Preliminary studies of the production of a single Z^0 in a fusion process $\mu^+\mu^- \rightarrow \nu_\mu \bar{\nu}_\mu Z^0$

using ILCroot

Background studies

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Muon Collider Physics and Detector Meeting

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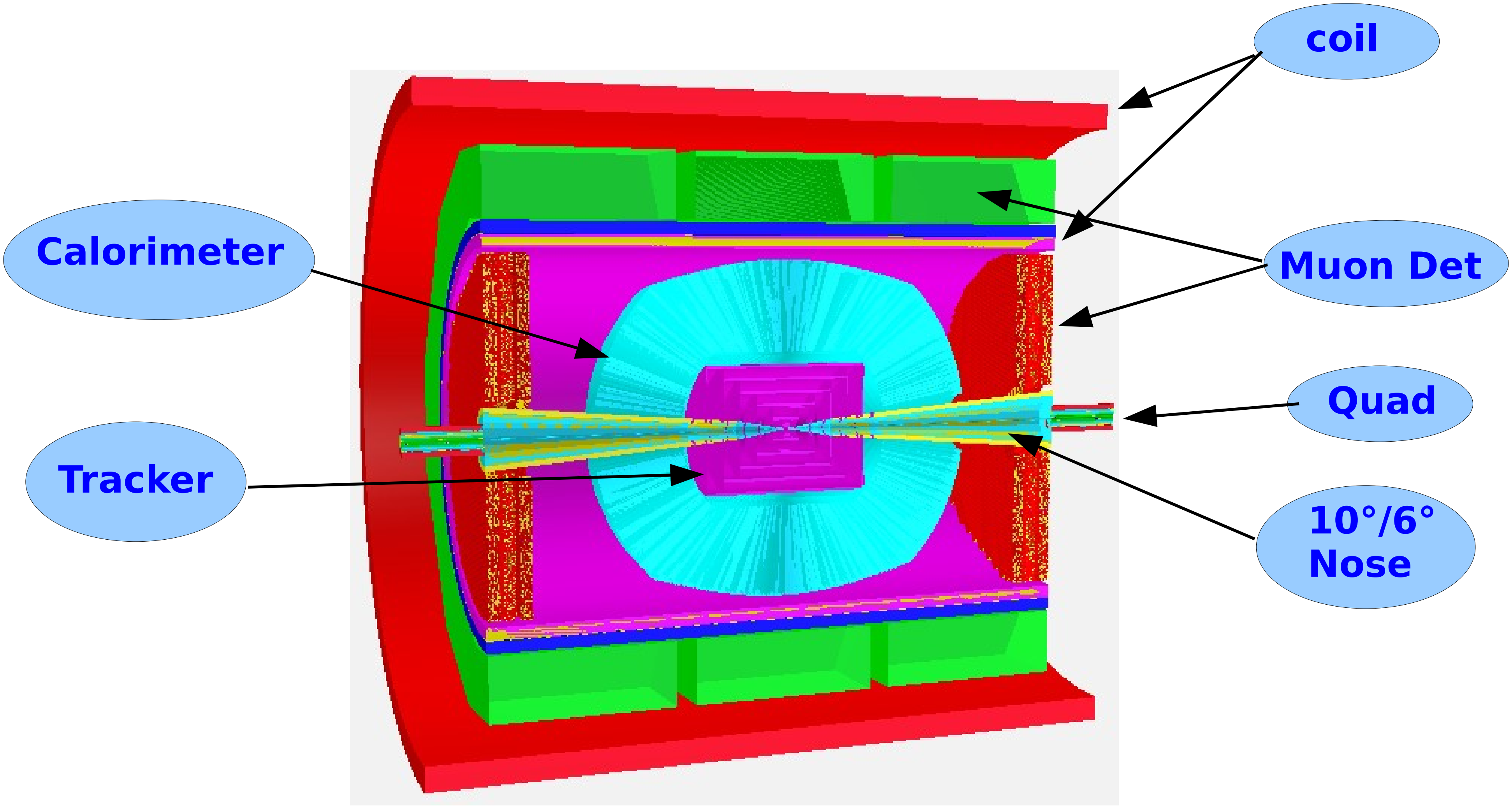
Fermilab

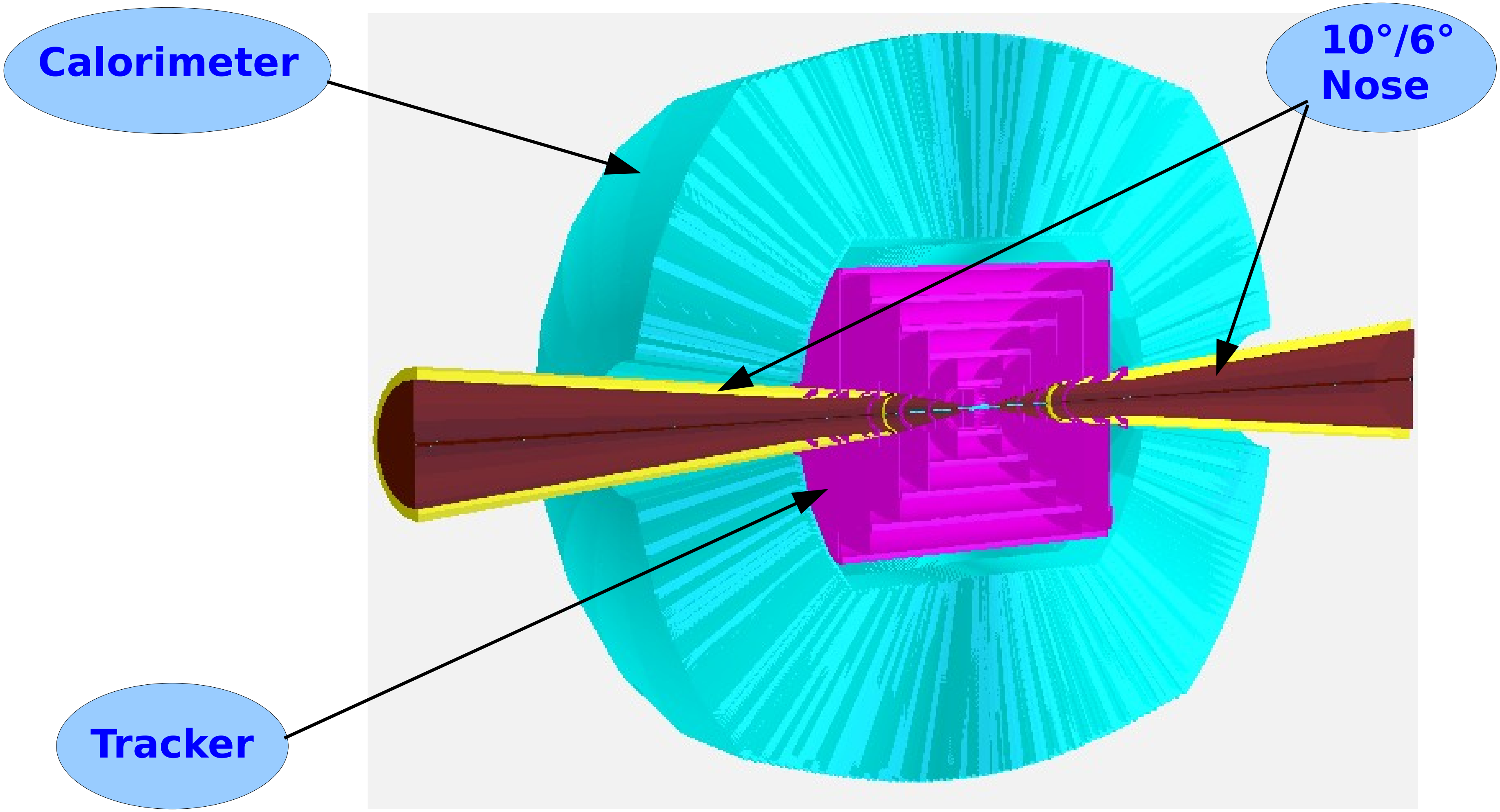
Outline

- **Detector baseline**
- **MARS event**
- **Background studies**
- **Merging issues**
- **Conclusions**

Detector baseline



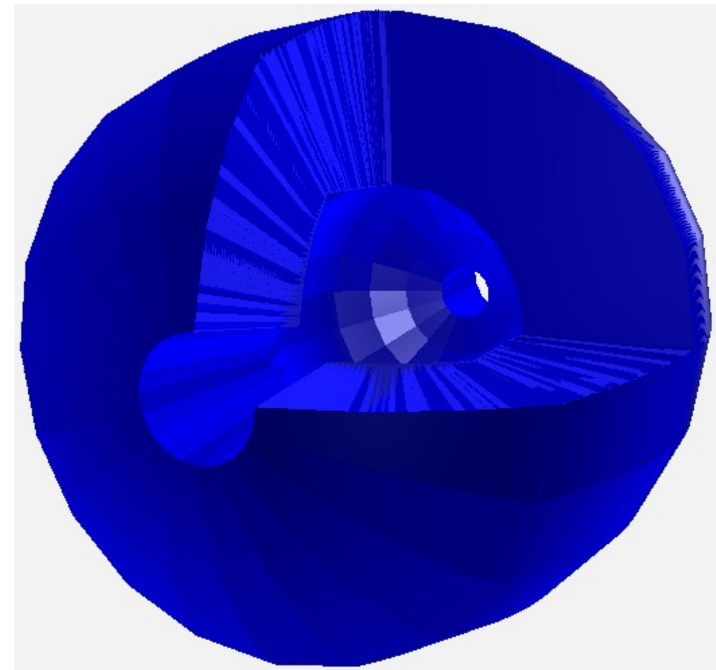
Detector baseline zoom

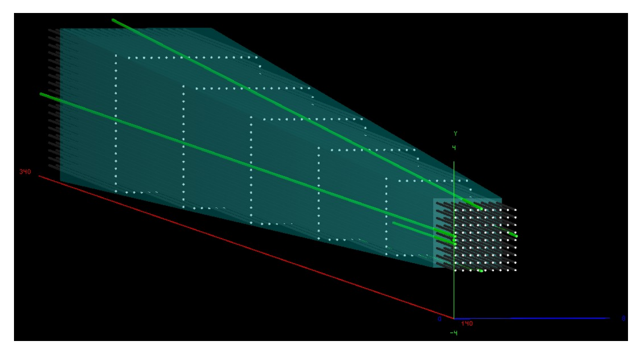


Detector baseline

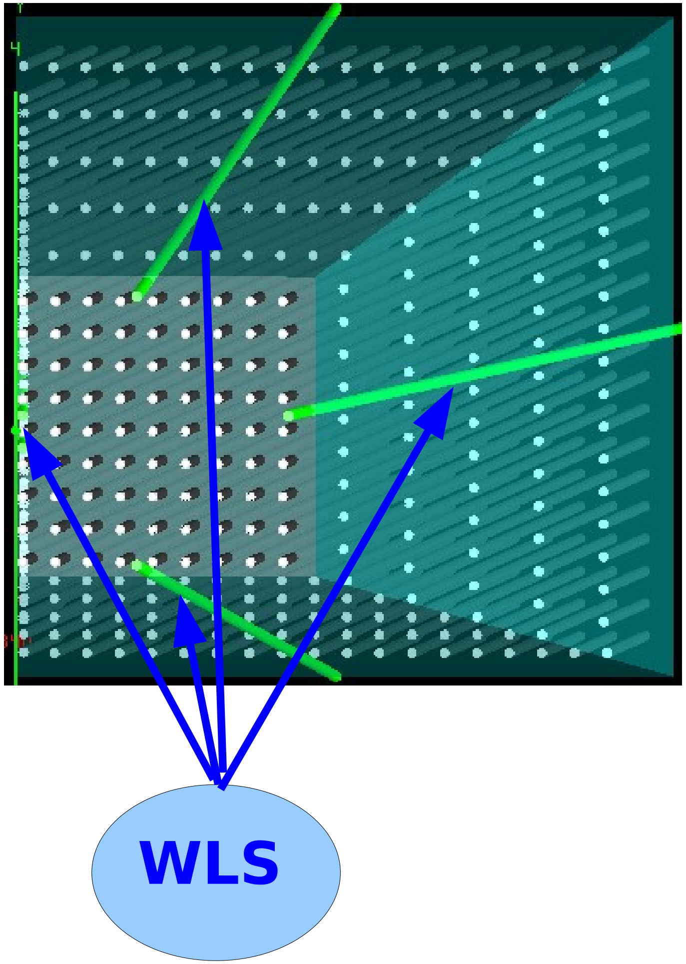
ADRIANO Calorimeter

- Lead glass + scintillating fibers
- ~1.4° tower aperture angle
- 180 cm depth
- ~ 7.5 λ_{int} depth
- >100 X_0 depth
- Fully projective geometry
- Azimuth coverage
  down to ~8.4° (Nose)
- Barrel: 16384 towers
- Endcaps: 5544 towers





Detector baseline



- **WLS's collect Cerenkov photons generated in lead glass (front and back readout)**
- **Scint fibers generate and collect scintillating photons (front and back readout for fibers in the core of the tower; only back readout for the other fibers)**
- **Simulation include:**
  - **SiPM with ENF=1.016**
  - **Fiber non-uniformiti response = 0.8% (scaled from CHORUS)**
  - **Threshold = 3 p.e. (SiPM dark current< 50 kHz)**
  - **ADC with 14 bits**
  - **Gaussian noise with σ= 1 p.e.**

Simulating MARS event

- **Simulated 1 MARS event**
  - **Origin of the particles: cone**
  - **Background particles files for μ^+ and μ^- within 25 m and beyond 25 m**
  - **Particle in a MARS event ~$1x10^8$, almost all originated within 25 m**
  - **Particles from file within 25 m have weight ~ 20**
    - **These particles are split using azimuthal symmetry**
  - **Particles from file beyond 25 m have weight << 1**
    - **Pick up randomly these particle, taking care the integral weight is the same**
    - **This have been done 10 times, then the average signal have been used**

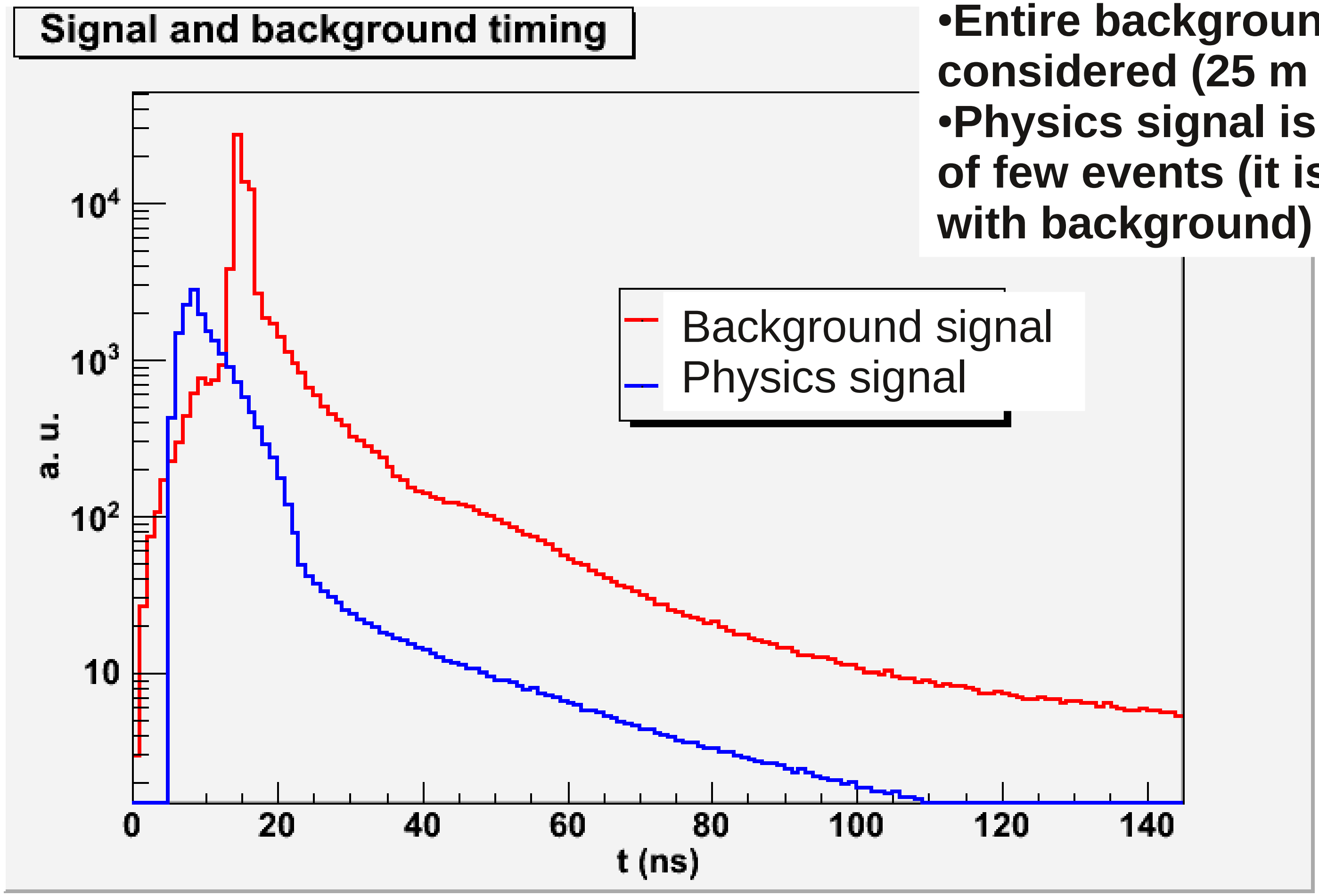
Simulating MARS event

- **Time and disk space needed to simulate 1 MARS event using full geometry and full simulation**
  - **Weighted particles:**
    - **1 CPU <-> 200 h**
    - **150 Gb disk space**
  - **Unweighted particles;**
    - **1 CPU <-> 2000 h**
    - **1 Tb disk space**
- **Disk space and CPU time can be reduced using simplified geometry and fast simulation**

MARS event overview

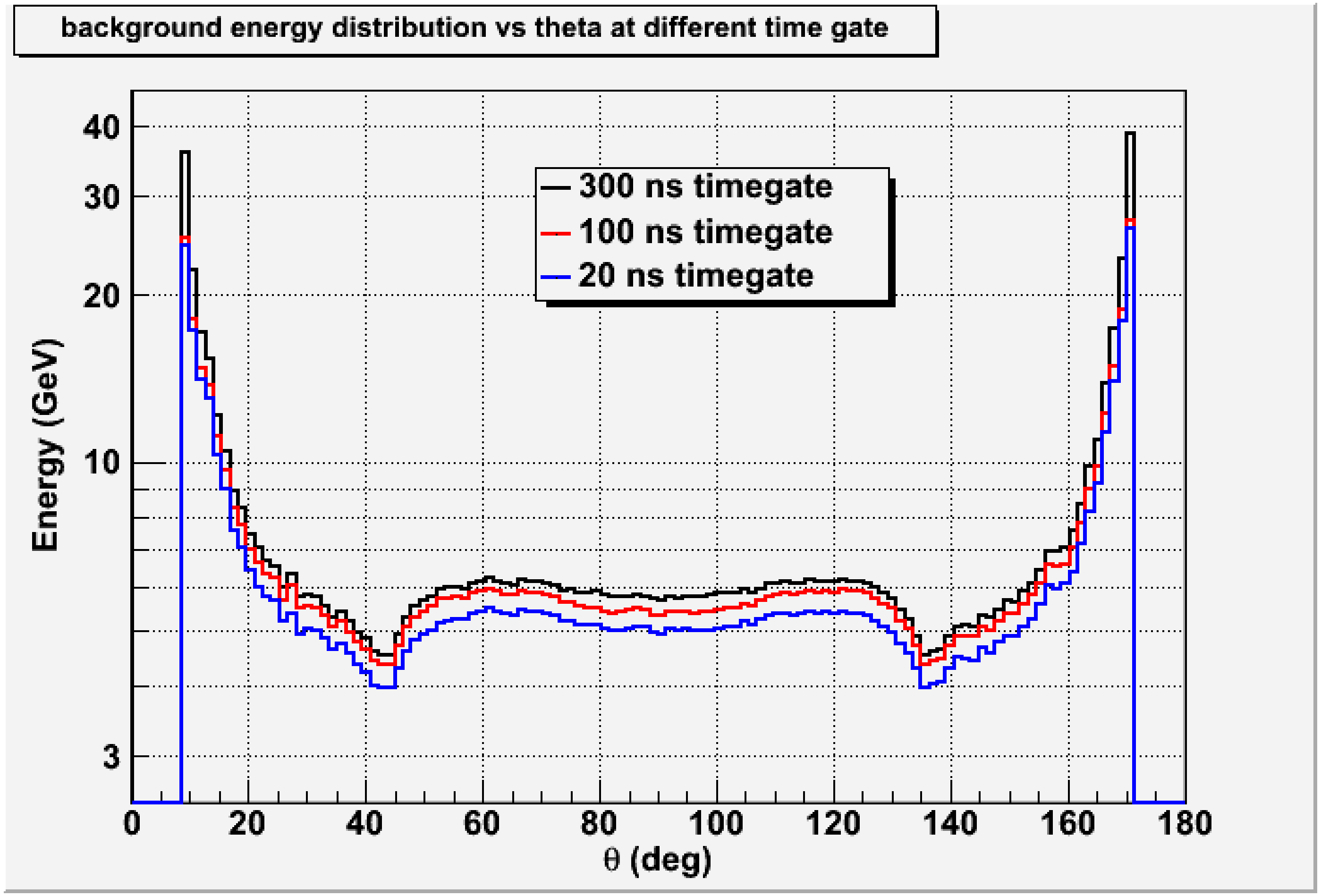
Timing and space distributions of one background event into the calorimeter

