EXPERIMENTS ON THE SPONTANEOUS FISSION OF CM-248 USING THE FISSION SPECTROMETER VERDI

UPPSALA UNIVERSITET

*A. Al-Adili *, A.M. Gómez L., S. Oberstedt, D. Tarrío, A. Solders, S. Pomp, C.L. Fontana, W. Geerts, M. Macías, M. Vidali, A. Oberstedt*

** Department of physics and astronomy, Uppsala University, Sweden*

JRC EUROPEAN COMMISSION

APRENDE

ARIEL

Vetenskapsrådet Swedish Research Council

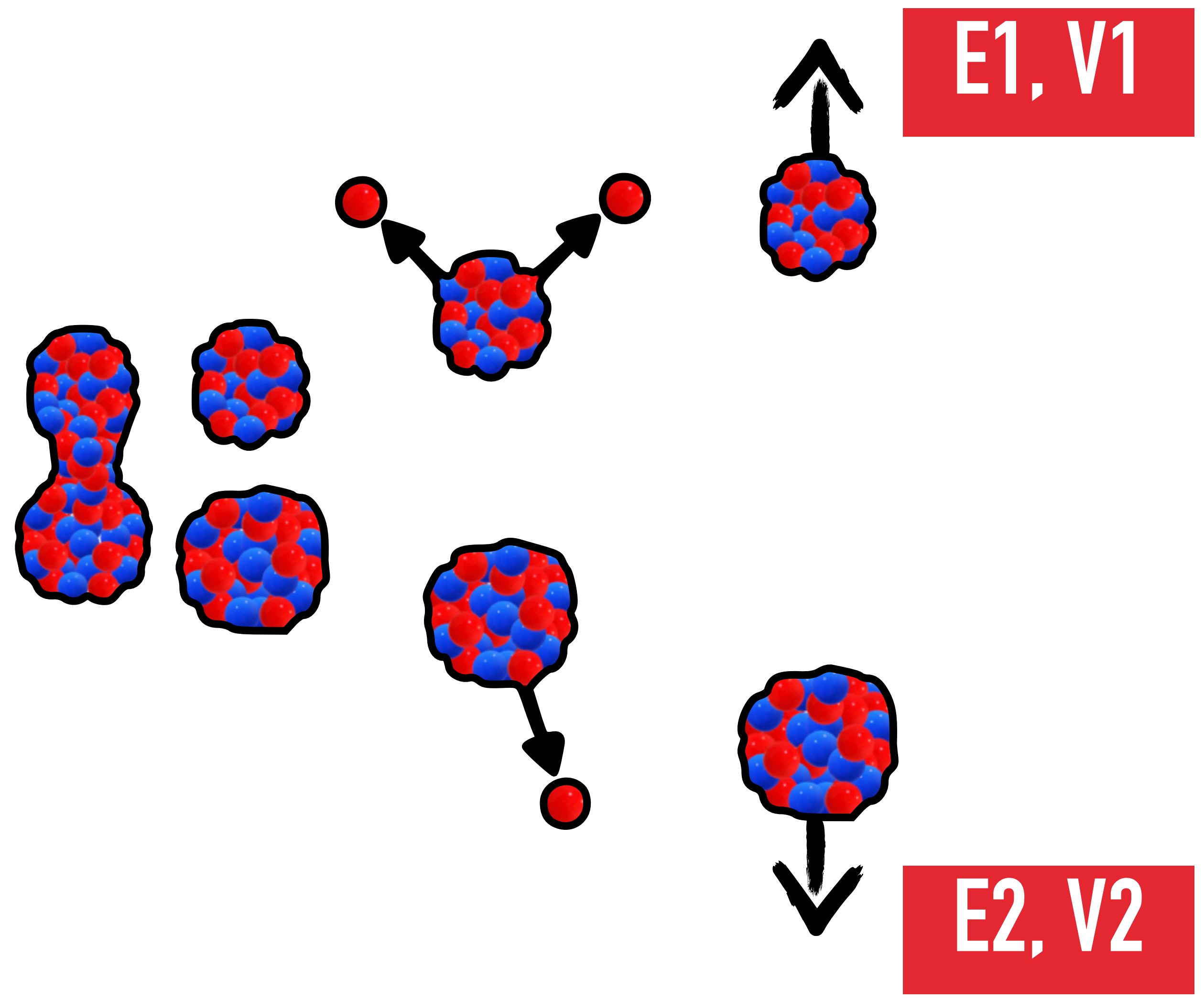
Energimyndigheten

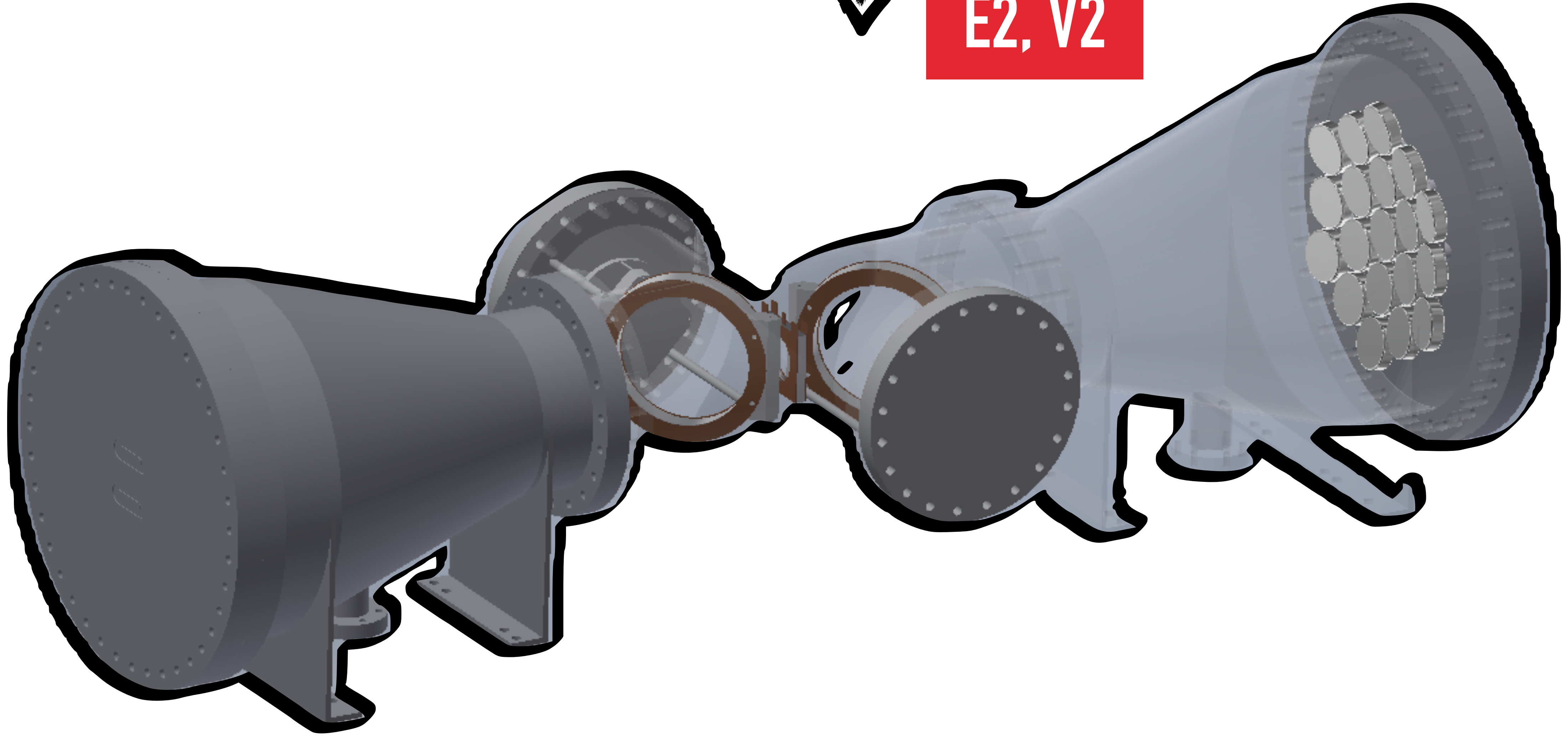
MÅSTE GEN 4 CLEAN POWER PRODUCTION

CARL TRYGGERS STIFTELSE FÖR VETENSKAPLIG FORSKNING

2E–2V FISSION YIELD INSTRUMENTS

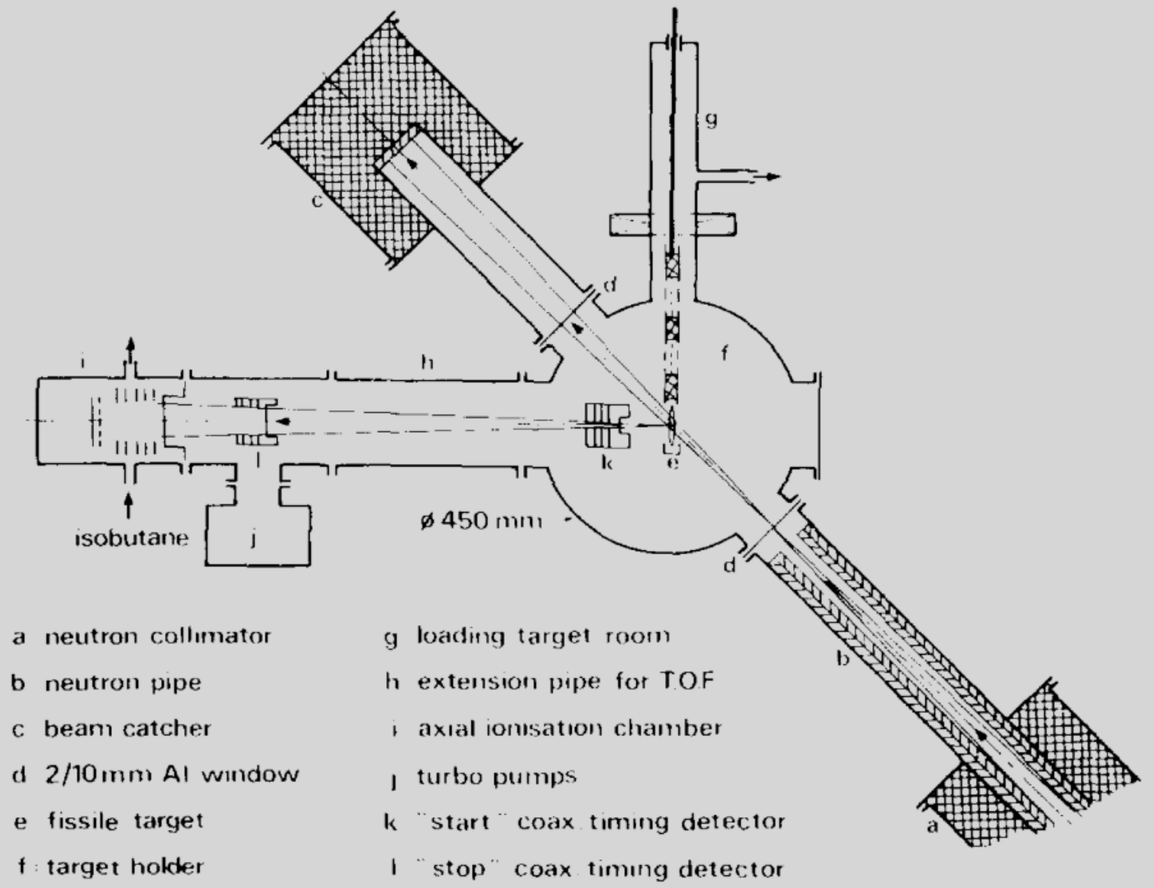
Mass resolution 1< σ_A < 2 u



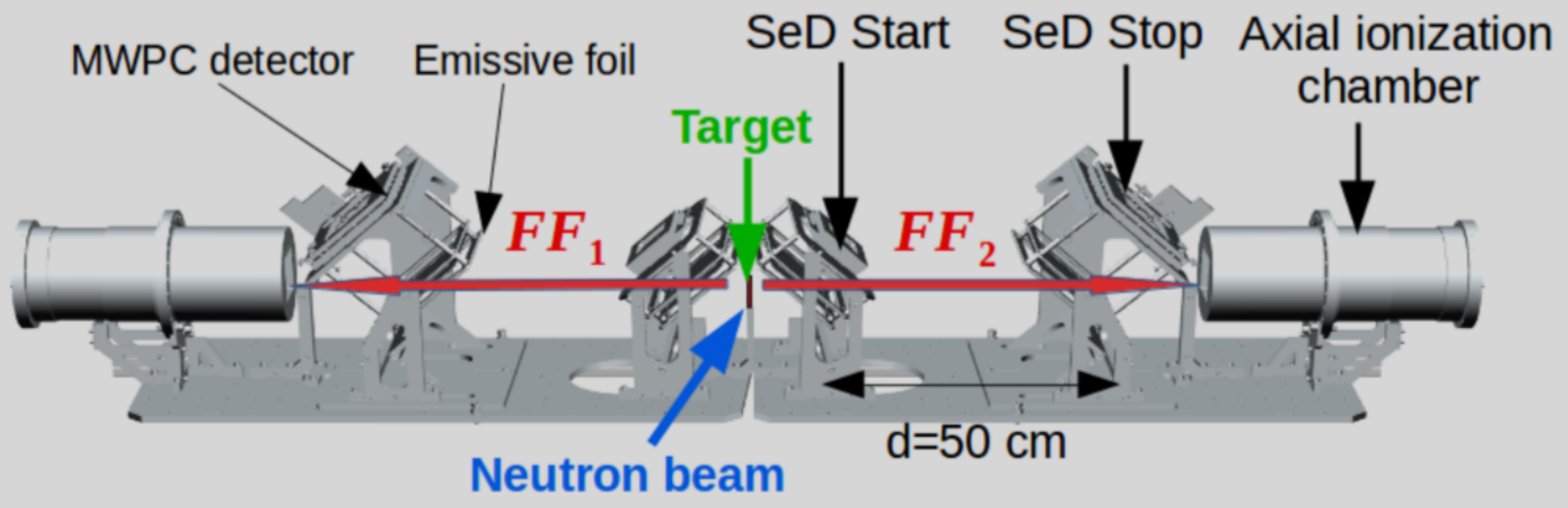


VERDI (VELOCITY FOR DIRECT PARTICLE IDENTIFICATION)

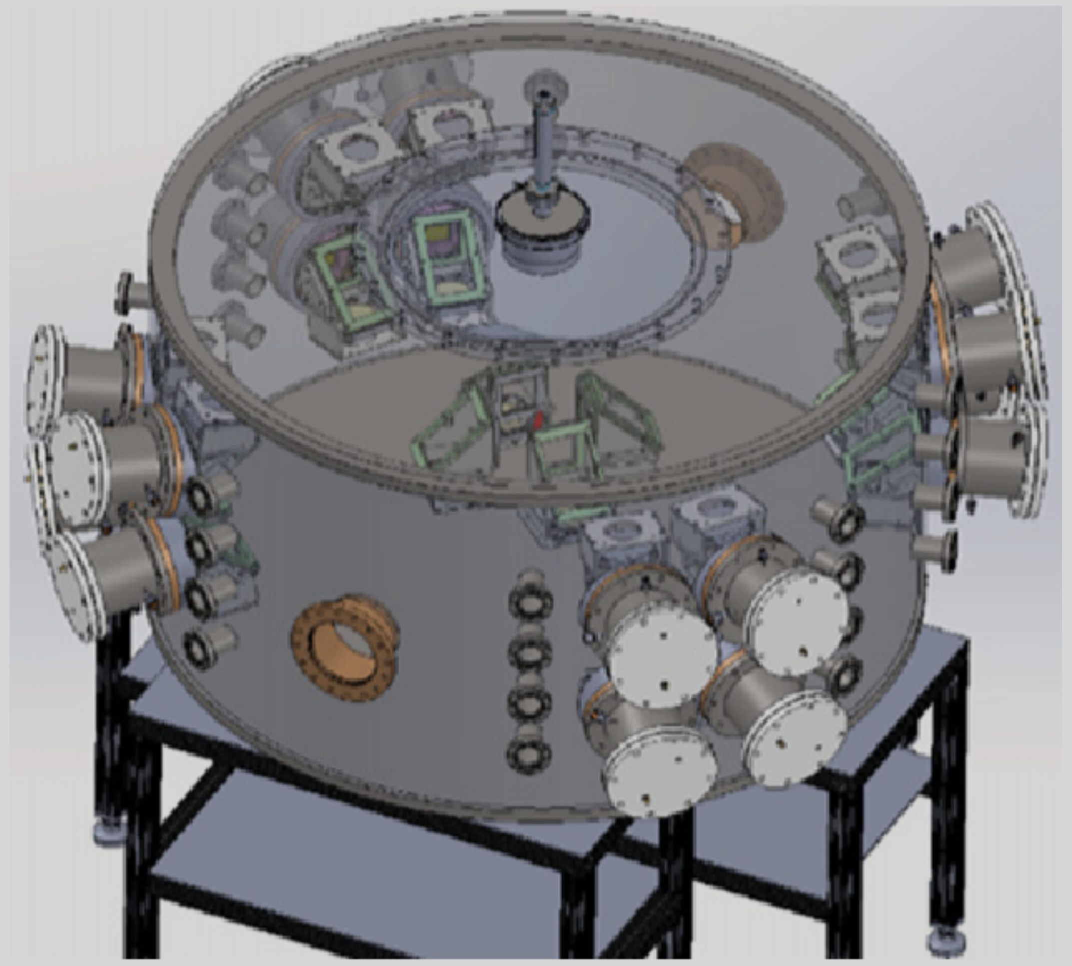
Cosi-Fan Tutte, ILL



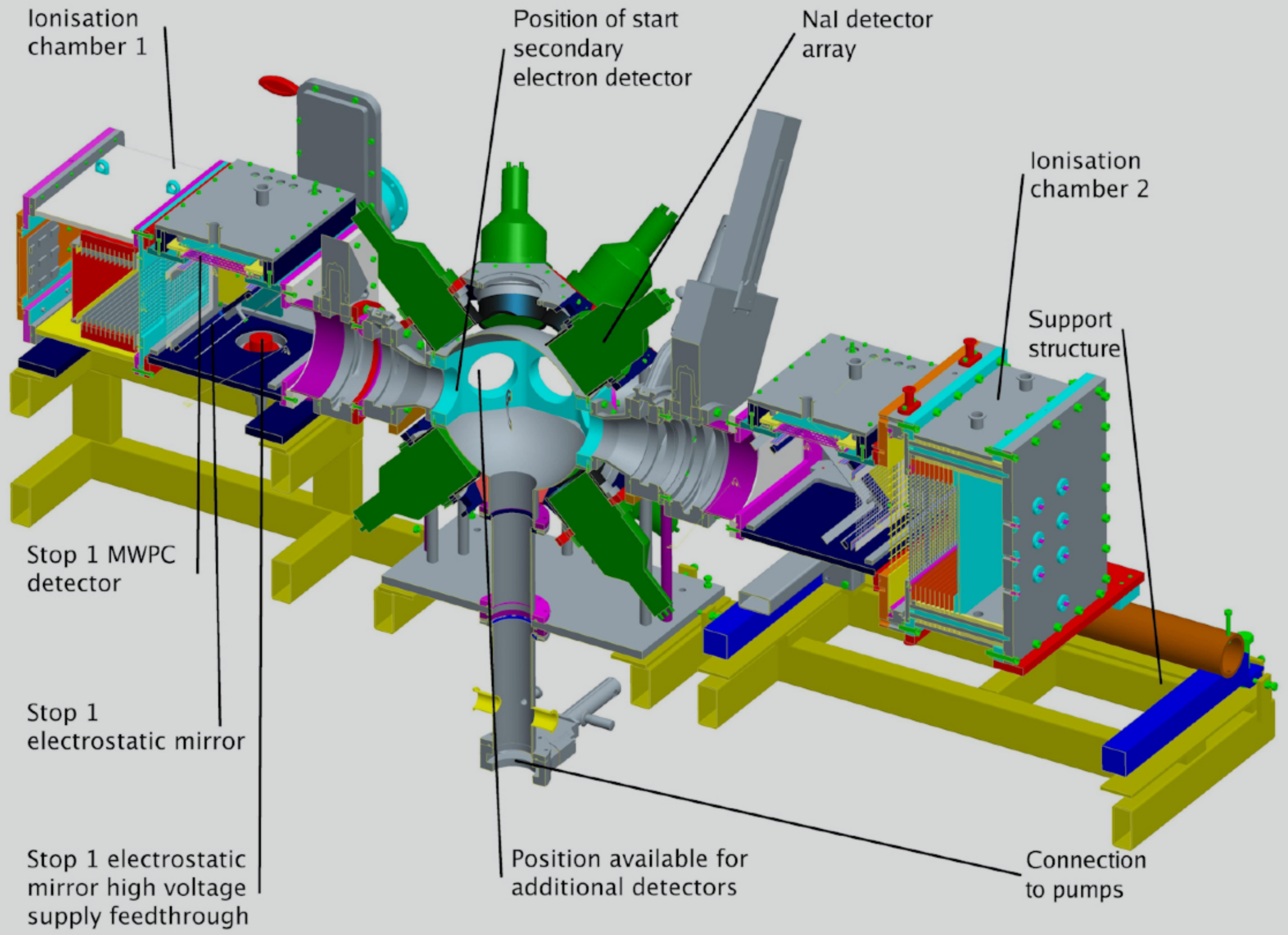
FALSTAFF, GANIL



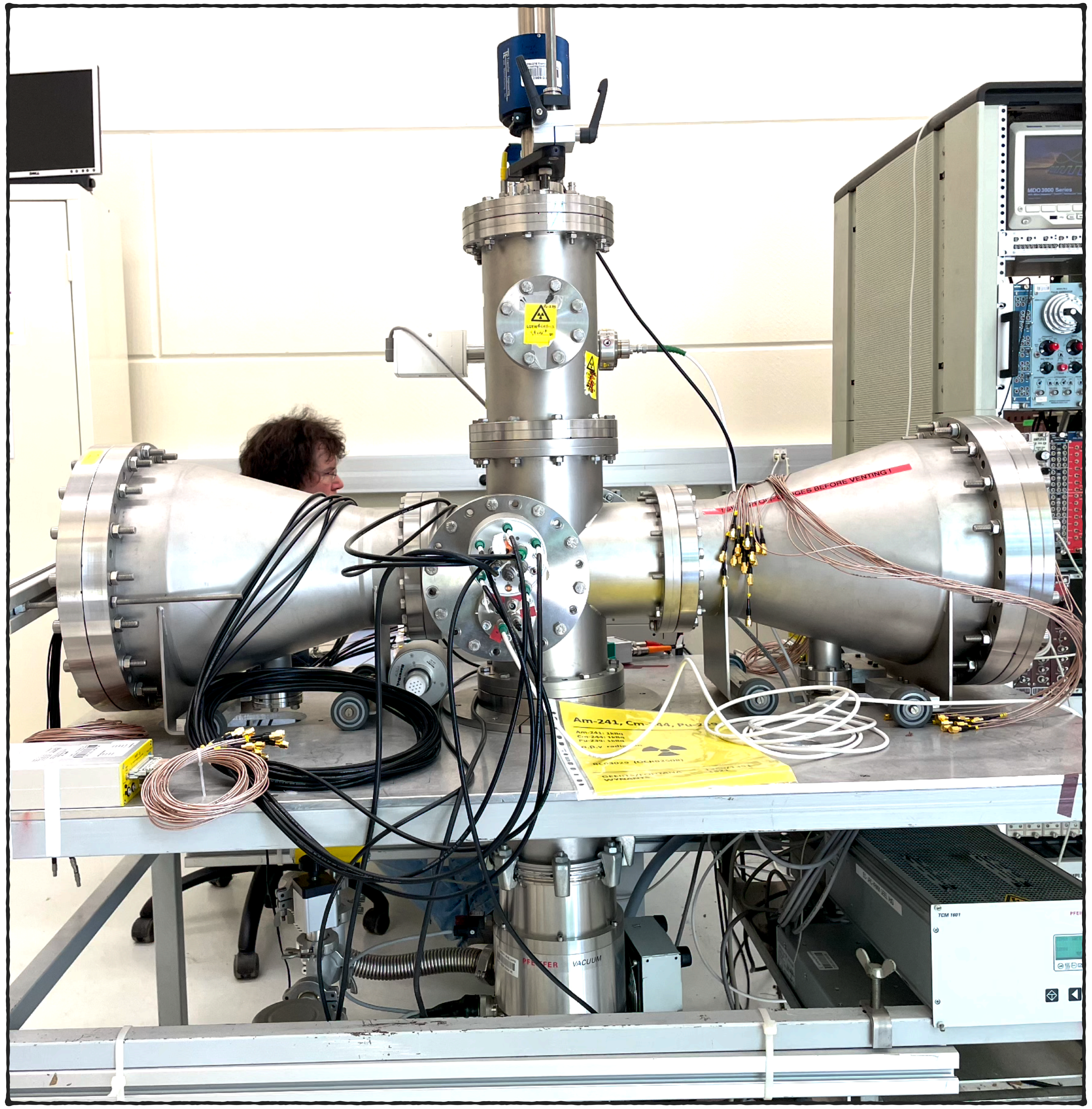
SPIDER, Los Alamos



STEFF, n_tof



VERDI (VELOCITY FOR DIRECT PARTICLE IDENTIFICATION)



