High Energy Prompt Fission Neutron Spectrum Measurements for the Spontaneous Fission of ^{252}Cf Using a Multiple Gamma Tagging Method

E. Blain, B. Casel, Y. Danon

Gaerttner Linear Accelerator Center
Rensselaer Polytechnic Institute, Troy, NY, 12180

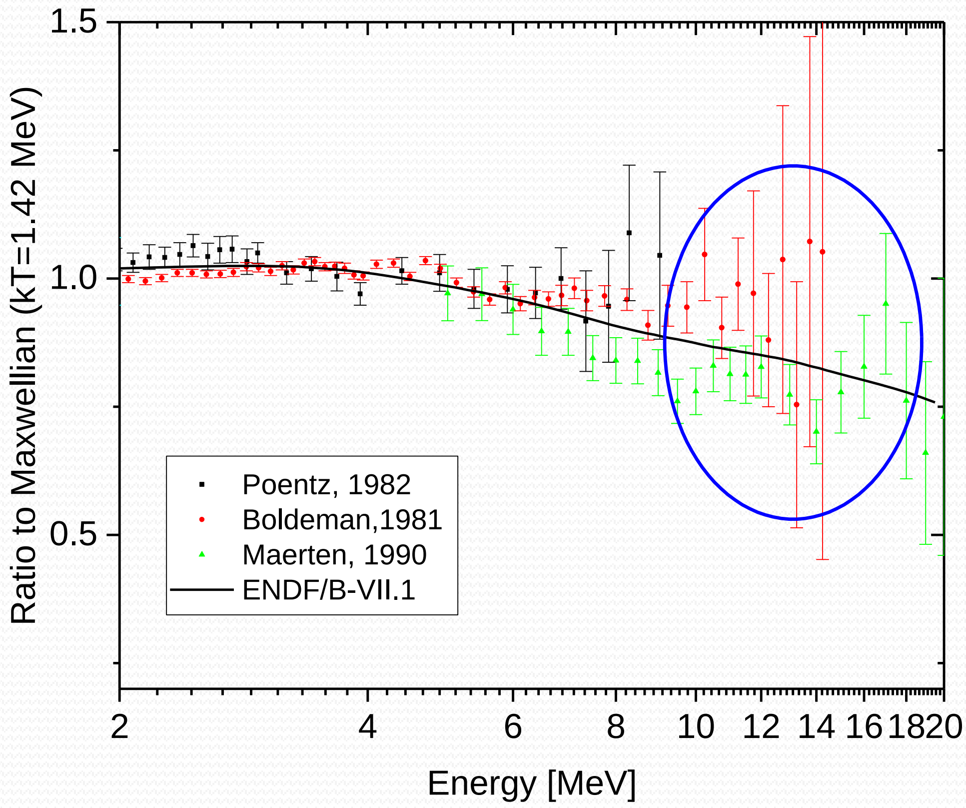
FIESTA, FIssion ExperimentS and Theoretical Advances 2017, Santa Fe, New Mexico, September 17-22, 2017

Motivation

- ^{252}Cf spontaneous fission is considered a standard for the prompt fission neutron spectrum
- Isotopes of particular interest such as ^{235}U and ^{239}Pu are often measured as a ratio to the ^{252}Cf spectrum
- Very little experimental prompt fission neutron spectrum data is available for the high energy region E>10 MeV
- Relative standard deviations for this energy region are in the range from 3% at 10 MeV up to 75% at 20 MeV
- Targeted accuracy for this region is less than 5% uncertainty

Previous ^{252}Cf Measurements

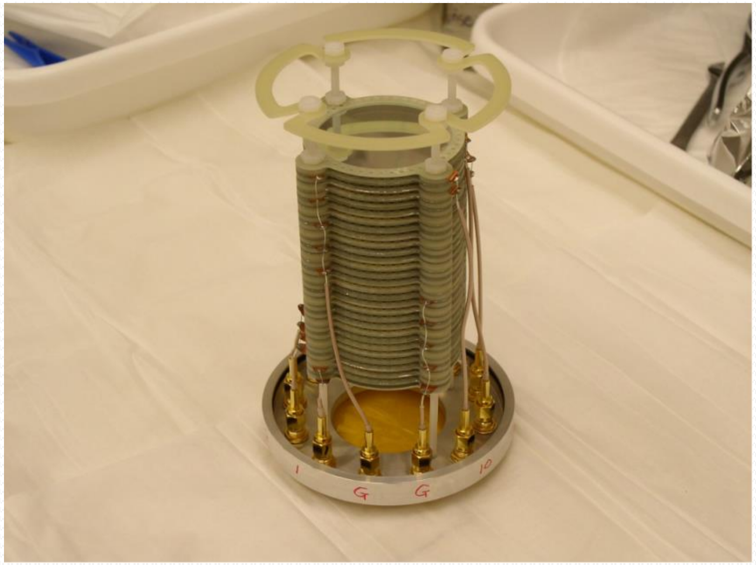
- Manhart Evaluation (1987), Currently used in ENDF/B-VII.1
- Experiments at high energy > 10 MeV very high uncertainty on data and only 2 datasets



