The Fission Time Projection Chamber Project

Mike Heffner

Lawrence Livermore National Laboratory

5 Nov 2010

Improving on 60 years of $^{239}Pu(n, f)$ measurements

Why Make this Measurement?

- Precision measurements of ^{239}Pu(n,f) are needed
- Current errors on ^{239}Pu(n,f) are at least 2-3% (below 14MeV) and not completely understood
- The TPC is a powerful instrument that has not been applied to this problem

- Goal: Measure (n,f) cross sections to sub-percent accuracy
- Method: Use a Time Projection Chamber (TPC)

$^{239}Pu(n, f)$

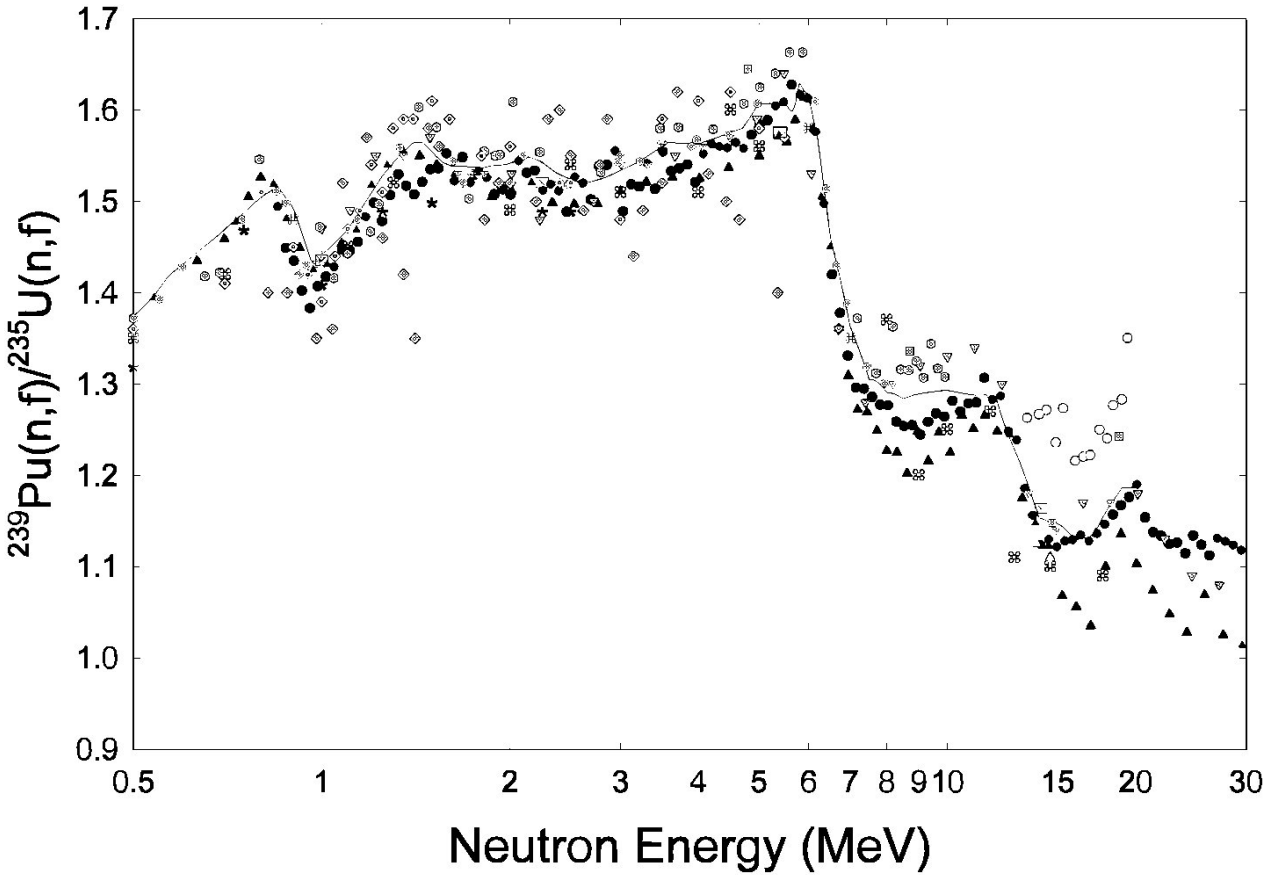
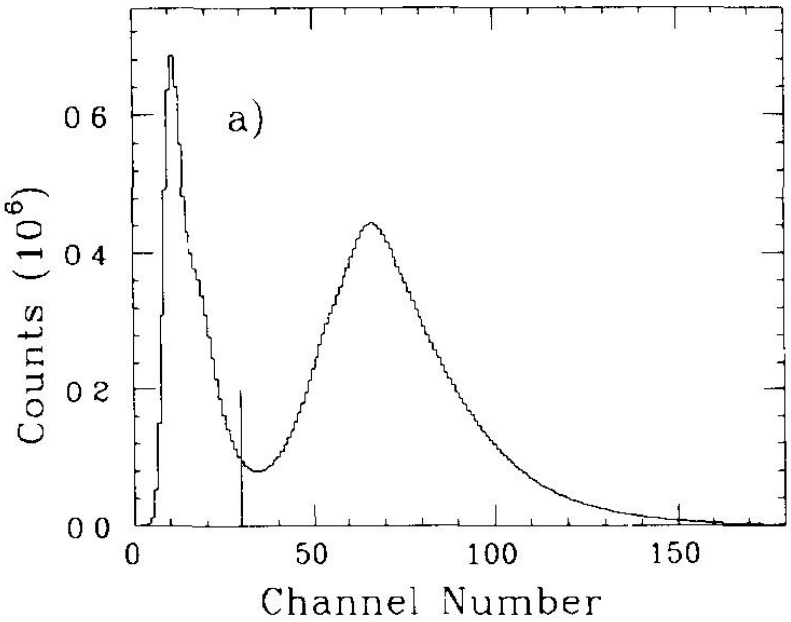


Fig. 3. Ratio of neutron-induced fission cross sections for $^{239}Pu/^{235}U$ to 30 MeV compared to other measurements (Refs. 1, 7, 8, 17, 19, 20, 23, 24, 25, 26, and 28) and ENDF/B-VI (solid line).

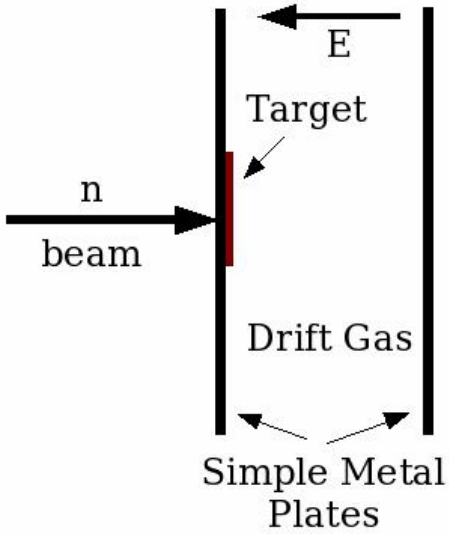
NUCLEAR SCIENCE AND ENGINEERING VOL. 129 JUNE 1998

The Fission Chamber

- Only the total energy is recorded
- Particle identification is difficult
- No event topology



