Superheavy Element Research at the Berkeley Gas-filled Separator

Jacklyn M. Gates

Lawrence Berkeley National Laboratory

Outline

- BGS
- Gas mixtures
- GRETINA@BGS

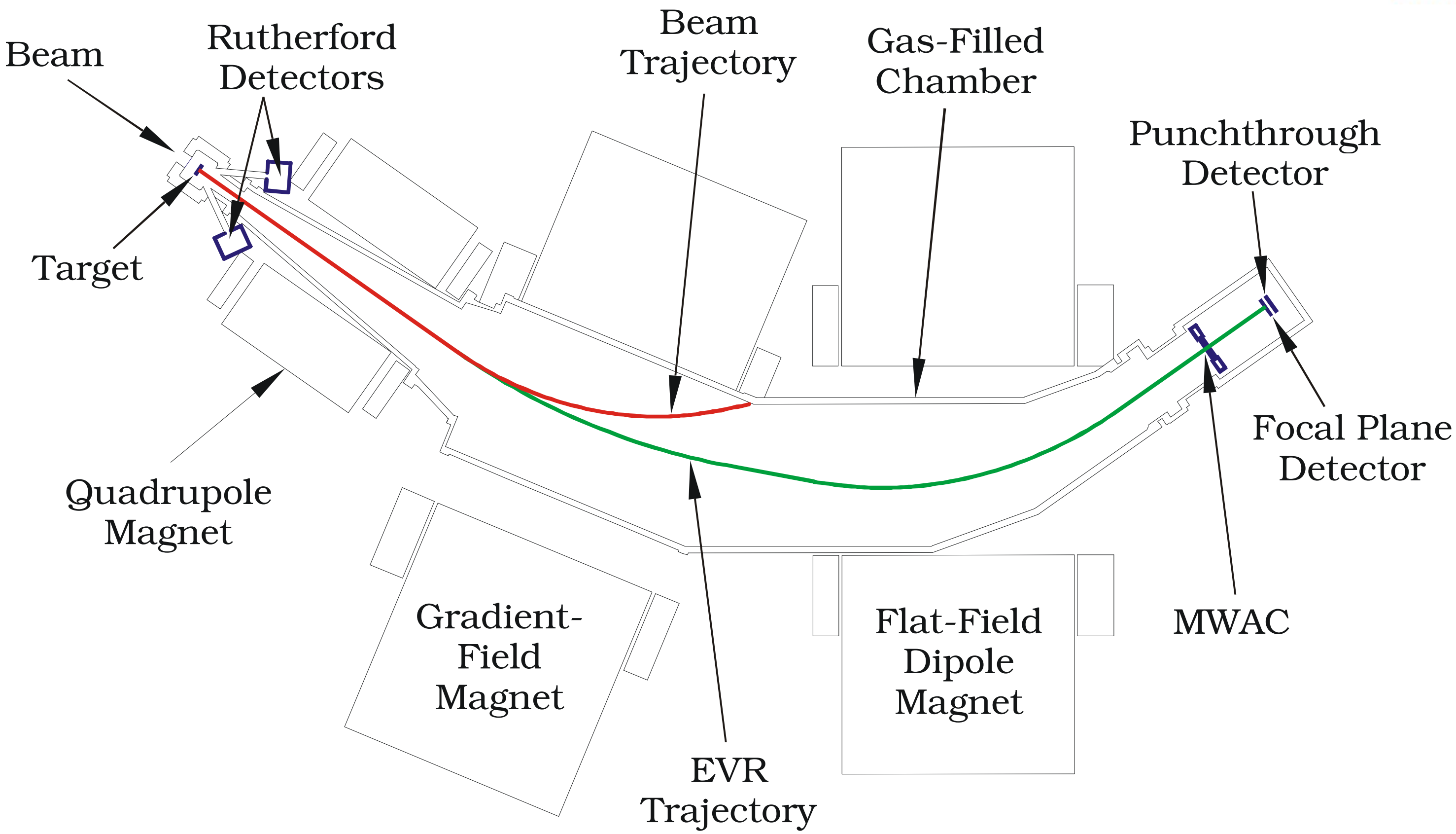
LBNL Heavy Element Group

Heino Nitsche	Group Leader, UCB Prof. of Chem.
Ken Gregorich	Senior Staff Scientist
Jacklyn Gates	Project Scientist
Gregory Pang	Postdoctoral Fellow
Paul Ellison	Graduate Student/Postdoctoral Fellow
Oliver Gothe	Graduate Student
Nick Esker	Graduate Student
Joe McLaughlin	Undergraduate Student

With help from

The Nuclear Structure Group
Walter Loveland (Oregon State U.)
and others

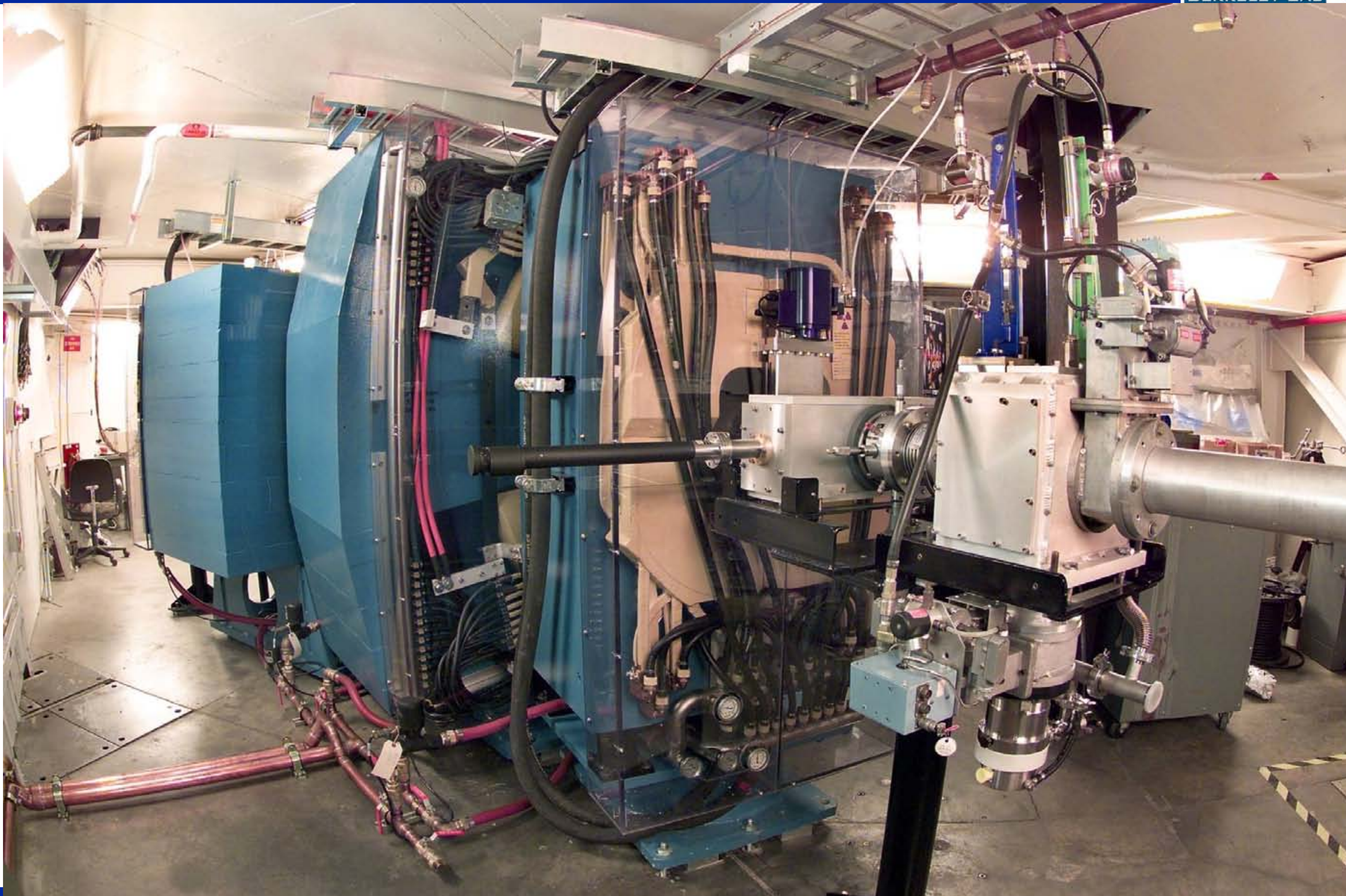
Berkeley Gas-filled Separator (BGS)



- Compound nucleus recoils are ejected from the target with the momentum of the beam
- In 0.5-Torr He, they experience many charge-changing collisions, giving 100% charge acceptance
- Average charge is (nearly) proportional to velocity, giving *LARGE* velocity acceptance
- Compound nucleus evaporation residues (EVRs) are focused on the detector array everything else has a smaller magnetic rigidity, and takes a left turn

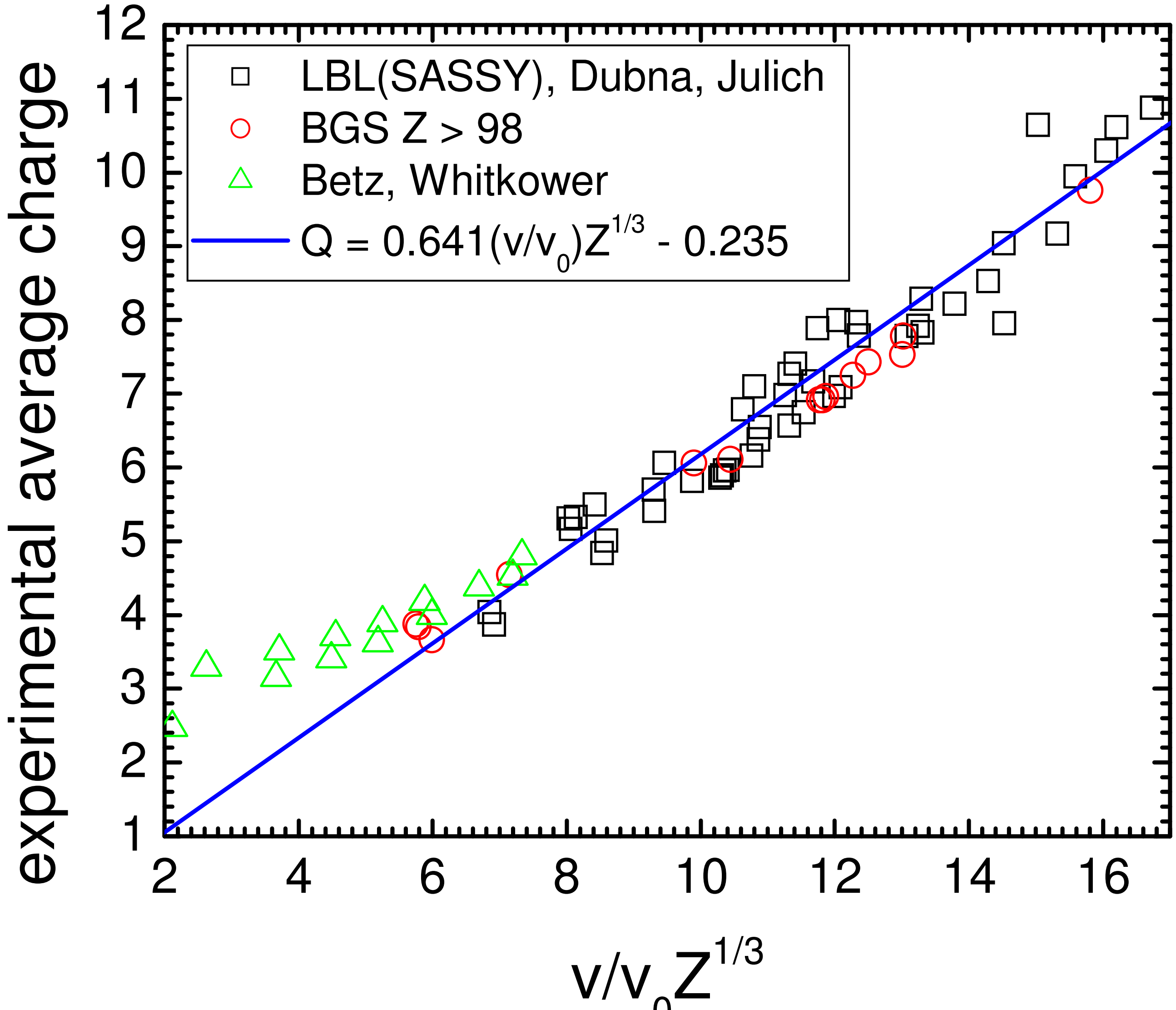
Berkeley Gas-filled Separator (BGS)

BERKELEY LAB



Understanding Magnetic Rigidity in He Gas

Back to basics . . .



Back in 1948, Neils Bohr suggested a

$q = vZ^{1/3}$ dependence

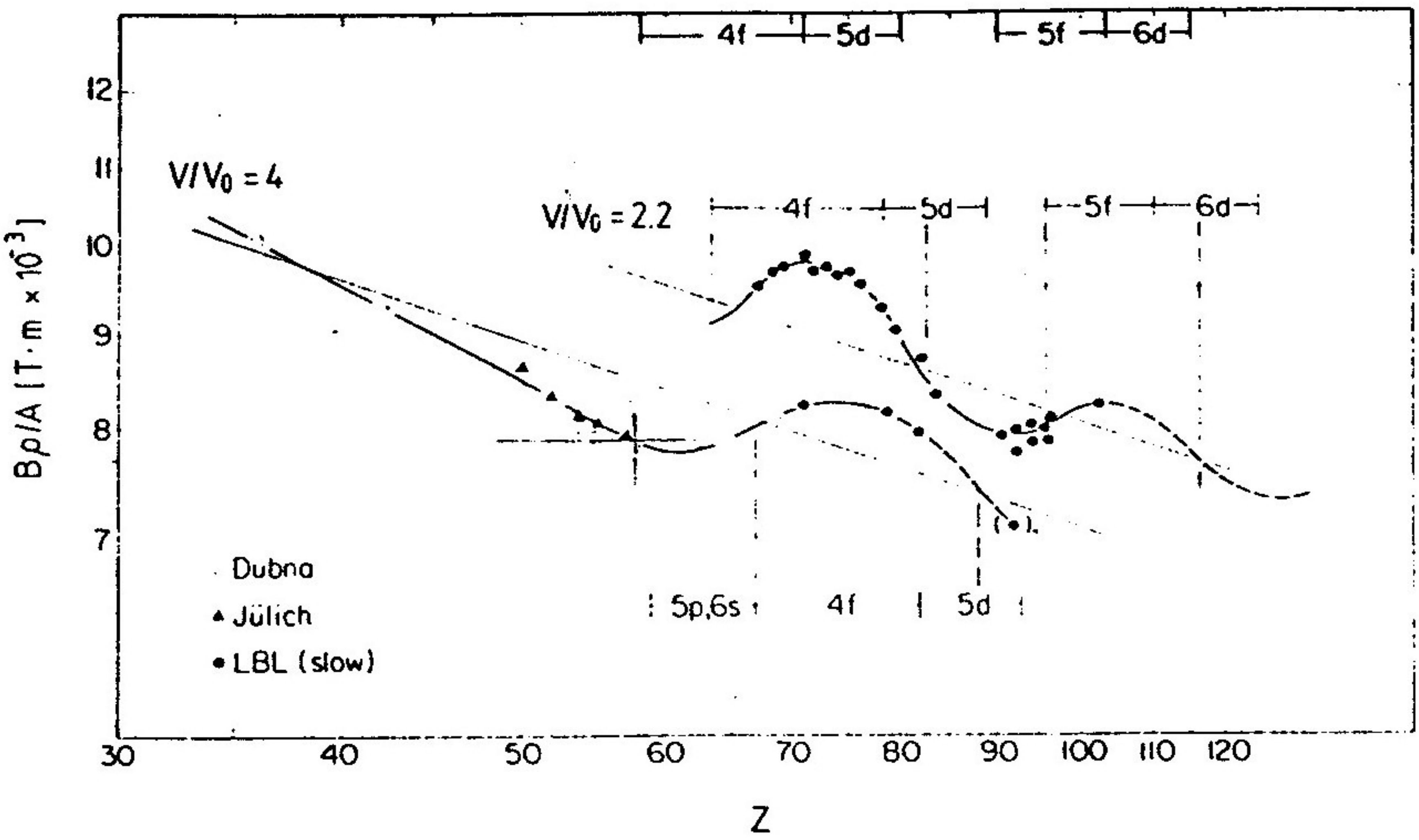
Two problems:

1) There is lots of scatter. Deviations are +/- 10%. Can this be understood in terms of the electronic shell structure of the stripped ions?

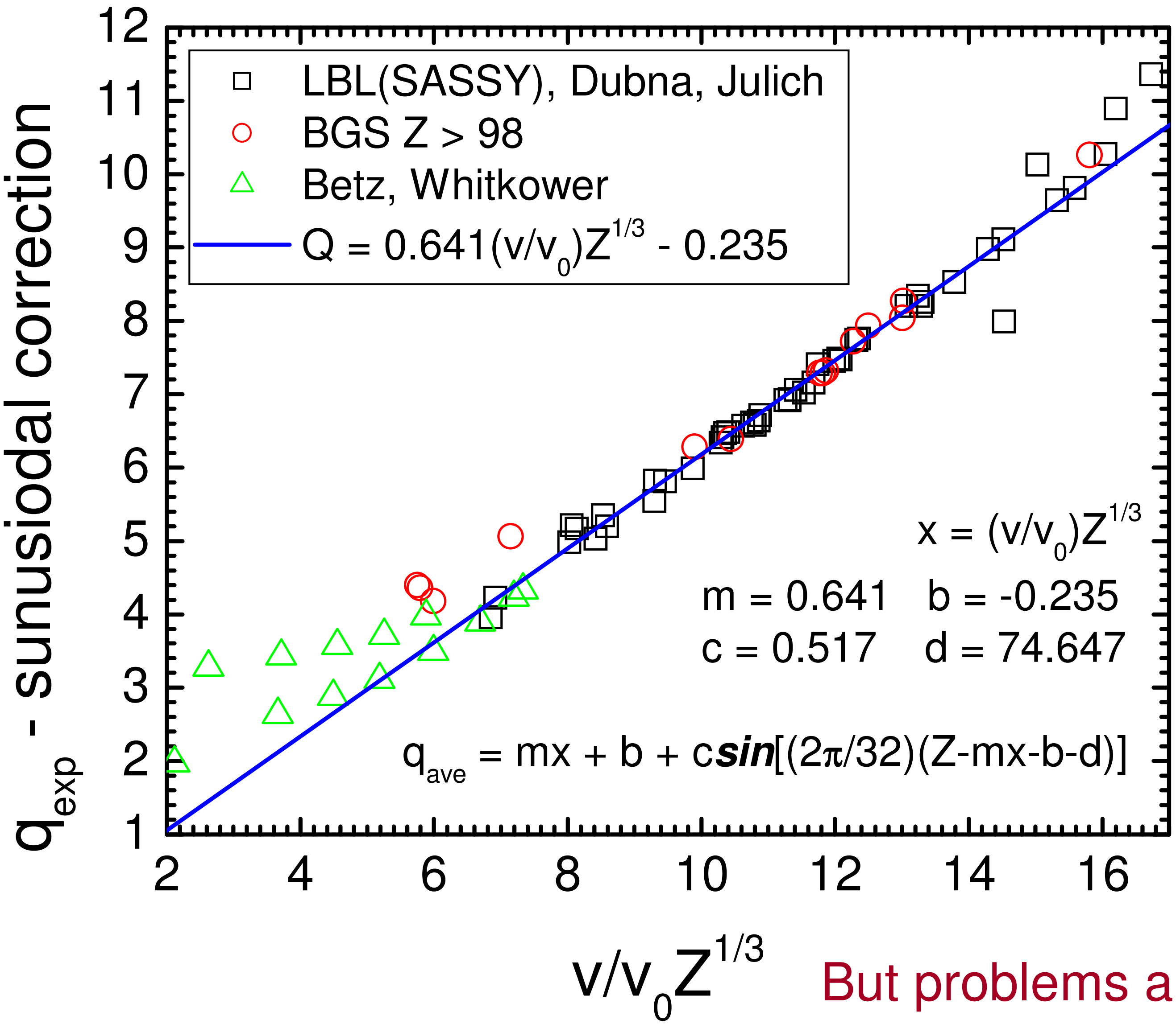
2) Strong deviations at low velocities due to the high ionization potential of He.

