Status of GADGET II: A TPC for decay spectroscopy at FRIB

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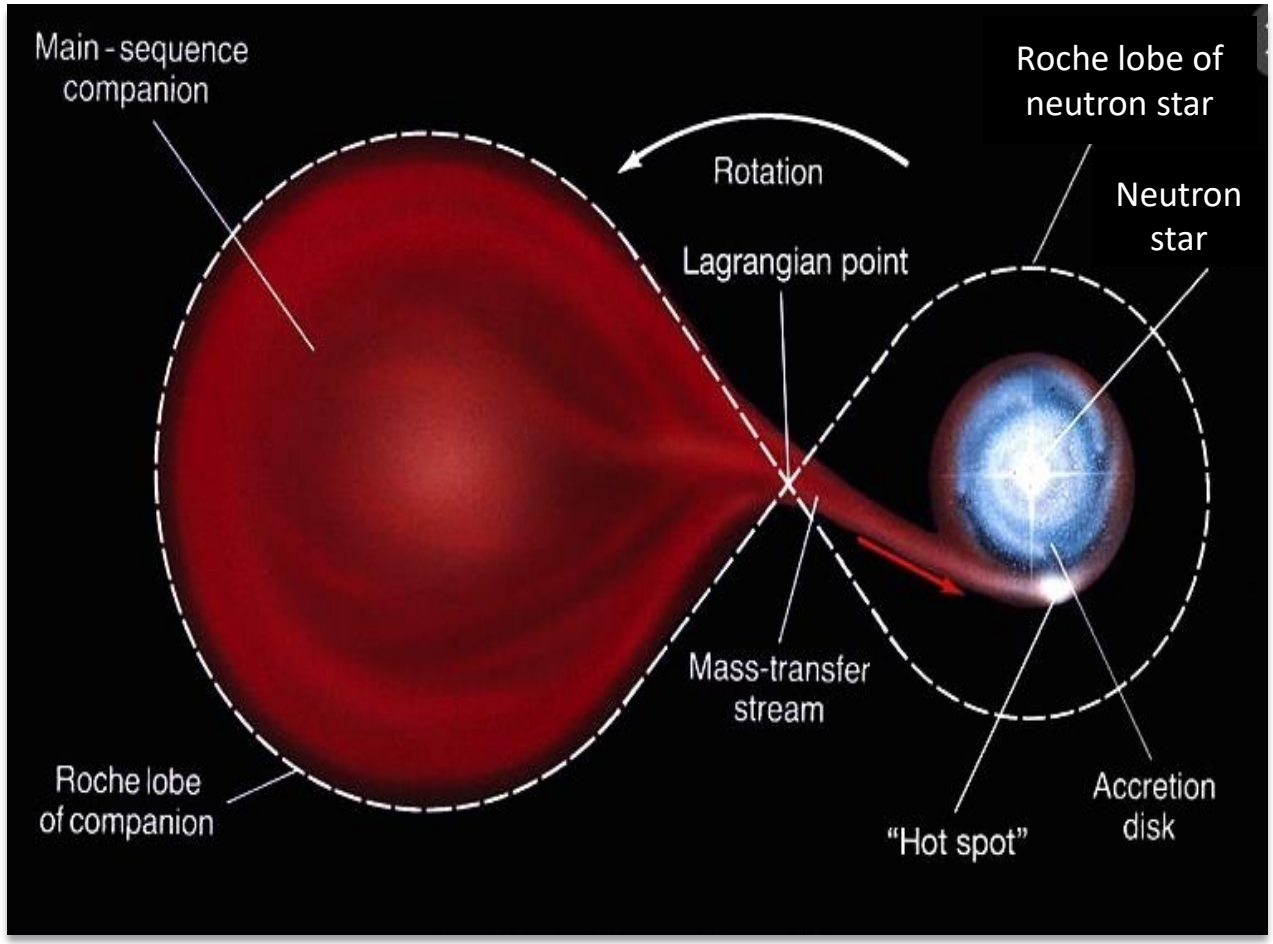
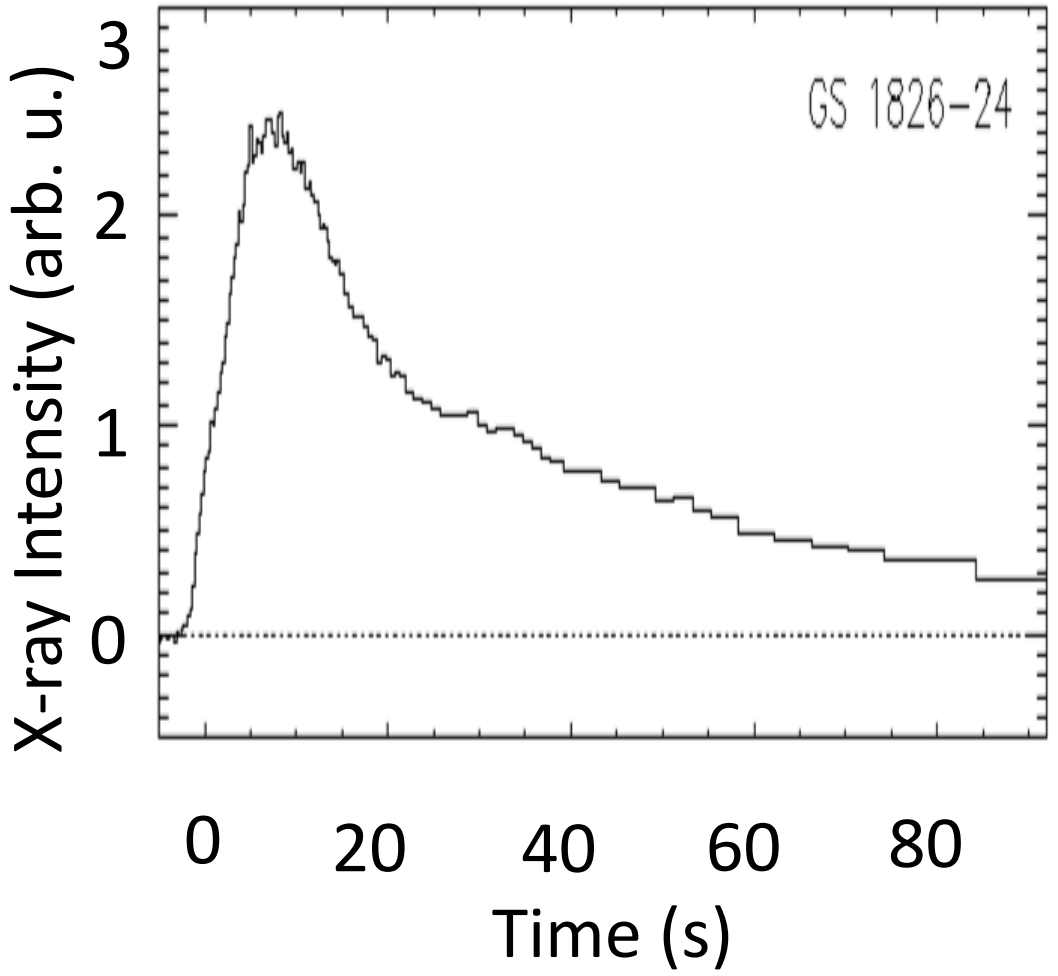
Outline

- **Astrophysical Motivation**
- **Constraining the $^{15}O(\alpha, \gamma)^{19}Ne$ Reaction Rate**
- **GADGET II : TPC**
- **Detector Simulation**
- **Source Test with 241Am**
- **Summary and outlook**

