Analysis of EXP 23.015 and EXP 22.096: Challenges, Solutions, and Future Directions

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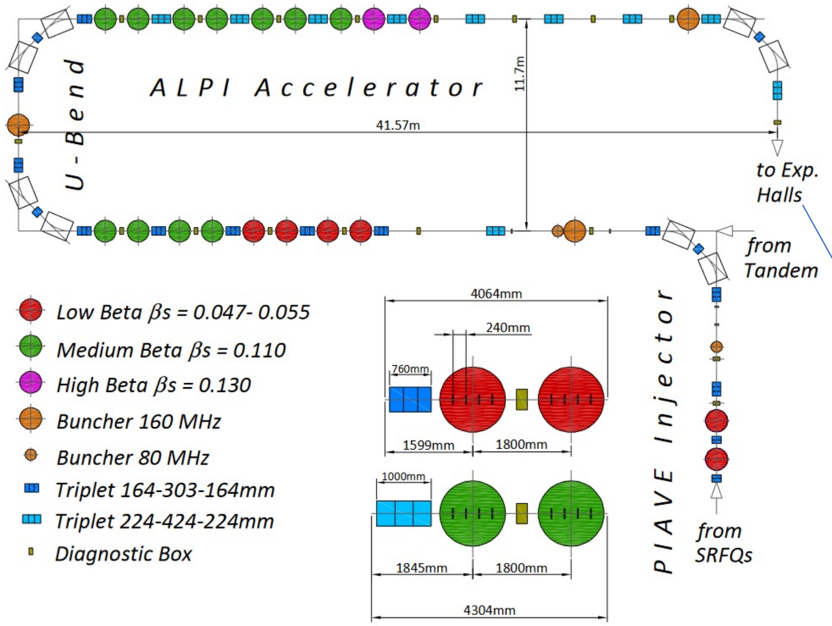
EXP 23.015 - Introduction

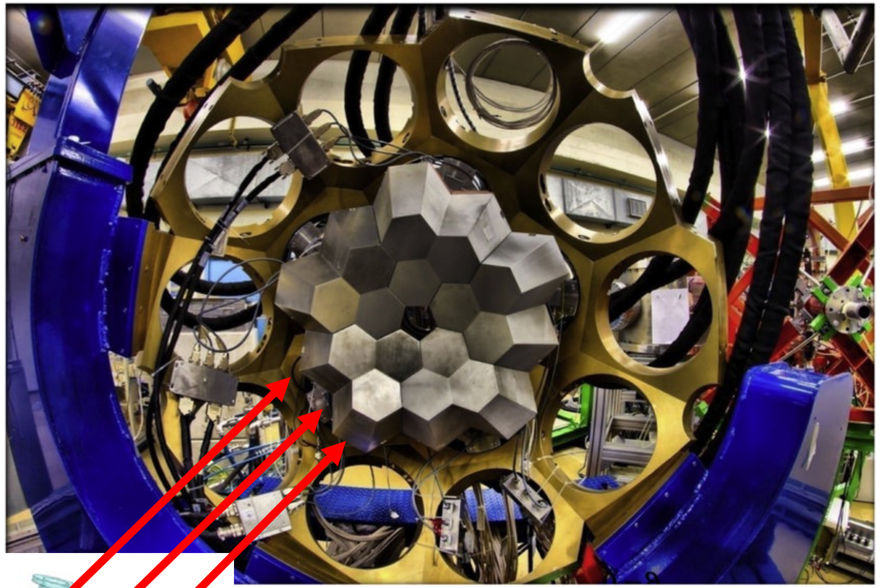
- Study the decay-out mechanisms of the highly deformed rotational bands in ^{136}Nd and ^{137}Nd to understand their structure and behaviour at high spin.
- These bands challenge current nuclear structure theories as they survive in high-energy regions where damping is expected.

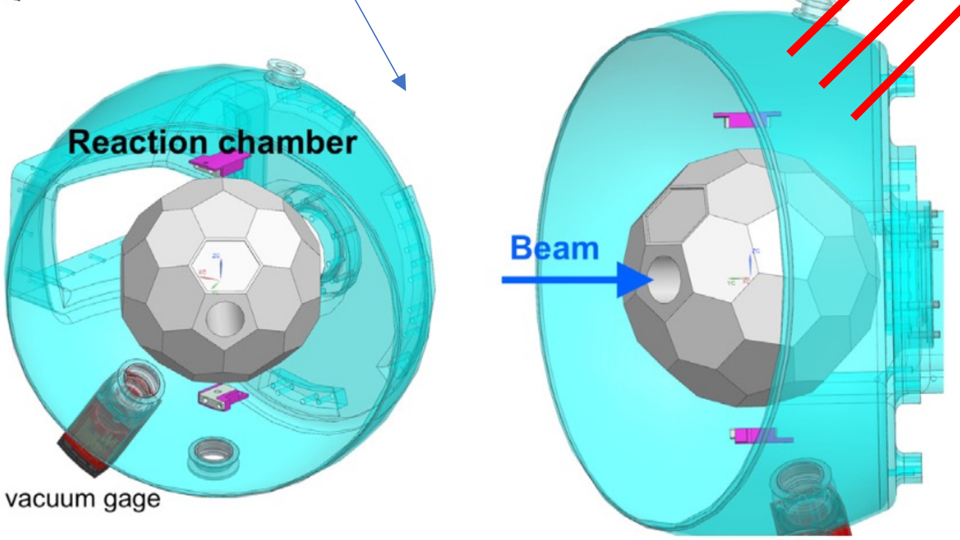
- **Perform a high-statistics thin-target measurement with the AGATA detector array using ^{33}S + ^{110}Pd reaction.**
- AGATA 1π, 15ATCs, ~13% peak absolute-efficiency
- **EUCLIDES ancillary can be used to disambiguate γ-rays originating from αxn and $2pxn$ channels.**

- Link observed bands to low-lying states and determine their spins and parities.
- Test theoretical models of nuclear structure at high spins.

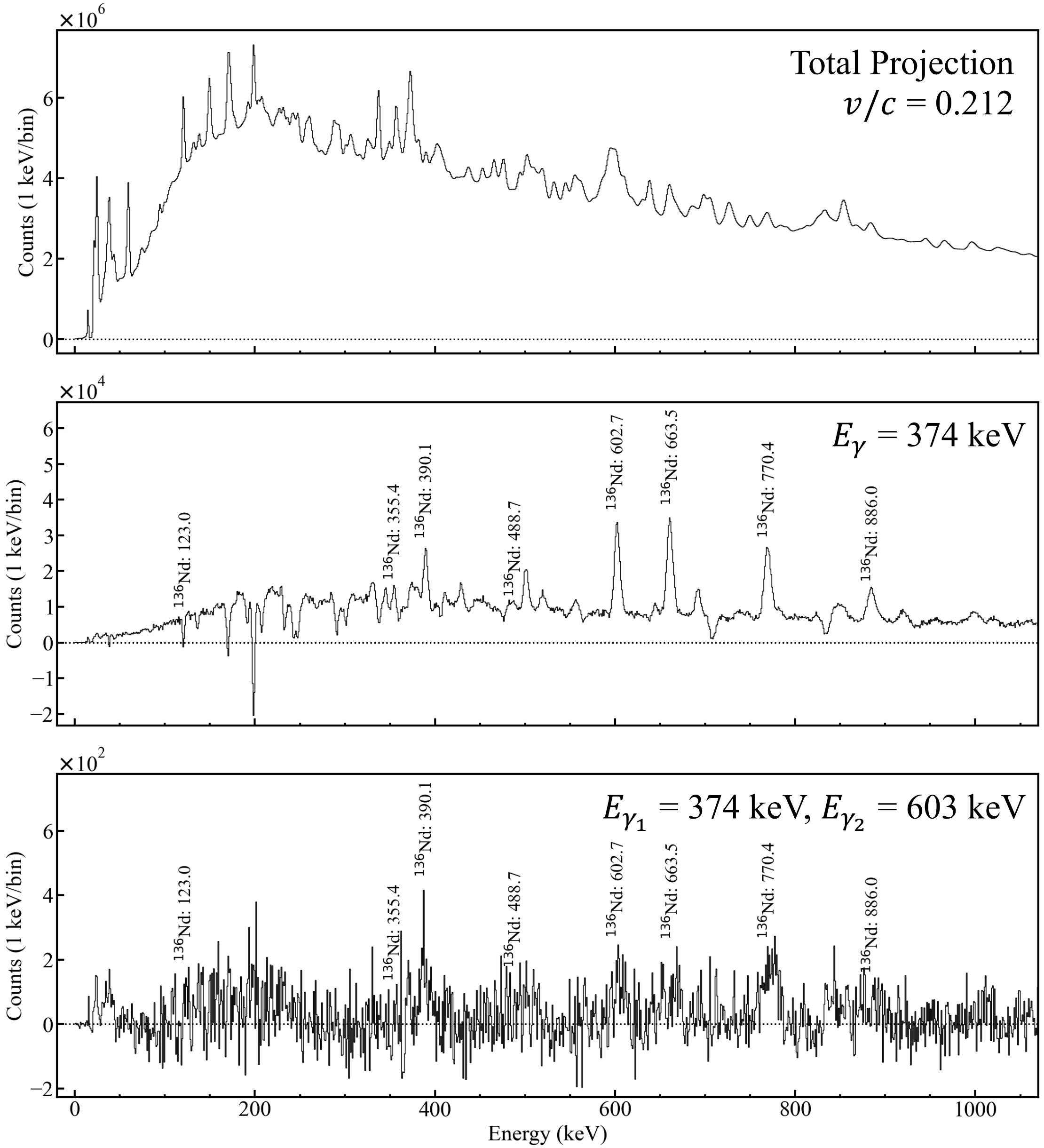
EXP 23.015 – Experimental Setup







EXP 23.015 – AGATA Standalone

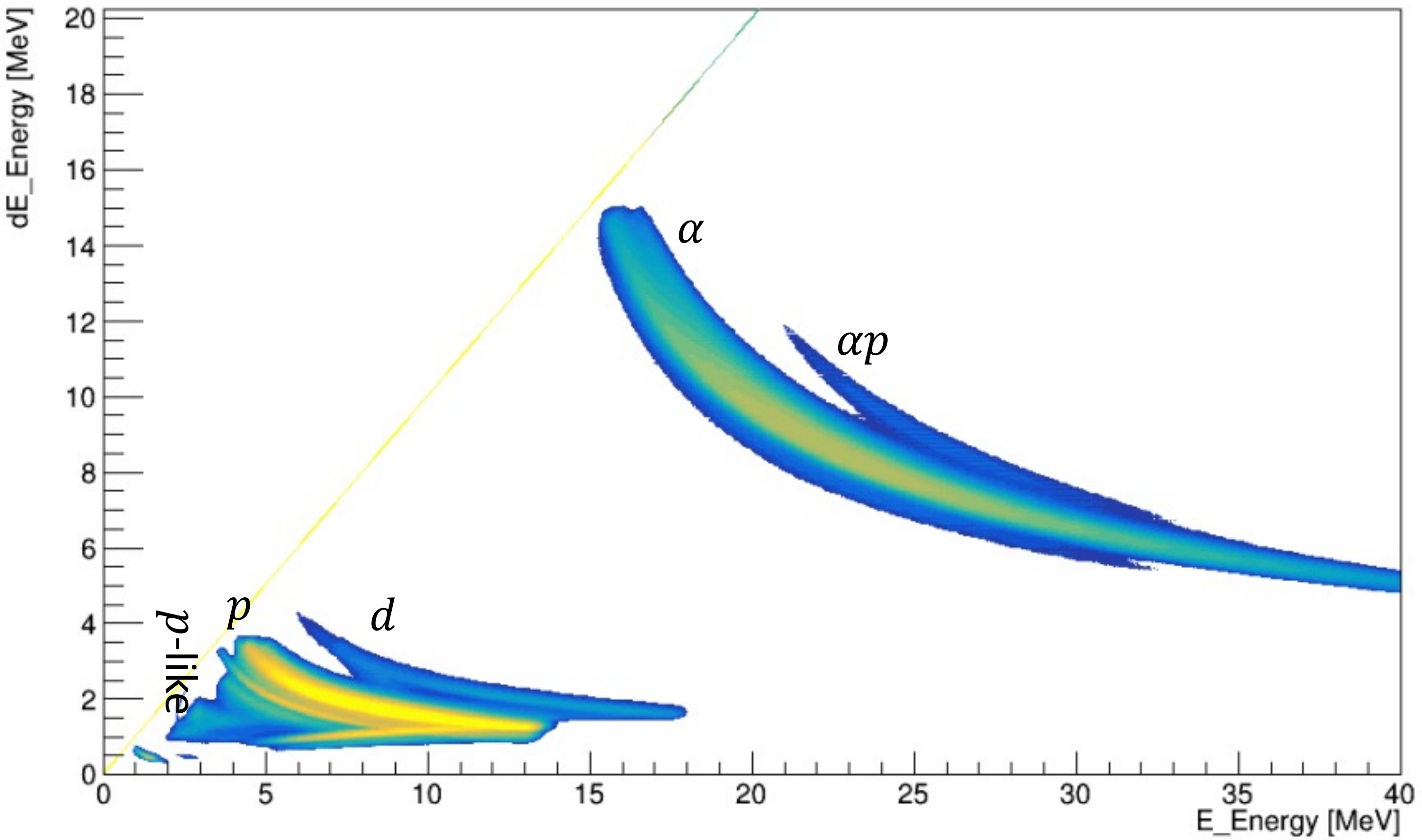


- Total Projection does not exhibit excellent peak-to-background

- Gate placed at 374 keV, low-spin members of ^{136}Nd g.s band visible among other contaminants.
- Lots of unsubtracted background though the background gate was placed at 365 keV with similar background counts under the curve.

- ggg matrix (cube) produced using CubeBuilder software.
- Very few counting statistics in the cube, peaks barely visible among background.
- Substantial decrease in total count with each applied gate. Low efficiency?

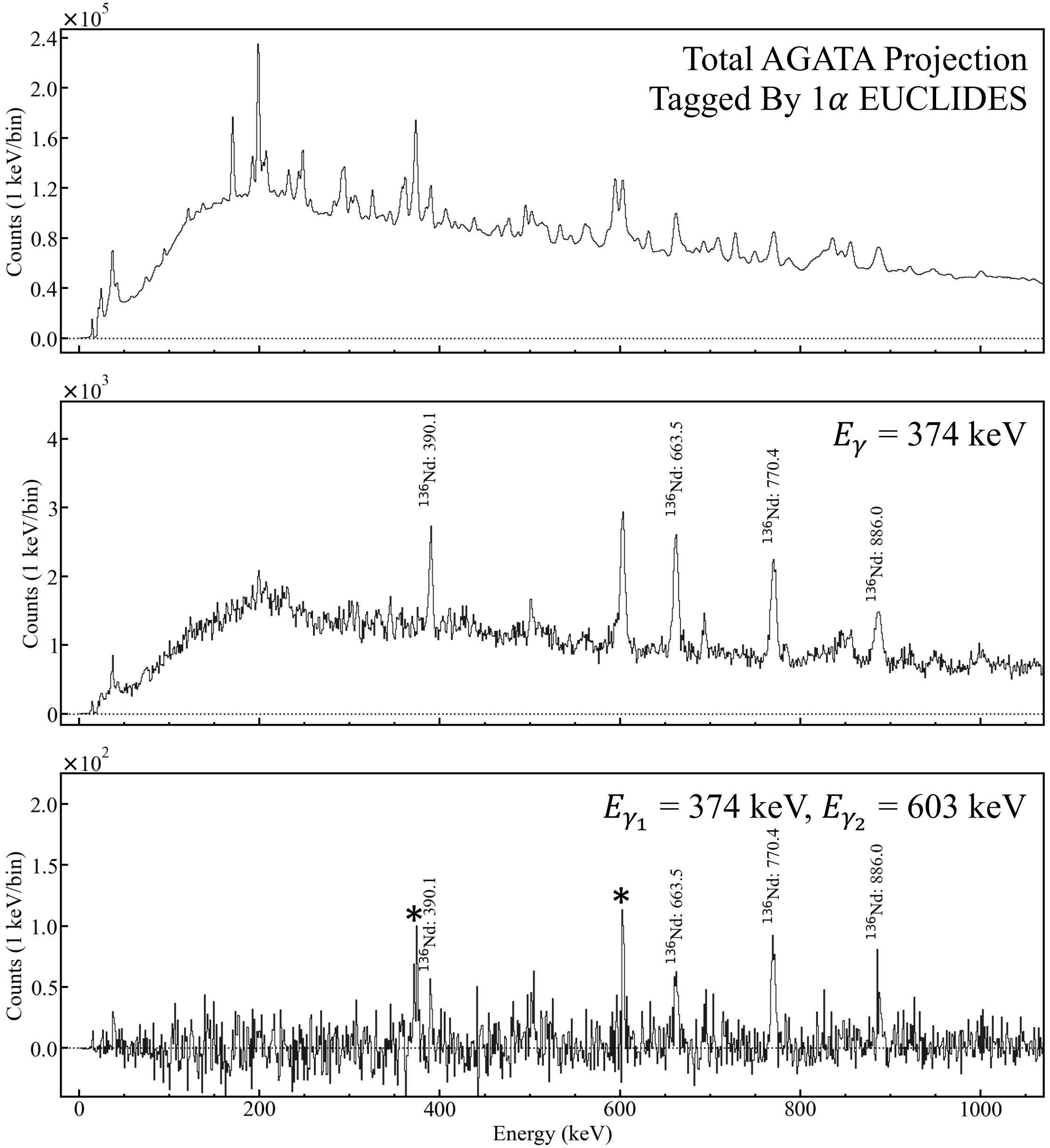
EXP 23.015 – EUCLIDES Calibration



- EUCLIDES provides particle identification through $E - dE$ method
- Calibration to true energies necessary to enable EUCLIDES event-by-event Doppler correction
- Instead of using alpha source data, use in beam.
  - Use SRIM to calculate the expected punch-through energy of protons and alphas in $130\ \mu m$ dE layer, map top of banana to this energy
  - Calculate expected punchthrough proton energy for $1130\ \mu m$ dE+E layers, map bottom of banana

- Now can place 2D gates around the bananas corresponding to different decay channels. Let's have a look at 1α decay channel which gives us ^{136,137}Nd…

