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EEEmeeting@CentroFermi

Detector Simulation Working Group (DeSi-WG)
EEE telescope simulation update

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Contents

Report activity working groups:

- Lecce group – GEMC-EEE simulation data
- Cagliari group – data quality check
- Genova-Bologna group – Efficiency estimation
- Messina Group – topological stability map and efficiency

Summary and paper road-map

Introduction

Simulation framework description: MRPC detector response; Cosmic muon flux model; Telescope geometry and location description; digitalization-reconstruction. Done! Simulation chain operative at Genova, Cagliari, Lecce and Messina.

We are working on simulation framework validation to:

- Understand the reliability of simulation (Genova, Cagliari, Lecce, Messina)
- Obtain the efficiency correction to estimate the asbolute rate (Genova-Bologna, Messina)
- Understand if it is possible to parametrize correctly the environment of telescopes sites. (Lecce)

Consequently, we need data stability information to look for good telescope condidate for exp.-sim. data comparison (Cagliari)

Lecce group – GEMC-EEE simulation

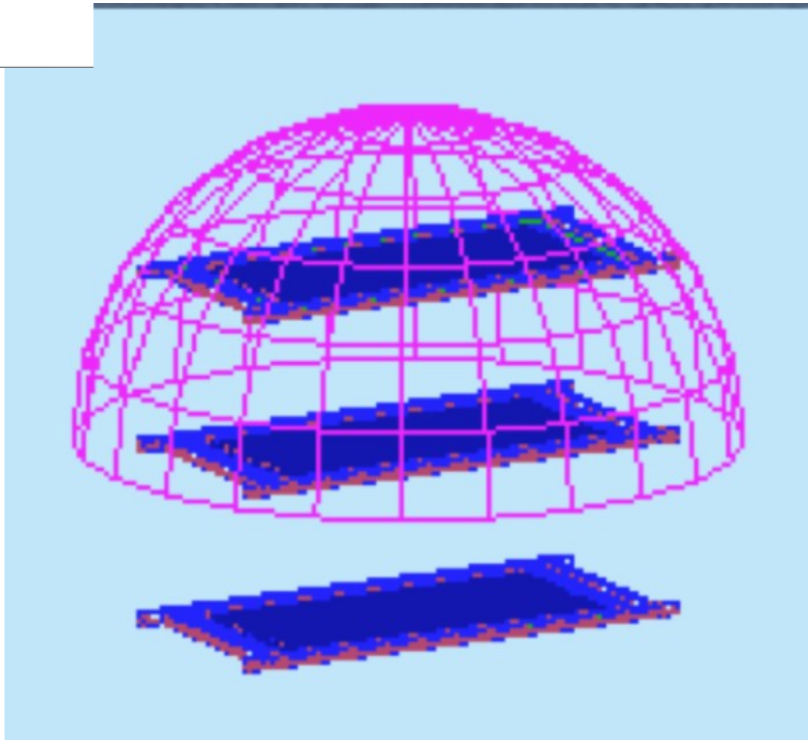
$$\frac{dI_\mu}{dE_\mu} = 0.14\left[\frac{E_\mu}{GeV}\left(1+\frac{3.64GeV}{E_\mu(\cos\theta^*)^{1.29}}\right)\right]^{-2.7}\left[\frac{1}{1+\frac{1.1E_\mu\cos\theta^*}{115GeV}}+\frac{0.054}{1+\frac{1.1E_\mu\cos\theta^*}{850GeV}}\right]$$

$$\cos\theta^* = \sqrt{\frac{(\cos\theta)^2+P_1^2+P_2(\cos\theta)^{P_3}+P_4(\cos\theta)^{P_5}}{1+P_1^2+P_2+P_4}}$$

