An m/q Spectrometer for FRIB

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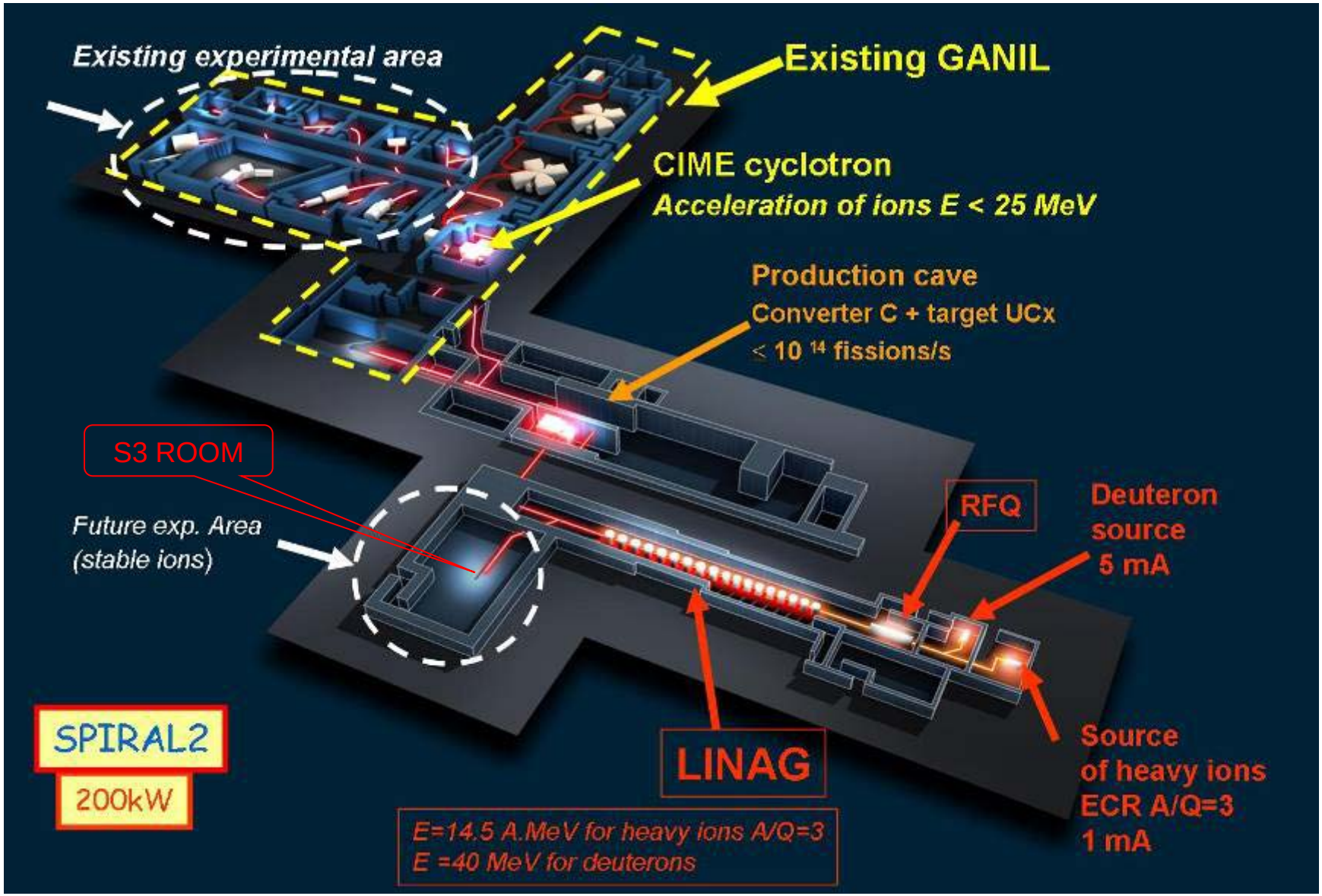
A spectrometer for use with reaccelerated beams at FRIB

Electromagnetic mass separators are essential tools for studies of exotic nuclei at stable beam facilities especially for in-beam gamma spectroscopy.

Similar devices will be indispensible for experiments with reaccelerated radioactive beams at FRIB.

This group has started to look at the recently designed m/q spectrograph planned for construction for SPIRAL2 stable beams at GANIL.