EXP 23.015 – EUCLIDES Alpha Tag

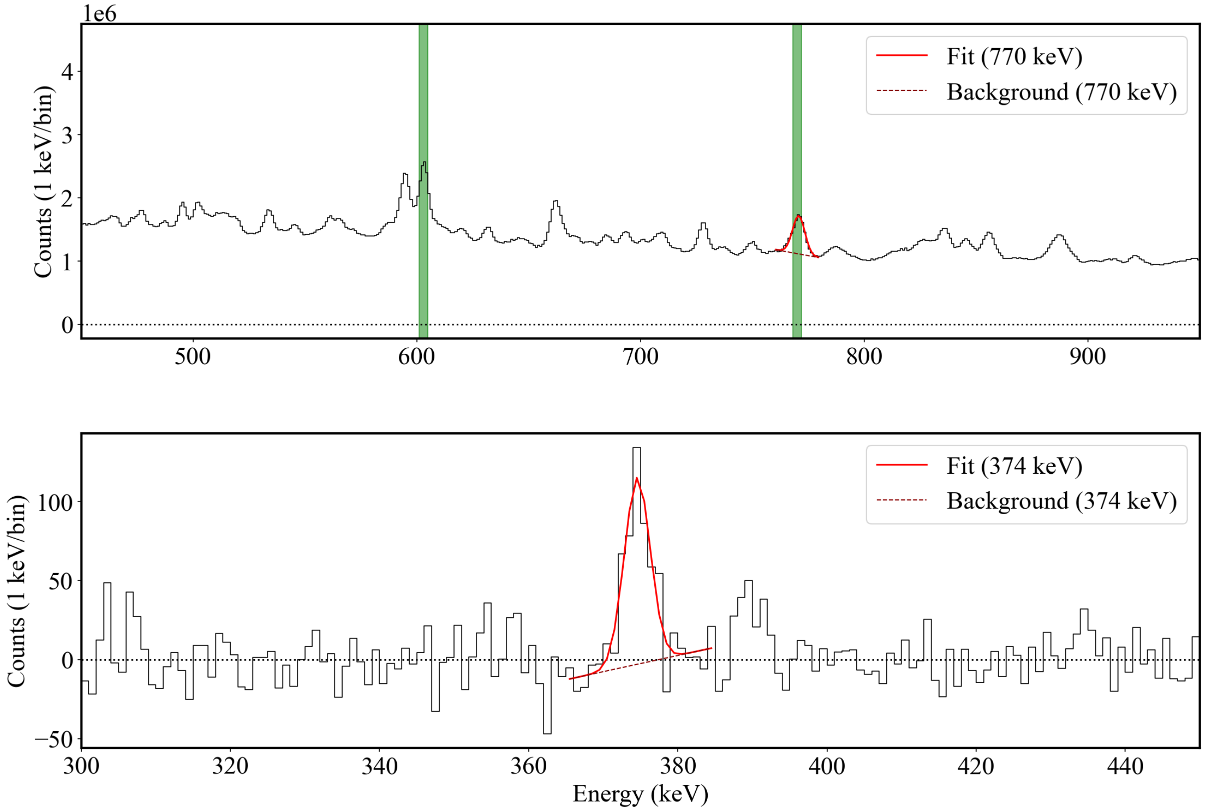


- Tidier projection afforded by filtering out other channels.
- Fewer counts overall
  - EUCLIDES 1α efficiency is ~40%
  - 1α channel ~35.9% of data (PACE4)
  - Expected 14% of total data, measured amount is consistent at ~22%

- gg projection cleaner than standalone but still suffering from background.

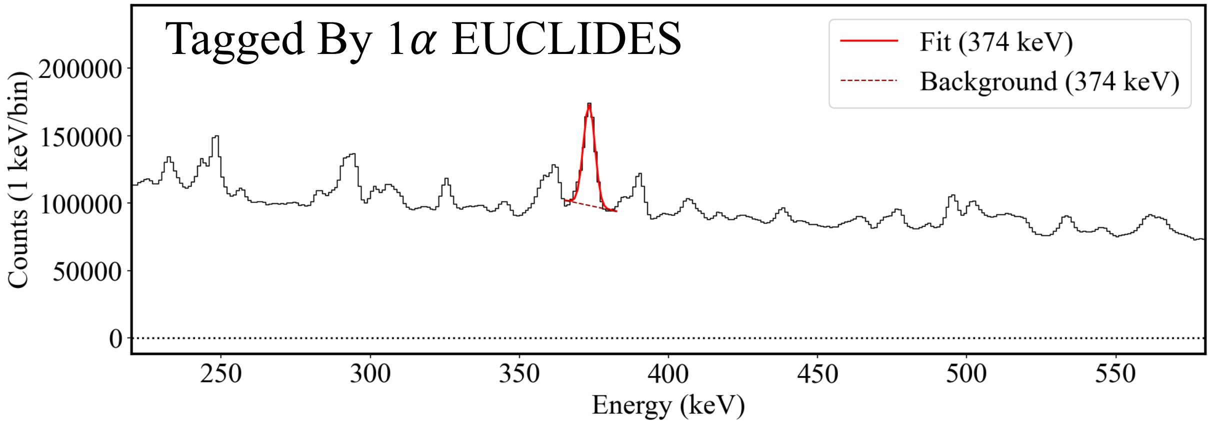
- The cube is much cleaner, but the level of statistics too small to do anything with.

EXP 23.015 – Efficiencies



- Approximate measurement of spectrometer efficiency from ggg-matrix.
- Measure number of counts in ^{136}Nd $6^+ \rightarrow 4^+ = 770$ keV
  - $\boldsymbol{N_{770} = 4.15 \times 10^6}$
- Gate on ^{136}Nd $6^+ \rightarrow 4^+ = 770$ keV, and $4^+ \rightarrow 2^+ = 603$ keV
- Measure number of counts in ggg $2^+ \rightarrow 0^+ = 374$ keV
  - $\boldsymbol{N_{374,ggg} = 514}$
- Let average AGATA efficiency be E_{ff}, then
  - $\boldsymbol{E_{ff} = \sqrt{\frac{N_{374,ggg}}{N_{770}}} = 1.1\%}$

EXP 23.015 – Efficiencies



- Another method is to compare predicted ^{136}Nd yield with actual.
- PACE4 predicted cross section: 147 mb
  - *PACE4 known to predict ~10x too high in this mass region, let's call it 15 mb*

- Predicted yield over 86 hours: $\mathbf{9.8 \times 10^8}$
- Measured yield from ^{136}Nd $2^+ \rightarrow 0^+$ in EUCLIDES α-tagged spectrum: **360,446**
- **AGATA Efficiency = ratio of yields adjusted for EUCLIDES efficiency**

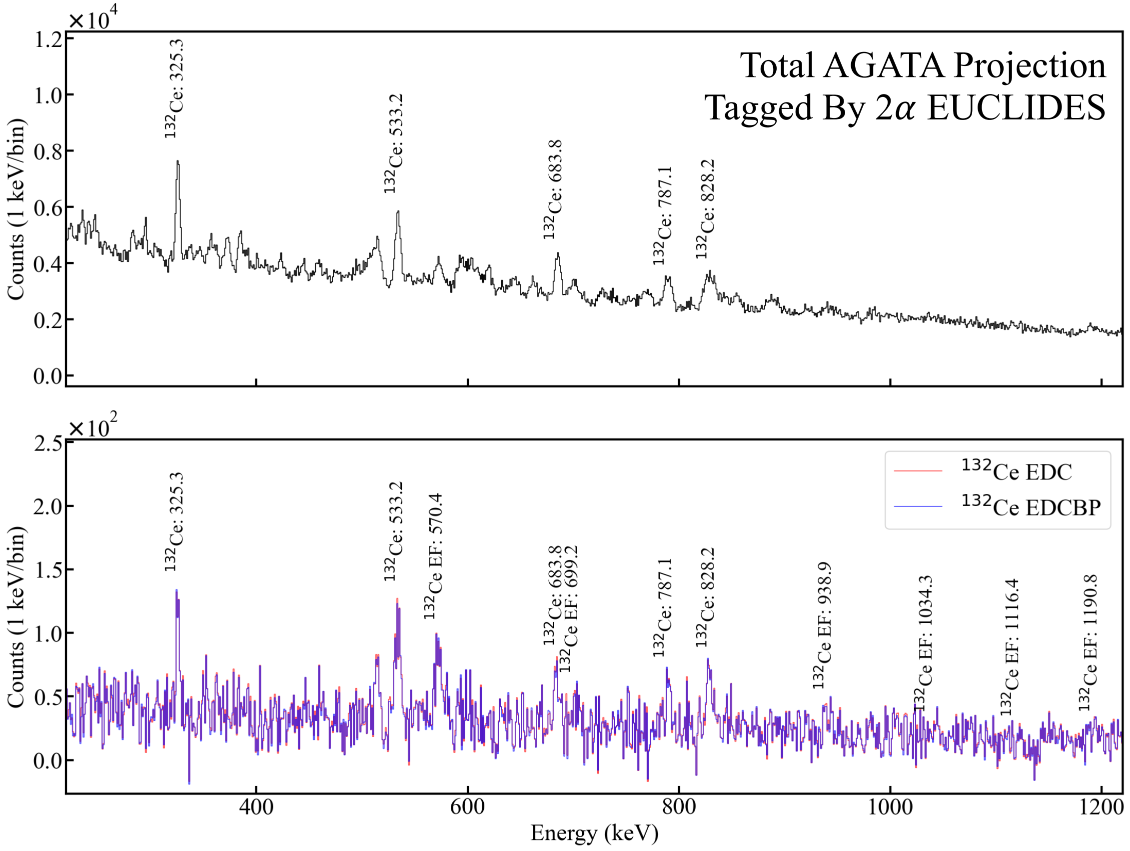
$$= \left(\frac{3.6 \times 10^5}{9.8 \times 10^8} \times 100\right) \times \frac{1}{0.4} = \mathbf{0.9\%}$$

- Both measurements subject to uncertainty not quantified here, but consistent with each other and indicative of systematic faults..

EXP 23.015 – What's The Problem?

- AGATA does not *actually* have low absolute efficiency
- AGAVA System Limitations:
  - AGAVA used to send particle data to the TP; designed to handle up to 20 kHz.
  - Dead time increases drastically beyond 6-7 kHz, reaching 87% at 16 kHz.
  - This caused over 90% of particle information to be lost at the TP level.
- Trigger Processor (TP) Dead Time:
  - The TP has a significant dead time, roughly 1% per kHz of incoming trigger requests.
  - At higher rates (30-40 kHz observed in this experiment), this results in a 30-40% loss of trigger requests.
- Potential Solutions
  - Hardware gate on the events sent from AGAVA to trigger processor - *implemented*
  - More selective trigger requirement: e.g using EUCLIDES E-layer only
  - Run at an overall lower intensity.

EXP 23.015 – EUCLIDES Event-By-Event Reconstruction



- Top spectrum illustrates the power of EUCLIDES for identifying niche decay channels, ^{132}Ce = 0.6% of total reaction cross-section!
- We see the yrast band past the first (EF) alignment to at least $I = 20\hbar$
- ^{132}Ce could underlie a useful future commissioning experiment since it has strongly populated SD bands…

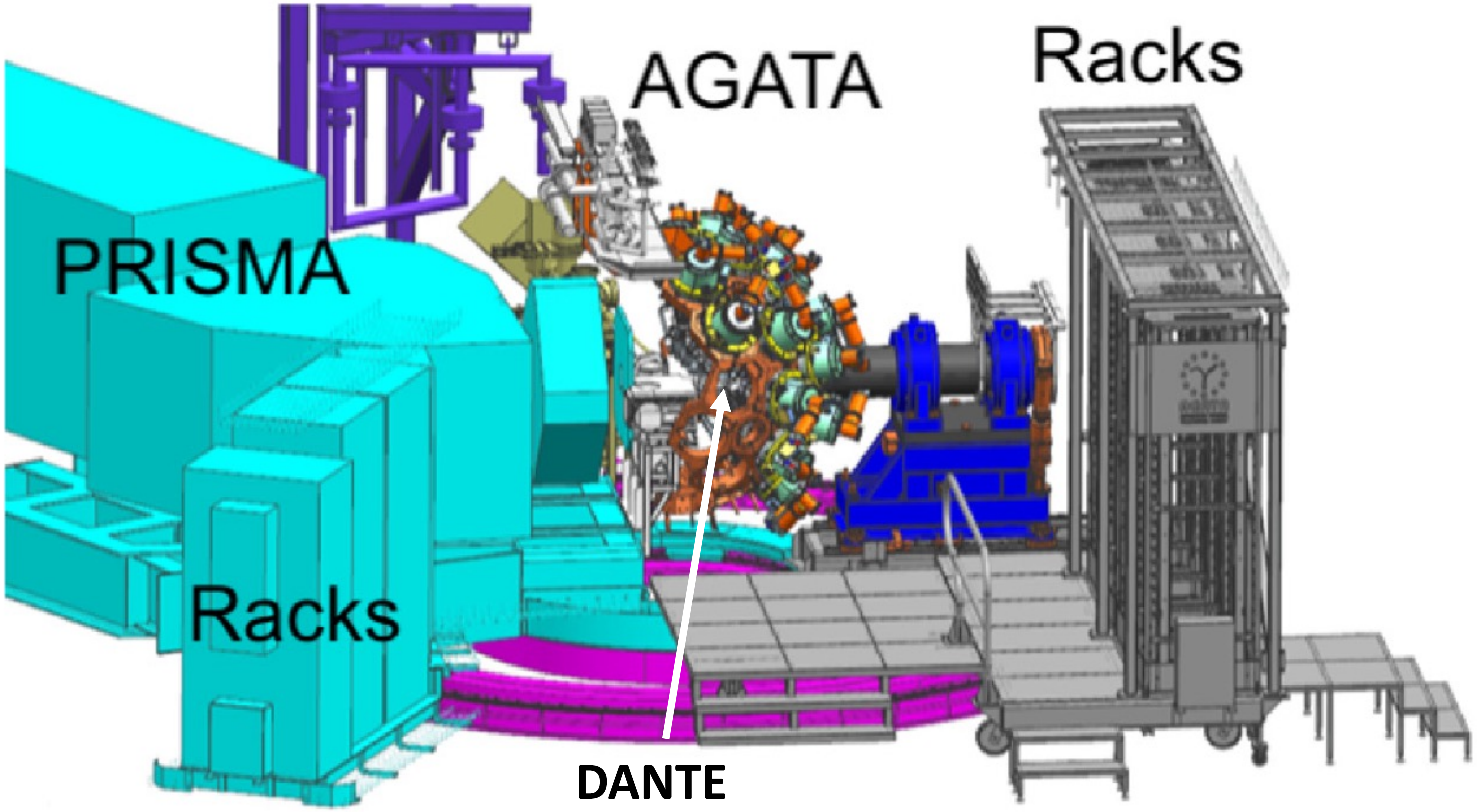
EXP 23.015 – Conclusion

- High dead time on the TP and AGAVA systems led to significant data loss.
- New hardware gate may reduce AGAVA-related dead time and partially improve TP processing, but high-rate experiments will still pose challenges.
- The experiment highlights the need for careful consideration of trigger conditions, particularly for high-fold experiments with AGATA.
- New “commissioning” experiment to test AGAVA hardware gate and more restrictive trigger processor rules?

EXP 22.096 - Introduction

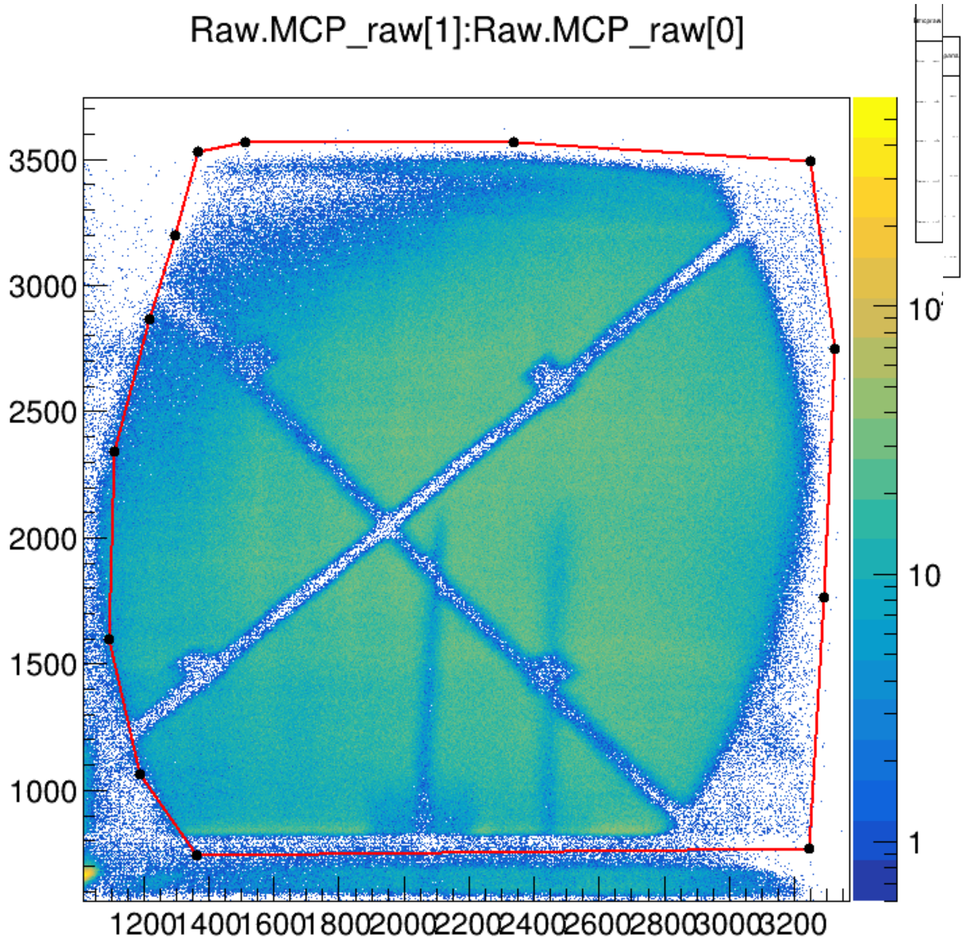
- Investigate octupole deformation in uranium isotopes, particularly ^{226}U and ^{228}U, which may exhibit "pear-shaped" structures.
- **Use AGATA, PRISMA, and DANTE detectors with a ^{129}Xe beam on a ^{232}Th target to study these isotopes via multinucleon transfer reactions.**
- Provide evidence for octupole deformation in uranium isotopes, contributing to the understanding of nuclear structure and informing CP violation studies.
- Success could lead to extended studies on transition elements and insights into fundamental physics beyond the Standard Model.

