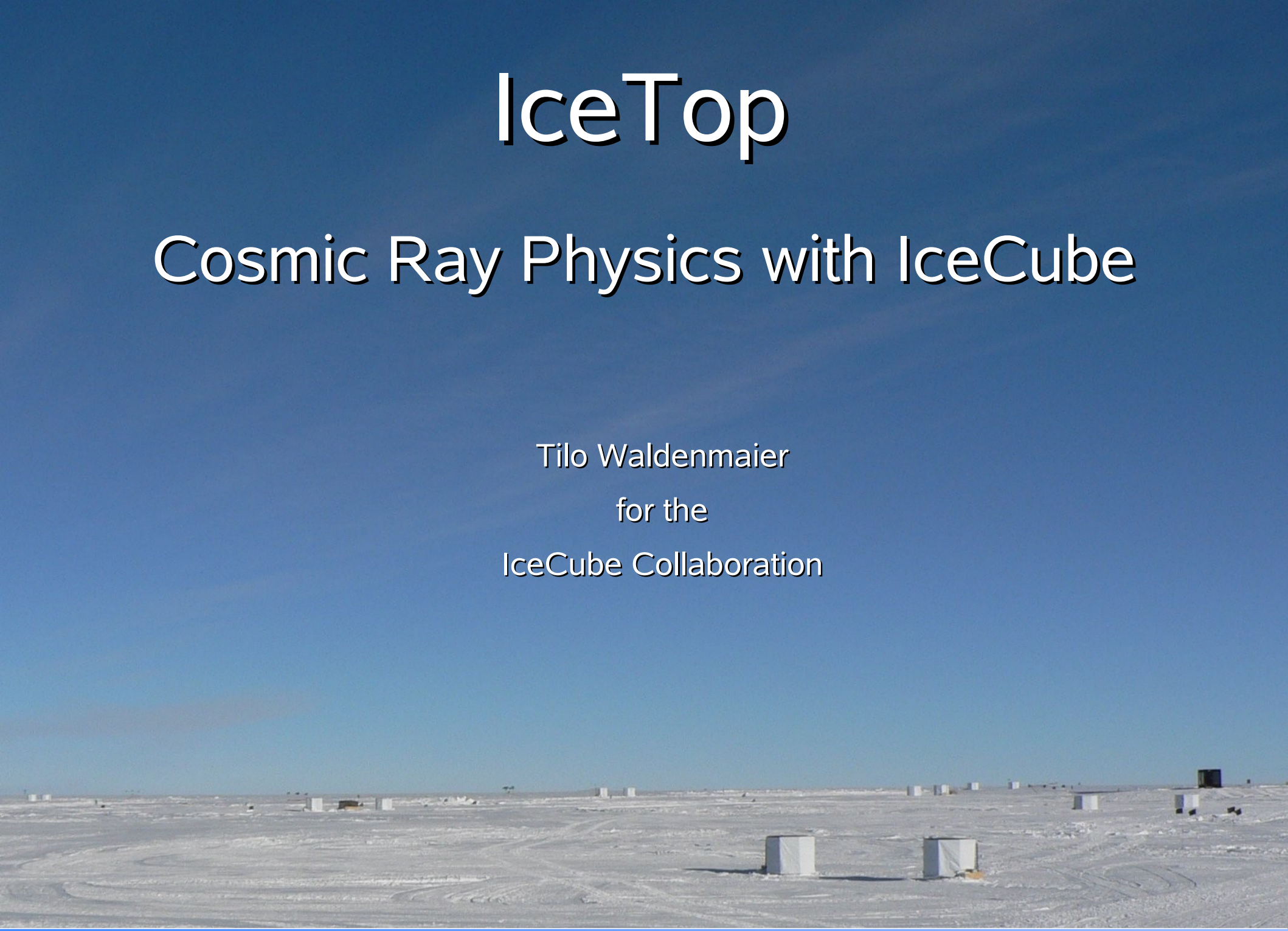


IceTop

Cosmic Ray Physics with IceCube

Tilo Waldenmaier

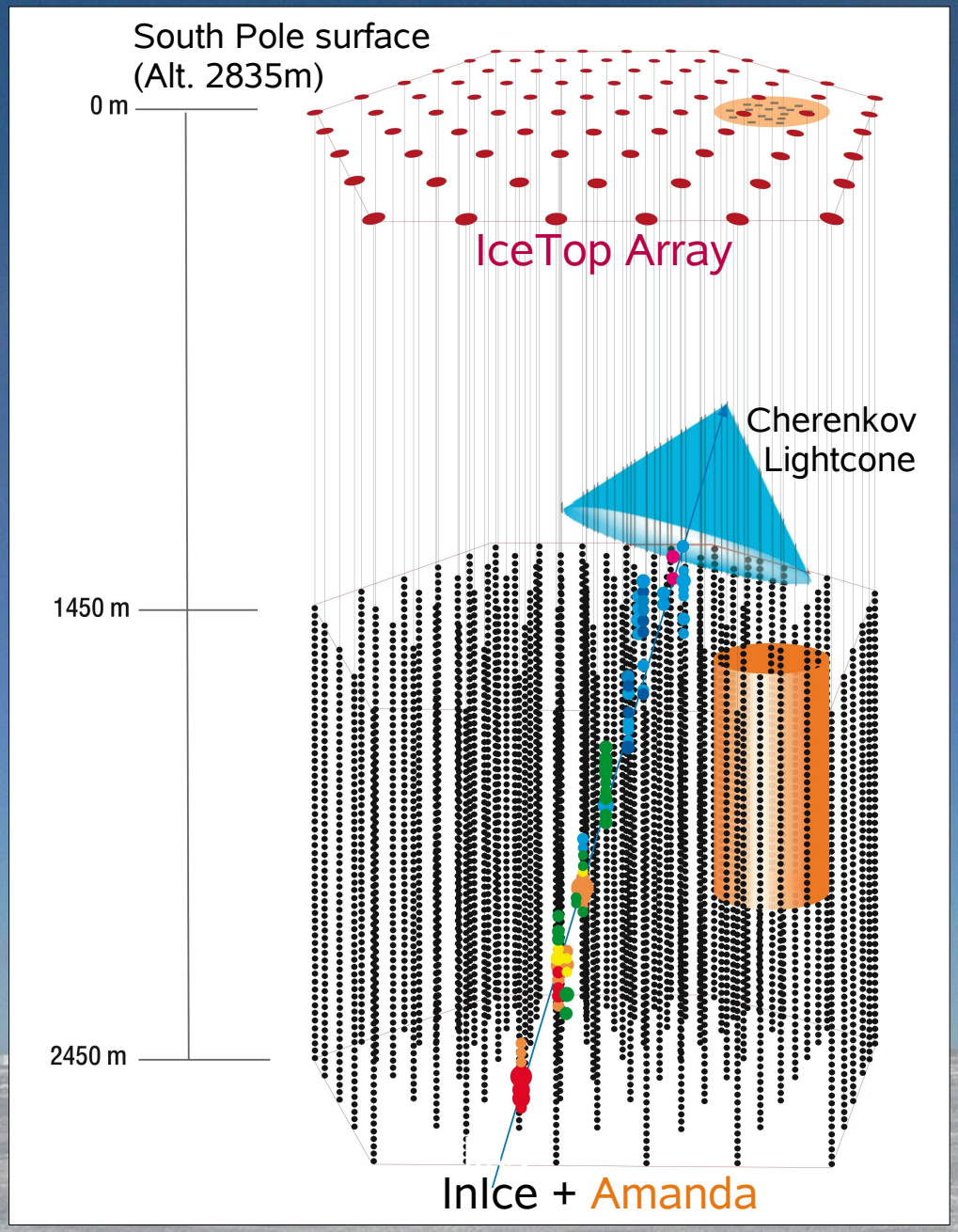
for the

IceCube Collaboration

Outline

- The IceCube Detector
  - Current Status
- Air Shower Reconstruction
  - Core & angular resolution
  - Lateral distribution function
  - Energy conversion
- IceTop-InIce Coincidences
  - Single Station coincidences
  - How to study composition
- Summary & Outlook

