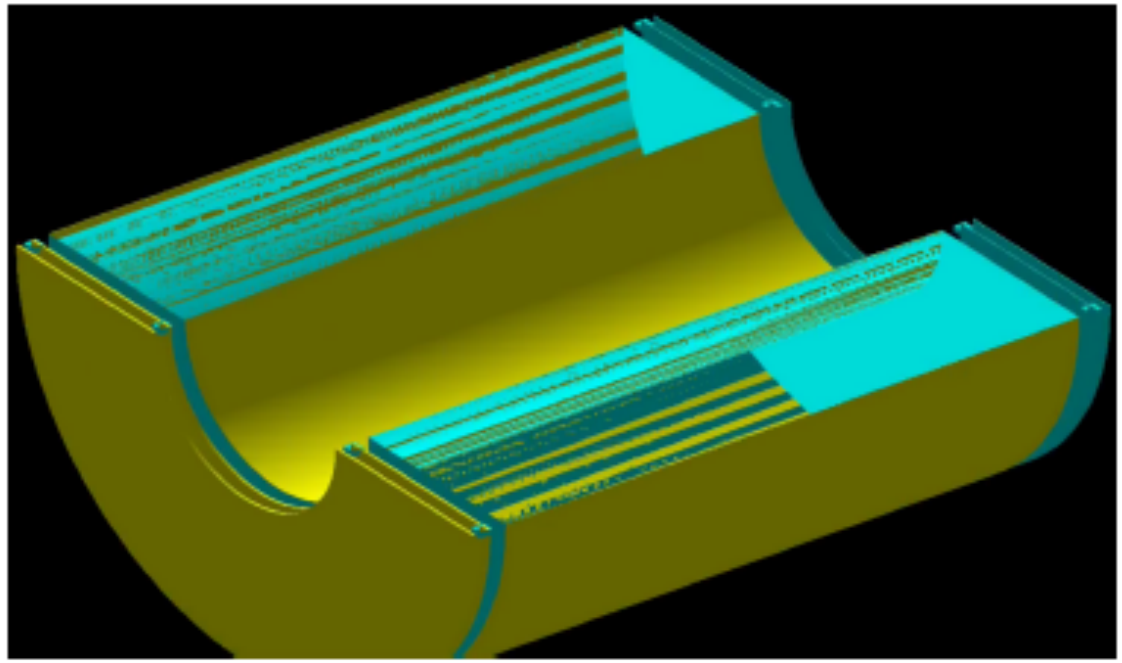
Garfield Setup (offline Analysis)





- A few simple entries into the Ntuple for code development
- Diffusion noted as sqrt(path length)
- Analysis framework getting close to producing real results…

GEANT and Fun4ALL Setup (by Sanghwa)



Preliminary Geometry in GEANT

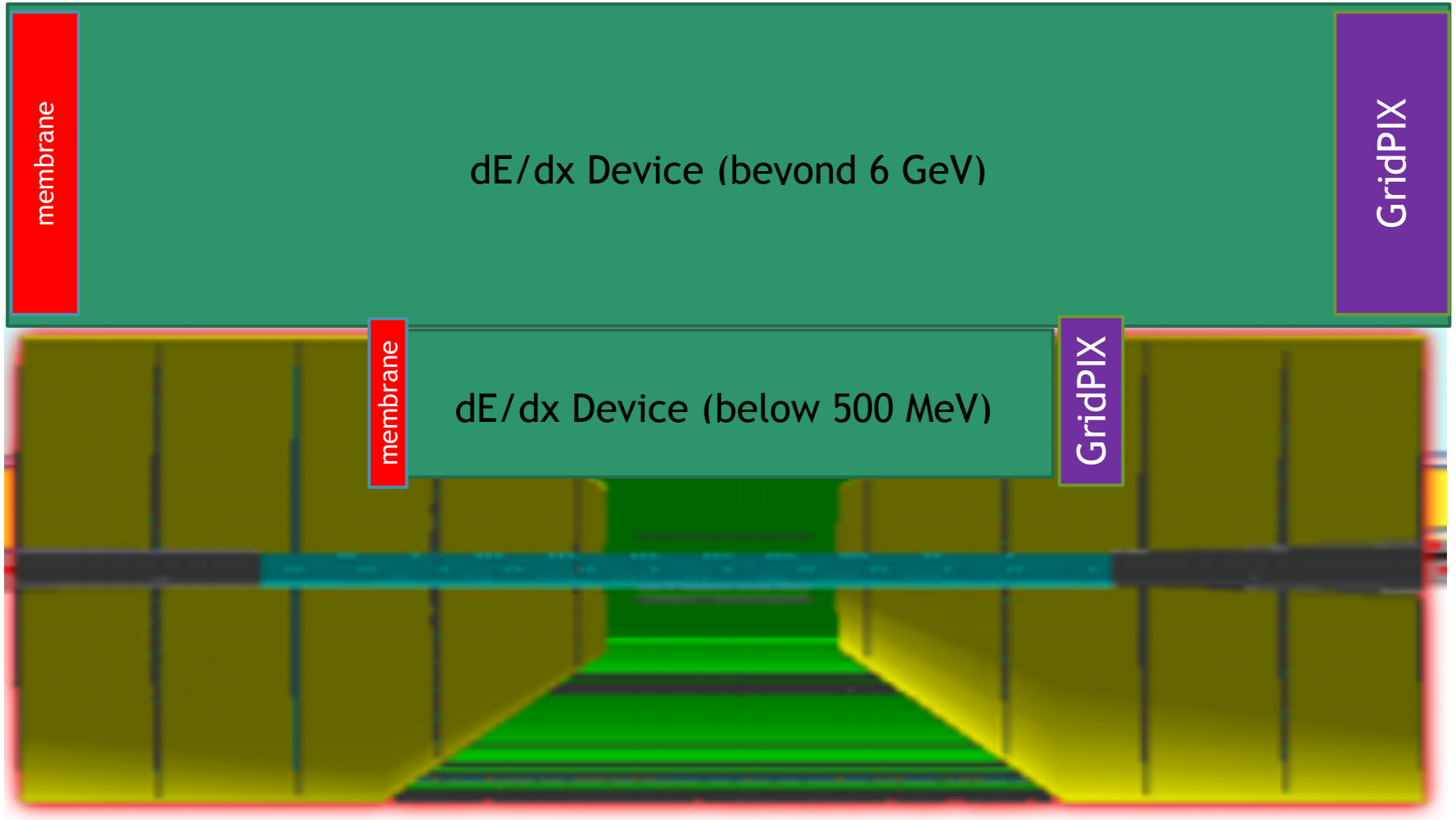
Care required!