Timing of the Physics signal and background event

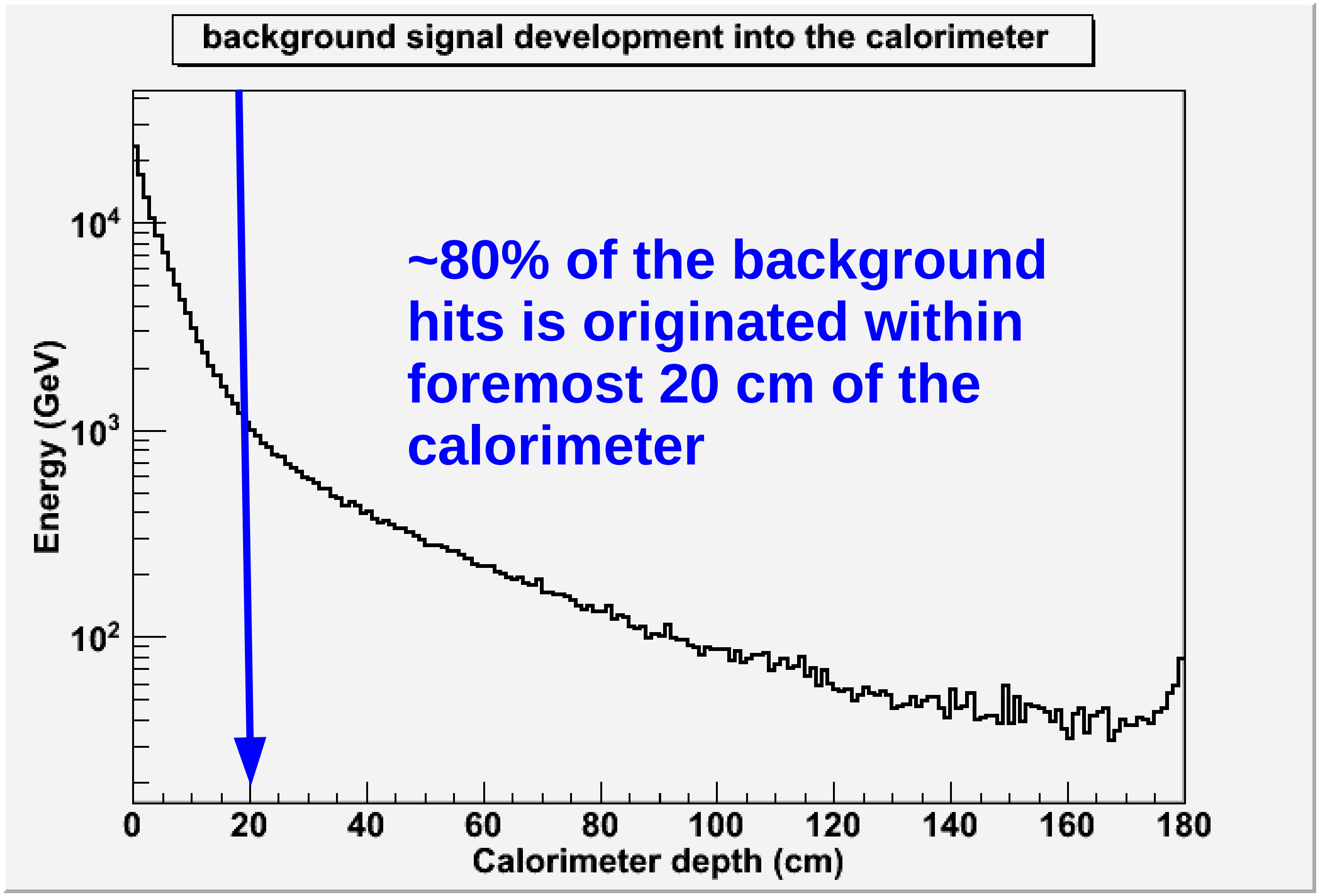


- Entire background considered (25 m + 250 m)
- Physics signal is an average of few events (it is not in scale with background)

background vs theta for different calorimeter integration time



Development of the background event into the calorimeter

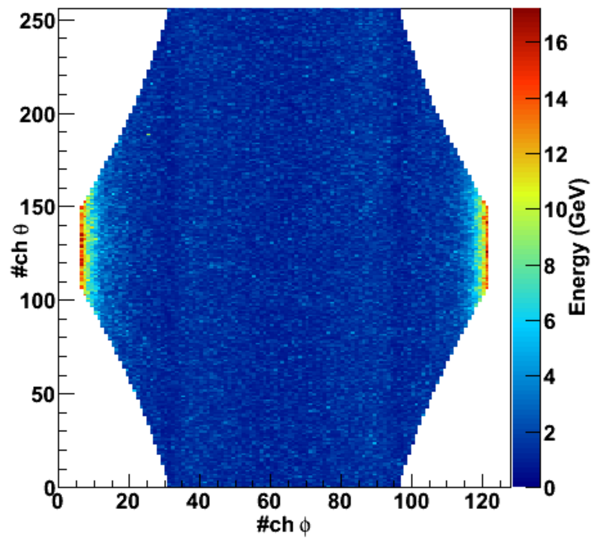


MARS event overview

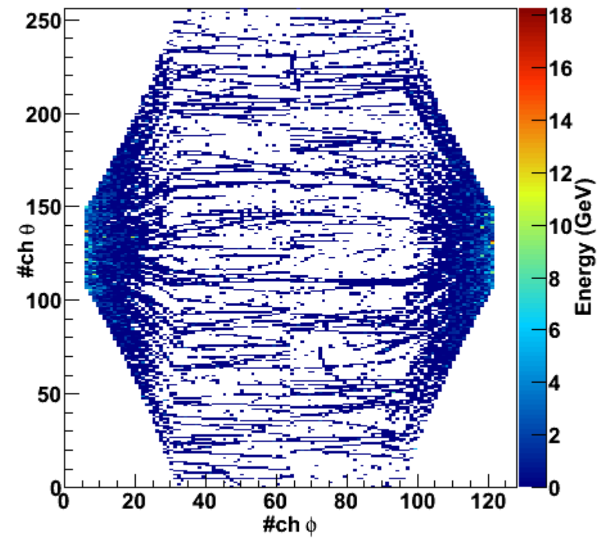
Energy distribution of the background per tower for different species using different time gate

Energy distribution per tower. MARS input file within 25 m; Integration time gate [0 – 300] ns

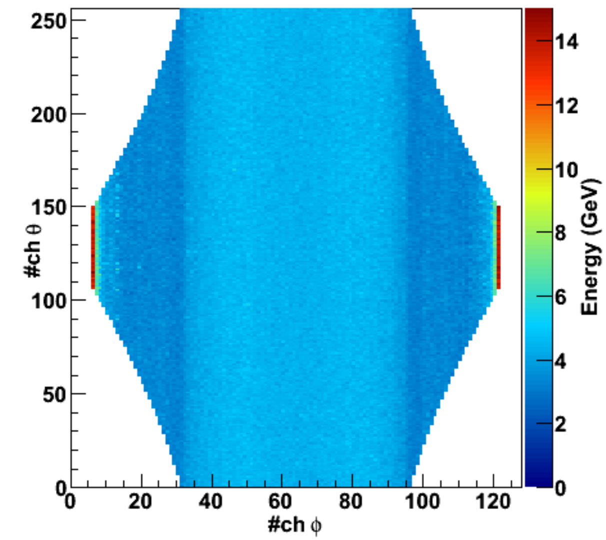
neutrons



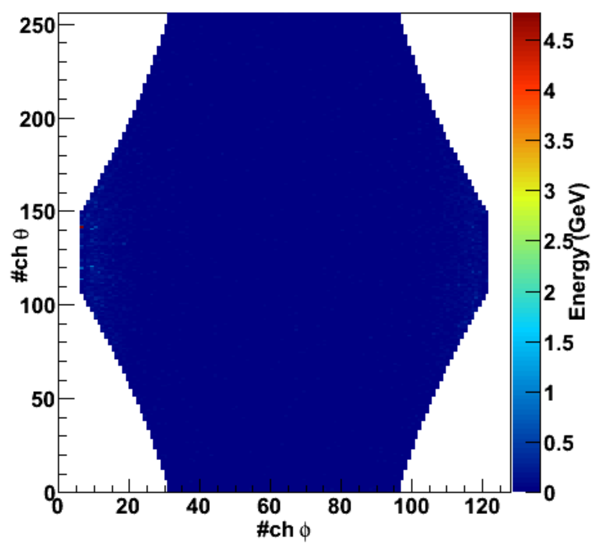
muons



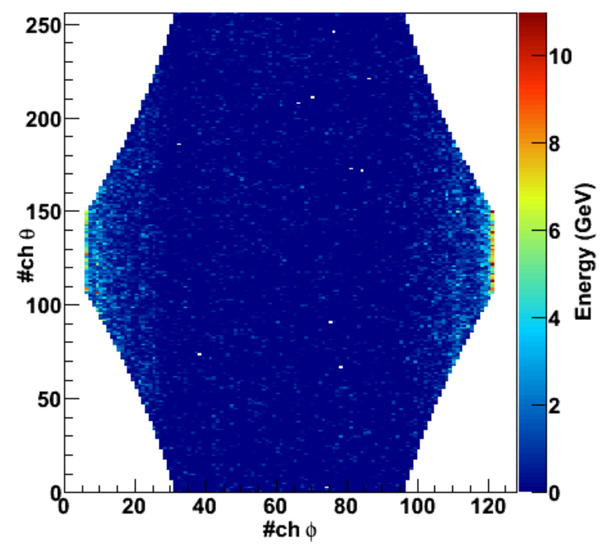
gammas



electrons



others

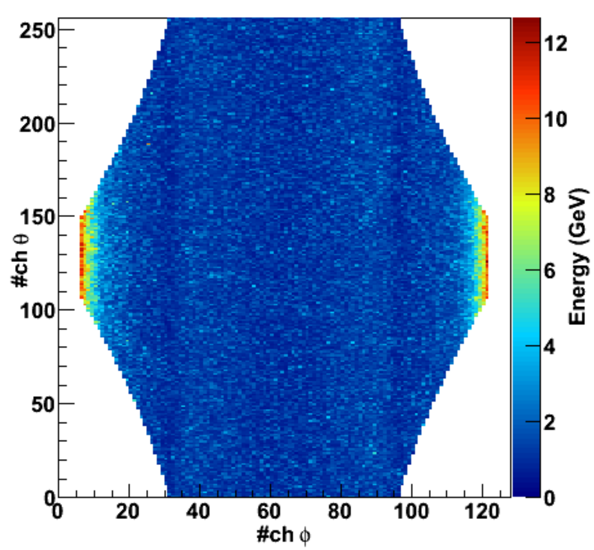


1 entry = energy of 1 tower

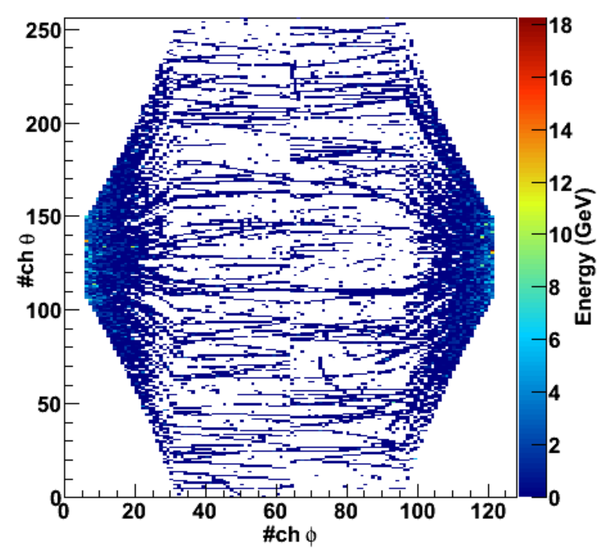
Most of the energy is in the endcaps originated by Neutrons and gammas

Energy distribution per tower. MARS input file within 25 m; Integration time gate [5 – 105] ns

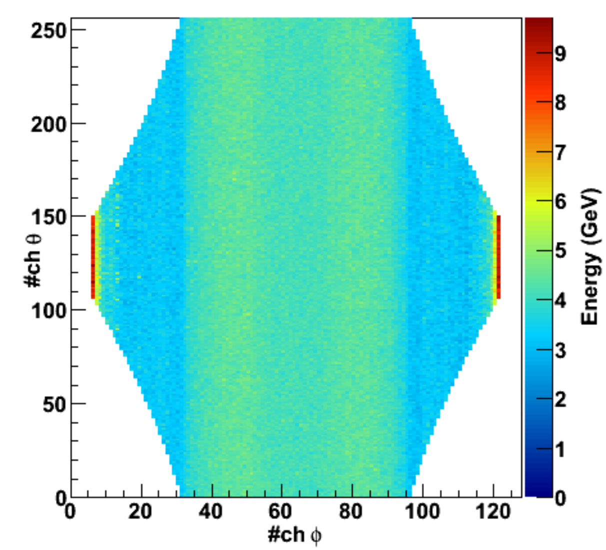
neutrons



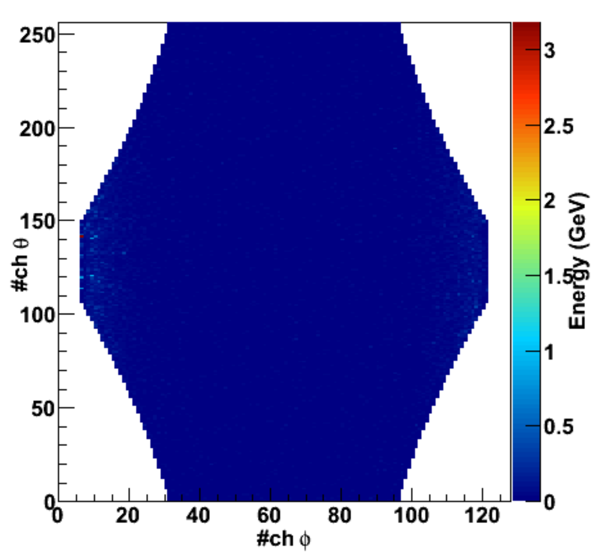
muons



gammas



electrons



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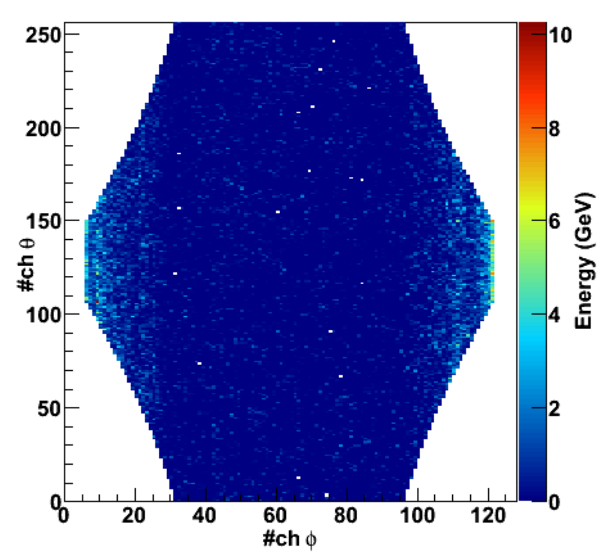
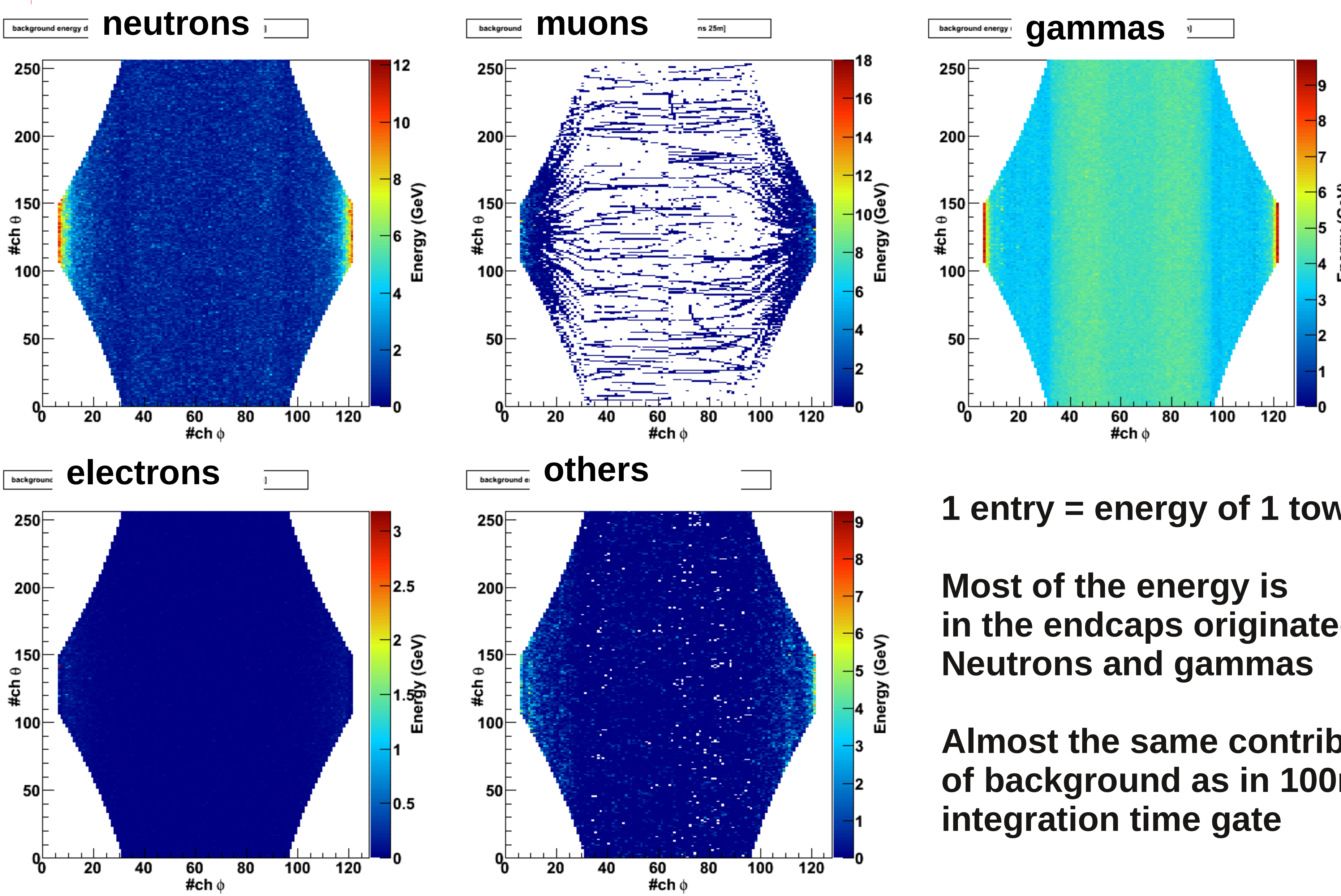


1 entry = energy of 1 tower

Most of the energy is in the endcaps originated by Neutrons and gammas

With shorter integration time gate background is reduced

Energy distribution per tower. MARS input file within 25 m; Integration time gate [5 – 25] ns