Difficulties with measuring High Energy Region of PFNS

- Low Count Rate
  - Several orders of magnitude less neutrons at higher energies than in the peak of the PFNS spectrum
  - Need large samples in order to measure statistically significant data in a reasonable period of time
  - Very sensitive to neutron background rate and benefits from a high signal to background ratio
- Short Time of Flight
  - Requires high timing resolution in order to obtain accurate neutron energy information at short times of flight

Limitations of Fission Chamber

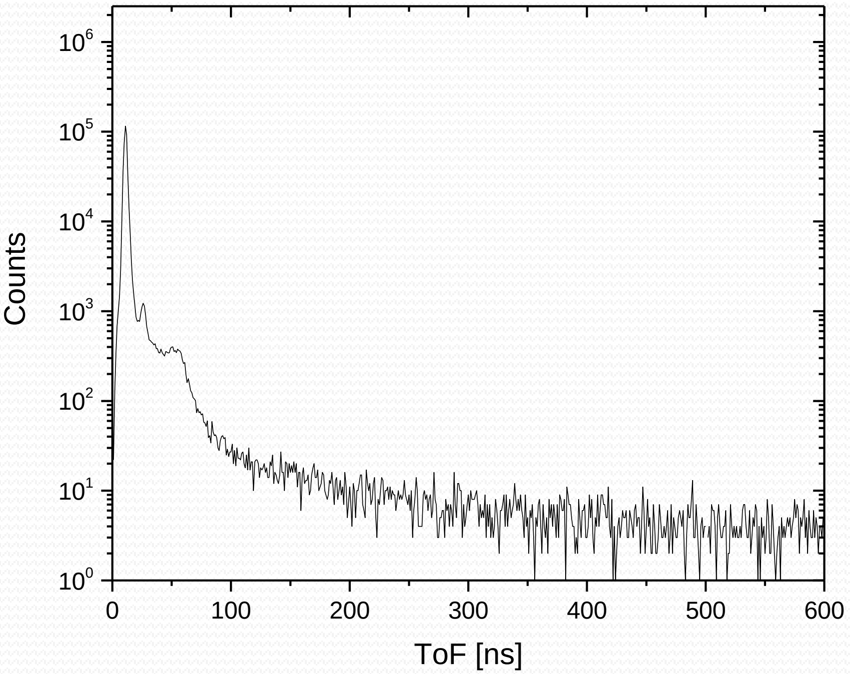


[1]Robert C Haight, et al. "Progress in the Measurement of Prompt Neutron Output in Neutron-Induced Fission of ^{239}Pu: The Chi-Nu Project", LA-UR-12-25233 (2012)

- Advantages
  - High Detection efficiency
  - Directly measures the fission event
- Disadvantages
  - **Limited to thin samples**
  - Larger sample masses require complex multi-plate fission chambers
  - **Timing resolution is dependent on preamplifier electronics**

Limitations of Single Gamma Tagging

- Advantages
  - Larger sample mass can be used
  - Good detection efficiency
  - Timing resolution dependent on Gamma detectors



- Disadvantages
  - **Large room background**
  - **Late gamma rays cause large uncertainty in timing of fission event**