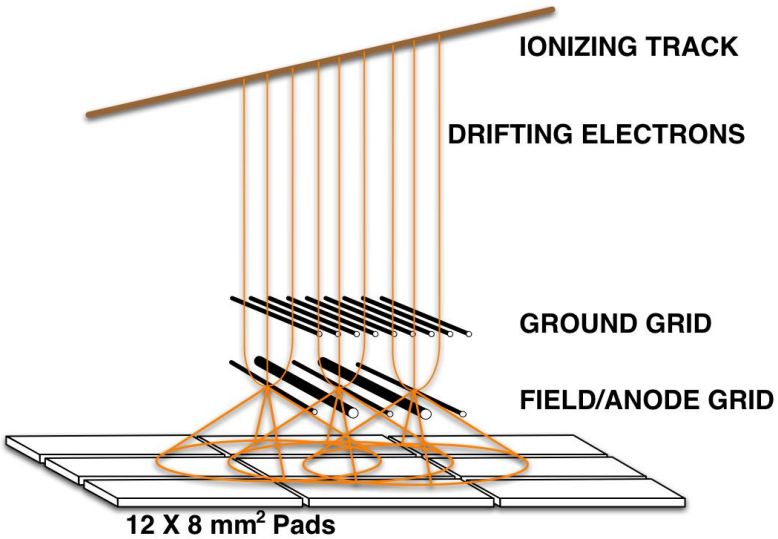
Example of a Fission Chamber



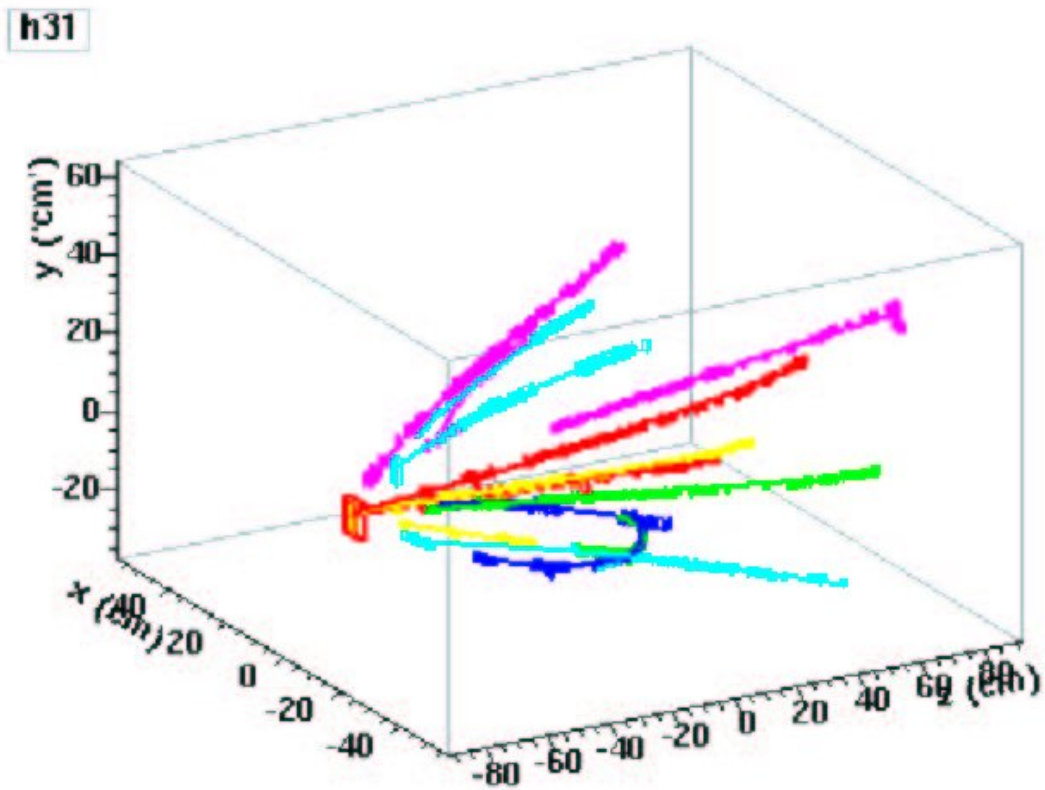
The Time Projection Chamber

A picture is worth a few million (ADC) words

- 30 year old technology
- Initially Developed in particle physics
- Full 3D event reconstruction
- Particle Identification
- "Snapshot" of the event



Example of TPC Data



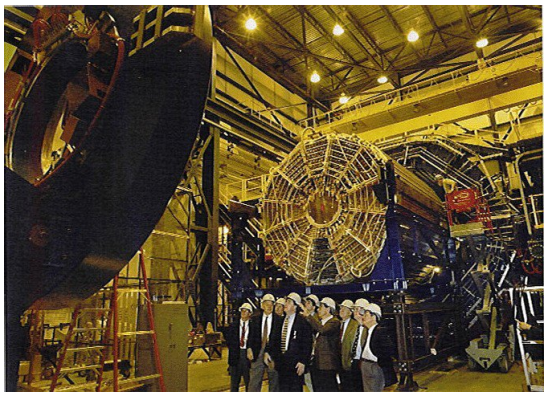
The Time Projection Chamber

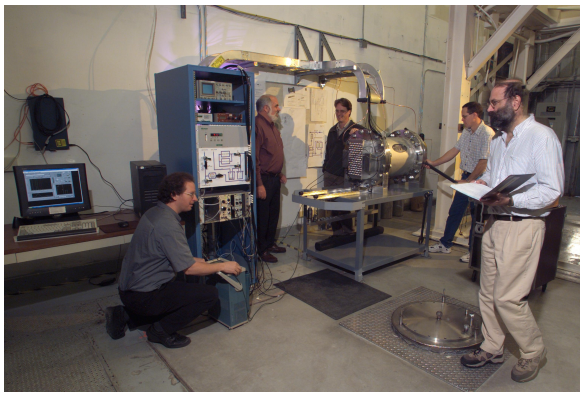
NP TPC Examples

- Rel. Hvy. Ion: EOS, NA49, STAR, ALICE
- Lower Energy NP: MAYA, ACTAR, PANDA TPC, AT-TPC, fissionTPC

Beyond Precision Cross Sections (with fissionTPC)

- Energy of fission fragments
- A and Z of fission fragments
- Ternary and quaternary fission
- Direct reactions on active targets
- Combine with other detectors

