Investigating ISGR in unstable nuclei: the active target ACTAR@GANIL

Damien THISSE

ECT* Workshop

12-07-2022

Measuring ISGR in nuclei with active targets

How to populate resonances ?

Inelastic scattering at E_{beam} ~ 35 – 100 MeV/A in inverse kinematic

Isoscalar target (T = 0) → Isoscalar resonance $\Delta T = 0$ } α, d

Without spin (S = 0) → Electric resonance $\Delta S = 0$ } α

Energy of the beam → Angular distribution defining multipolarity ΔL

How to measure them ?

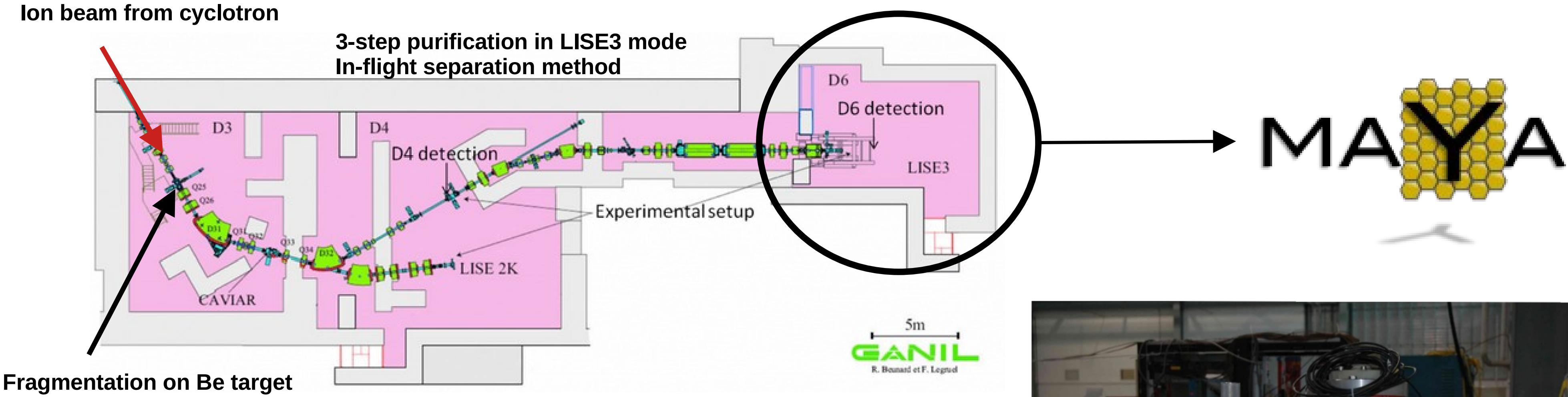
Missing mass method: recoil particle kinematic energy + reaction angle → E*

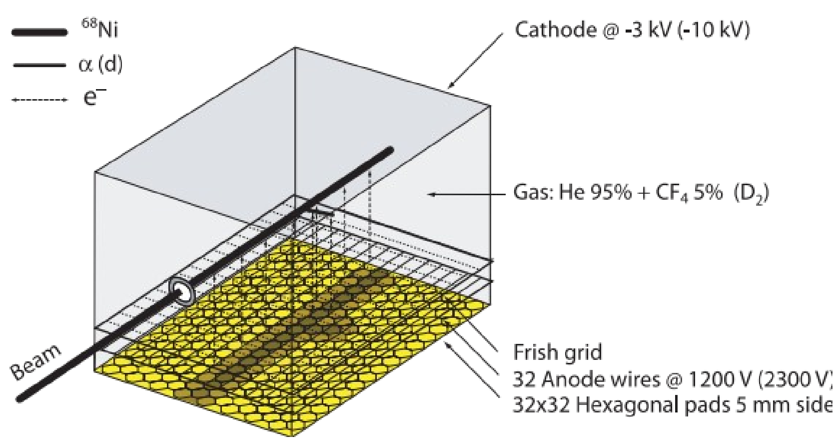
Why do we use active targets ?

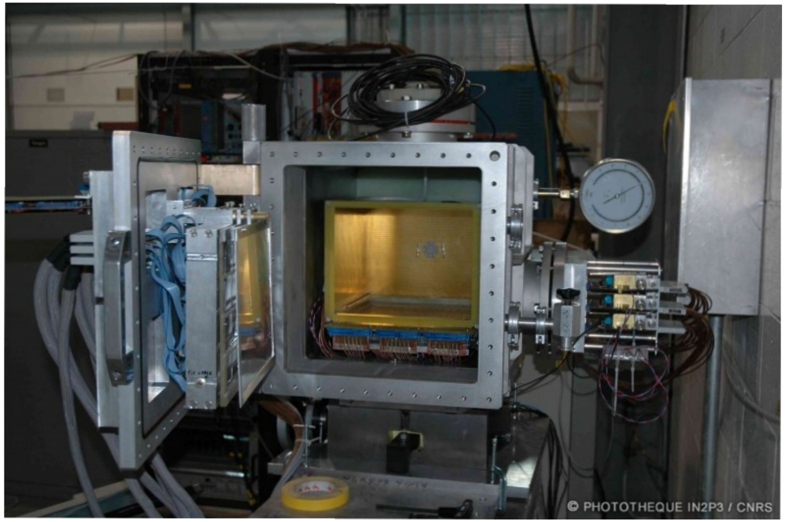
Improve the detection efficiency of low kinetic energy recoiling particles

Need of a high efficiency setup to compensate for the lower production rate of exotic nuclei

Experiments at the GANIL facility





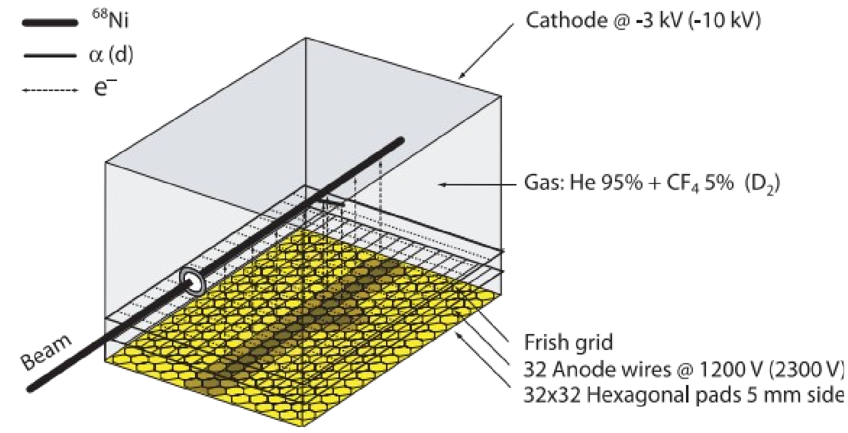


C.E. Demonchy et al. NIM A 583, 341-349 (2007)

See talk of S. Bagchi

Goals of MAYA experiments (related to GR)

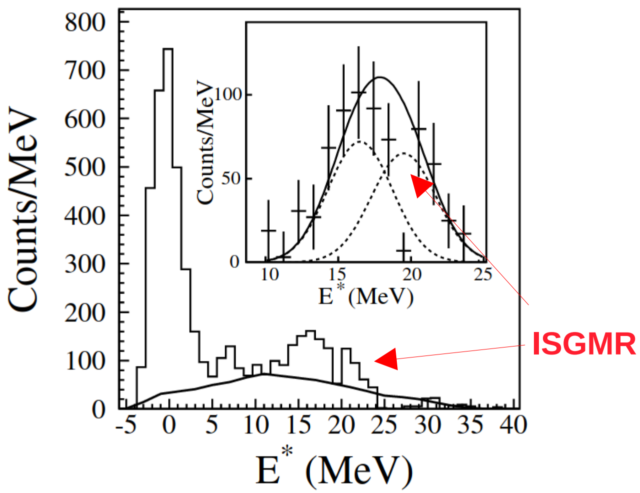
Evolution of the incompressibility of nuclear matter with the N/Z ratio.
Nickel isotopic line is well suited as it ranges over wide N/Z ratios.



C. Monrozeau et al. Phys. Rev. Lett. 100, 042501 (2008)

$E^*(^{56}Ni)_{ISGMR}$ = 19.3 ± 0.5 MeV
$EWSR(^{56}Ni)_{ISGMR}$ = 136 ± 27 %

SPEG + MAYA @GANIL (2005)
(d, d')



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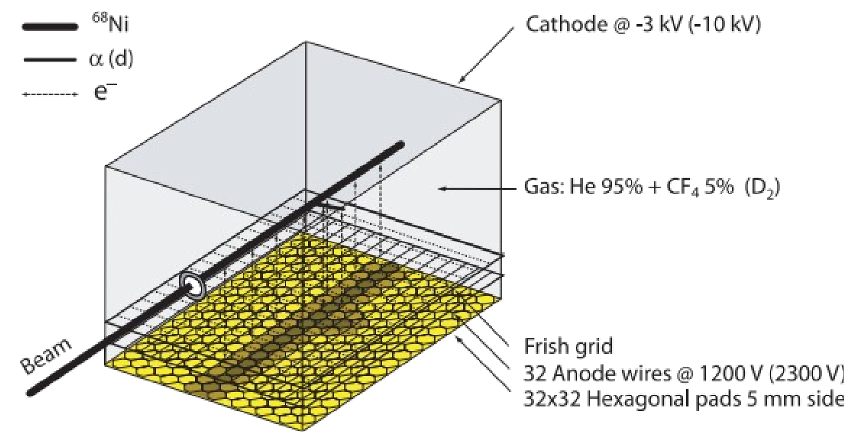

