The *CATRiNA* Deuterated Neutron Detector @ FSU

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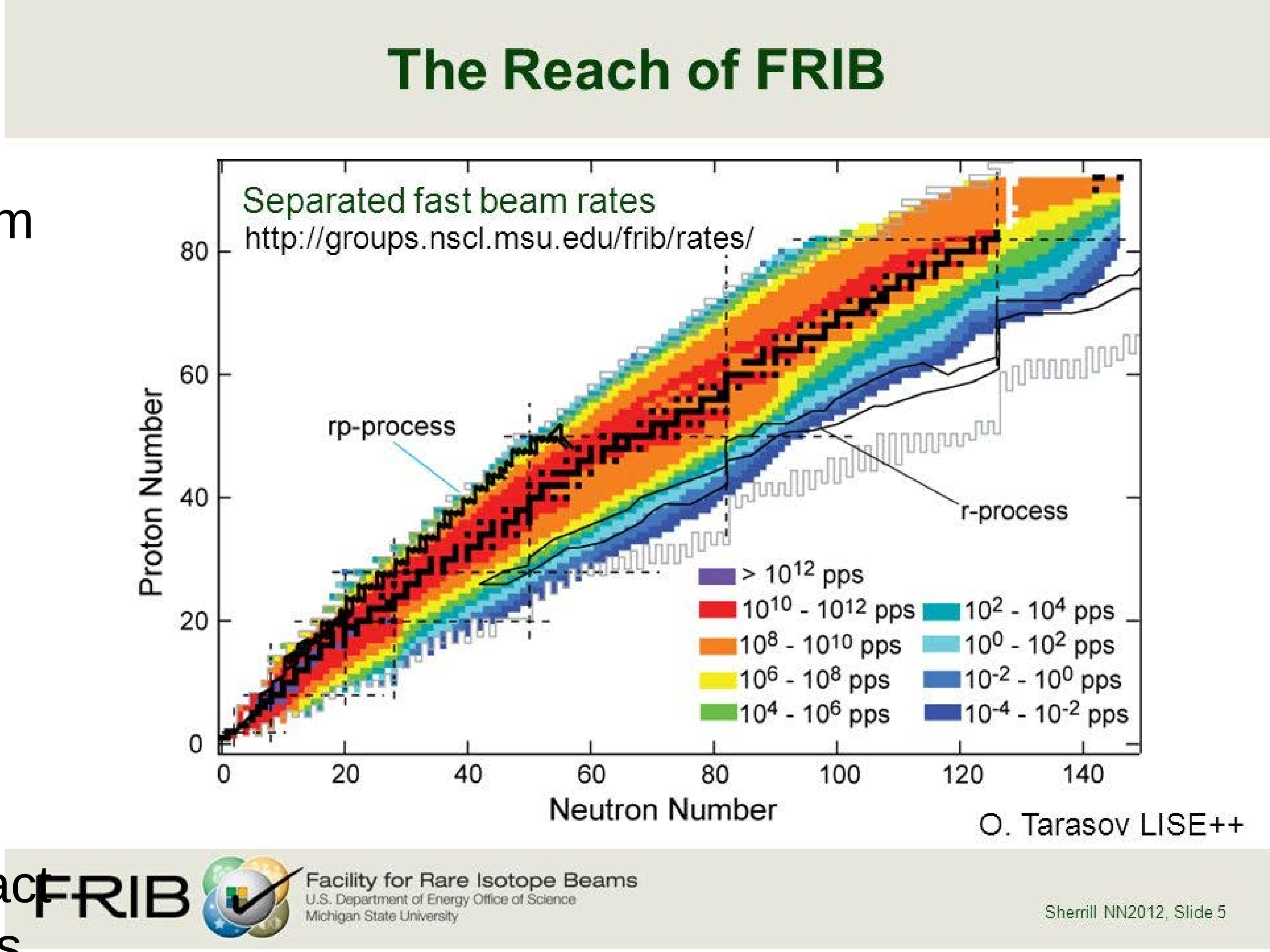
Motivation

- One of the primary goals of present-day radioactive beam facilities is the study of neutron-rich nuclei

- Neutron emission can occur for states at lower excitation energies than in nuclei near stability

- Neutron spectroscopic techniques become increasingly relevant to extract information from experiments



Neutron Detectors

- There are man types of neutron detectors like the ones presented here today, all with different characteristics.
- Organic scintillators with hydrogen based compounds → based on the high *(p,n)* elastic scattering cross section.
- Standard Liquid scintillators *NE213* (C_6H_6) fast, n/γ separation, high cross section

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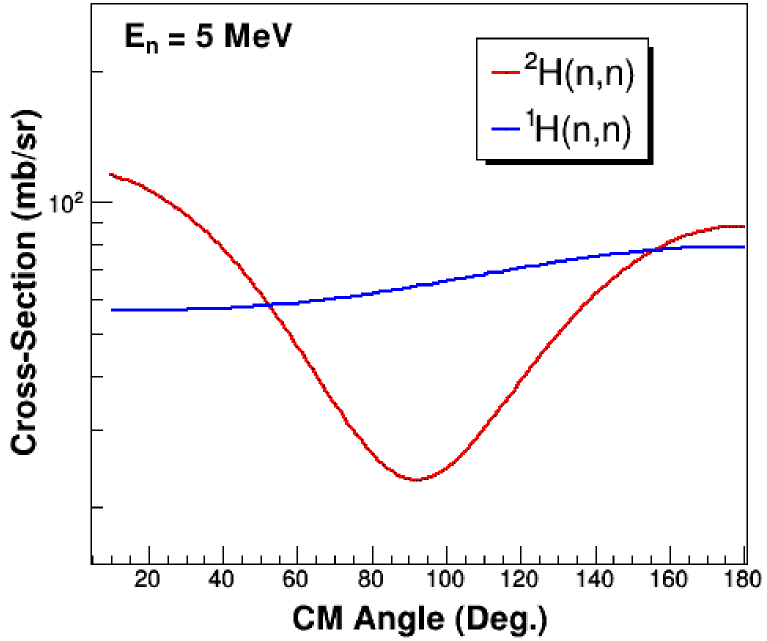
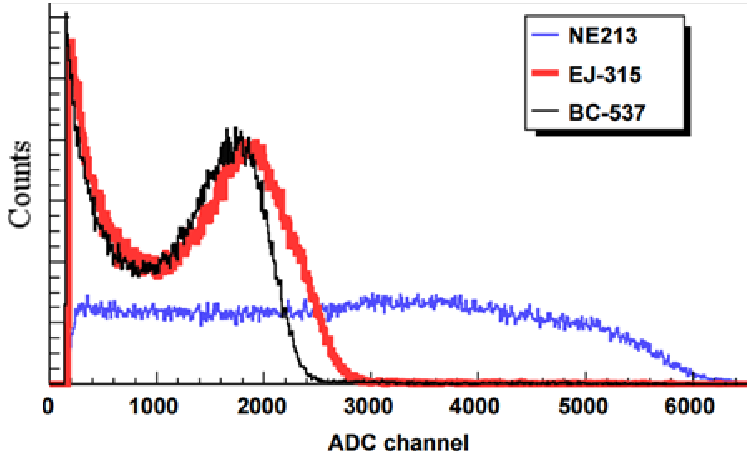
- Standard Liquid scintillators *NE213* (C_6H_6) fast, n/γ separation, high cross section
- *Deuterated Liquid scintillators* (C_6D_6), based on the *(d,n)* cross section, fast, good PSD capabilities, and structured pulse height spectra!

- *DESCANT @ TRIUMF*
- Deuterated Scintillator Array @ UM (UM-DSA)

M. Febbraro, et al., NIMA (2015) 784:184-188





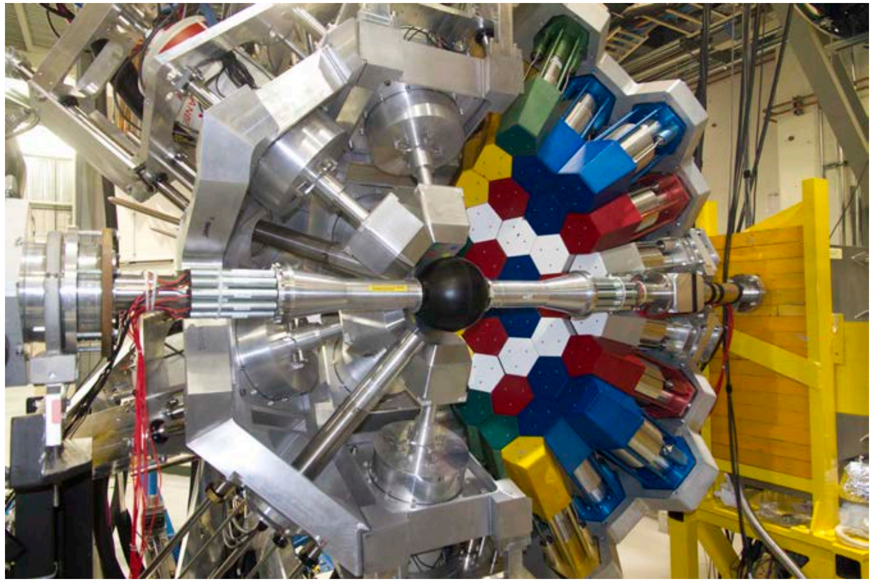
V. Bilstein et al., NIMA (2013) 729: 188-197

Deuterated liquid scintillators Detectors

DESCANT @ TRIUMF

- 70 deuterated benzene (C_6D_6) liquid detectors
- DESCANT has been designed to be coupled with the TIGRESS and GRIFFIN γ-ray spectrometers to enable neutron tagging in fusion-evaporation reactions, and β-delayed neutron studies

P.E. Garret, Hyperfine Interact (2014) 225:137–141



"Overall the deuterated scintillators showed a performance comparable to or surpassing that of the non-deuterated scintillator with the additional benefit of a structure on the pulse-height spectra which might be used to distinguish multiple-scattering events in a neutron detector array."

