TASCA Commissioning Experiments

Lessons from the BGS

Ken Gregorich
Lawrence Berkeley National Laboratory

But First: What about the gas?
Then: Expected cross sections for Rf-Hs with ^{244}Pu targets
And: Measurements of EVR ranges in MYLAR
Finally: What (not) to do with TASCA

The LBNL Heavy Element Group

(apologies for not showing this on Monday)

Principal Investigators:

Heino Nitsche	(UCB Chemistry Faculty, group leader)
Ken Gregorich	

Staff:

Ralf Sudowe	
Chris Düllmann	
Robert Eichler	(visiting staff scientist)

Postdoc

Cody Folden	(in his “spare time”)

Graduate Students

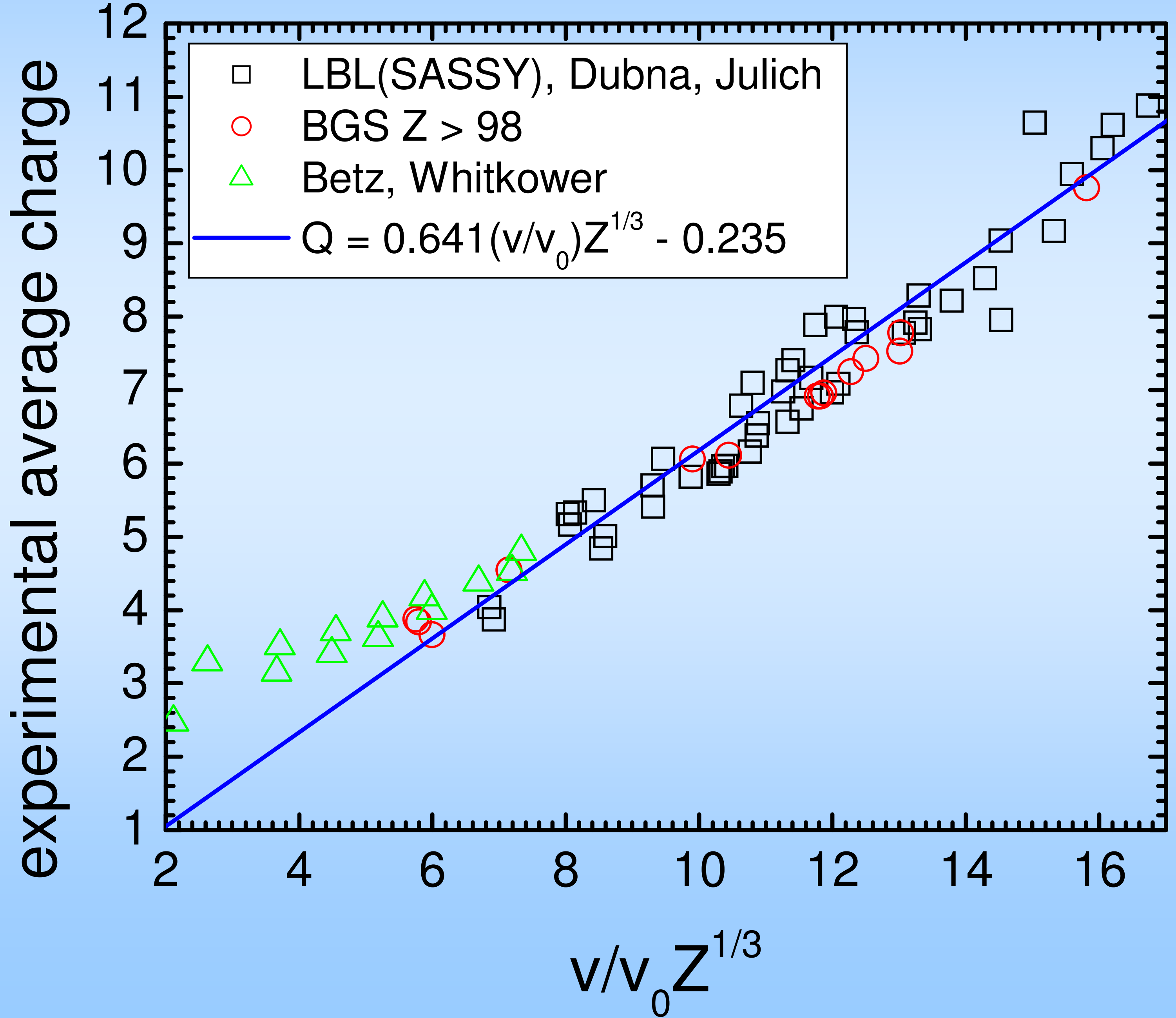
Irena Dragojevic	(1st yr; heavy elements)
Mitch Andre Garcia	(1st yr; gas phase chemistry)
Jacklyn Gates	(1st yr; hot fusion; Db extraction chemistry)
Sarah Nelson	(2nd yr; cold fusion)

Collaborators

OSU, PSI/Bern, GSI, TUM, ANL . . .

Understanding Magnetic Rigidity in He Gas

Back to basics . . .



Back in 1948, Neils Bohr suggested a

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

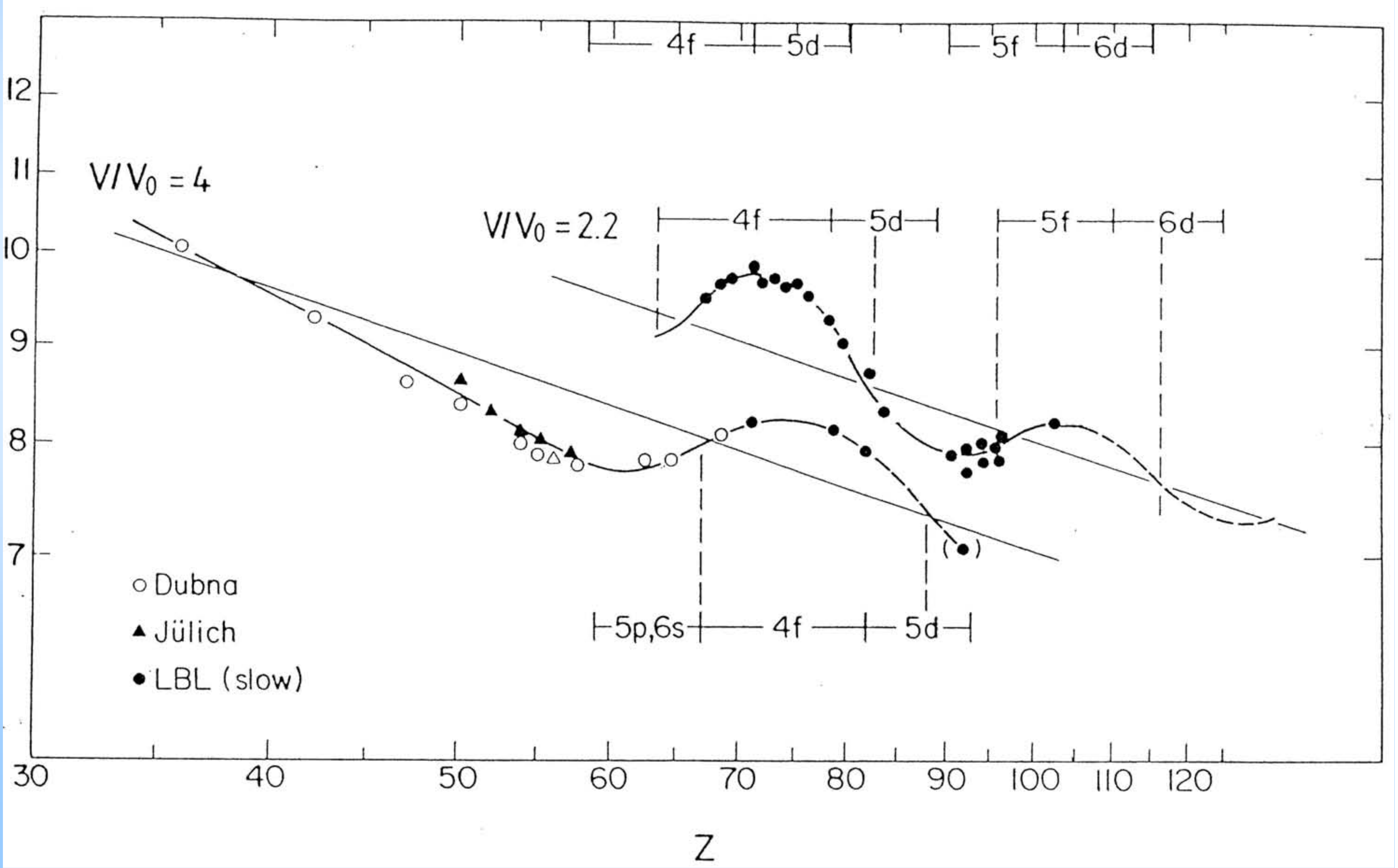
This fit shows much scatter. Deviations are +/- 10%. Can this be understood in terms of the electronic shell structure of the stripped ions?

