March 6 2019
EEE Meeting
Torino

Detector Simulation Working Group (DeSi-WG)

EEE telescope simulation
an update on model validation

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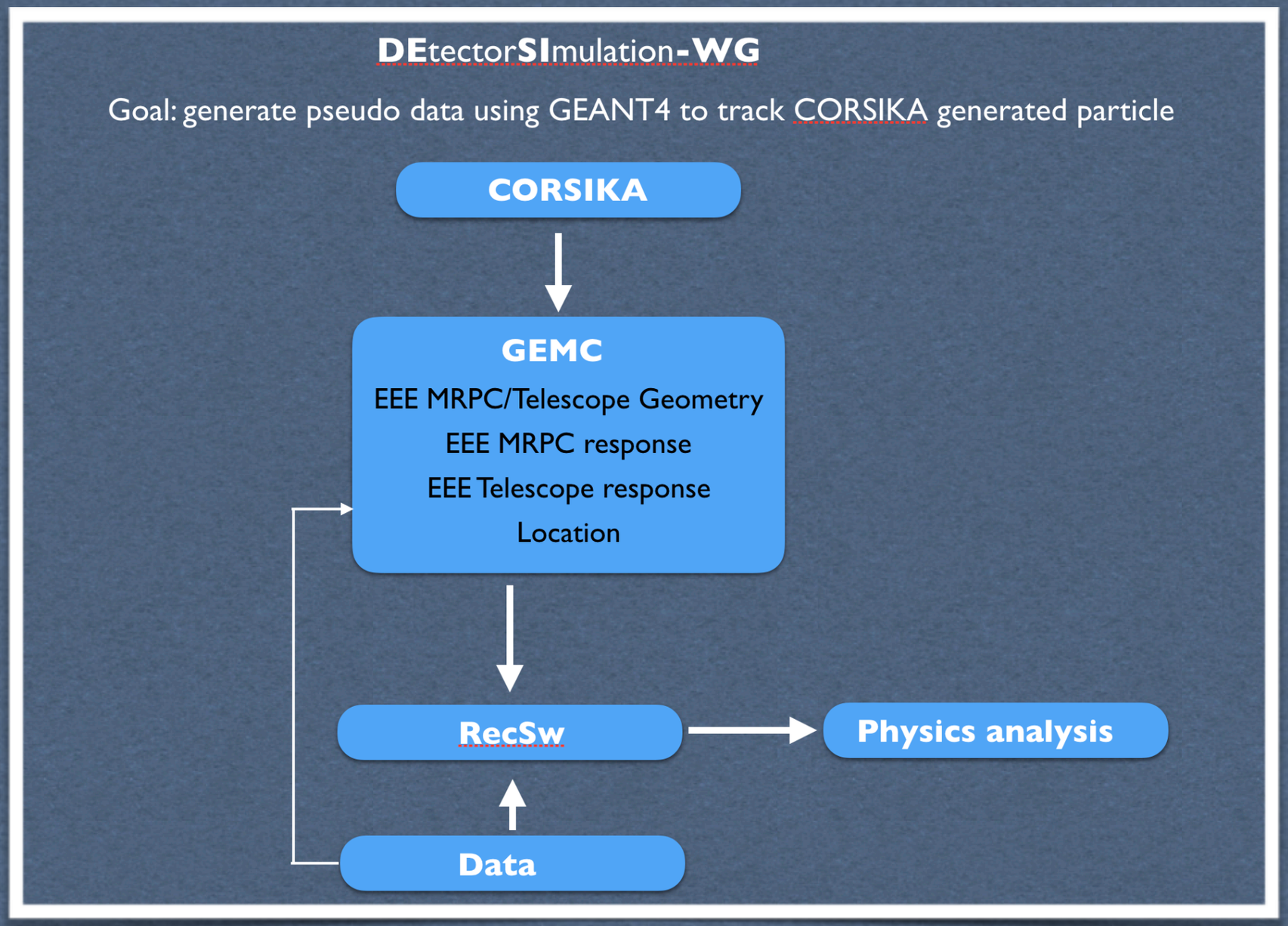
F.Coccetti, F.Noferini, M.Ungaro



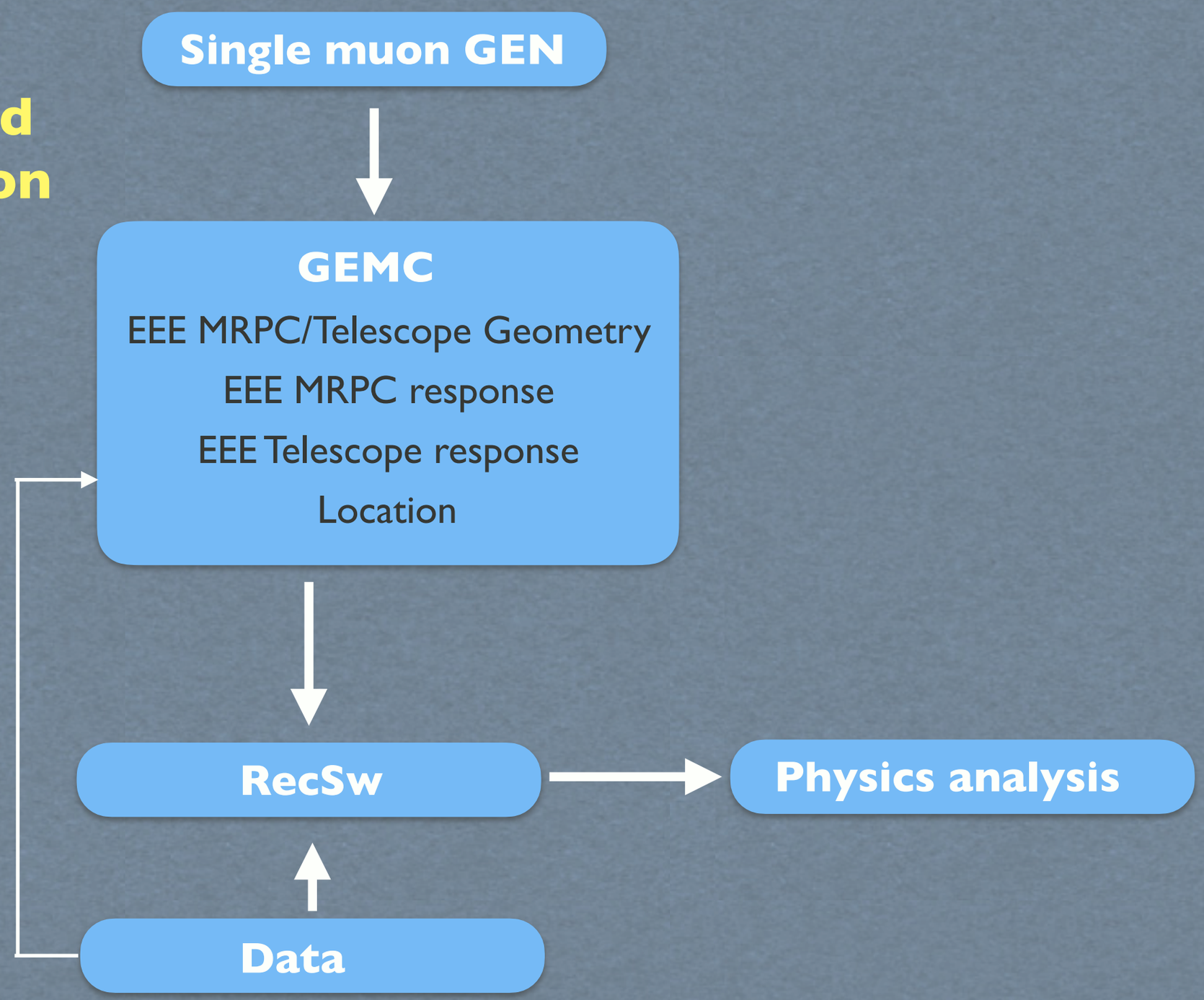
In stand-by

- waiting for high statistics CORSIKA simulation
- validation of simulation on single-mu events
- quantitative understanding of telescope performance (data)

DEtector**SI**mulation-**WG**

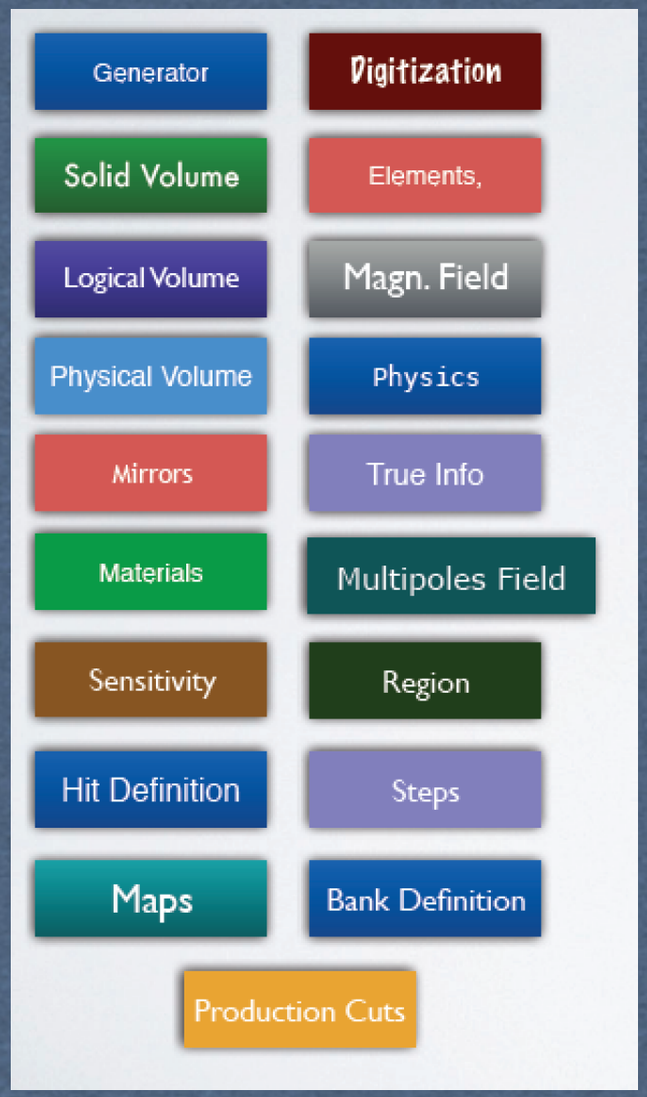
Goal: generate pseudo data using GEANT4 to track CORSIKA generated particle

