Update on CIELO Related Nuclear Data Measurements at the Gaerttner LINAC Center at RPI

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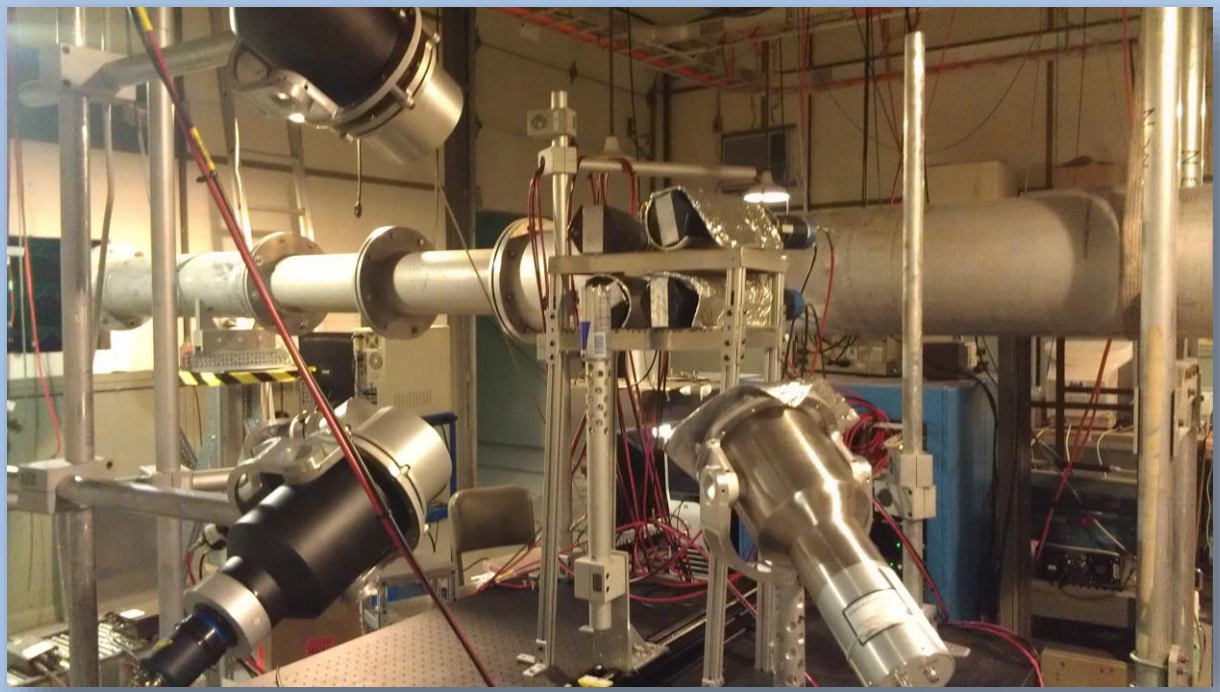
The Nuclear Data Program at the Gaerttner LINAC Center

- Driven by a 60 MeV pulsed electron LINAC ~**10^{12} n/s**
- **Neutron transmission**
  - Resonance region: 0.001 eV- 1000 keV,
  - High energy region: 0.4- 20 MeV
- **Neutron Capture**
  - Resonance region: 0.01-1000 eV
  - New detector array at 45m: 1 keV ~ 500 keV
- **Neutron Scattering**
  - High energy region: 0.4 MeV- 20 MeV
- **Prompt Fission neutron spectrum**
- **Lead Slowing Down Spectrometer**
  - Fission cross section and fission fragment spectroscopy.
  - (n,α), (n,p) and (n,γ) cross sections on small (radioactive) samples.

Summary of Related Activity

- ^{235}U fission and capture yield up to 3 keV.
  - Data was delivered to Leal (ORNL) for inclusion in the evaluation.
- ^{56}Fe - high resolution transmission, 0.5-20 MeV
  - Data was delivered to Leal (ORNL) for inclusion in the evaluation.
- Neutron scattering 0.5-20 MeV
  - Data on ^{238}U published.
  - Data on Fe finalized, publication in process.
- Prompt fission neutron measurements
  - Data on ^{238}U in progress.

