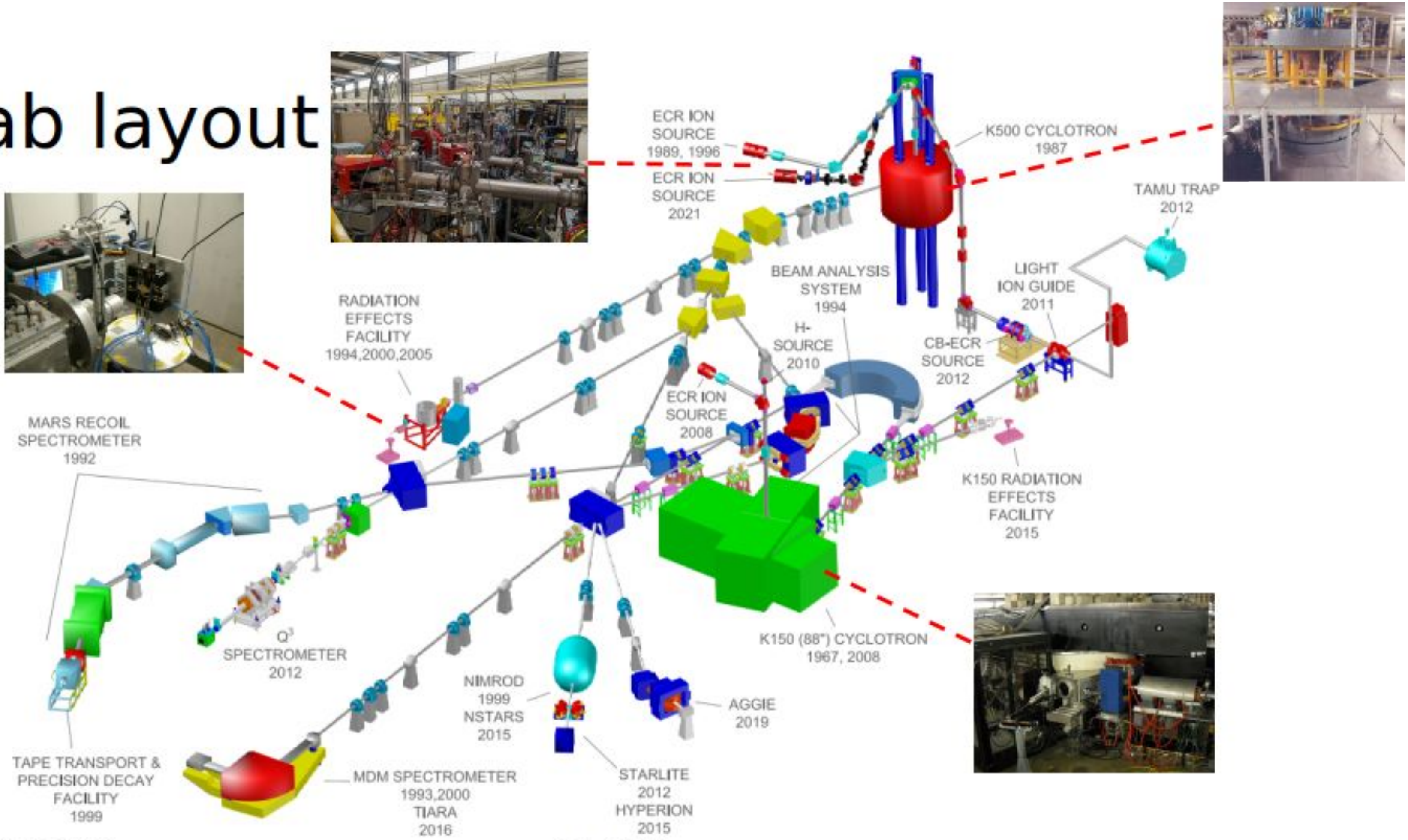
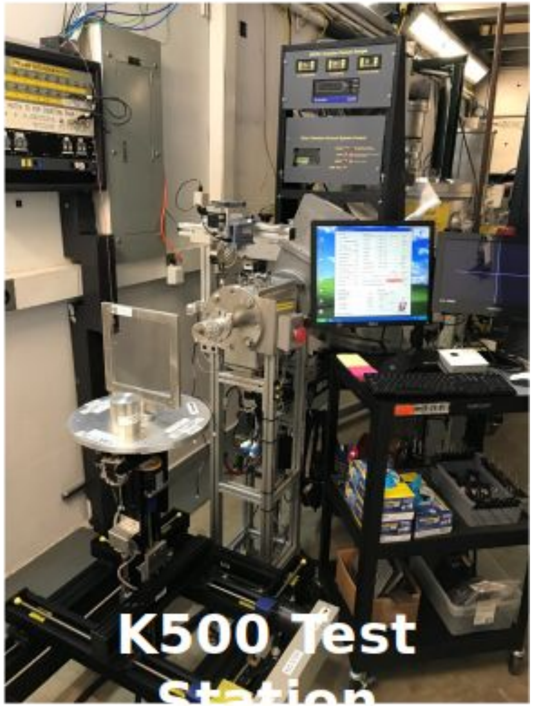
Lab layout