P_1	P_2	P_3	P_4	P_5
0.102573	-0.068287	0.958633	0.0407253	0.817285

arXiv:1509.06176

MUON GENERATION

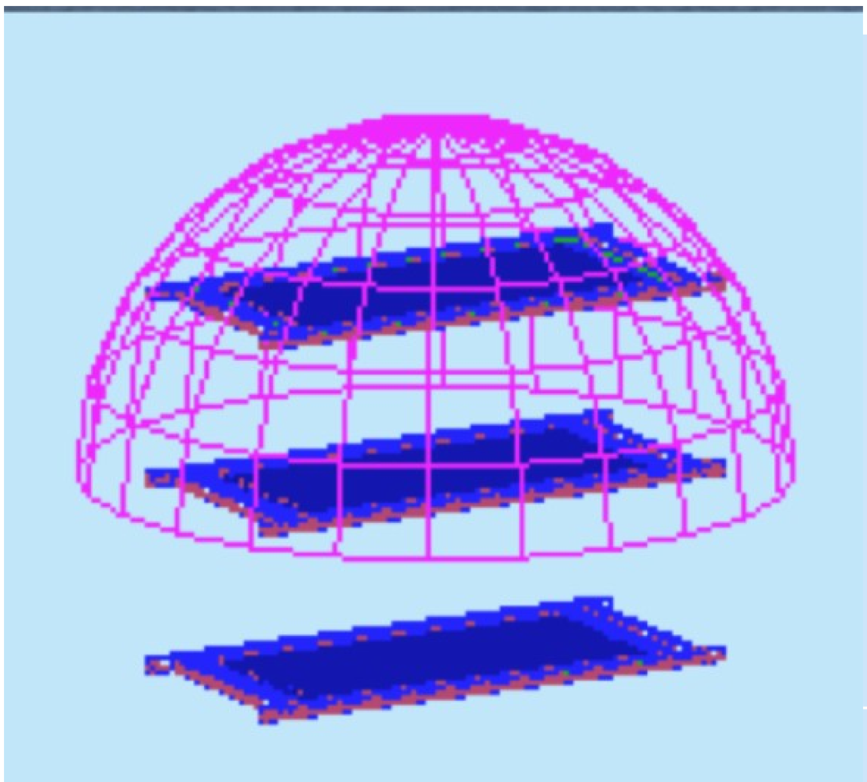


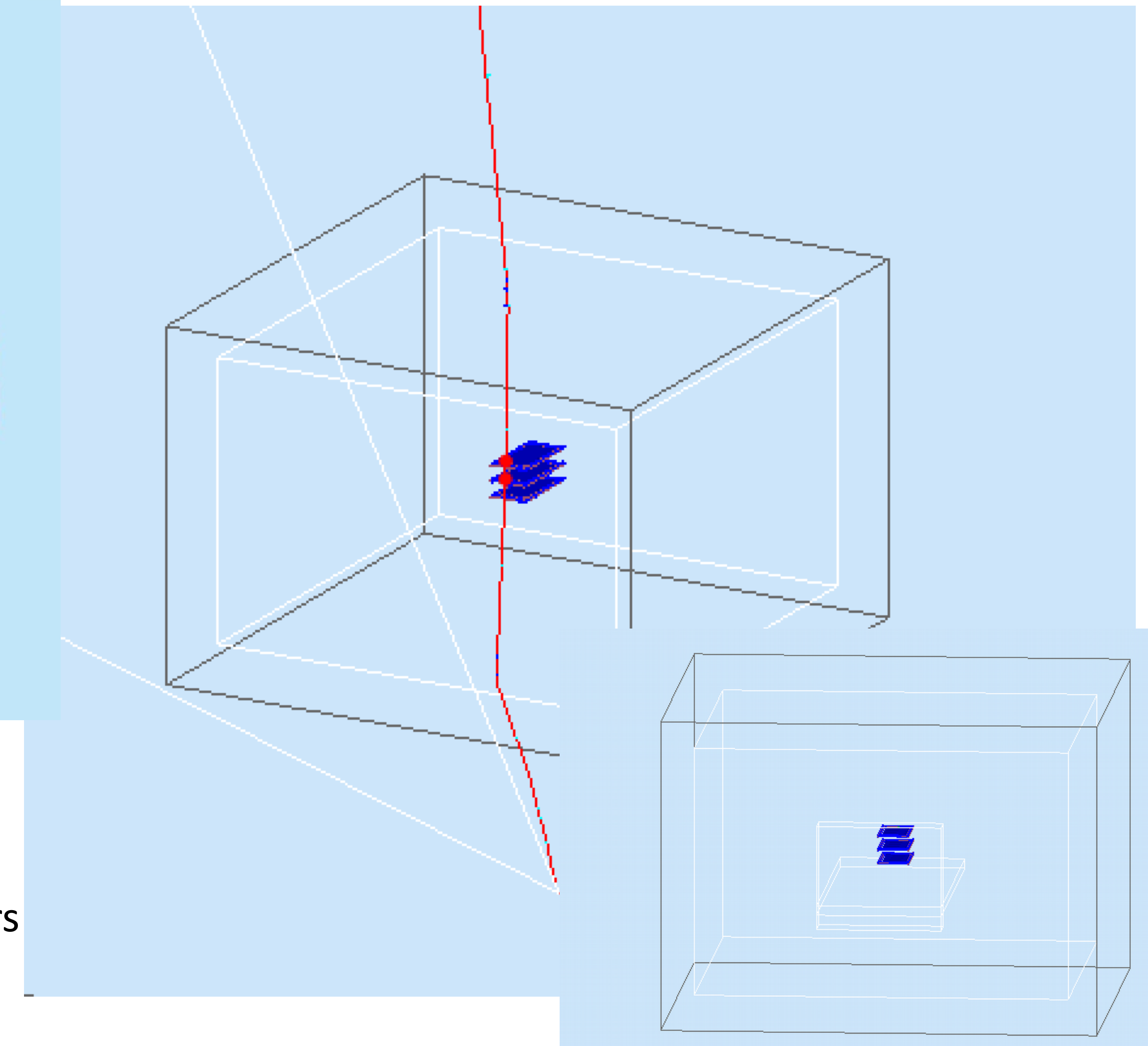
MUON POPULATION
Different weigth

Energy	fraction of the spectrum (%)	Rate 1248.8Hz * Rec/Gen	Rate -50cm/0/+50cm
0.2 - 2 GeV	44.5	60.1Hz	26.8Hz
2- 10 GeV	41	53.5Hz	22.0Hz
10- 100 GeV	14.2	38.7Hz	5.5Hz
100 - 500 GeV	0.3		
Tot	100		54.3Hz

GEMC-EEE simulation

MRPC Environment : concrete vault , reasonable agreement



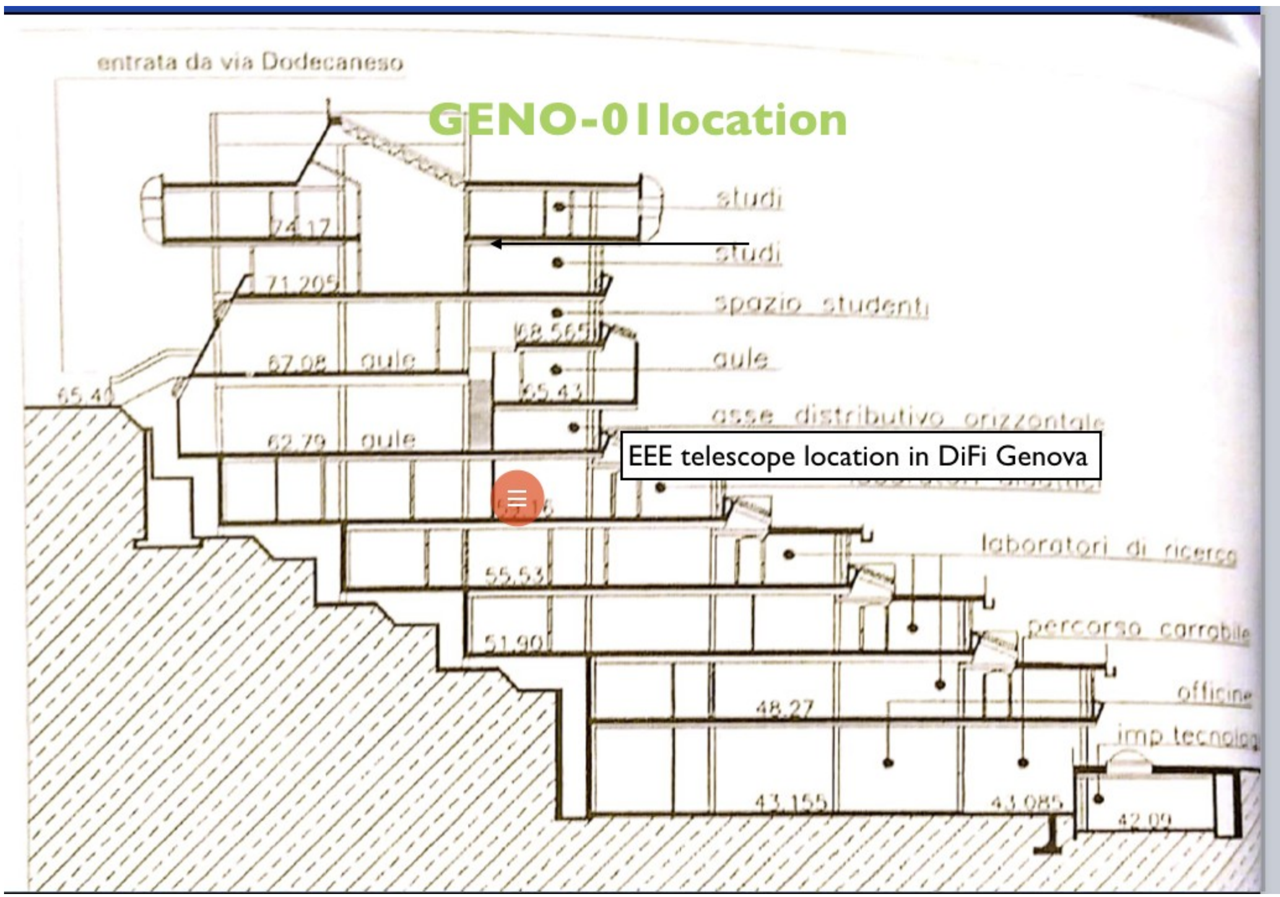


FIRST STEP:
GEMC simulation with Window and floors

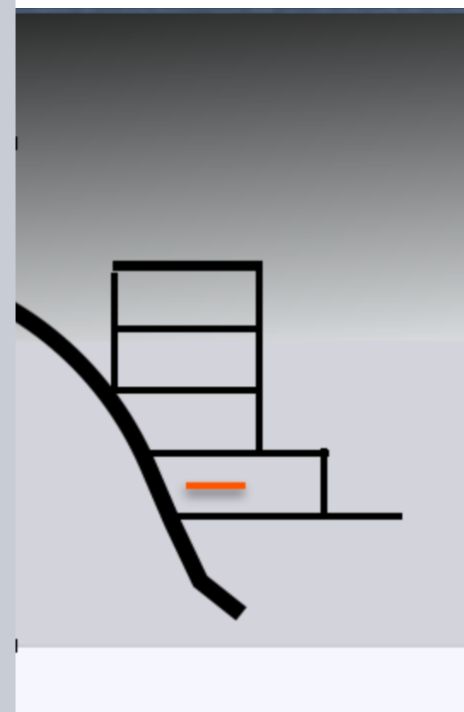
Lecce: Panetta

GEMC-EEE simulation

More complicated location:
as an example GENO-01 (Physics Departement)