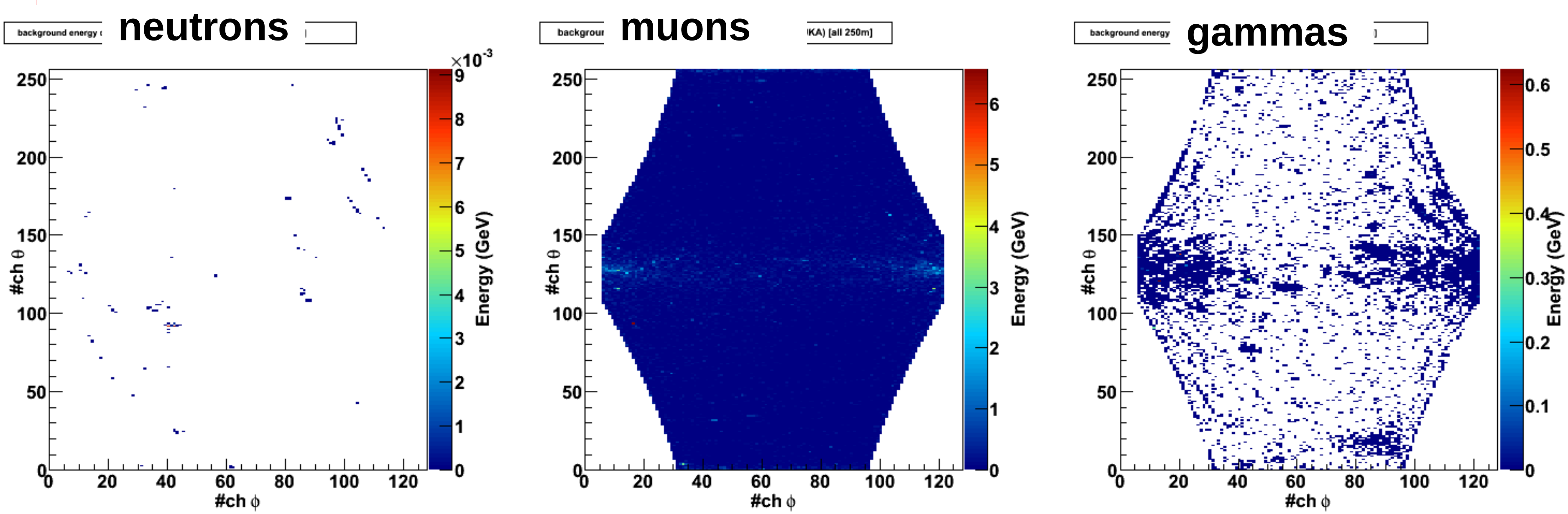


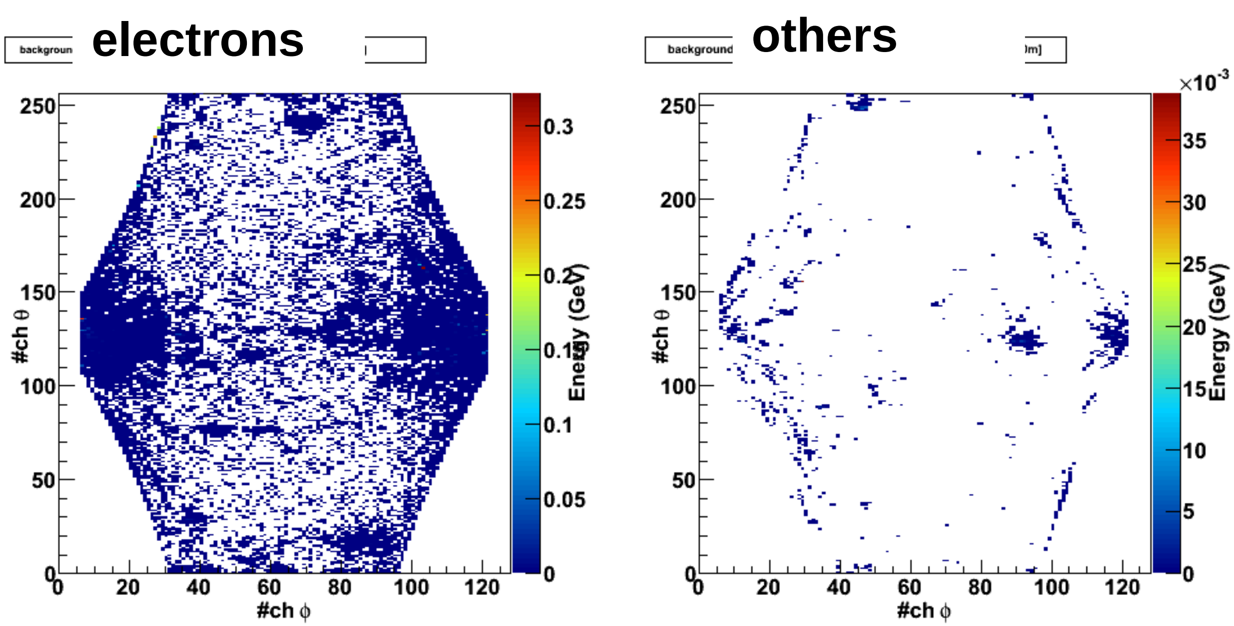
1 entry = energy of 1 tower

Most of the energy is in the endcaps originated by Neutrons and gammas

Almost the same contribution of background as in 100ns integration time gate

Energy distribution per tower. MARS input file within 250 m; Integration time gate [0 – 300] ns

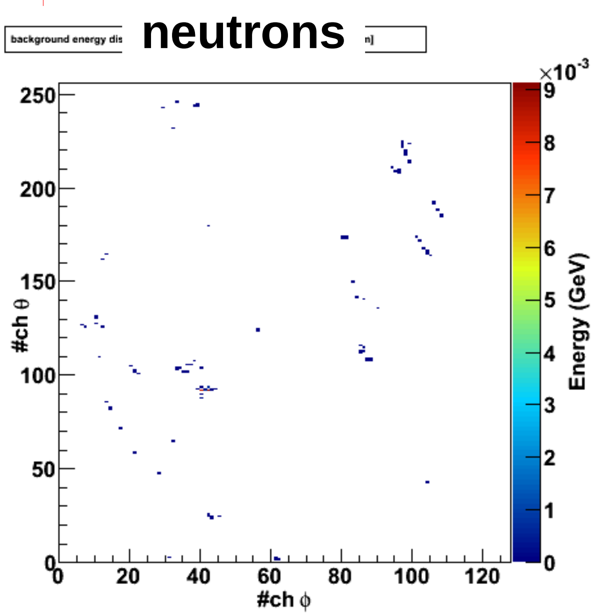


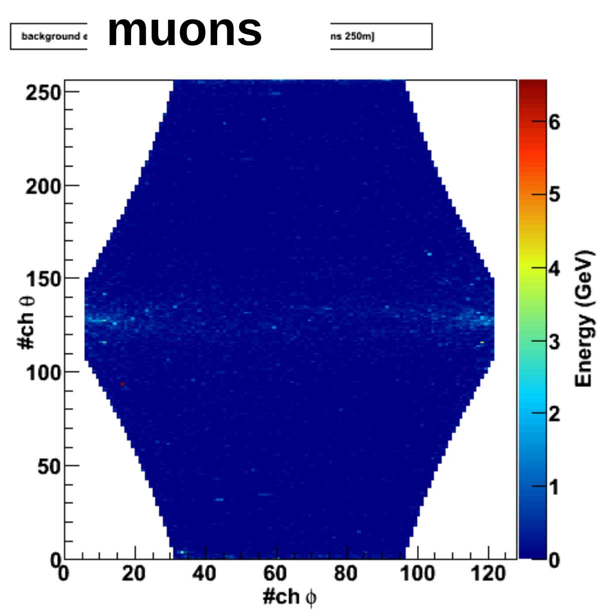


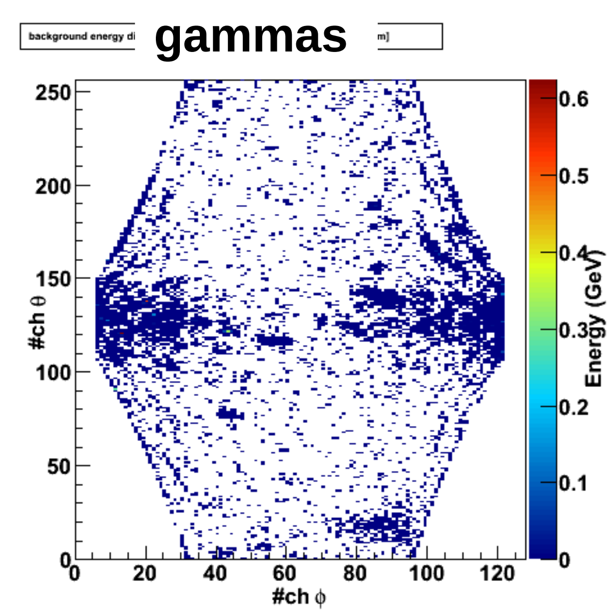
1 entry = energy of 1 tower

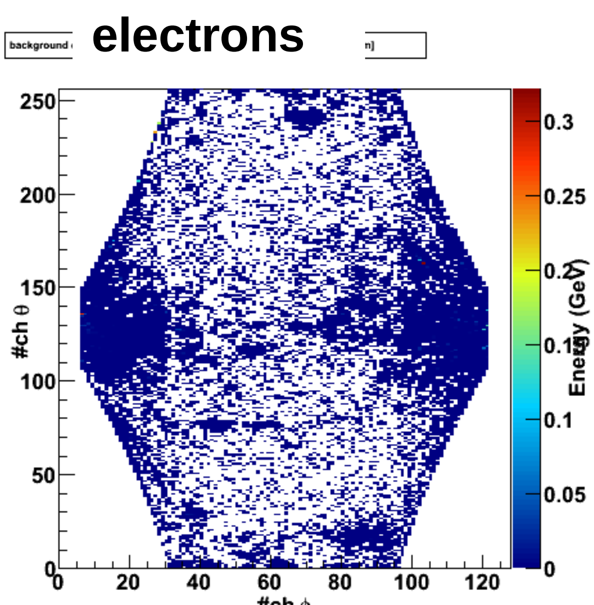
Most of the energy is in the endcaps originated by some muons hotspot

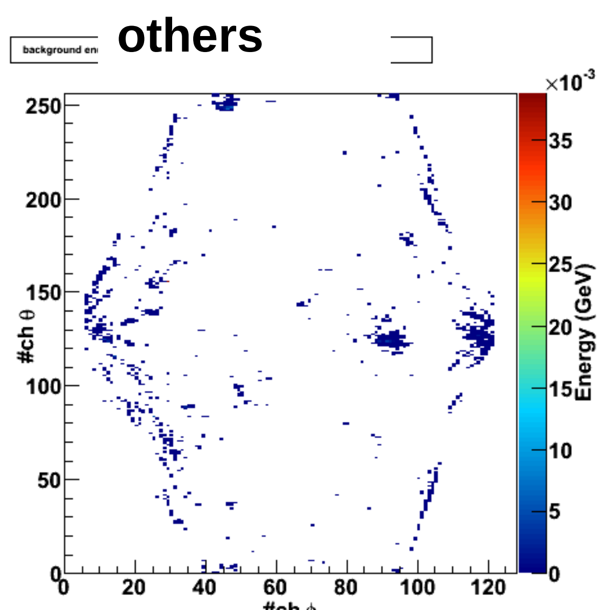
Energy distribution per tower. MARS input file within 250 m; Integration time gate [5 – 105] ns









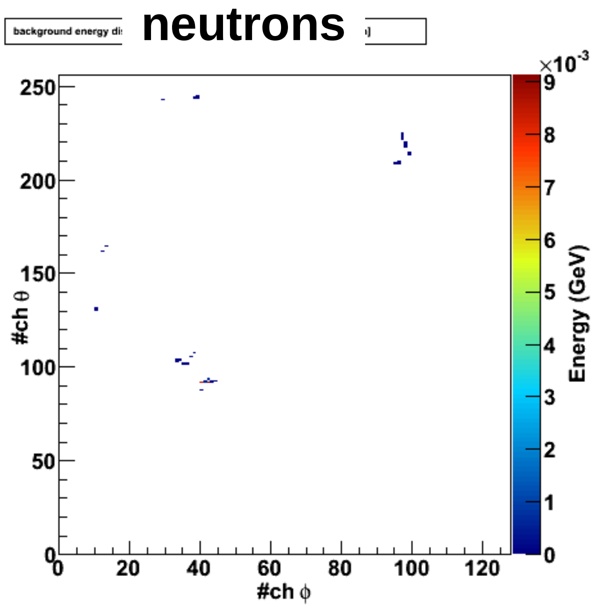


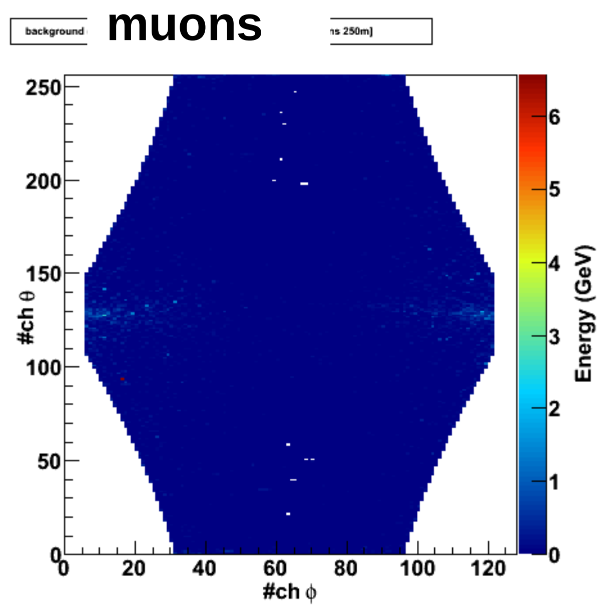
1 entry = energy of 1 tower

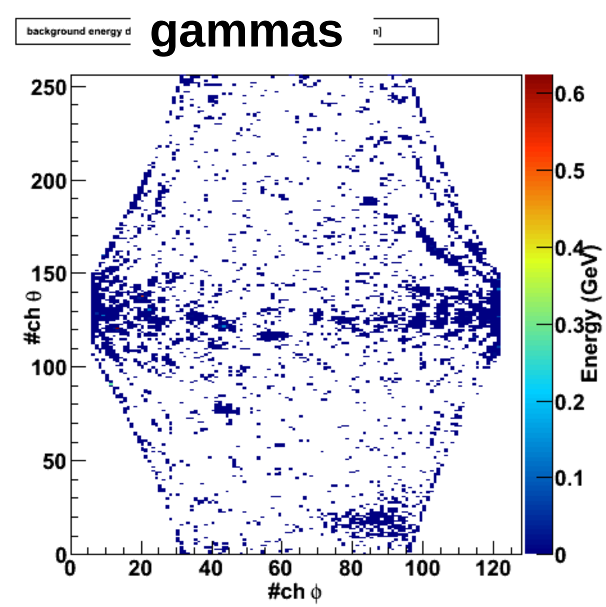
Most of the energy is in the endcaps originated by some muons hotspot

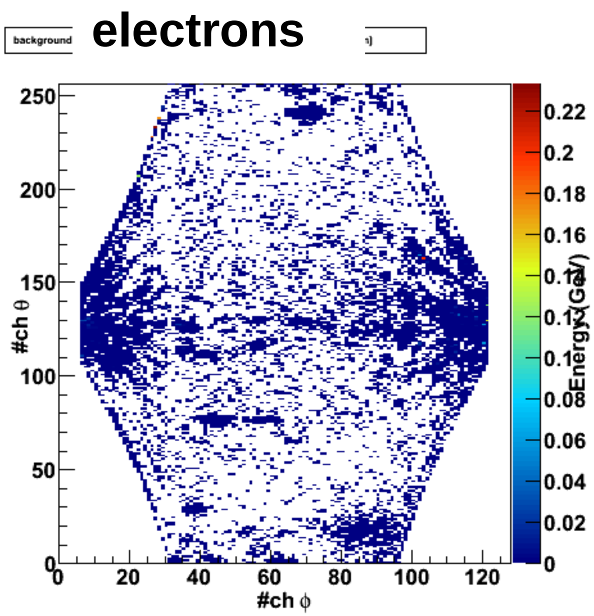
No difference using shorter integration time gate

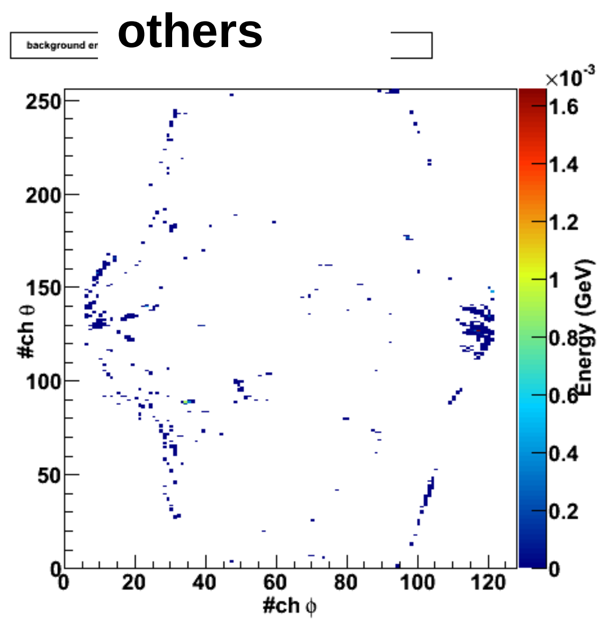
Energy distribution per tower. MARS input file within 250 m; Integration time gate [5 – 25] ns











1 entry = energy of 1 tower

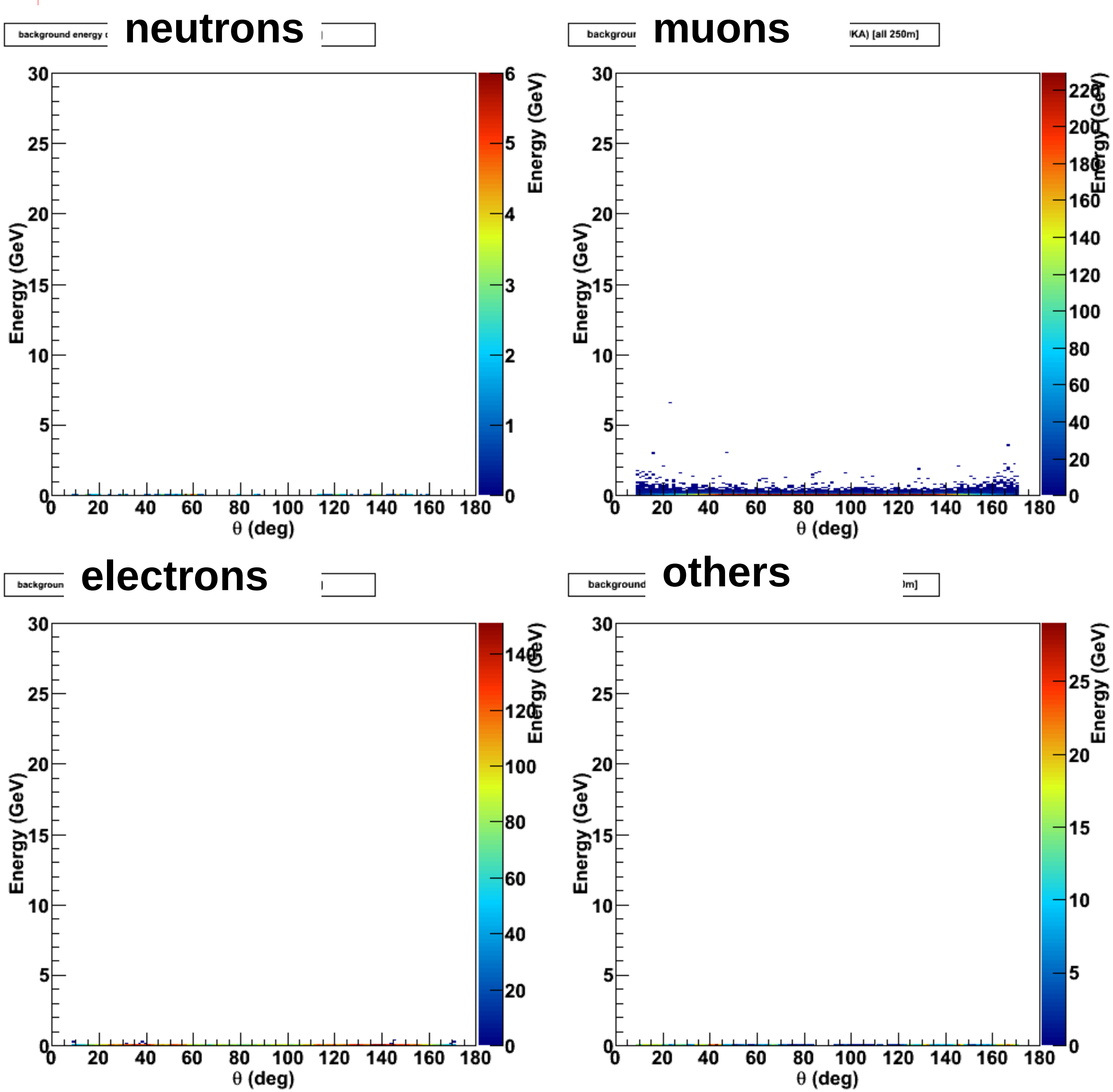
Most of the energy is in the endcaps originated by some muons hotspot

No difference using shorter integration time gate

MARS event overview

Energy distribution of the background per tower vs theta for different species using different time gate

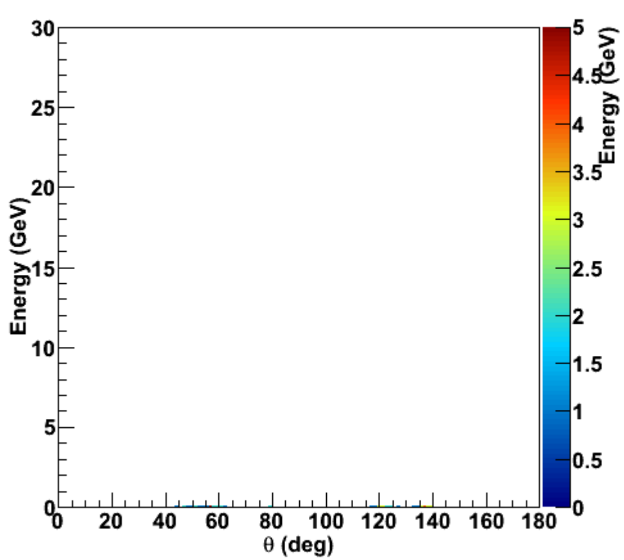
Energy distribution per tower vs theta. MARS input file within 250 m; Integration time gate [0 – 300] ns



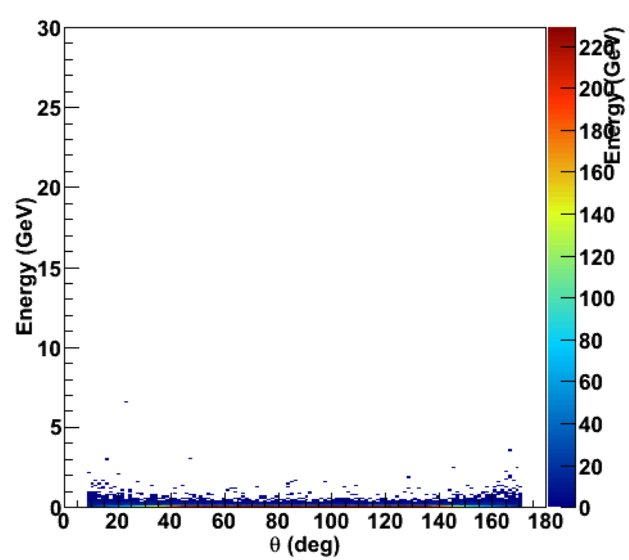
With background particles from 250 m only muons contribute to energy into the calorimeter

