GRETINA: status and future plans

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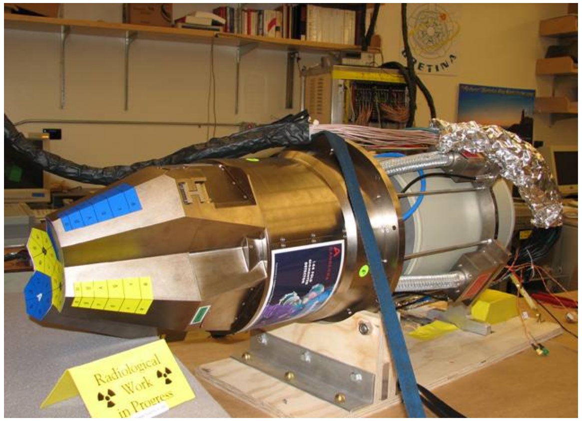
Lawrence Berkeley National Laboratory

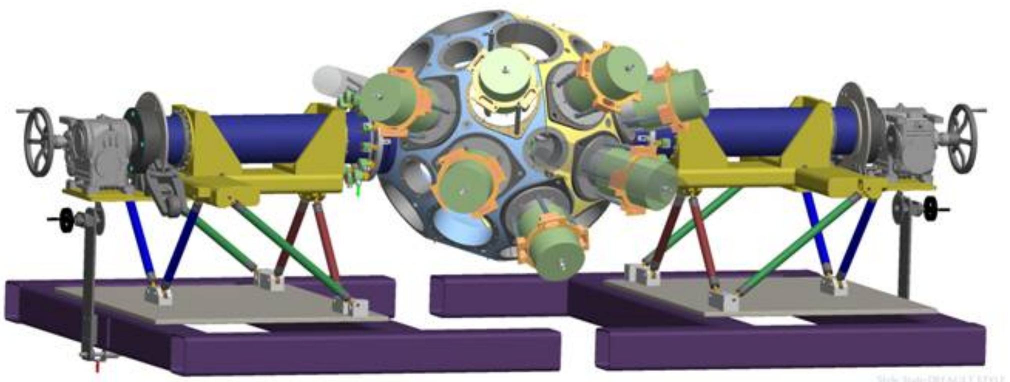
Nuclear Structure Physics with Advanced Gamma–Detector Arrays (NSP13)

10-12 June 2013 Palazzo del Bo', Padova, Italy

GRETINA

- Array covers ¼ of 4π solid angle (ε =7.5%)
- 28 36-fold segmented Ge crystals
- Mechanical support structure
- Data acquisition system:1120 digitizers
- Data processing system: 500 cores
- Funded by US DOE NP $20M





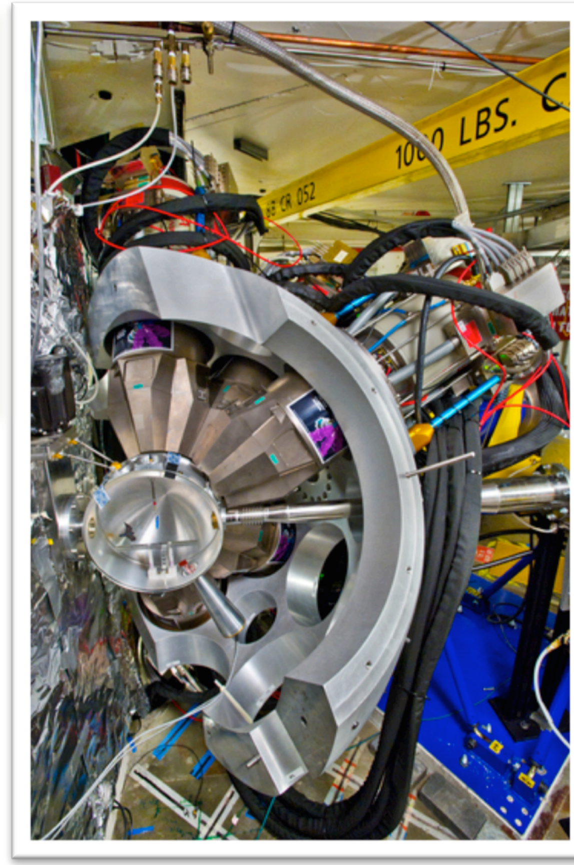
GRETINA Schedule

- Start Construction June 2005
- Start of Operation April 2011
- Engineering & commissioning at LBNL - March 2012
- Operation at NSCL/MSU July 2012 – July 2013
- Operation at ATLAS/ANL

GRETINA, was built and commissioned at LBNL.

Engineering runs **tested, characterized, and debugged** the array, showing success of decomposition and tracking.

The device was **further tested, debugged and commissioned** in a campaign at the Berkeley Gas-Filled Separator, to study the heaviest elements.



GRETINA at BGS

GRETINA commissioning results

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The performance of the Gamma-Ray Energy Tracking In-beam Nuclear Array GRETINA

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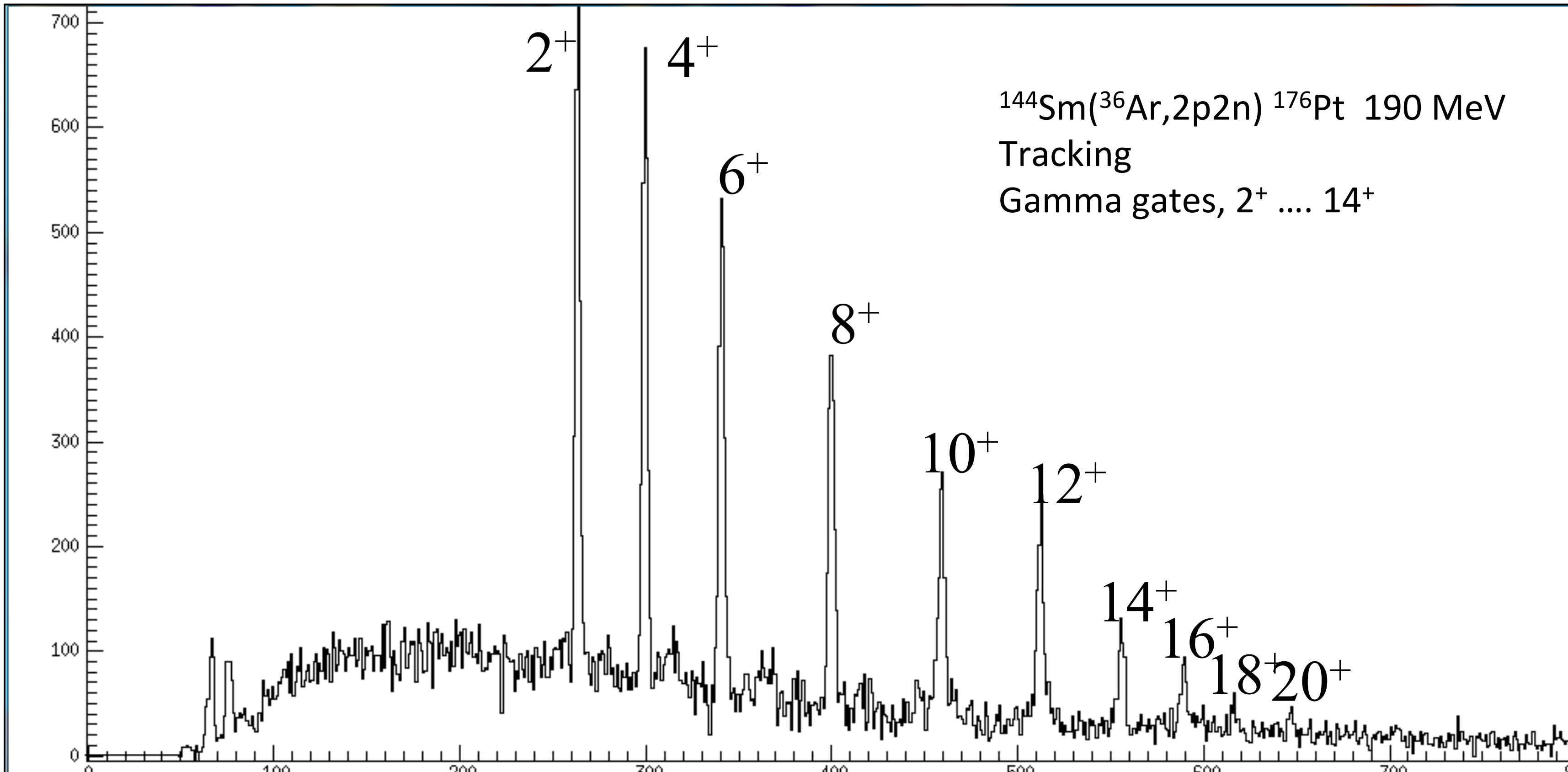
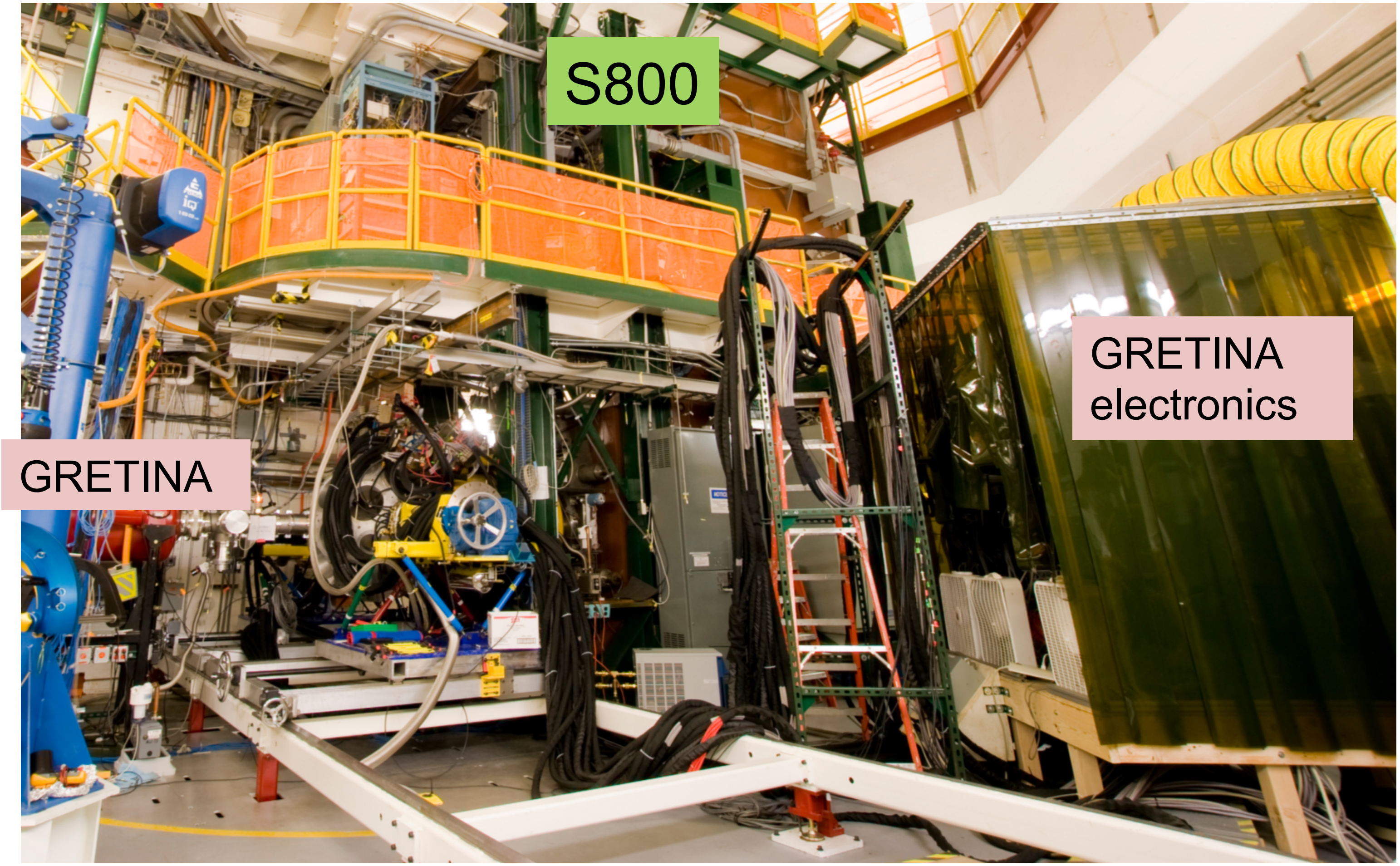
Test experiment at BGS

