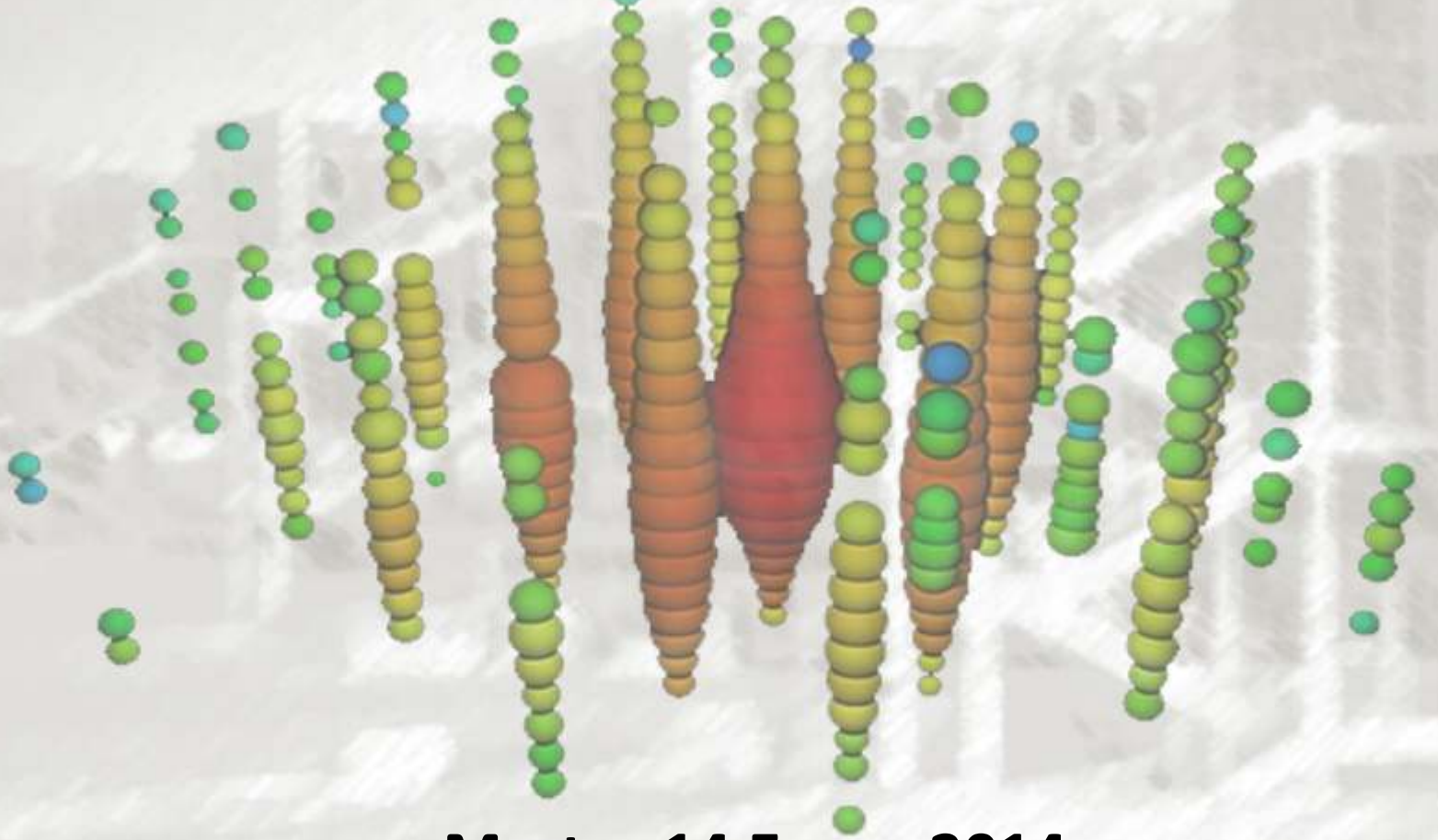
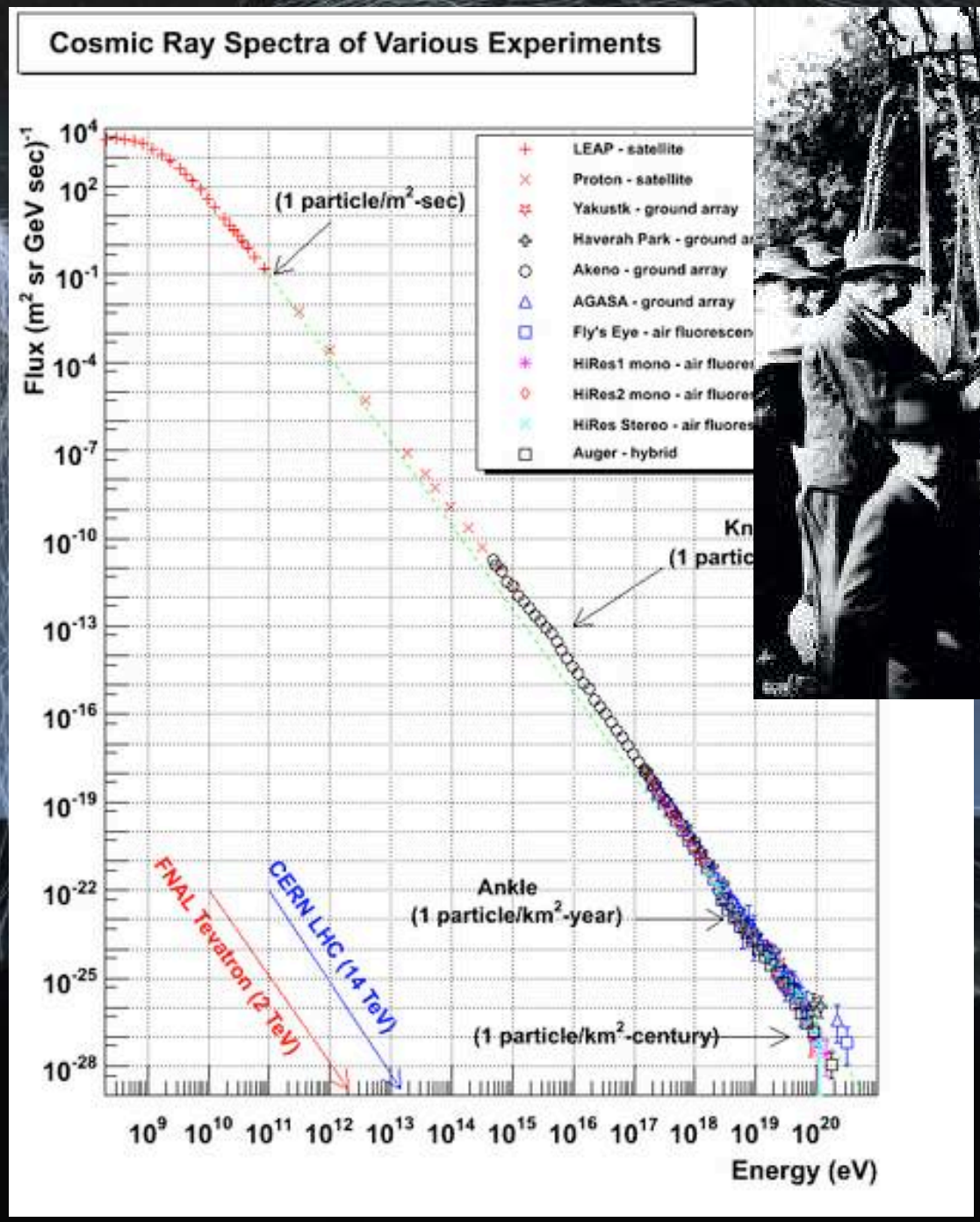
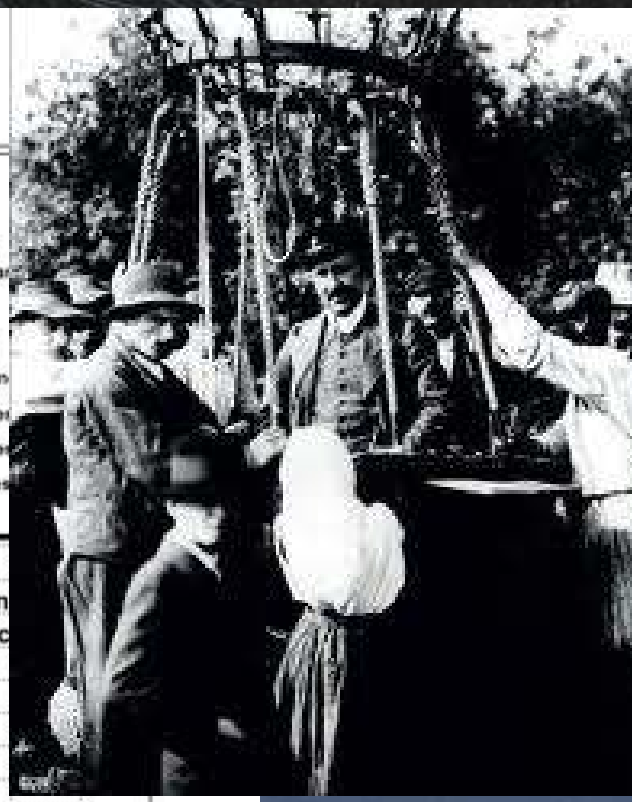
Neutrinos Ultraenergéticos y últimos resultados de ICECUBE

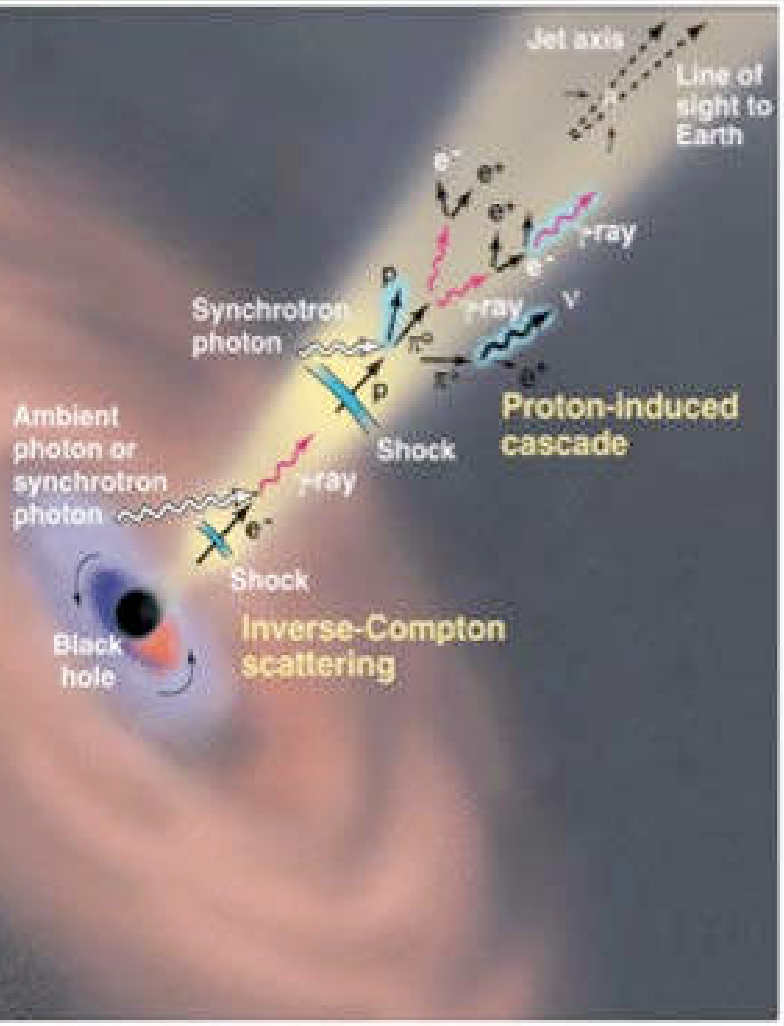


Martes 14 Enero 2014

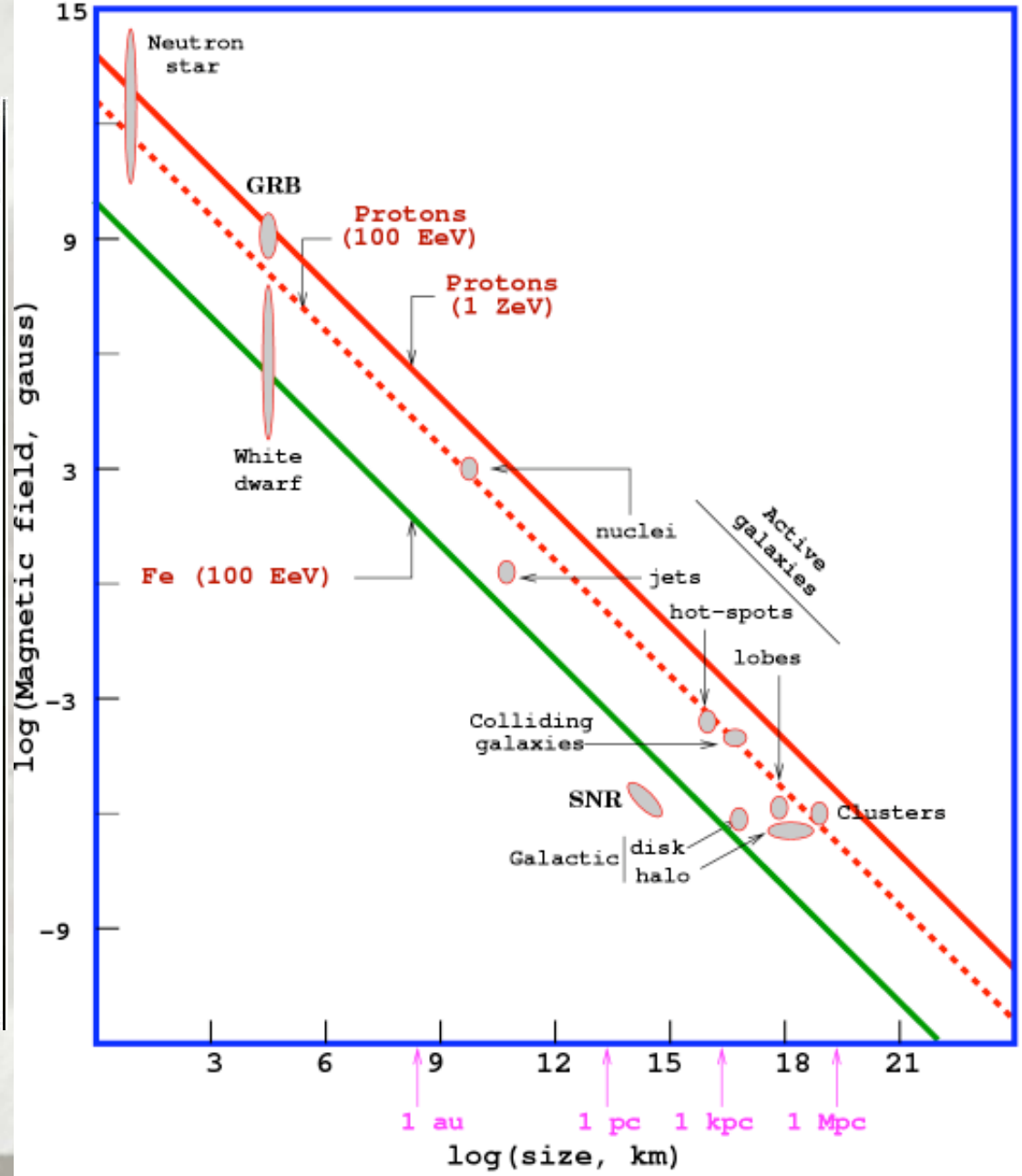
Martes Cuánticos. Carlos Pobes

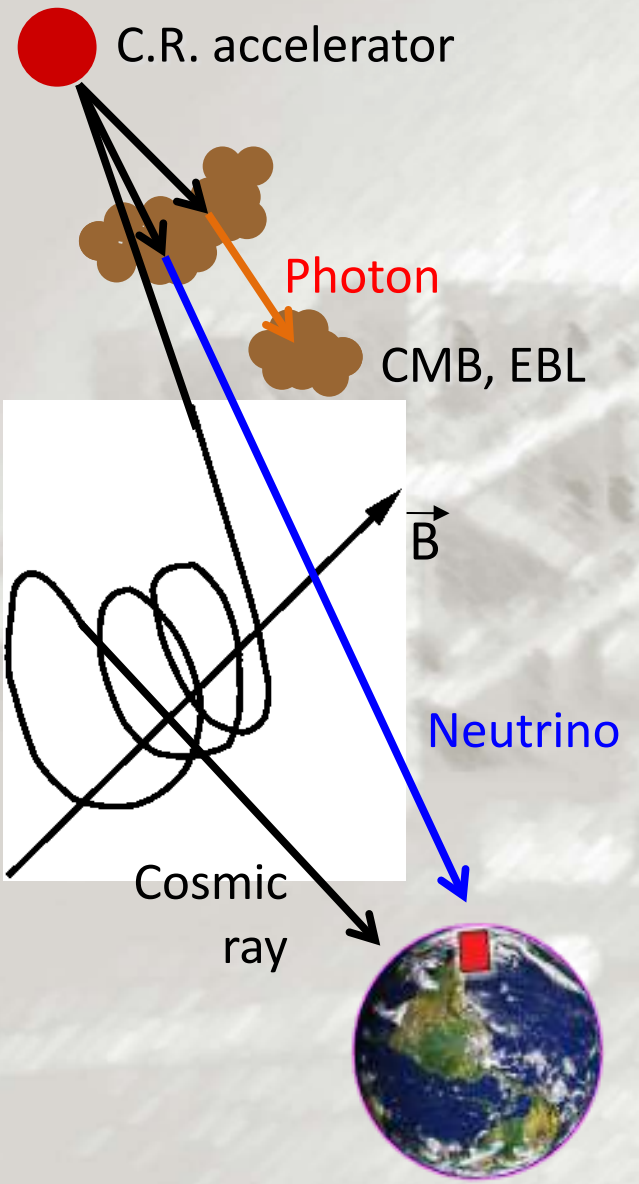

Cosmic Ray Spectra of Various Experiments
Flux (m² sr GeV sec)⁻¹
Energy (eV)
LEAP - satellite
Proton - satellite
Yakustk - ground array
Haverah Park - ground a
Akeno - ground array
AGASA - ground array
Fly's Eye - air fluorescen
HiRes1 mono - air fluore
HiRes2 mono - air fluore
HiRes Stereo - air fluores
Auger - hybrid
(1 particle/m²-sec)
Kn
(1 partic
Ankle
(1 particle/km²-year)
(1 particle/km²-century)
FNAL Tevatron (2 TeV)
CERN LHC (14 TeV)

