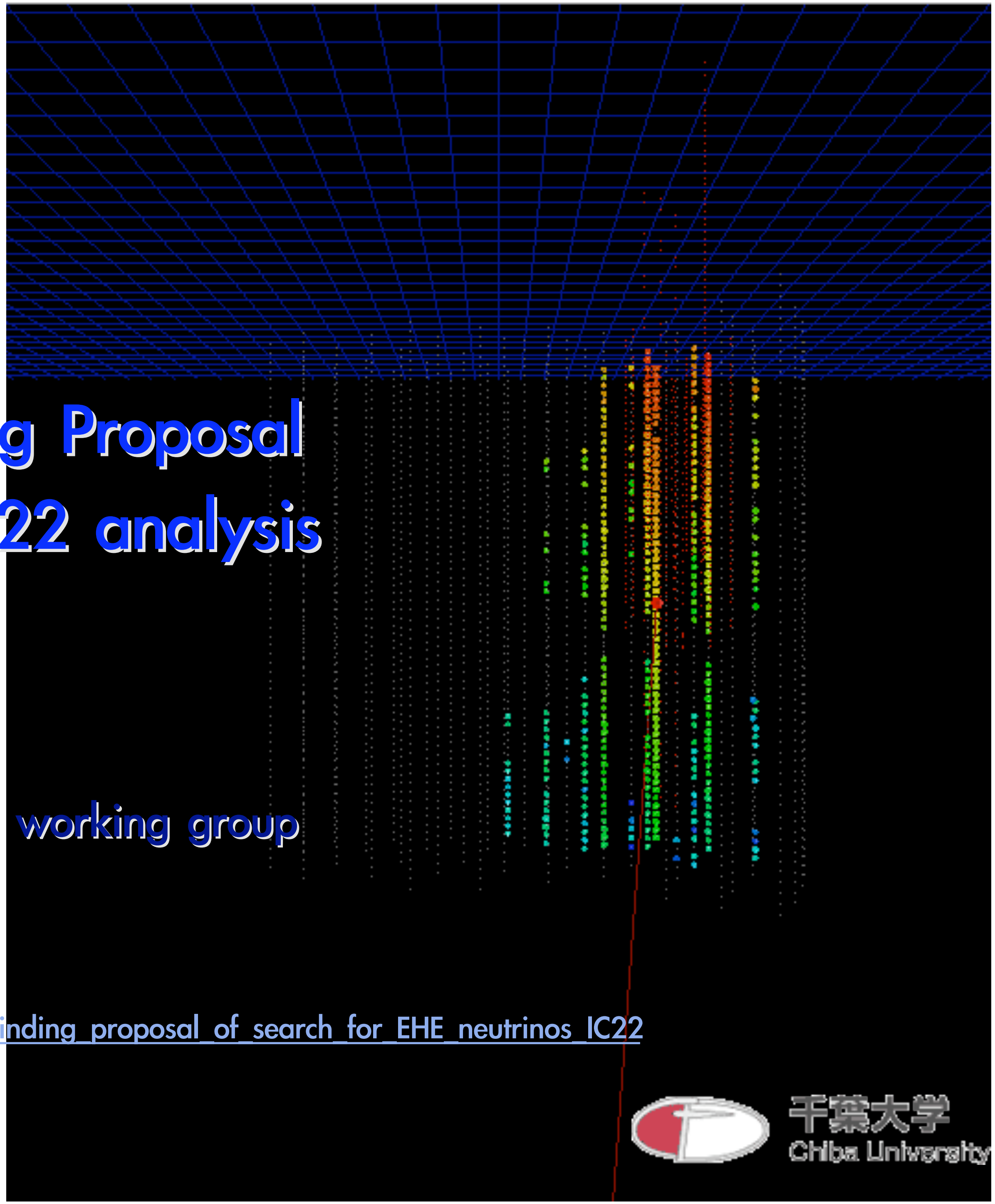


The Unblinding Proposal for the EHE IC22 analysis

K. Mase for the EHE working group

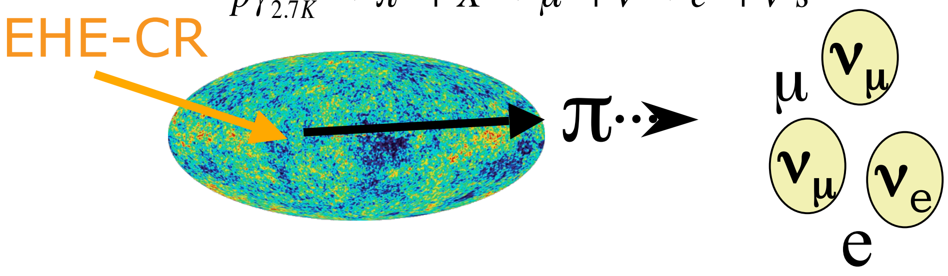
http://wiki.icecube.wisc.edu/index.php/Unblinding_proposal_of_search_for_EHE_neutrinos_IC22

2009.03.19 Analysis phone call

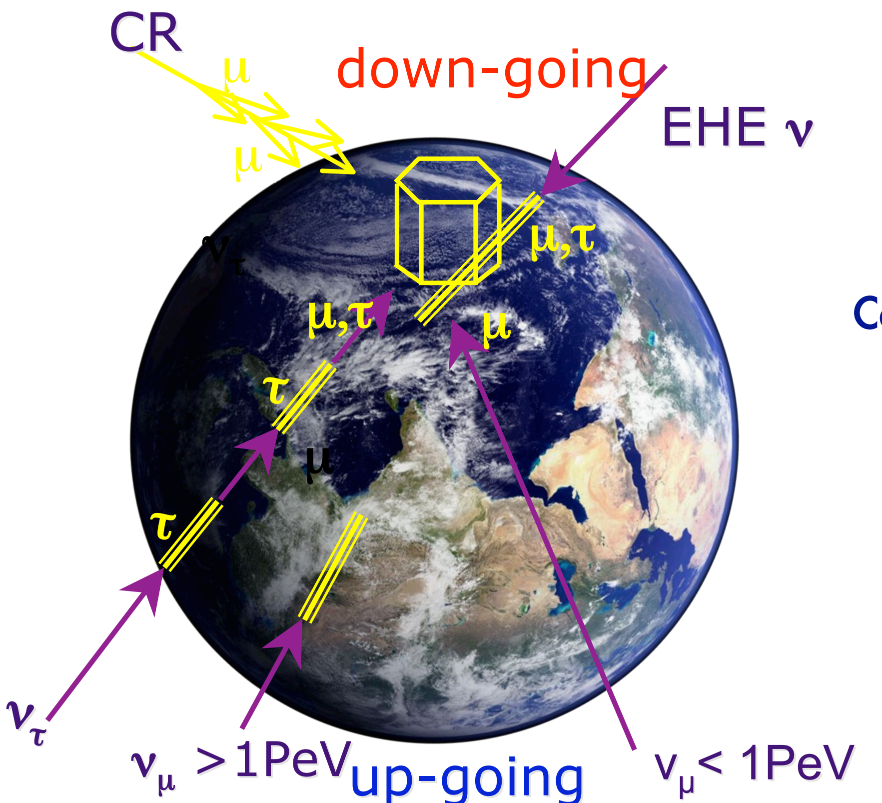
The EHE neutrinos

Searching for very energetic neutrinos (mainly >10^8 GeV)

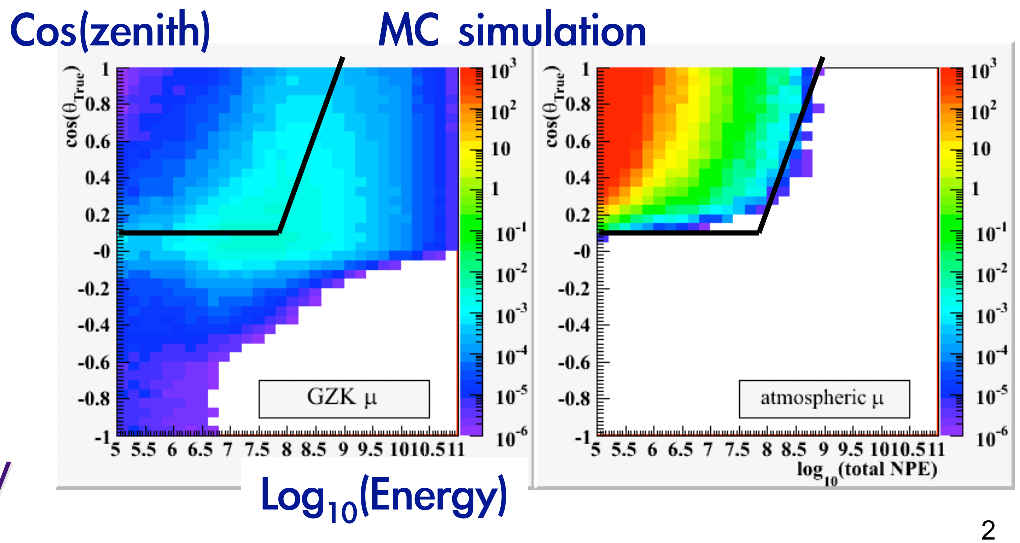
$$p\gamma_{2.7K} \rightarrow \pi^{\pm} + X \rightarrow \mu^{\pm} + \nu \rightarrow e^{\pm} + \nu's$$



- EHE neutrino signal
  - horizontally (opaque to the earth)
  - extremely high energy



- Atmospheric muon background
  - down-going
  - relatively low energy (the energy spectrum is steep ($E^{-(3-4)}$))



The mid-term plan 2008-9

http://wiki.icecube.wisc.edu/index.php/EHE_Analysis_MidTerm_Plan_2008-9

The mid-term plan is made after the last collaboration meeting, taking into account comments mainly from IC9 paper referees. (Thanks)