V. Bilstein et al., NIMA (2013) 729: 188-197

The CATRiNA Detector

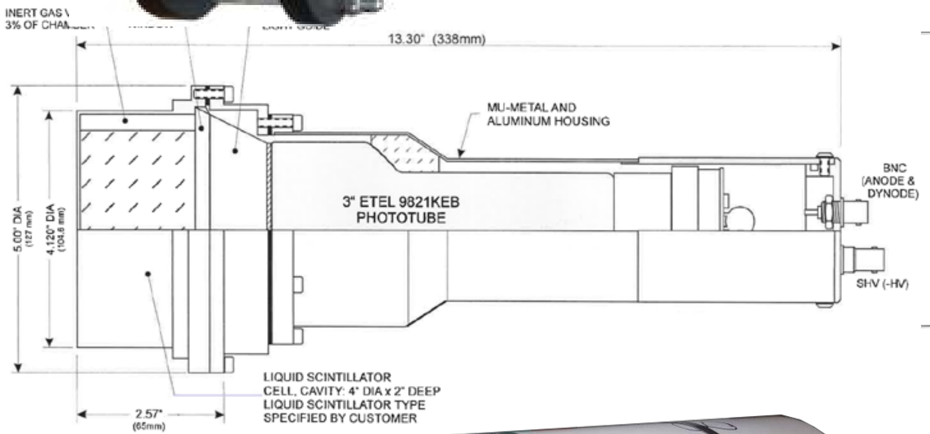
At FSU we are developing a neutron detector array consisting of 16 deuterated liquid scintillator detectors (EJ-315)

Compound Array for Transfer Reactions in Nuclear Astrophysics (CATRiNA)

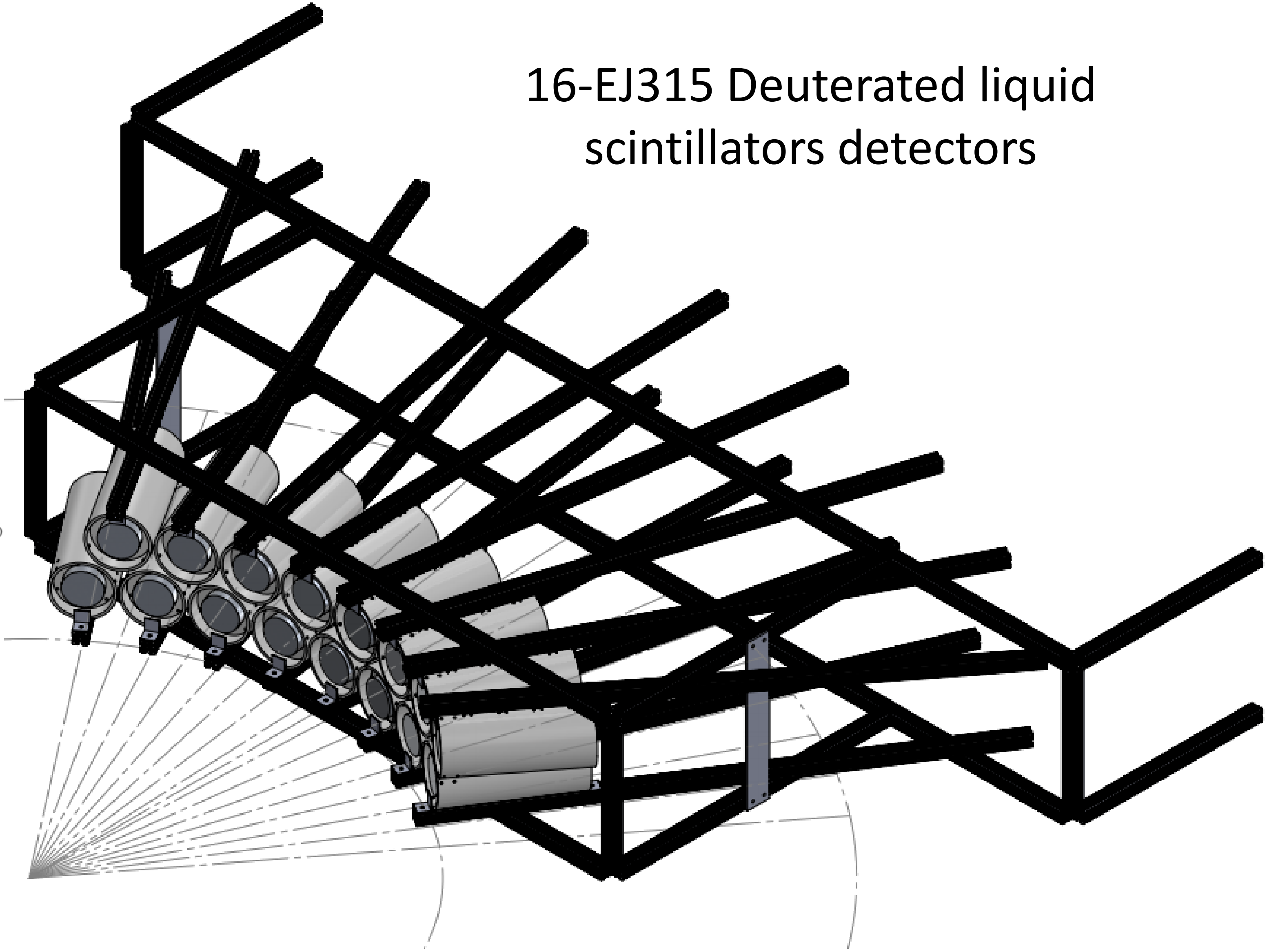
CATRiNA is designed to:

- Study resonances in exotic nuclei
- Use neutrons in coincidence with charged particles and γ-rays.
- ($^{3}He,n+p/\gamma$) & ($d,n+p/\gamma$) reactions

The CATRiNA Detector

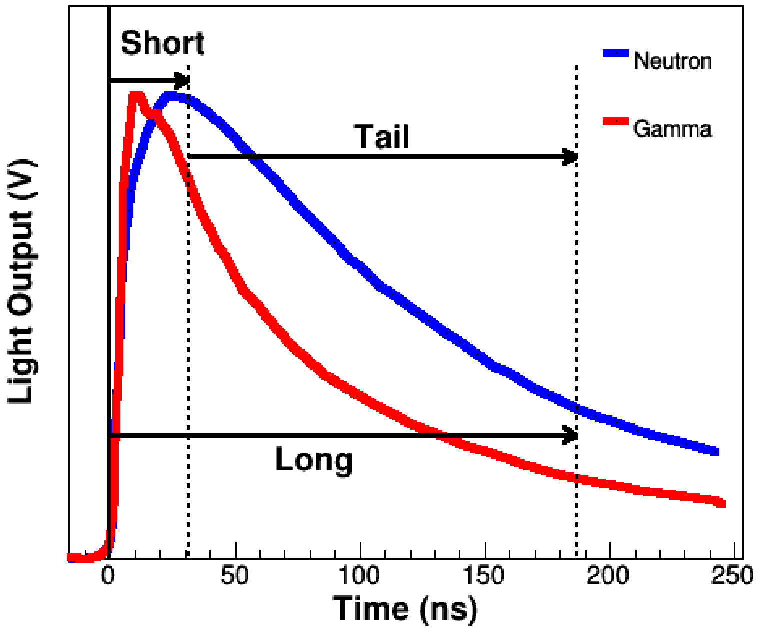


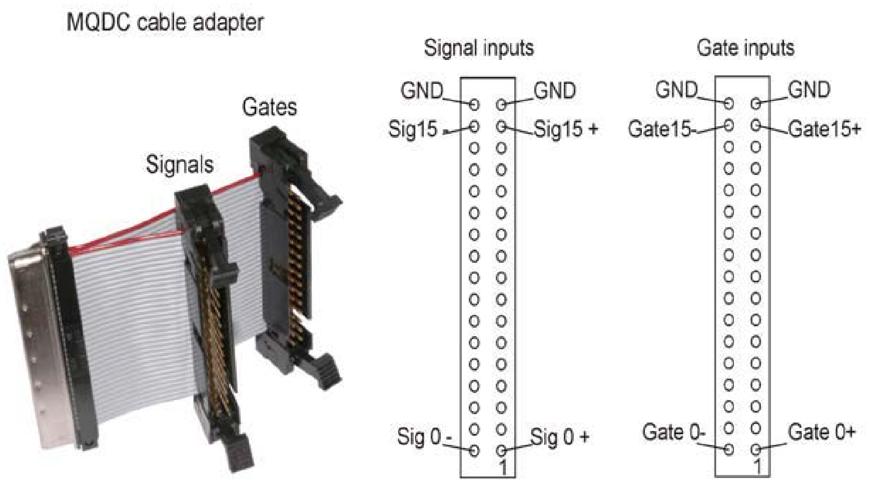
16-EJ315 Deuterated liquid scintillators detectors



