The IceTop Air Shower Array:

detector overview, physics goals, first results

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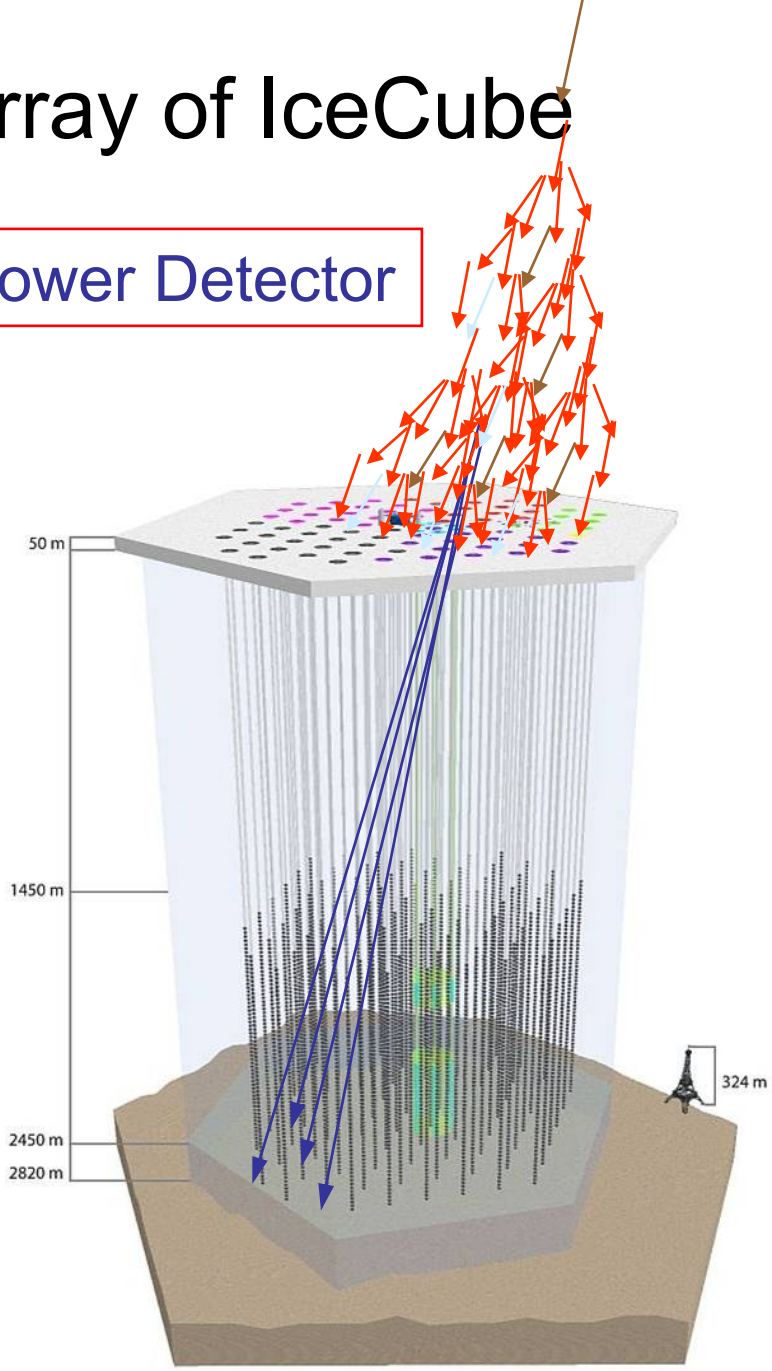
for the IceCube Collaboration

IceTop - the air shower array of IceCube

IceCube with IceTop is a 3-dim Air Shower Detector

- Cosmic Ray energy spectrum 10^{14} – 10^{18} eV
- Composition analysis with IceTop + IceCube
- Galactic – extra-galactic transition
- physics of airshowers
- heliospheric physics, transient events
- EAS Veto for neutrinos in IceCube
- direction calibration
- and more