Strong deviations at low velocities due to the High ionization potential of He

Understanding Magnetic Rigidity in He Gas

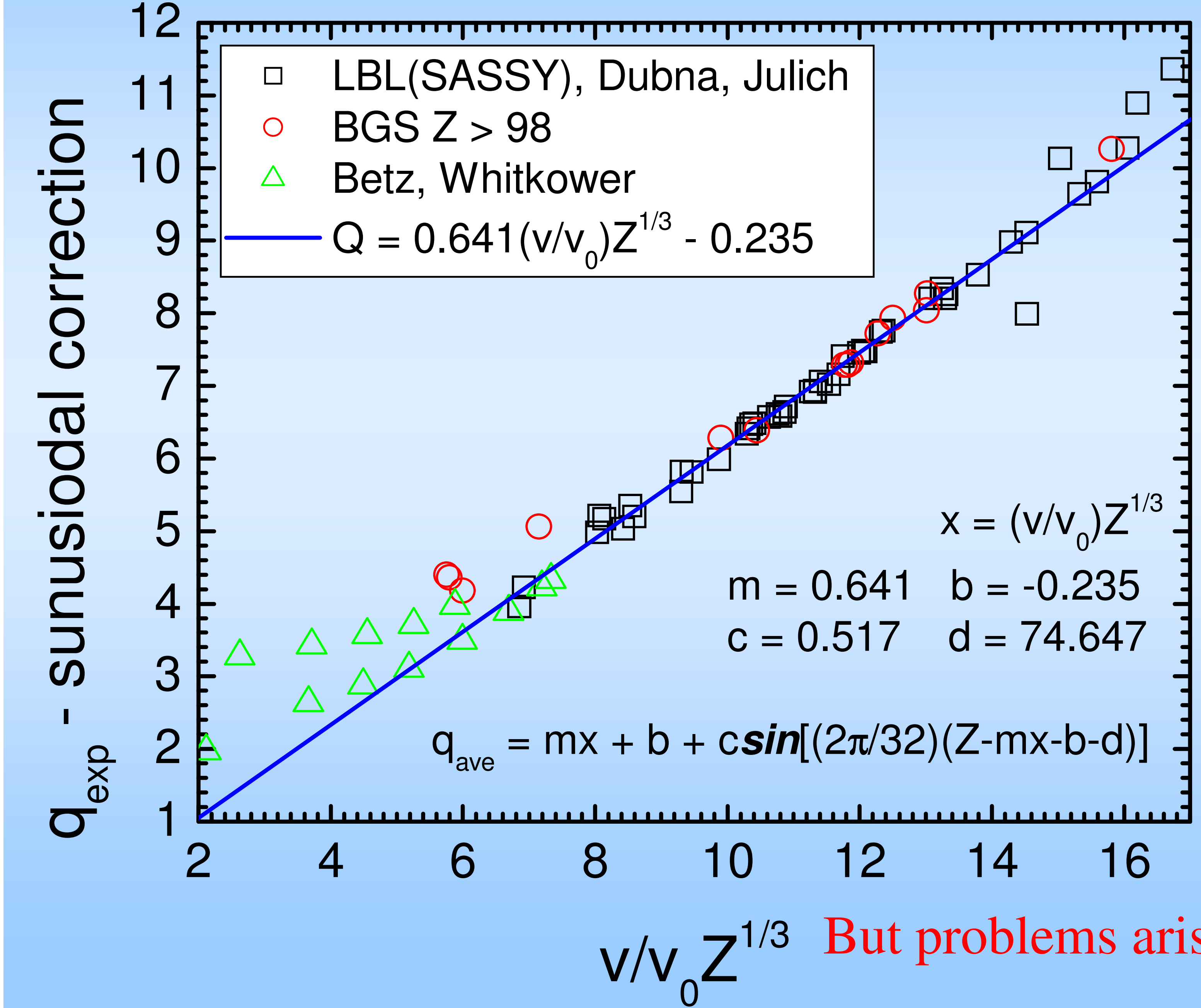
Ghiorso and Armbruster say look at electronic shells . . .

$B\rho/A$ (Tm * 10^{-3})



What is the $^{283}112$ magnetic rigidity?

Applying a sinusoidal correction . . .



Semi-empirical understanding of why this works:

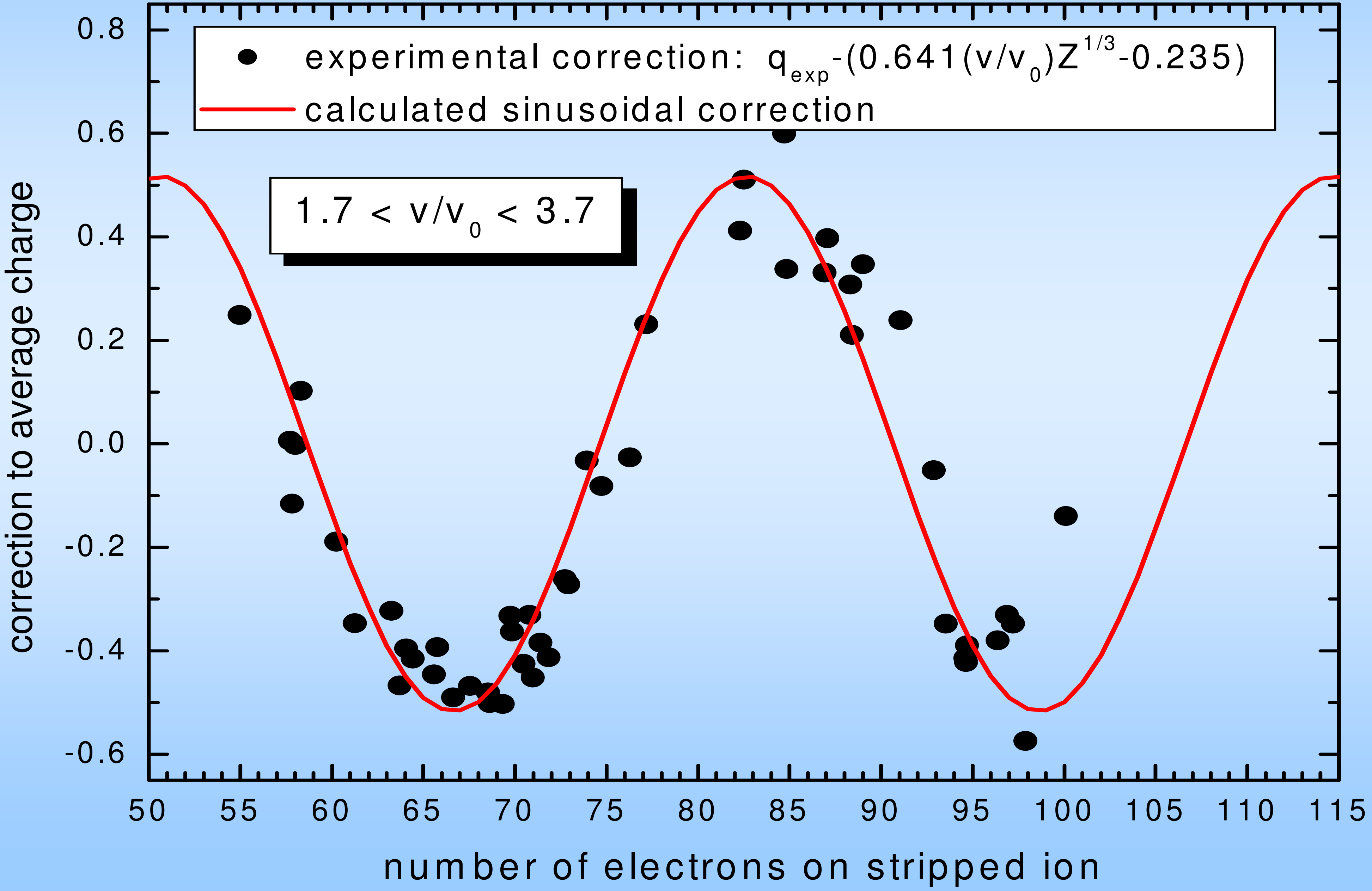
If the stripped ion is in an f-orbital, the most loosely bound electrons are inner electrons, and are less available for stripping by the gas, giving a lower q.

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!

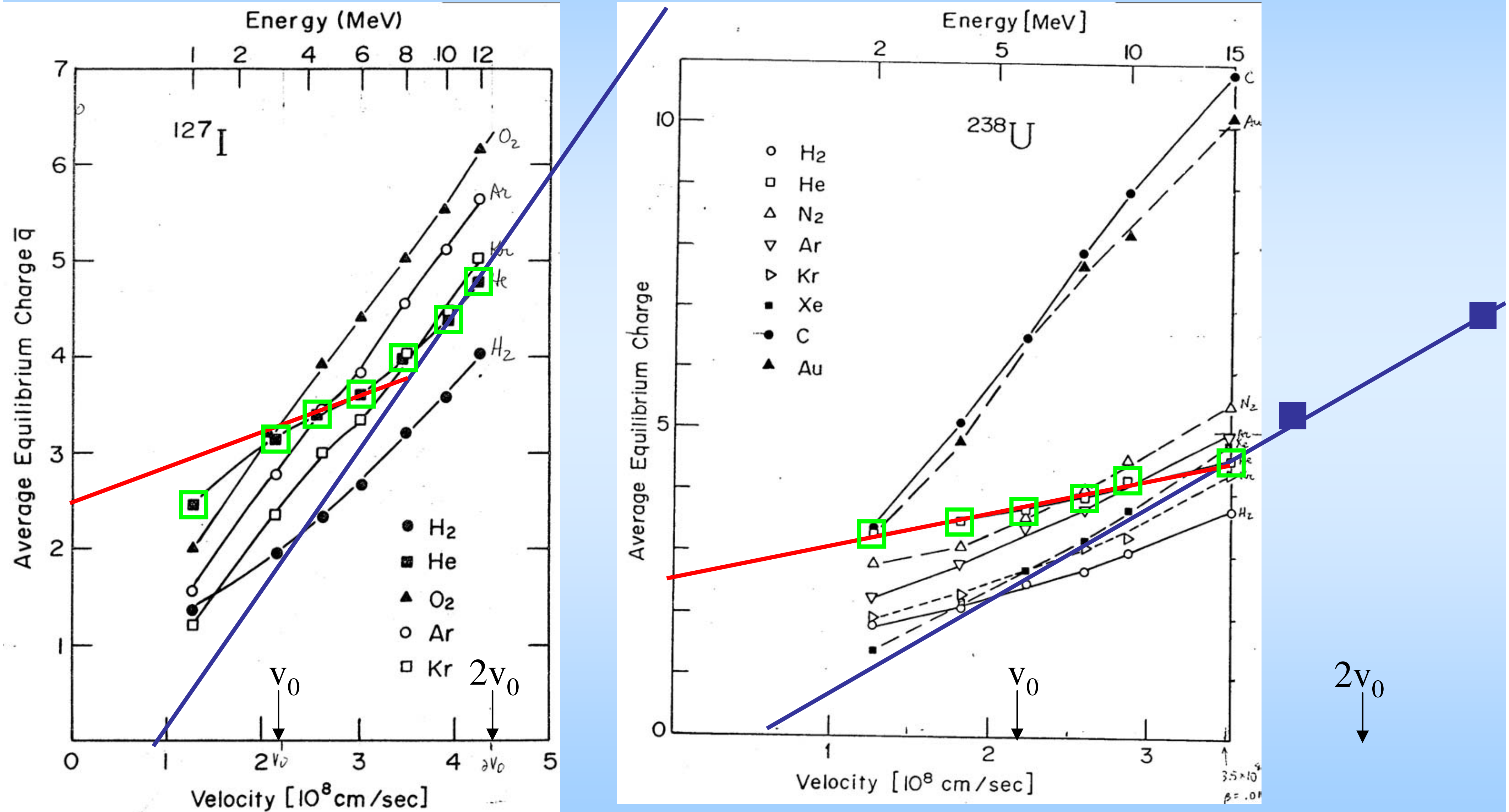
Sinusoidal Corrections to Average Charge in He

