THE MORA PROJECT

MATTER'S ORIGIN FROM RADIOACTIVITY

DETECTION OF MORA

MORA WORKSHOP
(2-5th MAY,22)
JYFL, Finland

Nishu GOYAL
On behalf of MORA collaboration

AGENCE NATIONALE DE LA RECHERCHE ANR

Normandie Université

RÉGION NORMANDIE

OUTLINE

THE MORA PROJECT

- General Review of Detection setup
  - Detectors/ installation wrt the Trap Centre
- P Degree measurement
  - Si Detectors
- D Measurement
  - Phoswich Detectors
  - RIDE (Recoil Ion DEtectors)
- Current Progresses at JYFL with MORA DETECTORS.
- Future Perspectives

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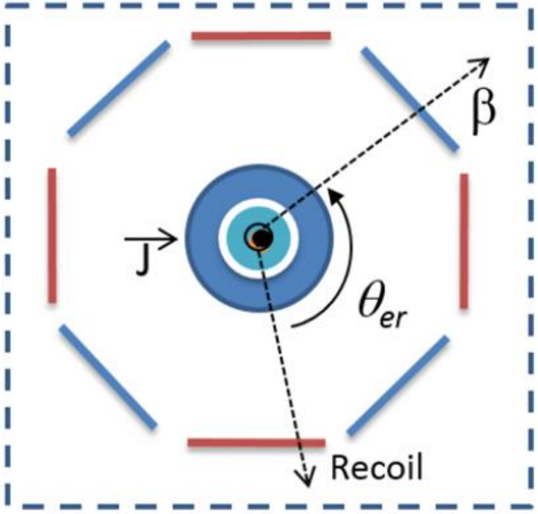
General Review of Detection Setup

$$D \cdot \left(\frac{\langle \vec{J} \rangle}{J} \cdot \left(\frac{\vec{p_e}}{E_e} \times \frac{\vec{p_\nu}}{E_\nu} \right) \right)$$

P-even T-odd

$$D \propto \left(\frac{N^{(\theta_{er}\in[0,\pi])}_{(\beta r)coin} - N^{(\theta_{er}\in[0,-\pi])}_{(\beta r)coin}}{N^{(\theta_{er}\in[0,\pi])}_{(\beta r)coin} + N^{(\theta_{er}\in[0,-\pi])}_{(\beta r)coin}} \right)$$

D-correlation parameter



An EMIT exp. Like Detection setup

General Review of Detection Setup

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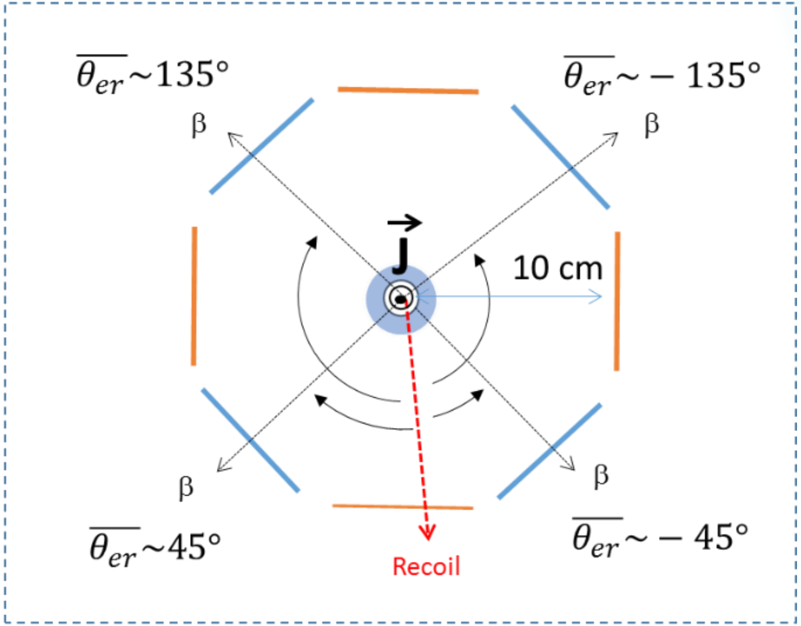
$$D \propto \left(\frac{N_{(\beta r)coin}^{(\theta_{er}\in[0,\pi])} - N_{(\beta r)coin}^{(\theta_{er}\in[0,-\pi])}}{N_{(\beta r)coin}^{(\theta_{er}\in[0,\pi])} + N_{(\beta r)coin}^{(\theta_{er}\in[0,-\pi])}} \right)$$

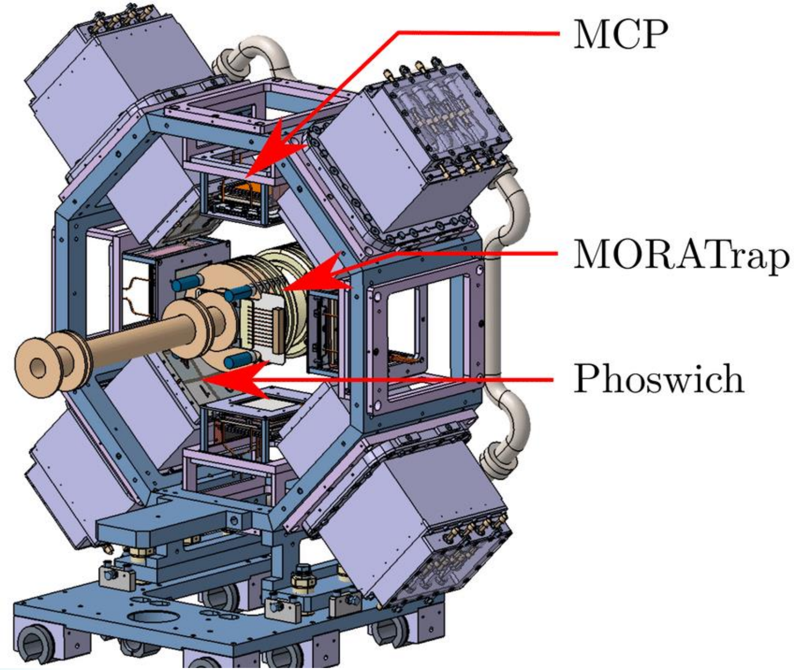
$$\frac{N_{coinc}^{+45^\circ} + N_{coinc}^{+135^\circ} - N_{coinc}^{-45^\circ} - N_{coinc}^{-135^\circ}}{N_{coinc}^{+45^\circ} + N_{coinc}^{+135^\circ} + N_{coinc}^{-45^\circ} + N_{coinc}^{-135^\circ}} = \delta \cdot D \cdot P$$

Discussed by Abhilasha Singh
Ms. Post Doc

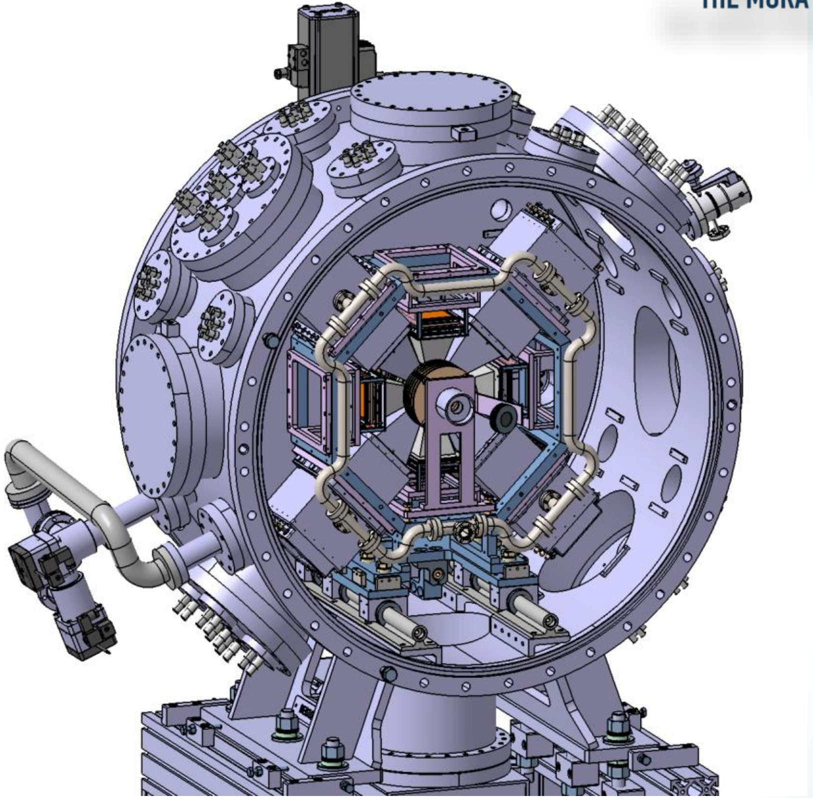


Magnified view of the D correlation detection setup, showing the different types of β-recoil coincidences

General Review of Detection setup



CAD cross section of the D- correlation Detection setup



CAD view of the MORA Detection setup inside the Vacuum Chamber

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Detector Installations

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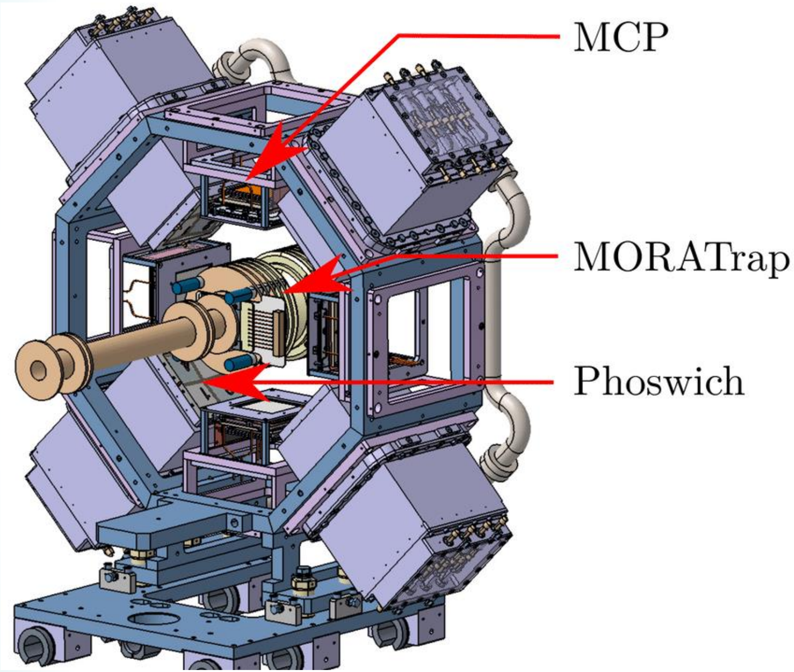
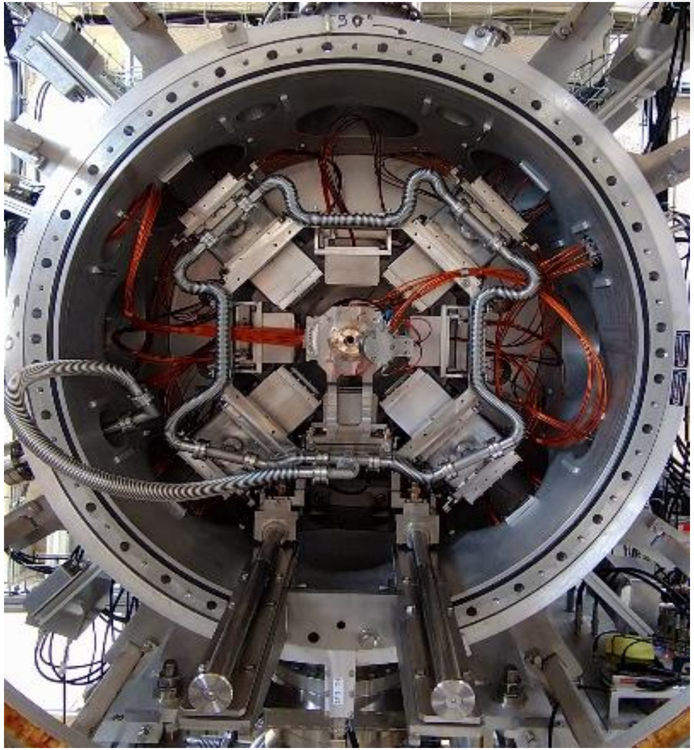


CAD cross section of the D- correlation Detection setup



Detectors installation around the Trap In MORA Chamber during the first installation in Jyväskylä, FINLAND

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Polarization Degree

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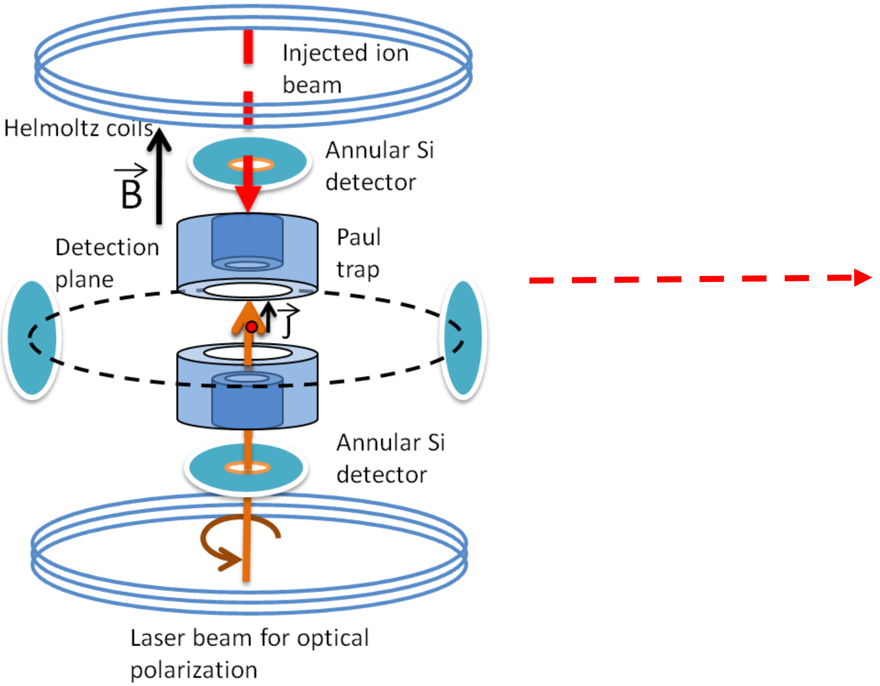
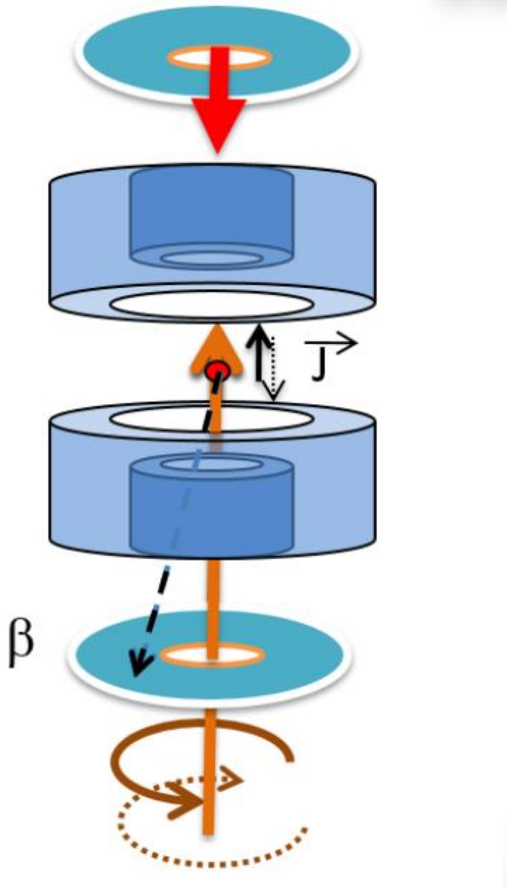
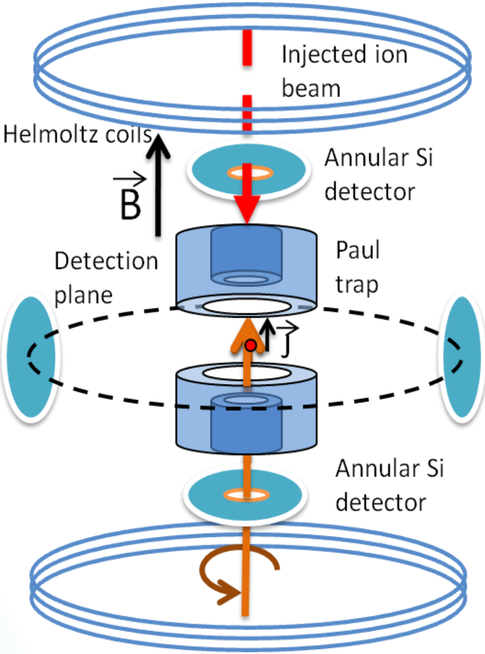




