(SHEXI) PSA

- Why do I need Pulse Shape Analysis ?
  - Recap on a typical detection set-up for SHE
  - Physics example
- electron / alpha discrimination set up
- Results
  - template method
  - “simple” features → Neural Network
- Conclusions

Zakopane 2024: D-SHEXI

agence nationale de la recherche

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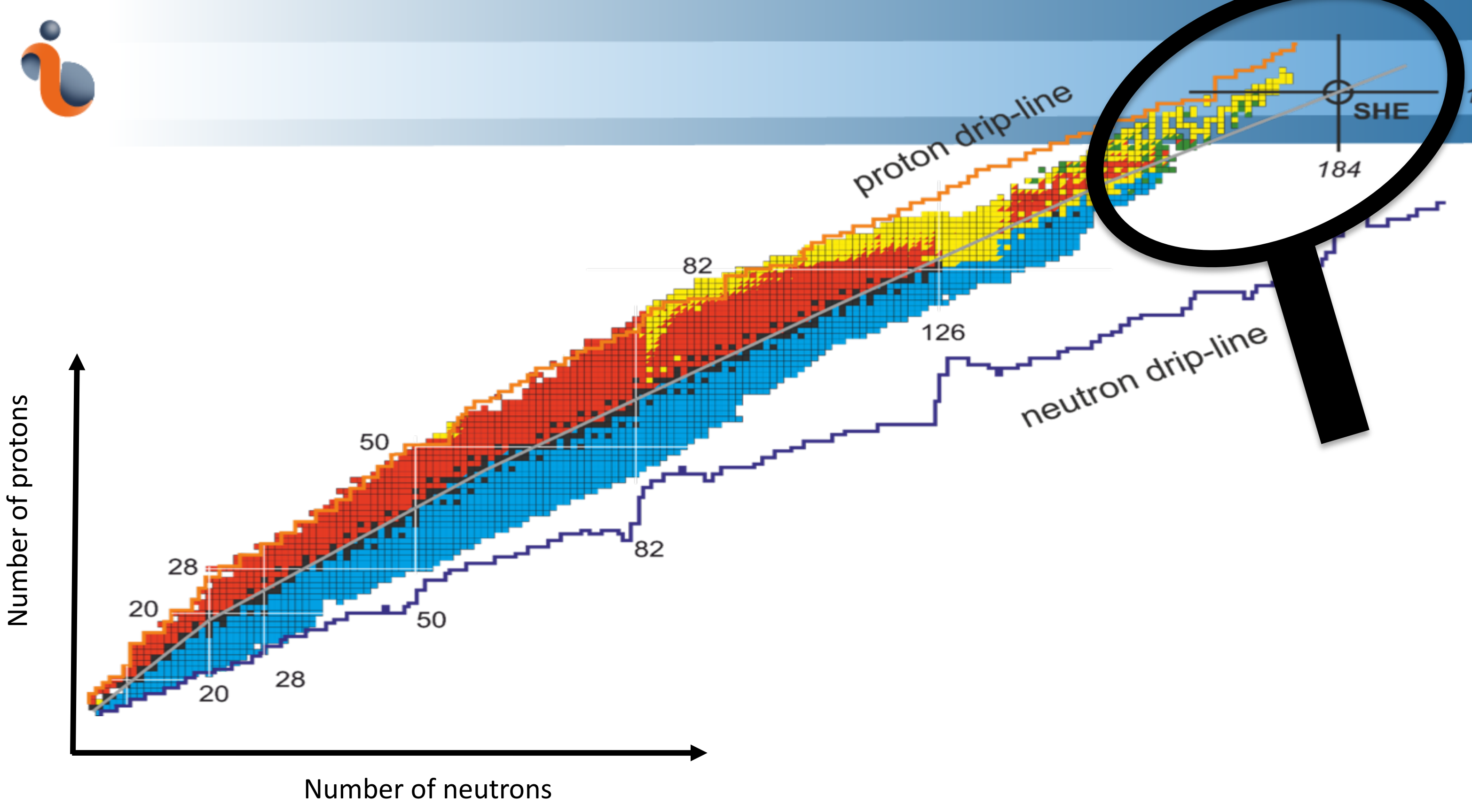
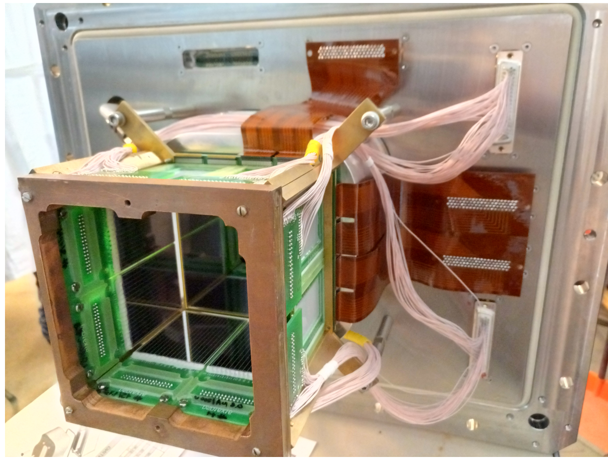
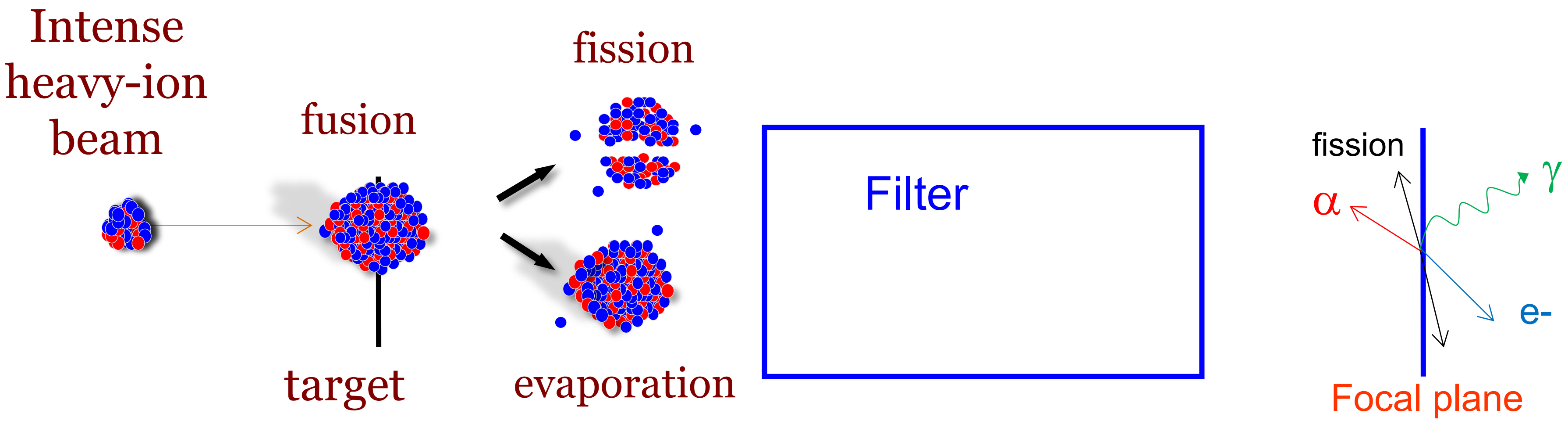
(LASCALA)

