The prompt fission neutron spectrum of $^{235}\text{U}(n,f)$

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Jason McGinnis - PhD dissertation project
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(M.S. thesis project elsewhere)

Danula Godagama – PhD student  (partial support)
$^{235}$U(n,fn) Prompt Neutron Energy Spectra

Prompt fission neutron spectra from fission induced by 1 to 8 MeV neutrons on $^{235}$U and $^{239}$Pu using the double time-of-flight technique

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A. Chatillon, T. Granier, G. Bélié, and J. Taieb
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T. Kawano and P. Talou
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(Received 8 June 2010; published 10 March 2011)
Note the relatively small high-energy fission yield
Project Timeline

April, 2016: Fission proposal submitted to LANSCE/WNR (Approved)

June, 2016: 16 neutron detectors assembled at LANSCE, tested with Cf-252 source

September, 2016: Scintillator response data collected at UKy accelerator

January, 2017: U-235 fission neutron spectra collected at LANSCE

February, 2017: Cf-252 spectra collected at LANSCE

April, 2017: Fission proposal submitted to LANSCE (Approved)

Summer & Fall, 2017: MCNP model developed, & January, 2017 data analyzed

December, 2017: Neutron detectors assembled in 4FP15L channel at LANSCE

January, 2018: Prompt neutron fission spectra collected on U-235 and Cf-252

TODAY: RESULTS OF A VERY PRELIMINARY ANALYSIS
16 scintillators @ 10 cm x 10 cm x 200 cm

Light mixer and pm at each end

Position as a "canopy" over $^{235}$U PPAC at 150 cm and 90 deg central polar angle.

Measure fission neutron TOF with mean time, and neutron position with L/R time difference

**Advantages:**

- large solid angle $\Omega \sim 1 \text{ sr}$
- good position (n angle) resolution $\sigma \sim 9 \text{ cm}$
- good efficiency $\eta \sim 32 - 47\%$
- continuous polar angle coverage $59 - 121 \text{ deg}$
- uniform mean response $< 4\%$
- good n energy resolution $1 - 2 \text{ MeV}$

**Disadvantage:** No PSD option
Advantages:

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The TOF “window” for 3 – 10 MeV prompt fission neutrons: 34 – 73 nsec
Suppression of Prompt Backgrounds in 4FP15L

Detector Array

\[ \text{n} @ 3-10 \text{ MeV} \]

\[ 34 - 73 \text{ ns} \]

\[ 5 \text{ ns} \]

\[ ^{235}\text{U PPAC} \]

Concrete Walls & Floor

Pit
Prompt Neutron Backgrounds

$T_n > 16 \text{ MeV}$

$34 - 73 \text{ ns}$
Prompt Neutron-to-Gamma Backgrounds

\[ T_n > 10 \text{ MeV} \]

34 – 73 ns

\[ T_n > 10 \text{ MeV} \]
Non-prompt backgrounds

1. Delayed gammas from fragments
   most fall within 20 ns of fission trigger

2. Delayed neutrons and gammas from walls, floor, spallation target, etc.
   measure the time- and position-dependence of the accidental triggers in the neutron detector array, then subtract
4FP15L neutron channel at LANSCE/WNR
800 MeV spallation source

Double-TOF method:

PPAC time determines energy of beam neutron and the time start for fission neutron TOF measurement
Parallel plate avalanche counter (LLNL) 10 foils of U-235 fission fragment detection with good timing

1 - 800 MeV neutron source 120 macropulses/sec @625 µs micropulse spacing 1.8 µs
Ceiling “neutron bounce” is delayed out of range
**U-235 PPAC** 100 mg $^{235}\text{U}$ on 10 Ti backing foils @3 \(\mu\text{m}\)

time resolution ~ 1 ns
Position-sensitive “tagger detector” below neutron array uses back-to-back coincidence detection of 511 keV gammas to monitor adc and tdc channels
Th-228 source of 2.6 MeV gammas provides continuous monitor of scintillator calibrations.

1 of 32 ADC spectra

MCNP model
Cf-252 PPAC

Spontaneous fission source

single-layer
Cf-252 E-deposit vs neutron energy (via TOF)

E-deposit

10 MeVee
5 MeVee
3 MeVee
0

0 4 MeV 8 MeV 12 MeV $T_n$
Cf-252 E-deposit vs neutron energy (via TOF)

Neutron Signal

Backgrounds

10 MeVee

5 MeVee

0

0 4 MeV 8 MeV 12 MeV
MCNP simulation of 16-bar scintillator array

Uses UKy measured response of BC-408

E-deposit

6 MeVee

3 MeVee

Neutron energy (via TOF)
Prompt neutron energy spectra, 4 - 10 MeV, for each of 16 bars with Cf-252 source (blue) [2 weeks of collection]

MCNP simulation of detected neutron spectra for Cf-252 (red)

MCNP normalized to data at 7 MeV neutron energy

Compare the slopes...
Very good statistics of source data will allow accurate characterization of detector response.
Beam-on U-235 PPAC response

ADC channel

Alphas

Fission fragments
U-235  

E-deposit vs neutron energy (via TOF) for 1 scintillator bar

Neutron Signal
Residual Background Subtraction (2D cut applied)

Blue: $ trigger
Red: Accidental trigger

$^{n_s}$
Prompt neutron energy spectra, 3 - 10 MeV, for each of 16 bars with U-235 target (blue) [2 weeks of collection]

MCNP simulation of detected neutron spectra for Cf-252 (red)

MCNP normalized to data at 7 MeV neutron energy

**Compare the slopes...**
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Jason McGinnis - Dissertation project

Detailed analysis of the data is just starting

MCNP simulation continues to be improved

Expect final results in ~6 months