Ghiorso and Armbruster suggest that deviations are due to electronic shell structure of stripped ions

A. Ghiorso et al. / SASSY, a gas-filled magnetic separator



Understanding Magnetic Rigidity in He Gas
Sinusoidal correction based on electronic structure of stripped ion . . .



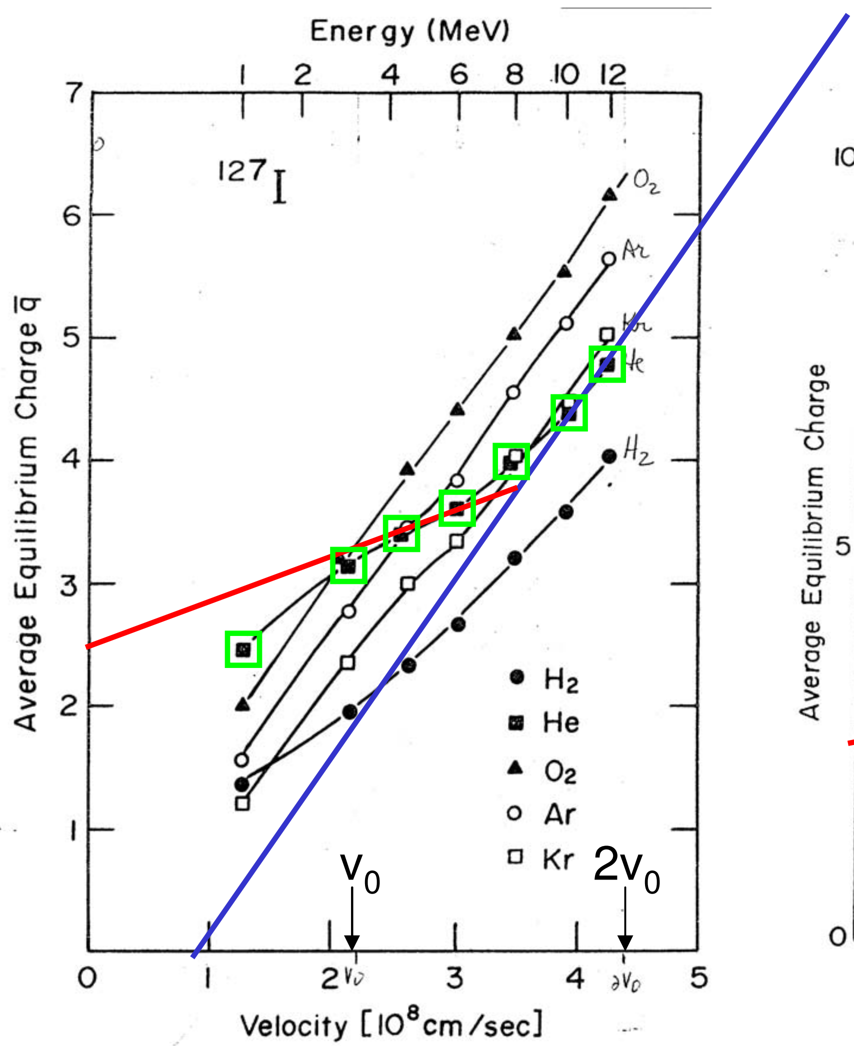
Semi-empirical understanding of why this works:

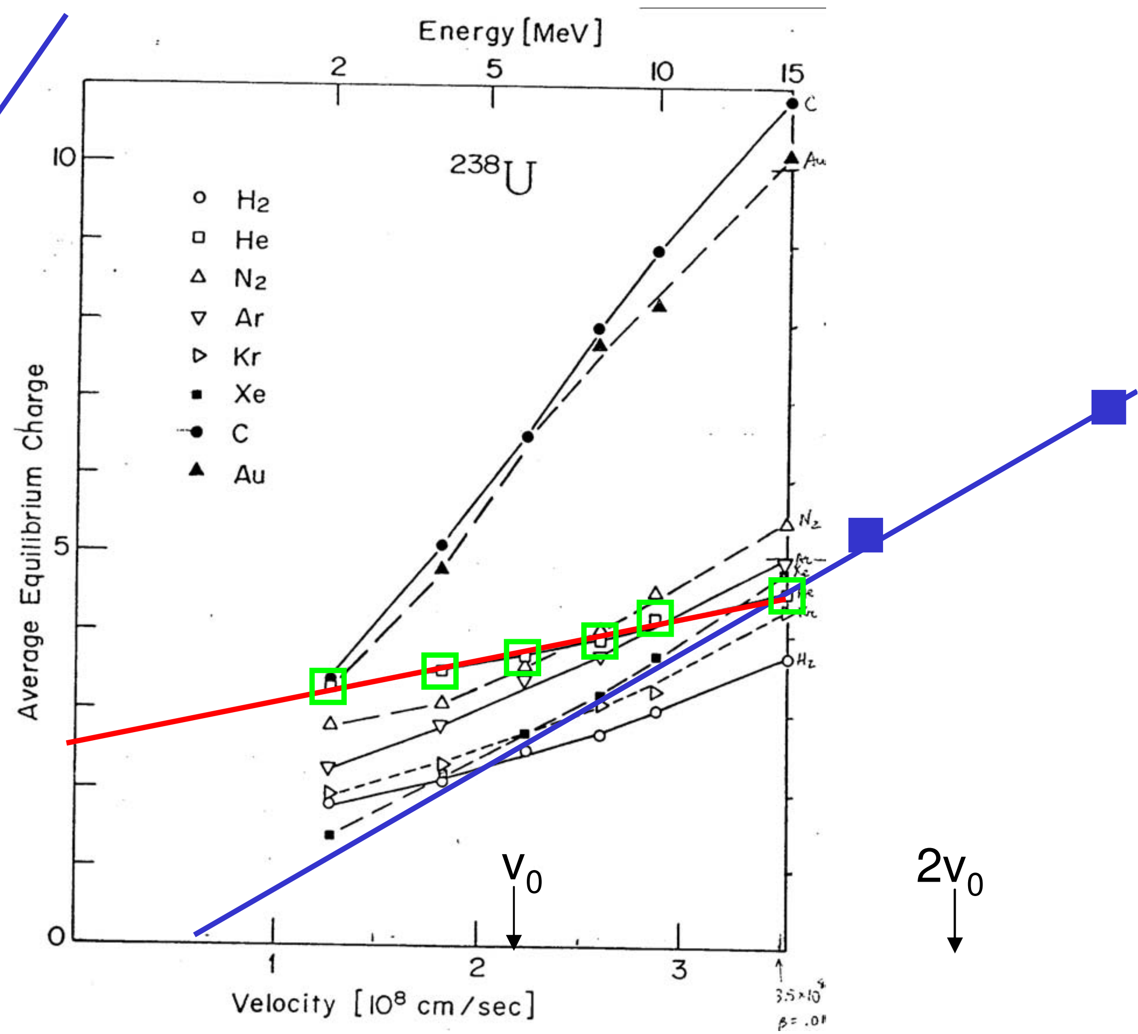
If the stripped ion is in an f-orbital, the most loosely bound electrons are inner electrons, and are less available for stripping by the gas, giving a lower q.

If the stripped ion is in a p-orbital, the most loosely bound electrons are outer electrons, and are readily available for stripping by the gas, giving a higher q.

But problems arise at low velocities!

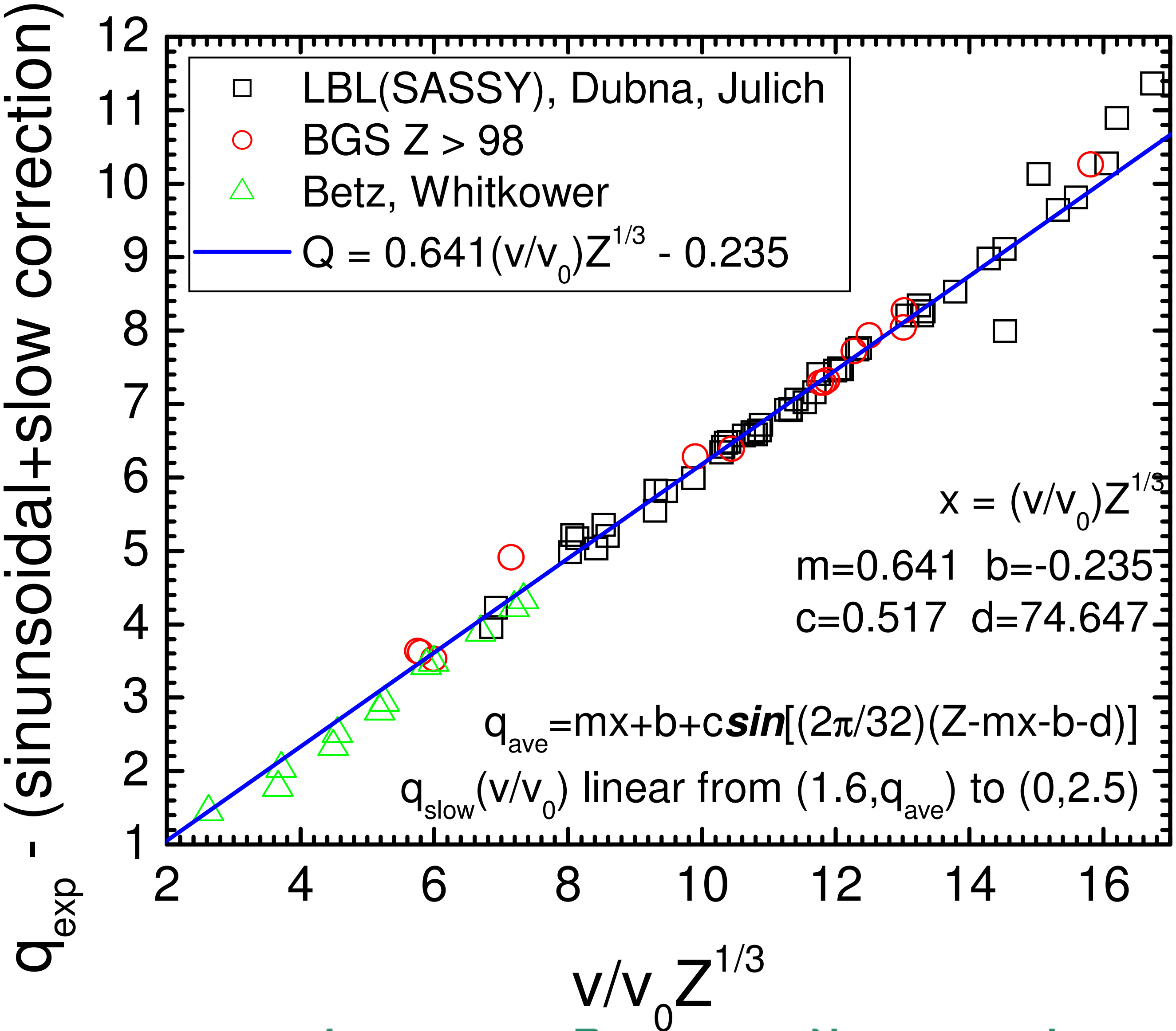
Understanding Magnetic Rigidity in He Gas
Iodine and uranium data show a break below v = 1.6v_0





The red lines trend toward q = 2.5 at v = 0 because the first of ionization potential of He is 25 eV. This is usually between the second and third ionization potentials of heavy elements.

Understanding Magnetic Rigidity in He Gas
After applying a slow velocity correction . . .

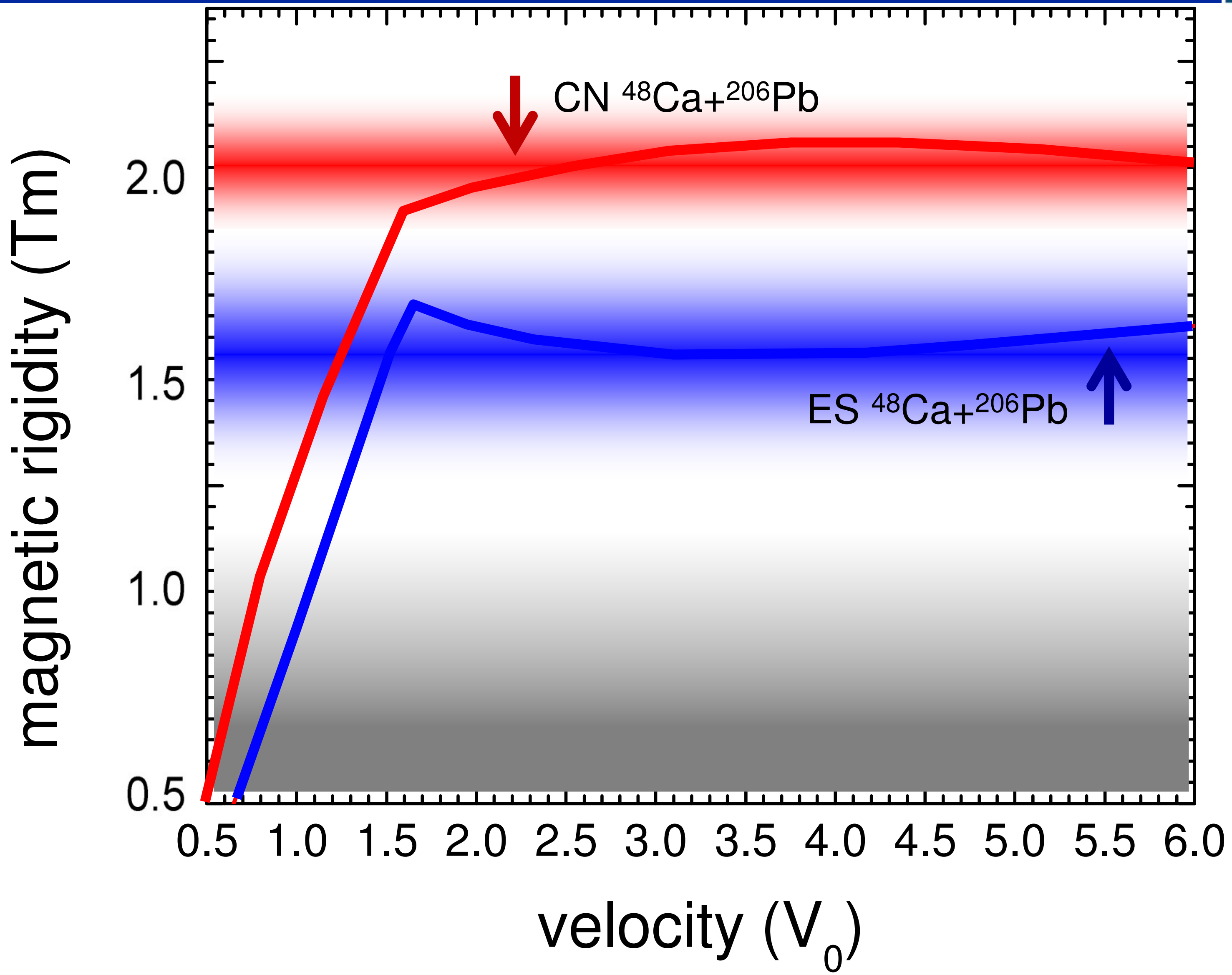


Cause of low-velocity problem: average charge tends toward positive value at low velocities because of the large He ionization potential.

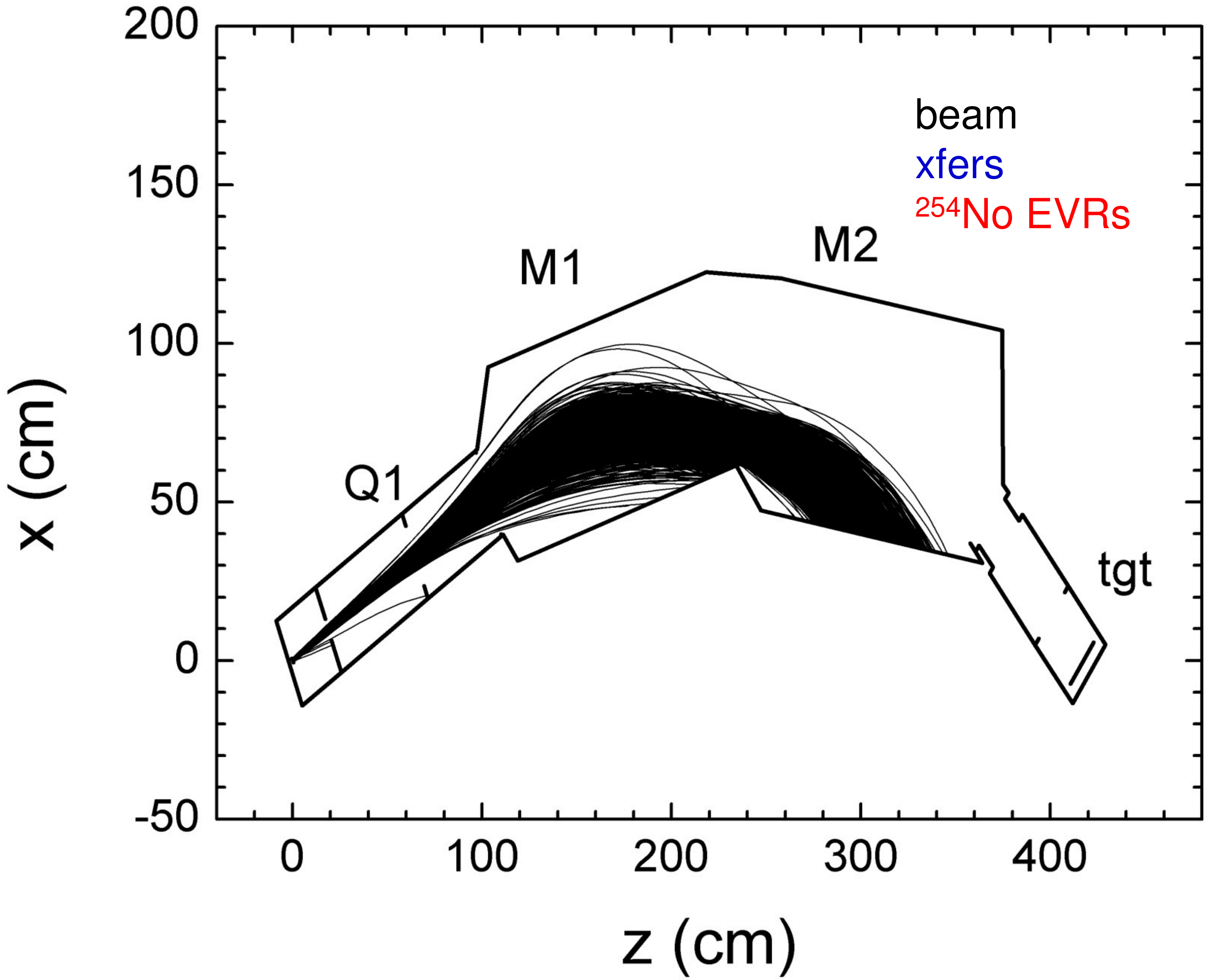
Apply correction based on simplest assumption:

Charge changes linearly between $v/v_0 = 1.6$ and $q = 2.5$ at $v=0$

Symmetric Reactions



Symmetric Reactions: $^{48}Ca+^{206}Pb$



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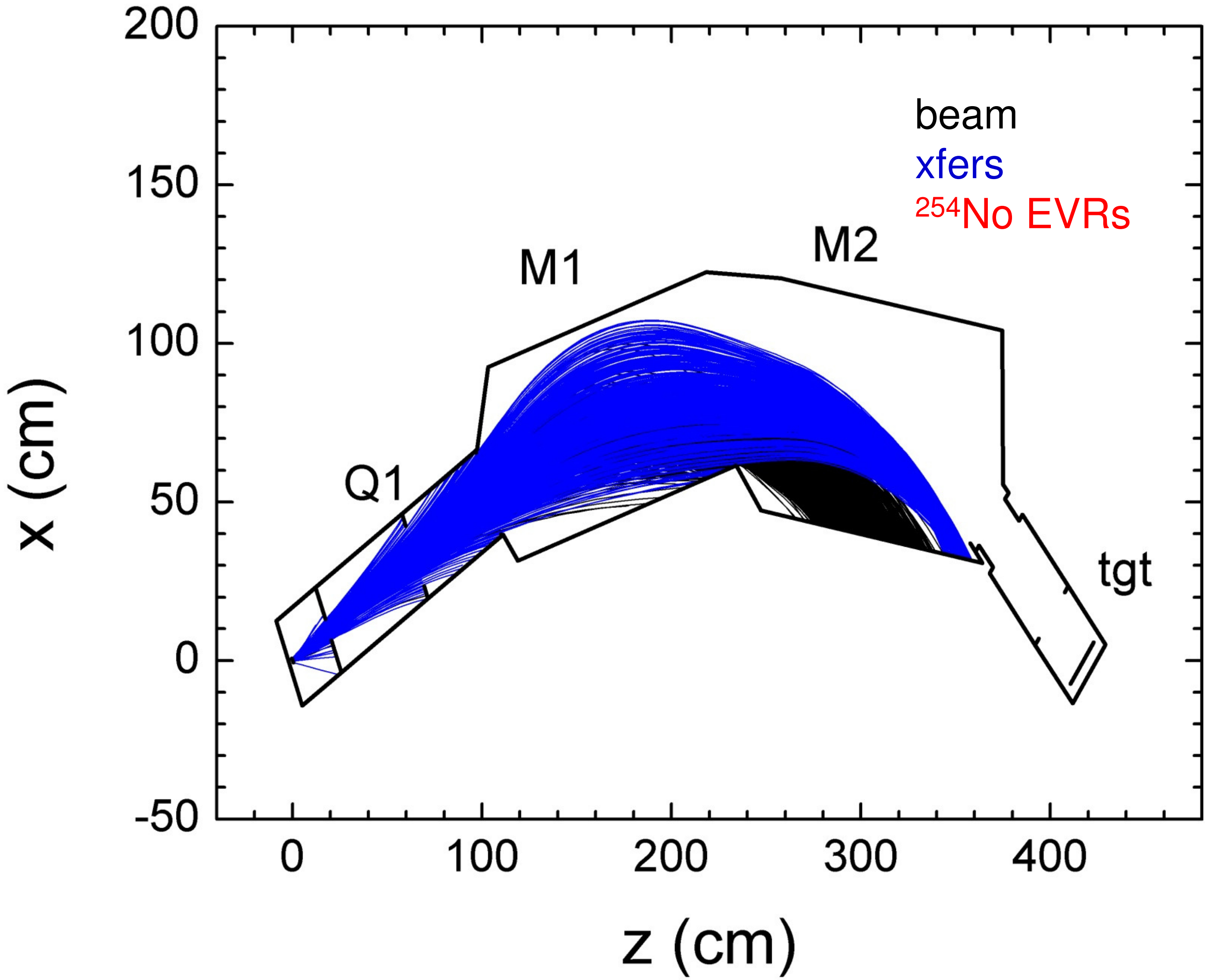

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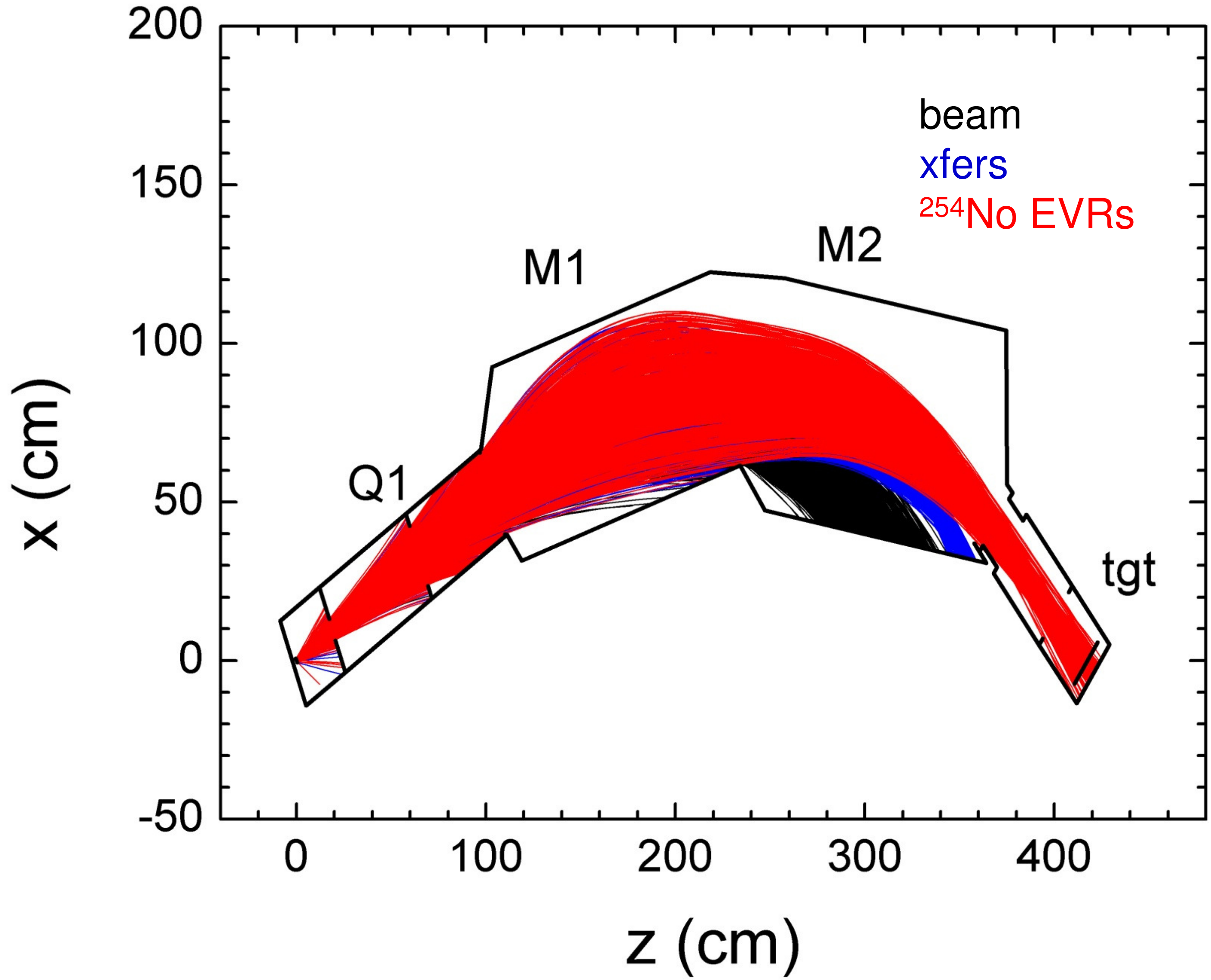
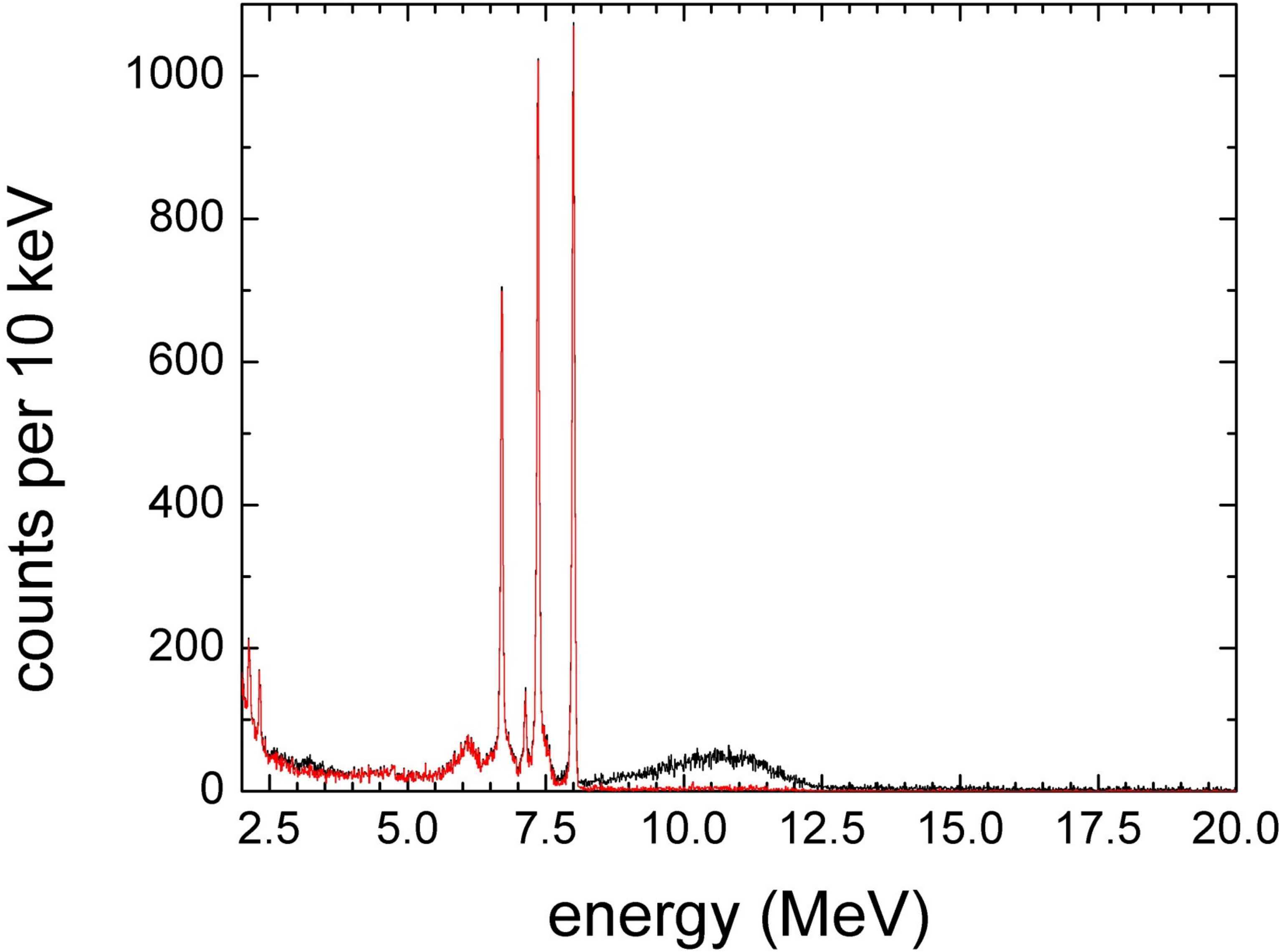
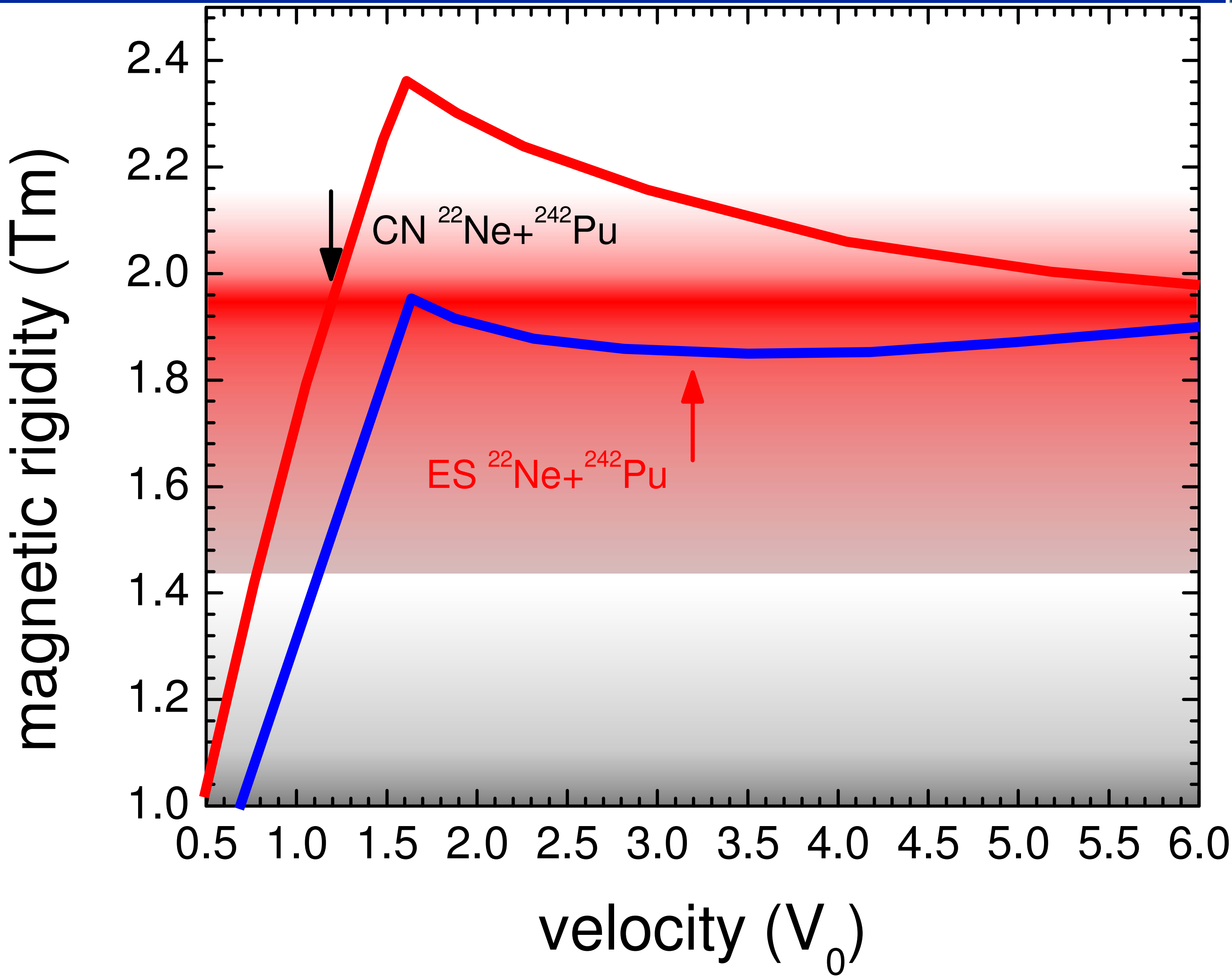


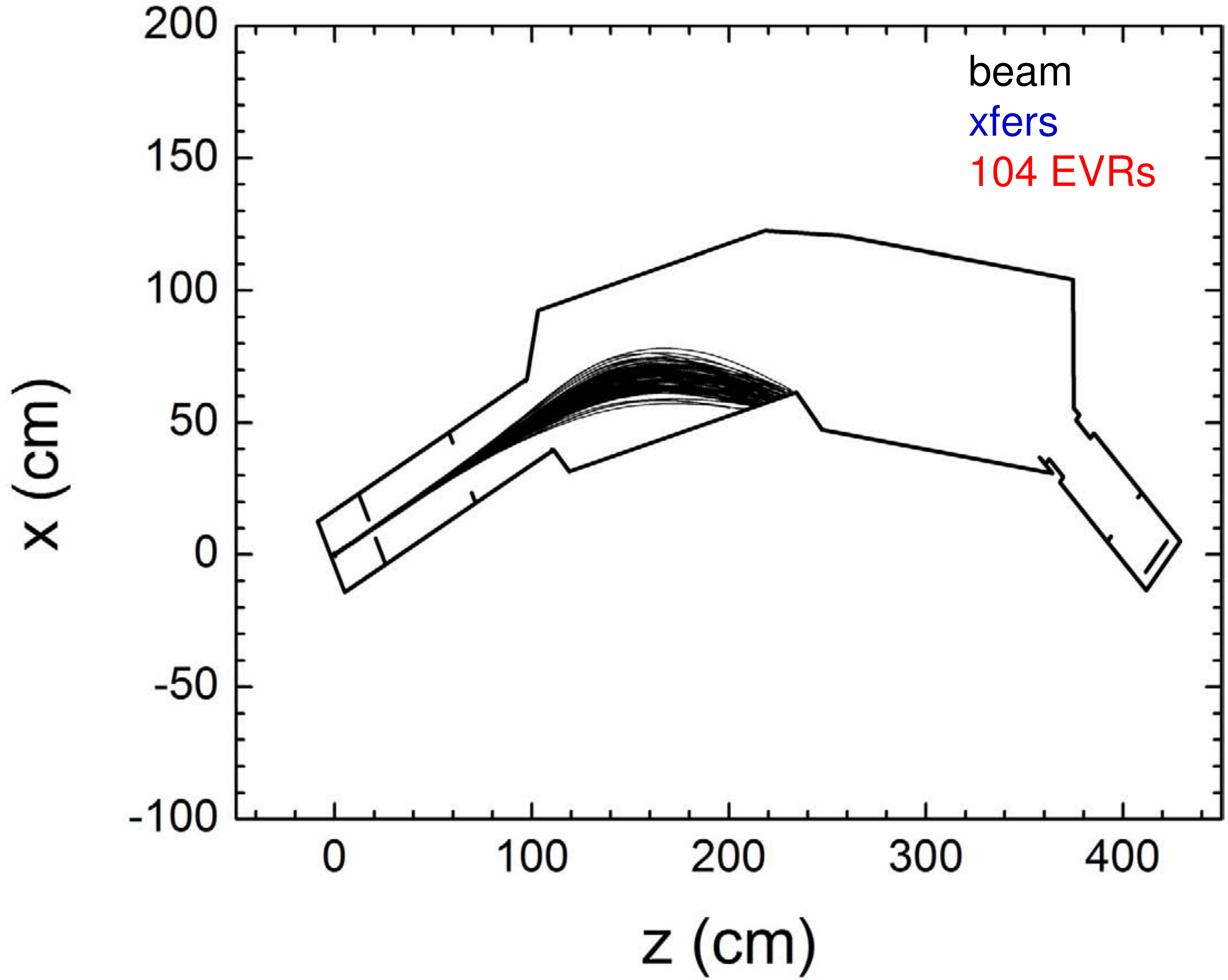
All Low Energy Events: $^{48}Ca+^{208}Pb$



