Recent Measurements on ^{13}C, ^{7}Li, and ^{19}F using a digital Data Acquisition System at the University of Kentucky Accelerator Laboratory

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LLNL
Anthony Ramirez

- UnivKY Lab Overview
- dDAQ
- 13C
- 7Li
- 19F

U.S. DEPARTMENT OF ENERGY

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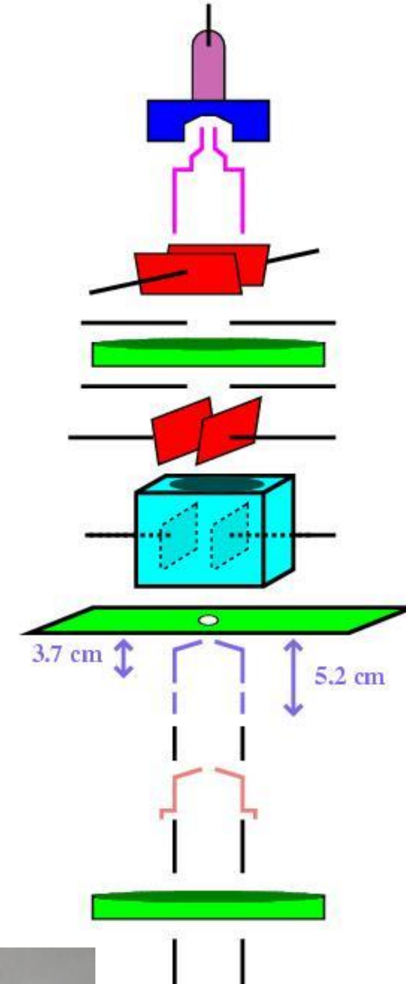
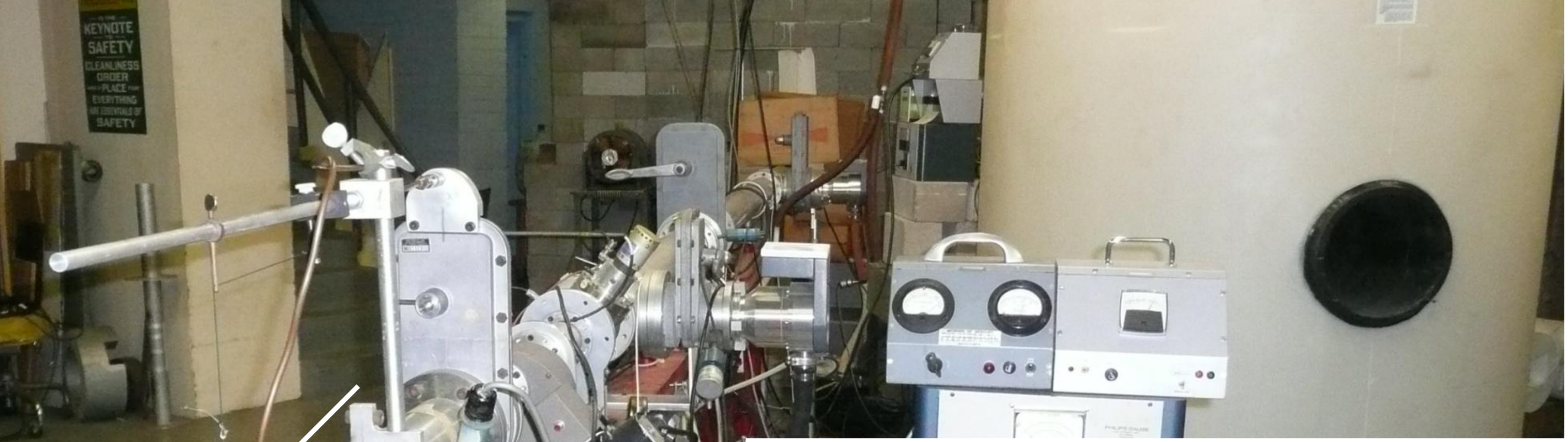
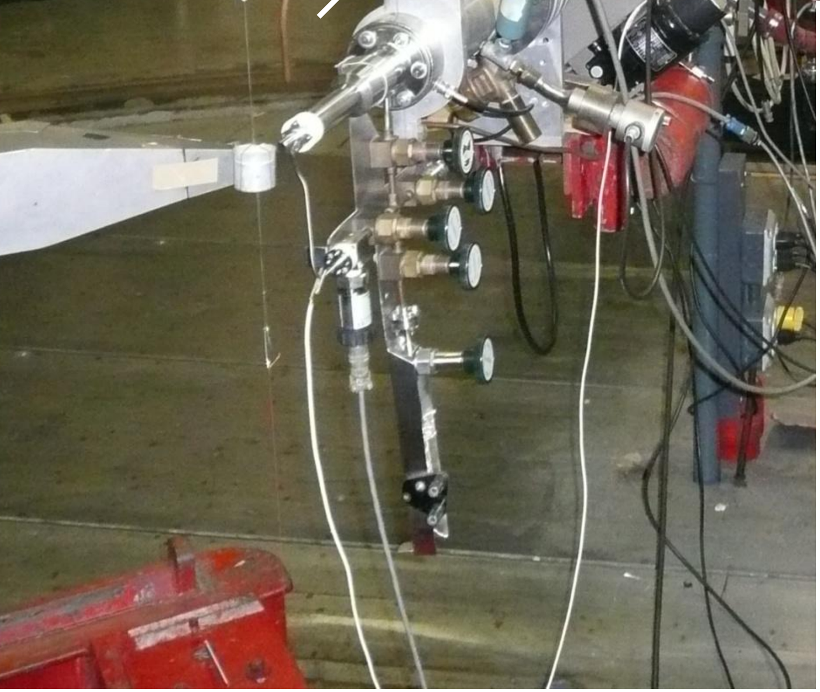
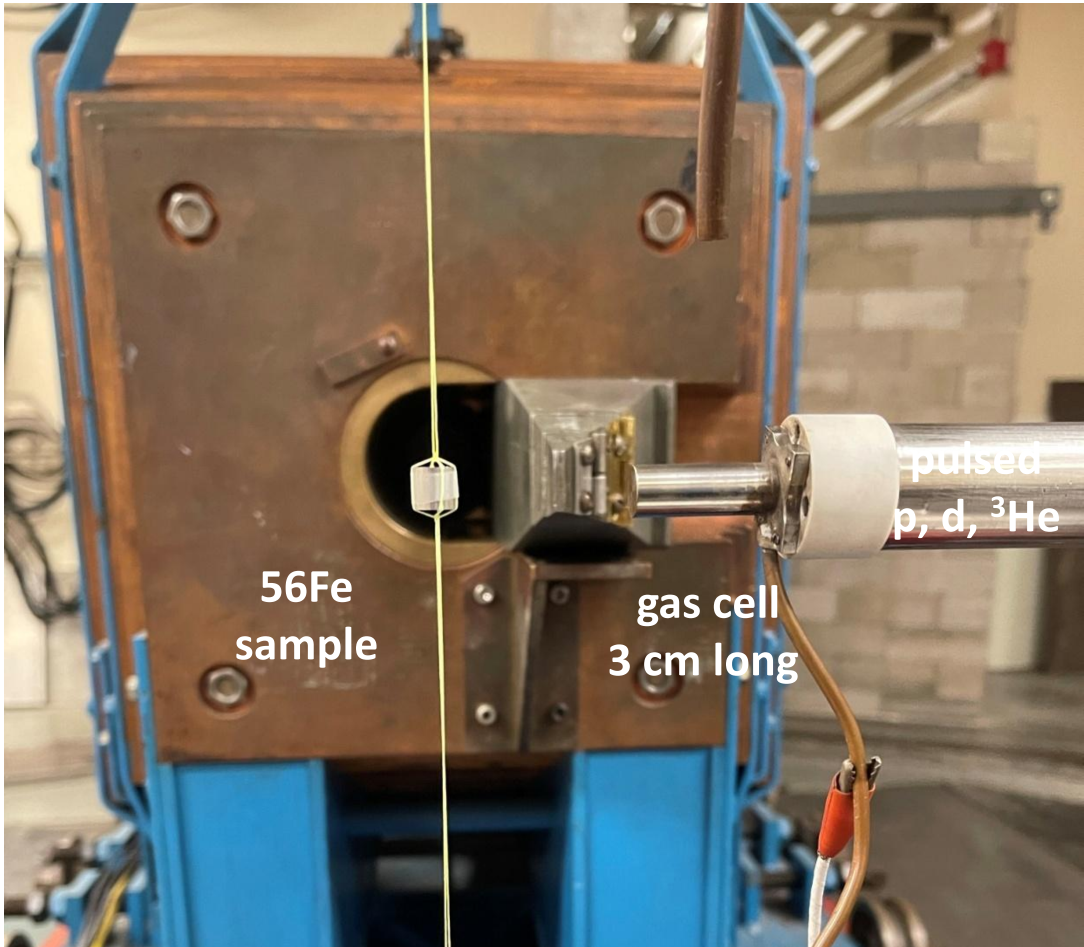
SC0021424, SC0021243, SC0021175, SSC000056

- **Accelerator**
  - HVEC Model CN: 7 MV
  - rf source
  - p, d, ^{3}He, α, … ions
  - Authorized for ^{3}H gas targets
  - measure exit neutron energy
  - 1 ns pulse widths every 533 ns
- **Basic Nuclear Science**
  - Nuclear Structure via (n,n'γ)
    - Level Schemes & Transitions
    - Spectroscopic Information
    - DSAM Lifetimes
  - (^{3}He,nγ)
- **Applied Nuclear Science**
  - Differential (n,n') Cross Sections
    - ^{12,13}C, ^{7}Li, ^{19}F , ^{54,56}Fe , ^{23}Na , ^{28}Si
  - Detector Development
    - Univ Guelph / TRIUMF
    - UKnox / UNLV
    - RMD