Test and validation of the whole chain



GEant4 Monte Carlo: GEMC

M.Ungaro

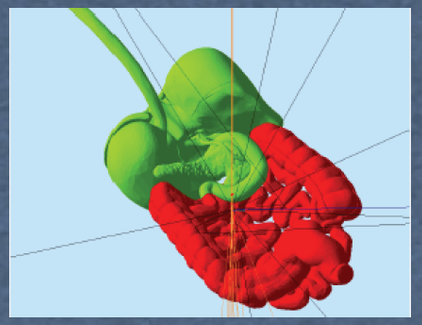


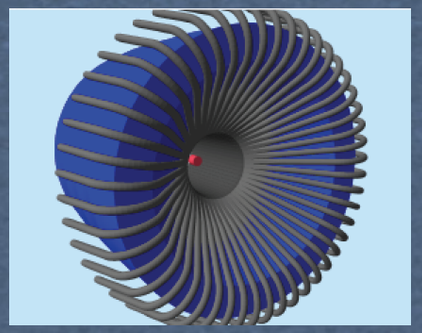
Realistic detector simulation

GEMC

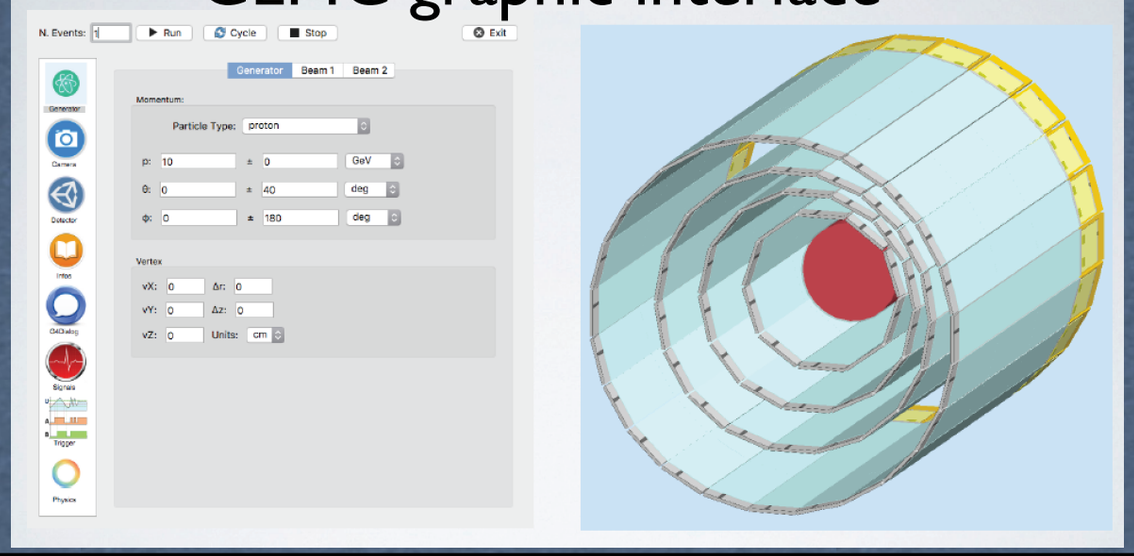
A GEANT4 libraries based simulation tools

- components description
- components interaction
- user-defined geometry and hit
- internal generator (included cosmic rays)
- multiple input/output format
- CAD geometry accepted
- interactive/batch mode
- source on GitHub





GEMC graphic interface



Installed (and now working!) in EEE cluster at CNAF!

EEE-MRPC response to cosmic rays in GEANT4

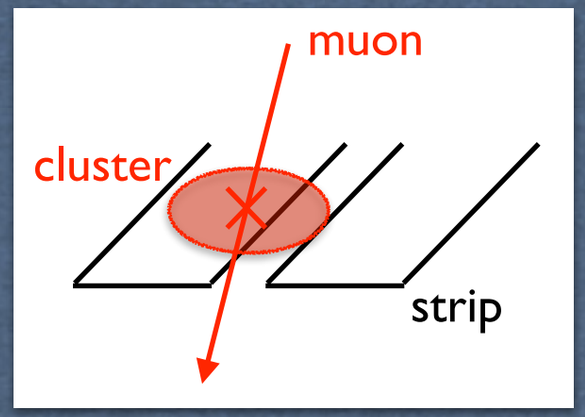
- MRPC geometry: material, size, …
- MRPC response (parametrized)
- Telescope response: geometry, trigger, …
- Telescope location: effect of roof, walls, surrounding materials, …
- Telescope: muon rates for different multiplicities
- Multi-telescopes: coincidence rates
- Single/multiple telescope(s) studies: bottom-up muons, …

✳ EEE MRPC response

✳ No avalanche simulated in details

✳ Effective hit process:

- Sample XY (and Z) muon hit on on bottom strip plane
- Assume both strips and gaps are active
- Apply a spread to account for multiple hits and spread position resolution X and Y and T



✳ MRPC parameters

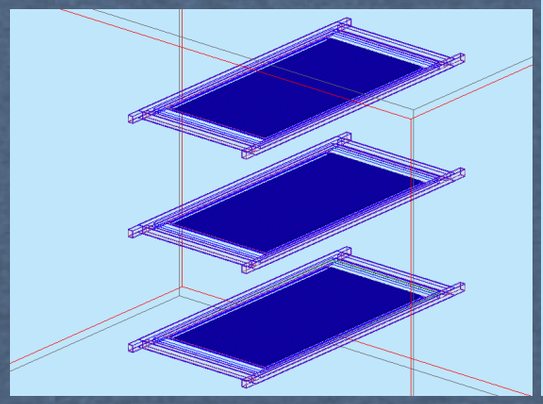
- 90x160 active area
- Active: 2.5cm x 24 strips + 0.7cm x (24-1) gaps
- Time spread: σ = 238ps
- Cluster size: σ_X = 9.2 mm
- Cluster size: σ_Y = 15 mm
- Light speed: 15.8 ns/cm
- HIT_{XY} is gaussian-spread and projected on the sensitive area to derive strip multiplicity

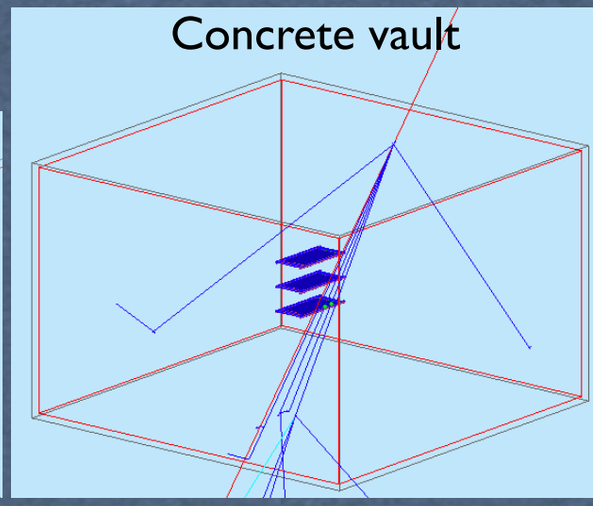
Ref: JINST13(2018)P08026

✳ Telescope parameters

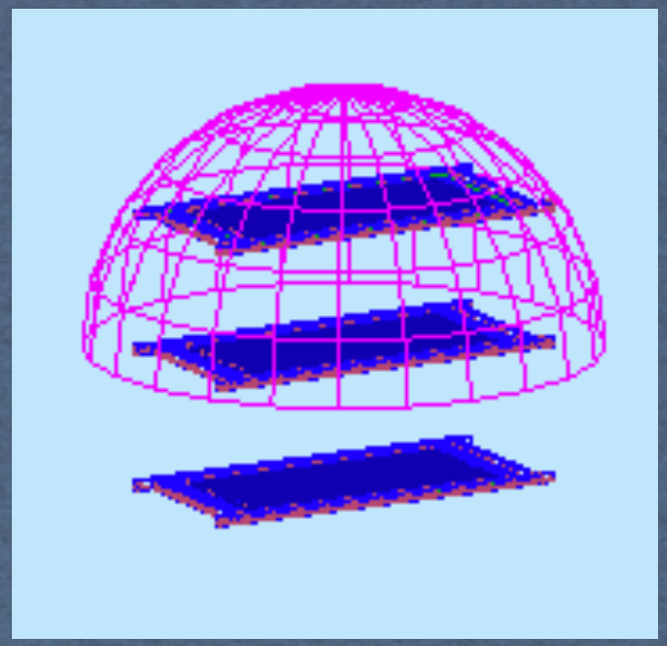
- 3 chambers
- -50/0/+50 cm apart
- placed in a concrete box wall on all sides (140cm concrete)

Ref: GENO-01





Muon generation



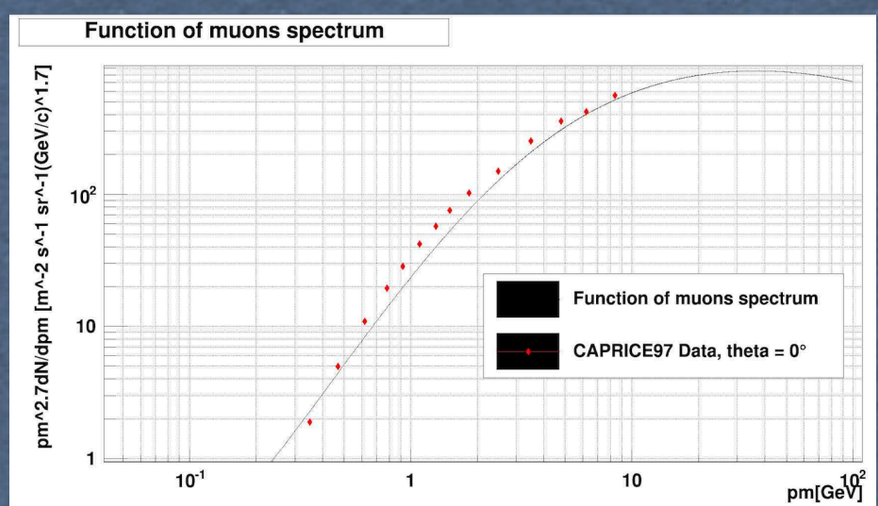
- Single-muon generation
- Semi-sphere generation such as to obtain a flat distribution on a plane surface
- Improved Gaisser parametrization for Flux(E_μ,Θ) to include Earth curvature (all latitudes) and low energy muons (<100GeV)

