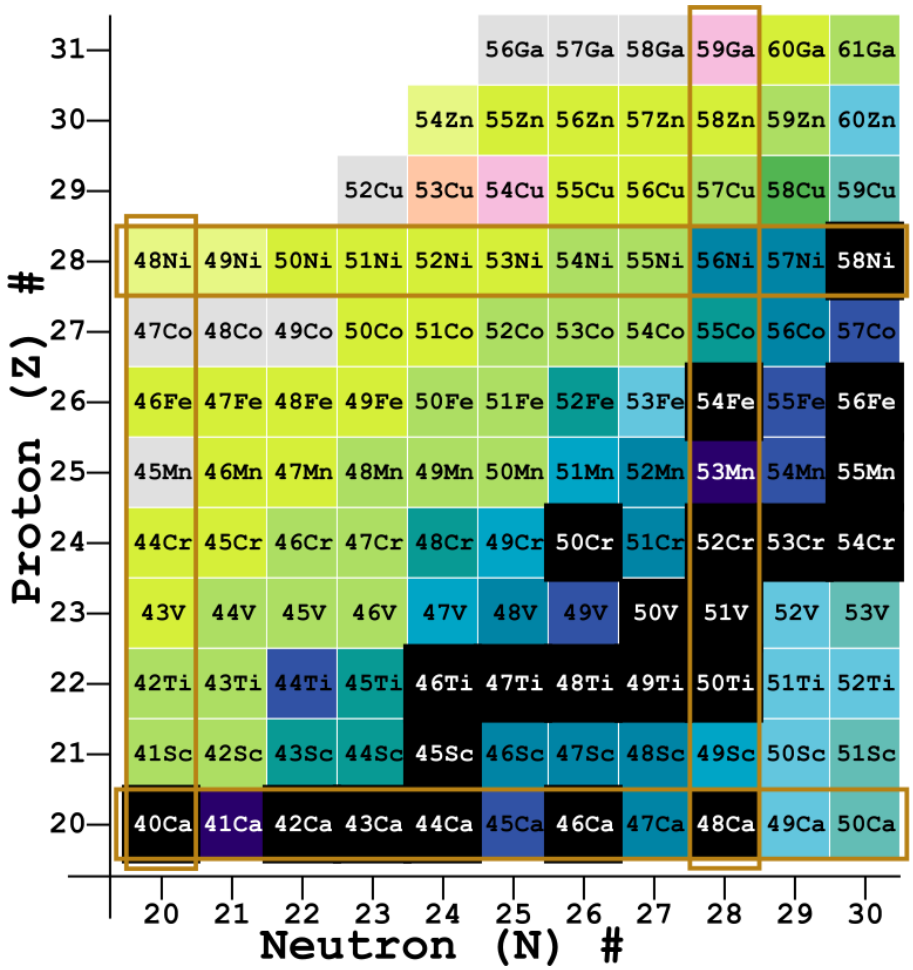
Mirror symmetry in the $f_{7/2}$ shell below ^{56}Ni: excited states and electromagnetic transition rates in ^{55}Ni and ^{55}Co

Heinz Asch

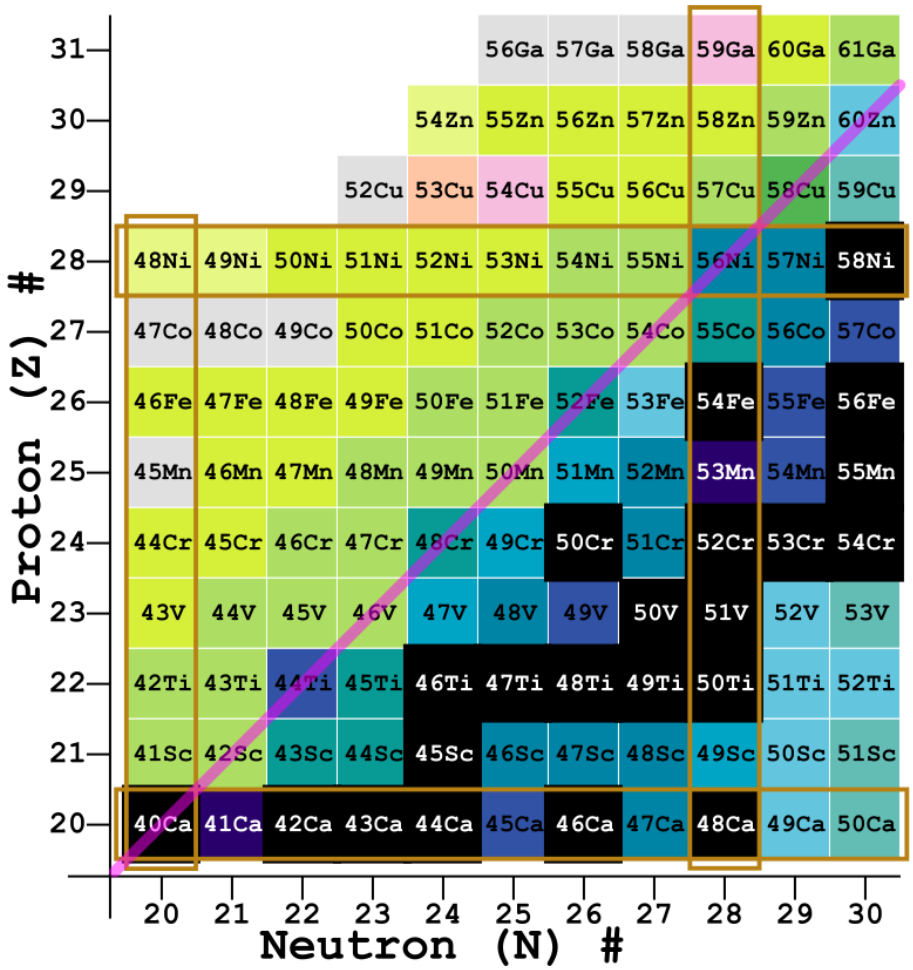
Department of Physics
Simon Fraser University

