Transfer Reactions on Unstable Nuclei for Nuclear Science Applications

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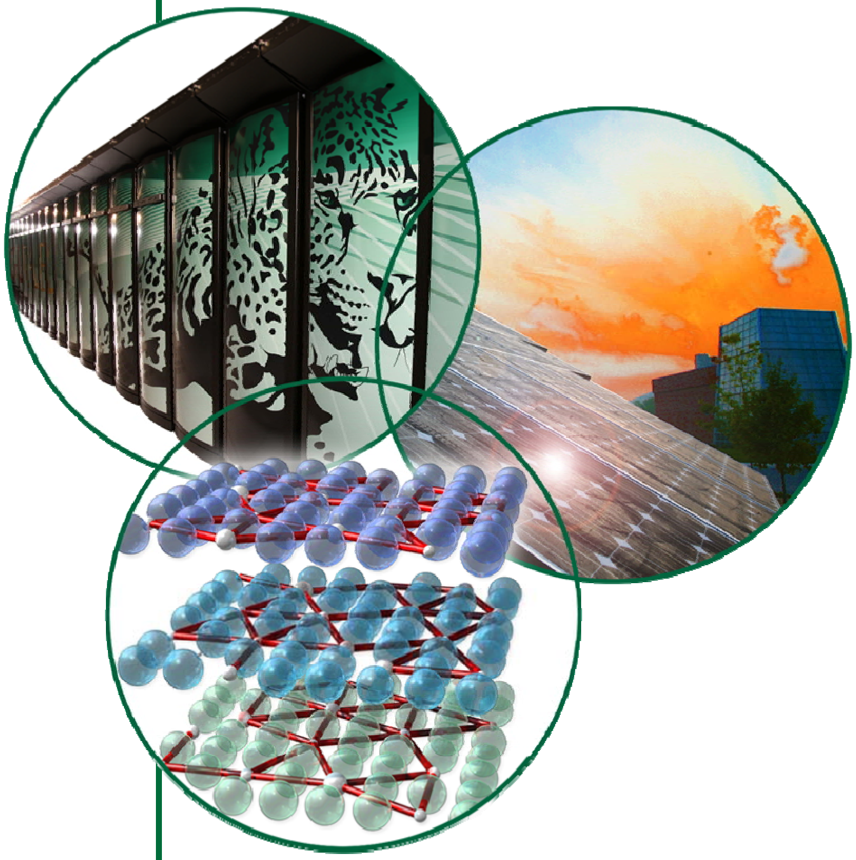


U.S. DEPARTMENT OF ENERGY

OAK RIDGE NATIONAL LABORATORY

MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

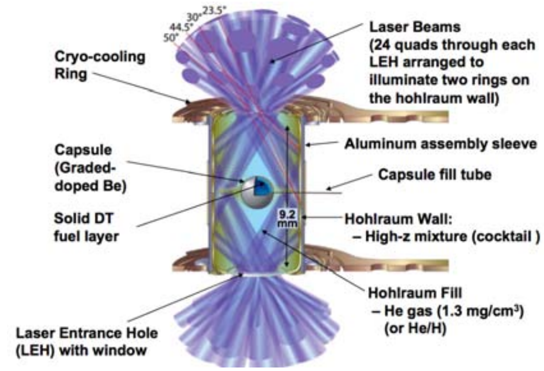
Motivation

- Fully realize nucleon transfer reactions for diagnosing the physics of high-temperature thermonuclear burning.

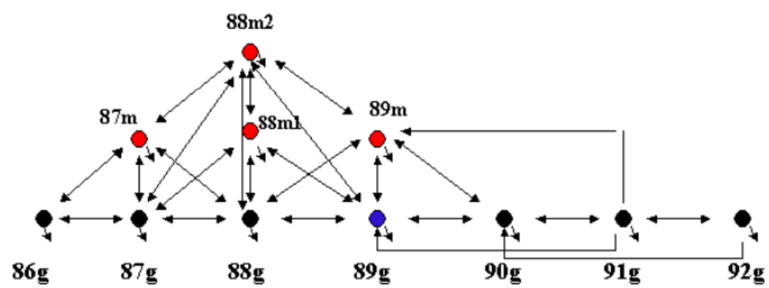
- Provide an empirical foundation for indirect determinations of neutron fluxes in extreme thermonuclear environments including
  - internal confinement fusion capsules,
  - nuclear devices,
  - nuclear reactor fuel rods,
  - and even exploding stars.

- The determination of such fluxes can give invaluable clues to the mechanisms of these extreme events that are so important for the energy independence and security of our Nation.

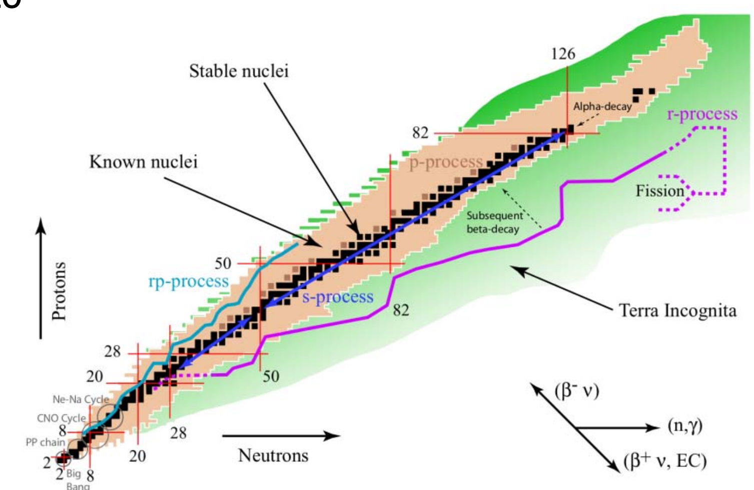
- Need to understand structure and reactions on radioactive neutron-rich nuclei.



Internal Confinement Fusion at NIF showing capsule of doped Be for diagnostics

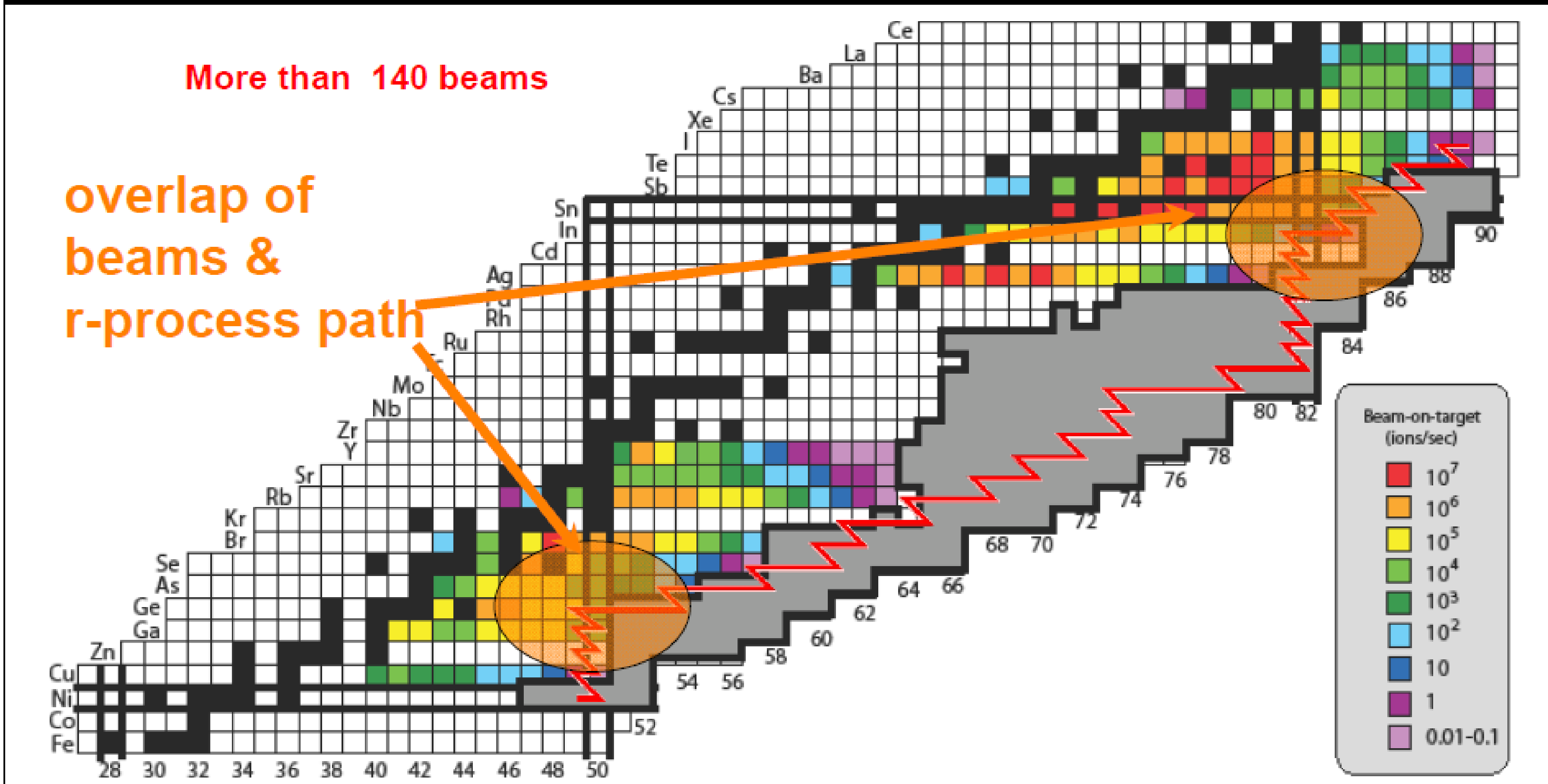


Reaction network of Y isotopes needed for nuclear device diagnostics



Astrophysical reactions

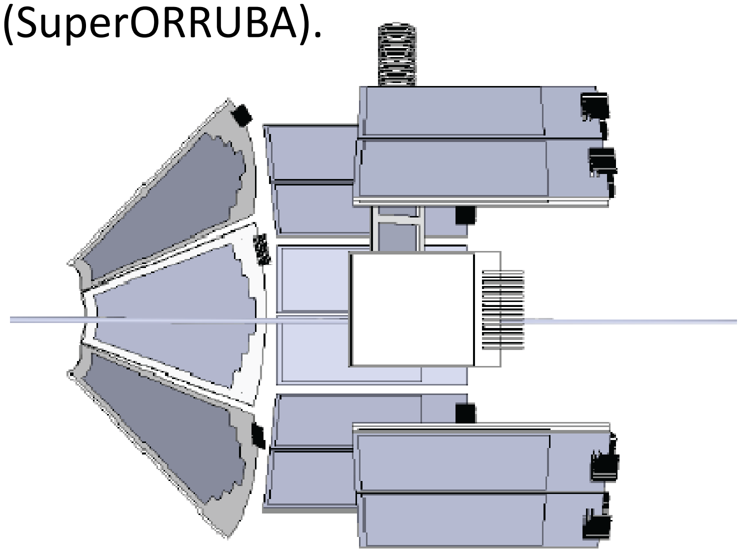
Unique neutron-rich unstable beams for transfer



