Status report on experiment G302

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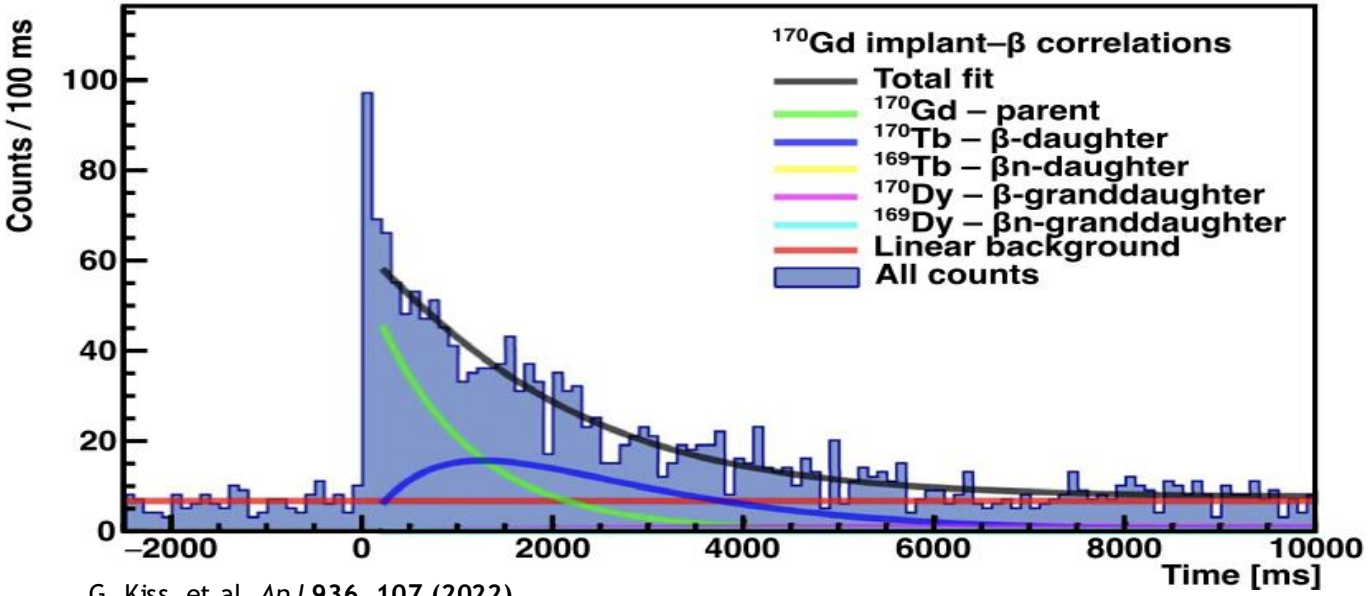
G302 at a Glance - Motivation

Experiment Goals:

- Measure $t_{1/2}$ for isotopes at low implantation rates
- Test detectors in implantation stack

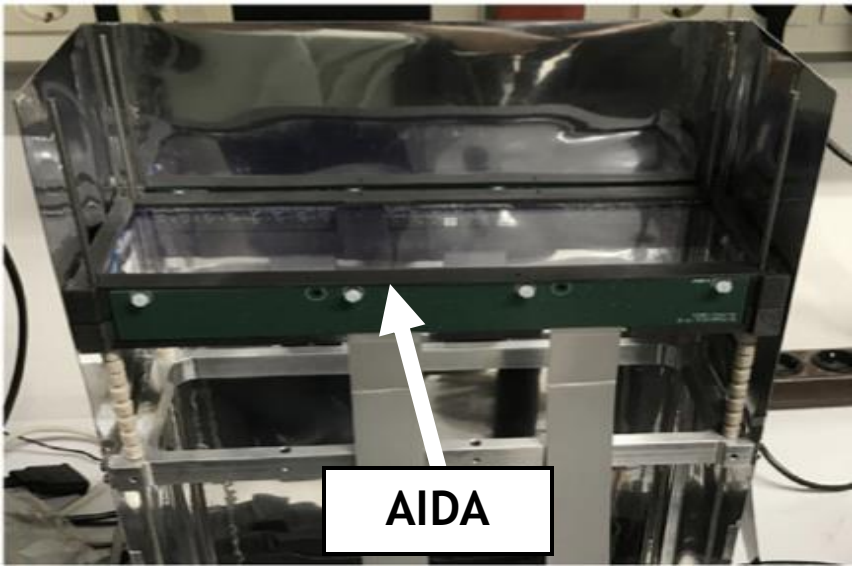


G. Kiss, et al. *ApJ* **936, 107 (2022)**

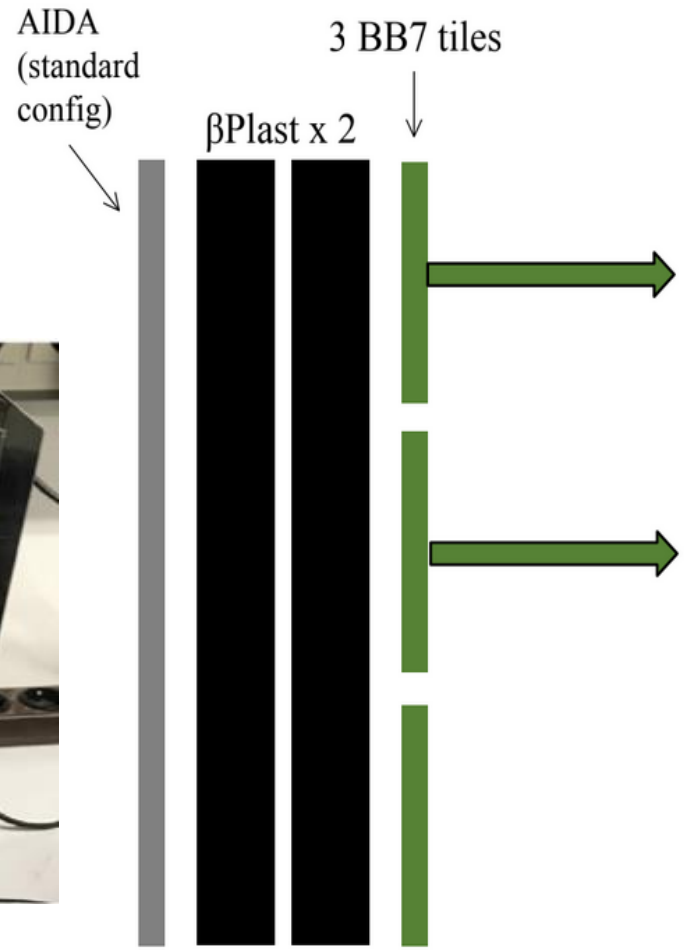
$^{107}Ag^{43+}$ Primary Beam on ^{9}Be target
1Gev/u @ 1· 10^{8} Hz
Centered on ^{84}Mo
FRS rates at S4 ~200 Hz

83Tc	84Tc	85Tc 100 ns p ?	86Tc 55 ms ε+β+=100% εp ?	87Tc 2.1 s ε+β+=100% εp<0.7%
82Mo ε+β+=100% εp ?	83Mo 6 ms ε+β+=100% εp ?	84Mo 2.3 s ε+β+=100% εp ?	85Mo 3.2 s ε+β+=100% εp=0.14%	86Mo 19.1 s ε+β+=100%
81Nb 40 ns ε+β+ ? εp ? p ?	82Nb 50 ms ε+β+=100% εp ?	83Nb 3.9 s ε+β+=100% εp ?	84Nb 9.8 s ε+β+=100% εp ?	85Nb 20.5 s ε+β+=100%
80Zr 4.6 s ε+β+=100% εp ?	81Zr 5 s ε+β+=100% εp=0.12%	82Zr 32 s ε+β+=100% εp ?	83Zr 41.5 s ε+β+=100% εp ?	84Zr 26 min ε+β+=100%

G302 at a Glance – DESPEC Setup



A.K. Mistry, et al. *NIM-A*, **1033, 166662 (2022)**

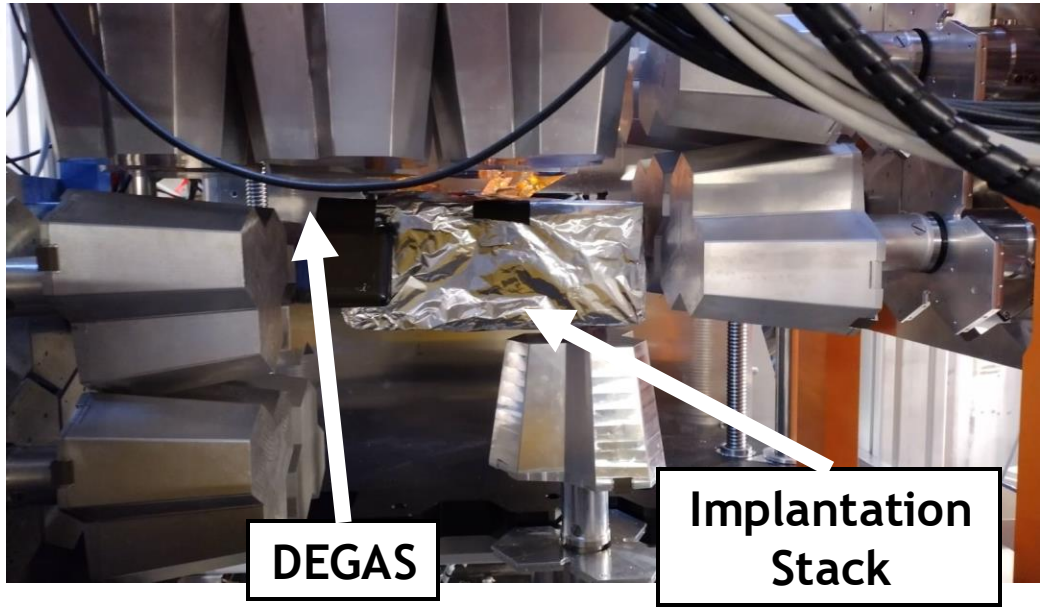


Implantation Stack:

- 1x AIDA DSSSD (wide)
- 2x bPlast Plastic Scintillator
- 1x BB7 DSSSD (AIDA DAQ)
- 2x BB7 DSSSD (FEBEX DAQ)

Gamma Detectors:

- 15x DEGAS HPGe (3x Crystals)

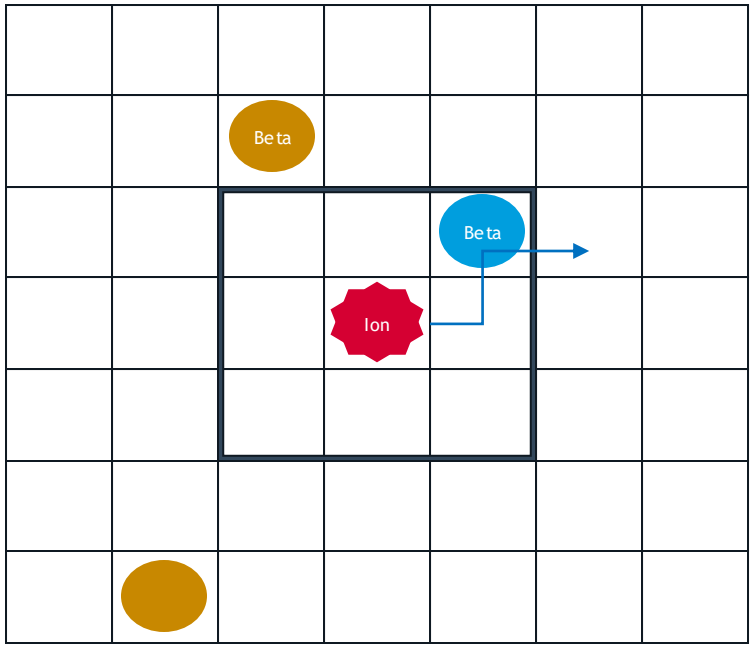


Implant-decay correlation methods

Different implant-beta position correlation methods investigated:

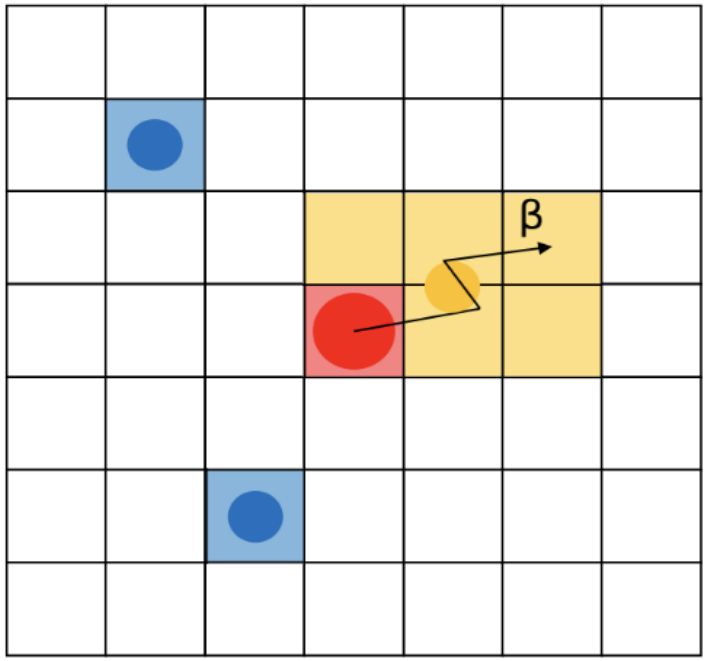
Centroid position correlation:

- Utilises cluster centroids
- Increased ß acceptance
- Lower random correlation suppression



Cluster position correlation:

- Utilises cluster shape
- Minimal change in ß acceptance
- Higher random correlation suppression



O. Hall *PhD Thesis* **(2020)**

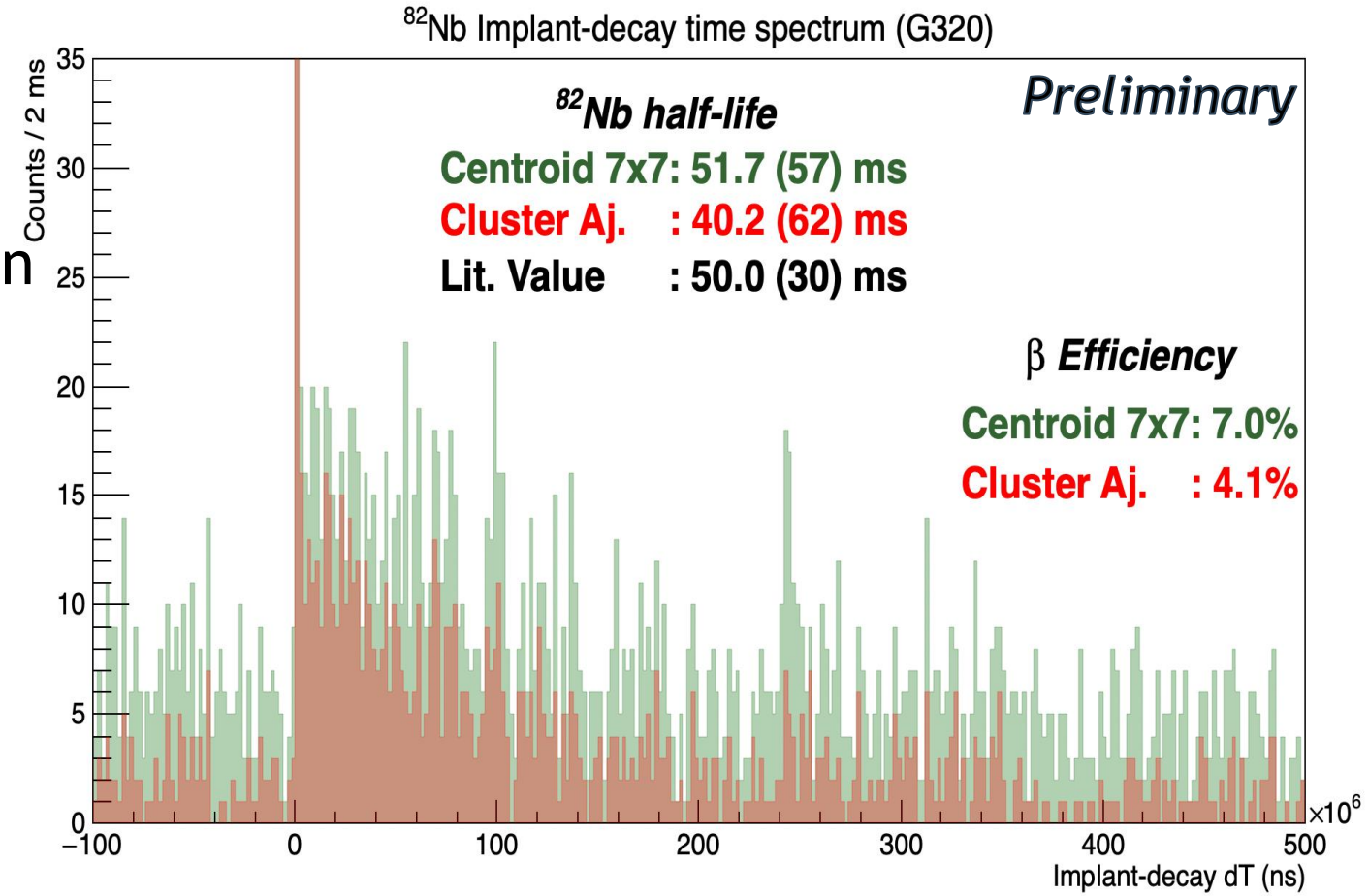
Implant-decay correlation methods

Results show cluster position correlation performing worse.

Adjacent cluster position correlation & 7x7 centroid position correlation → Comparable beta efficiency.

^{82}Nb $t_{1/2}$:

Cluster position correlation shows incorrect $t_{1/2}$ & reduced beta efficiency.



Geant4 simulation - Motivation

We need a method of accurately simulating β electron behaviour & DAQ response in AIDA + other DESPEC subsystems

Goals :

- Realistic treatment of β electrons propagation
- Recreate event building
- Germanium response for β delayed gammas

Focus:

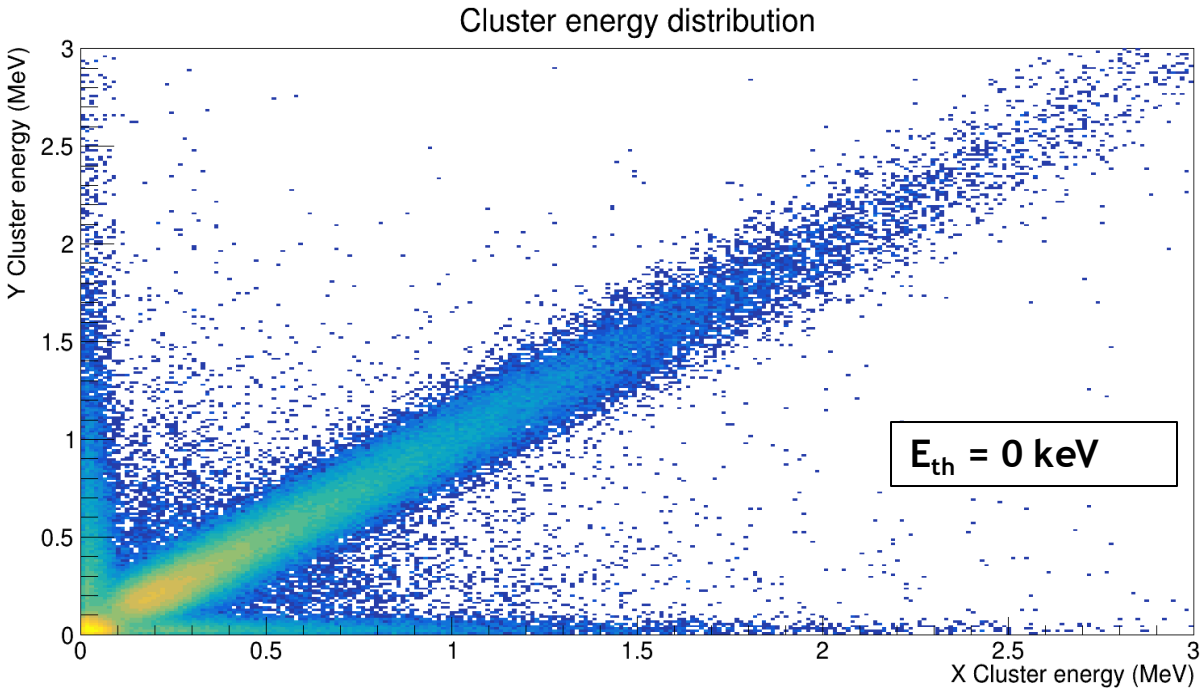
Look to vary Q_β and strip E_{th} and investigate:

- β cluster shape
- β efficiency
- β delayed gamma spectra
- Noise

Geant4 Simulation – E_{th} irregularities

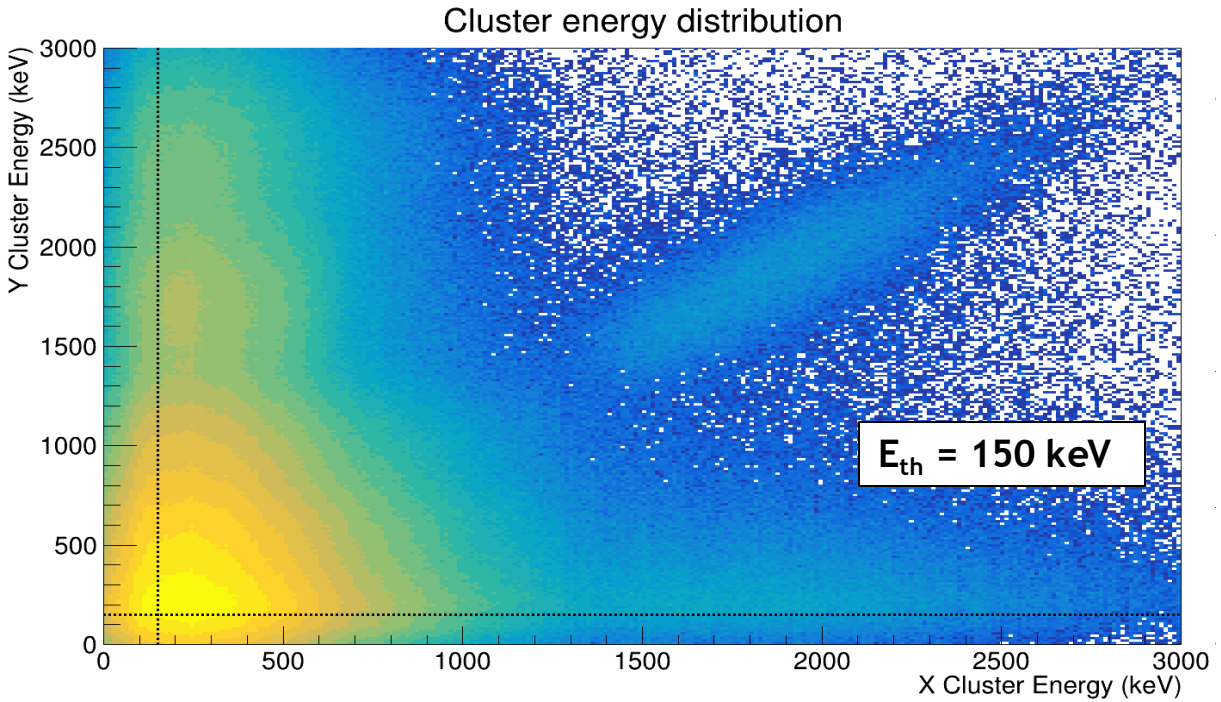
Simulation

Expected E_β distribution w/
Diagonal & off-diagonals.

