Cluster method of primary neutron identification and energy reconstruction by the HGND

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for the HGND team

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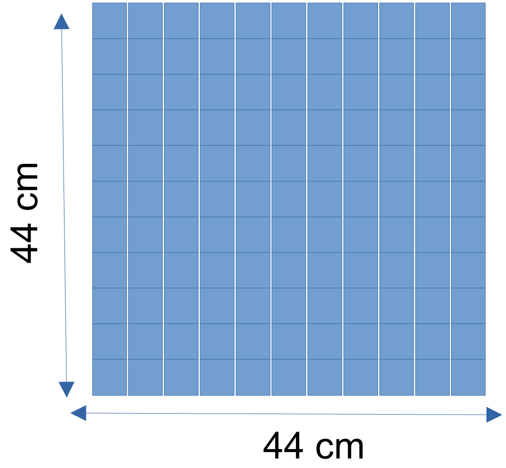
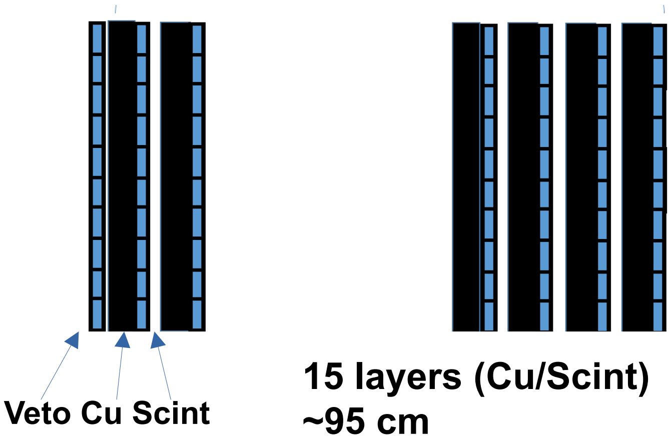
Outline

- High Granular Neutron Detector (**HGND**)
- Algorithm of **cluster** search
- **Selection** of clusters corresponding to neutrons
- **Efficiency** of the algorythm
- **Purity** of the algorythm
- **Conclusions**

Structure of HGND

- Transverse size of one layer: 44 x 44 cm^2,
- number of layers: – 15 + Veto,
- structure of layer:
- 3 cm Cu (absorber) + 2.5cm Scint. + 0.5cm (SiPM+FEE)
- size of scintillation detectors (cells): 4x4x2.5 cm^3,
- total number of cells: 1936
- light readout: one SiPM with sensitive are 6 x 6 mm^2 per cell
- total length of the HGN: ~ 95 cm (~3 λ_{in})



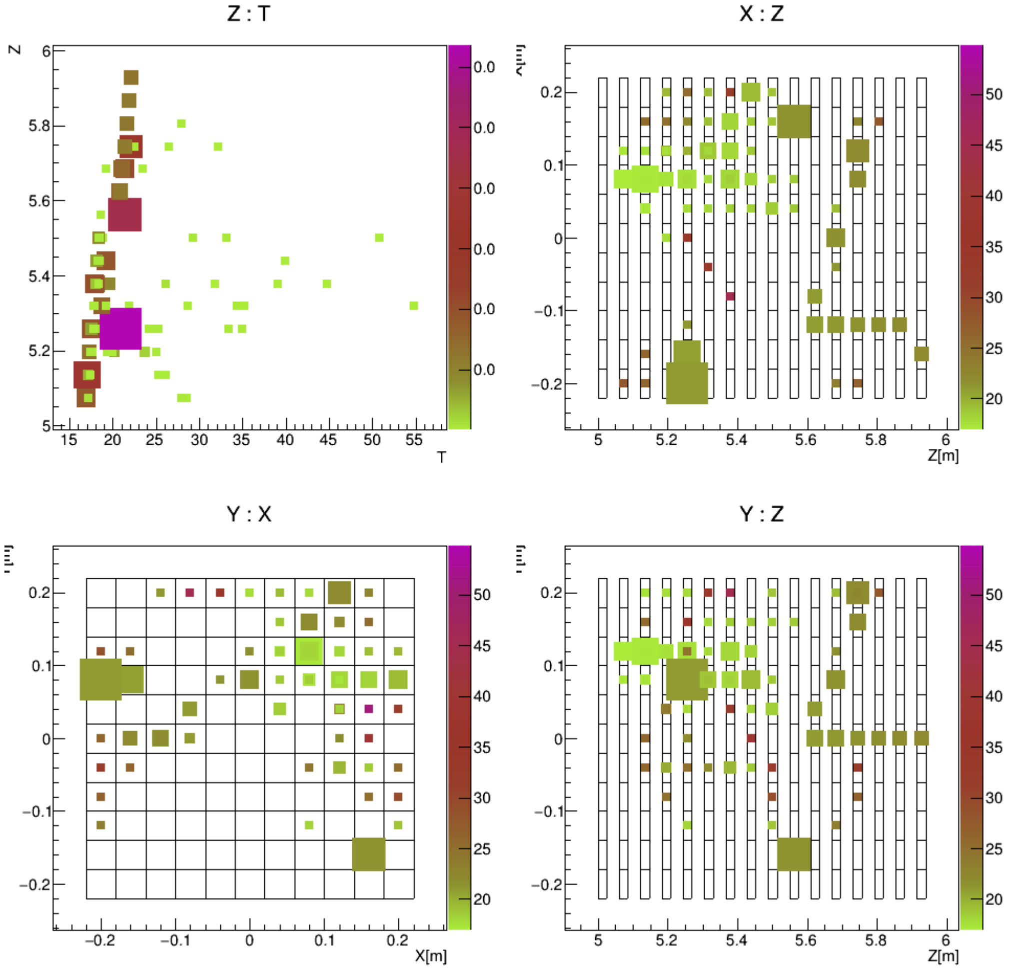


Motivation

- Several particles hit detector in one event
- One particle cause firing of several cells

- Hits in HGND must be joint into **clusters**

- For flow analysis we must select **primary neutrons**



Neutron multiplicity distribution on the entrance of the HGN

Primary neutrons
Primary neutrons with time < 25nsec.
Background neutrons
Background neutrons with time < 25 nsec
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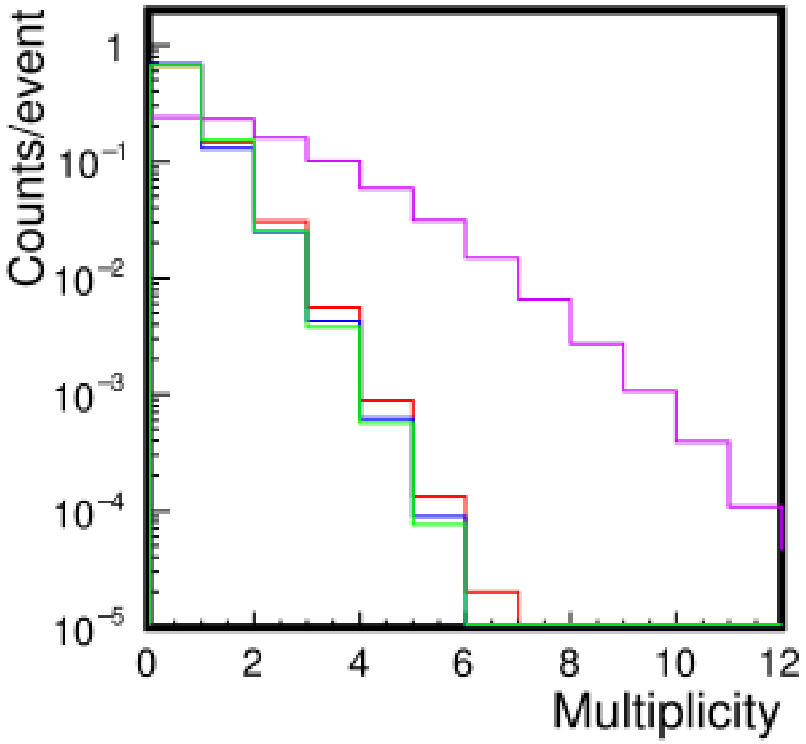


Algorithm of cluster search

1. Sort fired cells by time.
2. Find first unchecked fired cell, make new cluster.
3. Check all neighbouring cells.
   - if the cell fired
   - if firing of the cell can be caused by the checked cell ($d < c \cdot t$)
   - if the cell don't belong to any cluster yet

   If all conditions fulfilled => add neighbouring cell to the cluster, mark it as unchecked, go to next neighbouring cell.