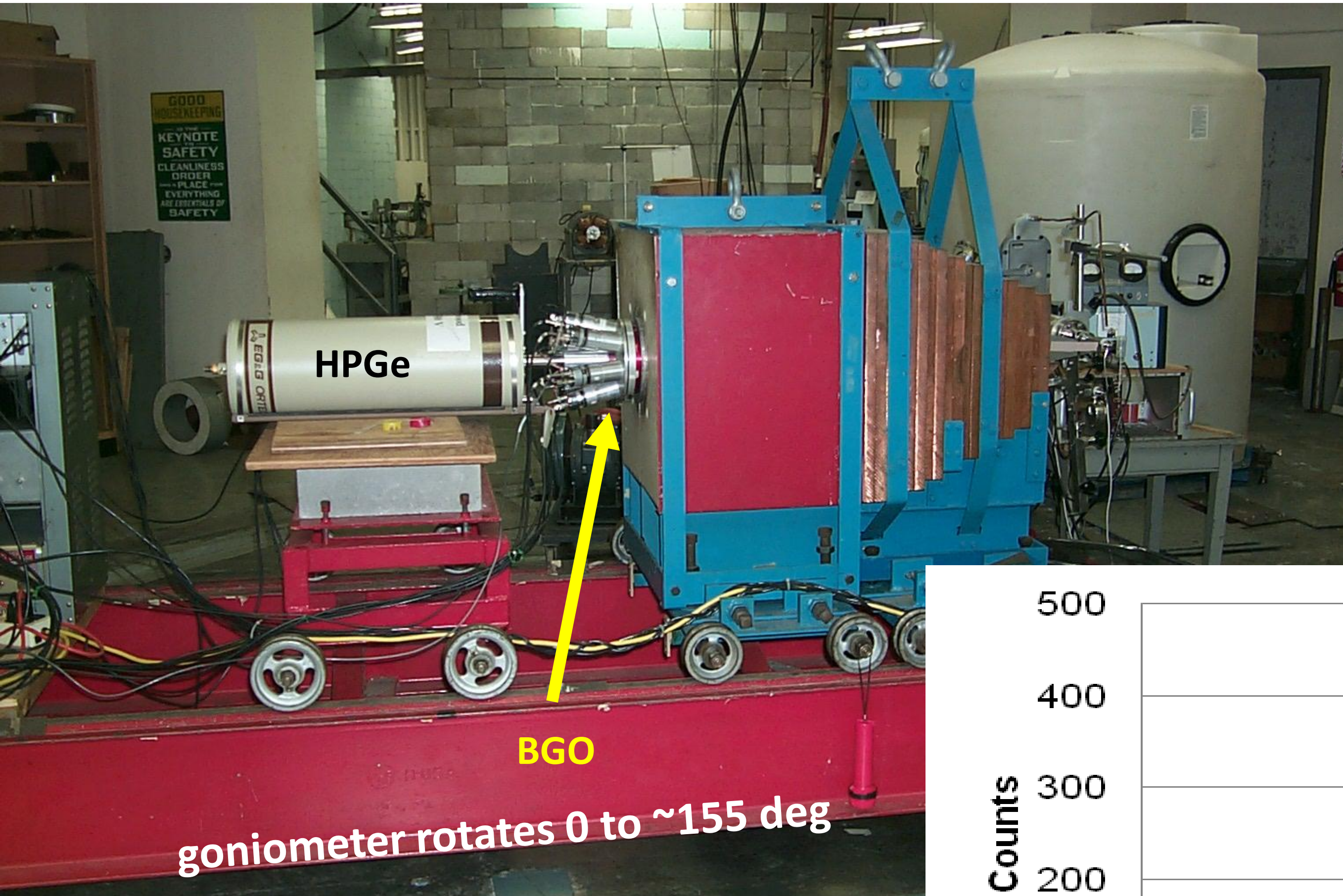

KEYNOTE
SAFETY




56Fe
sample
gas cell
3 cm long
pulsed
p, d, 3He

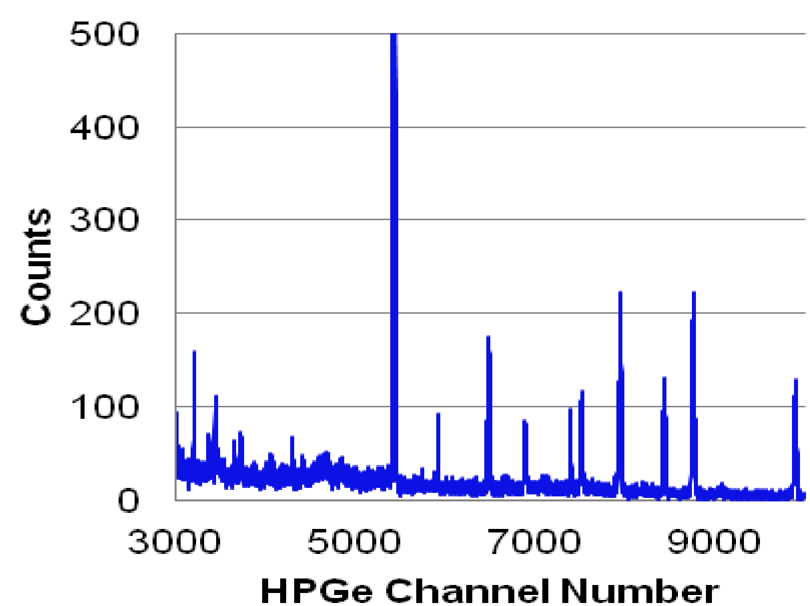
γ-Ray Detection (singles setup)

TOF gated on γs



BGO removes Compton events

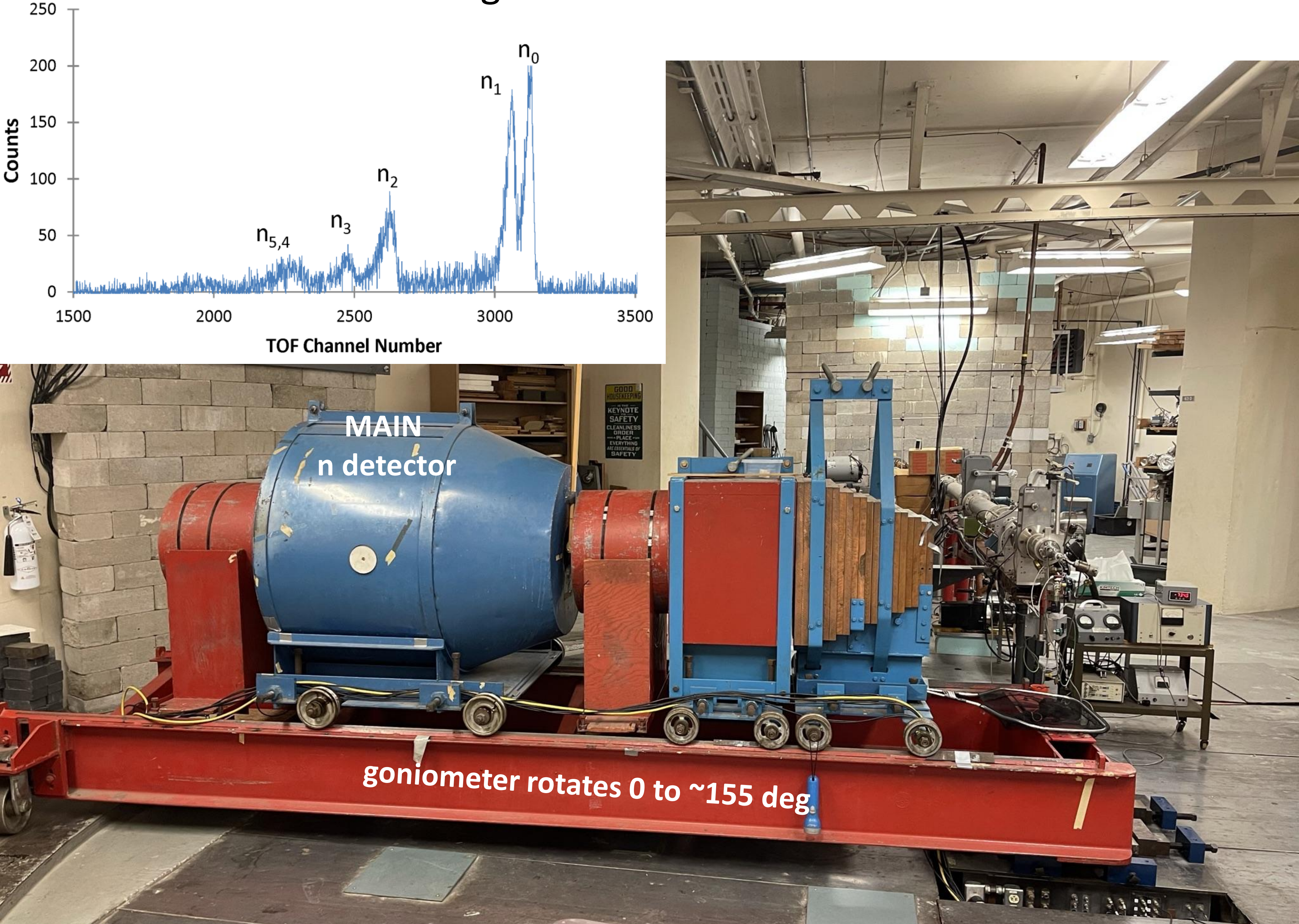
pulsed beam allows for uncorrelated background rejection
~ 1 good / 4 total

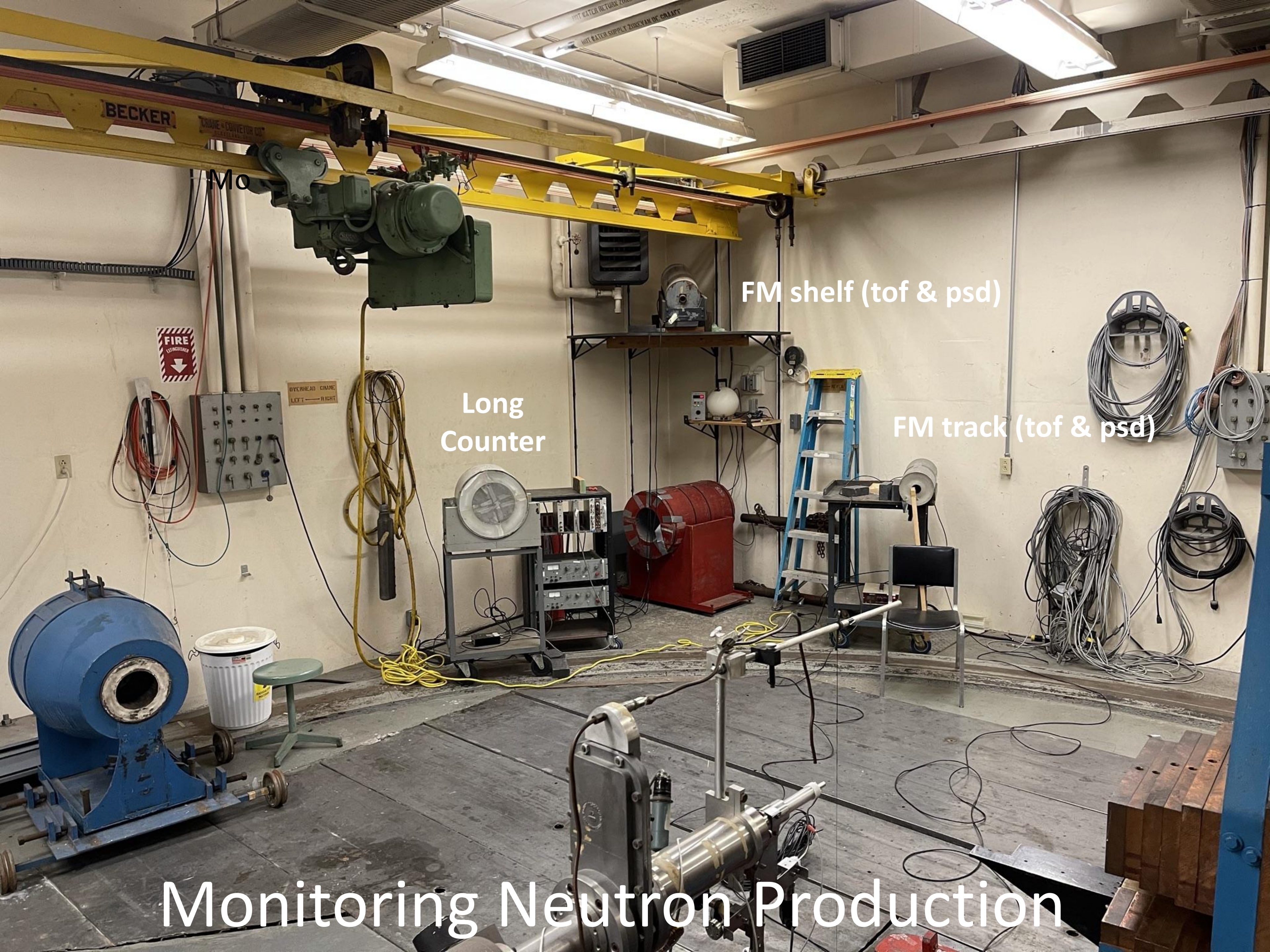


Purchasing new HPGe.

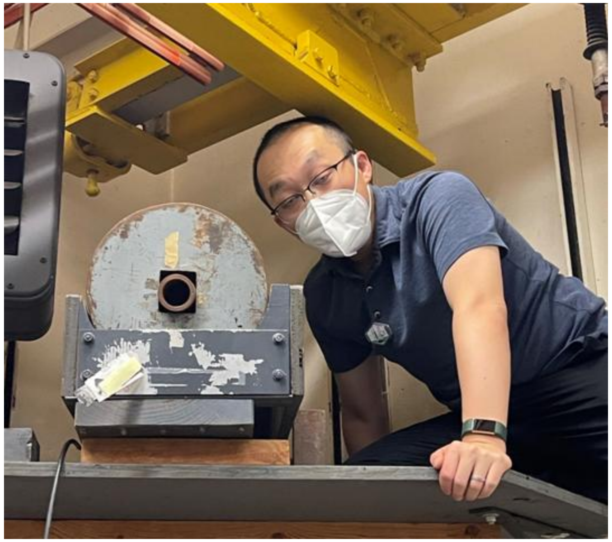
Hope to do γ–γ coincidence again.

