The University of New Mexico Fission Fragment Spectrometer

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Part of the LANL SPIDER collaboration

FIESTA Workshop
Santa Fe, NM
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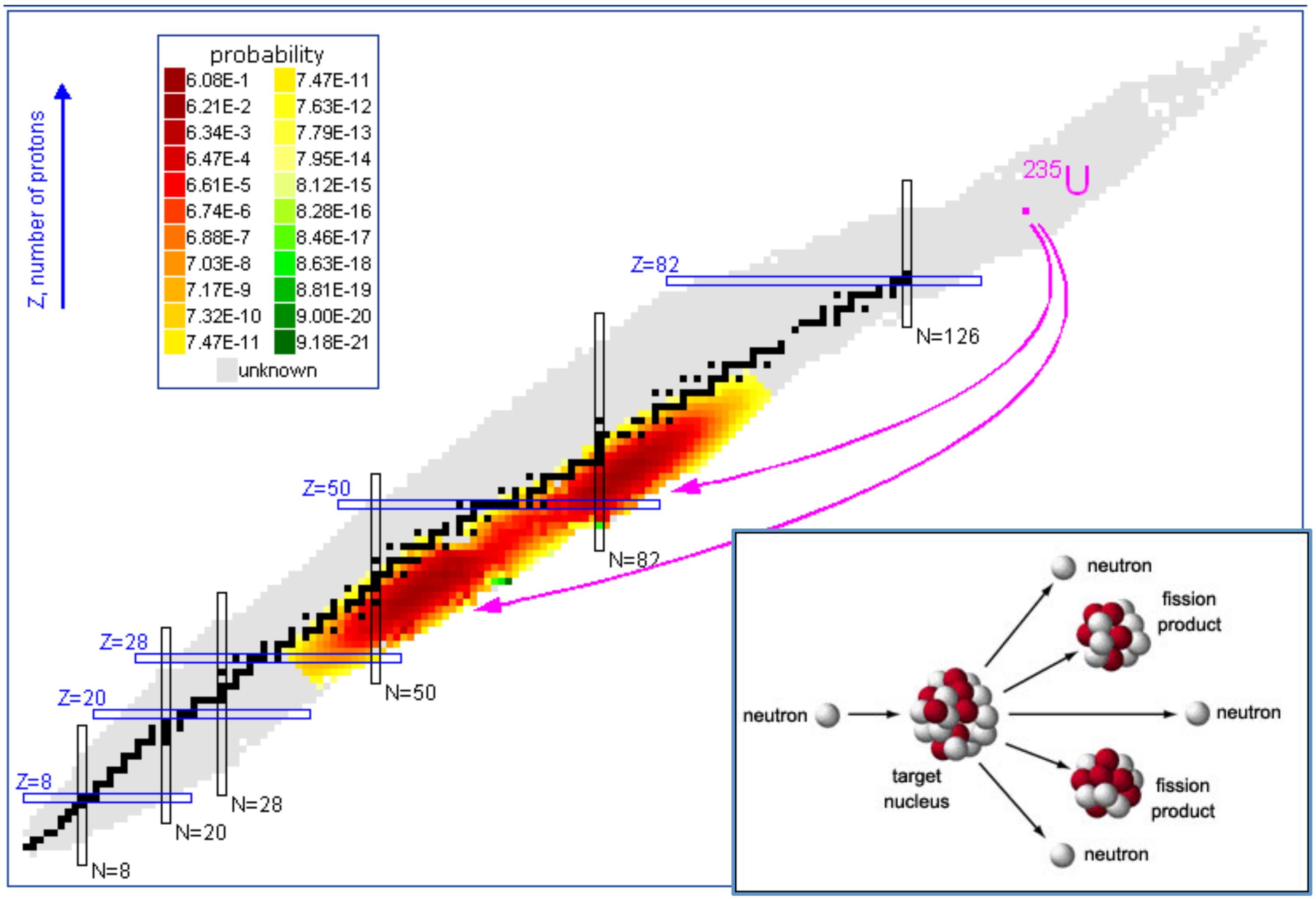
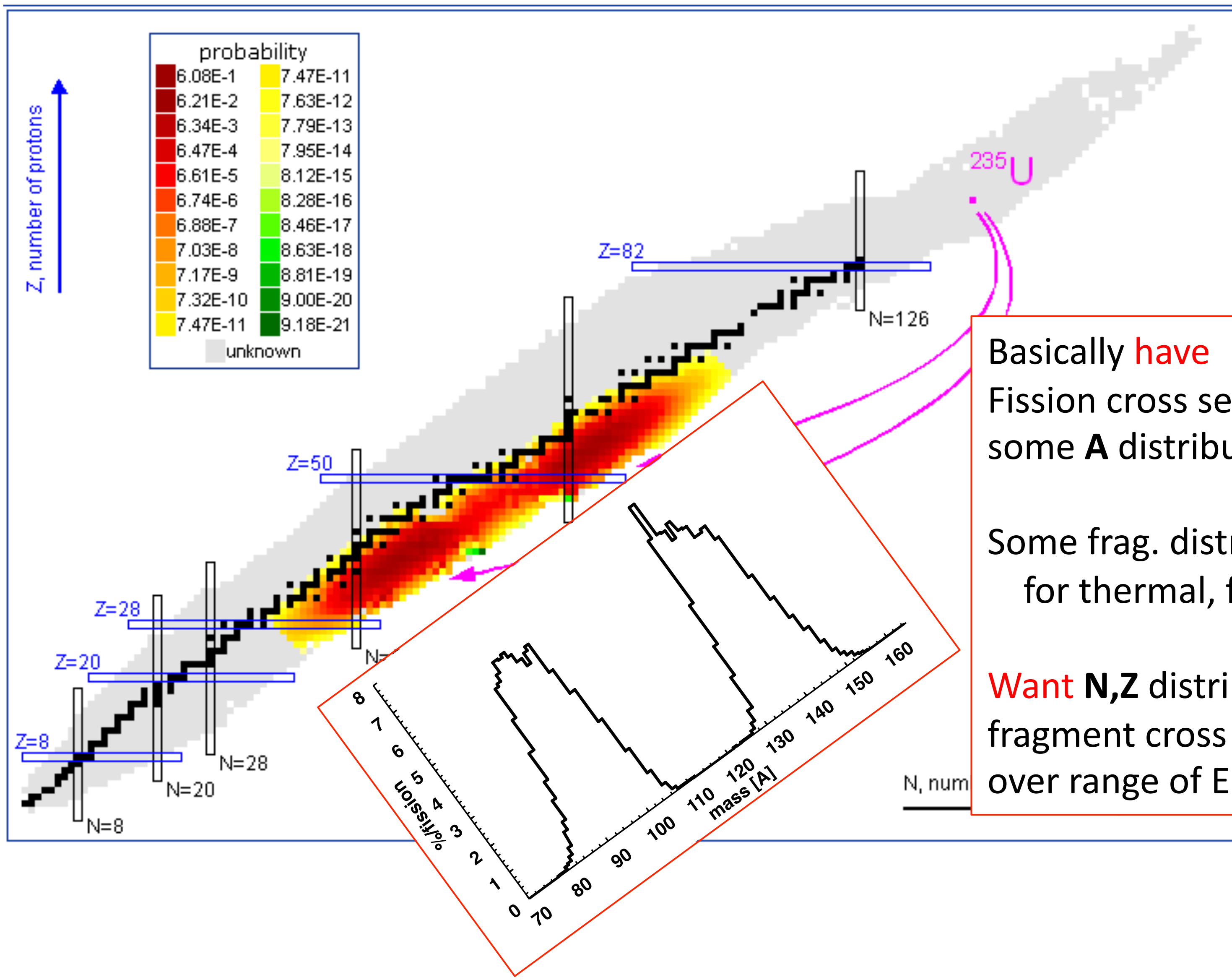
UNM Fission Fragment Spectrometer

- Motivation for fission fragment data
- Method
- Hardware
- Characterization and preliminary results
- Next steps
- Summary

The desired data to understand fission, delayed radiation



The desired data to understand fission, delayed radiation

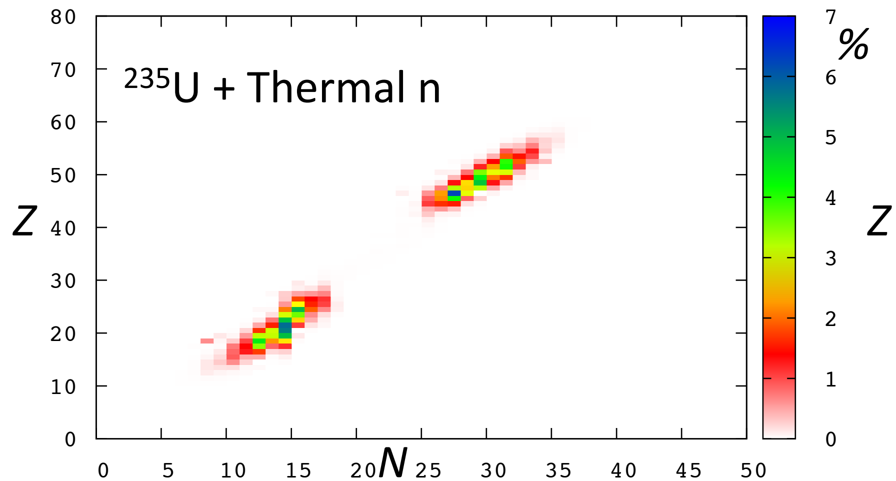


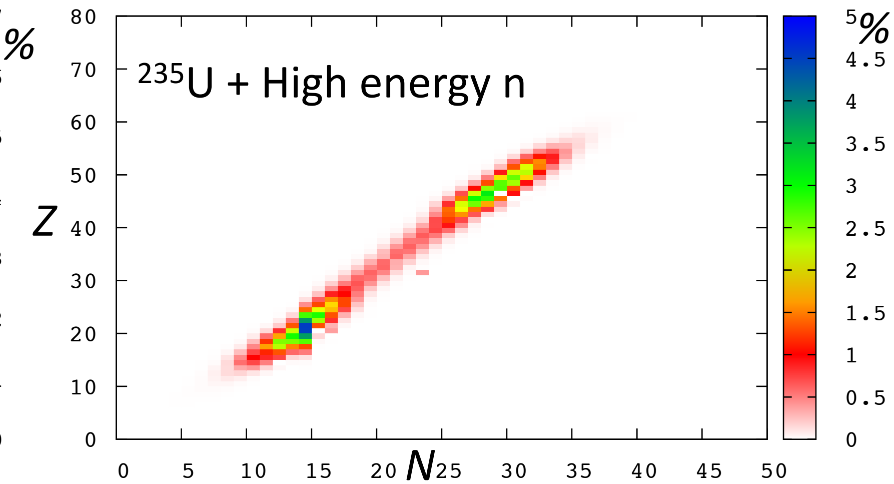
Basically have
Fission cross section
some **A** distributions