On behalf of the
TIP, EMMA, & TIGRESS
Collaborations

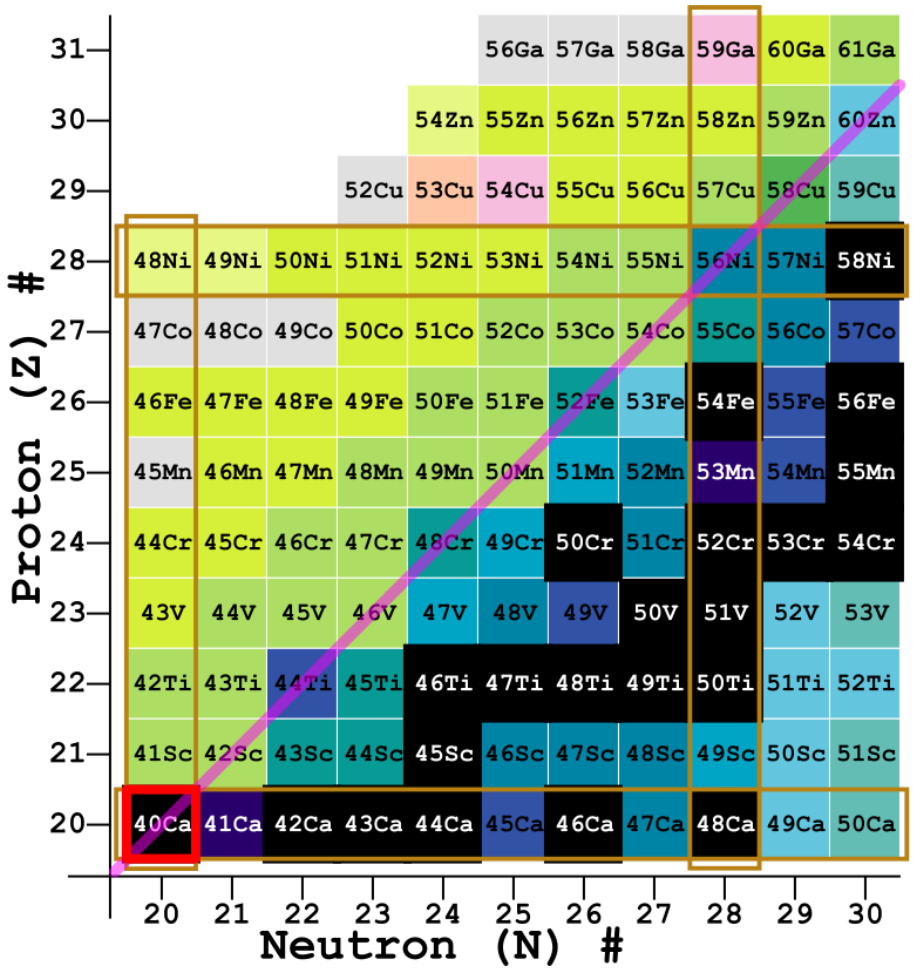
Structure studies along the N=Z line



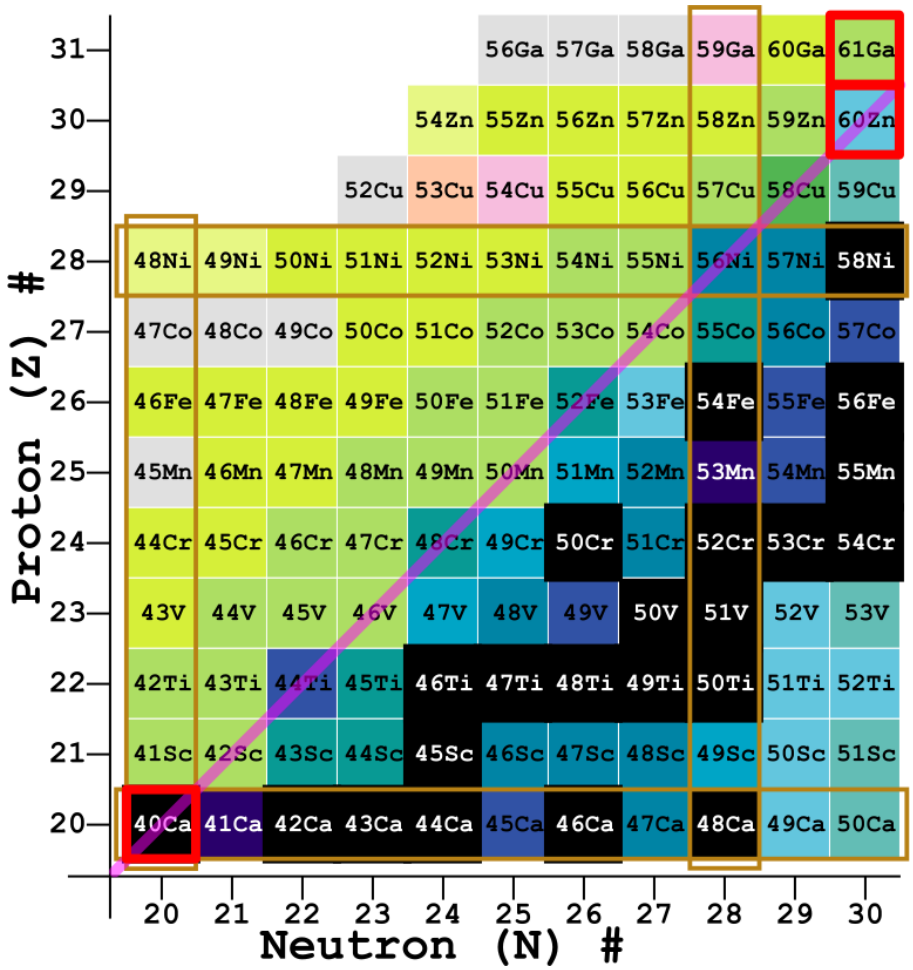
Structure studies along the N=Z line



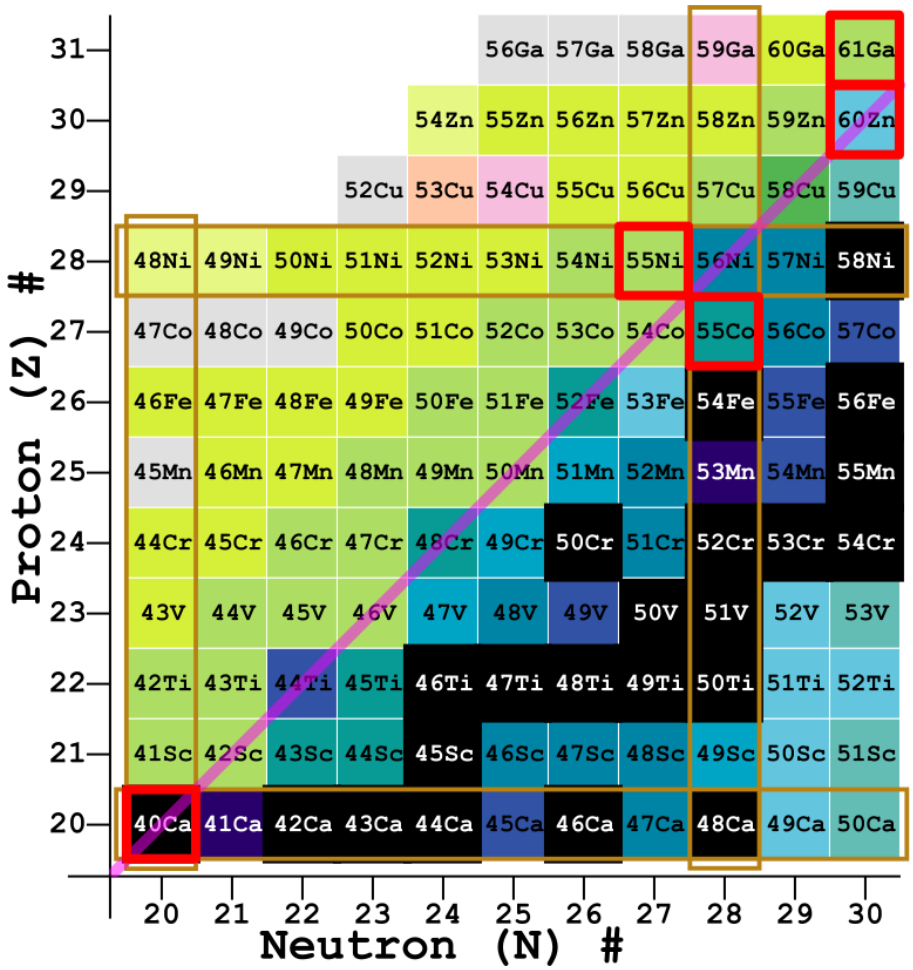
Structure studies along the N=Z line



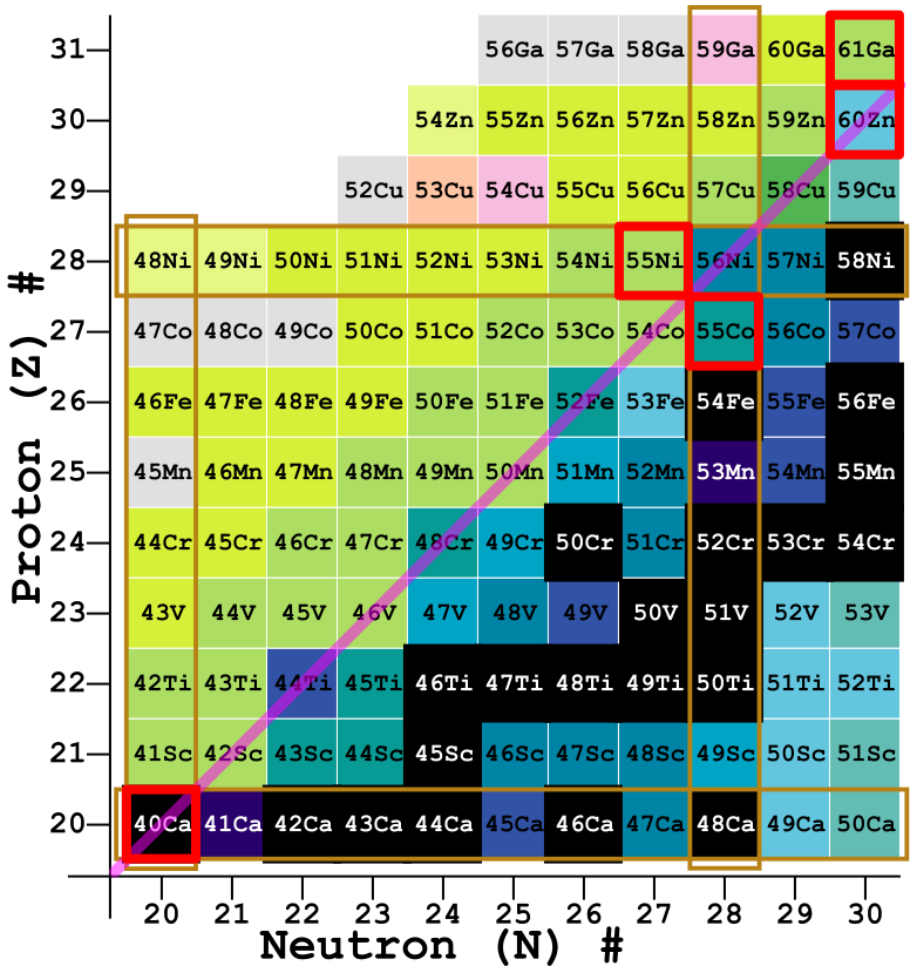
Structure studies along the N=Z line



Structure studies along the N=Z line

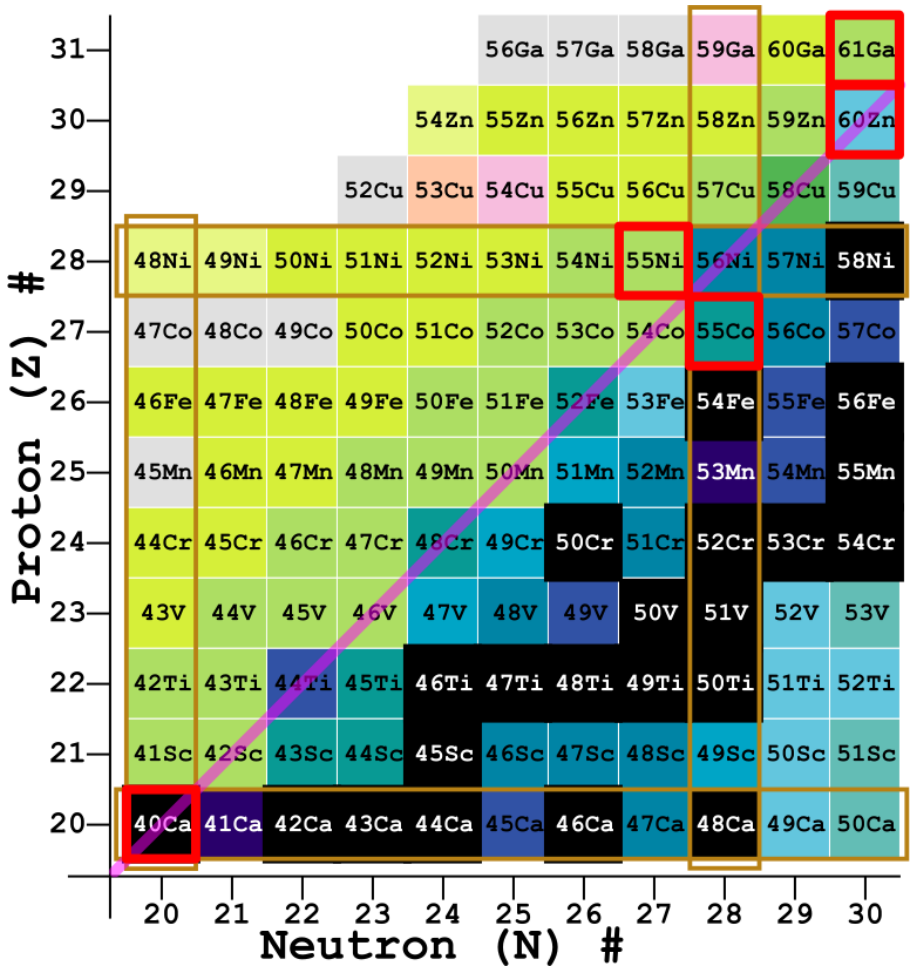


Structure studies along the N=Z line



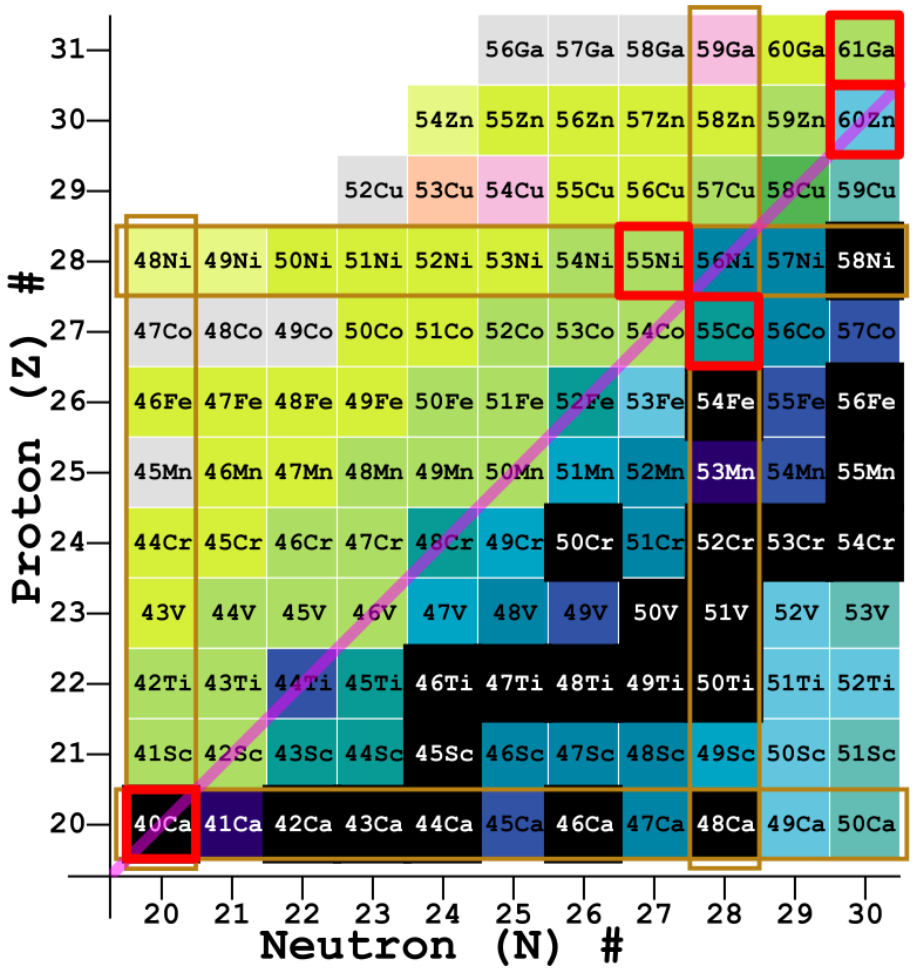
- Energy, spins, and parities of excited states,

Structure studies along the N=Z line



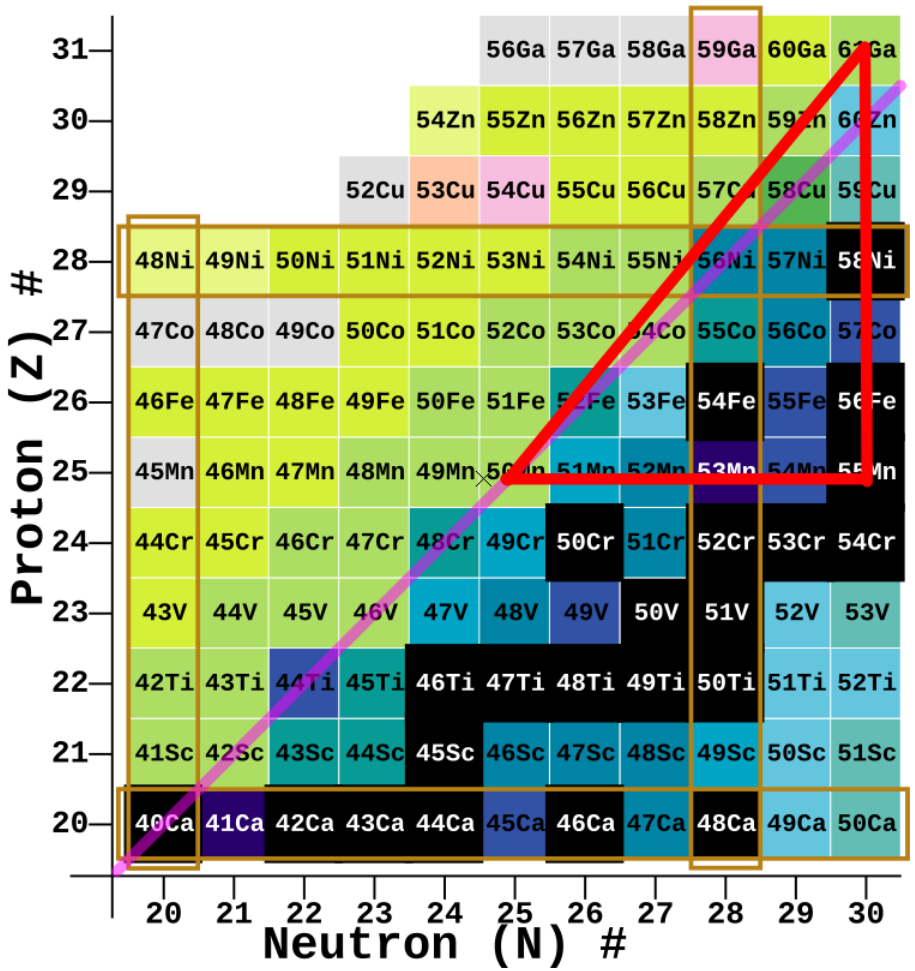
- Energy, spins, and parities of excited states,
- Angular correlations/polarization of γ-rays,

Structure studies along the N=Z line



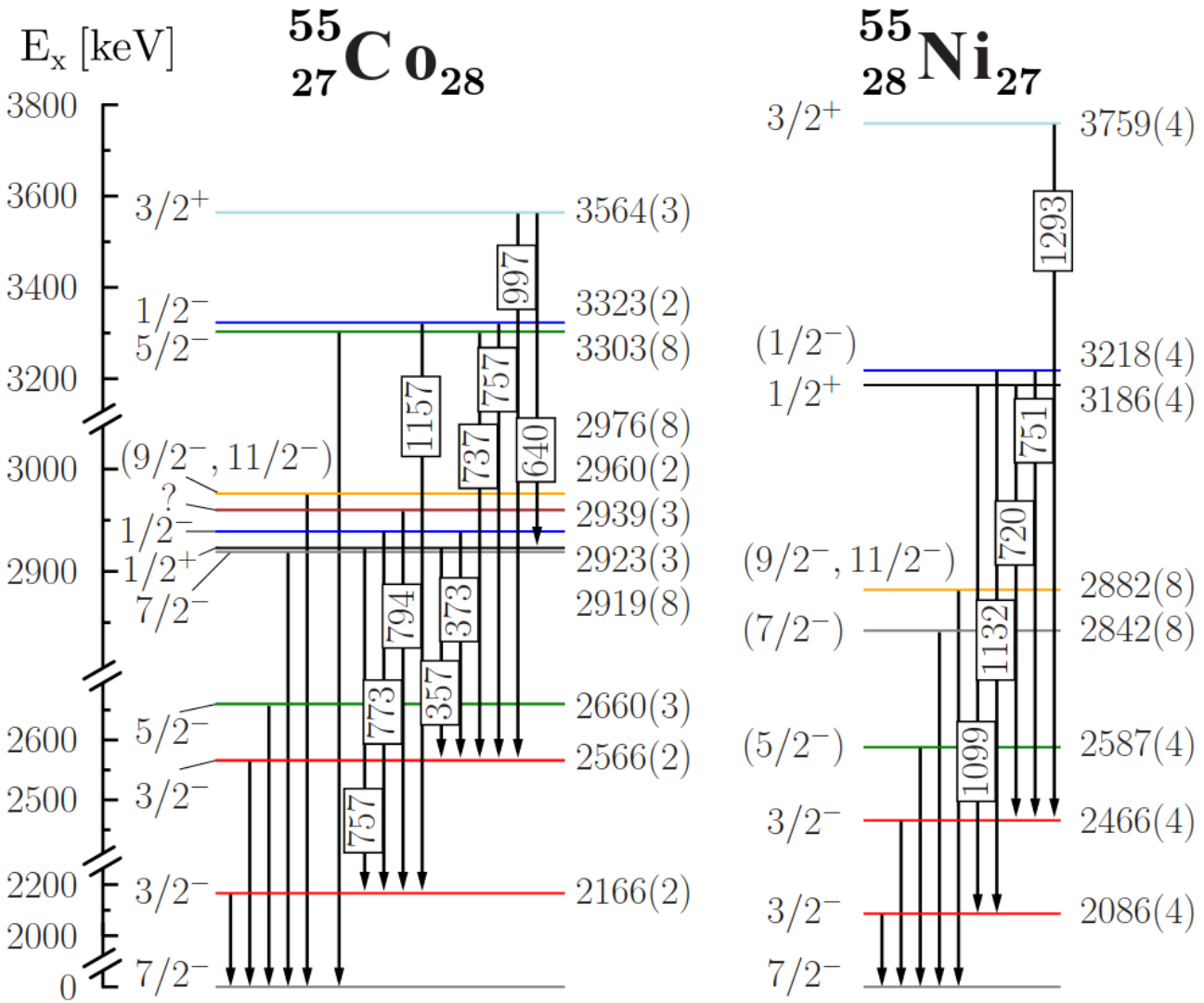
- Energy, spins, and parities of excited states,
- Angular correlations/polarization of γ-rays,
- Data for Shell Model of $f_{7/2}$ neutron hole states near ^{56}Ni.

