Precise Measurements of The $^{238}U(n,2n)^{237}U$ Cross-Section by Activation at TUNL

Matthew Gooden

Nuclear Data Week at BNL

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Researchers

- **Duke**
  - Krishichayan → principal researcher
  - Werner Tornow
- **NC State**
  - Matthew Gooden*

* Currently a Postdoc at Los Alamos National Laboratory

Outline

- Motivation
- Experimental Setup
- Results
- Future

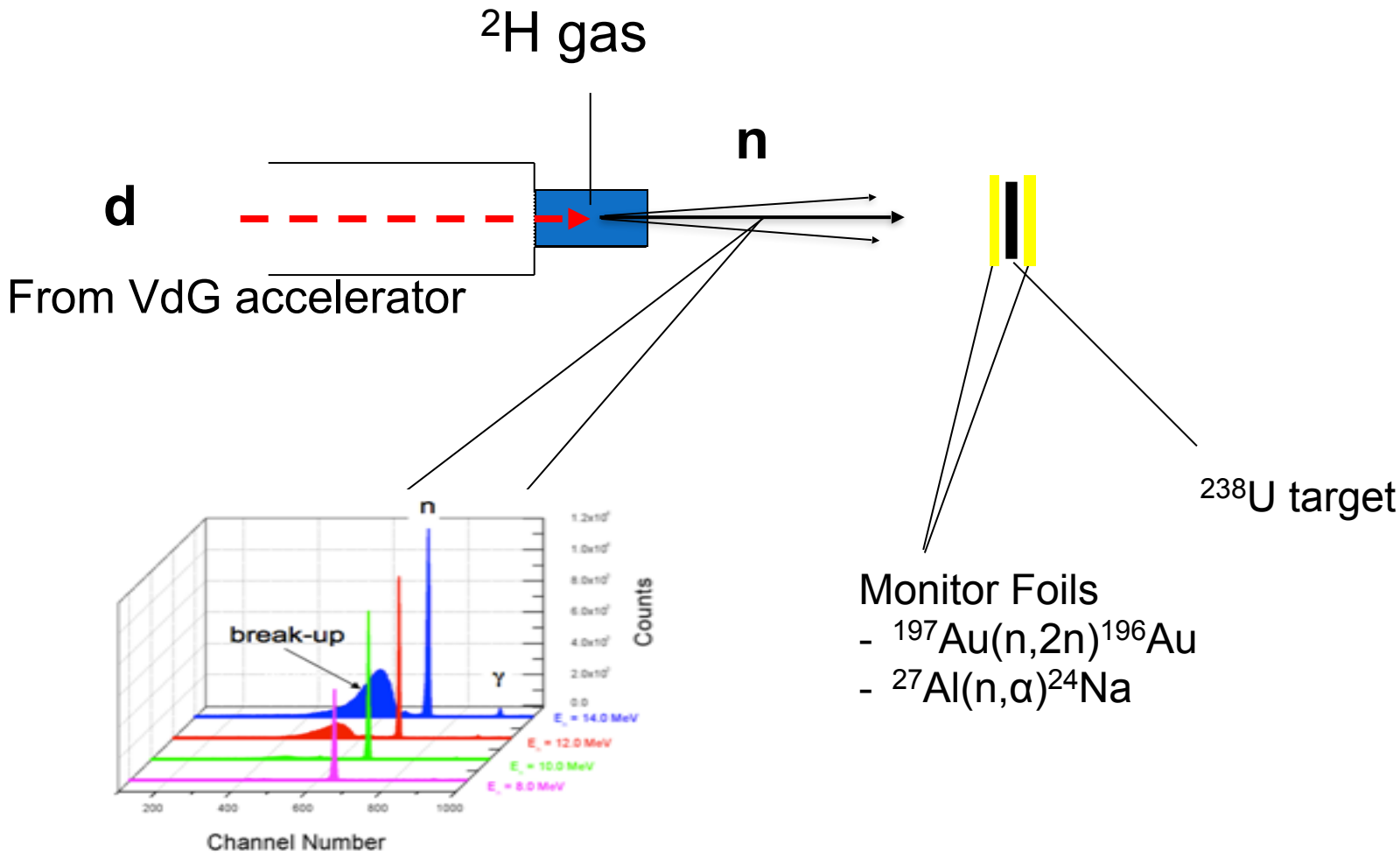
Motivation

- **Nuclear Database**
  - Database for Nuclear Device performance (i.e., fast reactor, advanced heavy water reactor)
  - Testing bench for nuclear models
  - Homeland security