Some frag. distributions N,Z
for thermal, fast, 14 MeV n

Want **N,Z** distributions,
fragment cross sections,
over range of En

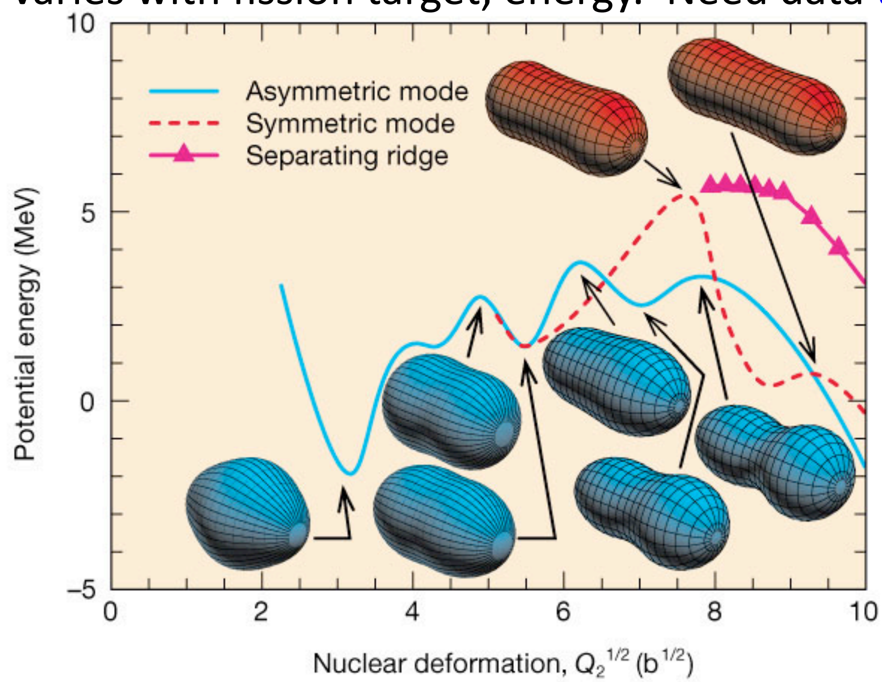
Motivation – fission theory

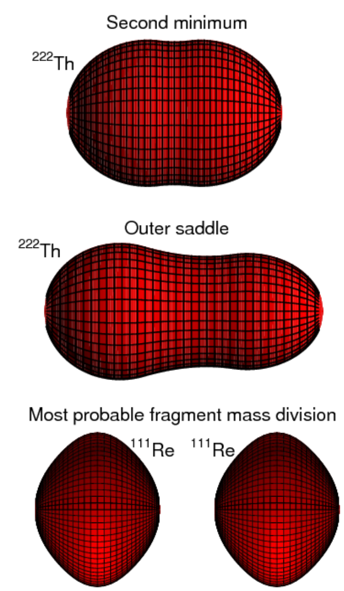




^{235}U numbers from England and Rider via http://ie.lbl.gov/fission.html

Yield varies with fission target, energy. Need data to work back to fission preformation states.



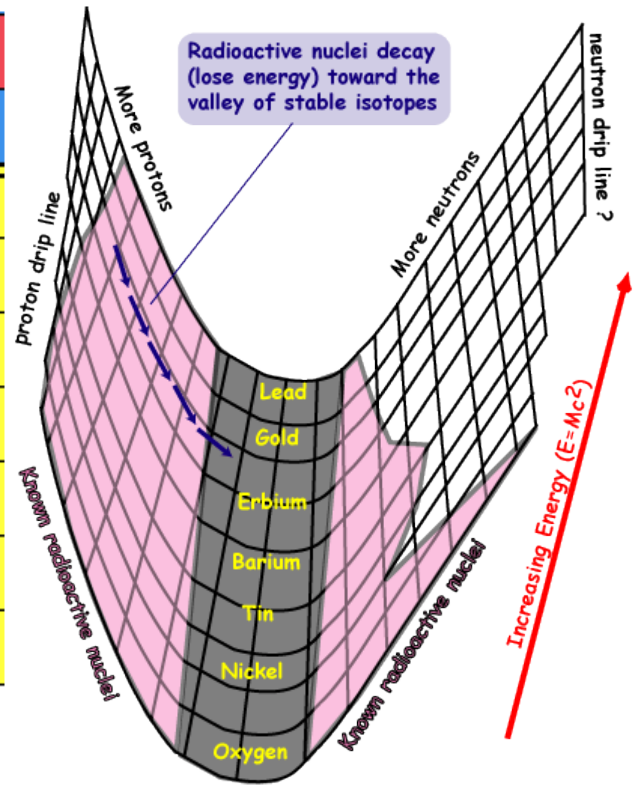


P. Möller et al., Nature 409, 785-790(15 February 2001)

Motivation – active interrogation
Delayed signal from β, $\beta(n)$ decay

Delayed radiation:
Beta decay, gamma emission, some neutron emission

43	Tc 94 4.883h	Tc 95 61d	Tc 96 4.28d	Tc 97 2.6e+06y	Tc 98 4.2e+06y	Tc 99 2.11e+05y	Tc100 15.46s	Tc101 14.2m
42	Mo 93 4000y	Mo 94 9.25	Mo 95 15.92	Mo 96 16.68	Mo 97 9.55	Mo 98 24.13	Mo 99 2.747d	Mo100 9.63
41	Nb 92 3.47e+07y	Nb 93 100	Nb 94 2.03e+04y	Nb 95 34.99d	Nb 96 23.35h	Nb 97 1.202h	Nb 98 51.3m	Nb 99 2.6m
40	Zr 91 11.22	Zr 92 17.15	Zr 93 1.53e+06y	Zr 94 17.38	Zr 95 64.03d	Zr 96 2.8	Zr 97 16.74h	Zr 98 30.7s
39	Y 90 2.667d	Y 91 58.51d	Y 92 3.54h	Y 93 10.18h	Y 94 18.7m	Y 95 10.3m	Y 96 9.6s	Y 97 3.75s
38	Sr 89 50.53d	Sr 90 28.79y	Sr 91 9.63h	Sr 92 2.71h	Sr 93 7.423m	Sr 94 1.255m	Sr 95 23.9s	Sr 96 1.07s
37	Rb 88 17.77m	Rb 89 15.15m	Rb 90 4.3m	Rb 91 58.4s	Rb 92 4.492s	Rb 93 5.84s	Rb 94 2.702s	Rb 95 0.3775s
36	Kr 87 1.272h	Kr 88 2.84h	Kr 89 3.15m	Kr 90 32.32s	Kr 91 8.57s	Kr 92 1.84s	Kr 93 1.286s	Kr 94 0.2s
35	Br 86 55s	Br 87 55.6s	Br 88 16.5s	Br 89 4.4s	Br 90 1.92s	Br 91 0.541s	Br 92 0.343s	Br 93 0.102s