ECR ION SOURCE 1989, 1996
ECR ION SOURCE 2021
K500 CYCLOTRON 1987
TAMU TRAP 2012
BEAM ANALYSIS SYSTEM 1994
LIGHT ION GUIDE 2011
RADIATION EFFECTS FACILITY 1994,2000,2005
H- SOURCE 2010
CB-ECR SOURCE 2012
ECR ION SOURCE 2008
MARS RECOIL SPECTROMETER 1992
K150 RADIATION EFFECTS FACILITY 2015
Q^3 SPECTROMETER 2012
K150 (88") CYCLOTRON 1967, 2008
NIMROD 1999
NSTARS 2015
AGGIE 2019
TAPE TRANSPORT & PRECISION DECAY FACILITY 1999
MDM SPECTROMETER 1993,2000
TIARA 2016
STARLITE 2012
HYPERION 2015

The Radiation Effects Facility provides over 4000 hours per year for testing between the two cyclotrons

- K500 beams available:
  - 15 MeV/u (He, N, Ne, Ar, Cu, Kr, Ag, Xe, Pr, Ho, Ta, Au);
  - 25 MeV/u (He, N, Ne, Ar, Kr, Ag, Xe);
  - 40 MeV/u (N, Ne, Ar, Kr)
- K150 beams available:
  - 15 MeV/u (He, N, Ne, Ar, V, Cu, Kr)
  - Protons in tunable energies from 6 – 45 MeV
- Custom SEUSS software provides complete dosimetry (flux, fluence, dose), as well as controlling the moveable platter and in-vacuum beam degraders
- Beams selectively defocused upstream to deliver >90% beam uniformity at the in-air end station

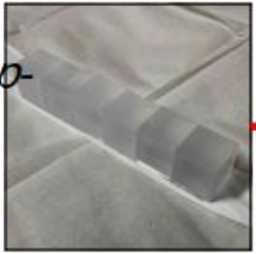


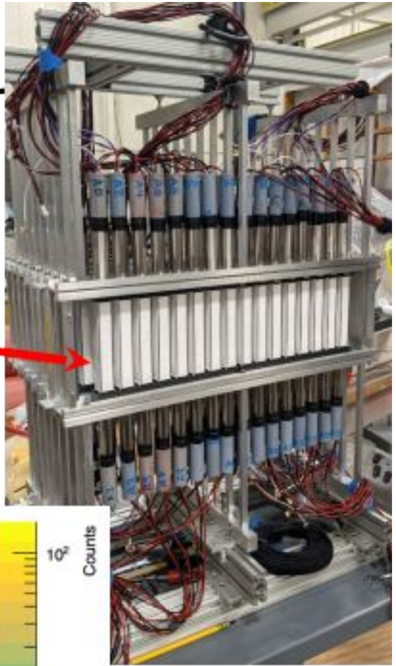
For additional information, visit the REF website: https://cyclotron.tamu.edu/ref/