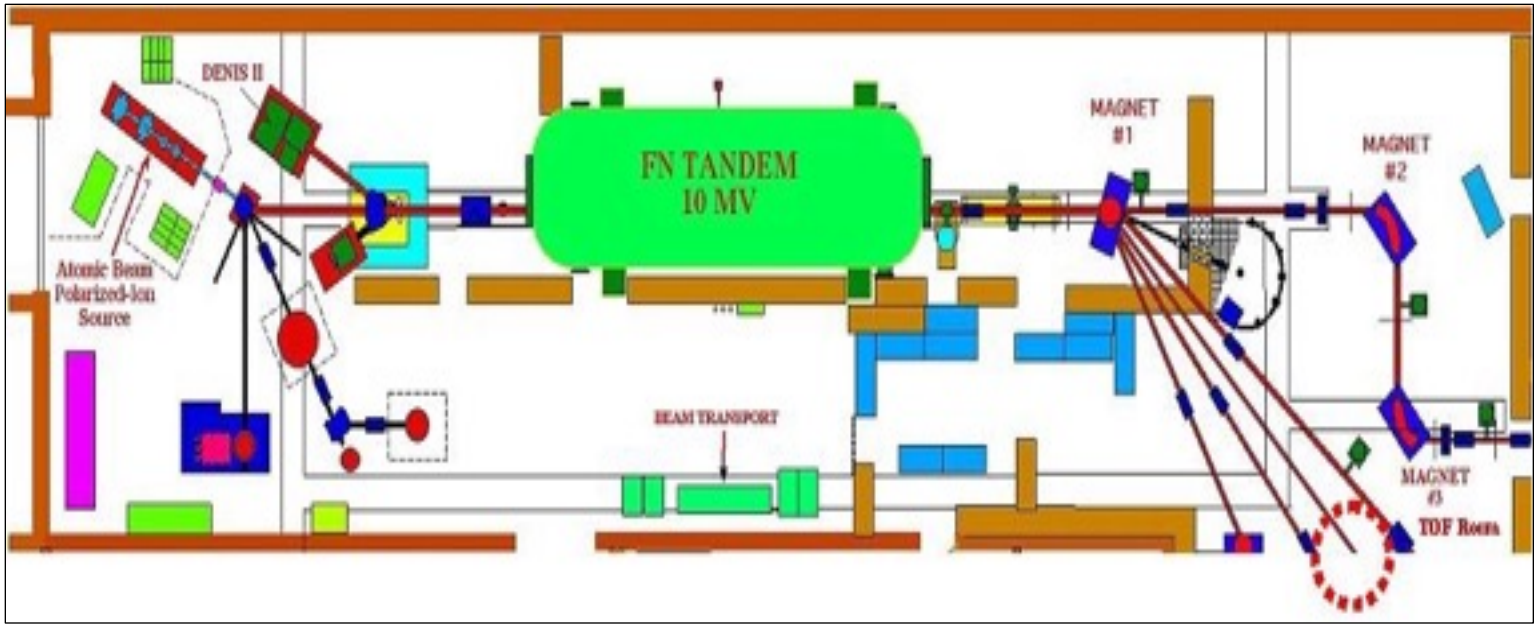
- **Existing data sets are discrepant**
  - Below ~14 MeV evaluations are discrepant
  - Each evaluation is relying on data which are discrepant by 20-30% from each other