Neutron Time-of-Flight




Mo
FM shelf (tof & psd)
Long Counter
FM track (tof & psd)
BECKER
FIRE
Monitoring Neutron Production

Yongchi Xiao



V1730 500 MS/s
scintillators nTOF
MAIN & FM
beam pulse

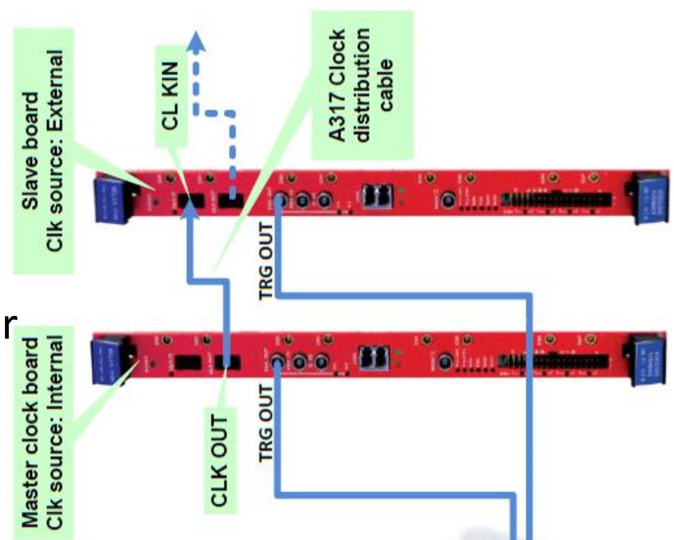
V1782 100 MS/s
HPGe
Long Counter

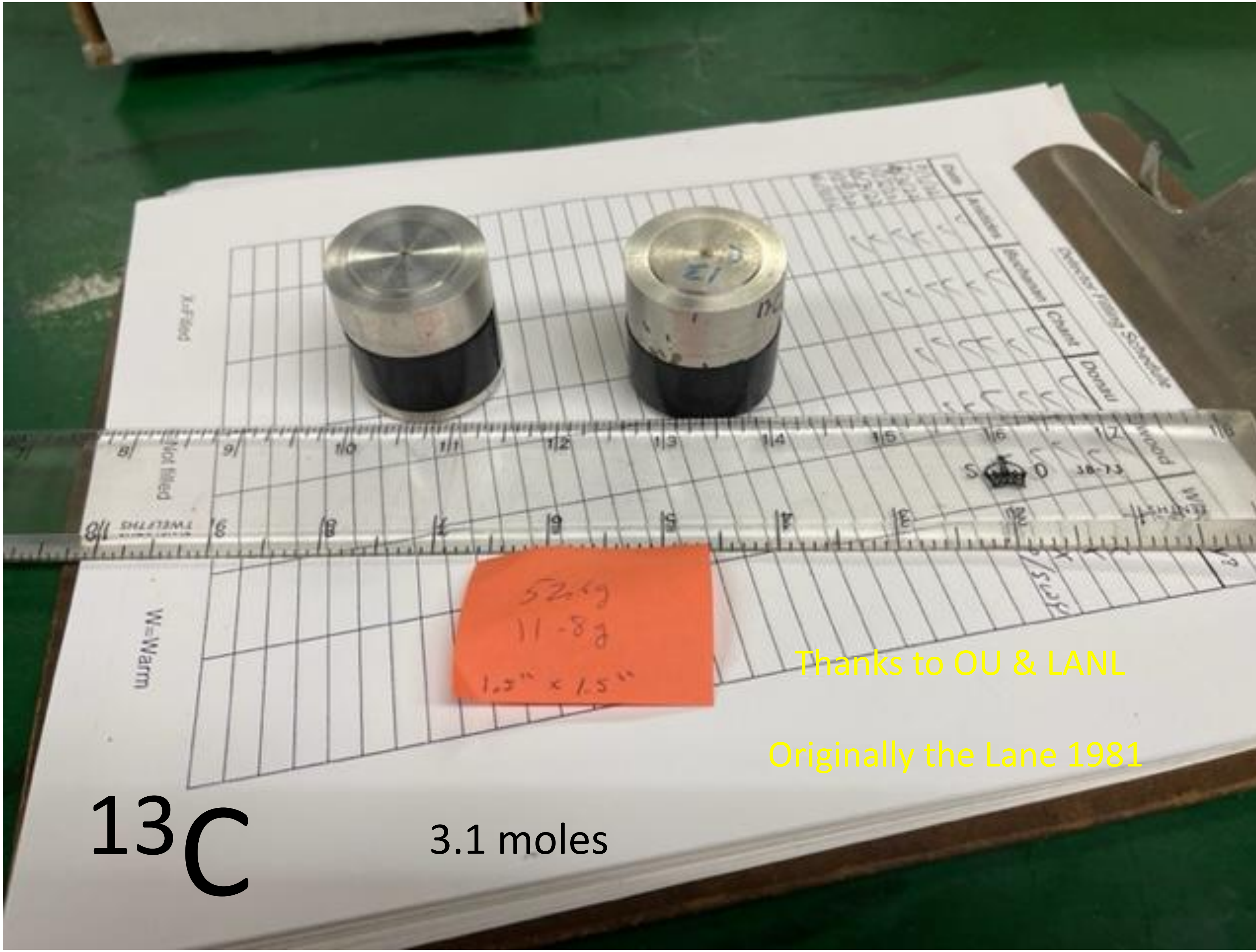
+ can record time-dependent γ-ray spectra
+ observe time dependence of background
+ trapezoidal filter can be fine tuned for each detector, kinda
+ can replay data & change your mind about settings
+ n detector efficiencies less of a hassle
+ can actually digitize the 1.875 MHz beam pulse

- can't do detailed live-monitoring of data coming in
- time consuming development, testing, refining
- modules may not perform as expected or play well together

  CAEN did not think about some things

- γ peak shapes fill hard disks & buffers fast
- new ways to do things wrong





^{13}C

3.1 moles

Thanks to OU & LANL

Originally the Lane 1981

Previous work on 13C

PHYSICAL REVIEW C VOLUME 23, NUMBER 5 MAY 1981

States in ^{14}C from σ_T and $\sigma_{el}(\theta)$ for ^{13}C$+n$: Measurement, R-matrix analysis, and model calculations

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University of California, Los Alamos National Scientific Laboratory, Los Alamos, New Mexico 87545

(Received 16 October 1980)

Experimental σ_{tot} total Cross section measured at the old LANL Tandem.

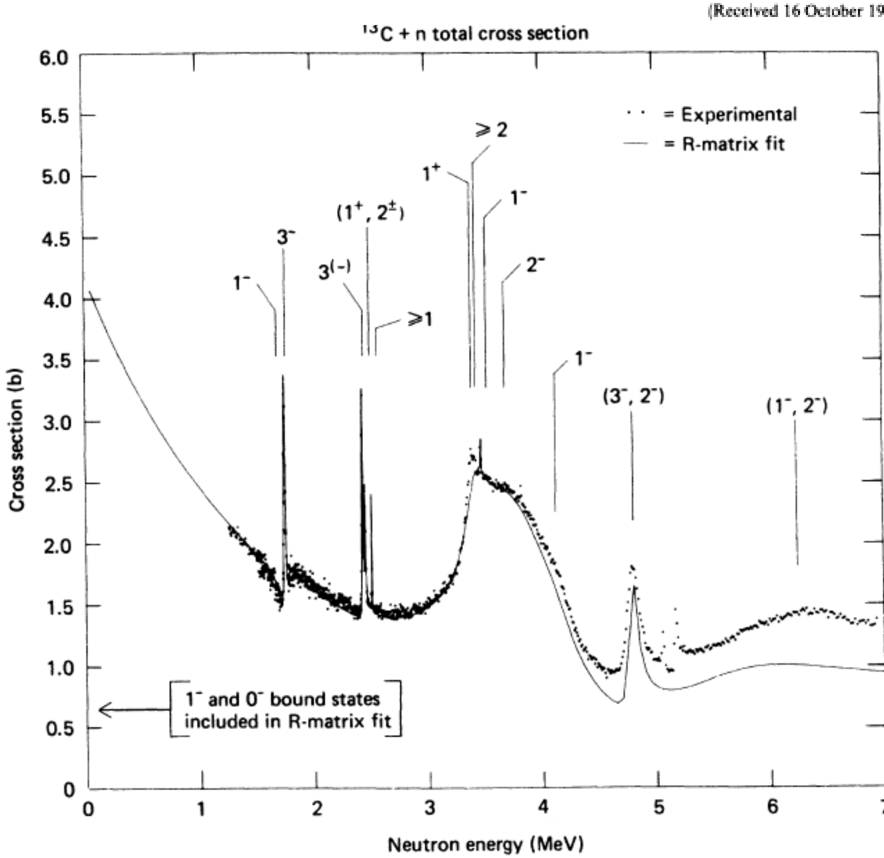


FIG. 3. Total cross section σ_T (points) from Ref. 7 and integrated elastic scattering cross section σ_{el} (curve) from R-matrix analysis for ^{13}C$+n$. The J^π assignments and approximate locations for states in ^{14}C resulting from the R-matrix analysis are indicated in the figure. Only a representative number from the full set of data points for σ_T are shown to portray adequately the features of the total cross section. The scatter in the points is taken as the measure of errors on σ_T. For the 1⁻ resonance near 1.75 MeV the location of the resonance dip is indicated rather than the calculated resonance energy (see Fig. 4).

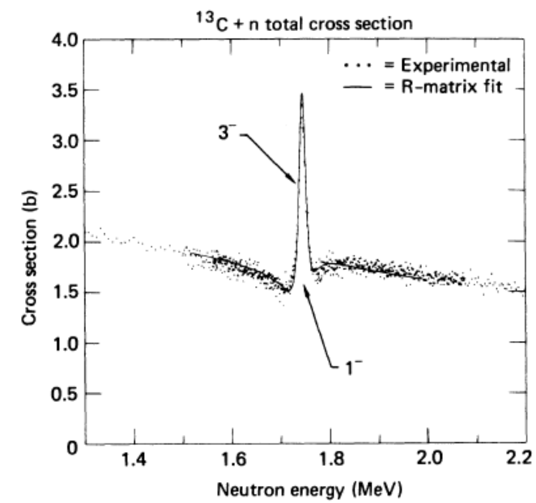
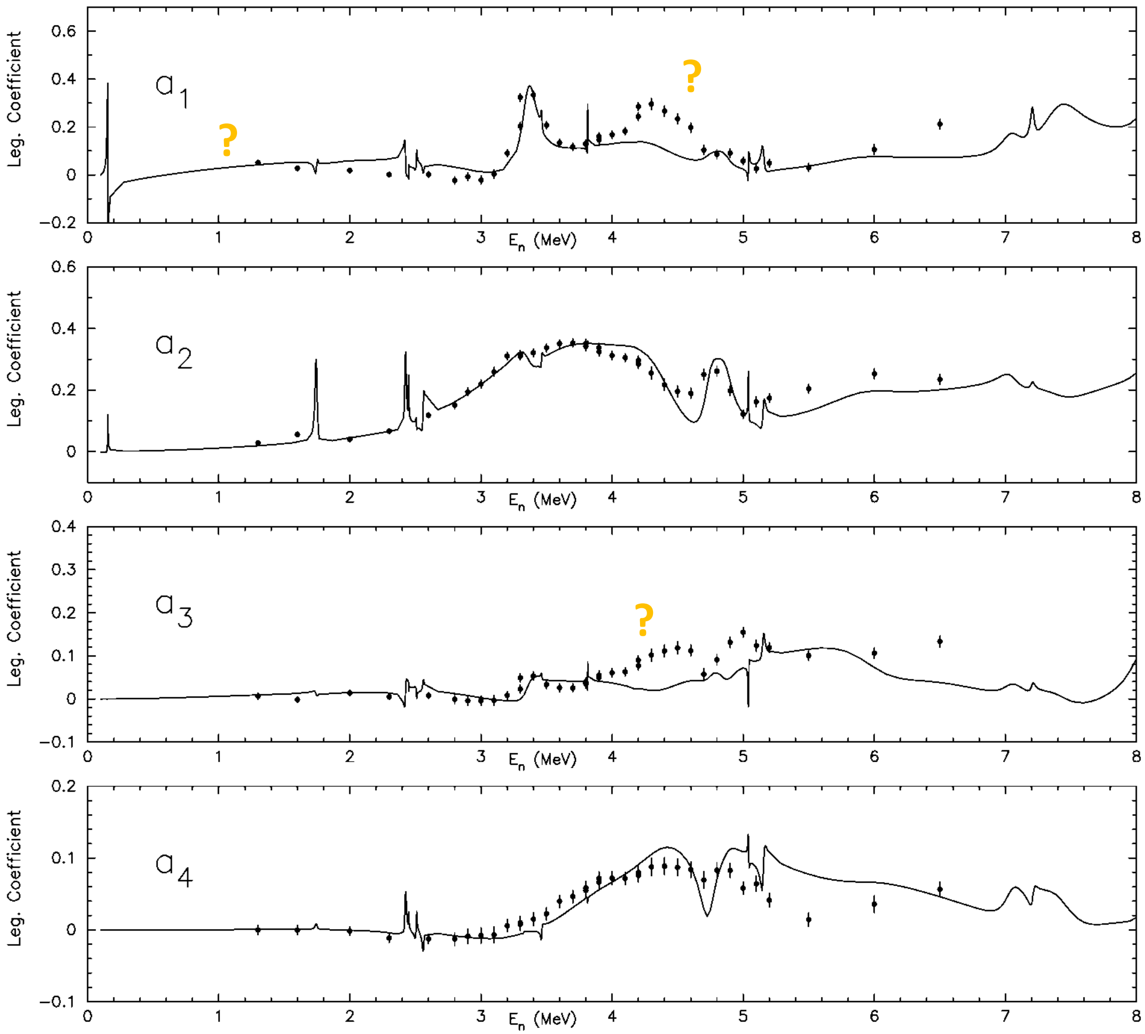