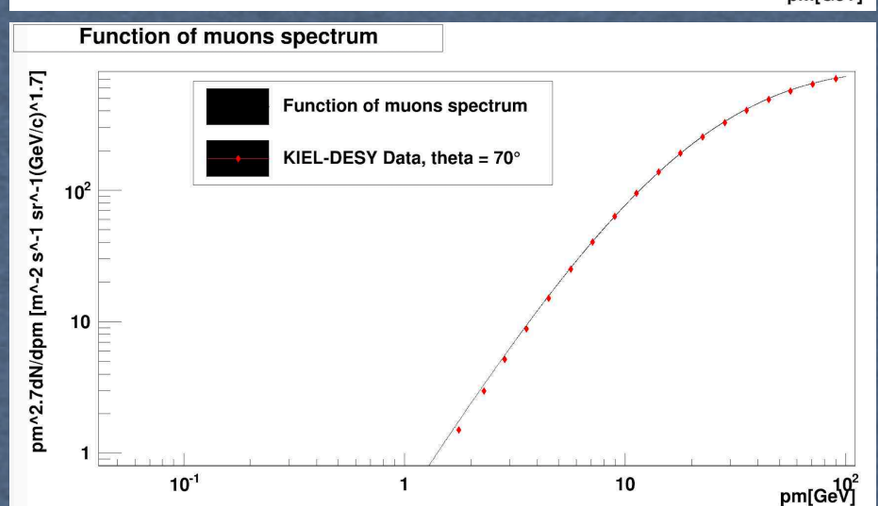
$$\frac{dI_\mu}{dE_\mu} = 0.14\left[\frac{E_\mu}{GeV}\left(1+\frac{3.64GeV}{E_\mu(\cos\theta^*)^{1.29}}\right)\right]^{-2.7}\left[\frac{1}{1+\frac{1.1E_\mu\cos\theta^*}{115GeV}}+\frac{0.054}{1+\frac{1.1E_\mu\cos\theta^*}{850GeV}}\right]$$

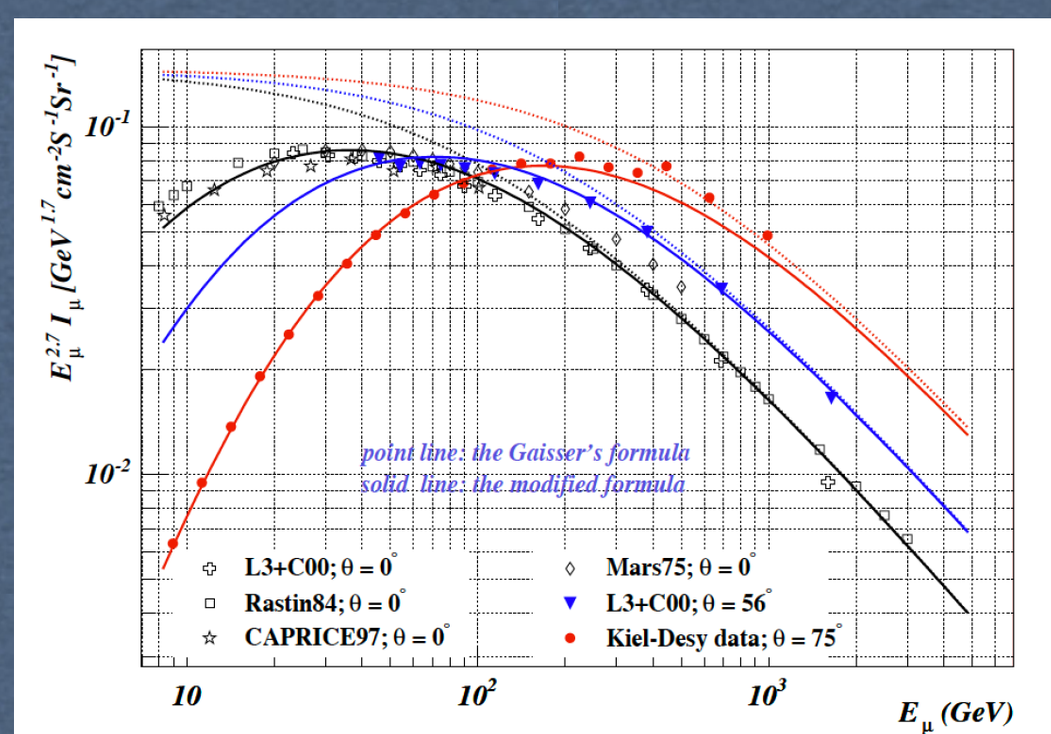
$$\cos\theta^* = \sqrt{\frac{(\cos\theta)^2+P_1^2+P_2(\cos\theta)^{P_3}+P_4(\cos\theta)^{P_5}}{1+P_1^2+P_2+P_4}}$$

P_1	P_2	P_3	P_4	P_5
0.102573	-0.068287	0.958633	0.0407253	0.817285

arXiv:1509.06176







- good agreement with previous data
- low/high energies, small/large angles
- our implementation checked on data
- Generation split in 3 E_μ intervals:
  - [0.2 GeV - 2 GeV]
  - [2GeV-10 GeV]
  - [10GeV-100 GeV]
- Normalization factor for absolute flux:
  - 1.06 μ cm^{-2} min^{-1}

Simulations should provide:

- Absolute and angular efficiency
- ABSOLUTE single-mu rates (to be compared to the telescope response)
- effective comparison to world data parametrisation
- description (and compensation) of surrounding materials
- easy way to compare telescopes with different parameters (e.g. distance between the chambers)
- cross check of data quality and working conditions of different telescopes

Simulation needs to be validated comparing data

- Find a set of variables/parameters to compare to
- Find some telescopes with smooth and stable response
- Reasonably easy location to avoid unknown from the environment

- GENO-01, BOLO-01: smooth operations but complicated locations (second batch)
- TORI-01: smooth and simple location (just a room at the last floor)
- CERN-01: smooth and simple location with a different chamber separation (44cm/44cm)
- SAVO-01: smooth and simple location with a different chamber separation (46cm/46cm)

★ Experts are supporting the data performance assessment (D. De Gruttola, C. Ripoli)

★ Next stage: involve schools and do a systematic analysis on all telescopes

GENO-01

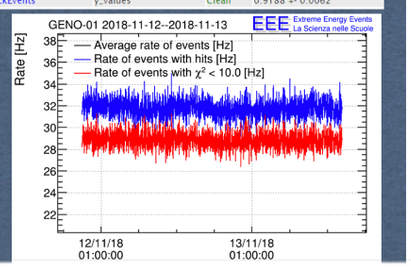
- First test: comparison to GENO-01
- The complicated location prevented a straightforward comparison
- Data shows an anisotropy in PHI difficult to correctly implement in simulation

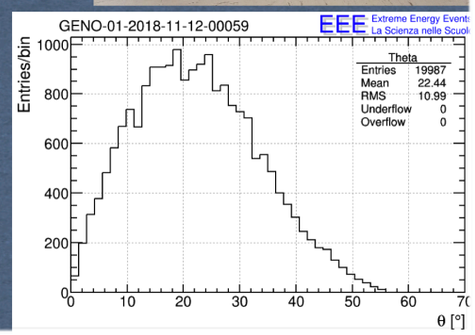
Comparison with GENO-01

- Comparison to GENO-01 telescope
  - built in March 2017 at CERN and delivered in Oct 2017
  - installed at the 4th floor (4 floors above) of Dpt.Physics/INFN-GE
  - Commissioned in Aug '18, data taking since Sept '18
  - full control of geometry and environmental parameters
  - The location and surrounding materials can be an issue

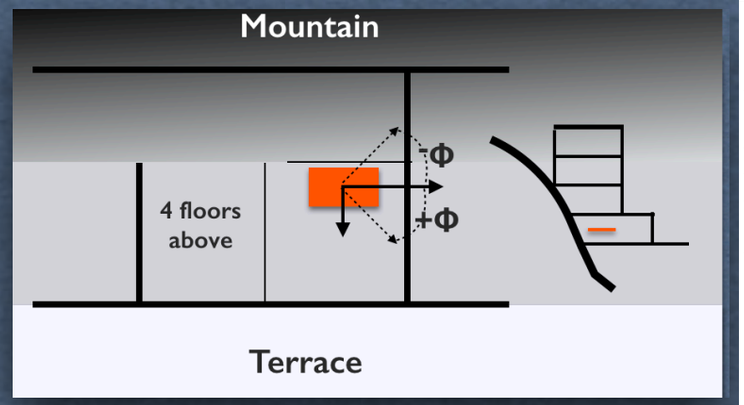
Plot	Alarm	Status	Output
RateHitEvents	y_values	Clean	30.54 +- 0.71
DeltaTime	exp_fit_lambda	Clean	31.81 +- 0.22
HitMultTop	x_average	Clean	1.2898 +- 0.0044
HitMultMid	x_average	Clean	1.2569 +- 0.0044
HitMultBot	x_average	Clean	1.1956 +- 0.0039
HitMultTotal	x_average	Clean	3.7390 +- 0.0093
ClusterMultTop	x_average	Clean	1.0627 +- 0.0025
ClusterMultMid	x_average	Clean	1.0925 +- 0.0029
ClusterMultBot	x_average	Clean	1.0751 +- 0.0026
ClusterMultTotal	x_average	Clean	3.2303 +- 0.0065
ChiSquare	x_average	Clean	2.188 +- 0.029
RateTrackEvents	y_values	Clean	27.62 +- 0.67
FractionTrackEvents	y_values	Clean	0.9188 +- 0.0062