Existing experimental area
Existing GANIL
CIME cyclotron
Acceleration of ions E < 25 MeV
Production cave
Converter C + target UCx
< 10 14 fissions/s
S3 ROOM
Future exp. Area
(stable ions)
RFQ
Deuteron
source
5 mA
SPIRAL2
200kW
LINAG
Source
of heavy ions
ECR A/Q=3
1 mA
E=14.5 A.MeV for heavy ions A/Q=3
E =40 MeV for deuterons

Beam parameters and optic requirements for S^3

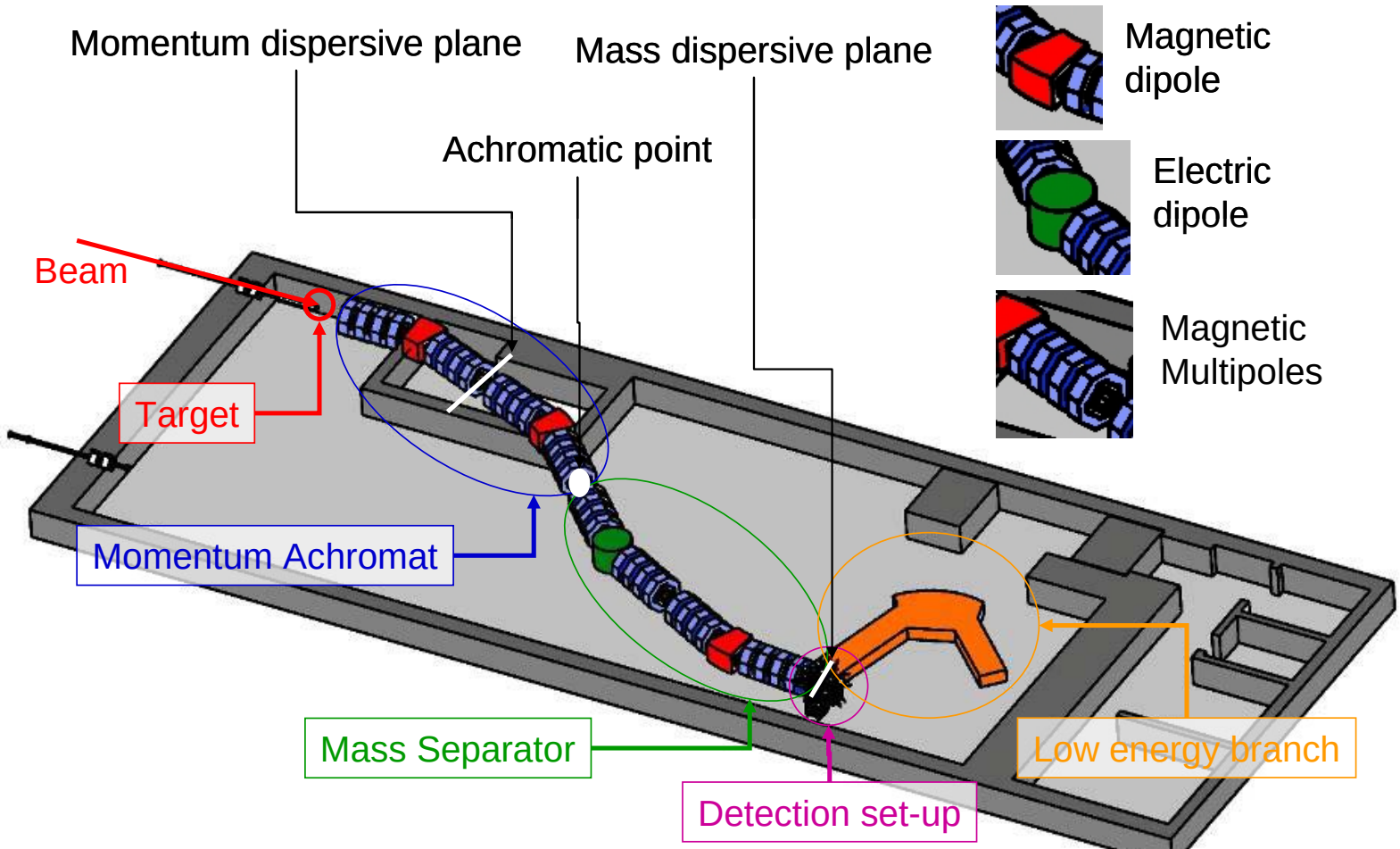
- ❑ **Intense Beam ≈ 1E+14 particles/second**
- ❑ **Low Energy < 5Mev/nucleon**
- ❑ **Angular acceptance > +/- 60 mrad in X and Y**
- ❑ **Bρ acceptance: +/- 10%**
- ❑ **$B\rho_{max}$ (reaction products) = 2Tm**
- ❑ **$E\rho_{max}$ = 12 MV**
- ❑ **Mass resolution = 1/350**
- ❑ **Additional constraints to accommodate detector and experimental requirements**

