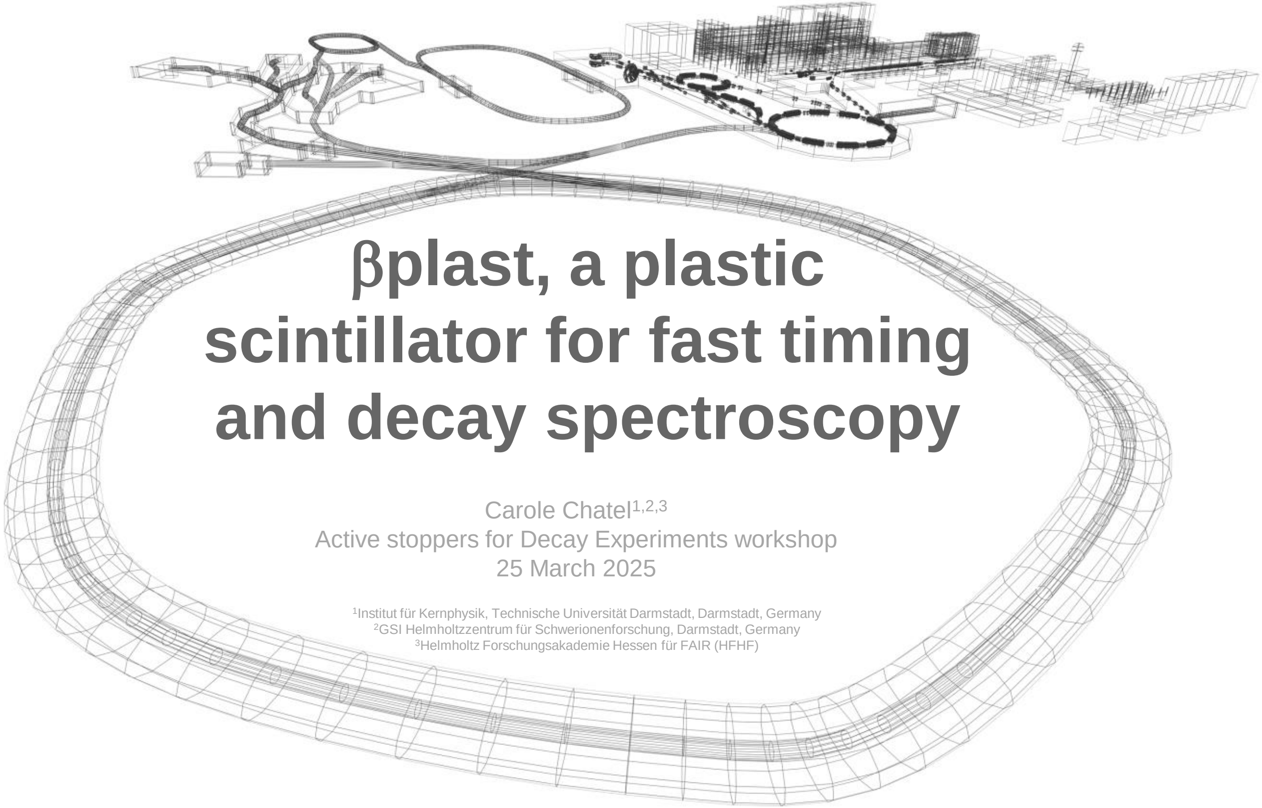

βplast, a plastic scintillator for fast timing and decay spectroscopy

Carole Chatel[1,2,3]

Active stoppers for Decay Experiments workshop

25 March 2025

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[3]Helmholtz Forschungsakademie Hessen für FAIR (HFHF)

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- The DESPEC setup
- The βplast detectors
  - Detector principle
  - Detector response
  - Position reconstruction capabilities
- Conclusion and outlook

