Discovery Experiments with the Modular Total Absorption Spectrometer (MTAS) at FRIB

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What MTAS Measures

For neutron rich nuclei βs, γs, and neutrons will be present in almost every decay. MTAS can measure them all. By measuring all as a function of energy, we can measure the β-strength function in one experiment.

MTAS γs

Detects single γs with a 98%+ efficiency

Detects **level** feeding, which is directly relatable to Gamow-Teller strength

MTAS βs

Detects βs with E > 3 MeV with 90%+ efficiency

MTAS Neutrons

Detects neutrons with ~15% efficiency

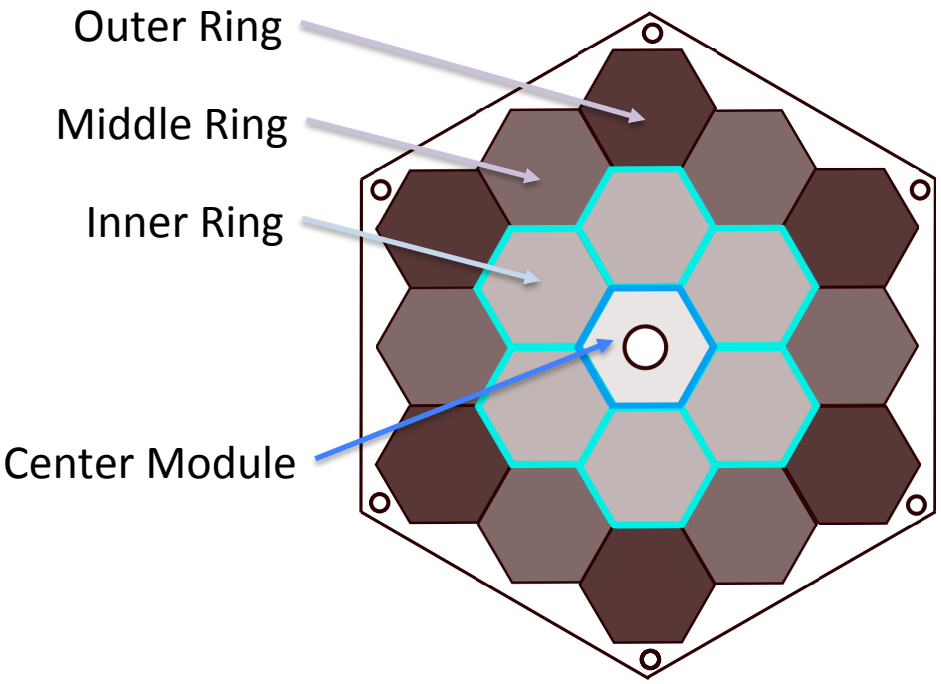
Measures neutron energy ~100keV sigma

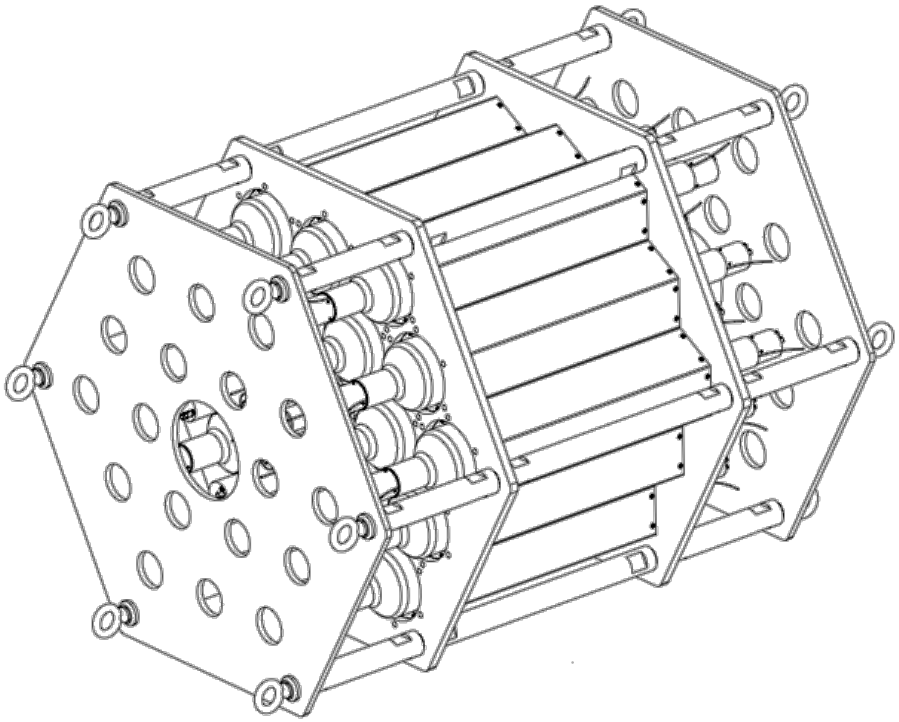
Detects very low energy neutrons

Detects neutron fine structure (γs following β-delayed neutron decay) feeding intensities

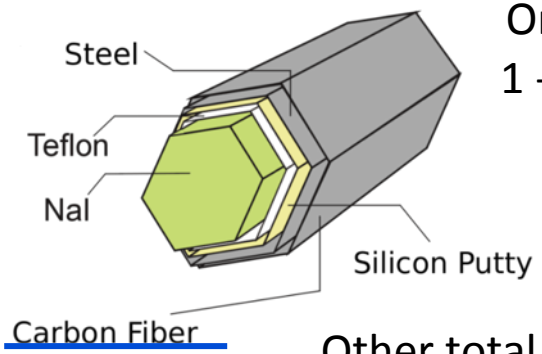
Measuring all three with one detector in one experiment is ideal, therefore MTAS is unique and powerful device.