- Separation of very rare events from intense backgrounds
- Large beam acceptance and high selectivity for weak reaction channels are required

No existing instruments can presently achieve this. The design of S^3 is unique and challenging in this respect

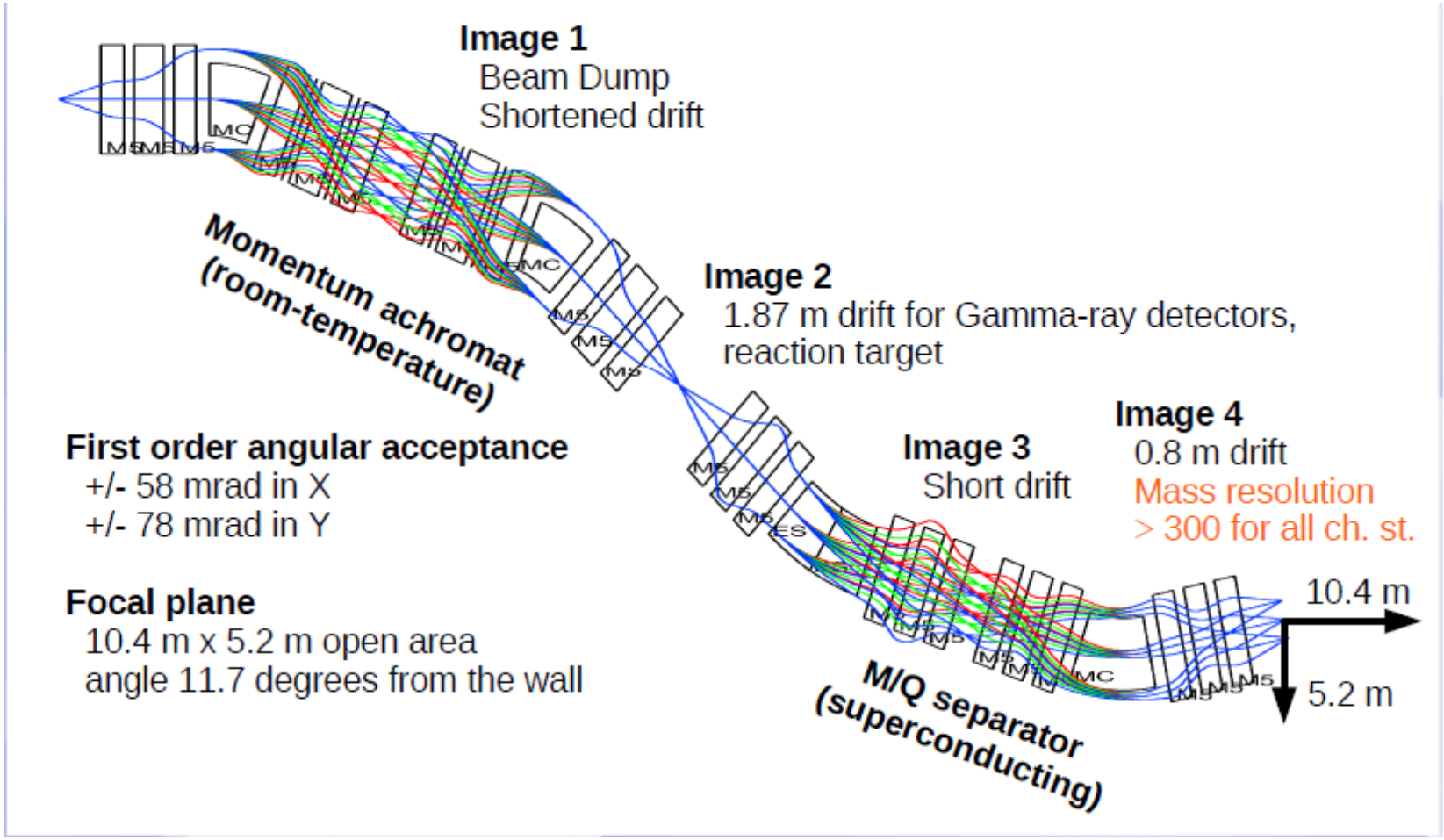
Proposed Solution: Two-stage selection (Bρ and m/q) that will achieve very good rejection of both the beam and adjacent mass channels of reaction products