Type I x-ray burst

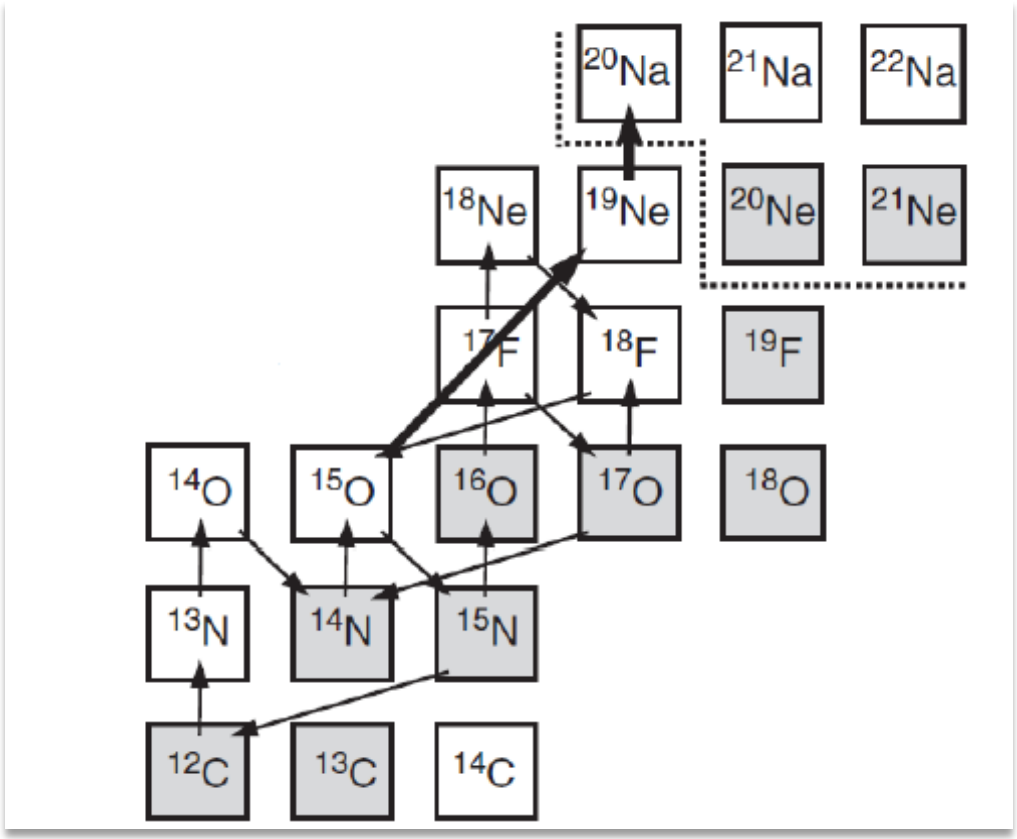




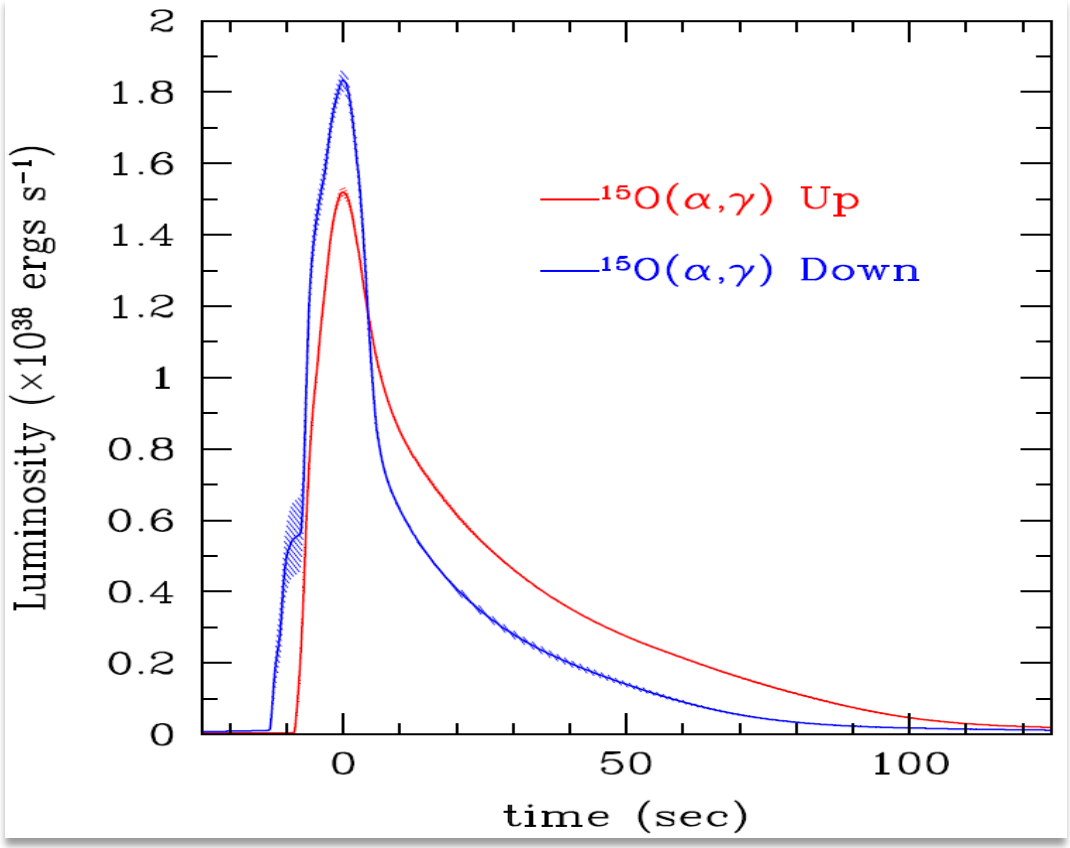
Credit: David A. Hardy, www.astroart.org
RXTE; Galloway et al., Astrophs. J. 179, 360 (2008)

X-ray Burst Light Curves

The $^{15}O(\alpha, \gamma)^{19}Ne(p, \gamma)^{20}Na$ reaction sequence

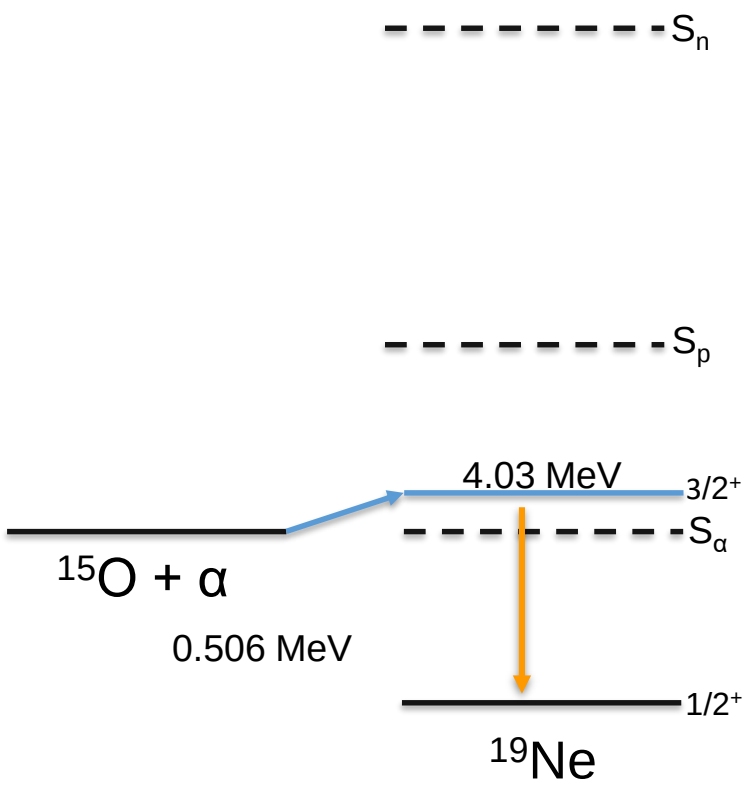


X-ray burst light curve variations in a multi-zone model



R. Cyburt *et al.*, Astrophys. J. 830, 55 (2016)

The $^{15}O(\alpha, \gamma)^{19}Ne$ reaction proceeds by resonant capture



- Reaction rate: $\langle\sigma v\rangle = [(2\pi)/(kT\mu)]^{3/2}h^2e^{-Er/kT}\omega\gamma$
- Resonance Strength:

$$\omega\gamma = \frac{2J+1}{(2J_\alpha+1)(2J_{15O}+1)}\frac{\Gamma_\alpha\Gamma_\gamma}{\Gamma}$$

$$\omega\gamma \propto \frac{\Gamma_\alpha}{\Gamma} \times \Gamma$$

- Only need to measure the alpha particle branching ratio to determine the reaction rate.

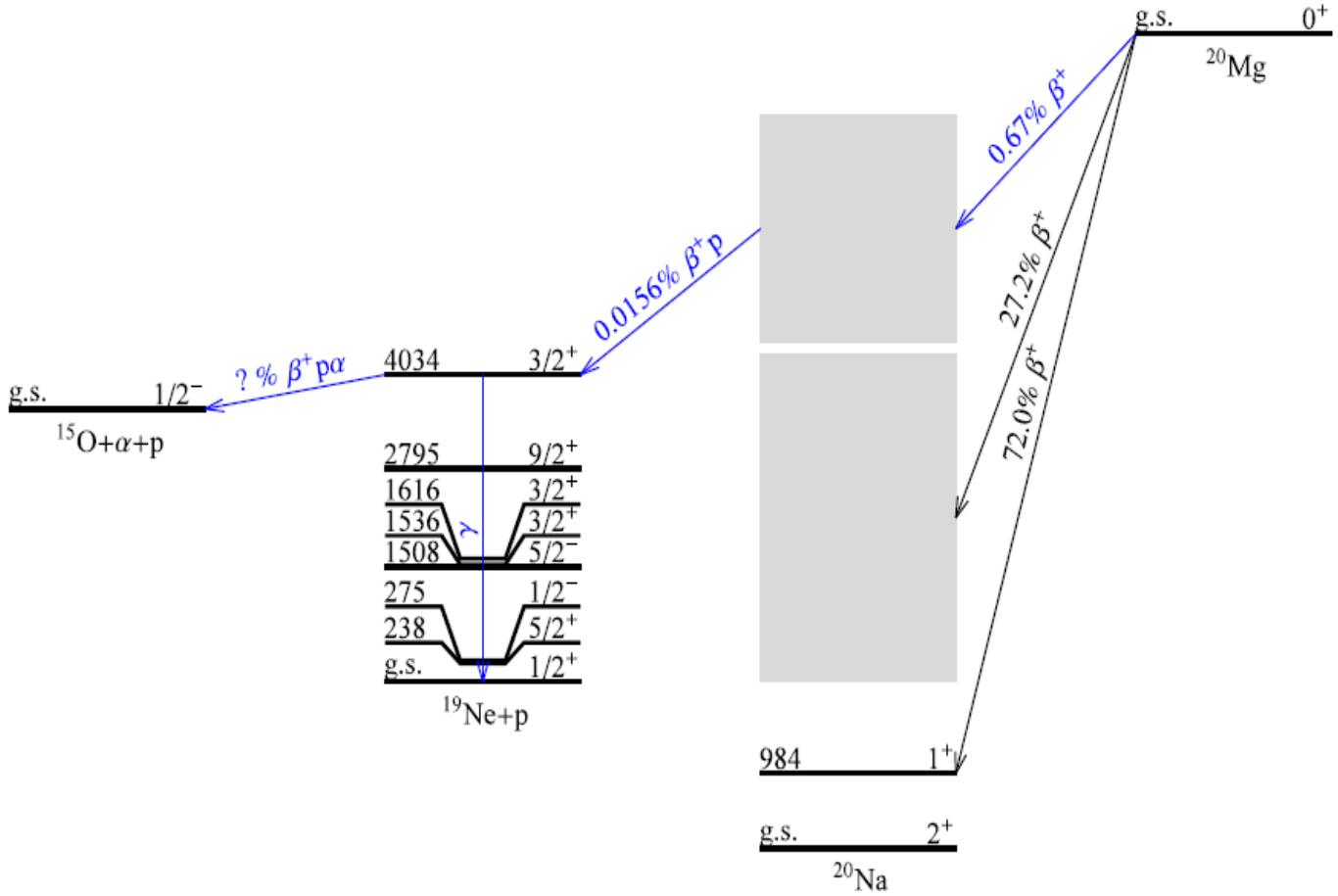
B. Davids, R. H. Cyburt, J. José, and S. Mythili, Astrophys. J. **735**,40 (2011)

β decay of ^{20}Mg to probe key ^{15}O(α,γ)^{19}Ne resonance

Reaction	$\Gamma_\alpha/\Gamma_\gamma$
p(^{21}Ne, ^{3}H)^{19}Ne* Phys. Rev. C **67**, 065808 (2003)	<~ 4.3 x 10^{-4}
^{3}He(^{20}Ne, α)^{19}Ne* Phys. Rev. C **67**, 065809 (2003)	< ~ 6 x 10^{-4}
^{19}F(^{3}He, t)^{19}Ne Phys. Rev. Lett. **98,** 242503(2007)	< ~(2.9 ± 2.1) x 10^{-4}

