Nuclear structure studies in the vicinity of Z=28 neutron-rich isotopes

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Physics Motivation

Physics of the $\nu g_{9/2}$ beyond N=40

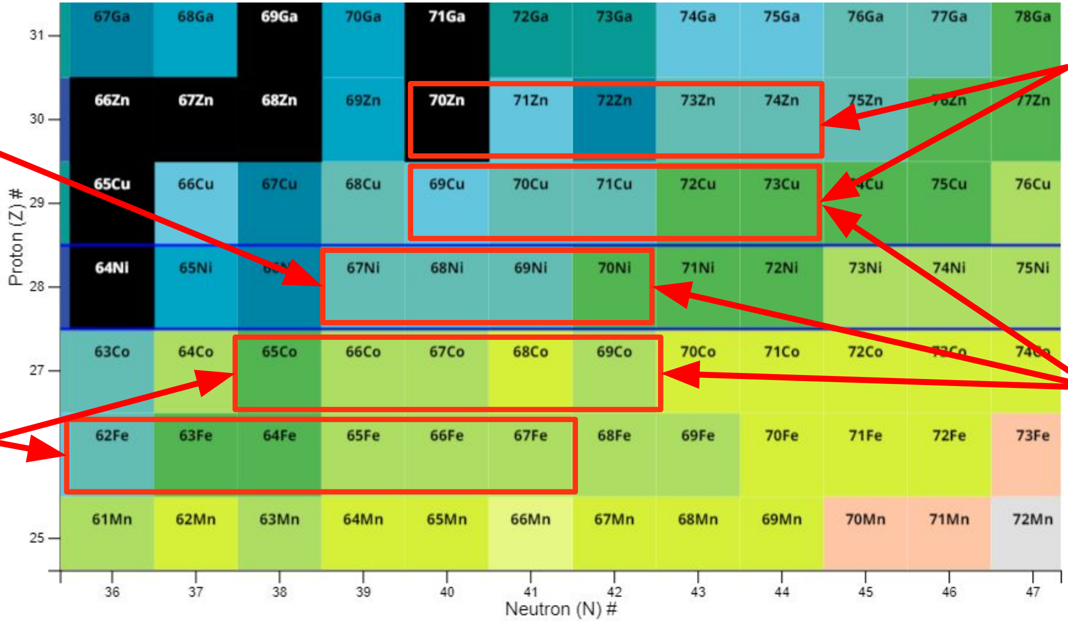
Joint proposal aiming to study the physics of the $\nu g_{9/2}$ beyond N=40:

- Collectivity and seniority conservation in $\nu g_{9/2}$ orbital
- Shape coexistence and octupole vibrations in ^{68}Ni
- Island of inversion and the role of intruders at N~40

Lifetimes and spectroscopy

A. Investigation of the Seniority Conservation in the $\nu g_{9/2}$ shell towards ^{78}Ni

C. Lifetime measurements in neutron-rich $^{67-73}$Cu and $^{70-74}$Zn nuclei above N=40



D. Spectroscopy and lifetime measurements neutron-rich Co and Fe isotopes

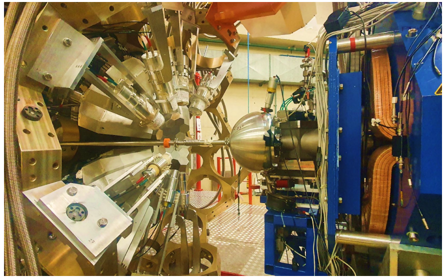
B. Effects of multiple shape coexistence on low-lying octupole vibrations and couplings

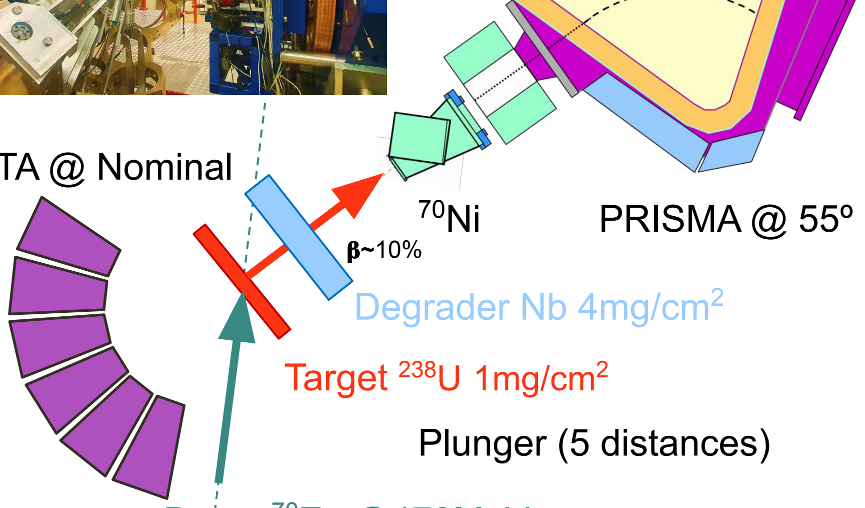
One of the best approaches to explore this mass region (from Zn to Fe) and populate low-to-medium angular momentum states is via multi-nucleon transfer reactions involving ^{70}Zn.

Experiment

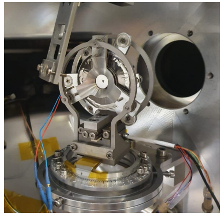
AGATA+PRISMA+Plunger

March 2024 at LNL.





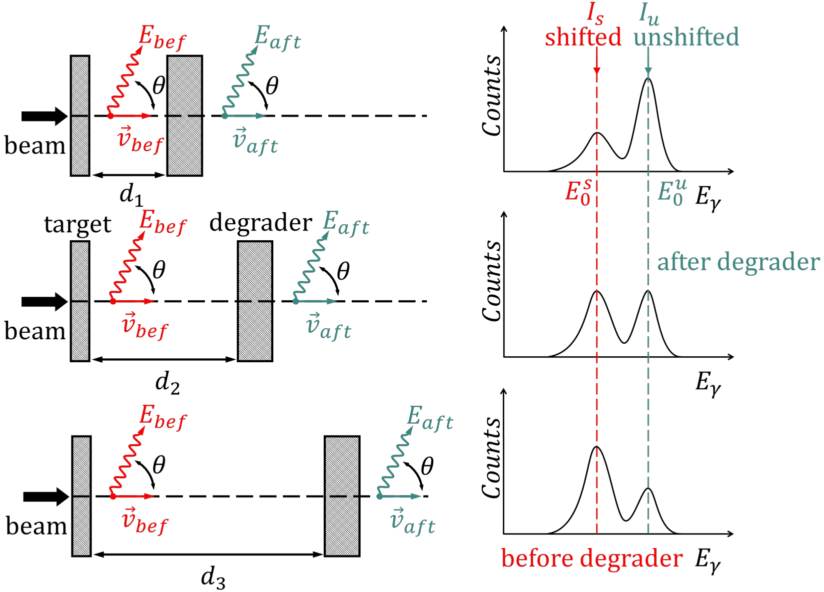
Multi-nucleon Transfer



RDDS technique

(Recoil Distance Doppler-Shift)

