RIKEN Isospin Diffusion Experiment

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Introduction to Symmetry Energy

- Nuclear EOS relates energy, pressure, temperature, density, and isospin asymmetry (*δ*) of nuclei:

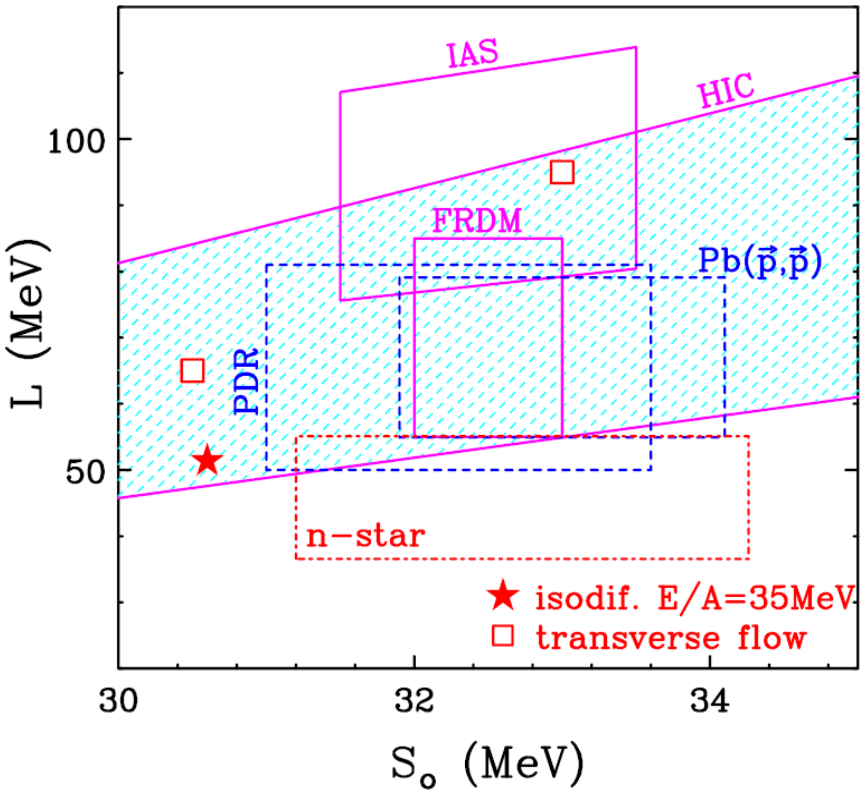
$$E(\rho, \delta) = E(\rho, \delta=0) + E_{sym}(\rho)\delta^2$$

$$\delta = (\rho_n-\rho_p)/(\rho_n+\rho_p)$$

- Symmetry energy influences
  - neutron-skin thicknesses
  - neutron star radii, maximum masses, and cooling rates
- One parameterization:

$$E_{sym}(\rho) = S_0 - L\frac{\rho_0 - \rho}{3\rho_0}$$

- Current constraints from HIC weigh heavily on isospin diffusion



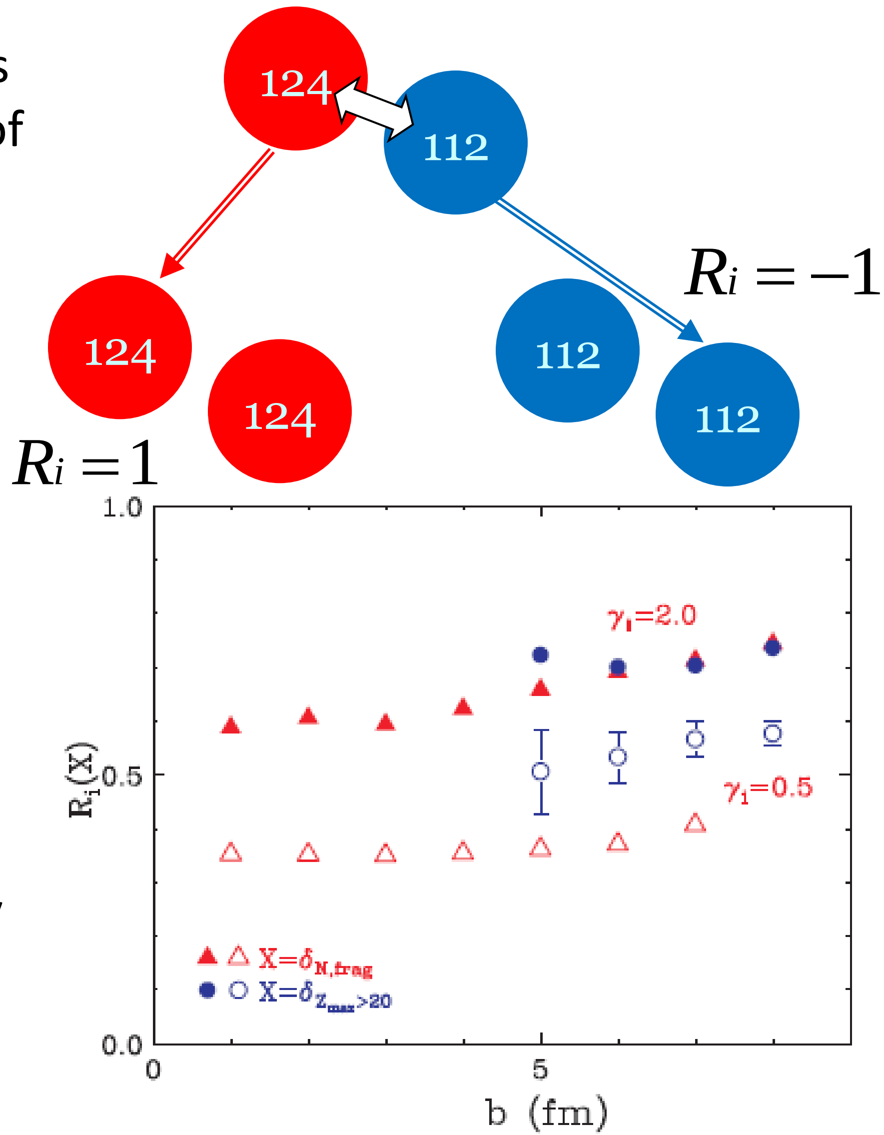
Isospin Diffusion

- Asymmetric systems (A+B) move towards isospin equilibrium under the influence of symmetry energy.
- Symmetric systems (A+A; B+B) provide reference values, do not have isospin diffusion
- Isospin transport ratio $R_i(X)$

$$R_i = \frac{2x - (x_{AA} + x_{BB})}{x_{AA} - x_{BB}}$$

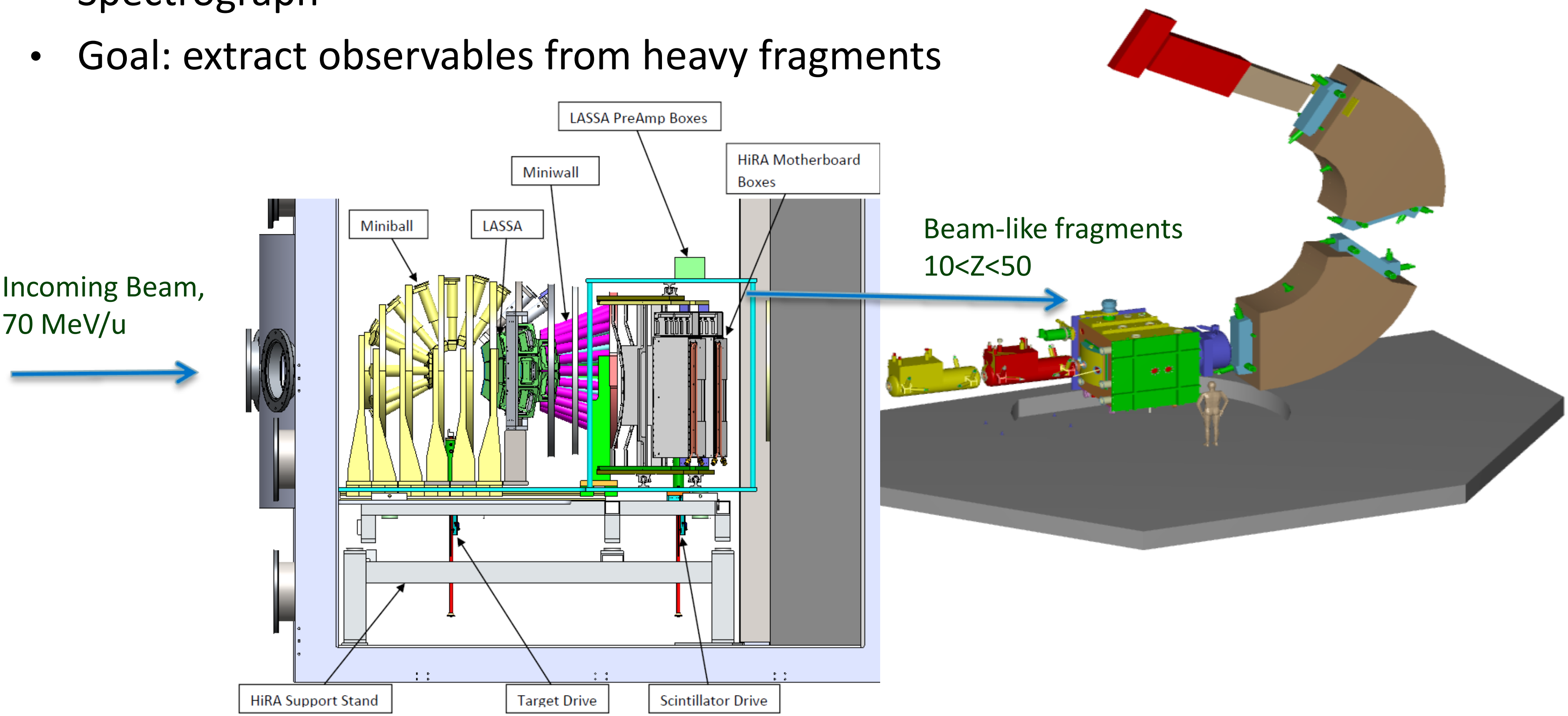
- Different amount of isospin diffusion for heavy residues, provide another observable sensitive to symmetry energy