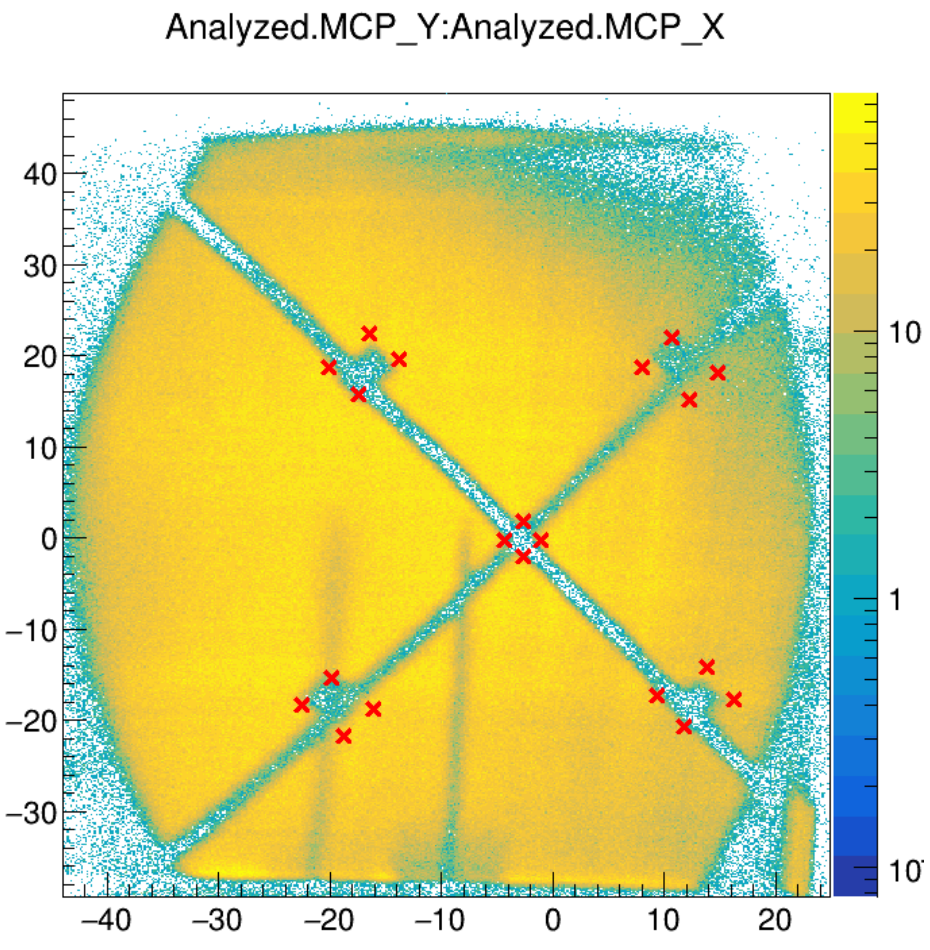
EXP 22.096 – Experimental Setup



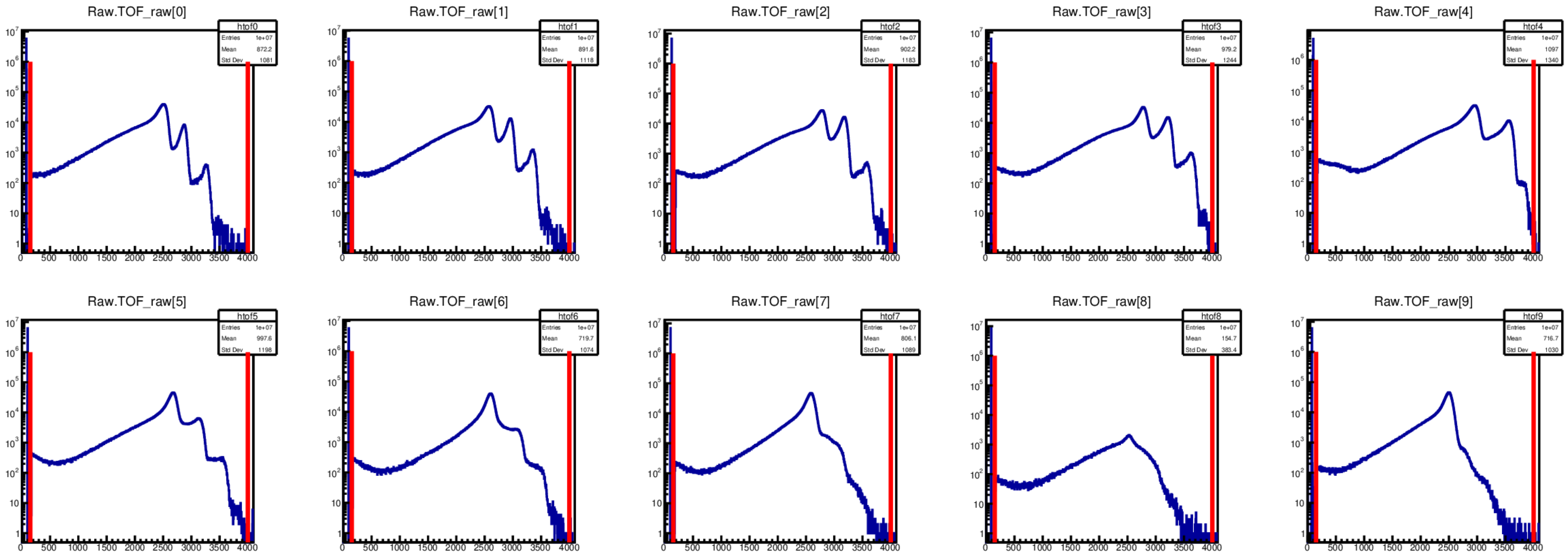
EXP 22.096 – PRISMA Calibration - MCP

- Using the “new” calibration points distributed in June.

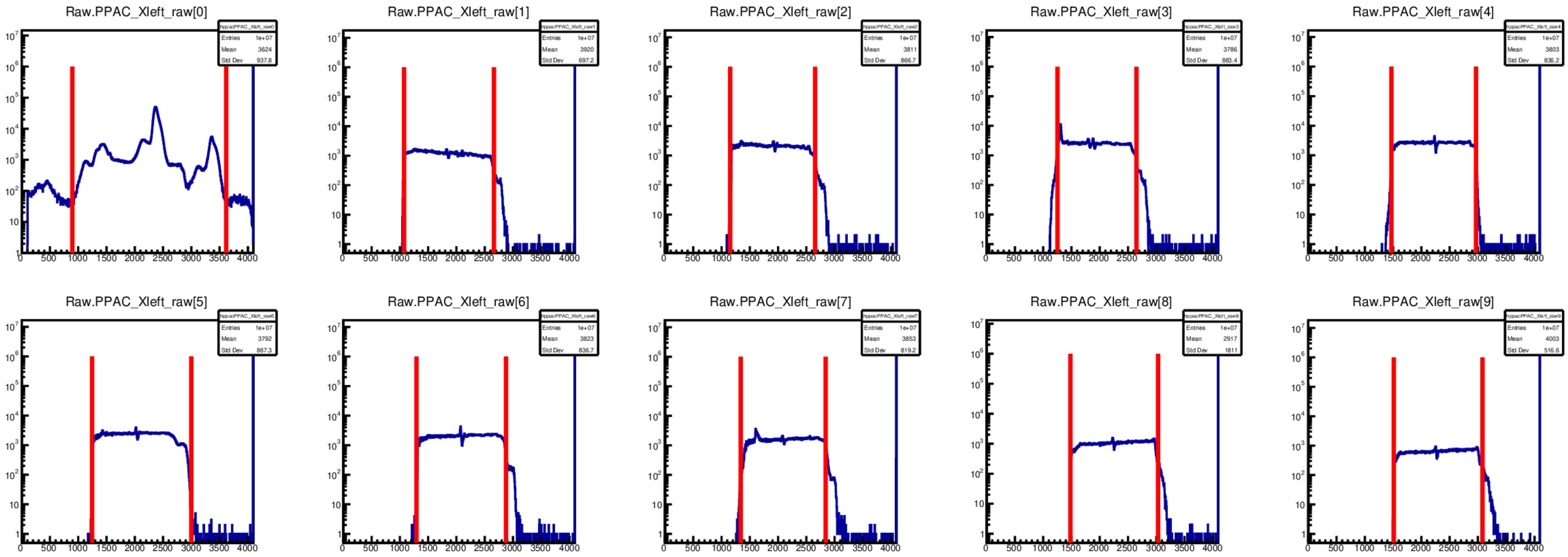




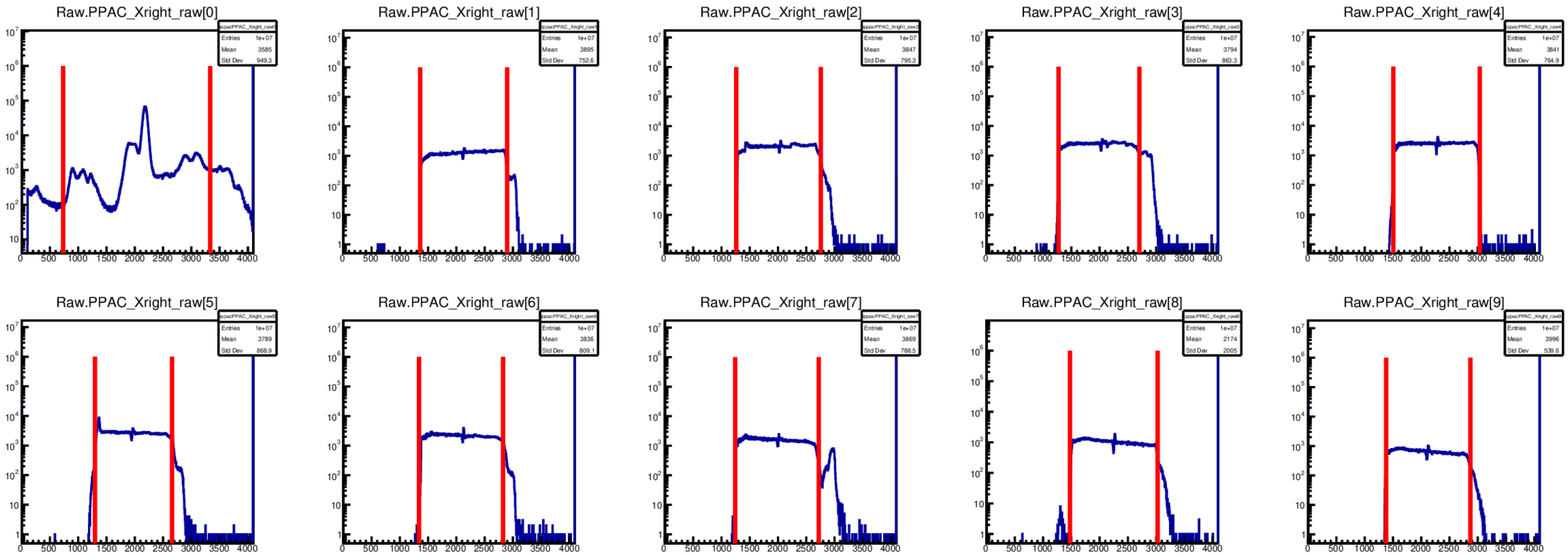
EXP 22.096 – PRISMA Calibration – PPAC ToF



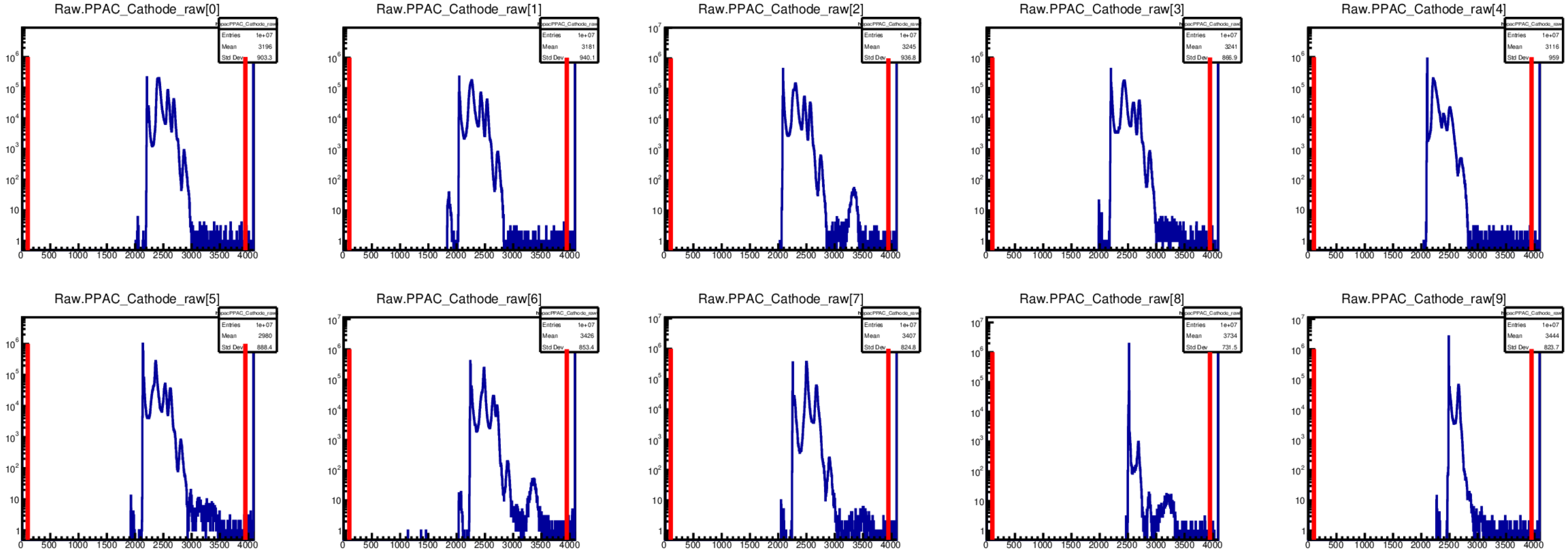
EXP 22.096 – PRISMA Calibration – PPAC X_Left