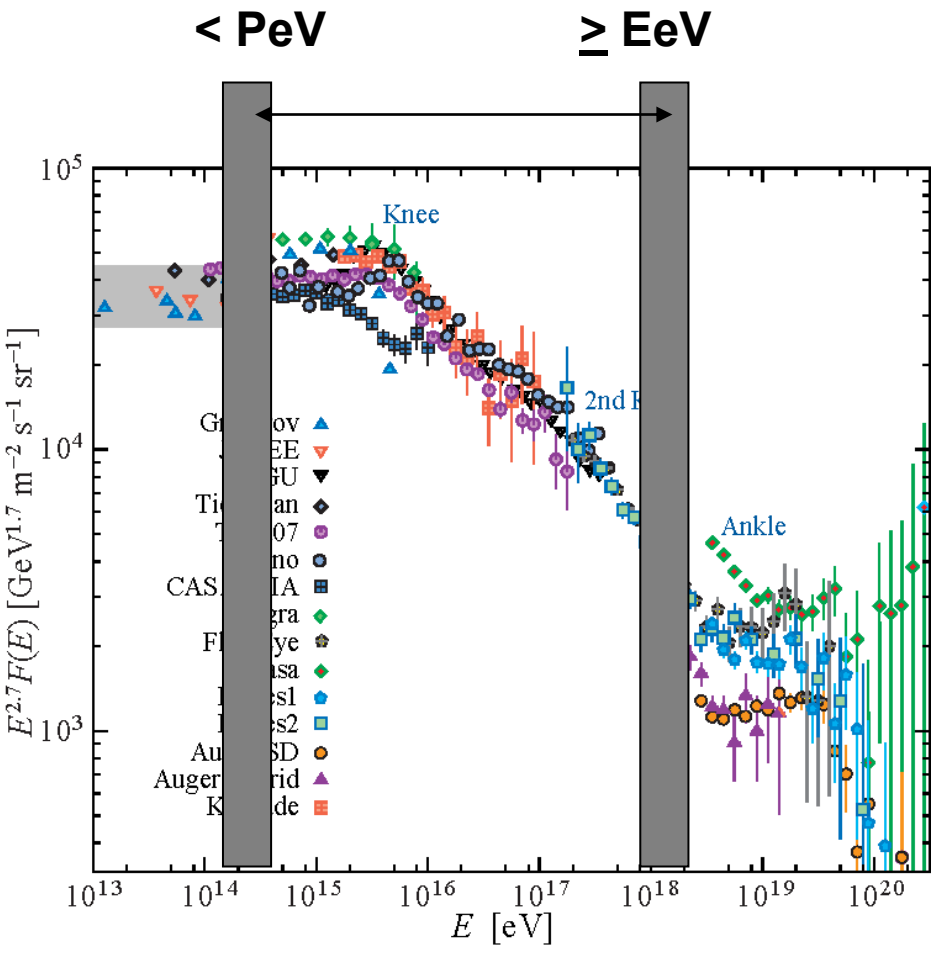
Energy range of IceCube/IceTop

Threshold energy

- ≤ 300 TeV

Maximum energy

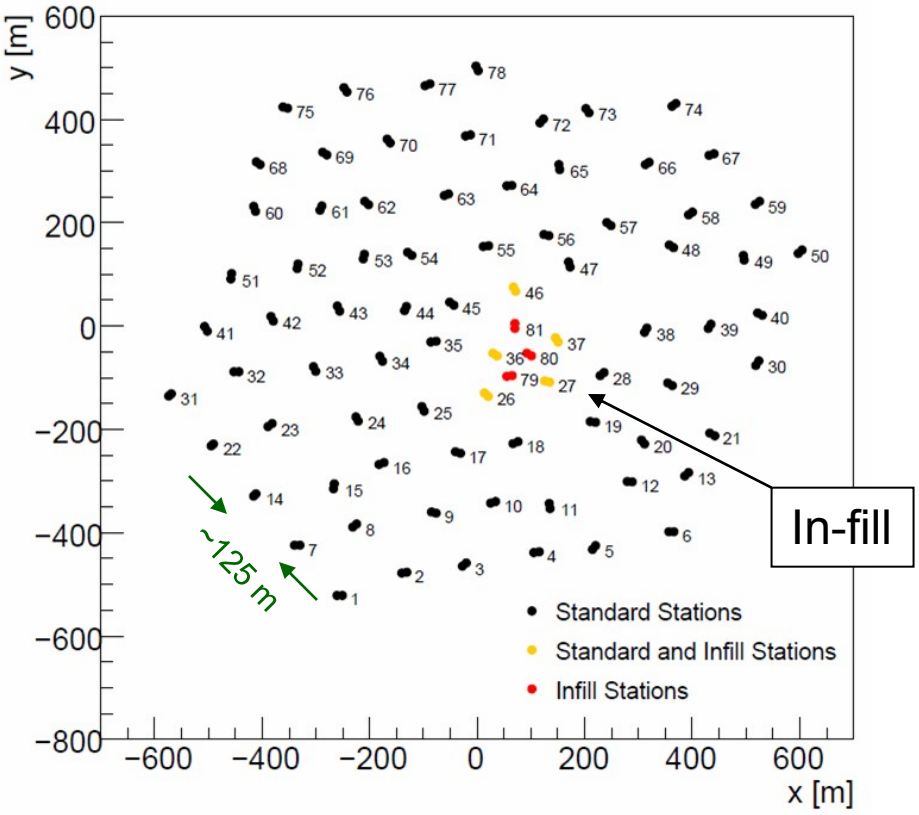
- Limited by km² size
- Coincident events
  - $A \cdot \Omega = 0.3$ km² sr
  - E_{max} = EeV
- IceTop only ($\theta < 60^o$)
  - $A \cdot \Omega = 3$ km² sr
  - E_{max} = 3 EeV

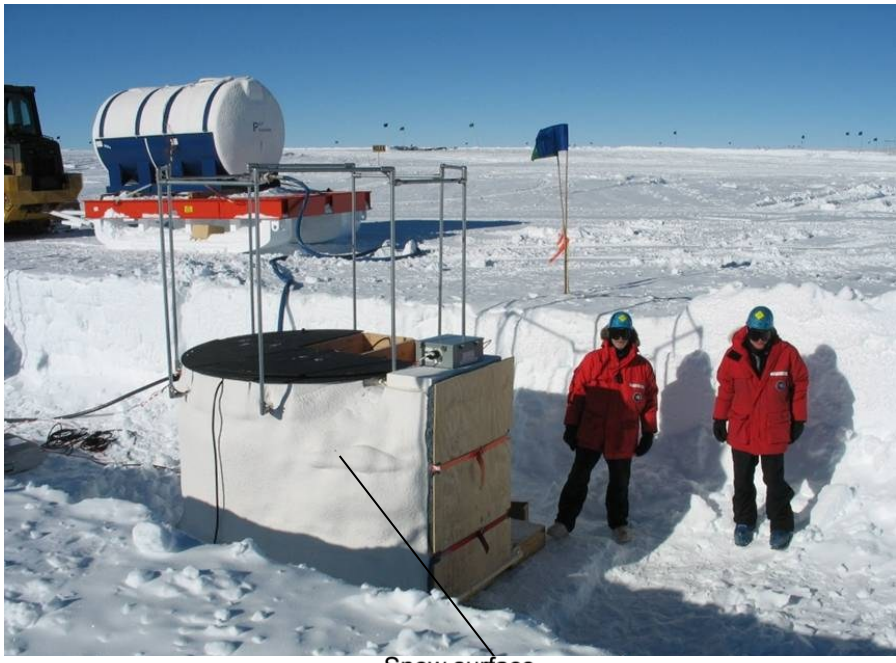


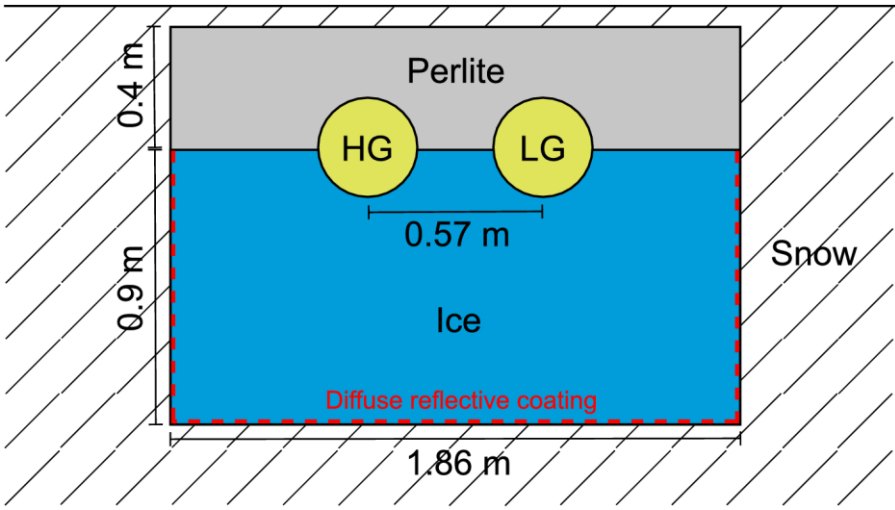
Anchor to direct measurement of composition ~300 TeV

Look for transition to extra-galactic < EeV

Final IceTop Detector Array 2011





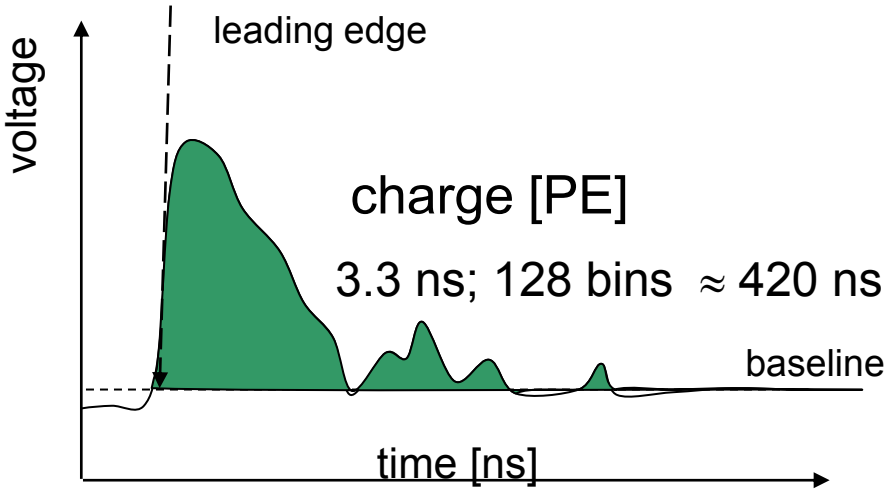


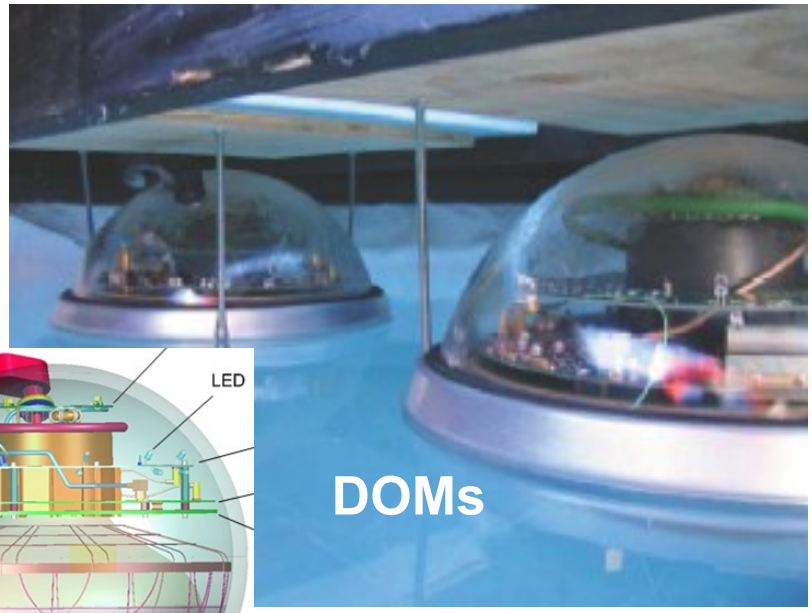
final detector:

81 stations (162 tanks)

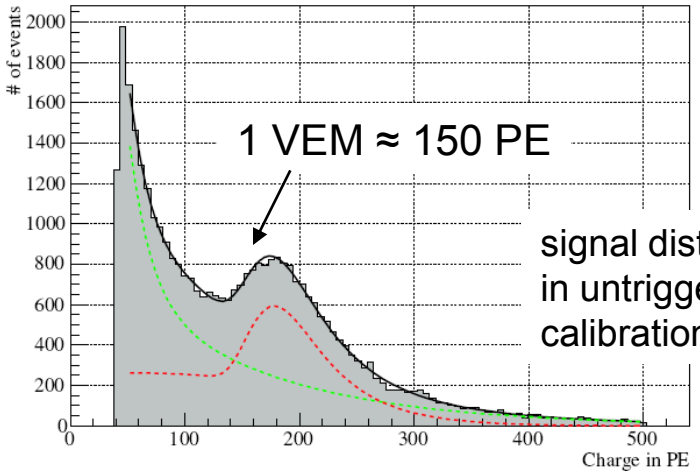
mostly ~ 125 m; 3 inserts (+5 closest)

IceTop Signal Recording





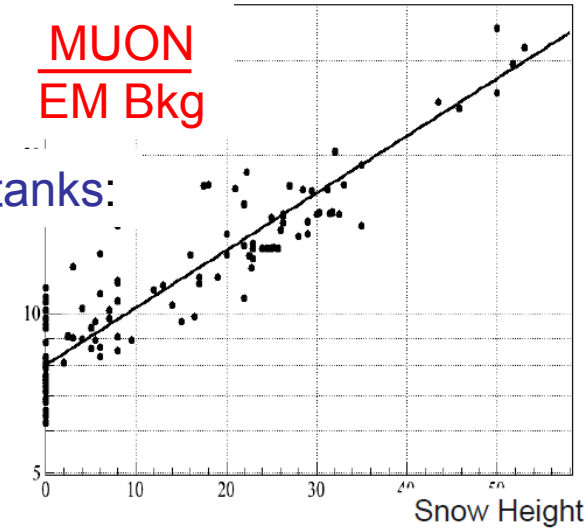
conversion to
Vertical **E**quivalent **M**uons



signal distribution
in untriggered
calibration runs

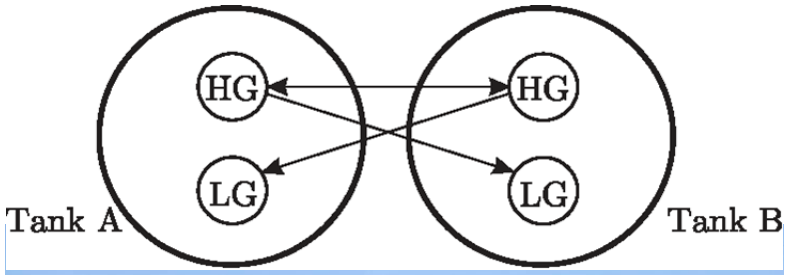
MUON
EM Bkg

... and snow on the tanks:



paper #899

Trigger and Data Selection



Single DOM above threshold:
⇒ digitization of waveform (3.3 ns bins)

Local Coincidence (=HLC):
require both with DOMs above threshold
⇒ readout of full waveform to IceCube Lab

Soft Local Coincidence (=SLC):
upon a trigger any DOM above threshold is read out with timestamp and integrated charge
⇒ catch single muons

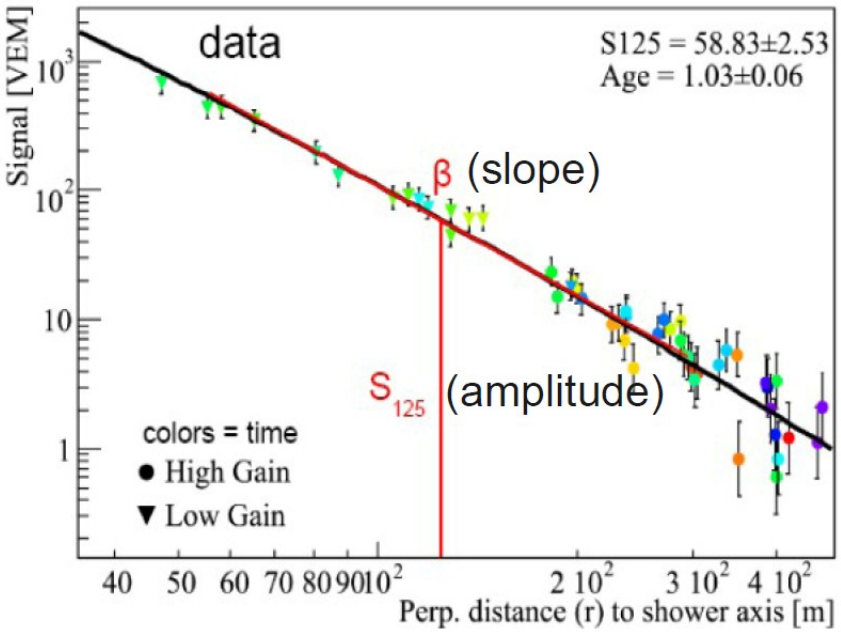
MinBias
downscaled for calibration with single muons

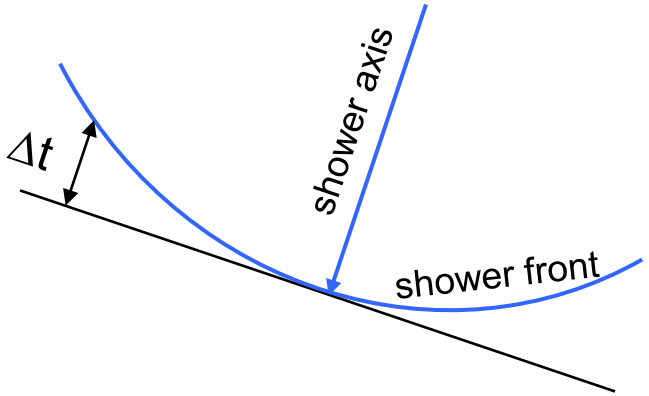
Reconstruction:
standard: 5 stations ⇒ ≥ 1 PeV
infill extension: ≥ 3 stations ⇒ ≥ 100 TeV

Full Shower Reconstruction

see also poster #336

tank signals = $(\vec{x}_i, q_i, t_i) \Rightarrow$ 6 free parameters: $(S_{125}, \beta, \vec{x}_c, \theta, \phi)$