Comparison of experimental and calculated



Understanding Magnetic Rigidity in He Gas

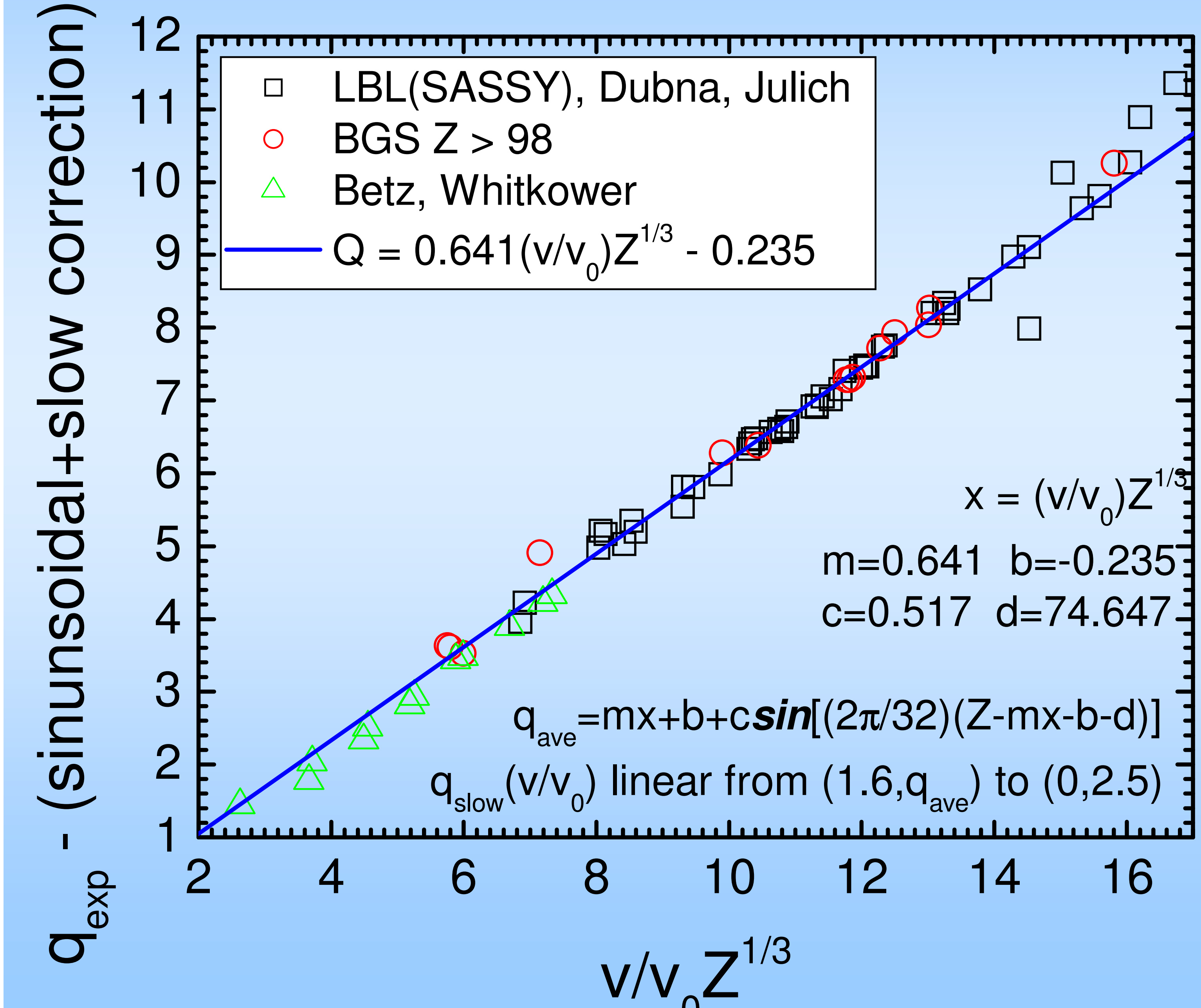
Iodine and uranium data show a break below v = 1.6v_0



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 applyting a slow velocity correction . . .

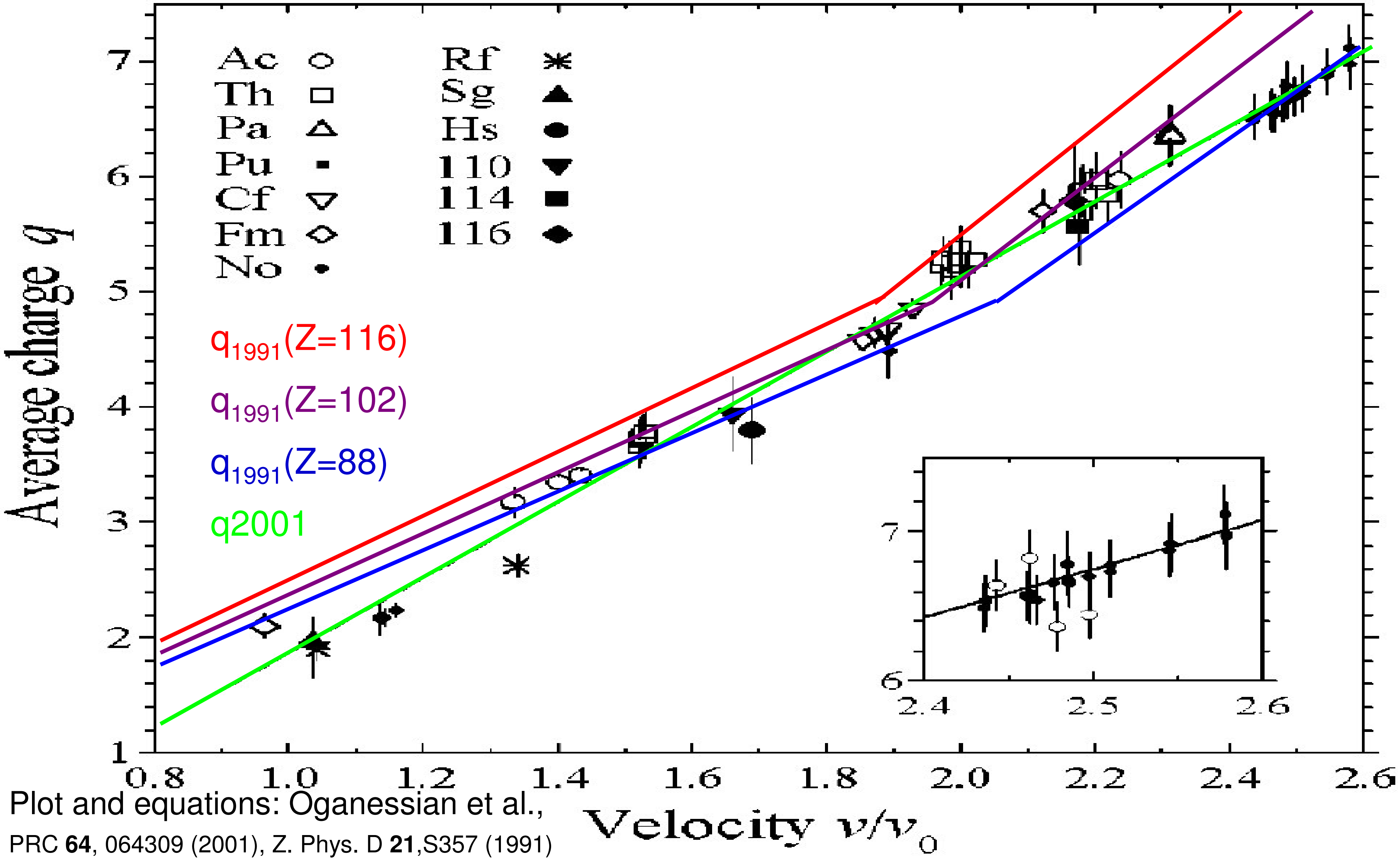


Simplest assumption:

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

Understanding Magnetic Rigidity in H_2 Gas

Fits used in the DGFRS work . . .