EXP 22.096 – PRISMA Calibration – PPAC X_Right

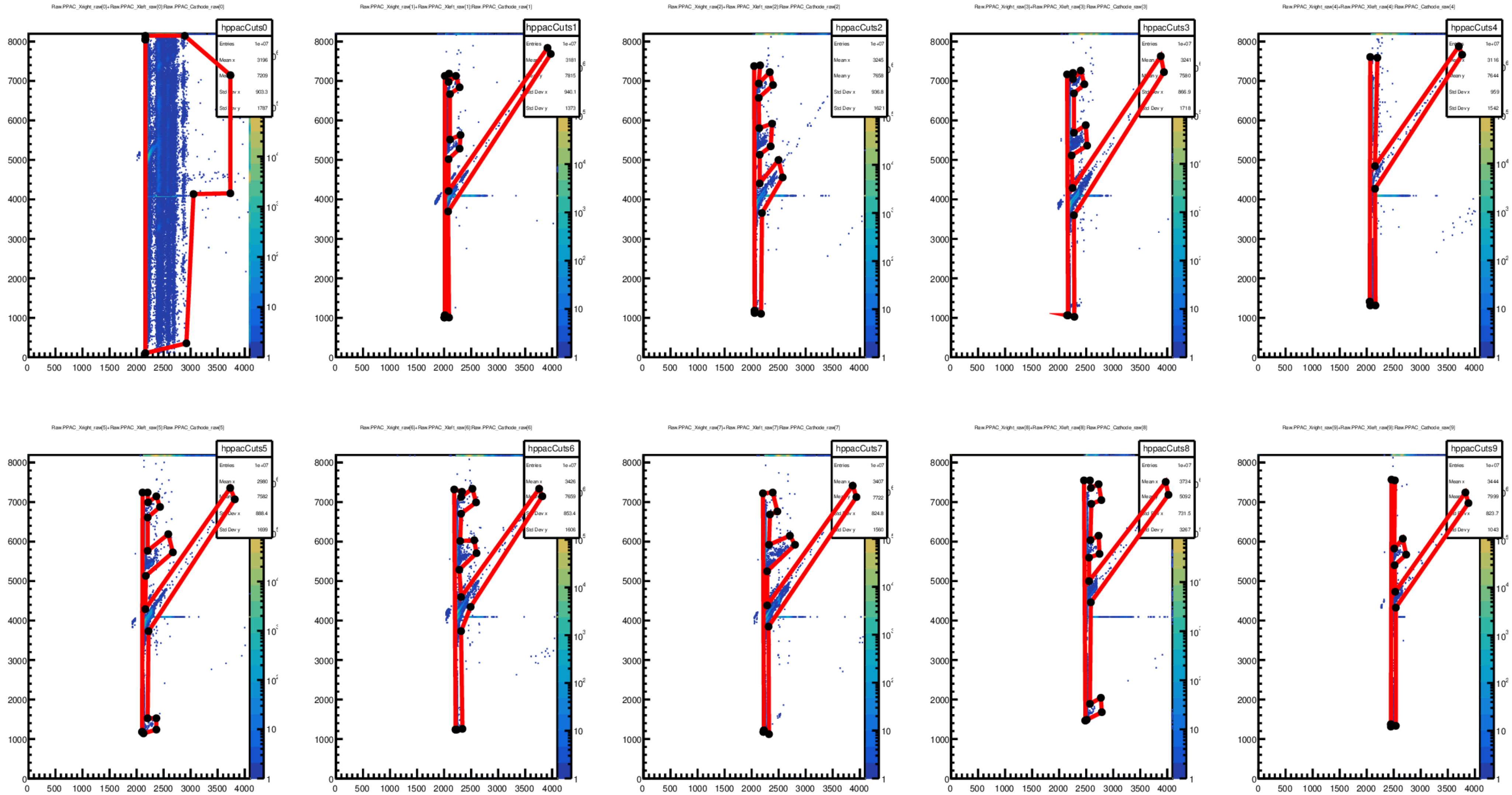


EXP 22.096 – PRISMA Calibration – PPAC Cath

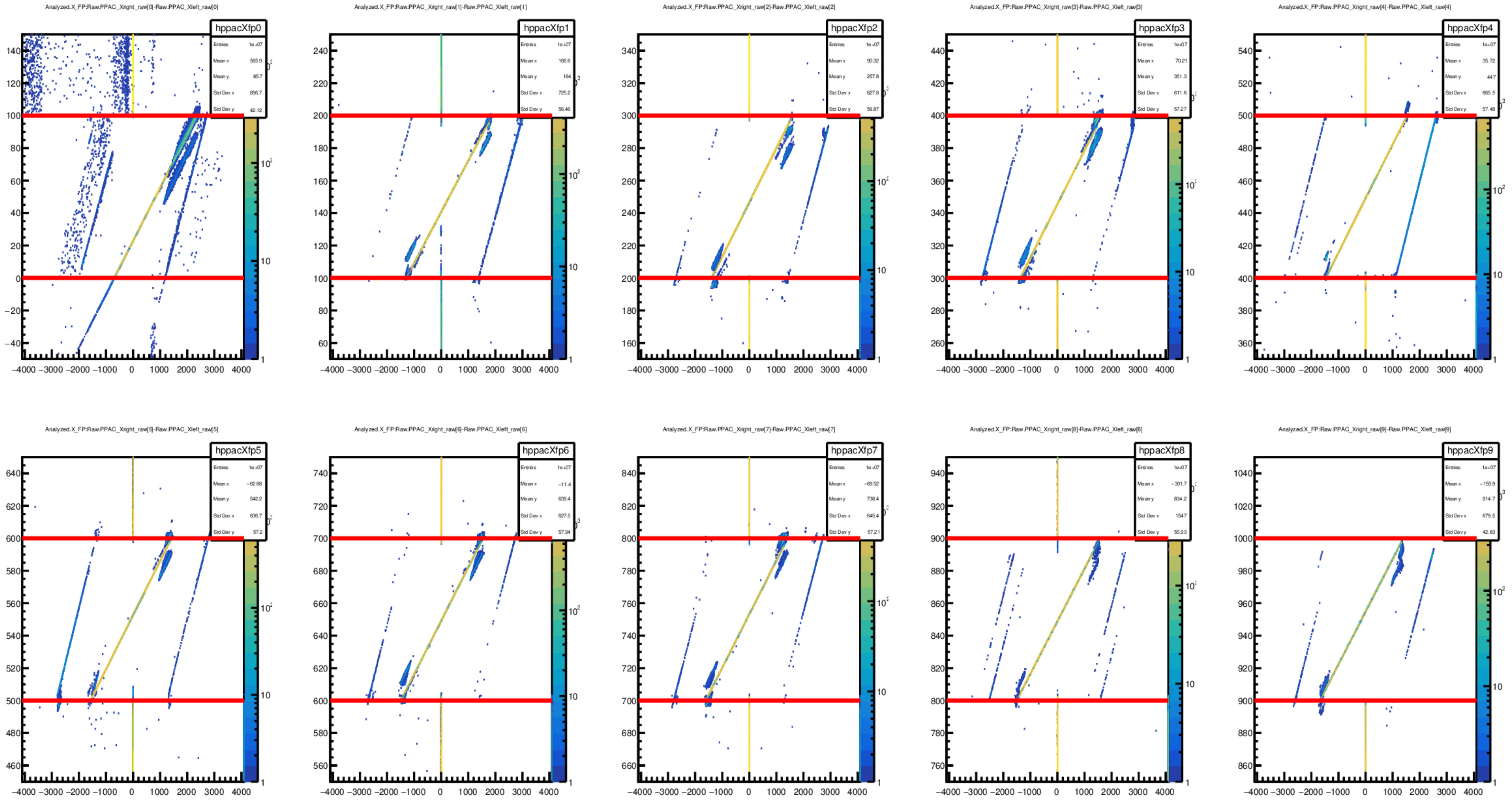


EXP 22.096 – PRISMA Calibration – PPAC Bans

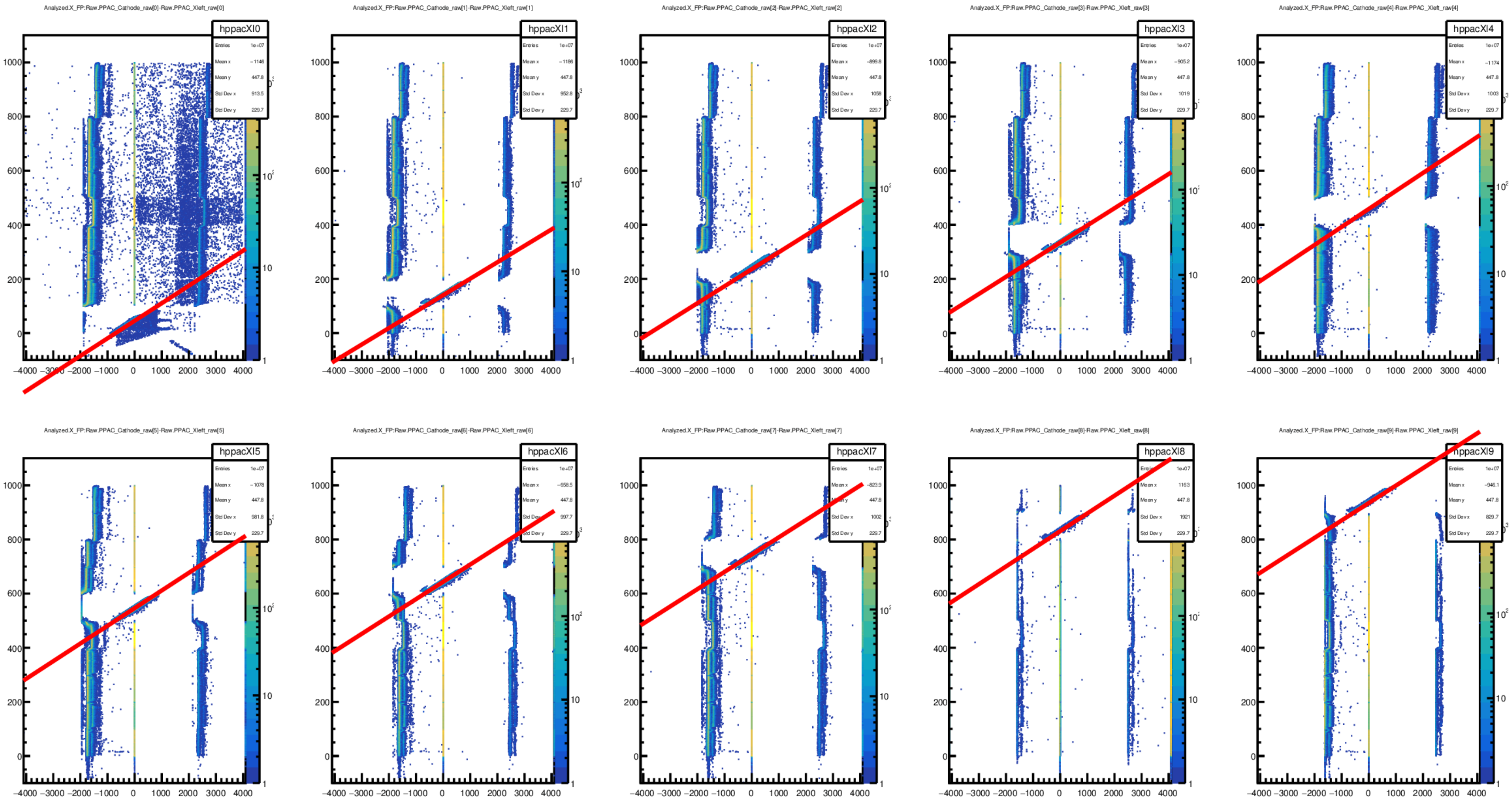
- What's wrong with PPAC[0]?



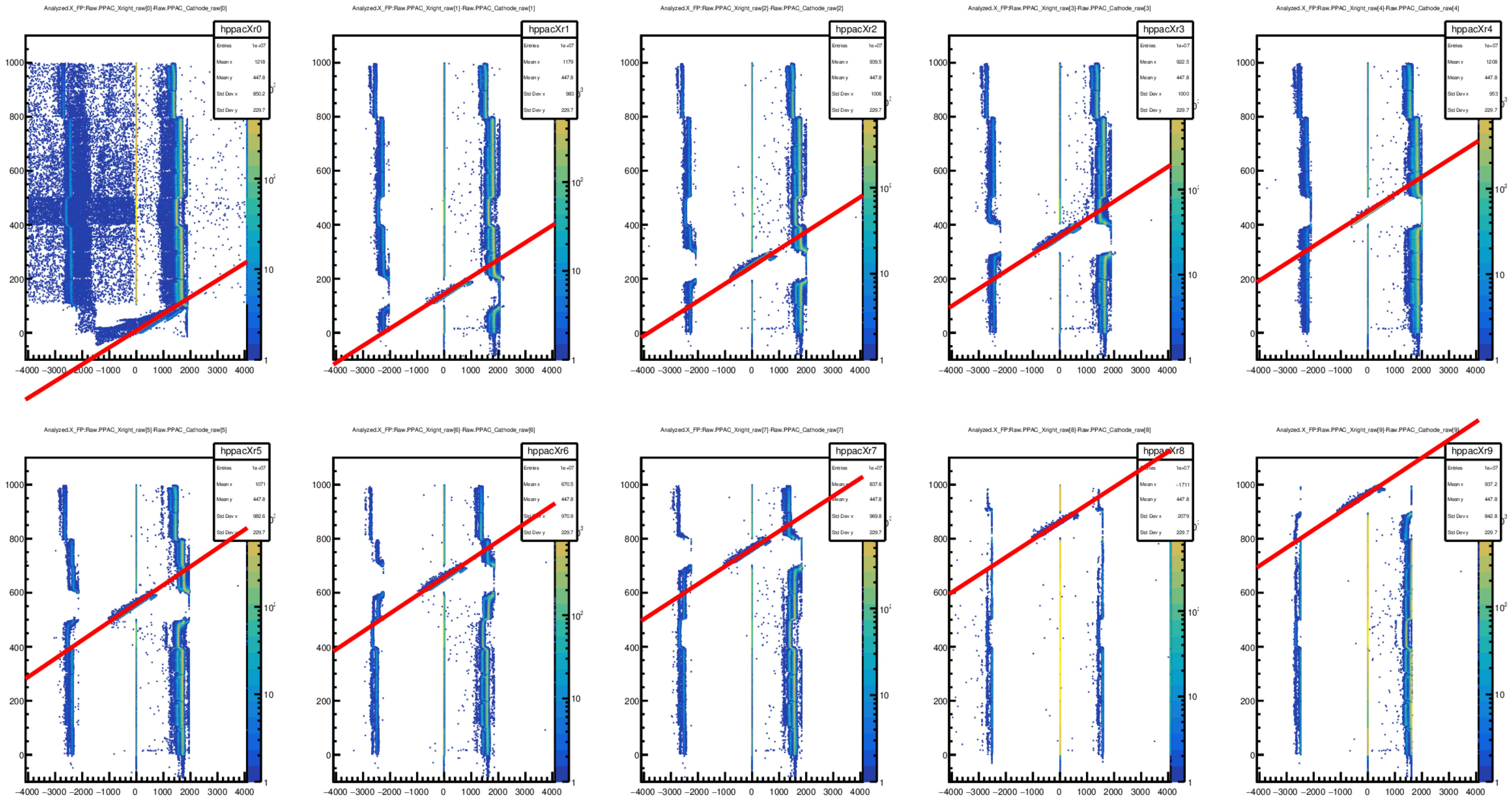
EXP 22.096 – PRISMA Calibration – X_FP Calib and Thresholds



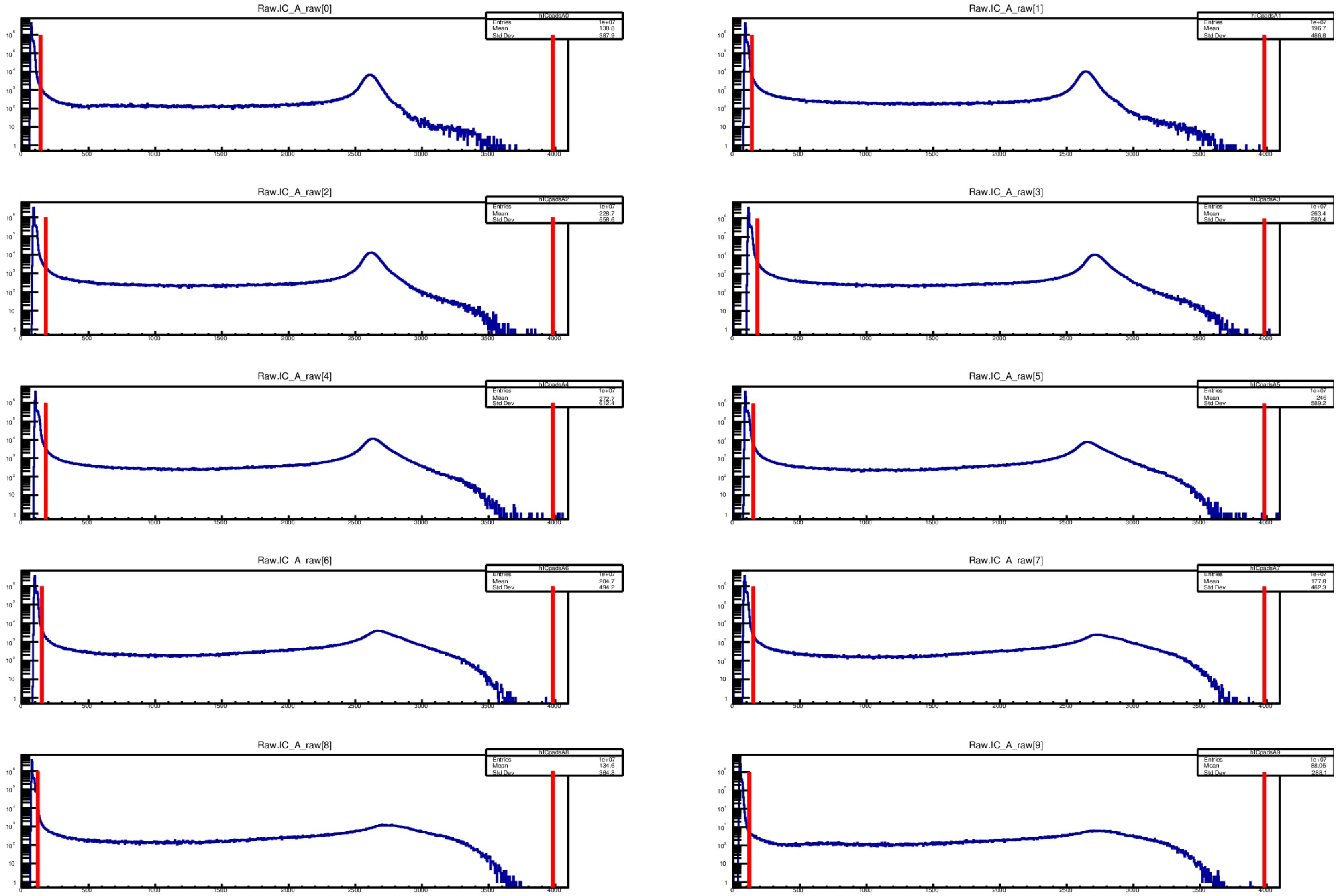
EXP 22.096 – PRISMA Calibration – XL_Cal