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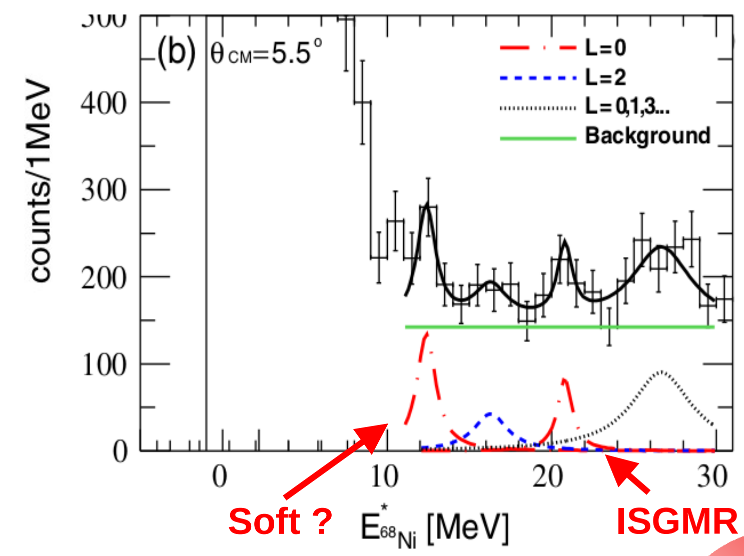
$E^*(^{68}Ni)_{ISGMR}$ = 20.9 ± 1.0 MeV (d,d') — **LISE + MAYA @GANIL (2010)**

$E^*(^{68}Ni)_{ISGMR}$ = 21.1 ± 1.9 MeV (α,α')



Previous achievements with the active target MAYA

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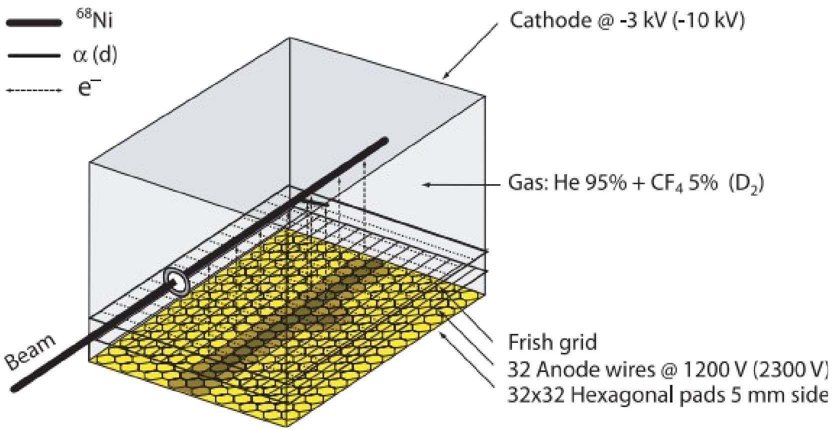

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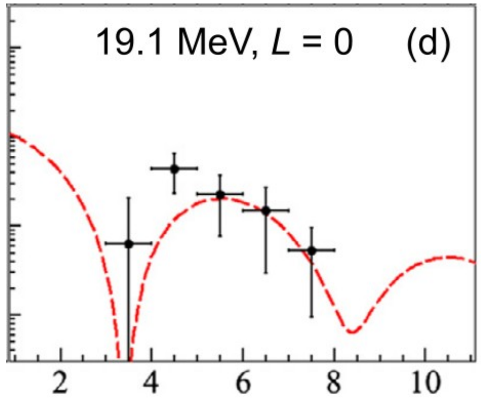

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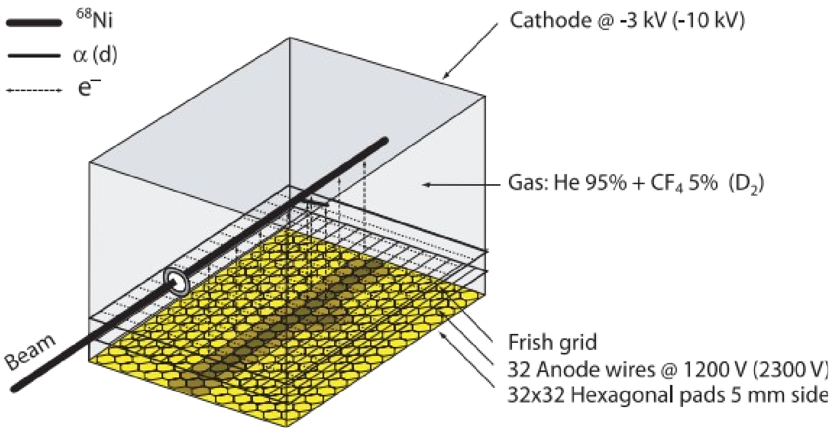

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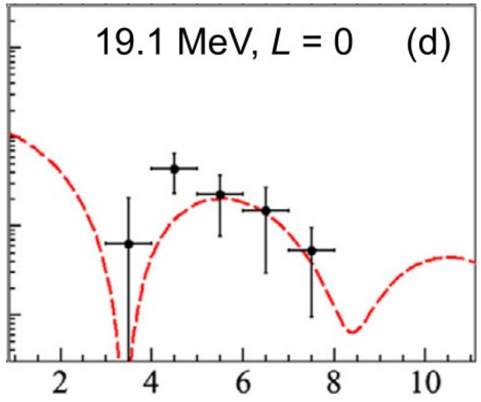
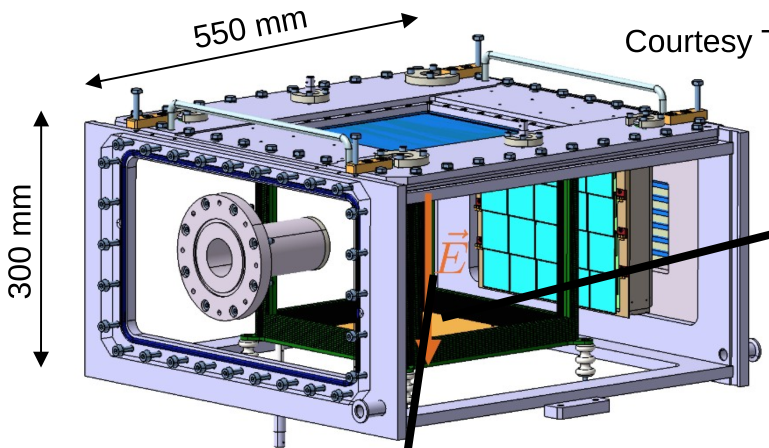


Limitation of MAYA: efficiency and angular resolution for low energy particles...

… lead to the development of ACTAR-TPC

T. Roger *et al.*, NIMA 895, 126 (2018)



Courtesy T. Roger

128 x 128 pixels of 2 mm²
16 384 channels in a square of 25.6 x 25.6 cm²

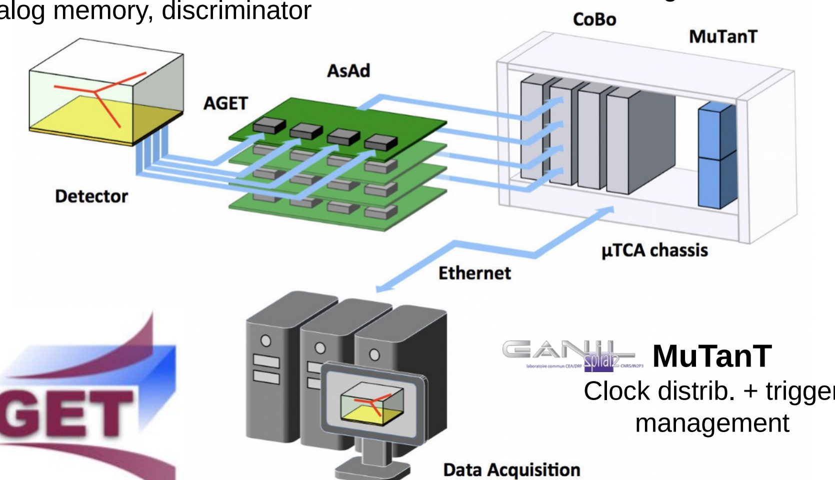
Drift region: filled with He (95%) and CF_4 (quencher)

Dedicated electronics

AGET
64 channels signal processing (CSA + shaper), analog memory, discriminator

AsAd
4 AGET chips + ADC

CoBo
4 AsAd boards digital data management



MuTanT
Clock distrib. + trigger management

E. C. Pollacco *et al.*, NIMA 887, 81 (2018)

Output format:
Pixel ID (x, y)
Time w.r.t. to trigger (z)
Charge deposited (q)

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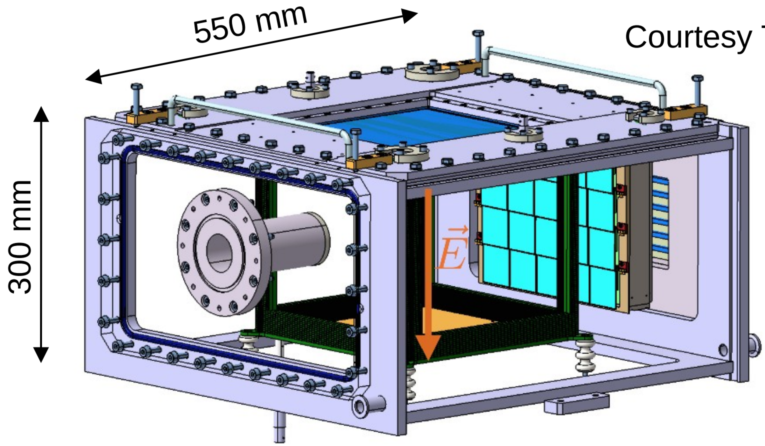