Highly Asymmetric Reactions



Asymmetric Reactions: $^{22}Ne+^{242}Pu$



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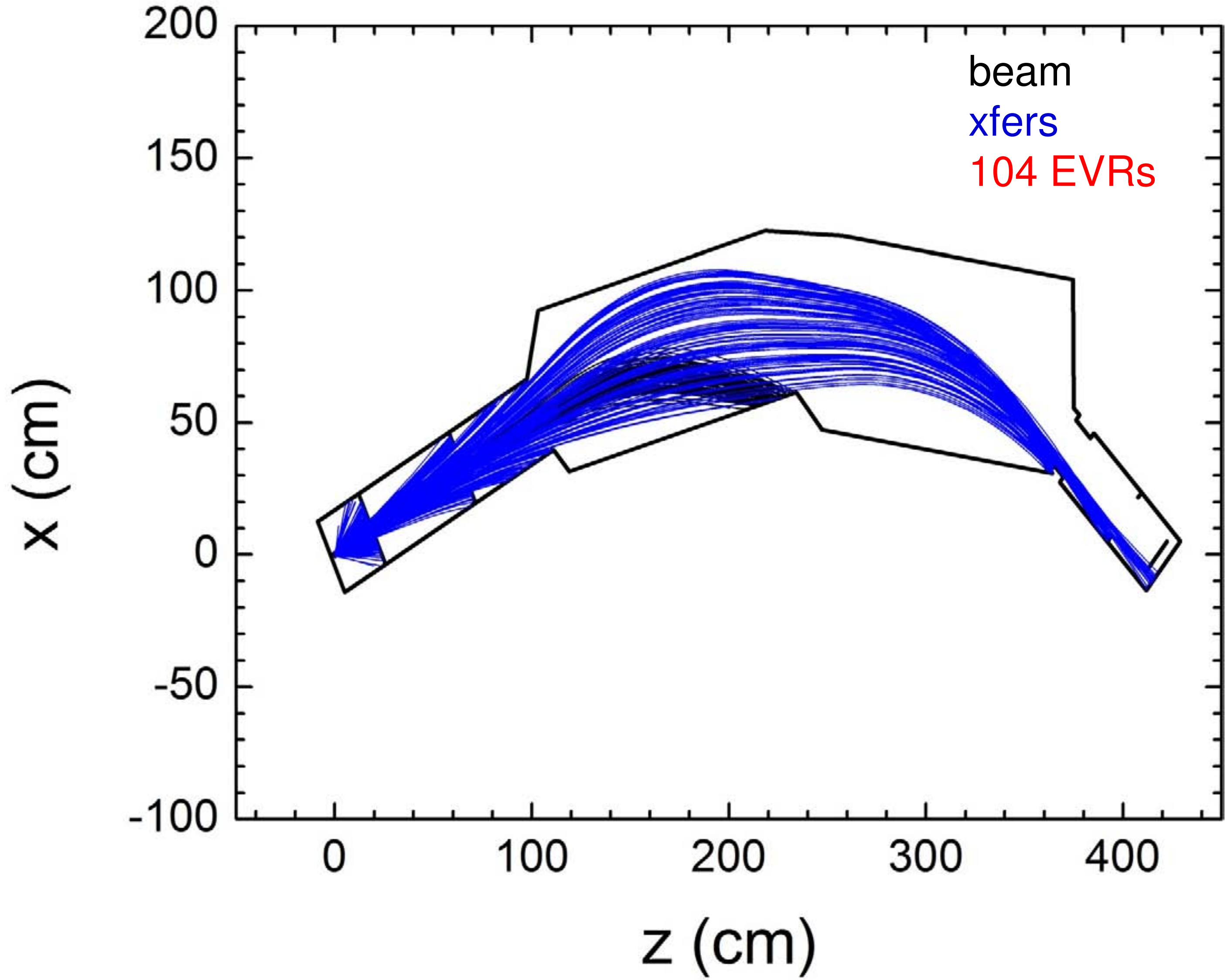

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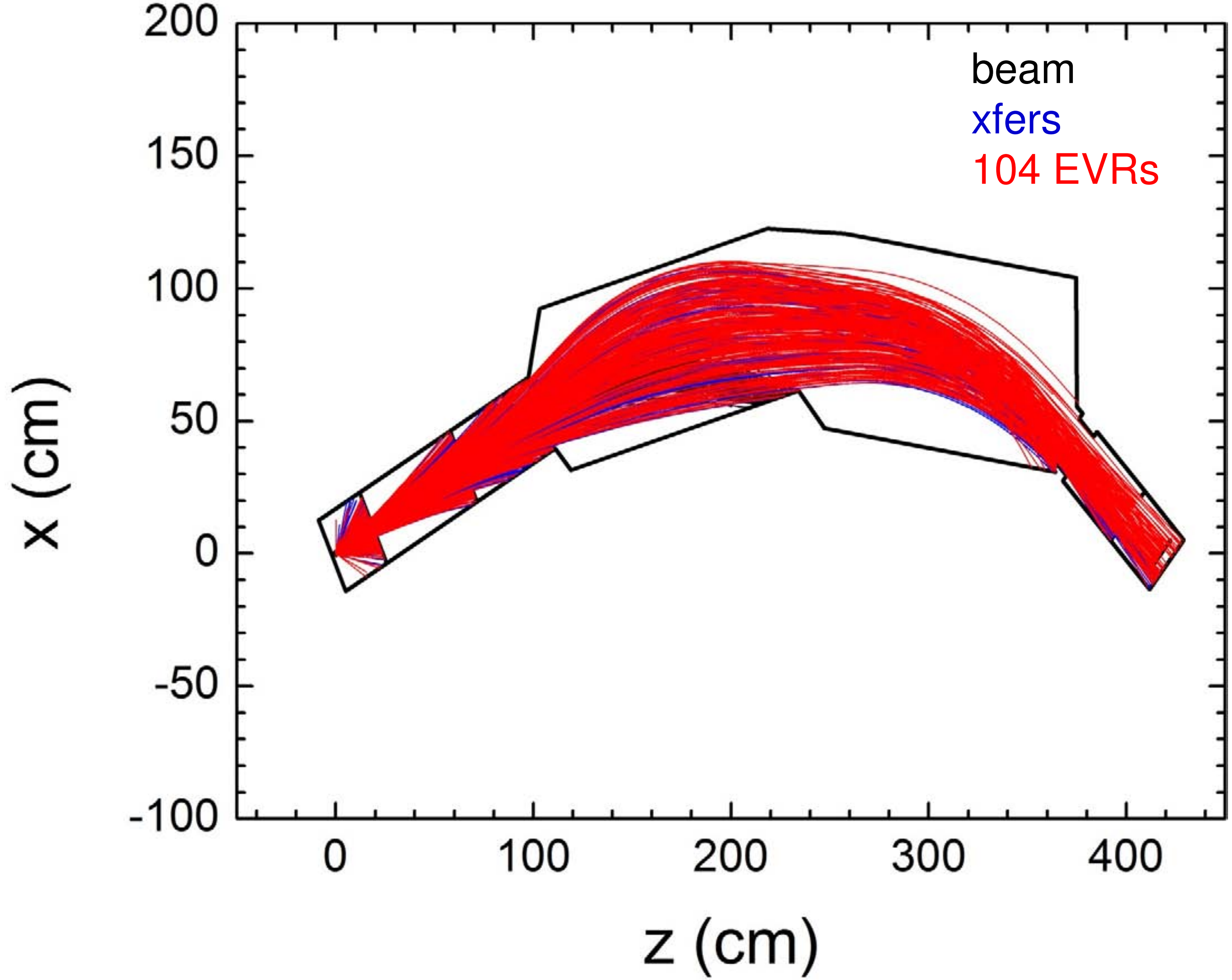
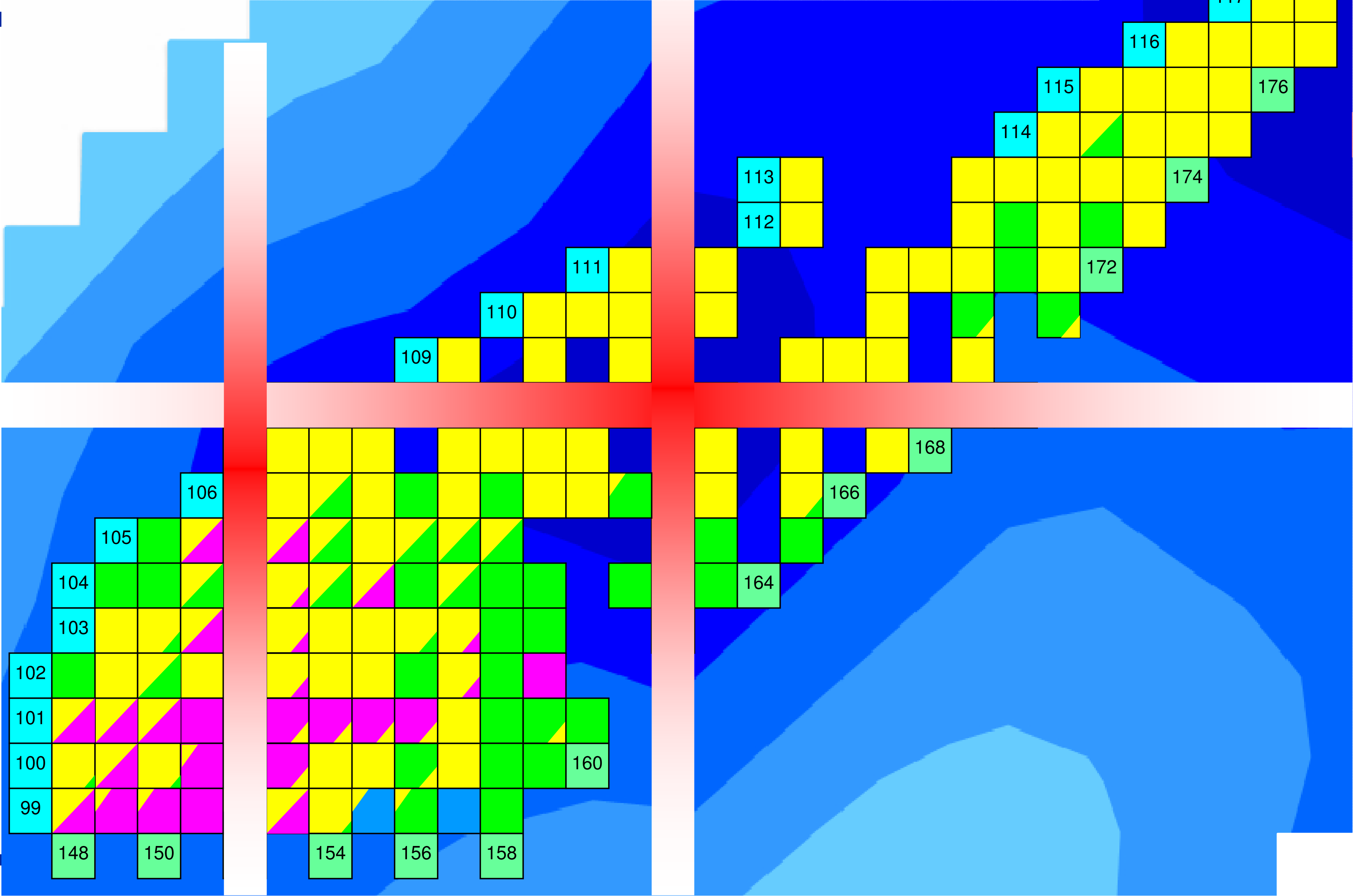


Problem areas for the BGS:

low velocity recoils from highly asymmetric reactions



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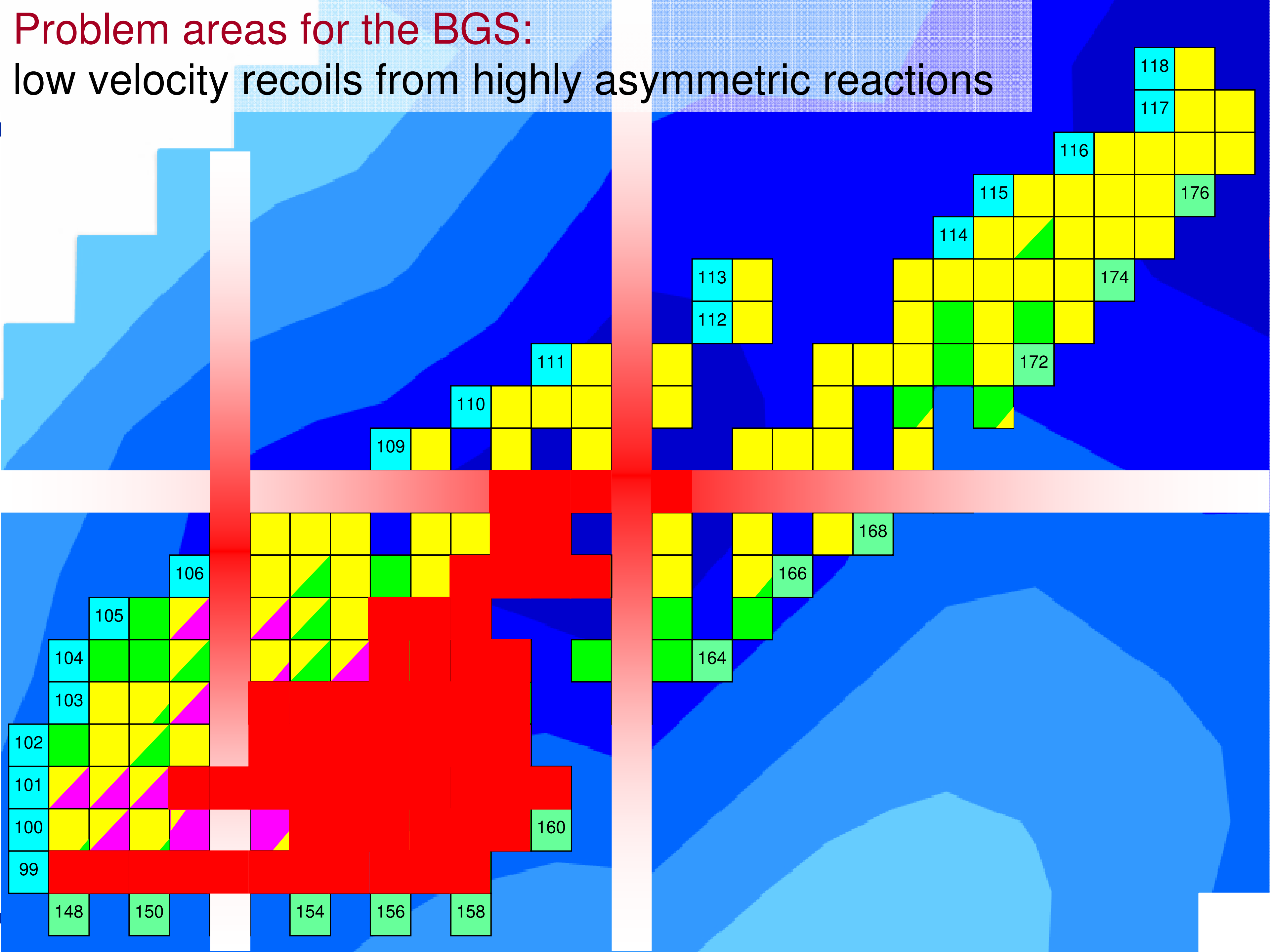
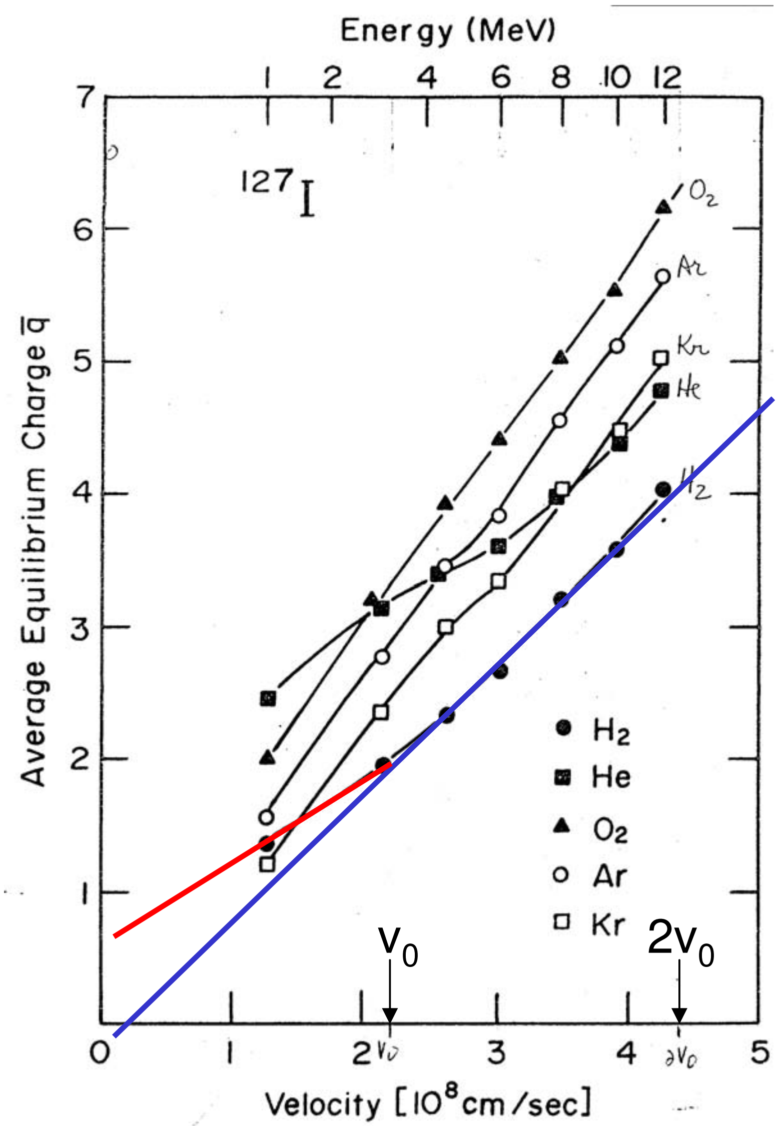
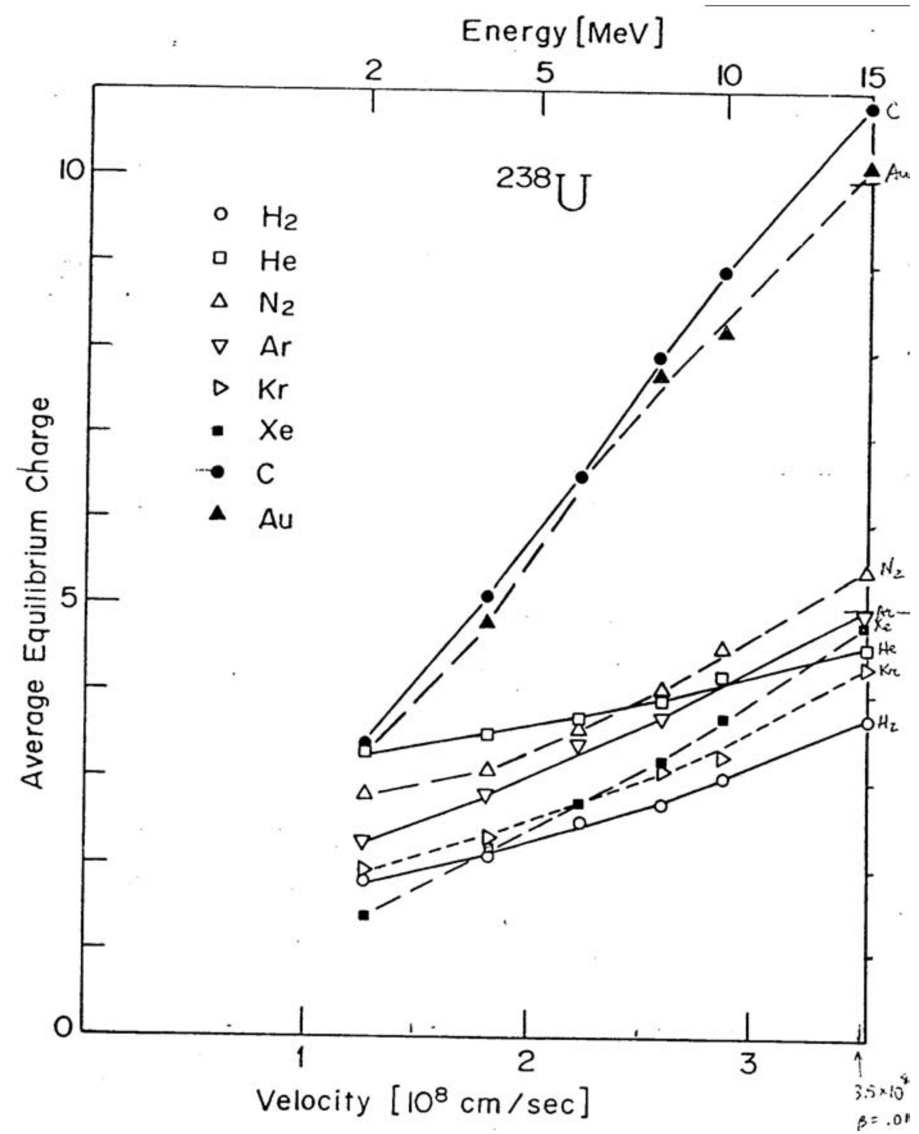
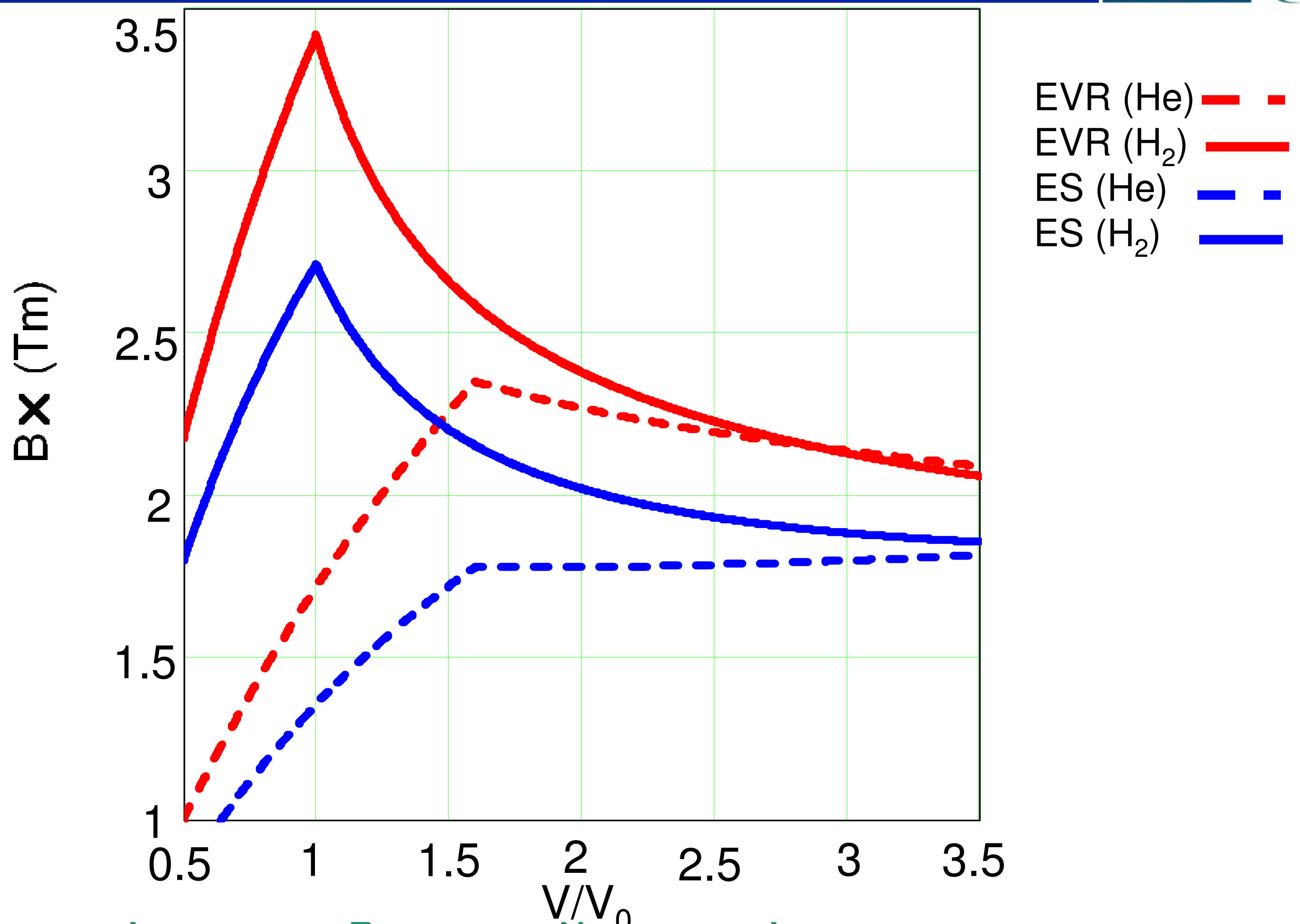