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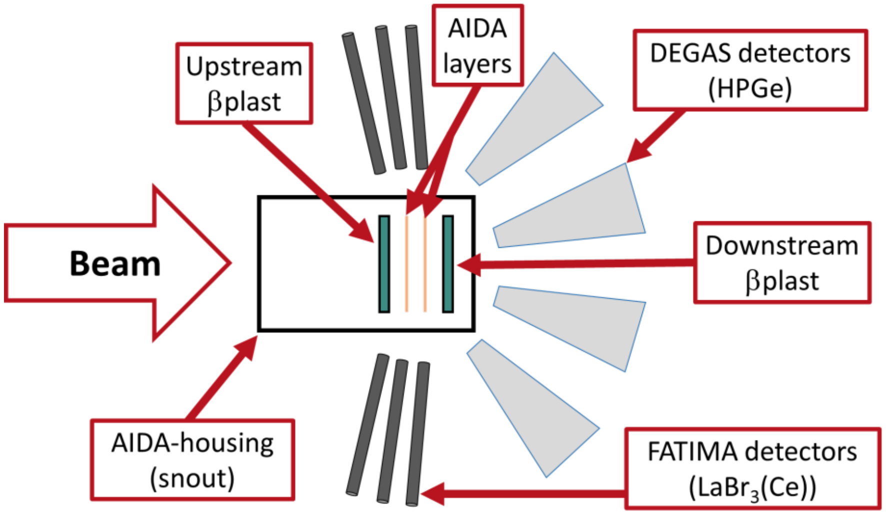
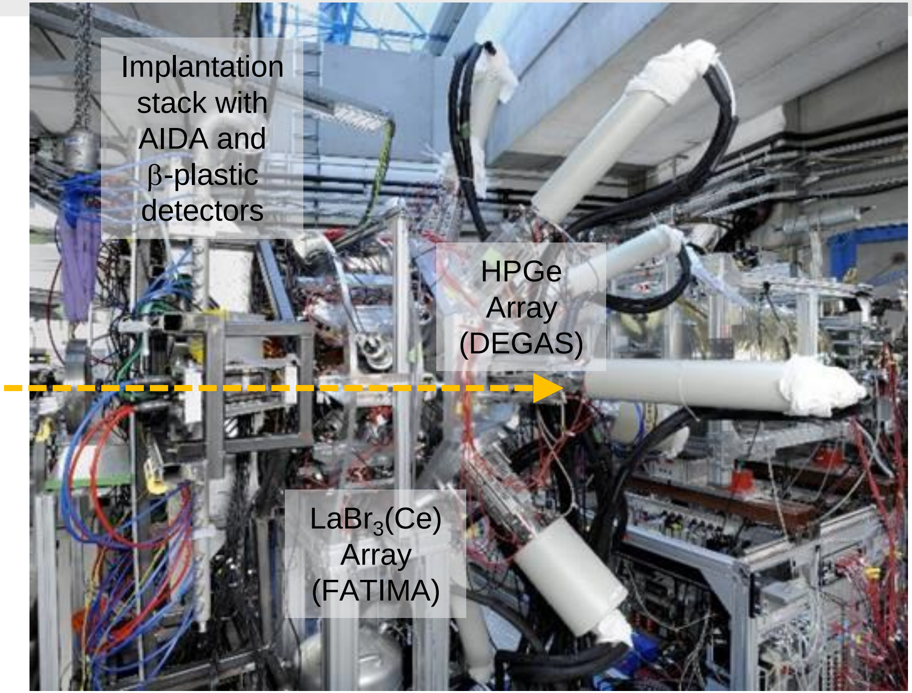
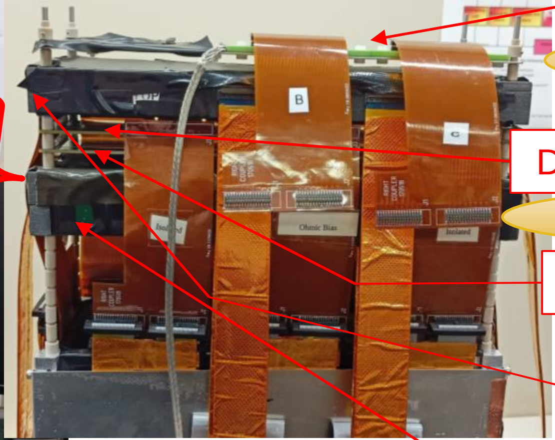
The DESPEC setup

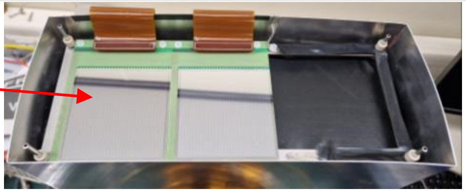




- Nuclei of interest obtained by fragmentation reactions, separated and identified by the FRagment Separator (FRS)
- Implantation of those nuclei in the AIDA silicon detector
- Detection of the α, β, γ from radioactive decays

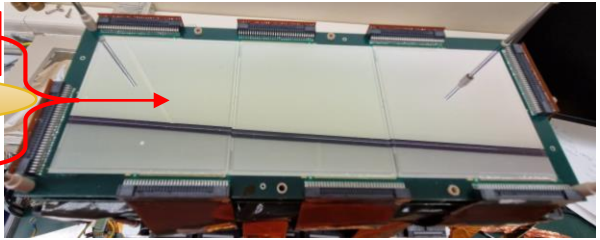
The implantation stack





BB7 (potentially)

See talk M. Polettini, Tues. 14:30



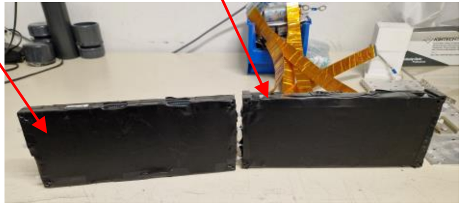
Downstream AIDA

See talk T. Davinson, Mon. 15:00

Upstream AIDA

Downstream βplast

Upstream βplast



2 sizes of snout to fit to the experimental needs

- ✓ Narrow (8*8 cm²)
- ✓ Wide (24*8 cm²)

Aims and constraints of βplast

Aims

- Detection of decays products (from AIDA or implanted in bplast itself)
- Provide excellent timing resolution (a few 100 ps) for decay particles emitted by the exotic ions of interest
- Veto for light particles or punch-through events for downstream bplast
- Good position resolution (~1-2 mm for implants and α-particles, 5 mm for β-particles)

Constraints

- Low budget material (to avoid γ-rays absorption)
- Match the experimental geometrical constraints

