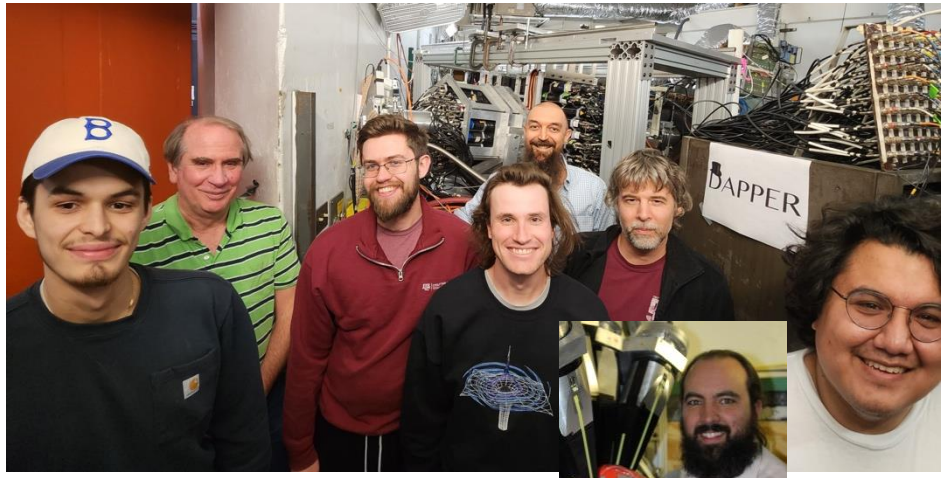
The Detector Array for Photons, Protons, and Exotic Residues

Alan B. McIntosh
Texas A&M University

WANDA 2026



DAPPER

Texas A&M University

Austin Abbott (Ph.D. 2024)
Arthur Alvarez
Jerome Gauthier
Kris Hagel
David Shelden
Alan McIntosh
Shuya Ota (now BNL)
Sebastian Regener
Maxwell Sorensen (Ph.D. 2024)
Sherry J. Yennello

CENTER FOR EXCELLENCE IN NUCLEAR TRAINING AND UNIVERSITY-BASED RESEARCH
CENTAUR

TEXAS A&M UNIVERSITY Cyclotron Institute

National Nuclear Security Administration

NNSA: CENTAUR: DE-NA0003841, DE-NA0004150
DOE-NP: DE-FG02-93ER40773

External Collab 1st Campaign

Aaron Couture (LANL)
Anna Simon (Notre Dame)
Grigory Potel (LLNL)
Andrea Richard (LLNL/Ohio)

External Added 2nd Campaign

Sudarsan Balakrishnan (Rutgers, ORNL)
Rajesh Ghimire (LLNL)
Mara Grinder (Rutgers, ORNL)
Toby King (ORNL)
Steve Pain (ORNL)
Ratkiewicz (et al LLNL)

External Adding 3rd Campaign

Darren Bleuel (LLNL)
Stephanie Lyons (PNNL)
Austin Rambo (Ohio)
Adriana Sweet (LLNL)
Mathis Wiedeking (LBL)

Los Alamos NATIONAL LABORATORY EST. 1943

OHIO UNIVERSITY

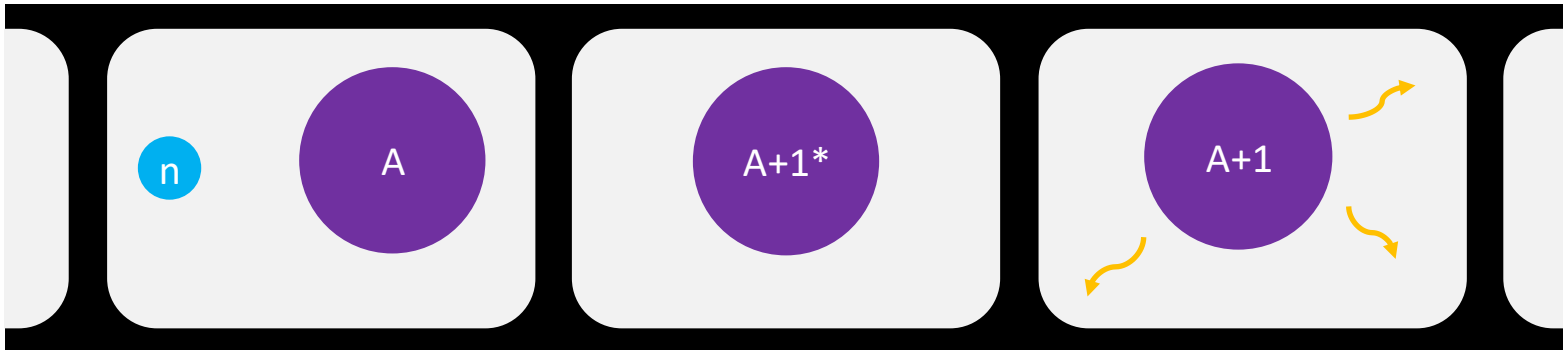
OAK RIDGE National Laboratory

PNNL

Brookhaven National Laboratory

Need: neutron capture cross sections

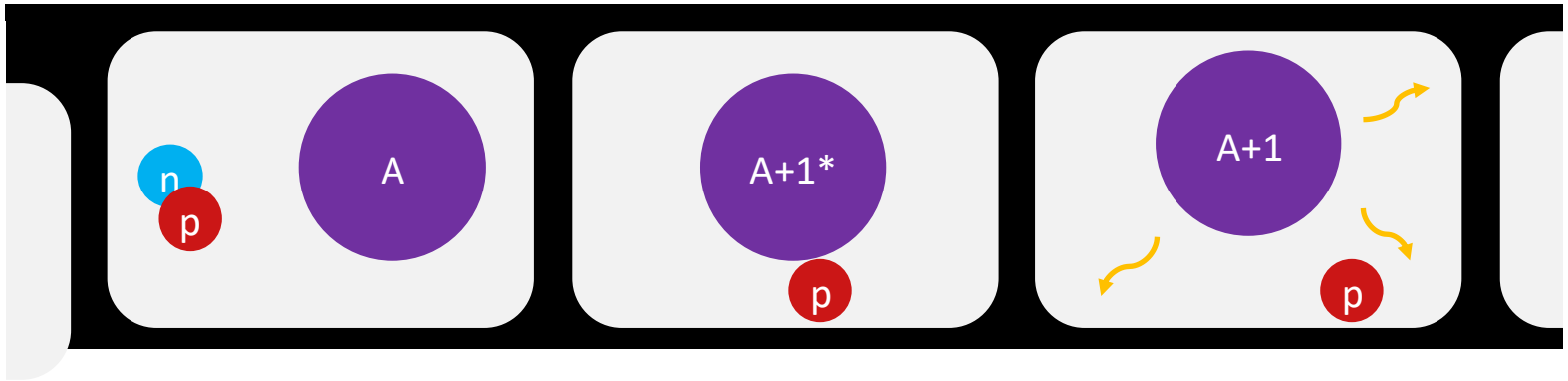
- Stockpile science
- Nonproliferation
- Reactor design
- Nuclear astro, nucleosynthesis



Issues

- Many critical nuclides unstable
- Too many to measure

→ Predictions needed



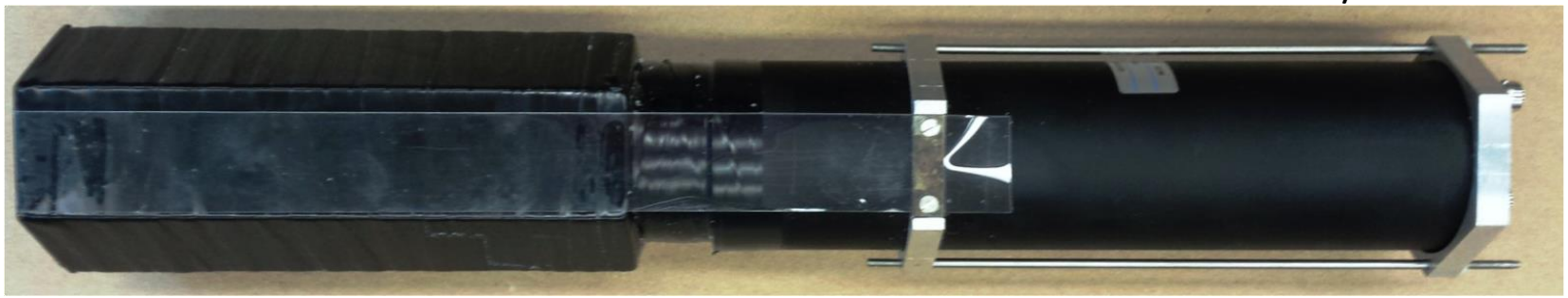
Goal

- Measure photon strength functions and
- and Nuclear Level Densities
- with surrogate reactions like (d,p), (p,p')
- in inverse kinematics (radioactive beams)
- to support improved model calculations.

- Measure for key nuclides
- And along isotopic chains (systematics)

