

Characterization of the FATIMA fast-timing detectors array

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Supervisors: Dr Vasil Karayonchev,
Giorgio Bruni-Campanella Spezza

Outline



Motivations
for
Lifetime
Measurements

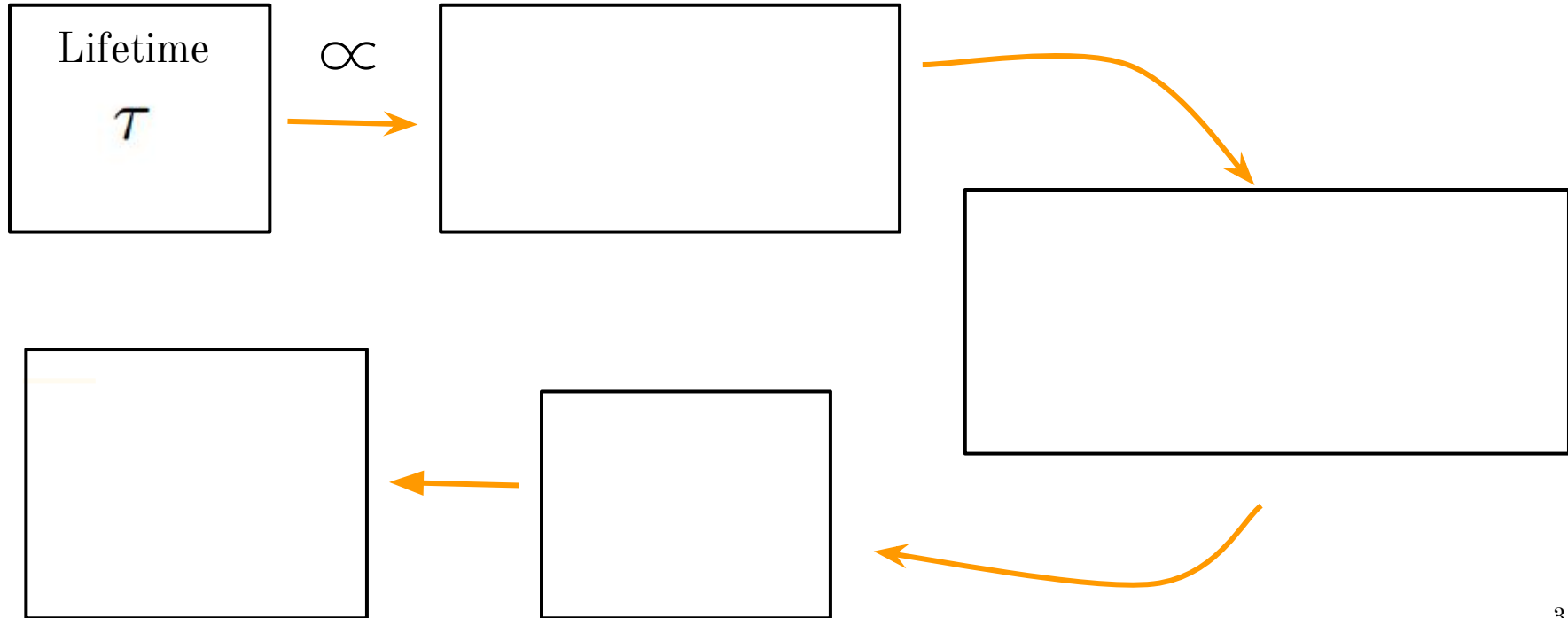
FAst
TIMing
Array
(FATIMA)