Br91 (0.5s) –> Kr91 (8.6s) –> Rb91 (58s) –> Sr91 (9hr) –> Y91…

http://wwwndc.jaea.go.jp/CN10/CN010.html

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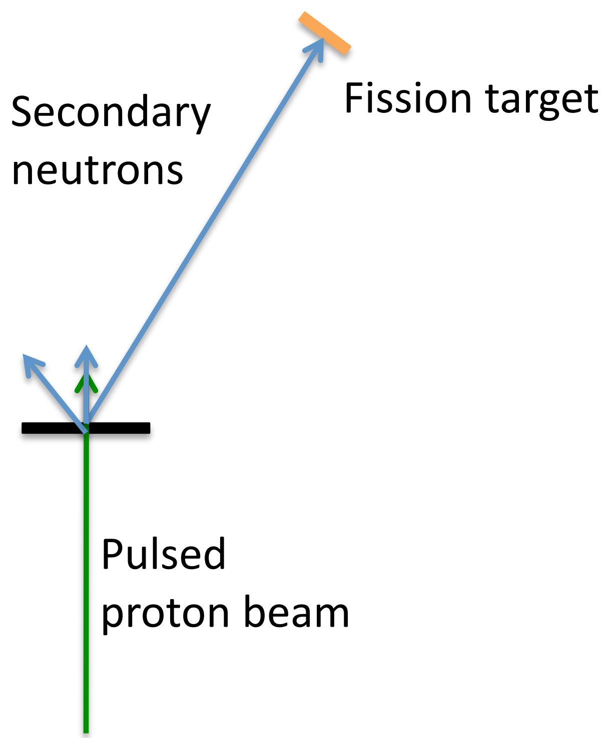
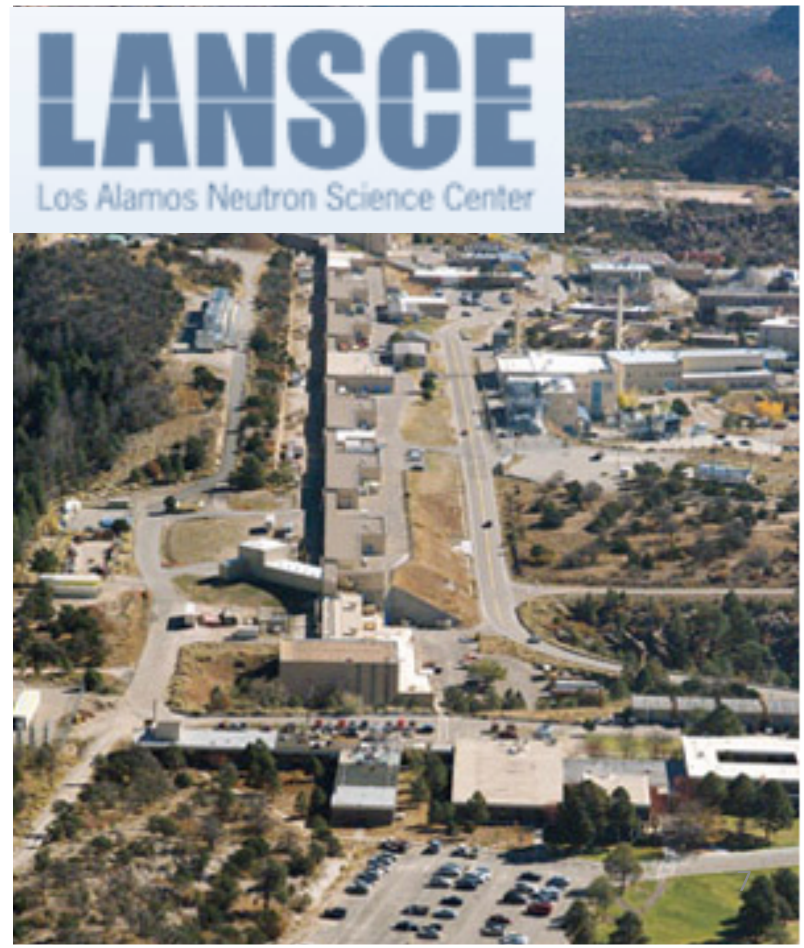
The plan: Measure fission fragments vs. N energy, event by event
Pulsed P beam on N convertor
N on fission target

Neutron Time Of Flight to fission target gives En





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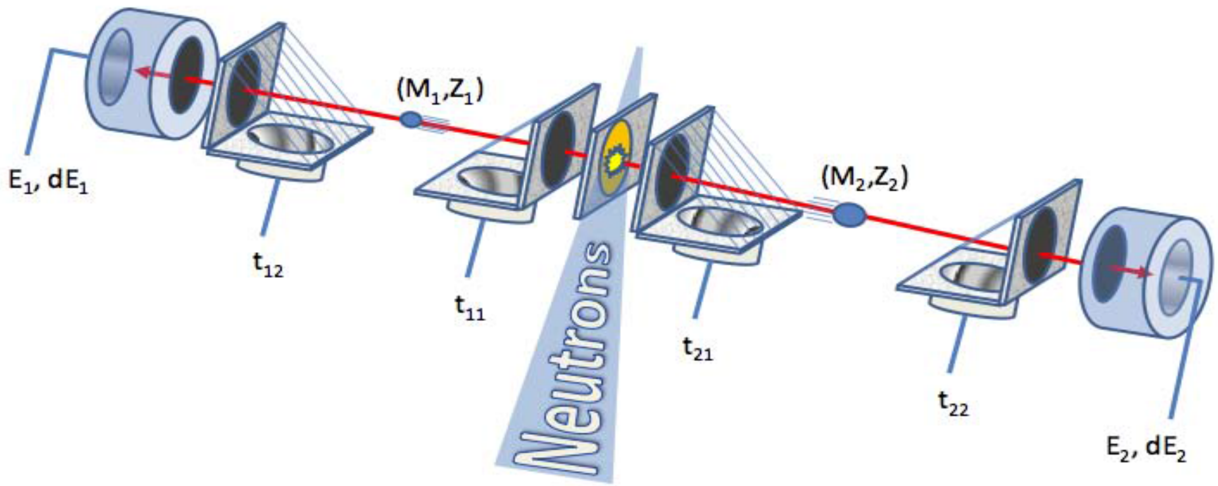
Method, E-v spectrometer



TOF followed by Ionization Chamber: TOF-IC

A, Z, E measurements

v: TOF

E: Ionization chamber

A: $m = \frac{2E}{v^2} = \frac{2Et^2}{l^2}$ $\quad\quad \frac{\delta m}{m} = \sqrt{\left(\frac{\delta E}{E}\right)^2 + \left(2\frac{\delta t}{t}\right)^2 + \left(2\frac{\delta l}{l}\right)^2}$

Z: Ionization chamber rewiring and analysis, will describe

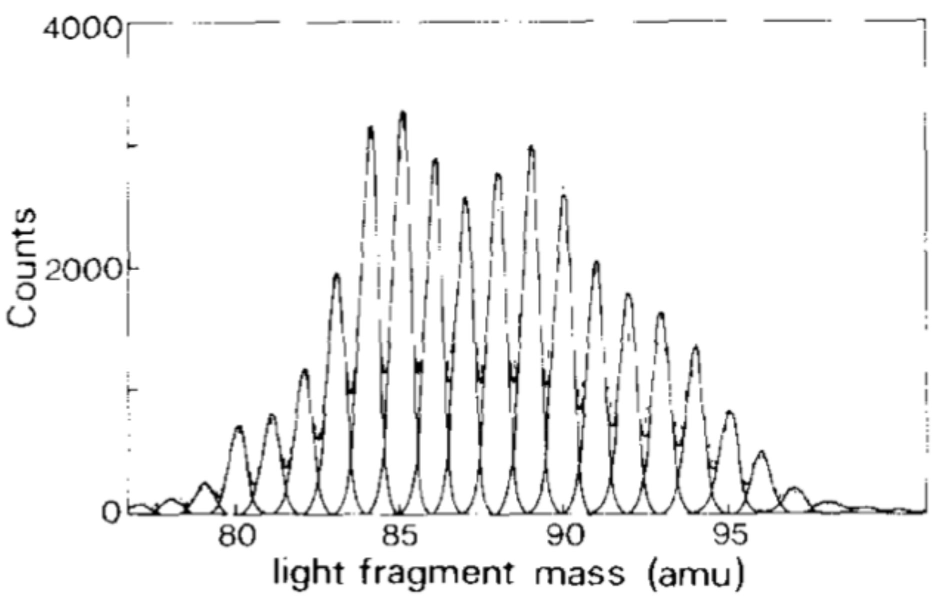
N: A and Z → N

Moving towards dual arm for UNM Fission Fragment Spectrometer: get TKE, ν

Mass Resolution Requirements

$$m = \frac{2E}{v^2} = \frac{2Et^2}{l^2}$$

$$\frac{\delta m}{m} = \sqrt{\left(\frac{\delta E}{E}\right)^2 + \left(2\frac{\delta t}{t}\right)^2 + \left(2\frac{\delta l}{l}\right)^2}$$



A separation from Cosi Fan Tutte spectrometer

Boucheneb et al., Nuc. Phys. A502, 261c (1989).