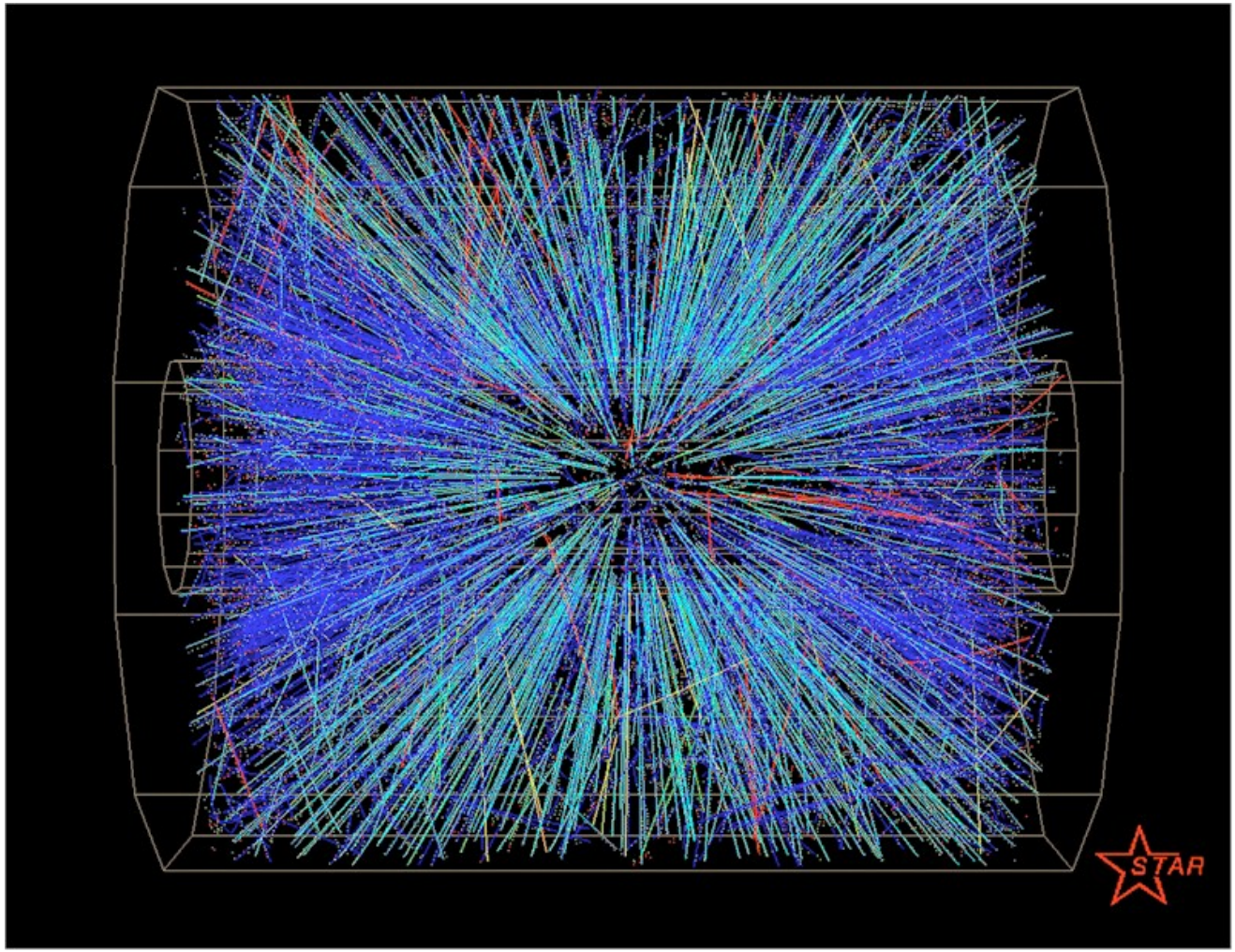




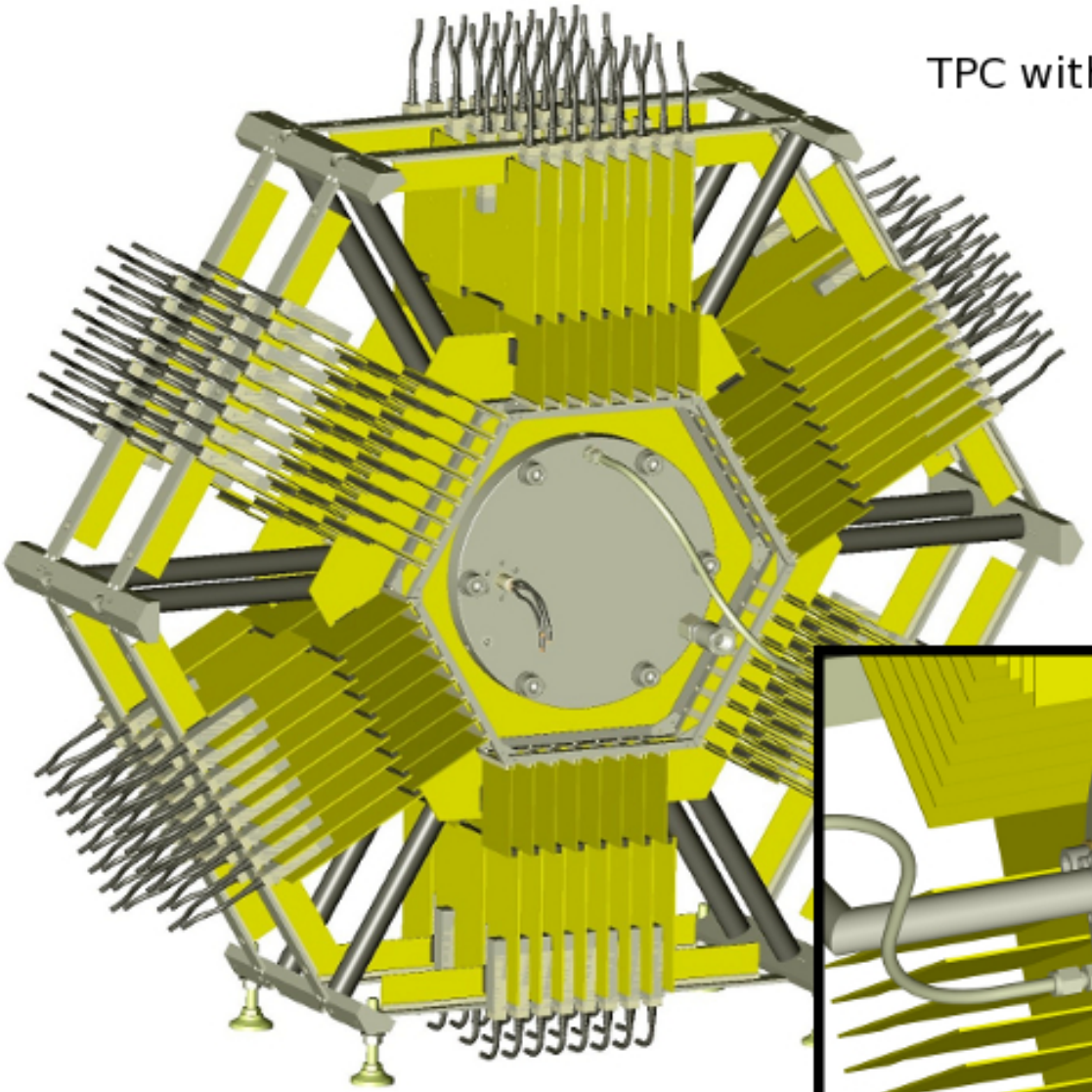
Rate is not a Problem

- fissionTPC sweep rate approximately 0.25MHz

Example from STAR TPC



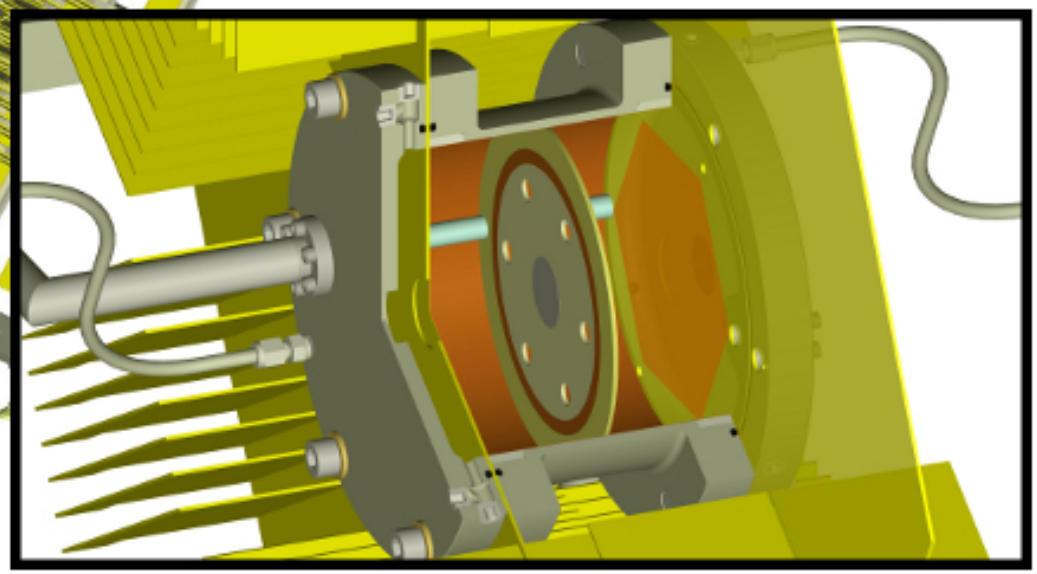
The Fission TPC



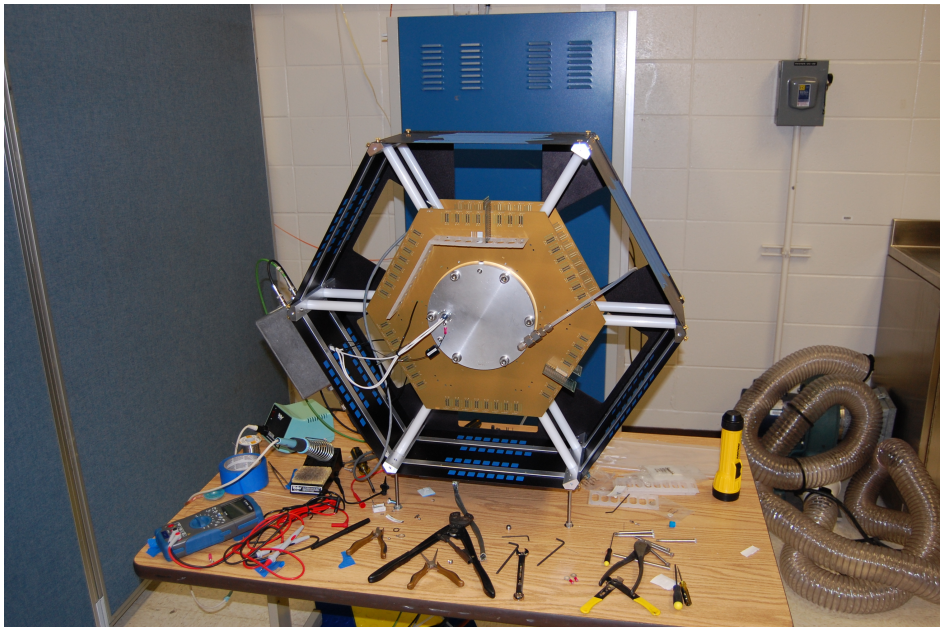
TPC with cooling baffles removed

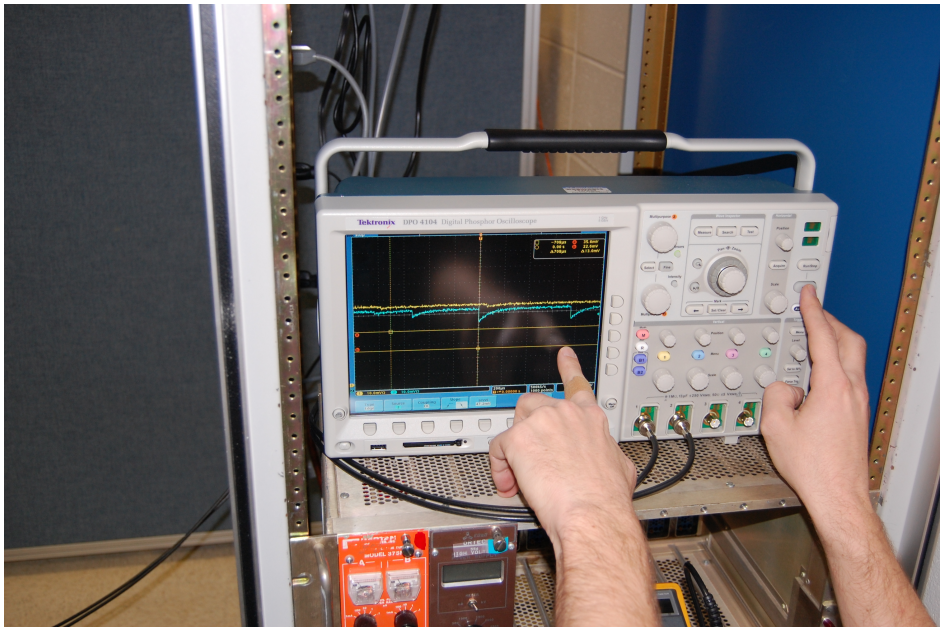
192 Front End electronics
Surround the Aluminum
Pressure Vessel