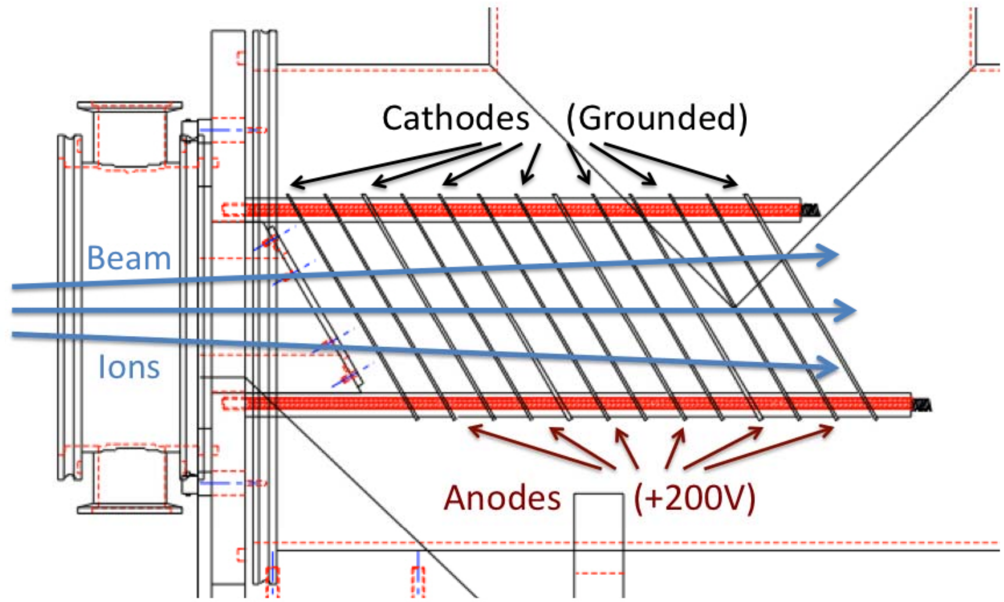
ORNL has capability - **unique in world** - to produce neutron-rich nuclei in or near the r-process path and measure transfer reactions with them

Project included 3 components to greatly improve ability to study single-nucleon (d,p) reactions in inverse kinematics.

(1) A large area barrel array of silicon strip detectors (SuperORRUBA).

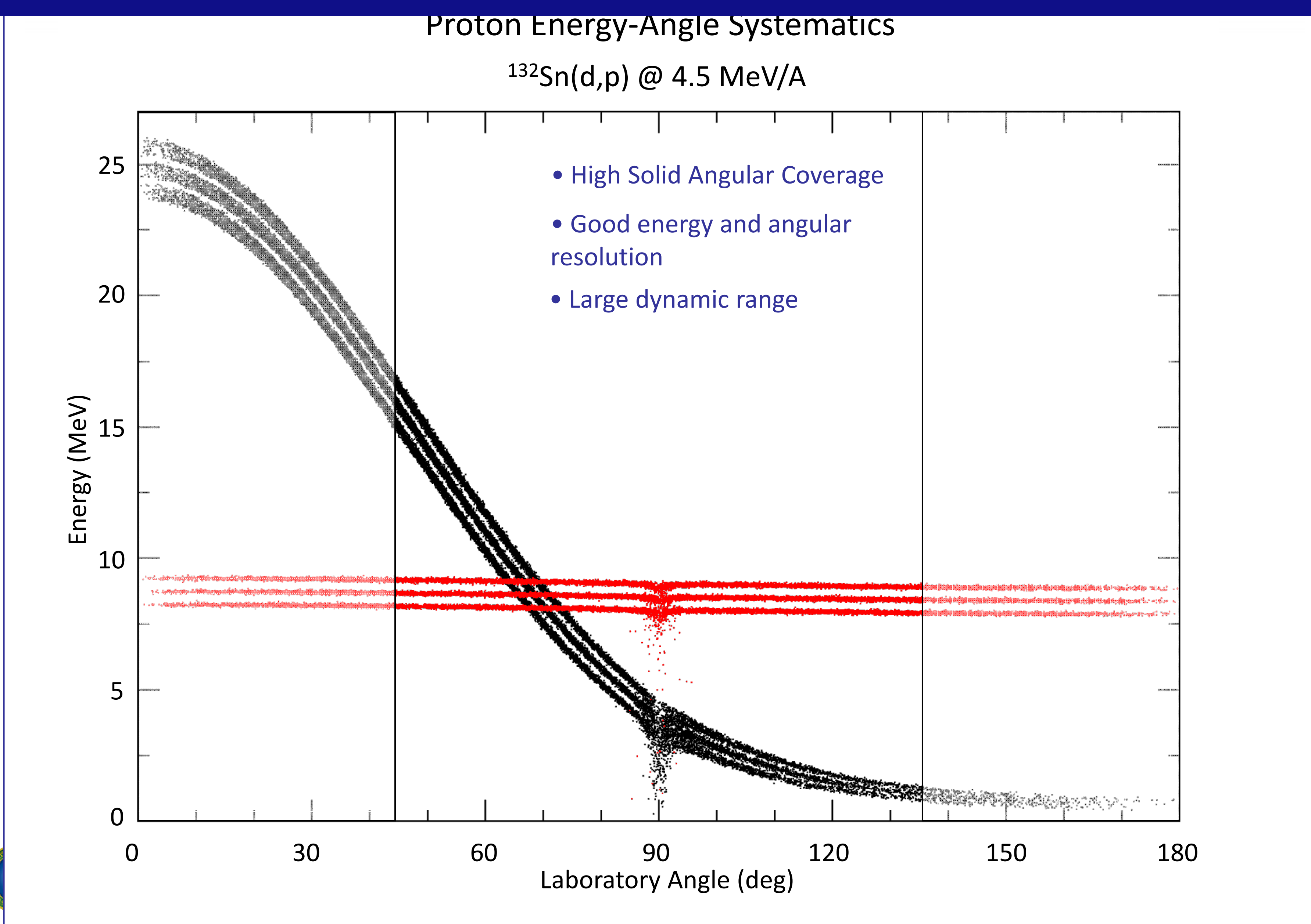


(2) A fast forward-angle ionization chamber for timing and identification of beam like recoils.

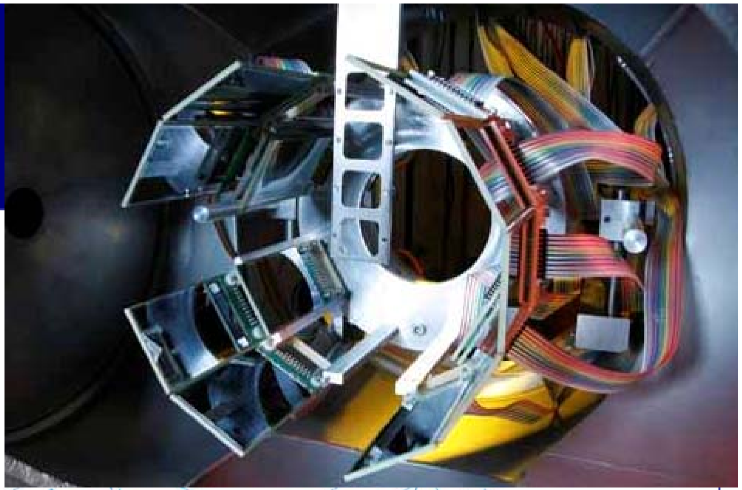


(3) A beam buncher to produce pulsed (~1 ns width) beams at HRIBF.

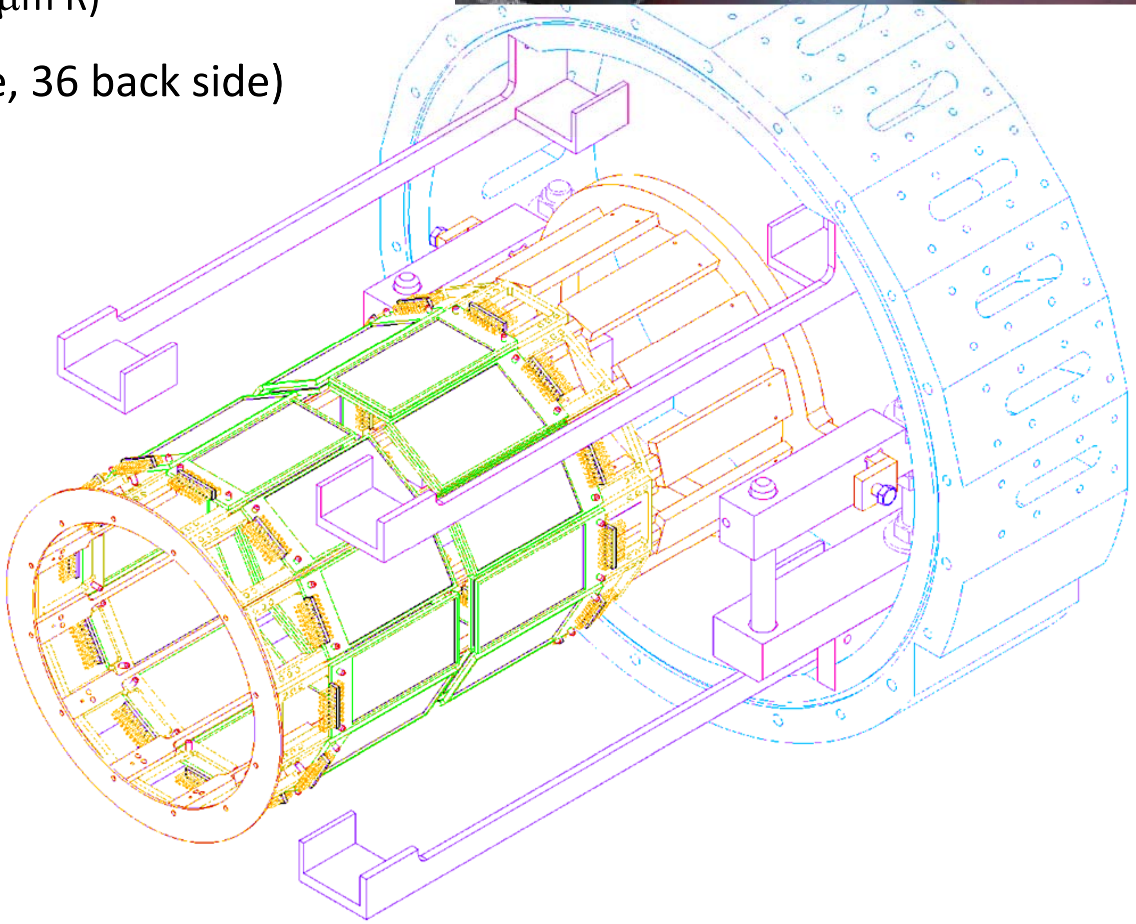
Requirements of the Oak Ridge Rutgers University Barrel Array (ORRUBA)