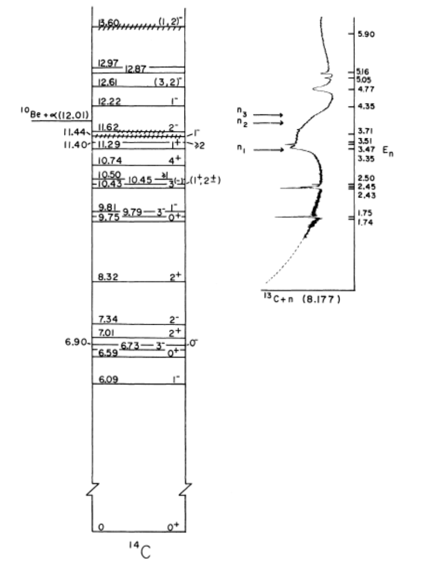
FIG. 4. Expanded plot of the total cross section (points) from Ref. 7 and integrated elastic scattering cross section (curve) from R-matrix analysis for ^{13}C$+n$ for the resonances near 1.75 MeV. The curve has been averaged over the experimental resolution of FWHM =3.5 keV. Note that in Table I the energy of the 3⁻ resonance (peak) is actually slightly lower than that of the 1⁻ resonance (dip). The apparent reversal of this order occurs in this case because of the slight asymmetry of the 1⁻ dip and the nearly equal energies of the resonances. The full data set for σ_T is shown from $E_n \simeq 1.6$ to 2.0 MeV while only a partial set is displayed outside this region to aid in relating to other figures. The scatter in the points is taken as a measure of the errors.

Comparison of the ENDF8.0 Legendre Coefficients compared to the coefficients from the LANE1981 experimental measurements.



There's also a significant discrepancy btw 4-5 MeV

The LANE1981 coefficients were obtained by fitting the LANE 1981 data posted in EXFOR.

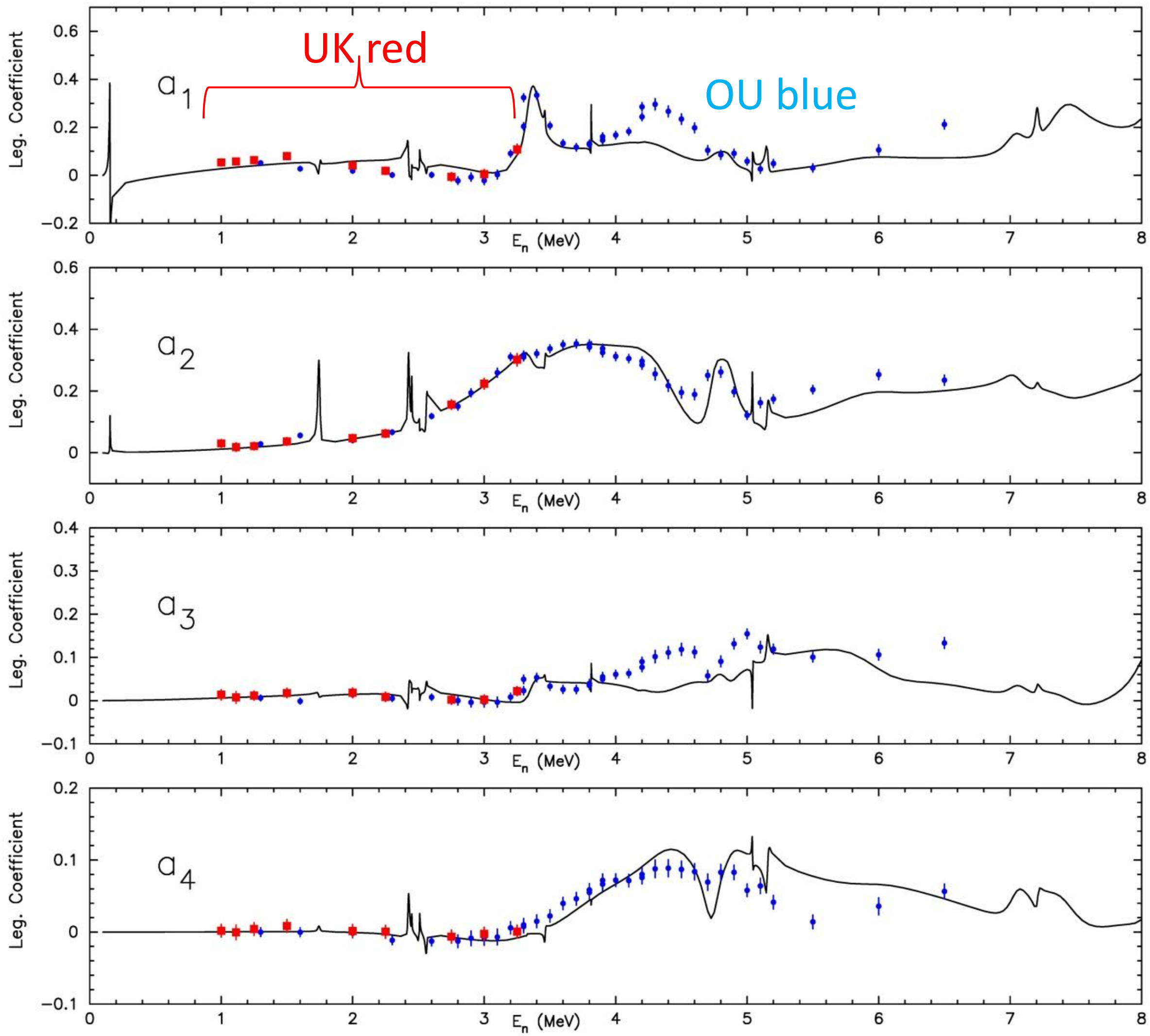


There are discrepancies btw current ENDF & the 1981 experimental measurements.

There are few measurements below 2 MeV which are important for encorporating subthreshold resonances and potential scattering.

Alan Carlson (NIST), Gerry Hale, & Mark Paris (LANL) want us to measure elastic angular distributions from as low as we can go and connect into the OhioU data. --- that's 0.5 MeV to 3 MeV.

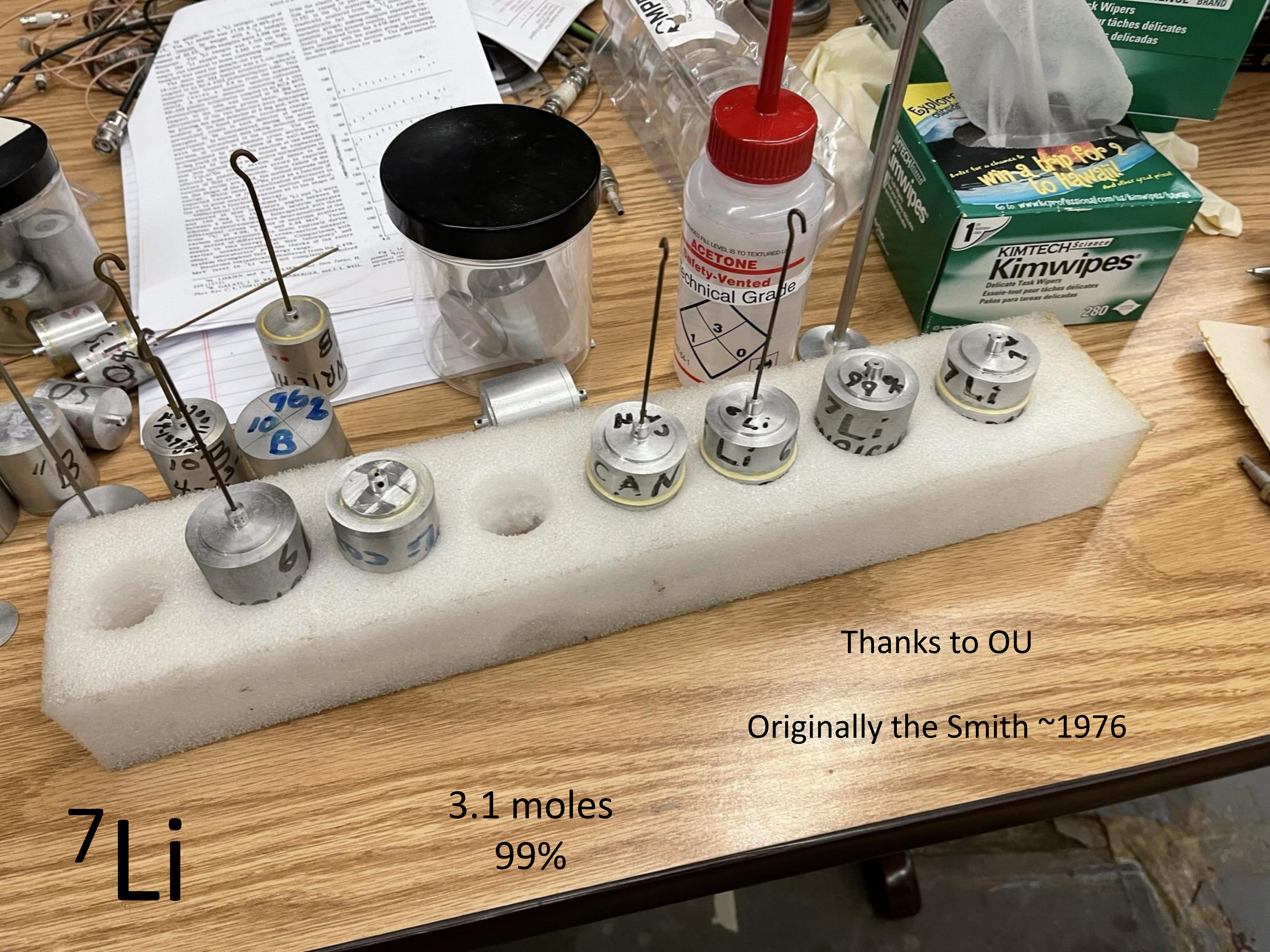
13C Elastic Legendre Coefficients (ENDF convention)



So far,
we are
right on the money !