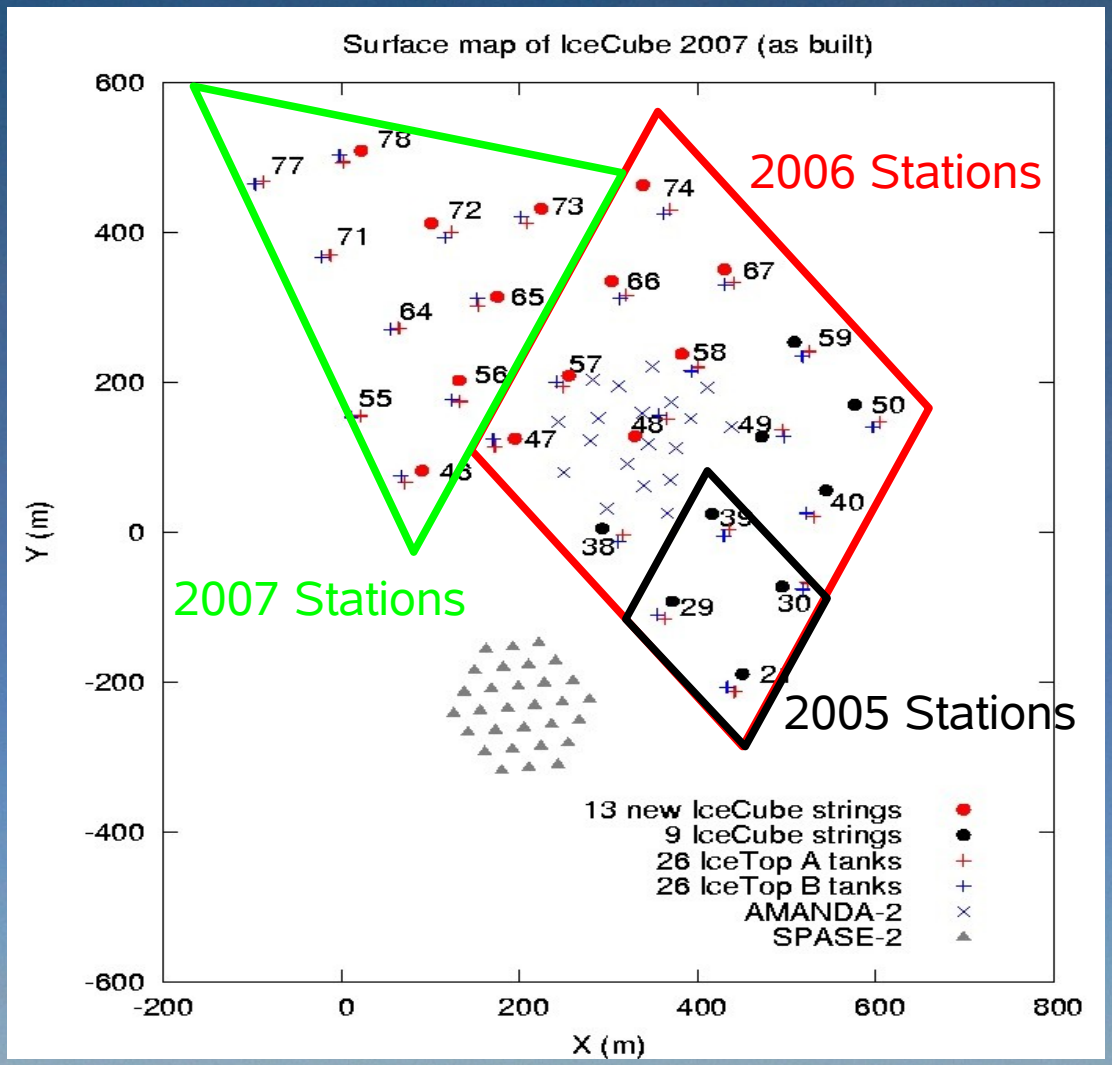
The IceCube Detector



- IceTop:
  - 80 Stations with 2 Tanks.
  - 2 DOMs (HG and LG) per Ice-Cherenkov-Tank.
  - Tank spacing: 10 m
  - Station spacing: 125 m
- InIce:
  - 80 Strings with 60 DOMs.
  - Depth: 1450 – 2450 m
  - Vertical spacing: ~17 m

Expected completion in 2010/11

Current Status (2007)



- 22 InIce Strings
- 26 IceTop Stations

Data taking with new detector components started this month!