Structure studies along the N=Z line



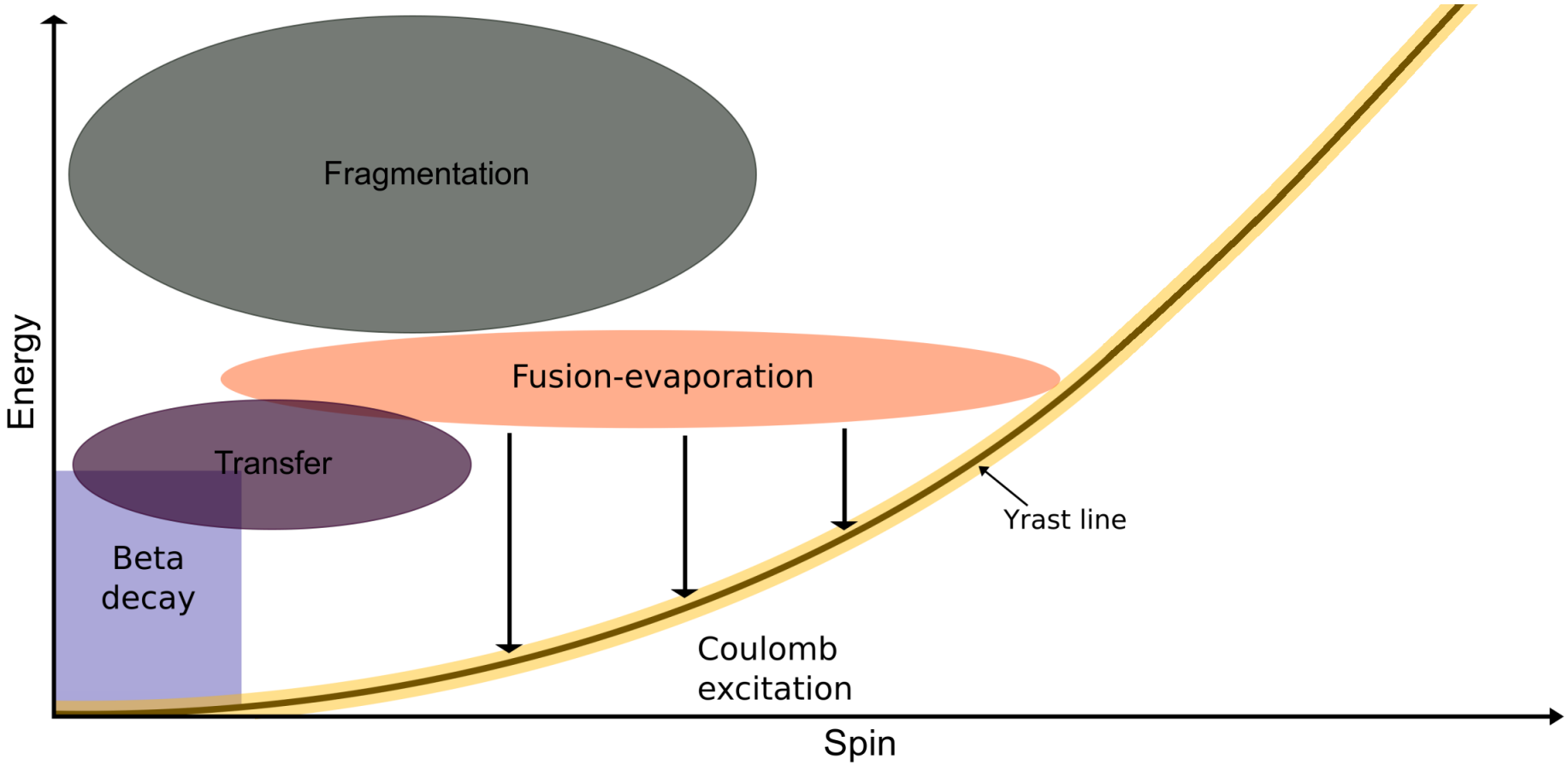
- Energy, spins, and parities of excited states,
- Angular correlations/polarization of γ-rays,
- Data for Shell Model of $f_{7/2}$ neutron hole states near ^{56}Ni.

Mirror Energy Differences via Knockout

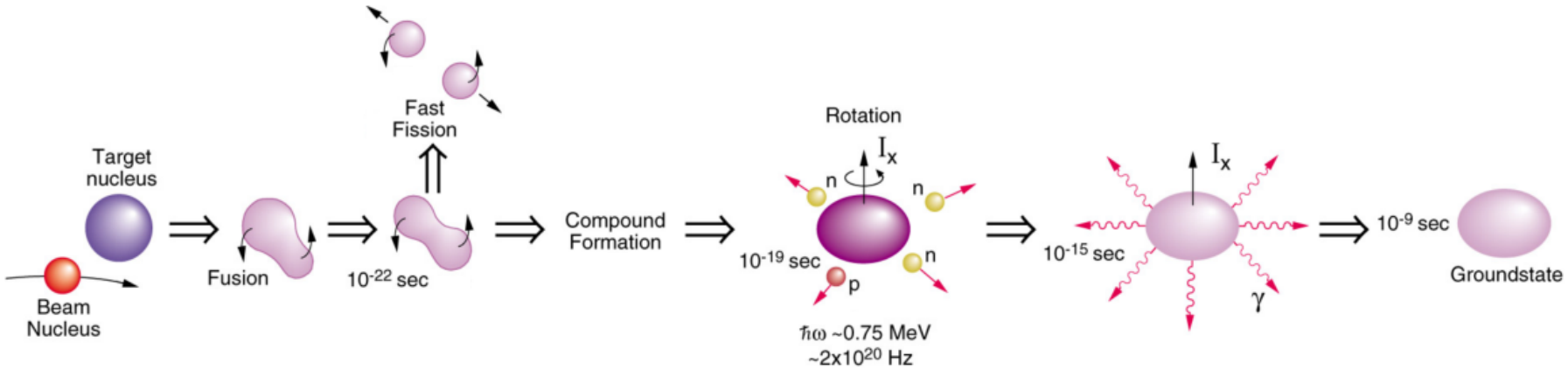


M. Spieker et al., Physical Review C, 2019

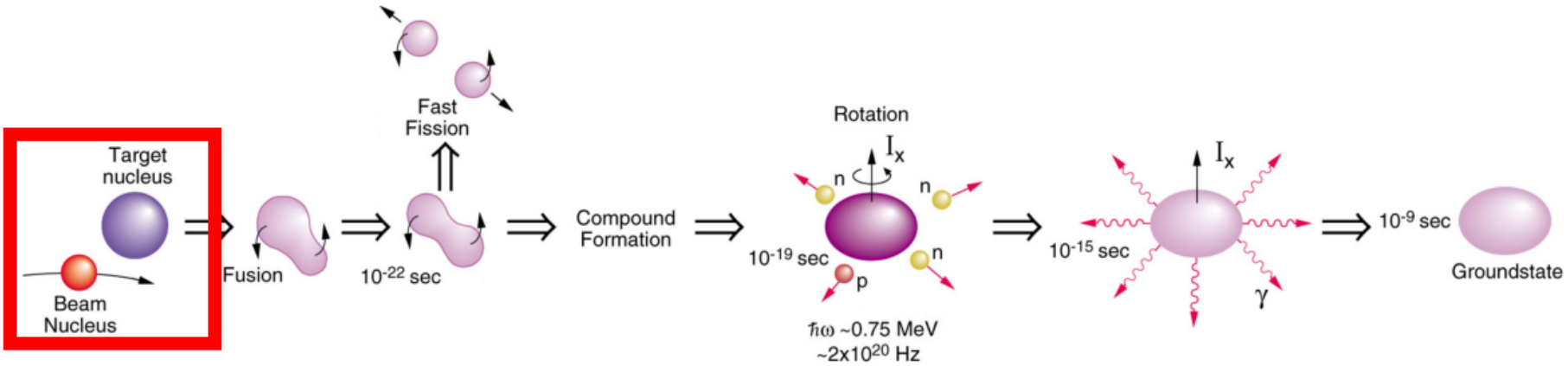
Yrast Line and Reaction Mechanisms



Fusion Evaporation Reaction

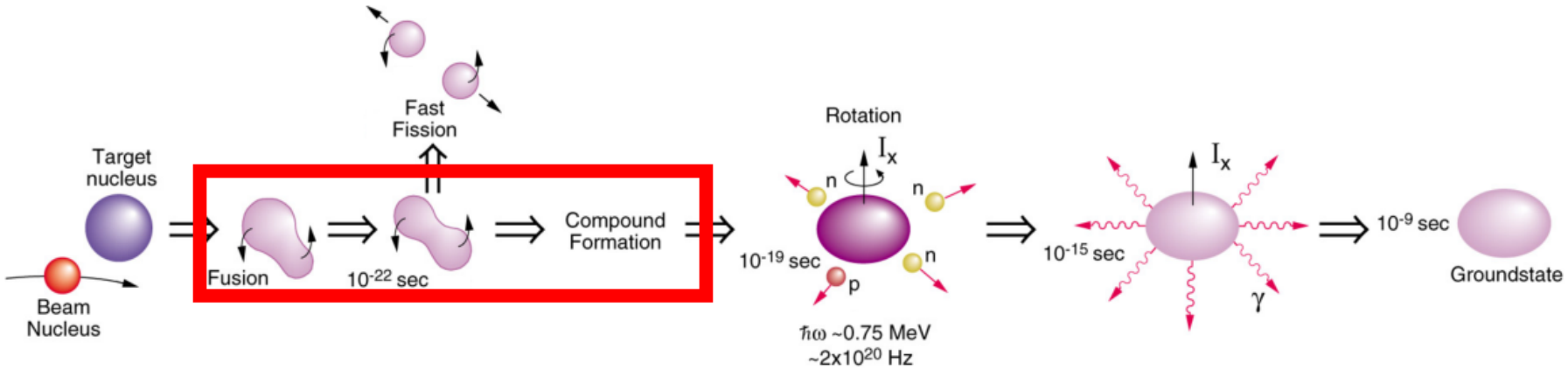


Fusion Evaporation Reaction



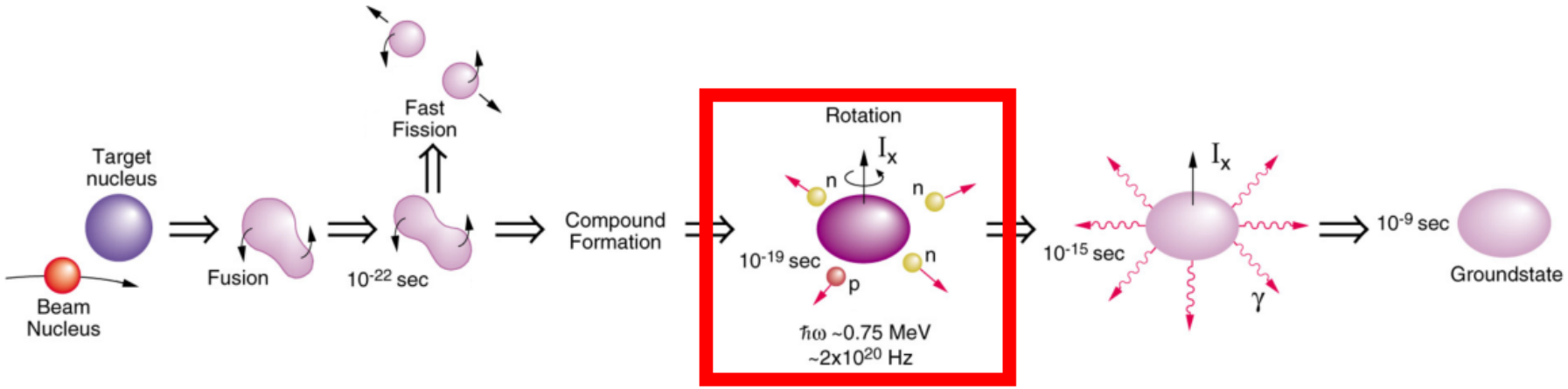
- $^{20}Ne + {}^{40}Ca$
- $^{21}Na + {}^{40}Ca$