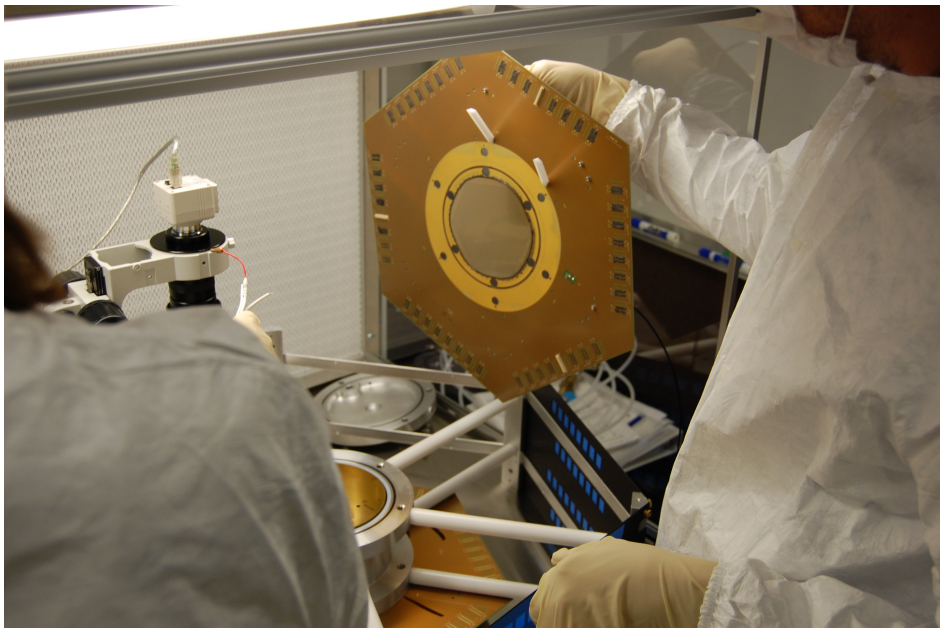
Cutaway of Central Section

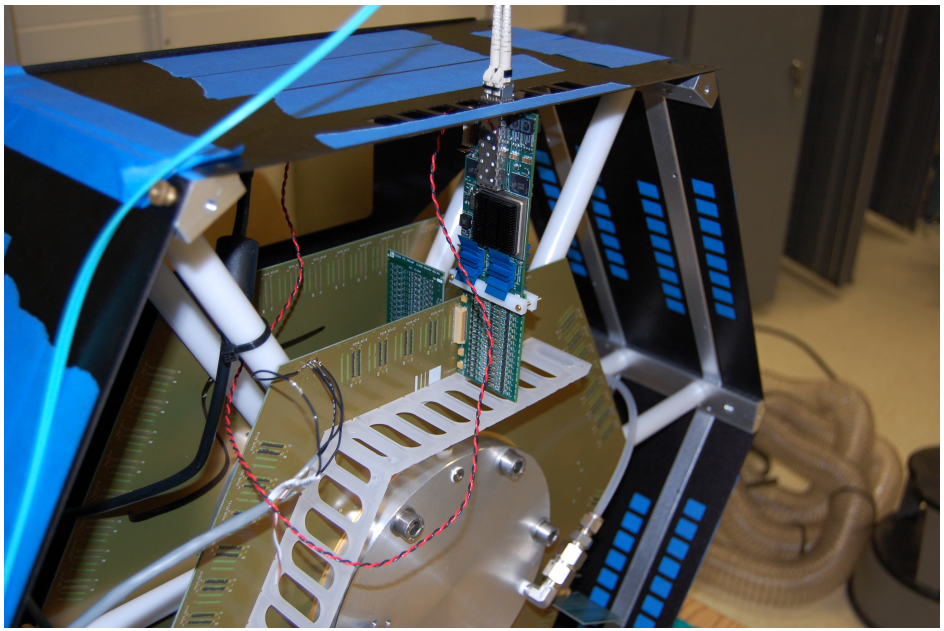


The Prototype TPC

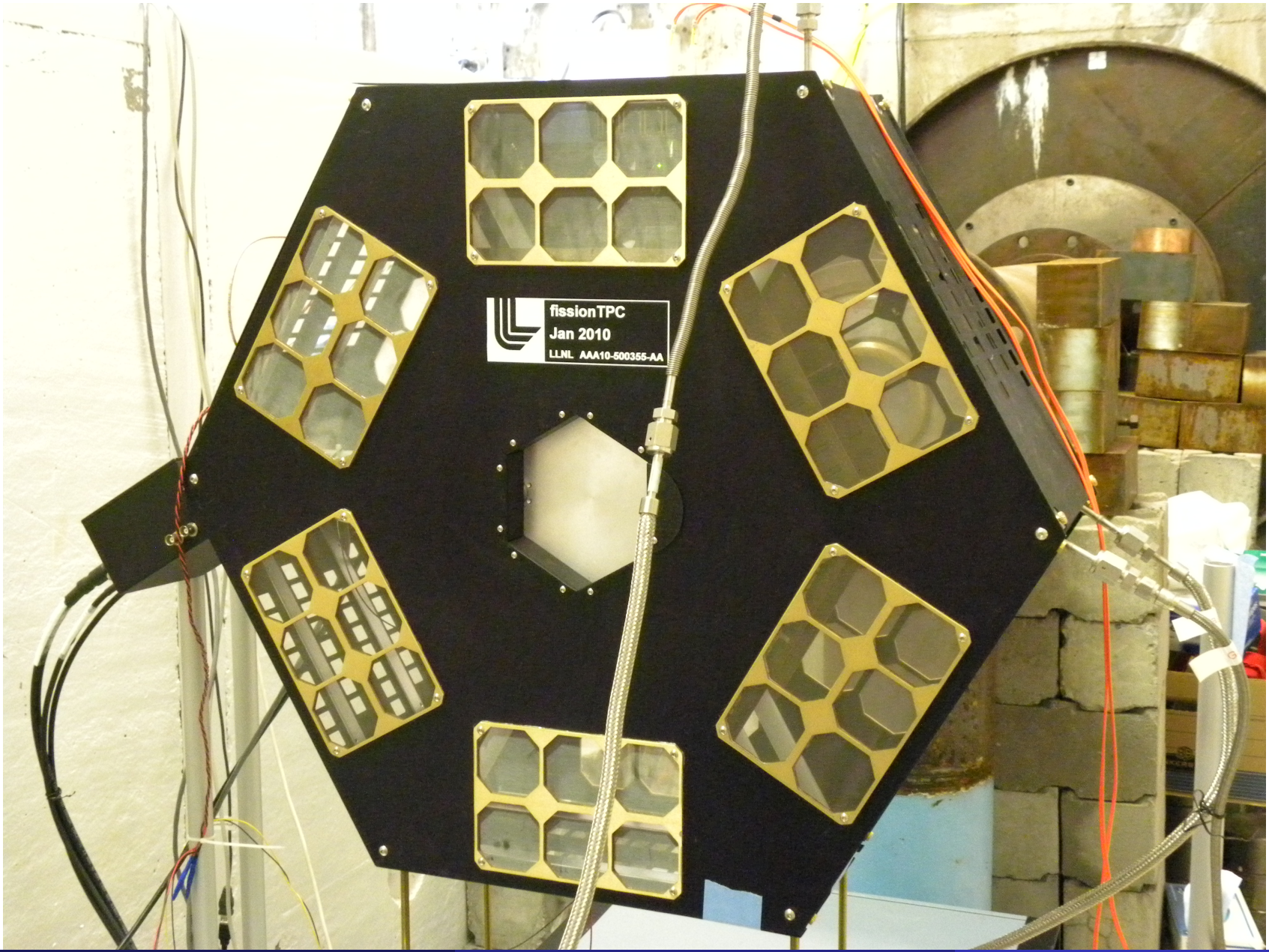




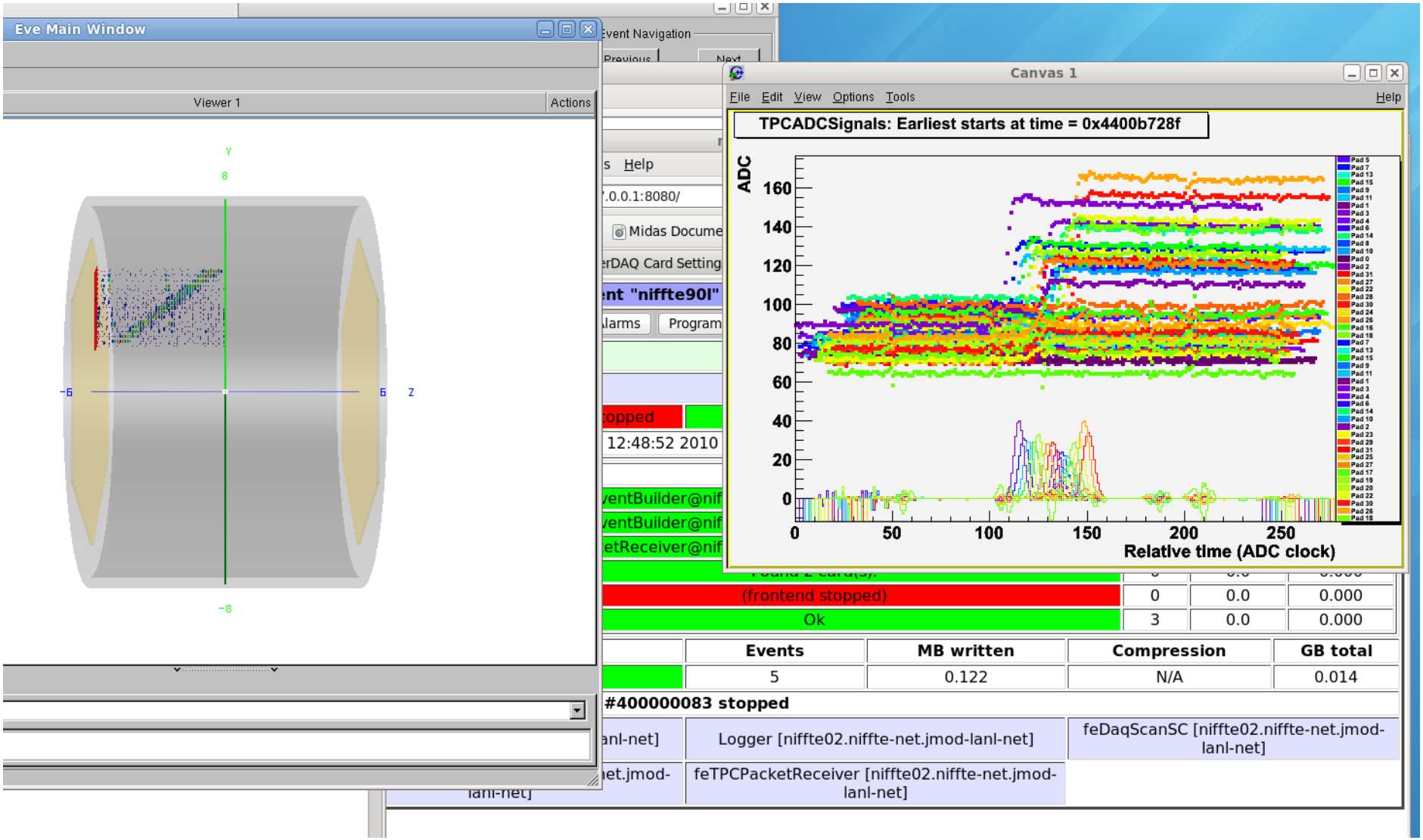




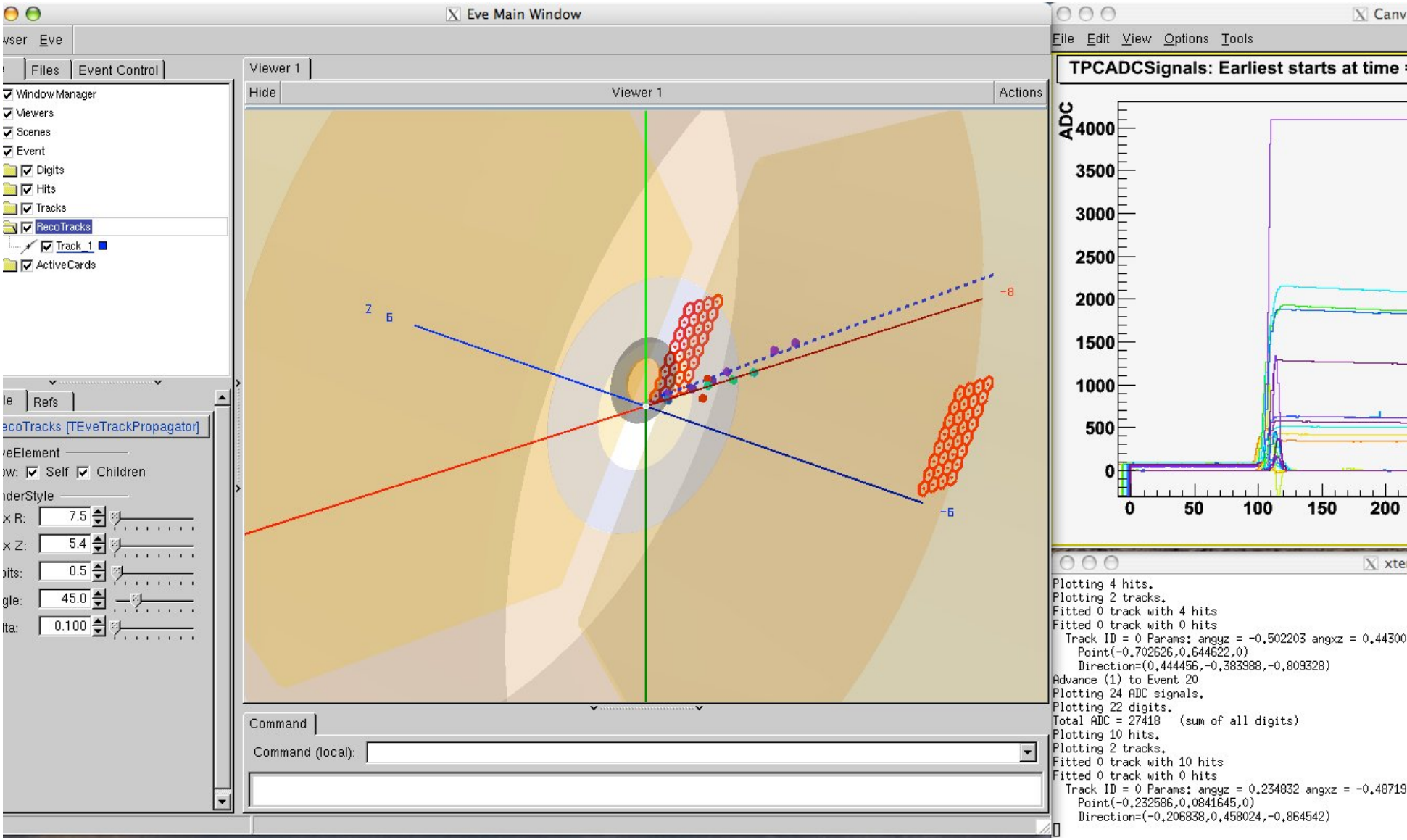
Installation at LANSCE 90L



Track in the Prototype Fission TPC



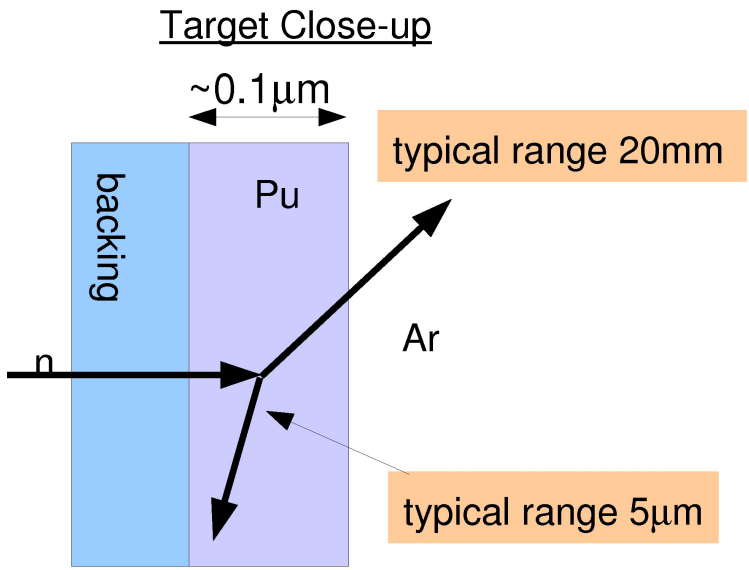
Hit Finding a Tracking with Alpha Source



Fission Chamber vs. the TPC

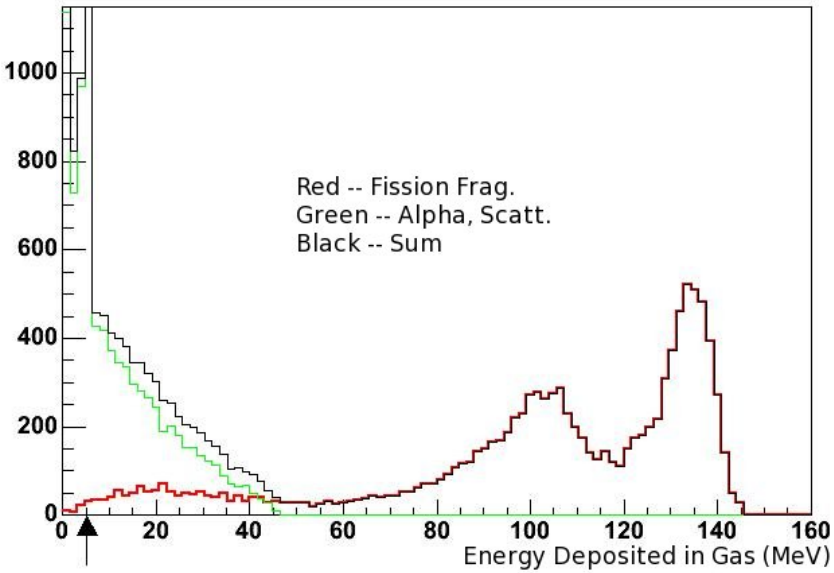
