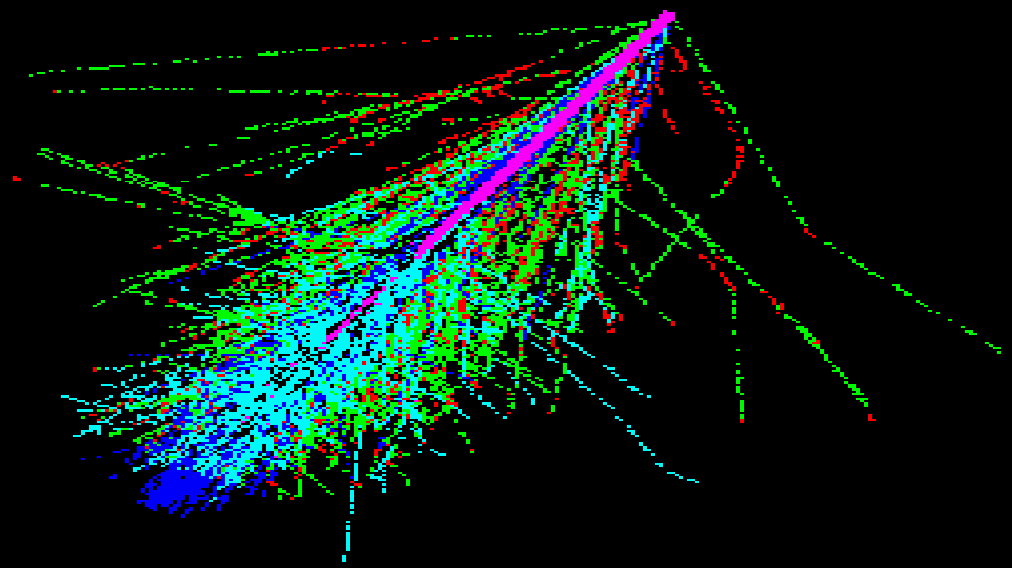
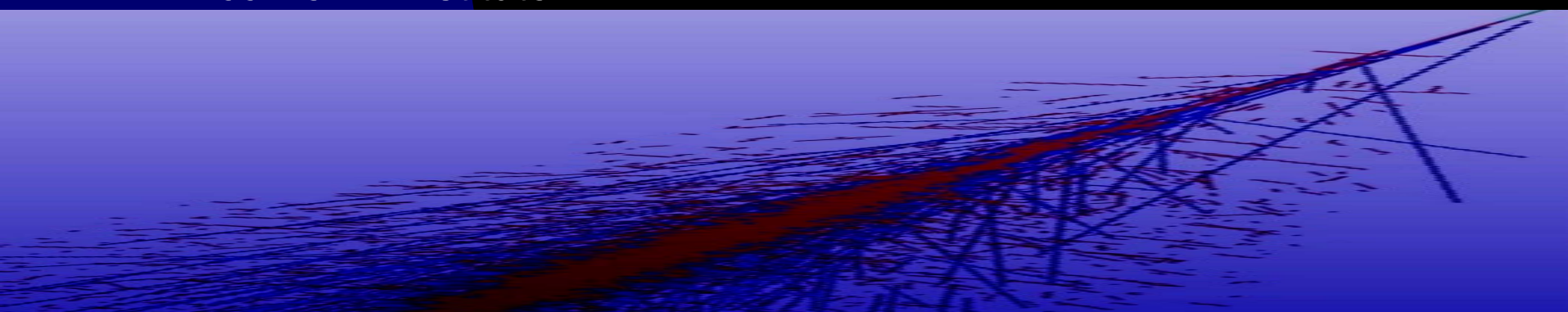
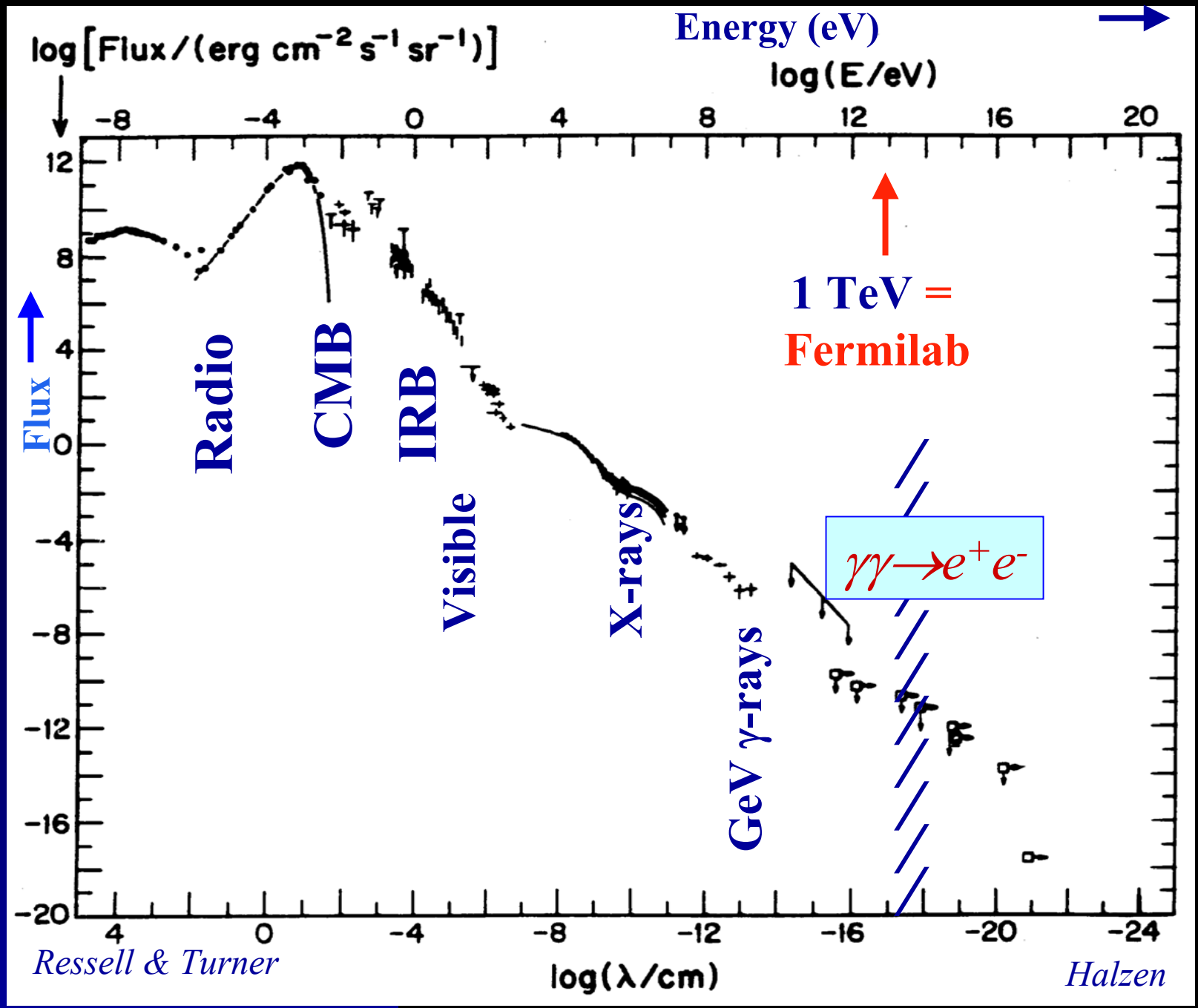
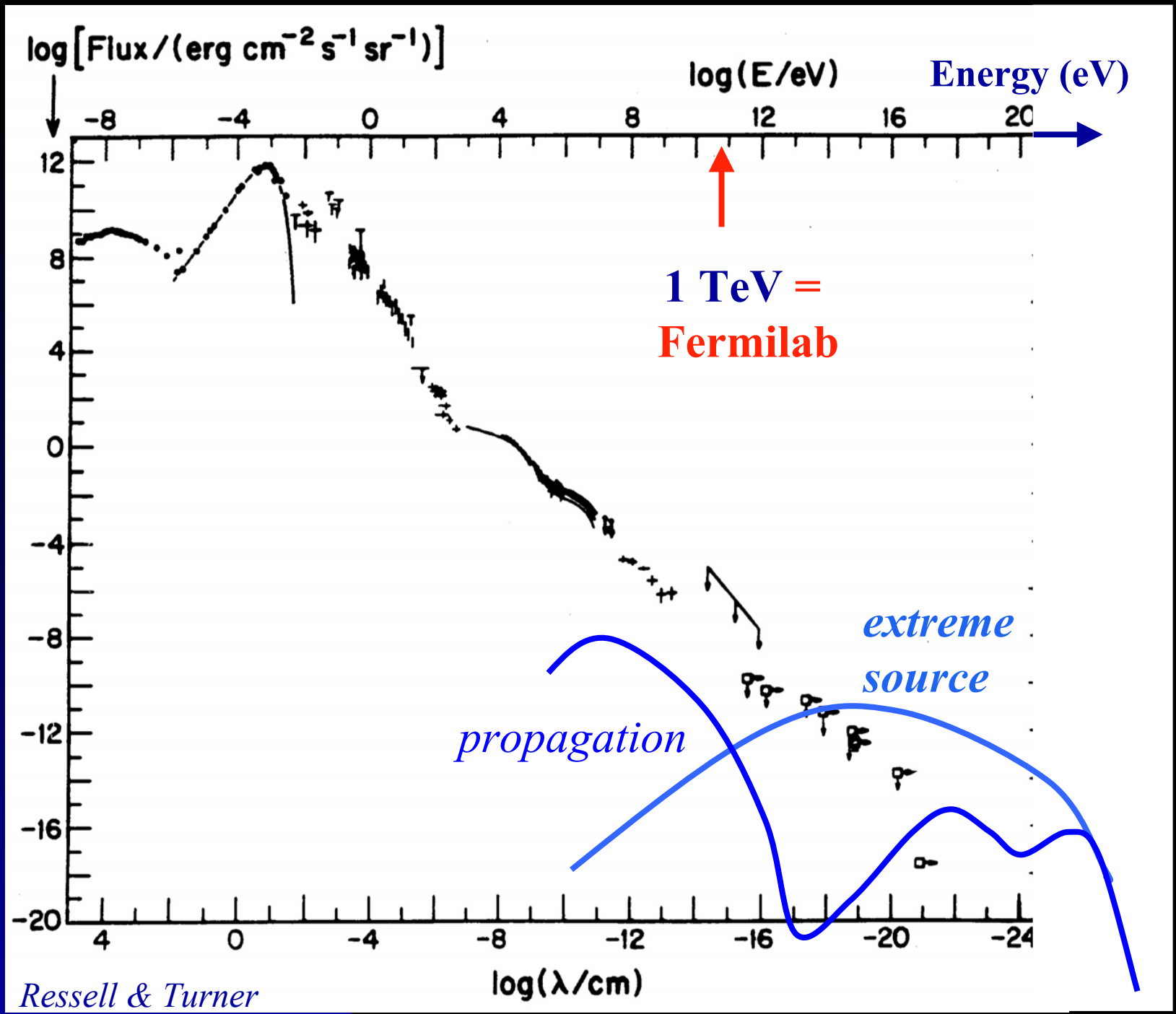
Messengers of the Extreme Universe



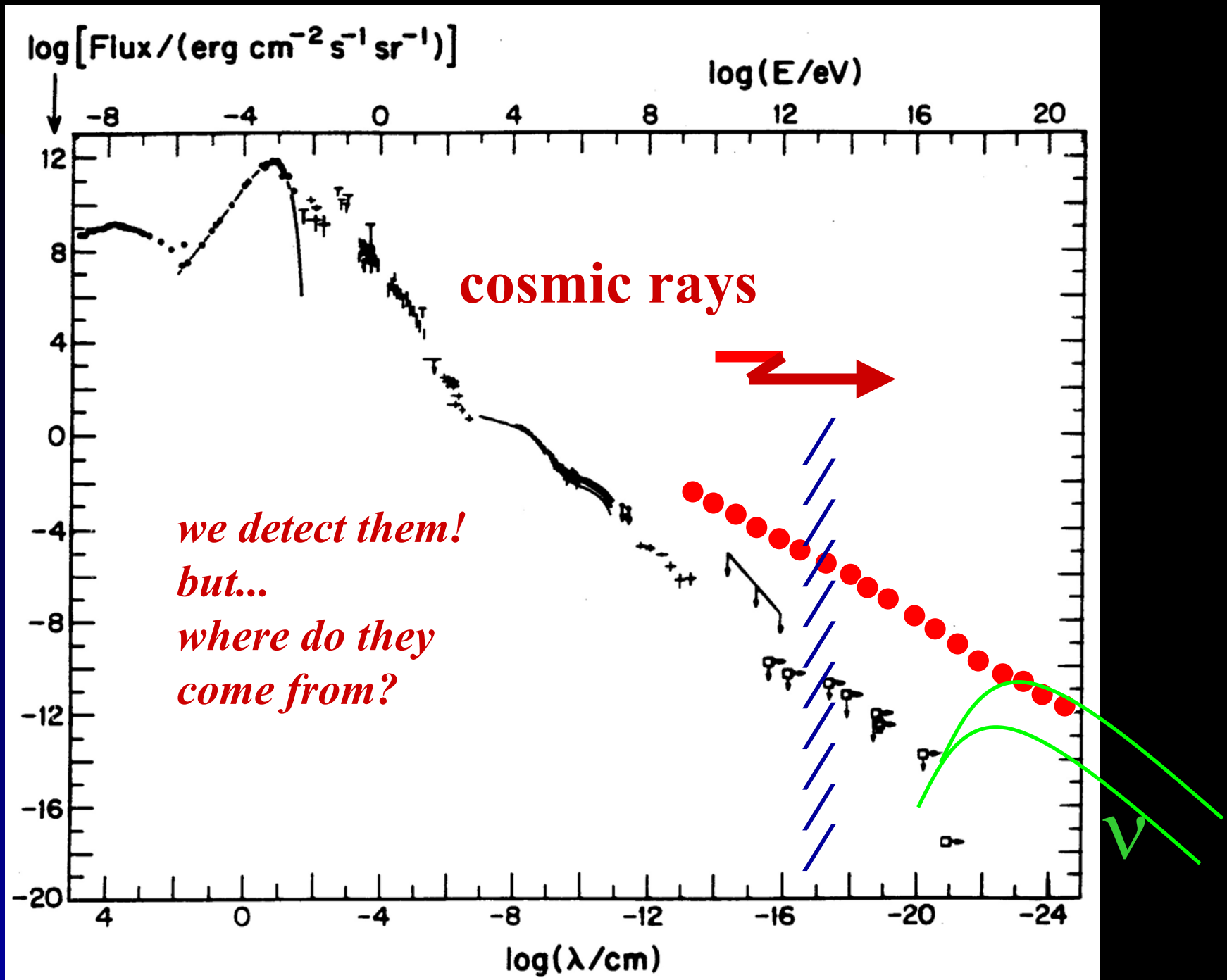
Angela V. Olinto
Center for Cosmological Physics
Astronomy & Astrophysics
Enrico Fermi Institute



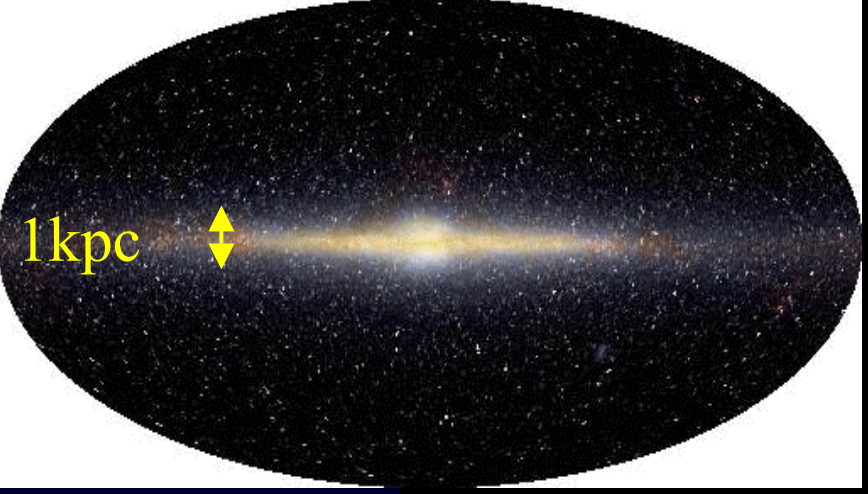

log [Flux / (erg cm⁻² s⁻¹ sr⁻¹)]
Energy (eV)
log (E/eV)
-8
-4
0
4
8
12
16
20
12
8
4
0
-4
-8
-12
-16
-20
Flux
Radio
CMB
IRB
Visible
X-rays
GeV γ-rays
1 TeV =
Fermilab
γγ→e⁺e⁻
4
0
-4
-8
-12
-16
-20
-24
log (λ/cm)
Ressell & Turner
Halzen



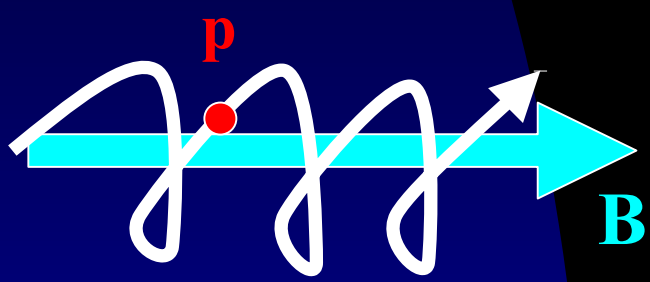
Ressell & Turner

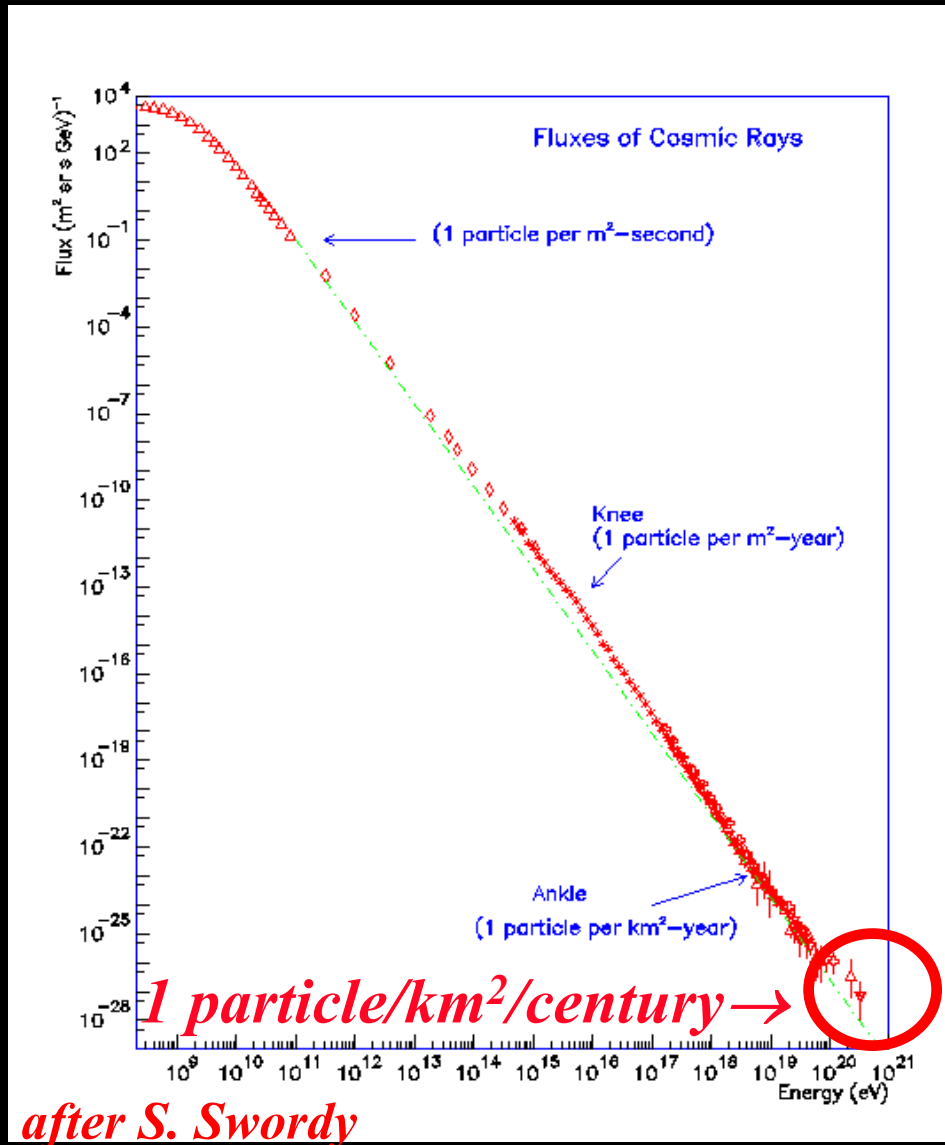

log[Flux/(erg cm^{-2} s^{-1} sr^{-1})]
log(E/eV)
-8
-4
0
4
8
12
16
20
12
8
4
0
-4
-8
-12
-16
-20
cosmic rays
we detect them!
but...
where do they
come from?
4
0
-4
-8
-12
-16
-20
-24
log(λ/cm)
ν

Cosmic Rays



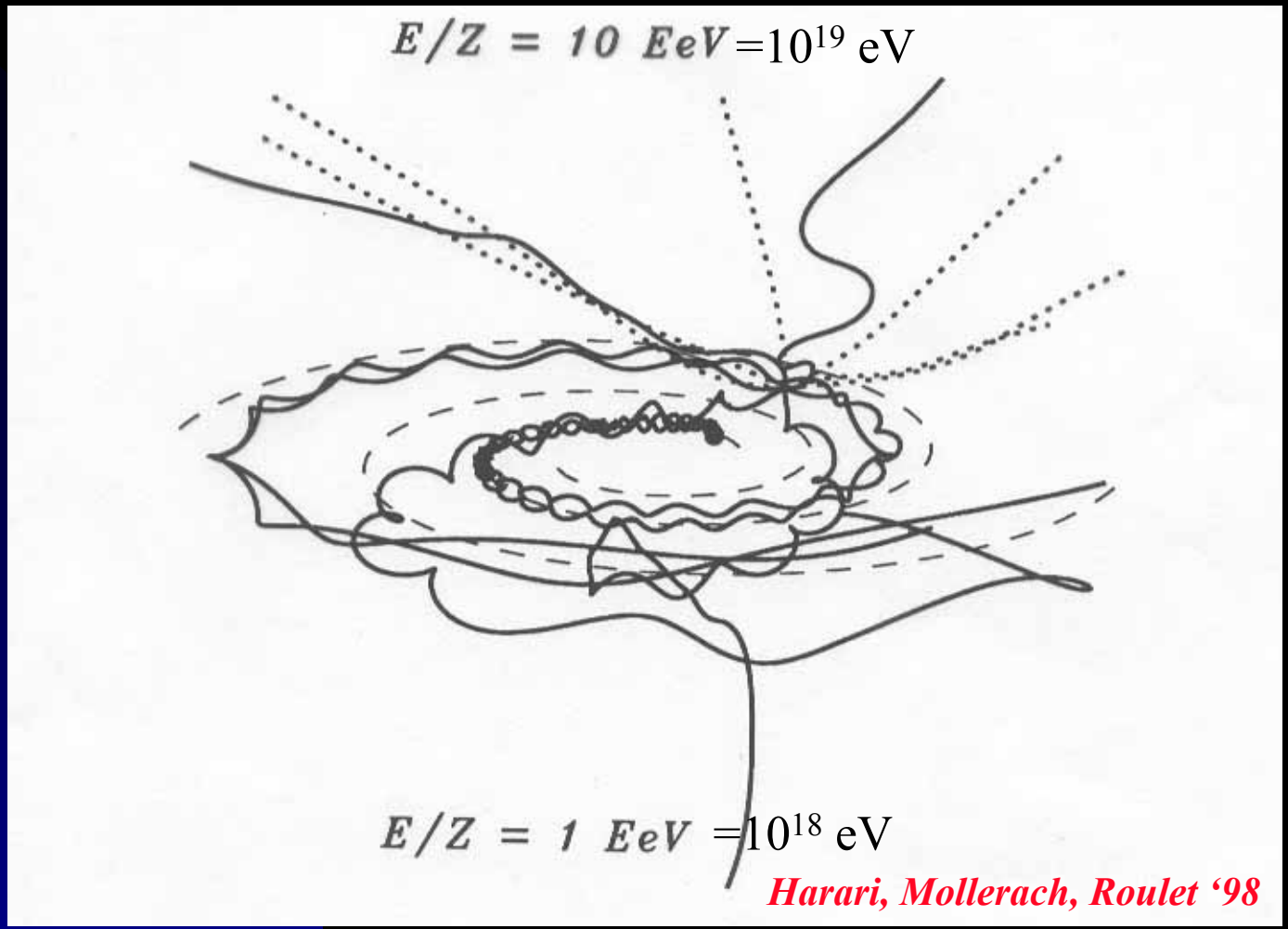
$$R_{gyro} = 3.7\ \text{kpc}\ E_{19}/ZB_{3\mu G}$$





after S. Swordy

UHECR trajectories in Galactic B



Harari, Mollerach, Roulet '98

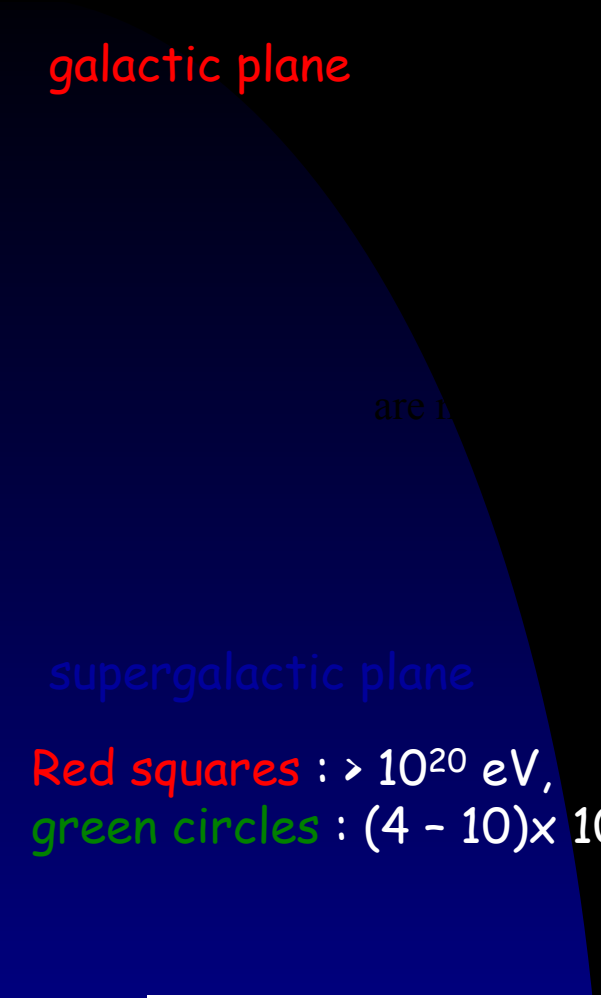
UHE proton trajectories in Extra Galactic B

at the Highest Energies (10^{20} eV) *- should point to sources*
(unless Magnetic Fields are stronger &/or Z is larger)

Isola, Lemoine, Sigl '02

lower bound 2 10^{19} eV to 3 10^{20}eV, $E^{-2.4}$ injection, B_{Mpc} ~0.3 μG, Kolmog

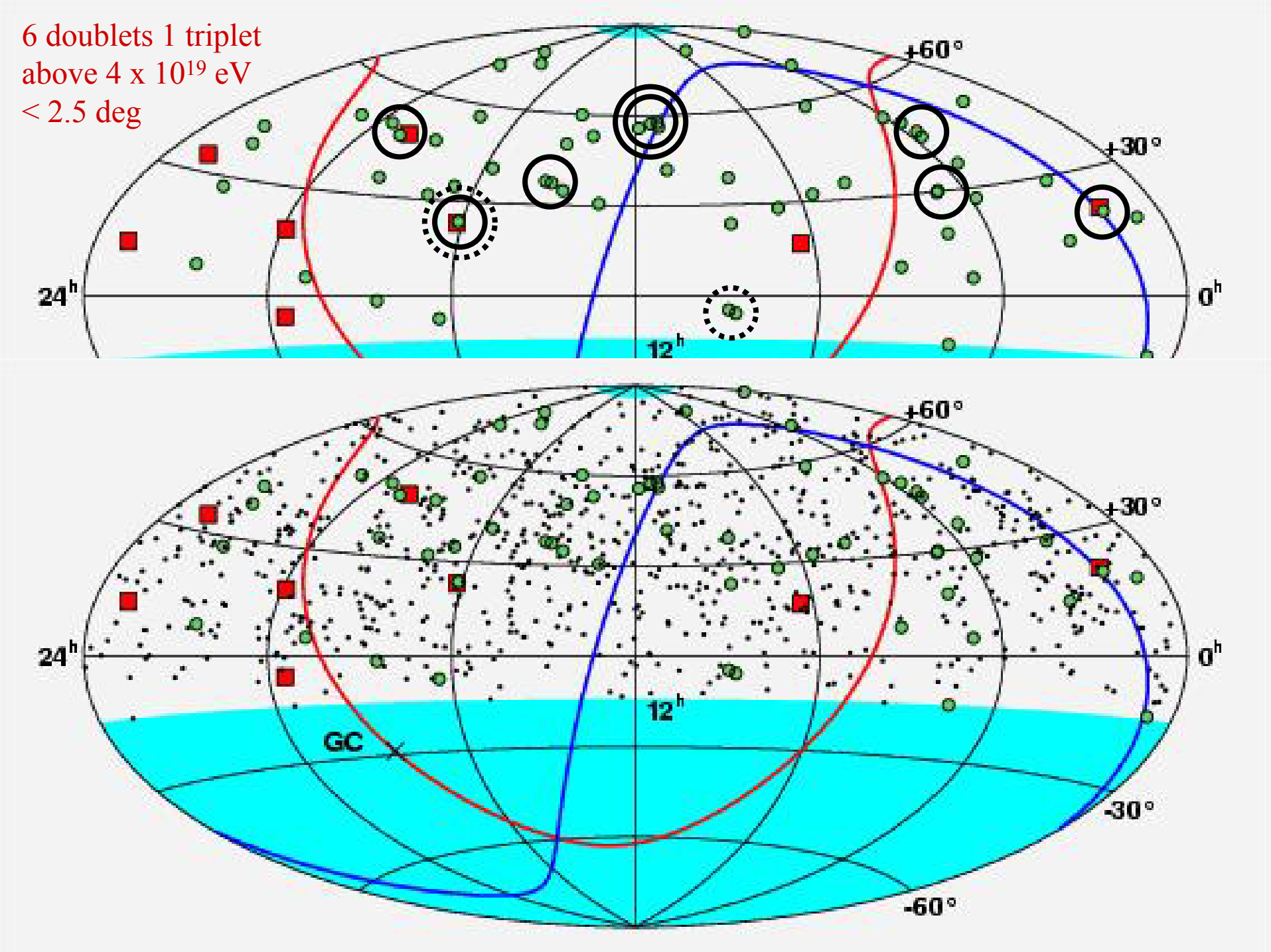
Isotropic + Clustering at Highest Energies



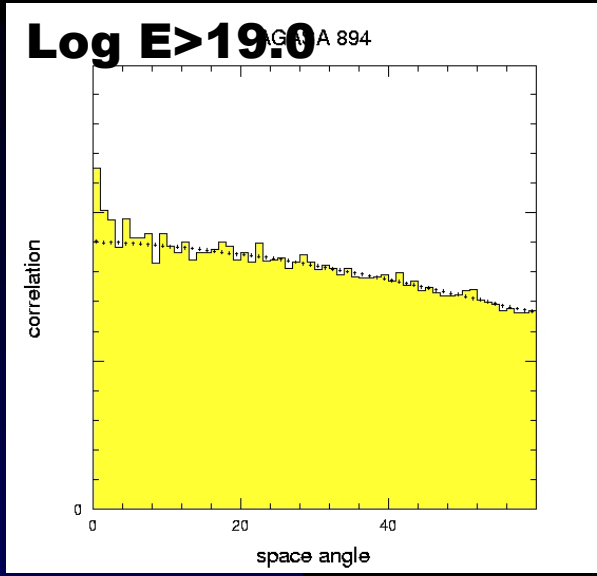
5 Doublets
1 Triplet

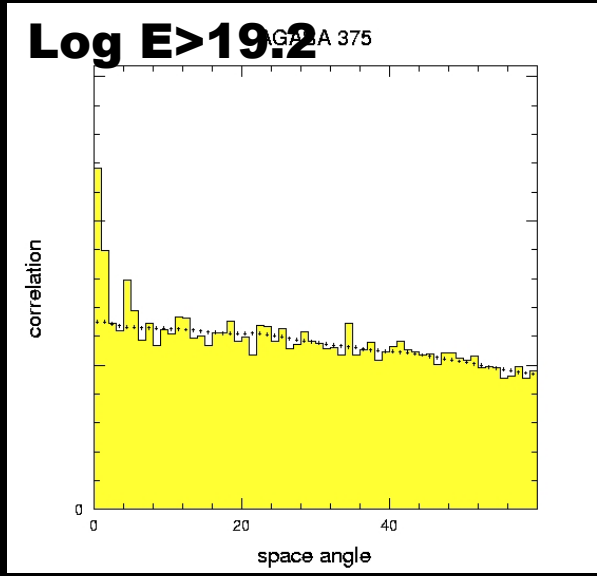
Red squares : > 10^{20} eV,
green circles : (4 – 10)x 10^{19}eV

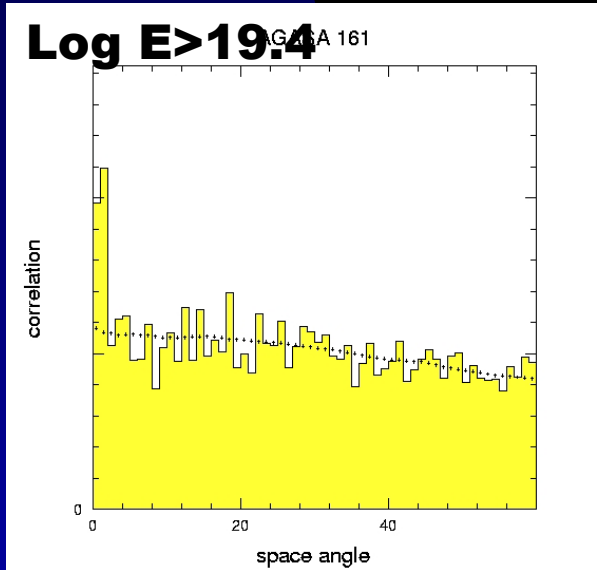
First Hints of Extragalactic Sources?