- GRETINA – BGS coincidence
- Data are acquired using separate systems
- Use time stamps to correlate data



GRETINA at NSCL MSU

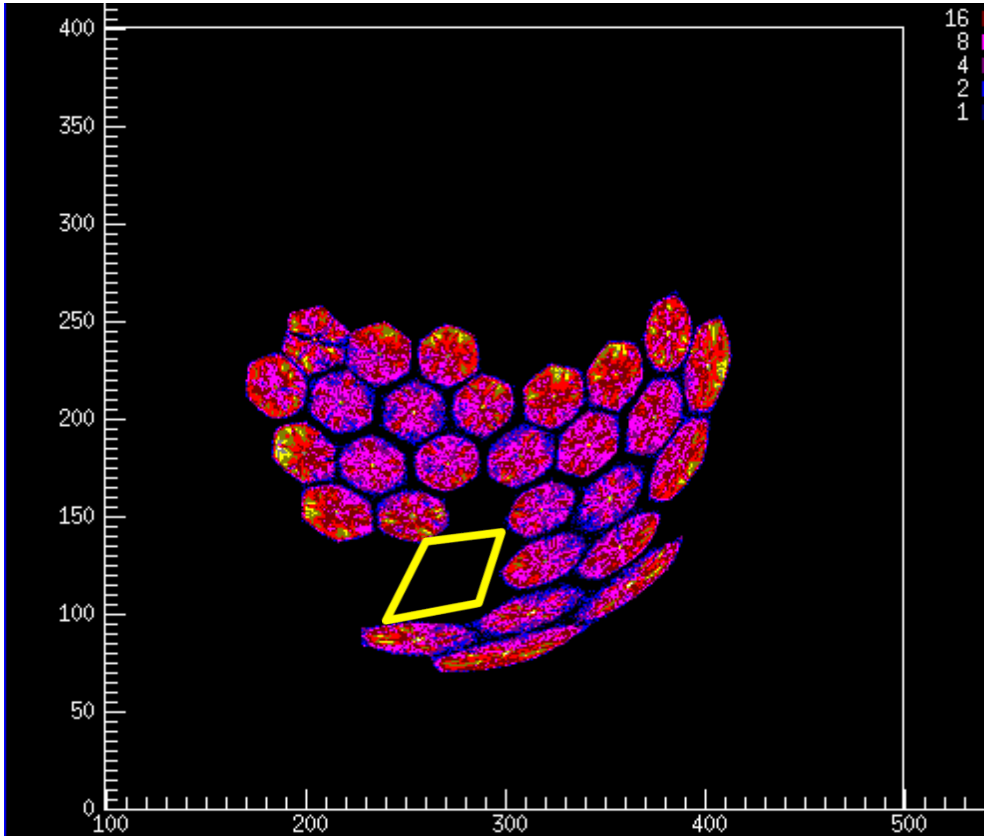
- GRETINA at target position of S800 spectrograph
- Operating from July 2012 to July 2013



Source measurements at NSCL

- Efficiency
- Peak-to-total
- Tracking efficiency
- Efficiency vs. P/T trade-off
- Time resolution

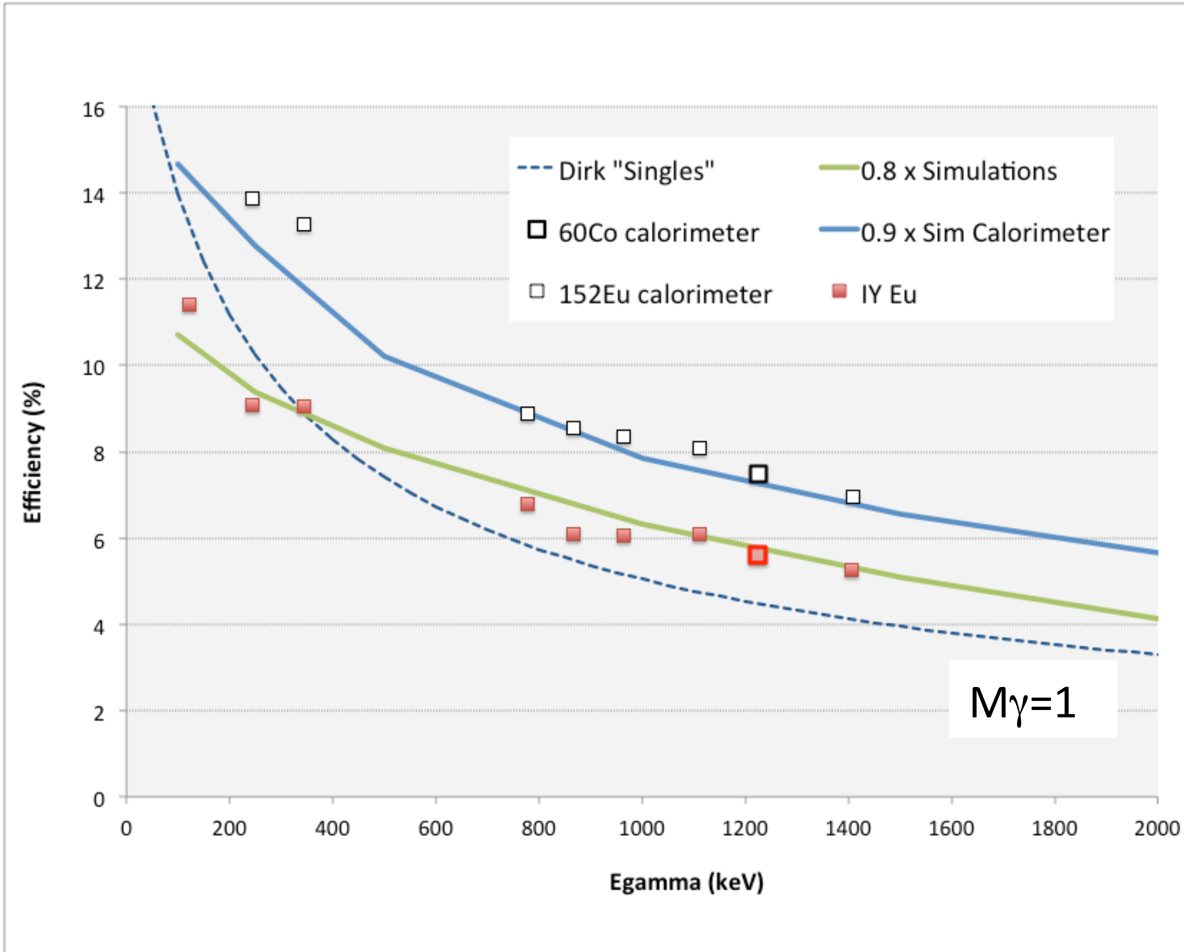
^{60}Co, ^{152}Eu, ^{133}Ba etc..