MTAS





MTAS: 18 - 8”x 7”x 21” (20cm x 17.8cm x 53.3cm) hexagon NaI(Tl) modules
Organized in 3 Rings of 6 modules each (Inner, Middle, and Outer)
1 - Center module, same dimensions but with a 2.5” diameter hole
Over 1 ton of NaI(Tl)!

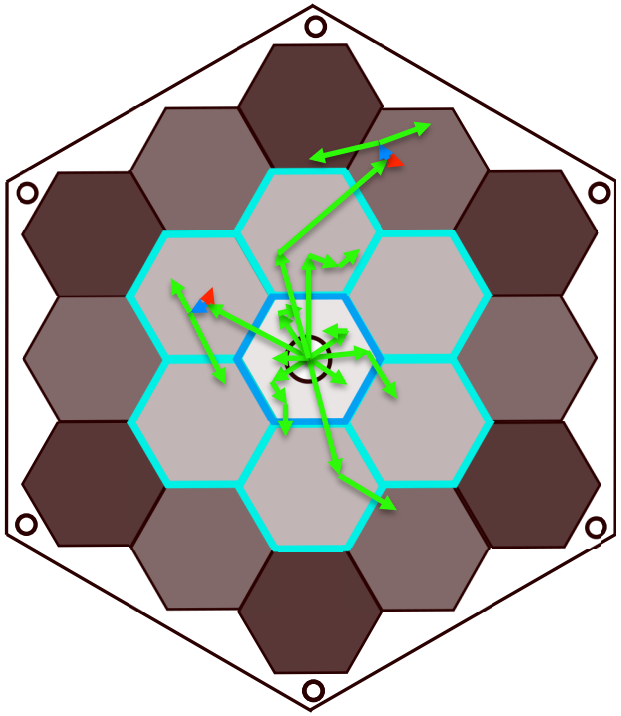


Over 5 tons of lead shielding + neutron shielding

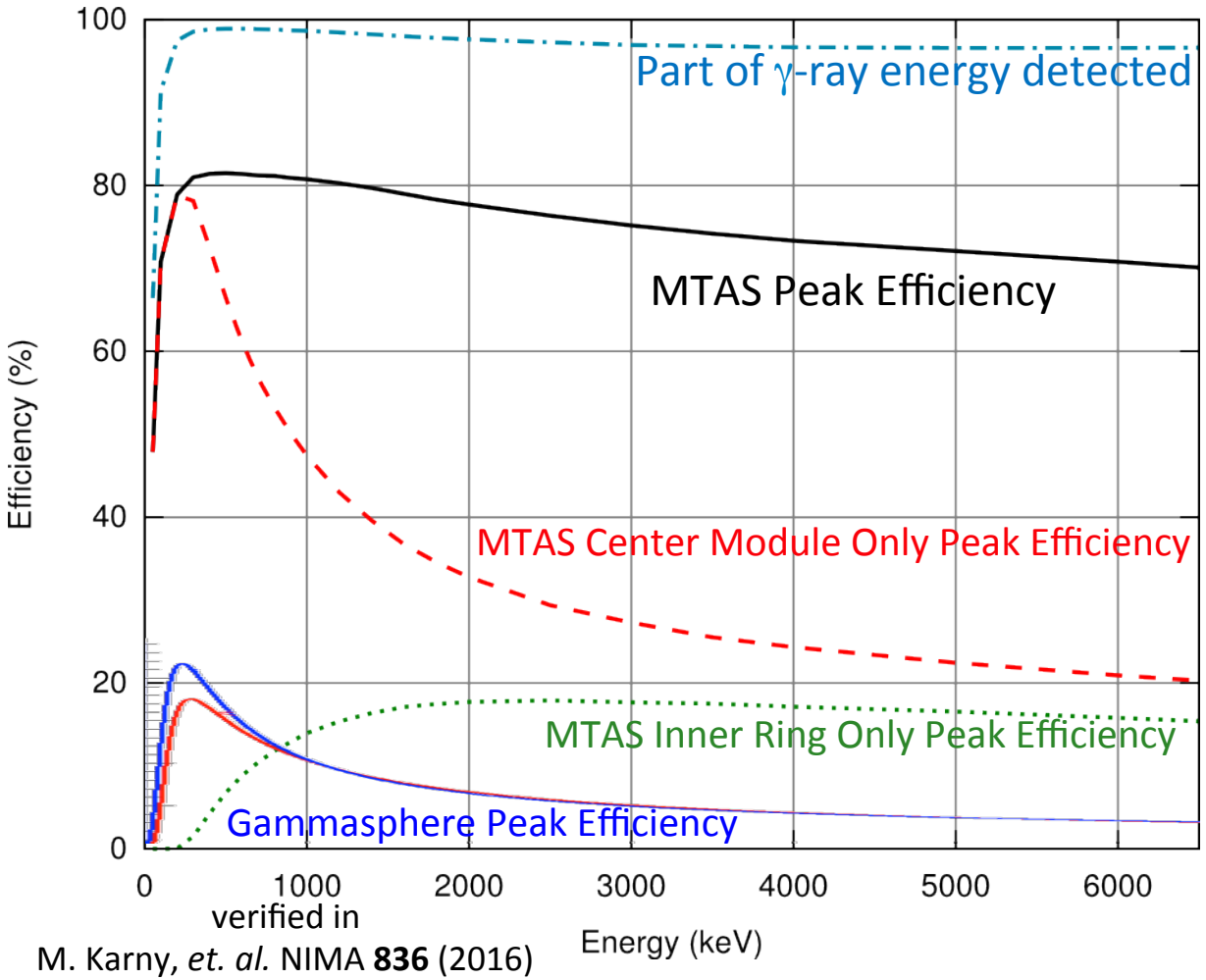
Other total absorption spectrometers include the TAS at ISOLDE, Lucrecia, TAS at GSI (now at UML), SuN (MSU), DTAS (Valencia, Jyvaskyla).

