A New Idea for an Old Problem: The Fission TPC and ^{239}Pu(n,f)

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Old Problem: Need High Precision ^{239}Pu(n,f)

Focus of this Work

Perform experiments to improve understanding the systematic errors in the experimental cross section of ^{239}Pu(n,f)

Goal

Sub-percent accuracy on ^{239}Pu(n,f) cross section

In principle is it simple. Just Measure:

- Number of neutrons on target
- Number of ^{239}Pu atoms in the target
- Number of fissions

In practice there are a LOT of details at the sub-percent level

Wide scatter among experiments of ^{239}Pu(n,f)

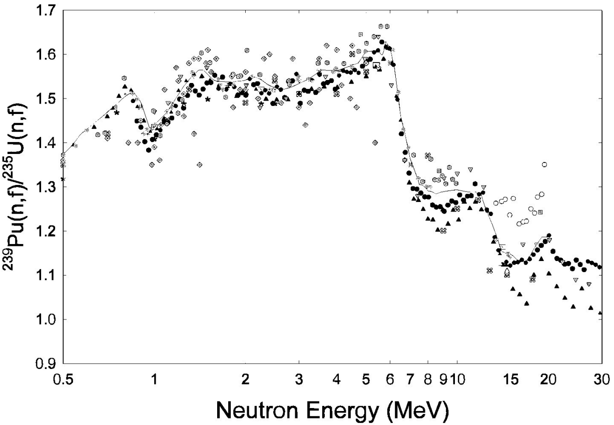

Fig. 3. Ratio of neutron-induced fission cross sections for ^{239}Pu/^{235}U to 30 MeV compared to other measurements (Refs. 1, 7, 8, 17, 19, 20, 23, 24, 25, 26, and 28) and ENDF/B-VI (solid line).

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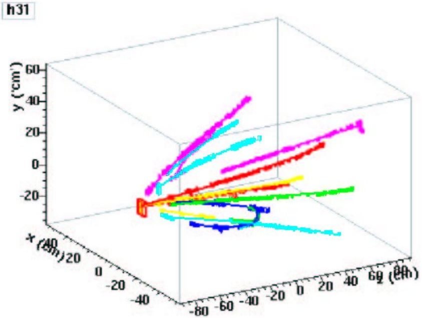
The New Idea

Build a Time Projection Chamber to measure fission cross sections.
TPC are not new (over 30 years old) but not used in fission until now.



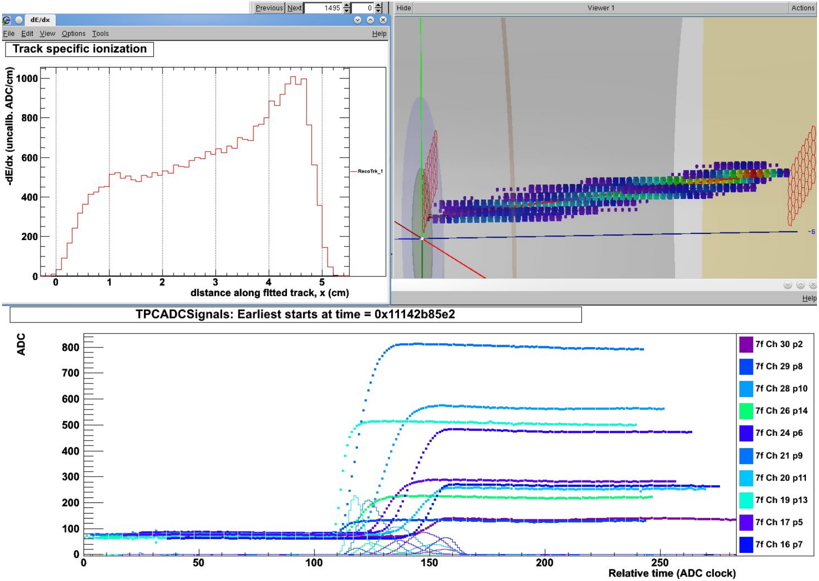
What Can a TPC do?