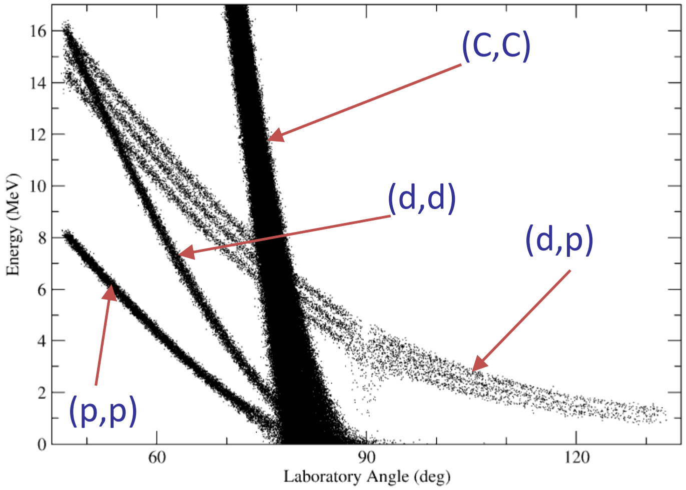


Oak Ridge Rutgers University Barrel Array (ORRUBA)

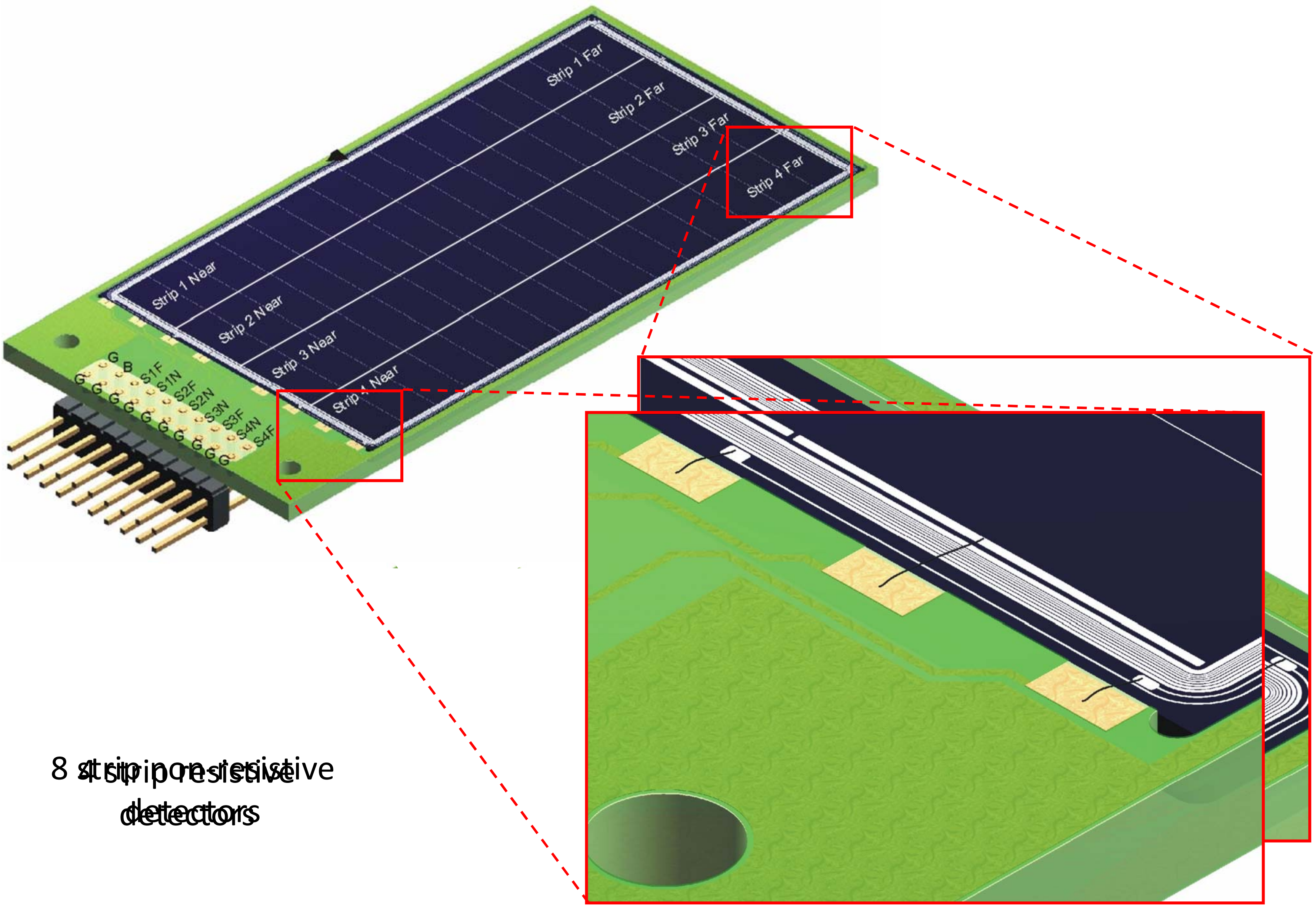


- ORRUBA gives ~80% ϕ coverage over the range 47° →132°
- 2 rings – θ < 90°: 12 telescopes (1000μm R + 65μm NR)
  – θ > 90°: 12 detectors (500μm R)
- 324 channels total (288 front side, 36 back side)
- HI beam
- Deuterated plastic targets