Courtesy T. Roger

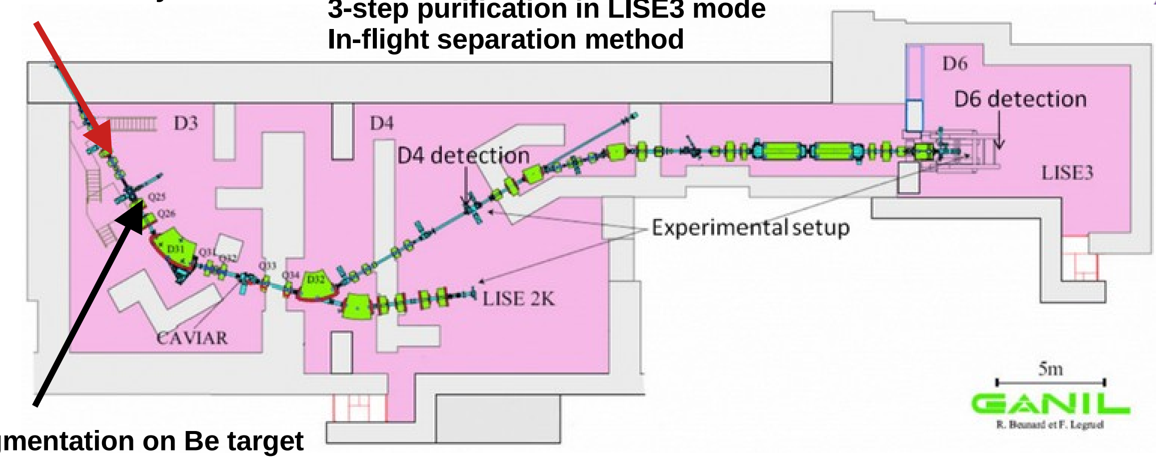
P = 400 mbar
E_{beam} = ~50 MeV/A

2 experiments done and being analysed:

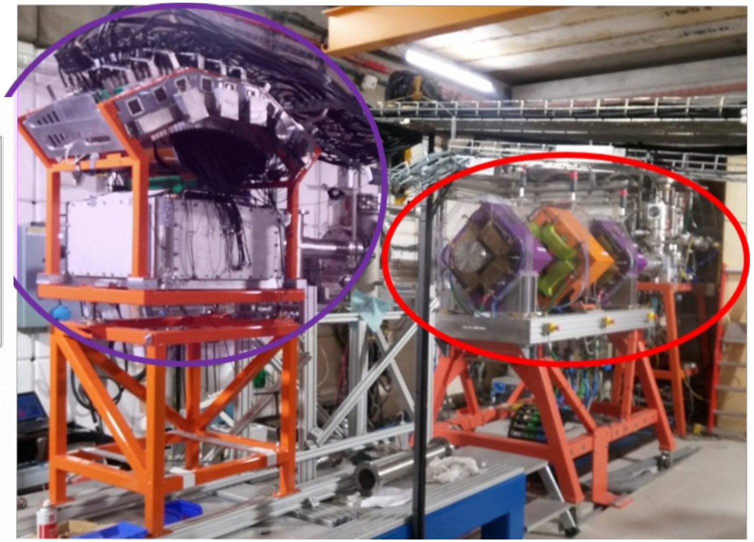
ISGMR in ^{58}Ni and ^{68}Ni (2019)

Ion beam from cyclotron

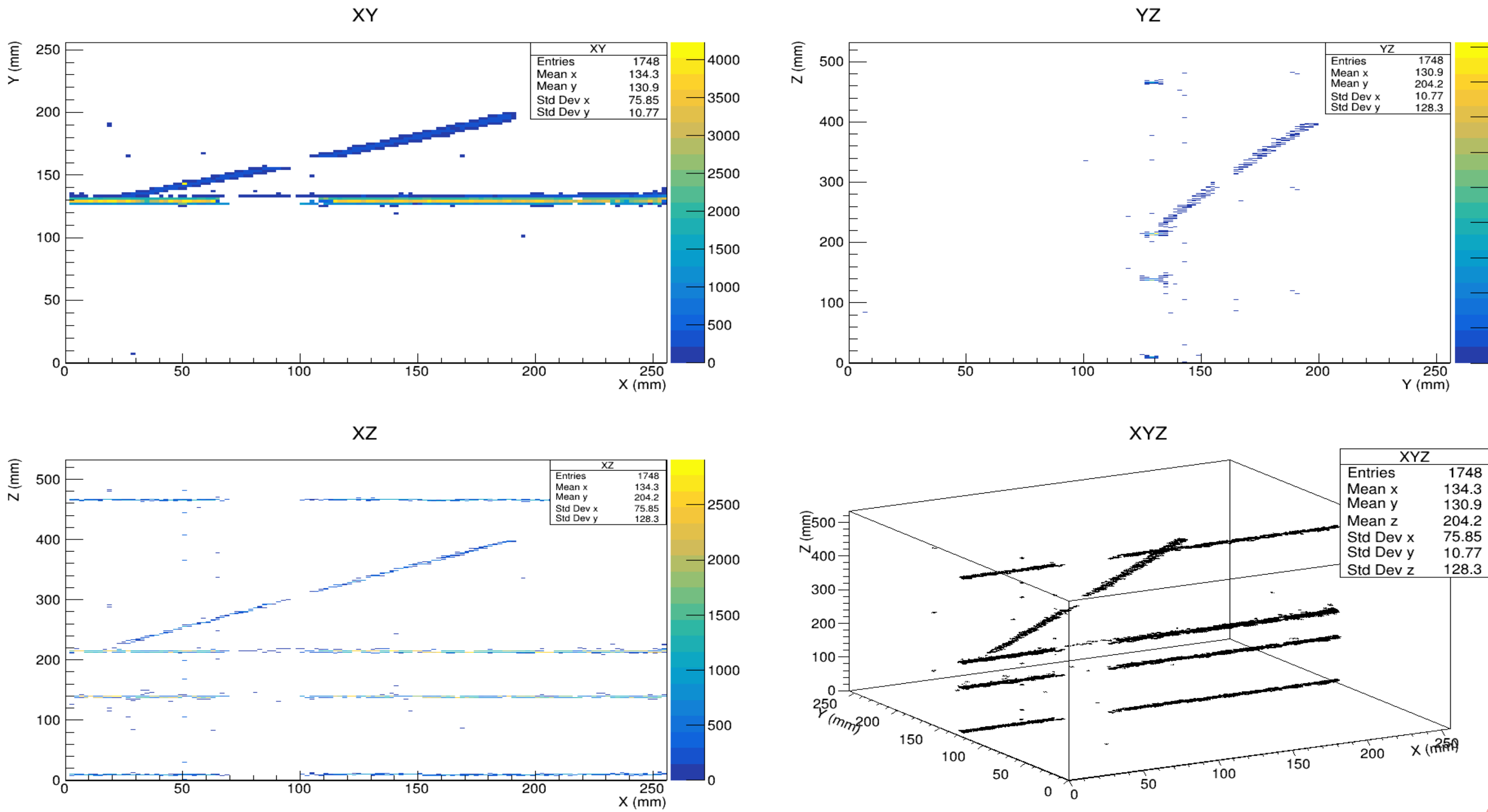
3-step purification in LISE3 mode
In-flight separation method