Old Average Charge Data from Betz and Whitkower

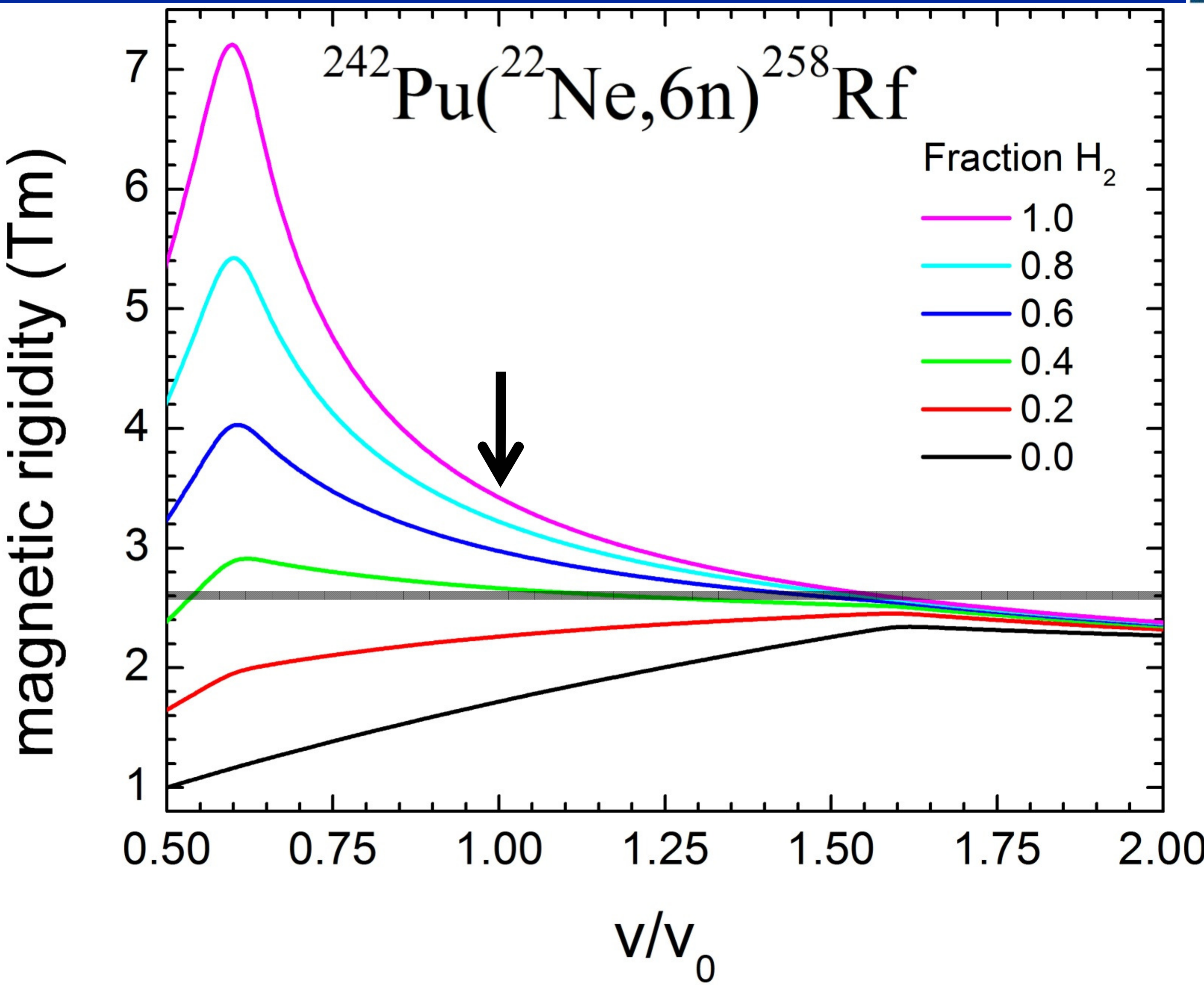




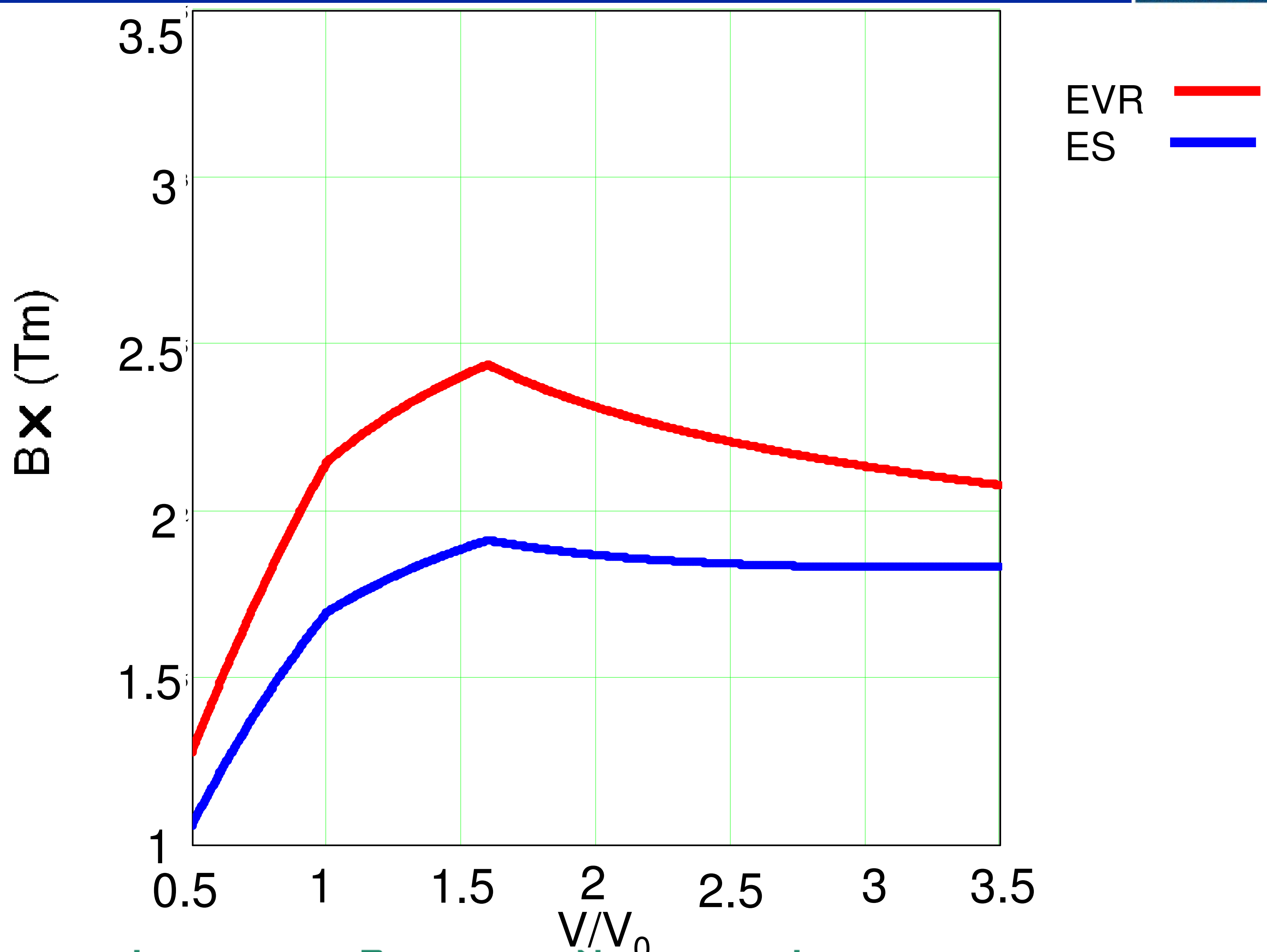
$^{22}Ne + ^{242}Pu$: Br in He, H_2

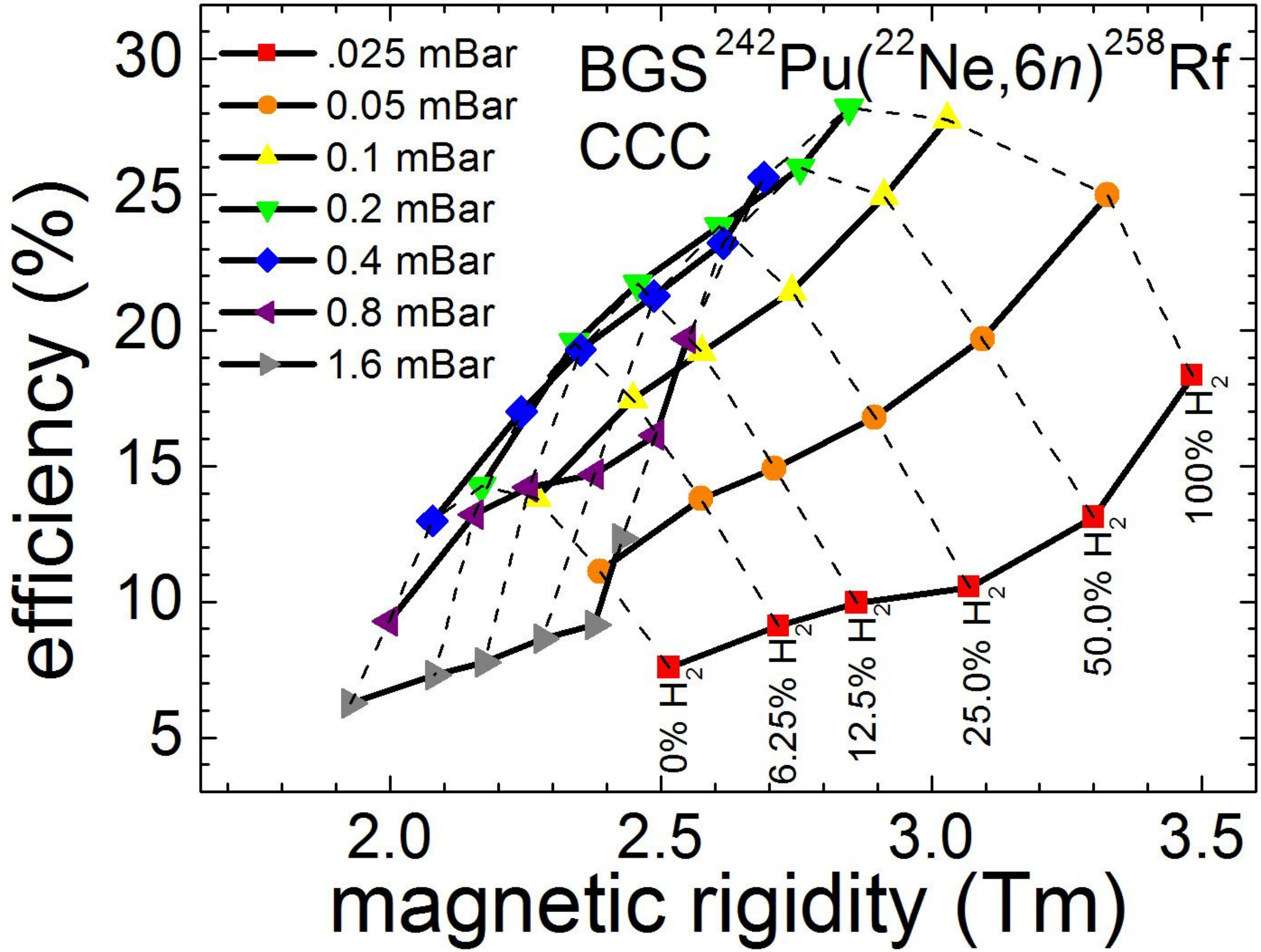


Predicted Combinations of H_2:He



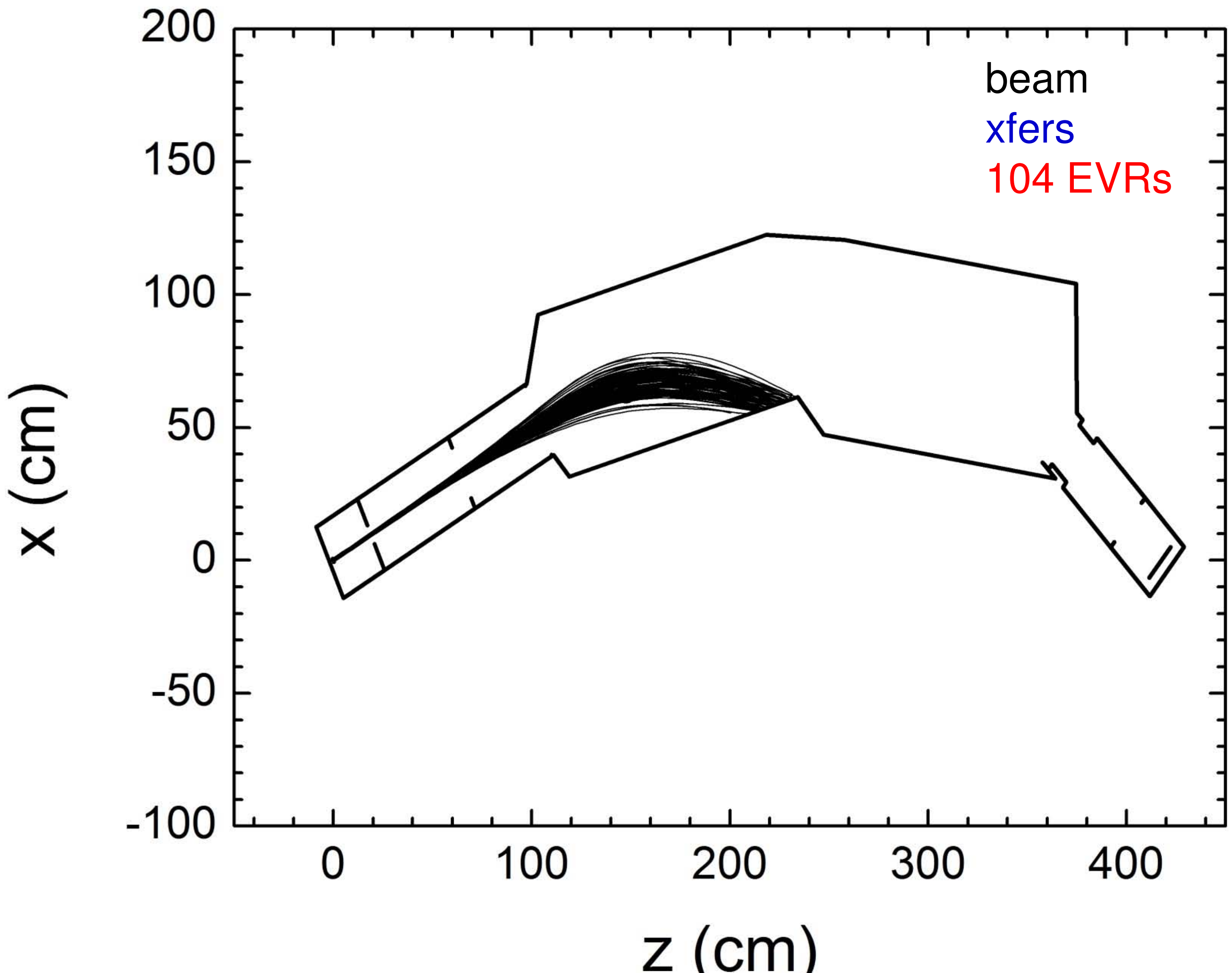
$^{22}Ne+^{242}Pu$: Br in 60:40 $He:H_2$ mixture





.025 mBar
0.05 mBar
0.1 mBar
0.2 mBar
0.4 mBar
0.8 mBar
1.6 mBar
BGS 242Pu(22Ne,6n)258Rf
CCC
0% H2
6.25% H2
12.5% H2
25.0% H2
50.0% H2
100% H2
efficiency (%)
magnetic rigidity (Tm)
30
25
20
15
10
5
2.0
2.5
3.0
3.5