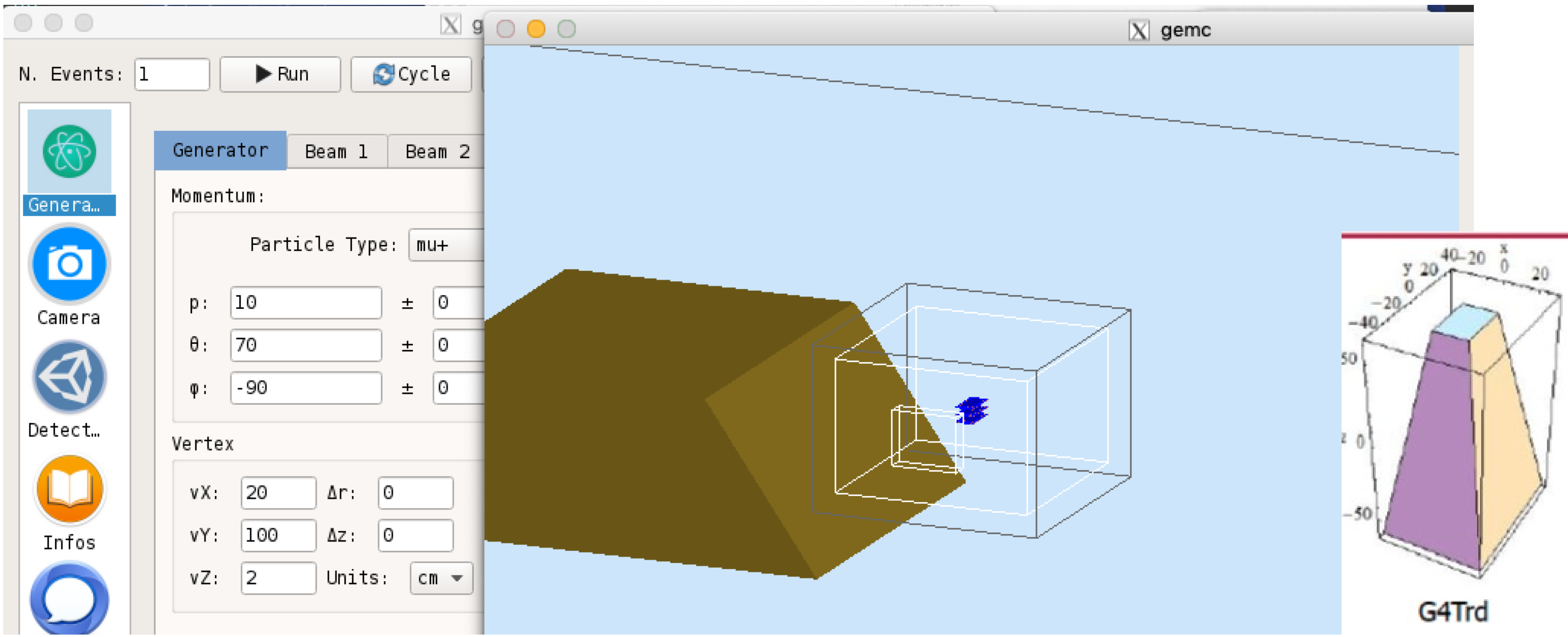
planimetry →



A simpler outline with a mountain

GEMC-EEE simulation

More complicated location:
as an example GENO-01 (Physics Departement)



planimetry →

A simpler outline with a mountain

Working in progress for massive data production by implementing realistic environment modellization of telescope sites.

Lecce: Panetta

Stability check using χ^2 test

Something to be tuned

Changed definition on chi square and looking at the effect

Before

$$\chi^2 = \sum_{i=1}^{N_{bins}} \frac{\left(\nu_i - N \cdot \frac{\nu_{prev,i}}{N_{prev}}\right)^2}{N \cdot \frac{\nu_{prev,i}}{N_{prev}}}$$

Now

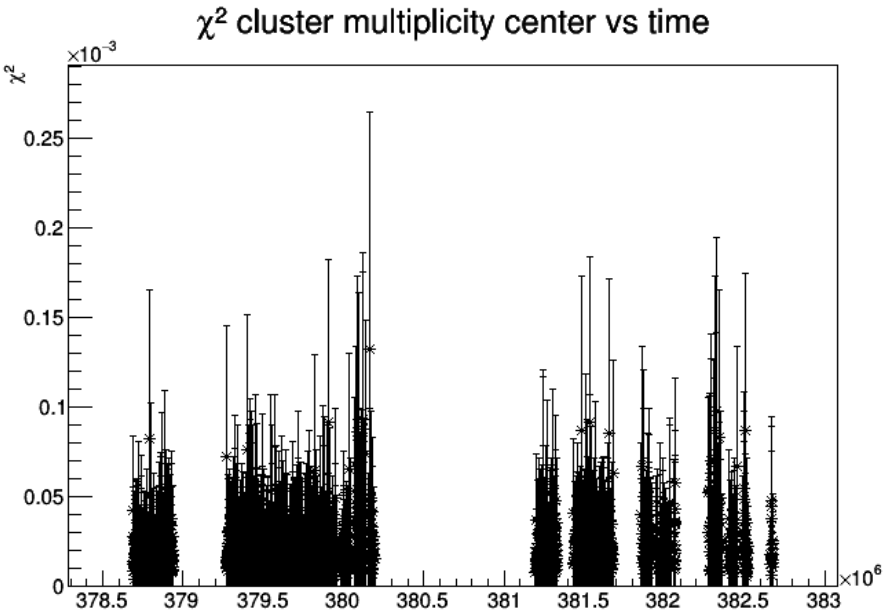
$$\chi^2 = \sum_{i=1}^{N_{bins}} \frac{\left(\frac{\nu_i}{N} - \frac{\nu_{prev,i}}{N_{prev}}\right)^2}{\frac{\nu_{prev,i}}{N_{prev}}}$$

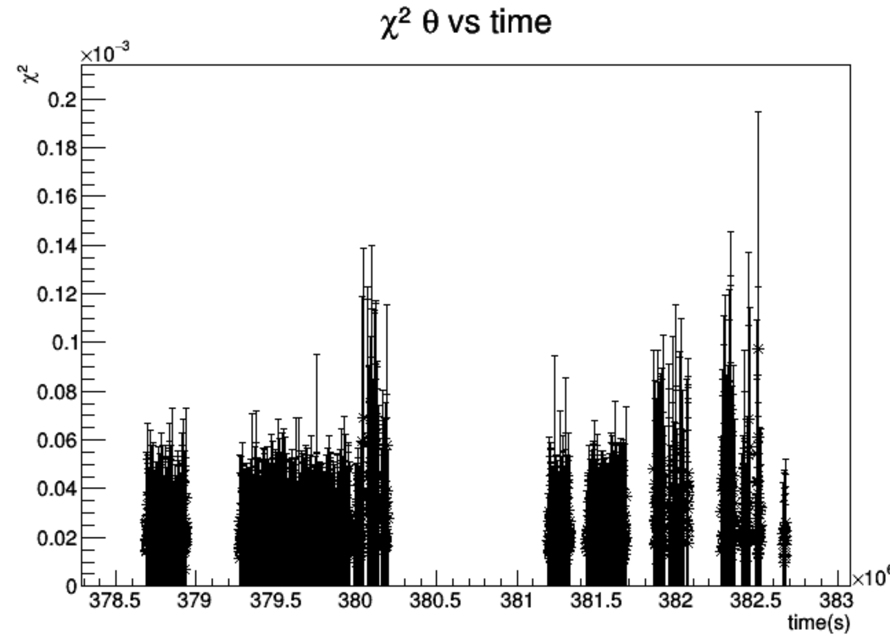
All zero of denominator are suppressed

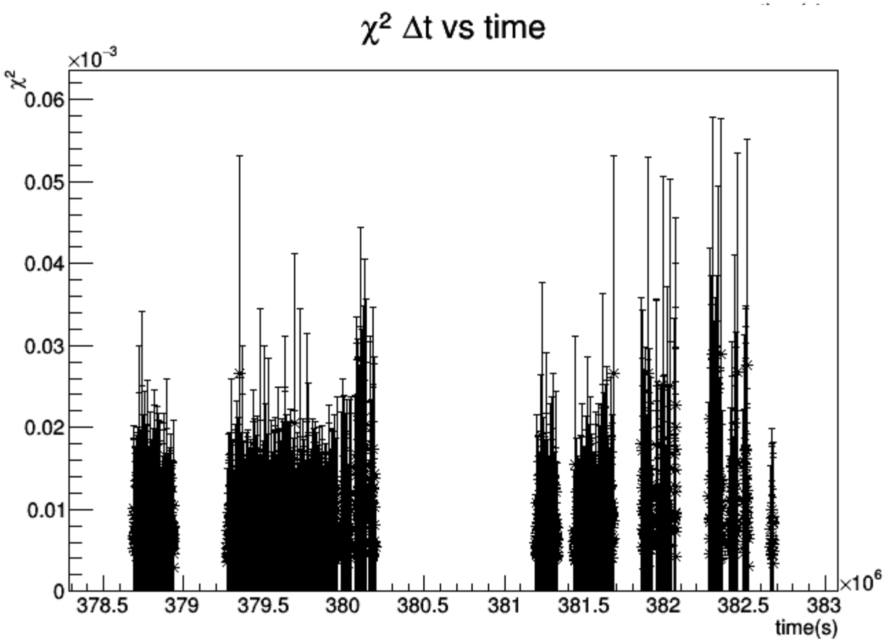
Stability check study useful to look for a good experimental data sets, useful for exp-sim data comparison, but also useful for other investigations!