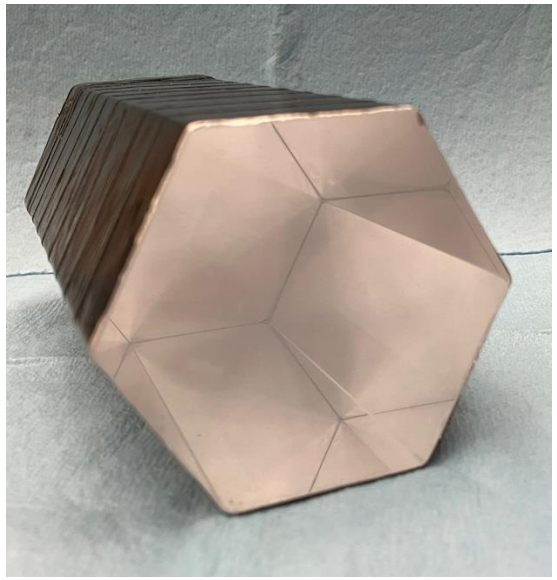
Barium Fluoride 128 modules

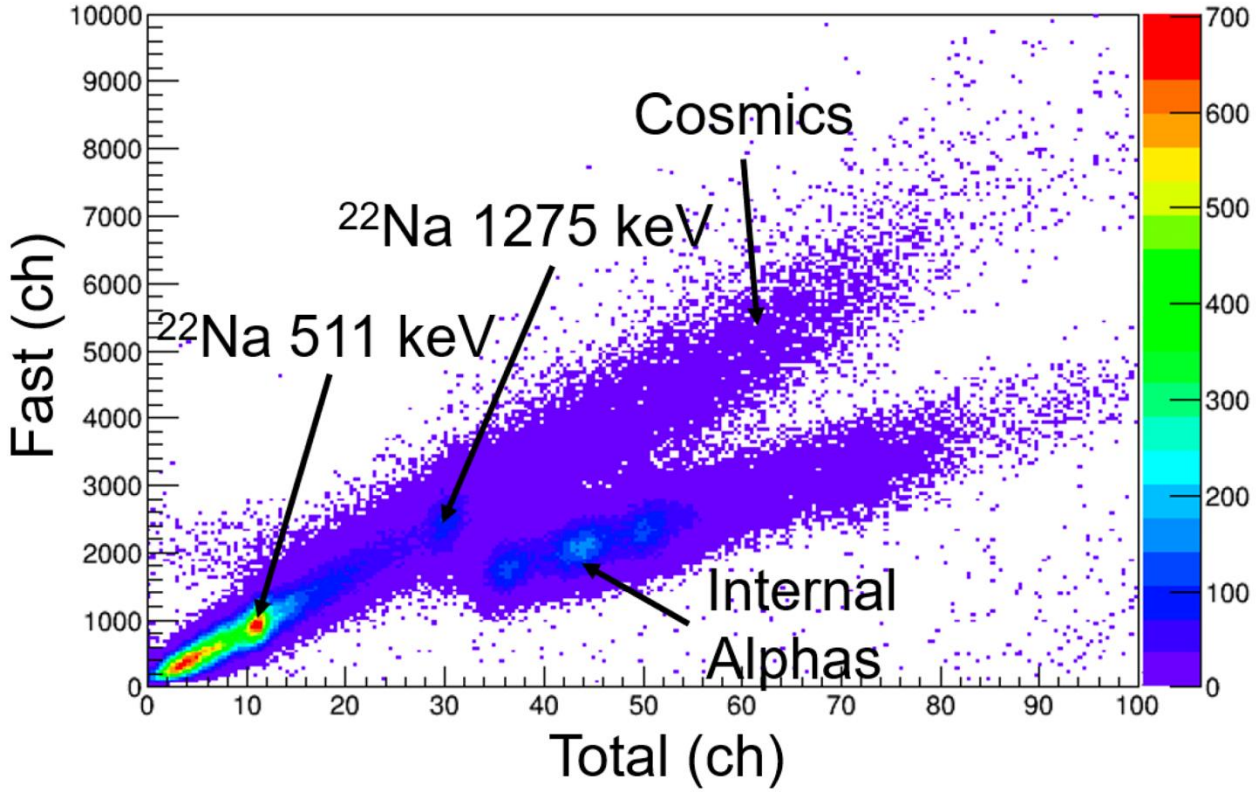
TAMU/ORNL BaF2

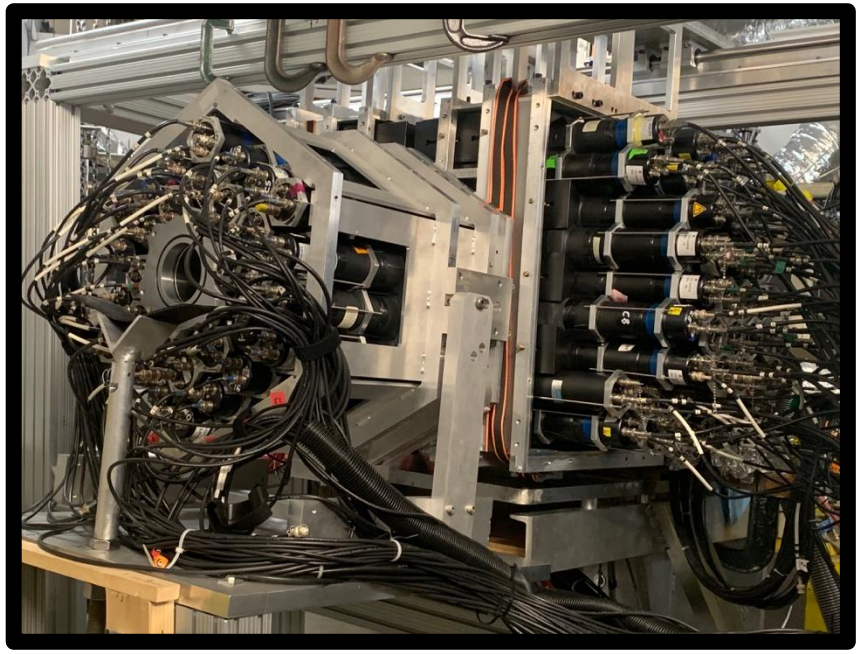


crystal 20 cm x 6.5 cm

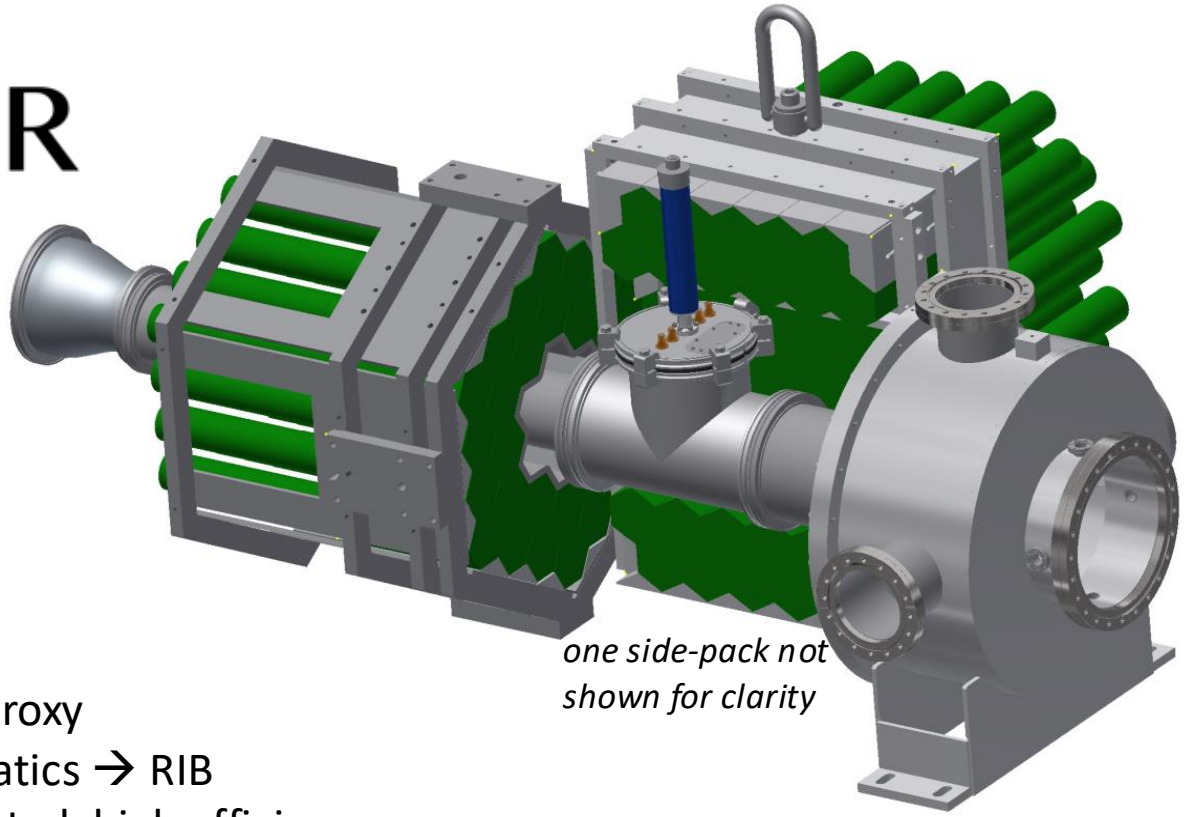
silicone oil coupling, quartz window, PMT