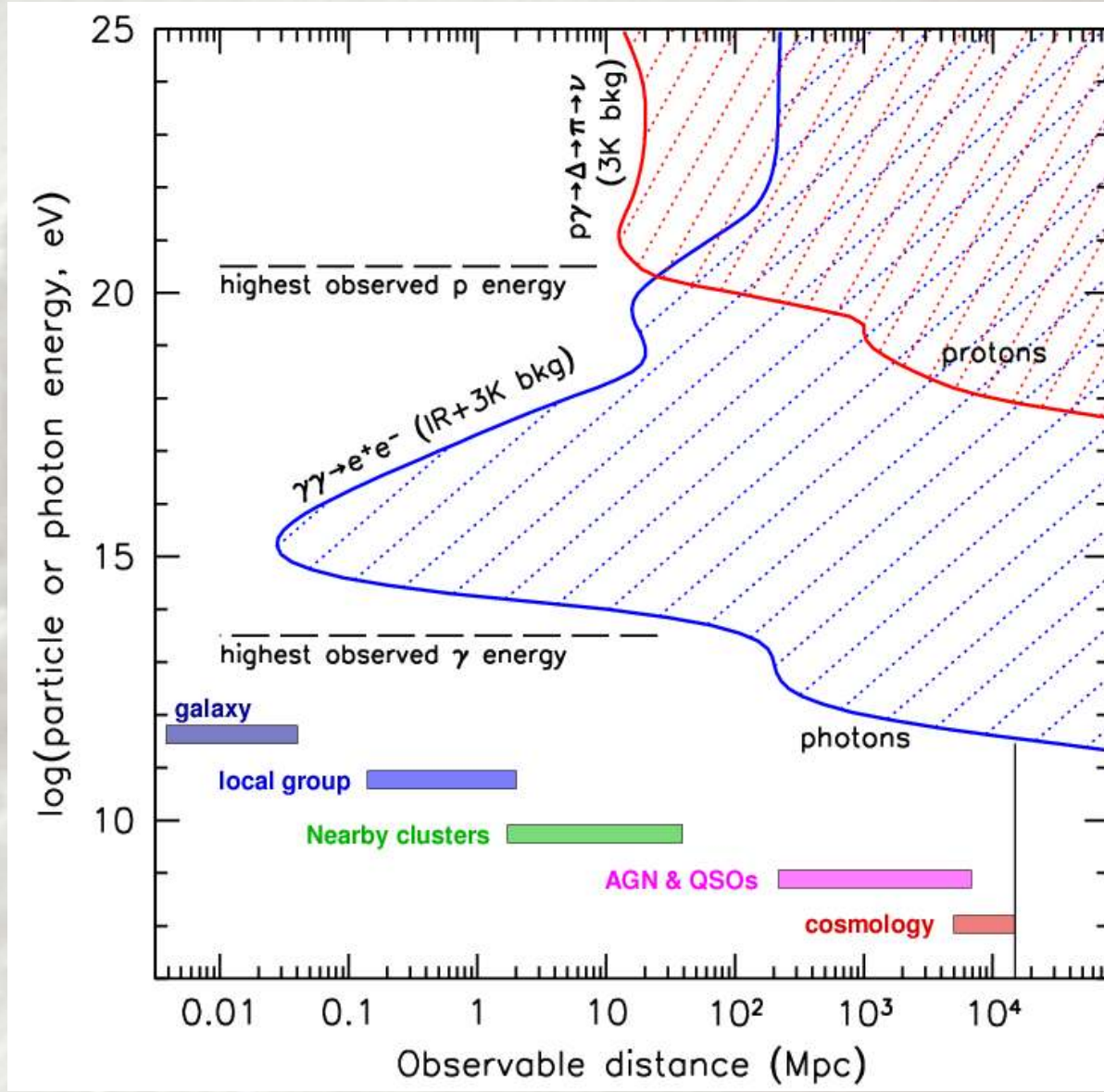




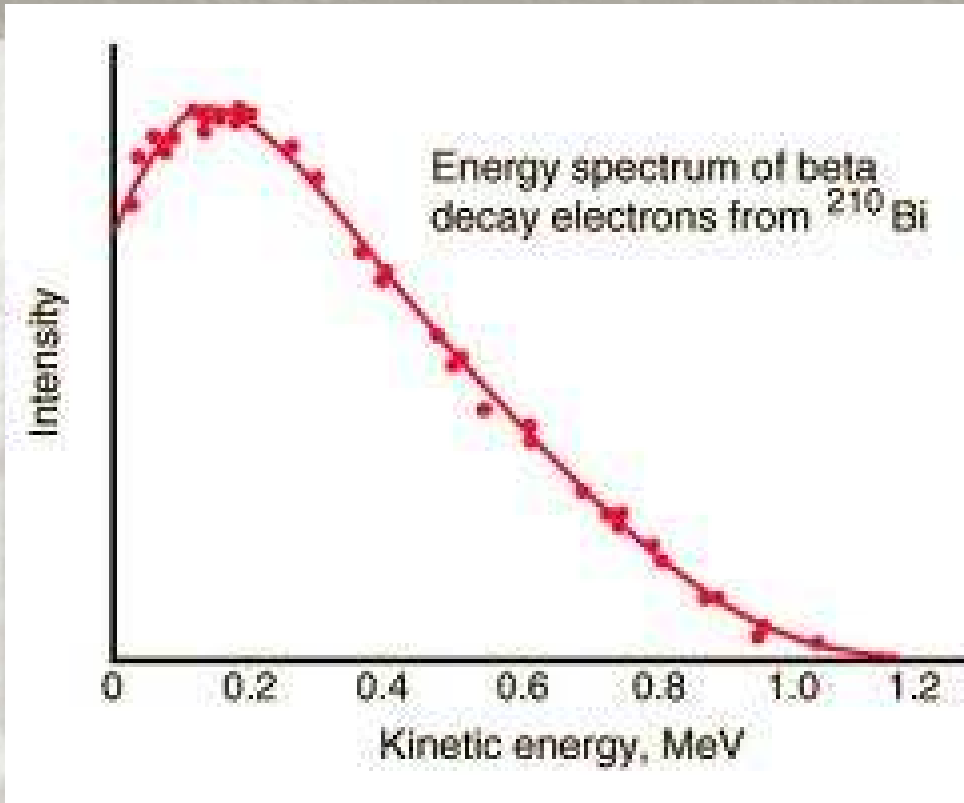
Hillas-plot
(candidate sites for E=100 EeV and E=1 ZeV)



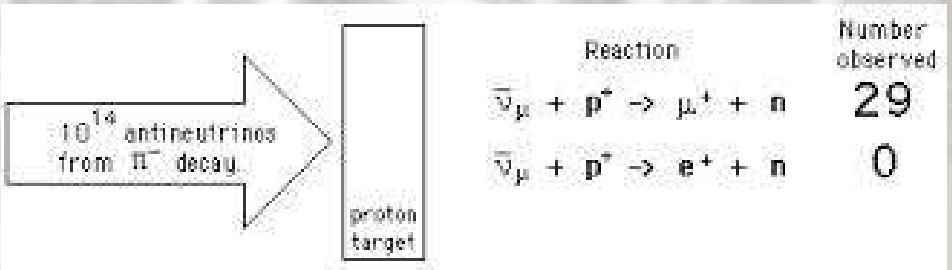

C.R. accelerator
Photon
CMB, EBL
$\vec{B}$
Neutrino
Cosmic ray

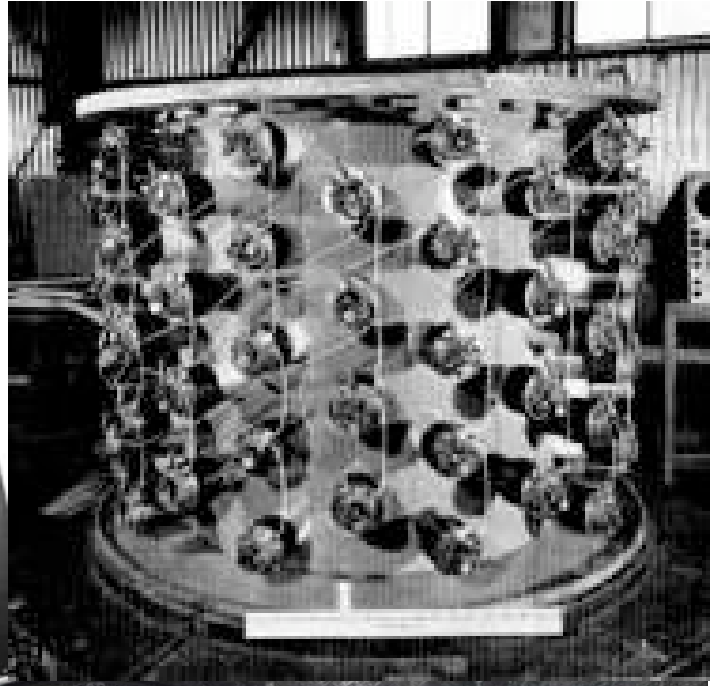

log(particle or photon energy, eV)
Observable distance (Mpc)
25
20
15
10
0.01
0.1
1
10
10^2
10^3
10^4
$p\gamma \to \Delta \to \pi \to \nu$ (3K bkg)
highest observed p energy
protons
$\gamma\gamma \to e^+e^-$ (IR+3K bkg)
highest observed γ energy
photons
galaxy
local group
Nearby clusters
AGN & QSOs
cosmology

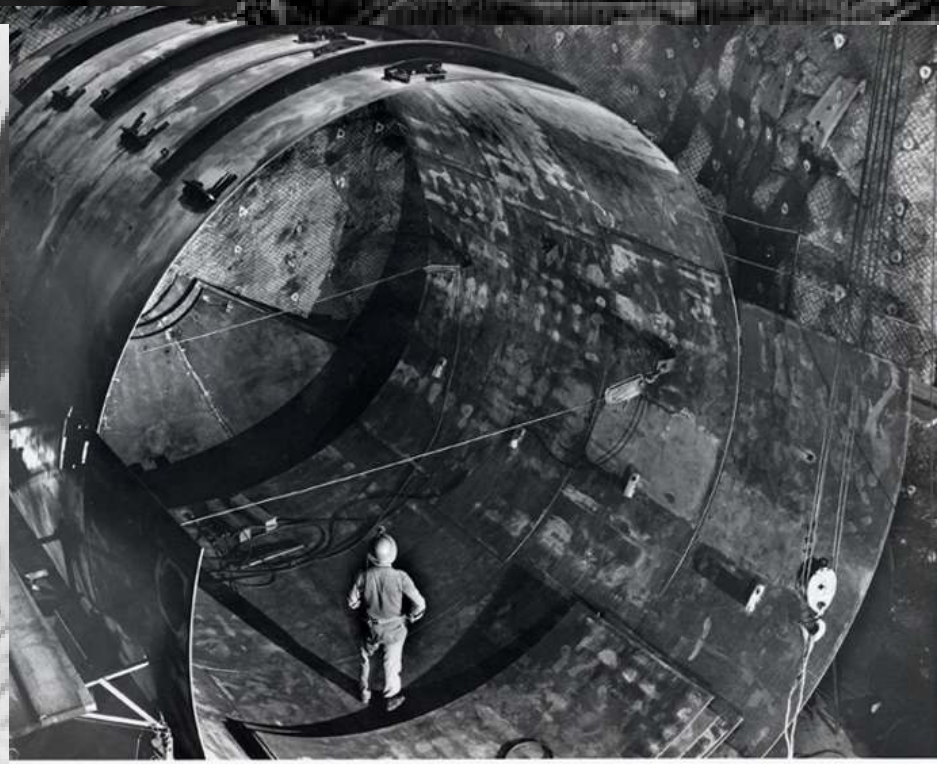
- 1910-20 Beta decay. Espectro continuo.
- 1930 Pauli-Fermi hipotesis neutrino y teoria
- Esquema desintegración:
- n -> p + e- + ν (anti)



- Reines-Cowan 1956. p+anti-ν -> n + e+
- Davis 60´s. Solar neutrinos. n + ν -> p +e-
- Lederman 60´s neutrino flavour
- Pontecorvo. Neutrino Oscillation







Años 80-90. neutrinos atmosféricos
1987 supernova sn1987a
‘90-’00 hipótesis oscilación confirmada.
Esquema oscilación. Autoestados masa y sabor. Matriz PMNS mezcla.
2012 medición theta13

(ν_e, ν_μ, ν_τ) <-> (ν1, ν2, ν3)

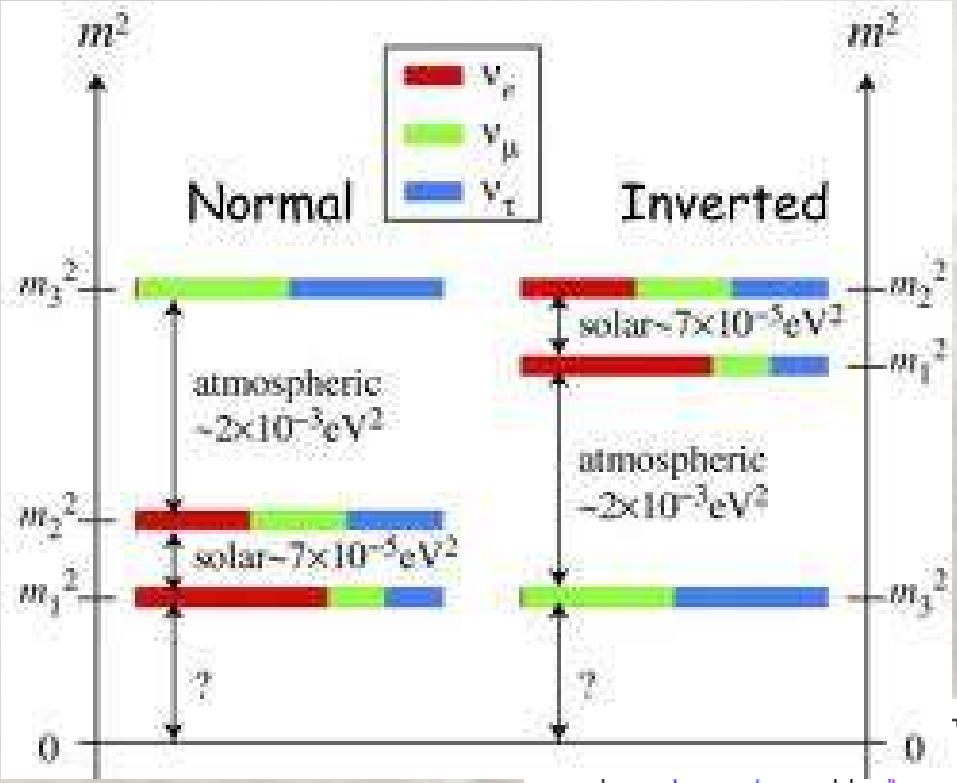
$$P_{\alpha\to\beta} = |\langle \nu_\beta | \nu_\alpha(t)\rangle|^2 = \left|\sum_i U^*_{\alpha i} U_{\beta i} e^{-i m_i^2 L/2E}\right|^2 .$$