light fragments

fwhm/centroid = 1/90 = 1.1%

PUSHING TO heavy fragments

fwhm/centroid = 1/140 = 0.7%

Interplay of variables

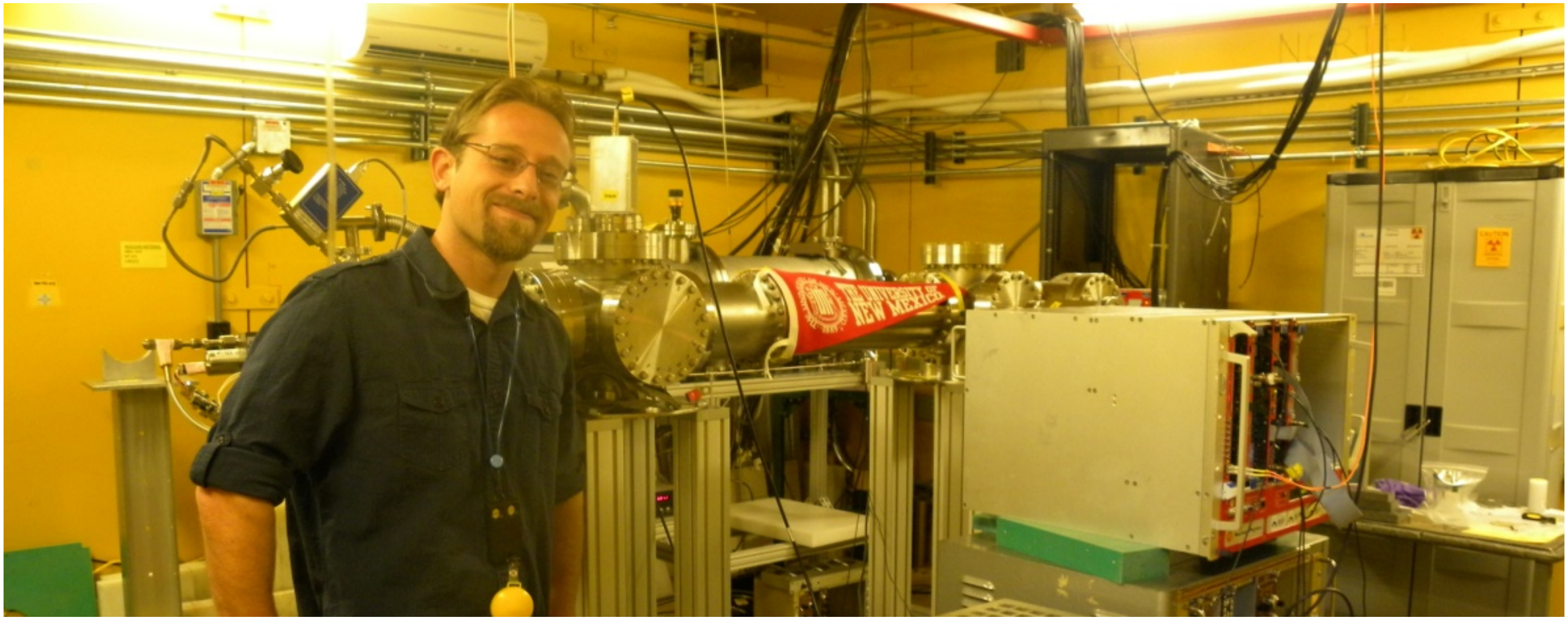
L good, for 1 m need < 7mm

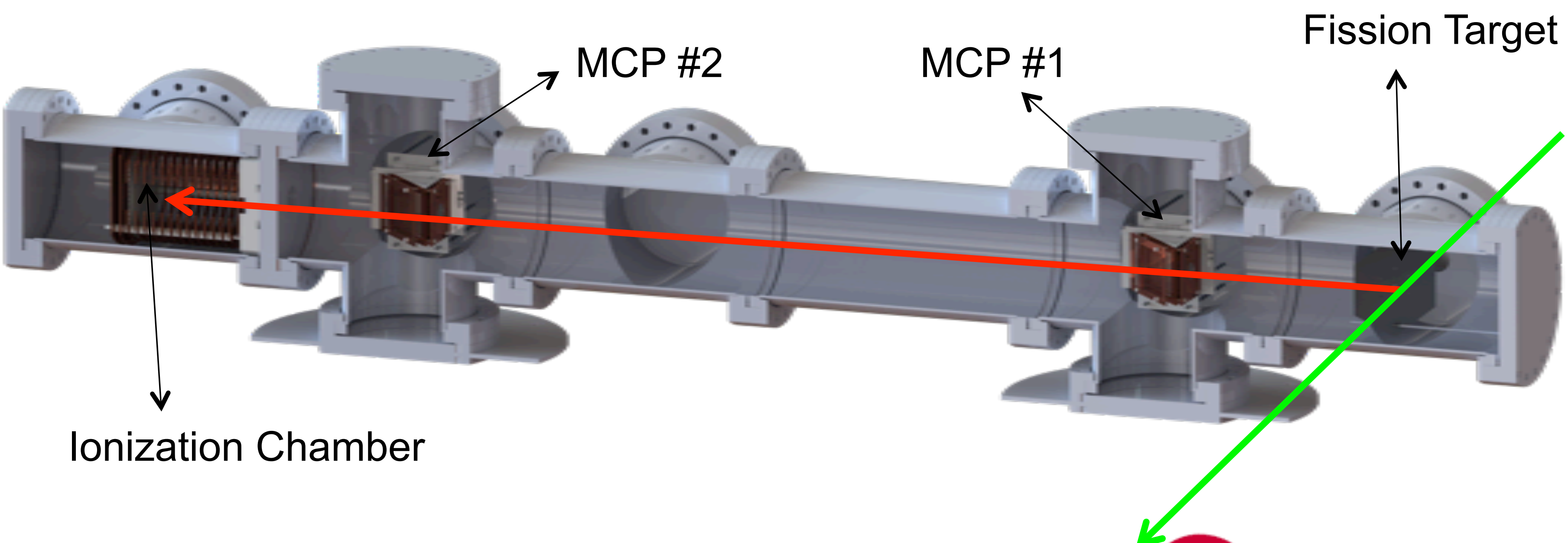
really depends on E and t

absolute max

need $\delta E/E < 0.7\%$

need $\delta t/t < 0.35\%$





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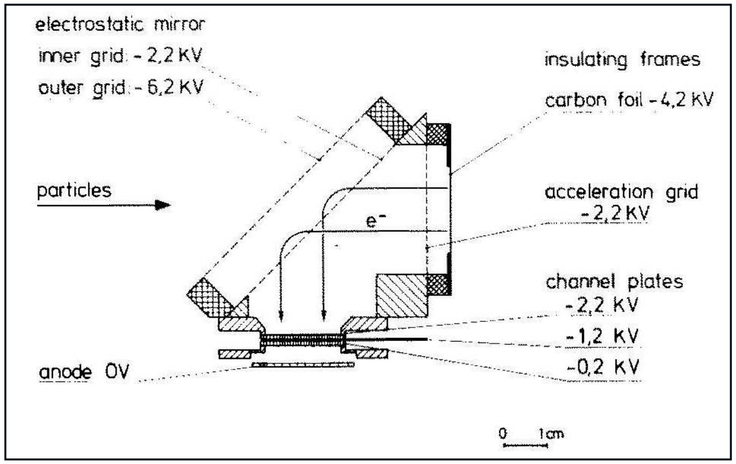
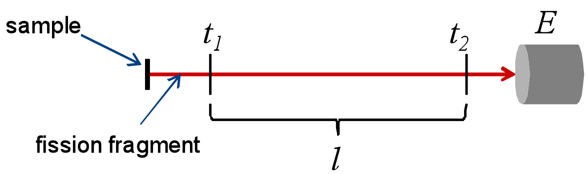
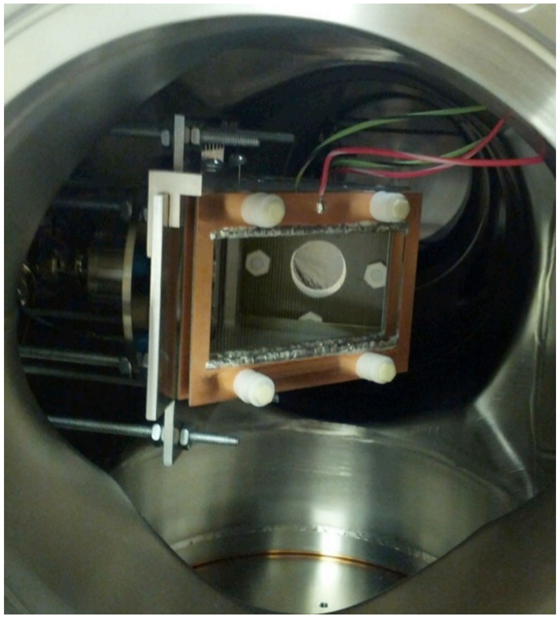
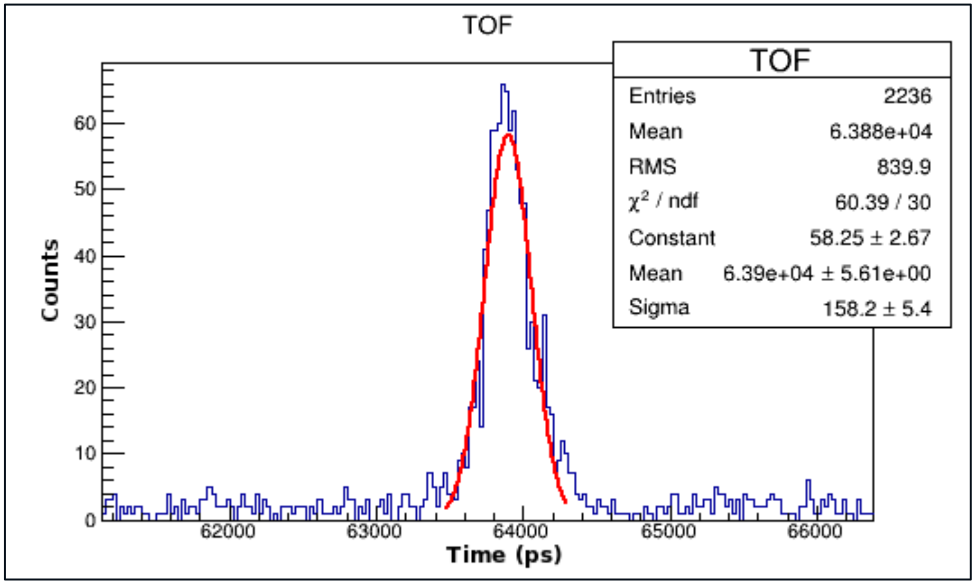
Overview of Instrumentation
Time-of-Flight









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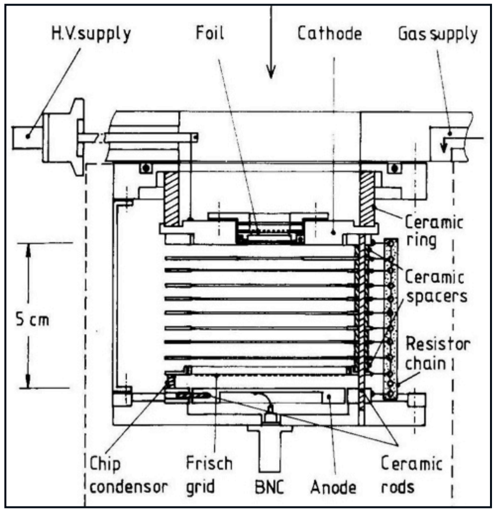
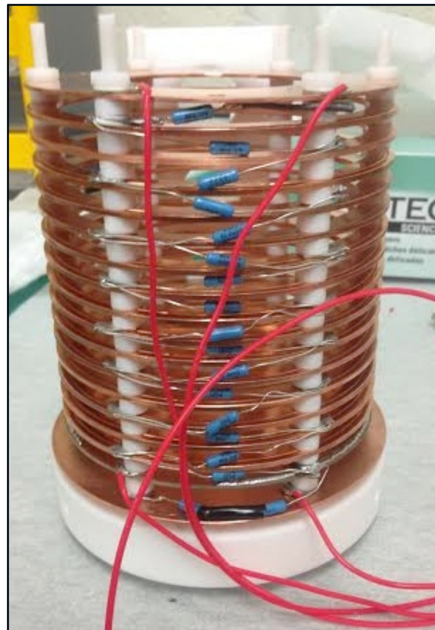
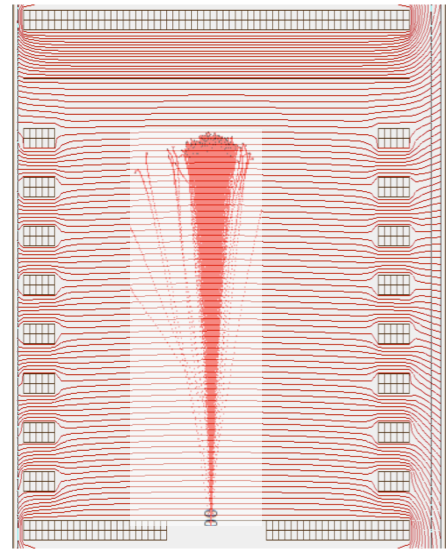
Overview of Instrumentation
Ionization Chamber