Fusion Evaporation Reaction



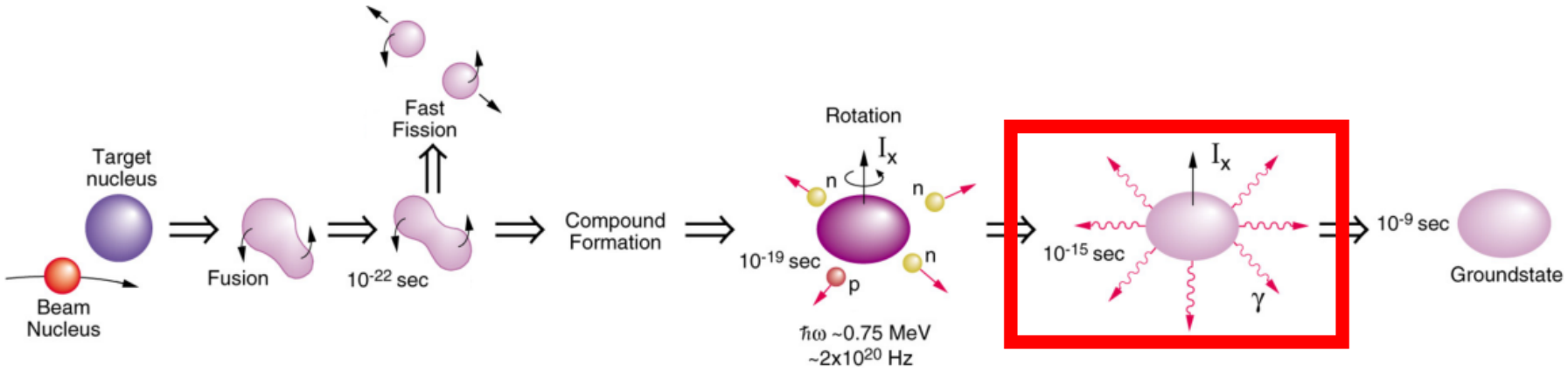
- $^{20}Ne + {}^{40}Ca \rightarrow {}^{60}Zn$
- $^{21}Na + {}^{40}Ca \rightarrow {}^{61}Ga$

Fusion Evaporation Reaction



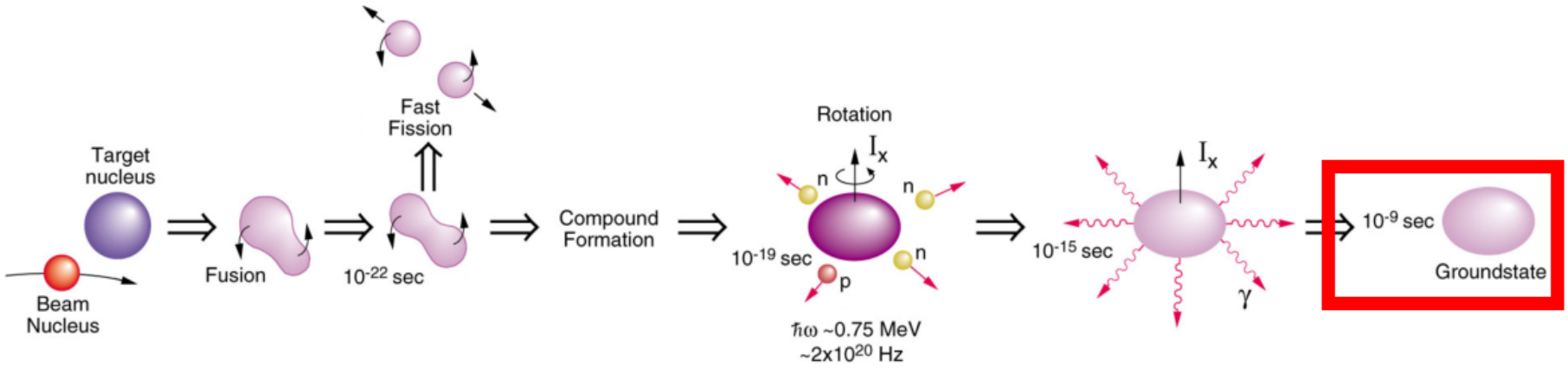
- $^{20}\mathrm{Ne} + {}^{40}\mathrm{Ca} \rightarrow {}^{60}\mathrm{Zn} \rightarrow {}^{55}\mathrm{Co}^{\star} + \alpha p$
- $^{21}\mathrm{Na} + {}^{40}\mathrm{Ca} \rightarrow {}^{61}\mathrm{Ga} \rightarrow {}^{55}\mathrm{Ni}^{\star} + \alpha pn$

Fusion Evaporation Reaction



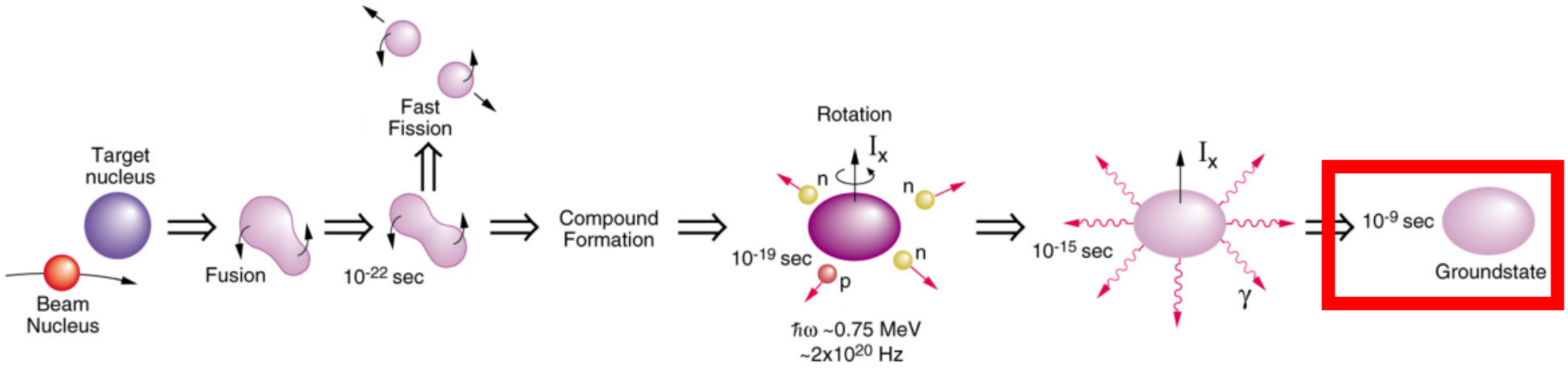
- $^{20}\mathrm{Ne} + {}^{40}\mathrm{Ca} \rightarrow {}^{60}\mathrm{Zn} \rightarrow {}^{55}\mathrm{Co}^{\star} + \alpha p \rightarrow {}^{55}\mathrm{Co} + \alpha p + \mathrm{n}\gamma$
- $^{21}\mathrm{Na} + {}^{40}\mathrm{Ca} \rightarrow {}^{61}\mathrm{Ga} \rightarrow {}^{55}\mathrm{Ni}^{\star} + \alpha pn \rightarrow {}^{55}\mathrm{Ni} + \alpha pn + \mathrm{n}\gamma$

Fusion Evaporation Reaction

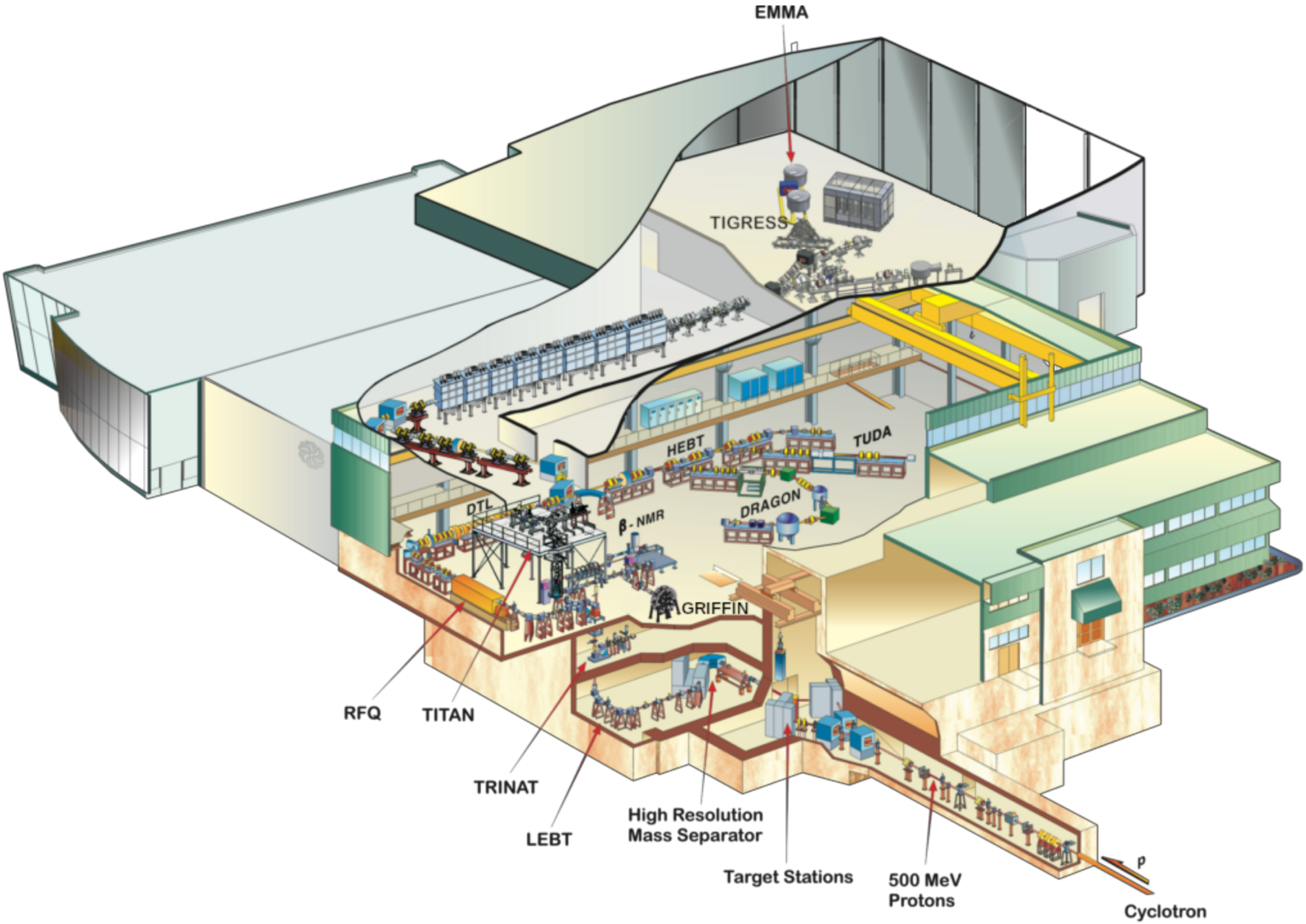


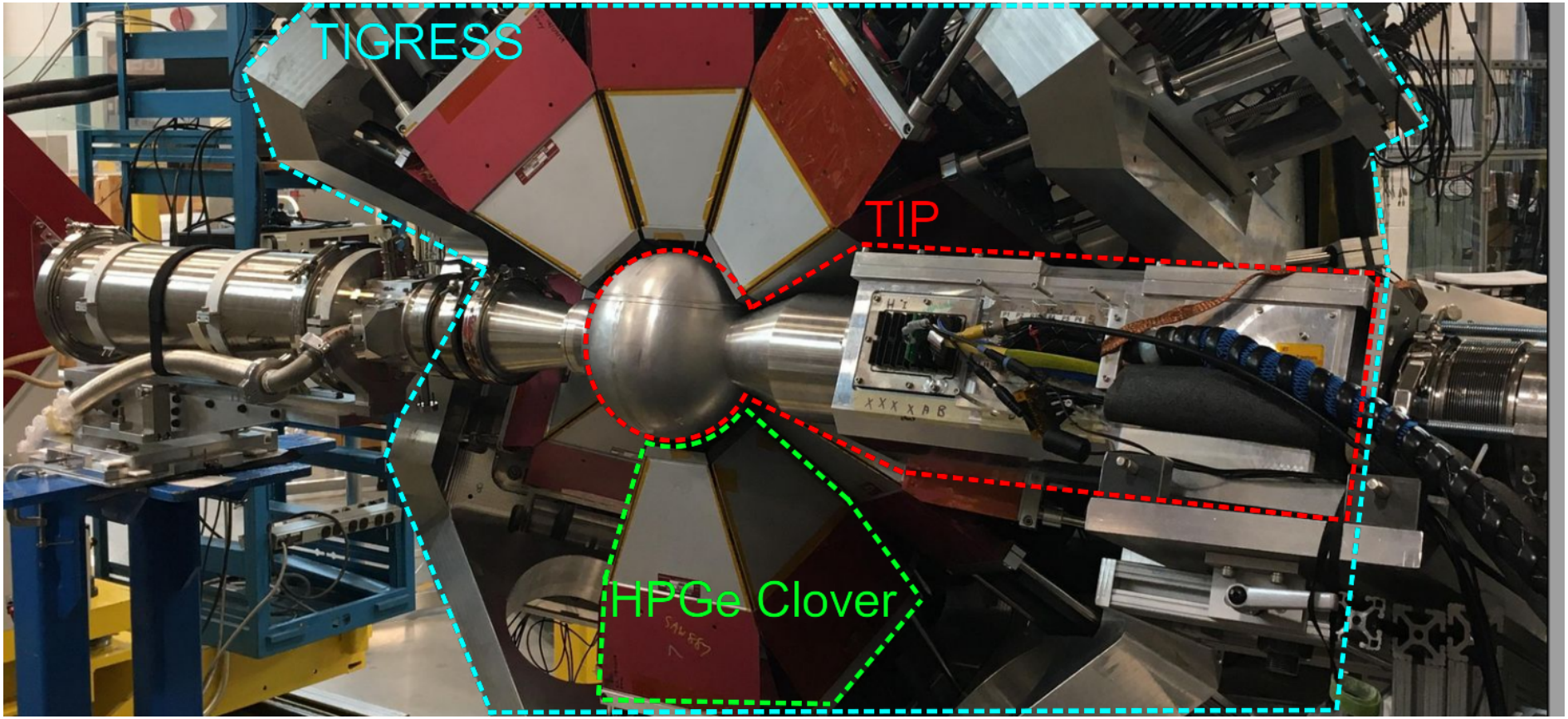
- $^{20}\mathrm{Ne} + {}^{40}\mathrm{Ca} \rightarrow {}^{60}\mathrm{Zn} \rightarrow {}^{55}\mathrm{Co}^{\star} + \alpha p \rightarrow {}^{55}\mathrm{Co} + \alpha p + \mathrm{n}\gamma + \ldots$
- $^{21}\mathrm{Na} + {}^{40}\mathrm{Ca} \rightarrow {}^{61}\mathrm{Ga} \rightarrow {}^{55}\mathrm{Ni}^{\star} + \alpha pn \rightarrow {}^{55}\mathrm{Ni} + \alpha pn + \mathrm{n}\gamma + \ldots$