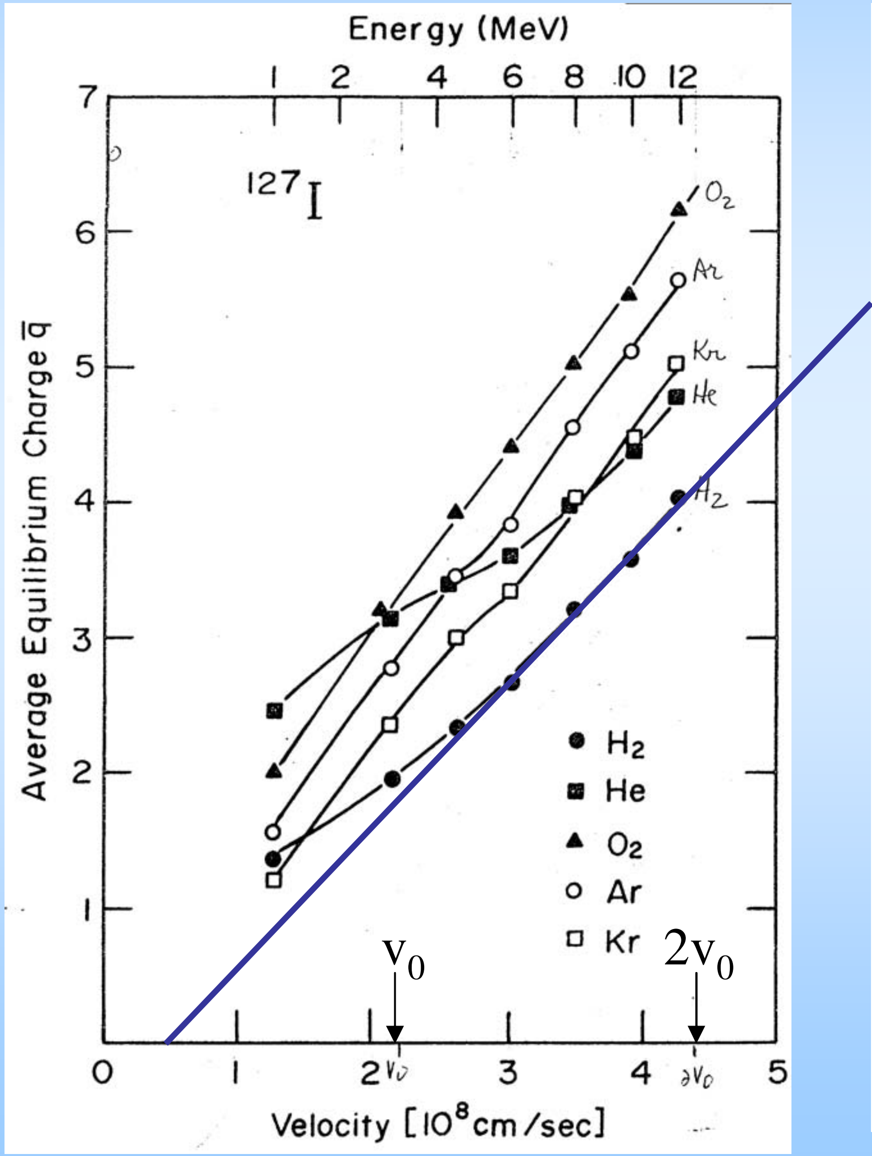


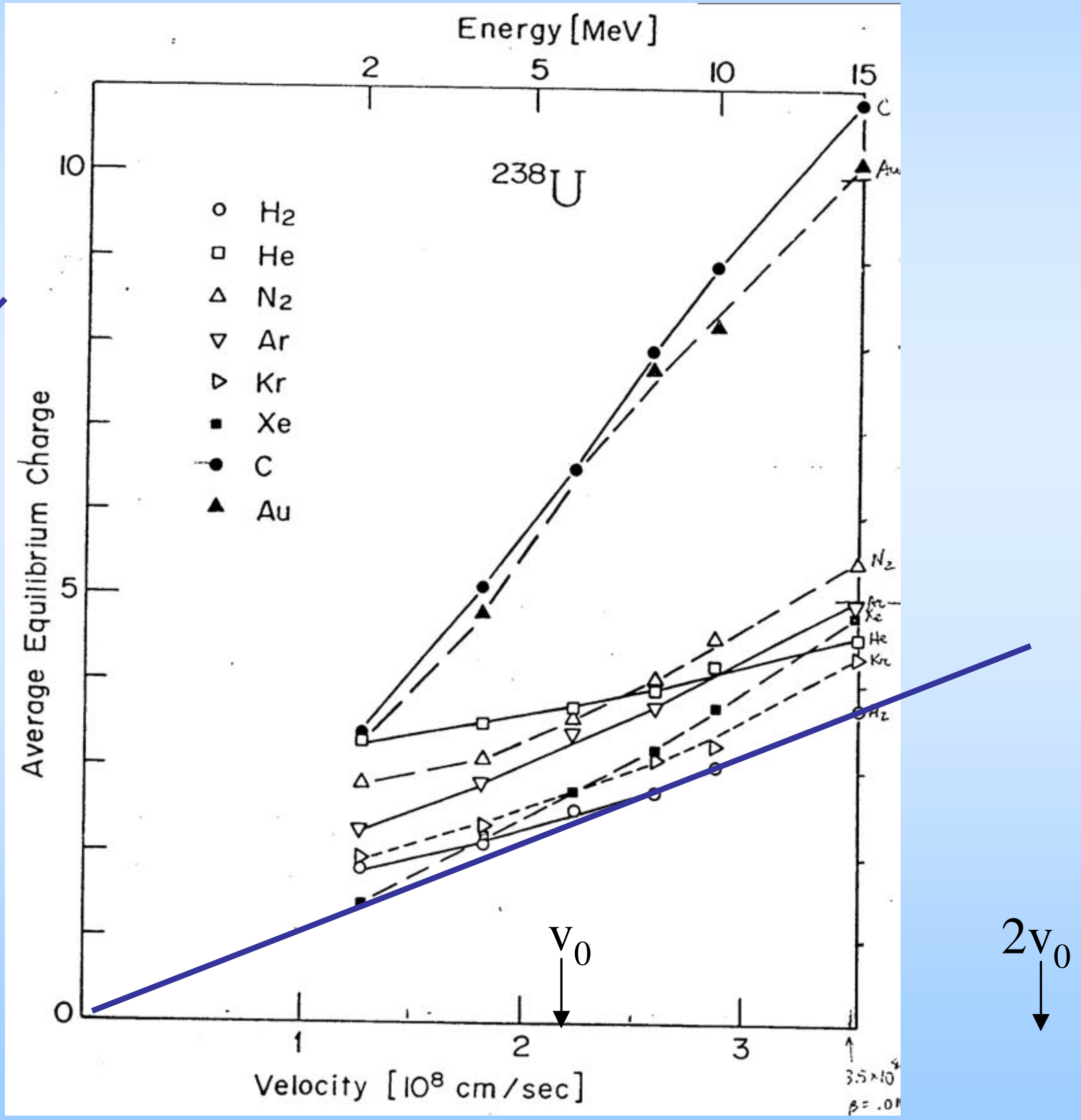
Plot and equations: Oganessian et al.,

PRC **64**, 064309 (2001), Z. Phys. D **21**,S357 (1991)

Understanding Magnetic Rigidity in H_2 Gas

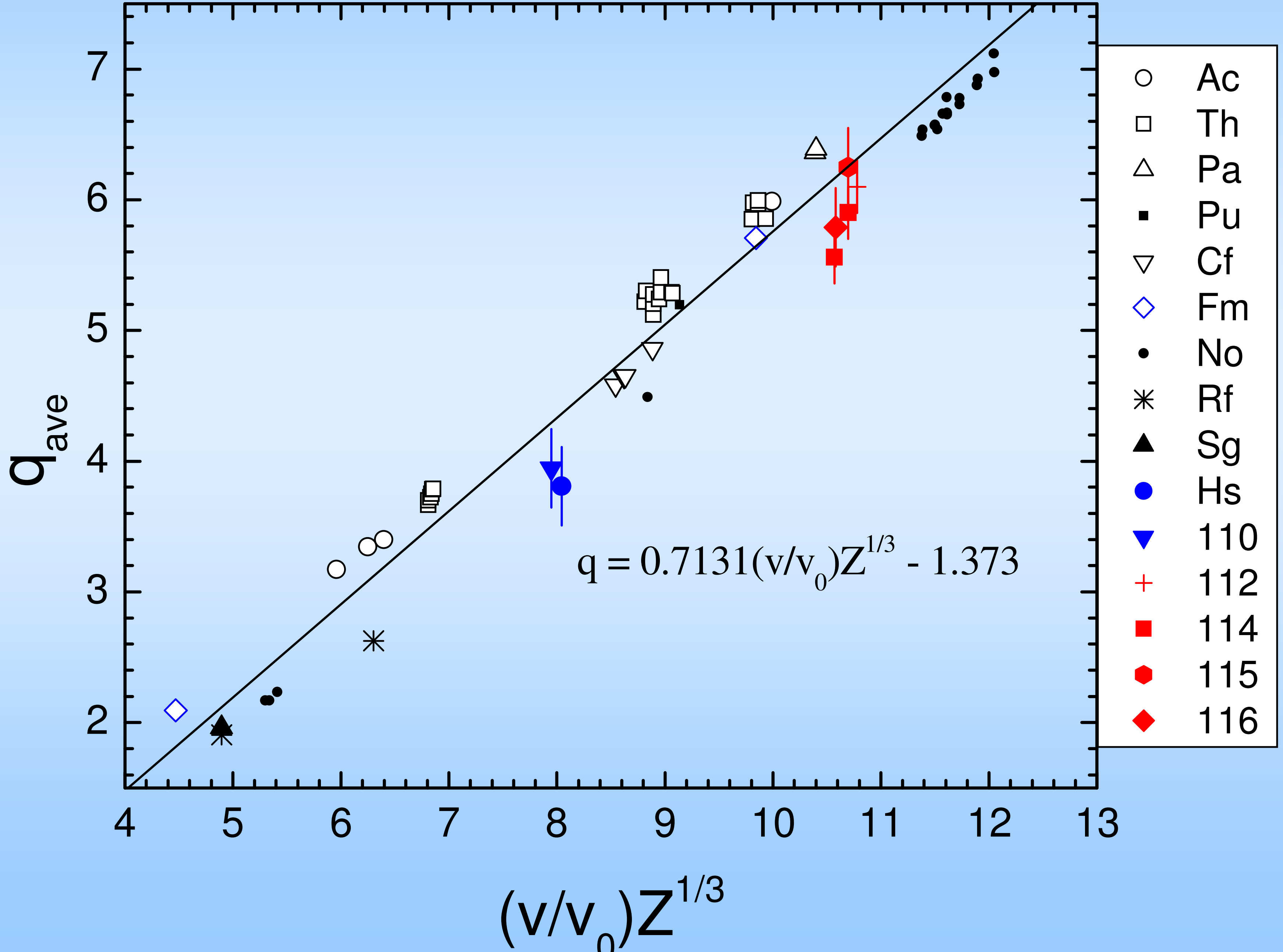
Iodine and uranium are linear to below $v = 1.2v_0$





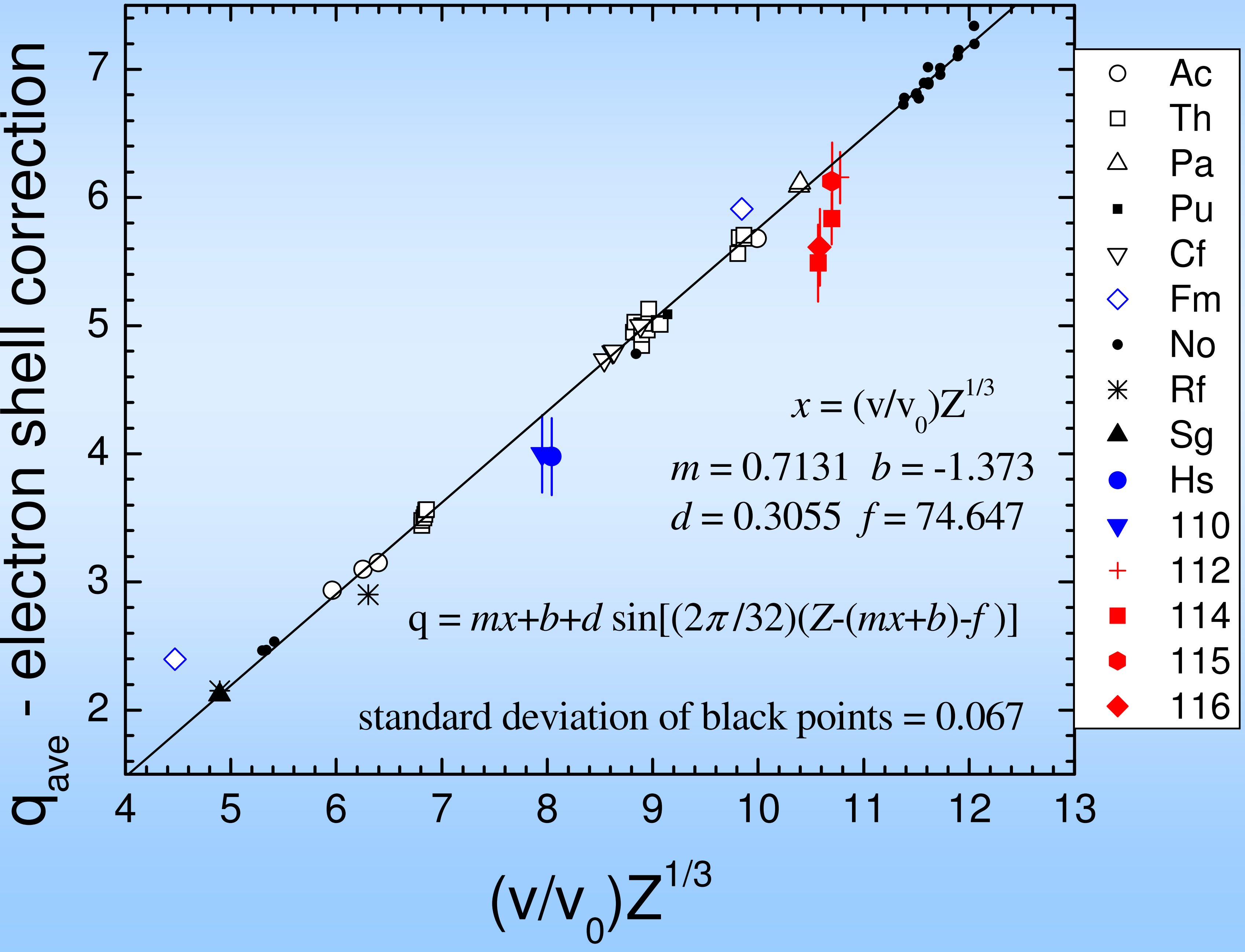
Understanding Magnetic Rigidity in H_2 Gas

Simple $vZ^{1/3}$fit . . .