S³ Layout



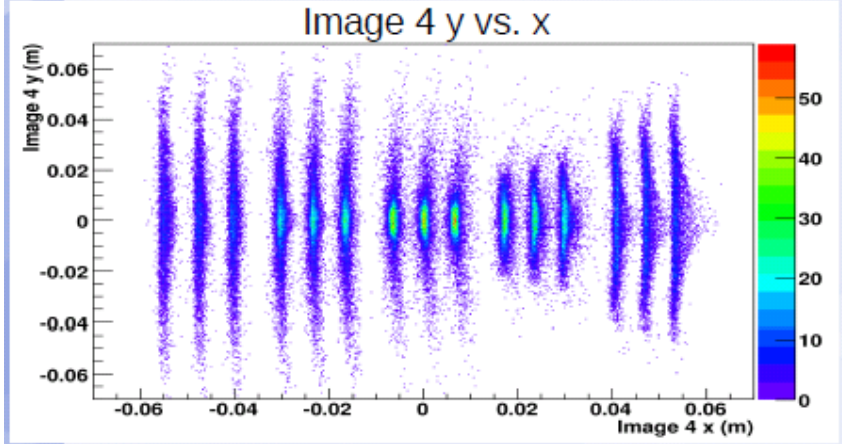
- Inner dimension of the room: 31m X 15m , S3 device 28.1m
- 2 doublets before target to adjust spot shape
- Beam swinger not shown; could be added

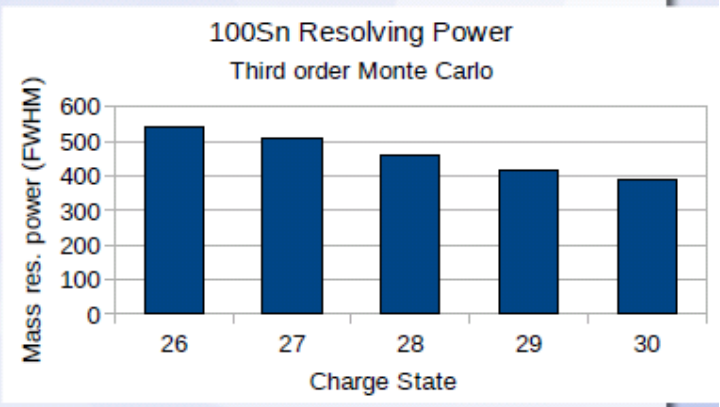
Current Optimized design for S3 (Matt Amthor, GANIL)

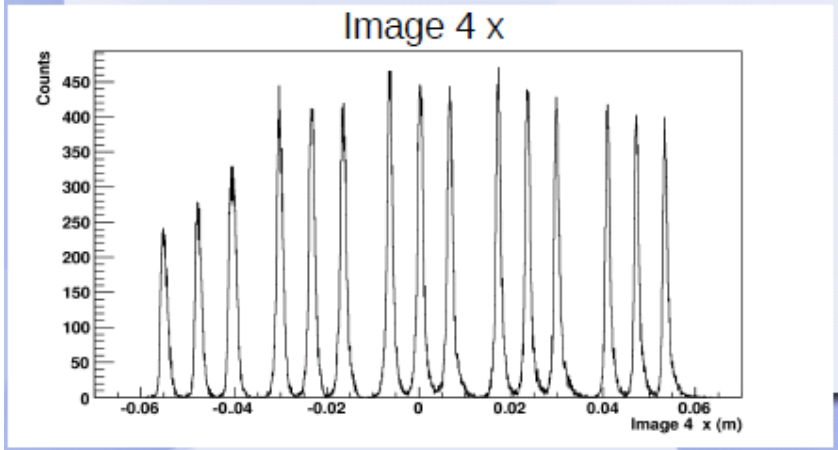


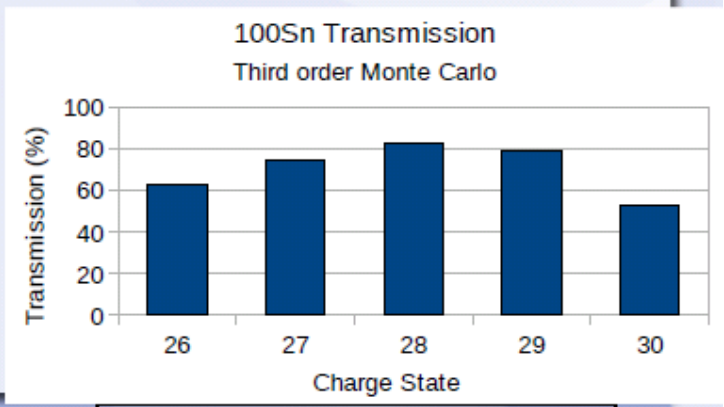
^{100}Sn Resolution and Transmission (Matt Amthor, GANIL)