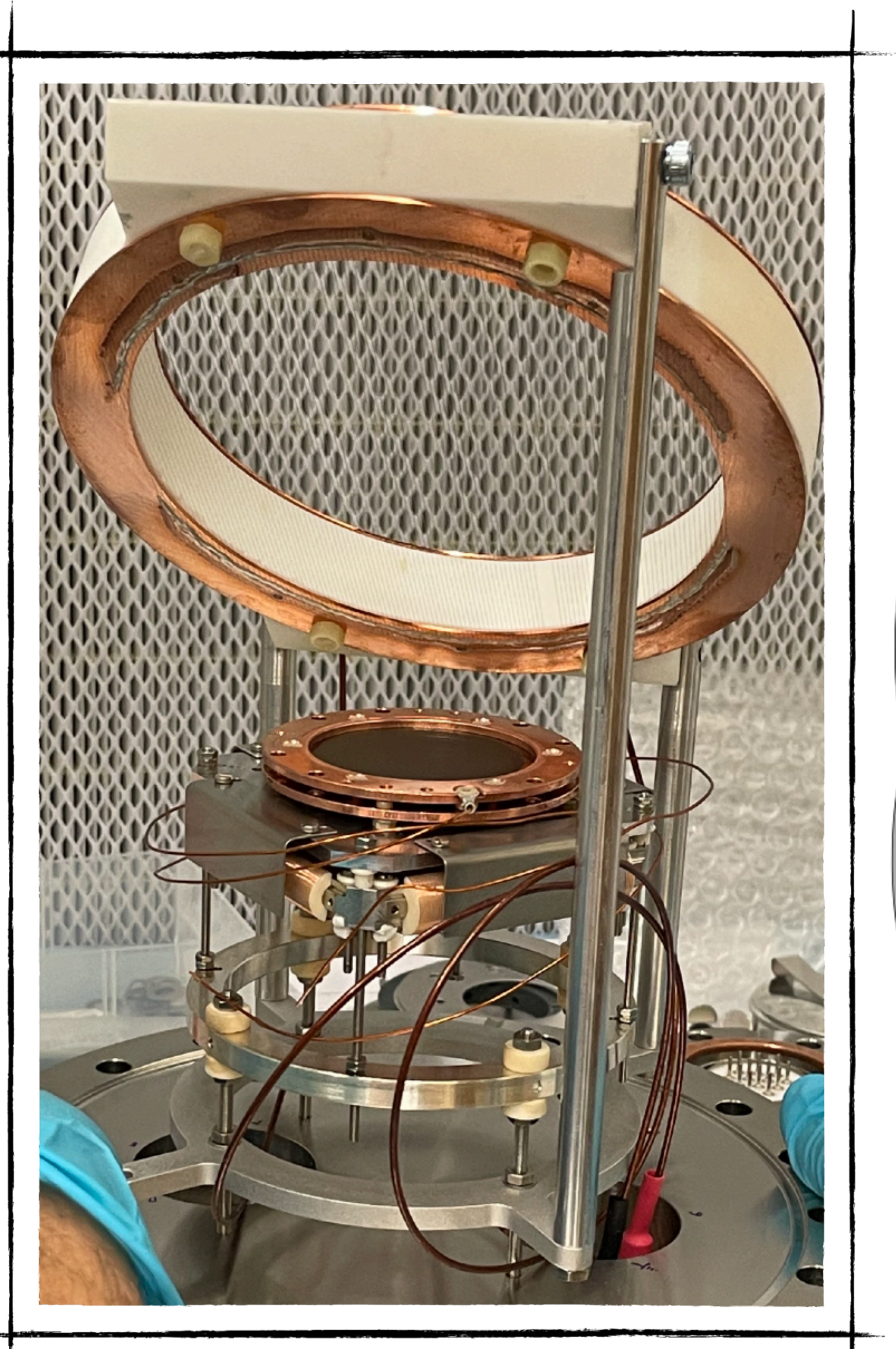
European Commission

JOINT RESEARCH CENTRE

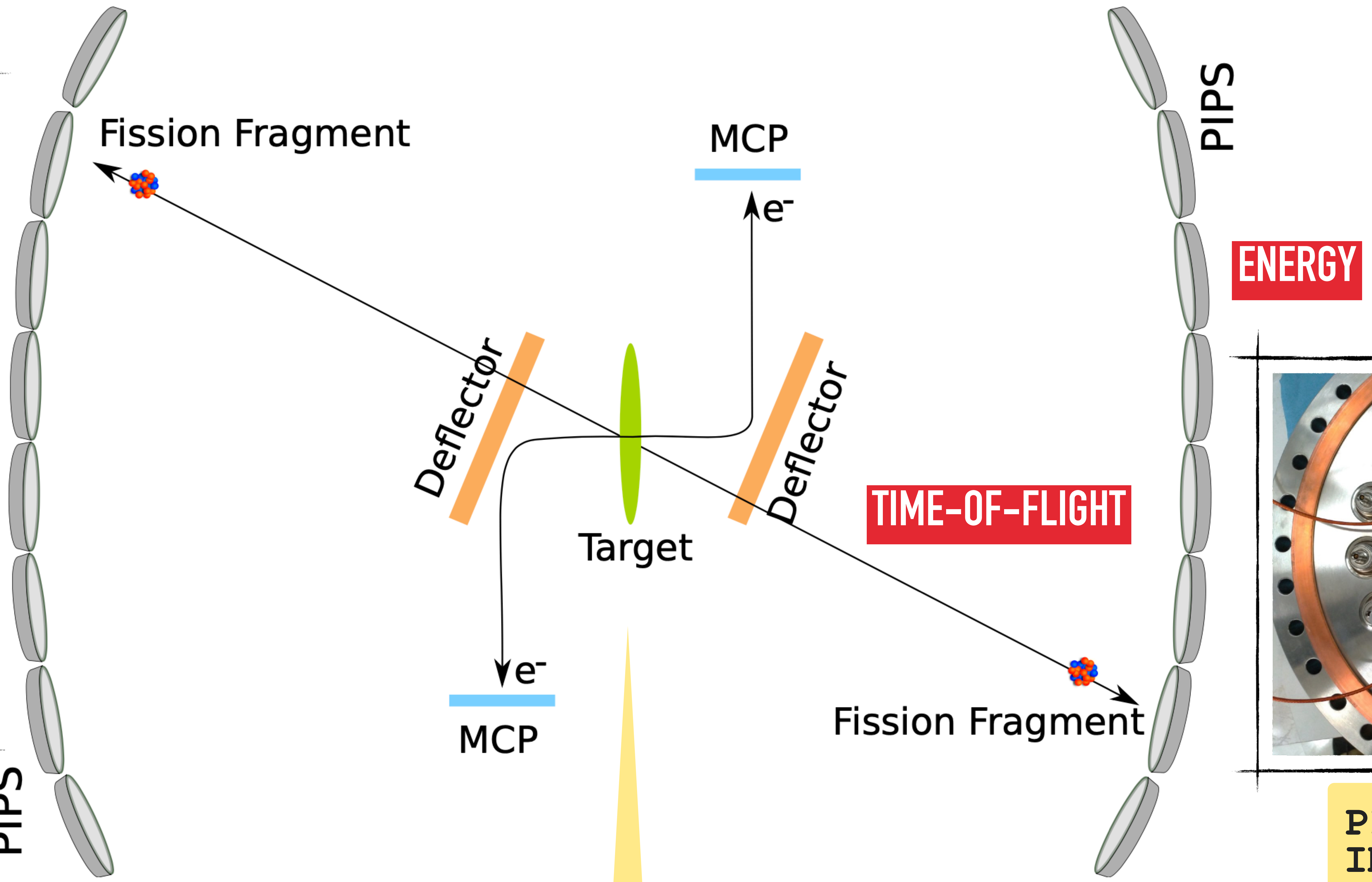
Ph.D. studnet Ana Maria Gomez Londoño

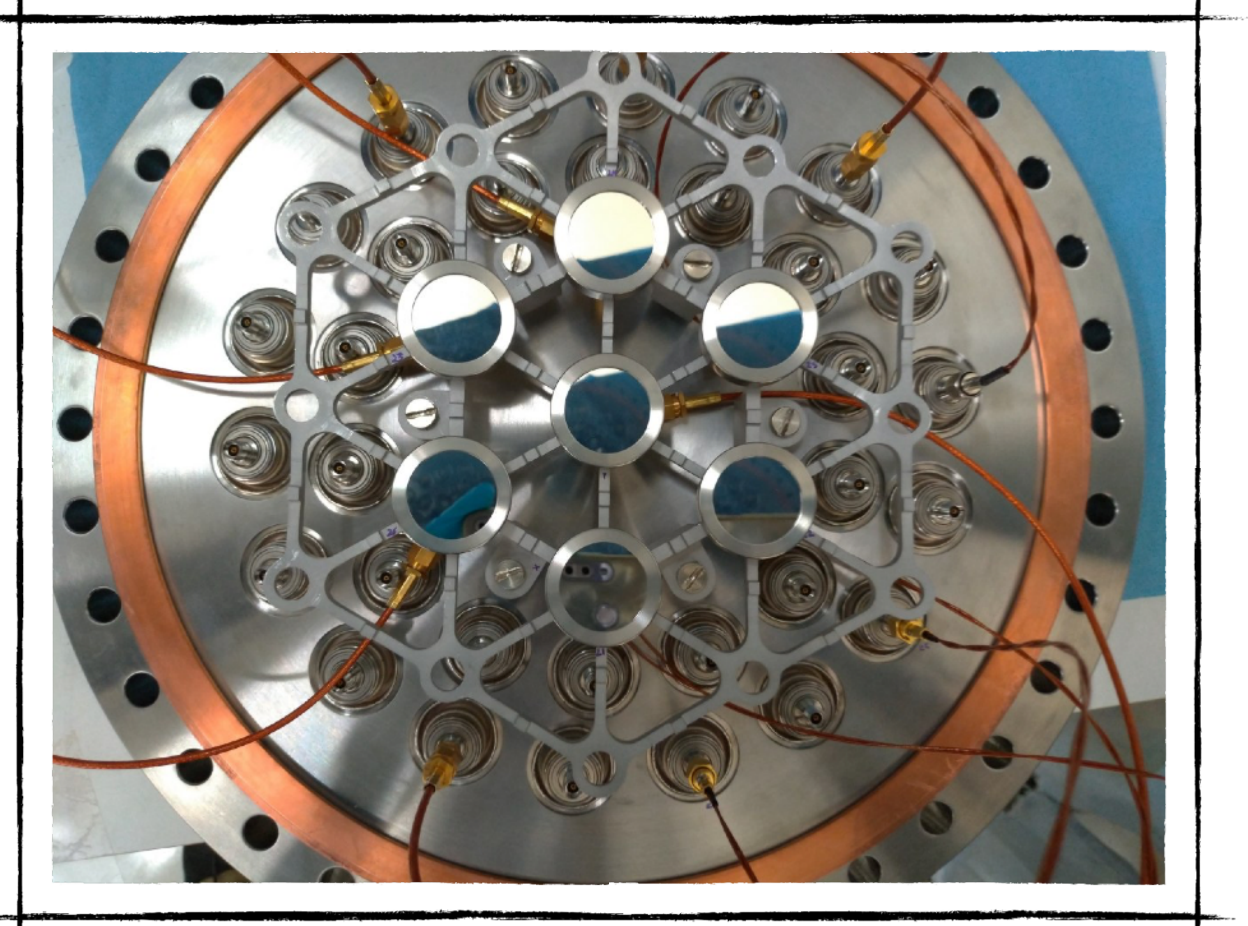
MEASUREMENT TECHNIQUE

CARL TRYGGERS STIFTELSE
FÖR VETENSKAPLIG FORSKNING



MICRO CHANNEL PLATES

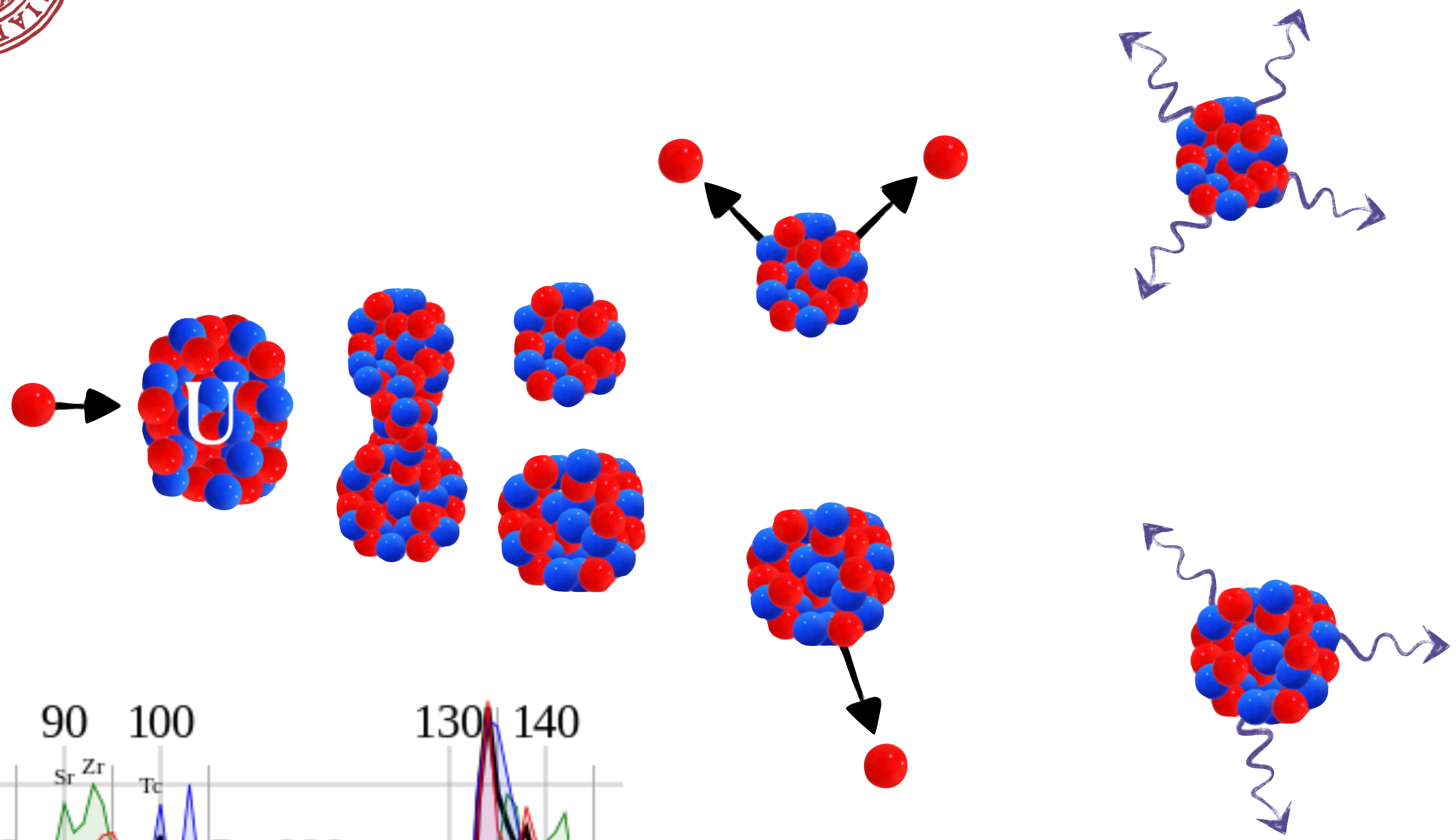


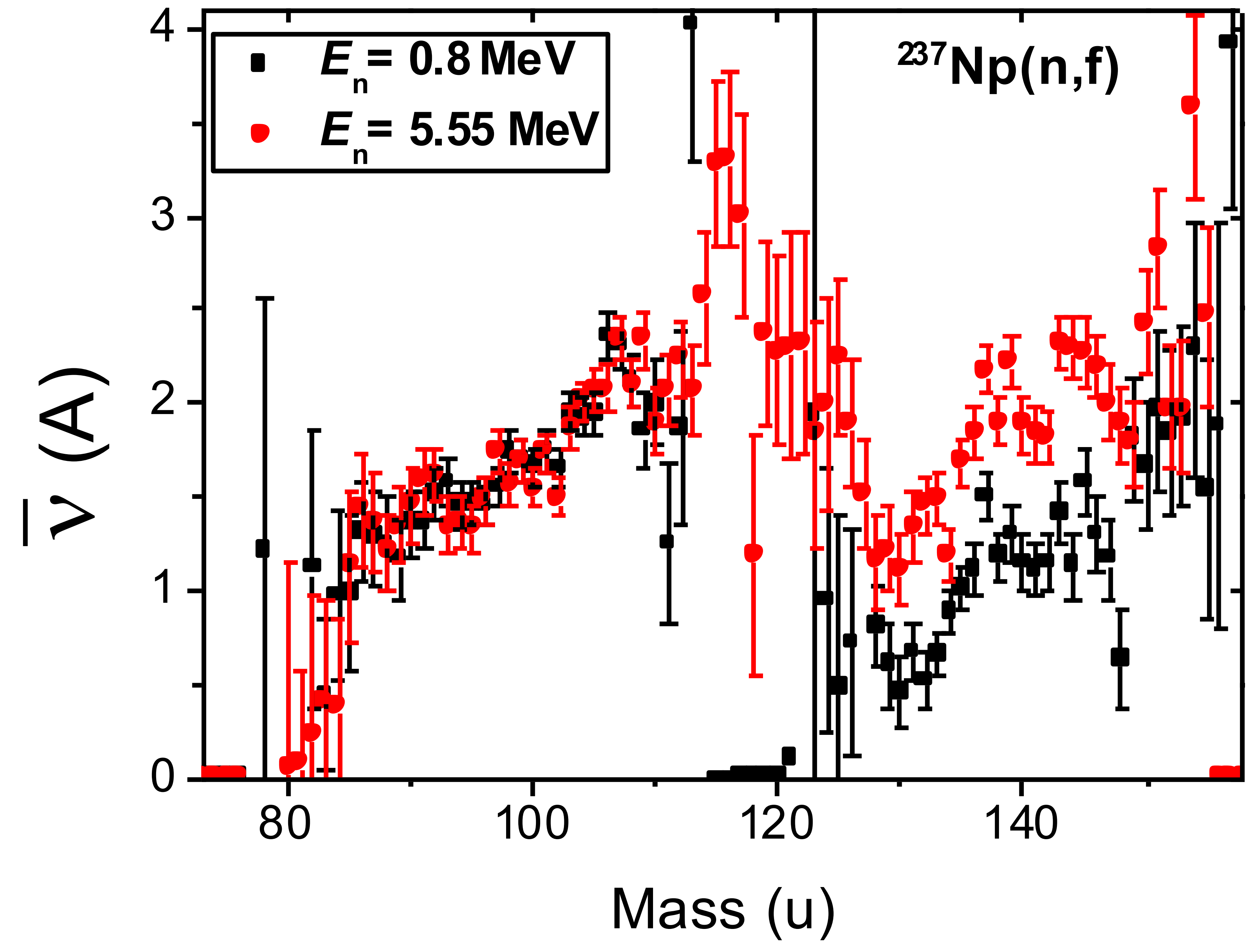


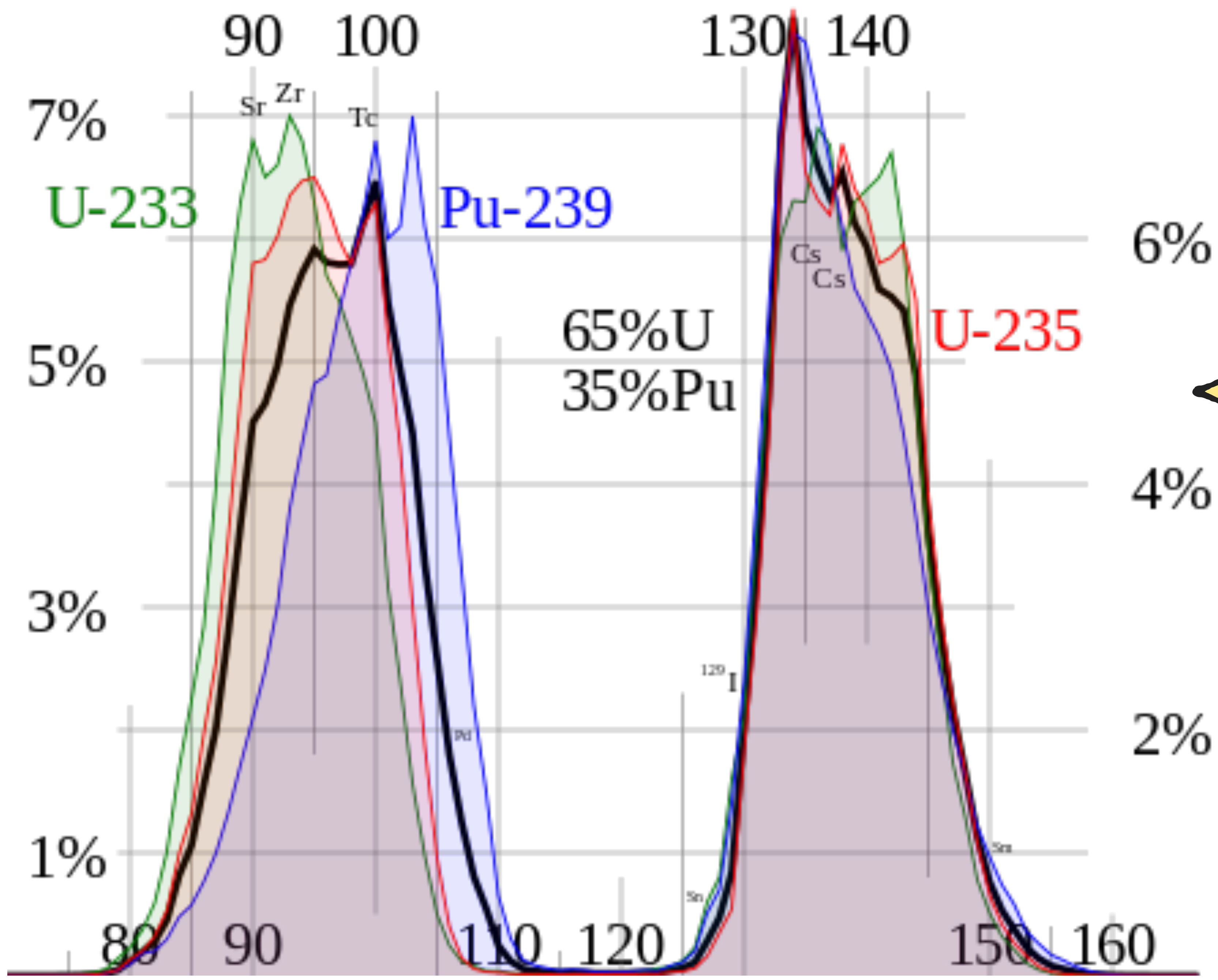
PIPS (PASSIVATED IMPLANTED PLANAR SILICON) DETECTORS

START TIME BY USING THE SUPPORT FOIL OF THE ACTINIDE DEPOSIT ITSELF AS ELECTRON-EMISSIVE FOIL.

