# Energy Dependent Fission Product Yields

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Lawrence Livermore National Laboratory

**Workshop for Applied Nuclear Data Activities (WANDA)**

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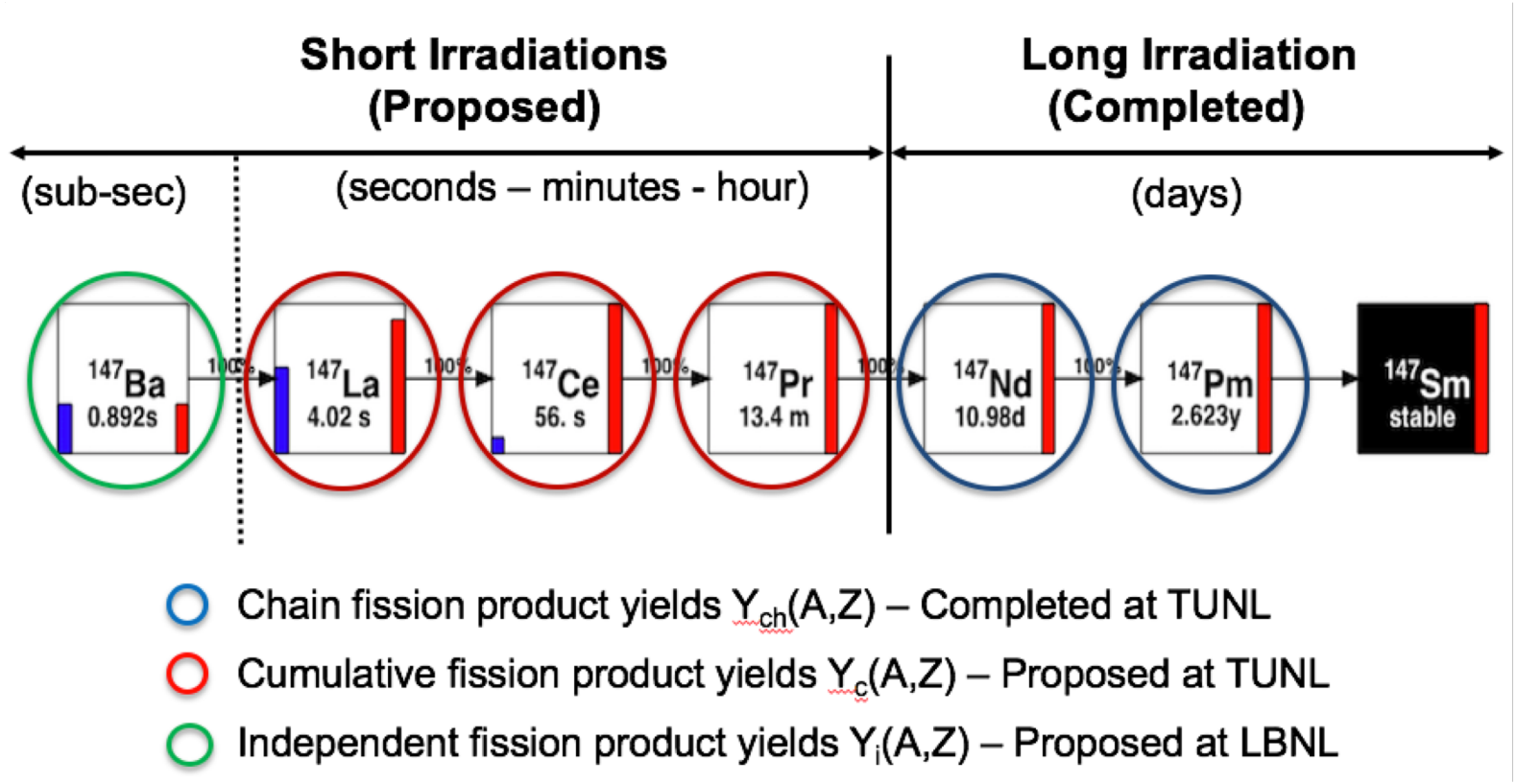
# Motivation: Toward new energy dependent FPY data to support fission theory and evaluation