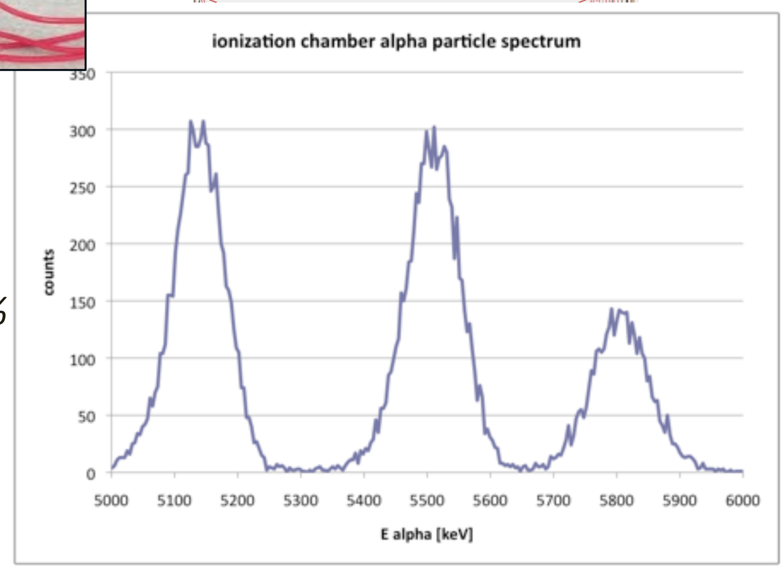


Designs following Oed et al.
NIM 205 (1983) 455-459





Pu, Am, Cm alpha source
<1.5% resolution, ff expect <0.4% fwhm/centroid



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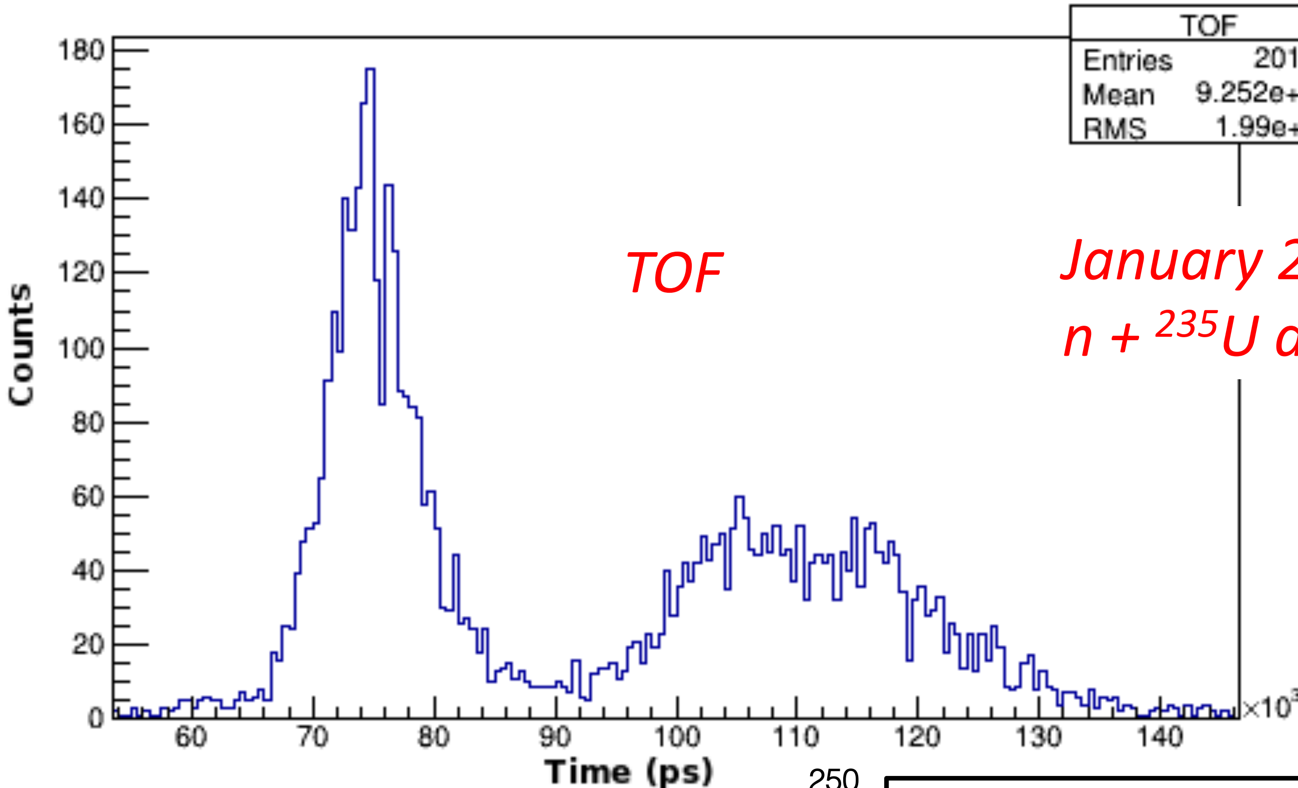
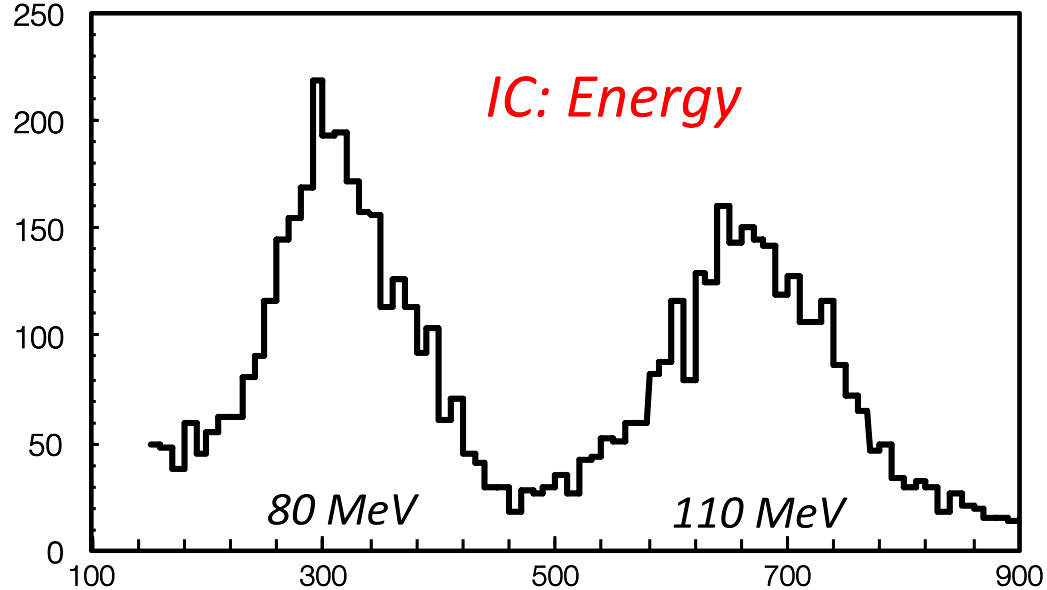
January 2014 results from $n + {}^{235}U$ at LANSCE





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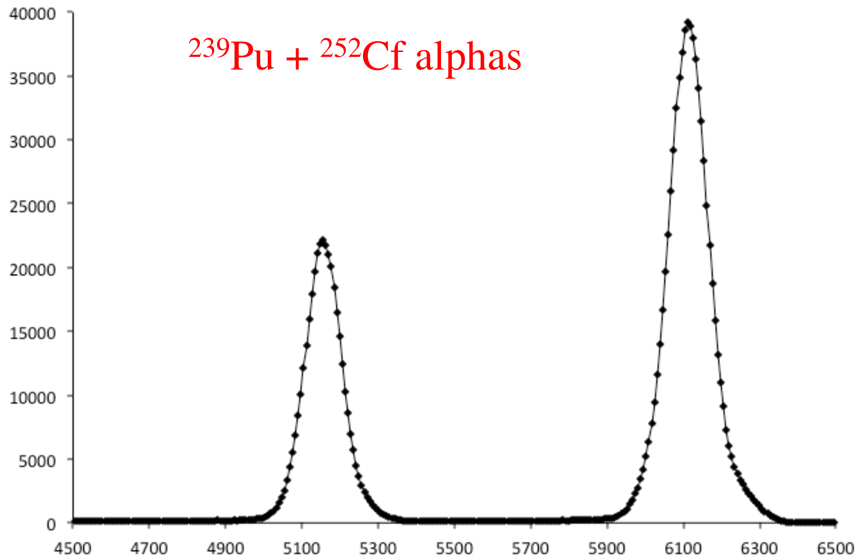
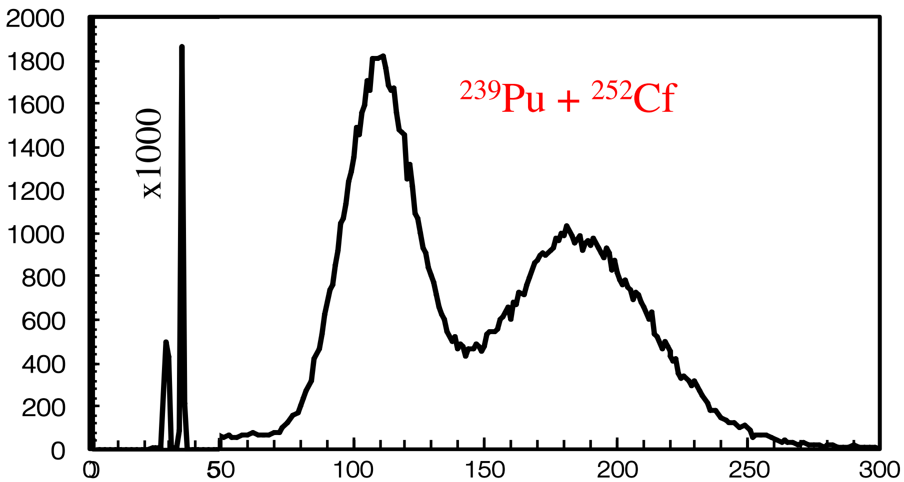
Recent Characterization Results
Ionization Chamber