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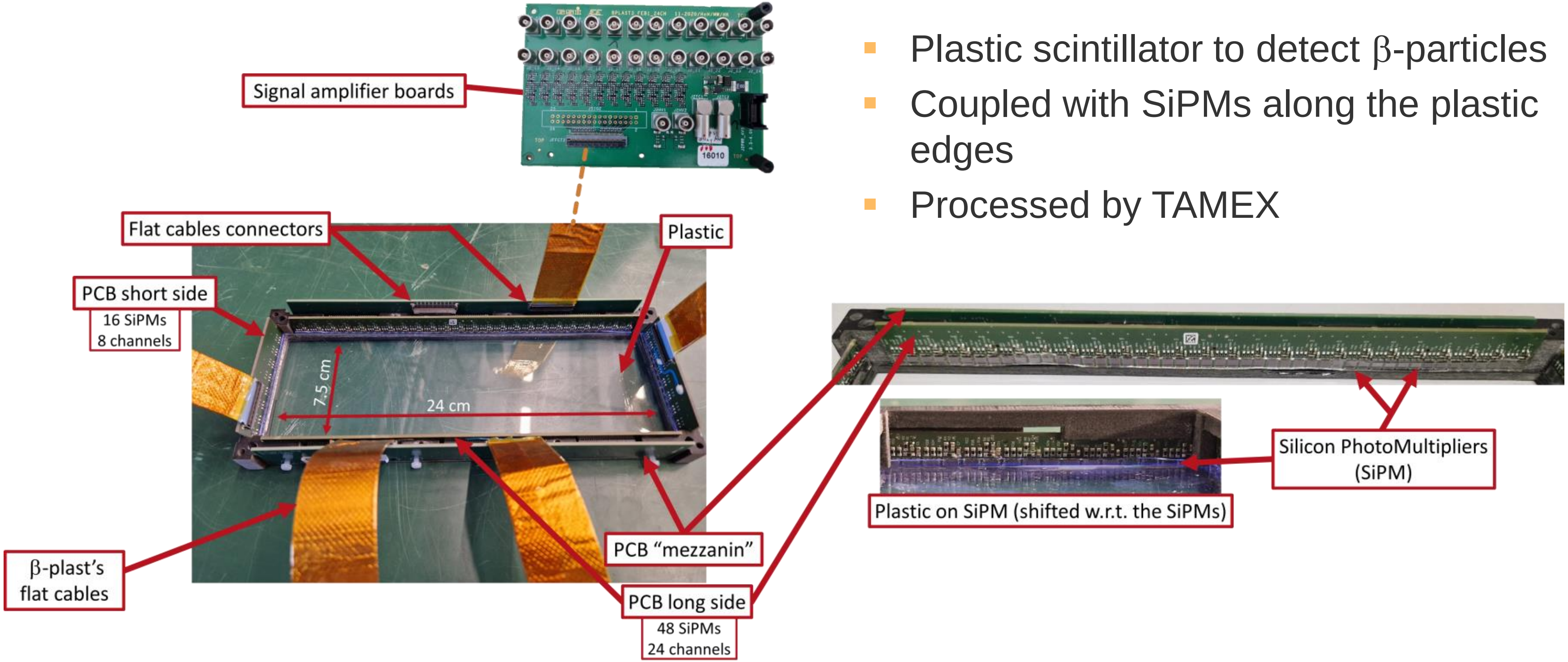
βplast - overview

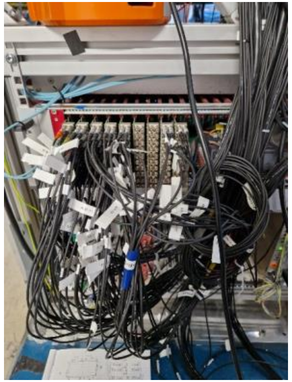
- Plastic scintillator to detect β-particles
- Coupled with SiPMs along the plastic edges
- Processed by TAMEX



βplast – signal processing

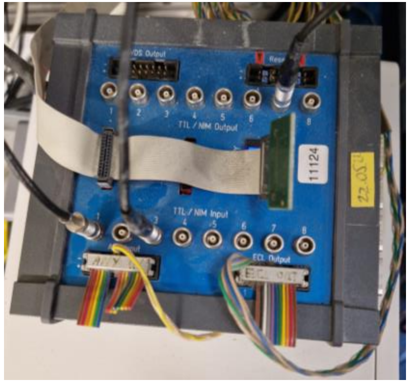
From detector to amplifier boards…

…to the TAMEX cards…



…to the multiplicity unit…
(to provide a trigger)

…to the trigger box



<u>TAMEX cards</u>

- Developed at GSI
- FPGA-based (Field programmable gate array) TDC (time-to-digital converter)
- Custom analog electronics for amplification and efficient analog signal processing
- Analog front-end card ‘‘TwinPeaks“ connected to the TAMEX4 TDC card
- used to measure
  - leading edge of pulses
  - width of pulses

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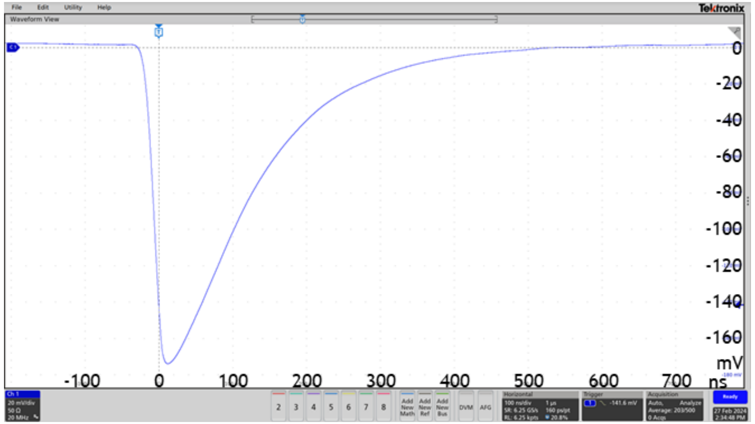
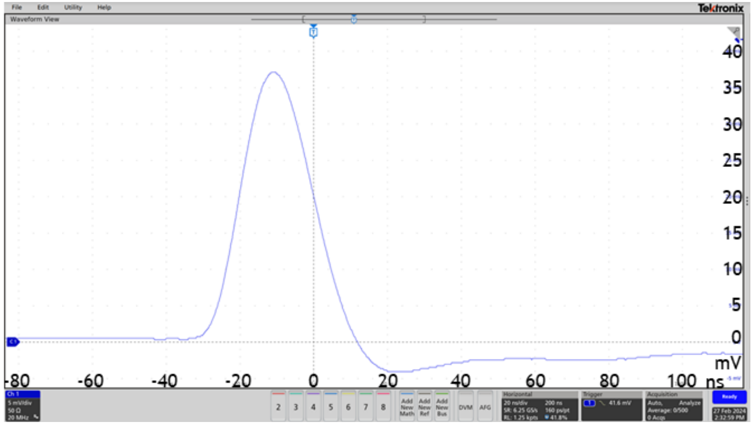
βplast – signal from SiPMs



