A Time Projection Chamber for precision ²³⁹Pu(n,f) cross section measurement



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Compound-Nuclear Reactions Workshop 25th October 2007

Why measure ²³⁹Pu(n,f)

- Current errors on ²³⁹Pu(n,f) are at least 2-3% (below 14MeV) and not completely understood
- Better measurements of ²³⁹Pu(n,f) supports:
 - The Stockpile Stewardship program
 - GNEP/AFCI has needs for better cross sections measurements, including ²³⁹Pu(n,f)
- The TPC is a powerful instrument that has not been applied to this problem



Current ²³⁹Pu(n,f) measurements



Fig. 3. Ratio of neutron-induced fission cross sections for ²³⁹Pu/²³⁵U 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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Systematic differences of 10-20% are not unusual



| Table 38 | | | | | | | |
|------------|------------|----------|-------|---------|-----|---------|--|
| Results of | the target | accuracy | study | for the | LFR | reactor | |

| Isonope | Cross- | Energy range | Uncertainty | | Isotope | Cross- | Energy range | Cocert | laiwty | Isotope | Cross- | Energy cange | Uncertainty | |
|---------|----------|------------------|-------------|----------|-------------|---------|------------------|---------|--------------------|----------------|----------------|------------------|-------------|---------|
| | section | | Initial | Required | | section | | Initial | Required | Required | | | Initial | Require |
| U-238 | Page | 1.35 MeV-498 keV | 5 | 2.9 | Po-240 | (Cape | 1.35 MeV-498 keV | 20 | 8.4 | Zr-90 | 64 | 498-183 keV | 20 | .9.8 |
| | 1000 | 498-183 keV | 5 | 2.4 | | 10.52 | 498-183 kgV | 29 | 5.8 | | 114.1 | 183-67.4 keV | 20 | 10.8 |
| | | 183-67.4 kzV | 5 | 2.4 | | | 183-67.4 keV | 20 | 5.4 | | | 67.4-34.8 keV | 20 | 10.3 |
| | | 67.4-34.8 keV | 5 | 2,4 | | | 67.4-24.8 keV | 20 | 5.7 | | Paul | 6.07-2.23 MeV | 20 | 8.6 |
| | | 24.8-9.12 keV | 5 | 2.7 | | | 24.8-9.32 keV | 10 | 6.8 | Pb-206 | Page | 183-67.4 keV | 20 | 9.8 |
| | e fan | 6.07-2.23 MeV | 5 | 2.6 | | Sec. | 6.07-2.23 MeV | 5 | 4.1 | | 64 | 1.35 MeV-498 keV | 20 | 6.5 |
| | | 2.23-1.35 MeV | 5 | 2.6 | | | 2.23-1.35 MeV | . 5 | 3.7 | | | 498-183 keV | 20 | 7 |
| | fast | 6.07-2.23 MeV | 15 | 3.8 | | | 1.35 MeV 498 keV | 1 5 | 2.1 | | σ_{mel} | 19.6-6.07 MeV | 40 | 15.9 |
| | | 2.23-1.35 MeV | 10 | 3.1 | | | 498-183 kzV | 5 | 4.1 | | | 6.07-2.23 MeV | 40 | 4.6 |
| | | 1.35 MeV 498 keV | 10 | 2.9 | | ¥ | 1.35 MeV-498 keV | / 2 | .1.8 | | | 2.23-1.35 MeV | 40 | 4.4 |
| | | 498-183 keV | 10 | 4.2 | Pp-241 | 640 | 1.35 MeV-498 keV | / 50 | 4.9 | | | 1.35 MeV-498 keV | 45 | 5.3 |