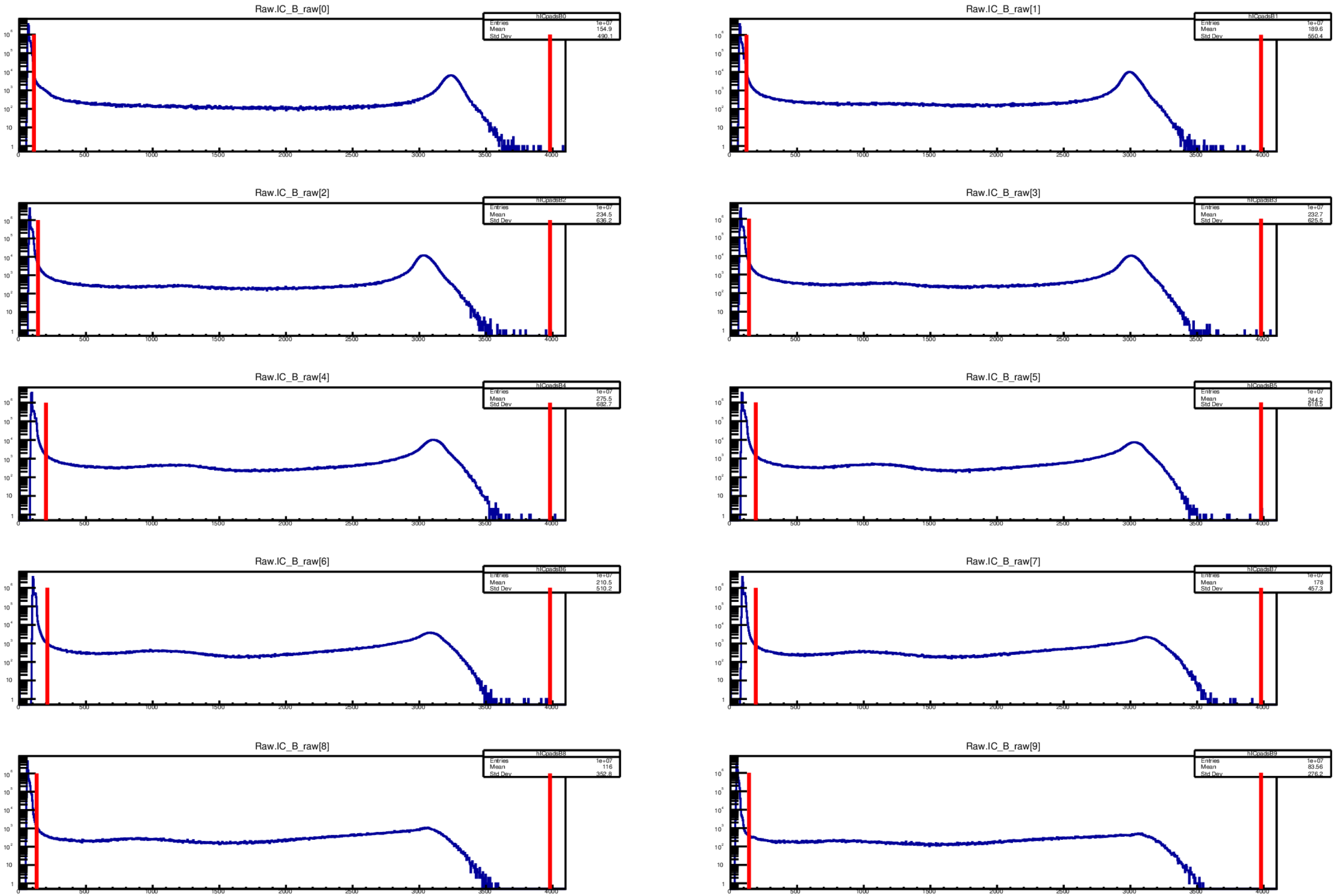
EXP_017 – PRISMA Calibration – XR_Cal



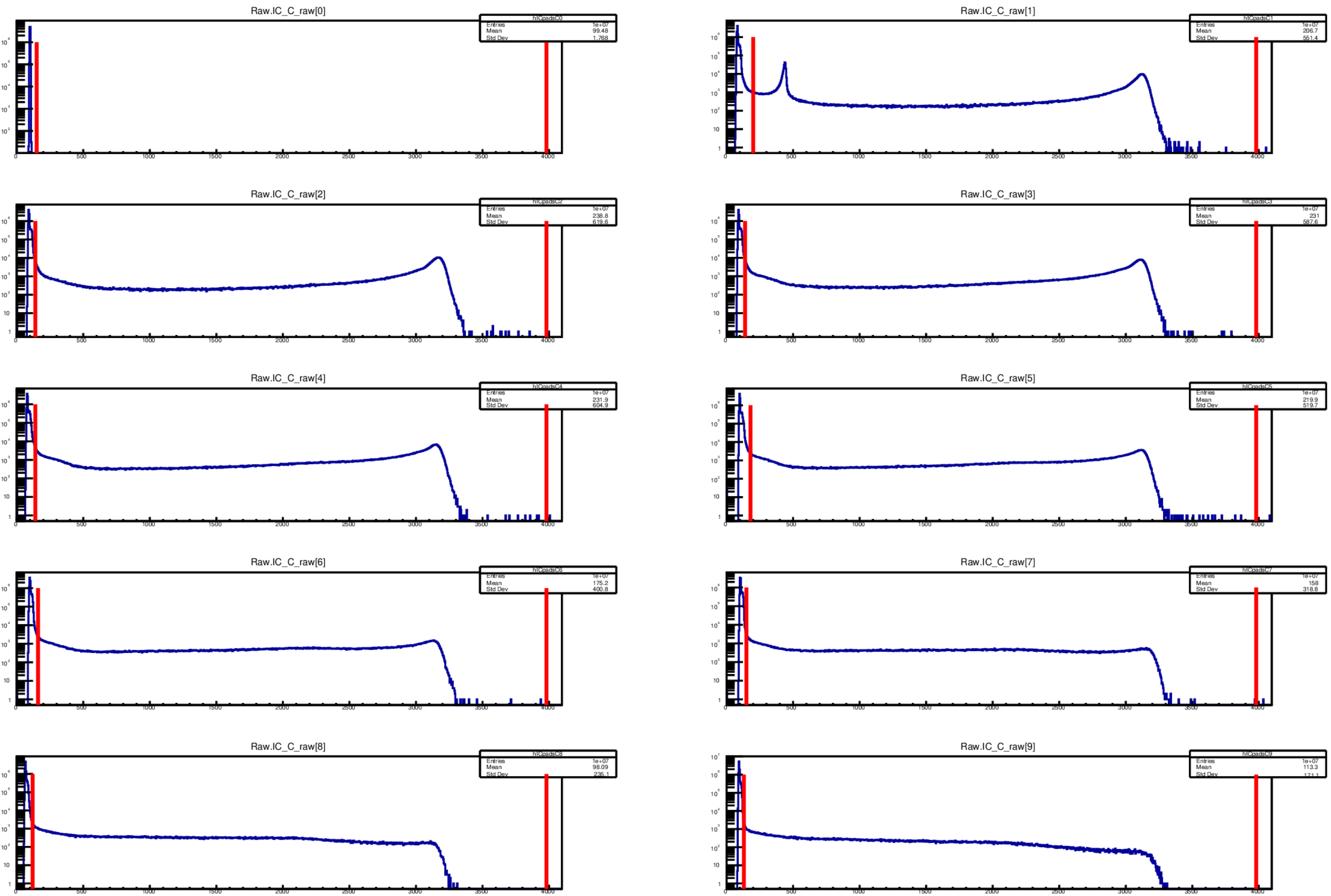
EXP 22.096 – PRISMA Calibration – Ionisation Chamber Row A



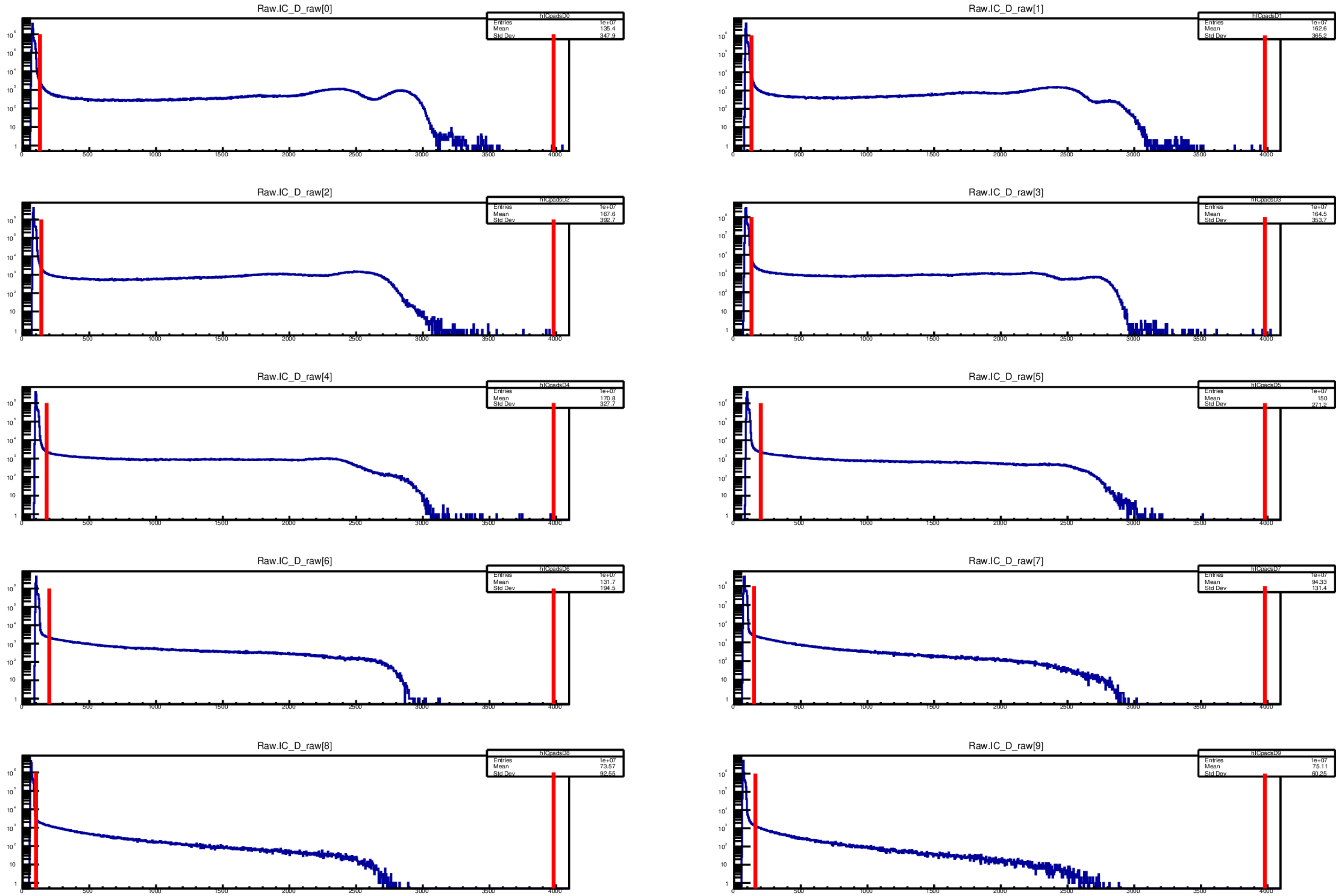
EXP 22.096 – PRISMA Calibration – Ionisation Chamber Row B



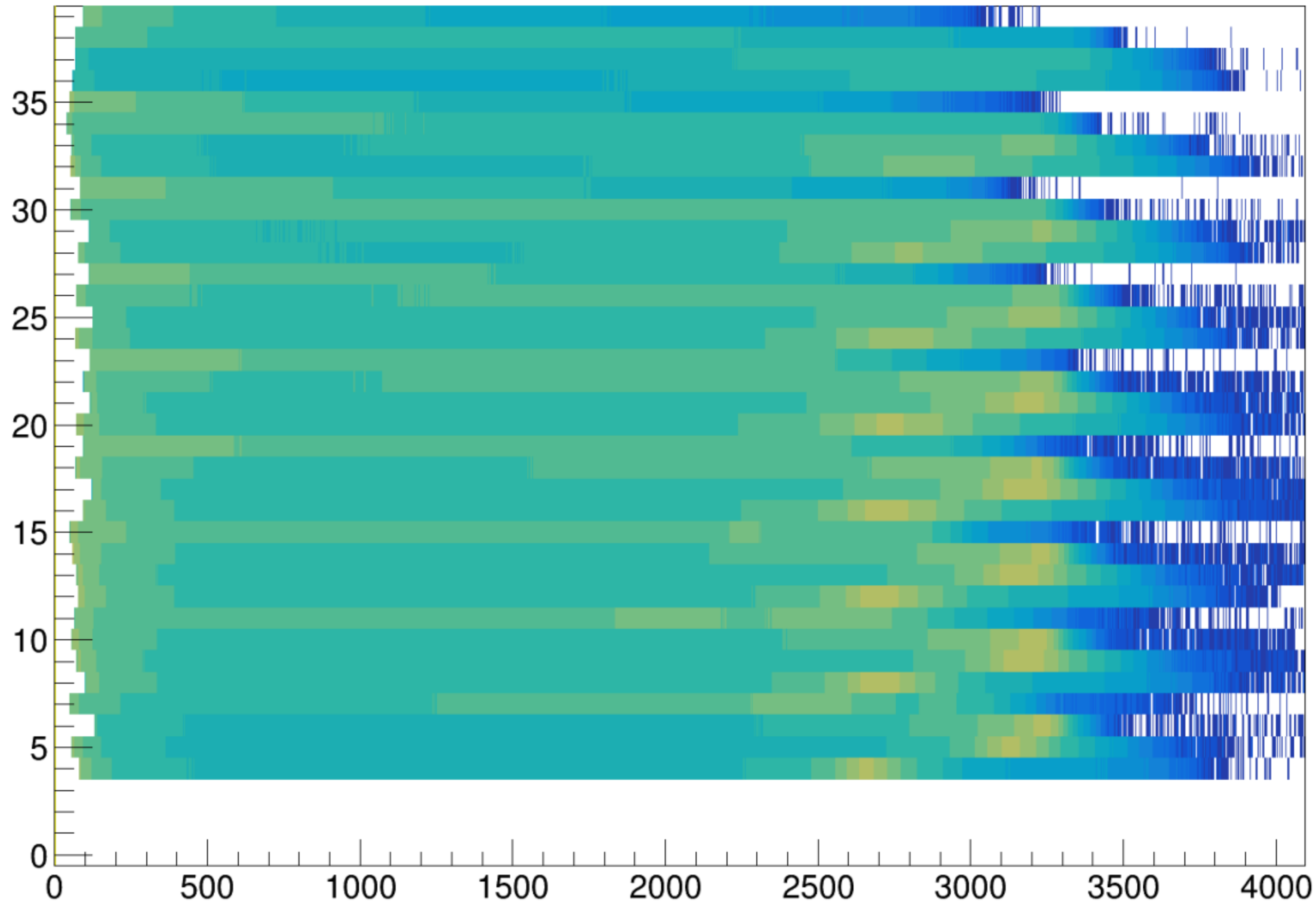
EXP 22.096 – PRISMA Calibration – Ionisation Chamber Row C



EXP 22.096 – PRISMA Calibration – Ionisation Chamber Row D

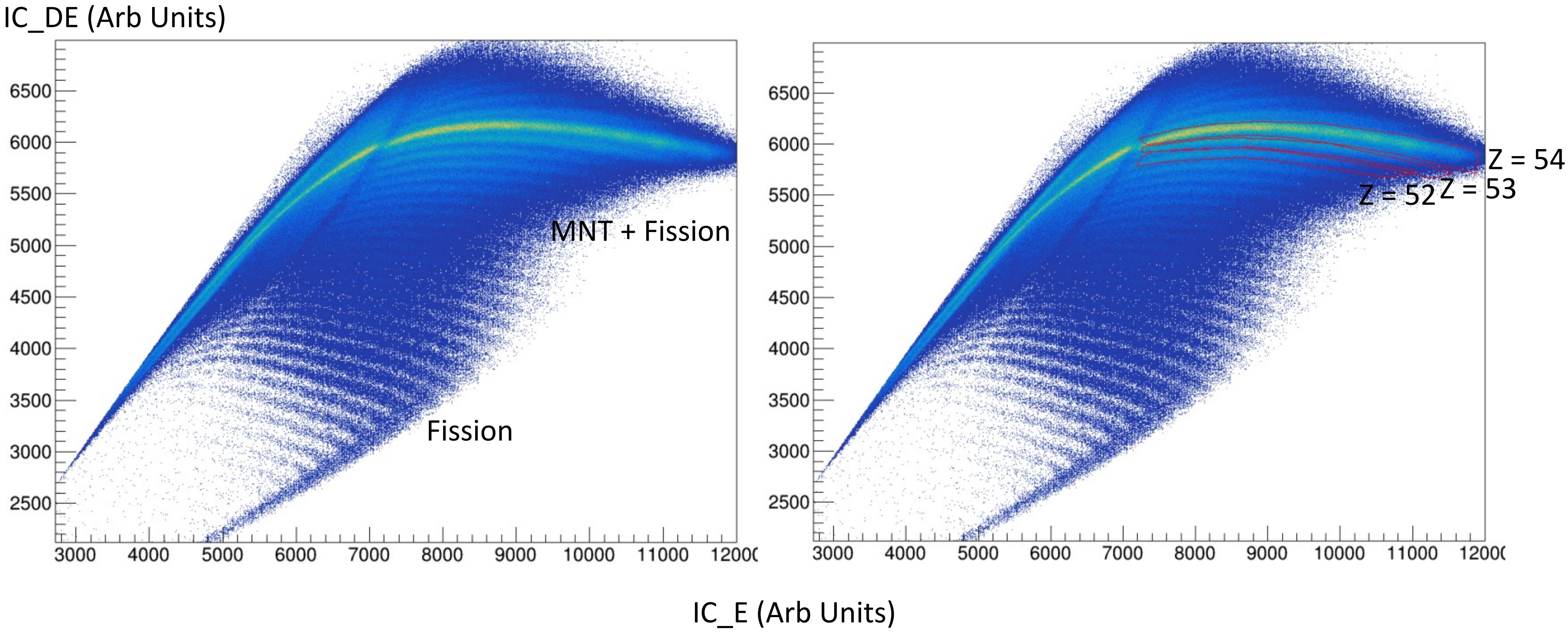


EXP 22.096 – PRISMA Calibration – Ionisation Chamber ICNr vs ICE

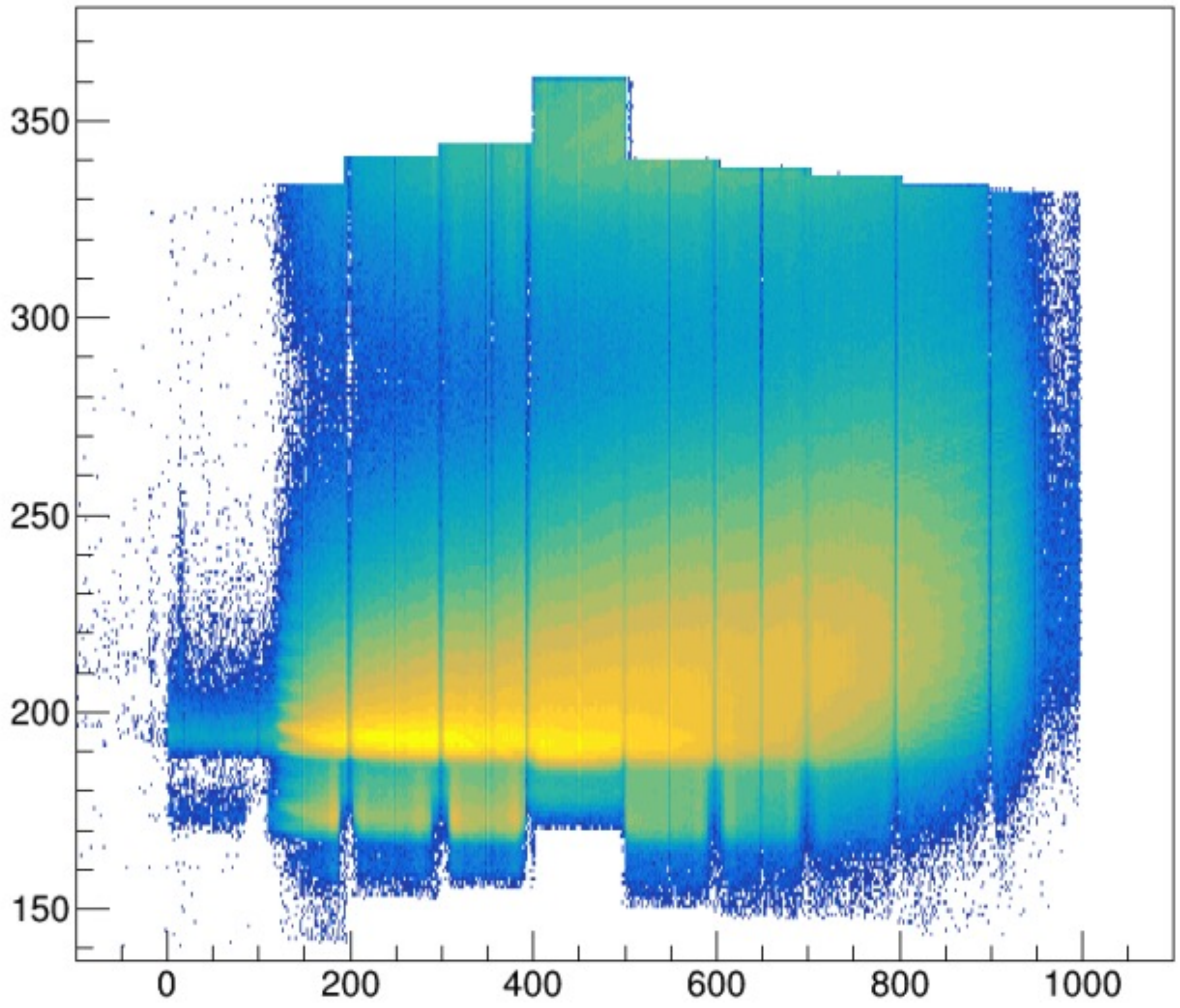


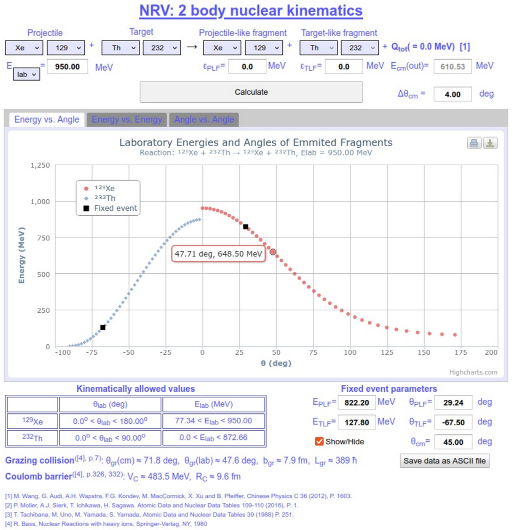
EXP 22.096 – PRISMA Calibration – Z Selection