Slow branch after amplification



Fast branch

βplast – signal processing

SiPM

Fast

Slow

Selected and amplified by the **booster boards**

TAMEX-TwinPeaks cards

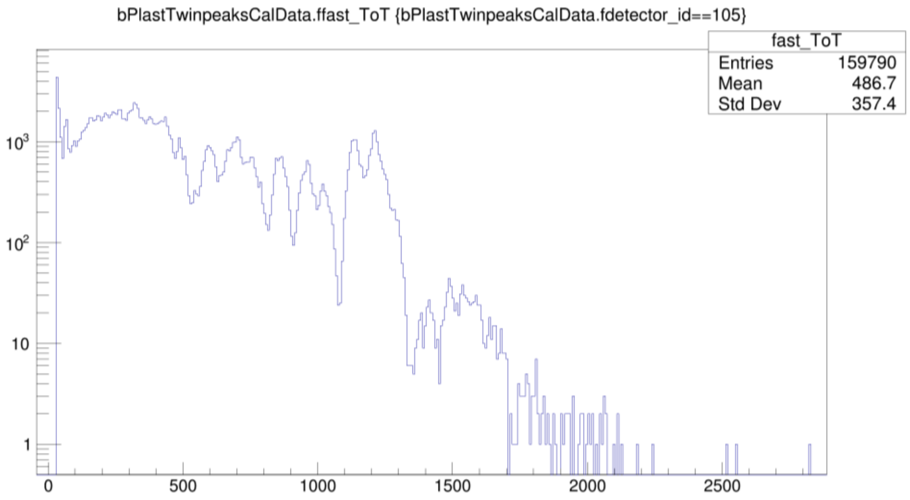
Fast

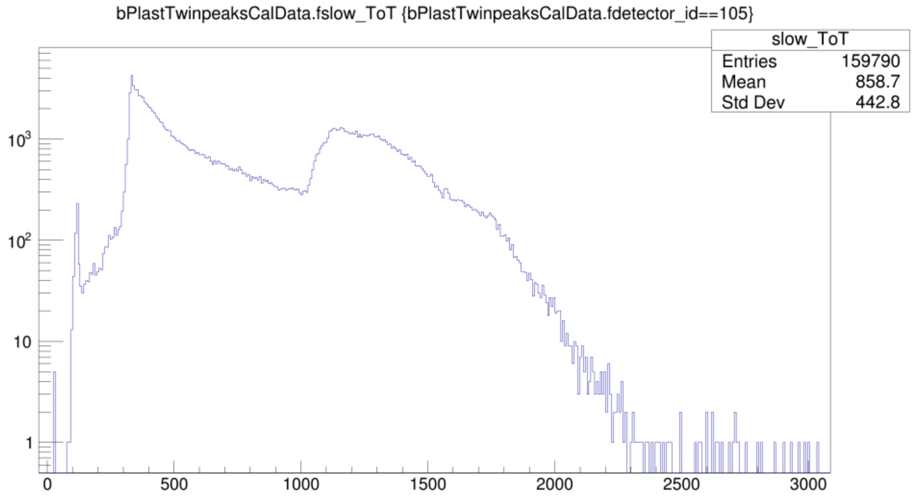
Time over Threshold (ToT)
Logarithmically proportional to energy