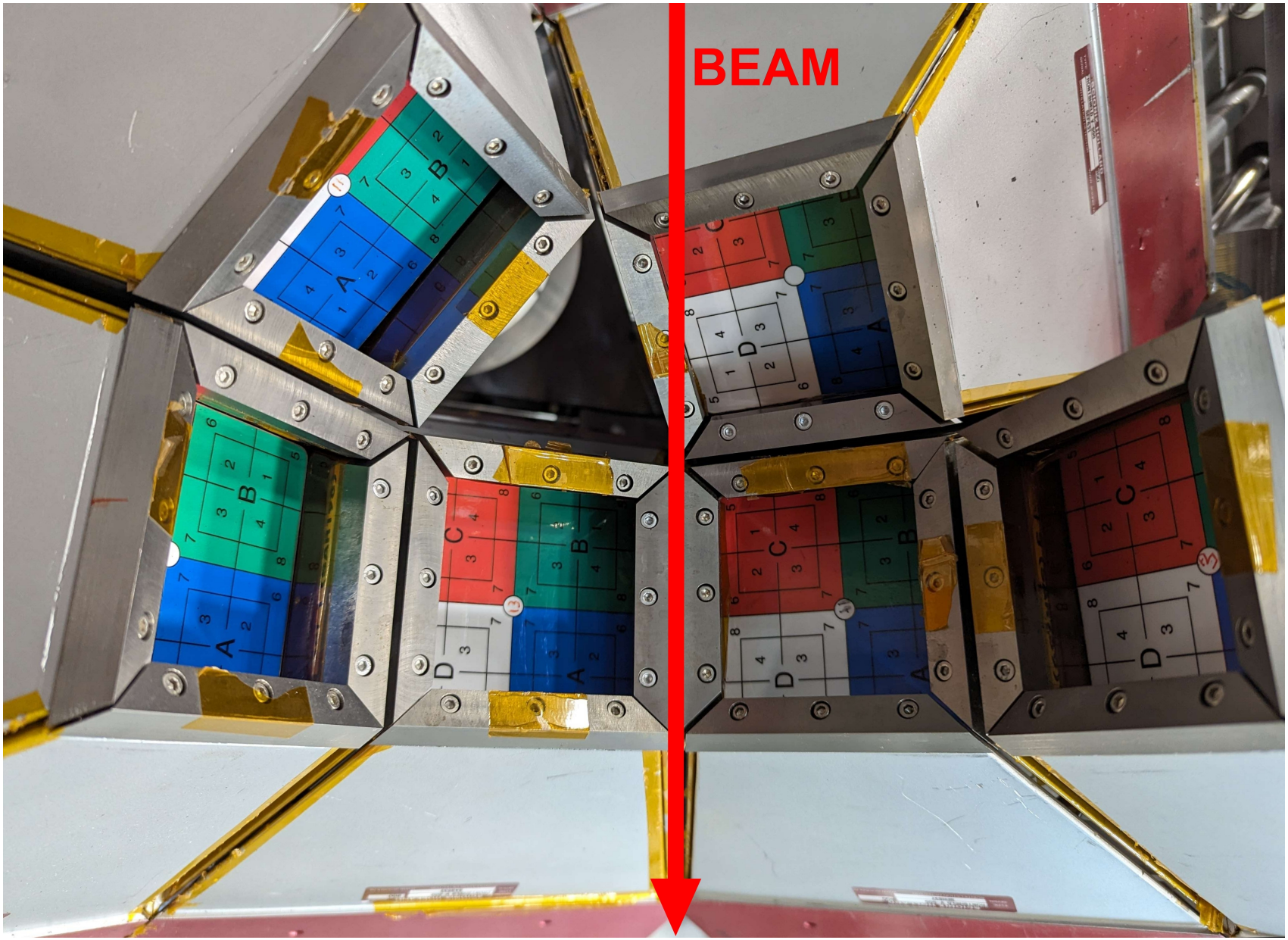
Fusion Evaporation Reaction



- $^{20}\mathrm{Ne} + {}^{40}\mathrm{Ca} \rightarrow {}^{60}\mathrm{Zn} \rightarrow {}^{55}\mathrm{Co}^{\star} + \alpha p \rightarrow {}^{55}\mathrm{Co} + \alpha p + \mathrm{n}\gamma + \ldots$
- $^{21}\mathrm{Na} + {}^{40}\mathrm{Ca} \rightarrow {}^{61}\mathrm{Ga} \rightarrow {}^{55}\mathrm{Ni}^{\star} + \alpha pn \rightarrow {}^{55}\mathrm{Ni} + \alpha pn + \mathrm{n}\gamma + \ldots$
- These are just two among dozens of other products.

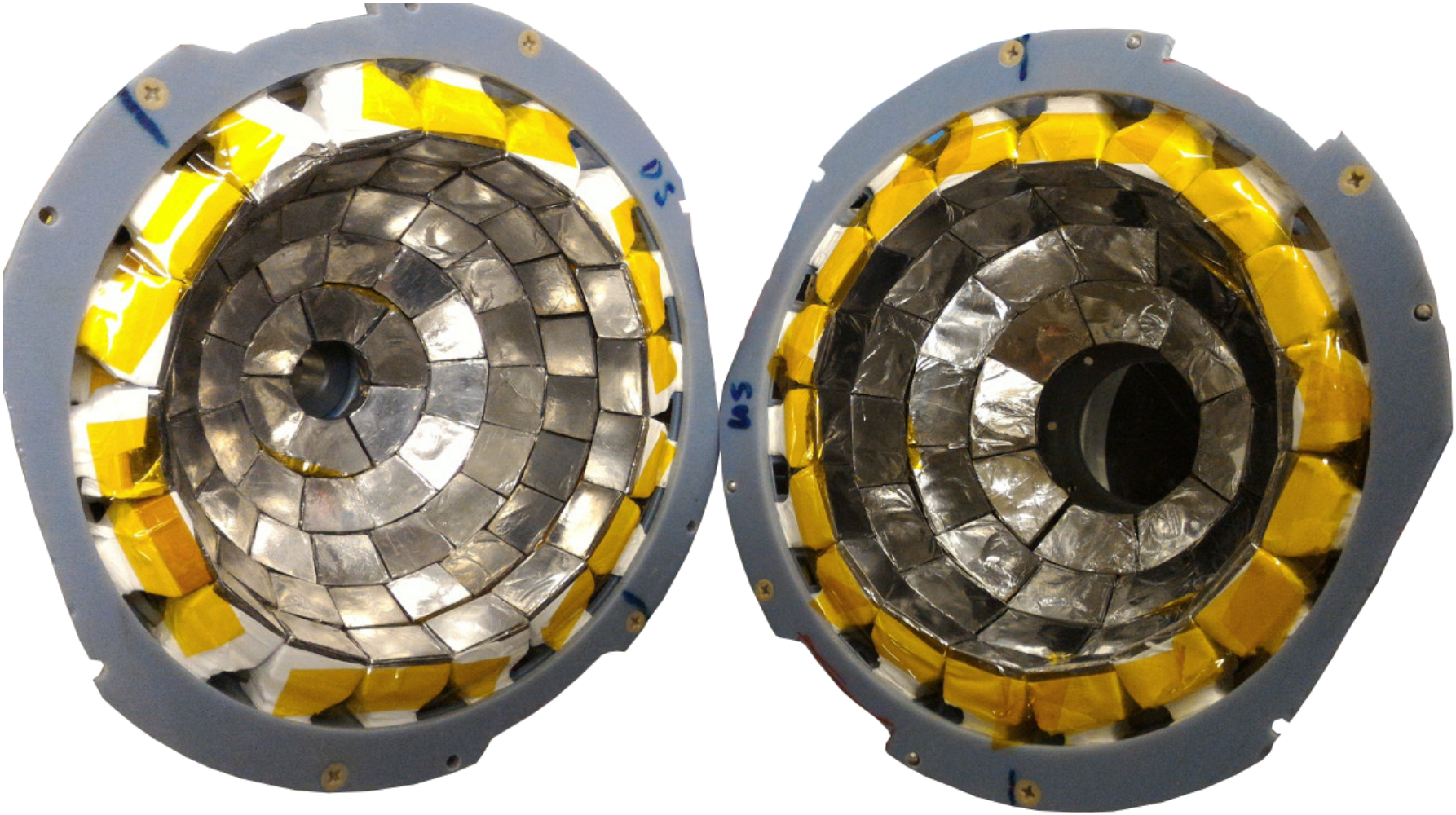

EMMA
TIGRESS
HEBT
TUDA
DRAGON
DTL
β-NMR
GRIFFIN
RFQ
TITAN
TRINAT
LEBT
High Resolution
Mass Separator
Target Stations
500 MeV
Protons
p
Cyclotron