- Used ICDEAB_ICE_7 since easier to visualise the bananas here.

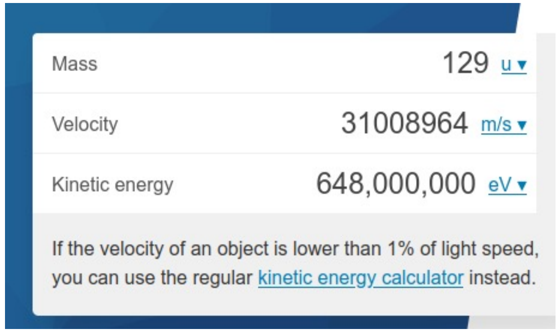


EXP 22.096 – PRISMA Calibration – ToF Offset and Alignment





- PRISMA was set at the grazing angle 46 deg (https://gal-serv.lnl.infn.it:20443/exp_22.96/page)



- Assuming negligible energy loss in target (SRIM has 20-30 MeV) then the ToF estimate comes from relativistic kinematics https://www.calctool.org/relativity/relativistic-ke

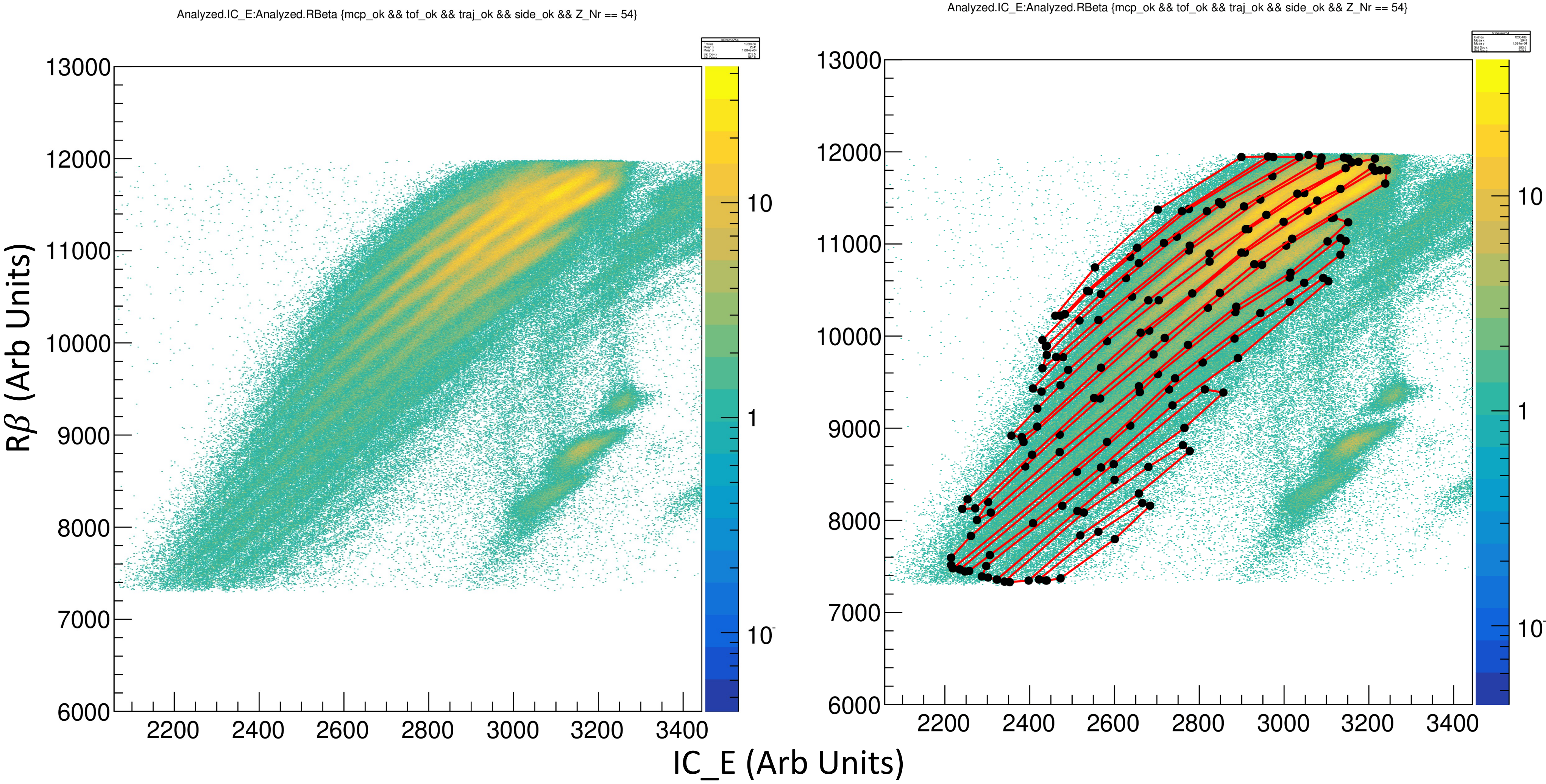
- **ToF = 6 metres / 31008964 m/s = 193.4 ns**

EXP 22.096 – PRISMA Calibration – Q Selection

- Charge states identified and labelled by comparison with output from REACTION code.

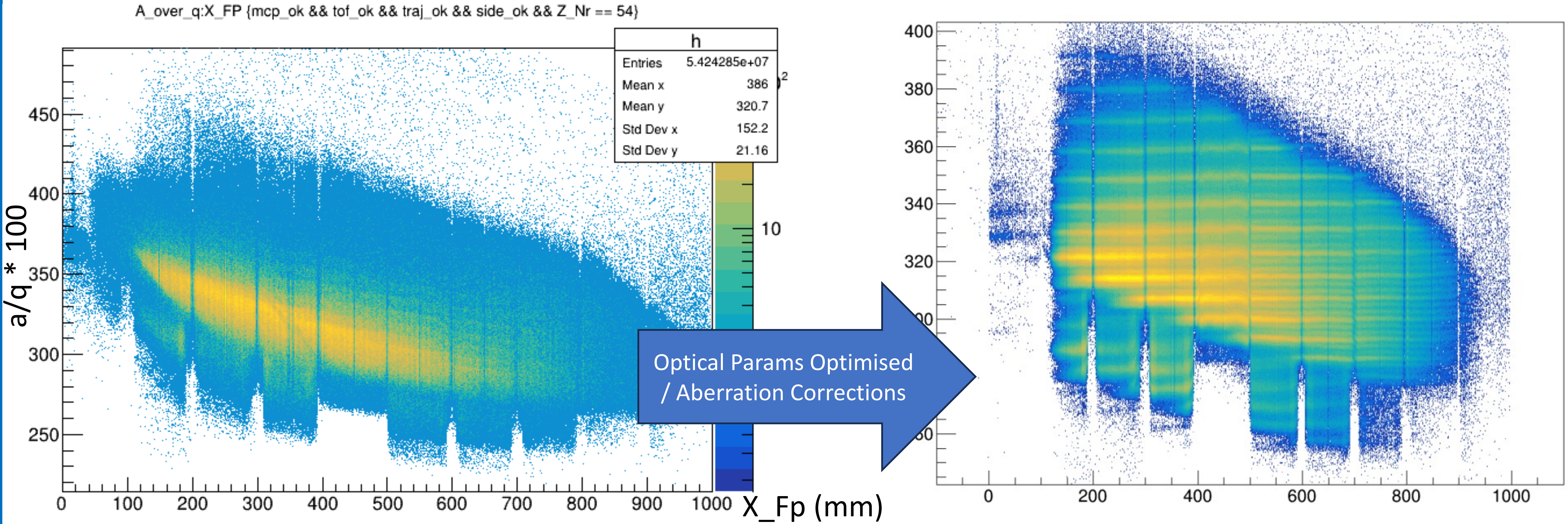
$$\frac{A}{q} = \frac{B\rho}{D/TOF}$$

$$E_{IC} \sim q\rho v.$$

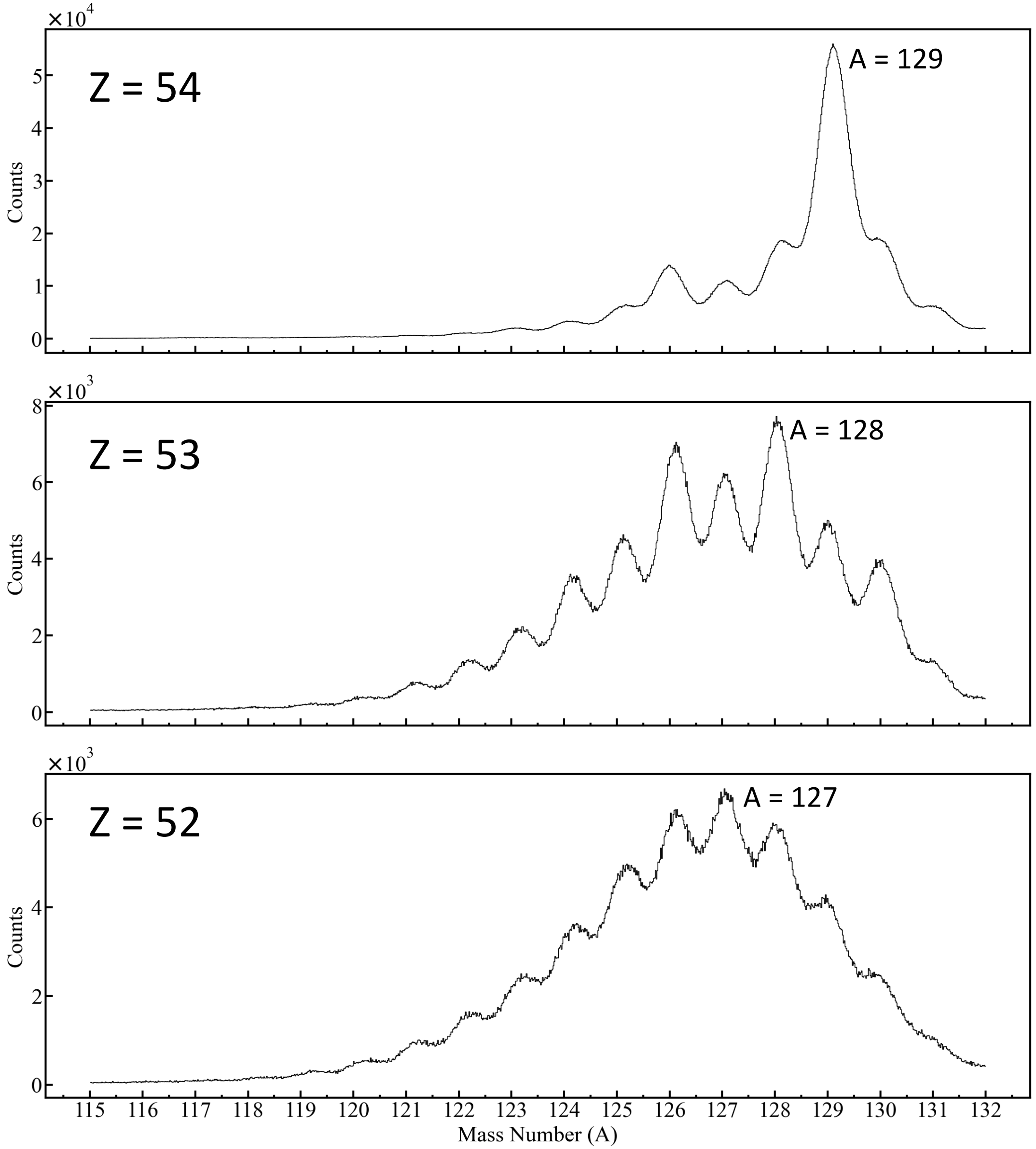


EXP 22.096 – PRISMA Calibration – A/q Optimisation

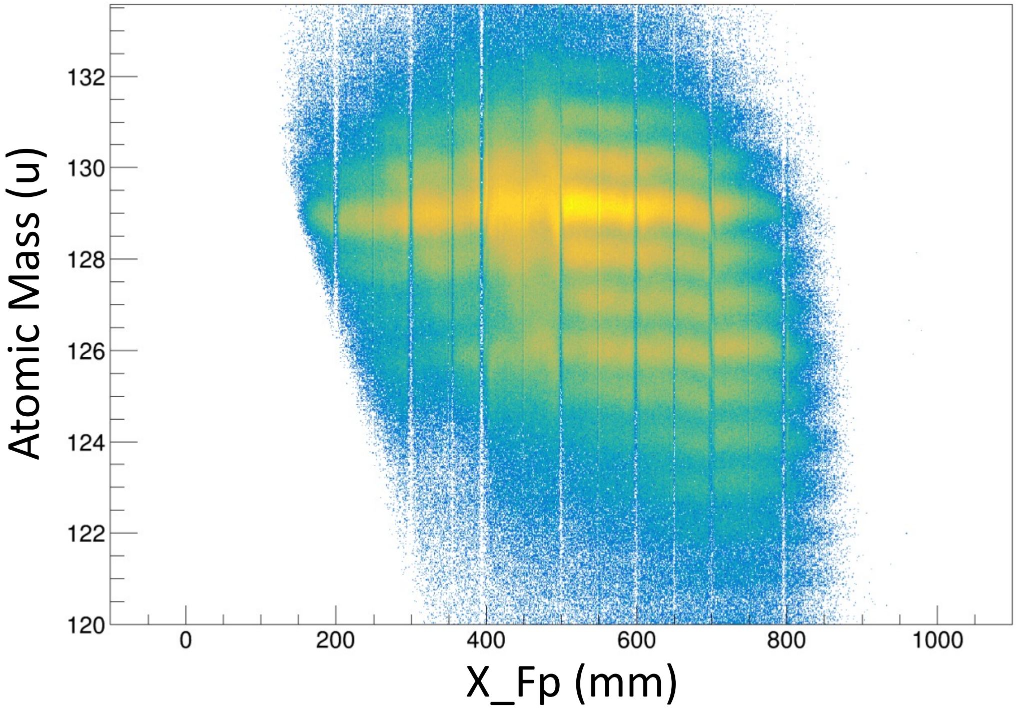
- A/q vs X_Fp for Z = 54. We can see that the right-hand side (X_Fp > 500 mm) much nicer resolution than the left.
- Segment 4 (400 – 500 mm) particularly low resolution. **Can this be fixed?**



