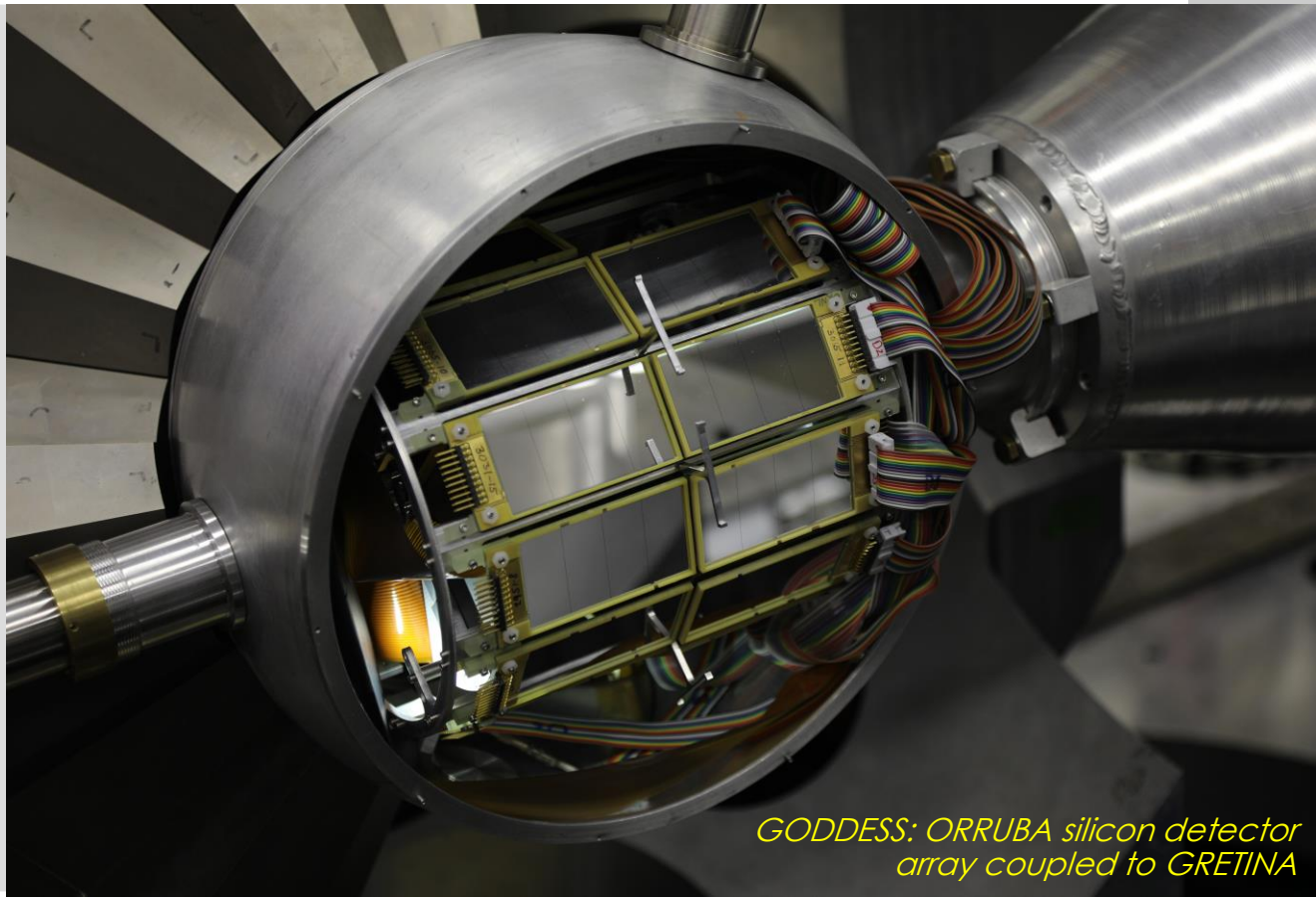
OAK RIDGE National Laboratory

ORRUBA/GODDESS

- Overview of ORRUBA/GODDESS
  - detectors, DAQ etc
  - Scope of physics program
  - Recoil detectors
- Upgrades/Needs
  - Coupling to GRETA (4π pγ spectrometer for FRIB)
  - Expansion of DAQ
  - Improved targets
  - Recoil detection



GODDESS: ORRUBA silicon detector array coupled to GRETINA

S.D. Pain

Town Hall Meeting

ANL, Nov. 2022

ORRUBA
Si detector array

GODDESS

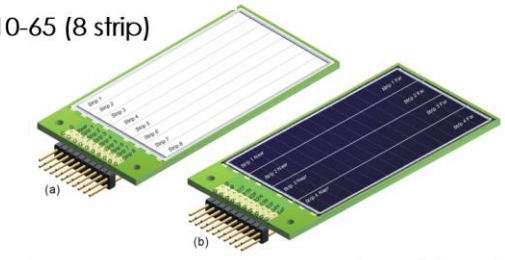
GODDESS 2021

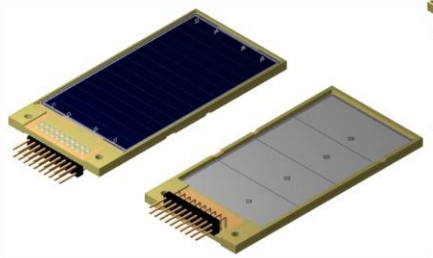
ORRUBA

Common system to ~140 Si detectors
(FE electronics, DAQ)

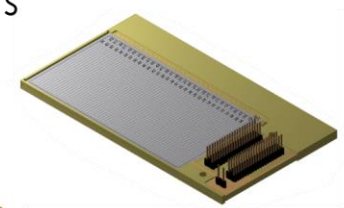
- *Largest Si suite for RIB physics in US*
- *Designed around reaction kinematics*
- *Originally conceived as a standalone device, but increasingly coupled to other instruments*
- *Detector/FE compatibility (ANASEN, ND, …)*

BB10-65 (8 strip)





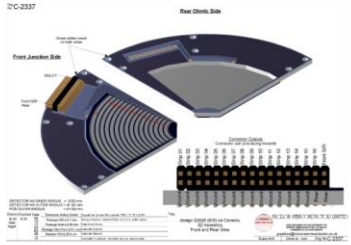
BB15-1000 (64 strip, DSSD)



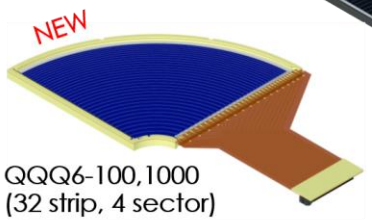
X3-500,1000 (4 resistive strip)

sX3-1000 (4 resistive strip, DSSD)

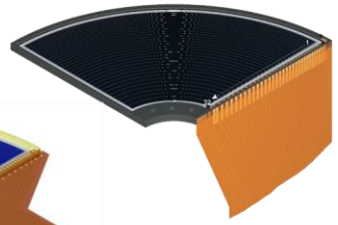
YY1-65,100,300,500,1000
(16 strip, 1 sector)



QQQ2-25,1000
(16 strip, 1 sector)



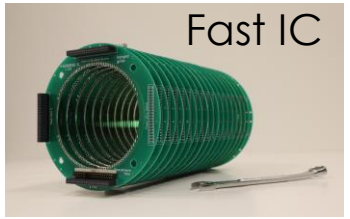
QQQ6-100,1000
(32 strip, 4 sector)

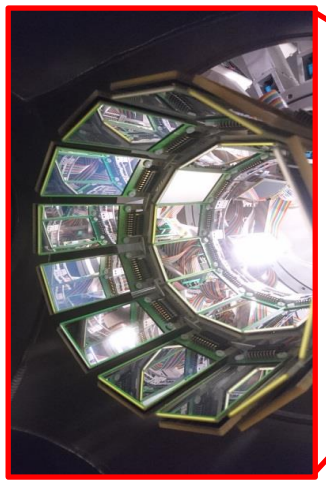


QQQ5-100,1000
(32 strip, 4 sector)

Recoil detectors (channel selection)