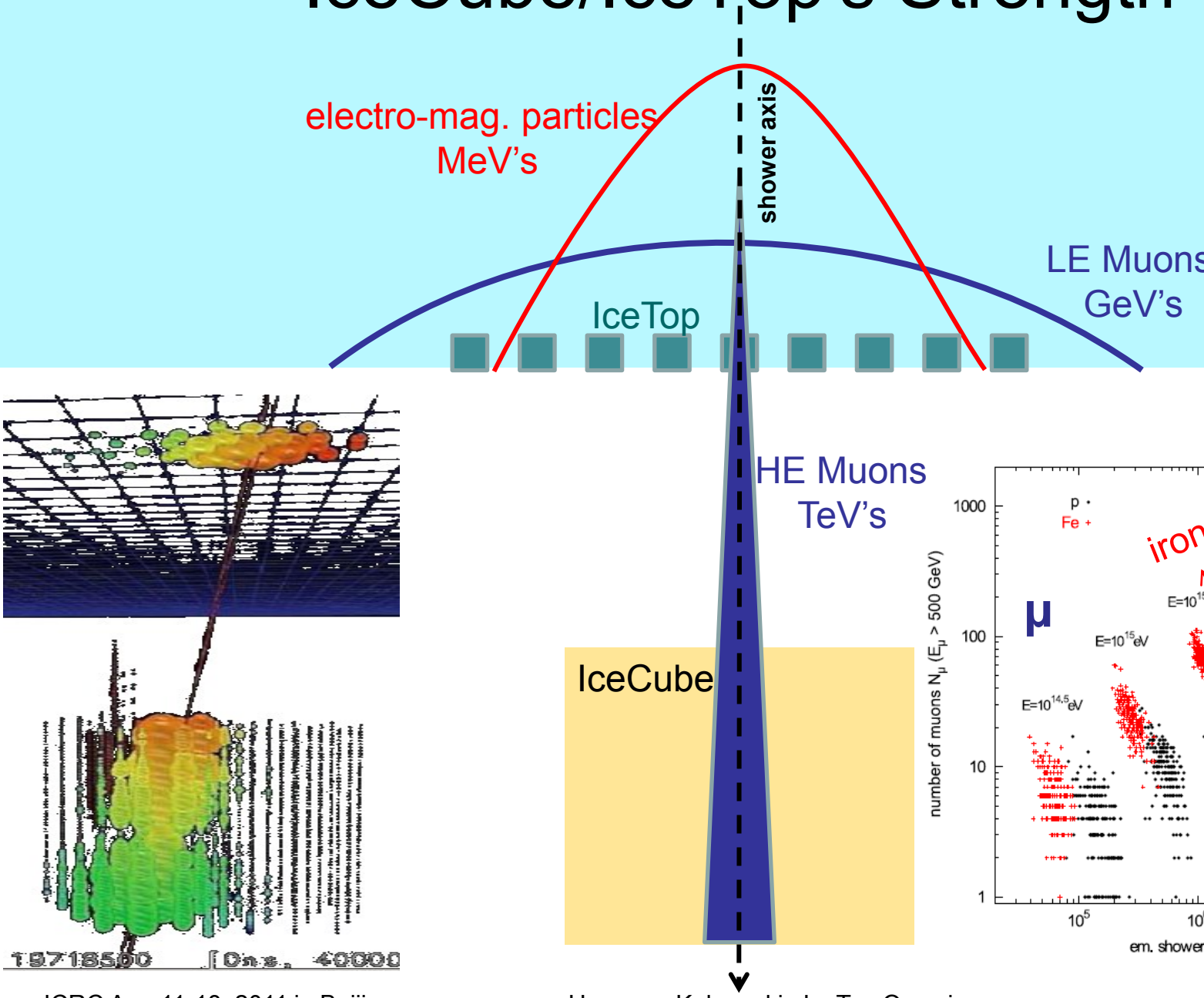




$$\log S(R) = \log S_{\rm ref} - \beta \log\left(\frac{R}{R_{\rm ref}}\right) - \kappa \log^2\left(\frac{R}{R_{\rm ref}}\right)$$

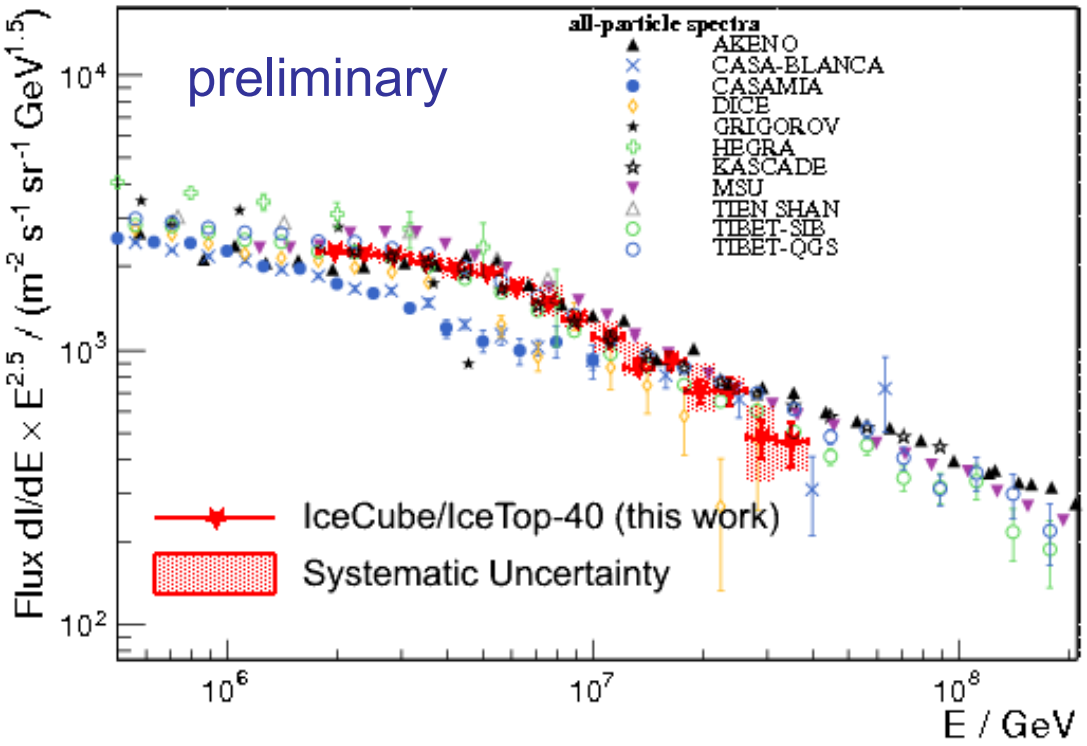
$$\Delta t(R) = a\,R^2 + b\left(\exp\left(-\frac{R^2}{2\sigma^2}\right) - 1\right)$$

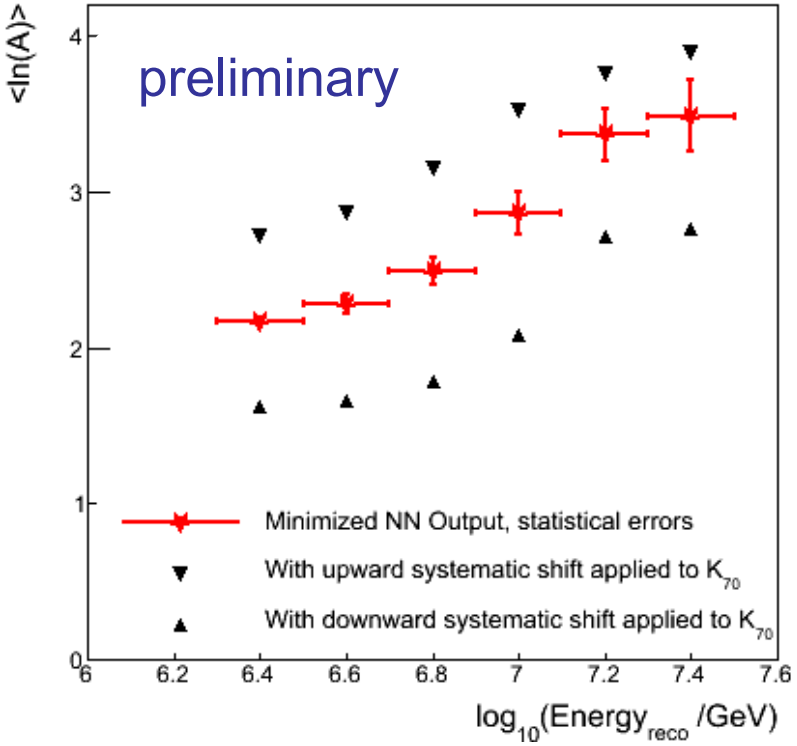
IceCube/IceTop's Strength



First IceCube Composition Measurement
IC 40

talk #923





~ 1month of IC40 subarray (with little snow)