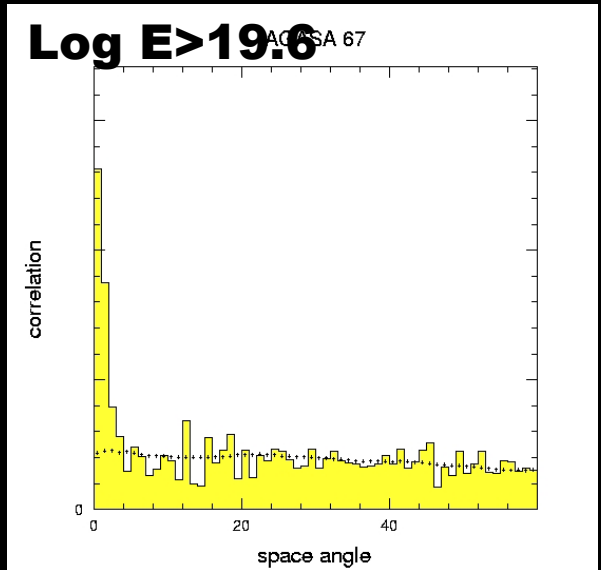

6 doublets 1 triplet
above 4 x 10^19 eV
< 2.5 deg
+60°
+30°
24h
0h
12h
GC
-30°
-60°

Angular Correlations

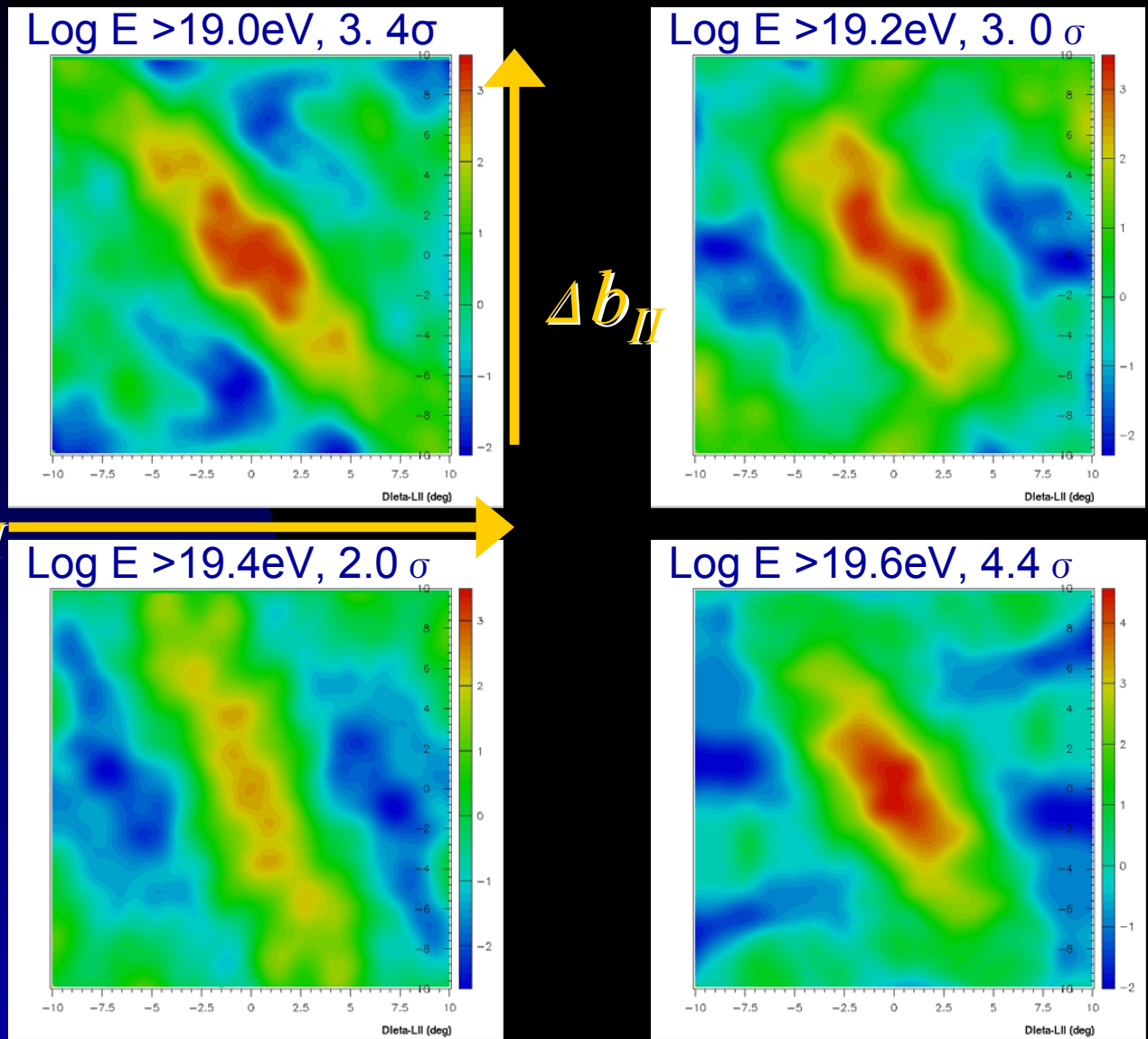






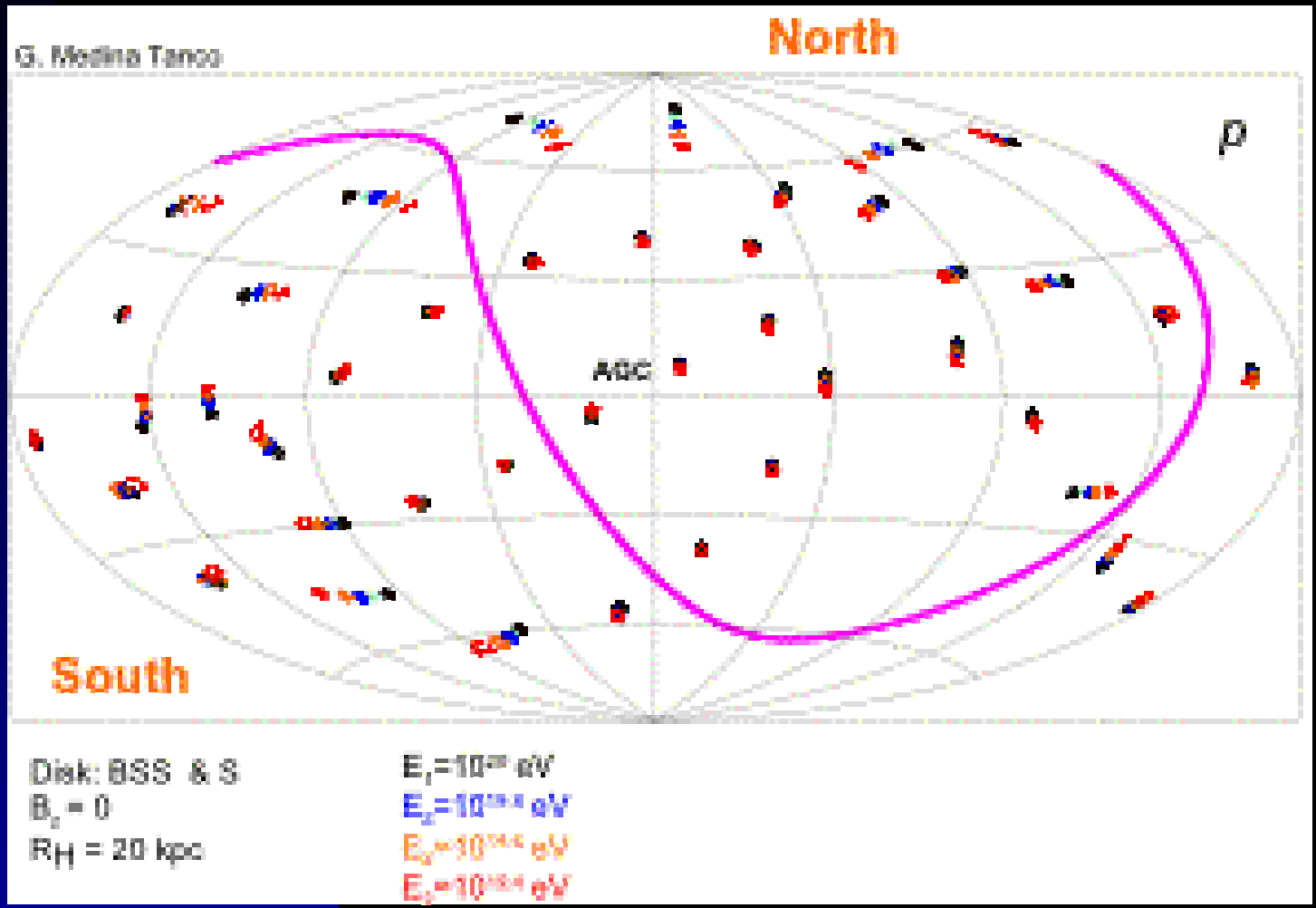


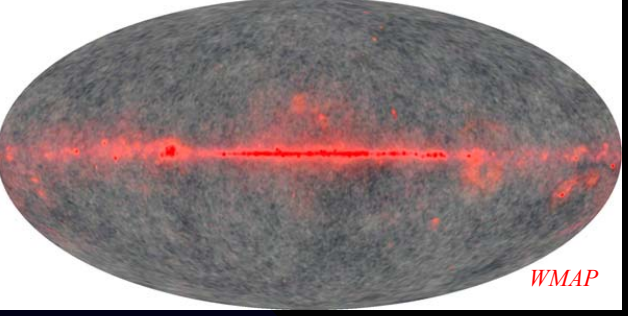
2D-Correlation Map in (Δl_{II} ,Δb_{II})



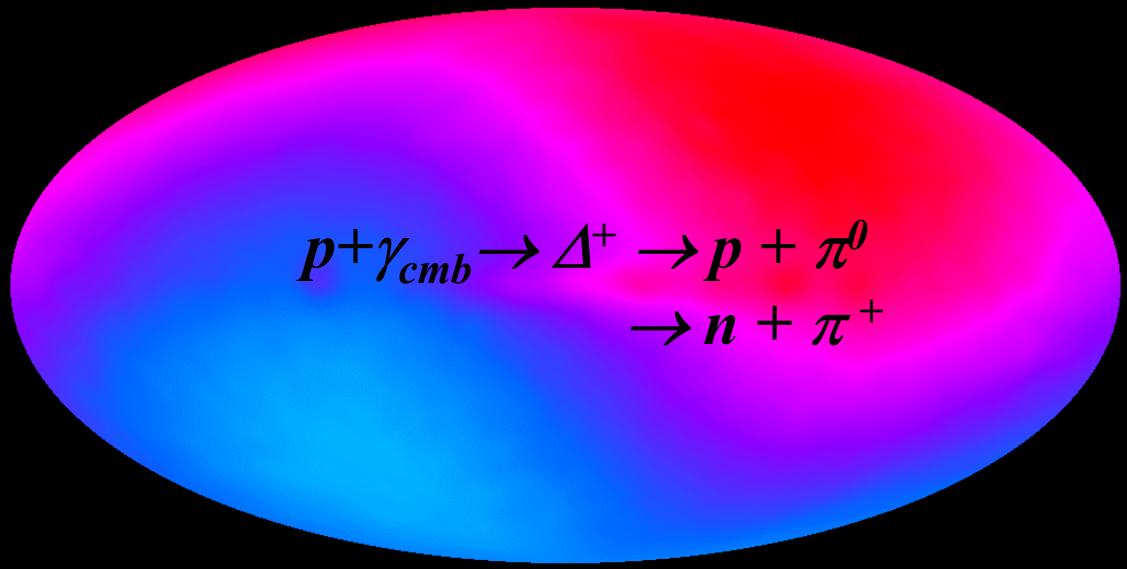
Polarization studies will limit B gal and B Xgal

Polarization

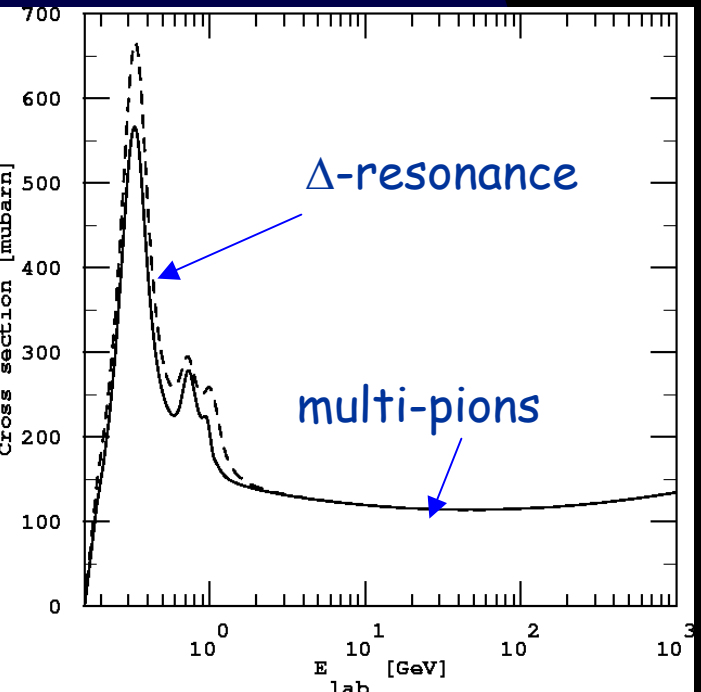




High Energy Proton sees Cosmic Microwave Background as High Energy Gamma Rays!



Proton Horizon



GZK Cutoff

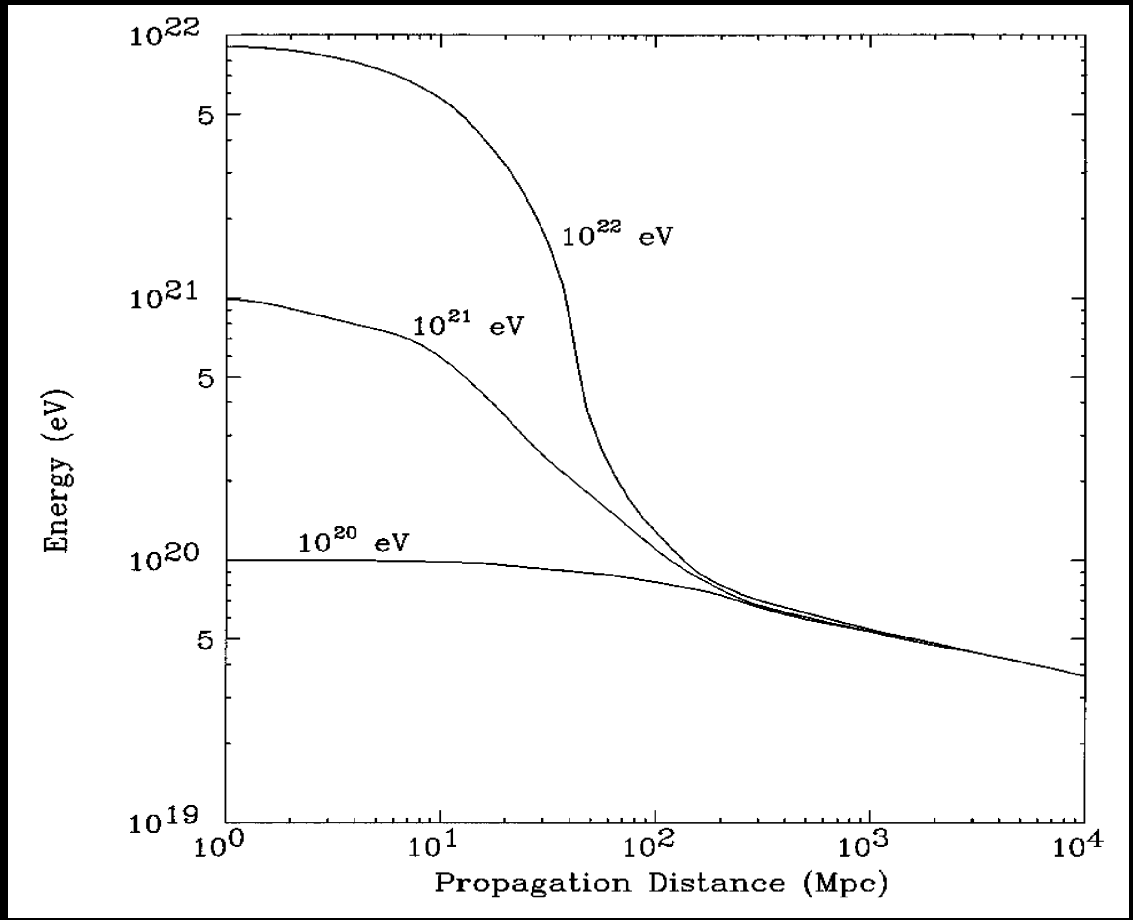
Greisen '66, Zatsepin & Kuzmin '66

Extragalactic UHE Protons lose Energy

Photo Pion production off

cosmic microwave background (CMB)

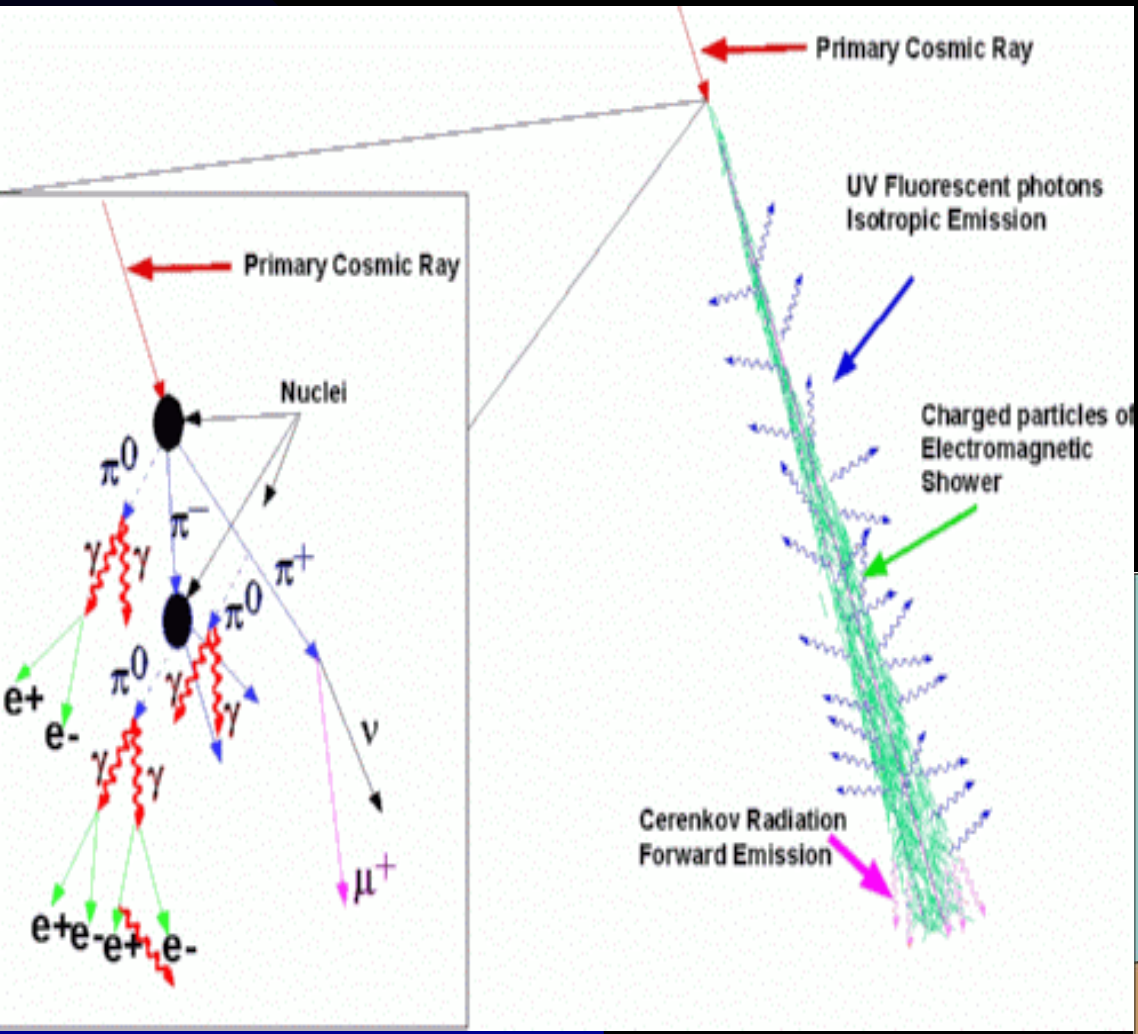
$p+\gamma_{cmb} \rightarrow \Delta \rightarrow p/n+\pi$



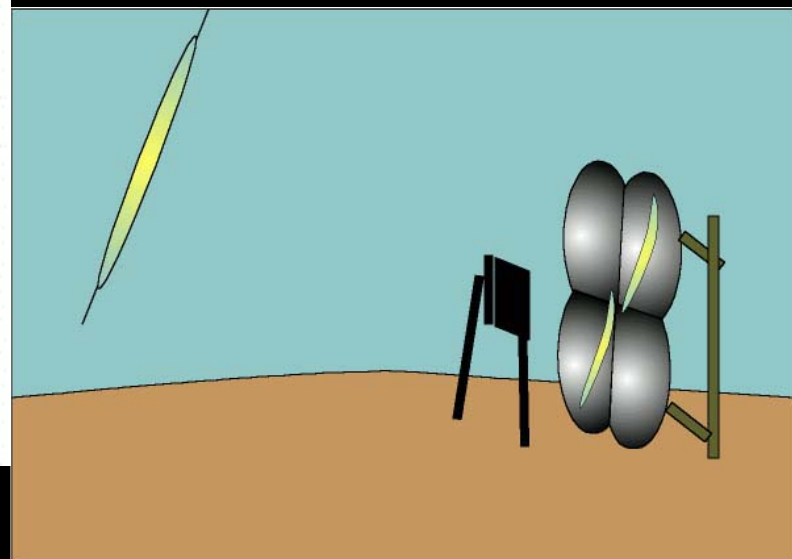
Proton energy vs. distance (J. Cronin)

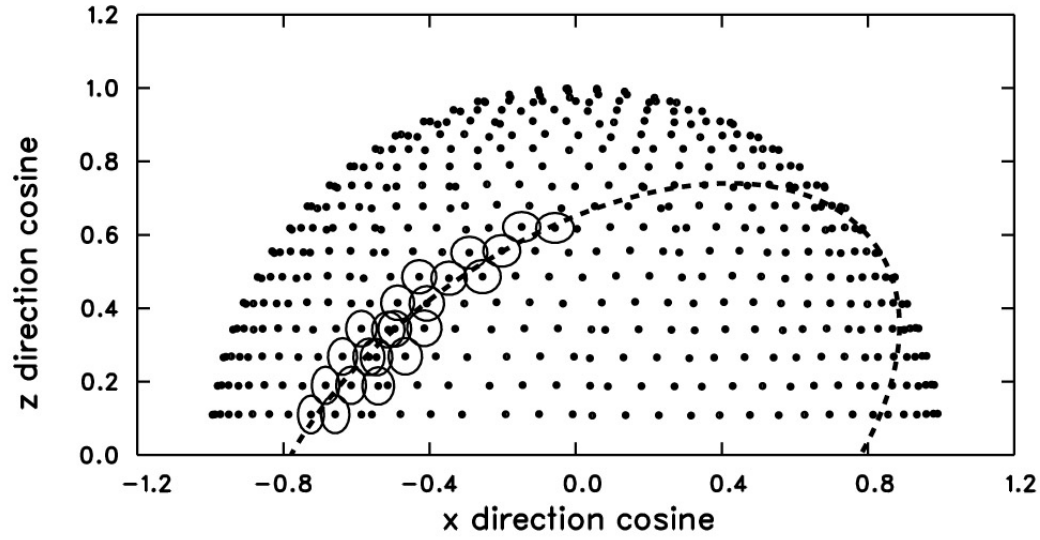
Fluorescence Detectors

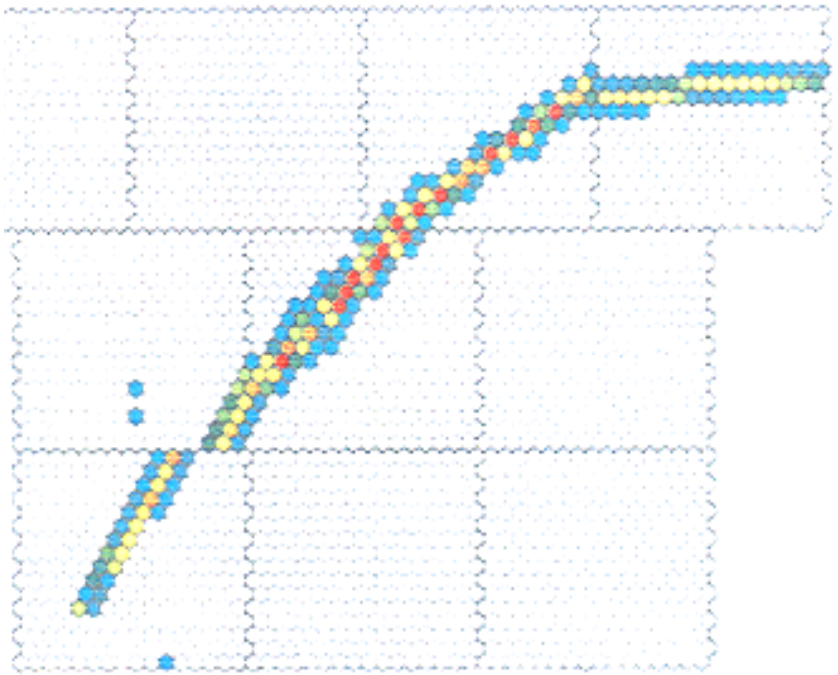
Particle shower lasts about 10^{-5} sec.



Faint glow (100 watt UV light at c) seen by extremely fast, sensitive, electronic cameras (FADC) on clear, moonless nights.







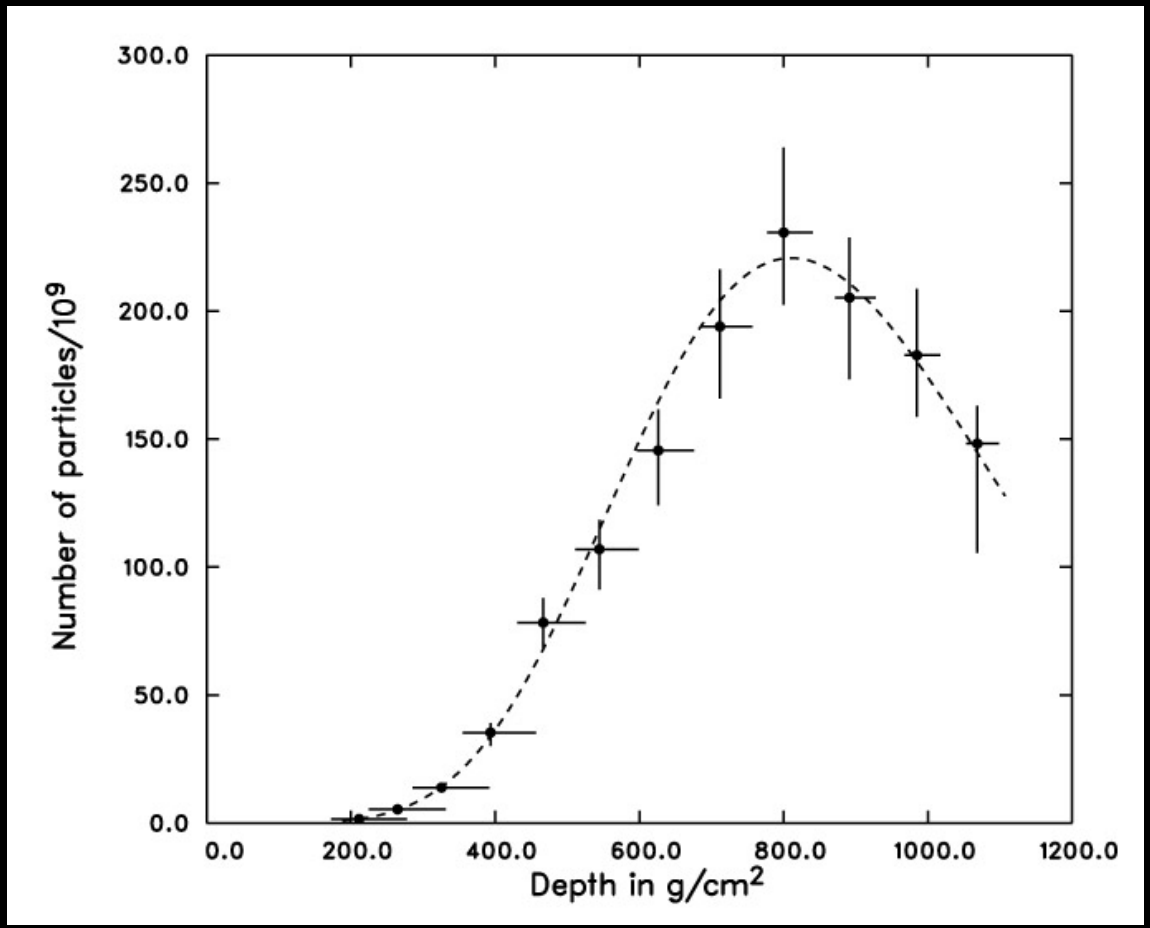
Fly's Eye

Fluorescence Detector

Fly's Eye

1991

3 x 10^{20} eV
"Super-GZK" event



There are ZeV
= 10^{21} eV
Accelerators in
the Universe!!!

ZeVatrons

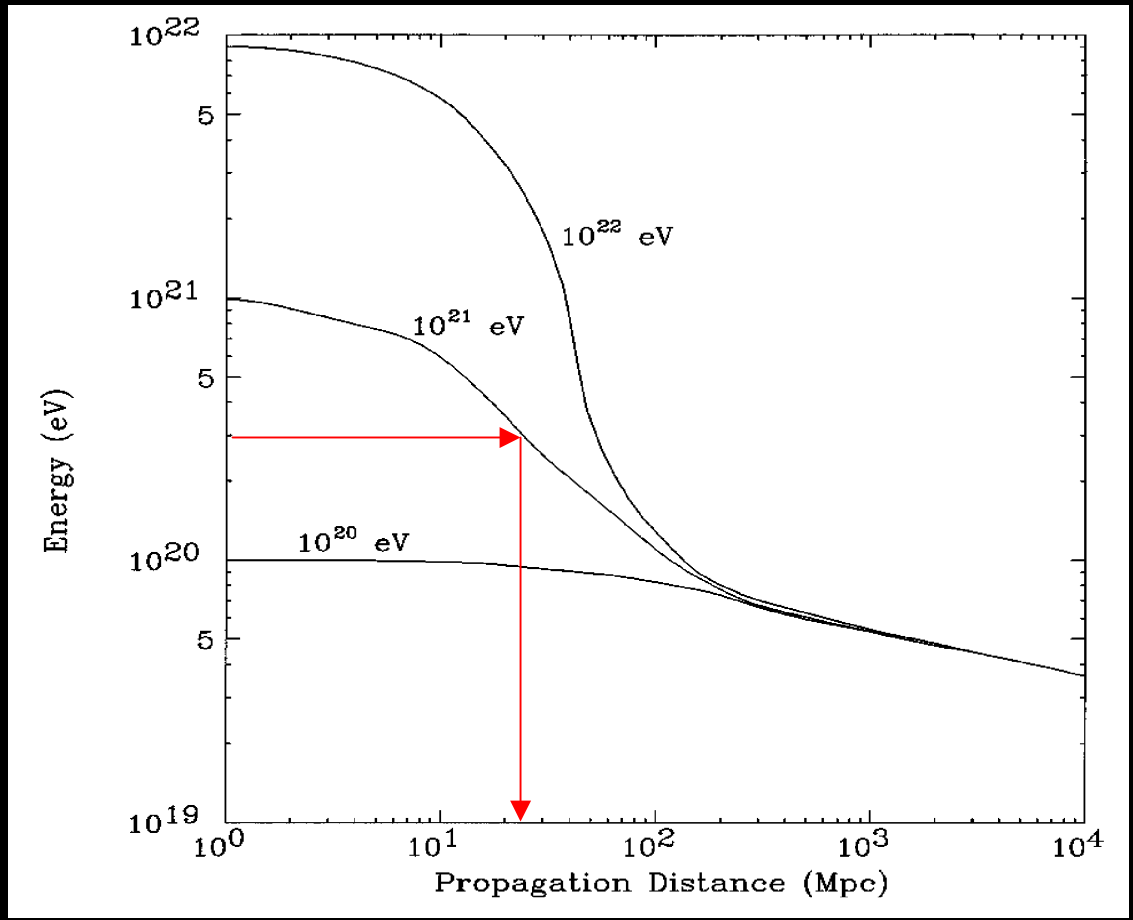
This energy is equivalent to the kinetic energy of a tennis ball with ~ 400 km/h!!

Extragalactic UHE Protons lose Energy

Photo Pion production off

cosmic microwave background (CMB)

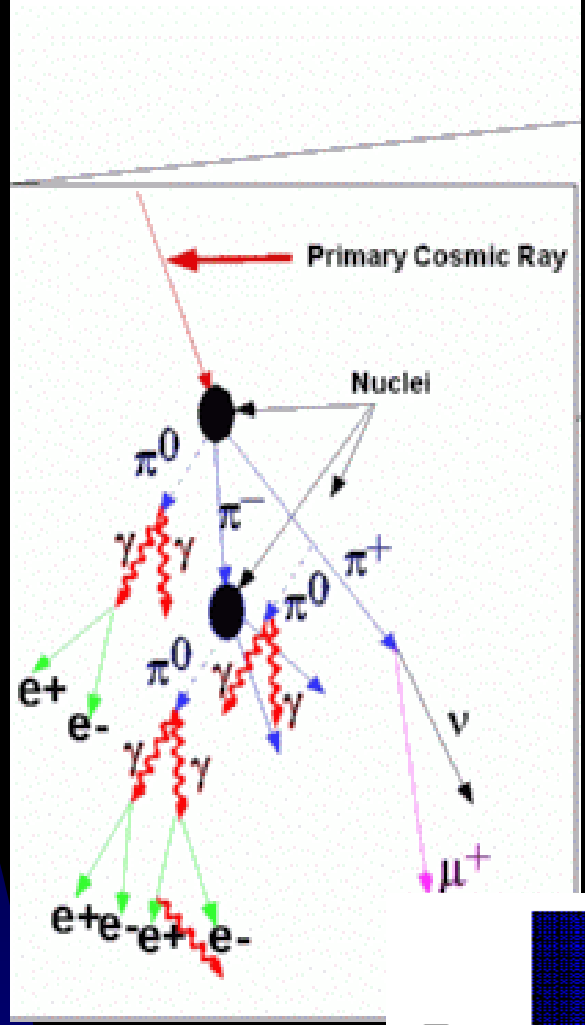
$p+\gamma_{cmb} \rightarrow \Delta \rightarrow p/n+\pi$

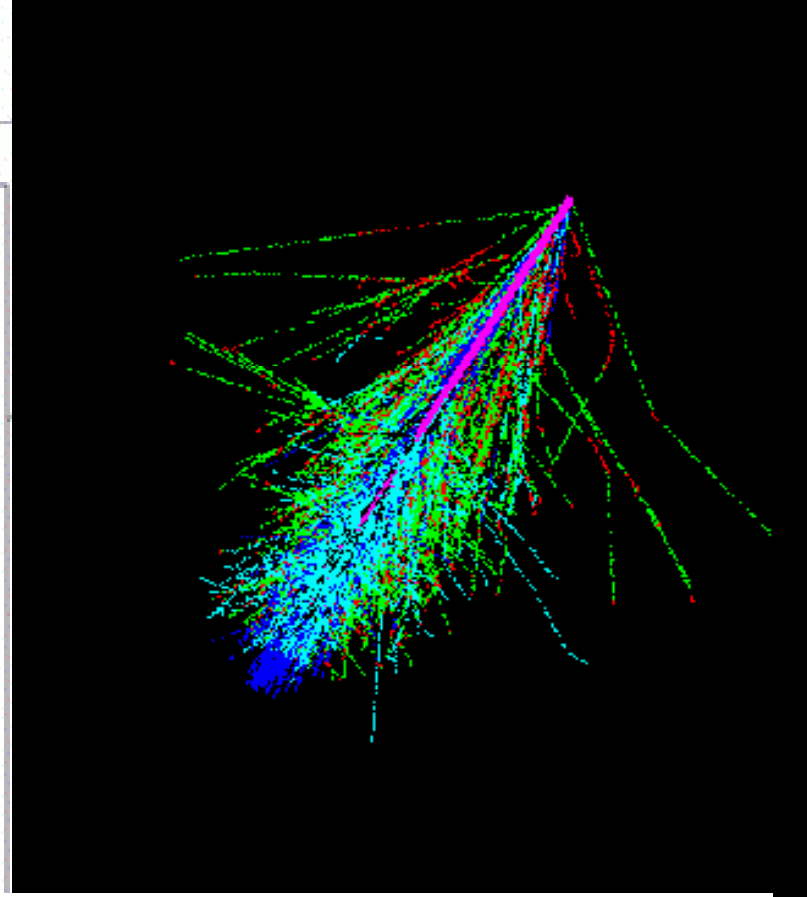


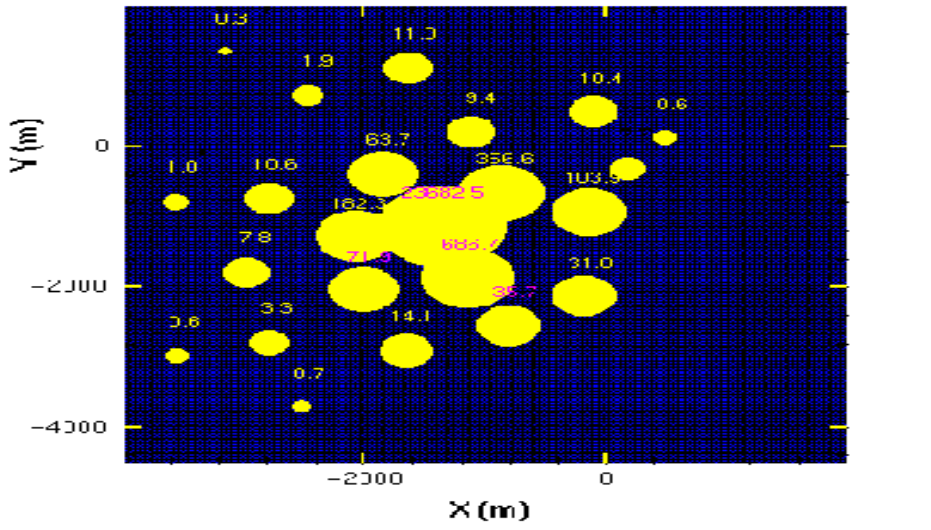
Proton energy vs. distance (J. Cronin)

Expect to observe only nearby at EHE!