| | | 183-67.4 keV | 10 | 4.8 | | | 498-183 keV | - 10 | 3.5 | Pb-207 | 64 | 1.35 MeV-498 keV | 20 | 6.8 |
| Pu-238 | (Pass | 1.35 MeV-498 keV | 10 | 4.5 | | | 183-67.4 keV | 30 | 3.5 | | | 498-183 keV | 20 | 7.5 |
| | | 498-183 keV | 10 | 4.5 | | | 67.4-24.8 keV | 10 | 4.2 | | Paul | 19.6-6.07 MeV | 40 | 26.6 |
| | | 183-67.4 keV | 10 | 6.2 | | | 24.8-9.12 keV | 0.0 | 4.9 | | | 6.07-2.23 MeV | 40 | 5.5 |
| | | 67.4-24.8 keV | 30 | 7.4 | | | 9.12-2.03 keV | 10 | 7,3 | | | 2.23-1.35 MeV | 40 | 6.7 |
| | | 24.8-9.12 keV | 30 | 8.7 | Pp-242 | 464 C | 1.35 MeV-488 keV | / 30 | 5.3 | | | 1.35 MeV-498 keV | 45 | 4 |
| | | 9.12-2.03 keV | 30 | 12.8 | Am-241 | diagt | 498-183 kgV | 10 | 7.3 | Pb-308 | 04 | 6.07-2.23 MeV | 20 | 8.4 |
| Pu-239 | d'une | 495-183 keV | 15 | 5.7 | | | 183-67.4 keV | | 7.1 | | 12200 | 2.23-1.35 MeV | 20 | 7.7 |
| | 0.0 | 183-67.4 keV | 15 | 5.4 | | 6 Mar. | 1.35 MeV-498 keV | / 50 | .7.1 | | | 1.35 MeV-498 keV | 20 | 3.7 |
| | | 62 4 21 2 4 4 | | 6 | Am-242m | d'Alex | 498-183 keV | 29 | 10.9 | | | 498-183 keV | 20 | 4.7 |
| | | 24.8-9.12 keV | 10 | | Cm-244 | diam. | 1.35 MeV-498 keV | 40 | 8.6 | | Paul | 19.6-6.07 MeV | 40 | 9.4 |
| | 1 | 6.07-2.23 MeV | 5 | 3.3 | Cm-245 | dia. | 1.35 MeV-498 keV | 40 | 13.8 | | | 6.07-2.23 MeV | 40 | 4.9 |
| , | | 2.23-1.35 MeV | 5 | 2.9 | | | 498-183 keV | -40 | 9.6 | | Pala | 19.6-6.07 MeV | 100 | . 53.1 |
| | / | 1.35 MeV-498 keV | 5 | 1.4 | | | 183-67.4 | | | 2.12 | -2.05 K | - JU | | 12.0 |
| | | 498-183 keV | 5 | 1.1 | | | 67.4-24.8 Pu | . 220 | | 108 | 102 10 | | | 57 |
| | | 183-67.4 keV | 5 | 1.2 | 17100 11226 | | 24.8-9.12 | -239 | σ_{capt} | 490- | 105 KC | / 15 | | 5.7 |
| | | 67.4-24.8 keV | 5 | 1.5 | 8 > 56 | 24 | 183-67.4 | | | 183- | 67.4 ke | V 15 | | 5.4 |
| | A | 24.8-9.12 keV | 3 | 1.9 | | dimit. | 6.07-2.23 | | | 67.4 | 24 8 k | •V 10 | | 6 |
| • | | 9.12-2.03 keV | 5 | 3 | | | 2.23-1.35 | | | 01.1 | -24.0 kc | N 10 | | 0 |
| | | 498-183 keV | 1 | 8.9 | / | | 1.35 MeV | | [| 24.8- | -9.12 ке | V 10 | 8 | 6.1 |
| - | | | - | | | | | | $\sigma_{ m fiss}$ | 6.07- | -2.23 M | leV 5 | | 3.3 |
| | | | | | | | | | | 2.23- | -1.35 M | leV 5 | | 2.9 |
| | | | | | | | | | | 1.35 | MeV-4 | 98 keV 5 | | 1.4 |
| | | | | | | | | | | 498- | 183 ke | J 5 | | 11 |
| | | | | | | | | | | 193 | 67 A ka | 5 | | 1.1 |
| | | | | | | | | | | 185 | 07.4 Ke | V S | | 1.2 |
| | | | | | | | | | | 67.4 | -24.8 Ke | :V 5 | | 1.5 |
| | | | | | | | | | | 24.8- | -9.12 ke | eV 5 | | 1.9 |
| | | | | | | | | | | 9.12 | -2.03 ke | eV 5 | | 3 |
| | | | | | | | | | v | 498- | -183 ke | √ 1 | | 0.9 |
| | Wren | ce Livermon | e | | | | | | - 10 | 1983-1993 - 19 | 1000 Co. 1000 | / 200 | | |
| 🗖 N? | ationa | I Laboratory | / | | | • | | | | | | | | |

