Spectroscopy and fission studies in inverse kinematics: ^{208}Pb + ^{9}Be with AGATA and PRISMA

Report on EXP_009 *(LNL 22.23)*

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INFN - LNL

AGATA Collaboration Council Meeting

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Physics case : Evolution of N = 50 shell gap

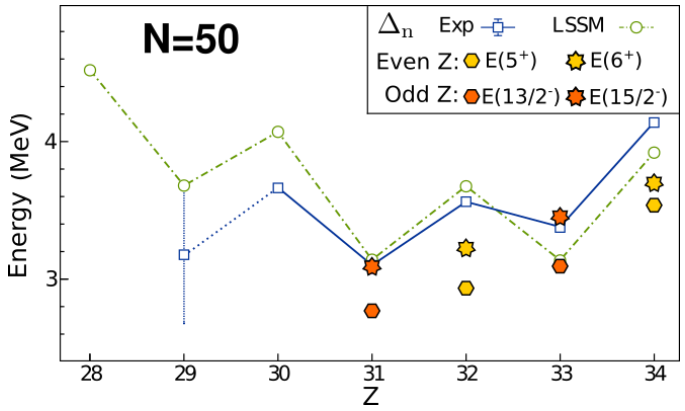
Decrease in the N=50 energy gap towards ^{78}Ni: compatible behaviour with **two different methods**

1. Mass measurements: decrease of gap up to ^{81}Ga
   Re-increase measured for ^{80}Zn

S. Baruah et al., Phys. Rev. Lett. 101, 262501 (2008)
J. Hakala et al., Phys. Rev. Lett. 101, 052502 (2008)

$\Delta n = BE(Z,N=51)+BE(Z,N=49)-2\cdot BE(Z,N=50)$ **Mass gap**

2. "Spectroscopic" gap estimated from energy of lowest core-breaking neutron excitations in N=50 isotones



J. Dudouet et al, Phys. Rev. C 100, 011301(R) (2019)
T. Rzaca-Urban et al., Phys. Rev. C76, 027302 (2007)

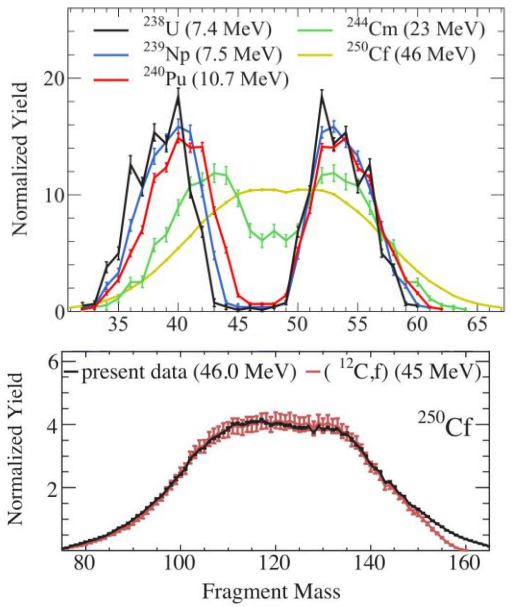
$5^+,6^+,7^+$ states in even Z, $13/2^-$, $15/2^-$ in odd Z

In ^{80}Zn J≥5 cannot be reached only by valence protons

→ 1p-1h neutron excitations

Spectroscopy of ^{80}Zn
Fission populates medium-high spins

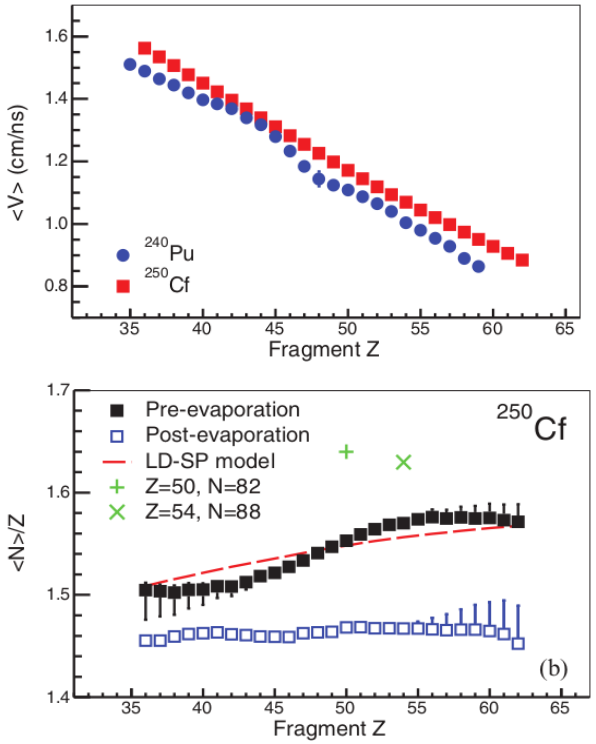
Physics case: Fission studies



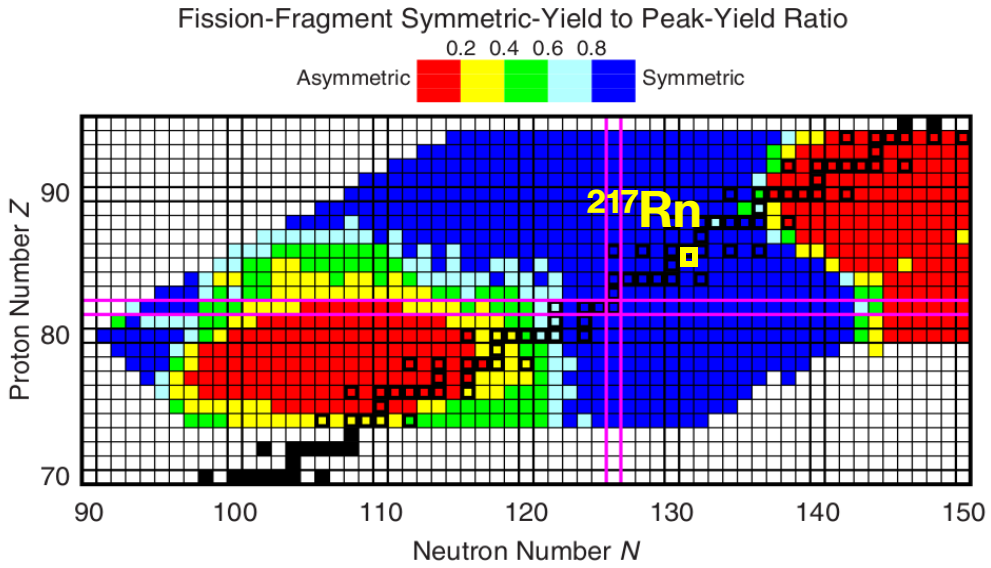
D. Ramos et al., Phys. Rev. C 97, 054612 (2018)

Inverse kinematics allows the study of kinematic fission observables: yields, velocity distributions, N/Z

Fission fragment structure affects the scission and formation of the final system



M. Caamaño et al., Phys. Rev. C 92, 034606 (2015)



P. Möller and J. Randrup, Phys. Rev. C 91, 044316 (2015)

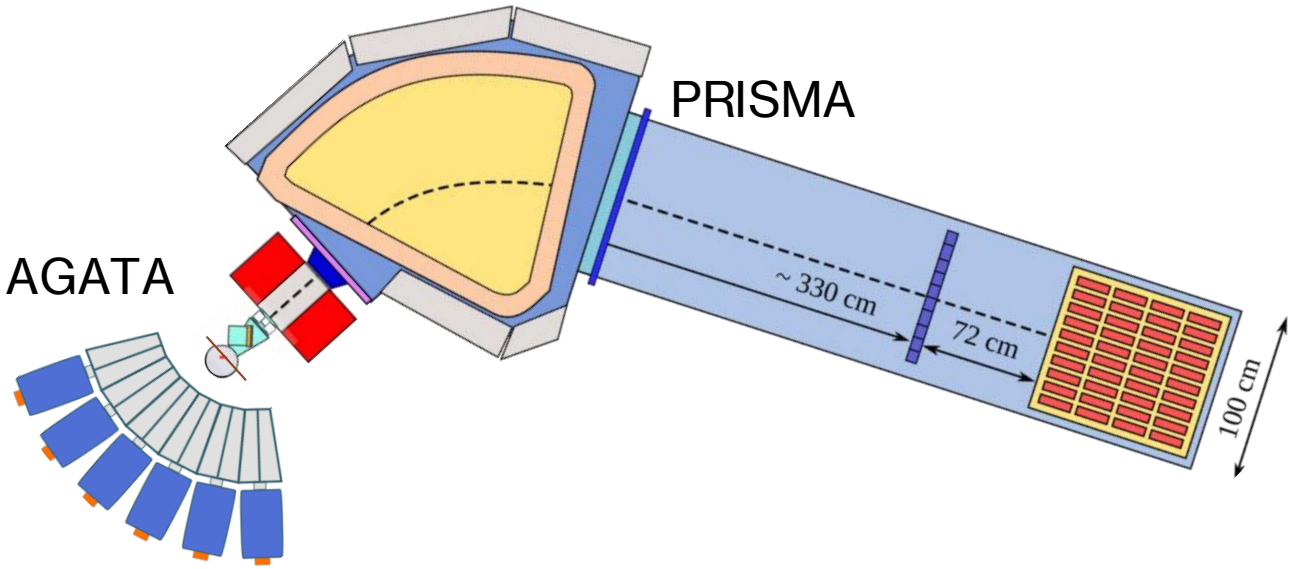
^{217}Rn: **symmetric** fission is expected