   4. When all neighbours of the cell are checked, mark the cell as "checked".
   5. Go to next unchecked cell in this cluster.

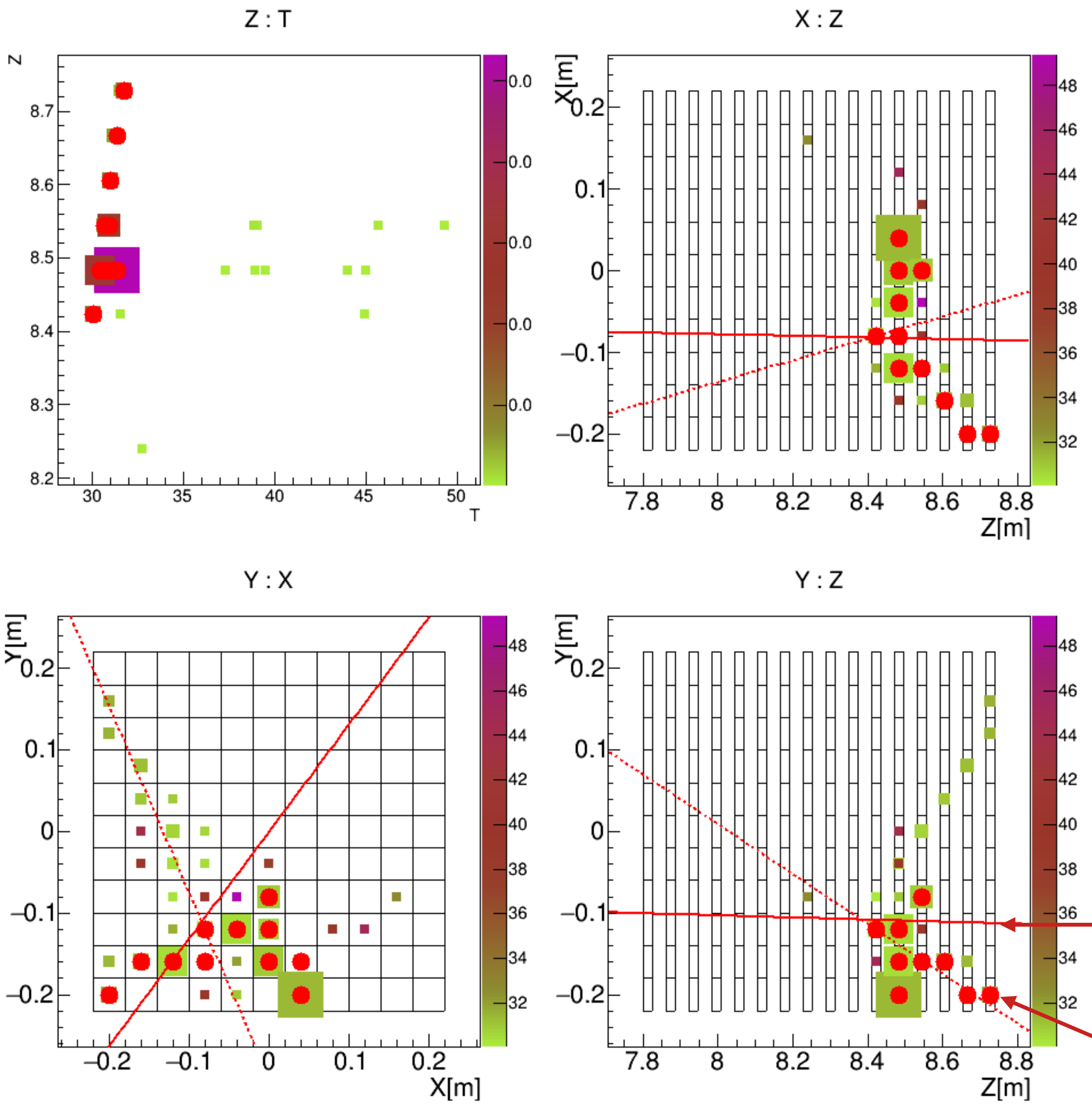
Selection of neutrons

6. When all cells of the cluster are marked as "checked", analize the cluster:
- if the cluster contains cells of veto layer → reject it, assuming this is charged particle
- define time of flight; if it's greater than threshold, reject the cluster
- assuming this is a neutron, define its kinetic energy by the time of flight
- if the cluster contains less than 2 cells, reject it
- define the direction of movement; if it doesn't coincide with target, reject the cluster
- calculate deposited energy in cluster

7. Search for new cluster untill all fired cells are marked as "checked"

Example

- **Simulation:**
- Box generator
- Only single neutrons
- 0 degrees
- Distance = 780 cm
- E neutron = 2.65 GeV



Simulated trajectory of a neutron

Reconstructed trajectory of a neutron

Varied parameters of the algorithm

- Cut on deposited energy in cell (1-3 MeV)
- Cut on deposited energy in cluster (3 MeV * nCells)
- Cut on number of fired cells (Nfired > 1)
- Cut on reconstructed direction ($\theta < 45^\circ$)

Analysis of cluster

- Define beta by fastest fired cell → Energy of neutron
- Reconstruct direction of movement (very rough)
- Sum deposited energy in cluster

Quality of the algorithm

- **efficiency**

$$\frac{number\ of\ correctly\ recognized\ neutrons}{number\ of\ neutrons\ crossed\ the\ detector\ volume}$$

- if we accept all clusters,
- efficiency → 1

- **purity**

$$\frac{number\ of\ correctly\ recognized\ neutrons}{number\ of\ clusters\ recognized\ as\ neutrons}$$

- if we reject all clusters,
- purity → 1

Efficiency

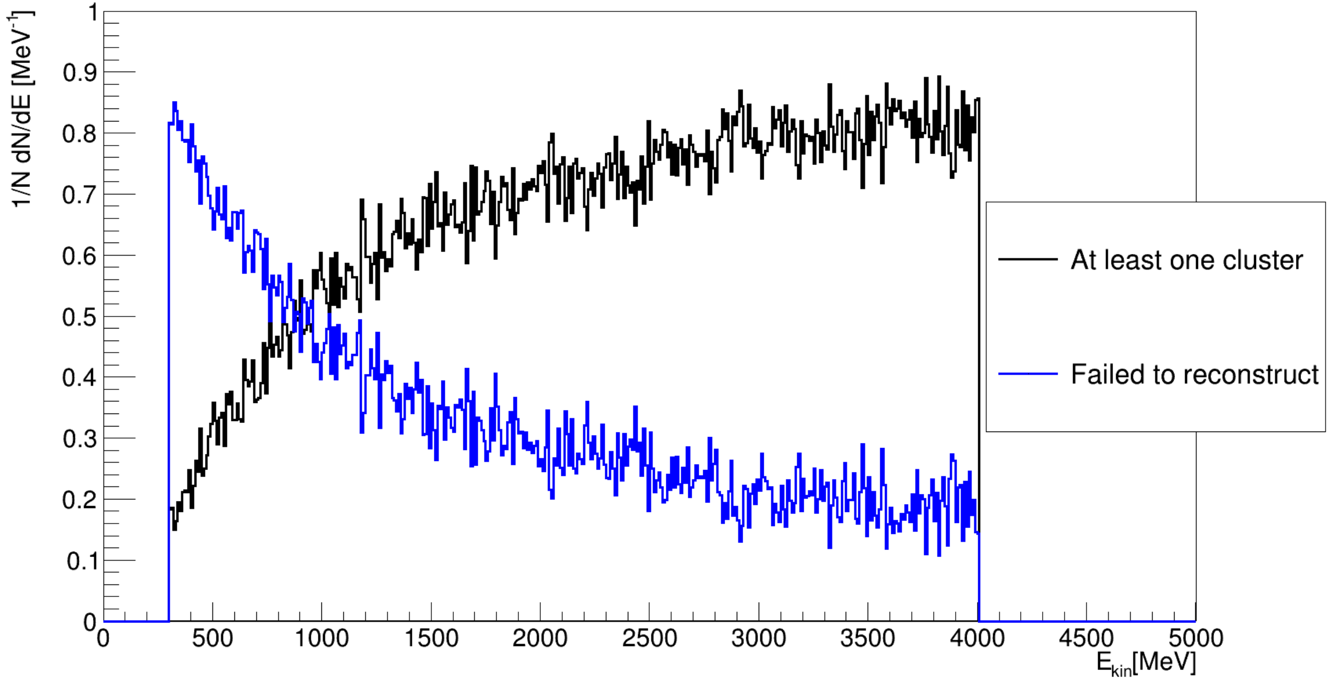
$$efficiency = \frac{number\ of\ correctly\ recognized\ neutrons}{number\ of\ neutrons\ crossed\ the\ detector\ volume}$$

The efficiency is determined by the following probabilities:

- probability to interact with detector & fire N>1 cells
- probability not to fire veto layer
- **probability to find at least 1 cluster by the algorithm**

The resulting efficiency is product of these probabilities.