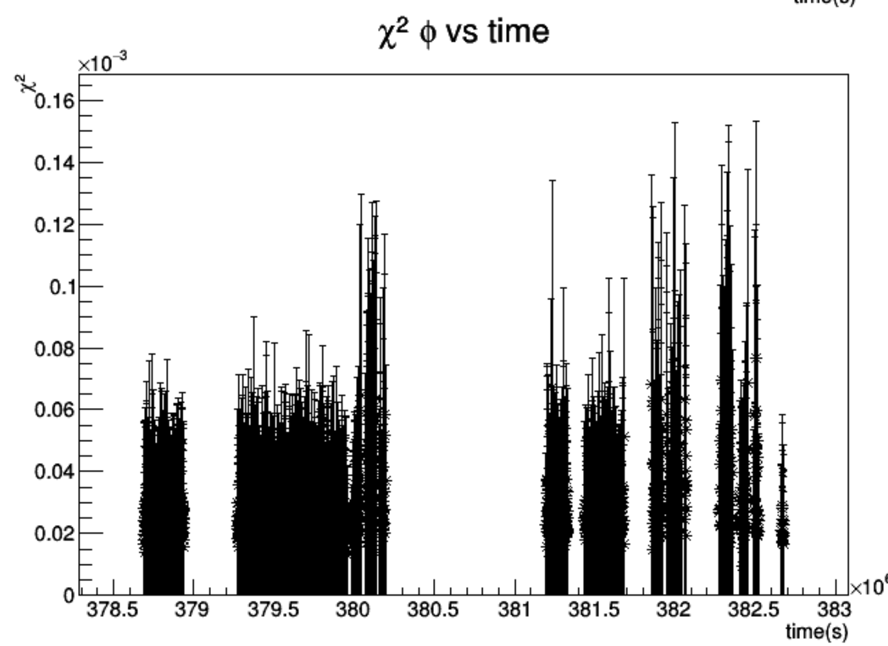
Cagliari: Boi

Stability check using χ² test









Cagliari: Boi

Systematic uncertainties estimation

- Considering N histograms of the same variable (e.g. θ distribution) of N different data sets (runs) $H_1, H_2, \ldots, \mathrm{H_i}, \ldots, \mathrm{H_N}$

- $\tilde{\chi}_i^2 = \frac{\chi_i^2(H_i, H_{i-1}) + \chi_i^2(H_{i-1}, H_i)}{2}$ mean value of chi squares
- $\delta\tilde{\chi}_i^2 = \frac{|\chi_i^2(H_i, H_{i-1}) - \chi_i^2(H_{i-1}, H_i)|}{2}$ half difference of chi squares

Where $\chi_i^2(H_i, H_{i-1})$ is the chi square of histogram "i", compared with histogram "i-1"
$\chi_i^2(H_{i-1}, H_i)$ is the chi square of histogram "i", compared with histogram "i-1".

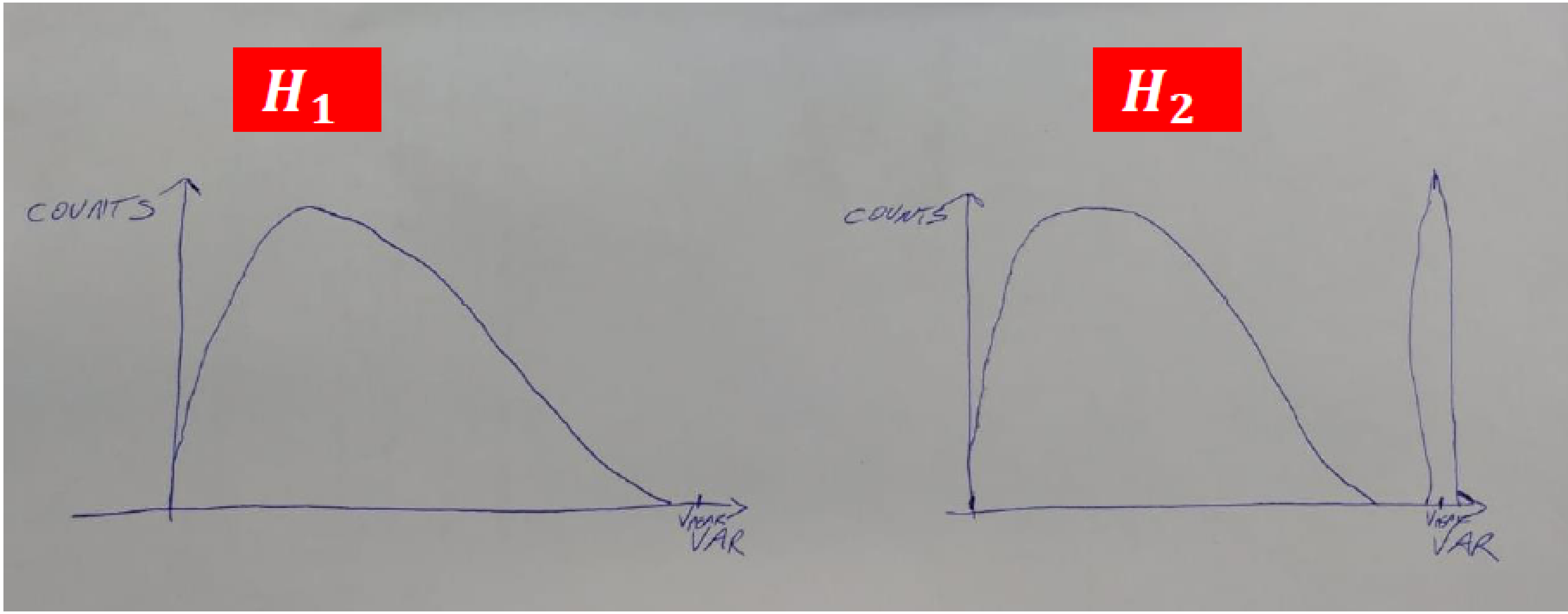
Considerations on $\delta\tilde{\chi}_i^2$

$\delta\tilde{\chi}_i^2 \rightarrow 0$ if both histograms haven't 0 bin content (χ^2 should be used only if every bin content is major than 0)

Two considerations:

1. We must pay attention considering $\tilde{\chi}_i^2$ as a statistical chi square
2. $\delta\tilde{\chi}_i^2$ could be an instability indicator (see graph on next page)

Considerations on $\delta\tilde{\chi}_i^2$

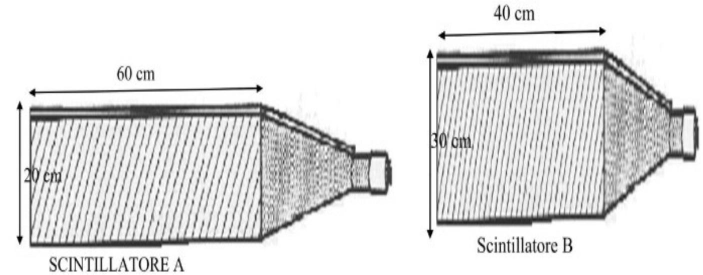


$\chi^2(H_2, H_1) > \chi^2(H_1, H_2)$ because in second case we must suppress V_{peak} to avoid 0 on denominator of chi square definition .