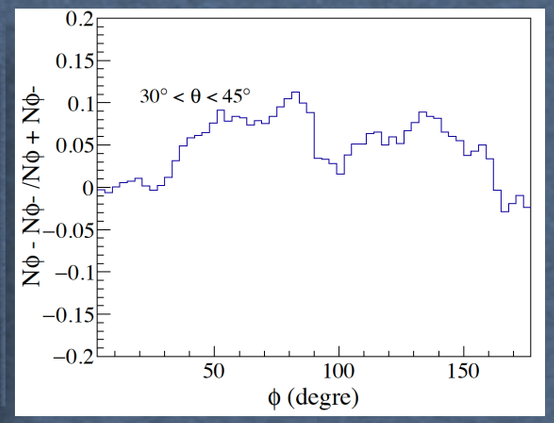
- Data are stable

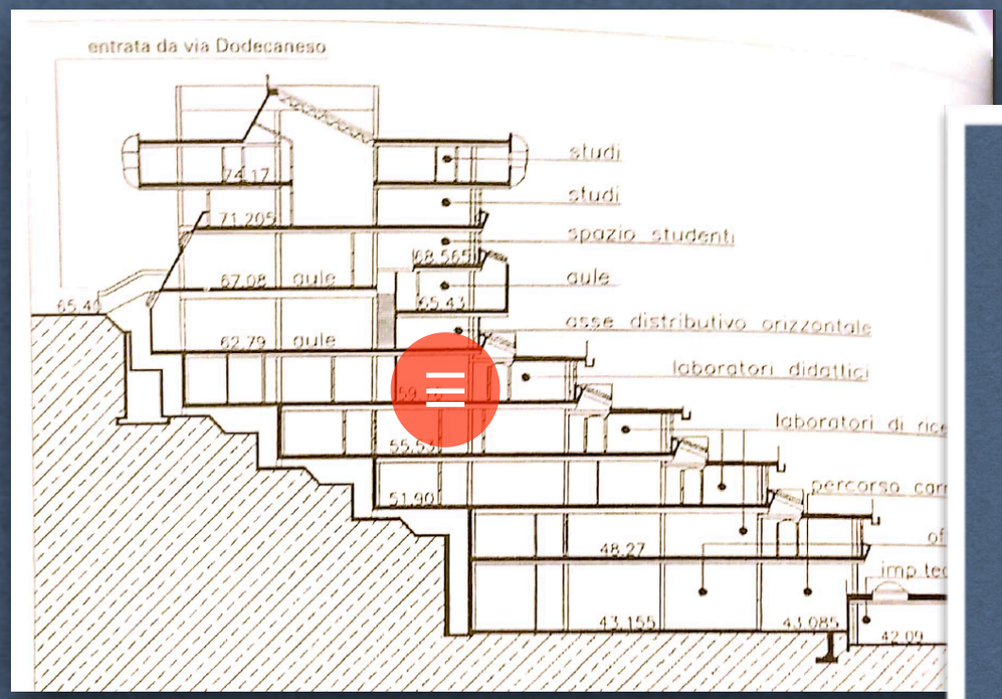




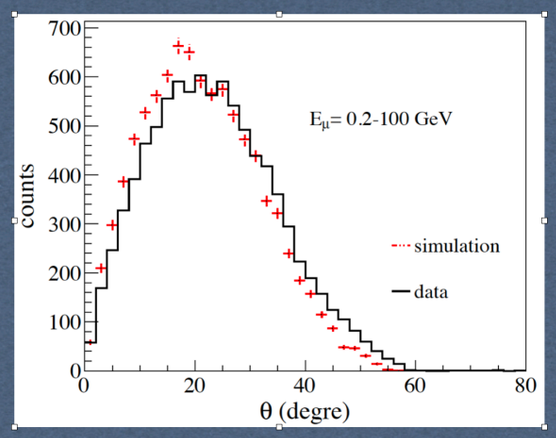
S.Grazzi

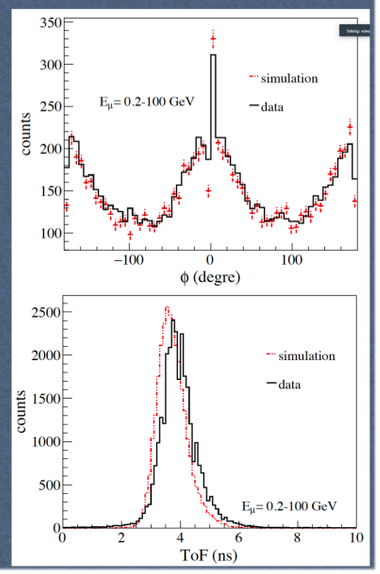






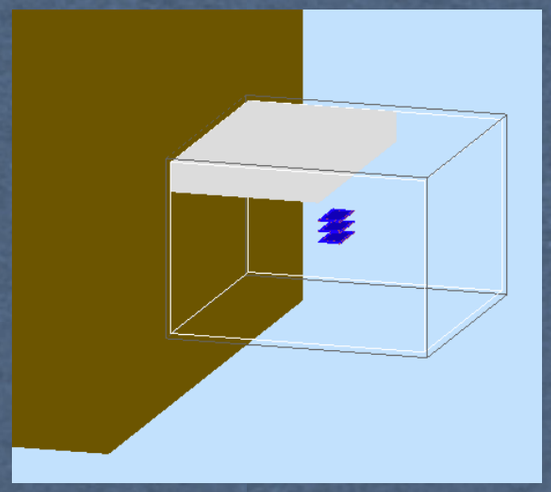
GENO-01/SIM comparison



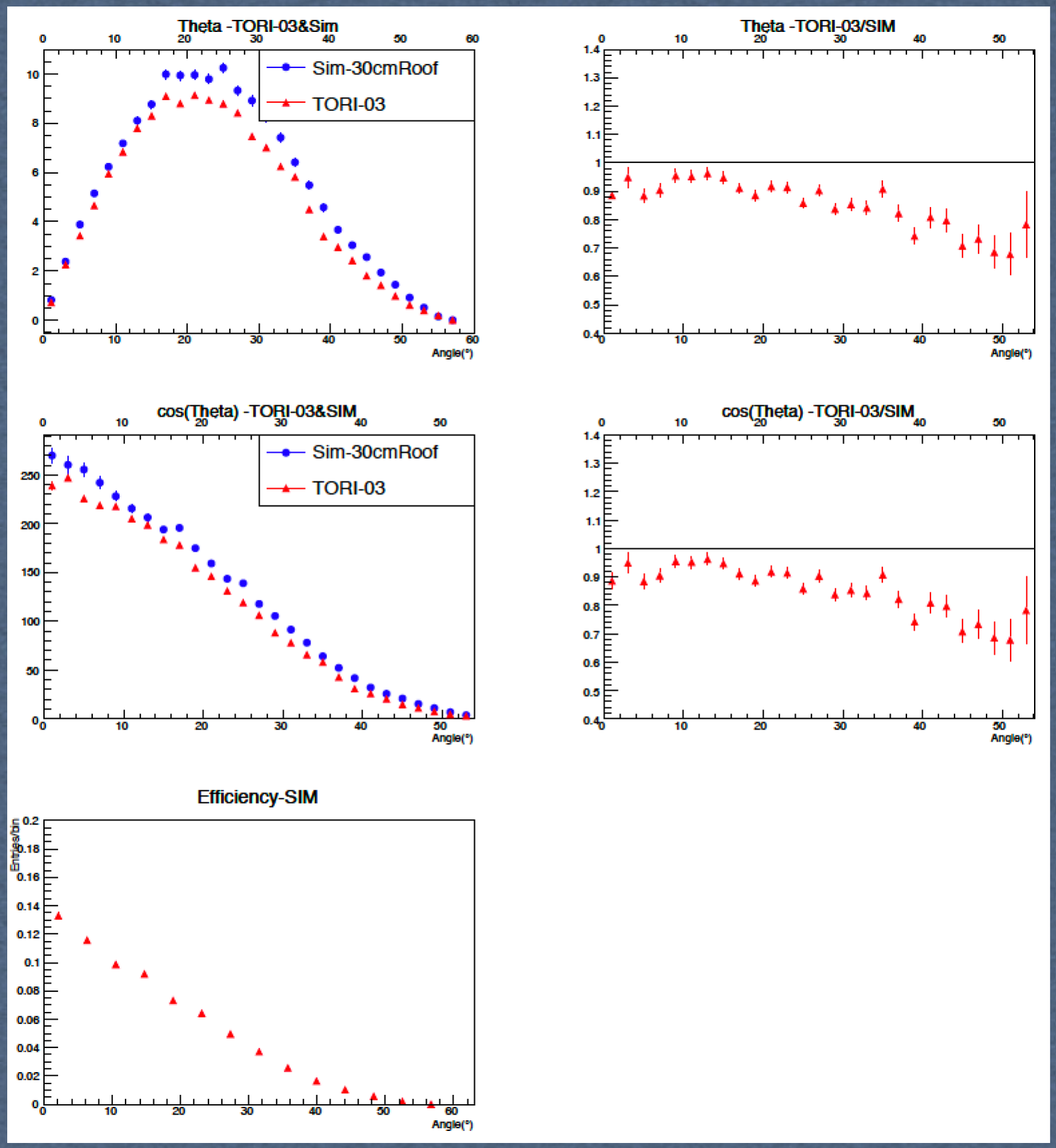


- Sim 10% higher than data rate (absolute)
- Sim theta distribution shifted down by ~1-2°
- Good consistency with high energy muons