Efficiency



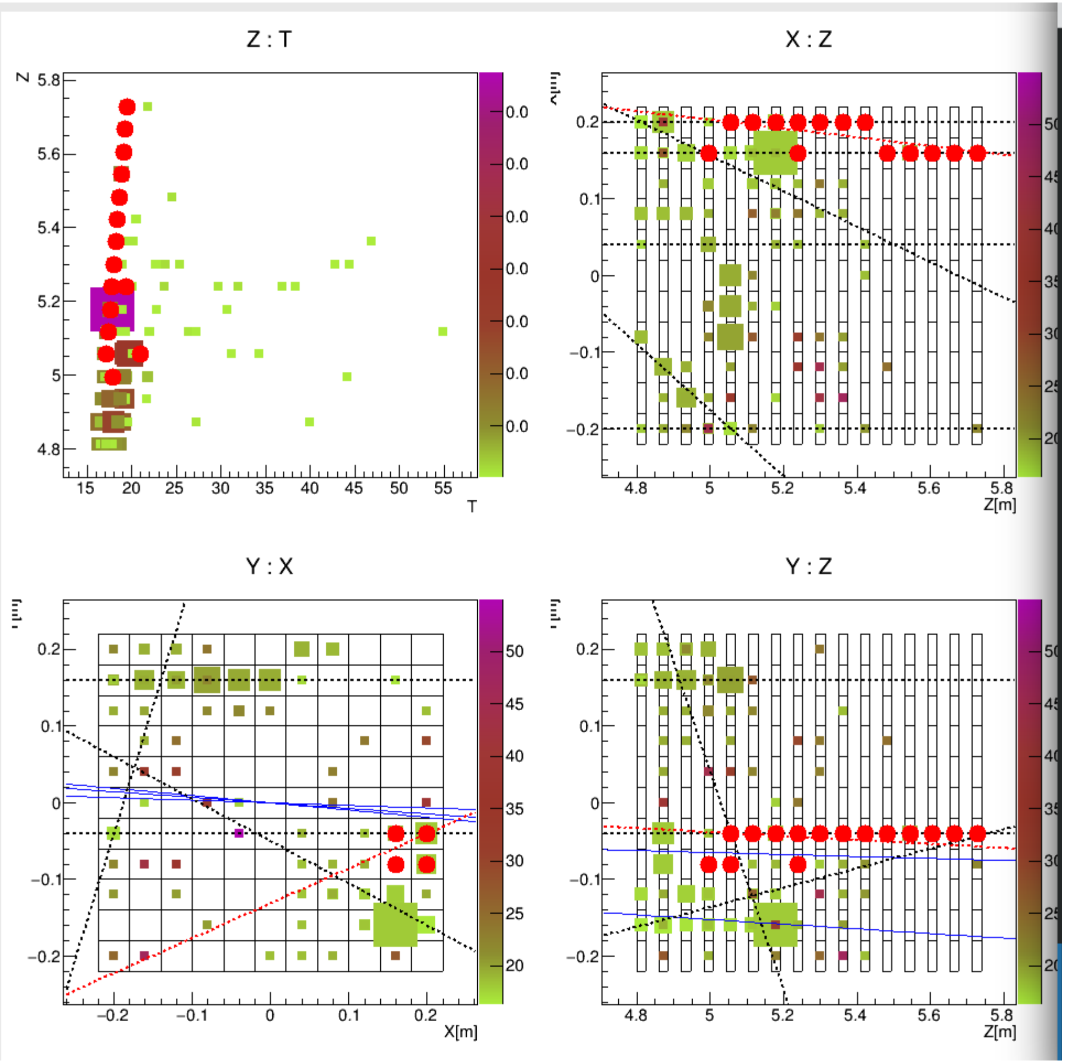
- **Simulation:**
- Box generator
- Single neutrons
- 0 degrees
- 780 cm from target
- Ekin 300-4000 MeV

Purity

$$purity = \frac{number\ of\ correctly\ recognized\ neutrons}{number\ of\ clusters\ recognized\ as\ neutrons}$$

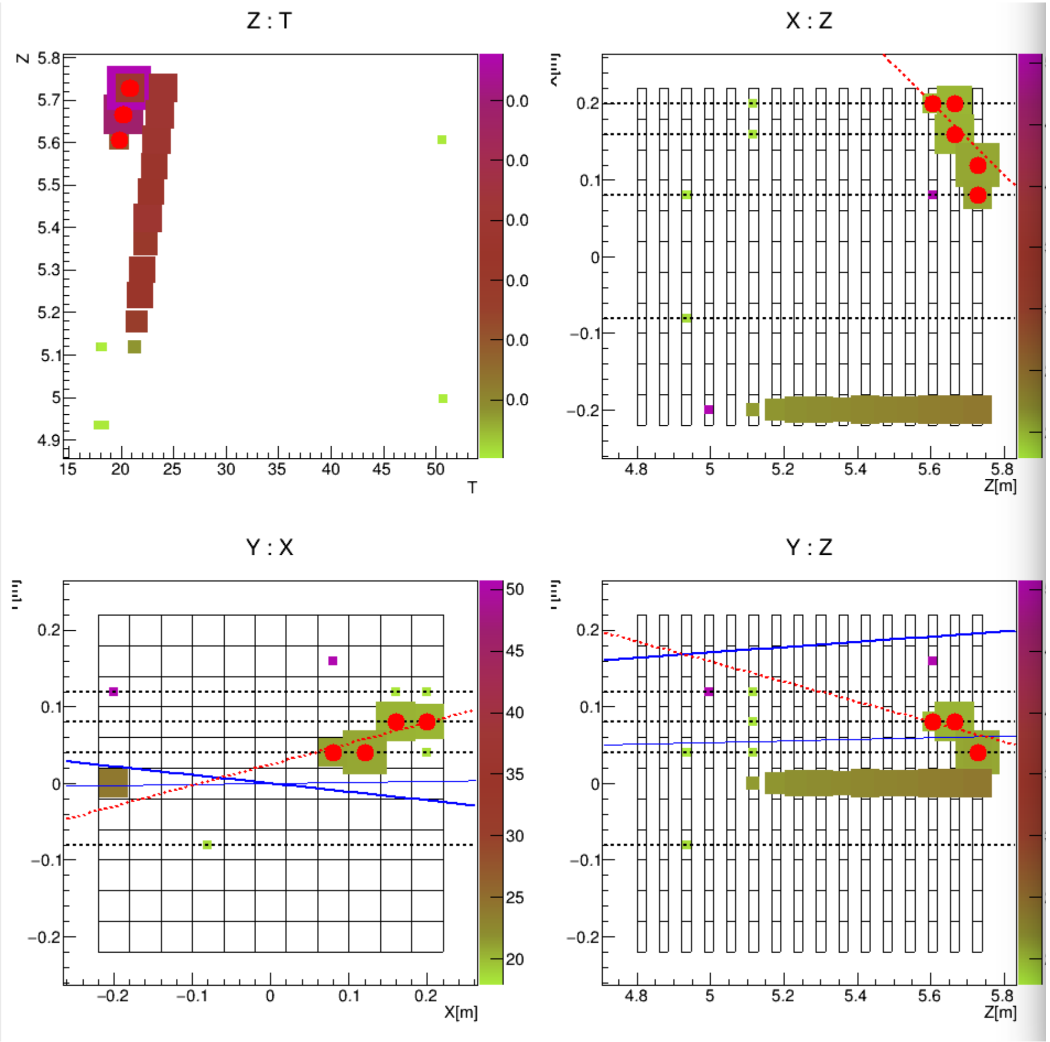
- **Sources of impurity:**
- probability to recognize charged particle as neutron
- probability to recognize gamma as neutron
- probability to recognize several clusters corresponding to one neutron
- probability to recognize secondary neutron as primary

Example 1



- **Simulation:**
- Full BMaN geometry
- Reaction Bi+Bi 3 AGeV
- No primary neutrons
- 480 cm from target
- -22.3 degrees

Example 2'