KH, M. Chabot, E. Raully
IJCLab

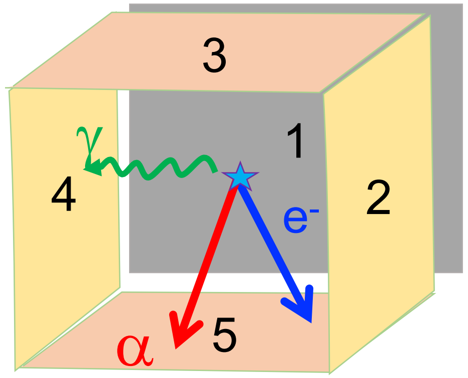


proton drip-line
neutron drip-line
SHE
14
184
126
82
50
28
20
Number of protons
Number of neutrons



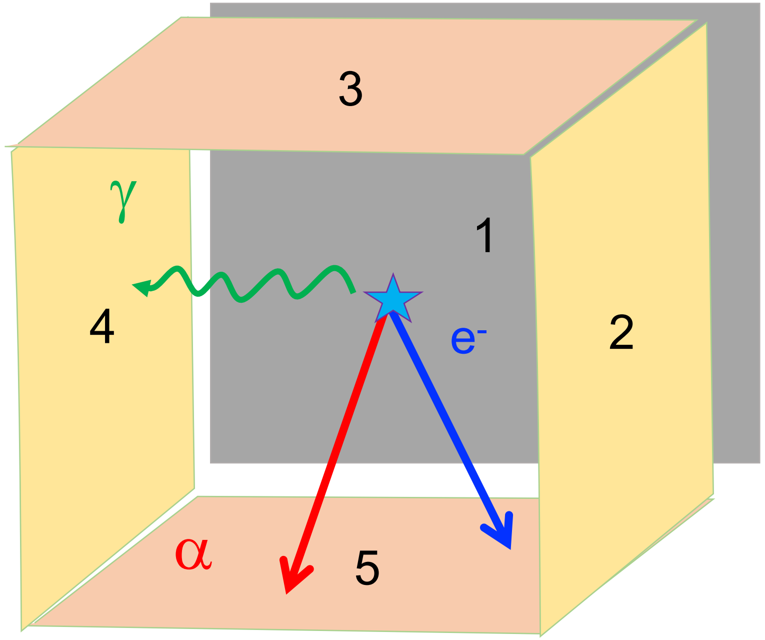


Intense heavy-ion beam
fusion
target
fission
evaporation
Filter
fission
α
γ
e-
Focal plane

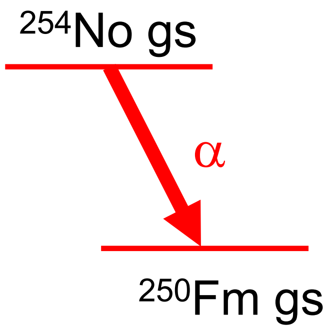


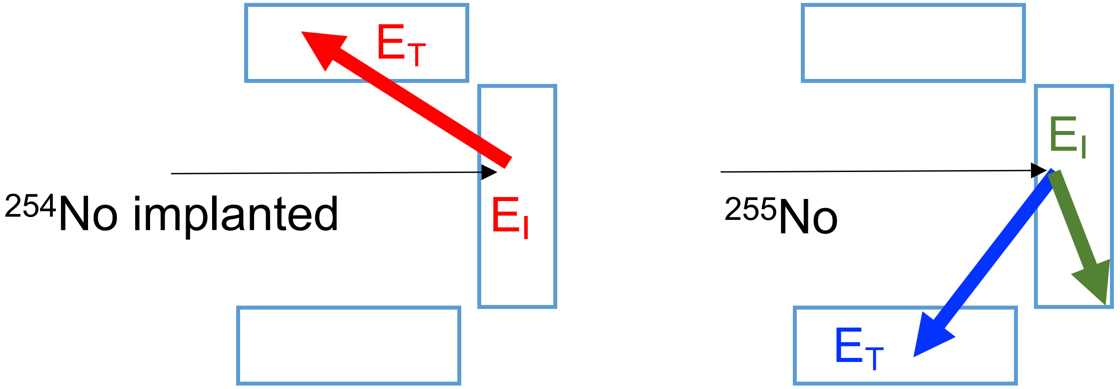
3
1
4
2
γ
e-
α
5

Why PSA ?

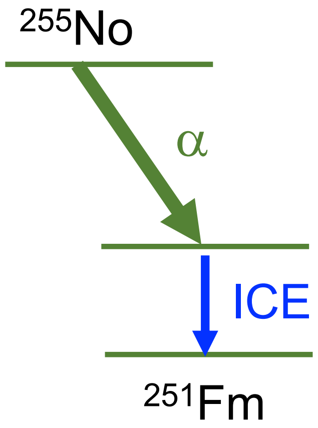


$^{208}Pb(^{48}Ca,2n)^{254}No$

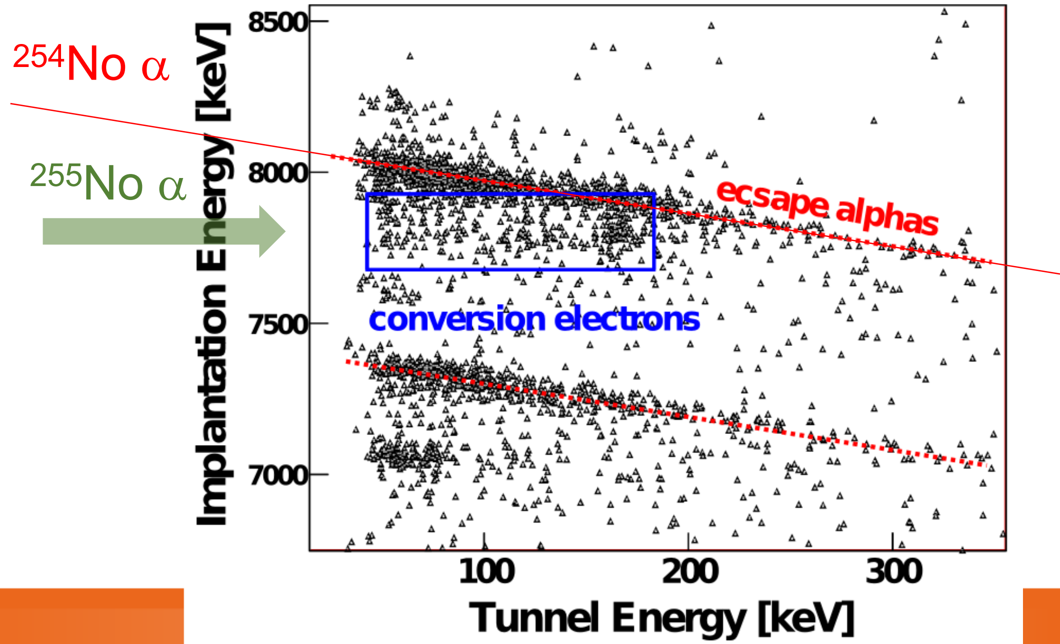




$^{208}Pb(^{48}Ca,1n)^{255}No$



b)



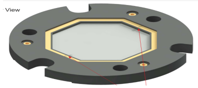
How do we remove these escape alphas ??