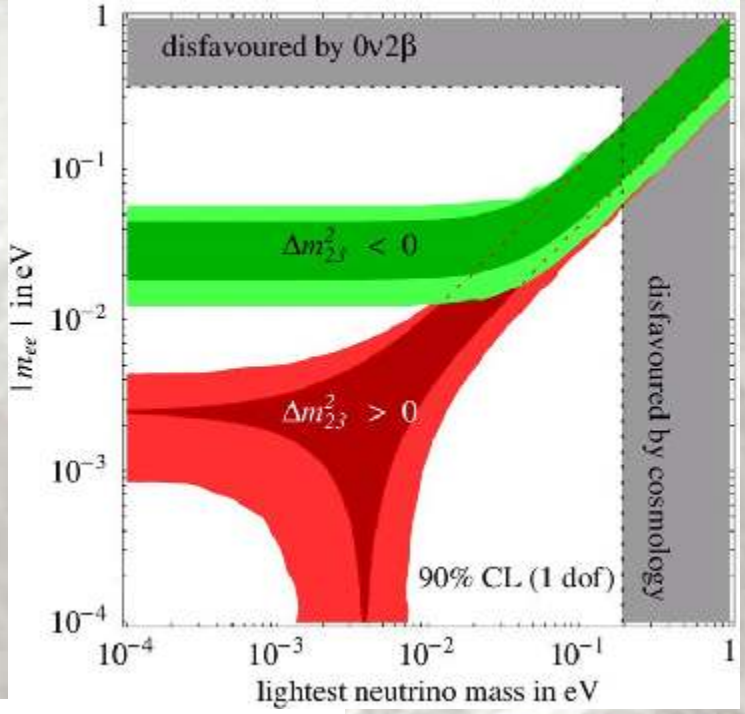
$$P(\nu_\mu \to \nu_\mu) = 1 - \sin^2(2\theta_{23})\sin^2(1.27\Delta m^2_{32} L/E),$$

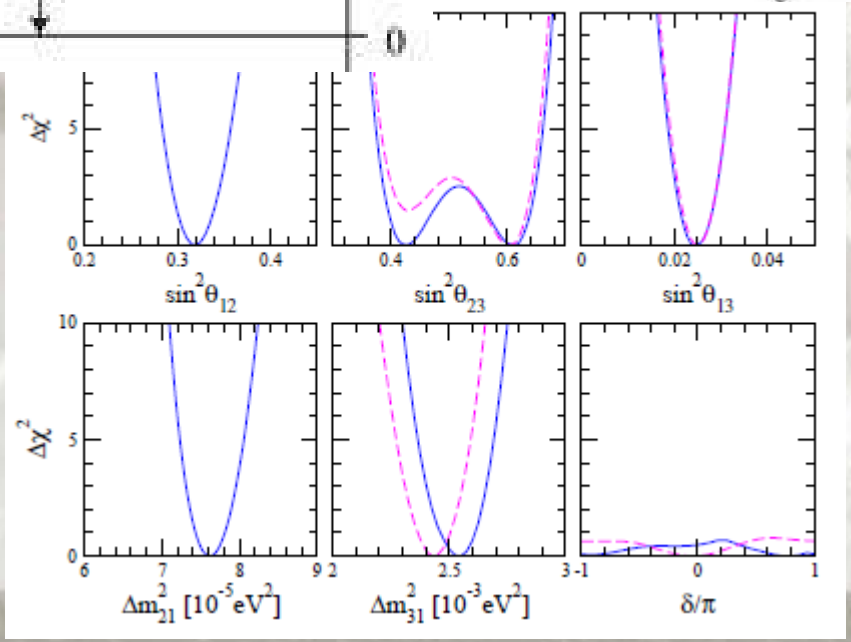
$$U = \begin{bmatrix} U_{e1} & U_{e2} & U_{e3} \\ U_{\mu 1} & U_{\mu 2} & U_{\mu 3} \\ U_{\tau 1} & U_{\tau 2} & U_{\tau 3} \end{bmatrix}$$

$$= \begin{bmatrix} 1 & 0 & 0 \\ 0 & c_{23} & s_{23} \\ 0 & -s_{23} & c_{23} \end{bmatrix} \begin{bmatrix} c_{13} & 0 & s_{13}e^{-i\delta} \\ 0 & 1 & 0 \\ -s_{13}e^{i\delta} & 0 & c_{13} \end{bmatrix} \begin{bmatrix} c_{12} & s_{12} & 0 \\ -s_{12} & c_{12} & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} e^{i\alpha_1/2} & 0 & 0 \\ 0 & e^{i\alpha_2/2} & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

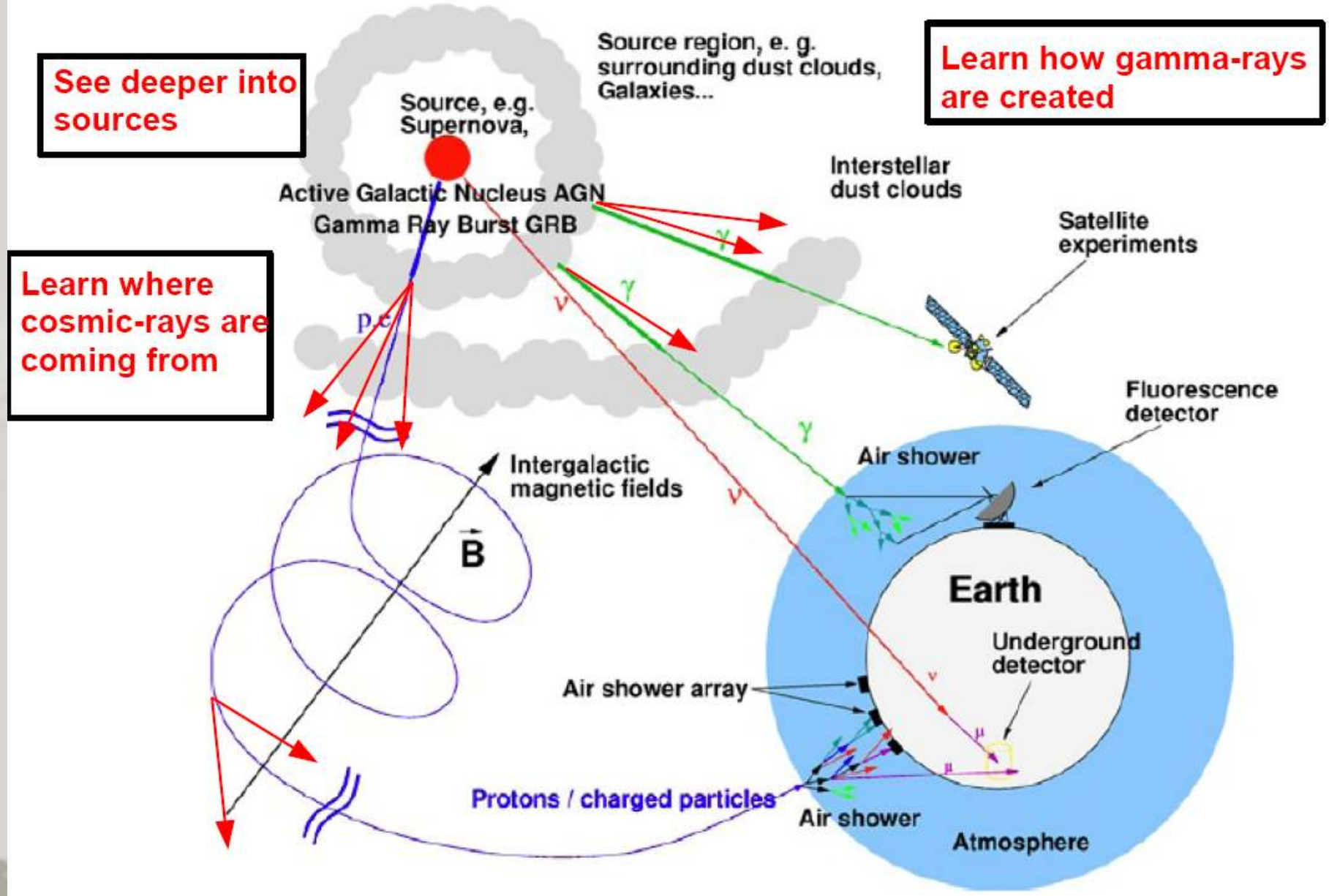
$$= \begin{bmatrix} c_{12}c_{13} & s_{12}c_{13} & s_{13}e^{-i\delta} \\ -s_{12}c_{23} - c_{12}s_{23}s_{13}e^{i\delta} & c_{12}c_{23} - s_{12}s_{23}s_{13}e^{i\delta} & s_{23}c_{13} \\ s_{12}s_{23} - c_{12}c_{23}s_{13}e^{i\delta} & -c_{12}s_{23} - s_{12}c_{23}s_{13}e^{i\delta} & c_{23}c_{13} \end{bmatrix} \begin{bmatrix} e^{i\alpha_1/2} & 0 & 0 \\ 0 & e^{i\alpha_2/2} & 0 \\ 0 & 0 & 1 \end{bmatrix}$$


m^2
ν_e
ν_μ
ν_τ
Normal
Inverted
m_3^2
m_2^2
m_1^2
atmospheric
~2×10⁻³eV²
solar~7×10⁻⁵eV²
?
0


disfavoured by 0ν2β
$\Delta m^2_{23} < 0$
$\Delta m^2_{23} > 0$
90% CL (1 dof)
disfavoured by cosmology
$|m_{ee}|$ in eV
lightest neutrino mass in eV


$\Delta\chi^2$
$\sin^2\theta_{12}$
$\sin^2\theta_{23}$
$\sin^2\theta_{13}$
Δm^2_{21} [10^{-5}eV^2]
Δm^2_{31} [10^{-3}eV^2]
δ/π

Neutrino Astronomy



n -> p + e- + ν (anti)