Understanding Magnetic Rigidity in H_2 Gas

Reduced shell effect amplitude gives excellent fit . . .



$x = (v/v_0)Z^{1/3}$

$m = 0.7131 \quad b = -1.373$

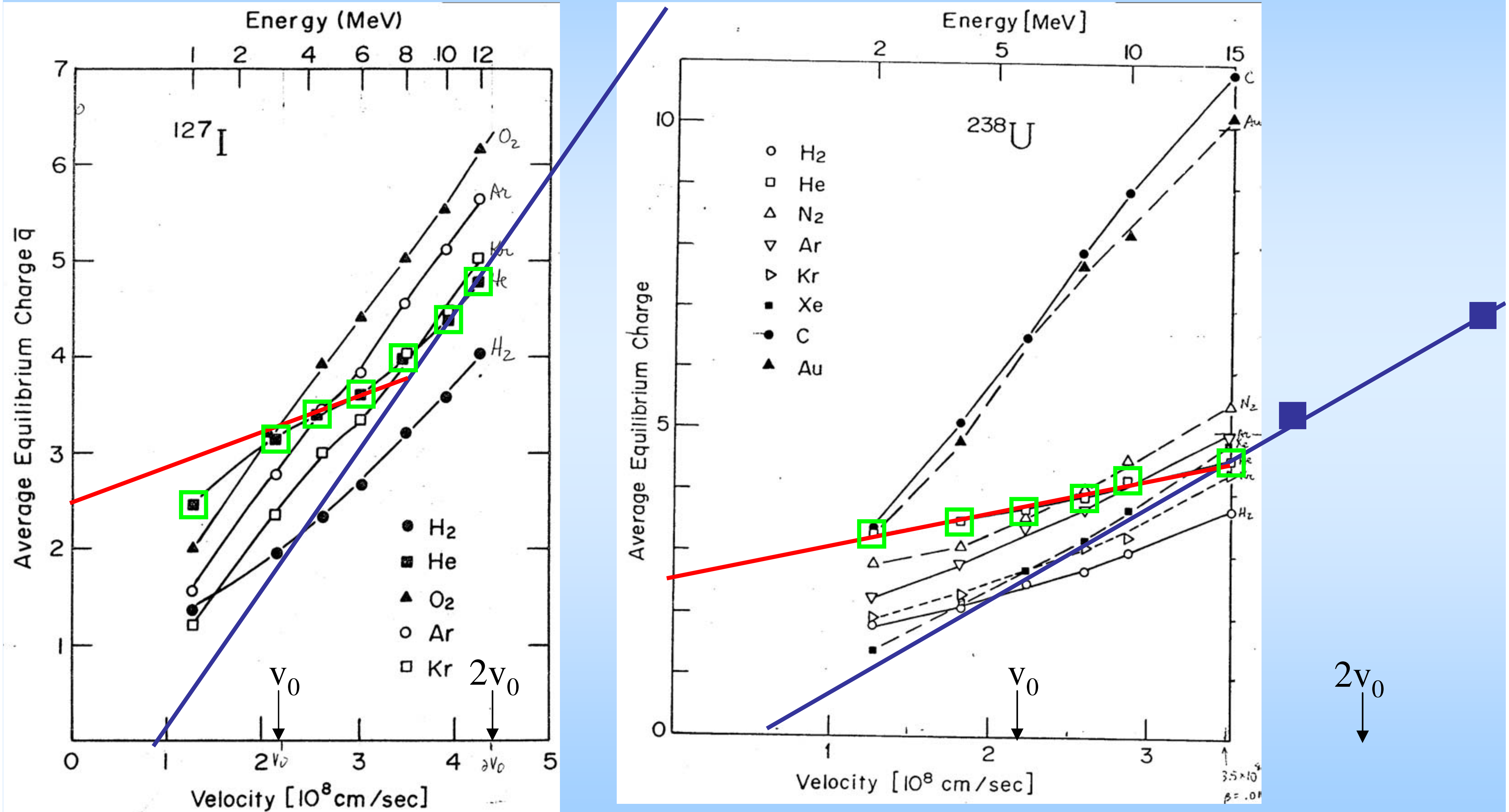
$d = 0.3055 \quad f = 74.647$

$q = mx + b + d \sin[(2\pi/32)(Z-(mx+b)-f)]$

standard deviation of black points = 0.067

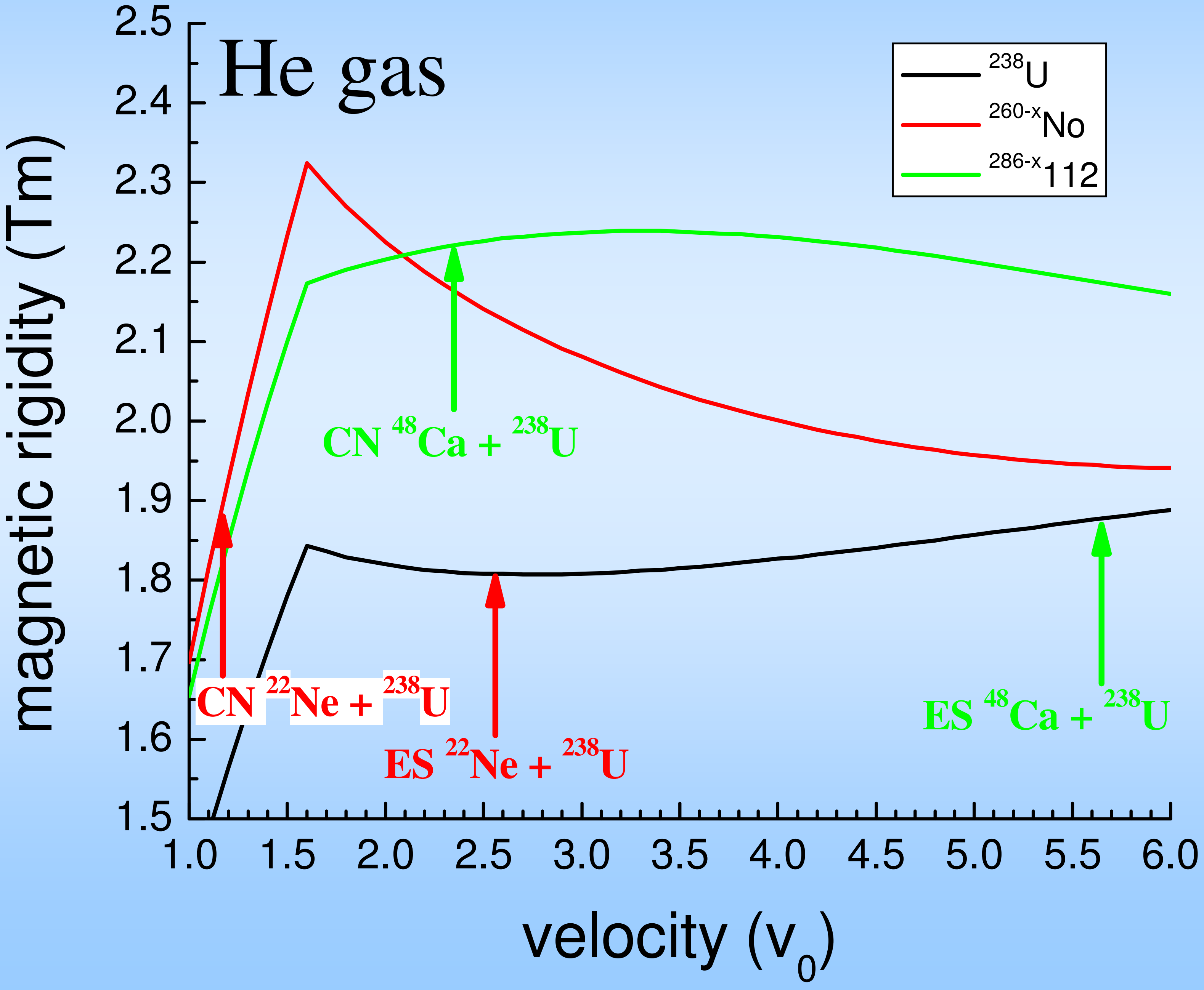
Asymmetric Reactions in He Gas