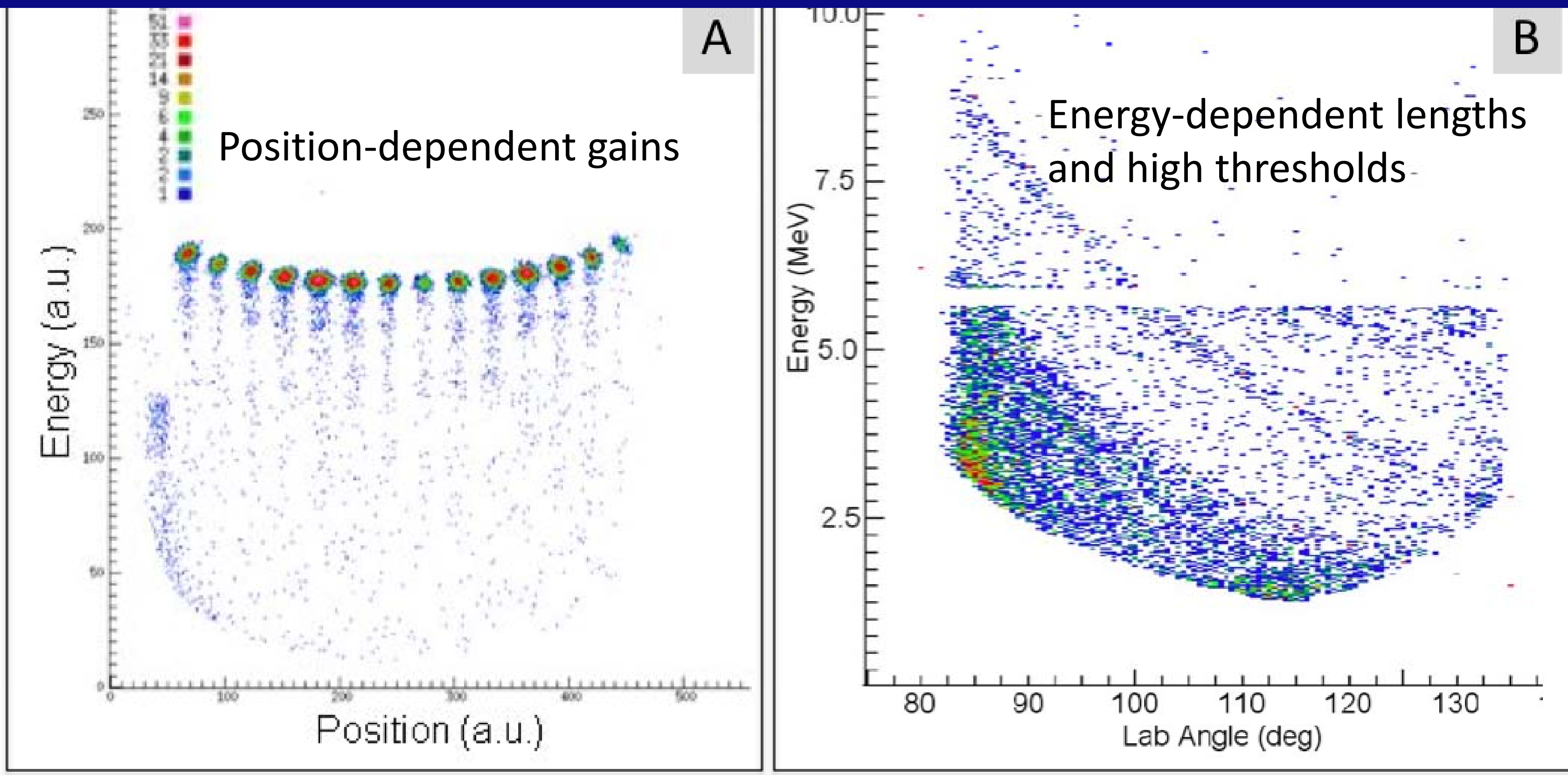
ORRUBA Detector Design



8 strip non-resistive detectors

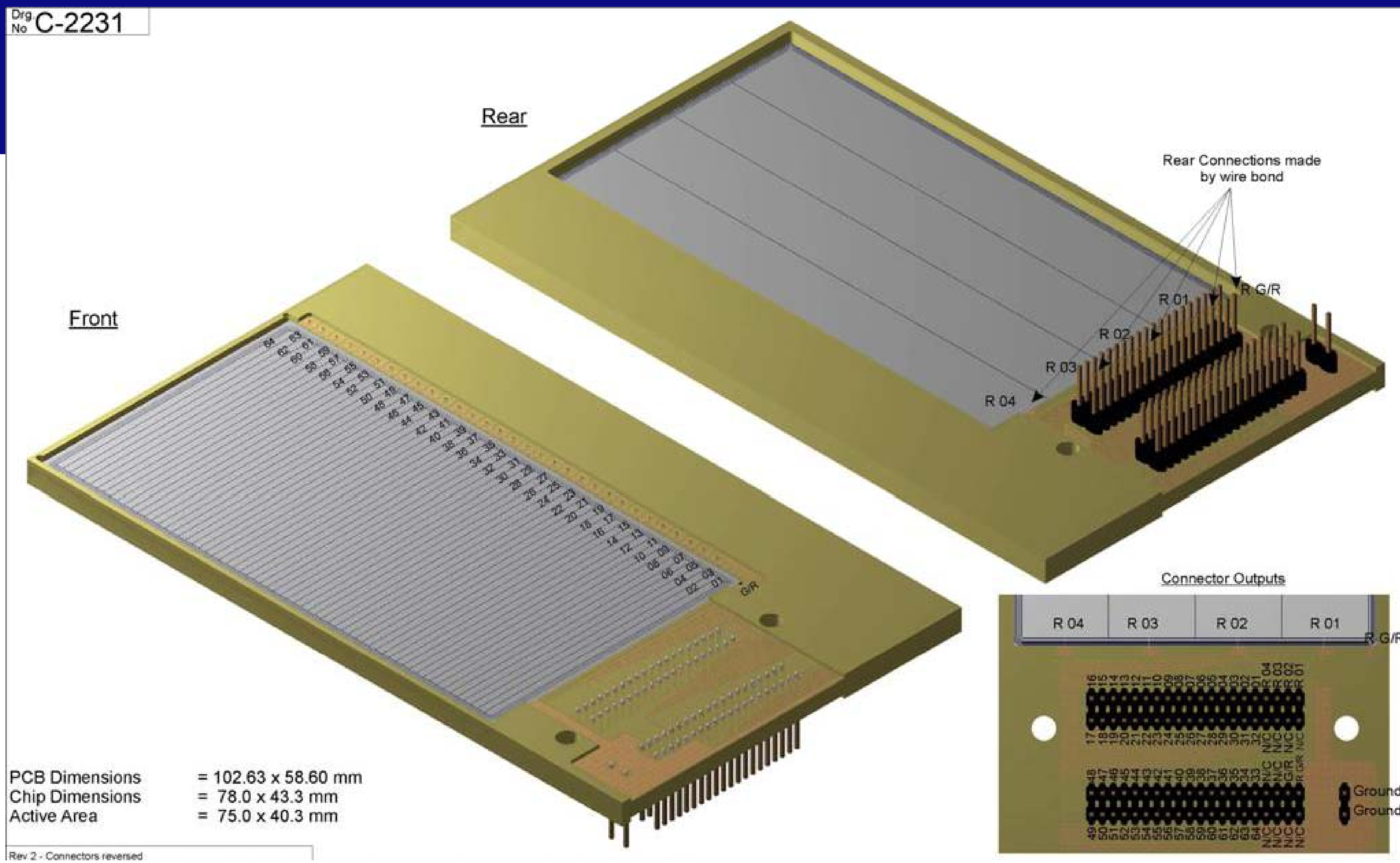
4 strip resistive detectors

Multiple Disadvantages of Charge Division

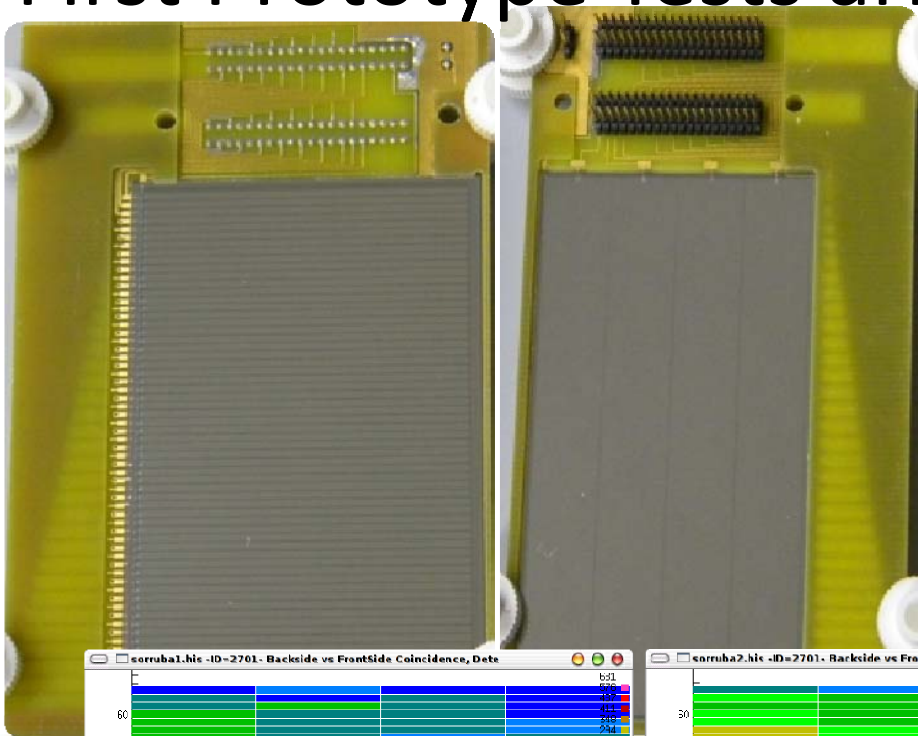


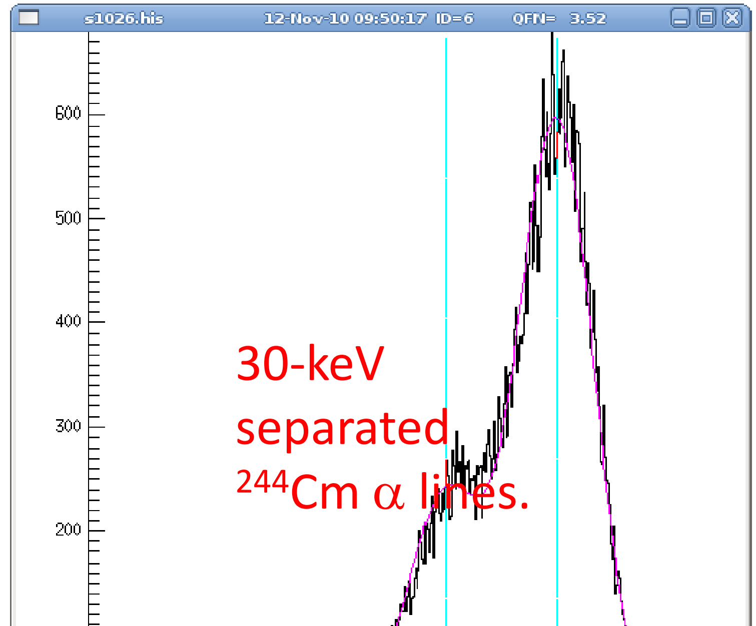
C – Uncertain energy and position calibrations – Must float detectors in space by several millimeters to match observed data kinematics