CATRiNA's DAQ

Currently we are using *analog* electronics:
MESYTEC MQDC Modules
Two independent integration times for PSD analysis using charge integration method
Integrated to the NSCL DAQ





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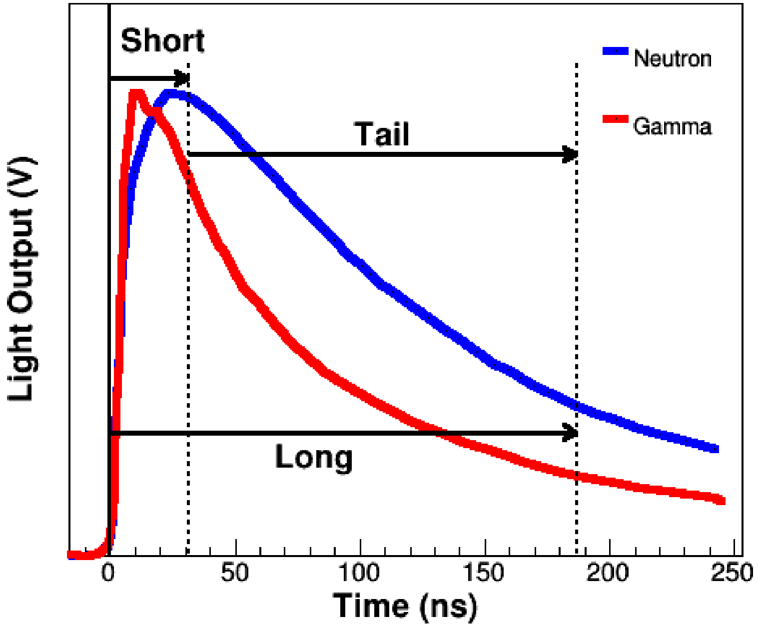
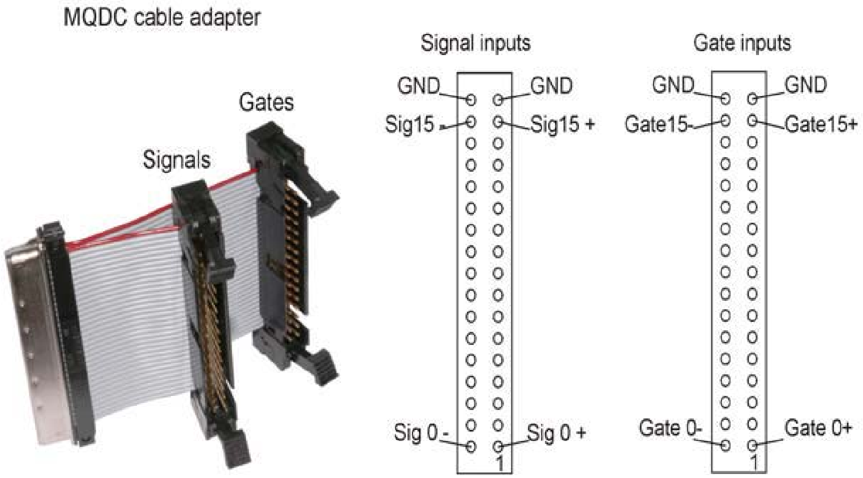
Plan to upgrade to Digital electronics … soon, suggestions are welcome!

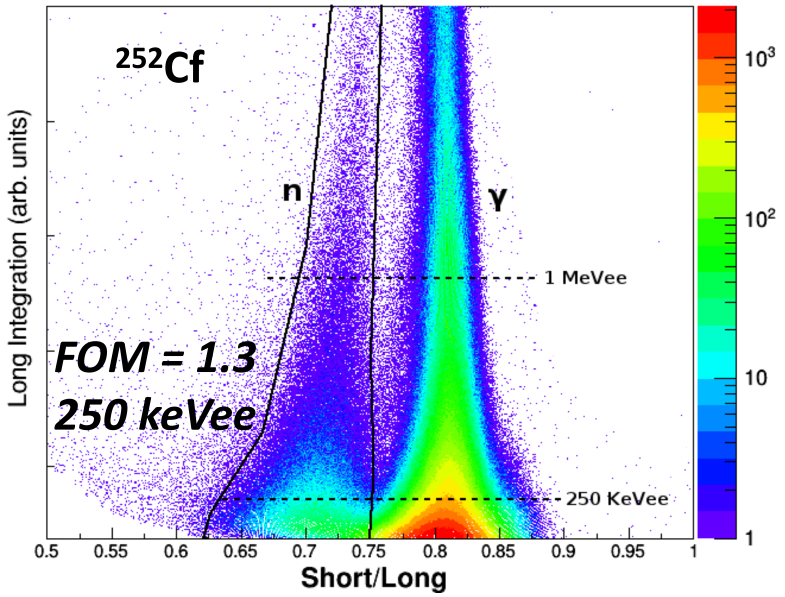




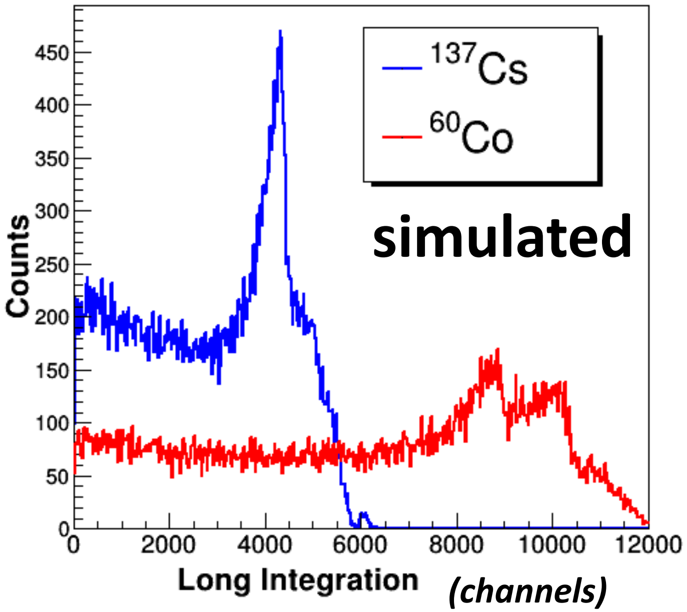
CATRiNA's characterization

Gamma ray sources(^{60}Co, ^{137}Cs) and neutron source (^{252}Cf) were used to characterized the detector:
optimize PMT voltages, light response, MQDC parameters, integration gates (32,187)

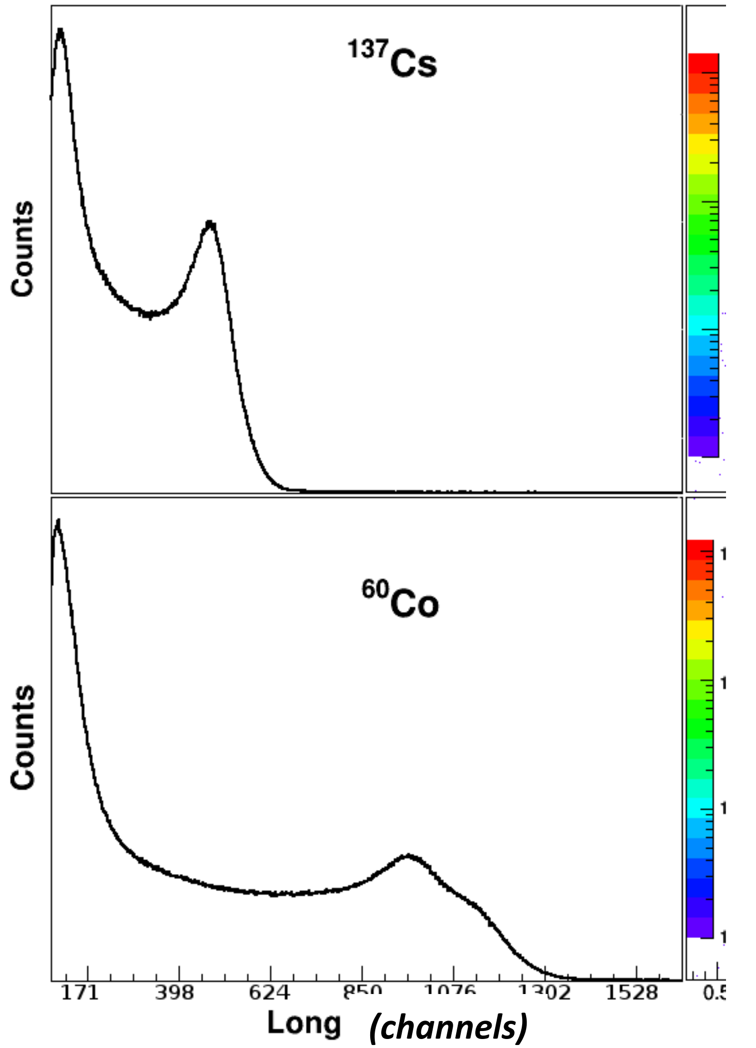
$$FOM = \frac{\Delta_c}{\Delta_n + \Delta_\gamma}$$