- Full 3D reconstruction of charged particles
- Occupancies of a few tens of tracks not a problem
- $\approx$200 micron pointing of tracks to target
- Few degree angular accuracy
- Total energy of individual tracks (even when overlapping)
- Specific ionization of each track (robust particle identification)
- In situ autoradiograph
- Measure beam gas interactions, and multiple scattering
- Ex post facto fiducial cuts
- etc...

What can a Fission Chamber Measure?

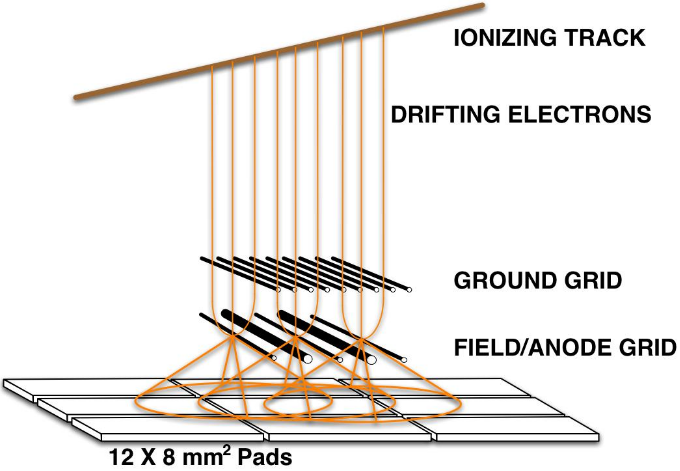
- Total charged particle energy (Whole event, not per track)

Example of Alpha in the TPC

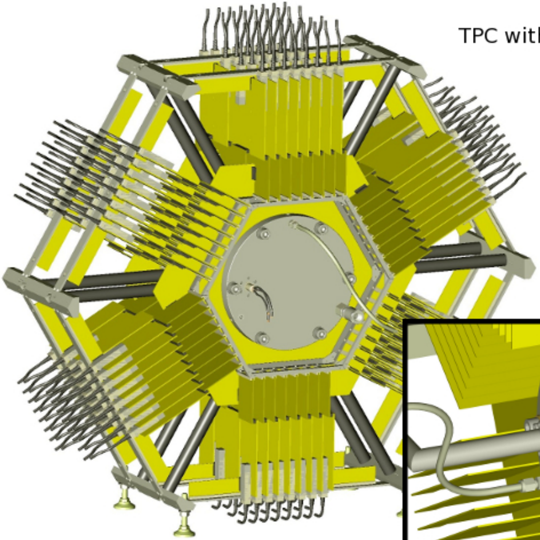


How does the TPC work?

A frisch gridded fission chamber with gas gain, a field cage, a finely segmented anode and medium speed waveform capture on each pixel.



