Simulation for gamma exposure

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Takashi Asada
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Outline

- Description of the exposure test to ^{241}Am
- Geant4 based simulation
- Study NIT emulsion response to electrons
- Clustering with DBSCAN algorithm
- Results

Exposure to ^{241}Am

Radioactive source

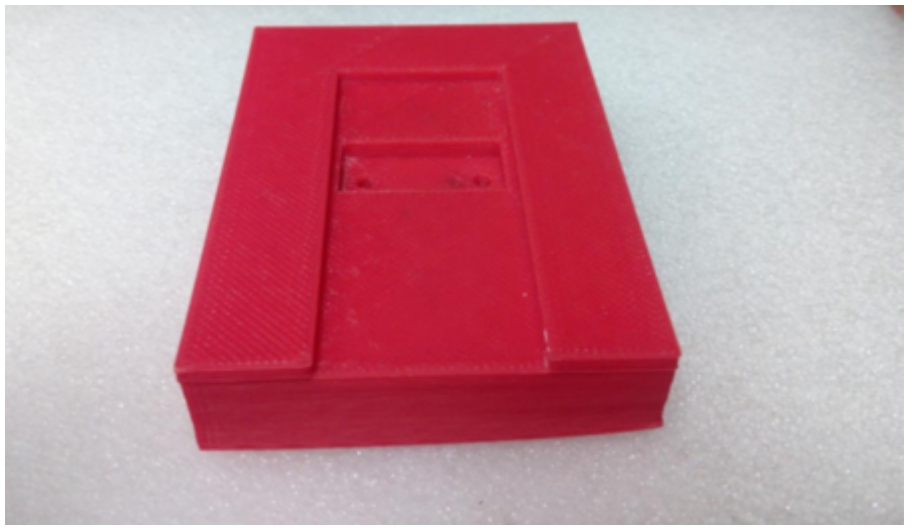
FEATURES

Diameter: 1mm

Activity: 421.45 kBq

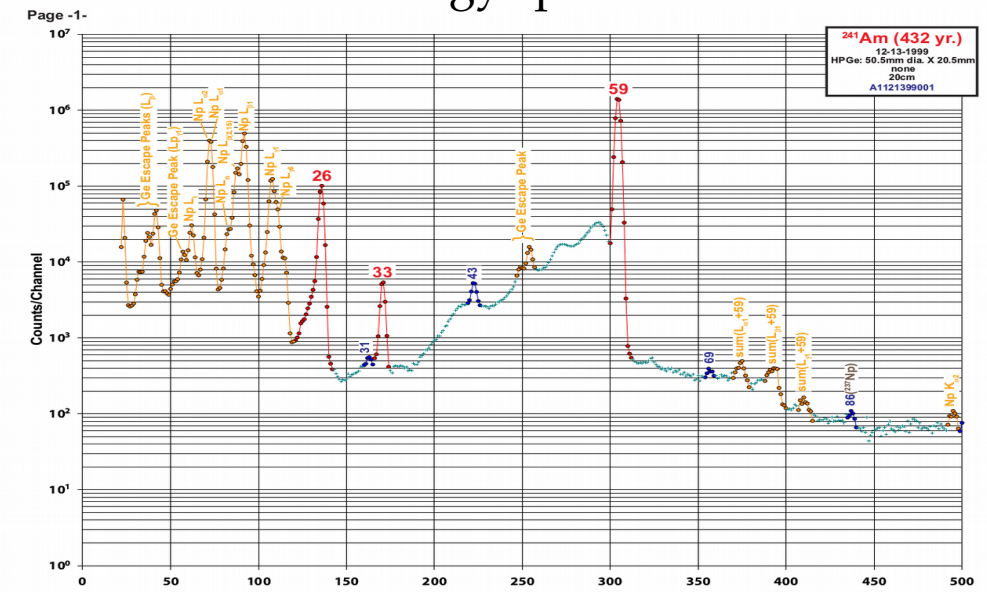
Distance from NIT: 2mm

Exposure time: 120s



Emulsion film and source placed in the pocket folder

^{241}Am Energy spectrum



Aim:

Study NIT response to electrons in low temperature condition

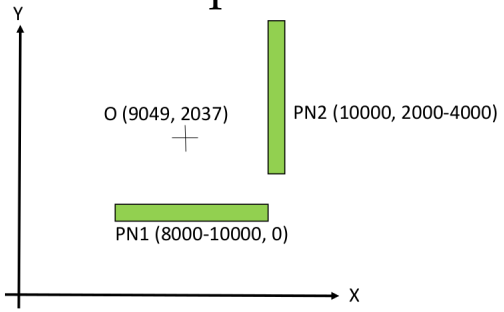
Two exposures were performed:

1. Environmental temperature
2. Low temperature (~ -15°C)

Exposure to ^{241}Am

Naka-san report

Scanned area for the test at room temperature



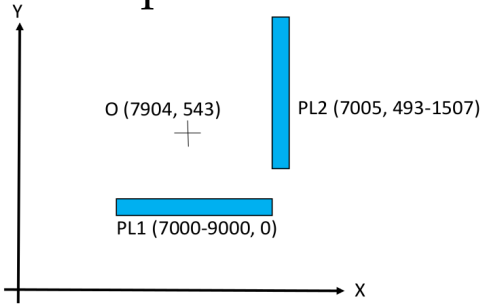
Shrinkage: 0.6
Event density ~ 1.15
Fog in RR ~ 0.45

RR → Reference Region

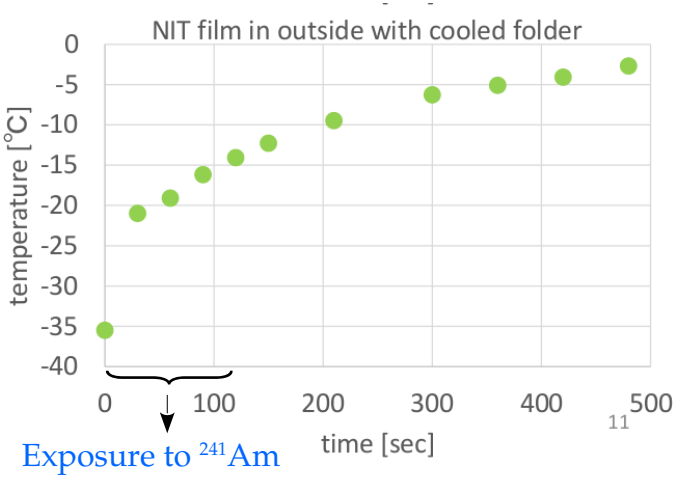
Event density normalized to $(10um)^3$

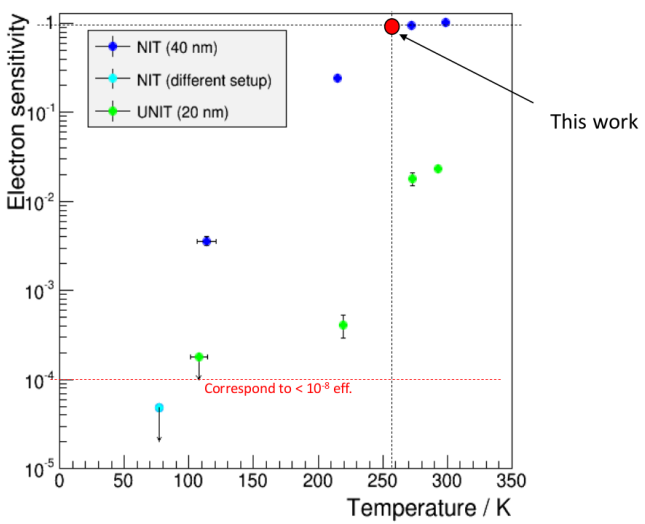
O(x,y) derived from a gaussian fit of x and y distribution

Scanned area for the test at low temperature



Shrinkage: 0.6
Event density ~ 1.68
Fog in RR ~ 0.38





M. Kimura et al., NIM A 845 (2017) 373 -377

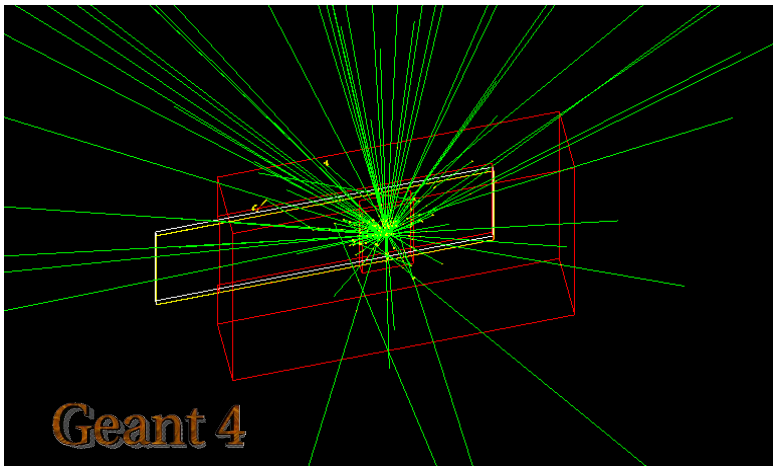
No reduction for the sensitivity in this range as expected (see Kimura et al. plot)