Prompt Fission Neutron Spectra



The Gamma Tagging Method

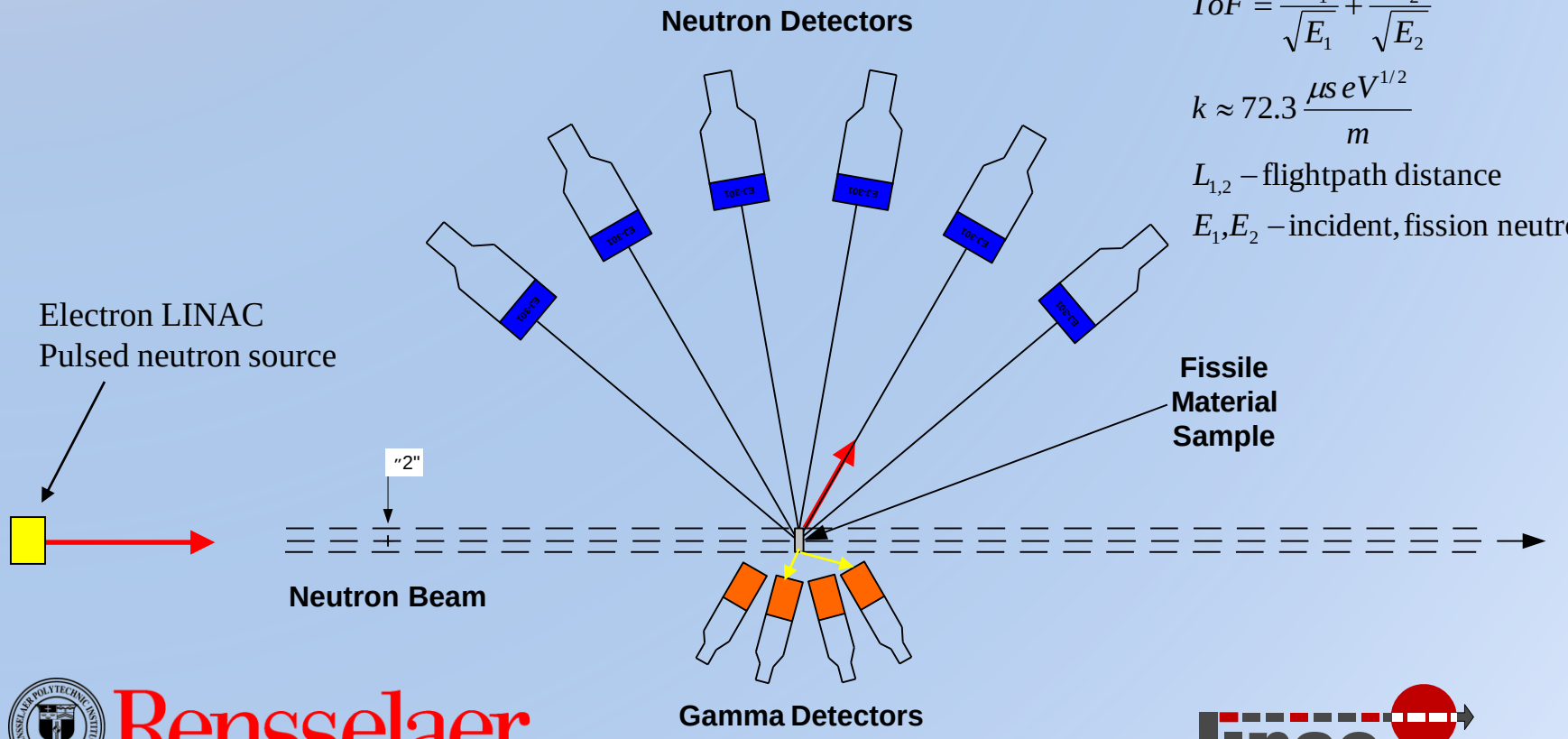
- Use the double TOF method
- Use a gamma tag for fission (instead of traditional fission chamber)
- Use a combination of Liquid Scintillators and Li-Glass neutron detectors