The Time Projection Chamber

- Introduction to a TPC
- How it could improve ²³⁹Pu(n,f)
- Other measurements with the fissionTPC
- Status and plan for the fissionTPC projects



TPCs have been used in Particle Physics for 25+ years



EOS TPC Heavy Ion Physics 1980's ~1 m³



Star TPC Relativistic Heavy Ion Phy. 1990's ~50 m³



nTPC Homeland Security 2004 ~.036m³



PEP-4 TPC Particle Physics e⁺e⁻ Inventor David Nygren 1979 ~6m³



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Typical TPC

Event

How the fission TPC works



TPC Capabilities

- •3D event reconstruction
- •High background rejection
- Particle identification
- •Standalone or incorporation to existing detectors

Possible Measurements

- •Precision ²³⁹Pu(n,f), other (n,f) cross sections (e.g. 235,238)
- •Fission fragment energy, mass and direction
- •Neutron energy, direction, number
- •Correlations with γ -rays
- Lawrence Livermore National Laboratory

Requires specially designed

TPC and/or additional

equipment

Top Systematic Errors using a Fission Chamber



TPC/Fission Chamber Comparison: Geant Simulation of α Rejection



Significant α /fragment resolution even before using dE/dx(x)



Simple Simulation of Fragment Identification

energy/length:length

National Laboratory



Project Status

| | | was. | Task Elctionary | Labor | - | Total |
|----------------------------|---------------------------------------|----------------|--|-----------|-----------|-----------|
| Final an T | | | Pasion TPC Experiment frage, but, and species and otherce WC is research to restar index of species and the species of the spe | \$4,638 K | \$1,338 K | \$5,974 K |
| FISSION I | PC Draft Project | | Referringent mesors even debetations | | | |
| Dian | | | Design, field and commission the THC | 5500 K | \$295 K | SLIPPER |
| Fian | | 11 | First challed design that contains defails such as wall thebreases, person which contained contains and have of fails, fails over containing all | | | |
| | | 12 | Pressure Vessel Despy, built and pressure centry. Should be trade up to tobar with presentar the same ment without additional taments. SouthY, and signs | \$75 K | 510 K | 545 K |
| | | 1.2.5 | Design | 953 K | 50 K | 953 K |
| | | 1.2.5.5 | Invitial Design | \$15 K | 90 K | 515 K |
| | UCRL- TR- 217600 | 1212 | Safety Design Review Anven design with safety organism. Out engrowing safety role for pressure operation, formour, and phoneses. Review Design | \$15 K | 50 K | \$15 K |
| LAWRENCE | | | False desprise accommodate salisty spot. Decument desprise an allowables considered. Have productive drawing made | e | | |
| UNERWORK. | | 122 | But parts, have then webal | | BEOK | 825 K |
| LABORATORIA | | 1.2.3 | Send in the pressure ship to be higher-leased, and then ultraconcally deared after | 10 K | 101 | -01 |
| Construction of the second | Inner ative Finales Managements | 13 | HV/ field cage Design, built and vesify breakdown live operation | \$105 K | 932 K | \$137 K |
| | Innovative Fission Measurements | 1.3.4 | Design Design and decomment. | \$83 K | \$2 K | 585 × |
| \$25525220255 | with a Time Projection Chamber | 1.3.1.3 | Invited Design Design to regenerated seech. | _ 545 X | 92.6 | 847 K |
| | with a fifthe filogeoutori orianitoer | 1.3.1.1. | Generative a physical description that meets the reads of the experiment. | 130 5 | 92.6 | 932 6 |
| | | 1312 | Service dedecates with Navellor service Selety Design Review Review design risk salety organism. Candido decorrect design review for Allow salety review. | \$15 K | 50 K | 515 K |
| 000000000 | | 1.3.1.3 | Real Design Refere design to accommodate safety input. Desurrori design cheates an | \$23 K | 50 K | \$23 K |
| | P. D. Barnes, Jr. M. Heffner, J. Klav | 1.3.2 | alternatives considered. Yaive productive drawing made Construction (b) path, and mattern and/or have coalings made as reason. Furthere (W supply and cable | - 58 K | \$20 K | \$28 K |
| | | 1.3.3 | Text field cape for proper operation and breakdown free | | STOK | \$25 K |
| Real Property lies | | 141 | Design, gent requests Design, gent requests Prostingen text | 11135 | 123 5 | 3136 5 |
| | December 6, 2005 | 1411 | Build pretering to verify construction federations and performance. Find pane | \$23 K | 92 K | 925 K |
| | | 1412 | Design, leyest pdb, and have consected. Nicostregas | 515 K | 53 K | \$16 K |
| | | 1413 | Design, and increased inspectingues on pds Test stand Balls a test stand for the microscopes/per plane. This and data shall value gas existing, HV, and some amplifient and scope. Safety review and HVS solutions have | 545 K | \$20 K | 565 K |
| | | 14.1.4 | Partermanue texting Aur the system and drash for high volkage scalably, gain, signal is more. | \$30 K | 50 K | \$30 K |
| | | 1.4.2 | Design | \$23 K | 90 K | 923 K |
| | | Overse 31, 386 | Official the Only | | | p. 8 (C) |
| | | | | | | |
| | | | | | | |
| | | | | | | |