DAPPER

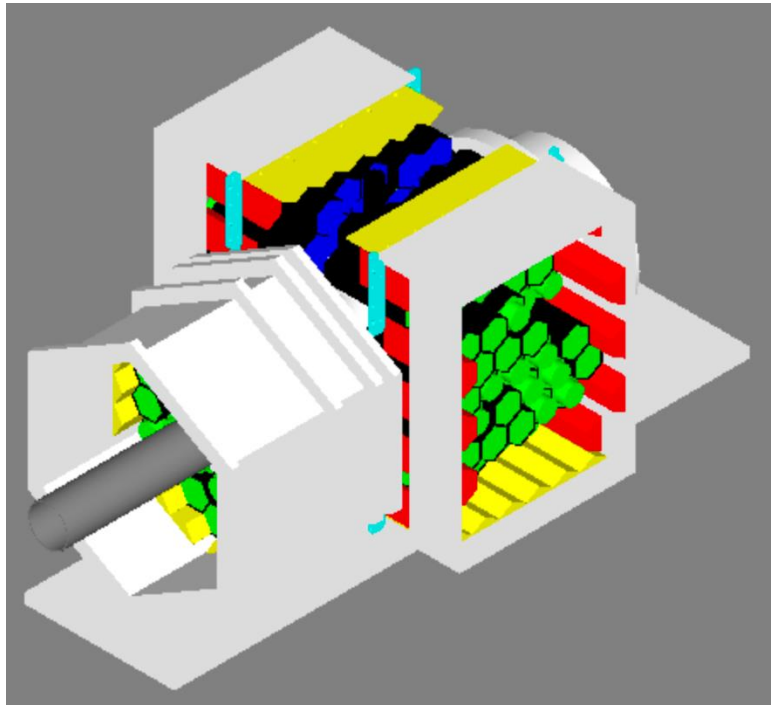


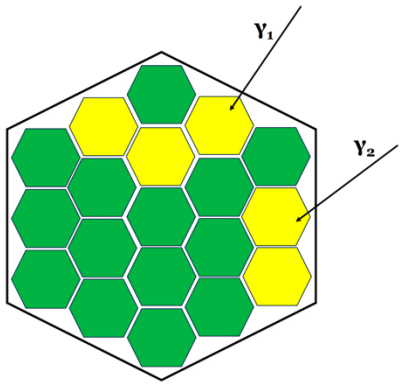
one side-pack not shown for clarity

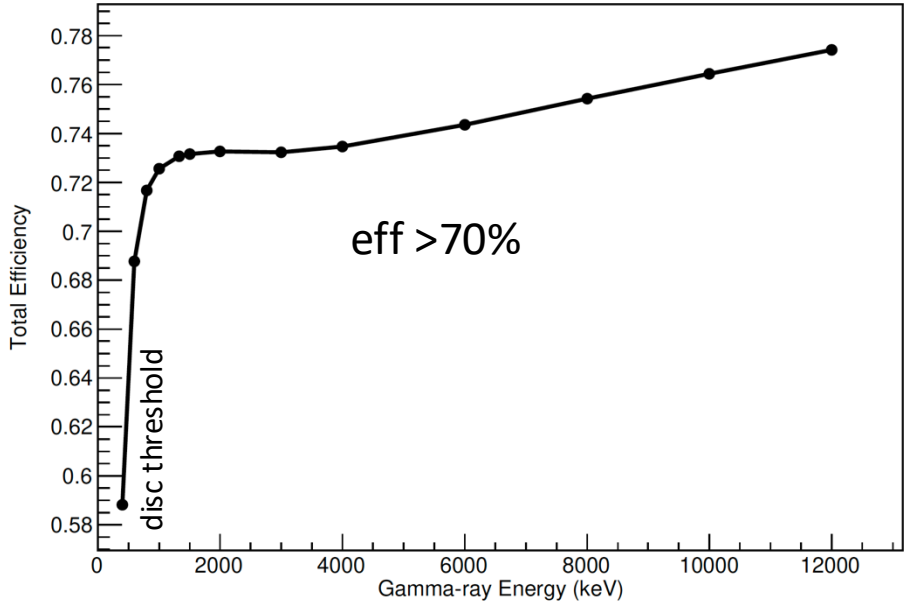
- (d,p) as (n,g) proxy
- Inverse kinematics → RIB
- Highly segmented, high efficiency
  - Excitation energy
  - Gamma multiplicity
  - Total gamma energy
  - Individual gamma energies
  - Accurate Doppler

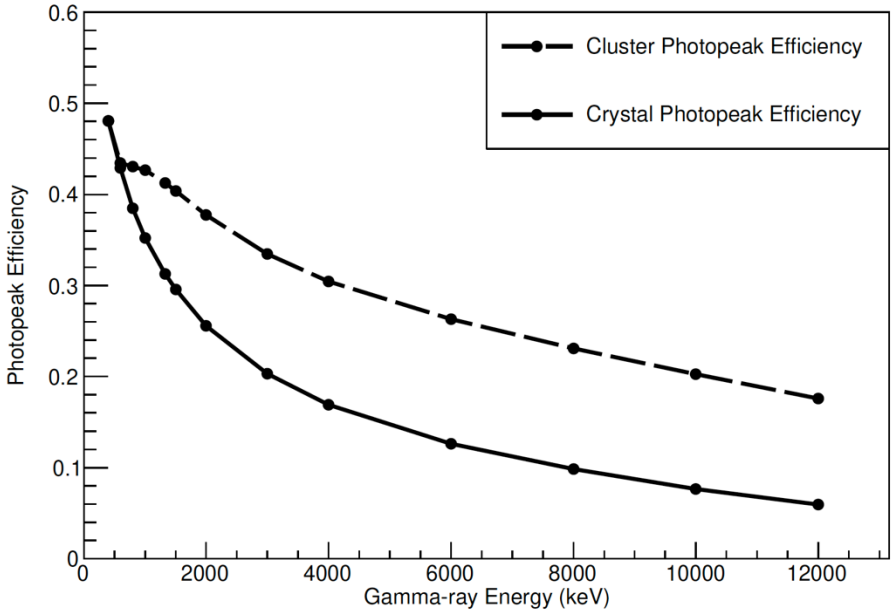
→ Photon strength function
→ Improve neutron capture model predictions

Efficiency of DAPPER







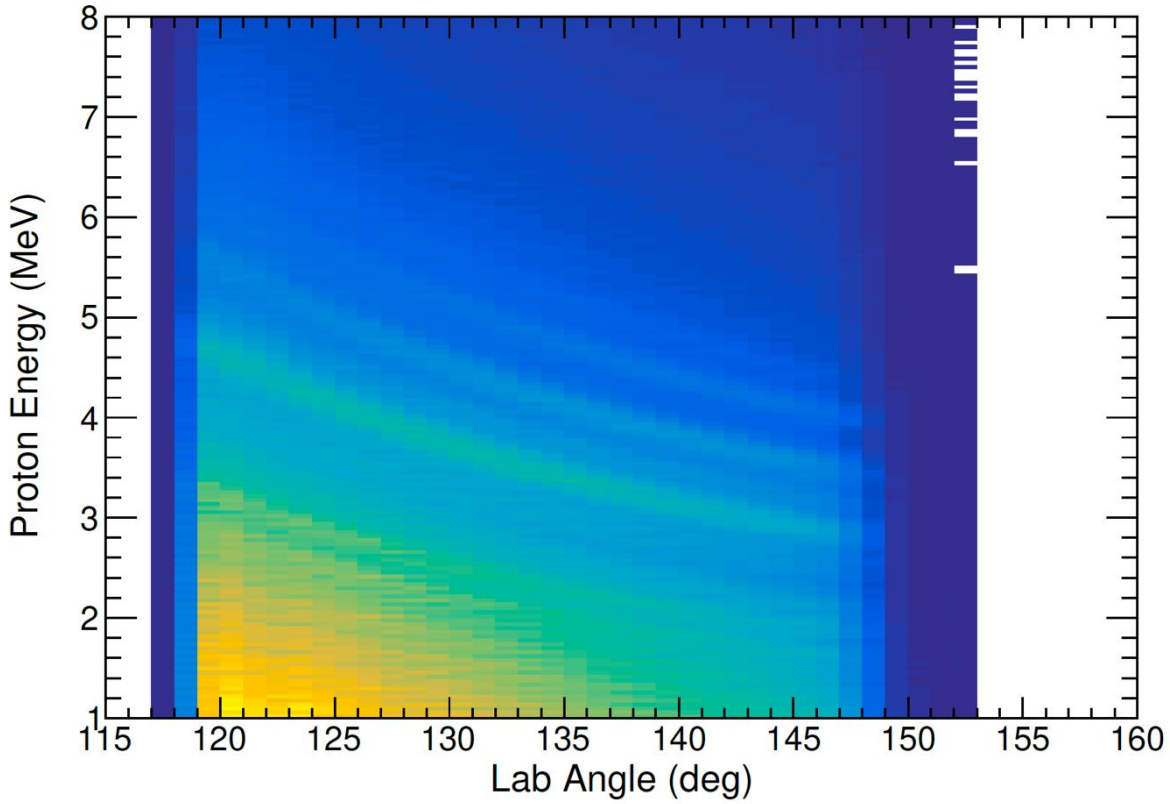


Commissioning and First Physics Measurement: 2021

57Fe(d,pg)

Excitation Energy

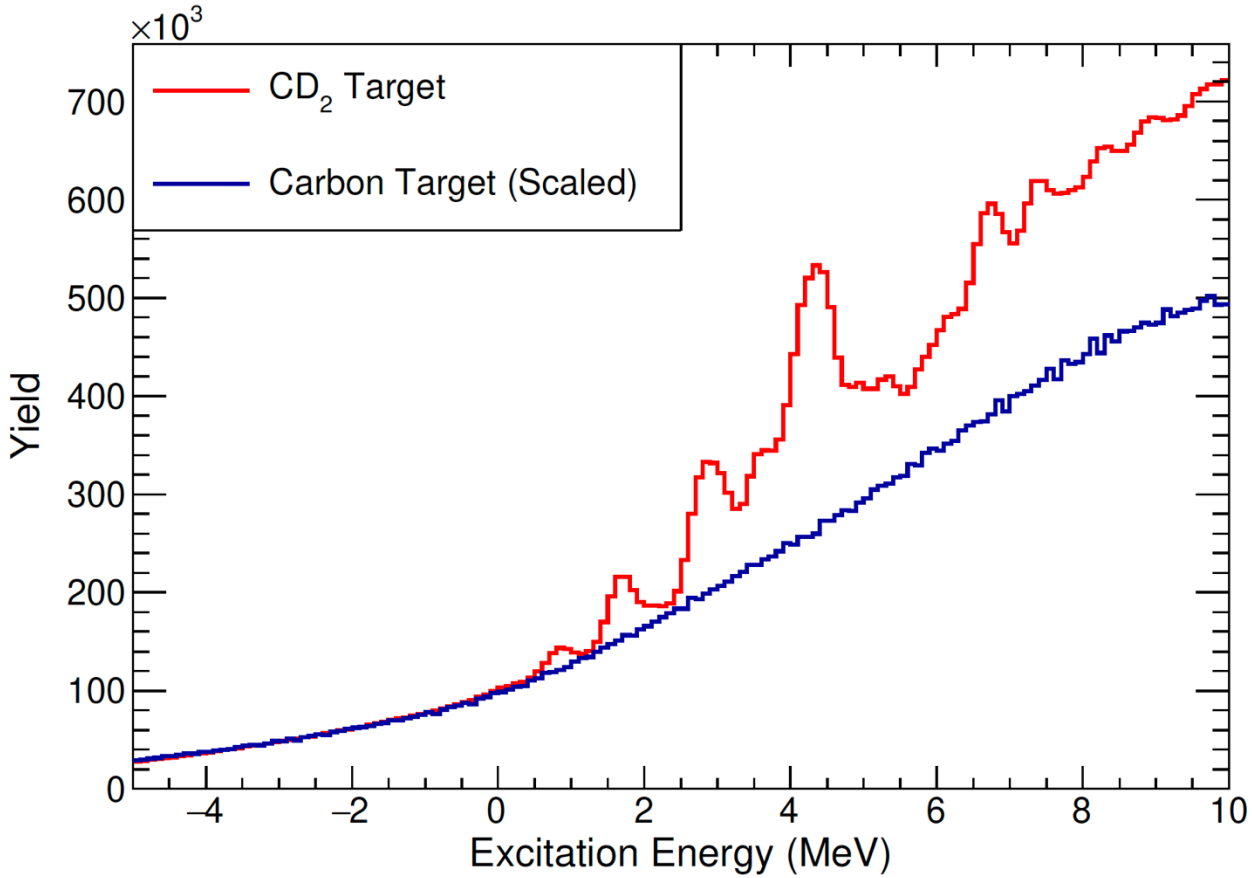
57Fe(d,pg)