The mid-term plan is summarized below

- Priority in the present analysis is to keep robustness
- The CORSIKA issue
- Extensive comparison between data and MCs
- Systematic study with the IceTop detector

The datasets

http://wiki.icecube.wisc.edu/index.php/Data_samples_and_quality_check_%28EHE-IC22%29

Three datasets are used in this analysis:

1. Observational data (242.1 days)

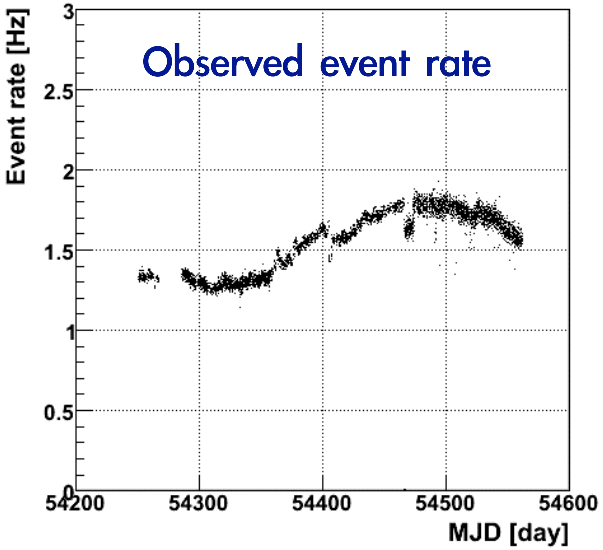
   EHE level1 data (NDOM>=80) (without droop correction)

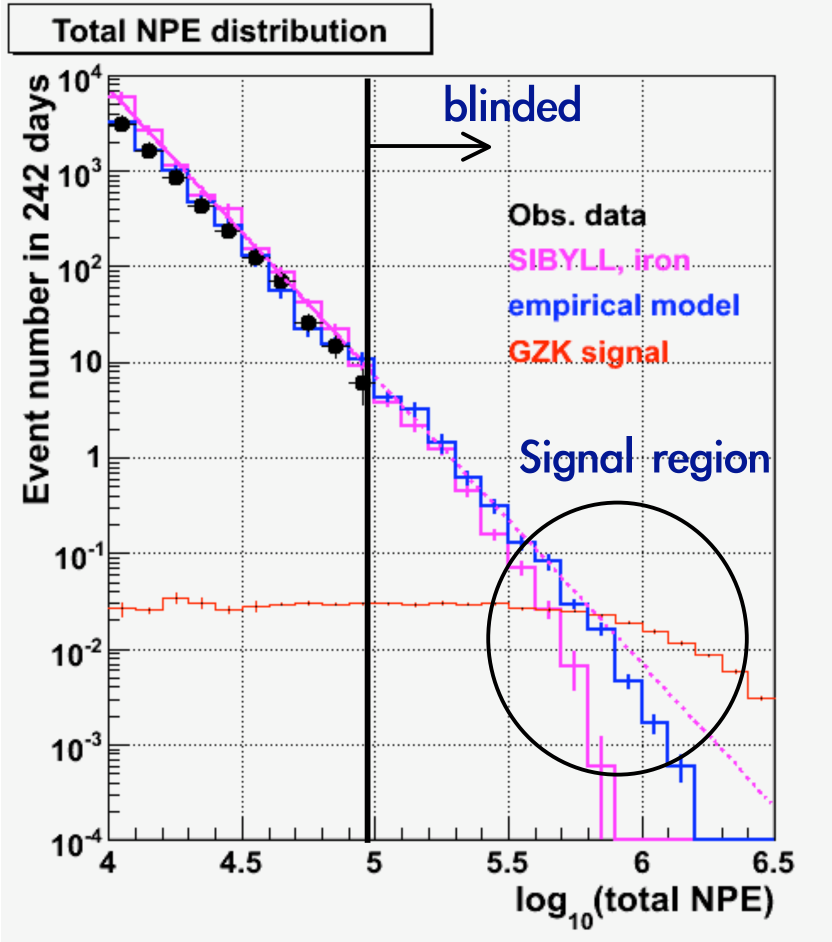
2. JULIeT data

   Signal and backgrounds (single muon assumption) with different weights

3. HE CORSIKA data (SIBYLL)

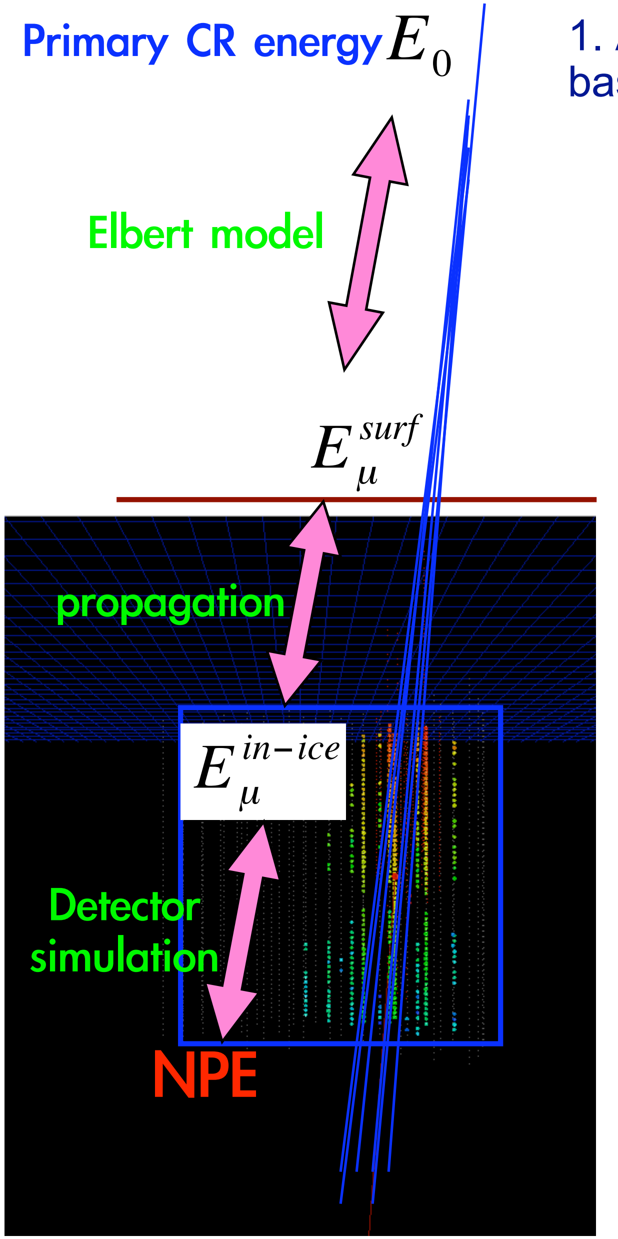
   Backgrounds. (Up to 10^{10} GeV, which will underestimate backgrounds in the signals region. Therefore, cross check purpose.)





The Background modeling

http://wiki.icecube.wisc.edu/index.php/The_optimization_of_the_empirical_model_%28IC22%29



1. An empirical model is constructed to express the BG based on the Elbert model.

$$\text{Elbert model: } < N_\mu > = \frac{E_T}{E_\mu} \frac{A}{\cos\theta} \left(\frac{E_0}{AE_\mu} \right)^{\alpha} \left(1 - \frac{AE_\mu}{E_0} \right)^{\beta}$$

$$\sum E_\mu^{surf} \equiv \int_{E_{th}^{surf}}^{E_0/A} \frac{dN_\mu}{dE_\mu} E_\mu dE_\mu$$

$$\approx E_T \frac{A}{\cos\theta} \frac{\alpha}{\alpha - 1} \left(\frac{AE_{th}^{surf}}{E_0} \right)^{-\alpha+1}$$

This formula relates primary CR energy and the bundle energy at surface.

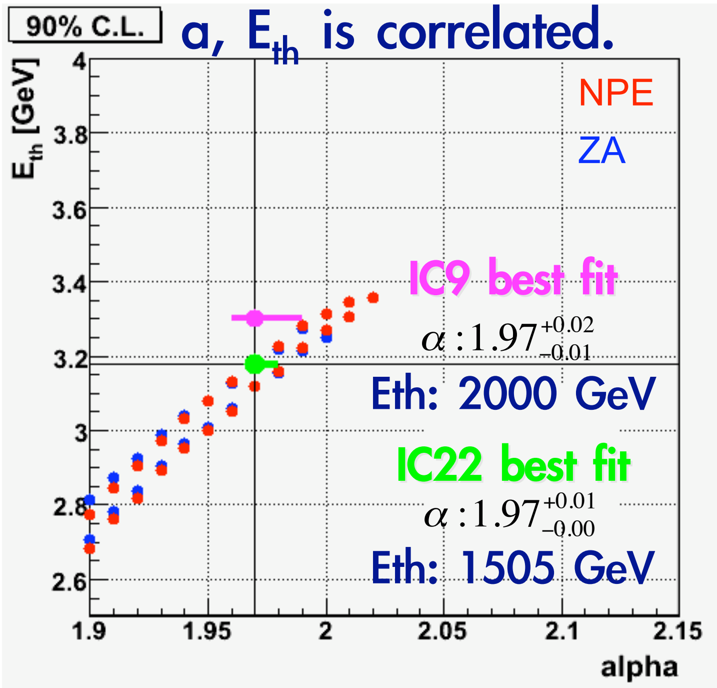
2. The surface bundle energy is also connected with NPE which is our observable with help of simulation.