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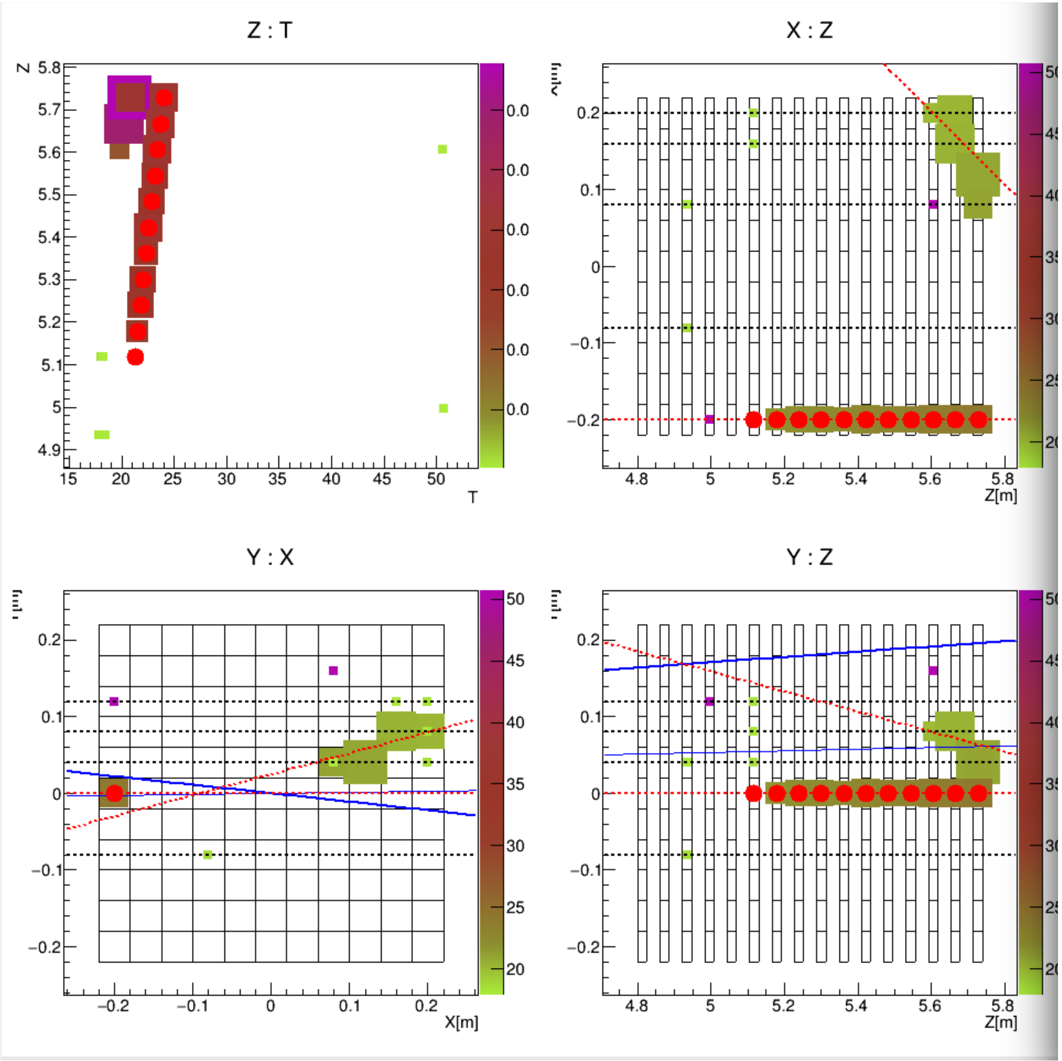
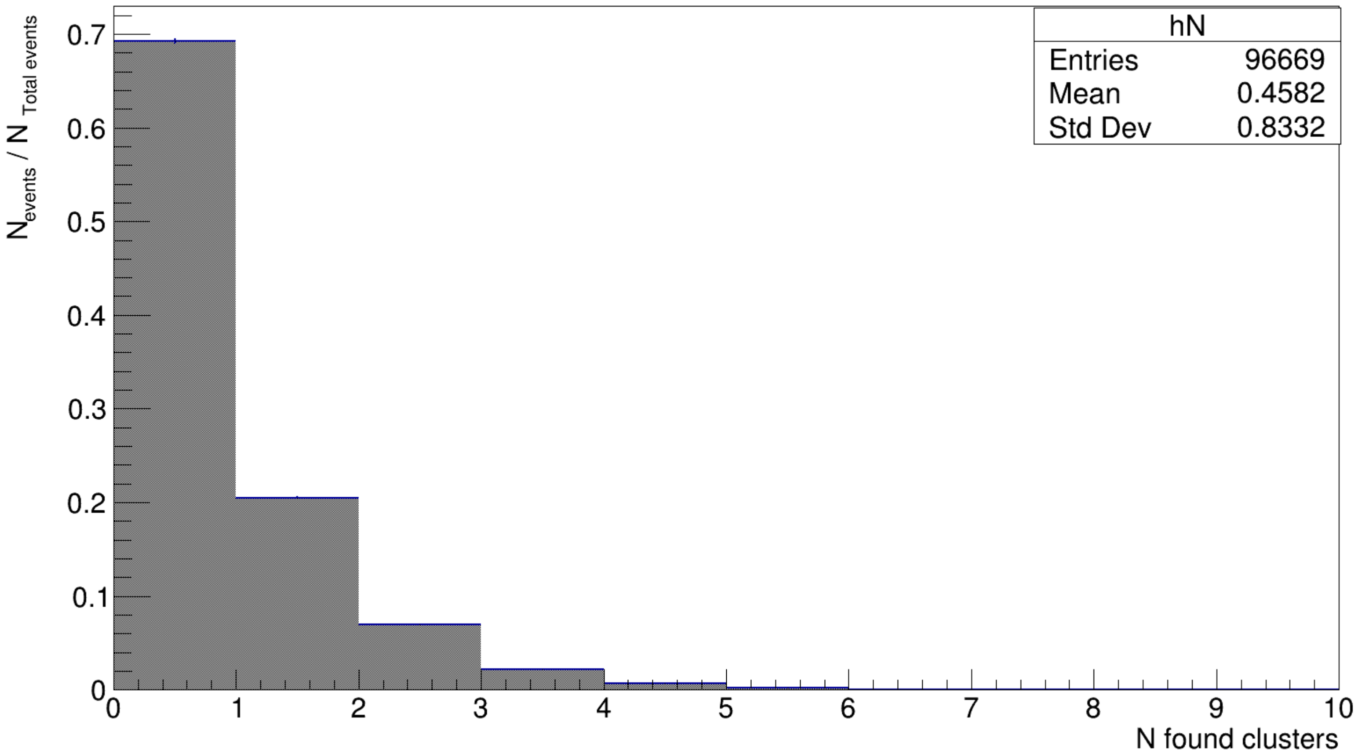