IC data overnight,
low drift, < 2% E resolution alphas



IC: fragment data

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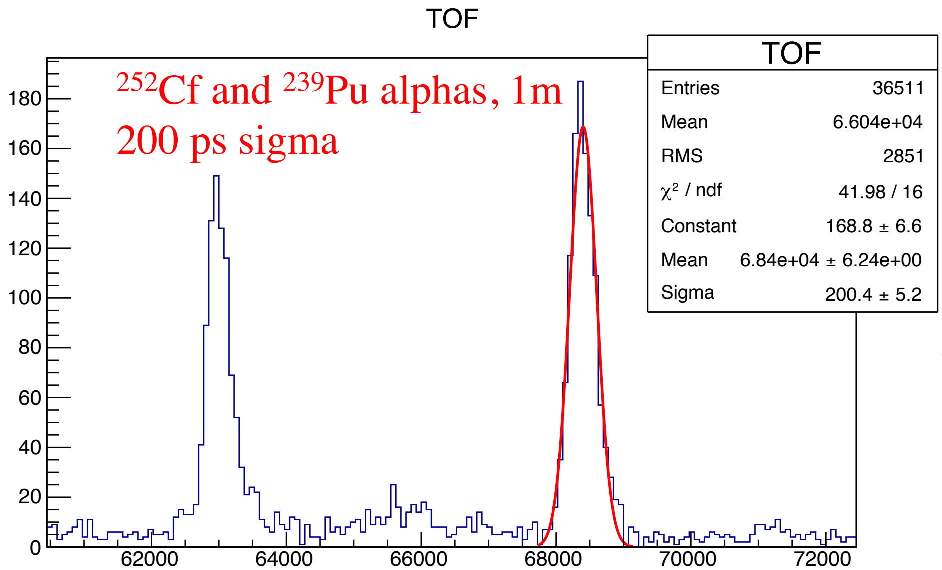
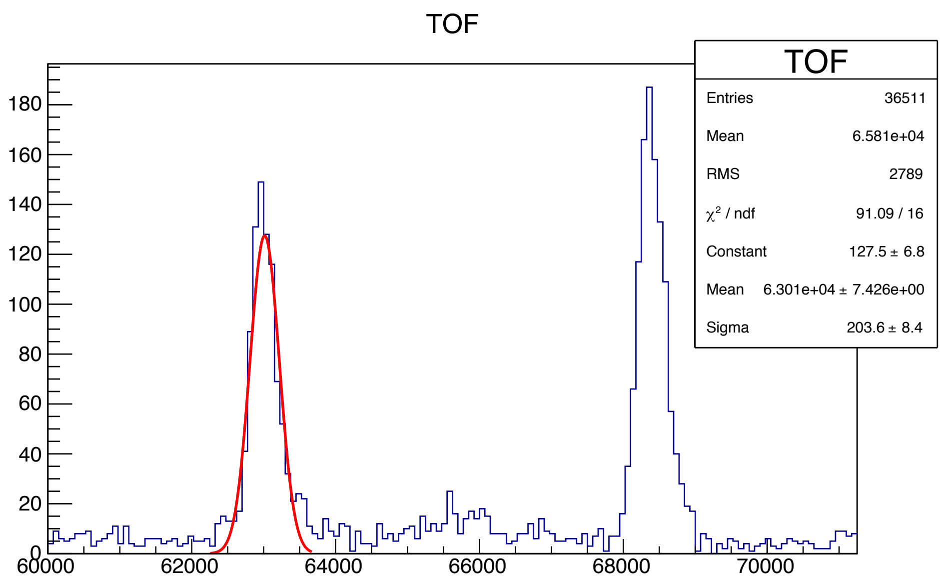
Recent Characterization Results
Time Of Flight





Alphas 63 and 68 ns, 0.7% resolution

resolution with 100 μg/cm² C foils

Changing to 20 ug C foils, lower straggling

especially for fragments - higher Z

→ improve TOF resolution

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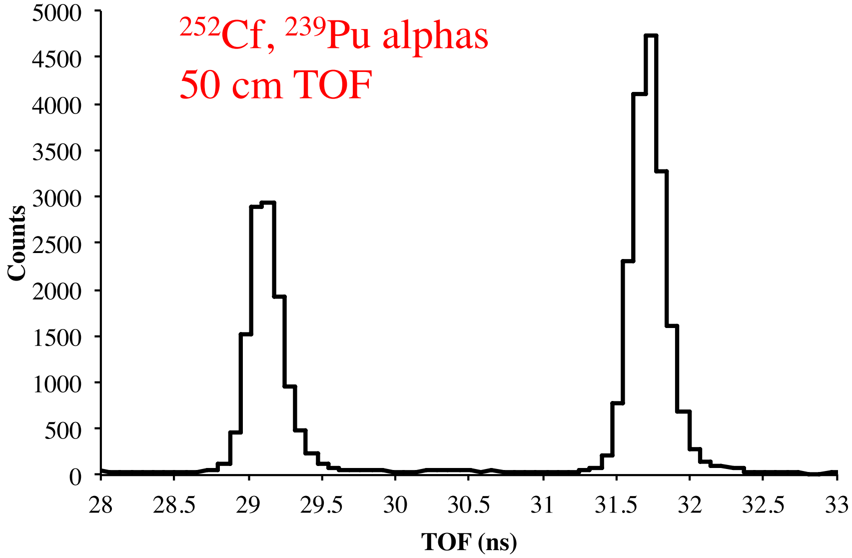
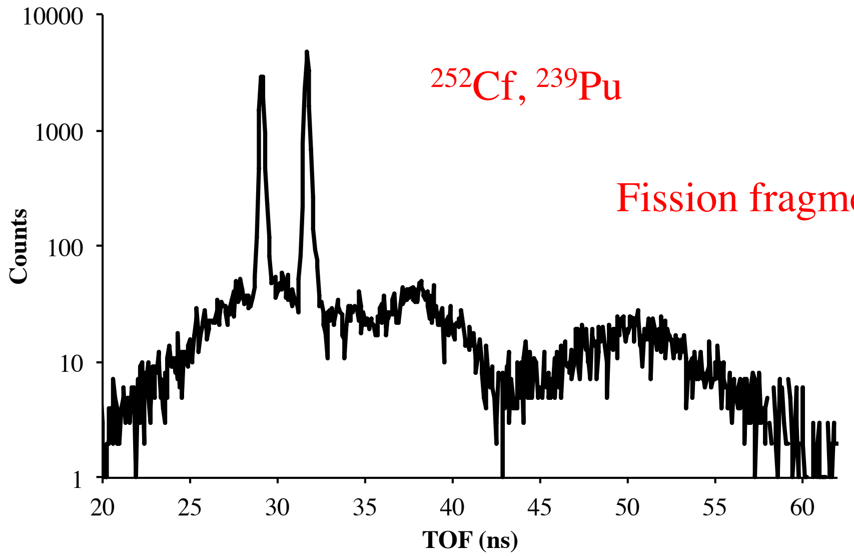
Recent Characterization Results
Time Of Flight





Fission fragments from Cf (50 cm TOF)

Next Steps

- Correlated TOF/KE data → extract mass distribution
- Improve Resolution:
  - Thinner TOF foils → less t straggling
    - from 100 to 20 ug C foils
  - Thinner IC window → less E straggling
    - switched to 1.5 um mylar (from 2.5)
    - will change to 0.2 μm SiN
- Z information from Ionization Chamber
  will have A,Z,N, KE
- Dual arm: direct measurement of TKE, ν