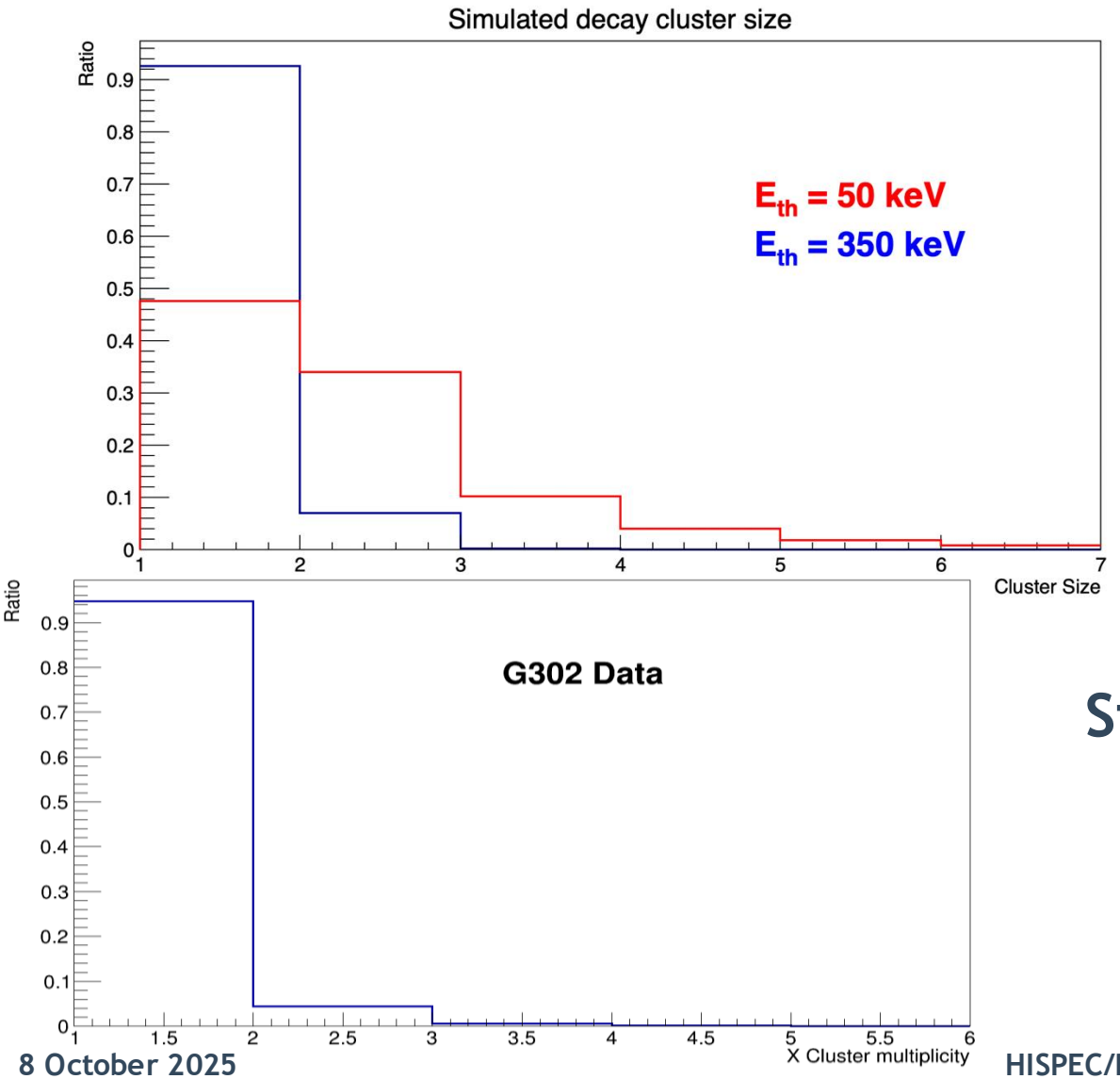


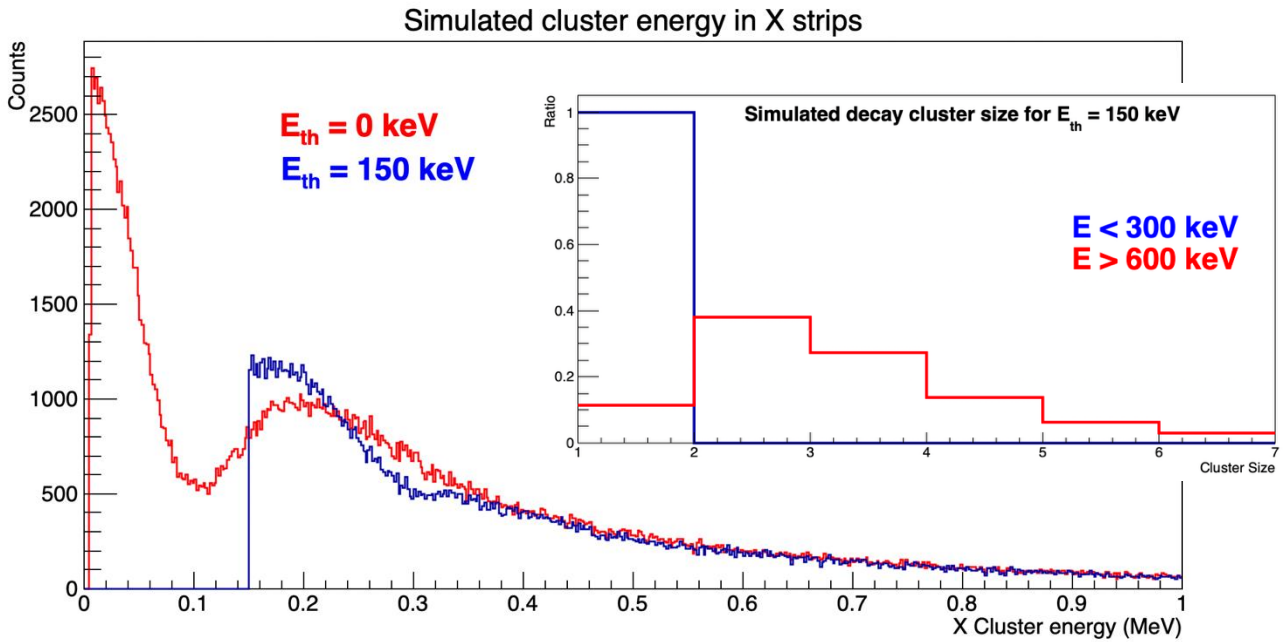
Experiment

Expected distribution for
protons & alphas, not betas



Geant4 simulation – Cluster Sizes

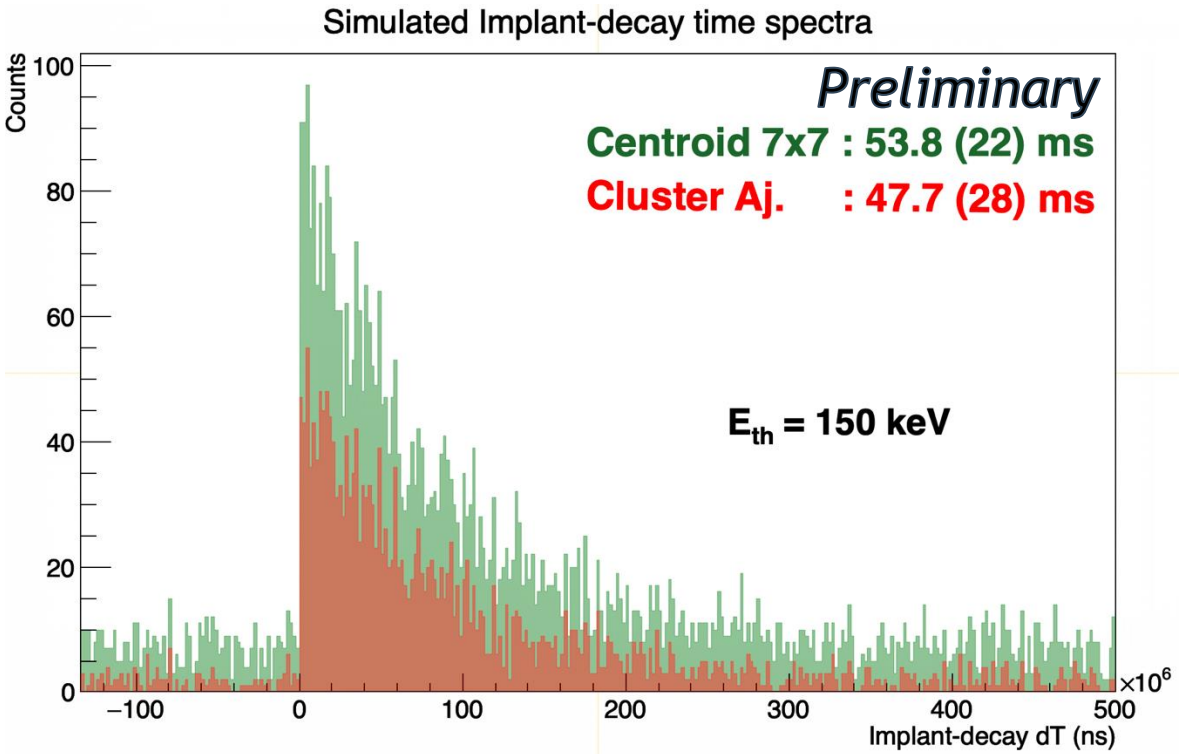


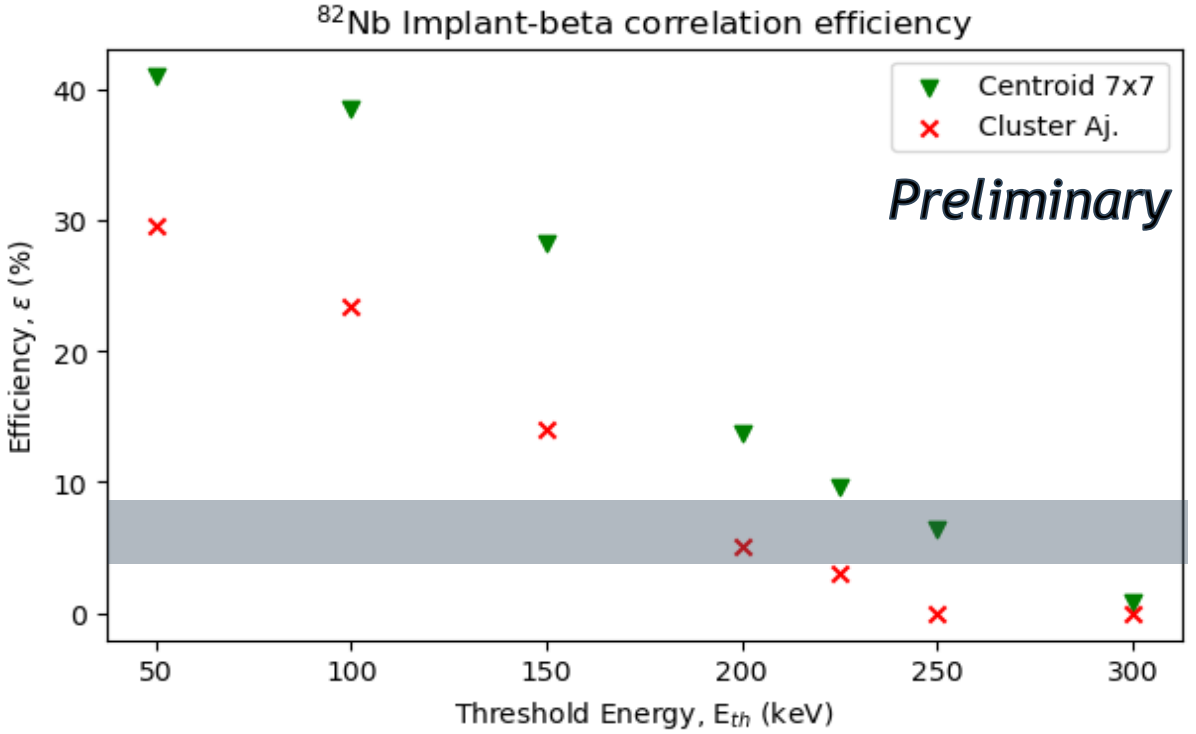


Single strip problem:

- Clusters overrepresented by strip multiplicity of 1
- Cluster strip multiplicity highly dependent on E_{th}
- Overrepresentation → Indication AIDA is not operating at hardware thresholds

Geant4 Simulation – Implant-beta correlations





Beta correlation efficiencies:

- Beta efficiencies for all corr. methods converge at high E_{th}
- Based on correlation efficiencies, AIDA operates at an effective E_{th} ~ 250 keV

Geant4 Simulation – Noise

Noise in G302:

- Average DSSD noise rates in G302-> ~5000 Hz
- Noise rates per ASIC → ~156 Hz
- Average noise event per ASIC → ~6 ms

Cluster – Frontback discrepancies:

- EM noise affects clusters and frontback hits differently
- Relative efficiency for G302 → ~24 %
- Noise unlikely to arise from electronics

Noise rate / ASIC (Hz)	Number of clusters	Number of frontback	Relative efficiency (%)
0	18984	10363	54.6
10	199611	10367	5.19
100	1823874	10524	0.38
1000	18045771	29491	0.16

Parting Comments

Conclusion:

- Development of simulation to assist development and analysis during the proposal, nearline and offline analysis stages.
- Cluster sizes and beta efficiencies indicate effective DSSD thresholds differ greatly from nominal values.
- Simulations point to random beta correlations dominated by source other than electronic noise.

