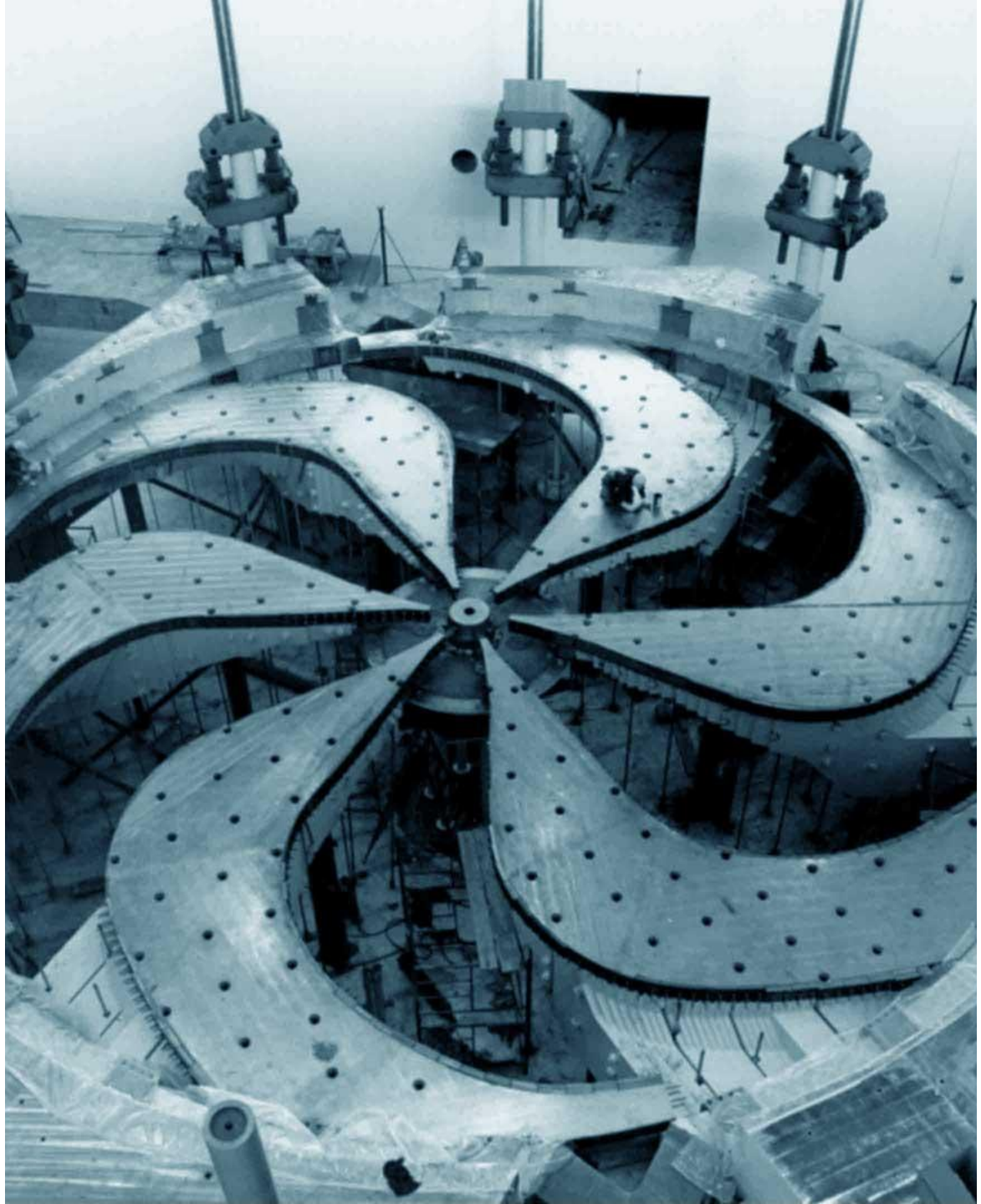
TRIUMF

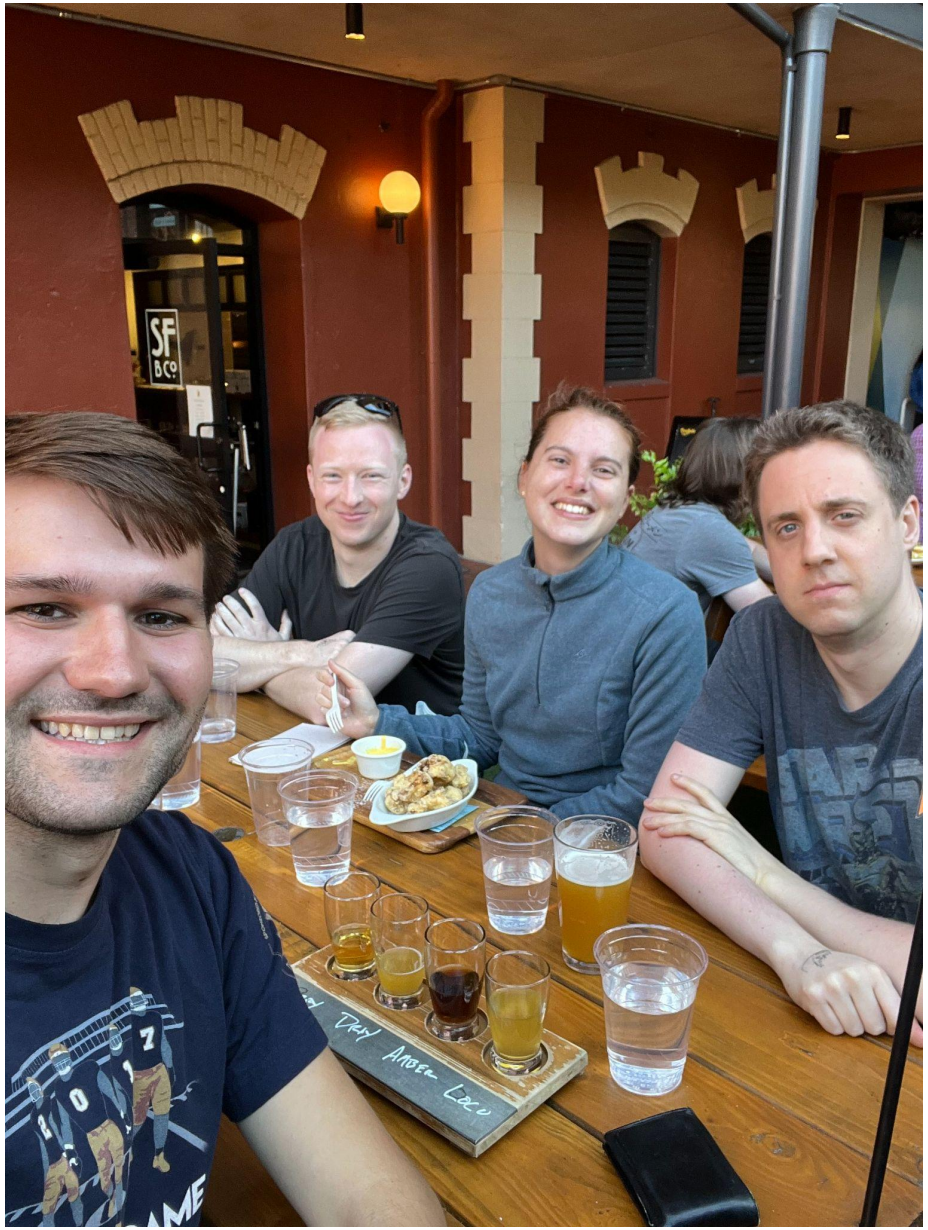
Charting the *N* = *40* Island of Inversion with neutron-rich iron isotopes at TITAN

Sam Porter

Nuclear Structure -- June 16th, 2022



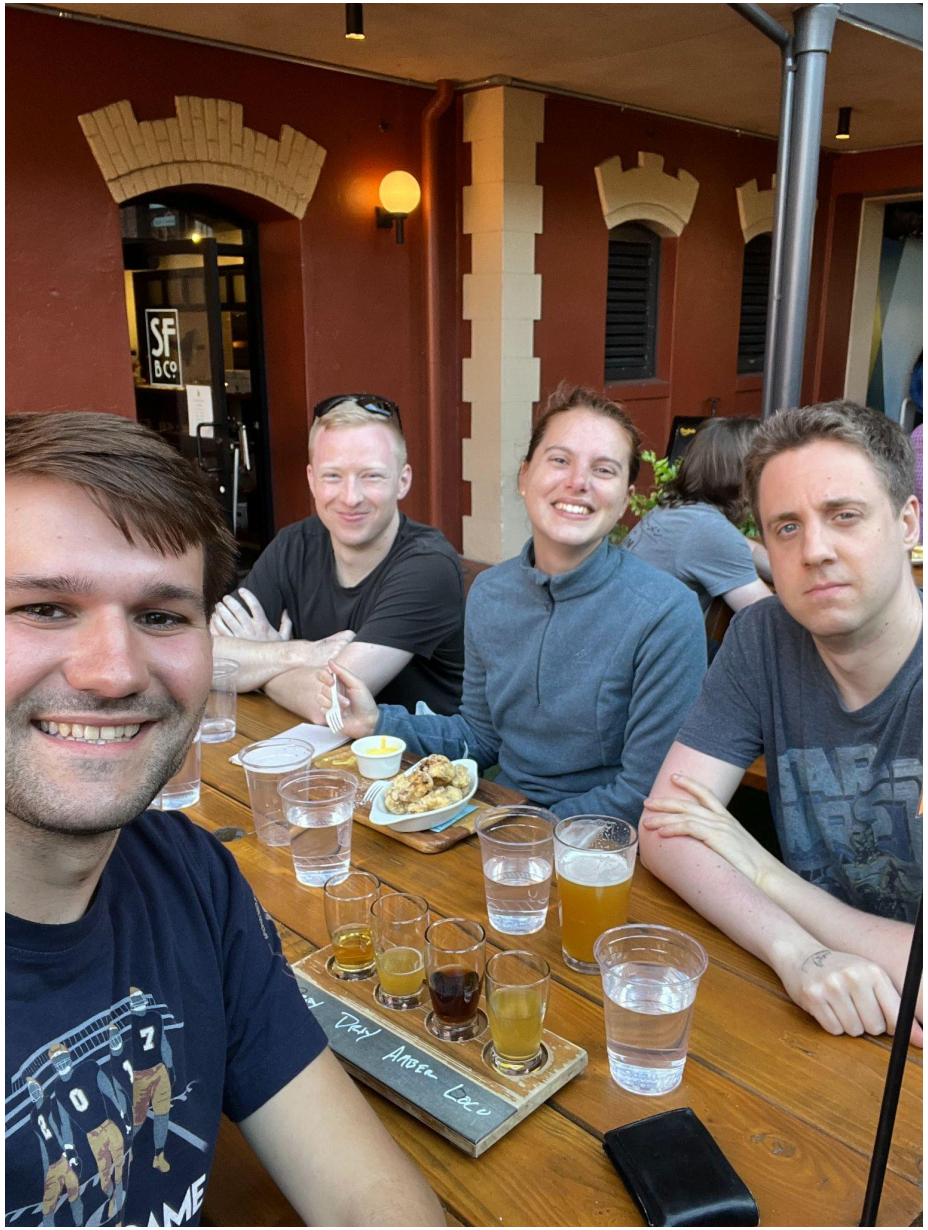
Discovery, accelerated



Previous talk

J. Williams *et. al*., San Francisco Brewing Company (2022)

Current talk



Previous talk

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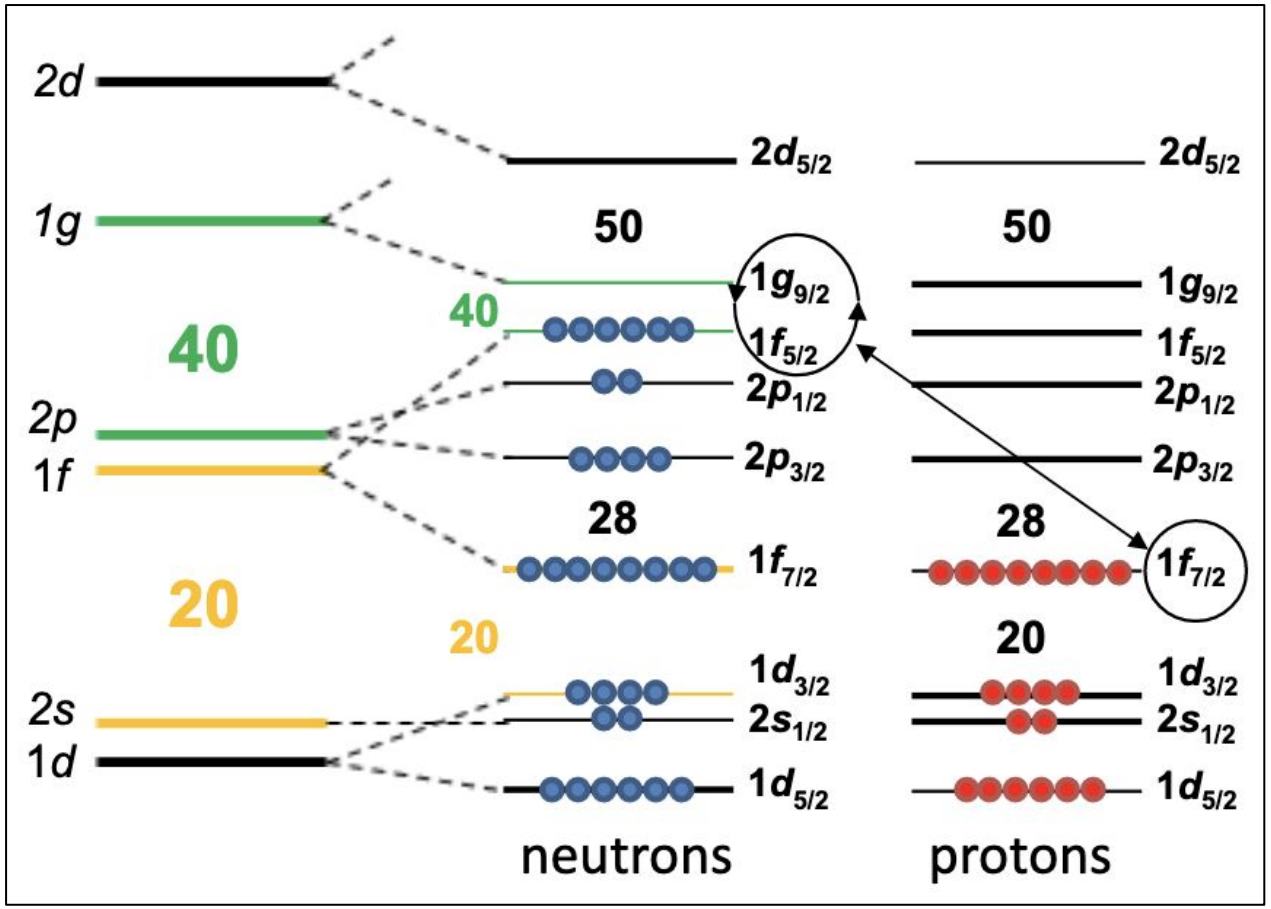
Next talks