Shell effects should be smaller, but no study was done on the influence of shell effects in this area

Study of fission mechanism

AGATA + PRISMA experiment at LNL

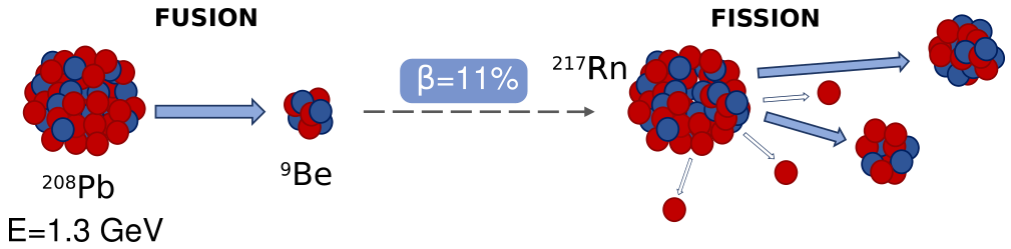
Exp. 22.23, december 2022



^{208}Pb+^{9}Be fusion-fission in inverse kinematics

Kinematic focusing of fission fragments (A,Z) identification with PRISMA at 20°-23°

Measurement of de-excitation ɣ rays with AGATA



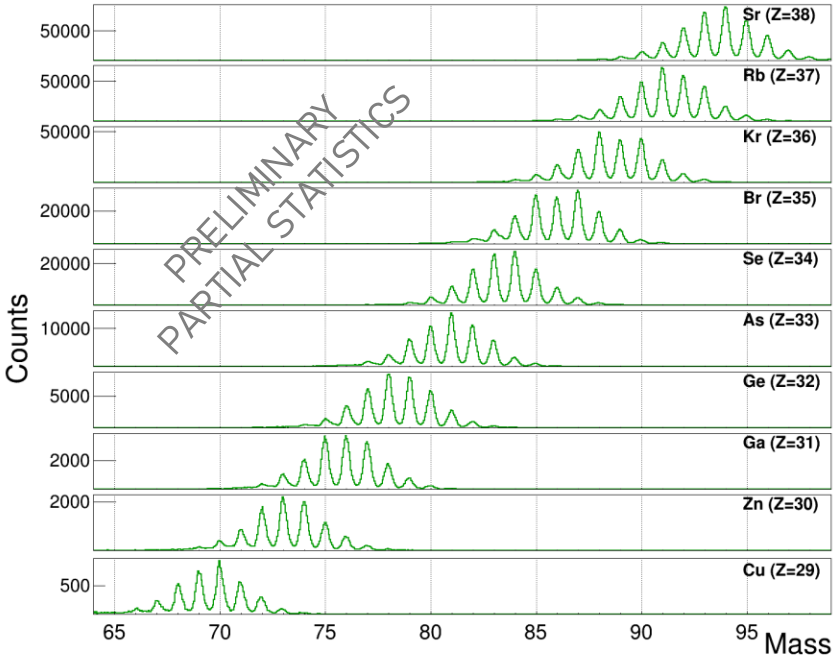
CN: ^{217}Rn with E_{ex} = 39.9 MeV, J = 17.5 ħ

Issues with TP during acquisition: **low statistics in gamma-ray spectra**

Previous year and current status

Last year's status:

- Calibration of **PRISMA** masses for Z=29-38
- Optimization of **AGATA** processing



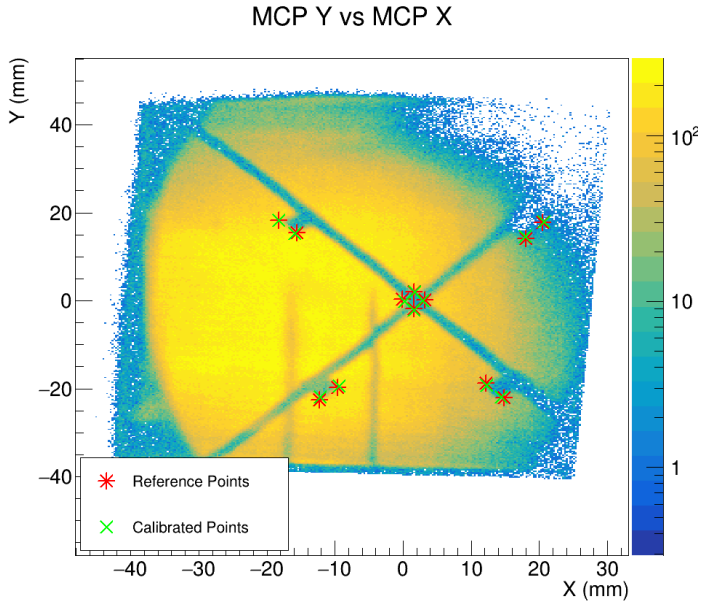
This year's to do list:

- Optimize **Doppler correction**
- Sum statistics for **gammas in exotic channels** (N=50)
- Start systematic calibration of PRISMA for **fission studies**

Doppler correction optimization

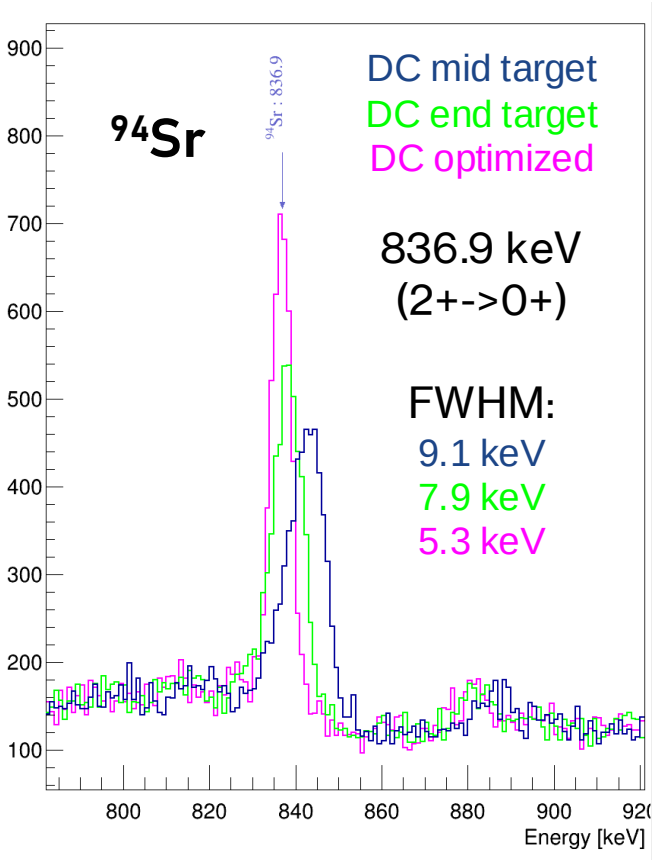
Modifying geometric parameters (AGATA and PRISMA angles, positions) to optimize **centroid** and **FWHM** of the DC peaks (***Optimizer*** function of the AgataSelector)

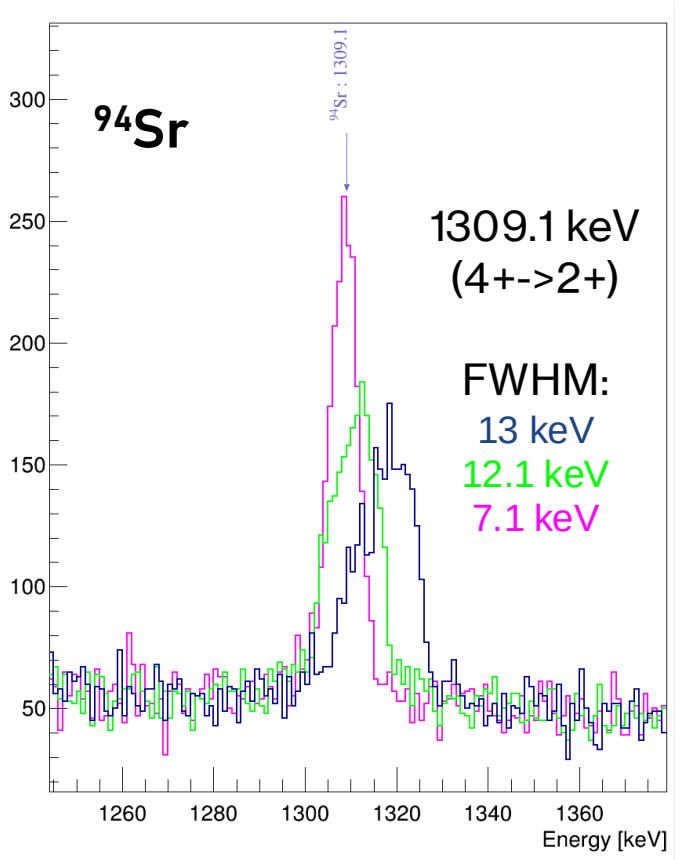
MCP X,Y scale has a big impact! Optimal values are 0.5-0.7. **Wrong MCP position** ?