Experimental
Setup

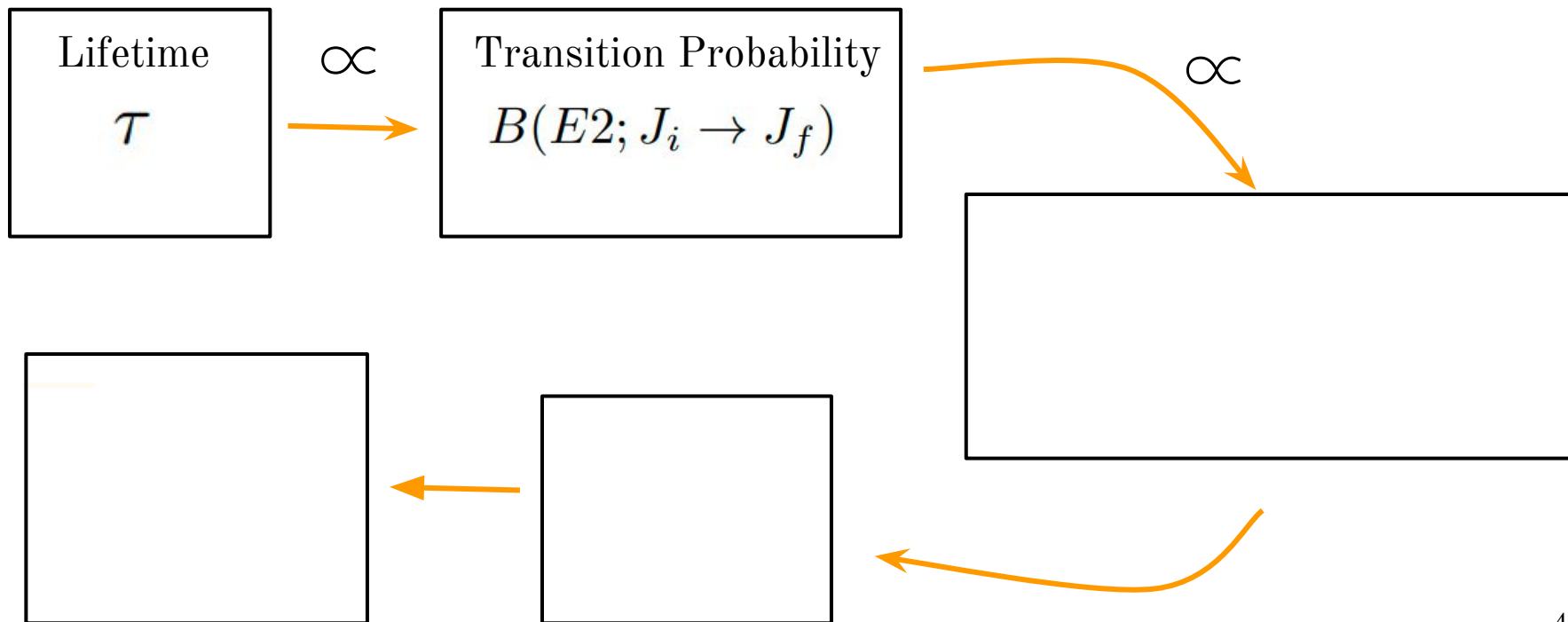
Results
&
Conclusion

sulla densità

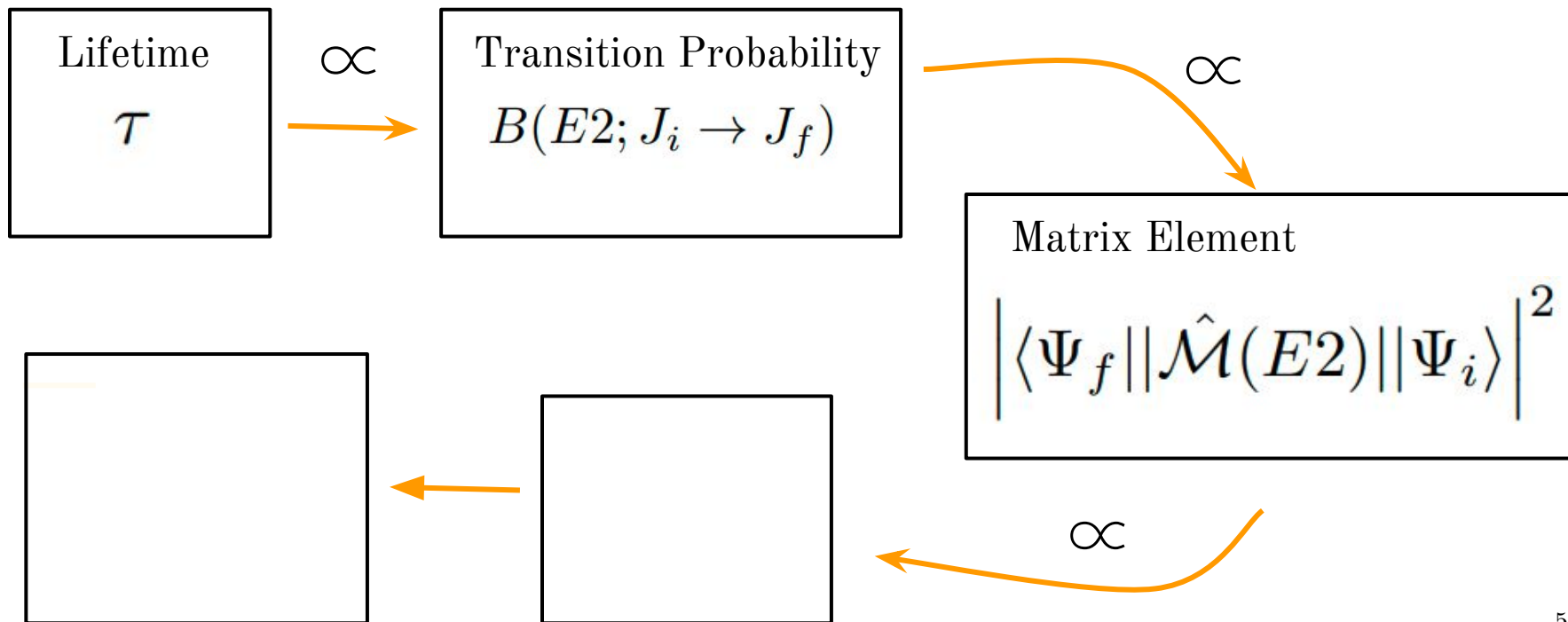
Lifetime measurements



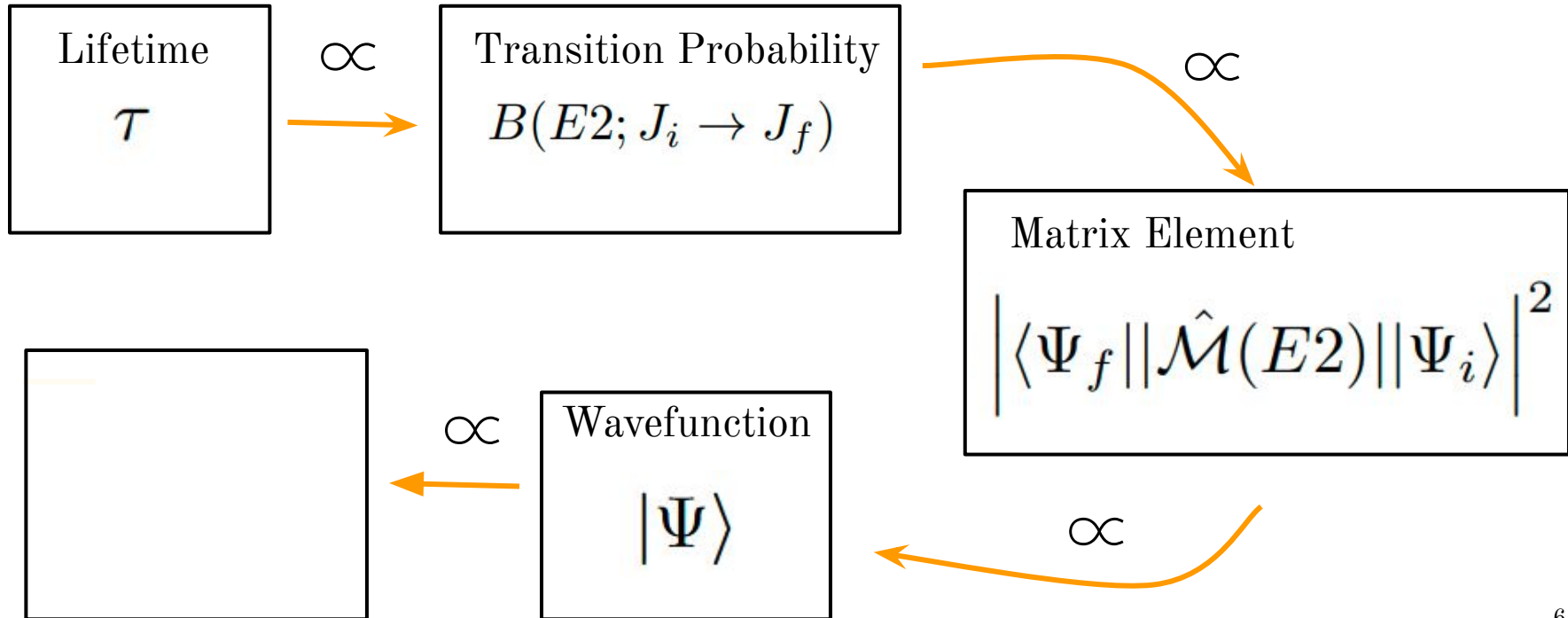
Lifetime measurements



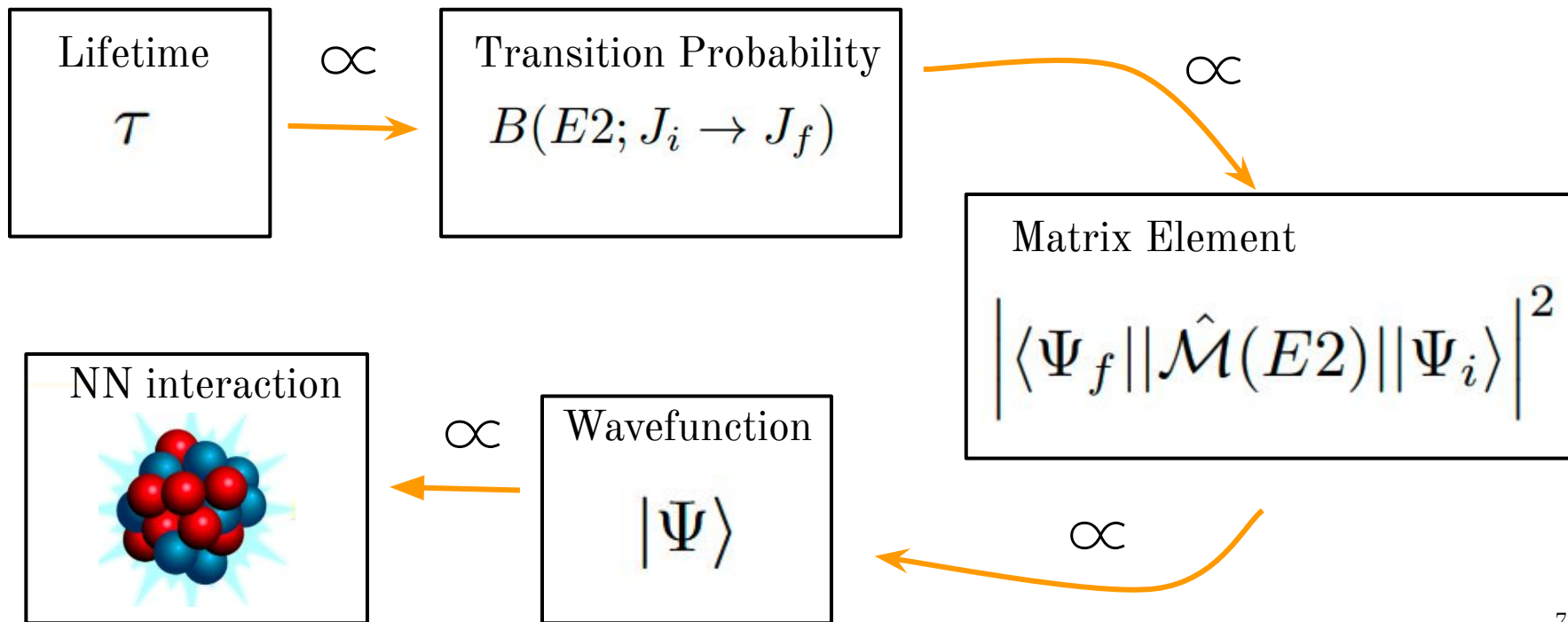
Lifetime measurements



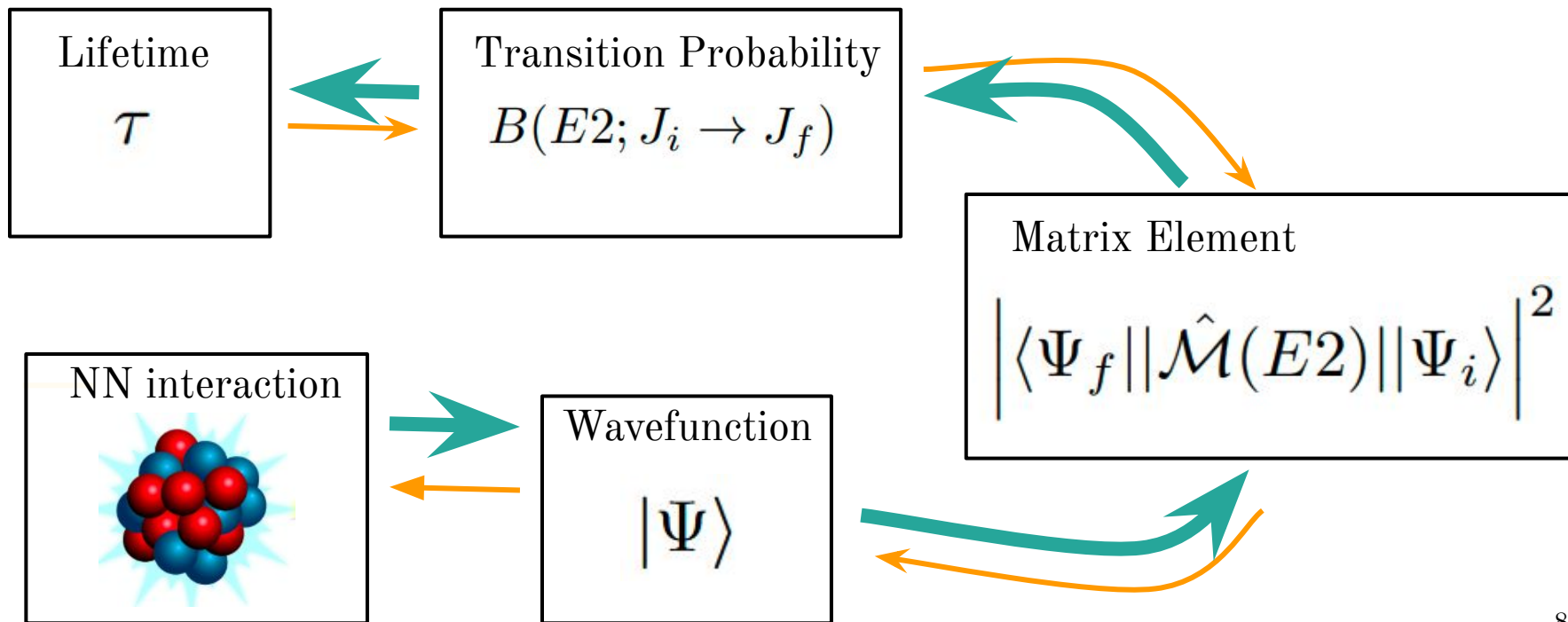
Lifetime measurements



Lifetime measurements



Lifetime measurements



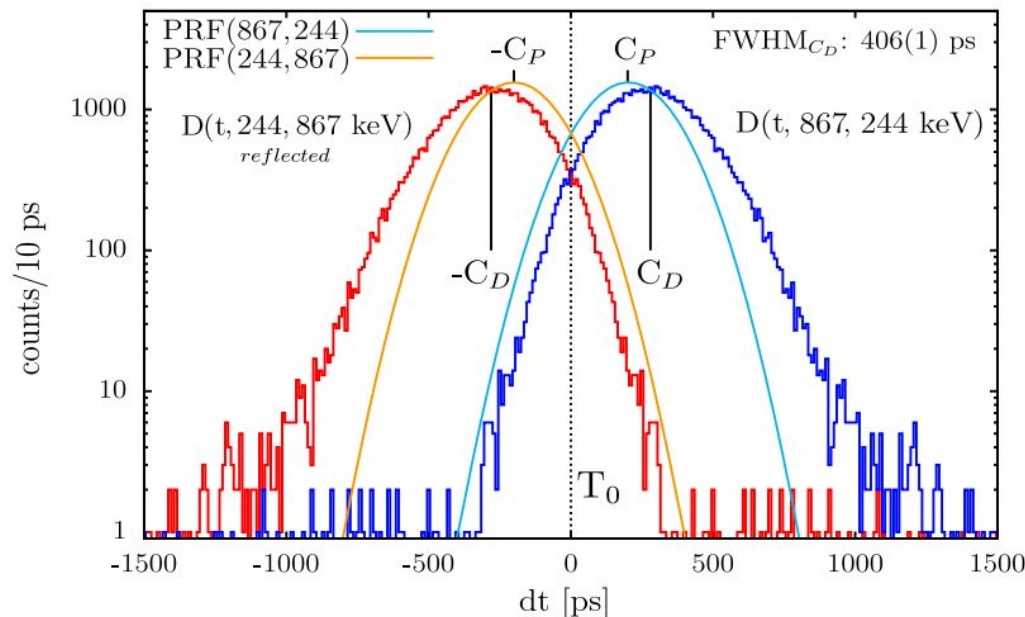
Lifetime Measurements: Fast Timing



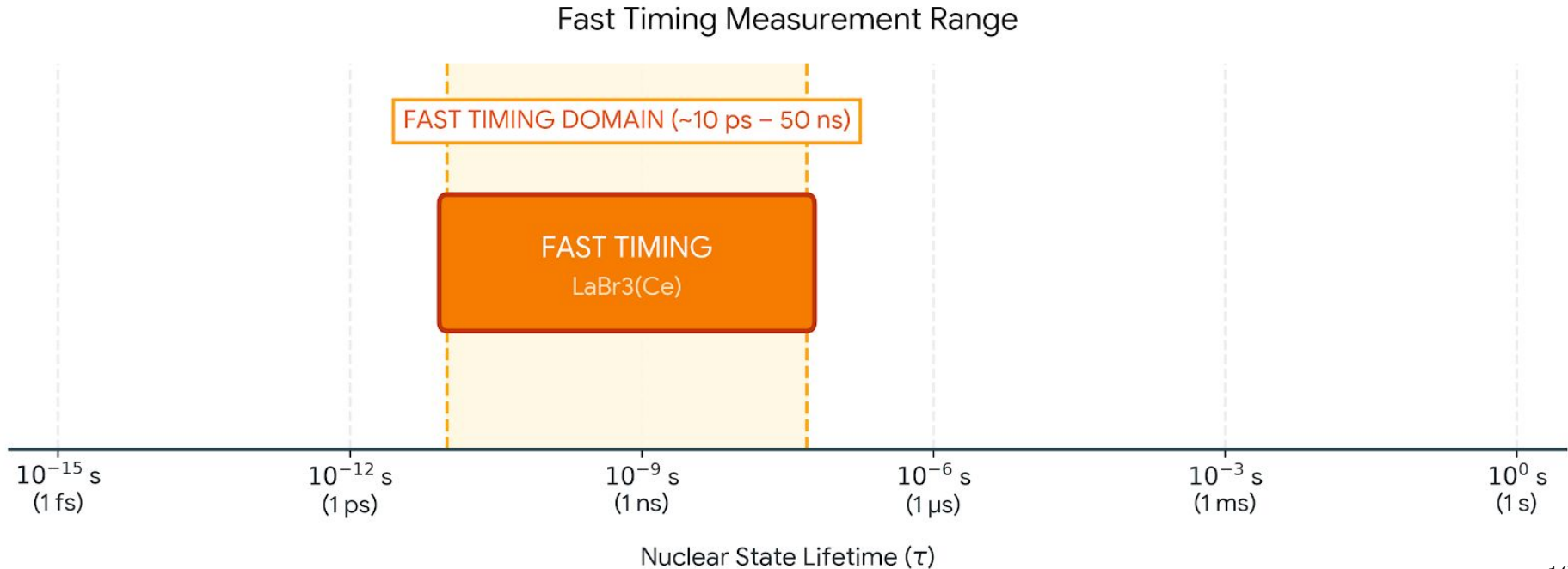
Goal:
 τ lifetime of excited state.