$^{22}Ne+^{242}Pu$ in 30% H_2:70% He



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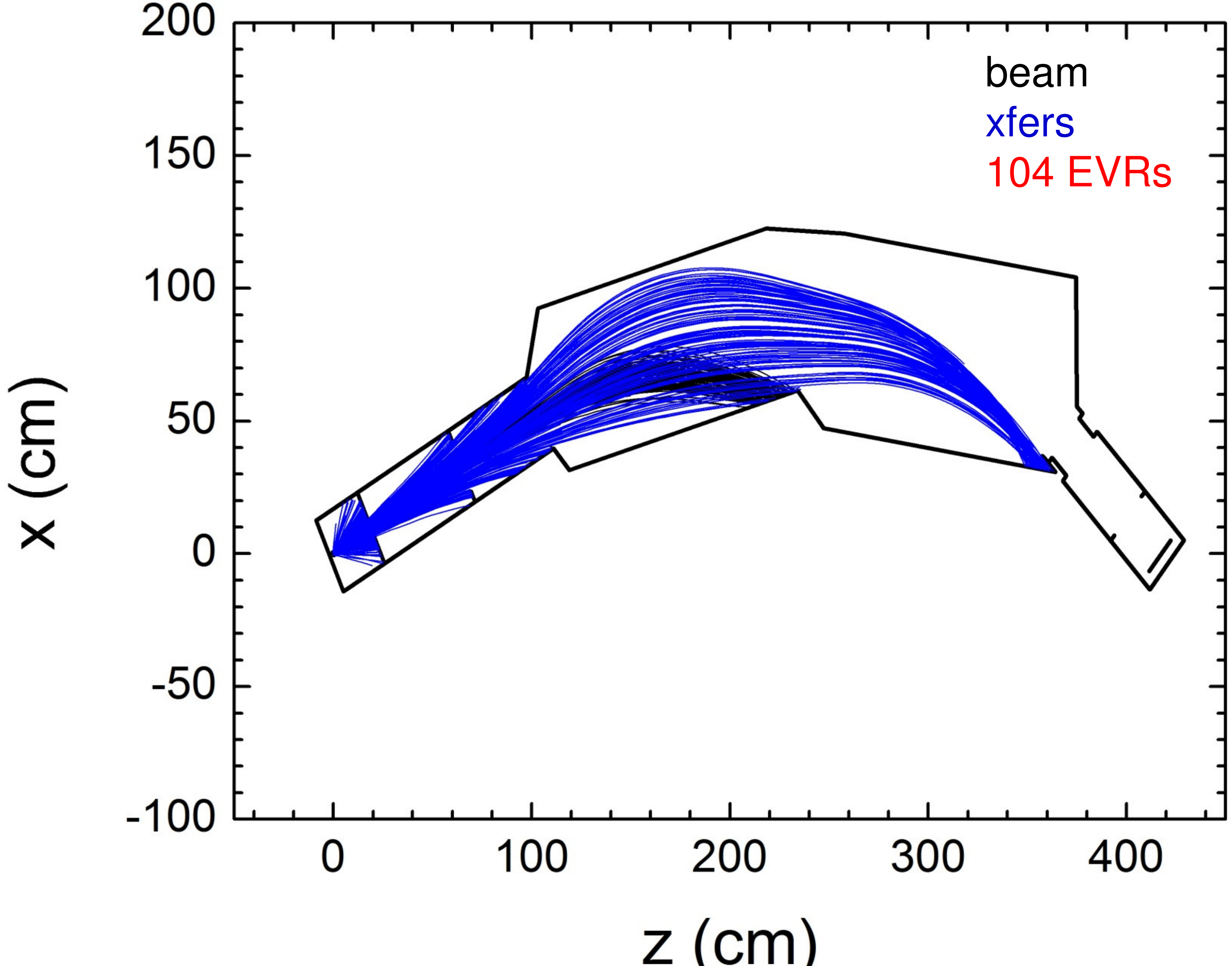

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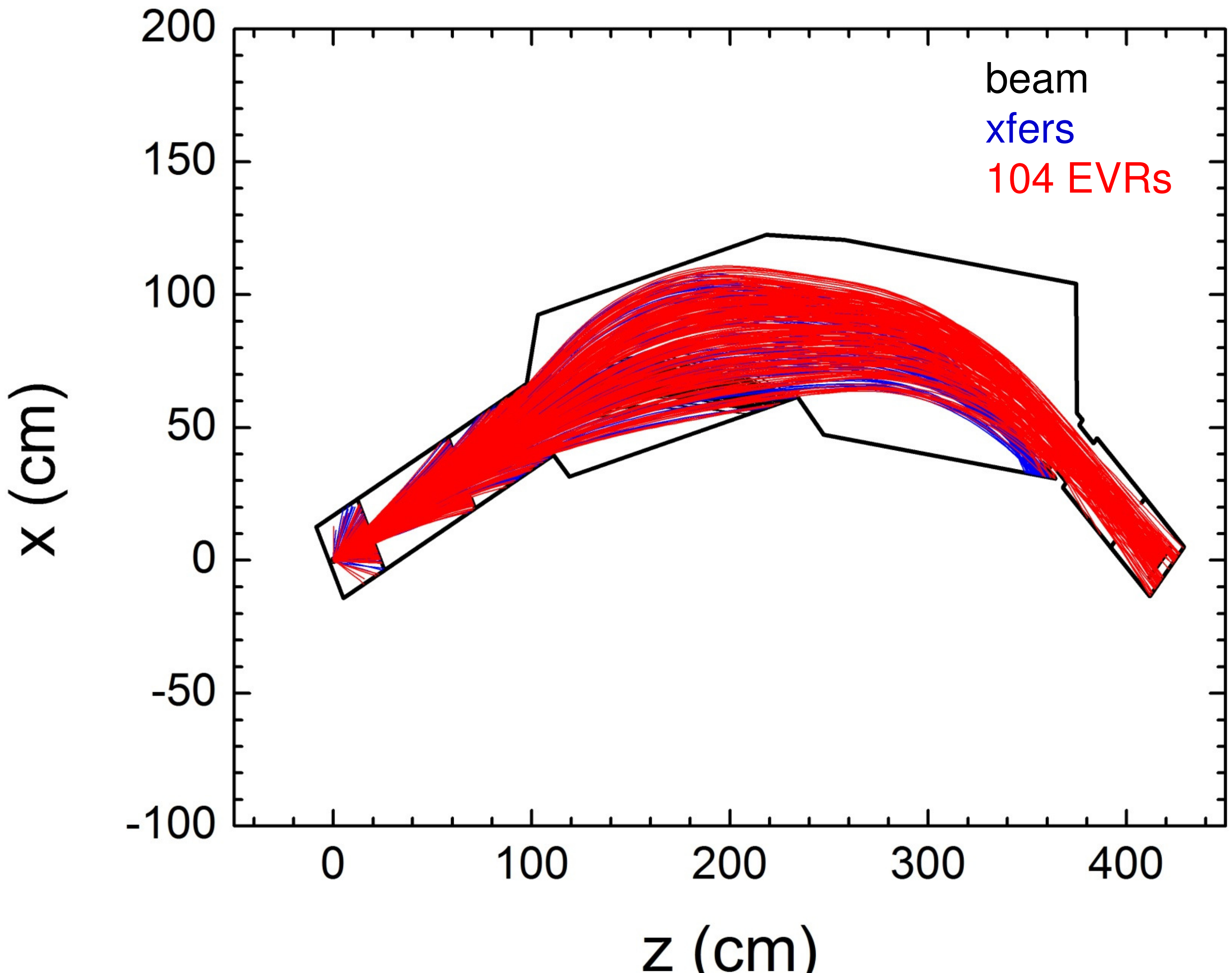
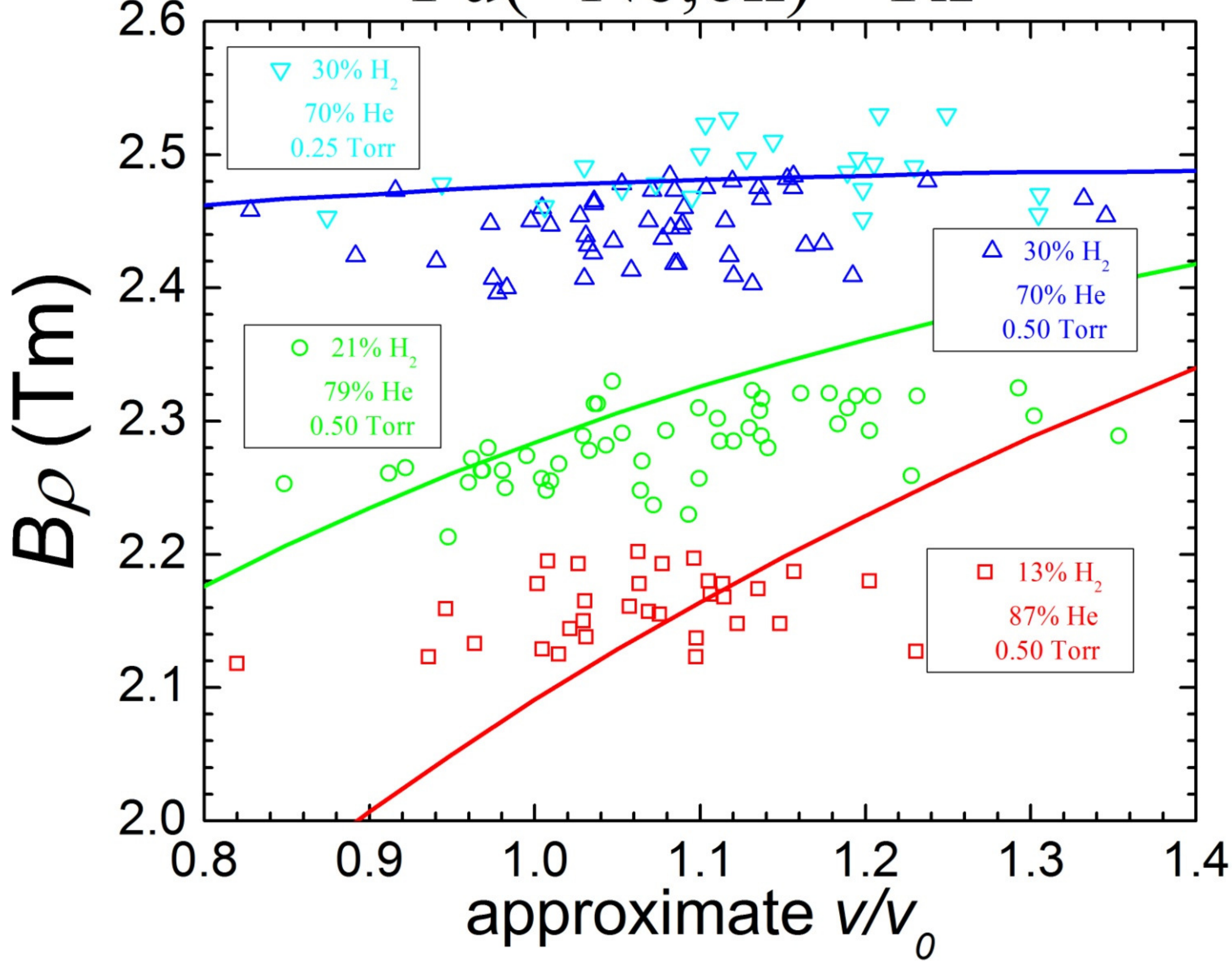
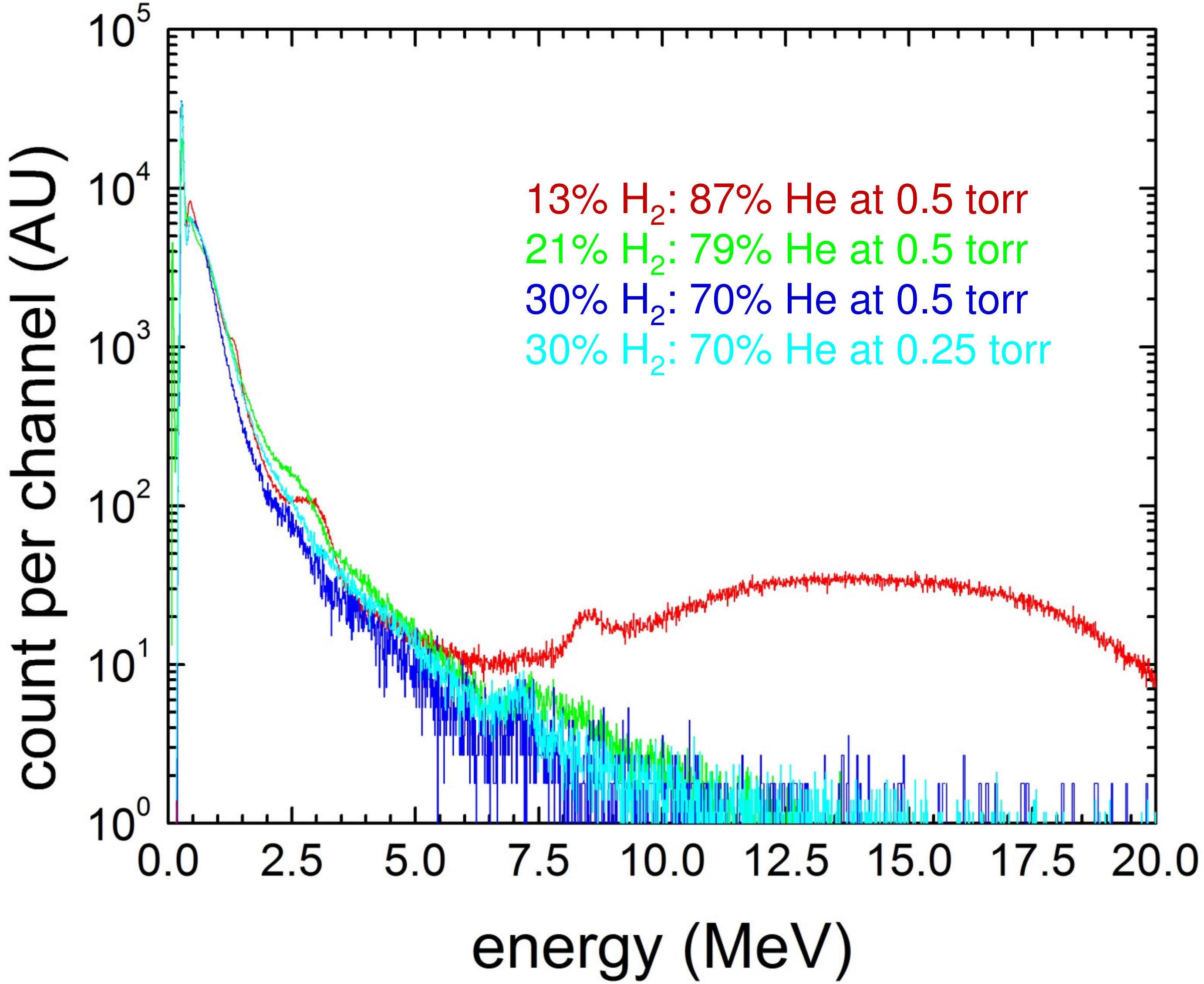


$^{242}Pu(^{22}Ne,6n)^{258}Rf$

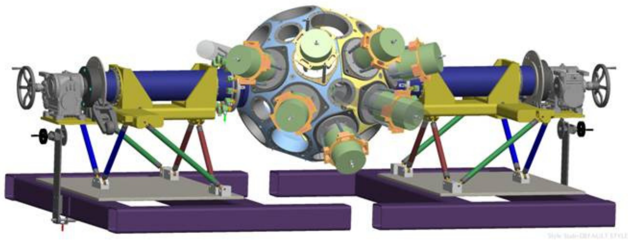


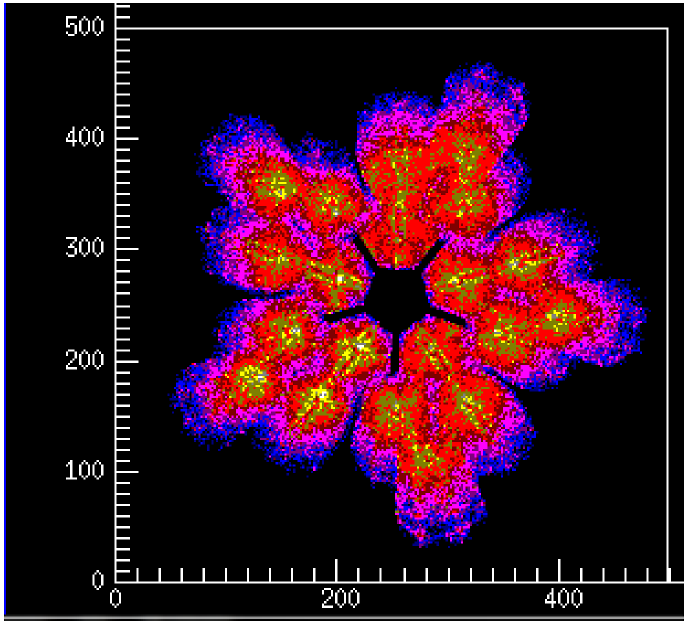


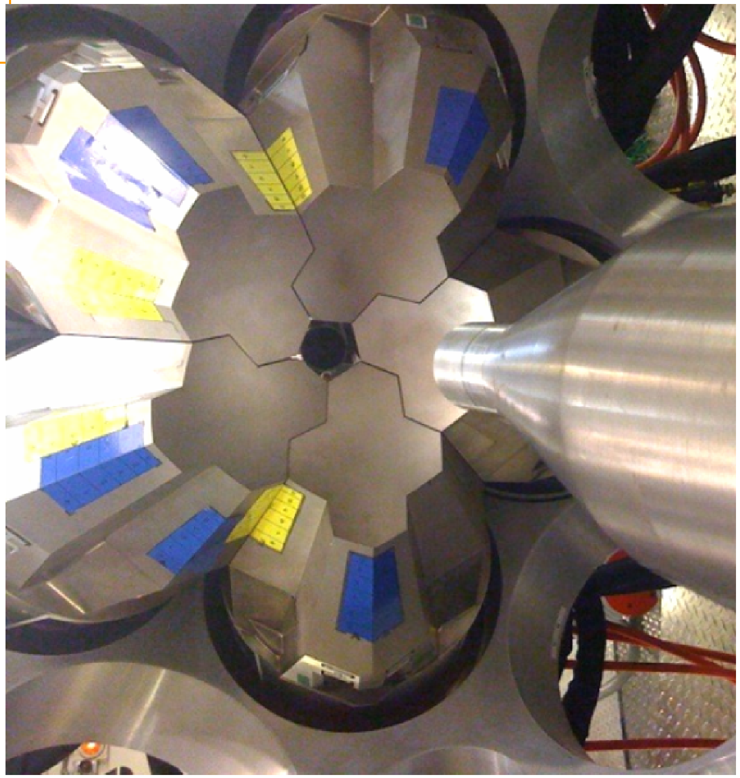
13% H2: 87% He at 0.5 torr
21% H2: 79% He at 0.5 torr
30% H2: 70% He at 0.5 torr
30% H2: 70% He at 0.25 torr
count per channel (AU)
energy (MeV)
10^5
10^4
10^3
10^2
10^1
10^0
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0