The Monitoring of P degree with an asymmetry observed in two annular Si detectors on the axis of the trap

Polarization Degree



$$\frac{N^{\uparrow}_{\beta+} - N^{\downarrow}_{\beta+}}{(N^{\uparrow}_{\beta+} + N^{\downarrow}_{\beta+})} \propto A_\beta \cdot P$$

$N^{\uparrow}_{\beta+\ coinc}$, $N^{\downarrow}_{\beta+\ coinc}$ no. of coincidences between detected recoil ion and positron

$$\frac{N^{\uparrow}_{\beta+\ coinc} - N^{\downarrow}_{\beta+\ coinc}}{(N^{\uparrow}_{\beta+\ coinc} + N^{\downarrow}_{\beta+\ coinc})} = (\alpha \cdot A_\beta + \beta B_\nu) \cdot P$$

$$\frac{\sigma_P}{P} \simeq \frac{\sqrt{N^{\uparrow}_{\beta+\ coinc} + N^{\downarrow}_{\beta+\ coinc}}}{N^{\uparrow}_{\beta+\ coinc} - N^{\downarrow}_{\beta+\ coinc}}$$

P degree Measurement

Si Detectors

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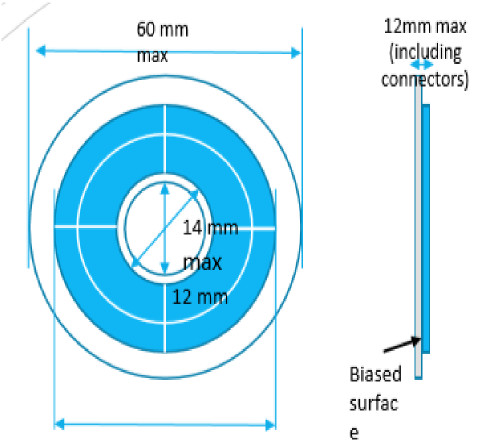
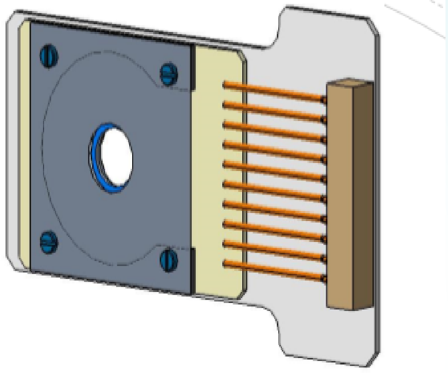
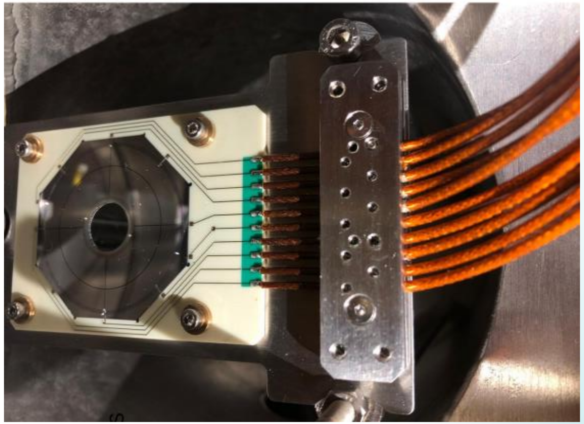
- Inner Active radius: 14.9mm
- Outer Active radius: 20mm
- Outer flat-to-flat: 43mm
- Wafer thickness: 1mm
- Active area separation: 0.13mm
- Al. Protection layer: 100 micron





2 annular rings divided into 8 sectors



Det. provided by Micron Technologies..

P degree Measurement

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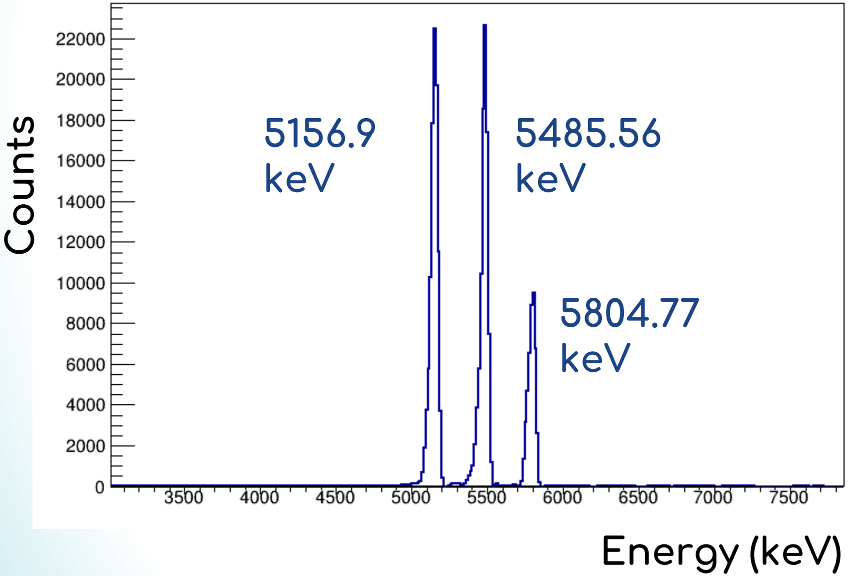
First testings @ GANIL, Caen

Calibration with Alpha source:



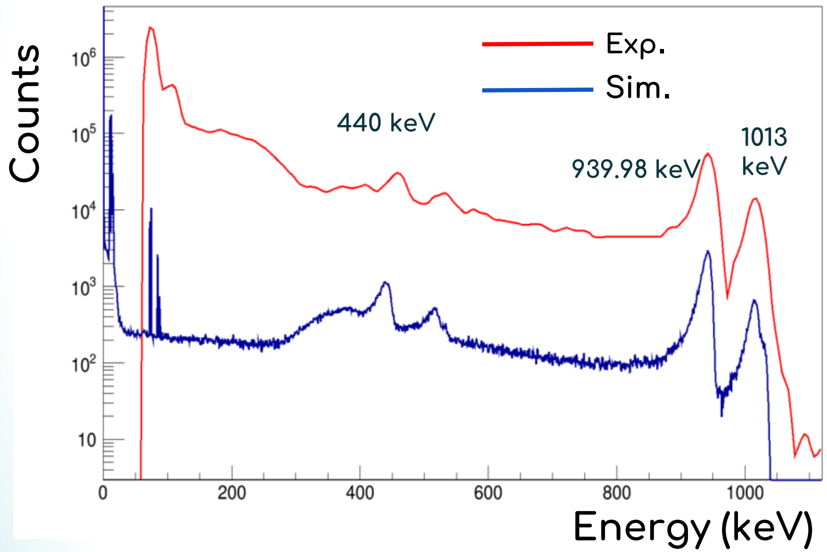
Obtained Resolution:
With Alphas
(28-30 keV FWHM)

3-alpha spectra obtained in a preliminary testings with Si Detector (without Aluminum plate)

P degree Measurement

First testings @ GANIL, Caen

Calibration with electron source:



Obtained Resolution With Electrons <u>21-30 keV</u> FWHM (for 1 MeV peak) – consistent with calculated straggling Energy of ~ <u>40 keV</u> in Al. protection Cover

Threshold : from 400 keV to 70 keV (Mesytech-Preamplification)

^{207}Bi electron energy deposited in Silicon detector: Comparison of experimental data with Monte Carlo (PENELOPE) simulations

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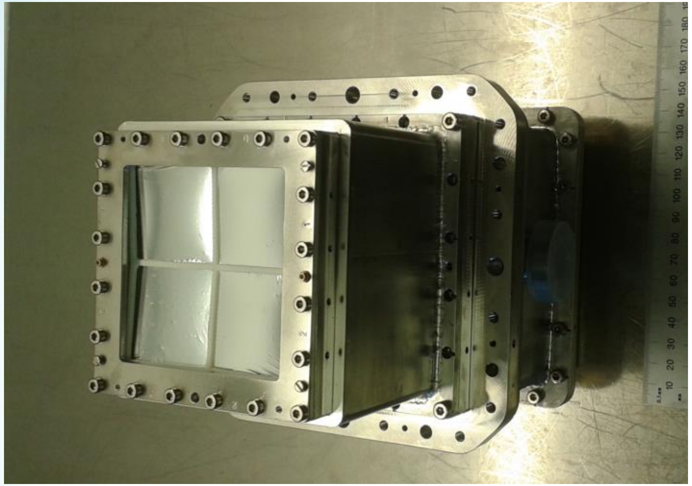
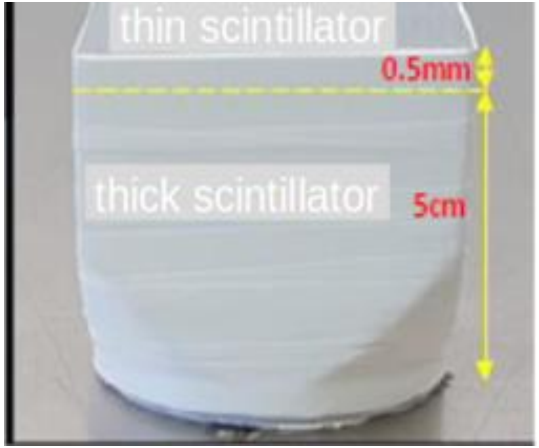
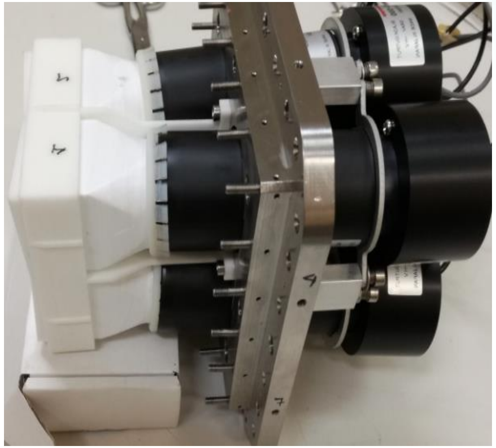
Phoswich Detectors for β



Phoswich Detector Assembly

Tested and CAlibrated @LPC,Caen

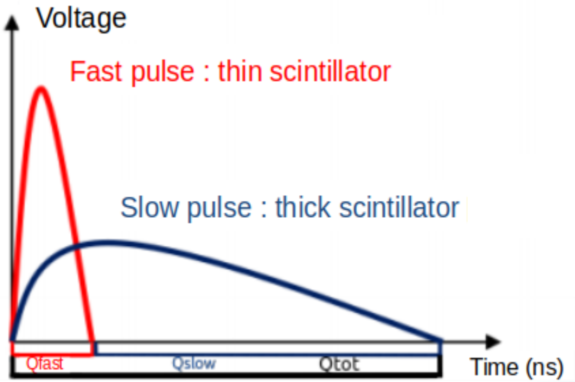




Combination of 2 plastic scintillators: Connected to a common PMT

ΔE: thin (0.5 mm) & fast (t = 1.8 ns) "Q_fast"

E: thick (5 cm) & slow (t = 285 ns) "Q_slow"



Phoswich Detectors for β

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Detector Response Function:

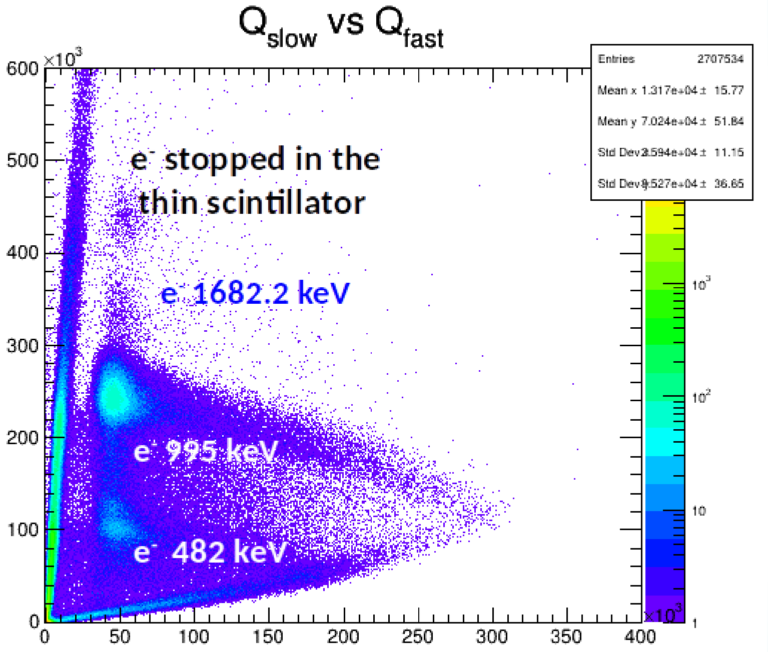
First Testings: 207Bi

Various IC electrons – weighted means:

481.7keV(1.5%), 556.90.02%)

Some gamma rays:
570 keV (97.76%) , 1063 keV (74.5%), 1770 keV (6.87%)

PMT Signals → Integrated Charges: Q_{fast}, Q_{slow}, Q_{tot}



Good e⁻ & γ discrimination!!!