TIGRESS
TIP
HPGe Clover

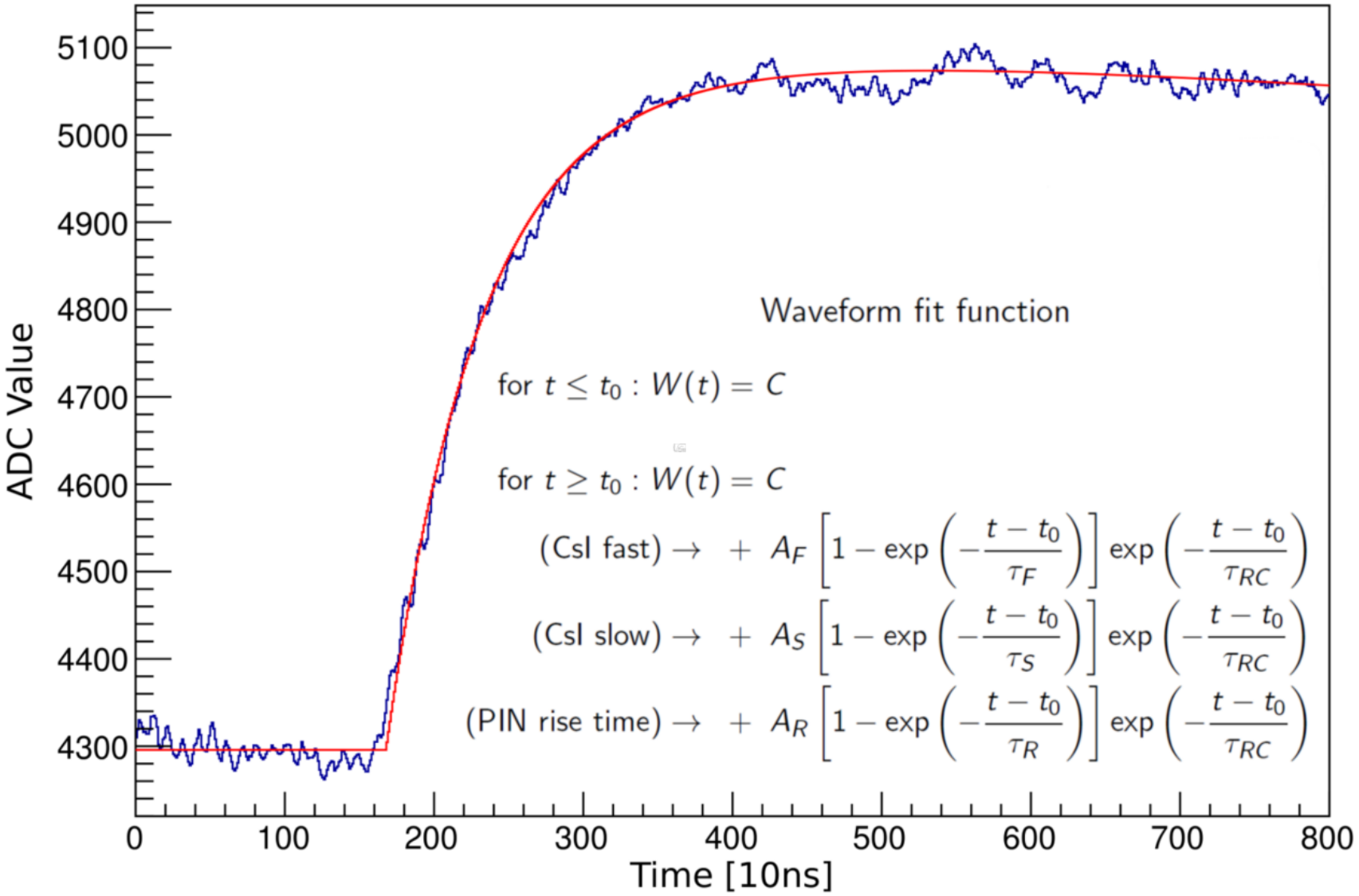

BEAM

TIGRESS Integrated Plunger

SFU

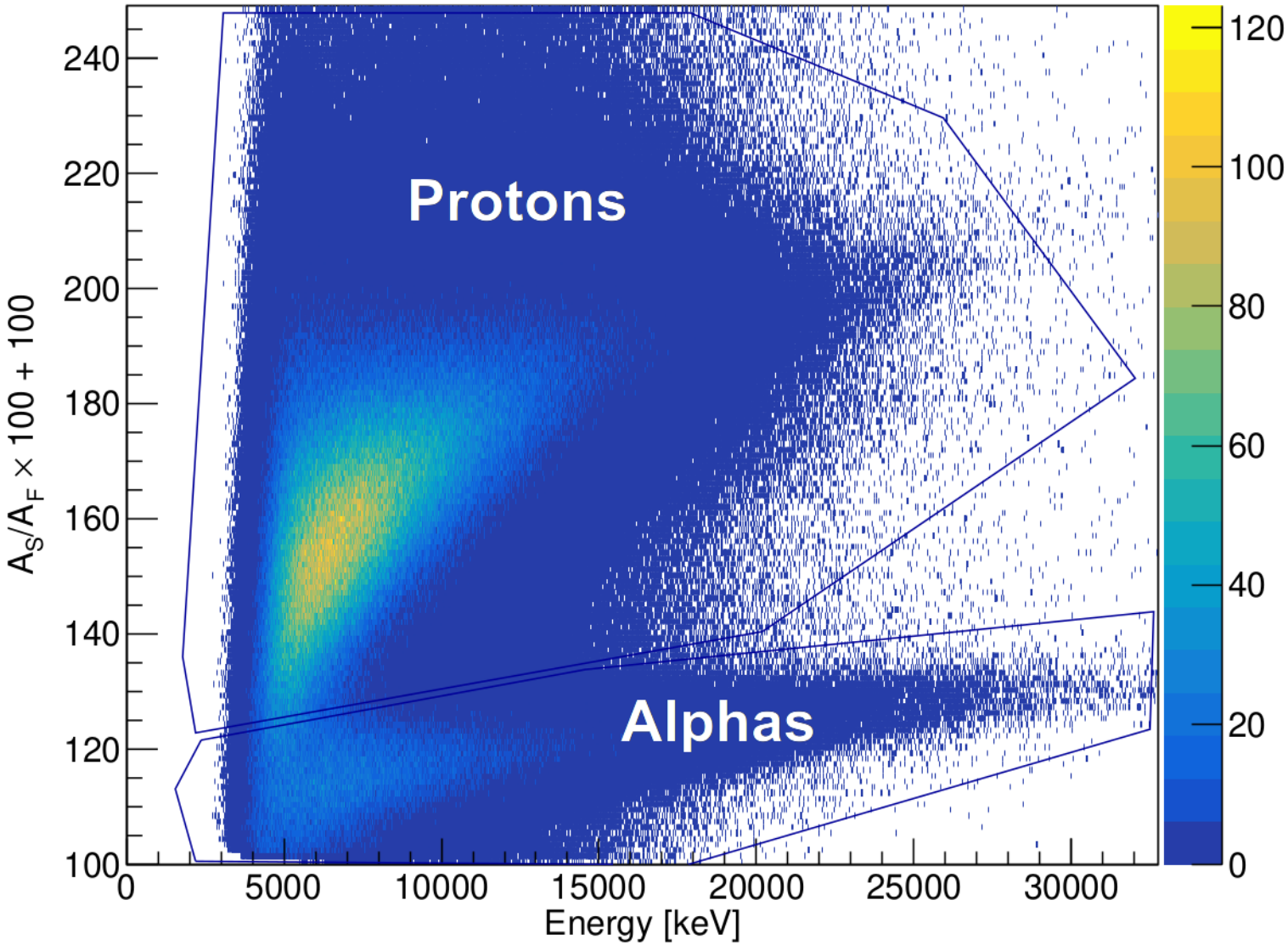


Charged Particle Waveform Fitting

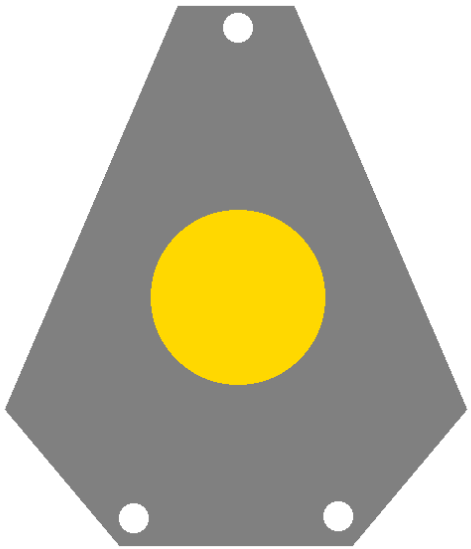


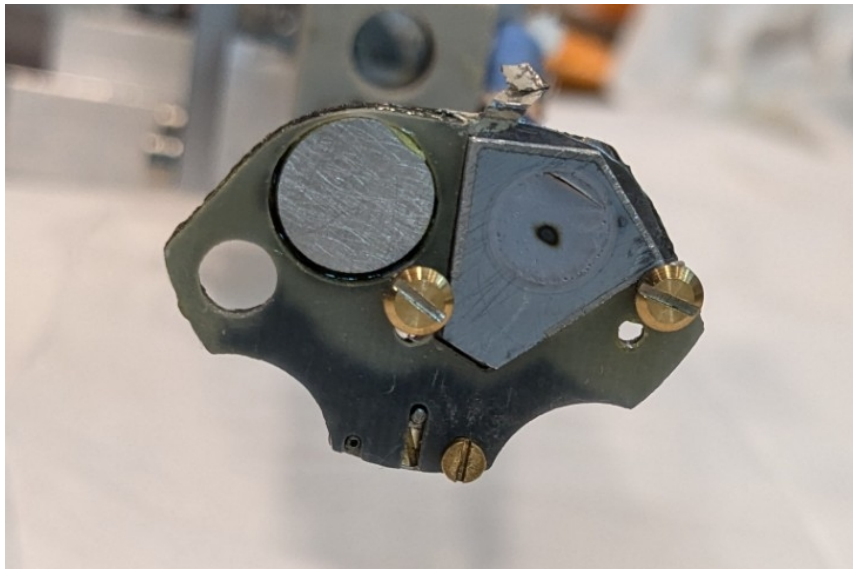
J. Williams, PhD Thesis, 2019

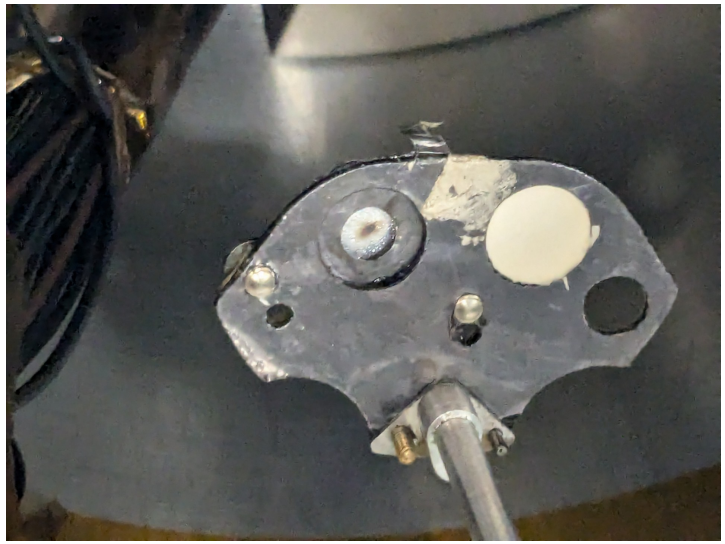
Charged Particle Gates



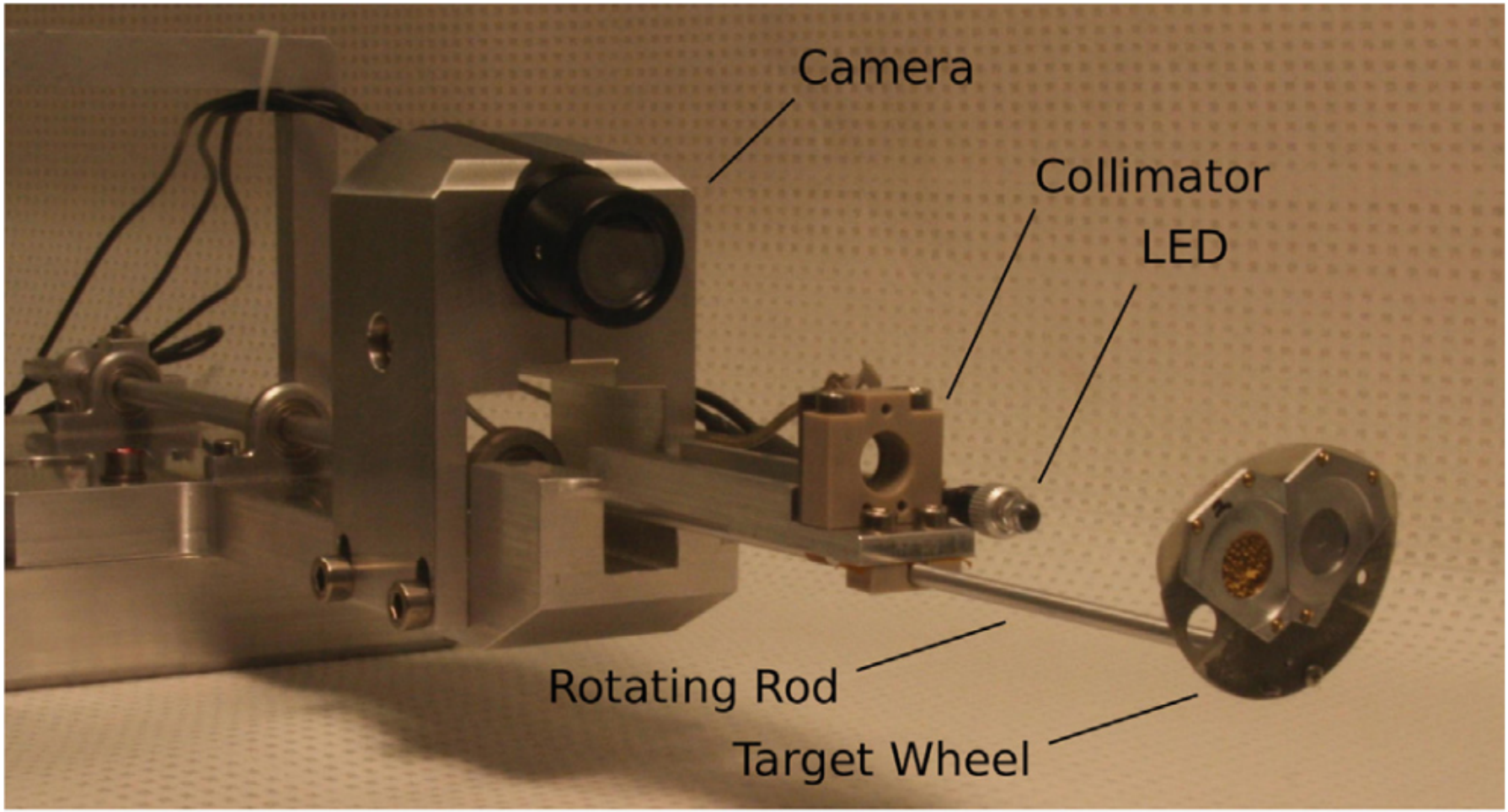
Calcium Targets