GRETINA@BGS Project

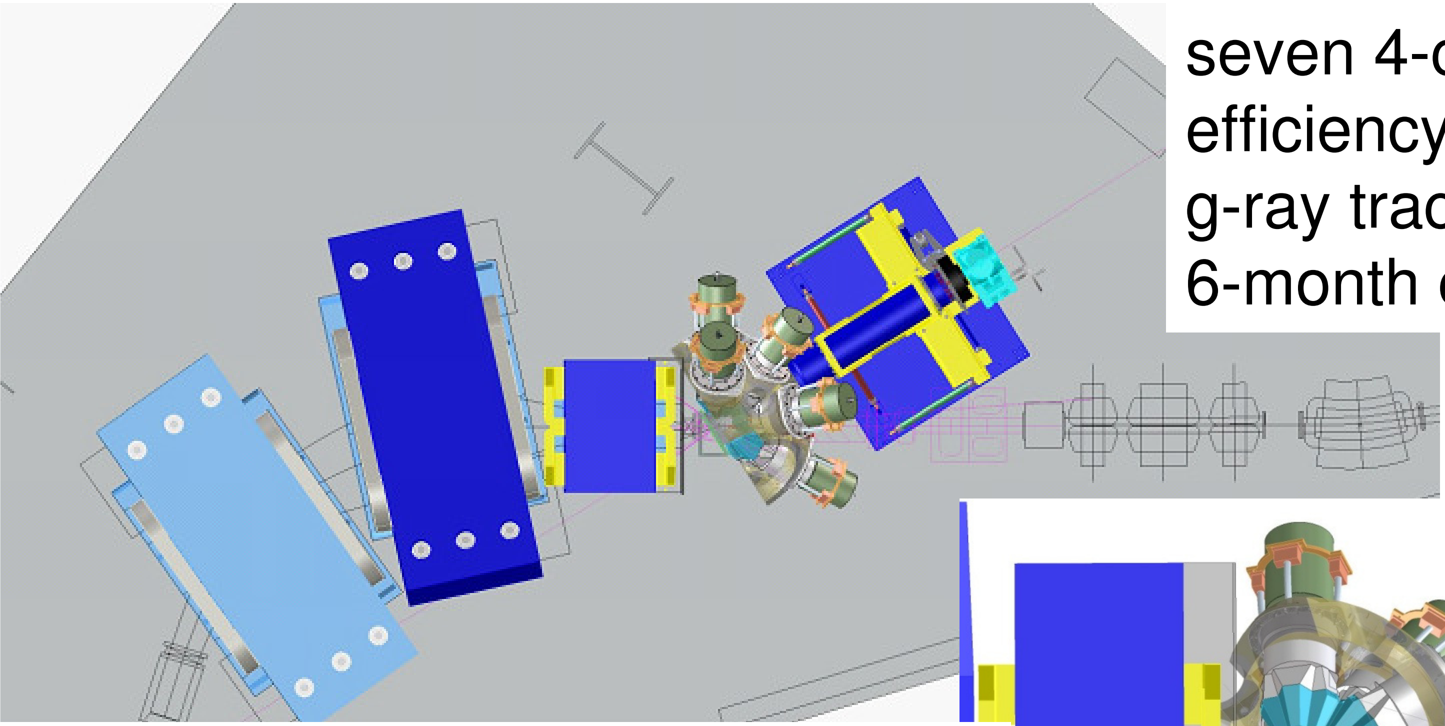
- Gamma-ray energy tracking array
- Covering ¼ of 4p solid angle with
  28 segmented Ge crystals
- Mechanical support structure
- Acquisition system



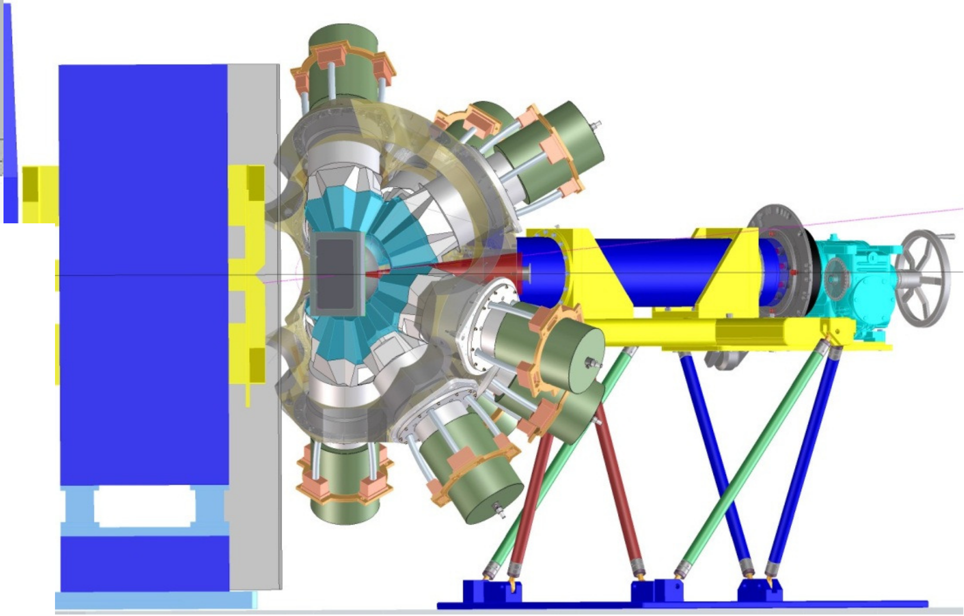




GRETINA@BGS Expeiments, Fall 2011

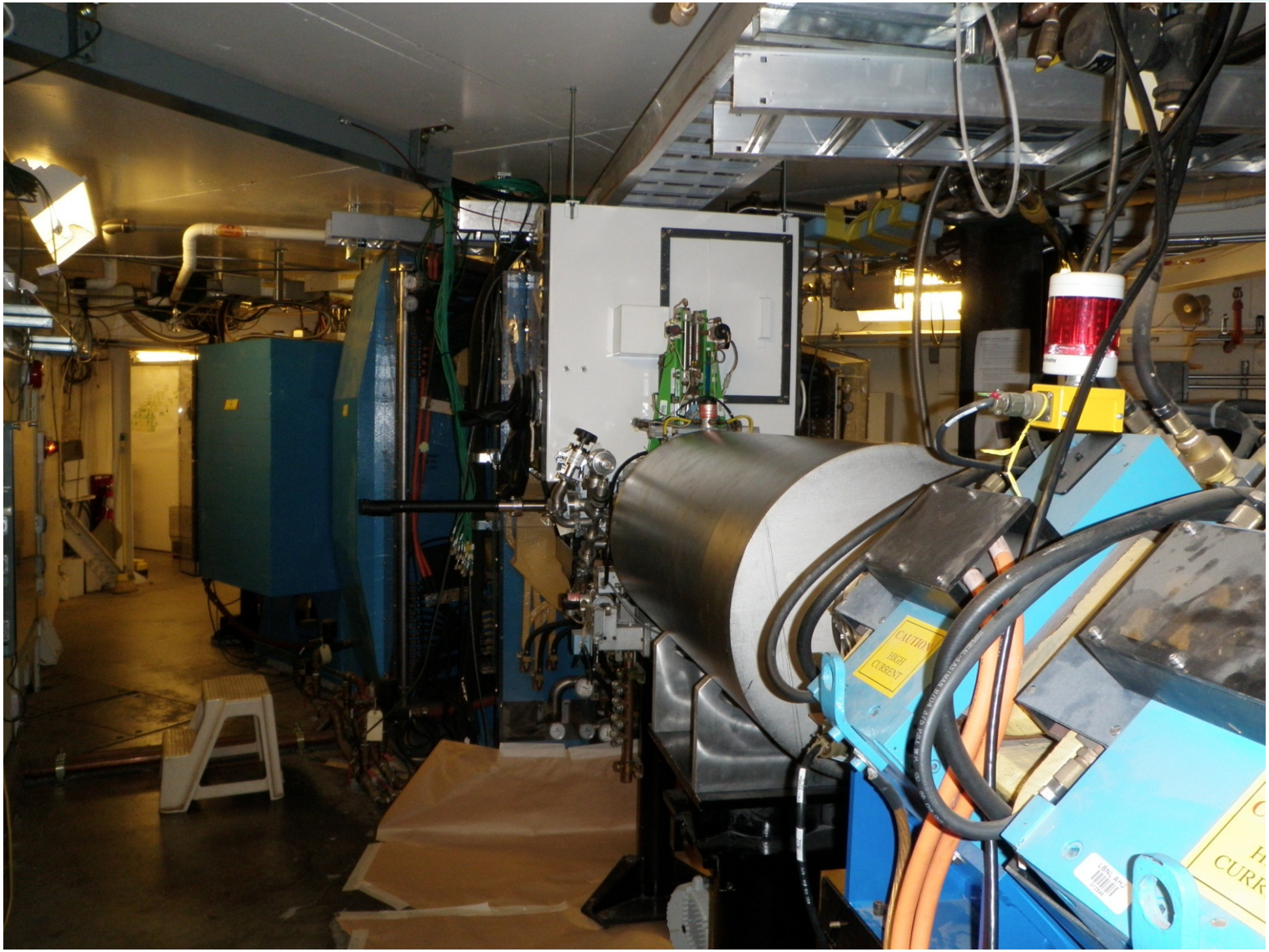


seven 4-crystal modules
efficiency similar to GS
g-ray track reconstruction
6-month campaign



In-beam spectroscopy exp:
$^{208}Pb(^{48}Ca,2n)^{254}No$,
•10x statistics improvement
$^{208}Pb(^{50}Ti,1\text{-}2n)^{257,256}Rf$,
•highest-Z for in beam spect.

GRETINA@BGS: Preparation



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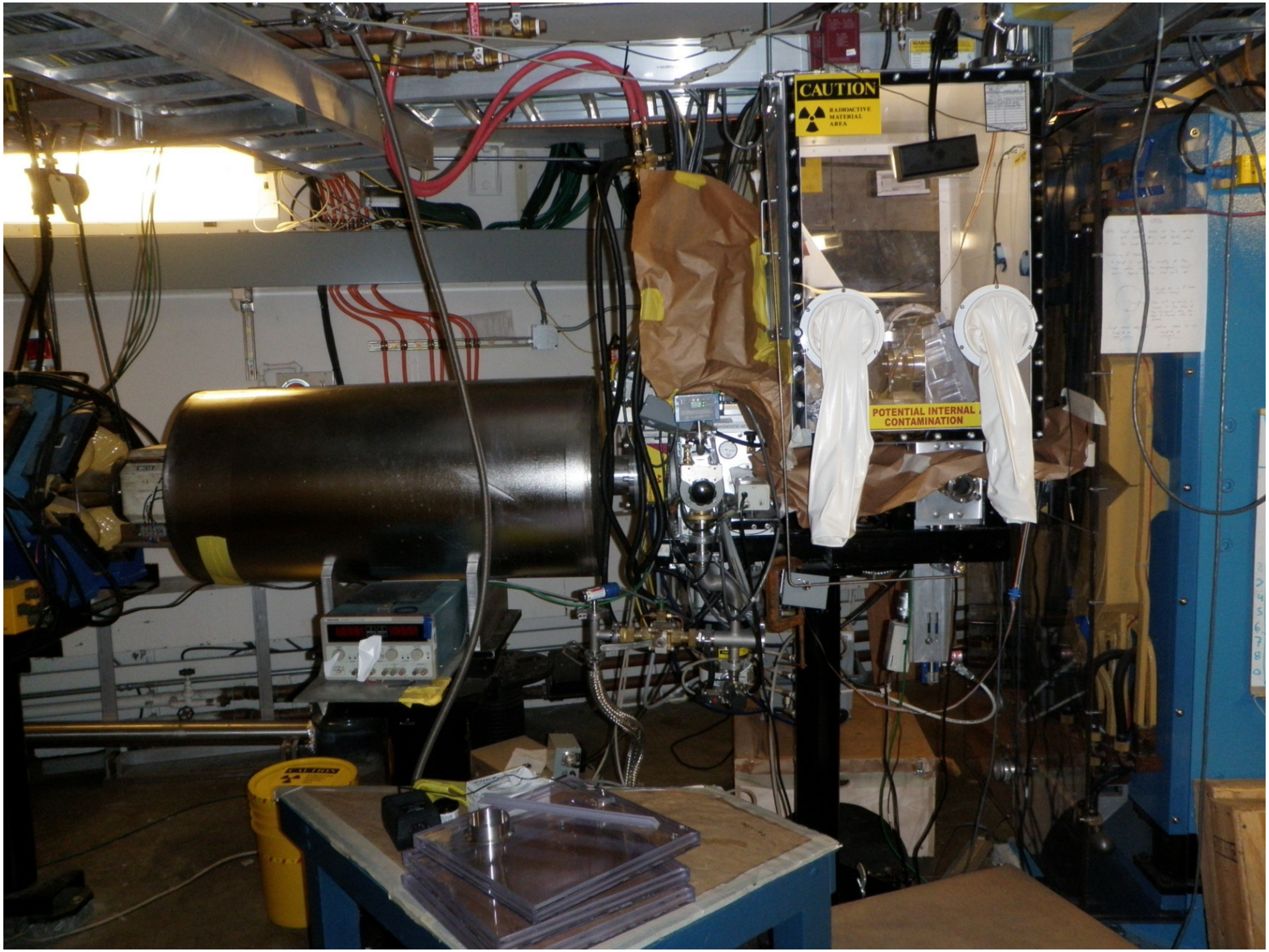
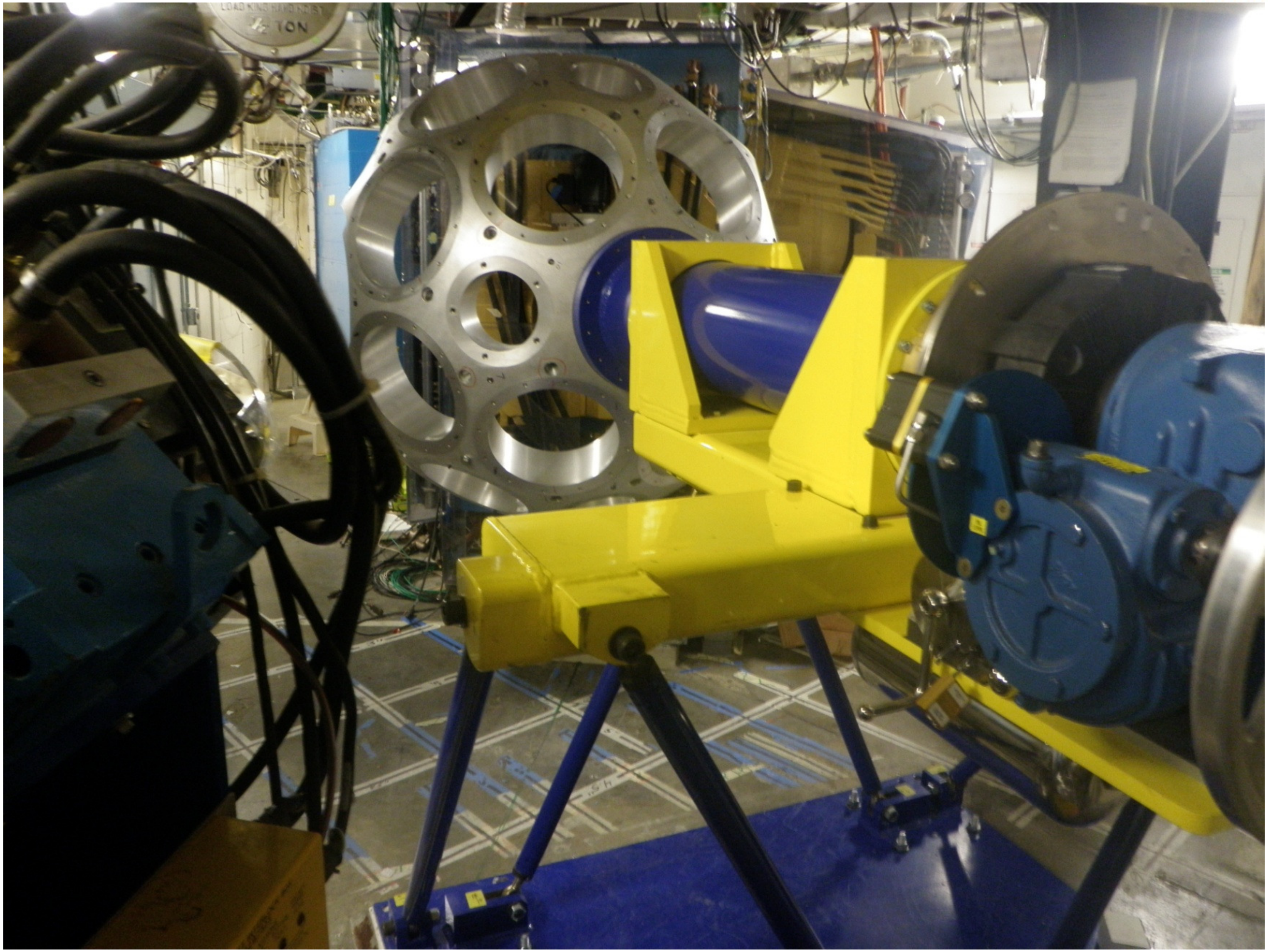


GRETINA@BGS: Installation



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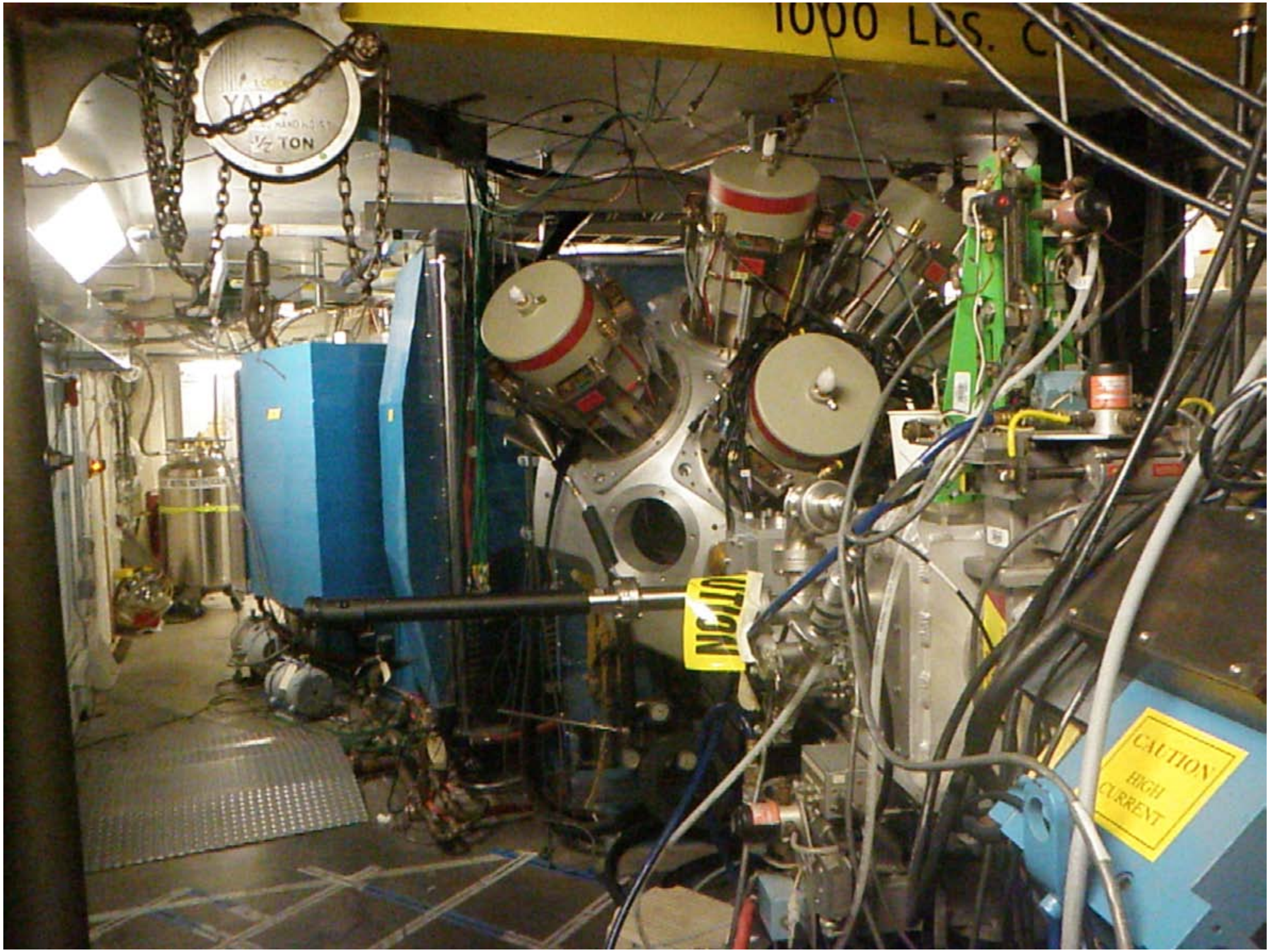