$$ToF = \frac{kL_1}{\sqrt{E_1}} + \frac{kL_2}{\sqrt{E_2}}$$

$$k \approx 72.3 \frac{\mu s\, eV^{1/2}}{m}$$

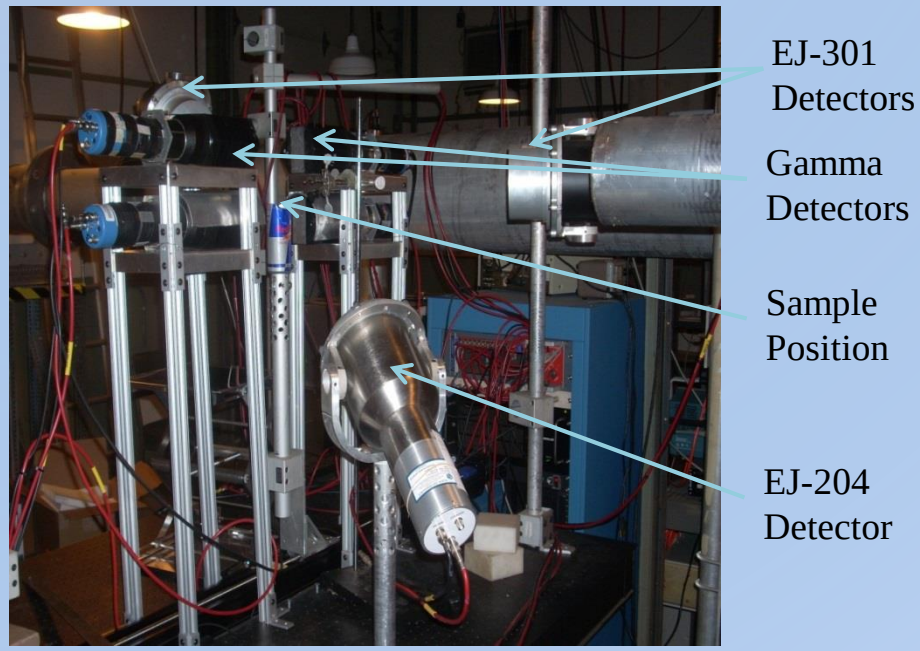
$L_{1,2}$ – flightpath distance

E_1, E_2 – incident, fission neutron energy



Experimental Setup

- Neutron Detectors
  - EJ-204 Plastic Scintillator
    - 0.5” x 5”
    - 47 cm away from center of sample
  - 2 EJ-301 Liquid Scintillators
    - 3” x 5”
    - 50 cm away from center of sample



- Gamma Detectors
  - 4 BaF_2 detectors on loan from ORNL
  - Hexagonal detectors 2” x 5”
  - 10 cm from center of sample
  - ¼” lead shield between detectors
    - Reducing scattering between detectors

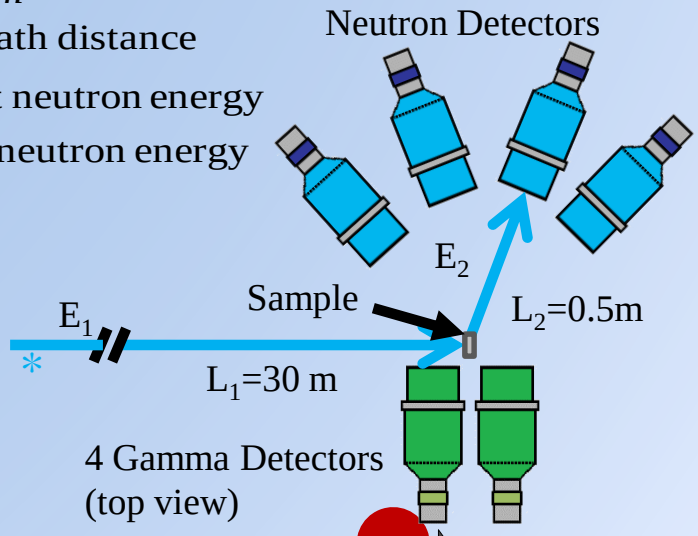
$$ToF = \frac{kL_1}{\sqrt{E_1}} + \frac{kL_2}{\sqrt{E_2}}$$