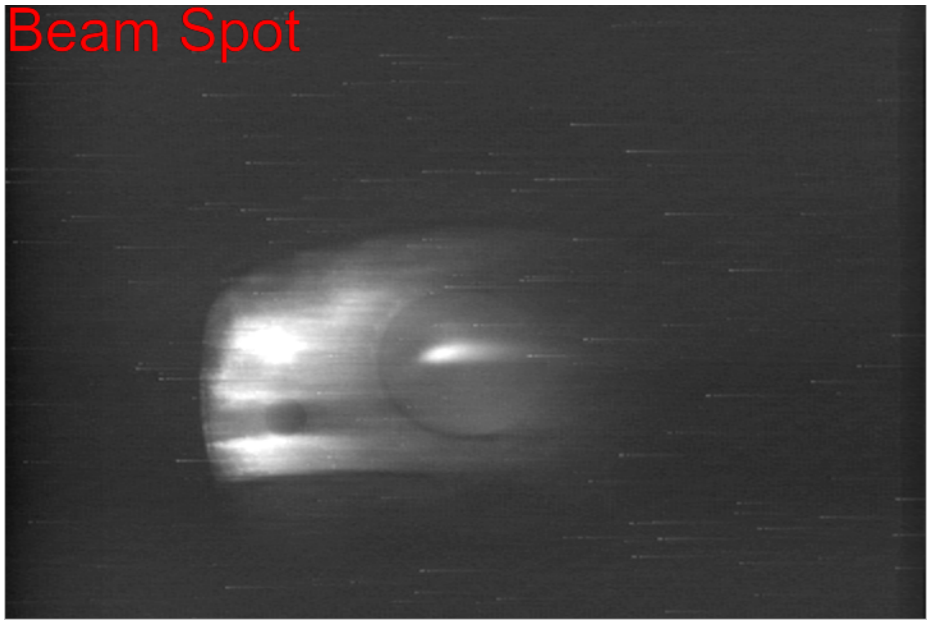


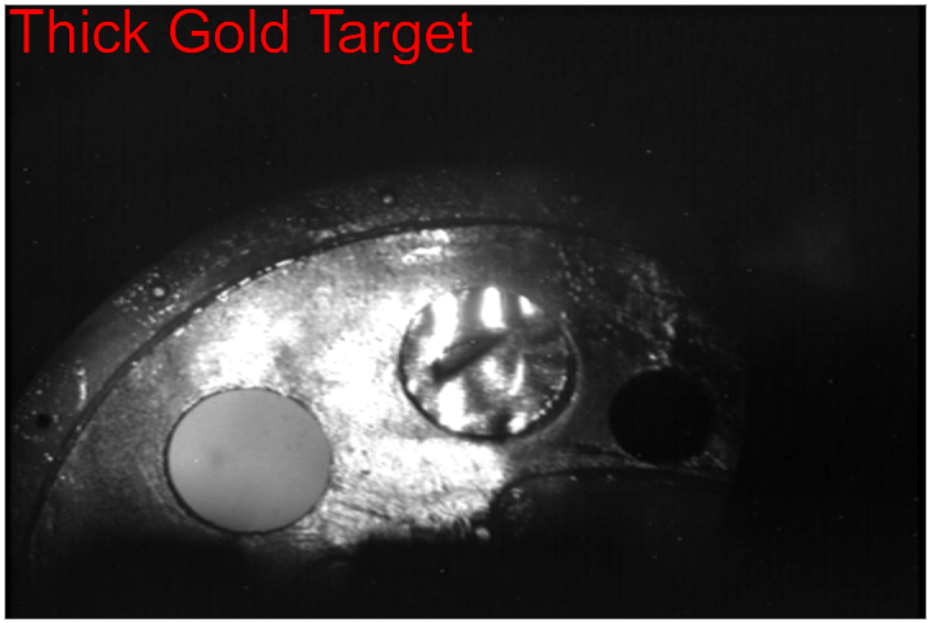


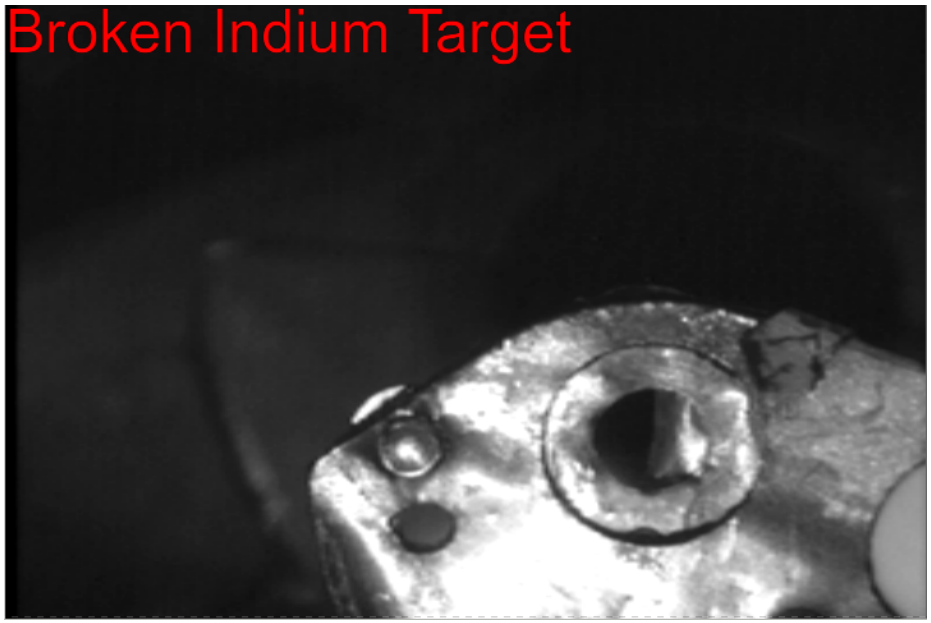
Target Wheel Assembly

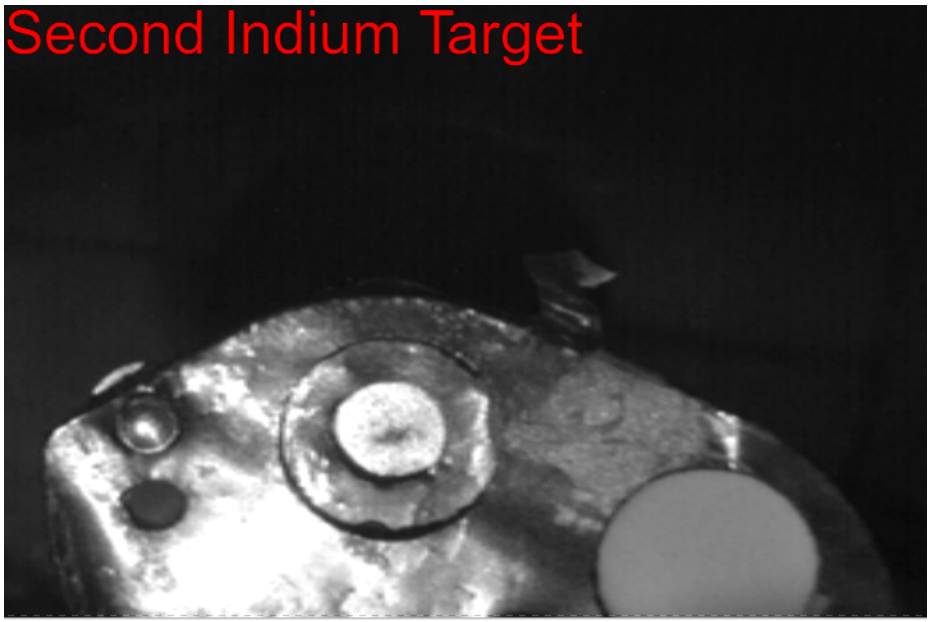


TIP Camera


Beam Spot

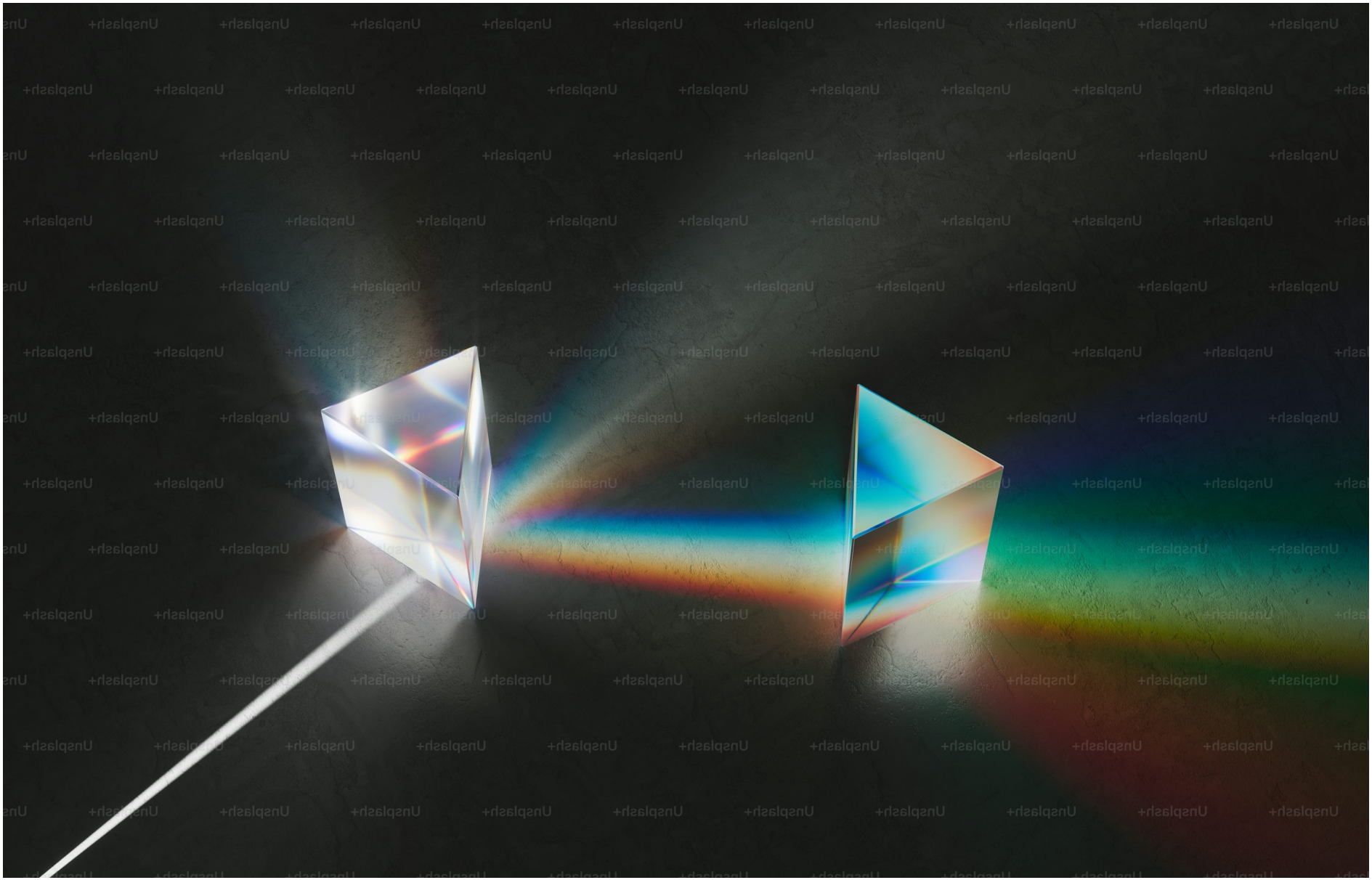

Thick Gold Target


Broken Indium Target

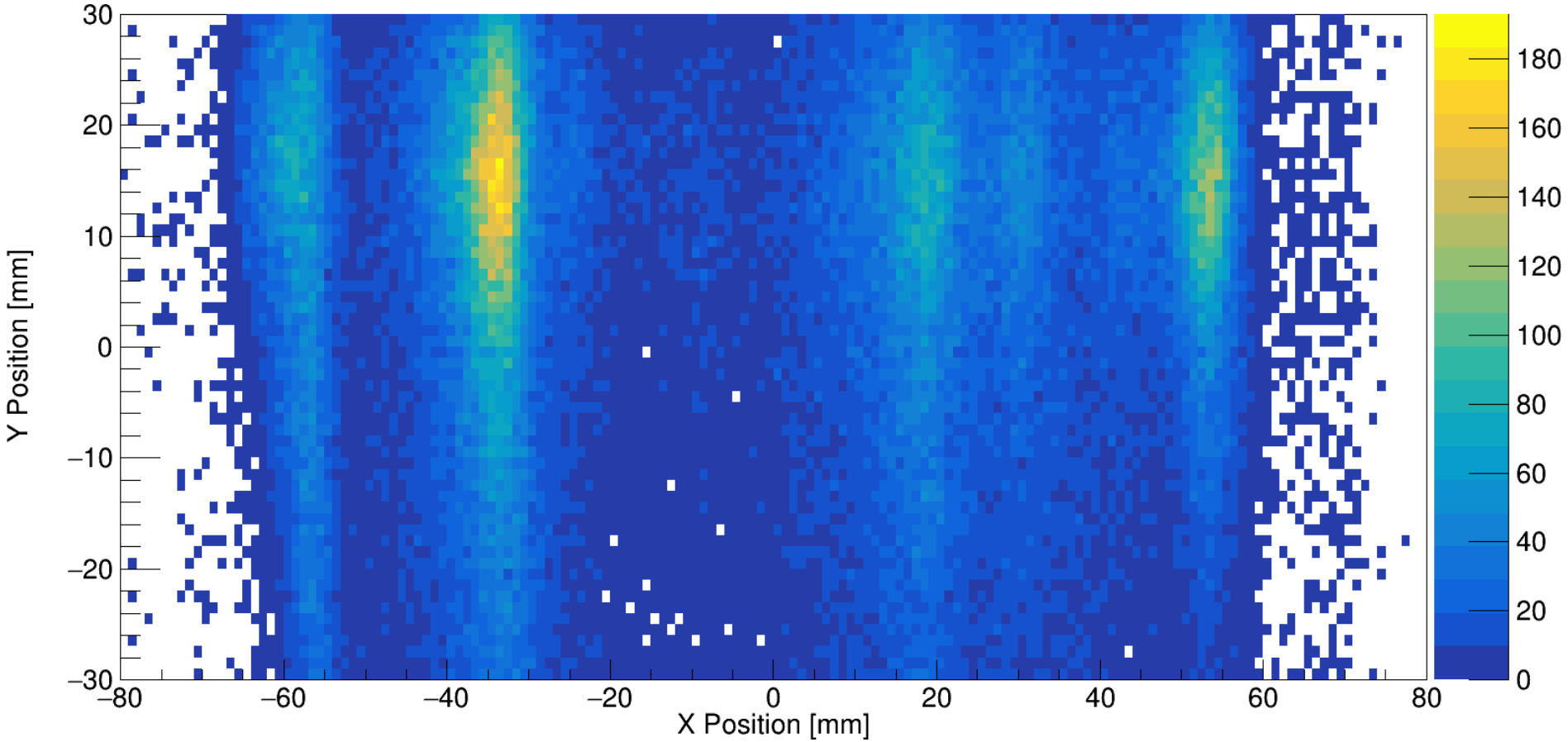

Second Indium Target

ElectroMagnetic Mass Analyzer

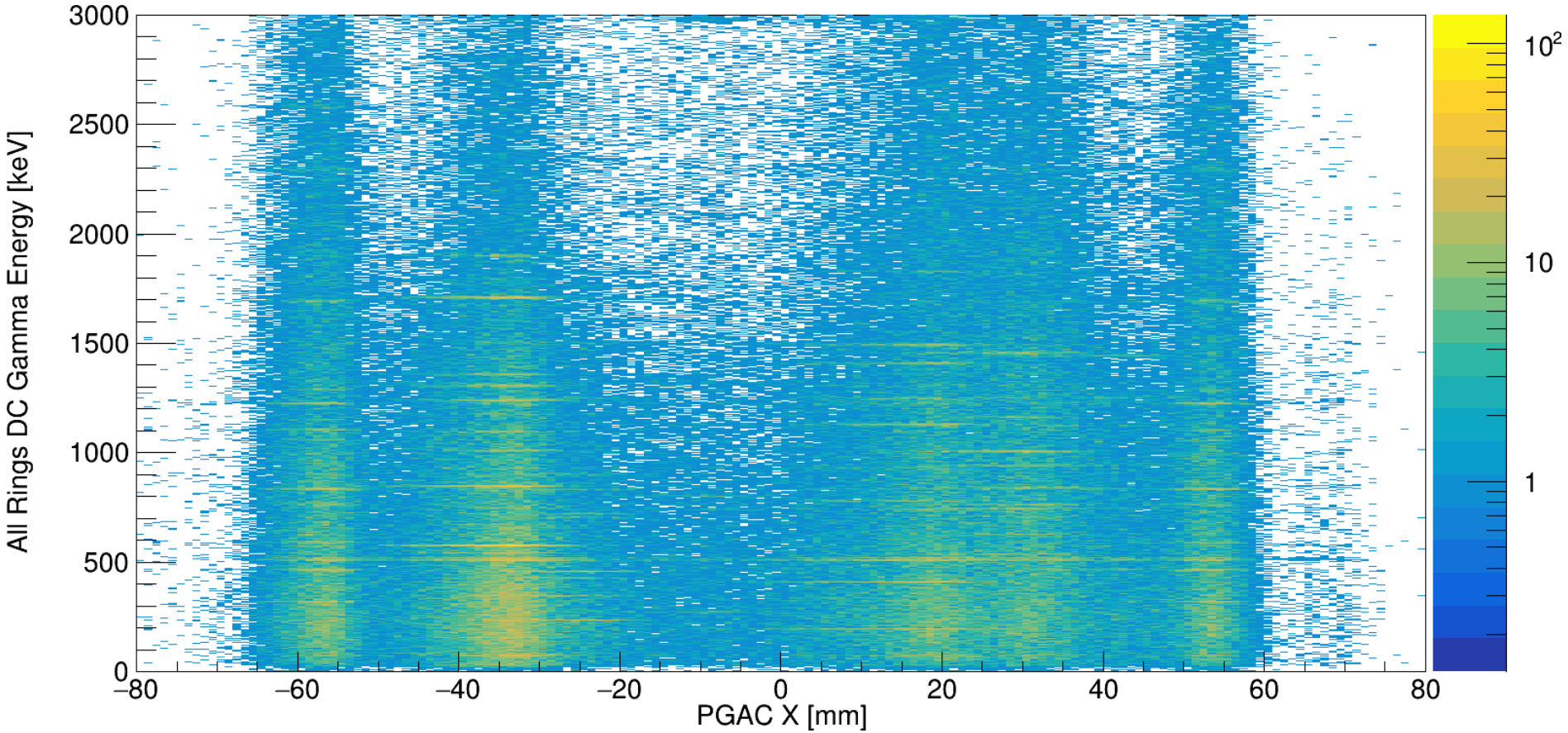
EMMA as a "Prism"