WHAT WE CAN MEASURE







FISSION YIELDS

PRE-NEUTRON EMISSION

POST-NEUTRON EMISSION

KINETIC ENERGY DISTRIBUTIONS

& TERNARY FISSION!

NUBAR(A) →
EXCITATION ENERGY
SHARING!

KINEMATICS

- Calculate the pre-neutron emission mass from the velocities:

$$m_{1,2}^{pre} = m_{CN} \frac{v_{2,1}^{cm}}{v_1^{cm} + v_2^{cm}}$$

BASED ON:
- CONSERVATION OF MOMENTUM
- CONSERVATION OF MASS
- ISOTROPIC EMISSION OF NEUTRONS IN CM REFERENCE FRAME

- Calculate the post-neutron mass and thus $\bar{\nu}(A)$ from the measured energy and velocity

$$m^{post} = \frac{2E_{post}}{v_{post}^2}$$

$$\bar{\nu}(A) = m_{pre} - m_{post}$$

KINEMATICS

- Calculate the pre-neutron emission mass from the velocities:

$$m^{pre}_{1,2} = m_{CN} \frac{v^{cm}_{2,1}}{v^{cm}_{1} + v^{cm}_{2}}$$

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$$m^{post} = \frac{2E_{post}}{v^{2}_{post}}$$

$$\bar{\nu}(A) = m_{pre} - m_{post}$$

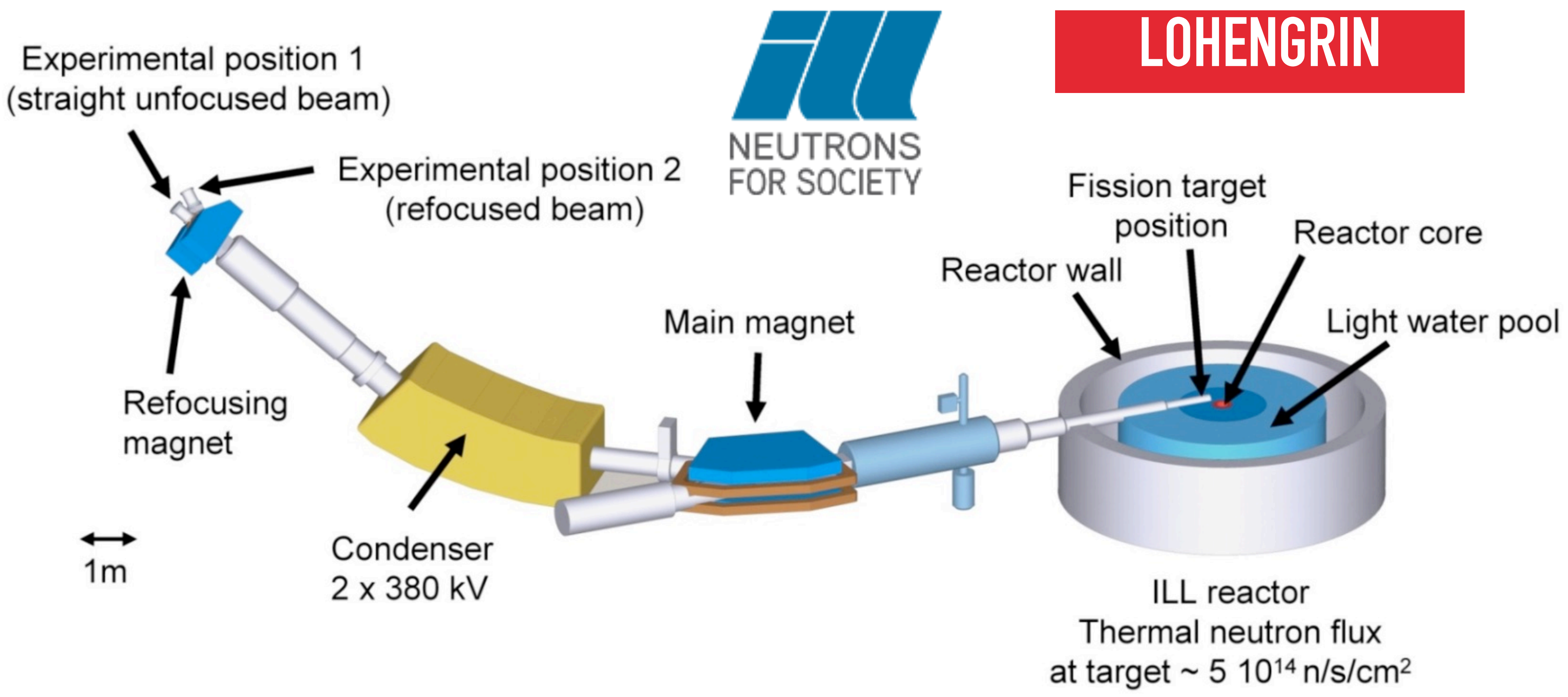
Mass yield resolution given by:

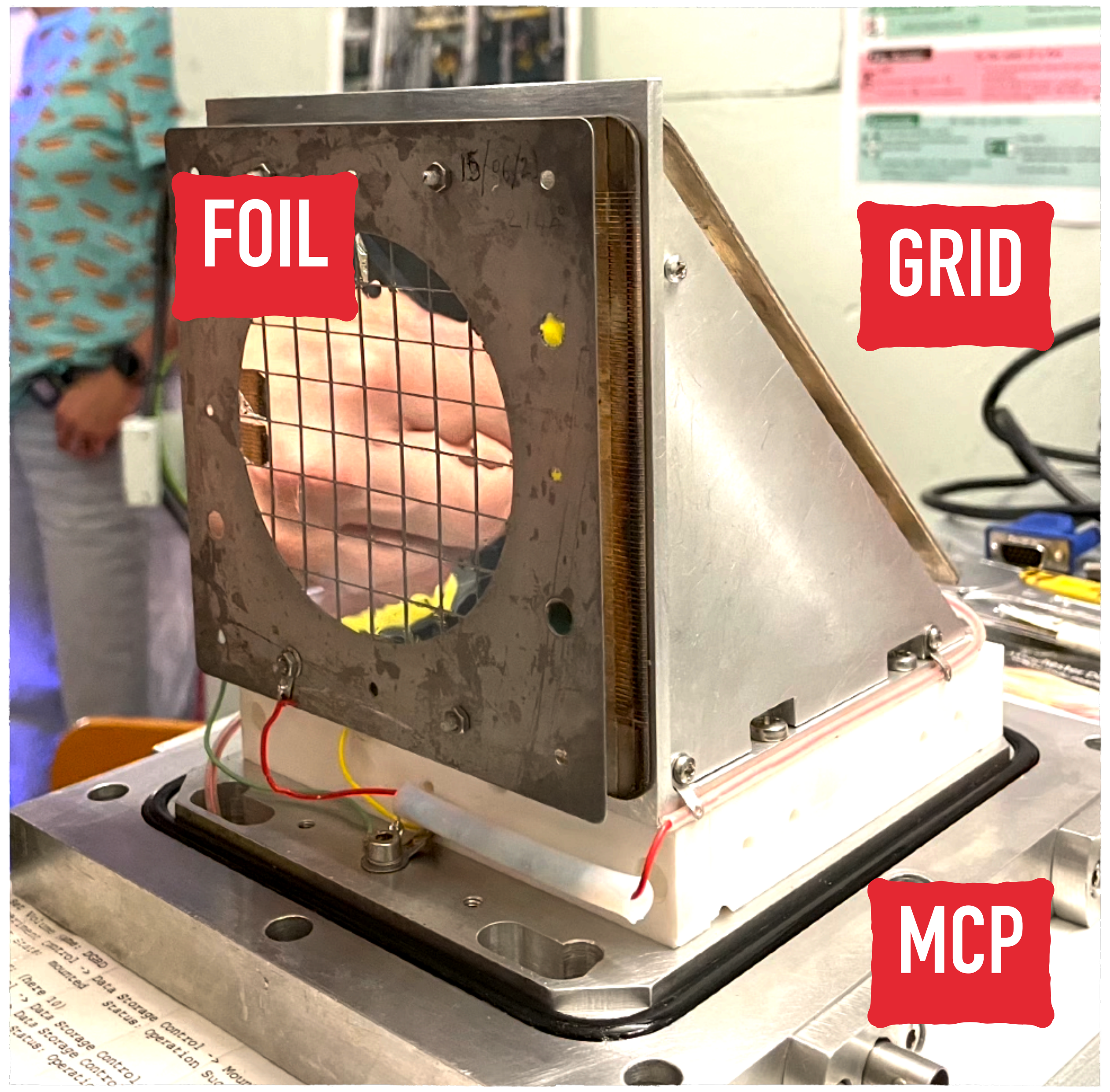
$$\frac{\Delta m}{m} = \sqrt{\left(\frac{\Delta E}{E}\right)^2 + 4\left(\frac{\Delta t}{t}\right)^2 + 4\left(\frac{\Delta d}{d}\right)^2}$$

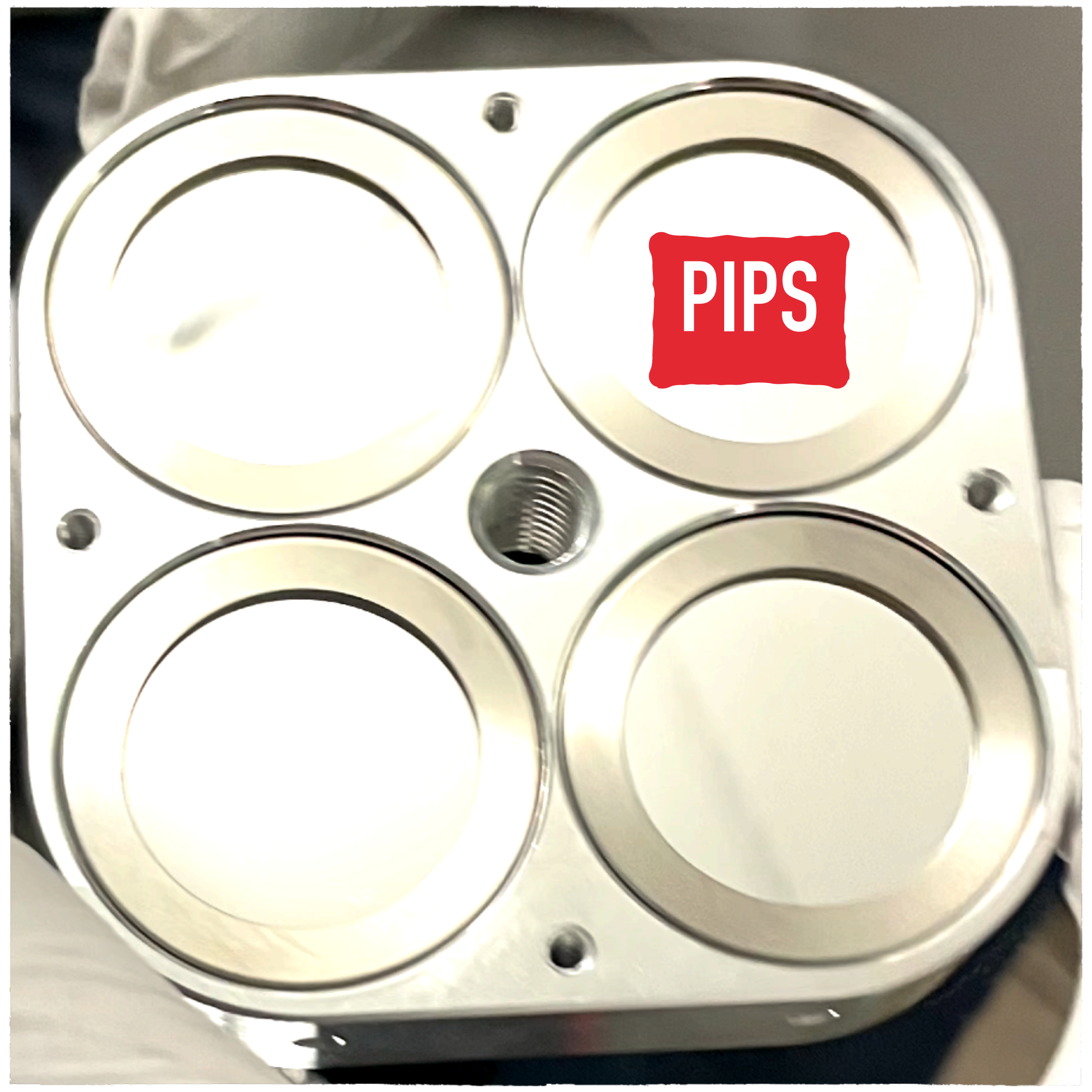
We need a TOF resolution around 200 ps (FWHM) and ΔE/E = 0.3%

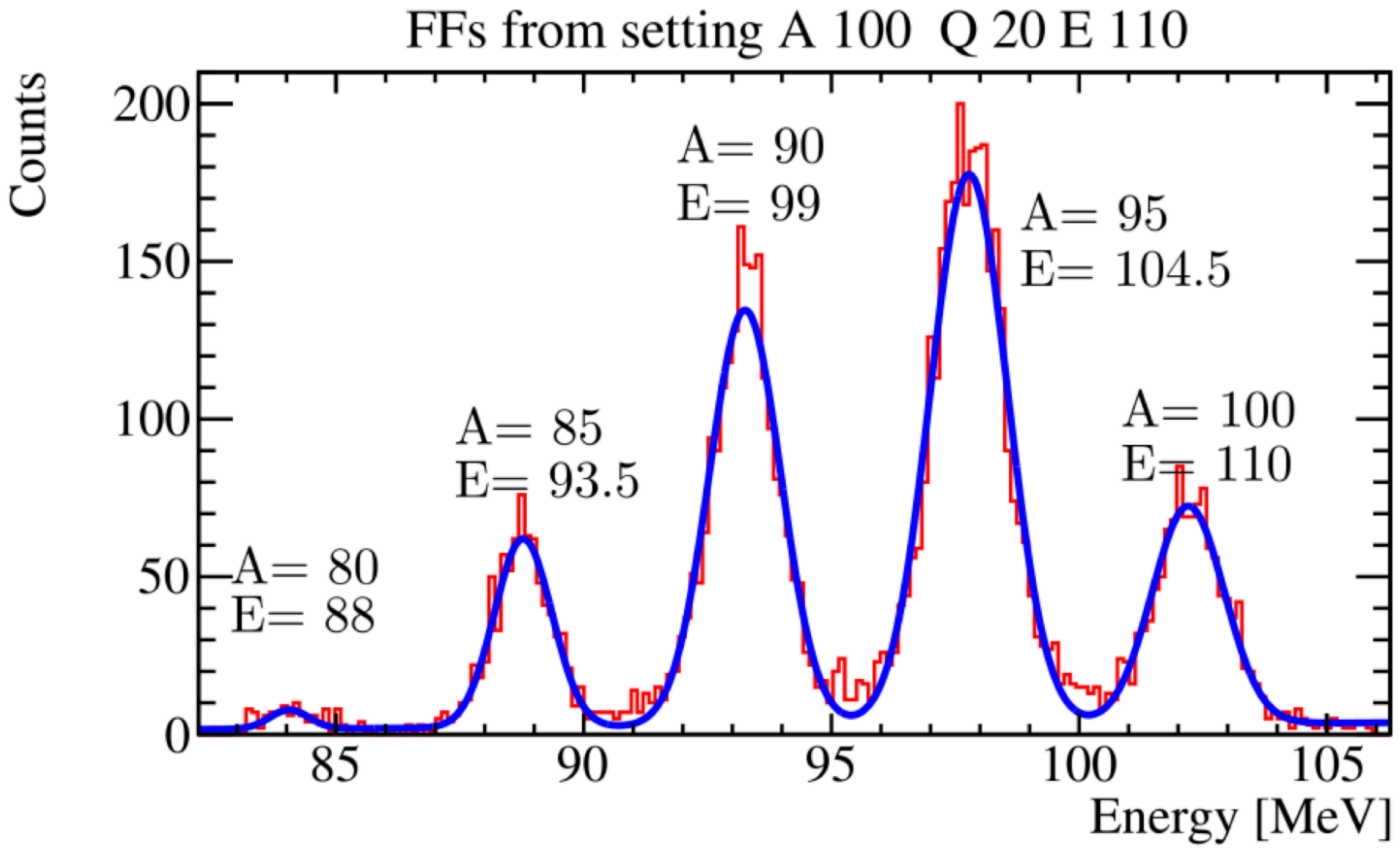
CHALLENGE: TIME AND ENERGY CORRECTIONS

TO STUDY THE TIMING AND ENERGY RESPONSE OF OUR PIPS DETECTORS!









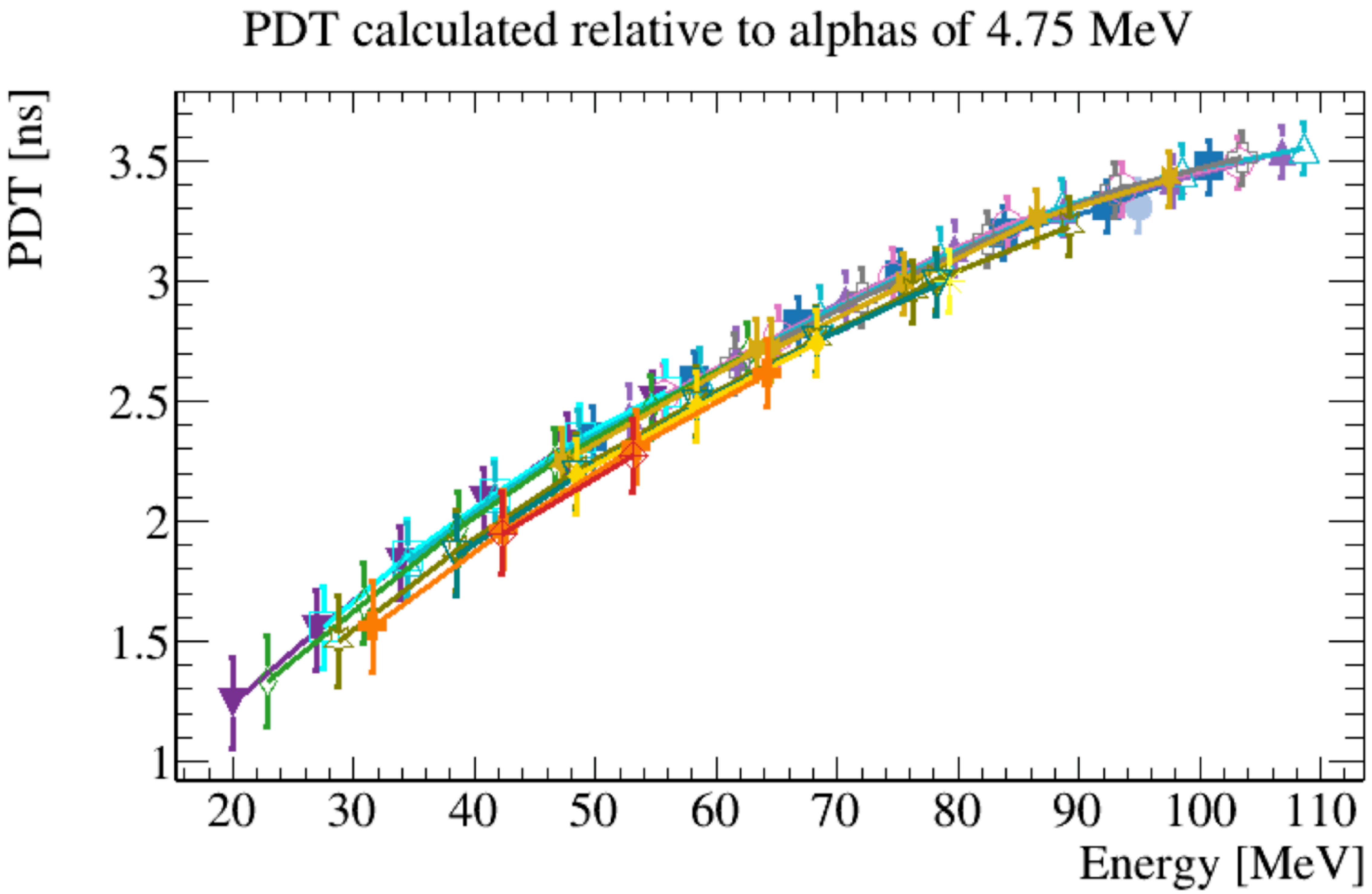
LOHENGRIN RESULTS

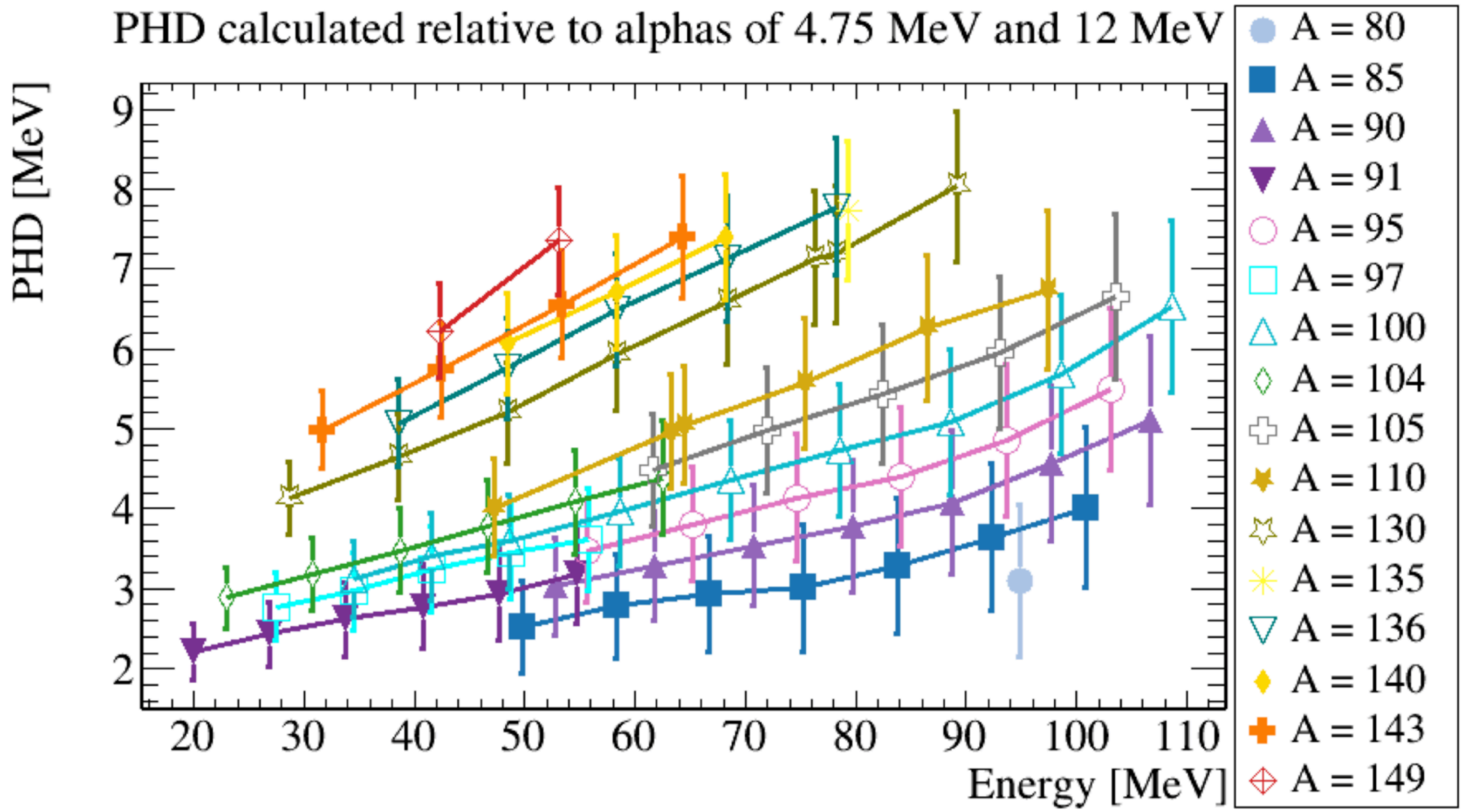
Energy and mass dependencies of the Plasma delay time (PDT) and the Pulse Height Defect (PHD) in PIPS

Eur. Phys. J. A (2025) 61:51
https://doi.org/10.1140/epja/s10050-025-01509-5
THE EUROPEAN PHYSICAL JOURNAL A
Check for updates
Regular Article - Experimental Physics

Plasma-delay studies on heavy ion detection using PIPS at the LOHENGRIN recoil separator

Ana M. Gómez L. [1,a], Ali Al-Adili[1,b], Diego Tarrío[1], Andreas Solders[1], Zhihao Gao[1], Alf Göök[1], Stephan Pomp[1], André Poussette[1], Samuel Bennett[5], Yung Hee Kim[3], Ulli Köster[3], Andreas Oberstedt[6], Gavin Smith[5], Nikolay V. Sosnin[4,5], Stephan Oberstedt[2]

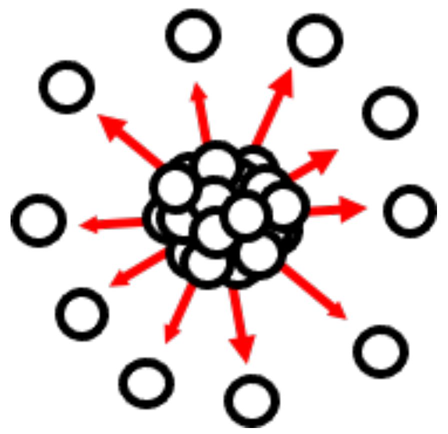




SIMULATION WORK REVEALING SOME ISSUES!