3. The CR flux is known, so that we can predict NPE distributions.

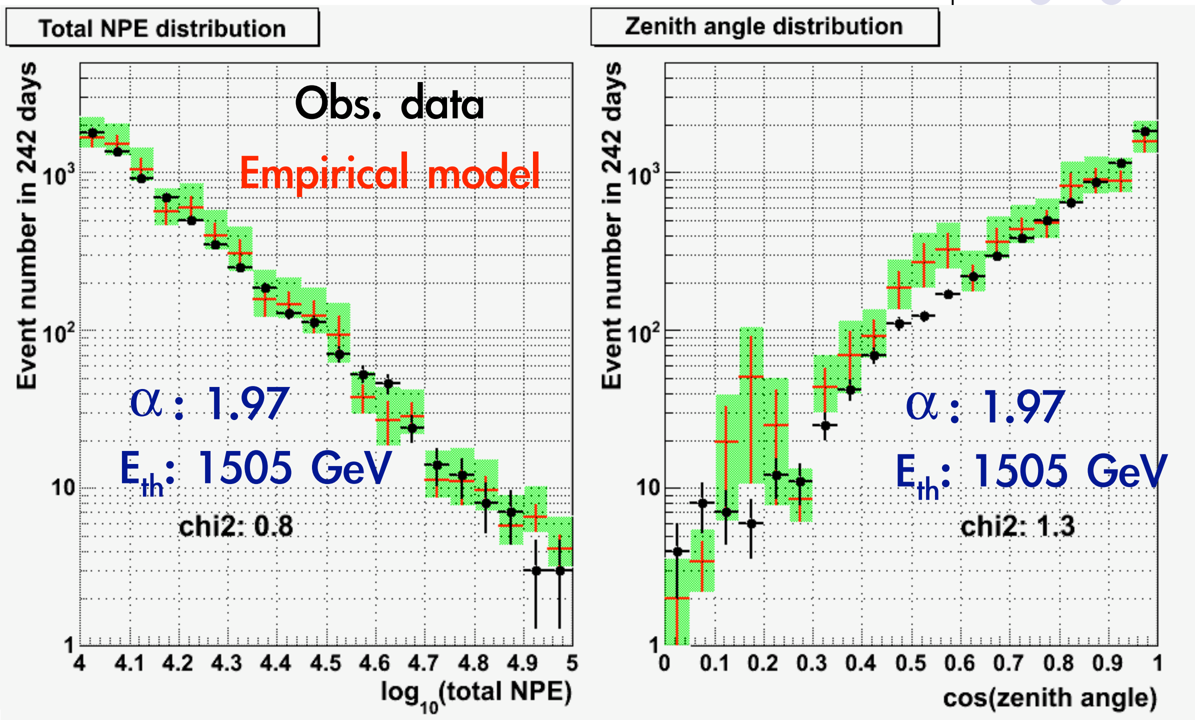
4. Fit obs. data (NPE and ZA distributions) with the empirical model by changing α and E_{th} as free parameters

The optimization of the empirical model

6516 events



Allowed region for NPE and ZA shows same trend



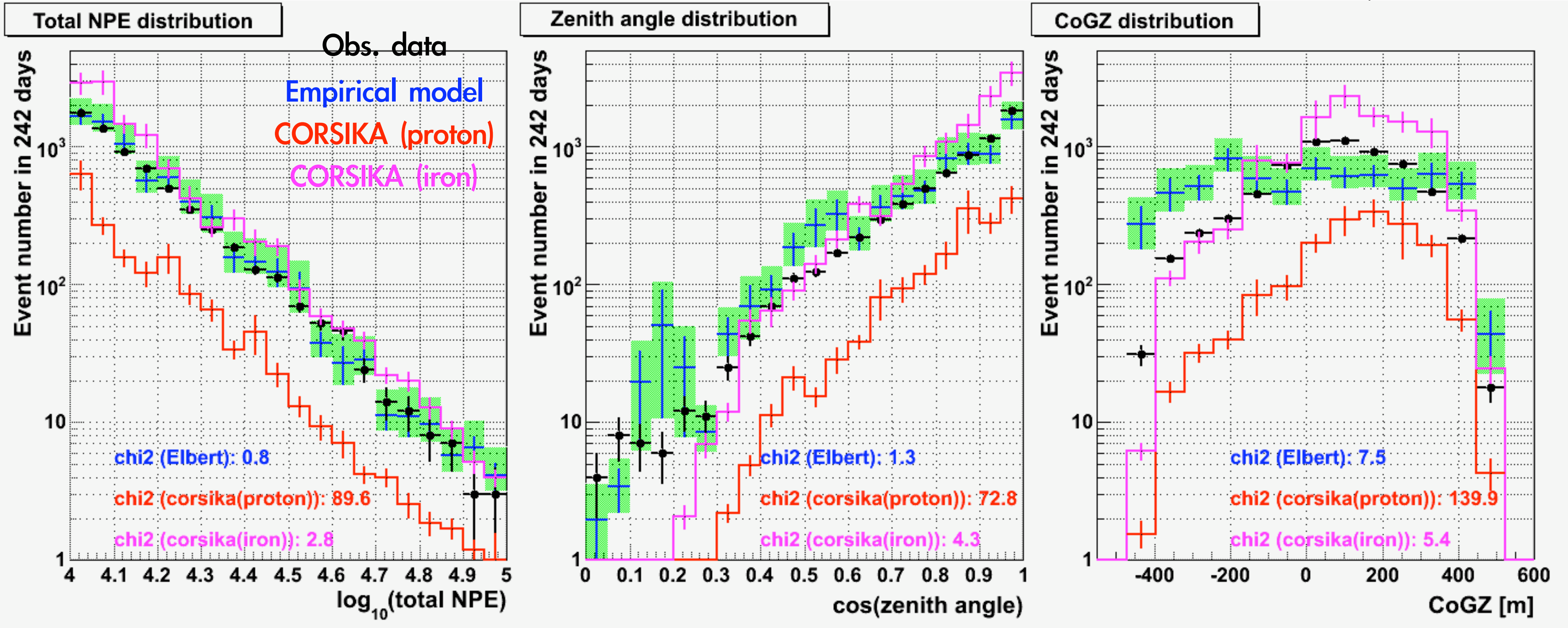
The empirical model express the obs. data quite well.

The chi-square is equally good for the NPE and ZA distributions with the same optimized value.

The green shade include the model uncertainty and the statistical error.

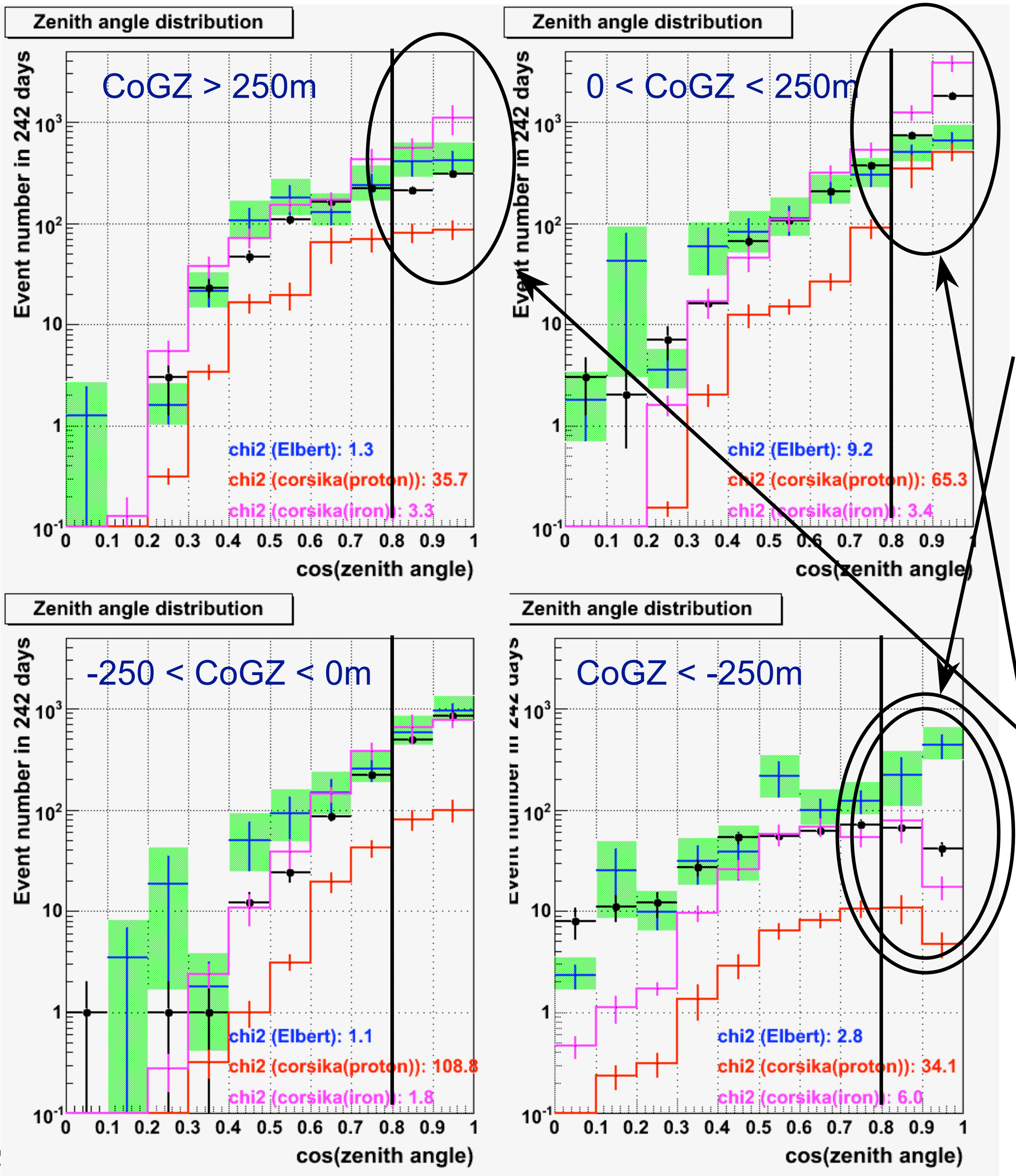
The data comparisons (level2 (NPE>10^4))

http://wiki.icecube.wisc.edu/index.php/Comparison_between_the_observational_data_and_MCs_%28EHE-IC22%29



- The empirical model express obs. data well except the CoGZ distribution at level2 cut.
- The pure CORSIKA proton and iron (SIBYLL) bracket the obs. data as expected.
- Less events in large ZA region for CORSIKA (discussed later)
- The CoGZ distribution is not perfectly expressed by any MCs.