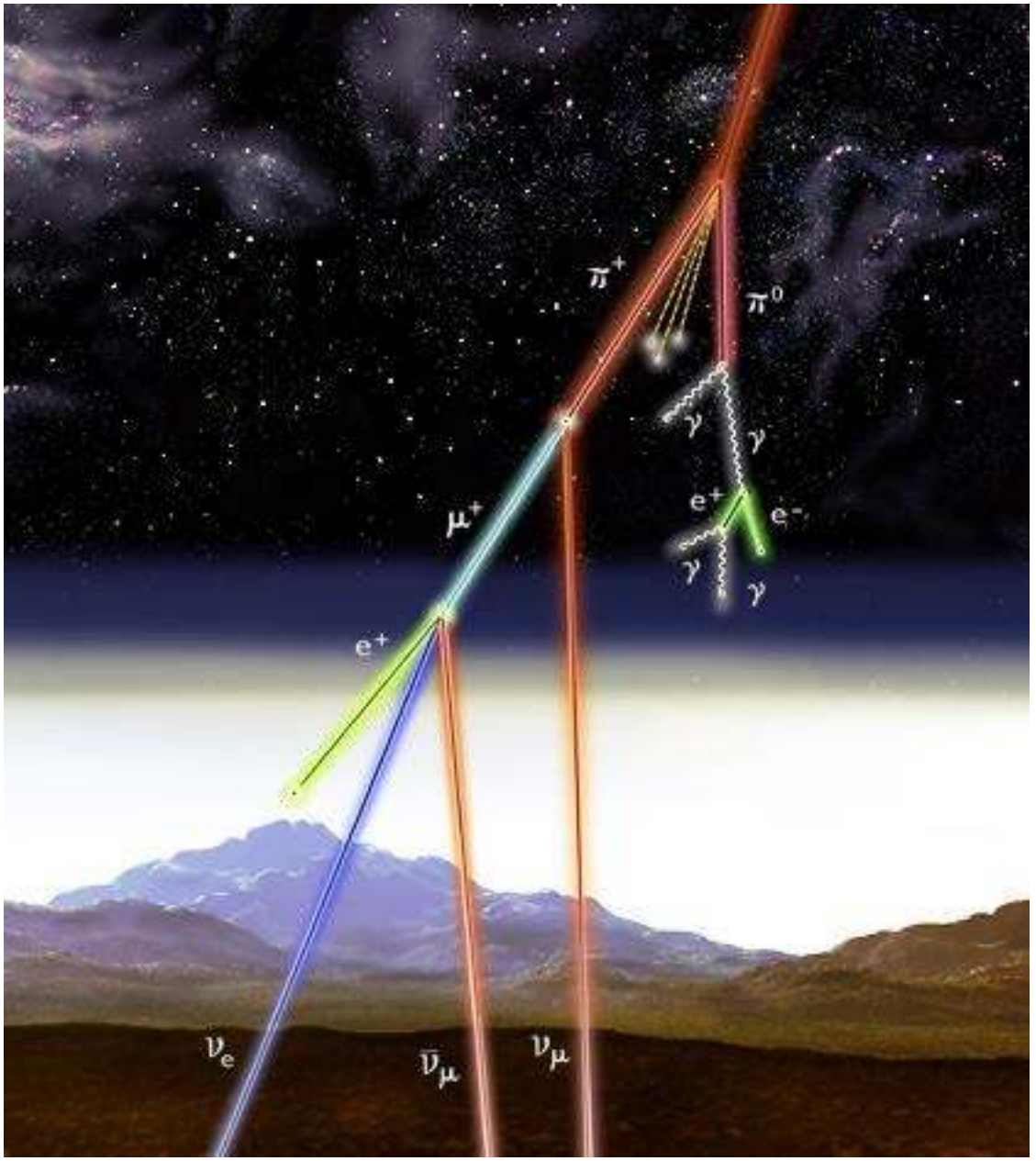
$$\pi^+ \rightarrow \mu^+ + \nu_\mu$$

$$\mu^+ \rightarrow e^+ + \nu_e + \bar{\nu}_\mu$$

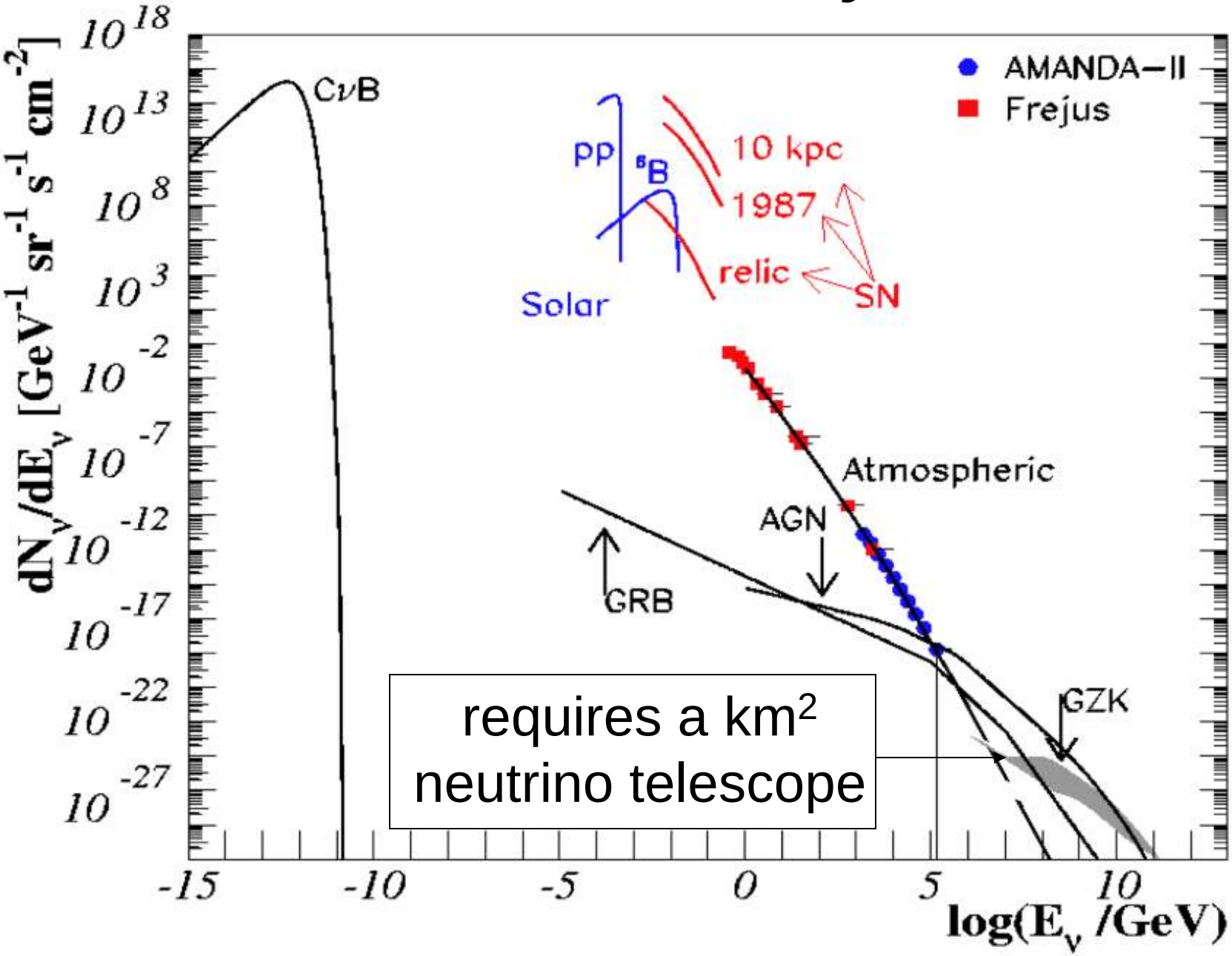
> 100 EeV

$$p + \gamma_{\mathrm{CMB}} \rightarrow \Delta^+ \rightarrow n + \pi^+$$

$$p + N, O \rightarrow \pi^\pm$$



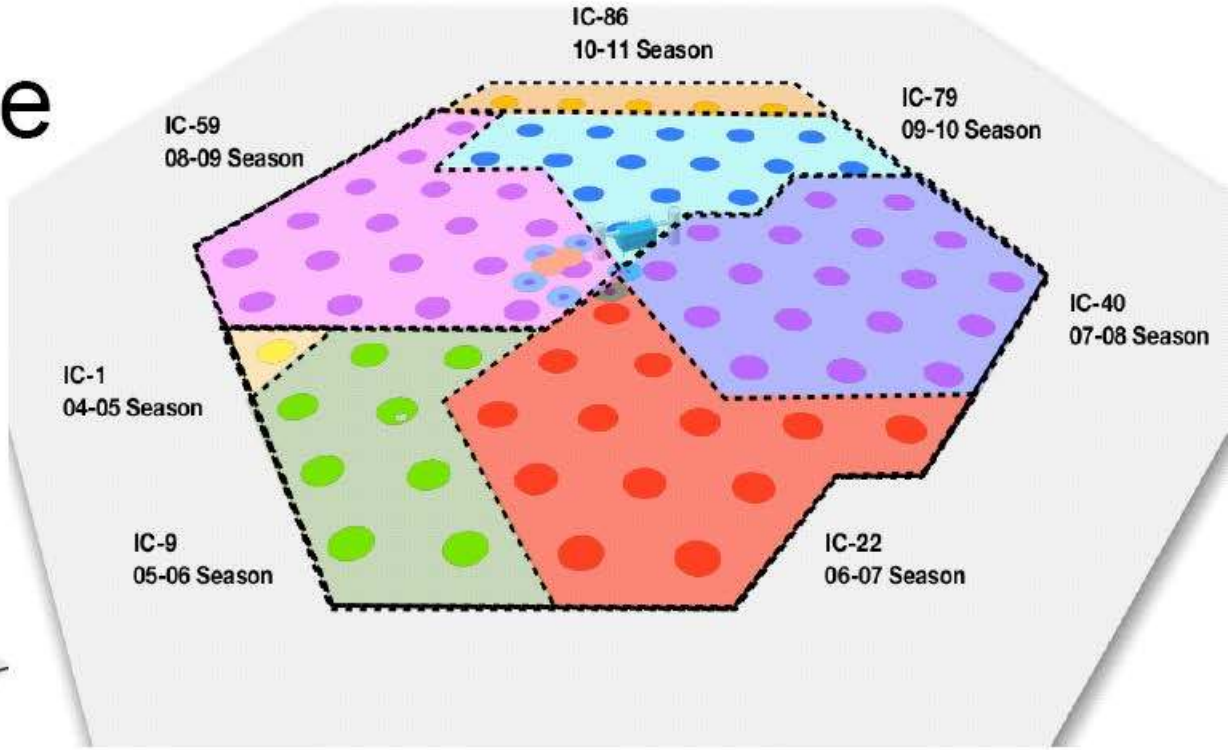
neutrino sky



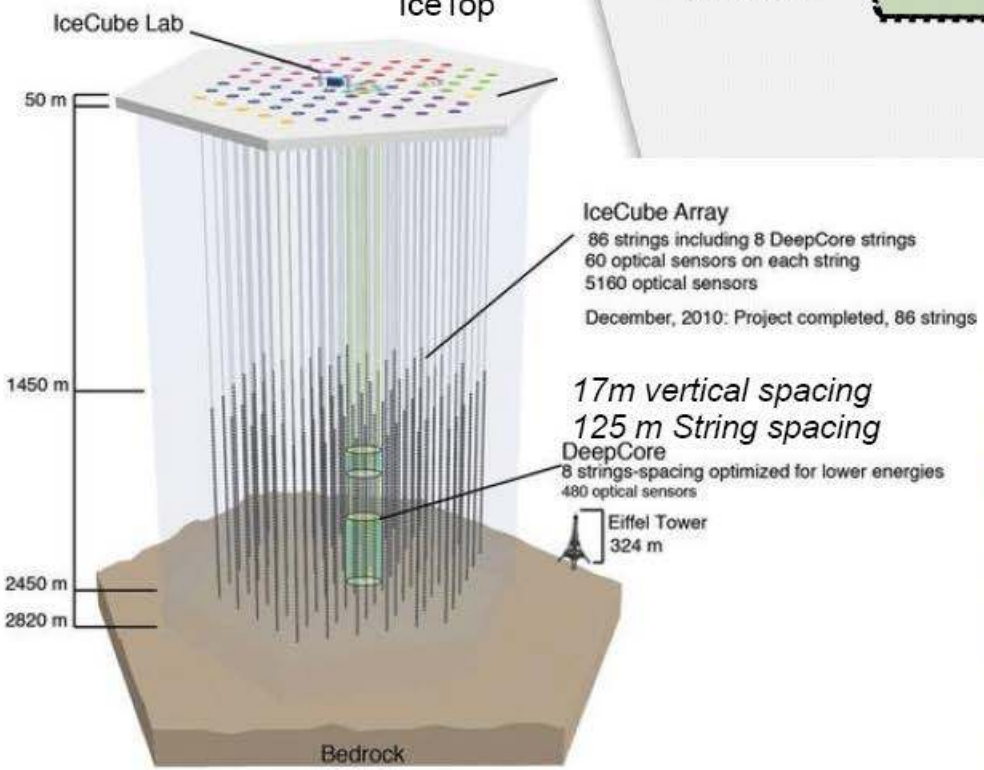
requires a km^2 neutrino telescope

The IceCube Detector

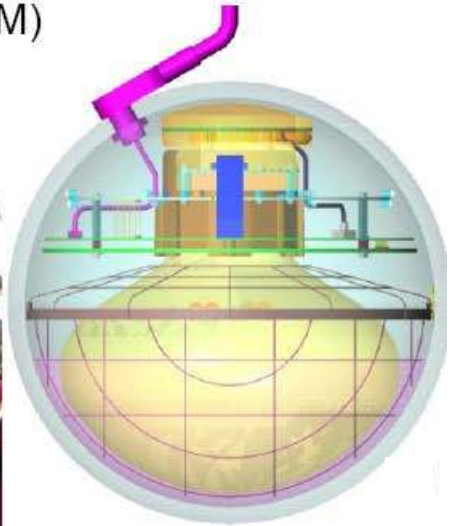
Completed 2 yrs ago!

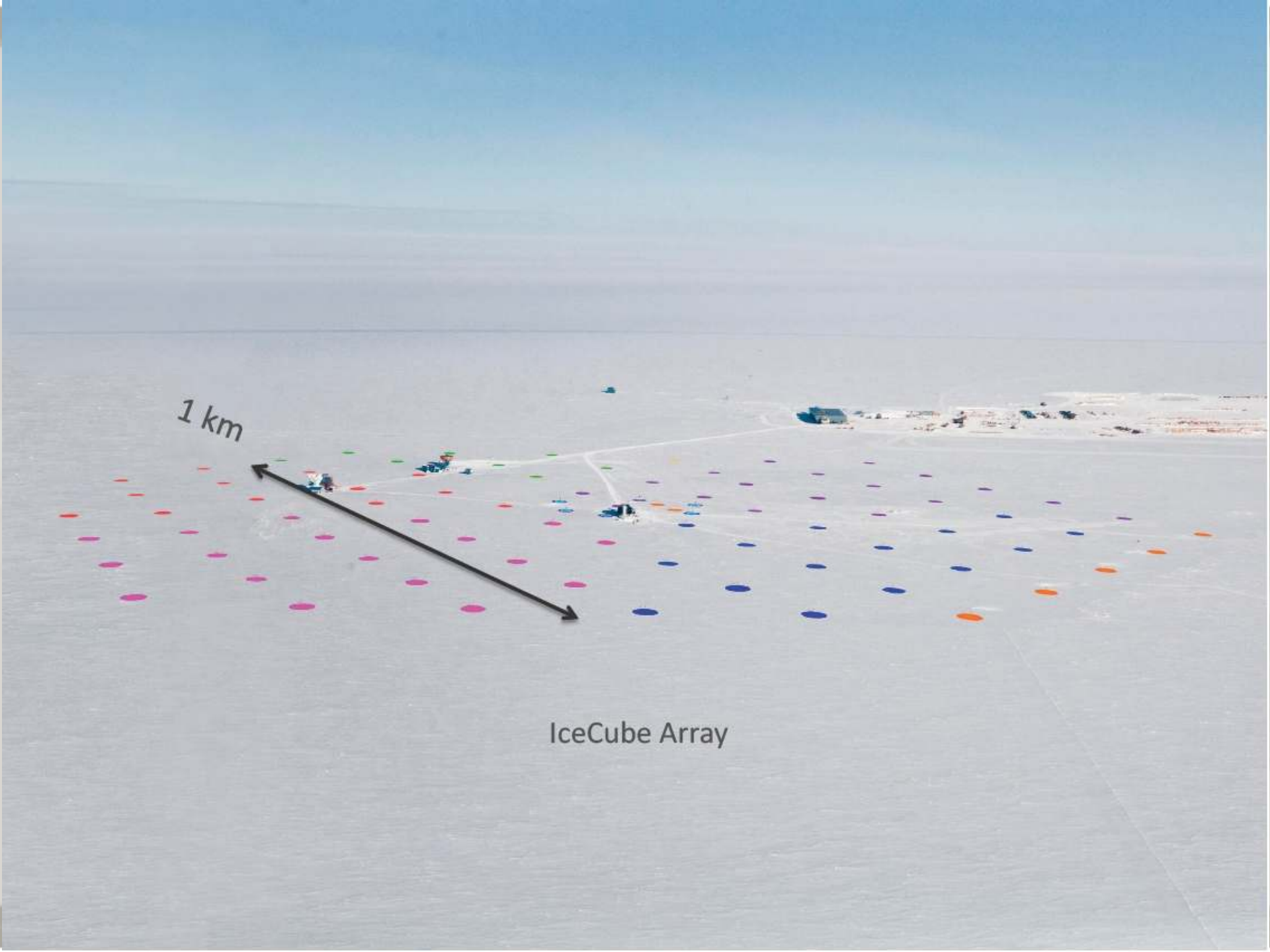


IceCube and it's two extensions
DeepCore
IceTop



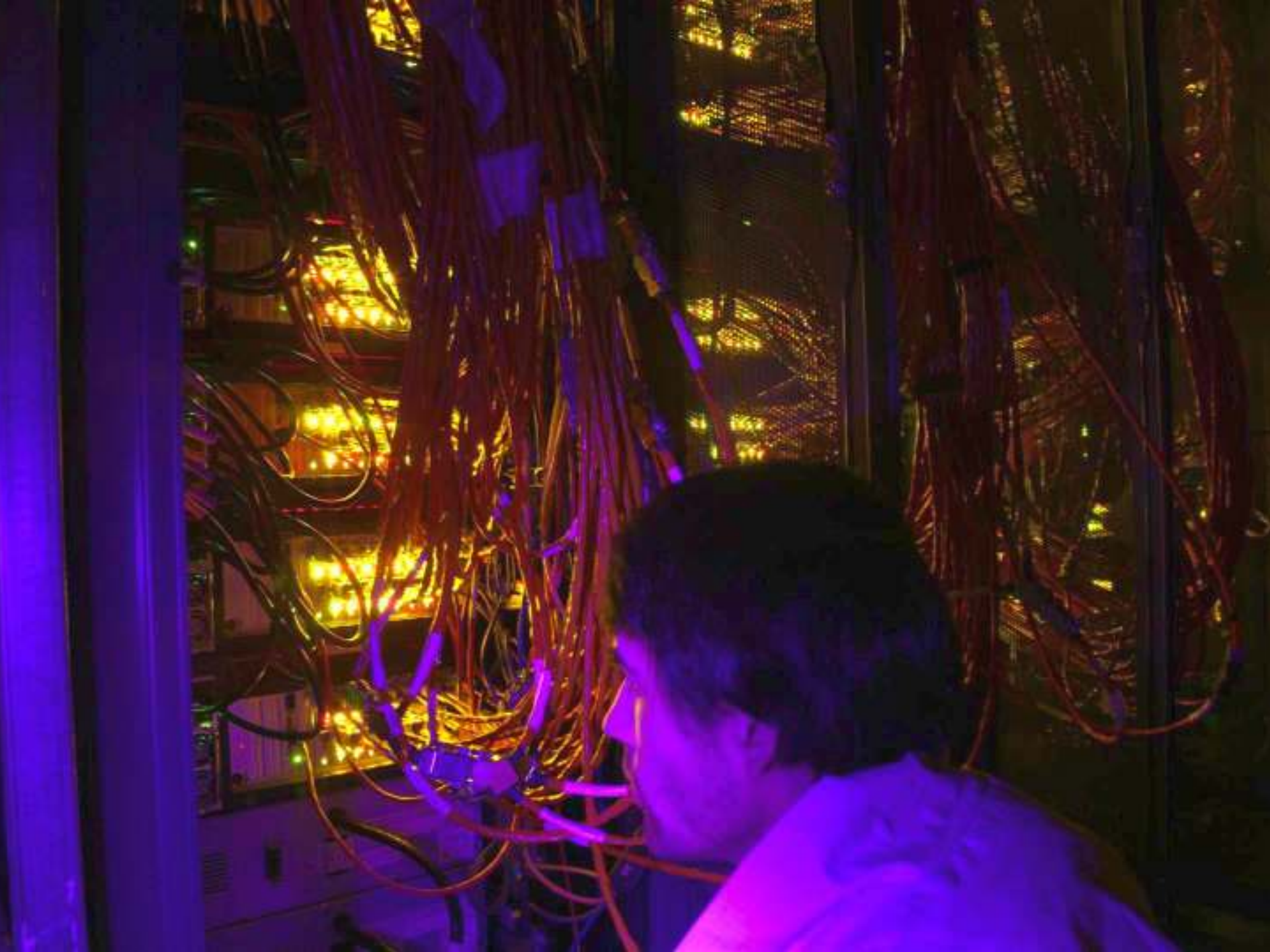
Digital Optical Module (DOM)




1 km
IceCube Array

drilling.flv

descending.flv



SPS Status

Data Acquisition

Current run: **120391** (2h:39m:22s)
Run config: sps-IC86-change-some-DOM-settings-after-the-pilot-run-V207
DAQ release: Ale_Asylum_12772:83769
Events: 24675661
Active DOMs: 5400

Light mode: **dark** Change: LID

Control Details

pdaq RUNNING

Other Components

DB	RUNNING	stop
GammaFollowUp	RUNNING	stop
I3DAQDispatch	RUNNING	stop
I3MoniDomMon	RUNNING	stop
I3MoniDomSn	RUNNING	stop
I3MoniDomTcal	RUNNING	stop
I3MoniMover	RUNNING	stop
I3MoniPhysA	RUNNING	stop
OpticalFollowUp	RUNNING	stop
PFFiltDispatch	RUNNING	stop

Recent Alerts from Components

Condition	Triggered
filter mask added	10 hours, 20 minutes ago
filter mask added	10 hours, 24 minutes ago
crash	10 hours, 25 minutes ago
crash	10 hours, 25 minutes ago
crash	10 hours, 25 minutes ago
crash	10 hours, 25 minutes ago
crash	10 hours, 25 minutes ago
crash	10 hours, 25 minutes ago
crash	10 hours, 25 minutes ago
crash	10 hours, 25 minutes ago

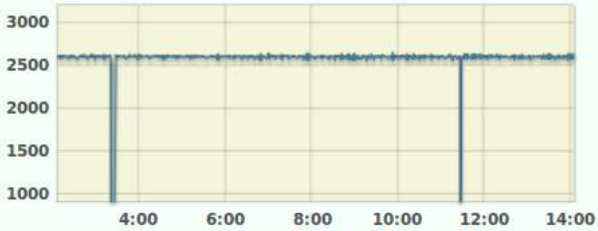
.... 282 more.