Fragmentation on Be target



An event in ACTAR TPC



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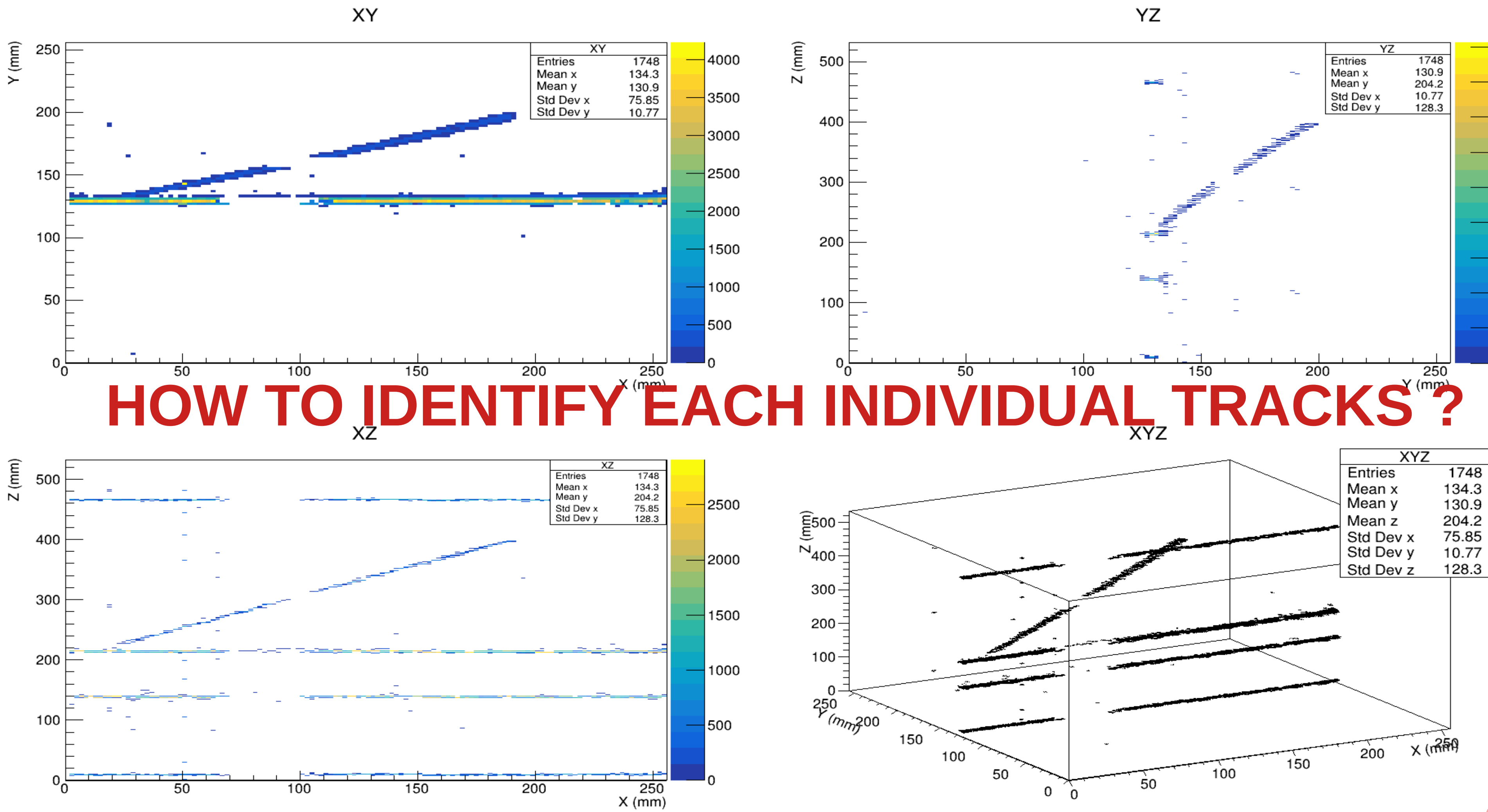
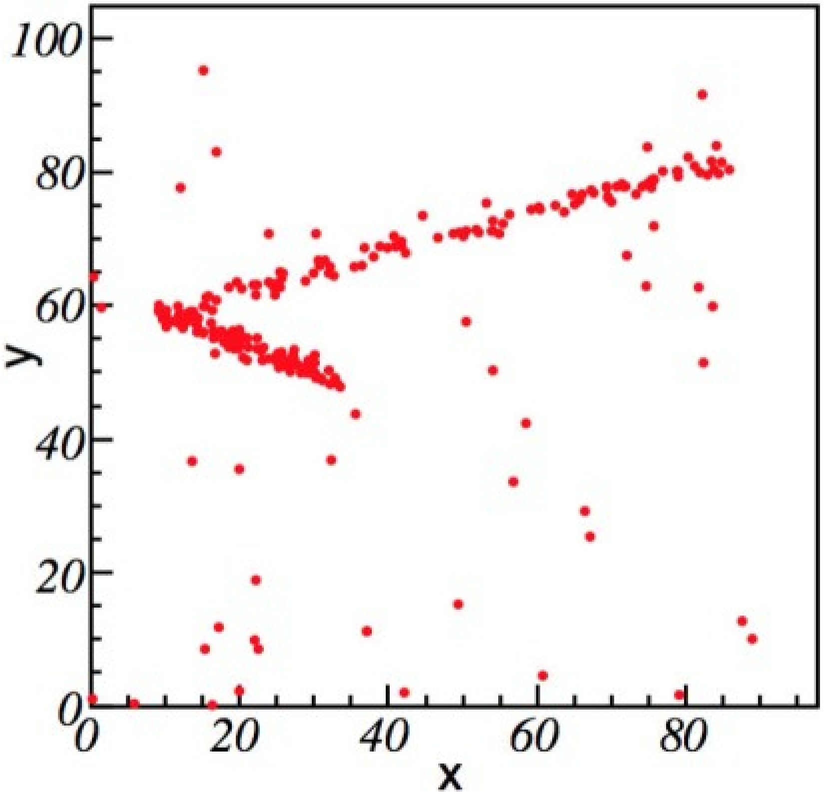


HOW TO IDENTIFY EACH INDIVIDUAL TRACKS ?

RANSAC method: iterative method to find the tracks

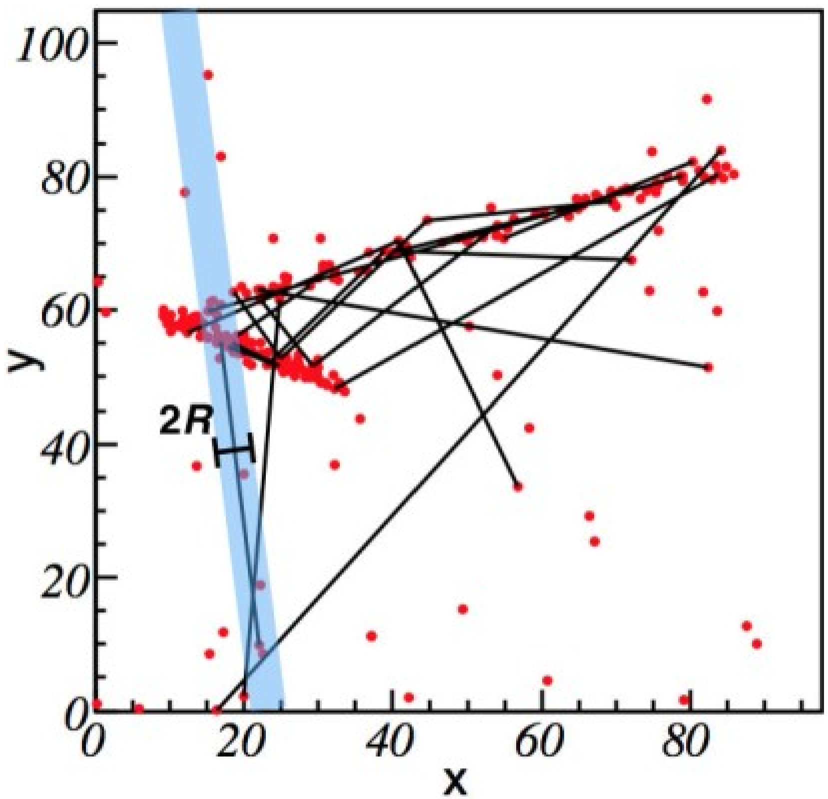
A 2D example



From: B. Mauss, PhD Thesis (2019)

RANSAC method: iterative method to find the tracks

A 2D example



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N pair of points randomly chosen

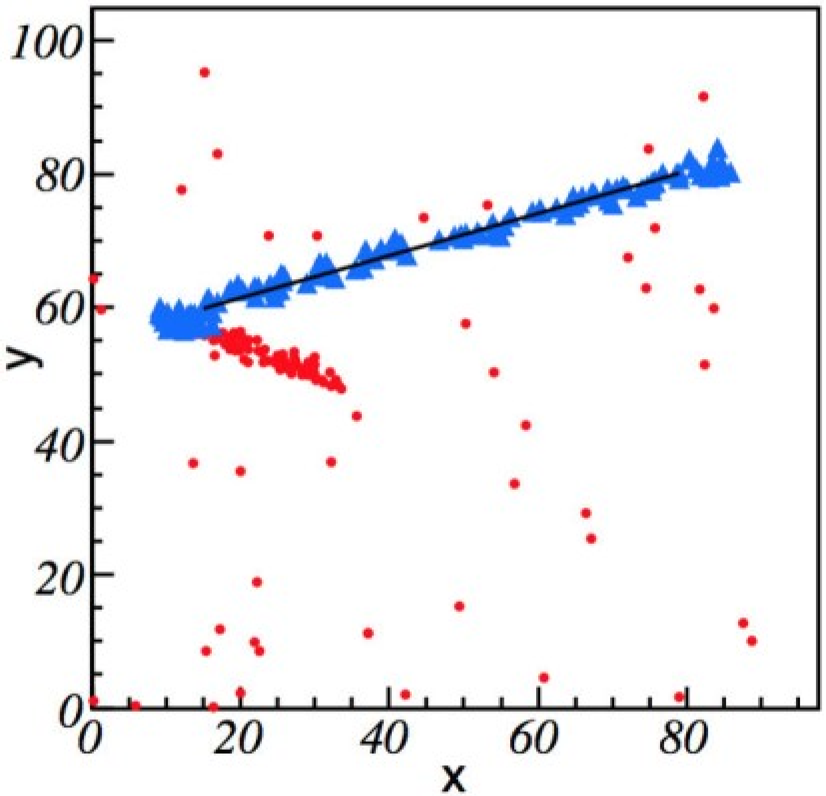
Voxels grouped inside cylinders (radius R)

For each, the total charge and the number of voxels inside are calculated.