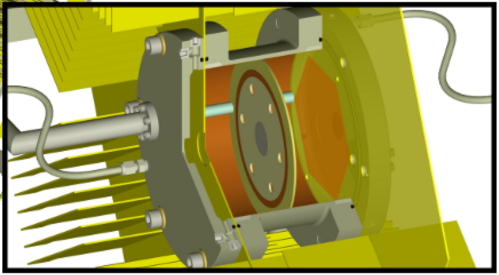
The Fission TPC



TPC with cooling baffles removed

192 Front End electronics
Surround the Aluminum
Pressure Vessel

Cutaway of Central Section

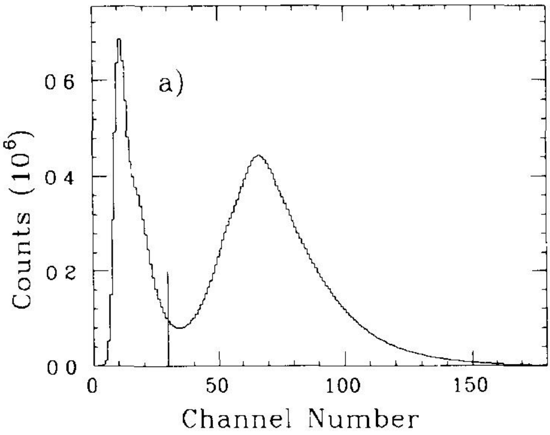


A List of Systematic Errors

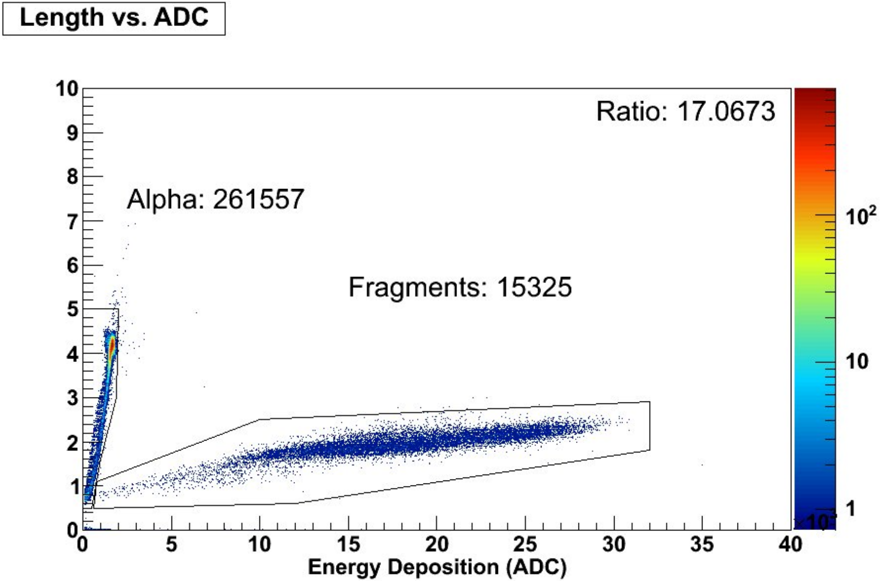
Source of Uncertainty	Estimated Uncertainty	
	Fission Chamber	TPC
Total	**1.62% + ??**	**0.48%**
Neutron Beam		
Neutron Energy TOF	0.10%	0.10%
Flux Measurement, ^{235}U vs. H_2 ref	1.00%	0.40%
Beam Profile	?	Very Small
Energy Position Dependence	?	Very Small
Beam Flux Outside Target	?	Very Small
Beam Spreading and Attenuation	0.30%	Very Small
Target		
Purity	0.10%	0.10%
Surface Contamination	?	Very Small
Non-uniform Target Density	0.70%	0.10%
Energy Loss in Target, 2 components:		
1. Complete Loss	0.10%	0.05%
2. Particle ID Degradation	1.0%	0.20%
Fragments		
Partial Containment Track	0.00%	0.00%
Pulse Height Variation	?	0.00%

Particle Identification – Fission Chamber

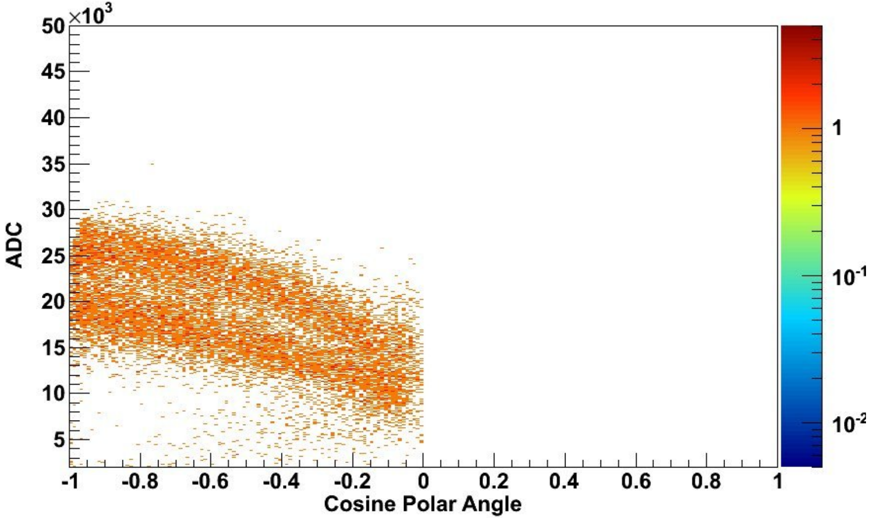
Energy loss in the target causes alpha and fragment peaks to overlap