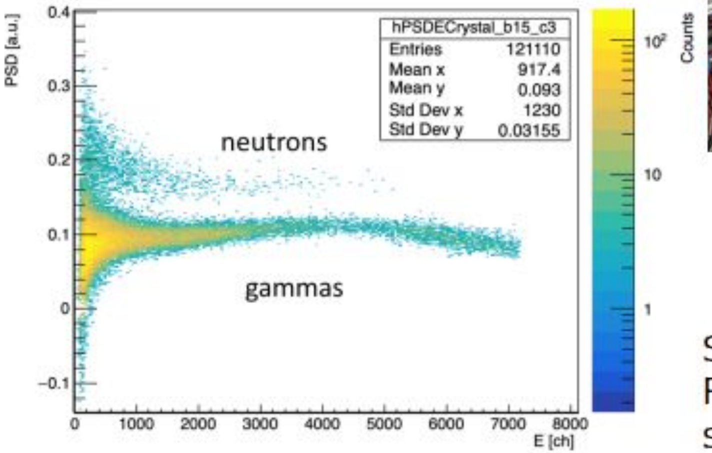
TexNeut – Texas Neutron Detector

- Consists of up to 117 pseudobar modules* constructed from 2x2x2cm^3 *p*-Terphenyl scintillator, with module characteristics:
  - Timing resolution <1ns FWHM
  - PSD threshold of ~150 keVee
  - Energy threshold of ~300keVee
- Array read out using PSD-capable ASIC chips and NSCLDAQ
- Commissioning experiments of ^{7}Li(p,n), ^{6}He(p,n), ^{9}Li(p,n) currently under analysis!

*D.P. Scriven *et al.*, *NIMA* **1010**, 165492 (2021) .

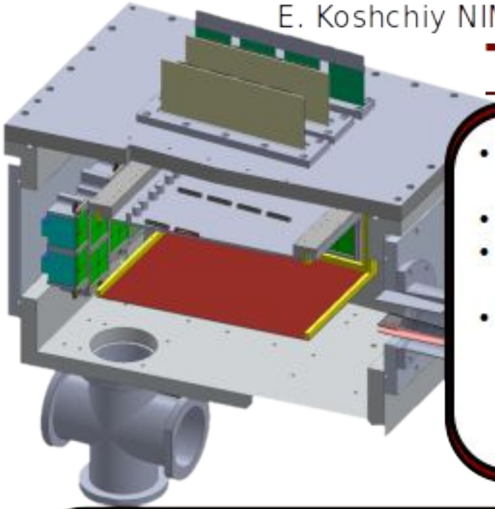






Single crystal PSD for ^{252}Cf source.

E. Koshchiy NIMA 957, 163398 (2020)



TexAT TPC

- Rectilinear general purpose TPC
- GEM+MM w/GET
- Si+CsI telescope backing
- Mainly RIBs from MARS (+TRIUMF+OU neutrons)

Past experiments

^{8}B(p,p) – first TexAT experiment!