3rd order corrected but aberrations up to 5th order considered



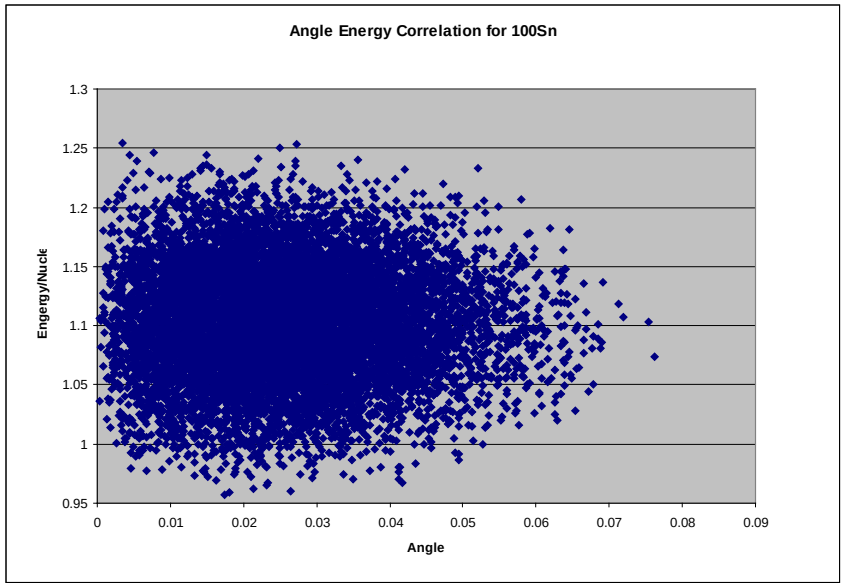


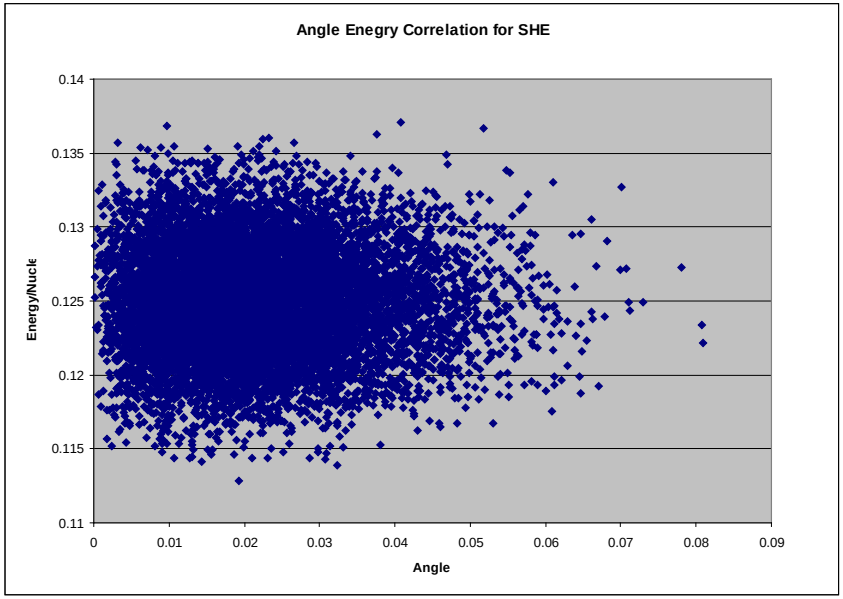




Folded Transmission = 56%

Angle Energy Correlation in the recoil beam





Separator for Unique Products of Experiments with Radioactive beams "SUPERB"

- Based on the mass separator section of S3
- Large M/Q acceptance +/-10%
- Large distance between the target and the separator to accommodate a 4π Ge array (1 m drifts)
- Cost ~$4M