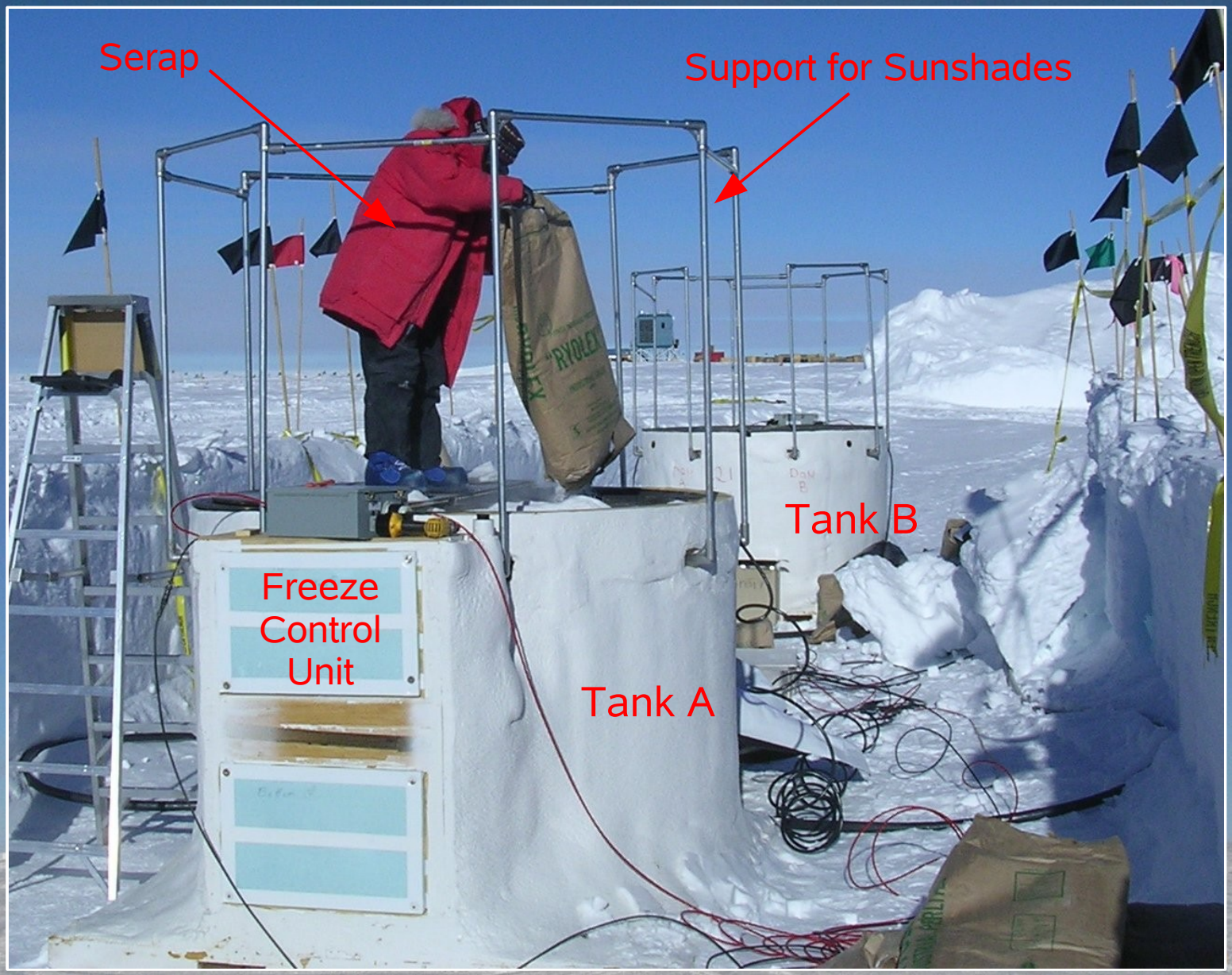
Sunshades

Station 55

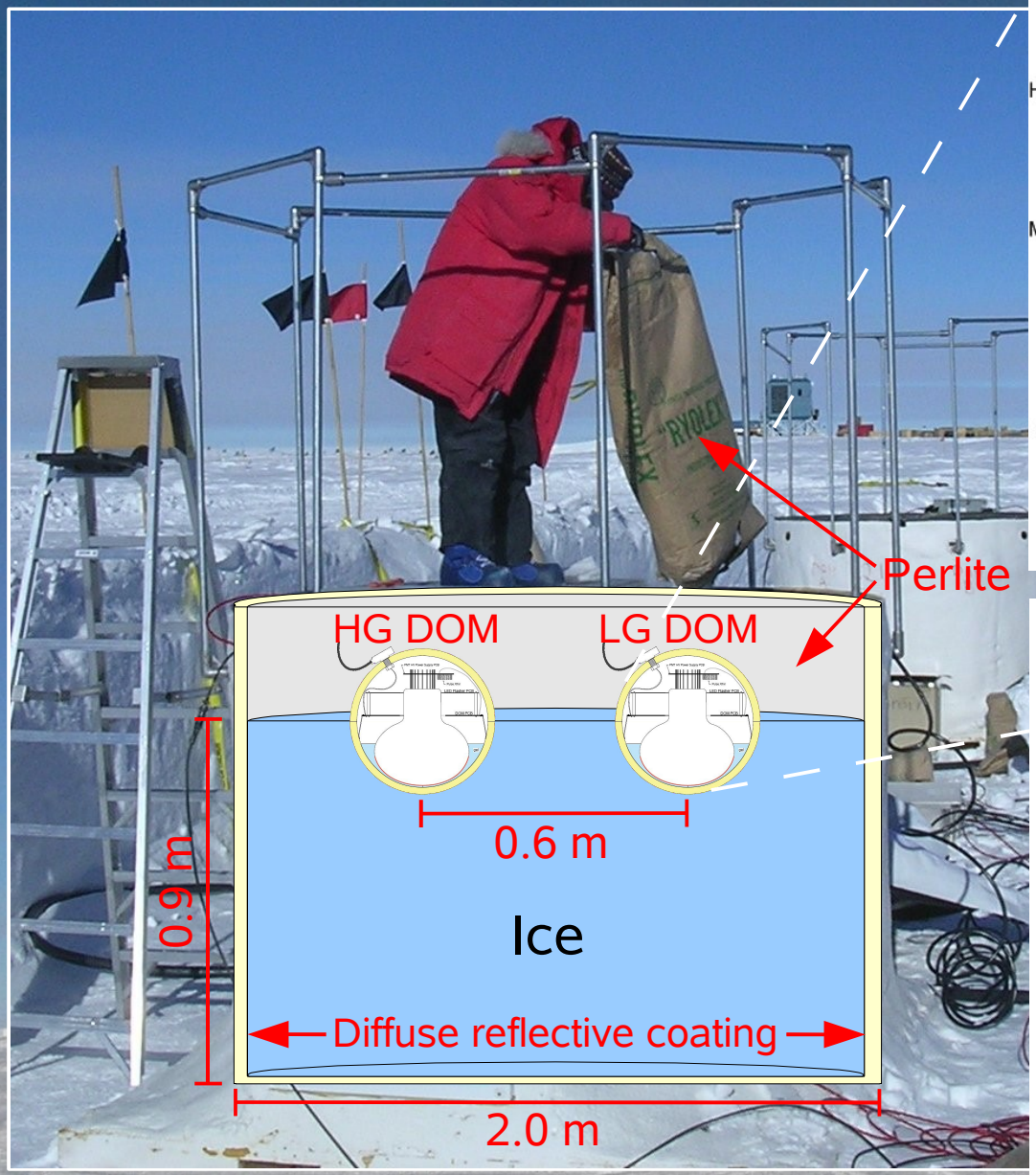
Station 56

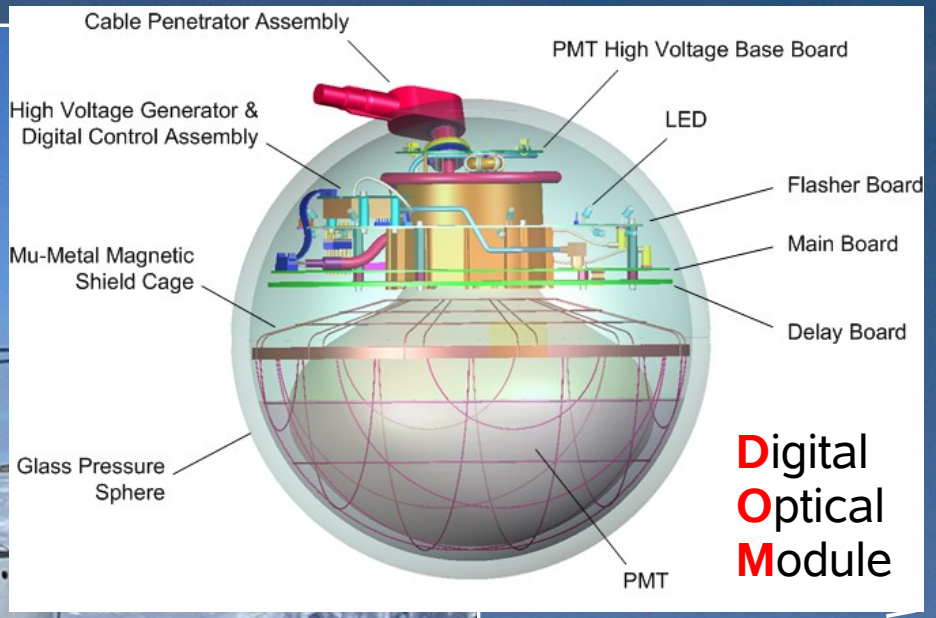
Station 46

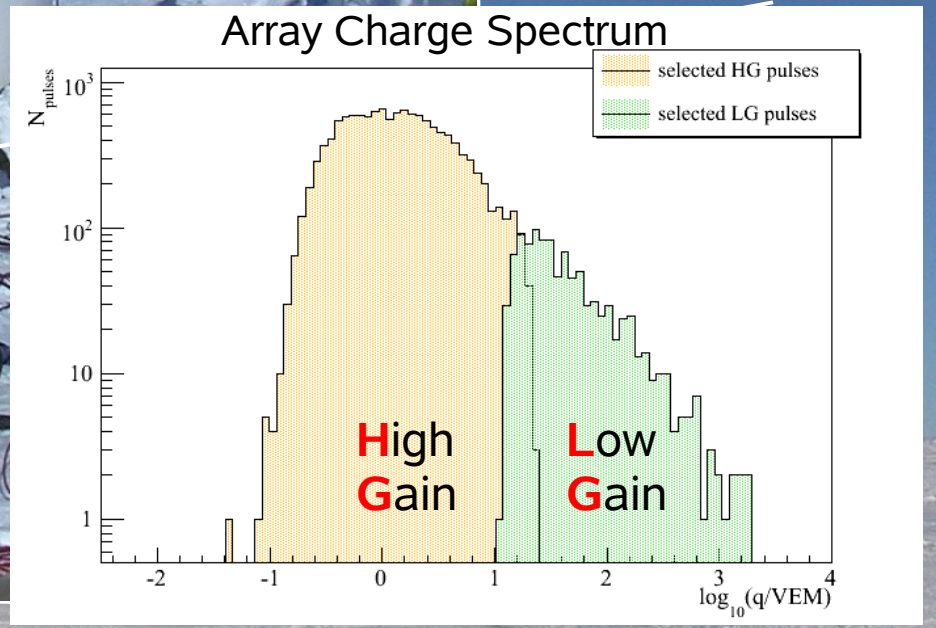
IceTop Station



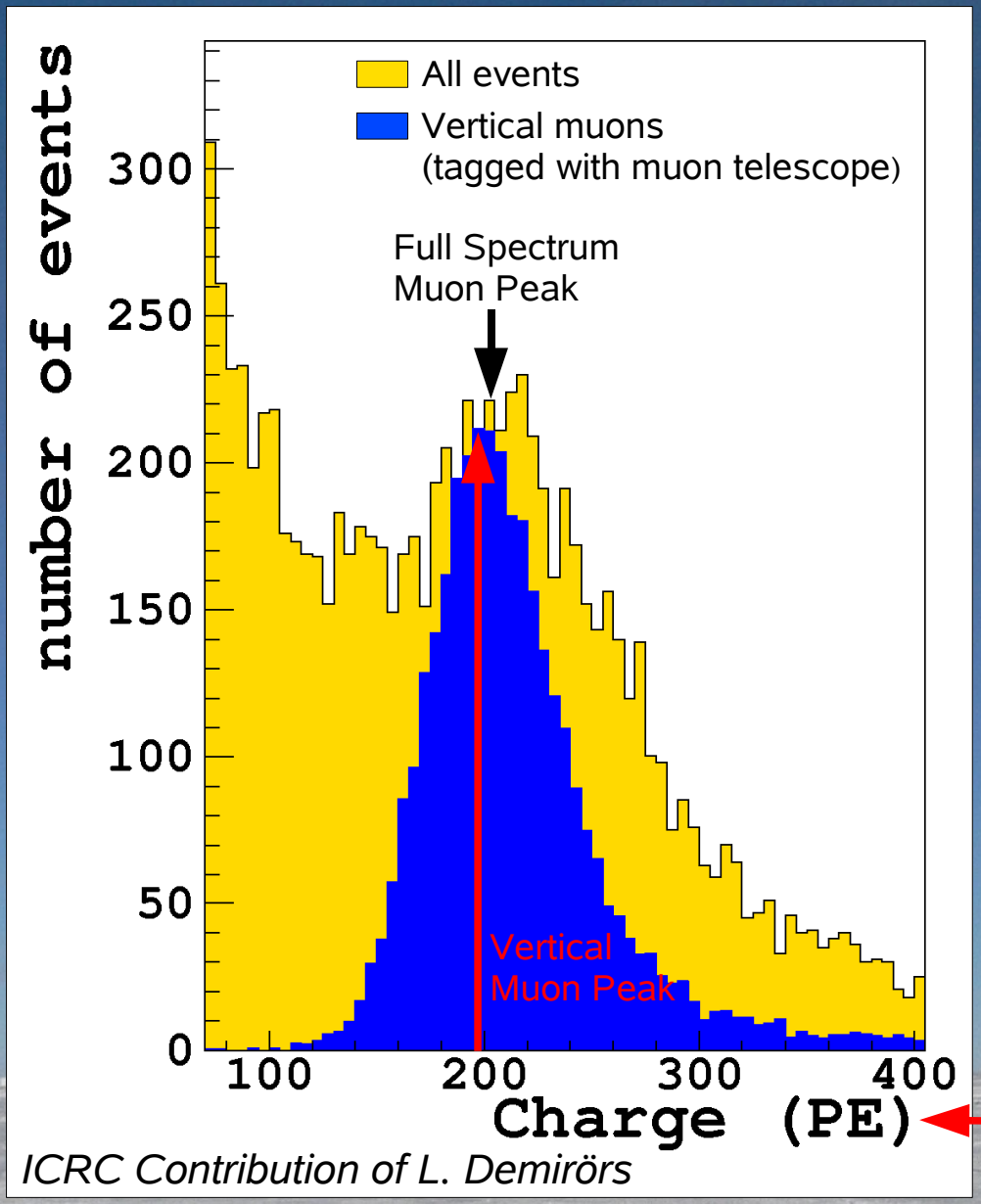
Ice-Cherenkov Tanks







Tank Calibration