- Distribution of interaction points determined by signal decomposition
- In a compact configuration

Efficiency

Measured efficiency is lower than simulation value



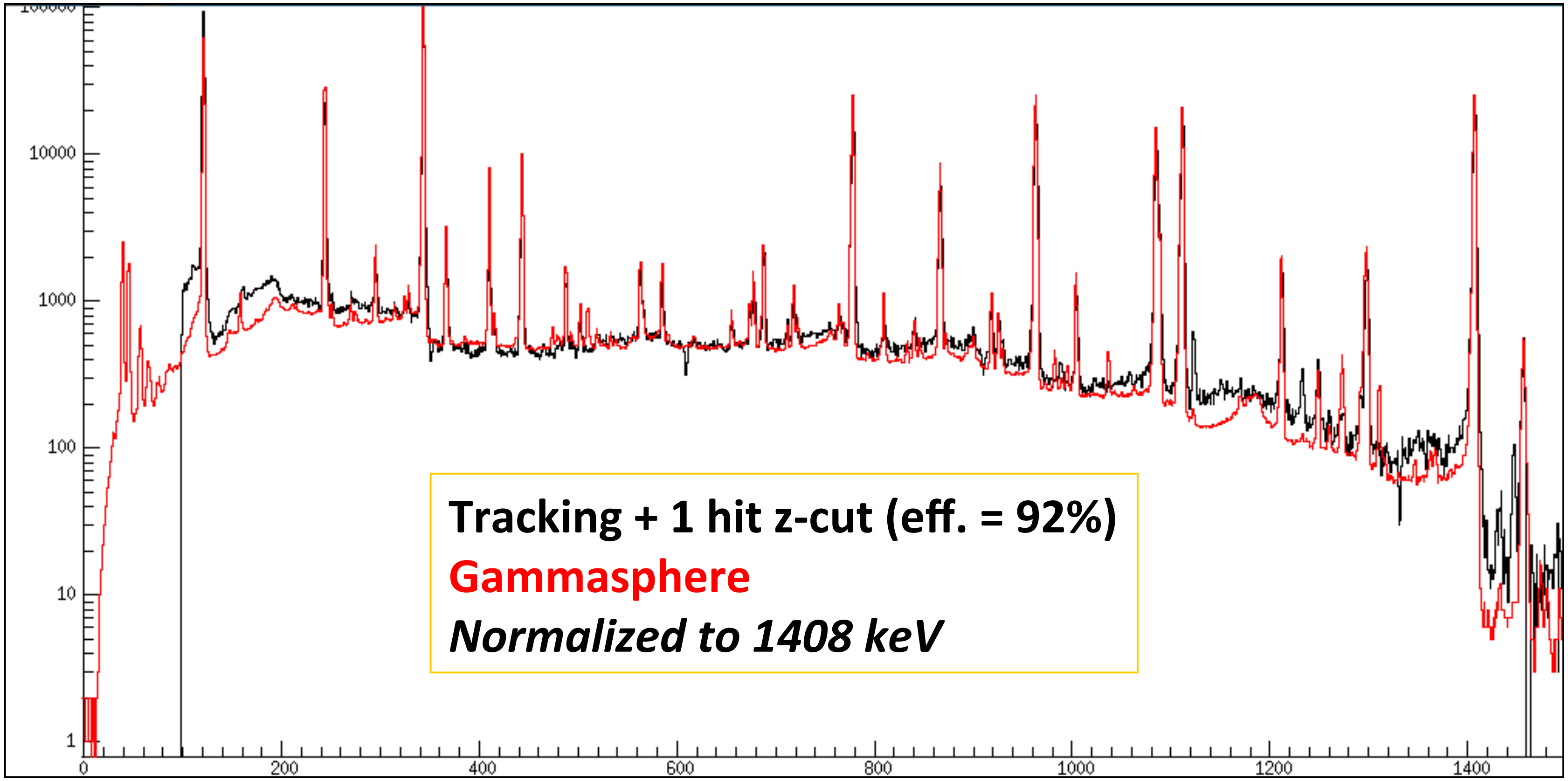
0.85 FOM Cut and 1-hit with z-dependence selection

P/T ^{60}Co source

Singles	0.22
Clustered	0.40
Tracking no Single-hits	0.54
Tracking with Single-hits	0.49