Ground Arrays

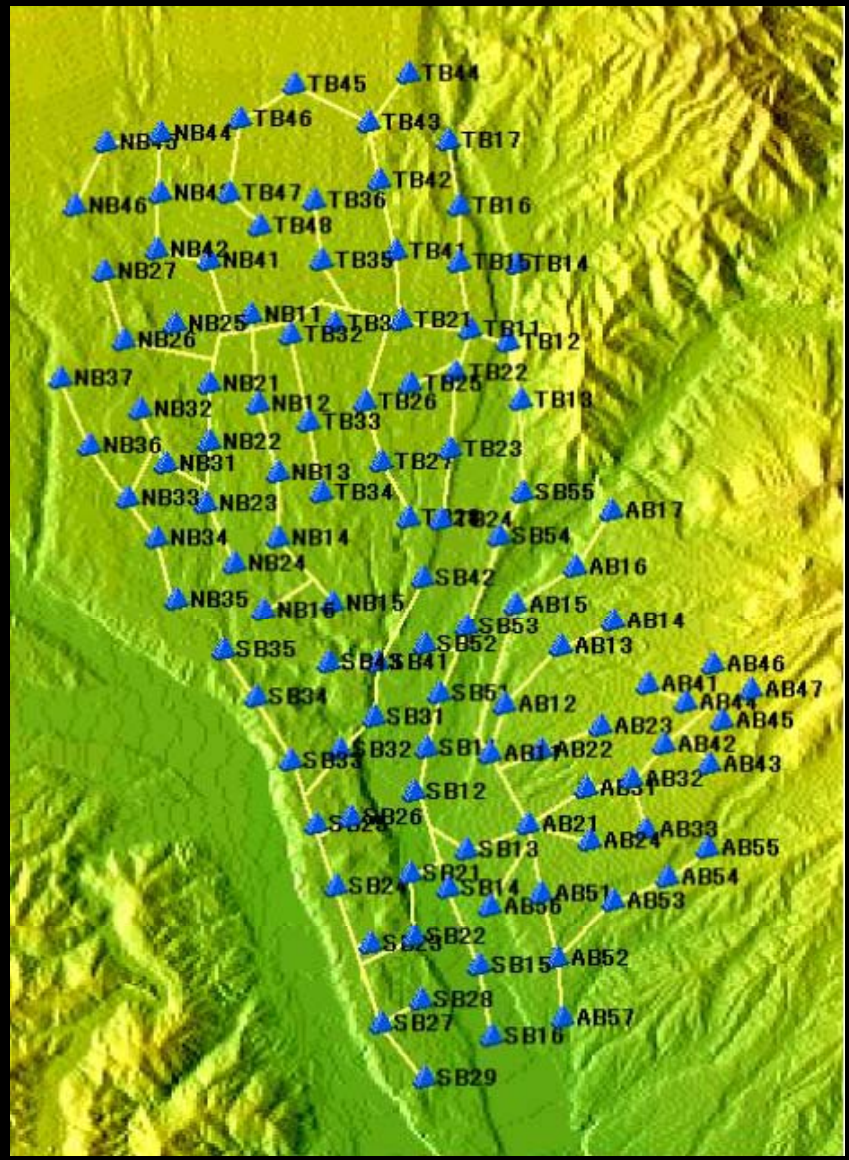






Volcano Ranch
Yakutsk
Haverah Park
SUGAR
Akeno,
AGASA

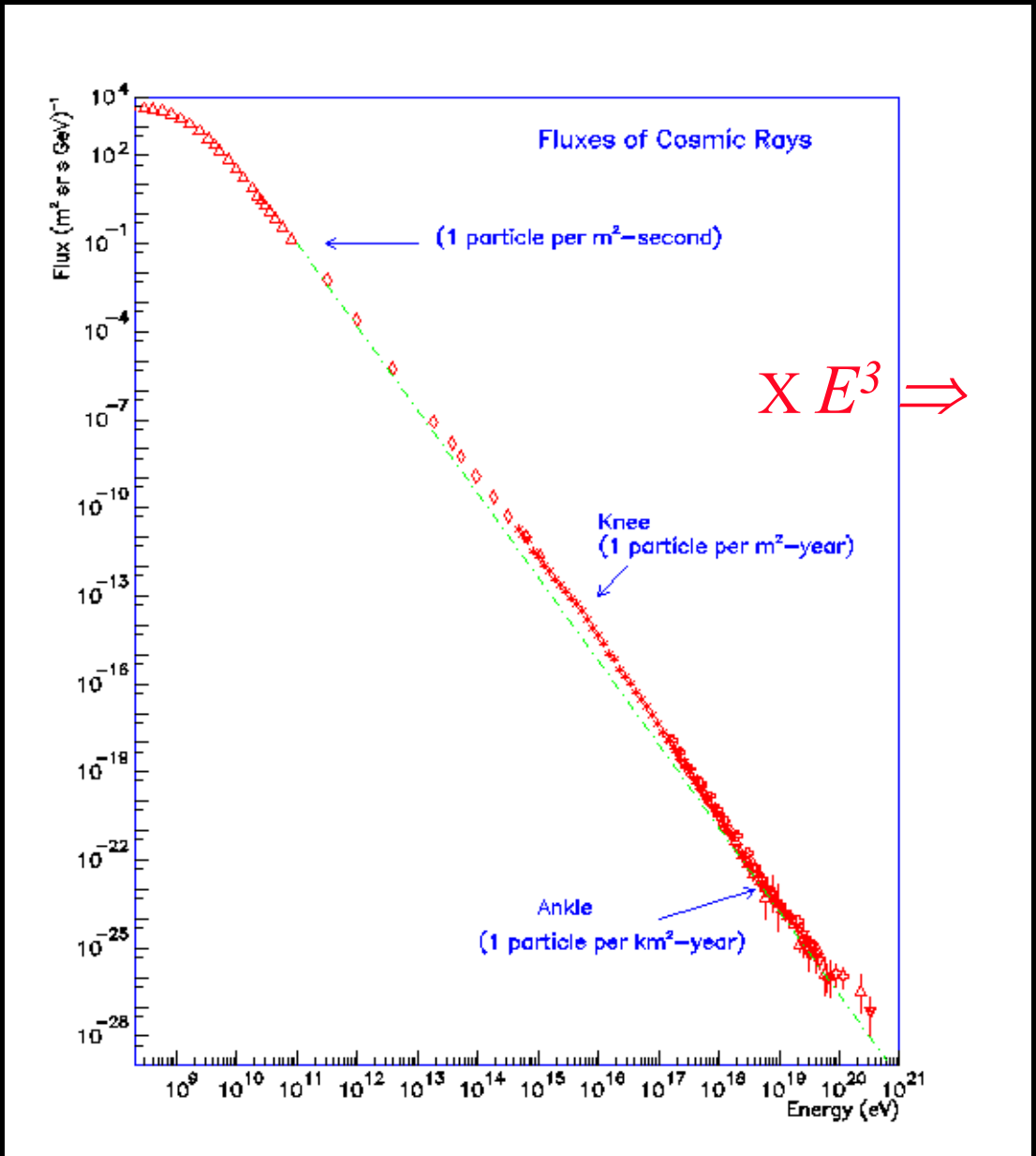
AGASA



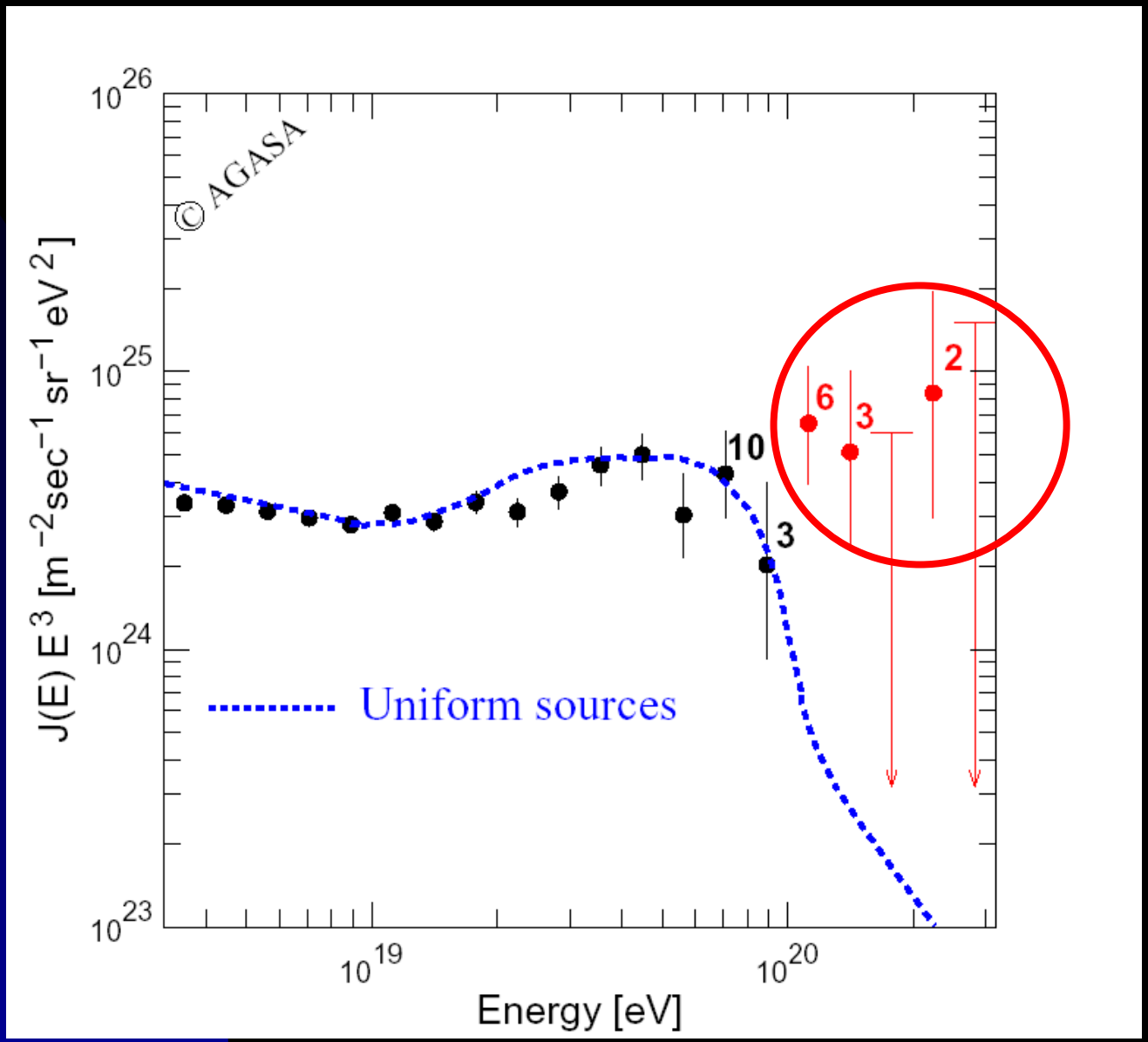
100 km^2 scintillators + muon detectors

Cosmic Ray Spectrum

$dN/dE \sim E^{-2.7}$ to E^{-3}



Highest Energy Spectrum



AGASA: ~ 11 events above 10^{20} eV!!!

UHECR Puzzle

Why no GZK cutoff?

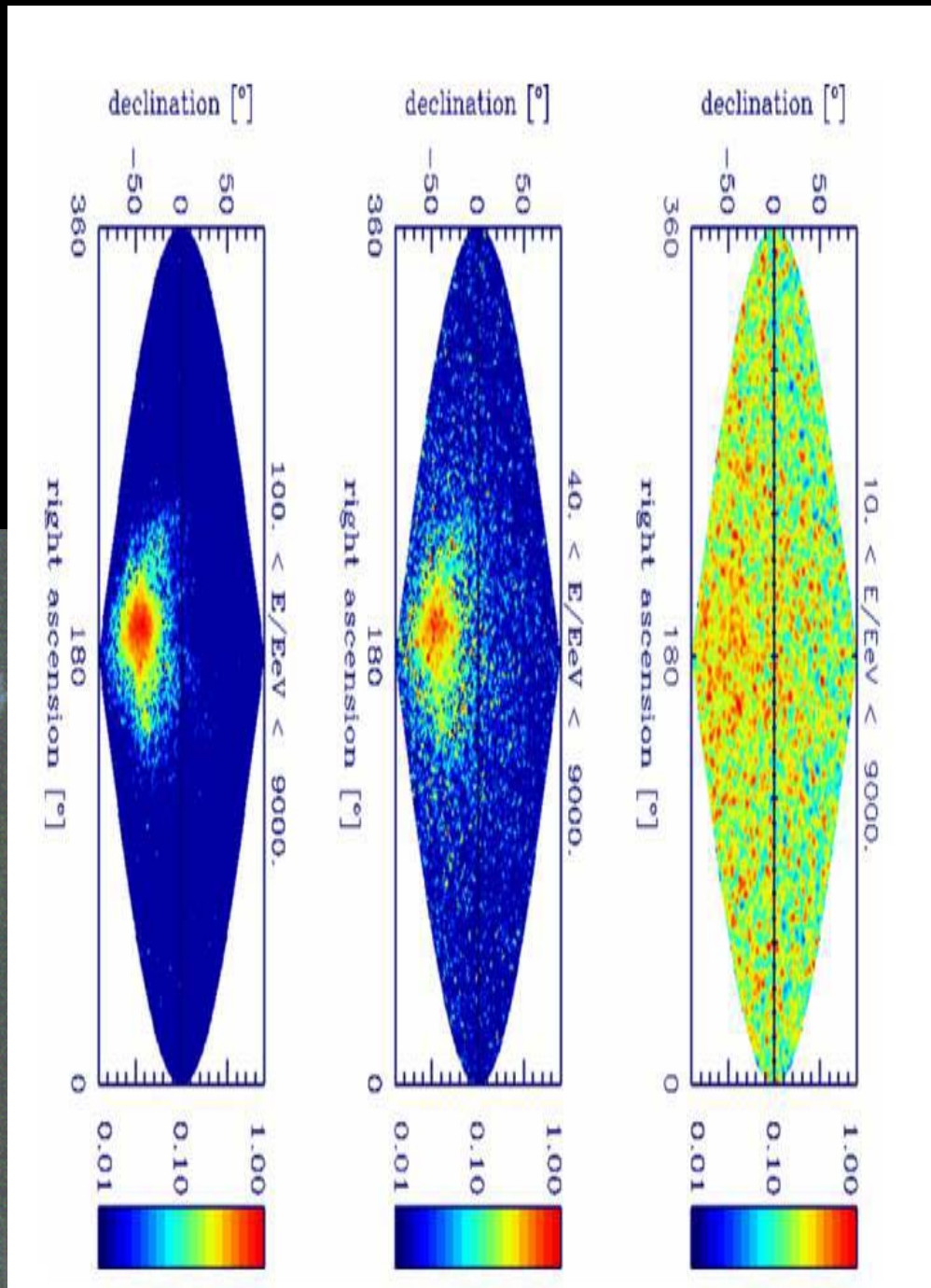
Extragalactic Proton Sources $\Rightarrow$ GZK feature

Nearby EG Source such as M87 or Cen A?

Where is the Hot Spot?

Cen A

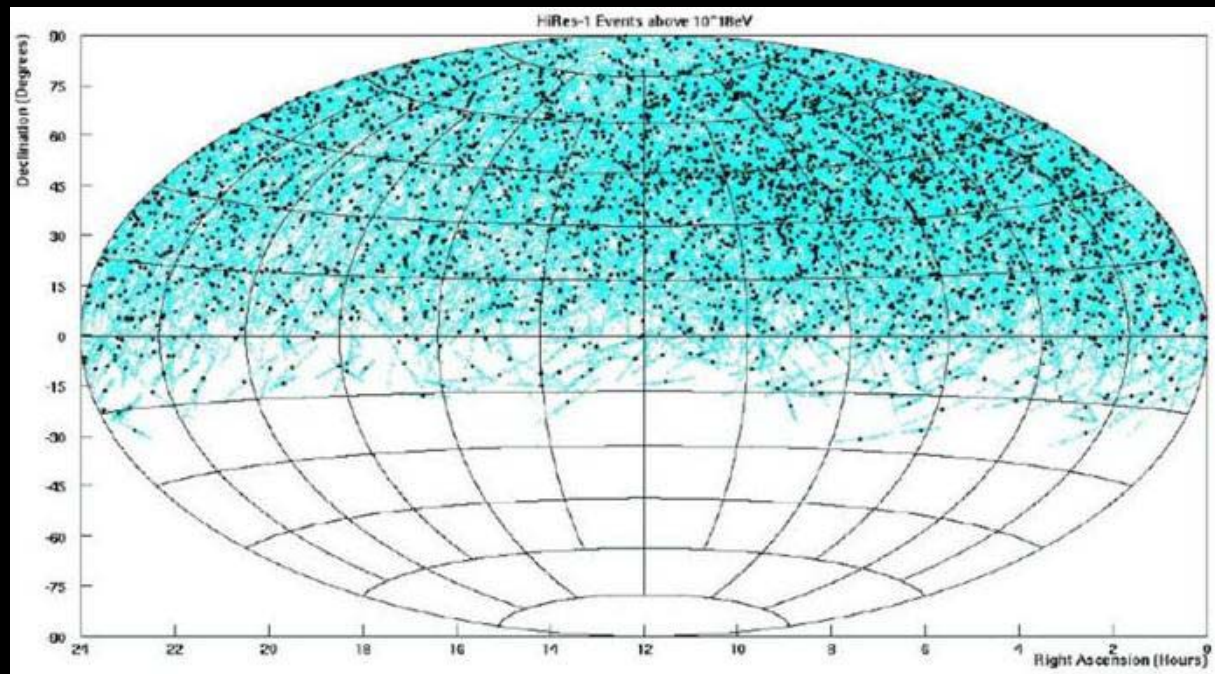
M87



Isotropic Distribution of Arrival Directions

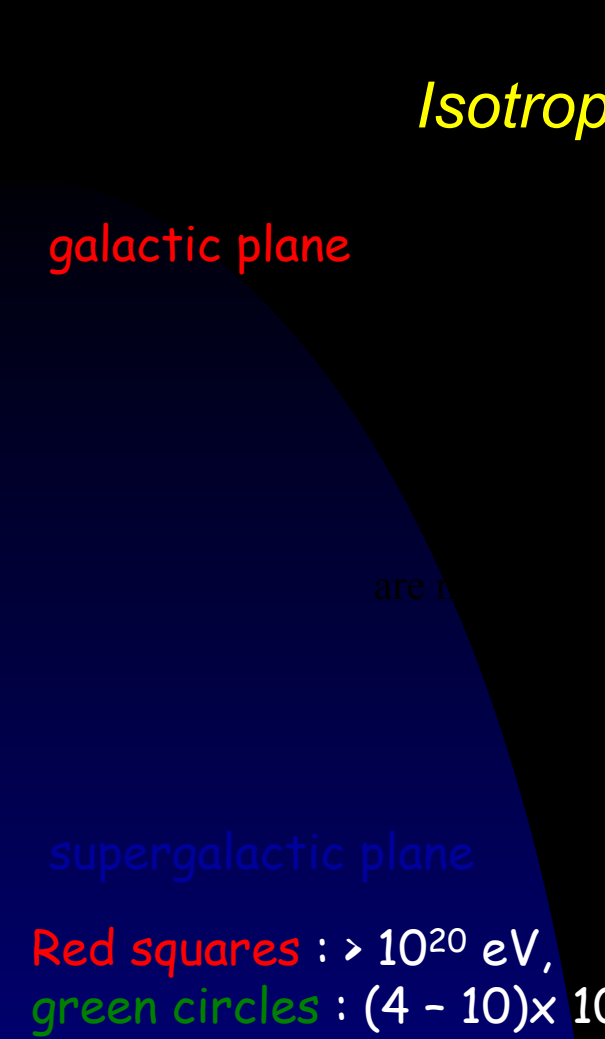
AGASA
$> 10^{19}$ eV

HiRes



Isotropy inconsistent with a single source!

Isotropic + Clustering at Highest Energies



5 Doublets
1 Triplet

Red squares : > 10^{20} eV,
green circles : (4 – 10)x 10^{19}eV

Clusters do not point to M87 or Cen A

UHECR Puzzle

Why no GZK cutoff?

Extragalactic Proton Sources $\Rightarrow$ GZK feature

Nearby EG Source such as M87 or Cen A?

No! GZK feature from other sources
+ hot spot in the sky - not isotropic!

UHECR Puzzle

Why no GZK cutoff?

Extragalactic Proton Sources $\Rightarrow$ GZK feature

Nearby EG Source such as M87 or Cen A?

No! GZK feature from other sources
+ hot spot in the sky - not isotropic!

Galactic Source such as Young Neutron Stars?

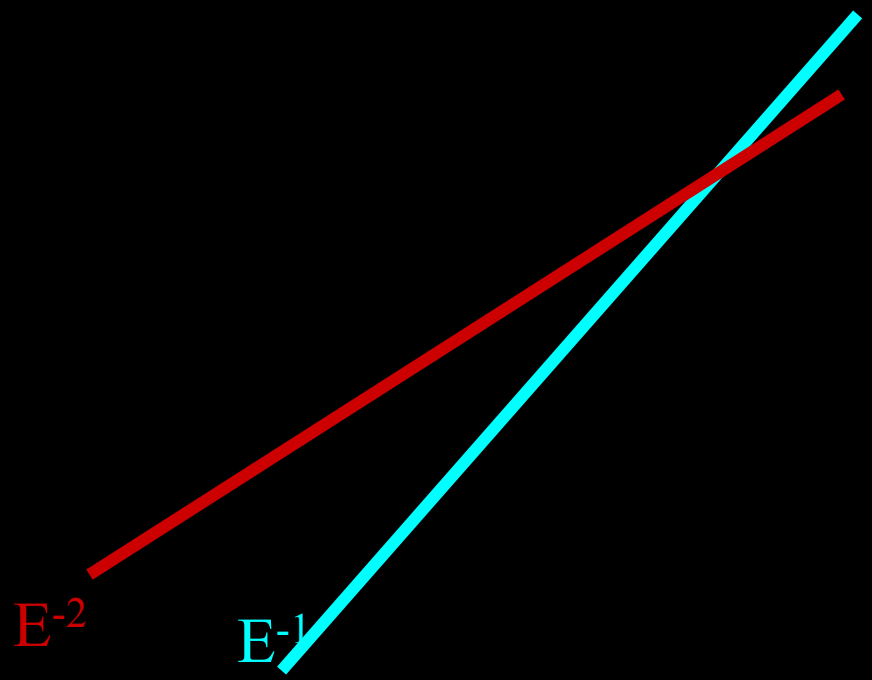
Only if primary is heavy (Fe) & B_{gal} strong!

Local Source - New Component

Young Neutron Star Winds: a Galactic Fe option

$$R_{gyro} = 1.4\ kpc\ E_{20}/Z_{26}B_{3\mu G}$$

Crab Nebula



Neutron Stars:
10 km 1.4 M_{solar} can rotate 3000/sec at birth!!

Blasi, Epstein, AO '00

UHECR Puzzle

Why no GZK cutoff?

Extragalactic Proton Sources $\Rightarrow$ GZK feature

Nearby EG Source such as M87 or Cen A?

No! GZK feature from other sources
+ hot spot in the sky - not isotropic!

Galactic Source such as Young Neutron Stars?

Only if primary is heavy & $B_{gal\ halo}$ stronger!

Other Astrophysical Zevatrons?

No good candidates - all show GZK feature!

UHECR Puzzle

Why no GZK cutoff?

Extragalactic Proton Sources $\Rightarrow$ GZK feature

New Physics Option:

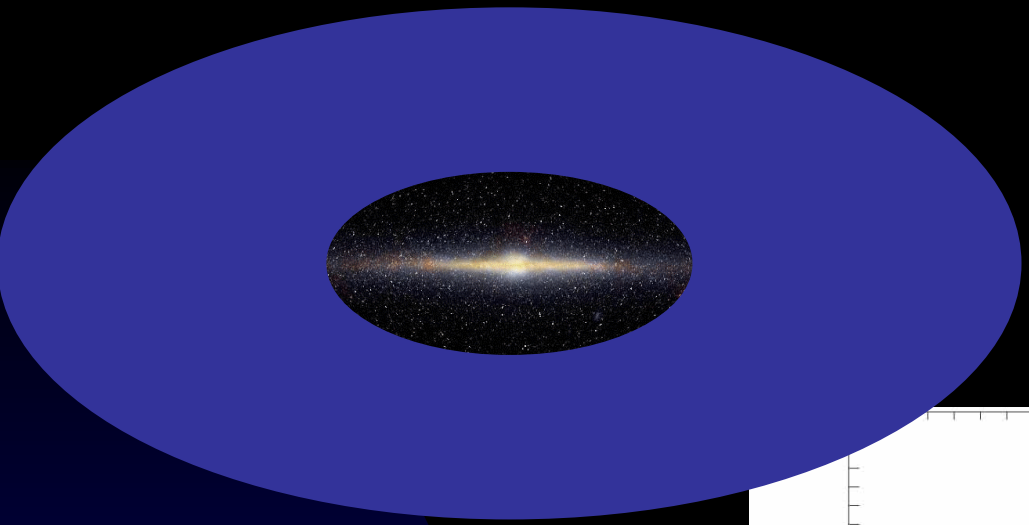
Super-Heavy Particle Relics

(in Galactic halo)

$\Rightarrow$ ***no GZK feature for Protons***

$\Rightarrow$ ***Photons at all Energies***

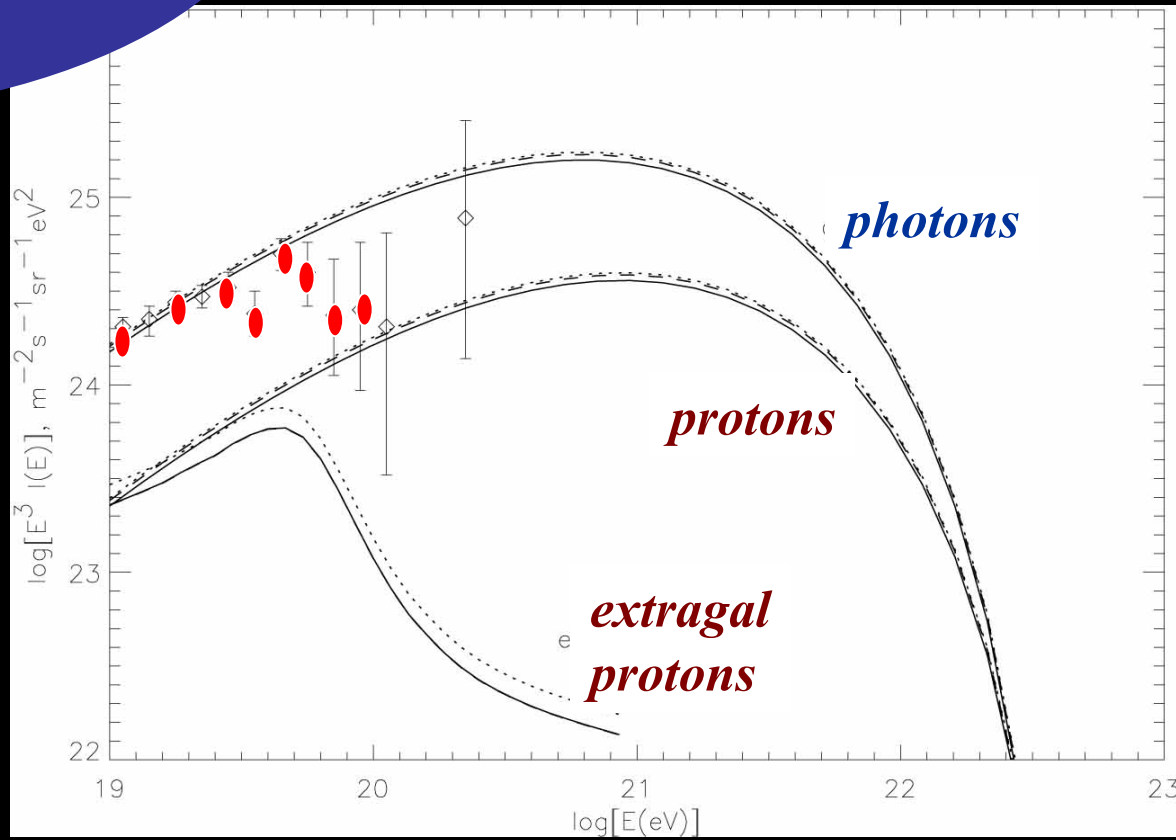
$\Rightarrow$ ***New component***



Super Heavy Relics

in the Dark Halo of our Galaxy

Dark Matter = 23% Universe
(83 % matter in U)
baryons only 4%



problems w/composition at lower energy

Berezinsly, Blasi, Vilenkin `99

UHECR Puzzle

Why no GZK cutoff?

Extragalactic Proton Sources $\Rightarrow$ GZK feature

New Physics Option:

Super-Heavy Particle Relics

(in Galactic halo)

$\Rightarrow$ ***no GZK feature for Protons***

$\Rightarrow$ ***Photons at all Energies***

$\Rightarrow$ ***New component***

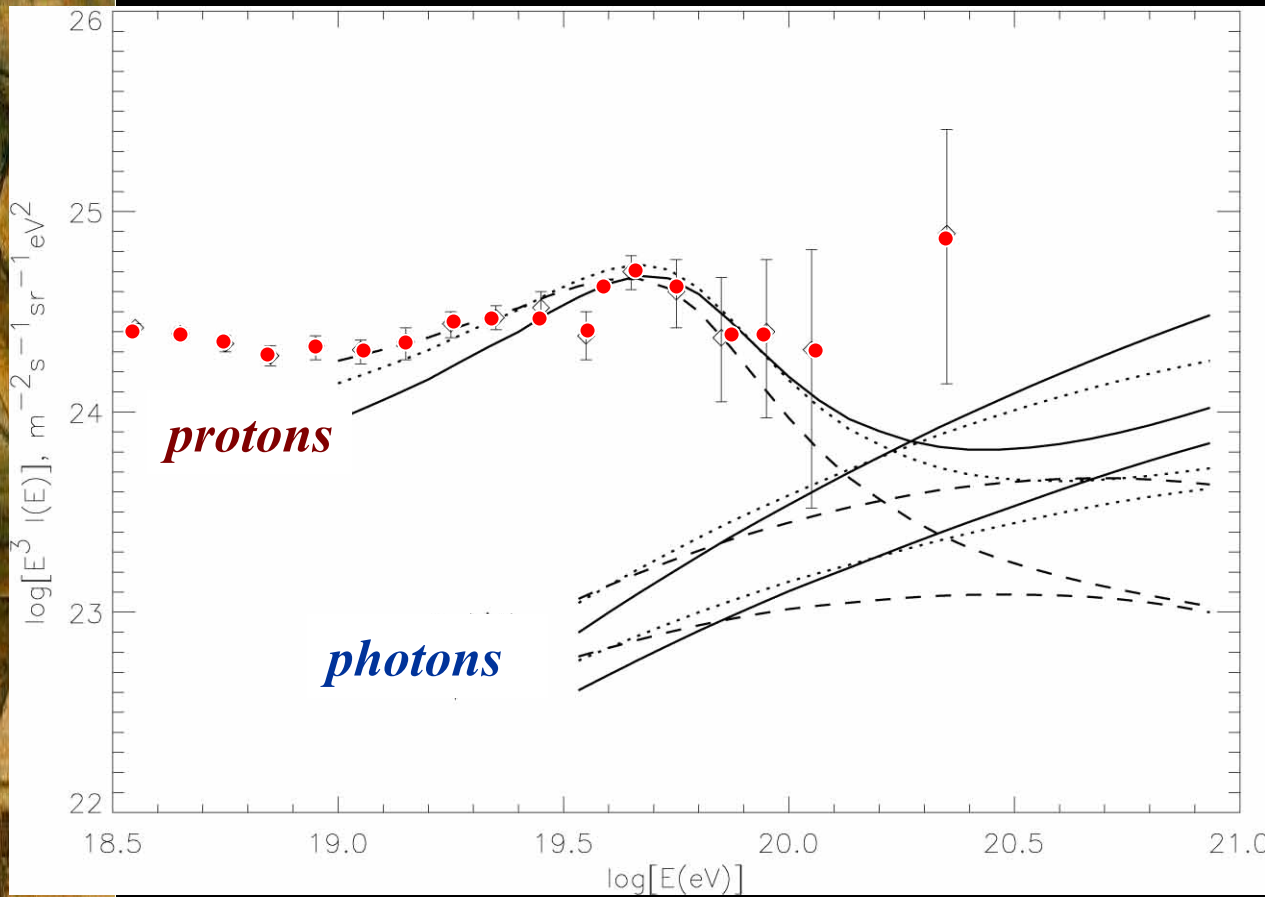
Topological Defects ***= extragalactic***

$\Rightarrow$ ***GZK feature for Protons***

$\Rightarrow$ ***Photons at the Highest Energies***

Topological Defects

Cosmic Necklaces



Berezinsly, Blasi, Vilenkin `99

Some Possible Resolutions…

If Photons, NEW PHYSICS: TD, Super Heavy Dark Matter: only at EHE

If Protons, B strong local source + very hard injection spectrum + GZK feature

If Protons + no GZK feature - violation of LI !

If Heavies, Galactic or Extragal Zevatrons + strong Magnetic Fields

*To Solve the Puzzle - need a lot **More Data**:*

Full Sky Coverage
Many More Events
***** Composition *****

High Resolution Fly's Eye

HiRes I - 22 mirrors, 256 PMT/mir, 360^{o} azimuth, 17^{o} elevation, - ('98-).