Currently Watched Alerts

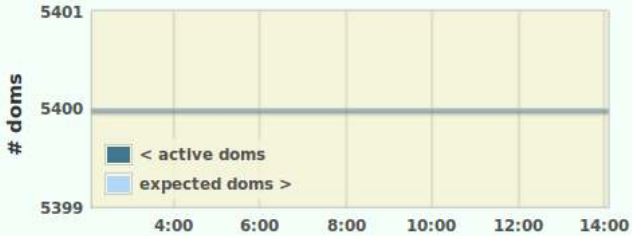
runfail	OK
multirunfail	OK
min_pdaq_activeDOMs=5390,5390	OK
/mnt/data/pdaqlo...n.tar file count	OK
Detector not taking data	OK
ICL overtemp max1	OK
ICL overtemp max2	OK
ICL overtemp min2	OK
ICL temperature too high	OK
Lots of LBM overflows	OK

Graphs

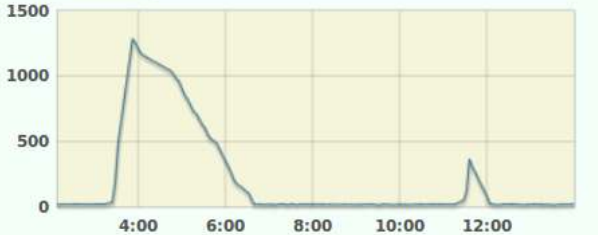
(Detailed rates page)
pDAQ Event Rate (Hz)

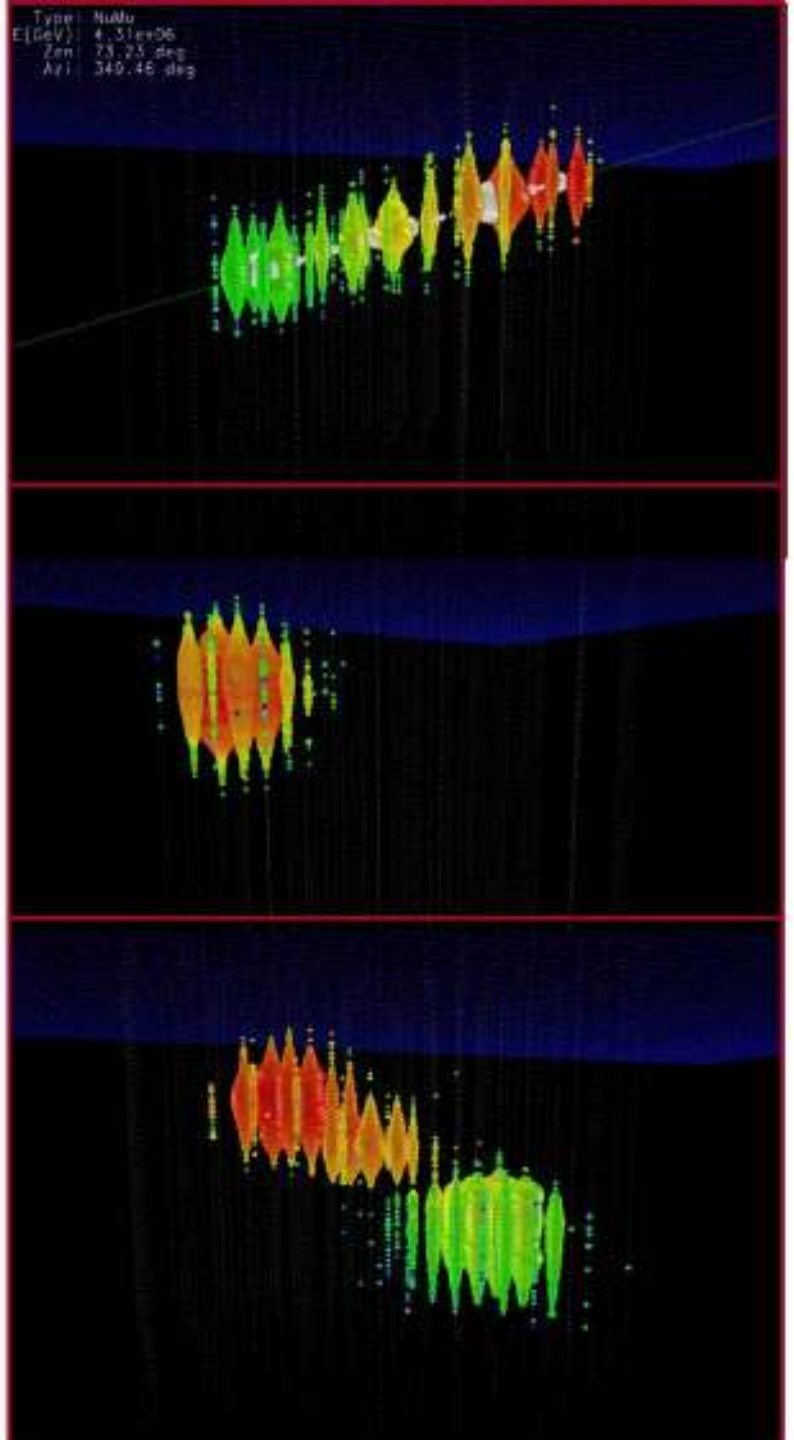


Active DOMs



PnF Latency (sec)





νμ CC

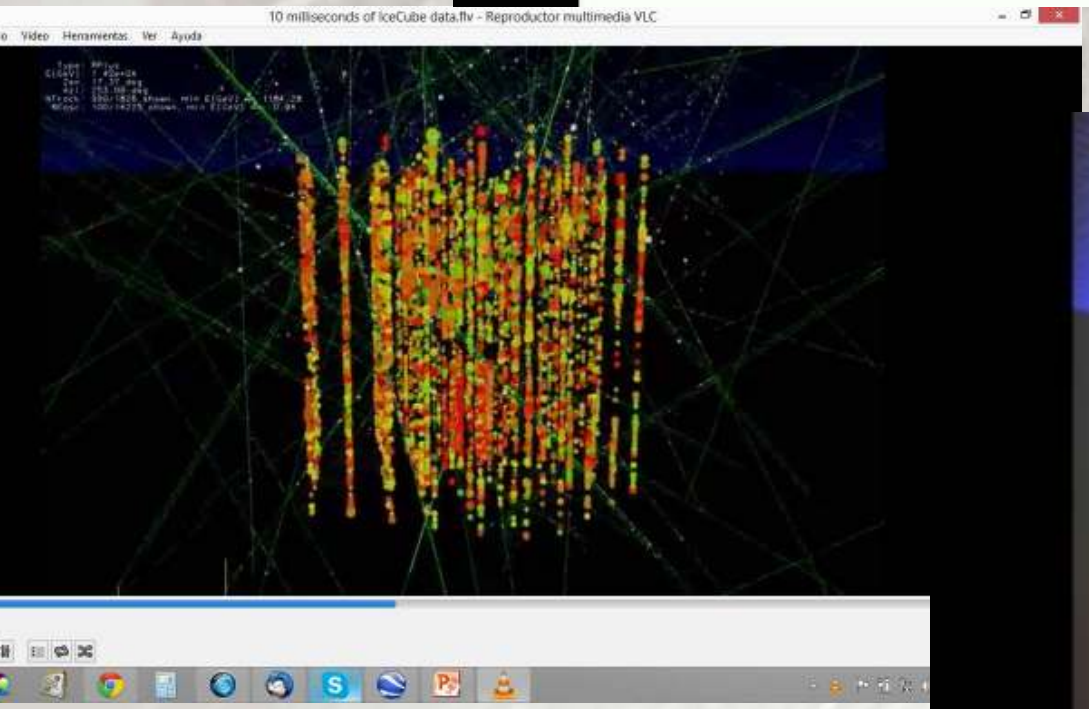
νμ + N -> μ + cascade

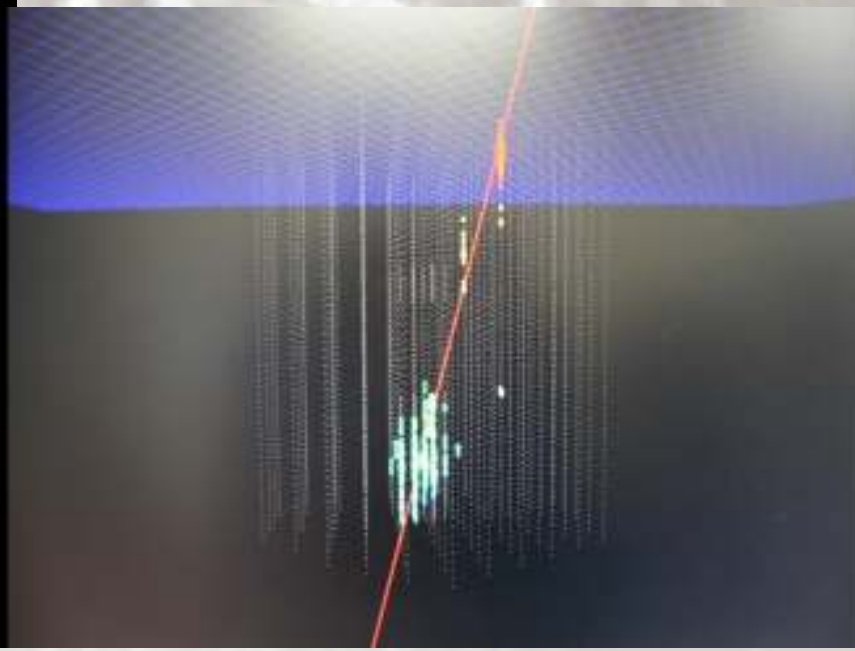
ν NC + νe CC

ν + N -> ν + cascade

ντ CC

ντ + N -> τ + cascade

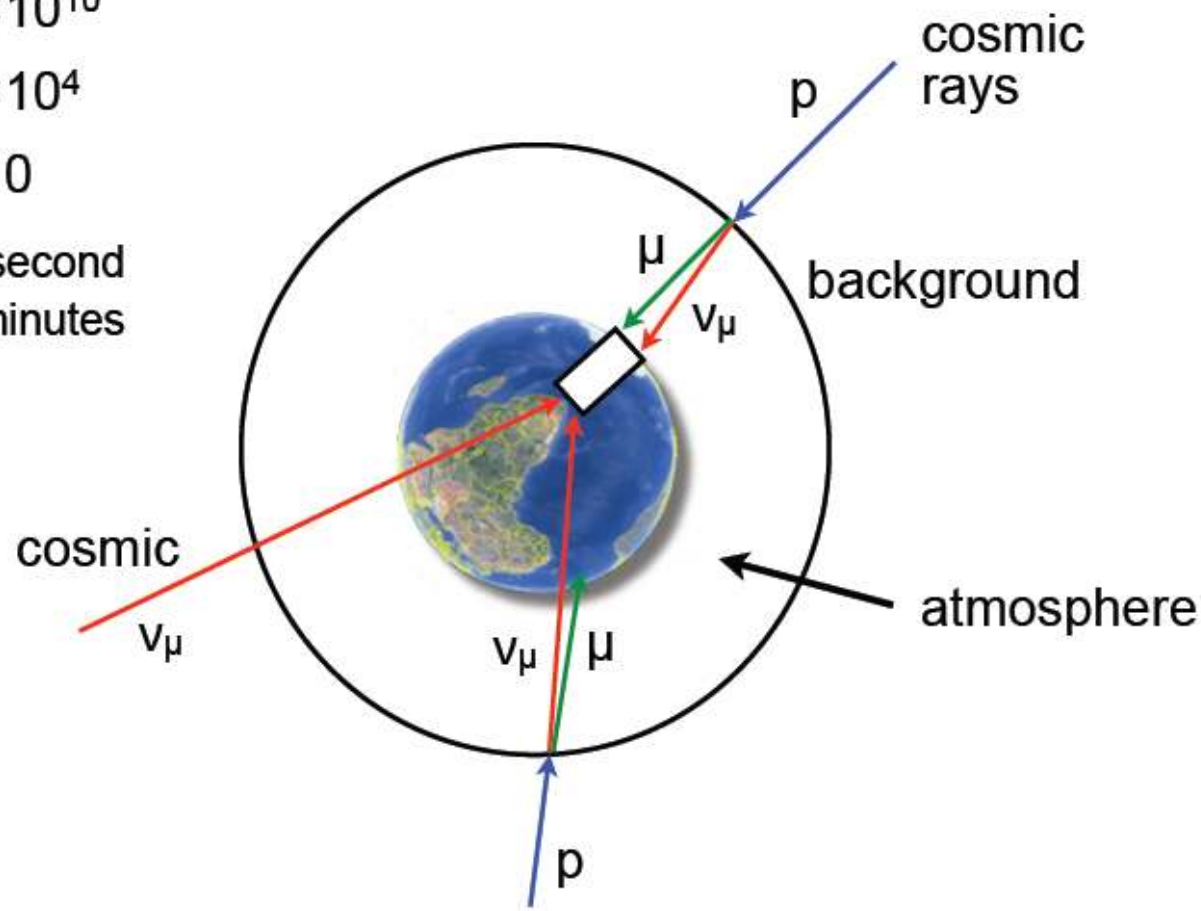

10 milliseconds of IceCube data.flv - Reproductor multimedia VLC
Video
Herramientas
Ver
Ayuda

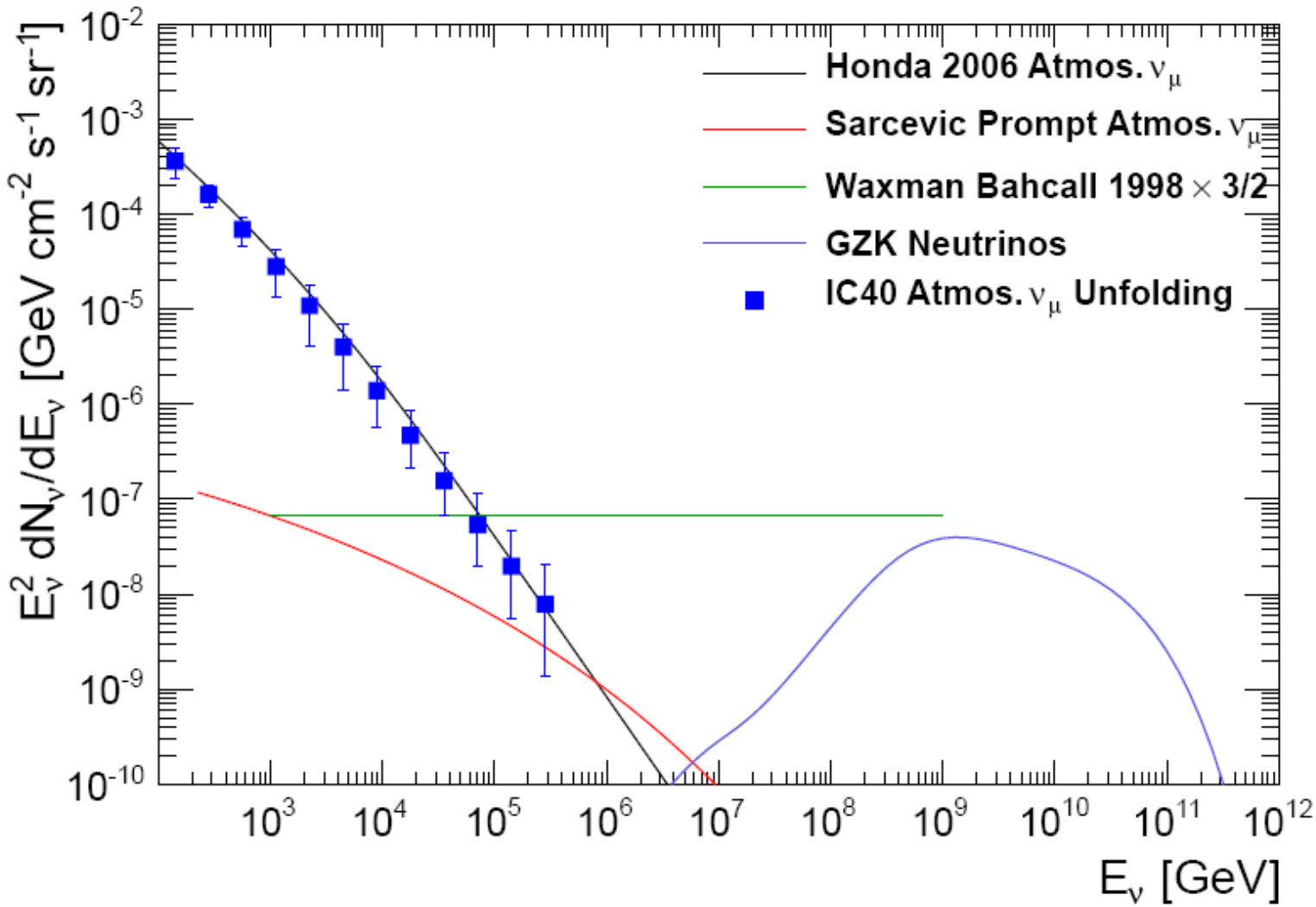


Muons detected per year

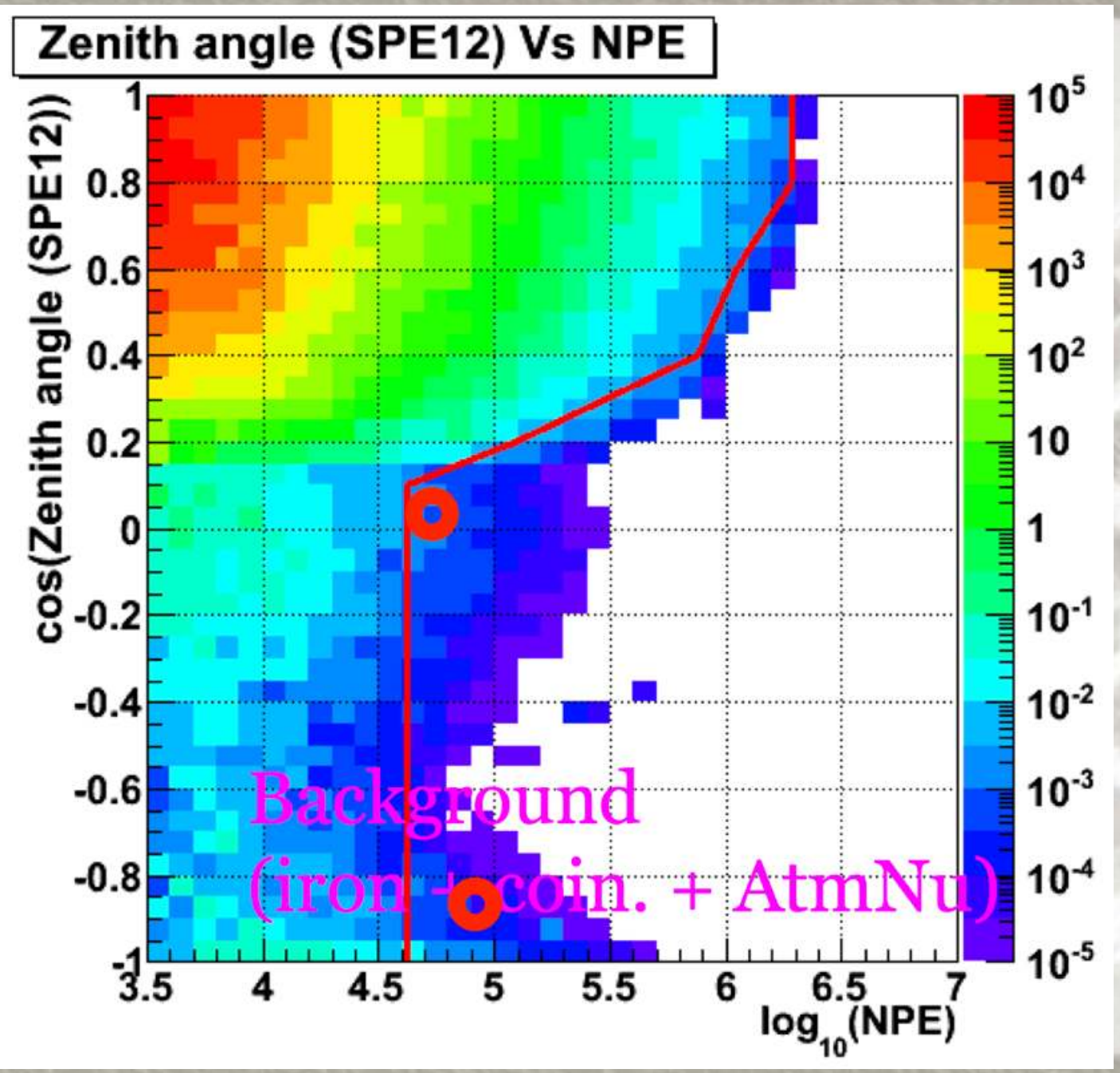
- atmospheric* μ 7×10^{10}
- atmospheric** $\nu\rightarrow\mu$ 8×10^{4}
- cosmic $\nu\rightarrow\mu$ ~10