Lifetimes expected from ~1 to ~50 ps



Δβ=1,2%

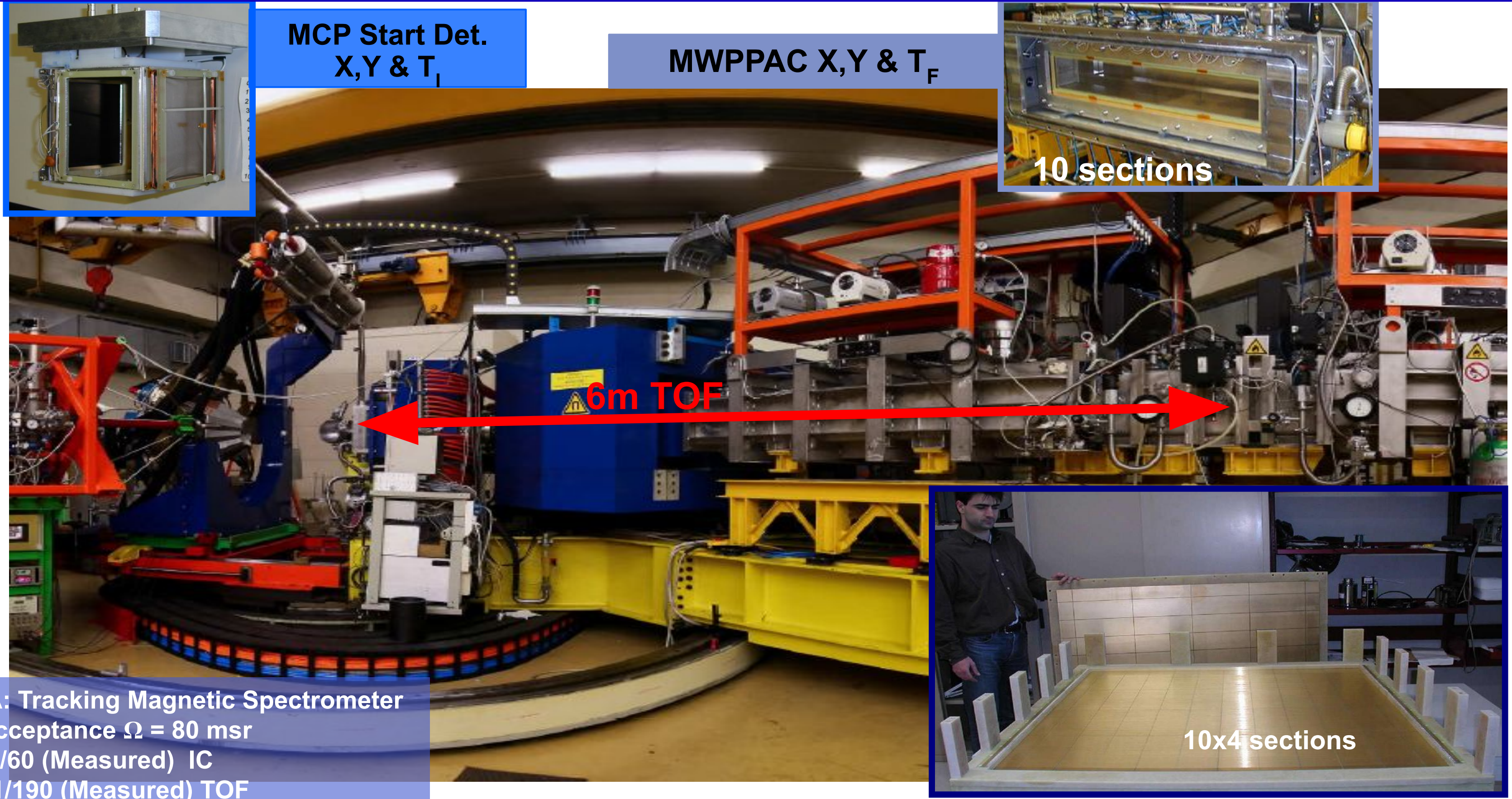
ΔE=10keV@1000keV

$$E = E_0 \frac{\sqrt{1-\beta^2}}{1-\beta\cos\theta}$$

Experiment: PRISMA

MCP Start Det.
X,Y & T_I

MWPPAC X,Y & T_F



Ionisation Chamber ΔE - E

PRISMA: Tracking Magnetic Spectrometer
Large acceptance Ω = 80 msr
$\Delta Z/Z \approx 1/60$ (Measured) IC
$\Delta A/A \approx 1/190$ (Measured) TOF
Energy acceptance ±20%
Max. $B\rho$ = 1.2 T.m.

AGATA analysis steps

PostPSA filter

Neutron Damage correction

Recalibrations with offsets.

Global time alignment.

PRISMA analysis steps

MCP

Position (x,y) calibration.

MWPPAC

- Position (x,y) calibration.
- Time of Flight (ToF).

Ionization Chamber (IC)

- ΔE-E matrix
- Z identification
- Aberration corrections.

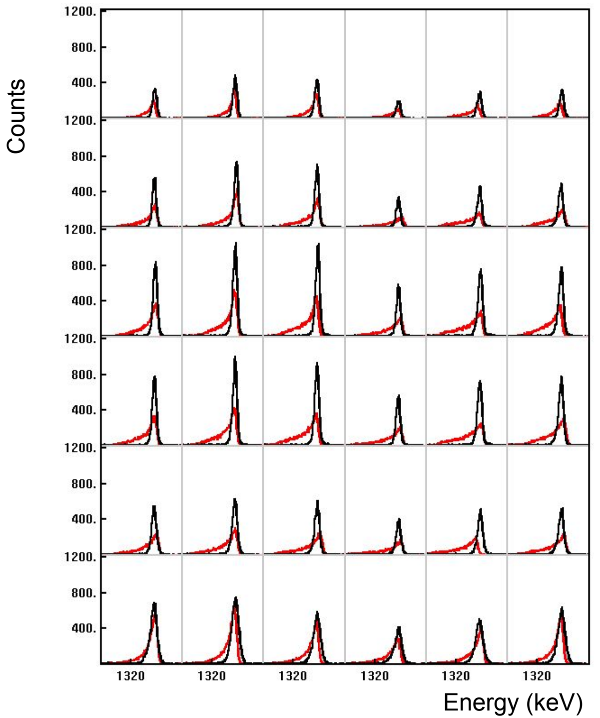
A identification

- Q identification
- A/Q.
- Aberration corrections.
- A identification.

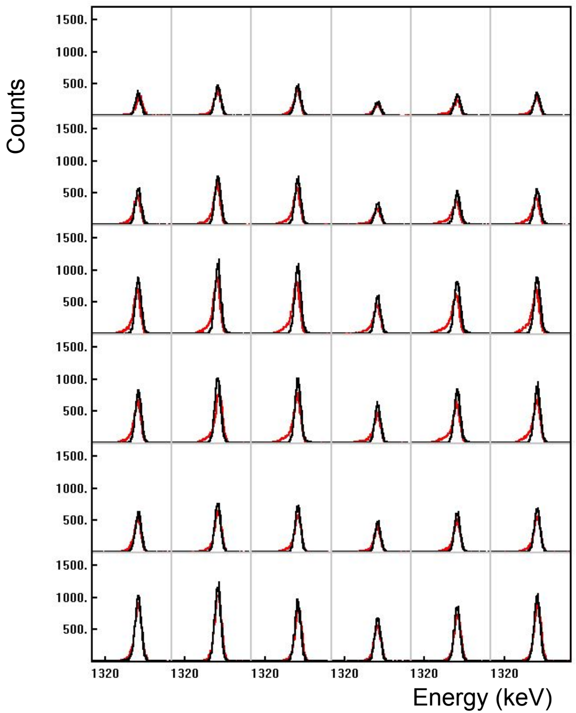
Analysis status: AGATA

Neutron Damage Correction

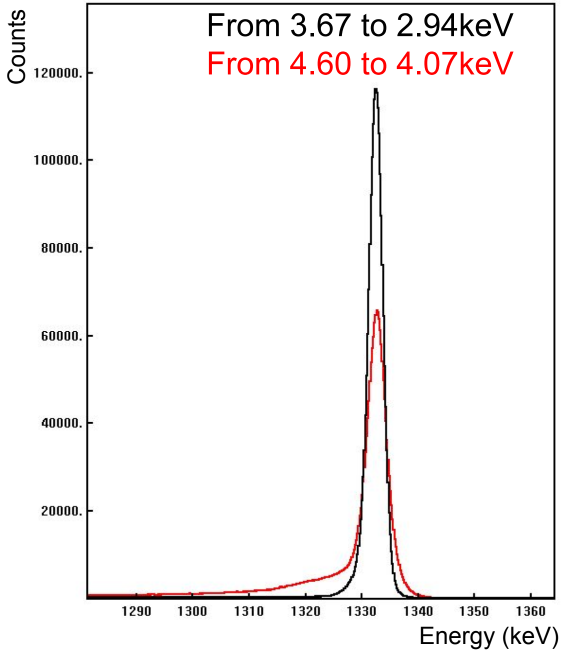
- ^{60}Co source .
- Energy calibration to 1332.5keV.
- Total detectors: 33
- Example taken here: **00A** detector.