Tests using a GRIT prototype

{^{239}Pu, ^{241}Am,^{244}Cm}, ^{133}Ba, ^{207}Bi

(energy degrader for alphas)

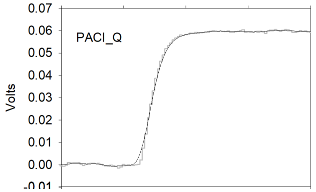
Ohmic



NTD, 500µm, 5.7kΩ/cm, dead-layer ~0.5µm
(successfully used to distinguish p,t,d with E >3 MeV)

Junction
[HV]

PA

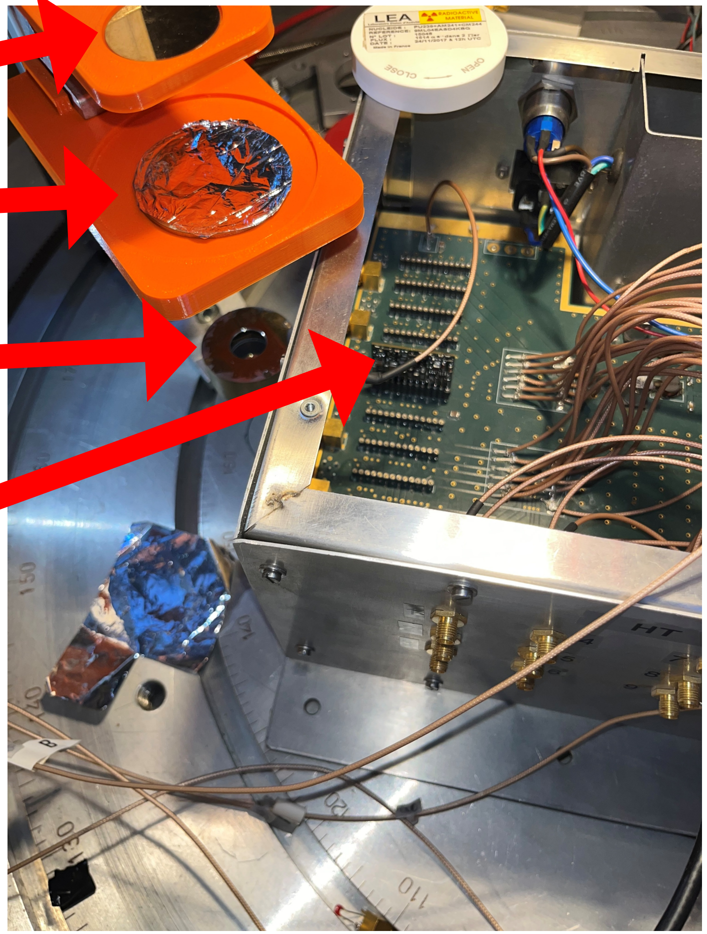


PACI (#10)	Q & I
CREMAT	Q
PARC05_50MHz	I

digitise

- 250MHz (NI)
- 1GHz (Lecroy)

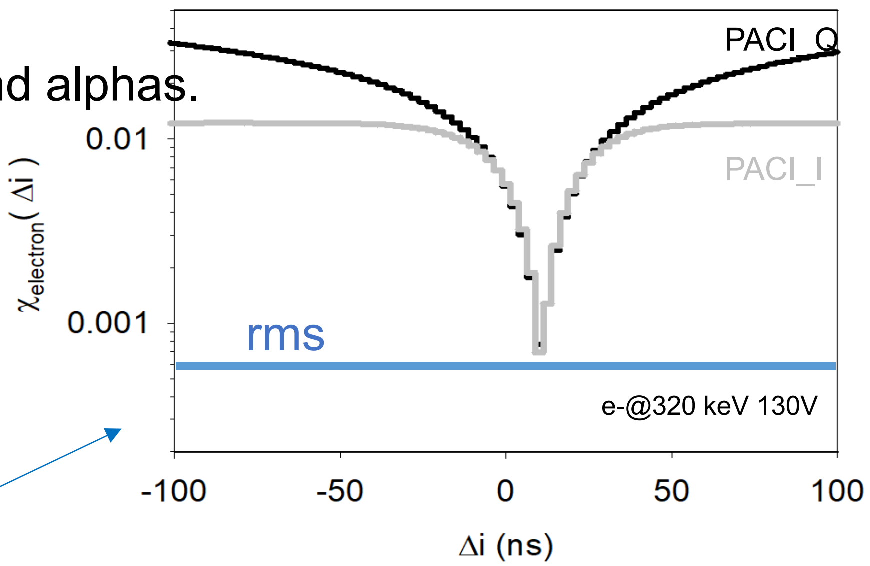
C.A.J. Ammerlaan, et al., Nucl. Instr. and Meth. 22 (1963) 189
M. Mutterer, et al., IEEE Trans. Nucl. Sci. 47 (2000) 756.



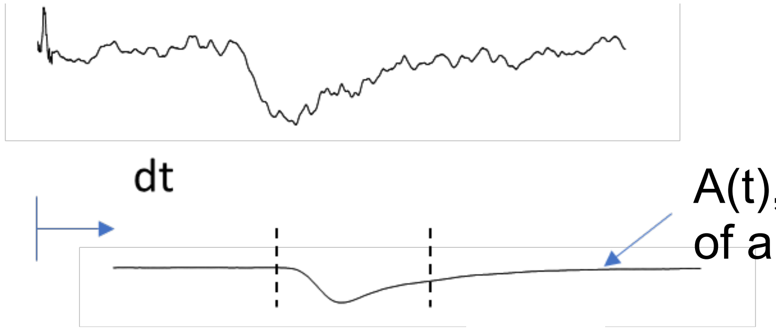
M. Chabot, et al., NIM B 197 (2002) 155
J.A.Duenas et al, NIM A 676 (2012) 70
B. Genolini et al., NIM A 732 (2013) 87
M. Assié et al. ,EPJA 51 (2015) 51
J.-J. Dormand et al., NIM A (2021) 165641

“template” matching → particle discrimination

For a given energy (bin) the average signal is calculated for both electrons and alphas.



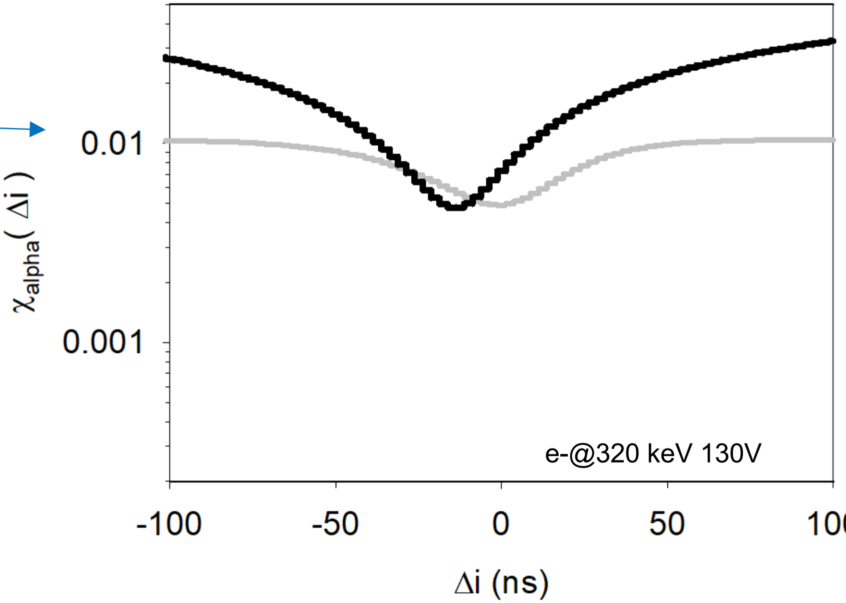
Signal, S(t)