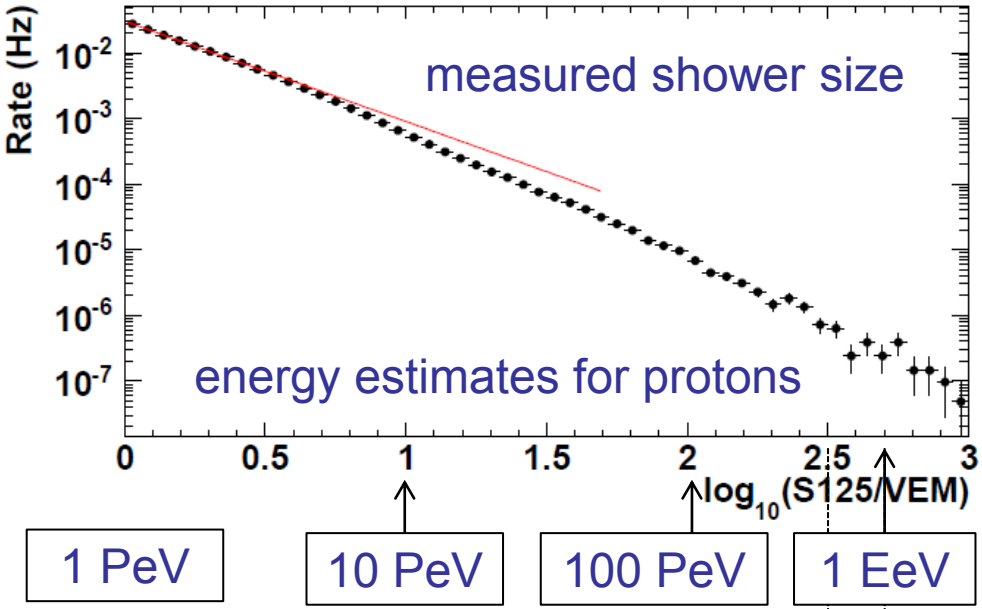
energy from 1 to 30 PeV (only)

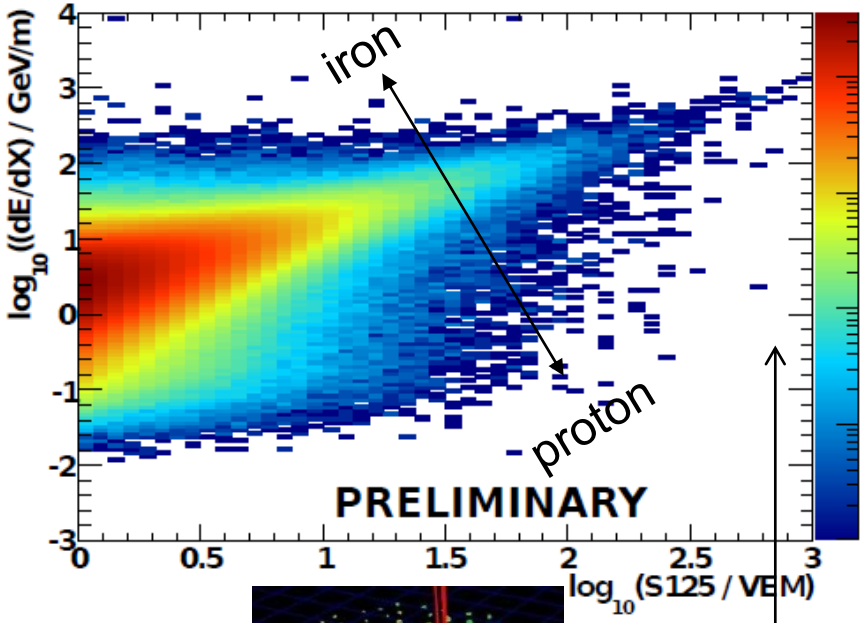
still systematics dominated

First Look into 2010 Data

Nearly complete detector IC79 / IT73
demonstrates acceptance and capability of detector

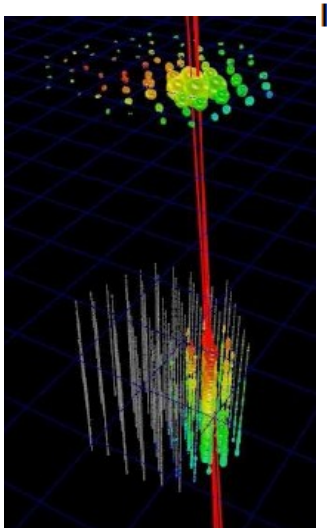
paper #838





~ 15 ev./year
> 1 EeV

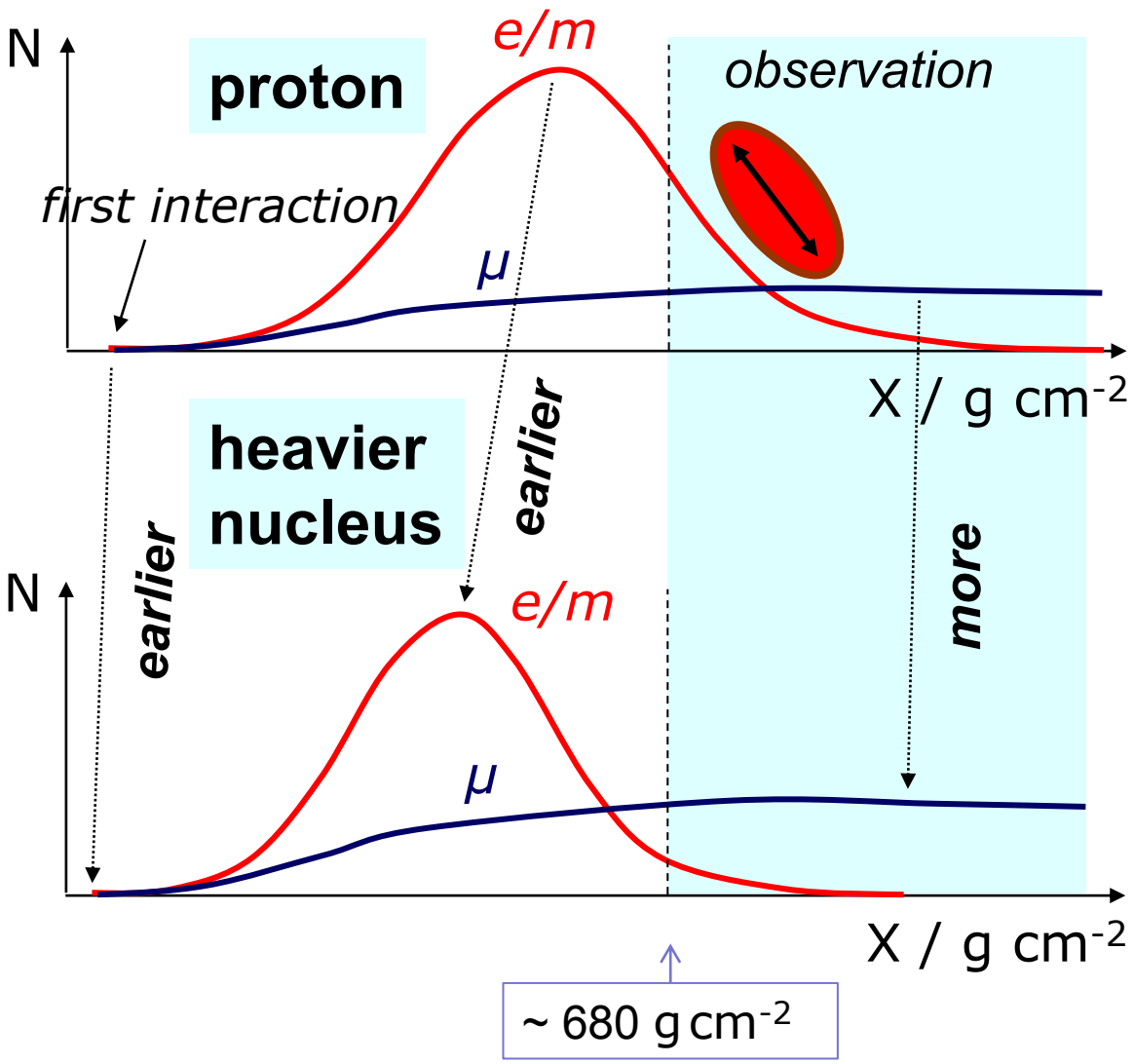
~ 150 ev./year
> 300 PeV



interestingly
narrow band

unique mass?