**Goal: Predicting independent and cumulative FPYs data simultaneously and consistently in the energy-dependent manner**

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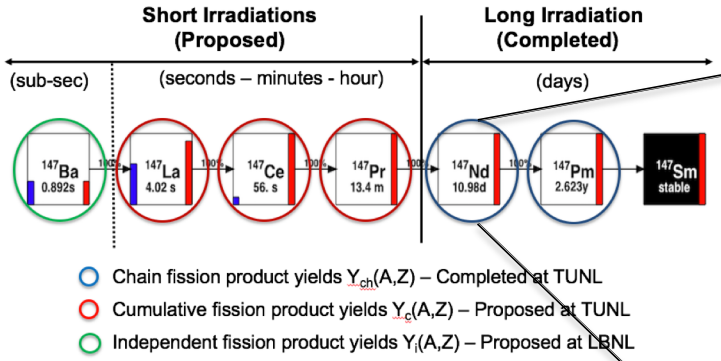
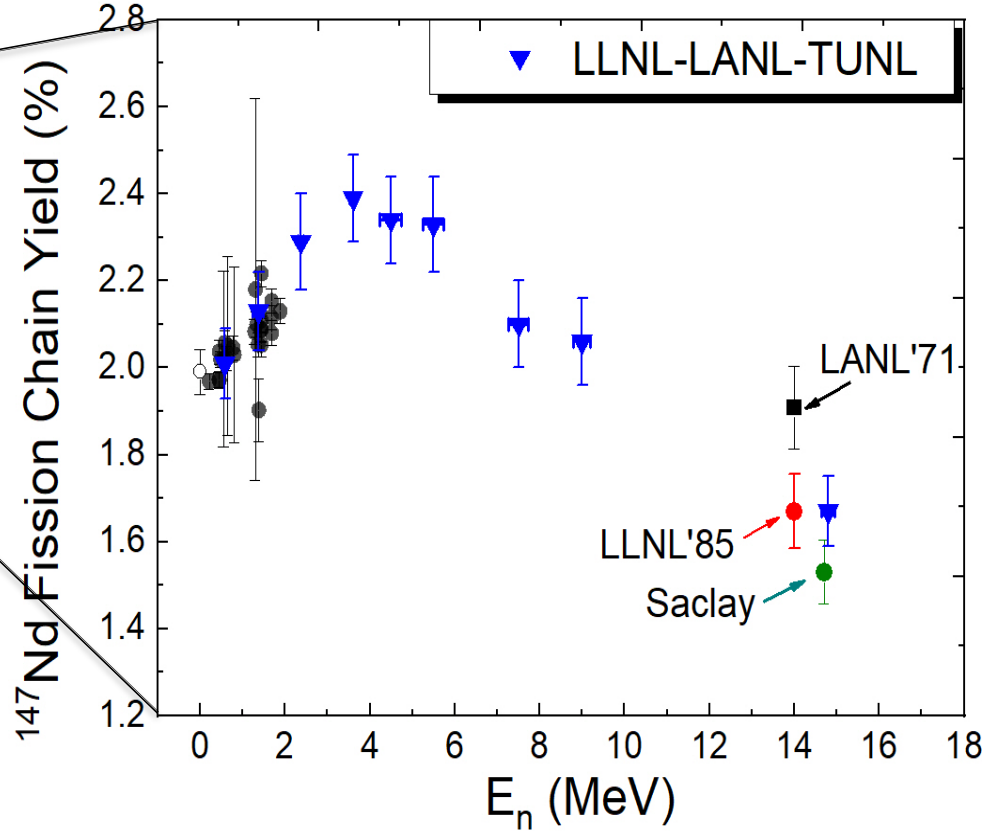