* 2000 per second
** 1 every 6 minutes

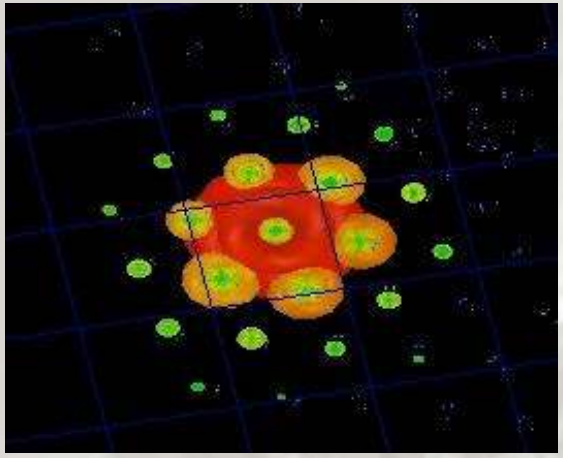




- π/K Atmospheric Neutrinos (dominant $<$ 100 TeV)
- Charm Atmospheric Neutrinos ("prompt", $\sim$ 100 TeV)
- Astrophysical Neutrinos (maybe dominant $>$ 100 TeV)
- Cosmogenic Neutrinos ($>$ 10^6 TeV)

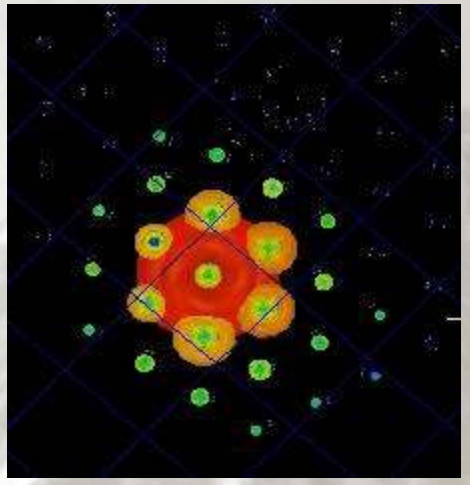


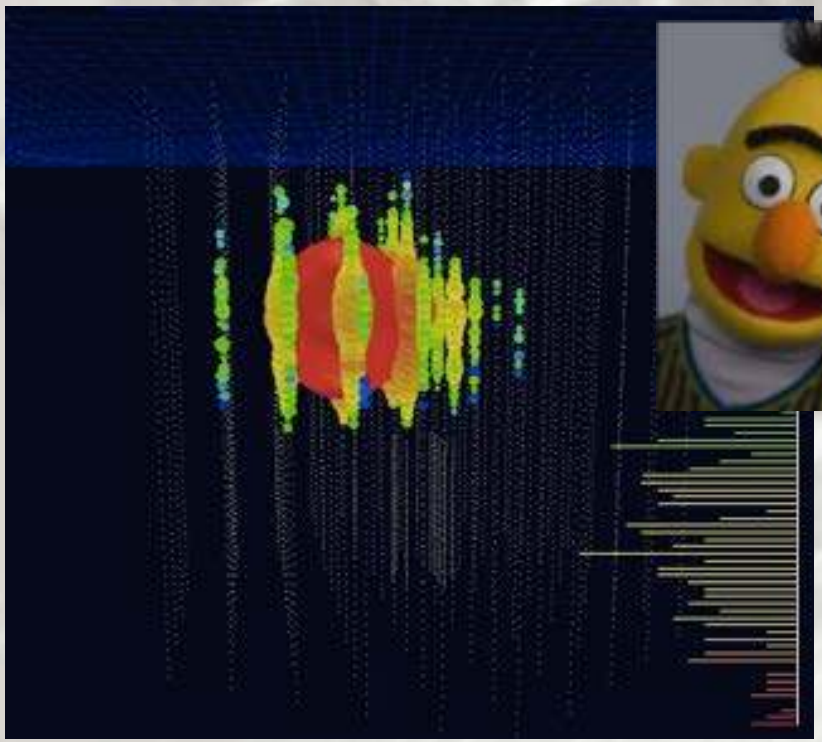
- 0.08 background event expected
- 2 Events Observed
- 2.8 sigma

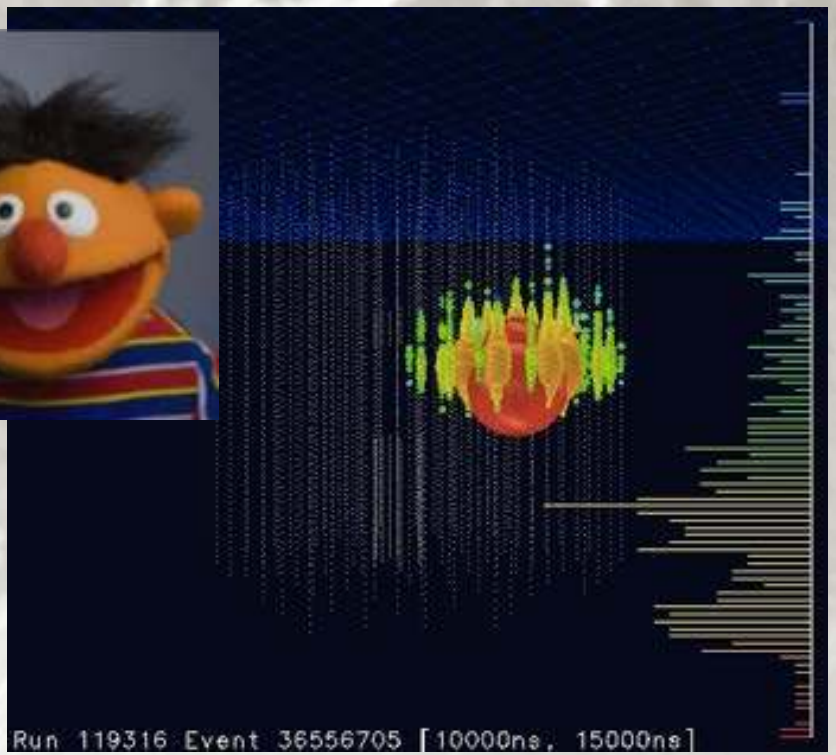


PeV neutrinos!!!

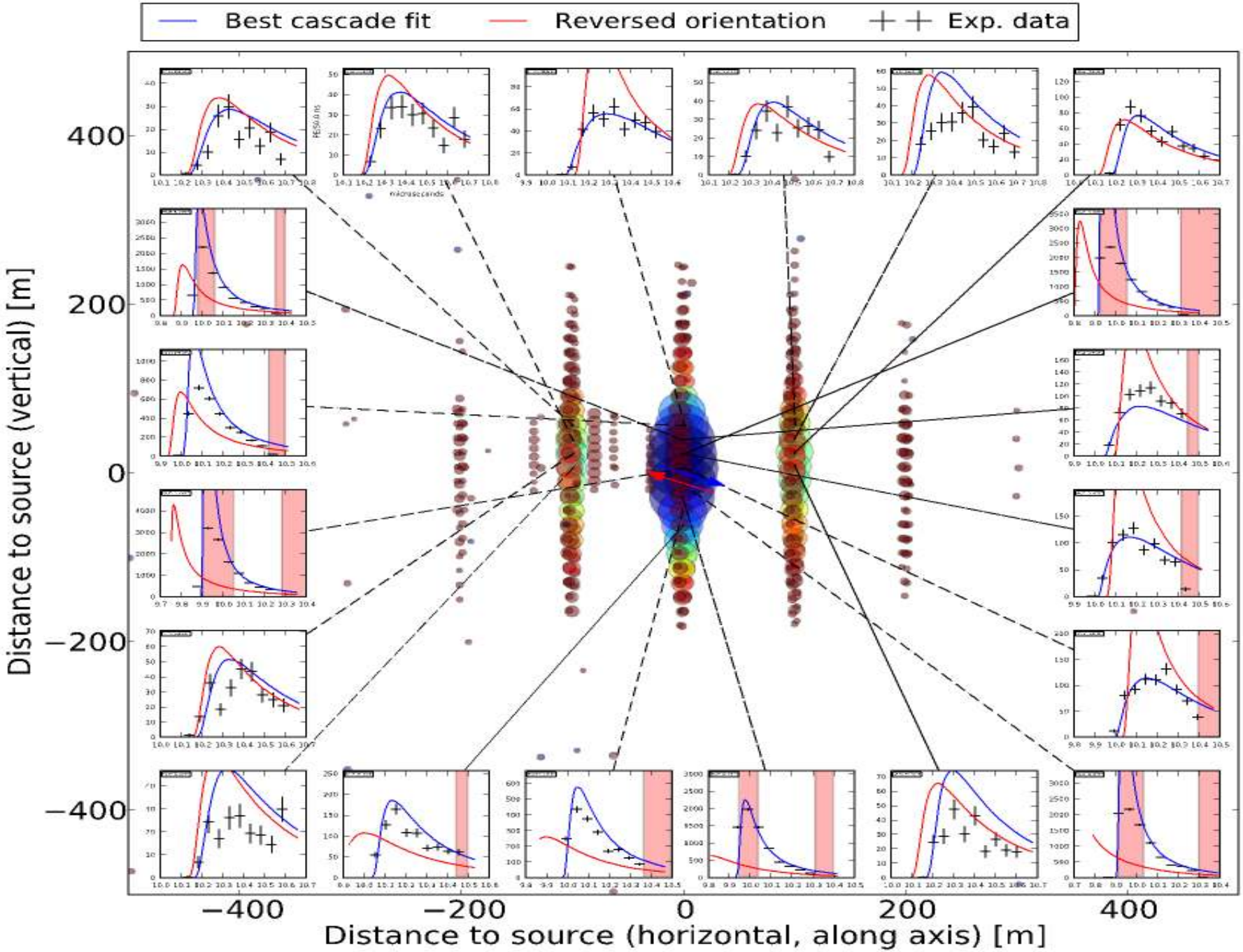
Bert Ernie

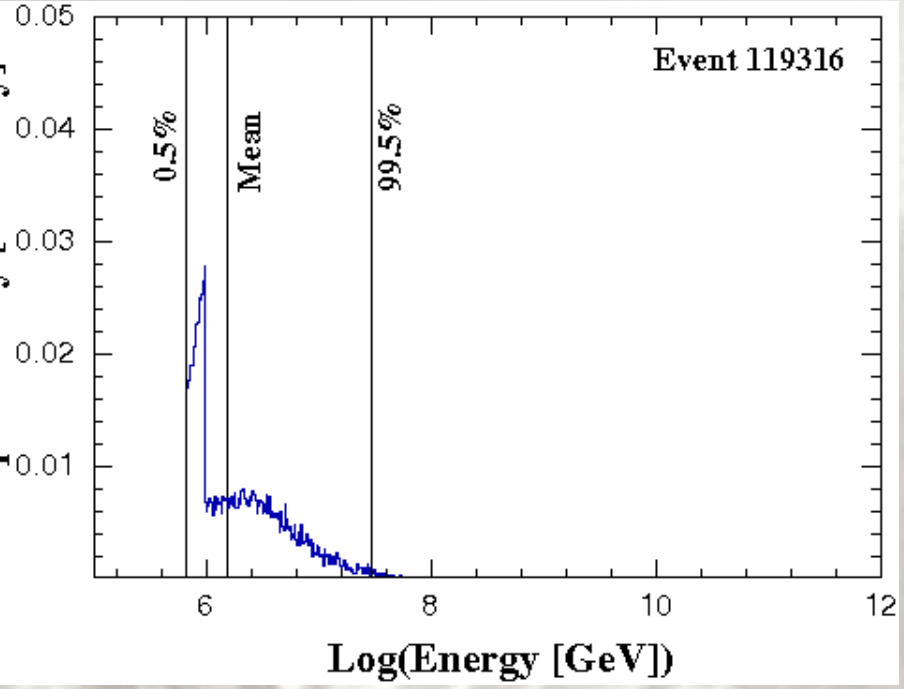


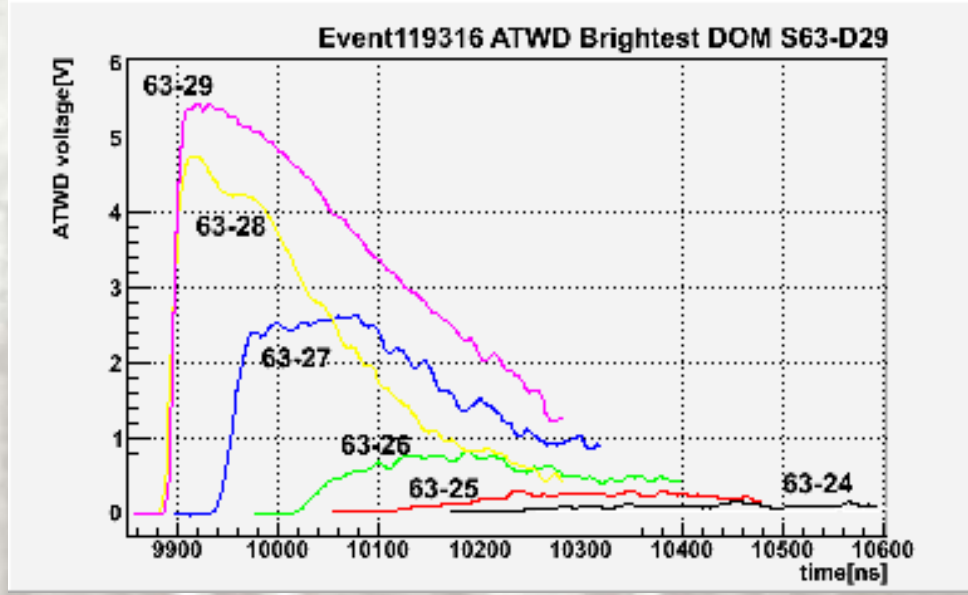




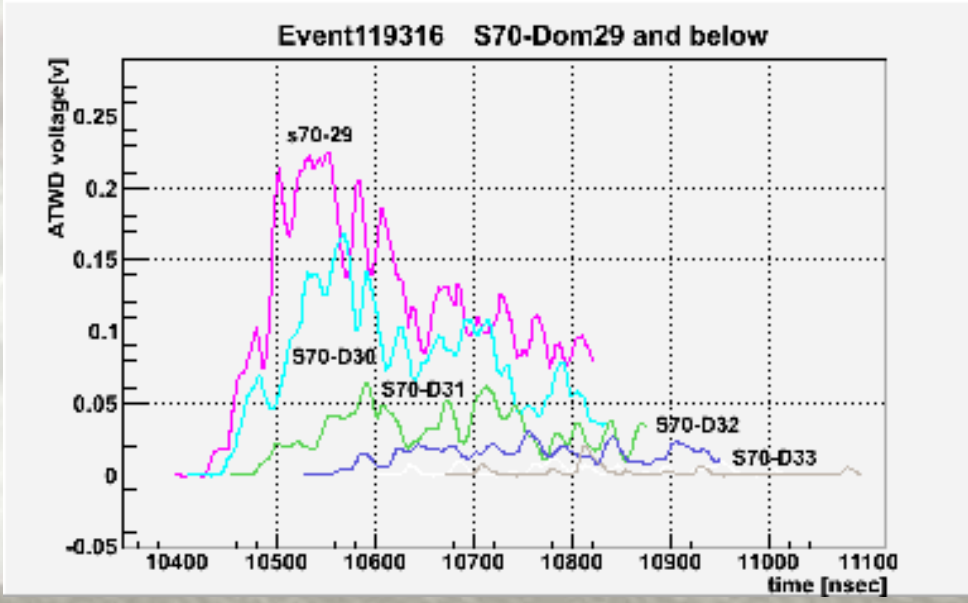
Phys. Rev. Lett. 111, 021103 (2013)