Systematic Errors

- Foil Mass (non-uniformity, surface defects, contamination)
  - Autoradiograph and tracking to the target
- Energy loss from target (α contamination)
  - Detailed tracking, and specific ionization
- Loss of both fragments
  - Detailed tracking to the target
- Edge Effects
  - Fiducial cuts
- ^{235}U reference
  - H_2 reference in the drift gas

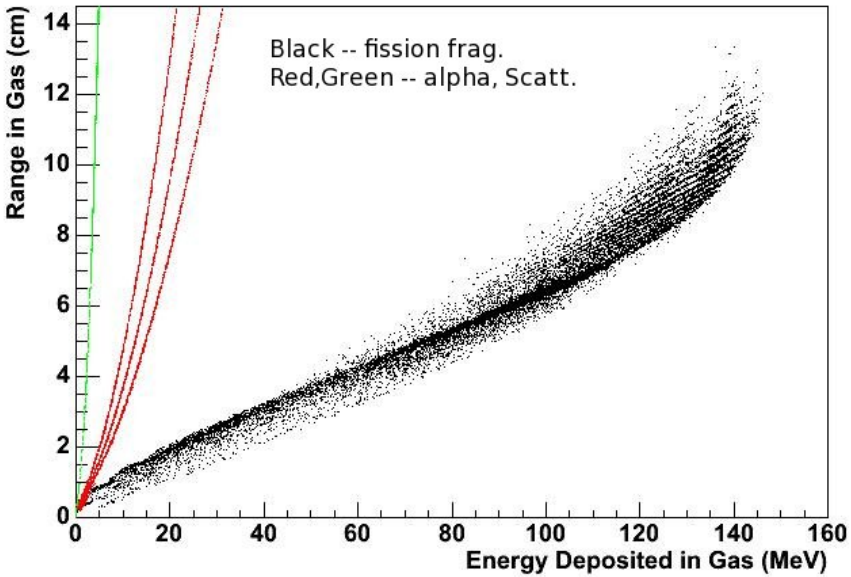


Example Simulation of How the TPC Outperforms a Fission Chamber: Particle Identification

