Influence of the Metallization on the Charge Collection Efficiency of Segmented Germanium Detectors

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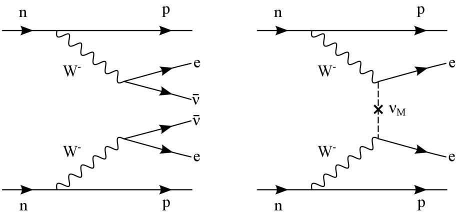
Outline

Neutrinoless double beta decay ($0\nu\beta\beta$): $^{A}_{Z}\mathrm{X} \rightarrow {}^{A}_{Z+2}\mathrm{X} + 2e^{-}$



- Lepton number violating
- Majorana/Dirac particle?
- Effective neutrino mass m_{ee}?
- Neutrino mass hierarchy?

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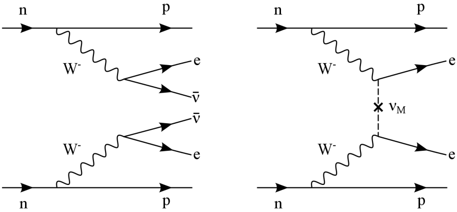
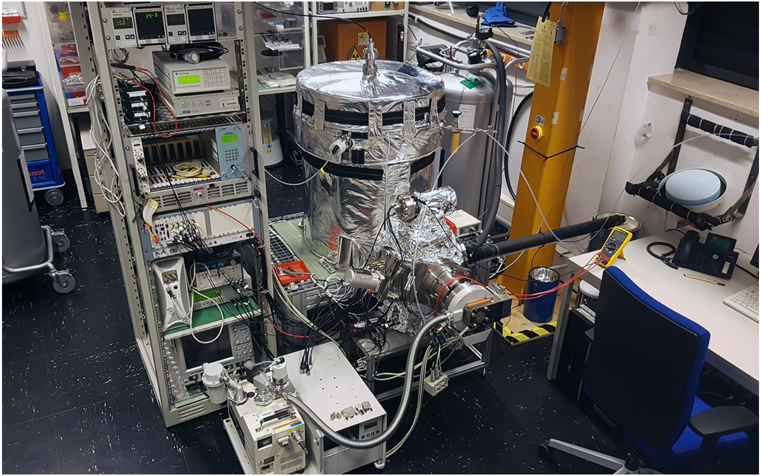


- Lepton number violating
- Majorana/Dirac particle?
- Effective neutrino mass m_{ee}?
- Neutrino mass hierarchy?

$\rightarrow$ The GERmanium Detector Array (GERDA) Experiment

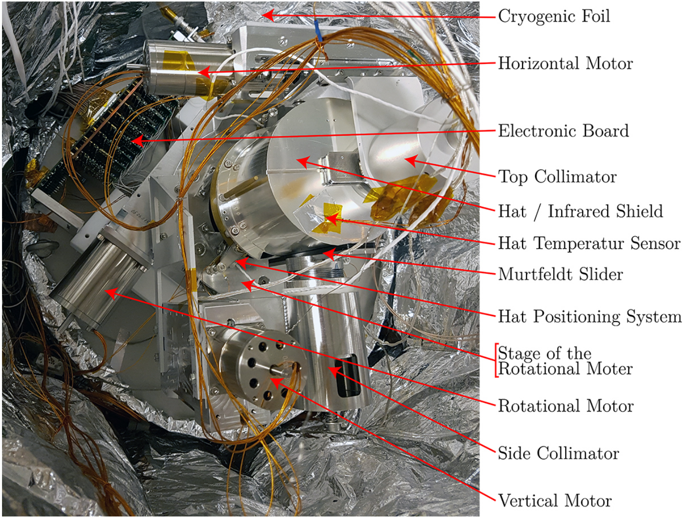
- ^{76}Ge is a possible candidate for $0\nu\beta\beta$
- ^{76}Ge enriched germanium is used as source and detector
- $T_{1/2} > 5.3 \times 10^{25}$ yr
- Biggest challenge: Further reduction of background