Experimental Design

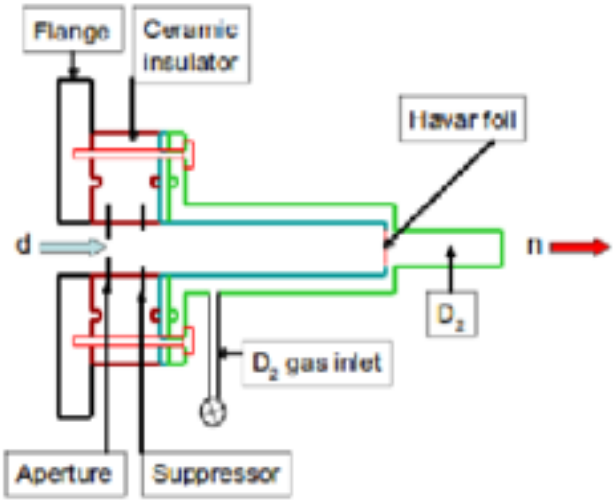
Monoenergetic Neutron Irradiation



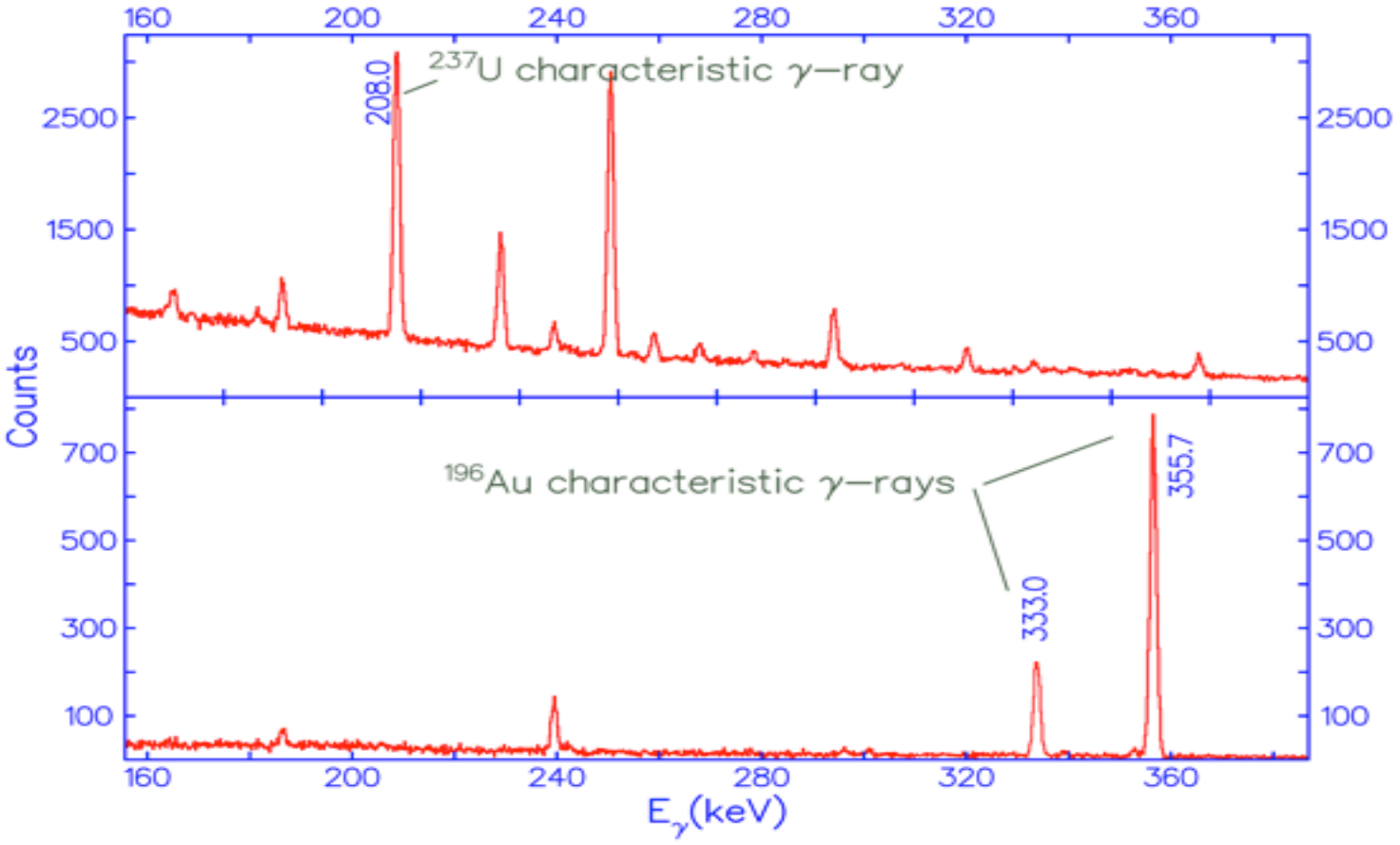
10 MV Tandem facility at TUNL

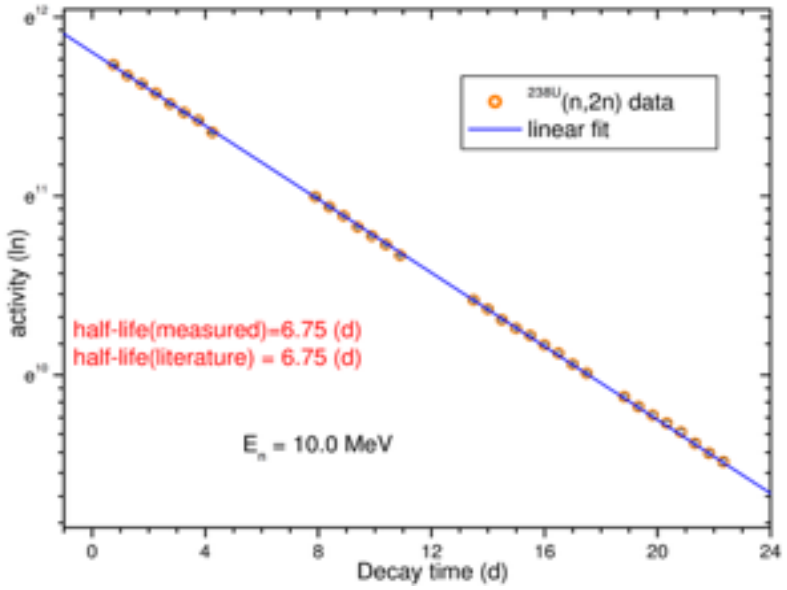


- Neutrons produced by:
  - $^{2}H(d,n)^{3}He$
  - $^{3}H(d,n)^{4}He$
- Target positioned 2.5 cm from end of neutron production source
  - ^{197}Au monitor foils on either side of target