Re-measurement of the MCP mask

New calibration improves both **PRISMA reconstruction** and **Doppler correction**





AGATA-PRISMA

Issue with AGATA Trigger Processor

Validation of less events than expected

Efficiency check on ^{84}Se, ^{88}Kr, ^{94}Sr (core spectrum):

Single efficiency: γ singles in 2^+ / Ions in PRISMA
Coincidence efficiency: 4^+-gated γγ counts in 2^+ / γ singles in 4^+
AGATA efficiency: Efficiency curve estimated with ^{152}Eu

Isotope - E(2+)	88Kr - 775 keV	94Sr - 837 keV	84Se - 1455 keV
Single eff.	0.95%	0.92%	0.62%
Coinc. eff.	3.46%	3.35%	2.39%
Ratio	3.64	3.64	3.85
AGATA eff.	3.96%	3.85%	2.97%

Assuming every detected ion emits a 2+ gamma, we seem to be validating **~4 times** gamma counts less compared to PRISMA counts

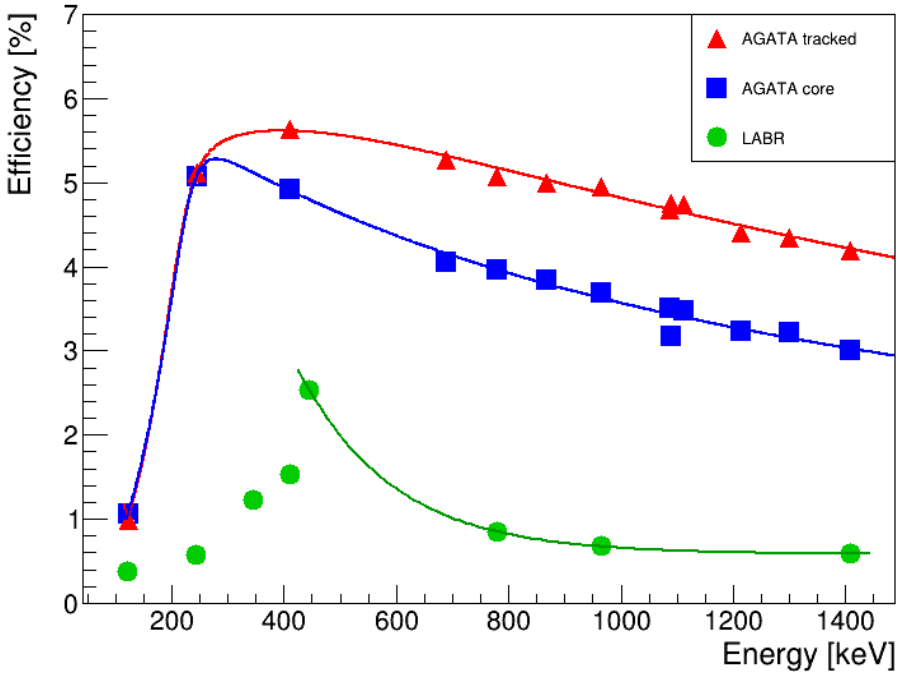
Ratio reaches **>5** with **tracked** and **addback** spectra

Comparison with LaBr3

Comparison with **LaBr3** (5 detectors 3"x3"):

Counts in 2+ peak / Ions in PRISMA
AGATA core, AGATA tracked and LABR spectra
Normalized by efficiency curve

	Isotope - E(2+)	78Ge- 619 keV	88Kr - 775 keV	94Sr - 837 keV
a	Core 2+ / Ions	0.95 %	0.95 %	0.92 %
b	Core efficiency	4.32 %	3.96 %	3.85 %
c	Tracked 2+ / Ions	1.05 %	1.09 %	1.00 %
d	Tracked efficiency	5.42 %	5.18 %	5.08 %
e	LABR 2+ / Ions	0.59 %	0.53 %	0.61 %
f	LABR efficiency	1.28 %	0.86 %	0.775 %
	Norm. LABR / core	2.1	2.6	3.3
	Norm. LABR / tracked	2.4	2.9	4.1



Norm. LABR / core = (e / f) / (a / b) **[Expected ratio is 1]**
Norm. LABR / tracked = (e / f) / (c / d) **[Expected ratio is 1]**

Large factor of discrepancy between the AGATA and LABR data

Gamma spectroscopy of Cu isotopes

Most exotic channels **do not have enough statistics** to see gamma transitions

Spectroscopy of less neutron-rich isotopes with **Z=29-32, N=40-50** is possible
Unreported transitions are found.

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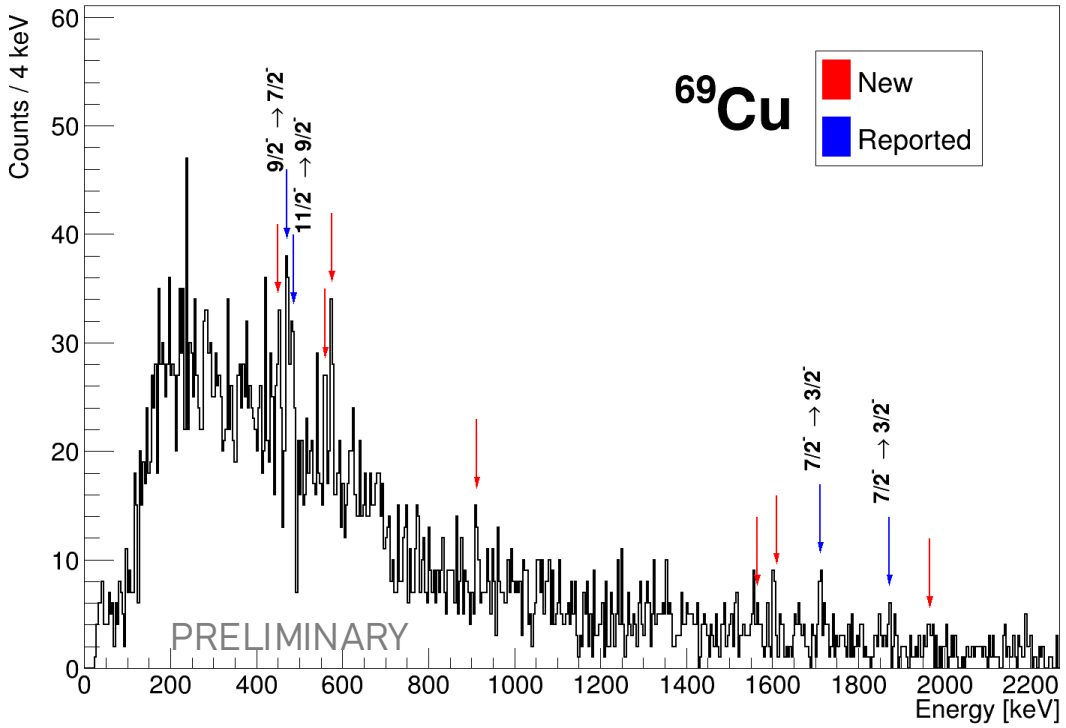
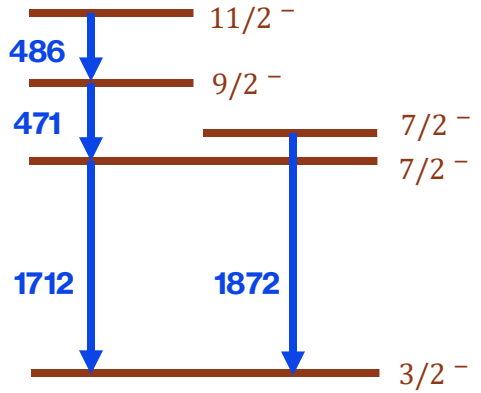
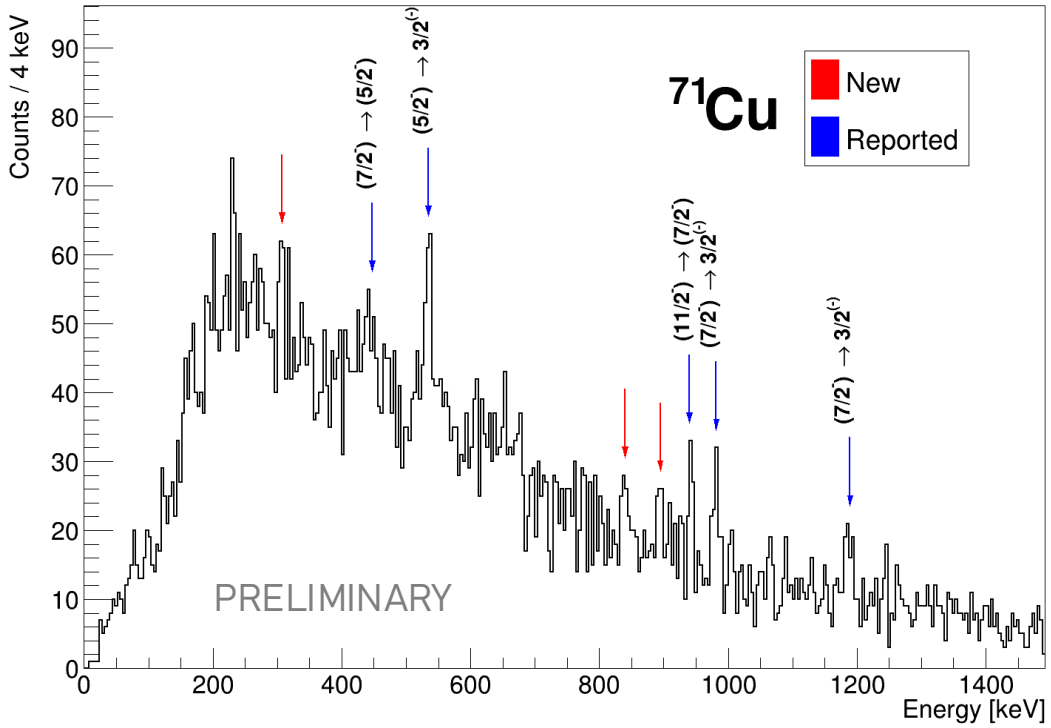
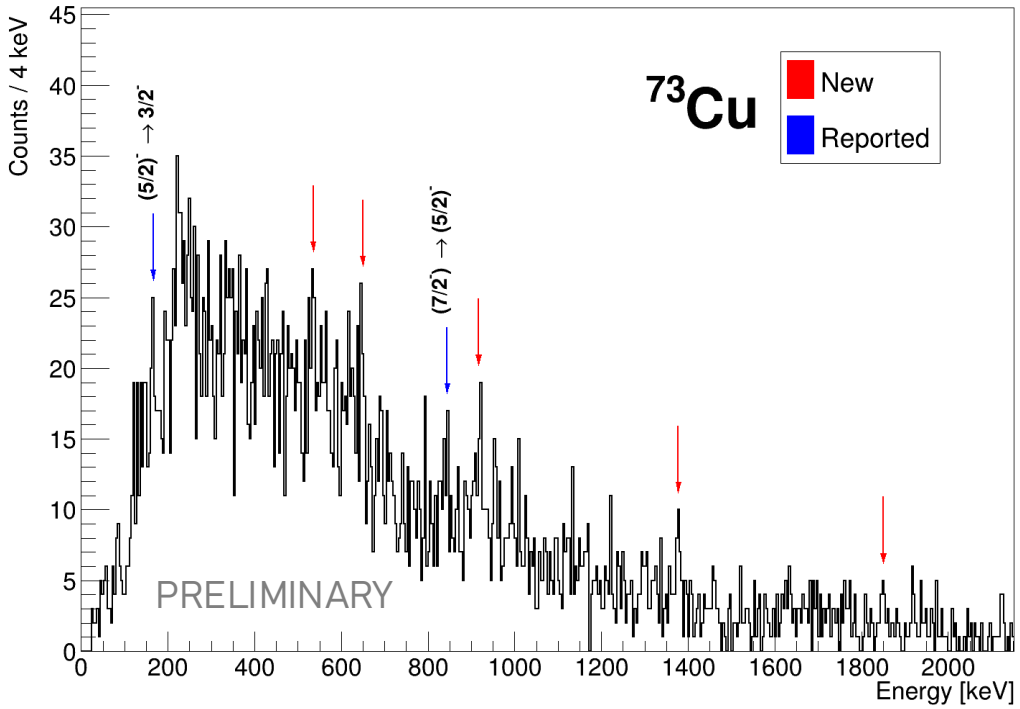
Spectroscopy of less neutron-rich isotopes with **Z=29-32, N=40-50** is possible
Unreported transitions are found.
Spectra of **Cu isotopes** show many unidentified peaks