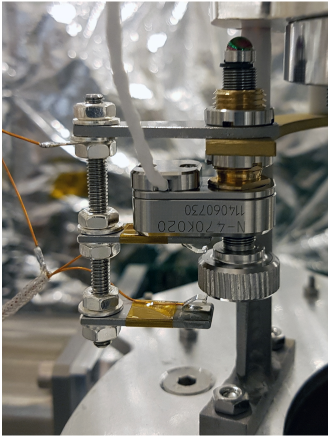
GermAnium LAser TEst Apparatus

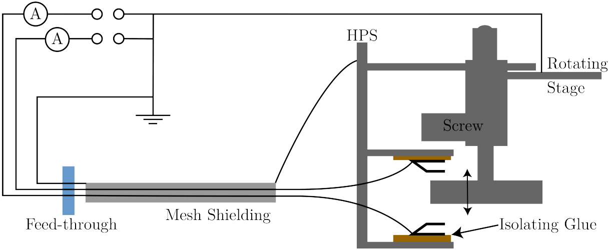


Experimental Setup

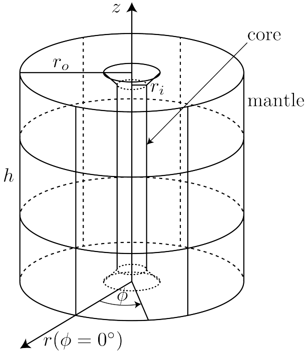
Inside

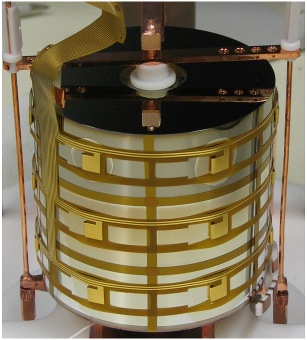






A
A
HPS
Rotating
Stage
Screw
Feed-through
Mesh Shielding
Isolating Glue





$h = 70.1\,\text{mm}$ $\quad$ $r_o = 37.5\,\text{mm}$

$m_D = 1662\,\text{g}$ $\quad$ $r_i = 5.0\,\text{mm}$

At the beginning:

- Just cross-talk from core to segments

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Now:

- Cross-talk from core to segments
- Cross-talk from segments to segments
- Cross-talk from segments to core is all equal

Energy Recalculation

At the beginning:

- Just cross-talk from core to segments

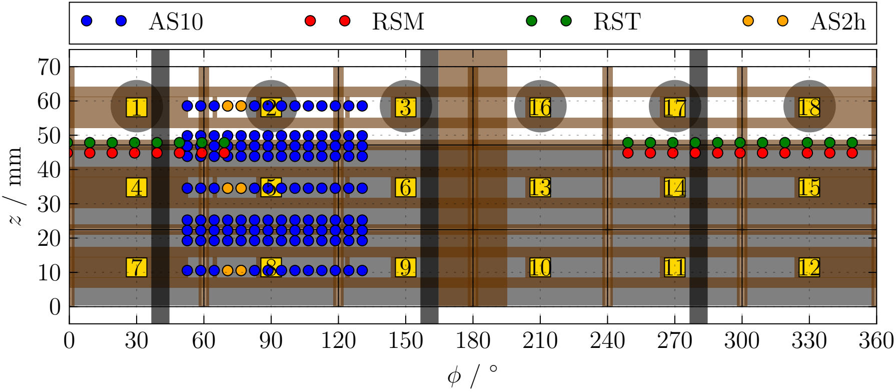
Now:

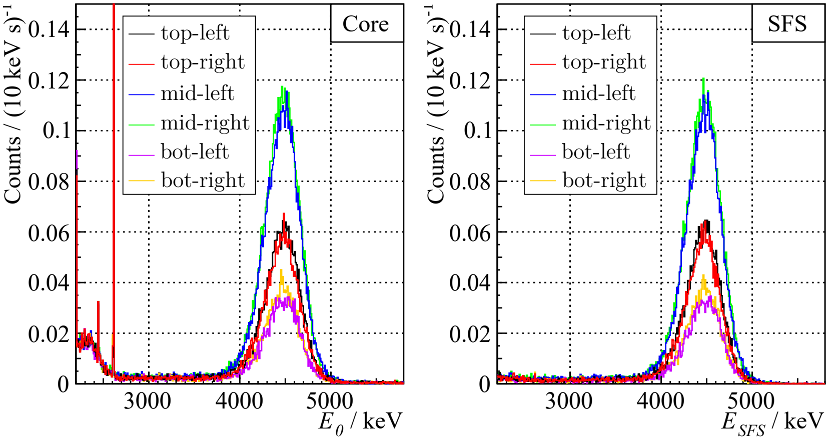
- Cross-talk from core to segments
- Cross-talk from segments to segments
- Cross-talk from segments to core is all equal

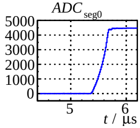
→ Calibration of the core just through known photon lines

→ Resolution of the core gets a bit worse.