Previous talk

Current talk

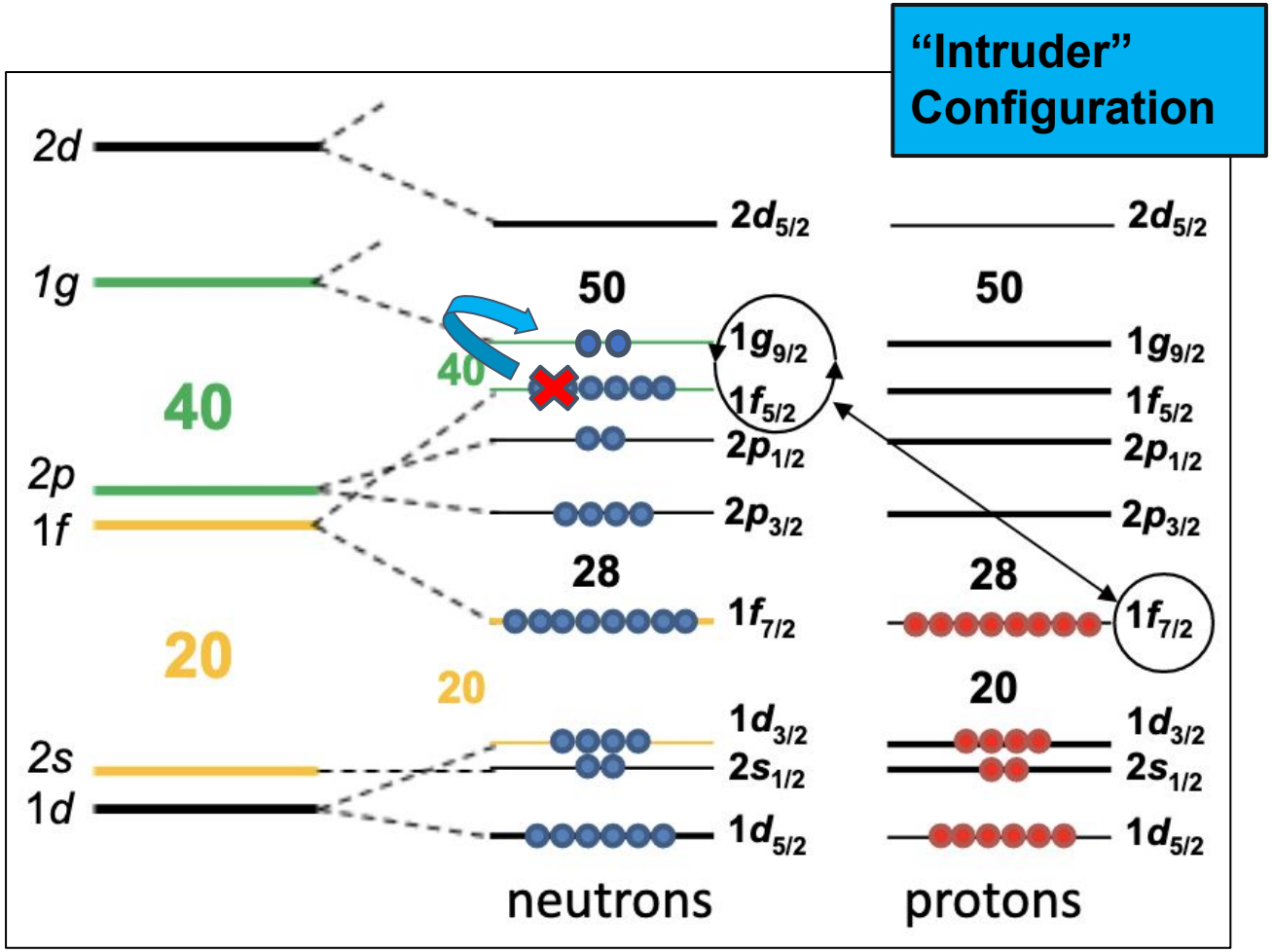
J. Williams *et. al.*, San Francisco Brewing Company (2022)

The N = 40 Island of Inversion



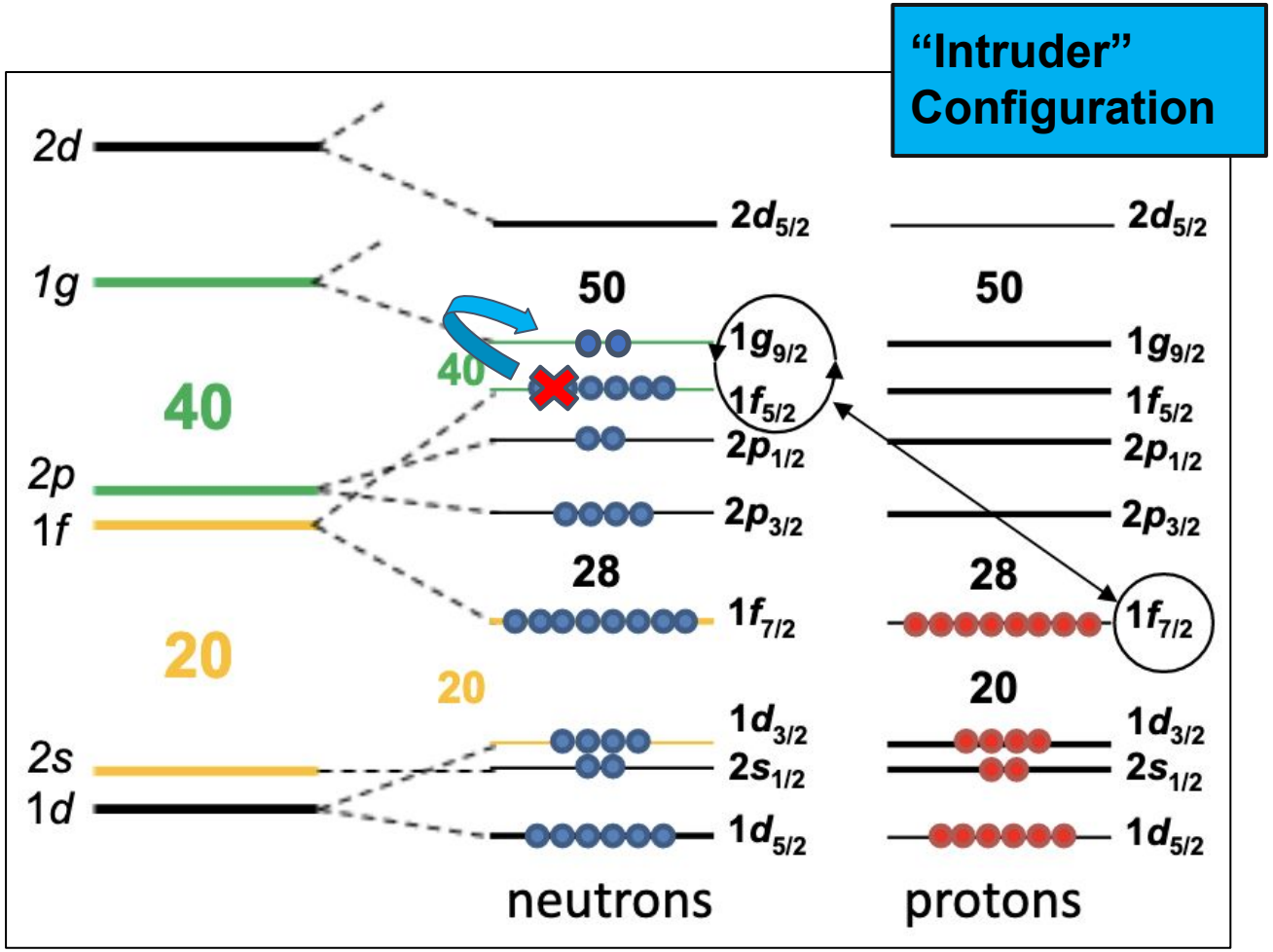
V. Manea, ISOLDE Addendum IS532 (2016)

The N = 40 Island of Inversion



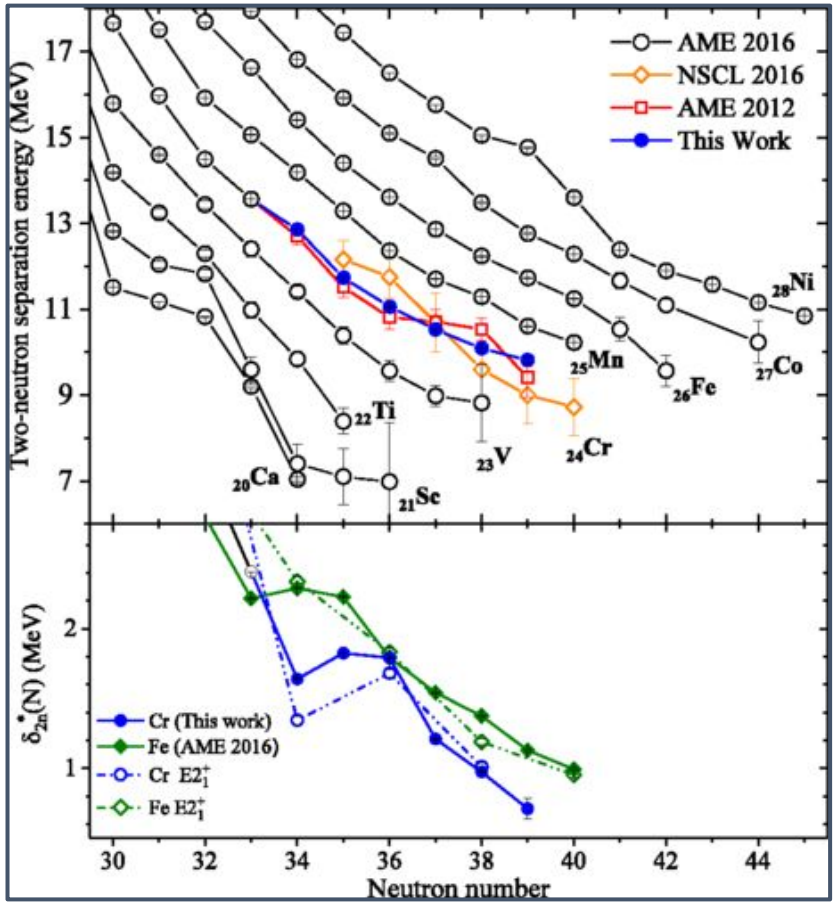
V. Manea, ISOLDE Addendum IS532 (2016)

The N = 40 Island of Inversion



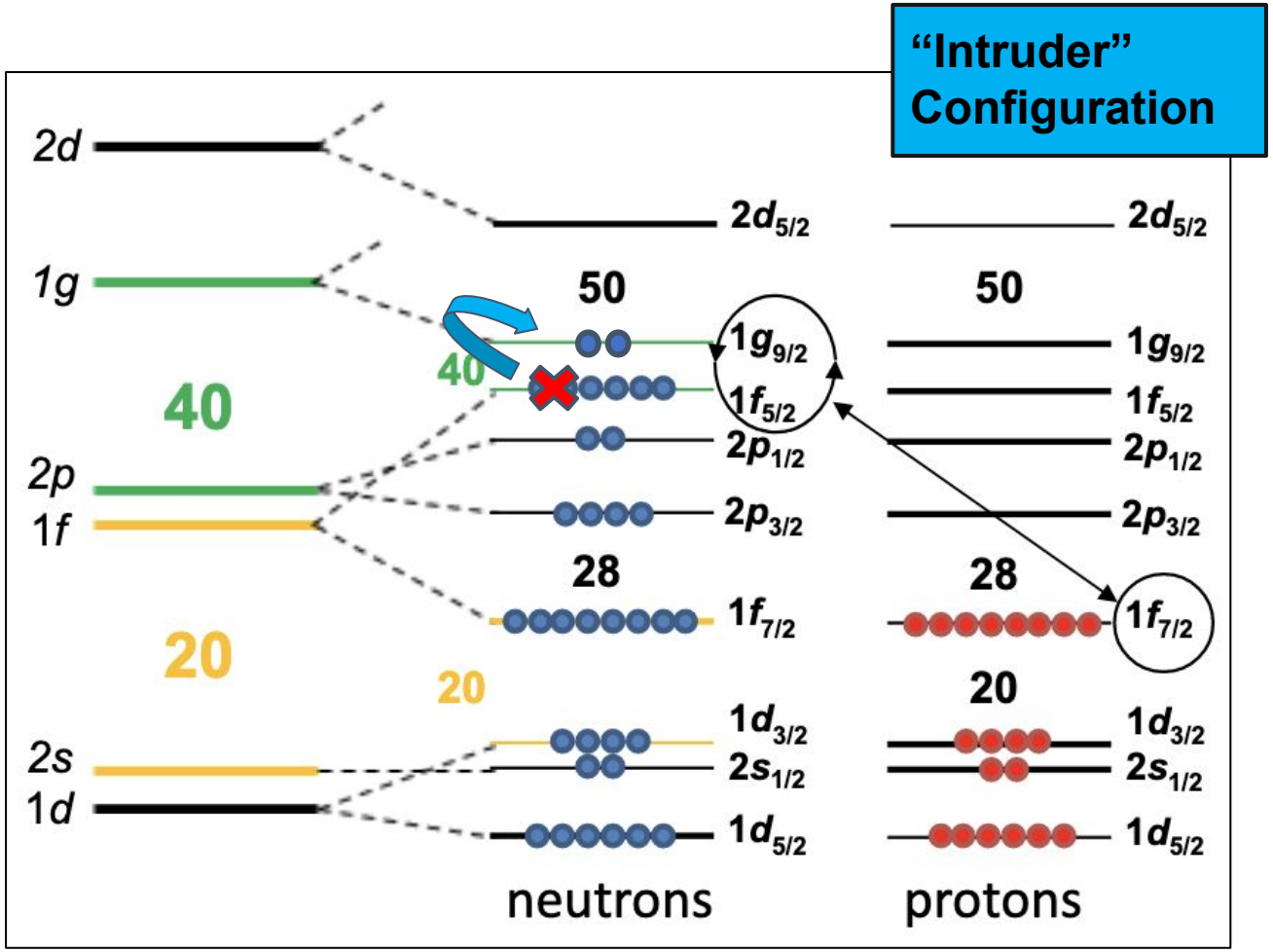
V. Manea, ISOLDE Addendum IS532 (2016)