HiRes II - 42 mirrors, FADC electronics - ('99 -)

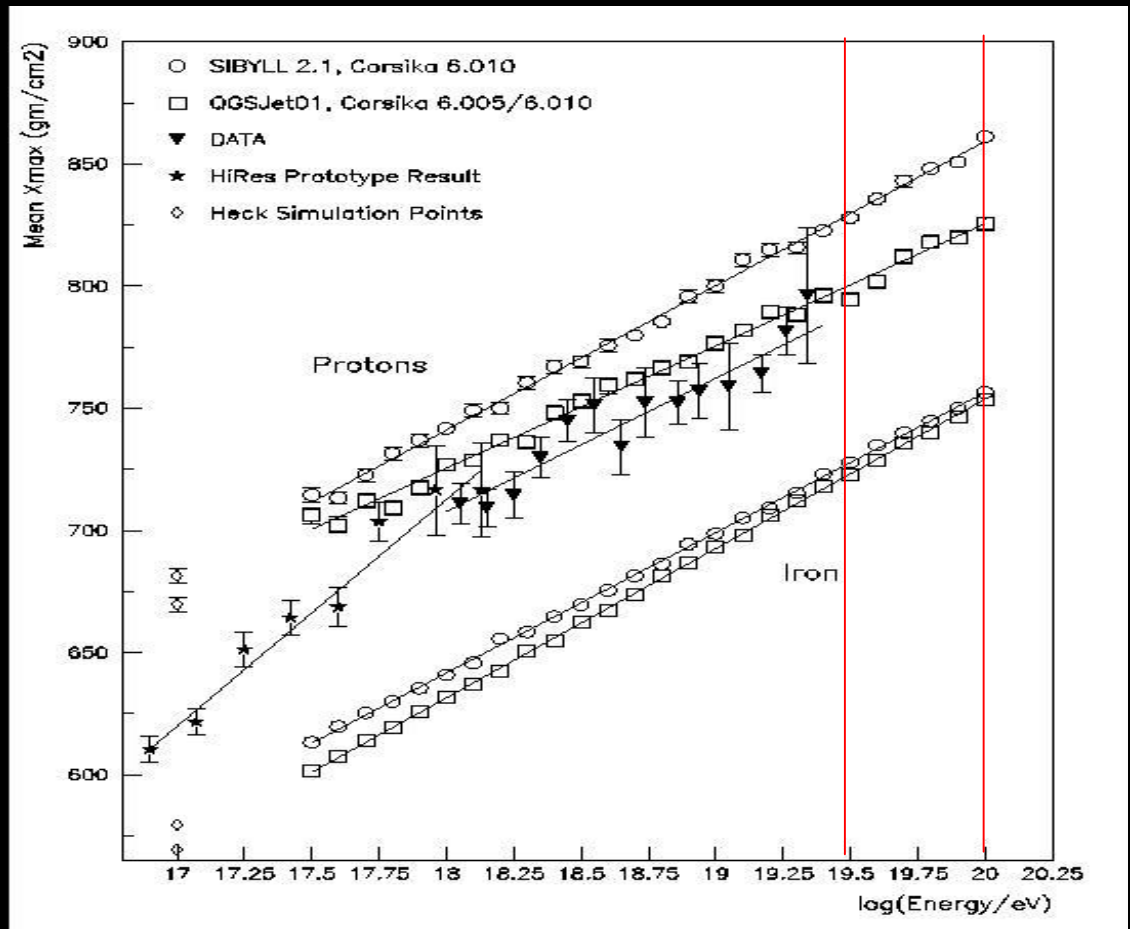
HiRes

Composition:

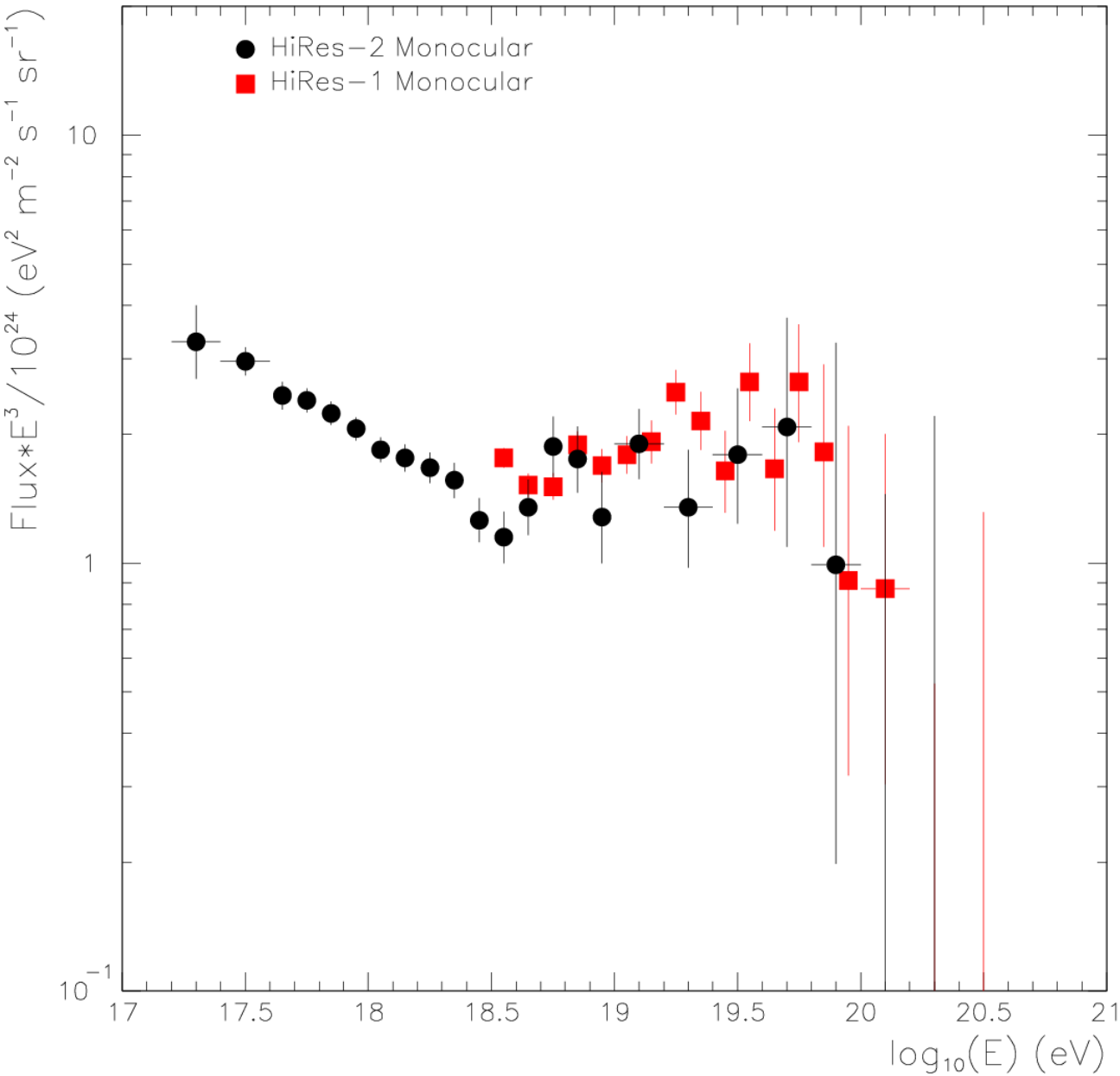
HiRes Stereo: unchanging, light composition above 10^{18} eV
Stereo HiRes and HiRes Prototype-MIA consistent in overlap region

HiRes Prototype-MIA Hybrid changing composition (Heavy to Light) between 10^{17} and 10^{18} eV

No significant information near GZK region yet

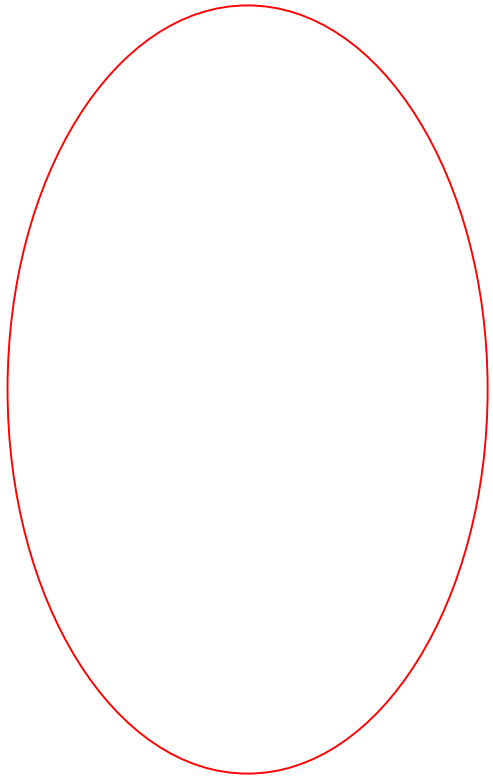


HiRes Spectrum 2003



Comparisons 2003

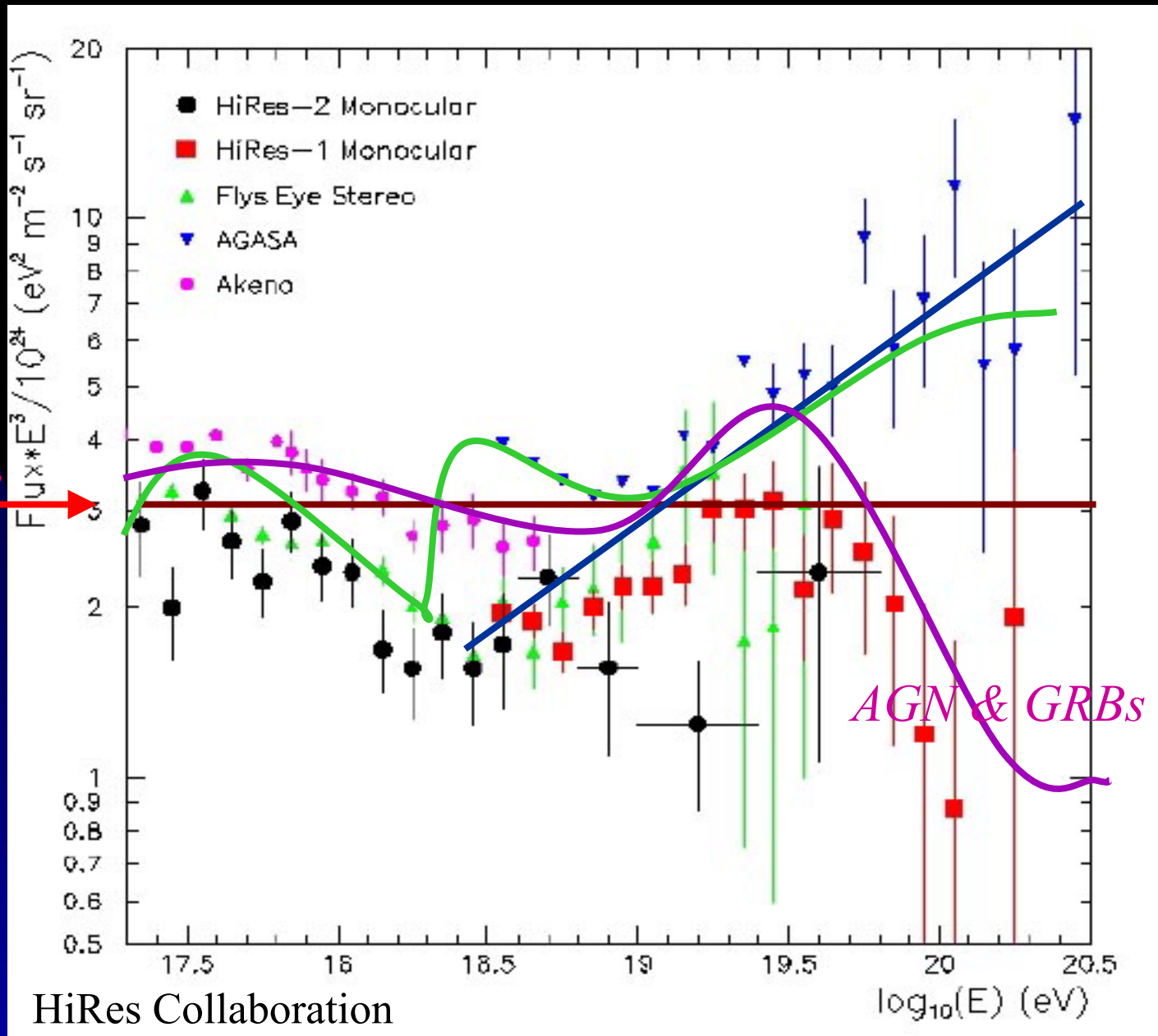
QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.



A Theorist's Field Day

HiRes + AGASA

Lorentz Invariance Violation



HiRes Collaboration

Second UHECR Puzzle

Why the two experiments disagree?

Systematic Errors
on at least one of the experiments if not both

Problems in both experiments

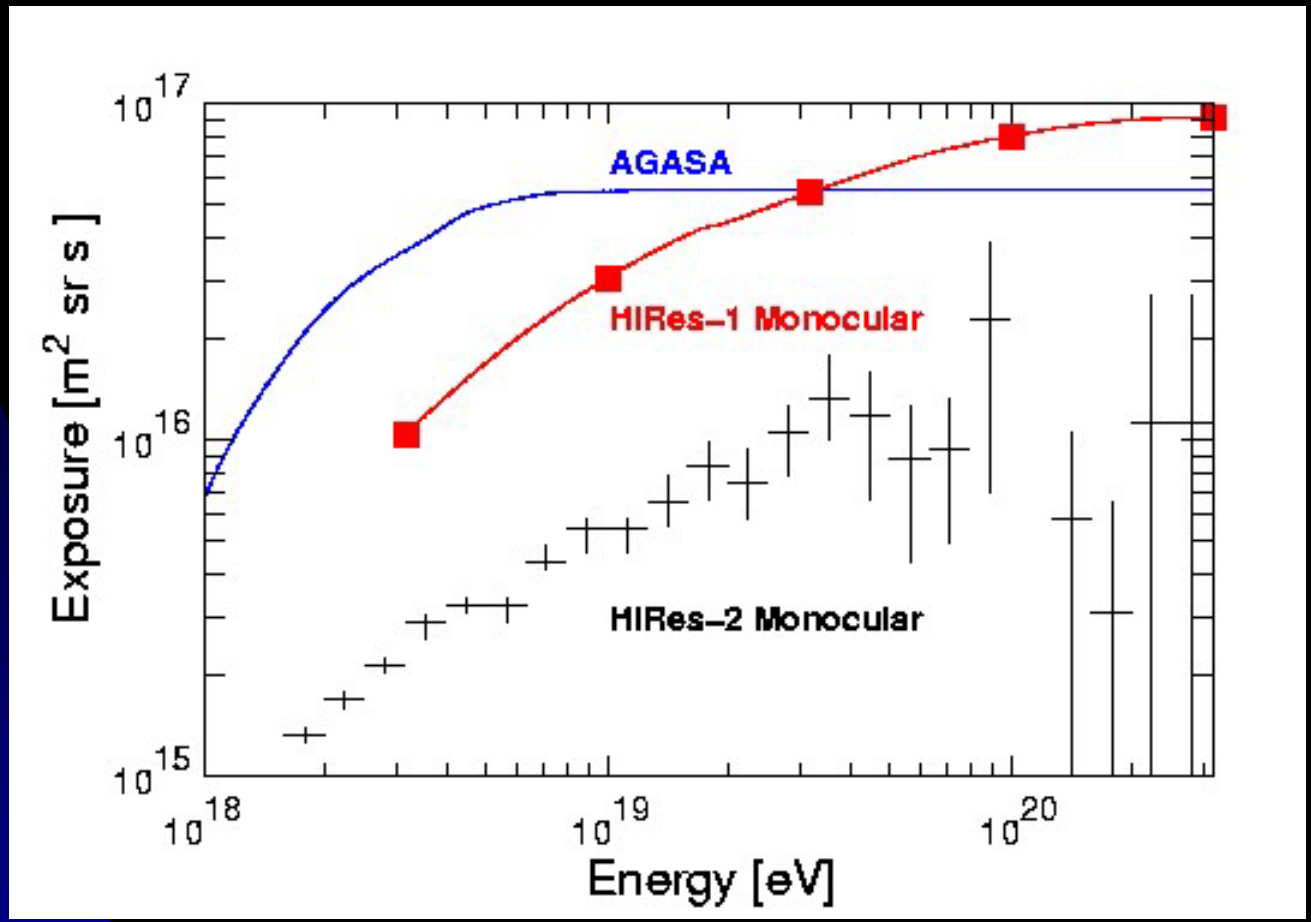
- AGASA
  - Energy estimation is dependent on Monte Carlo
    - Need Cross calibration with Air Fluorescence detector
- HiRes
  - Atmosphere
    - Need detailed atmospheric monitoring online
  - Need Air fluorescence yield for 391nm line.
  - Need the Stereo Spectrum

These errors are energy dependent!!

Need Cross-Calibration of 2 Techniques!!

ICRC03

Most Recent Exposures



Thanks to HiRes and AGASA Collaborations

Second UHECR Puzzle

Why the two experiments disagree?

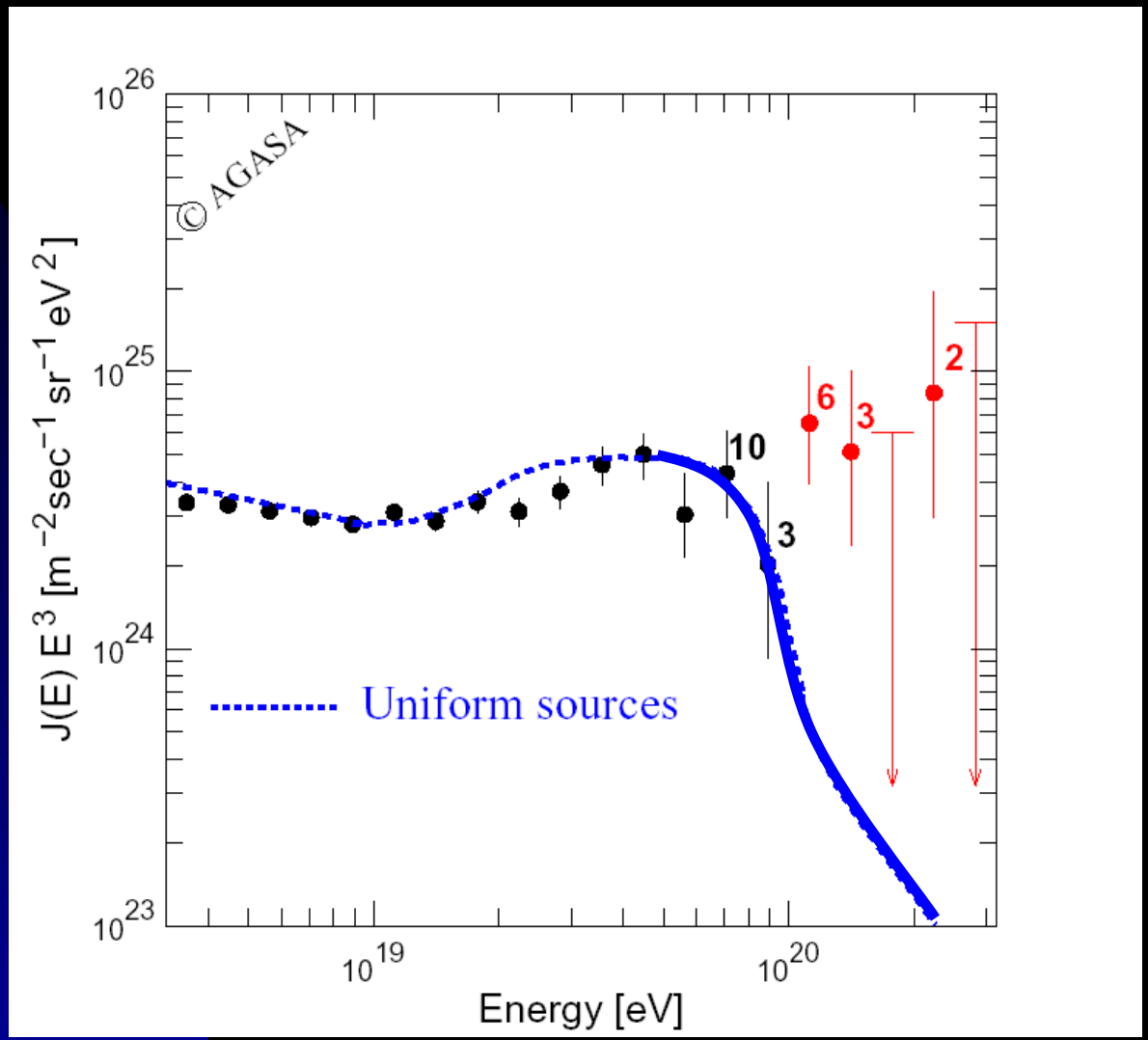
Systematic Errors
on at least one of the experiments of not both

Exposures are not Comparable Yet!
No Stereo exposure and large uncertainties

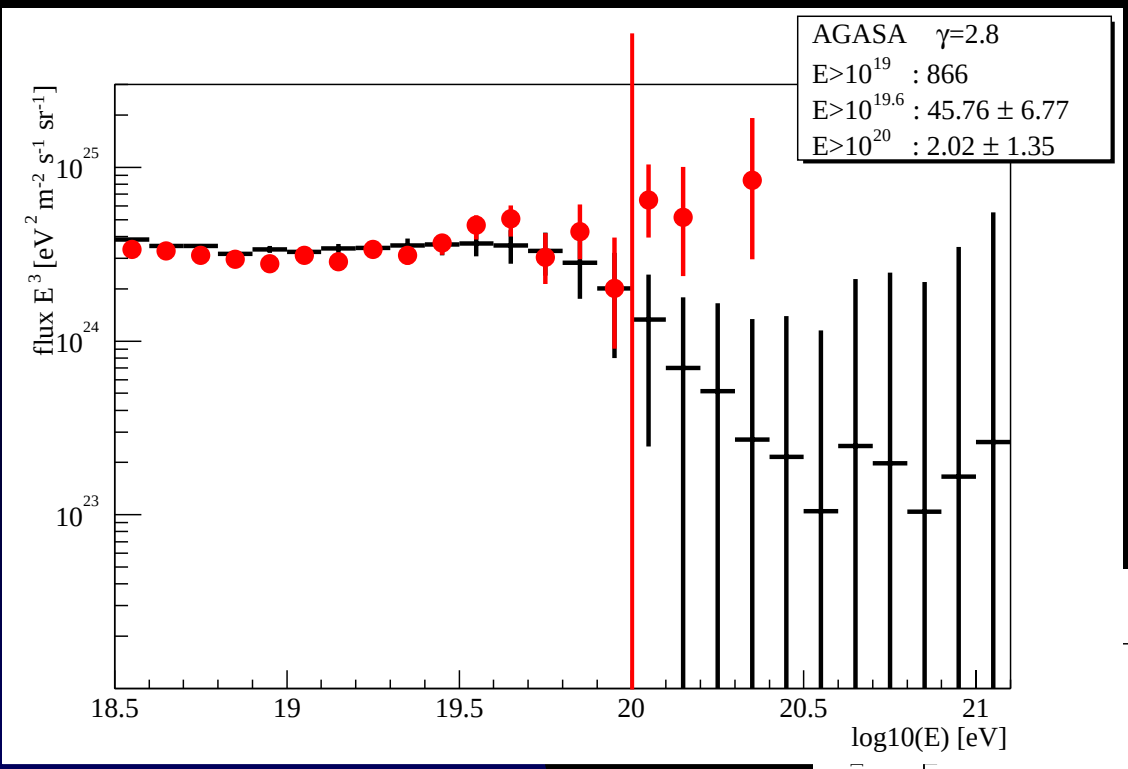
Statistics Too LOW!
pion production is stochastic

Extragalactic Protons - GZK feature

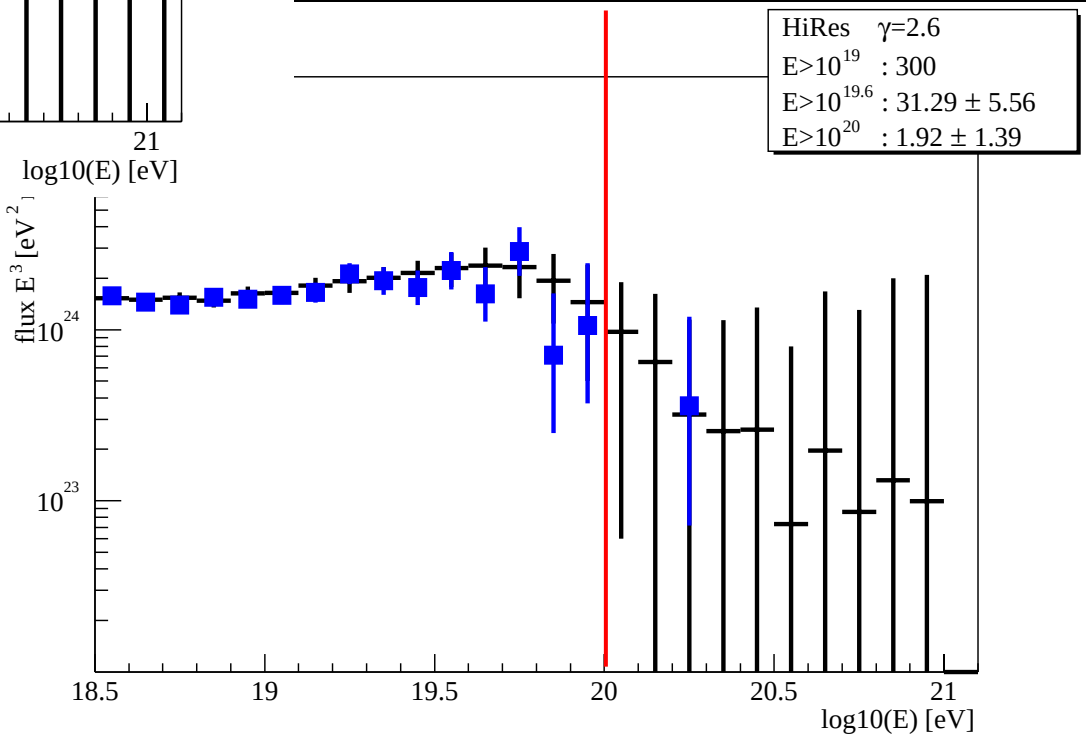
On Average! But statistics is too low!



Fluctuations about GZK feature are large for AGASA & HiRes

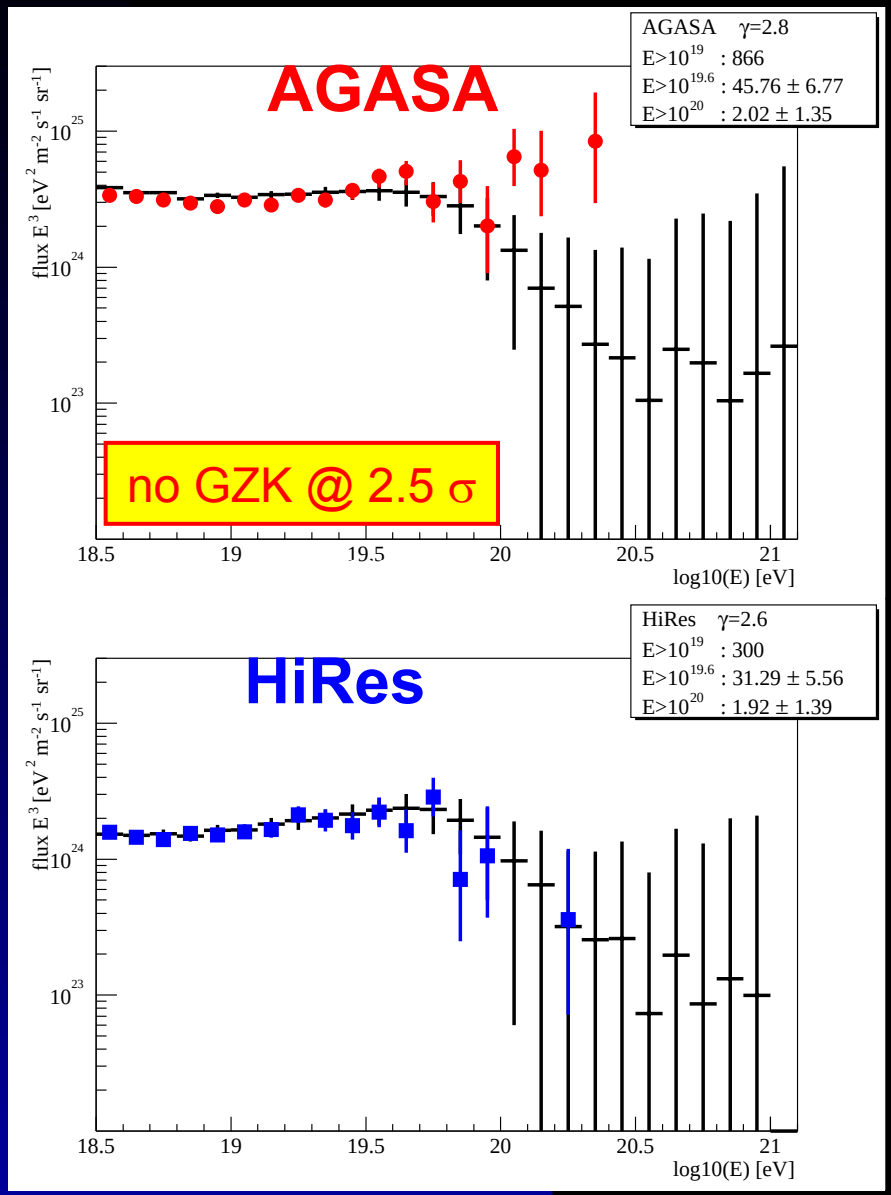


400 realizations of GZK feature for low statistics



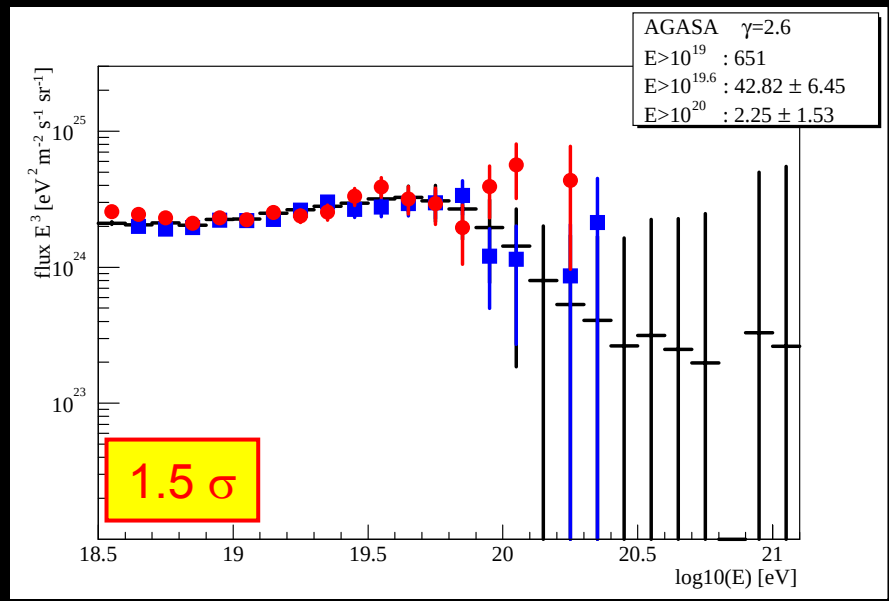
DeMarco, Blasi, & A.O. '03

systematic errors by hand…



AGASA-15%

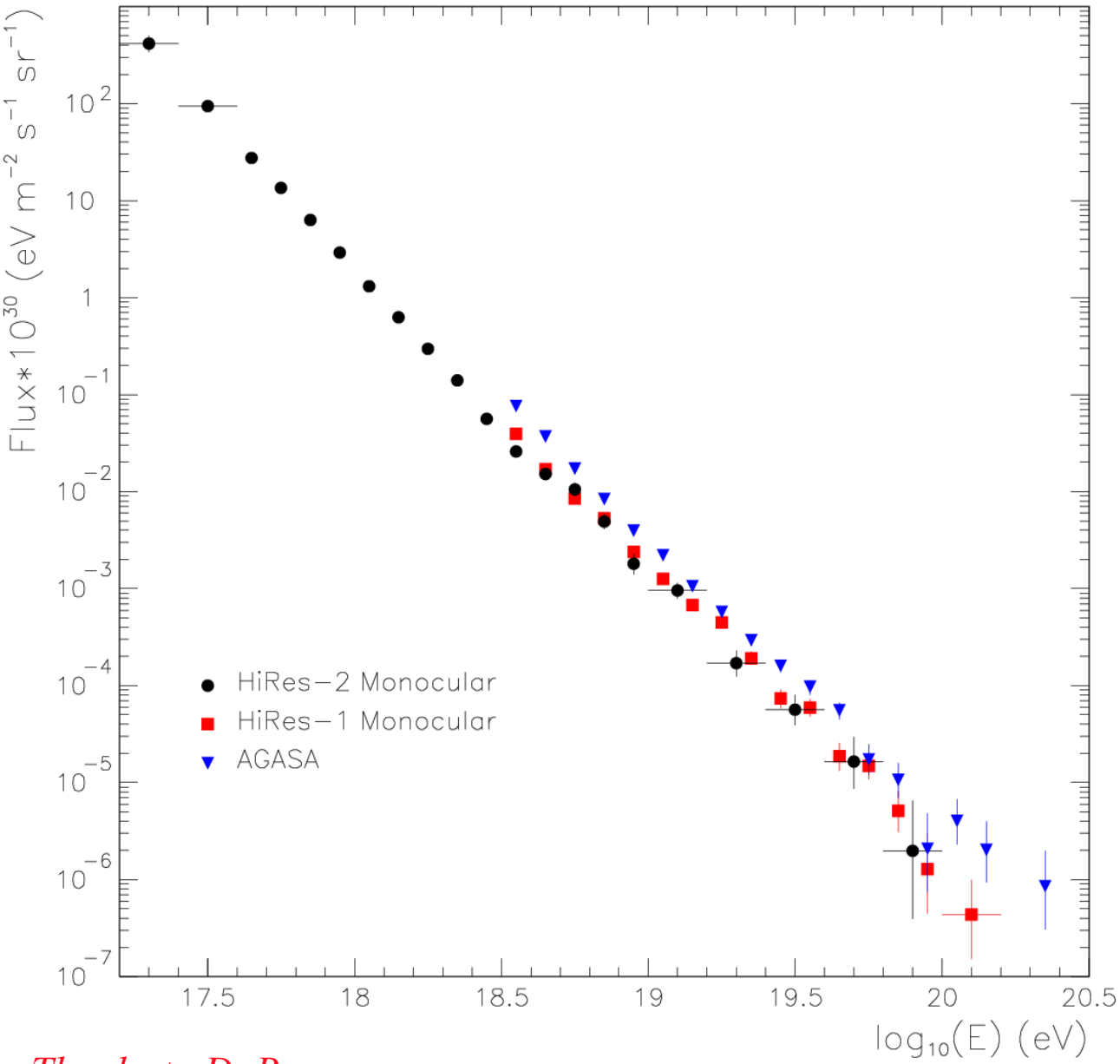
HiRes +15%



$E_{max}=10^{21.5}$ eV

DDeMarco, Blasi, AO '03

Systematic off-set



Thanks to D. Bergman

GZK Uncertainties

AGASA & HiRes discrepancy ~ 2 to 3 σ

But AGASA hints of Super-GZK events

- very interesting!!

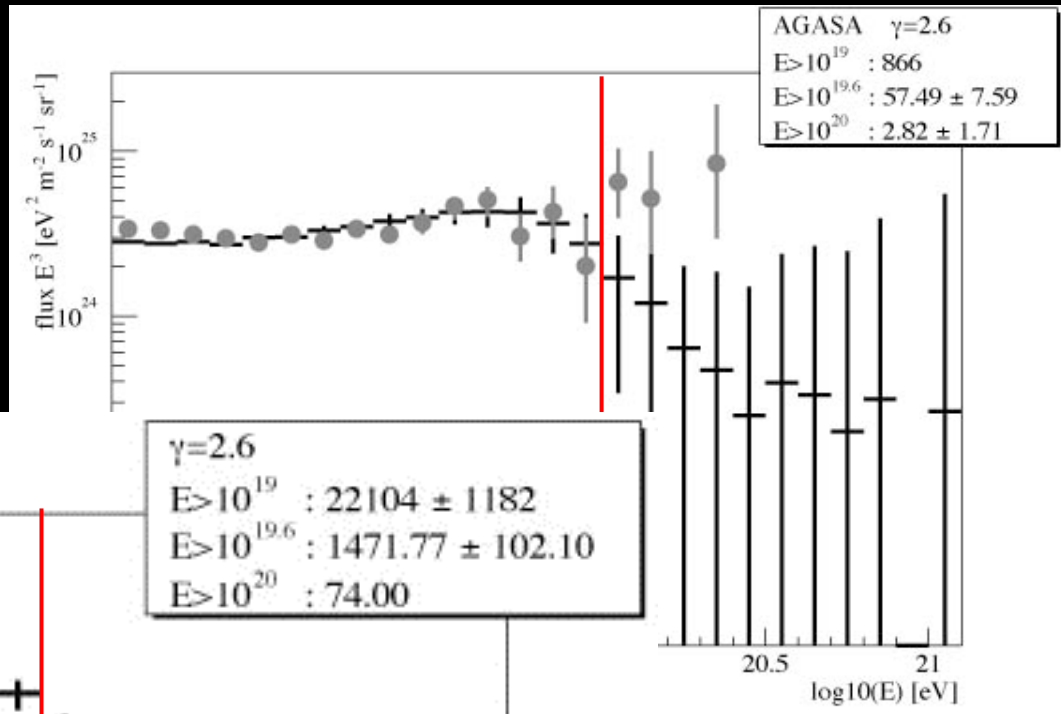
HiRes hints of GZK feature

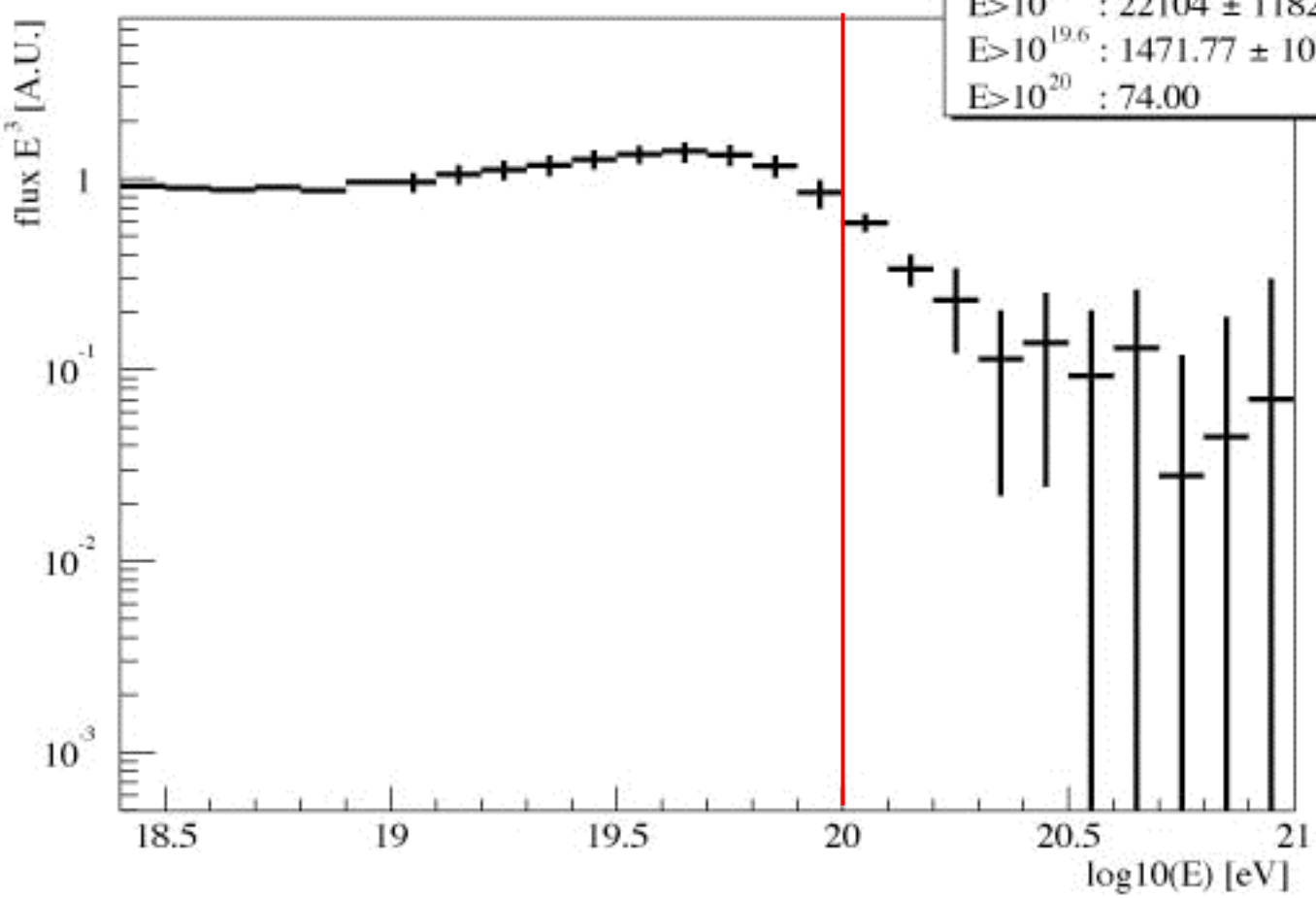
- reassuring - point sources

- But statistics too LOW to discover Zevatrons

AUGER... *EUSO, OWL...*

Auger (S) x AGASA





DeMarco, Blasi, A.O. '03

Time to get the Pros!