Slow

Time over Threshold (ToT)
linearly proportional to energy

βplast – signal processing

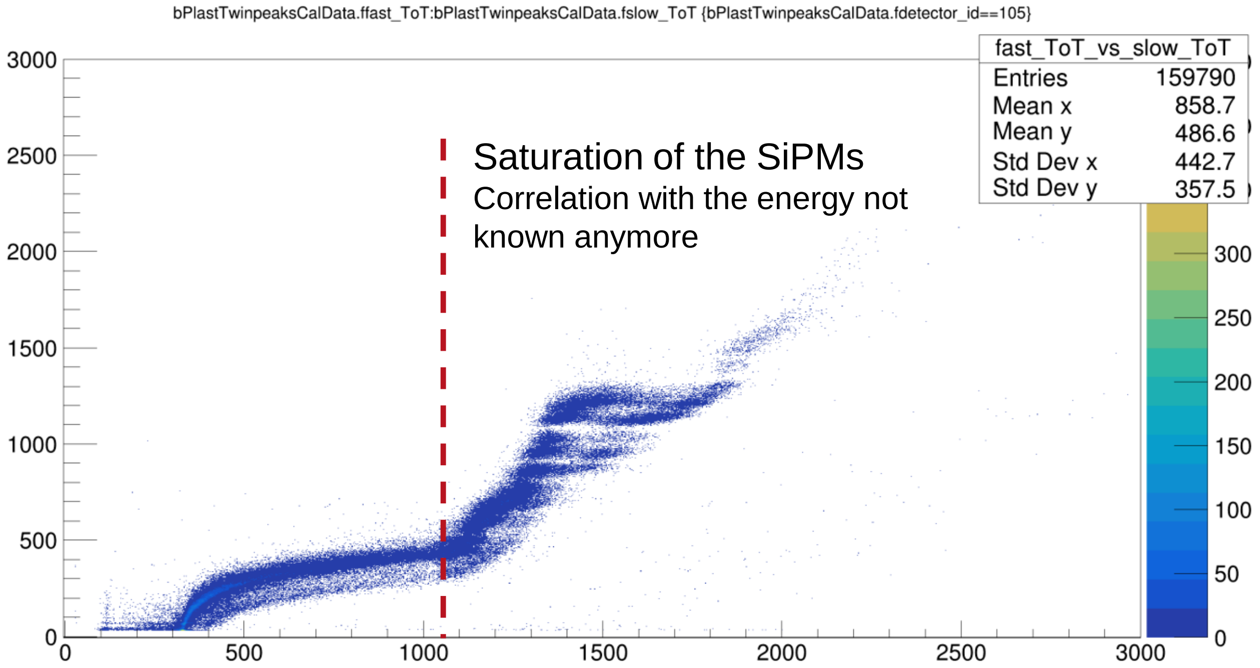




Fast ToT
logarithmically proportional to energy

Slow ToT
linearly proportional to energy

βplast – signal processing



Fast ToT vs Slow ToT
"banana curve"

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Goal

- Improving the position resolution of the bplast detectors

- **Good position resolution** is needed for
  - **implanted ions**
  - **subsequent decays**

  enable correlations

- With the **narrow** and **wide** version of bplast

- Method: using a lookup table

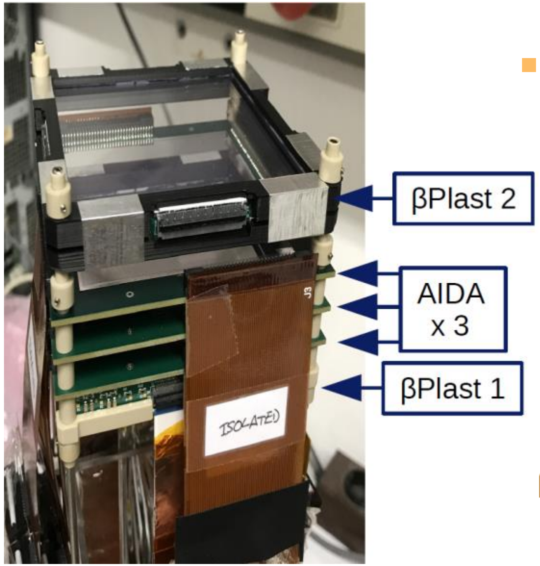
Data used

First done with the narrow bplast:

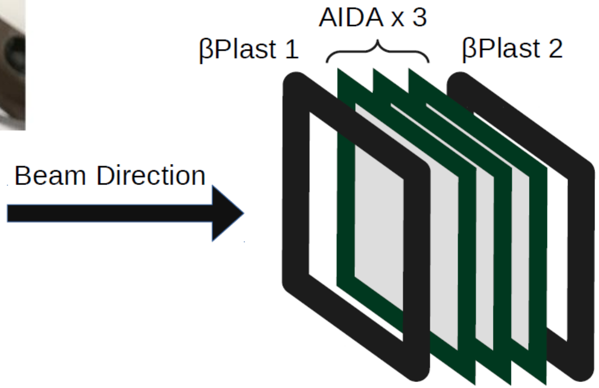
- Data collected during **DESPEC FAIR Phase-0** experiment in 2021 (S460)
- Fragmentation of ^{238}U on ^{9}Be

→ ions with A~220-230 and Z~80-90

- Defocussed beam profile in x direction but narrow in y



- Ion trajectories passing through the stack are assumed to be orthogonal to detector surfaces



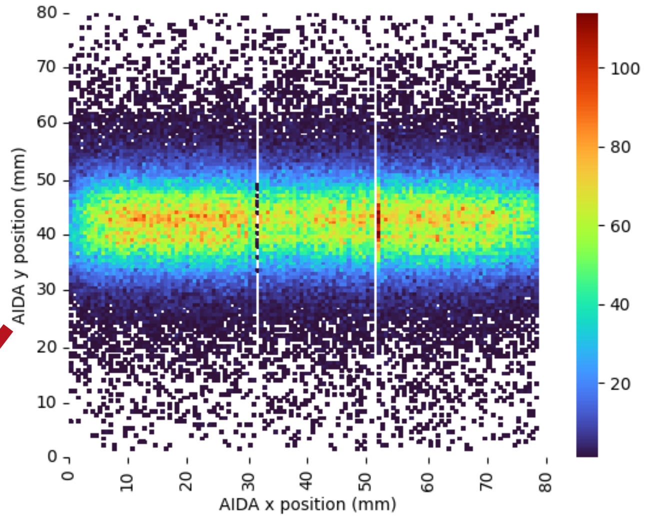
- AIDA: DSSD
  - highly segmented (128x128)
  - pixel size ~0.5 mm
  - >99% efficiency for heavy ions