$$E_{sym}(\rho) = S_k \left(\frac{\rho}{\rho_0}\right)^{2/3} + S_i \left(\frac{\rho}{\rho_0}\right)^{\gamma_i}$$



Previous Experiment: e07038

- Investigates the density-dependence of the nuclear symmetry energy
- ^{112,118,124}Sn+ ^{112,118,124}Sn Collisions
- Combines the MSU Miniball+WU Miniwall, the LASSA Array, and the S800 Spectrograph
- Goal: extract observables from heavy fragments



Data taken at MSU (Experiment 07038)

- $^{112,118,124}Sn + ^{112,118,124}Sn$
- ~5 mg/cm^2 Targets
- 70 MeV/u beam energy
- Event rates 200-300/s
- Beam Rate $2*10^7$/s to $6*10^7$/s
- Millions of events:

Beam	Target		
	^{112}Sn	^{118}Sn	^{124}Sn
^{112}Sn / 43hr	11.4M/11.2hr	x	8.7M/11.3hr
^{118}Sn / 43hr	3.8M/2.8hr	10.7M/8.4hr	x
^{124}Sn / 43 hr	12.3M/10.6hr	10.1M/9.5hr	15.2M/10hr

S800 Spectrometer Analysis (Experiment 07038)

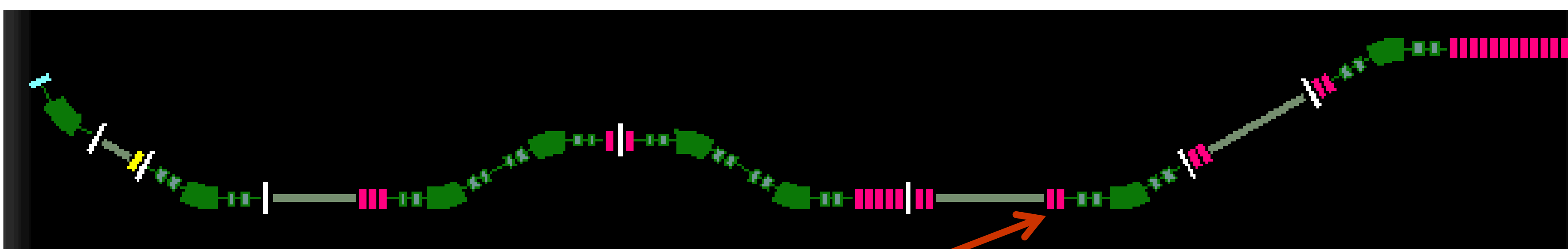
- S800 analysis relies on ΔE vs. TOF data (analogous to Z vs. Q/A) to separate fragment isotopes
- Better isotopic resolution using position correction of fragments
- Will probably not separate charge states
- Select Z, A regions with Bρ settings in magnet
- Wanted 5-6 Bρ settings per beam but did not have enough time
- Chose 2-3 Bρ regions further from beam

RIKEN Experimental Plan

- Primary beam: ^{124}Xe (10-30 pnA)
- Detect residues: have larger cross sections than the light fragments previously measured, so we can use unstable beams and increase δ difference
- No ^{124}Sn beam because there is no ^{132}Xe primary beam
- ^{108}Sn, ^{112}Sn beams at 73 MeV/U
- ^{112}Sn, ^{124}Sn targets at ~50 mg/cm^2
- Expect event rates <100/s

Beam	Target	
	^{112}Sn	^{124}Sn
^{108}Sn	~18 hours	~19 hours
^{112}Sn	~14 hours	~15 hours