Pierre Auger Project

2 Giant AirShower Arrays

South – Argentina Funded
North – Not Yet Funded

1600 particle detectors over 3000 km^2
+ 4 Fluorescence Detectors

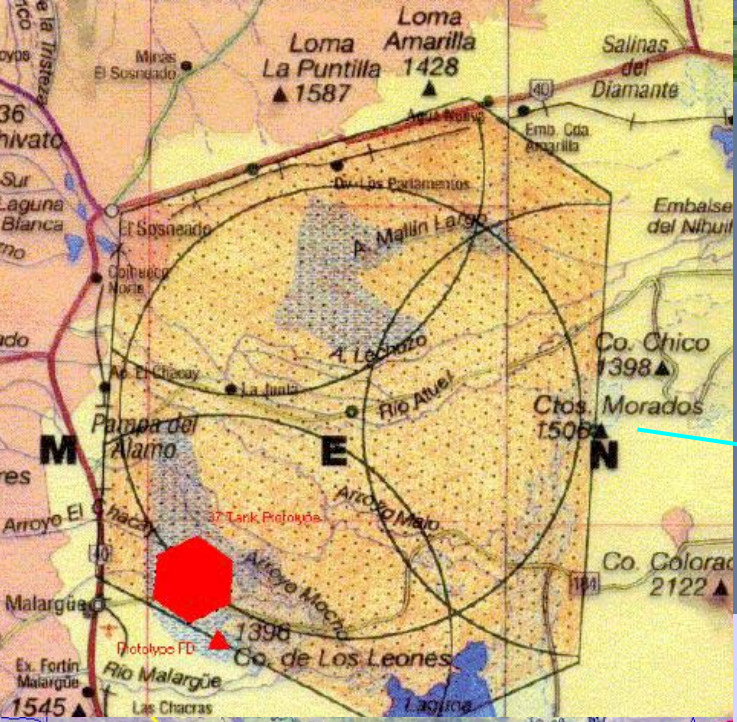
Will Measure Direction, Energy, & Composition of

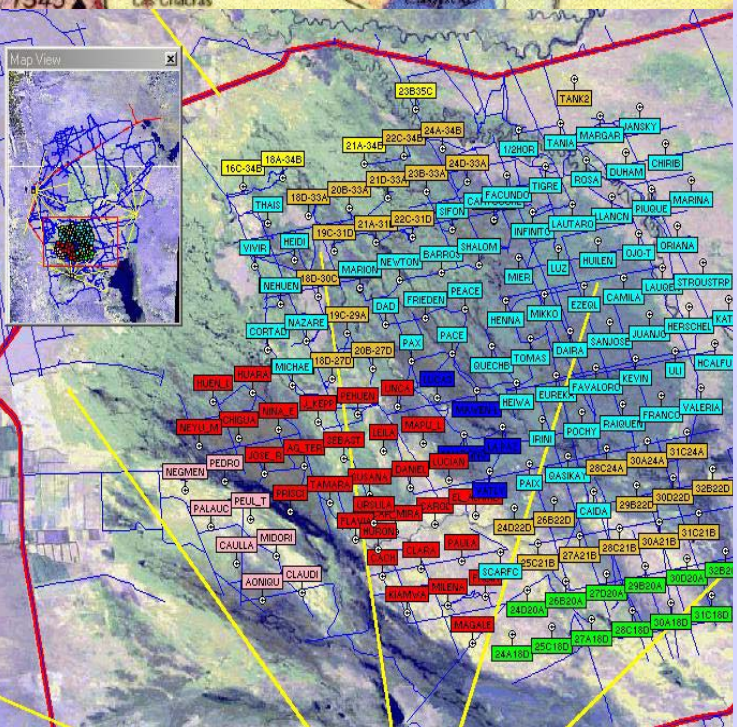
~ 60 events/yr $E > 10^{20}eV$
~ 6000 events/yr $E > 10^{19}eV$

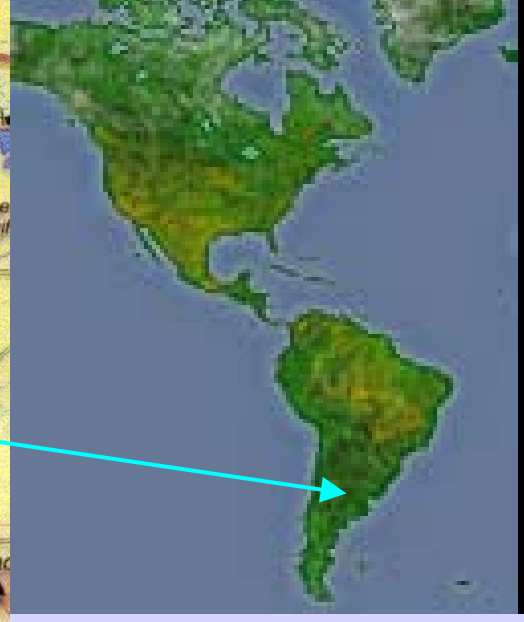
> 250 scientists from 16 countries

J. Cronin and T. Yamamoto

sample of **- Auger Collaboration**

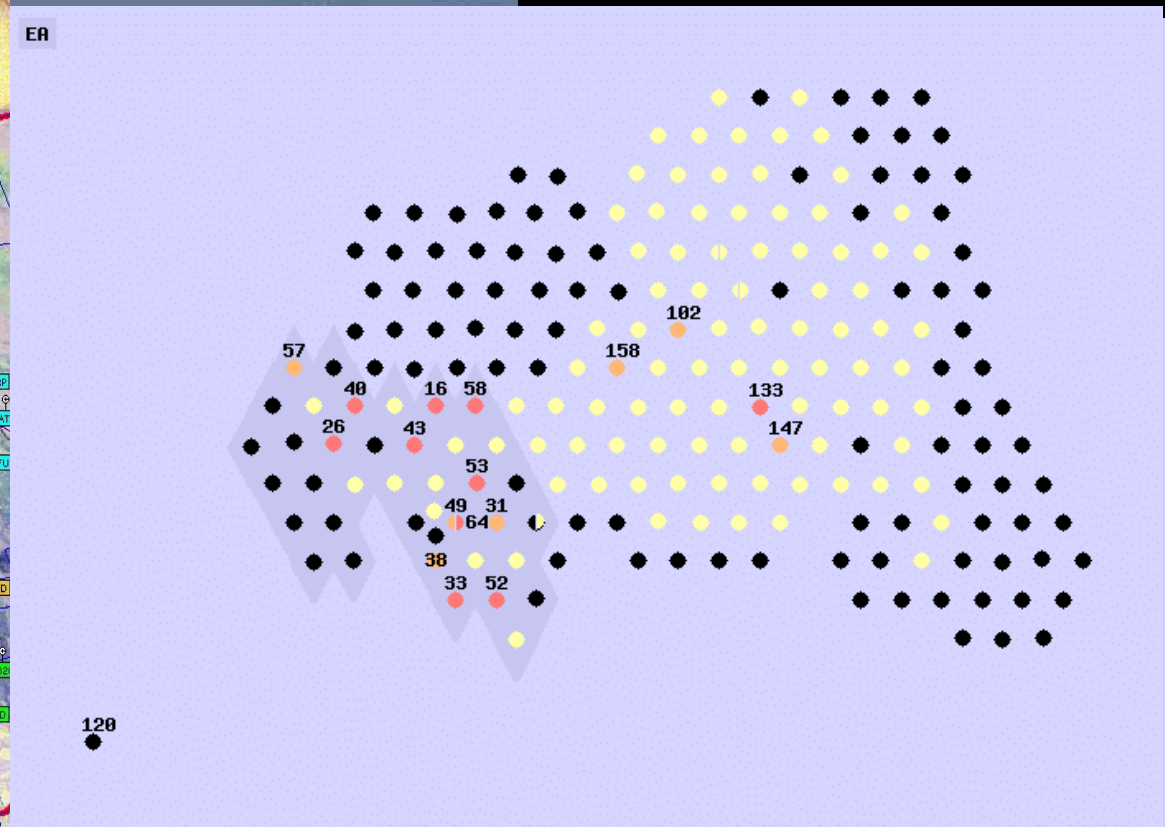






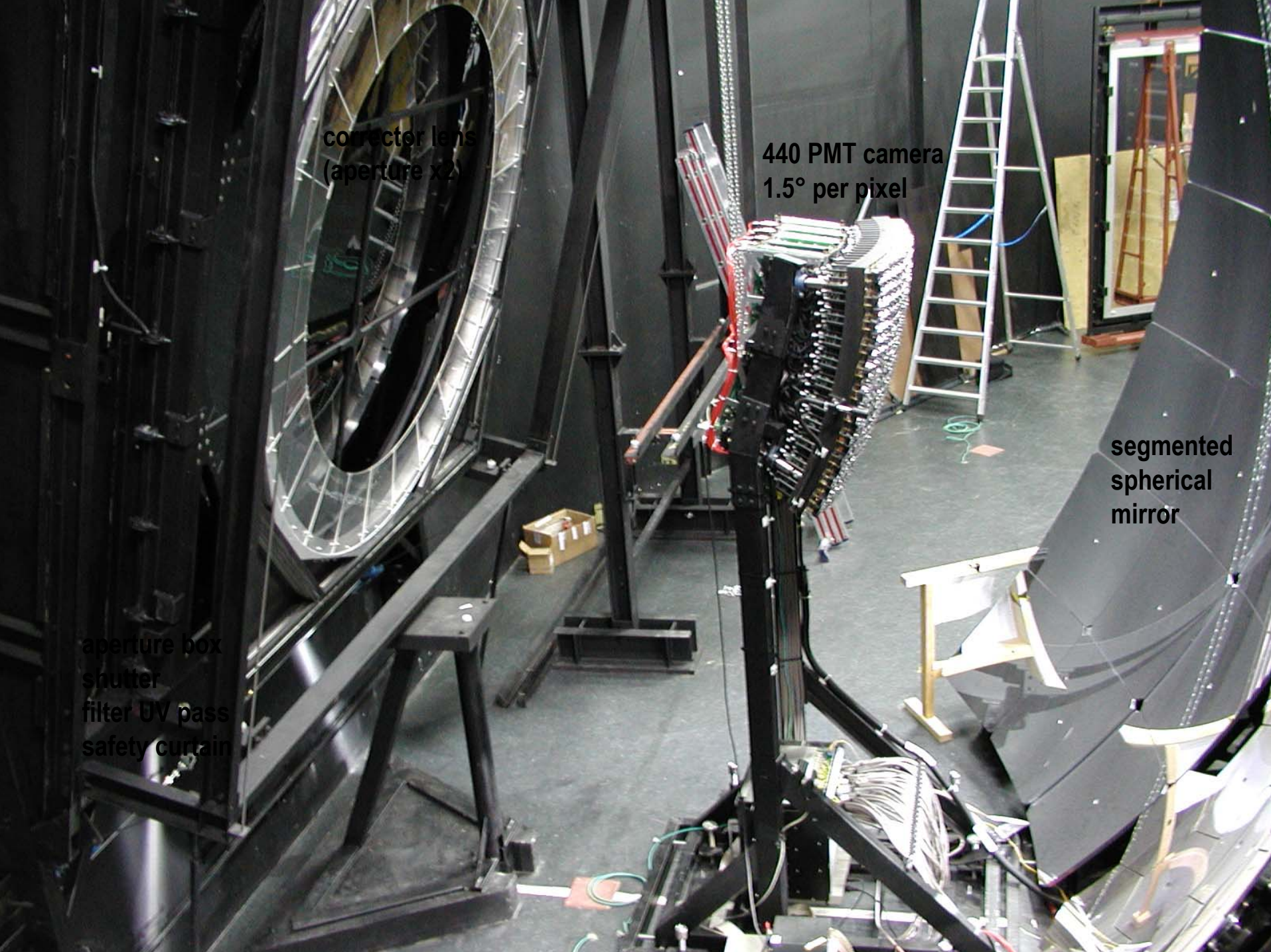
Auger South

110 active tanks
+40 EA



Argentina's Pampa Amarilla desert is filling up with water. Across thousands of square kilometres of the desert's flat plains, engineers are busy building water tanks. By 2005, 1,600 of the 11-cubic-metre tanks will be in place.

Nature 419, 2002

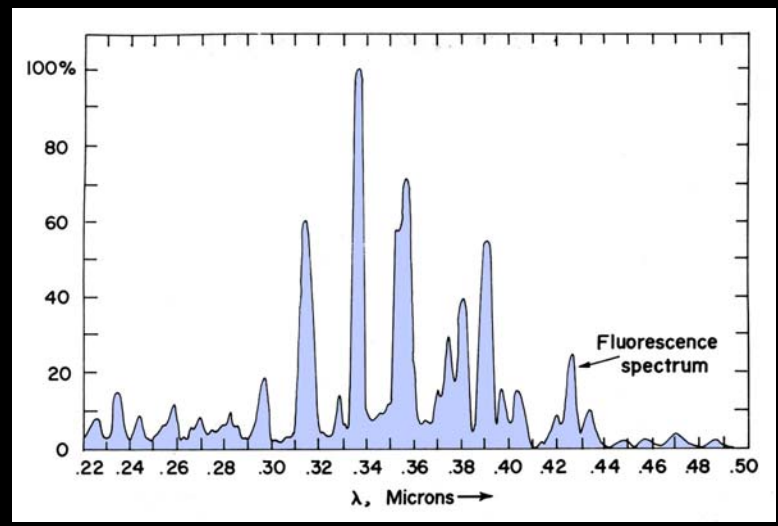

corrector lens
(aperture x2)
440 PMT camera
1.5° per pixel
segmented
spherical
mirror
aperture box
shutter
filter UV pass
safety curtain

Pierre AUGER:
Present Status

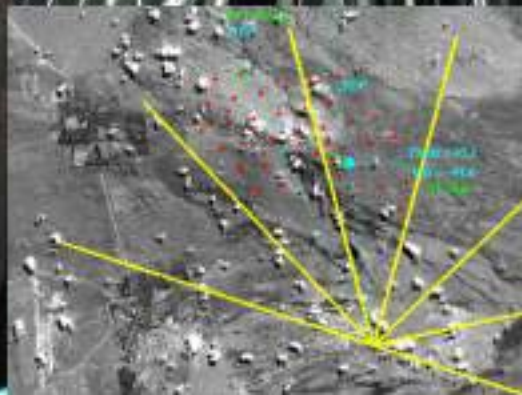
Engineering Array (40 tanks)
completed
Pre-production phase:
140 tanks installed (now) + 600 (‘04) + rest (‘05)
+ FD at Los Leones & Coiheco.
The buildings on the central campus are completed.
Many Hybrid Events!

Atmosphere

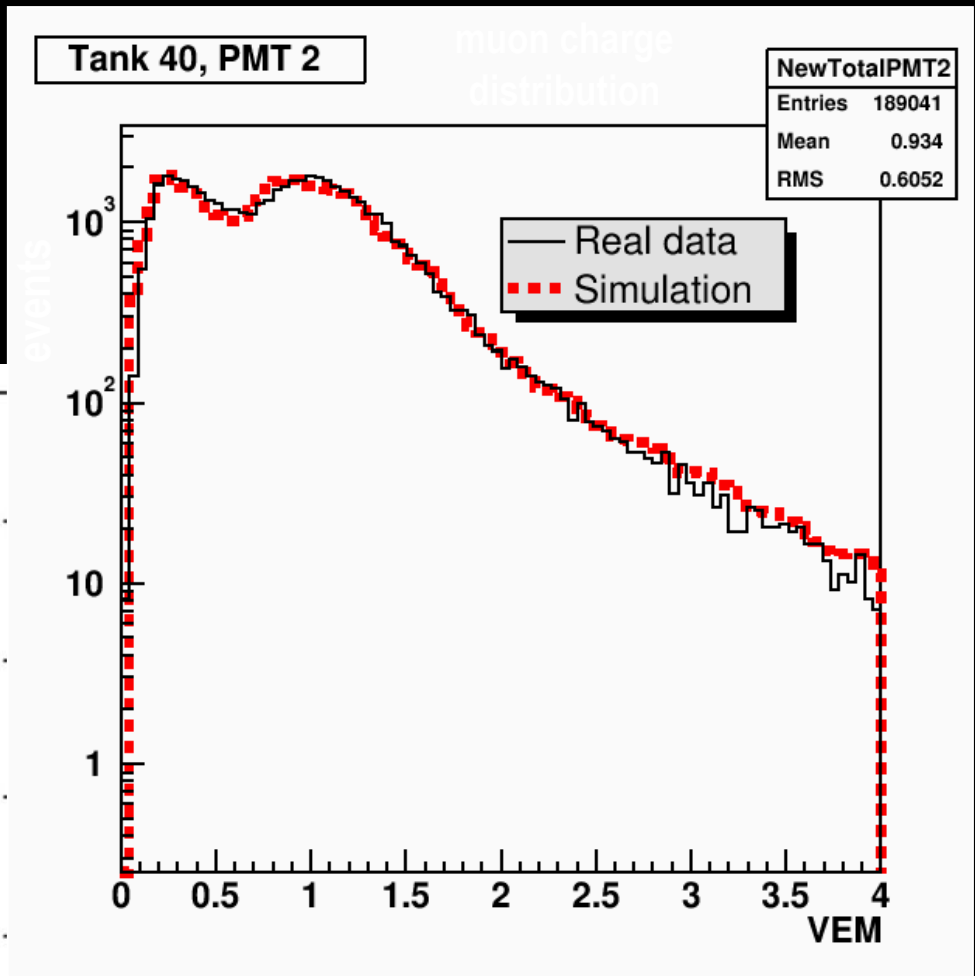
lasers – LIDAR – balloon
radio sondes – cloud
monitors – calibrated
(movable) light sources

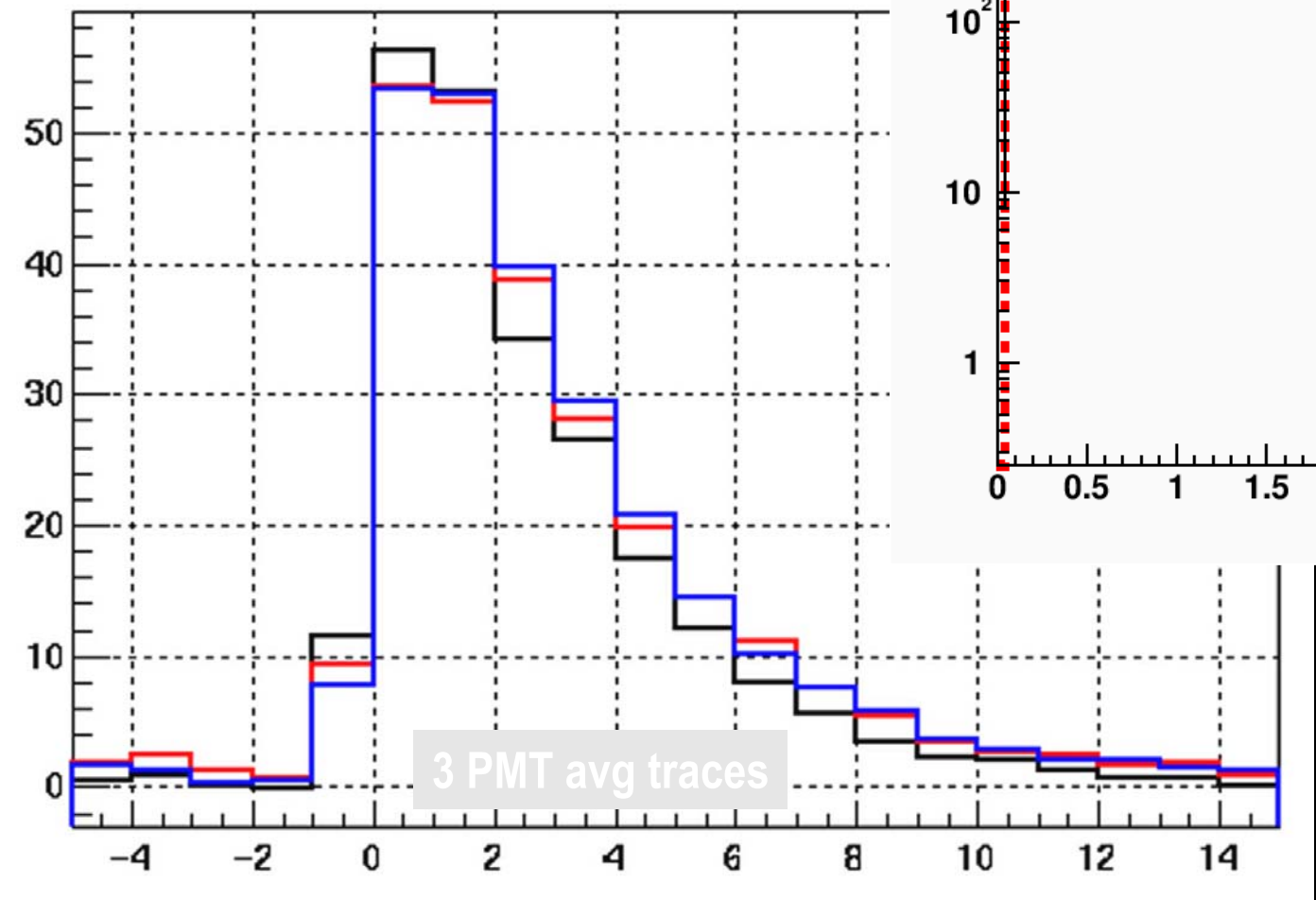


3000 km^2 - 1600 water tank array



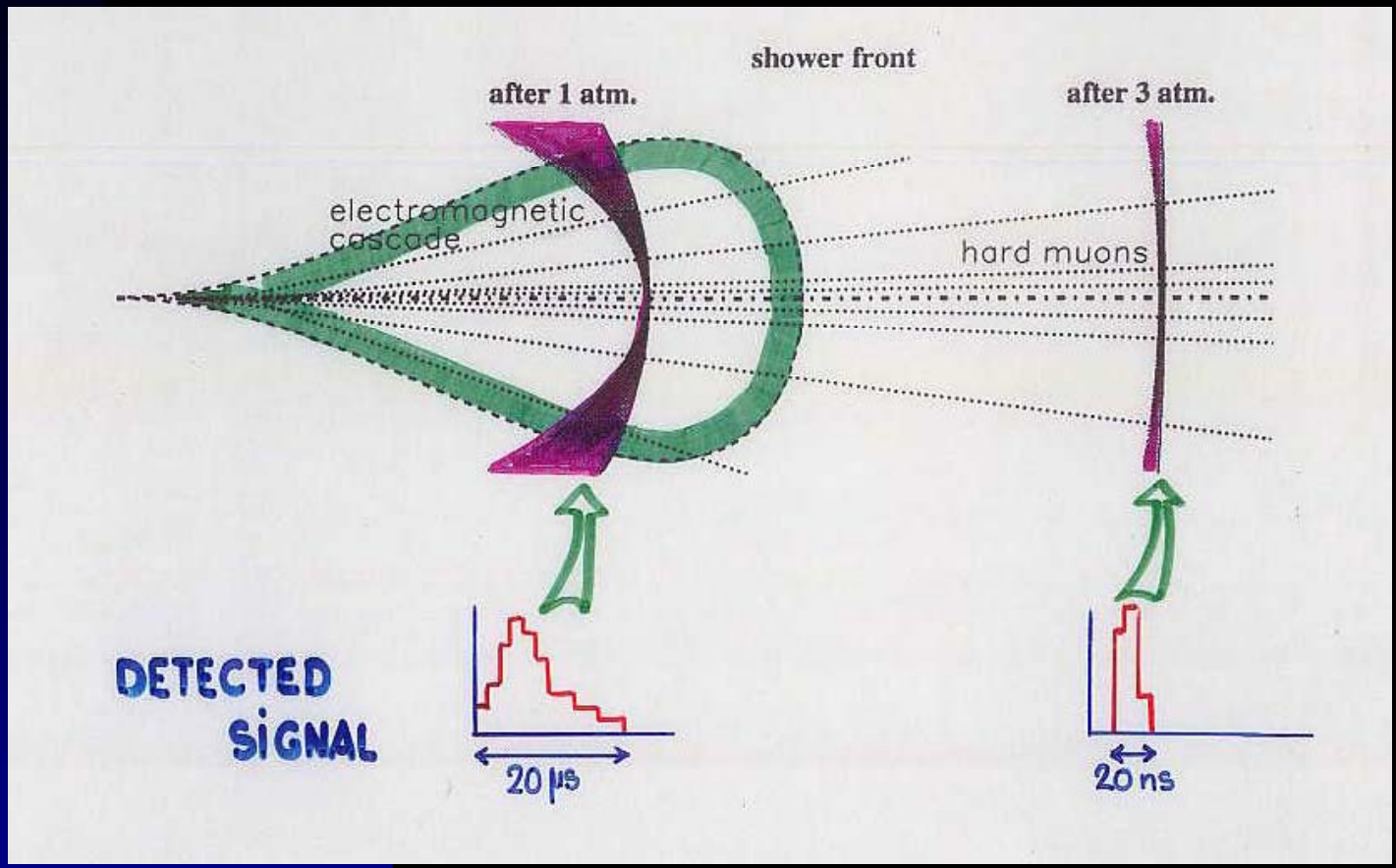
self-calibrating surface detectors



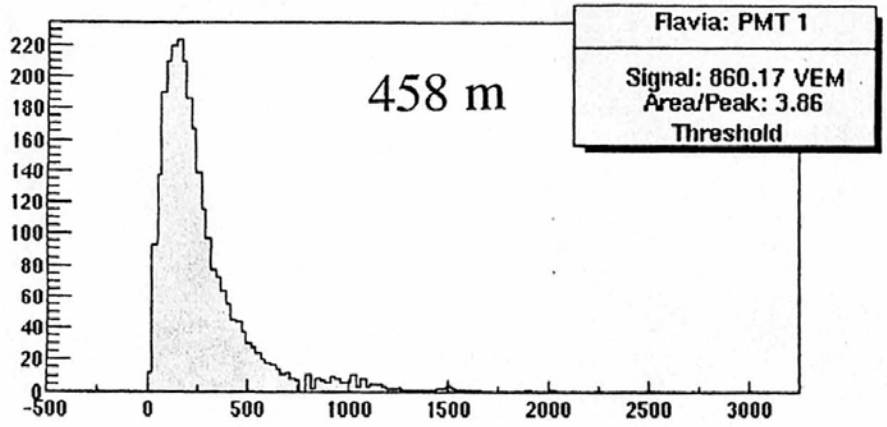


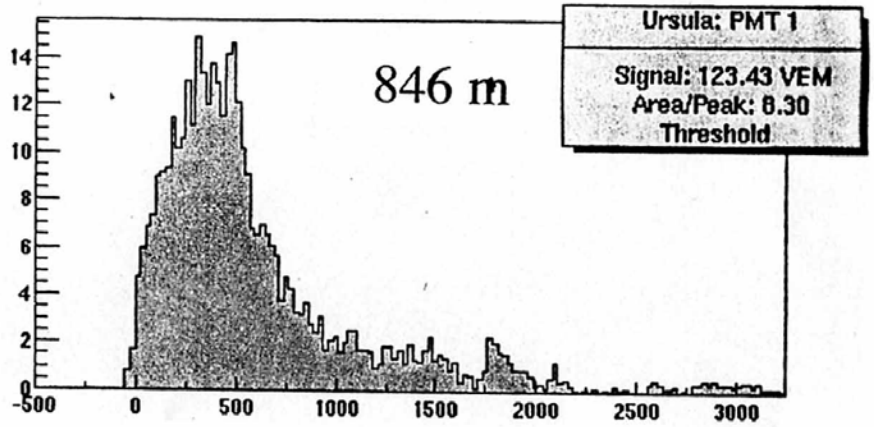
X. Bertou et al '03

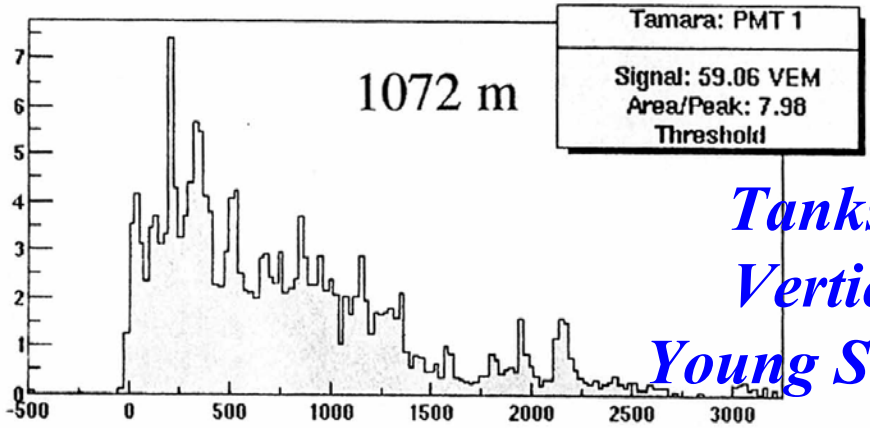
Showers OLD and YOUNG

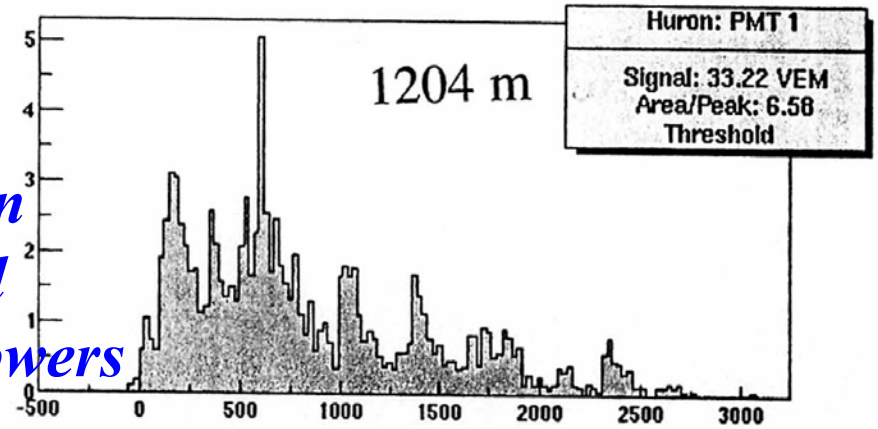


Billoir '99

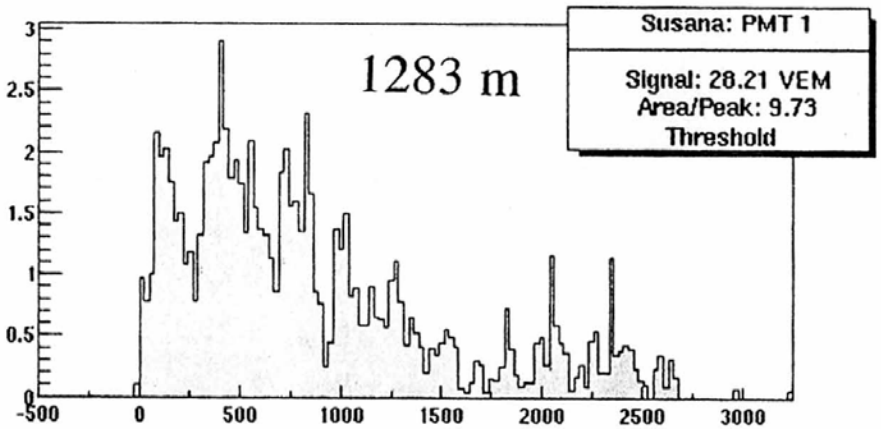


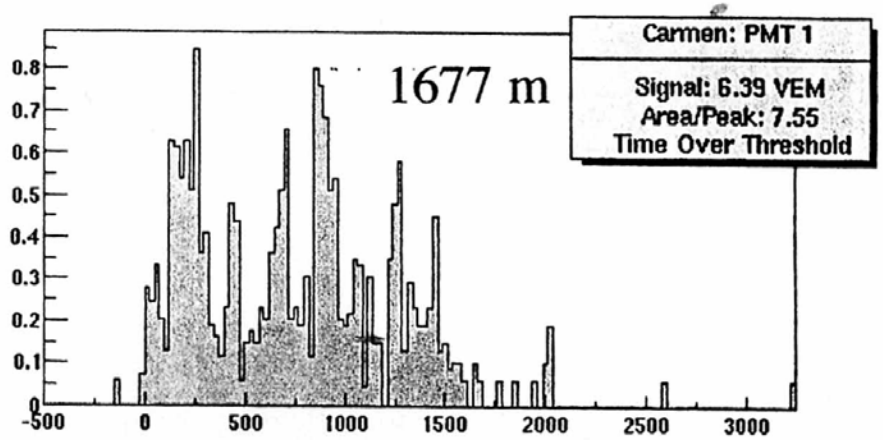




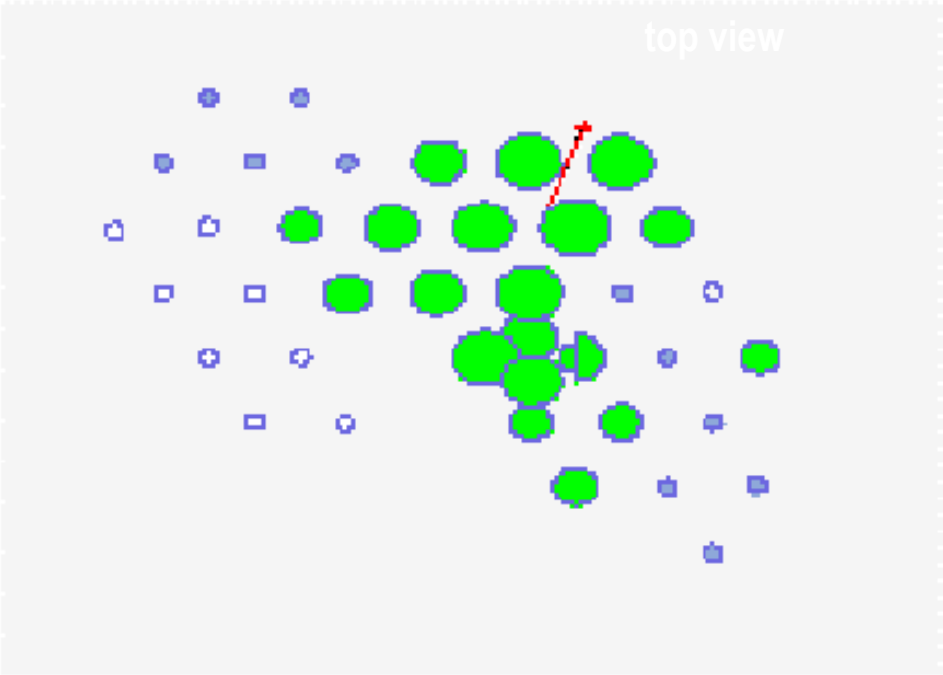


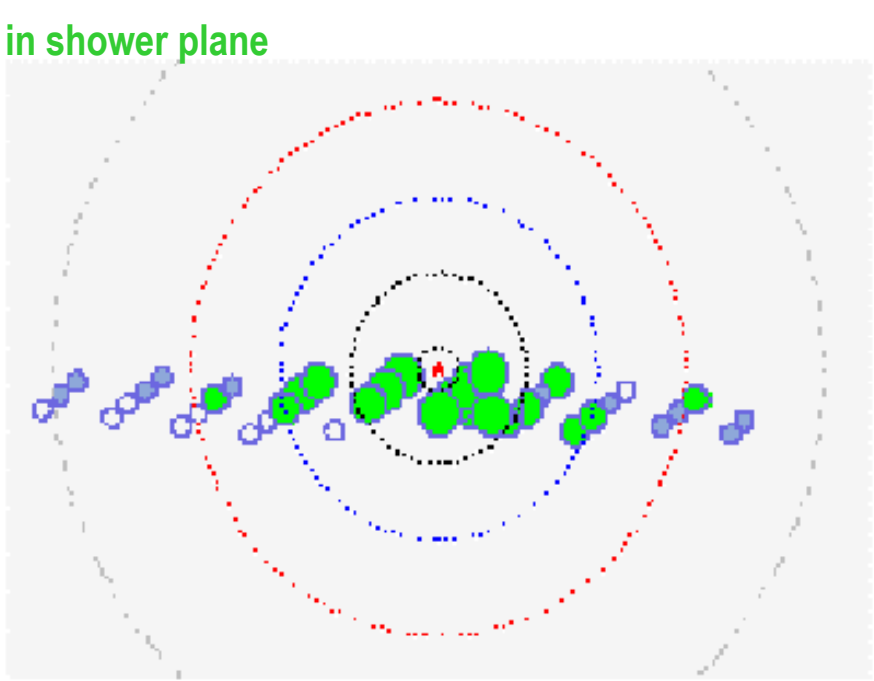
Tanks in Vertical Young Showers





Inclined showers



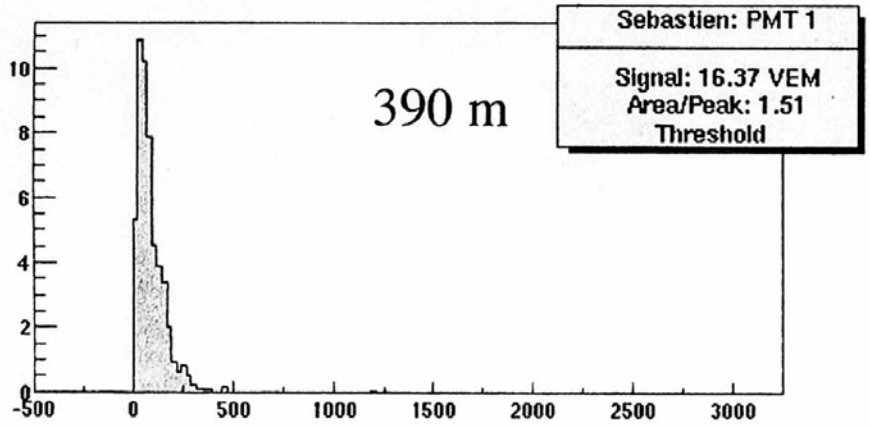


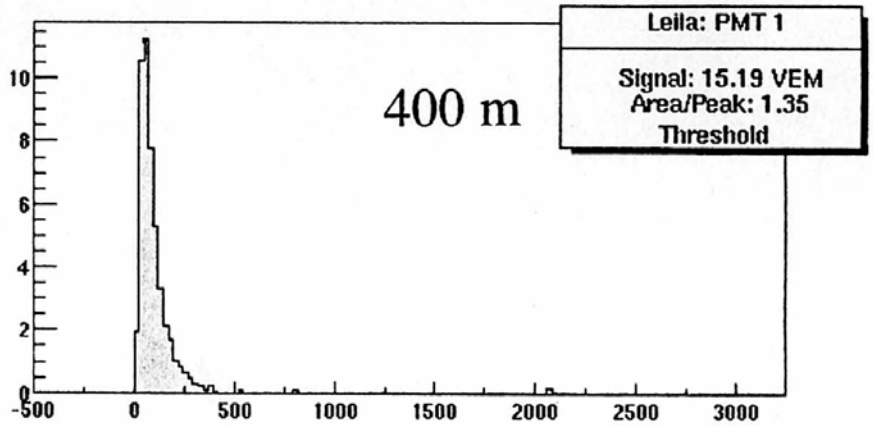
Great Resource for

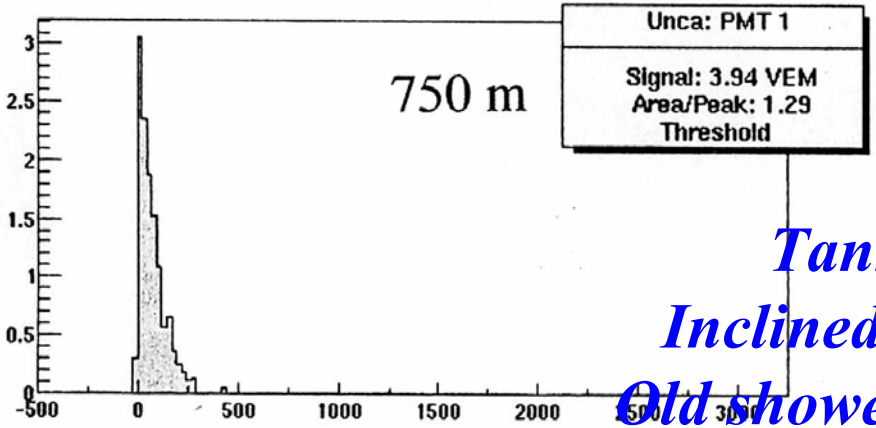
Asymmetry of Showers M. T. Dova et al ICRC03