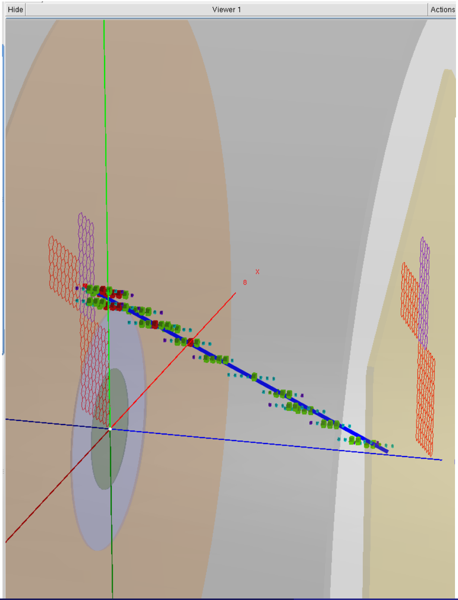
Particle Identification – TPC

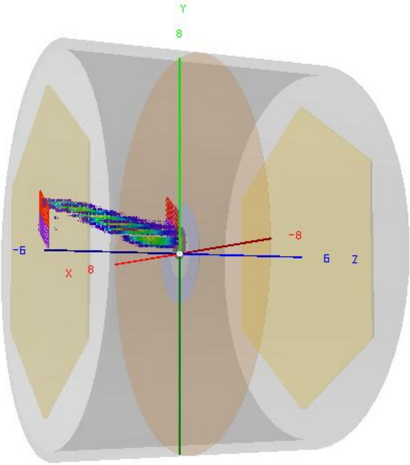


Heavy and Light Fragments



Proton to Fragment Dynamic Range





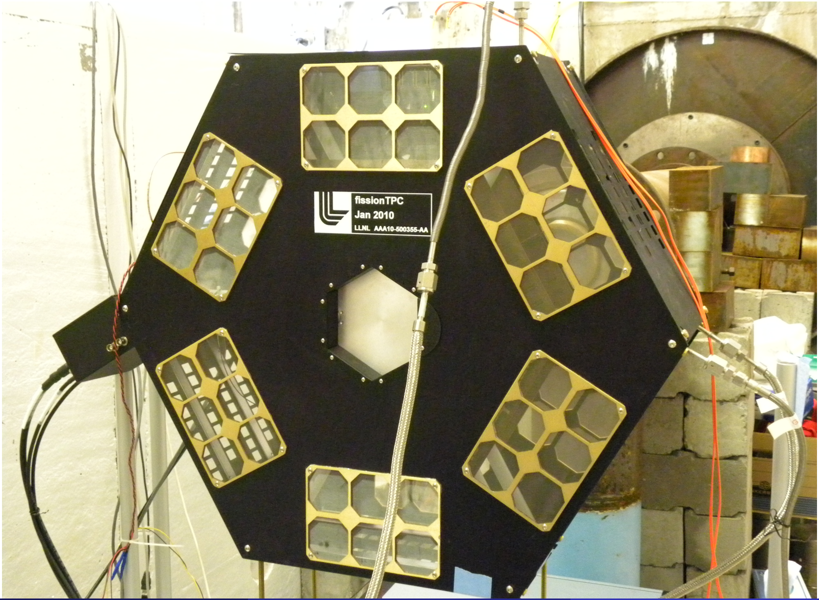
Project Status

- Design completed
- TPC built
- 1/6 electronics completed
- Currently testing in beam