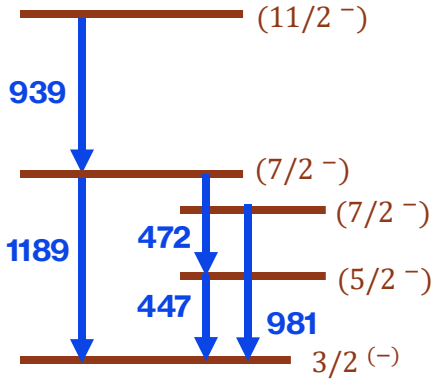


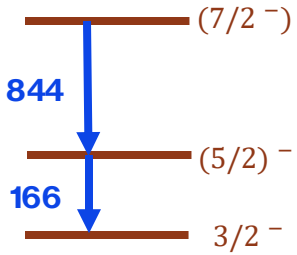


Gamma spectroscopy of Cu isotopes: odd-even

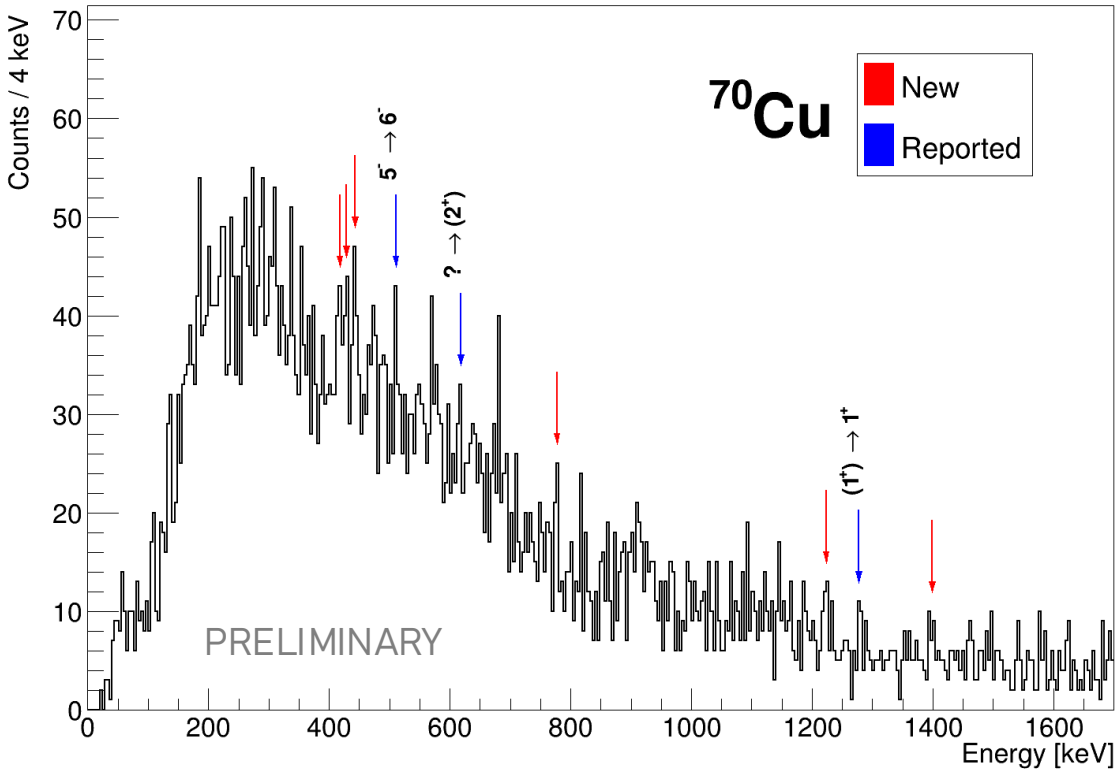


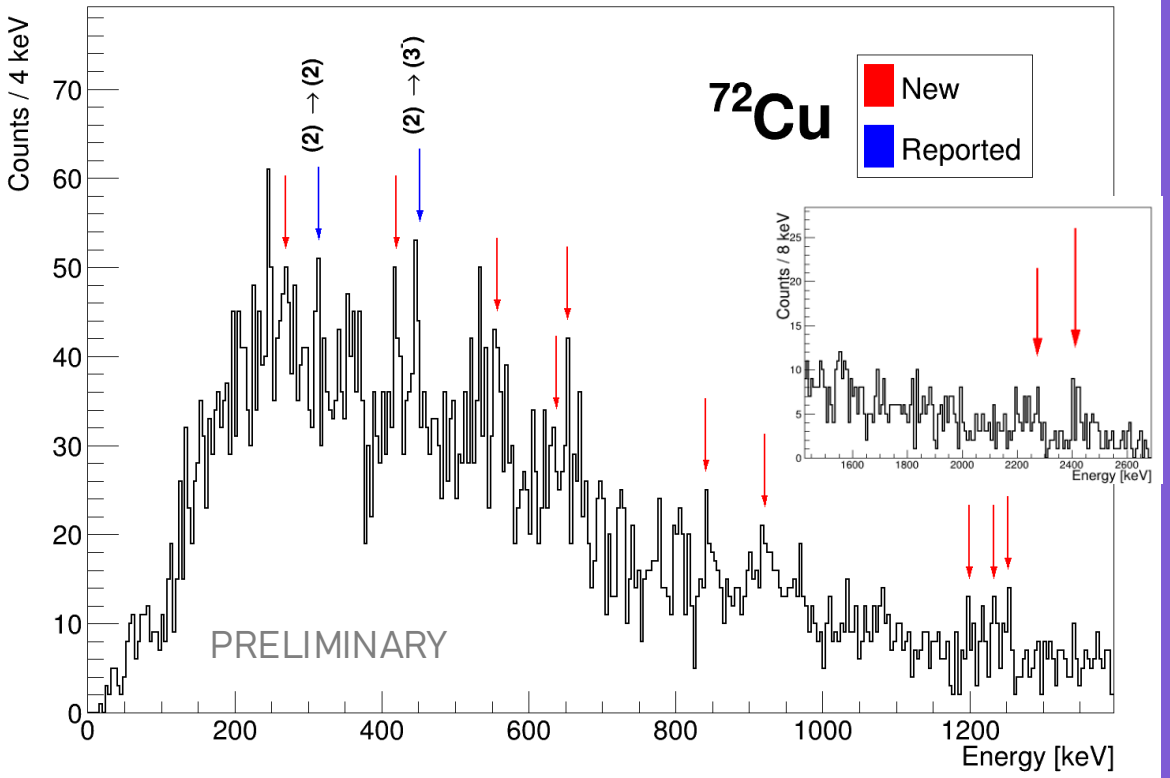


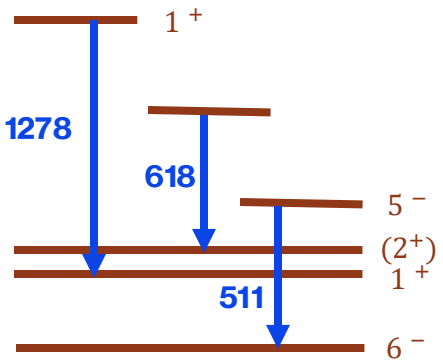


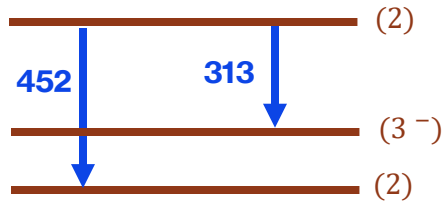


Gamma spectroscopy of Cu isotopes: odd-odd