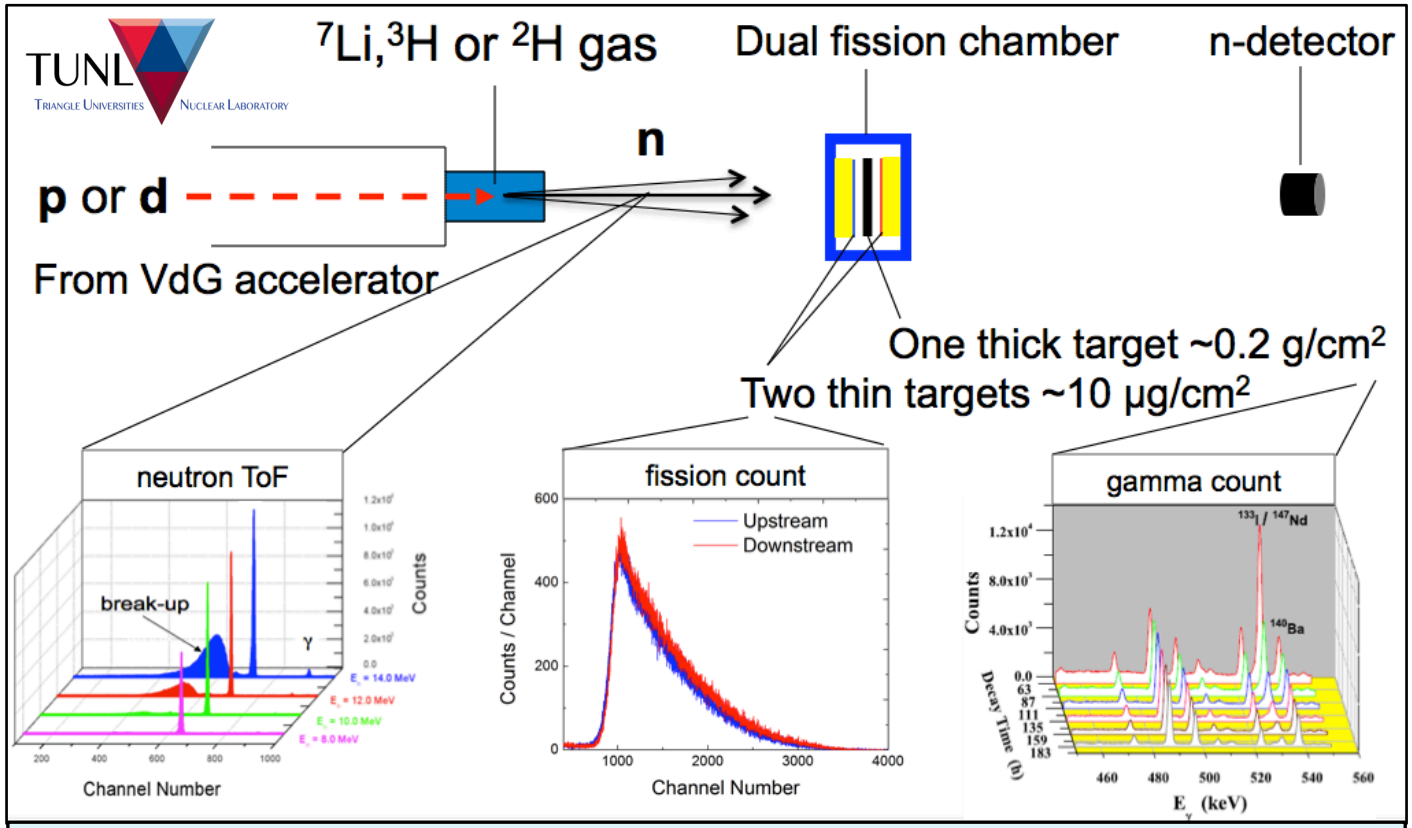

- Peculiar energy dependency
- There is a positive slope of the $^{147}$Nd FPY from 0.5 to ~4.0 MeV:

  $\Delta Y(^{147}Nd)/\Delta E_n = (5.8\pm1.5)\%/MeV$
- At higher energies the FPY for $^{147}$Nd turns over and decreases