What MTAS Measures - γs

γs in MTAS



Single γ-ray efficiency of various MTAS regions and comparison with a high-efficiency HPGe Array.



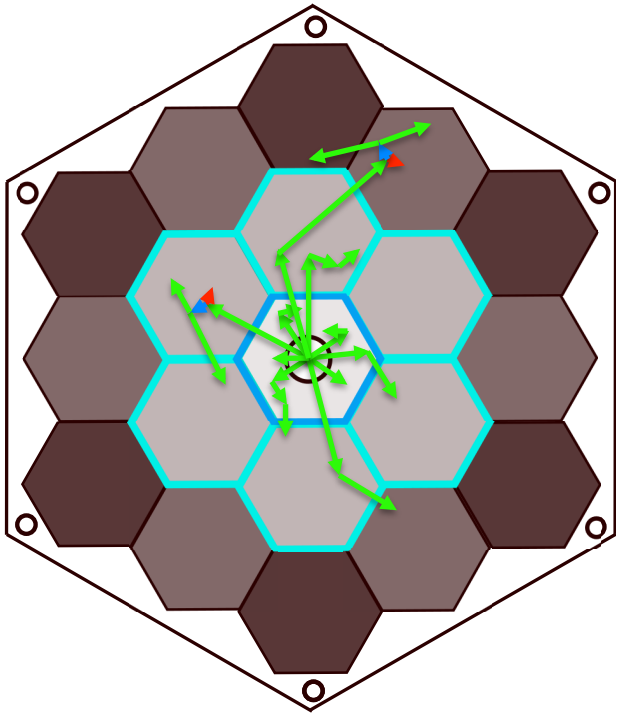
verified in

M. Karny, *et. al.* NIMA **836** (2016)

Rasco NIMA **788** (2015)