Outlook:

- Continue development of Geant4 simulations to include realistic AIDA & germanium geometry, implantation propagation and degrader effects.
- Investigate source of random beta correlations and real effective E_{th} of AIDA.

Thank you for your attention!

G. Bruni-Campanella[1,2], J. Bormans[1,3], D. Brugnara[1,3], C. Chatel[3,1], H. Albers[1], T. Davinson[5], J. Gerl[1], M. Górska[1], N. Hubbard[1], C. Jones[6], A. Jungclaus[7], M. Kundu[2], J.E. Larsson[1,3], A.I. Morales[4], M. Polettini[1,3], D.R. Rodriguez[4], and the **HISPEC-DESPEC collaboration**

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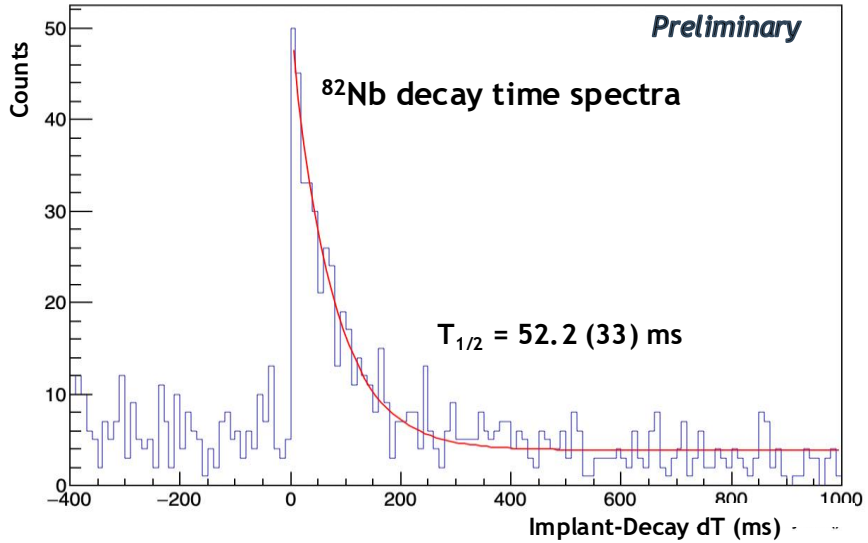
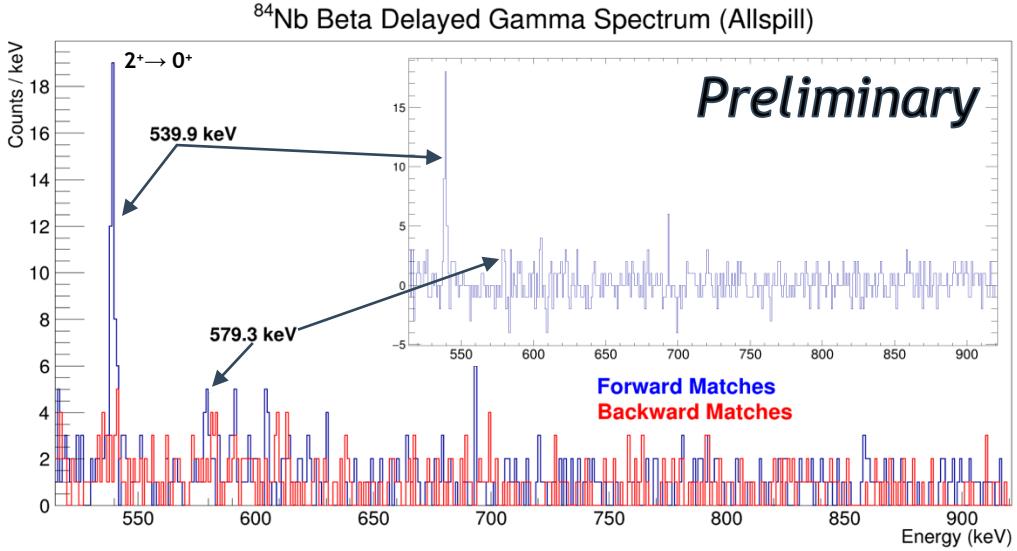
[6]*Department of Physics, University of Surrey, Guildford, UK*
[7]*Instituto de Estructura de la Materia, CSIC, Madrid, Spain*

Backup Slides

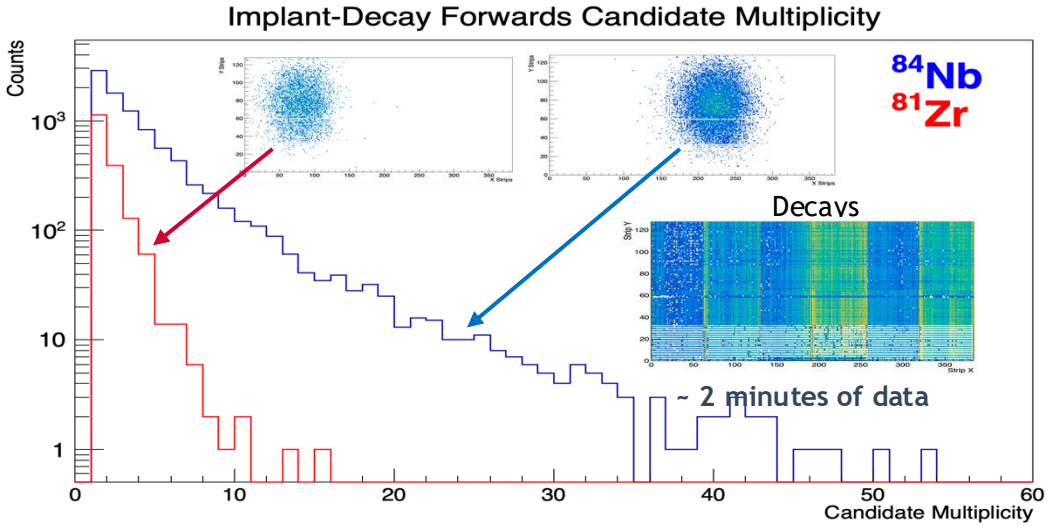
Recap of last update meeting





Remarks:

- Advancements made in **data handling** and **analysis** of AIDA at GSI.
- Implant decay correlation **demonstrated for $t_{1/2}$ ~ 50 ms, improvements needed for $t_{1/2}$ ~ 9.8 s.**
- AIDA capable of **implant decay gamma correlation** and **available for previous experiment analysis.**



Improvements in FRS-AIDA implantation efficiency

Problem:

- Low implantation correlation efficiency in AIDA compared to nearline analysis.
- Offline analysis: ~2000 ^{82}Nb implants
- Nearline analysis: ~12000 ^{82}Nb implants (A. Jungclaus)

Reason:

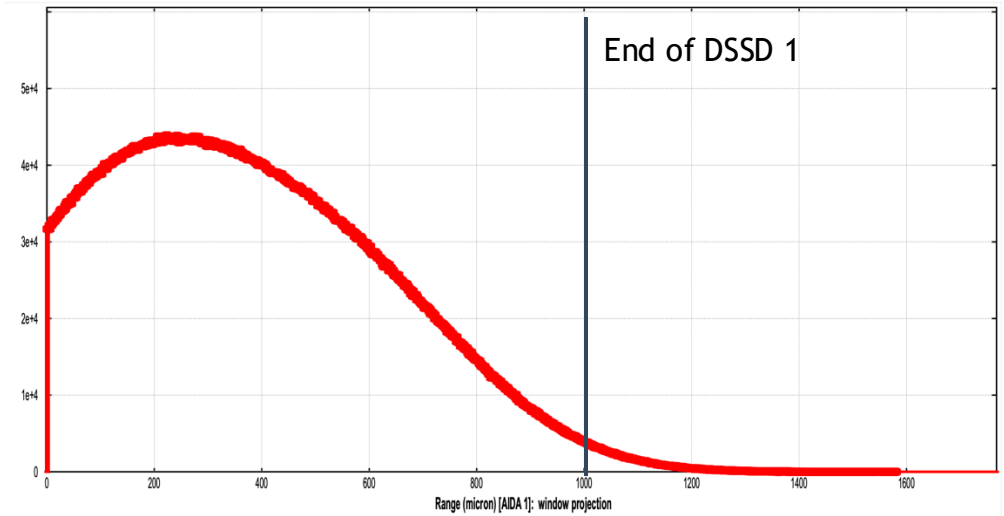
- Stopped flag w/ bPlast undercounting stopped implants.
- Rudimentary stopped flag w/ implant E_{dep}

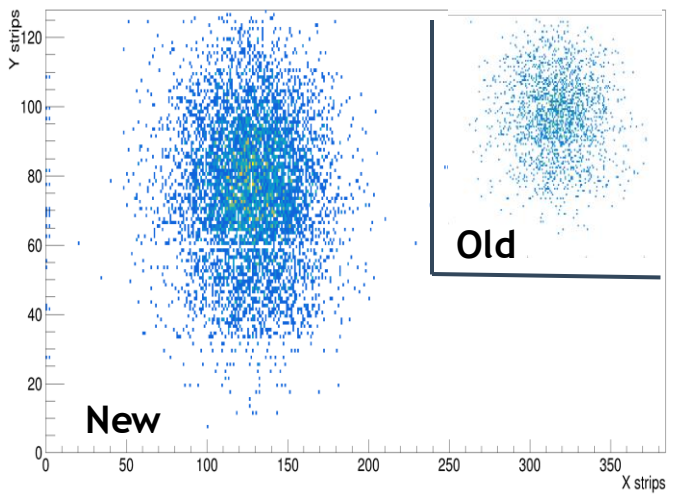
New implantation counts:

~ 11000 ^{82}Nb implants (w/o Sci42 gate)

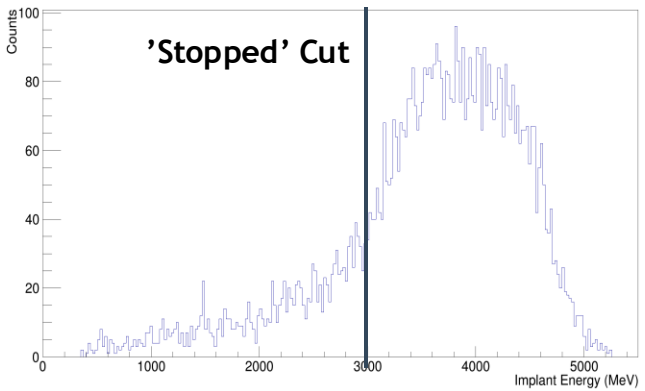
~ 7500 ^{82}Nb implants (w Sci42 gate)

^{82}Nb implantation profile (AIDA)





^{82}Nb Implantation energy



Implantation-beta correlation software

Formalised implant-beta-gamma correlation for GSI AIDA analysis.