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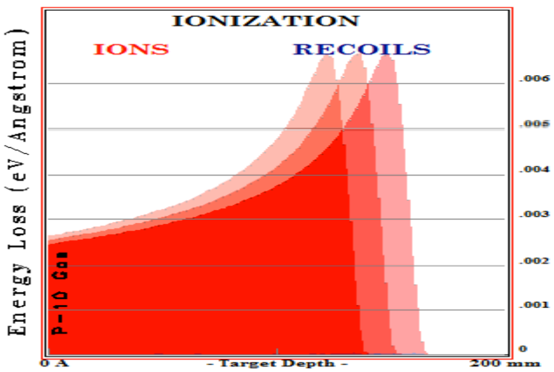
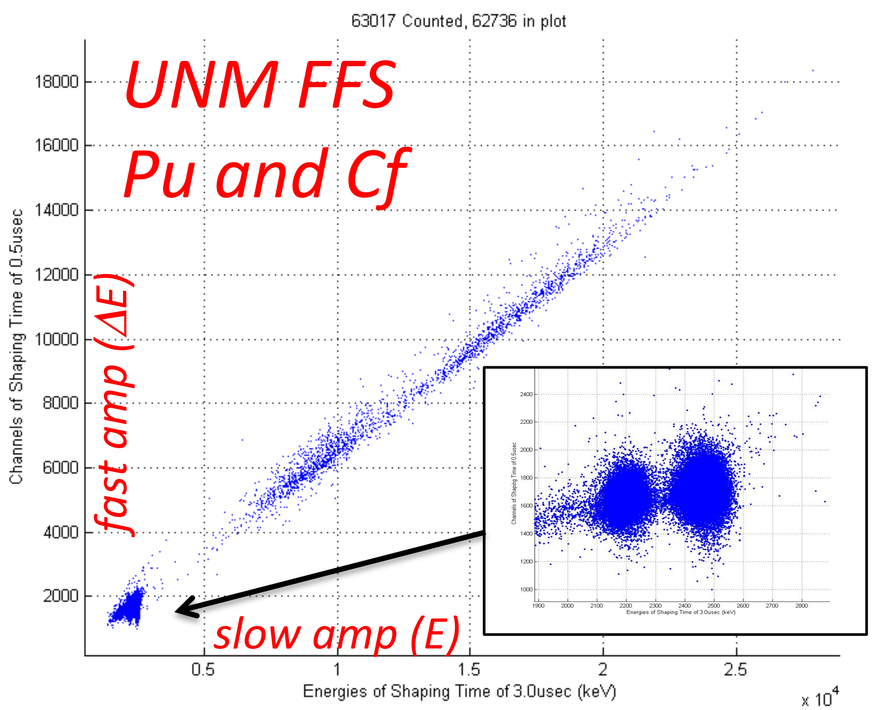
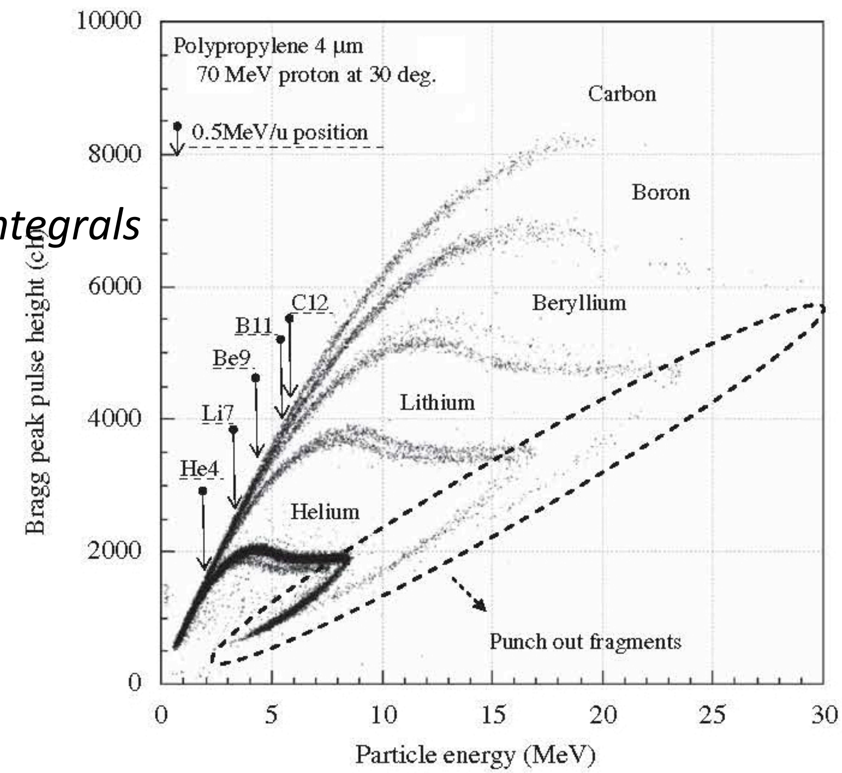
Z determination - Bragg curve analysis (> 1MeV/amu, light fragments)



Bragg curves in P-10 gas
tri-nuclide α source
similar peaks, different integrals
(fast vs. slow amps)





T. Sanami et al. NIM A 589 (2008) 193-201

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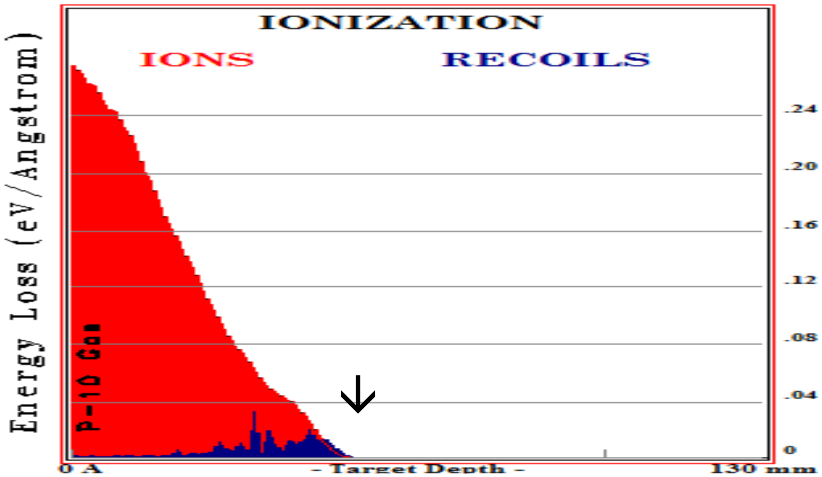
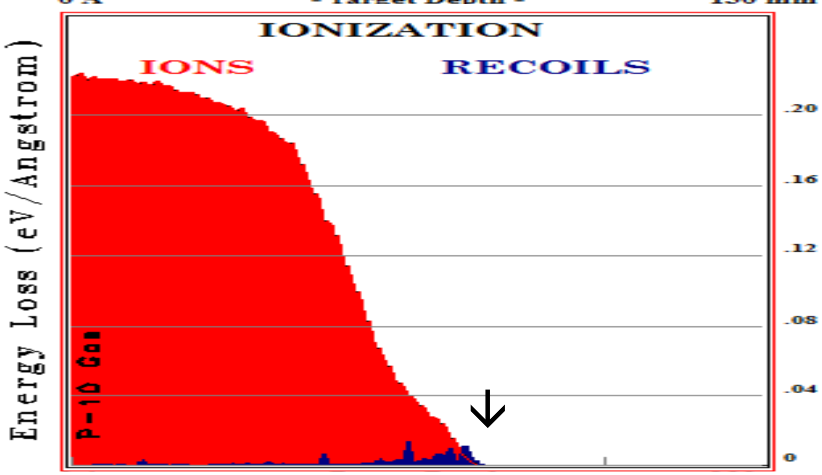
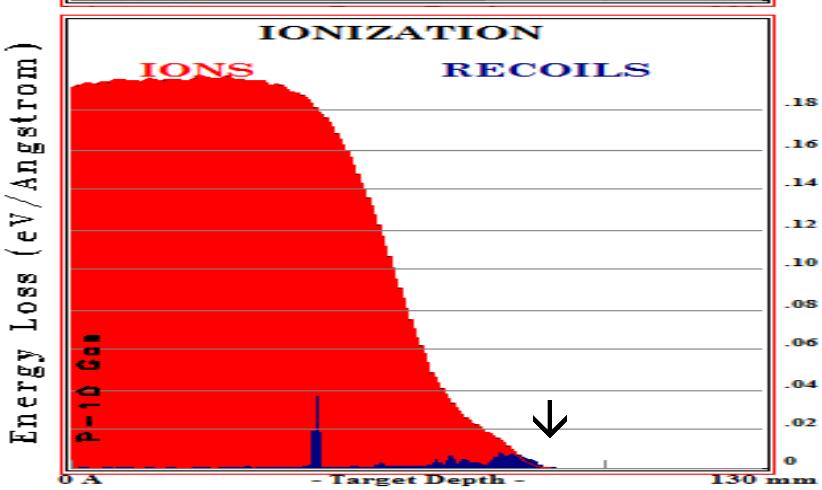
Range follows Bethe formula
Z, v (thus E, m) dependent
SRIM calc. fission fragments (300 torr P-10)



^{140}Xe, 70 MeV



^{90}Sr, 115 MeV



^{80}Ge, 121 MeV

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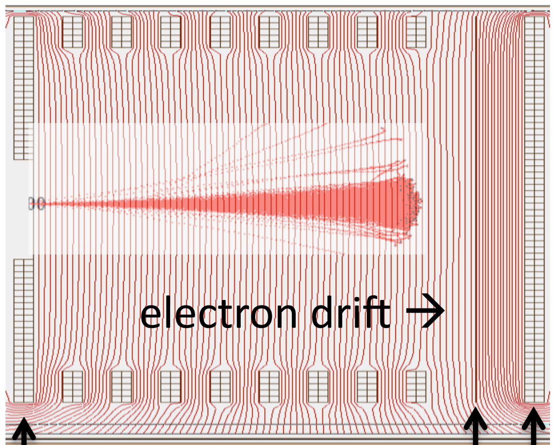
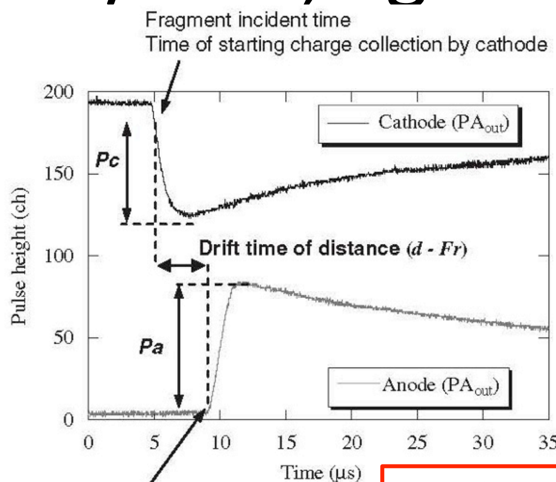
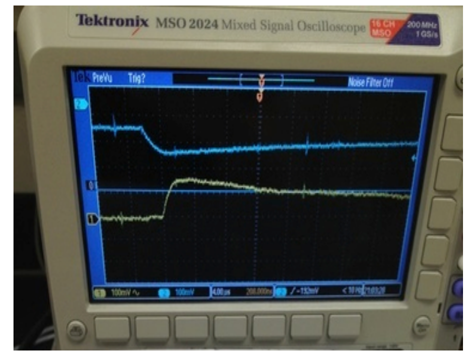
Z determination - Active Cathode (> 0.5 MeV/amu, light and heavy)