What MTAS Measures - γs

γs in MTAS

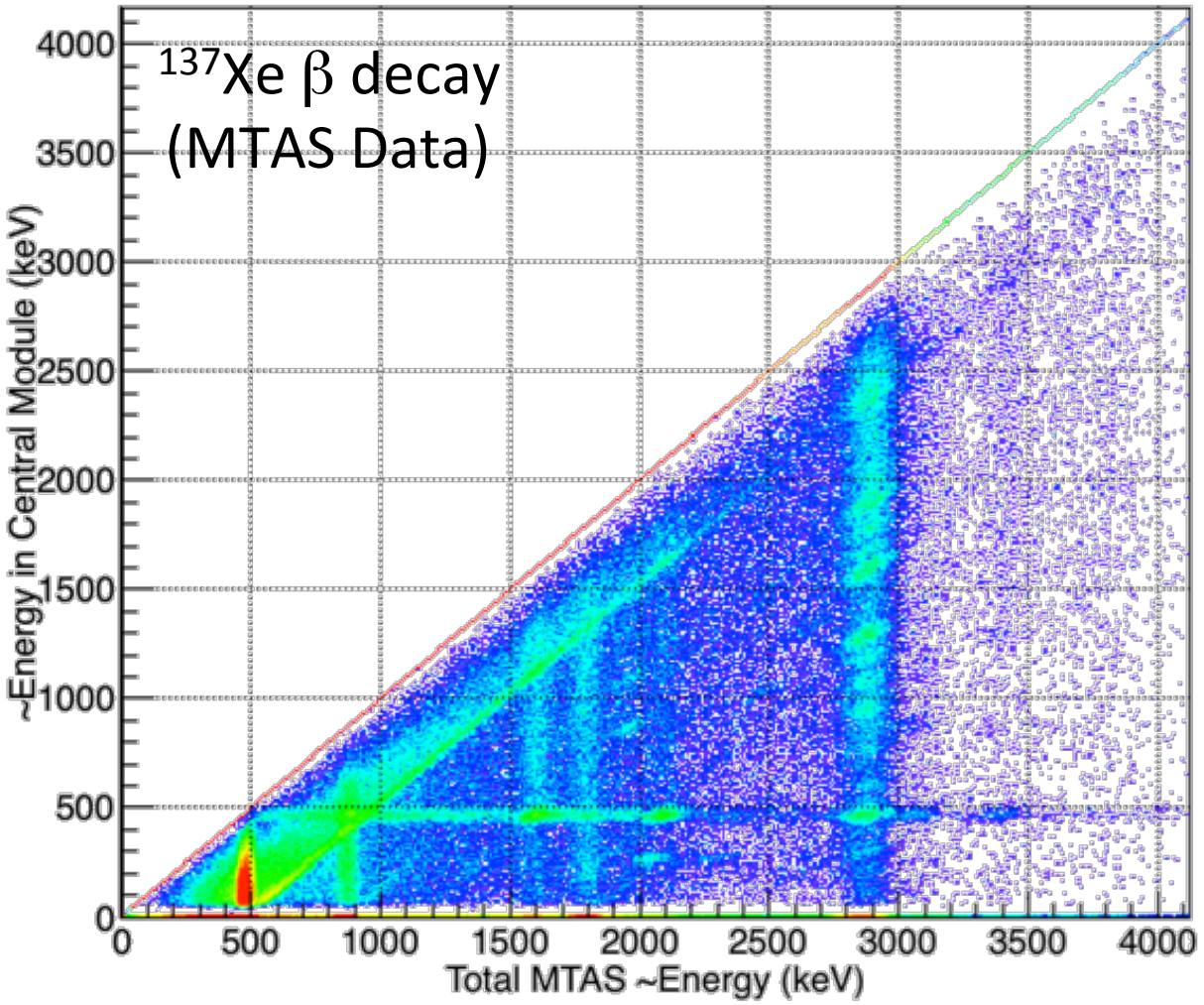


Segmentation is powerful.

Can see dominant decay paths from various energy levels.

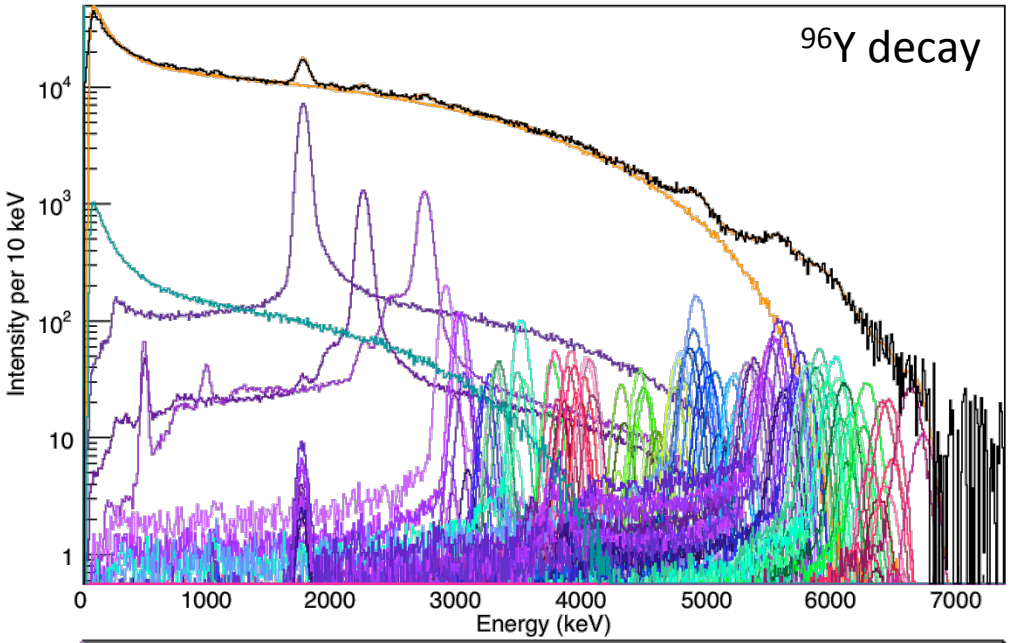
Modularity to see individual decay paths

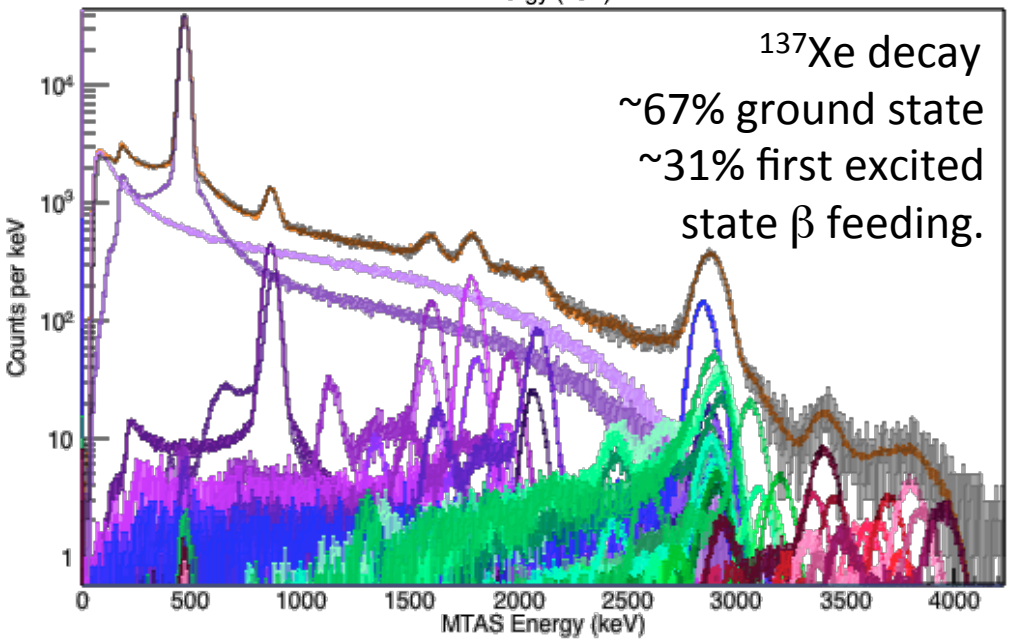
MTAS Center vs Total Energy



B.C. Rasco, *et. al.*, JPS Conf. Proc. 6, 107 (2015)