$$k \approx 72.3 \frac{\mu s\, eV^{1/2}}{m}$$

$L_{1,2}$ – flightpath distance

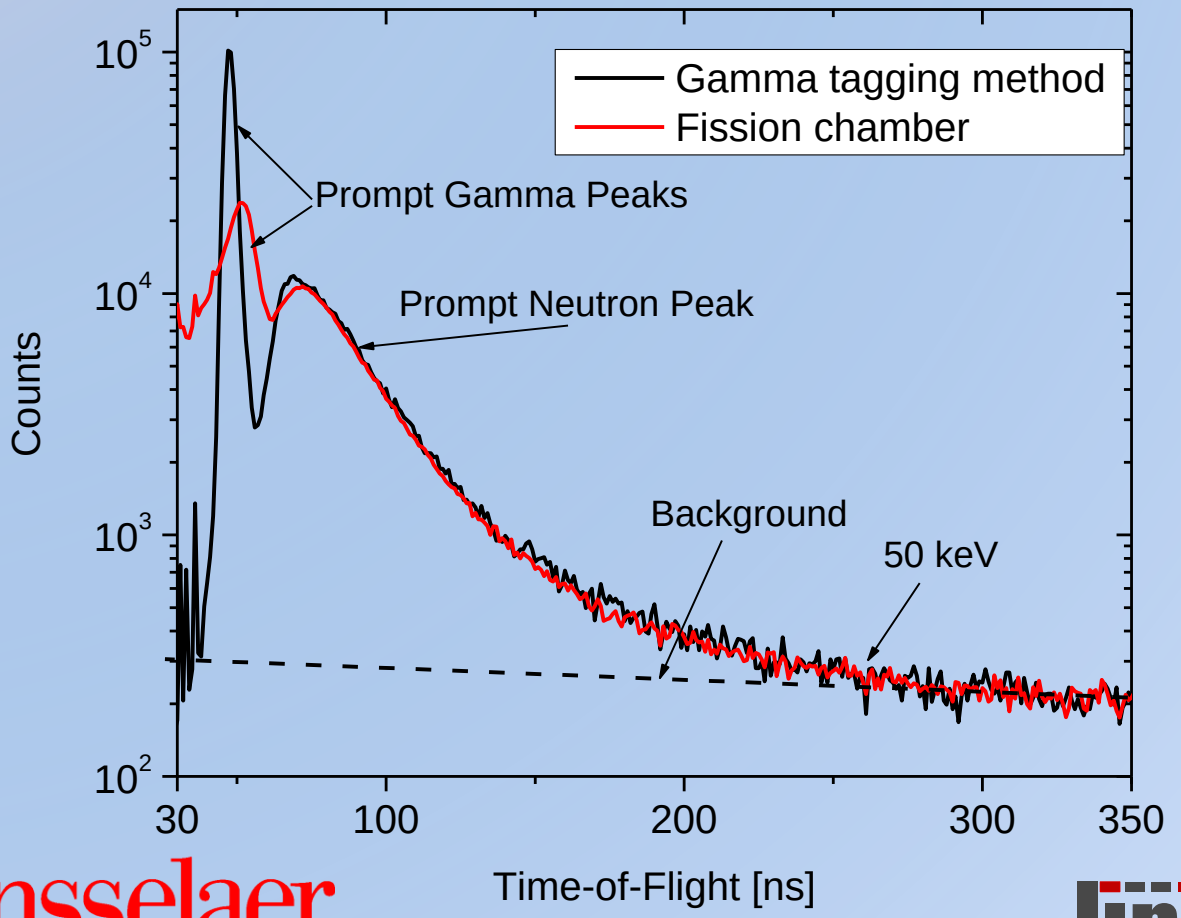
E_1 – incident neutron energy

E_2 – fission neutron energy