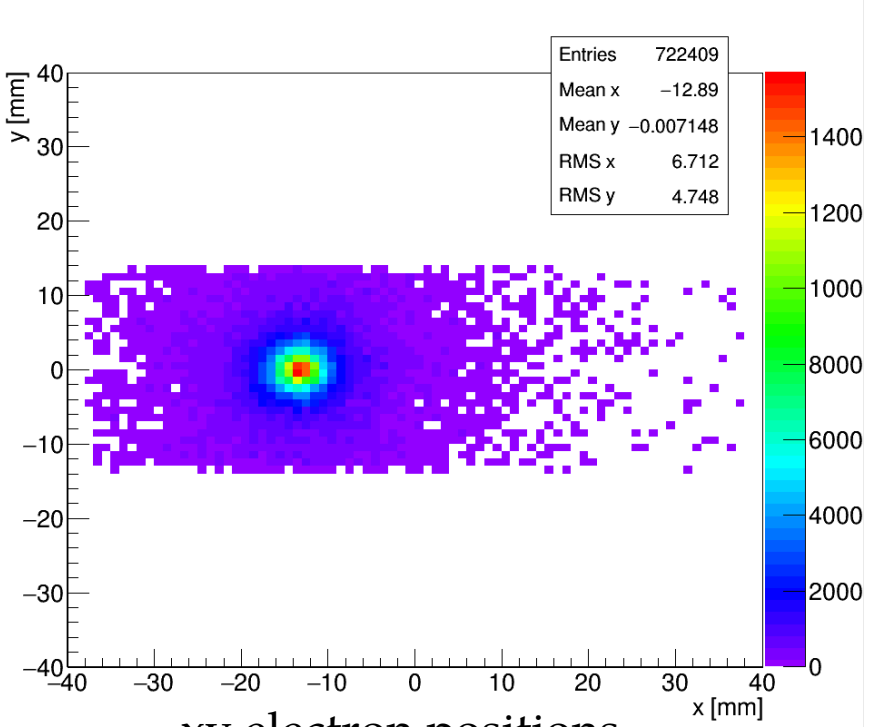
Geant4 simulation

Geant4 implementation

Physics list: LIVERMORE

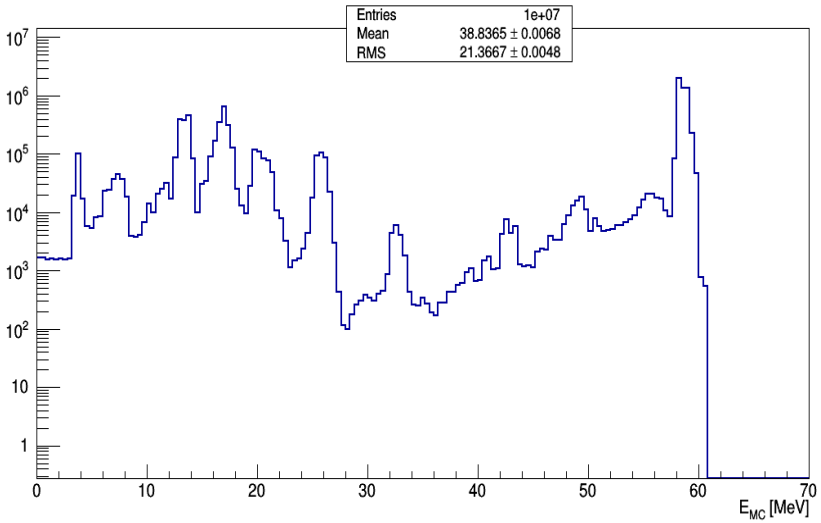
No. electrons stored in NIT: 722.5 %
No. electrons stopped in NIT: 380.8 %
Primary electrons: 66.0 %
Secondary electrons: 314.8 %