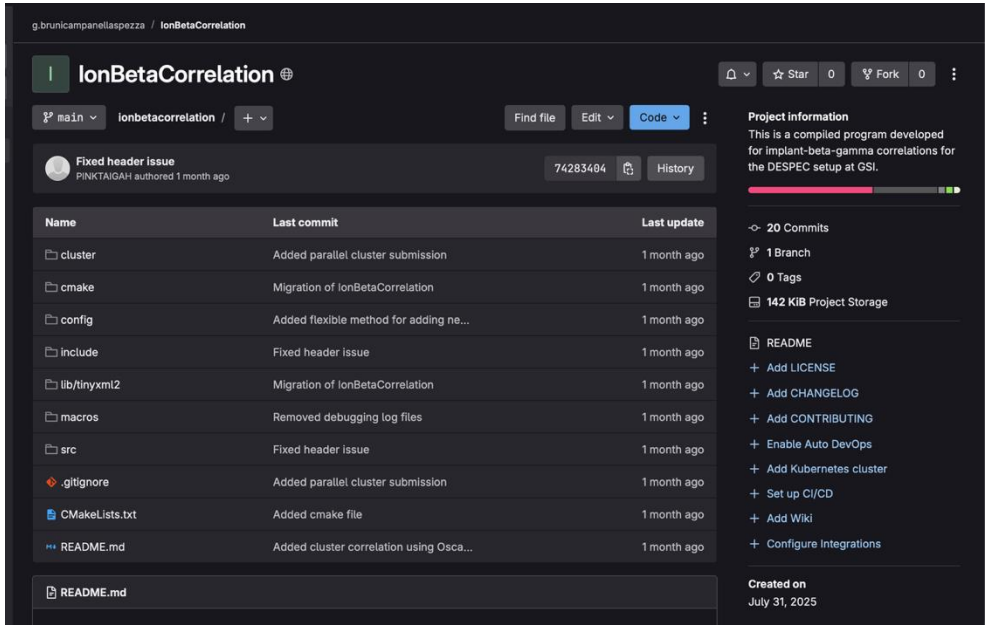
Designed for offline and nearline analysis.

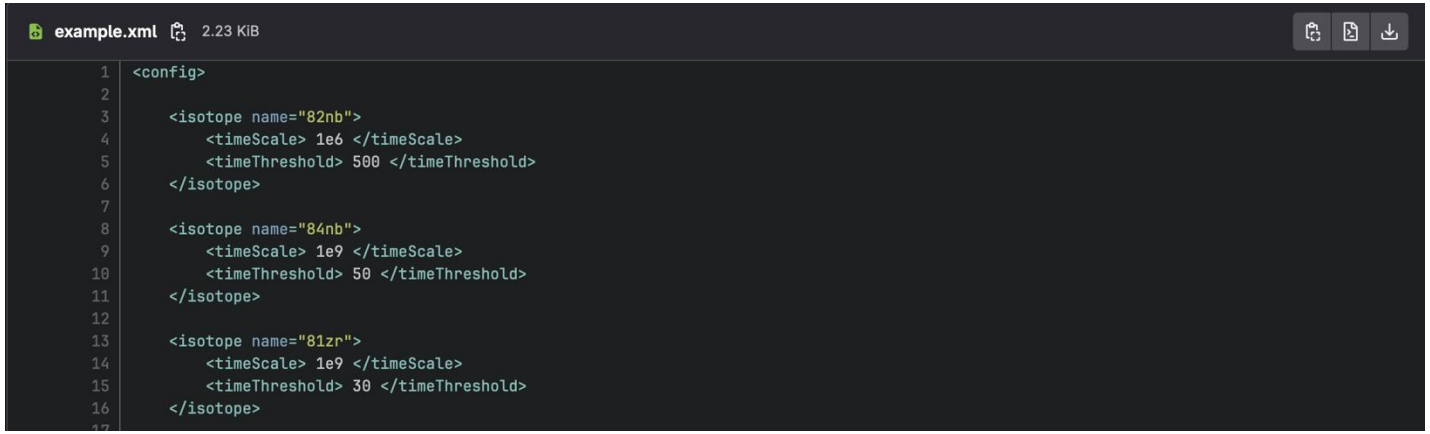
Goals:

- Standardisation of AIDA analysis at GSI
- Scalability and optimisation
- Ease of use for shifters
- Switching settings on-the-fly

Applied to:

- S100
- S115
- G302
- S460 w/ Go4 → C4Root conversion (M. Polettini)

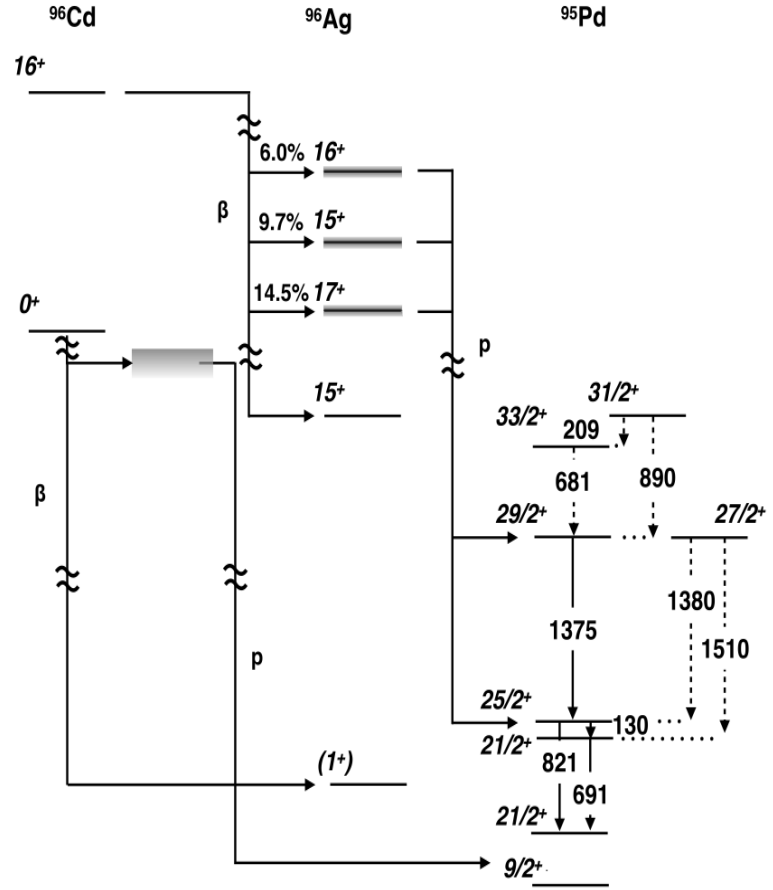




G302 at a Glance – Physics Goals

Physics experiments of original experiment accessible in G302:

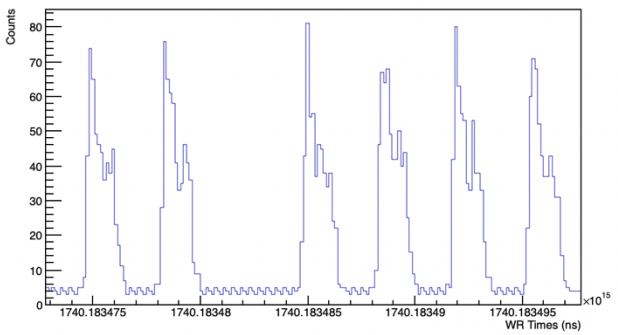
- Determine existence of $J_{1/2}=16^+$ spin gap isomer in ^{84}Mo
- Obtain constraints on isospin symmetry breaking correction term for super allowed β^+ decay in A > 80
- Determine ground state β^+ decay properties of ^{84}Mo, ^{82}Nb, ^{86}Tc
- Search for non-analogue β^+ decay branches to excited states in A>80 N=Z isotopes



P.J. Davies, et al. *Phys. Lett. B.* **767, 474-479 (2017)**

G302 Isotopes implanted in AIDA

Spill Structure



β^+ Half lives (NNDC)