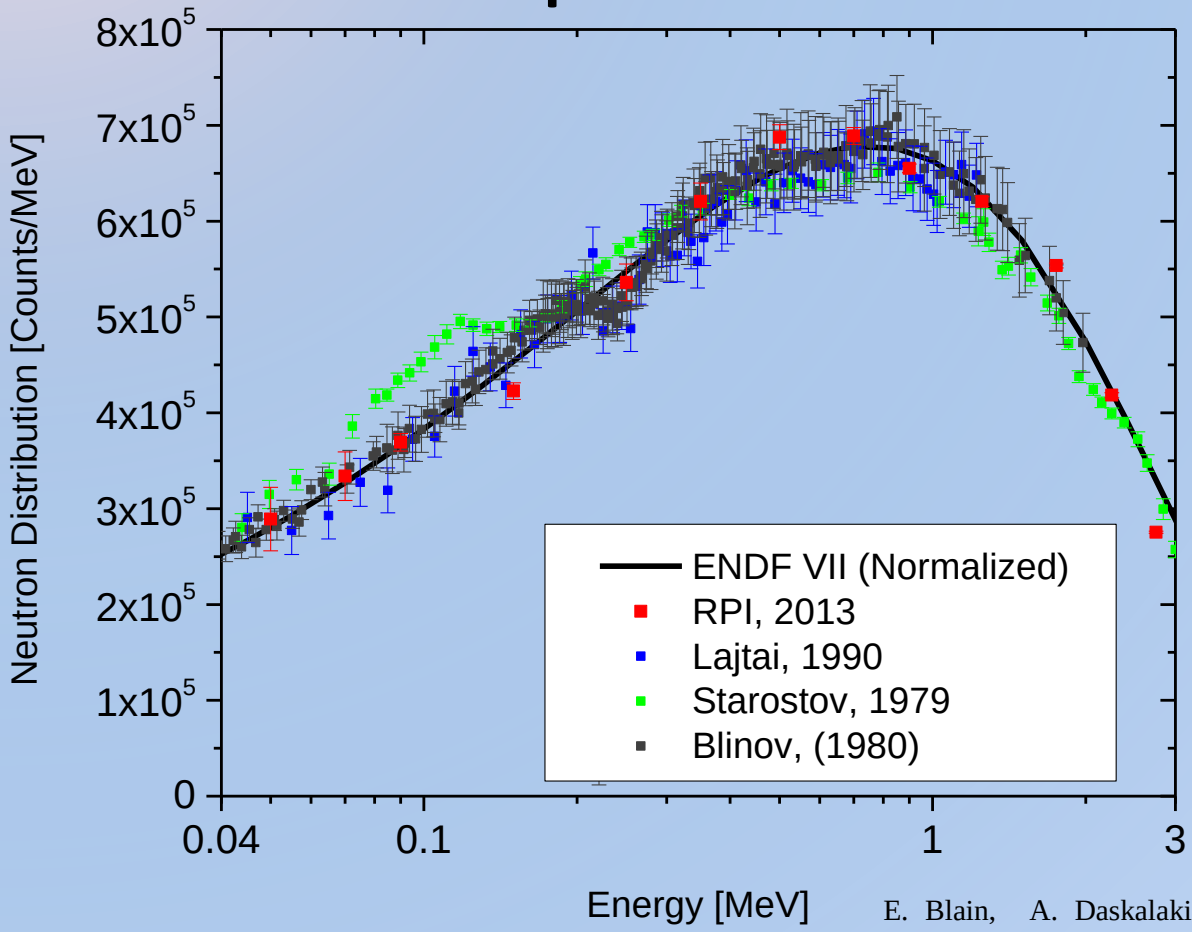


Gamma Tagging - EJ-204

- Gamma tagging method corrected for 30% detection efficiency compared to 83% detection efficiency with fission chamber