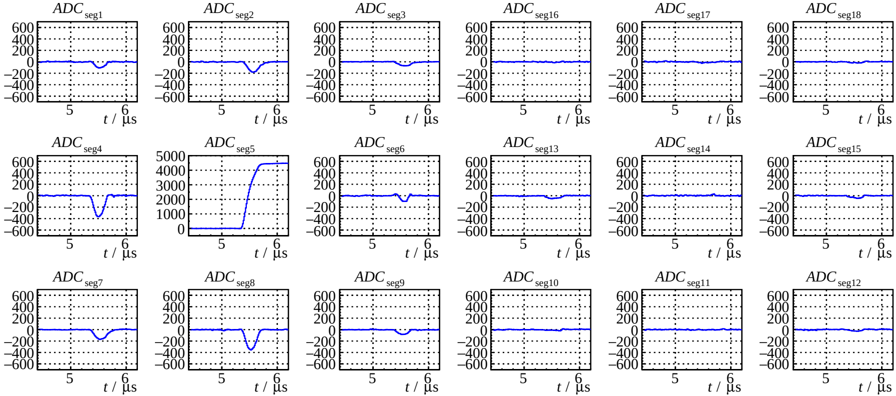
^{241}Am: $E_\alpha = 5485.56\,\mathrm{keV}$
$E_\gamma = 59.54\,\mathrm{keV}$




Core
top-left
top-right
mid-left
mid-right
bot-left
bot-right
Counts / (10 keV s)$^{-1}$
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
3000
4000
5000
E_0 / keV
SFS
top-left
top-right
mid-left
mid-right
bot-left
bot-right
Counts / (10 keV s)$^{-1}$
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
3000
4000
5000
E_{SFS} / keV



$$A_{hor} = \frac{MPA_{left} - MPA_{right}}{MPA_{left} + MPA_{right}} \qquad A_{ver} = \frac{MPA_{top} - MPA_{bot}}{MPA_{top} + MPA_{bot}}$$



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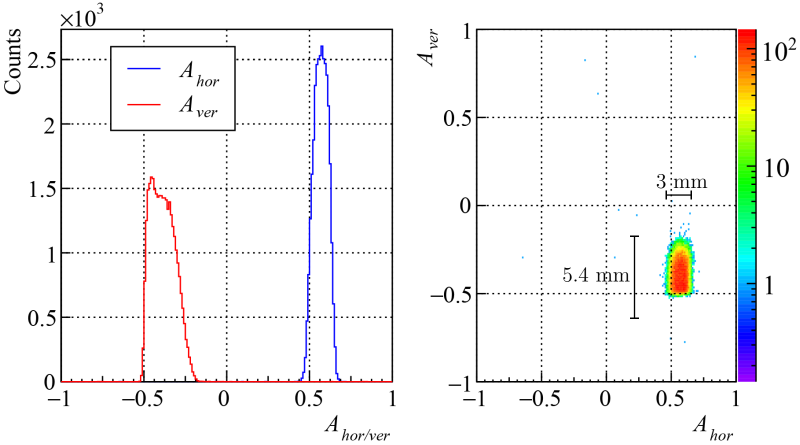
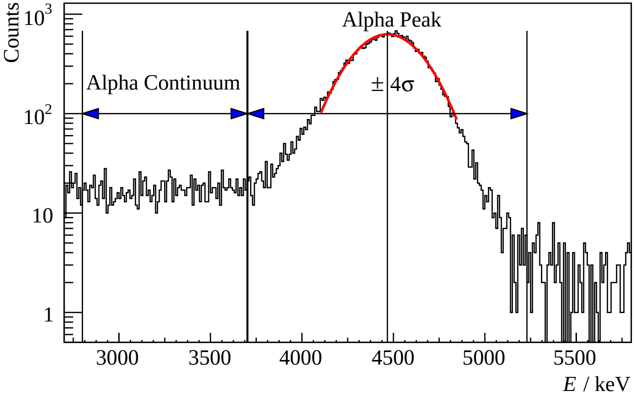
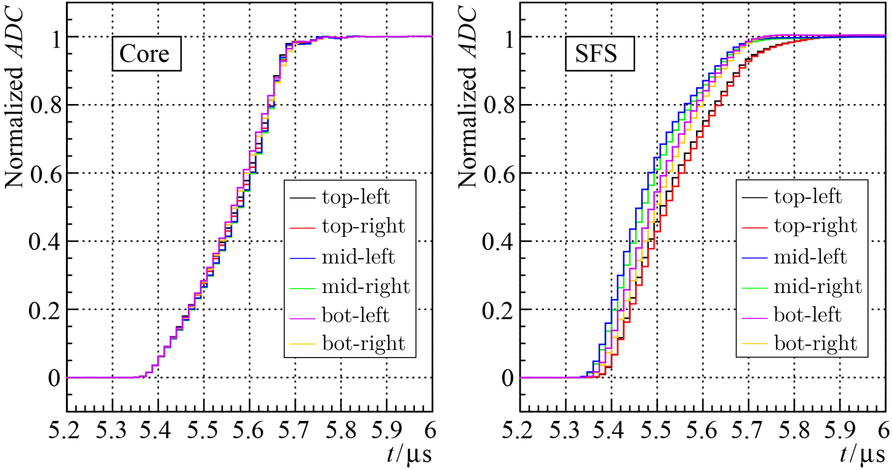