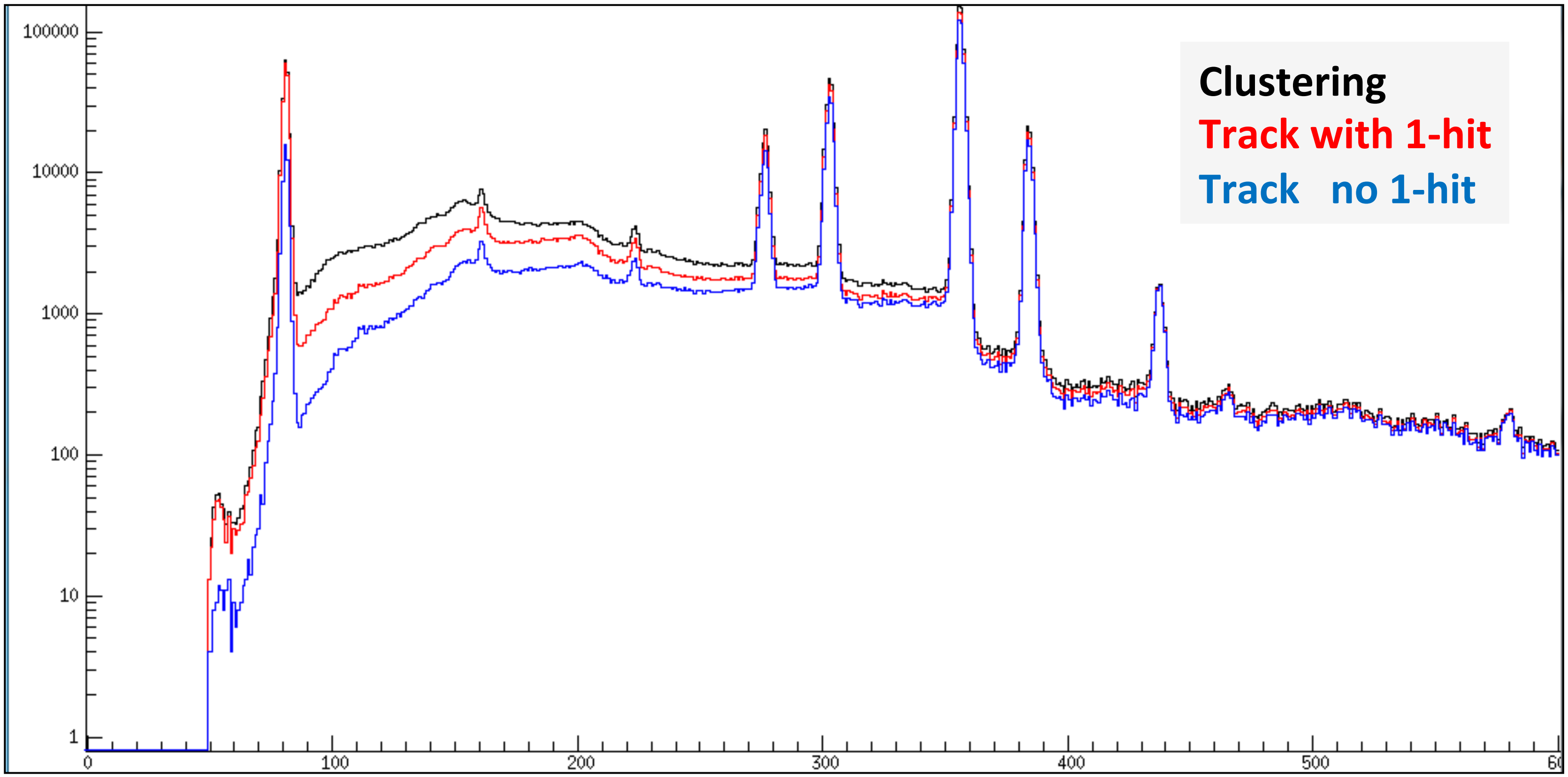
^{152}Eu GRETINA vs. Gammasphere

P/T similar to that of Gammasphere



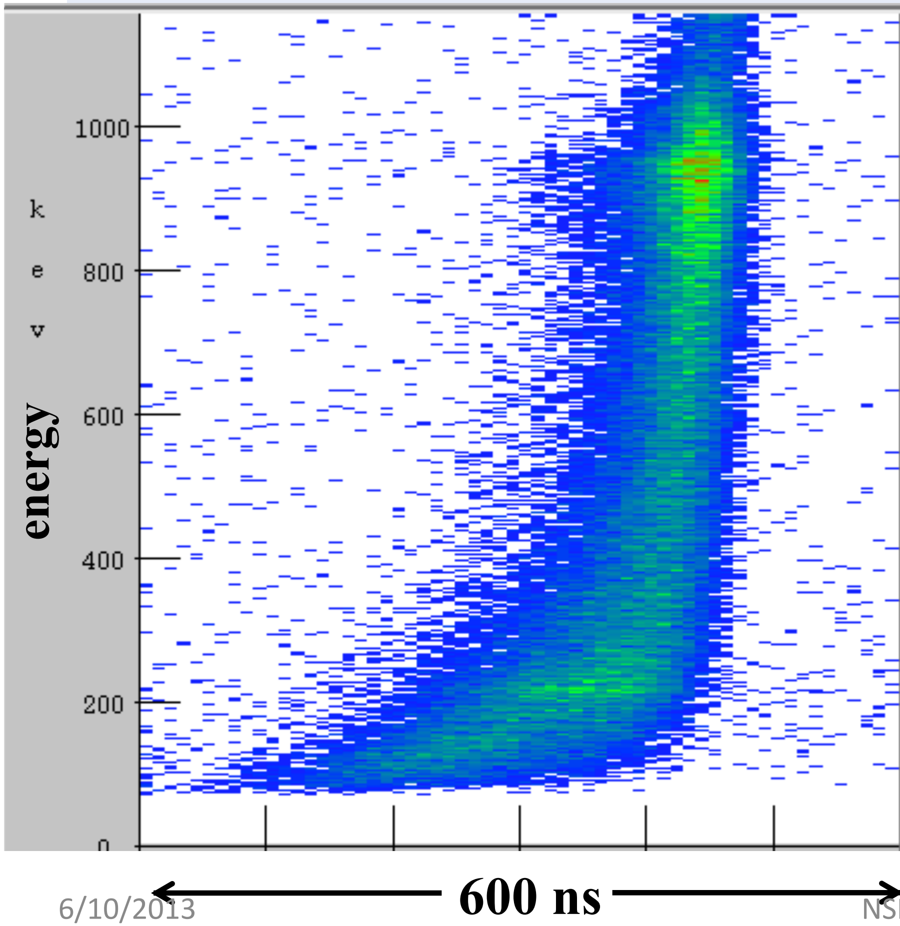
Effect of single hit events: ^{133}Ba

- Improvement of spectral quality with tracking
- Tracking requires 2 or more interaction points
- Adding back 1-hit events depending on depth of interaction

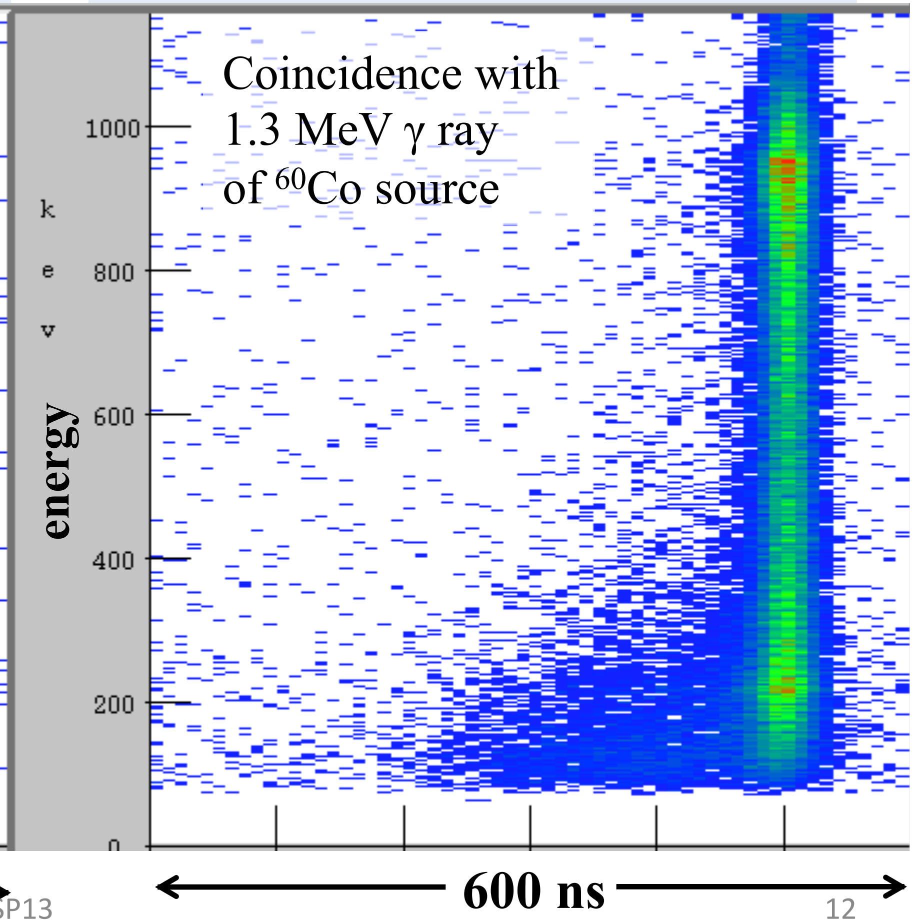


GRETINA time resolution

GRETINA leading edge timing
This timing quality is available as prompt signal (~200 ns latency) for a trigger logic.



GRETINA 't0' timing:
This timing quality is available after decomposition, i.e. in the data analysis.



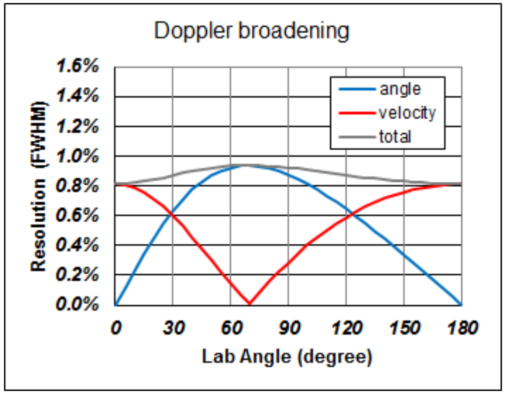
GRETINA + S800 at NSCL

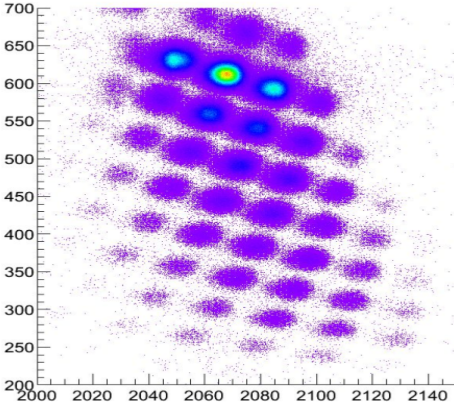
NSCL produces radioactive beams from fragmentation reactions
With velocity V/c ~ 0.35

GRETINA provides:
High efficiency
→ Use lower beam and γ-γ
Position resolution
→ Better Doppler correction
Tracking → Background reduction

S800 provides:
Identification of product (A, Z)
→ Clean spectra for each isotope
Momentum of products
→ Doppler correction