Energy distribution per tower vs theta. MARS input file within 250 m; Integration time gate [5 – 105] ns

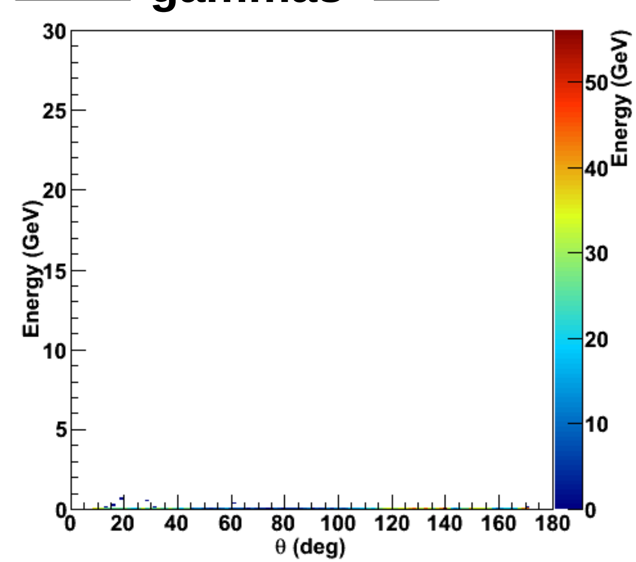
neutrons



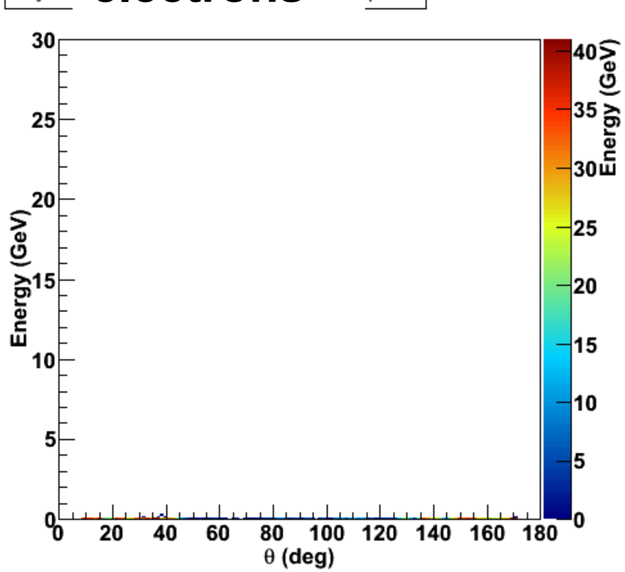
muons



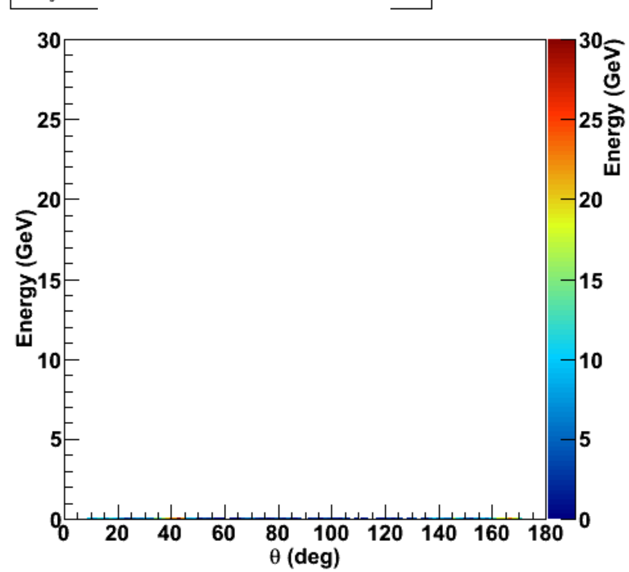
gammas



electrons



others

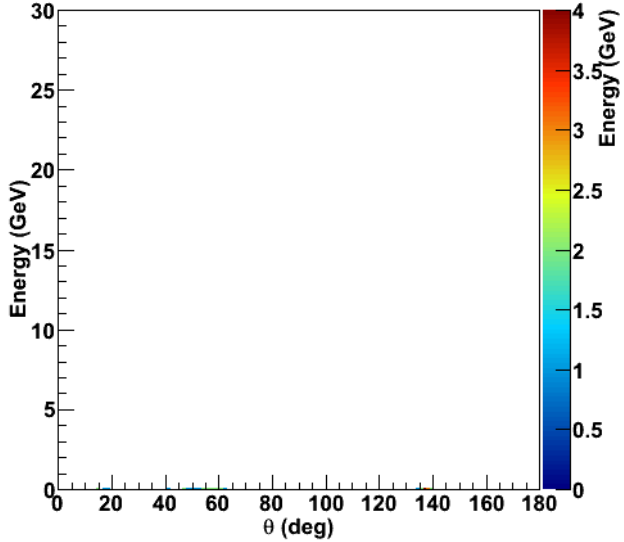


With background particles from 250 m only muons contribute to energy into the calorimeter

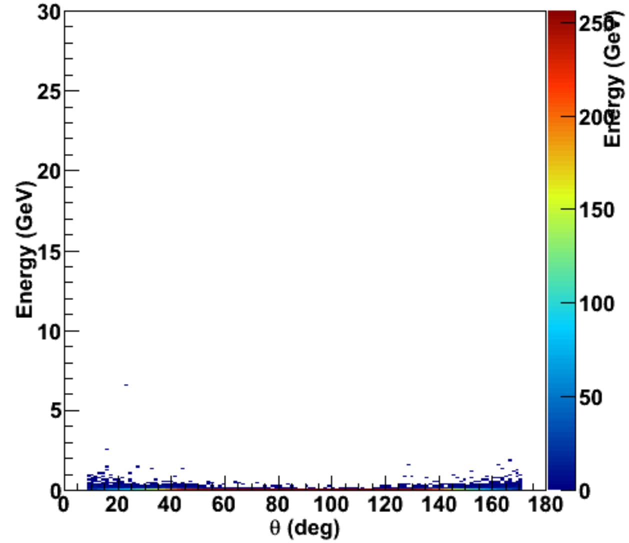
No difference using shorter integration time gate

Energy distribution per tower vs theta. MARS input file within 250 m; Integration time gate [5 – 25] ns

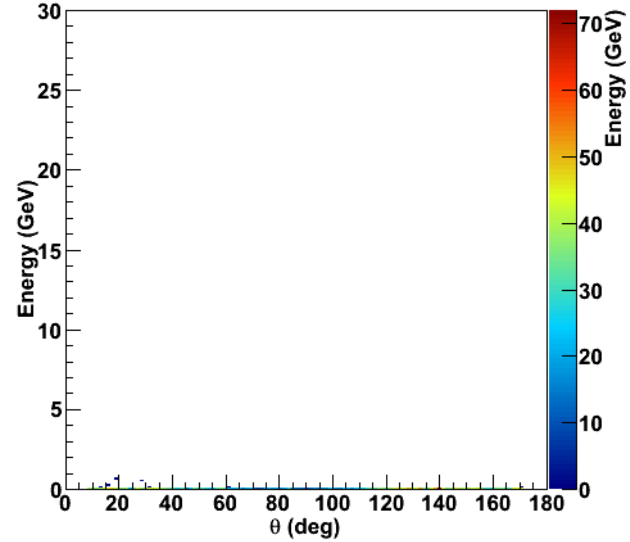
neutrons



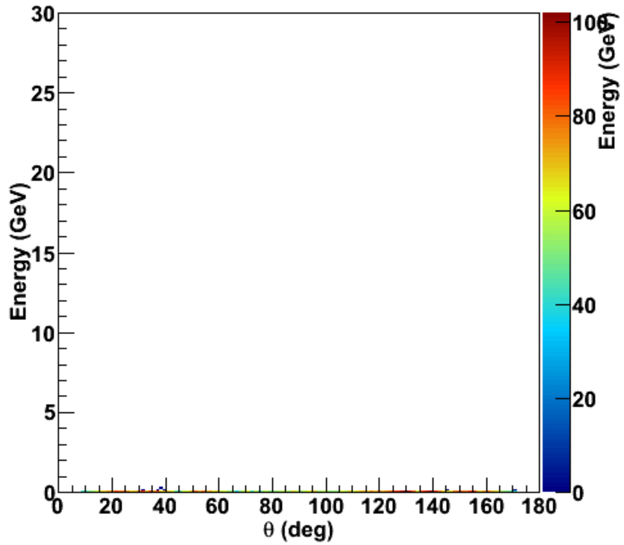
muons



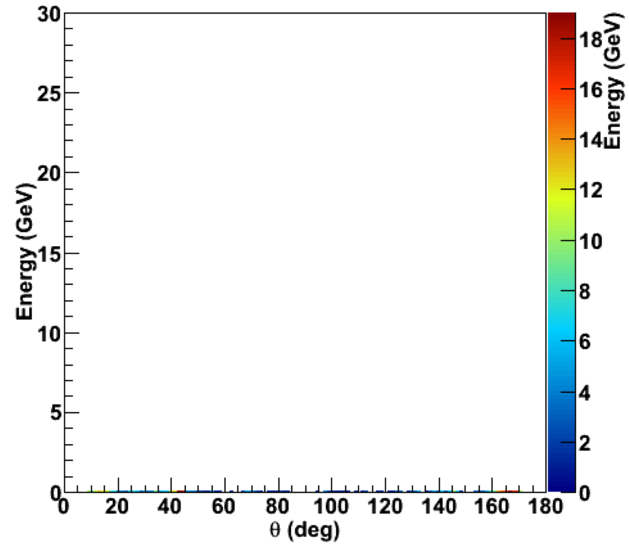
gammas



electrons



others

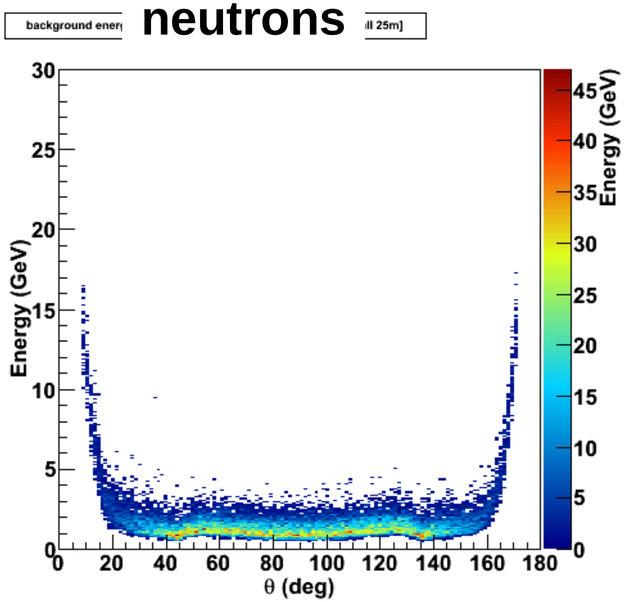


With background particles from 250 m only muons contribute to energy into the calorimeter

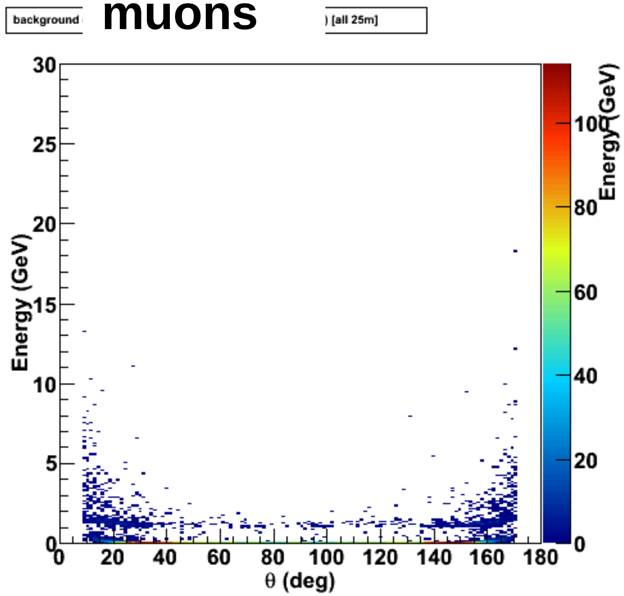
No difference using shorter integration time gate

Energy distribution per tower vs theta. MARS input file within 25 m; Integration time gate [0 – 300] ns

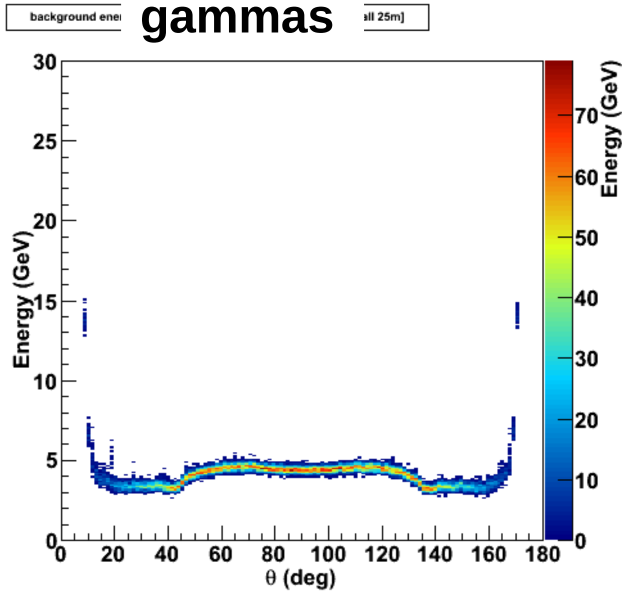
neutrons



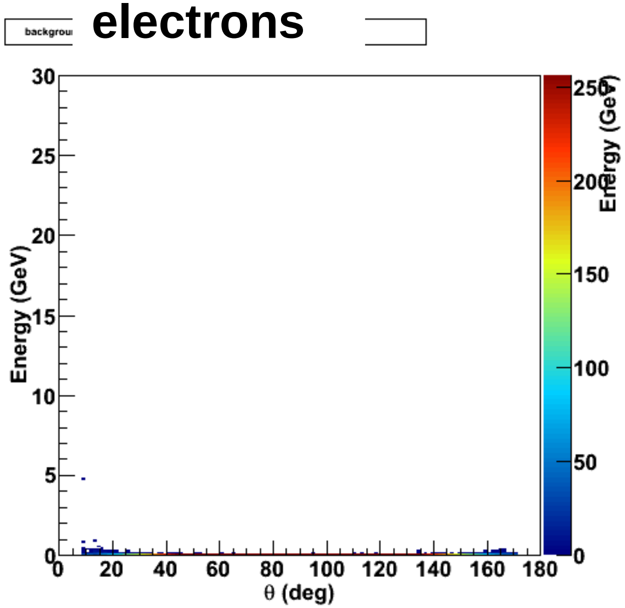
muons



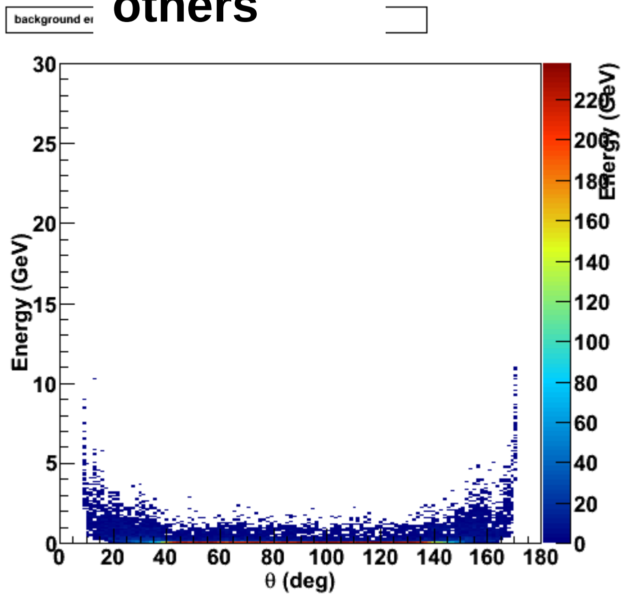
gammas



electrons



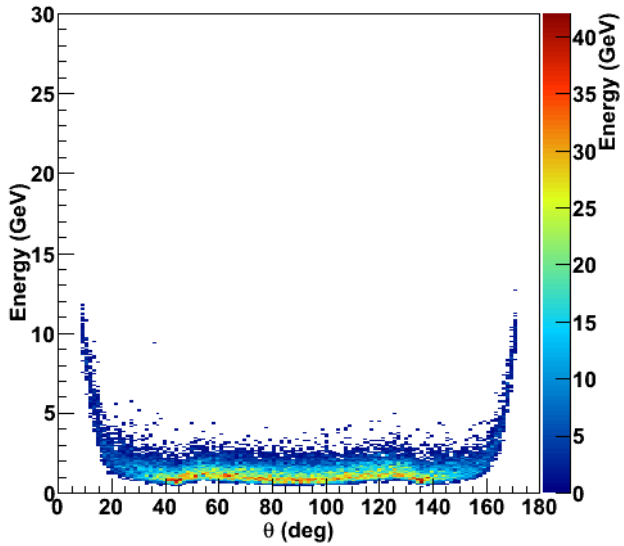
others



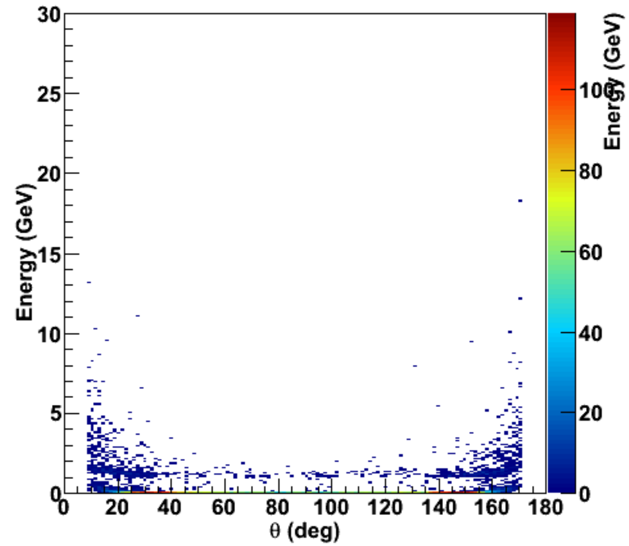
With background particles within 25 m mostly neutrons and gammas contribute to energy into the calorimeter

Energy distribution per tower vs theta. MARS input file within 25 m; Integration time gate [5 – 105] ns