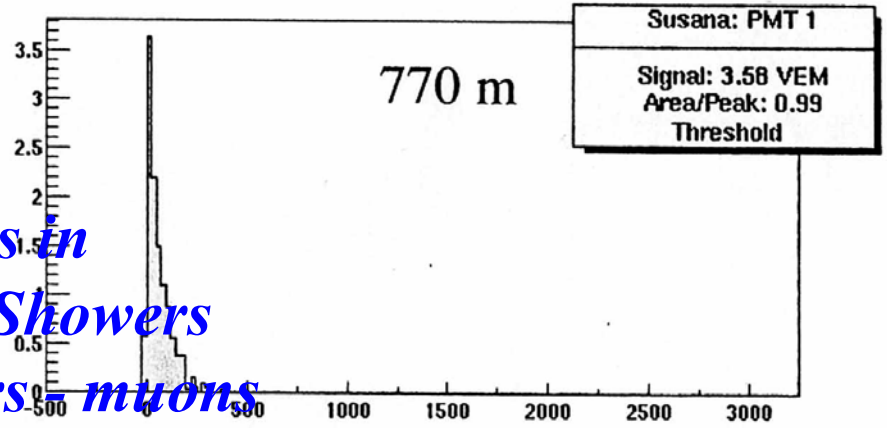
which lead to novel

Composition Studies M. Ave et al ICRC03

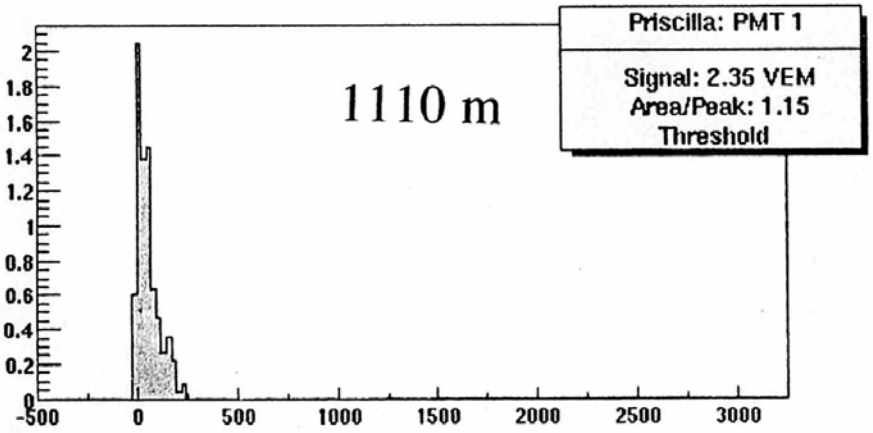


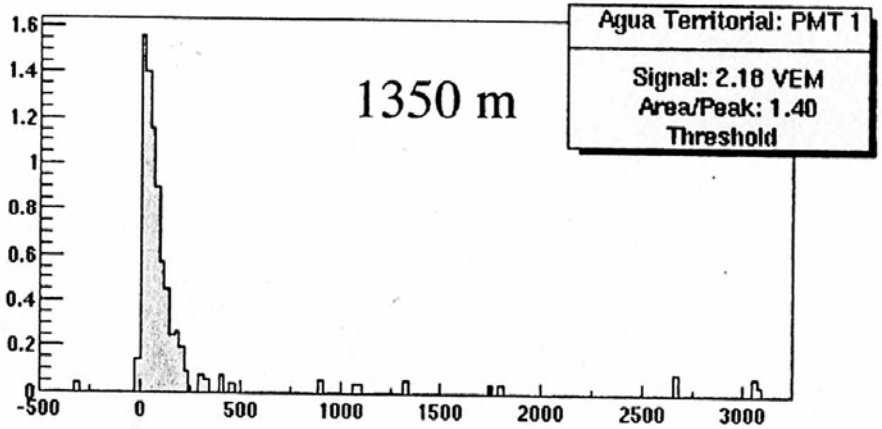


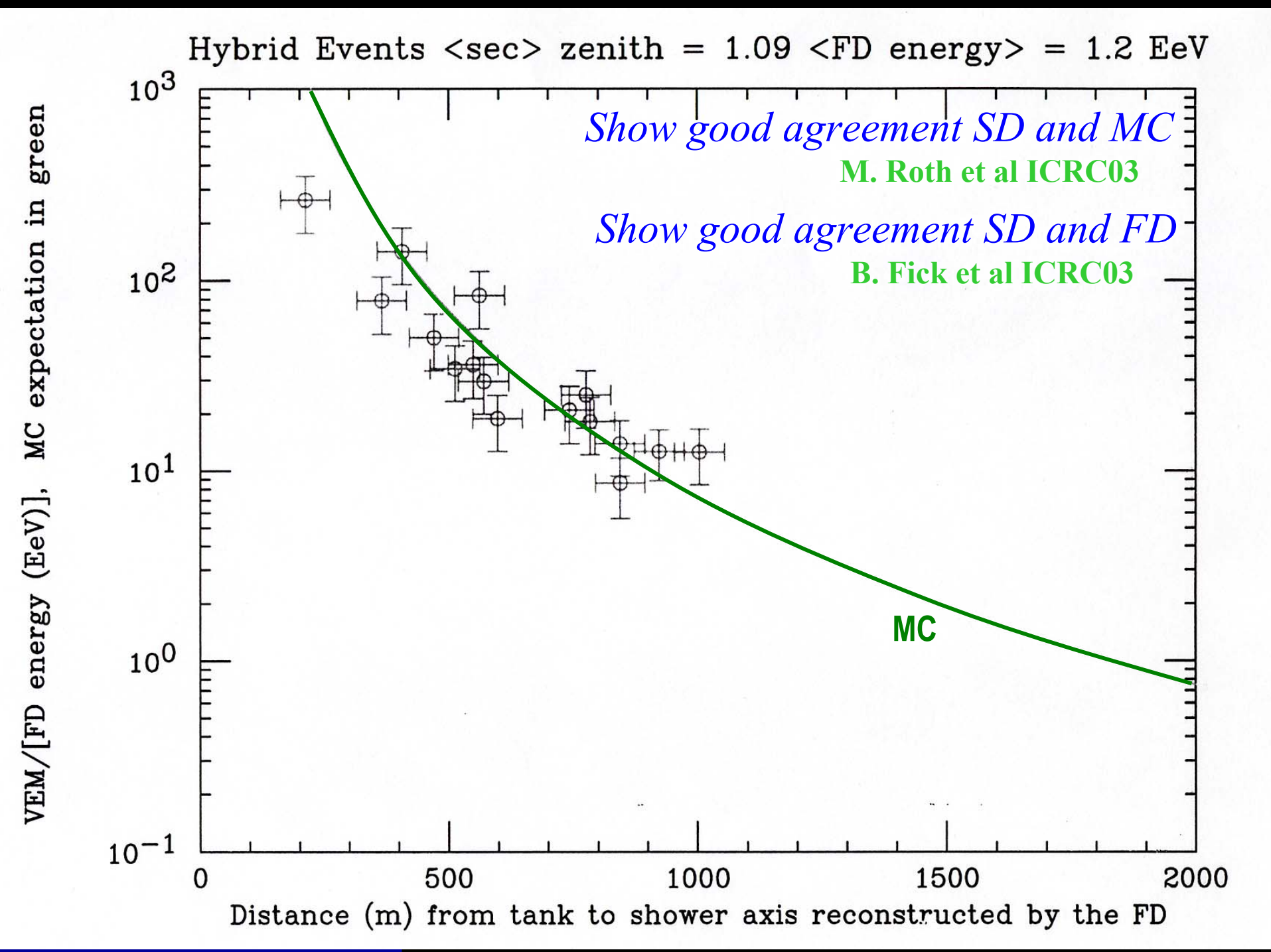




Tanks in
Inclined Showers
Old showers - muons

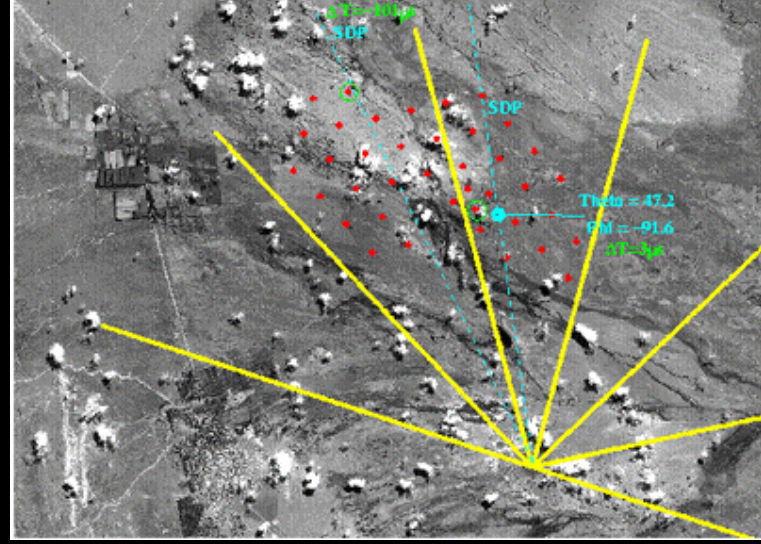





Hybrid Events <sec> zenith = 1.09 <FD energy> = 1.2 EeV
VEM/[FD energy (EeV)], MC expectation in green
Distance (m) from tank to shower axis reconstructed by the FD
Show good agreement SD and MC
M. Roth et al ICRC03
Show good agreement SD and FD
B. Fick et al ICRC03
MC

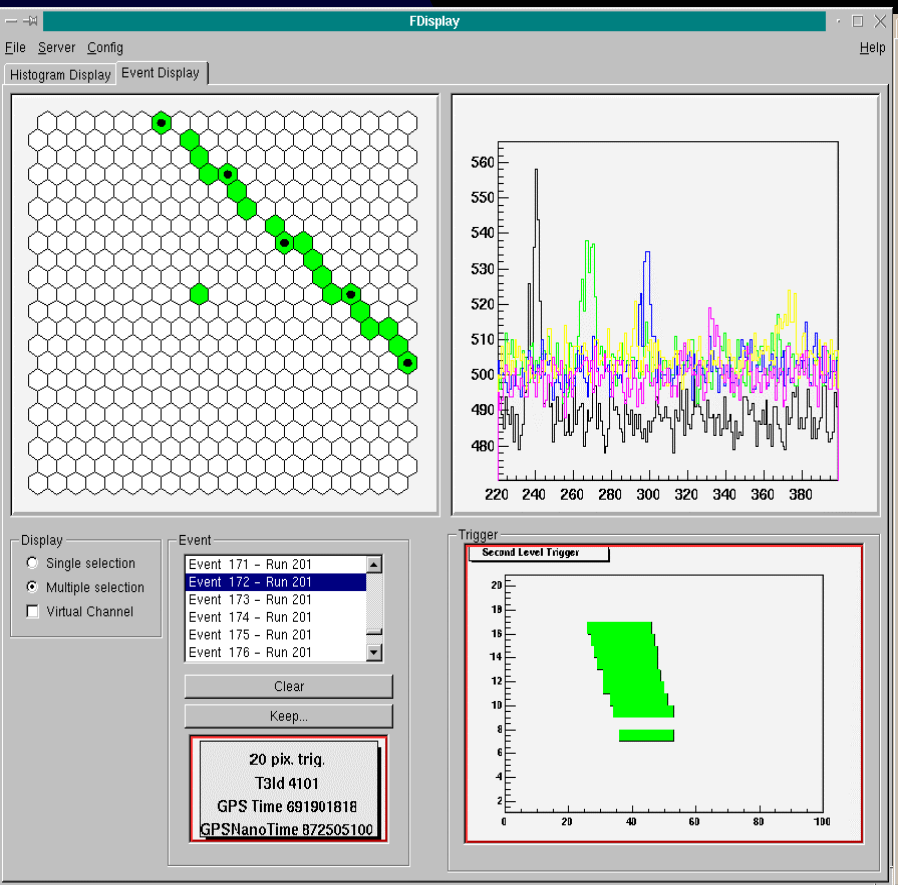
Hybrid Events & Horizontal Events

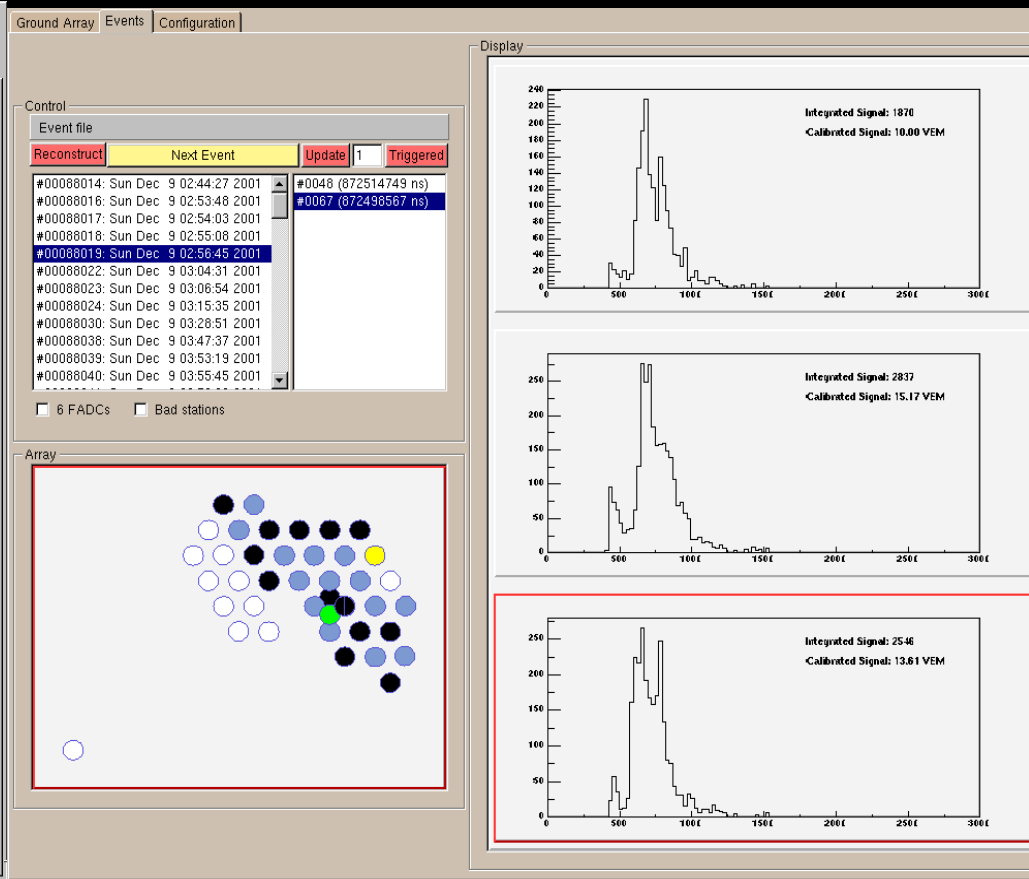
Sun 9 Dec. 02:56:45 2001 -
Auger sees first hybrid event



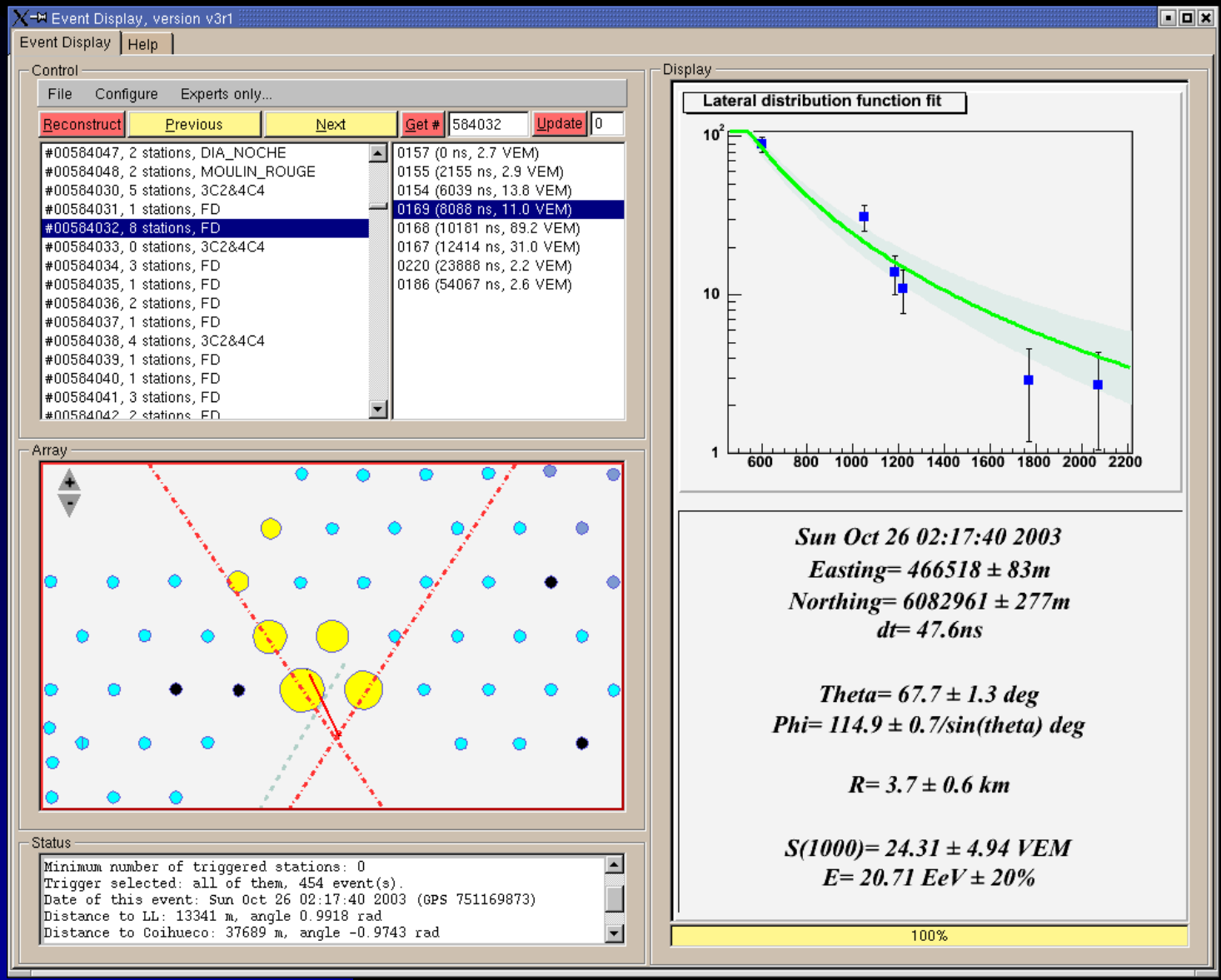
Los Leones Bay 4

Tank Huron

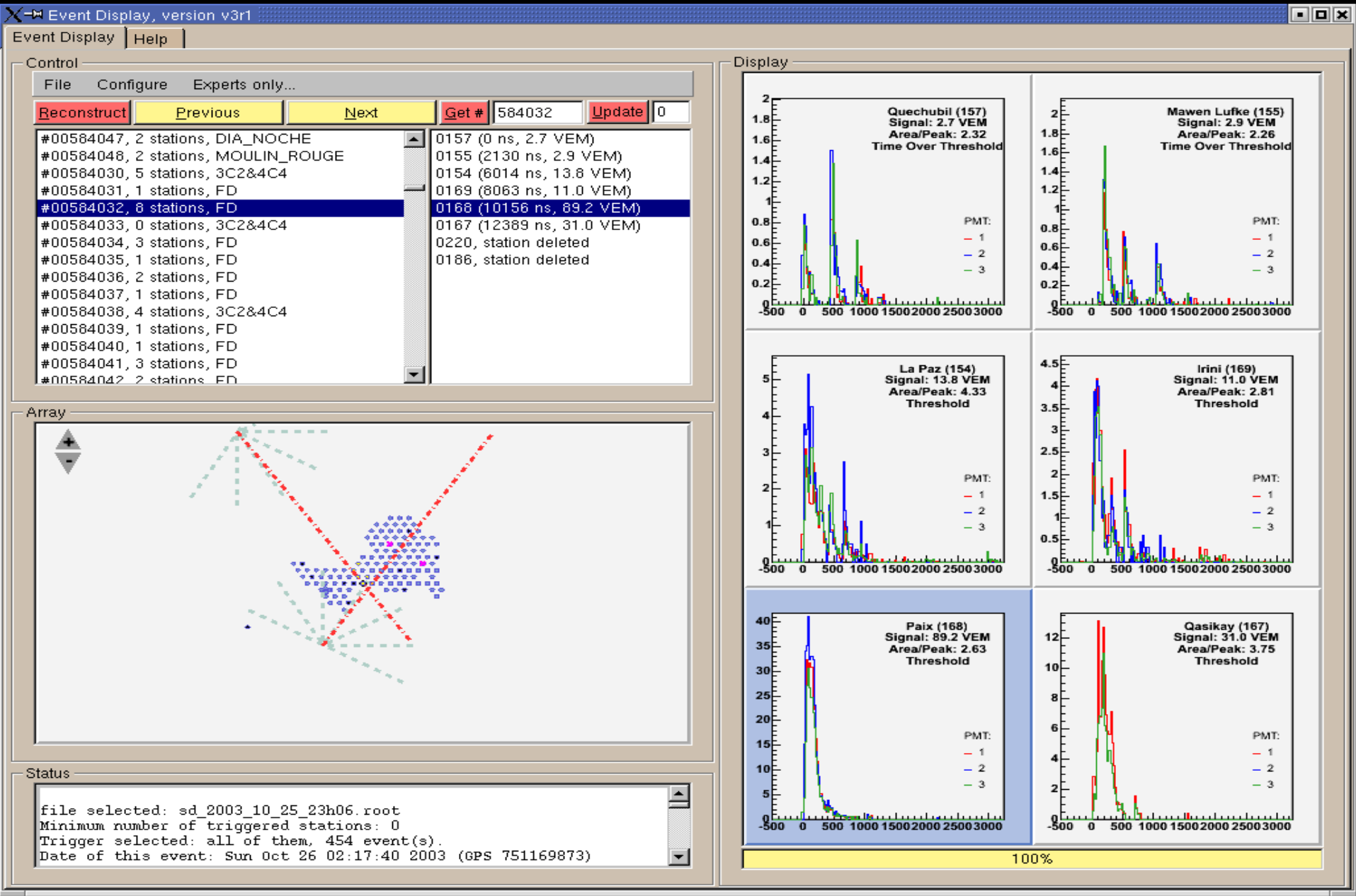




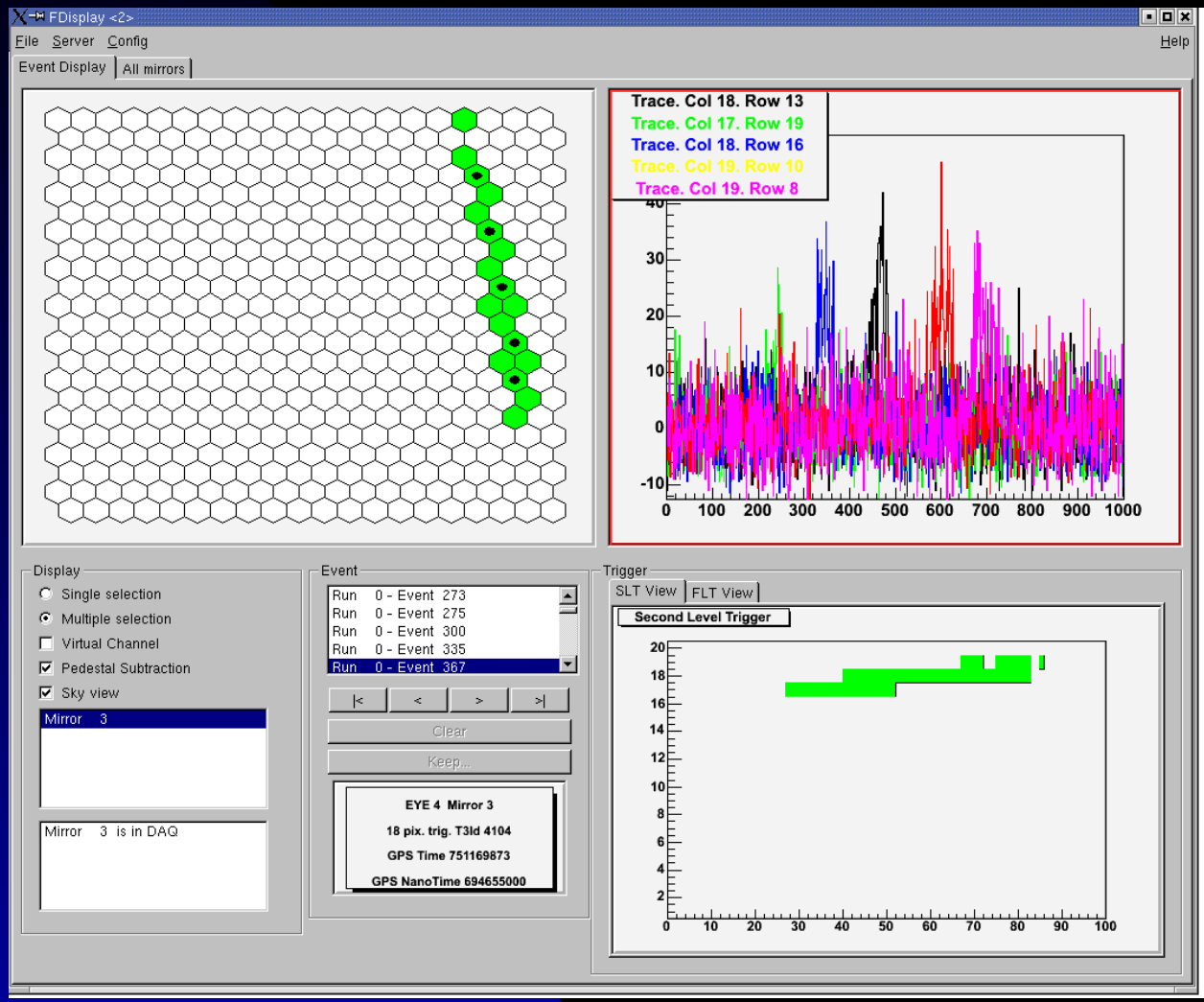
First Stereo hybrid event, October 25 23:17:40 2003, local time

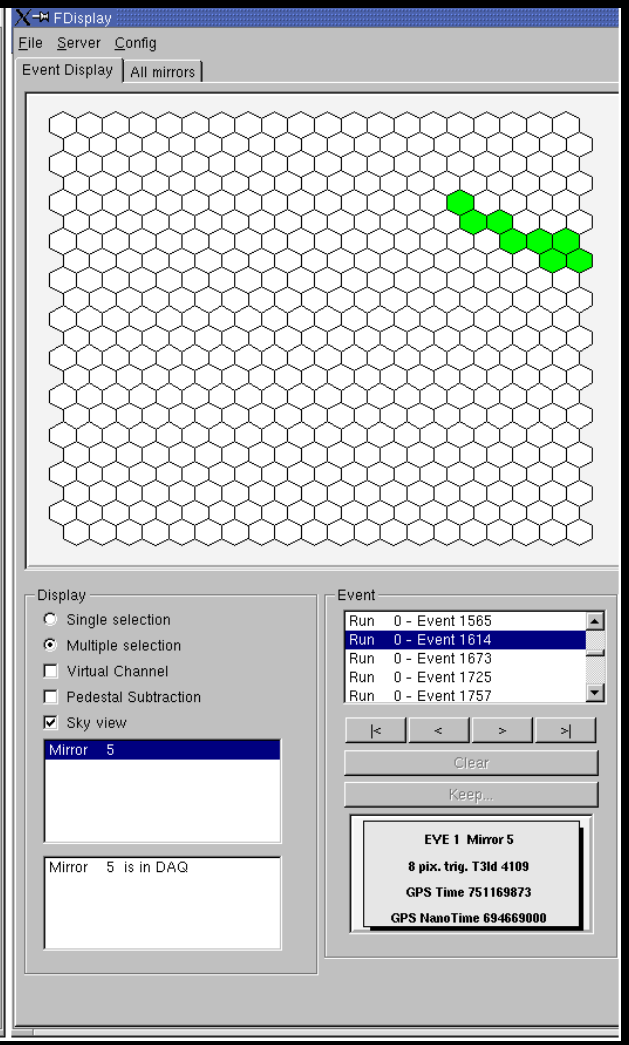


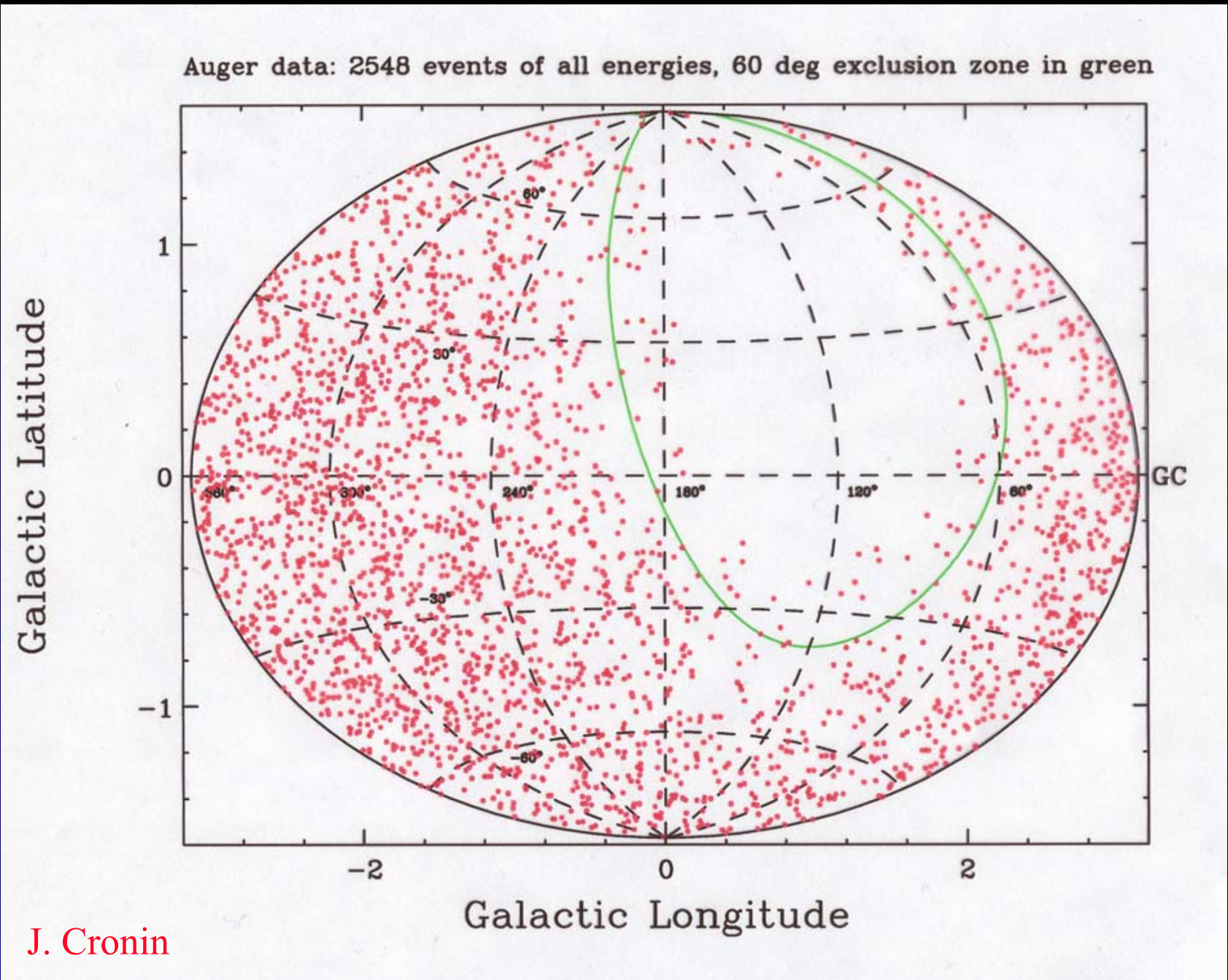
SD


Event Display, version v3r1
Event Display
Help
Control
File
Configure
Experts only...
Reconstruct
Previous
Next
Get #
584032
Update
0
#00584047, 2 stations, DIA_NOCHE
#00584048, 2 stations, MOULIN_ROUGE
#00584030, 5 stations, 3C2&4C4
#00584031, 1 stations, FD
#00584032, 8 stations, FD
#00584033, 0 stations, 3C2&4C4
#00584034, 3 stations, FD
#00584035, 1 stations, FD
#00584036, 2 stations, FD
#00584037, 1 stations, FD
#00584038, 4 stations, 3C2&4C4
#00584039, 1 stations, FD
#00584040, 1 stations, FD
#00584041, 3 stations, FD
0157 (0 ns, 2.7 VEM)
0155 (2130 ns, 2.9 VEM)
0154 (6014 ns, 13.8 VEM)
0169 (8063 ns, 11.0 VEM)
0168 (10156 ns, 89.2 VEM)
0167 (12389 ns, 31.0 VEM)
0220, station deleted
0186, station deleted
Array
Status
file selected: sd_2003_10_25_23h06.root
Minimum number of triggered stations: 0
Trigger selected: all of them, 454 event(s).
Date of this event: Sun Oct 26 02:17:40 2003 (GPS 751169873)
Display
Quechubil (157)
Signal: 2.7 VEM
Area/Peak: 2.32
Time Over Threshold
Mawen Lufke (155)
Signal: 2.9 VEM
Area/Peak: 2.26
Time Over Threshold
La Paz (154)
Signal: 13.8 VEM
Area/Peak: 4.33
Threshold
Irini (169)
Signal: 11.0 VEM
Area/Peak: 2.81
Threshold
Paix (168)
Signal: 89.2 VEM
Area/Peak: 2.63
Threshold
Qasikay (167)
Signal: 31.0 VEM
Area/Peak: 3.75
Threshold
PMT:
1
2
3
100%