- Fast ICs
- Recoil separators
  - *S800*
  - *FMA*
  - *SECAR*

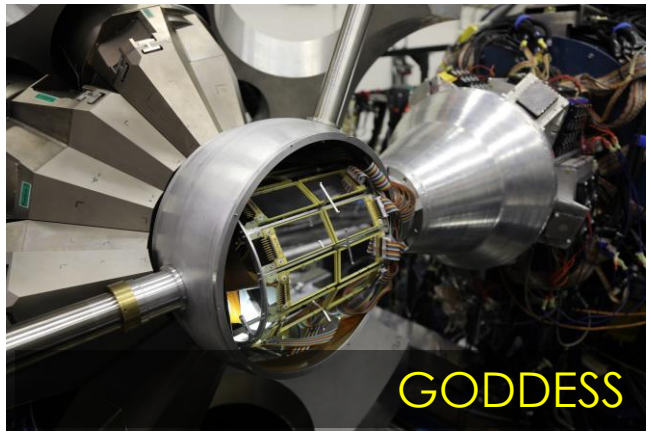




Gamma-ray detectors

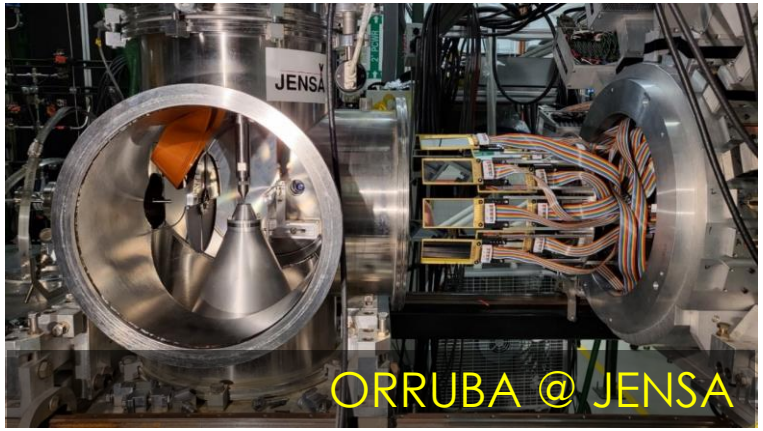
- Gammasphere
- GRETINA

GODDESS



Targets

- main detector for JENSA
- Cryogenic (solid) target (future)



GODDESS

2015 GS (3 expts)

2019 GT (3 expts)

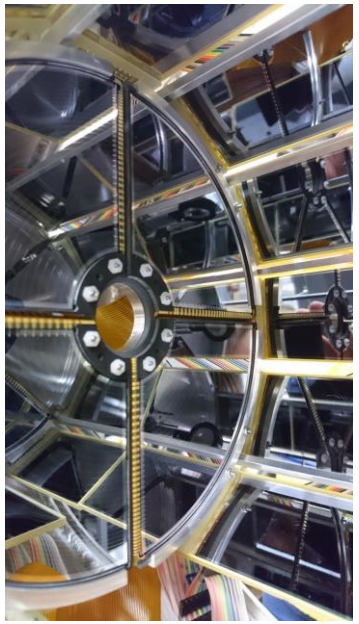
2021 GT (7 expts)
(5 mo, 1/3 ATLAS)