NIM A **757,** 7 (2014); Nucl. Data Sheets **119**, 121 (2014); Nucl. Data Sheets **119**, 324 (2014), J. Rad. Nucl. Chem 10.1007 (2015); PRC **91**, 064604 (2015); PRC **93**, 014611 (2016); Nucl. Data Sheets **131**, 319 (2016), PRC **95**, 024608 (2017); NIMA **854**, 40 (2017); Two Conference Proceeding (2016, 2017)

# Fission Product Yield Measurements at TUNL using Monoenergetic Neutron Beams

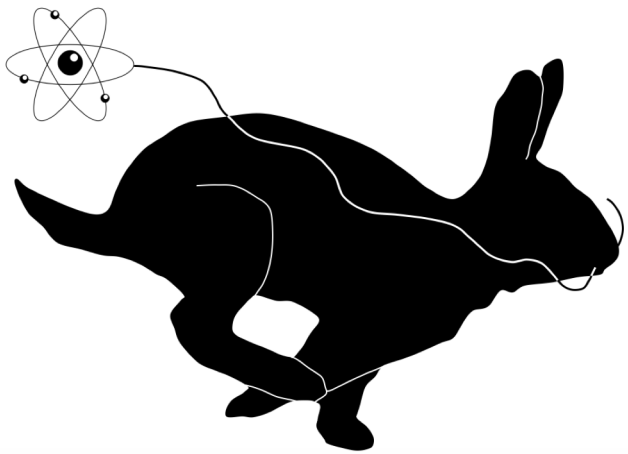



$$FPY = (Gamma\_count) / Fission\_count) * (m_{thin} / m_{thick}) * C_i$$

NIM A **757,** 7 (2014); Nucl. Data Sheets **119**, 121 (2014); Nucl. Data Sheets **119**, 324 (2014), J. Rad. Nucl. Chem 10.1007 (2015); PRC **91**, 064604 (2015); PRC **93**, 014611 (2016); Nucl. Data Sheets **131**, 319 (2016), PRC **95**, 024608 (2017); NIMA **854**, 40 (2017); Two Conference Proceeding (2016, 2017)

# Building the Fastest Sample-Irradiated Transfer System in the Entire NNSA Complex

**RA**pid
**B**elt-driven
**I**rradiated
**T**arget
**T**ransfer
**S**ystem



**RABITTS**


**Features**

- Fully automated operation
- Fully synchronized with the DAQ system and beam time structure
- User defined cycles ($t_{irr}$, $t_{dec}$, $t_{mes}$) can be repeated many times
- List-mode digital DAQ based on digital electronics
- Transfer time = 400ms/1m or 1s/10m
- Highly reproducible irradiation and counting positions (+/- 40 $\mu$m)
- Properly oriented target with respect to the irradiation beam and $\gamma$-ray detectors
- Soft acceleration and deacceleration
- Sample weight is not a speed limitation

Initially supported by NA-113

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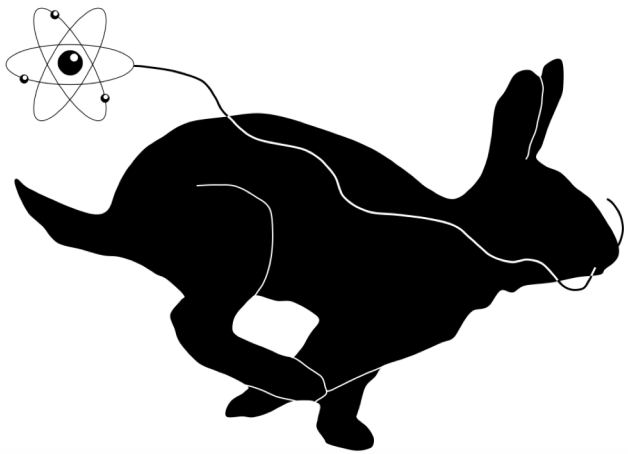