FD

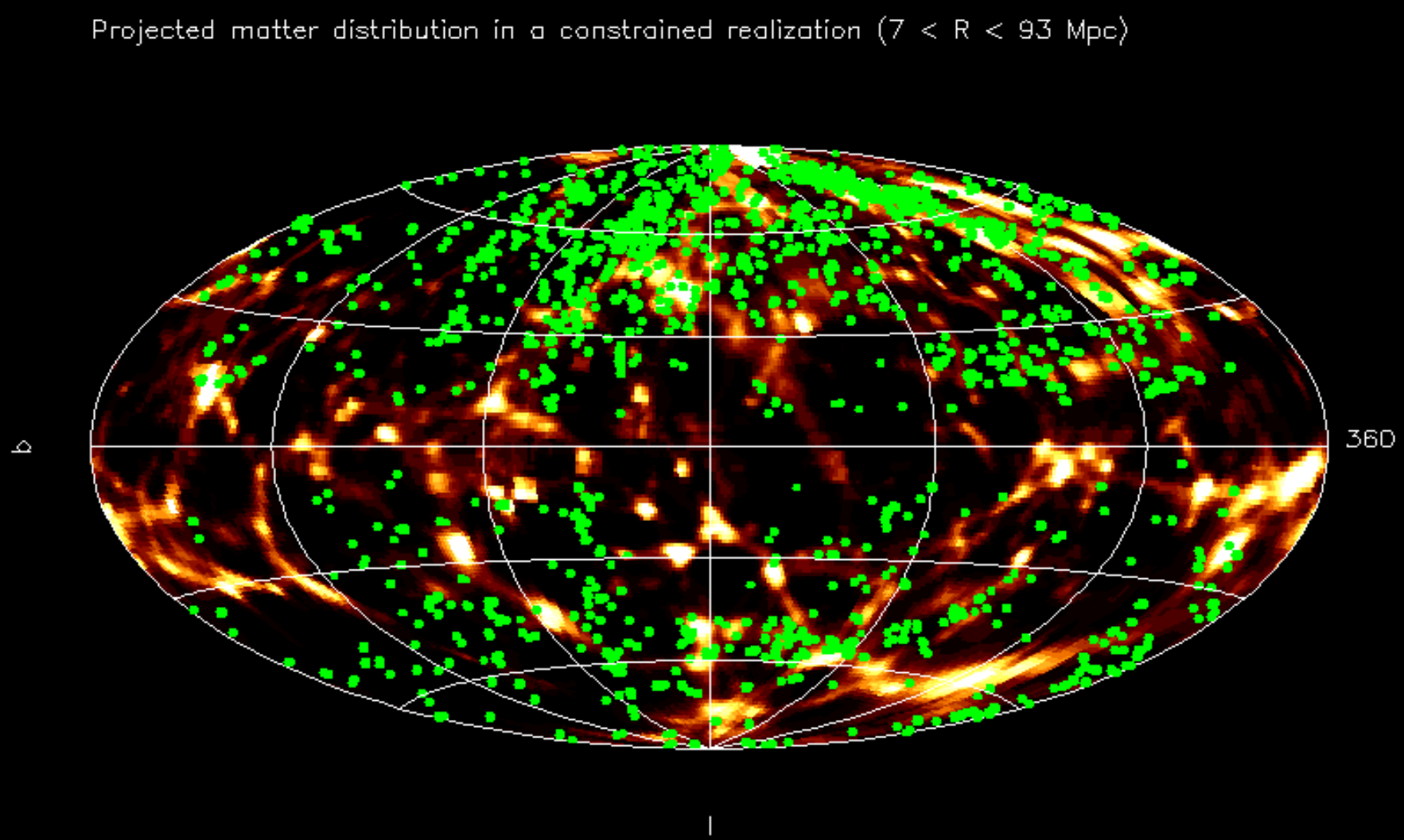

FDisplay <2>
File Server Config
Help
Event Display
All mirrors
Trace. Col 18. Row 13
Trace. Col 17. Row 19
Trace. Col 18. Row 16
Trace. Col 19. Row 10
Trace. Col 19. Row 8
Display
Single selection
Multiple selection
Virtual Channel
Pedestal Subtraction
Sky view
Mirror 3
Mirror 3 is in DAQ
Event
Run 0 - Event 273
Run 0 - Event 275
Run 0 - Event 300
Run 0 - Event 335
Run 0 - Event 367
Clear
Keep...
EYE 4 Mirror 3
18 pix. trig. T3ld 4104
GPS Time 751169873
GPS NanoTime 694655000
Trigger
SLT View
FLT View
Second Level Trigger


FDisplay
File Server Config
Event Display
All mirrors
Display
Single selection
Multiple selection
Virtual Channel
Pedestal Subtraction
Sky view
Mirror 5
Mirror 5 is in DAQ
Event
Run 0 - Event 1565
Run 0 - Event 1614
Run 0 - Event 1673
Run 0 - Event 1725
Run 0 - Event 1757
Clear
Keep...
EYE 1 Mirror 5
8 pix. trig. T3ld 4109
GPS Time 751169873
GPS NanoTime 694669000


Auger data: 2548 events of all energies, 60 deg exclusion zone in green
Galactic Latitude
Galactic Longitude
GC
60°
30°
0°
-30°
-60°
300°
240°
180°
120°
60°
1
0
-1
-2
0
2

J. Cronin

Matter and Galaxies



A. Kravtsov

- see through Galactic Center

Pierre Auger Project

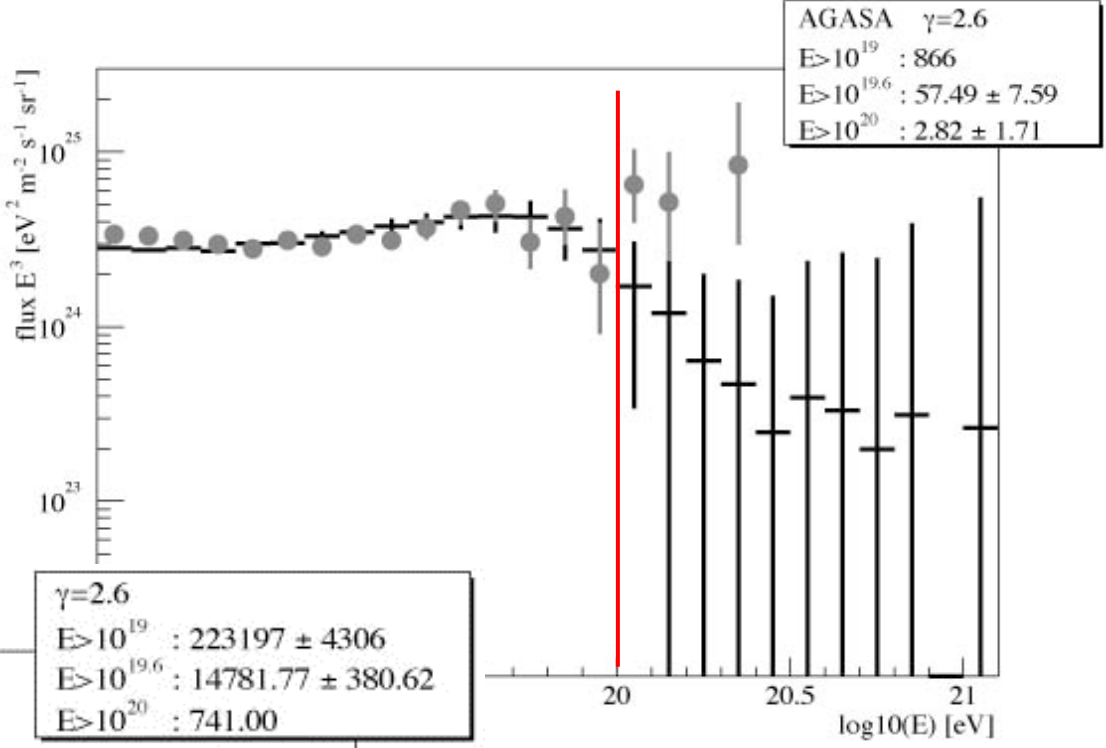
North and South

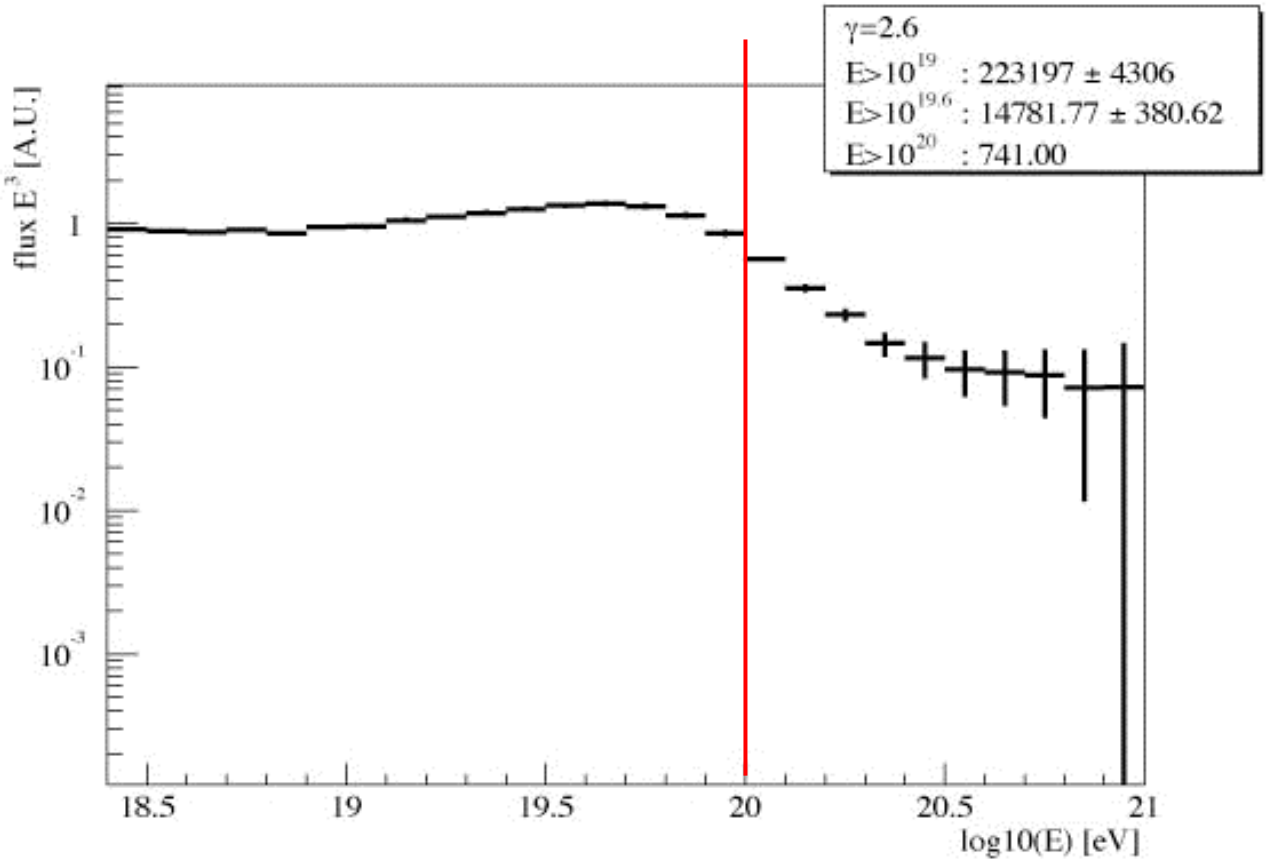
Near future: 6000 km^2

(future: enlarge to >14000 km^2)

to discover the origin of EHECRs
and study EHE Neutrinos!

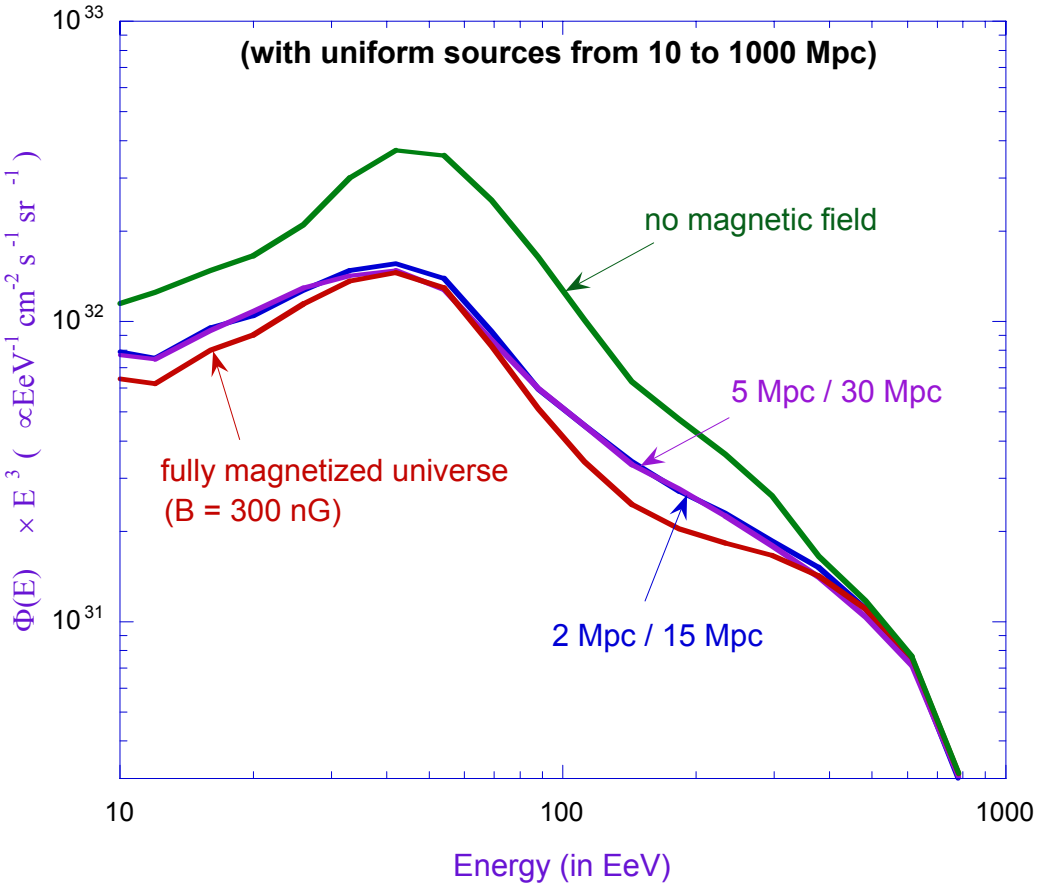
Auger (N/S) or EUSO x AGASA





DeMarco, Blasi, A.O. '03

GZK cut-off is model and B dependent…



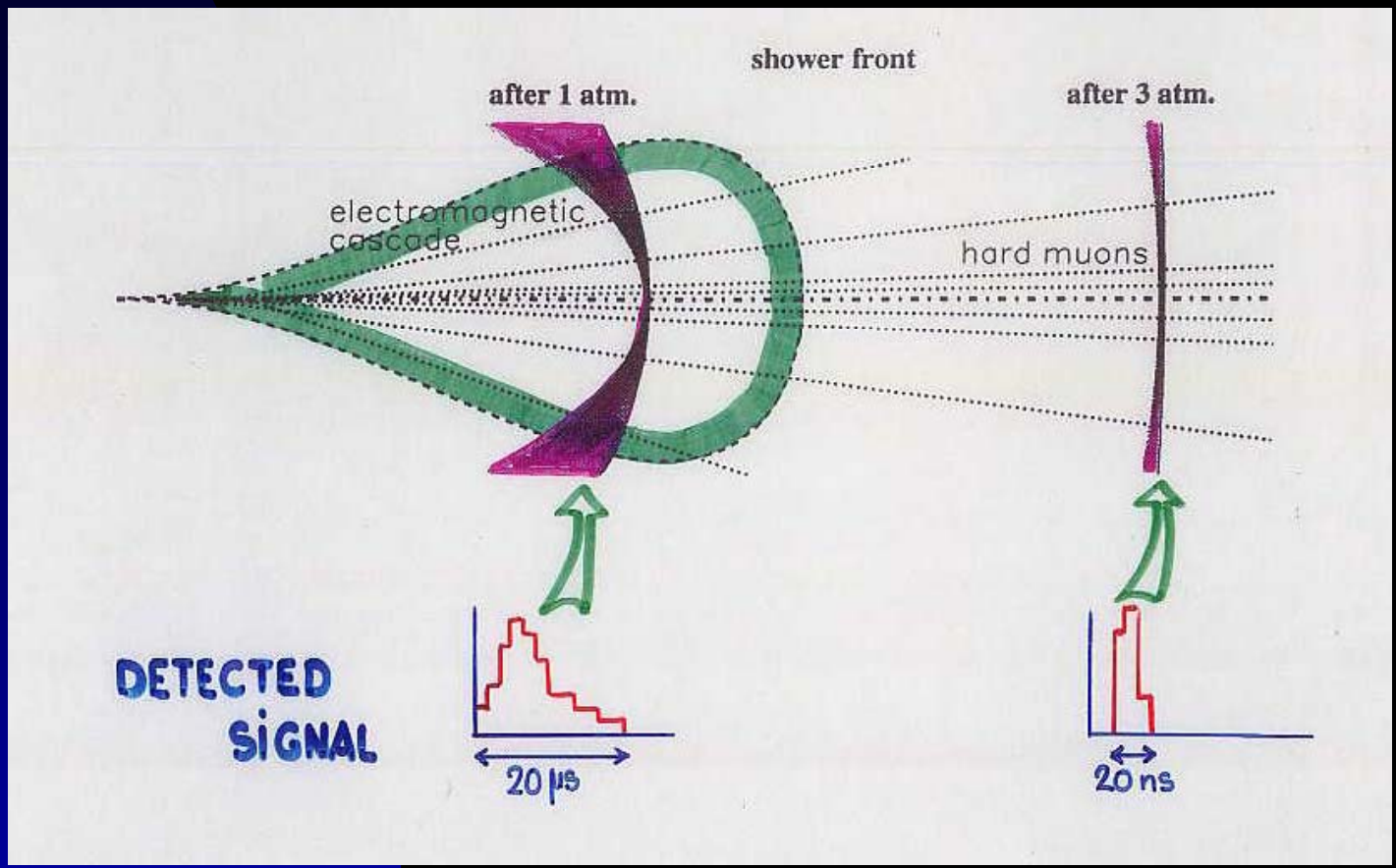
Magnetized Local Super-Cluster - better fit to spectrum (Blasi, A.O. '99)

E. Parizot et al. '03

Horizontal Showers

produced by

Extremely High Energy Neutrinos!

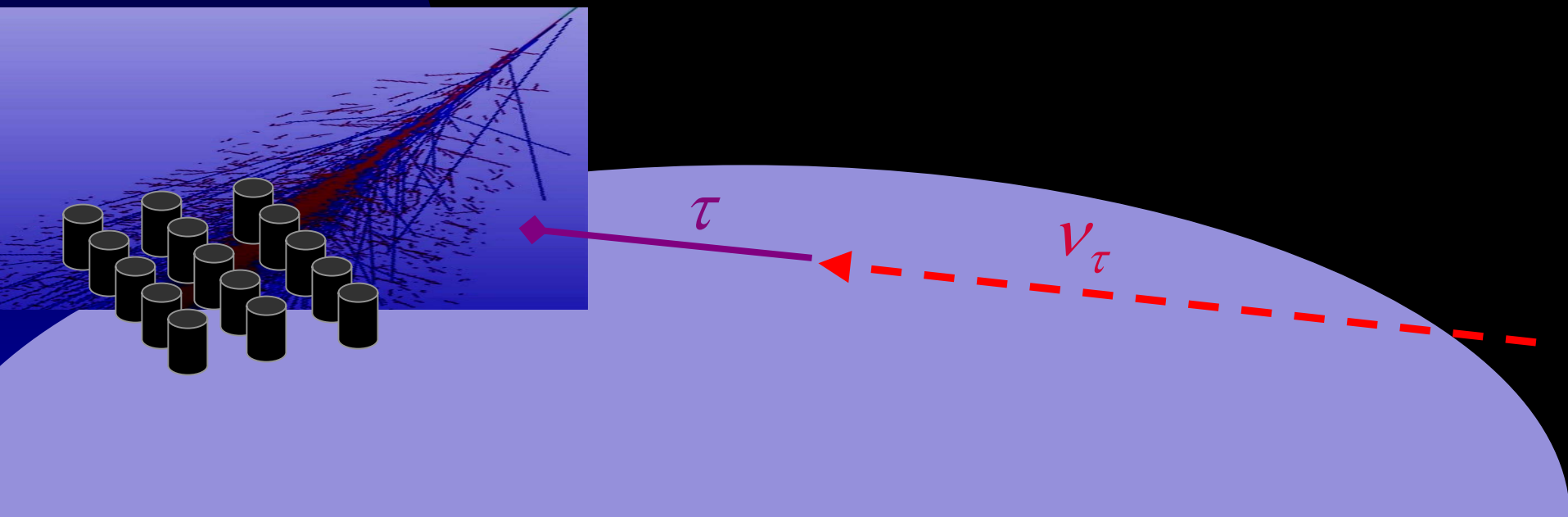


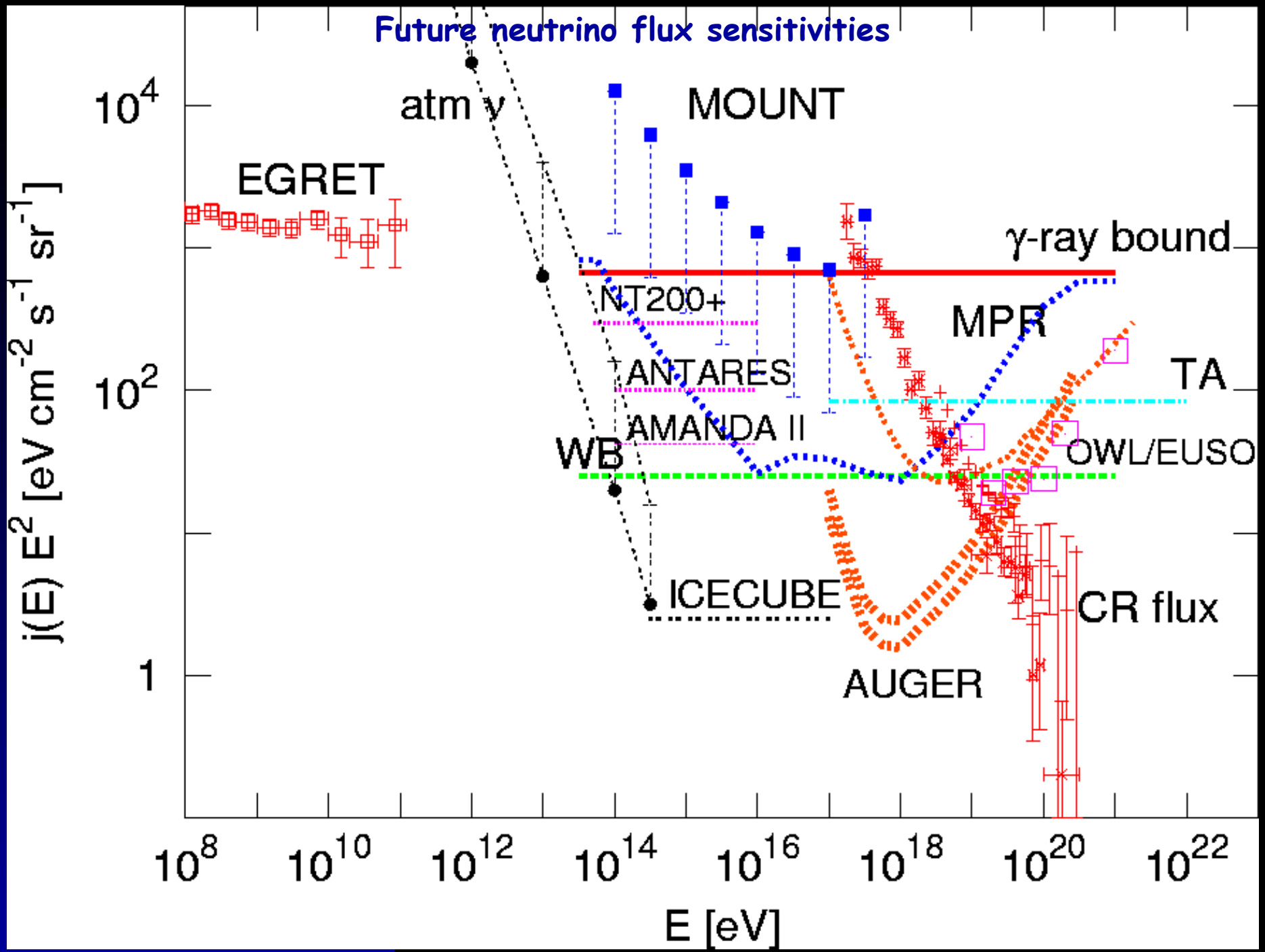
Billoir '99

Earth Skimming ν_τ

Auger exposure to tau Neutrinos

zenith angle > 90°



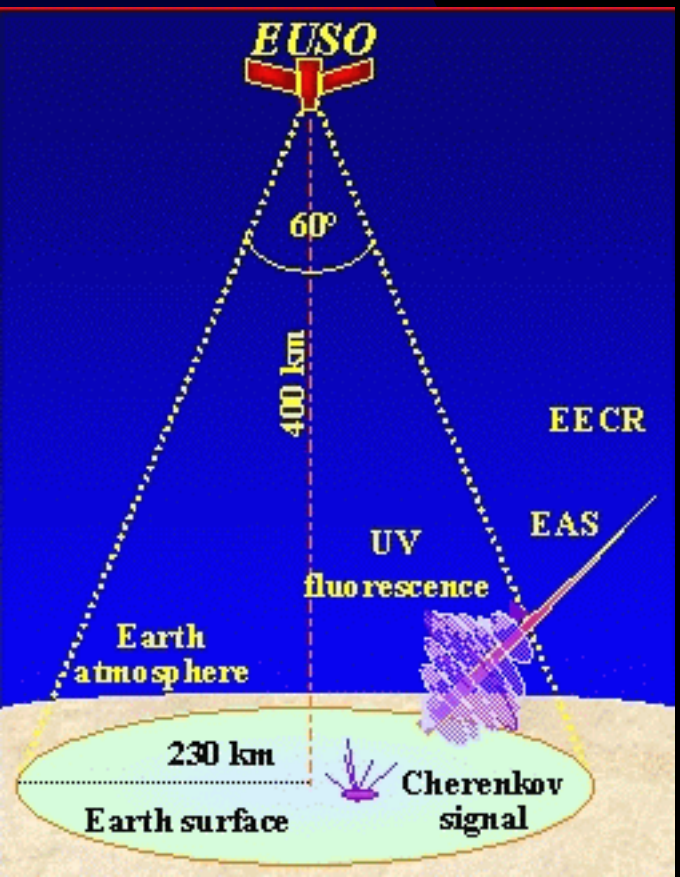

Future neutrino flux sensitivities
atm ν
MOUNT
EGRET
γ-ray bound
NT200+
MPR
ANTARES
TA
AMANDA II
WB
OWL/EUSO
ICECUBE
CR flux
AUGER
j(E) E² [eV cm⁻² s⁻¹ sr⁻¹]
E [eV]
10⁴
10²
1
10⁸
10¹⁰
10¹²
10¹⁴
10¹⁶
10¹⁸
10²⁰
10²²

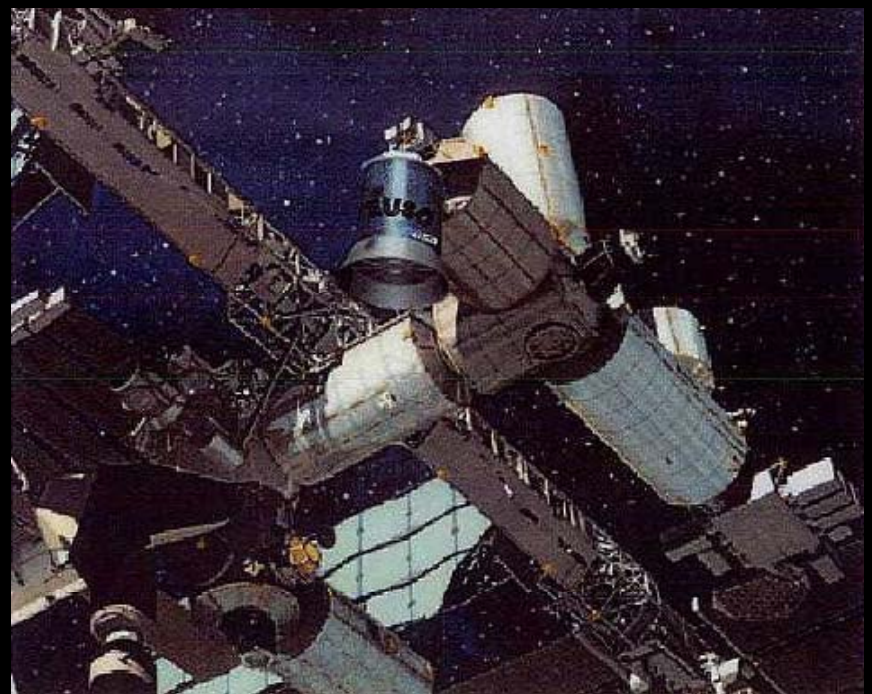
EUSO

Extreme Universe Space Observatory

In ISS for few yrs

UHE Neutrinos!





Pierre Auger Project
&
EUSO

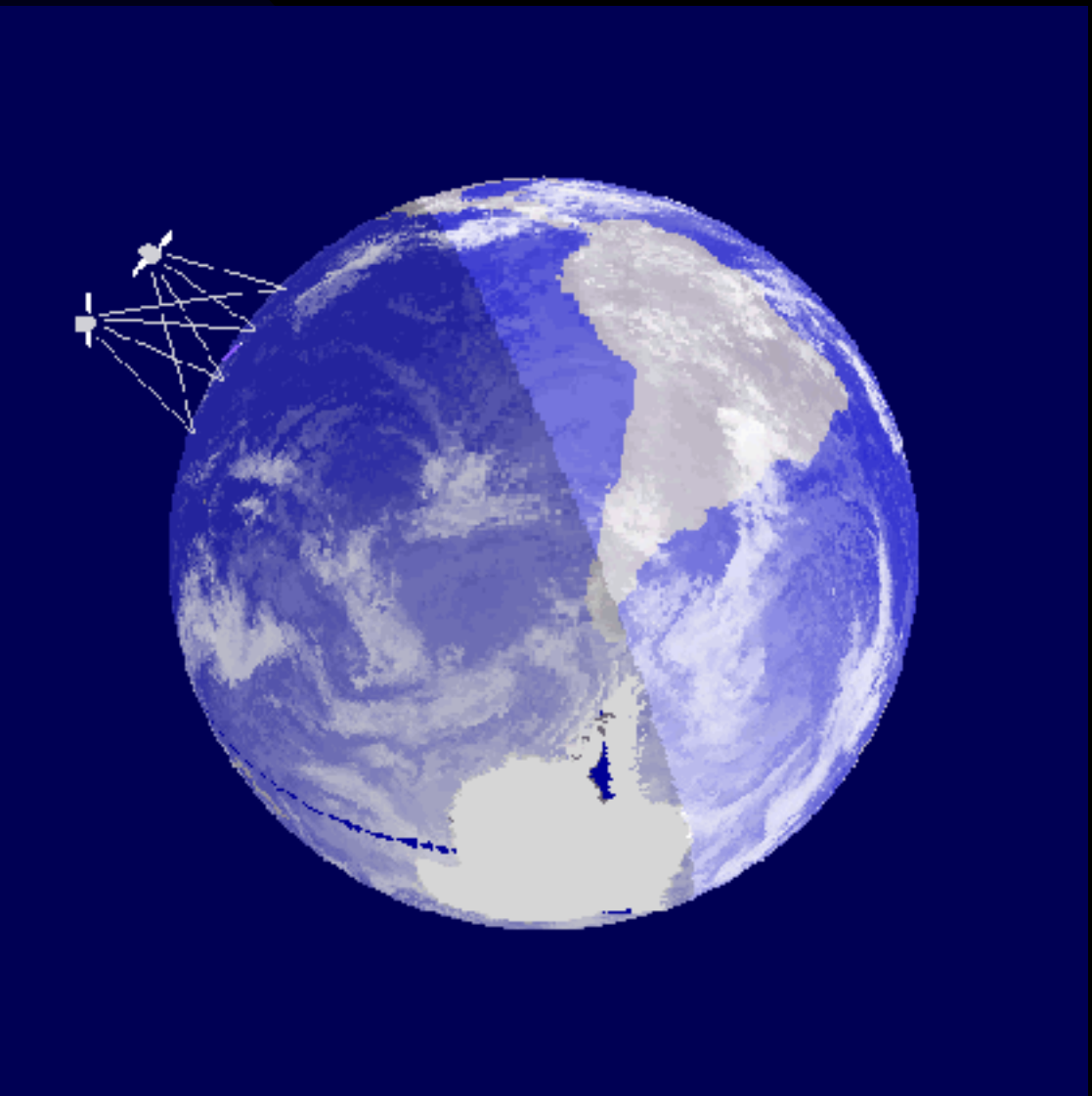
North and South
will search the sky for the
Highest Energy Accelerators
ever observed since the

EUSO

Extreme Universe Space Observatory

QuickTime™ and a YUV420 codec decompressor are

OWL

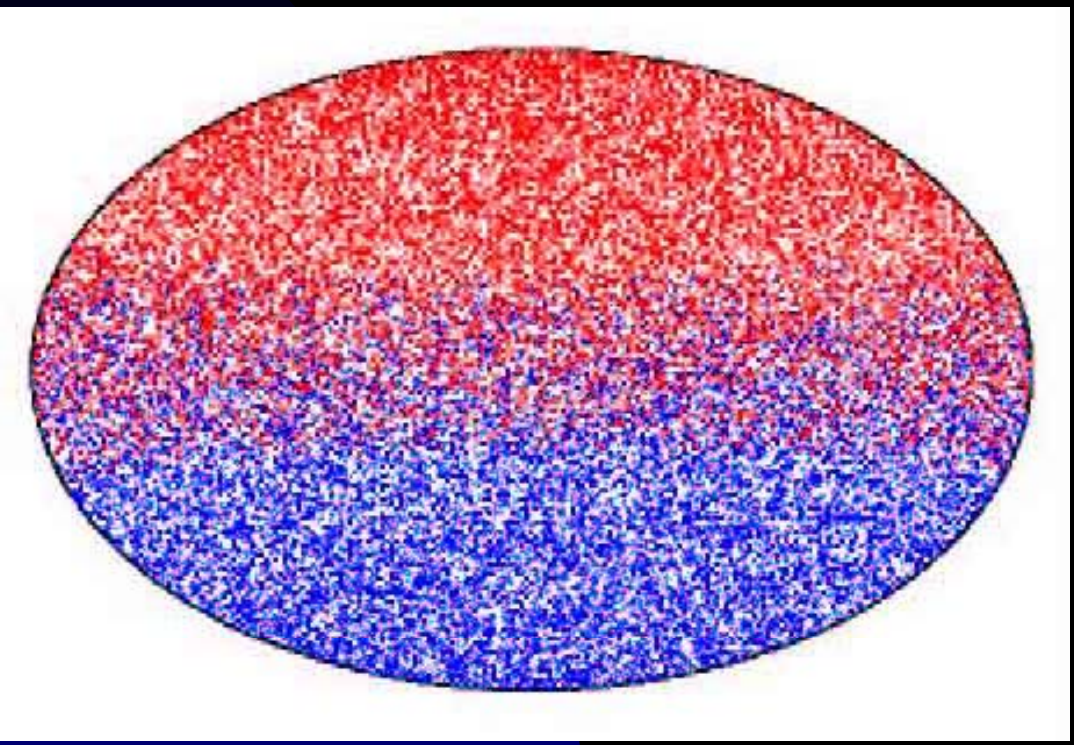


STEREO
Ni Fluorescence
from ABOVE!

3000 events/year
$E > 10^{20}$eV !!!

UHE Neutrinos!