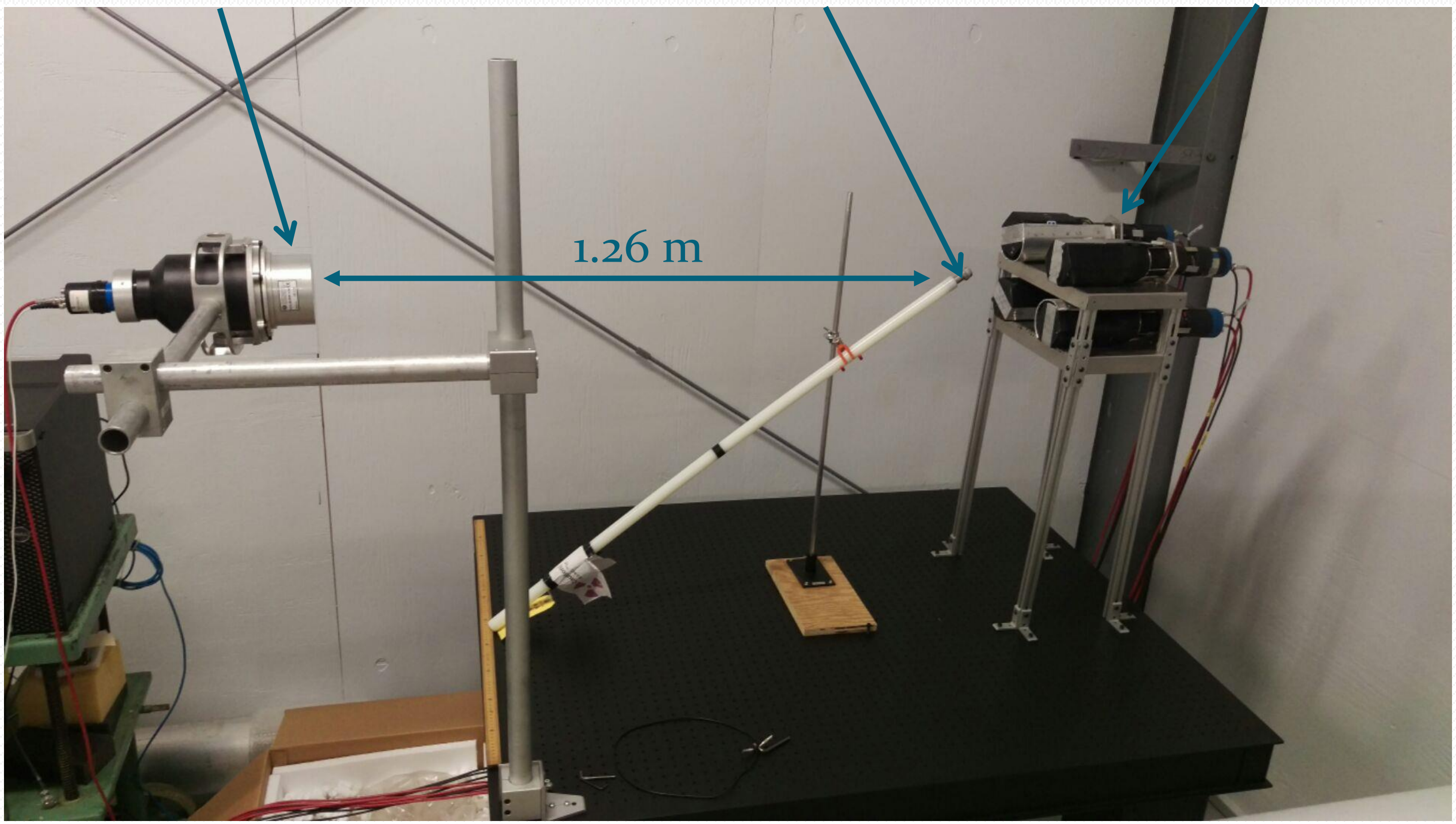
Multiple Gamma Tagging Criteria

- Coincidence of at least 2 on an array of 4 BaF_2 detectors
- 300 keV Energy threshold on each detector
- 2 MeV upper threshold on each detector (further reduces unwanted coincidence due to capture interactions in the sample)
- Require coincidence with detected neutron events within 600ns
- Simulated fission detection efficiency 36.8% at 10 cm