$$S_{2n} = m(N,Z) - m(N-2,Z) + 2m_n$$



M. Mougeot *et. al.*, PRL, **120** 232501 (2018)

The N = 40 Island of Inversion



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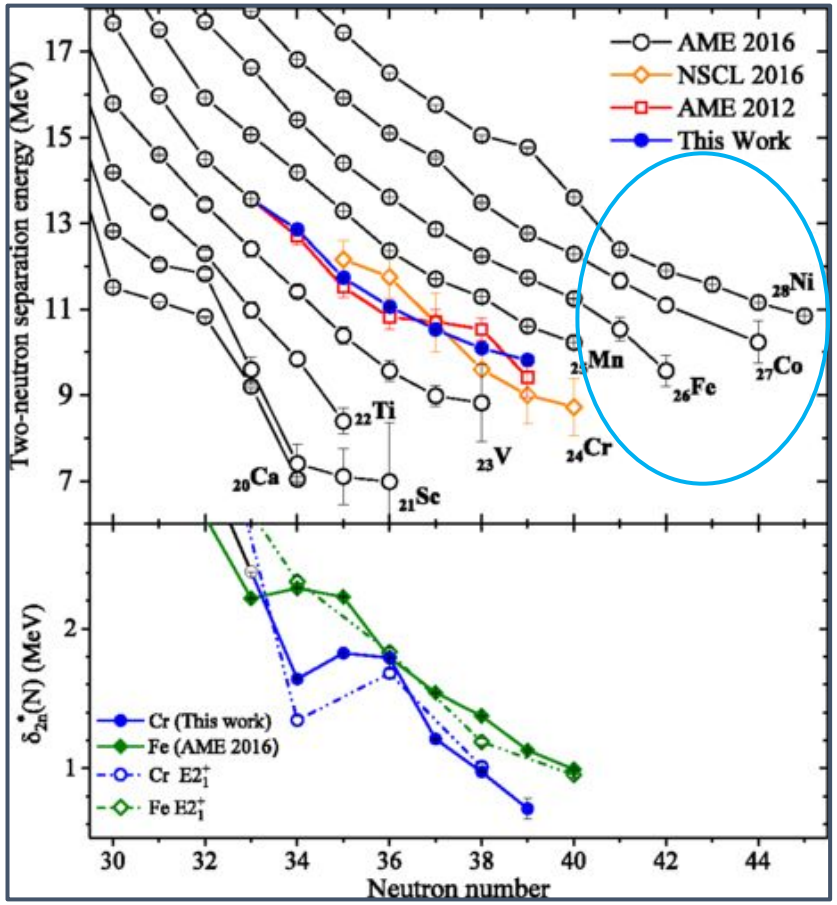
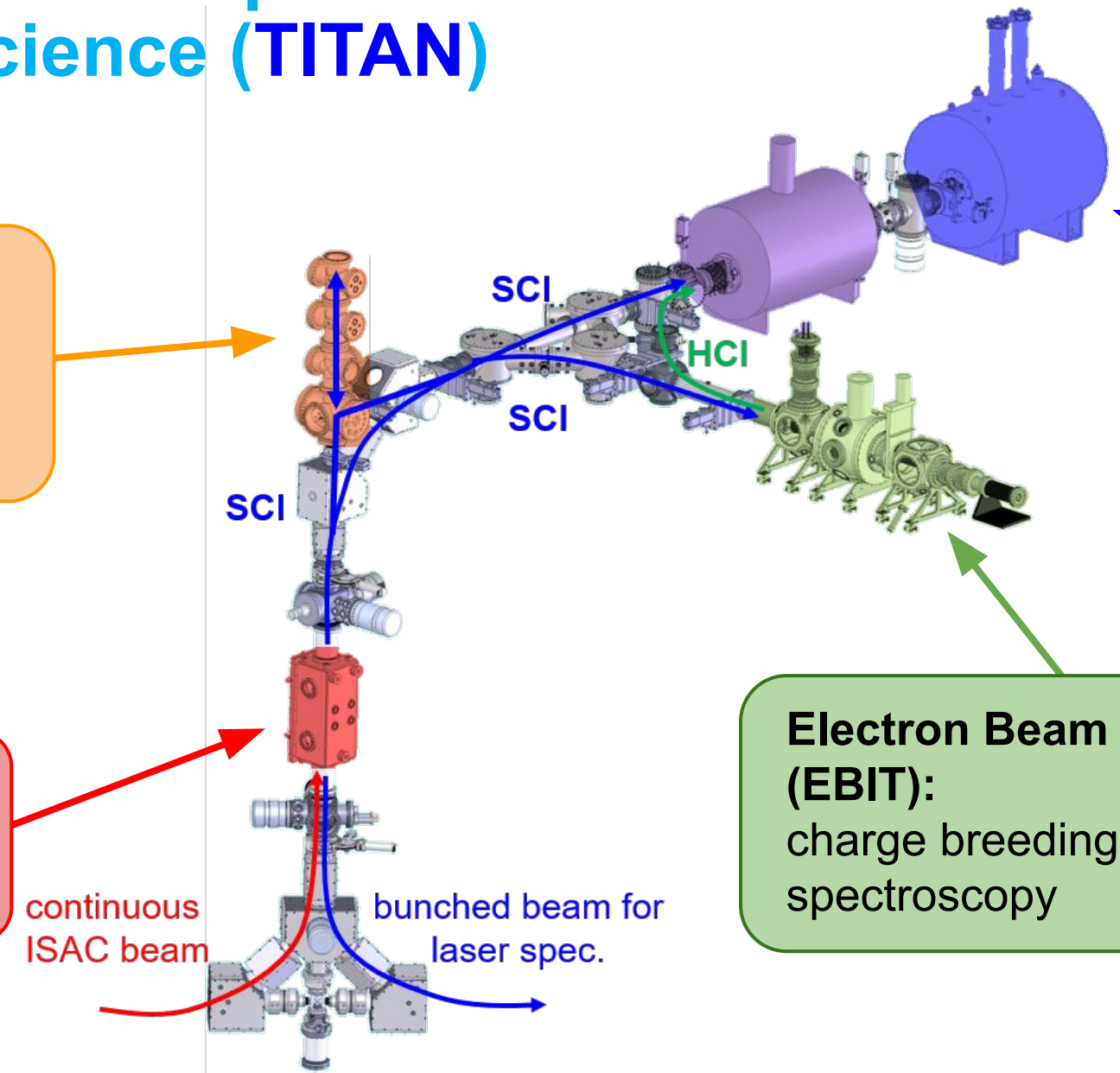


M. Mougeot *et. al.*, PRL, **120** 232501 (2018)

TRIUMF's Ion Trap for Atomic and Nuclear Science (TITAN)

MR-ToF-MS:
mass separation via time-of-flight

TITAN RFQ:
cools and bunches beam

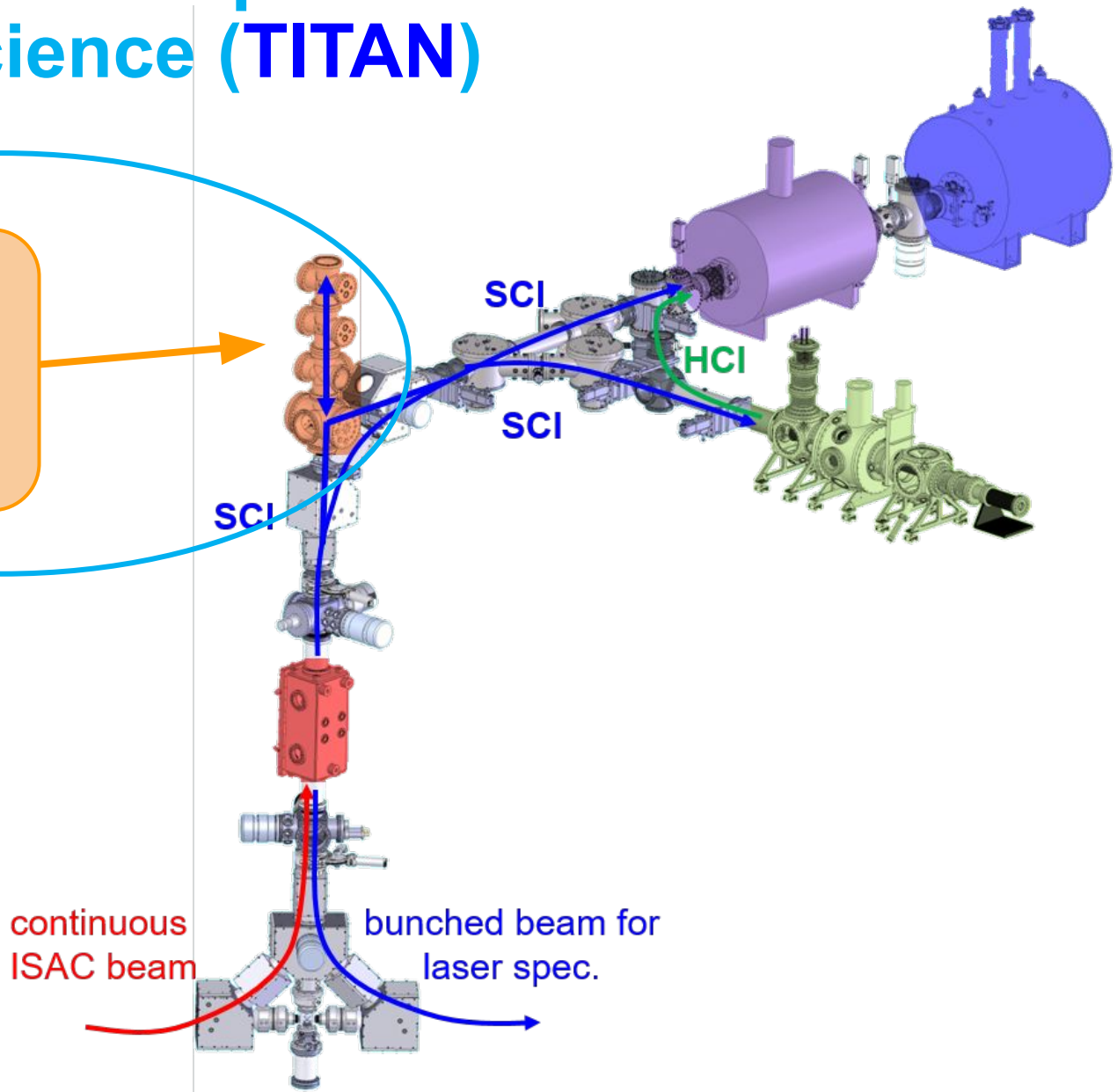


Measurement Penning Trap (MPET):
high precision mass measurements

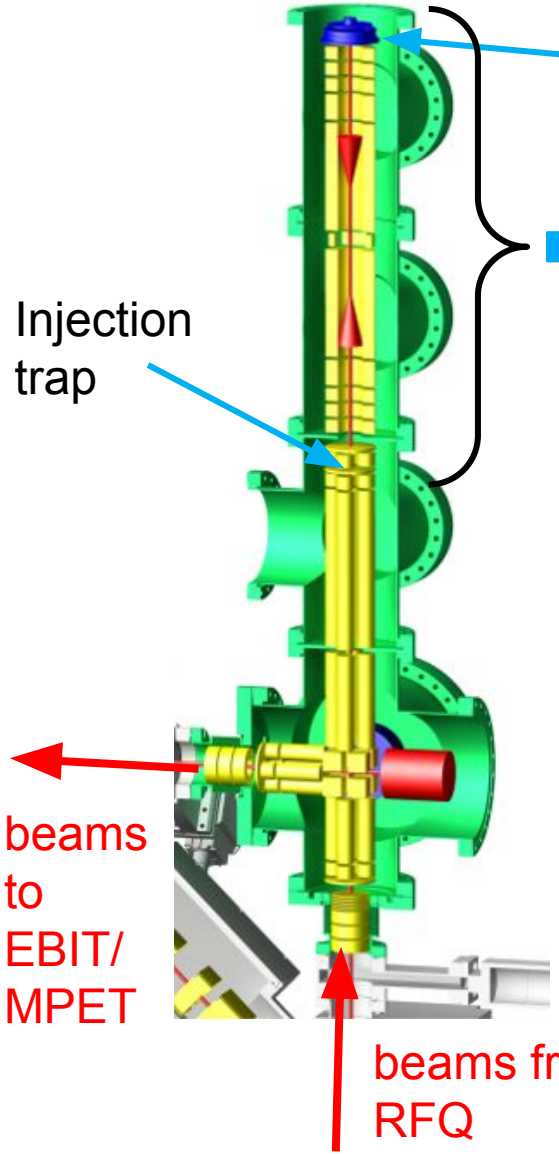
Electron Beam Ion Trap (EBIT):
charge breeding and decay spectroscopy

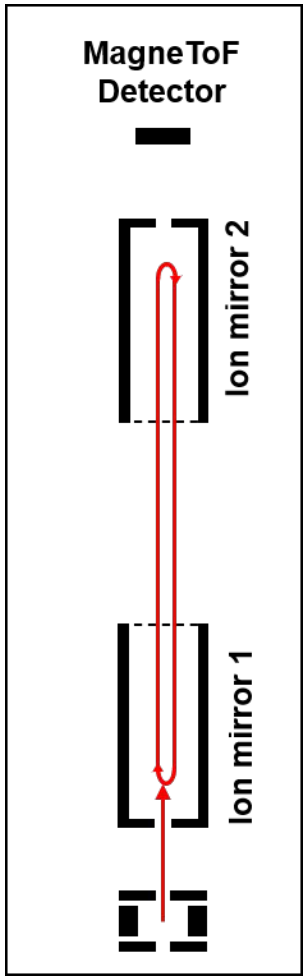
TRIUMF's Ion Trap for Atomic and Nuclear Science (TITAN)