Fast-timing:
START : Populating γ
STOP: Depopulating γ

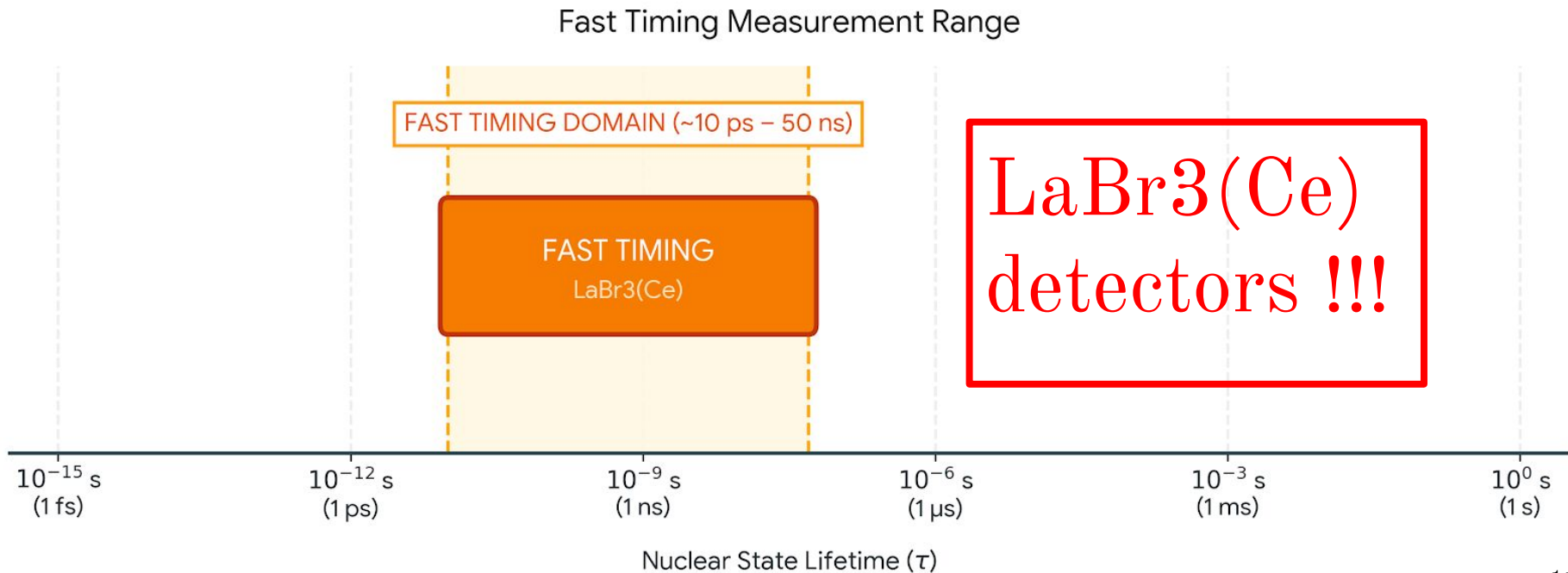
$$\Delta t = t_{\text{stop}} - t_{\text{start}}$$



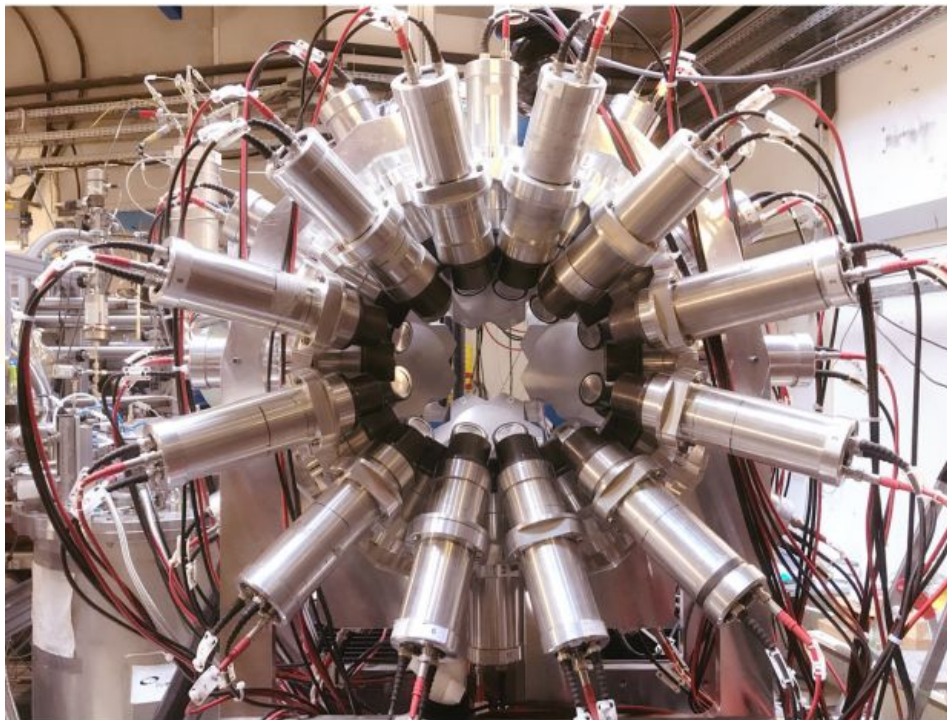
Lifetime Measurements: Fast Timing



Lifetime Measurements: Fast Timing



FAst TIMing Array



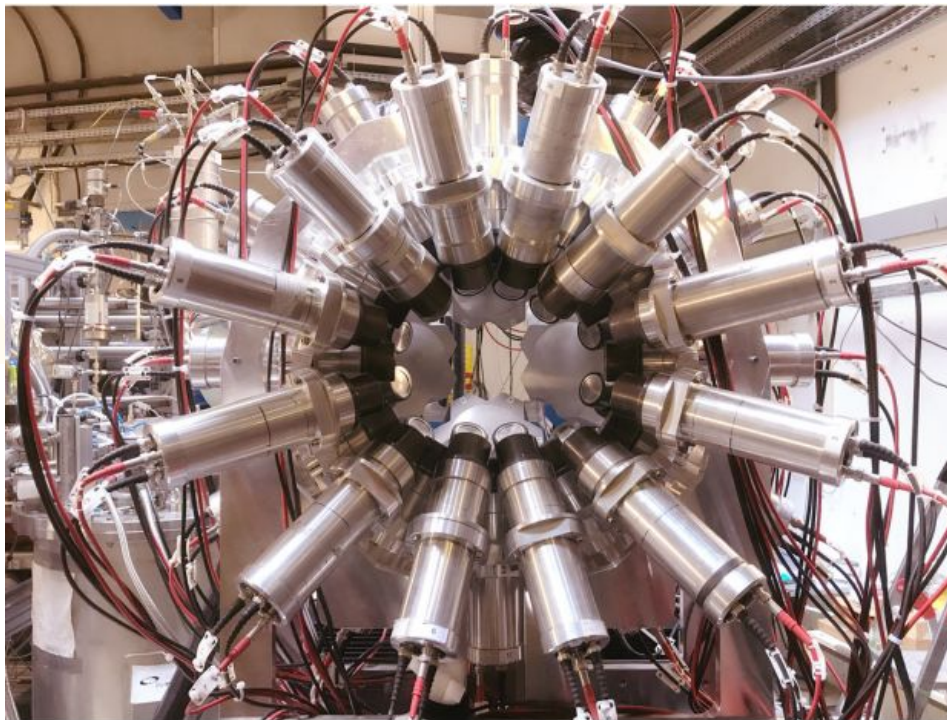
Array of
36
 $\text{LaBr}_3(\text{Ce})$
scintillators

Good energy
resolution
of $\sim 3\%$ at
the 662 keV peak
 ^{137}Cs

FAst TIMing Array



**Exceptional
time
resolution
of ~ 320 ps
for the
 ^{60}Co
cascade**



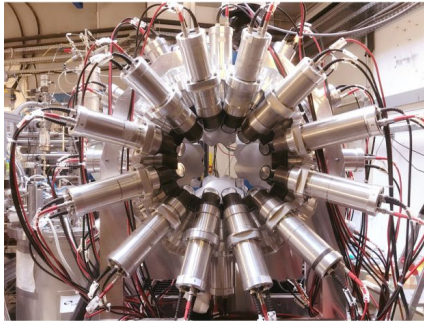
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FAst TIMing Array

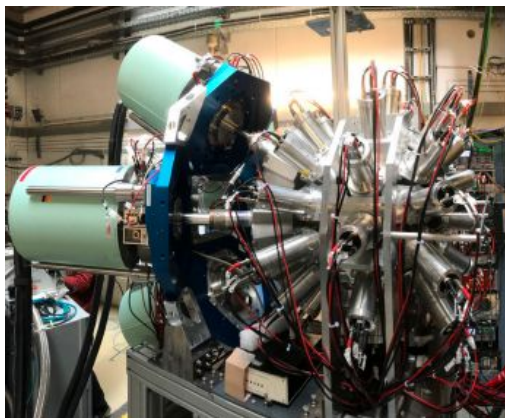
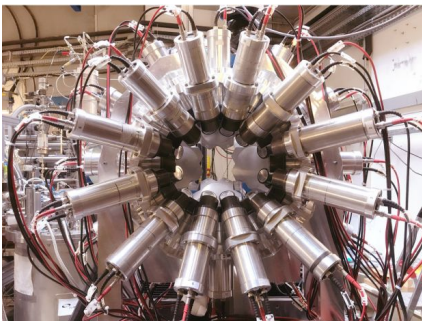