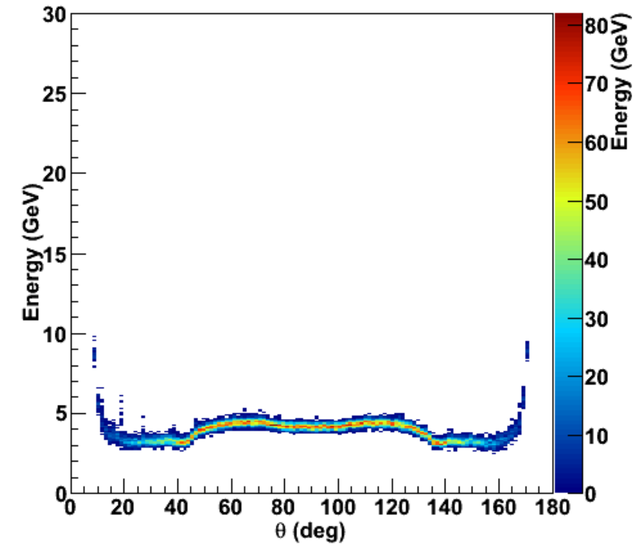
neutrons



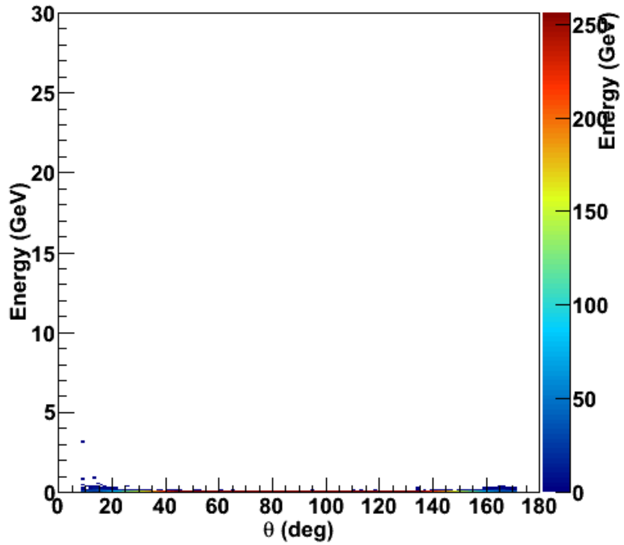
muons



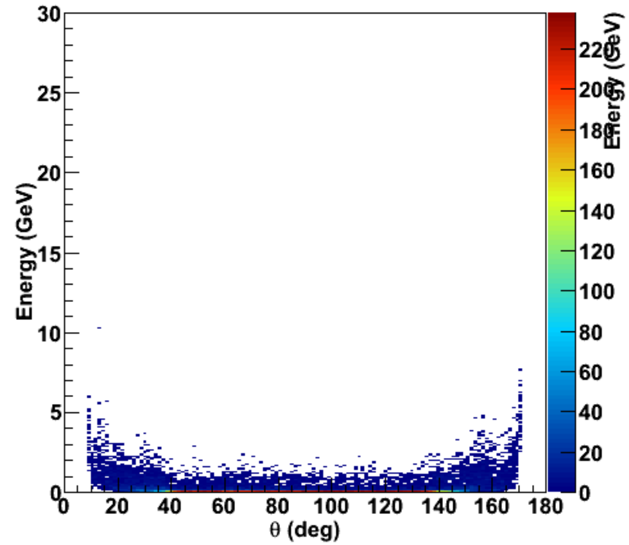
gammas



electrons



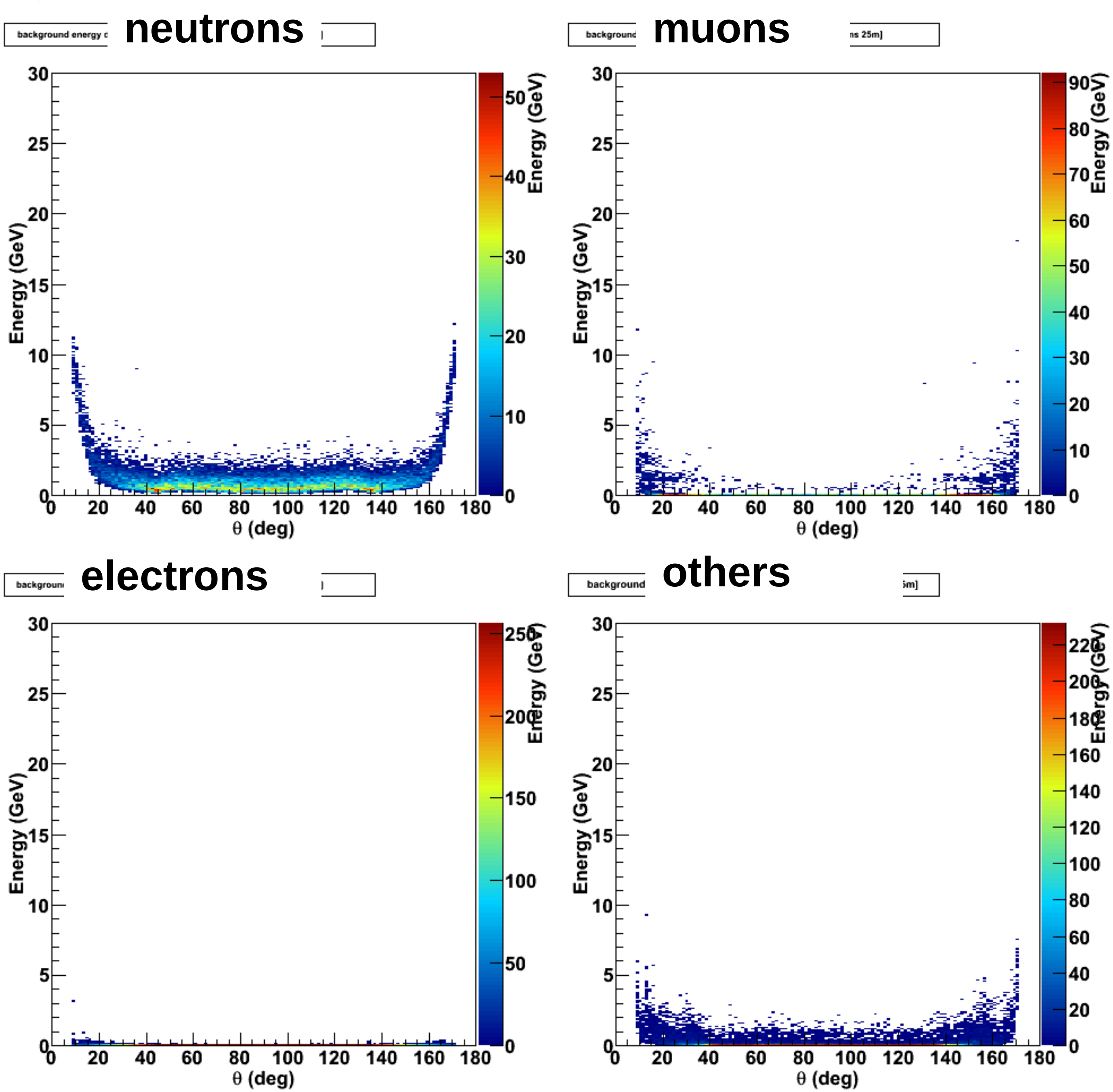
others



With background particles within 25 m mostly neutrons and gammas contribute to energy into the calorimeter

Small difference using shorter integration time gate

Energy distribution per tower vs theta. MARS input file within 25 m; Integration time gate [5 – 25] ns



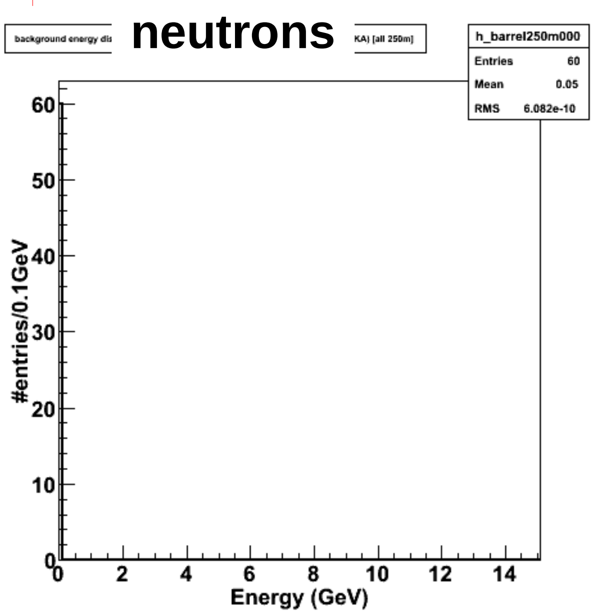
With background particles within 25 m mostly neutrons and gammas contribute to energy into the calorimeter

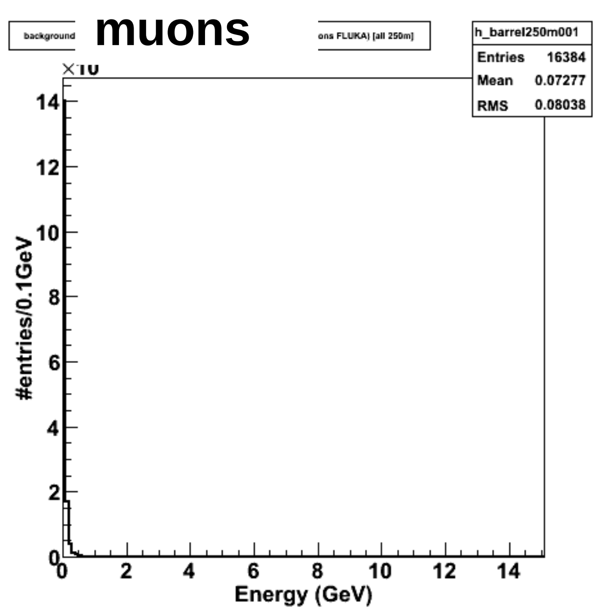
Small difference using shorter integration time gate

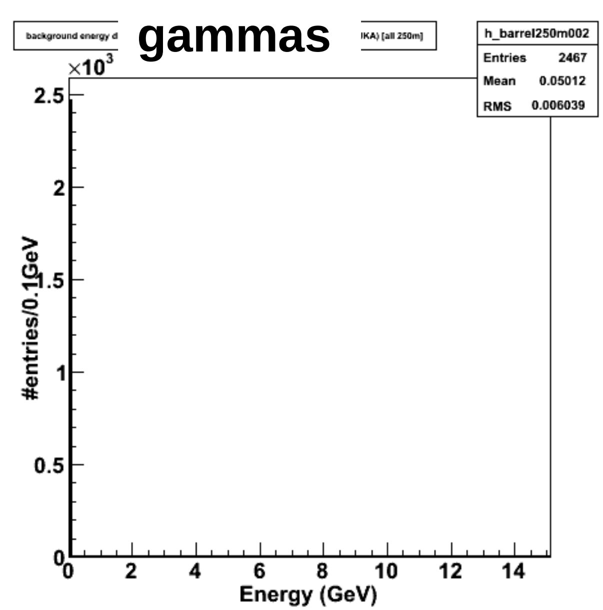
MARS event overview

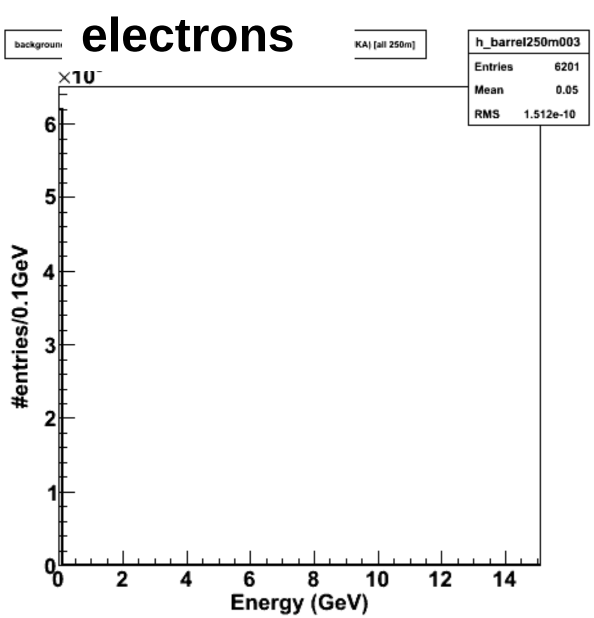
Energy distribution of the
background per tower
in barrel section
for different species
using different time gate

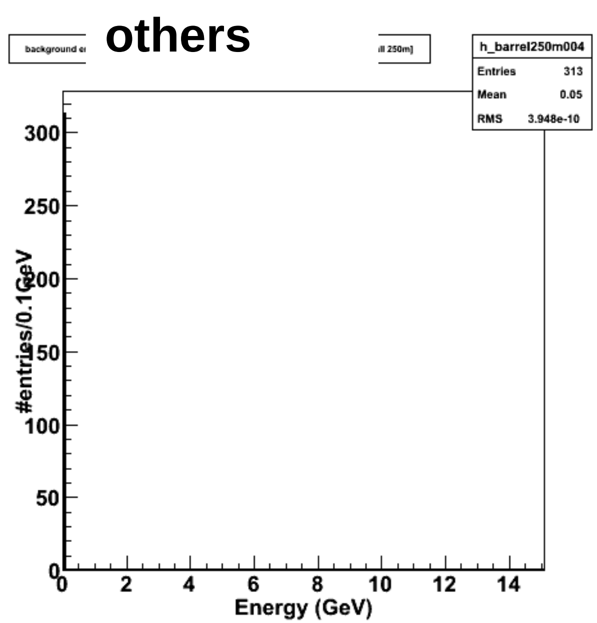
Energy distribution per tower in barrel. MARS input file within 250 m; Integration time gate [0 – 300] ns





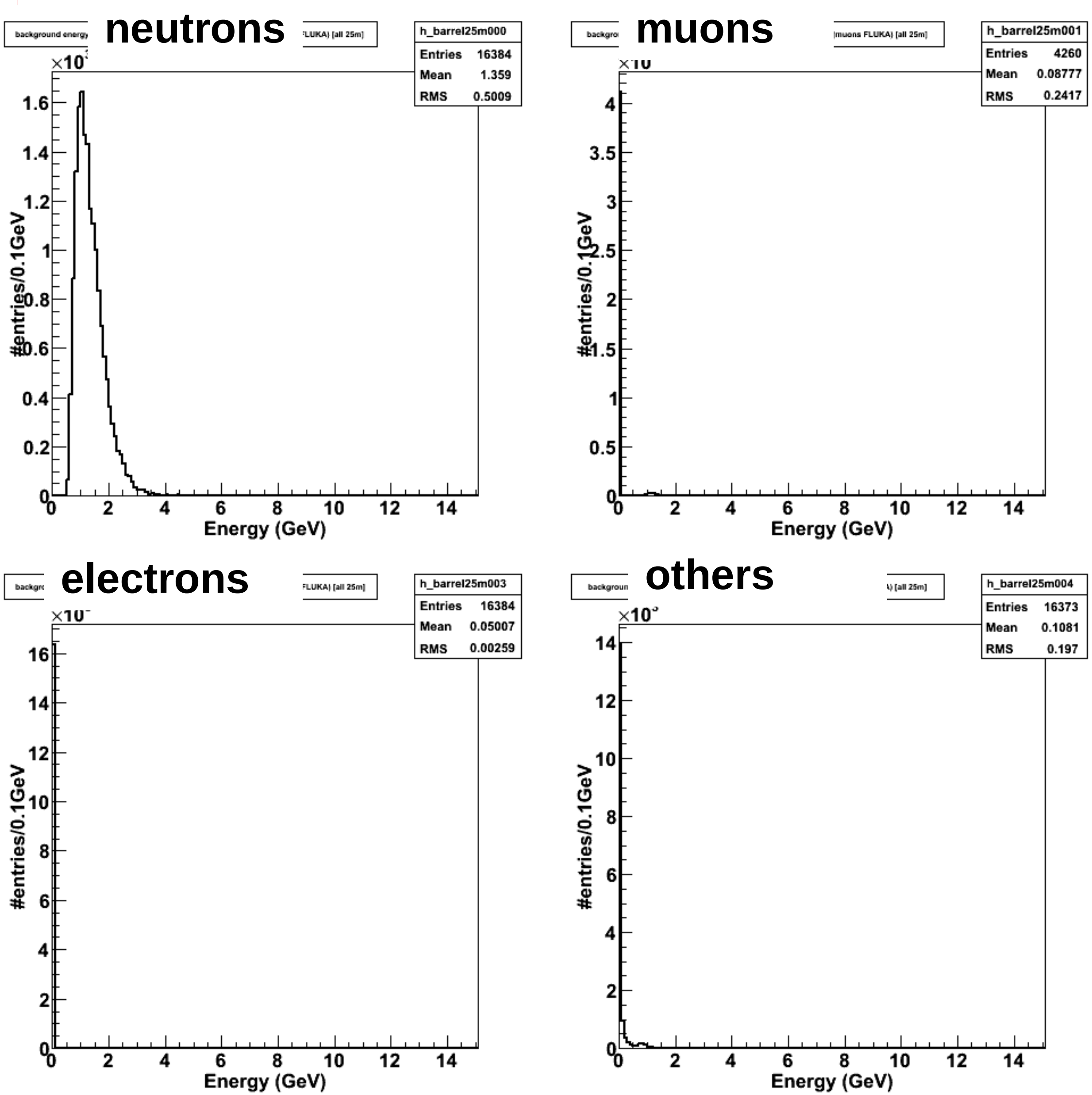






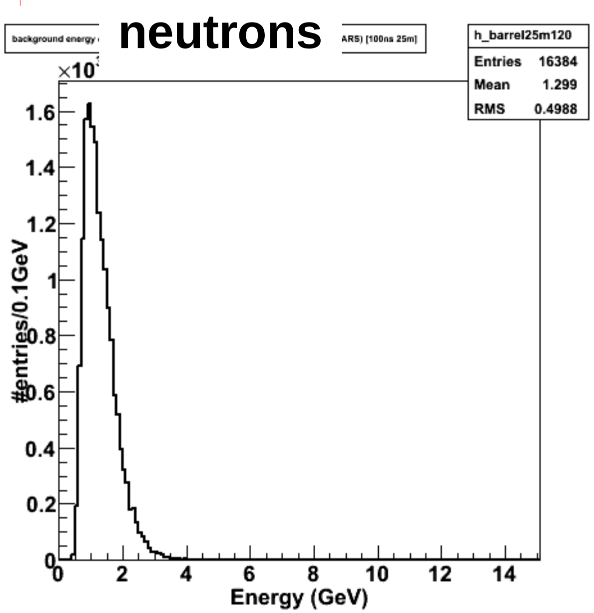
Negligible background for all integration time gate

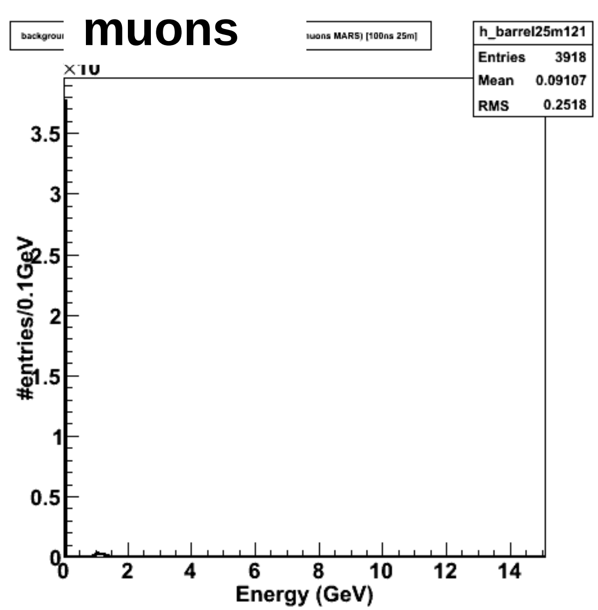
Energy distribution per tower in barrel. MARS input file within 25 m; Integration time gate [0 – 300] ns

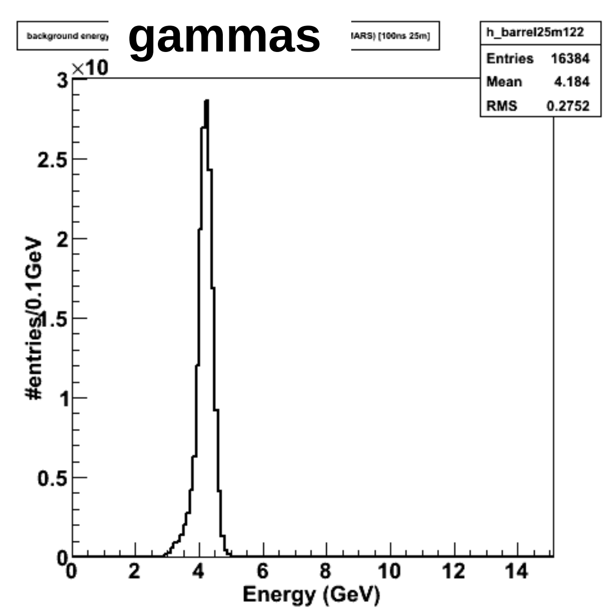


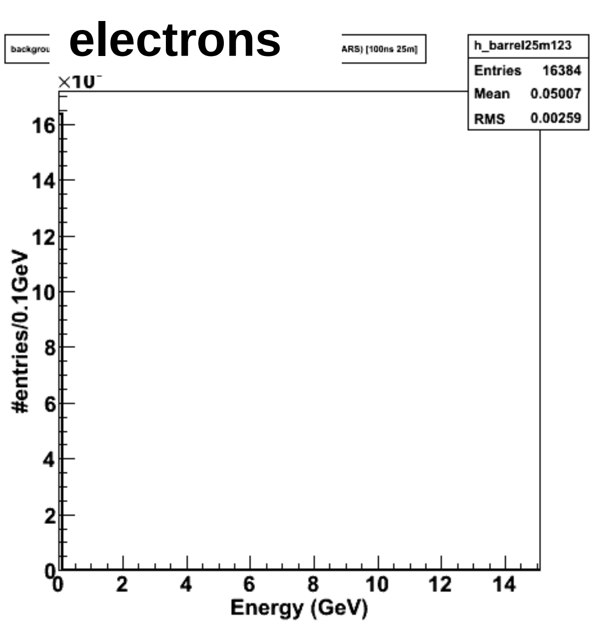
With background particles within 25 m mostly neutrons and gammas contribute to energy into the calorimeter

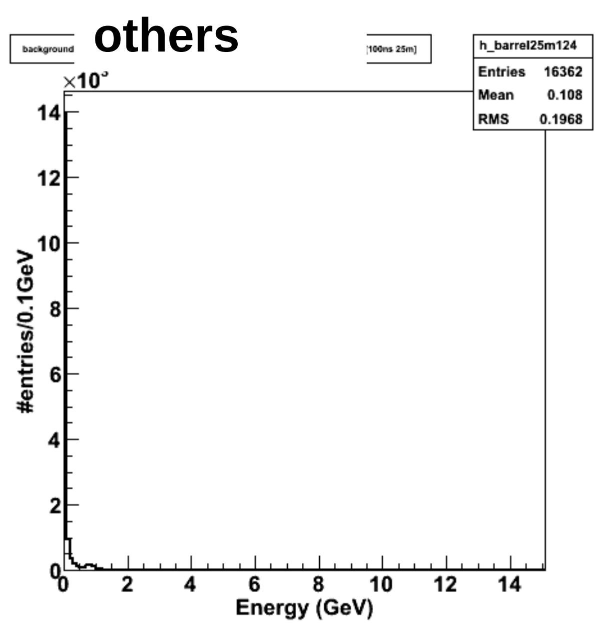
Energy distribution per tower in barrel. MARS input file within 25 m; Integration time gate [5 – 105] ns