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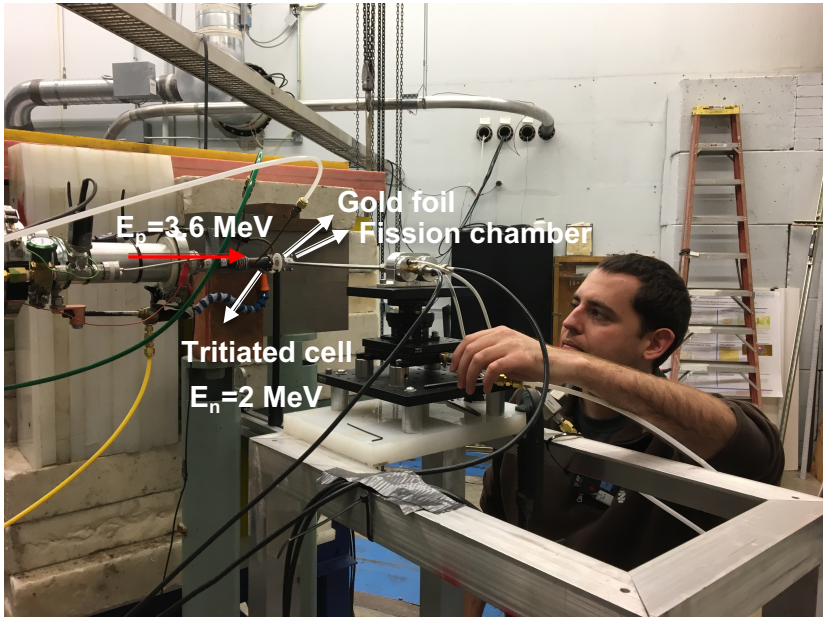
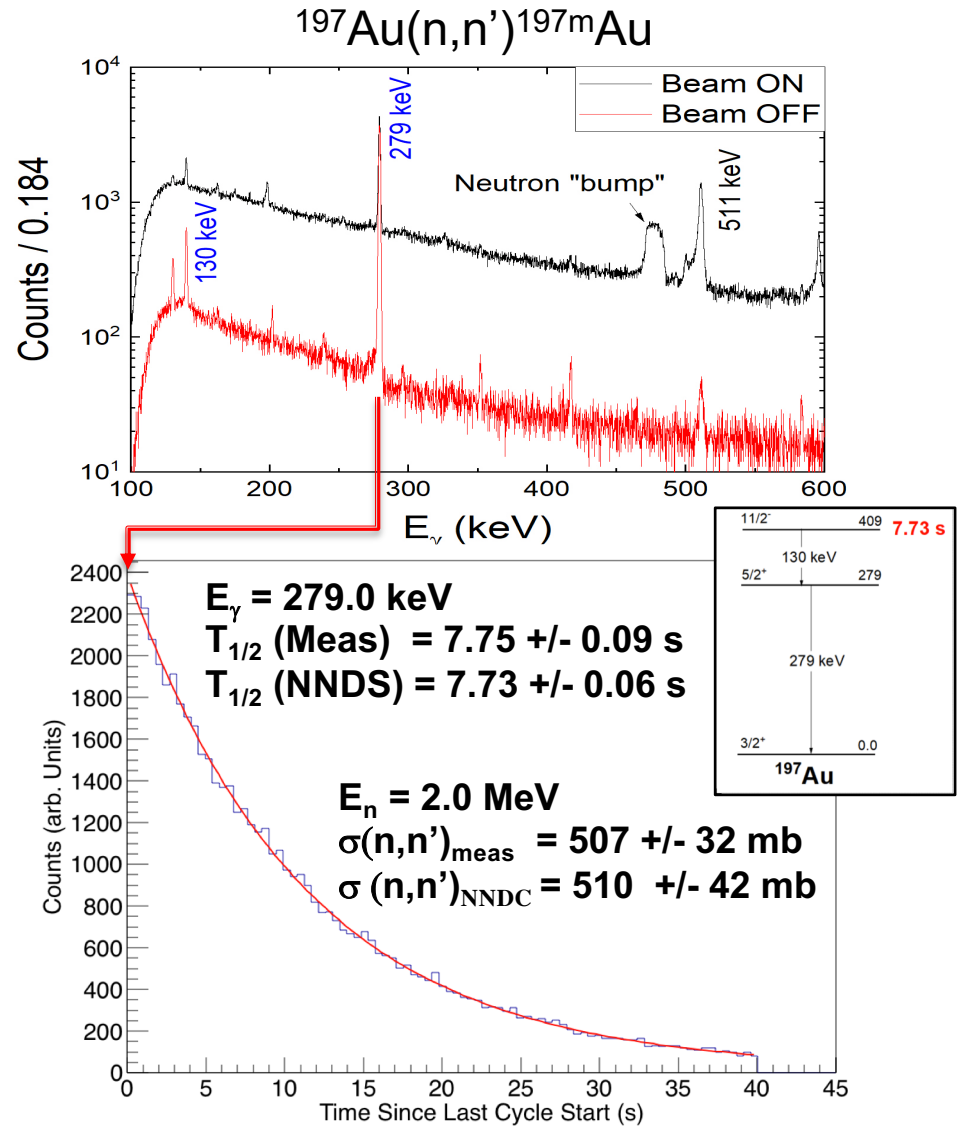
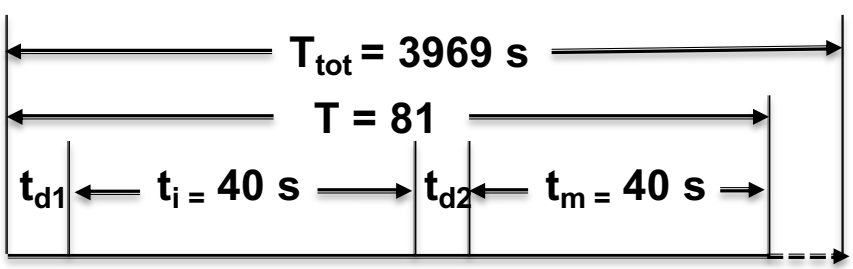
# Proof-of-principle: Establishing Gold Standard