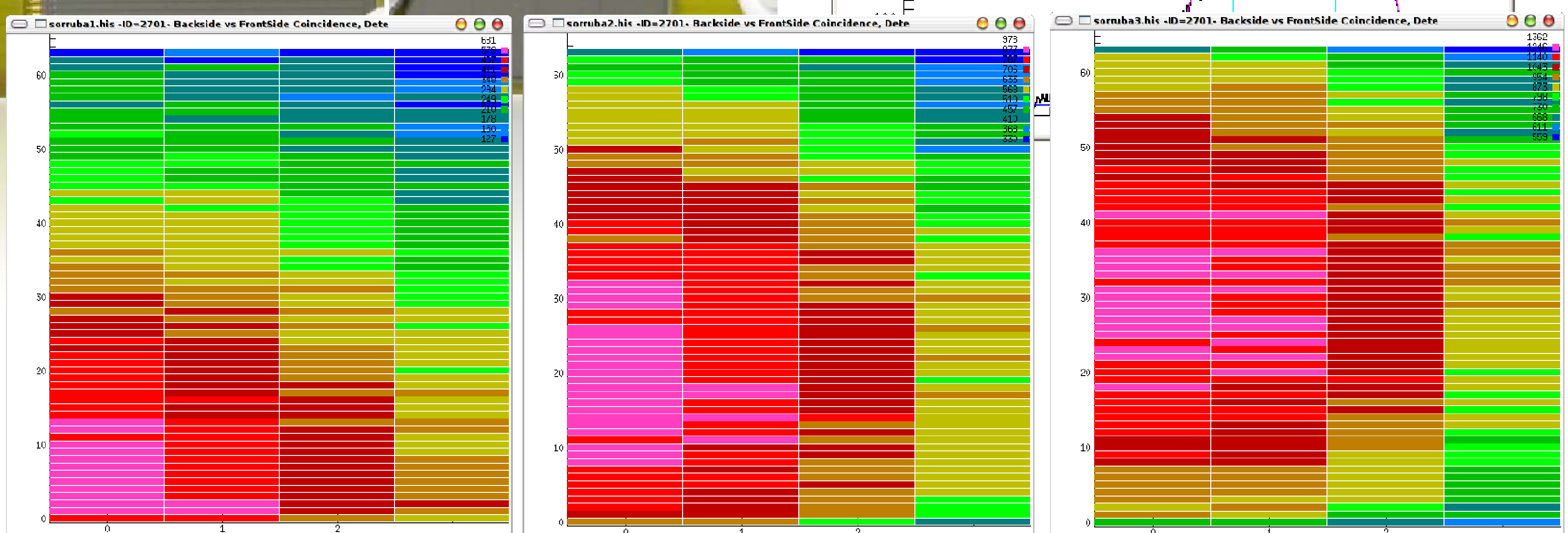
SUPER ORRUBA



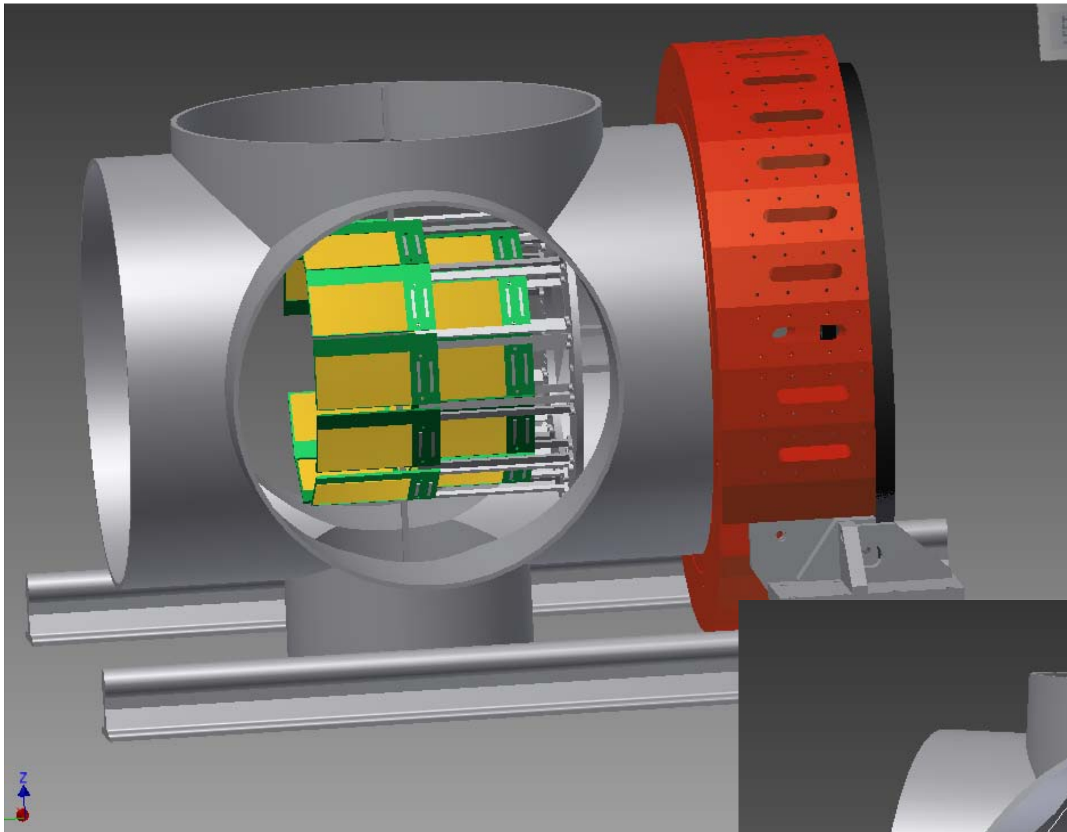
First Prototype Tests arrived Fall 2010

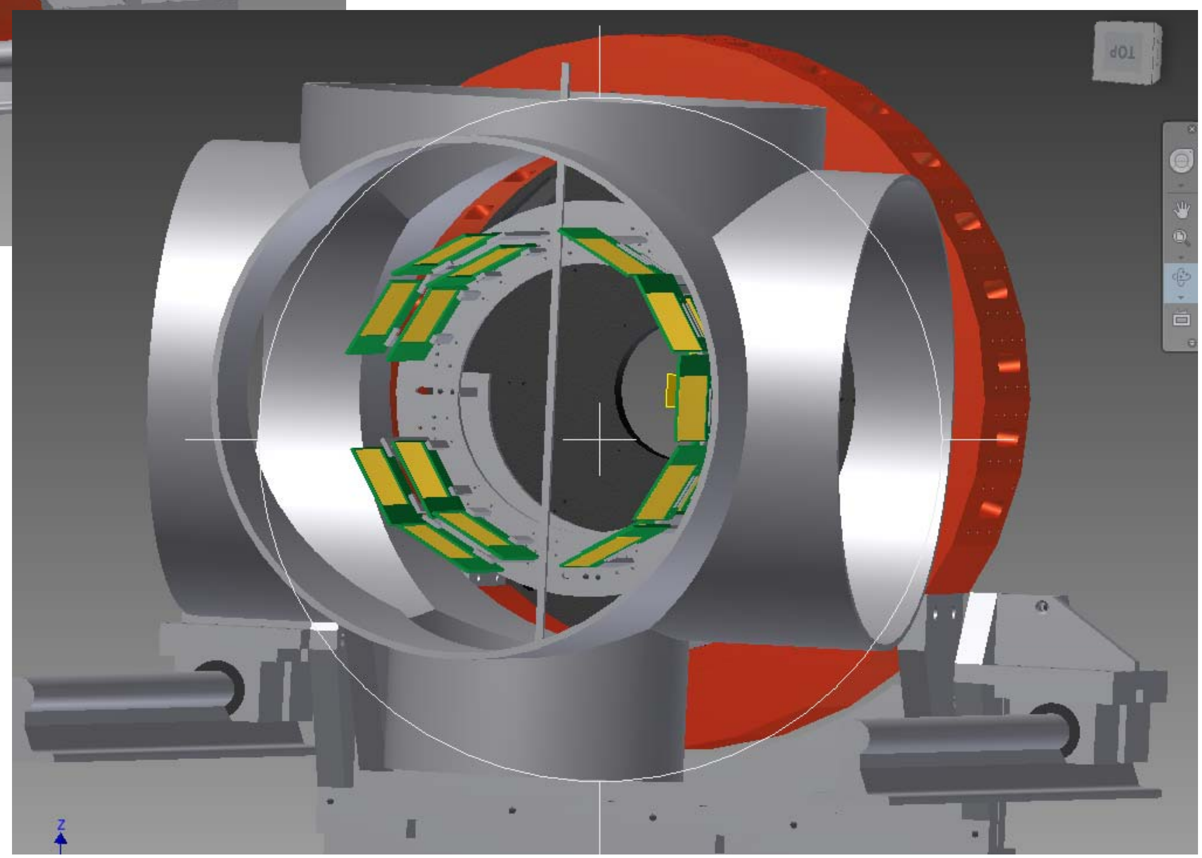






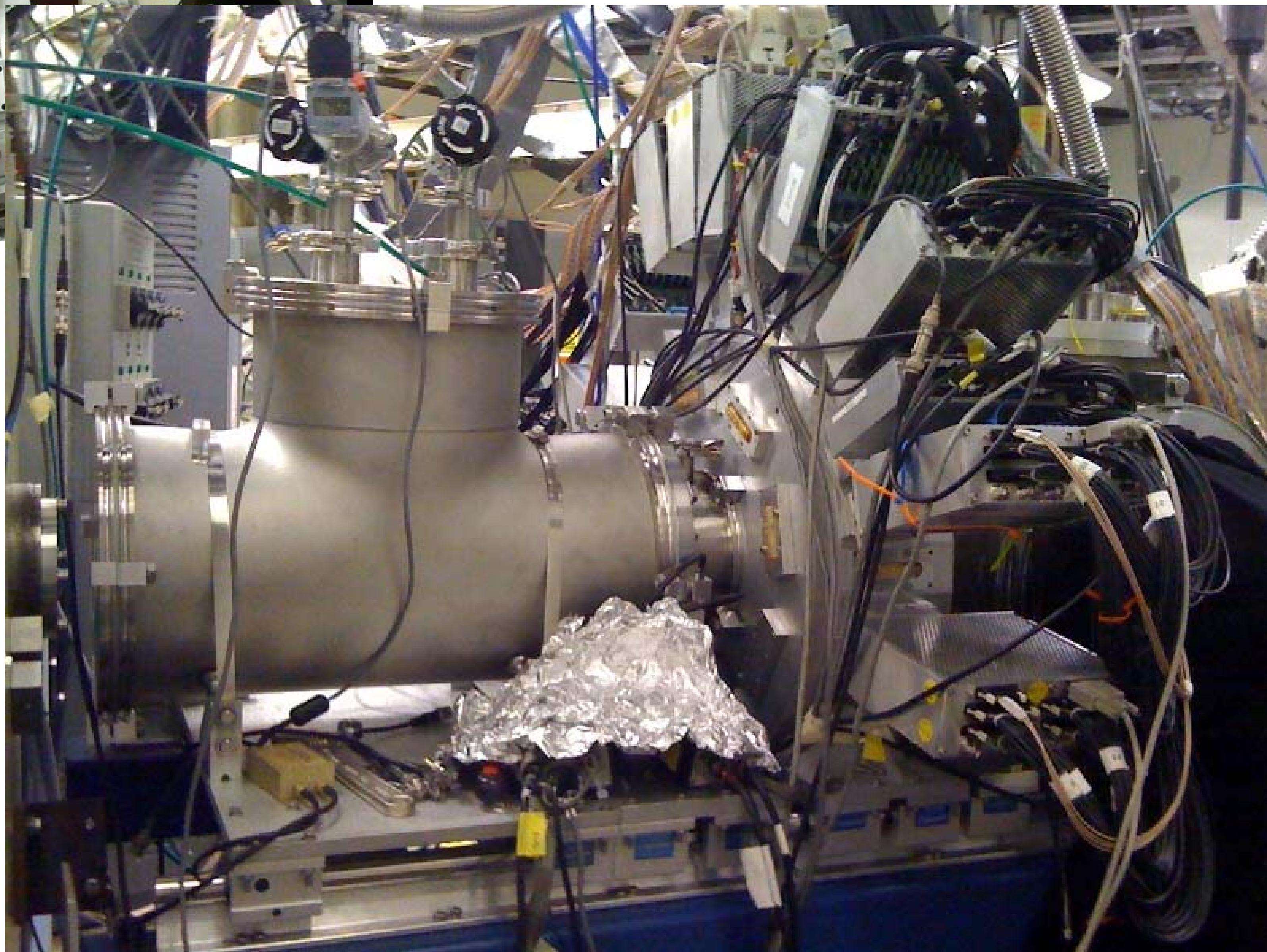
^{244}Cm source imaged in alpha particles



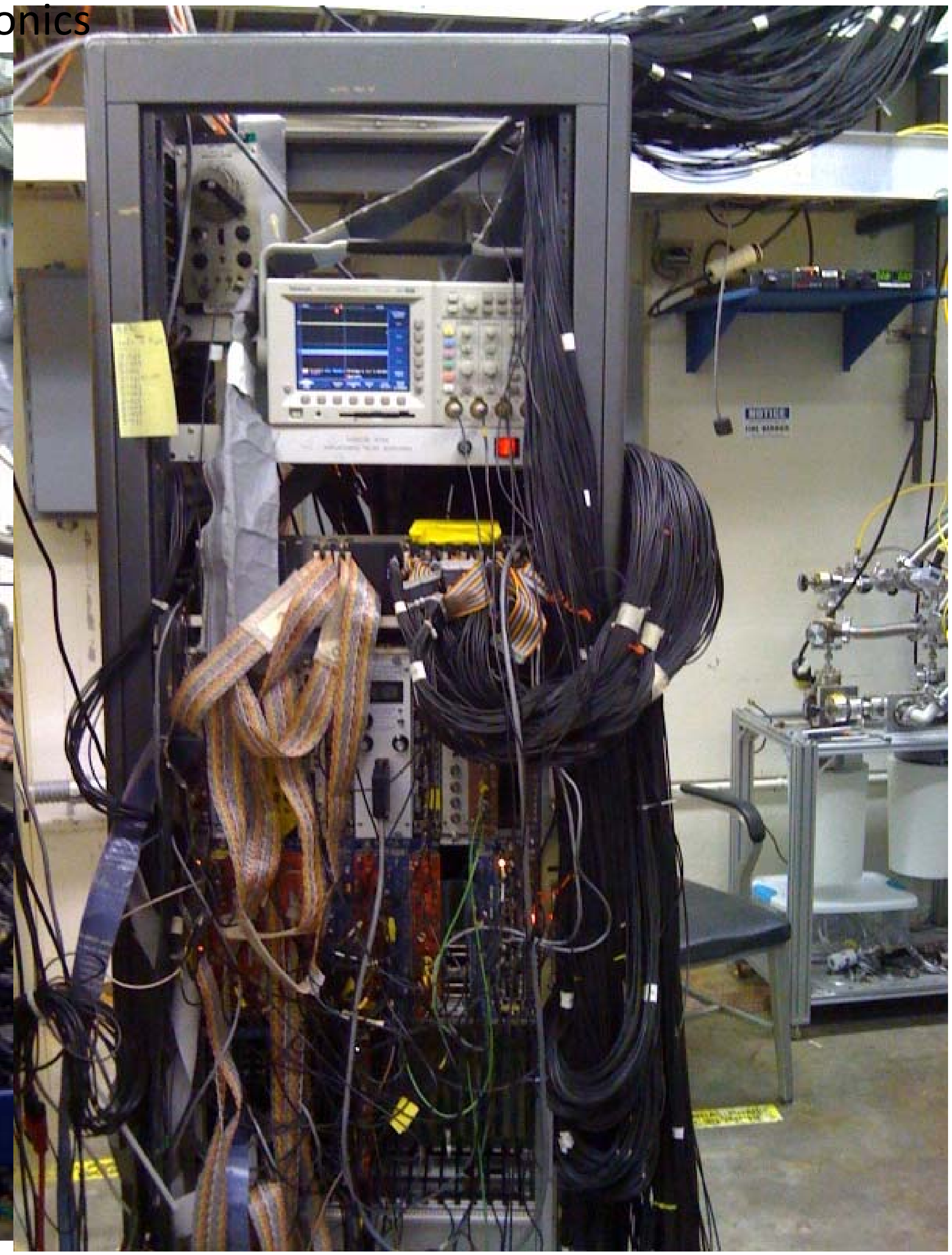


Mechanical Design by Surrey Grad Student Stephen Hardy (March 2011)

Construction April-May 2011



900 Channels Fed into single Rack of Electronics

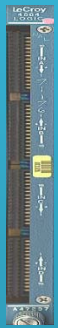


ASICs (Washingon U. Collaboration)

Implemented at ORNL by T. Ahn (U. Tenn.), R. L. Varner(ORNL) and M. Matos (LSU)