NERI-c funded !

Universities Abilene Christian University - Rusty Towell California Polytechnic State University at San Luis Obispo - Jenn Klay Colorado School of Mines - Uwe Greife Georgia Institute of Technology - Nolan Hertel, Eric Burgett, Ian Ferguson Ohio University - Tom Massey, Steve Grimes, Carl Brune Oregon State University - Walter Loveland **National Laboratories** Idaho National Laboratory - John Baker Lawrence Livermore National Laboratory - Michael Heffner Los Alamos National Laboratory - Tony Hill

A paper study and WBS of the

TPC is done

TPC specific Laboratory funding

•Significant support for work at LLNL starts FY08 with internal money

•INL, LLNL, and LANL also expect Nuclear Energy money FY08

Prototyping and initial detailed mechanical design has begun

3D Solid Model



Plan





Summary

- A need exists for better ²³⁹Pu(n,f) measurement
- The TPC has been selected as the instrument to make this measurement and is now funded
- How can the investment in this instrument be leveraged to further the science goals of the nuclear physics community?



EXTRA SLIDES



²³⁹Pu(n,f) evaluation





TPC Design Spec's

Parameter Value Drift gases 1H 3He (neutron measurement) P10 (as in fission chambers) 5 bar. nominal Gas pressure (0–10 bar range) Typical fragment track length 18 mm Magnetic field None Beam diameter 20 mm Readout structure 0.9 mm X 0.9 mm square pads Typical samples per track 20 20 mm Target diameter Fiducial area guard radius 9 mm, (50% of track length) Drift length, including fiducial guard radius 27 mm = 18 mm + 9 mmPad plane diameter $74 \text{ mm} = 20 \text{ mm} + 2 \times 27 \text{ mm}$ Number of pads per side $5300 = (74 \text{ mm}/0.9 \text{ mm})2 \pi/4$ Gas amplification **MICROMEGAS or GEM** Drift field 5 kV/cm Maximum field 27 kV @ 10 bar Drift velocity 11.5 mm/us Drift time 2.35 μs Sampling rate 13 Mhz

2.5bar

36mm

2mm X 2mm hex

4.7μs 70Mhz ²³⁹Pu(n,Fission)





Example TPC Data: STAR



The TPC Readout Section



Gas Amplifier/Frisch Grid

LLNL pcb shop can work with the old dry film soldermask



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.

National Laboratory



Fig. 2. Schematic setups for normalization and absolute effective-gain measurement in semitransparent (a,c), reflective (b,d) and double TGEM (a,e) modes.





Fission chamber



How a TPC Works



Possible TPC Improvements

Gaseous Pu target:

Removes target energy loss problems

³He drift gas:

measure neutrons





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gain,pads, readout