What MTAS Measures - βs



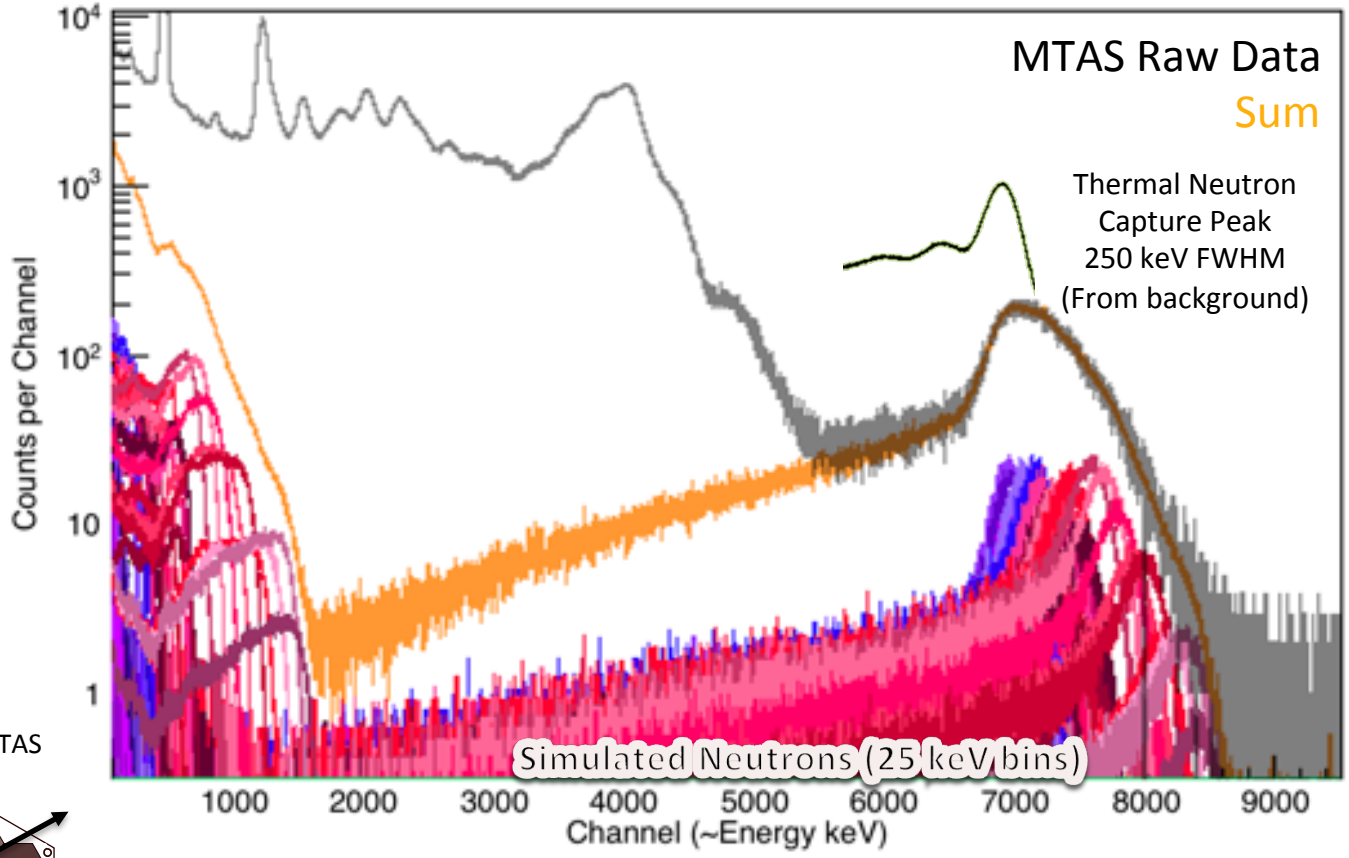


^{96}Y decay -95% ground state feeding
i.e. only βs

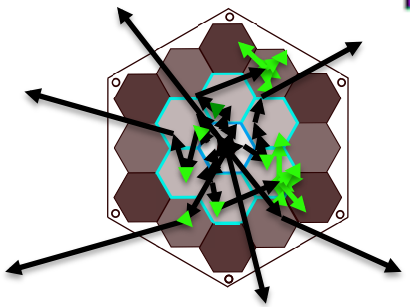
MTAS can identify βs by their broad response function and occur mostly in the center module