Shaping Amplifier + OR Logic Unit + Gate&Delay Generator(GDG) + ADCs + VME I/F

Shaping Amplifier

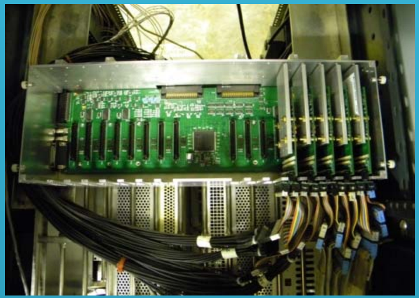


OR Logic Unit

GDG

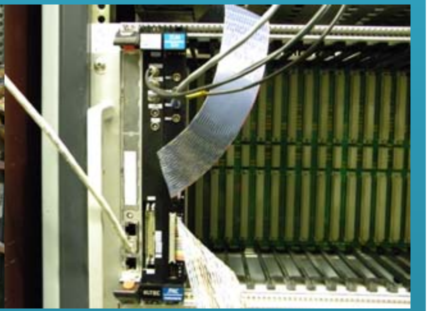
ADCs + VME I/F

ASICs Array + Motherboard + XLM + VME I/F



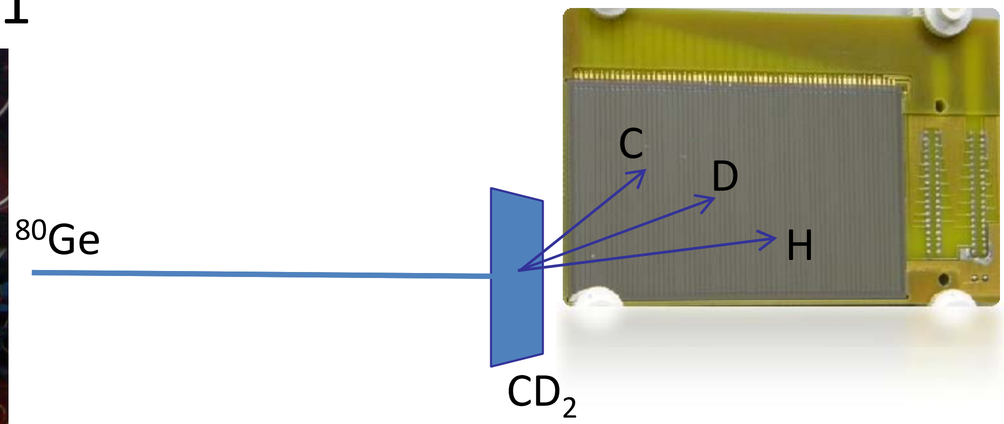
ASICs + Motherboard

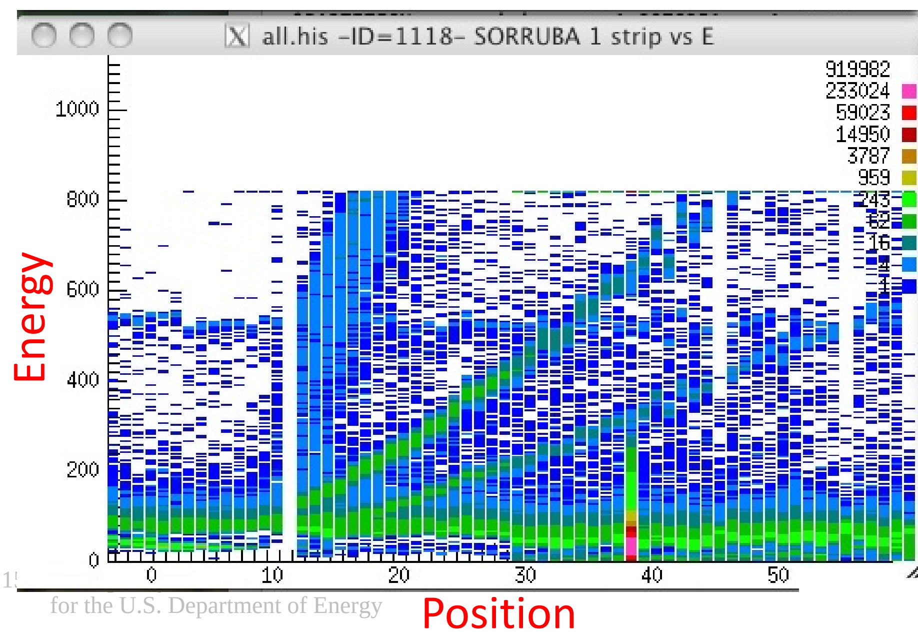
ECL/Nim Converter + Power Supply

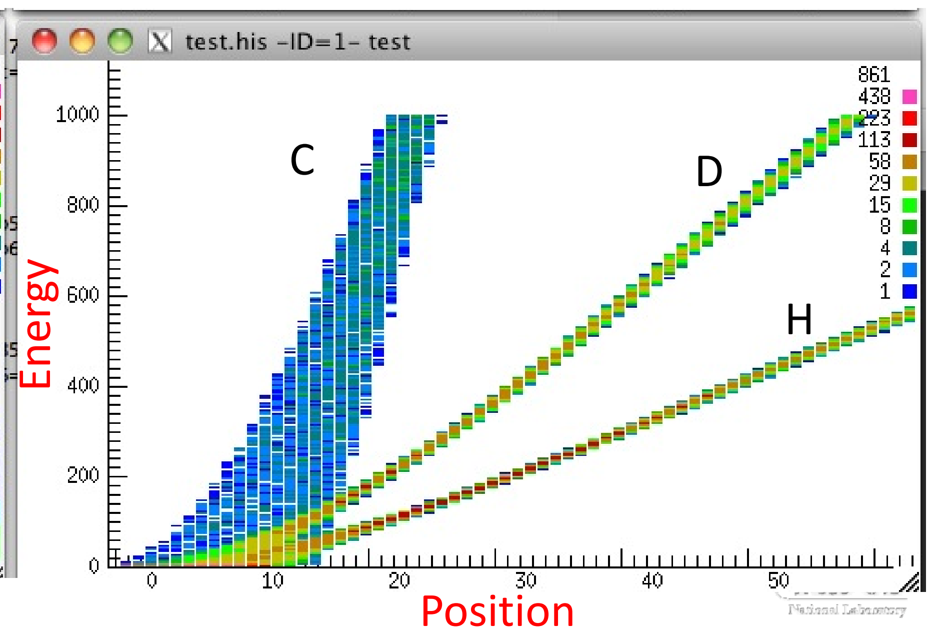


XLM + VME I/F

$^{2}H(^{80}Ge,p)^{81}Ge$ Run – April 2011

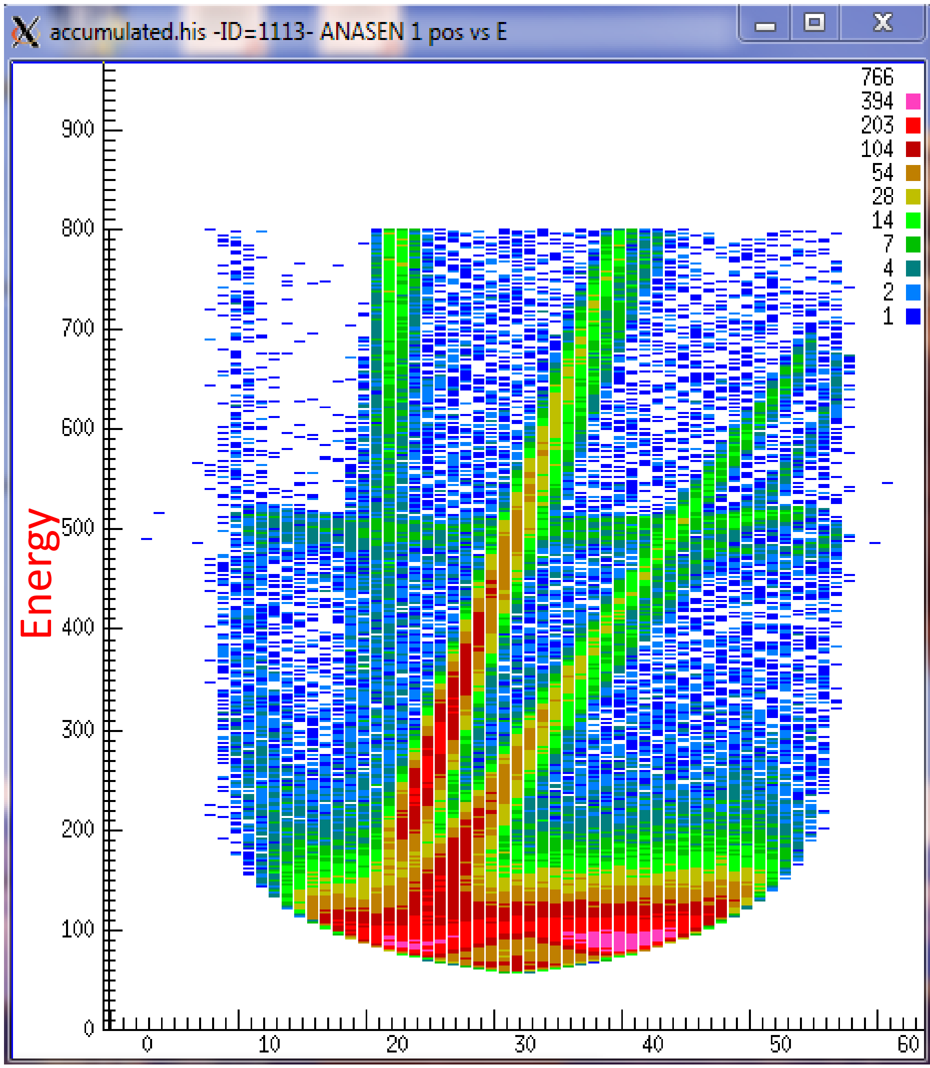






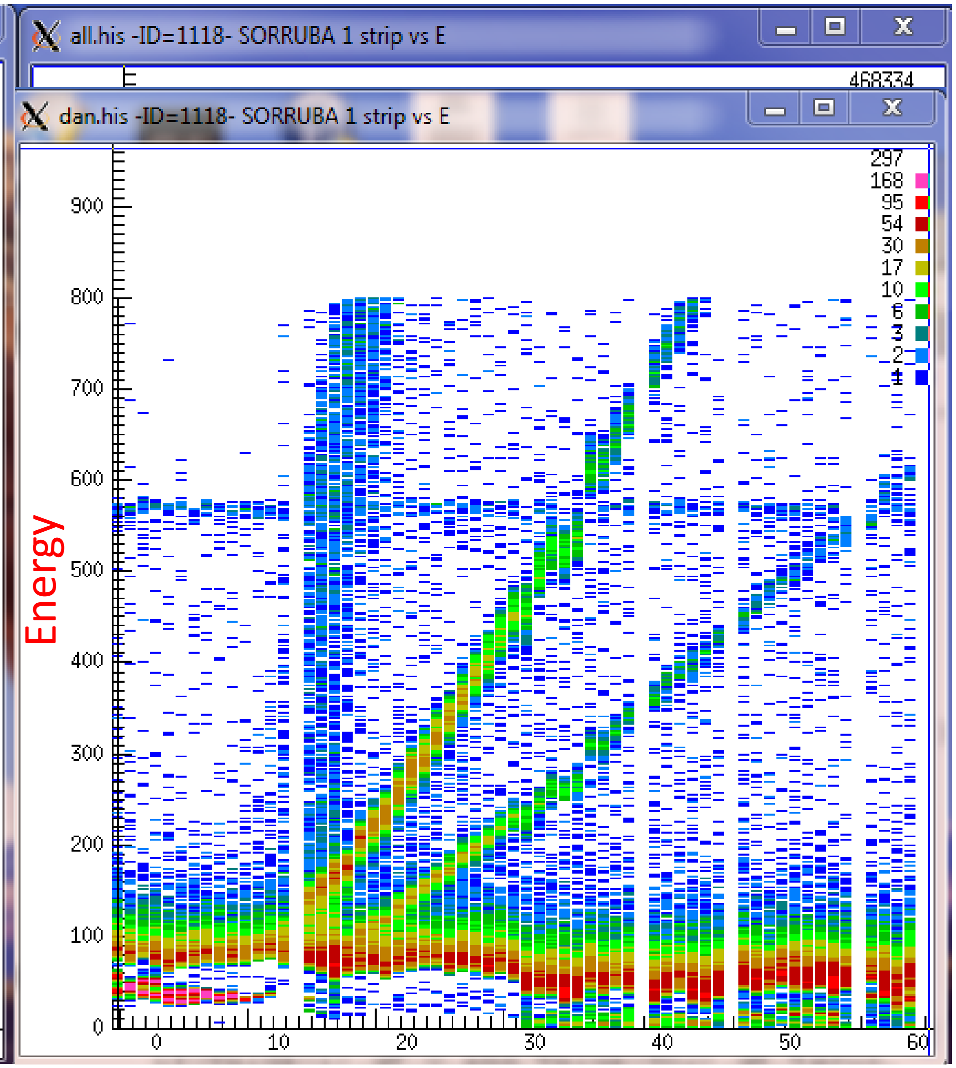
Comparison of elastic scattering results

