Fermilab
50 Years of Discovery

HP Gas TPC

Overview and Answers to Questions

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DUNE Near Detector WS

6-Nov-2017

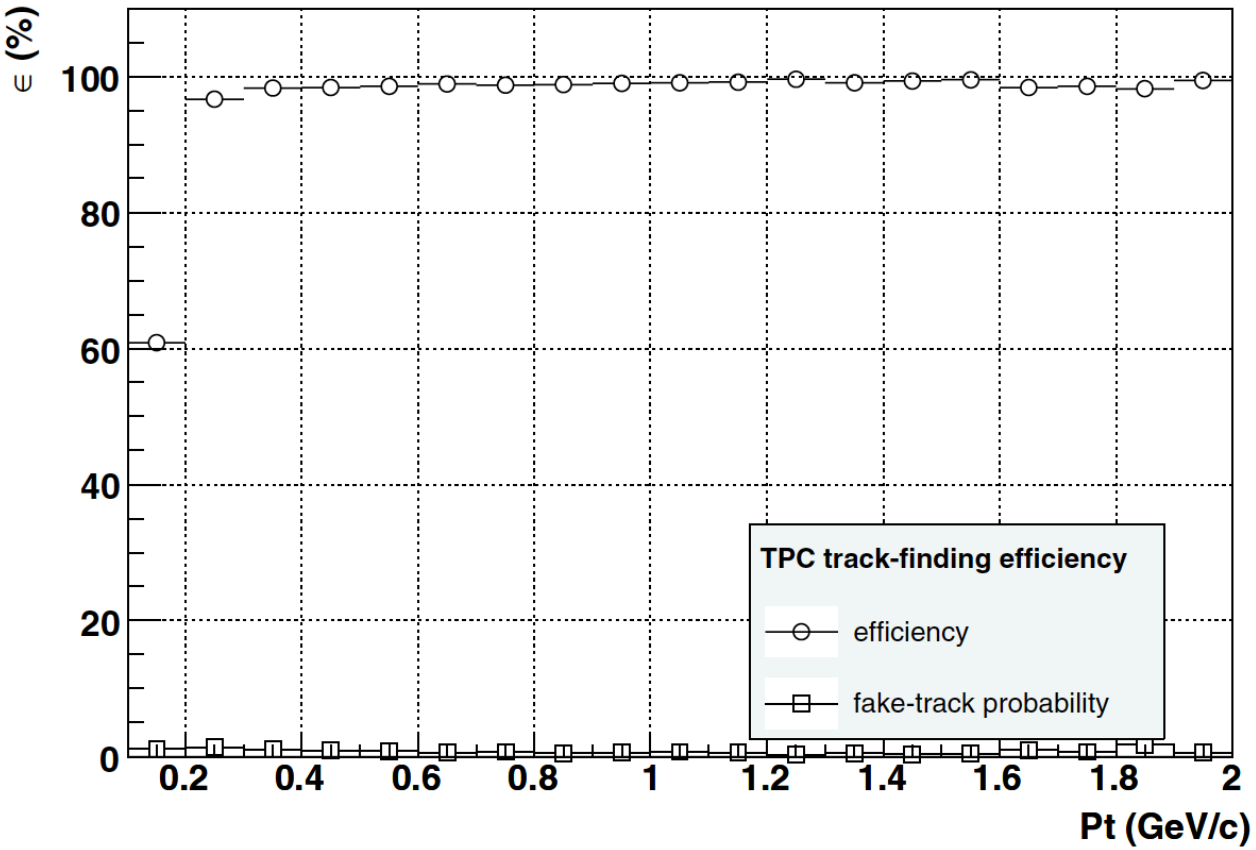
HP Gas TPC

- A magnetized Gas TPC provides two functions:
  - Aids in event containment/reconstruction for the LAr
    - Provides a high-resolution μ spectrometer
    - Can Help measure Hadronic energy
      - dE/dx (in conjunction with μ tag) for particle ID
      - Momentum measurement
    - However, both are dependent on exact configuration details
      - Cryo wall thickness in radiation lengths, pressure vessel thickness, magnet geometry/coil thickness, etc.
  - Stand-alone experiment
    - At 10 ATM, neutrino event yield is ~ 4M ν_μ CC events in 3 yr ν running (For size we had been considering - ~ $80m^3$)
      - **97% of events on nucleons in Ar nuclei (P10 gas – 90-10 Ar-CH_4)**
        - Possibly can reach 99% with optimized gas choice
    - A HP Gas TPC offers unprecedented "3D vertex visualization" for an electronic detector
      - Only surpassed by emulsion detectors