Track = cylinder fulfilling a given condition

RANSAC method: iterative method to find the tracks

A 2D example



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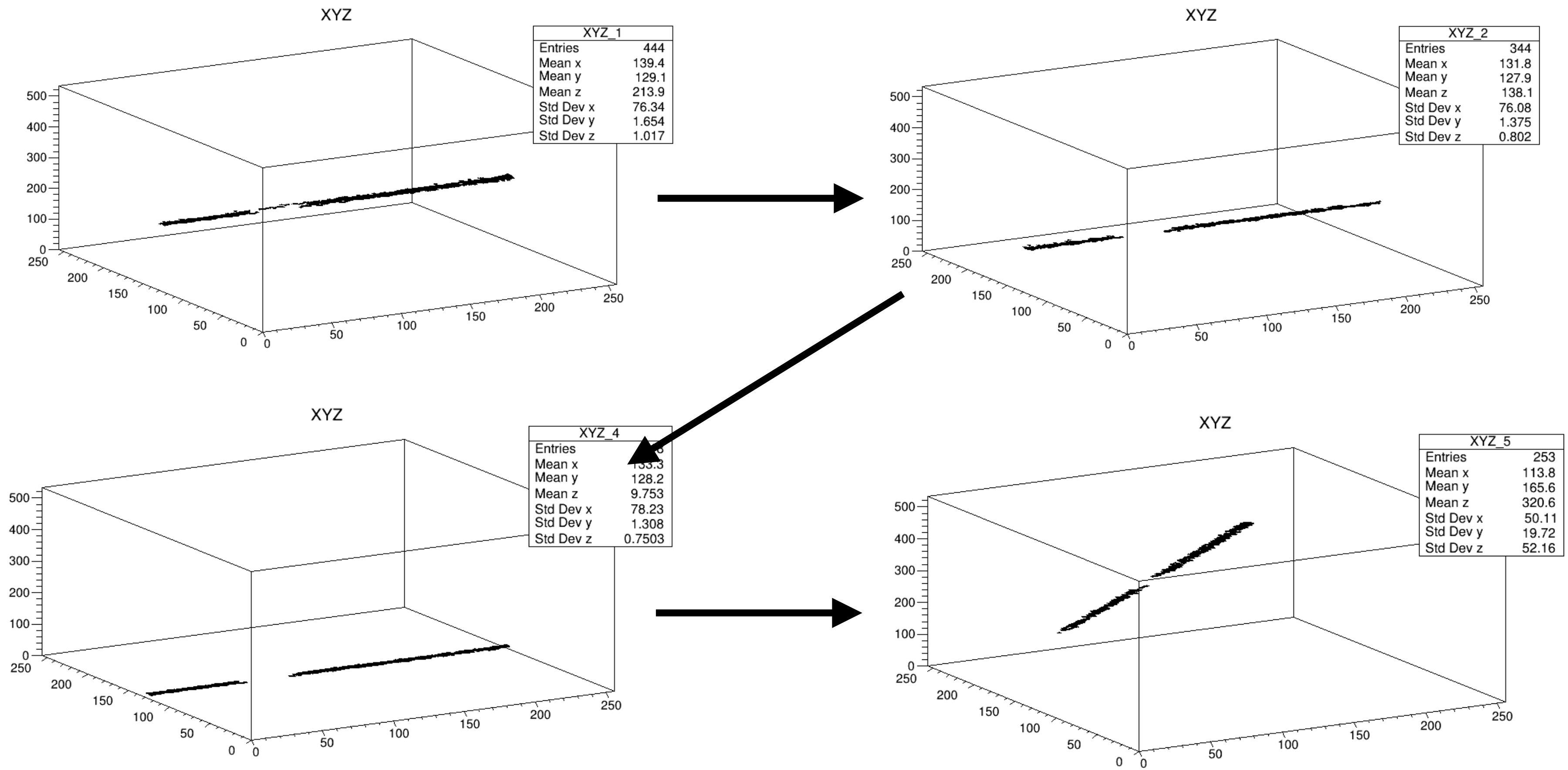
Track = cylinder fulfilling a given condition

The process is repeated until a stop condition is fulfilled.

RANSAC method: iterative method to find the tracks



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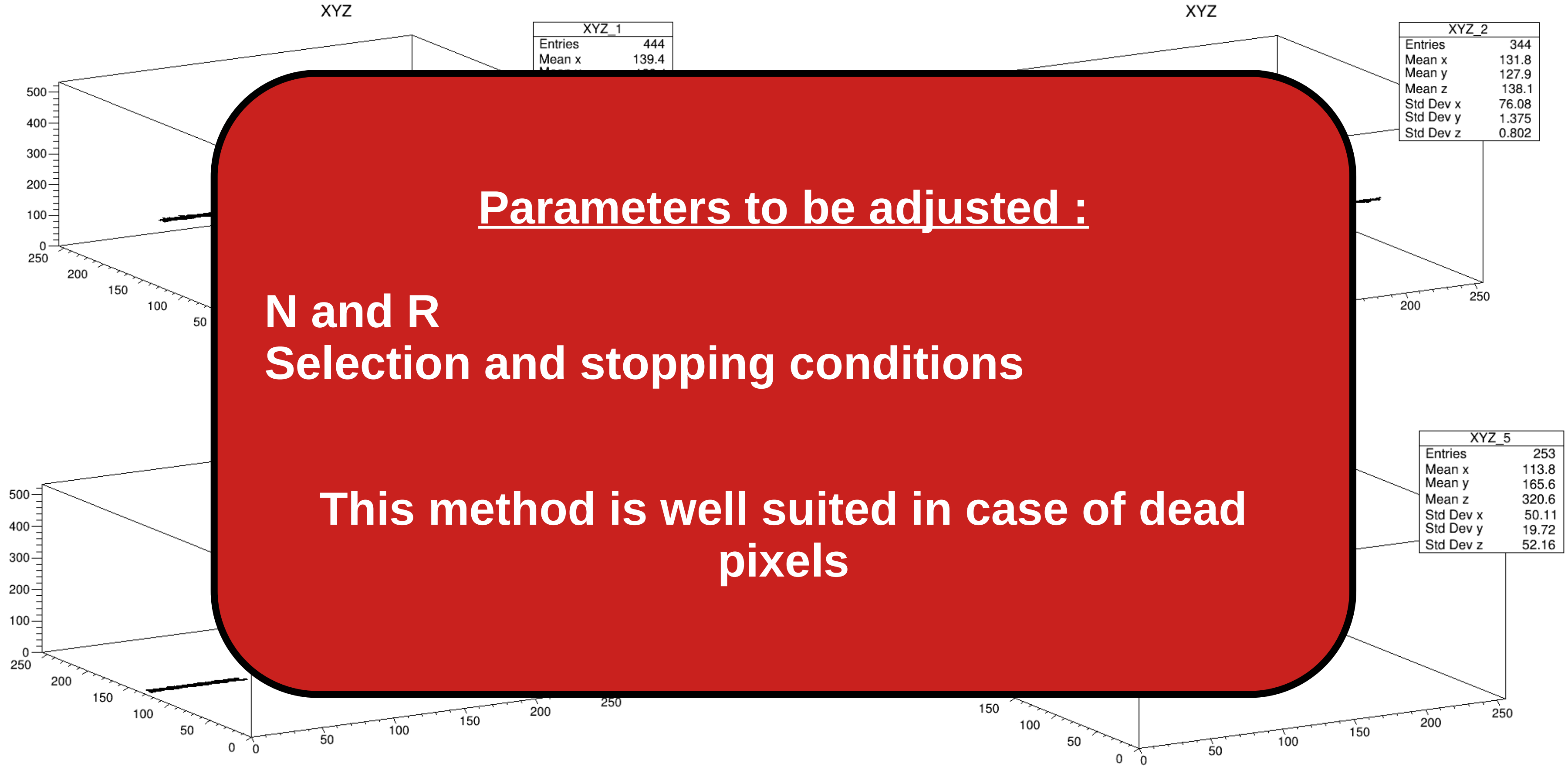
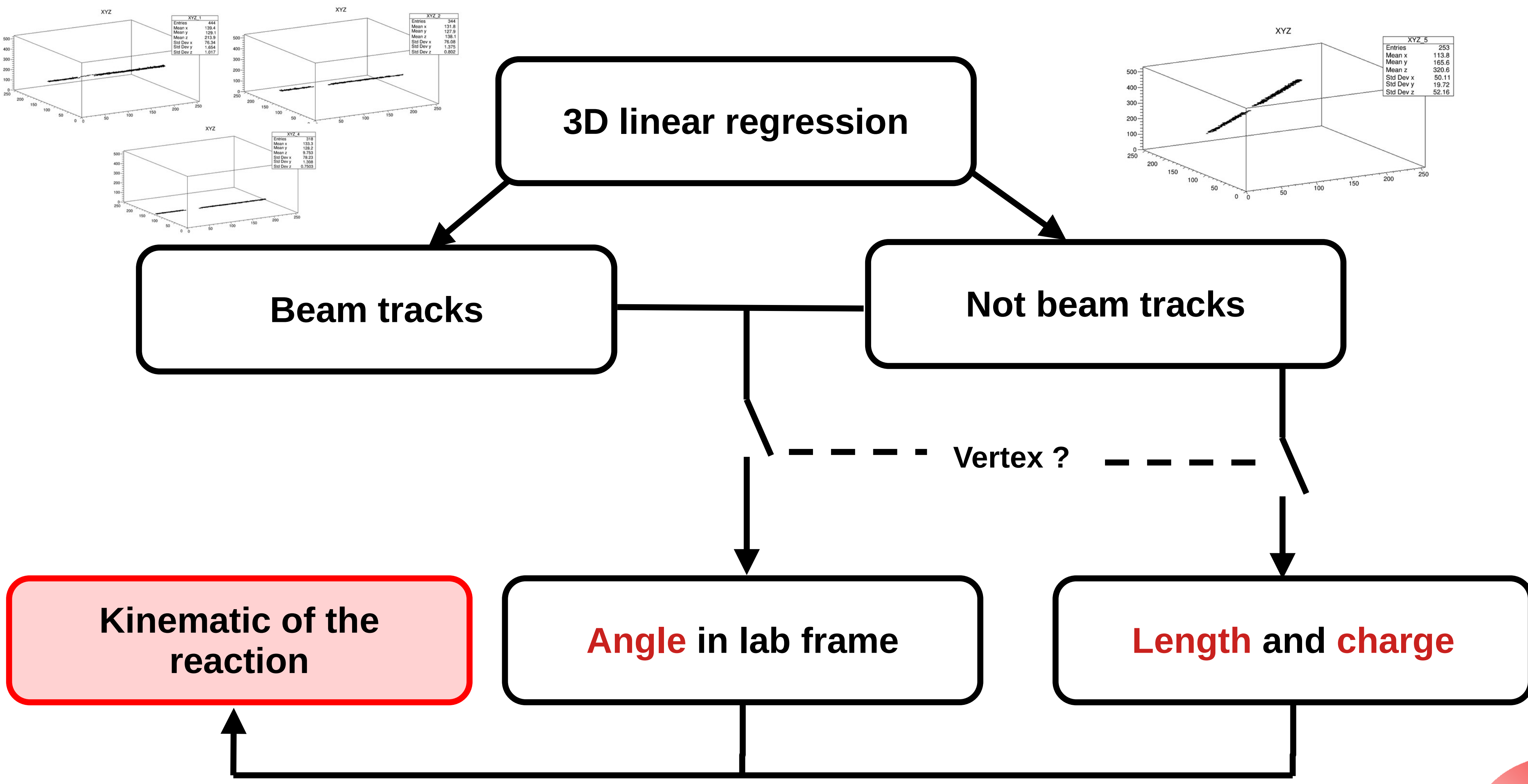