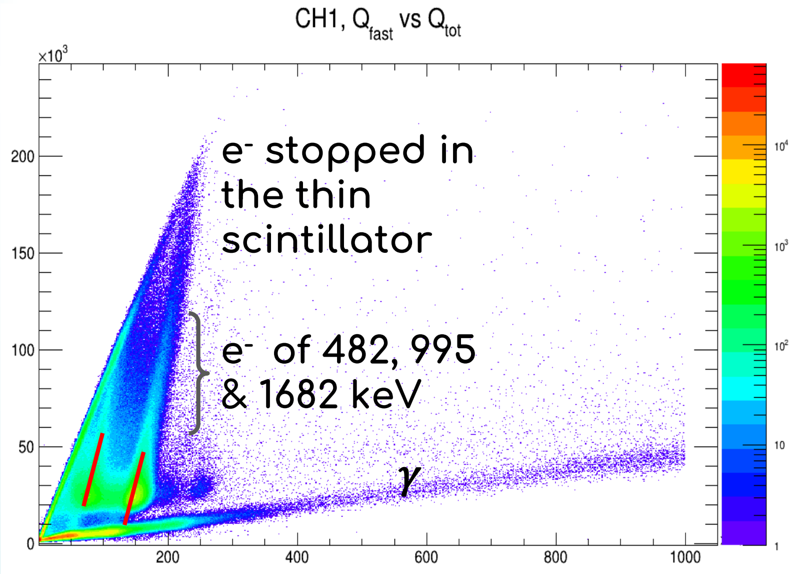
Phoswich Detectors for β

Energy Calibration

$E = \gamma\, Q_{fast} + \alpha\, Q_{slow} + \beta$ with $Q_{tot} = Q_{fast} + Q_{slow}$

$\rightarrow\quad E = \alpha\, Q_{tot} + Q_{fast}\,(\gamma - \alpha) + \beta$

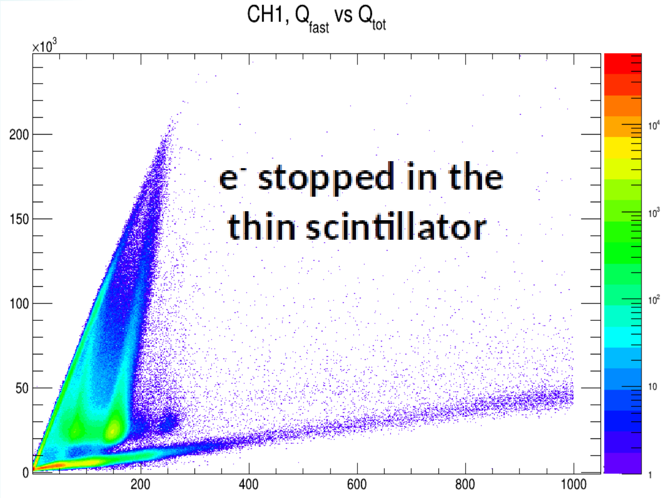
If $= 0 \quad \rightarrow \quad E = \alpha\, Q_{tot} + \beta$



$$Q_{tot}^{c} = Q_{tot} - aQ_{fast}$$

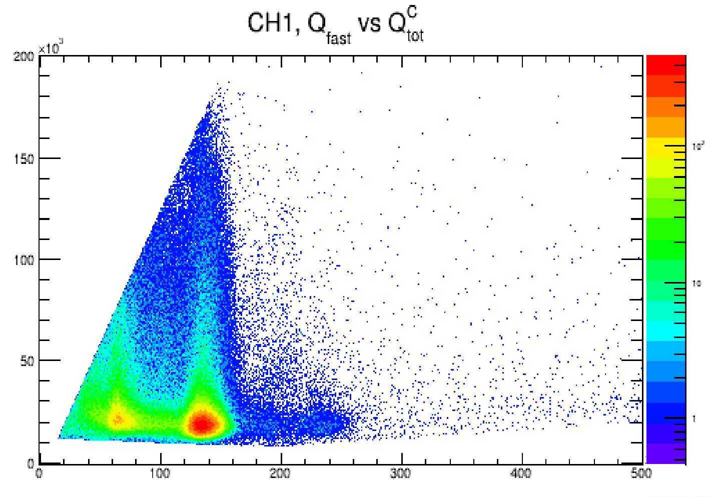
Phoswich Detectors for β

Energy Calibration



After Correction and cuts (γ and stopped electrons)

$$Q^c_{tot} = Q_{tot} - aQ_{fast}$$

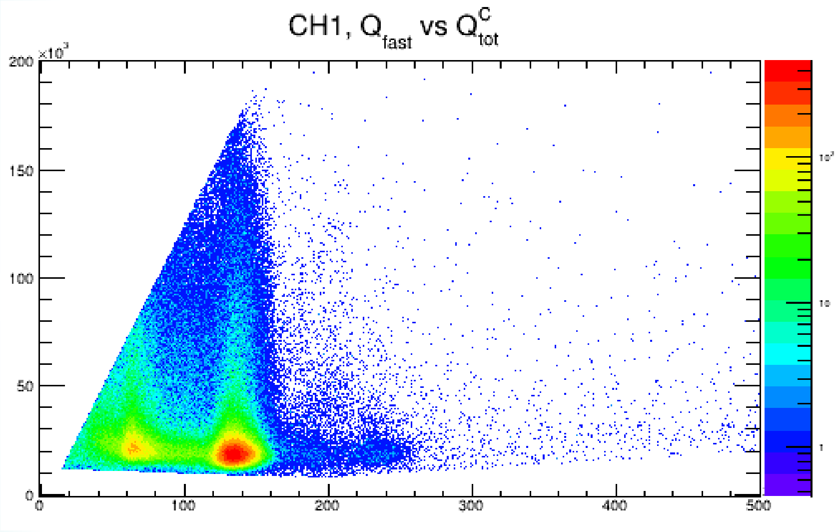


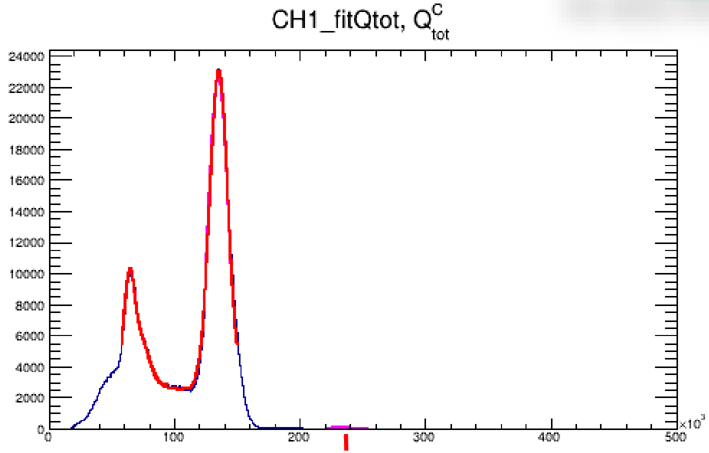
$$\rightarrow \quad E = \alpha\,(Q^c_{tot} + a\,Q_{fast}) + Q_{fast}\,(\gamma - \alpha) + \beta = \alpha\,Q^c_{tot} + (\alpha a + \gamma - \alpha)\,Q_{fast} + \beta \;=\; \alpha\,Q^c_{tot} + \beta$$

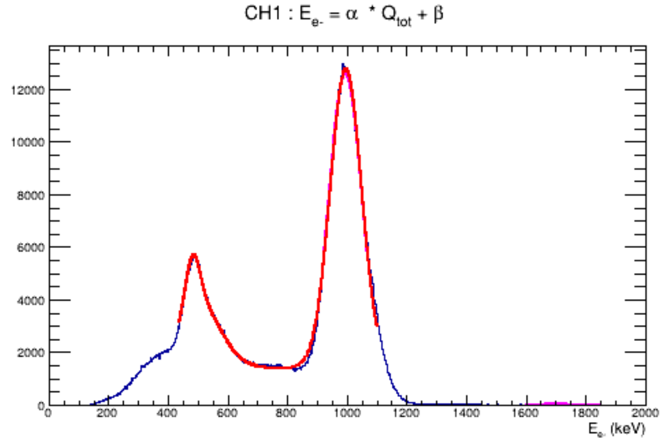
If this correction well done, this term vanishes!

Phoswich Detectors for β

Energy Calibration:

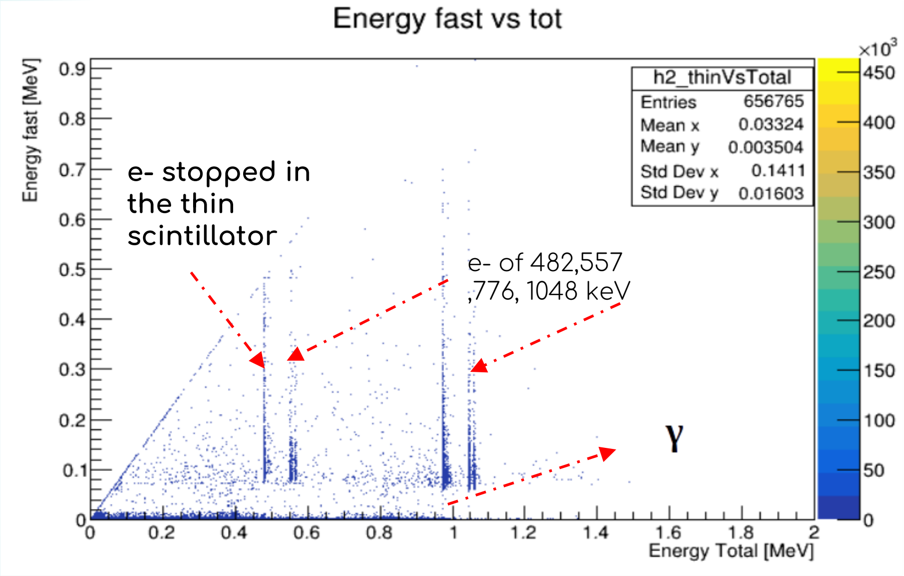




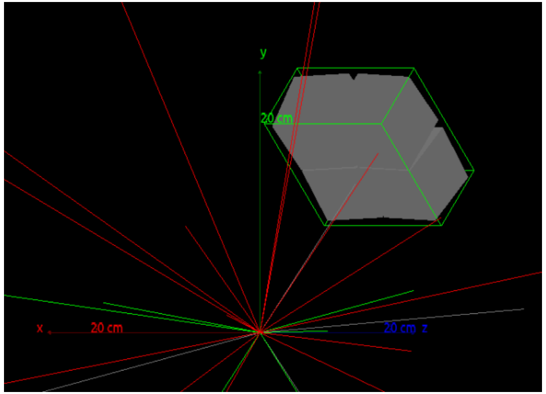


Calibrated spectrum showing peaks of 481.7 keV & 994.6 keV

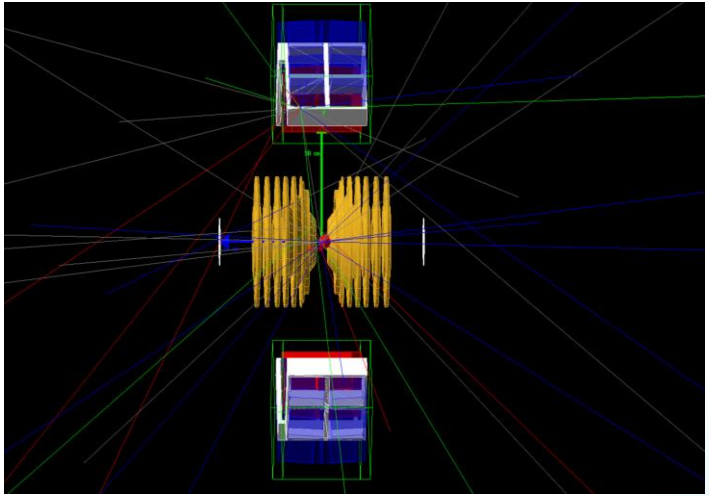
Study of Response function (Geant4 Simulation)



Preliminary Simulations of MORA detection setup in Geant4 (still ongoing for recently introduced geometry of silicon detectors)



Test Configuration to study Phoswich detectors



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Study of Response function
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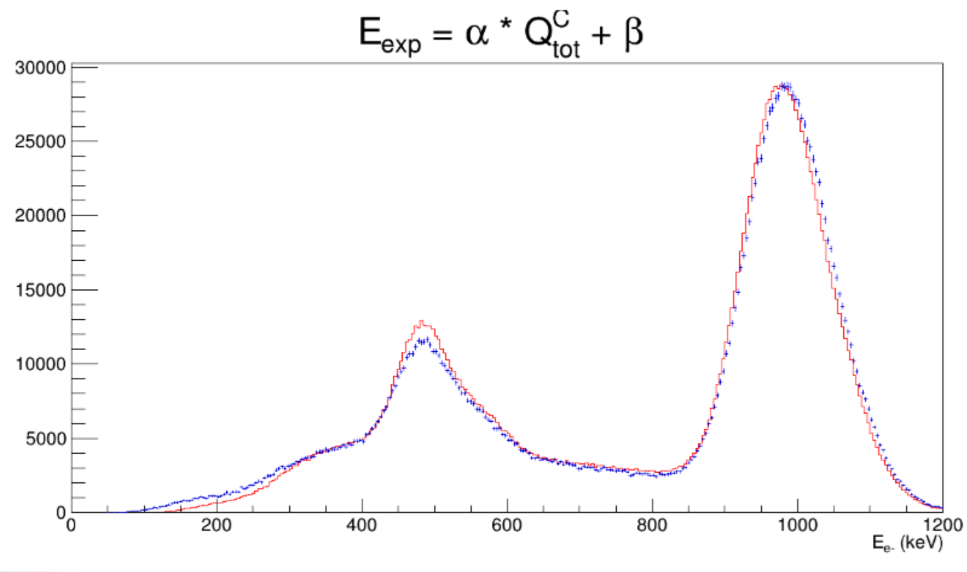
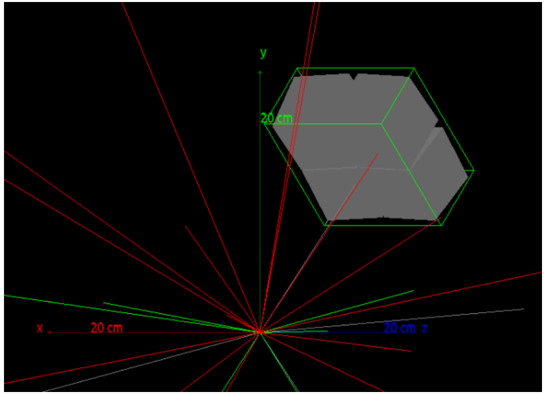