$v/C = 0.35$
$\Delta\theta = 1.4^\circ$
$\Delta\beta/\beta = 0.02$





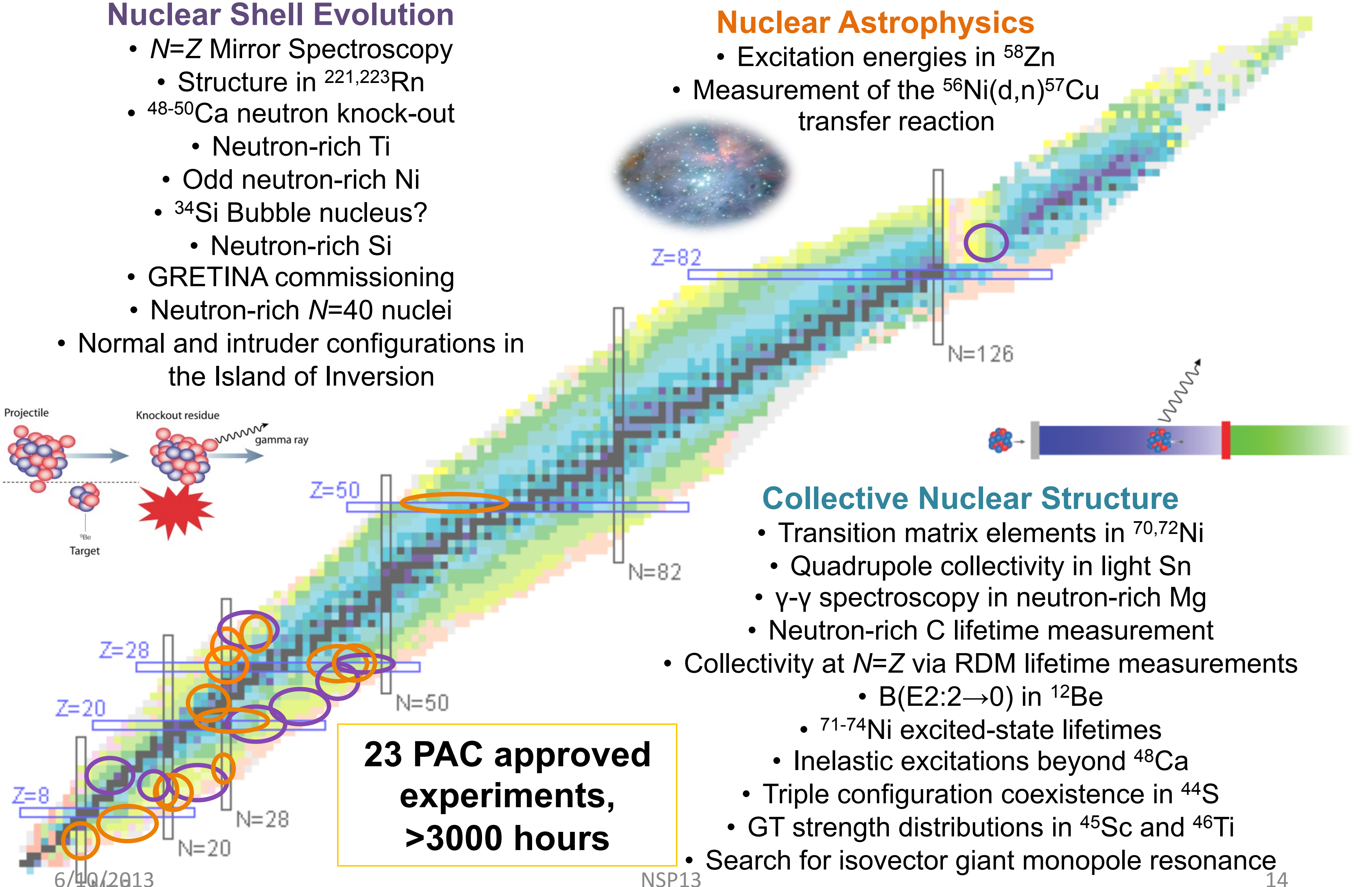
Experiments at NSCL

Nuclear Shell Evolution

- *N*=*Z* Mirror Spectroscopy
- Structure in ^{221,223}Rn
- $^{48\text{-}50}$Ca neutron knock-out
- Neutron-rich Ti
- Odd neutron-rich Ni
- ^{34}Si Bubble nucleus?
- Neutron-rich Si
- GRETINA commissioning
- Neutron-rich *N*=40 nuclei
- Normal and intruder configurations in the Island of Inversion

Nuclear Astrophysics

- Excitation energies in ^{58}Zn
- Measurement of the ^{56}Ni(d,n)^{57}Cu transfer reaction



Collective Nuclear Structure

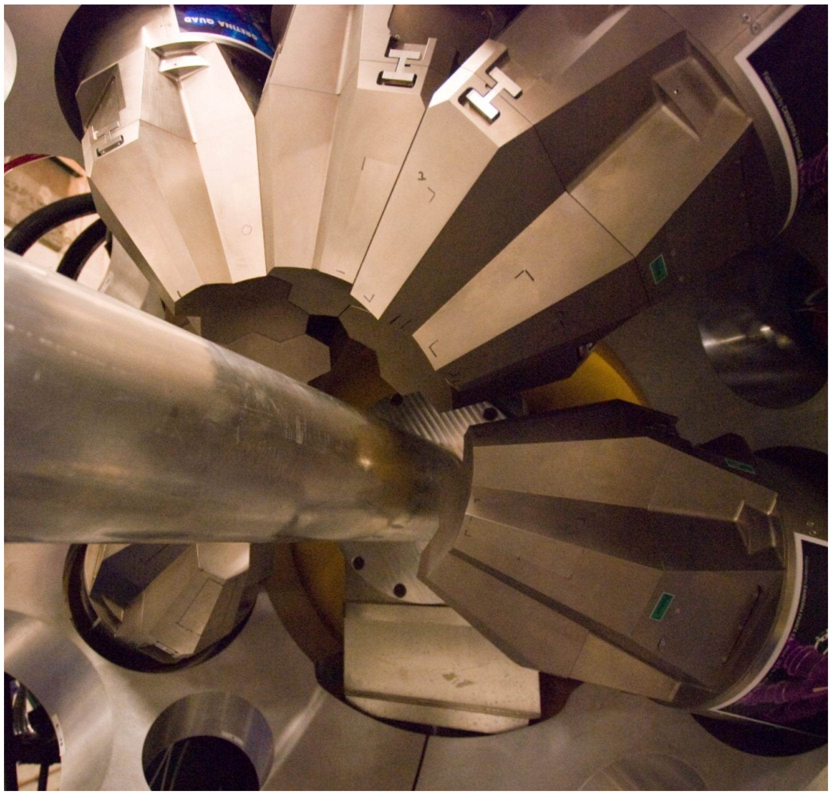
- Transition matrix elements in ^{70,72}Ni
- Quadrupole collectivity in light Sn
- γ-γ spectroscopy in neutron-rich Mg
- Neutron-rich C lifetime measurement
- Collectivity at *N*=*Z* via RDM lifetime measurements
- B(E2:2→0) in ^{12}Be
- $^{71\text{-}74}$Ni excited-state lifetimes
- Inelastic excitations beyond ^{48}Ca
- Triple configuration coexistence in ^{44}S
- GT strength distributions in ^{45}Sc and ^{46}Ti
- Search for isovector giant monopole resonance

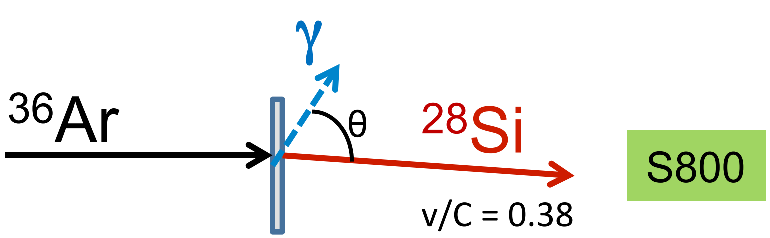
23 PAC approved experiments, >3000 hours