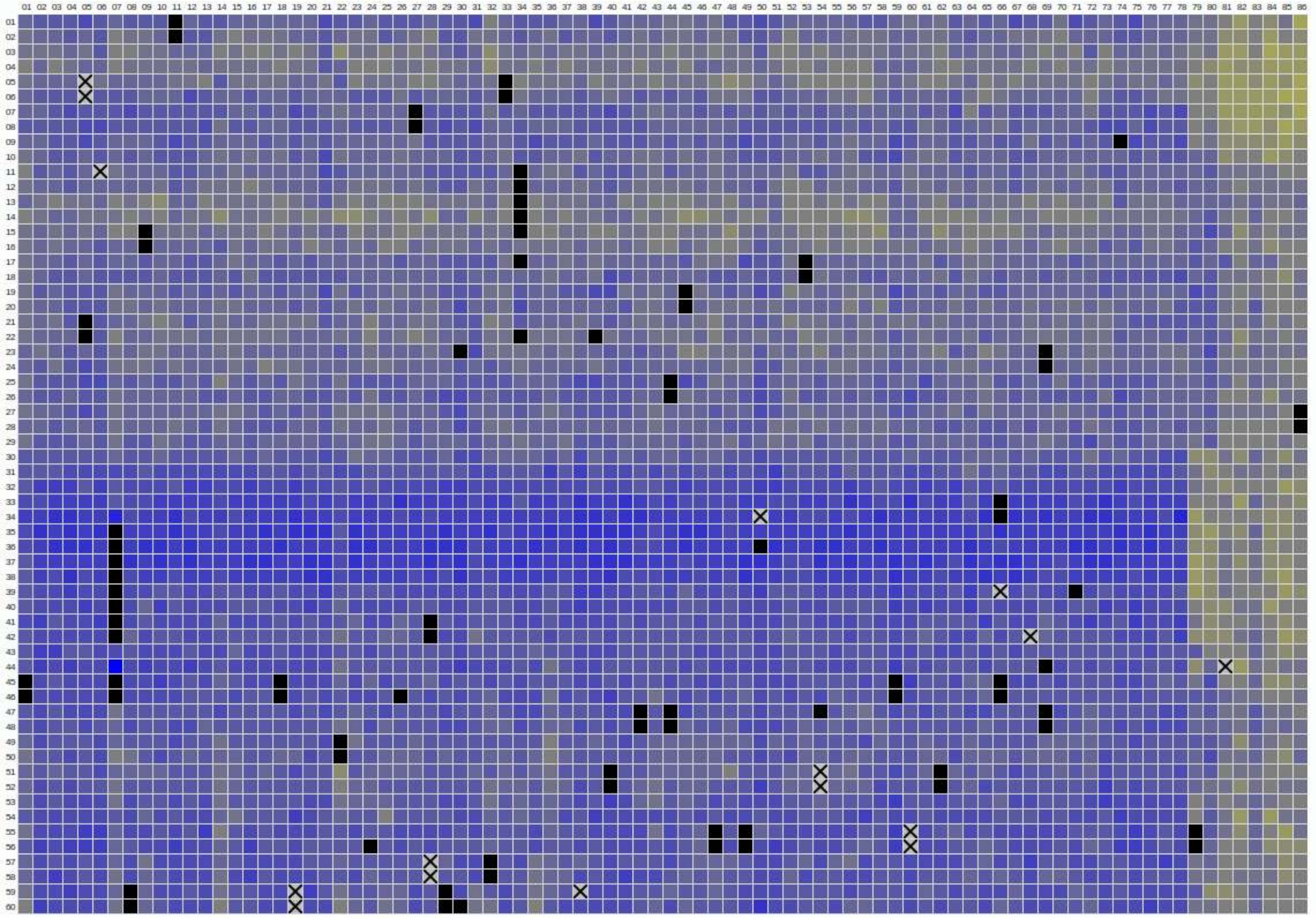

Best cascade fit
Reversed orientation
Exp. data
Distance to source (vertical) [m]
Distance to source (horizontal, along axis) [m]
400
200
0
−200
−400
−400
−200
0
200
400

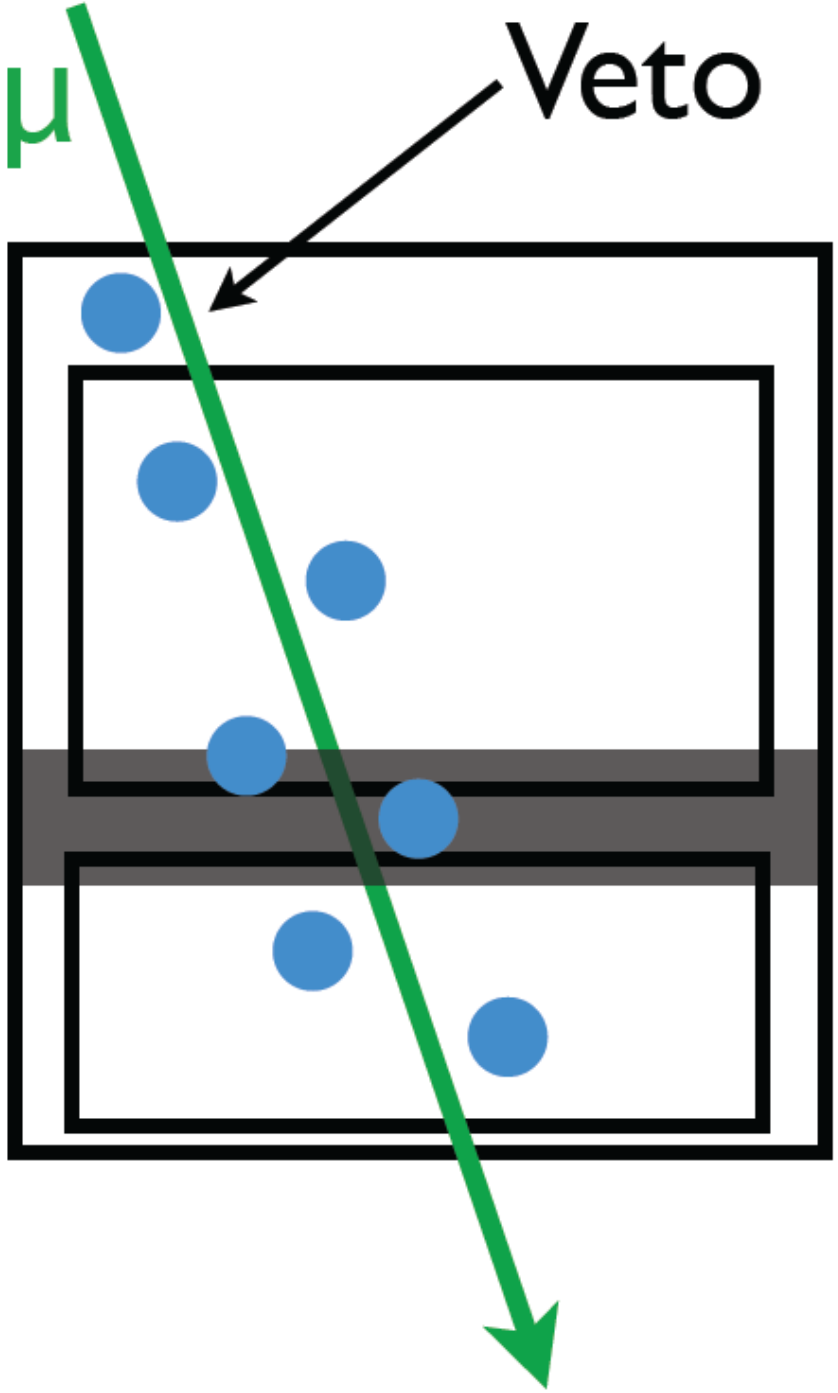


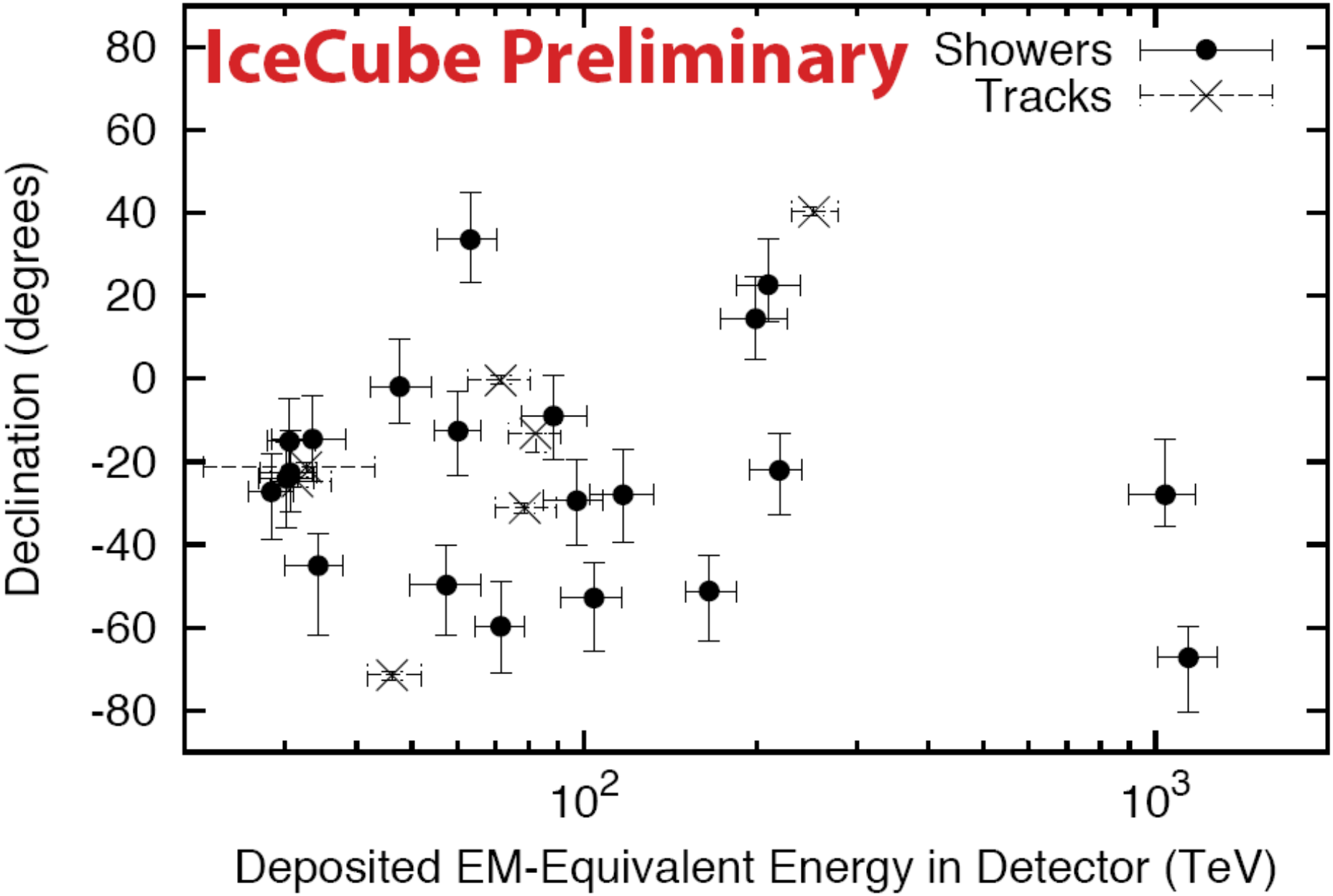


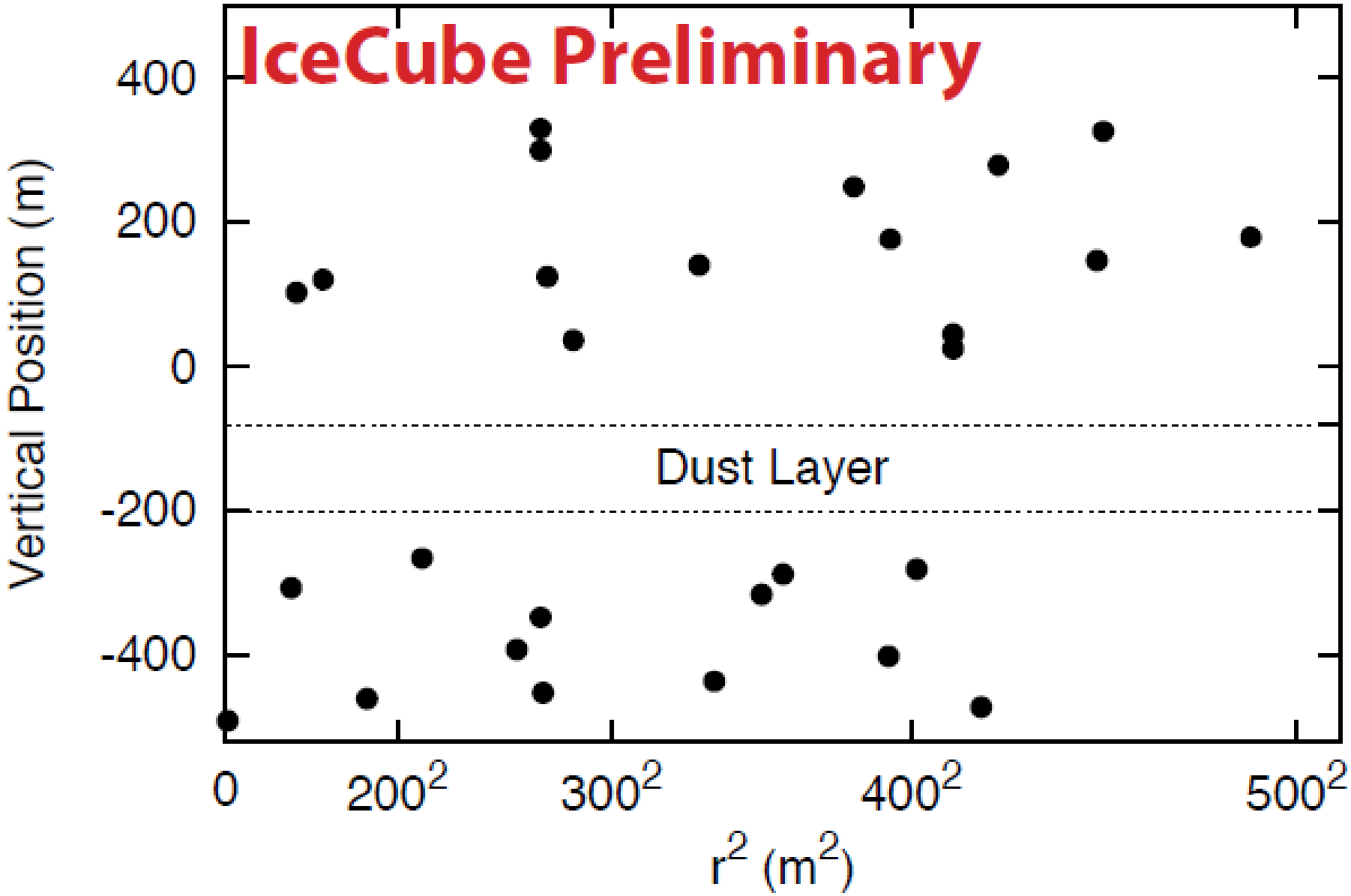
Run119316-Event36556705
Jan 3rd 18:34:01 2012
NPE 9.628×10^4
Nch 312
cos θ(iLF) -0.8658
cos θ(SPE12) -0.8273
cos θ(PoleL2MPE) -0.9994
cos θ(PoleMuonLlh) -0.8983
azimuth(iLF) -0.67
azimuth(SPE12) 0.88
rLogL(SPE12) 7.634
Brightest DOM
S63-D29
NPE 1.796×10^4
x=-66.7, y=276.9, z=21.24

