Algorithm of neutron identification with the HGND at the BM@N experiment

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Outline

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4. Selection of clusters produced by neutrons
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5. Analysis of groups of selected clusters
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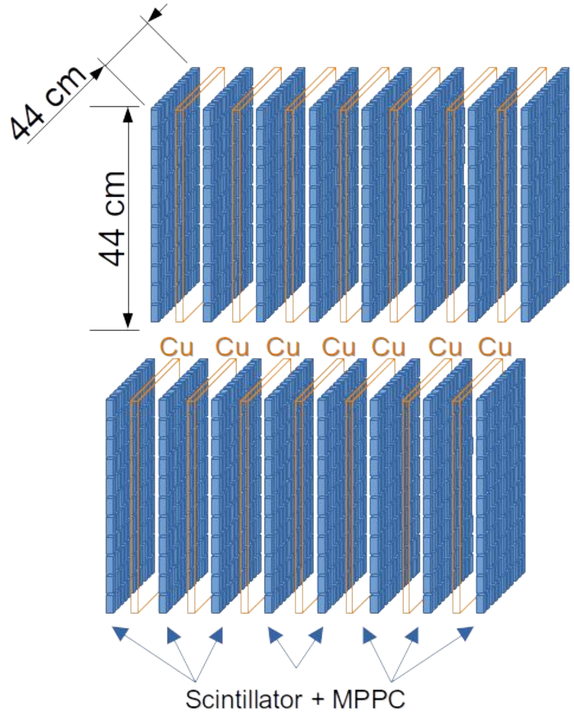
6. Conclusion

Motivation

- HGND has been developed to measure **neutrons**
- Neutrons must be **identified** amongst other particles hitting the detector with **only HGND** (no other detectors are involved in this analysis)
- Each particle fire **many cells** in HGND
- Fired cells are combined into **clusters**. The analysis of data is carried out on the level of clusters
- Cluster method of analysis includes the following steps:
    - **recognition** of clusters
    - **selection** of clusters produced by neutrons
    - **analysis** of selected clusters

HGND detector

- Two parts
- 8 layers of scintillator 11x11 cells
- 7 layers of Cu convertor in between of scintillator layers
- MPPC connected directly to scintillator
- Time resolution ~130 ps



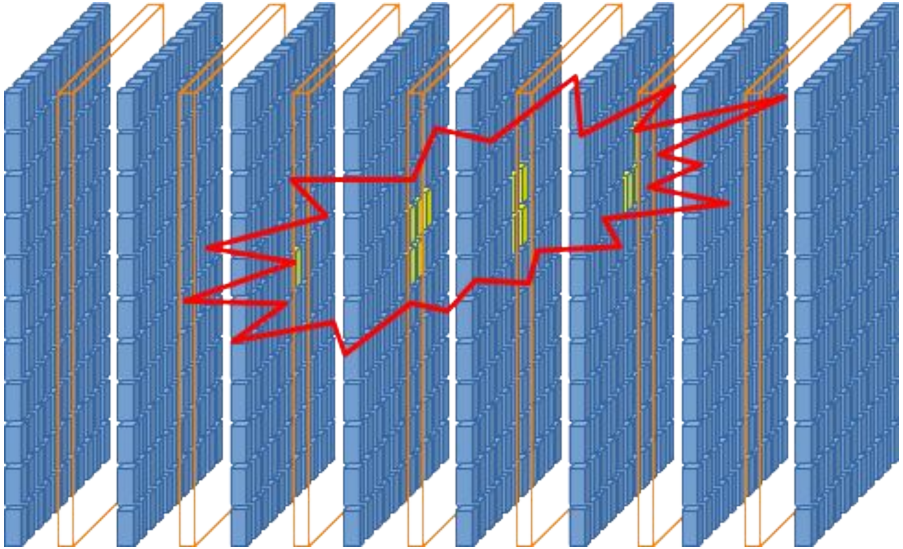
Clusters

The particles traversing HGND can fire many cells in one event. Analysis of data starts from combination of fired cells into clusters.

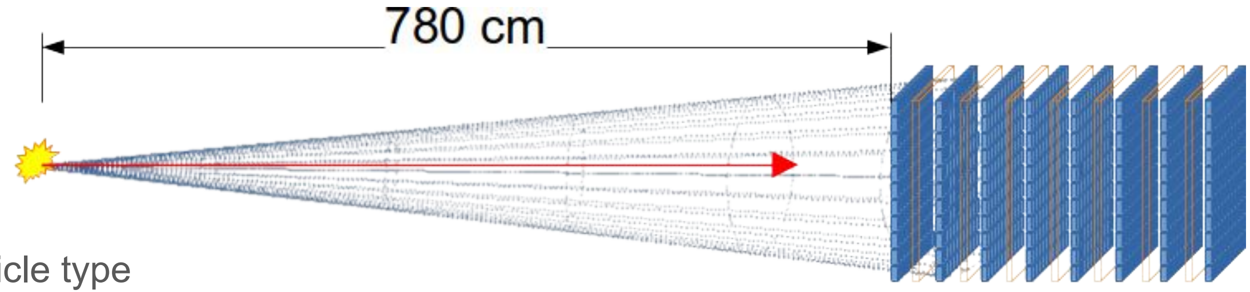
- Deposited energy in each cell **Edep>3 MeV**
- Cluster is a set of **neighbouring fired cells** with **close timestamps**
- Number of fired cells **n>1**