^{10}C/^{14}O(α,α) – nuclear clustering

(^{12}N,β3α) & (^{13}O,β3αp) - β-delayed particle decay

^{8}B+^{40}Ar – direct fusion measurements

$^{12/13}$B(d,^{3}He) – transfer reactions

^{12}Be(p,p) – ^{13}Be g.s. through IAS

^{9}Li(p,p) – ^{10}Li g.s. through IAS

^{9}Li(p,n) – ^{10}Li g.s. through IAS + **TexNeut**

^{12}C(n,n$_2$)3α – Neutron-induced reactions

^{14}O(α,p) - XRB

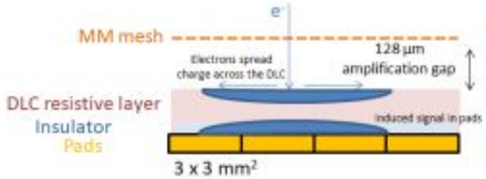
Coming soon: TeBAT TPC

Building on 7+ years of experience with TexAT

Collaborating with Univ. Birmingham, UK

1k MM channels ▯ 8k MM channels

Resistive DLC



Pos. resolution improves from ~1.5 mm to ~300 µm

^{3}He target and recycling system

^{3}He recycling and purification system for ^{3}He:CO2 as an active-target gas

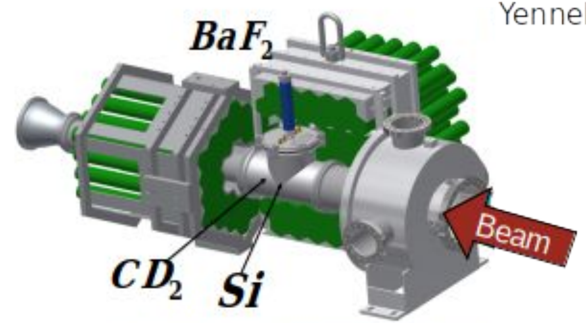
Designed and prototype currently being tested

(^{3}He,d) and (^{3}He,n) experiments with RIBs

Indirect probe of (p,g) for astrophysical scenarios

DAPPER Detector Array for Photons, Protons, and Exotic Residues

McIntosh, Hagel, Gauthier, Sorensen, Abbott, Rider, Couture, Yennello



Extract Photon Strength Function
- Oslo & Forward Methods

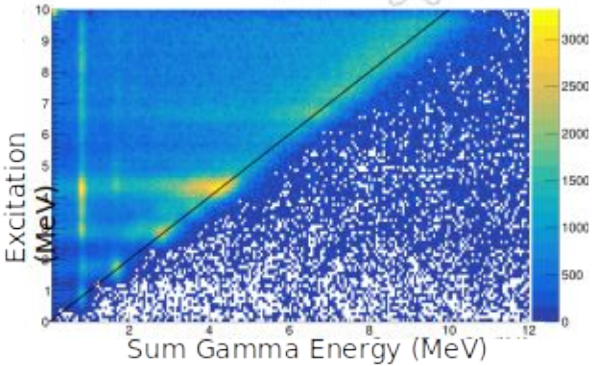
Constrain n-capture x-sect
- Away from stability
- Improve model predictions

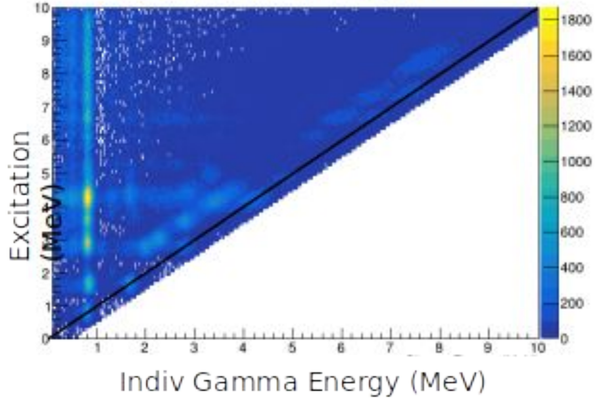
Rxn: (d,pg) inverse kinematics
- make use of rare isotope beams

128 BaF2: gamma energy & mult
Annular silicon: excitation energy
High efficiency: 46% @ 6.1 MeV
Commissioning: 57Fe(d,pg)58Fe
Compare: 58Fe PSF to DANCE (n,g)

Future:
- 59Fe(d,pg)60Fe (s-proc branch)
- PSF along isotopic chains
- --> nuclear data input