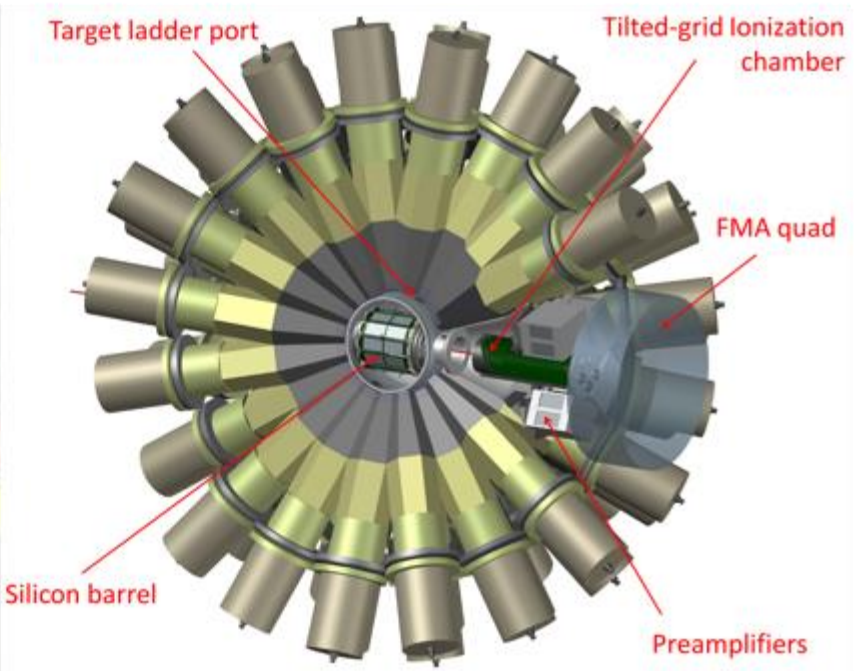
720 ch Si

2-3 layer telescopes

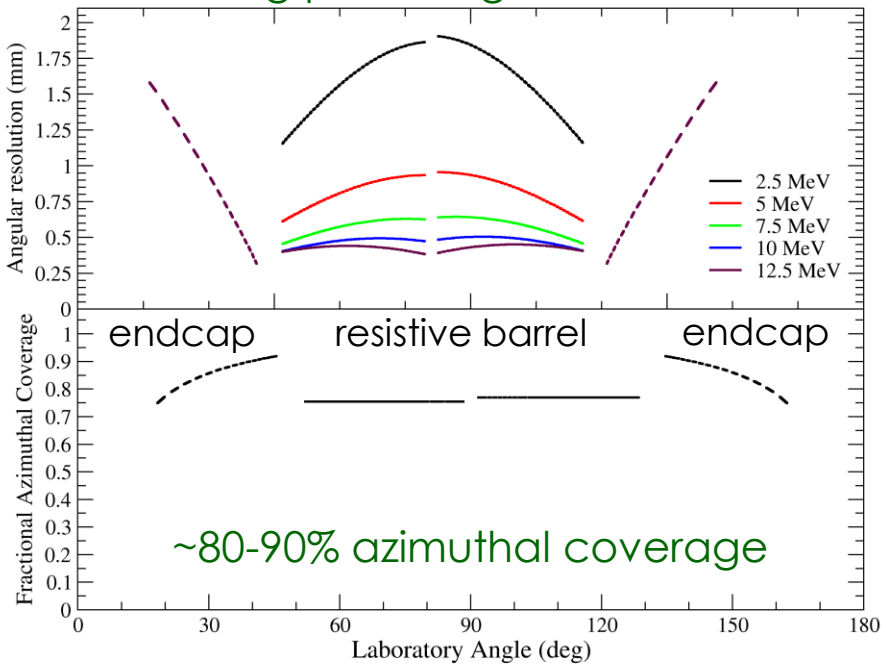
65-1000 μm detectors

Built around reaction symmetries





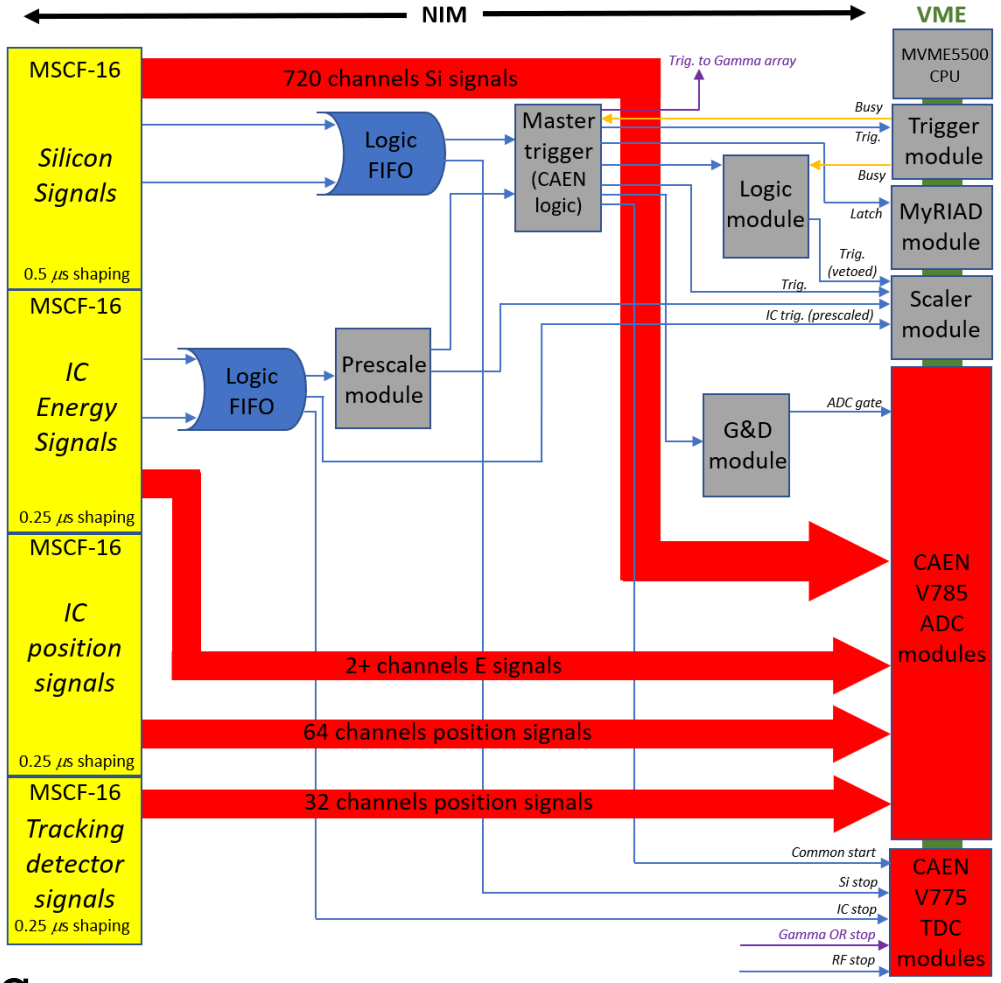
~1 deg polar angle resolution



~80-90% azimuthal coverage

RRUBA

GODDESS



DAQ properties

- Conventional VME system (MVME5500)
- 768 ch Mesytec MSCF-16 (0.5 μs typical)
- 768 ch CAEN V785 (2 bridged VME backplanes)
- V775 TDCs (common start)
- SIS scaler (10 MHz, TS, event-by-event scaler readout)
- MyRIAD
- ORPHAS (broadcast to GEB, GRETINA run control)
- Real-time data analysis (sub-second)
- Multiple trigger types (including PS beam samples)
- Trigger type recorded

Triggering

- Si singles (+ slave detectors; GRETINA, S800, HRS)
- Built coincidence OR+Aux (< 500ns)

Data

< 4kB per event (every ch, typical ~50ch/evt)
< 32 MB/s (10 kHz events, maxed out)
< 1-10% typical

Si detector array

ORRUBA

Experimental program

ATLAS (RIB/SIB)

NSCL/FRIB (fast/ReA)

HIγS (γ-induced), ...

Z=50, N=82

N=50

Direct spectroscopic (α,p) for XRB

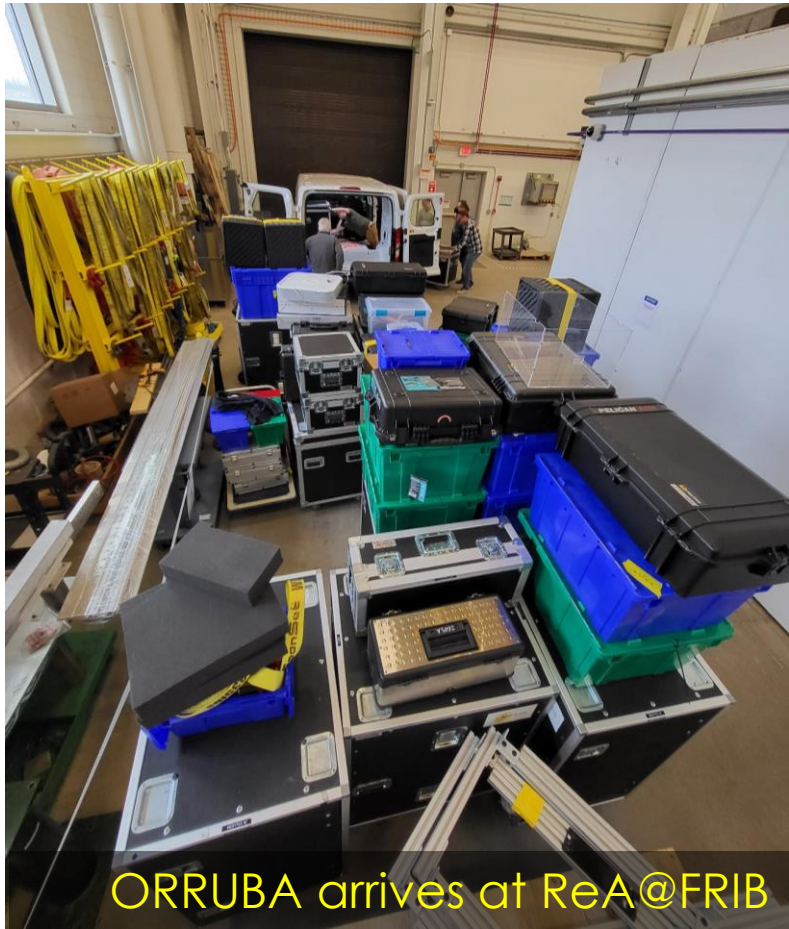
JENSA ^{56}Ni(α,p)

JENSA ^{34}Ar(α,p)

JENSA ^{26}Al(α,p)

(p,γ) via mirror sym.

p-shell nuclear structure



ORRUBA arrives at ReA@FRIB

Si detector array

RRUBA

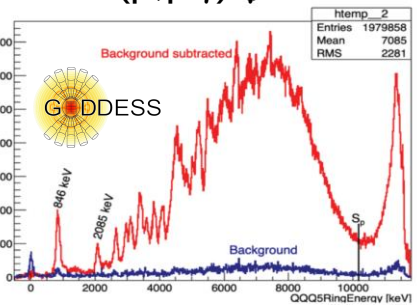
Experimental program

Some recent examples

(students, PDs)

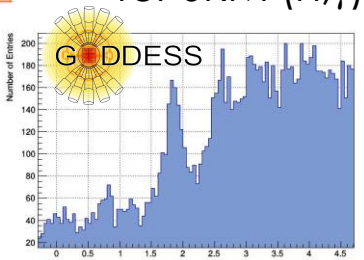
Kgashane Malatji (iThemba)

^{56}Fe(p,p'γ) γ SF



Z=50, N=82

^{95}Mo(d,pγ) for SRM (n,γ)



Heather Garland (Rutgers)

N=50

Direct spectroscopic (α,p) for XRB

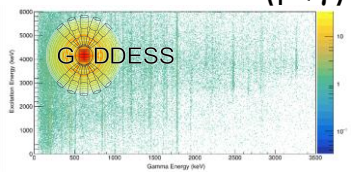
JENSA ^{56}Ni(α,p)

JENSA ^{34}Ar(α,p)

JENSA ^{26}Al(α,p)

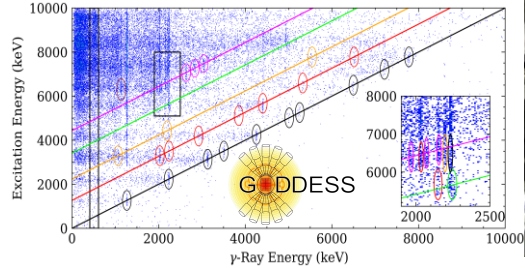
(p,γ) via mirror sym.

^{58}Ni(^{3}He,t) for ^{57}Ni(p,γ)



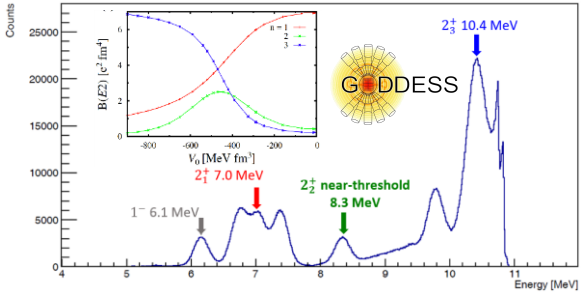
Scott Carmichael (Notre Dame)

^{30}P(d,pγ) for (p,γ)



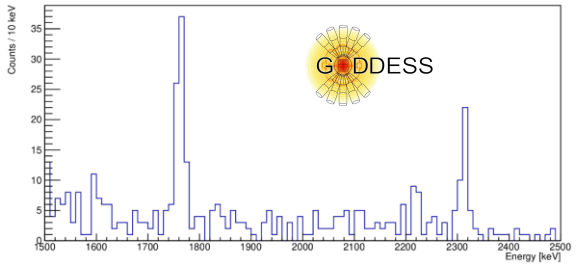
Rajesh Ghimire (UTK/ORNL)

^{9}Be(^{6}Li,pγ)^{14}C cont. coupling for SMEC



Giacomo Corbari (U. Milano)

^{15}C(d,pγ) (DSAM) 3N forces



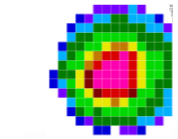
Irene Zanon (Legnaro/USF)