^{86}Tc: 55 (7) ms

^{82}Nb: 50 (3) ms

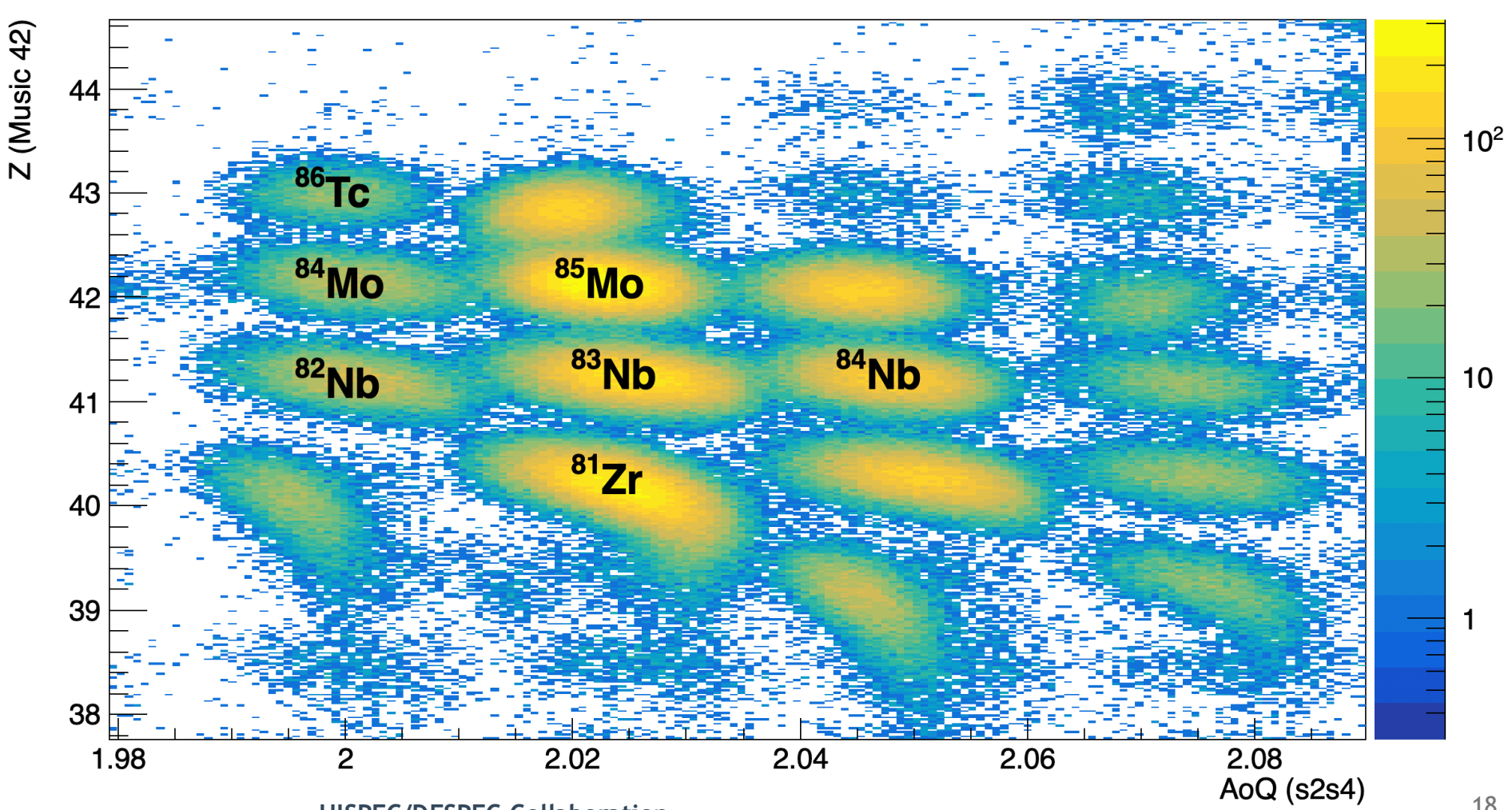
^{84}Nb: 9.8 (9) s

^{84}Mo: 2.3 (4) s

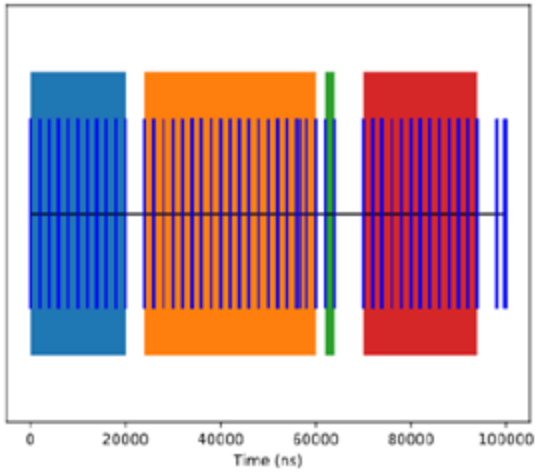
^{85}Mo: 3.2 (2) s

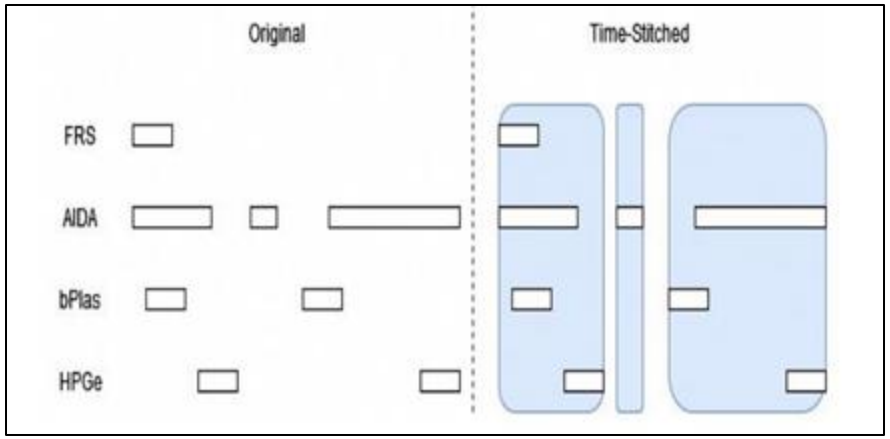
^{81}Zr: 5.0 (2) s

~ 10 hours of data



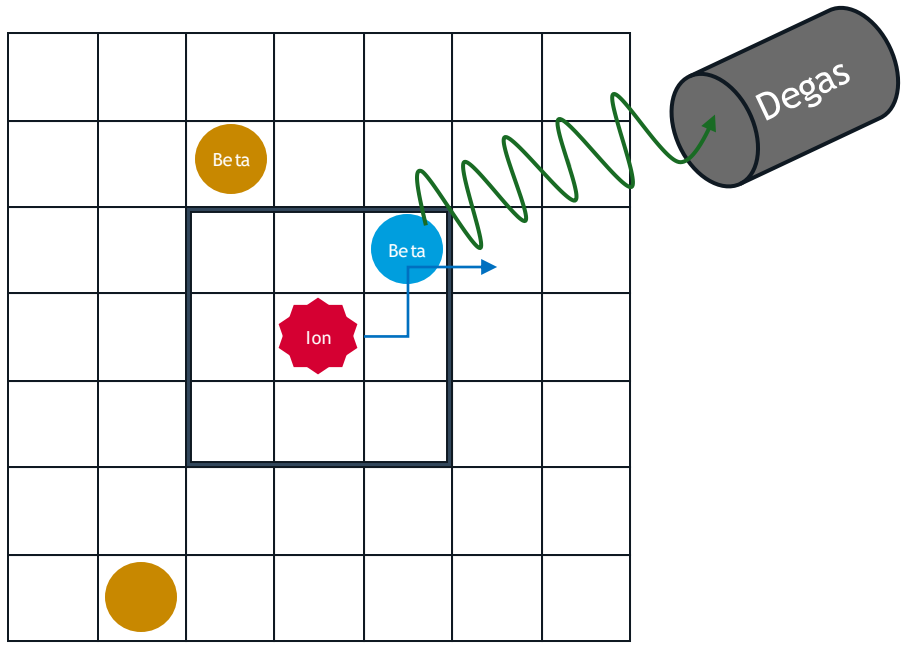
Implant Decay Matching – Data Flow





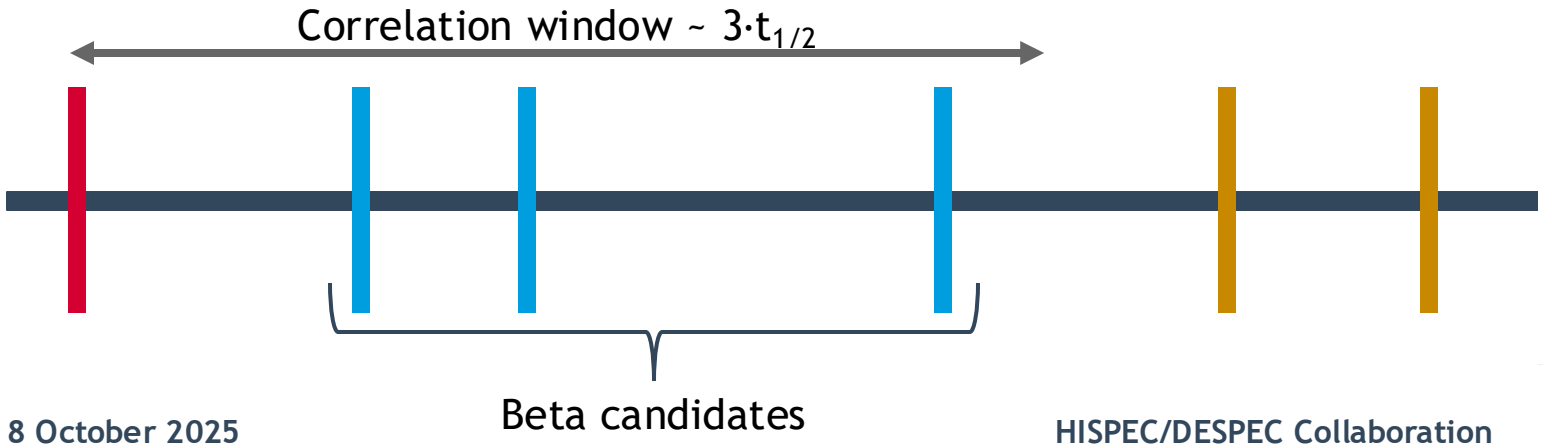
Figures: N. Hubbard

Implant Decay Matching - Algorithm

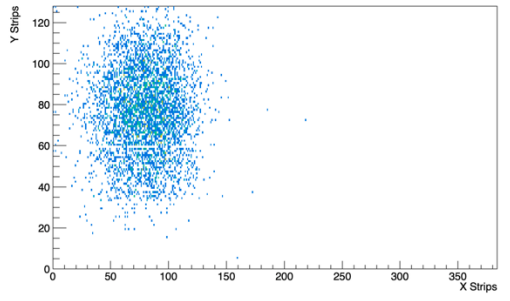


Algorithm in a Nutshell:

- Find pixel of FRS-gated implant
- Assign position and time correlation window
- Correlate decay events to implant
- Correlate gammas to matched decay event

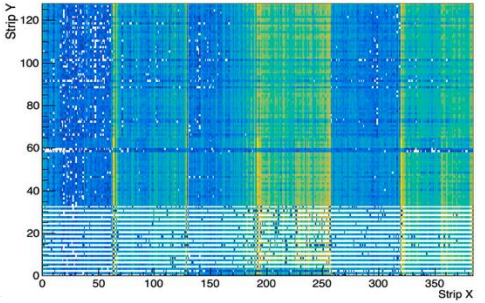


^{81}Zr (FRS-gated) Implant



~ 10 hours of data

Decays



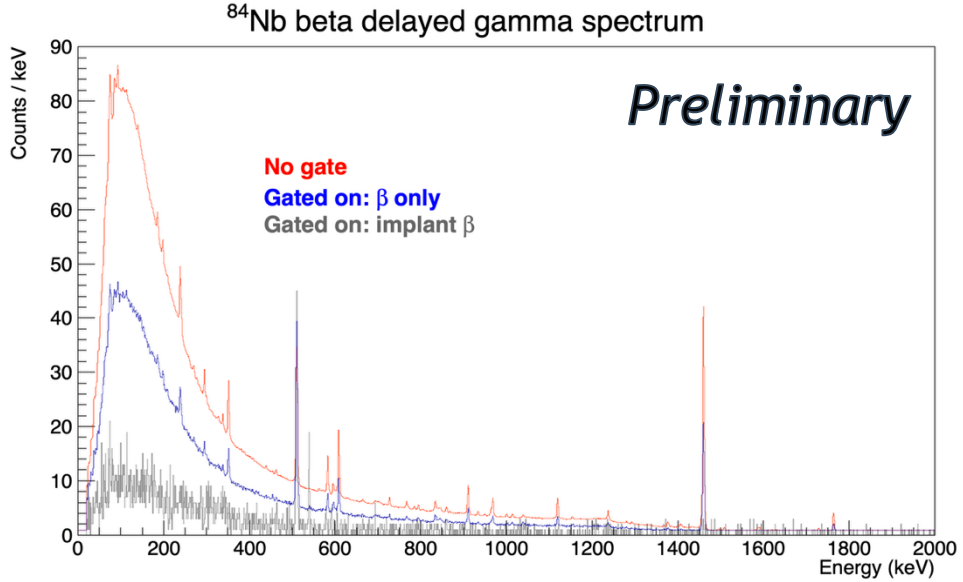
~ 2 minutes of data

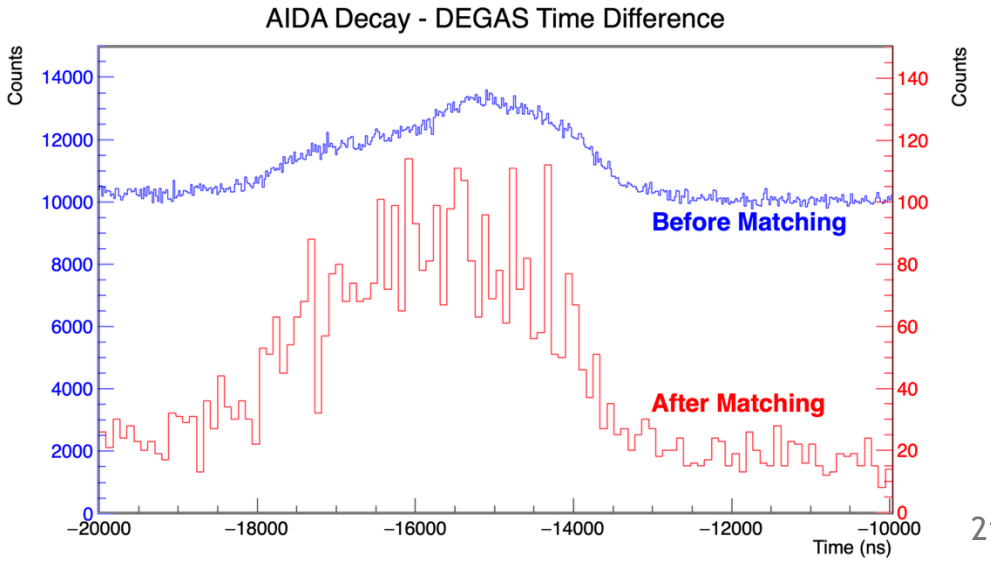
Implant Decay Gamma Correlation

Implant decay gamma correlation **successfully demonstrated** in **G302** and **S100.**

Overview of results:

- Reduction of **background lines** and **Compton continuum**.
- Increased sensitivity to **beta delayed lines.**
- S/B ratio of dT increase from ~**0.3** → ~**4.3.**