Needs:
- stable and exotic RIB
- radiation-hard energy detectors
- neutron target + RIB storage ring






Astrophysics


Advanced Reactor Design

Knockout and transfer

$^{4}He + ^{12}C$ @ 60 MeV/u shown

Also measured:

$^{4}He + ^{16}O, ^{24}Mg, ^{27}Al, ^{28}Si$ @ 60 MeV/u

$^{4}He + ^{12}C$ @ 25 MeV/u

$^{1}H + ^{12}C, ^{28}Si$ @ 60 MeV/u

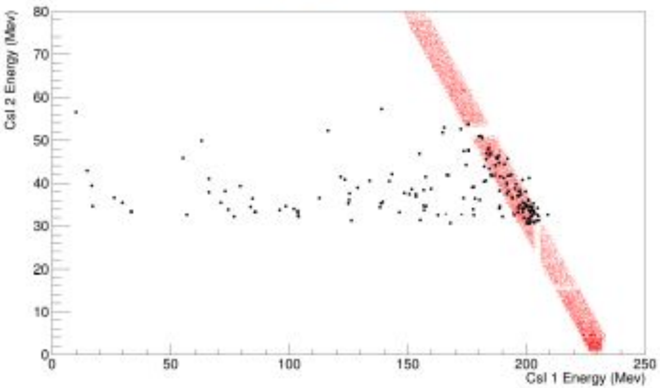
Cyclotron Institute
Texas A&M University

NIMROD @ Texas A&M

Neutron Ion Multi-detector for Reaction Oriented Dynamics

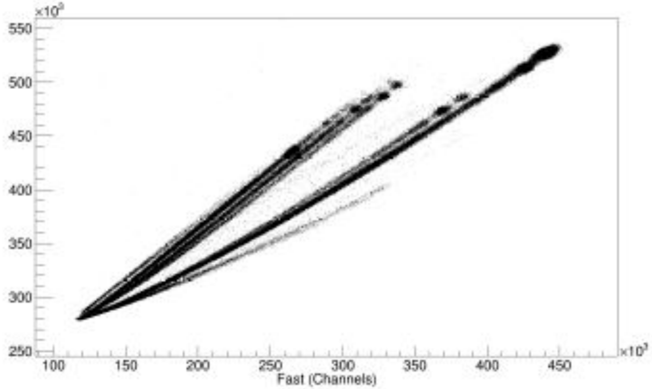
4pi (charged) + 4pi (neutrons) detector

$^{12}C(\alpha,\alpha'\alpha)$



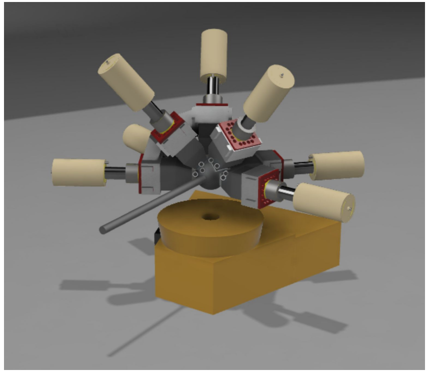
Black: data for single detector pair.
angle gate implies finite energy range as seen
Red: phase space simulation of knockout rxn.
no angle gate on simulation.
This is just for a small amount of data
The Point: significant yield in the region of phase space for knockout.
Knockout can tell us about the cluster structure

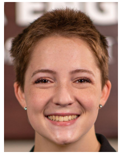
$^{12}C(\alpha,LCP)$



Particle ID plot; from L to R: p,d,t,h,a,Li+
Significant yield of elastic, quasi elastic, transfer products, smaller knockout products.