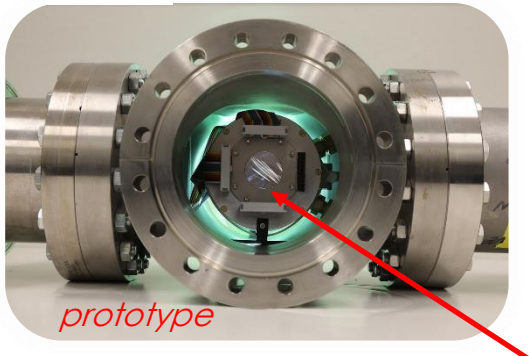
p-shell nuclear structure

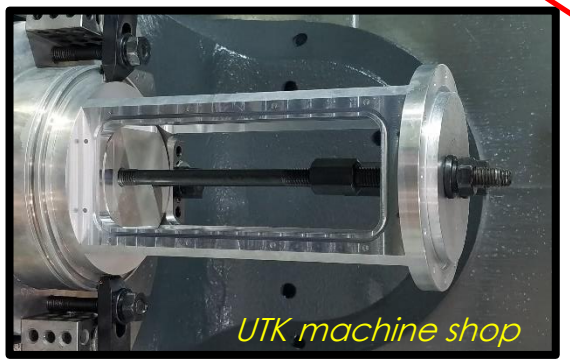
GODDESS

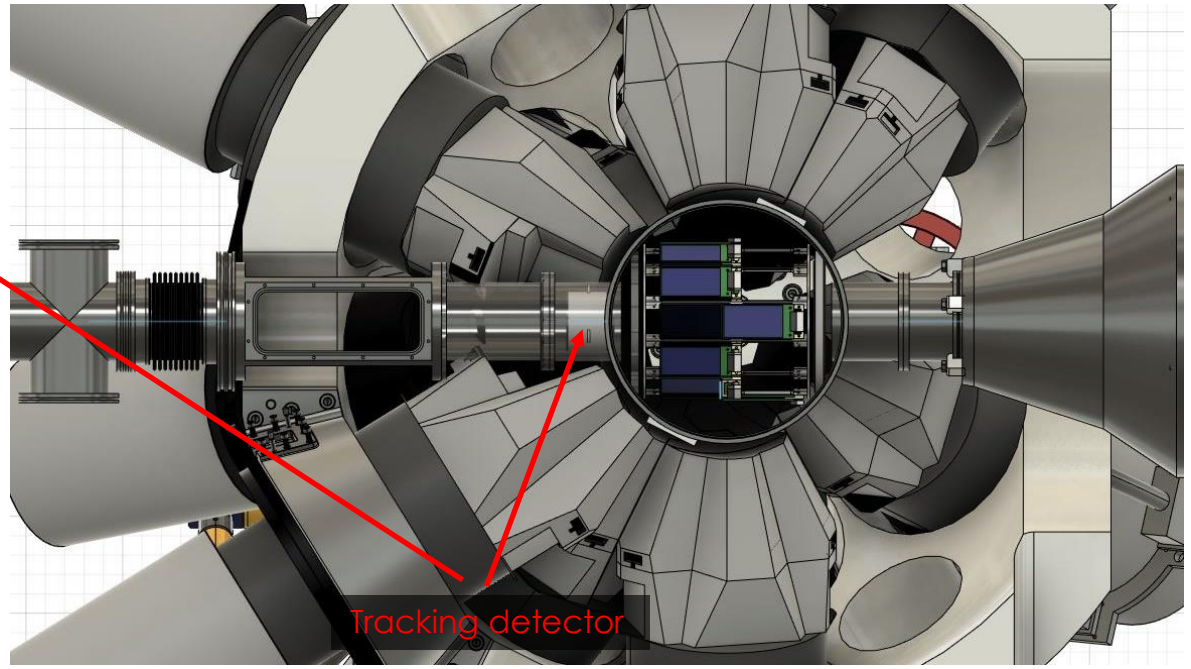
Toward GRETA…

- Based around GRETINA, *with GRETA in mind*
  4π particle-gamma spectrometer for FRIB
- Upgrades
  - New central chamber (triplet compatibility)
  - New endcaps (QQQ6 detectors)
  - New signal routing
- Recoil separator compatibility in mind
  - compact tracking detectors (fast beams)