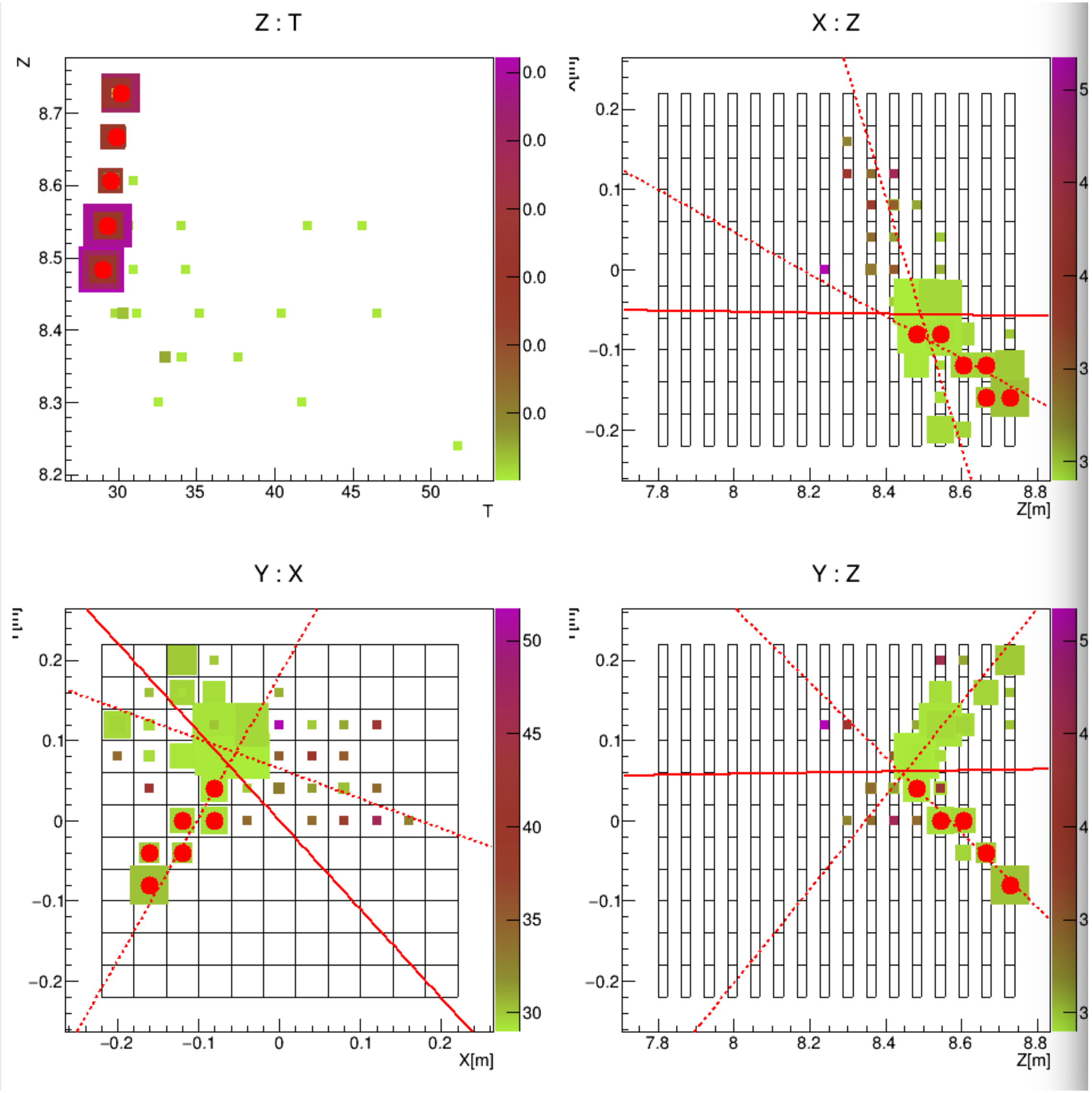
Example 2"

- **Simulation:**
- Full BMaN geometry
- Reaction Bi+Bi 3 AGeV
- No primary neutrons
- 480 cm from target
- -22.3 degrees

Number of recognized primary neutrons (Must be 0)

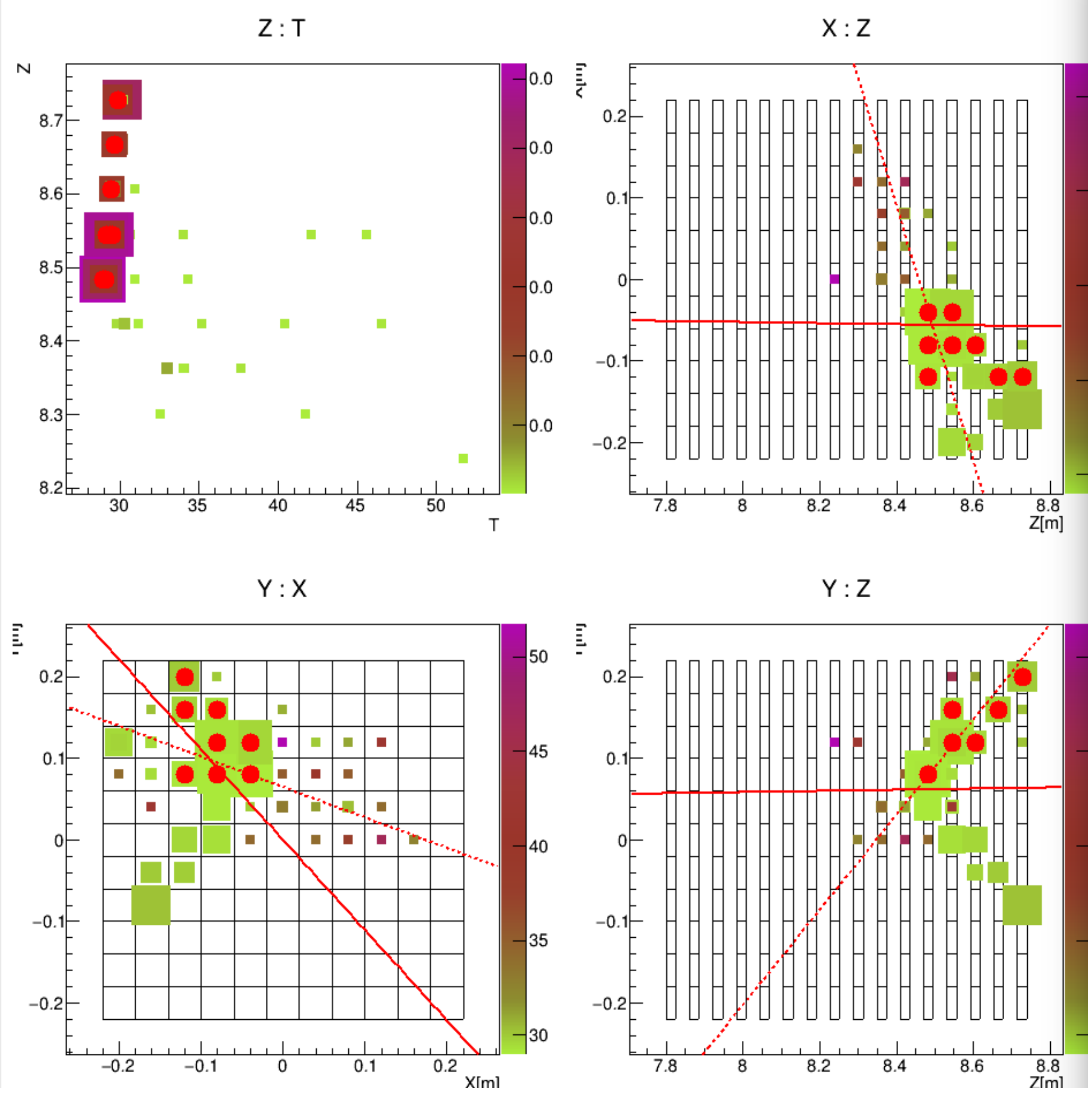
- **Simulation:**
- Full BMaN geometry
- Reaction
- Bi+Bi @ 3 AGeV
- No primary neutrons
- 480 cm
- -22.3 degrees





Example 3'

- **Simulation:**
- Box generator
- Only single neutrons
- 0 degrees
- Distance = 780 cm
- E neutron = 4.48 GeV

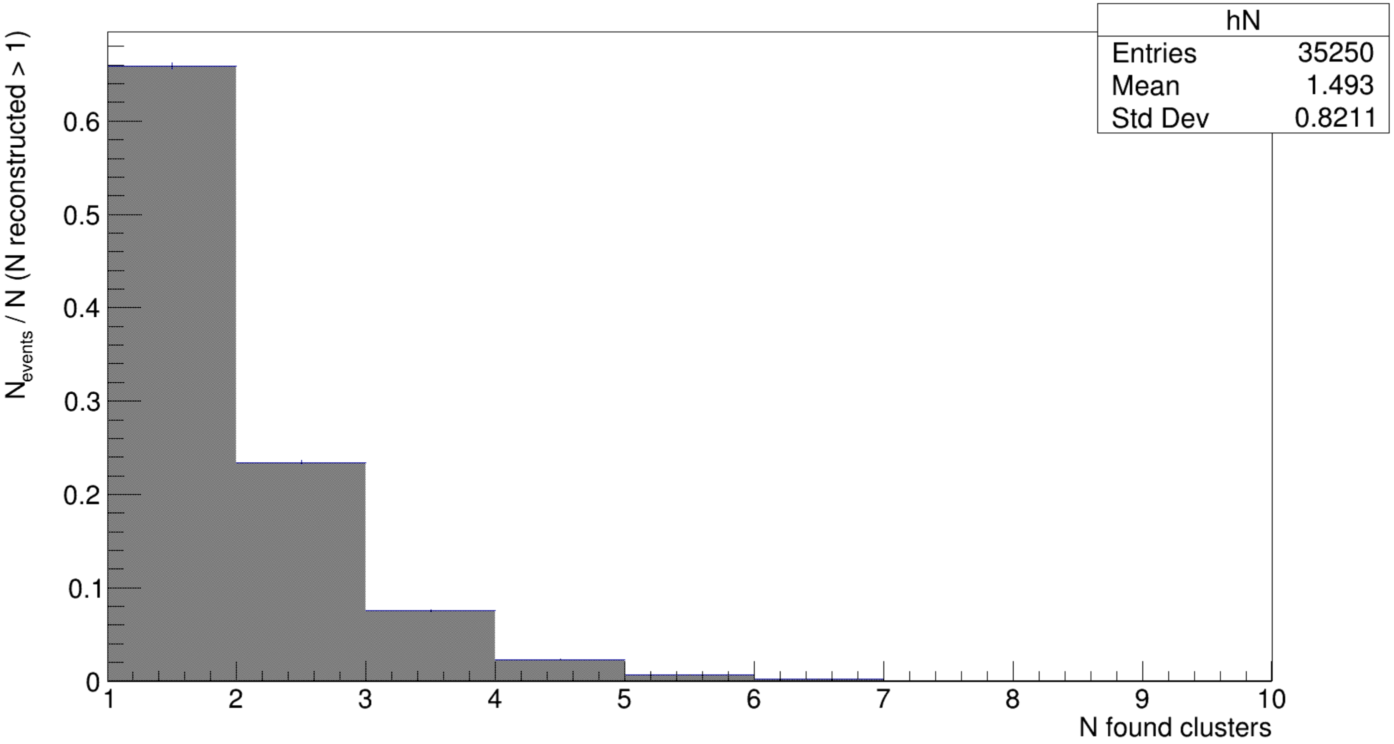


Example 3"