- Reasonable agreement but not optimal



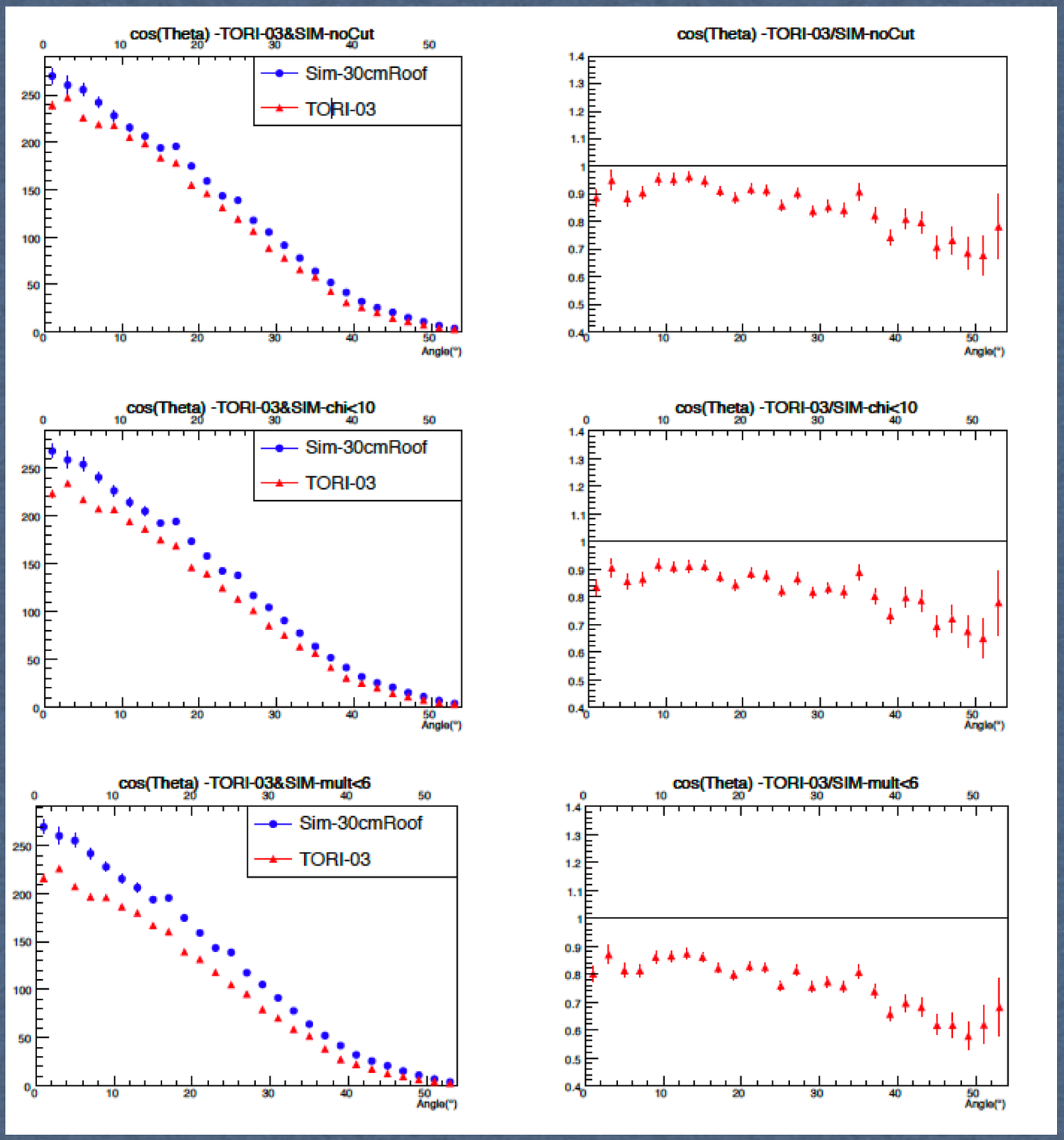
- Still working to implement a more realistic geometry of surrounding materials



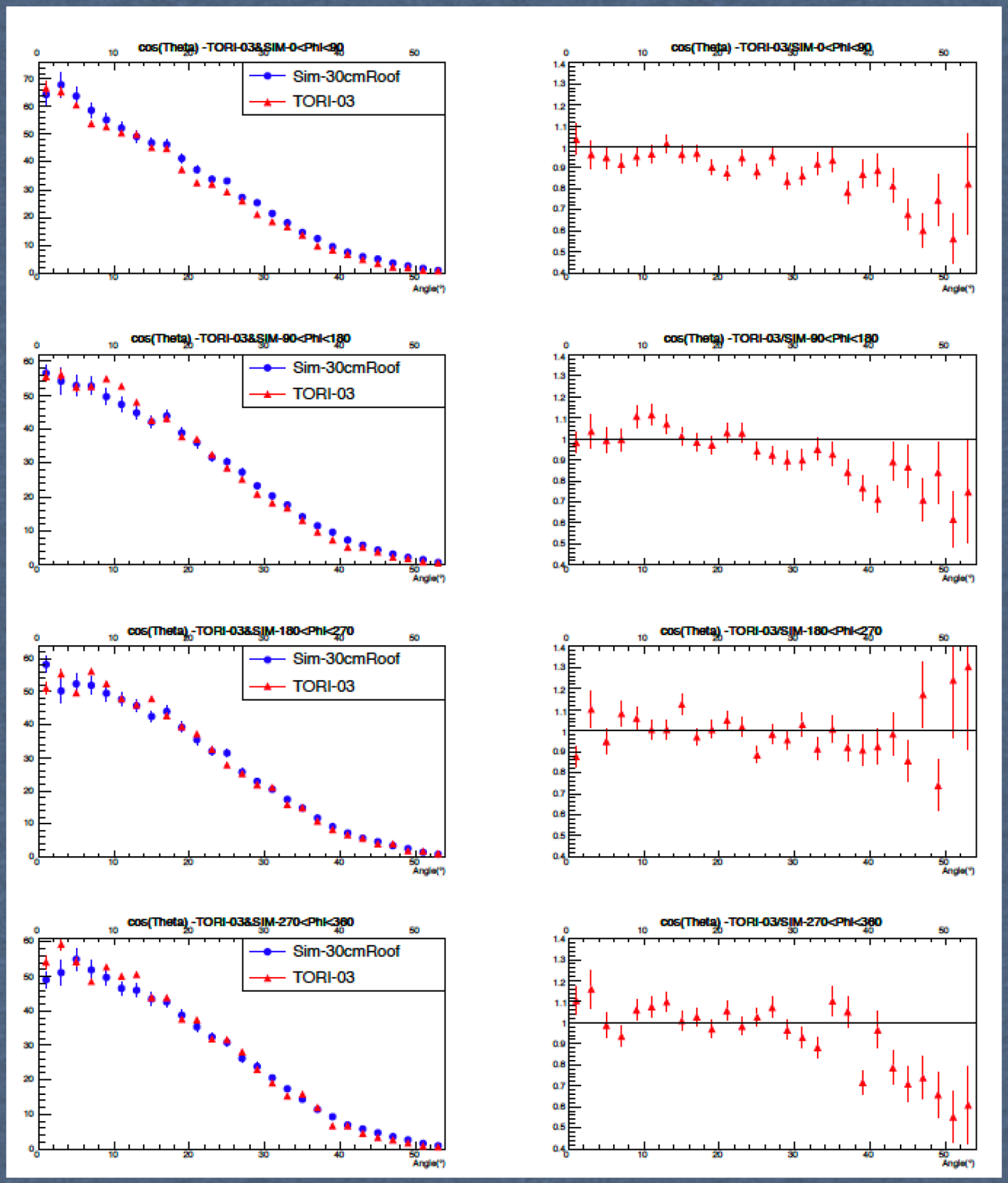
TORI-01

- ✳ Good agreement between data and simulation (world-data parametrization) both for absolute and angular behaviour
- ✳ Data are 10% lower with a reasonably smooth and constant ratio
- ✳ The region where the agreement is less good corresponds to large angles where the efficiency drops by a factor of ten
- ✳ Can have a better agreement in selected kinematics regions?

TORI-01

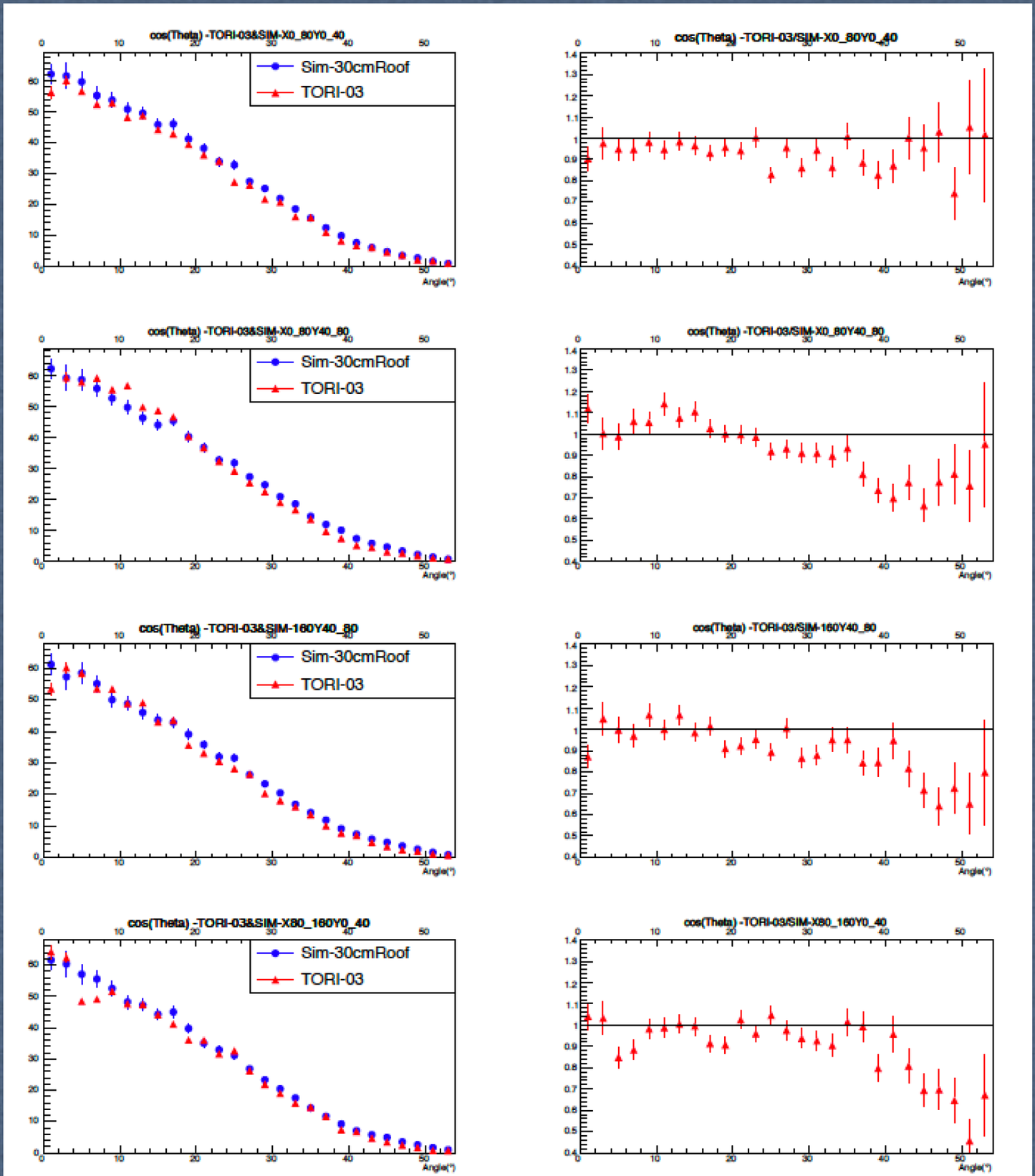


- Cuts on Chi2<19=0 does not help
- Either a cut on track multiplicity does not help