Iodine and uranium data show a break below v = 1.6v_0



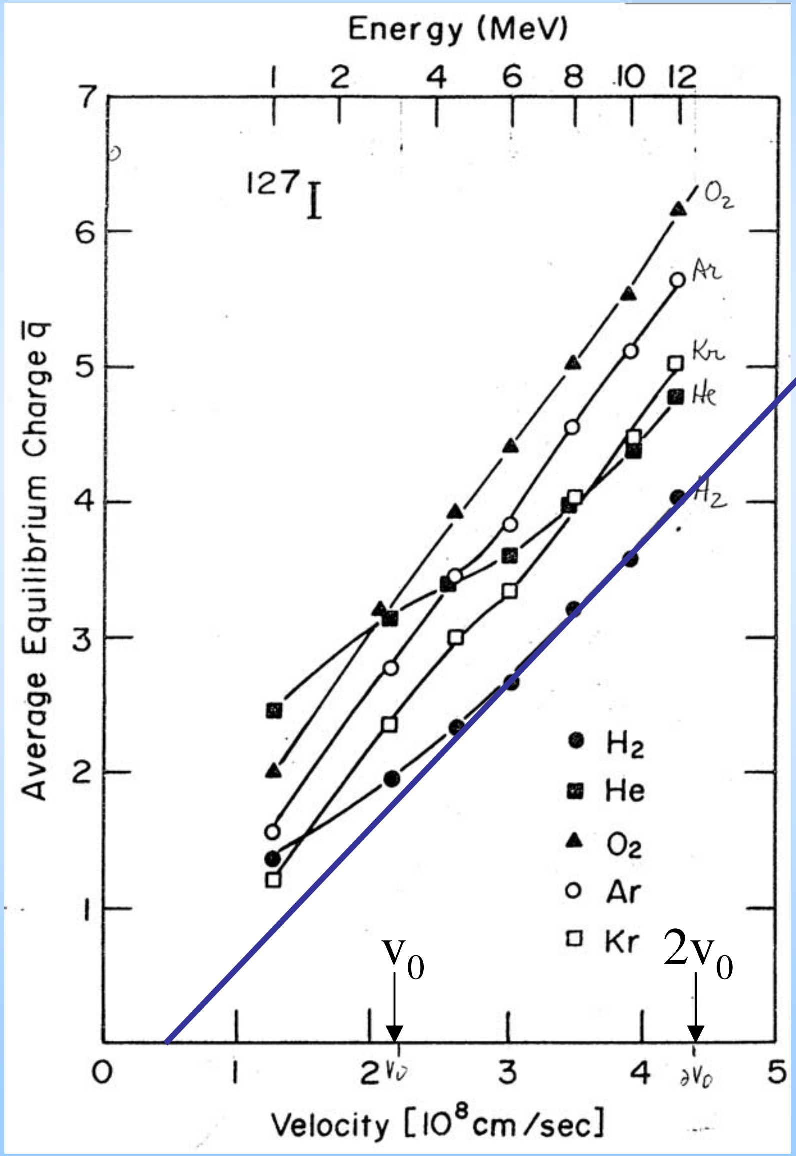
Separation of transfer products in He

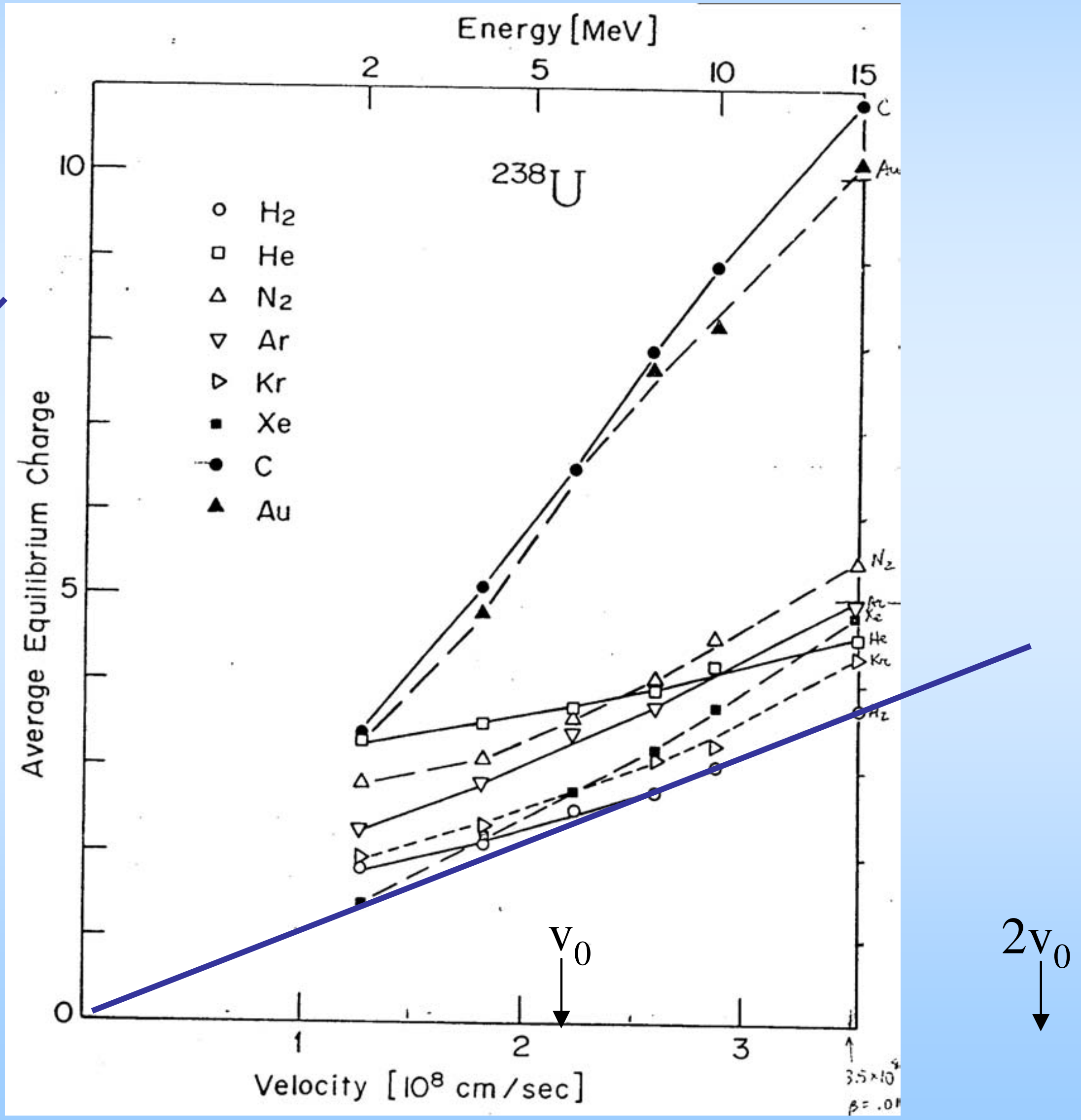
He gas presents problems for asymmetric reactions . . .



Understanding Magnetic Rigidity in H_2 Gas

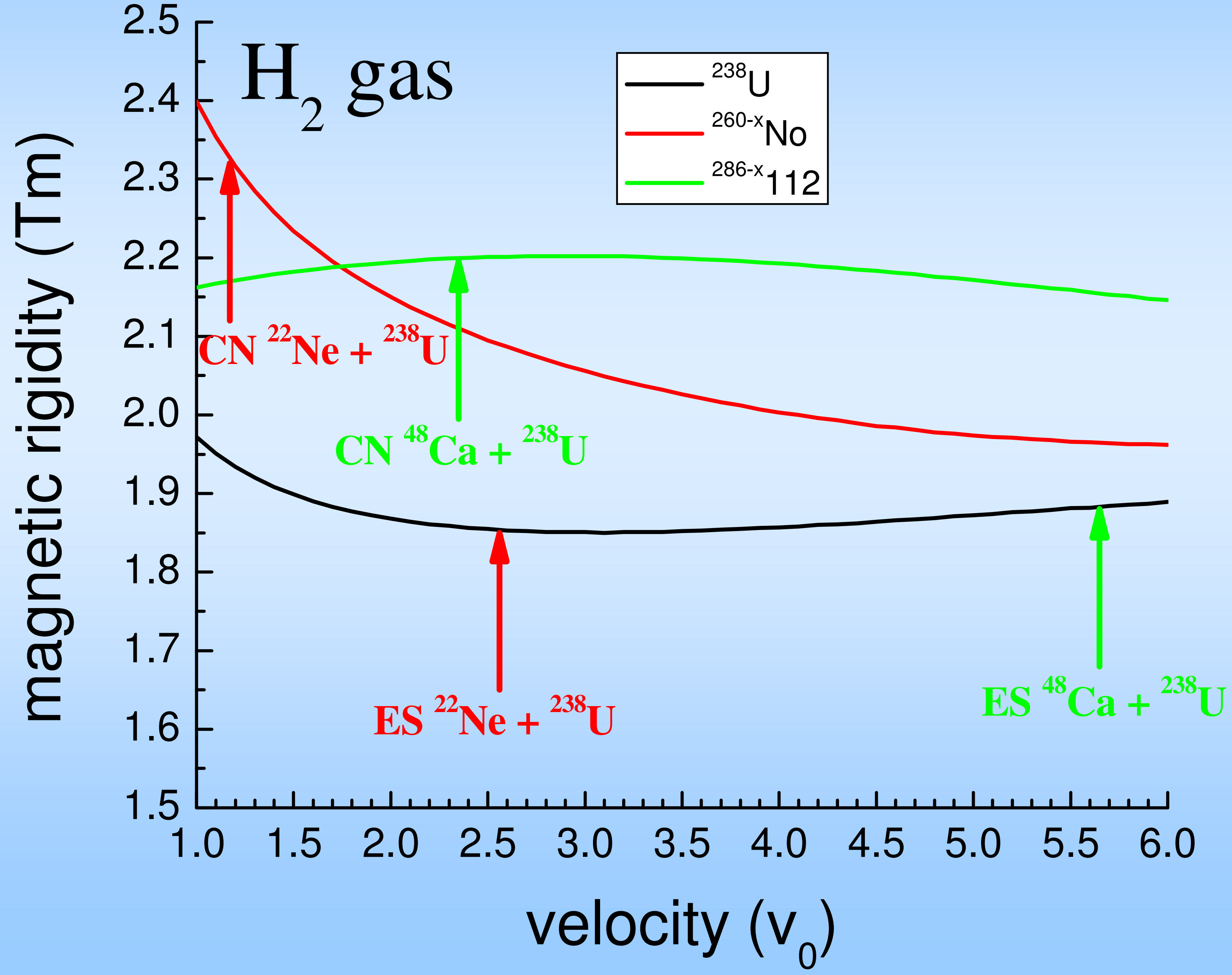
Iodine and uranium are linear almost down to $v = 1.0v_0$