Artefact due to central assumption on unchanged fragment velocity

$$m_{1,2}^{pre} = m_{CN} \frac{v_{2,1}^{pre}}{v_1^{pre} + v_2^{pre}} \approx m_{CN} \frac{v_{2,1}^{post}}{v_1^{post} + v_2^{post}}$$



Eur. Phys. J. A (2018) **54**: 114
DOI 10.1140/epja/i2018-12544-0

THE EUROPEAN PHYSICAL JOURNAL A

Regular Article – Experimental Physics

The impact of neutron emission on correlated fission data from the 2E-2v method

Kaj Jansson[1], Ali Al-Adili[1,a], Erik Andersson Sundén[1], Alf Göök[2], Stephan Oberstedt[2], and Stephan Pomp[1]

SIMULATION WORK REVEALING SOME ISSUES!

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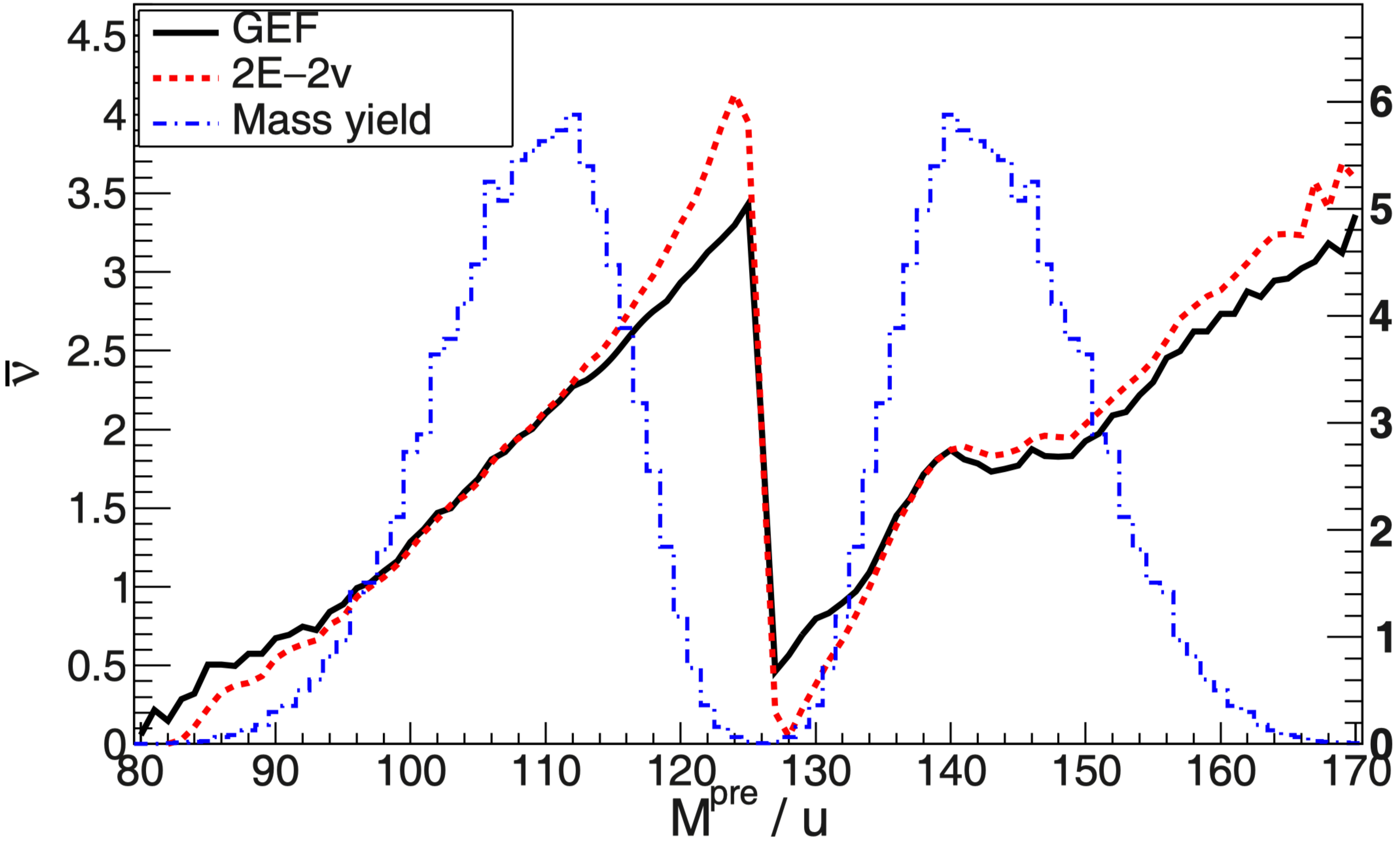

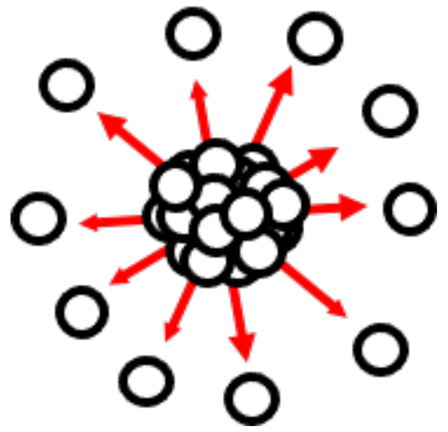

Possible to solve: Unfold the resolution function…

Eur. Phys. J. A (2018) **54**: 114
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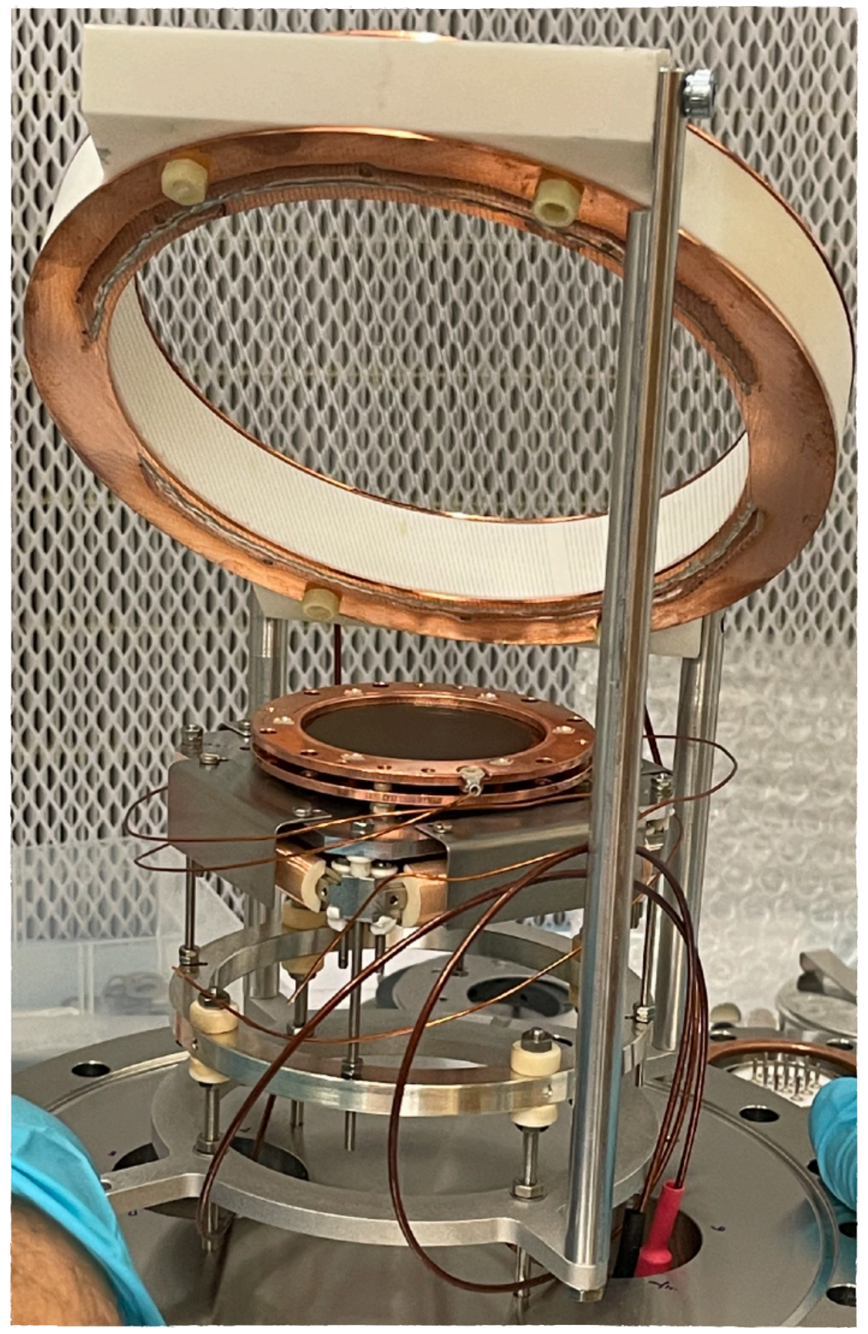
THE EUROPEAN PHYSICAL JOURNAL A

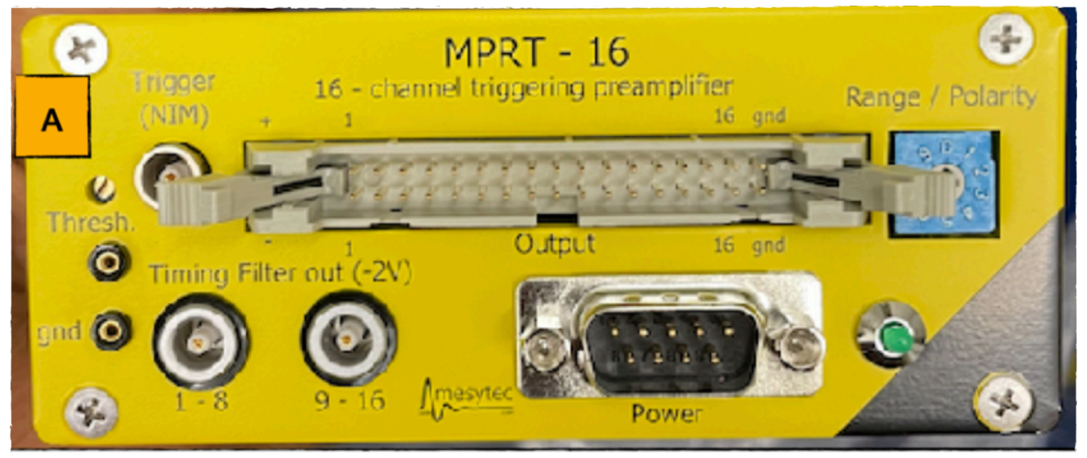
Regular Article – Experimental Physics

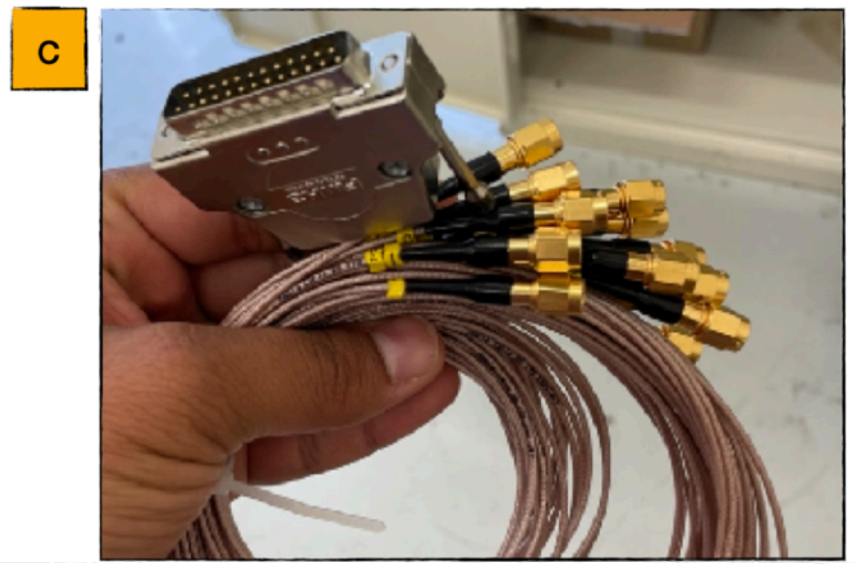
The impact of neutron emission on correlated fission data from the 2E-2v method

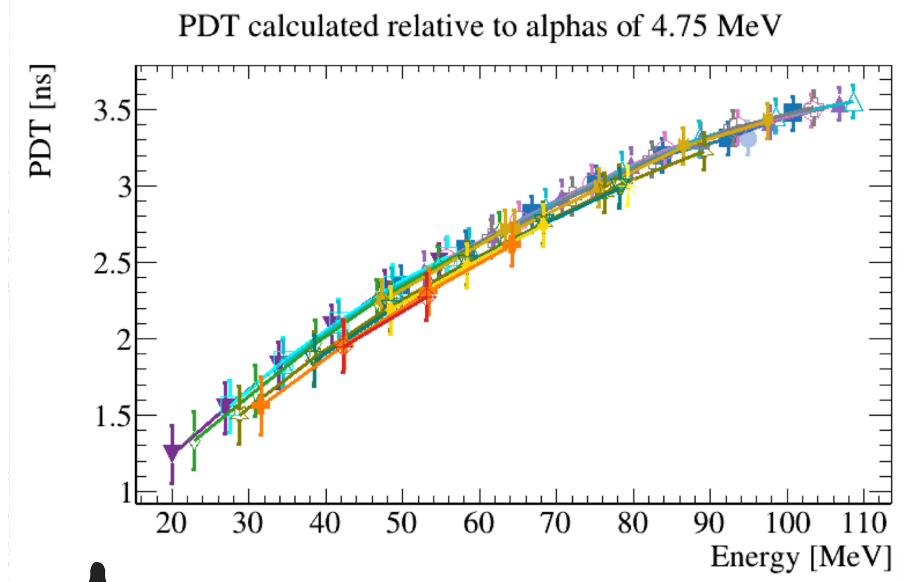
Kaj Jansson[1], Ali Al-Adili[1,a], Erik Andersson Sundén[1], Alf Göök[2], Stephan Oberstedt[2], and Stephan Pomp[1]