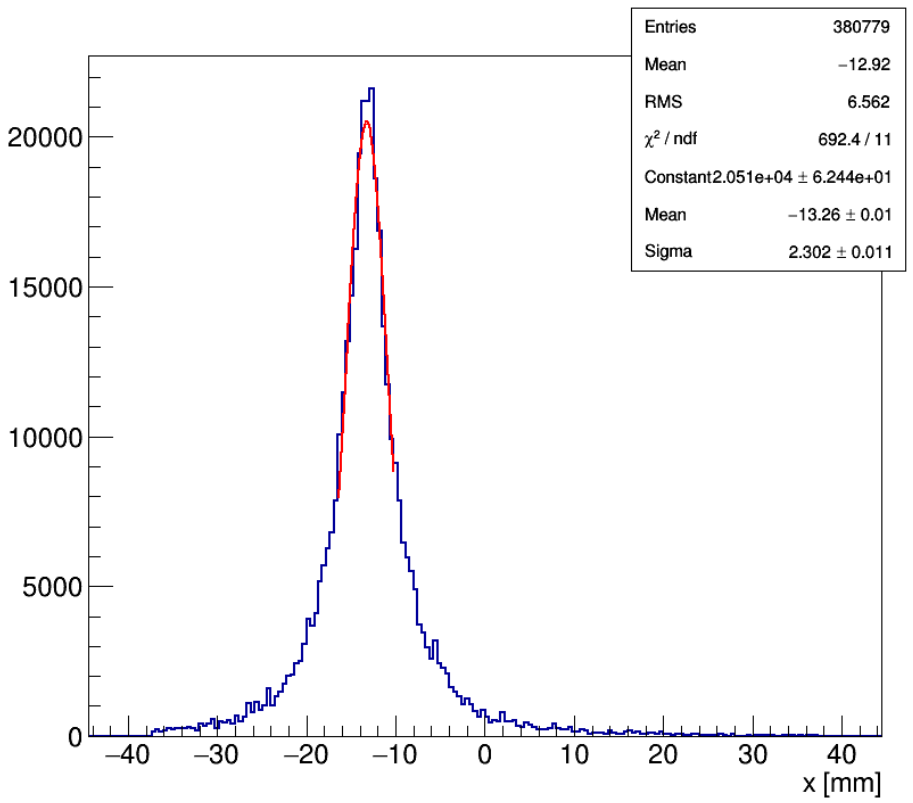
xy electron positions

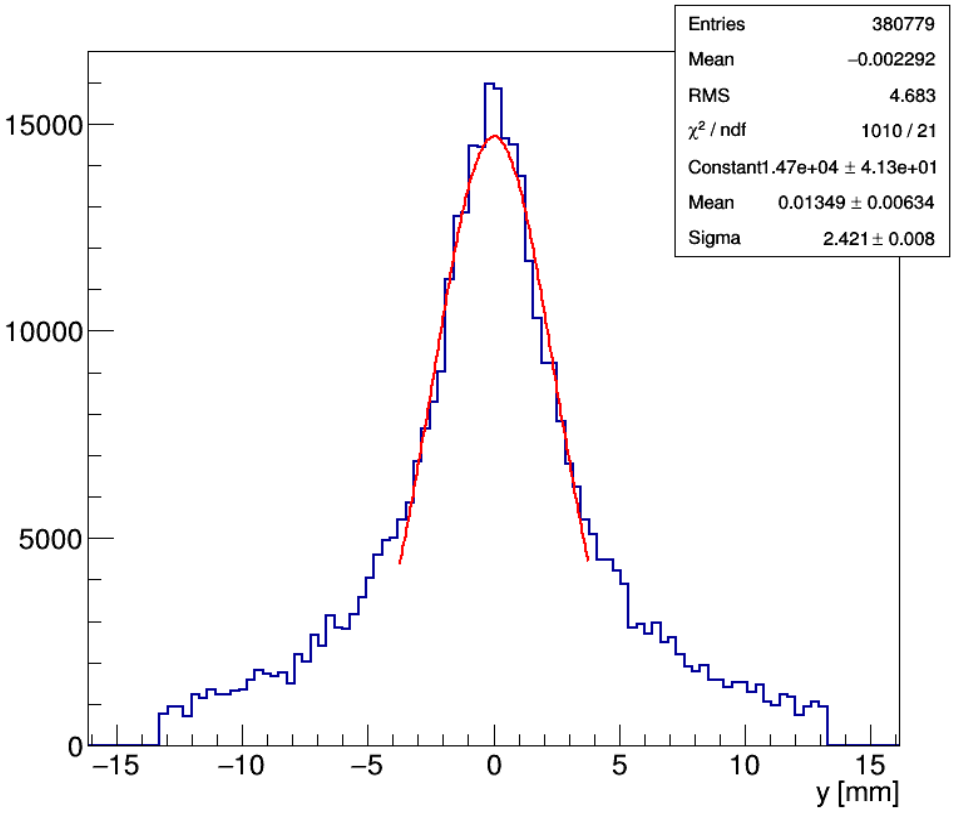
Energy spectrum simulated



Geant4 simulation

Source position wrt NIT film

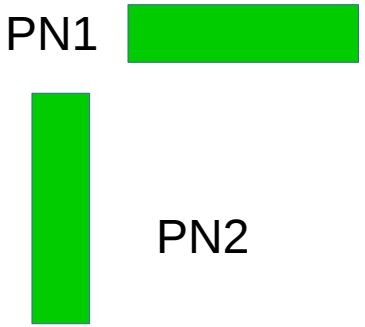




Origin coordinate O (-13.25 , 0.01) mm

Geant4 simulation

Electron propagation



Density of all stopped electrons $(10um)^3$

PN1: 24

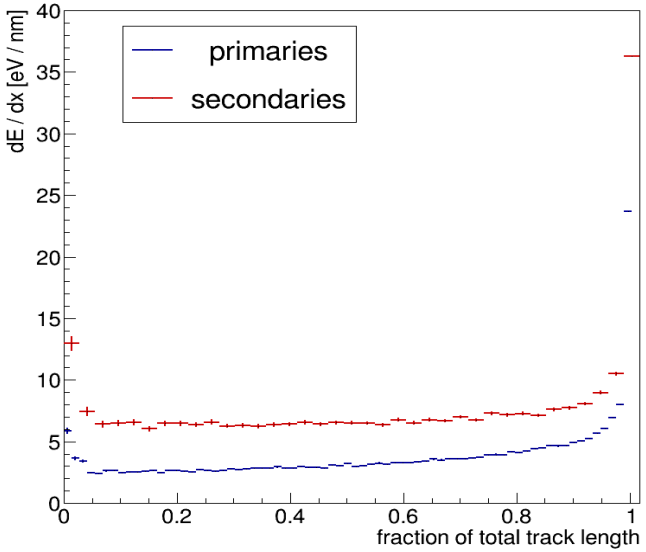
PN2: 32

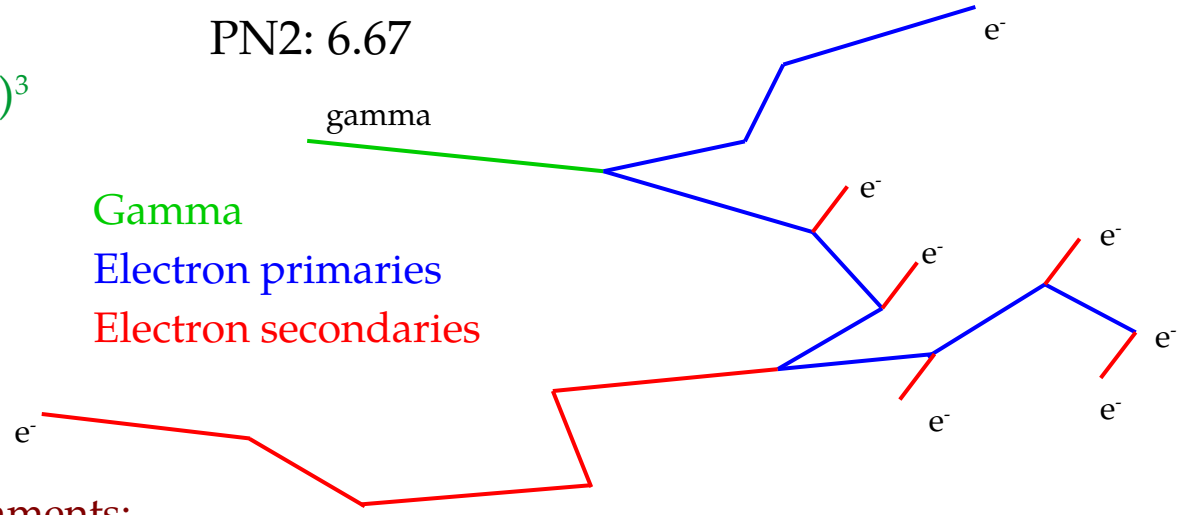
Density of primaries stopped electrons $(10um)^3$

PN1: 4.87

PN2: 6.67

Measured event density ~ 1.15 $(10um)^3$





Gamma

Electron primaries

Electron secondaries

Comments:

1. The simulation is too detailed with respect to the scanning data
2. Secondaries release the same energy of primaries at the end point
3. They cannot be exclude from the counting
4. Secondaries can be move very far from primaries
5. A clustering approach is needed to fit the measured density

Clustering

Density based algorithm

DBSCAN example

Principle:

Each point is characterized by a local density

A set of point in a cluster is spatially connected

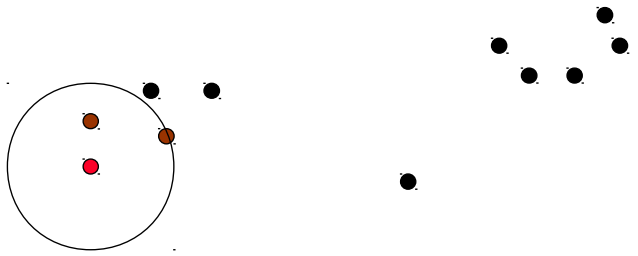
Local density:

$$N_{\varepsilon}(x) = \{ y \in D \mid dist(x, y) \leq \varepsilon \}$$

Clustering

Density based algorithm

DBSCAN example



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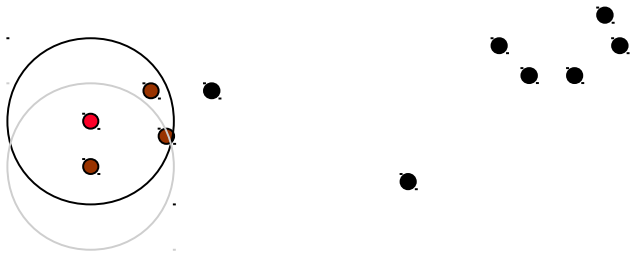

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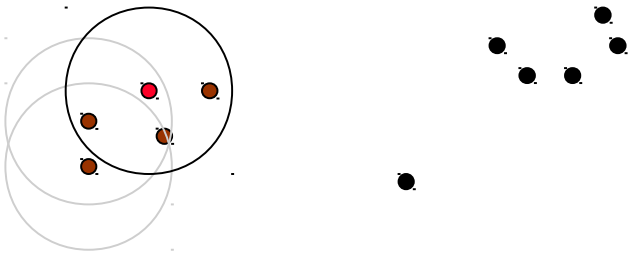

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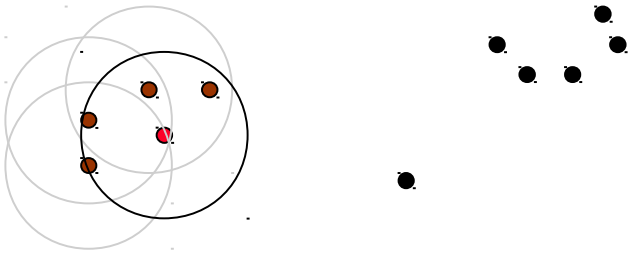

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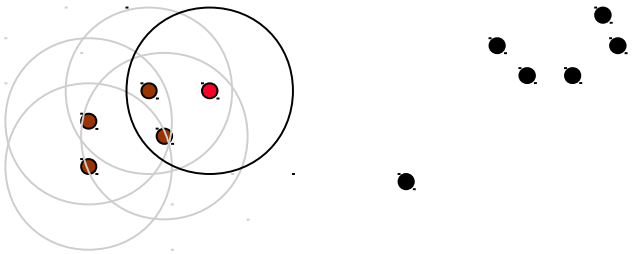

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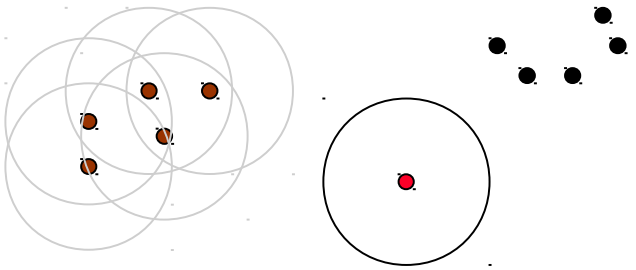

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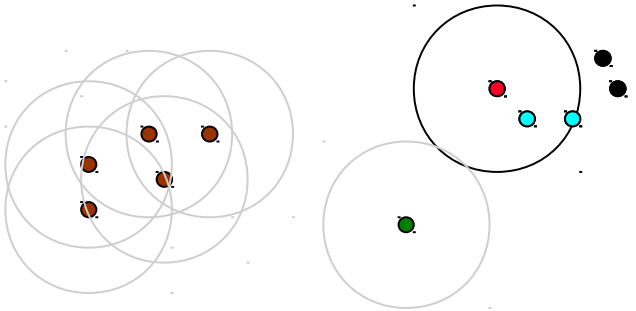

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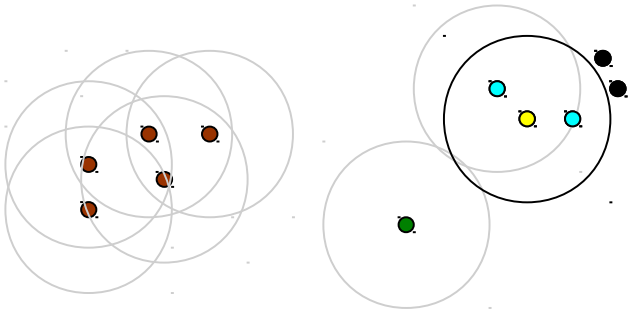