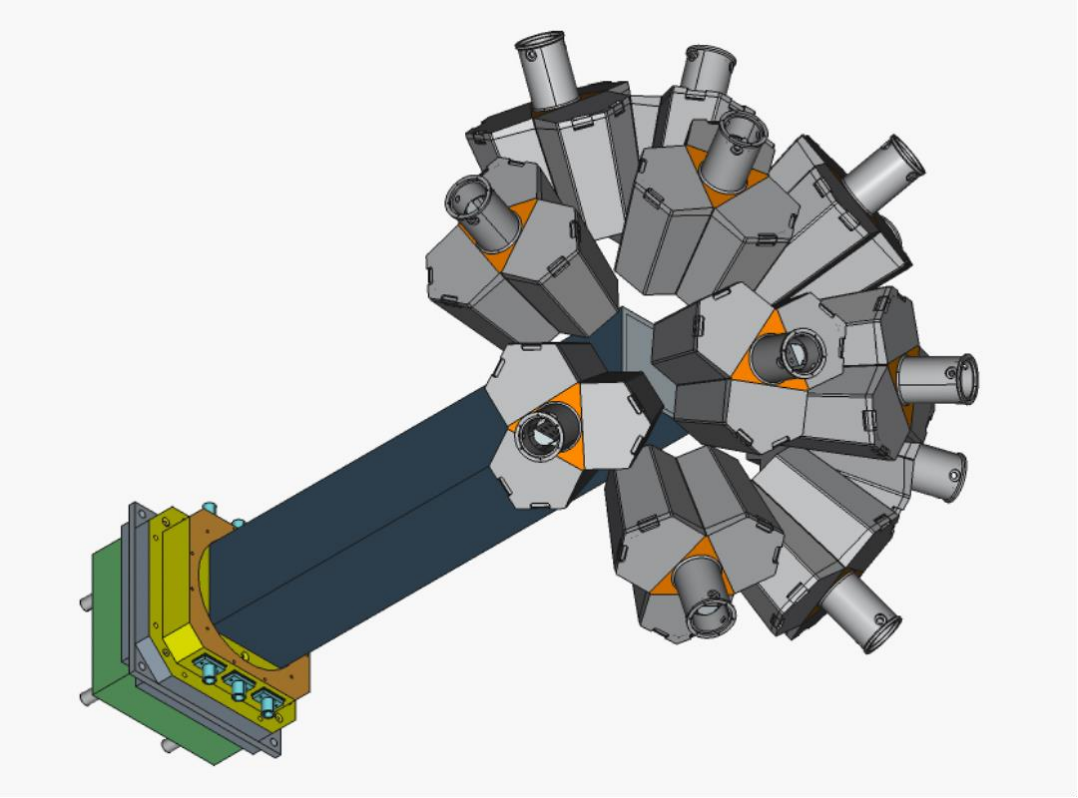
Geant4 simulation - Simulation

Features:

- AIDA DSSD (wide)
- DEGAS (GDML)
- Realistic spills & rates
- Realistic decay products

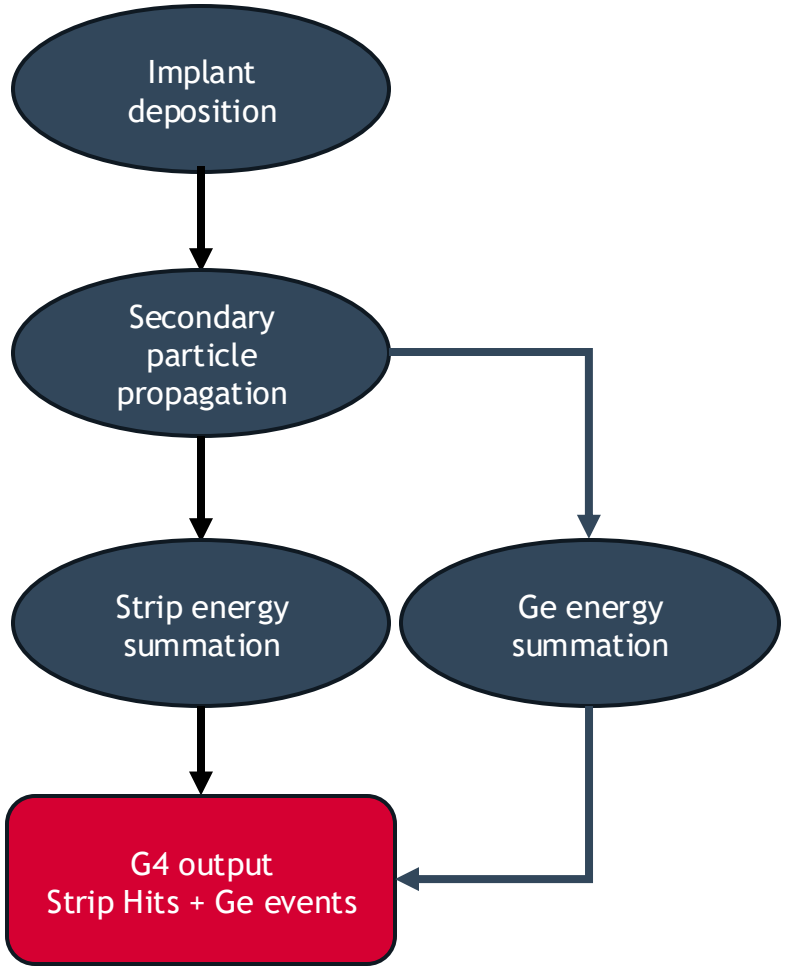
Caveats:

- Non-realistic implantations
- Hybrid germanium setup
- No depletion zone consideration
- No inter-strip material

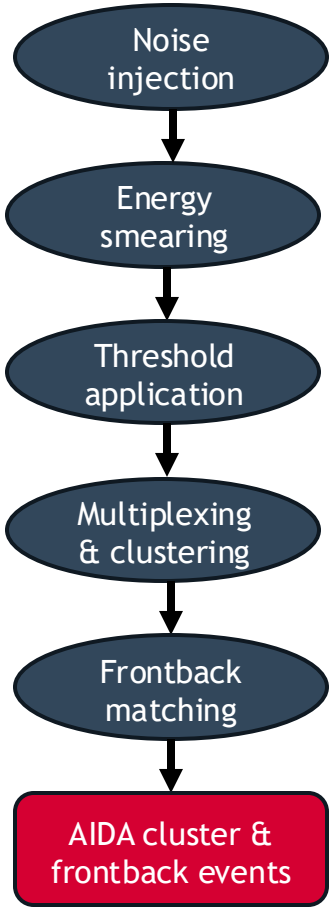


Geant4 simulation – Simulation chain

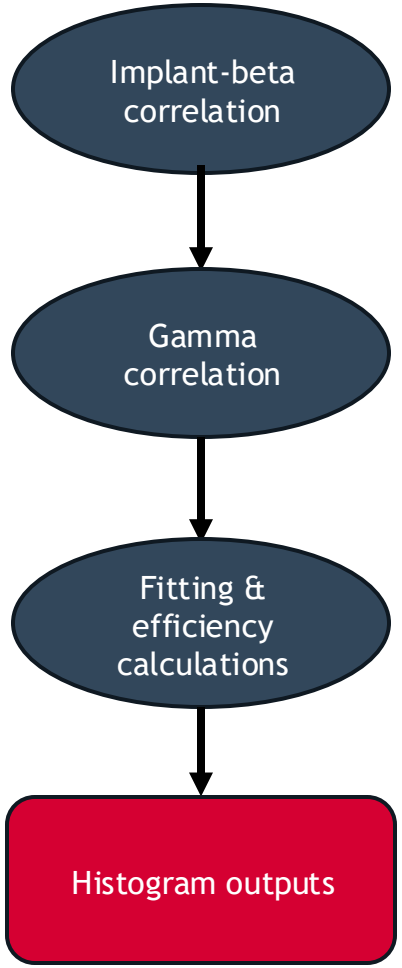
Geant 4 Simulation



Event Building



Analysis



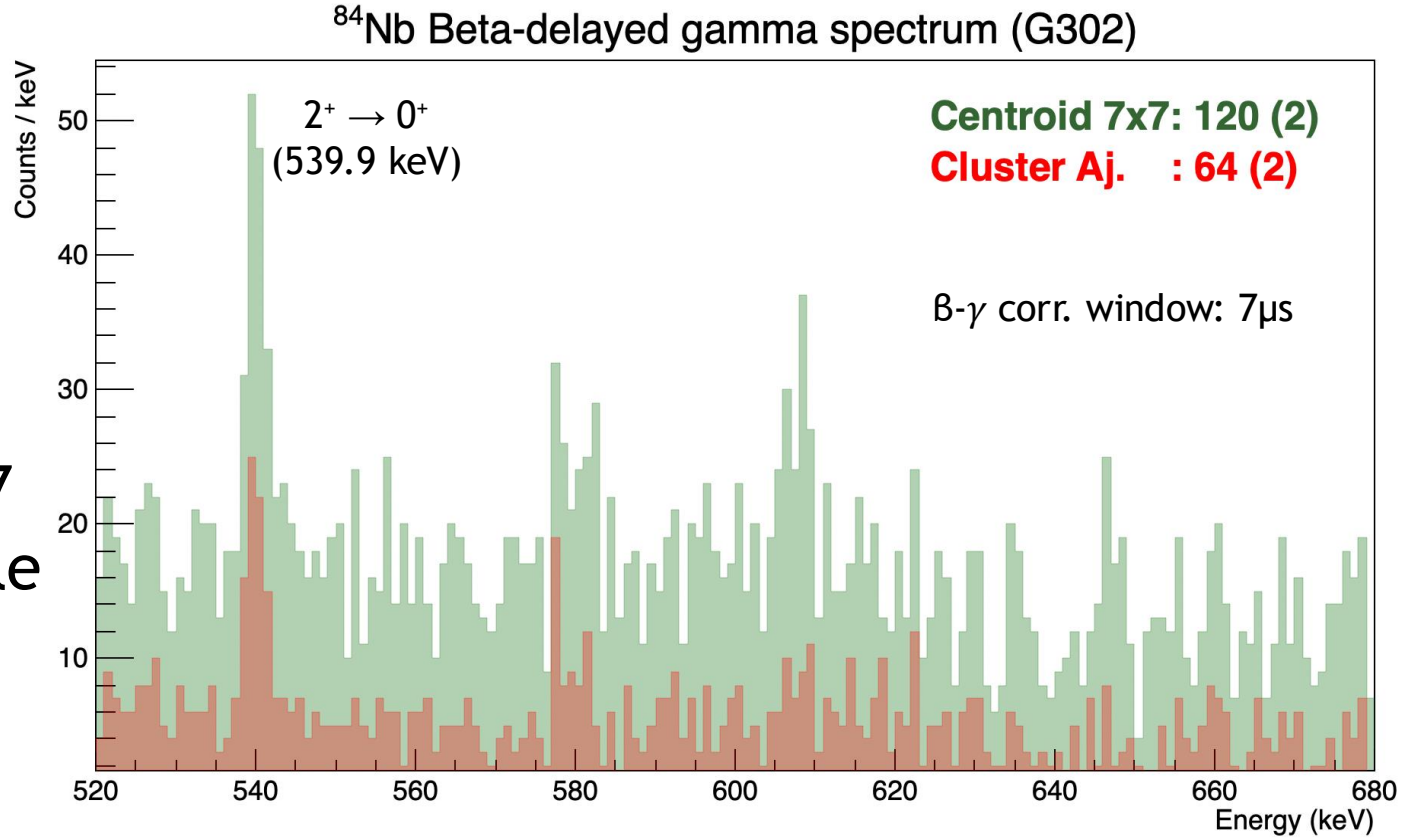
Implant-decay correlation methods

Results show cluster pos. correlation systematically performing worse.

Adjacent cluster pos. correlation & 7x7 centroid pos. correlation → Comparable beta efficiency.