This imply $\delta\tilde{\chi}^2 > 0$

- From preliminary analysis there is a direct correlation on results with all considered variable
- Many considerations should be done on quantify detector stability using chi square, due to the problem with bin contents
- Systematic uncertainty appears to be an estimator of detector stability

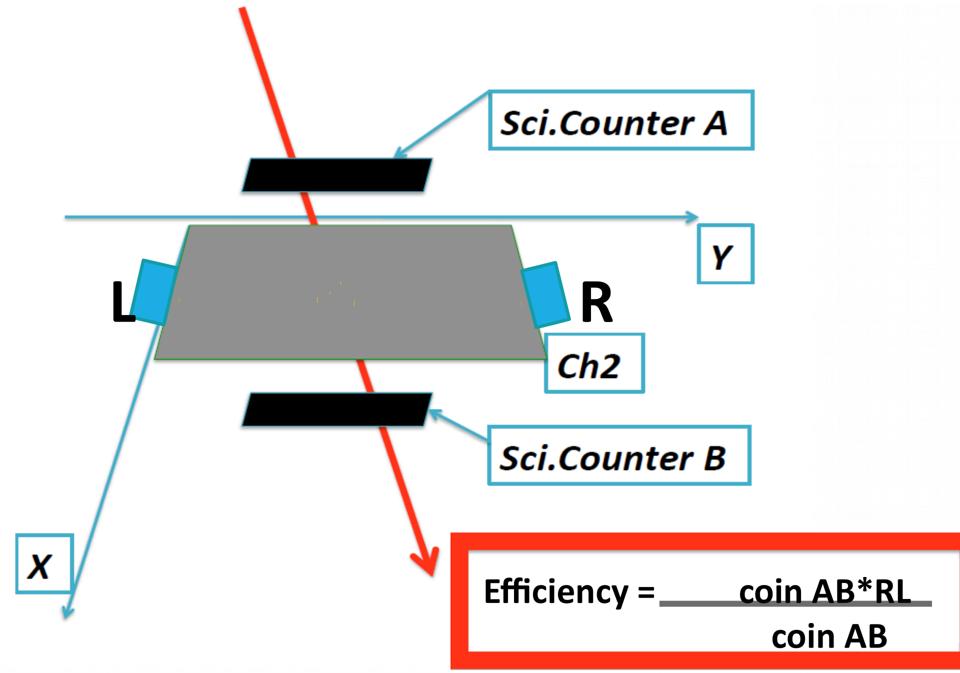
Scintillator Measure



Measurement performed on GENO-01 telescope on 15-17 / 02/2019

Used two plastic scintillators read with phototubes and nim electronics

Done then the ratio of the chamber, obtained by taking the OR, and scintillation counts



- The values of working voltage efficiency with scintillators were:
  - CH1 => 0.92 +/- 0.03
  - CH2 => 0.95 +/- 0.03
  - CH3 => 0.89 +/- 0.03

Genova: Battaglieri - Grazzi

Efficiency program

- The program, starting from the reconstructed data, find the coordinates of the events on the two chamber not under examination.
- The y from the reconstructed strip and x from the difference of the arrival times of the correct signals for the time shift.
- It reconstructs the trace from these two points and geometrically identifies the possible point of impact on the third in question.

Preparation for Comparison

- In order to obtain a comparable measurement of scintillator data with the program, the data had to be appropriately selected:
  - Time period preceding the 40-day measurements with the telescope in the same conditions as the measurement
  - No subsequent measures were taken because some converters and voltages were changed
  - Identification of the area where the individual measurements were made and imposed cuts for which to calculate efficiency only at that point

Comparison

- The values returned by the program were:

```
nev_eff = 11236239
chamber distance = 50.000000 50.000000
609.000000 26003.000000 2931.000000
0.914414 +/- 0.010840, 0.968743 +/- 0.001062, 0.897153 +/- 0.005314
```

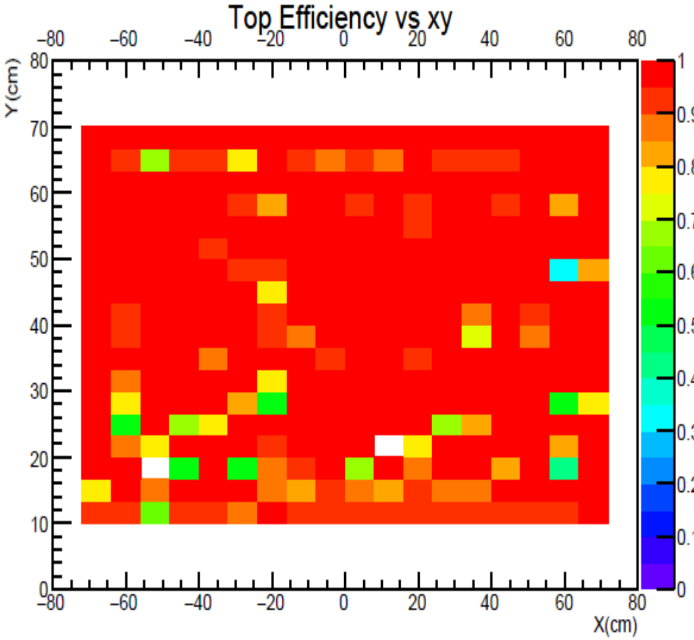
CH1 | CH2 | CH3

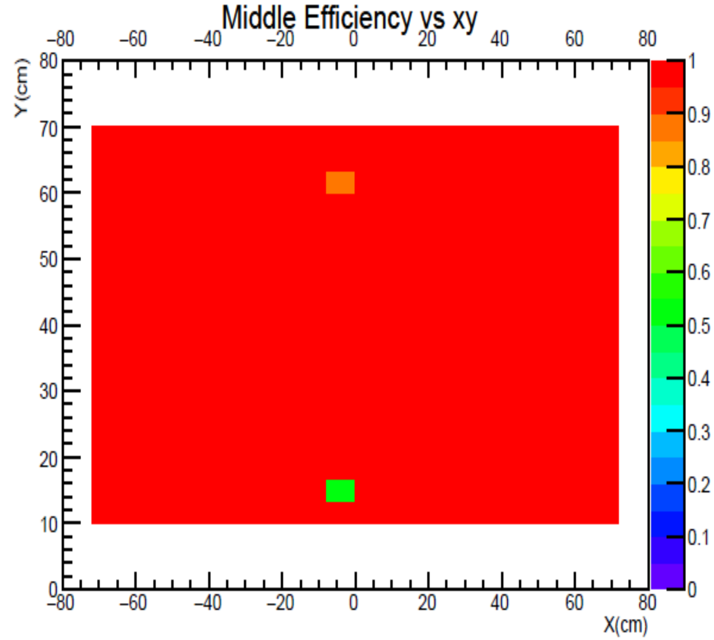
- Compatible with values obtained with scintillators within the statistical error:
  - CH1 => 0.92 +/- 0.03
  - CH2 => 0.95 +/- 0.03
  - CH3 => 0.89 +/- 0.03

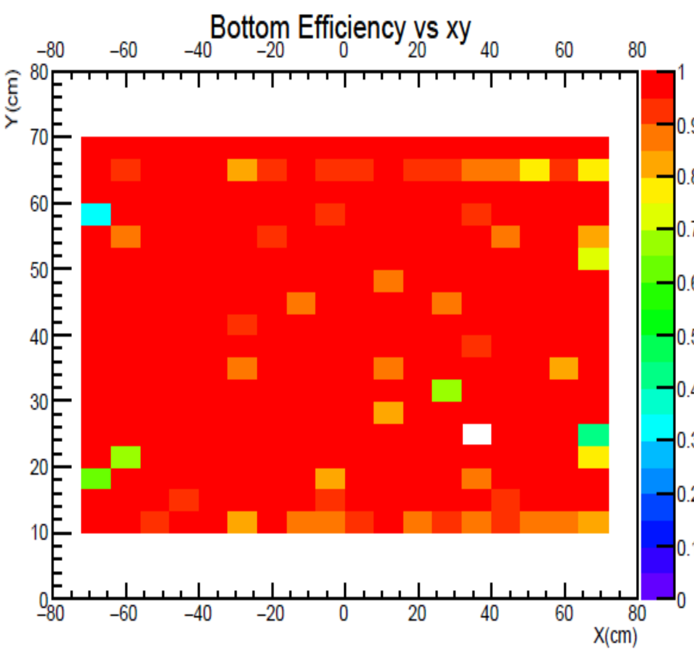
Simulation

- Test program on simulated reconstructed data
- Sample of 22 million events (equivalent to 4-5 days of data)
- Modified the program to take into account that simulations are given. Ex .: Place TimeShift to zero

Simulation data test








```
nev_eff = 608106
chamber distance = 50.000000 50.000000
10166.000000 36871.000000 9768.000000
0.993453 +/- 0.000797, 0.999810 +/- 0.000072, 0.994603 +/- 0.000739
56213 9821 9821 41125 36878 36878 582566 10233 10233
time shift used = 0.000000 0.000000 0.000000
time shift to be used = -0.034433 5.544002 4.718041
```

- Good compatibility with the expected value
- The sample to be tested must be increased