Fission Chamber

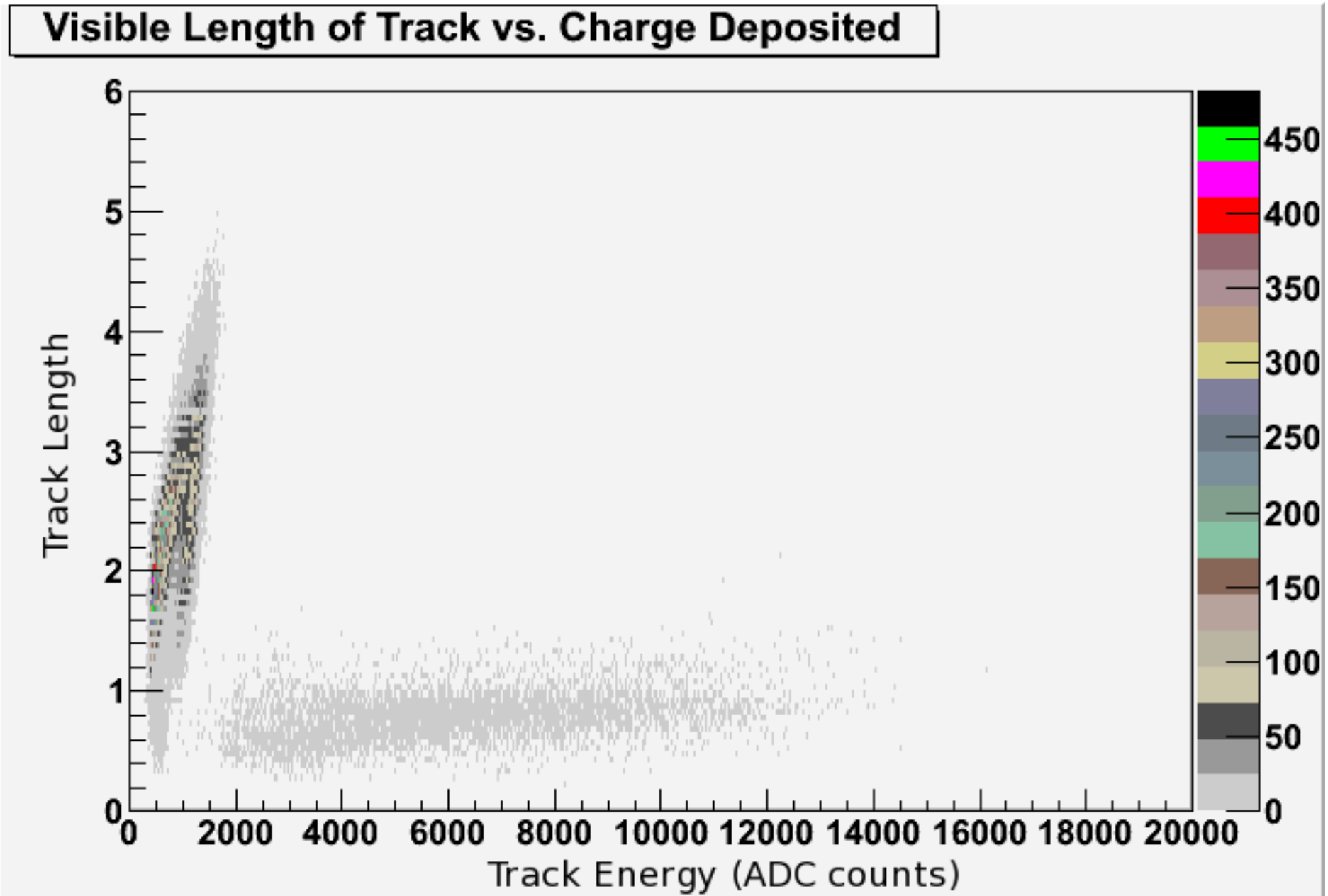


TPC



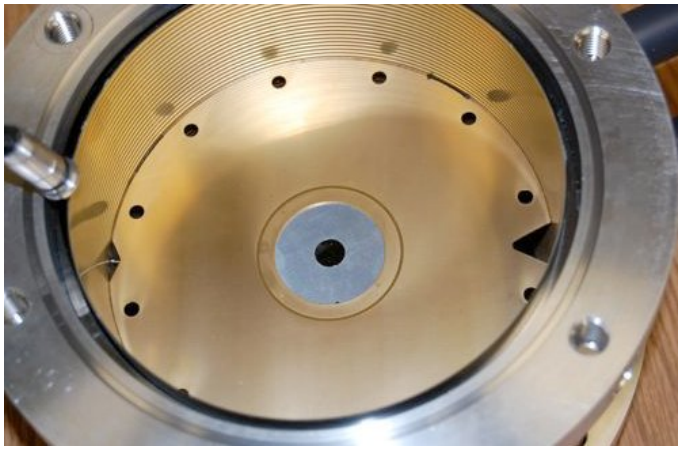
The TPC can cleanly identify particles that the fission chamber can not.

Uncalibrated Alpha/Fragment Separation



Field Cage, Pressure Vessel, and Drift Gas

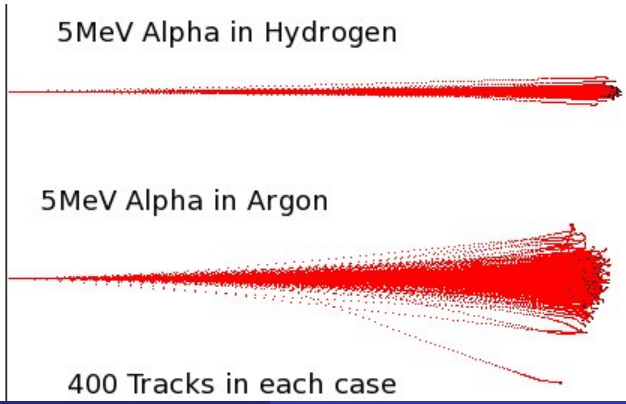
Field Cage in pressure vessel



- Printed circuit board construction
- 146mm dia X 108mm tall
- 27kV max voltage
- 5 bar pressure

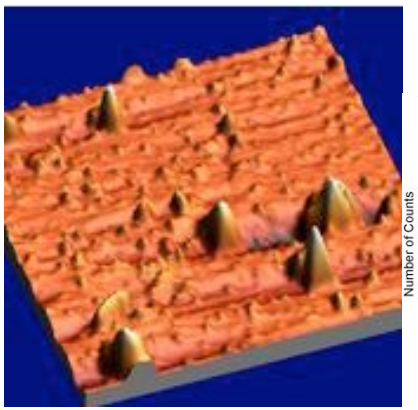
Drift Gas

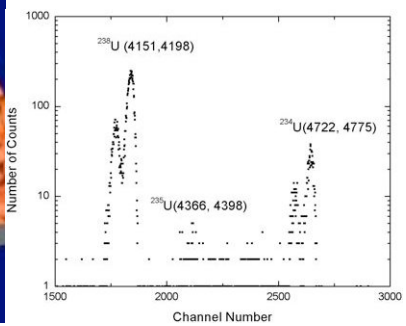
- Light gases are better to lower coulomb scattering
- Helium scatter from the neutron beam is difficult to distinguish from alpha decay
- Hydrogen is not very fast or stable, but does work well at low gain
- Hydrogen also serves as a reference target for (n,p)

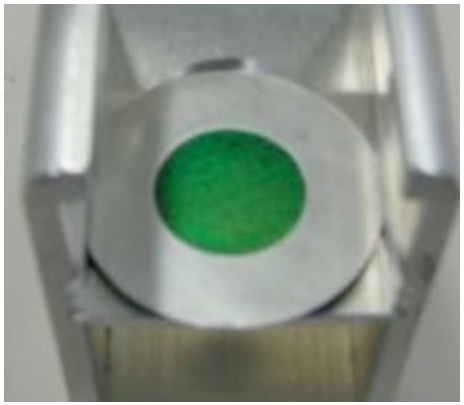


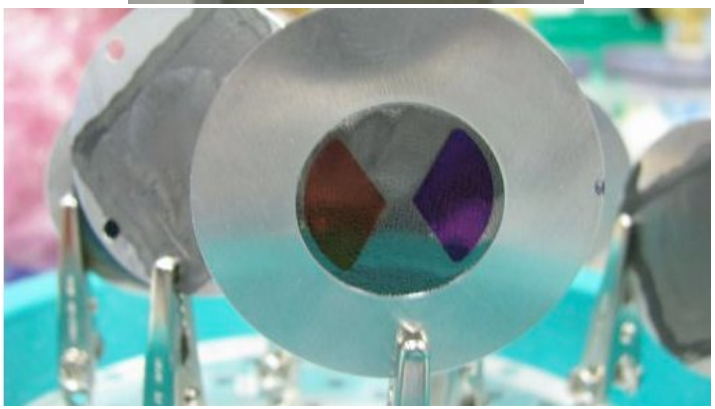
Target

- Thin backing
  - Using carbon foils
  - 30 to 100 $\mu g/cm^2$
- Focusing on uniform deposit of actinides
- Gas Target? plutonium hexafluoroacetylacetonate



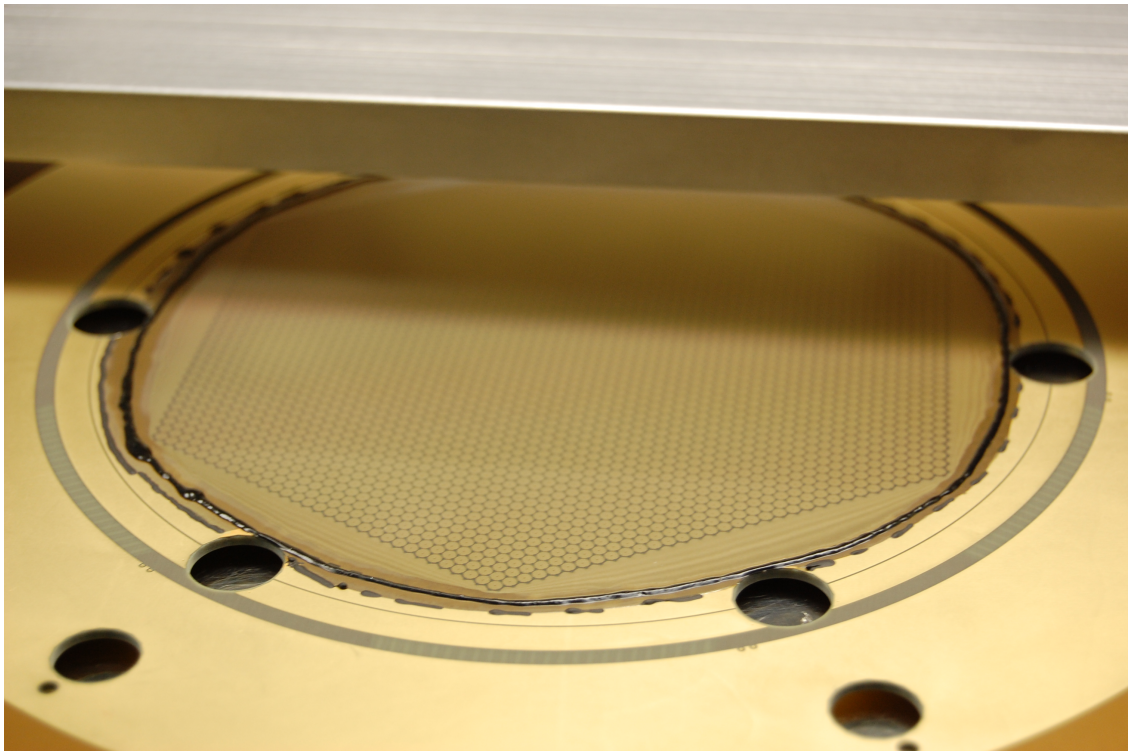






MicroMegas/Pad Plane

- First Prototype MICROMEGAS
- FR4 substrate, gold coated copper pads, dry film soldermask pillars
- About 3000 hexagon pads with 2mm pitch