Our concept for HP Gas TPC

- Re-purpose ALICE readout chambers
  - Existing chambers will be replaced in 2019 for High-lumi LHC
    - In discussion with ALICE management
    - Represents significant ~$5m contribution (if we used all chambers)
      - NOTE: If we use all chambers, Vol is ~ 80 m^3
  - They have only operated at 1 ATM, but calculations indicated that operation at 10ATM looks doable without introducing electrostatic instability
    - Test stand now being setup at Fermilab using one of ALICE's inner readout chambers (IROC) (See Guillermo's talk)
- Tremendous synergy with ArgonCube
  - Target nucleus
    - 100% Ar in LAr and 97% Ar in gas.
  - Raw 3-D data
  - Similar FE electronics architecture
    - Front-end chip design
  - Same DAQ
  - Common data structure
  - Common pattern recognition, track finding, event recon. Algorithms
  - Light detection – maybe

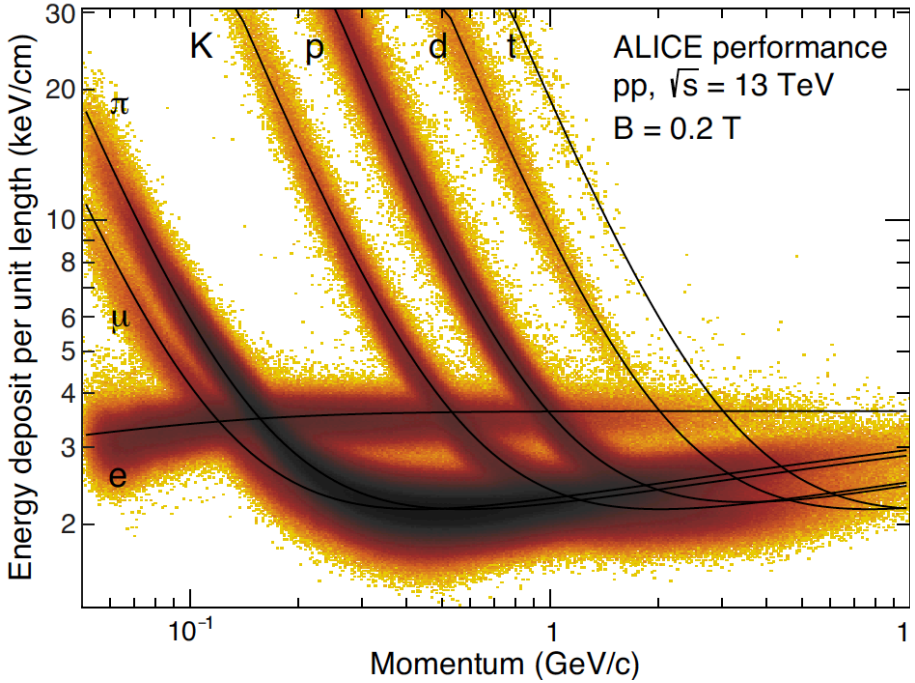
ALICE TPC: Tracking efficiency

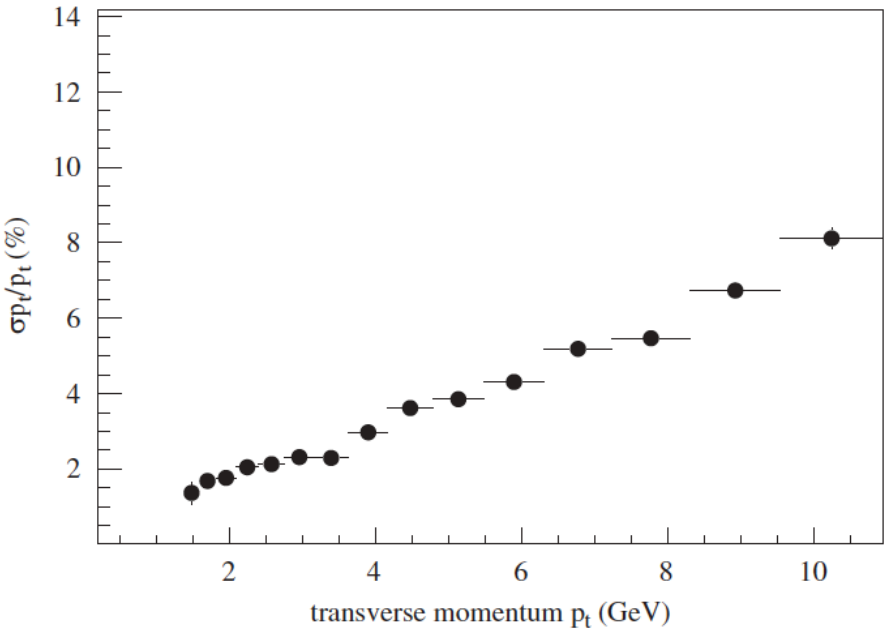


>99% for p_T > 1 GeV/c
For for events with
> 24,000 tracks

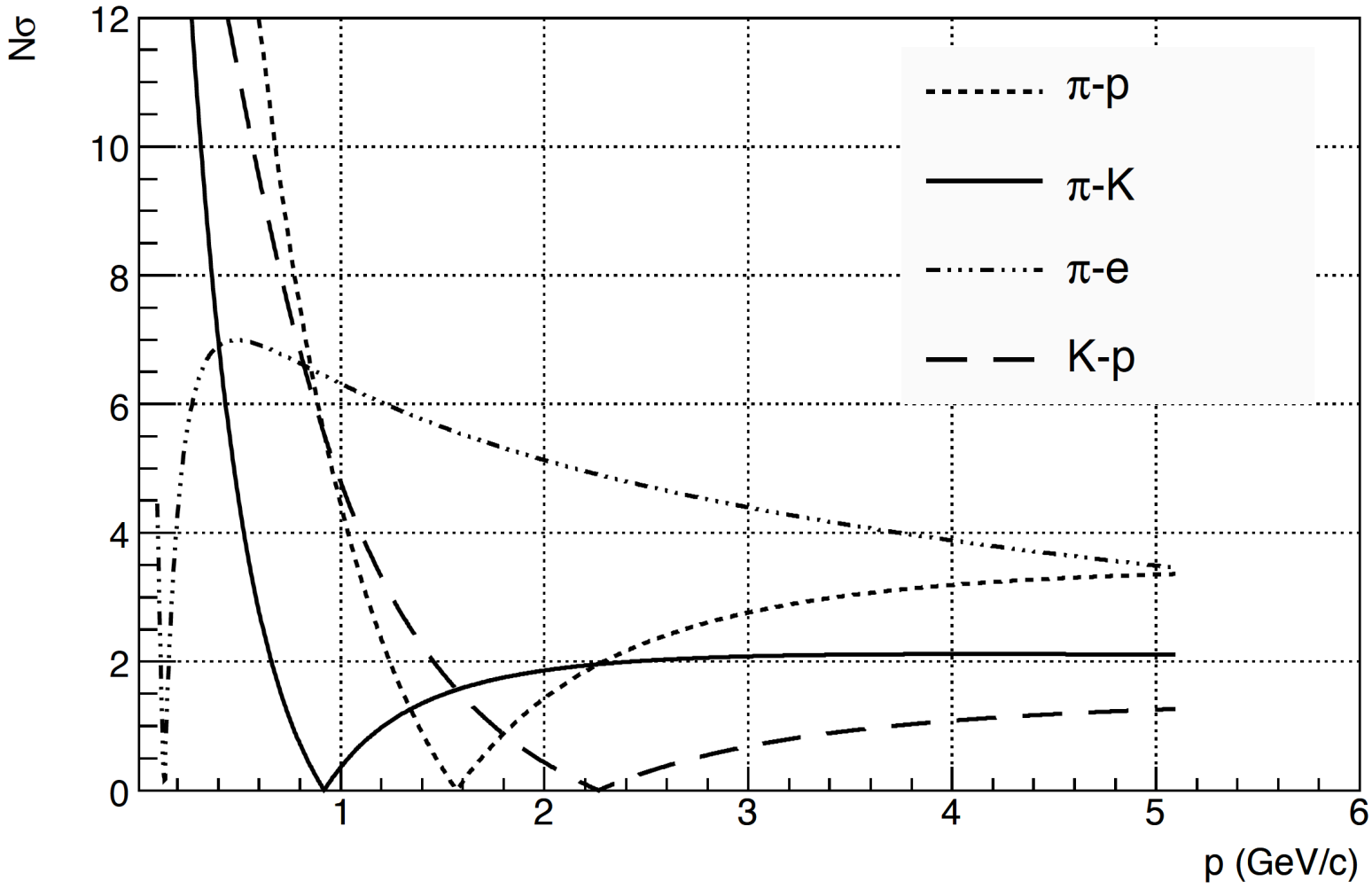
Figure 5.12. Efficiency of the TPC track-finding software as a function of particle transverse momentum for central Pb–Pb collisions ($dN_{ch}/d\eta = 6000$).