A(t), Average of signals of a given particle type

Courtesy of M. Chabot

Then a χ^2 is calculated for every signal using both the electron template and the alpha template



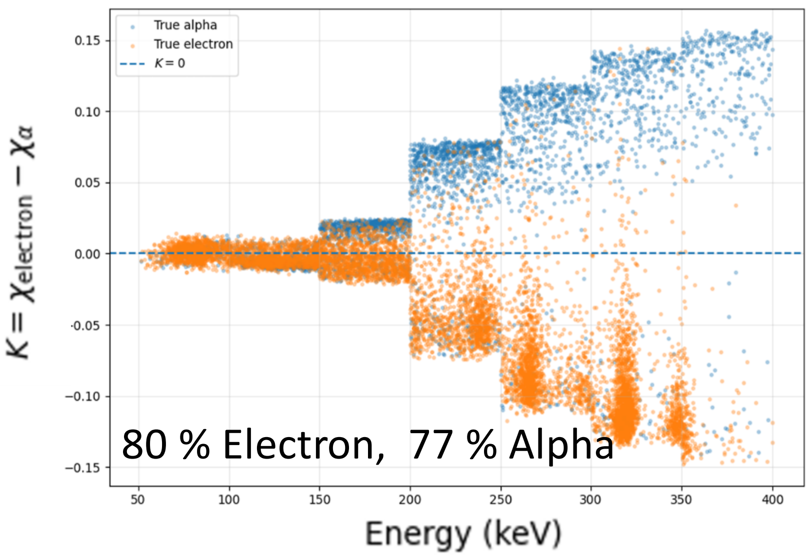
$$\chi^2_{species}(dt) = \frac{1}{n}\sum_{i=j}^{j+n}\left(A_{species}(i) - S(i-dt)\right)^2$$

M. Chabot, et al., NIM B 197 (2002) 155

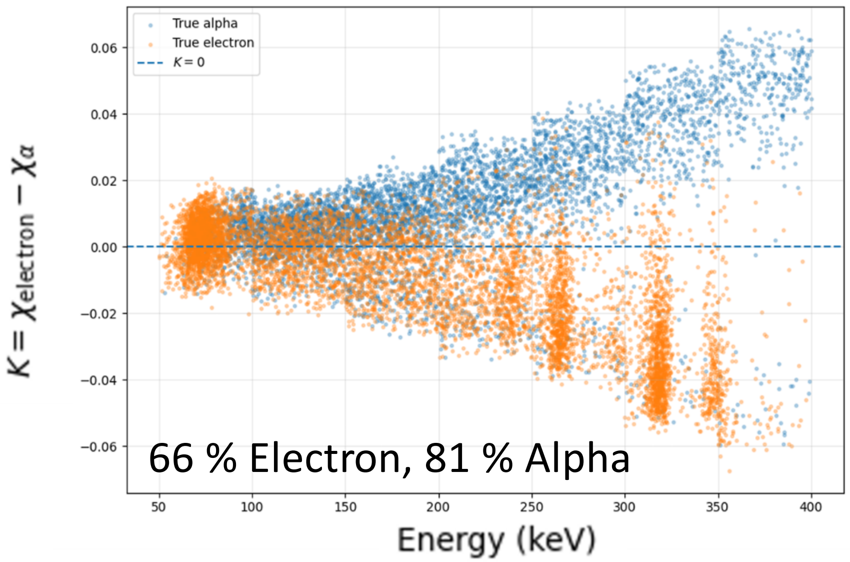
Excellent separation, works on both charge and current signals, (online?)