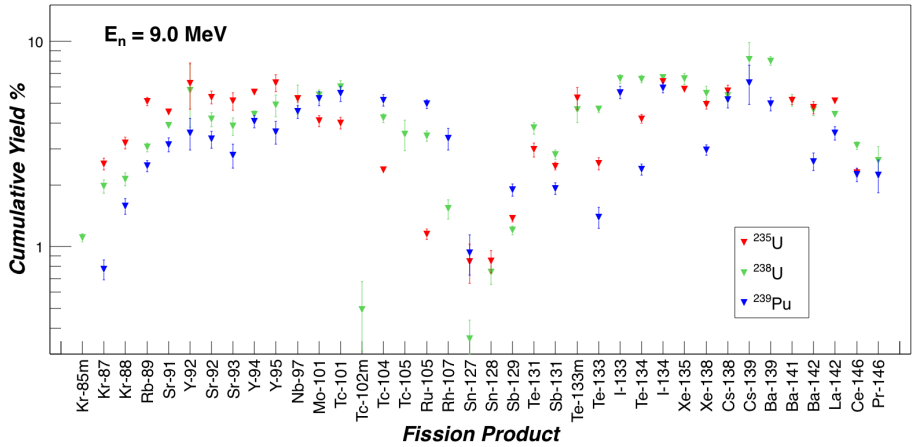



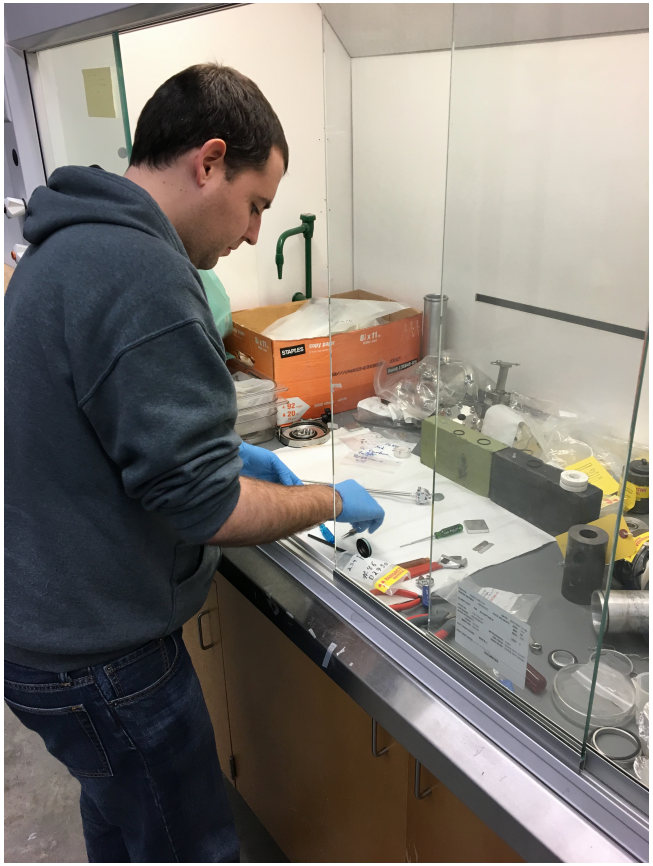

## Cycle information:



# Short-Lived Fission Product Yields (min – hours)

- **Three irradiations on $^{235}U$, $^{238}U$, and $^{239}Pu$ at 14.8 MeV**
  - **$t_{irr}$= 1 h**
  - **$t_{tra}$ ~ 4 minutes using the JACK-RABITT System**