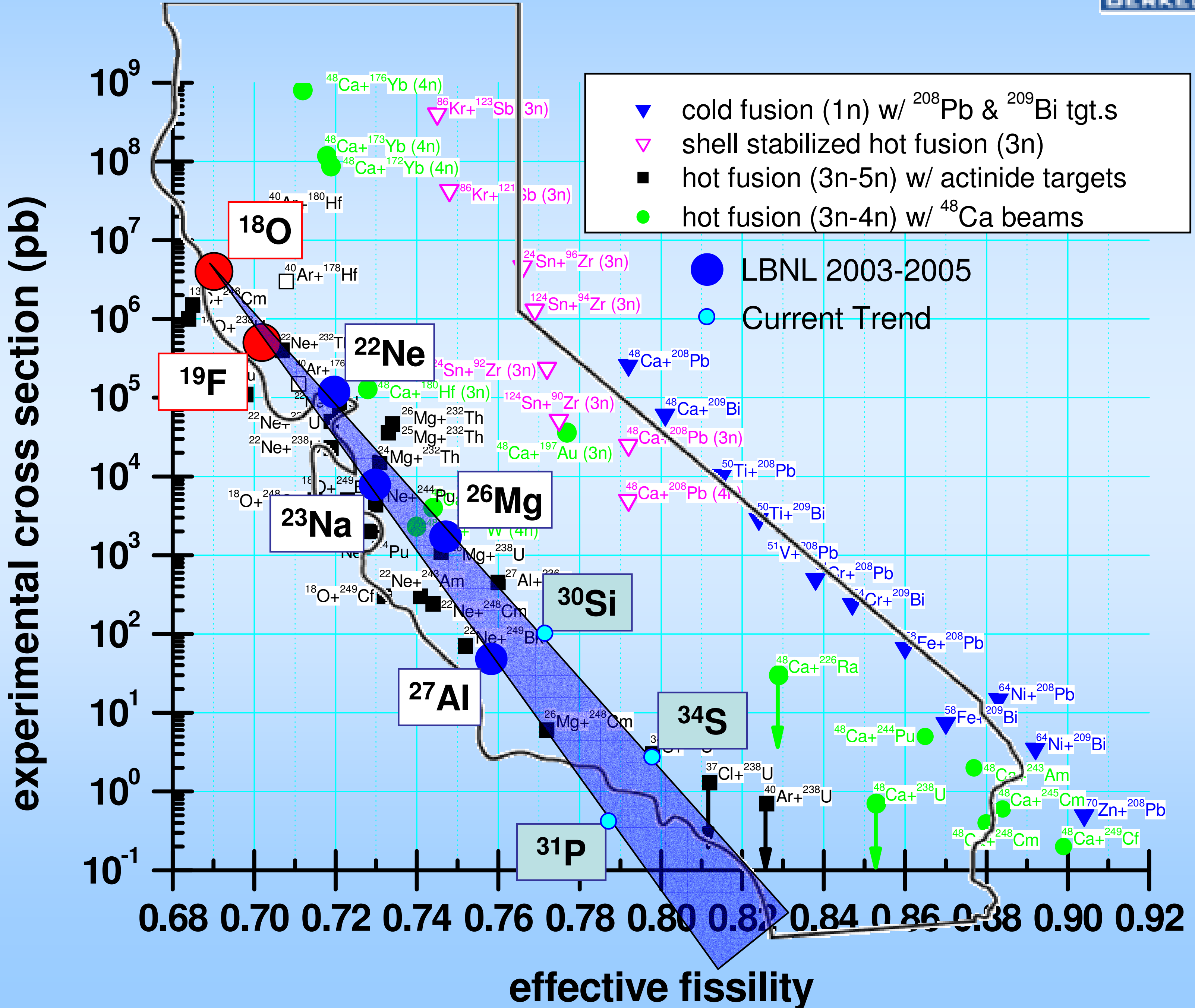
Separation of transfer products in H_2

He should be better for asymmetric reactions . . .



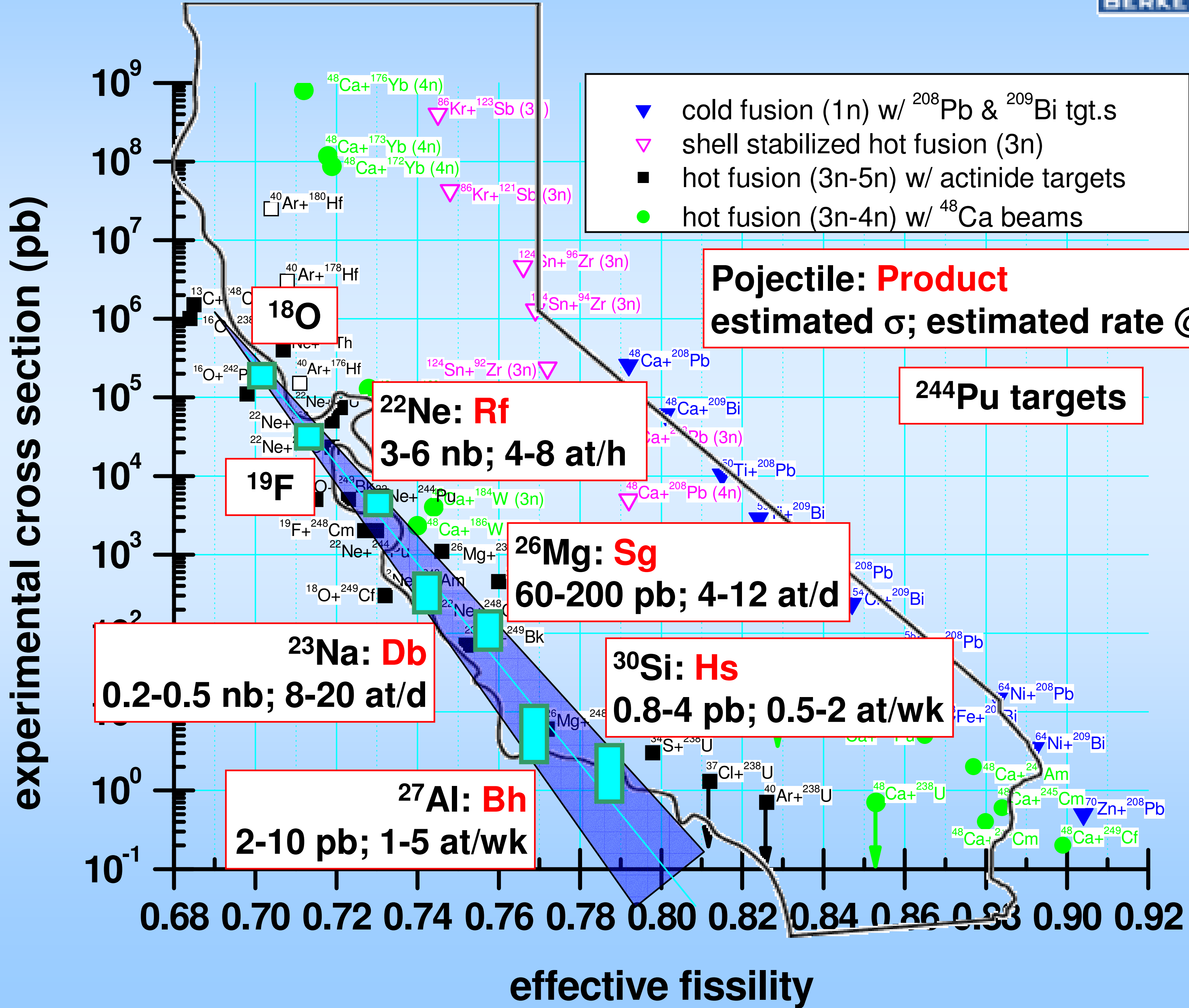
Cross Section Systematics with ^{238}U Targets

Summary of preliminary results . . .



Scale to ^{244}Pu Targets by Effective Fissility

Conservative esitmates of target thickness and beam intensities



^{18}O

^{22}Ne: Rf
3-6 nb; 4-8 at/h

^{19}F

^{26}Mg: Sg
60-200 pb; 4-12 at/d

^{23}Na: Db
0.2-0.5 nb; 8-20 at/d

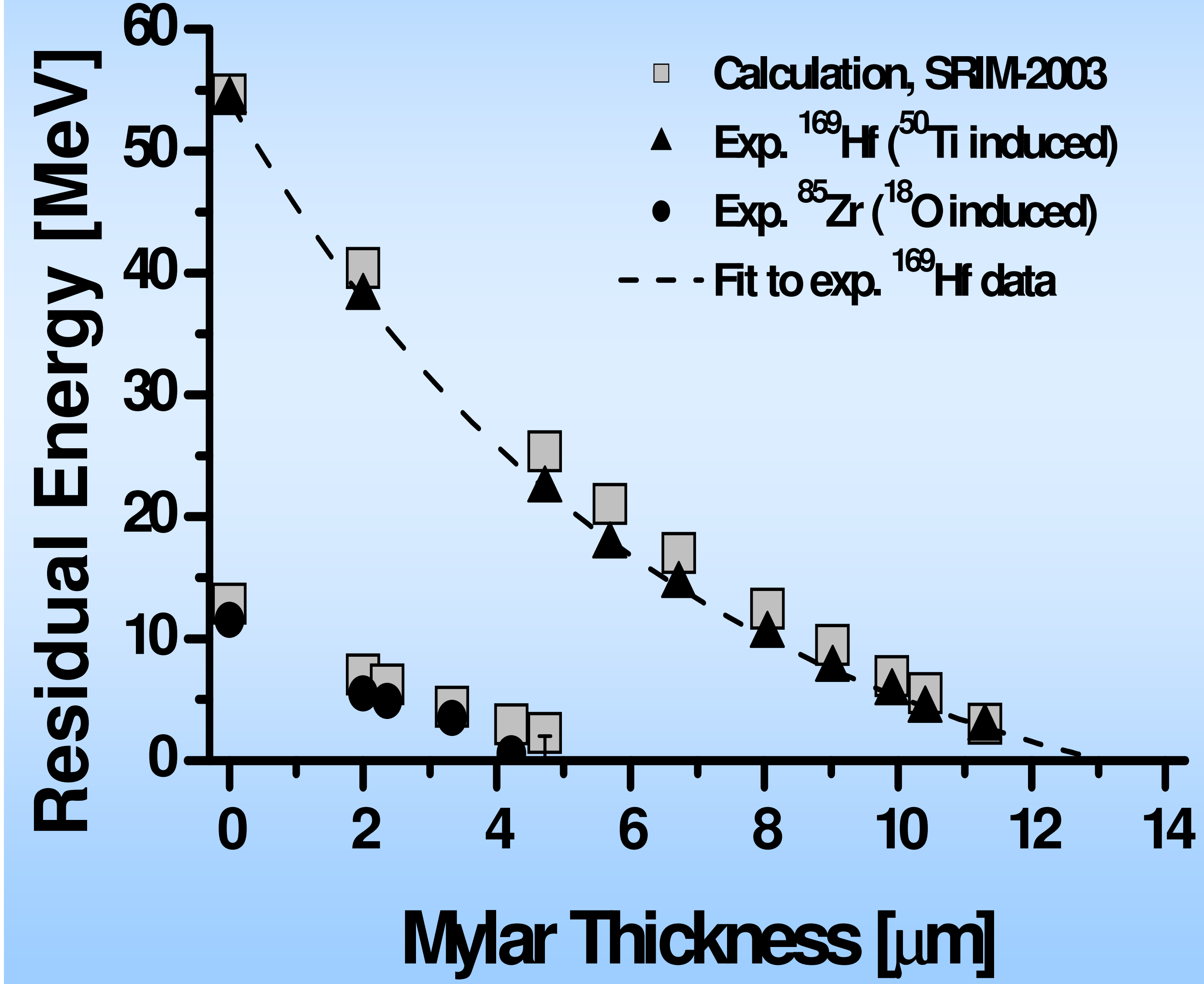
^{30}Si: Hs
0.8-4 pb; 0.5-2 at/wk

^{27}Al: Bh
2-10 pb; 1-5 at/wk

Pojectile: Product
estimated σ; estimated rate @ BGS

^{244}Pu targets

Range Measurements in MYLAR



MYLAR range experiments:

^{nat}Ge(^{18}O,xn)^{85}Zr
^{124}Sn(^{50}Ti,5n)^{169}Hf
^{176}Yb(^{37}Cl,xn)$^{213\text{-}x}$Fr
^{208}Pb(^{37}Cl,3n)^{245}Es
^{238}U(^{22}Ne,xn)$^{260\text{-}x}$No
^{208}Pb(^{50}Ti,xn)$^{258\text{-}x}$Rf

Conclusions:
SRIM2003 does a good job of predicting ranges.