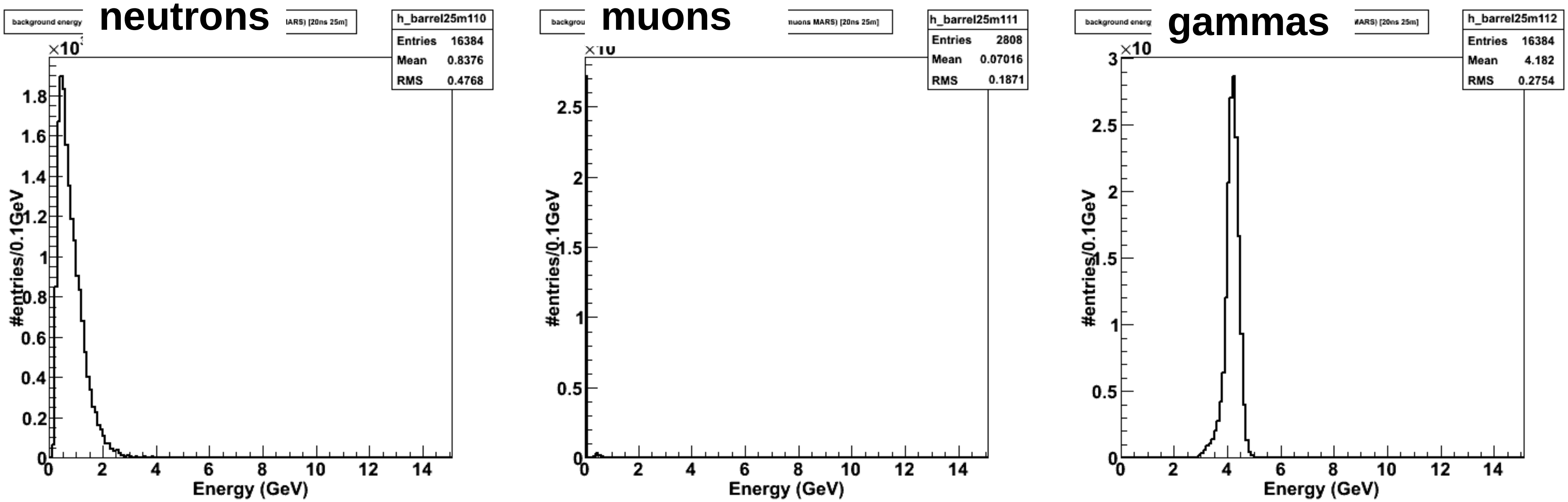


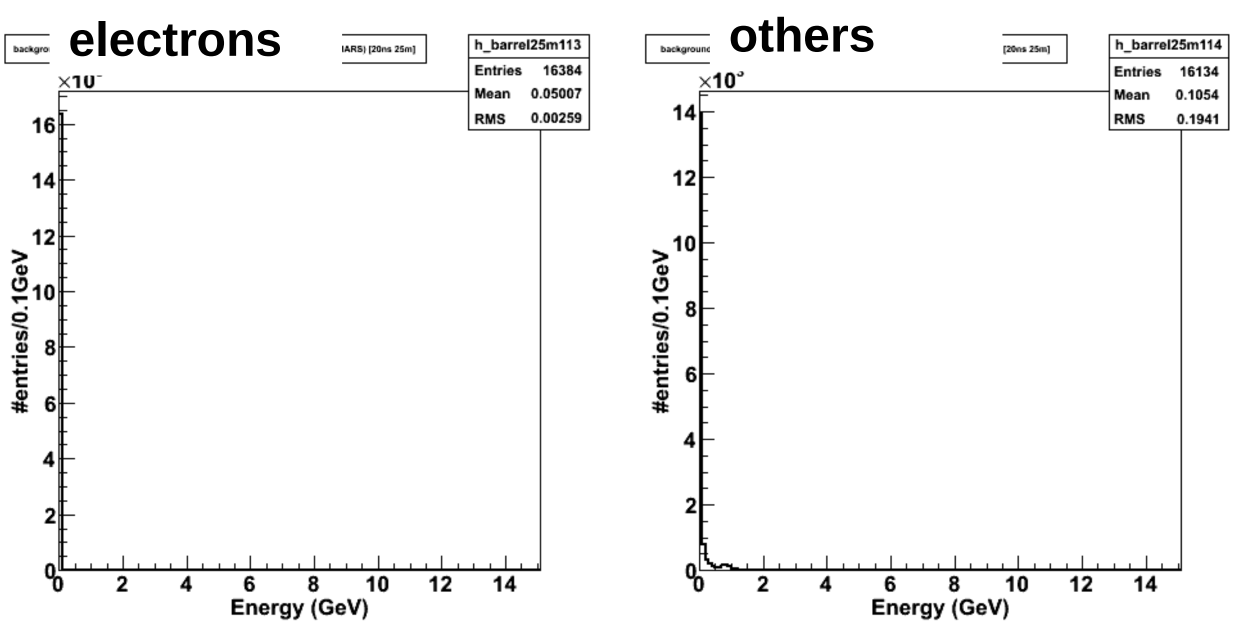


With background particles within 25 m mostly neutrons and gammas contribute to energy into the calorimeter

Small difference using shorter integration time gate

Energy distribution per tower in barrel. MARS input file within 25 m; Integration time gate [5 – 25] ns





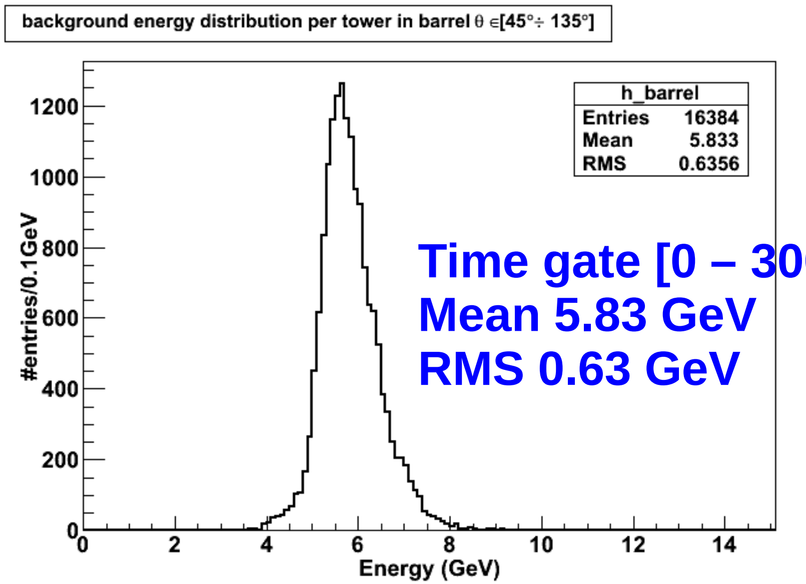
With background particles within 25 m mostly neutrons and gammas contribute to energy into the calorimeter

Small difference using shorter integration time gate

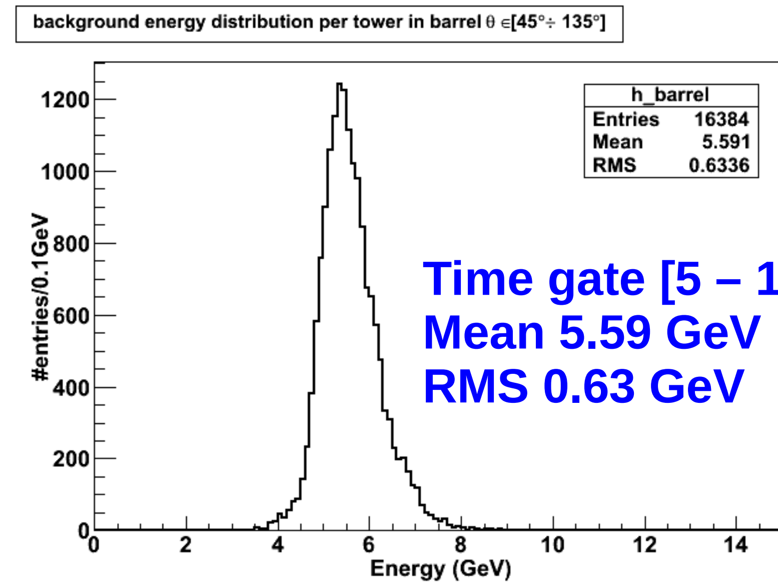
MARS event overview

Summary: total energy distribution of the background per tower
In barrel section [45° - 135°]
and endcap sections [20° - 45°]
And [8° - 20°]
using different integrated time gate

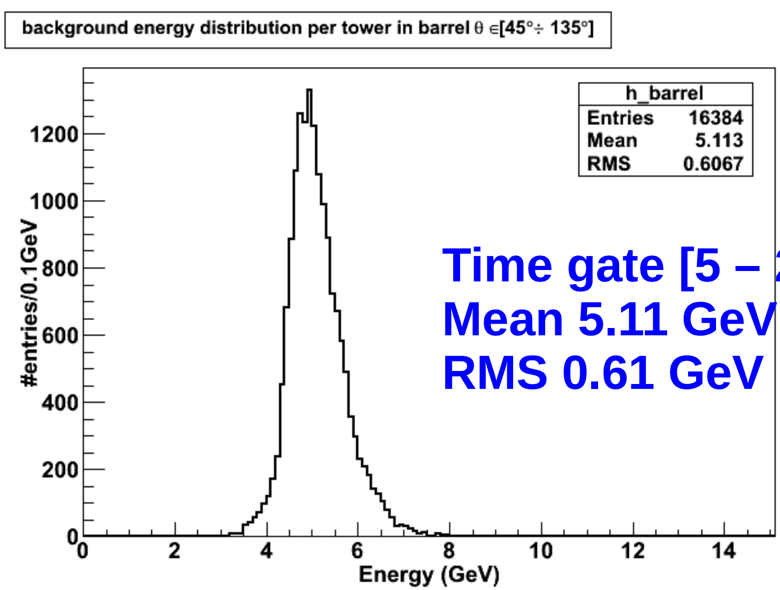
Energy distribution per tower in barrel [45°-135°]. Full MARS event



Time gate [0 – 300] ns
Mean 5.83 GeV
RMS 0.63 GeV



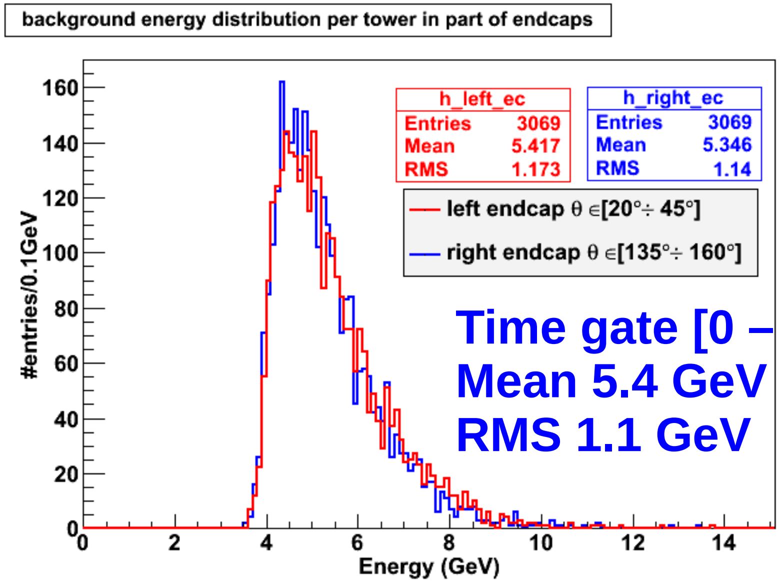
Time gate [5 – 105] ns
Mean 5.59 GeV
RMS 0.63 GeV



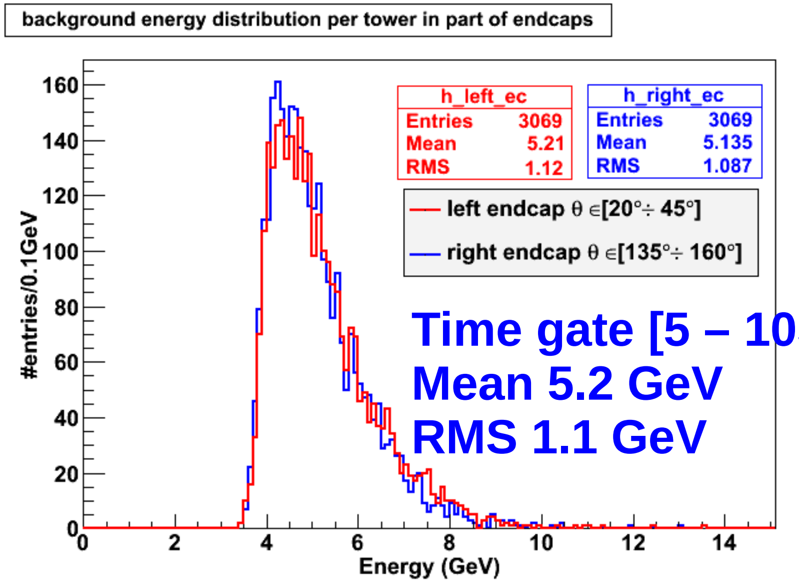
Time gate [5 – 25] ns
Mean 5.11 GeV
RMS 0.61 GeV

In the barrel the background fluctuation is ~ 12%

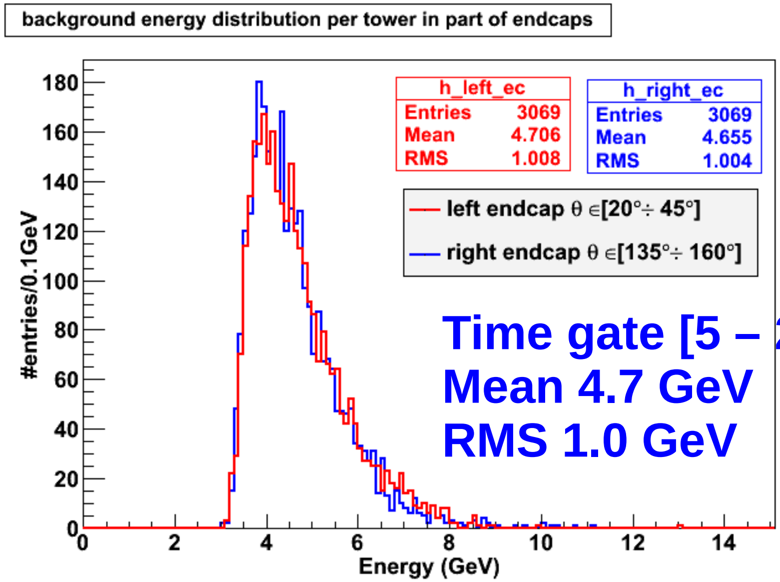
Energy distribution per tower in endcap [20°-45°] and [135°- 160°]. Full MARS event



Time gate [0 – 300] ns
Mean 5.4 GeV
RMS 1.1 GeV



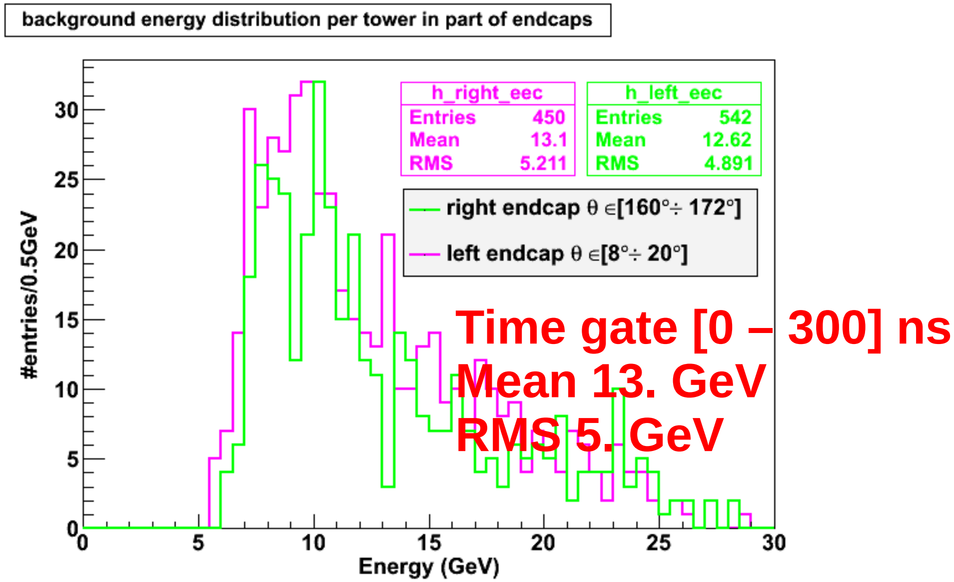
Time gate [5 – 105] ns
Mean 5.2 GeV
RMS 1.1 GeV

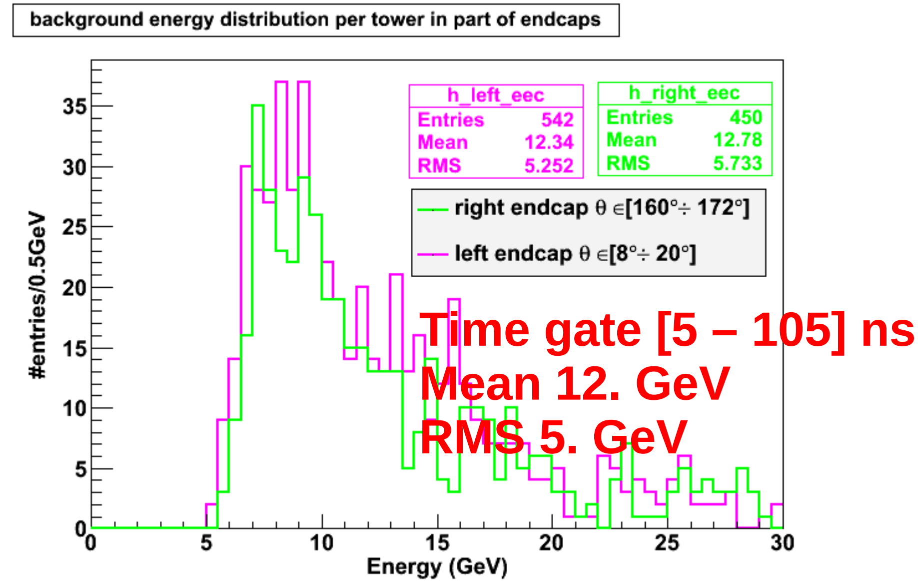


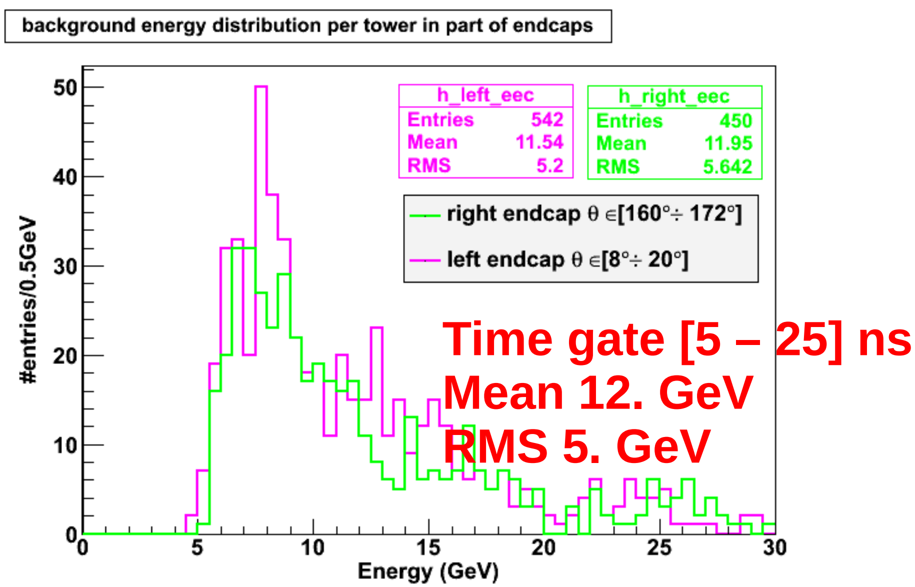
Time gate [5 – 25] ns
Mean 4.7 GeV
RMS 1.0 GeV

In the endcap section [20°-45°] the background fluctuations are ~ 20%

Energy distribution per tower in endcap [8°-20°] and [160°-172°]. Full MARS event







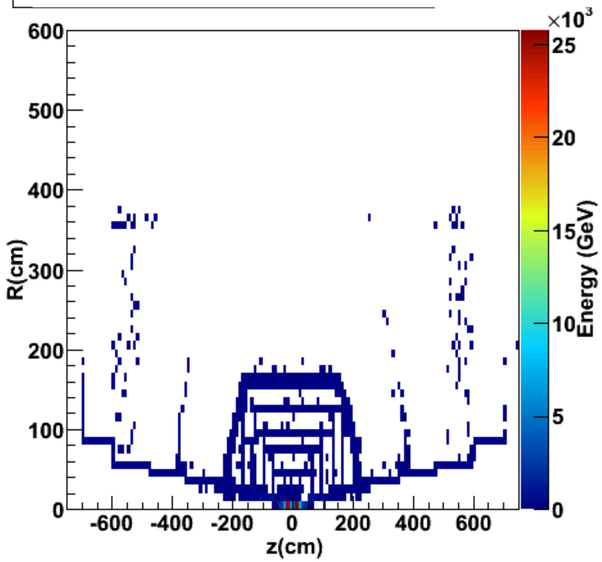
In the last endcap part the background fluctuations are very large ~40%

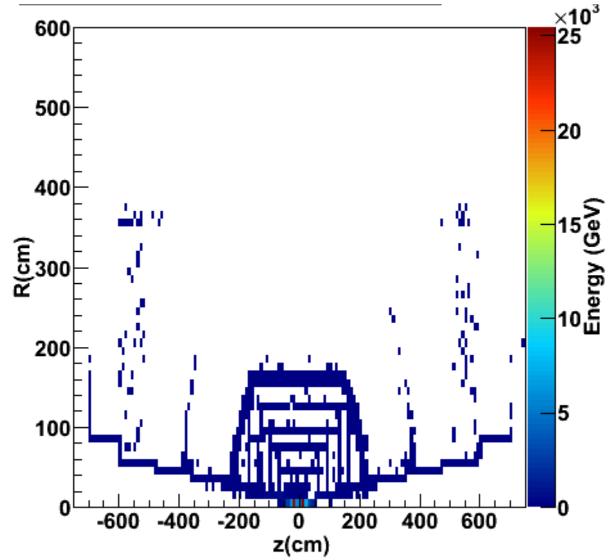
MARS event overview

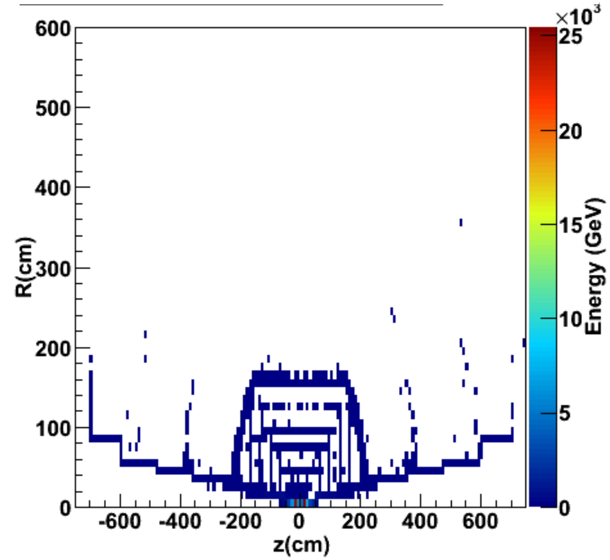
Point of origin of the background particles entering the calorimeter using different integration time gate

Origin of gammas that enter into the calorimeter.
MARS input file with background within 25 m.