Experimental Setup

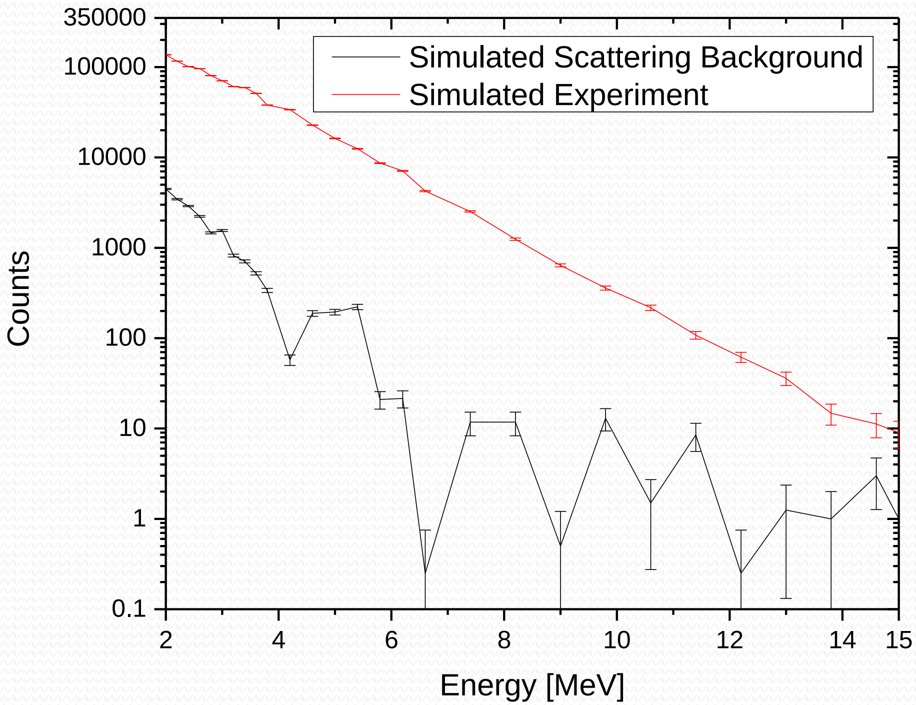
- Digital Data Acquisition
  - Struck SI3305 10 bit digitizer board
  - 1.25 Msamples/second (0.8 ns sampling rate)
- Neutron Detectors
  - 1 EJ-301 Liquid Scintillator
    - 3" x 5"
    - 1.26 m away from center of sample
- Gamma Detectors
  - 4 BaF_2 detectors on loan from ORNL
    - Hexagonal detectors 2" x 5"
  - 16 cm from center of sample
  - ¼" lead shield between detectors reducing scattering between detectors

Experimental Setup



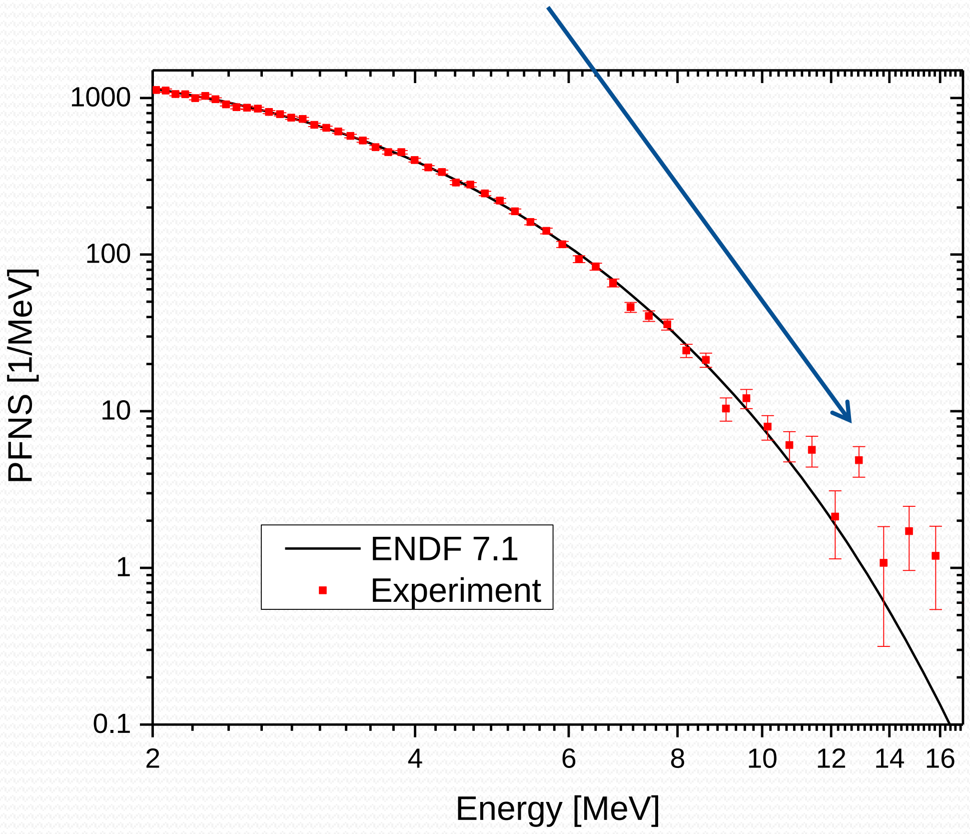
Time dependent neutron background simulations