^{252}Cf Prompt Fission Neutron Spectrum Low Energy

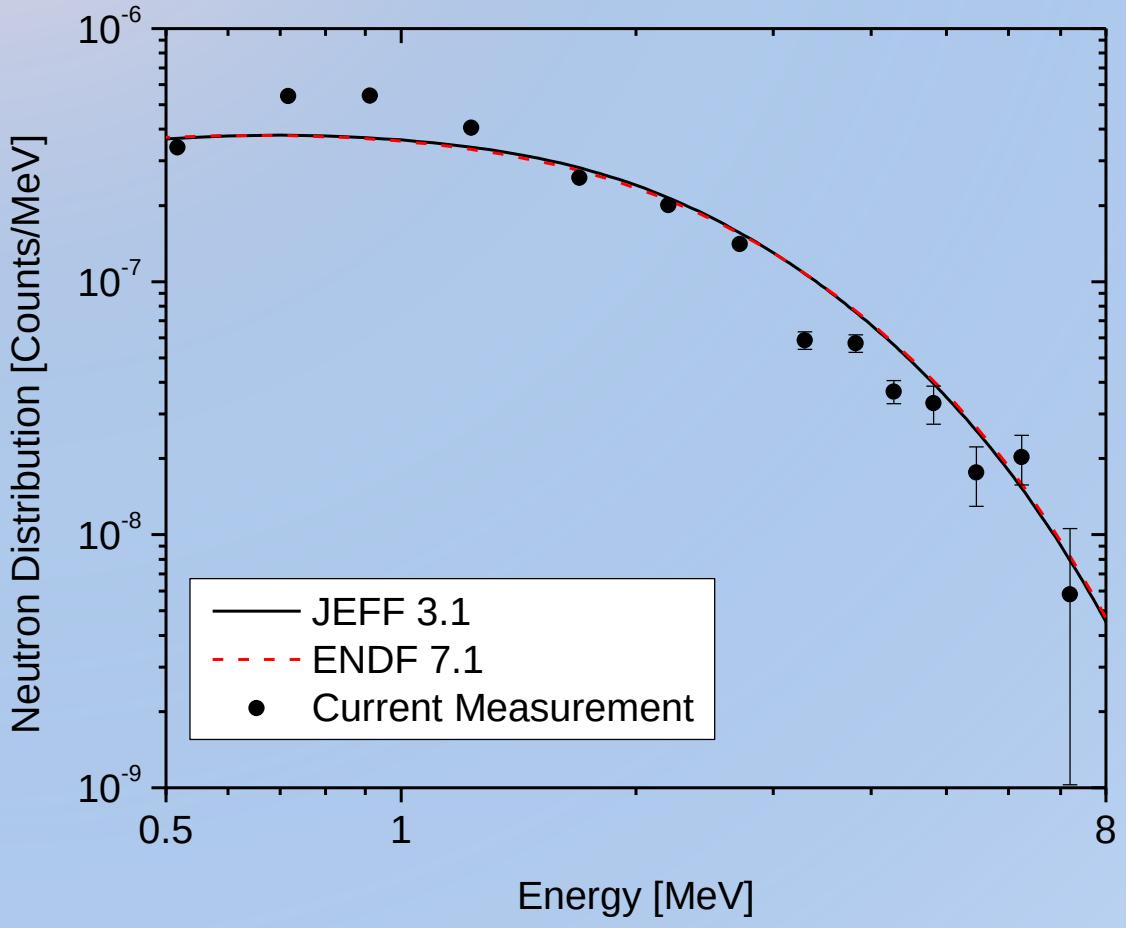


- Low energy data taken with 0.5” EJ-204 plastic scintillator
- RPI data show good agreement to Lajtai, Blinov data and ENDF evaluation
- Thin plastic detector allows for measurement down to 50 keV
- Gamma tagging method accurately reproduces PFNS for ^{252}Cf

E. Blain, A. Daskalakis, and Y. Danon, ”Measurement of Fission Neutron Spectrum and Multiplicity using a Gamma Tag Double Time-of-Flight Setup”, **invited talk**, International Conference on Nuclear Data for Science and Technology, New York, New York, March 4-8, 2013.