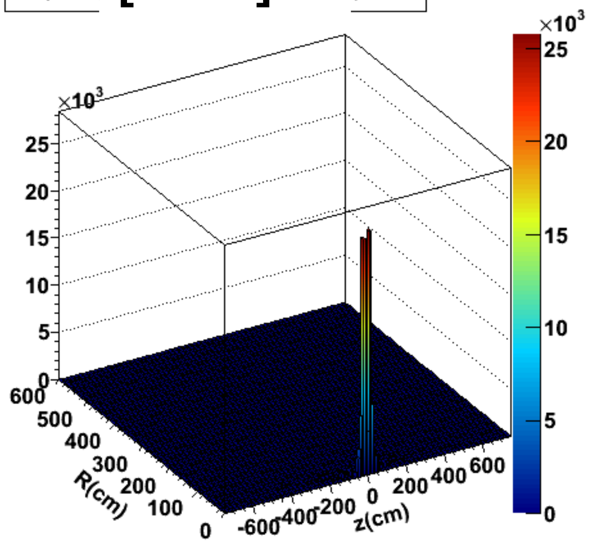
Each entries is the integrated energy in an area 10x10 cm^2 If a particle reach the calorimeter from the nose, it don't make shower into the tracker

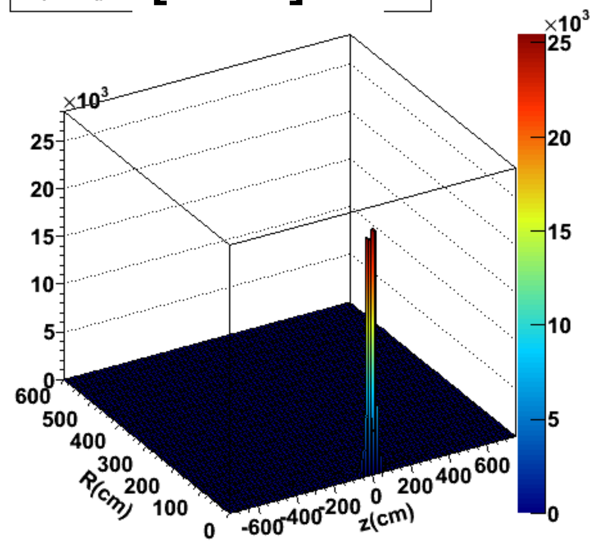


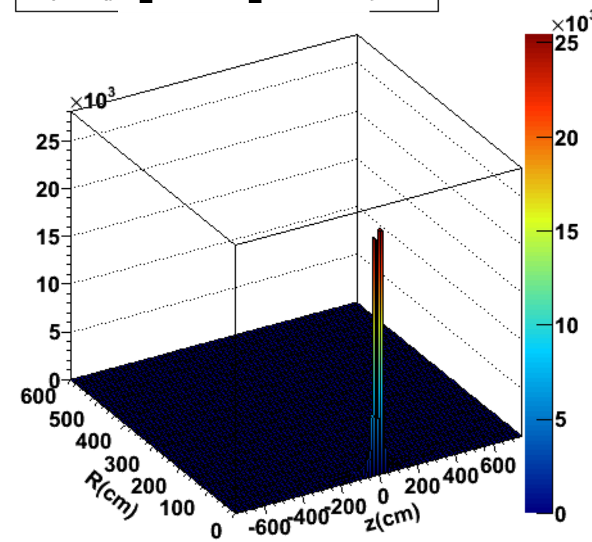




[0-300]ns **[5-105]ns** **[5-25]ns**

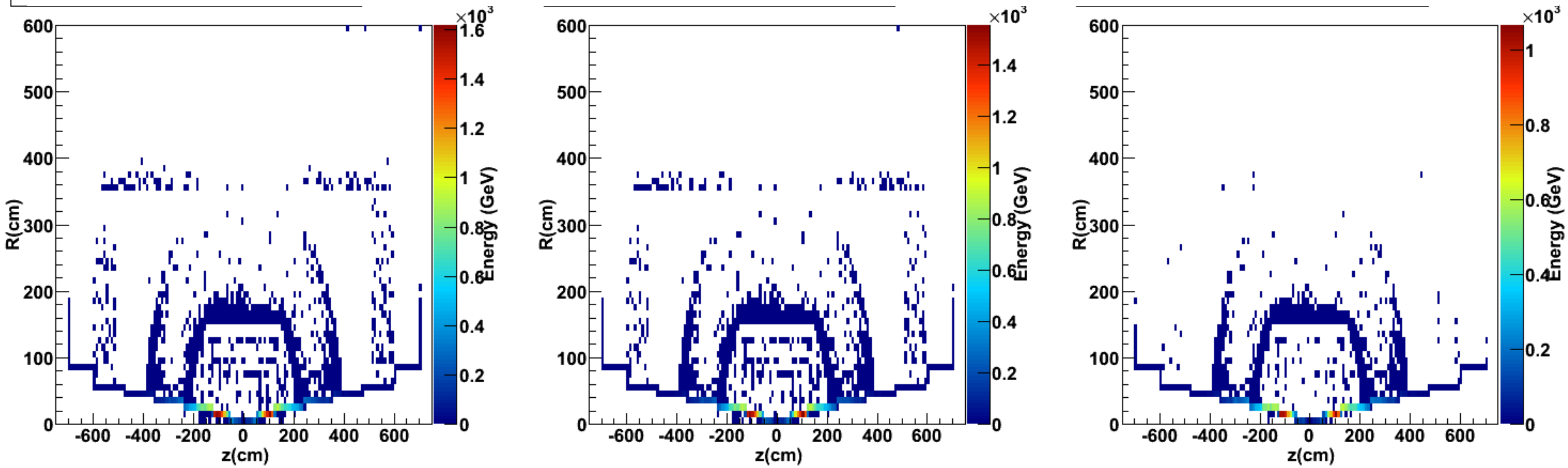




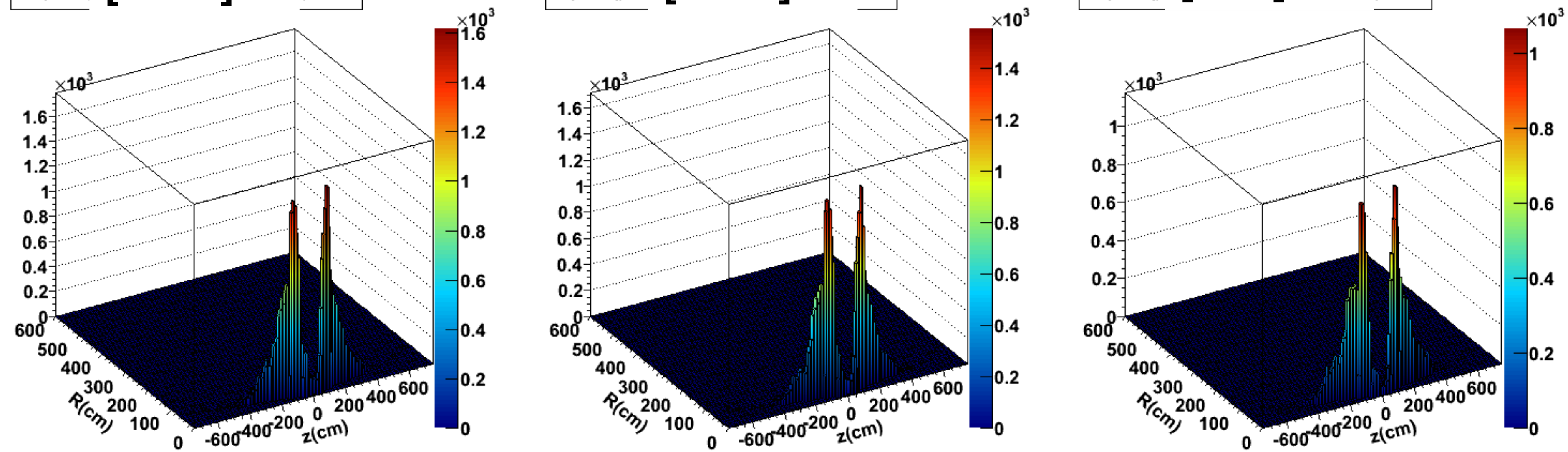


Origin of neutrons that enter into the calorimeter.
MARS file within 25 m.

Each entries is the integrated energy in an area 10x10 cm^2 If a particle reach the calorimeter from the nose, it don't make shower into the tracker

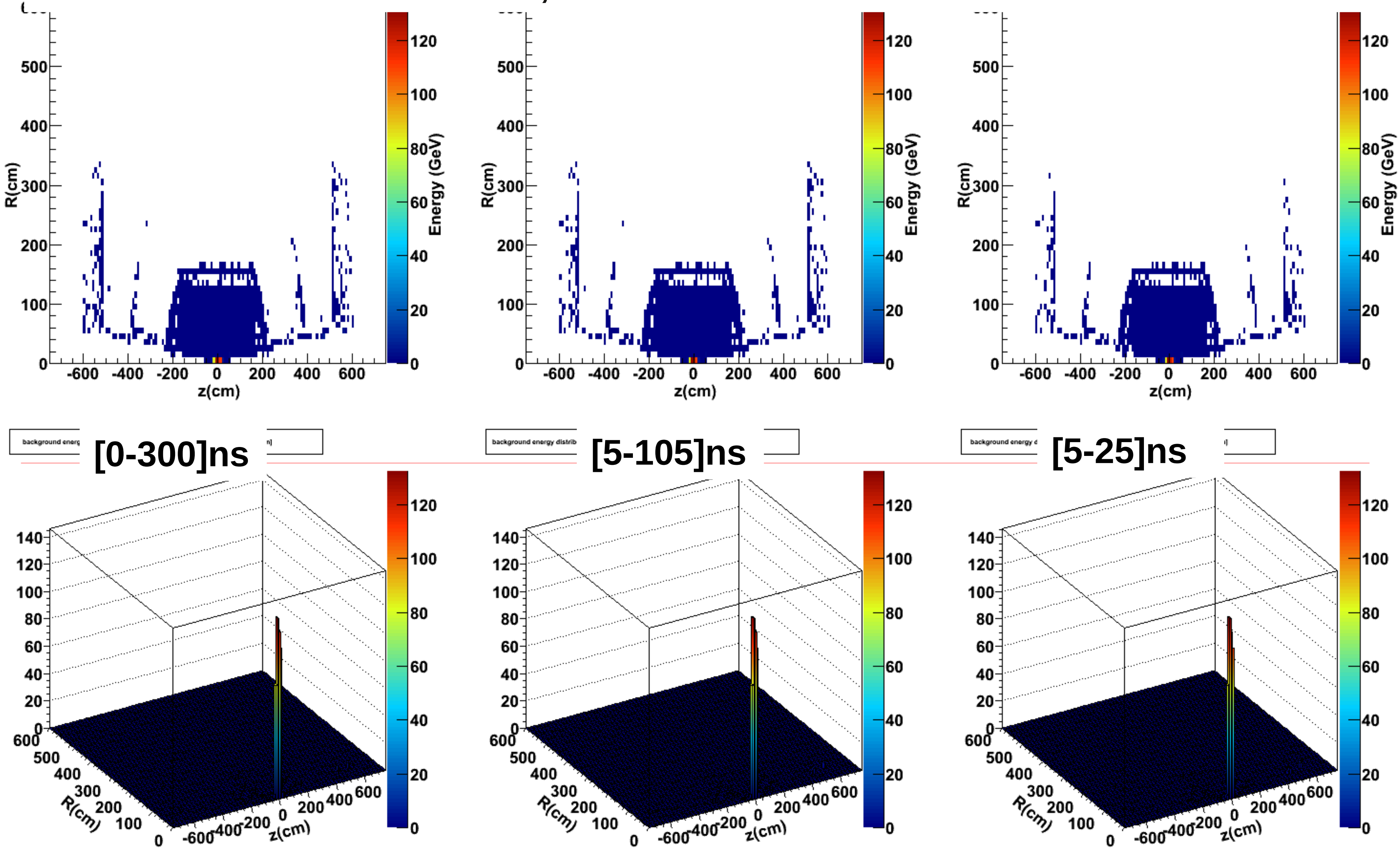


[0-300]ns [5-105]ns [5-25]ns



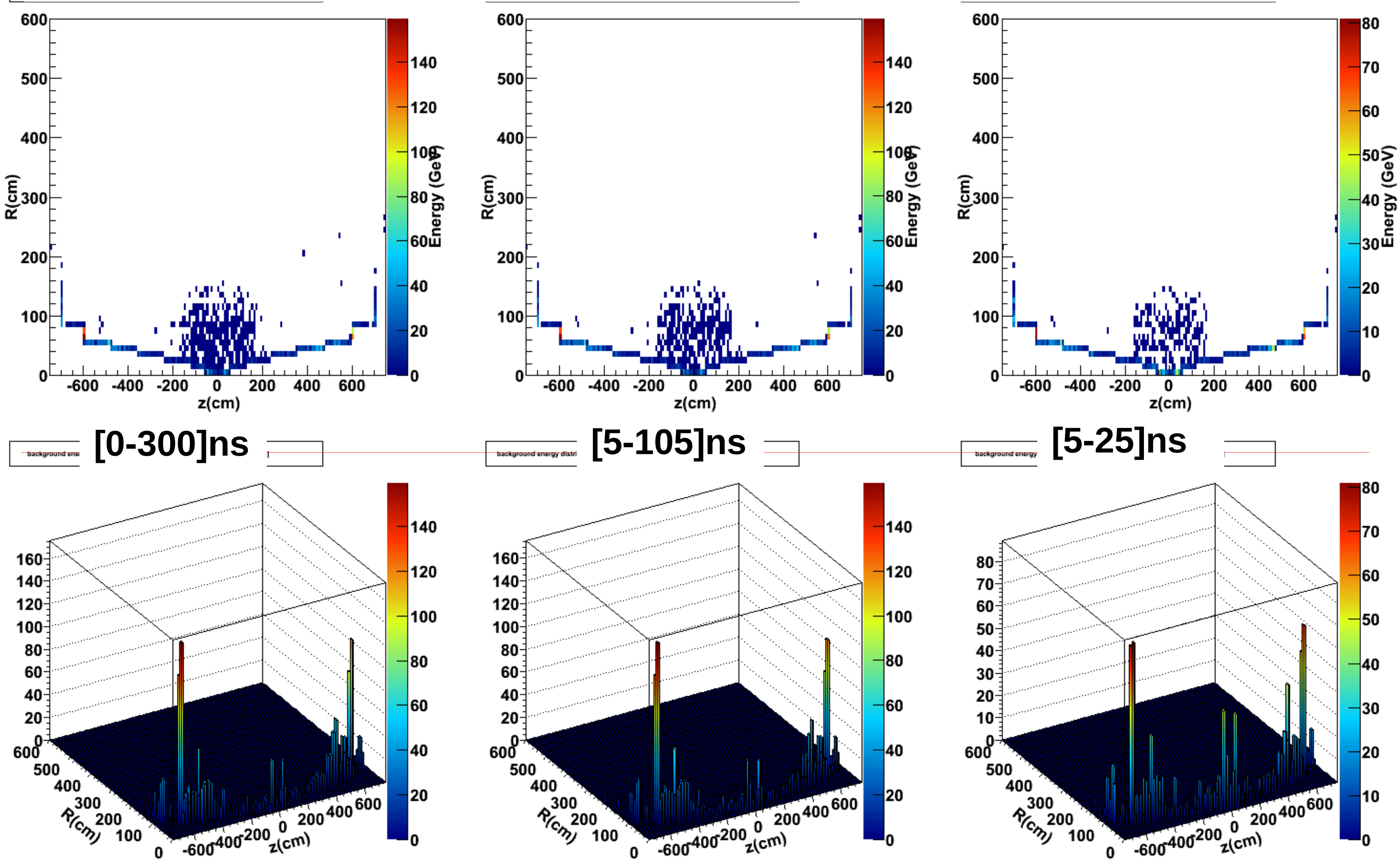
Origin of electrons that enter into the calorimeter.
MARS file within 25 m.

Each entries is the integrated energy in an area 10x10 cm^2 If a particle reach the calorimeter from the nose, it don't make shower into the tracker



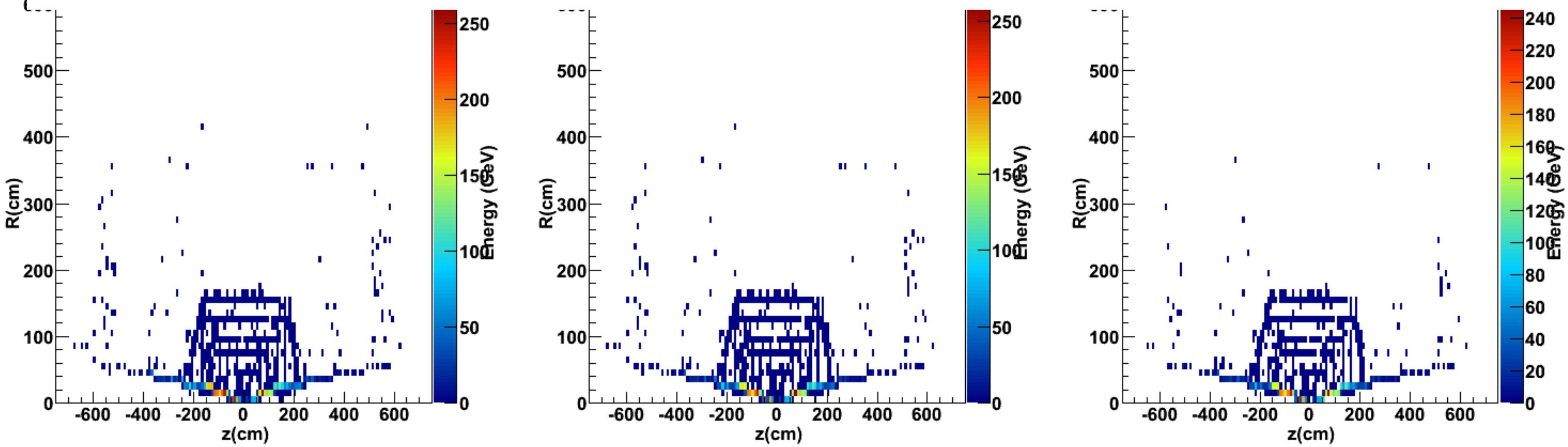
Origin of muons that enter into the calorimeter.
MARS file within 25 m.

Each entries is the integrated energy in an area 10x10 cm^2 If a particle reach the calorimeter from the nose, it don't make shower into the tracker

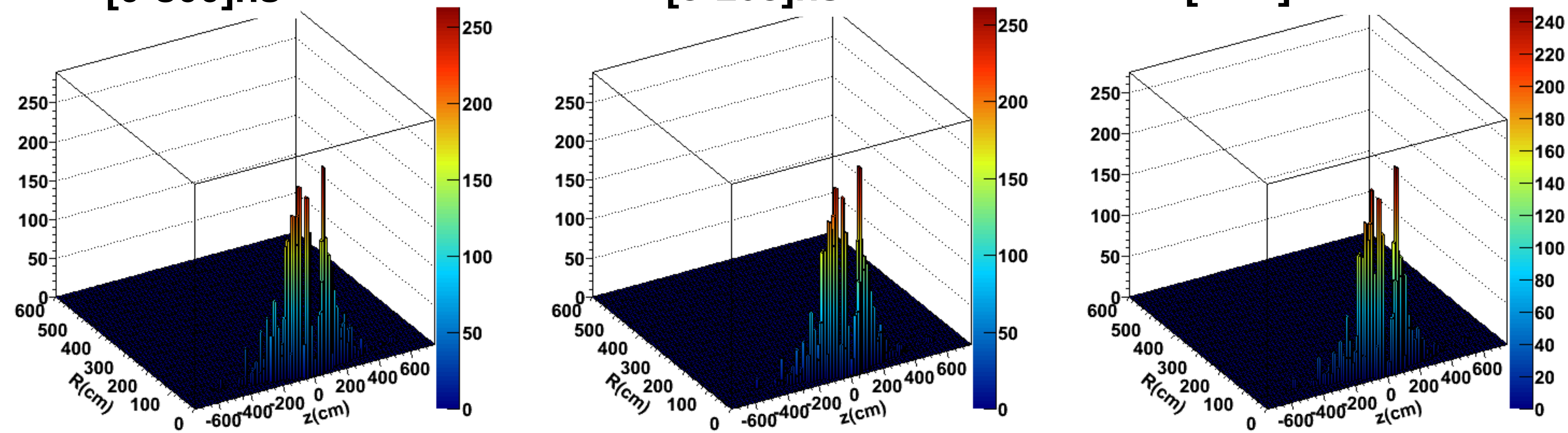


Origin of others that enter into the calorimeter.
MARS file within 25 m.

