Measurements of the Prompt Fission Neutron Spectra of $^{235}$U and $^{239}$Pu at Chi-Nu


CSEWG 2016
November 14, 2016
LA-UR-16-28935
The Chi-Nu Experiment

- Purpose: Measure the $\chi$-matrix for neutrons ($\chi_{\nu}$-matrix) incident on actinides

Accuracy goals

239Pu

$t_0$ Pulsed, White $n$ Source

$fission event (t_f)$

$E_{n}^{inc}$ $E_{n}^{out}$ $\chi$-Matrix

neutron detection ($t_n$)
Incident Neutrons: LANSCE and WNR

- **LANSCE**: Los Alamos Neutron Science Center
- **WNR**: Weapons Neutron Research
  - Receives high-energy $n$’s via spallation on a tungsten target
  - $0.5 \text{ MeV} \lesssim E_{n}^{inc} \lesssim 100 \text{ MeV}$ is of interest for Chi-Nu
Fission Detection: Parallel-Plate Avalanche Counter (PPAC)

- 6 Total PPACs:
  - $^{252}$Cf: Two, with different activities
  - $^{235}$U: One, with 50 mg total mass
  - $^{239}$Pu: Three, one with 50 and two with 100 mg total mass

- $^{235}$U and $^{239}$Pu PPACs contain 10 Ti target foils

- Significant modifications made to initial PPAC design to reduce $n$ scattering
  - G-10 is an issue
  - Change from G-10 to Al and glass improved PPAC performance
  - Other H-rich materials have also been reduced
Outgoing Neutron Detection:
Chi-Nu $n$-Detector Arrays

- Low $E_{n}^{out}$: 22 $^{6}\text{Li}$-glass (LiGl) Detectors
  - $E_{n}^{out} \leq 1 \text{ MeV}$
  - Operate via $^{6}\text{Li}(n, \alpha)t$ reaction

- High $E_{n}^{out}$: 54 Liquid Scintillators
  - $E_{n}^{out} \geq 0.5 \text{ MeV}$
  - Good PSD for $n$-$\gamma$ separation

Overlap region allows for a high- and low-energy measurements to be combined into a single PFNS result.
Detailed Models of the Chi-Nu Experiment

PPAC

$^6\text{Li}$-glass Array

top view

front view

Liquid Scintillator Array
A new method to reduce the statistical and systematic uncertainty of chance coincidence backgrounds measured with waveform digitizers


- Background changes shape based on the chosen $E_n^{inc}$
- Chance coincidence rate is measured using the *singles* rates of the PPAC and $n$ detectors

**No Need to Collect Separate Background Data**

**Collect Background as Data are Taken**

**Factor of 4 Improvement in use of Beam Time**
Measurement of the $\chi$-Matrix

The data for any combination of $E_n^{inc}$ and $E_n^{out}$ is simply projected out.
Preliminary Low-Energy $^{235}$U Results

PRELIMINARY

ENDF/B-VII.1
ENDF/B-VIII.0 $\beta_2$
Chi-Nu

$E_{\text{inc}} = 1.0-5.0$ MeV

PFNS (n/MeV/fission)

Outgoing Neutron Energy (MeV)
**Preliminary Low-Energy $^{239}$Pu Results**

- Only 1 Week of Low-Energy Data

- High $\alpha$-background rate is a serious problem
- Techniques have been developed to ensure that the highest precision result is obtained

**Neutron Energy (MeV)**

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**PFNS (arb. units)**

Chi-Nu Data Prelim. $E_n'^0 = 0.7$-$20$ MeV

Neudecker et al. $E_n'^0 = 1$ MeV
Past and Future Milestones for Chi-Nu

- **\(^{235}\)U Data Collected to Date:**
  - 3 months of data collected with the low-energy array
  - 1.5 months of data collected with the high-energy array
    - \(^{235}\)U data collection is complete

- **\(^{239}\)Pu Data Collected to Date:**
  - 2.5 Months of data collected with the low-energy array
  - Short high-energy data set collected to confirm ability to handle data rate

- **Future Data Collection Plans:**
  - Collect another ~1 month of low-energy \(^{239}\)Pu data before 2017
  - Collect high-energy \(^{239}\)Pu data in the spring/summer of 2017

- **Future Results Plans:**
  - Final high- and low-energy \(^{235}\)U results by mid-to-late 2017
  - Publication of \(^{235}\)U results shortly after final results are obtained
  - Initial low-energy \(^{239}\)Pu results by mid 2017
  - Initial high-energy \(^{239}\)Pu results by late 2017
The Chi-Nu Collaboration

- **Los Alamos National Lab:**
  

- **Lawrence Livermore National Lab:**
  
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