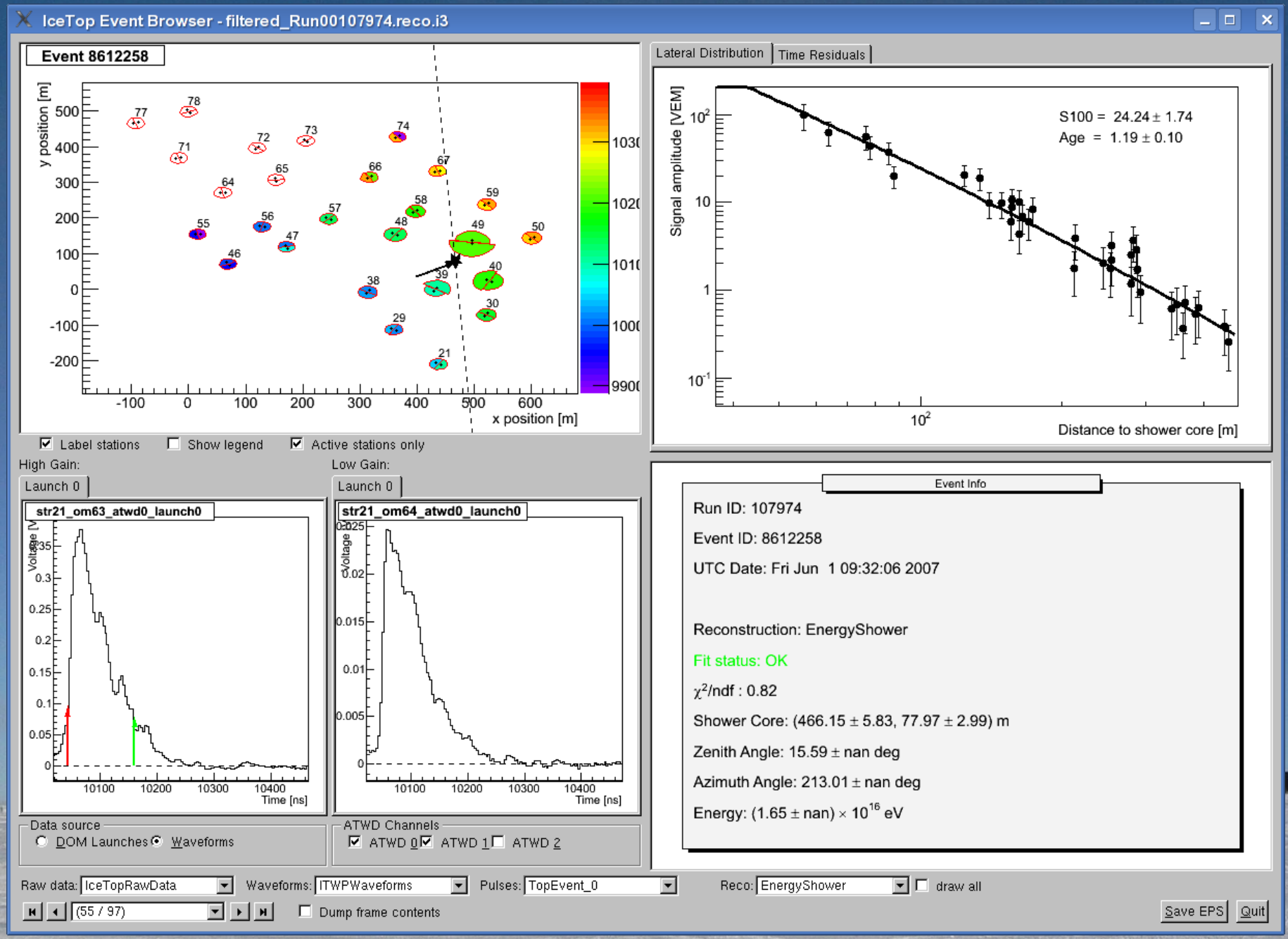


ICRC Contribution of L. Demirörs

- Vertical muons as “calibration light source” for tanks.
- Measurement of the tank charge spectra with special calibration runs.
- Determination of Full Spectrum Muon Peak.
- 1 Vertical Equivalent Muon (VEM) corresponds to ~ 95% of full spectrum peak charge.