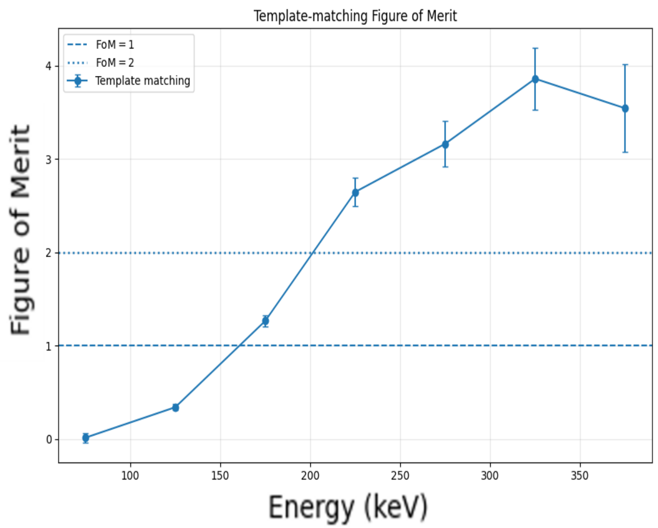
Results from M2 intern Tohirbek MUSAEV

130 V



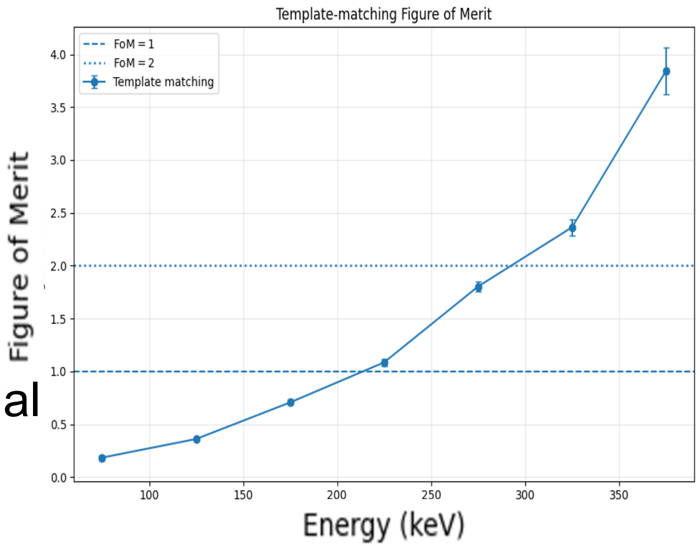
140 V



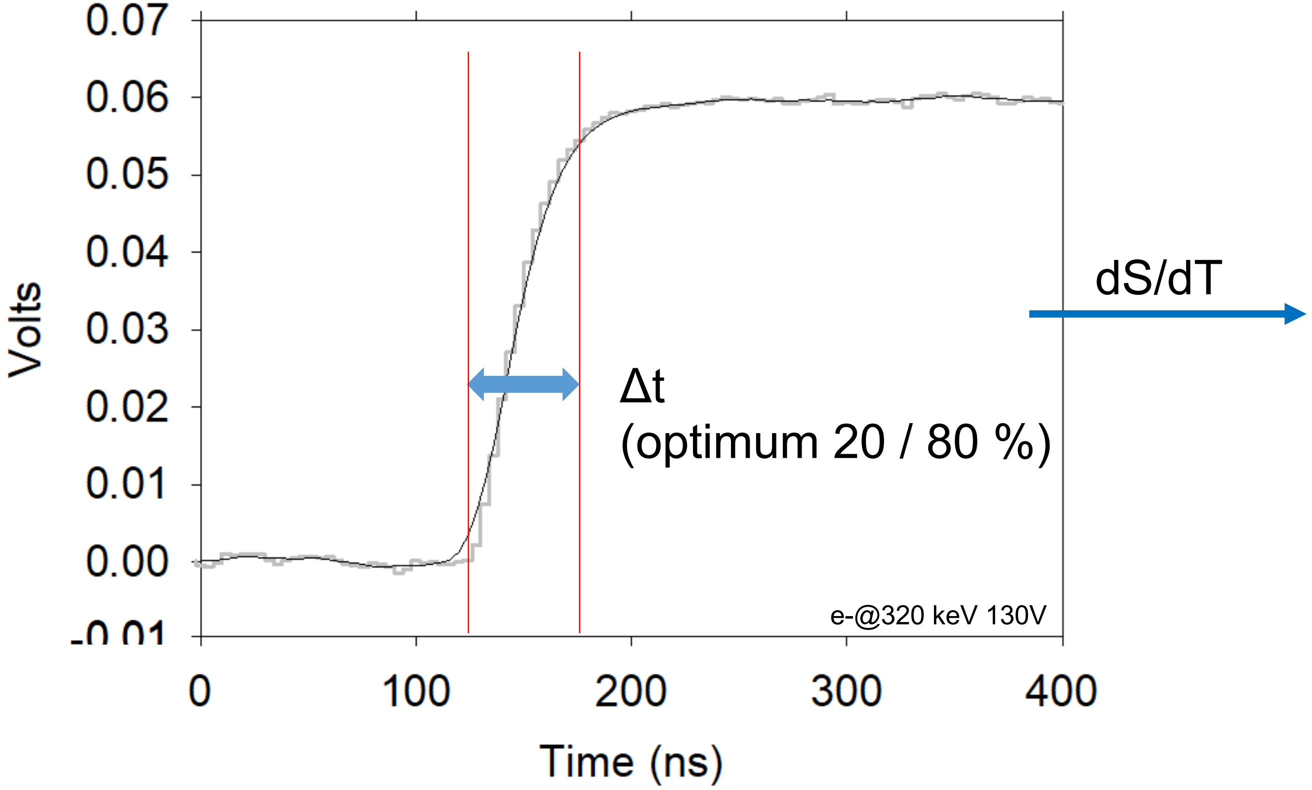


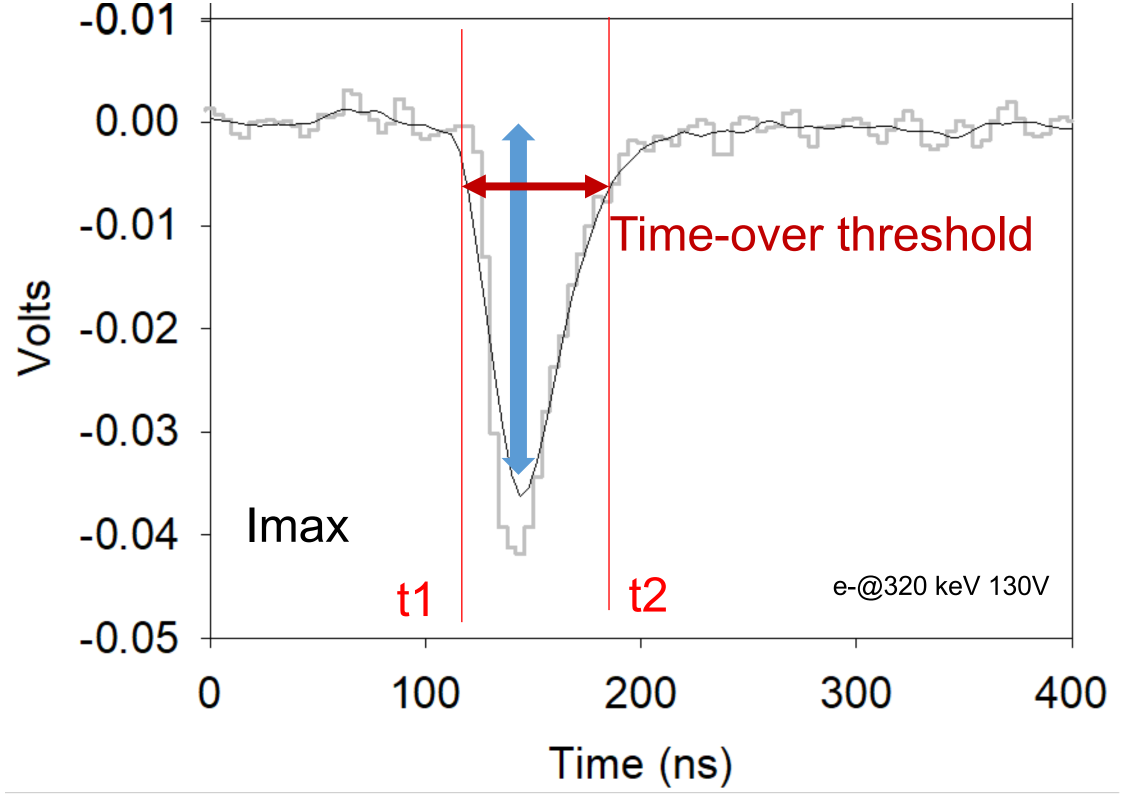
$$\mathrm{FoM} = \frac{|\mu_\alpha - \mu_e|}{2.355\,(\sigma_\alpha + \sigma_e)\,/2}$$