Parameters to be adjusted :

N and R
Selection and stopping conditions

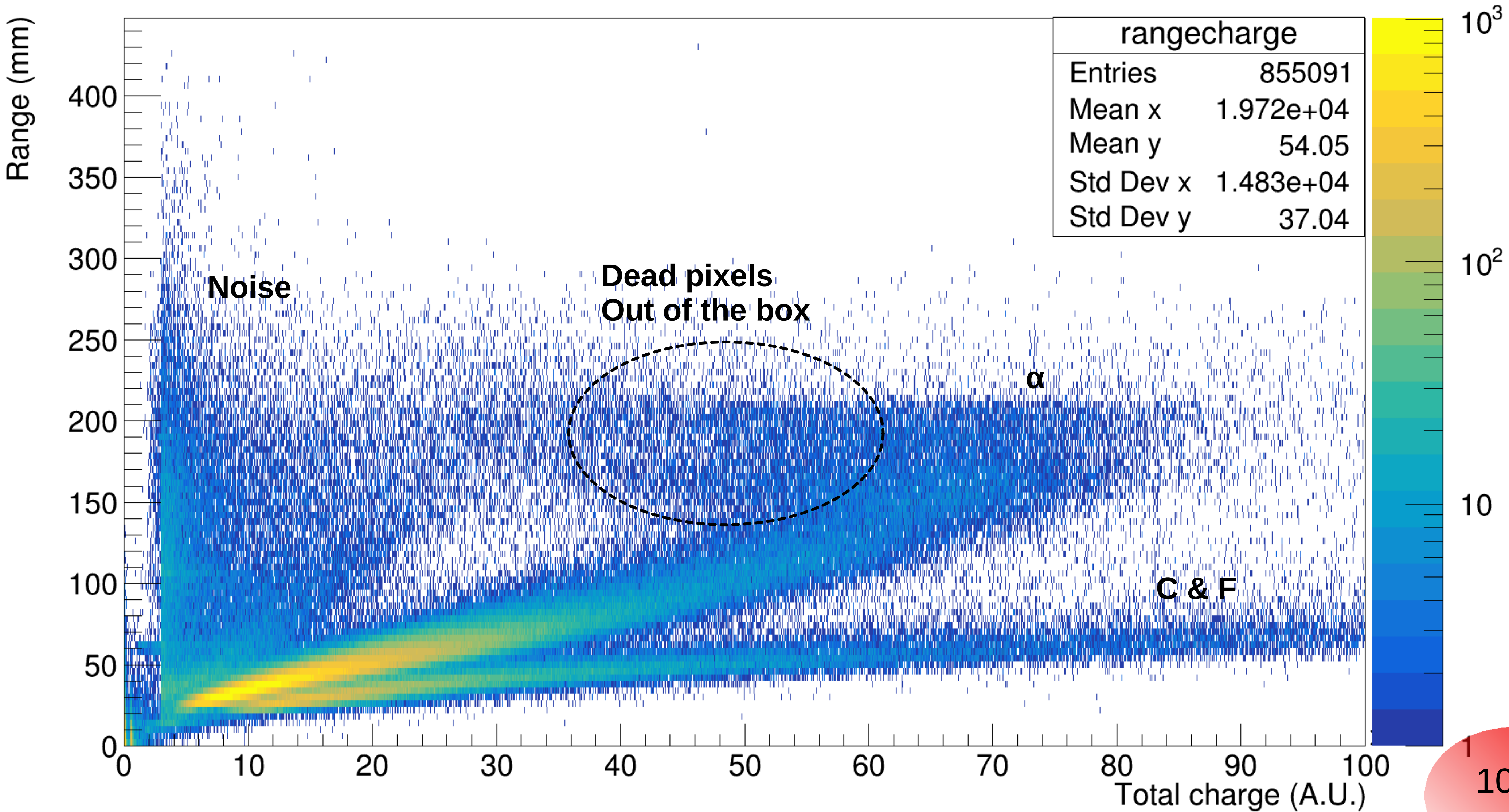
This method is well suited in case of dead pixels