What MTAS Measures - Neutrons

^{137}I Q_β= 6027 keV, $Q_{\beta\text{-}n}$= 2002 keV



Neutrons in MTAS

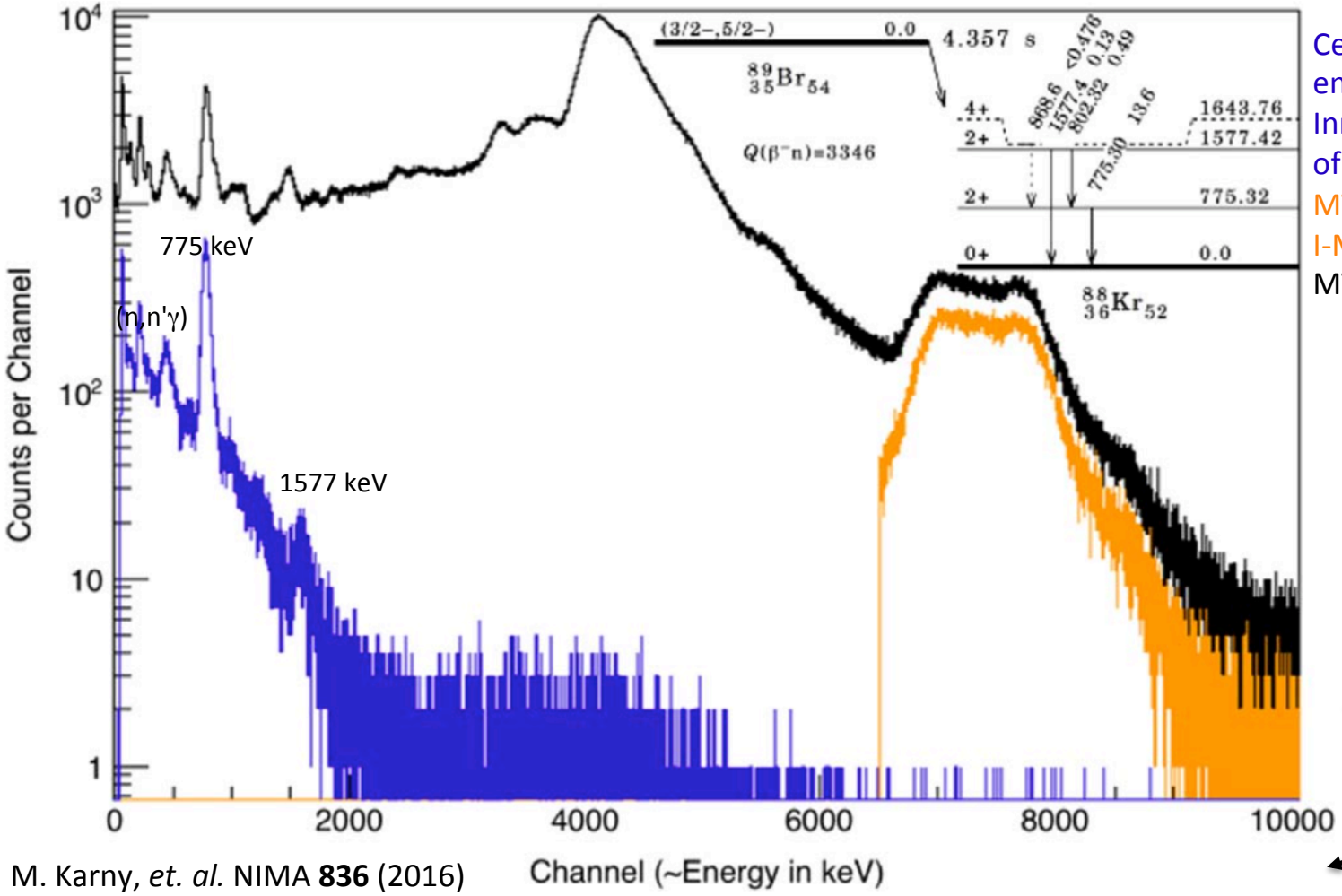


B.C. Rasco, PRC **95**, 054328 (2017)