I. Giomataris NIMA 376 (1996) 29-35

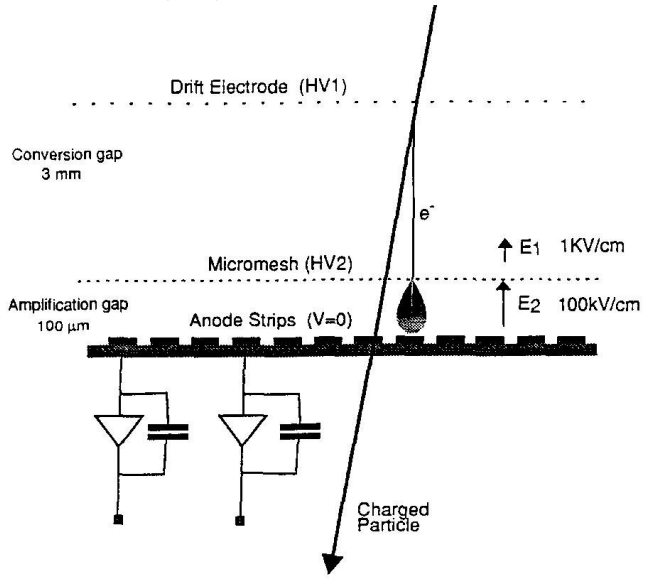
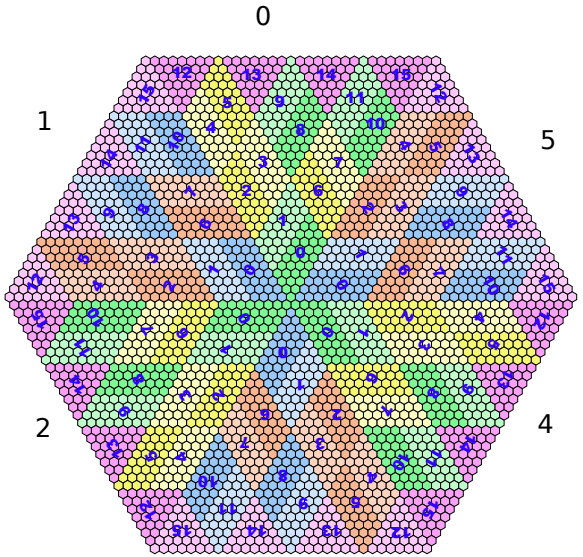
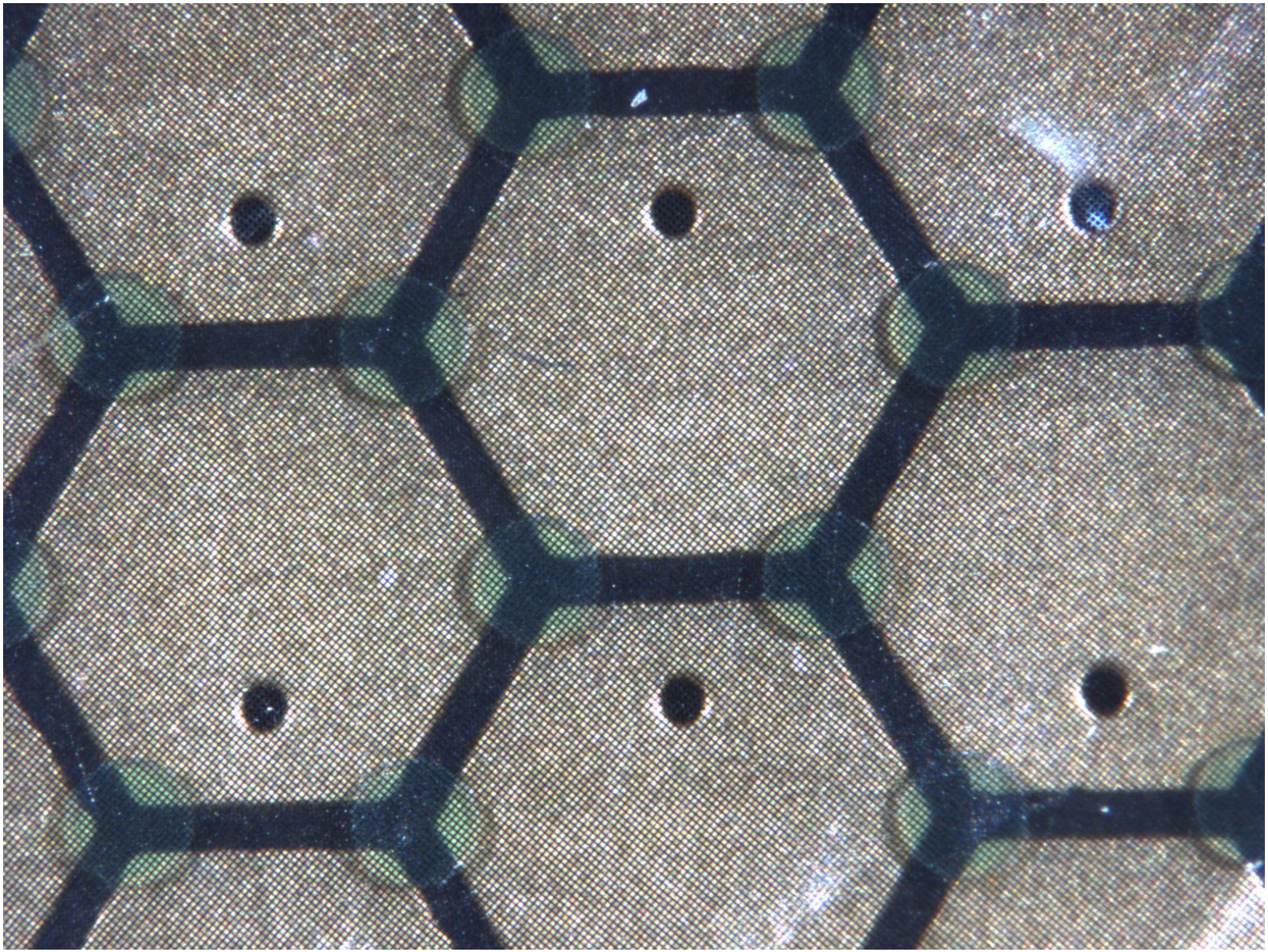


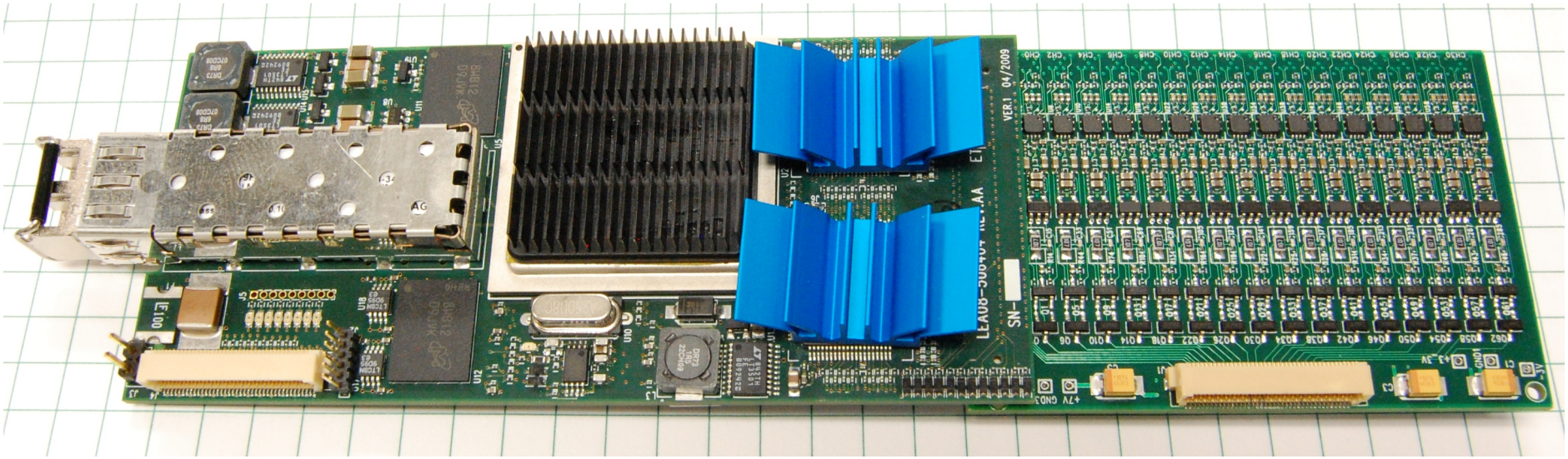
Fig. 1. A schematic view of MICROMEGAS: the 3 mm conversion gap and the amplification gap separated by the micromesh and the anode strip electrode.