ORRUBA



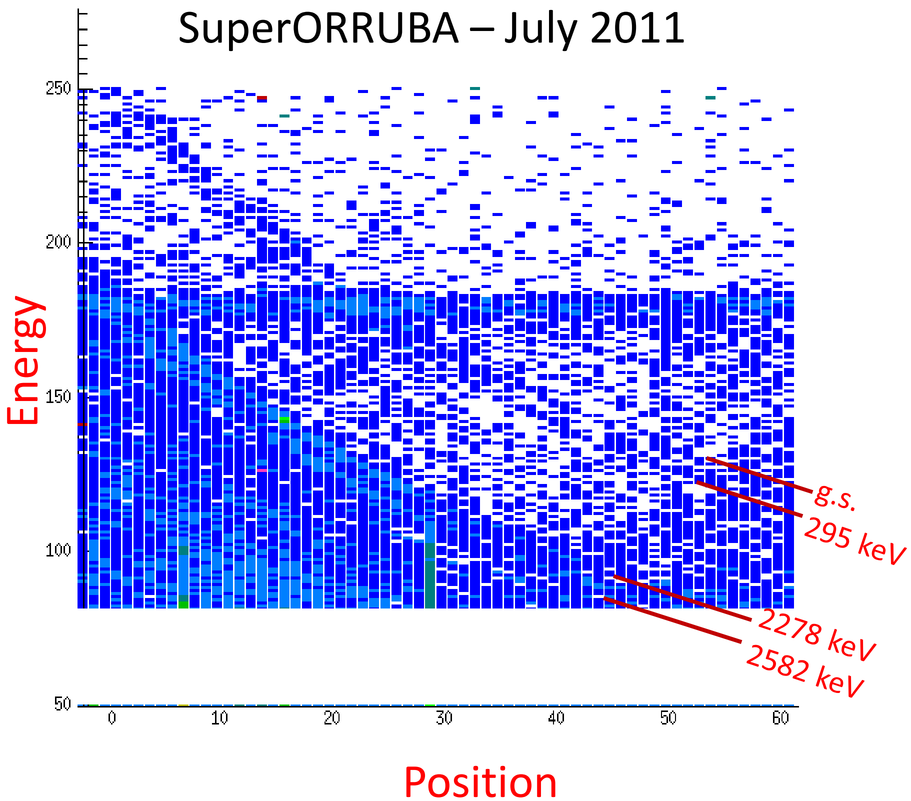
Position

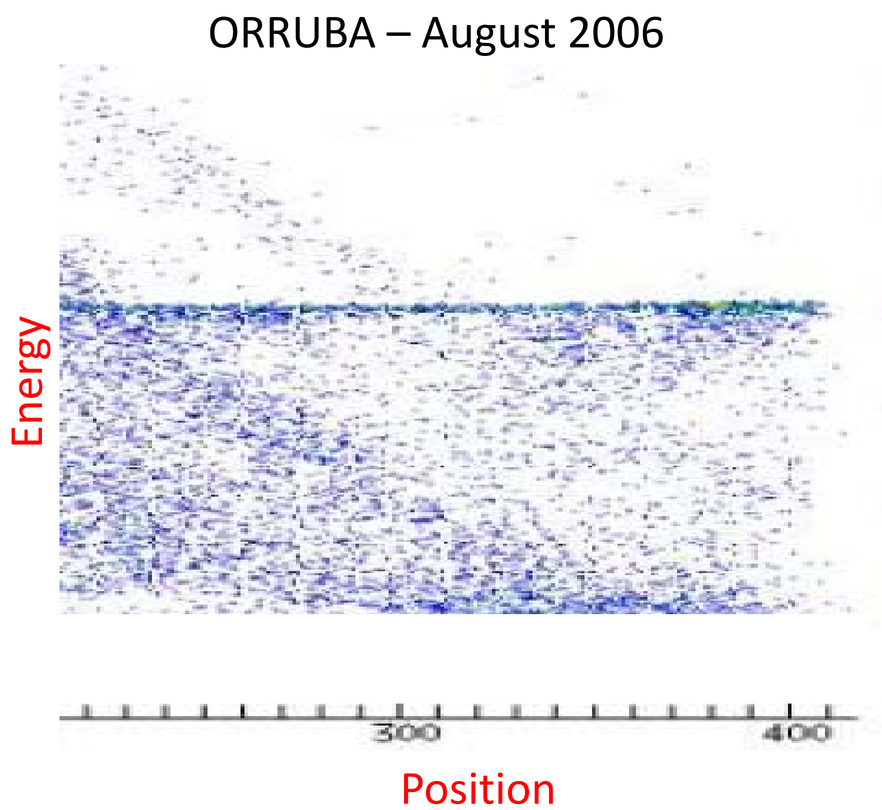
SuperORRUBA



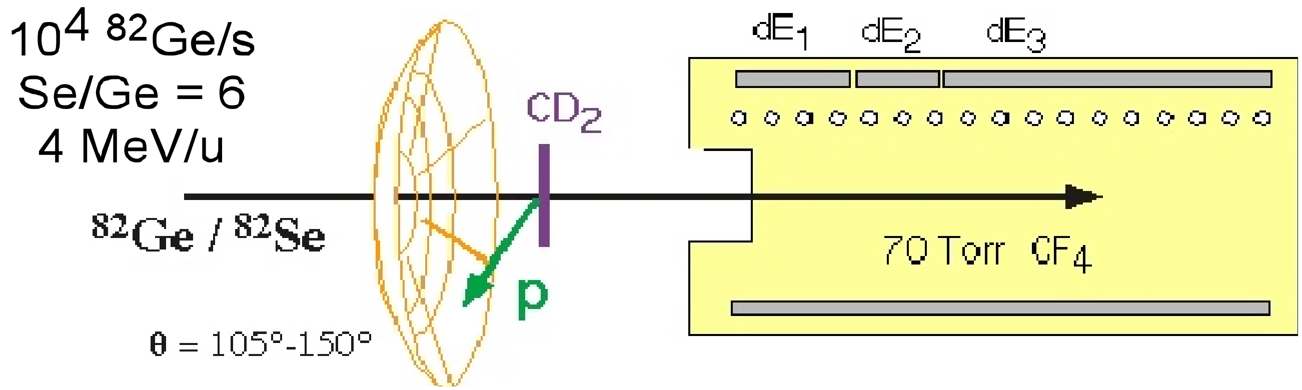
Position

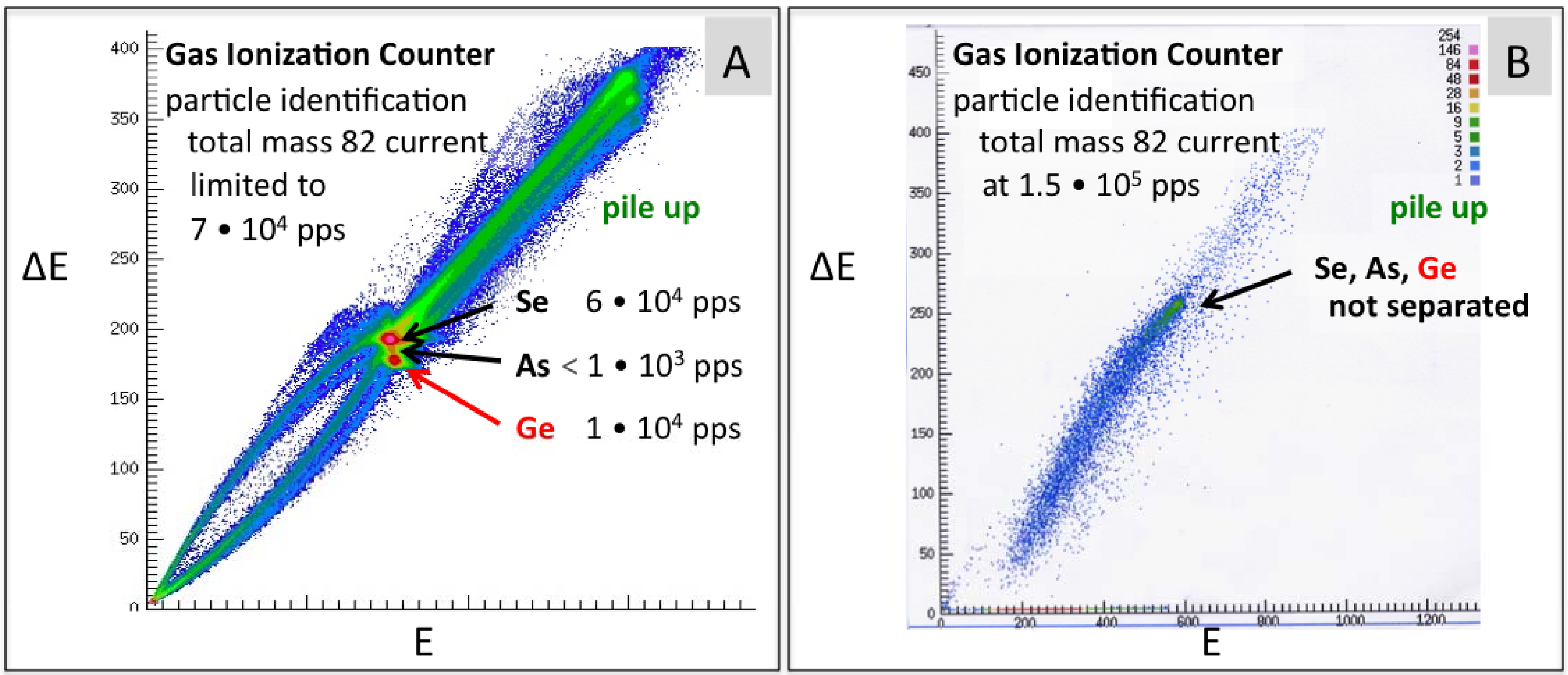
$^{2}H(^{130}Te,p)^{131}Te$ – July 2011



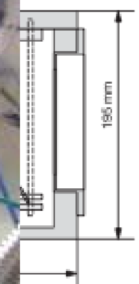


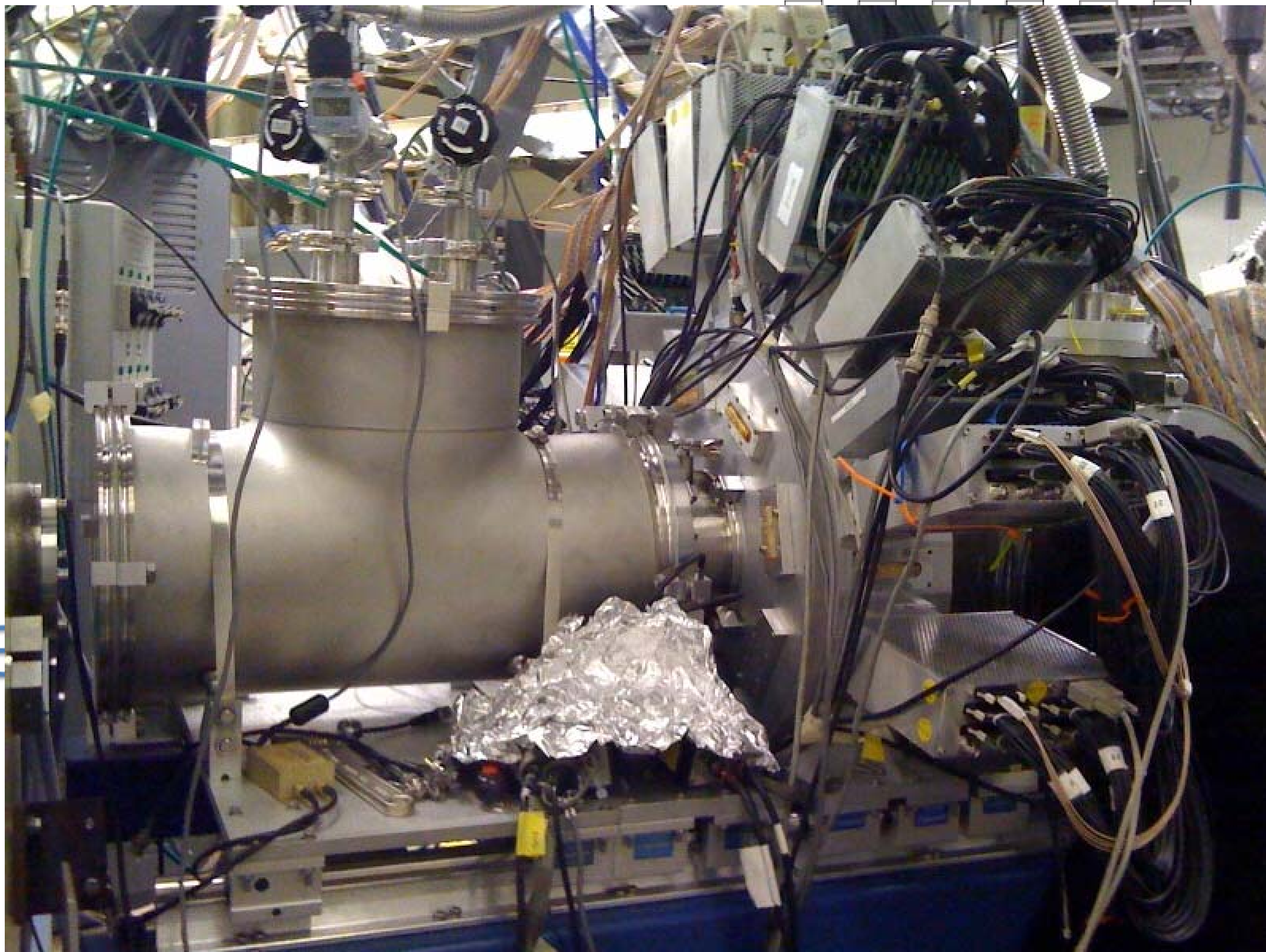
Project (2) – Fast Ionization Counter



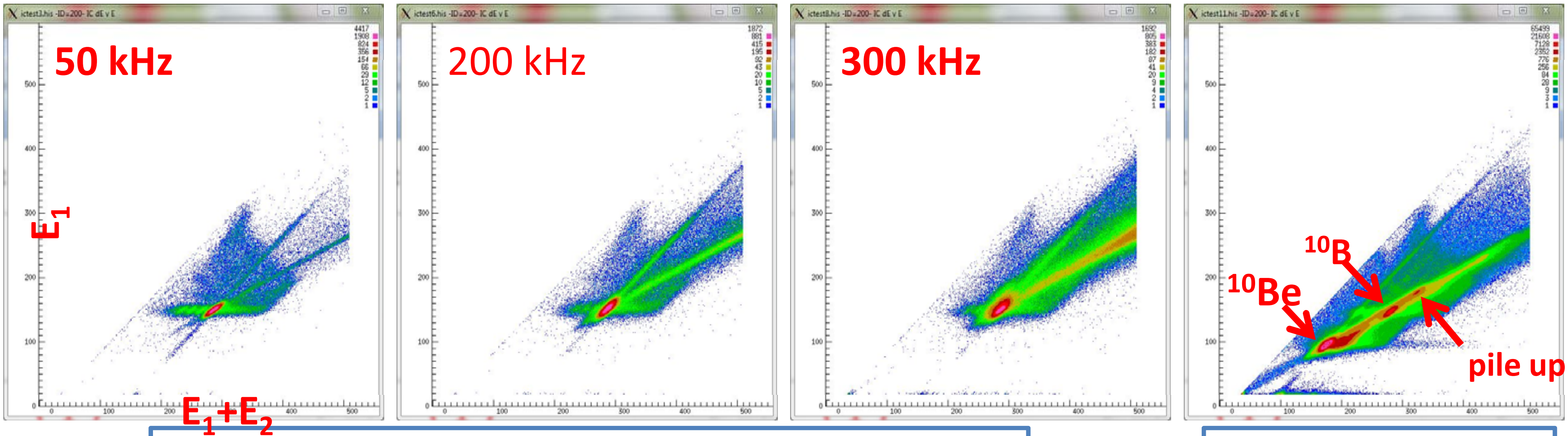


Fast Ion Counter design based on TEGIC used at RIKEN



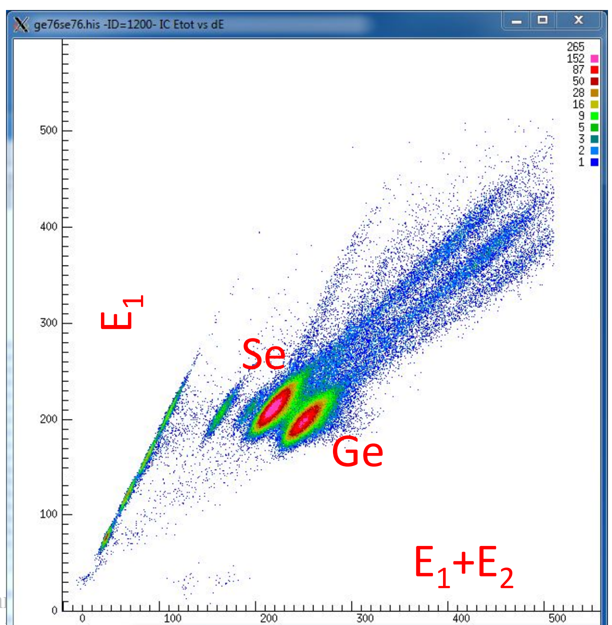


First Beam Tests done with $^{10}Be/^{10}B$ beam – July 2010



^{10}B beam, E_{beam} = 60 MeV

$^{10}B/^{10}Be$ cocktail beam



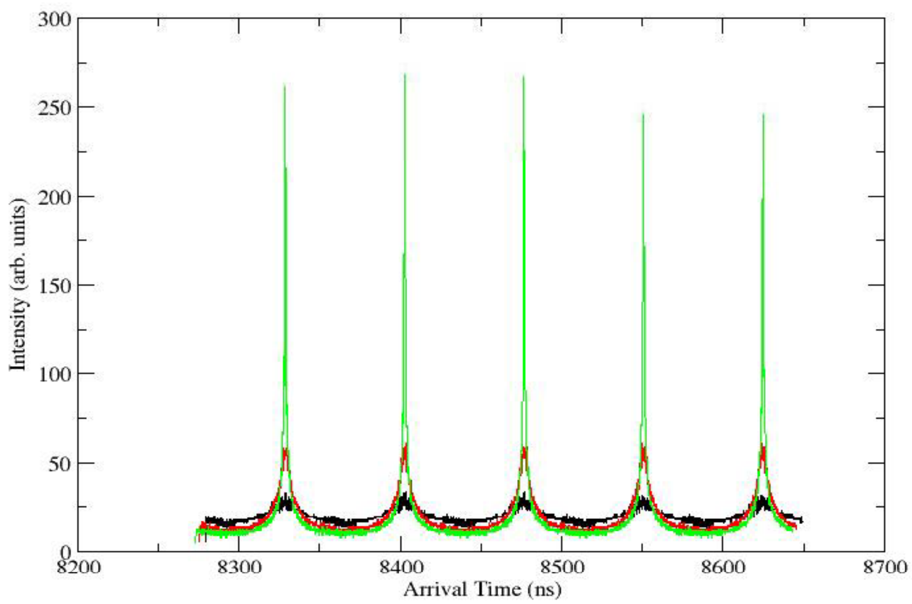
Mixed $^{76}Ge/^{76}Se$ beam at 500 kHz, 310 MeV. March 2011

Project (3) – Nanosecond Beam Buncher

•Particle identification of detected charged particles can be determined via time of flight.

•(d,p) proton – 1.8 ns