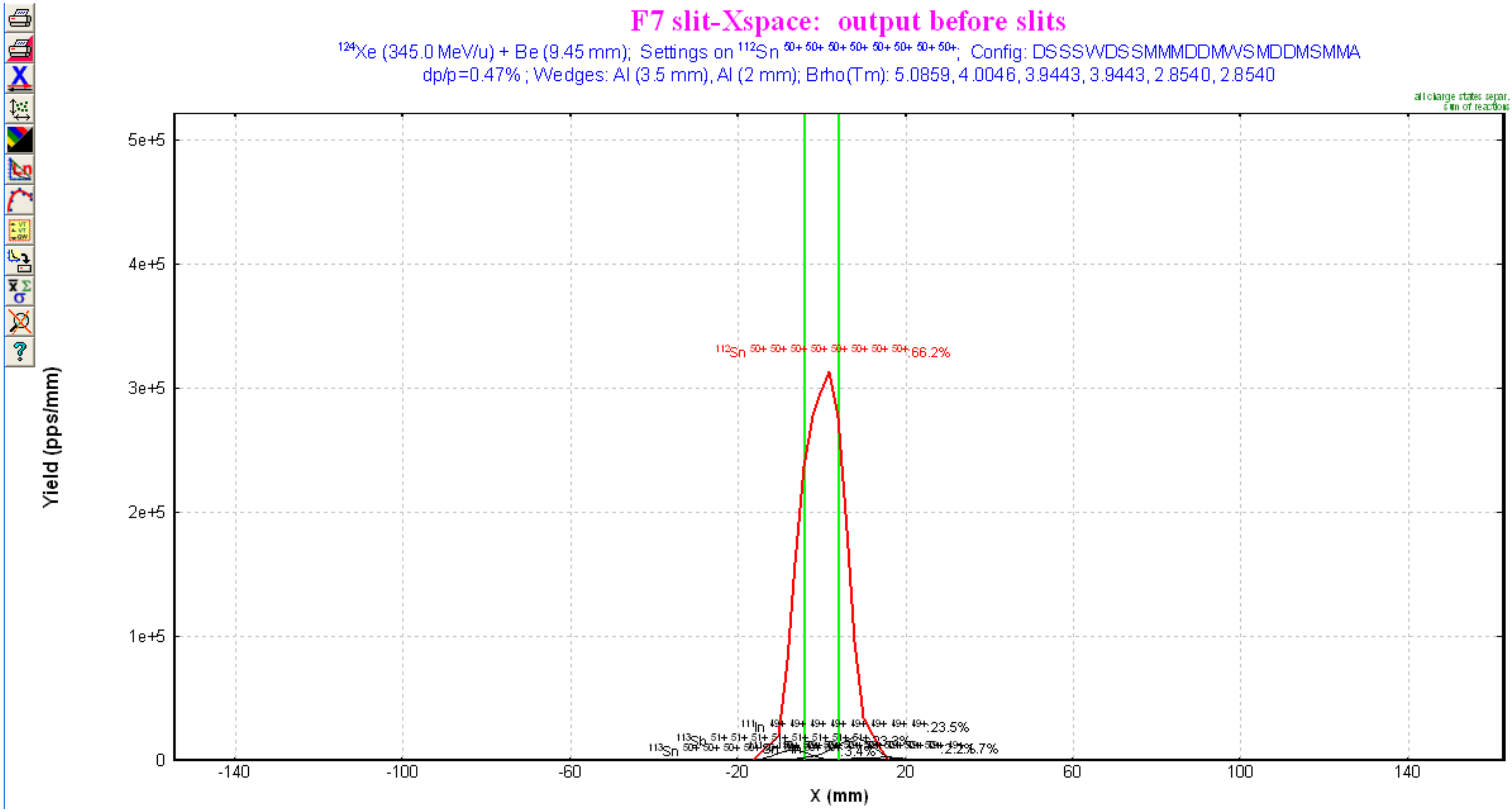
BigRIPS **Zero Degree Spectrometer**



Target

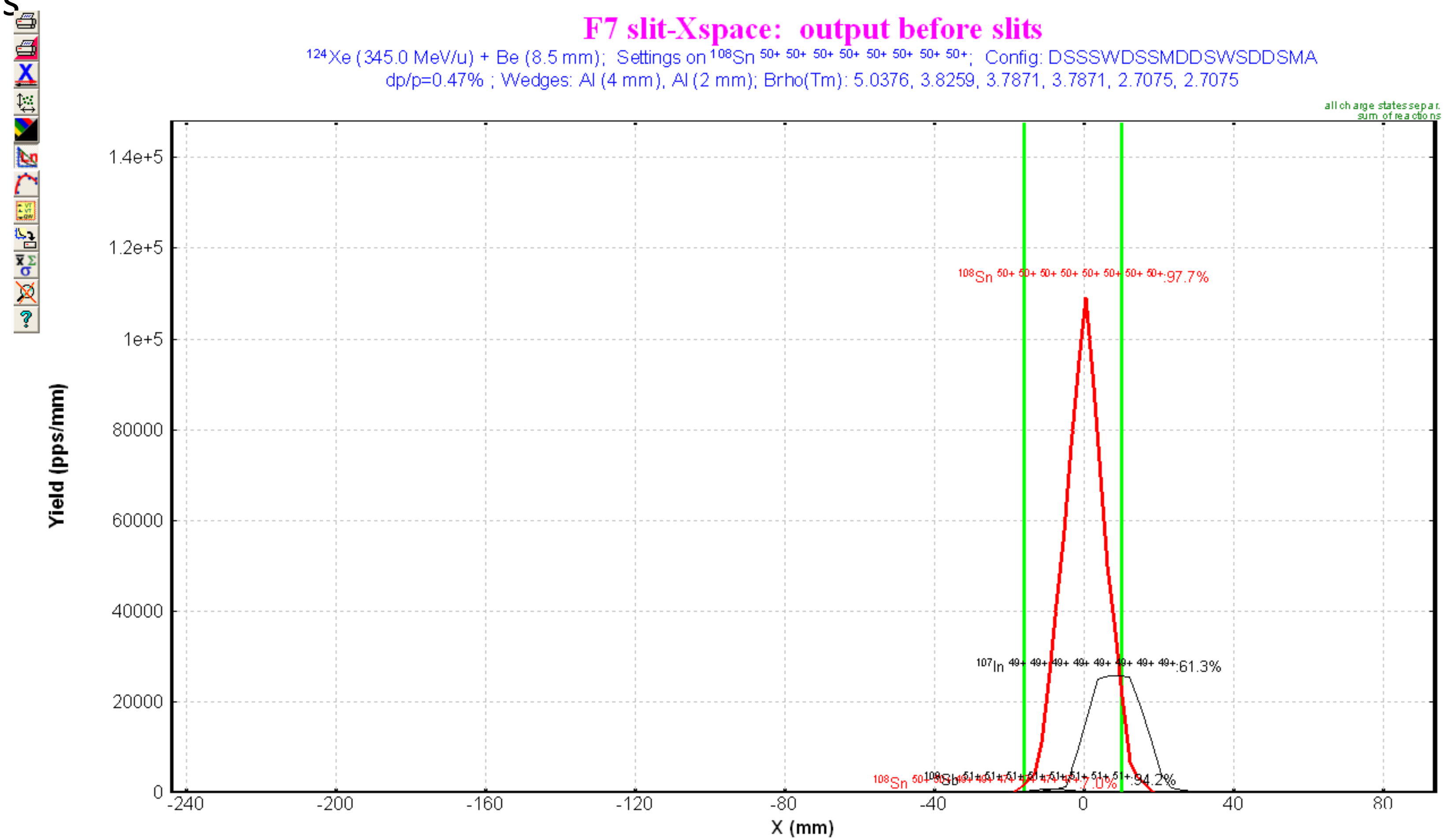
^{112}Sn Beam Calculations

- ^{112}Sn profile at target
- 97.8% purity
- 3e+6 pps

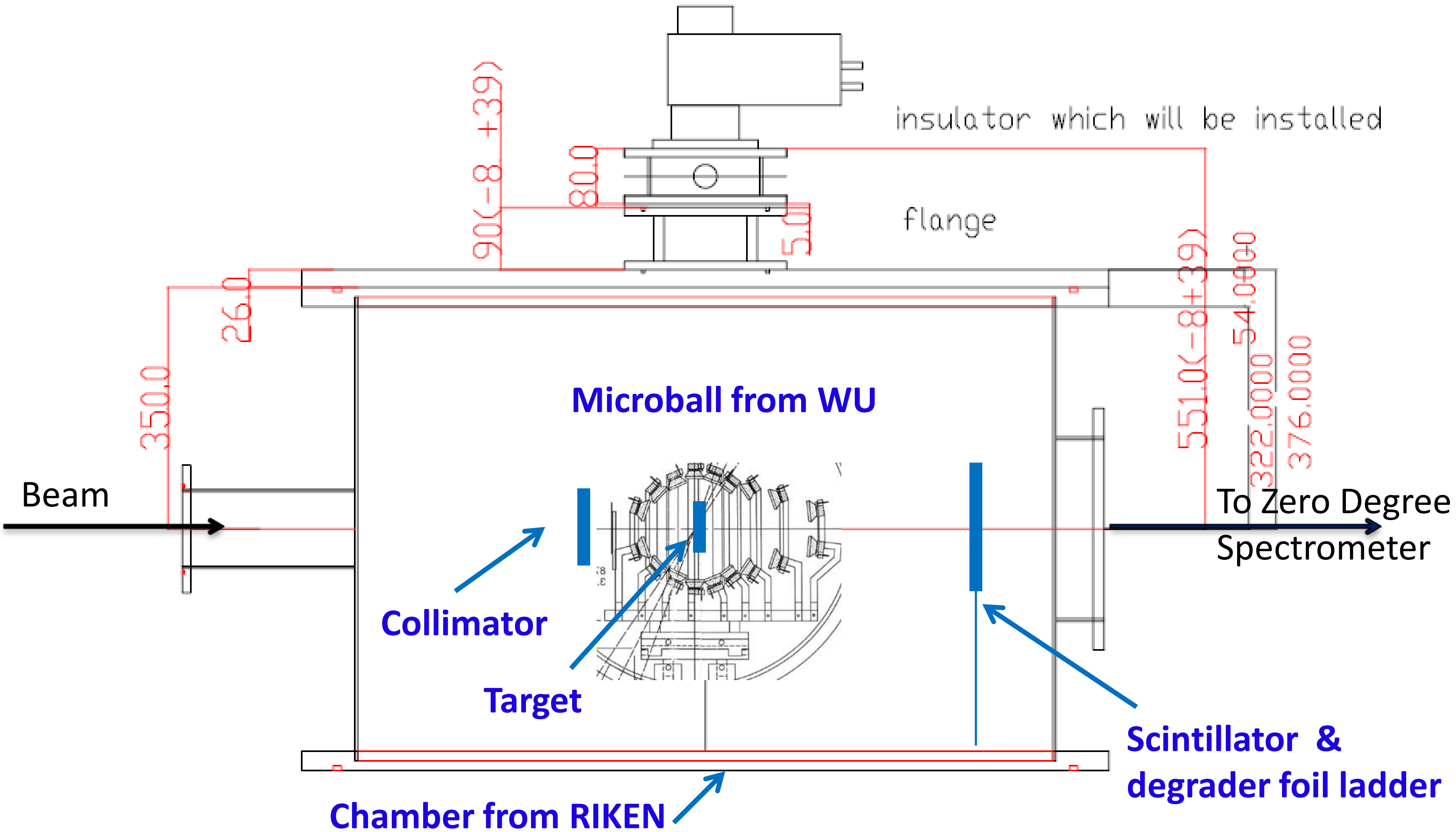


^{108}Sn Beam Calculations