FATIMA



FAsT TIMing Array

FATIMA



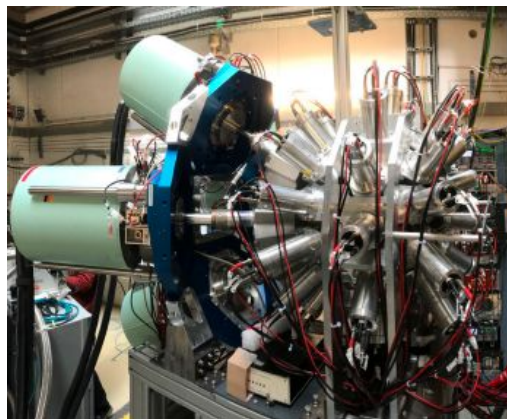
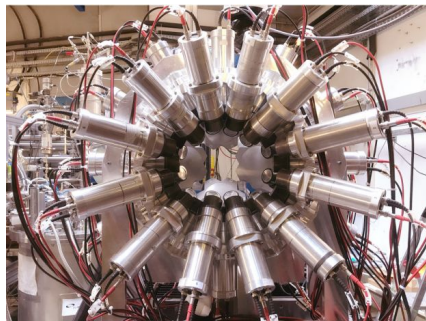
DESPEC:

FATIMA + HpGe

FAsT TIMing Array

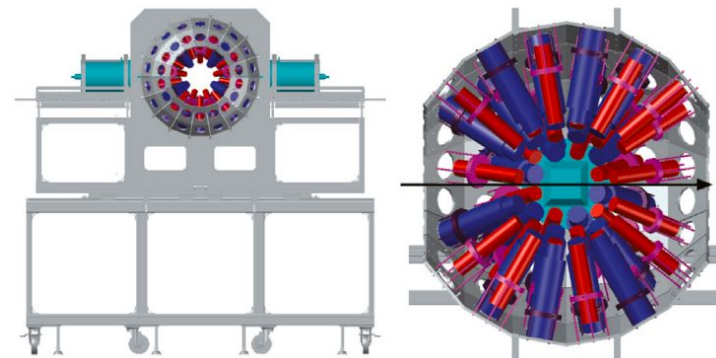


FATIMA



DESPEC:
FATIMA + HpGe

IDATEN :



FATIMA + KHALA

FATIMA Detectors



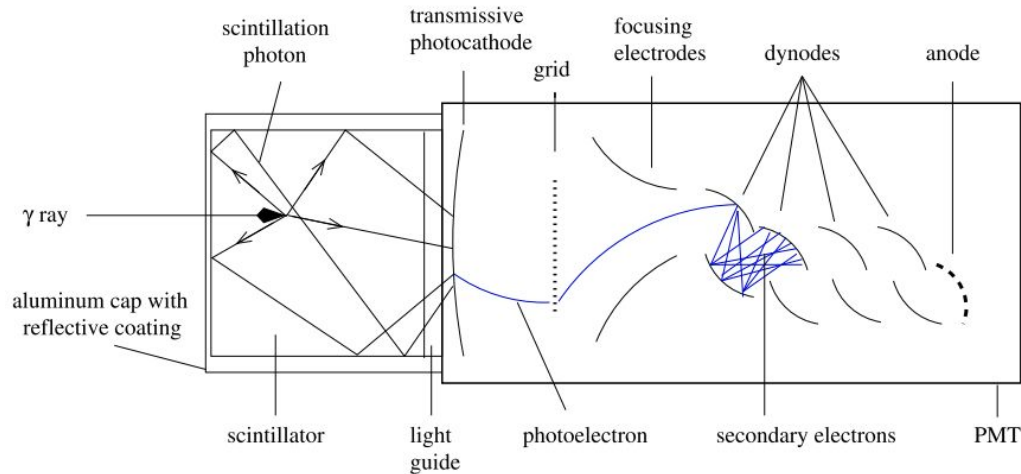
FATIMA Detectors



PhotoMultiplier Tube (PMT)

Hamamatsu R9779

Transit Time Spread of 250 ps



FATIMA Detectors



PhotoMultiplier Tube (PMT)

Hamamatsu R9779

Transit Time Spread of 250 ps



μ -metal coating
for magnetic field
tolerance



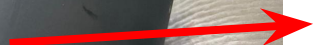
FATIMA Detectors



Al casing



No Al casing



FATIMA Detectors



High
peak-to-background

High scintillation light
output and fast decay
time ~ 20 ns

The **best** scintillator
detector for fast timing

LaBr₃(Ce)



FATIMA Detectors



Time resolution uncertainty

$$\delta t \approx \frac{1}{\sqrt{n}} \sqrt{\sigma_{\text{Sc}}^2 + \sigma_{\text{PMT}}^2}$$

Intrinsic decay time

Photon light yield

Size and geometry

TTS



Experimental Setup



Mechanical
support

HV voltage

^{152}Eu Source

Experimental Setup



Mechanical
support

HV voltage

^{152}Eu Source

Experimental Setup



Mechanical
support

HV voltage

^{152}Eu Source

**Transfer
Function:**
overall
amplitude-to-en-
ergy conversion
gain of the
detection system

Experimental Setup



Mechanical
support

HV voltage

^{152}Eu Source

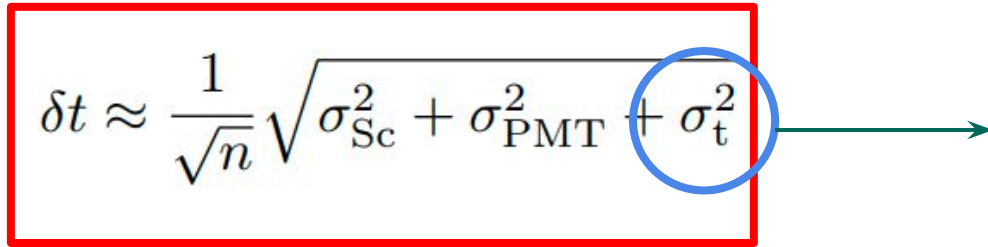
Experimental Setup: time-pickoff method



$$\delta t \approx \frac{1}{\sqrt{n}} \sqrt{\sigma_{\text{Sc}}^2 + \sigma_{\text{PMT}}^2 + \sigma_t^2}$$

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Time-pickoff method:

Conversion of the analog rising edge into a logic timing signal to accurately **timestamp** the event arrival

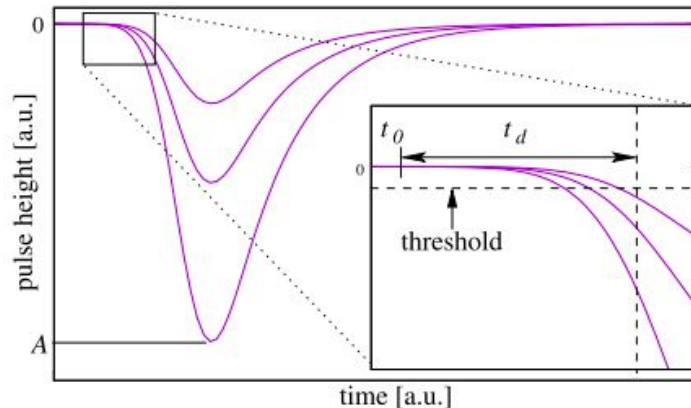
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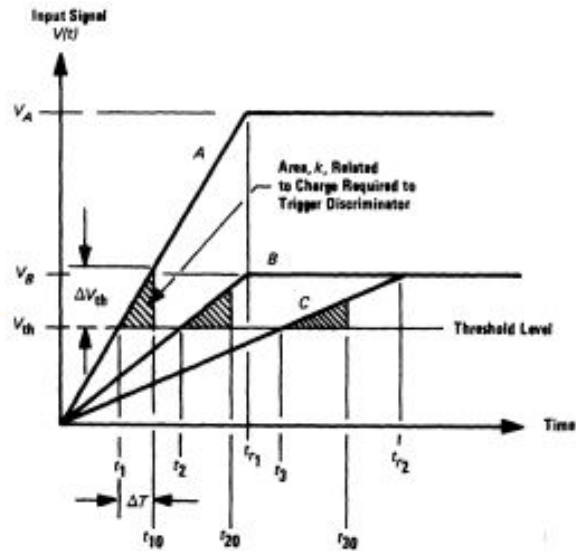


Leading-edge discriminator

Experimental Setup: time-pickoff method



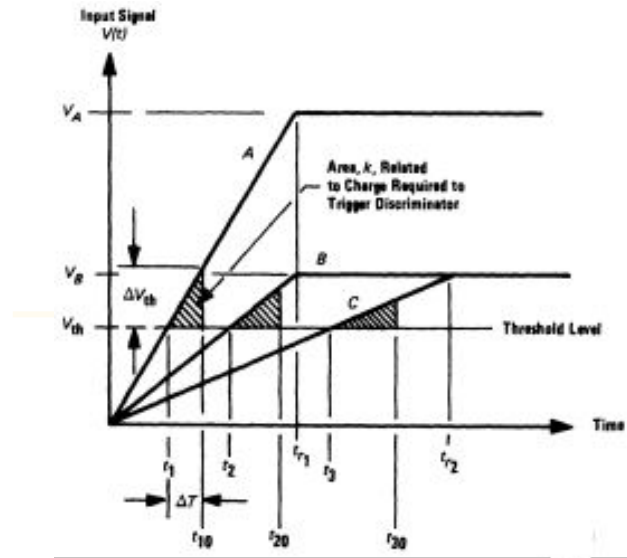
Problem : Time Walk



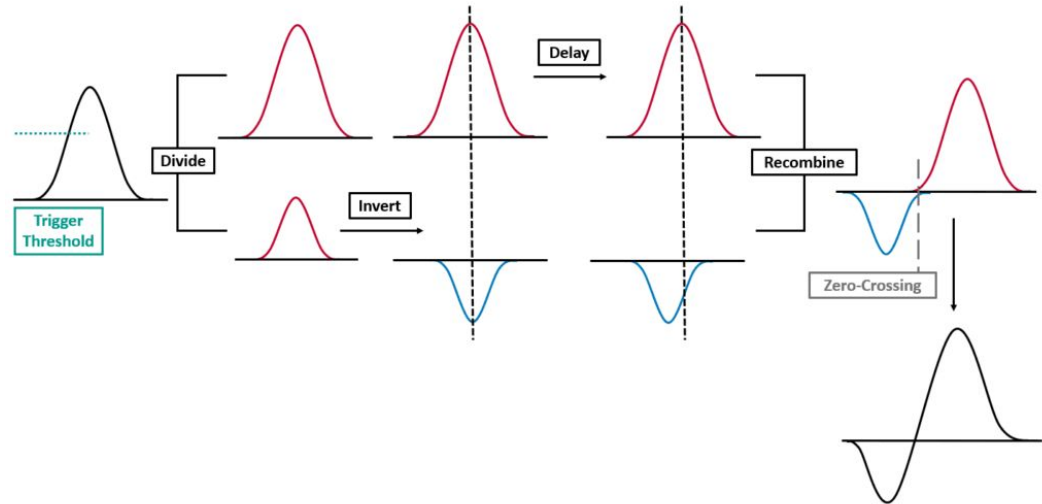
Experimental Setup: time-pickoff method



Problem : Time Walk



Solution: CFD

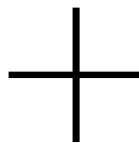
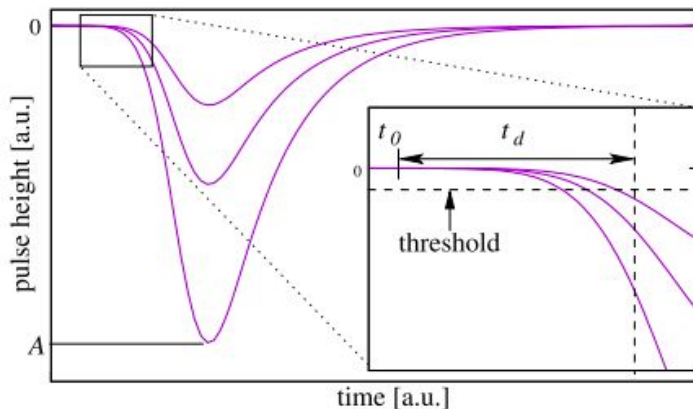