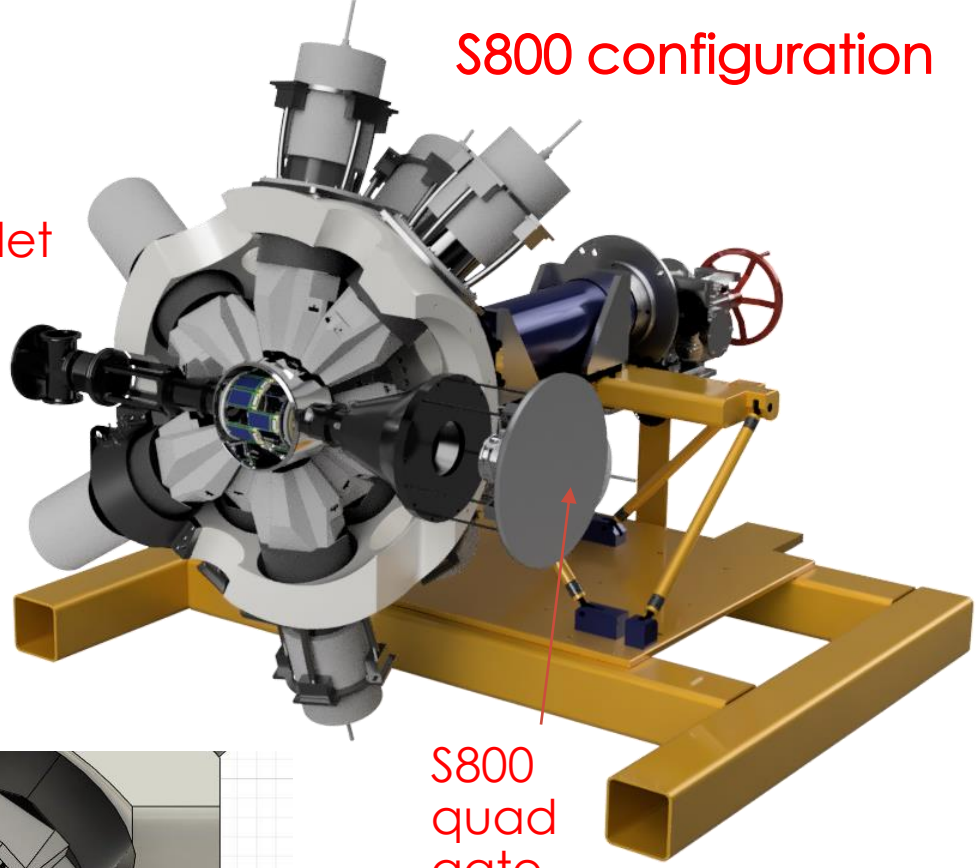




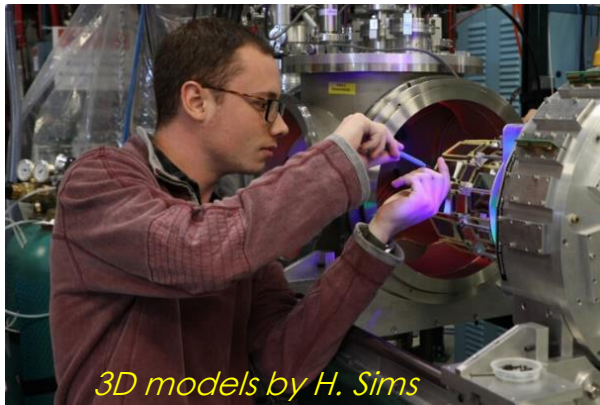


S800 configuration

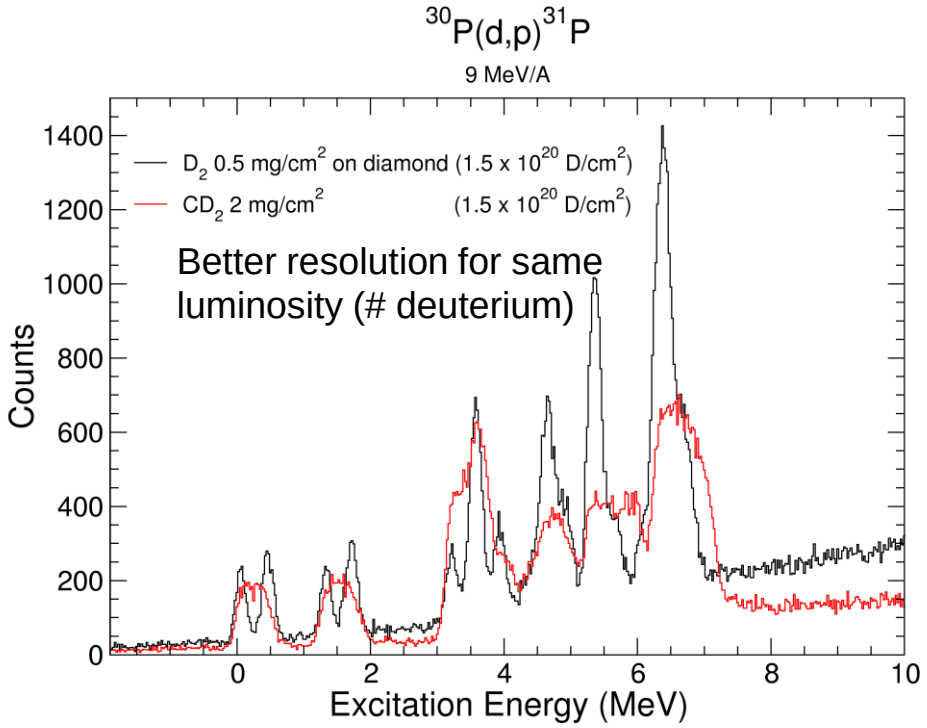
triplet

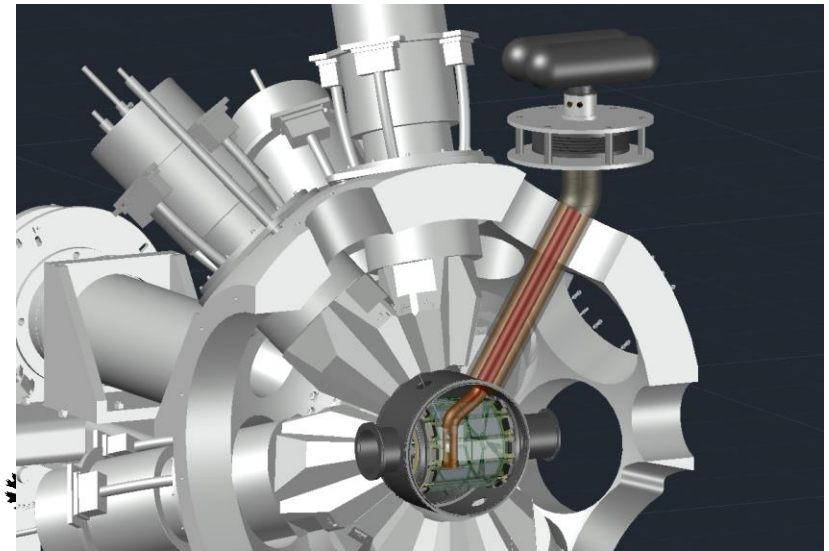


S800 quad gate valve



Thin Frozen H/D target





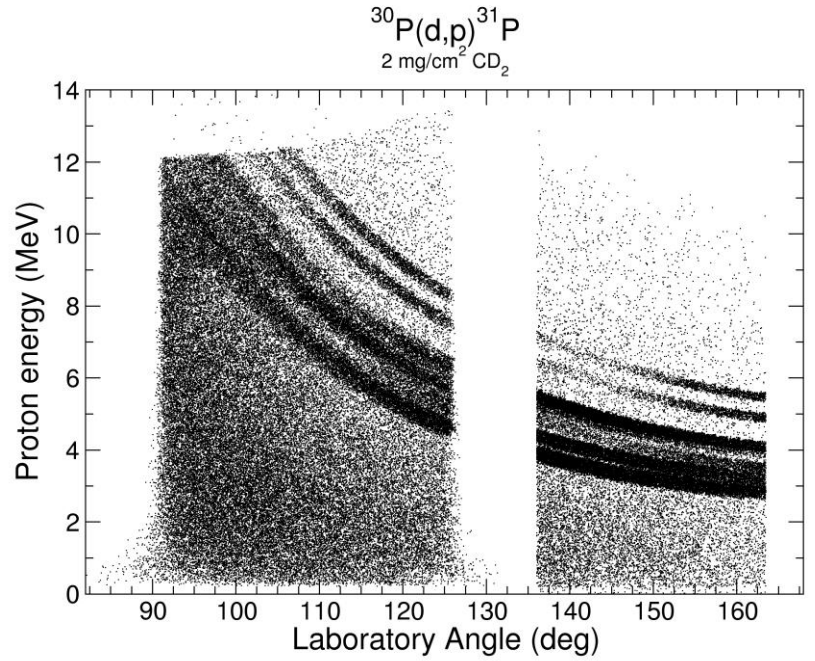
H/D-induced reactions on RIBs limited by plastic targets

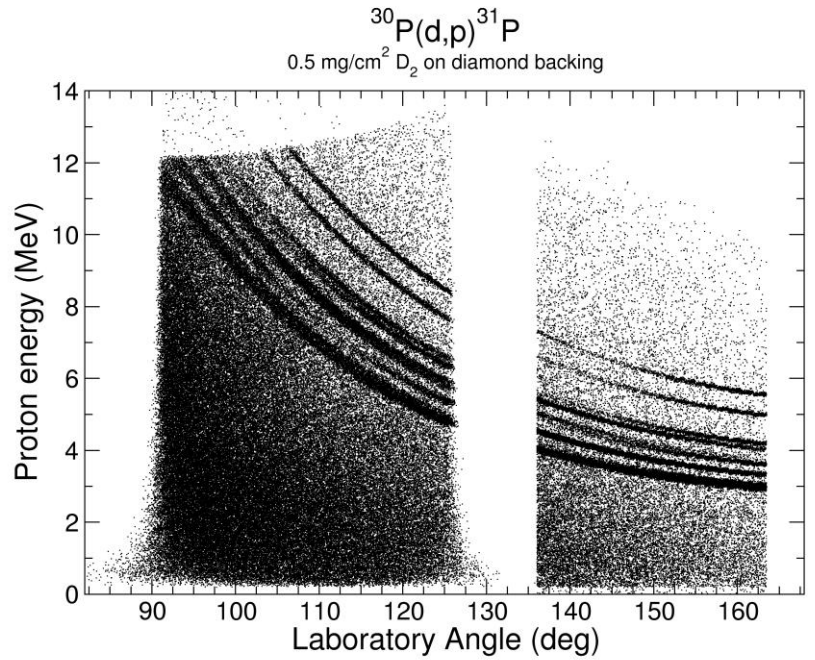
- FE background
- Greater dE (from C) – ie worse resolution/luminosity

- Solid D_2 – factor of 3 gain in luminosity/dE
- 10^{20} D/cm^2 ~ 1mg

> Typical jet densities 5e18 (limited gammas)

< liquid H target (1e23 + windows)