MR-ToF-MS: mass separation via time-of-flight



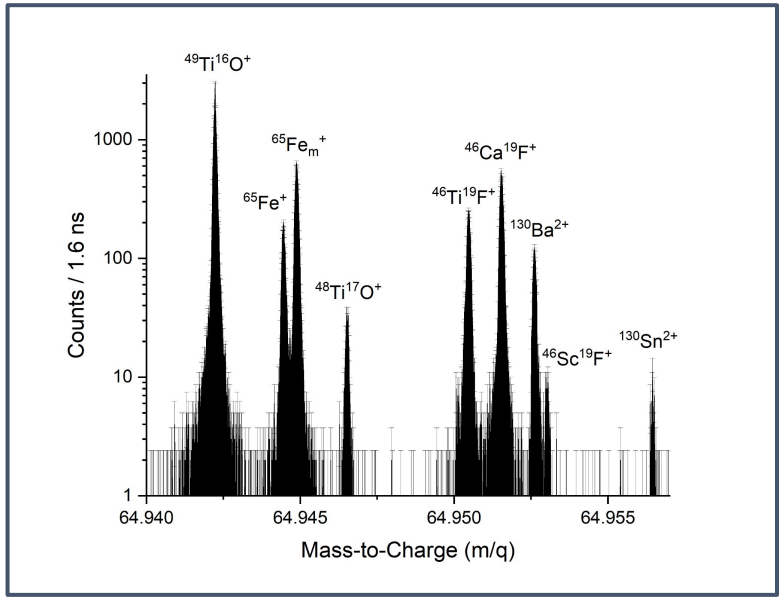
Multiple-Reflection Time-of-Flight Mass-Spectrometer (MR-ToF-MS)



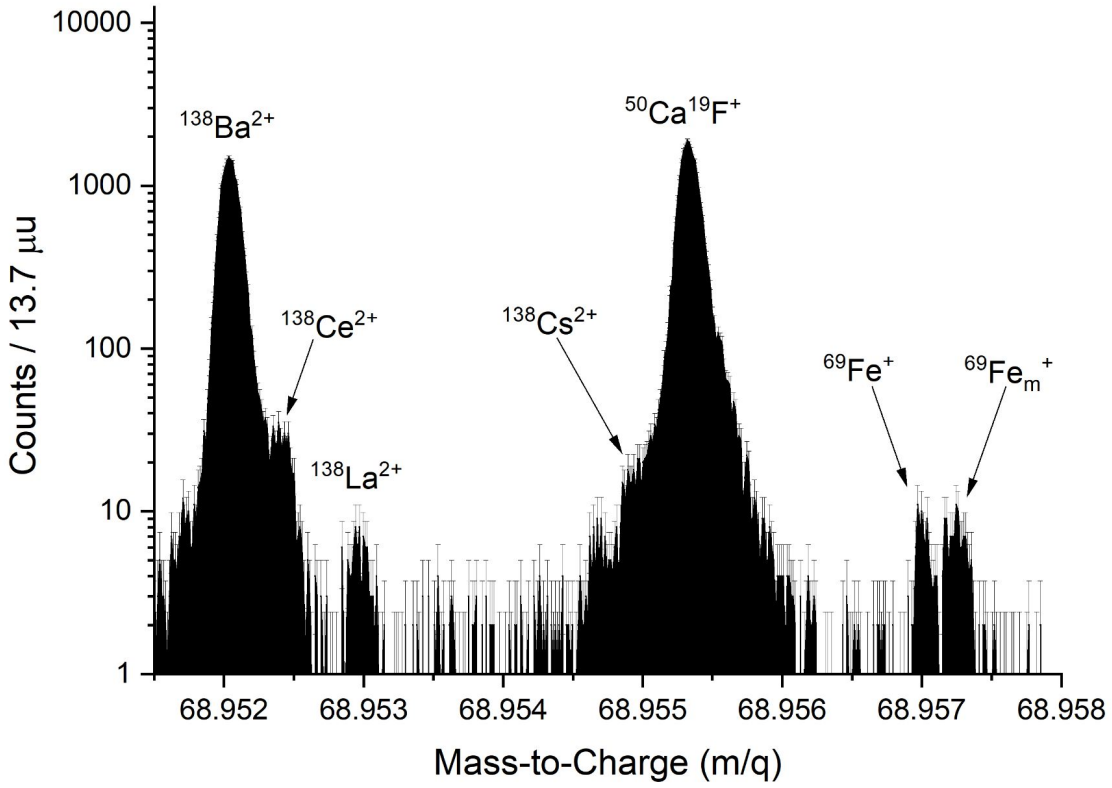


- **R ~ 500,000**
- measure masses w/ **$t_{1/2}$ > few ms**
- Ion-of-Interest to background ratios up to **$1:10^8$**

M.P. Reiter *et. al.*, Nuc. Inst. Methods B **463** (2020)

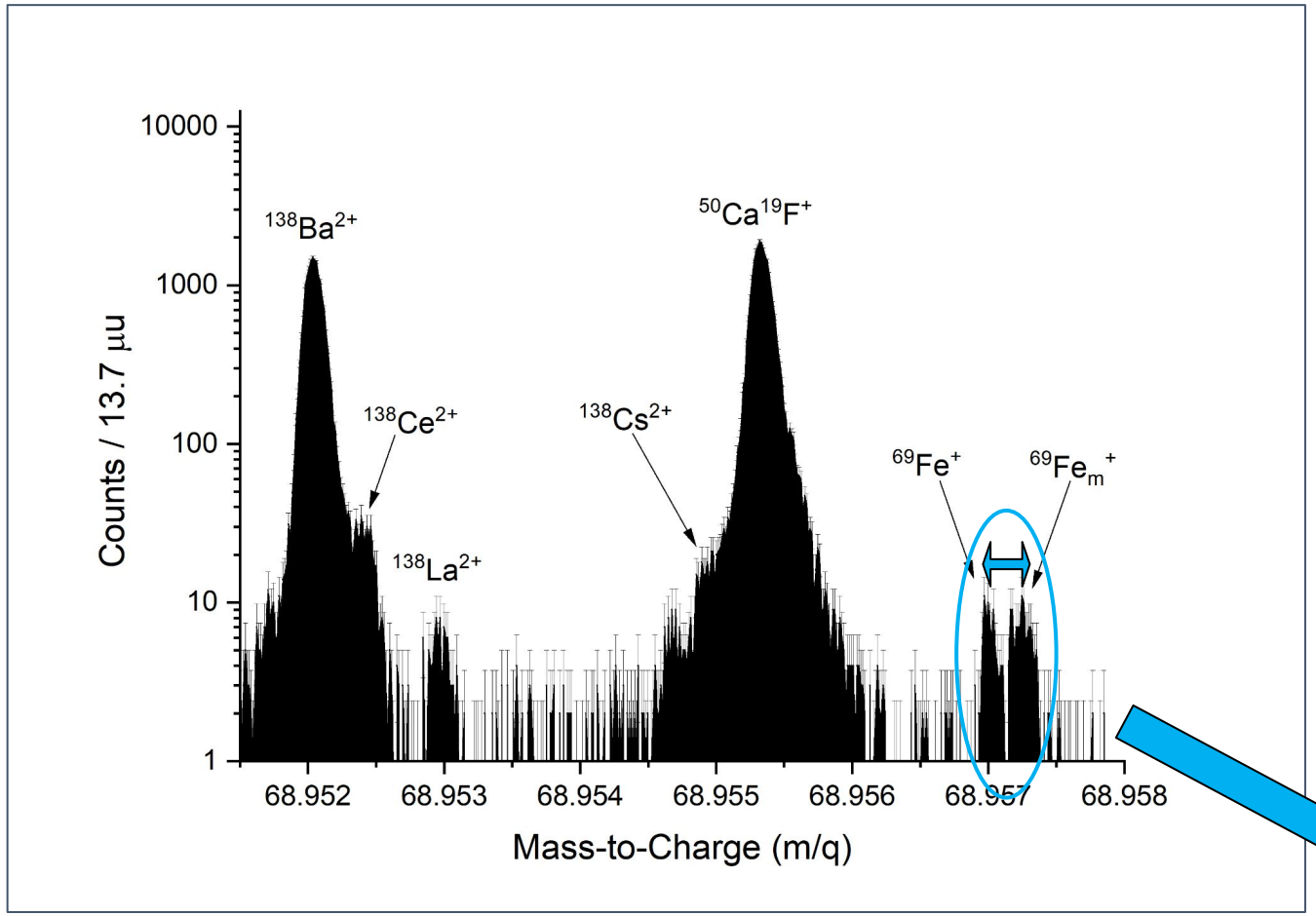


Isomeric Resolution



- **R ~ 600,000**
- **Highest resolving power achieved for RIB @ TITAN MR-ToF**

Isomeric Resolution



- **R ~ 600,000**
- **Highest resolving power achieved for RIB @ TITAN MR-ToF**

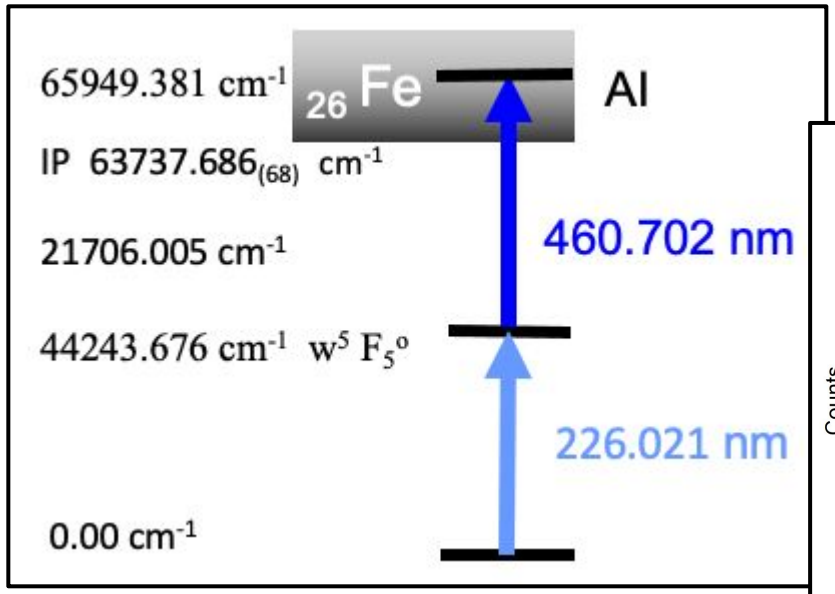
E_x ~ 200 keV

Fe @ an ISOL Facility?!

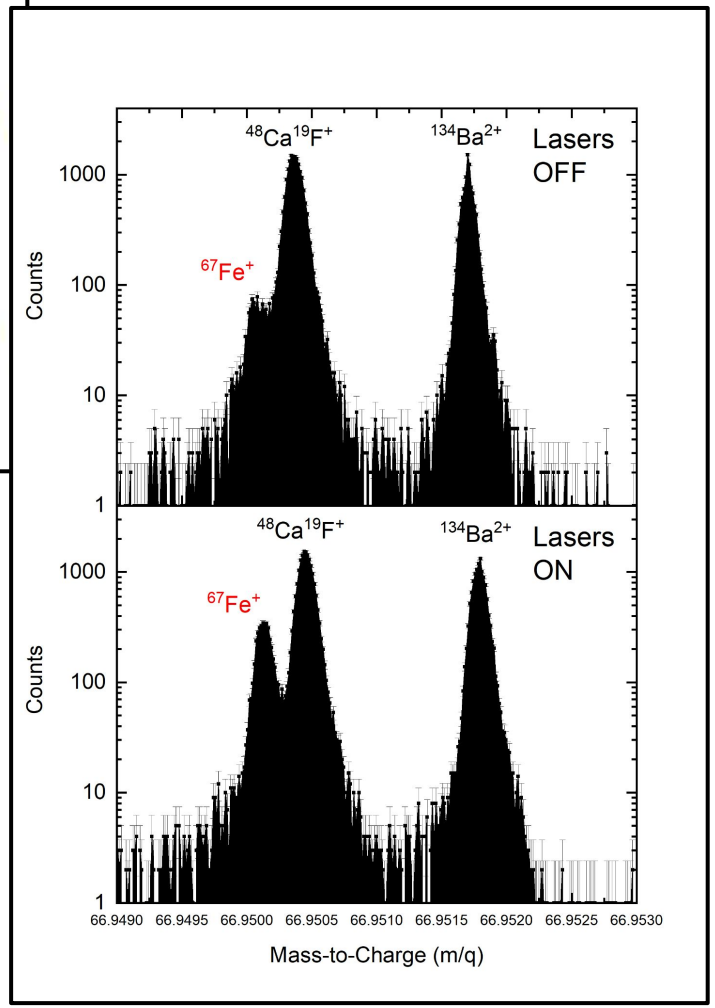
Courtesy of A. Jacobs

Fe @ an ISOL Facility?!