TORI-01

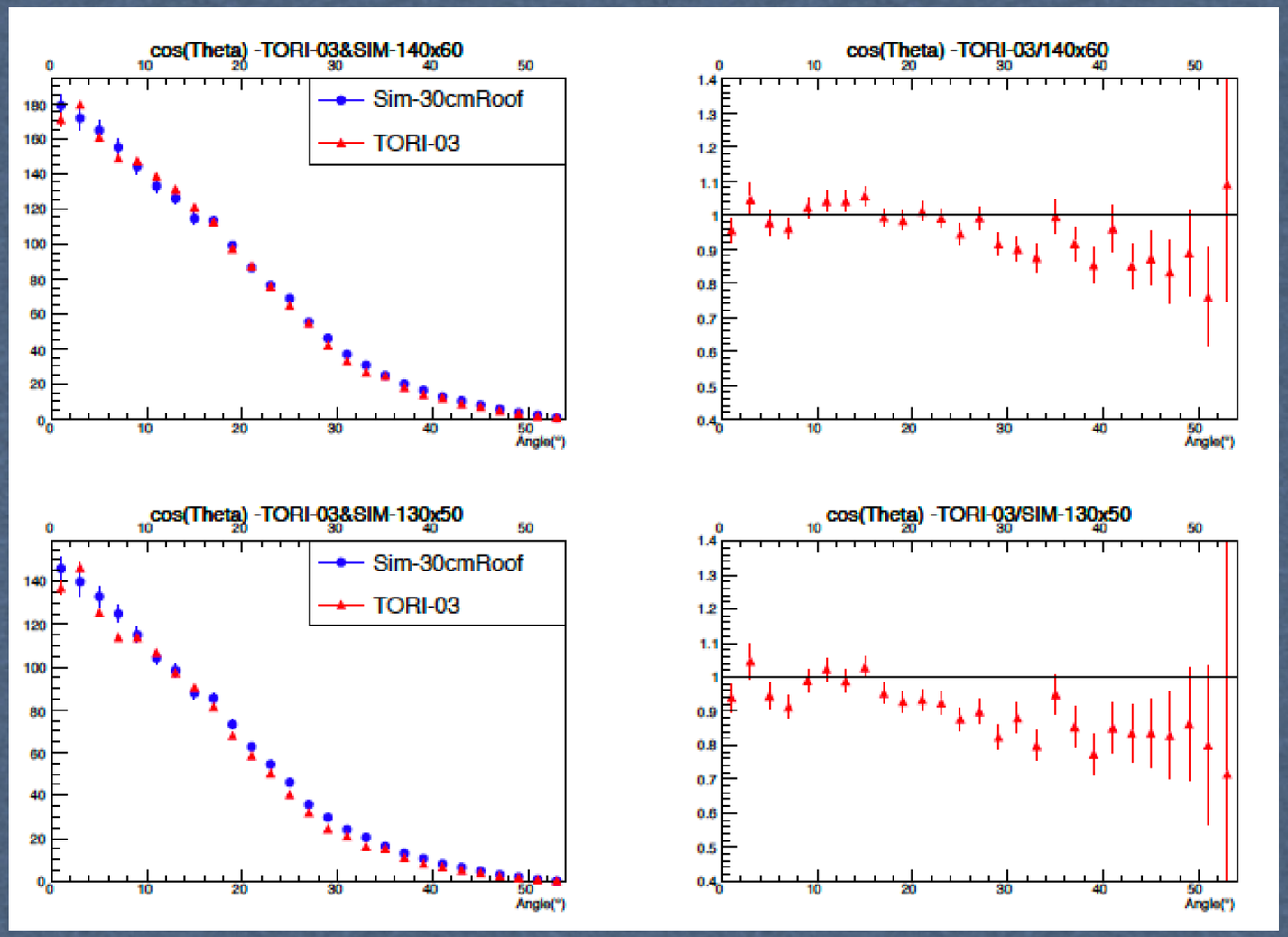
✳ Systematics checks on 4 directions (90deg each) confirms the same trend



TORI-01

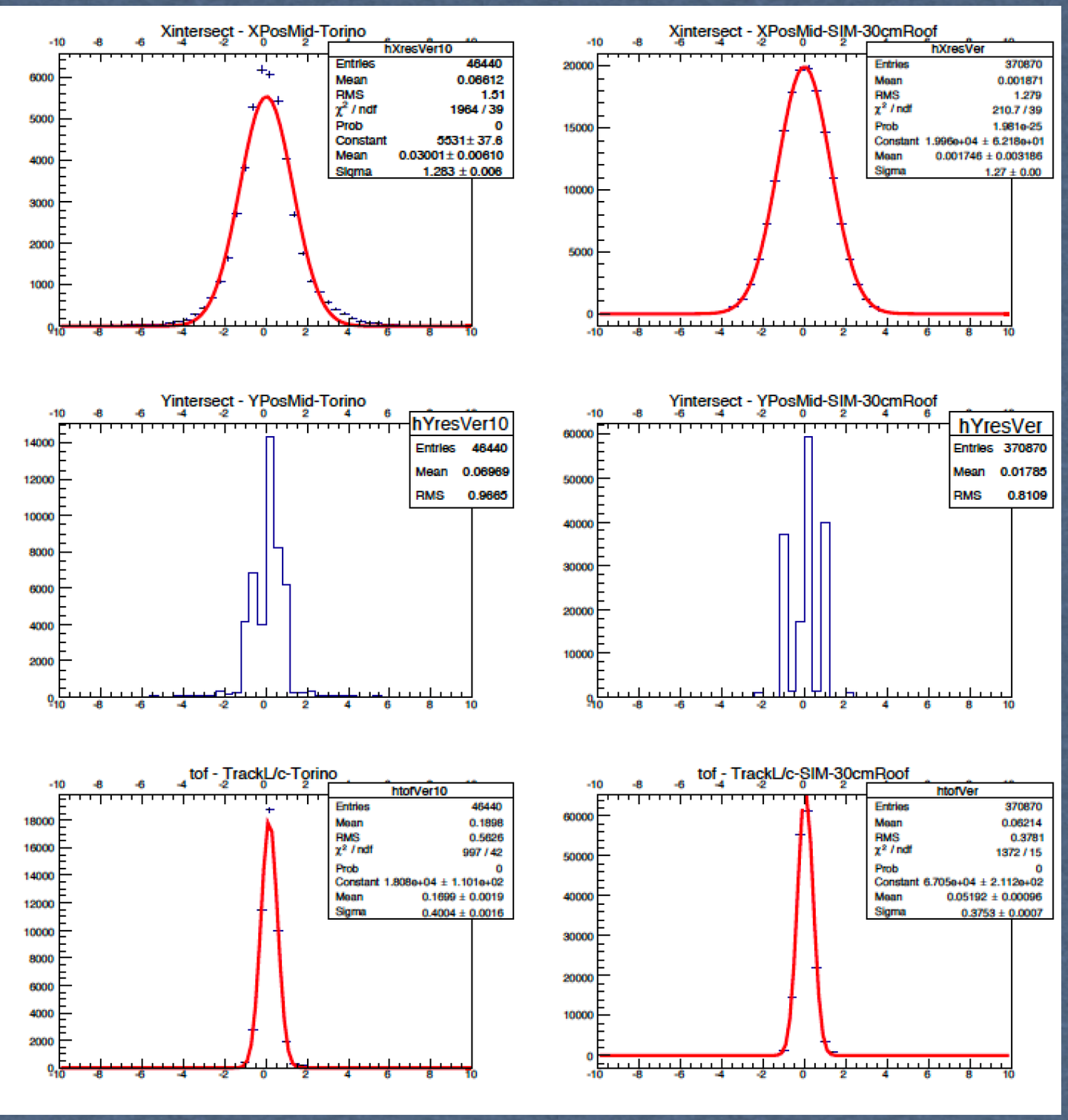
- Systematics checks on 4 quadrants (XY) may indicate some misbehaviour at large angles in certain area of the detector.