Experimental Setup: time-pickoff method

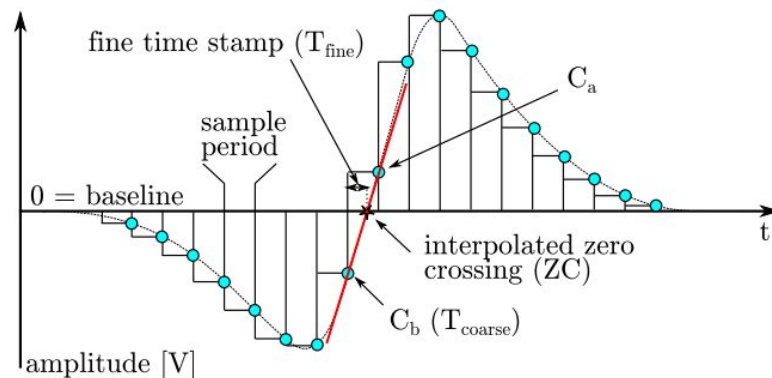


V1751 Digitizer

leading-edge discriminator



CFD

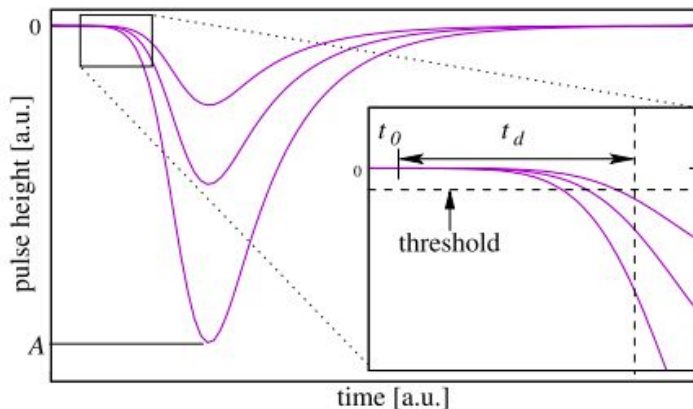


Experimental Setup: time-pickoff method



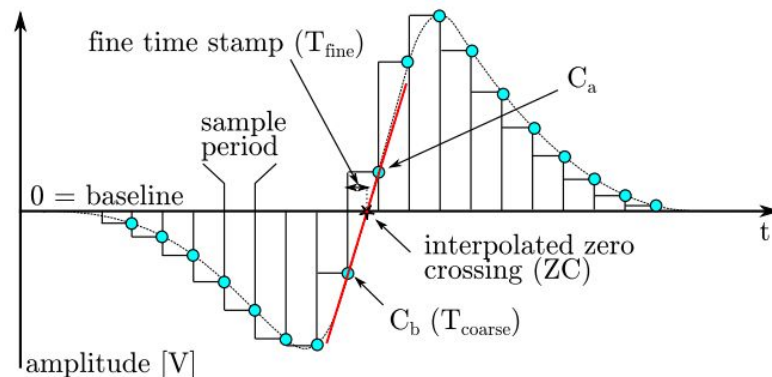
V1751 Digitizer

leading-edge discriminator



$$\delta t \approx \frac{1}{\sqrt{n}} \sqrt{\sigma_{\text{Sc}}^2 + \sigma_{\text{PMT}}^2 + \sigma_t^2}$$

CFD



Optical Recoupling



1. Disassemble the detectors
2. Remove optical grease with isopropyl alcohol
3. Recouple the PMT and the crystal
4. Alignment

Optical Recoupling



REPEAT FOR
ALL 20
DETECTORS



Optical Recoupling



PMT Hamamatsu R9779



la densità

Optical Recoupling



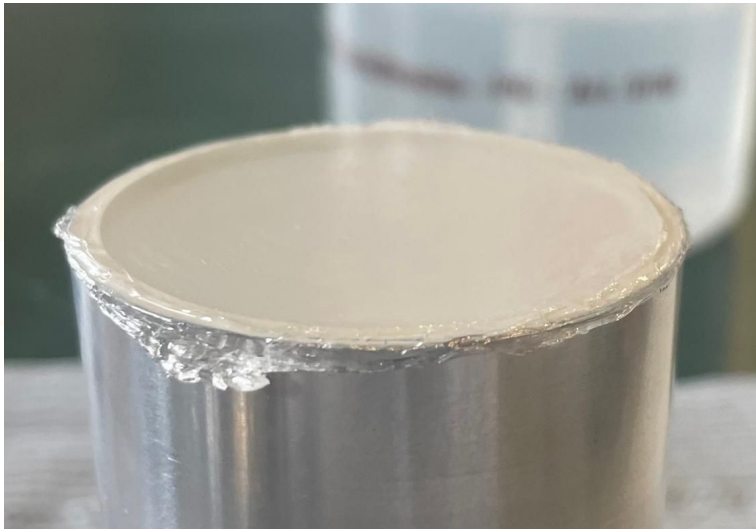
PMT Hamamatsu R9779



Optical Recoupling



$\text{LaBr}_3(\text{Ce})$ Crystals

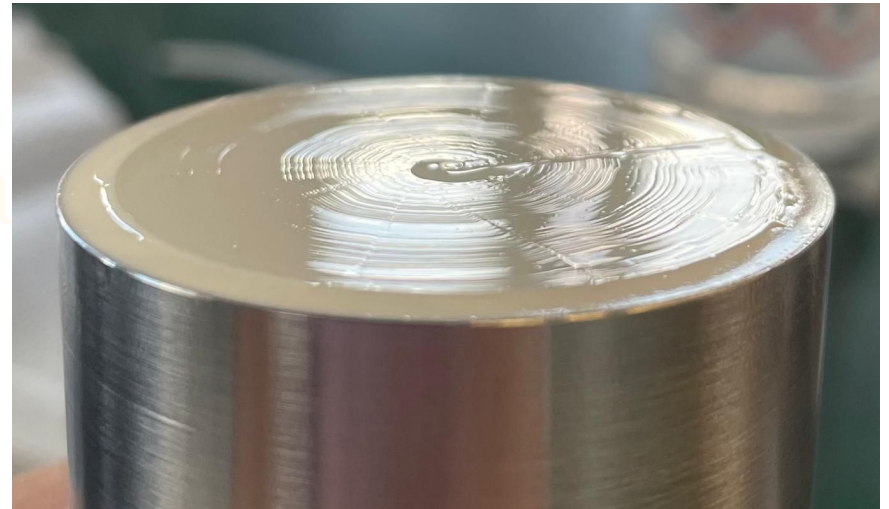
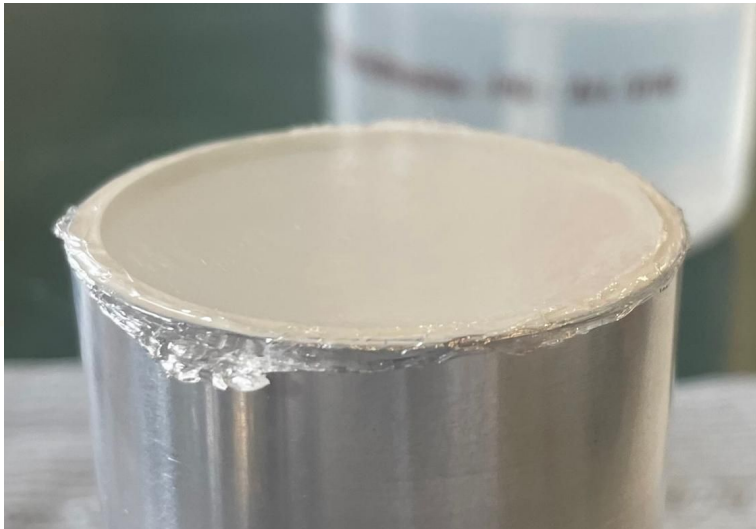


la densità

Optical Recoupling



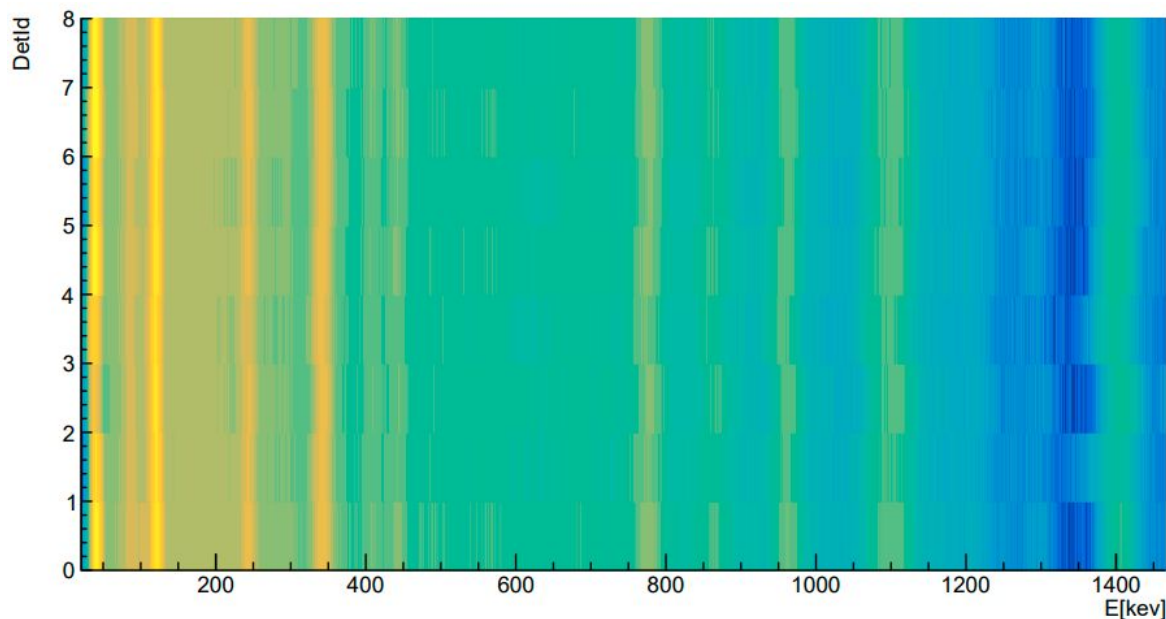
LaBr₃(Ce) Crystals



Resolution Measurement



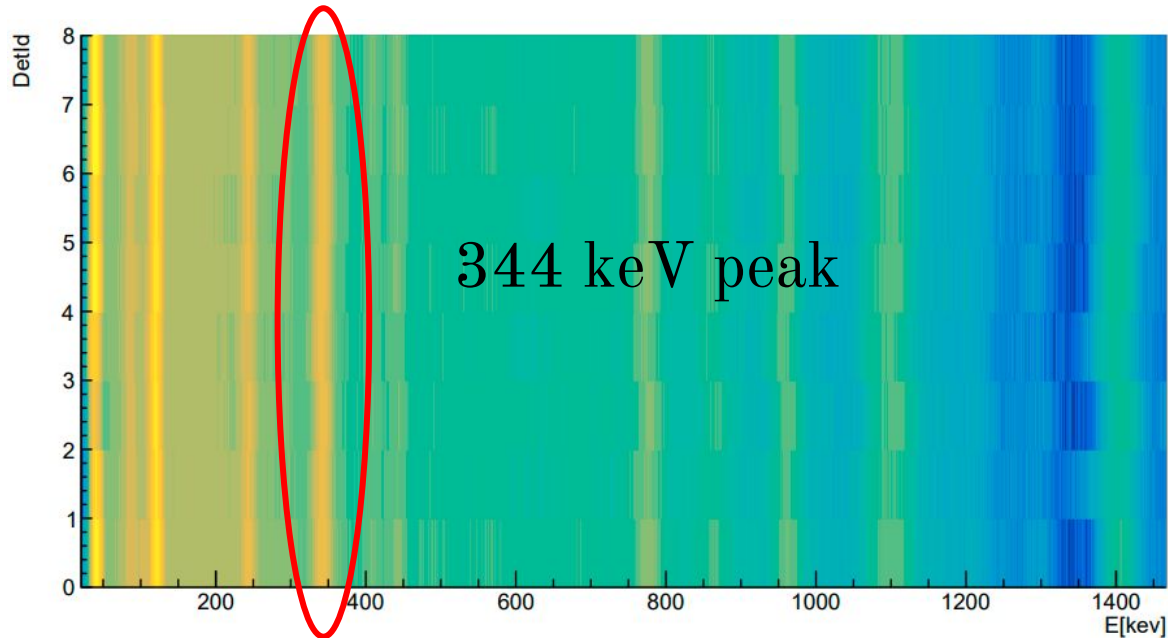
Energy Calibration for ^{152}Eu Spectrum