THE UPGRADED VERDI…

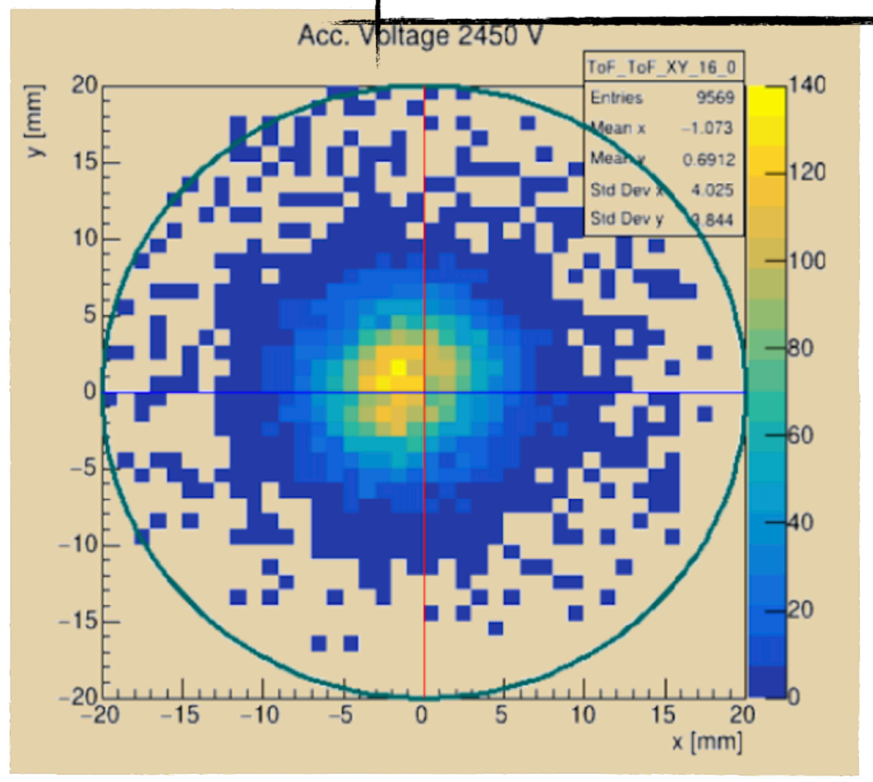








NEW PDT AND PHD SYSTEMATICS



CARL TRYGGERS STIFTELSE
FÖR VETENSKAPLIG FORSKNING

NEW DATA ACQUISITION SYSTEMS AND FEED-THROUGHS

NEW POSITION SENSITIVE MCP´S

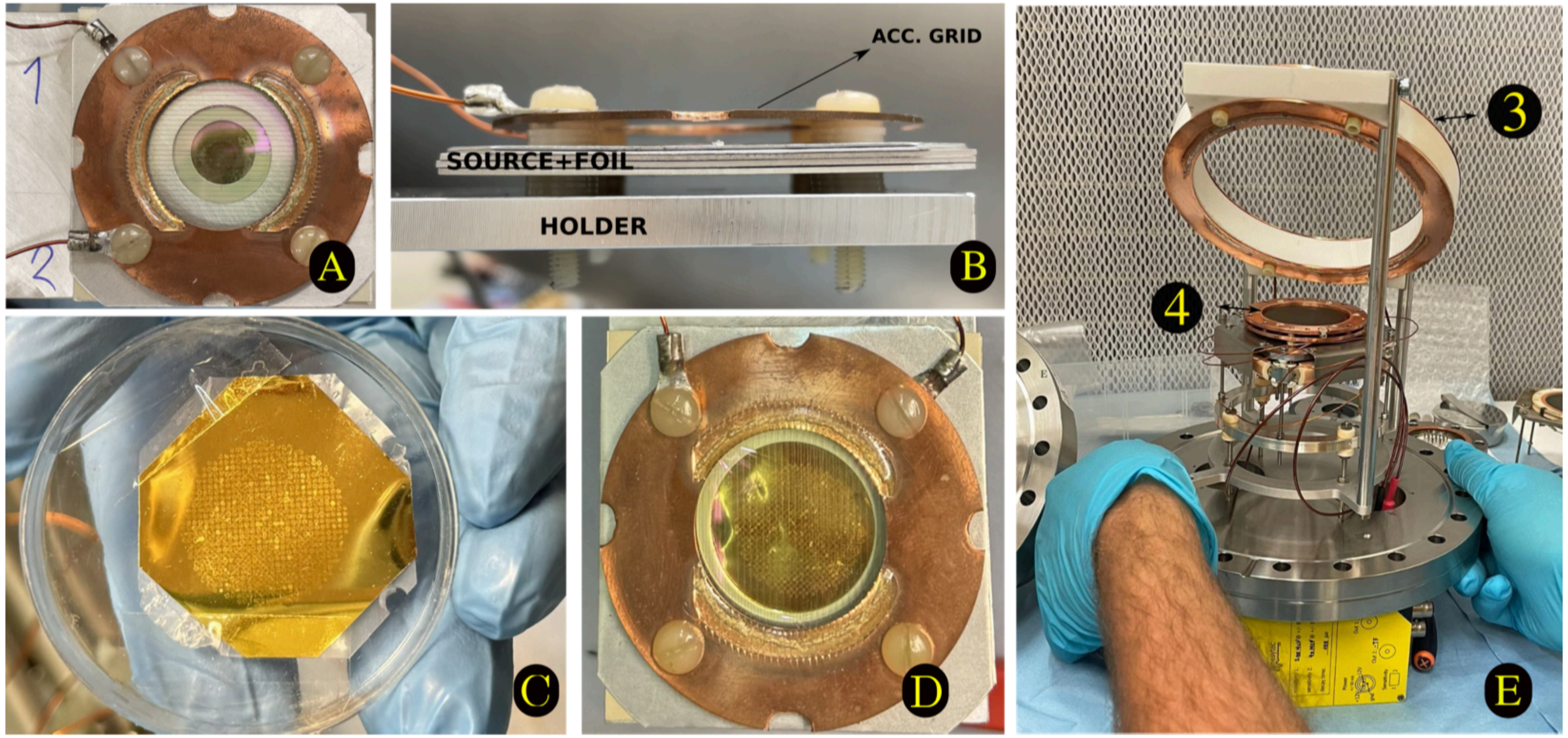
NEW PRE-AMPLIFIERS AND DETECTORS

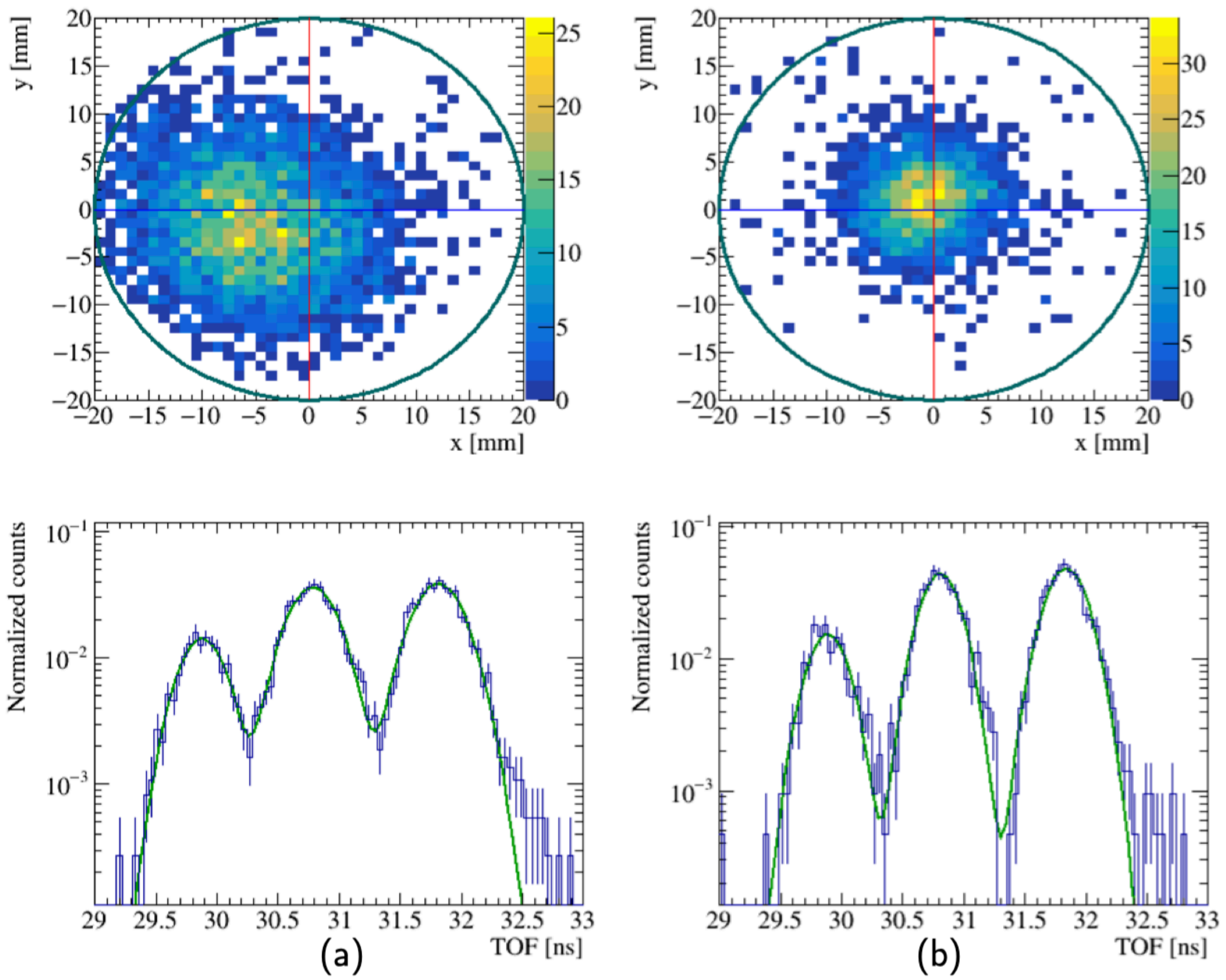
Suppported by APRENDE & ARIEL

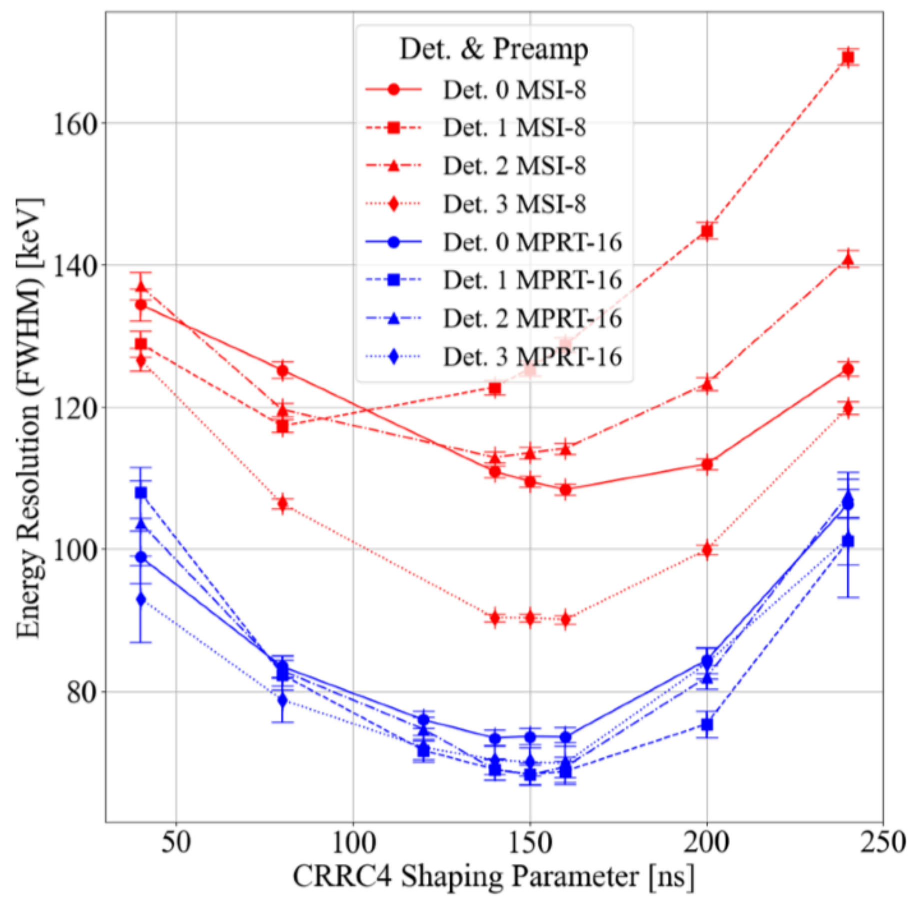
ARIEL

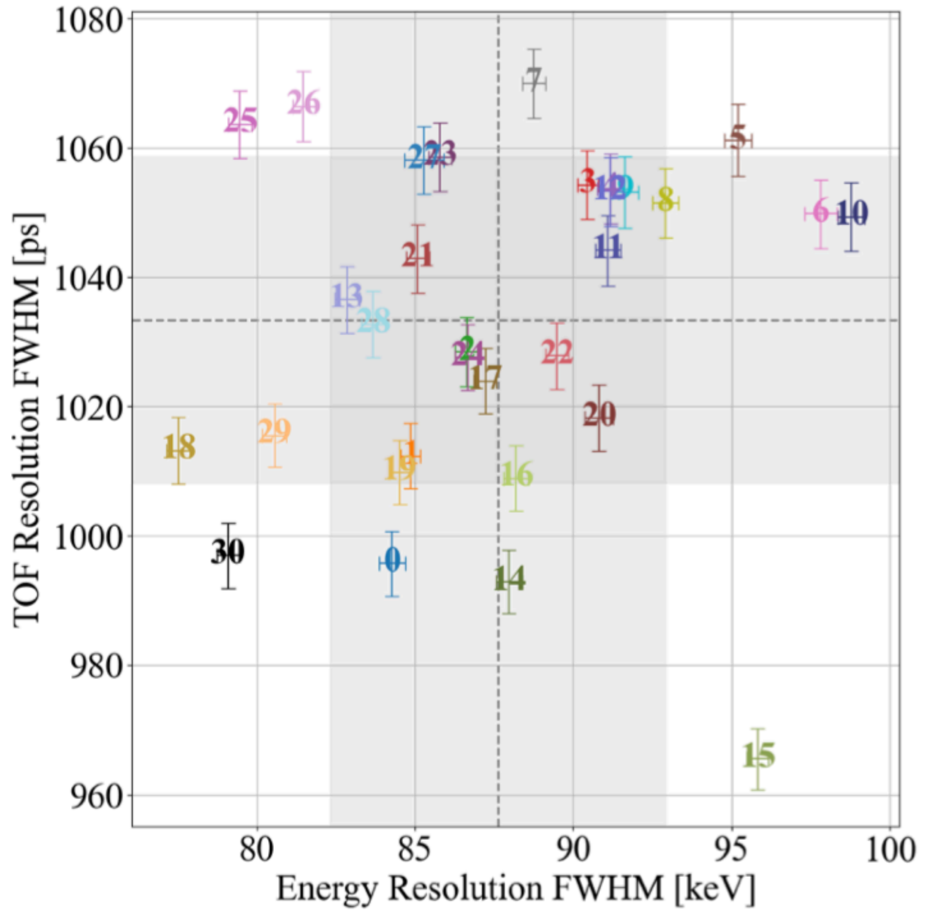
APRENDE

TECHNICAL STUDY ON VERDI OPTIMIZATION









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Nuclear Inst. and Methods in Physics Research, A

journal homepage: www.elsevier.com/locate/nima

ELSEVIER

Full Length Article

Optimization and re-operation of the fission fragment spectrometer VERDI

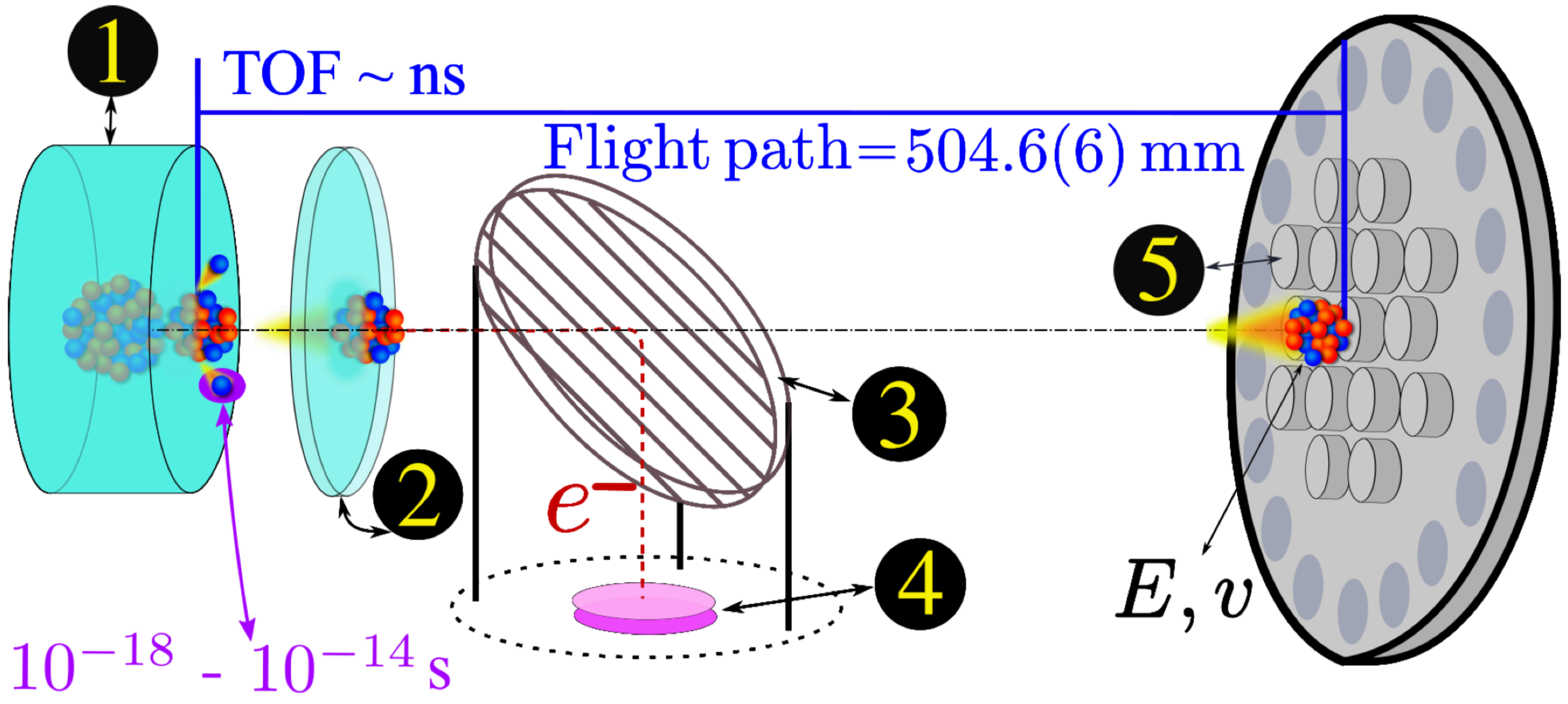
A.M. Gómez L. [a],*, S. Oberstedt [b], D. Tarrío [a], A. Solders [a], S. Pomp [a], C.L. Fontana [b], W. Geerts [b], M. Macías [b], M. Vidali [b], A. Oberstedt [c], A. Al-Adili [a]

Check for updates

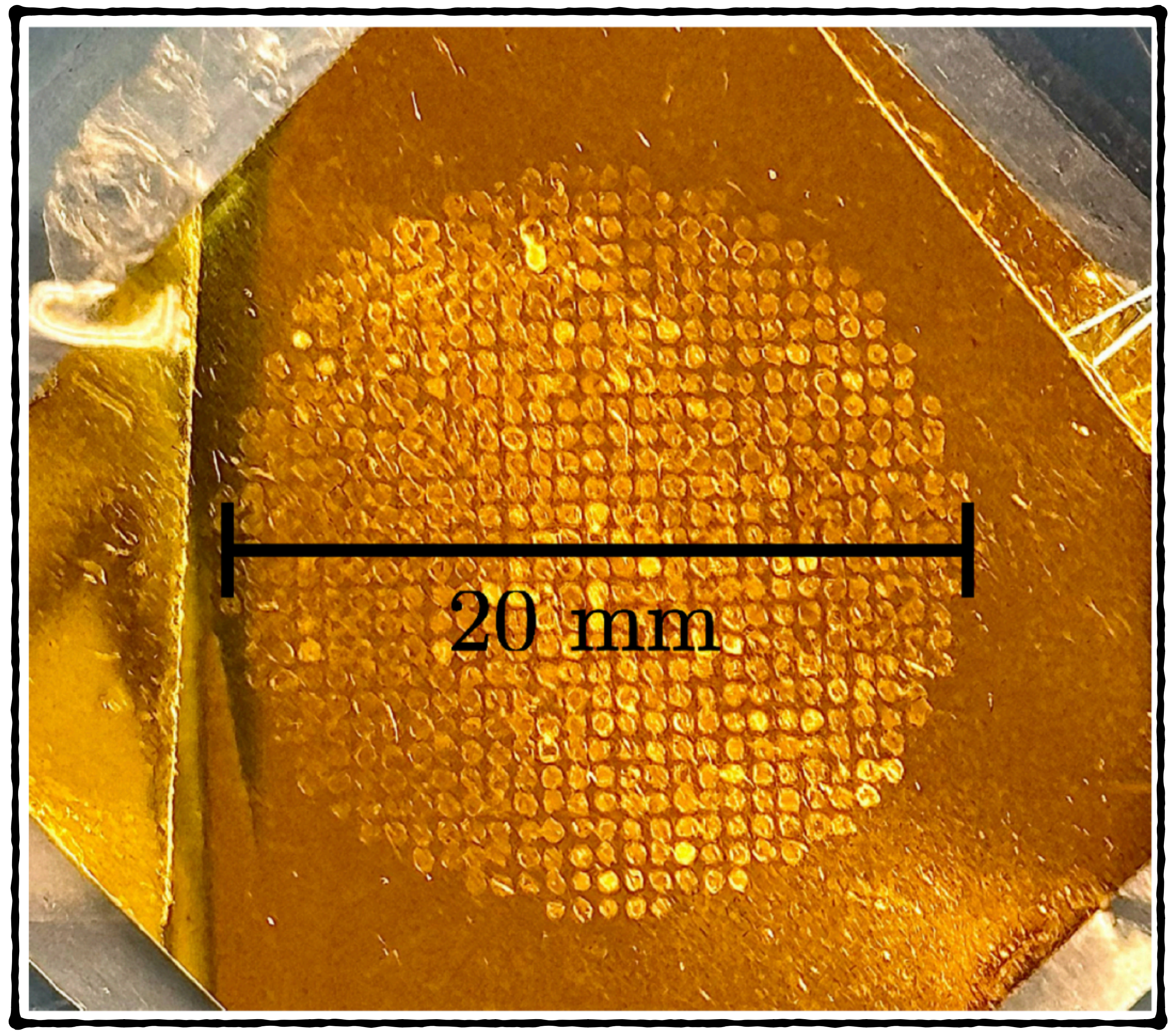
NEW CAMPAIGN ON CM-248(SF)

- Original idea was to measure $^{235}U(n_{th},f)$ at ILL. However, we have a shortage on transparent target supplies and do not have decent samples for our experiment.
- Instead we have ongoing experiments on $^{248}Cm(sf)$ with one arm of VERDI (1E-1v). With 31 PIPS detectors.

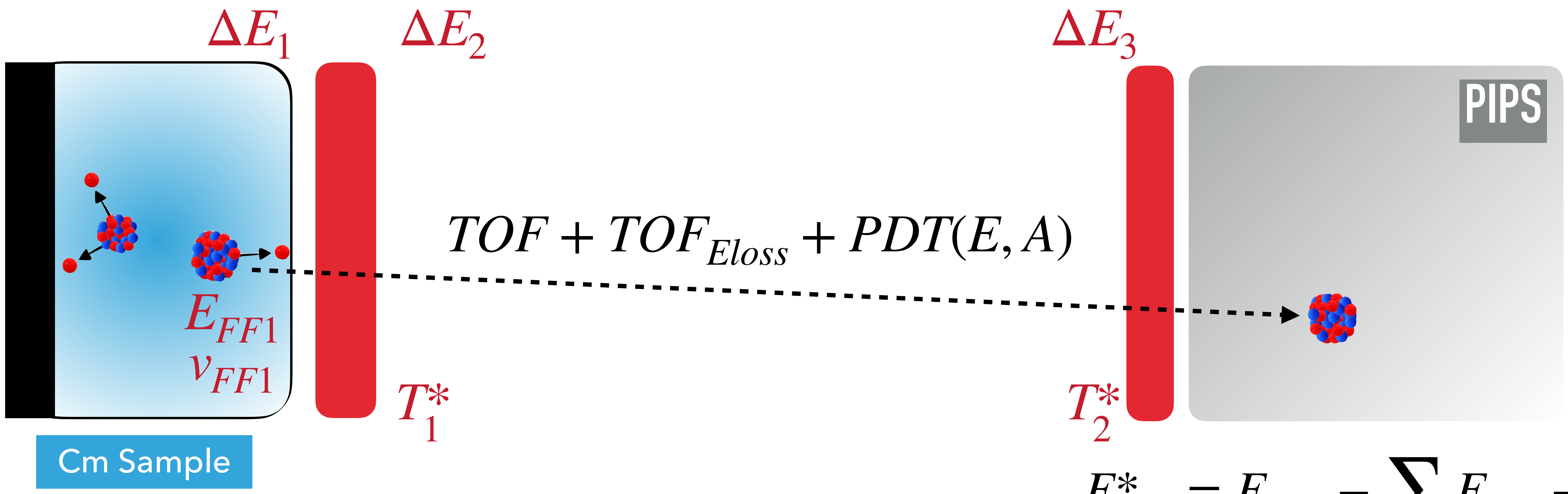
→ Cm248(sf) Less known reaction



drop-on-demand deposition (Mainz) ➡



1E-1V ANALYSIS



$$E^*_{FF1} = E_{FF1} - \sum E_{loss} - PHD(E, A)$$

Iterative mass calculation

$$E^*_{FF1} + \sum E_{loss} + PHD(E, A)$$

$$TOF - PDT(E, A) - TOF_{Eloss}$$

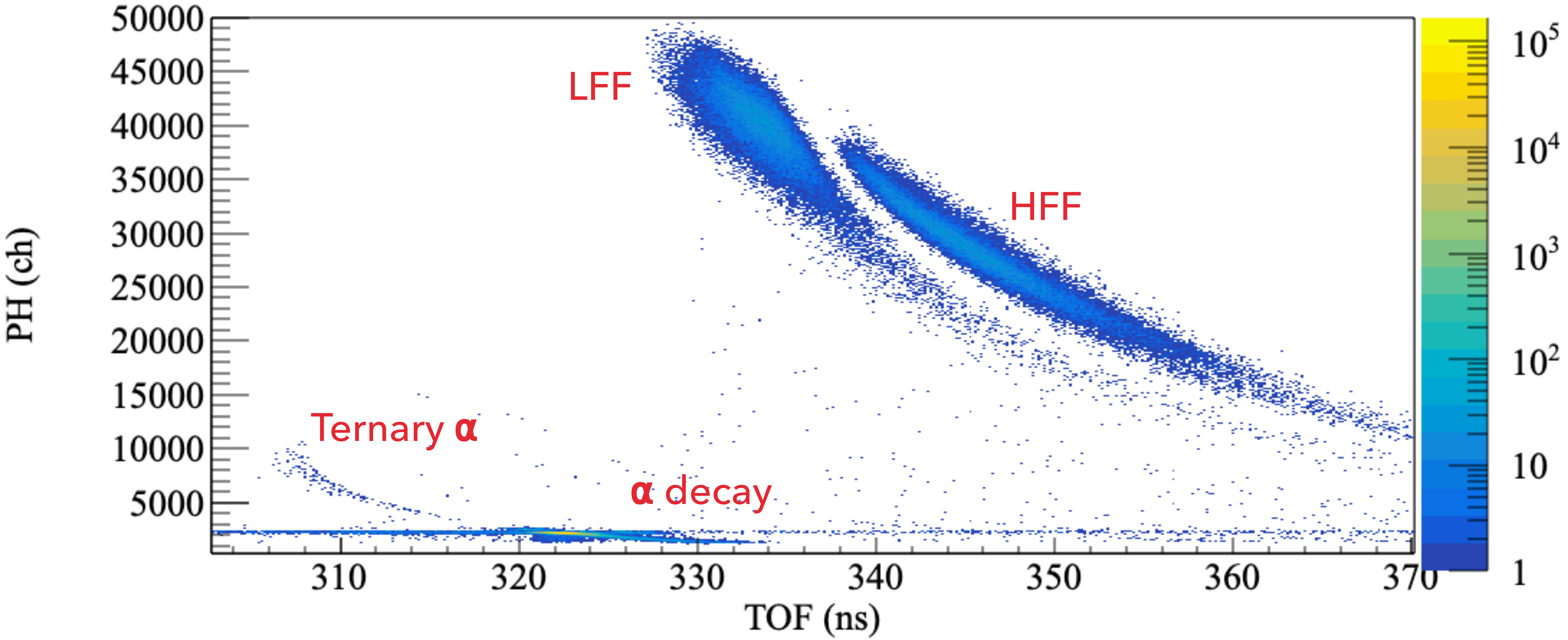
$$\mathtt{m}^{\mathtt{post}} = \frac{2\mathtt{E}_{\mathtt{post}}}{\mathtt{v}^2_{\mathtt{post}}}$$

$$\Delta m^{post} \leq 0.1$$

FINAL MASS!