Simulation vs data
(Phoswich Detectors)



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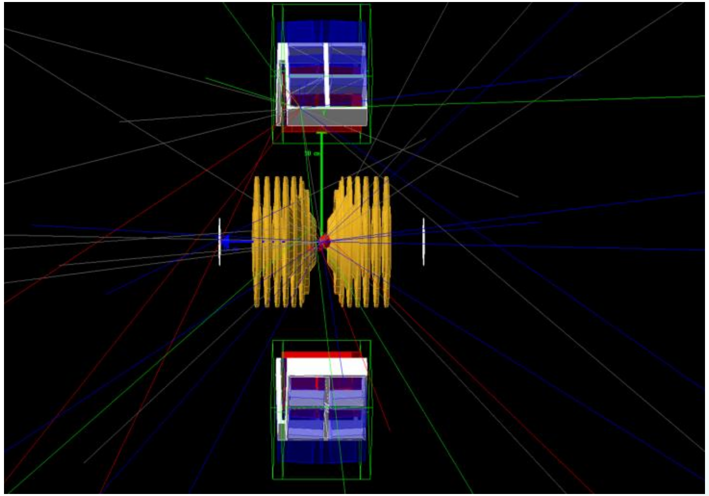

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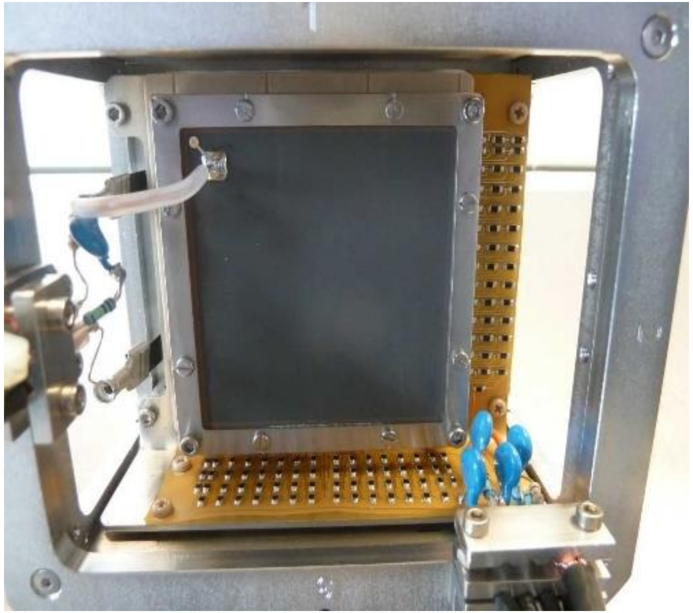
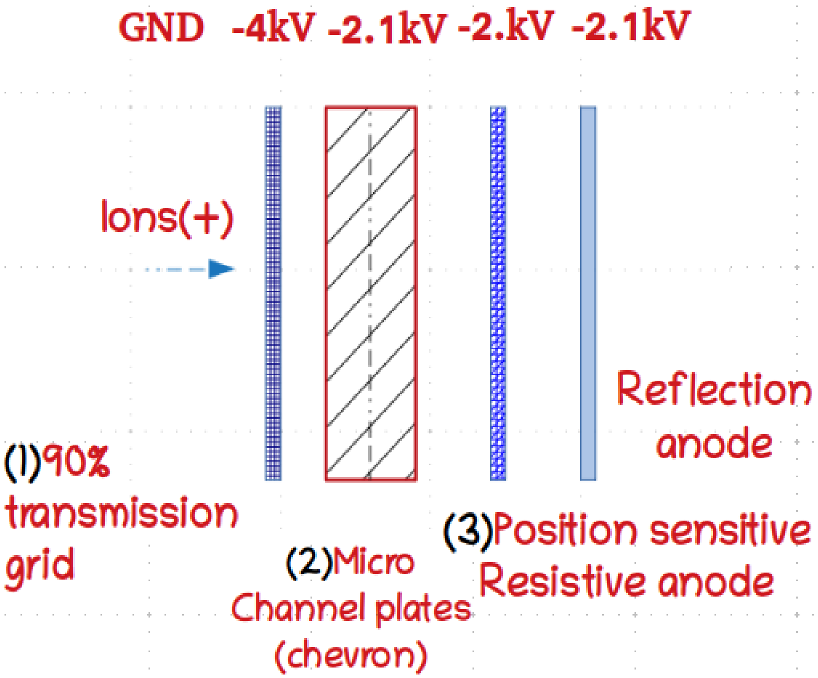
RIDE for Recoil Ion Detection



- RIDE Detectors equipped with Chevron Micro-Channel Plates(50*50) Provided by Photonis
- Front plate coated with MgO layer to increase the surface sensitivity to ions.

RIDE for Recoil Ion DEtection



1. 90% transmission grid
1. 4 KeV acceleration from Grid to MCP to post accelerate the ion
1. Resistive PSA (Position Sensitive Anode) collecting electrons from the MCP

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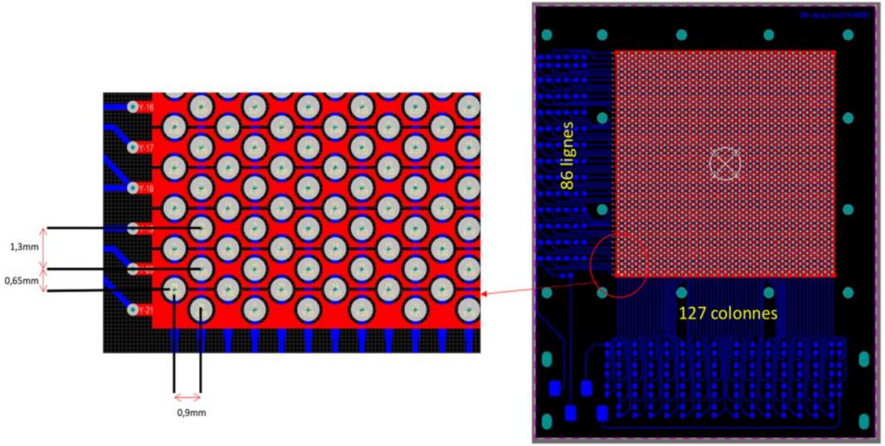
RIDE for Recoil Ion DEtection



Resistive PSA (Position Sensitive Anode) collecting electrons from the MCP
Horizontal Strips: Pitch 1.3mm
Vertical pads Pitch 0.9mm

- 5 signals: charge emitted by MCPs, charge collected on anodes (z1,z2,y1,y2)
- 3 Polarization Voltages: front MCP, back MCP=reflection electrode, Position anode

RIDE for Recoil Ion DEtection

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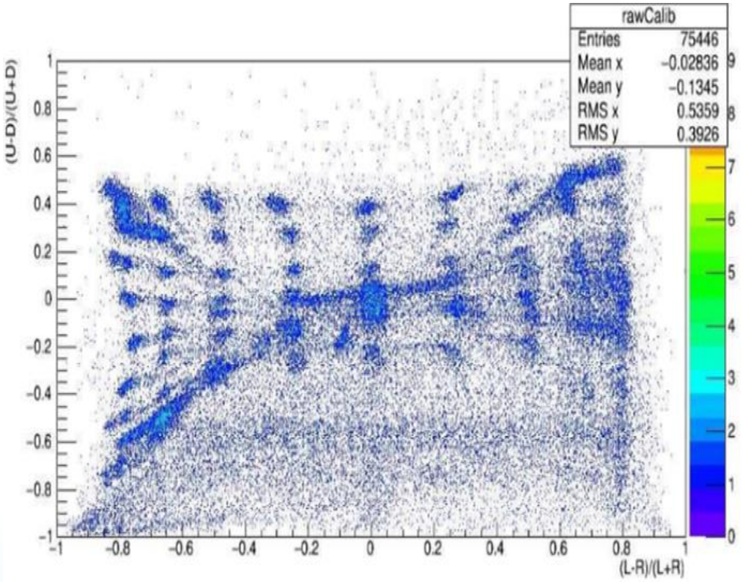
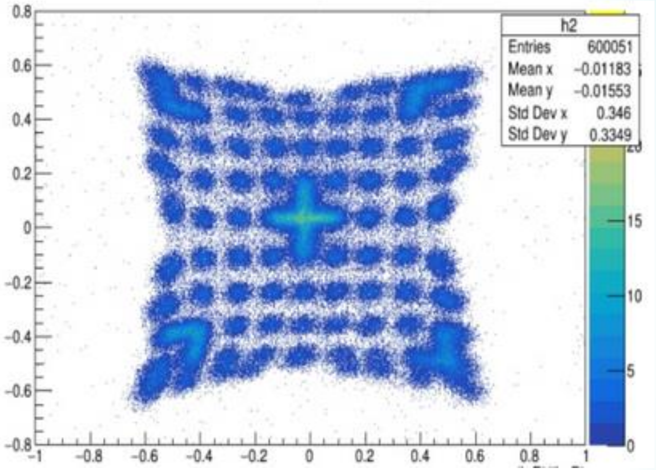
Testings with ALPHA source

Troubleshooting with PSA



Det. Image before changing the flex which eventually caused the spark while biasing the detector



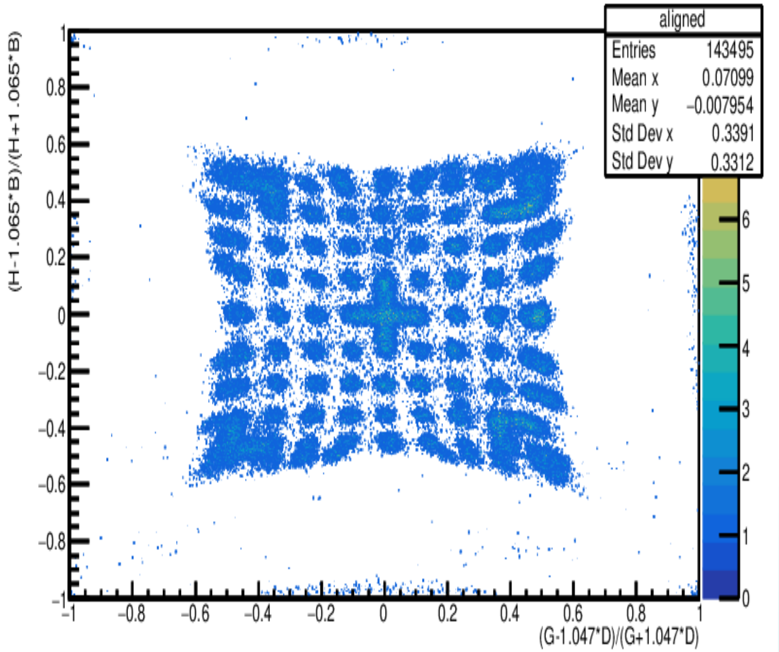
$$\widetilde{X} = (Qleft - Qright)/(Qleft + Qright)$$
$$\widetilde{Y} = (Qtop - Qbottom)/(Qtop + Qbottom)$$

Full image of the detector using the calibration mask on the top of the front plate

RIDE Image position Reconstruction: Corrections to determine Position Resolution

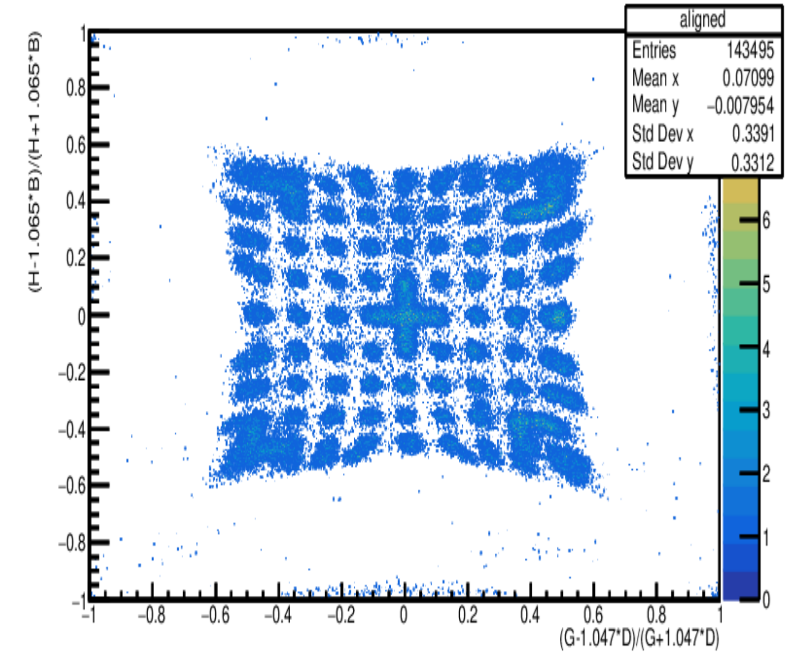
$$\tilde{x} = \frac{a \cdot Qright - b \cdot Qleft}{a \cdot Qright + b \cdot Qleft}$$

$$\tilde{y} = \frac{c \cdot Qtop - 1 \cdot Qbot}{c \cdot Qtop + 1 \cdot Qbot}$$

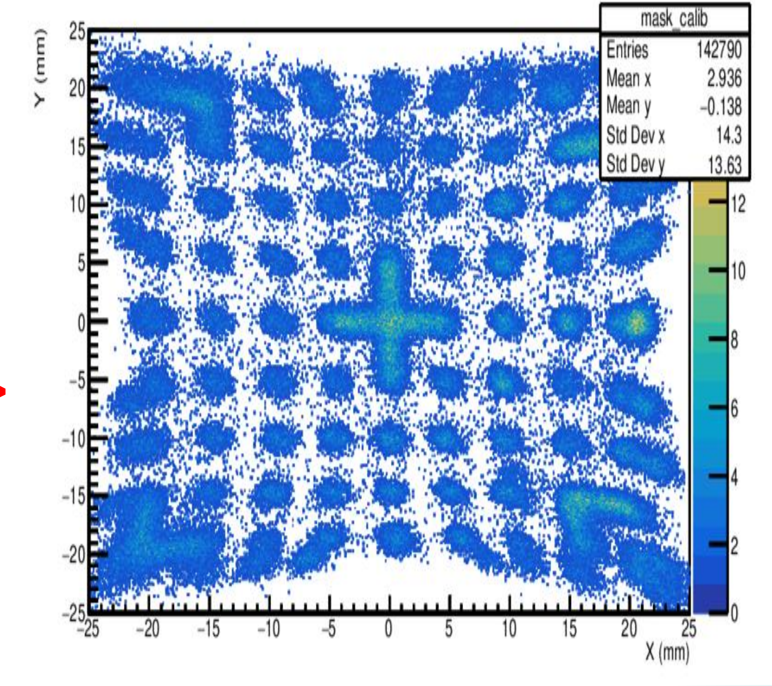


RIDE Image position Reconstruction:

1st Order correction/Calibration

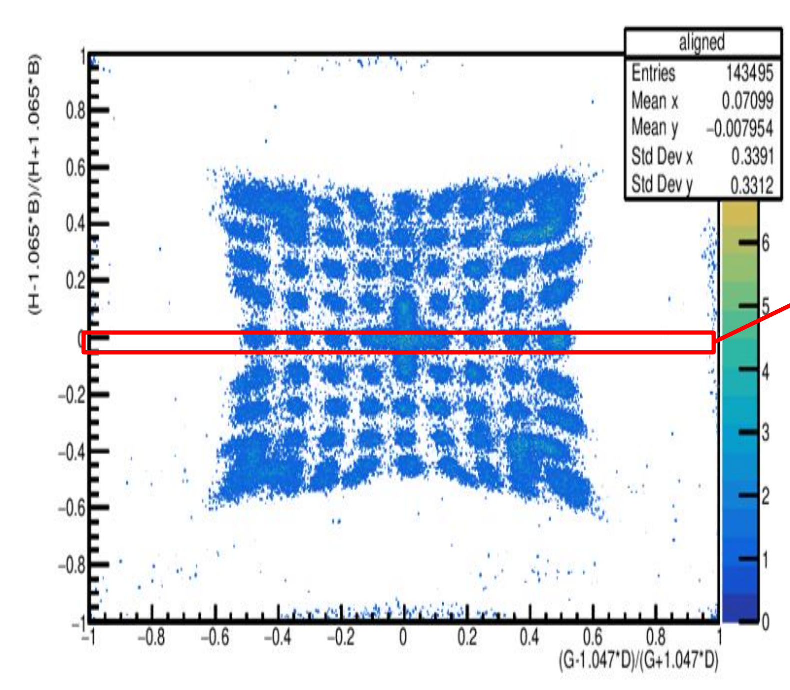


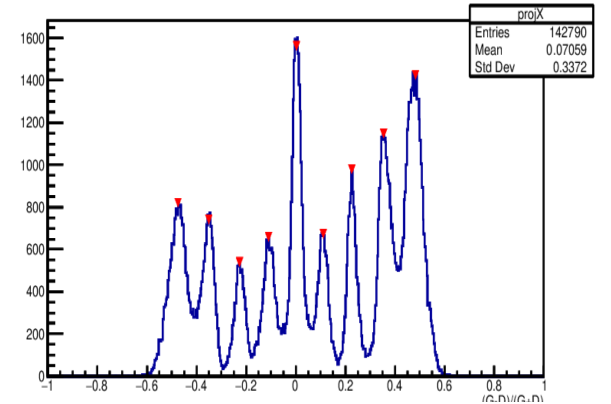
Raw RIDE Image With Calibration masque (centre aligned at (0,0), corrections to get the charge linearity in x and y dir.



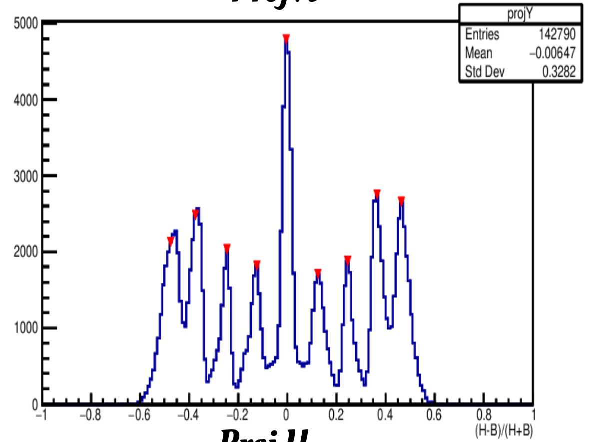
RIDE Image with First order correction aligned and calibrated in position(mm)

RIDE Image position Reconstruction:
1st Order correction/Calibration



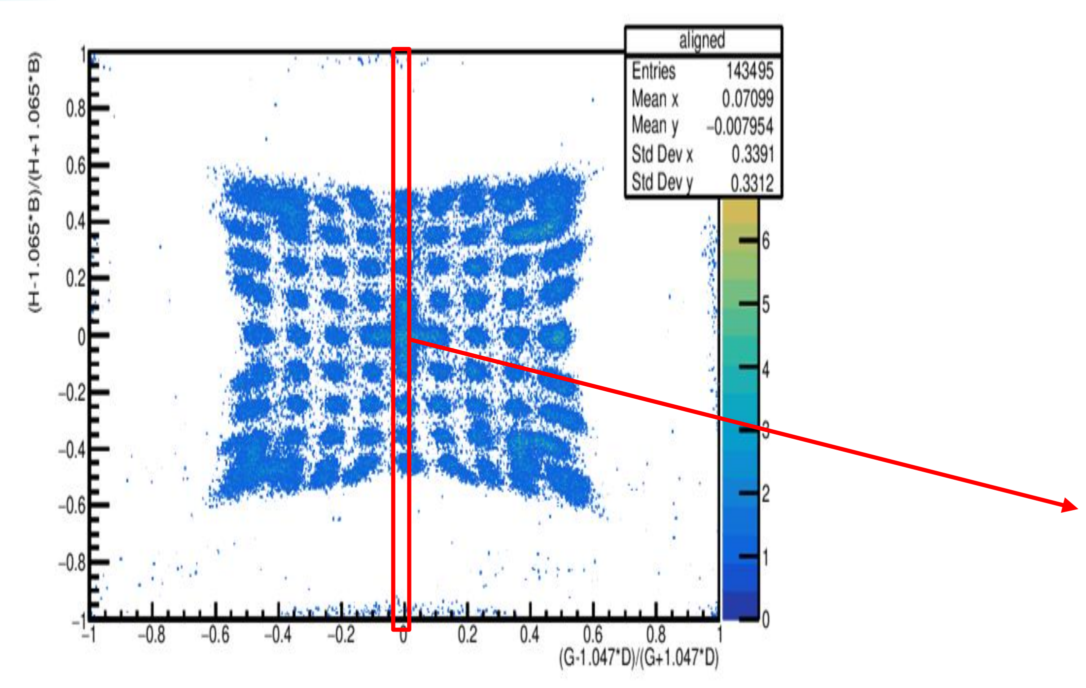


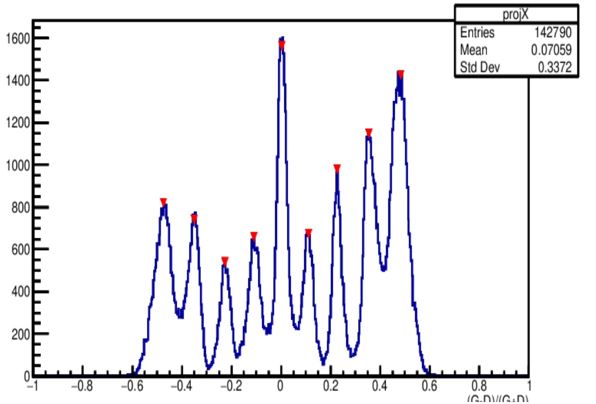
Proj X



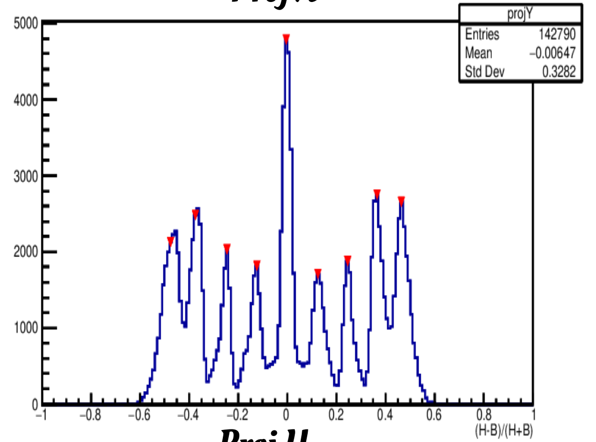
Proj Y

RIDE Image position Reconstruction:
1st Order correction/Calibration





Proj X

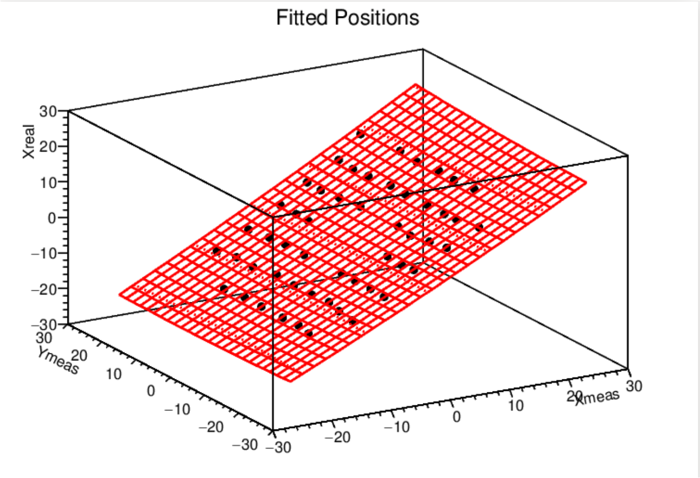


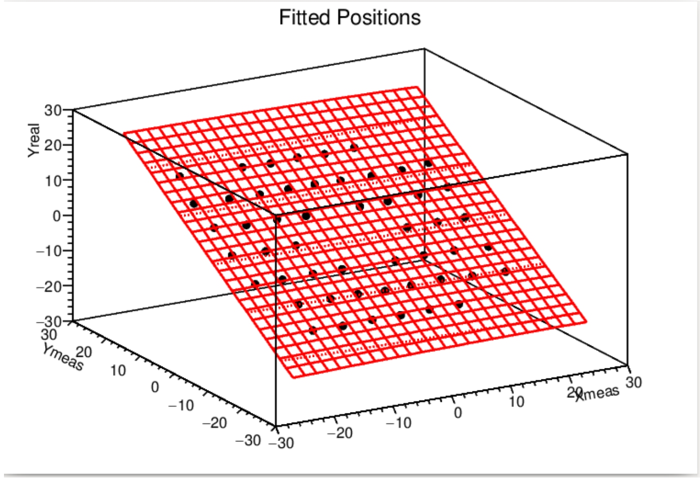
Proj Y

RIDE Image position Reconstruction:
2nd Order correction/Calibration

$$X_C = p_0 X^2 + p_1 XY + p_2 Y^2 + p_3 X + p_4 Y + p_5,$$

$$Y_C = q_0 X^2 + q_1 XY + q_2 Y^2 + q_3 X + q_4 Y + q_5.$$

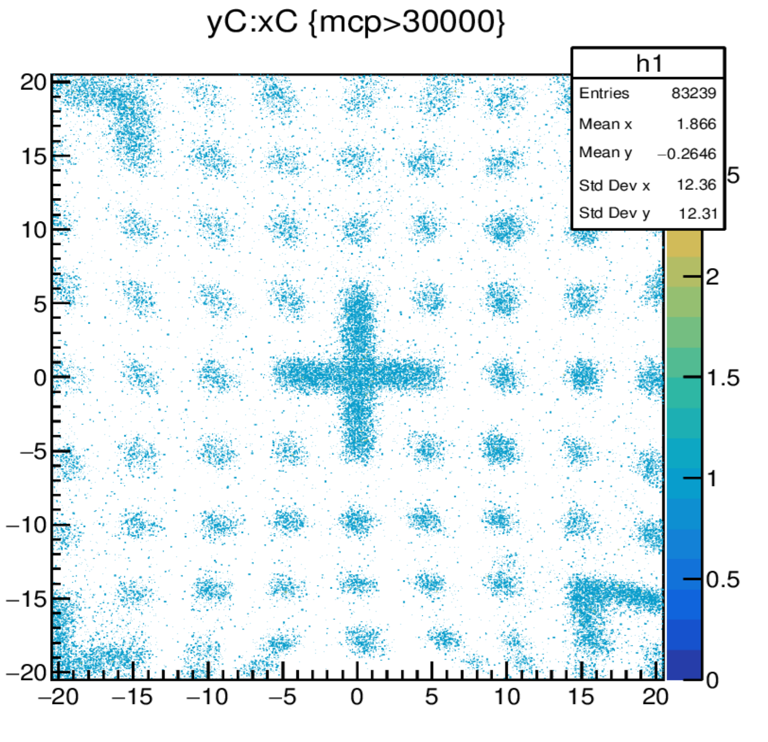




RIDE Image position Reconstruction:
2nd Order correction/Calibration

$$X_C = p_0 X^2 + p_1 XY + p_2 Y^2 + p_3 X + p_4 Y + p_5,$$

$$Y_C = q_0 X^2 + q_1 XY + q_2 Y^2 + q_3 X + q_4 Y + q_5.$$



RIDE Image position Reconstruction:
2nd Order correction/Calibration

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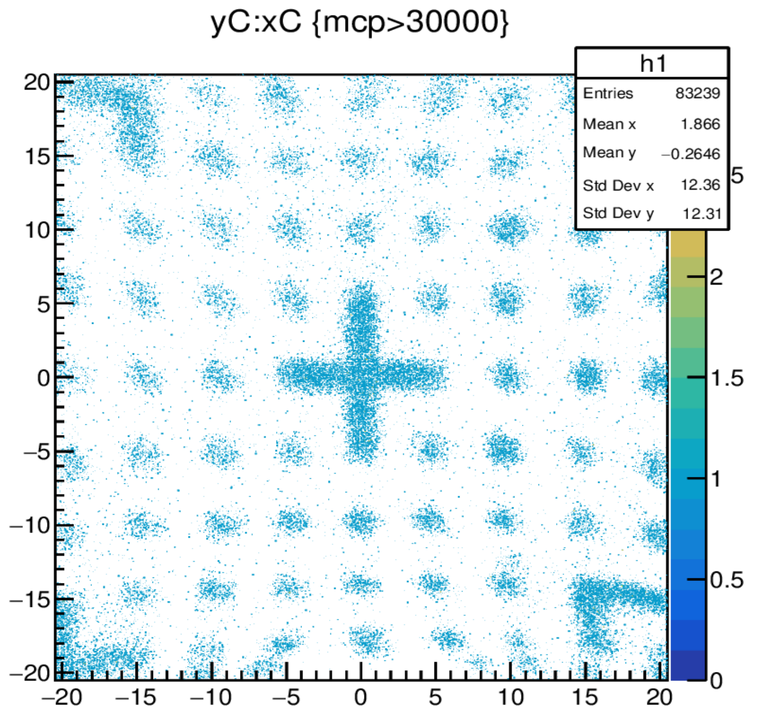
$$X_C = p_0 X^2 + p_1 XY + p_2 Y^2 + p_3 X + p_4 Y + p_5,$$

$$Y_C = q_0 X^2 + q_1 XY + q_2 Y^2 + q_3 X + q_4 Y + q_5.$$

Less distortion in the image after the second order correction.
(shifts of small holes close to their physical nominal value)