- Default GEANT insufficient job for ionization
- Electron-by-electron in clusters vital.
- Needs to know from DD4HEP team how they handles primary ionizations and clusters.

We had a discussion with Barkley Group also to make joint studies with Si tracking and GridPix to check the complementarity and optimization for tracking performance.

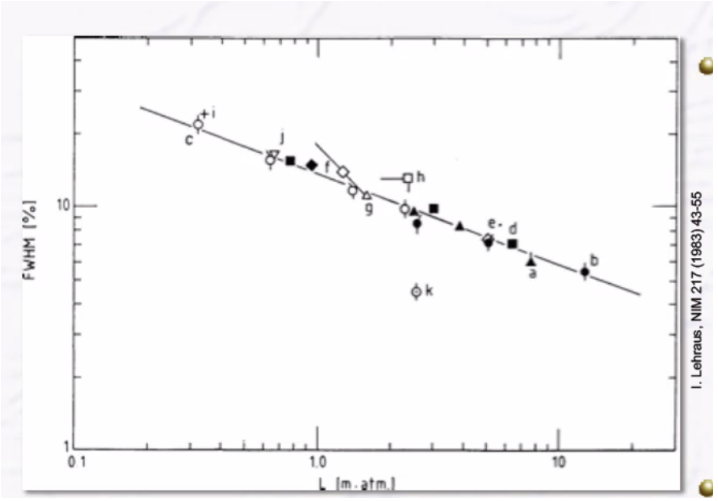
High Momentum PID Idea

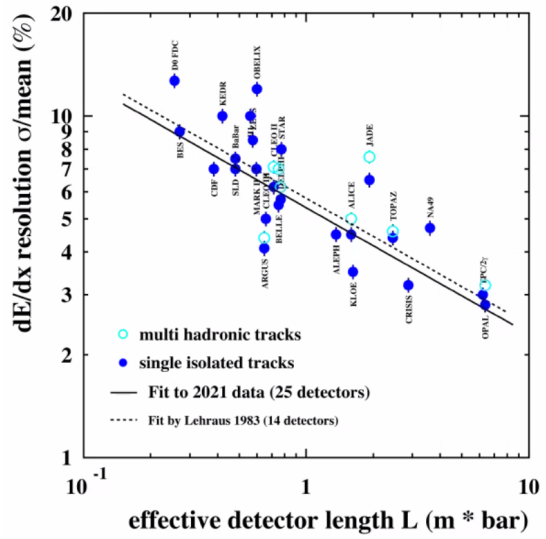
Presented by Tom in SIDIS WG Meeting: https://indico.bnl.gov/event/12138/