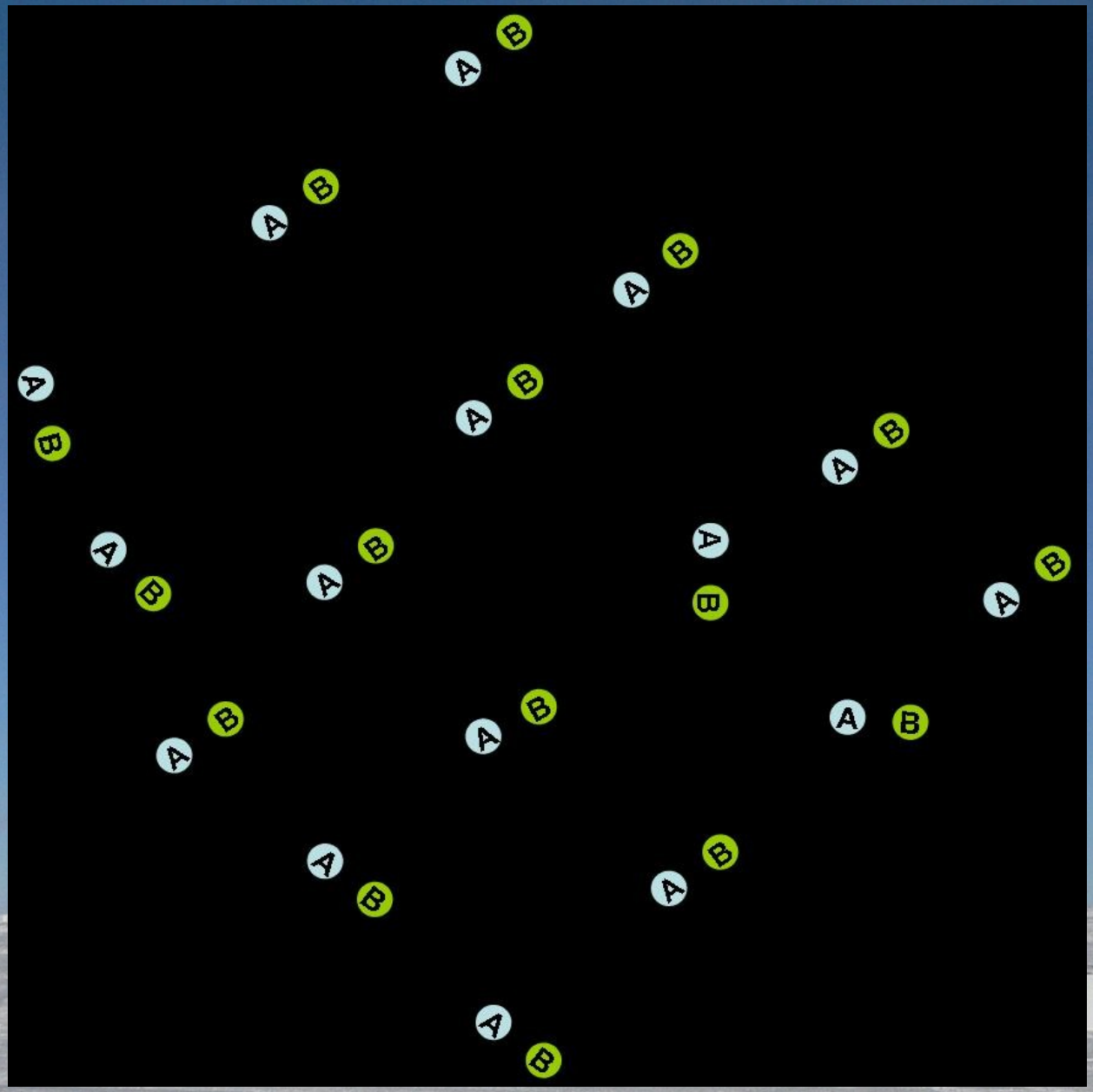
Photoelectrons

Air Shower Reconstruction



Angular & Core Resolution

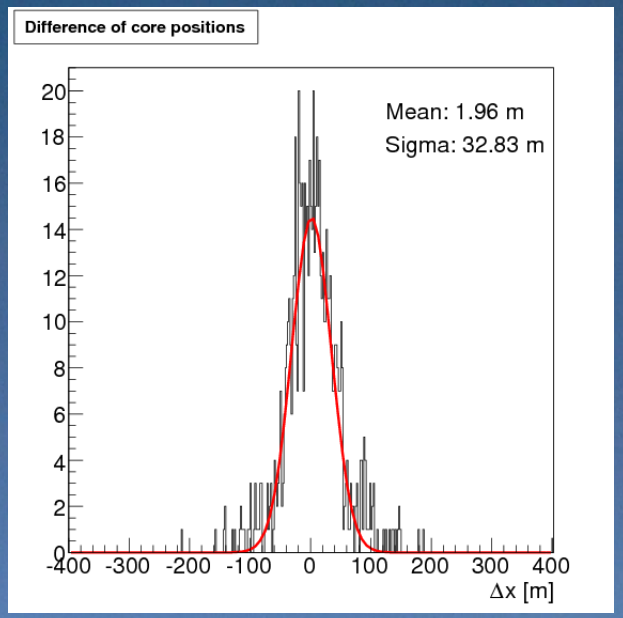
Sub-Array Analysis

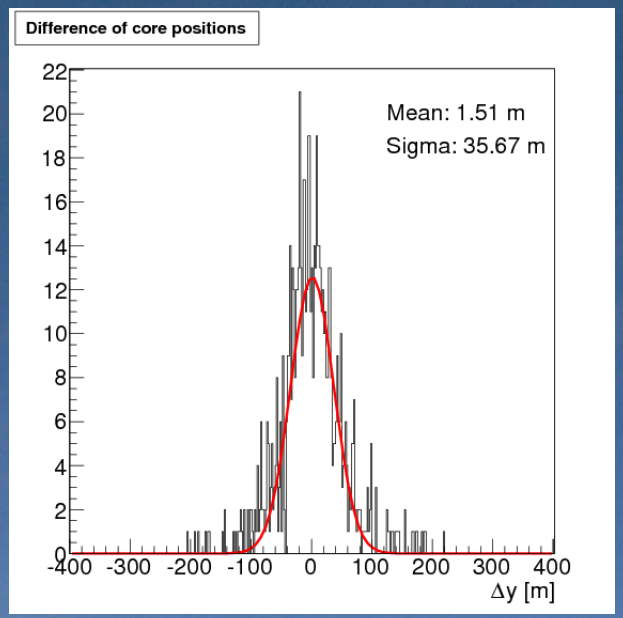


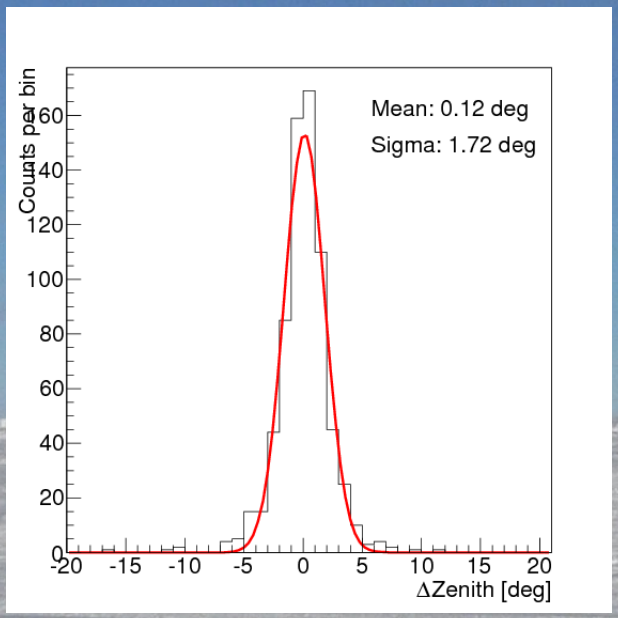
- Dividing array into two nearly identical sub-arrays of tanks A and B.
- Comparision of individual reconstructions.

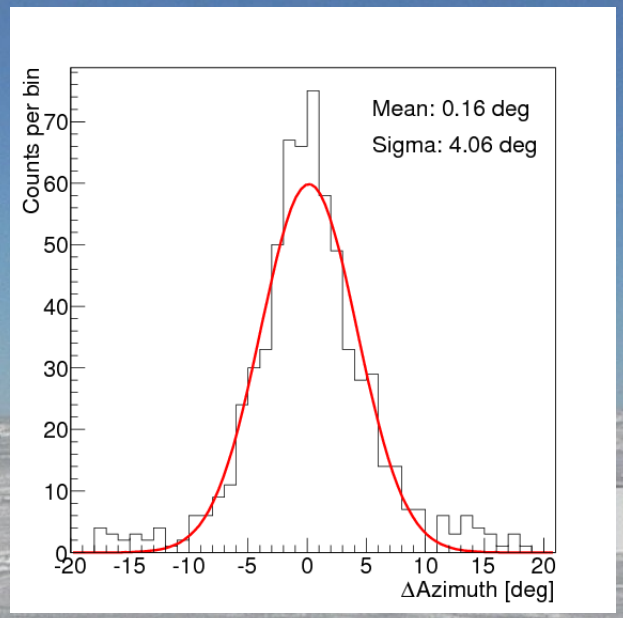
Angular & Core Resolution

Sub-Array Analysis









Measured and true σ's:

$$\sigma_{measured} = \sqrt{\sigma_A^2 + \sigma_B^2} = \sqrt{2} \cdot \sigma_{A,B}$$

$$\sigma_{true} \approx \frac{\sigma_{A,B}}{\sqrt{2}} = \frac{1}{2}\sigma_{measured}$$

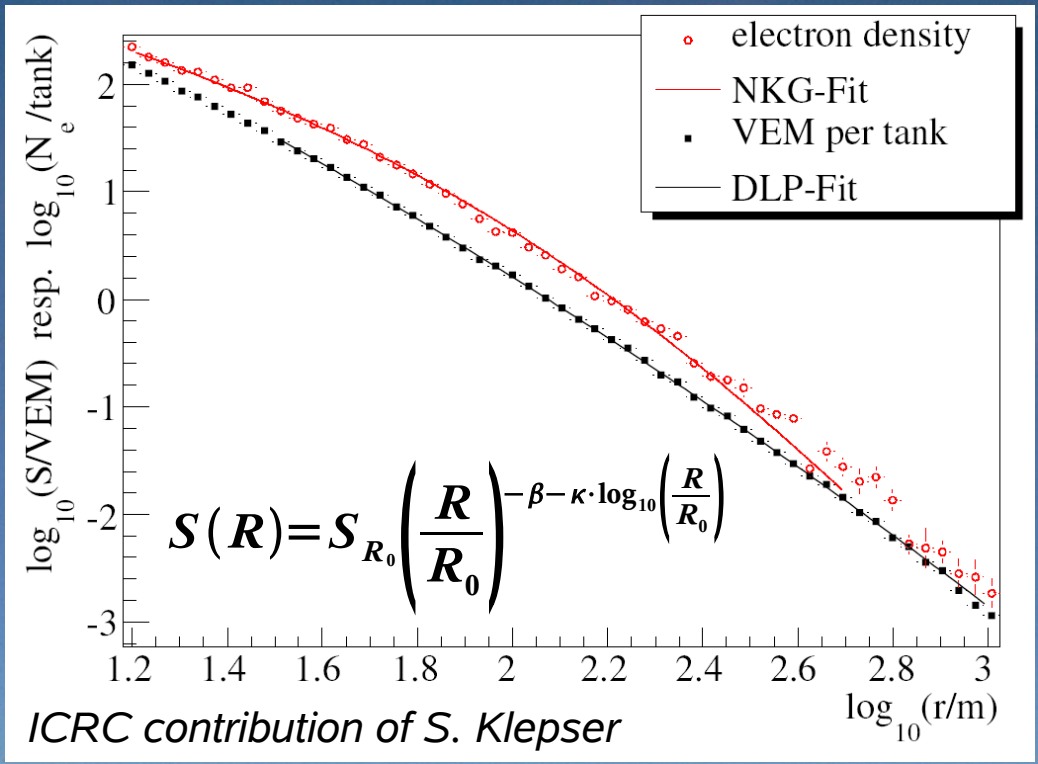
Resolutions of 16-station-array for $N_{Stations} > 5$:

- Core: ~ 17 m
- Zenith Angle: ~ 1°
- Azimuth Angle: ~ 2°

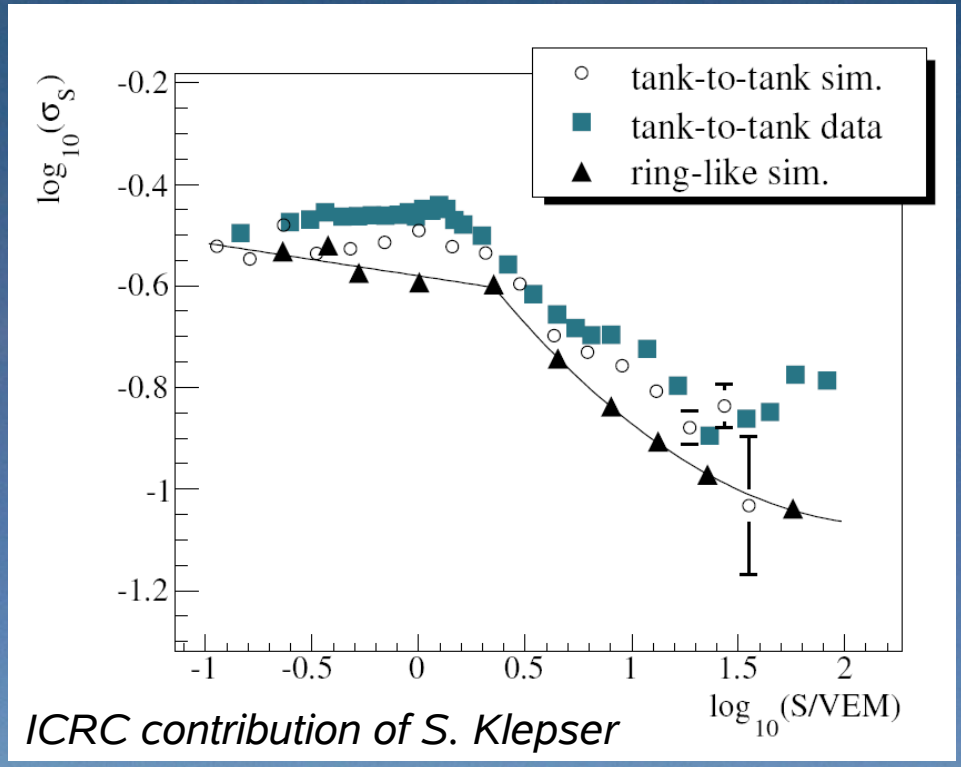
Precision will improve with larger array!