We need to
go lower & check out
the 4-5 MeV region

Need to load ENDF/B-VIII.0 into MCNP
& run jobs to simulate energy dependence of 1,2,3 scatters
-- impacts how one strips the yield out of TOF spectrum

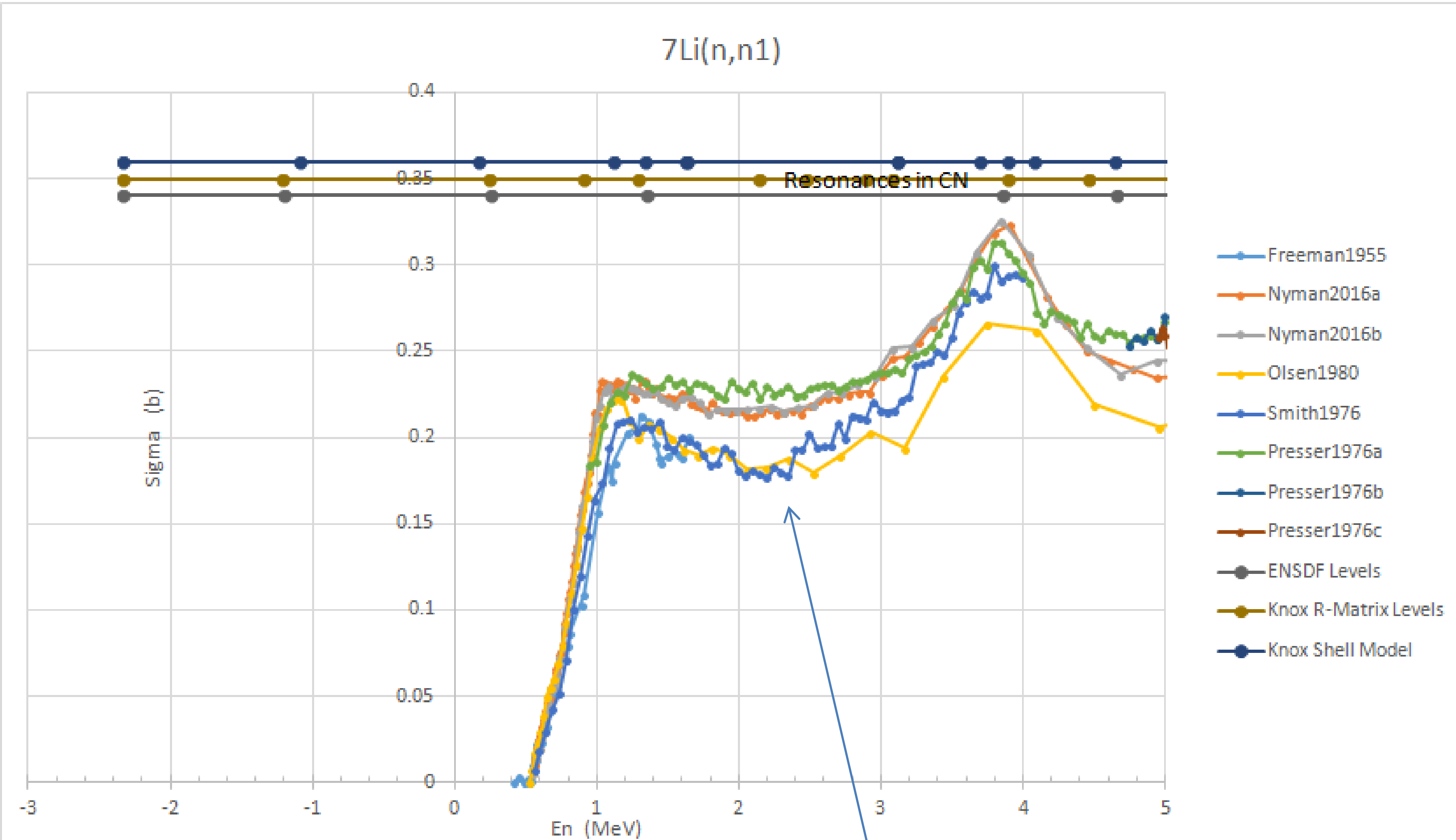


Thanks to OU

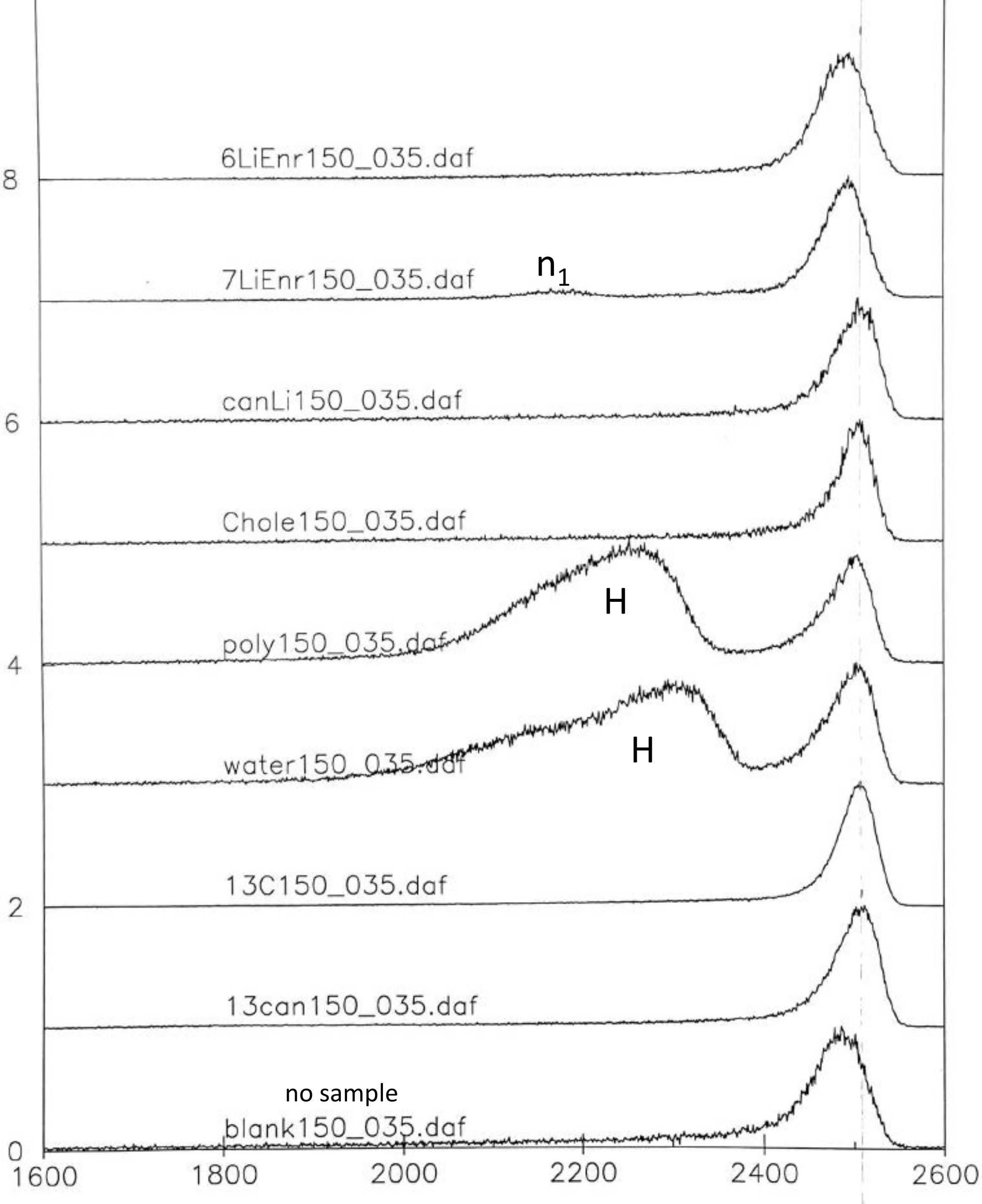
Originally the Smith ~1976

^{7}Li

3.1 moles
99%



a difference of opinions



All raw spectra at 035deg

Spectra are scaled to the same height

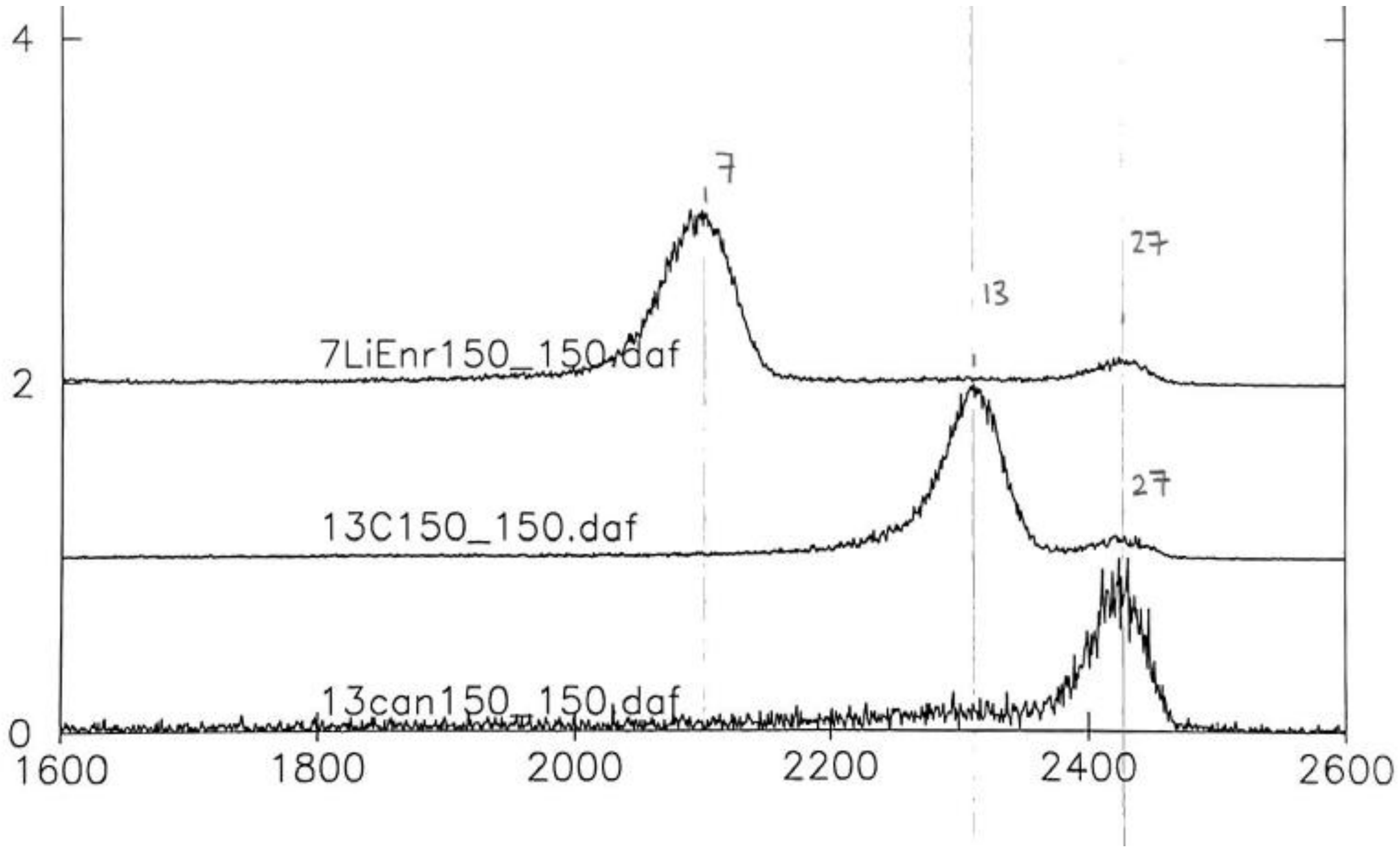
The poly and water samples indicate where H feature would occur in the ntof spectra. No hydrogen appears in any sample.

The small feature at c2150 in the 7Li spectrum is the 477keV 1st inelastic level.

Masses are not resolved for the heavier C, O, Al peaks.

The shape of the H is different in the water & poly samples.

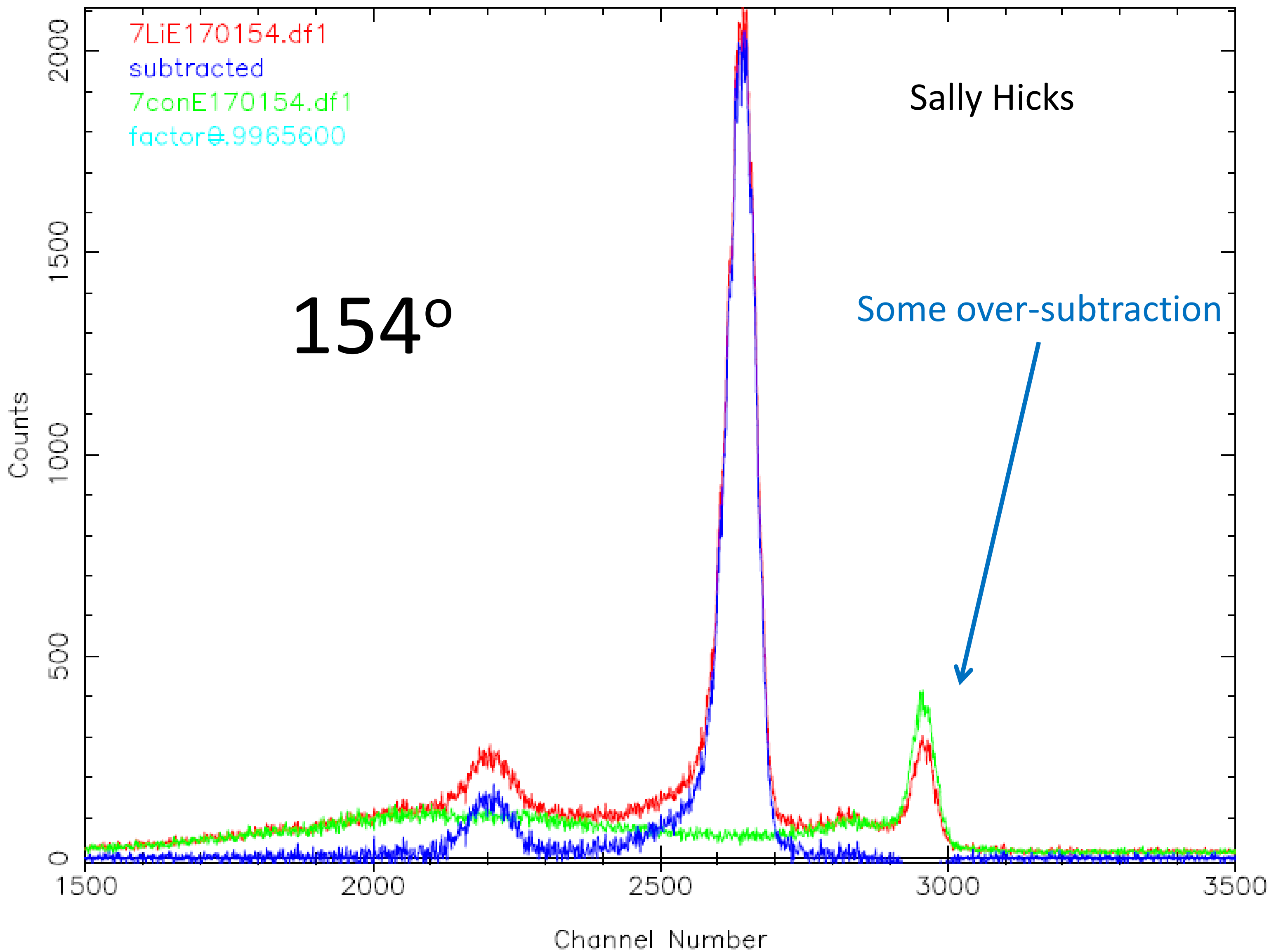
Ohio University loaned us historical enriched metal targets.
Targets appear free from N and O contamination