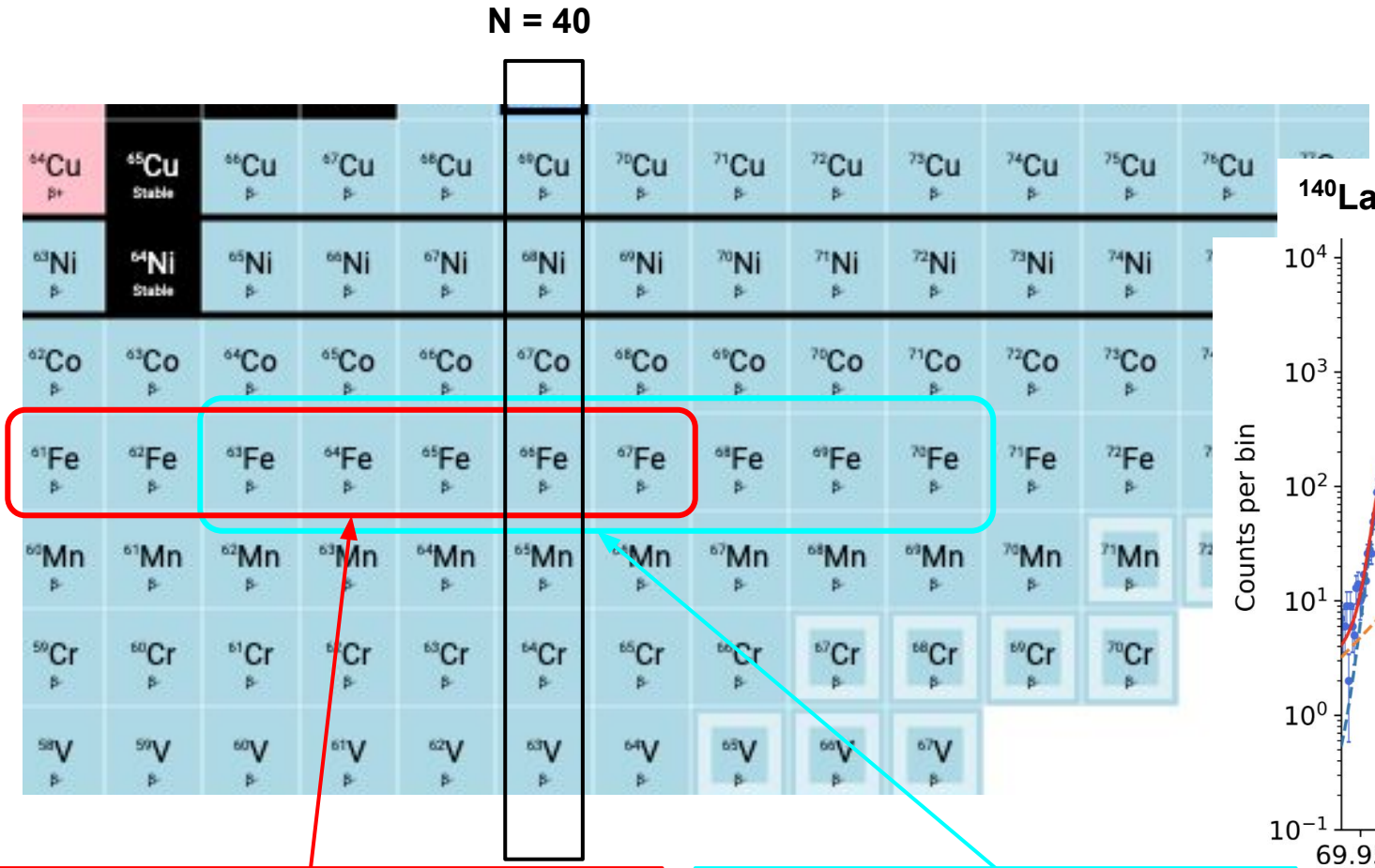
Courtesy of A. Jacobs

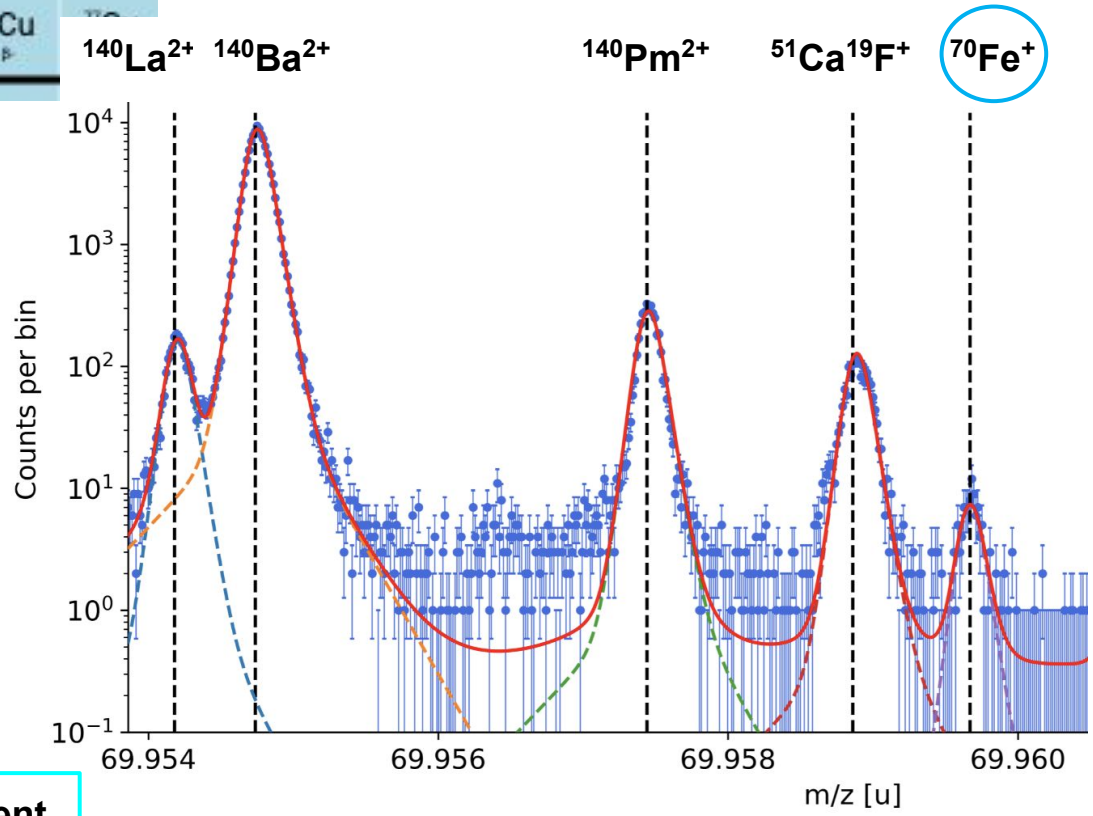


Courtesy of J. Lassen



n-rich Fe Mass Measurements





previous measurement with δm/m < 10^{-6}

TITAN MR-ToF-MS measurement

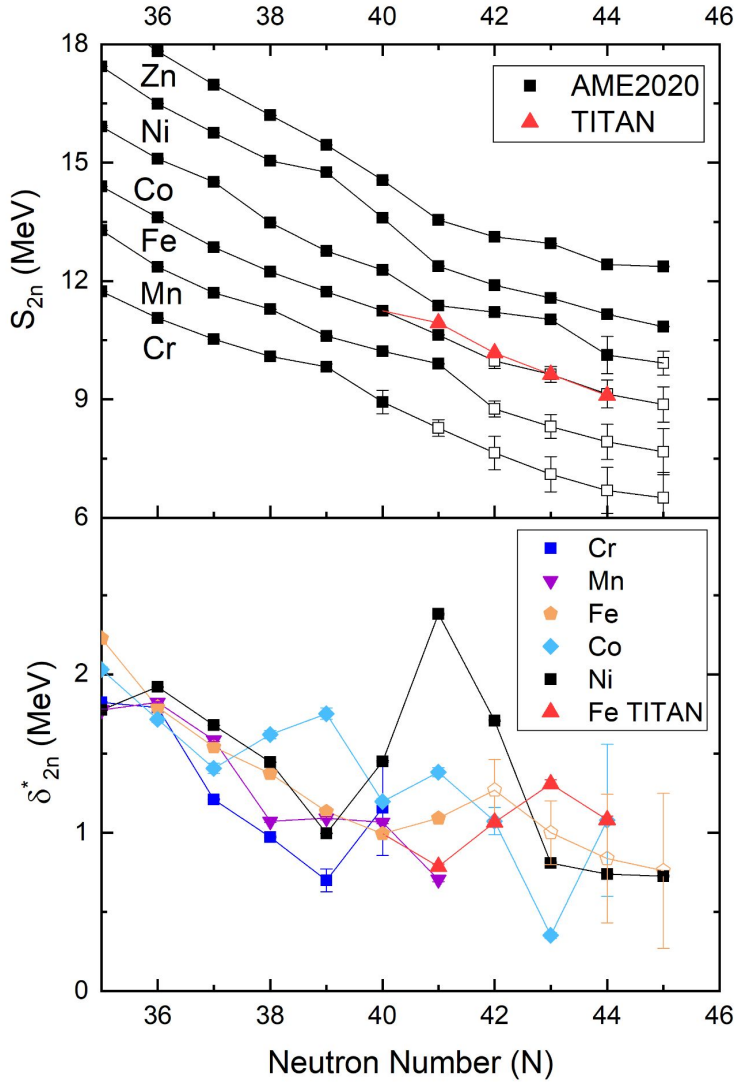
W.S. Porter *et. al.*, PRC, **105** L041301 (2022)

S. Naimi *et. al.*, PRC, **86** 014325 (2012)
R. Ferrer *et. al.*, PRC, **81** 044318 (2010)
L. Canete *et. al.*, PRC, **101** 041304(R) (2020)

Mass Surface around *N = 40*

$$S_{2n} = m(N,Z) - m(N-2,Z) + 2m_n$$

$$\delta^*_{2n} = S_{2n}(N-2,Z) - S_{2n}(N,Z)$$



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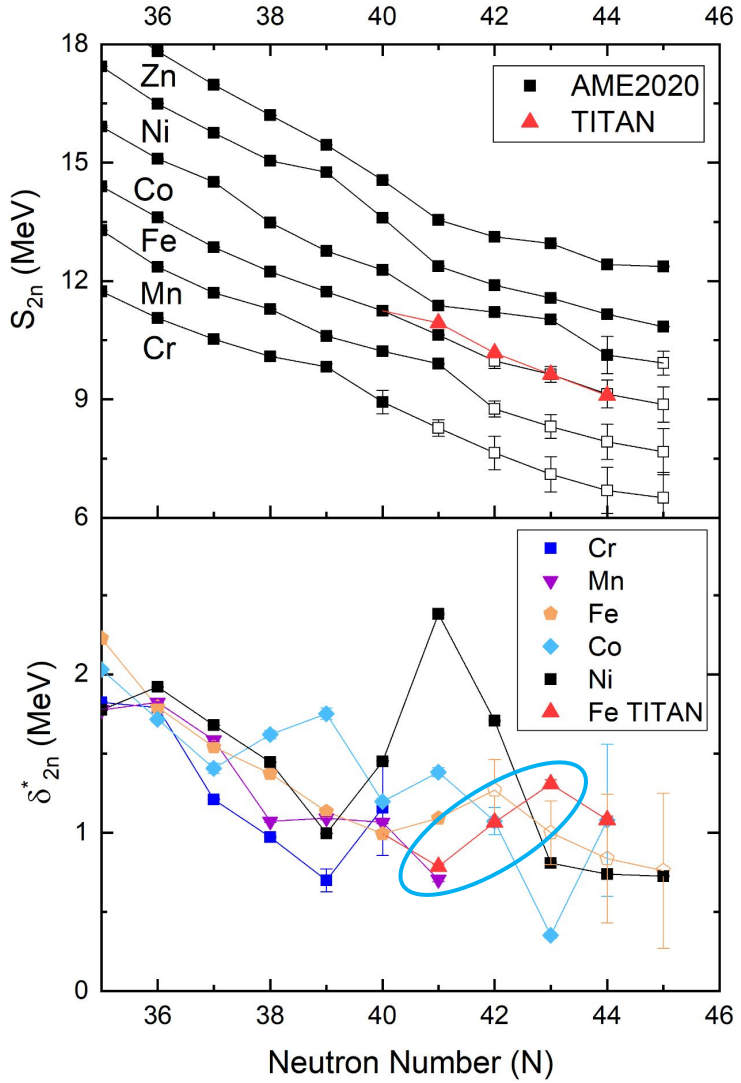