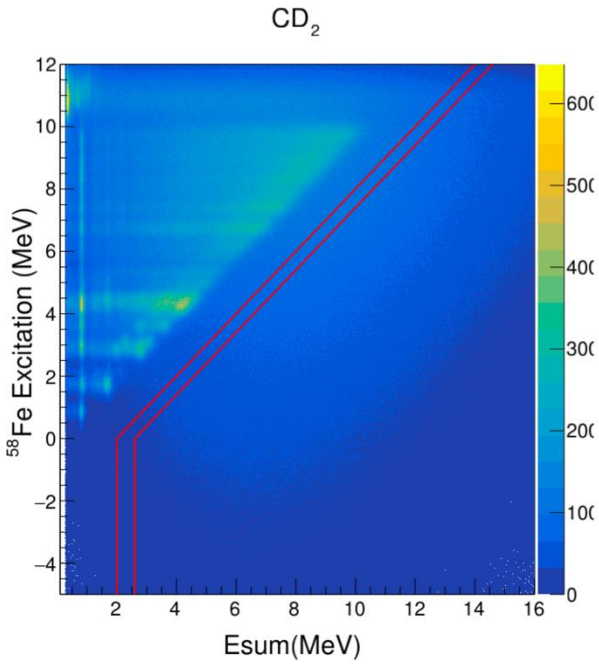


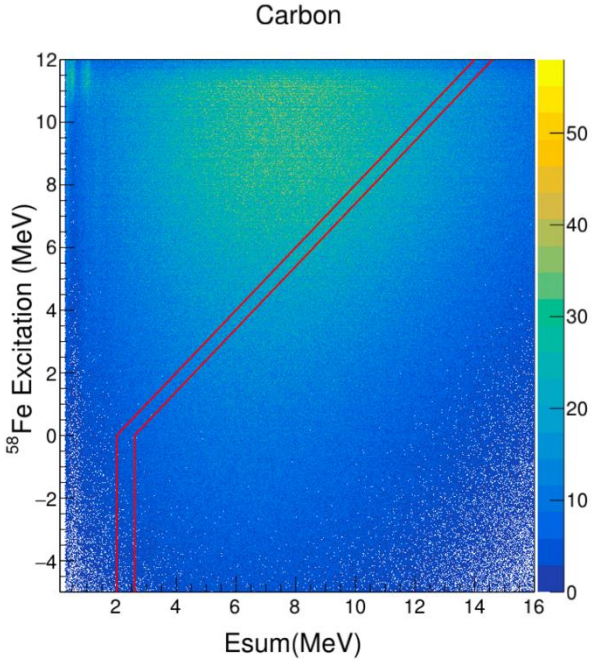
Silicon (S3) coverage 120-150 degrees
Kinematic selection of transfer, not fusion-evaporation

~500 keV E* resolution

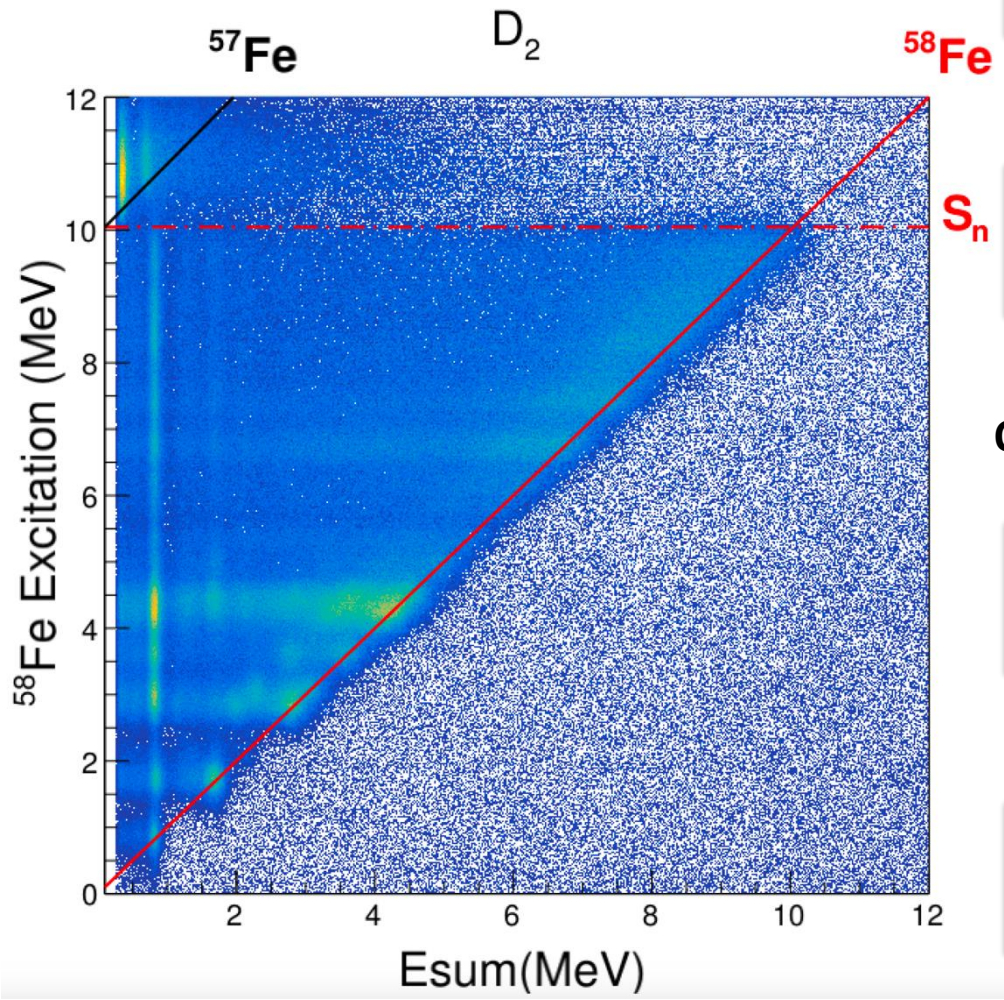
- target thickness
- beam diameter



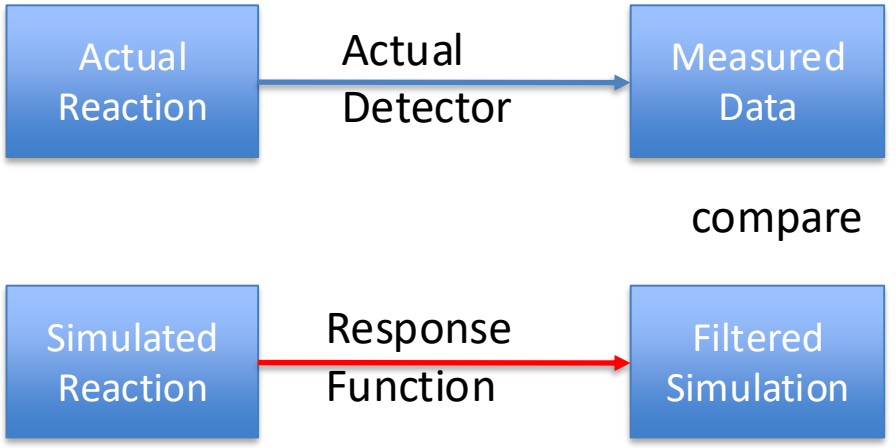




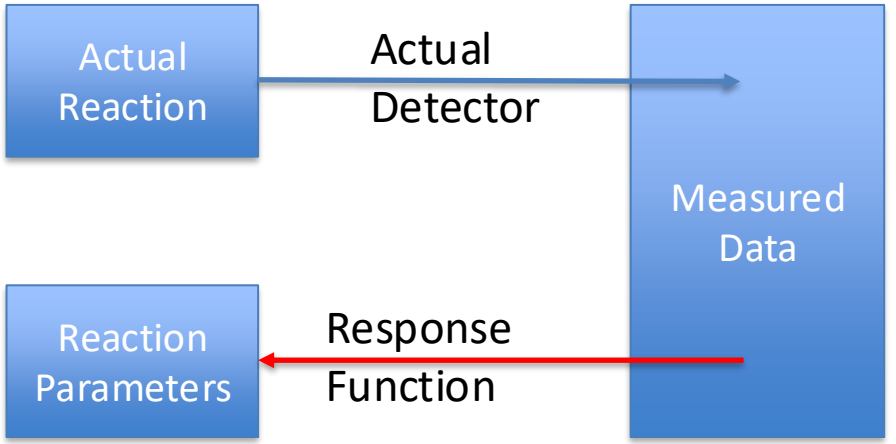
57Fe(d,pg) @ 7.5 MeV/u in DAPPER



Forward Method (Multi-step Cascade)

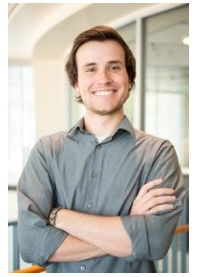


Oslo Method



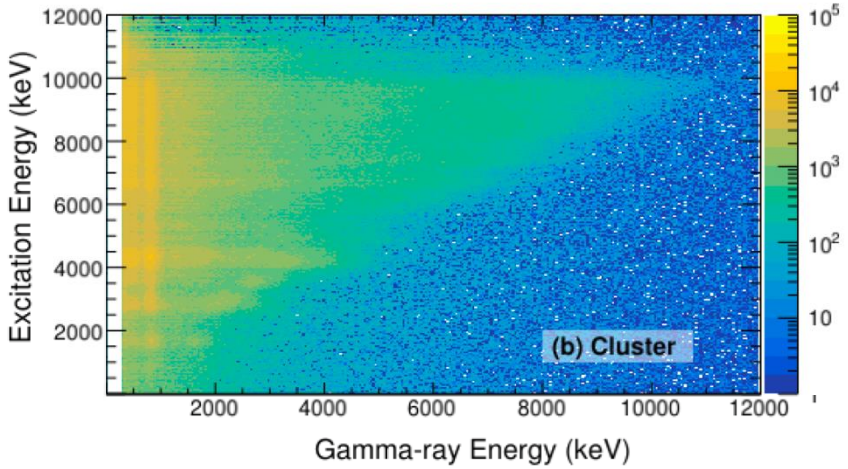
Oslo Method: 58Fe Photon Strength Function