Implemented to BmnRoot:

BmnNdetCluster
BmnNdetClusterFinder



Simulation setup



- Box generator
  - single particle
  - n,p,π,μ,e,γ
  - random direction
  - 100k events each particle type
  - 300 MeV < Ekin < 4000 MeV, uniform distribution
- Vacuum in cave, no other detectors
- No magnetic field
- One part of HGND, 780 cm from target

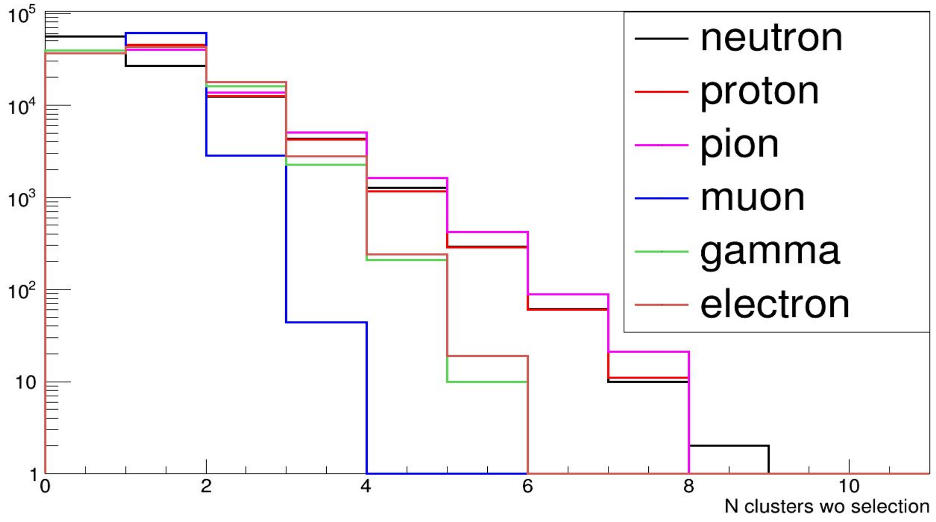
Number of recognized clusters

- Box generator
- Single particle
- 300 MeV < E < 4 GeV

One particle can produce several clusters!

In order to select neutrons, we must

- select clusters
- analyze groups of clusters



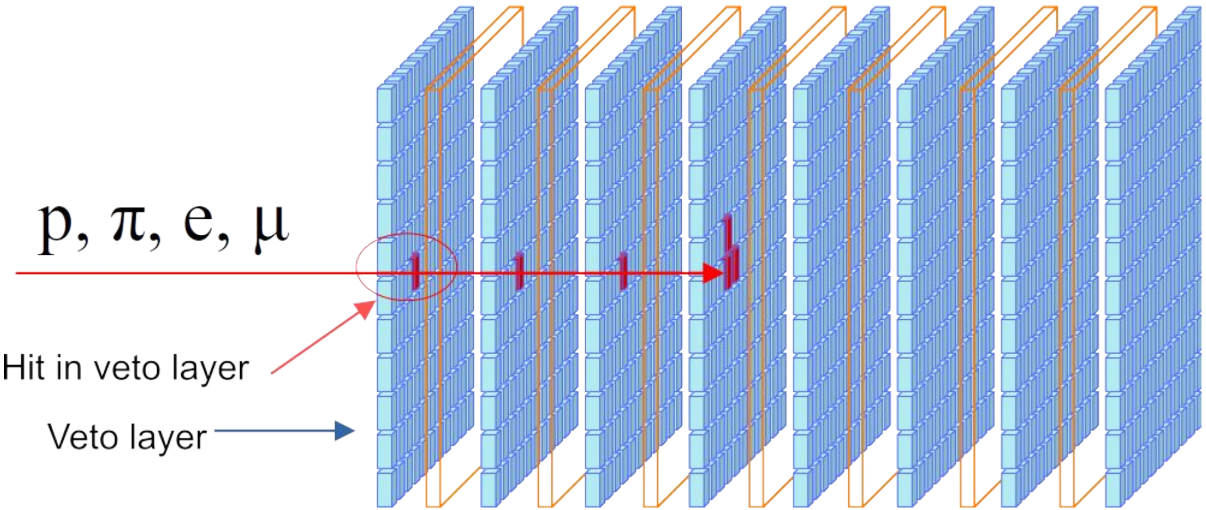
Separation of neutrons, charged particles, gammas

- Rejection of charged particles with **veto on 1st layer**
- Rejection of gammas with **veto on 2nd layer**
- Rejection of light particles (γ, e) with **β<1 cut**