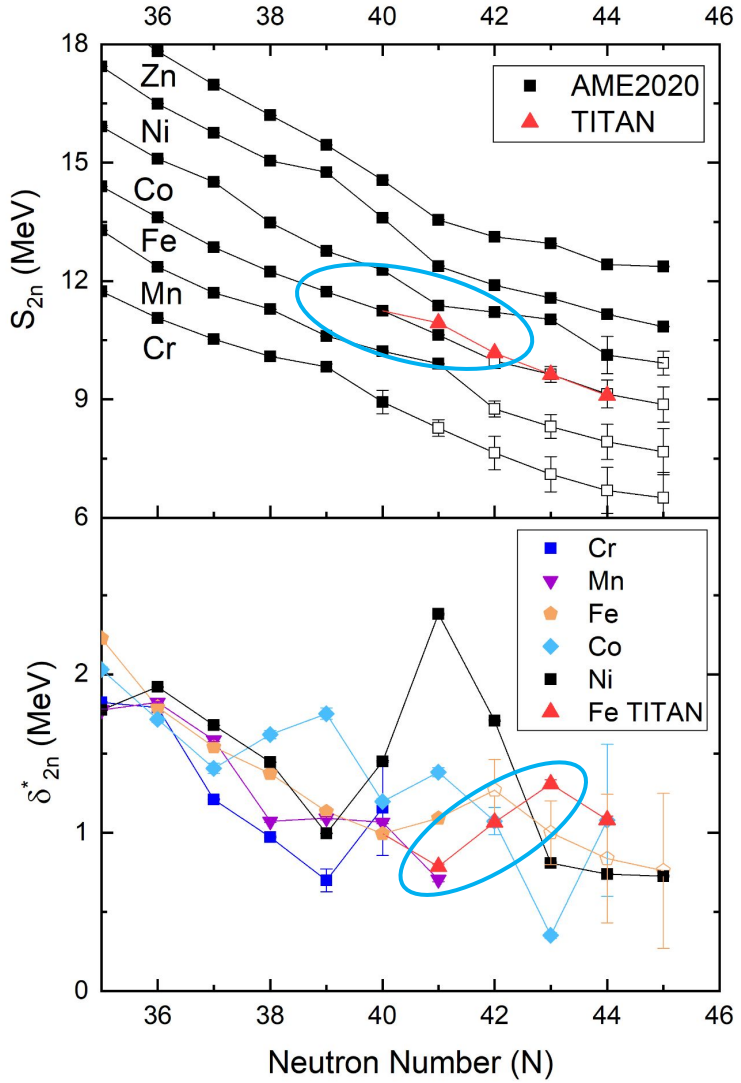
NO peak @ N = 42

NO indication of shell closure @ N = 40 in Fe

Mass Surface around *N = 40*

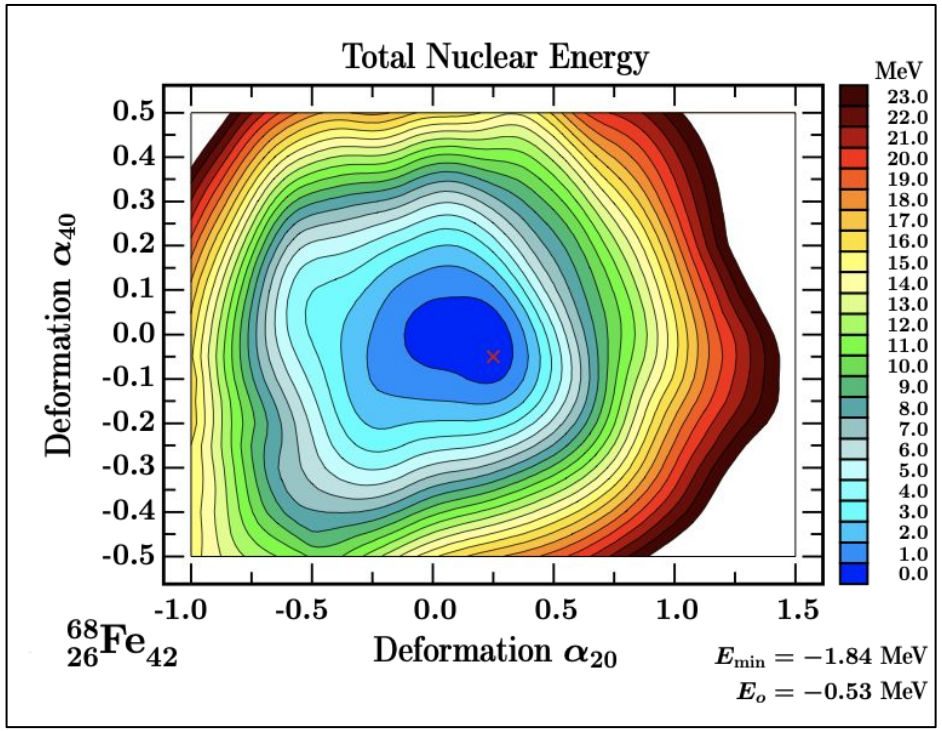
$$S_{2n} = m(N,Z) - m(N-2,Z) + 2m_n$$

$$\delta^*_{2n} = S_{2n}(N-2,Z) - S_{2n}(N,Z)$$



Minimum @ N = 41

Indication of maximum collectivity @ N = 41 in Fe



Courtesy of J. Dudek, I. Dedes and D. Curien

Mass Surface around *N = 40*

$$S_{2n} = m(N,Z) - m(N-2,Z) + 2m_n$$

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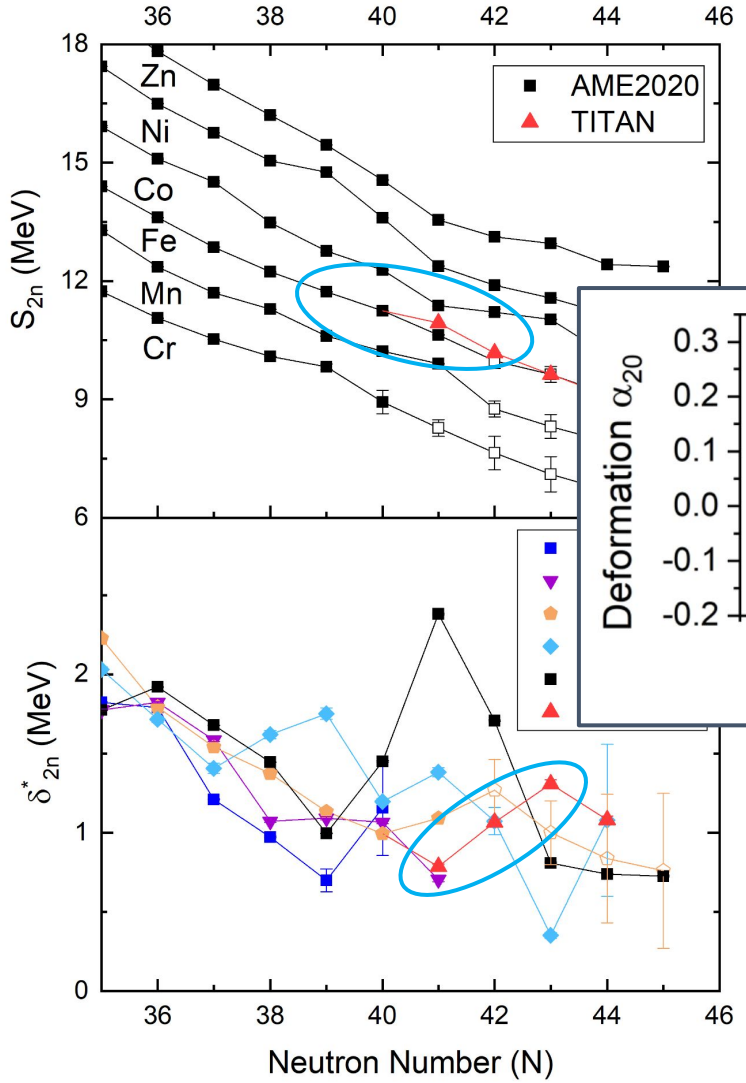
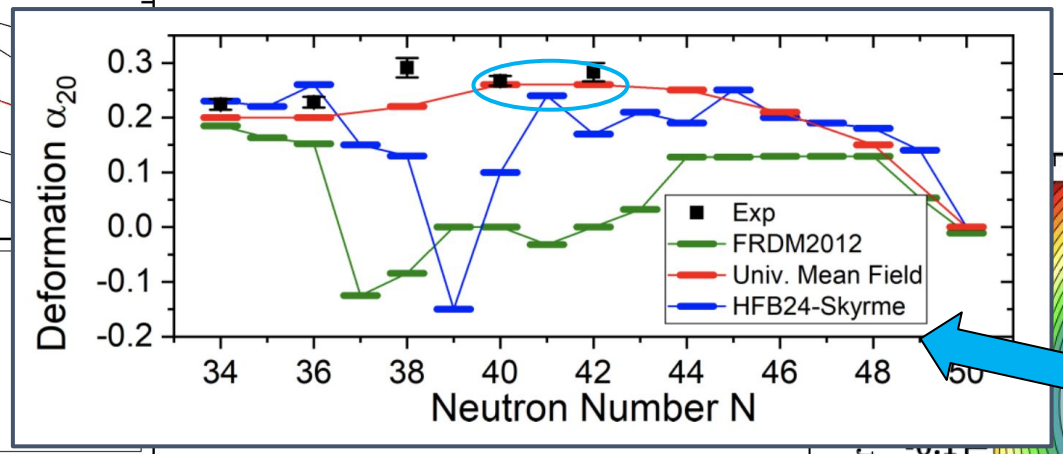
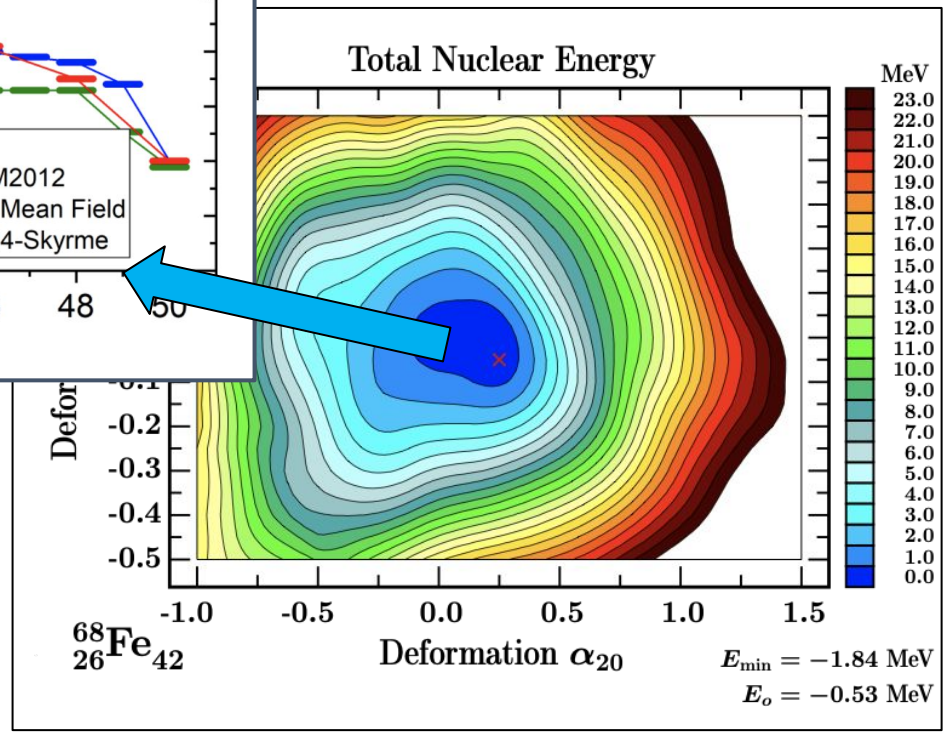


Minimum @ N = 41

Indication of maximum collectivity @ N = 41 in Fe





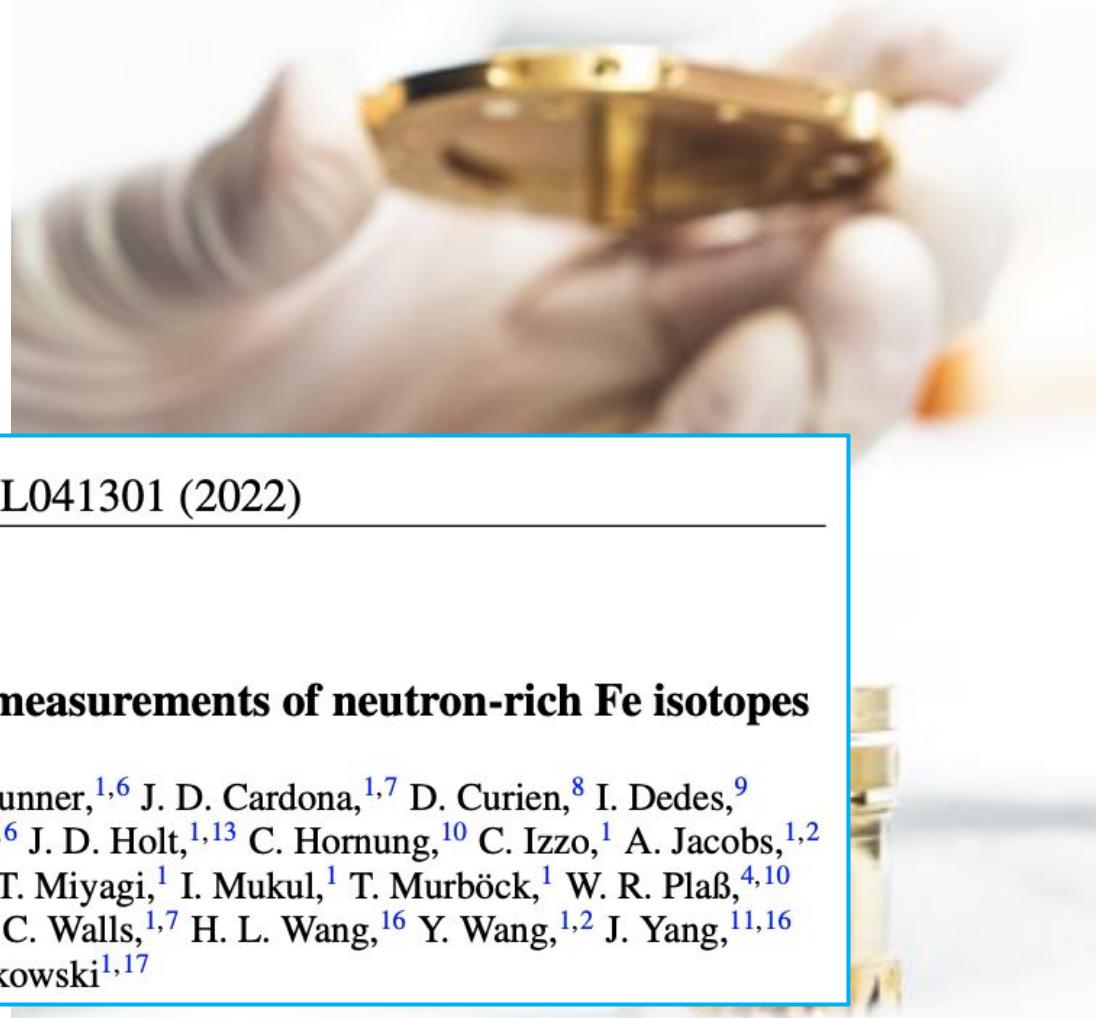
Courtesy of J. Dudek, I. Dedes and D. Curien

Conclusions

- The TITAN MR-ToF @ TRIUMF measured neutron-rich Fe masses around the *N* = *40* Island of Inversion
- High resolving power and Fe-specific laser ionization scheme enabled discovery of ^{69}Fe isomer
- Refined mass surface showed indications of a disappearance of the *N* = *40* shell gap and a collectivity maximum at *N* = *41*

Conclusions

- The TITAN MR-ToF @ TRIUMF measured neu… rich Fe masses around the *N* = 40 Isla…
- Hig… ioni… isor…
- Ref… a di… collectivity maximum at *N* = *41*

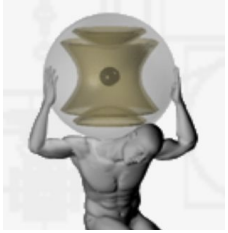


PHYSICAL REVIEW C **105**, L041301 (2022)

Letter | Editors' Suggestion

Mapping the $N = 40$ island of inversion: Precision mass measurements of neutron-rich Fe isotopes

W. S. Porter,[1,2,*] B. Ashrafkhani,[3] J. Bergmann,[4] C. Brown,[5] T. Brunner,[1,6] J. D. Cardona,[1,7] D. Curien,[8] I. Dedes,[9] T. Dickel,[4,10] J. Dudek,[8,11] E. Dunling,[1,12] G. Gwinner,[7] Z. Hockenbery,[1,6] J. D. Holt,[1,13] C. Hornung,[10] C. Izzo,[1] A. Jacobs,[1,2] A. Javaji,[1,2] B. Kootte,[1,7] G. Kripkó-Koncz,[4] E. M. Lykiardopoulou,[1,2] T. Miyagi,[1] I. Mukul,[1] T. Murböck,[1] W. R. Plaß,[4,10] M. P. Reiter,[1,4,5] J. Ringuette,[1,14] C. Scheidenberger,[4,10,15] R. Silwal,[1,†] C. Walls,[1,7] H. L. Wang,[16] Y. Wang,[1,2] J. Yang,[11,16] J. Dilling,[1,2] and A. A. Kwiatkowski[1,17]