GEANT4 simulation was developed

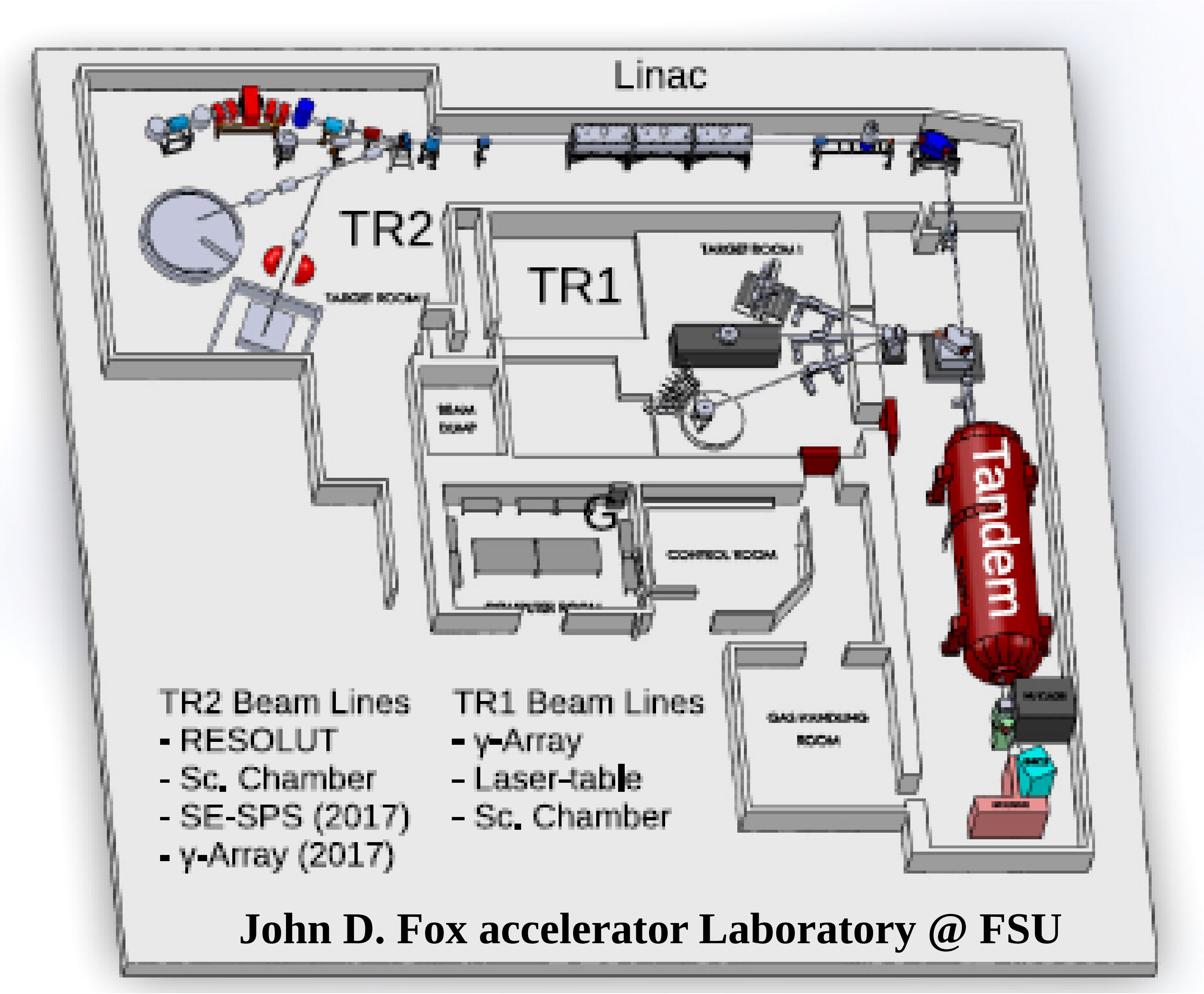


Measurements



$^7Li(p,n)^7Be$ measurement

Neutrons from the 7Li(p,n) reaction were measured with CATRiNA at the John D. Fox Lab at FSU.
Quasi mono-energetic neutrons
Measure efficiencies, Validate MC simulations



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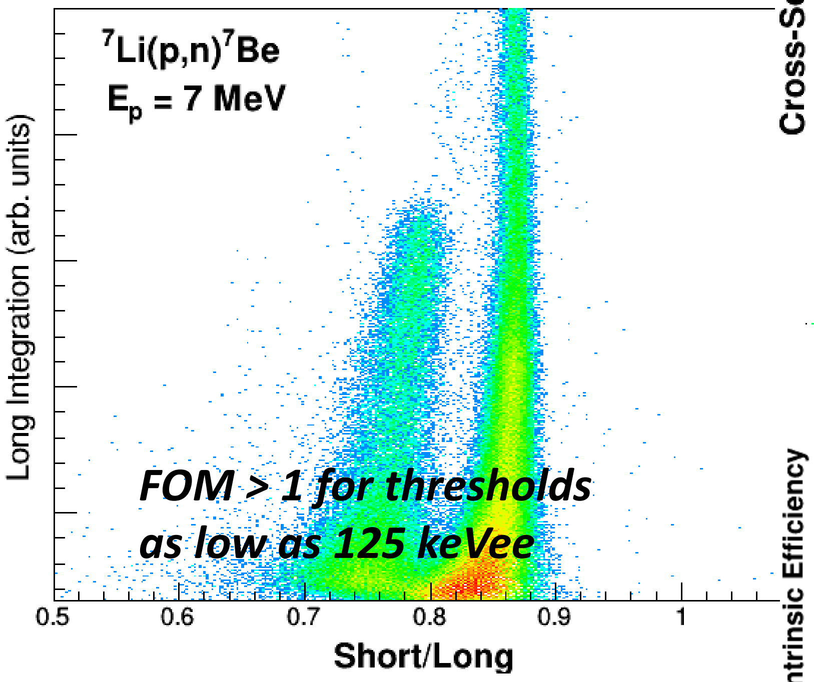
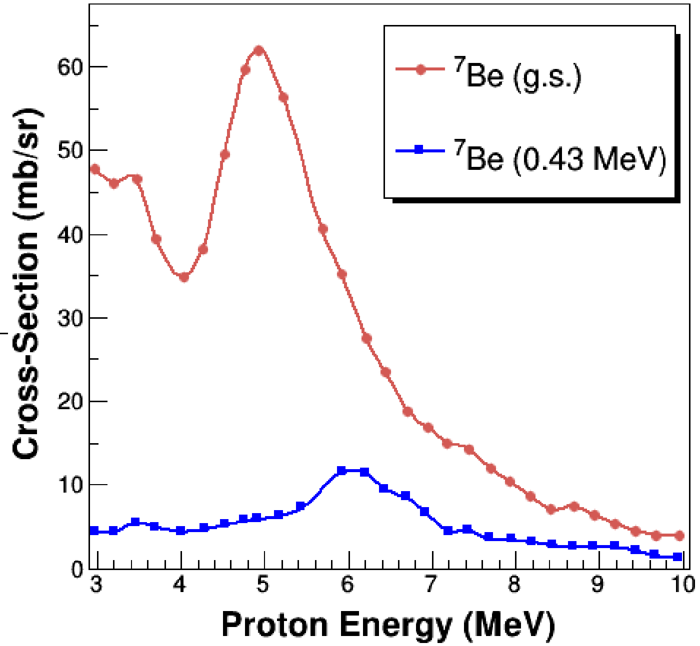
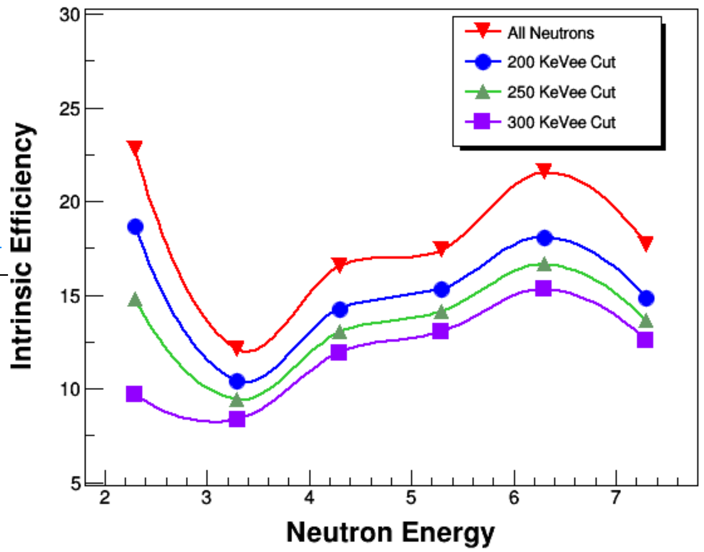
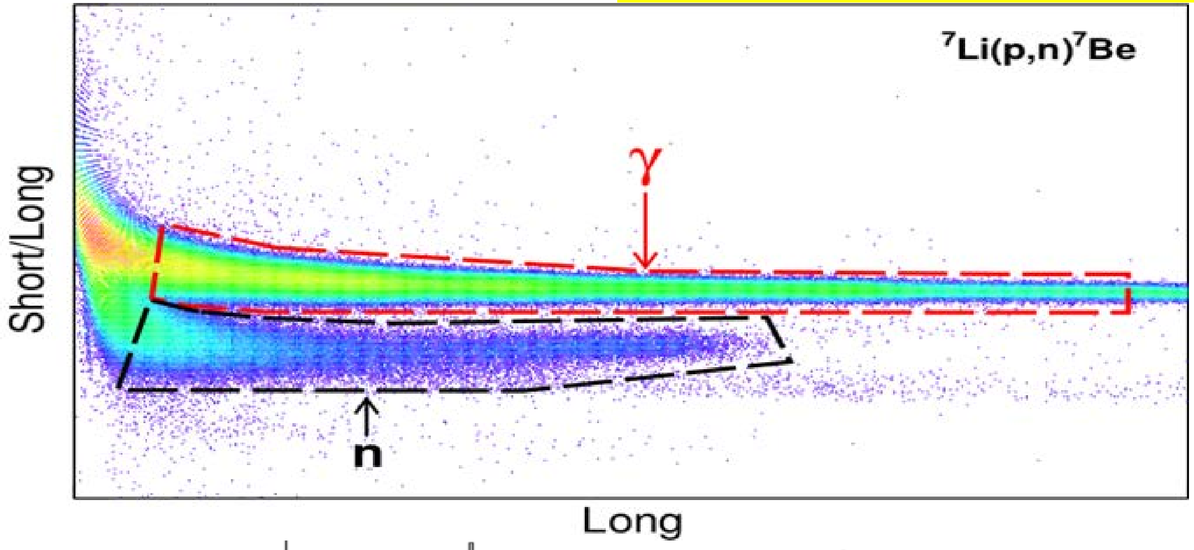