SG before neutron damage correction.
SG after the neutron damage correction.



CC before neutron damage correction.
CC after the neutron damage correction.

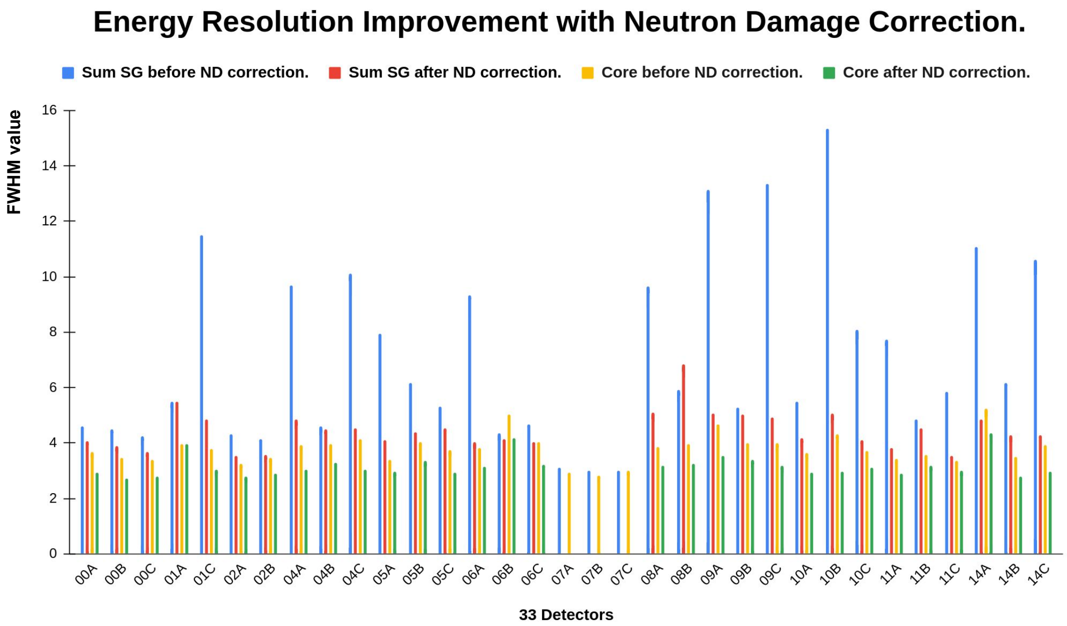


FWHM Sum SG after neutron correction.
FWHM CC after the neutron correction.

Analysis status: AGATA

Neutron Damage Correction

- ^{60}Co source .
- Energy calibration to 1332.5keV.
- Total detectors: 33



Average of energy resolution (FWHM) improvement ➡

Sum SG before ND correction.	Sum SG after ND correction.	Core before ND correction.	Core after ND correction.
7.1	4.5	3.8	3.2

Energy re-calibrations using ^{152}Eu source with offsets.

- ^{152}Eu source.
- Energy calibration to 1408keV.

Global energy resolution (FWHM) improvement:

Sum SG energy before correction	Sum SG energy after correction.
4.8keV	4.4keV

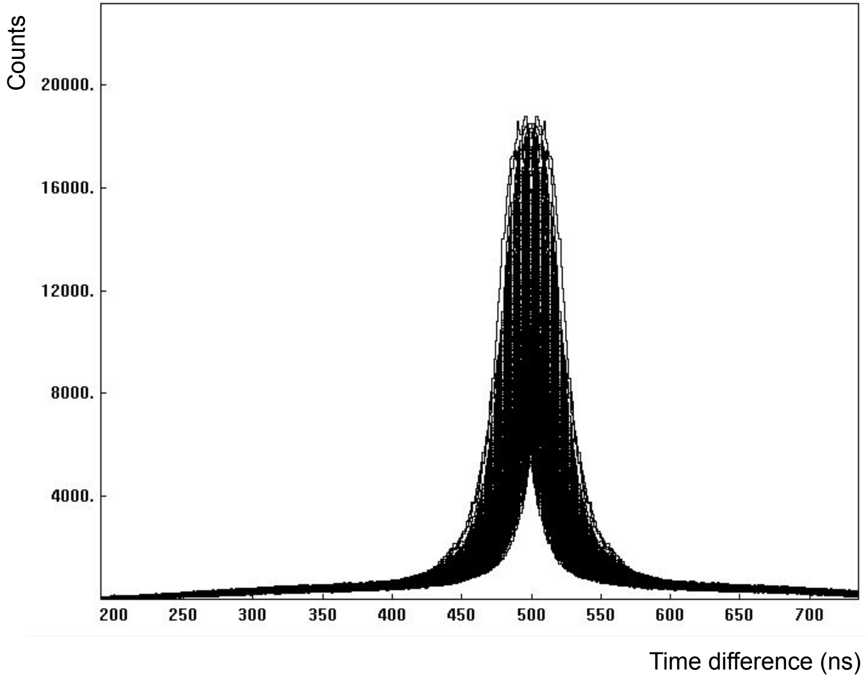
CC energy before correction.	CC energy after correction
3.5keV	3.1keV

Analysis status: AGATA

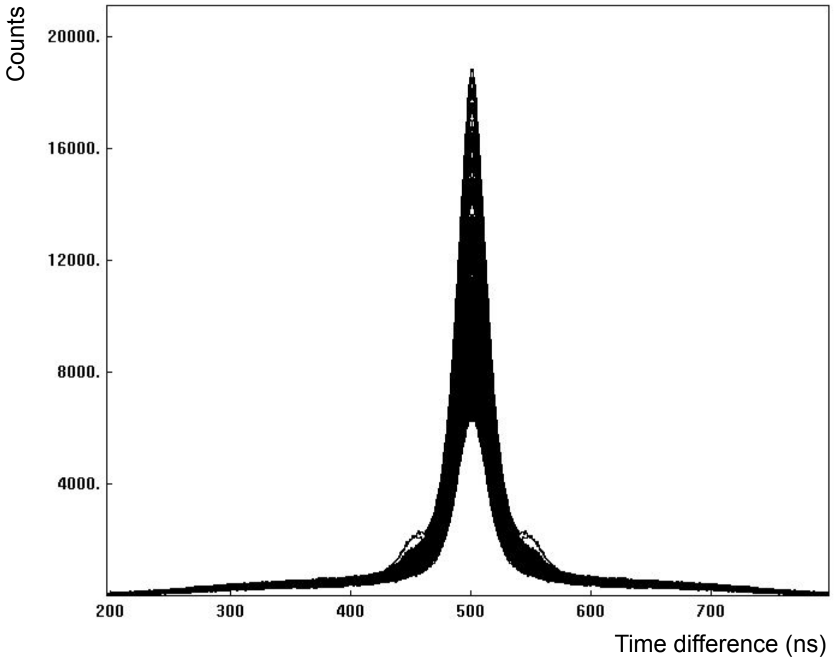
Global Time alignment

- Synchronize core time signals across all 33 detectors.

No Global Time alignment.



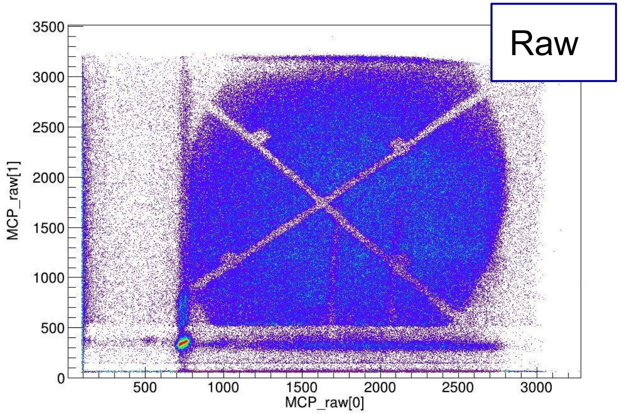
Global time alignment.