Measurement of the kinematics parameters

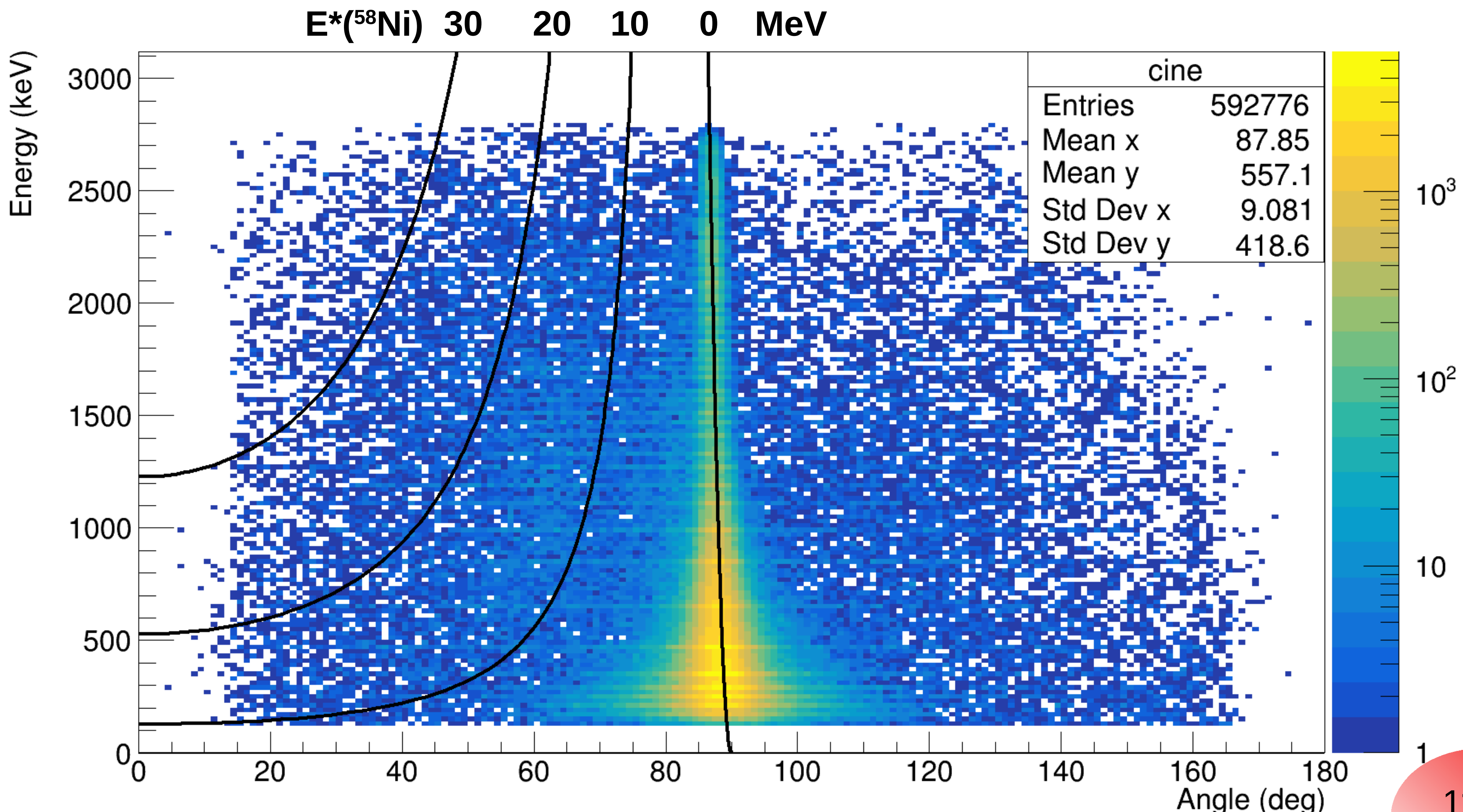


$^{58}Ni(\alpha, \alpha')^{58}Ni^*$ dataset

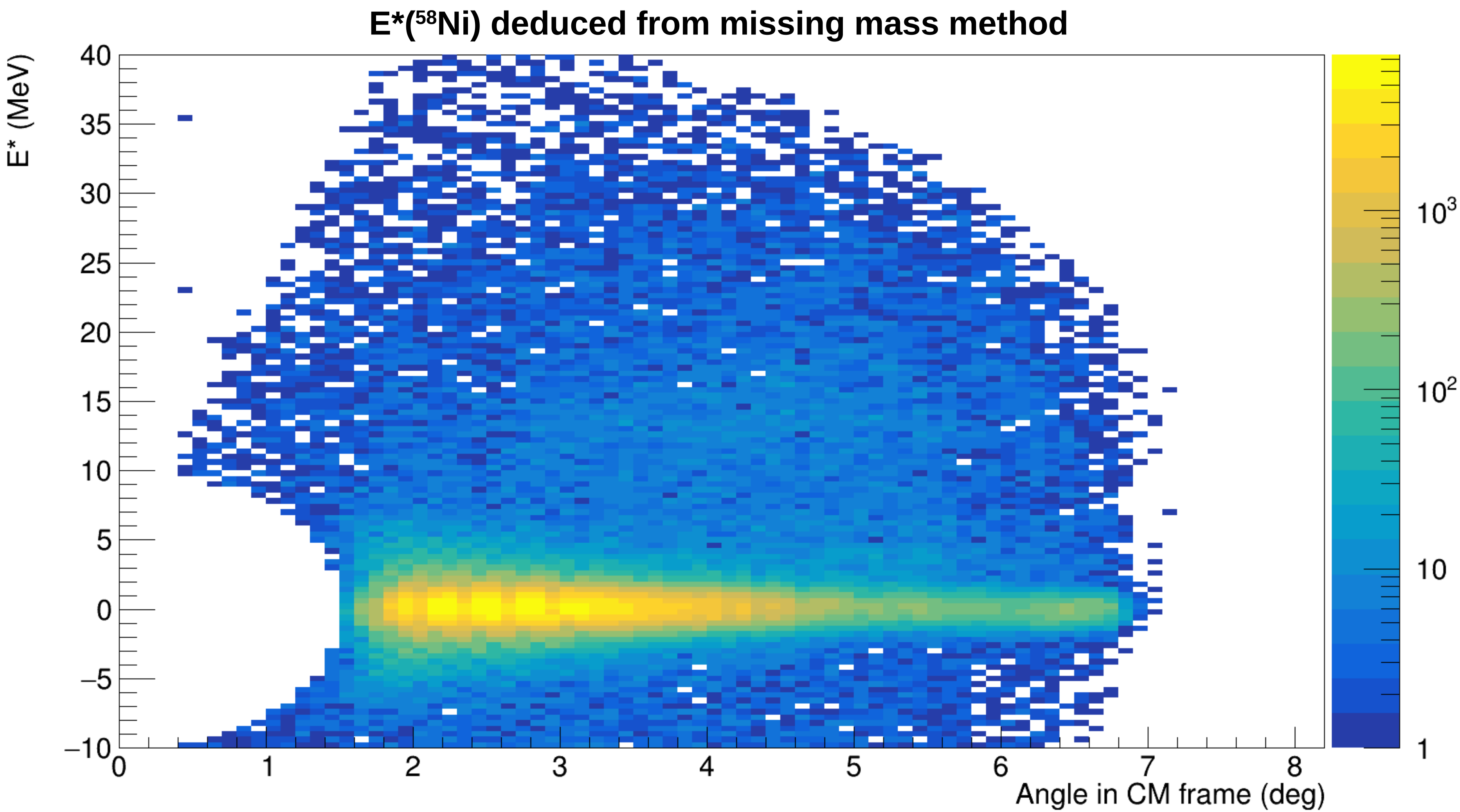
Particle identification: charge vs range



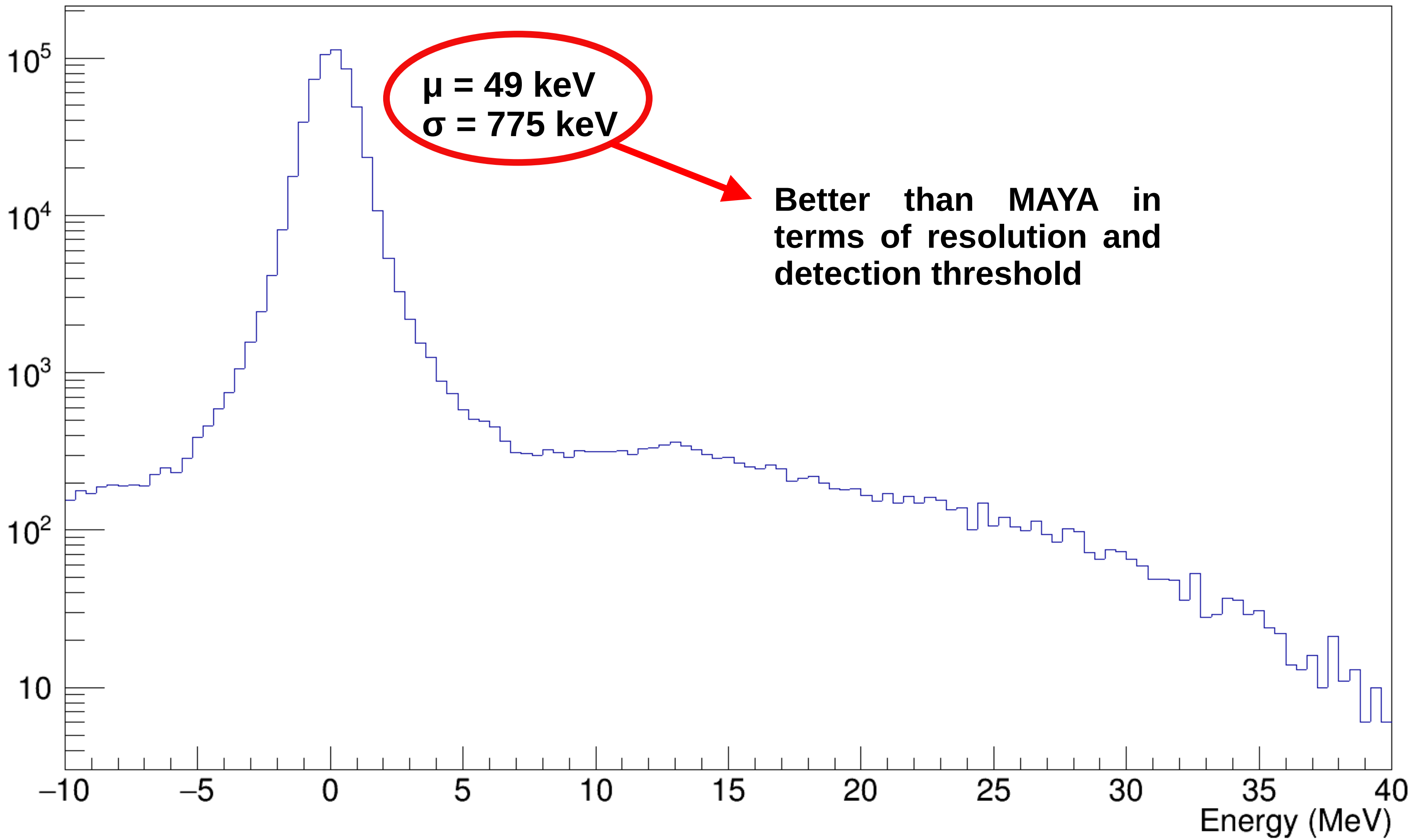
^{58}Ni(α, α')^{58}Ni* dataset
Kinematics: lab angle vs alpha energy