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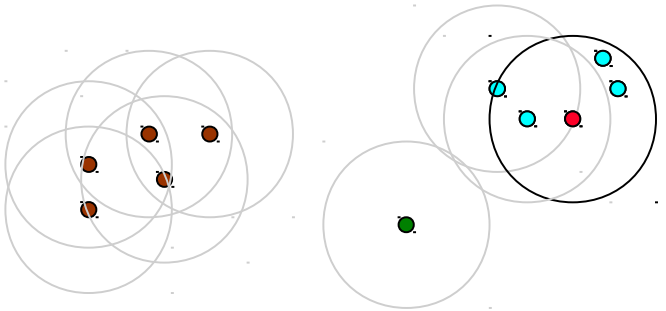

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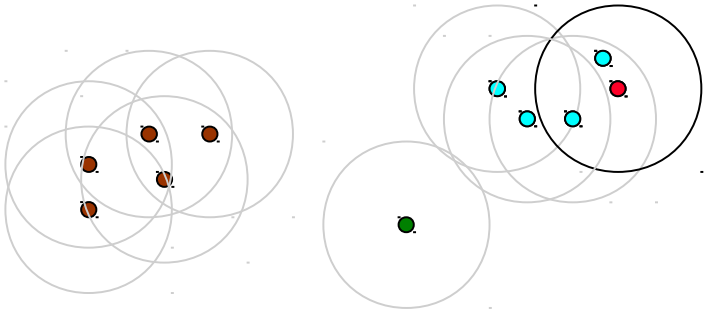

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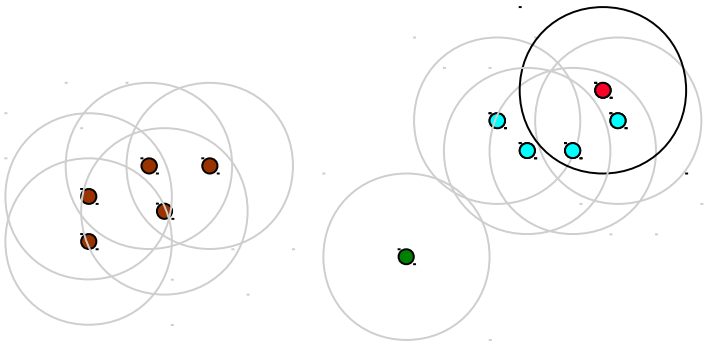

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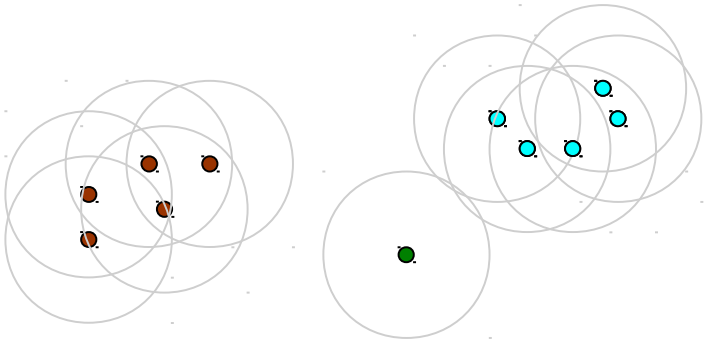