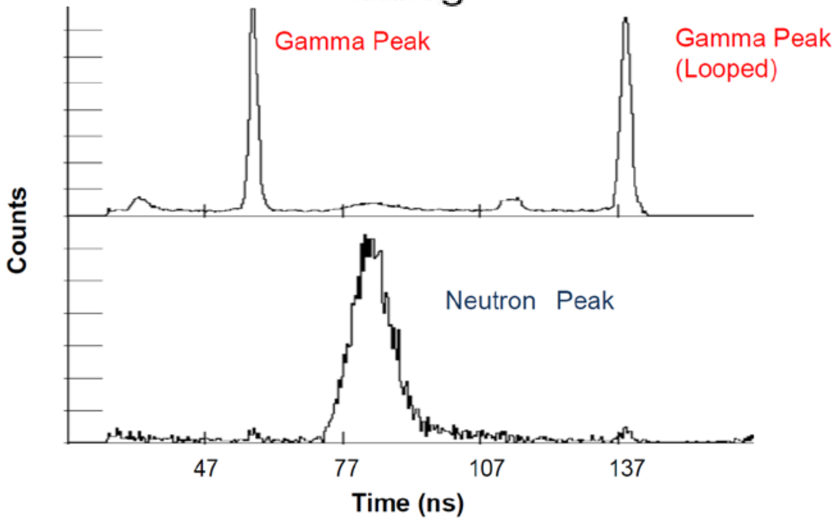


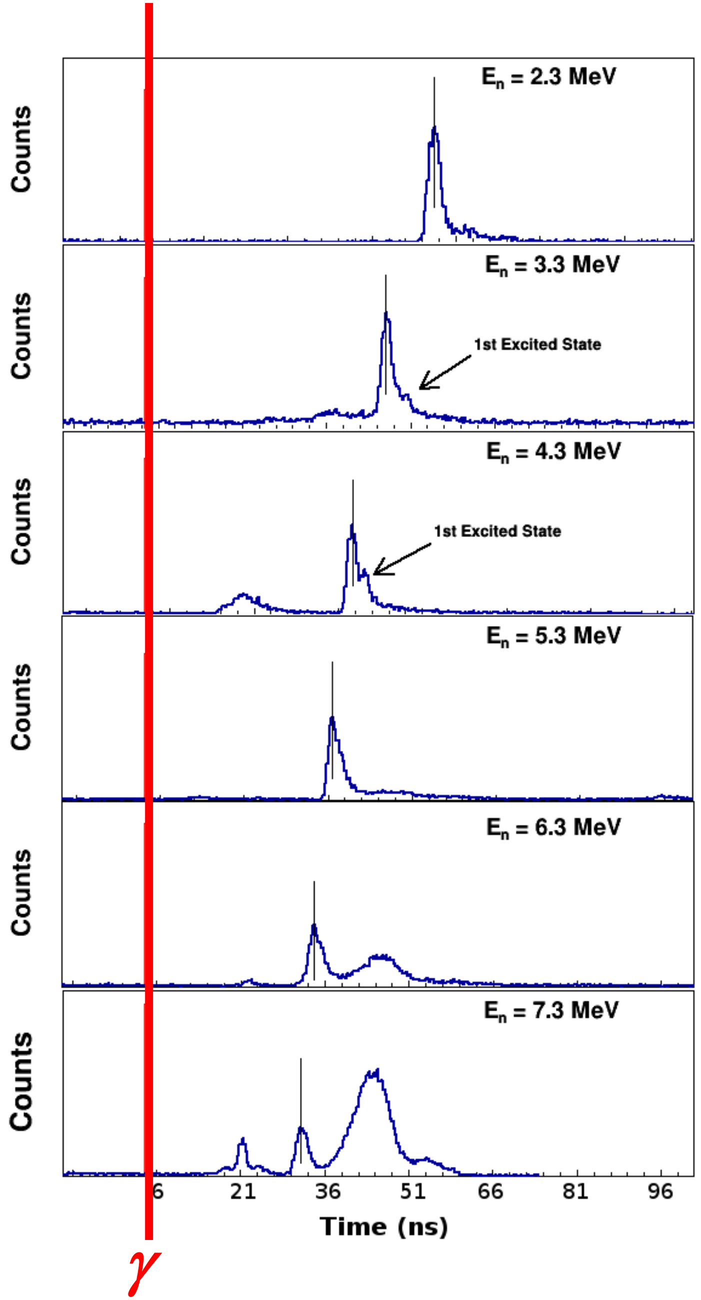


$^{7}Li(p,n)^{7}Be$ measurement

Neutron Energy: ToF

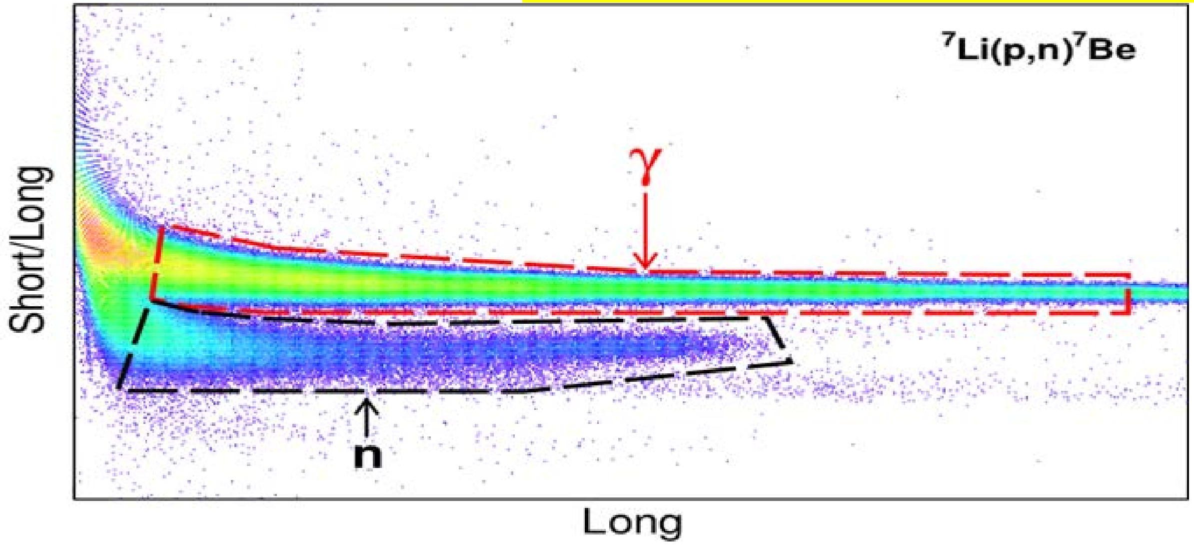


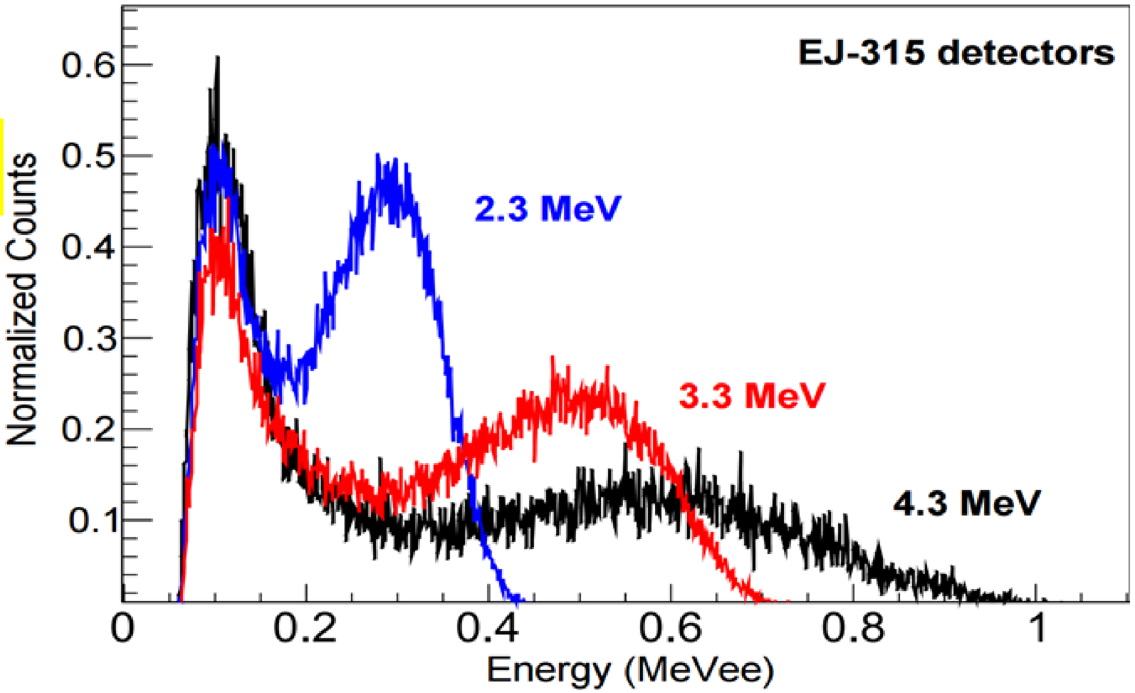


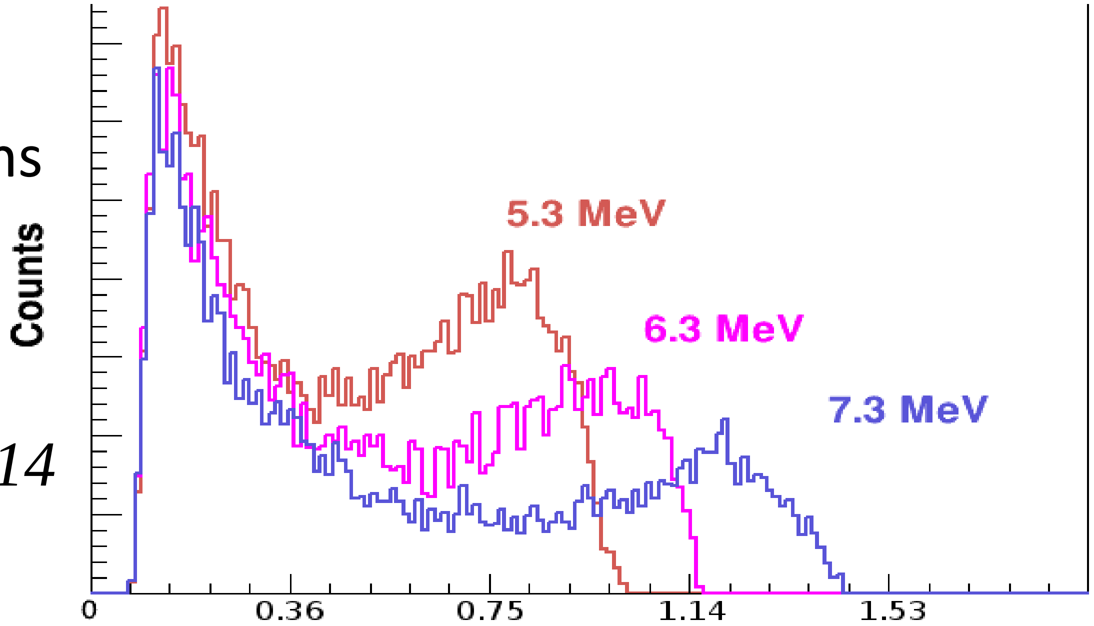


$^7Li(p,n)^7Be$ measurement

Neutron Energy: Pulse height







- There are indeed distinguishable groups of neutrons