Comparisons of ZA distributions for each CoGZ position



Obs. data

Empirical model

CORSIKA (proton)

CORSIKA (iron)

Difference is seen for the vertical events for the empirical model.

The vertical events penetrate into deep part (CoGZ < -250m).

→ due to simple single muon assumption

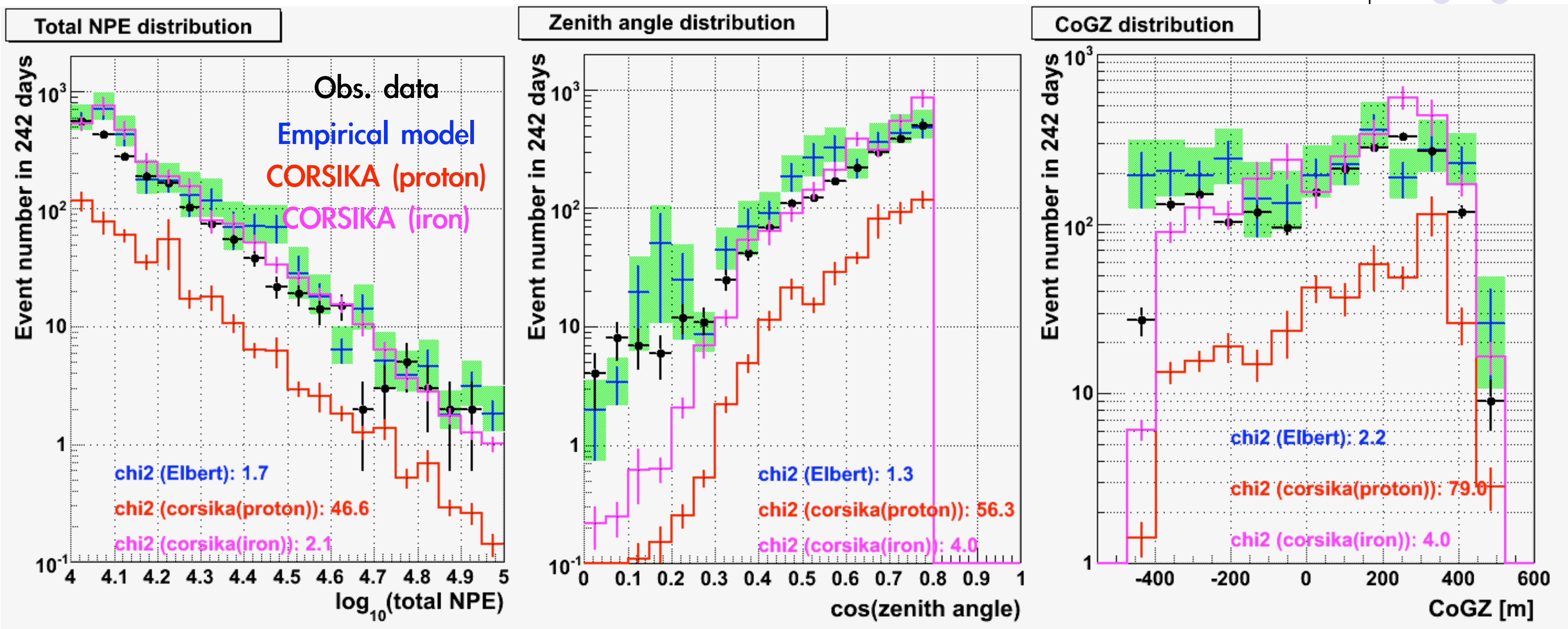
But, relatively good agreement for cos(ZA)<0.8.

→ cut cos(ZA)>0.8

On the other hand, vertical CORSIKA events attenuate at the top of the detector.

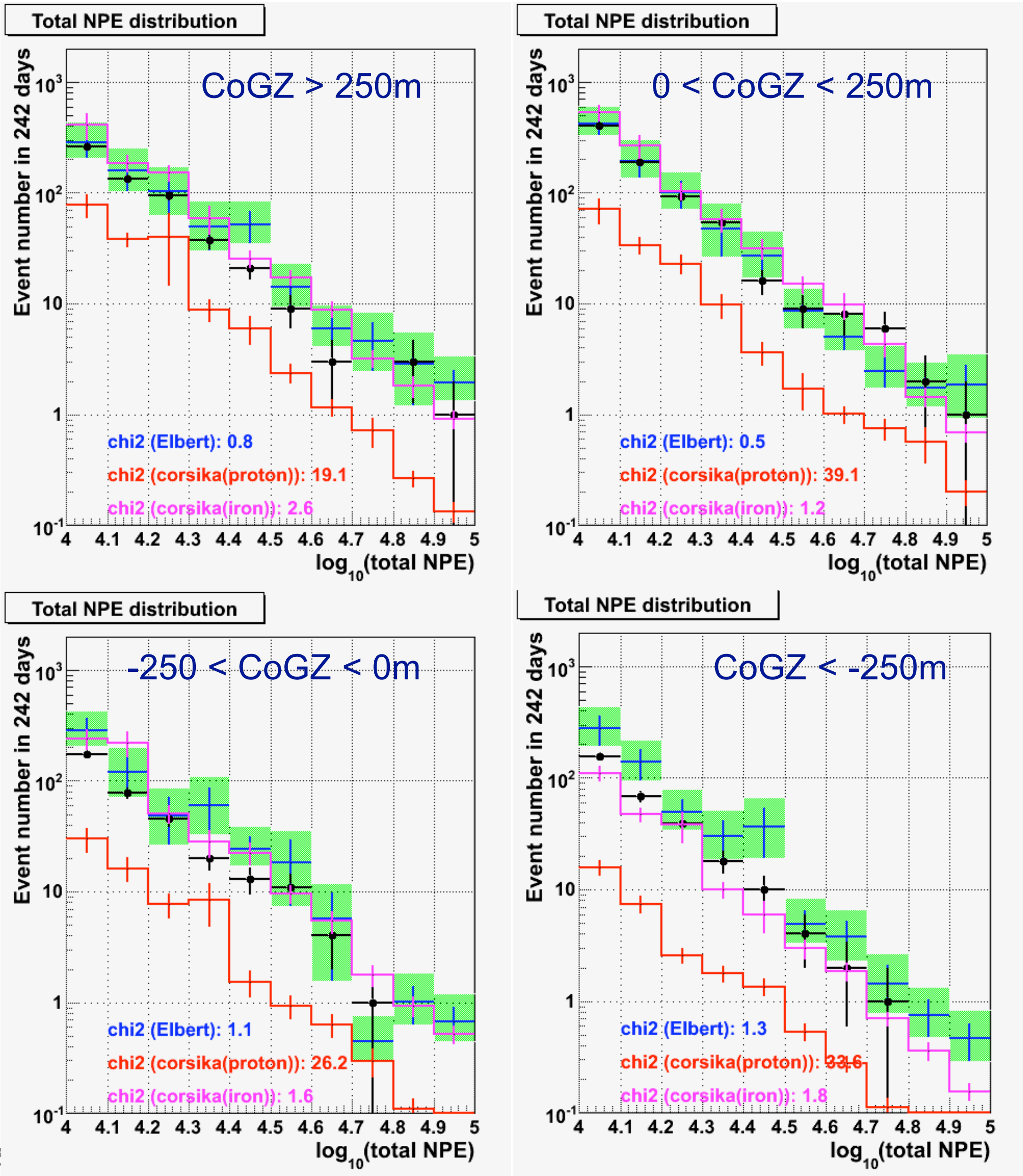
Less horizontal events for CORSIKA is universal, not depending on the CoGZ position. (discussed later)

❑ The data comparisons (level3 (NPE>10^4 && cos(ZA)<0.8))



At level 3 cut, the empirical model express the CoGZ distribution, too.