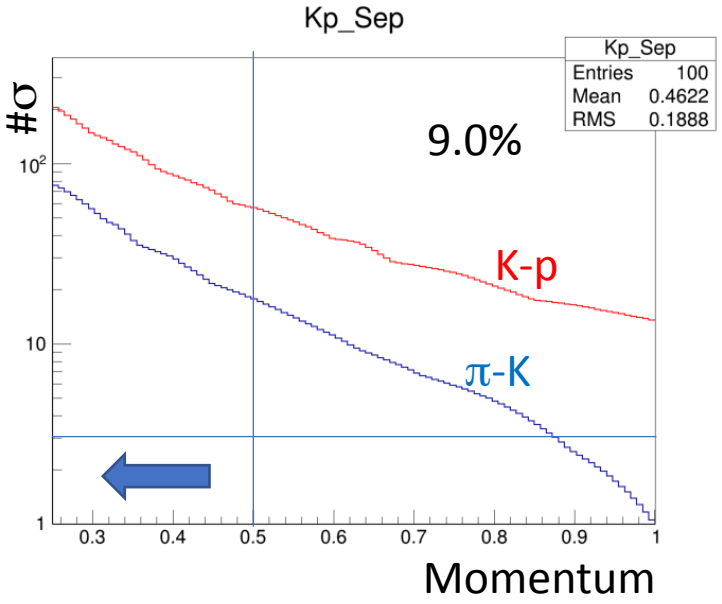
Mostly All-Si Tracker

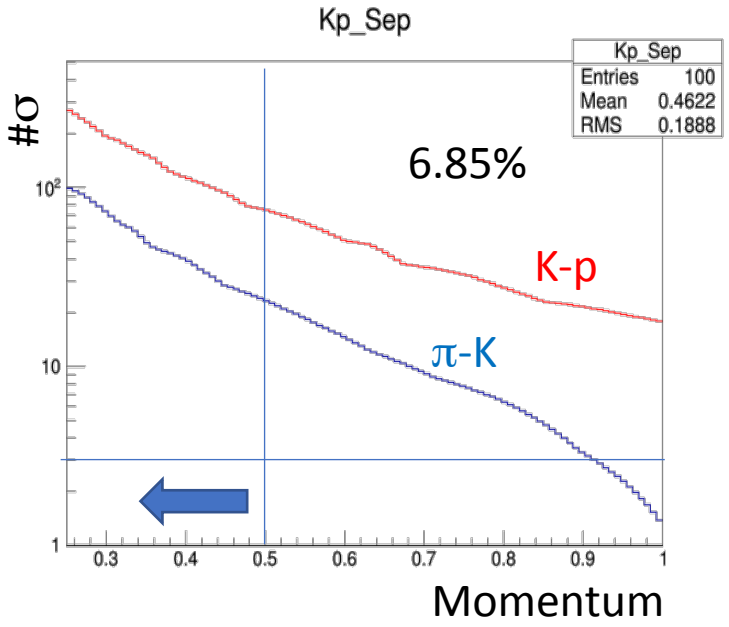
Anticipated dE/dx Resolution





- **Fit by *Lehraus* 1983:**
  dE/dx res. = 5.7 * $L^{-0.37}$ (%)
- **Fit in 2021 (25 large detectors):**
  dE/dx res. = 5.4 * $L^{-0.37}$ (%)





Lehraus Plot

- Using 5.4 as a standard TPC
  - $5.4*(0.25)^{-0.37} = 9.0$
- Measured for GridPIX (truncated Mean)
  - 4.1% at 1 meter
  - $4.1*(0.25)^{-0.37} = 6.85$
    - This was the prior assumption quoted by us.
- Roughly 20 sigma at 0.5 GeV/c
- Useful range overlaps with DIRC

Overly Simplified Momentum Resolution

- Figure of Merit:
  - $\sigma_p \propto \frac{\sigma_{hit}}{\sqrt{N_{meas}}} \equiv Figure\ of\ Merit$
- Can be compared to Silicon with detailed Monte Carlo
- Here is simple-minded estimate
  - $Figure\ of\ Merit(Si) = \frac{\frac{20\ \mu m}{\sqrt{12}}}{\sqrt{4}} = 2.9\ \mu m$
  - Gas:
    - Including efficiency ~3000 electrons (minimum!) per track
    - Each suffers digitization (σ = 55 μm/sqrt(12) = 16 μm)
    - Diffusion(Length) = $25\frac{\mu m}{\sqrt{cm}}\sqrt{L}$
      - D(2cm) = 35 μm ➔ FOM = 0.70 μm
      - D(25cm) = 125 μm ➔ FOM = 2.3 μm
      - D(50cm) = 176 μm ➔ FOM = 3.2 μm
      - D(100cm) = 250 μm ➔ FOM = 4.6 μm
    - Although ignoring many significant effects, initial result is on the order of the layers of silicon.