- We are looking into different spectra unfolding approaches:

✓ *M. Febbraro et al., NIMA 784(2015)184–188*

✓ *B. Pehlivanovic et al., Rad. Meas. 49 (2013) 109e114*

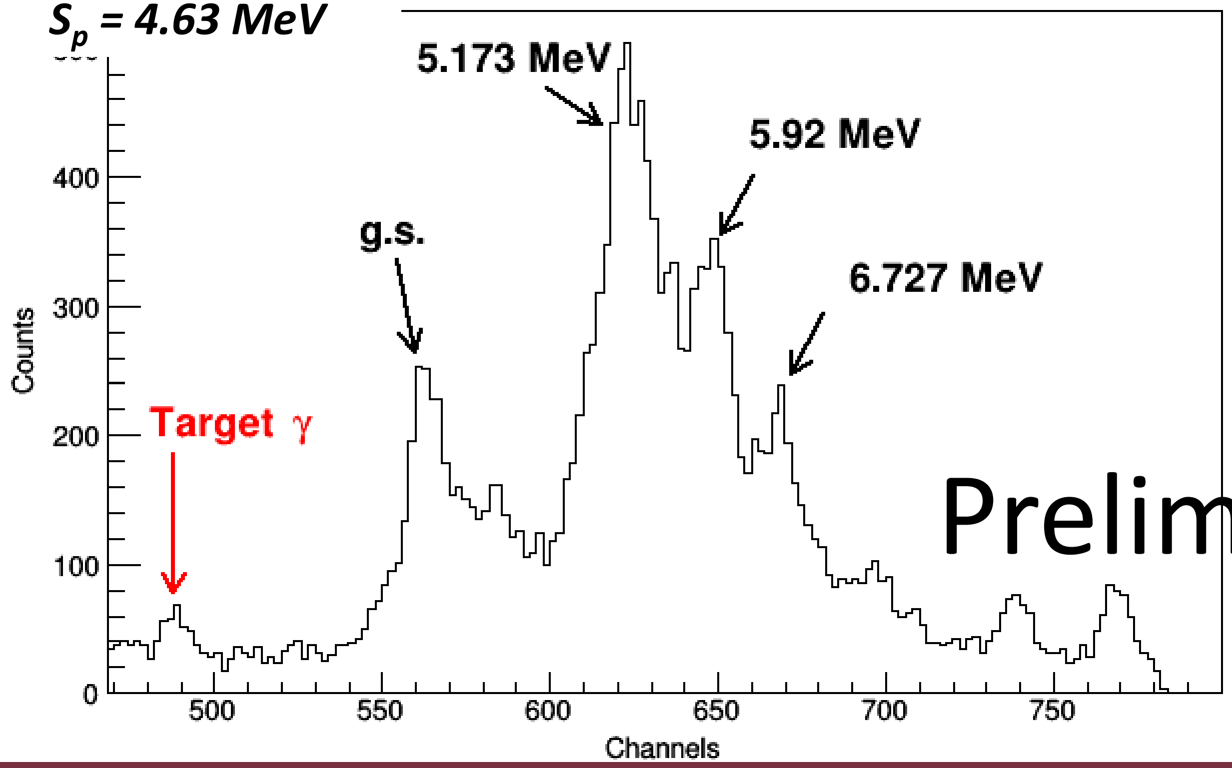
Outlook and future plans

- ^{7}Li(p,n)^{7}Be results are very promising
- Characterization phase is done
- Time to do some physics!!