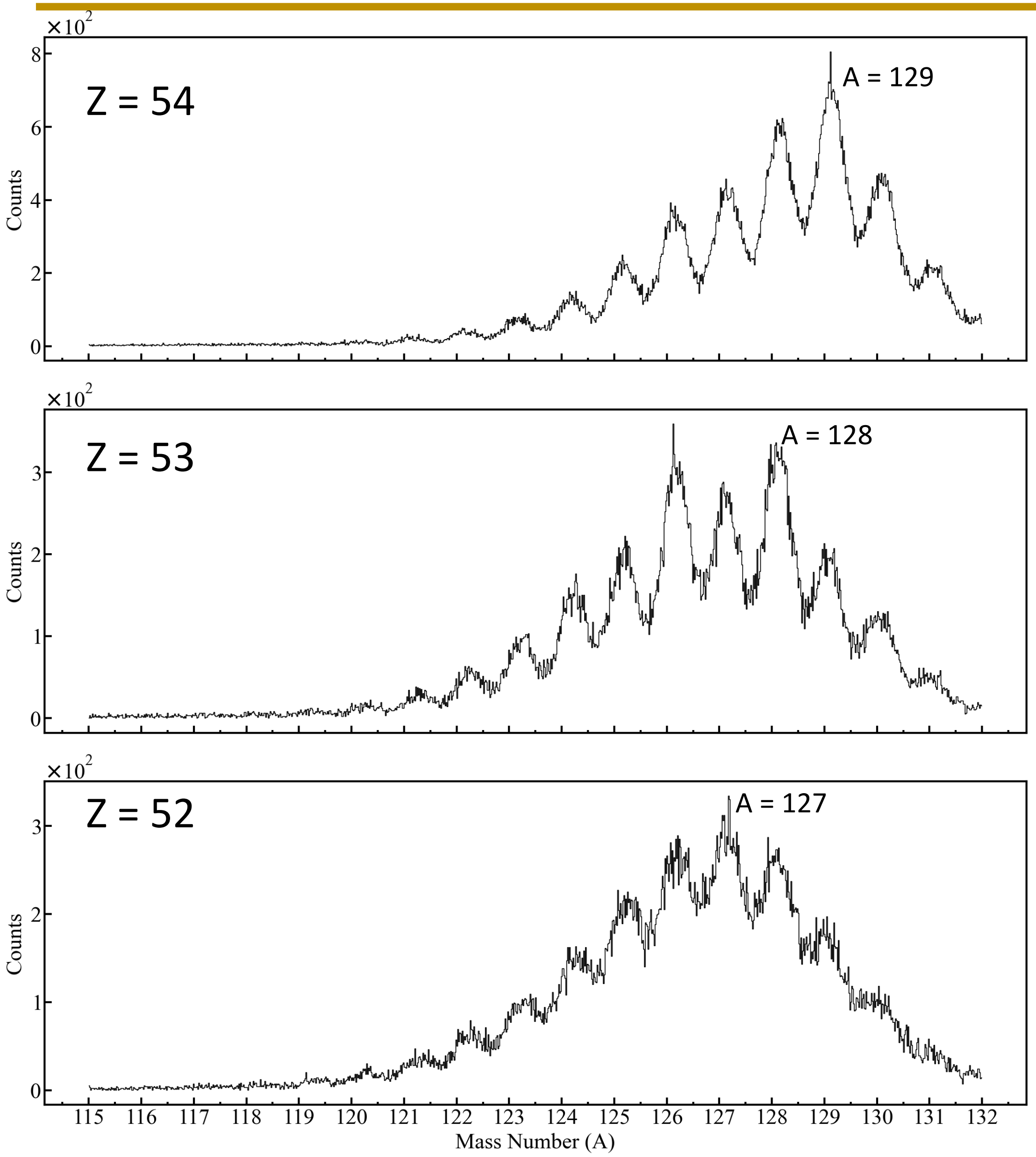
EXP 22.096 – PRISMA Calibration – Mass Selection All Runs After Run 115



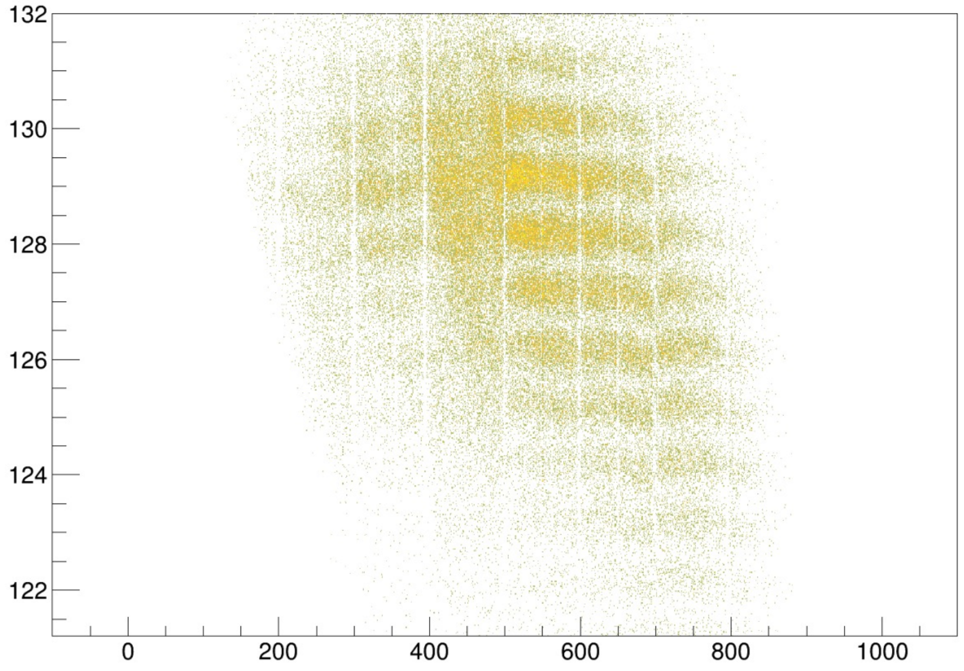
- Overall mass resolution not great, more optimisation needed?
- 2D Plot of Mass vs X_Fp for Z = 54 shows poor resolution in X_Fp 0 – 500 mm stemming from A/q



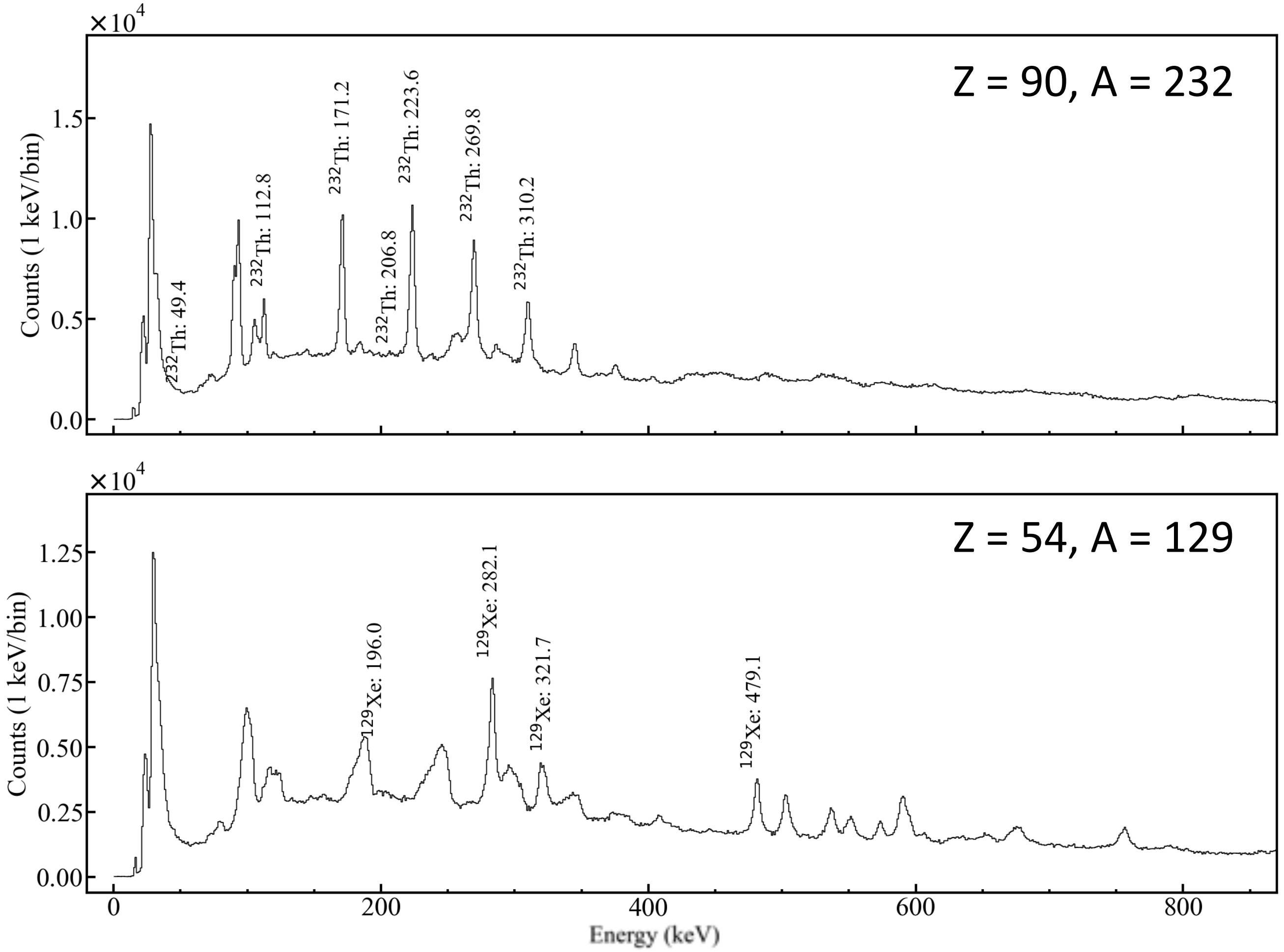
EXP 22.096 – PRISMA Calibration – Mass Selection Run 115 Only



- Original calibration performed only on Run 115 then extended to all other runs
    - Could do calibration run-by-run
- Mass resolution looks better here

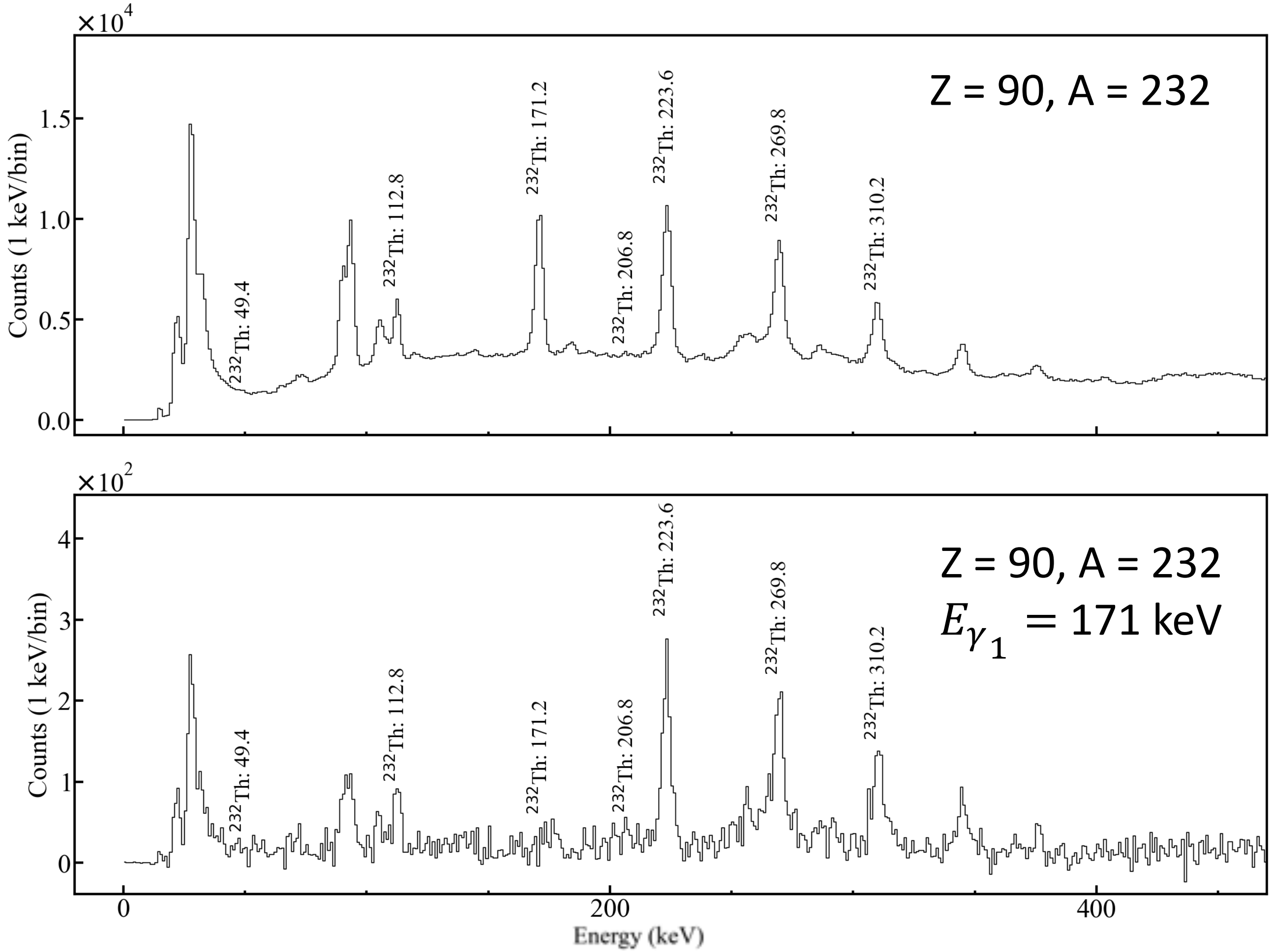


EXP 22.096 – PRISMA Calibration – Gamma Rays Z = 54



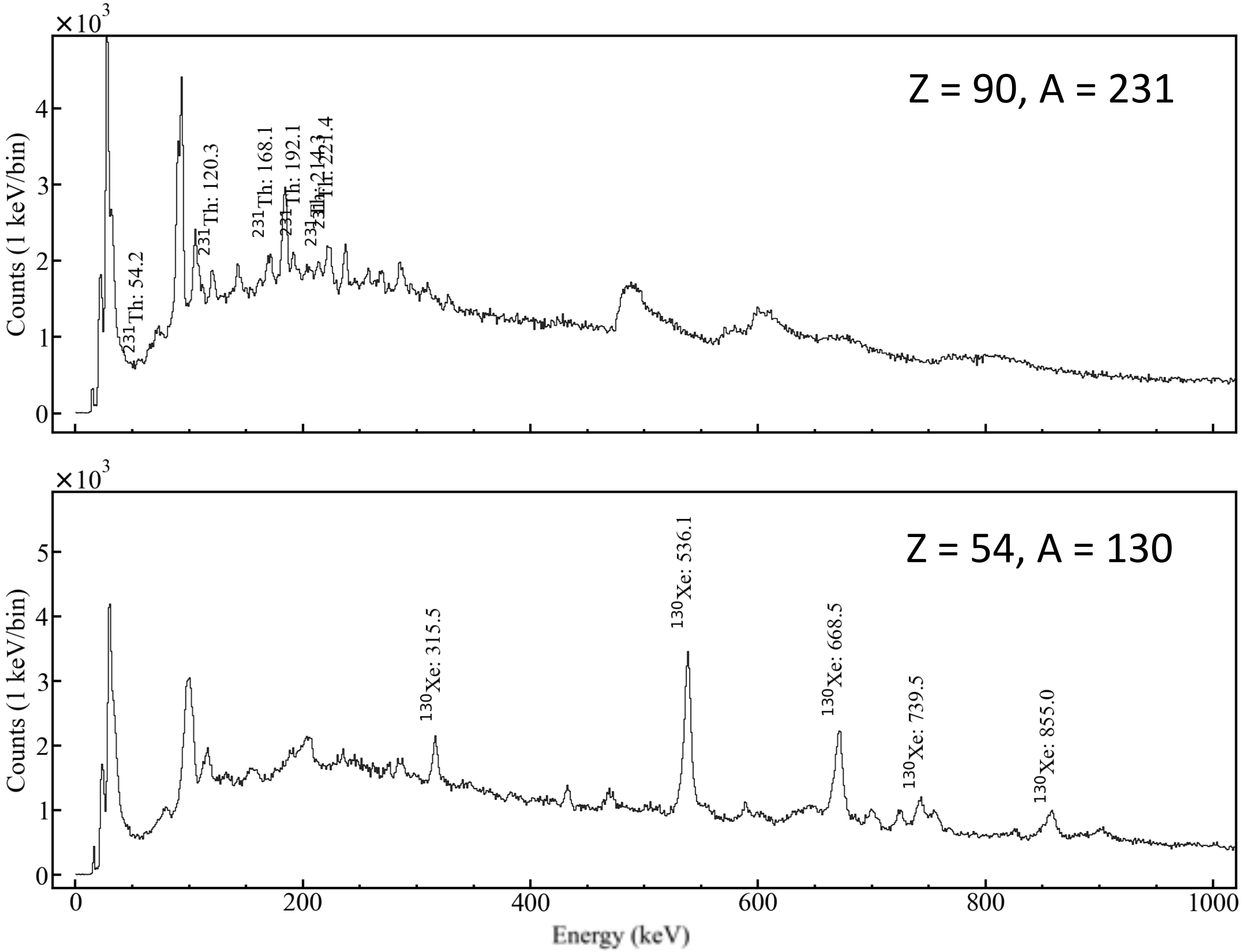
- Elastic scatters first
- Resolution looks reasonable
- Event-by-event Doppler correct working for both beam and target-like products