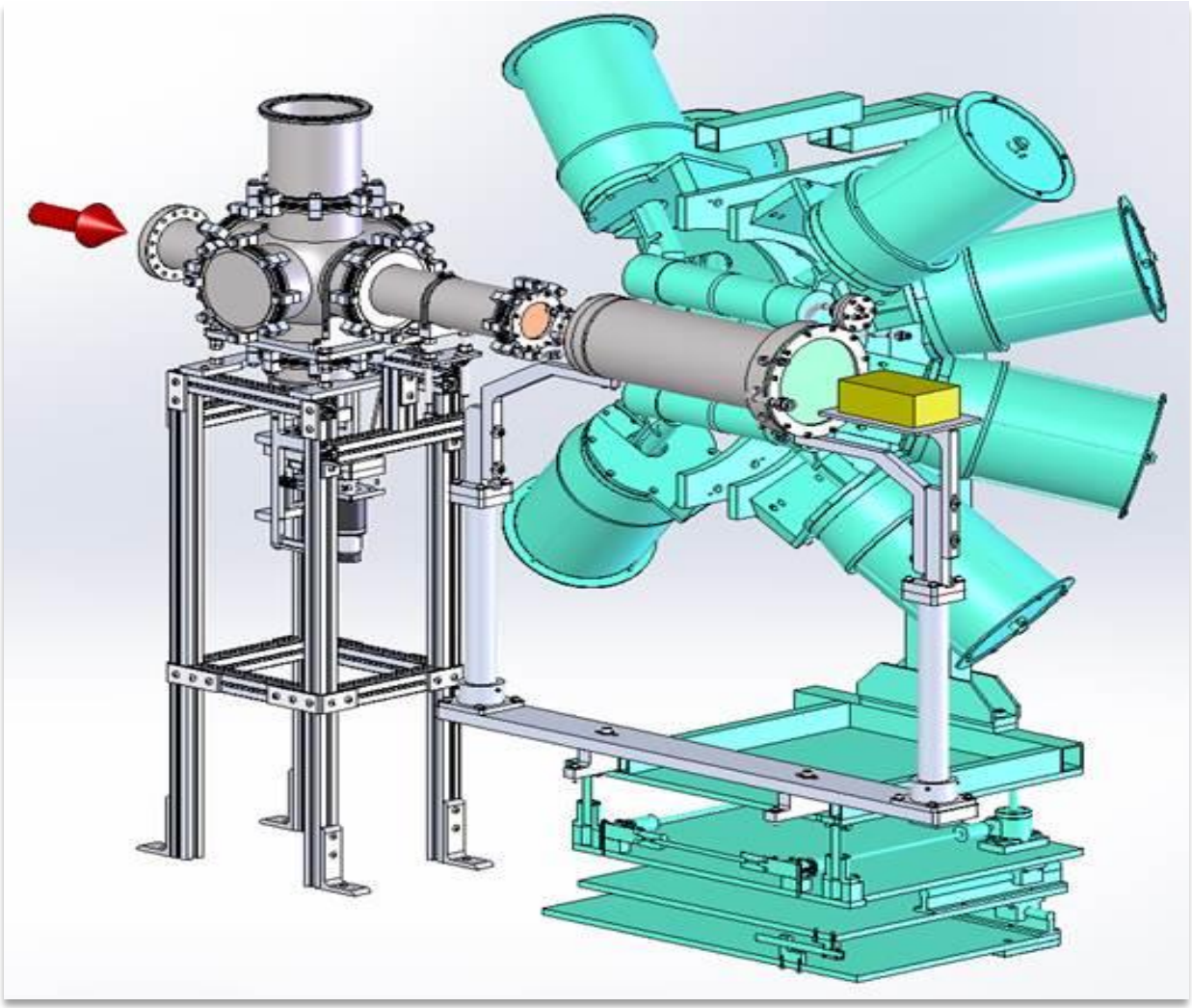
- Transfer reaction methods have been unable to produce finite measurements of the alpha branching ratio.

- AIM: To measure ^{20}Mg(βpα)^{15}O through 4.03-MeV ^{15}O(α,**γ**)^{19}Ne resonance to determine Γ_α/Γ



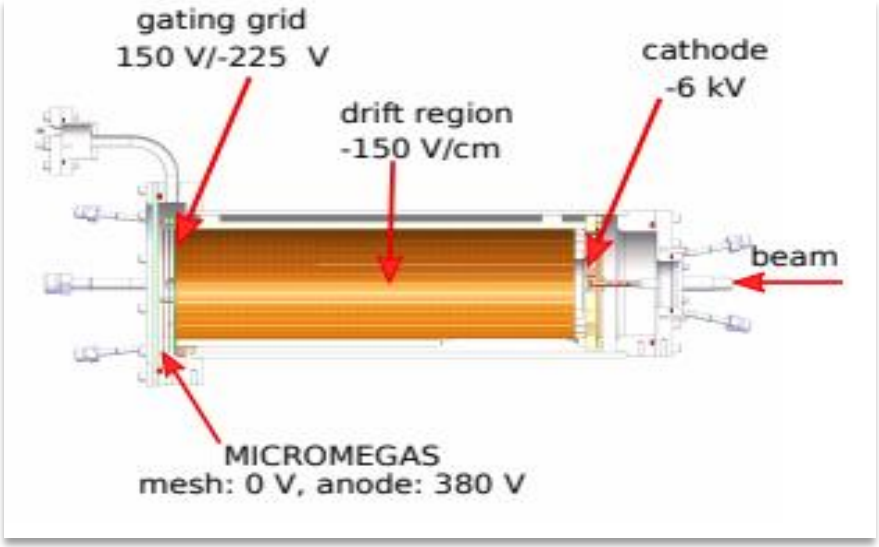
C. Wrede *et al.*, Phys. Rev. C 96, 032801(R) (2017)
B. Glassman *et al.*, Phys. Rev. C 99, 065801 (2019)

Gaseous Detector with Germanium Tagging (GADGET I) at NSCL



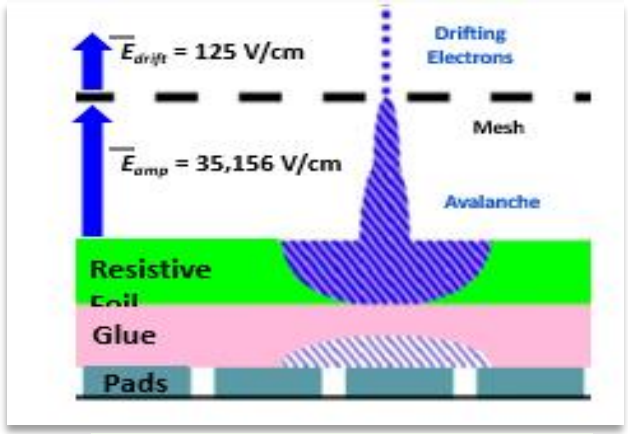
Main components:

1. Energy degrader
2. Proton Detector
3. Existing Segmented Germanium Array (SeGA)

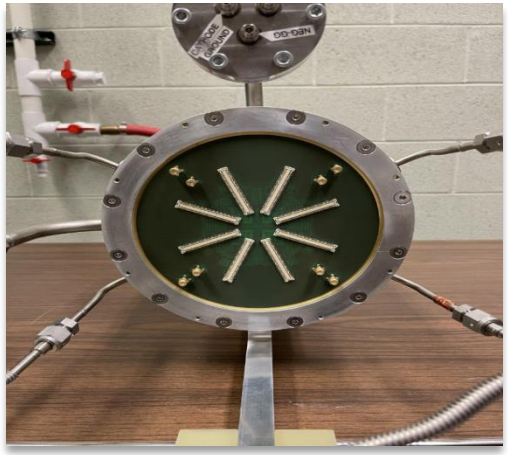


M. Friedman, D. Perez-Loureiro *et al.*, NIM A 940, 93 (2019)
Proton-detection technique adopted from ASTROBOX collaboration at TAMU