^{84}Nb 540keV :

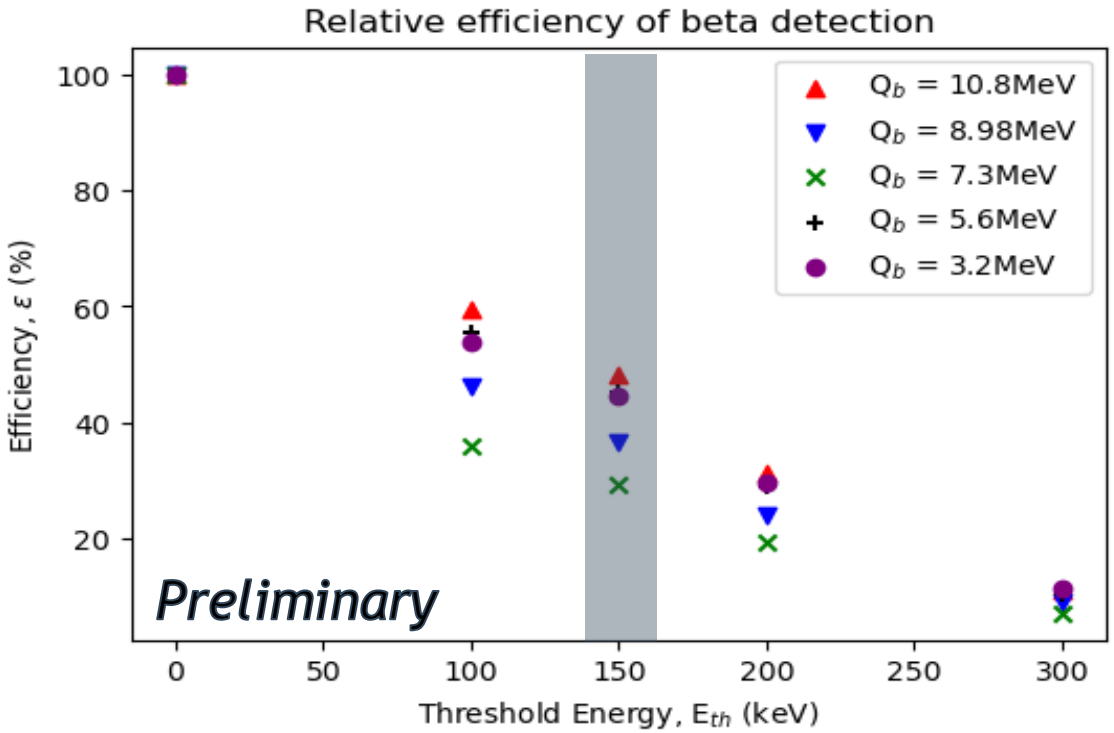
Confirms cluster pos. correlation is performing worse than nominal method



Geant4 Simulation – E_{th} irregularities

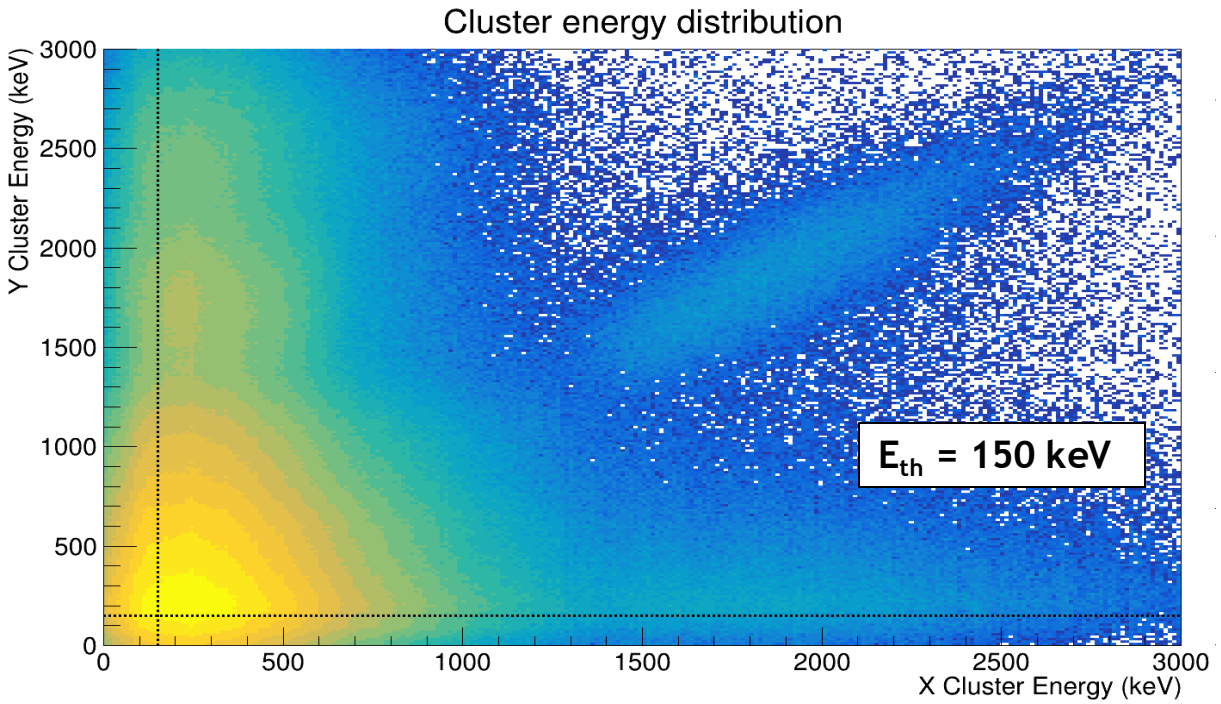
Nominal E_{th} drift should be ~10 keV. Real data suggests otherwise.

Relative efficiencies → AIDA thresholds operating greater than 150 keV.

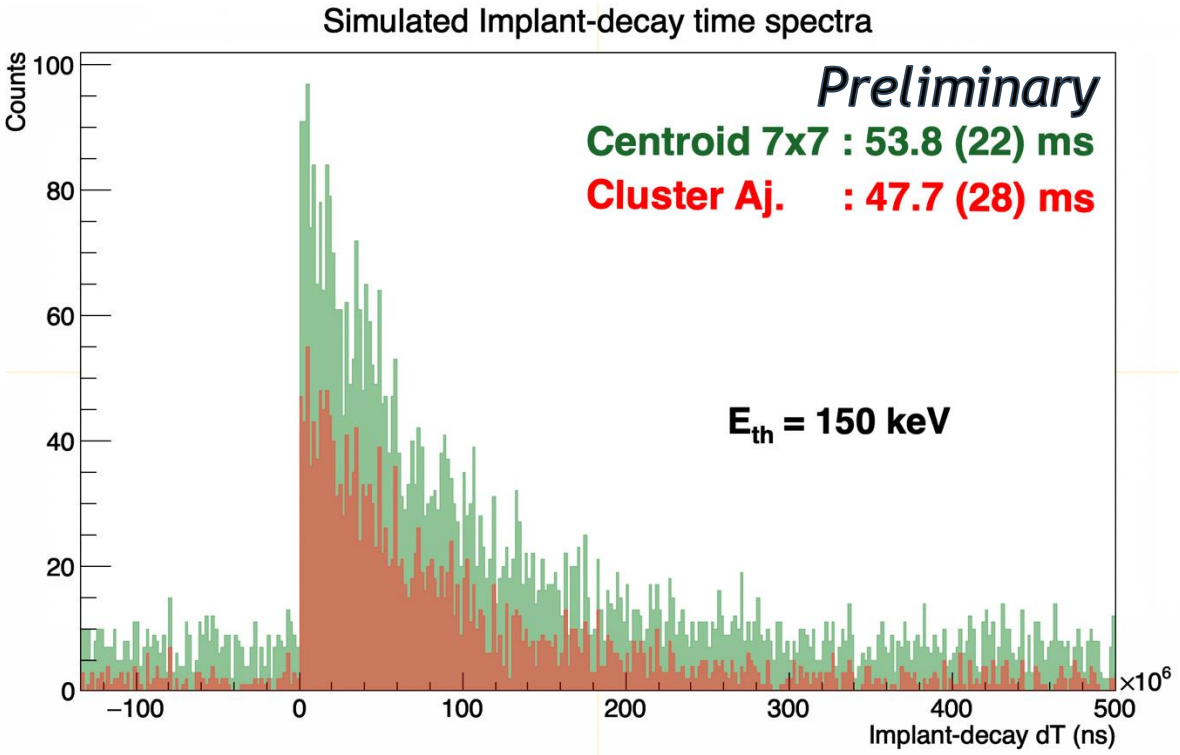


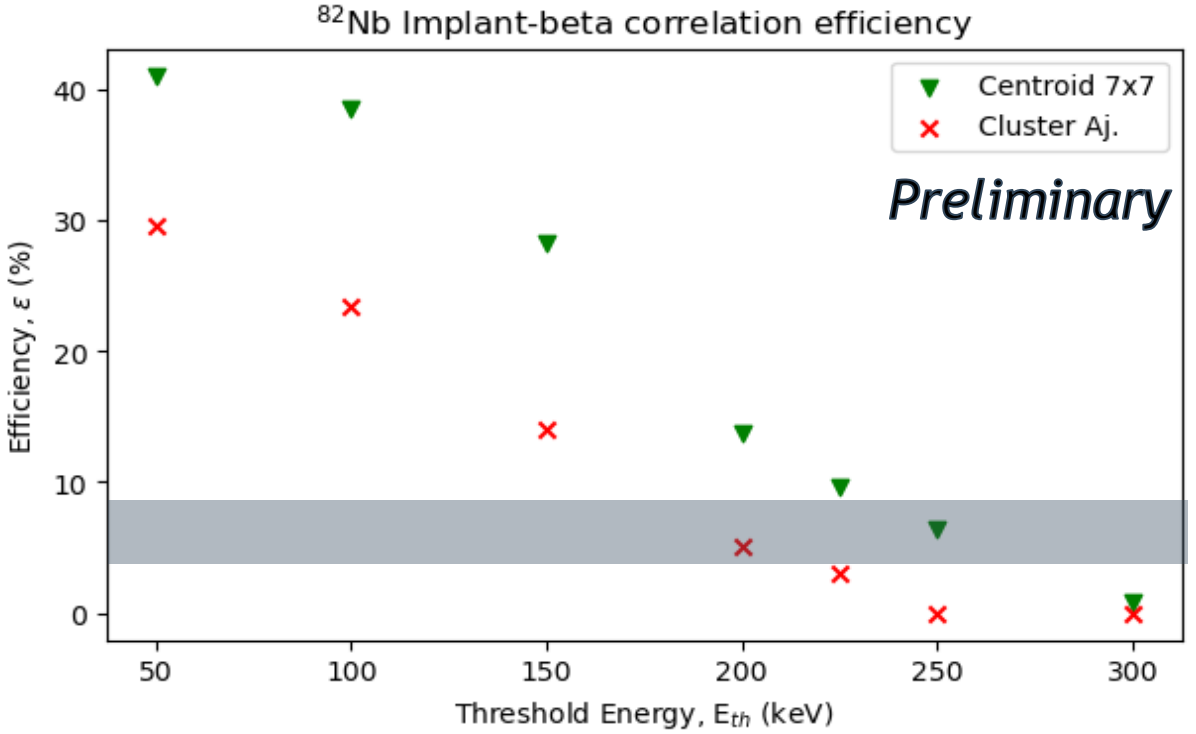
Experiment

Expected distribution for protons & alphas, not betas



Geant4 Simulation – Implant-beta correlations





Position correlation methods:

- Clustering correlation starts to lose advantages at E_{th} > 100 keV
- At 150 keV, we expect lifetime curves for all pos. correlation methods

Beta correlation efficiencies:

- Based on correlation efficiencies, AIDA operates at an effective E_{th} ~ 250 keV
- Beta efficiencies for all corr. methods tend to same efficiencies at high E_{th}

Geant4 Simulation – ^{84}Nb lifetimes