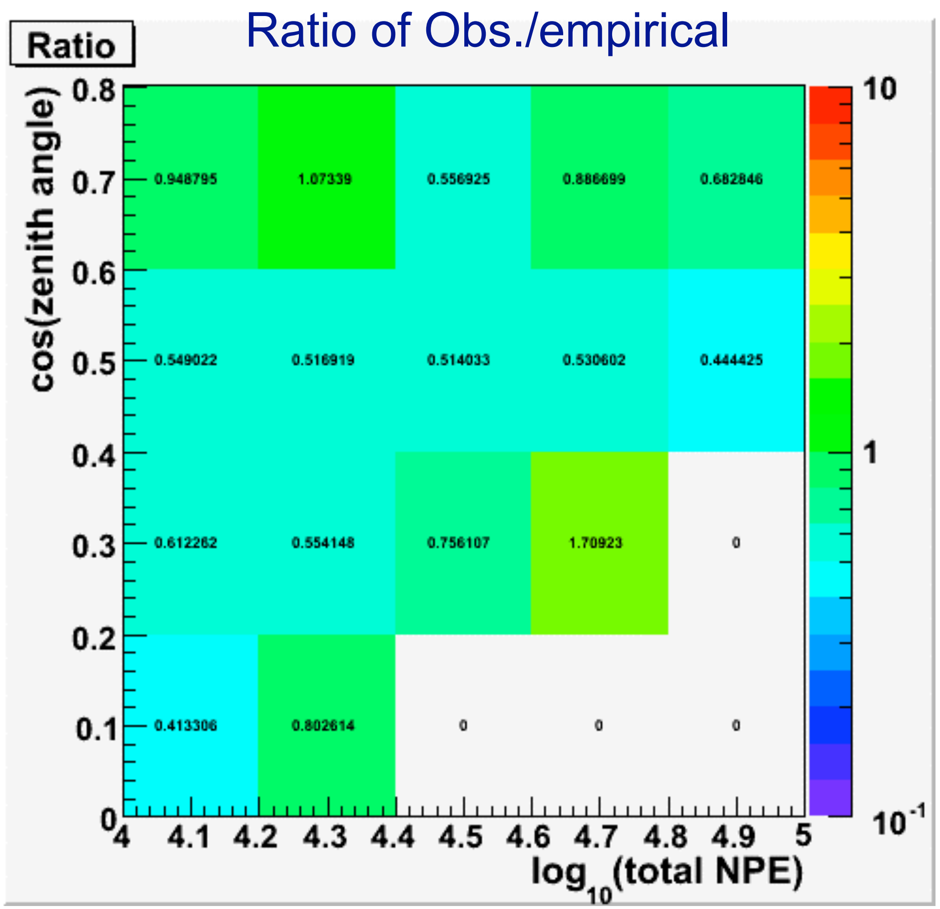
Comparisons of NPE distributions for each CoGZ position

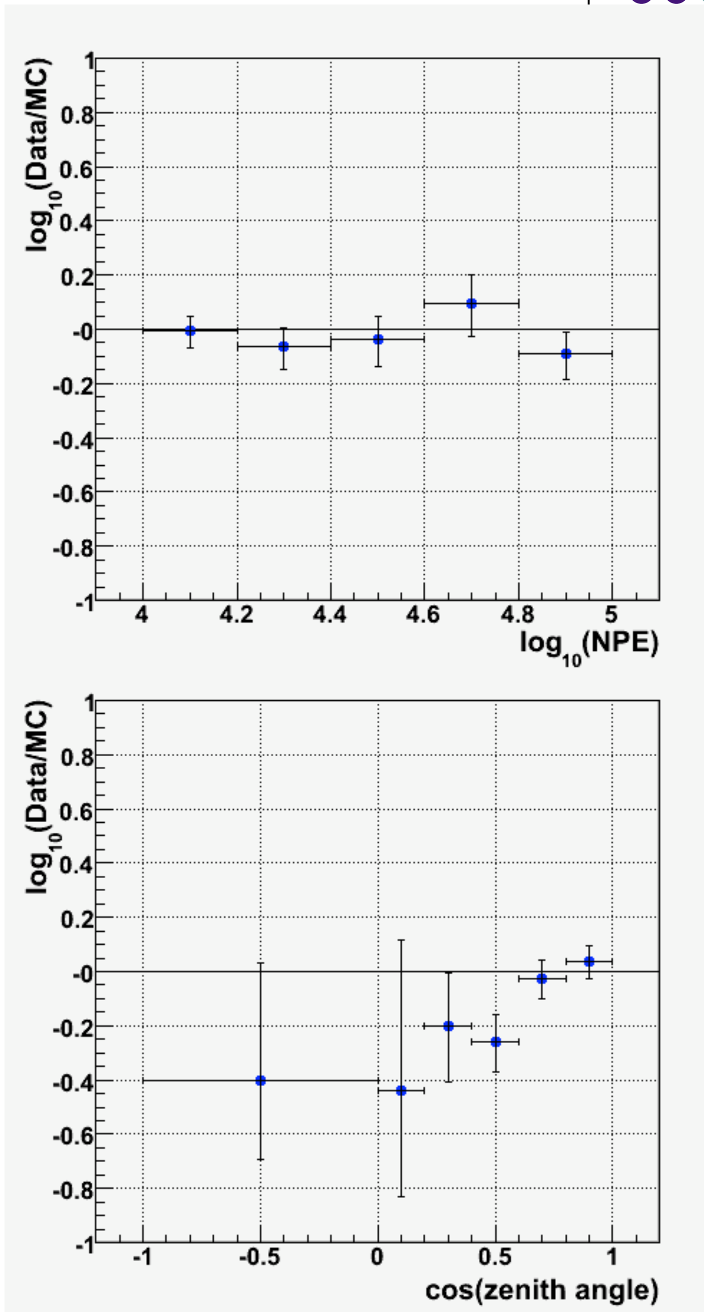


Obs. data
Empirical model
CORSIKA (proton)
CORSIKA (iron)

The empirical model express the observed NPE distribution very well for each CoGZ position.

Comparison of NPE and ZA plane





The ratio is unity within the statistical error in every NPE and ZA plane.

(The empirical model gives higher background compared to the obs. data at large ZA, though it's more conservative and within the error.)

The CORSIKA issue

See more detail in

http://wiki.icecube.wisc.edu/index.php/Comparison_between_the_observational_data_and_MCs_%28EHE-IC22%29#CORSIKA_issue

The small difference between the CORSIKA (SIBYLL) data and the obs. data is found.

- The CoGZ distribution

  More events concentrate on the top of the detector

- Less horizontal events indicating too good angular resolution

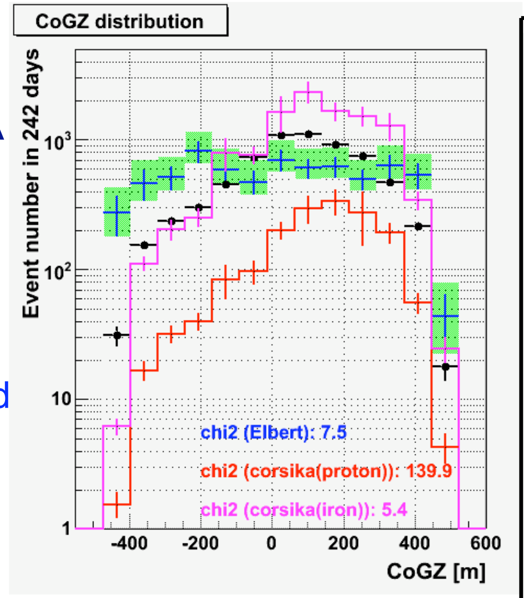
  → See right plots

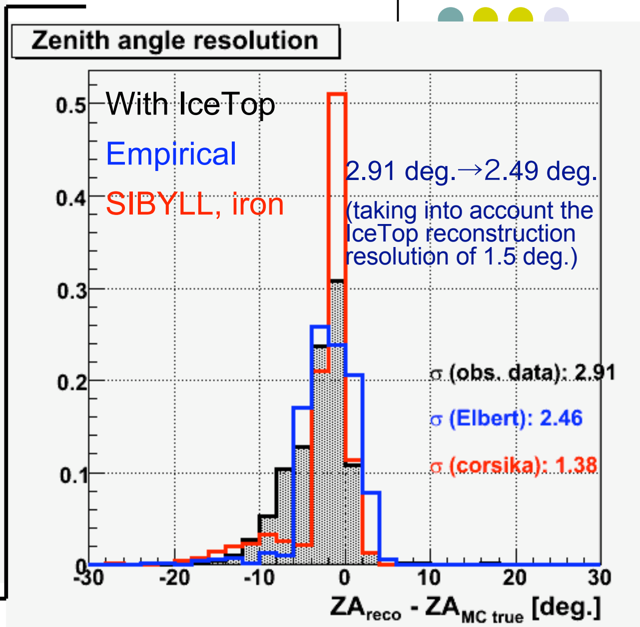
- NPE Vs CR energy relation

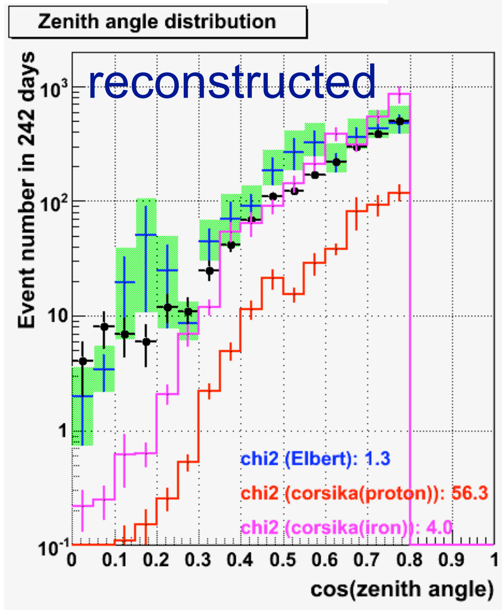
  →See next page

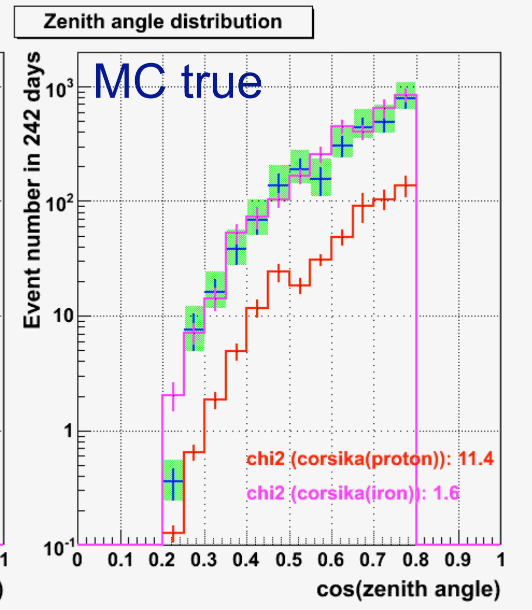
All these results seem to indicate that the muon bundles in CORSIKA consists of more lower energy muons in a bundle (higher multiplicity) which leads to less stochastic nature of the bundles.