150deg provides the best separation between masses. The 7Li and 13C have a small bump at mass 27 from their Al containers. No N or O contaminants are observed for either the 7Li or 13C, and there's no obvious 12C in the 13C.

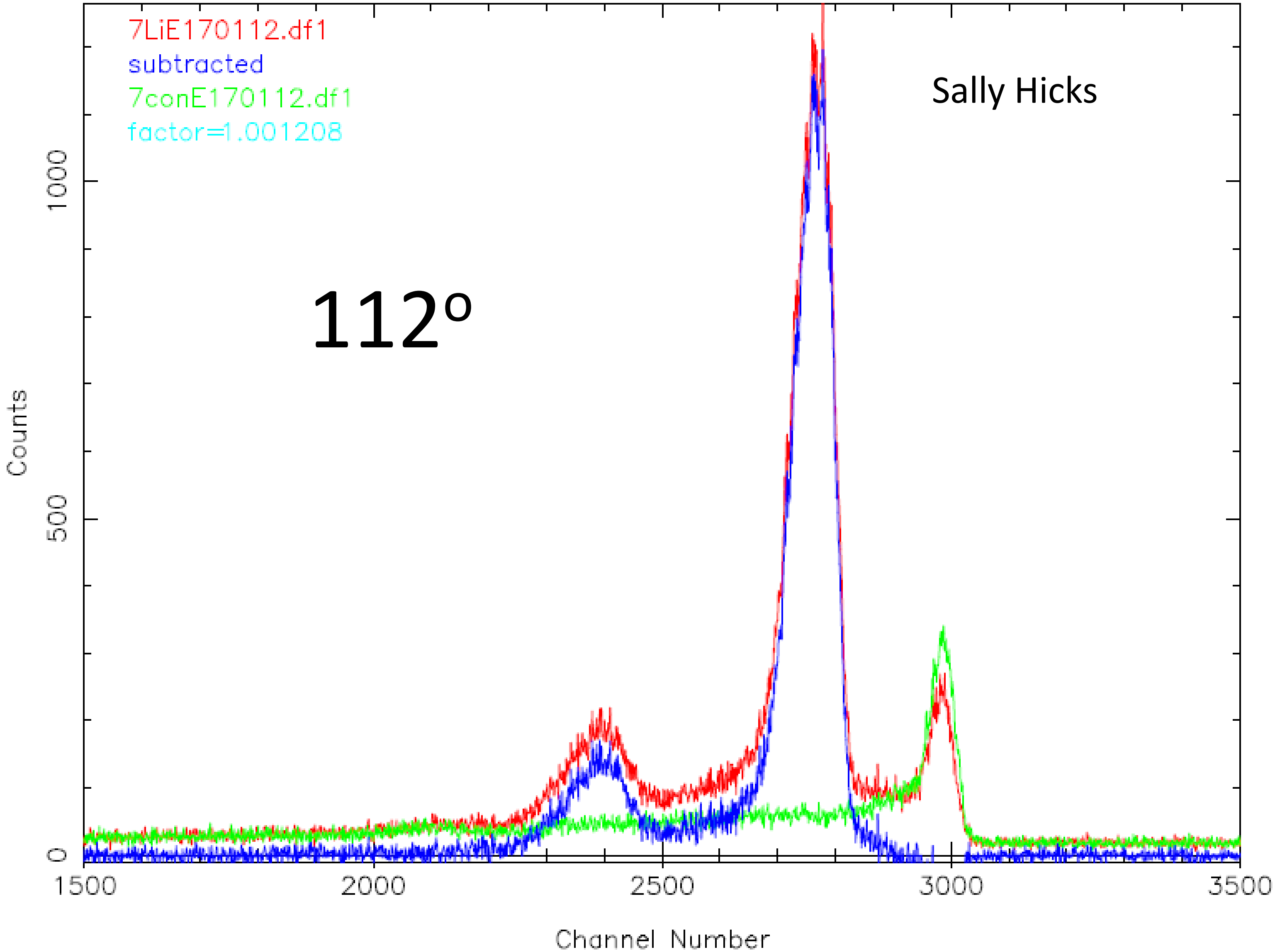
All raw spectra at 150deg

Unfortunately the empty container wasn't a perfect match for the 7Li sample



Things look tolerable at forward angles >80deg.

Unfortunately the empty container wasn't a perfect match for the 7Li sample



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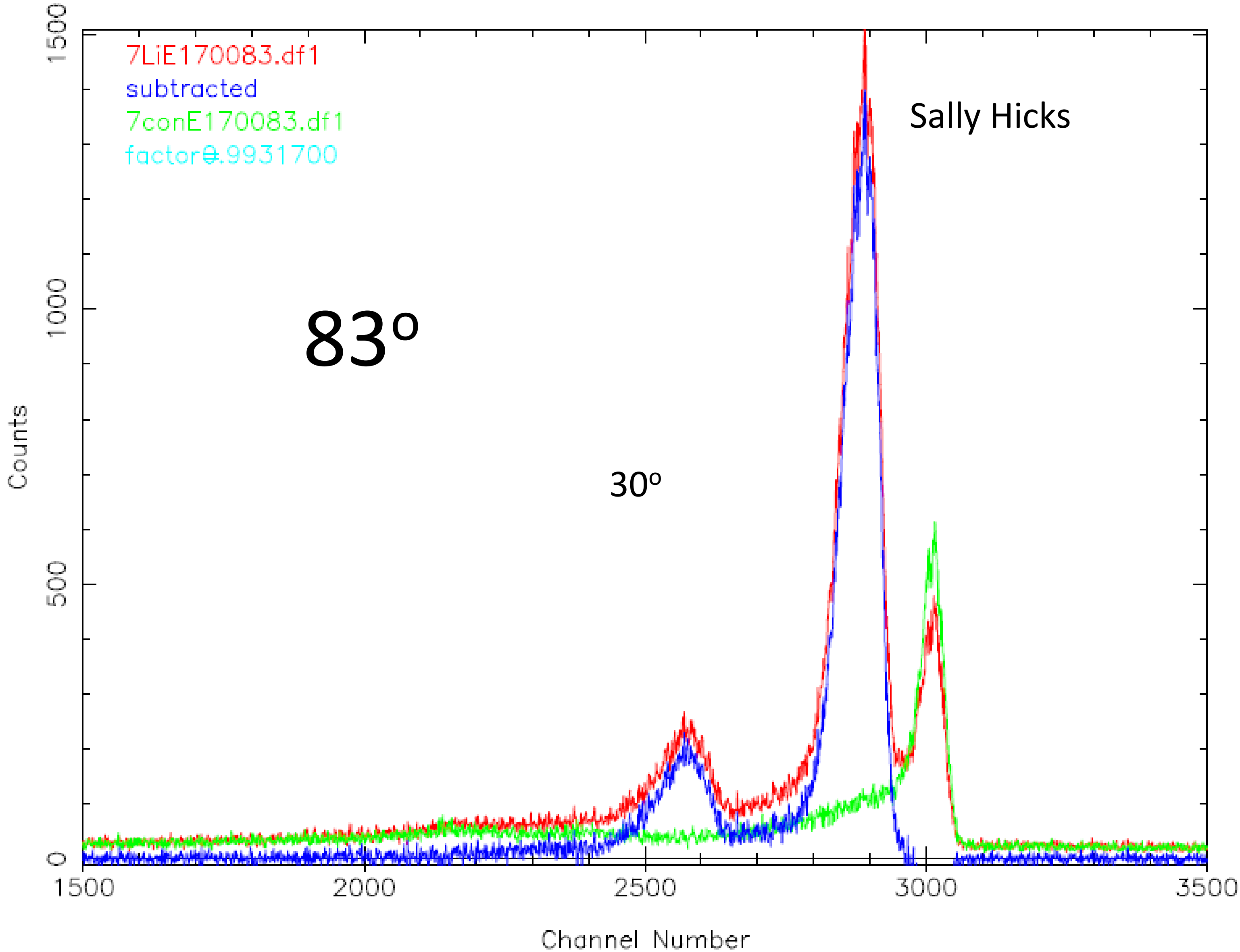