TRIUMF

SFU

University of Manitoba

University of Calgary

McGill

University of Victoria

University of Notre Dame

Colorado School of Mines

UBC

Justus-Liebig-Universität Giessen

Westfälische Wilhelms-Universität Münster

CNRS

Max-Planck-Institut für Kernphysik Heidelberg

university of groningen
kvi - center for advanced radiation technology

wporter@nd.edu

Thank you
Merci

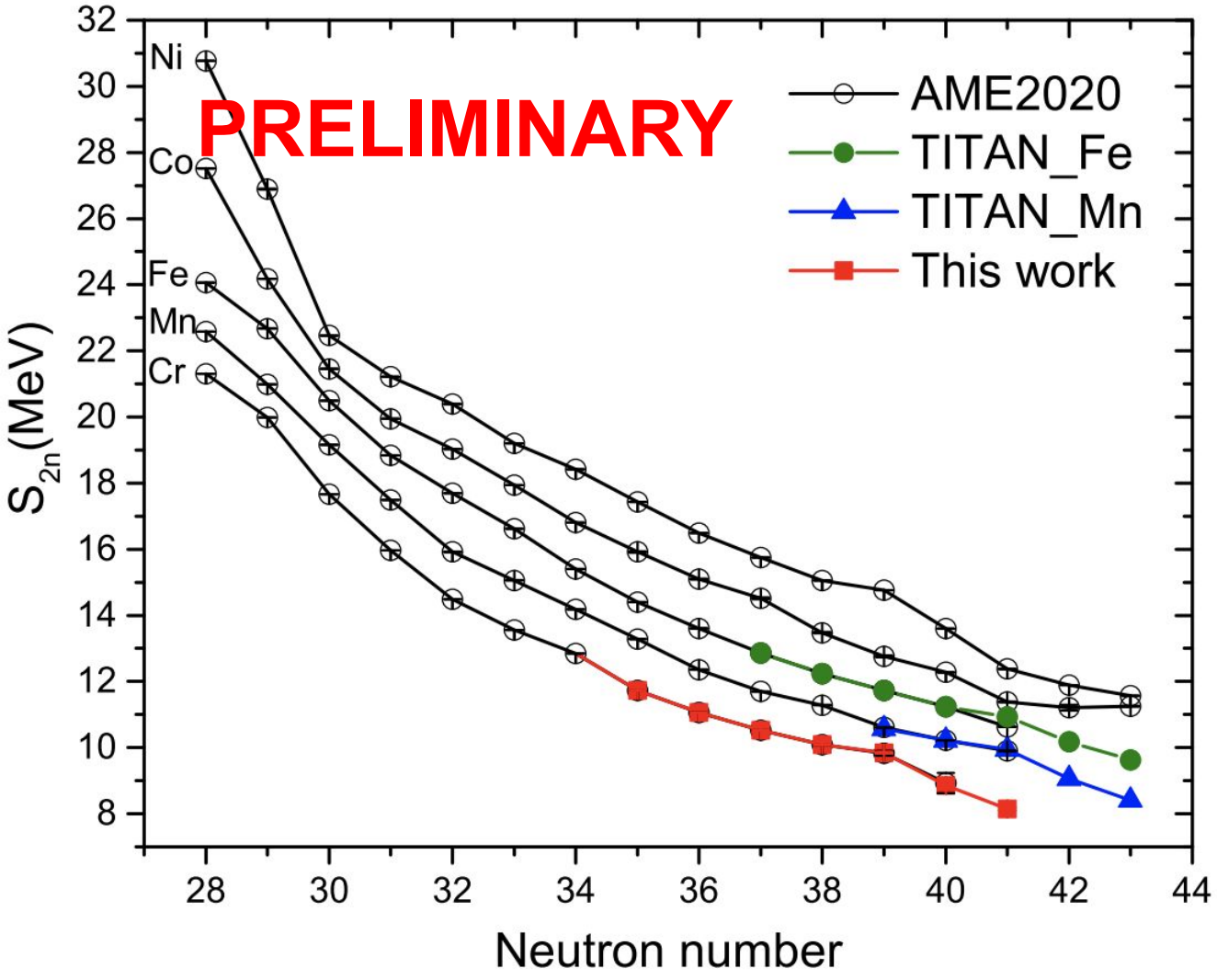
NRC·CNRC NSERC CRSNG DFG Deutsche Forschungsgemeinschaft

TRIUMF
www.triumf.ca

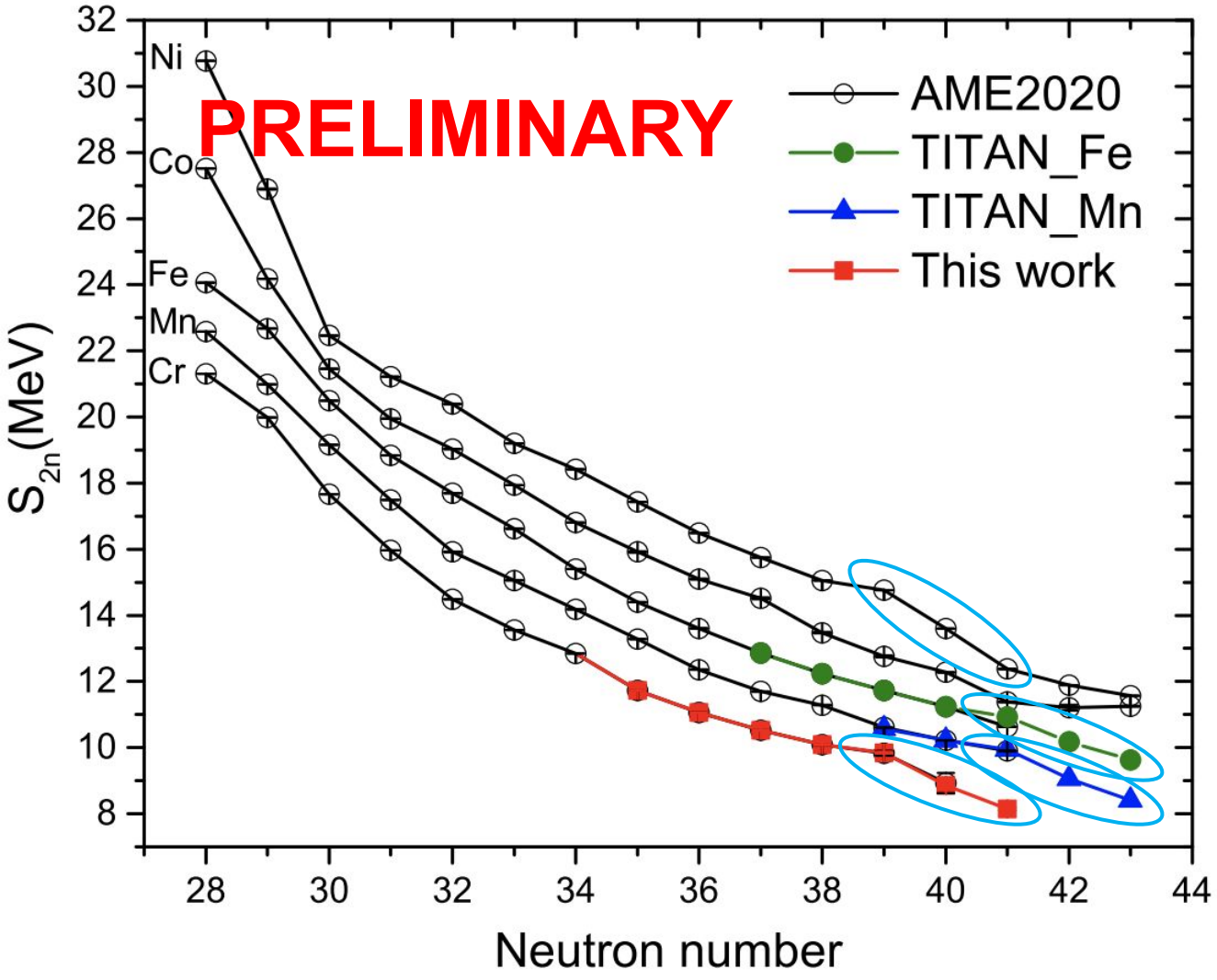
@TRIUMFLab

Discovery, accelerated

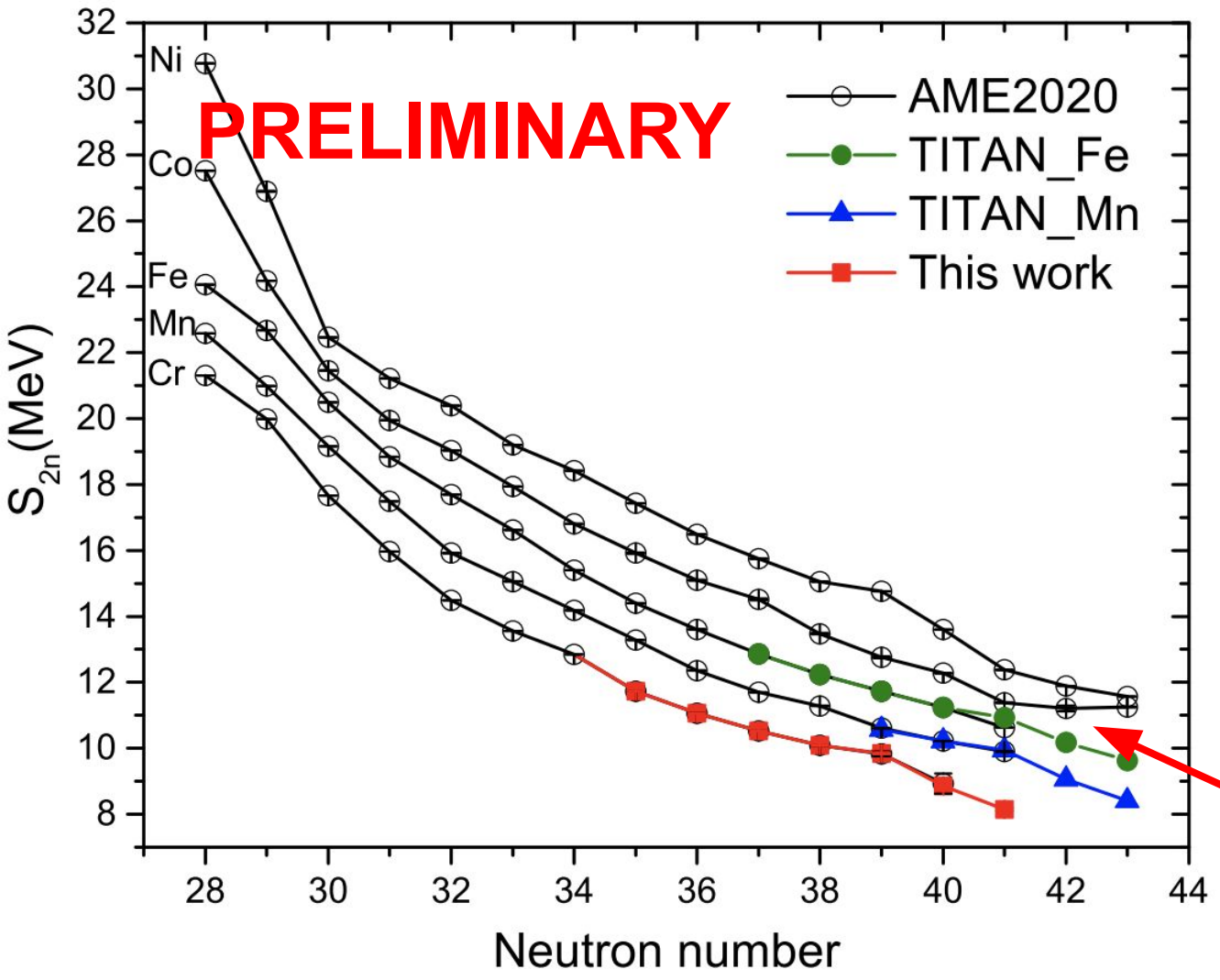
R. Silwal *et. al.*, PLB, *submitted*



R. Silwal *et. al.*, PLB, *submitted*

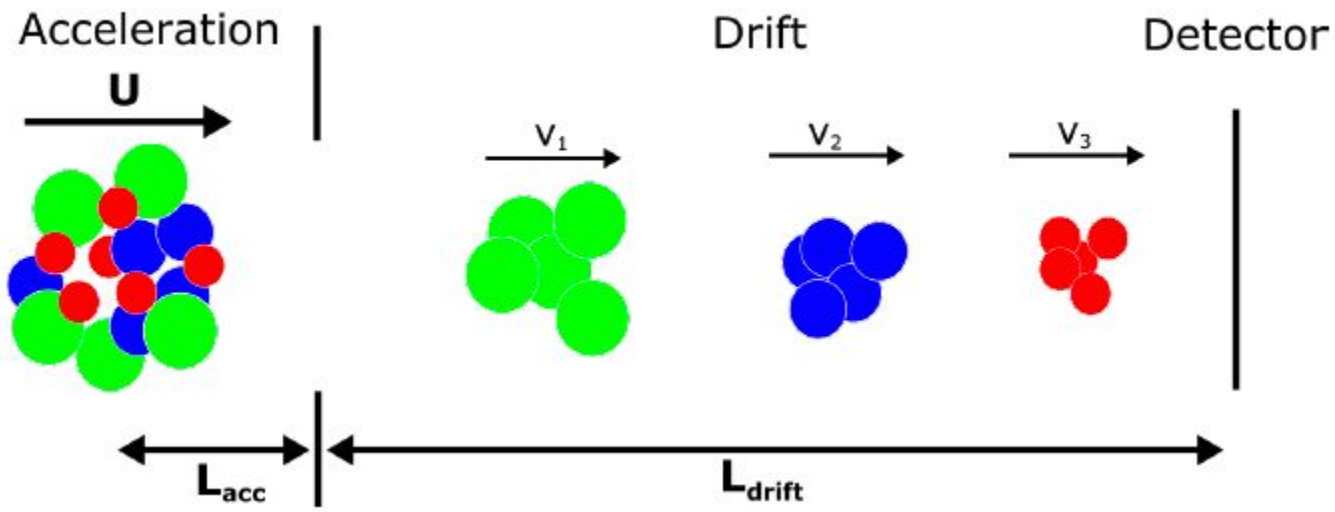


R. Silwal *et. al.*, PLB, *submitted*



- **Shifts approved at high priority at TRIUMF to measure n-rich Co up to N = 45**