DATA TREATMENT

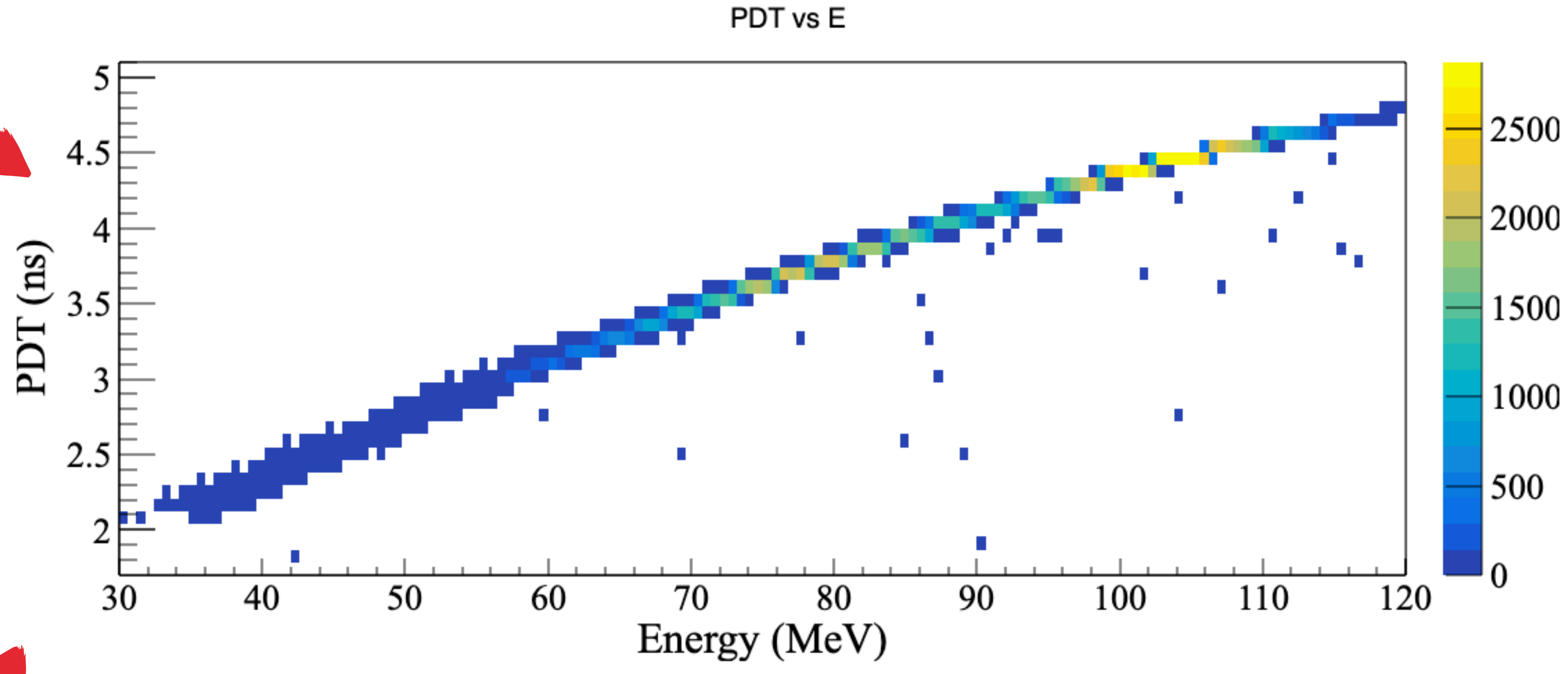
Pulse height of PIPS vs Time-of-flight

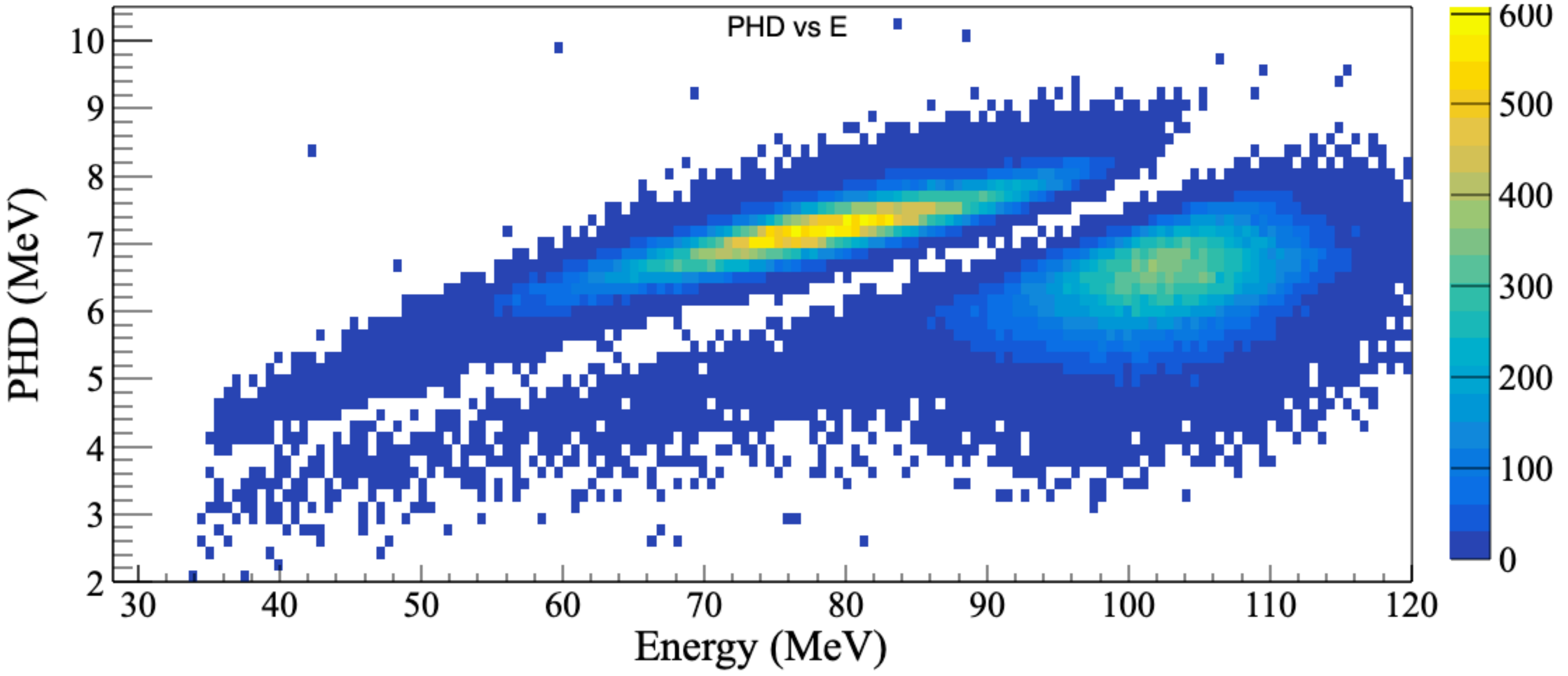


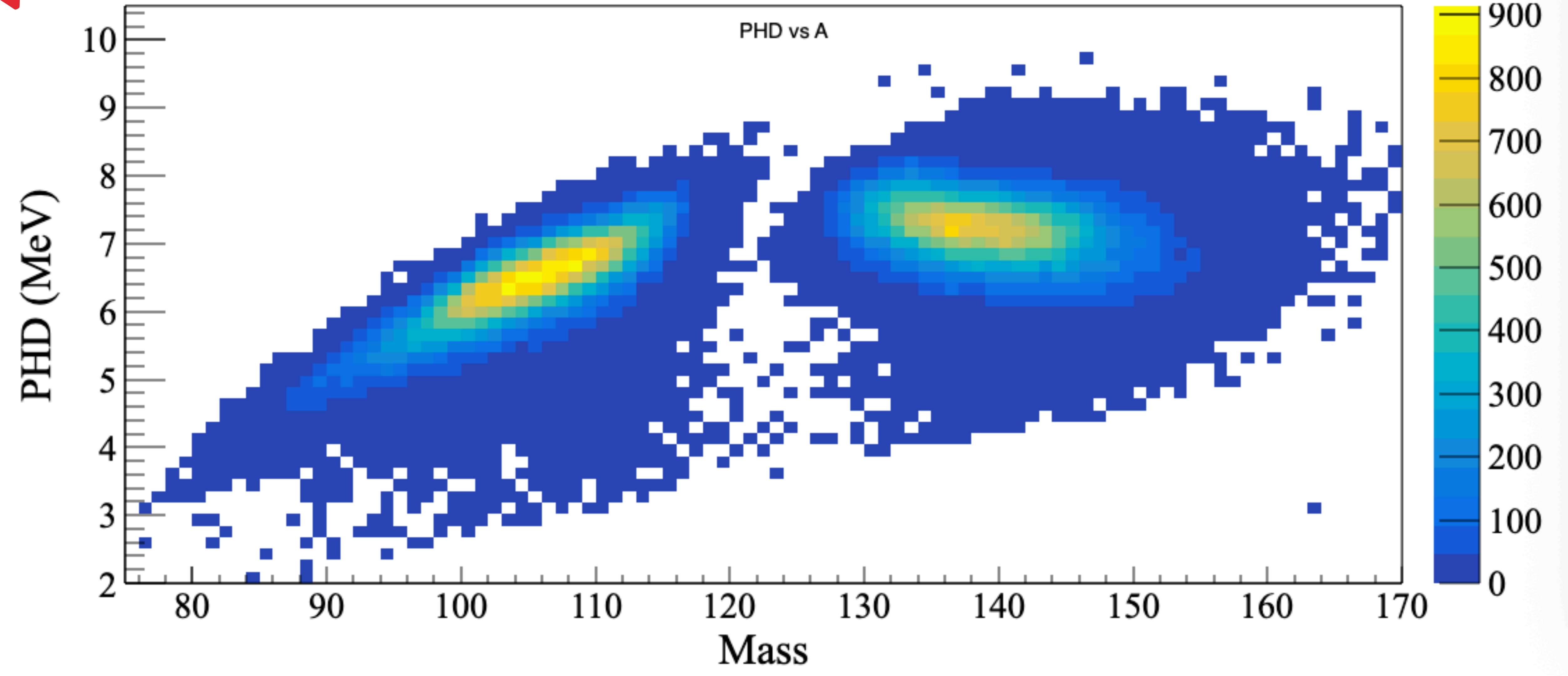
CORRECTIONS BASED ON LOHENGRIN DATA

Plasma delay time correction, as a function of energy

Pulse height defect correction, as a function of energy and mass

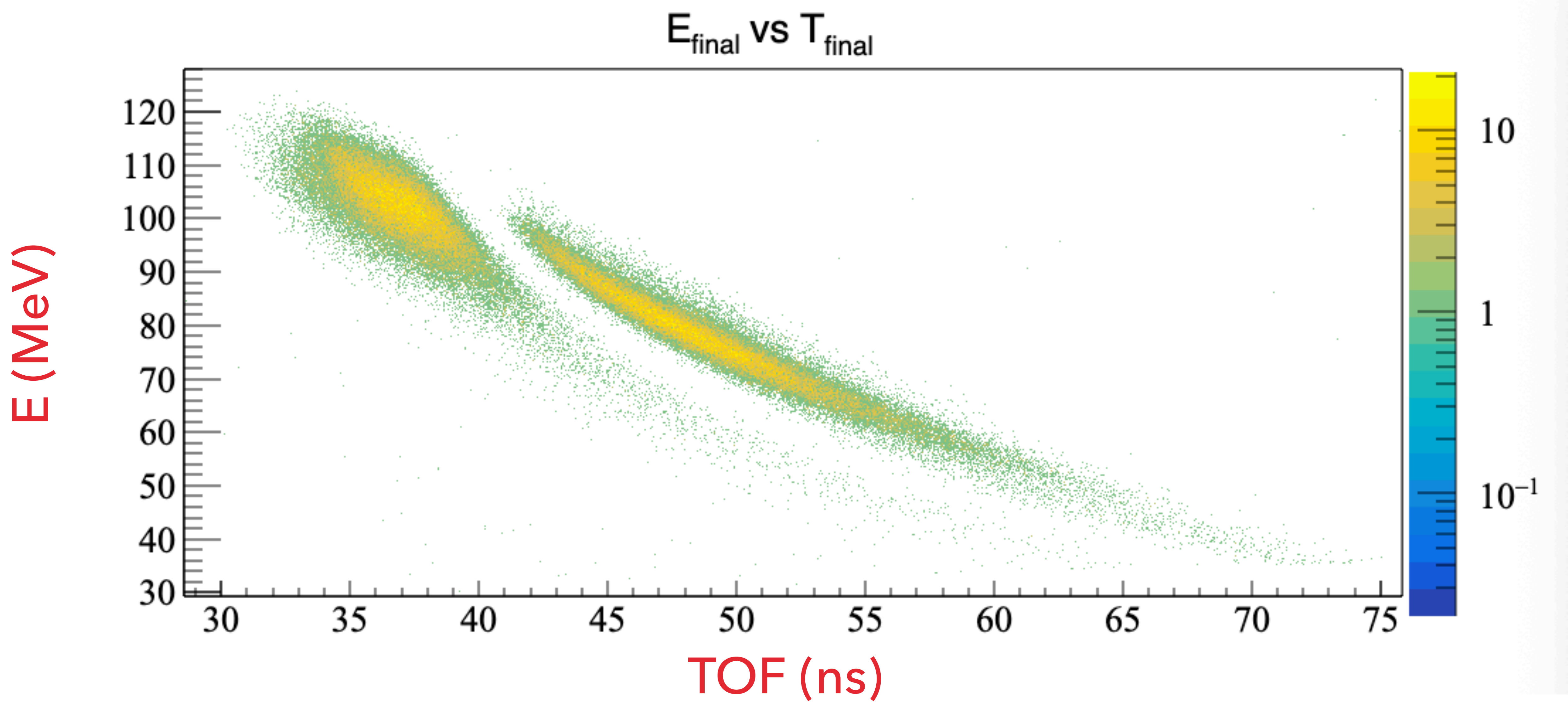


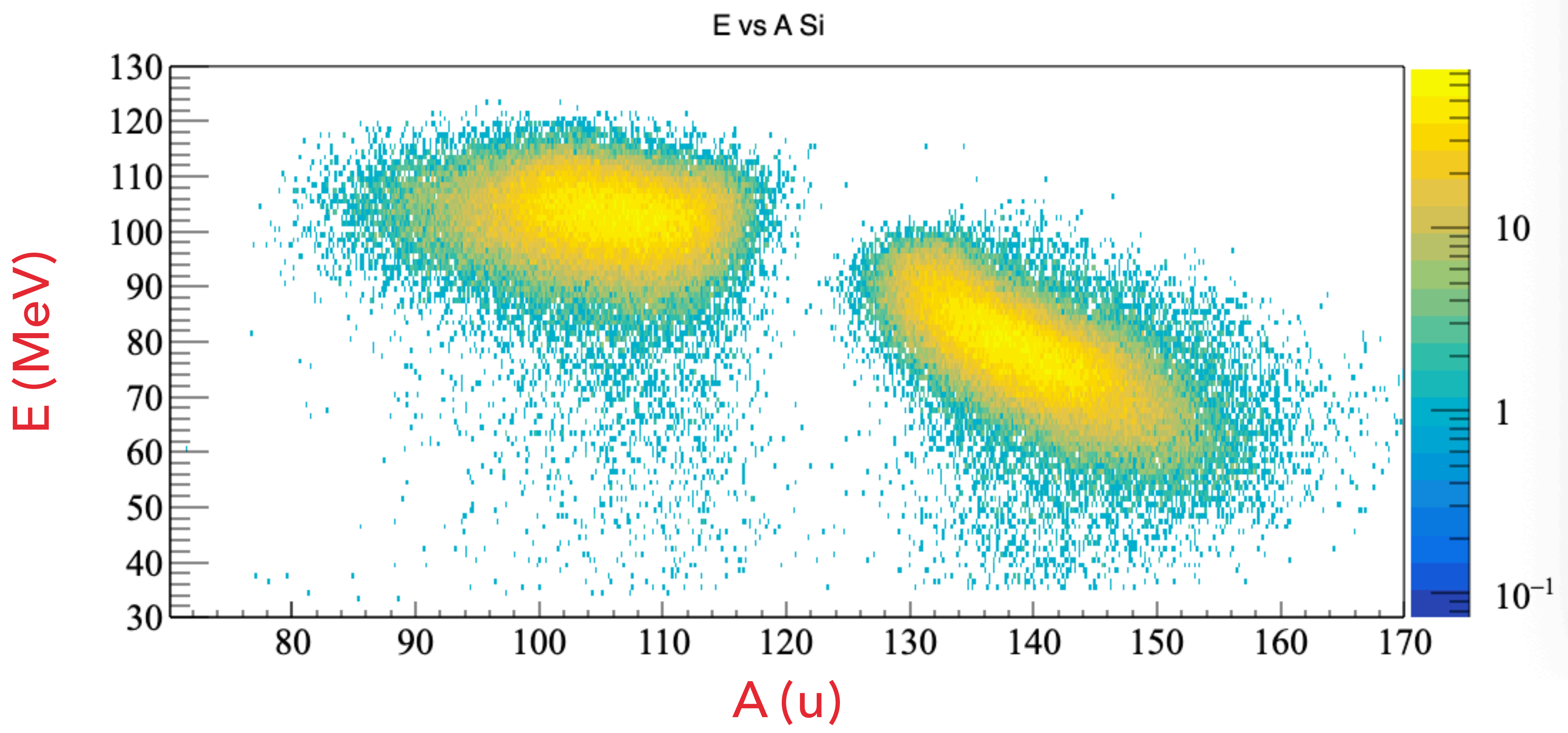




AFTER ITERATIVE PROCEDURE

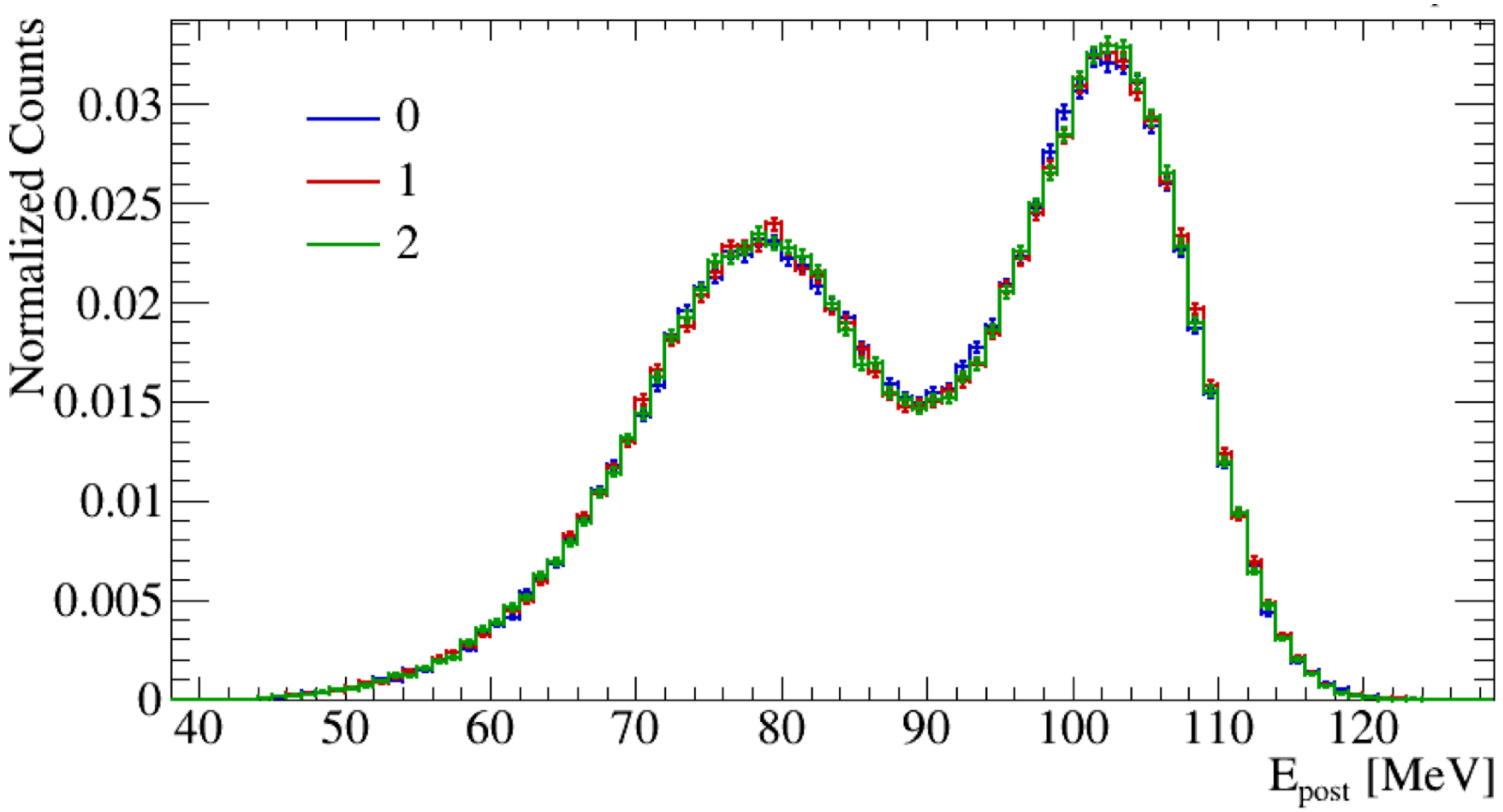
- Typically less than 5 iterations needed
- We still need to optimize energy Loss parameters
- We need a calibration measurement to a standard (e.g. Cf-252)!