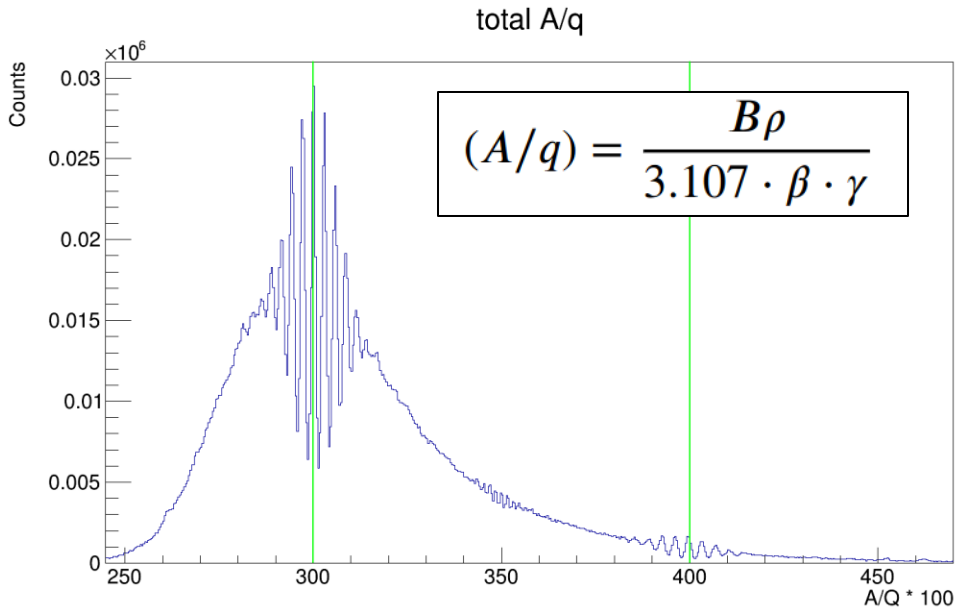








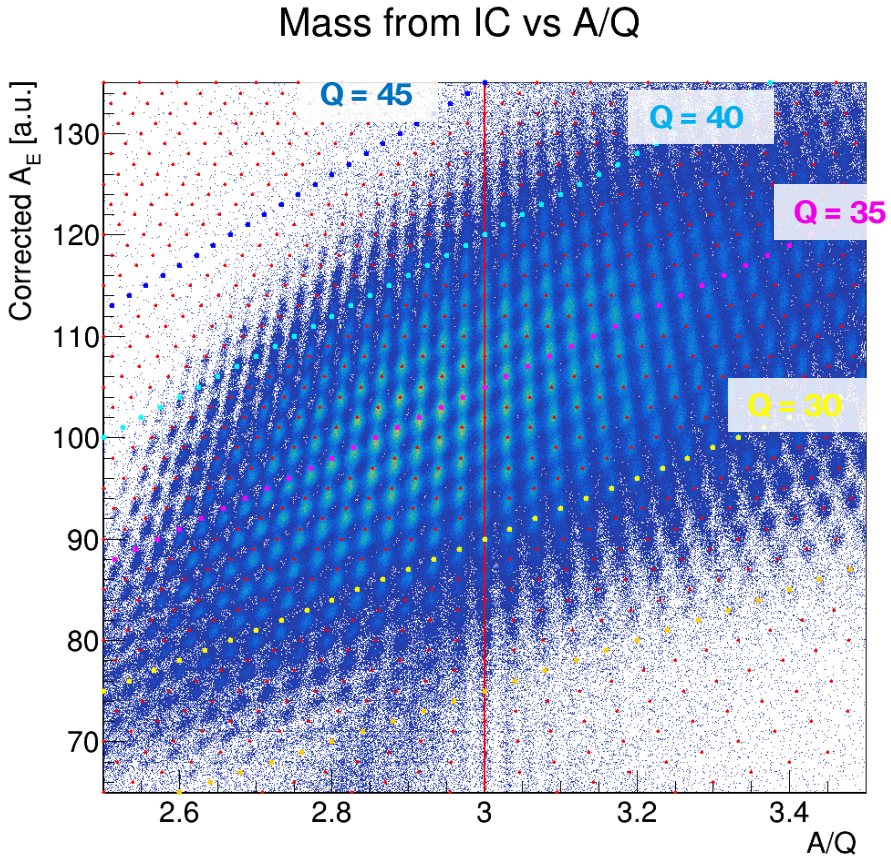
PRISMA analysis of fission fragments



A/Q from trajectory reconstruction (Brho)

A/Q must be a ratio of integer numbers

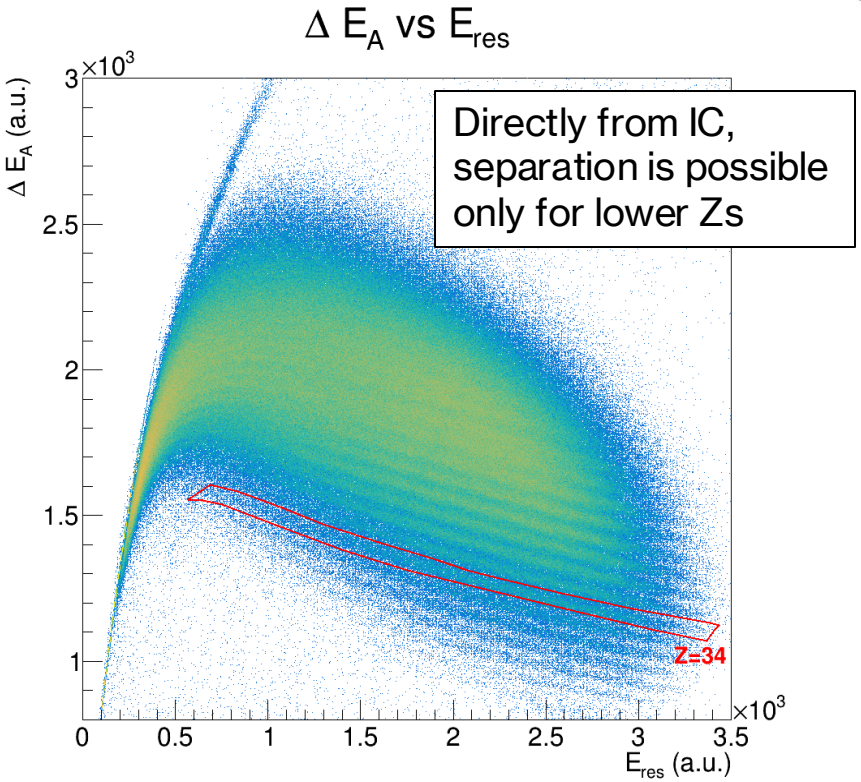
Theoretical values can be used to calibrate the variables (e.g. A/Q = 3)