1000lpi Electroform Mesh, only 3µm Thick

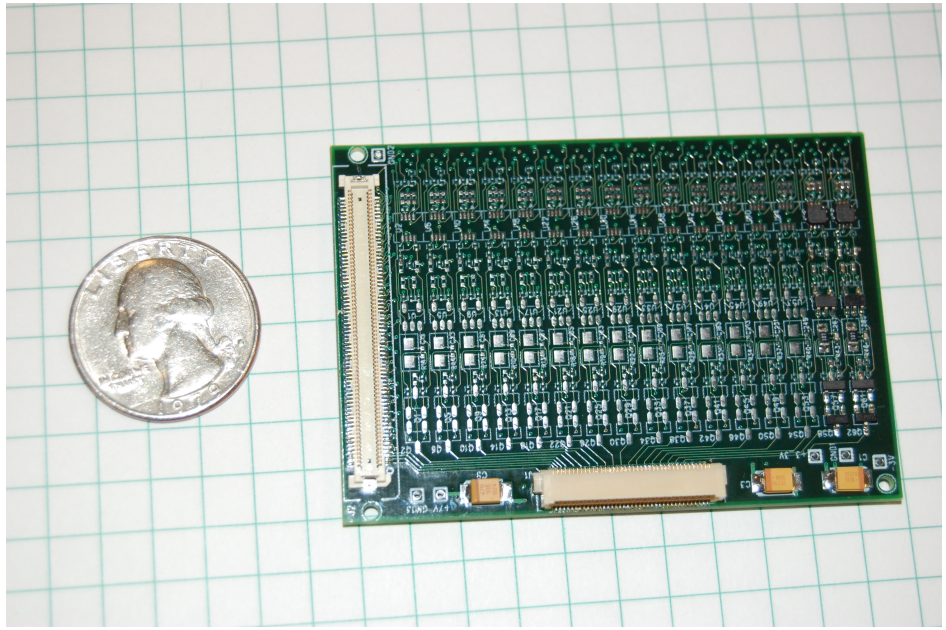


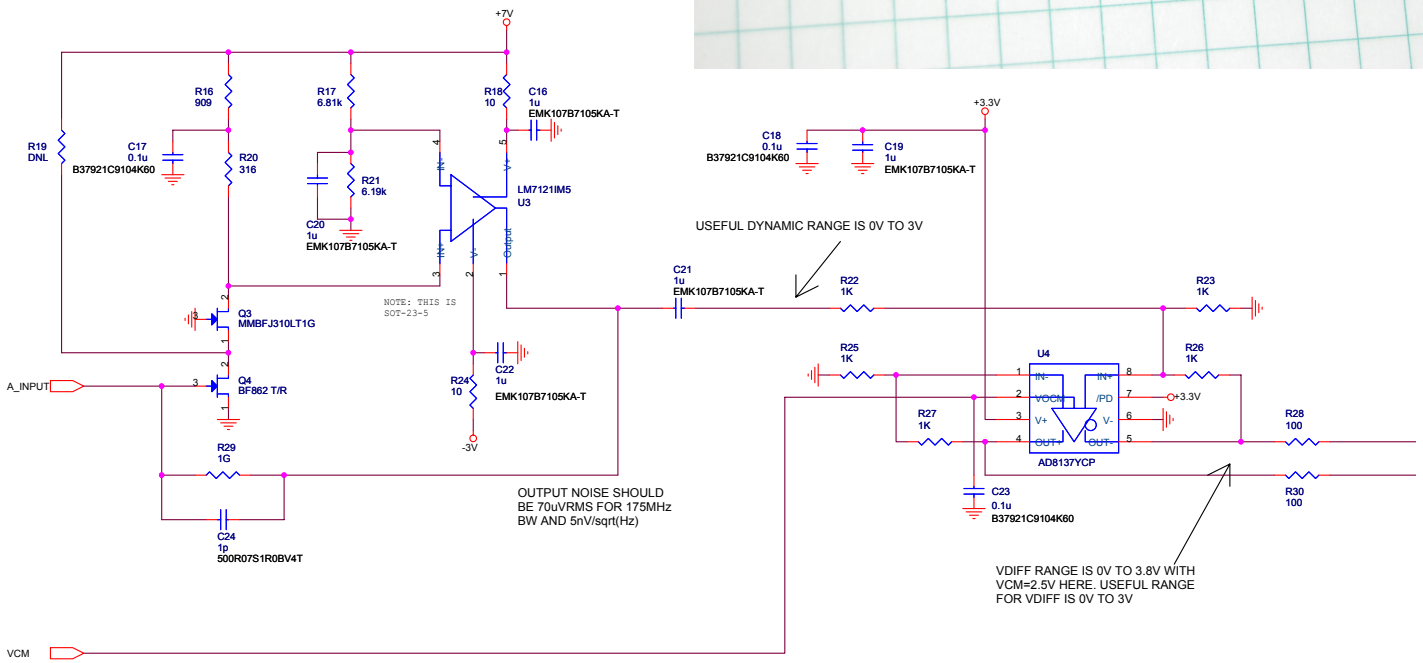
Electronics



Electronics – Preamp

- 32 channels per board
- Size of business card
- Off-the-shelf components
- Digital shaping



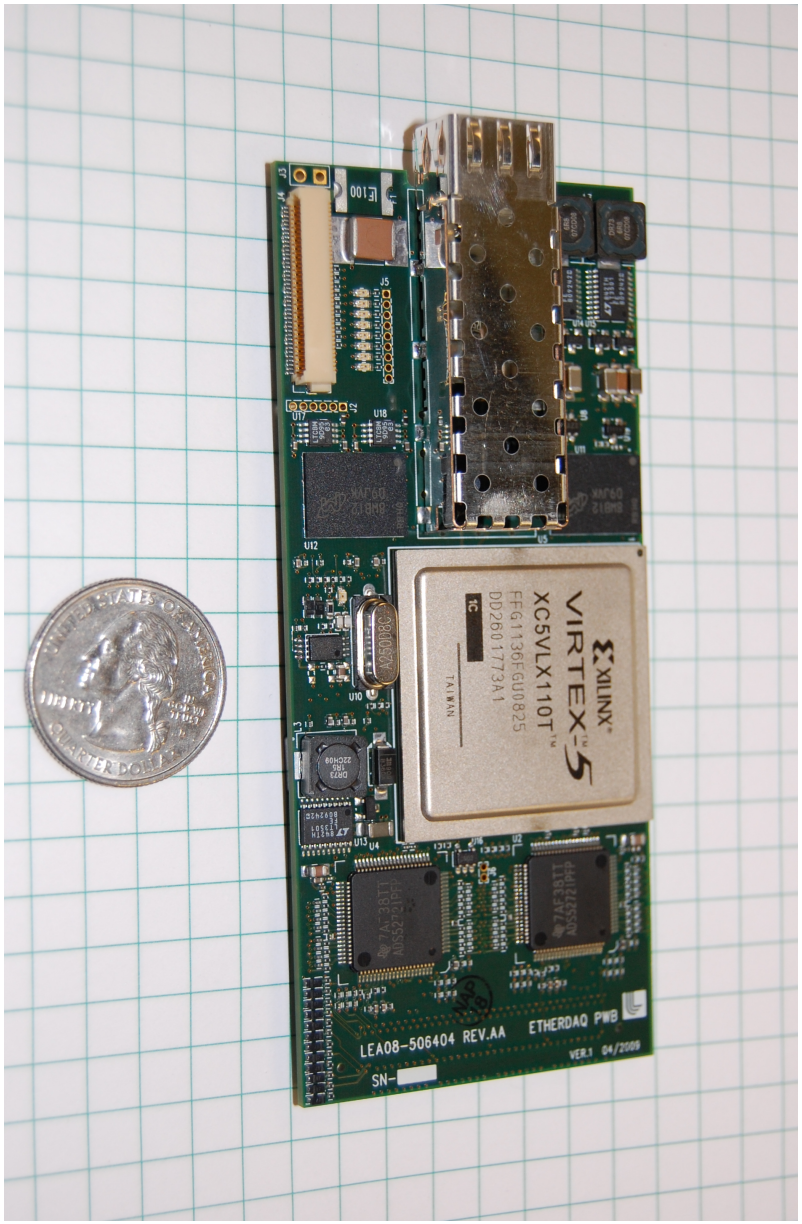


Electronics – Digital (EtherDAQ)

- ADC to Ethernet on one board
- 32 channels of 62.5MS/s
- 0.6TB/s for whole TPC

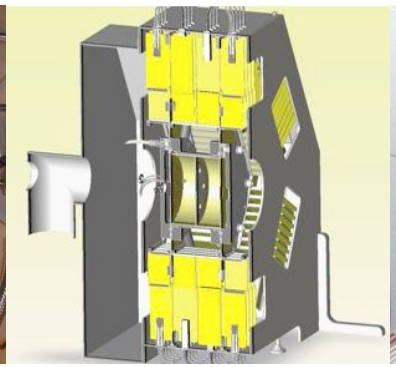
Components:

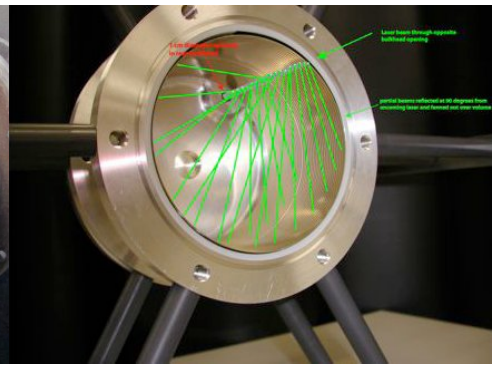
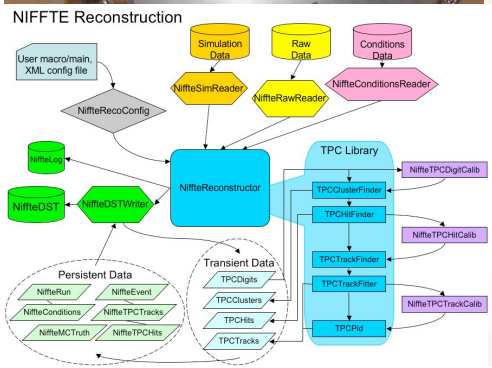
- ADC - Texas Instruments ADS5272 65MS/s 12bit
- FPGA - Xilinx Virtex 5 110T with Ethernet MAC built in
- Memory - 128MB (2x64MB) micron sdram
- Ethernet - Intel TXN31111 SFP 850nm optical GBit module



Support systems

- The TPC design and construction is only the start. There are many details to address in order to have a successful experiment.
- Installation design, hydrogen standard, simulation, analysis, computing, auxiliary detectors.


Summary

- Precision cross sections are needed
- The TPC has been selected to make these measurements
- We are well into the prototyping and have taken in beam data

NIFFTE Collaboration

Lawrence Livermore National Lab.• Los Alamos National Lab.• Idaho National Lab.• George Institute of Technology• Abilene Christian University• Oregon State University• California Polytechnic State University• Colorado School of Mines• Ohio University