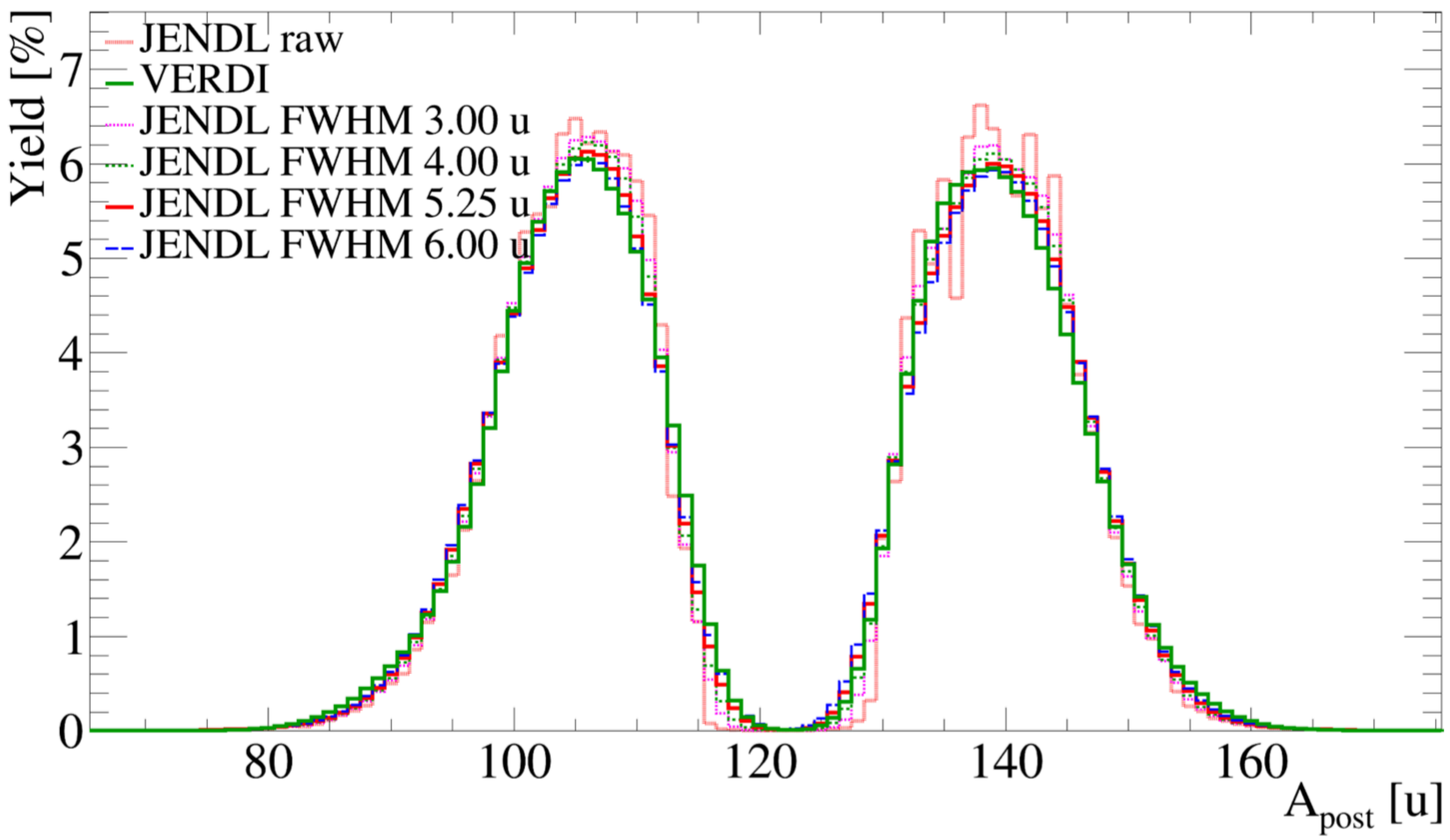


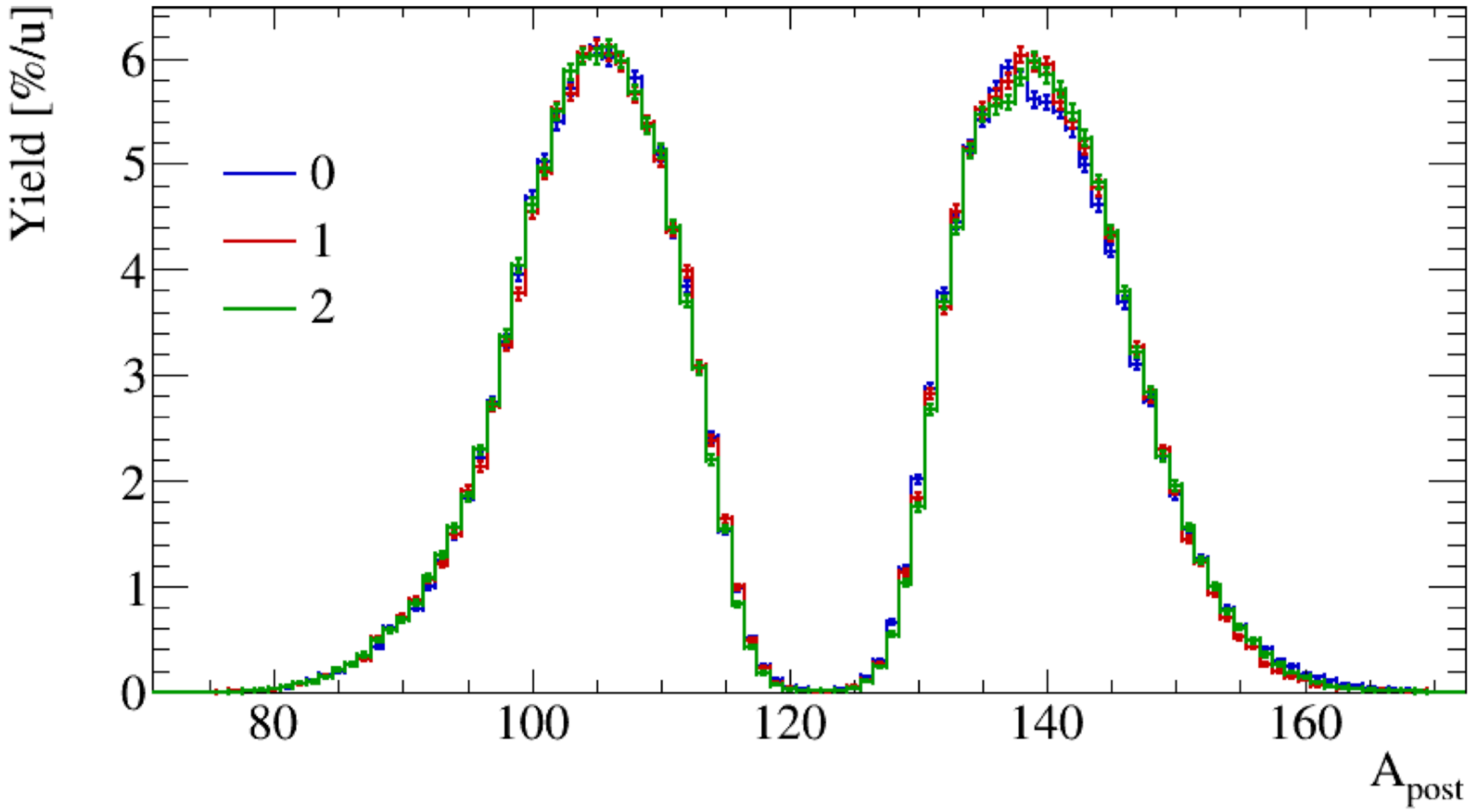


FISSION PRODUCT MASS

- 6.6 × 10^6 reconstructed fission events
- Good agreement across 31 detectors
- Post-neutron mass resolution estimated to about $\sigma_{A,post} \approx 2.2u$

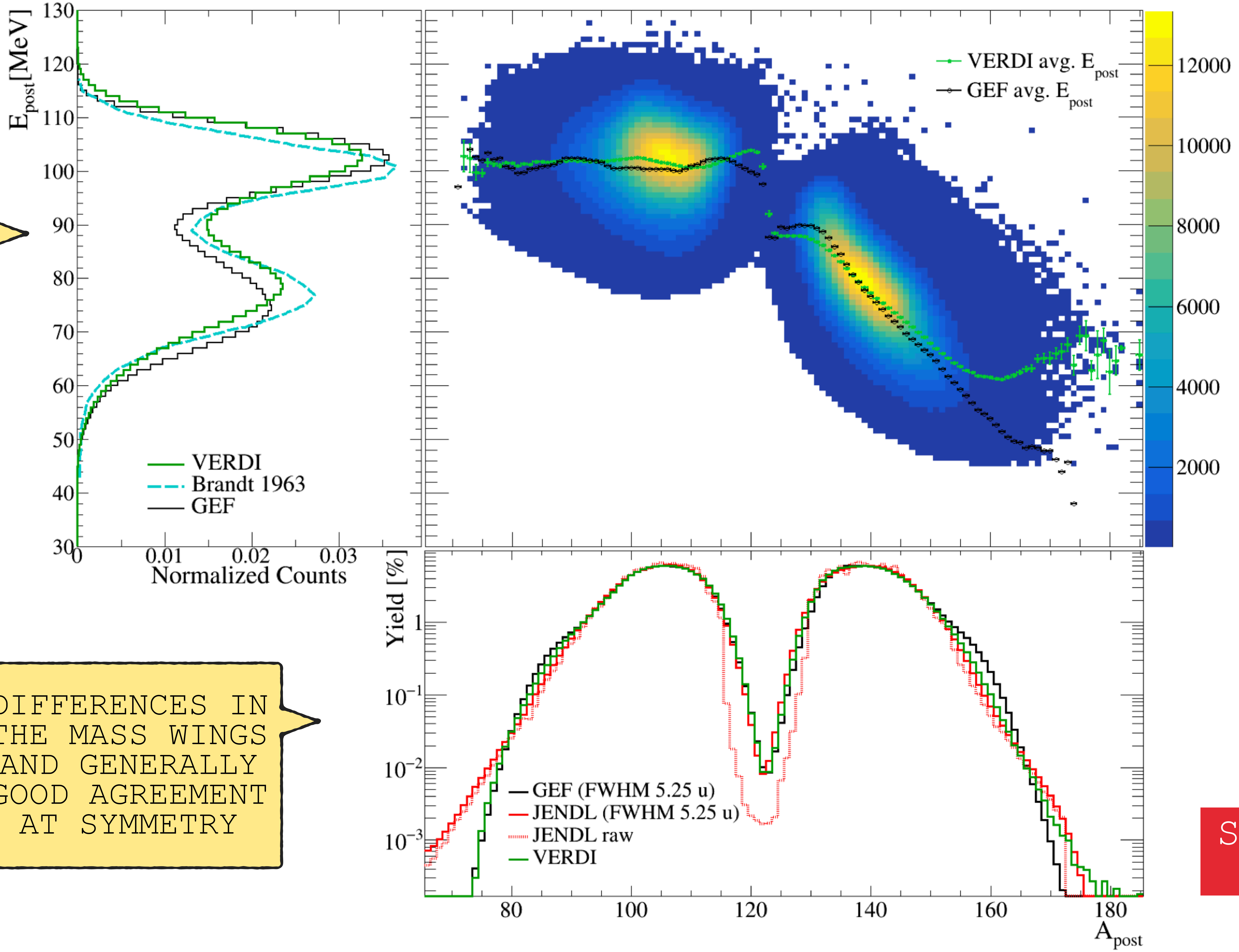






RESULTS

DIFFERENCES IN ENERGY TO GEF AND EARLIER DATA

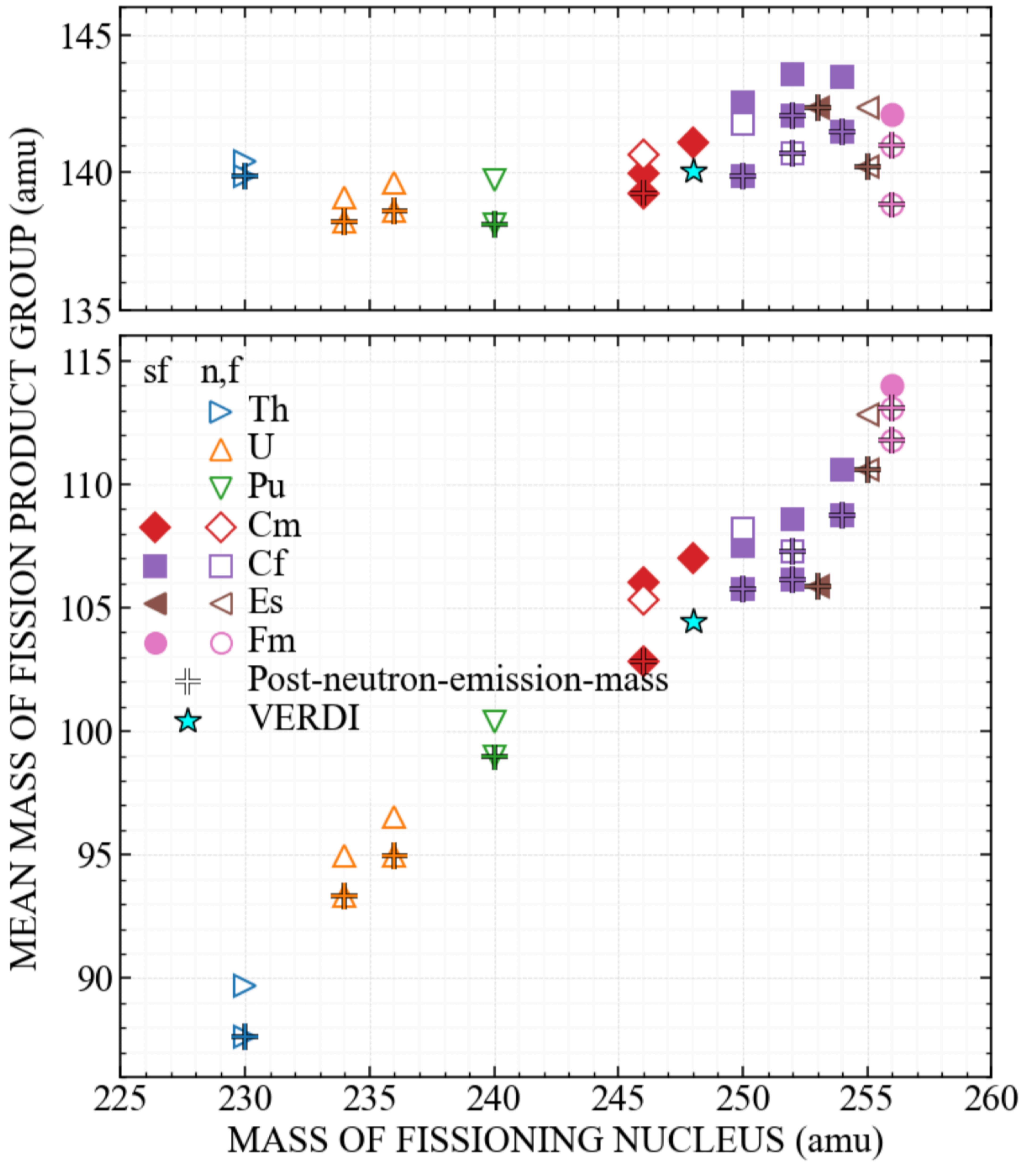


DIFFERENCES IN THE MASS WINGS AND GENERALLY GOOD AGREEMENT AT SYMMETRY

Submitted for publication

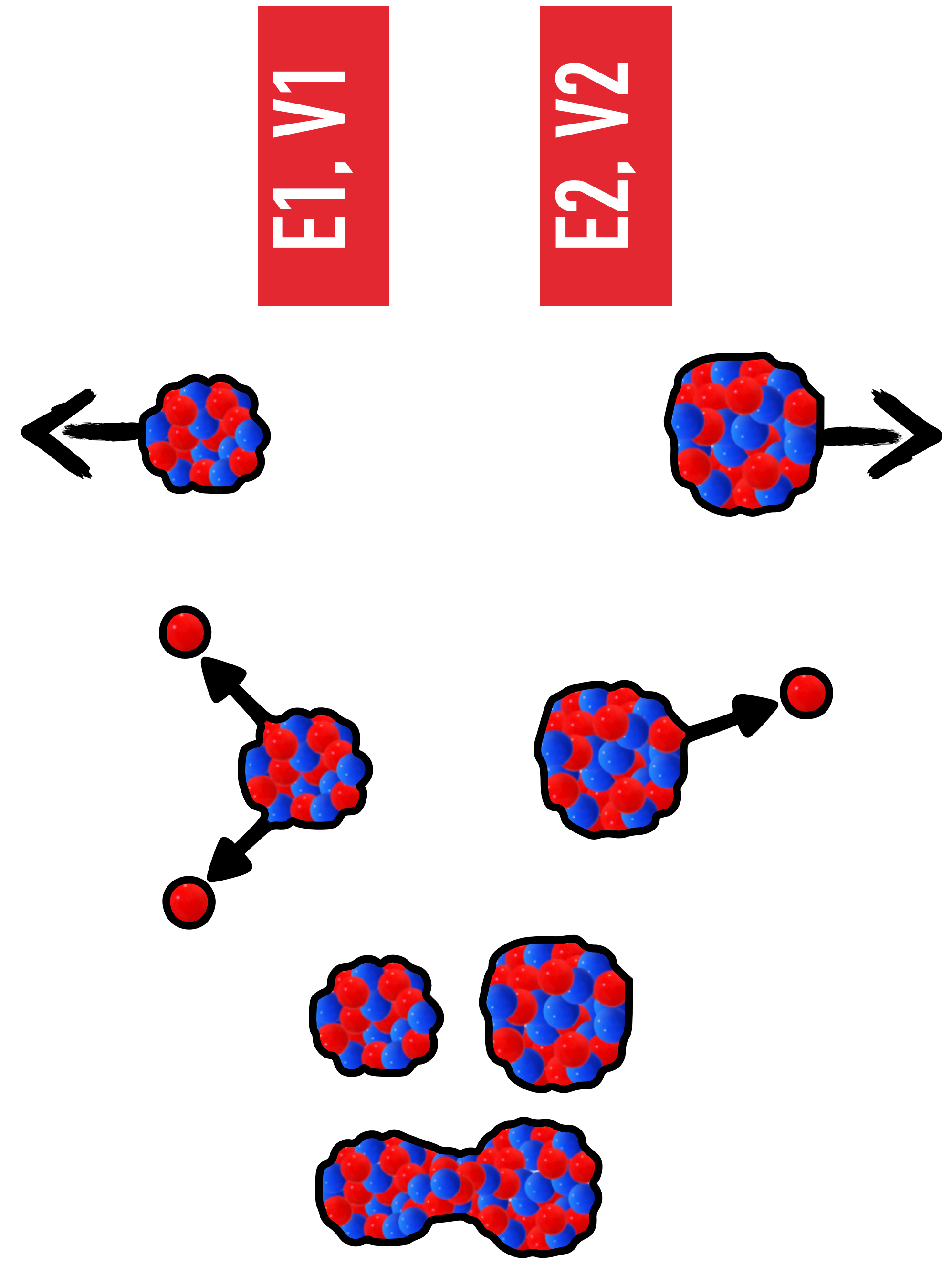
AVERAGE MASS AND THE VALUES, CM-248(SF)

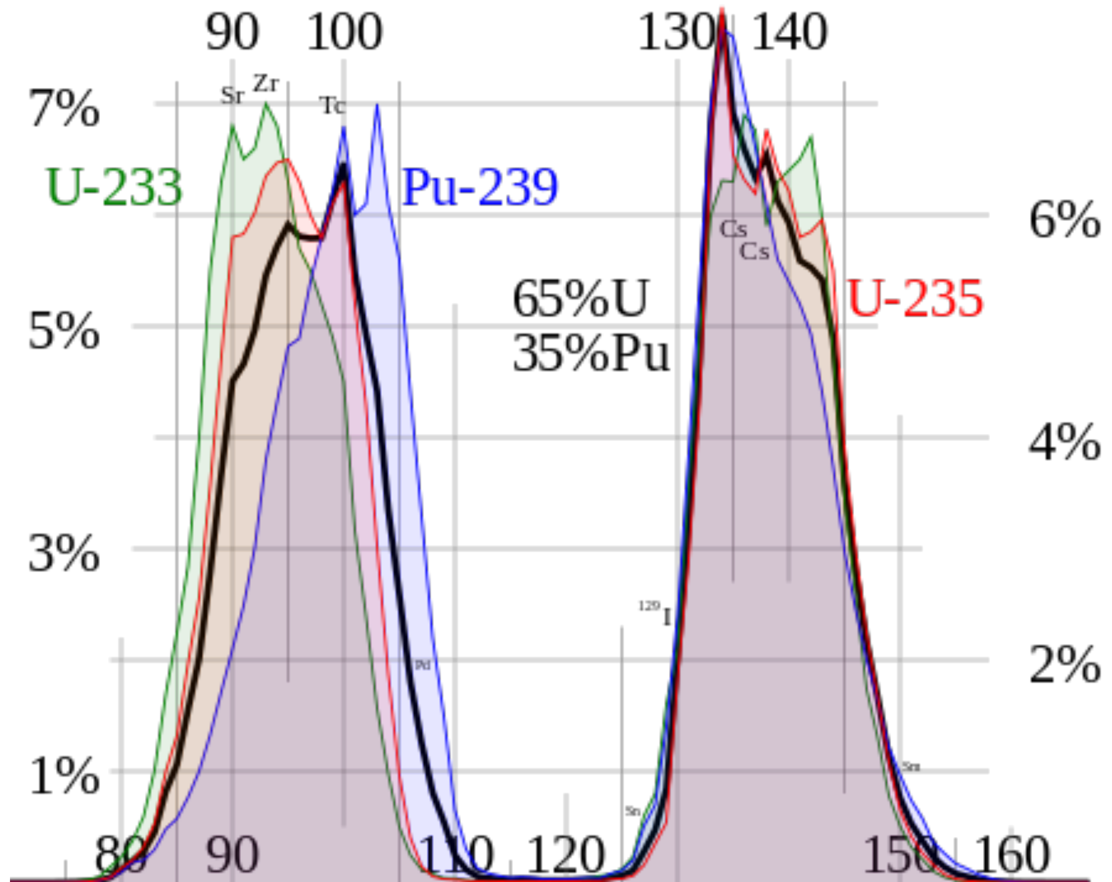
This work	GEF V2025-1.4
$\langle A_{post} \rangle \approx 122.2$	$\langle A_{post} \rangle \approx 122.4$
$\langle A_{H,post} \rangle \approx 140.0$	$\langle A_{H,post} \rangle \approx 140.6$
$\langle A_{L,post} \rangle \approx 104.4$	$\langle A_{L,post} \rangle \approx 104.2$
$\langle \nu_{tot} \rangle \approx 3.5$	$\langle \nu_{tot} \rangle \approx 3.2$
$\langle E_{post} \rangle \approx 89.6 MeV$	$\langle E_{post} \rangle \approx 88.7 MeV$
$\langle E_{H,post} \rangle \approx 77.7 MeV$	$\langle E_{H,post} \rangle \approx 76.6 MeV$
$\langle E_{L,post} \rangle \approx 101.6 MeV$	$\langle E_{L,post} \rangle \approx 100.7 MeV$
$\langle TKE_{post} \rangle \approx 179.2\mathrm{MeV}$	$\langle TKE_{post} \rangle \approx 177.3\mathrm{MeV}$



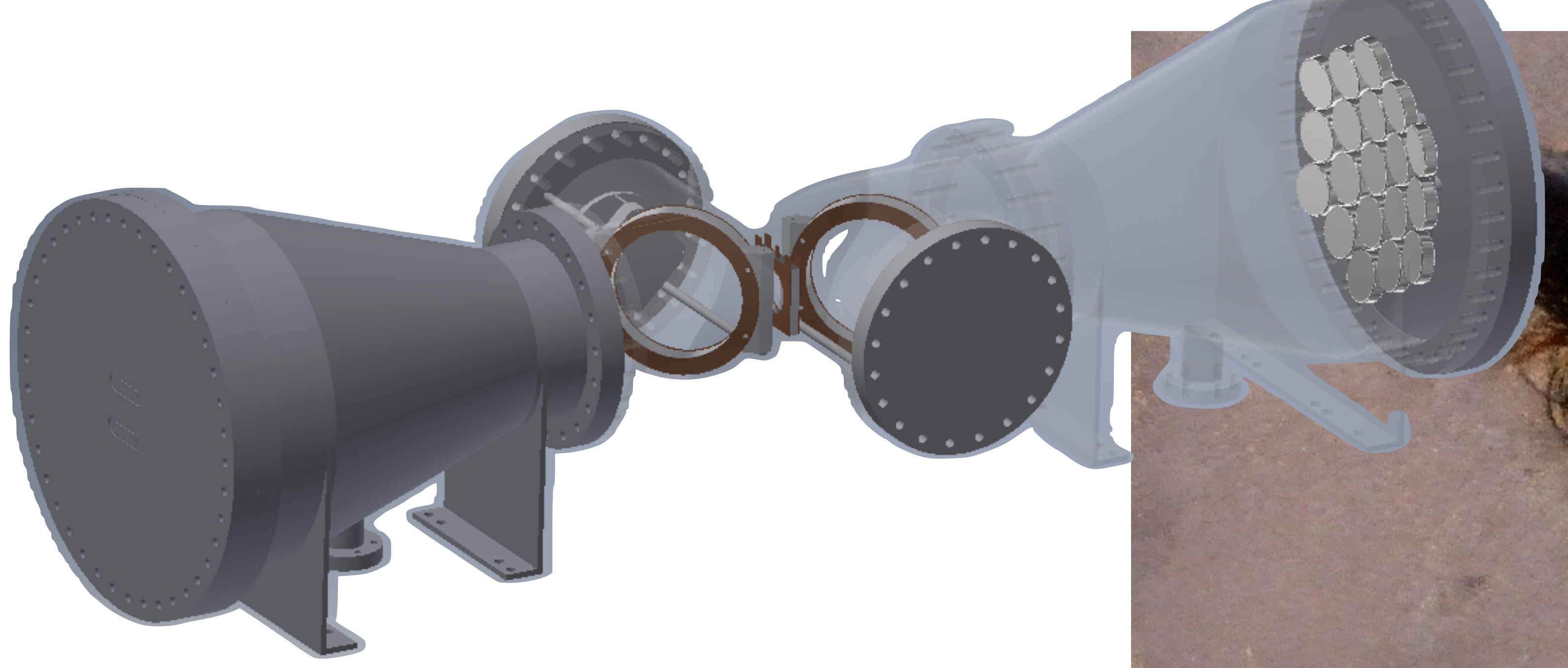
CONCLUSIONS

- VERDI is operational and optimized!
- Systematic characterization of Plasma delay times and Pulse Height Defects
- Technical paper published.
- Cm-248(sf) campaign completed and new product mass data submitted for publication
- Need to obtain transparent targets to facilitate upcoming 2E2v campaigns.
- Experiment with fast neutrons at GELINA or NFS





Experiments on the spontaneous fission of Cm-248 using the fission spectrometer VERDI



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* Department of physics and astronomy, Uppsala University, Sweden