The NPE and MC true ZA distributions agrees with the empirical model, so CORSIKA data is consistent with the empirical model to some level, but not perfect. (The empirical model express the obs. data better.)





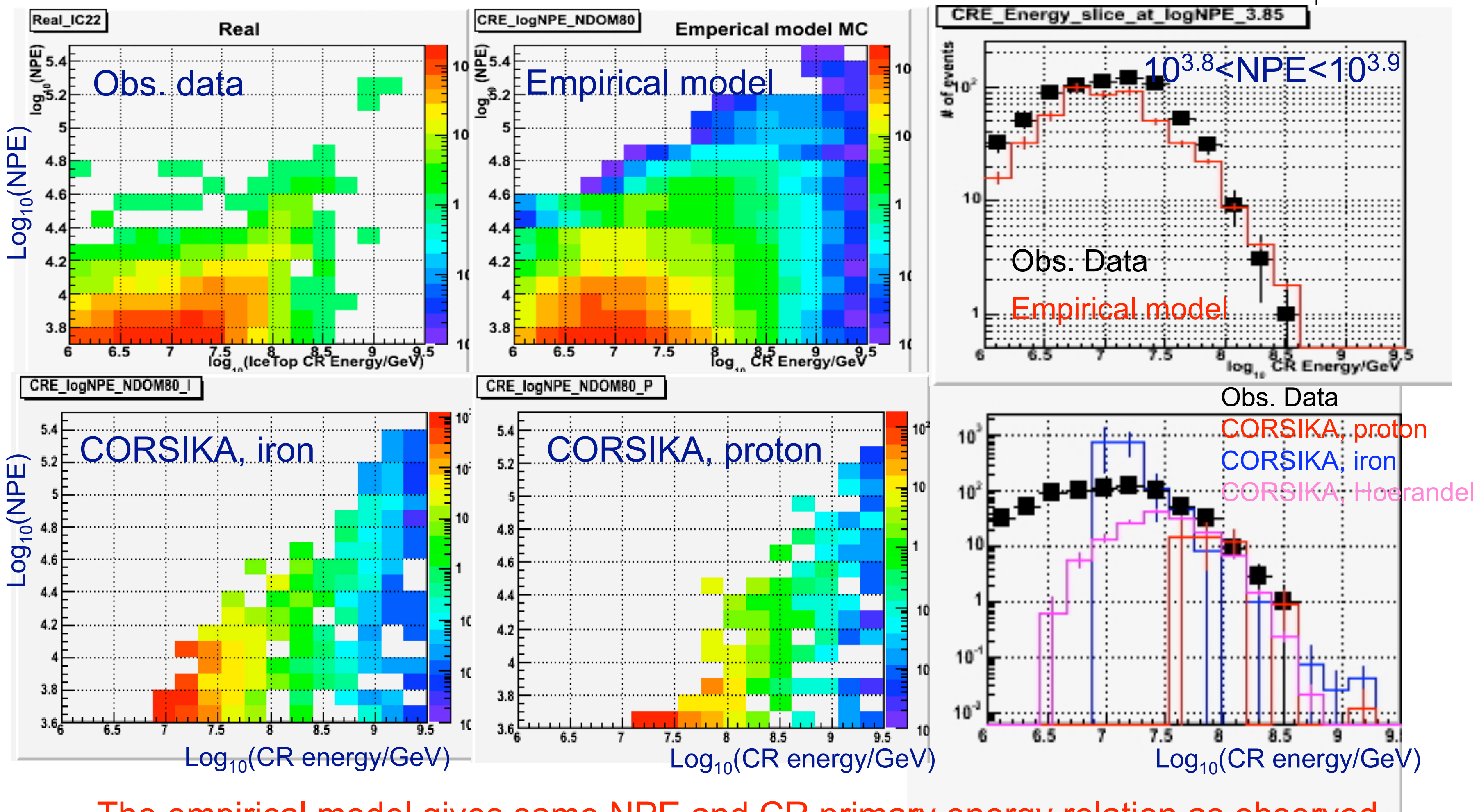




The confirmation of the empirical model with IceTop

http://wiki.icecube.wisc.edu/index.php/IC22_IceTop_EHE_Coincidence_Study done by A. Ishihara

The IceTop coincidence events are used to confirm the empirical model.

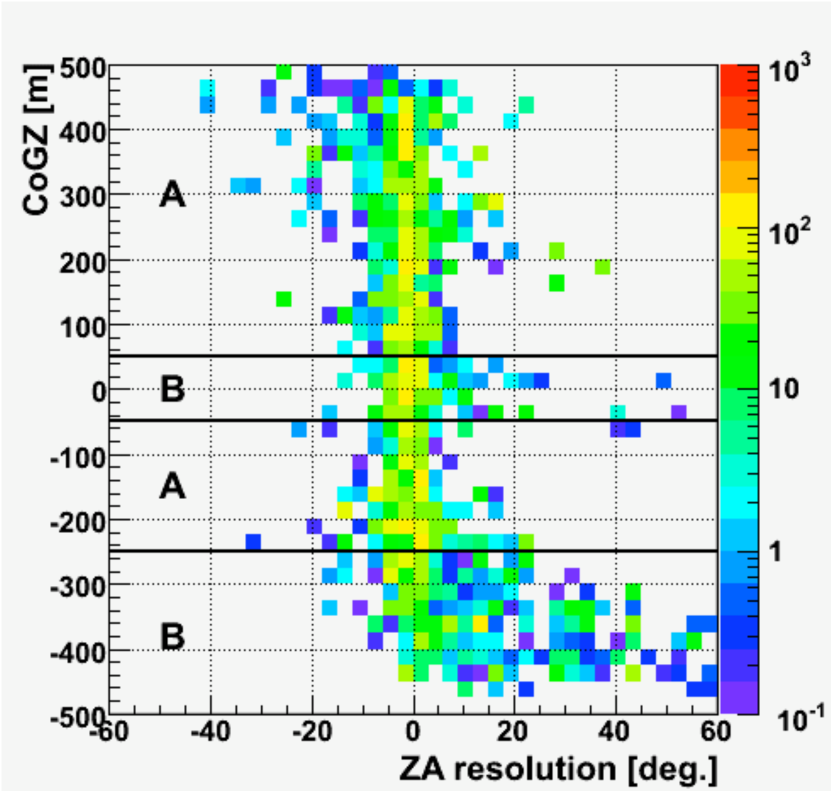


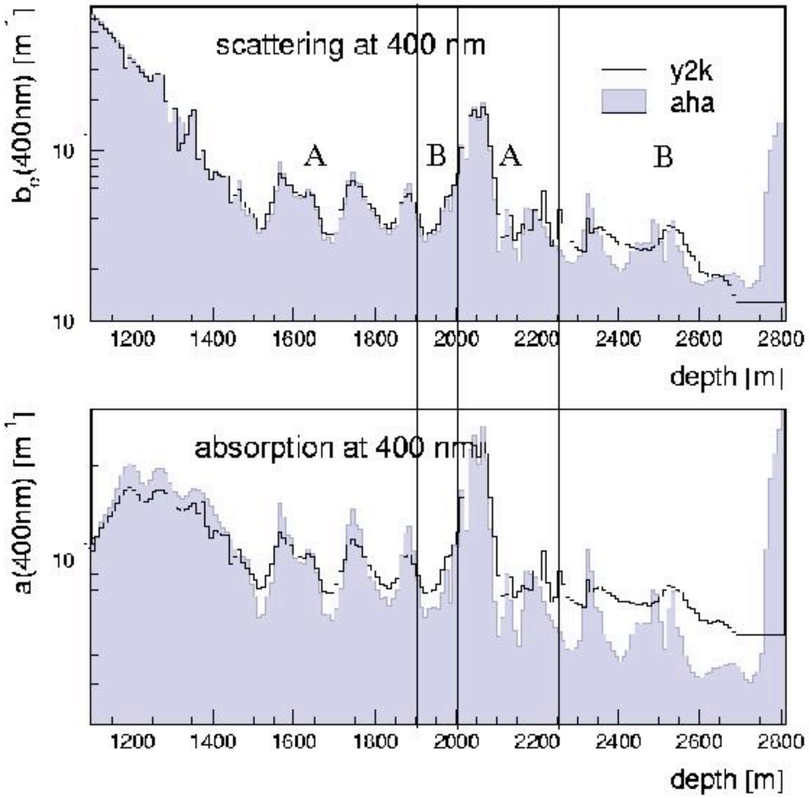
The empirical model gives same NPE and CR primary energy relation as observed.