Excellent separation,
single parameter,
works on both Q and I signal
BUT…



Simple parameters





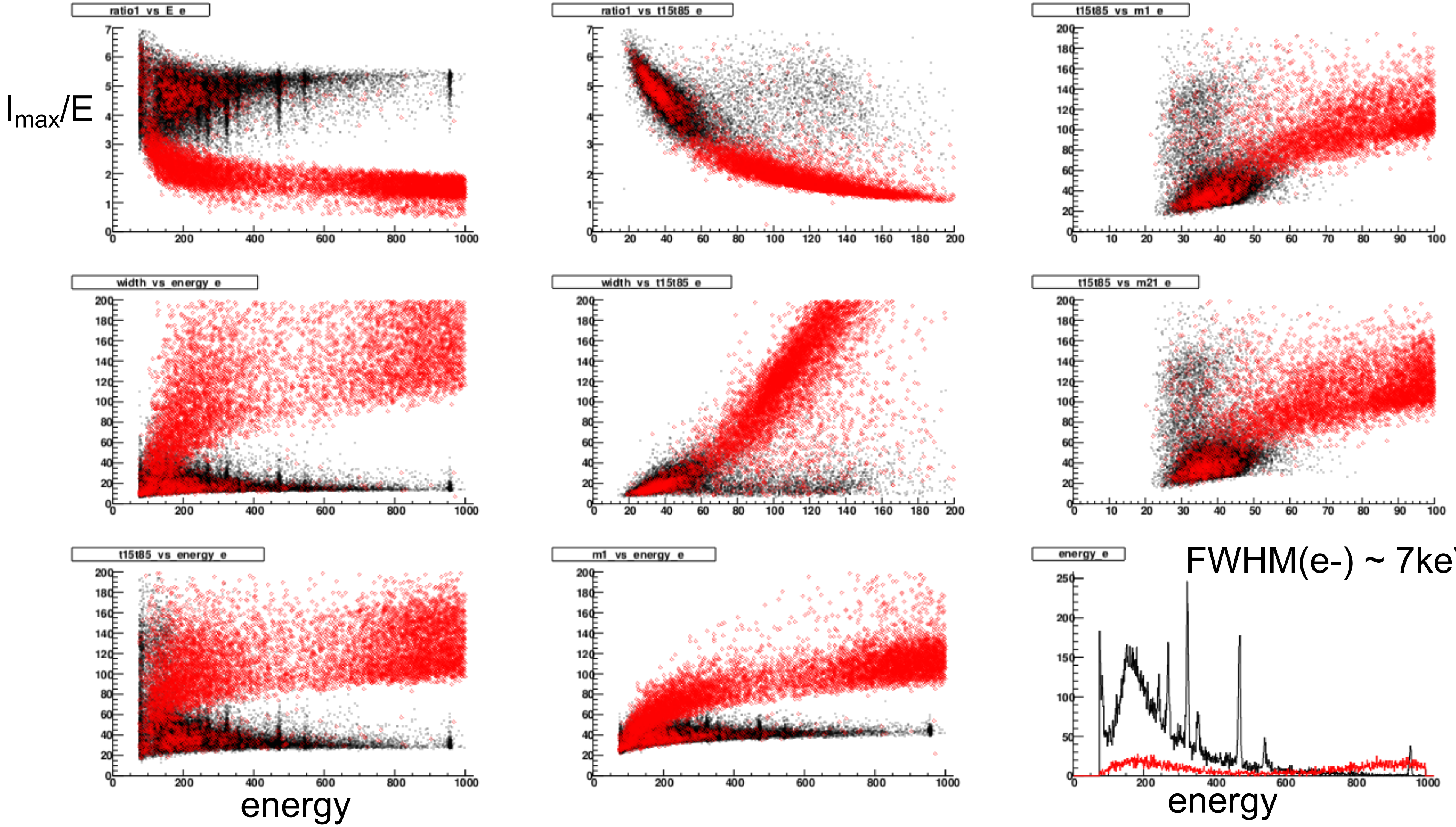
Signal rise-time

Maximum current

Current duration

Moments of the trigger (pseudo I) signal ? $M_n = \sum_{t=t1+1}^{t2} dS(t)\,(t-t1)^n$

Simple parameters plotted against one another



FWHM(e-) ~ 7keV [FS ~17 MeV]

What can a Neural Network bring to the party beyond simple cuts ?

Binary classifier Network architecture

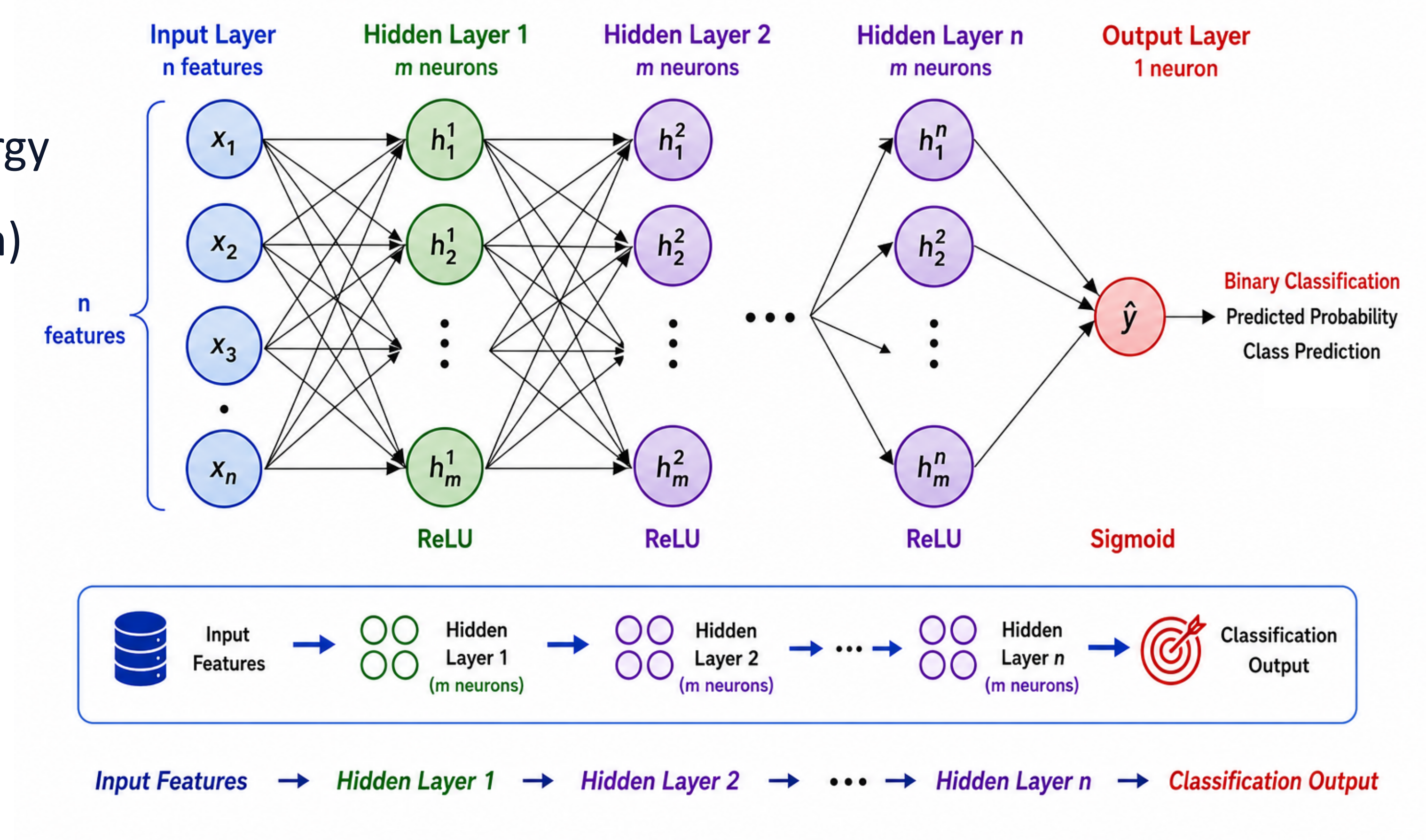
KH: TMultiLayerPerceptron (ROOT): [4I, 4H, 1O]
TM: Multi Layer Perceptron and Keras Sequential API Model: [4I, 4H, 4H, 1O]

Imax/Energy

ToT (Width)