Moulton et al. overestimate pulse-height defects for heavy elements in Si detectors

First Test . . . α-Particles

General operation can be tested by focusing α-particles through TASCA

  Bρ of ^{244}Cm α-particles is only 0.347 Tm, so magnetic fields may not have expected shapes

  This can provide an initial measurement of the angular acceptance

  A small fraction of decay will be He^{1+} with Br = 0.694 Tm

BGS first test with α-particles in Fall 1998:

  Noise from the SCR magnet power supplies was larger than α-pulses

  Noise problem was solved with induction coils in series with M2 current, but . . .

Install Hall probe in the dipole, and always record the value

  To detect histeresis and unexpected magnetic field changes

Second Test . . . Real Beam!

Beamstop design

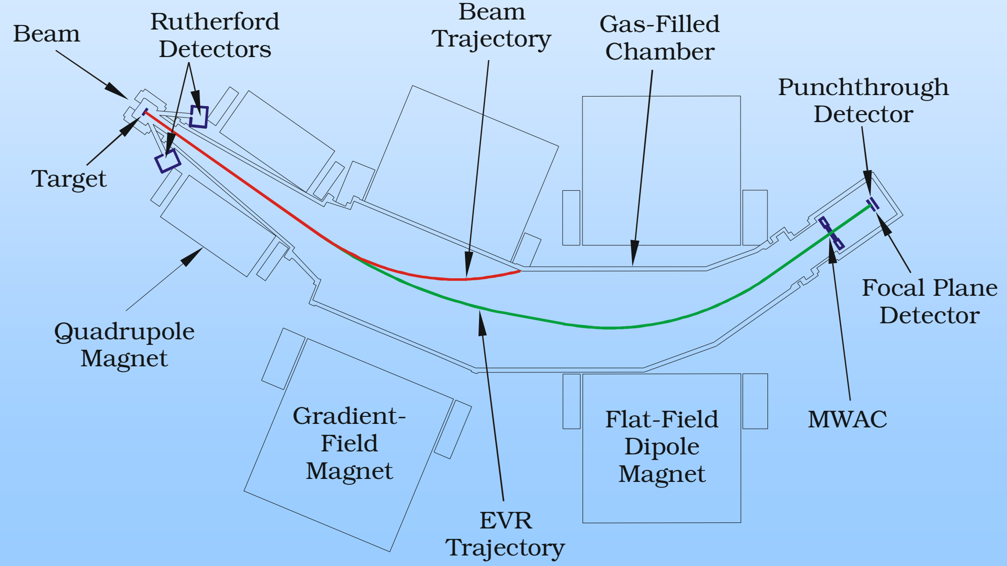
First test in the BGS was $^{197}Au(^{22}Ne,xn)^{219\text{-}x}Ac$

- Cross sections are huge, α-branches are large
- BGS had a simple beamstop . . . scattered beam dominated spectrum

- Fins were added to the beamstop, reducing the background rate
- Fins were enlarged to full vertical height in second beamstop iteration

While on the subject of the beamstop:

- The beam should only hit the targets and tantalum (collimator and beamstop)
- Neutron and gamma rates in the BGS cave are quite low
- Even with 1 pμA of beam, large-volume Ge detector sees only 2000 cps (singly scattered γs)



Third Test . . . High Intensity Beam

^{208}Pb(^{40}Ar,3n)^{245}Es used to test high-beam intensity operation

High-Intensity ^{40}Ar beams should be readily available at GSI
for tests of target cooling and durability

Stringent test of beam suppression

Test of EVR-α correlation techniques

High quality ^{208}Pb targets are readily available at GSI
TASCA should have the capability to use SHIP target wheels for cold-fusion studies

The Ultimate Test . . . ^{206}Pb(^{48}Ca,2n)^{252}No

and the Everyday Test

Test of EVR-α, EVR-SF, α-α, EVR-escape, α-escsape correlation search techniques

Measurement of EVR-α, EVR-SF, α-α, EVR-escape, α-escsape position resolution

Spontaneous fission energy calibration without contaminating detector

Accelerator energy matching (excitation function has been published from all separators)

Separator efficiency test (cross section is well known)

High magnetic rigidity separator test (Bρ is similar to most heavy element reactions)

The Everyday Test

A target can be chosen for each beam used in heavy element experiments that produces large amounts of α-decaying nuclides.

- Use α-decay for these tests (EVRs can be misleading because of αxn exit channels)
- Test for unexpected shifts in magnetic rigidity (always compare to past runs)
- Confirmation that the UNILAC delivers the requested beam
- Use for testing of data acquisition and any auxiliary detectors

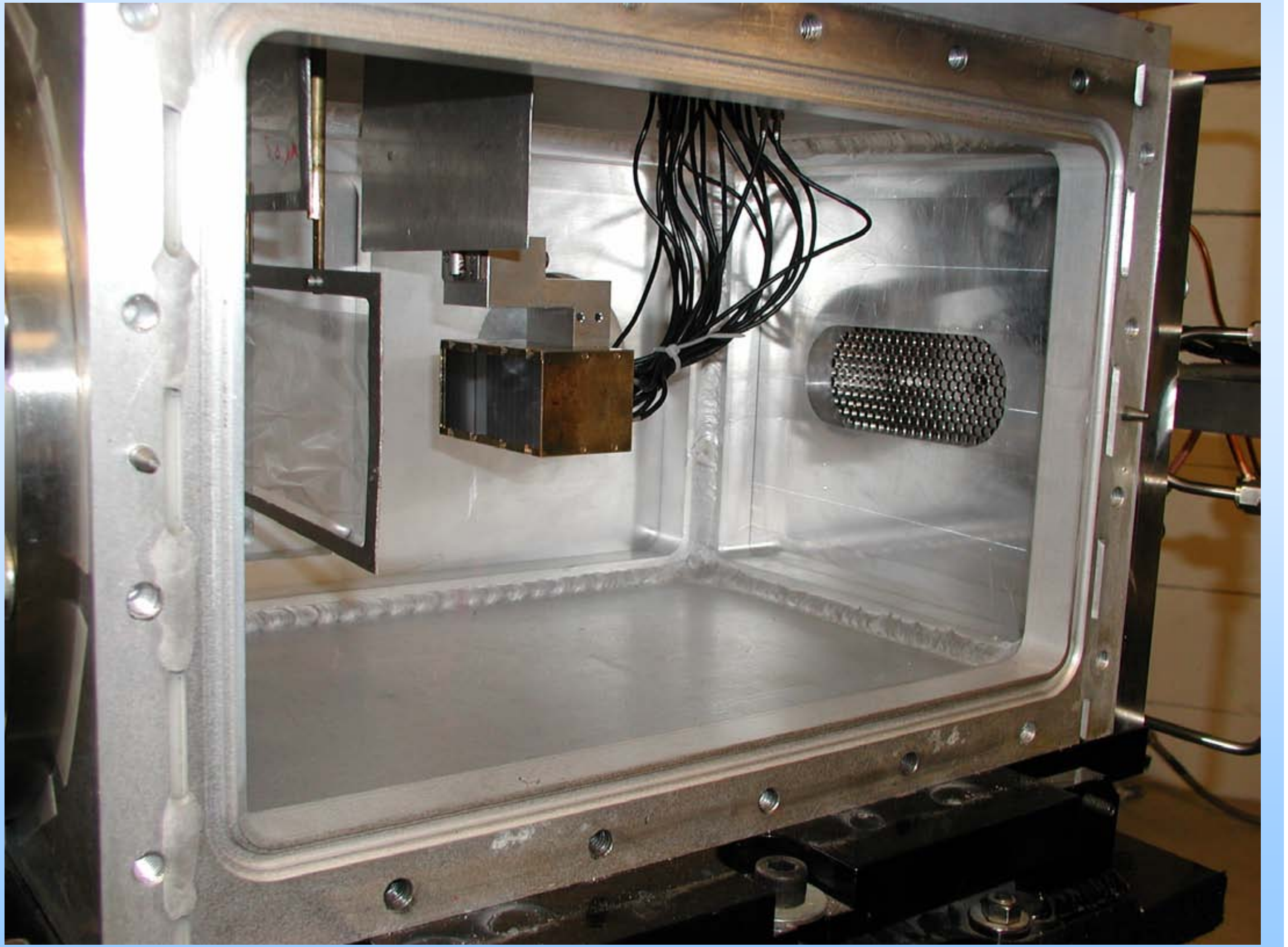
Recoil Transfer Chamber Issues

Wire support grid with square holes led to catastrophic failures

Solid support grid with round holes was uneventful during the “test to destruction”

Retractable “detector-on-a-stik” can hide behind a “wall”

Retractable degrader foils degrader foils to adjust EVR energy entering RTC window



“Detector Protector” . . . fast RF shutoff activated when Dipole field drops or when rate in detector exceeds 10^4 Hz

Knudsen formula for characteristic charge exchange length is correct! Distance between charge exchange collisions for beam velocities is ~1 meter

Other Essentials

Monitor gas purity with a residual gas analyzer . . . impurities can shift the Bρ distribution

Continuous monitoring of Rutherford-scattered beam particles is essential
- X1 experience confirms that knowledge of actual beam intensity is difficult
- Rutherford rate gives direct measure of luminocity (beam intensity x target thickness)

Calibration of magnetic rigidity with low-intensity beam ($^{40}Ar^{9+}$ and $^{40}Ar^{17+}$)
- We used a phosphor mounted in the detector position

Zero dispersion mode may be unuseable
- Transfer products will reach detector (or RTC)

Use of a punchthrough detector
- 1-MeV punchthrough events (evaporation of protons from PLF in beamstop)
- 2-MeV punchthrough events (evaporation of protons from TLF in beamstop)
- 8-MeV punchthrough events (forward scattering of He gas)

Know your data acquisition . . . DAQ errors cam mimic heavy element events
- On-line DAQ program should log module readout errors
- Temporary failure of detector components (MWPC sparking)

Conclusion

TASCA will provide a “beam-free” gas-jet for heavy element studies

Interfering transfer products will be suppresed by a large factor

Final word to the TASCA group . . . Have fun with your new toy!