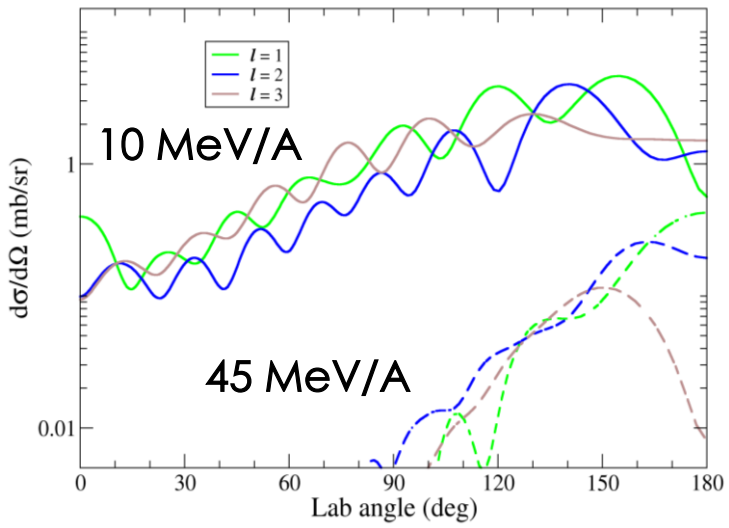




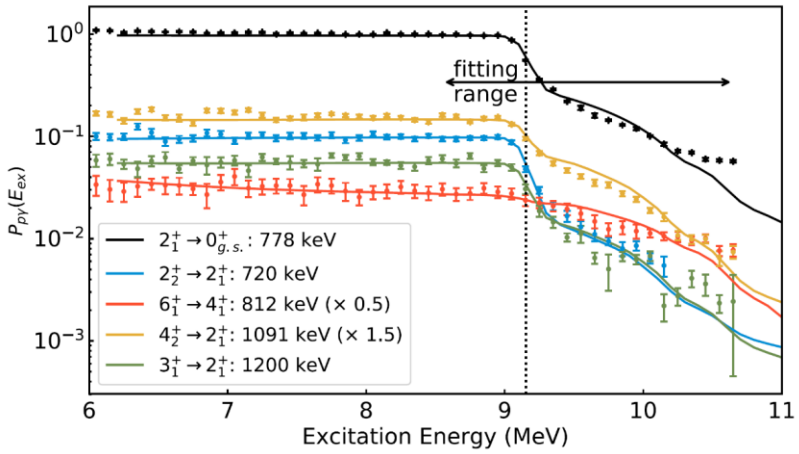
ReA12 – optimum for transfer/DR at FRIB

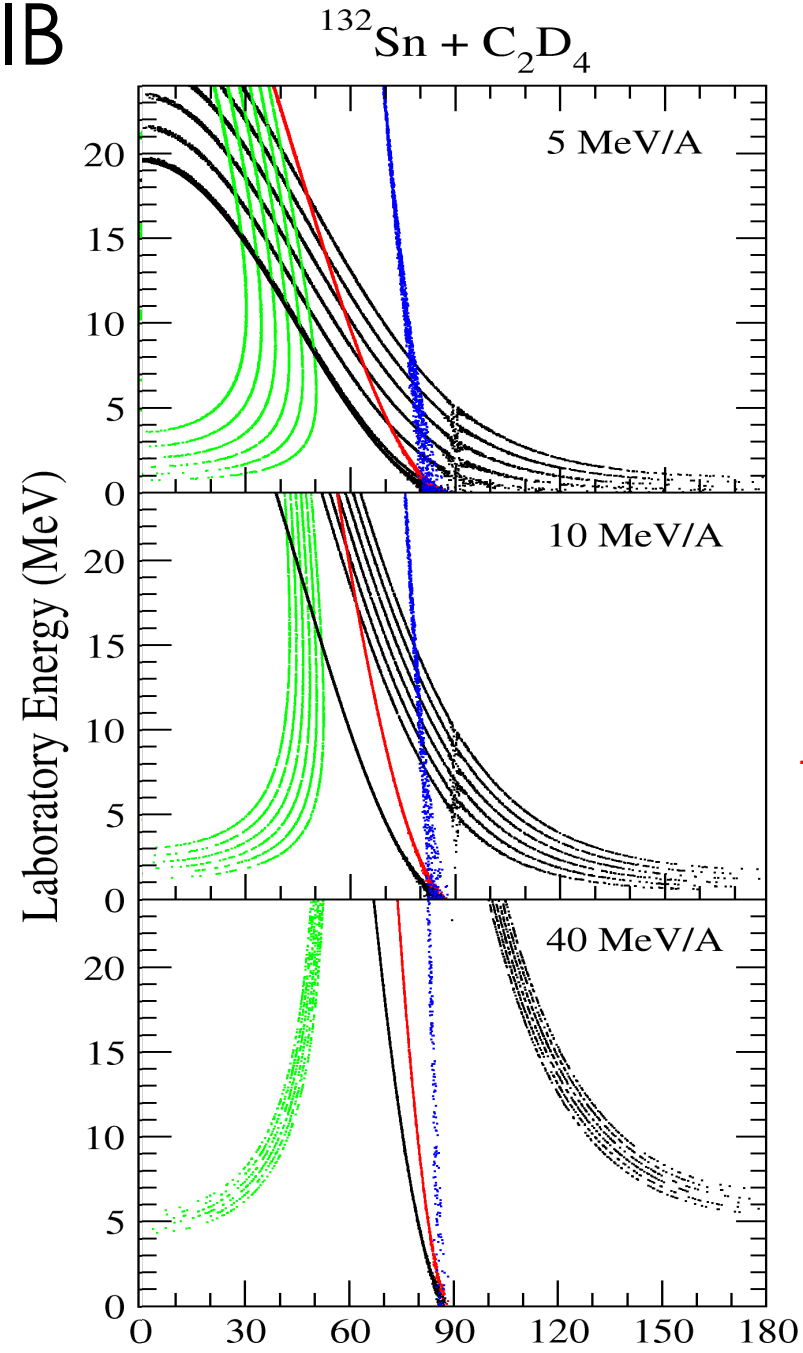
- Cornerstone of nuclear structure models, key indirect for astro
  - Evolution of SP structure E, J^{π}, ℓ, C^2S, …
- Best at ~CB energies
  - Resolution (kinematic compression)
  - Cross sections (magnitude, shape)
  - Dynamic range
- Reaccelerated preferable
  - Beam quality directly affects CoM energy resolution
- Need 10-15 MeV/A (ReA12)
  - to reach S_n, S_p, etc

  (eg SRM (d,p), (p,d), (p,p'))



Ratkiewicz et al., Phys. Rev. Lett. **122**, 052502 (2019)



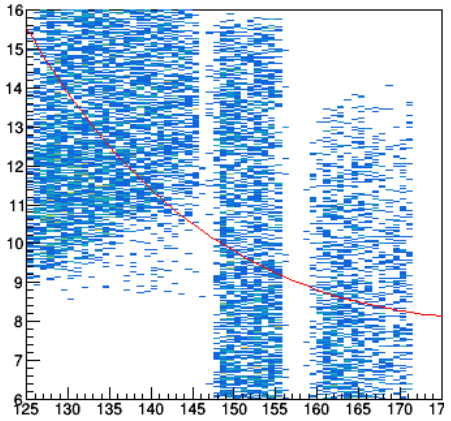


An experiment is only as good as its recoil detector…

Particle "singles"….