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MÅSTE GEN 4 CLEAN POWER PRODUCTION

Energimyndigheten

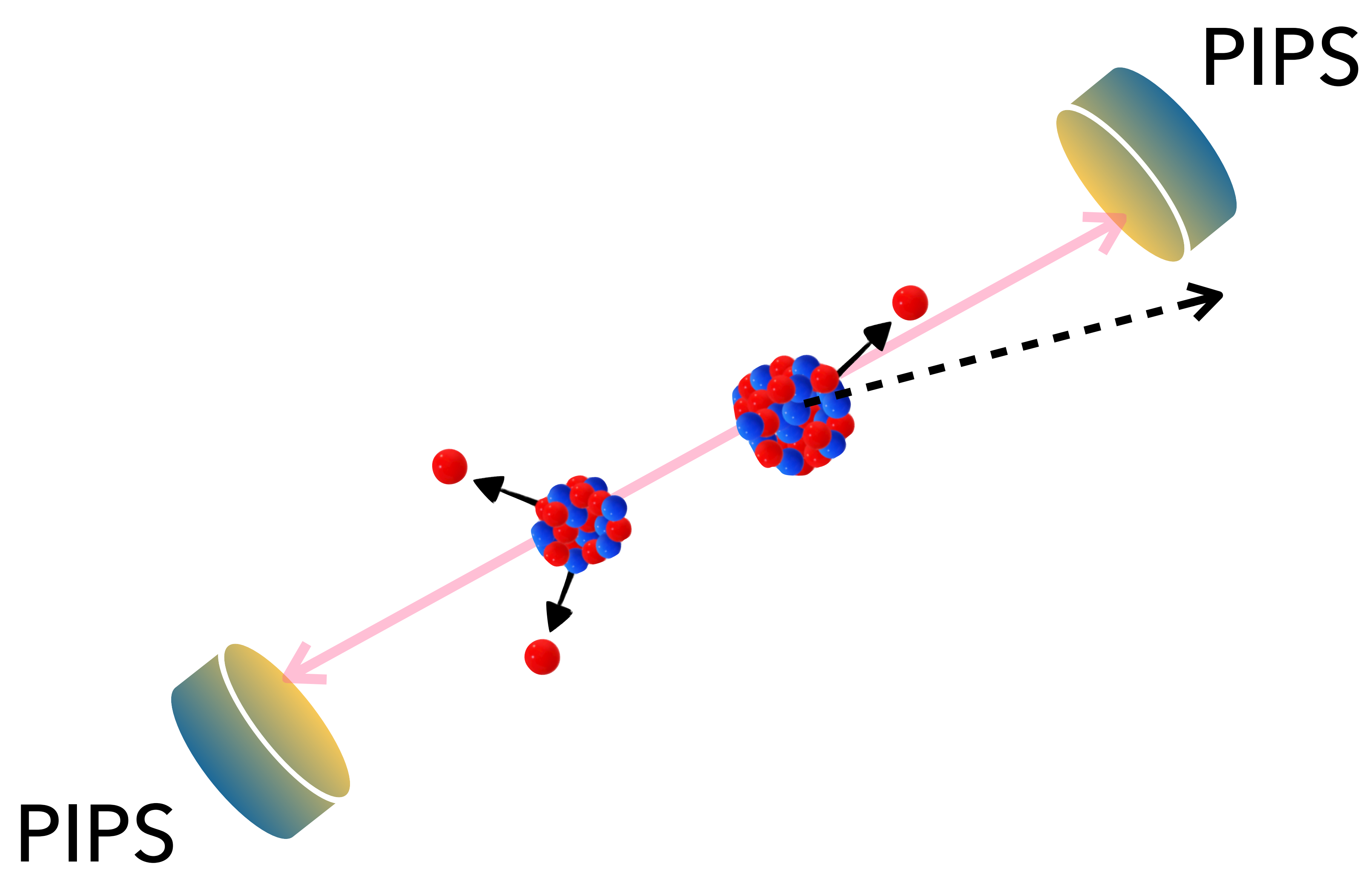
CARL TRYGGERS STIFTELSE FÖR VETENSKAPLIG FORSKNING

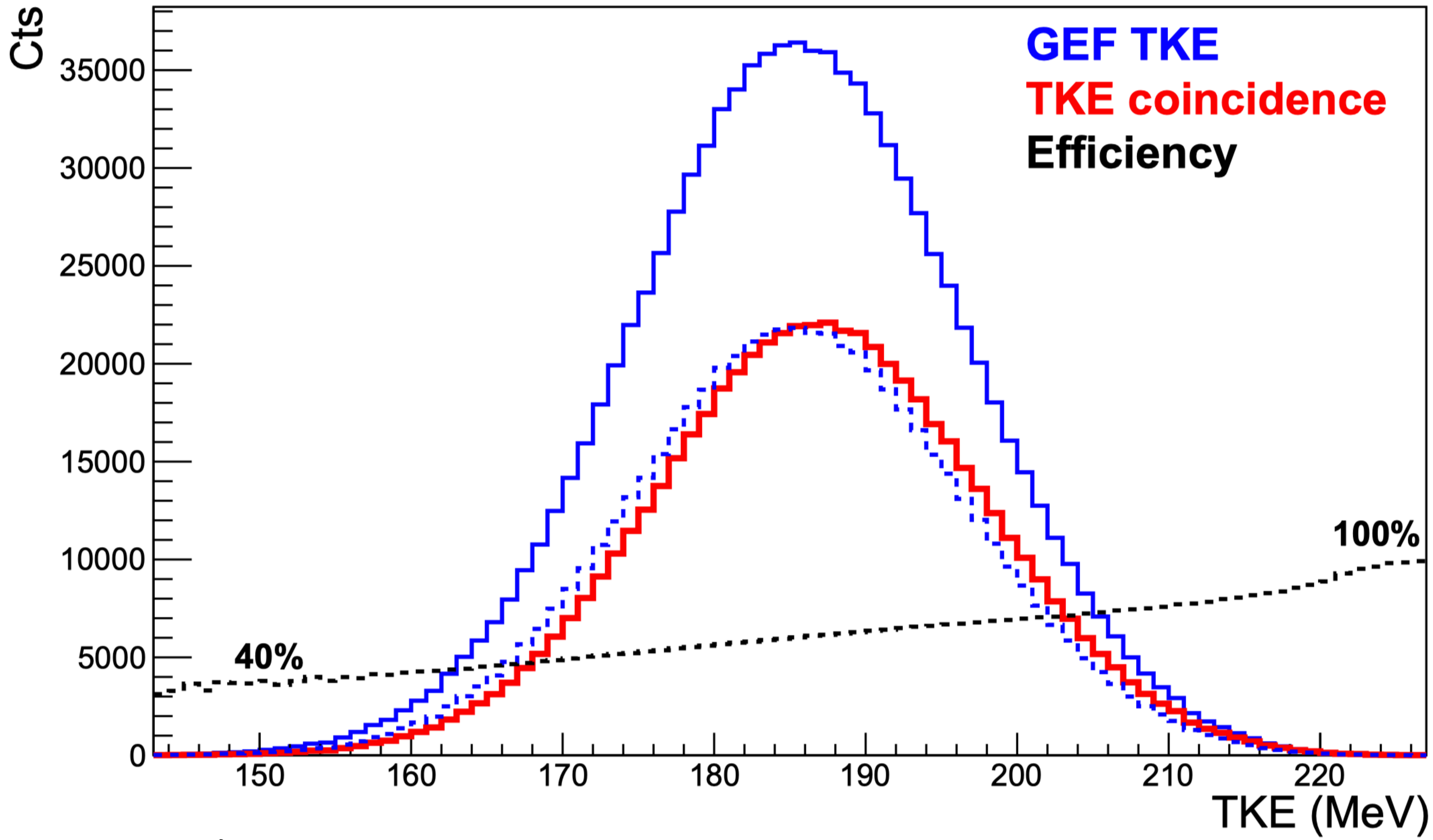
UPPSALA UNIVERSITET

Thanks for your attention!

SIMULATION WORK REVEALING SOME ISSUES!

The neutron emission gives a recoil to the fragments! FF might miss the detector





IMPORTANT TO CONSIDER THESE EXP. EFFECTS AS EVALUATORS! COULD CAUSE A BIAS IN THE DATA

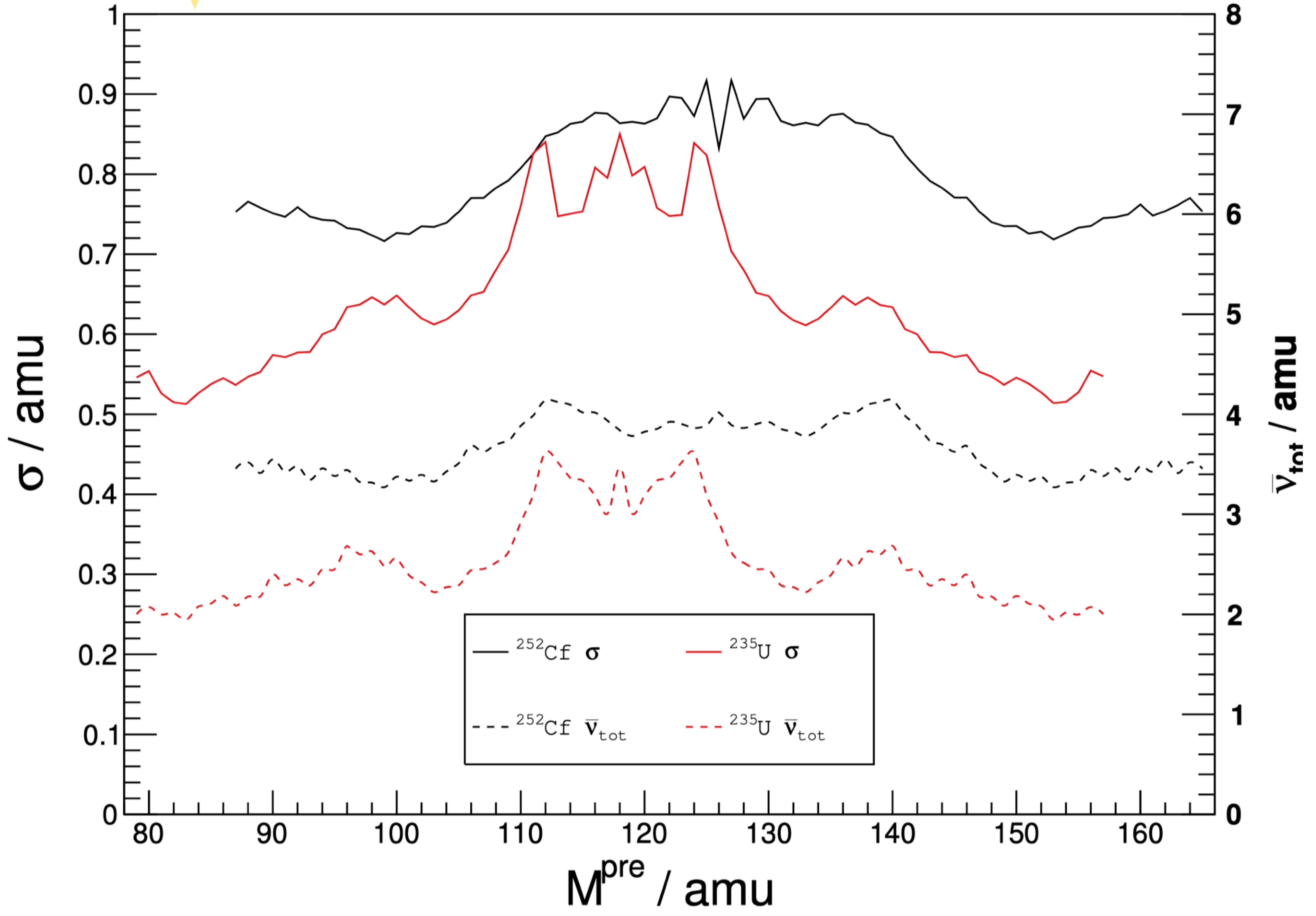
KEY ASSUMPTIONS DURING ANALYSIS

THE NEUTRON EMISSION INTRODUCES A VELOCITY SPREAD (1 %) AND THUS A MASS BROADENING

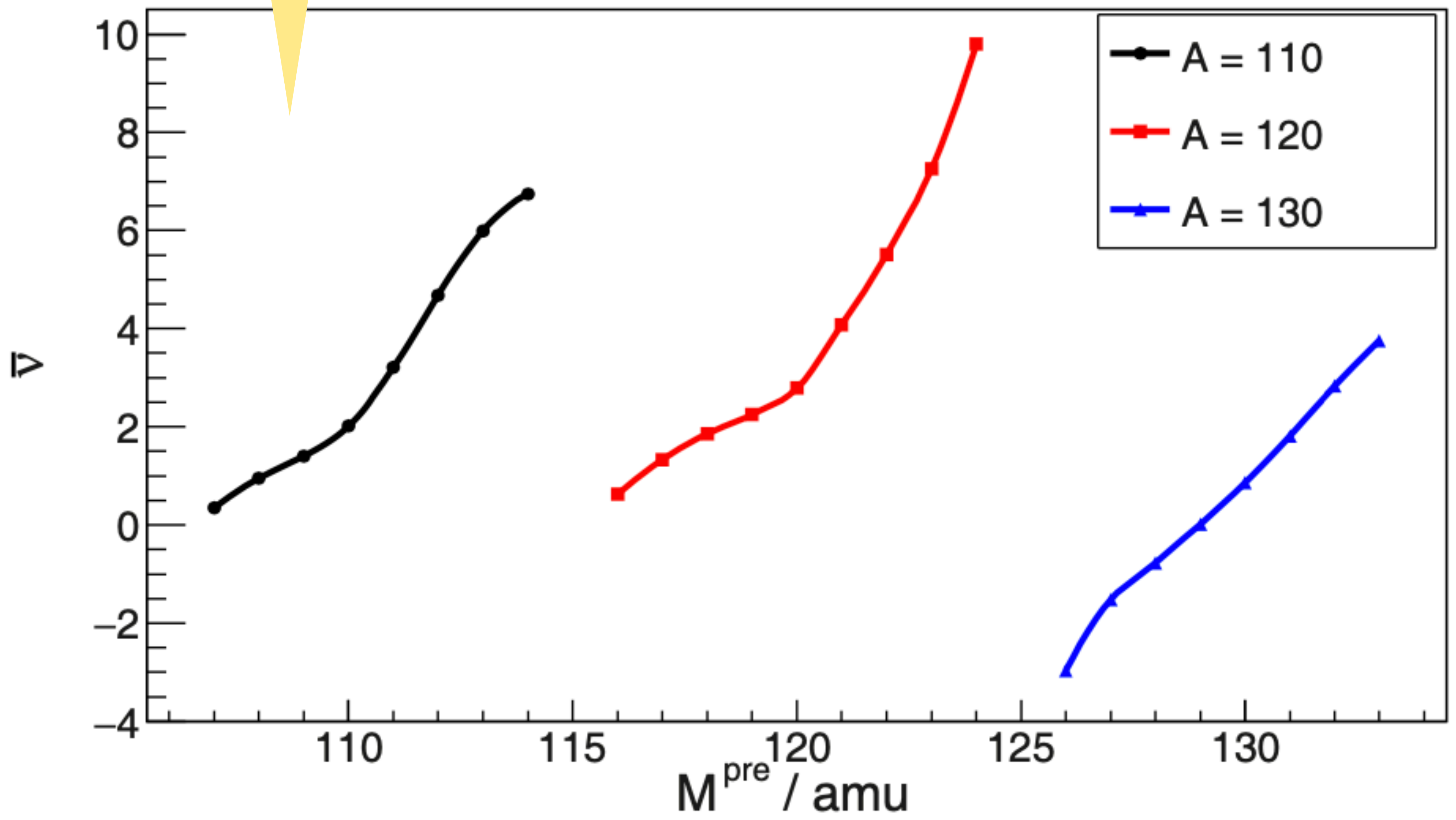
$$\bar{\nu}(A) = m_{pre} - m_{post}$$

AFFECTED

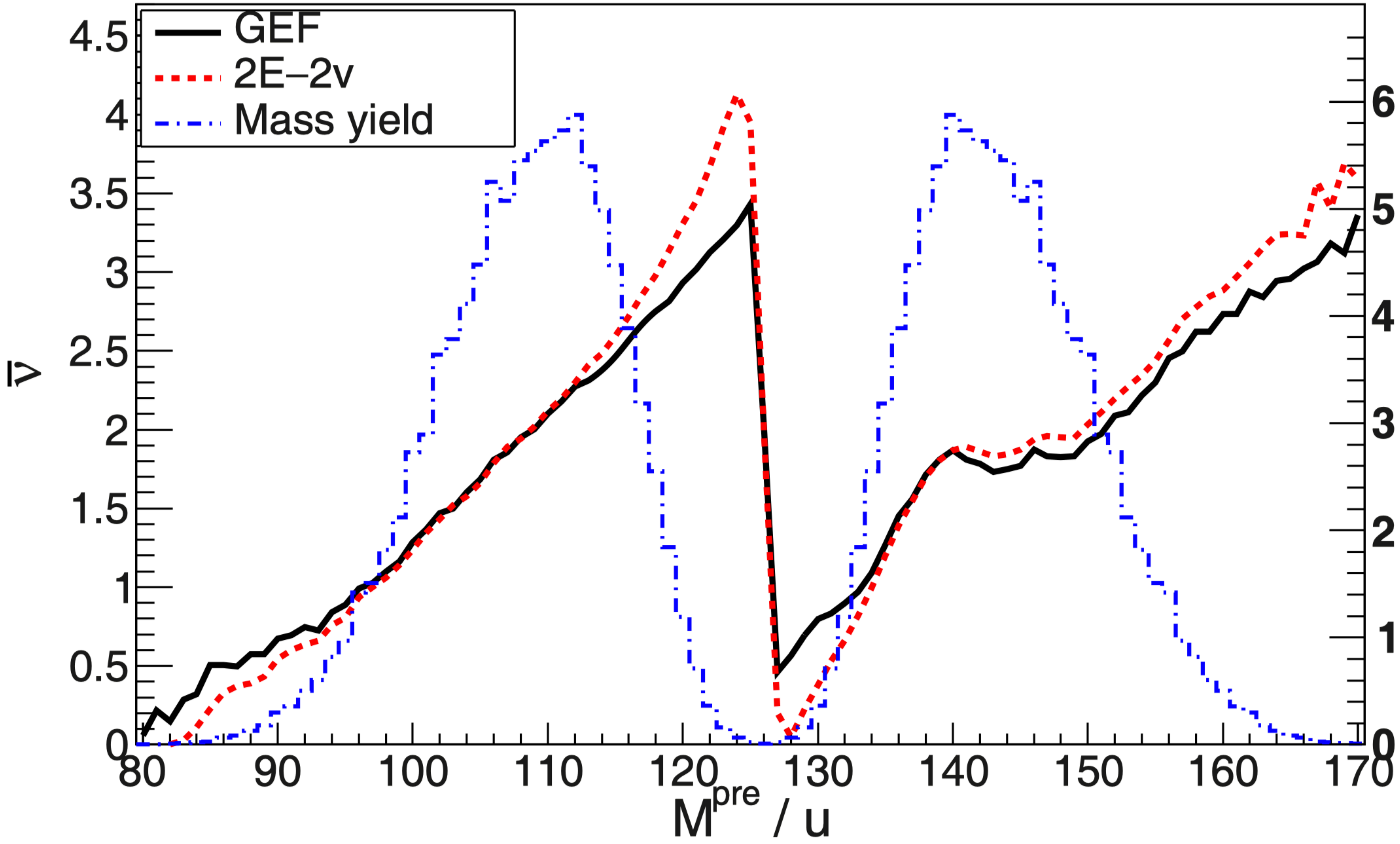
UNAFFECTED



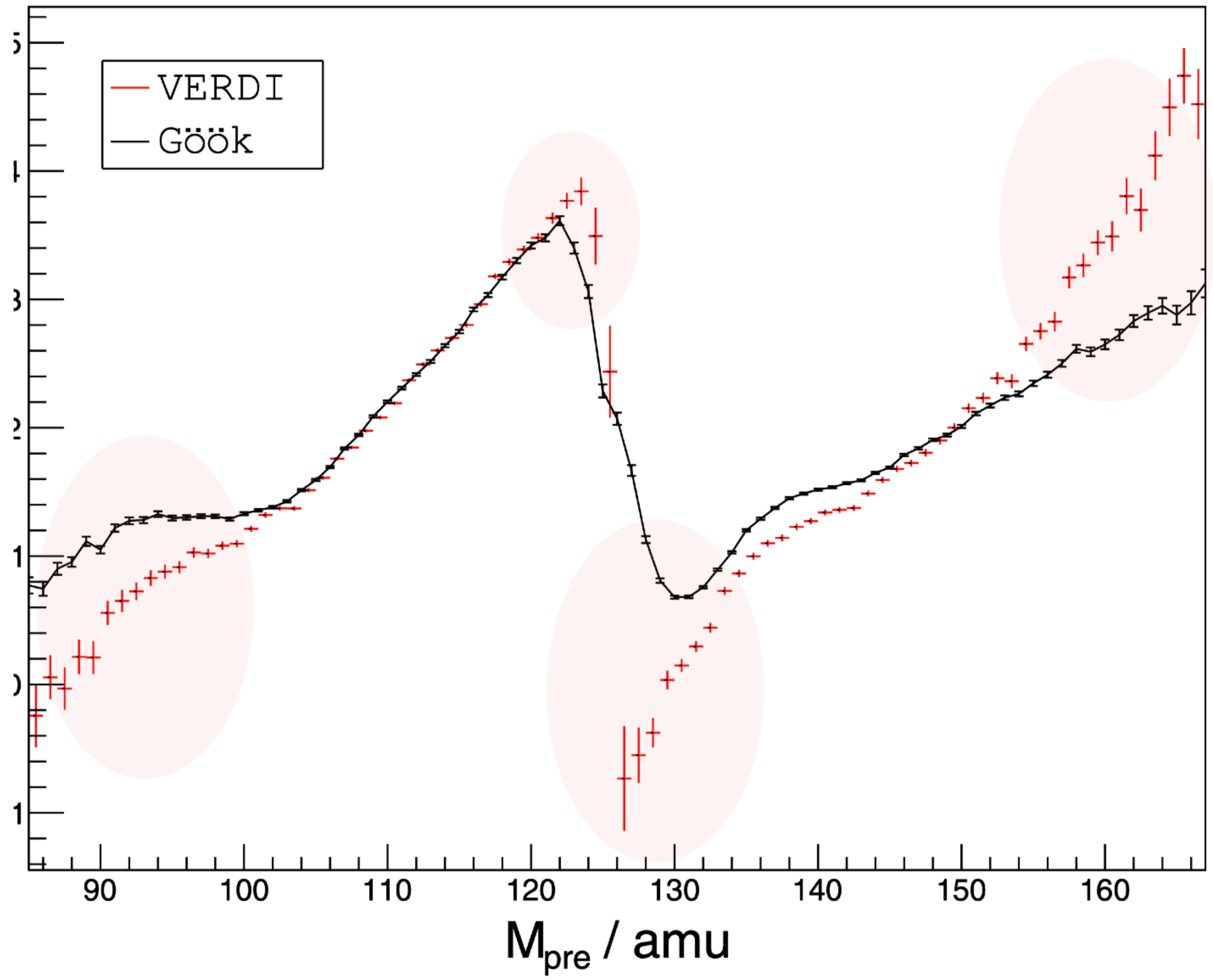
THUS A POSITIVE CORRELATION BETWEEN THE CALCULATED NUBAR AND THE CALCULATED PRE-MASS



KEY 2E–2V ASSUMPTIONS ANALYSED



WE SAW THIS TREND IN THE VERDI EXPERIMENTAL DATA!



BUT THERE IS A REMEDY… UNFOLD THE RESOLUTION FUNCTION…