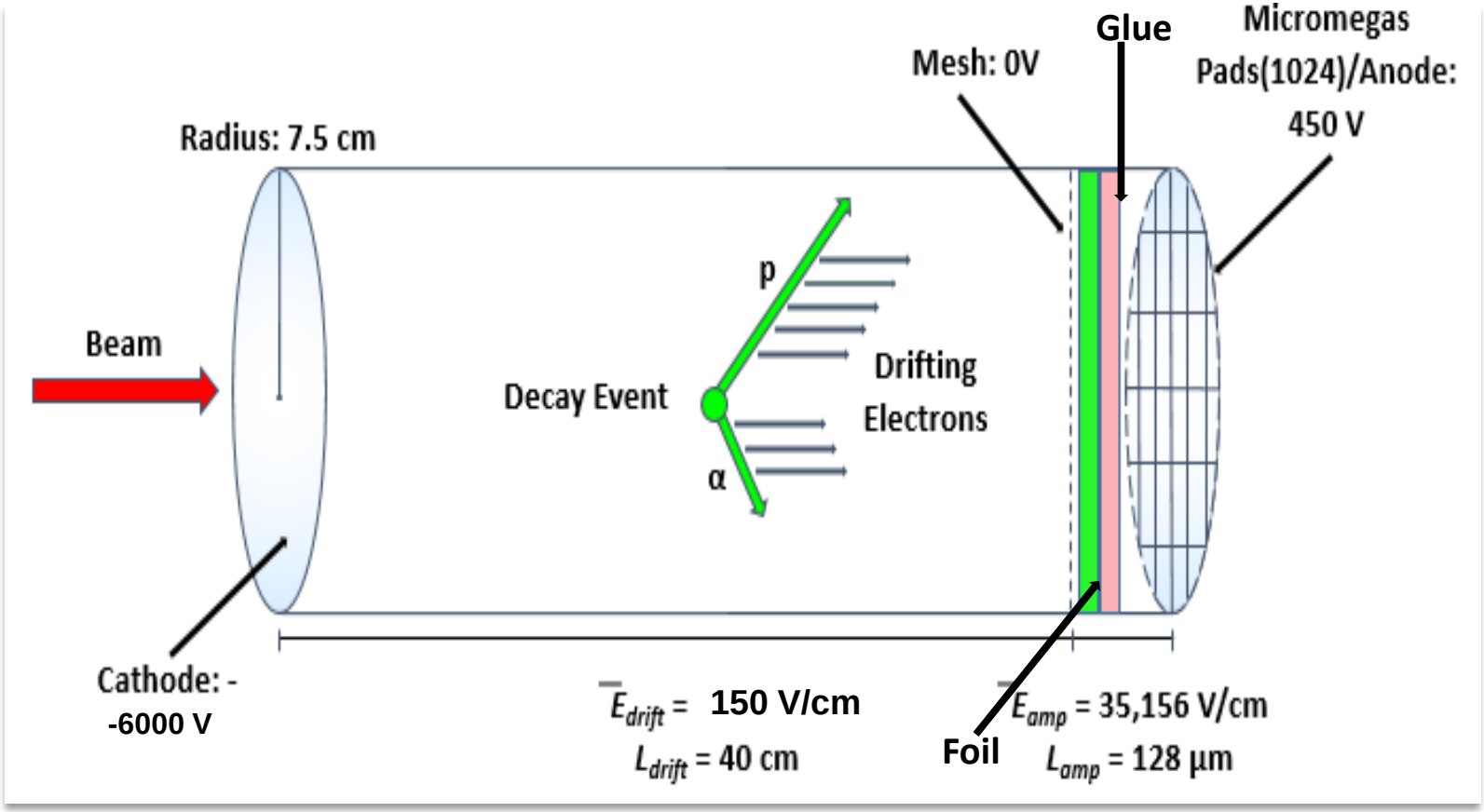
GADGET II: Time Projection Chamber (TPC)