^{58}Ni(α, α')^{58}Ni* dataset
Kinematics: E*(^{58}Ni) vs angle in CM frame



$^{58}Ni(\alpha, \alpha')^{58}Ni^*$ dataset
Nickel excitation energy spectrum



Better than MAYA in terms of resolution and detection threshold

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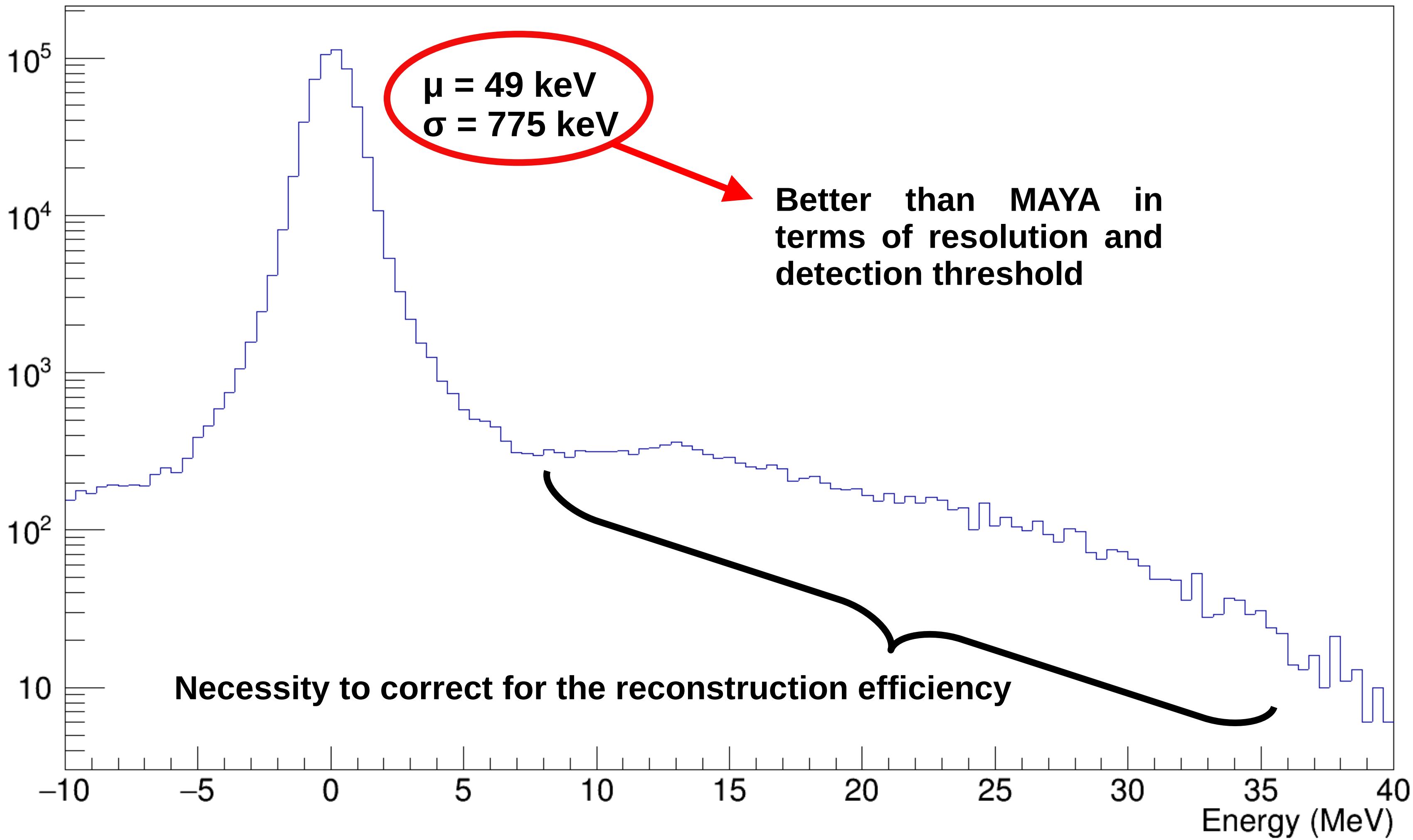
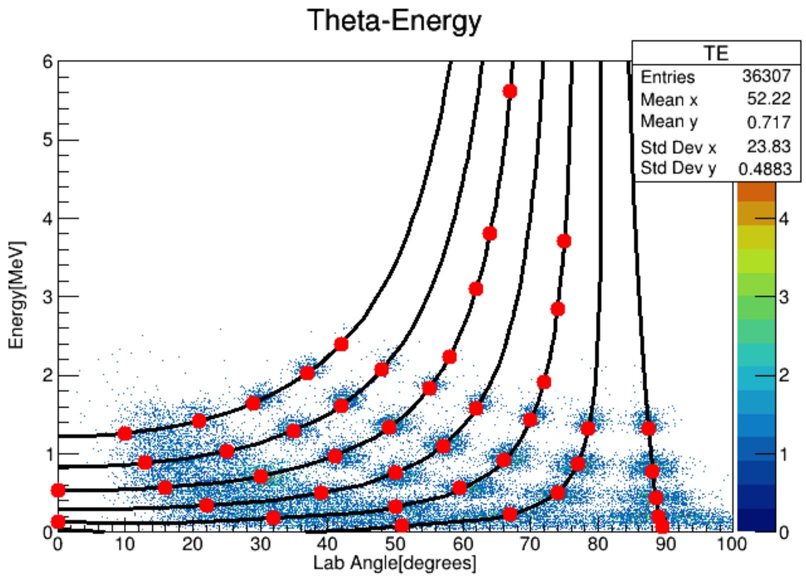
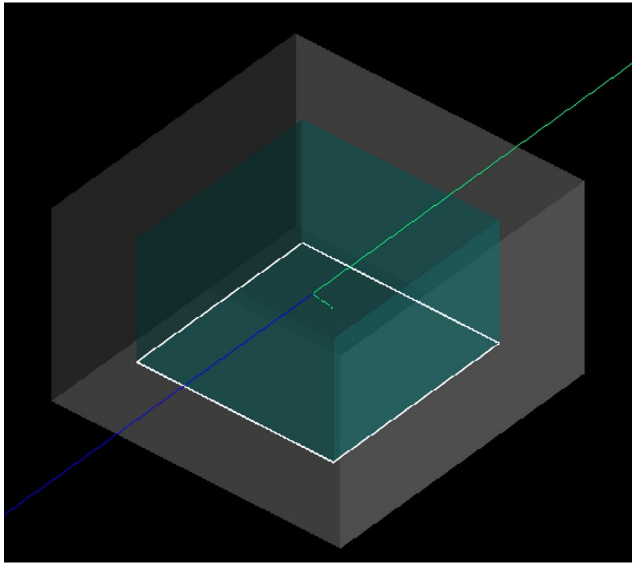


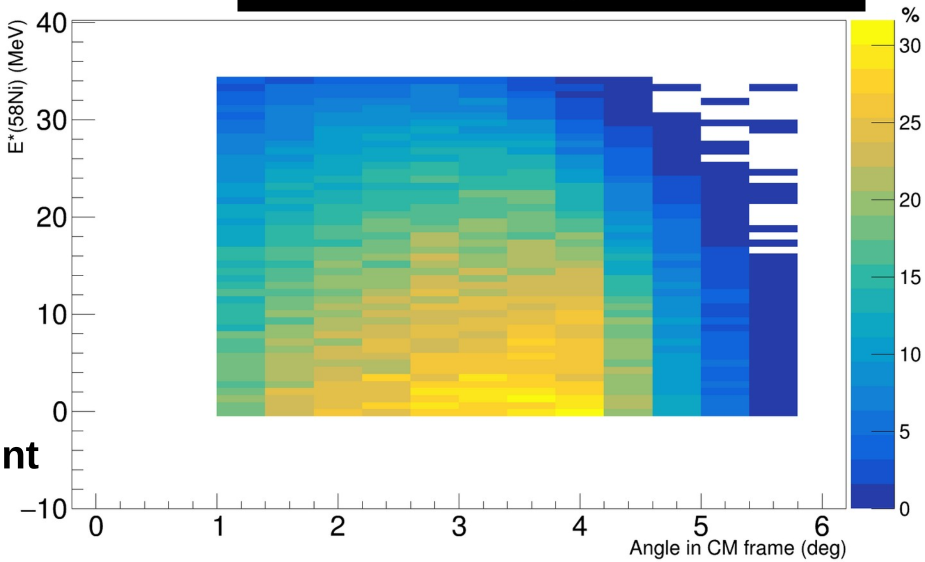
Simulation using nptool (GEANT4)

A Matta *et. al.,* J. Phys. G: Nucl. Part. Phys., 43 045113 (2016)

« Offer an unified framework for preparation and analysis of complex experiments, making an efficient use of Geant4 and ROOT toolkits »







Courtesy of Alex Arokia Raj (PhD thesis work)

« Reconstruction method » dependent

Summary

MAYA

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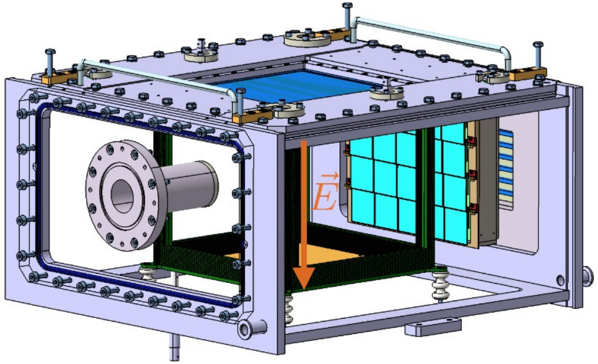
Improved
resolutions and efficiencies



ISGMR in ^{58,68}Ni
Soft monopole in ^{68}Ni

<u>Problematic of the analysis :</u>

Precision in the reconstruction of short tracks (small angles in CM frame)

Strong impact of the simulations on the analysis

<u>Next steps :</u>

Performing the simulation to obtain the efficiency of reconstruction and apply it on real data → validate the method on ^{58}Ni

Perform the same work on the ^{68}Ni data

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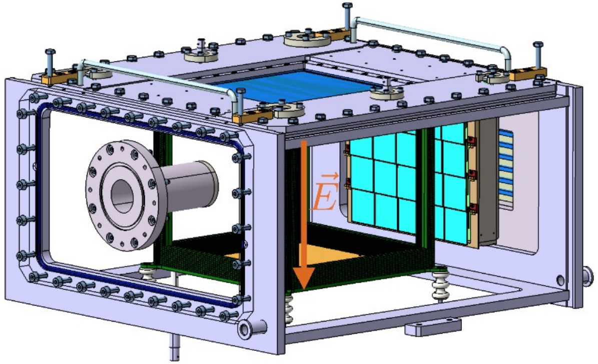

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Thank you

Range to energy conversion

From SRIM simulation