Commissioning experiment

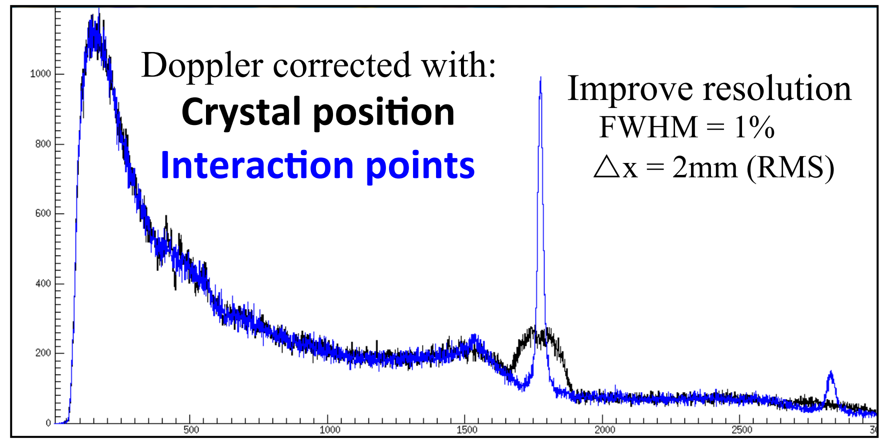
E11007 – D. Weisshaar *et al.*

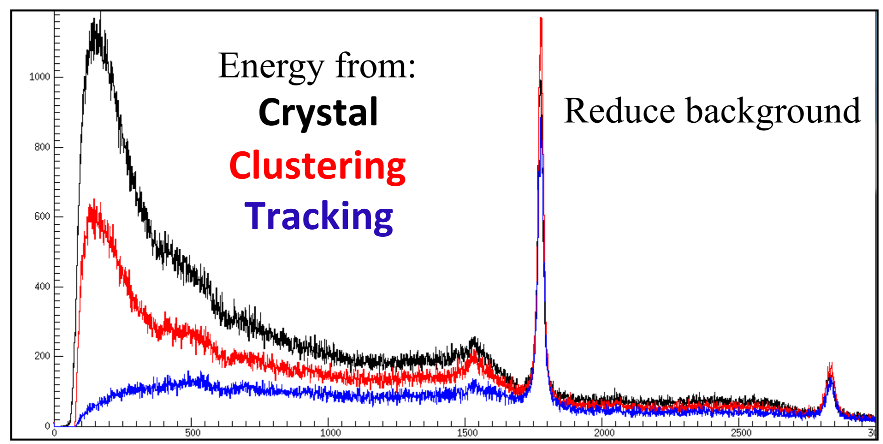
^{28}Si from ^{36}Ar fragmentation





Advantages of tracking array
- Improve Doppler correction
- Background reduction





Mirror Spectroscopy in the fp Shell

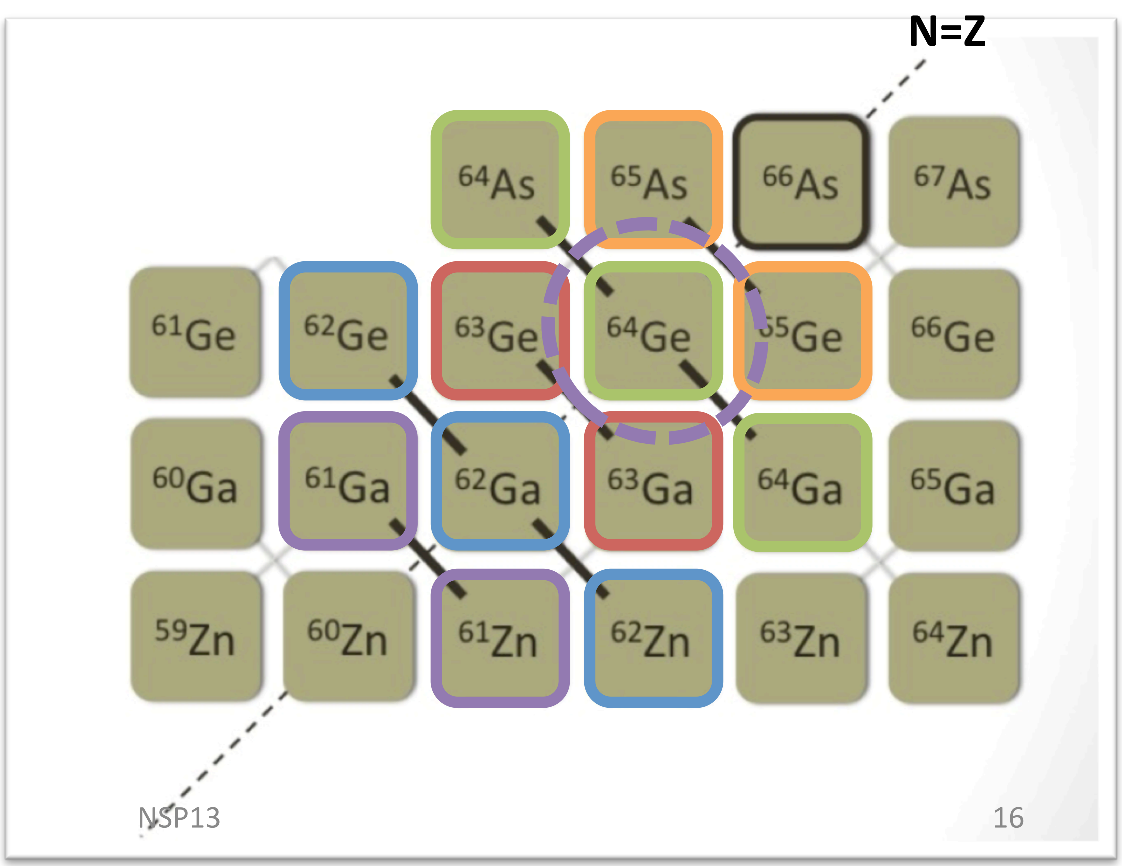
E11025 – M. Bentley, T. Henry, R. Clark et al.,

Through the 0$f_{7/2}$ shell there is relatively complete data, and some understanding of origin of isospin breaking terms, i.e. the J=2 anomaly.

Above *A*=60, only sporadic data exists – GRETINA + S800 offers unique capability to observe and understand **complex level schemes** to understand isospin breaking in this valence space, beyond the 0$f_{7/2}$ shell.

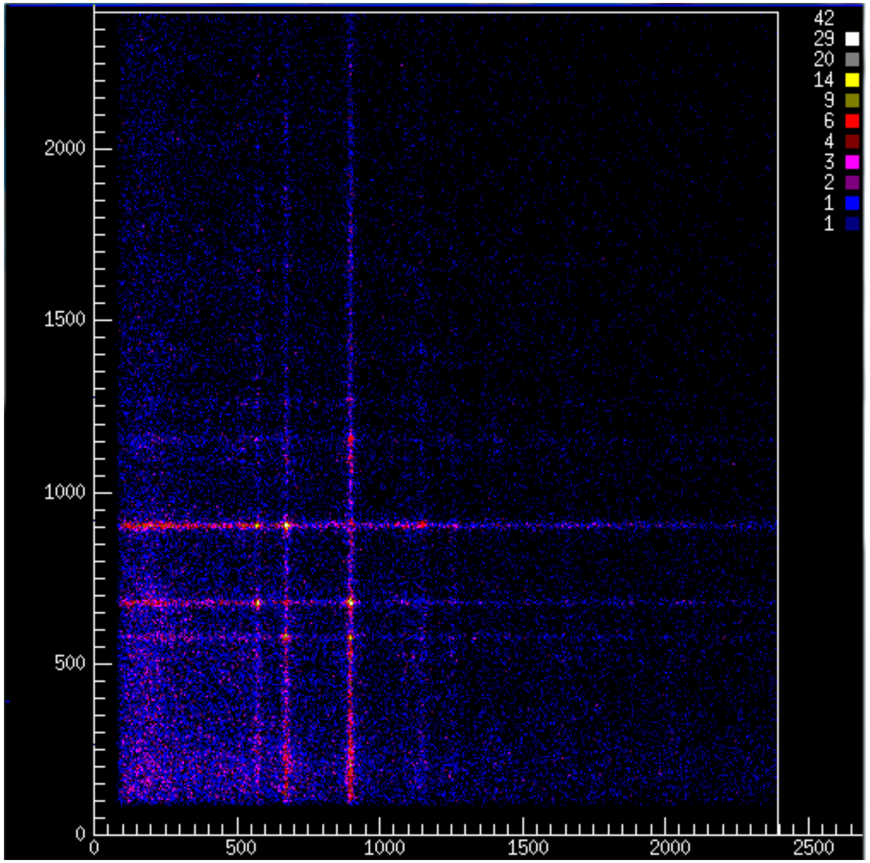
A=61 T=1/2 mirror pair
A=62 T=1 triplet
A=63 T=1/2 mirror pair
A=64 T=1 triplet
A=65 T=1/2 mirror pair