Particle-γ coincidences @ TAMU



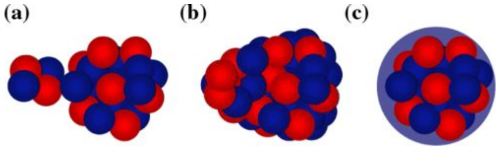


Current design by Madison Reuter, undergraduate nuclear engineering student @ TAMU

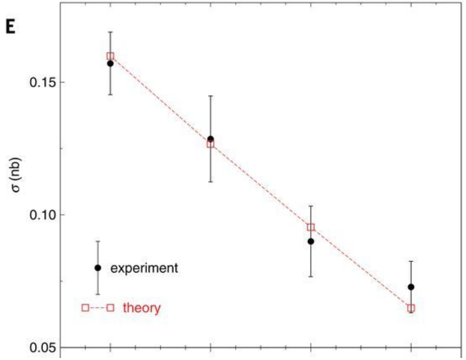
The MDM at the TAMU cyclotron Institute is (I think) the only cyclotron+spectrometer combination in North America

Inelastic scattering especially (α,α'γ) is a powerful tool for probing:
-the isoscalar part of the pygmy dipole response
-nuclear clustering - E0 and E1 (connection to IS PDR?)
-octupole coupling
-γ strength functions
-probably other things that I haven't considered

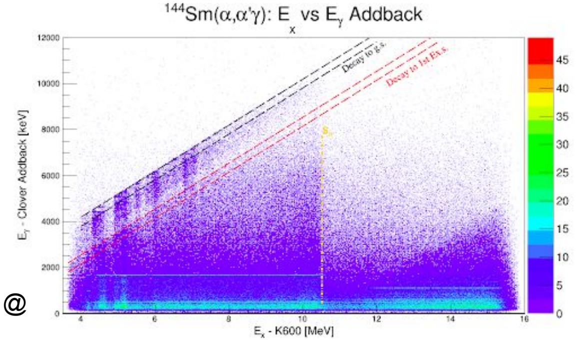
Coincidence transfer reactions:
-^{25}Mg(^{3}He,dγ) for ^{26}Al^{g}/^{26}Al^{m} production ratio
-^{12}C($^{6/7}$Li,dγ/tγ) for ^{12}C(α,γ)