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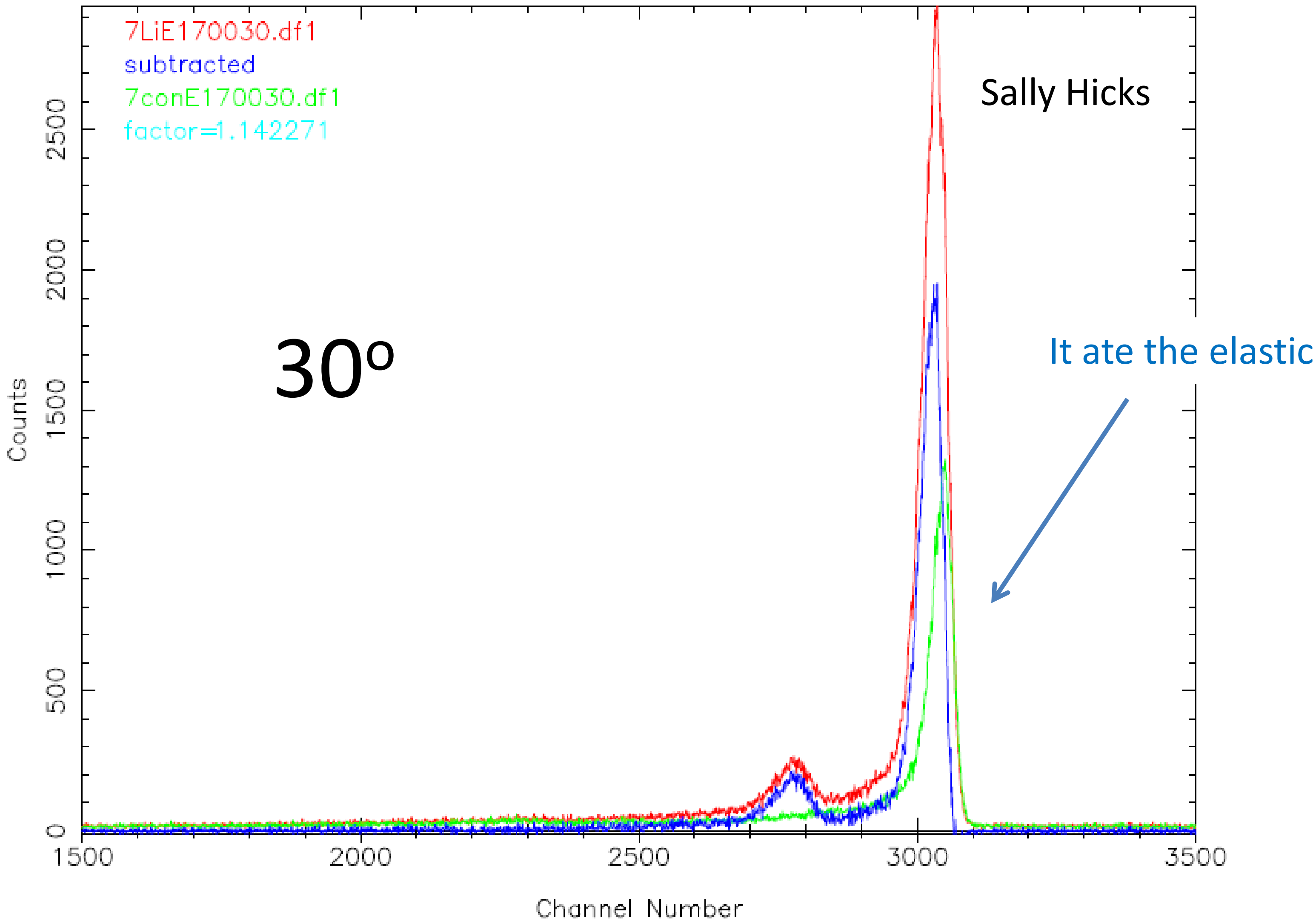
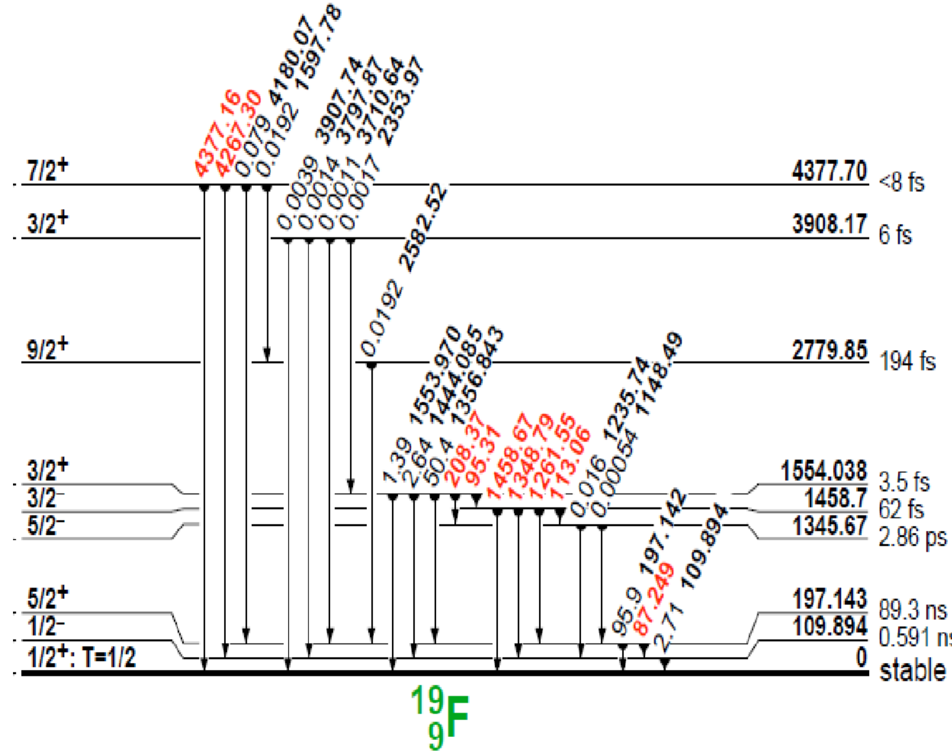


We have to fit the main peak well in order to deal with the elastic tail under the inelastic.

→ Best solution: re-can the sample

^{19}F



- Effectively no data since 1950s-1960s
- ^{19}F is evil
- 90 ns isomer
- Hard to normalize xs at low energies.
- Had to develop new DAQ

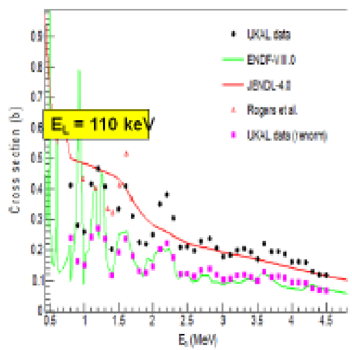
https://depositphotos.com/13830278/stock-illustration-cartoon-red-devil.html

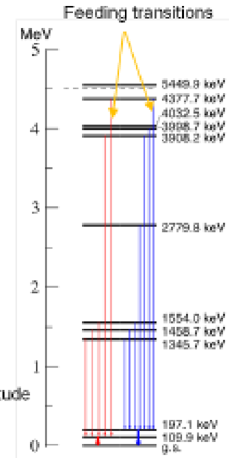
May 2018 Measurements at UKAL

110 keV ½+
isotropic

^{19}F

➢ Deducing ^{19}F level cross sections





- ENDF-VIII.0 and JENDL-4.0 differ in shape and magnitude
- Our data are closer to JENDL in terms of magnitude but follow the structure presented by ENDF-VIII.0
- UKAL data (renorm) is data multiplied by arb factor so that it agrees with ENDF.

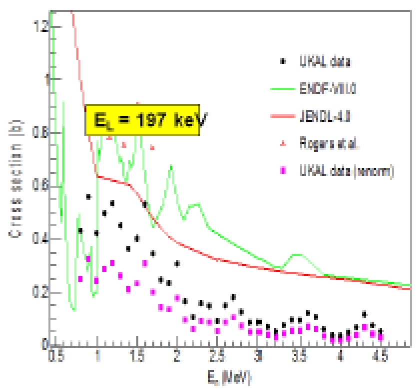
Anthony's results for the 110-keV 1st excited level are similar in magnitude to JENDL, but follow the fluctuations in ENDF better. Our results track ENDF very well over the whole range if we scale them by an arbitrary factor. The Rogers 1961 EXFOR points are scattered all over the place.

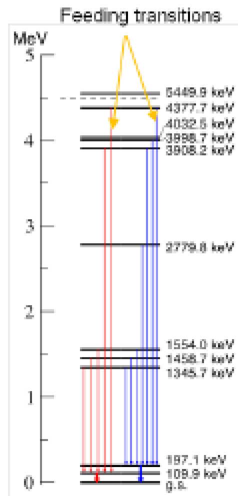
197 keV 5/2+
$a_4 \leq 0.1$

→ ~4% problem

^{19}F

➢ Deducing ^{19}F level cross sections





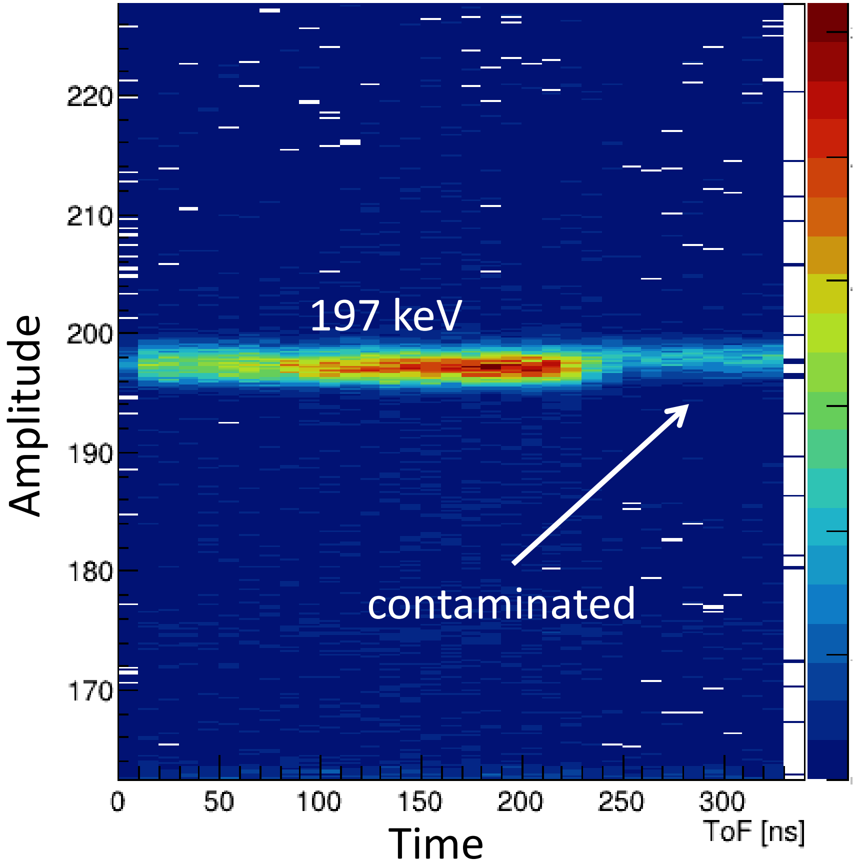
- E_L = 197 keV has a long lifetime with $T_{1/2}$ = 89.3 ns. Our spectra were obtained by gating the TAC on the prompt γ-ray region resulting to a large discrepancy in magnitude when compared to the values in evaluation libraries.

Anthony's results for the 197-keV 2nd excited level are significantly below the JENDL and ENDF. If we rescale them by the factor used previously, they get even worse.

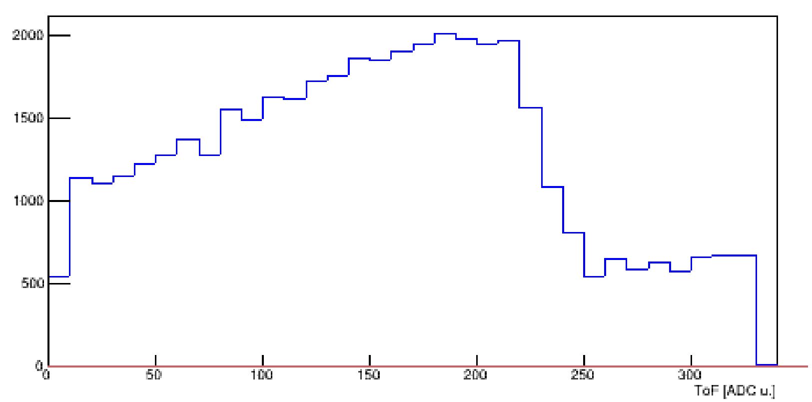
This problem occurs because we miss recording yield from the 90-ns isomer while using the analog DAQ system.

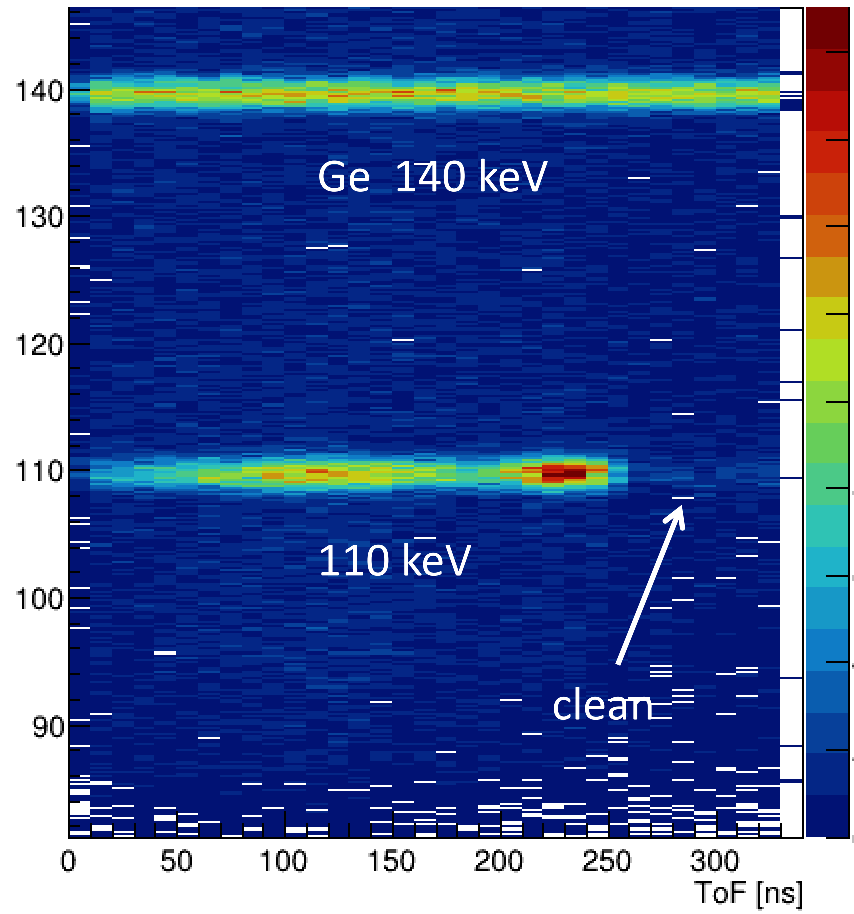
Marcus Nyman had similar problems w 2018 data @ GELINA