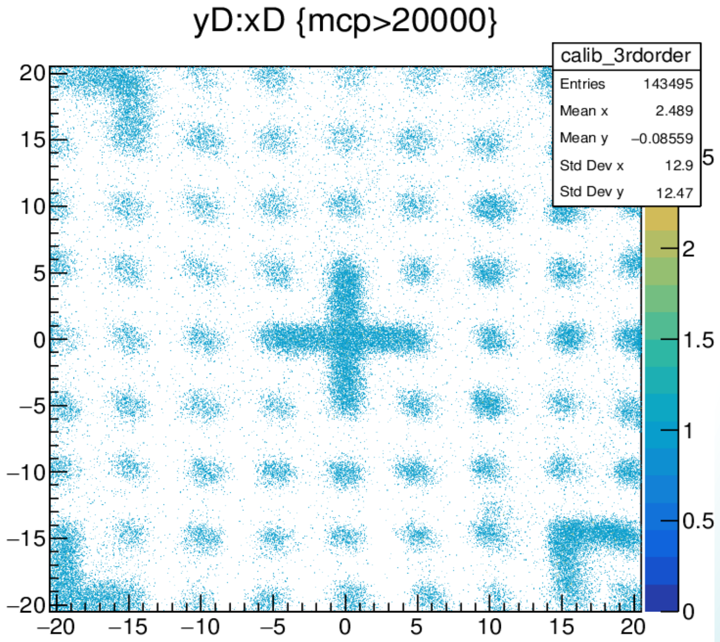


RIDE Image position Reconstruction:
3rd Order correction/Calibration

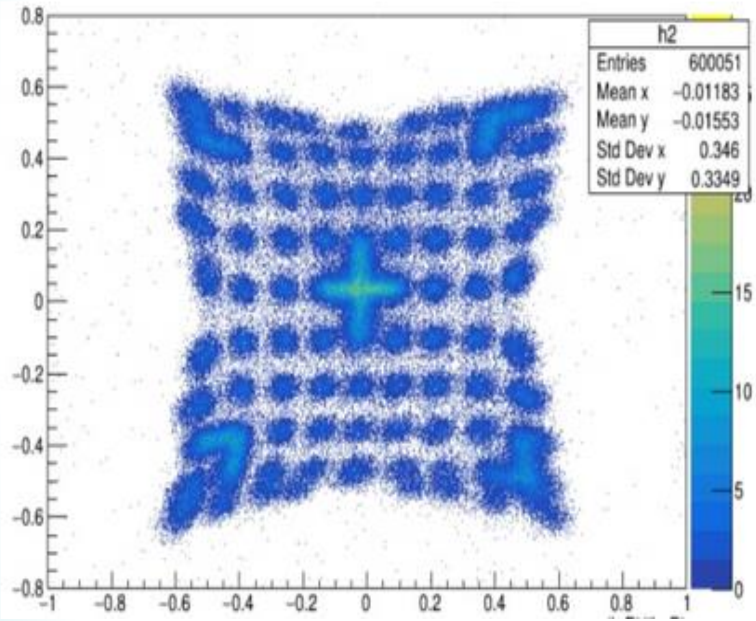
$$Xdest = a_0 + a_1 \cdot x + a_2 \cdot y + a_3 \cdot x^2 + a_4 \cdot y^2 + a_5 \cdot x \cdot y + a_6 \cdot x^3 + a_7 \cdot y^3 + a_8 \cdot x^2 \cdot y + a_9 \cdot x \cdot y^2$$

$$Ydest = b_0 + b_1 \cdot x + b_2 \cdot y + b_3 \cdot x^2 + b_4 \cdot y^2 + b_5 \cdot x \cdot y + b_6 \cdot x^3 + b_7 \cdot y^3 + b_8 \cdot x^2 \cdot y + b_9 \cdot x \cdot y^2$$

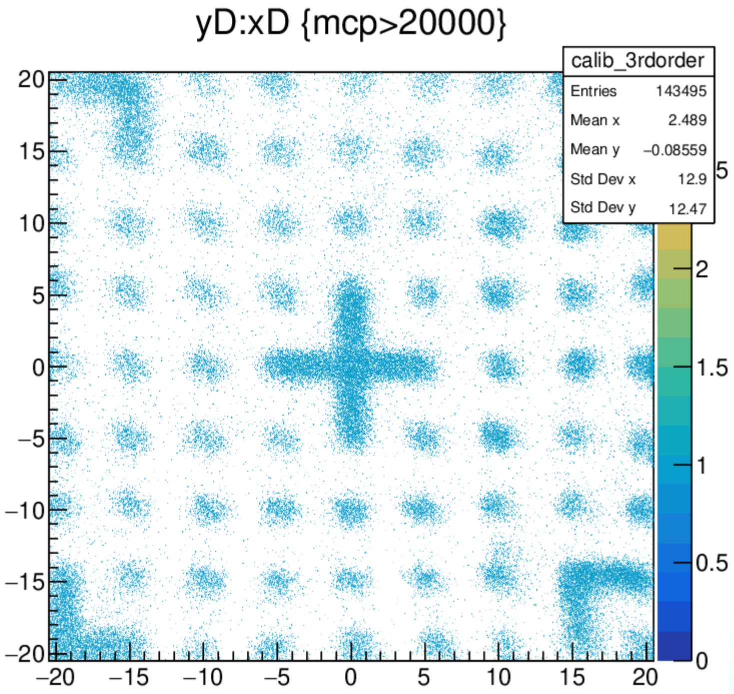
RIDE calibrated image in position (Corrections after Second order Polynomial Fit)



RIDE Image position Reconstruction:



Before



After

RIDE for recoil ion Detection

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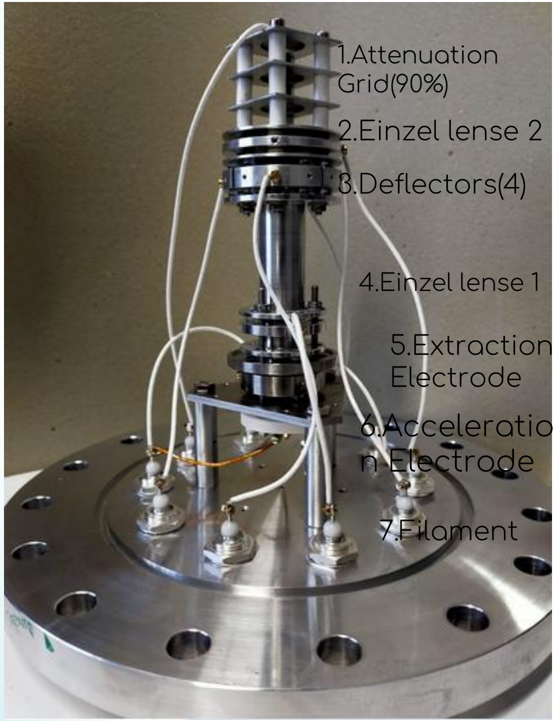
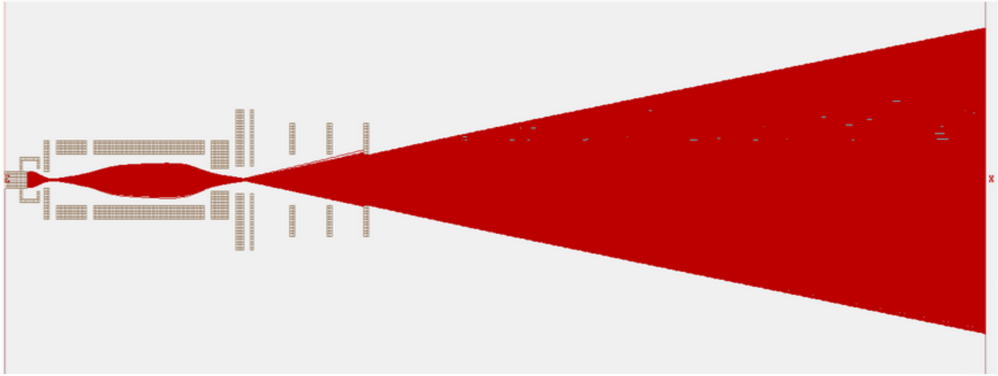
Testings with Ion source



-RIDE testings with Ion source(^{23}Na) pallet.

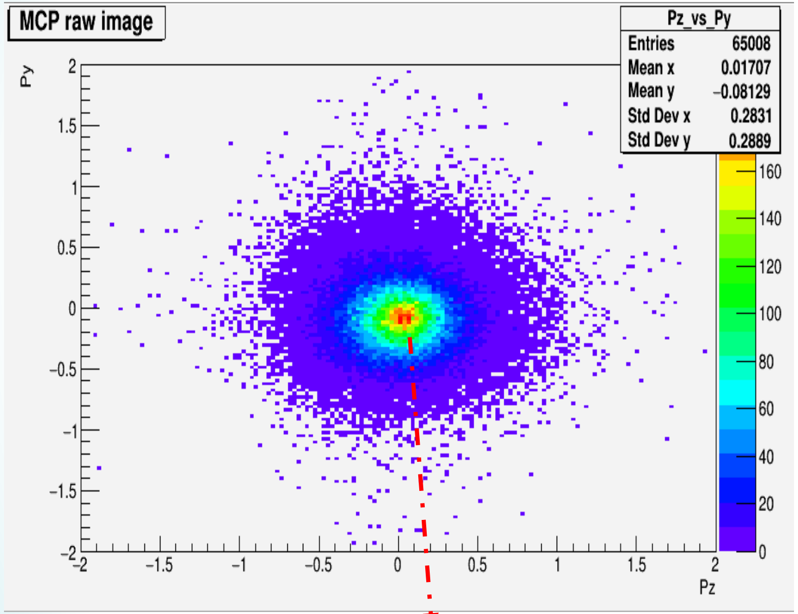
- Filament heating up at 4.5-5 volts, producing ions accelerating at 1.5keV hitting the front of MCP with 1.5-6 keV Energy depending on the bias Potential.



Ion gun simulation using SIMION software toolkit to reproduce ion beam behavior through the beam Optics

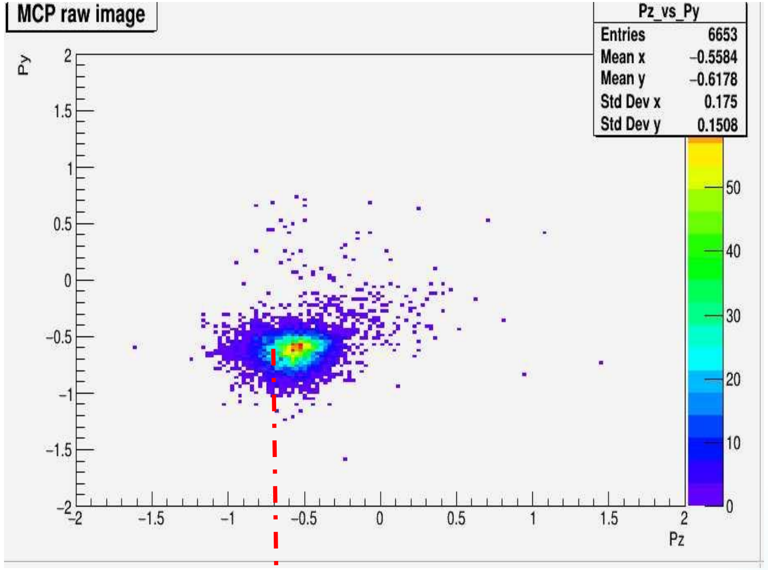
RIDE for recoil ion Detection:

Testings with Ion source:



Centred 1.5keV Ion beam without the Calibration mask on MCP

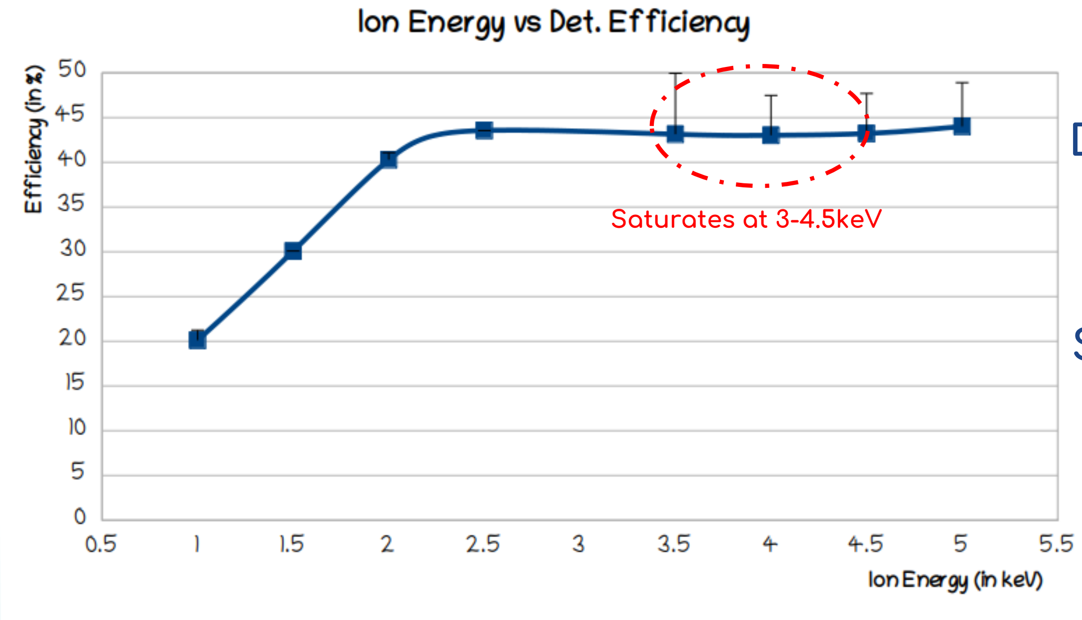
First Observation of High background (HOT-SPOT**)with MCP's without the Calibration mask



Instead, observation of high background on edges with biasing of 1.7kV

RIDE for recoil ion Detection

Testings with offline Surface Ionisation source



Detector Efficiency scan with respect to the energy of the ions reaches maximum efficiency plateau at 45%, Similar behaviour previously observed with delay line anodes.