^{238}U Prompt Fission Neutron Spectrum High Energy

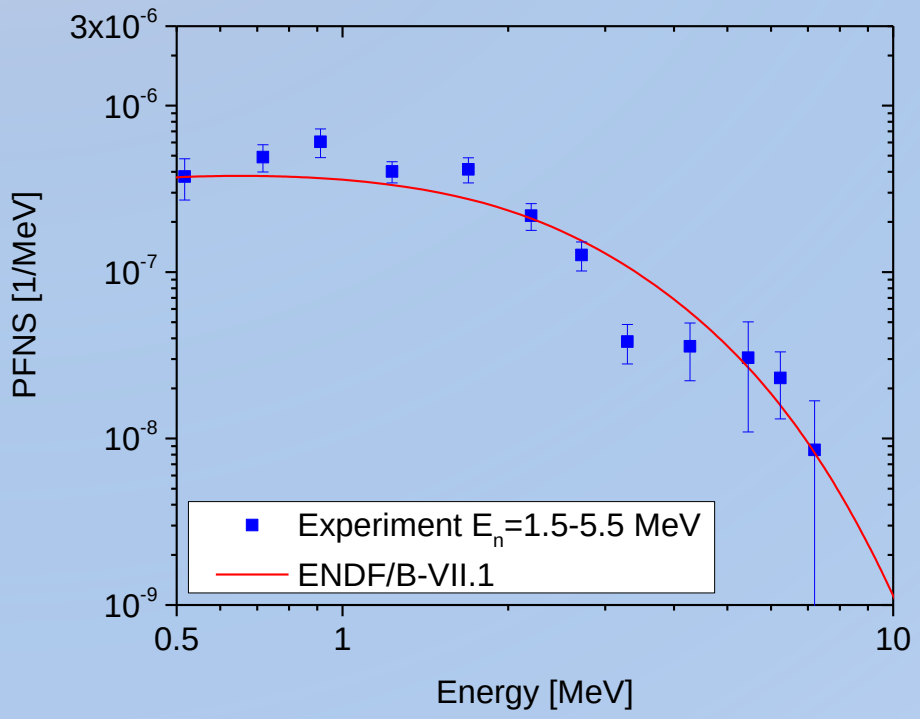
Preliminary Results

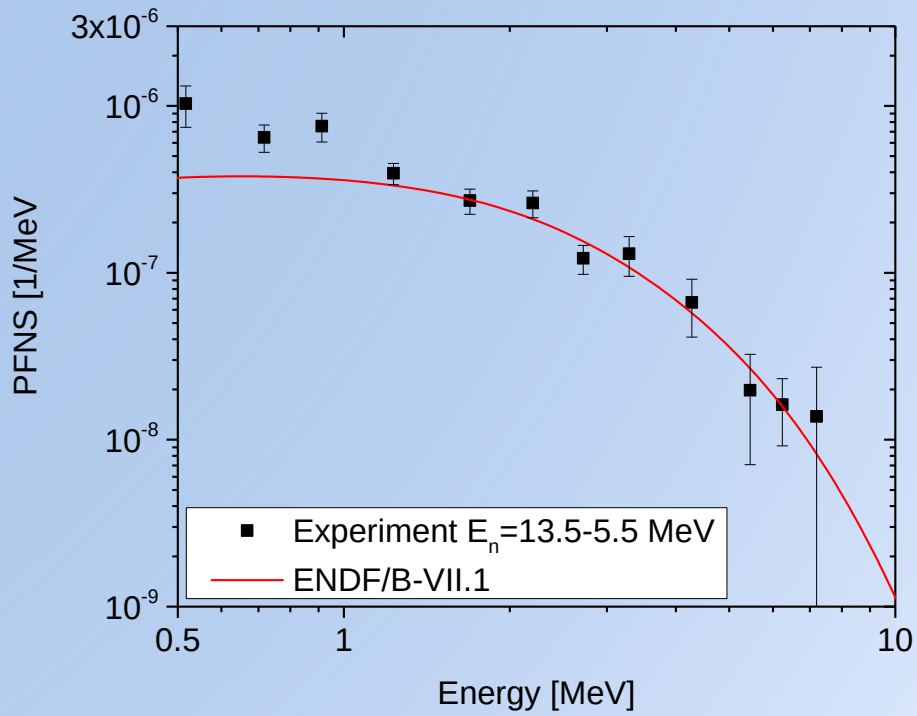


- Spectrum is normalized to ENDF/B-VII.1 at 1.2 MeV
- Spectrum is integrated over all incident time-of-flights
- Preliminary data show good agreement with current evaluations
- Increase near 1 MeV agrees with new data by Sardet et. al. (as presented in the FIESTA 2014 fission workshop at LANL)

PFNS for two incident energy groups

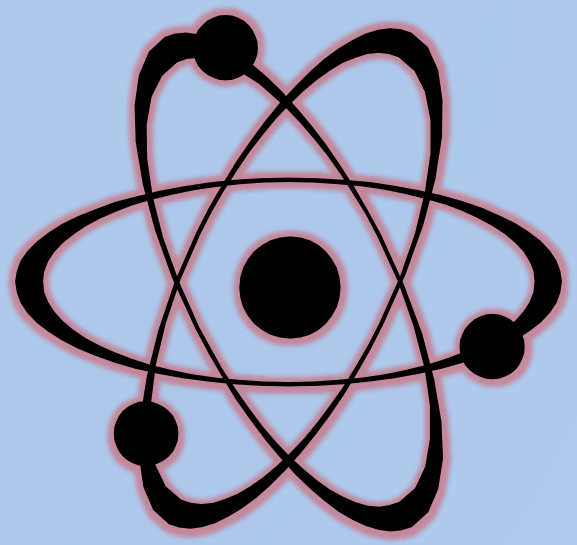
- Data shown above and below the 2nd fission barrier
- Above the 2nd barrier – some indication of increased yield below 1 MeV





Summary

- Neutron scattering in the energy range from 0.5-20 was measured for Fe and ^{238}U at several scattering angles.
  - Data and MCNP simulation were used as benchmark for cross section and angular distribution evaluations.
  - Based on FOM the ^{238}U and ^{nat}Fe data is in best agreement with the JENDL-4 evaluations.
  - Inelastic to elastic scattering ratio were obtained for the 1st excited state and compared with evaluations. All evaluations agree with experimental data within 1-2 times the experimental uncertainty.
- Prompt fission yields were measured using the gamma tag method
  - ^{252}Cf measured fission neutron spectrum below 1 MeV is in good agreement with evaluations
  - Experimental results for ^{238}U provide some information about the change in the PFNS as a function of energy.



Thank You