With excellent momentum and dE/dx resolution

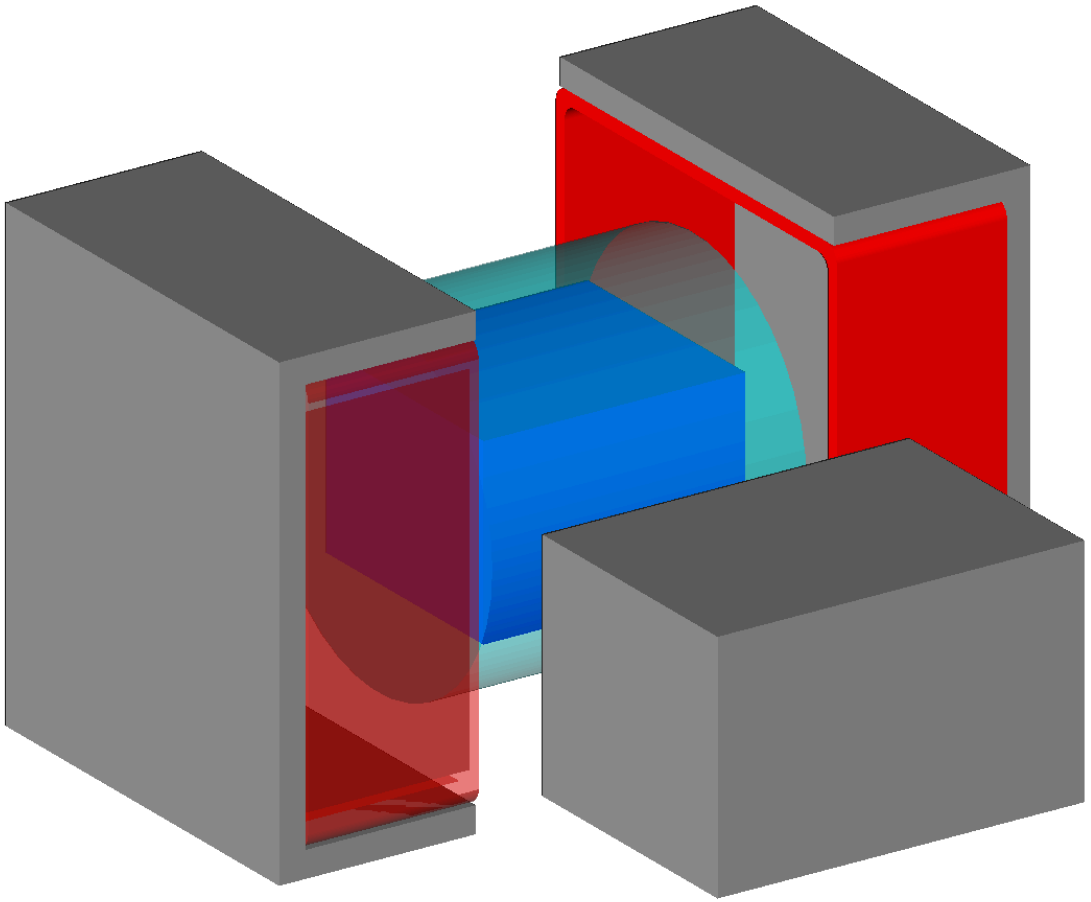




Tracking + dE/dx +E/p is very powerful



Conceptual layout



- Gas TPC:
  - Baseline we have been considering
    - 5m wide x 4.5m deep x 3.5m tall (~ 80m^3)
      - 5m: Drift direction, 2.5m drift from center electrode
      - E parallel to B
  - However, this does not fit in baseline magnet
    - Limited to ~ 15 m^3, Jeremy will discuss next
- Pressure vessel:
  - Could be rotated 90^o and would ~ double the active volume, but then the electronics is not accessible without removing the TPC

Interested groups and initial focus area

- Fermilab TPC and mechanical engineering, simulations
- SLAC DAQ
- LBL Front-end electronics
- Colorado Simulations
- Harvard Simulations
- MSU Low threshold/High-resolution tracking capabilities
- Bern Integration with LAr
- Aachen TPC gas studies

Questions and Answers (partial)

- **What is the realistic fiducial volume/mass for different vessels and readout concepts?**
  - *Reusing all the ALICE readout chambers, we can instrument an active volume of ~ 80 m^3. Assuming 10 ATM Ar operation, this is a total mass of ~ 1.4t. A detailed analysis still needs to be done, but a reasonable expectation is that a Fid. Mass of ~0.7t could be reached.*
- **What is expected numuCC per POT?**
  - *Based on the above size, we calculate for the optimized 80 GeV, 204 X 4 DP LBNF beam, we obtain ~ 1.4M ν_μ CC events per year in the 0.7t Fid. Vol.*
    - *#POT is 1.47 X 10^{21}/yr.*
- **What is the performance for pizero reconstruction in real environment (with rock muons and background events)?**
  - *Under study. From task force study, with good time-stamp on tracks escaping the TPC utilizing the ECAL, background is very small (<1%).*
- **Can photons be reliably associated to particular events?**
  - *With proper ECAL, yes. Based on ALICE experience.*
- **What about the coherent channel?**