Rejection of charged particles

Charged particles fire 1st layer

If cluster contains any cells of **1st layer**, the cluster is **rejected**

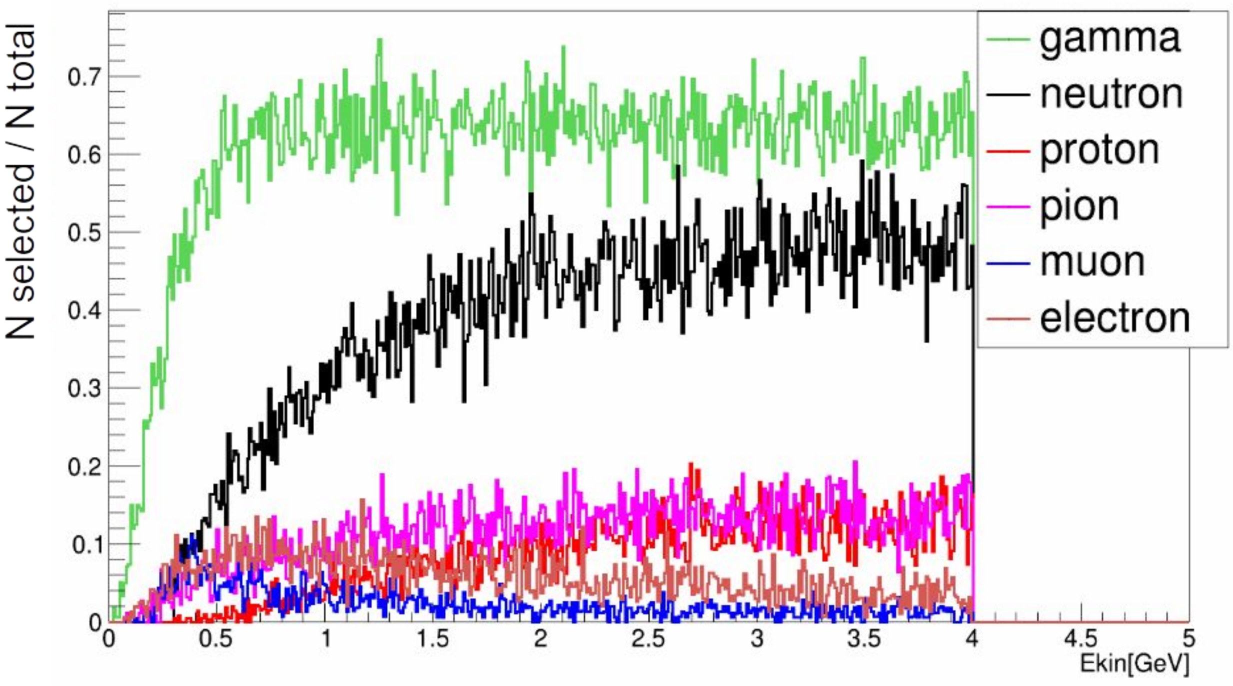


Veto on 1st layer

All clusters containing cells of 1 layer are rejected

If at least 1 cluster evade rejection, the histogram is filled

Charged particles are suppressed



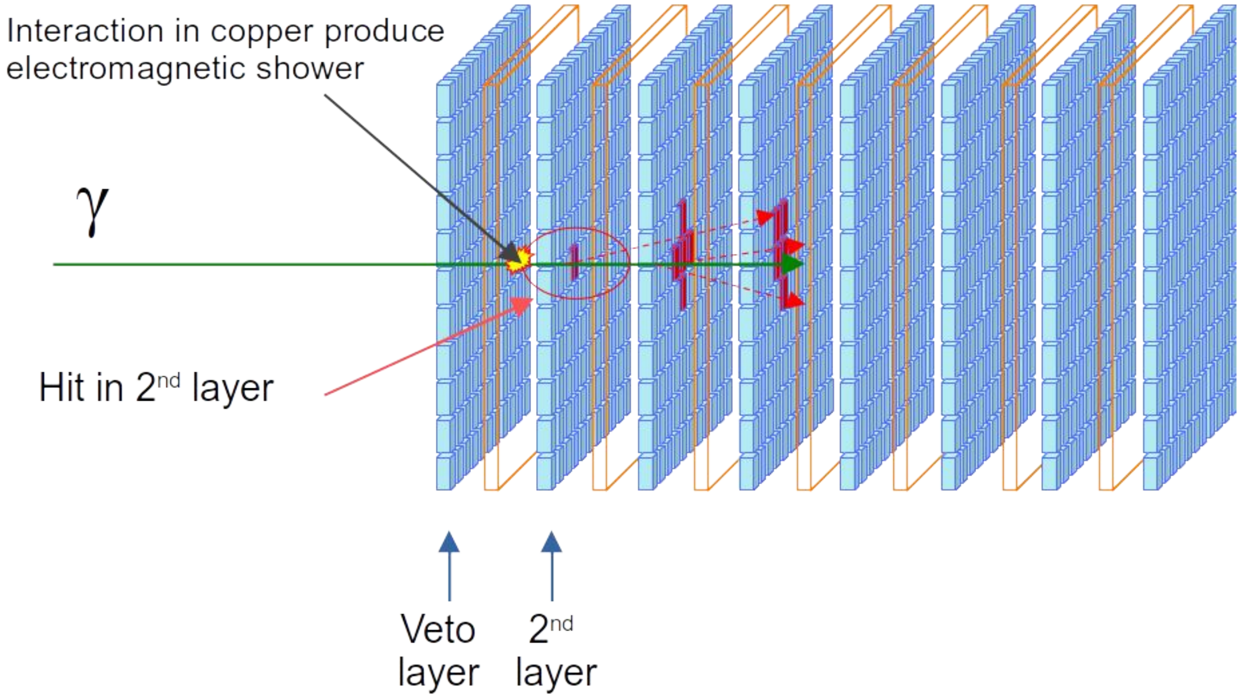
Rejection of γ - quanta

γ-quanta

don’t fire 1st layer,

do fire 2nd layer

If cluster contains any cells of **2nd layer**, the cluster is **rejected**