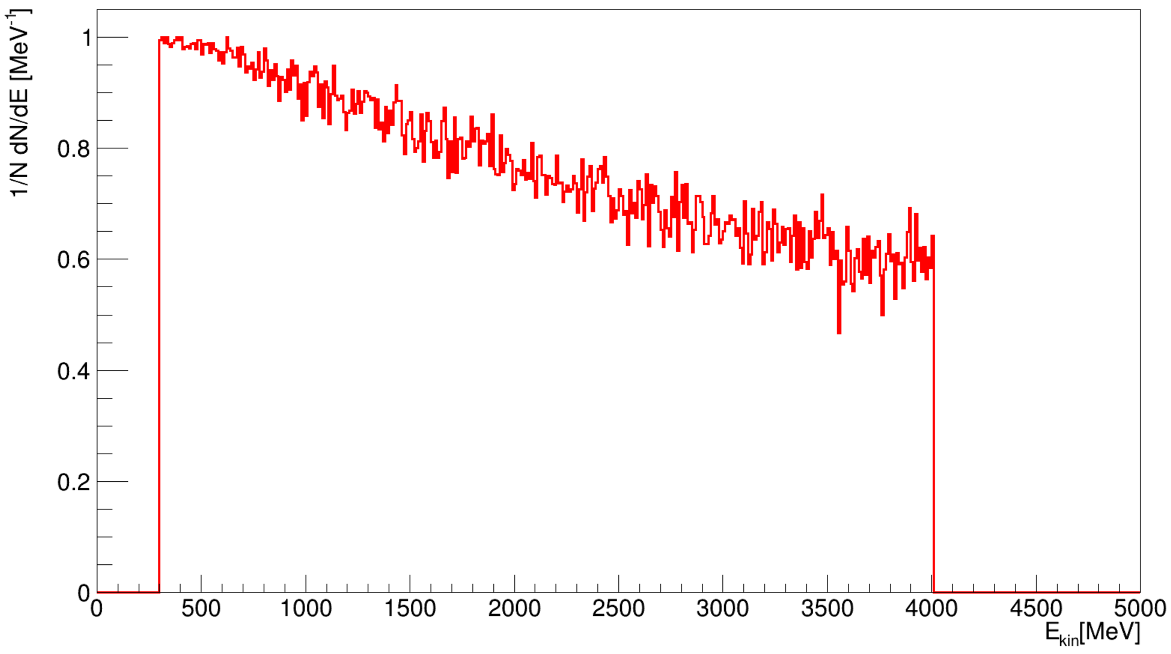
- **Simulation:**
- Box generator
- Only single neutrons
- 0 degrees
- Distance = 780 cm
- E neutron = 4.48 GeV

Number of recognized primary neutrons (Must be 1)

- **Simulation:**
- Box generator
- Single neutrons
- 780 cm
- 0 degrees
- E 300-4000 Mev



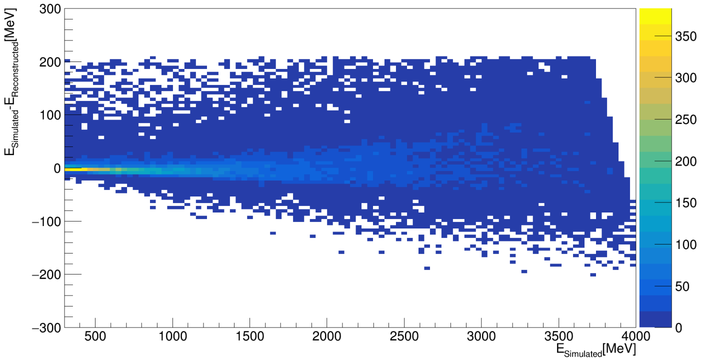
Purity depending on energy of neutron

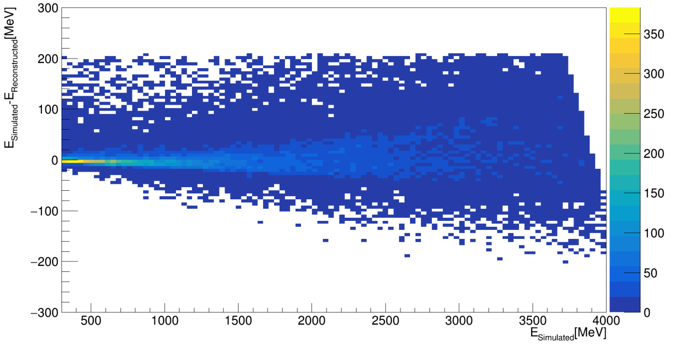


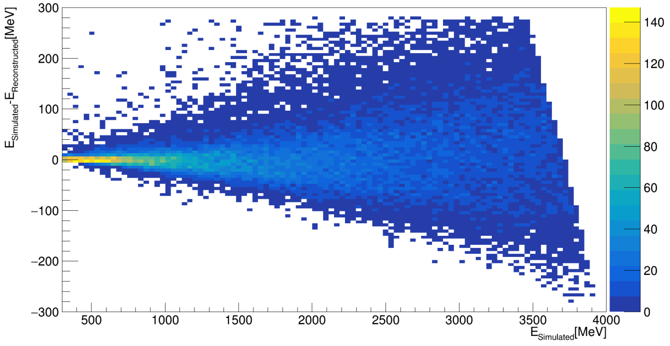
- **Simulation:**
- Box generator
- Single neutrons
- 0 degrees
- 780 cm from target
- Ekin 300-4000 MeV

Different methods of energy reconstruction

- First fired cell
- Fastest fired cell
- Mean velocity in cluster

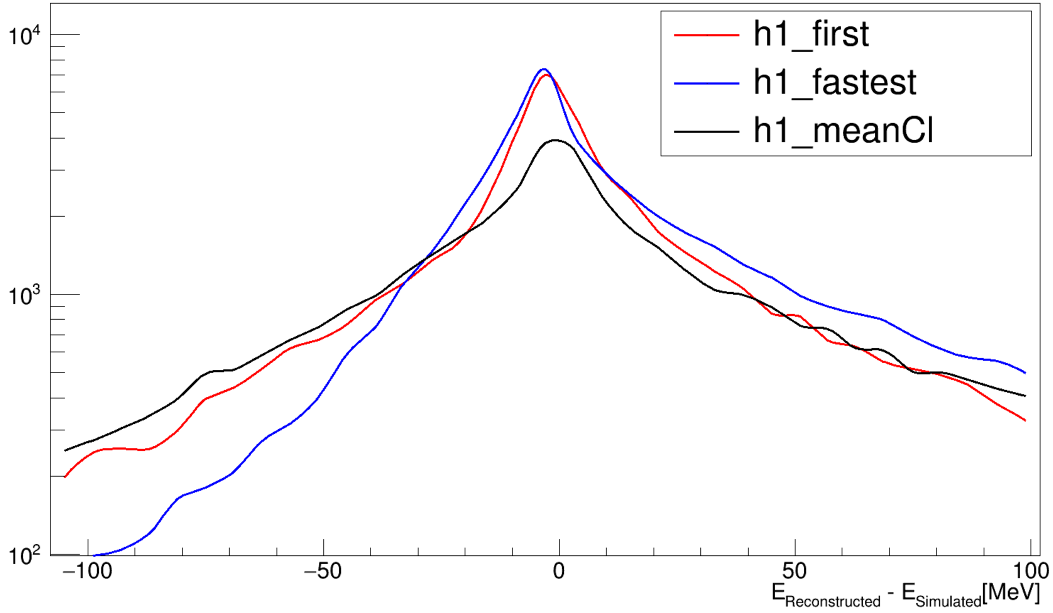






Calculate energy by the time of flight assuming m=939 MeV (mass of neutron)

Energy reconstruction



Different methods give similar results.