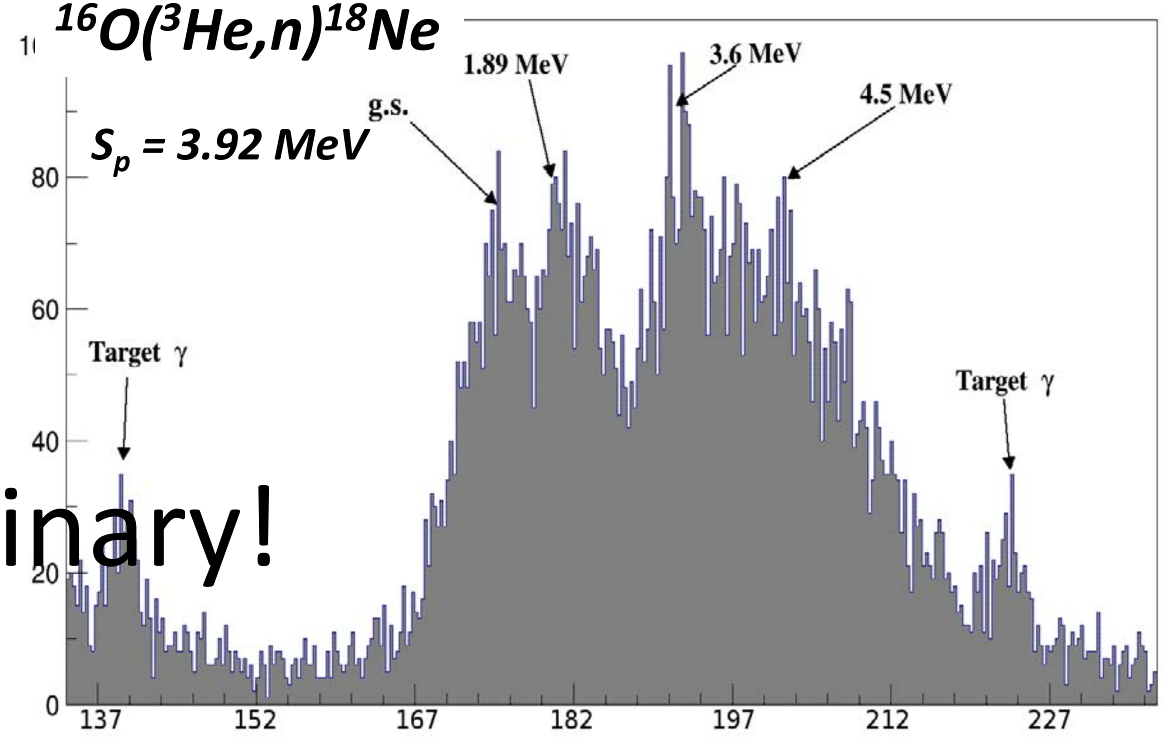
Astro-React.	Compound	Proposed React.
^{15}O(α,γ)^{19}Ne	^{19}Ne	^{19}F(p,n)
		^{17}O(^{3}He,n)
^{18}Ne(α,p)^{21}Na	^{22}Mg	^{20}Ne(^{3}He,n)
^{22}Mg(α,p)^{25}Al	^{26}Si	^{24}Mg(^{3}He,n)
^{26}Al(α,p)^{29}Si	^{30}P	^{28}Al(^{3}He,n)
		^{29}Si(p,n)
		^{28}Si(d,n)
^{30}S(α,p)^{33}Cl	^{34}Ar	^{32}S(^{3}He,n)
^{34}Ar(α,p)^{37}K	^{38}Ca	^{36}Ar(^{3}He,n)

^{12}C(^{3}He,n)^{14}O

S_p = 4.63 MeV



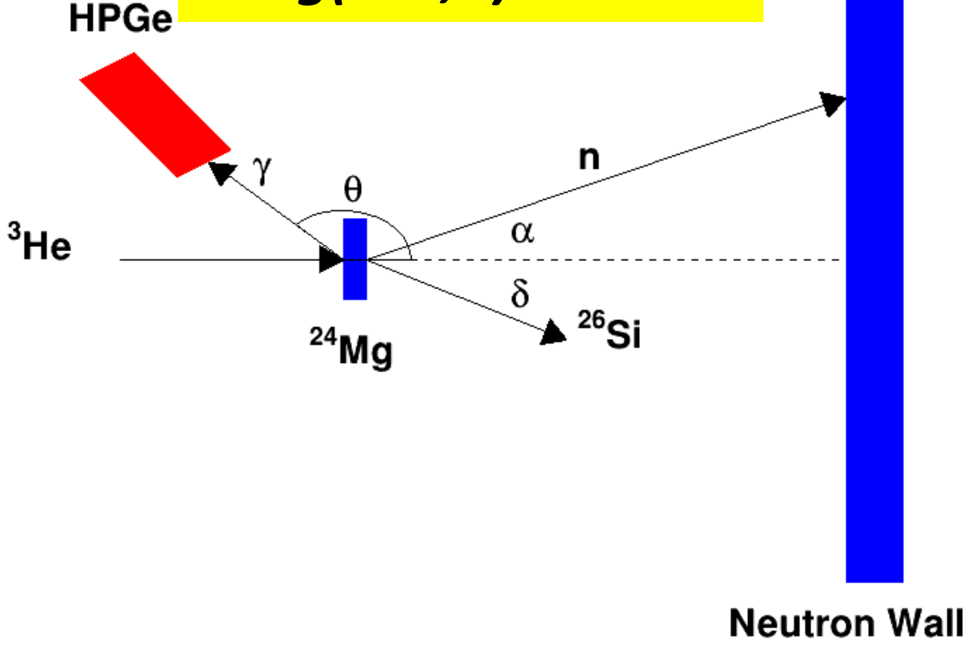
^{16}O(^{3}He,n)^{18}Ne

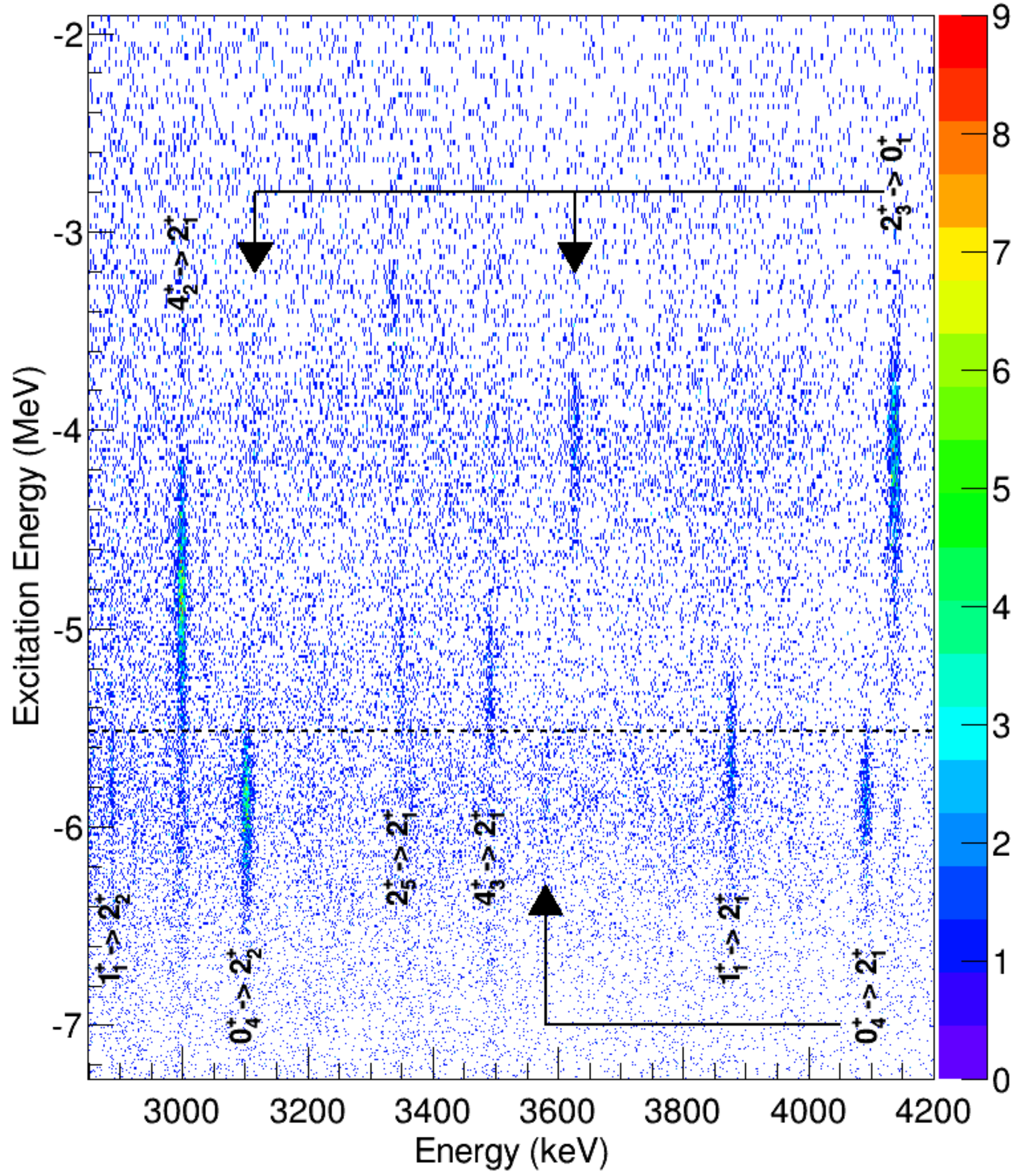


Preliminary!