M. Spieker, S. Pascu, A. Zilges, and F. Iachello Phys. Rev. Lett. 114, 192504

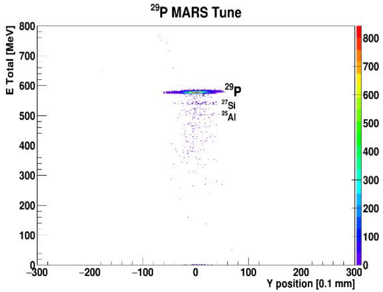


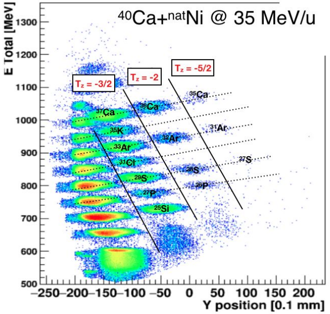
Tabaka++ Science 371 6526 260

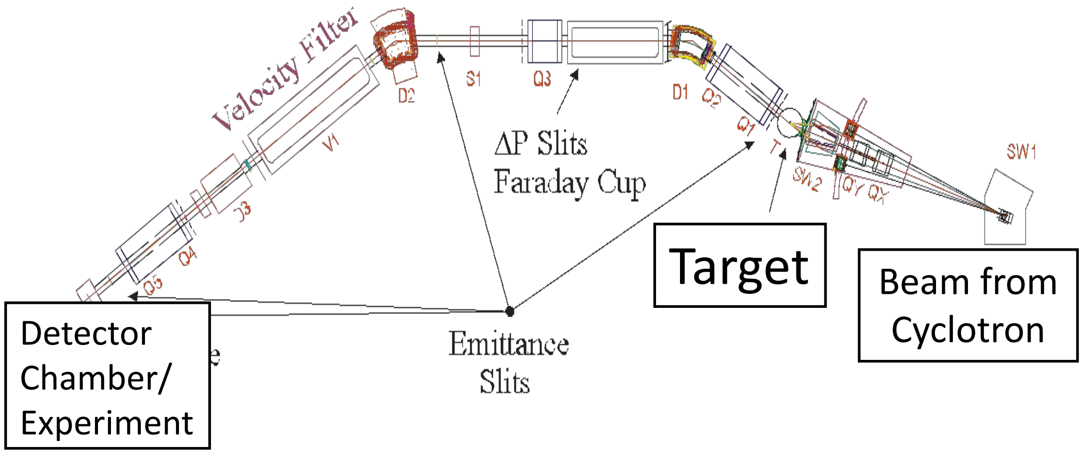


Courtesy of Harshna Jivan, PhD student @ Wits, South Africa - K600+BaGeL

MARS at TAMU-CI In-flight RIBs







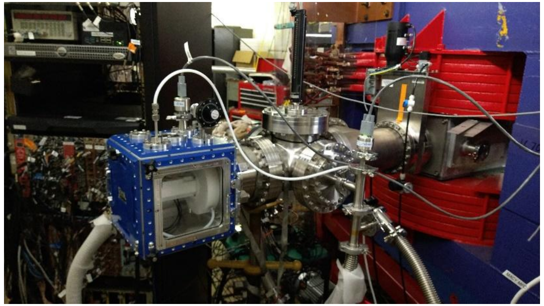
RIB beam	Reaction	Primary Beam	Purity	Intensity
^{10}C	p(^{10}B,^{10}C)n	^{10}B at 7 MeV/u	~100%	7*10^{3} p/s
^{14}O	p(^{14}N,^{14}O)n	^{14}N at 11 MeV/u	~95%	10^{4} p/s
^{42}Ti	^{4}He(^{40}Ca,^{42}Ti)2n	^{40}Ca at 32 MeV/u	~68%	1.6*10^{3} p/s
^{29}P	p(^{30}Si,^{29}P)2n	^{30}Si at 24 MeV/u	~99%	2.5*10^{4} p/s
^{12}N	^{3}He(^{10}B,^{12}N)n	^{10}B at 11 MeV/u	~94%	~100 p/s
^{8}B	^{3}He(^{6}Li,^{8}B)n	^{6}Li at 11.3 MeV/u	~50%	1*10^{3} p/s
^{9}Li	^{9}Be(^{11}B,^{9}Li)	^{11}B at 23 MeV/u	~11%	3*10^{3} p/s
^{12}B	^{9}Be(^{13}C,^{12}B)	^{13}C at 30 MeV/u	~2.6%	2*10^{6} p/s

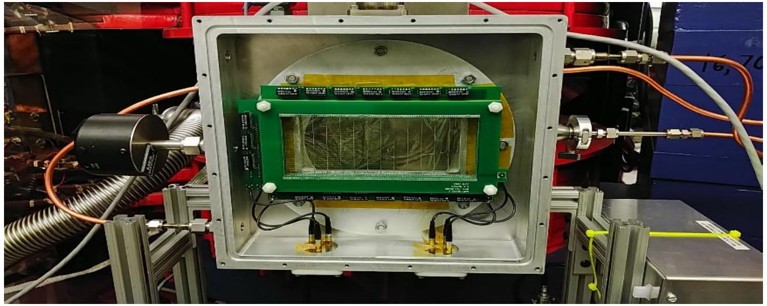
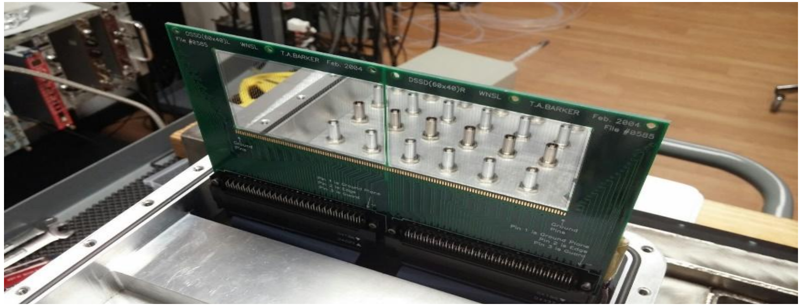
Parameters:

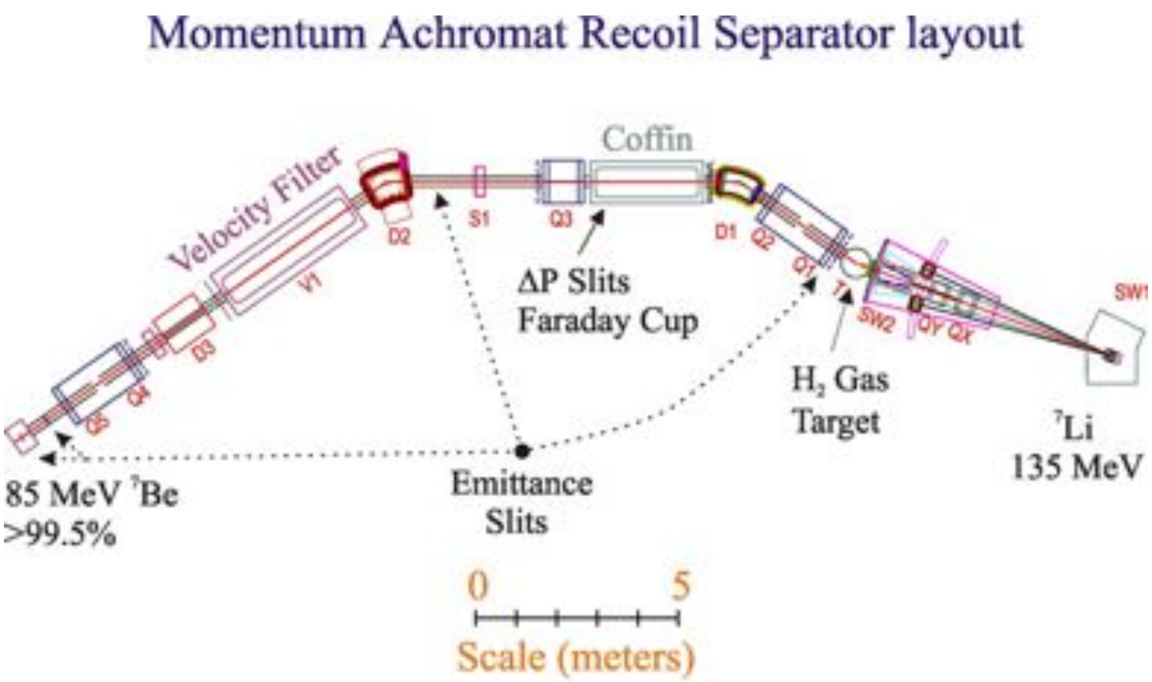
- Max rigidity : 2.0 T*m
- RIB beam energies: 1 – 40 MeV/u
- Typical Mass resolution: 1/300
- RIB Mass: A<60
- Production Reactions: Transfer, fusion-evaporation, “pseudo”-frag

AGGIE Gas-filled Separator for Heavy Elements

- Installed the new AGGIE gas-filled separator.
- Increased our beam intensity using first-harmonic (not third) beams from the K150 cyclotron.





MARS used for in-flight production of RIB

Various recent studies at the versatile end station

TexAT
-^{12}C Efimov studies with ^{12}N decay
-^{8}B+^{40}Ar fusion

DAPPER
-^{60}Fe photon strength function

Breakup studies using new LSU ^{3}He target for structure of light nuclei

^{18}Ne alpha resonance scattering for mirror studies