- MCNP simulations were performed to determine the effects of scattered neutrons on PFNS background
- Time dependent neutron background comes primarily from higher energy neutrons scattering with the environment and returning to the detector at a longer time of flight than their source energy
- Experimental table, floor, ceiling, detectors and walls simulated as scattering components



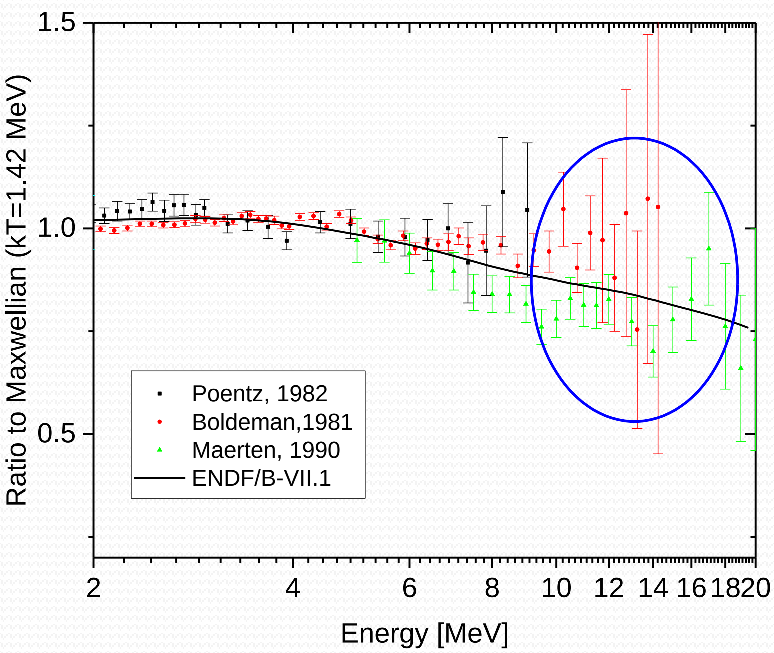
Results

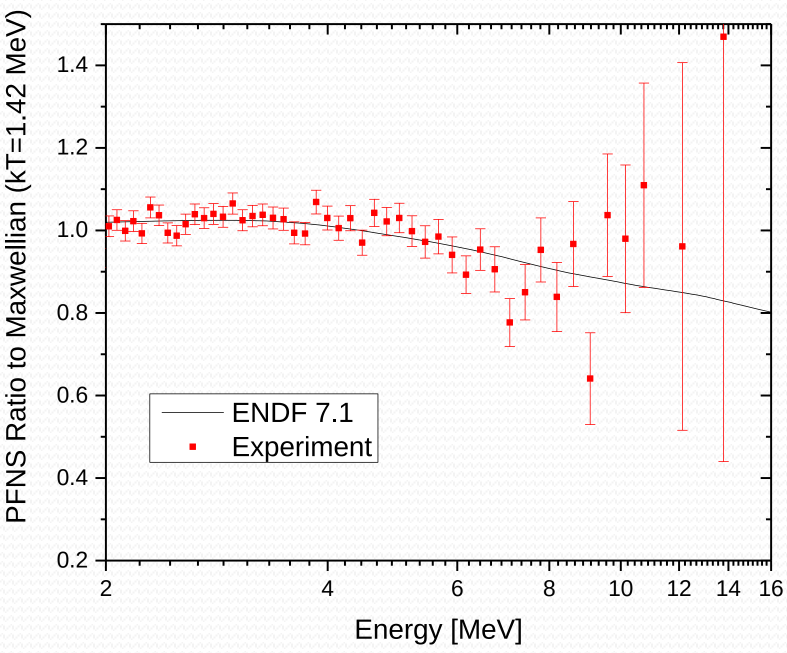
- New measurement agrees with ENDF 7.1 up to 10 MeV
- Current efficiencies found using SCINFUL modeling code
- Measured spectrum is higher than evaluation above 10 MeV
  - Investigate possible additional background components
  - Experimentally measure detector efficiency
  - Increase statistical accuracy for this region