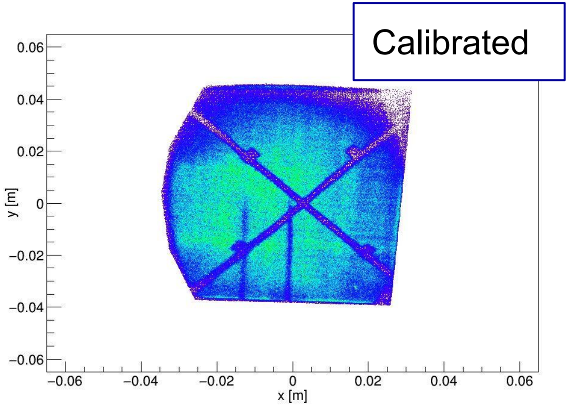


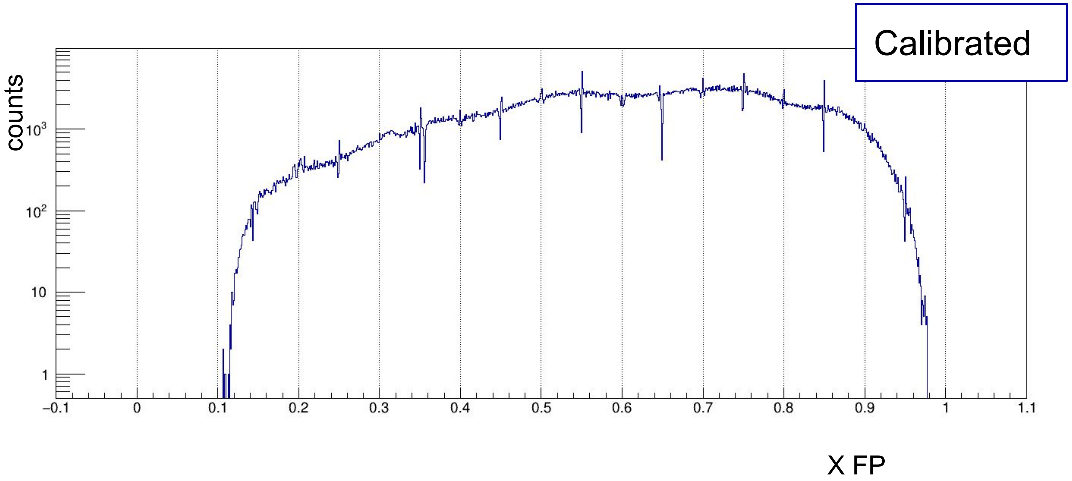
Analysis status: PRISMA

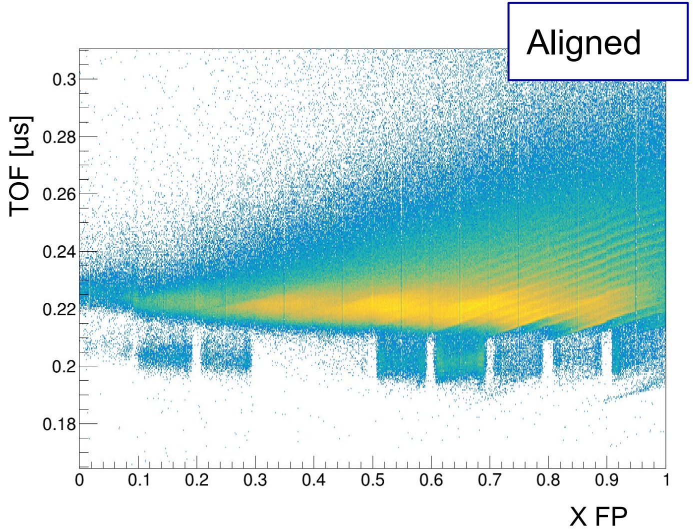
PRISMA calibration

MCP, MWPPAC, TOF calibration or alignment.







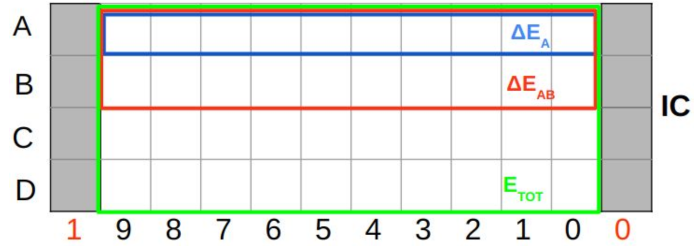


Analysis status: PRISMA

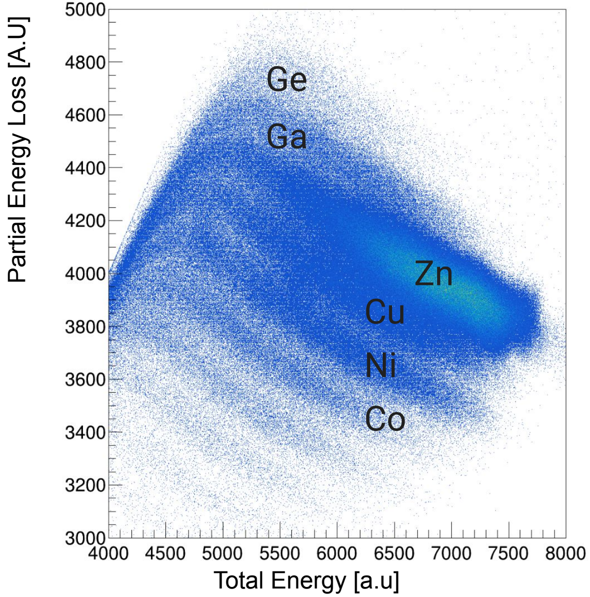
Ionisation Chamber (IC)

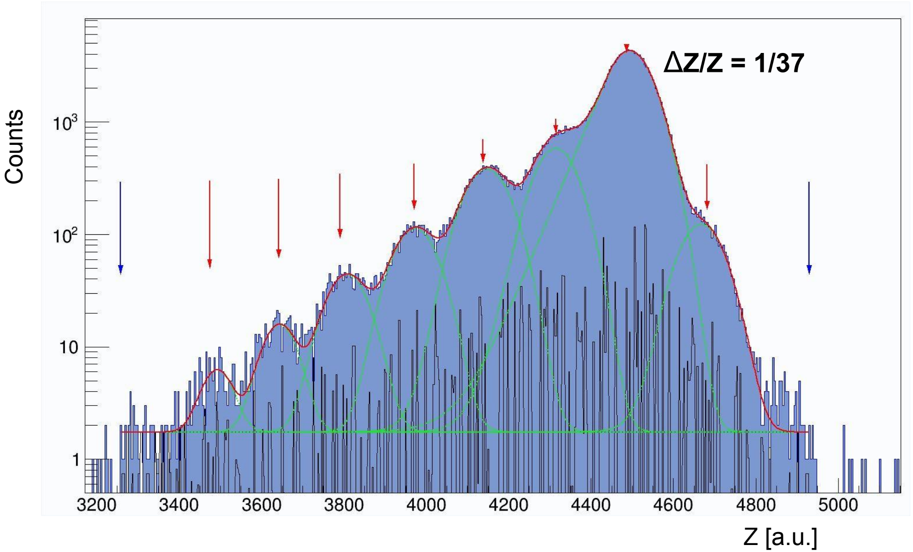
Z identification

- Construction of the ΔE and E matrix.
- Aberration corrections.
- Optimization of ΔZ/Z resolution.