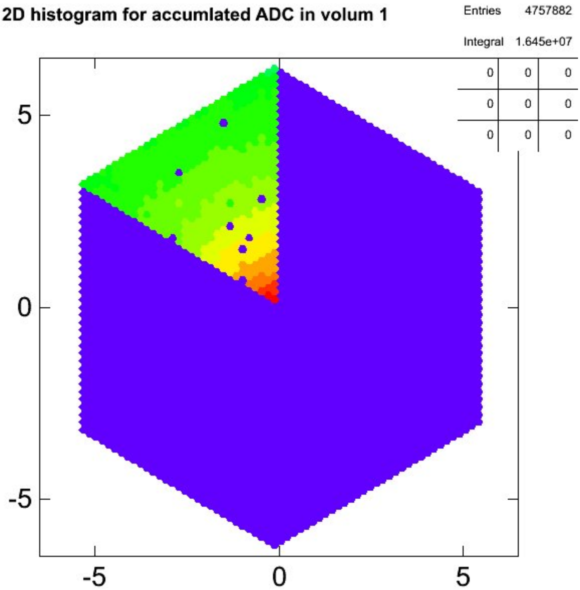
TO DO

- Finish building electronics
- Cathode Readout for TOF
- Power and Clock Distribution (Rack and Bus Boards)
- Take Data!

Installation at LANSCE 90L



Pad Map



2D histogram for accumlated ADC in volum 1
Entries 4757882
Integral 1.645e+07
0 0 0
0 0 0
0 0 0
5
0
-5
-5
0
5

Conclusion

- The fission TPC is a powerful instrument that we expect will provide insight to the systematic errors of the ^{239}Pu cross section.
- We would like to partner with interested folks at any time to get feedback, share early results and discuss any aspects well before publication.

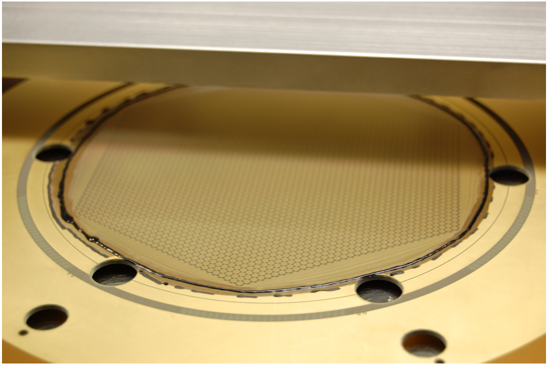
NIFFTE Collaboration

Lawrence Livermore National Lab.• Los Alamos National Lab.• Idaho National Lab.• Pacific Northwest Lab.• Idaho State Univ.• Abilene Christian Univ.• Oregon State Univ.• California Polytechnic State Univ.• Colorado School of Mines• Ohio Univ.

Extra Slides

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

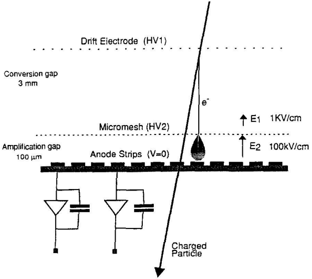
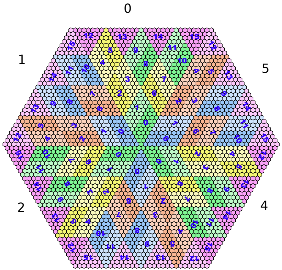
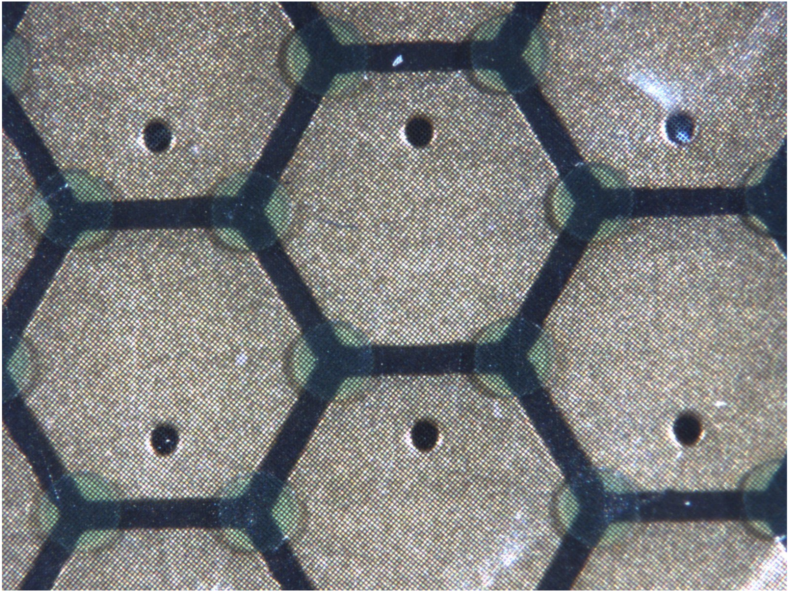