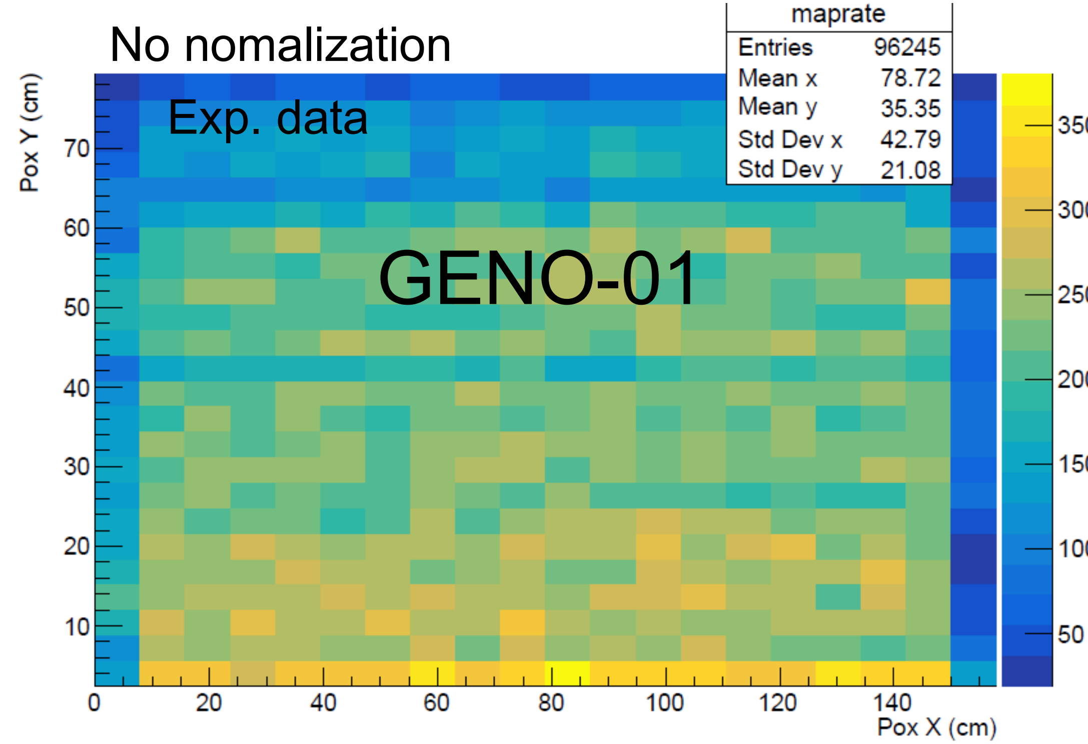
Investigation on exp. data in progress – results under discussion!

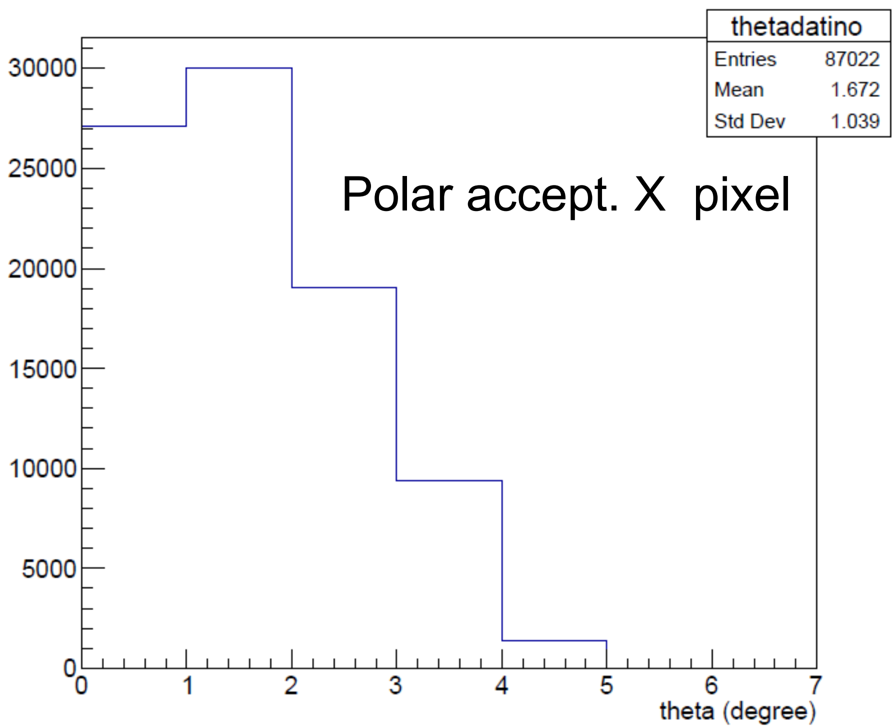
Genova: Battaglieri - Grazzi

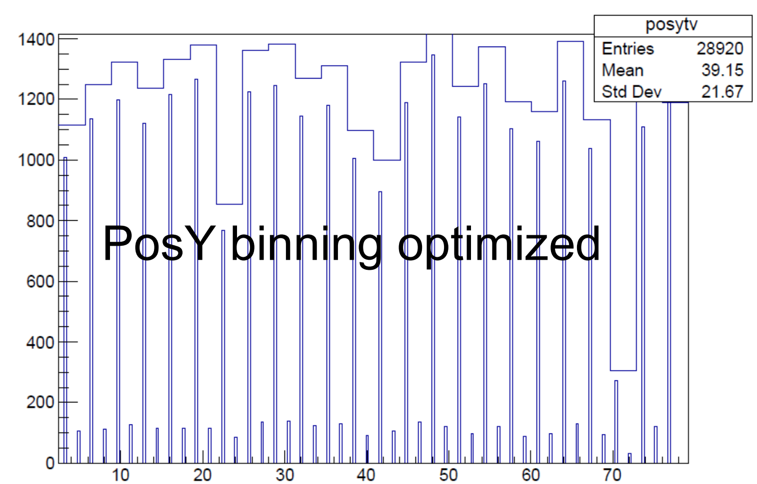
Vertical pixel coincidence map

Binning
Posy – 24 bin 2.45 cm - 79.25 cm
Posx – 20 bin 0. cm - 158.0 cm

24 bin for y-dir is the maximum possible, used to stress at limit the method, but probably not necessary!