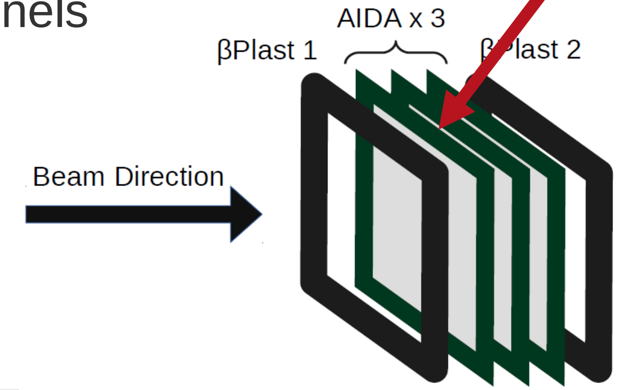
→ Use of AIDA as a position reference

Methodology

To begin:

- Coincidence requirement with FRS detectors
- Event measured in AIDA1 high-energy branch
- Hit is unique within event
- Selection of events having the highest multiplicity in bplast = all βplast channels fired





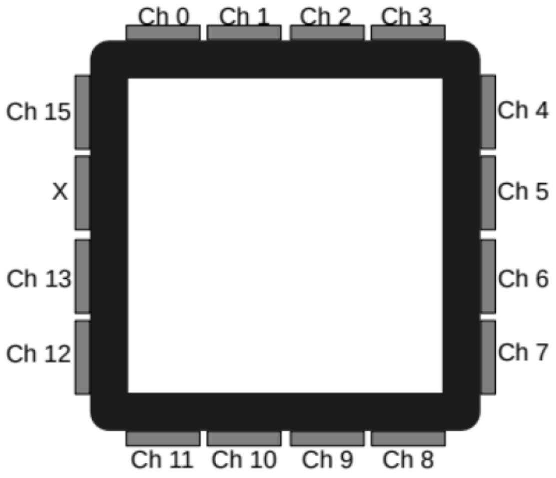
courtesy of H. Albers

Methodology

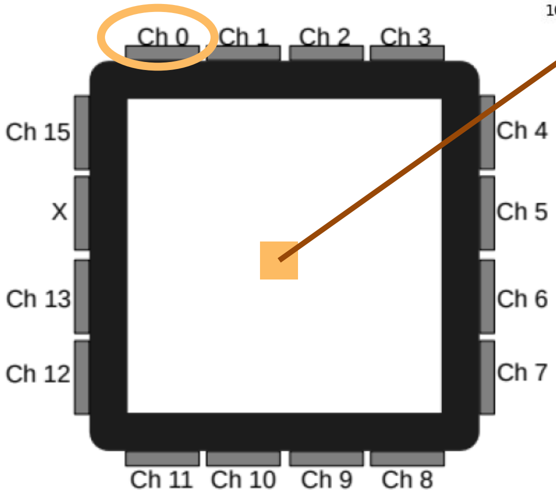
- Selection of **heavy ions** passing (straight) through bplast and AIDA
  - Heavy ions saturate all SiPMs → **no usable energy information!**
  - The high energies, saturating the SiPMs, improve the time resolution of the SiPMs

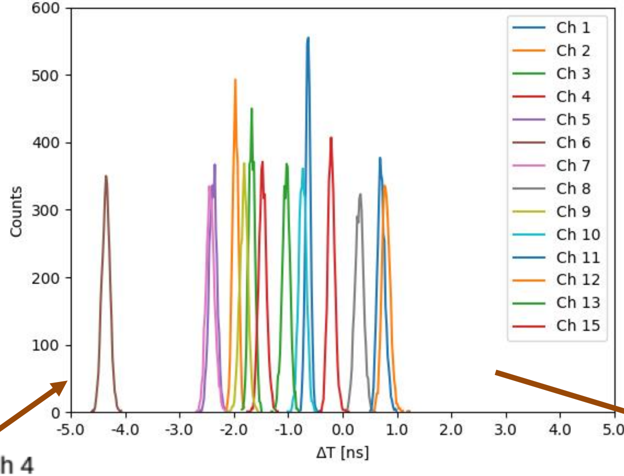
→ simple event selection, large amounts of light produced in scintillator material

- Use of time differences between the SiPMs (Leading edge times measured using TAMEX)
- Use of AIDA as a position reference
- Creation of a lookup table



- Use of Ch0 as reference

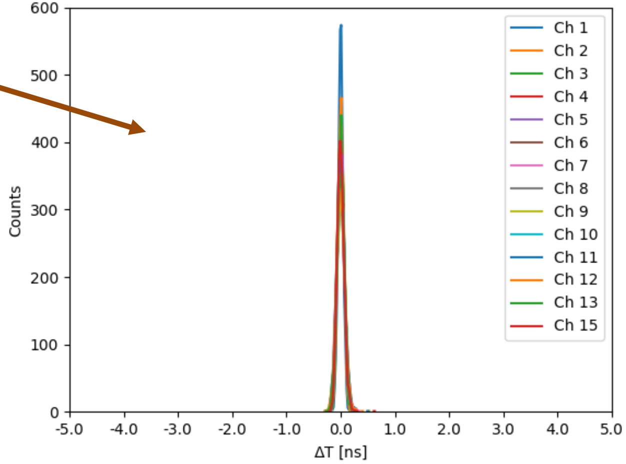




- For a centered event, calculation of the time difference for each channel to receive the light