TORI-01

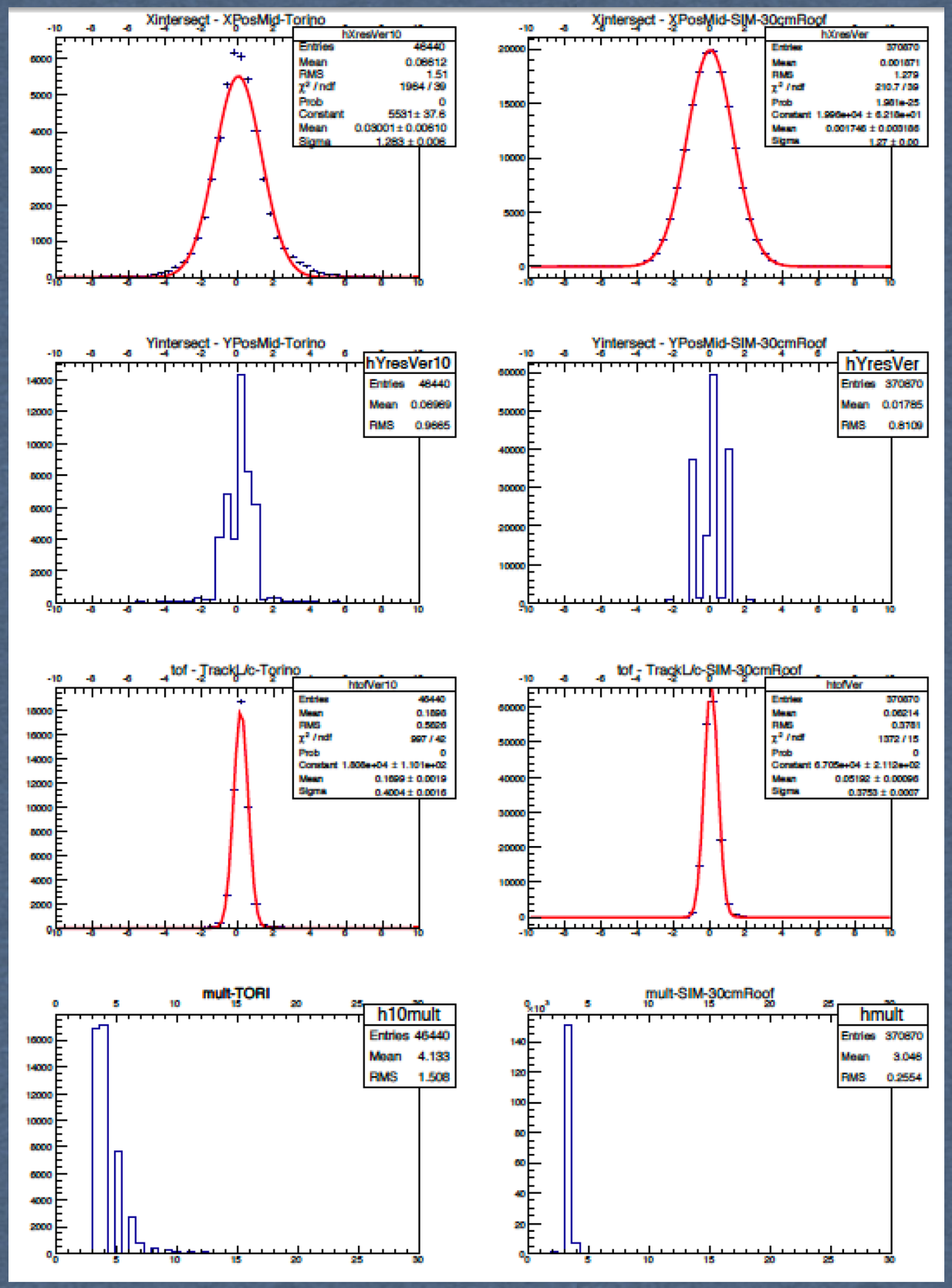


- Same conclusions when only a fiducial volume is considered

TORI-01



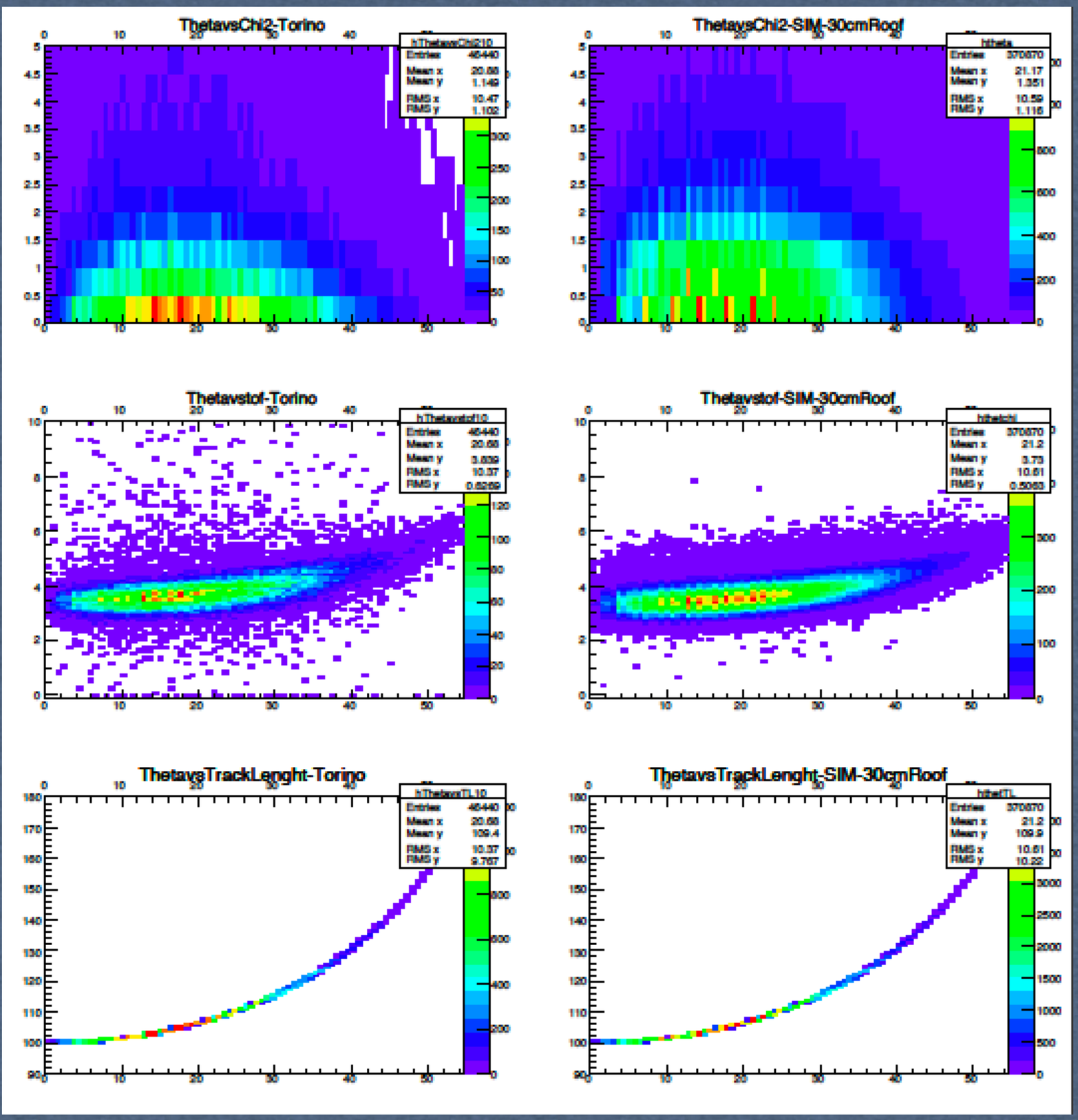
✳ Comparison of microsopic quantities



TORI-01

✳ Comparison of microsopic quantities shows a good agreement

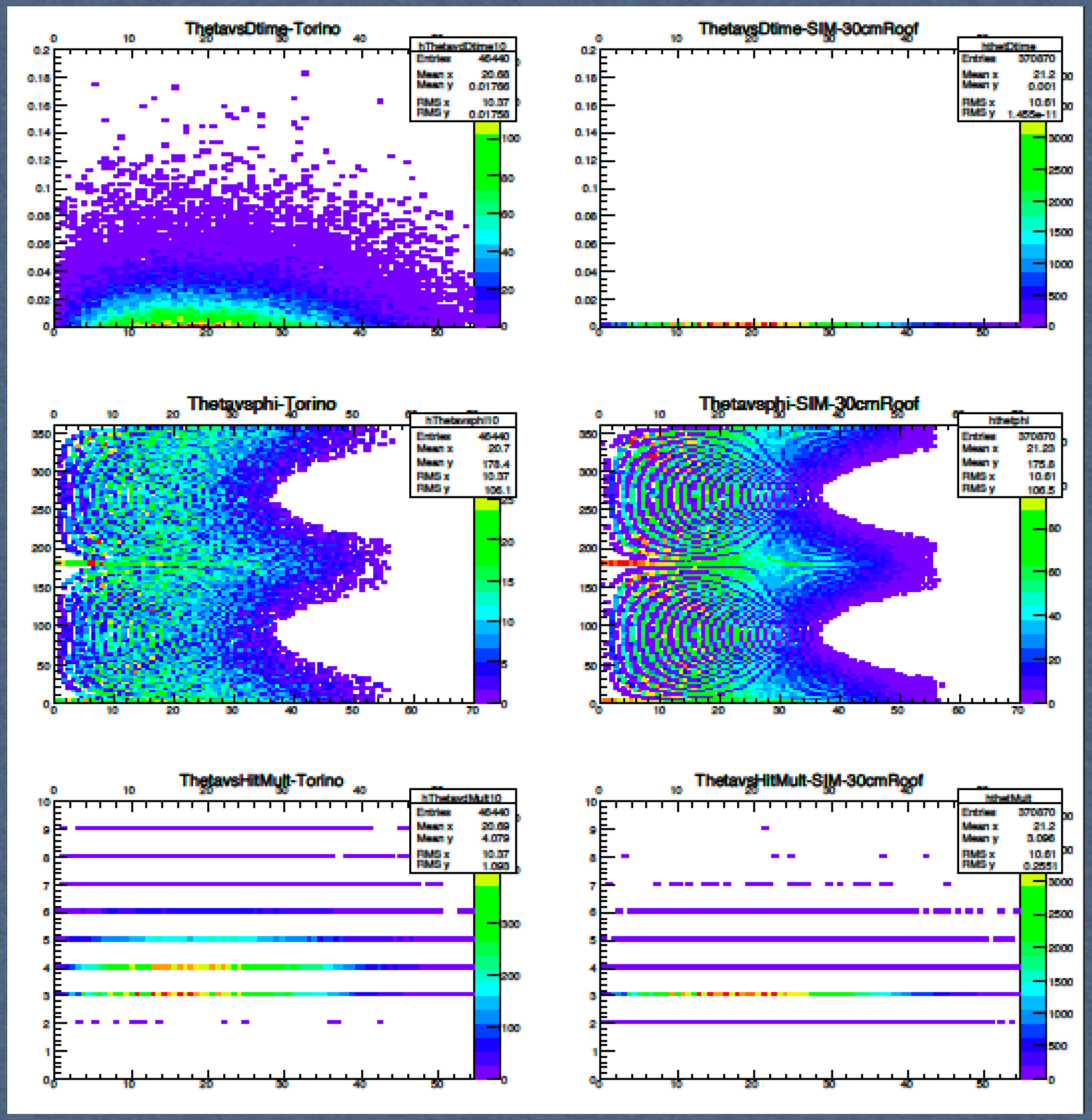
✳Multeplicity is different but can be easily adjusted