A. Abbott, Ph.D. Thesis, TAMU (2024)



A. Abbott

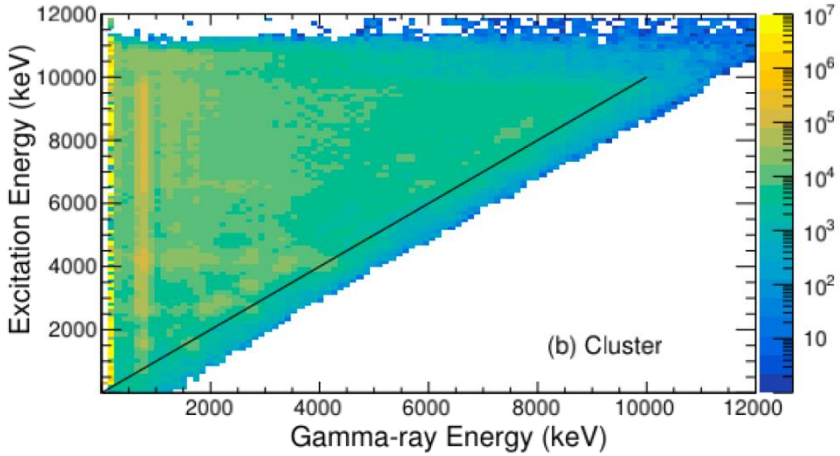
1. raw



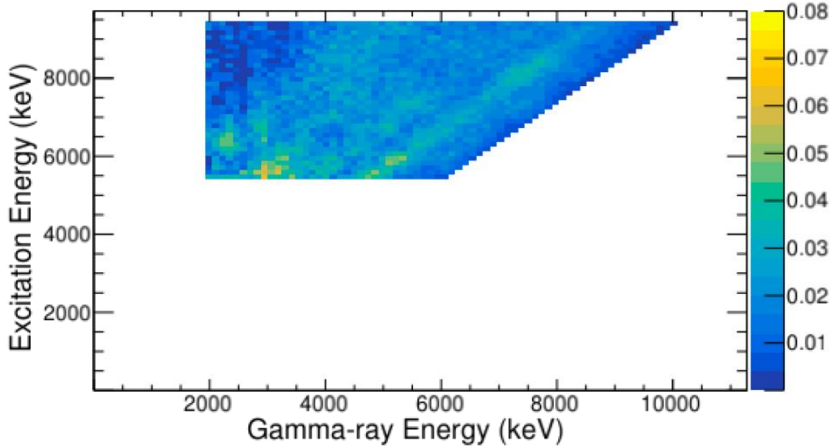
2. Doppler corrected “unfolded”
remove detector response

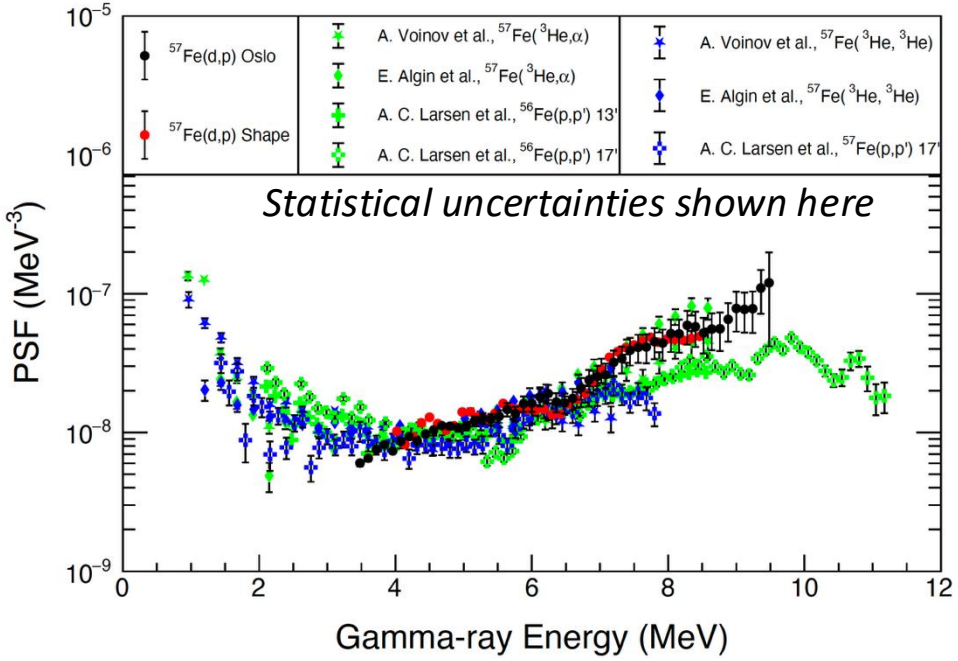
Doppler: 22% variation!

*DAPPER **segmentation** allows **inverse kinematics***



3. primary gamma rays only



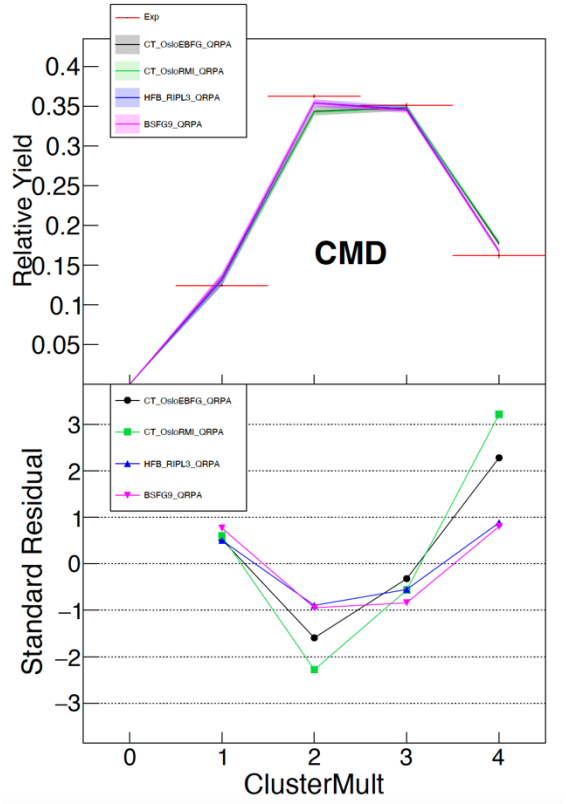


Forward Method: 58Fe Photon Strength Function

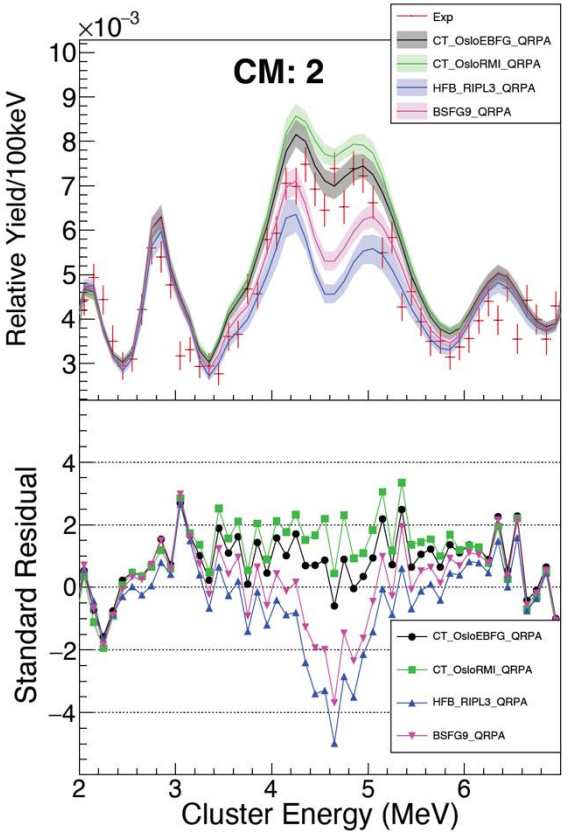
M. Sorensen Ph.D. Thesis, TAMU (2024)

M. Sorensen

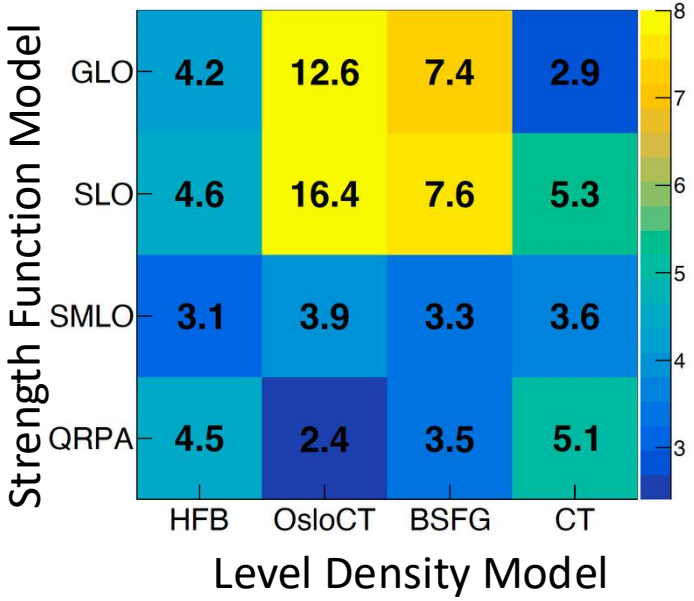
1a) Pick a PSF
1b) and pick a NLD
2) Simulate many 58Fe nuclei deexciting
3) Filter with detector response
4) Compare sim to exp:



also compare:
Energy Dist for Mult=3
Energy Dist for Mult=4



Model Agreement: χ2/N

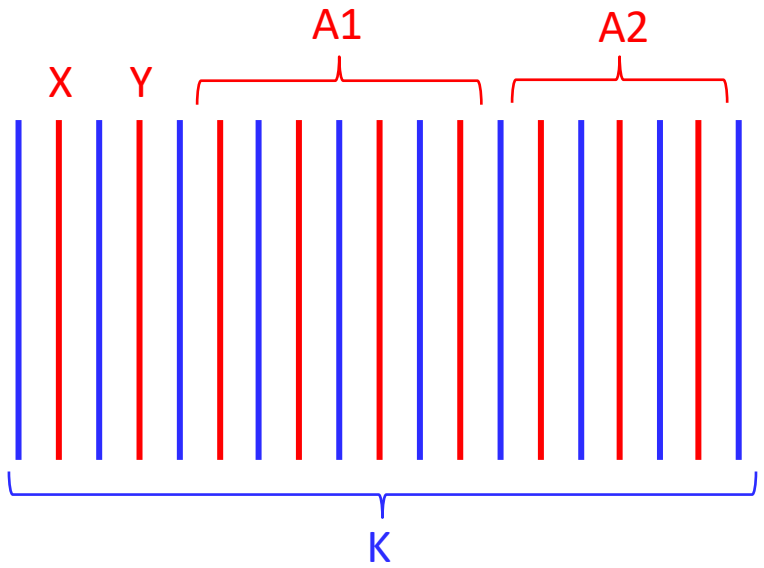


Second DAPPER Campaign: Add Zero-degree ionization chamber

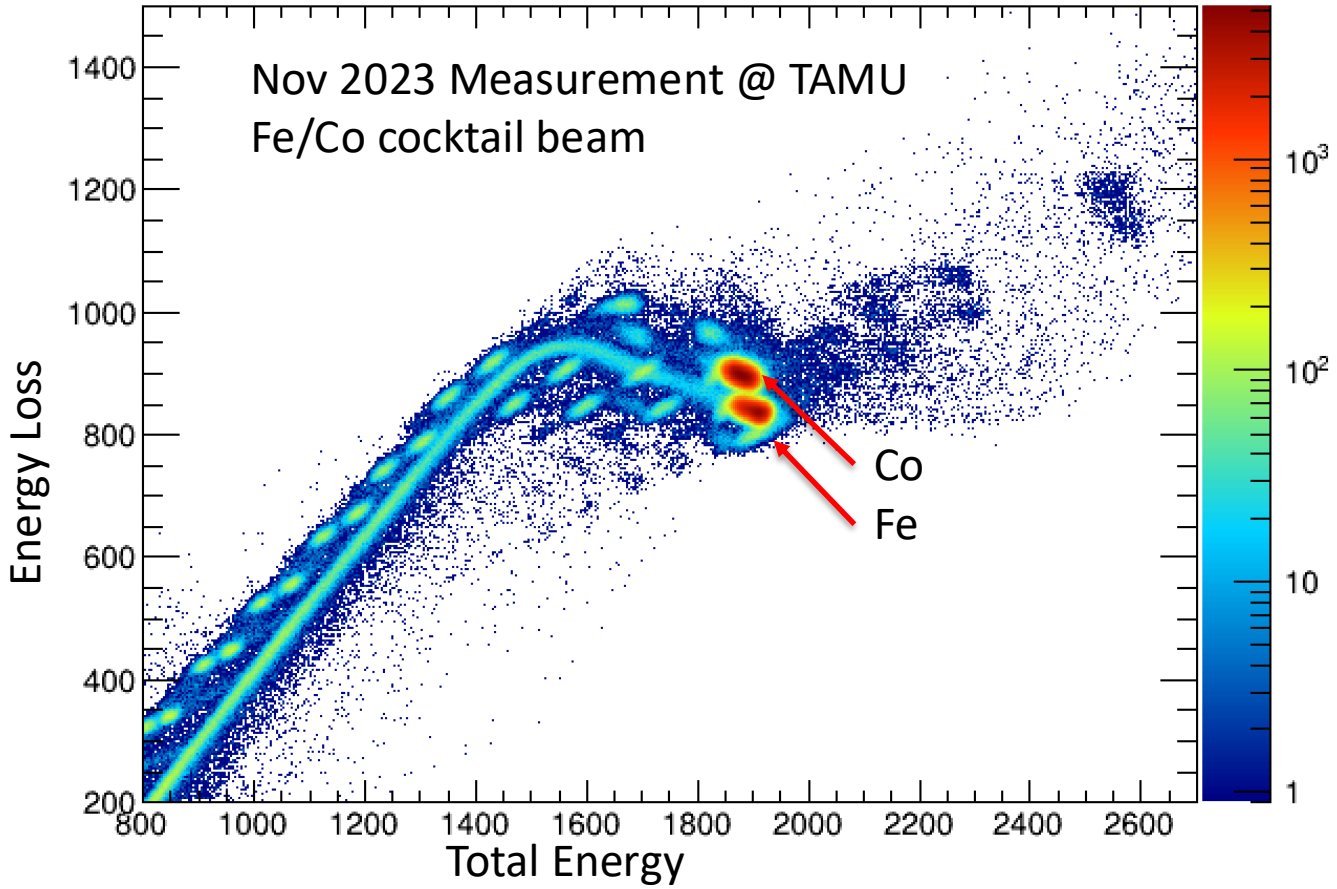
In collaboration with S. Pain (ORNL) et al., GODDESS IC

S. Pain, T.T. King, M. Grinder, S. Balakrishnan (ORNL)
A. Ratkiewicz, R. Ghimire (LLNL)

DE AC05-00OR22725 (ORNL), NNSA DE-NA0004066 (RU), NSF PHY-2110985 (RU)



~100 Torr C4H10
Wire planes, 99% transmission
Close spacing of wire planes
Fast preamplifiers, fast shapers
→ High Rate



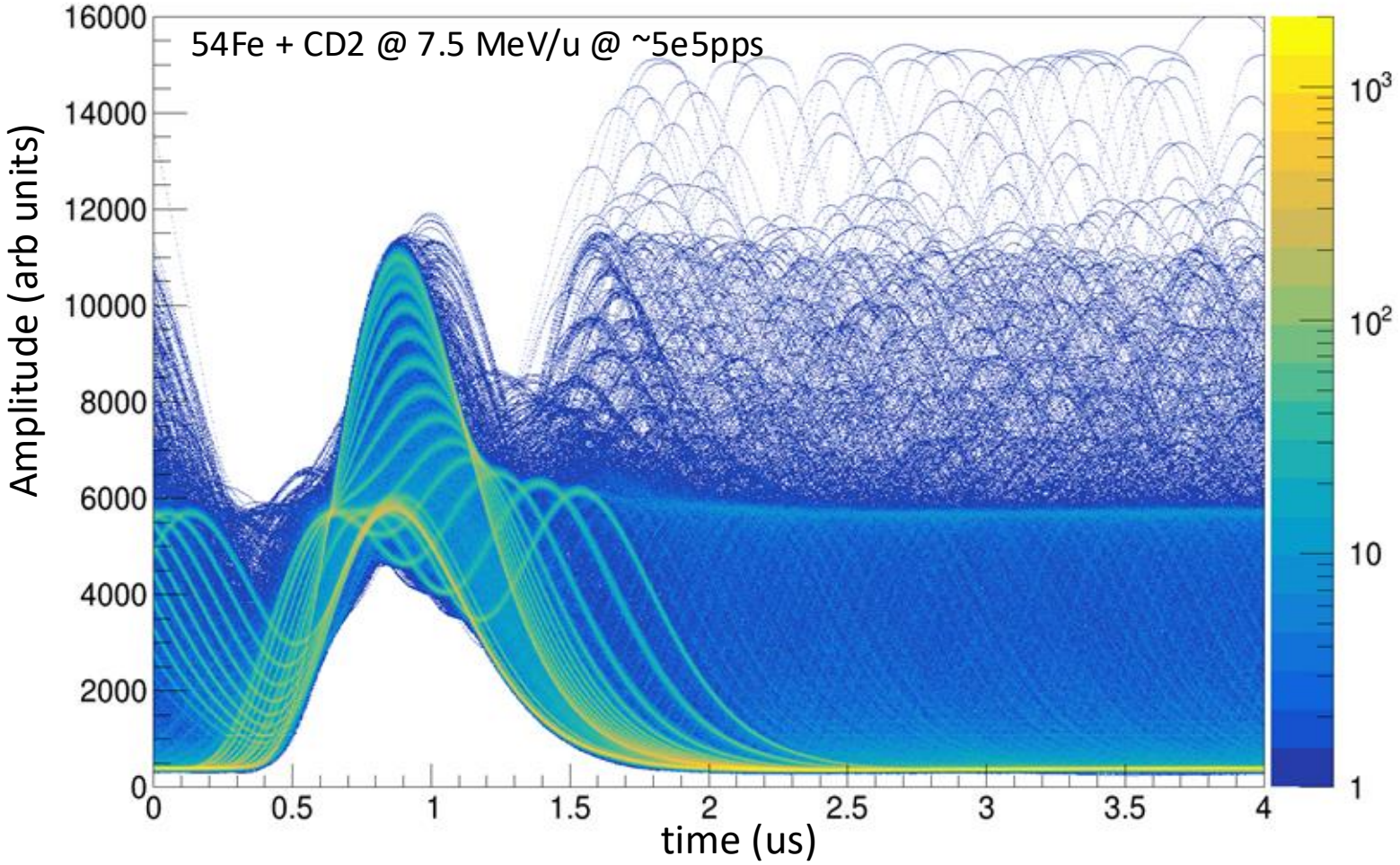
Unit Z separation
> 5e5 pps
dE-E technique

<u>other <= 1% features</u>
slit-scattering
stopping in wires
pile-up
combinations of these

Zero-degree ionization chamber

December 2023
Measure 54Fe(d,pg)55Fe with DAPPER
Residues at 0 deg in IC

Arthur Alvarez
Poster WANDA 2026



GODDESS IC Cathode (tot ene)
-> Preamplifier
-> Shaper
-> Waveform Digitizer

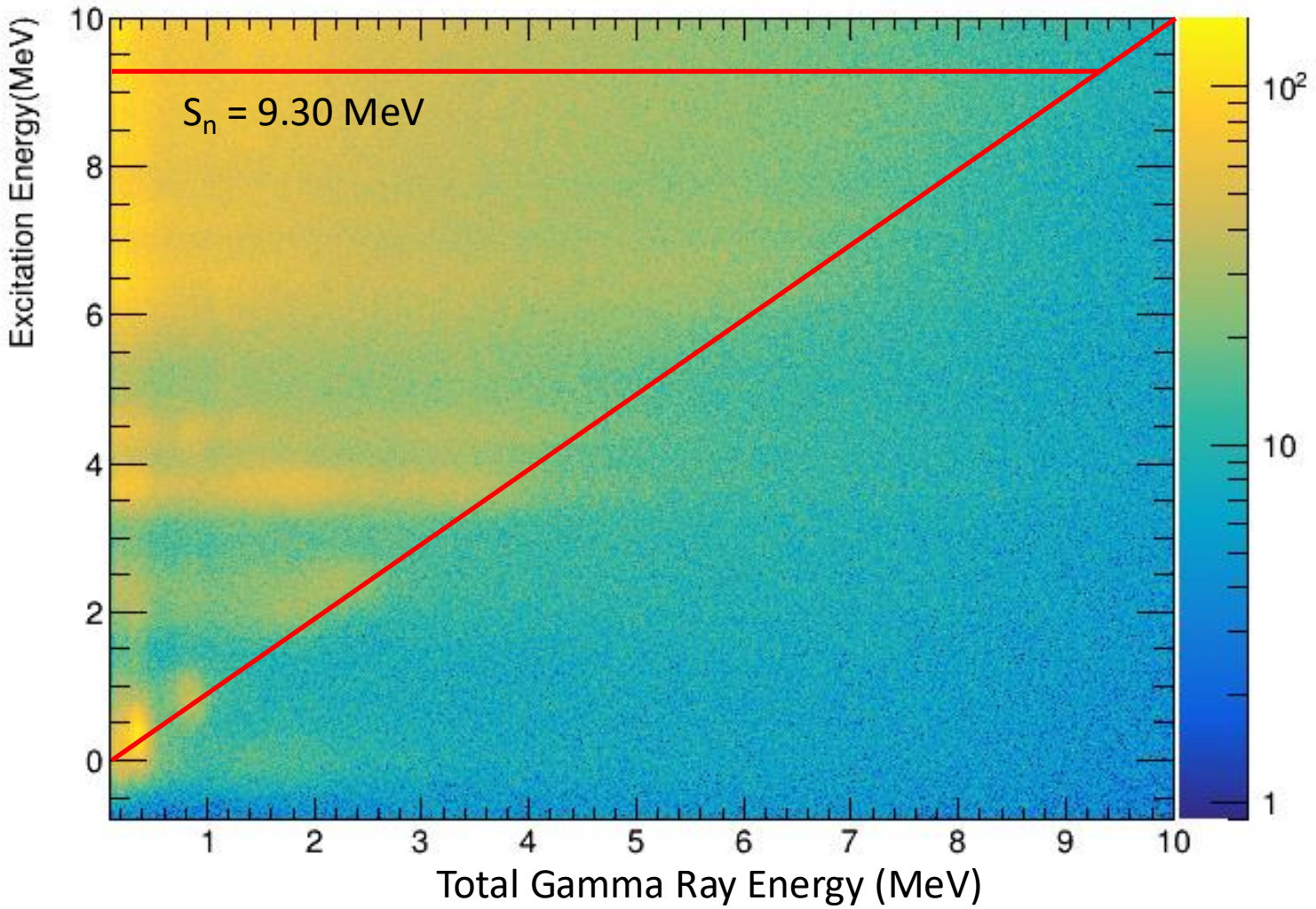
Pileup Clearly Observed
and distinguishable