  - **$t_{mea}$ = continuous one week of counting**
- **FPY data for more than 45 fission products with half-live of few minutes to a few days**
- **Time Dependent FPY information to the FIER* code**

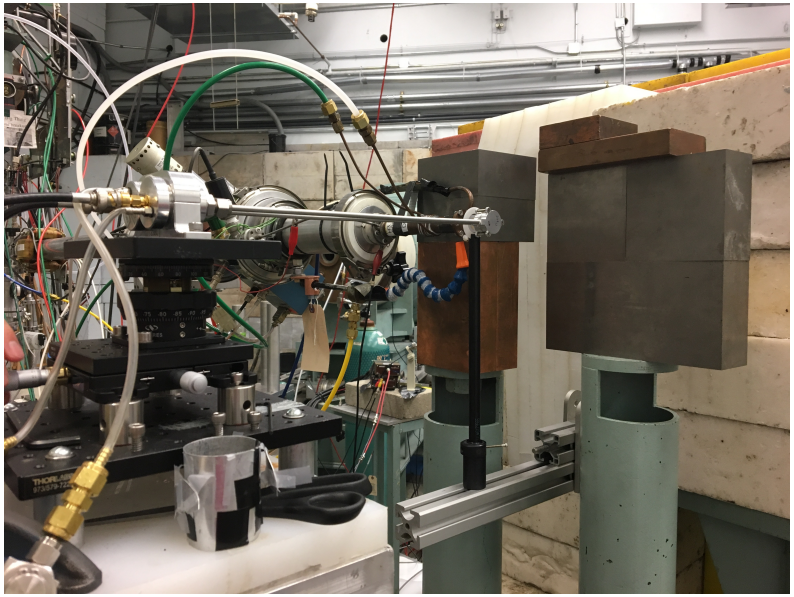


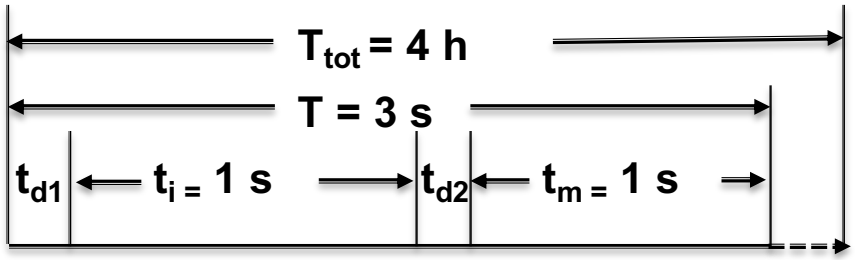
* E. Matthews *et al*. FIER code. NIMA A 891 (2018) 111–117