Results

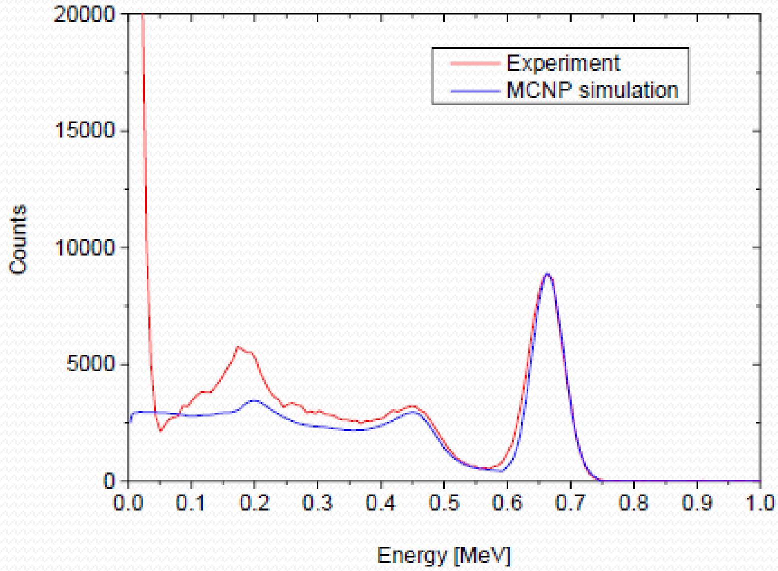
- Experimental data ratioed to Maxwellian at a kinetic temperature of 1.42 MeV
- Uncertainties are similar to previous measurements up to 8 MeV
- Additional measurement time will greatly reduce uncertainties at higher energies

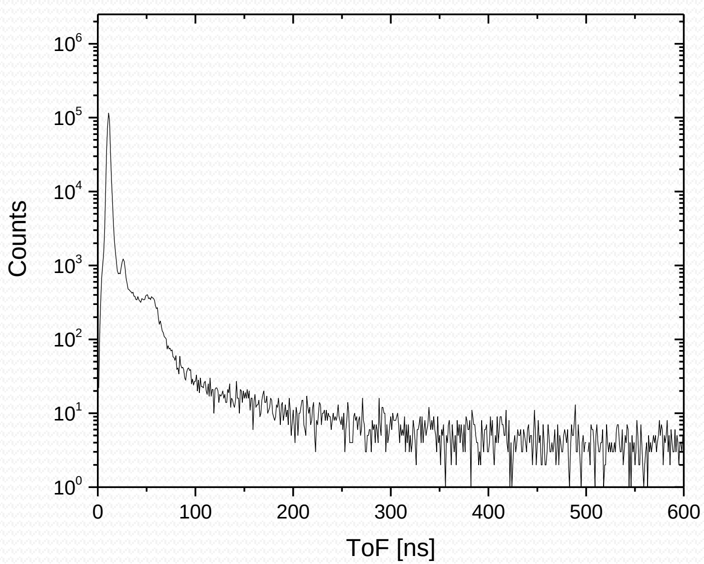




Planned prompt gamma measurements

- Measure the time and energy distribution of the prompt fission gammas using multiple gamma tagging
  - Utilize CLYC detector which has ~5% energy resolution (at 662 keV) for gamma detection
  - By gating on late ToF and constructing energy histogram more information can be obtained about isometric decay gammas





Future work

- Experimentally measure the neutron detection efficiency using mono-energetic beam
- Measure Prompt gamma time and energy distribution using CLYC detector
- Complete measurement of ^{252}Cf PFNS to obtain target uncertainties of less than 5% up to 15 MeV

Conclusions

- New measurements of prompt gamma time and energy distribution can be made using a CLYC detector
  - By determining the energy distribution for late gammas more information can be obtained on isometric states populated in the spontaneous fission process
- Good preliminary agreement between the previous evaluation and current measurements of ^{252}Cf PFNS
  - Increased run time is needed to reduce uncertainties in the region above 10 MeV
  - Mono-energetic beam measurements should be used to experimentally determine detector efficiency

Questions?