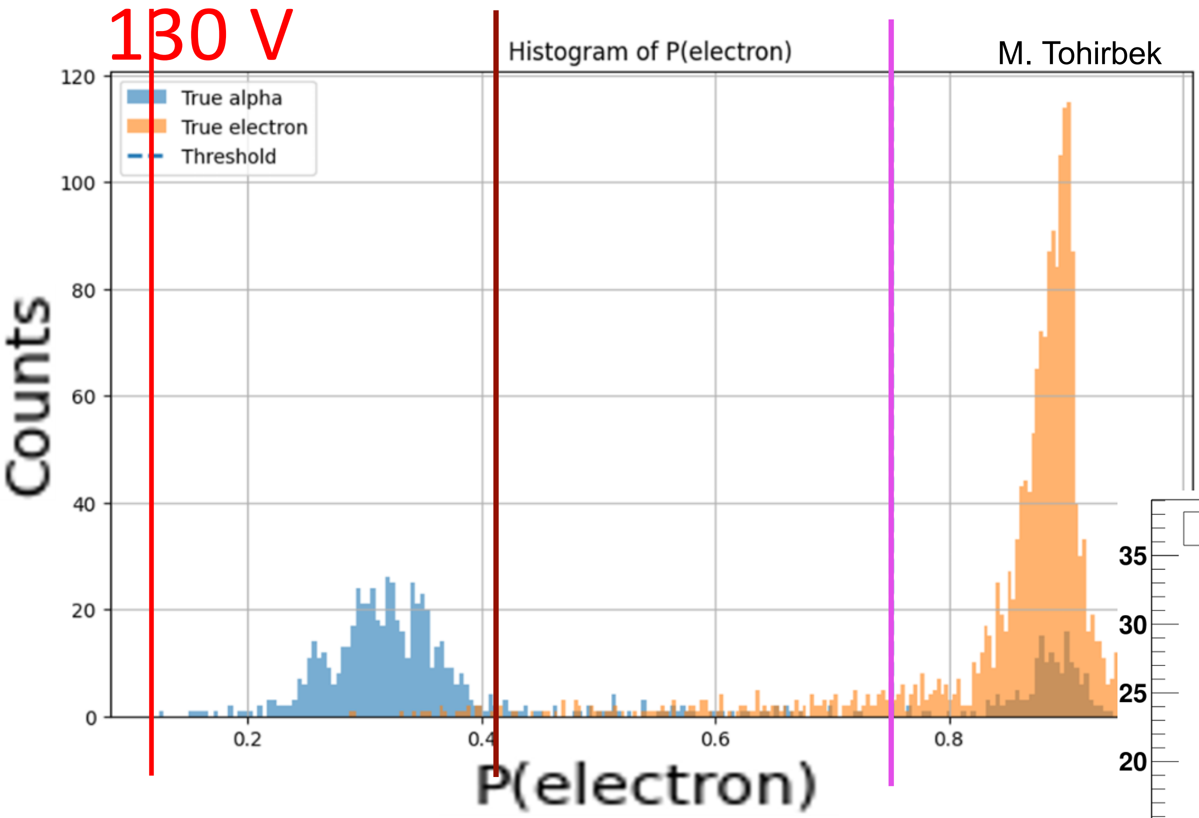
Energy

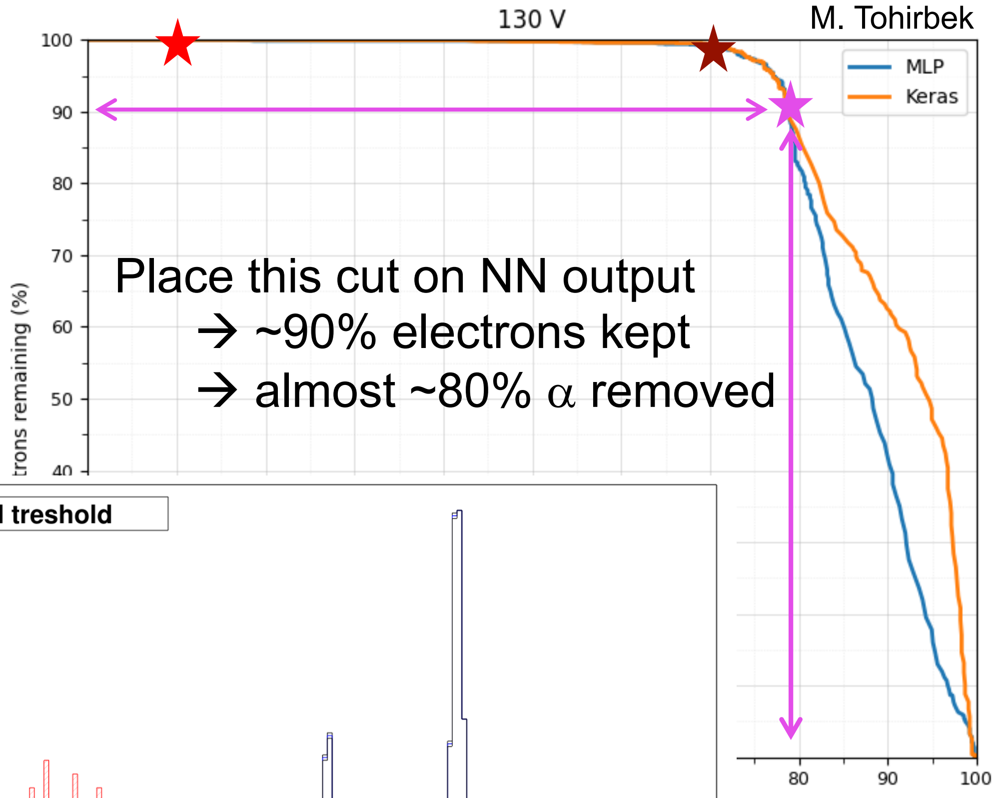
Rise time

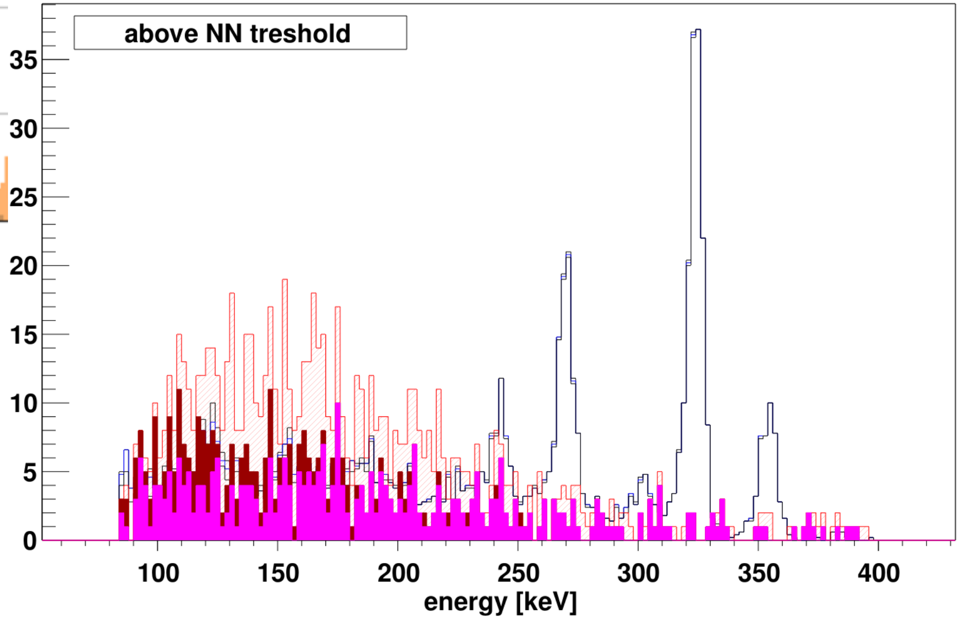


0 = alpha
1 = electron

Non-destructive thresholding → cleanliness vs statistics







Conclusions

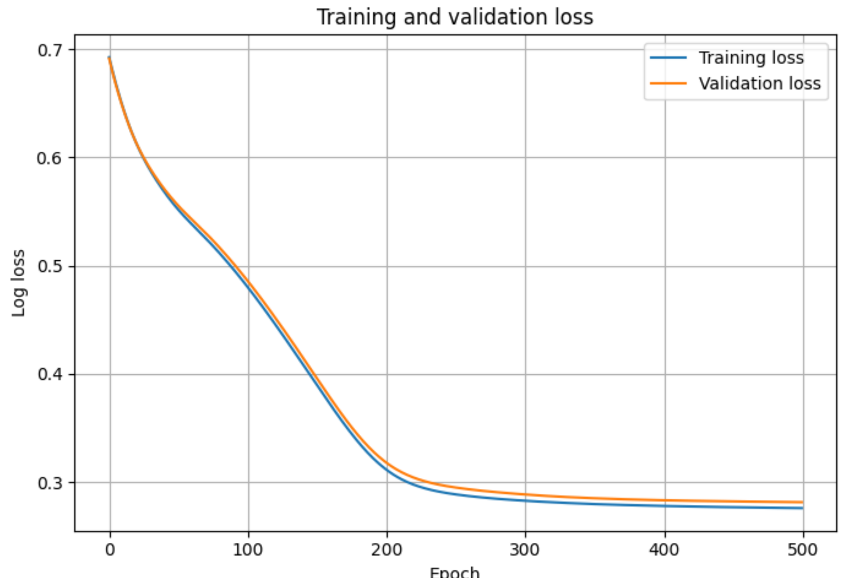
- Successful alpha-electron discrimination using simple NN
- 90% electrons kept, 80% alpha removed

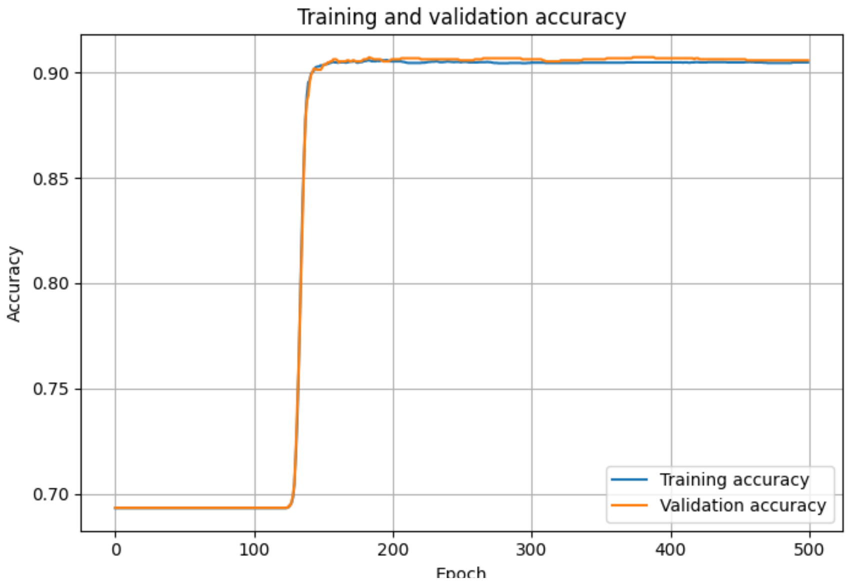