# Very Short-Lived Fission Product Yields (~1s)

- Three irradiations on $^{235}U$, $^{238}U$, and $^{239}Pu$ at 2.0 MeV
  - $t_{irradiation}$= 1 s
  - $t_{transition}$ ~ 0.5 s using the RABITT System
  - $t_{measurement}$ = 1 s, 5 s and 10s
  - $T_{tot}$ continuous of 4 h
- FPY data for with half-live of 1 second to a few minutes
- Time Dependent FPY information



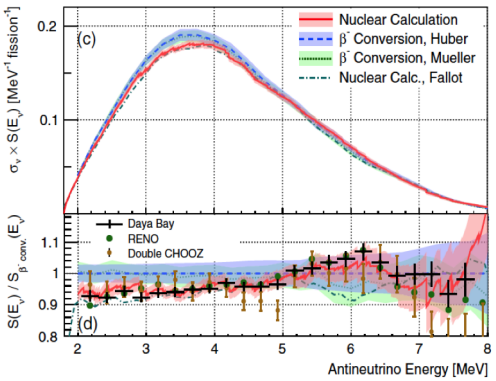
Cycle information:

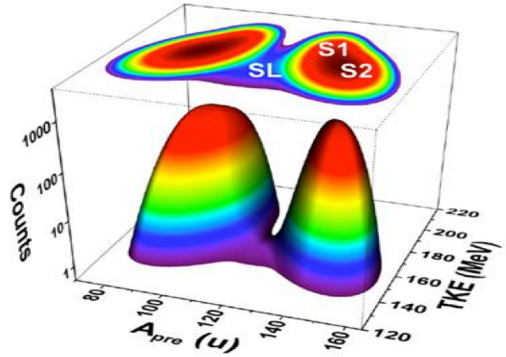



- ✓ Successful commissioning of the RABITT system
- ✓ The very short-lived FPY data is in our reach

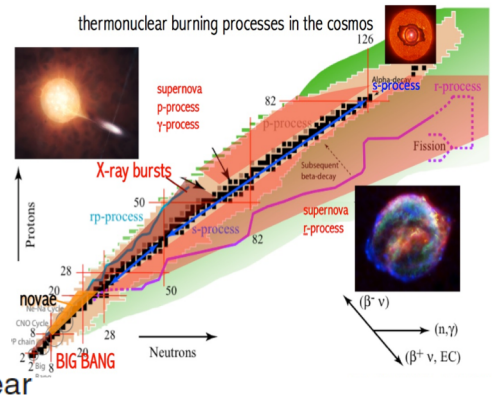
# Impact of the New Fission Product Yield Data

Basic Physics




New FPY data base




Reactor neutrino study

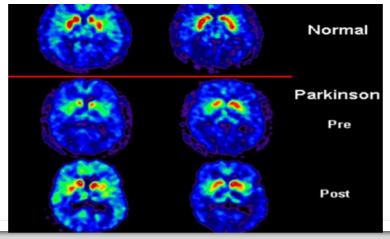
**Fission Product Yields**

Nuclear astrophysics and cosmochemistry

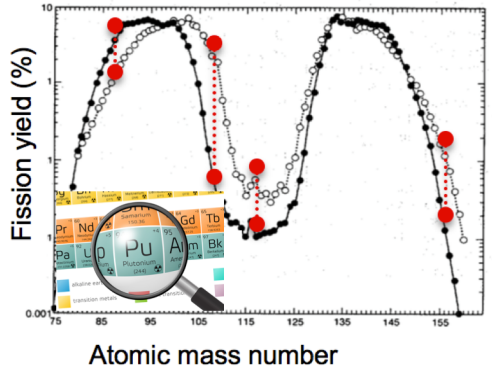
Nuclear Forensics

Nuclear energy

Radio-isotope production for medical applications




Application

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