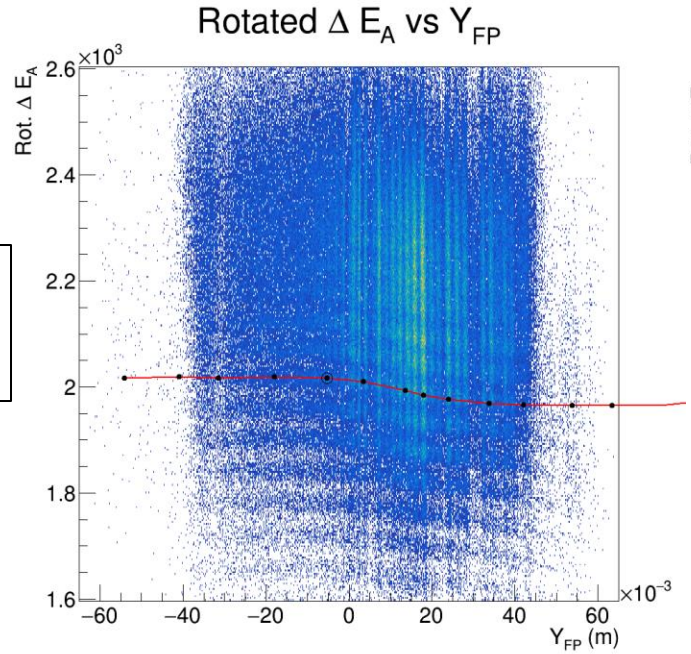


$$A_E = \frac{E}{u(\gamma - 1)}$$

Mass estimate from IC energy
Poor resolution, but useful to double check

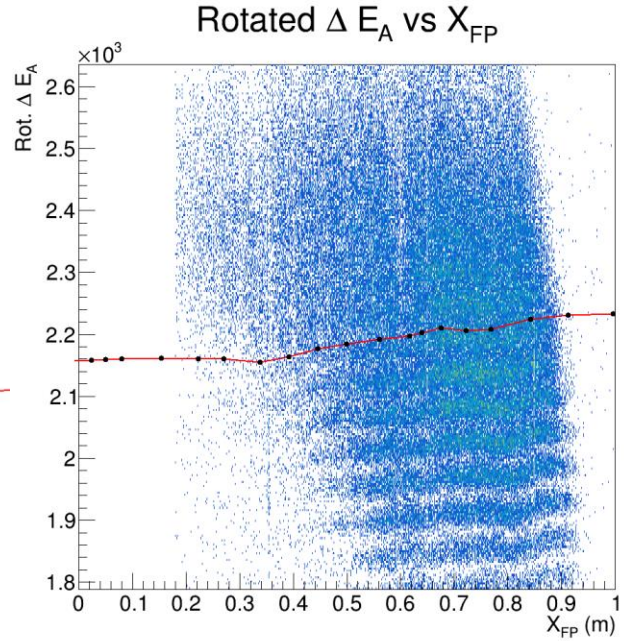
Atomic number Z selection





Dependence of Z bands on Y:

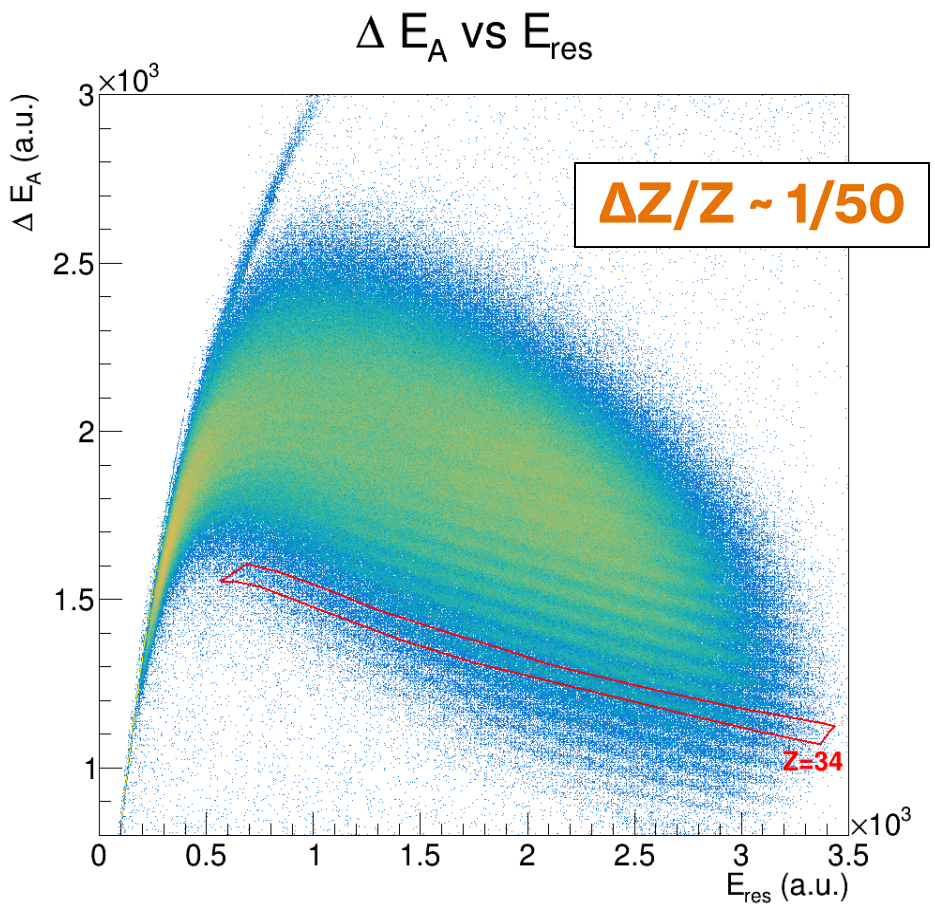
The longer drifts of charges in IC, the lower the collection efficiency

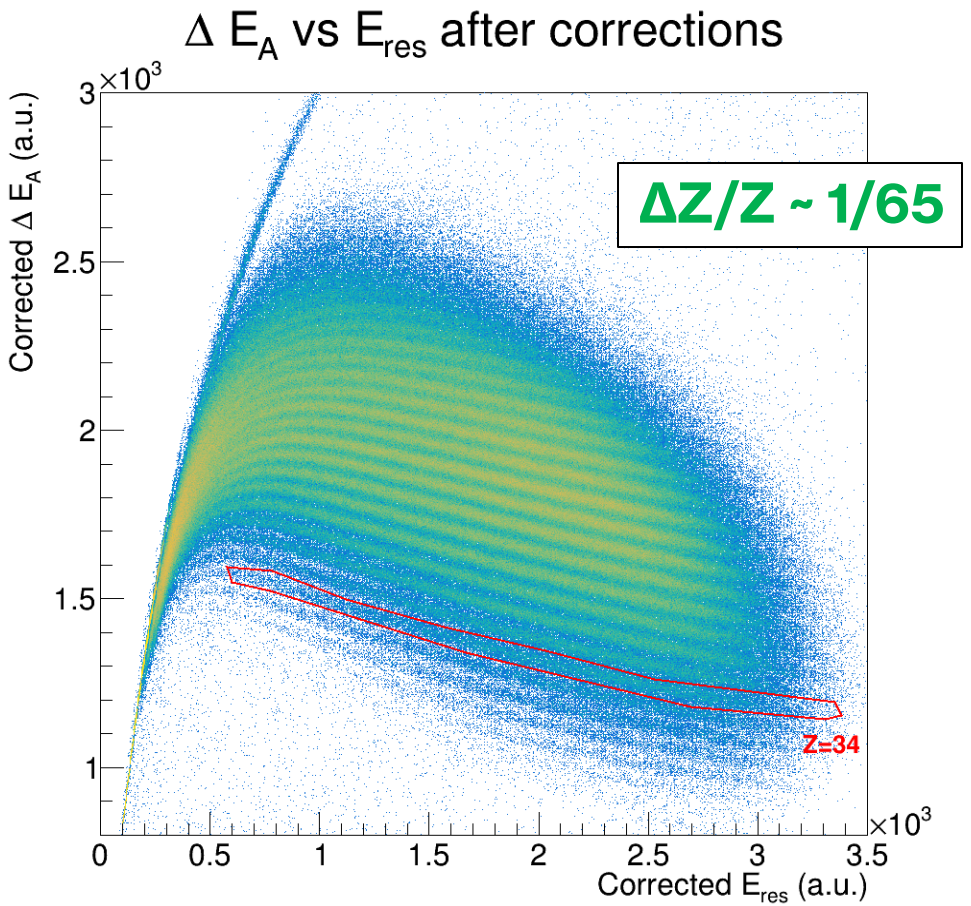


Dependence of Z bands on X:

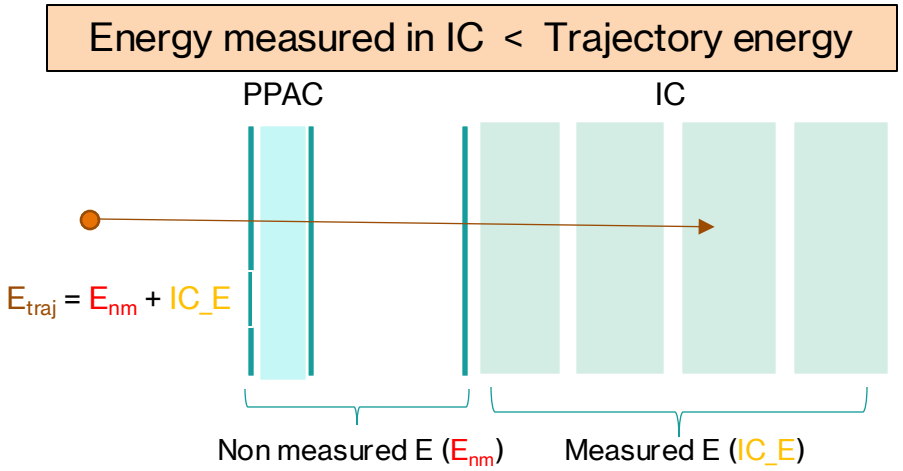
Not understood, but large effect

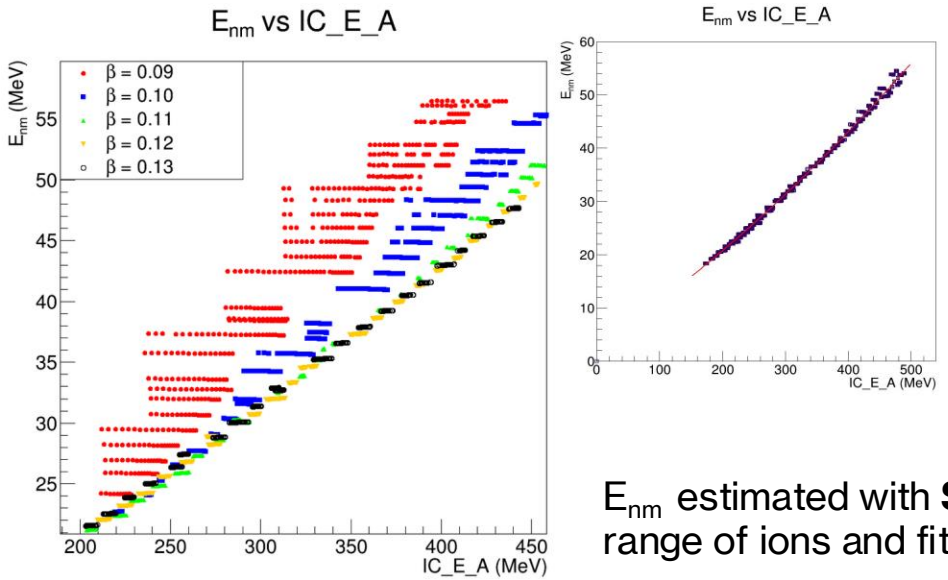
Atomic number Z selection



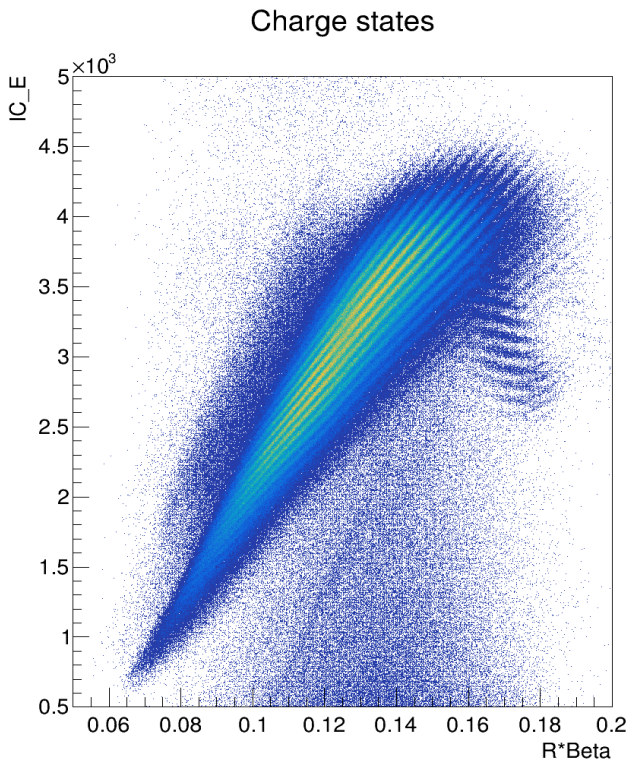


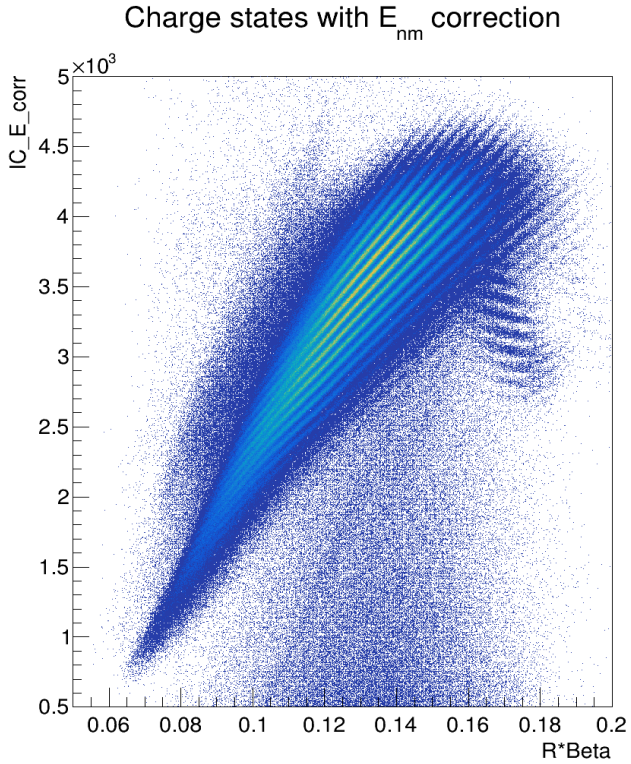
Charge state Q selection





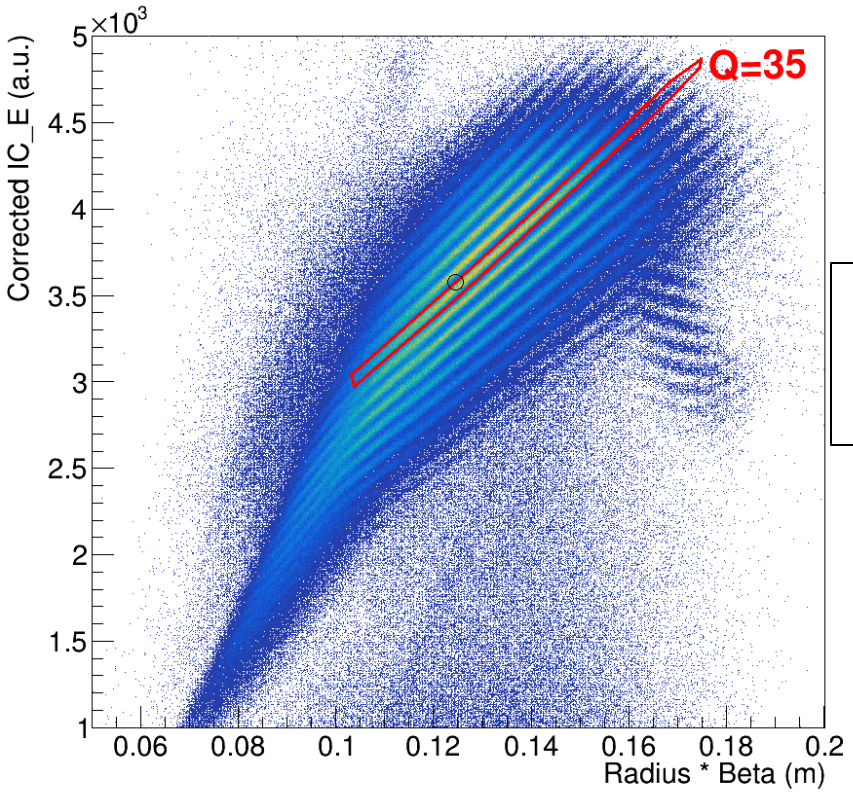
E_{nm} estimated with **SRIM** for a range of ions and fitted to IC_DE_A