$$f = \frac{N_{continuum}}{N_{Peak}} \rightarrow \text{No differences observed in respect to metallization}$$





Core
Normalized ADC
t/µs
top-left
top-right
mid-left
mid-right
bot-left
bot-right
SFS
Normalized ADC
t/µs
top-left
top-right
mid-left
mid-right
bot-left
bot-right

Summary and Outlook

Summary:

- Upgrade of GALATEA: Hat positioning system
- Improved the cross-talk correction and calibration
- No difference between full and partial metallization away from the end plates

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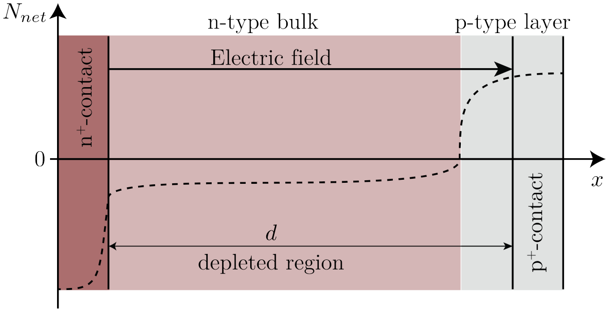
Outlook:

- Automatization of GALATEA
- Further improvement of the cross-talk correction and calibration
- Compare full and partial metallization close to the end plates
- Compare to simulations
- Verify results with other detectors
- Remove Kapton tape on the boundaries to study the boundaries with alphas
- Usage of a LASER to study a detector

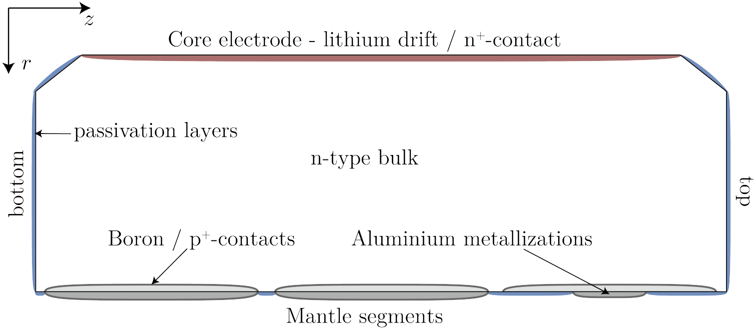
Thank you for your attention!