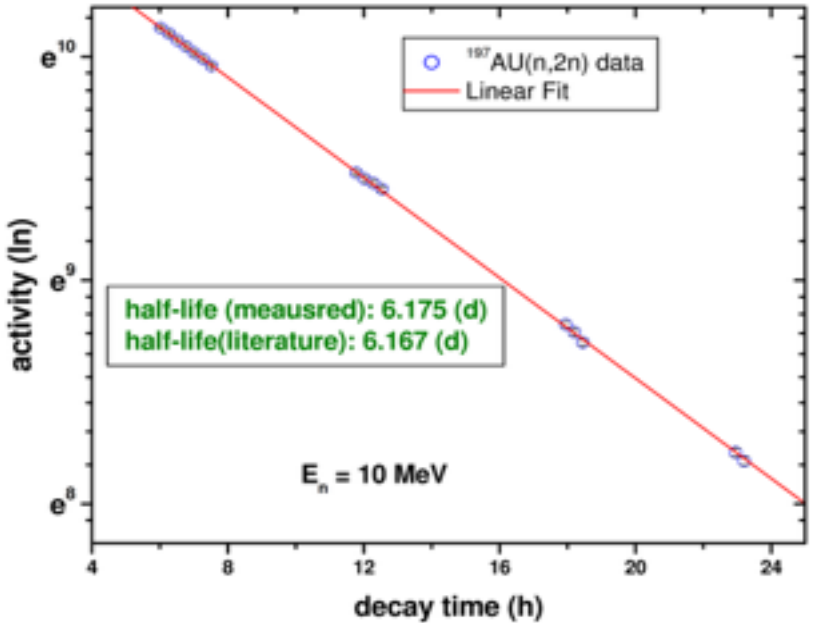


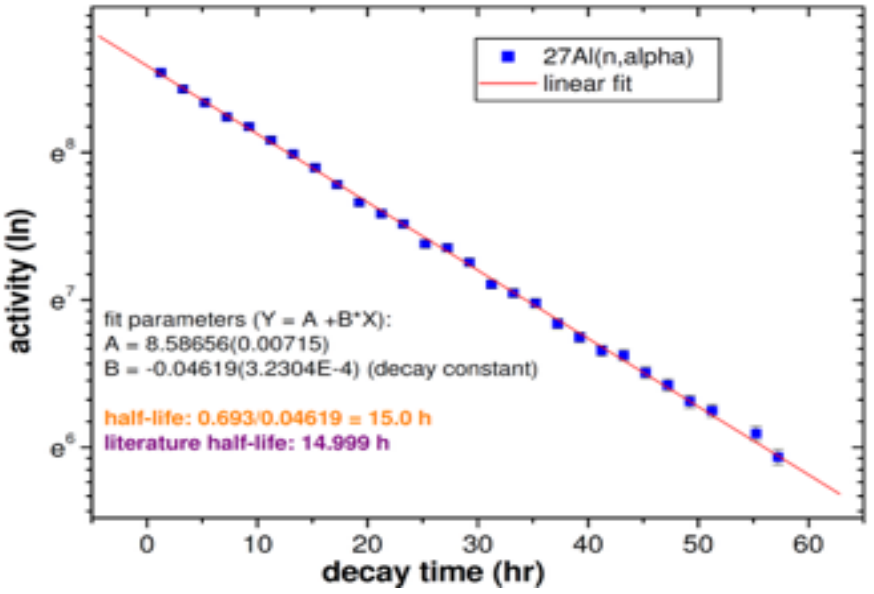
Characteristic gamma-lines belonging to ^{196}Au and ^{237}U





- **Decay curves for:**
  - **^{237}U**
  - **^{196}Au**
  - **^{24}Na**





Activation Method

$$\sigma = \frac{N_\gamma \lambda}{\phi \cdot \epsilon \cdot I_\gamma (1 - e^{-t_a \lambda}) e^{-t_d \lambda} (1 - e^{-t_m \lambda})}$$

N_γ = γ-ray counting yield

λ = decay constant for ^{237}U

ϕ = neutron flux given in n/(s·cm^2)

ϵ = γ-ray detector efficiency for line of interest

I_γ = Branching ratio for γ-ray line of interest

$t_{a,d,m}$ = times for activation, decay and measurement

- Neutron flux is determined with the same equation but relating to the activation foils were the cross-section σ is already known

Targets

- First measurements were done using the ^{238}U target from the TUNL-LANL-LLNL FPY measurements
  - 442 mg, 99.97% enriched

- LANL has provided 5 new ^{238}U targets which are being utilized to speed up data collection since the original target was being used in separate measurements