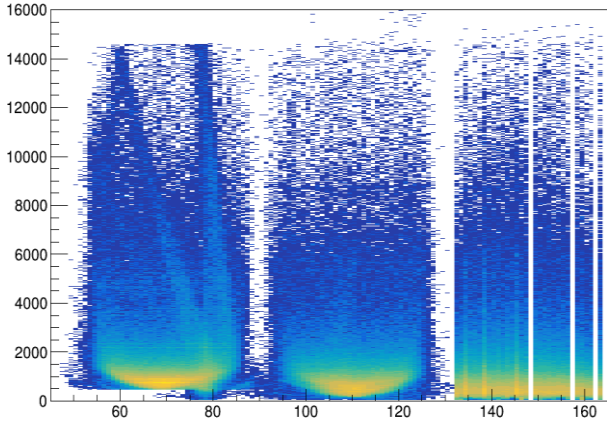
NSCL fast beam

^{84}Se(d,p) @ 45 MeV/u



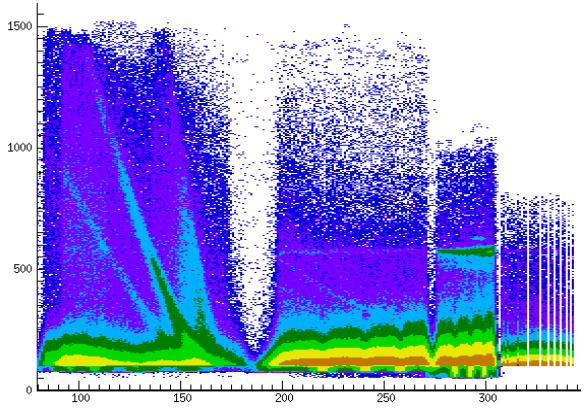
CARIBU beam

^{134}Te(d,p) @ ~10 MeV/u

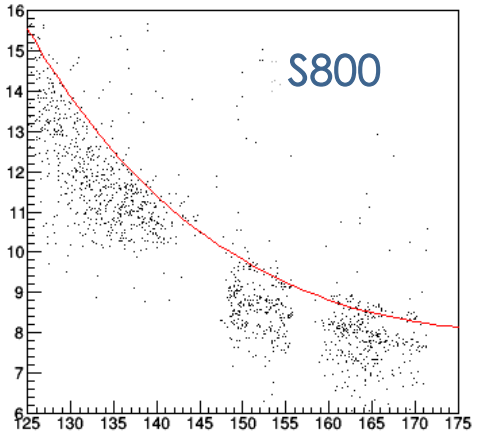


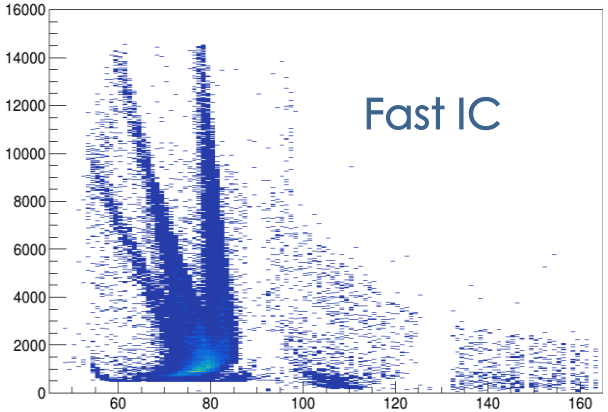
ReA3 beam

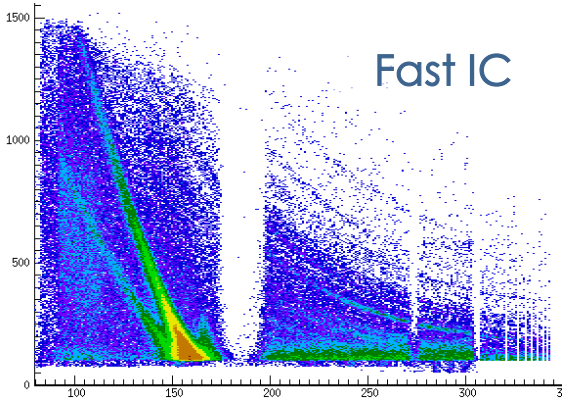
^{38}K(d,p) @ ~5 MeV/u



… and with recoil detector







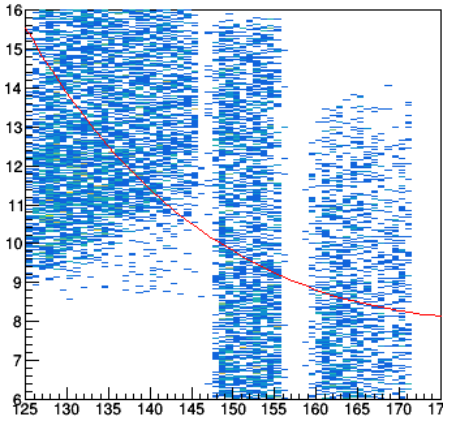
National Laboratory

An experiment is only as good as its recoil detector.

Particle "singles"….