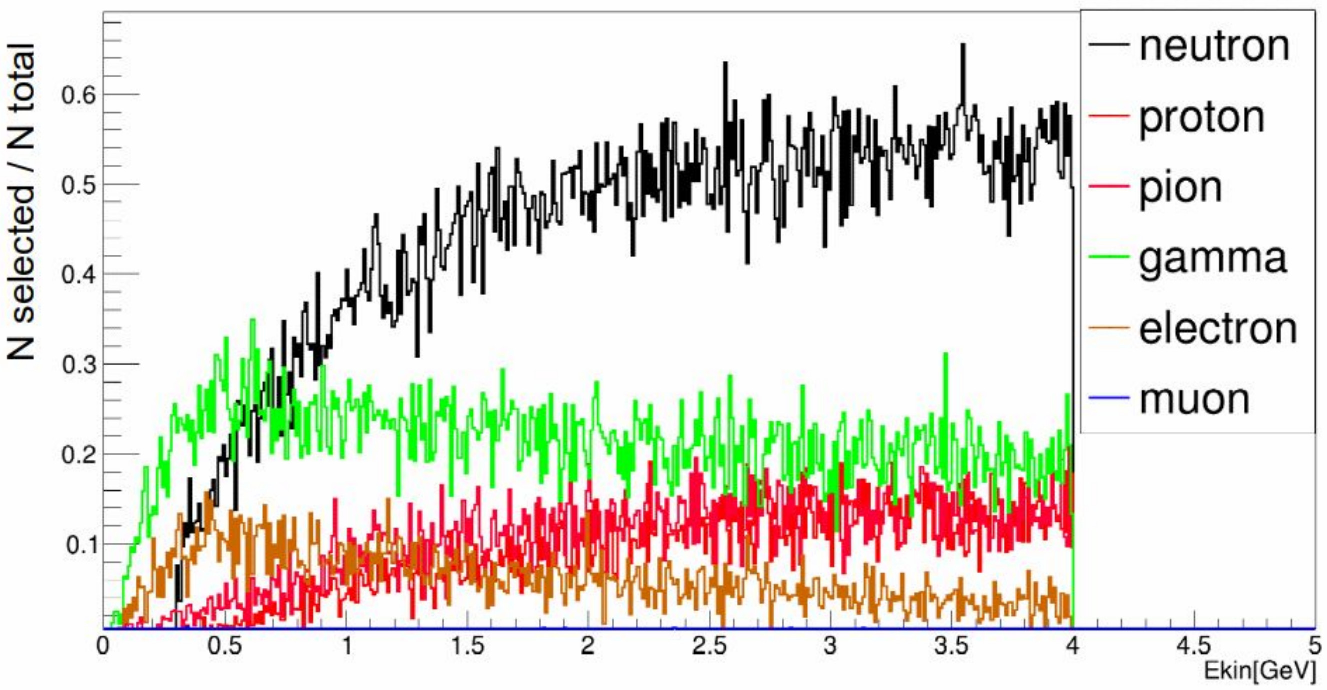


Veto on 1st, 2nd layers

All clusters containing cells of 1, 2 layers are rejected

If at least 1 cluster evade rejection, the histogram is filled

γ-quanta are suppressed

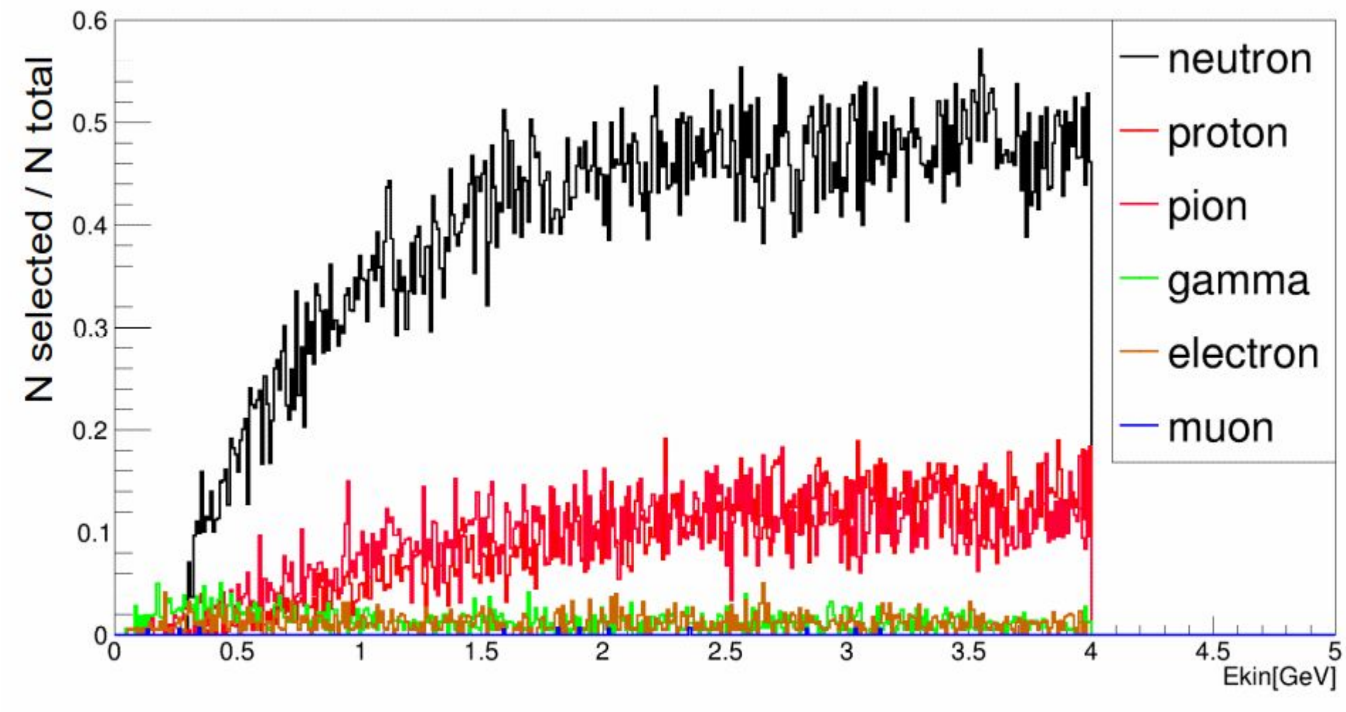


Veto on 1st, 2nd layers, cut β<1

All clusters containing cells of 1 or 2 layer or β=1 are rejected

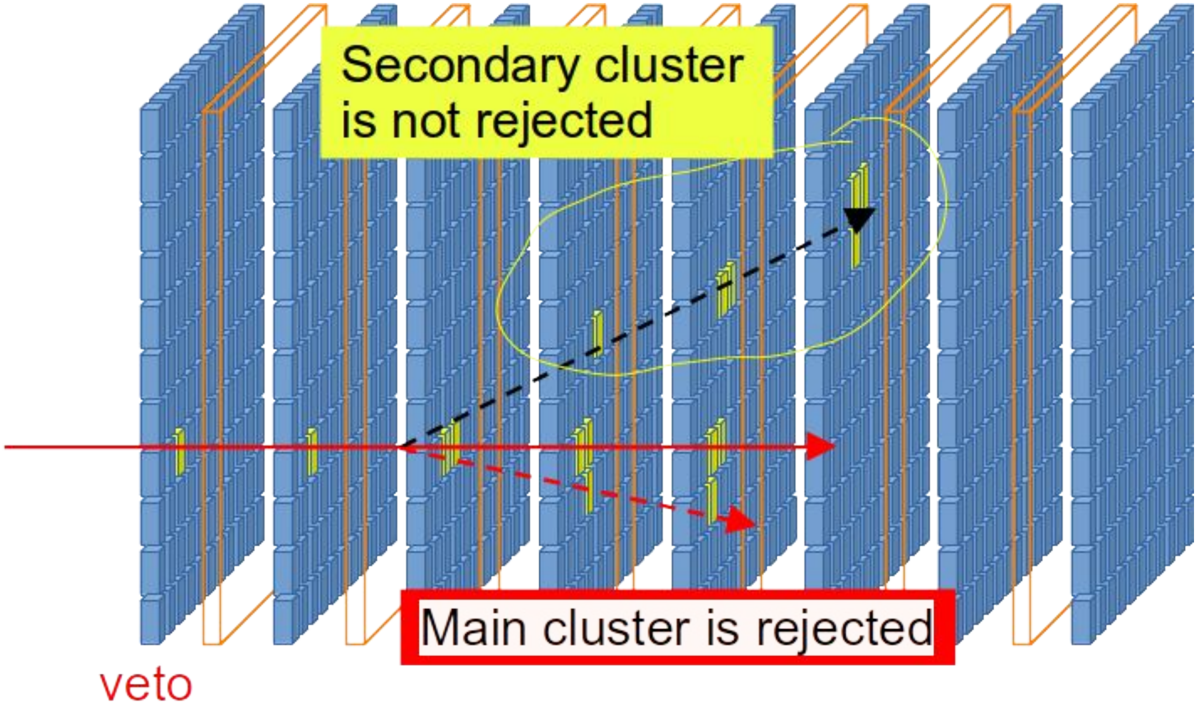
If at least 1 cluster evade rejection, the histogram is filled

γ-quanta, electrons are suppressed



Protons, pions

- protons and pions can produce hadronic shower
- γ, n of shower produce secondary clusters separated in space from main cluster
- These clusters are not rejected (no hit in 1, 2 layers, β<1)



Analysis of clusters

When we applied veto on 1st, 2nd layers, $\beta<1$ cut, only 3 types of clusters left:

- clusters produced by p, π (0 neutrons)
- clusters produced by 1 neutron
- clusters produced by 2 neutrons (or >2 neutrons)
- particles coming through side planes of HGND (not yet studied)

In order to distinguish between these cases, we need to use available data:

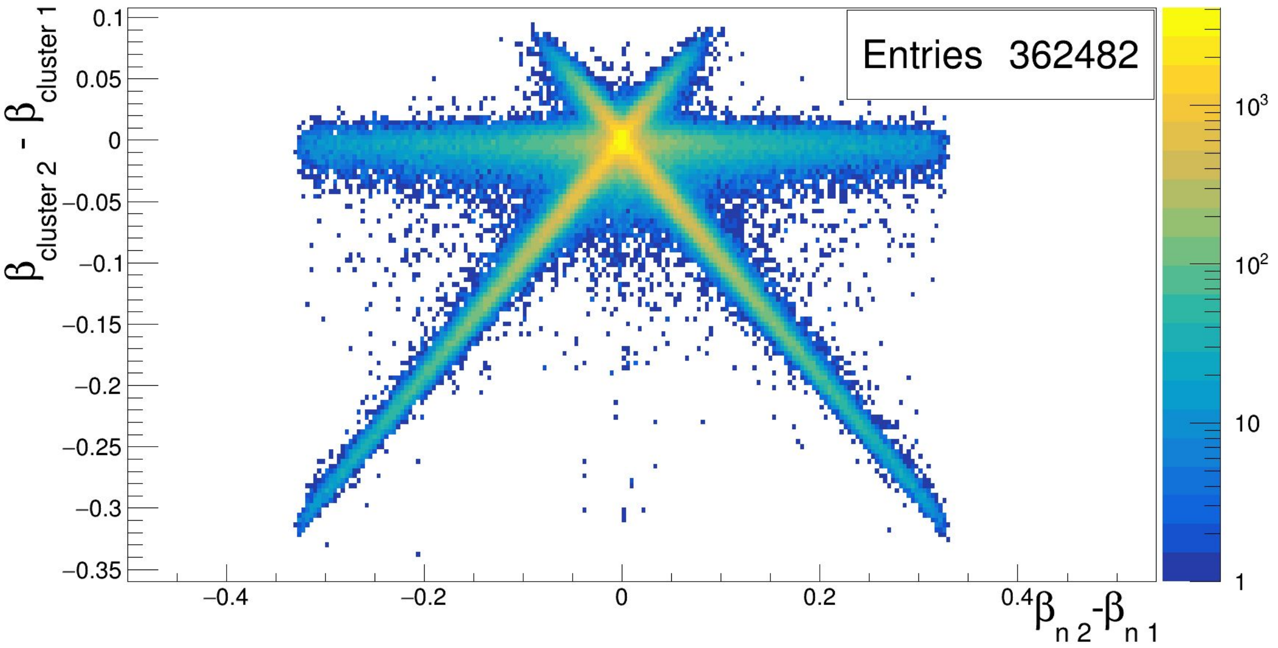
1. distance in time between clusters (~distance in reconstructed β)
2. deposited energy
3. number of fired cells
4. number of recognized clusters

Separation of clusters by β

Simulation: two neutrons in event with random energy

Plot: all possible combinations of reconstructed clusters in event

reconstructed β2-β1 **vs** simulated β2-β1



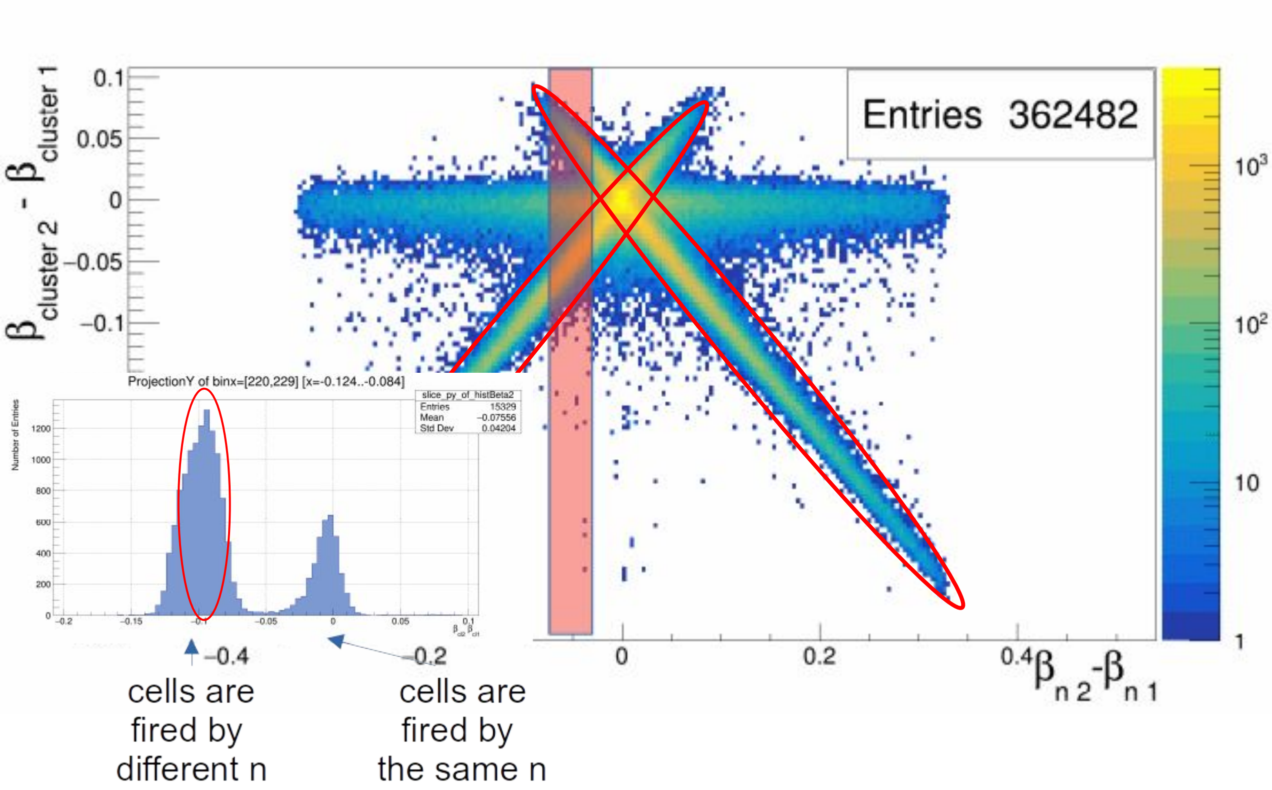
Separation of clusters by β

if

rec β2-β1≈ sim β2-β1

event lies on diagonal

this means clusters are produced by **different neutrons**.