^{100}Sn with radioactive beams – some options

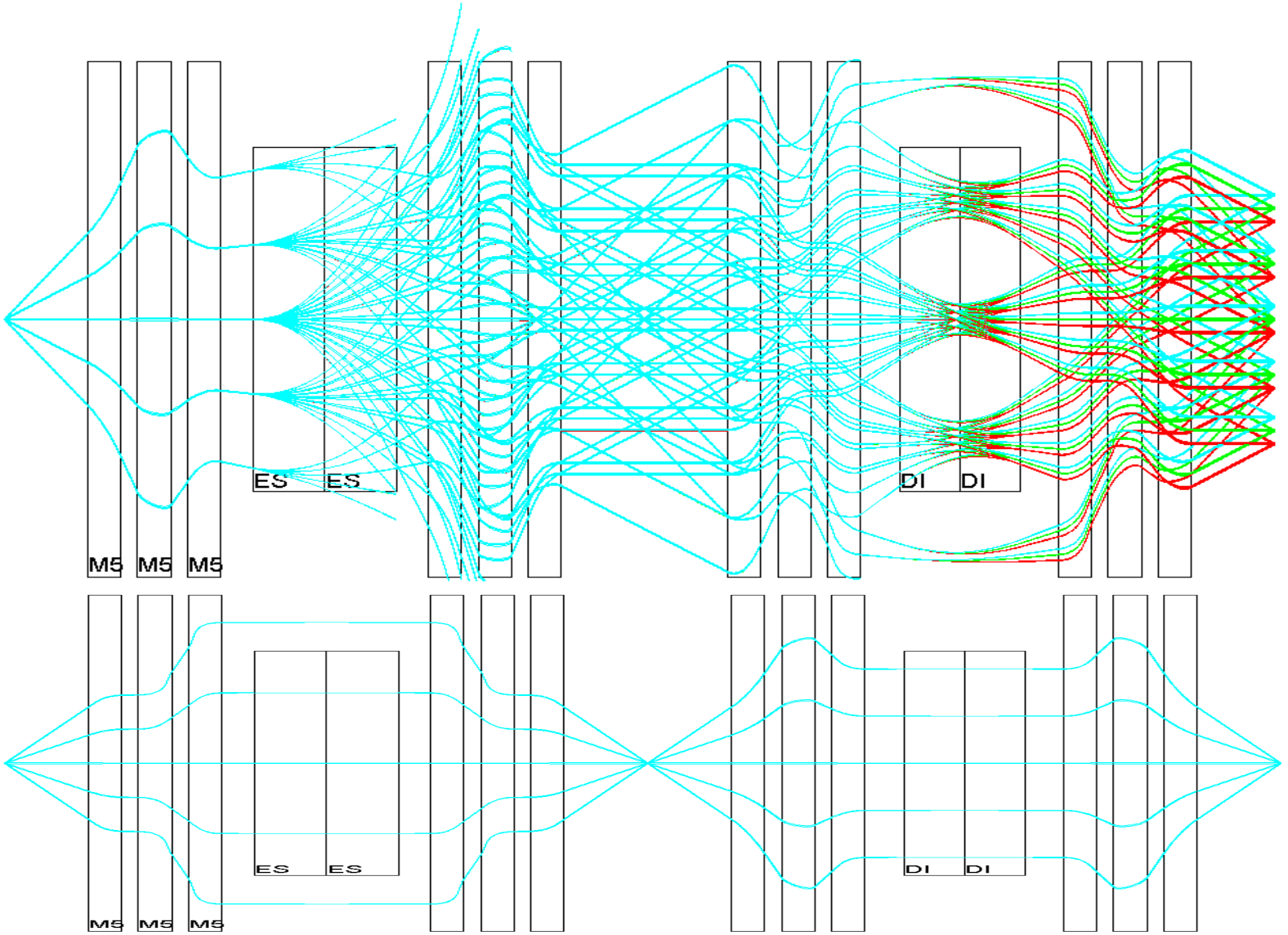
- ^{63}As+^{40}Ca→^{100}Sn+p2n
  - Beam intensity10^{8} part/s
  - Cross section 10 µb
  - Beam energy 207 MeV
  - Recoil energy and charge state 105/25 MeV/Q
  - Recoil energy 105/100 MeV/u
  - Electric field 420 kV / 20 cm
  - Yield 800 ^{100}Sn / day

Channel selection
by decay tagging

- ^{75}Rb+^{28}Si→^{100}Sn+p2n (10µb)
  - Beam intensity 10^{7} part/s
  - Cross section 10 µb
  - Beam energy 245 MeV
  - Recoil energy and charge state 151/28 MeV/Q
  - Recoil energy 155/100 MeV/u
  - Electric field 550 kV/20 cm
  - Yield 110 ^{100}Sn / day