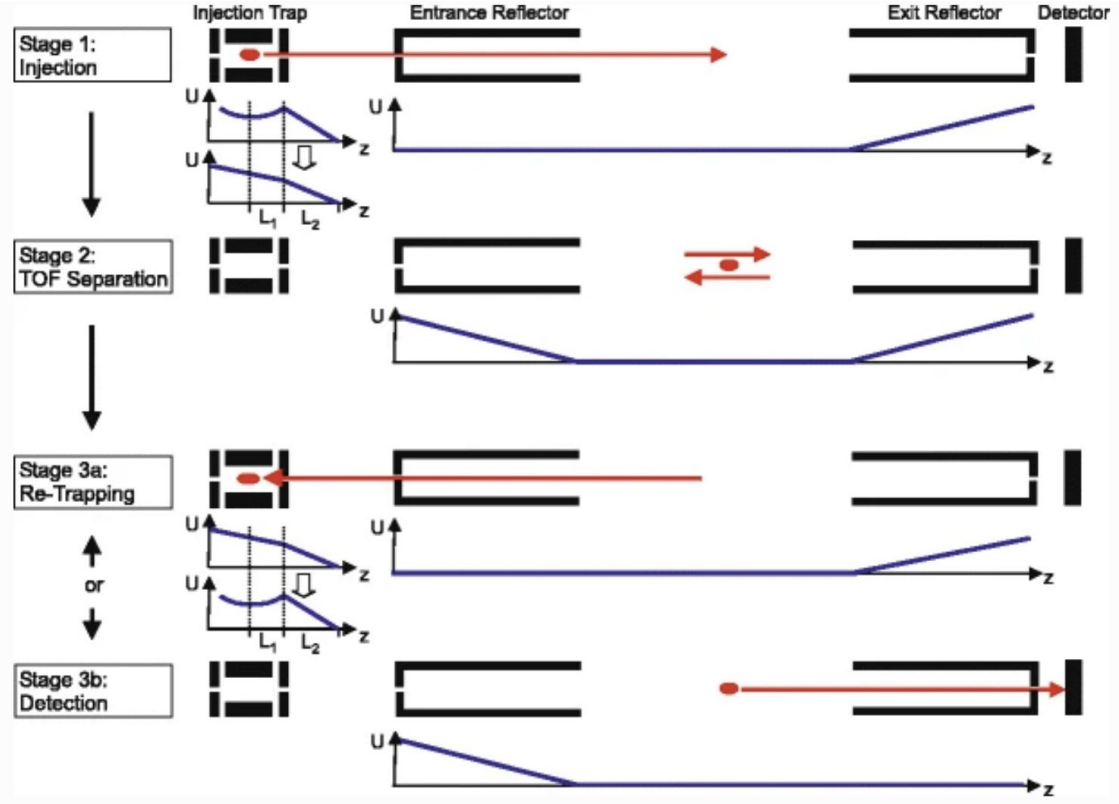
MR-ToF-MS Principles



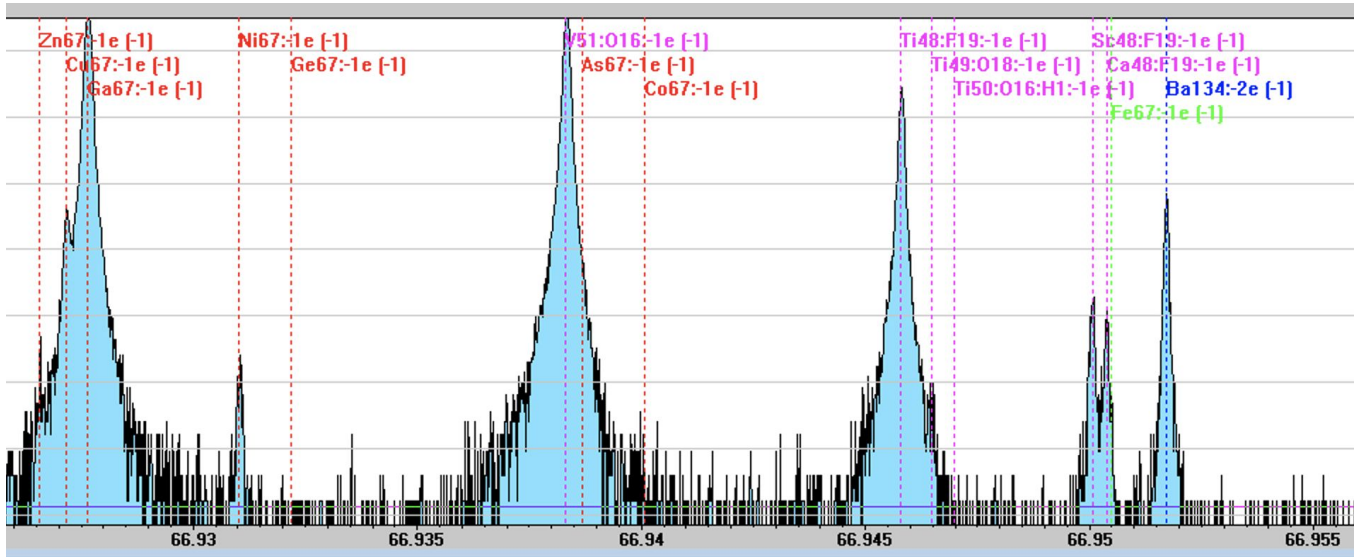
A. Jacobs, Master's Thesis (2019)

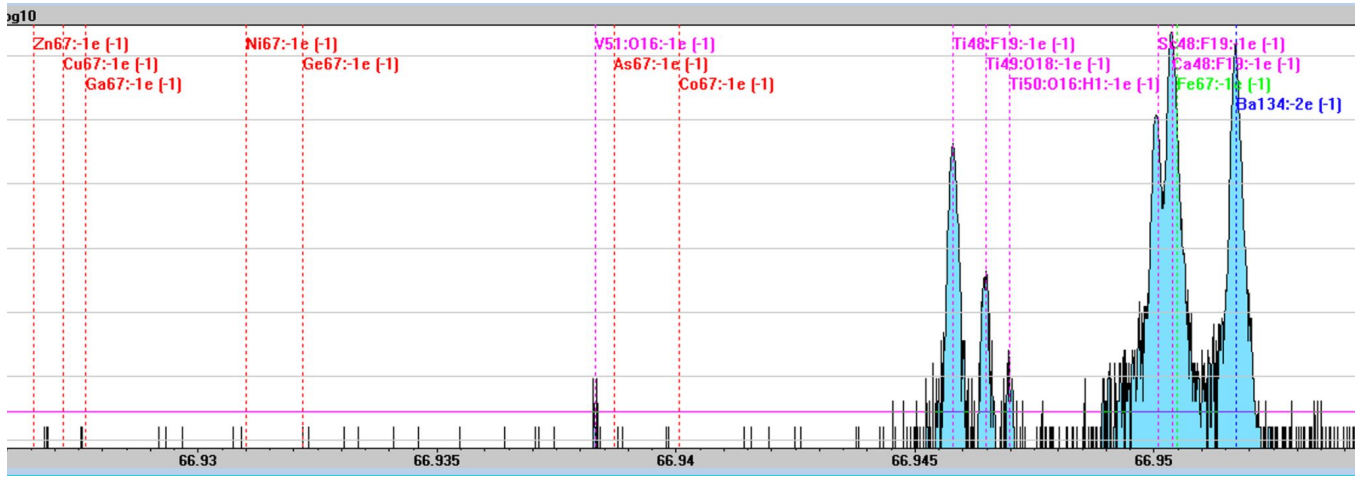
$$T = qU = \frac{1}{2}mv^2 \quad \Rightarrow \quad qU = \frac{1}{2}m\left(\frac{L}{t_{tof}}\right)^2 \quad \Rightarrow \quad t_{tof} = L\sqrt{\frac{m}{2qU}}$$

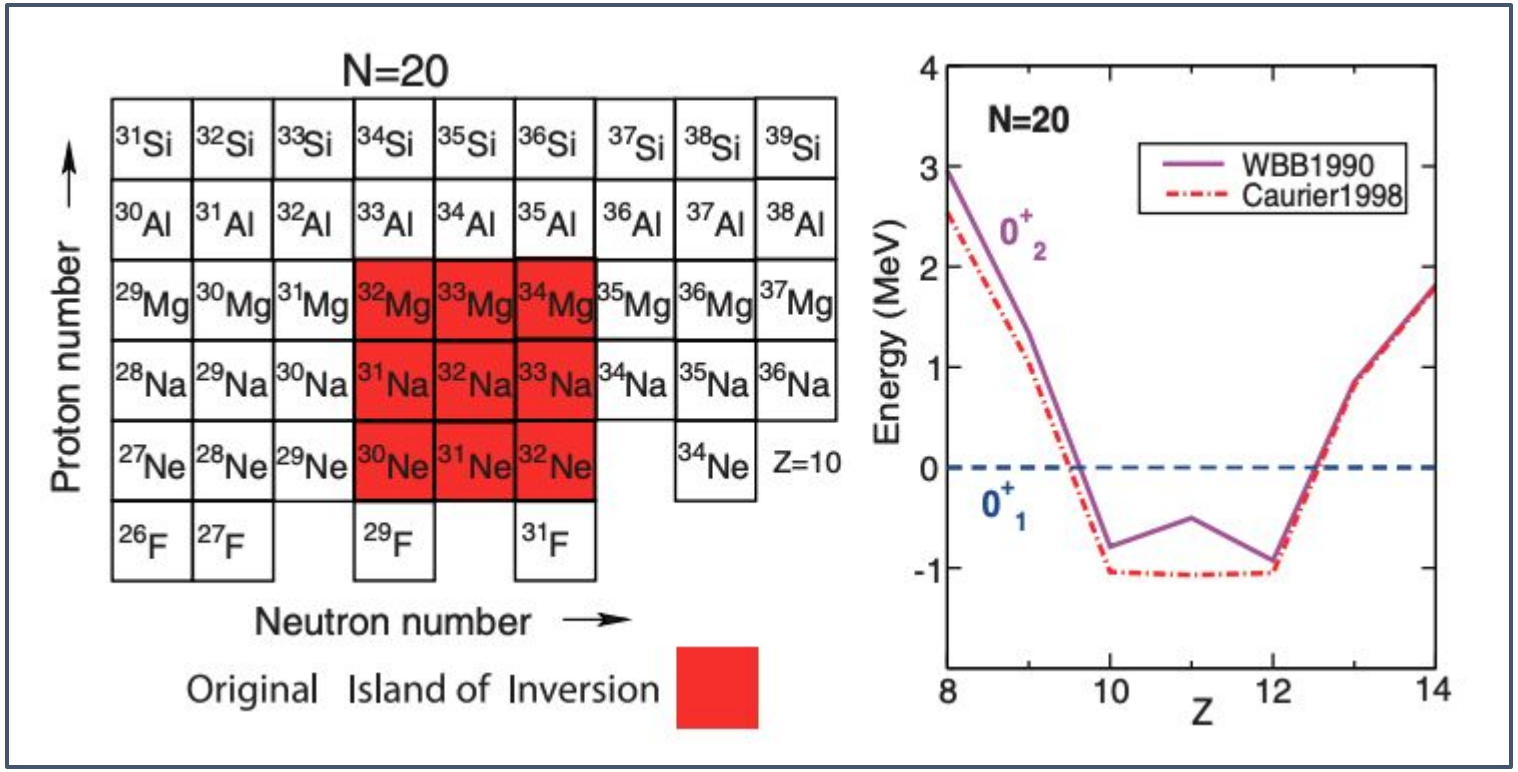
Mass-Selective Re-trapping

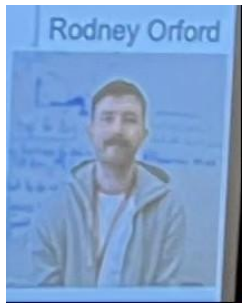


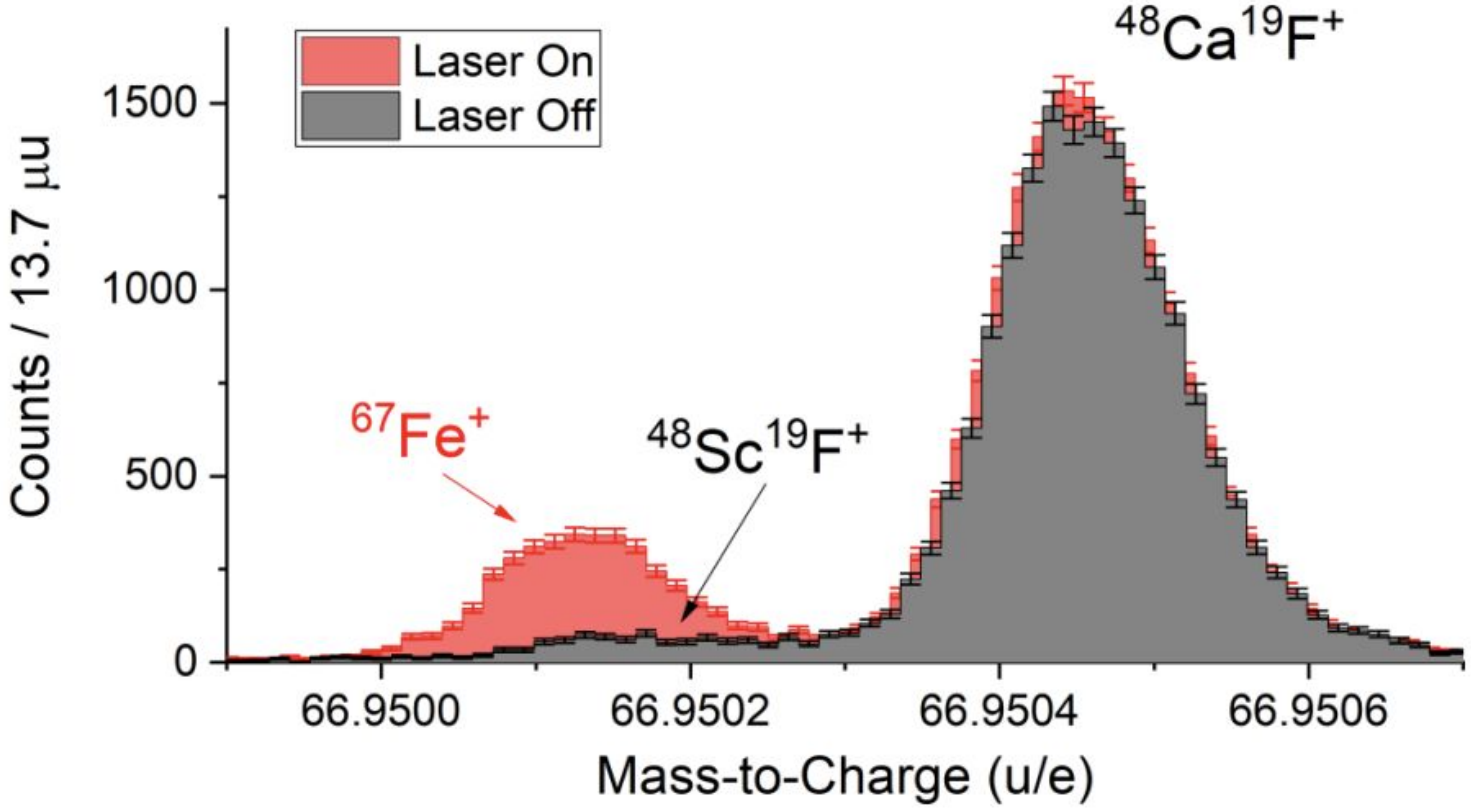
T. Dickel *et. al.*, IJMS **412** (2017)






N=20
31Si 32Si 33Si 34Si 35Si 36Si 37Si 38Si 39Si
30Al 31Al 32Al 33Al 34Al 35Al 36Al 37Al 38Al
29Mg 30Mg 31Mg 32Mg 33Mg 34Mg 35Mg 36Mg 37Mg
28Na 29Na 30Na 31Na 32Na 33Na 34Na 35Na 36Na
27Ne 28Ne 29Ne 30Ne 31Ne 32Ne 34Ne
26F 27F 29F 31F
Z=10
Proton number
Neutron number
Original Island of Inversion
N=20
WBB1990
Caurier1998
0+2
0+1
Energy (MeV)
Z


Rodney Orford


Laser On
Laser Off
$^{48}Ca^{19}F^{+}$
$^{67}Fe^{+}$
$^{48}Sc^{19}F^{+}$
Counts / 13.7 μu
1500
1000
500
0
66.9500
66.9502
66.9504
66.9506
Mass-to-Charge (u/e)