Separation of clusters by β

if

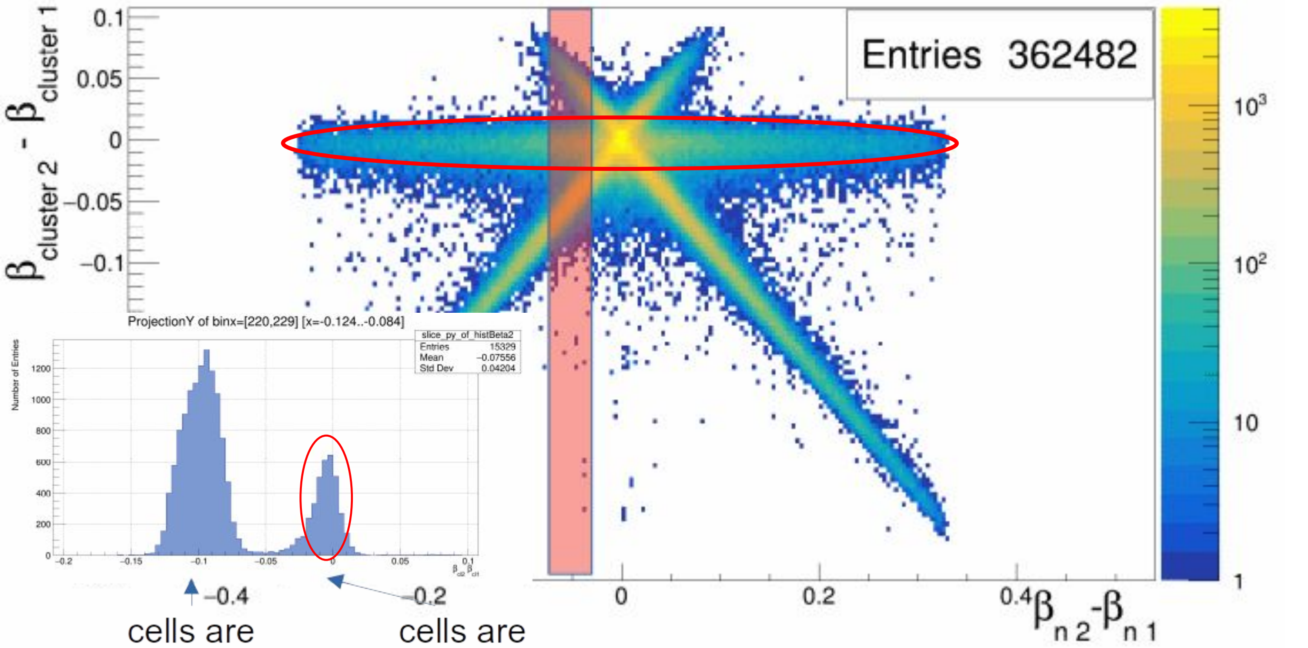
rec β2-β1≈0

event lies on horizontal line

this means clusters are produced by the **same neutron**.