Information about 197keV transition using time recording features of new dDAQ

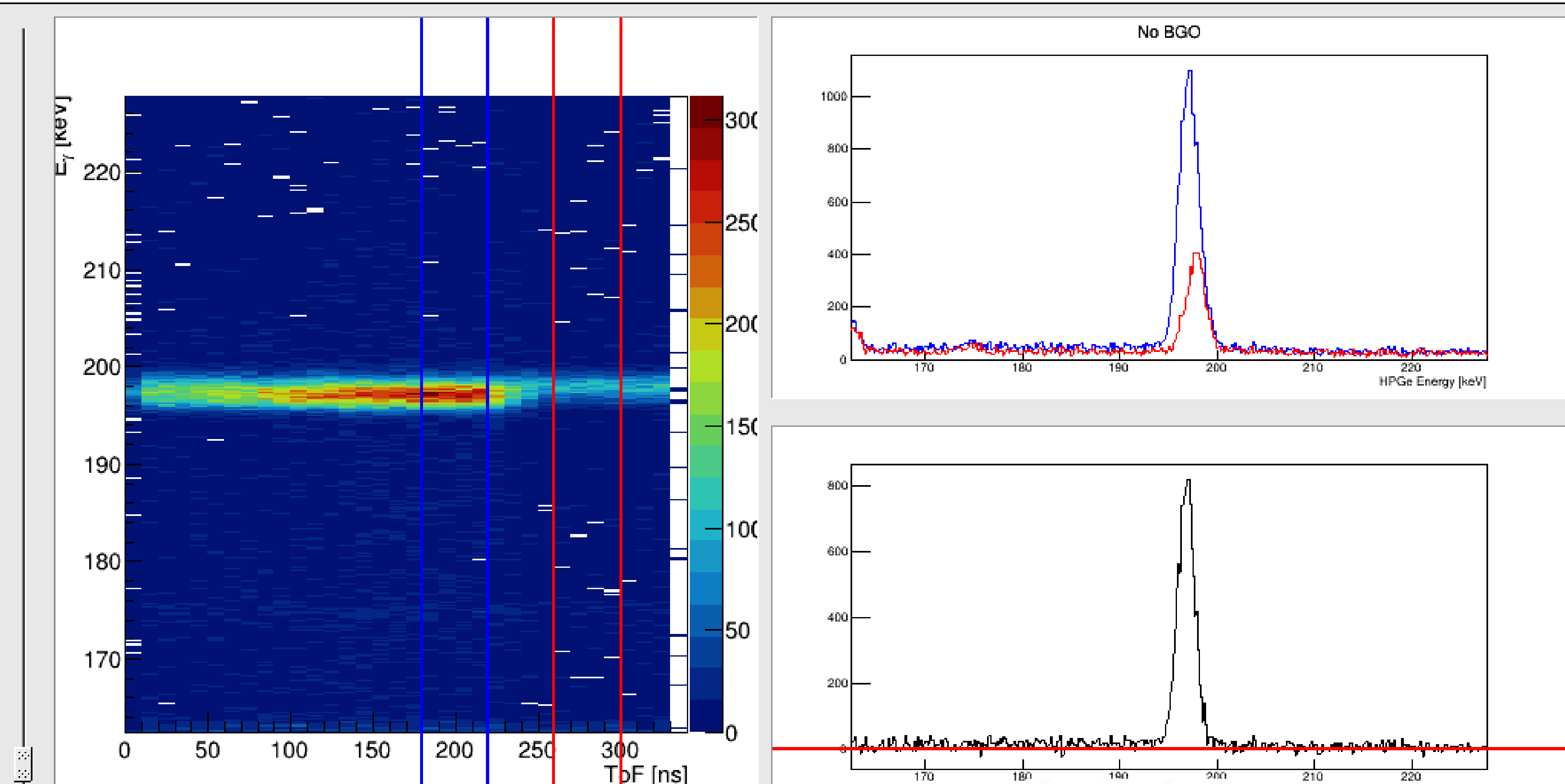


TOF distrib of 197, contaminated by 70Ge(n,γ)





It may be possible to subtract off the contribution from the 70Ge(n,γ) with sample-in & sample-out information.



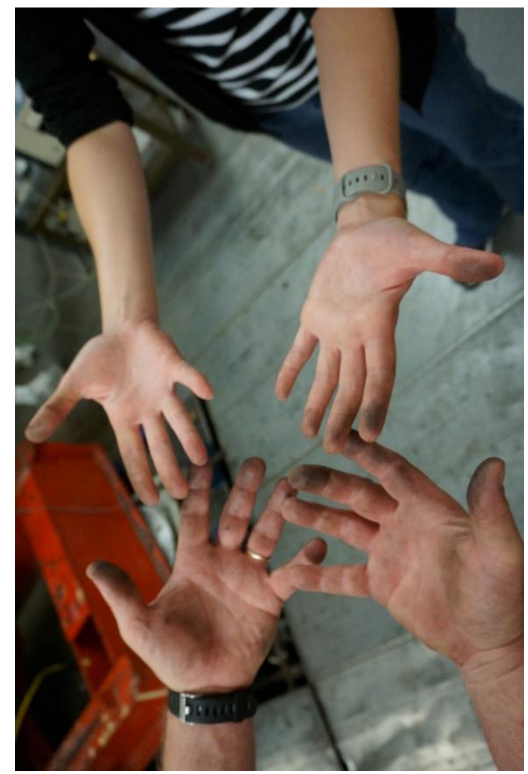
19F

Supported by U.S. DoE FY20/21/22 awards SC0021424, SC0021243, SC0021175, SSC000056

SUMMARY:

- The team is working on many projects.
- Weekly collaboration meetings.
- Many UnivKY runs during summer 2021 & 2022 to catch up from covid shutdown.
- Take more ^{13}C data.
- Re-can ^{7}Li and measure again.
- ^{19}F remains a problem.

NSF 1913028 / 2209178



Undergraduate students on the Carbon paper

ELSEVIER Nuclear Physics A 1023 (2022) 122446
www.elsevier.com/locate/nuclphysa

Neutron elastic and inelastic scattering differential cross sections on carbon

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E.A. Chouinard [d], B.M. Combs [d], B.P. Crider [b], E.C. Derdyn [d],
L. Downes [d], J.A. Erlanson [c], S.E. Evans [d], A.J. French [d], E.A. Garza [c],
J. Girgis [d], T.D. Harrison [c], S.L. Henderson [d], T.J. Howard [d],
D.T. Jackson [d], L.J. Kersting [d], A. Kumar [a], S.H. Liu [a], C.J. Lueck [d],
E.M. Lyons [d], P.J. McDonough [d], M.T. McEllistrem [b,1], T.J. Morin [d],
S. Mukhopadhyay [b], T.A. Nguyen [d], M. Nickel [d], S. Nigam [a], R.L. Pecha [d],
J. Potter [a], F.M. Prados-Estévez [a,b], B.G. Rice [c], T.J. Ross [a,b],
Z.C. Santonil [d], J. Schneiderjan [d], L.C. Sidwell [d], A.J. Sigillito [d],
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Industry, Compass Minerals

Ministry

MD U. Of KY (radiation oncology)

High school physics teacher

Unknown

Laboratory Tech, Eastfield College

Ph.D. U. of Wisc (Nuc Eng) **Sandia National Lab**

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Ph.D. Texas Tech (CE), Jacobs

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M.S. Notre Dame (EE), RF Eng at Lockheed Martin

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Ph.D Notre Dame (Nuc Phy)

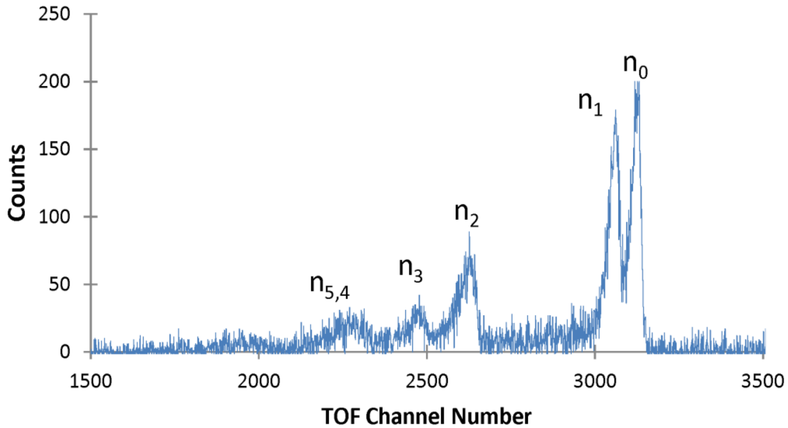
MD, Psychiatry, U. of Southern CA

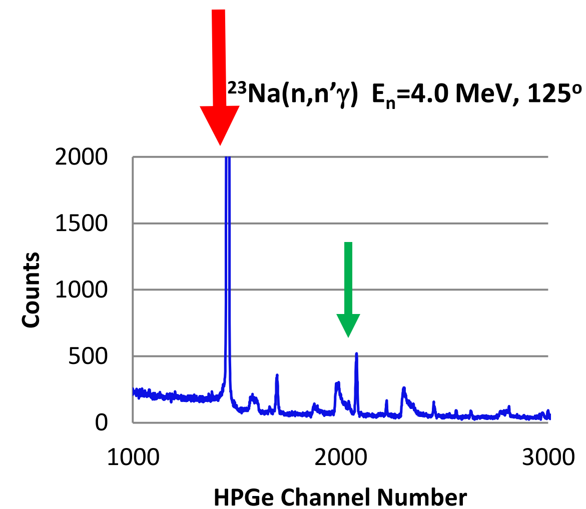
Ph.D. Candidate, UC Santa Barbara, Photonics

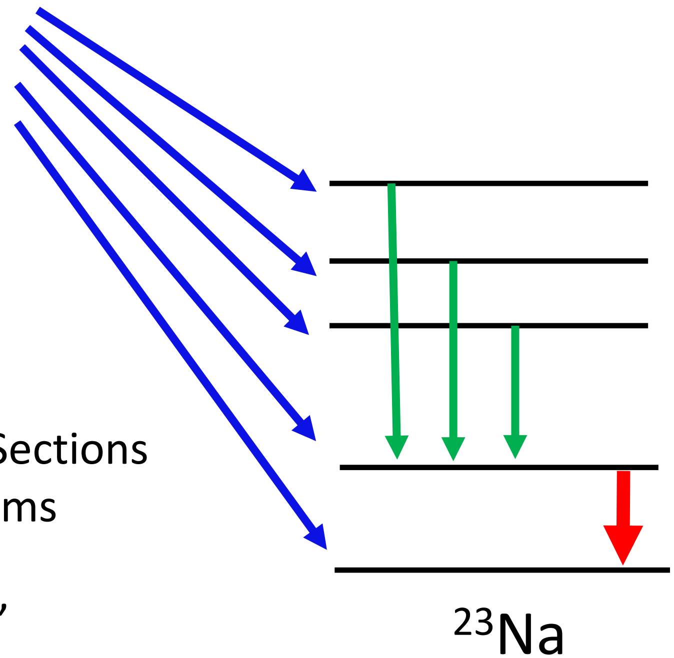
MD U. Of KY, Internal Medicine

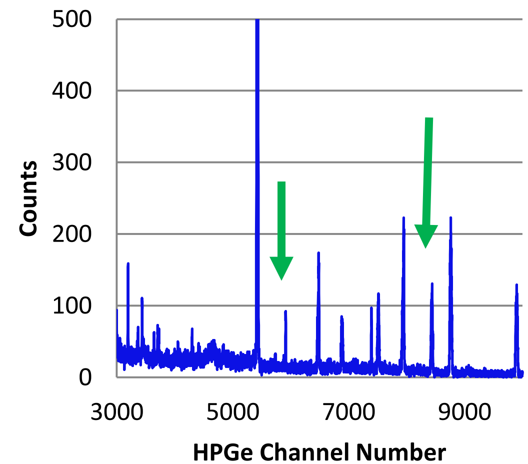
Ph.D. Princeton (EE); Faculty U. of PA

Complementary Measurements: Neutron Detection vs γ-Ray Detection









(n,n')

'Nuclear Data'

Differential Cross Sections

Reaction Mechanisms

(n,n'γ)

'Nuclear Structure'

Excited Levels & Properties

E_x, E_γ, br, δ, τ, BXL

Nuclear Potential Models