The CORSIKA shows less fluctuation.

using CoGZ information

http://wiki.icecube.wisc.edu/index.php/The_cut_and_the_optimization_%28EHE-IC22%29

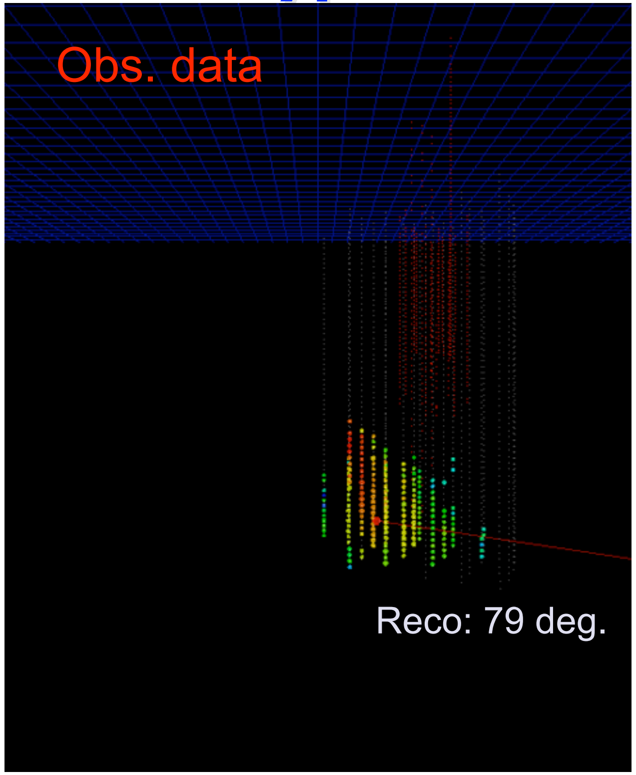


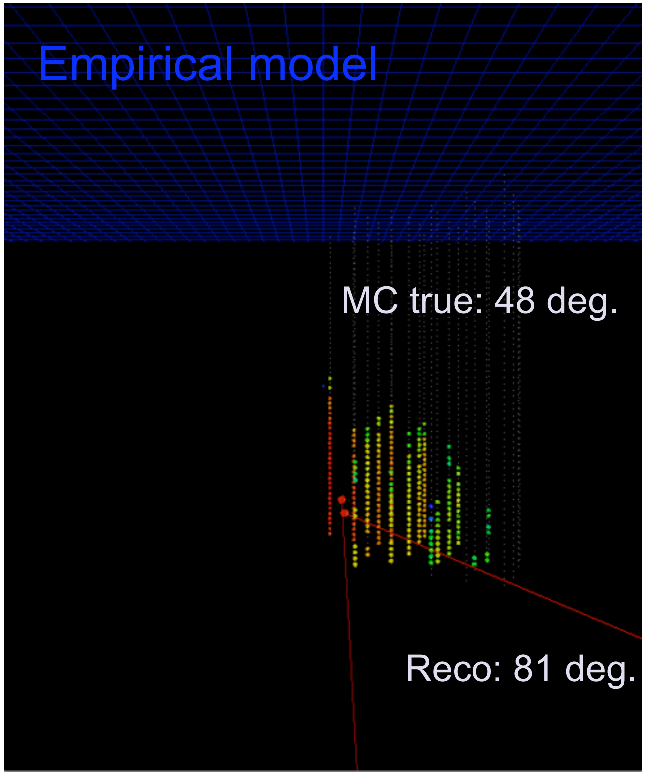


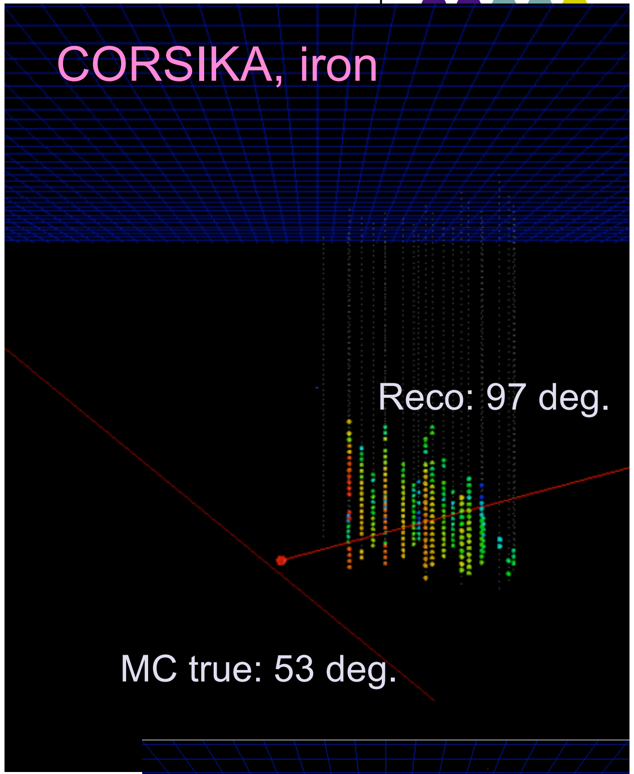
The mis-reconstucted events are correlated with CoGZ position.

We use the CoGZ information to cut the mis-reconstructed events effectively, dividing samples into two (region A and B).

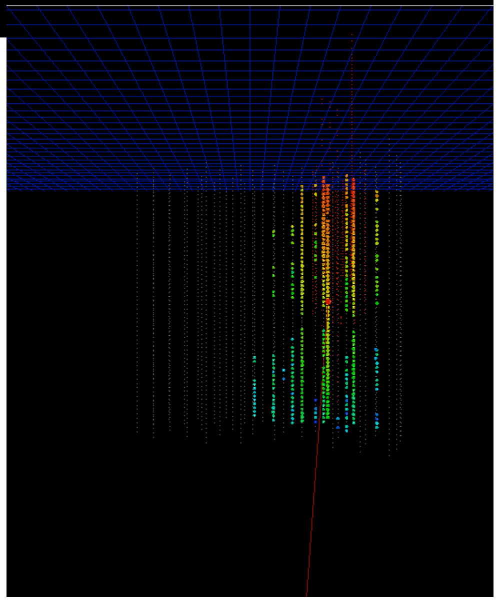
The typical mis-reconstructed events





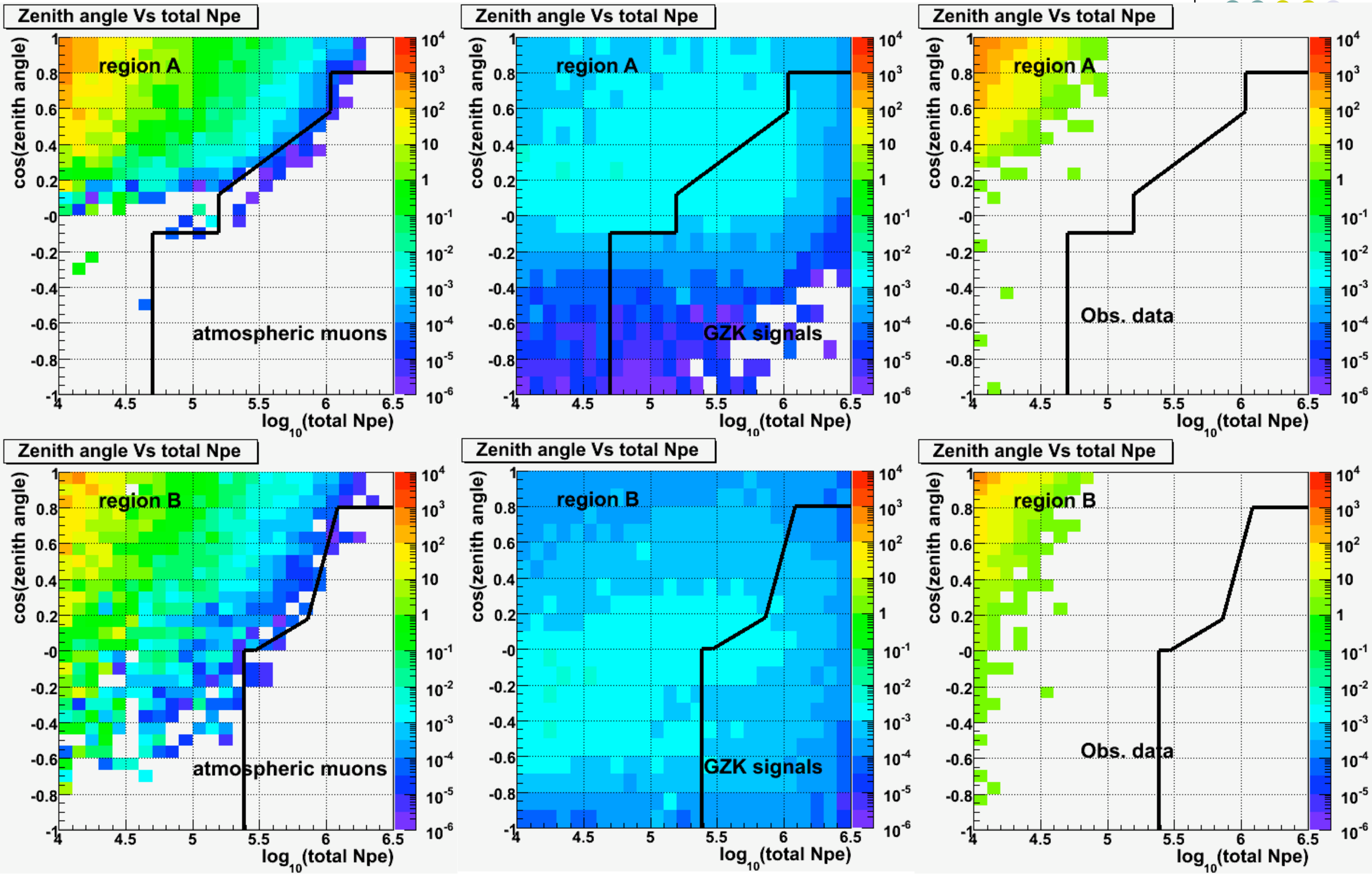


- When a track pass near the outside (or edge) of the bottom part of the detector, the track is mis-reconstructed.
- Since such mis-reconstruction is found both in the empirical model and CORSIKA MCs and the observed events are similar to those MCs, we are confident that the same thing is happening in reality.
- This is due to the boundary effect. The clean ice at bottom and the big dust layer also enhance the mis-reconstruction.
- The similar phenomenon is happening at above big dust layer.
- The big dust layer divide our detector into two.