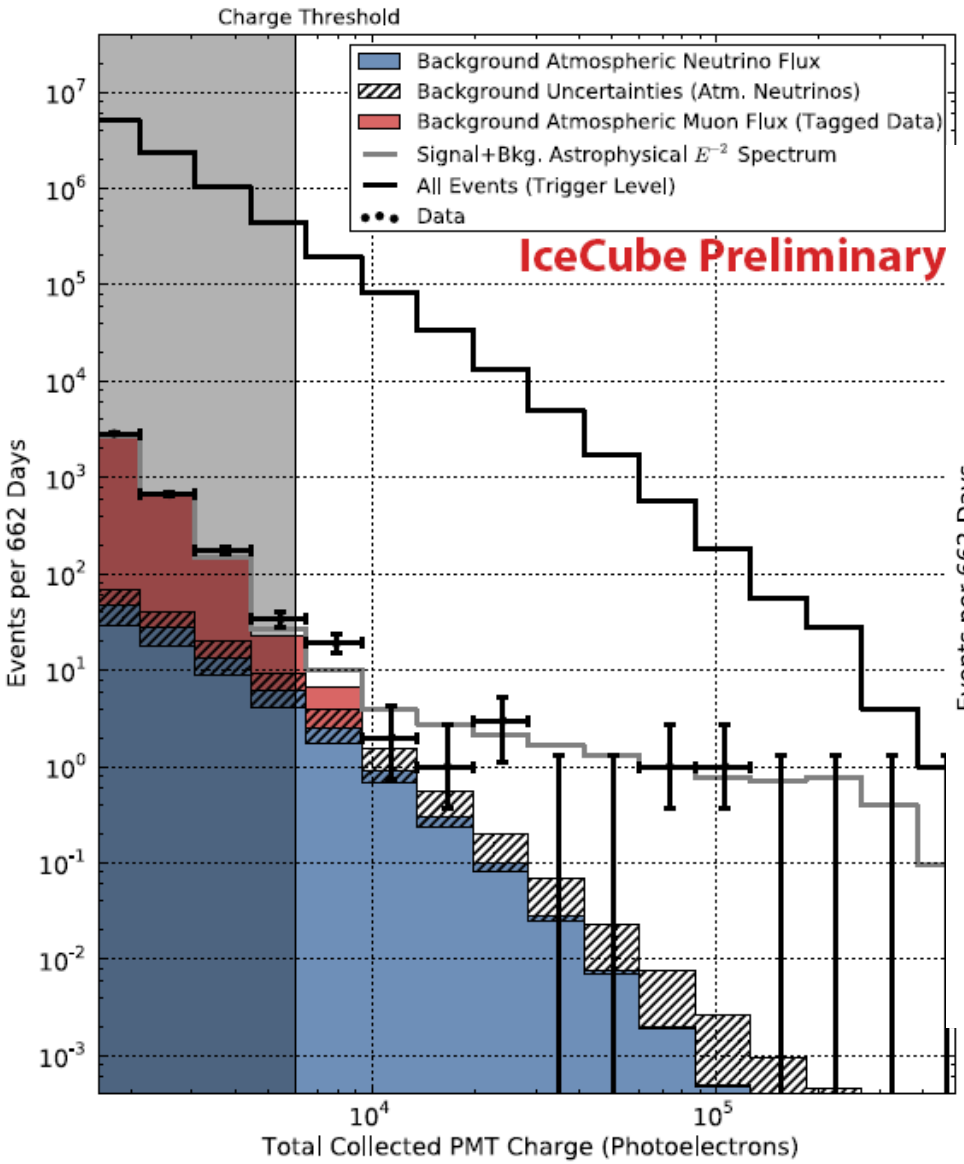


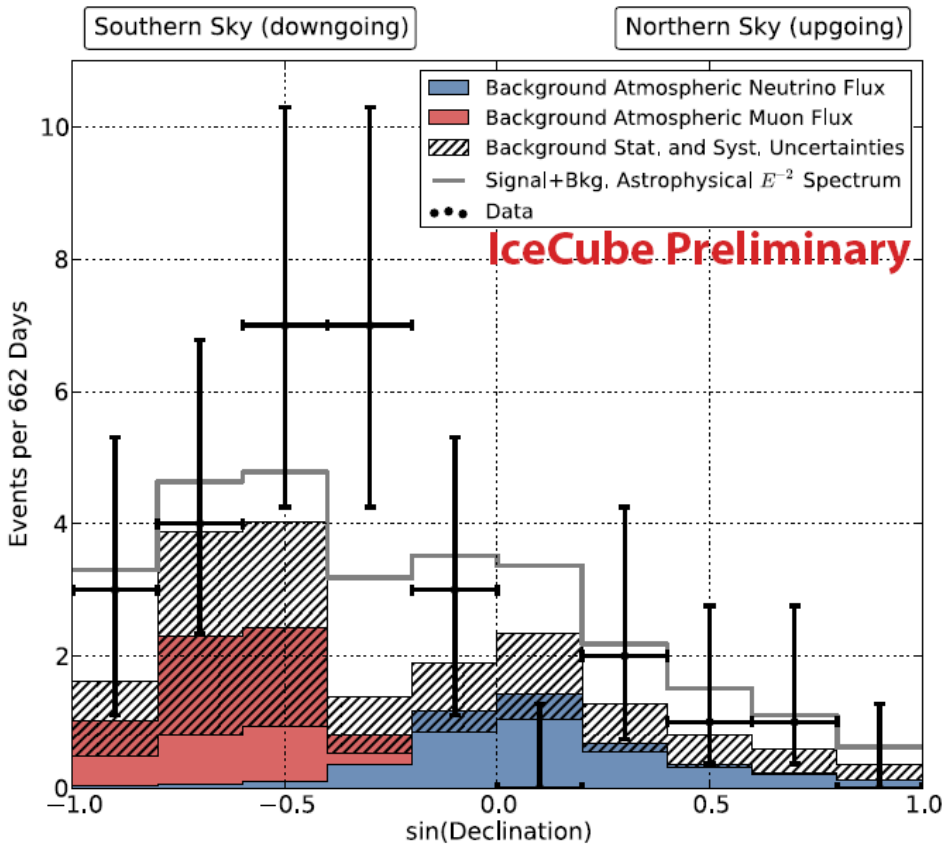



μ
Veto

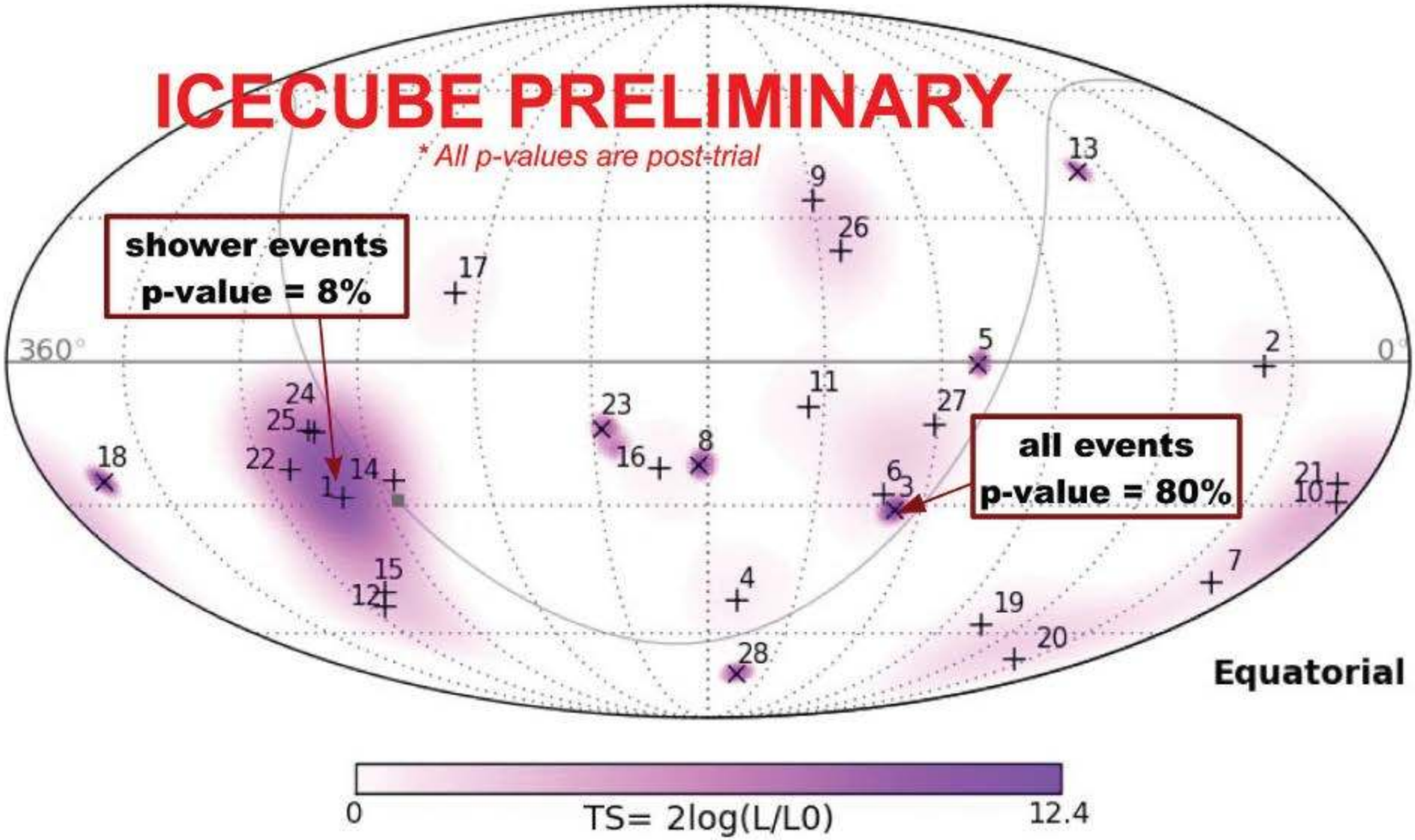

IceCube Preliminary
Showers
Tracks
80
60
40
20
0
-20
-40
-60
-80
Declination (degrees)
10^2
10^3
Deposited EM-Equivalent Energy in Detector (TeV)


IceCube Preliminary
Vertical Position (m)
400
200
0
-200
-400
Dust Layer
0
200²
300²
400²
500²
r² (m²)

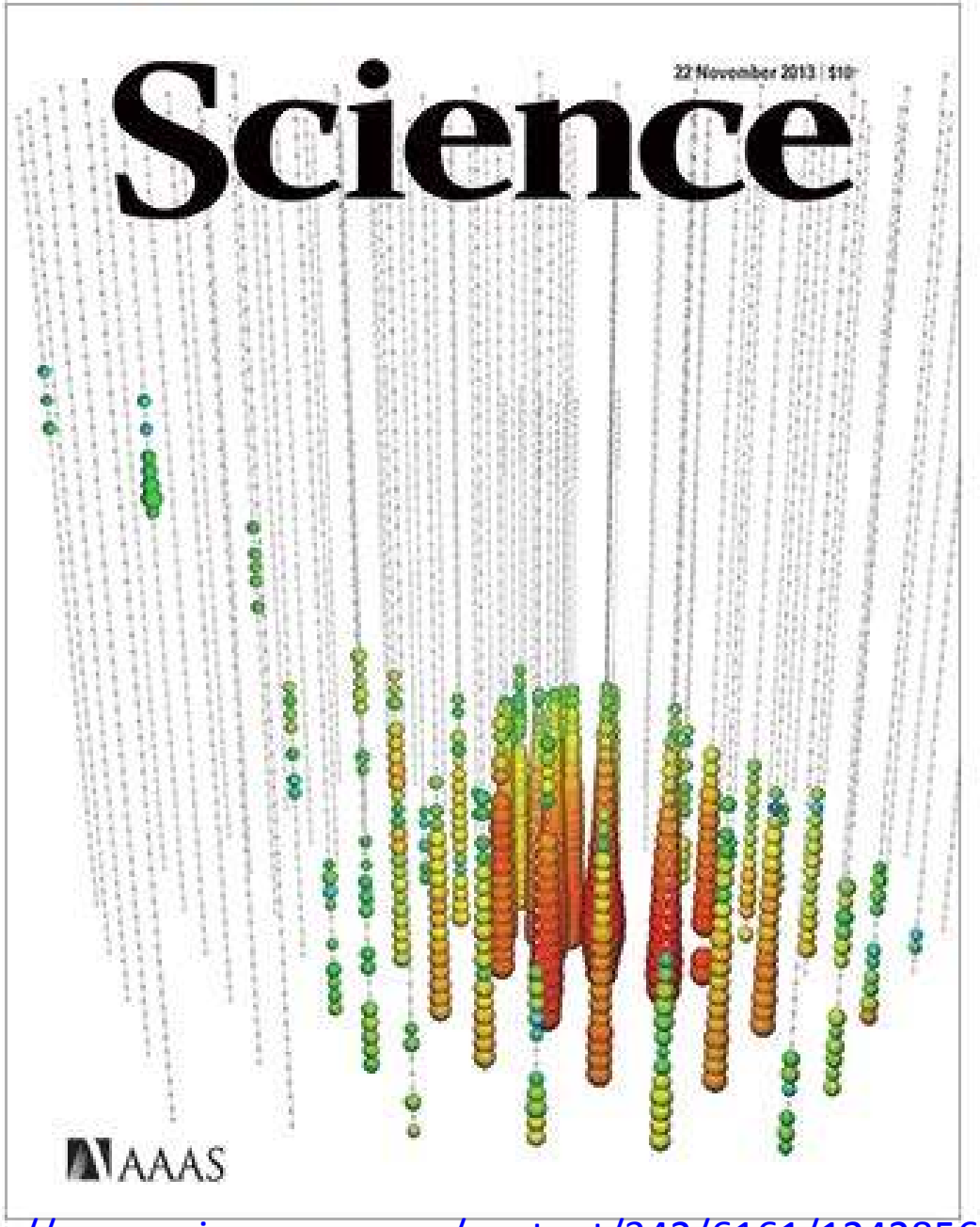




> 4 sigma excess !!! (28 vs 12)


ICECUBE PRELIMINARY
* All p-values are post-trial
shower events
p-value = 8%
all events
p-value = 80%
360°
0°
Equatorial
0
TS= 2log(L/L0)
12.4

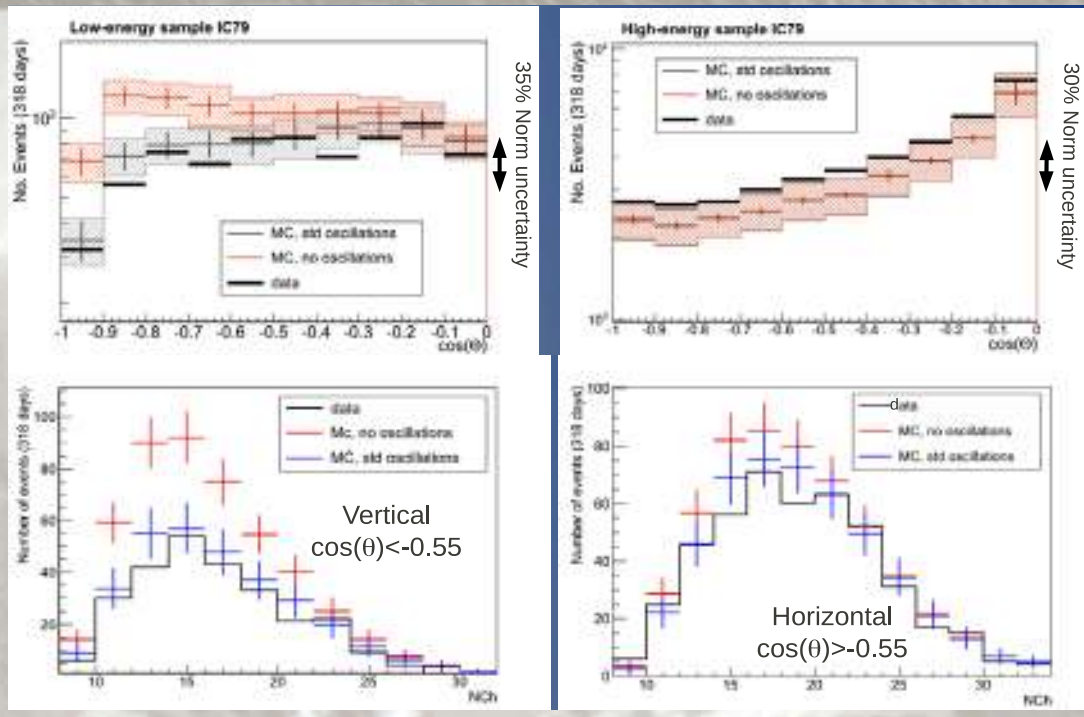
About the Cover

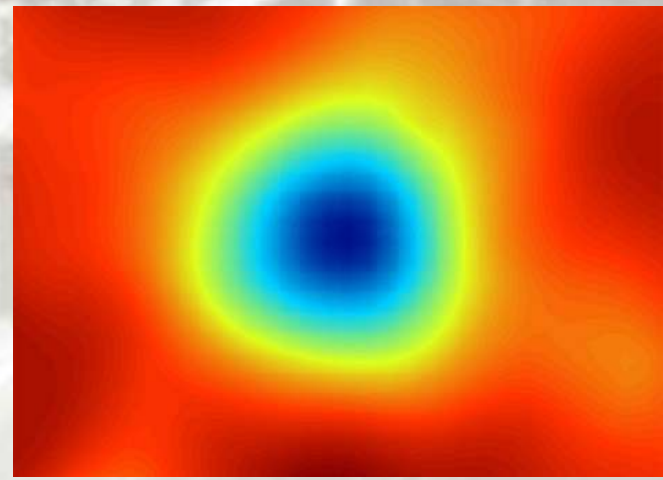


http://www.sciencemag.org/content/342/6161/1242856.full

And more …

- HE oscillations. 5.6sigma a 30GeV
- Indirect Dark Matter searches
- CR physics
- Monopoles, …



Future:

- Askarian Radio emission -> several km3 volume
- PINGU. LE extension for mass hierarchy and indirect DM
- …