Resolution Measurement



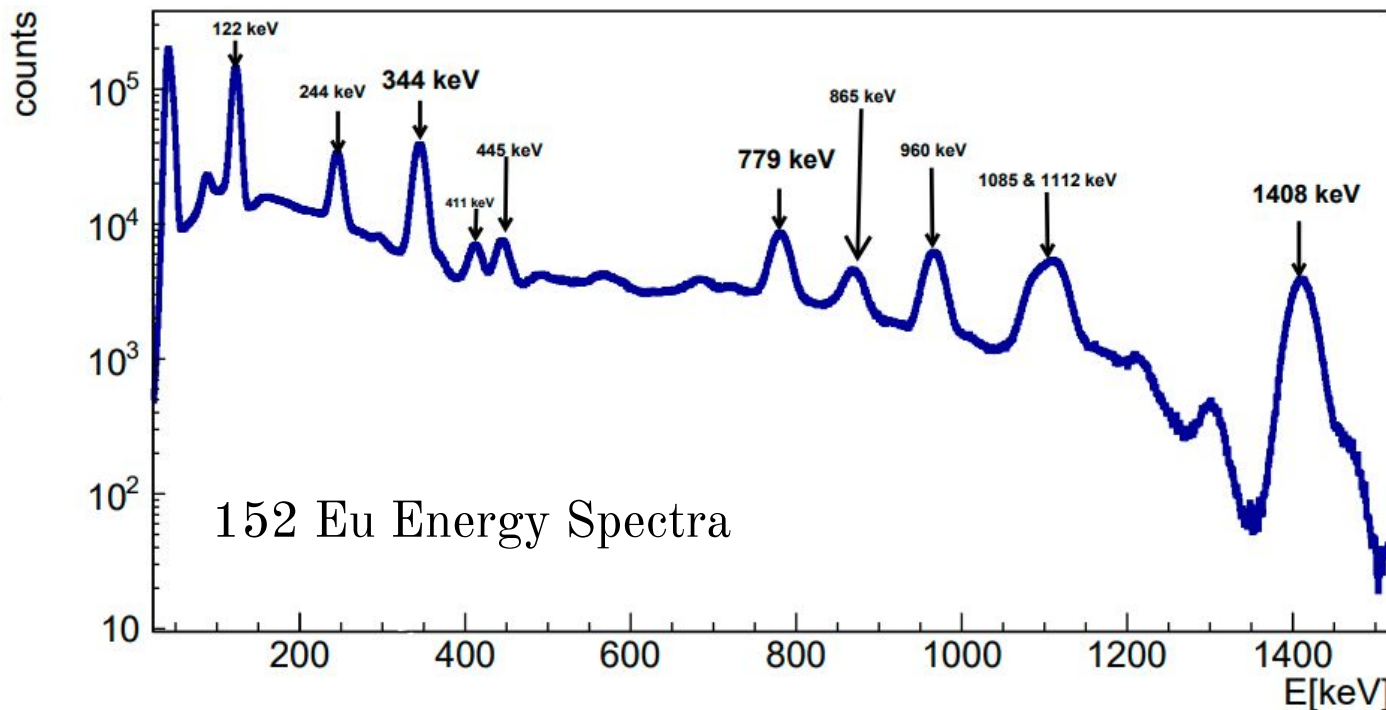
Energy Calibration for ^{152}Eu Spectrum