Lateral Distribution

DLP-Function



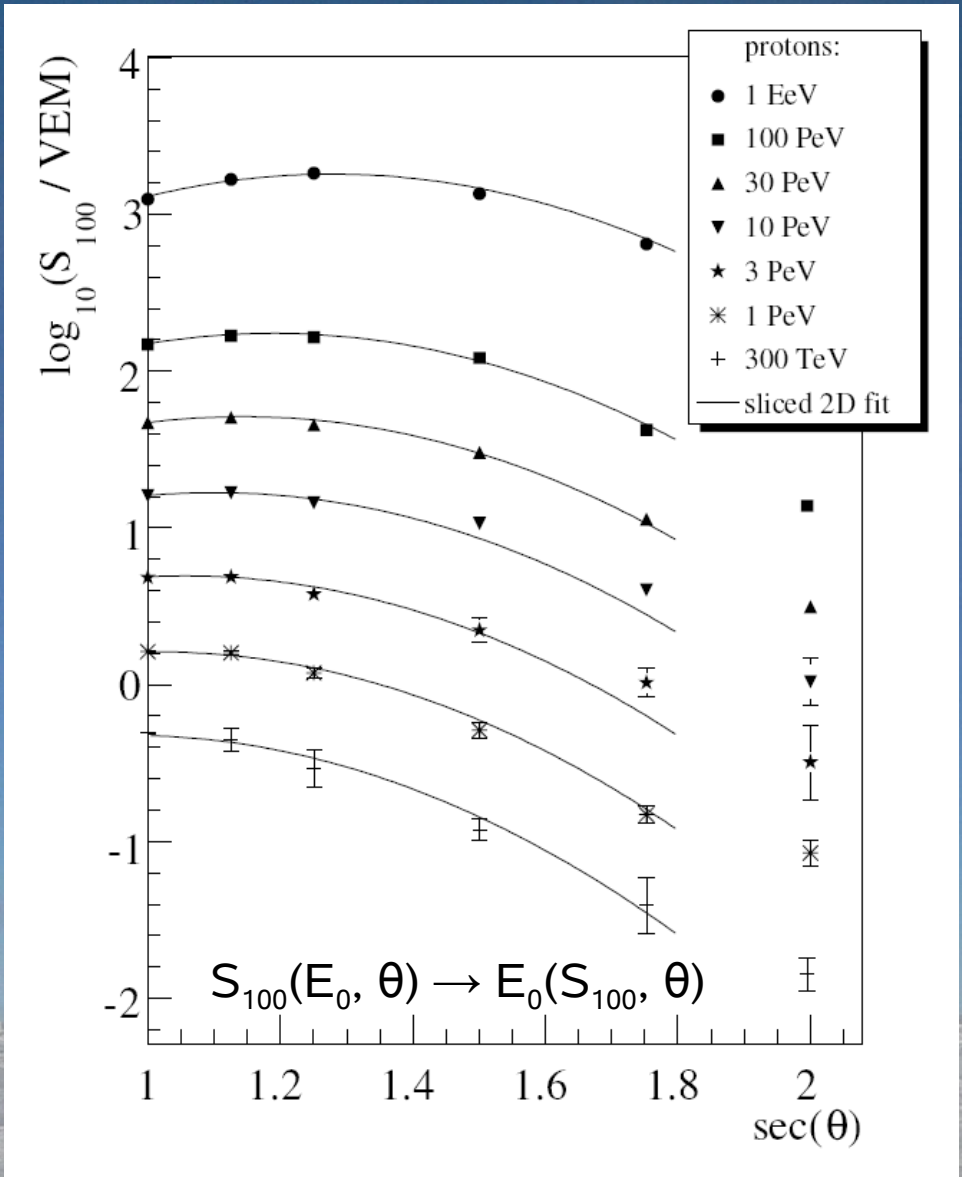
Signal fluctuations



- Lateral signal distribution in the tanks parametrized by Double Logarithmic Parabola (DLP).
- Log-Likelihood fit assuming log-normally distributed signal fluctuations.

Energy Estimation

CORSIKA Simulation:



- Signal (S_{100}) at R_0=100 m is measure for the primary energy.
- CORSIKA simulations for different primary energies E_0 and zenith angles θ.

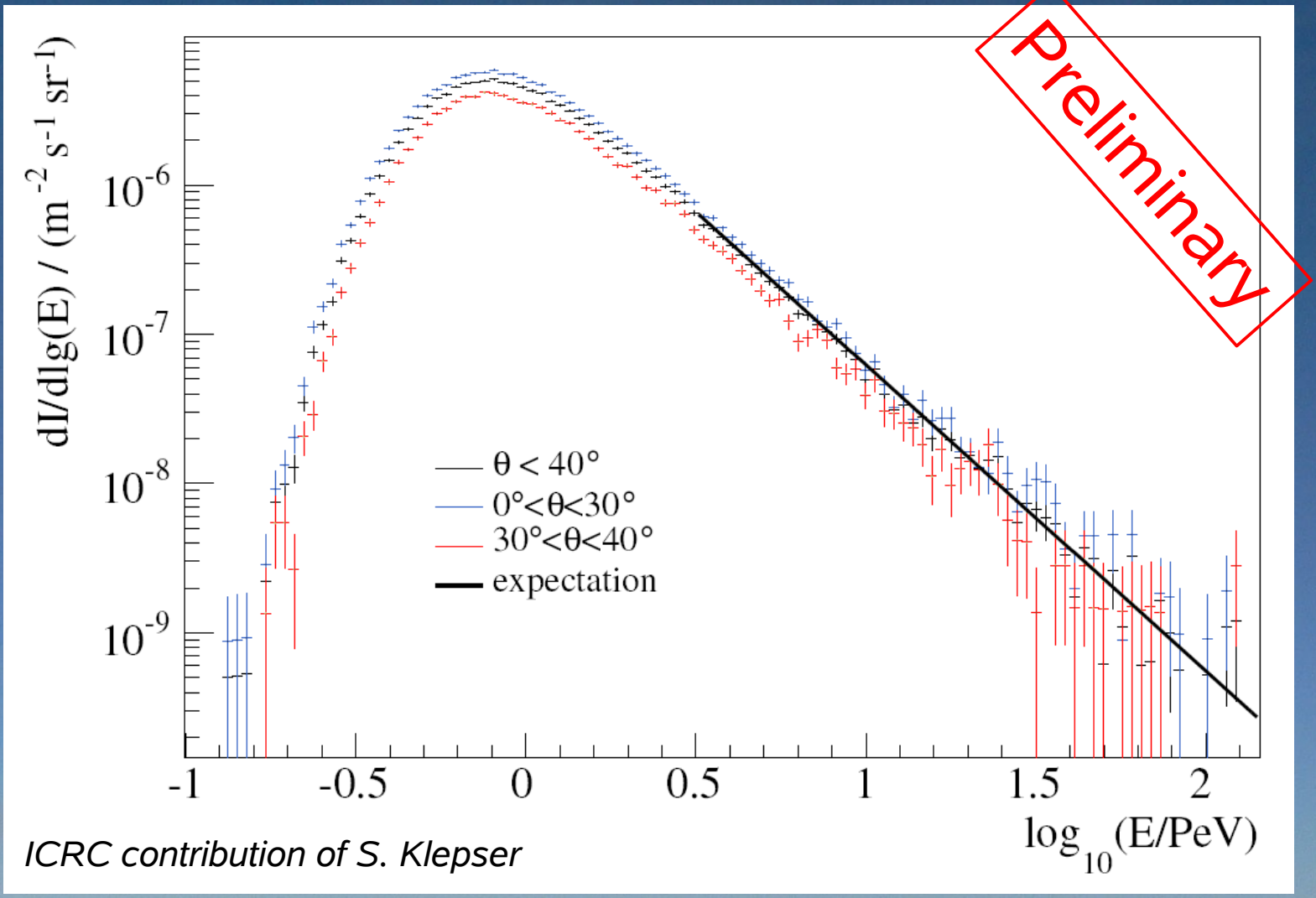
Conversion formula:

$$\log(E_0) = p_0 + p_1 sec(\theta) - \sqrt{p_2 + p_3 sec(\theta) - p_4 \log(S_{100})}$$

Parameters p_i follow from fit to simulation data.