Deconvolute to improve
efficiency at high rate

Preliminary E* / E_sum Matrix, 54Fe(d,pg)

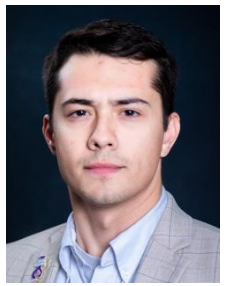
Toward 55Fe Photon Strength Function
→ systematics along Fe isotopic chain

Arthur Alvarez
Poster WANDA 2026

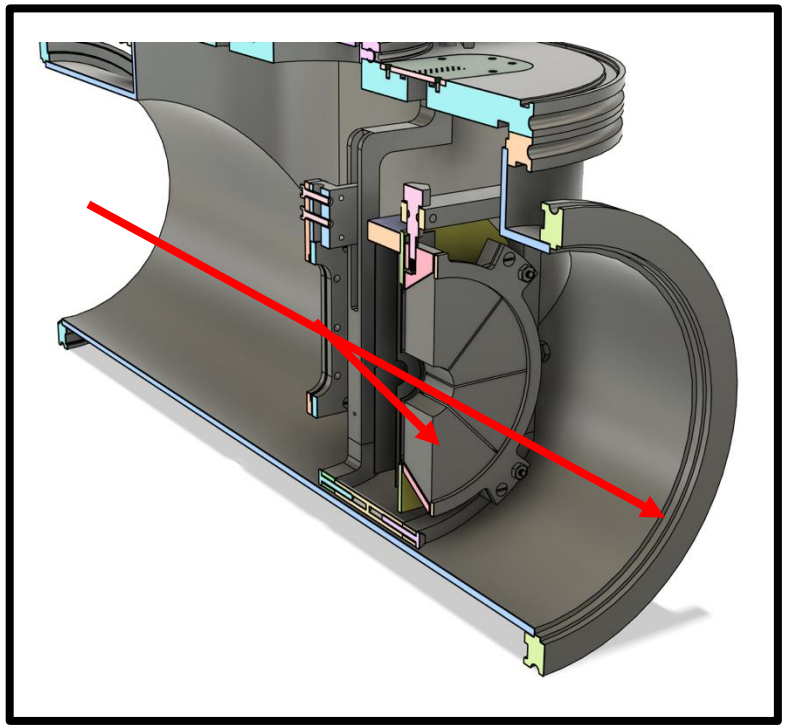


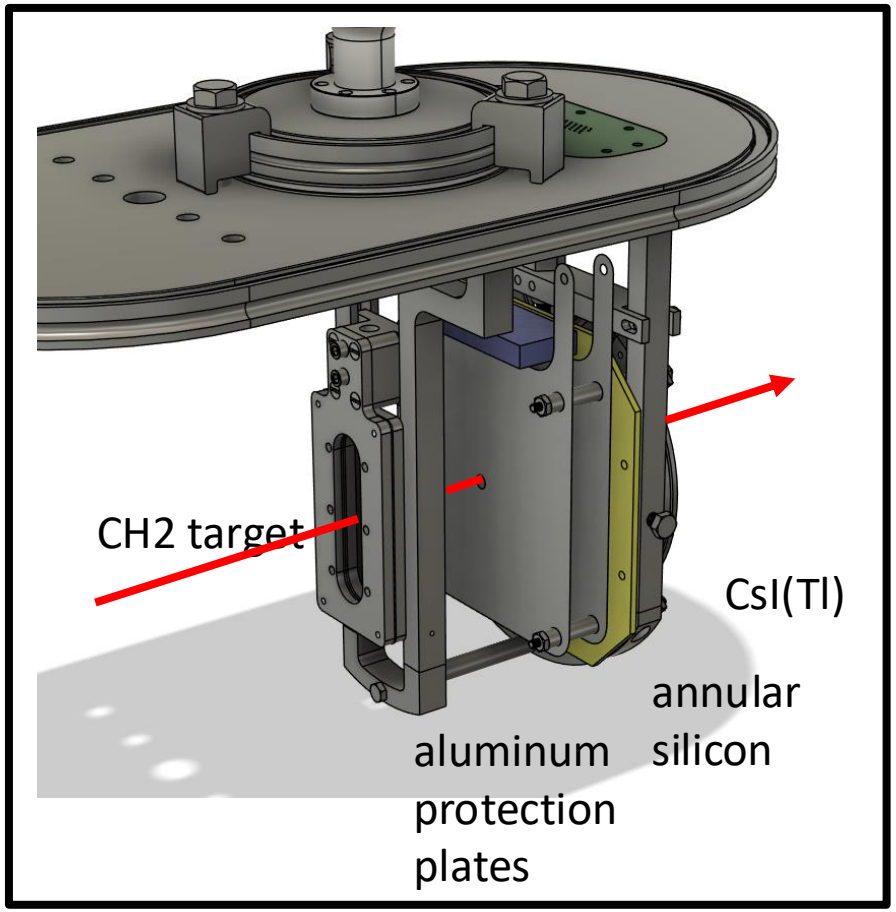
Preparations for third DAPPER campaign configuration for (p,p’) in inverse kinematics

Toward 136Xe Photon Strength Function
136Xe(p,p’g) @ TAMU



David Shelden (TAMU)
Hardware and
Detector Development





Austin Rambo (Ohio)
Kinematics and
Resolution Simulations
Poster WANDA 2026

This work was funded in part by the Office of Defense Nuclear Nonproliferation Research and Development within the U.S. Department of Energy’s National Nuclear Security Administration

In collaboration with D. Bleuel (LLNL), S. Lyons (PNNL),
A. Richard (Ohio), A. Sweet (LLNL), M. Wiedeking (LBNL)