•Elastically scattered protons – 5.8 ns
•Elastically scattered deuterons – 8.1 ns

•Beam bunches ~ 1 ns would provide enough resolution to resolve these groups.



Simulations have been performed with sinusoidal varying fields.

Achieved bunches of 0.4 ns width with 53% efficiency at a focal length of 5 m from the buncher for a ^{132}Sn beam.

Budget

	Budgeted (3 years)	Spent (1.75 years)
Labor (S. D. Pain, D. W. Bardayan, M. S. Smith)	$ 870 K	$ 385 K
Postdocs	$ 250 K	$ 66 K
SuperORRUBA	$ 494 K	$ 441 K
Ionization Counter	$ 80 K	$ 47 K
Beam Buncher	$ 150 K	$ 31 K
Subcontract – Jolie Cizewski	$ 56 K	$ 7 K
Total	$ 1900 K	$ 977 K (51% spent)

Participants

- D. W. Bardayan, K. Y. Chae, B. H. Moazen, S. D. Pain, M. S. Smith (ORNL)
- J. C. Blackmon, L. Linhardt, M. Matos (LSU)
- A. Ayres, T. Ahn, K. Schmitt (U. Tenn.)
- J. A. Cizewski, S. Strauss (Rutgers)
- S. Hardy (U. Surrey)