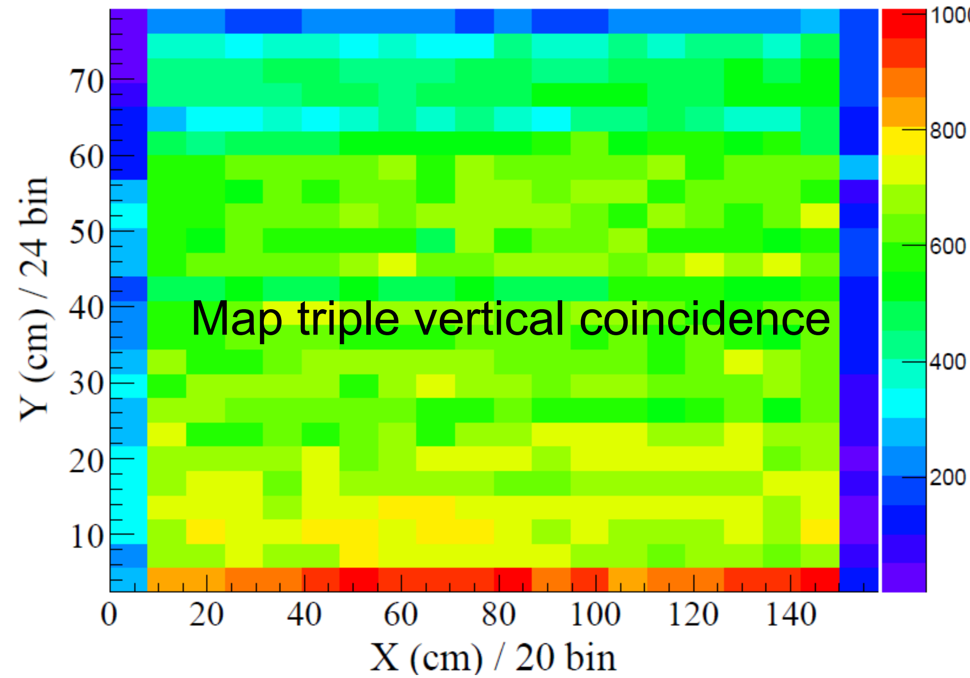
Relative track-efficiency estimation

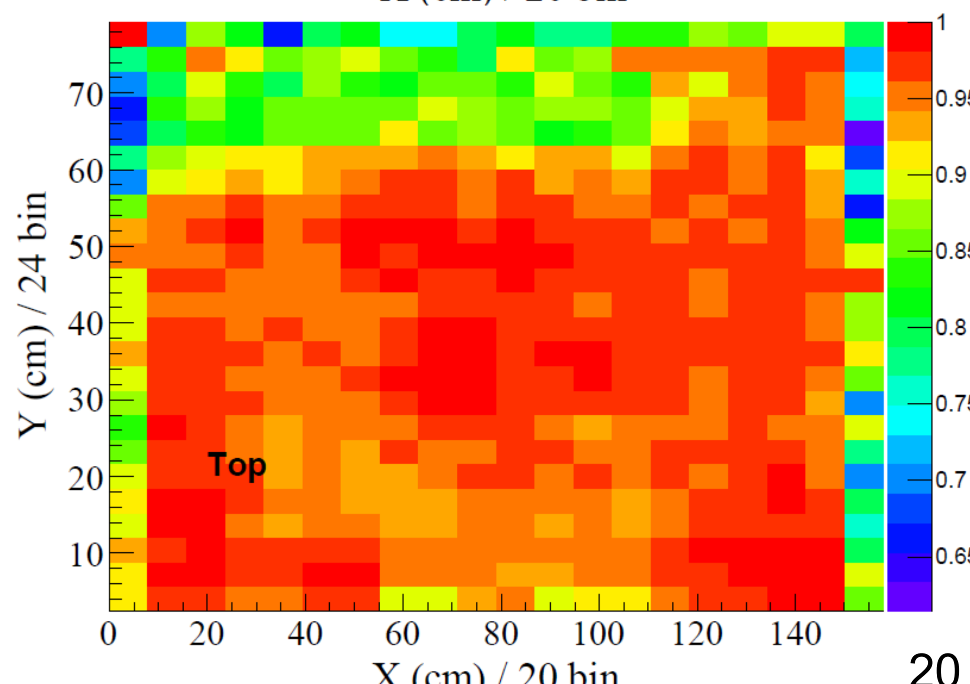
Criteria:
Ratio between triple vertical concidence obtained with three detected positions and triple vertical concidence obtained with two detected positions and one extrapolated + conditions or the difference between the extrapolated and measured position is lower than bidimentional bin-size or such difference is higher than two times the bidimentional bin-size.
|ΔX| > 16 cm or |ΔX| < 8 cm
|ΔY| > 6.4 cm or |ΔY| < 3.2

Investigation on other telescopes in progress – results under discussion!

Week point of the procedure:
The accuracy of the efficiency estimation depends of the noisness of the chamber.
Strength of the procedure:
Easy to be estimated.