$$N_{pairs} = \frac{E_{deposited}}{\varepsilon}$$

$\varepsilon = 2.96\,\mathrm{eV}$ at $77\,\mathrm{K}$

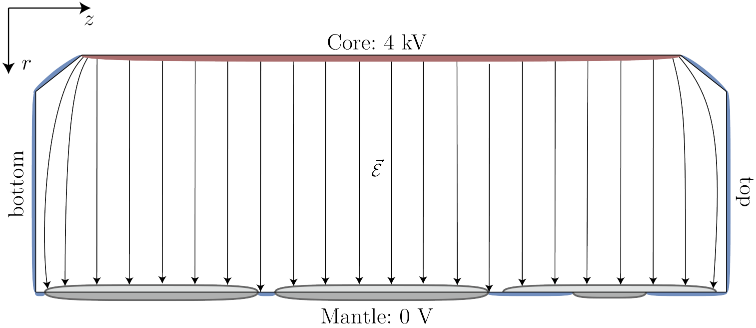
Radiation → electron-hole pairs → induced charge → amplification → signal

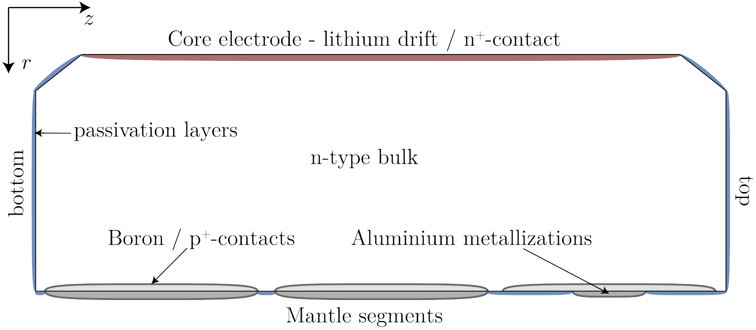


z
r
Core electrode - lithium drift / n+-contact
passivation layers
n-type bulk
bottom
top
Boron / p+-contacts
Aluminium metallizations
Mantle segments

Germanium Detector: Siegfried III

Siegfried III - Electrical Field




z
r
Core electrode - lithium drift / n+-contact
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top
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Aluminium metallizations
Mantle segments

Linearity: $\vec{E} \cdot \mathbf{C}^i \cdot \mathbf{F} \cdot \mathbf{C}^e \cdot \mathbf{A} = \vec{M} \quad \rightarrow \quad \vec{E} \cdot \mathbf{C}' = \vec{M}$

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Conservation of energy: $E_0 = \sum_{j=1}^{18} E_j \quad \rightarrow \quad 19 \times 19$ to 18×18

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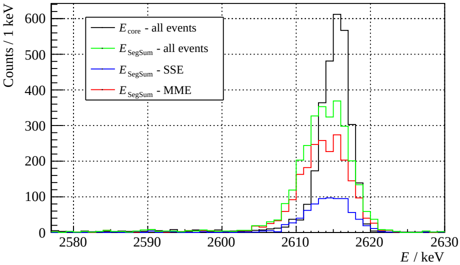
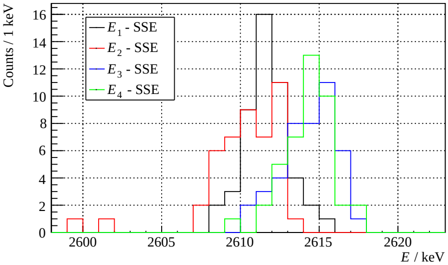
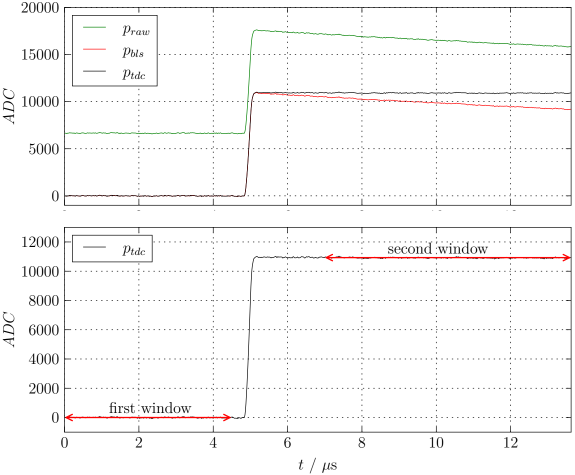
Single Segment k Events : $E_k = E_0 \wedge E_j = 0 \quad \forall \ j \neq k, 0$