Outlook and future plans

$^{24}Mg(^{3}He,n)^{26}Si$





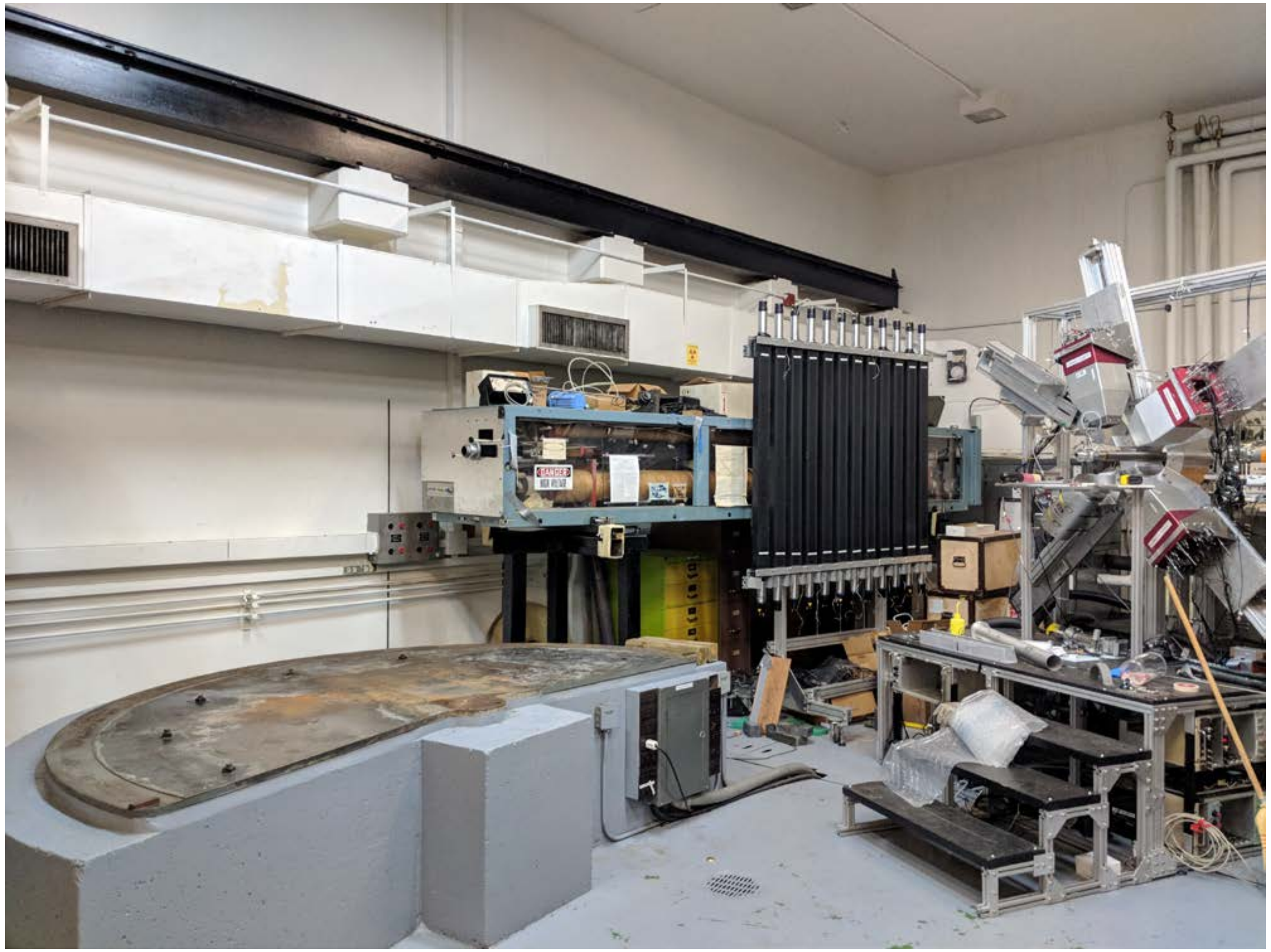
J. Parker, PhD Thesis, FSU (2017)

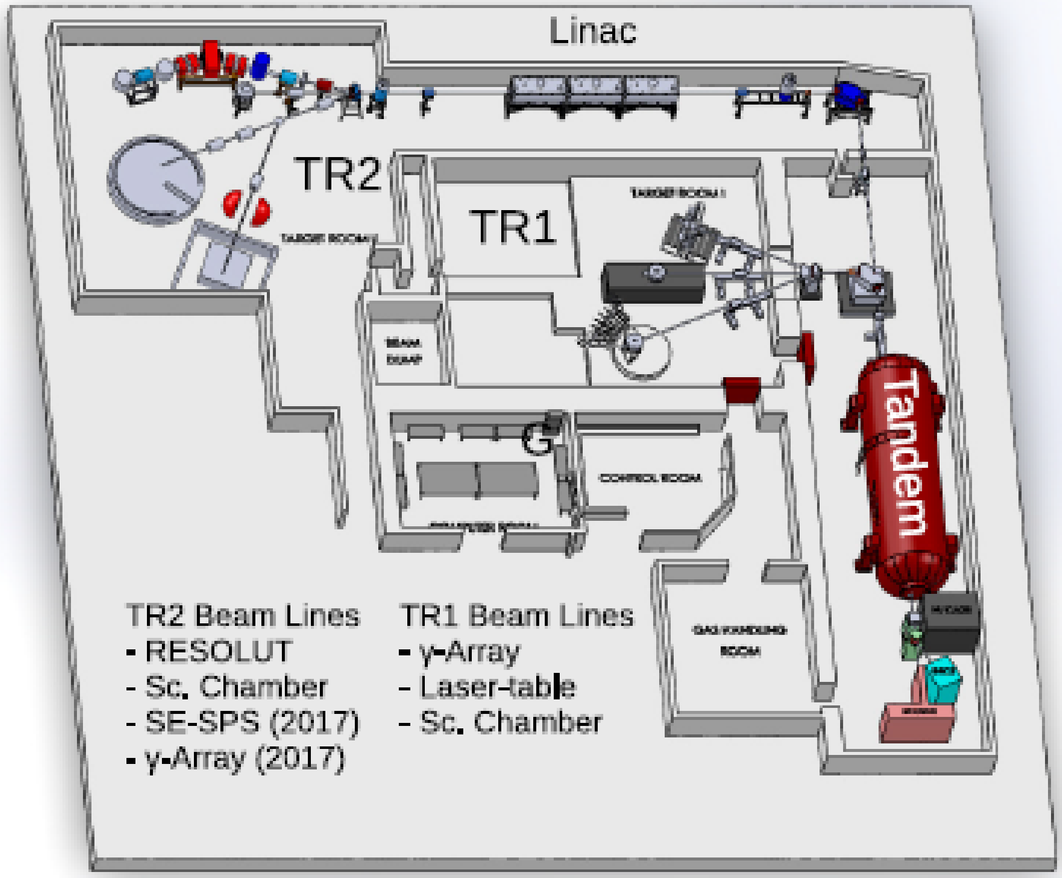
Characterization of the CATRiNA neutron detector system

J. F. Perello[a], S. Almaraz-Calderon[a], B. W. Asher[a], L. T. Baby[a], P. Barber[a], N. Gerken[a], K. Hanselman[a]

[a]Department of Physics, Florida State University, Tallahassee, Florida 32306, USA

Thank you!




Linac
TR2
TR1
Tandem
TR2 Beam Lines
- RESOLUT
- Sc. Chamber
- SE-SPS (2017)
- γ-Array (2017)
TR1 Beam Lines
- γ-Array
- Laser-table
- Sc. Chamber