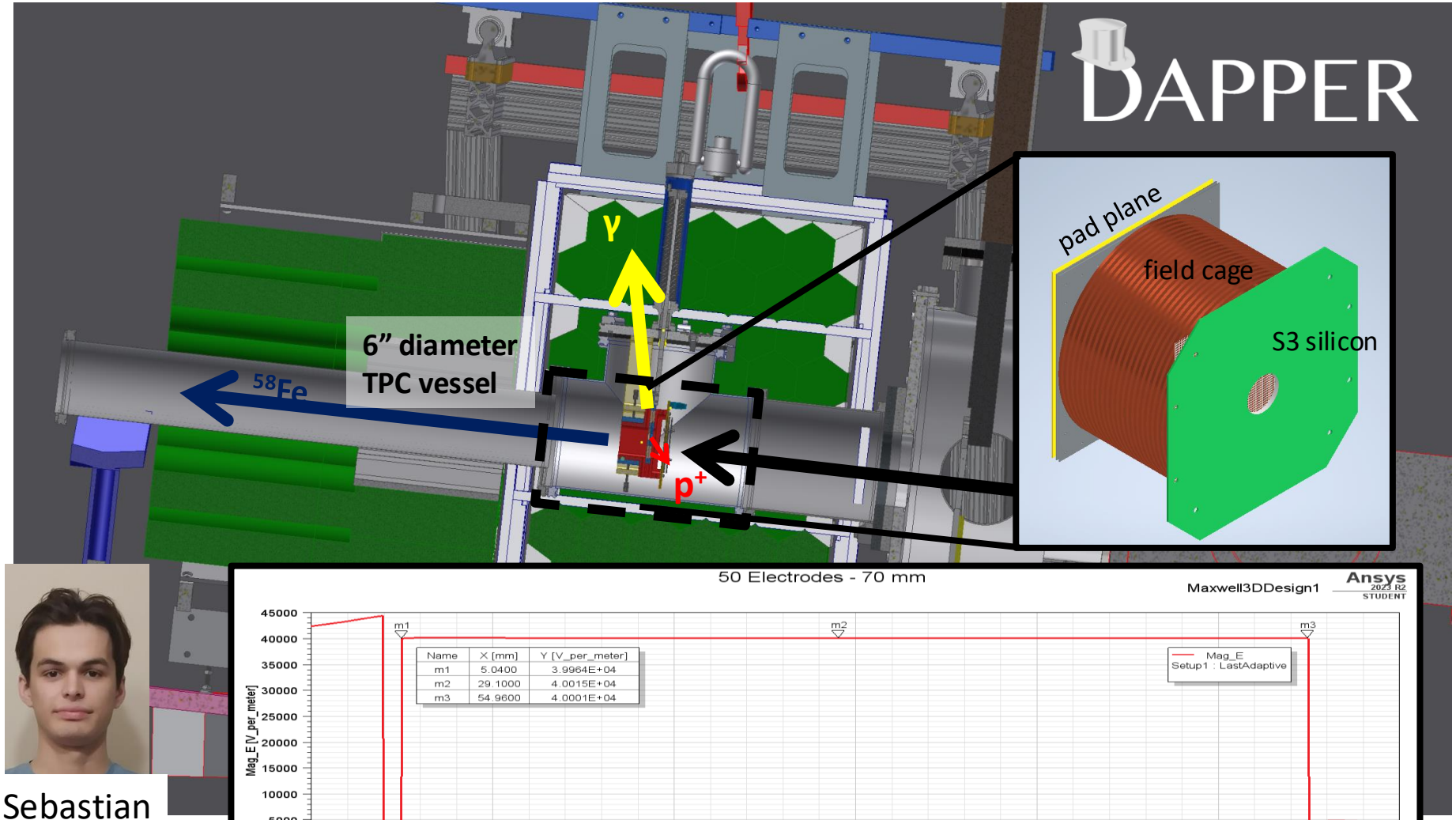
136Xe beta Oslo @ ANL

Future: TPC for DAPPER

Simulations in progress

10cm length x 10cm dia

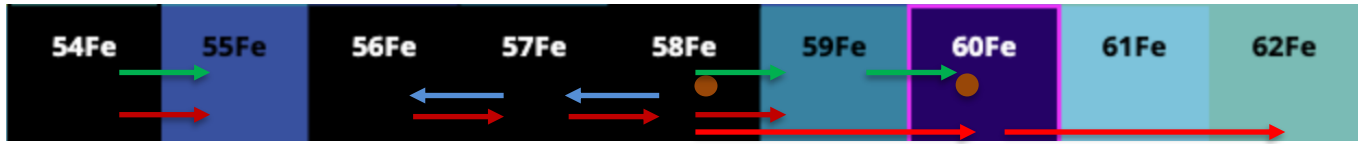
- no fusion-evaporation background
- no target degradation
- higher density of deuterium
- improved E* resolution (energy loss and angle)



Sebastian Regener

Extend Isotopic Chains – Iron Example: Nuclear Data in CENTAUR

59Fe is s-process branch
60Fe is interestingly abundant
Data along the isotopic chain constrains models more strongly



Previous PSF measurements for 56Fe, 57Fe using (3He,4He)
PSF measurement for 58Fe (DANCE) using (n,g)
Analysis for PSF done for 58Fe (DAPPER) using (d,p) (inverse kin)
Data for PSF obtained for 55Fe (DAPPER) using (d,p) (inverse kin)
Future: 59Fe(d,p)60Fe with DAPPER + RIB (inverse kin)

58Fe (Hyperion) using (d,p) or (p,p') (normal kin)

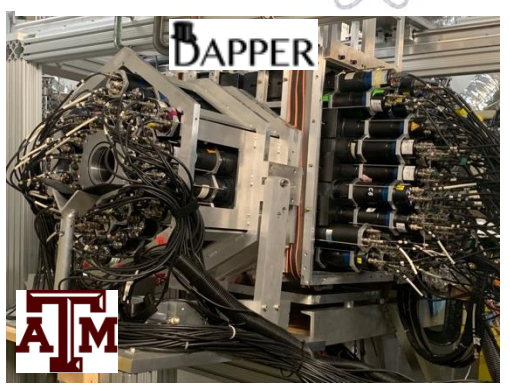
58Fe(t,p)60Fe with DAPPER + triton beams (normal kin)
60Fe(t,p)62Fe with DAPPER + triton beams (normal kin)
target activity only ~1 uCi
60Fe(p,p')60Fe with DAPPER

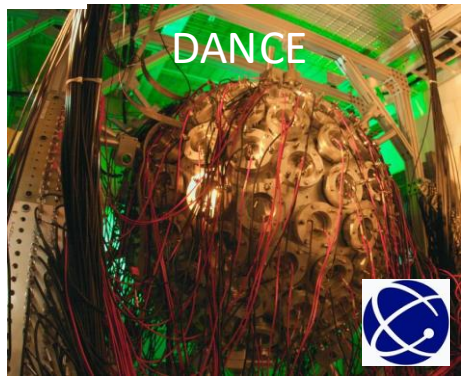
Fe(n,g) with UML reactor (M. Jandel)

Complementary
- Reactions
- Analysis Techniques
- Detector Arrays

→ Understand systematic Uncertainties
→ Stronger constraints for model calculations

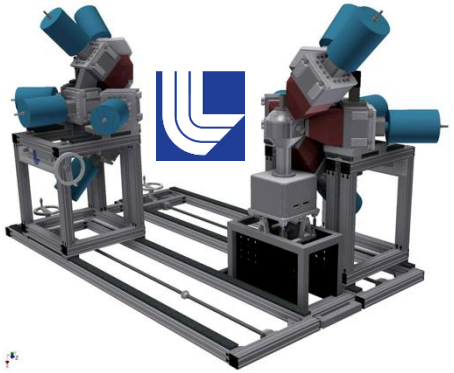
CENTER FOR EXCELLENCE CENTAUR IN NUCLEAR TRAINING AND UNIVERSITY-BASED RESEARCH





FSU Triton beams

UML Reactor



Hyperion Clover Array

Astrophysical Simulations Tracing Reactions And Elements

Visiting Scientists
Dr. Bradley Meyer (Clemson)
Dr. Mengke Li (Notre Dame)

Host
Phil Adsley (TAMU)

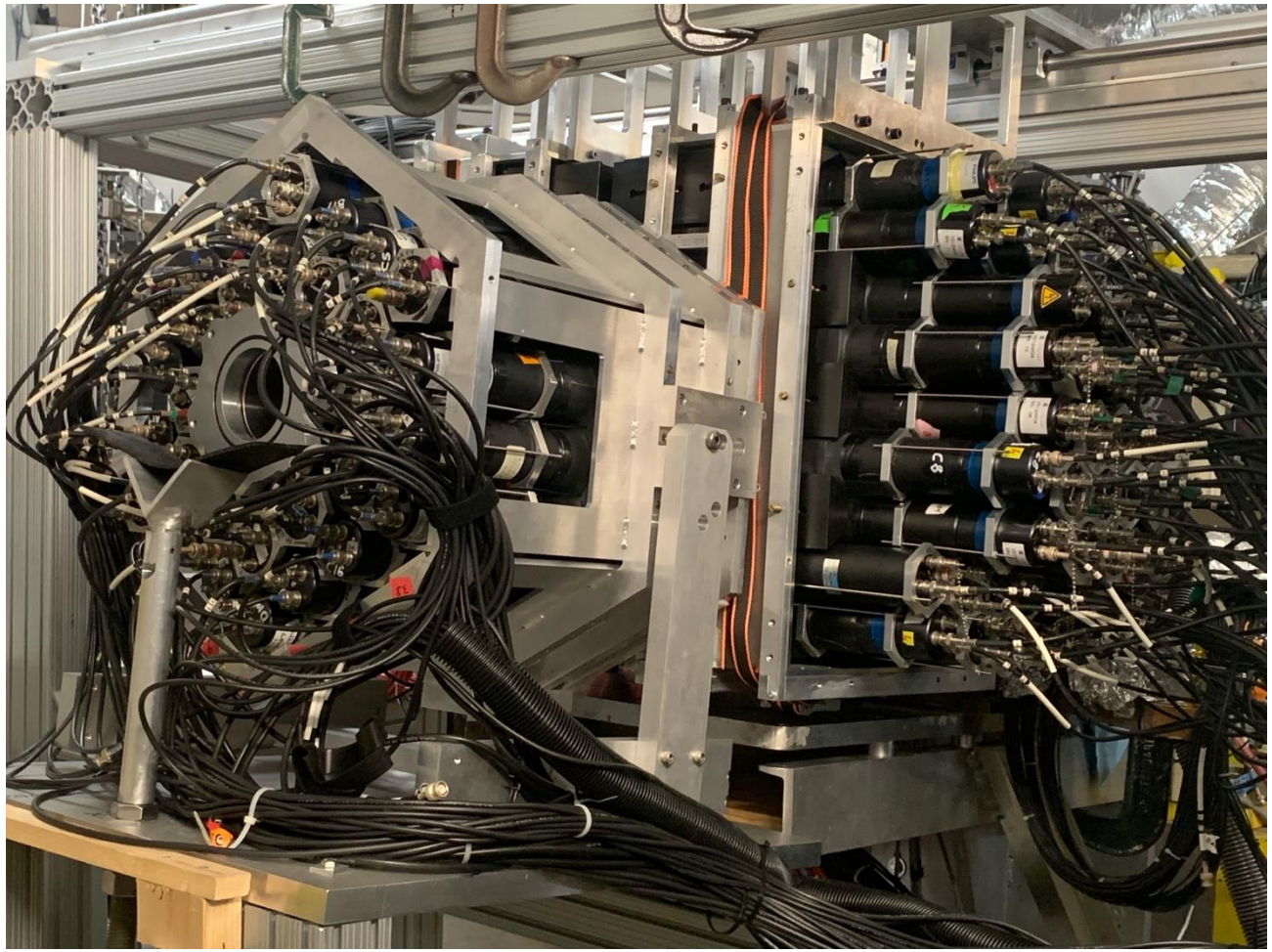
Feb 16-20, 2025
Texas A&M University
Cyclotron Institute

Nuclear data is needed for reaction network calculations.
Students are being educated to appreciate this and apply it.
Network calculation application:
nucleosynthesis, stockpile science, nuclear forensics, nuclear reactors

DAPPER

Data:
PSF & NLD
in inv kin

Capabilities
High Gamma Ray Efficiency
High Granularity
Total Gamma Energy
Gamma Multiplicity
Individual Gamma Energy
Good Doppler Correction
Inverse Kinematics
Secondary Beams
Unit-Z for Residues at High Rate



A. Abbott et al., Phys. Rev. C 111 (2025) 034322 “Using DAPPER to extract the photon strength function of 58Fe using the inverse Oslo and shape methods”

M.Q. Sorensen et al., Phys. Rev C 113 (2026) 014602 “Experimental study of the photon strength function of 58Fe via the (d, p) reaction in inverse kinematics using a forward method”

A. Abbott, Ph.D. Thesis, Texas A&M University (2024) “USING DAPPER TO EXTRACT THE PHOTON STRENGTH FUNCTION OF 58FE VIA THE INVERSE OSLO AND SHAPE METHODS”

M.A. Sorensen, Ph.D. Thesis, Texas A&M University (2024) “STUDY OF 58FE’S PHOTON STRENGTH FUNCTION VIA (D,P) REACTION IN INVERSE KINEMATICS USING A FORWARD METHOD”

A.B. McIntosh et al., Nucl. Phys. A 1057 (2025) 123038 “Development of the detector array for photons, protons, and exotic residues”

A.B. McIntosh et al., Nucl. Inst. Meth. A *(manuscript in preparation)*

Fin