- ^{108}Sn profile at target
- 83.7% purity
- 1e+6 pps



Experimental Setup: Overview

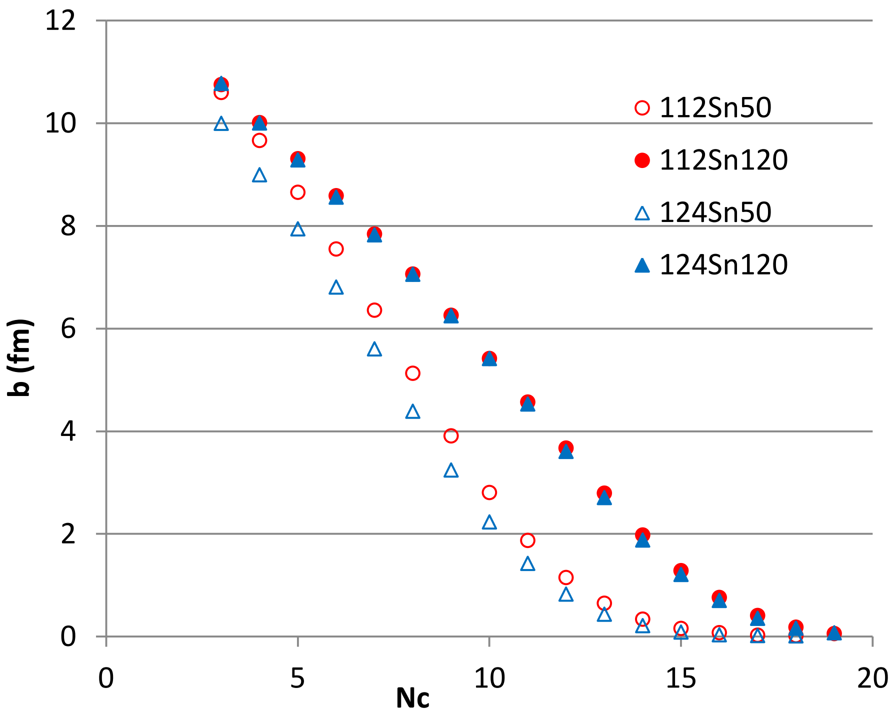


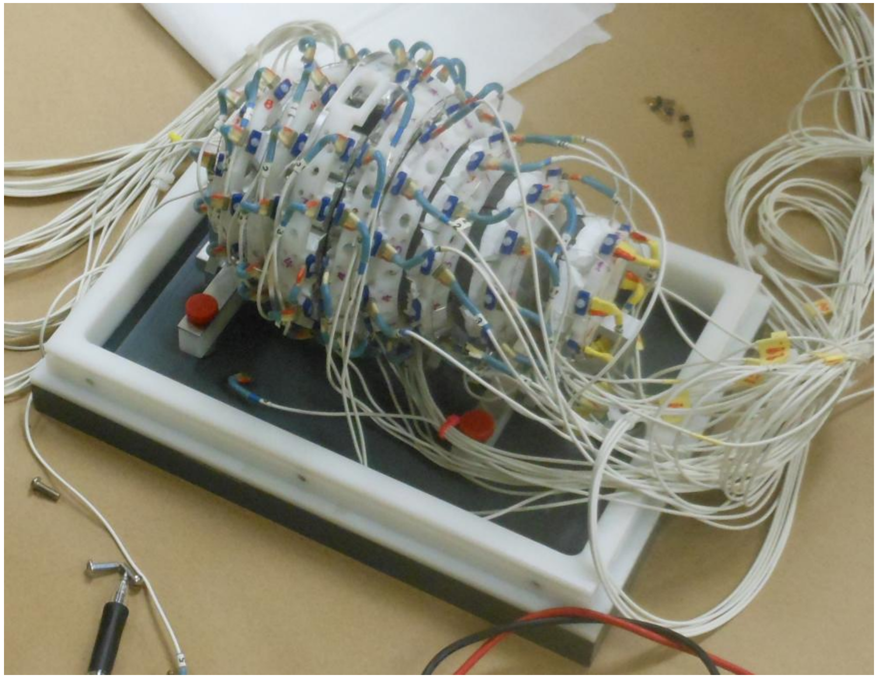
Zero Degree Spectrometer Analysis

- Fragments predicted to be emitted within 2.5^{o}
- 5-6 magnetic settings used to obtain residue fragments (avoid beam charge states)
  - May need to decrease number of settings due to time
- Detect Bρ, time at F3, F5, F7
- TOF (from 3 to 7), ΔE at F7 -> Z, A/Q
- Correct PID using track reconstruction through beamline, gives Bρ of fragment