Strategies of Composition Analyses



- **IceTop & InIce**

IceTop EM vs InIce MUON

- **IceTop**
  - zenith angle of e.m.
  - curv. of shower front
  - GeV-muons in IceTop:
- IceTop & Radio

(future, see paper #1102)

- shower max. X_{max}

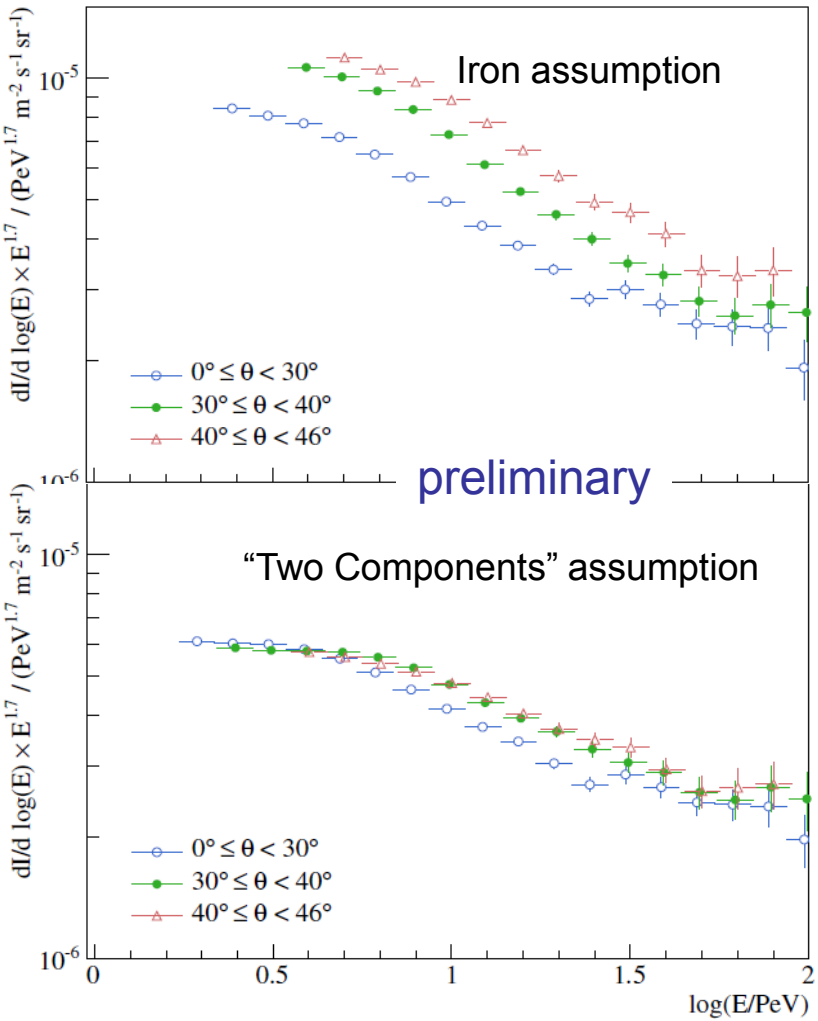
Complementary methods

⇓

reduce model dependency

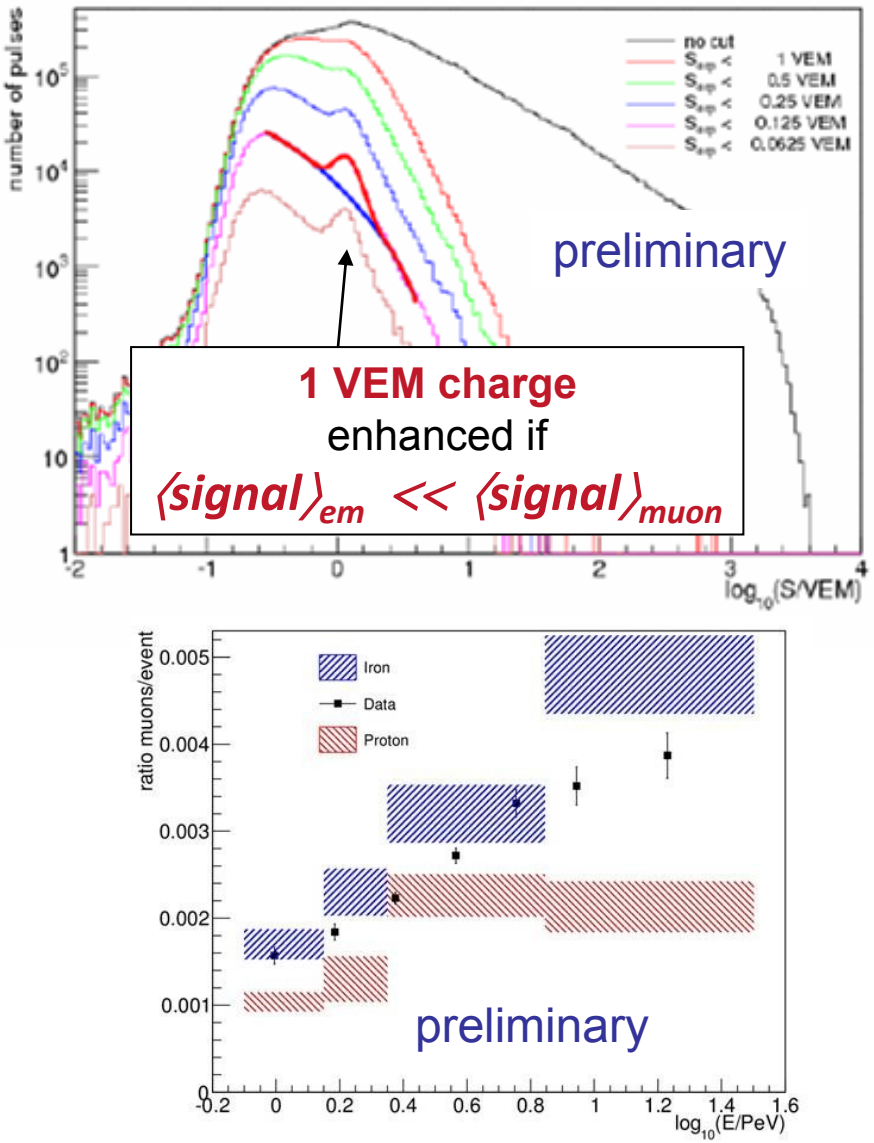
Supporting Composition Measurements

Zenith angle dependence of shower size

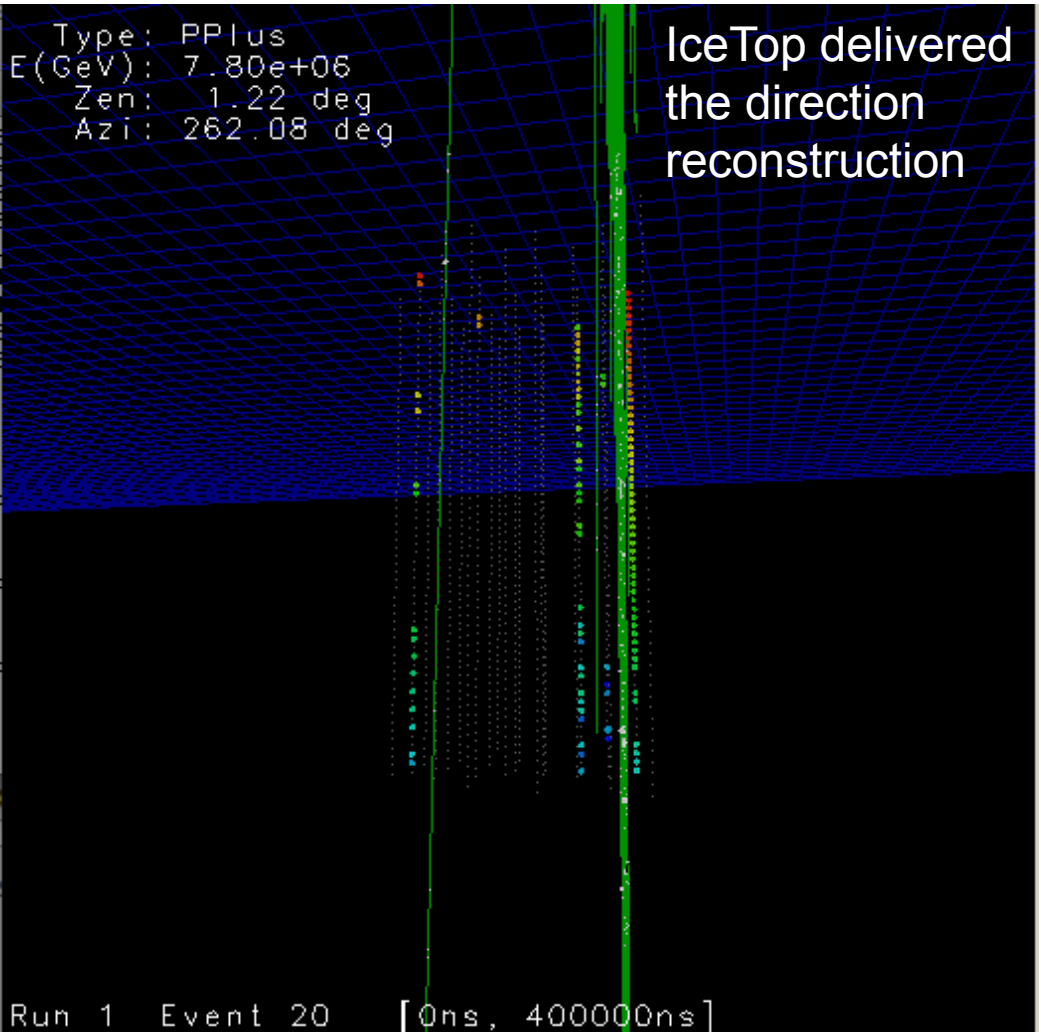


IT26 spectrum analysis 1-100 PeV

Muon counting in air shower data



High-p_T Muons in IceTop-IceCube (#323)