EXP 22.096 – PRISMA Calibration – Gamma Rays Z = 54, $\gamma\gamma$ performance



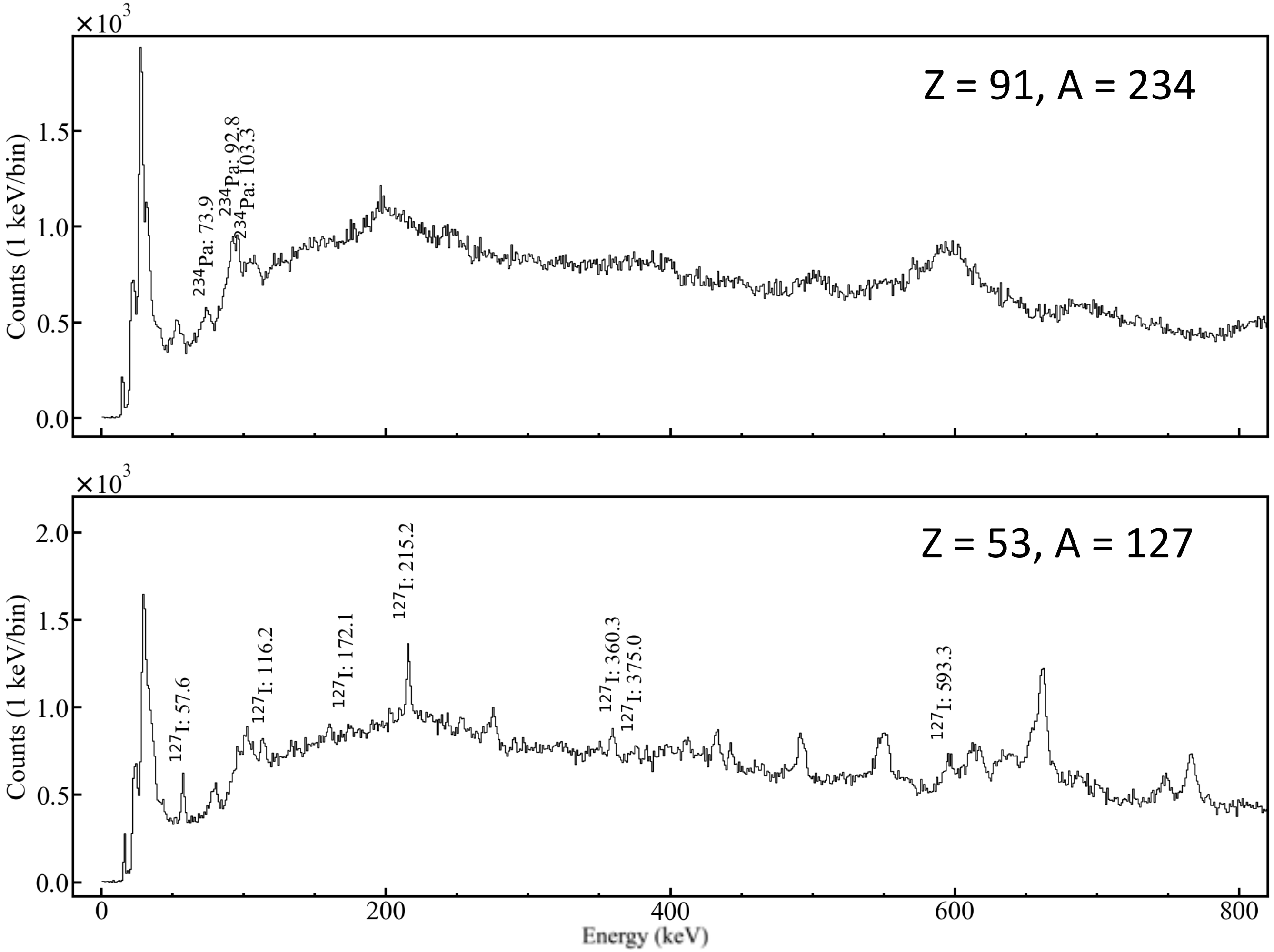
- $\gamma\gamma$ matrix looks very clean
- Placed gate at 10+ -> 8+ transition (270 keV) with 15,000 counts.
- Measured 8^+ -> 6^+ transition (224 keV) with 909 counts, adjusted to 2,065 counts considering internal conversion (0.44, BRICC).
- **Resulting efficiency: ~13%**

EXP 22.096 – PRISMA Calibration – Gamma Rays Z = 54



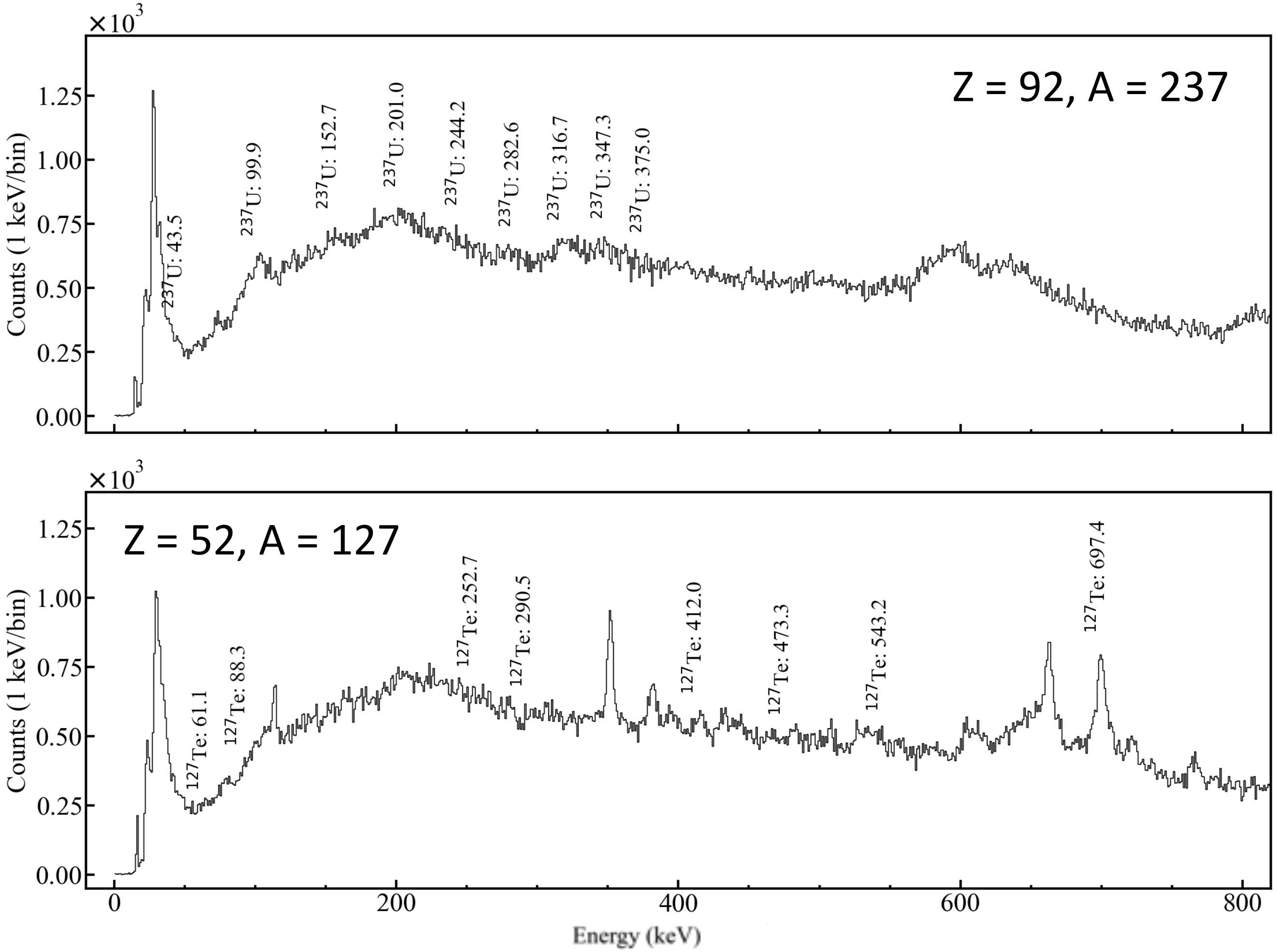
- Now we look at one-neutron transfer
- Clearly identified partners, but lots of background creeping in for the TLP.

EXP 22.096 – PRISMA Calibration – Gamma Rays Z = 53



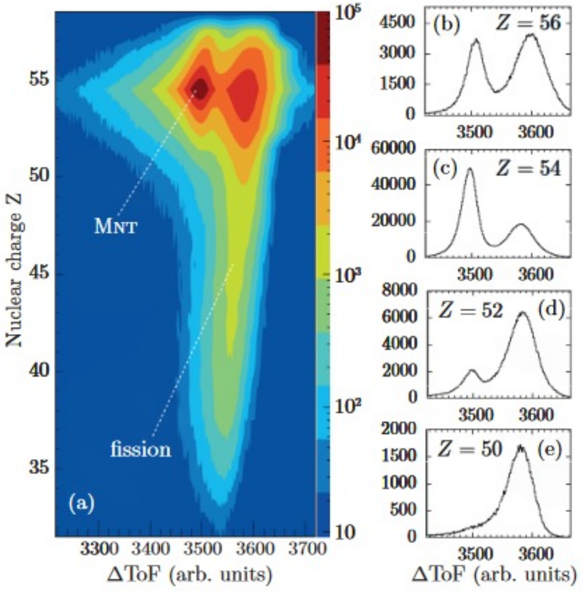
- Now we start looking at proton transfer channels
- Harder to identify the gammas because of the more intense background.

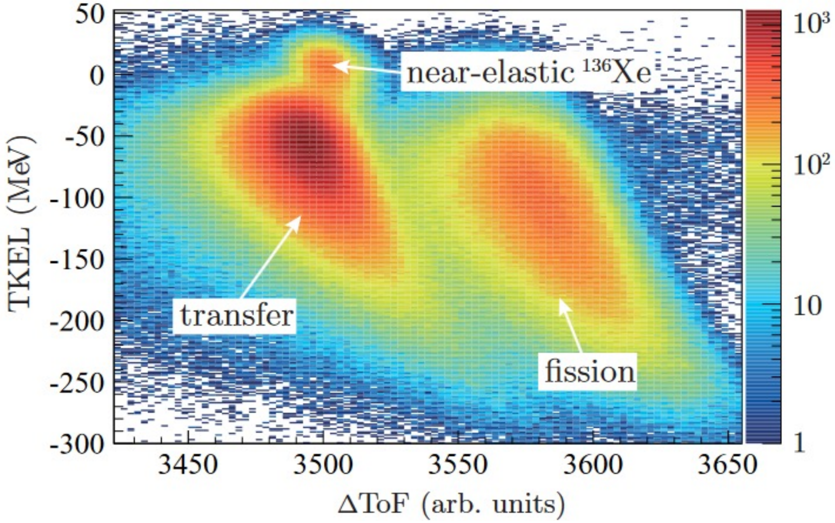
EXP 22.096 – PRISMA Calibration – Gamma Rays Z = 52



- Moving further away it is becoming increasingly hard to verify if the spectra are correct.
- Labelled gammas limited to “yrast” only from ENSDF database – other strong peaks in the BLP spectrum not labelled – what are these?
- Spectrum for TLP just background – needs cleaning. Small hint maybe of 99.9 keV gamma.

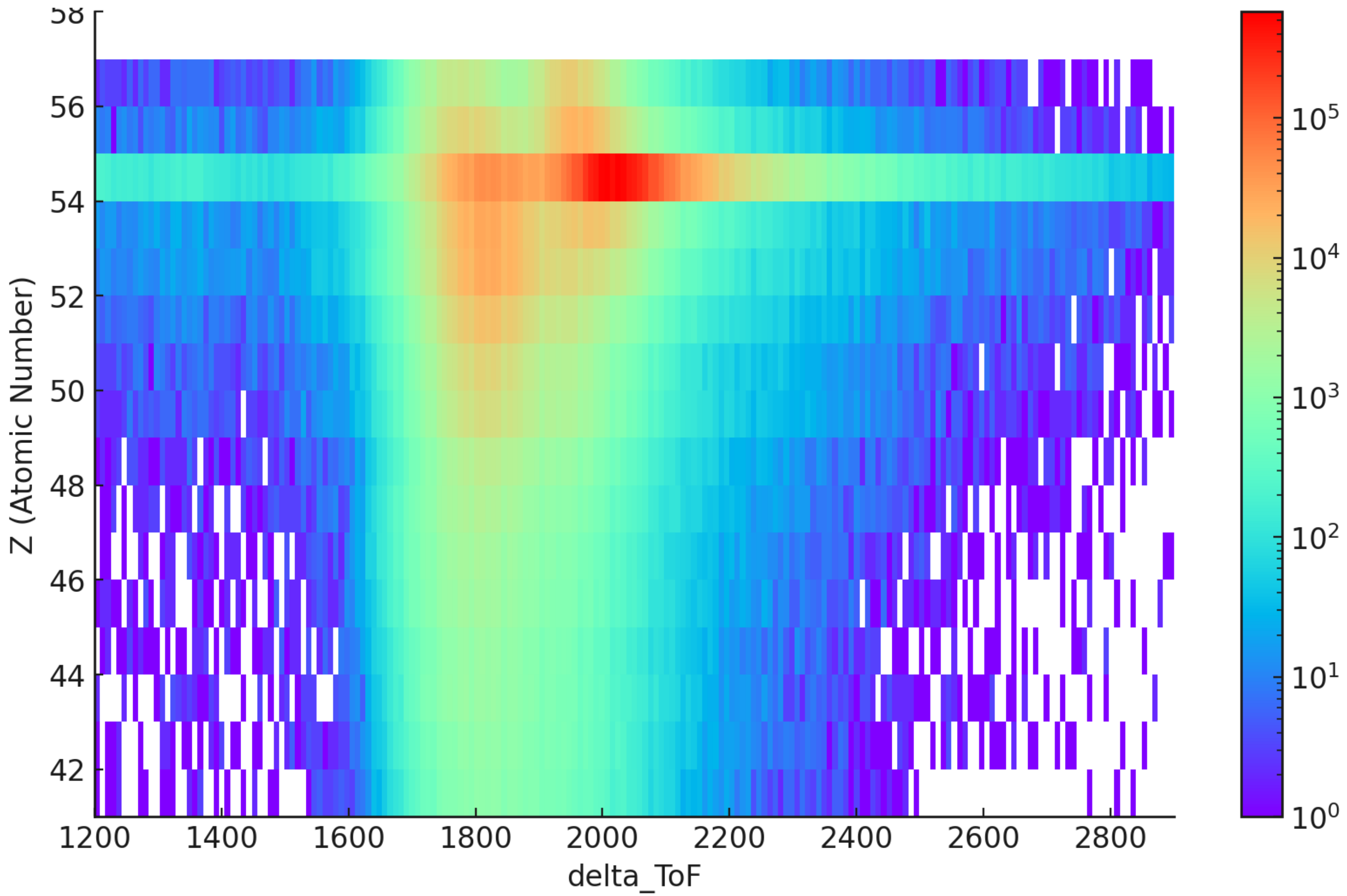
EXP 22.096 – PRISMA Calibration – Next Steps..



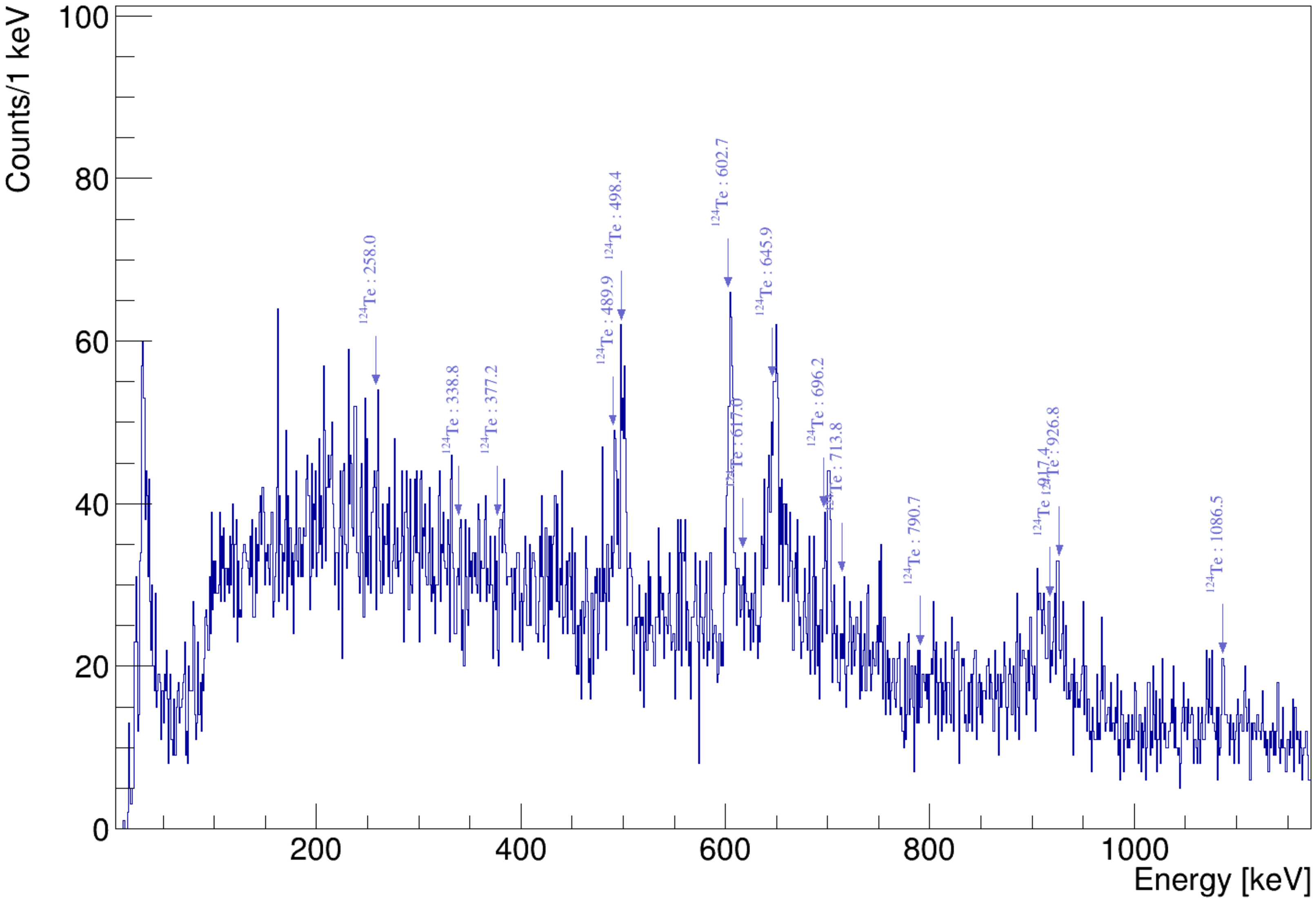


- The plots are from PhysRevC.92.024619 and show clear fission-MNT separation.
- The crucial separation comes from the ΔToF variable, which arises because of the different velocities of the beam-like MNT products compared to the fission products.

EXP 22.096 – PRISMA Calibration – Very Preliminary Stuff!!



EXP 22.096 – PRISMA Calibration – Very Preliminary Stuff!!



EXP 22.096 – Conclusion

- Move mass gates make sure everything is labelled correctly, EDCBP correct
- Change analysis to new selector from PrismaFilters, use the optimisation procedure on the PRISMA optical parameters
- Profit

Thanks For Listening!

Decay-out of the oblate, triaxial and highly-deformed bands in ^{136,137}Nd

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Special thanks to Alain, Javier, Daniele, Ksennia, Pablo, Hamid who put up with my many emails!

Search for octupole structures in the light U, Th and Pa isotopes via Multinucleon Transfer

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