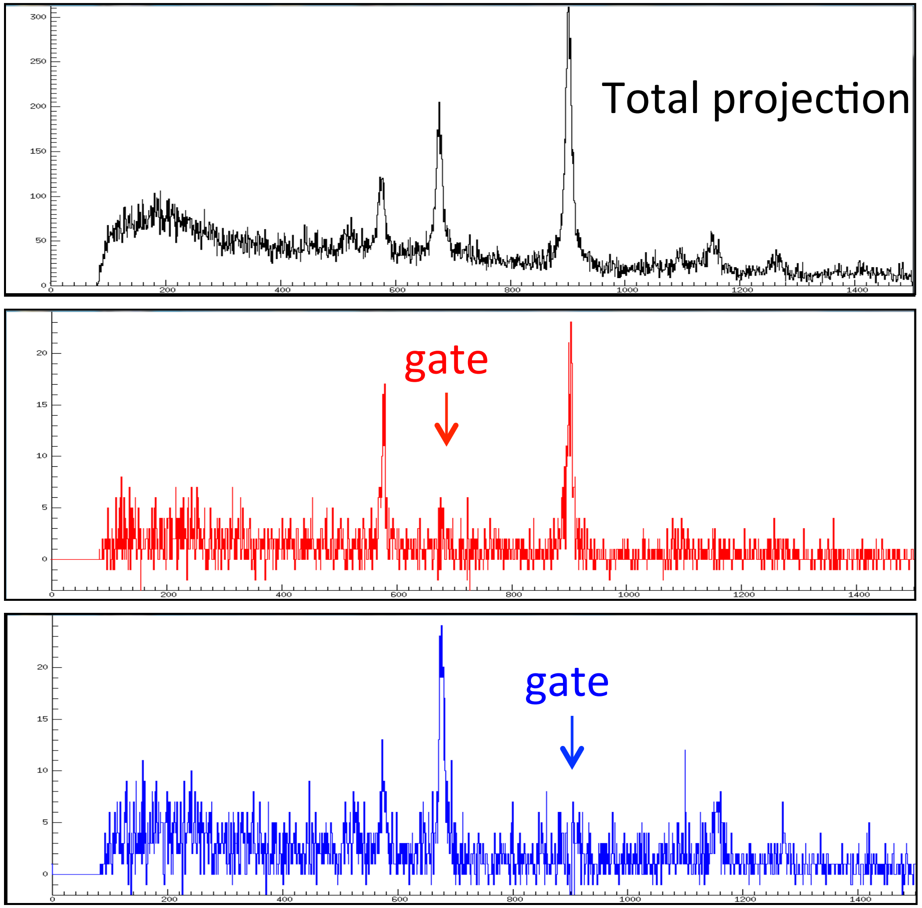
Mirror, mirror on the wall…



Gamma-Ray Tracking in ^{64}Ge

- ^{64}Ge populated following knockout from ^{65}Ge

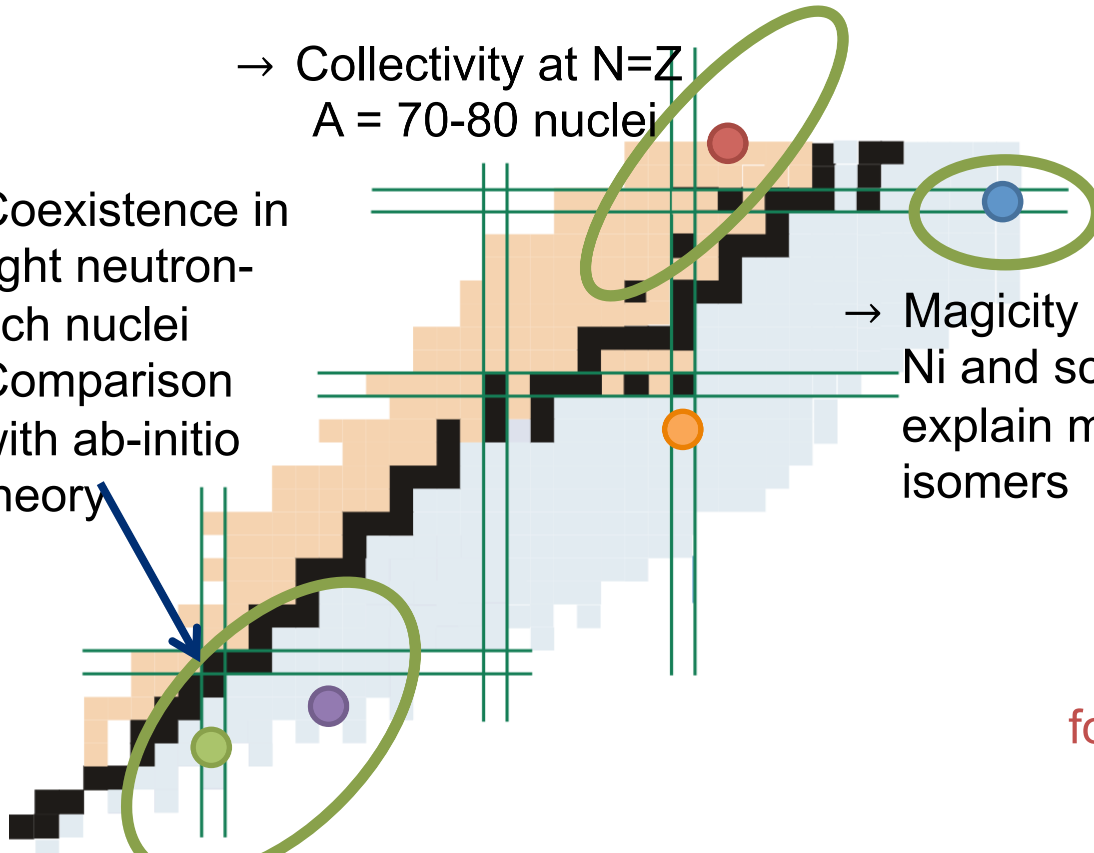




Reduce background by tracking allows, for the first time, the **spectra from fast beams** to have the spectral quality **comparable to that from anti-Compton arrays**.

Structure Across the Chart: Lifetimes

- E12009: D. Miller *et al*., **Direct lifetime measurements of excited states in $^{71-74}$Ni**
- E11013: H. Iwasaki *et al*., **Collectivity at the *N*=*Z* line and a novel plunger method**
- E12021: E. McCutchan *et al*., **Precise measurement of the B(E2: 2+ → 0+) in ^{12}Be**
- E12015: H. Iwasaki *et al*., **Coexistence in exotic C isotopes**
- E11031: I. Wiedenhoever *et al*., **Triple configuration coexistence in ^{44}S**

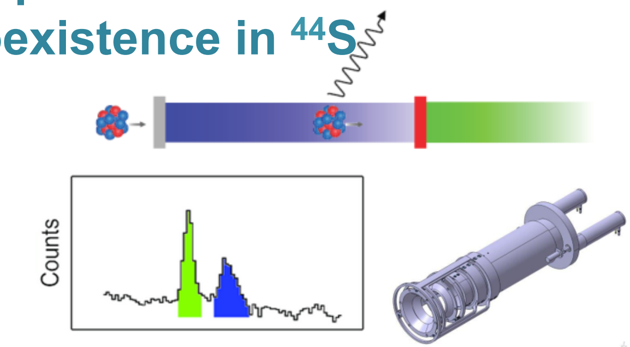


→ Collectivity at N=Z
A = 70-80 nuclei

→ Coexistence in light neutron-rich nuclei

→ Comparison with ab-initio theory

→ Magicity in n-rich Ni and scenario to explain missing 8^{+} isomers

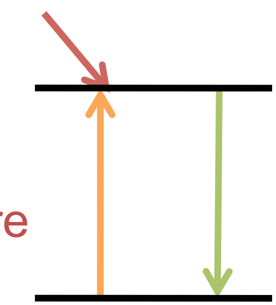


Plunger

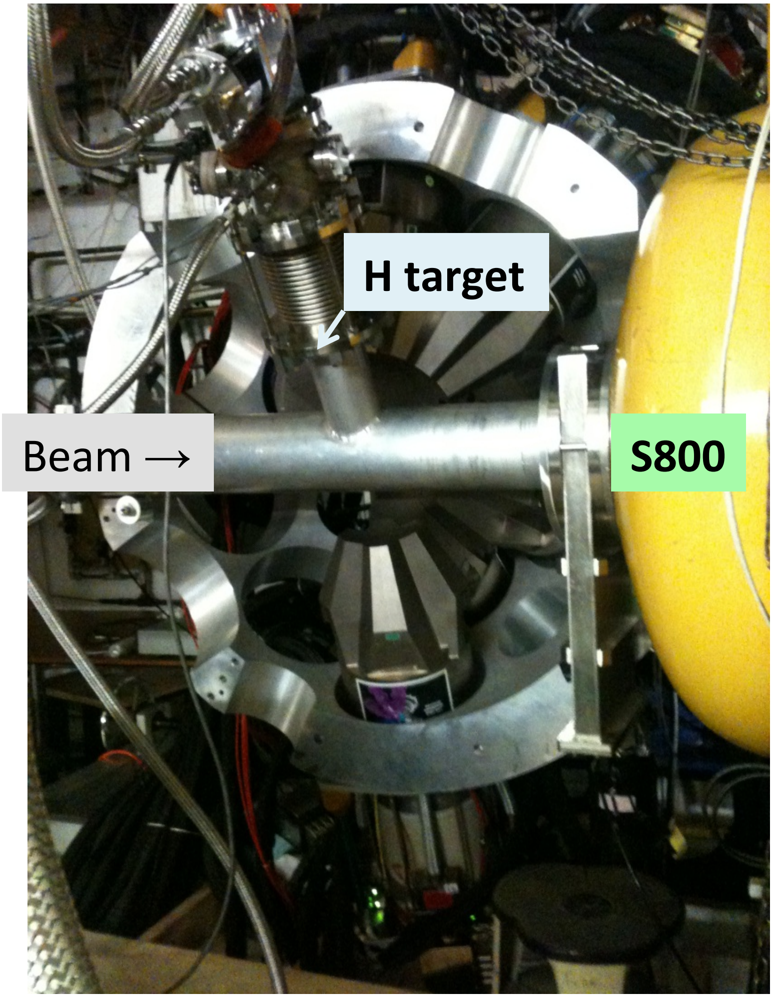
a **model-independent** method

Lifetimes

a sensitive probe for nuclear structure … B(E2), B(M1)



Experiments using liquid hydrogen target



11035— C. Campbell,
Anomalous quadrupole collectivity in light Sn isotopes

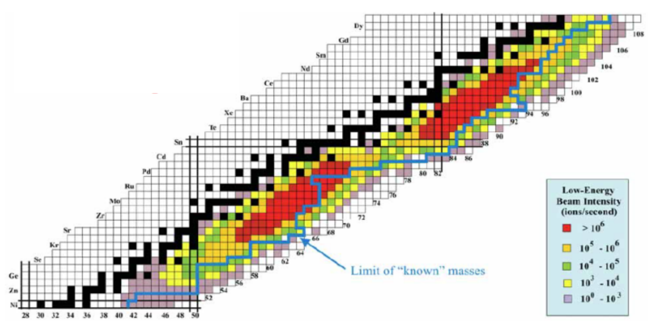
12016— G. de Angelis,
Proton Inelastic Scattering in ^{70,72}Ni: Proton and Neutron Transition Matrix Elements in the Neutron-rich Ni Isotopes

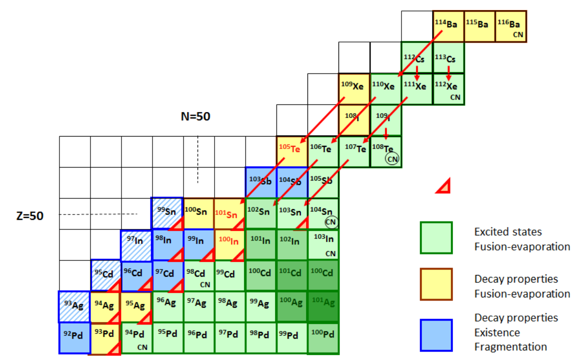
11037— L. Riley,
Inelastic Excitations Beyond ^{48}Ca

Future plans

- ATLAS Campaign: Fall 2013 – 2014.
  - Neutron-rich nuclei – CARIBU beams

    225 radioactive beams are expected with intensity > 10^4 /sec
  - Structure of nuclei in the ^{100}Sn region
  - (Super) heavy nuclei.





- Second NSCL Campaign: 2015 - …(proposed and endorsed)

ATLAS Campaign, Fall 2013

Workshop on Future GRETINA Science Campaigns – March 2, 2013

https://www.phy.anl.gov/atlas/GretinaWorkshop/index.html

Stand alone and at FMA - CARIBU Beams

- Efficiency ~ 1/2 of Gammasphere, comparable P/T
  ~ 3/4 in Calorimeter mode
- Position Resolution ~ 2-3 x better than Gammasphere
- Better response for high-energy gammas (>3MeV)
- Polarization sensitivity : Expect Q ~ 0.3 (AGATA)
- Compactness, optimum position for FMA experiments.
- Suite of Auxiliary Devices: CHICO2, Phoswich Wall, ORRUBA, ….