OUTLINE

THE MORA PROJECT

- General Review of Detection setup
  - Detectors/ installation wrt the Trap Centre.
- P Degree measurement
  - SI Detectors
- D Measurement
  - Phoswich Detectors
  - RIDE (Recoil Ion DEtectors)
- Current Progresses at JYFL with MORA DETECTORS
- Future Perspectives

Preparation period *(16/01/22- 15/02/22)*

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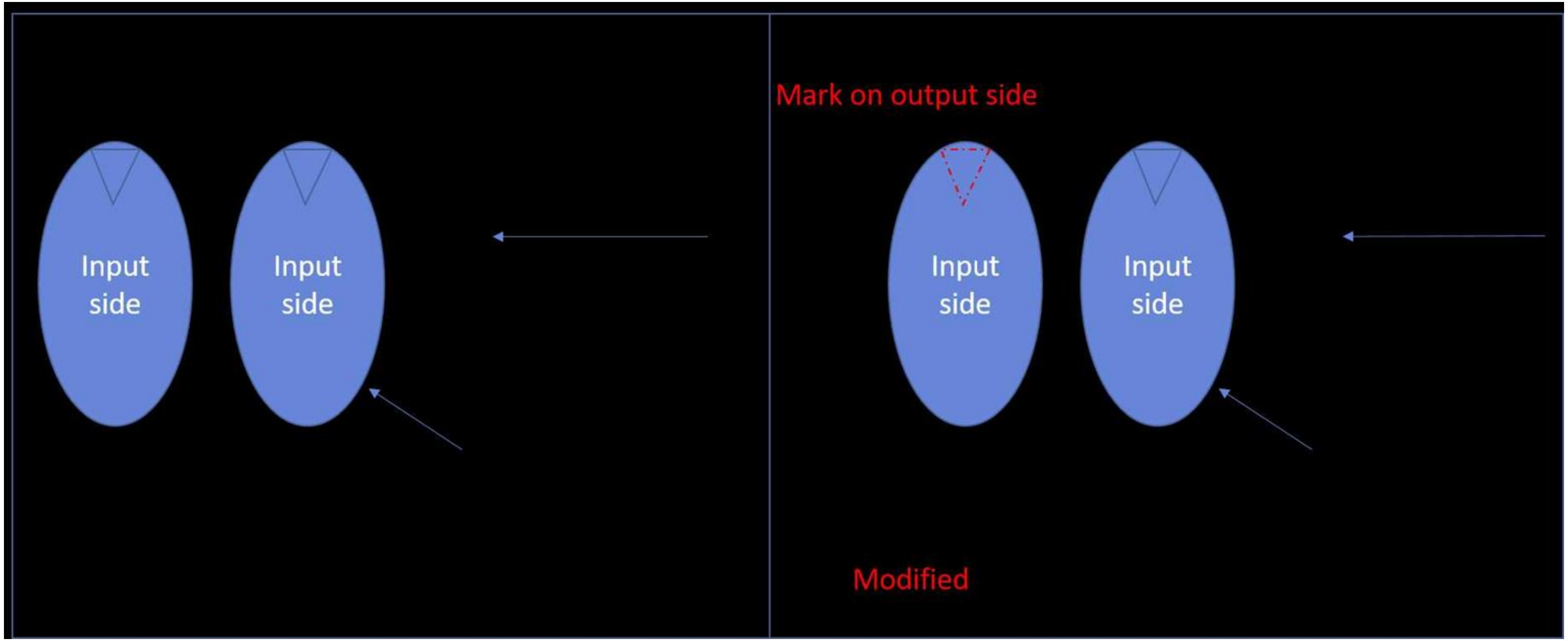
- The mysterious background on the recoil ion detectors was found to be MCPs wrongly positioned, originally by Photonis

- Instead of the standard chevron configuration the channels were aligned on all detectors exhibiting background.

- Identified as the cause for backfiring ions.
- Recoil ion detectors worked nominally (except the noise from RF) as the Si and Phoswich during the beam- period

RIDE Detectors(change in MCP Configuration)

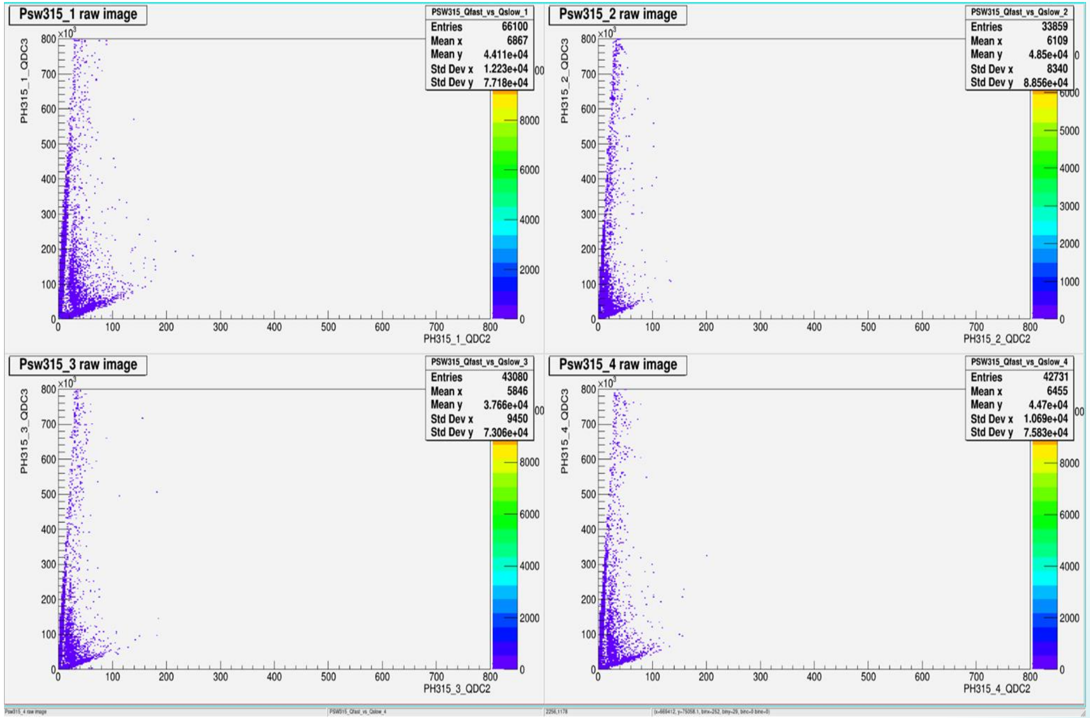


-Helped to get rid of the Afterpulsing seen every 20-40ns.
-Big issue of HOT SPOT on detector edges supposedly being solved

Progresses during the beam time (17/02/22-19/02/2022)

Phoswich Detectors

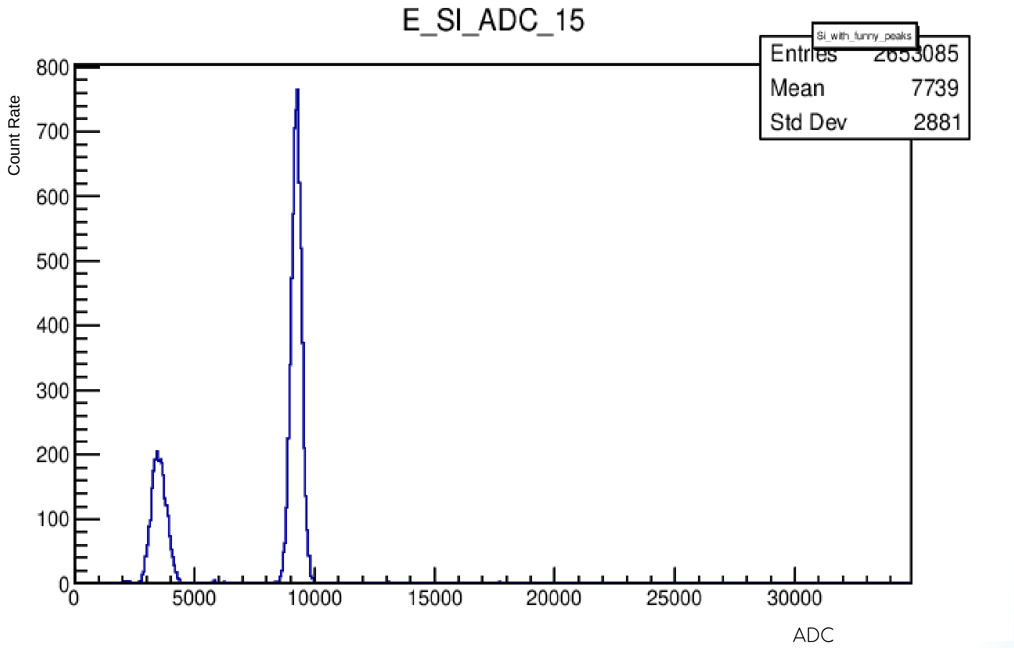
- Detectors worked Fine
- Observation of noise during the beam time with few Phoswich channels



Progresses during the beam time (17/02/22-19/02/2022)

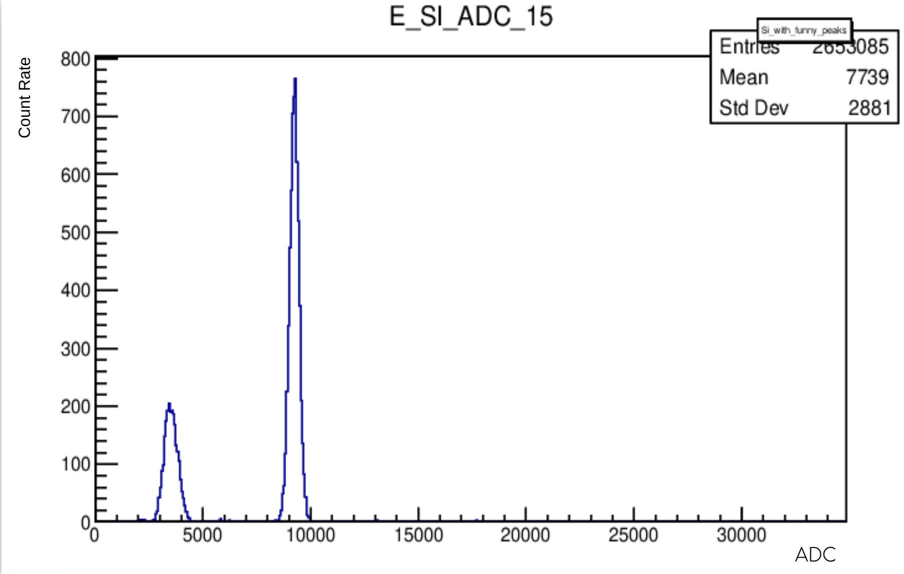
Si Detectors

- ❖ Detectors worked Fine.
- ❖ Optimized again to suppress as much possible background from unknown sources.
- ❖ Strange peaks were observed during the beam time(arising from the switching of RF)

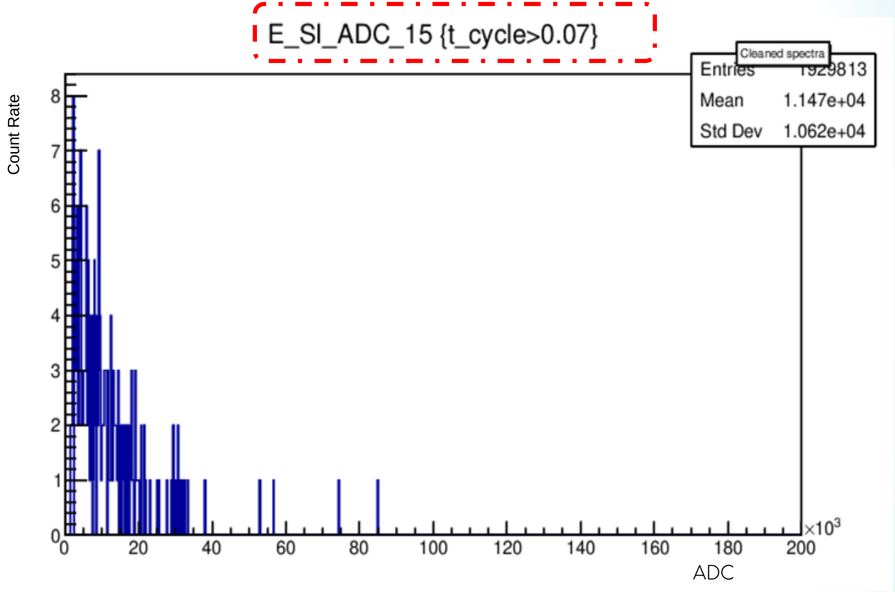


Progresses done in JYFL (during the first beam period)

RF noise observed in the detectors during the first beam time



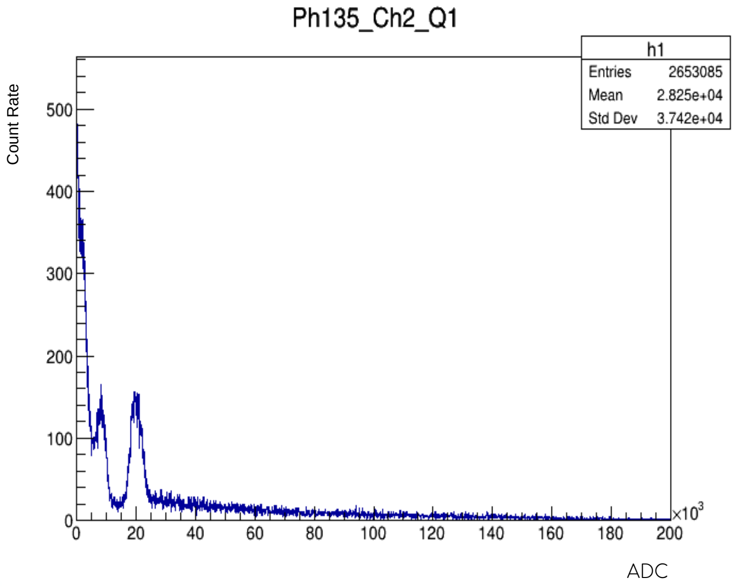
Silicon Channel with noise peaks shown, supposedly coming from the pulses of R3 and R4