Measure muon separation spectrum out to hundreds of meters

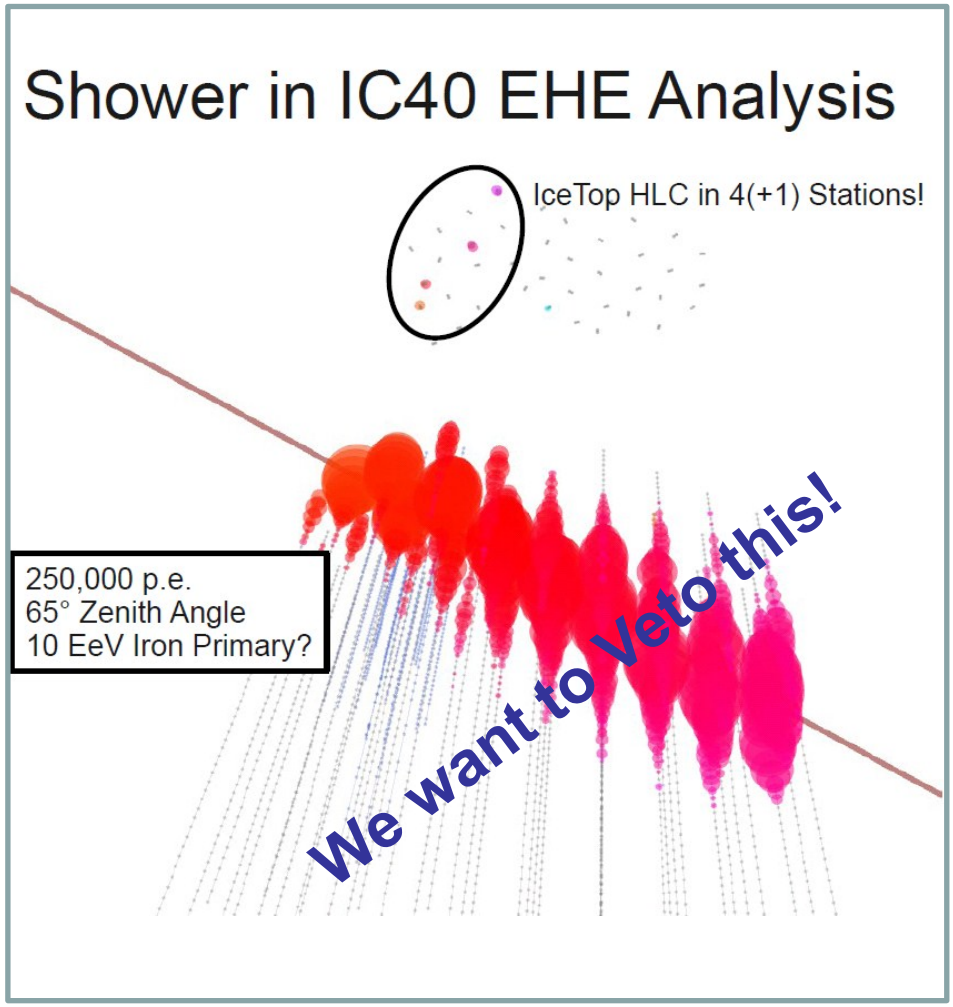
Another test of models:

pQCD predicts high–p_T muons from π, K, charm, bottom, ...

"prompt"

IceTop's EHE Veto (#778)

improving the search for GZK neutrinos



HLC = 'hard local coincidence':
both tanks of a station above threshold
⇒ full readout

Relaxe to SLC = 'soft local coincidence'
⇒ only charge & time stamp read out
⇒ available for any trigger

Opens an EHE neutrino window
for smaller zenith angles

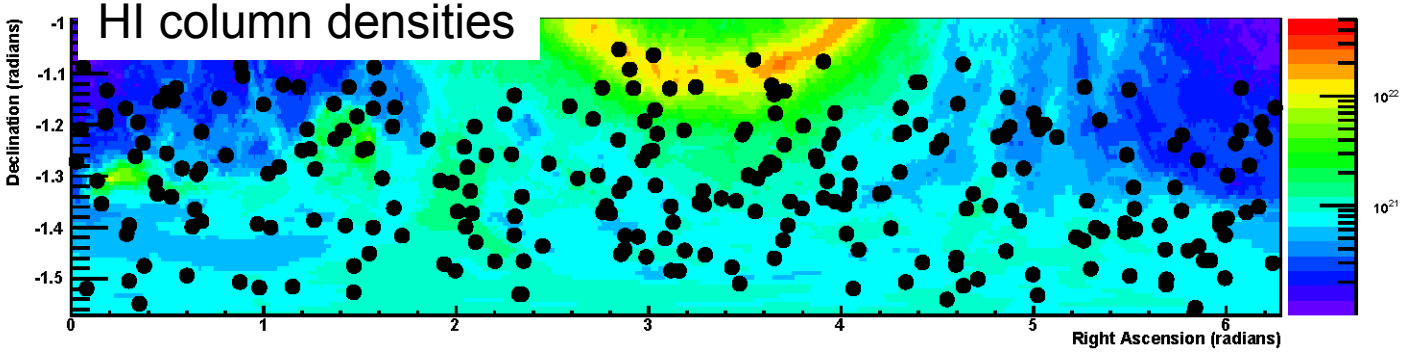
At sufficiently high energy:

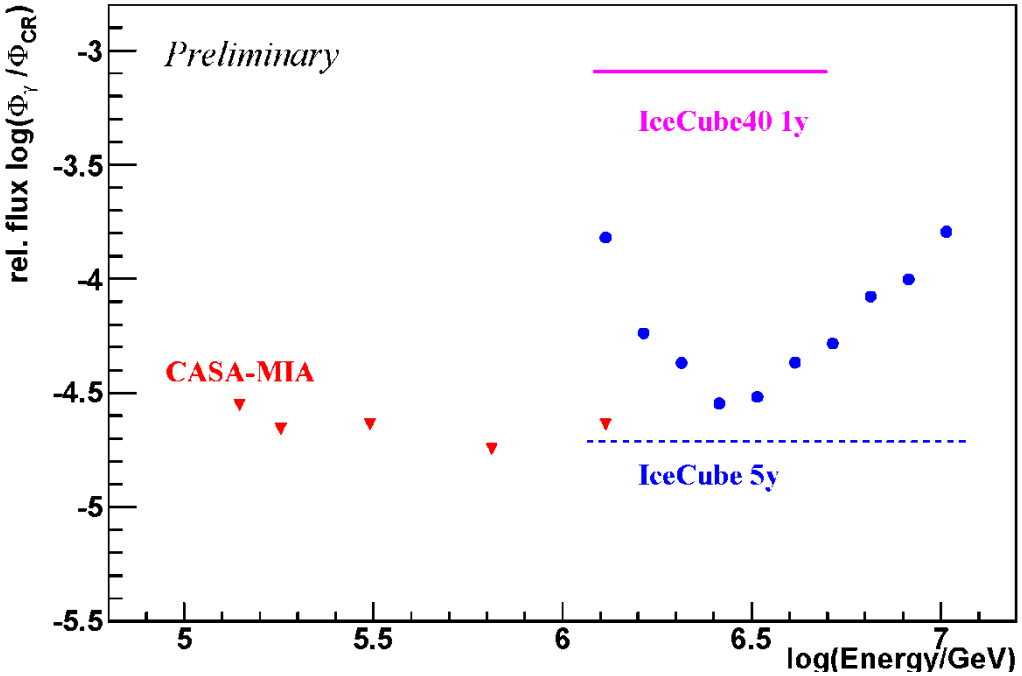
~ 100% background rejection
at > 90% signal efficiency

seems feasible , see poster #778

PeV Gamma with InIce Veto against muons

IceTop shower with no activity in IceCube paper #939



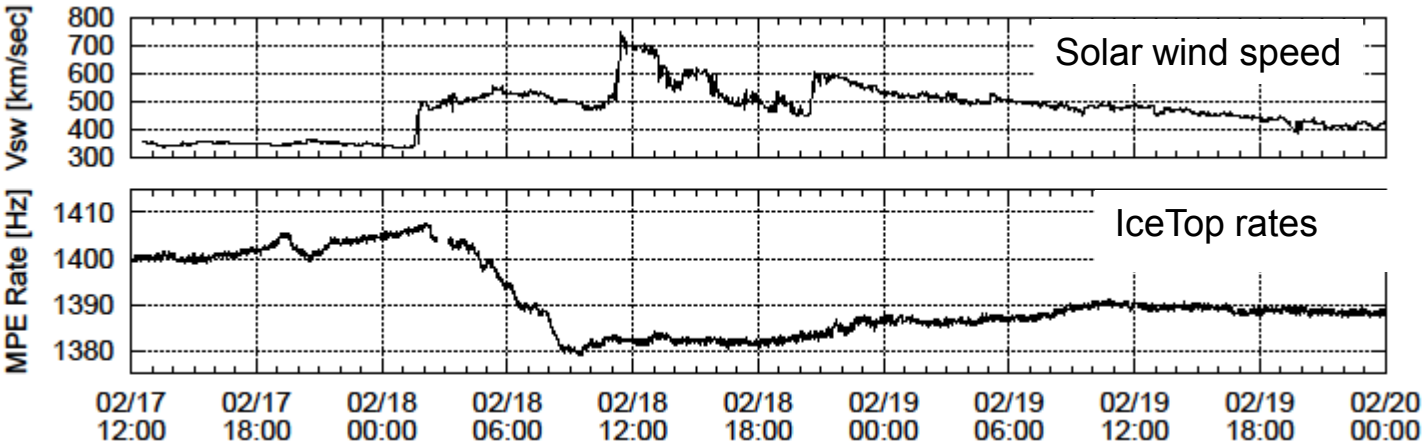


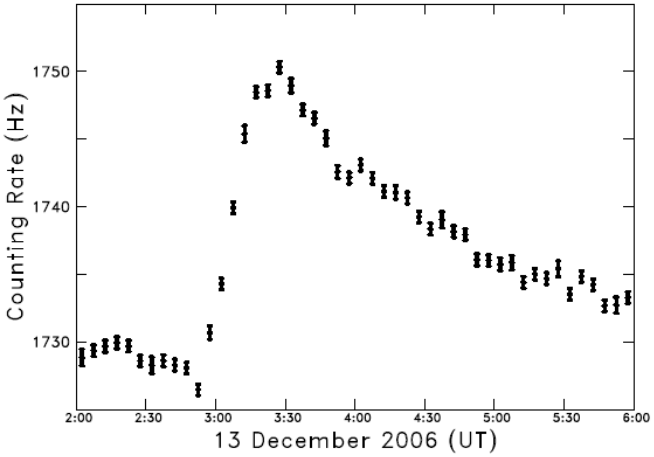
upper limit with $\gamma = -2$, at $E = 1.2$ PeV

$\Phi < 7.0 \cdot 10^{-19}\,\mathrm{cm^{-2}s^{-1}TeV^{-1}}$ (99% c.l.)

Low energy transient rate variations from Sun, SN, GRB, ...

Forbush Decrease in IceTop #921

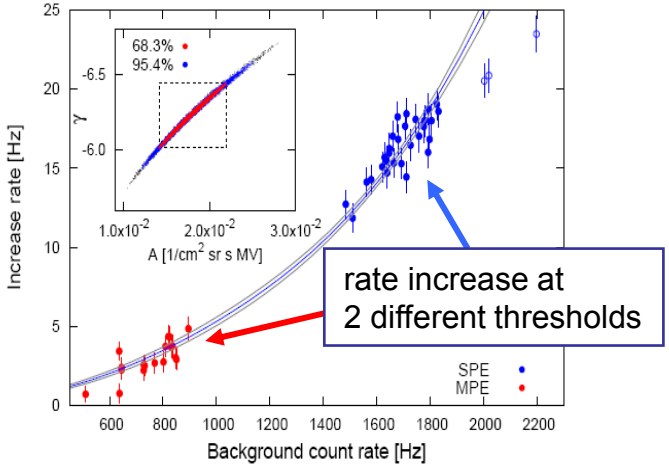




Since the first Sun flare observation Dec 13, 2006:

[ApJ Lett 689 (2008) L65]

IceTop increased spectral sensitivity taking differential rates at multiple thresholds



Summary

IceCube/IceTop is a unique 3-dim Air Shower Detector

First Results on:

- **Cosmic Ray energy spectrum 10^{14} – 10^{18} eV**
- **CR composition:**
  unique capability up to 10^{18} eV
- **Galactic – extrac-galactic transition**
- **physics of airshowers**
- **heliospheric physics, transient events**
- **EAS Veto for neutrinos in IceCube**
- **... and the future: radio extension (RASTA)**