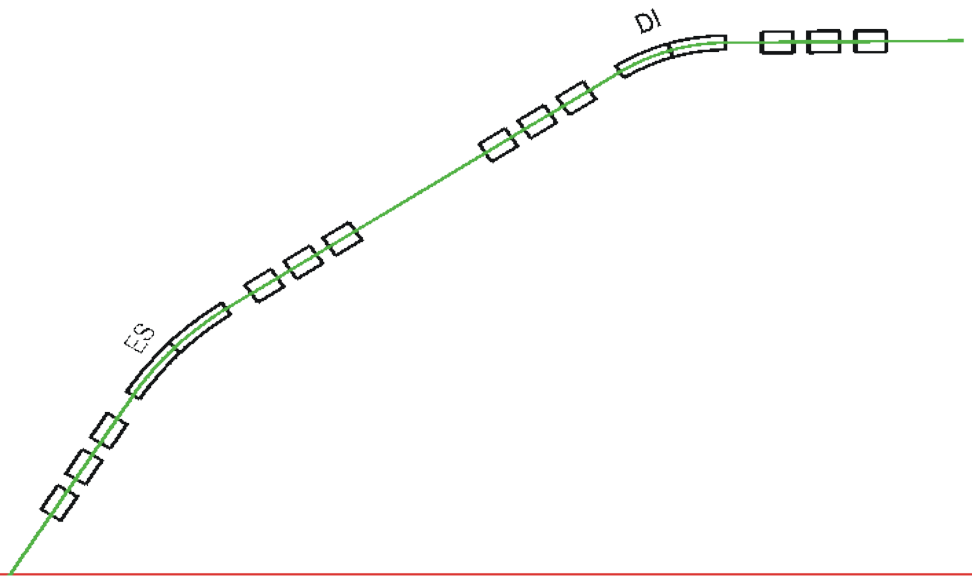
Channel selection
by direct ΔE measurement

SUPERB First Order Optics:



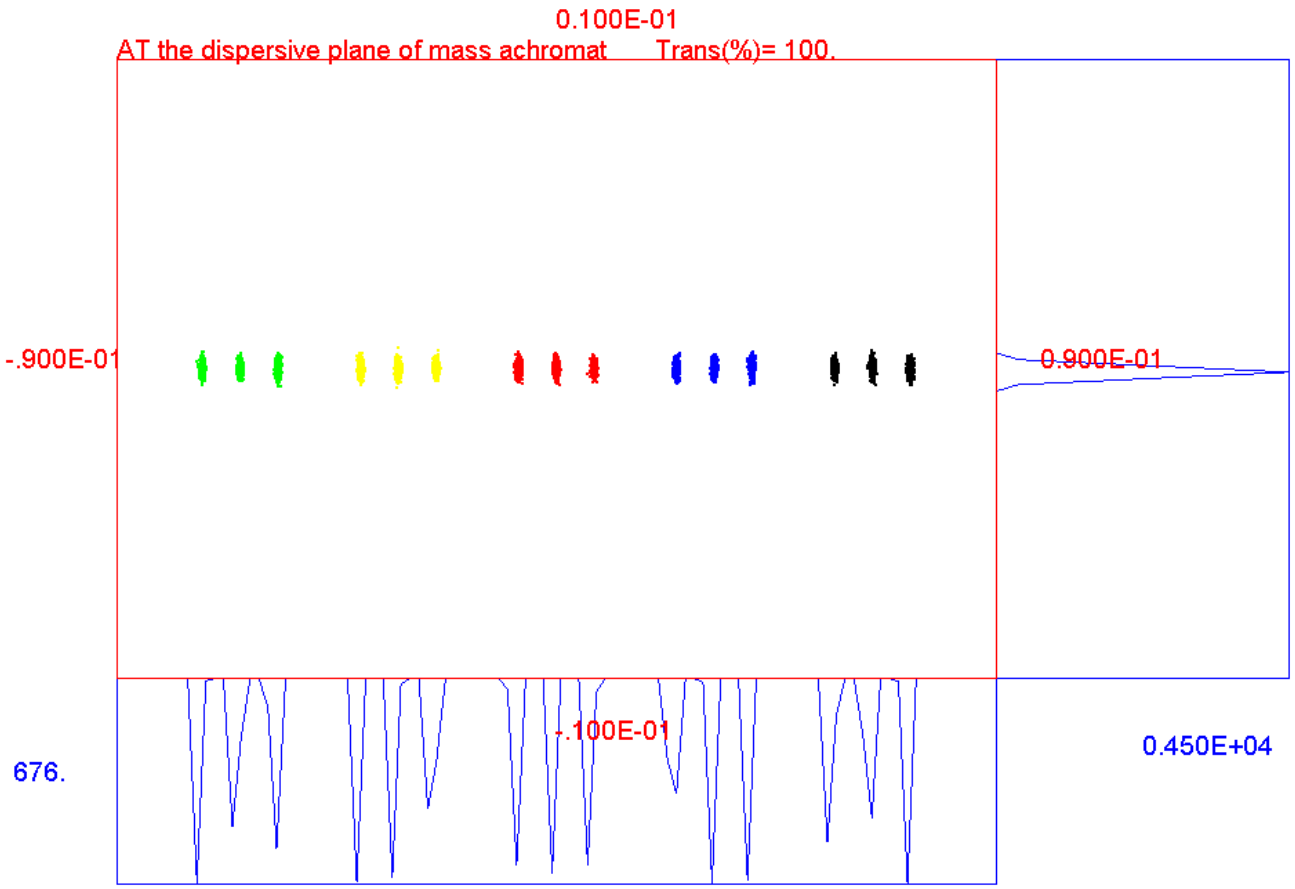
SUPERB Layout

Inner dimensions of the room 16mX13m



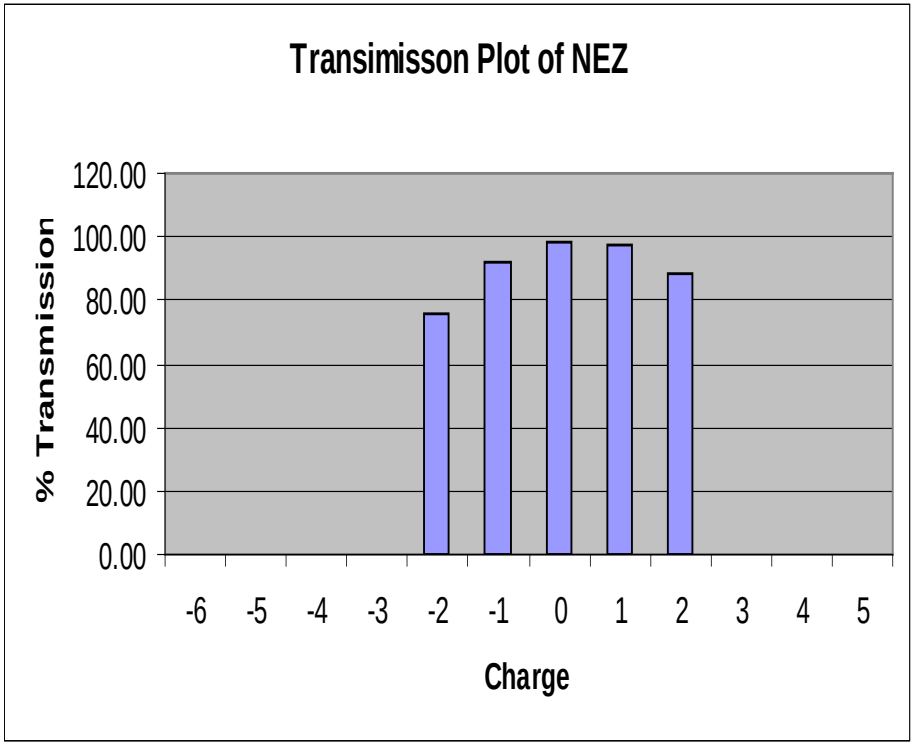
Final Mass dispersive focal Plane

7 mm per percent of the mass dispersion



First order Transmission for 100Sn

Δq	Transmission for NEZ (%)		
	58Ni+46Ti -> 100Sn+4n		%
	%	Order 1	
-6	0.4	0.00	0.00
-5	1	0.00	0.00
-4	2.4	0.00	0.00
-3	5.7	0.00	0.00
-2	10.8	75.89	8.20
-1	16.2	92.40	14.97
0	19.2	98.46	18.90
1	18.1	97.70	17.68
2	13.4	88.48	11.86
3	7.8	0.00	0.00
4	3.6	0.00	0.00
5	1.3	0.00	0.00
6	0	0.00	0.00
			71.61



Summary

- Vacuum separator with physical separation of 5 charge states of specific m/q values
- High transmission, ~70% for symmetric and slightly inverse kinematics fusion
- Useful for studies at ~100Sn and for heavy element spectroscopy, especially for in-beam gamma spectroscopy