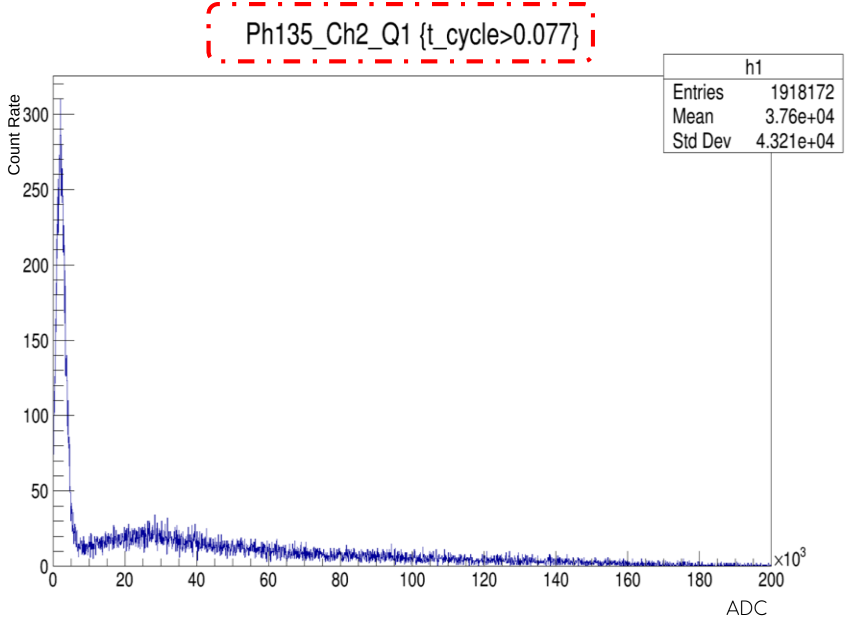
After Correction

noise observed because of the switching of RF, R3 and R4 in the detectors during the first beam time:

**Similar case with Phoswich in some of the Channels

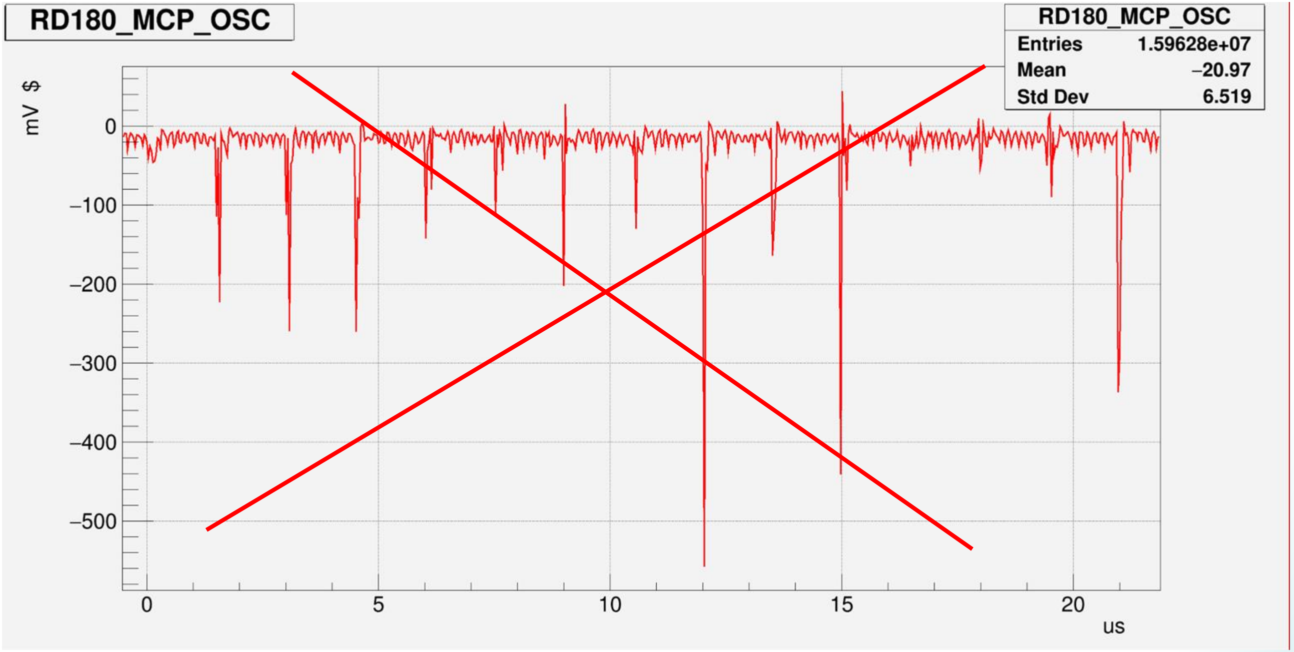


Same Correction applied to retrieve the beta activity in Phoswich



After Correction

RF noise hindered the recording of recoil-ion coincidences. Recoil ion detectors were ***OFF*** during the beam-time due to excessive noise



Outlook and Future Perspectives

THE MORA PROJECT

- Meas. of trapped radioactivity of ^{23}Mg ions
  Less contamination from ^{23}Na to trap more ^{23}Mg ions.
  Beam purity issue is being addressed by baking out the targets surroundings(spig electrodes) etc.

- Meas. of **β** -recoil coincidences.
  High background with RIDE, PHOSWICH and Si detectors has been addressed.
  Possible to filter out the noise from Switches using the time cycle information, no more noise from RF.

- Detector Response Function
  RIDE detectors to be calibrated again with Alphas in position.
  Simulations (Geant4/PENELOPE) to be used for final calibration of Si and phoswich Detectors *(in progress..)*

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In a hope to see more $^{23}Mg^{+}$ in the next scheduled experiment

(27-31st MAY,22)

Thank you for your attention!

THE MORA PROJECT

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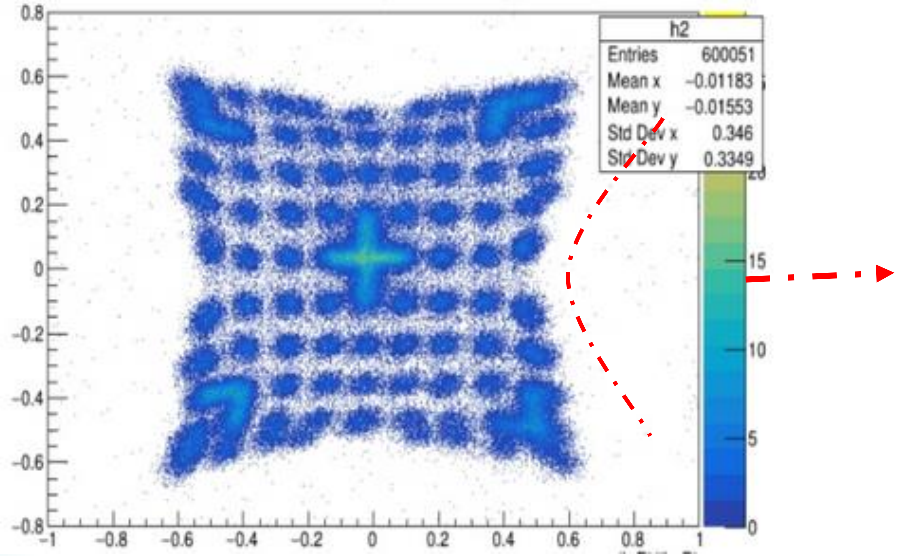
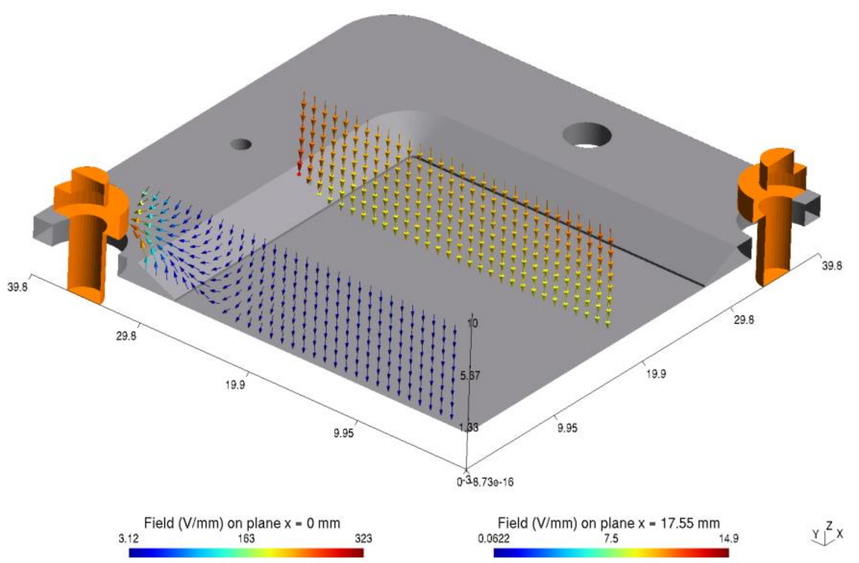
Backup

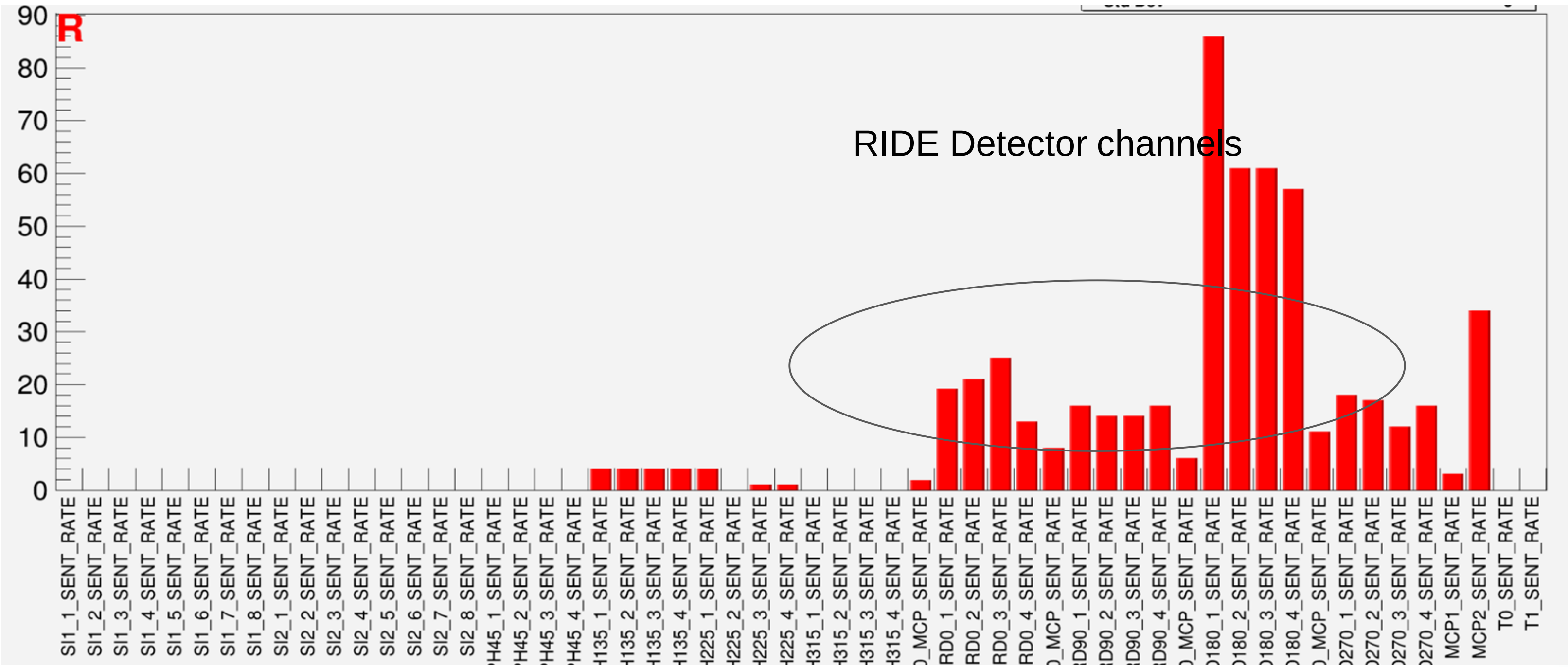




Deviation/Curvature in the RIDE image:

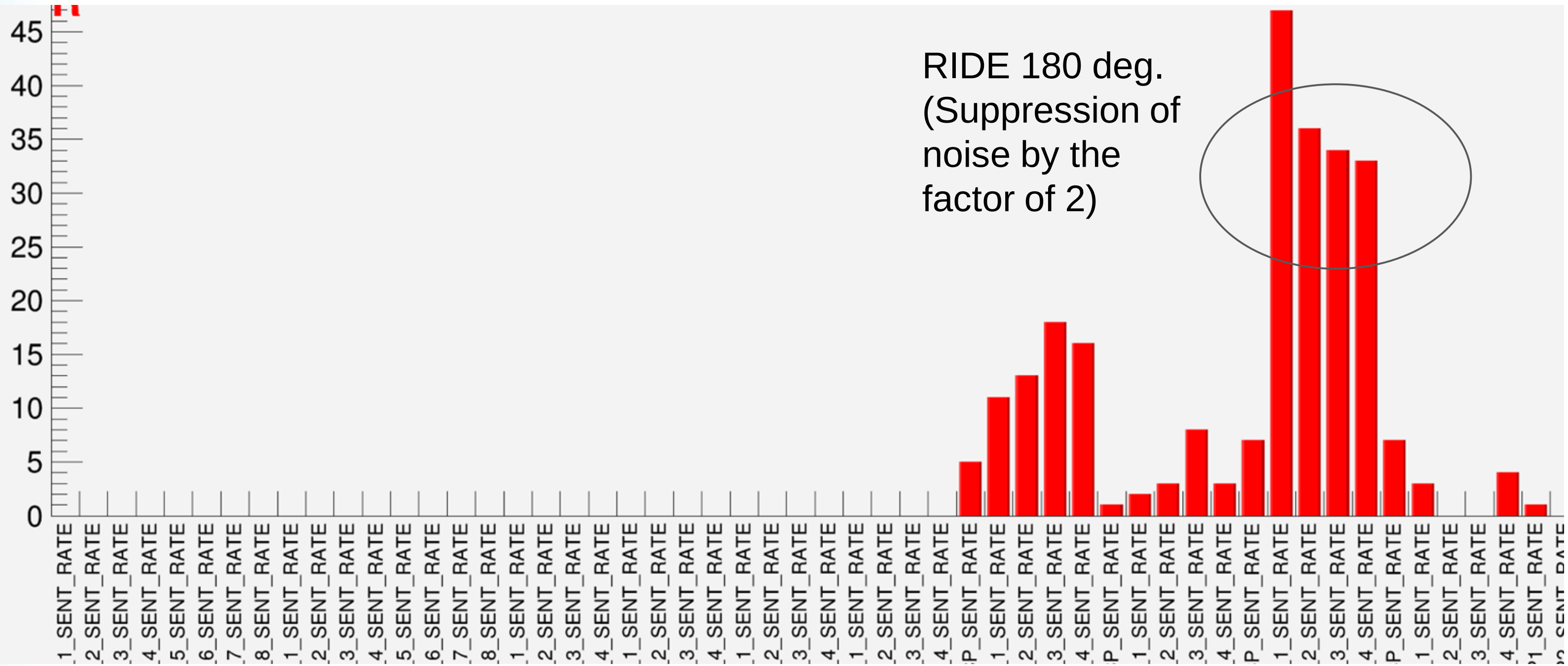
E field points toward the screws, thus the force exerted on electrons points away from the screws toward the center of the MCP plate.

Backup



In presence of RF

Backup



Without RF switch