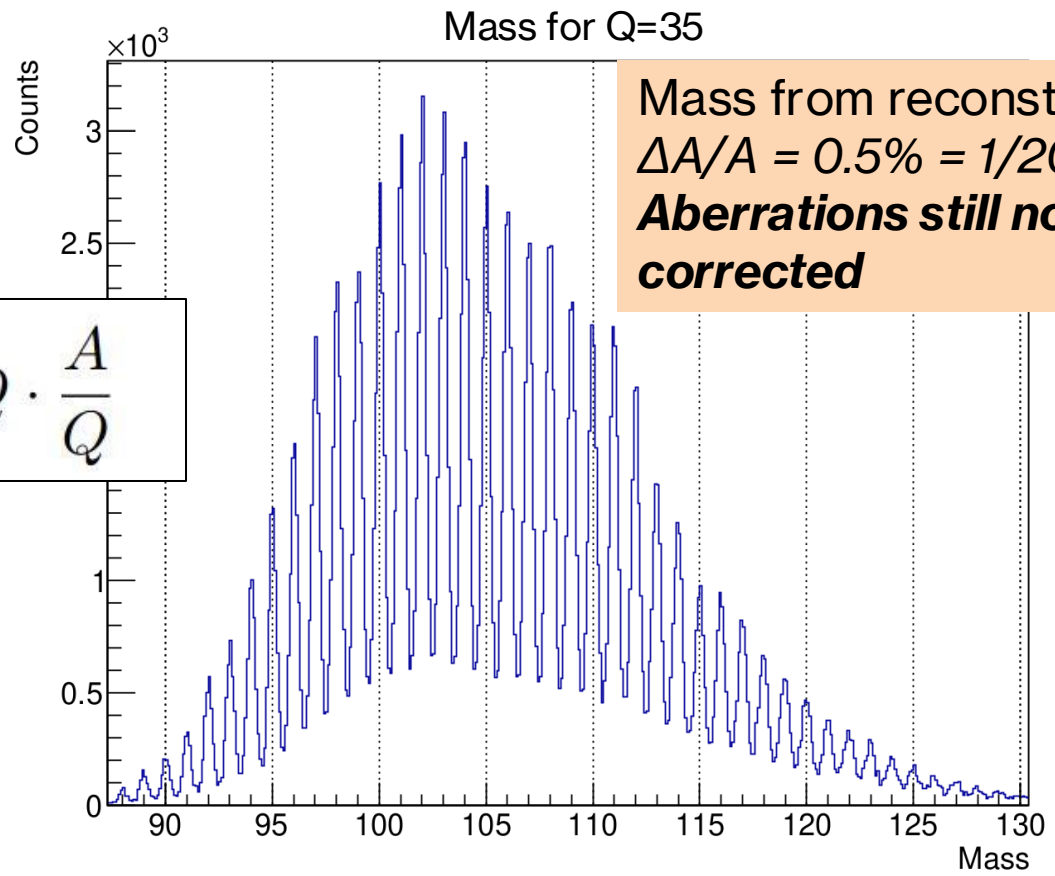


Correction proportional to IC_DE_A

Mass calibration



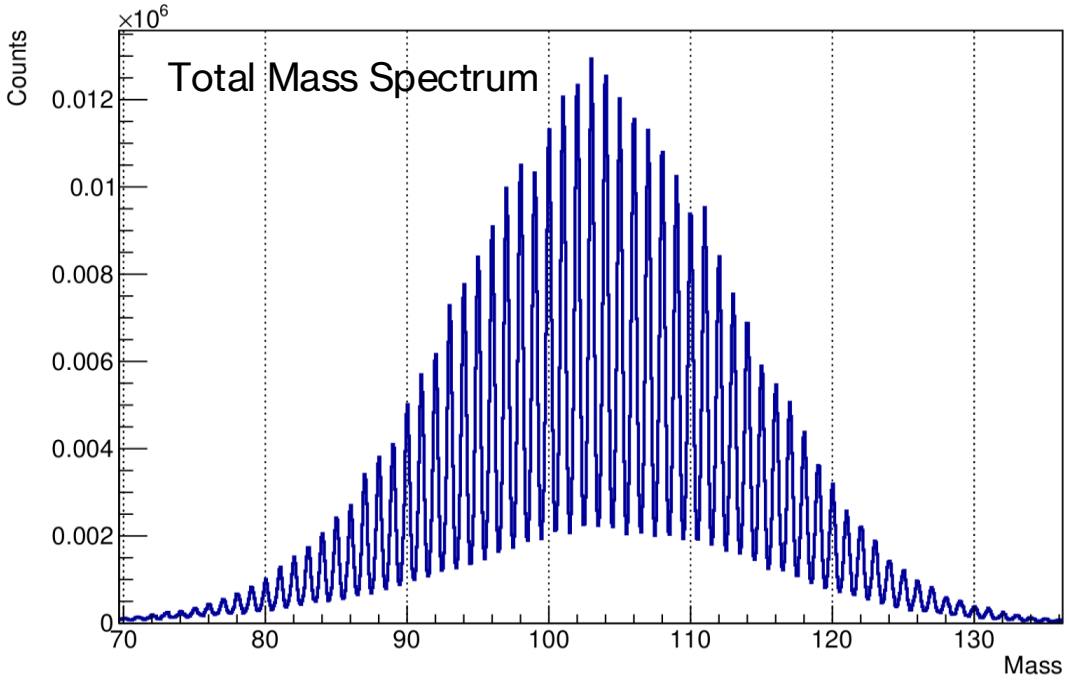
$$A = Q \cdot \frac{A}{Q}$$

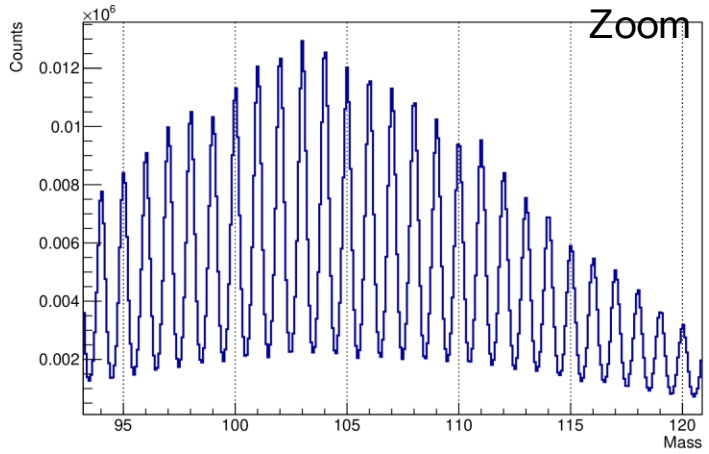


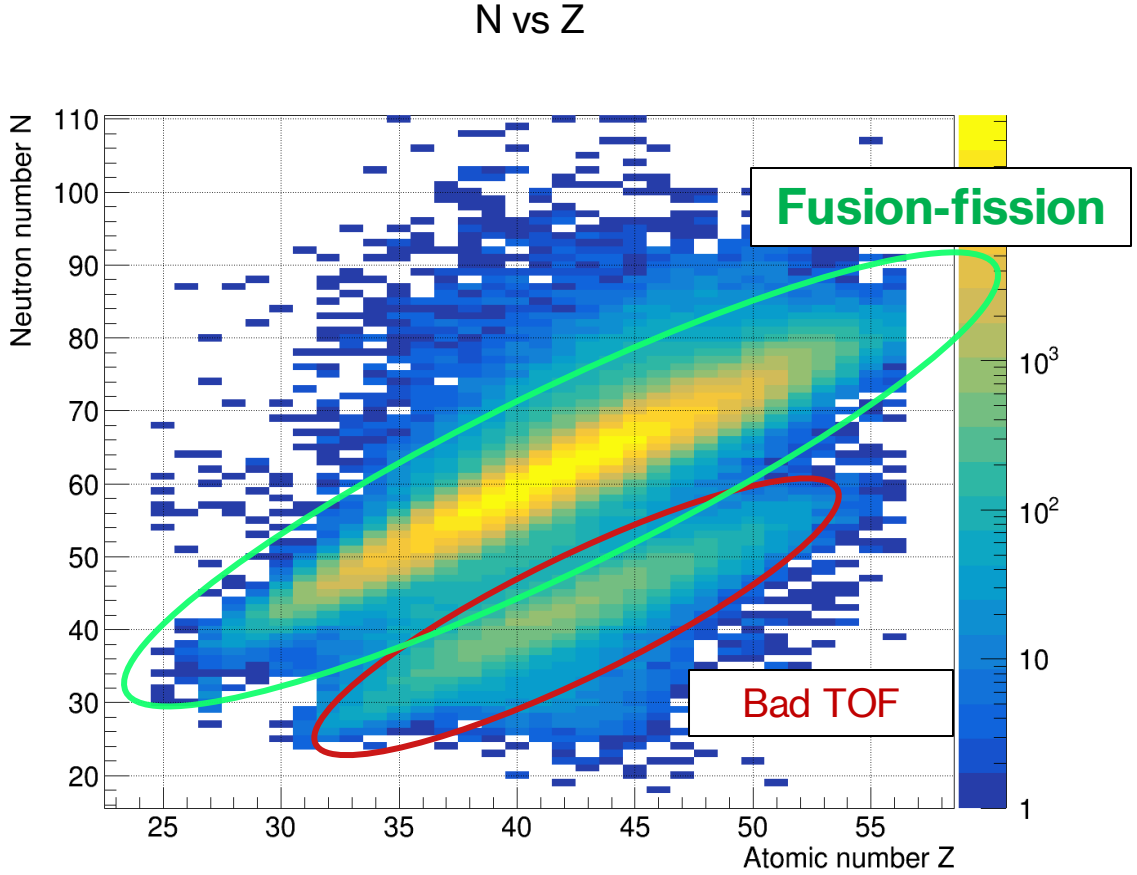
Mass from reconstruction:
ΔA/A = 0.5% = 1/200
Aberrations still not corrected

A/Q calibrated with TOF offsets of the PPAC sections
No extra calibration

FF yields and distributions







Symmetric mass distribution

Summary and outlook

	Fission fragments	Gamma spectroscopy
Summary	- **Global identification** of fragments	- **Optimization** of Doppler correction - New transitions for nuclei with **Z=29-32, N=40-50**
Outlook	• Extraction of **yields, TKE distributions** • Comparison with **calculations** to obtain features *-> University of Santiago de Compostela*	• Study of **coincidences** • Identification of **levels**