TORI-01

- Very consistent results (Data/Sim)
- Same behaviour

TORI-01

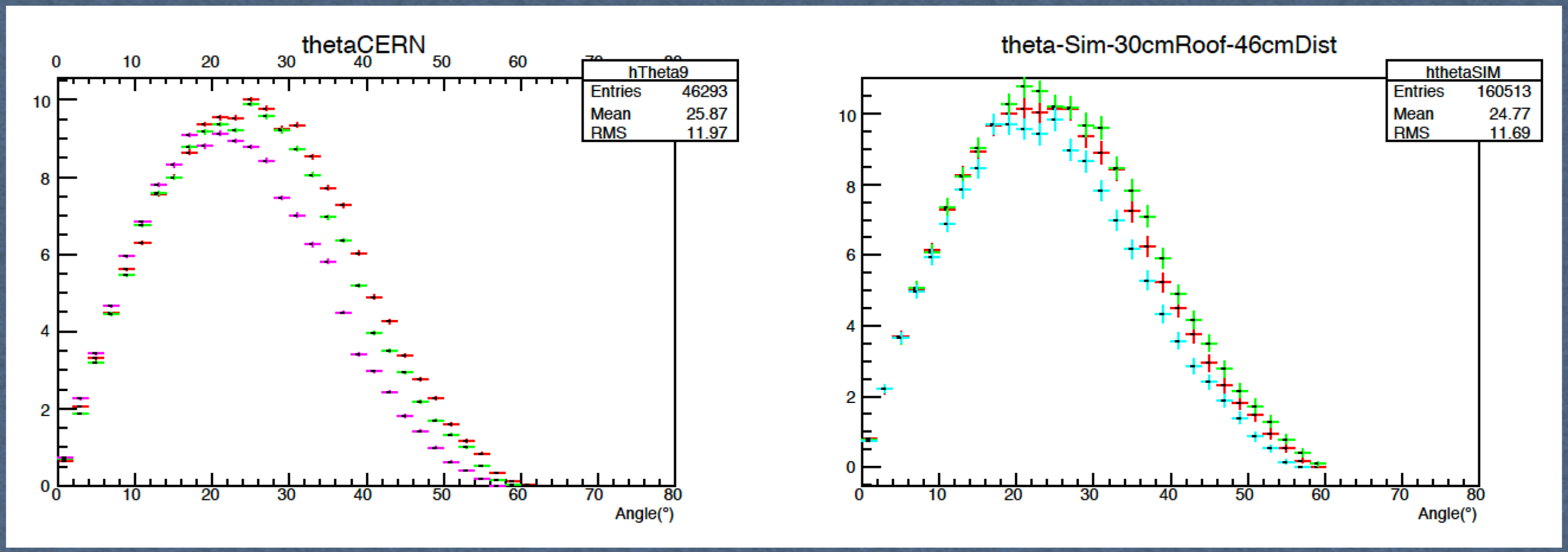


- Multeplicity needs to be fixed

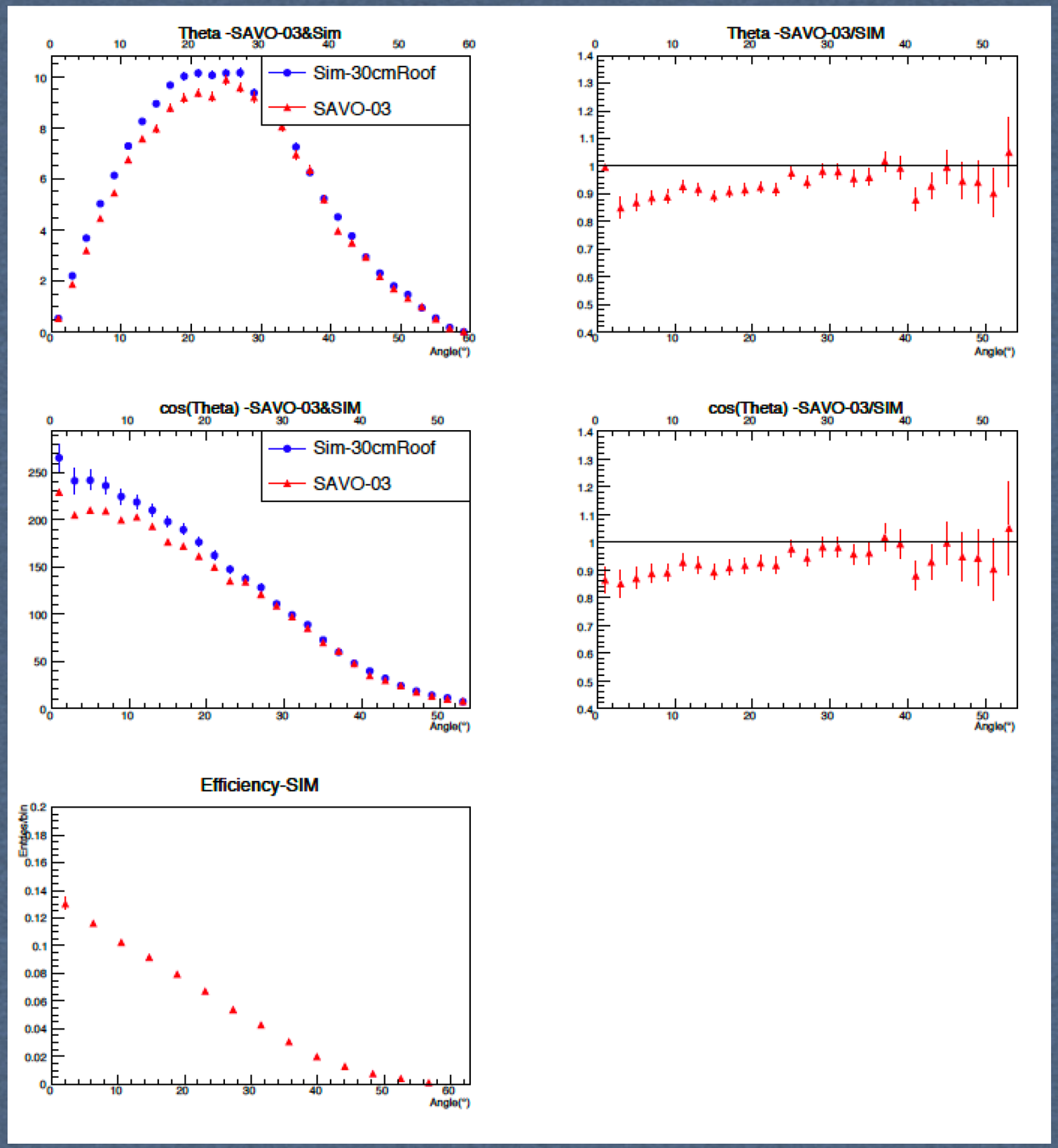
Check with some other telescopes

CERN-01: distance between chambers 44cm

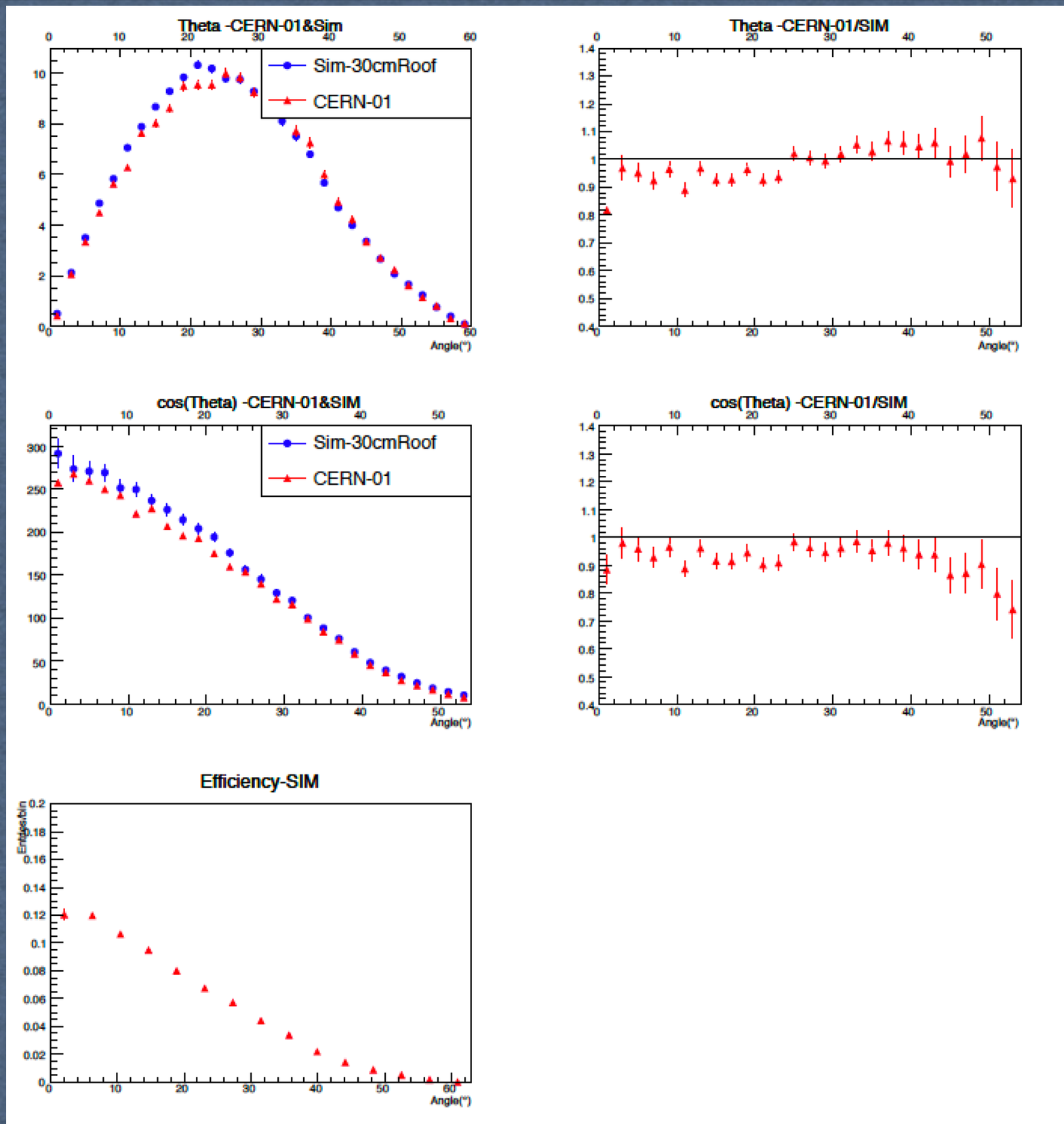
SAVO-01: distance between chambers 46cm



SAVO-01


Theta -SAVO-03&Sim
Sim-30cmRoof
SAVO-03
Angle(°)
Theta -SAVO-03/SIM
Angle(°)
cos(Theta) -SAVO-03&SIM
Sim-30cmRoof
SAVO-03
Angle(°)
cos(Theta) -SAVO-03/SIM
Angle(°)
Efficiency-SIM
Angle(°)

CERN-01


Theta -CERN-01&Sim
Sim-30cmRoof
CERN-01
Angle(°)
Theta -CERN-01/SIM
Angle(°)
cos(Theta) -CERN-01&SIM
Sim-30cmRoof
CERN-01
Angle(°)
cos(Theta) -CERN-01/SIM
Angle(°)
Efficiency-SIM
Angle(°)

Summary and future plans

- EEE MRPC response implemented in GEANT4
- Simulations matches (@10%) data angular and time distribution
- Absolute rates of single muon hits on the telescope (3 chambers) are comparable to measured rates
- Simulation can be used to understand variation of telescope parameters
- Disagreement for theta could be due to materials around the telescope
- Next steps:
  - systematically study other telescopes involving Daniele
  - involve other groups/schools to the data validation procedure
  - paraametrize complicated geometry and check sim result against data