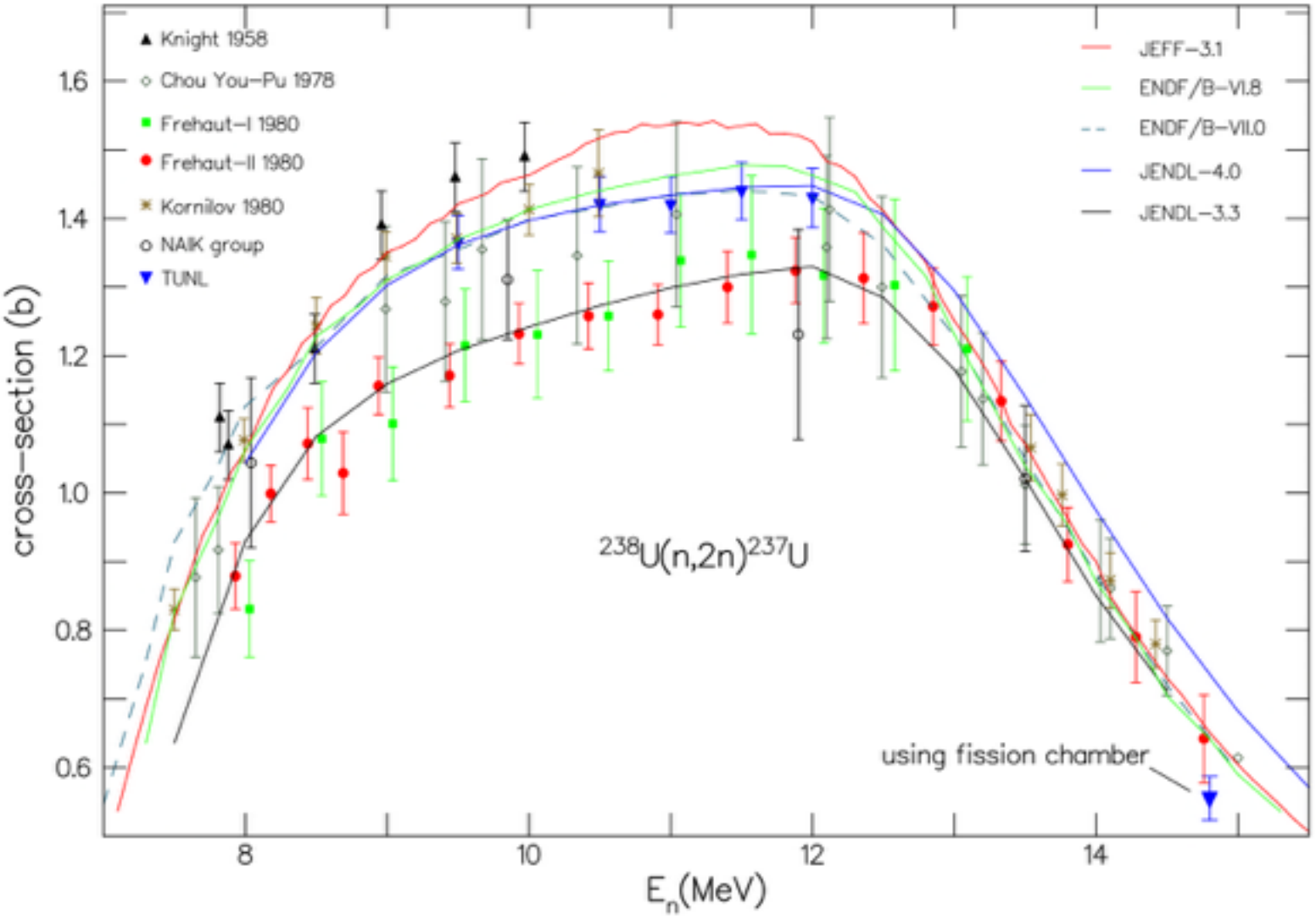
- The new targets are:
  - All enriched to 99.7%
    1) 172.5 mg
    2) 242.6 mg
    3) 240.8 mg
    4) 236.6 mg
    5) 260.7 mg

Current Status

E_n (MeV)	$^{197}Au(n,2n)^{196}Au$ σ (b)	$^{27}Al(n,\alpha)$ σ (b)	Flux (n/(s cm^2))	$^{238}U(n,2n)^{237}U$ σ (b)
9.5		0.079	2.75×10^7	1.36(0.04)
10.5	1.22		2.91×10^7	1.42(0.04)
11.0	1.42		2.93×10^7	1.42(0.04)
11.5	1.58		2.18×10^7	1.44(0.04)
12.0	1.71		1.97×10^7	1.43(0.04)

- Data also taken for:
  - 8.0, 8.5, and 9.0 MeV → analysis almost complete
  - 14.8 MeV* - taken on Friday
  - 7.5 MeV - taken on Sunday

Preliminary results



Summary

- Performed measurements at 9 incident neutron energies:
  - 7.5, 8.0, 8.5, 9.0, 9.5, 10.5, 11.0, 11.5, 12.0 and 14.8* MeV
  - repeating a measurement at 10.0 MeV
- Two separate & independent measurements were conducted at 14.8 MeV
  - Standard Activation with Au reference foils
  - Fission Chamber method - presenters talk from yesterday
- Both ^{197}Au and ^{27}Al reference foils were used and cross checked at 9.5 MeV
- The present data supports the JENDL-4.0 evaluation in the 8-12 MeV range
  - However, above 13 MeV the existing data are very consistent and JENDL predicts consistently higher cross-sections

THANK YOU

Preliminary results