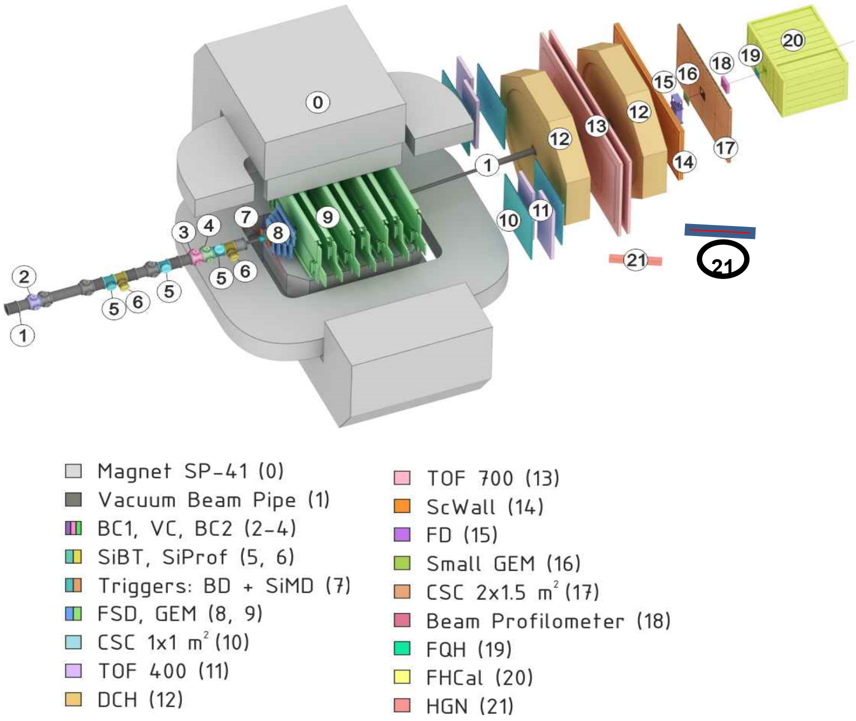
We choose method by fastest fired cell

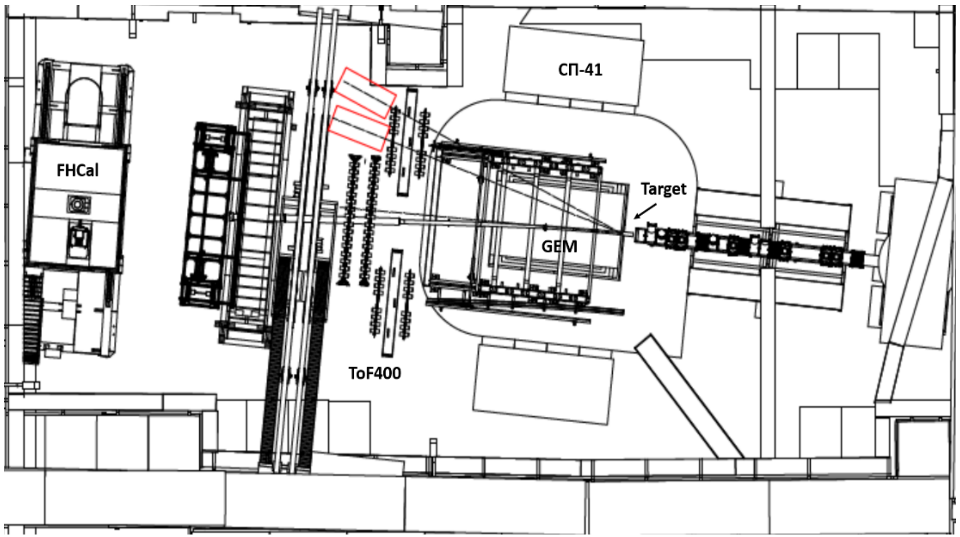
Conclusions

1. Algorithm of cluster search was developed
2. Efficiency of the algorithm reaches 80 % at high energies of the neutron
3. Purity of the algorithm is ~70 %, must be improved
4. Adjustment of parameters of the algorithm is needed to improve purity and efficiency

Thank you for your attention!

Positions of HGND at the BM@N



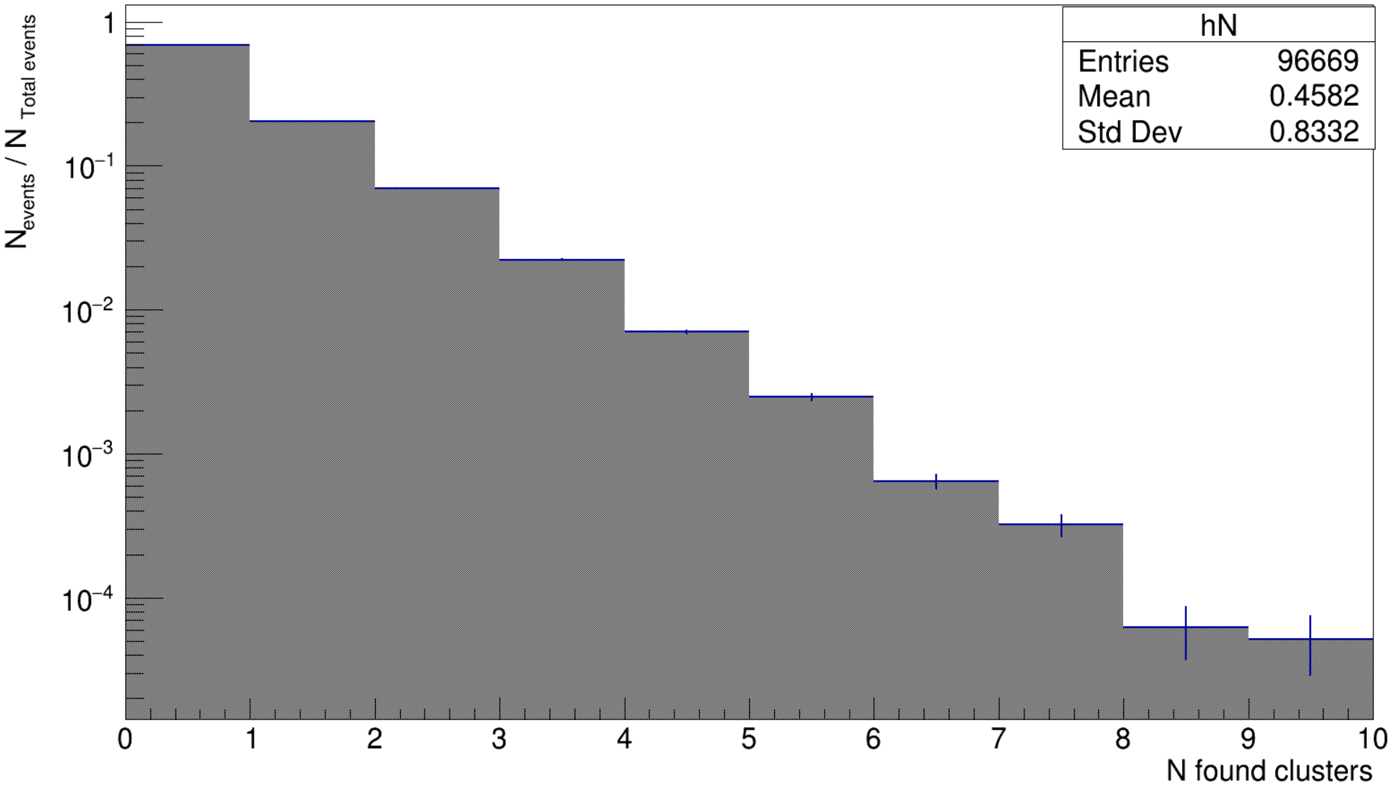


There are some constrains to install neutron detector at the BM@N:

- Angle to beam: 17 / 23 degrees
- Distance from target: 500 cm.