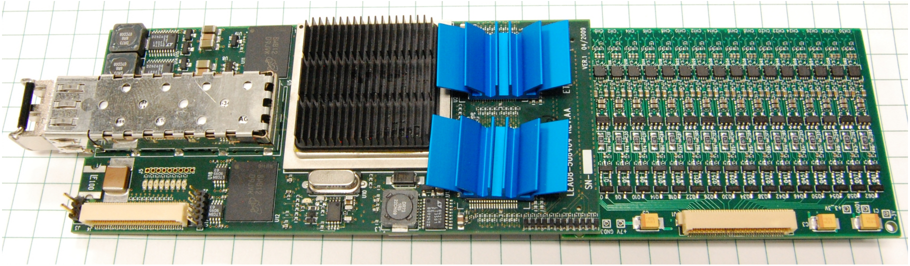
Fig. 1. A schematic view of MICROMEGAS: the 3 mm conversion gap and the amplification gap separated by the micromesh and the anode strip electrode.



1000lpi Electroform Mesh, only 3μm Thick

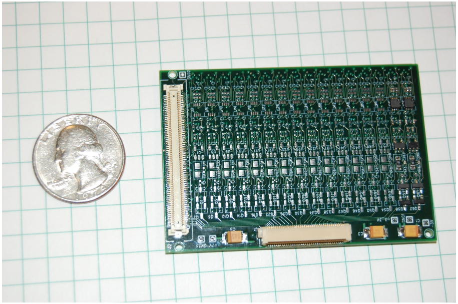


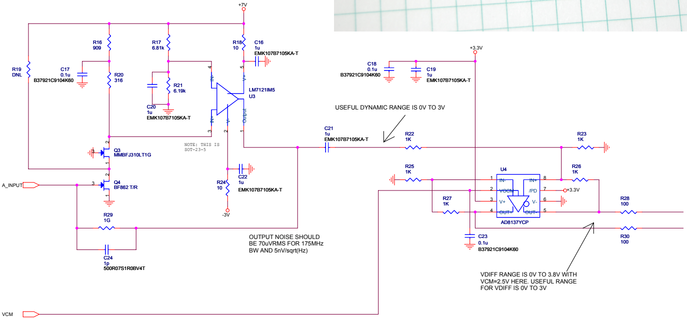
Electronics



Electronics – Preamp

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



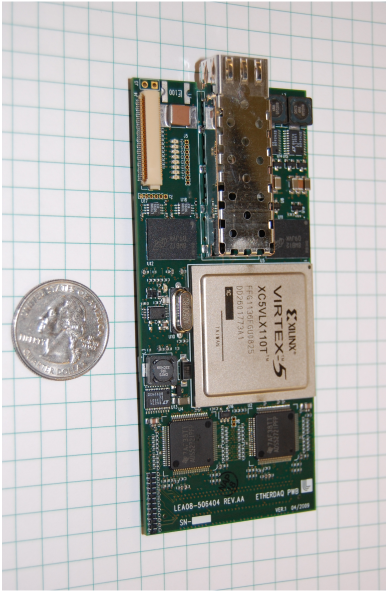


Electronics – Digital (EtherDAQ)