What MTAS Measures - Neutrons + γs

Neutron Fine Structure

β-n decay component

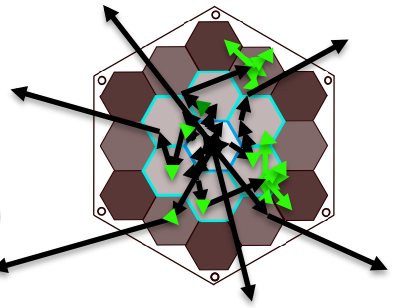


Center gated on large energy deposit in Inner-Middle-Outer rings of MTAS

MTAS Total gated on large I-M-O deposit

MTAS Total

Neutrons in MTAS



M. Karny, *et. al.* NIMA **836** (2016)

MTAS Required Implants

Fewest Counts Needed to Evaluate:
$T_{1/2}$: ~10 Counts

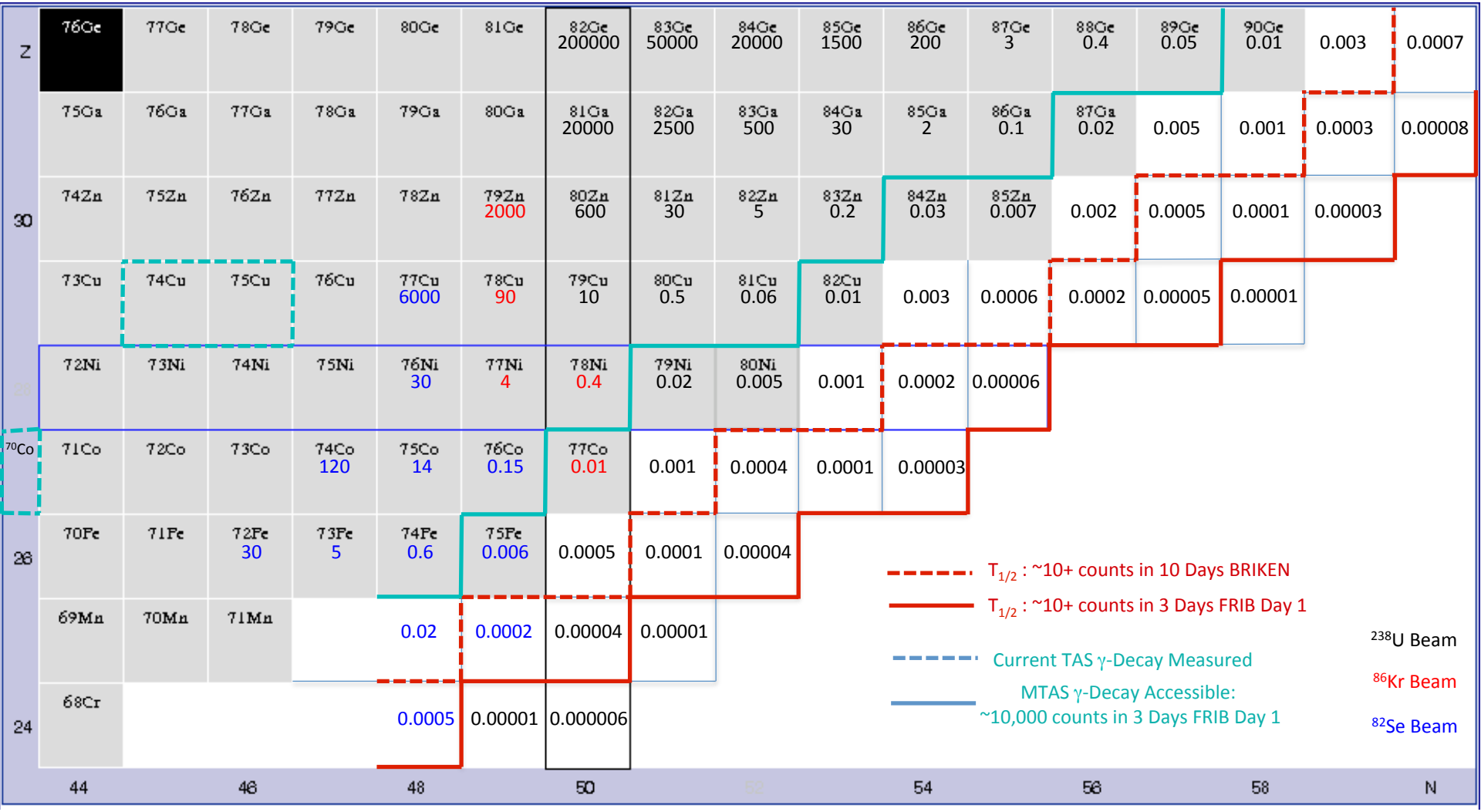
β-Decay Feeding Spectrum Counts:
GS + Excited States: ~10,000 Counts
Neutron: ~500 Counts

Average State Multiplicity: ~50,000 Counts
Neutron Fine Structure: ~500-1000 Counts

Assumptions:
FRIB Year 1 Rates from webpage "FRIB Estimated Rates 1.08"
3 day experiment
MTAS Neutron Efficiency 15%
Neutron Fine Structure Efficiency: ~5-10%
(~Neutron Efficiency * Low Energy MTAS Central γ Efficiency)