Resistive Anode

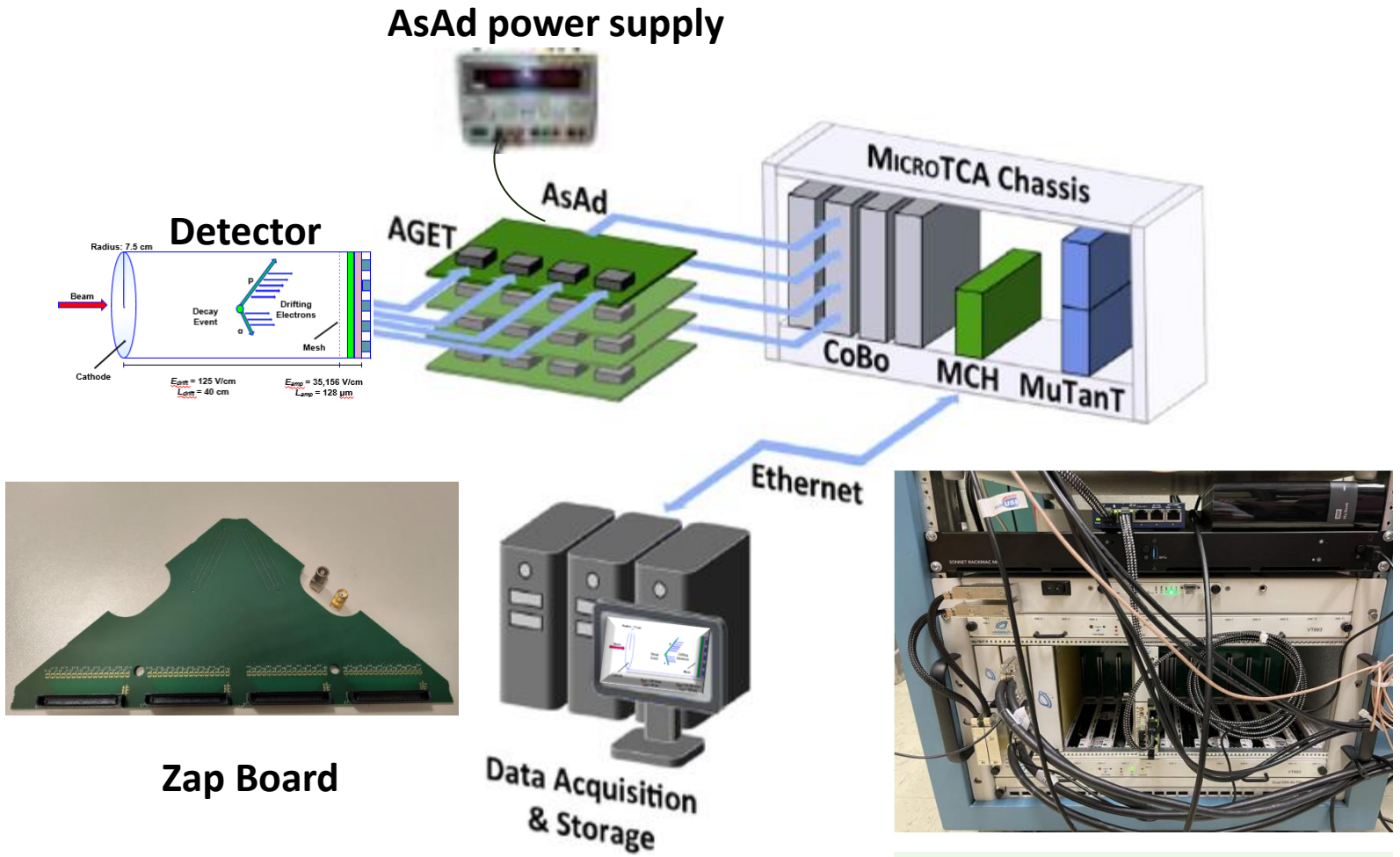


Installed GADGET II TPC MICROMEGAS



Inside view of Proton Detector with readout pad planes

GADGET II: Generic Electronics for TPC



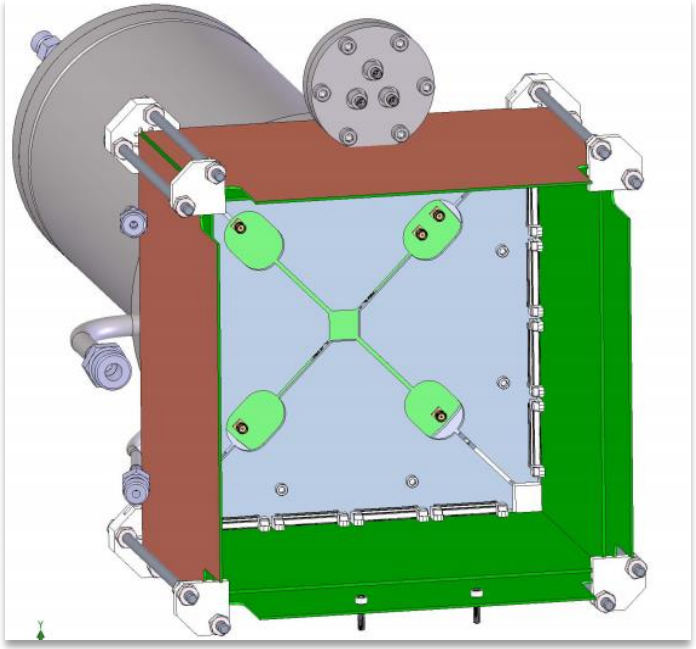
Assembled GET electronics

Components of GET system

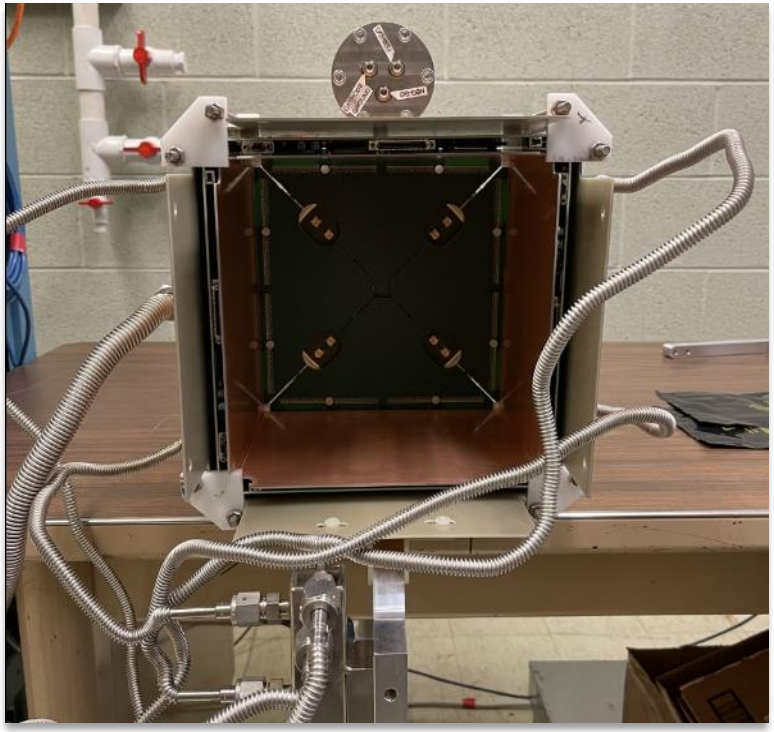
- AGET Chip
- AsAd board
- Zap board
- MicroTCA architecture
- Concentration Board (CoBo)
- Multiplicity and Time Trigger (Mutant board)