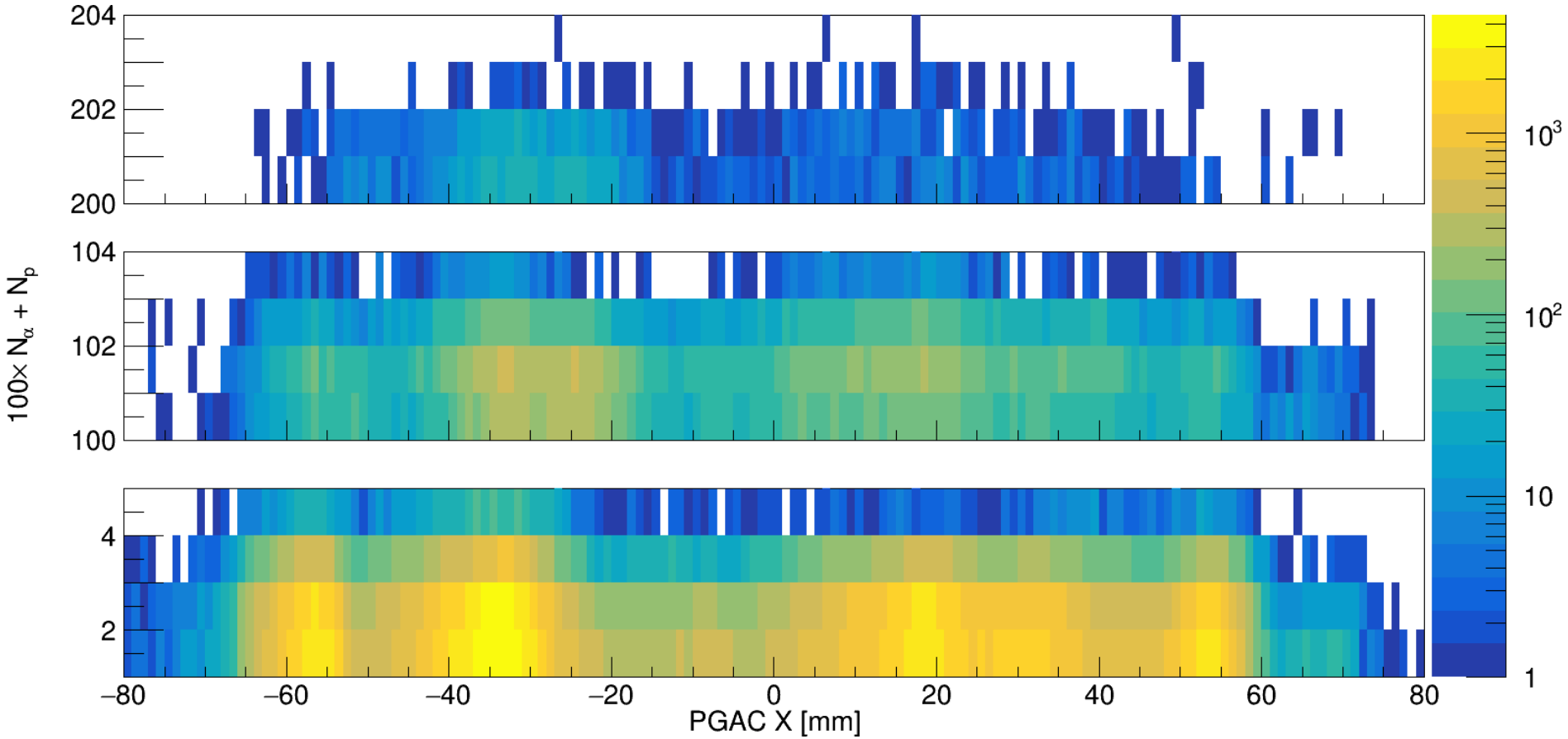
Parallel Grid Avalanche Counter



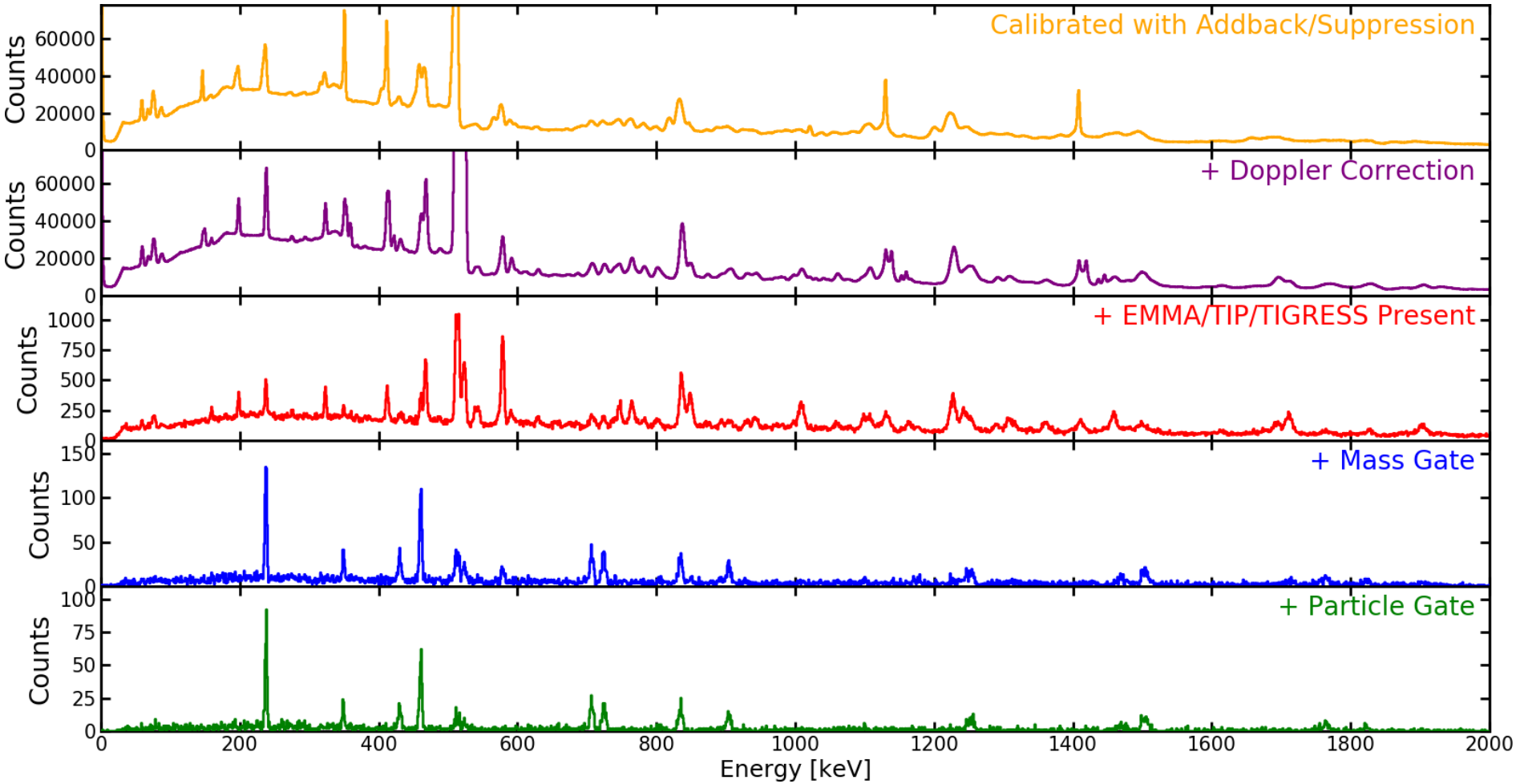
TIGRESS vs. EMMA PGAC



TIP PID vs. EMMA PGAC



Gamma Ray Spectra for ^{51}Mn



Summary

- Experiments were successfully conducted to pursue the production of ^{55}Co and ^{55}Ni.

Summary

- Experiments were successfully conducted to pursue the production of ^{55}Co and ^{55}Ni.
- Analysis is ongoing, and results are thus very preliminary.

Summary

- Experiments were successfully conducted to pursue the production of ^{55}Co and ^{55}Ni.
- Analysis is ongoing, and results are thus very preliminary.
  - Found: ^{57}Co, ^{56}Co, ^{55}Co, ^{54}Fe, and ^{51}Mn so far...

Summary

- Experiments were successfully conducted to pursue the production of ^{55}Co and ^{55}Ni.
- Analysis is ongoing, and results are thus very preliminary.
  - Found: ^{57}Co, ^{56}Co, ^{55}Co, ^{54}Fe, and ^{51}Mn so far...
- Mainly wish to highlight the capabilities of TRIUMF and SFU apparatus:

Summary

- Experiments were successfully conducted to pursue the production of ^{55}Co and ^{55}Ni.
- Analysis is ongoing, and results are thus very preliminary.
  - Found: ^{57}Co, ^{56}Co, ^{55}Co, ^{54}Fe, and ^{51}Mn so far...
- Mainly wish to highlight the capabilities of TRIUMF and SFU apparatus:
  - TIGRESS: for high-resolution γ-ray detection with Compton suppression and addback,

Summary

- Experiments were successfully conducted to pursue the production of ^{55}Co and ^{55}Ni.
- Analysis is ongoing, and results are thus very preliminary.
  - Found: ^{57}Co, ^{56}Co, ^{55}Co, ^{54}Fe, and ^{51}Mn so far...
- Mainly wish to highlight the capabilities of TRIUMF and SFU apparatus:
  - TIGRESS: for high-resolution γ-ray detection with Compton suppression and addback,
  - TIP: to enable charged particle spectra and PID gating,

Summary

- Experiments were successfully conducted to pursue the production of ^{55}Co and ^{55}Ni.
- Analysis is ongoing, and results are thus very preliminary.
  - Found: ^{57}Co, ^{56}Co, ^{55}Co, ^{54}Fe, and ^{51}Mn so far...
- Mainly wish to highlight the capabilities of TRIUMF and SFU apparatus:
  - TIGRESS: for high-resolution γ-ray detection with Compton suppression and addback,
  - TIP: to enable charged particle spectra and PID gating,
  - EMMA: for gating on recoil nucleus A, Z, and E,

Summary

- Experiments were successfully conducted to pursue the production of ^{55}Co and ^{55}Ni.
- Analysis is ongoing, and results are thus very preliminary.
  - Found: ^{57}Co, ^{56}Co, ^{55}Co, ^{54}Fe, and ^{51}Mn so far...
- Mainly wish to highlight the capabilities of TRIUMF and SFU apparatus:
  - TIGRESS: for high-resolution γ-ray detection with Compton suppression and addback,
  - TIP: to enable charged particle spectra and PID gating,
  - EMMA: for gating on recoil nucleus A, Z, and E,
  - ^{40}Ca Targetry: to access proton-rich exotic nuclei,

Summary

- Experiments were successfully conducted to pursue the production of ^{55}Co and ^{55}Ni.
- Analysis is ongoing, and results are thus very preliminary.
  - Found: ^{57}Co, ^{56}Co, ^{55}Co, ^{54}Fe, and ^{51}Mn so far...
- Mainly wish to highlight the capabilities of TRIUMF and SFU apparatus:
  - TIGRESS: for high-resolution γ-ray detection with Compton suppression and addback,
  - TIP: to enable charged particle spectra and PID gating,
  - EMMA: for gating on recoil nucleus A, Z, and E,
  - ^{40}Ca Targetry: to access proton-rich exotic nuclei,
  - ... a combination that has not occurred before these experiments.

Acknowledgements

- Thank you to my mentors, collaborators, and colleagues:

C. Andreoiu[1], C. Angus[2], D. Annen[3], M.D.H.K.G. Badanage[1], G. Ball[2], S. Buck[4], R.J. Coleman[4], B. Davids[2], J.S. Dodge[5], P.E. Garrett[4], E. Geerlof[2], S. Georges[2], B. Greaves[4], G. Hackman[2], J.D. Holt[2], K. Hudson[5], V. Karayonchev[6], E. Kasanda[4], P. Machule[2], M.S. Martin[56], A. Melson[7], J.R. Murias[2], C.R. Natzke[2], K. Ortner[1], K. Preocanin[5], A. Redey[8], D. Rhodes[2], L. Schmidt[4], P. Spagnoletti[1], K. Starosta[1], C.E. Svensson[4], D. Tam[5], N. Tanzi[5], V. Vedia[2], L. Wagner[2], K. van Wieren[7], J. Williams[2], F.T. Wu[1], D. Yates[2], Z. Yu[1]

[1]Department of Chemistry, SFU; [2]TRIUMF; [3]Department of Biomedical Physiology and Kinesiology, SFU; [4]Department of Physics, University of Guelph; [5]Department of Physics, SFU; [6]Argonne National Laboratory; [7]Science Technical Centre, SFU; [8]School of Engineering Science, SFU