Perspectives

- More degraded alpha data
- Triple alpha source has fine structure decay
  → Pure alpha source (eg. 148Gd)
- New undamaged detector, cooling
  → improve discrimination %
  → lower energy threshold
- Apply Network to an FPGA

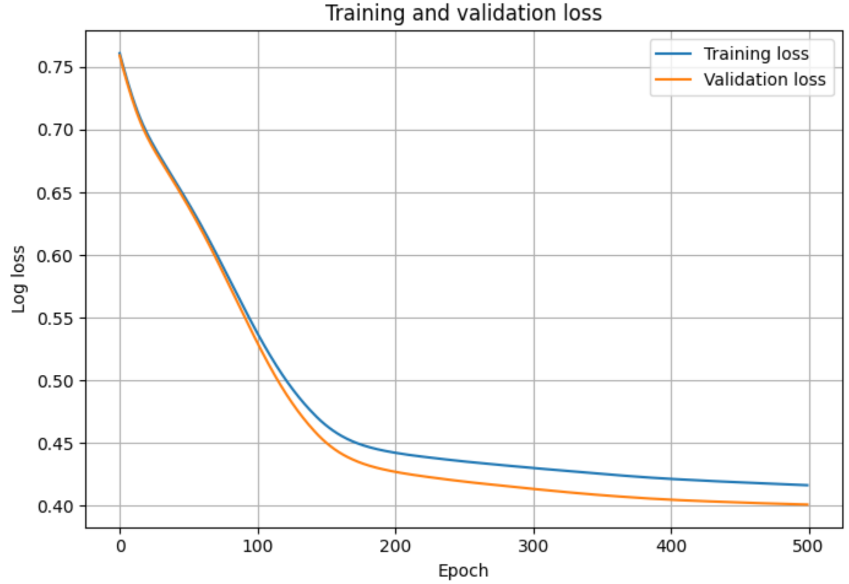
Neural Network: Validation

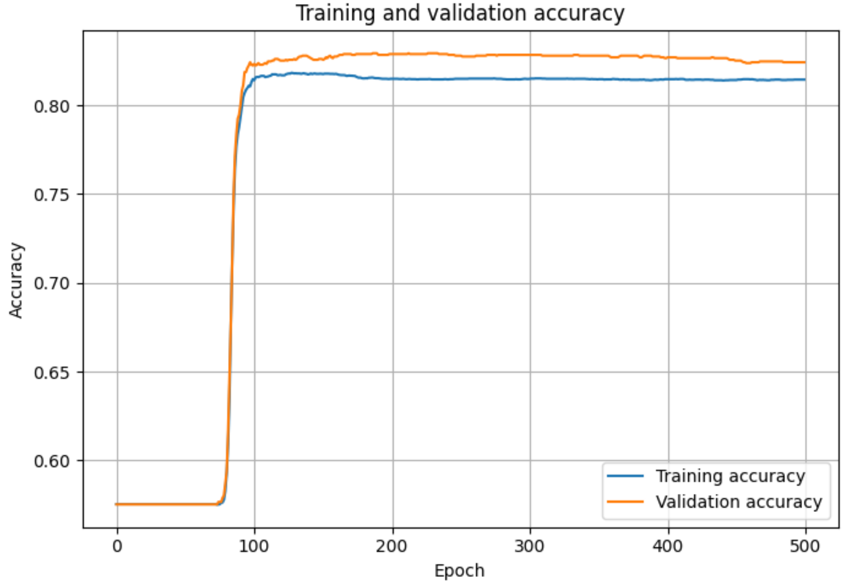
130 V





140 V





Rise time of the Triple alpha source