Low Z discrimination, particularly important for Zn and Cu discrimination



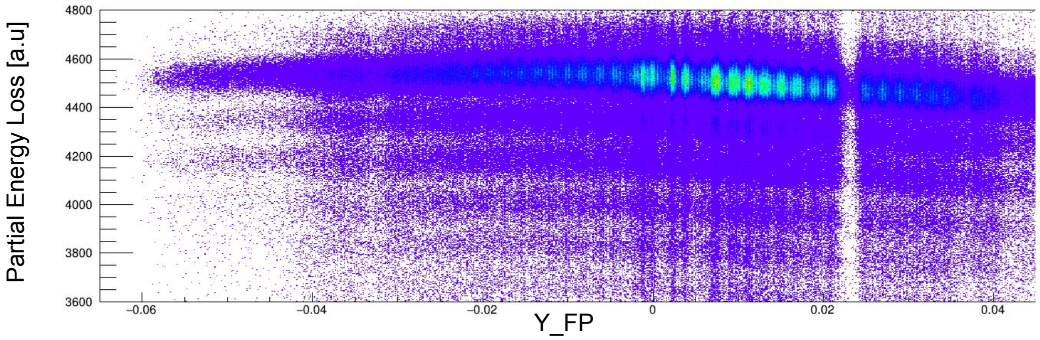


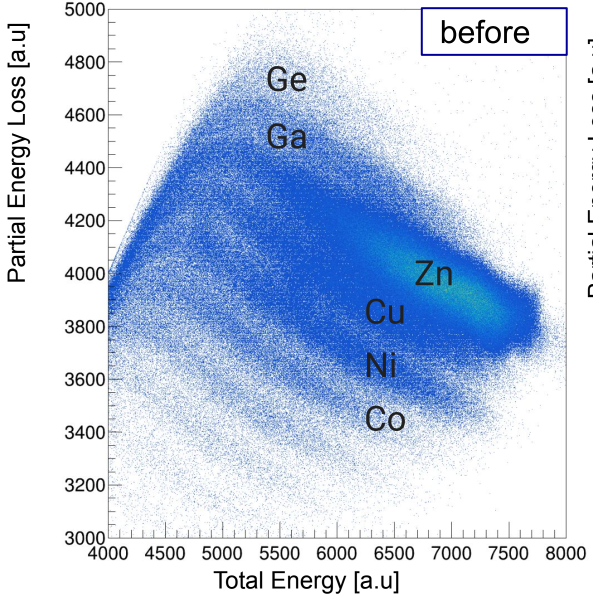
Analysis status: PRISMA

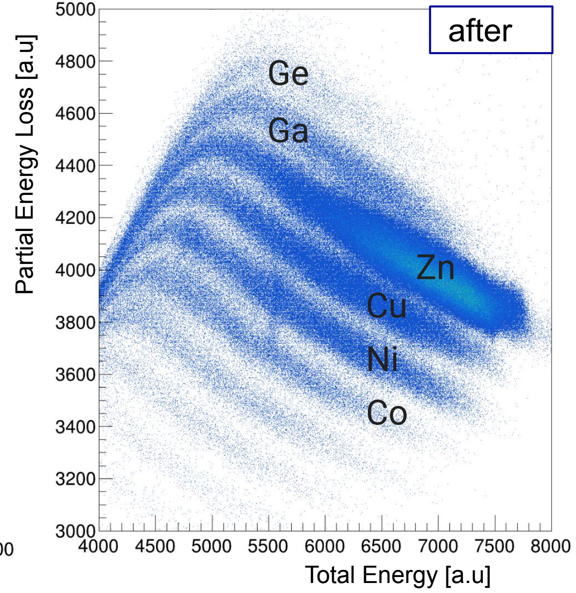
Ionisation Chamber (IC)

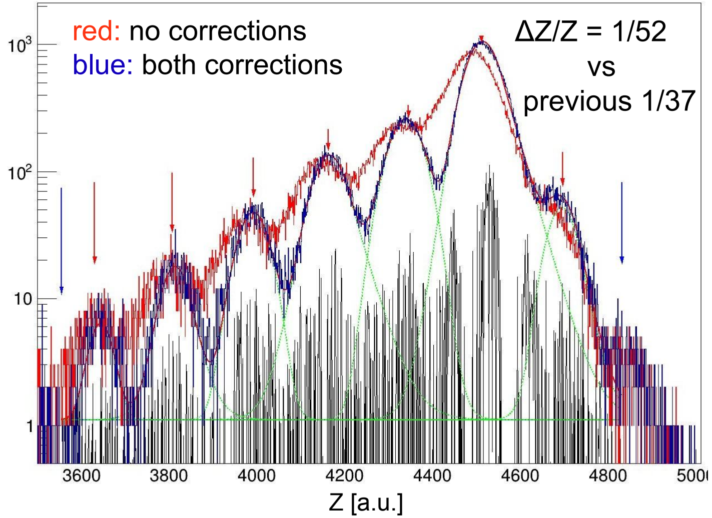
Residual trajectory dependences worsen the Z resolution in the IC.

Treated in the same way as A/Q aberrations.