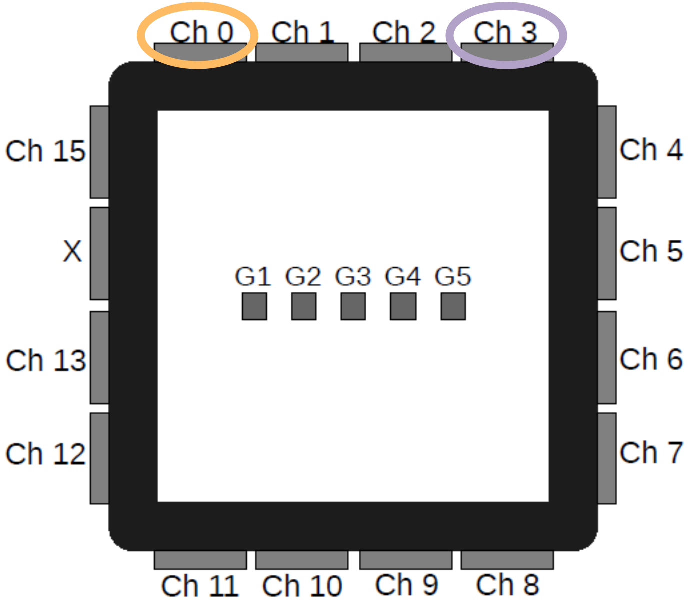
→ **ChX-Ch0**

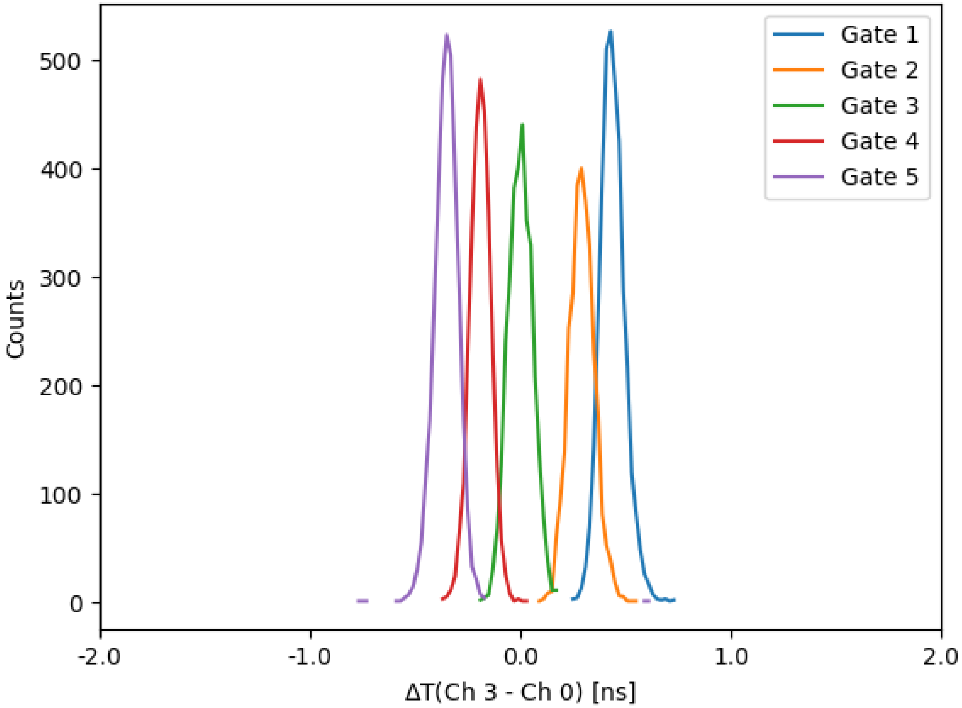
- Time alignment to compare more easily



courtesy of H. Albers

Processing: example for one channel





Proof-of-principle

- 5x5mm² gates in 1 cm steps
- Single-channel time differences demonstrate good level of sensitivity

courtesy of H. Albers

Lookup table

- Creation of the lookup table for each position for which AIDA has registered events

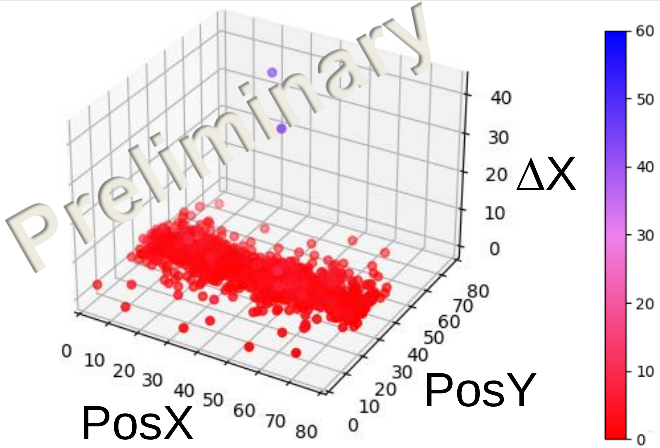
PosX	PosY	dT0	dT1	dT2	dT3	dT4	dT5	dT6	dT7	dT8	dT9	dT10	dT11	dT12	dT13	dT15
91	90	0	-0.0642287	-0.109513	-0.109452	-0.108665	-0.0907854	-0.0489191	0.0202923	-0.0406718	-0.0174948	-0.00612049	0.00687765	0.00670136	-0.00197111	-0.0563917
91	91	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
91	92	0	-0.0793157	-0.12705	-0.134371	-0.143239	-0.117952	-0.0978655	-0.0299068	-0.0708435	-0.042535	-0.0373934	-0.0321594	-0.0295418	-0.0245802	-0.0758714
91	93	0	-0.0765231	-0.154894	-0.155575	-0.153685	-0.134458	-0.0862165	0.00163878	-0.073651	-0.0469462	-0.0368783	-0.021429	0.00015852	-0.0188813	-0.070994
91	94	0	-0.0832659	-0.153694	-0.151327	-0.157002	-0.125989	-0.0851999	-0.0187286	-0.0693139	-0.055176	-0.0339633	-0.0171839	-0.032586	-0.0394784	-0.0735781
91	95	0	-0.0857524	-0.158187	-0.153342	-0.162543	-0.125704	-0.0889414	-0.0116579	-0.0802292	-0.0486826	-0.0402342	-0.0240862	-0.0203965	-0.0318646	-0.0764803
91	96	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
91	97	0	-0.112228	-0.167083	-0.167885	-0.159266	-0.129581	-0.0975844	0.00202333	-0.0720296	-0.0487381	-0.0263663	-0.0256226	-0.0167393	-0.0264432	-0.0736081