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

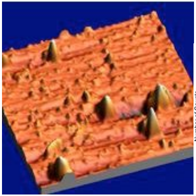
Components:

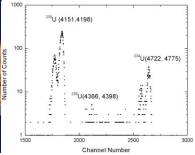
- ADC - Texas Instruments ADS5272 65MS/s 12bit
- FPGA - Xilinx Virtex 5 110T with Ethernet MAC built in
- Memory - 128MB (2x64MB) micron sdram
- Ethernet - Intel TXN31111 SFP 850nm optical GBit module

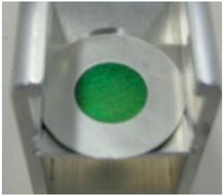


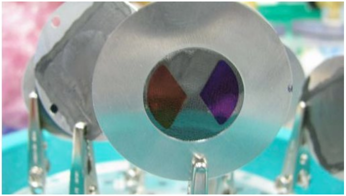
Target

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



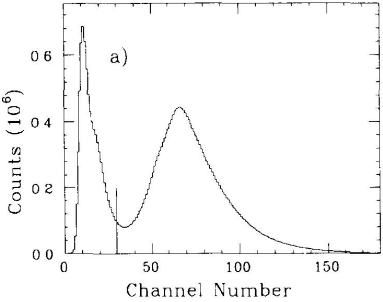




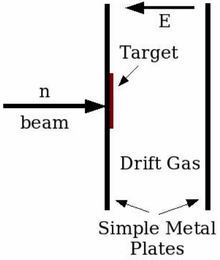


The Fission Chamber

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



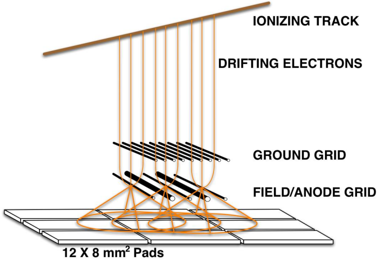
Example of a Fission Chamber



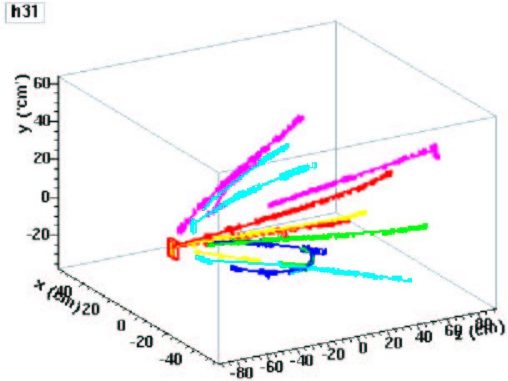
The Time Projection Chamber

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



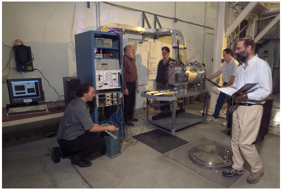
Example of TPC Data



The Time Projection Chamber

NP TPC Examples

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



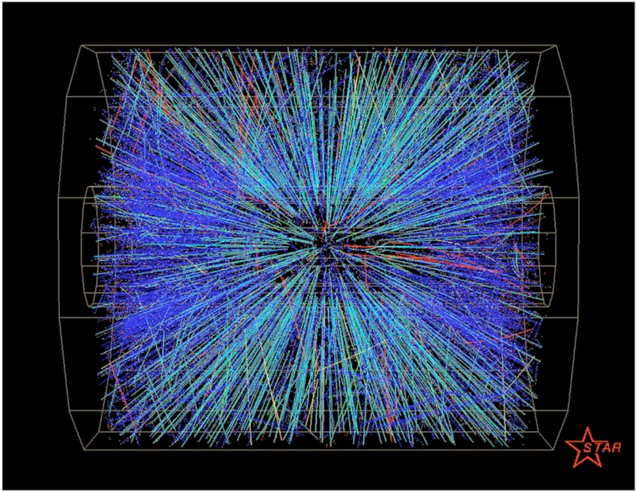
Beyond Precision Cross Sections (with fissionTPC)