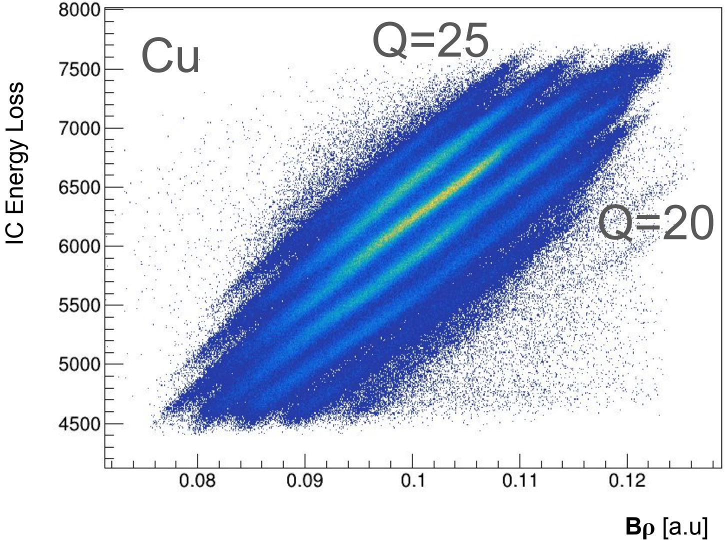


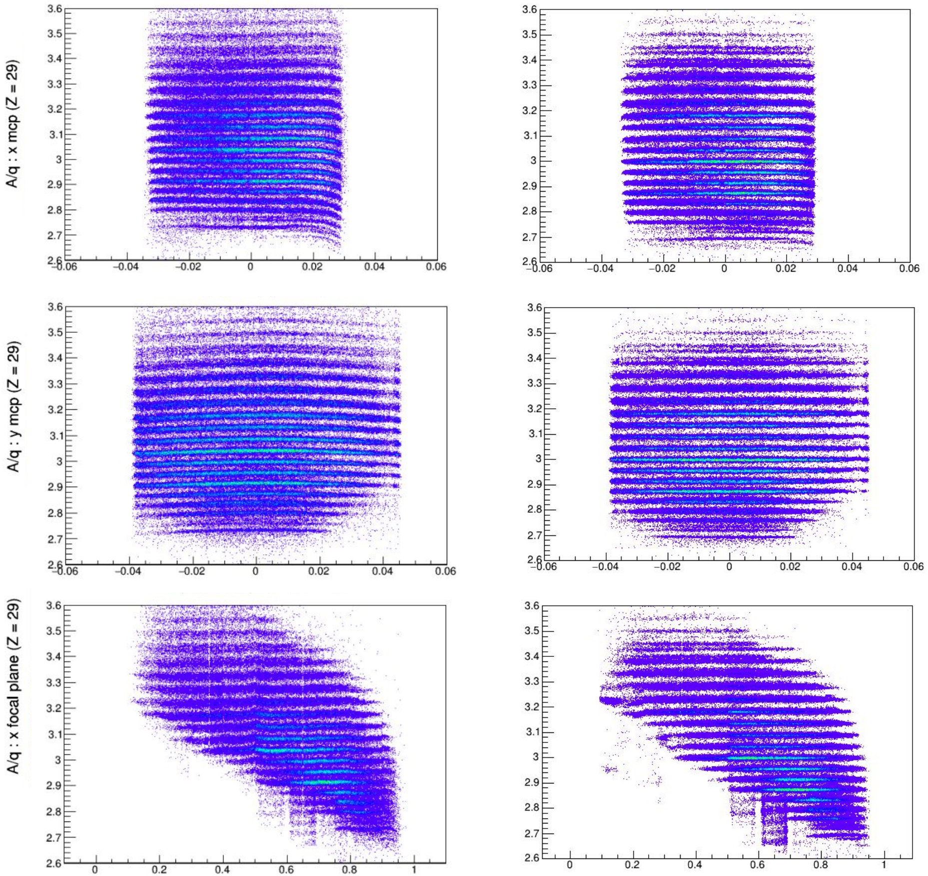


Analysis status: PRISMA

Q

A/Q

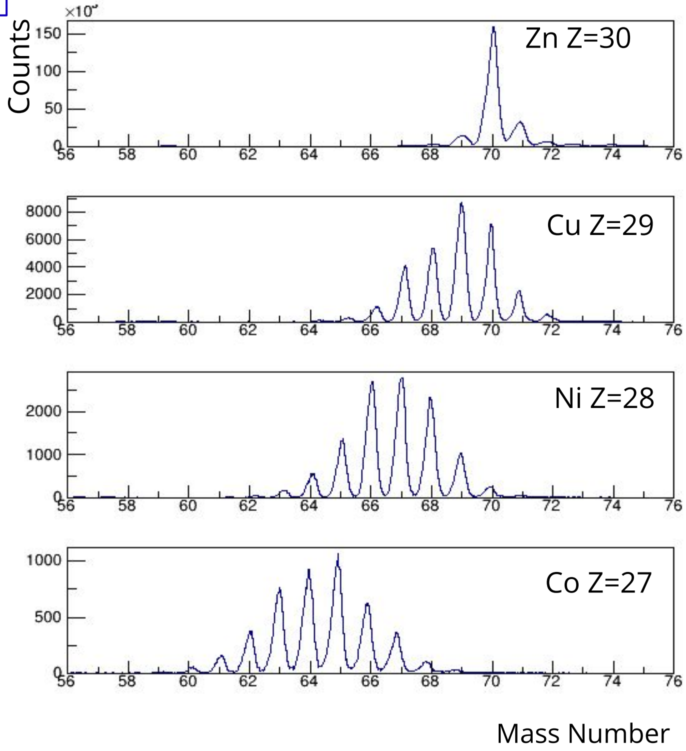




Analysis status: PRISMA

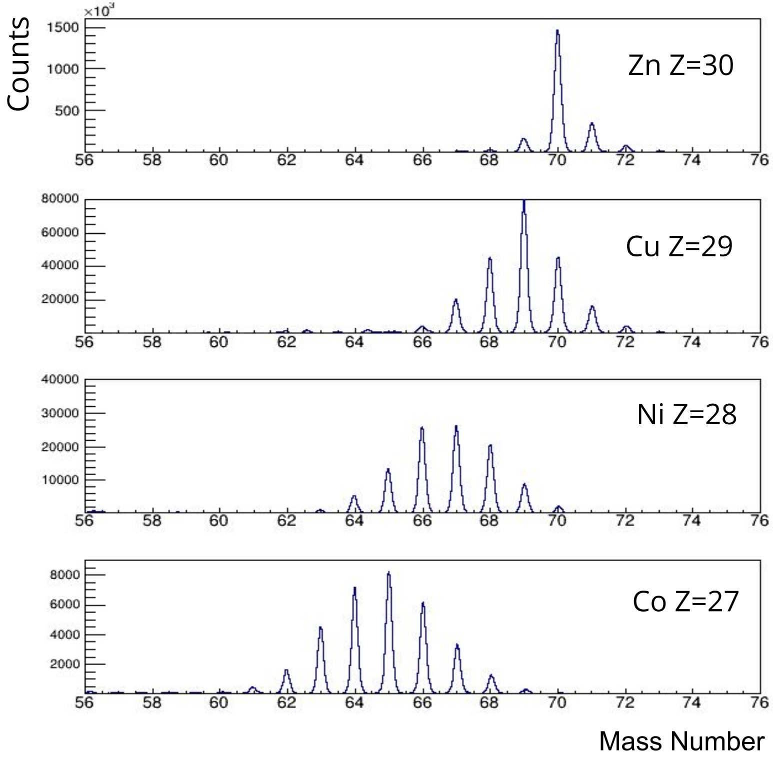
Mass (A)

Online analysis



ΔA/A = 1/232 on average.

Offline analysis



ΔA/A = 1/287 on average.

Summary

- Lifetime measurements were performed in March 2024 to study the nuclear structure in the vicinity of Z=28 neutron rich isotopes.
- The experimental setup was AGATA, PRISMA and a plunger. $^{70}Zn+^{238}U$ and Nb degrader.
- The current status of the analysis has been presented regarding the optimization of the AGATA and PRISMA data processing.

Next steps of the analysis

Further improvements AGATA analysis

- Check gain stability: possible gain drifts over time (Energy vs TS per crystal).
- Data quality tests: compare spectra with and without “Force Segments to Core” option.
- Tracking optimization.

Further improvements PRISMA analysis

- Mass assignment refinement: apply aberration corrections to improve isotope identification.

AGATA + PRISMA

- Doppler correction optimization.

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Thank you for your attention

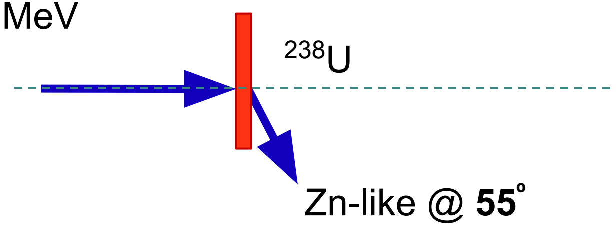
Production mechanism (back-up)

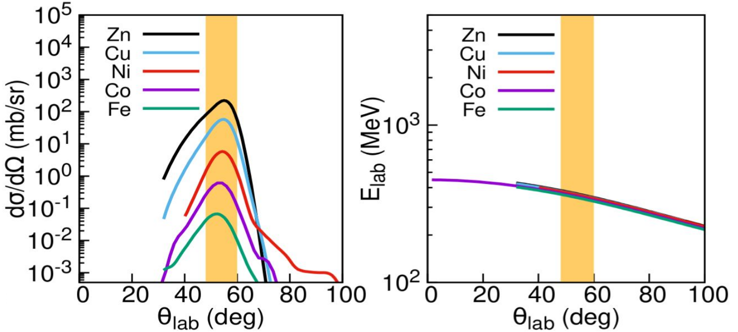
Production of the nuclei of interest optimized to accommodate different physics cases by considering the multi-nucleon transfer reaction involving ^{70}Zn .

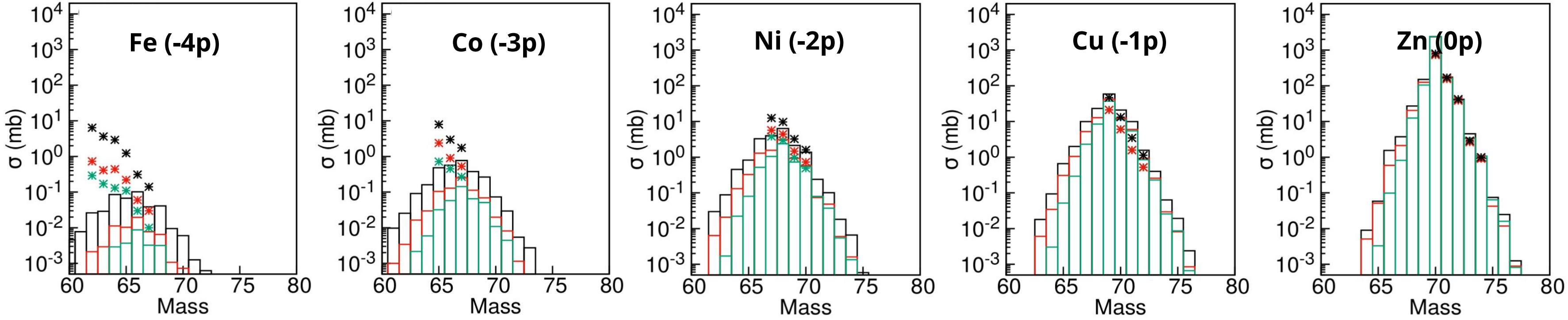
Multi-nucleon Transfer

- Reaction in direct kinematics

^{70}Zn @ 470 MeV







Grazing cross sections for the reaction ^{70}**Zn +**^{238}**U at 470 MeV**

✱ Estimated cross sections for the reaction ^{70}**Zn +**^{238}**U at 470 MeV** using grazing and experimental scaling*

*CLARA+PRISMA experiment

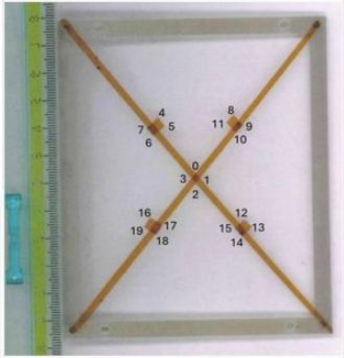
F. Recchia et al., Phys. Rev. C 85, 064305 (2012).