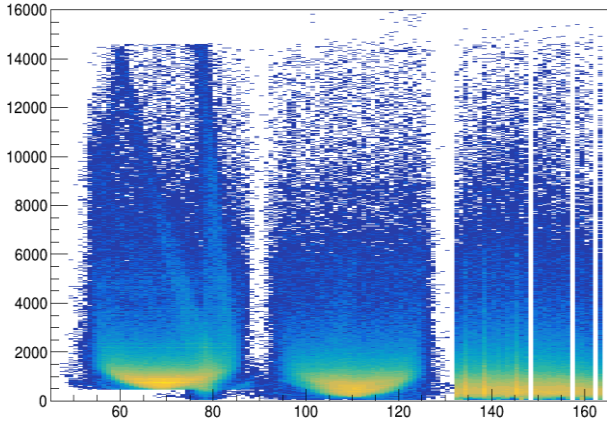
NSCL fast beam

^{84}Se(d,p) @ 45 MeV/u



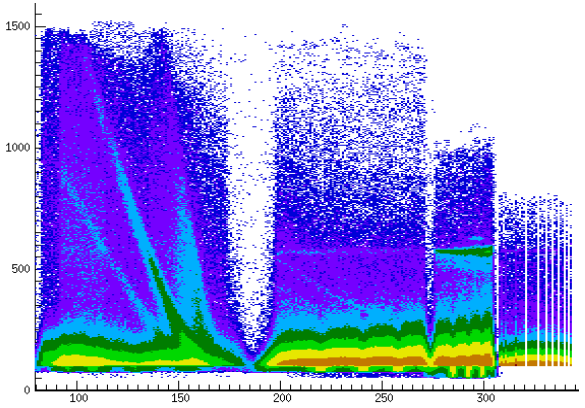
CARIBU beam

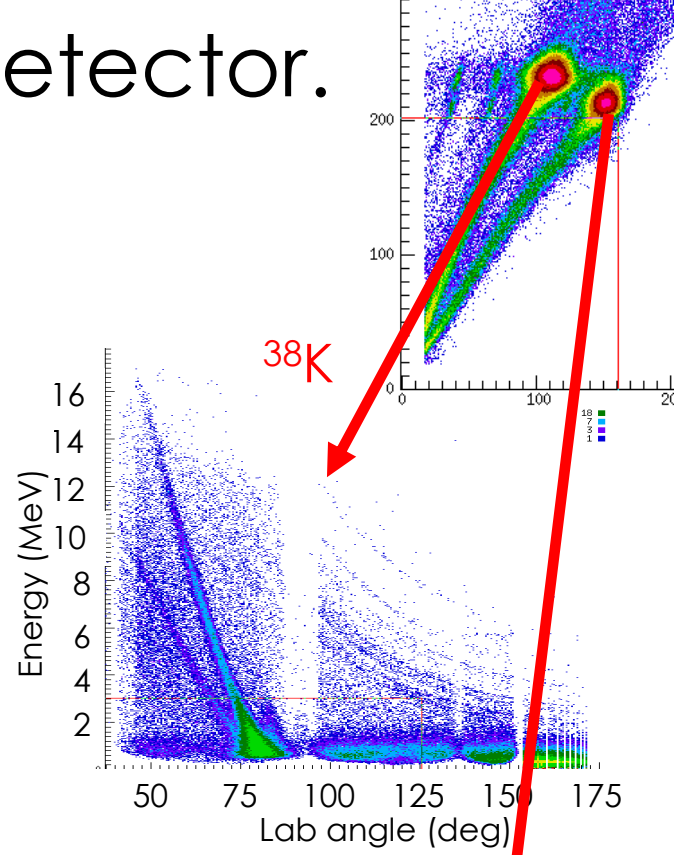
^{134}Te(d,p) @ ~10 MeV/u



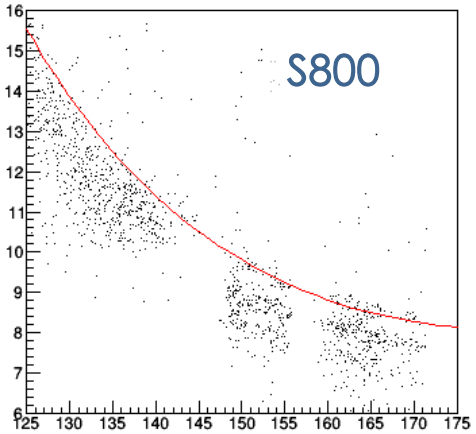
ReA3 beam

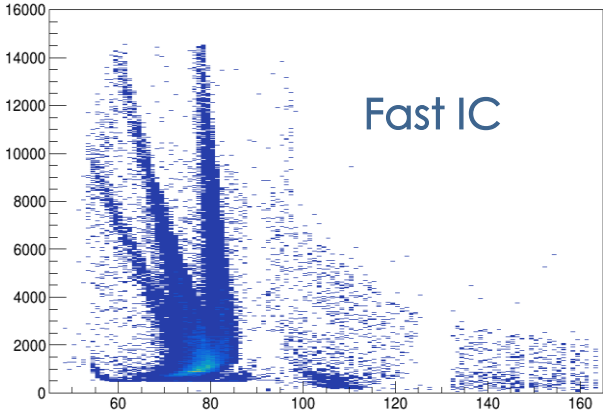
^{38}K(d,p) @ ~5 MeV/u

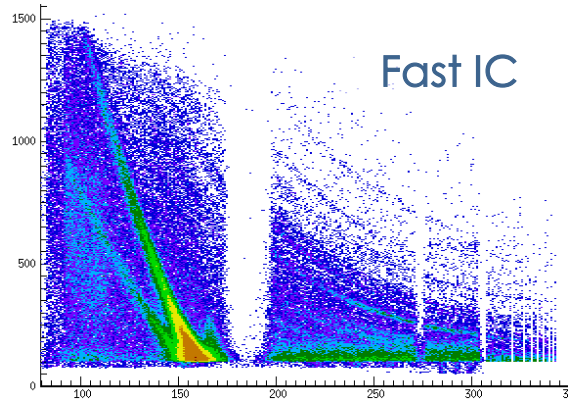


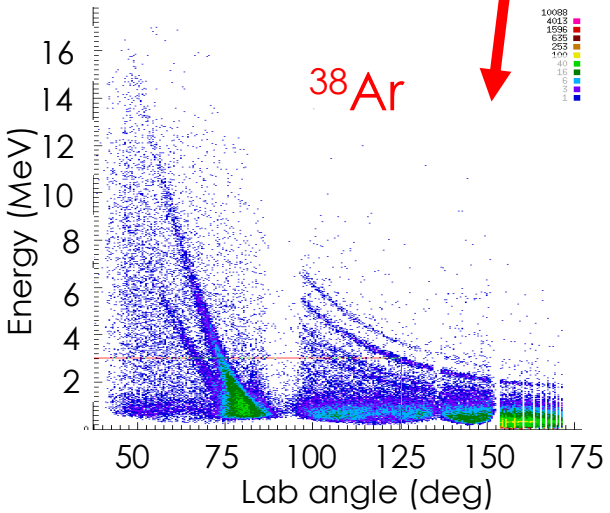


… and with recoil detector

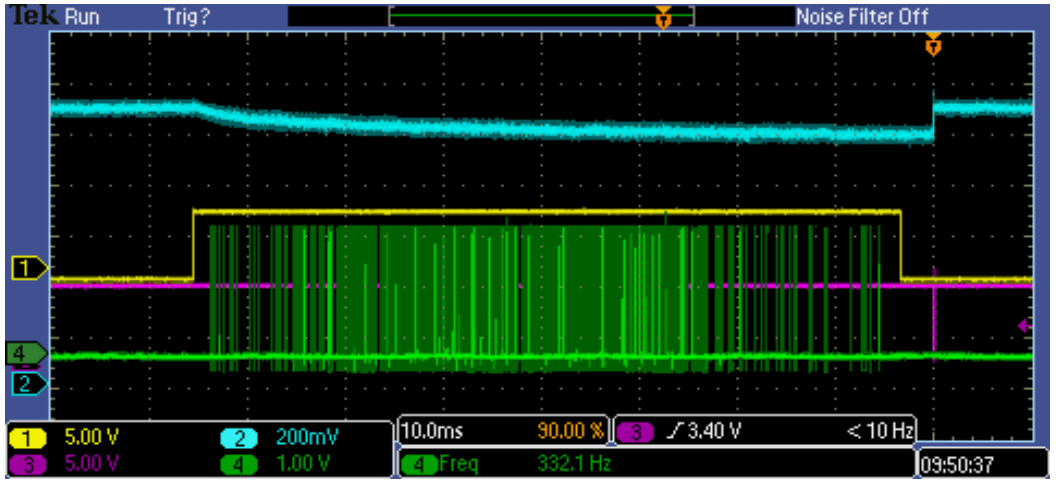




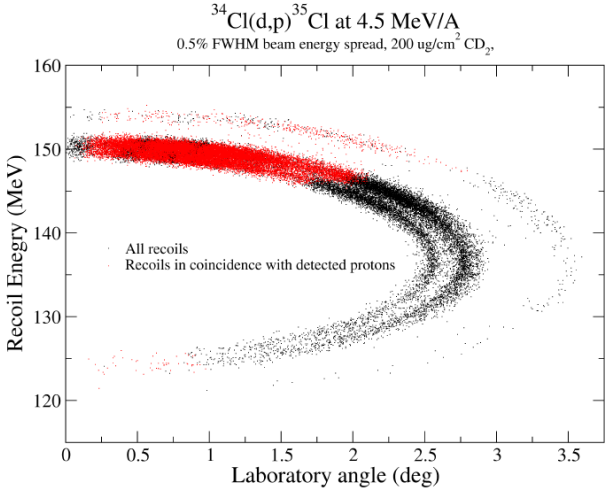


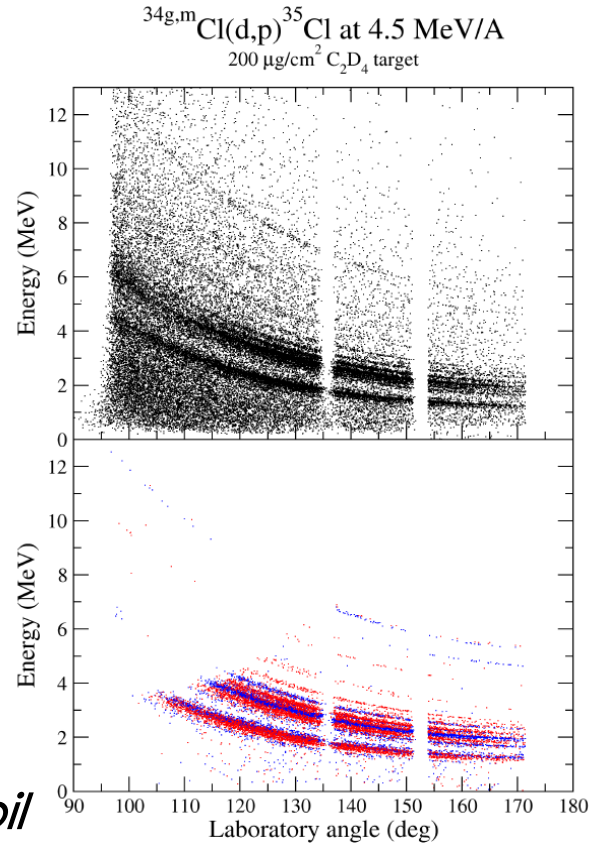


Transfer expts at ReA@FRIB…



Instantaneous rates = 10 – 100 x average





- Typically isobarically mixed beams (eg decay daughters) – need recoil detector
- Beam intensities will ultimately be substantially higher
  - Even PAC2 intensities are approaching IC limit (given EBIT time structure)
- EBIT spill structure – high instantaneous rates (x10-100 average; constraints on breeding times)
- A dedicated recoil separator is needed…
- ^{34g,m}Cl(d,p) experiment approved at FRIB PAC1
  - mirror study for (p,γ) resonance strengths
  - develop use of SECAR as recoil separator for transfer reactions

High-acceptance recoil separator (ISLA) needed!

- For direct-reaction program
- Enabling for (d,n) program

3-4 deg recoil (70 mrad)

Energy spread +/- 4% (+/- 2% ΔP)

OAK RIDGE National Laboratory

Summary

- ORRUBA – largest suite of Si detectors for RIB physics
- Thrives from coupling to other instruments
  - GODDESS (GS,GRETINA)

  with GRETA – 4π high-res particle-γ spectrometer (mm precision) for FRIB
  - Targets (JENSA, frozen H_2 under development)
  - Recoil detectors/separators crucial (ICs, S800, SECAR, FMA,)
- ReA12@FRIB - a step away from a world-leading high-quality direct-reaction experiments
  - Direct reactions are a cornerstone tool, ideally performed at ~10 MeV/A, reaccelerated beams
  - Energy upgrade is critical to many experiments (eg reaching $S_{n,p}$)
- To fully realize the direct-reaction program at FRIB, the ReA12 upgrade and a dedicated high-acceptance recoil separator, constructed in a timely manner, are the highest priorities

Thanks

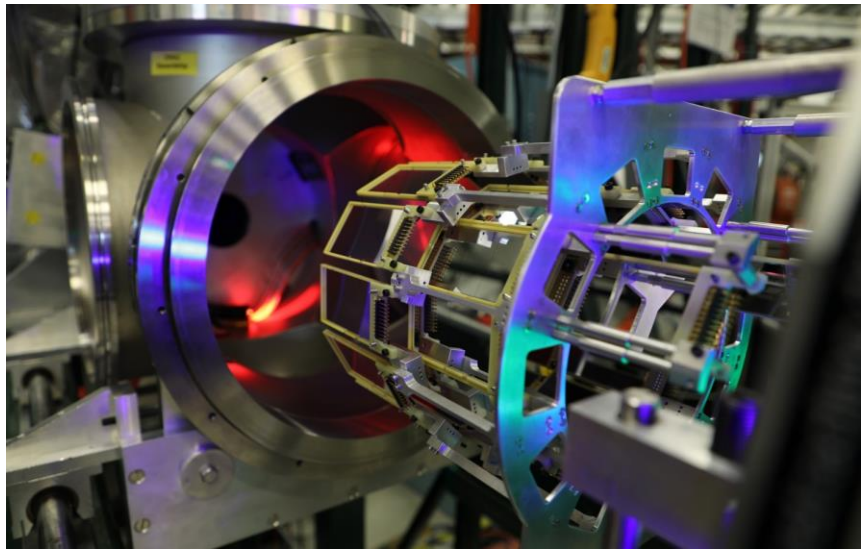
ORRUBA, GODDESS, JENSA and SECAR Collaborations

ORRUBA
Si detector array

JENSA

GODDESS

SECAR



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