→ ICRC Talk of S. Klepser

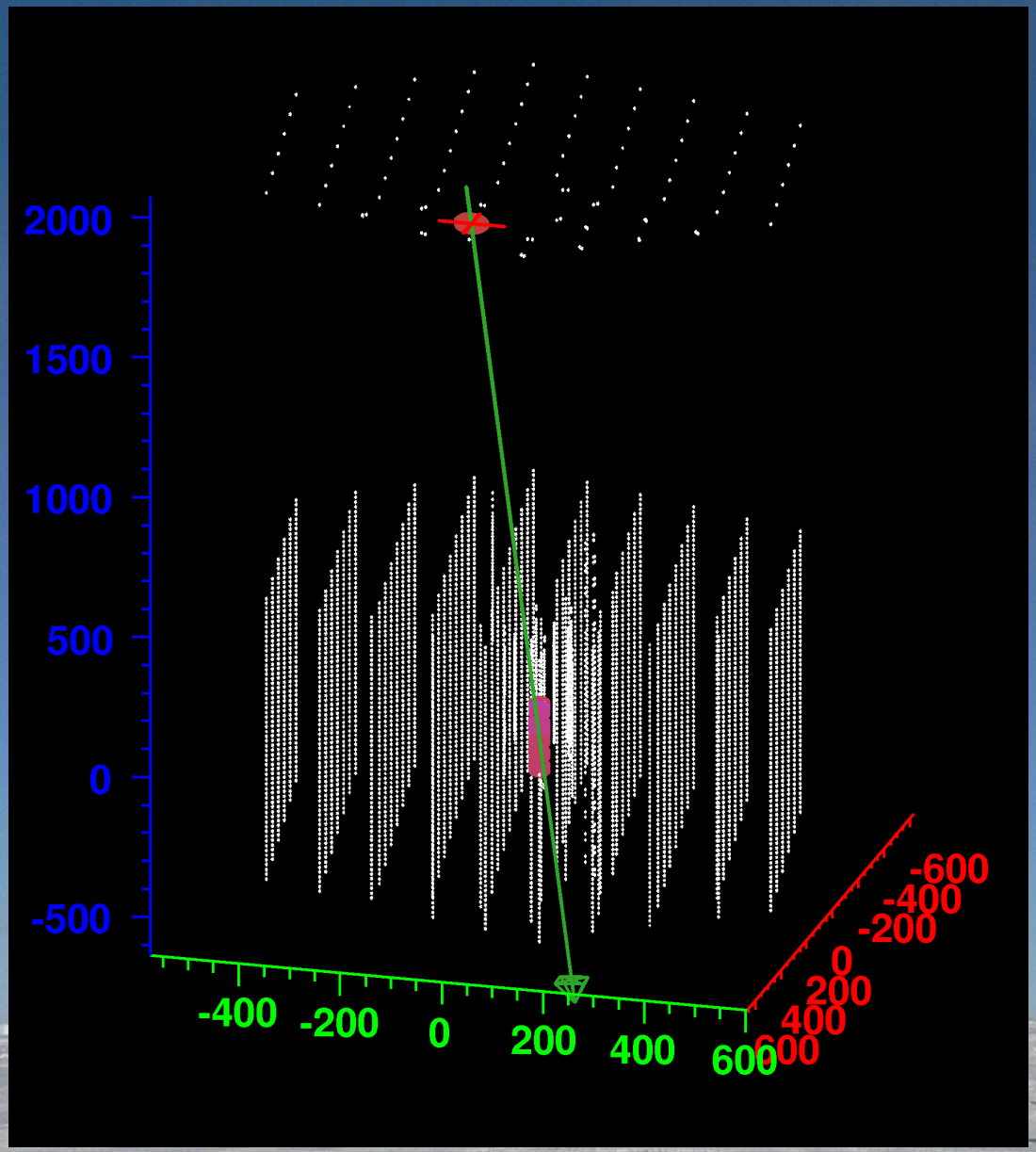
Raw Energy Spectrum



ICRC contribution of S. Klepser

- Not yet corrected for acceptance and detector response!
- Already reasonable values for absolute flux and spectral index.

Single Station – InIce Coincidences



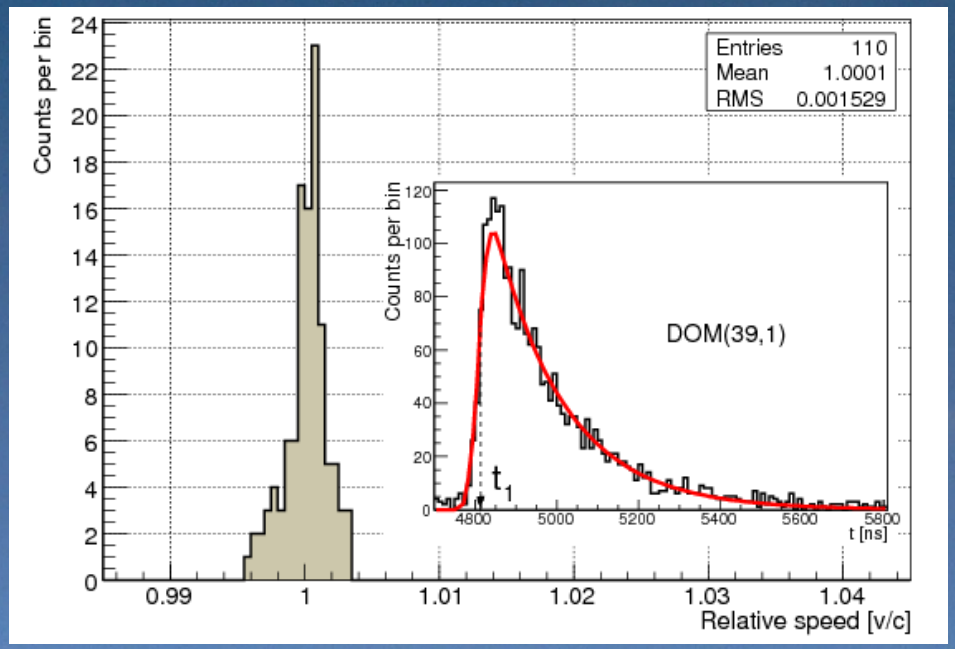
Single station rate for 16 station array: ~ 1.2 Hz

Providing tagged muons to test the detector performance and InIce reconstructions i.e.:

- Detector timing
- InIce direction reconstruction.
- Measurement of muon background.

Single Station – InIce Coincidences

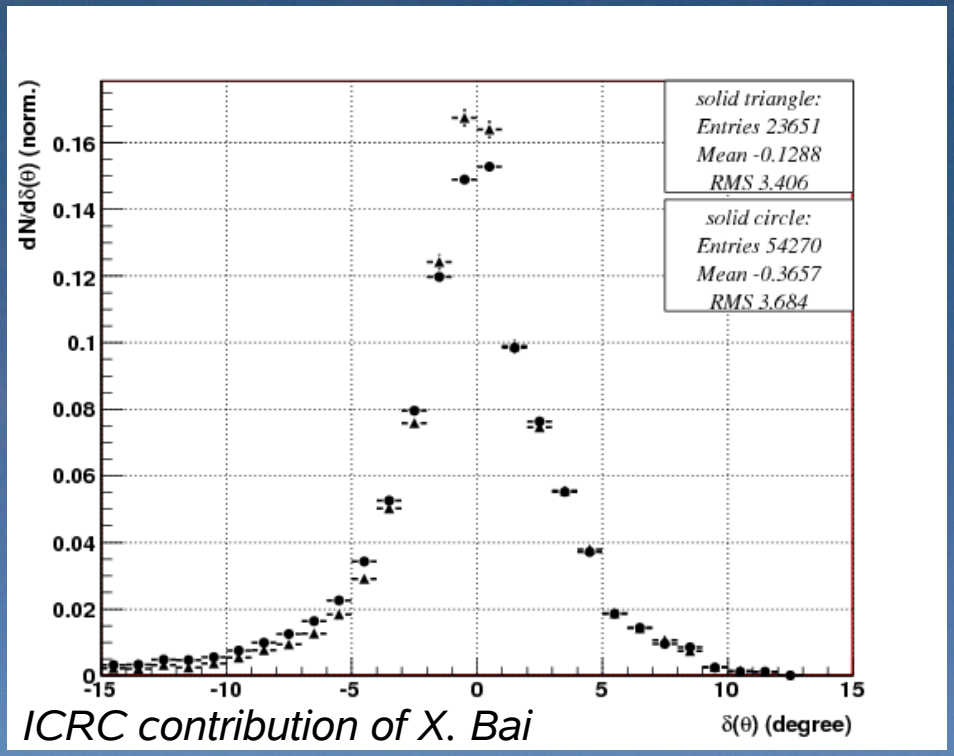
Detector timing:



- Muon velocity from distances and time differences between station and InIce DOMs.
- Spread reflects timing, geometry and methodical uncertainties.

→ Timing better than 12 ns.
(Measurement with flashers: 3 ns)

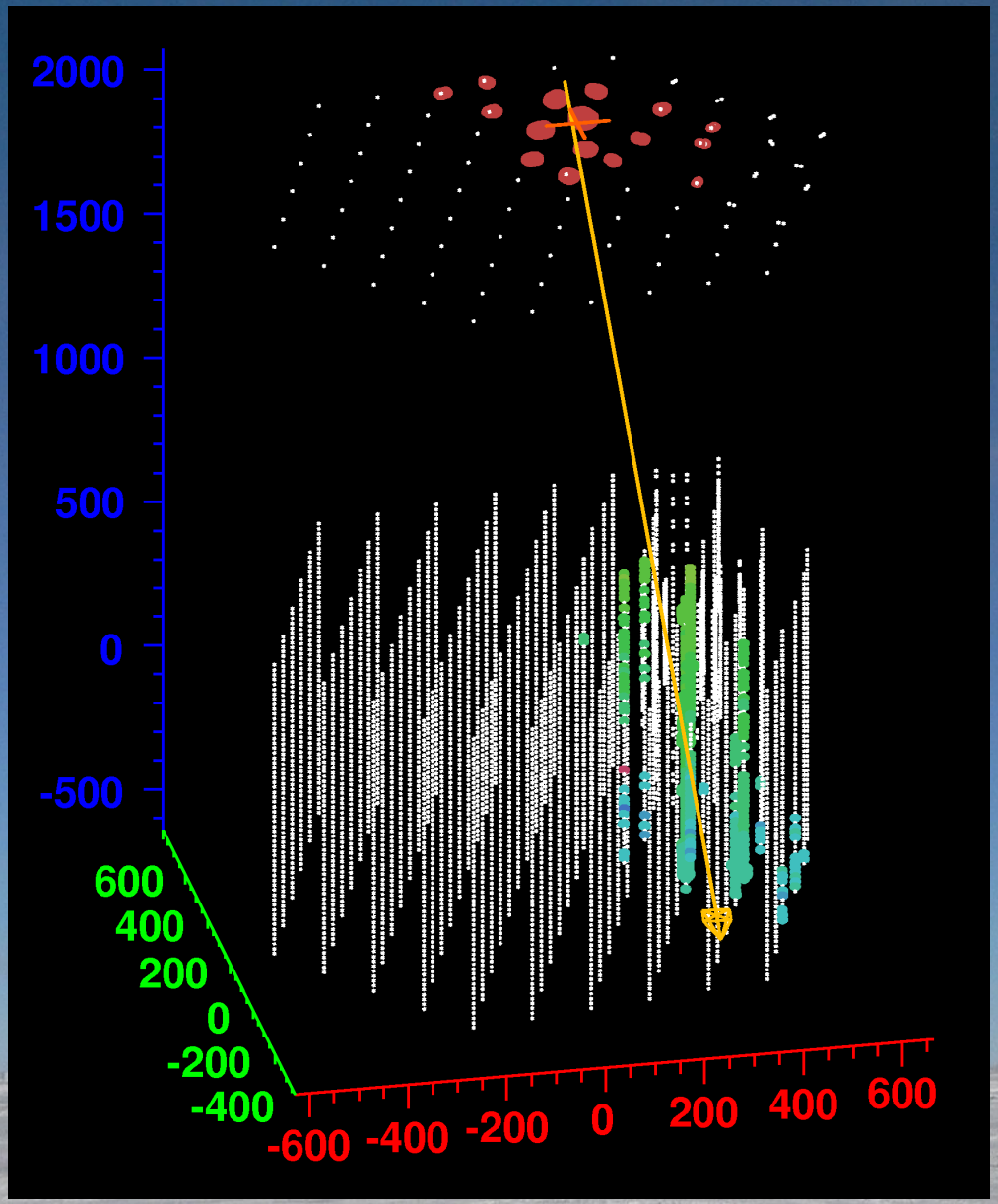
Direction reconstruction:

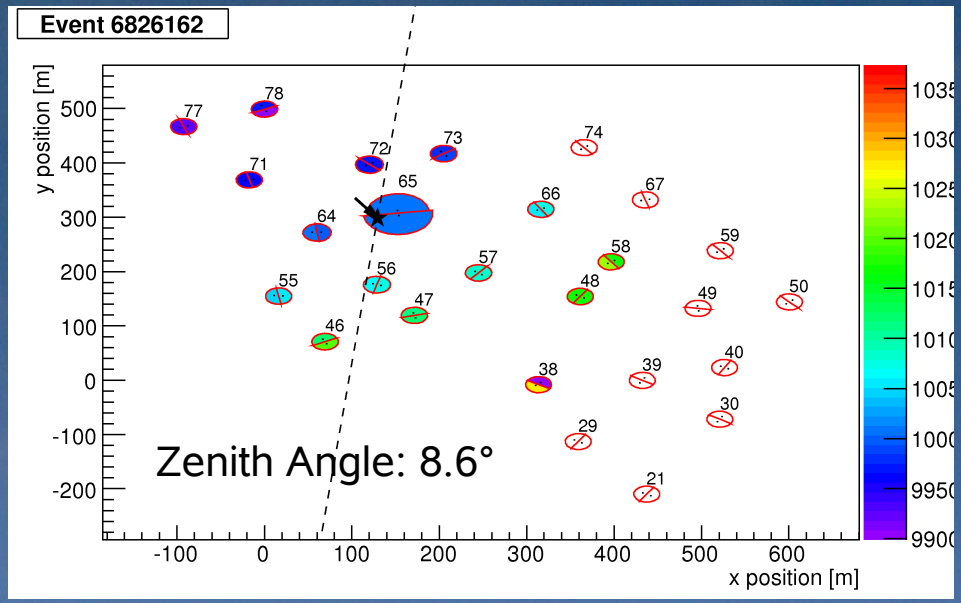


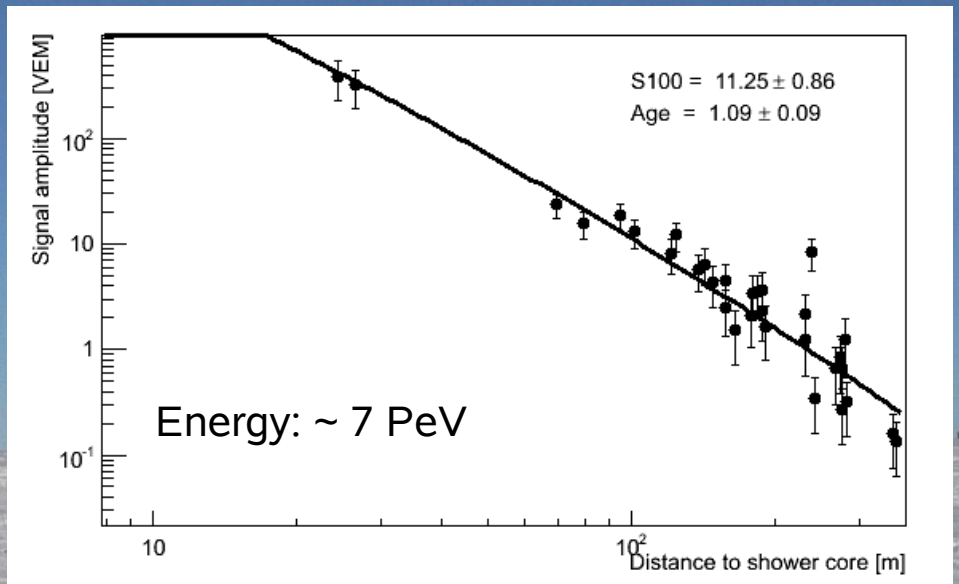
ICRC contribution of X. Bai

- Muon direction given by position of station and Center Of Gravity of InIce Signals.
- Comparison of InIce reconstruction to "known" muon direction.

IceTop – InIce Coincidences



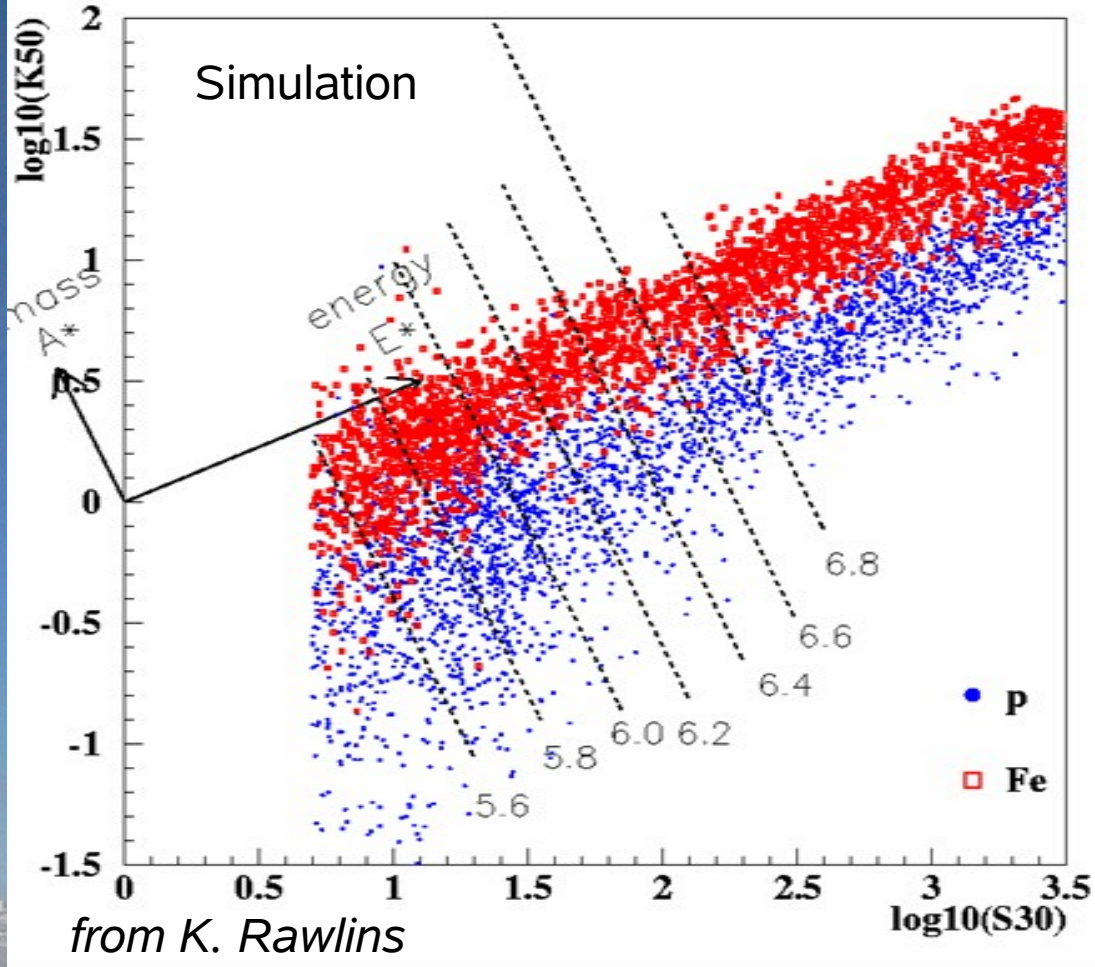




IceTop – InIce Coincidences

How to study composition with IceCube

Example plot from SPASE/AMANDA



from K. Rawlins

Reconstruction parameters:

- IceTop: S100
  Average signal at 100 m perp. distance to shower core.
- InIce: K50
  Average muon bundle light yield at 50 m perp. distance to shower axis at certain slant depth.
- Transformation into (A,E)-plane or 2D de-convolution enable composition study.

Summary & Outlook

- IceTop reconstruction works and improves steadily.
- Energy Spectrum still needs to be corrected for acceptance and detector response.
- Single station – InIce coincidences for detector and reconstruction checks.
- IceTop – InIce coincidences allow a study of the cosmic ray composition.
- Looking forward to analyze 2007 data.