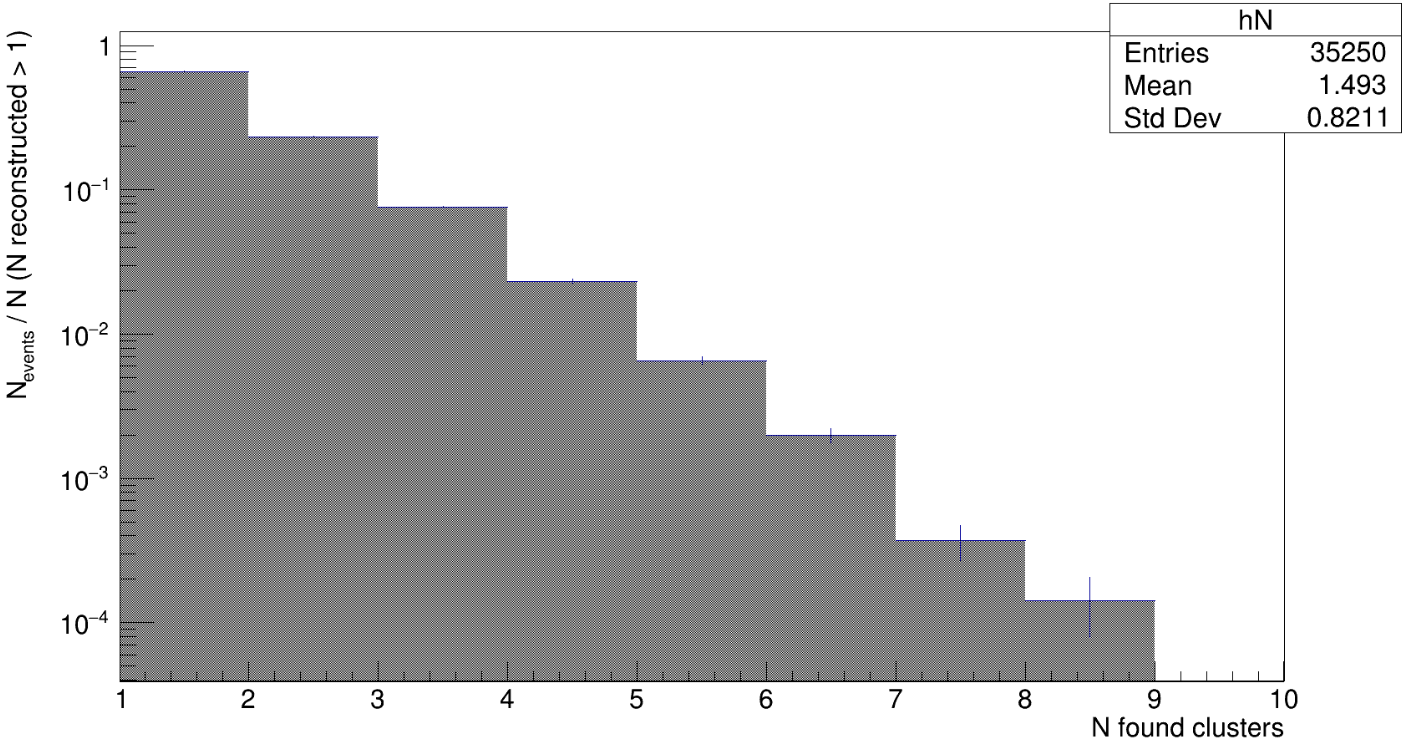
Number of recognized neutrons (Must be 0)

- Full BMaN simulation
- Reaction
- Bi+Bi @ 3 AGeV
- No primaty neutrons
- 480 cm
- -22.3 degrees

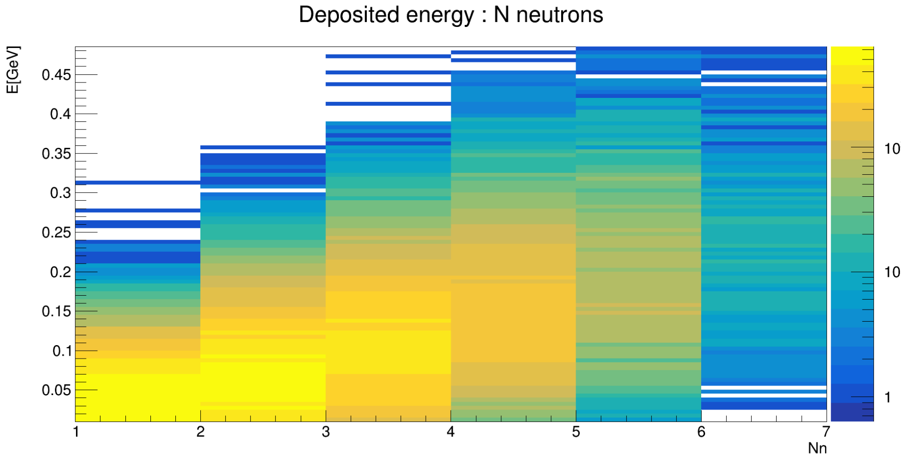


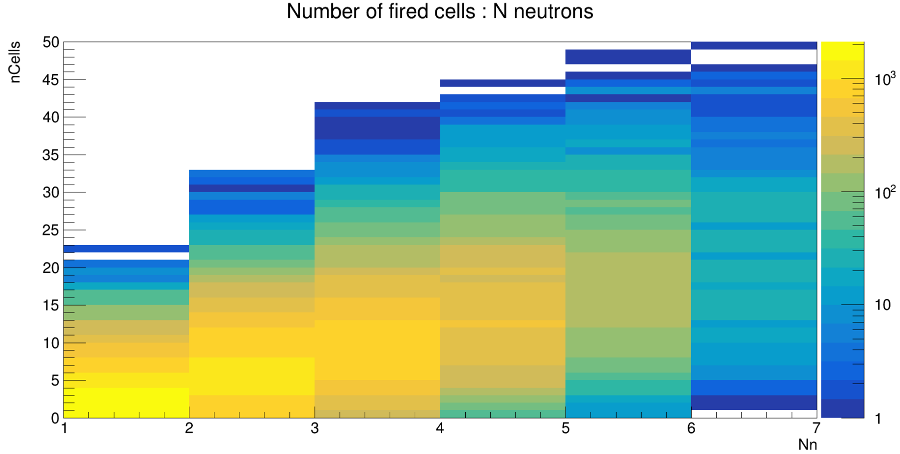
Number of recognized neutrons (Must be 1)

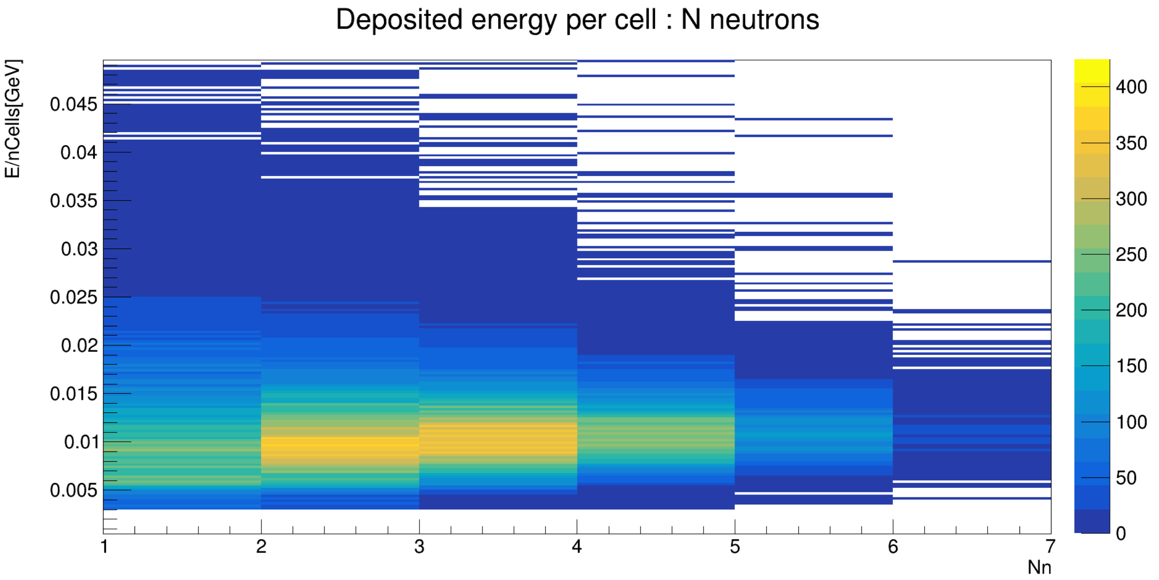
- Box generator
- Single neutrons
- 780 cm
- 0 degrees
- E 300-4000 Mev



Deposited energy, number of fired cells : number of neutrons







Box generator, 1-6 neutrons, 1000 MeV, 780 cm, 0 degrees, no BM@N detectors, no magnetic field