E. C. Pollaco et al., NIM A, 887 (2018) 81–93

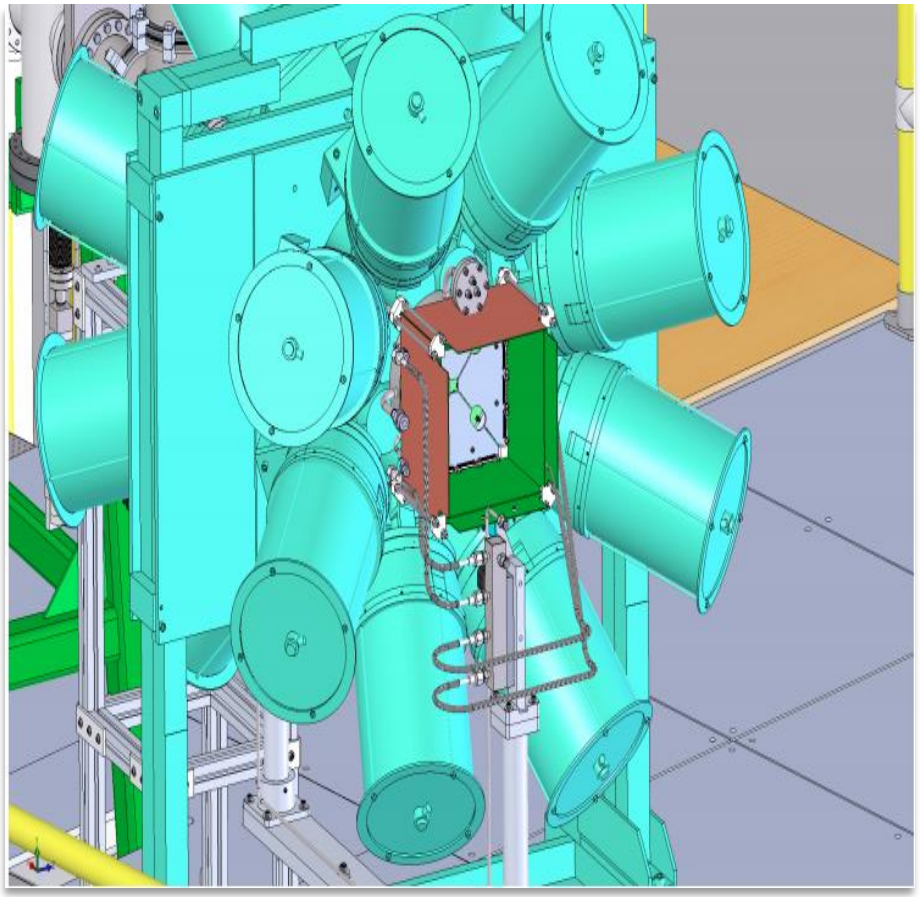
GADGET II: GET System & Final Design



Proposed AsAd Box Design



Assembled AsAd Box



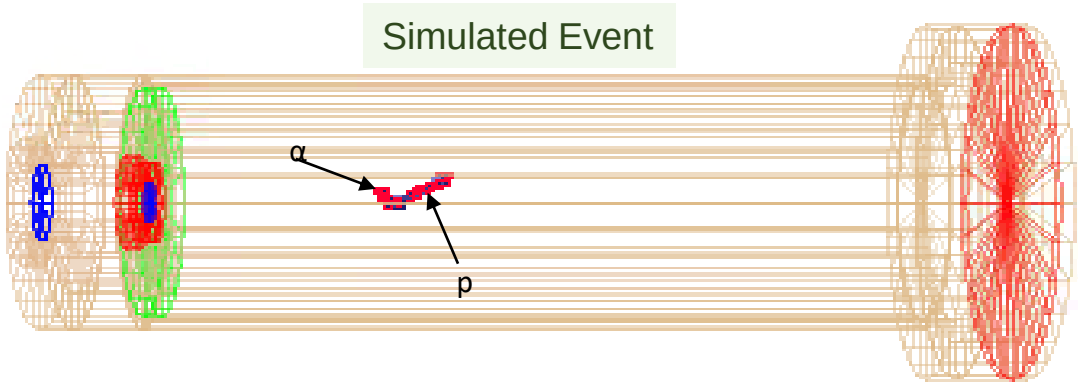
Final Design of GADGET II

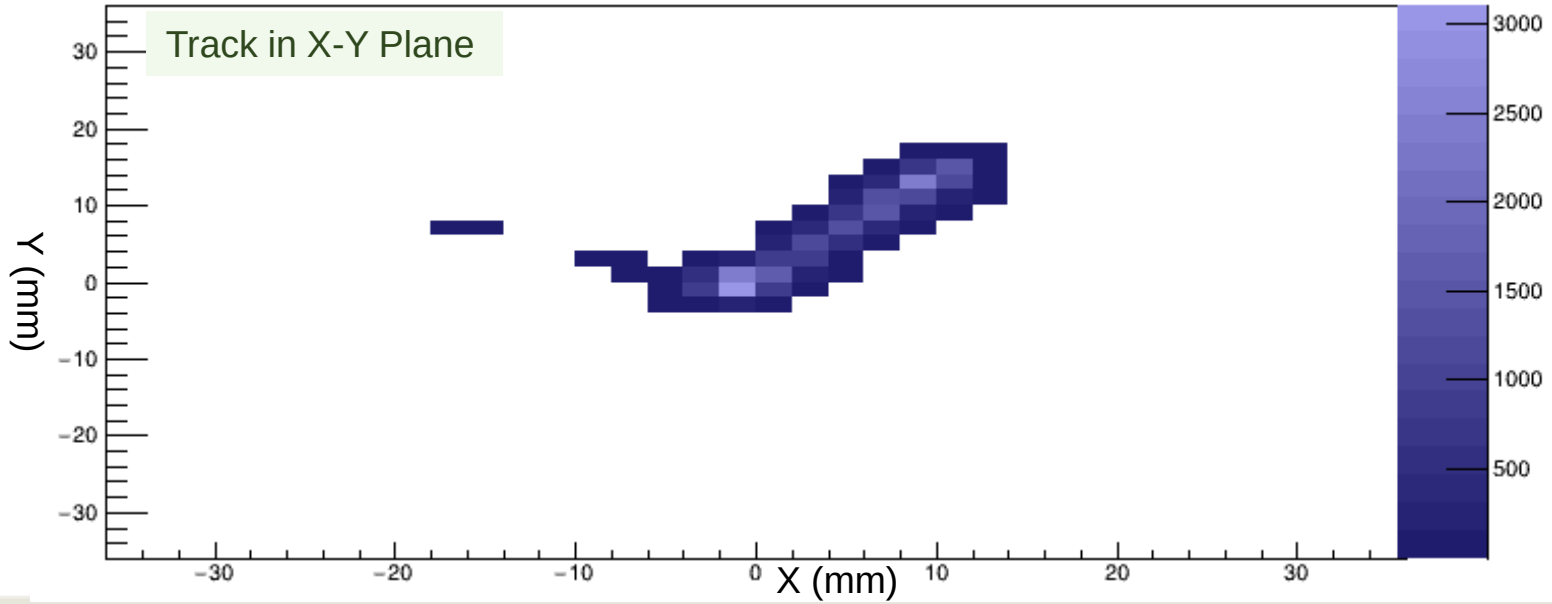
Left Figure Credit: Shelbi Anvar, *Internal Communication*

Proton Detector Simulation

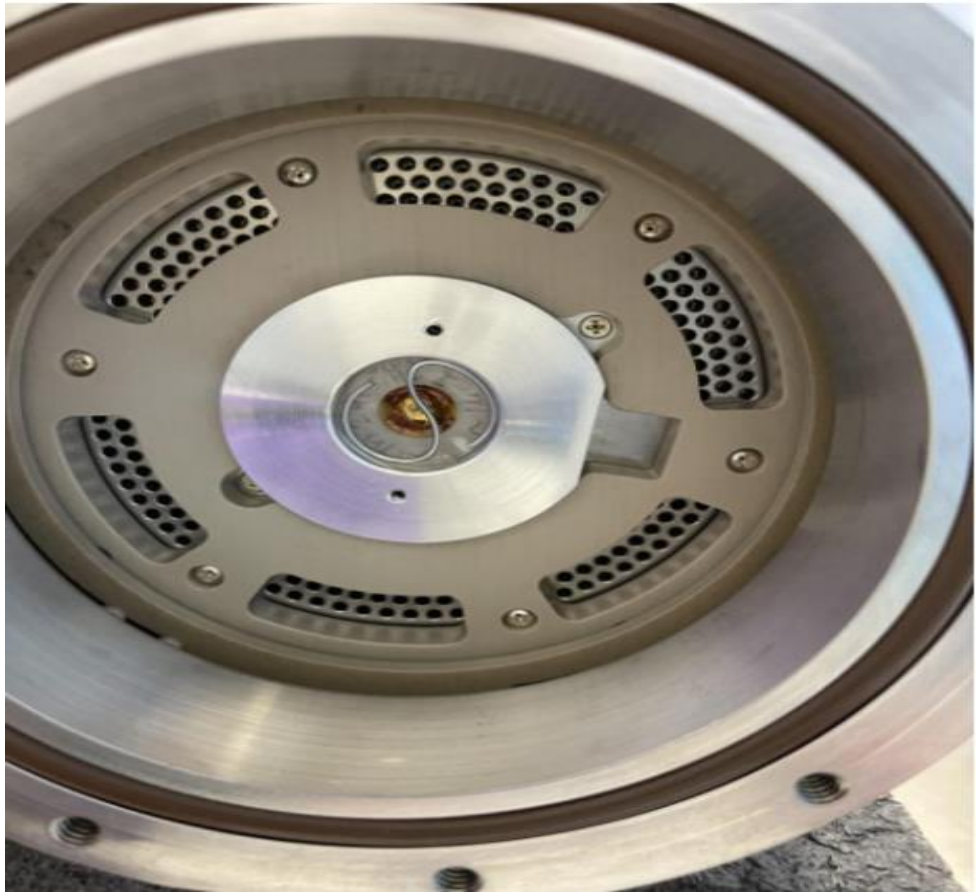
- ATTPCROOT framework based on FairRoot package (developed at FAIR).
- Contains a collection of scientific libraries used in nuclear physics: ROOT, Geant4, physics generators, management libraries.
- User defines a geometry that it is stored in a ROOT file.
- User defines a list of physics generators