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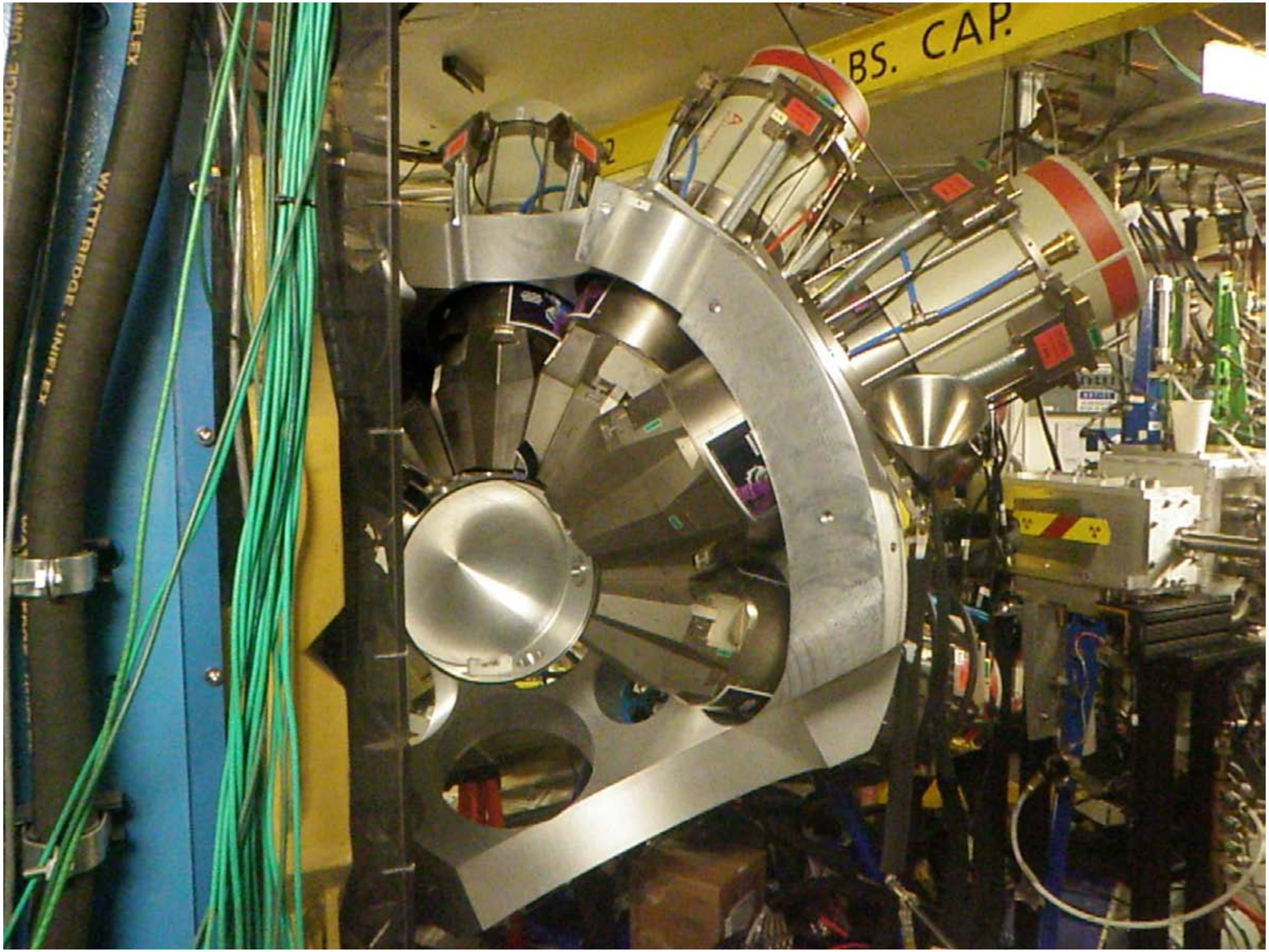

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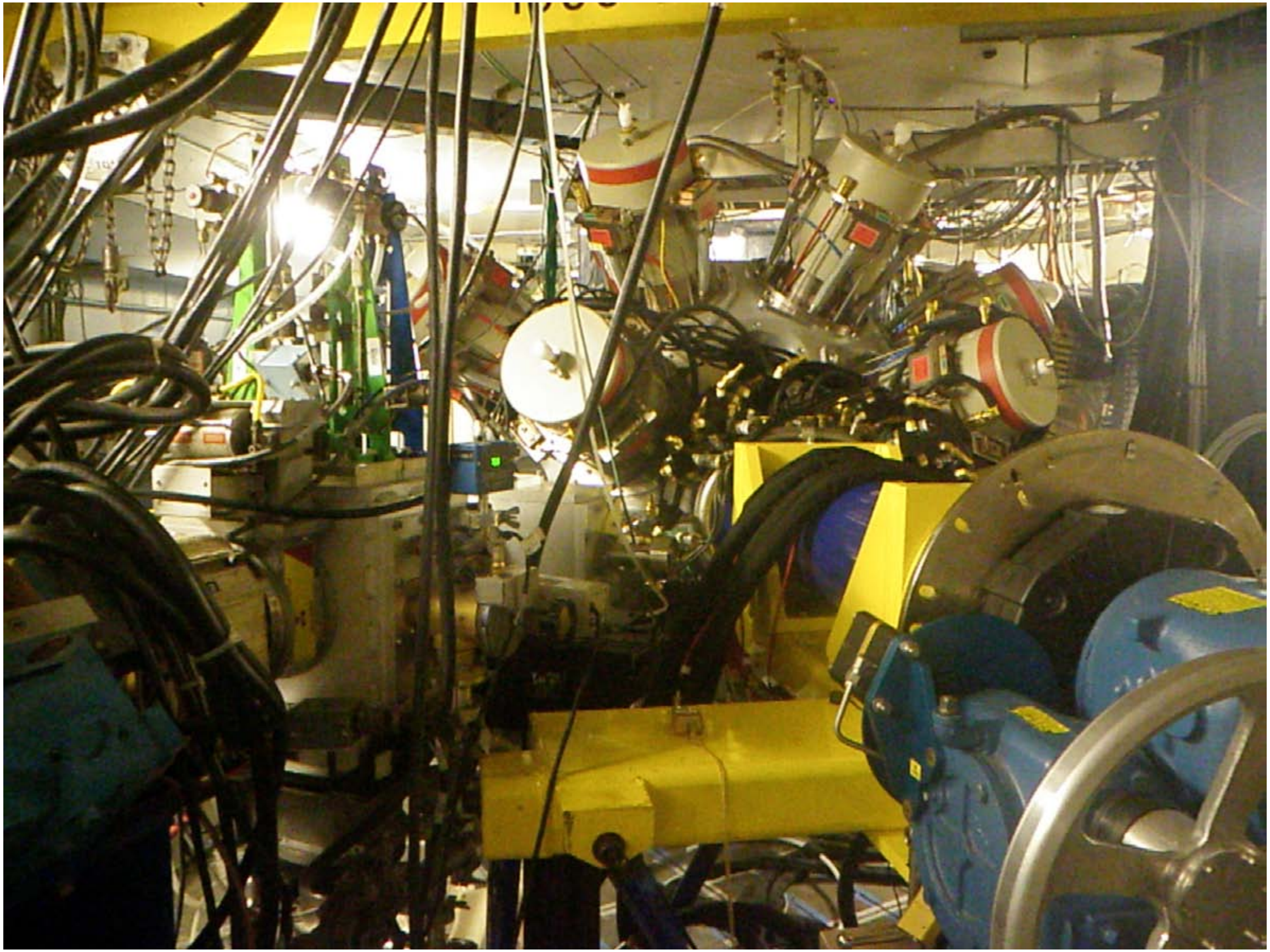

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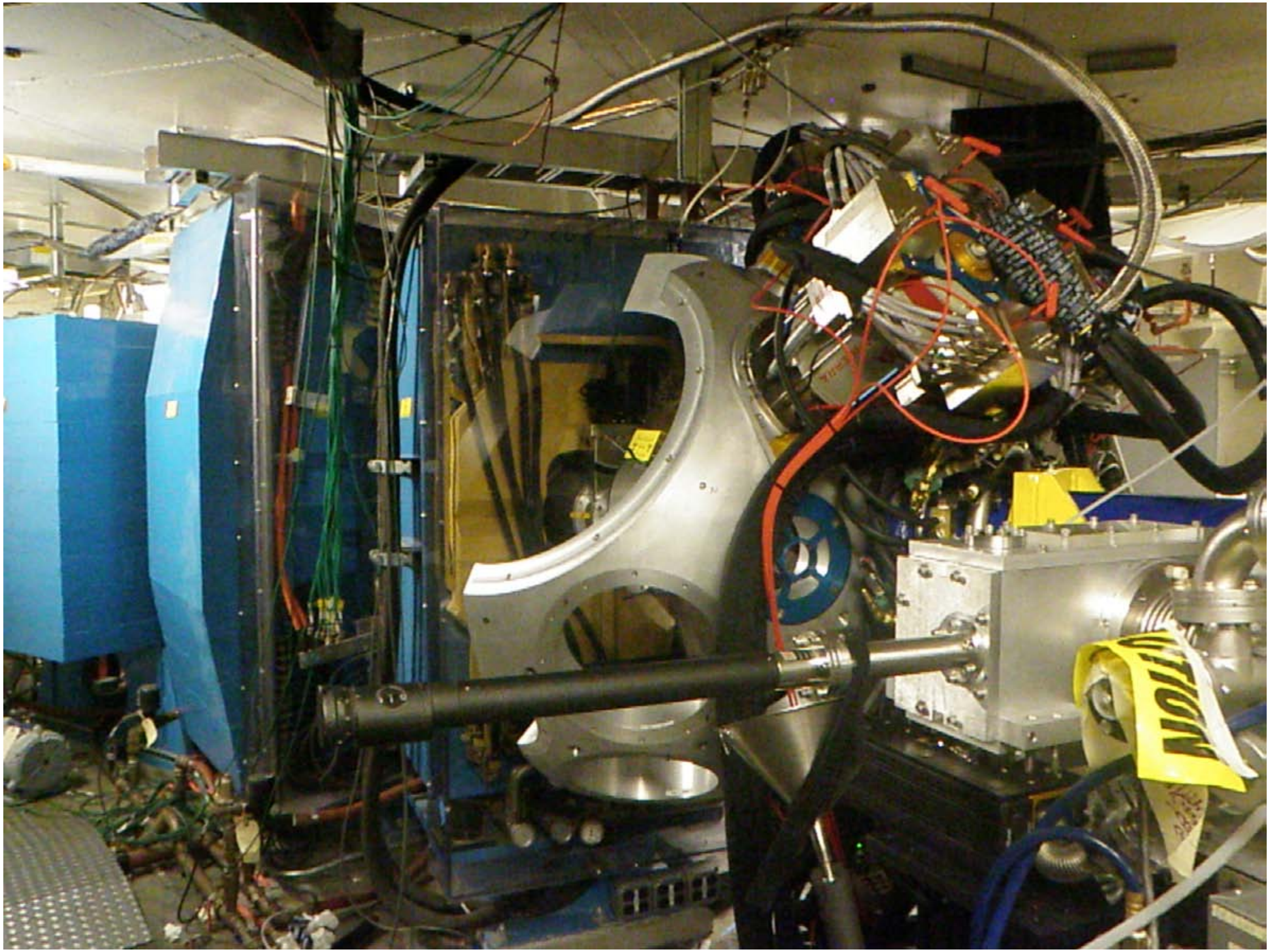
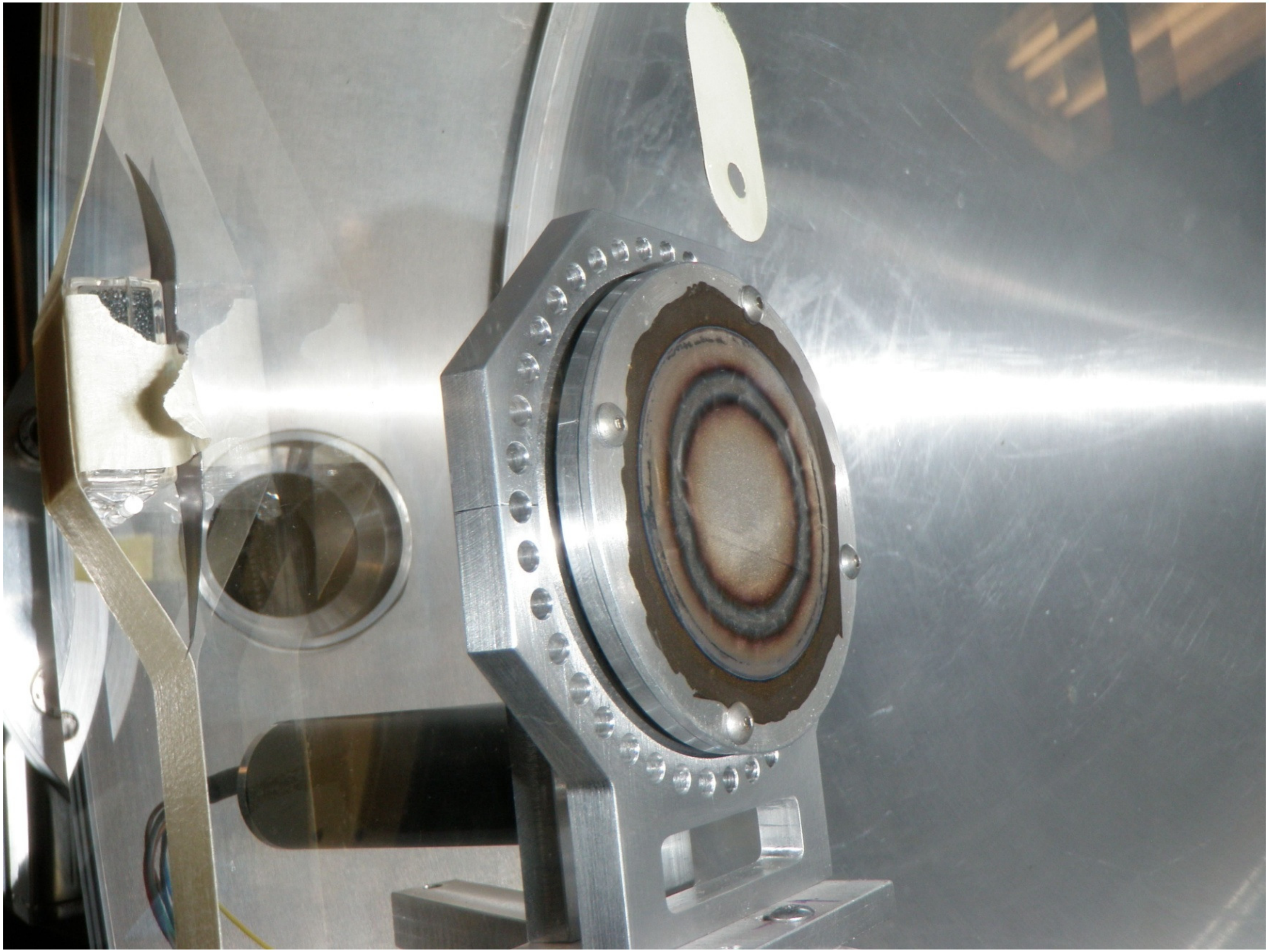


GRETINA@BGS: Target



GRETINA@BGS: Status

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  - The BGS and the new focal plane detectors are in great shape. We cleanly identify recoil implants, alpha decays, and electron bursts at the expected rates for the beam intensities we have been running

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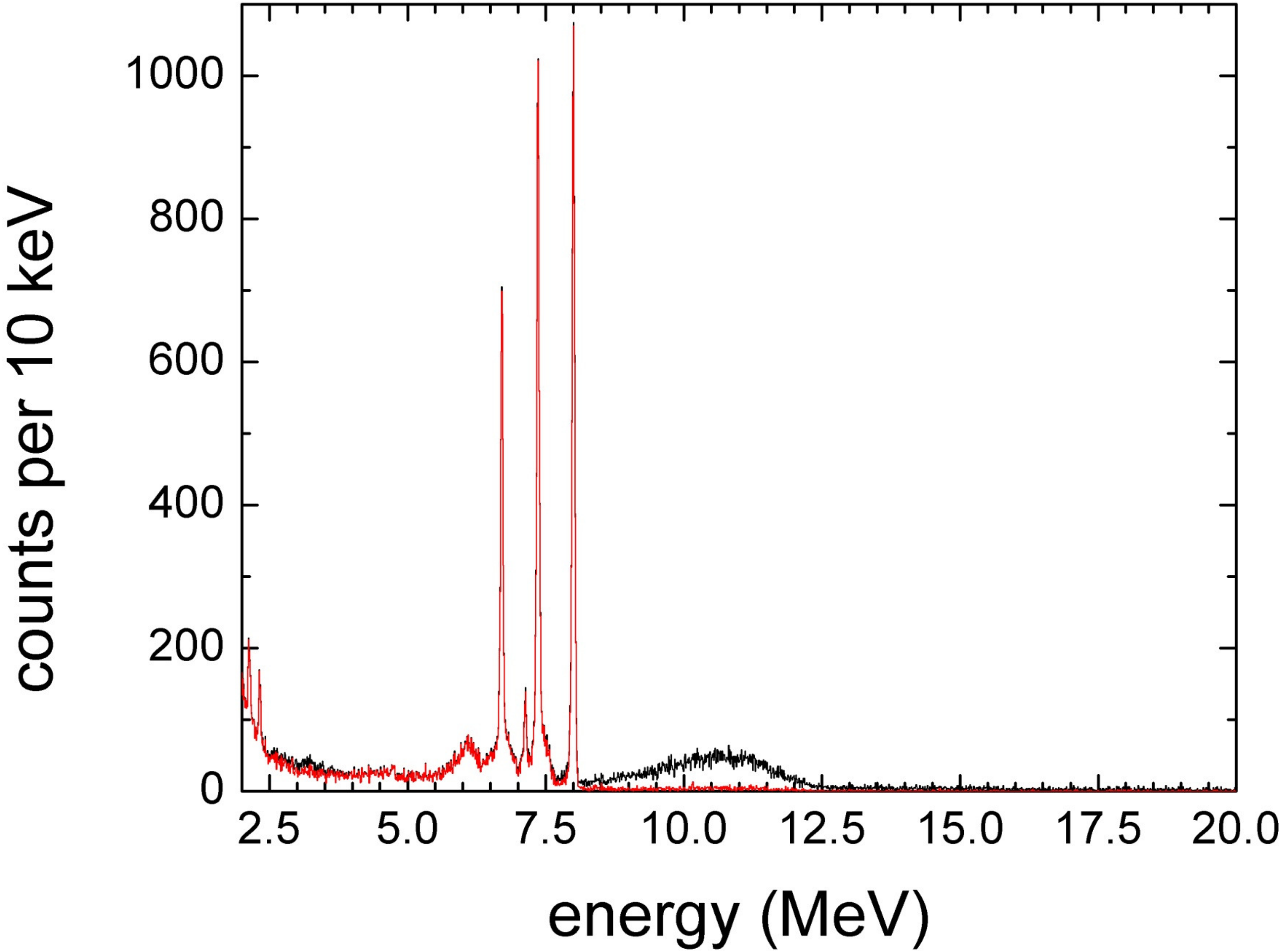

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  - –GRETINA was clearly able to see ground state band in ^{254}No although some improvements can be made to increase resolution
- New 20-day beamtime beginning 18 Oct
  - –Start with ^{254}No to test updated software
  - –Then ^{256}Rf???