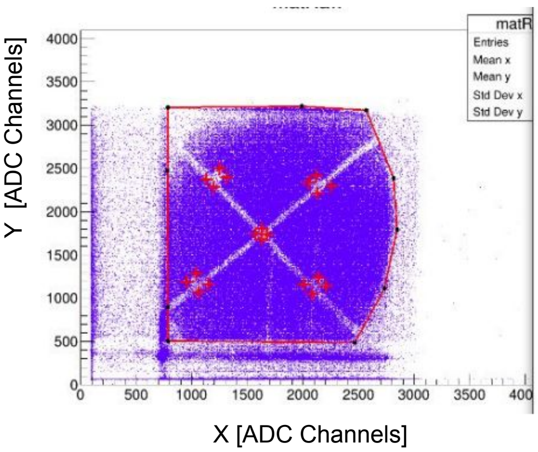
Analysis status: PRISMA   (back-up)

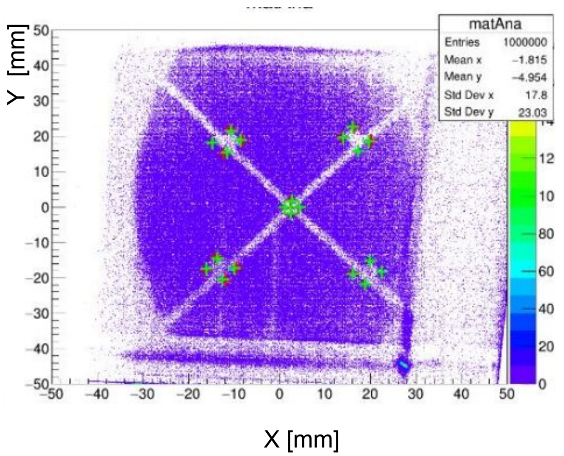
MPC position calibration

Wings up

#	X (mm)	Y (mm)
2	2.62	-2.07
3	1.04	-0.19
0	2.62	1.81
1	4.28	-0.26
4	-10.67	22.04
5	-8.02	18.74
6	-12.26	15.12
7	-14.82	18.07
8	16.45	22.48
9	20.07	18.71
10	17.37	15.79
11	13.75	19.66
12	19.80	-15.42
13	22.48	-18.27
14	18.76	-21.75
15	16.12	-18.77
16	-13.79	-14.12
17	-9.35	-17.22
18	-11.79	-20.67
19	-16.27	-17.77

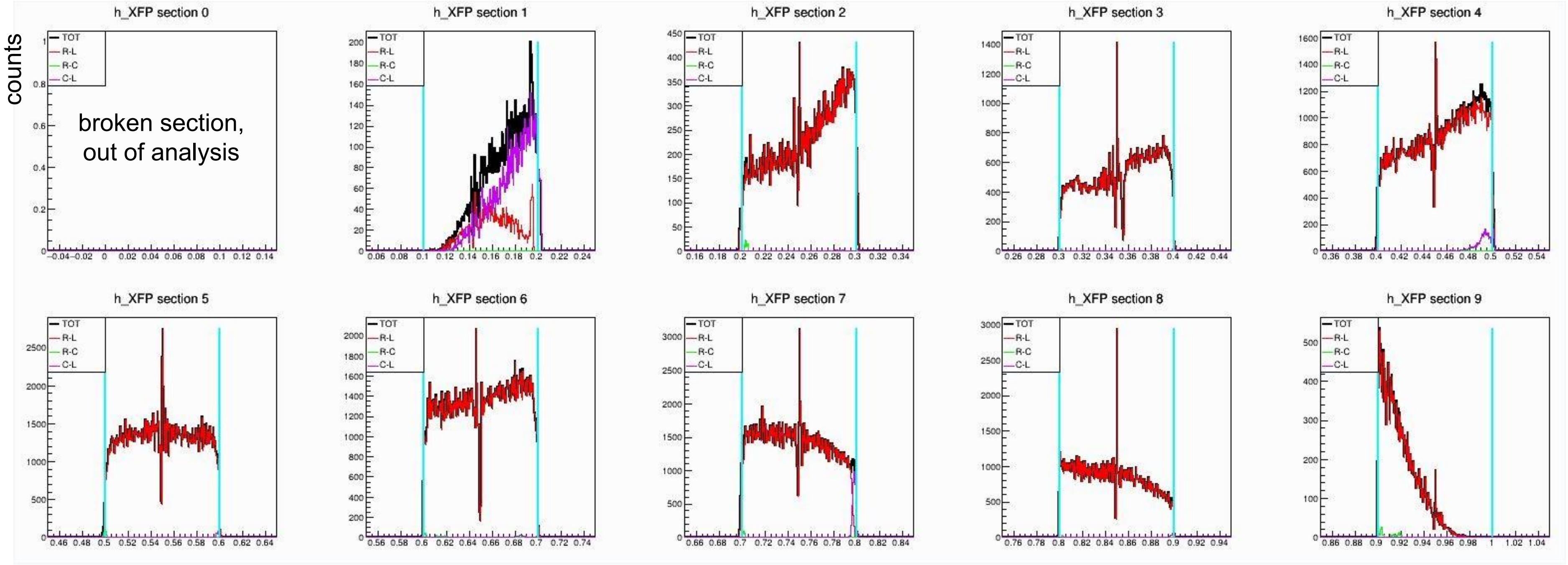






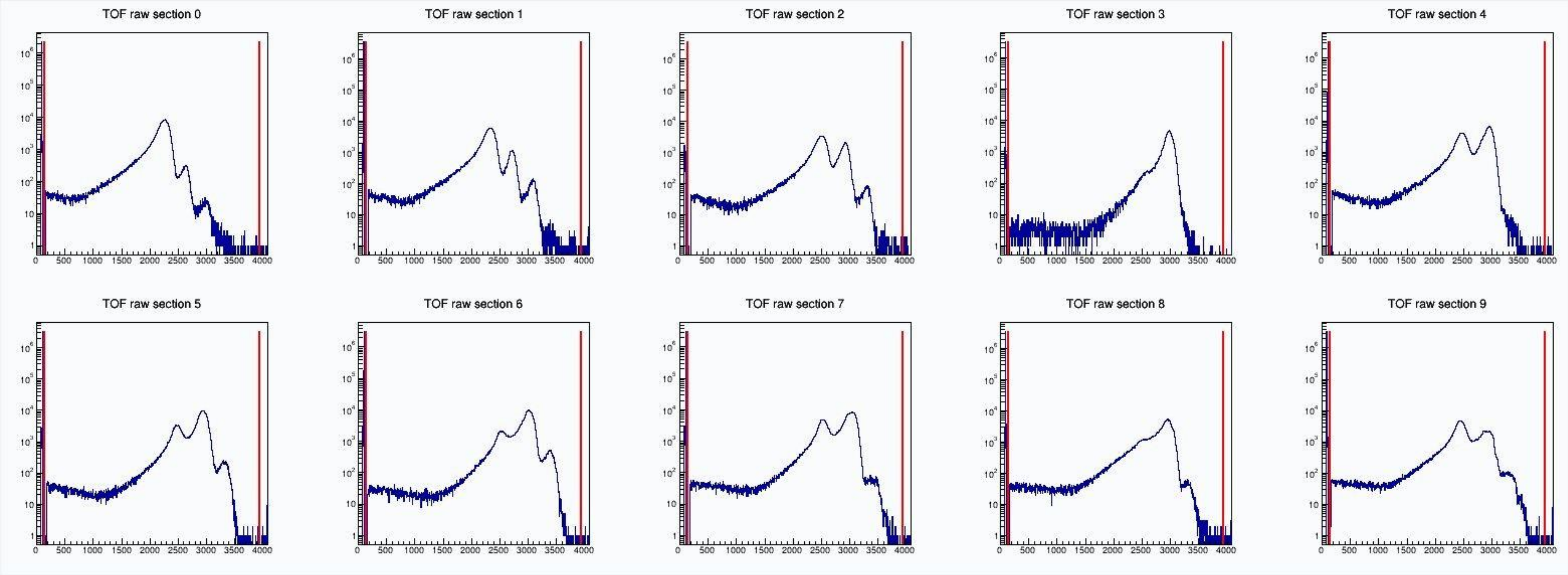
Analysis status: PRISMA (back-up)