Resolution Measurement



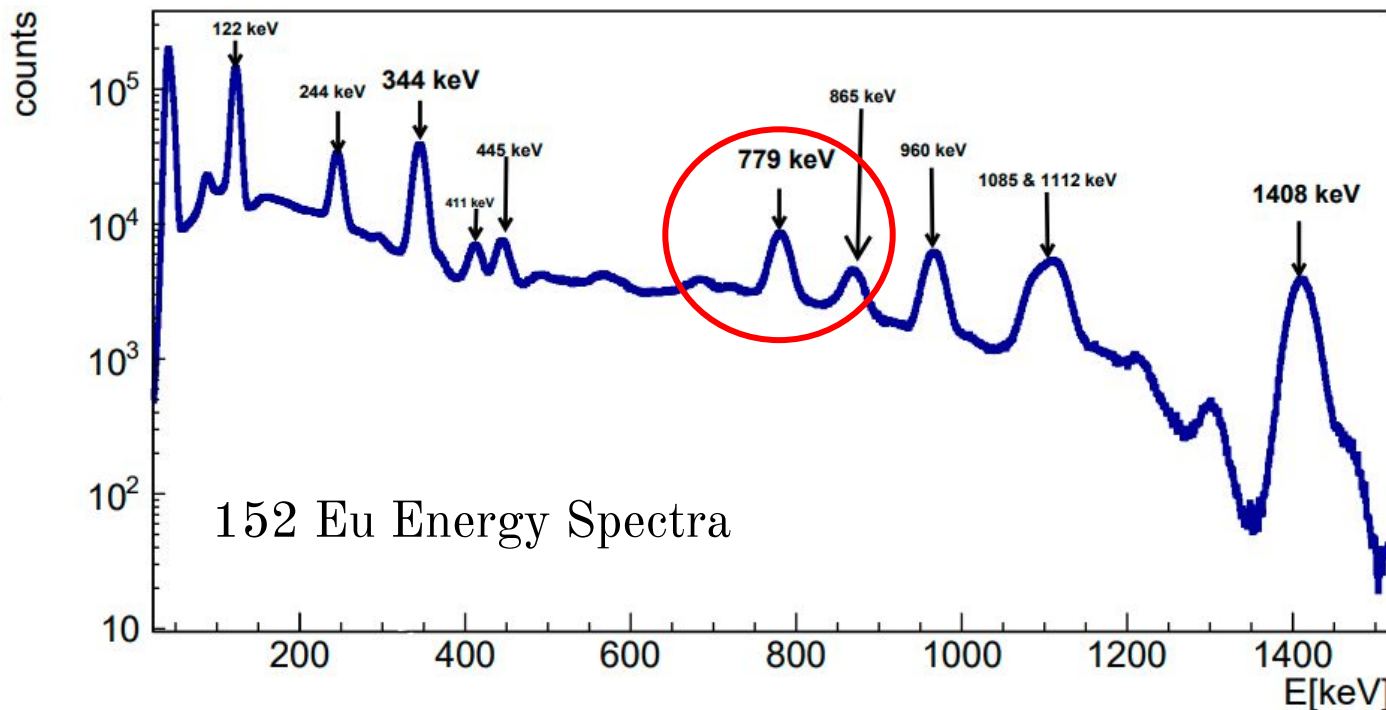
FWHM Extraction



Resolution Measurement



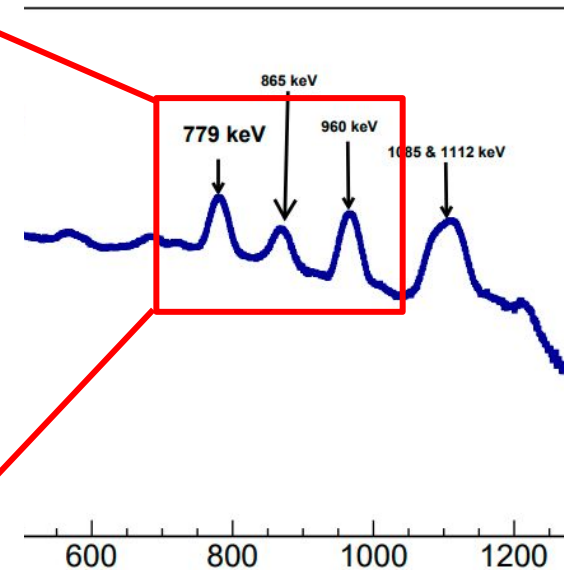
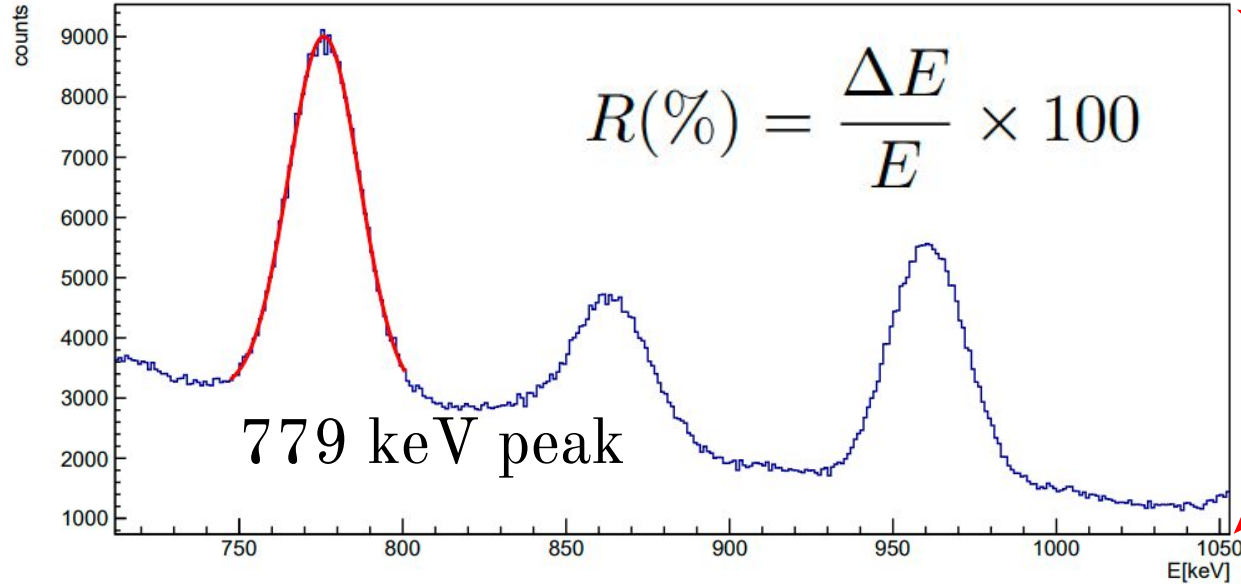
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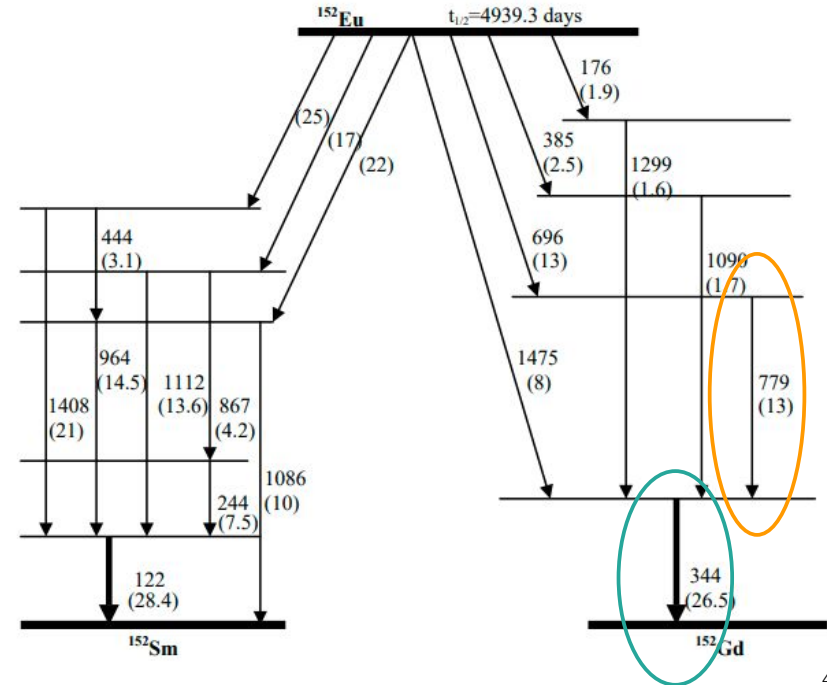
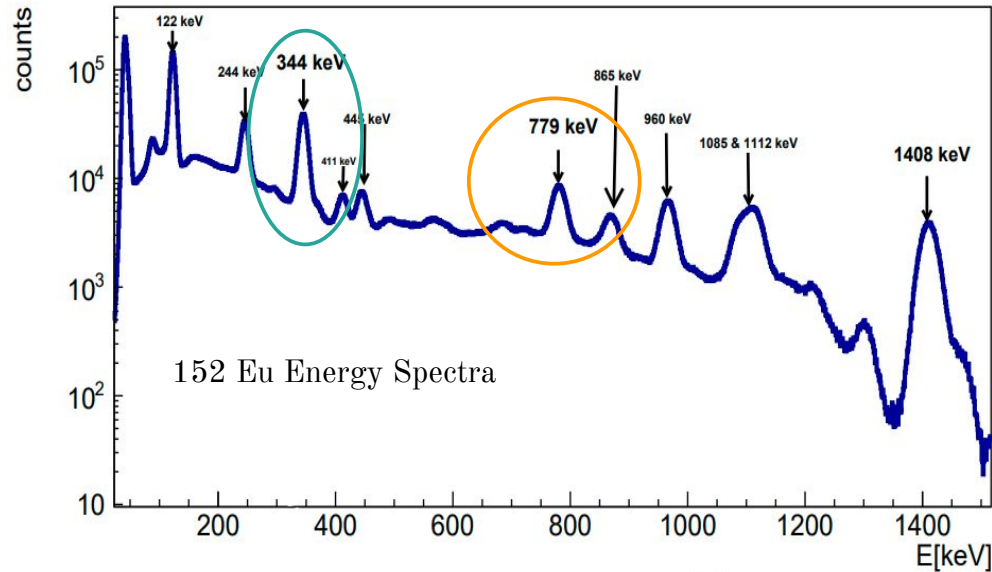
Resolution Measurement