Each entries is the integrated energy in an area 10x10 cm^2 If a particle reach the calorimeter from the nose, it don't make shower into the tracker

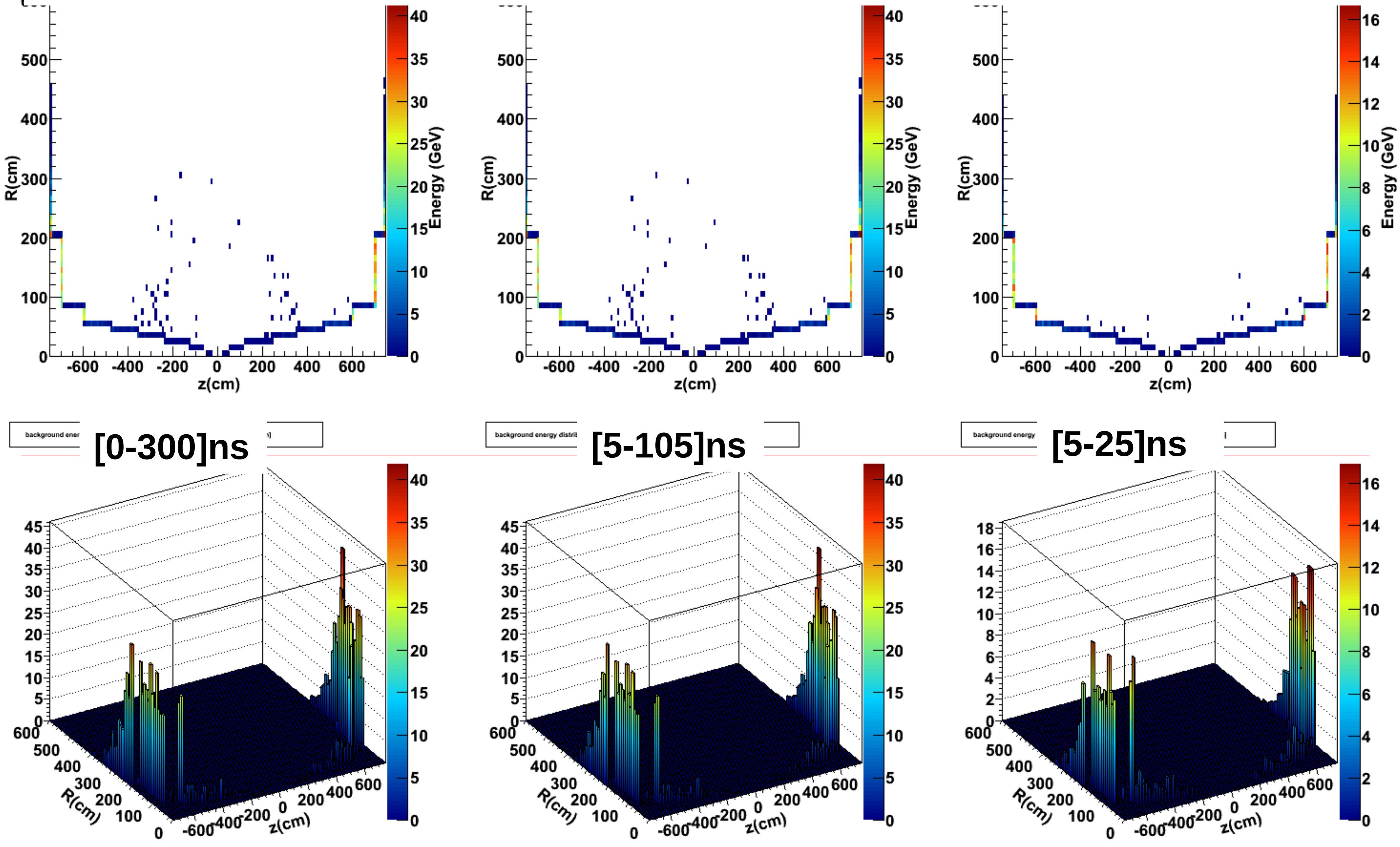


[0-300]ns [5-105]ns [5-25]ns



Origin of muons that enter into the calorimeter.
MARS file within 250 m.

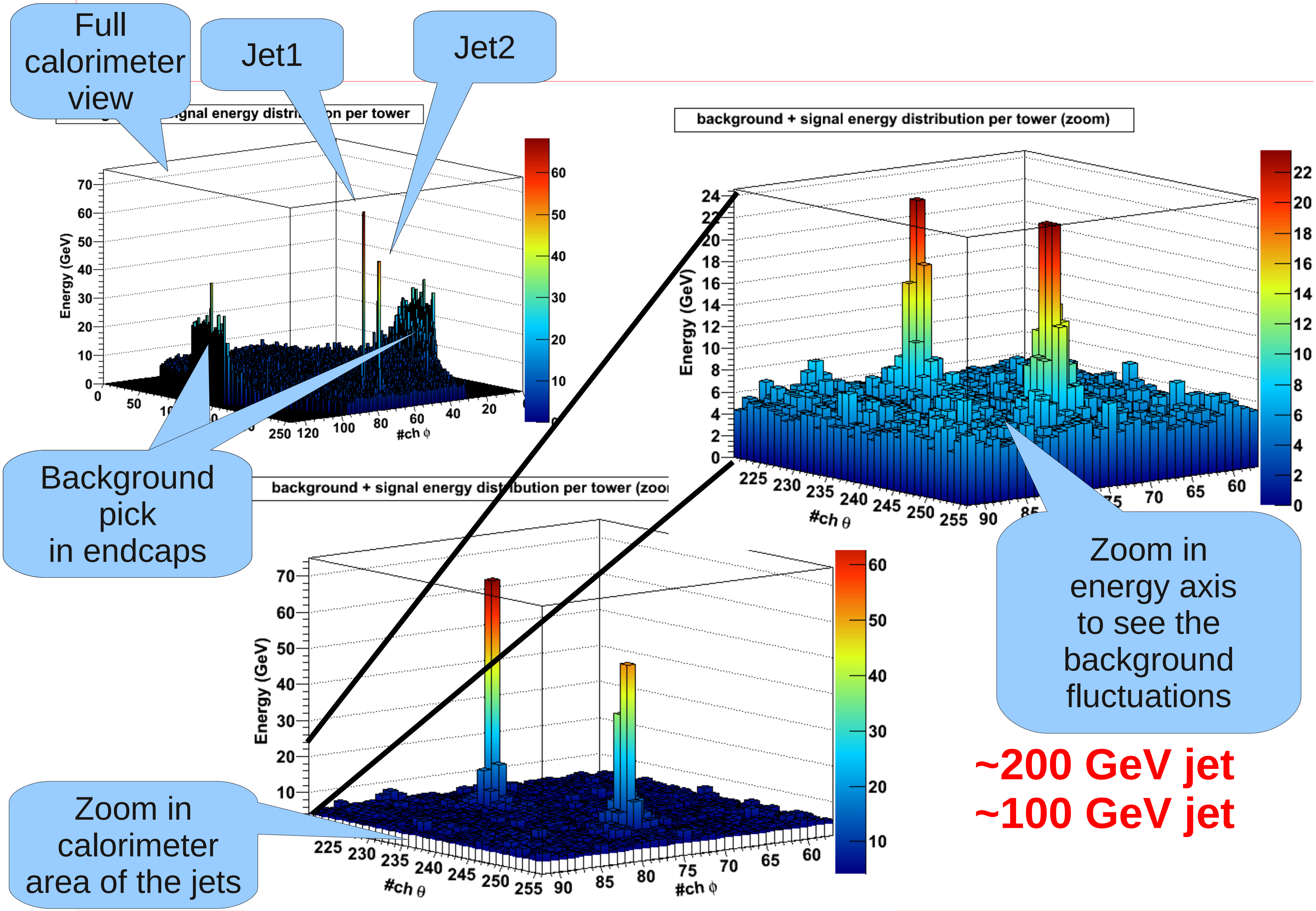
Each entries is the integrated energy in an area 10x10 cm^2 If a particle reach the calorimeter from the nose, it don't make shower into the tracker



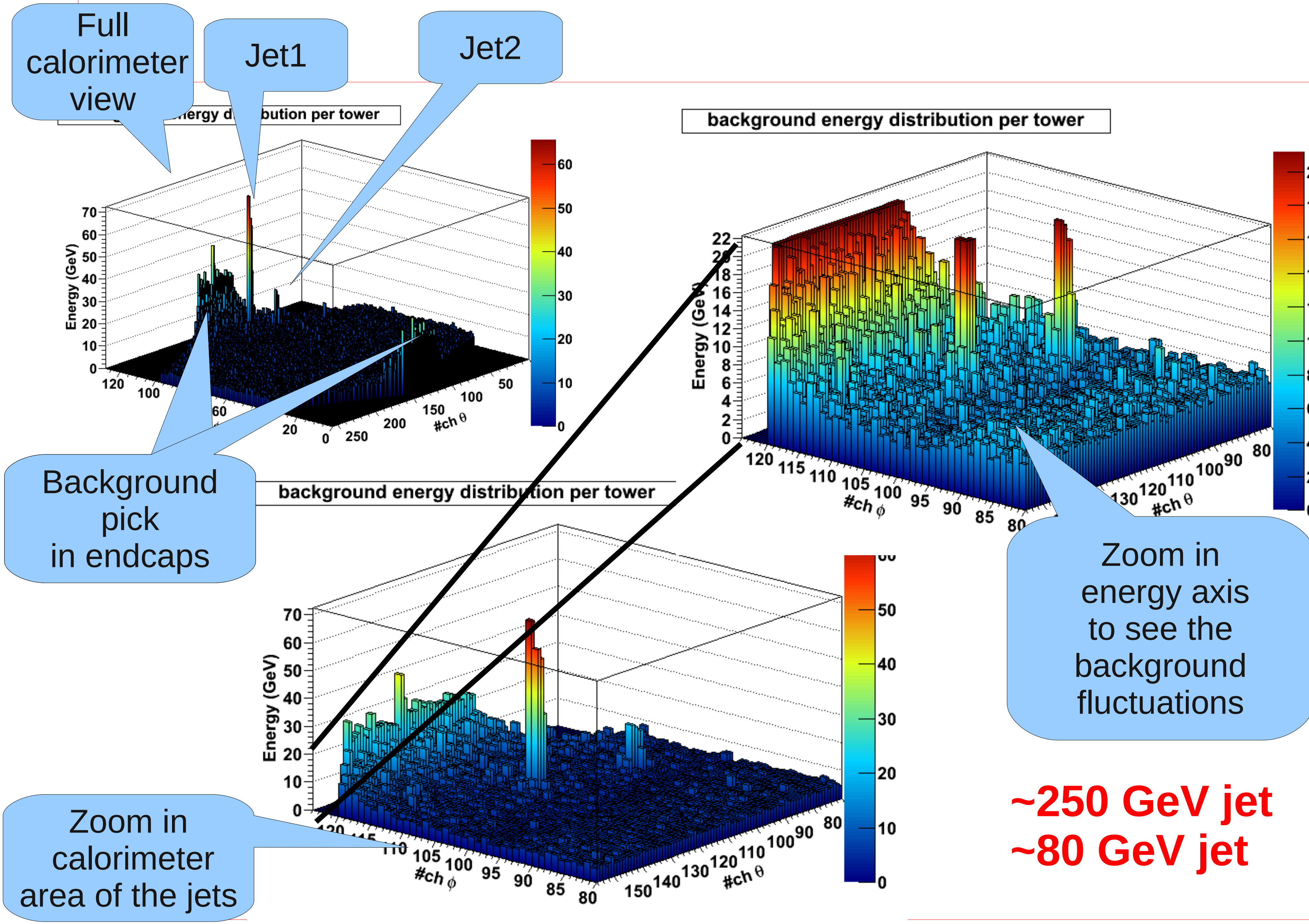
Physics processes vs background

First attempt to get MuonCollider background and Physics together

Z->jj event with MuonCollider background Event 3

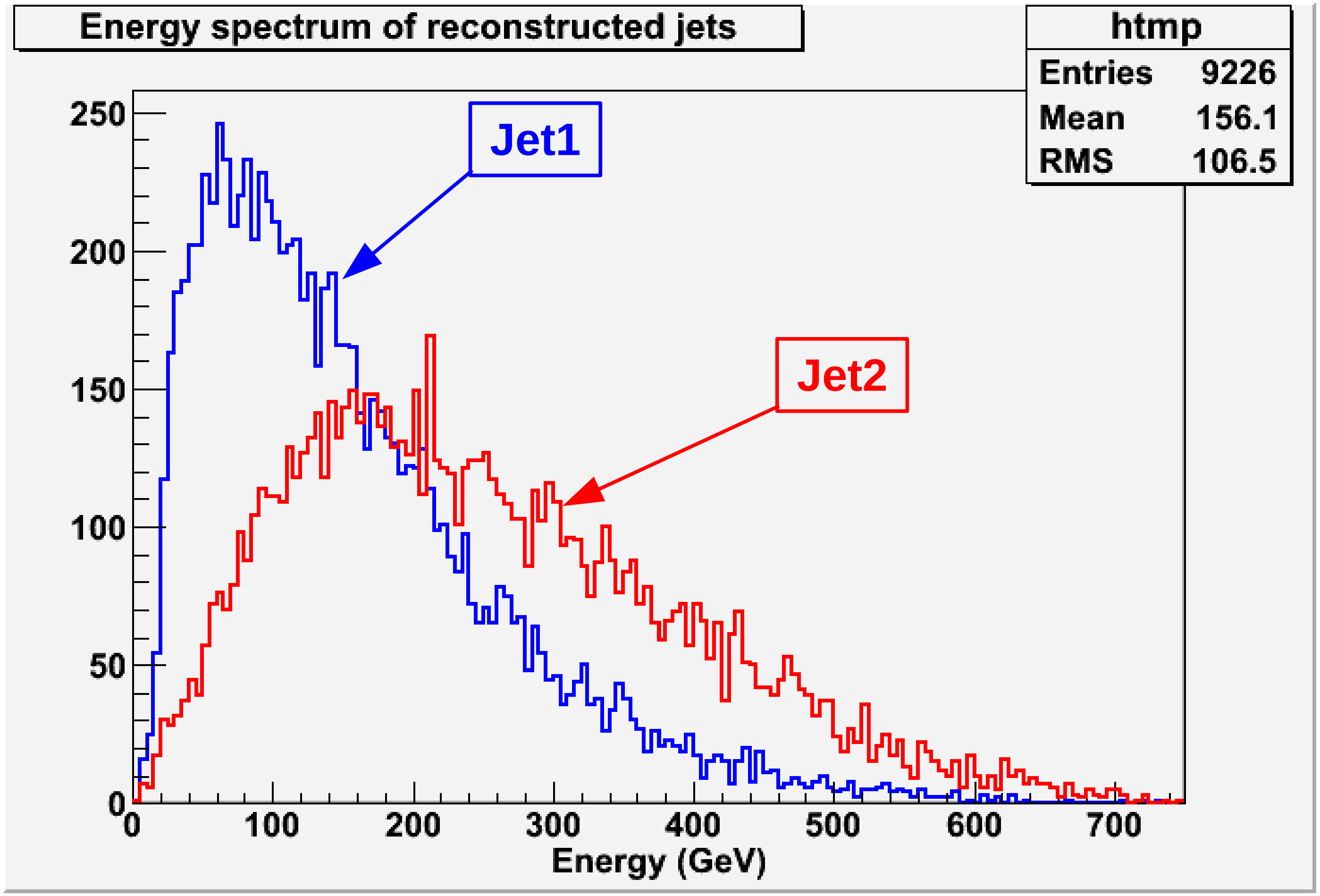


Z->jj event with MuonCollider background Event 8



~250 GeV jet
~80 GeV jet

Reconstructed jets energy spectrum



Jet's energy spectrum of reconstructed jets (bin = 5GeV) Pick between 100 – 200 GeV

Physics and background: some comment

- Jets develop in 16 – 25 towers; mean energy 150 GeV
- Background in barrel:mean energy 5 GeV RMS 0.6 GeV
  Jet energy fluctuation after background pedestal cut
  2.5 – 3 GeV
- Background in endcap > 20°: mean energy 5 GeV RMS 1. GeV
  Jet energy fluctuation after background pedestal cut
  5 – 6 GeV
- Background in endcap < 20°: mean energy 12 GeV RMS 5. GeV
  Jet energy fluctuation after background pedestal cut
  20 – 25 GeV

Merging issues to be addressed

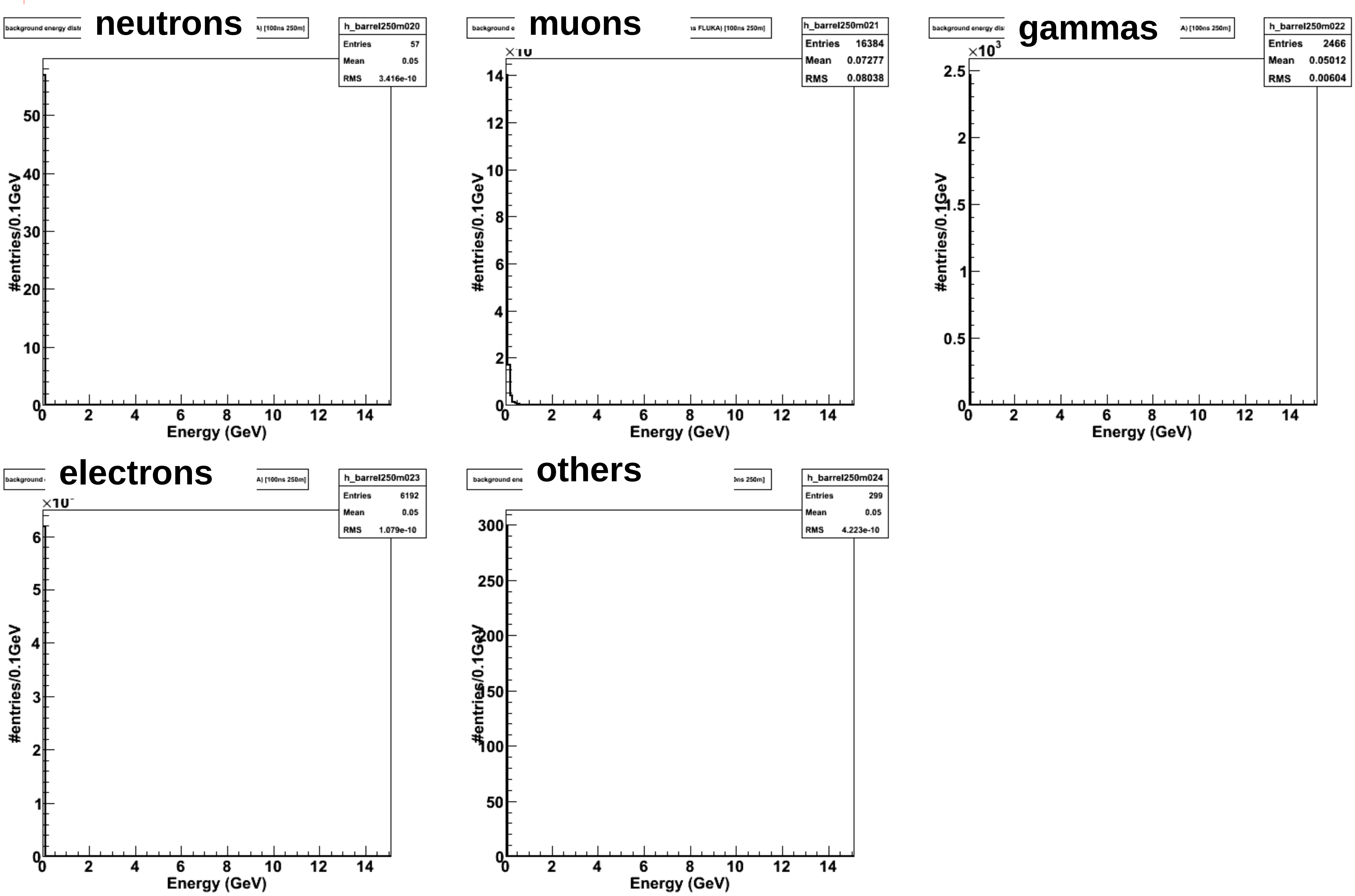
- Merging is done from SDigits to Digits (inherited by AliRoot)
- For Alice this work fine. In high multiplicity event PbPb ions they have ~$2x10^4$ particles per event
- In a MuonCollider MARS background event there are ~$1x10^8$ particles per event
- To be able to simulate a full MuonCollider background event I split it in ~$2x10^3$ subsections
- Using the classic merge technic is time expensive
- Different approach can be used: FastClusterization; it is less accurate but can be more efficient. Need some time to implement this merging technic

Conclusion

- Accurate study about MuonCollider background have been presented
- Below 20° is complicate do Physics
- Some time it is need to implement a more efficient merging of background and Physics

Back-up slides

Energy distribution per tower in barrel. MARS file within 250 m; Time gate [5 – 105] ns



Energy distribution per tower in barrel. MARS file within 250 m; Time gate [5 – 25] ns