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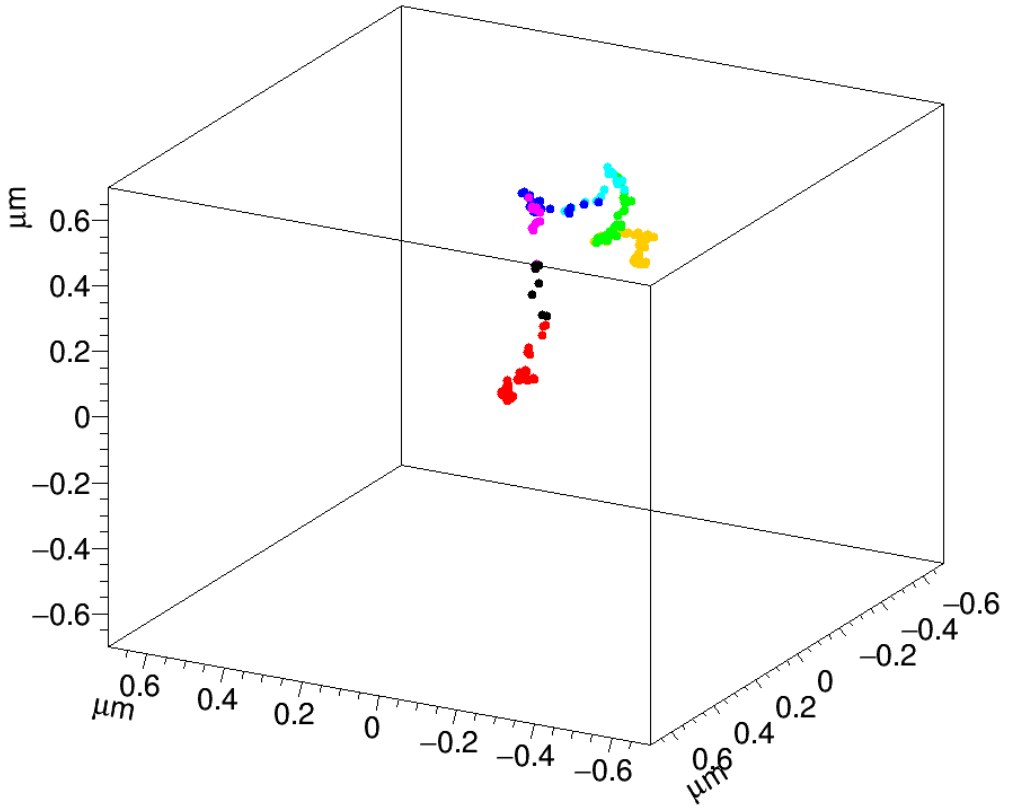
Density based algorithm

Single event simulation



Clustering

Density based algorithm

Aim → Tune the simulation with the data for the environmental exposure

Shrinkage : 0.6

Measured event density ~ 1.15 $(10um)^3$

$d_1 = 100$ nm → Average size of crystal + gelatine

$d_2 = 450$ nm → Minimum recognition distance in japanese microscope

Strategy:

1. Clustering event by event of the stopped electrons ($\varepsilon_1 = 100$ nm) → Small clusters
2. Study of energy threshold on small clusters
3. Clustering of survived small clusters over all the events ($\varepsilon_2 = 450$ nm) → Big clusters
4. Event density = Big clusters / Shrinkage / $(10um)^3$

Results

Data/simulaton comparison

Tune the simulation with the data for the environmental exposure

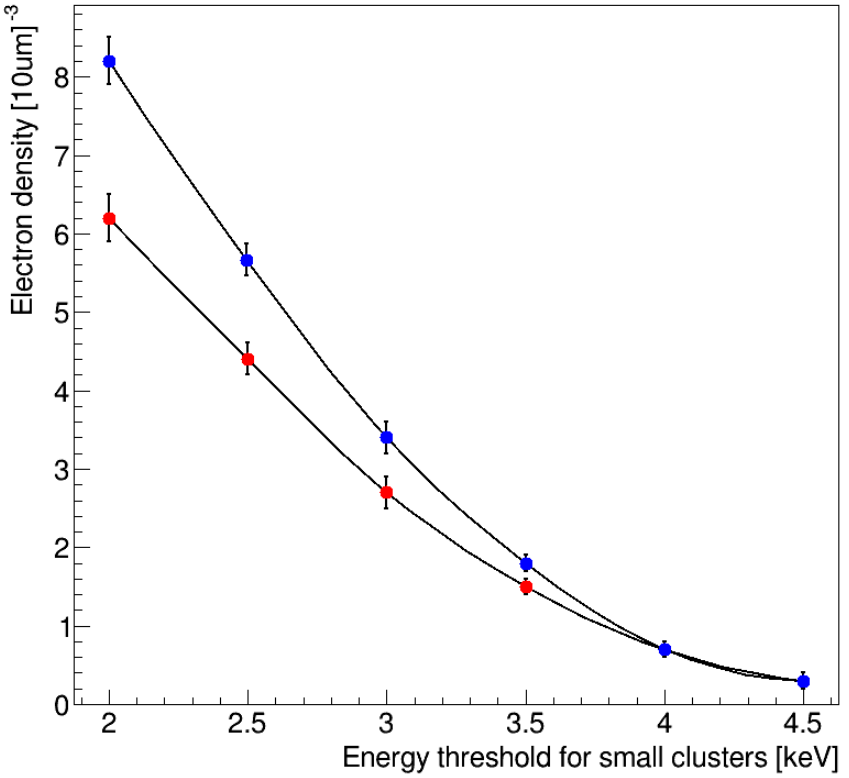
Measured event density ~ 1.15 $(10um)^3$

E_{thr} in 3.5 – 4 keV fits with the measured density

This value could represent the minimum energy required to produce a fog grain in NIT emulsion

This calibration needs to be validated with other exposure to gammas

Perspectives: simulation to ^{14}C to study the expected electron density



Thank you