Different neutrons are separable if

|β2-β1|>0.05



cells are fired by different n

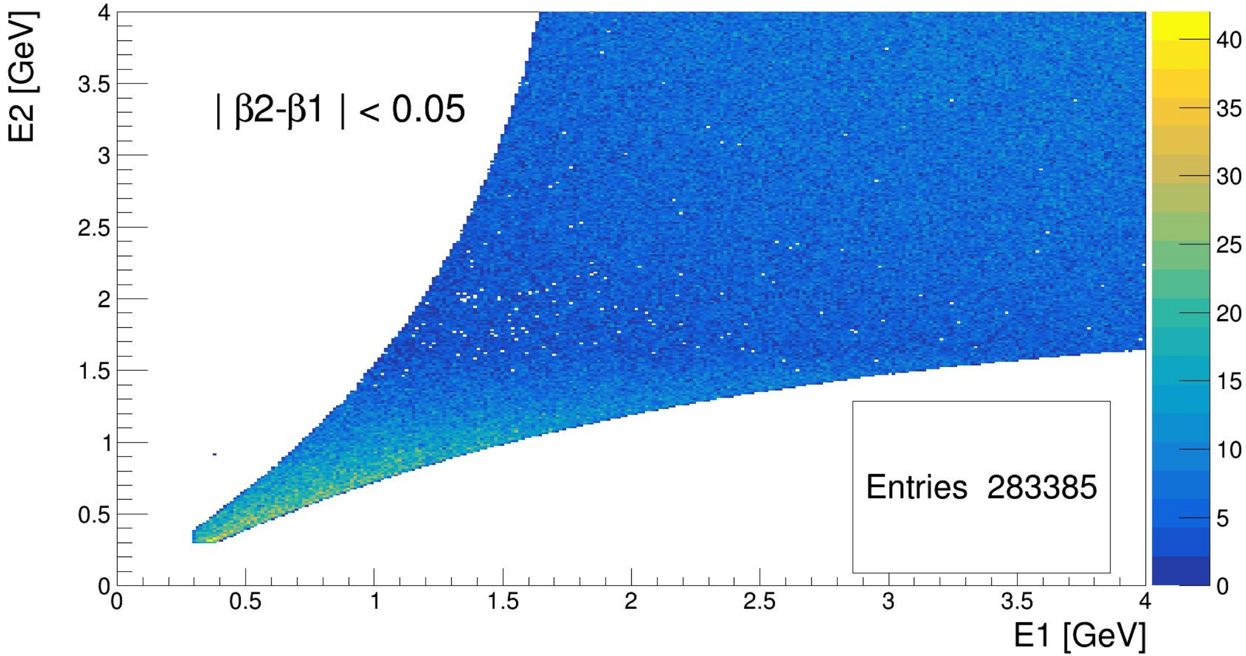
cells are fired by the same n

2 neutrons with close β

|β2-β1|<0.05

particles are not separable by β

But they may have very different energies!



Distinguish between 0n, 1n, 2n

At this step we already applied all cuts to clusters, divided **clusters** into **groups** with close β

These groups of clusters can be produced by:

1. 0 neutrons (proton or pion secondary clusters which evade cuts)
2. 1 neutron
3. 2 neutrons, not separable by β

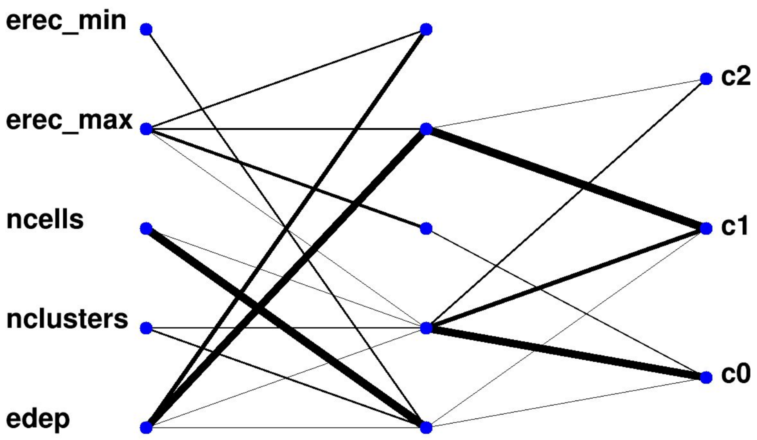
Let's develop criteria based on:

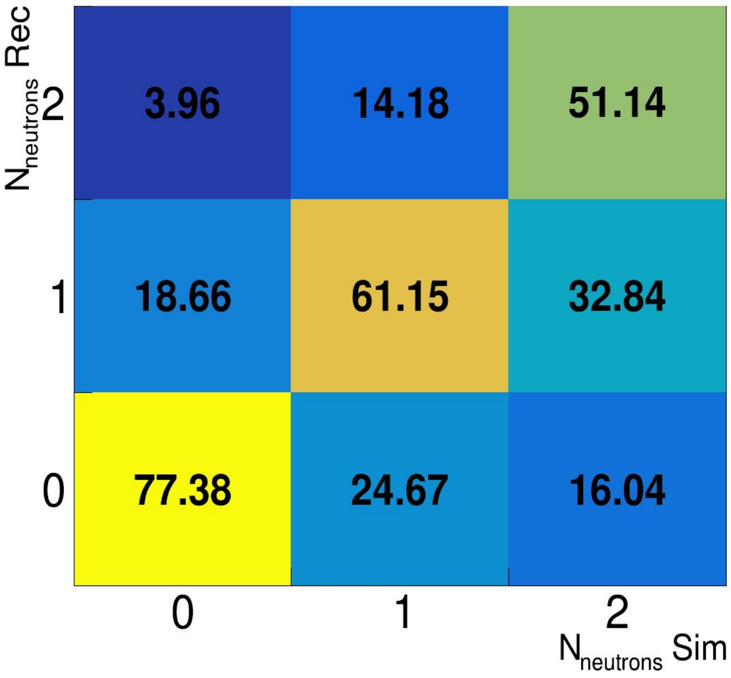
- deposited energy
- number of cells
- number of clusters
- largest reconstructed energy
- smallest reconstructed energy

This criterion is adjusted with neural network (**MultiLayerPerceptron**)

Distinguish between 0n, 1n, 2n

Multilayer perceptron allows to disentangle **the most difficult** cases with moderate precision





Conclusions

- Criteria for selection of clusters produced by neutrons were developed:
  - veto on 1st layer rejects charged particles
  - veto on 2nd layer rejects γ
  - $\beta<1$ cuts light particles (γ, e)
- Criterion for combination of clusters into groups is:
  - $|\beta 2-\beta 1|<0.05$
- Groups of clusters with 0 n, 1 n and 2 n are disentangled with neural network with input:
  - deposited energy
  - reconstructed kinetic energy
  - number of fired cells
  - number of found clusters

TODO:

- distinguish between primary and secondary neutrons
- study quality of reconstruction of realistic events