PPAC position calibration

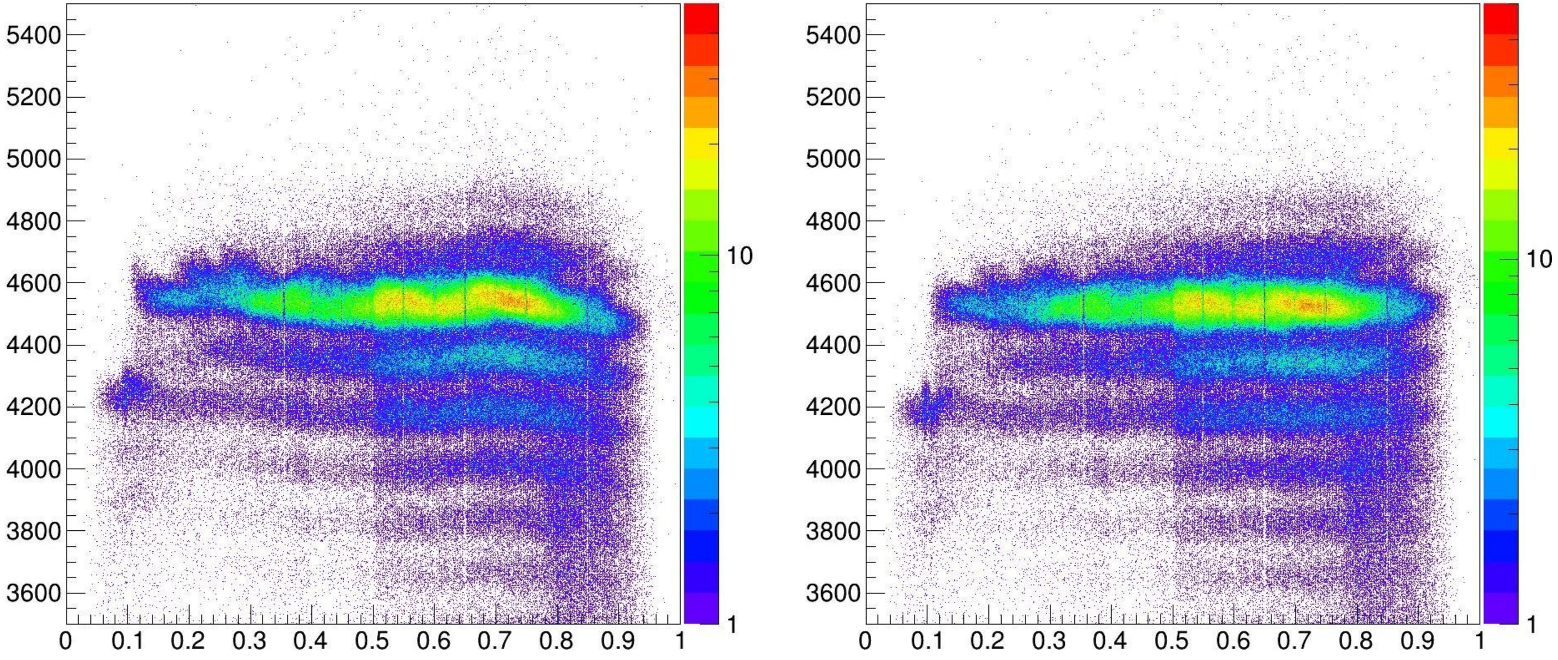


Analysis status: PRISMA (back-up)

PPAC Time of flight (ToF)



Analysis status: PRISMA (back-up)

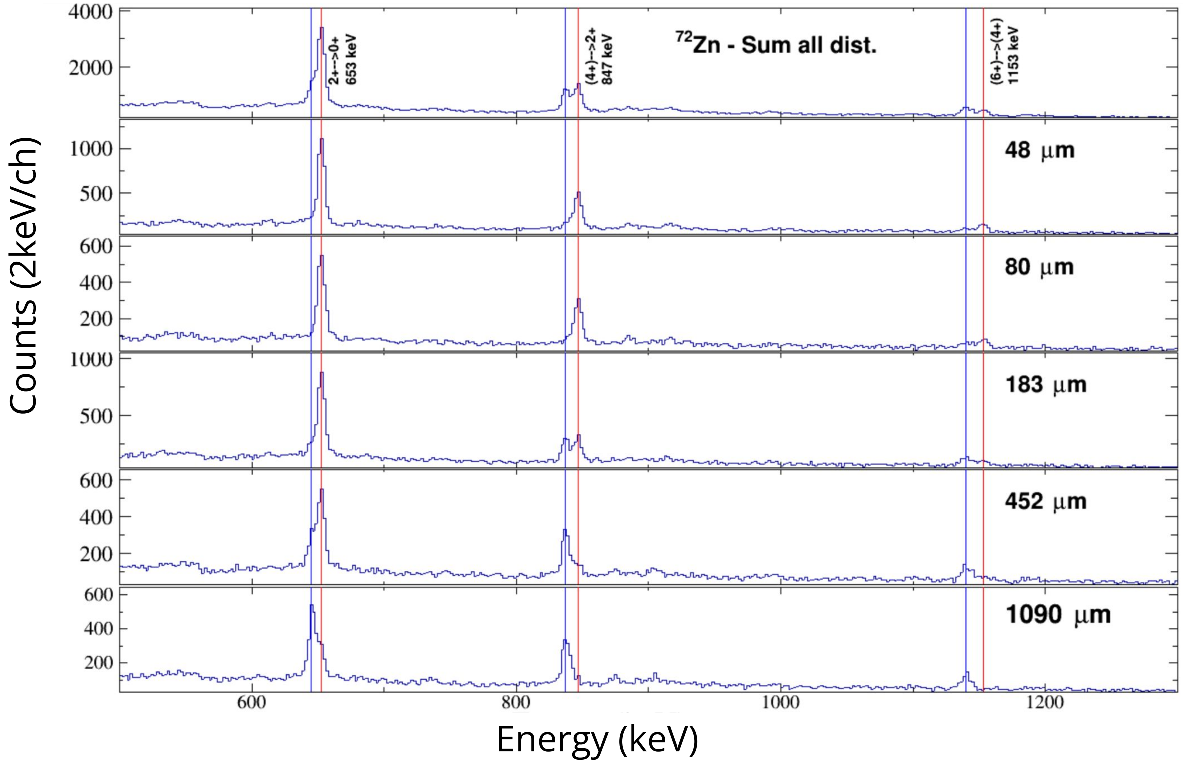


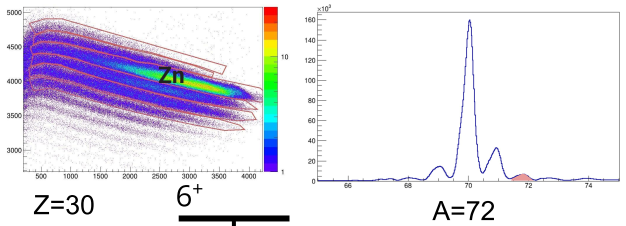
Aberration correction: DE_{ab} vs X_{fp}

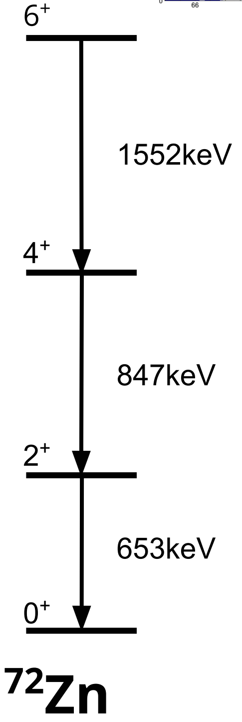
Analysis status: AGATA + PRISMA (back-up)

Online analysis

Gamma Spectra ^{72}Zn







Analysis status: AGATA + PRISMA (back-up)

Online analysis

AGATA: Gamma Spectra ^{64}Fe