$$\rightarrow M_j = E_k \cdot c_{k,j}$$

^{208}Tl photon line: $E_\gamma = 2615.533\,\mathrm{keV}$

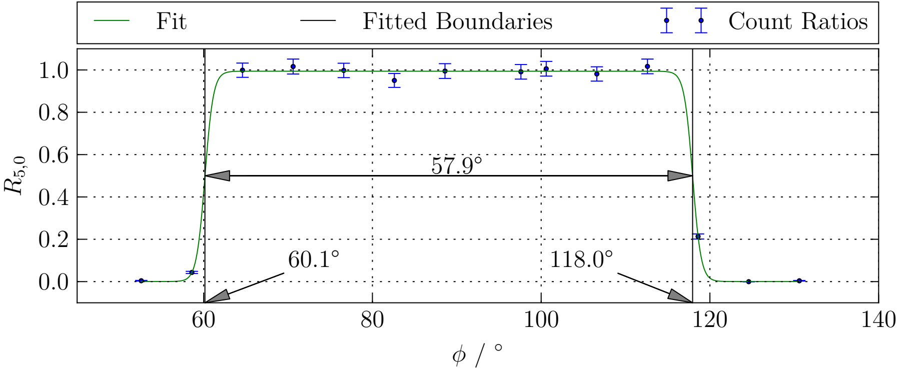


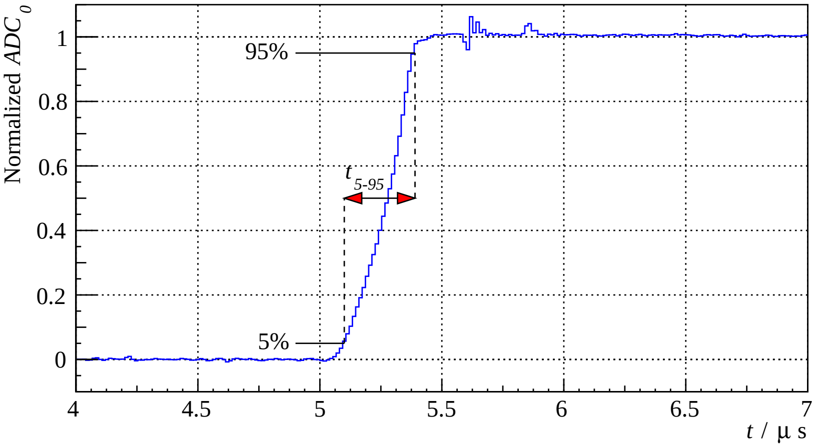




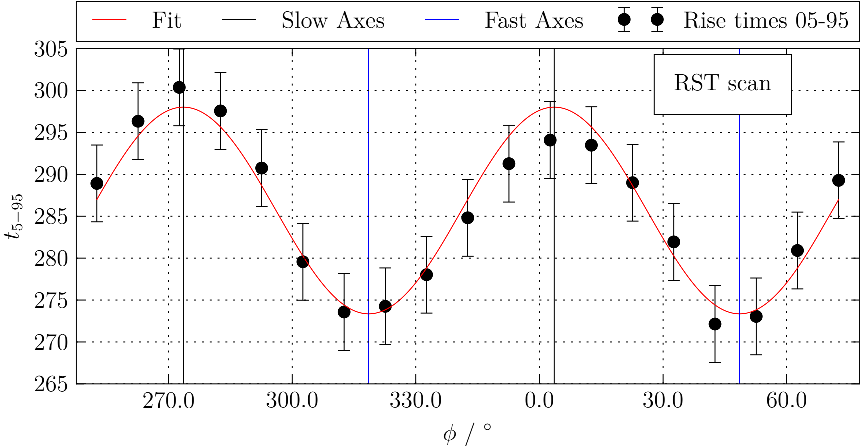
$\rightarrow M_i \rightarrow E_i$

$$R_{j,0} = \frac{N_j}{N_0}$$





Normalized ADC_0
1
0.8
0.6
0.4
0.2
0
95%
5%
$t_{5\text{-}95}$
4
4.5
5
5.5
6
6.5
7
t / μ s


Fit
Slow Axes
Fast Axes
Rise times 05-95
RST scan
305
300
295
290
285
280
275
270
265
t_{5-95}
270.0
300.0
330.0
0.0
30.0
60.0
ϕ / °

Analysis

Alphas - Charge Trapping