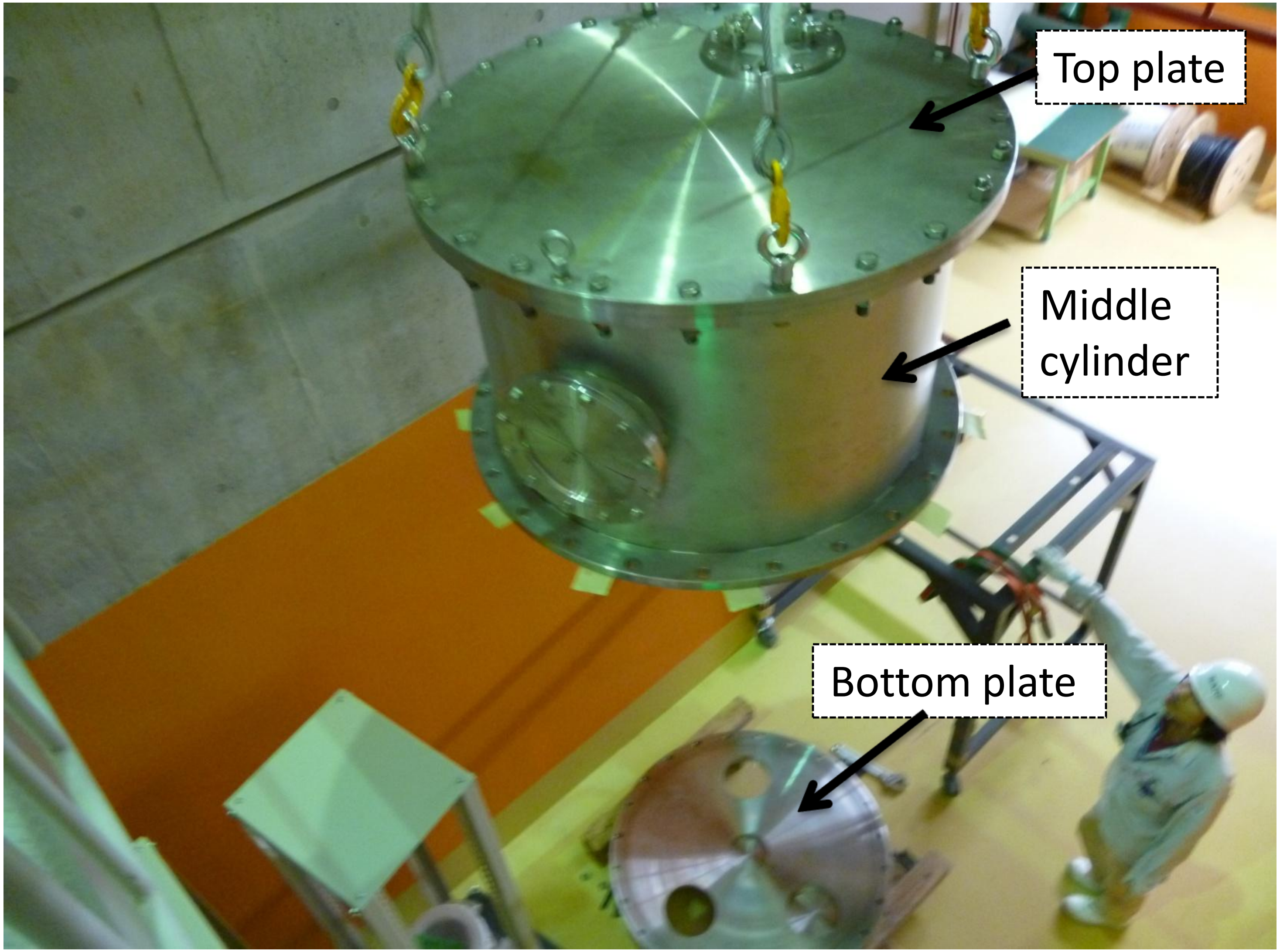
Microball Analysis

- Determination of b using N_C
- Requires downstream scintillator to normalize beam counts



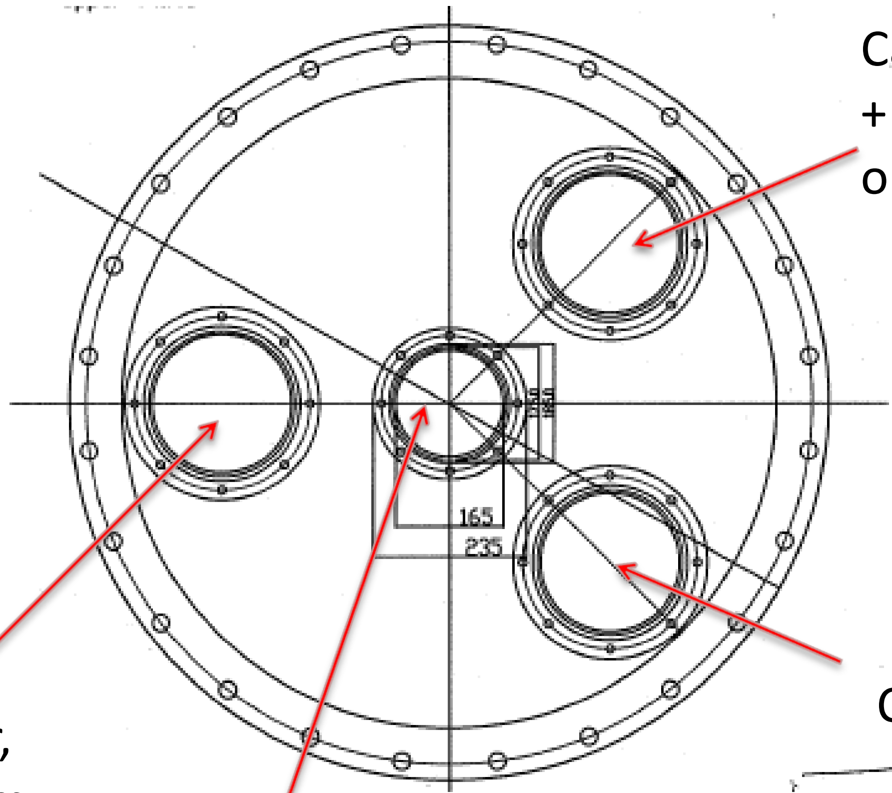


Chamber



Chamber: bottom plate design

To ZeroDegree Spectrometer



Beam

Cable flange
+ preamps mounted outside chamber

Cable flange

Scintillator, on platform with drive

Microball on stand
+ target ladder on drive
+ collimator

Preparation To Be Completed

- Microball Mount Design
  - Microball should be centered on beamline (splitting rings apart)
  - Platform mounts to center flange
  - Target drive mechanism moves from underneath
  - Attach collimator on platform
- Sn Target Ladder Design
  - Moves between the two halves of microball
  - Need enough room below microball platform for ladder length to move in/out of beamline
  - Rachel will roll out targets this week
- Scintillator/beam counter downstream of target
  - Design of movable platform
- Need to buy two target mechanisms, remote controlled

Preparation To Be Completed, continued

- Cables:
  - Length depends on position of microball, scintillator and distances to flanges
  - May need cable extenders for microball
- Electronics
  - WU preamps mounted outside chamber
- Adapters for flanges: based on cables used, designs of microball and scintillator platforms, preamps mounted to outside
- Machining:
  - Microball platform mount
  - Scintillator platform
  - Flange adaptors as needed

Rough Timeline

- February 15: finalize the design of the inside of chamber
- March 1: finalize design of target ladder
- April 1: start to order machining and other devices
- April 1: start to test electronics
- May 7: start to mount the detectors in chamber
- May 27: ready to install vacuum chamber to F8, check alignment. (Need to move the date in view of new schedule)
- June 10-15: Experiment runs (official as of Jan. 28)
- June 27: User Meeting