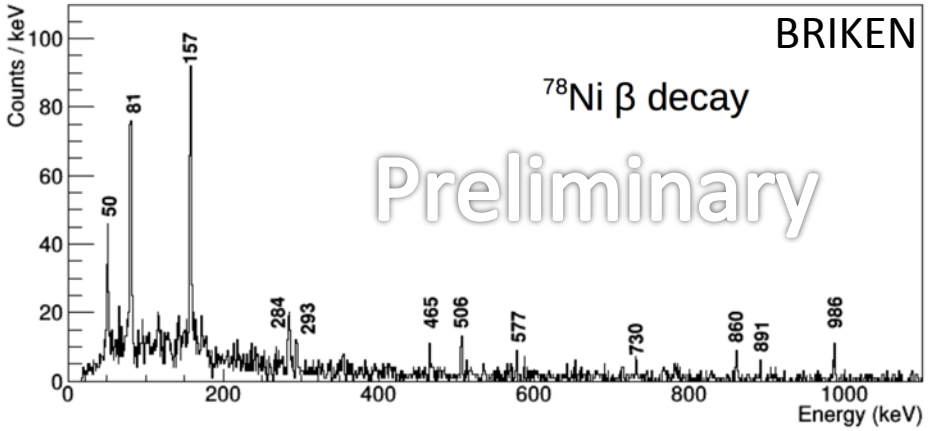
FRIB Day One Fast Beam Rates

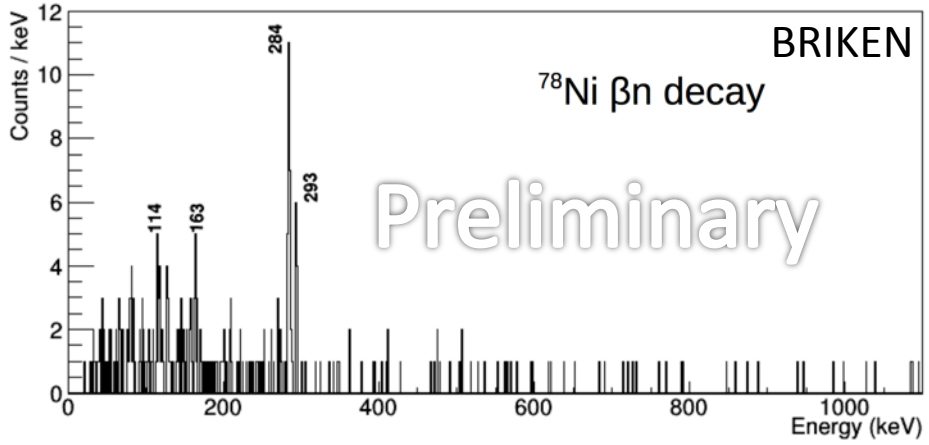
Year One Fast Beam Production Rates (in pps)



Lots of Total Absorption Measurement Possibilities!

Possible Day 1 MTAS Experiments





Total Absorption Spectroscopy of ^{78}Ni

$T_{1/2}$: 122(5)ms

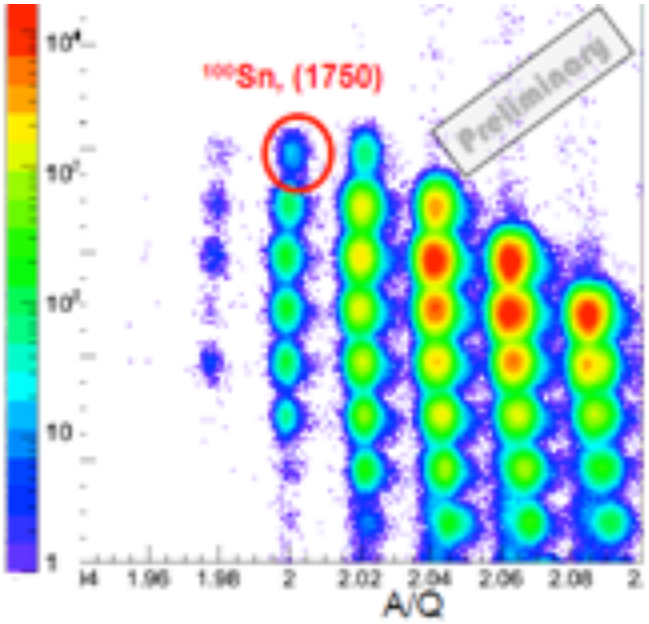
P_n: ~30%

(B)RIKEN: ~65k Events in 10 days
FRIB fast day one production rates:
0.4 pps (~100k in 3 days)

True β-decay feeding pattern informs overlap between ^{78}Ni and ^{78}Cu

MTAS neutron coincidence window only 500ns compared with 200μsec for ^{3}He tubes, so background rates will be suppressed compared with ^{3}He tubes

Possible Day 1 MTAS Experiments



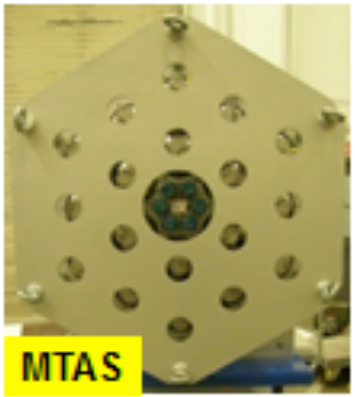
Total Absorption Spectroscopy of ^{100}Sn

$T_{1/2}$: 1.39(11)s

RIKEN: 2525 implants in EURICA
(D. Lubos, NS 2016)

FRIB fast beam day one production rates:
0.2 pps (~50k in 3 days)

GeDSSD offers safety to detect low energy γs/isomers but MTAS can detect down to 50 keV.



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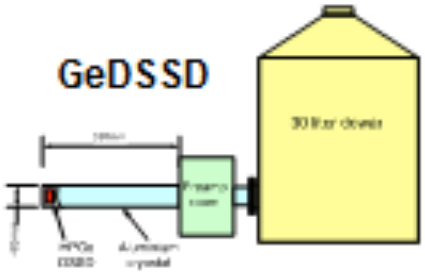

Increase sensitivity to low energy γs
Theory: 7+ ^{100}In ground state
So likely little β feeding to ground and low lying high spin states and likely multi-γ decay paths from GT fed levels

In addition to improved implant rates, MTAS is a big increase in efficiency over EURICA

MTAS is a Versatile Detector

For neutron rich nuclei βs, γs, and neutrons will be present in almost every decay

MTAS can measure them all

Measuring all three with one detector in one experiment is ideal to characterize exotic nuclei

MTAS is a unique and powerful detector that is capable of measuring all three expected particle types which leads to complete beta strength measurements*

*B.C. Rasco, PRC **95**, 054328 (2017)

Ongoing Developments

Segmented Center Module (Warsaw Funding)

Implantation DSSD Stack

(Matching FRIB ^{3}He Array Brewer talk)

Thank you