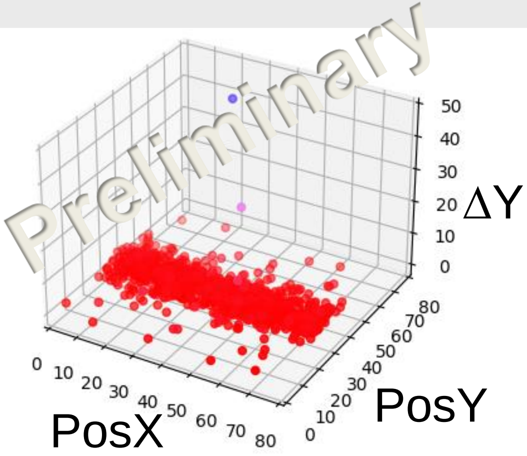
For each channel: time difference w.r.t. channel 0

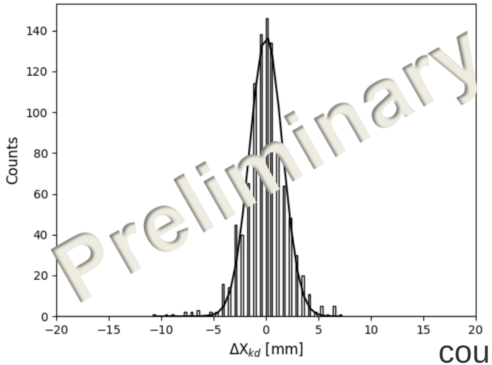
PosY: AIDA strip number in Y

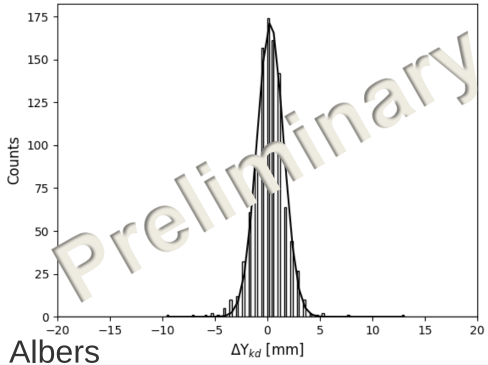
PosX: AIDA strip number in X

Lookup table: results









courtesy of H. Albers

Number of events	$\sigma_{kd,\,x}$ [mm]	$\sigma_{kd,\,y}$ [mm]
2.10^5	1.45(5)	1.28(3)

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Conclusion

- bplast: detector for β-particles
- Fully functional in the implantation stack
- Possibility to obtain the position with a good resolution for heavy ions

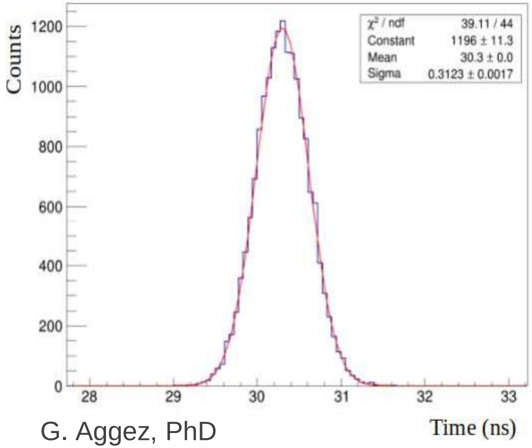
But still some questions:

- Look up table only for upstream detector

→ can we develop one for the downstream bplast?

- Can we obtain the position for β-particles?
    - → Analyze performed with the Lyso GSI scanner and a ^{22}Na source
    - → A position resolution of 5.7 mm (FWHM) obtained

→ what are the limitation as implant/decay correlation tool?

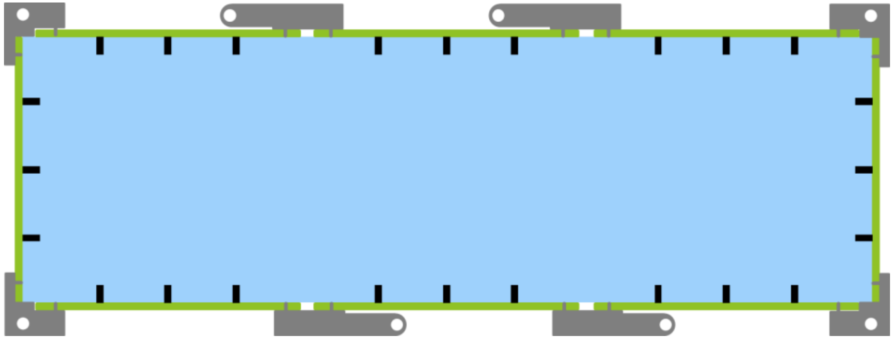


G. Aggez, PhD

- Redesign to fulfill all the current identified drawbacks

βplast envisaged improvements

- Improve light coupling
- Front-end amplifiers
- Reduce material budget
- Simplified and mechanically more robust setup



Thank you ☺