  - *Not yet studied. But, the TPC will be very powerful for the detection of very forward tracks and statistics should be adequate.*

Questions and Answers II

- **Is the good resolution and low threshold provided by HPTPC essential and useful for providing samples that give unique power in the oscillation program, i.e., samples with demonstrably better energy resolution or much better NC/CC separation than seen by other detectors (given insensitivity to neutrons and low rates)?**
  - *Under study. (You we hear from Luke tomorrow on that status)*
- **Considering HPTPC in a dipole: what is the shape of the vessel? How is it oriented? What does the readout look like? For example, if it's a cylinder, how is the long axis oriented and what direction do the electrons drift? How are they read out? This has implications for fiducial volume.**
  - *The vessel is cylindrical. Assuming a UA1-style magnet, the drift direction is perpendicular to the beam (mid-plane at HV and drift left and right from beam's view). Dirft is parallel to B field direction.* ***This is a requirement****. The vessel is oriented perpendicular to the beam. Fid. Vol./Active vol ratio determination would require full detector/magnet optimization. What we have assumed above is 50%.*
- **Must the ECAL be inside of the pressure vessel? What are the performance implications if it is (or is not)?**
  - *Current estimates on pressure vessel thickness (0.5 to 1 X_0) indicate that the ECAL could be either inside or outside. Requires detailed engineering and simulation iteration to determine what is best.*
- **Cost of 3.5x3.5x5.0m3 HPTPC?**
  - *Under study. Requires engineering effort currently not available.*

Required R&D

- R&D on the TPC is very limited (nothing pushing state-of-the-art)
  - Gas mixture (reach 99% Ar equivalent)
    - Although P10 would be fine, but would like to study alternatives.
  - Front-end electronics
    - Follow closely design for ArgonCube
- The TPCs largest effort is likely to be in mechanical engineering