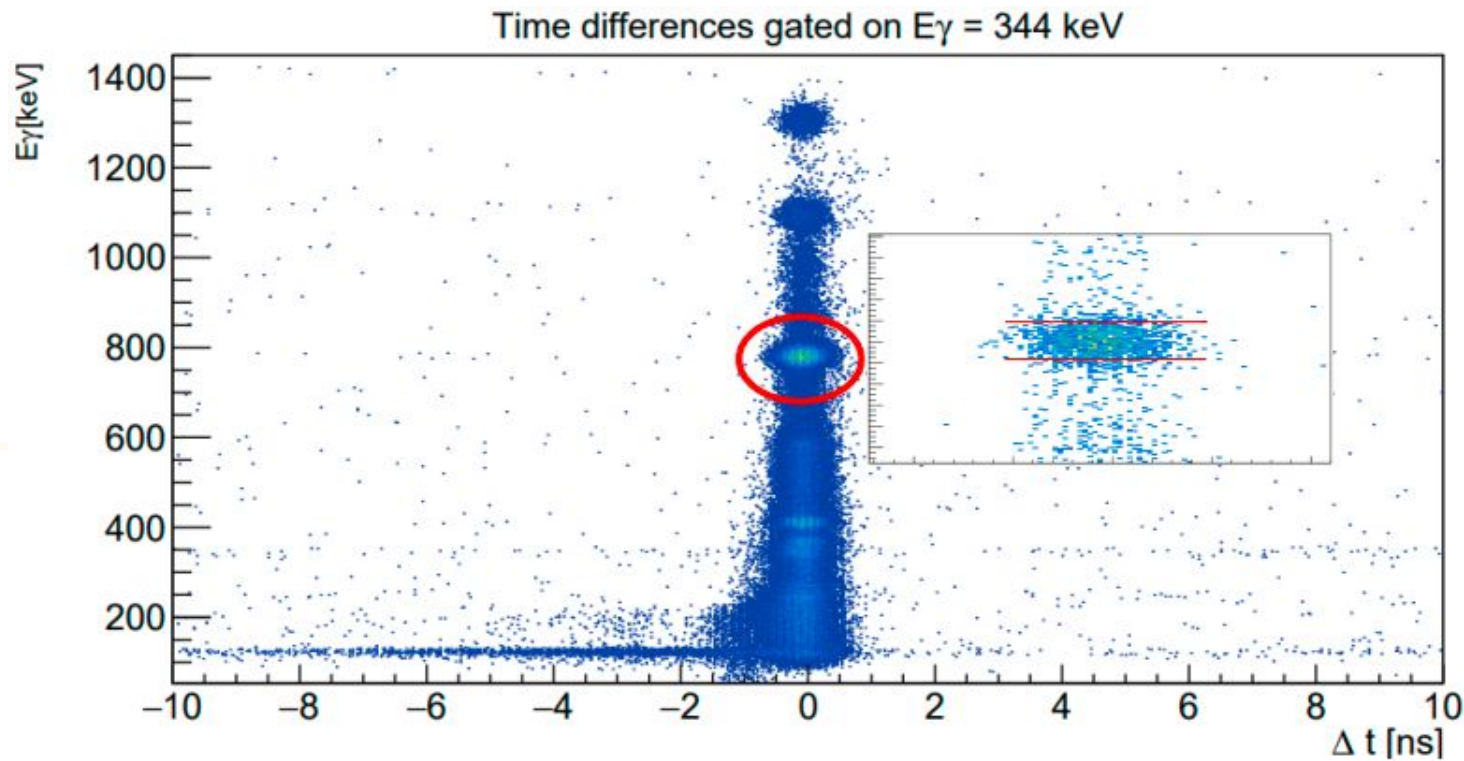
FWHM Extraction



Resolution Measurement



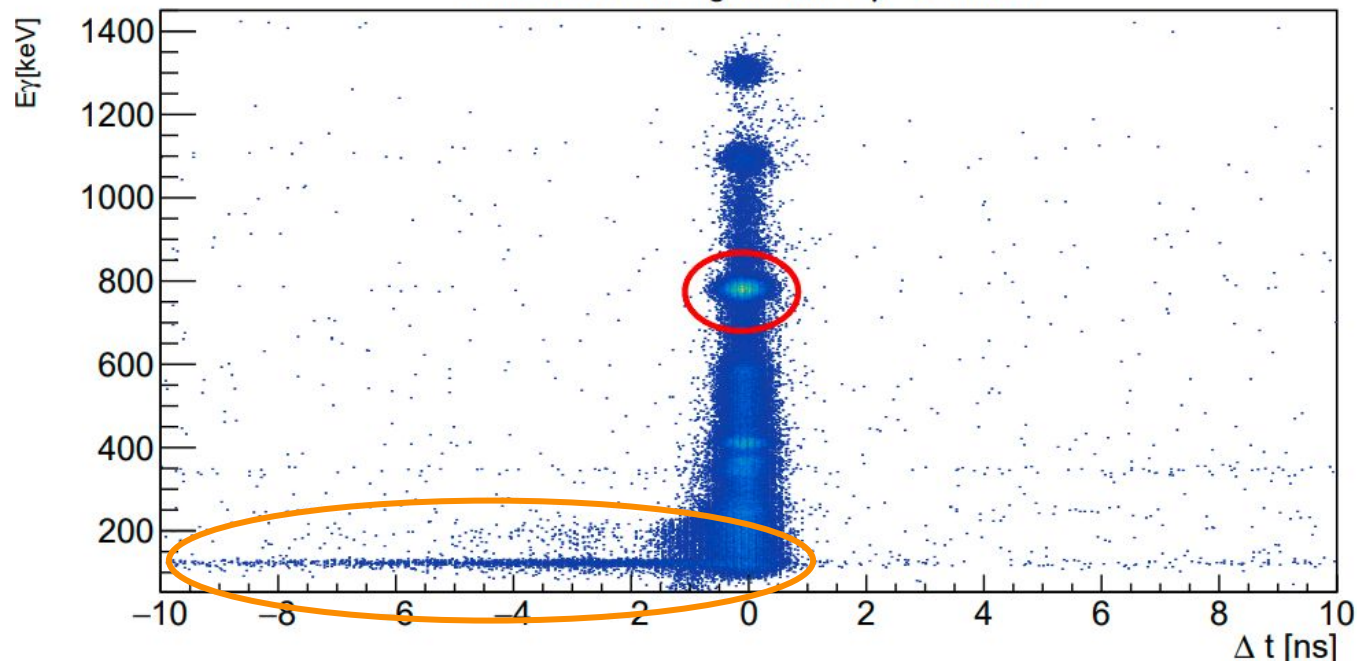
Resolution Measurement



Resolution Measurement

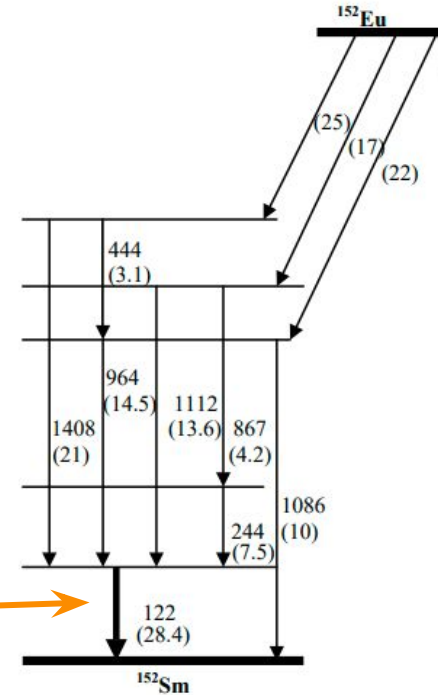
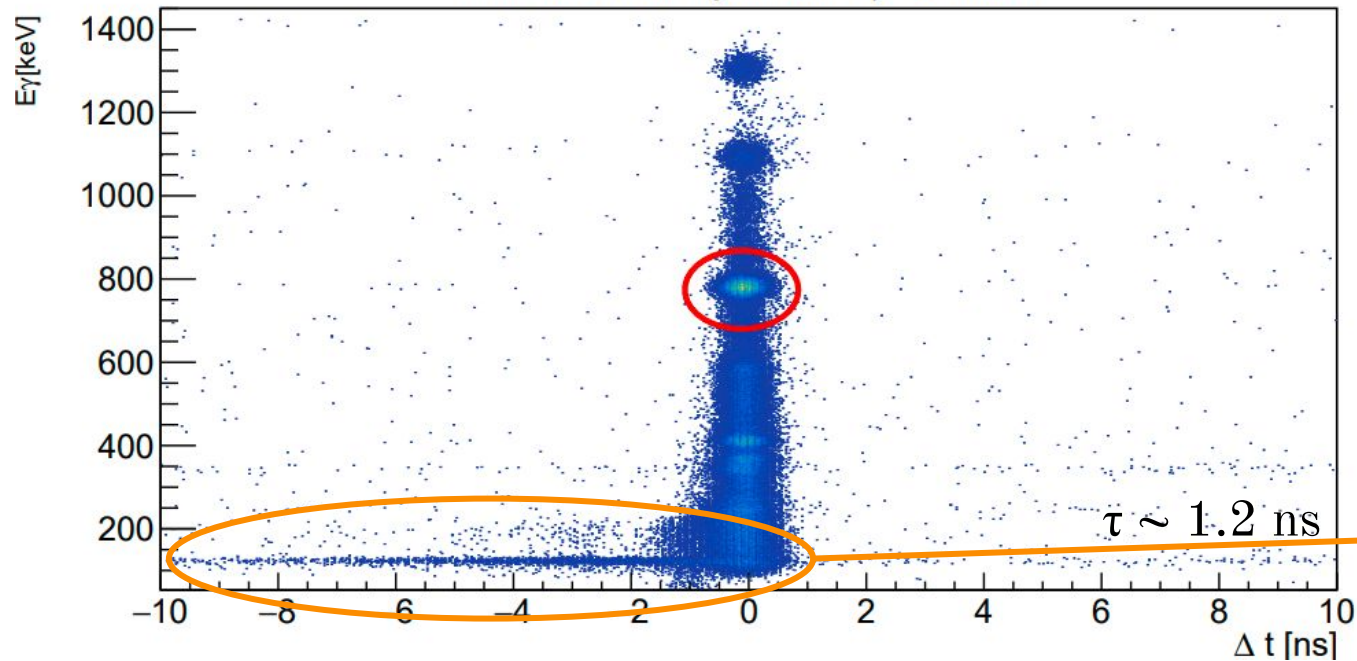


Time differences gated on $E_\gamma = 344$ keV

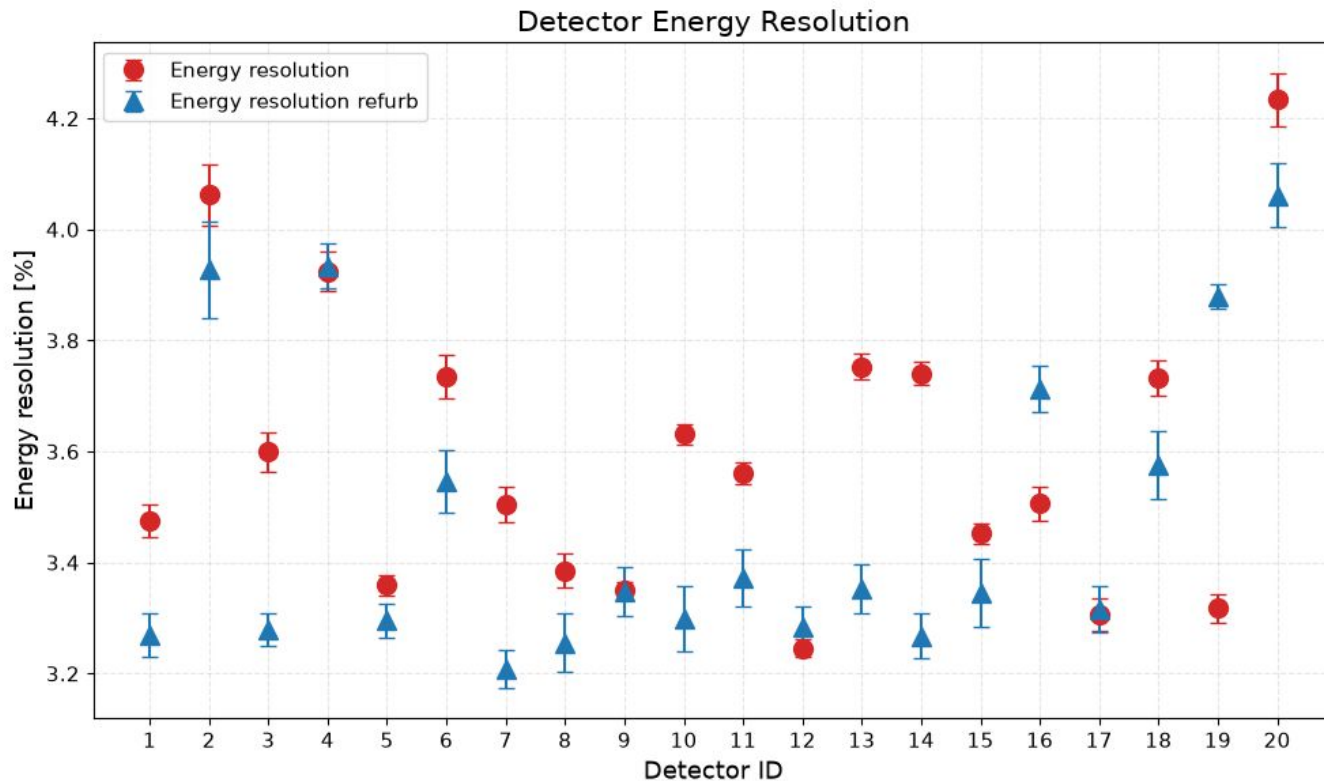


Resolution Measurement

Time differences gated on $E_\gamma = 344$ keV



Results: Energy Resolution at 779 keV

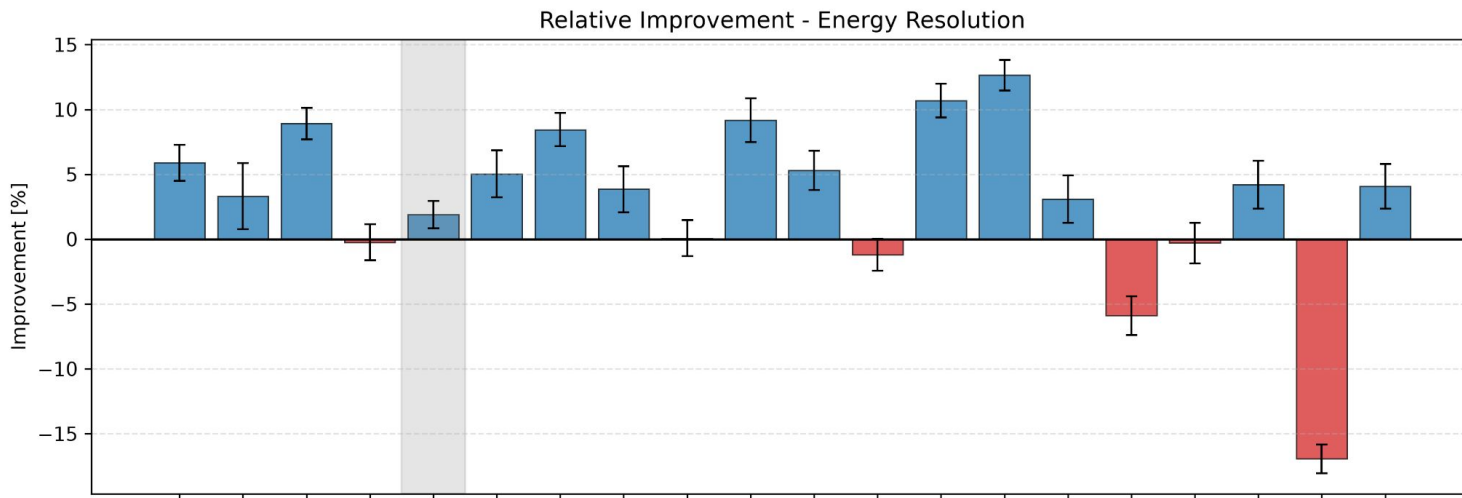


Results: Energy Resolution at 779 keV



Overall improvement in energy resolution.

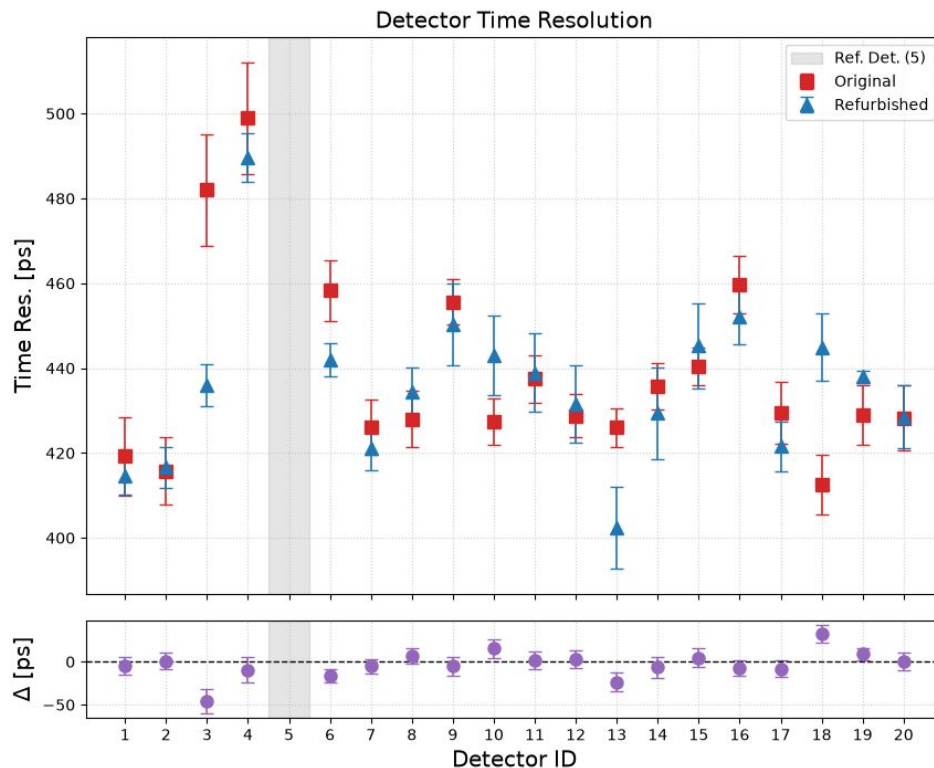
Best relative improvement in energy resolution: 14%



Results: Time Resolution



The dominant factor is the time-pickoff method.



No particular change
in Time Resolution

Conclusion



- The FATIMA detectors are now characterized.
- Refurbishment procedure proved to improve energy resolution, while maintaining the timing resolution performance.
- Best relative improvement of **14%** in energy resolution.
- There is room for future optimization

$$\delta t \approx \frac{1}{\sqrt{n}} \sqrt{\sigma_{\text{Sc}}^2 + \sigma_{\text{PMT}}^2 + \sigma_{\text{t}}^2}$$

The End



THANK YOU FOR
YOUR ATTENTION