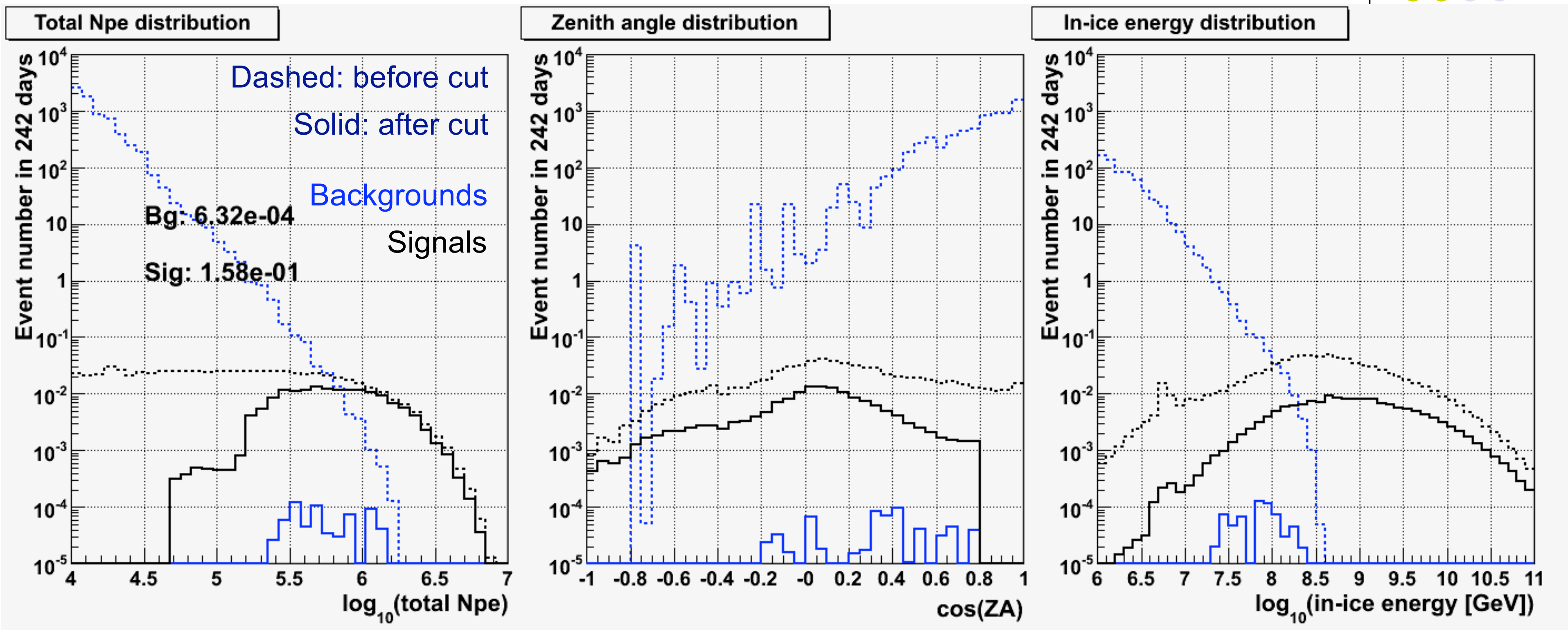


The level 4 (final) cut

region A: -250 < CoGZ < -50 m and CoGZ > 50 m
region B: CoGZ < -250 m and -50 < CoGZ < 50m

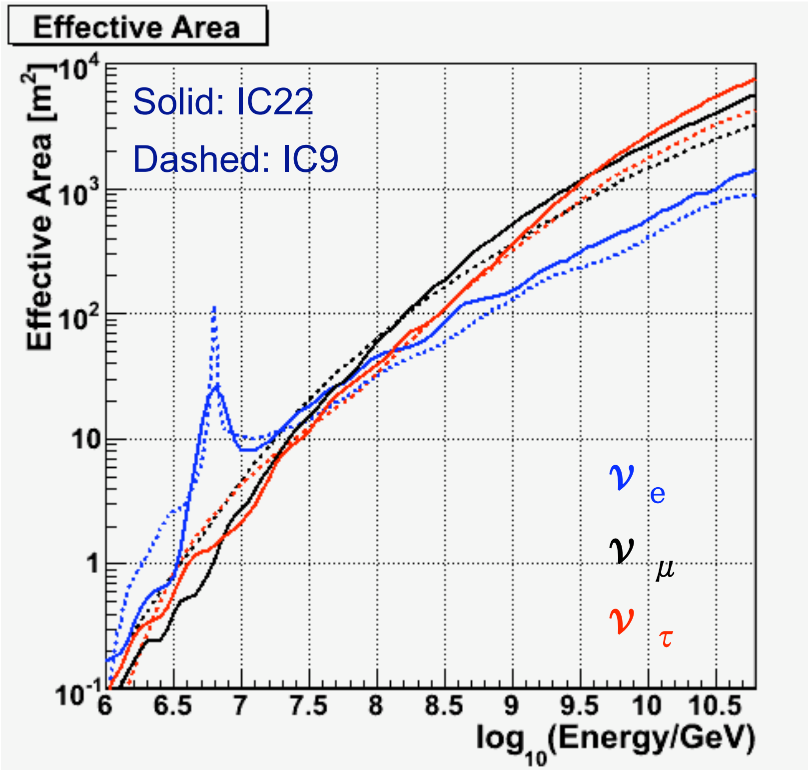


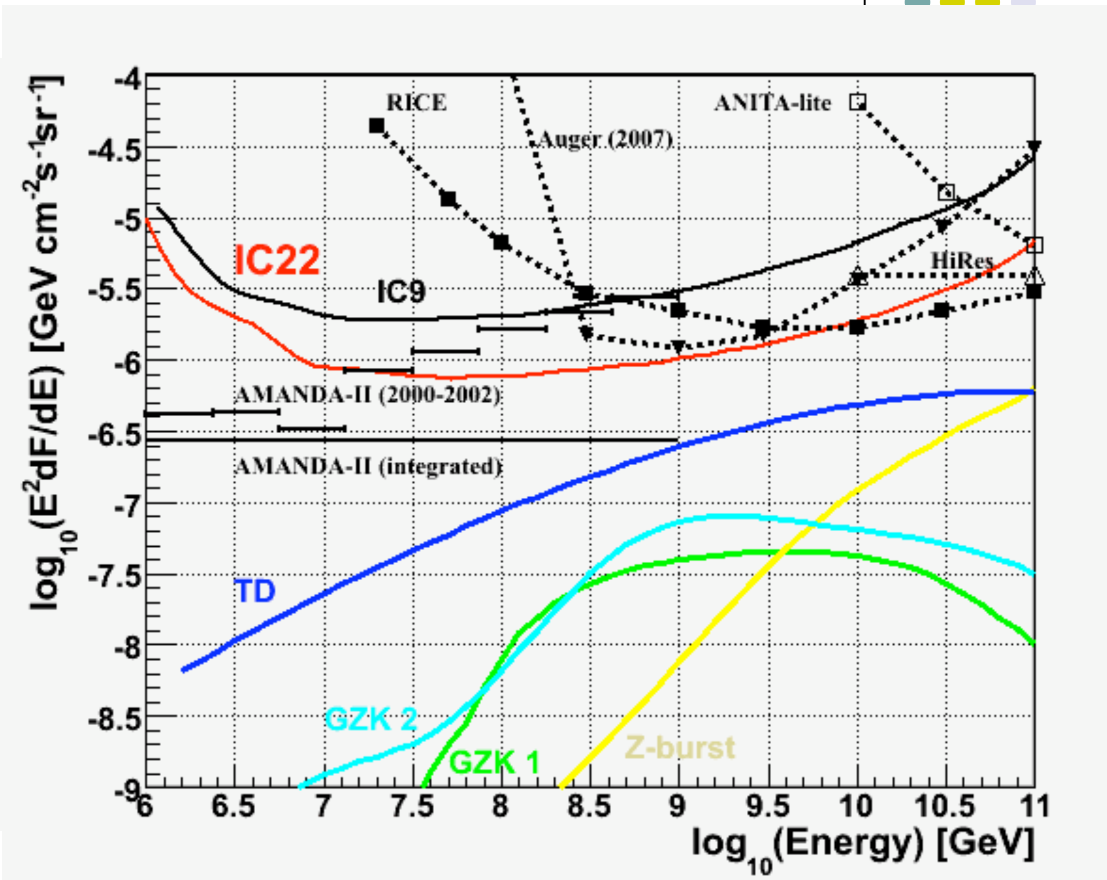
Distributions before and after the final cut



Signals (GZK)	0.158 / 242.1 days
Backgrounds	6.32×10^{-4} / 242.1 days

❑ The sensitivity of IC-22





- The effective are of IC22 is ~30% larger at the relevant energy (~10^9 GeV).
- The sensitivity is ~2.6 times better, taking into account the live time.
- The sensitivity is comparable to the Auger results.

❑ Summary

- The EHE IC22 analysis has been done, following the EHE mid-term plan.
- We compared the obs. data with MCs (the empirical model and CORSIKA) extensively.
- The empirical model express the obs. data quite reasonably.
- The obs. data is bracketed by the pure CORSIKA proton and iron.
- The empirical model agrees with CORSIKA to some level (NPE and MC true ZA distributions), but the slight difference was found. We interpreted the difference as the difference of the bundle nature. (The muon bundle in CORSIKA seems to consist of many low energy muons, leading to less stochastic nature.) Less horizontal events in CORSIKA underestimate the backgrounds. The empirical model gives more conservative background estimation compared to using CORSIKA data.
- We confirmed that the empirical model gives right NPE and CR primary energy relation with help of the IceTop coincidence events. (done by A. Ishihara)
- We found the CoGZ information is useful to cut the mis-reconstructed events.
- The final cuts are determined to cut backgrounds.
- The derived sensitivity is ~2.6 times better than one of IC9, and comparable to the Auger sensitivity. (The simple robust analysis works.)
- We request the data unblinding.

Time to open it!