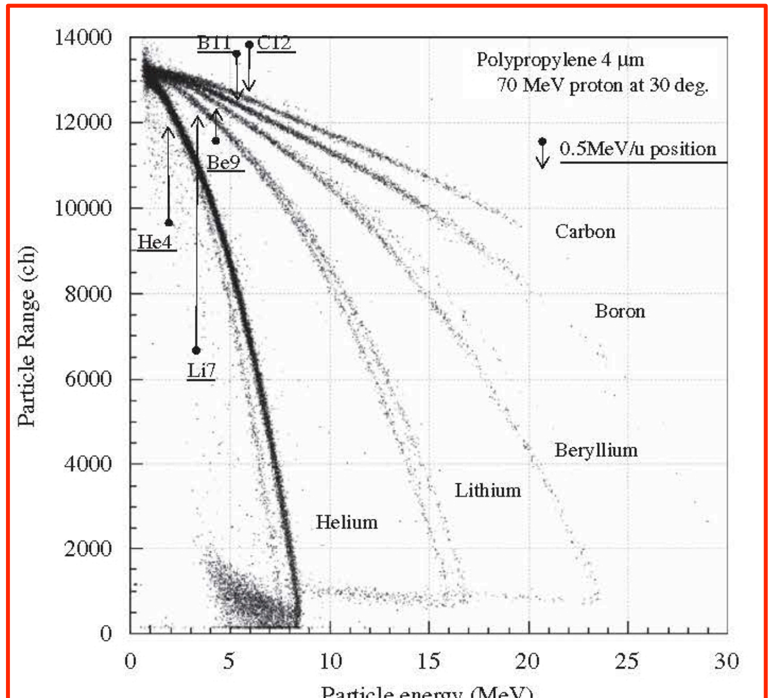






Range is Z dependent

Measure range from
Cathode time vs. anode time
using e drift velocity



T. Sanami et al. NIM A 589 (2008) 193-201

Range Z dependent

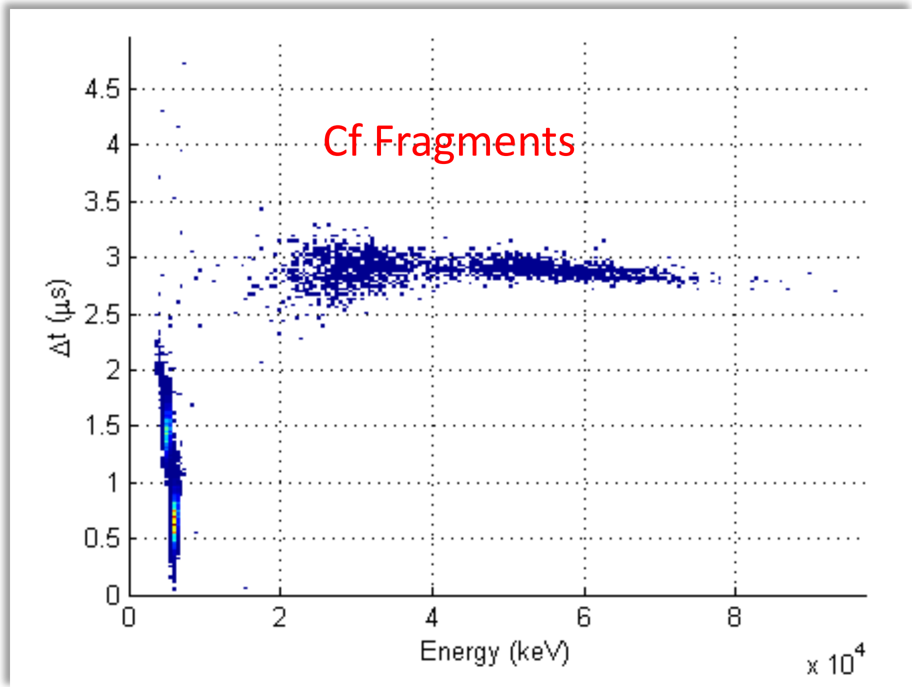
Measure range from

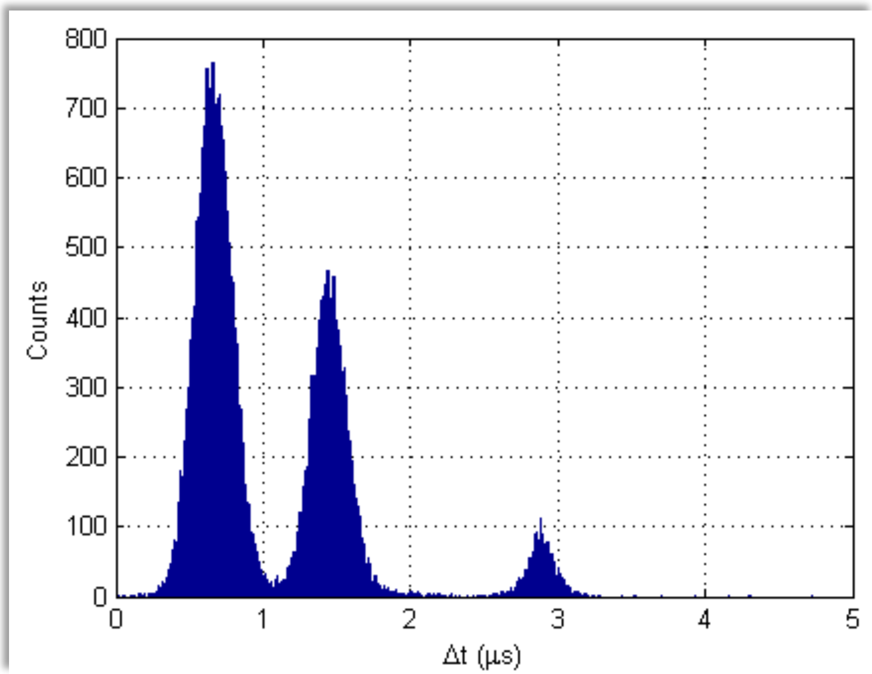
Cathode time vs. anode time using e drift velocity

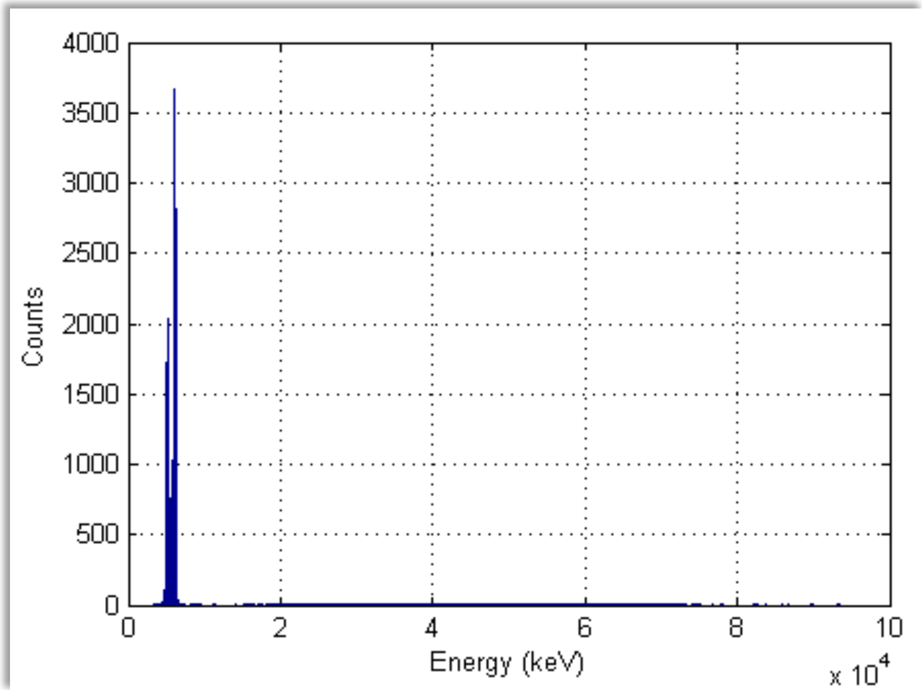
UNM FFS:

Δt vs. E Plotted, Cf and Pu

preliminary







Summary

- Prototyped Fission Fragment Spectrometer
  - TOF
  - Ionization Chamber
  - Tested with Cf at UNM, n+^{235}U at LANSCE
- Correlating TOF and KE for mass spectra
- Improving resolution
- Ionization Chamber tests for Z determination
  - Bragg spectroscopy
  - Active Cathode
- Implementing Z determination in full TOF/IC spectrometer

Thank you

Graduate students
- Rick Blakeley - TOF
- Lena Heffern - IC
- James Cole - IC
- Graduated MS student Drew Mader - IC

Undergraduate students
- Paul Gilbreath
- Corey Vowell

SPIDER collaboration

NEUP grant DE-NE0000732

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