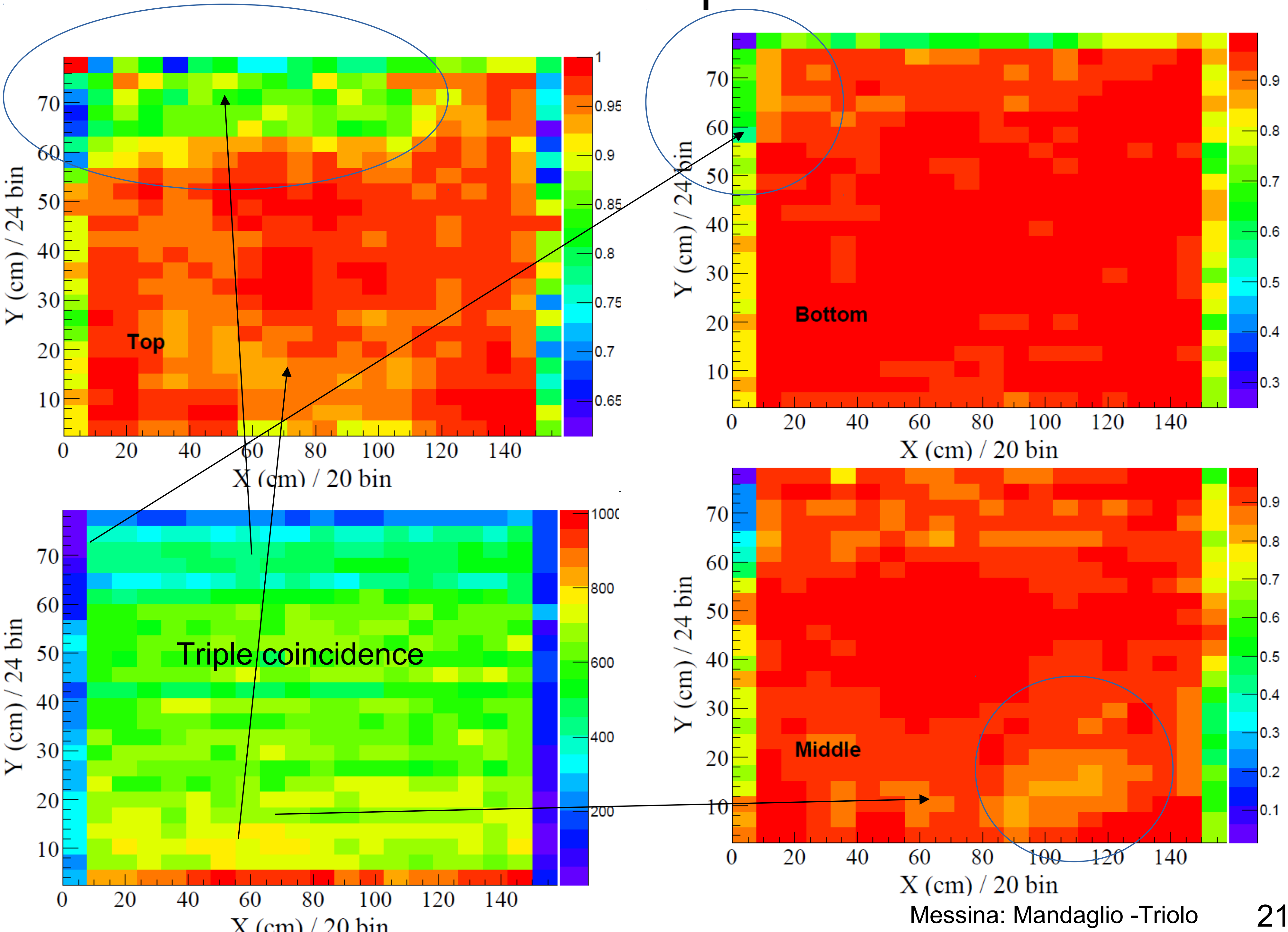
GENO-1 - April 2019





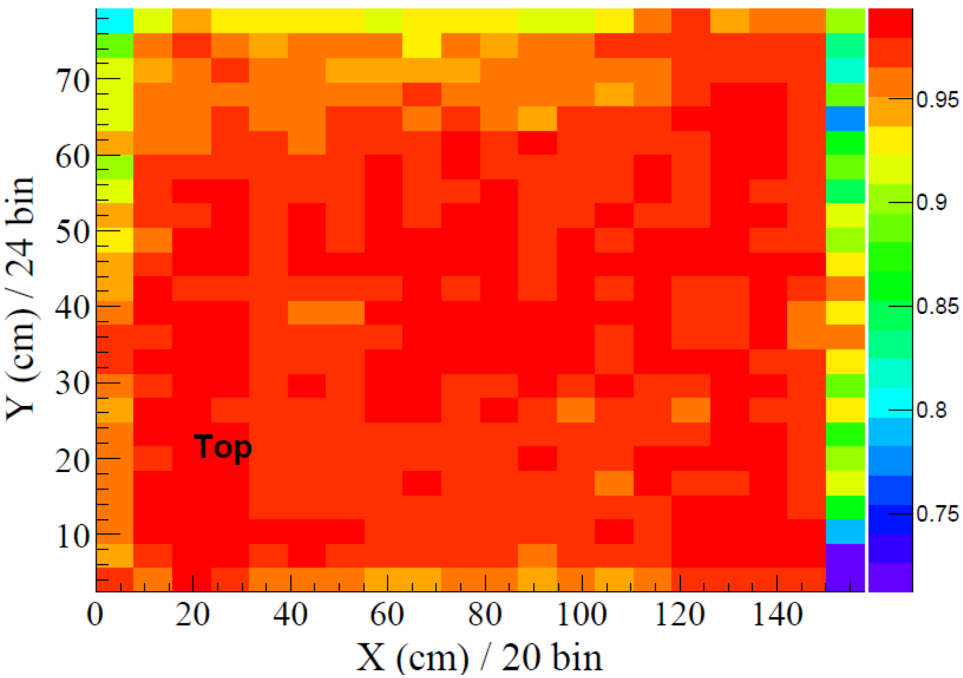
Messina: Mandaglio -Triolo

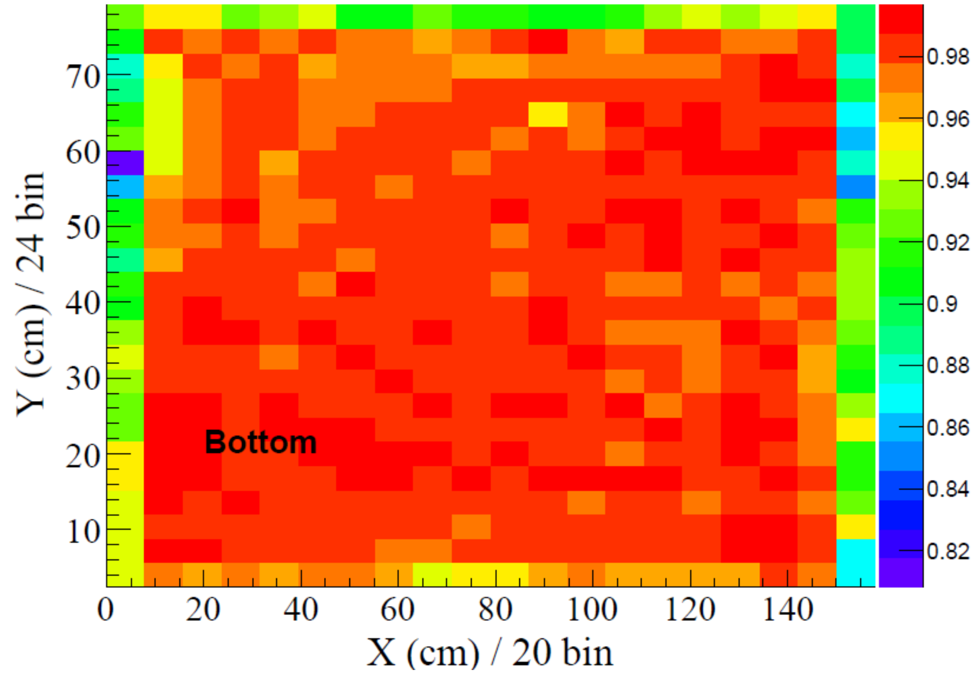
GENO-01 April 2019

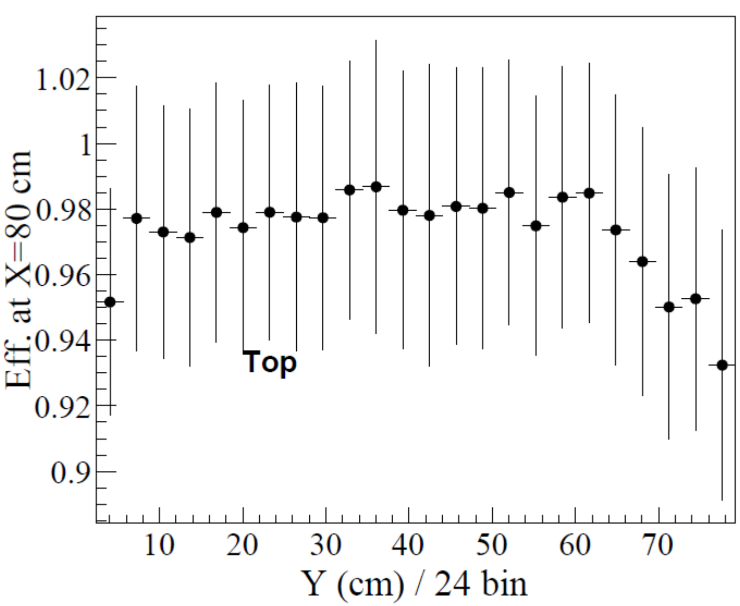


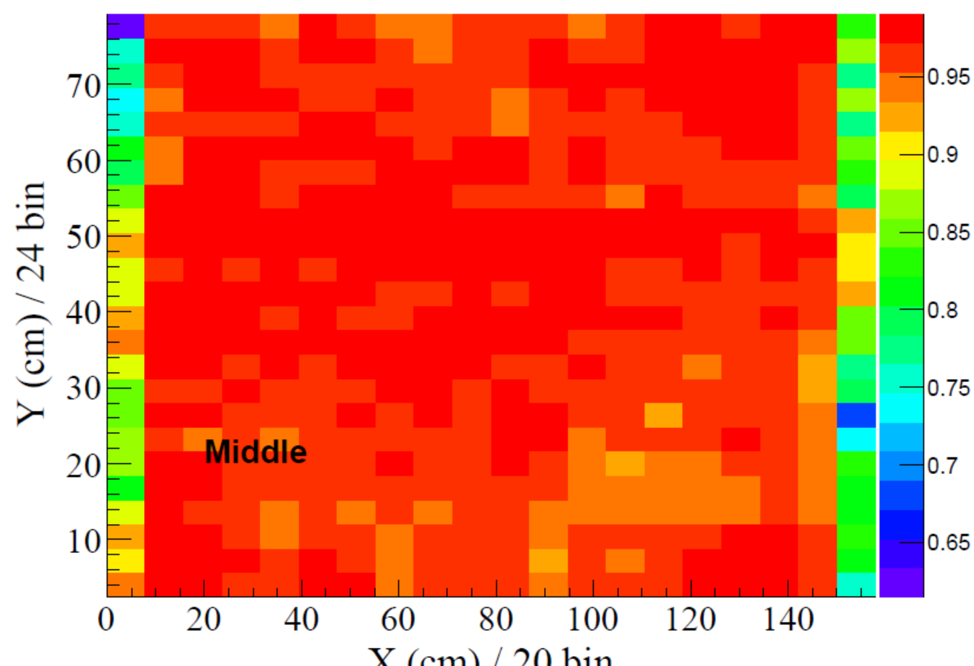
Messina: Mandaglio -Triolo

GENO-01 Jan-Feb 2019









Detector Simulation Working Group (DeSi-WG)

NIM paper in preparation

Simulation framework description

- ✳ MRPC detector response
- ✳ Cosmic muon flux model
- ✳ Telescope geometry and location description

done!

Simulation framework validation

- ✳ EEE data quality assessment (stability in space and time)
- ✳ Results for some study cases

In progress

- Simulation validation requires a stable (in time) and well understood (efficiency) set of EEE data to compare with
- The EEE Data Quality Assessment (DQA) is useful for all analysis WGs
- We plan to write the paper by the summer when progresses in DQA will allow some conclusions

The Extreme Energy Events (EEE) telescope simulation framework

The EEE Colllaboration[1]

[a]Museo Storico della Fisica e Centro Studi e Ricerche Enrico Fermi, Roma

Abstract

In this paper we describe the simulation framework of the Extreme Energy Events (EEE) experiment. Each EEE telescope is made by three Multi-gap Resistive Plate Chambers. By recording the triple coincidence of the three detectors, the cosmic muon track is fully measured providing a precise determination of the absolute time of the event and integrated/angular muon flux at Earth level. The response of the single MRPC and the combination of the three chambers have been implemented in a GEANT4-based framework to study the telescope response. The detector geometry, as well as details of the location have been included in the simulations in order to realistically reproduce the experimental set-upof each telescope. A model based on the latest parametrization of cosmic muon flux has been used to generate single-event muons. The framework has been validated by comparing EEE data to simulation results.

Keywords: cosmic rays, cosmic muons, MRPC, GEANT4

1. Introduction

The EEE experiment deployed a network of cosmic muons detectors in a area of XX Km^2. Each telescope is made by three Multi-gap Resistive Plate Chambers (MRPC) located in schools Telescopes distributed all over the Italy territory, are host by schools

2. MRPC detector response

3. Simulation and reconstruction frameworks

3.1. GEMC libraries

3.2. EEE data reconstruction

4. The cosmic muon flux model

5. EEE single muon detection response

6. Simulation framework validation

6.1. EEE data quality assessment

6.2. Results for some study cases

7. Results

7.1. Data-simulation comparison

8. Conclusion

Acknowledgments

References

Preprint submitted to NIMA *June 18, 2019*