p (1.2 MeV) +α (0.506 MeV) from ^{20}Mg decay





Future Plan: Source Test with ^{241}Am

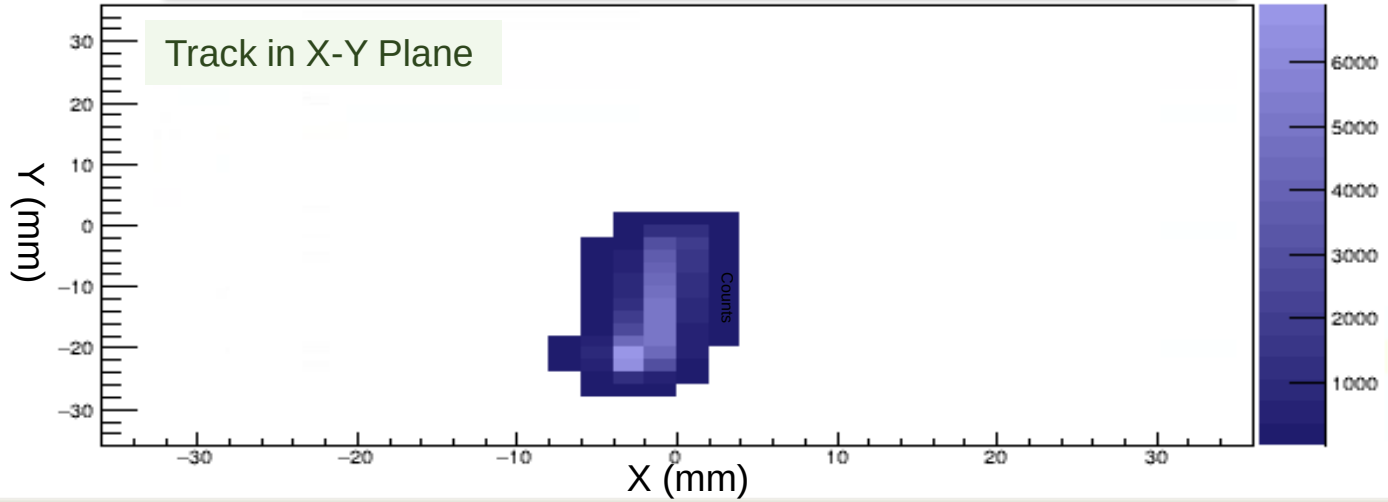


^{241}Am Source mounted inside the detector

α(5.485 MeV) + γ -ray (59.5 keV) event

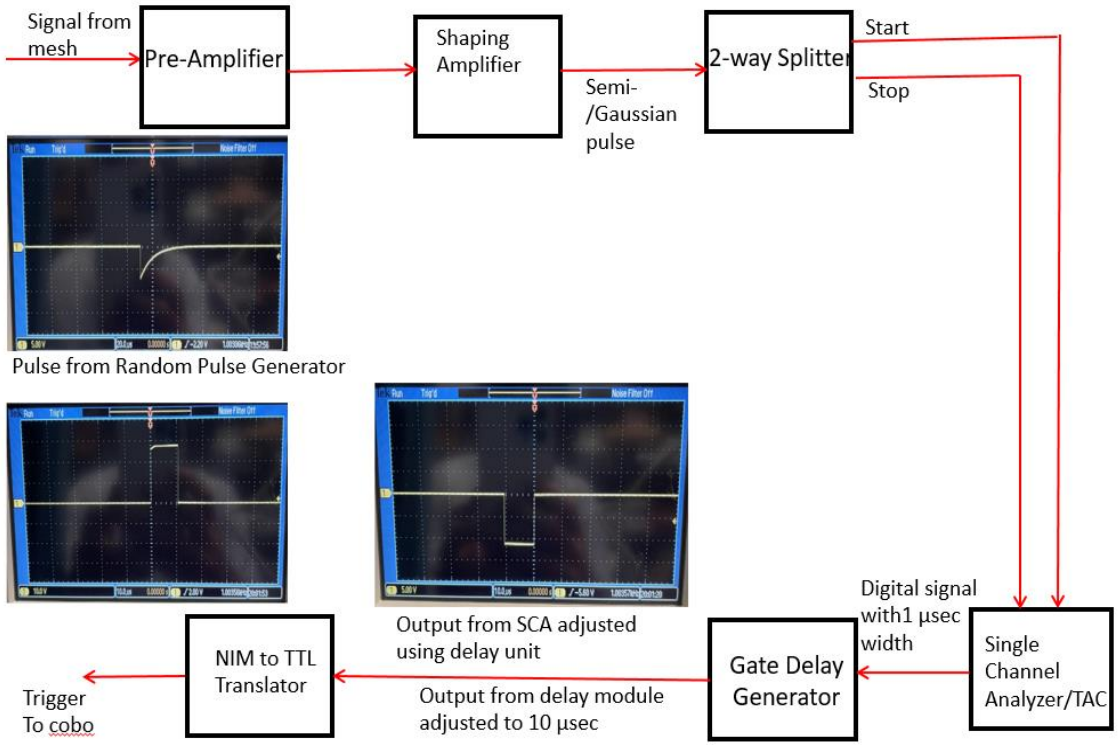
Simulated Event

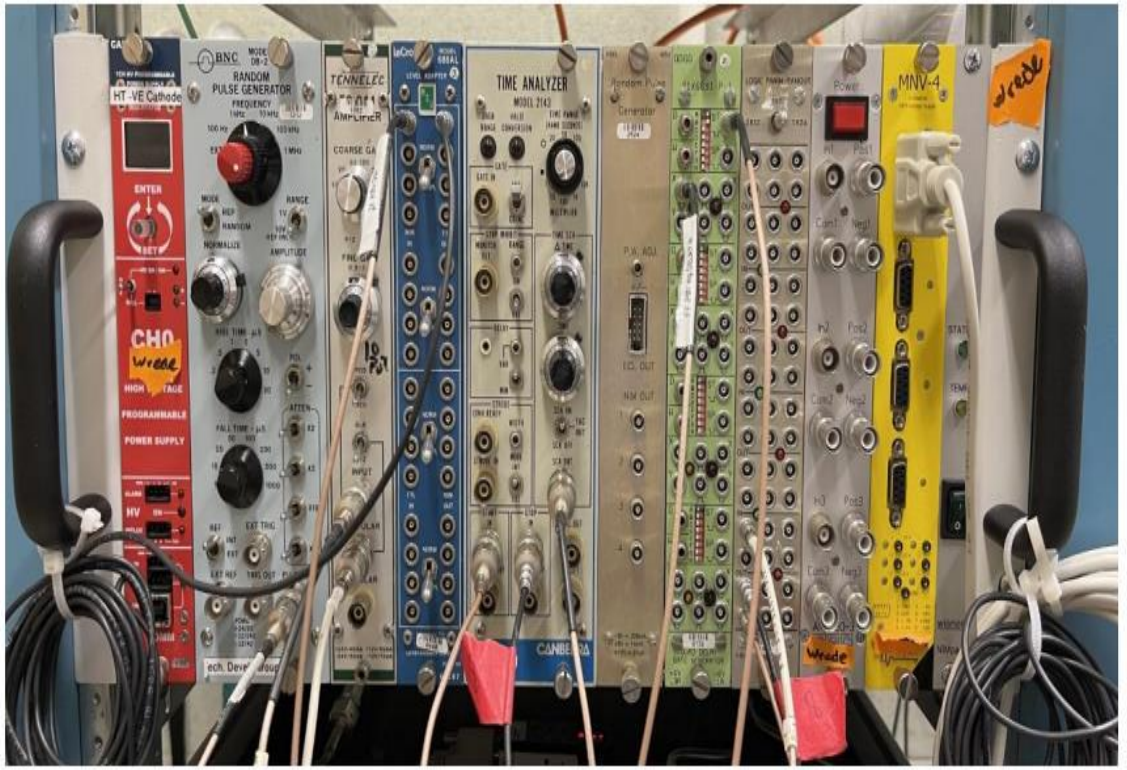
Track in X-Y Plane



Future Plan: Source Test with ^{241}Am

Block Diagram for Mesh trigger





Electronics Set up for Mesh Trigger

Summary and Outlook

- GADGET I is commissioned and producing science with NSCL beams.
- GADGET II TPC is upgraded to determine high impact $^{15}O(\alpha, \gamma)^{19}Ne$ reaction rate at FRIB.
- Once the reaction rate is calculated we will model X-ray burst light curves from neutron stars.
- We will test the detector with ^{241}Am source and this will help in initializing the operating parameters for the system.

Acknowledgments

List of Collaborators for GADGET II

NSCL, Michigan State University, USA
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