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

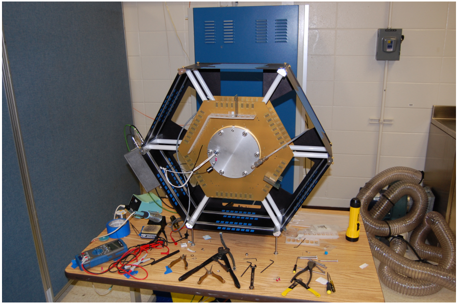
Rate is not a Problem

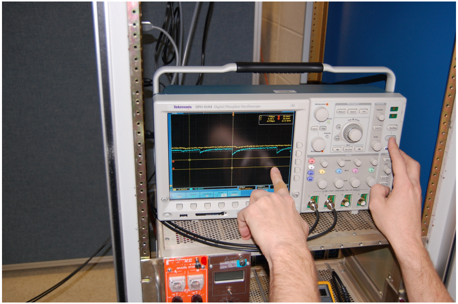
- fissionTPC sweep rate approximately 0.25MHz

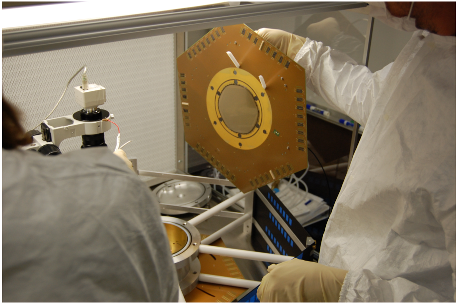
Example from STAR TPC

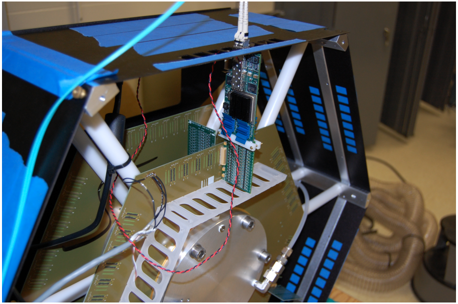


The Prototype TPC





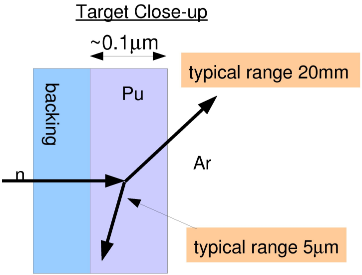




Fission Chamber vs. the TPC

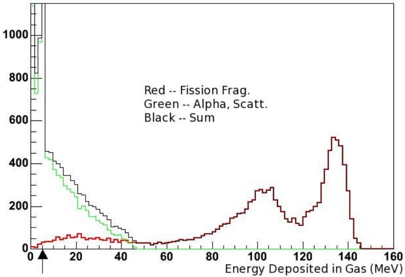
Systematic Errors

- 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

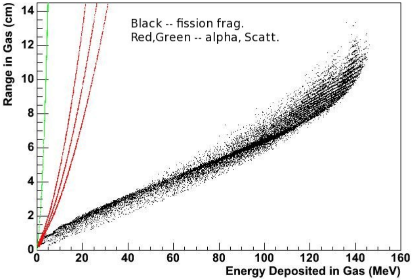


Example Simulation of How the TPC Outperforms a Fission Chamber: Particle Identification

Fission Chamber



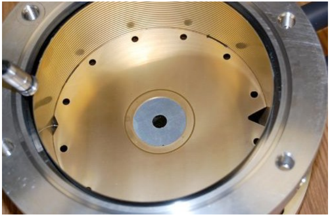
TPC



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

Field Cage, Pressure Vessel, and Drift Gas

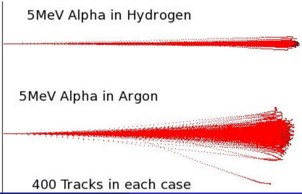
Field Cage in pressure vessel



- 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)



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.