Outstanding issues

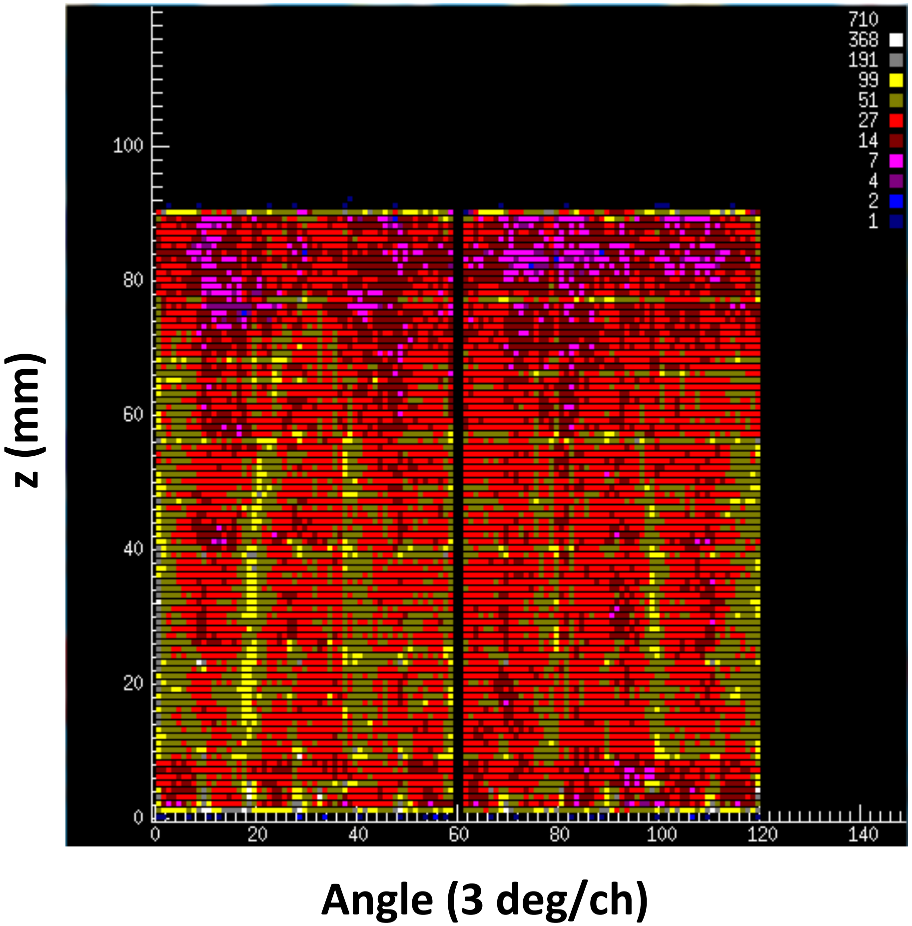
Position resolution:

- Non-uniform interaction point distributions
- Bi-furcation: 1 interaction → 2 interactions

➔ <u>Basis fidelity:</u>

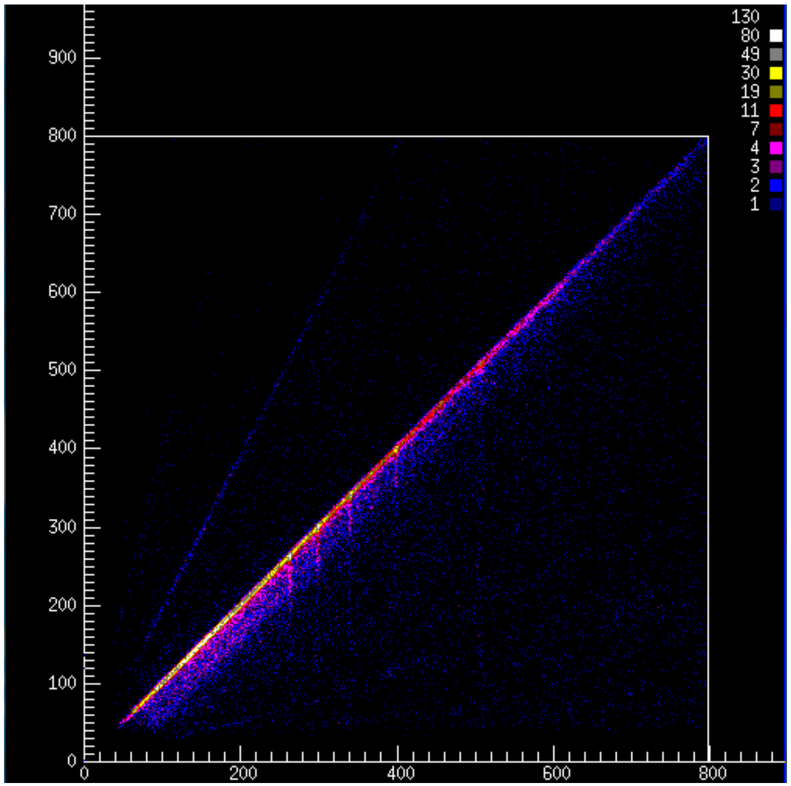
— Field, weighting potentials, drift velocity

— **<u>Electronic response corrections : rise time, cross talk etc.</u>**



Outstanding issues

E - sum of segments



E - central contact

High-Rate performance:

- Goal of 50kHz per detector has not been achieved
- Segment Sums do not recover expected resolution
- Segment Sums do not recover full energy

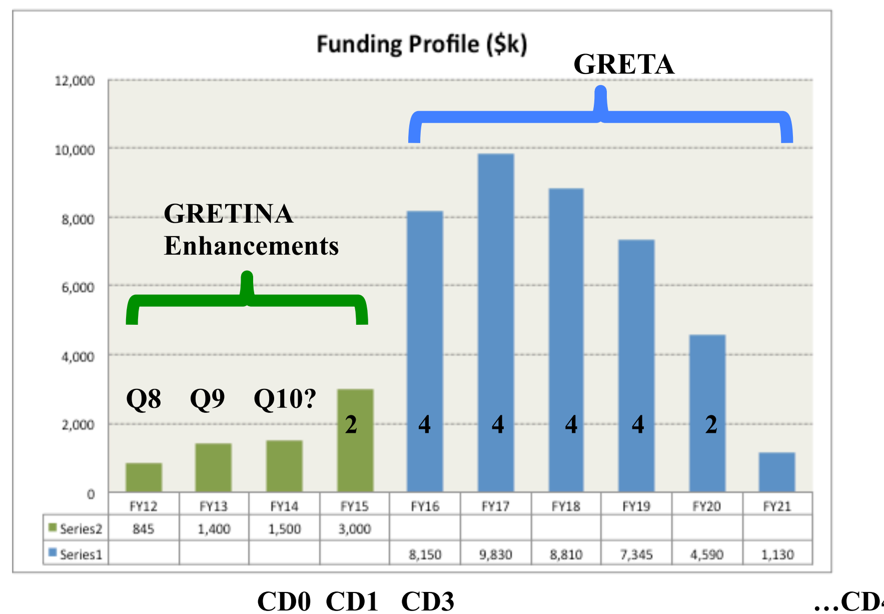
— Several factors seem to contribute

— A priority to take full advantage of GRETINA+FMA

Plan for GRETA

- Goal: Complete full 4π coverage
  - Unique instrument at FRIB for both fast and slow beams
  - Strong community support (DOE/NSF long range plan, FRIB Scientific Advisory Committee)

- A plan has been developed to complete GRETA for "day one" experiments at FRIB (2021). The completion of GRETA requires 23 additional detector modules together with the associated electronics, computing, and mechanical support.

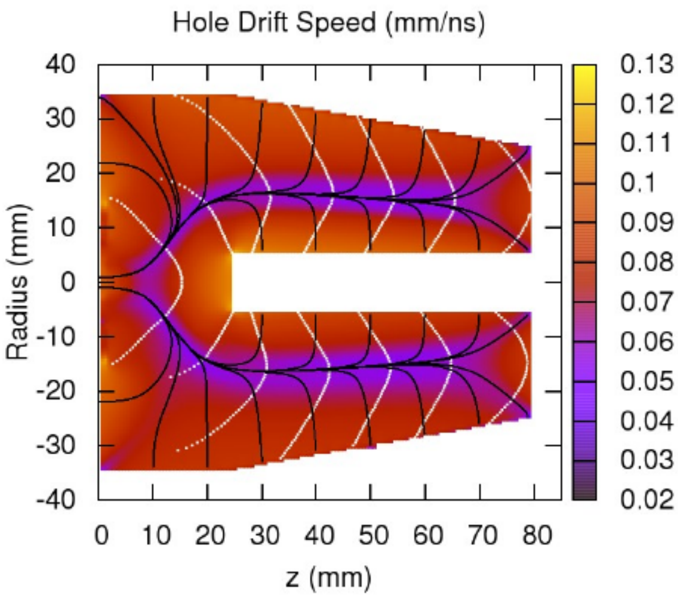


Possible upgrades for GRETA

Take full advantage of technological advances while maintaining compatibility with the present system.

Possible areas are:

- Detector
  - Point contact with new segmentation scheme
- Electronics
  - New preamp and digitizer
  - Minimize the use of cables
- Computing
  - New readout and analysis architecture



D.C. Radford

Summary

- GRETINA is completed, commissioned, and started its physics program.
- Early data of GRETINA at NSCL show outstanding performance, and indications of many new physics results.
- GRETINA will have an ATLAS campaign followed by another NSCL campaign.
- A plan for GRETA, to complete 4π coverage, is in place. A unique instrument for FRIB.

Acknowledgements

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A.O. Macchiavelli, C.M. Campbell, H. Crawford,M. Cromaz,R.M. Clark, P. Fallon, S. Paschalis, M. Petri, J. Rissanen, A. Wiens

NSCL

D. Weisshaar, F. Recchia, A. Gade, H. Iwasaki, C. Langer, F. Montes

GRETINA

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