2 is a lot more than 1



Number of sources ~ 2 (blue or red)

$$\mathbf{N \rightarrow 2 \times N}$$

Statistics improve by $\sqrt{2}$

Overlap region (purple)

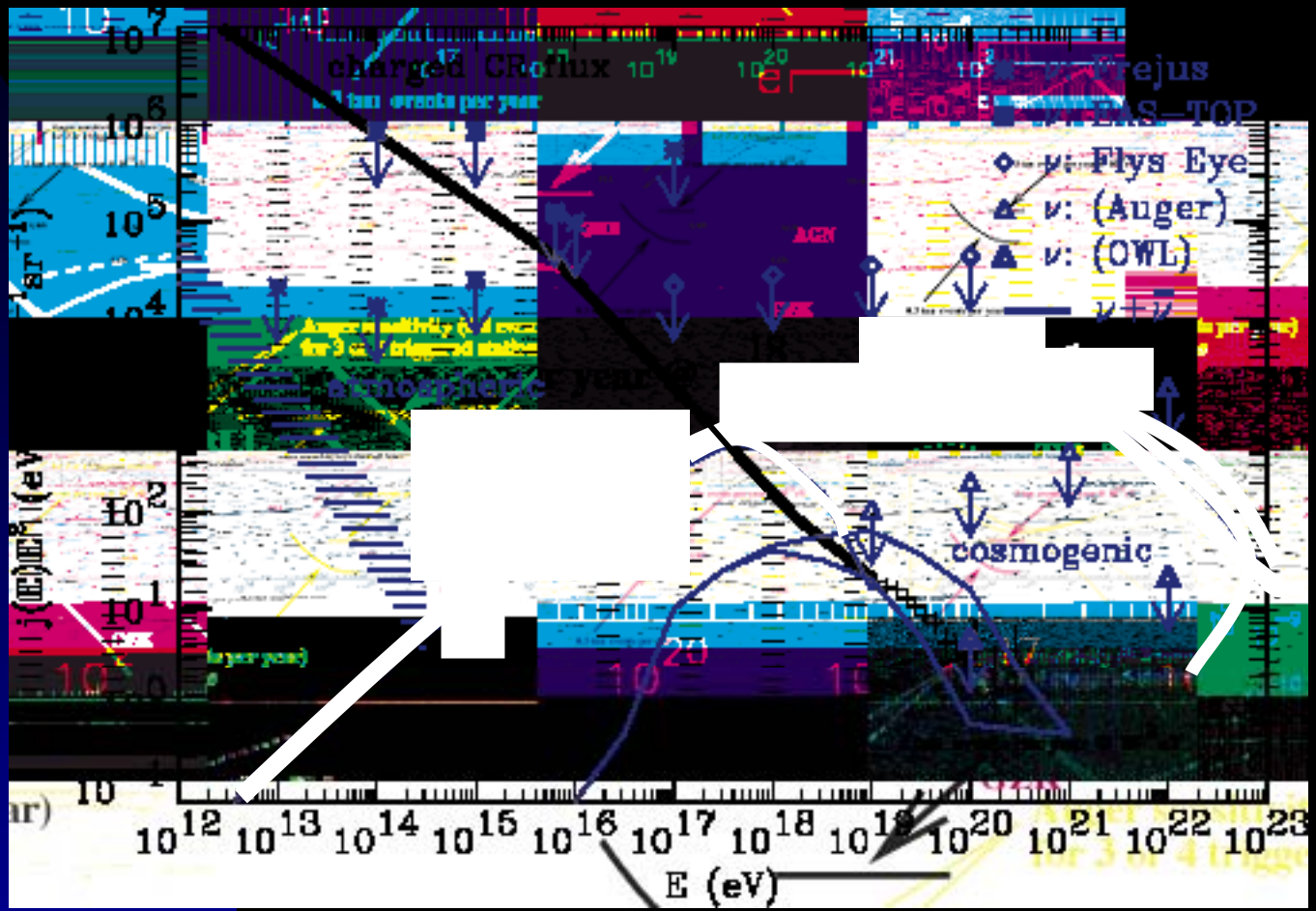
$$L \rightarrow L/\sqrt{2}$$

$$R \rightarrow 2^{1/4} \times R$$

$$\mathbf{N \rightarrow 2^{3/4} \times N}$$

P. Sommers '03

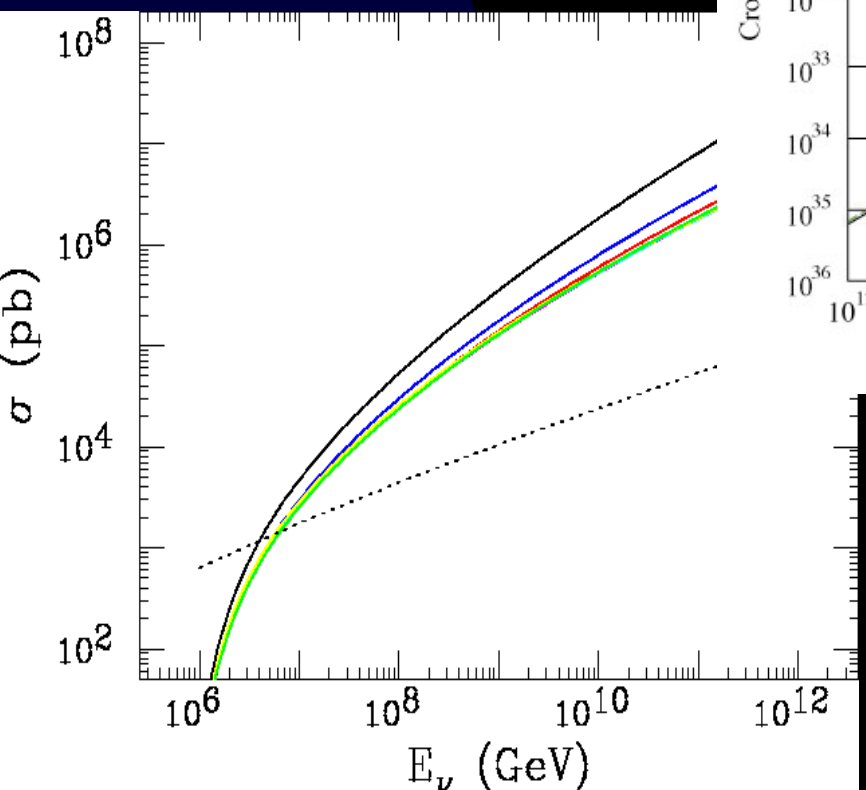
Neutrino Fluxes

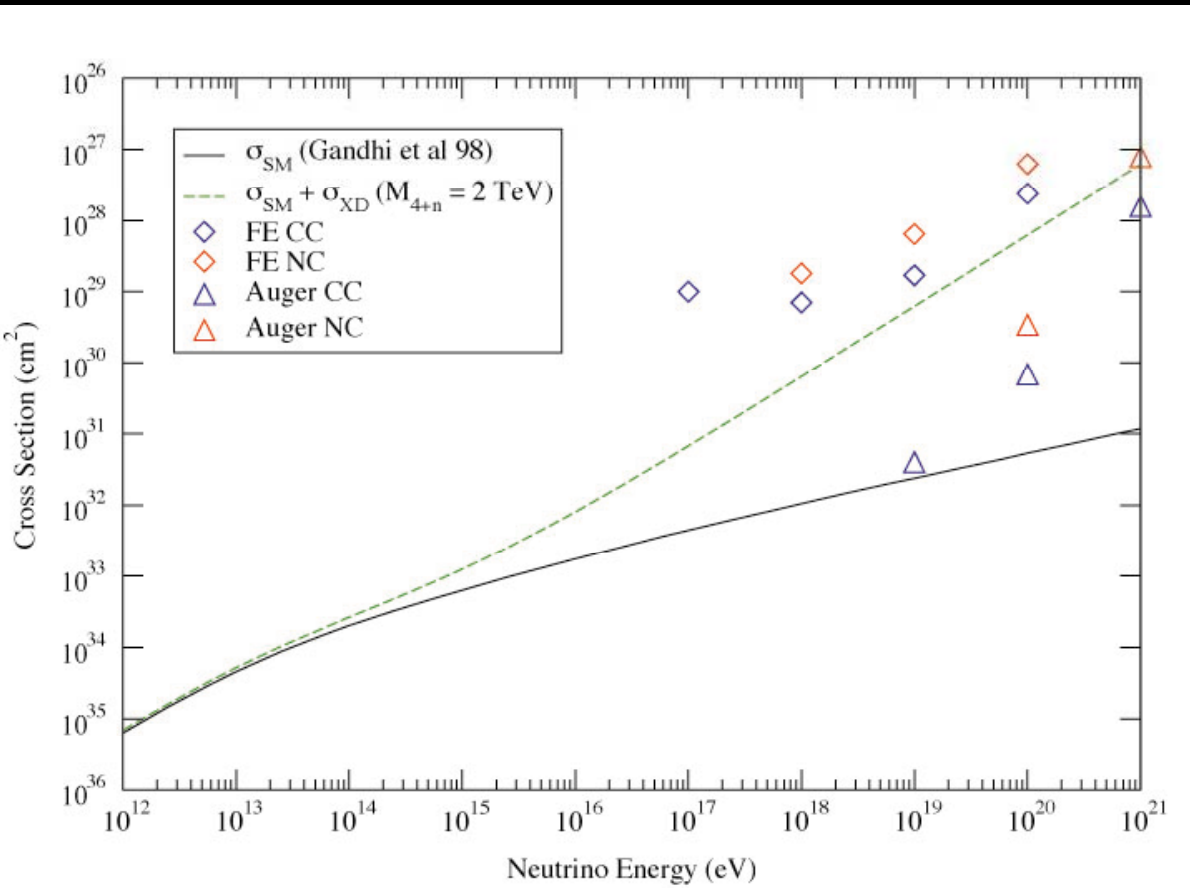


Tyler, A.O., Sigl, '01

HE ν Cross Section

Limits on Large Extra Dimensions w/ Production of ***Mini Black Holes p-Branes…***

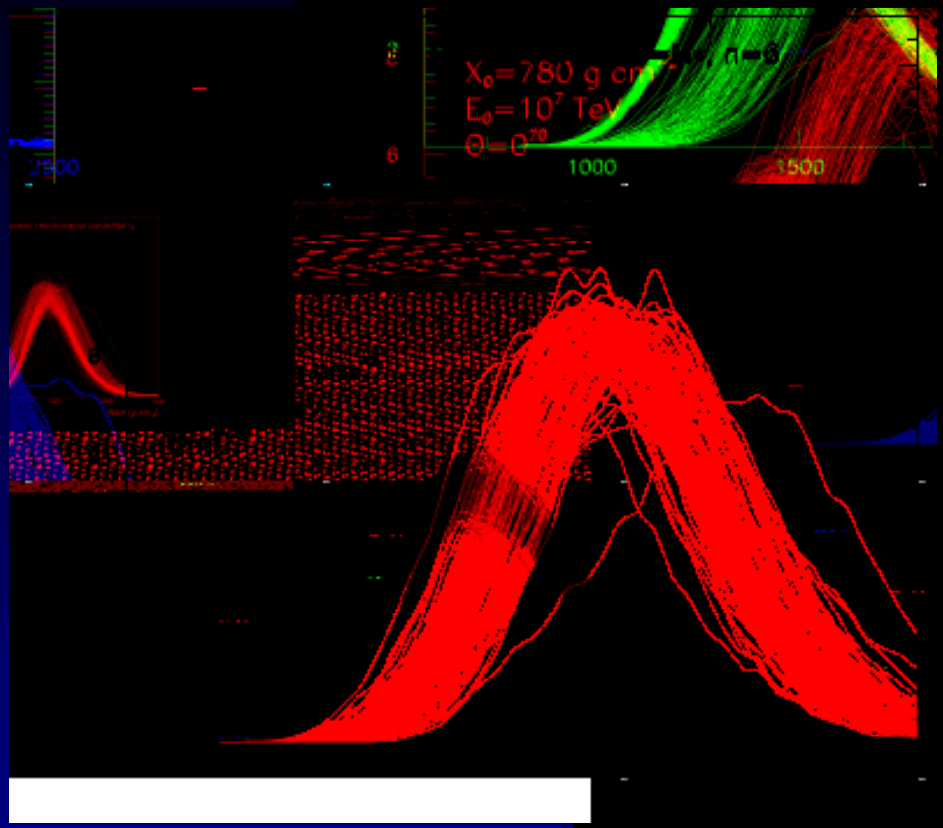




Tyler, A.O., Sigl, '01

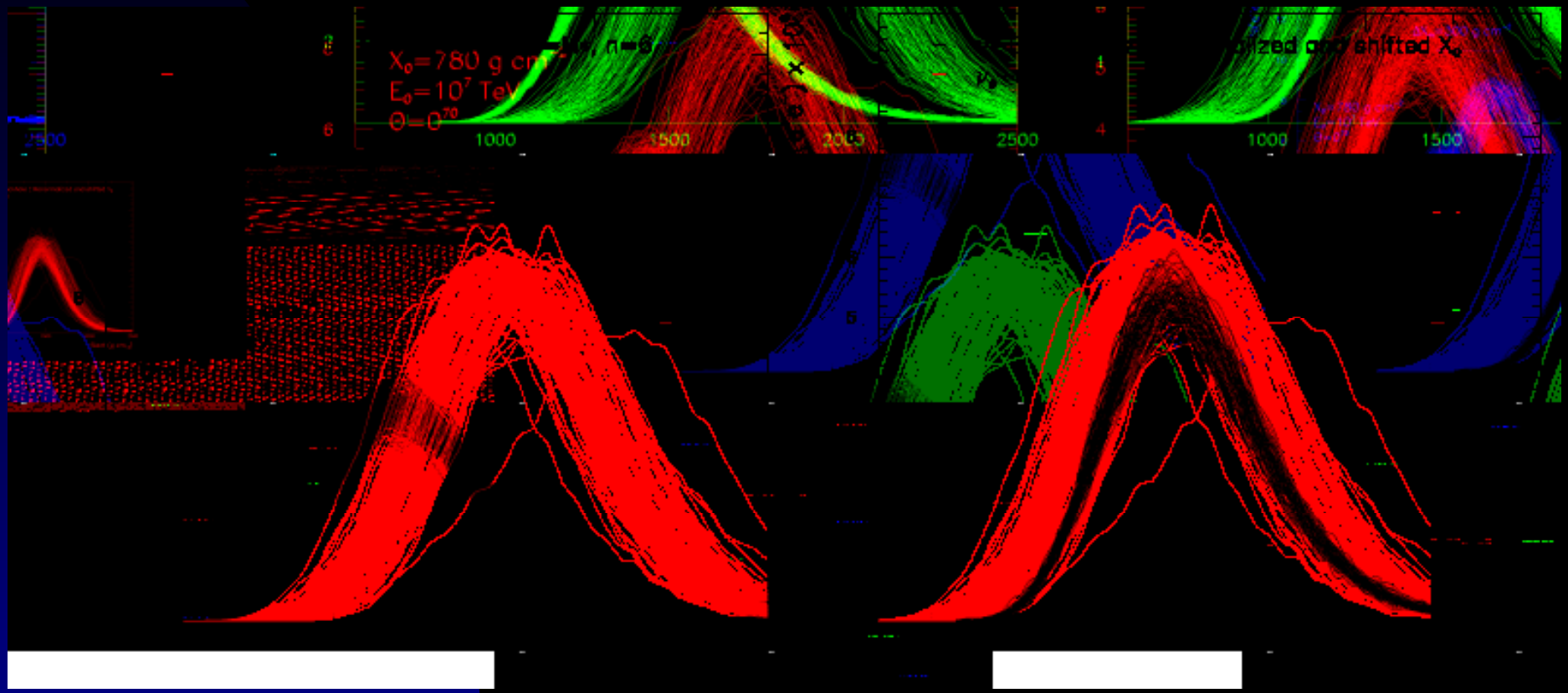
Feng, Shapere '01
Anh, Cavaglia, A.O.'02
and …

Large Extra Dimensions
TeV Gravity



Ahn, Ave, Cavaglia, AO ‘03

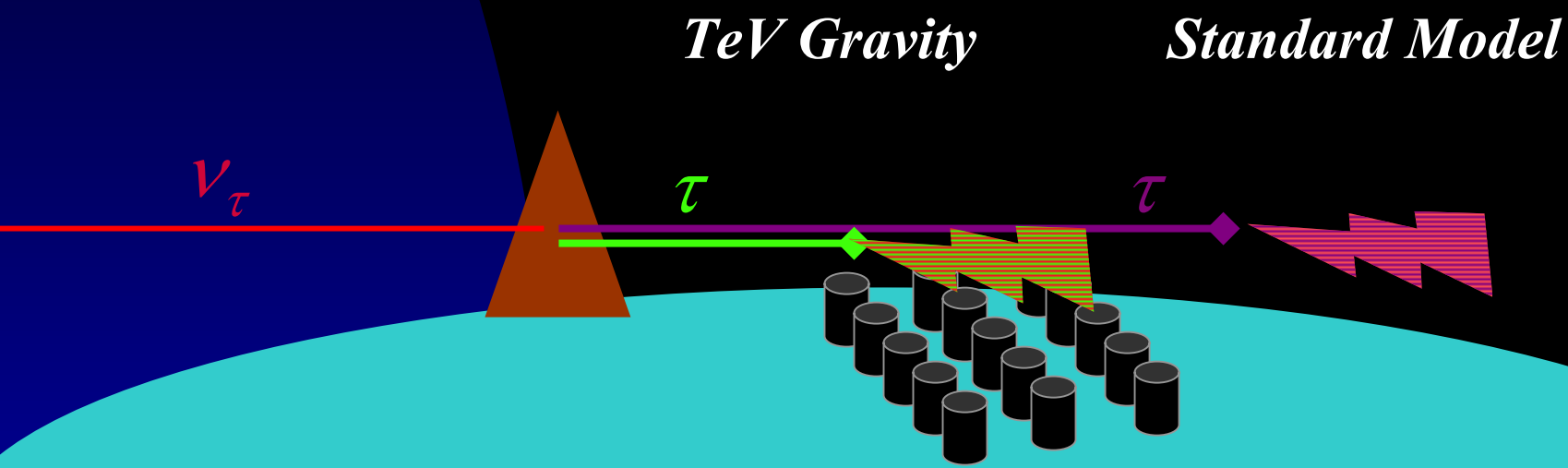
Large Extra Dimensions
TeV Gravity



Ahn, Ave, Cavaglia, AO ‘03

TeV gravity & EHE Tau Neutrinos

nice to be next to a Mountain range

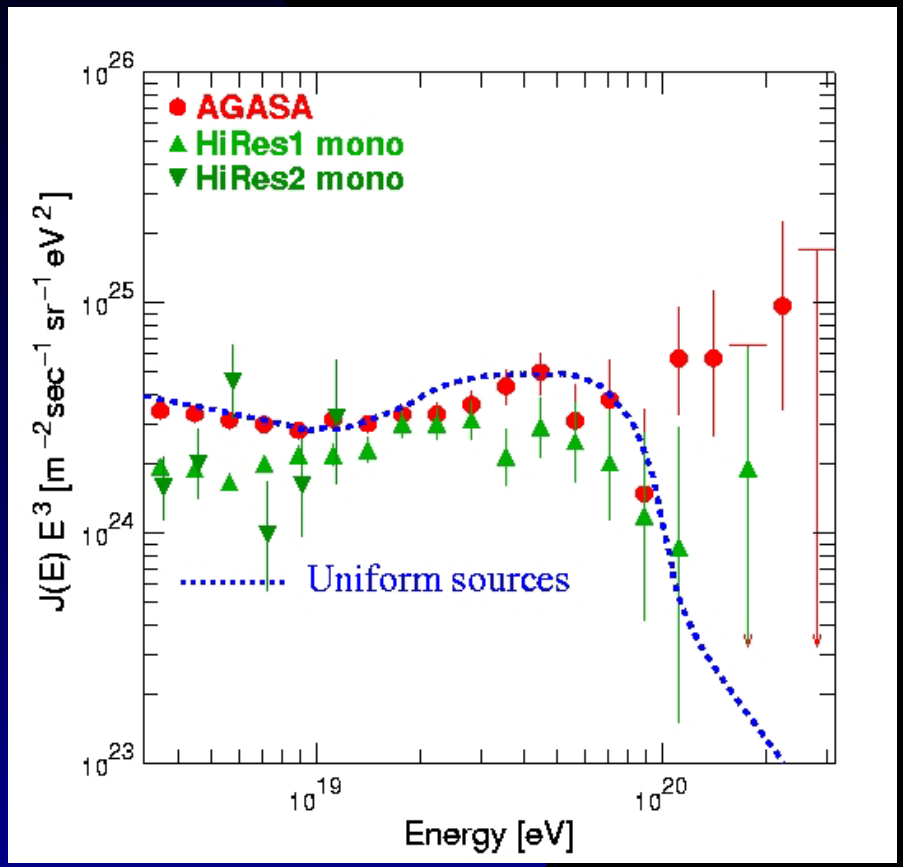


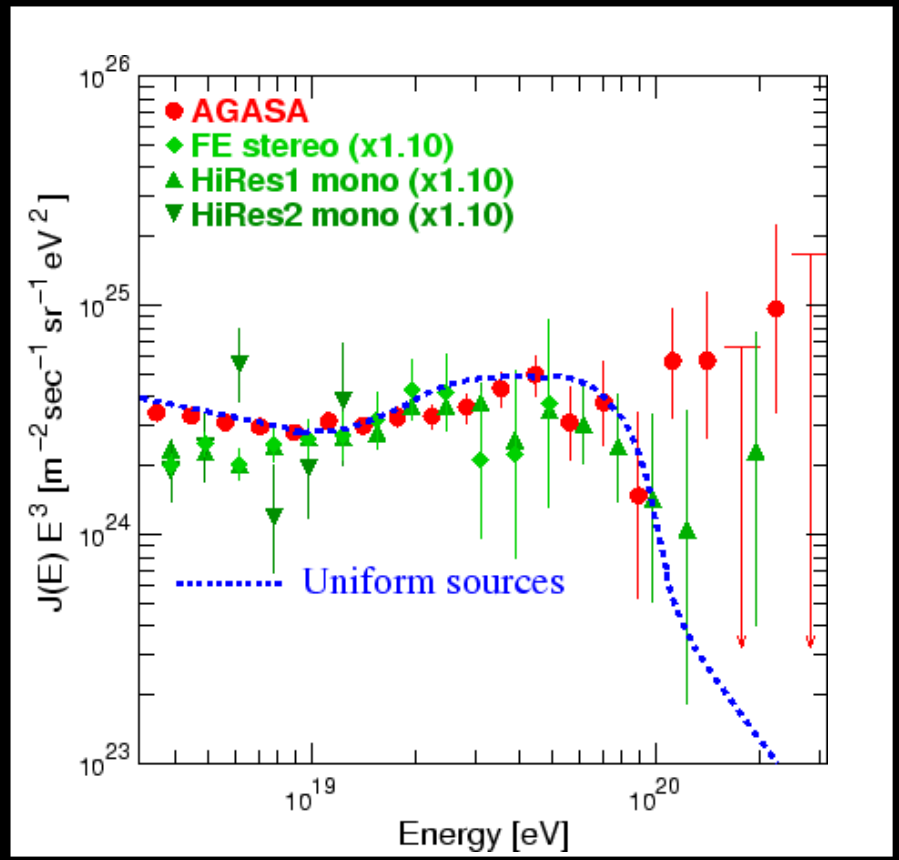
Ahn, Ave, Cavaglia, AO'03

Potential GZK Neutrino Detectors

Detector or Experiment	GZK threshold energy(1)	GZK Geometric volume(2)	target density	Effective interaction mass	Effective neutrino target area(3)	Accept-ance solid angle(4)	Aperture	actual or projected livetime/yr	GZK neutrino rate (minimum) (5)	GZK neutrino rate (maximum)
	EeV	km^3	gm/cm^3	km^3 w.e.	km^2	ster	km^2 ster	sec/yr	events per calendar yr	events per calendar yr
Active or completed:										
AGASA(6)	0.3	1000	1.00E-03	1	7.44E-04	2	1.49E-03	3.00E+07	9.8E-03	4.9E-02
AMANDA(7)	0.3	4	0.9	4	2.68E-03	1	2.68E-03	3.00E+07	1.8E-02	8.8E-02
GLUE(8)	300	100,000	2	200,000	1789	0.01	17.89	2.00E+05	1.9E-04	9.5E-04
Fly's Eye(9)	1	500	6.00E-04	0	3.44E-04	2	6.88E-04	3.00E+06	2.9E-04	1.4E-03
HiRes(10)	1	8500	6.00E-04	5	5.85E-03	2	1.17E-02	2.00E+06	3.3E-03	1.6E-02
EAS-TOP(11)	0.3	30	6.00E-04	0	1.34E-05	2	2.68E-05	1.00E+07	3.7E-05	1.9E-04
RICE(12)	0.3	1	0.9	1	6.69E-04	6	4.02E-03	3.00E+06	2.7E-03	1.3E-02
In construction or advanced planning:										
Auger(13)	1	1.50E+04	8.00E-04	12	1.38E-02	2	2.75E-02	3.00E+07	0.12	0.58
EUSO(14)	100	1.00E+06	1.00E-03	1,000	6.0	2	12.04	3.00E+06	1.5E-02	7.6E-02
IceCube(15)	0.3	40	0.9	36	2.68E-02	1	2.68E-02	3.00E+07	0.19	0.94
Telescope Array	1	3.00E+04	1.00E-03	30	3.44E-02	2	6.88E-02	2.00E+06	1.9E-02	9.6E-02
Proposed, pre-proposal, or conceptual										
OWL(16)	100	3.00E+06	1.00E-03	3,000	18.1	2	36.13	3.00E+06	4.6E-02	0.23
ANITA(17)	0.3	1.00E+06	0.9	900,000	669	0.01	6.69	2.50E+06	3.7	18.4
SALSA(18)	0.3	30	2.2	66	4.91E-02	6	0.29	3.00E+07	2.1	10.4
SuperRICE(19)	10	100	0.9	90	2.37E-01	6	1.42	3.00E+07	0.81	4.0

AGASA vs. HiRes I mono, HiRes II mono



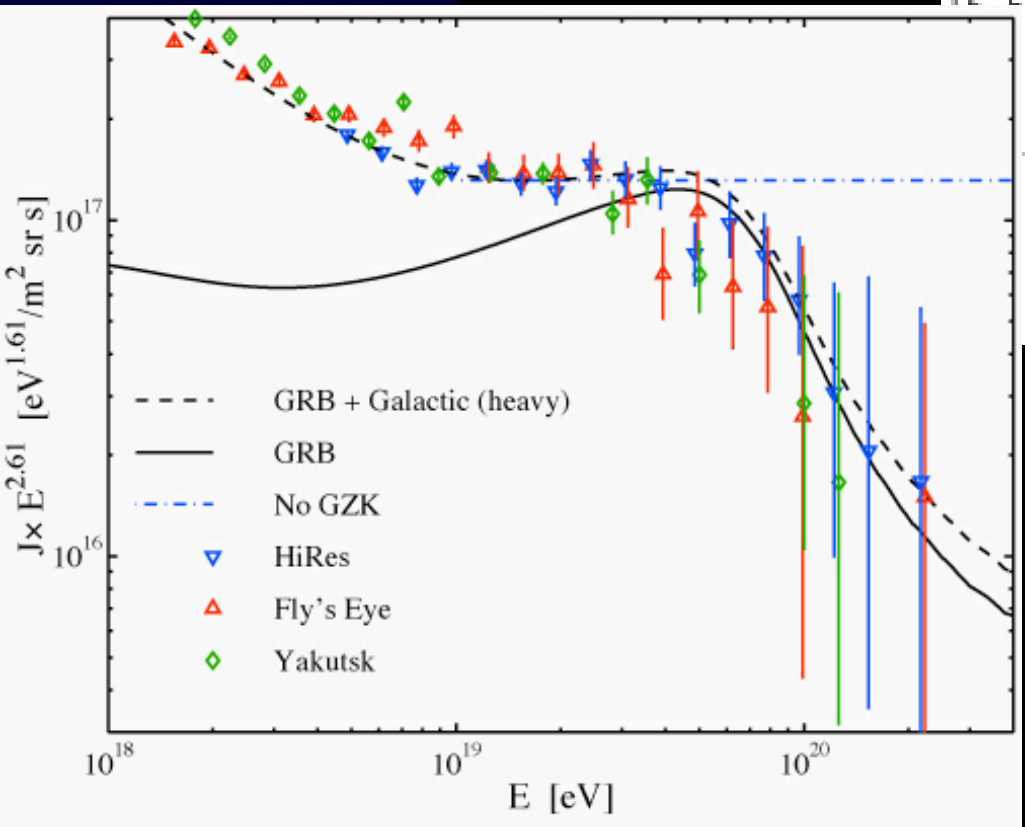


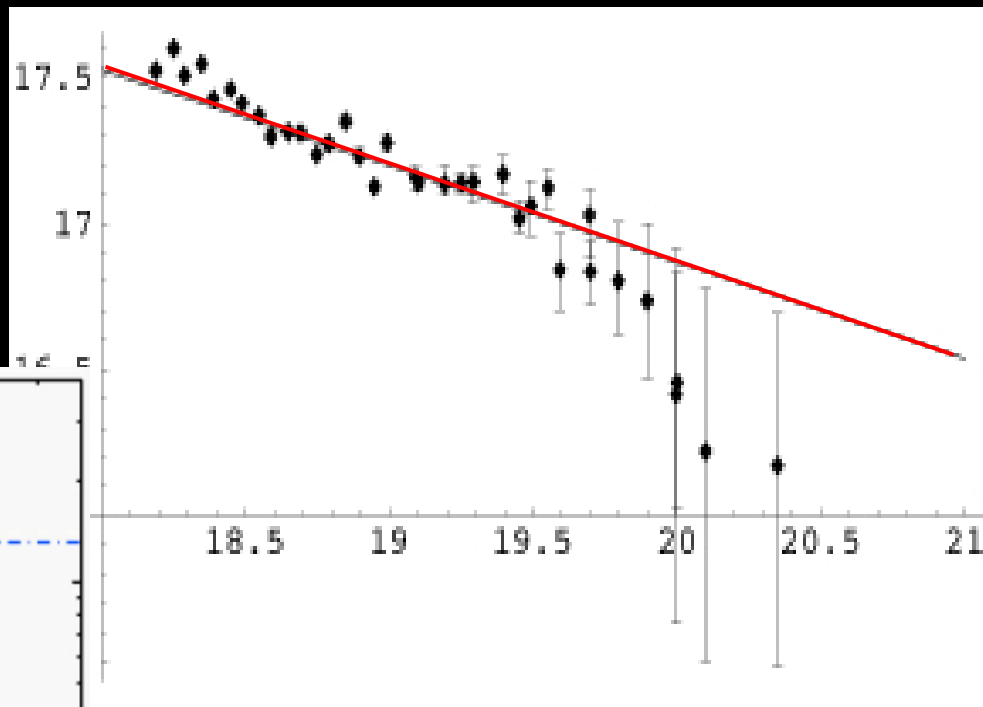
Teshima '02

Theorist B example

No AGASA data + re-scaling to Yakutsk data

Bahcall & Waxman '02





DeMarco, Blasi, AO '02

χ^2 (one power law)

=

χ^2 (GRB) / 2

Exploring New Techniques

Water Tanks

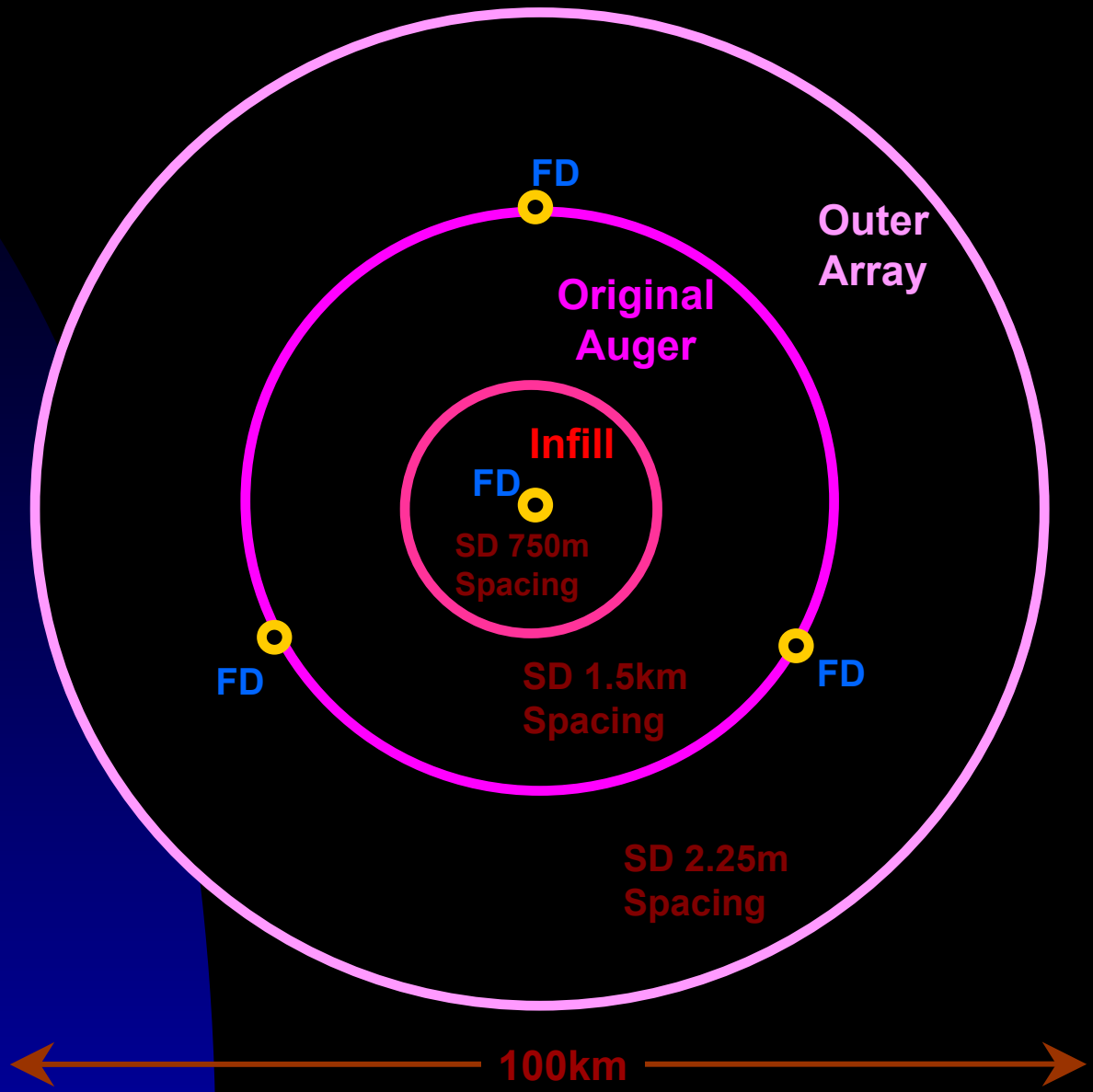
Scintilators

Muon Detectors

Fluorescence

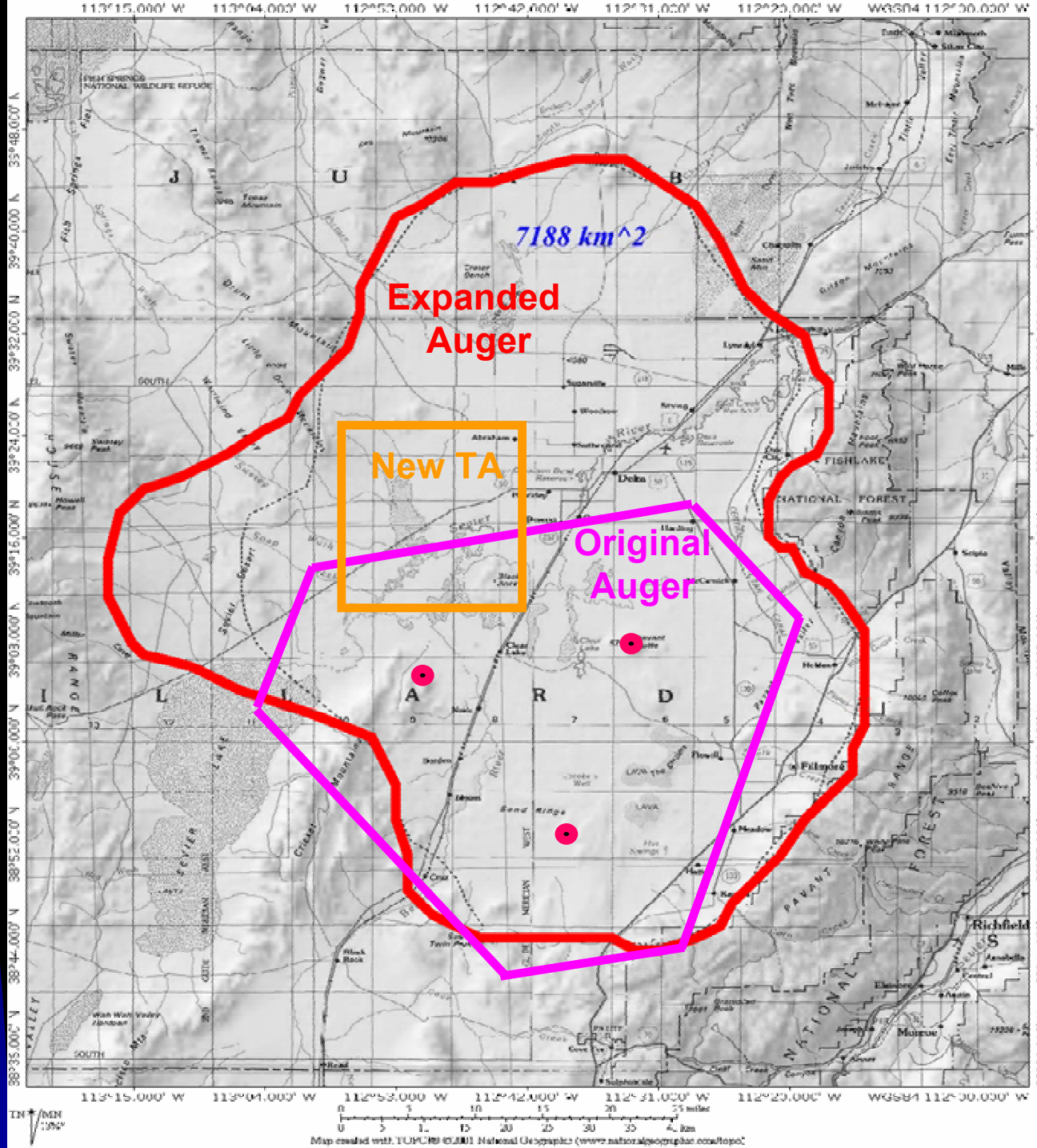
Radio

Exploring Extended Designs



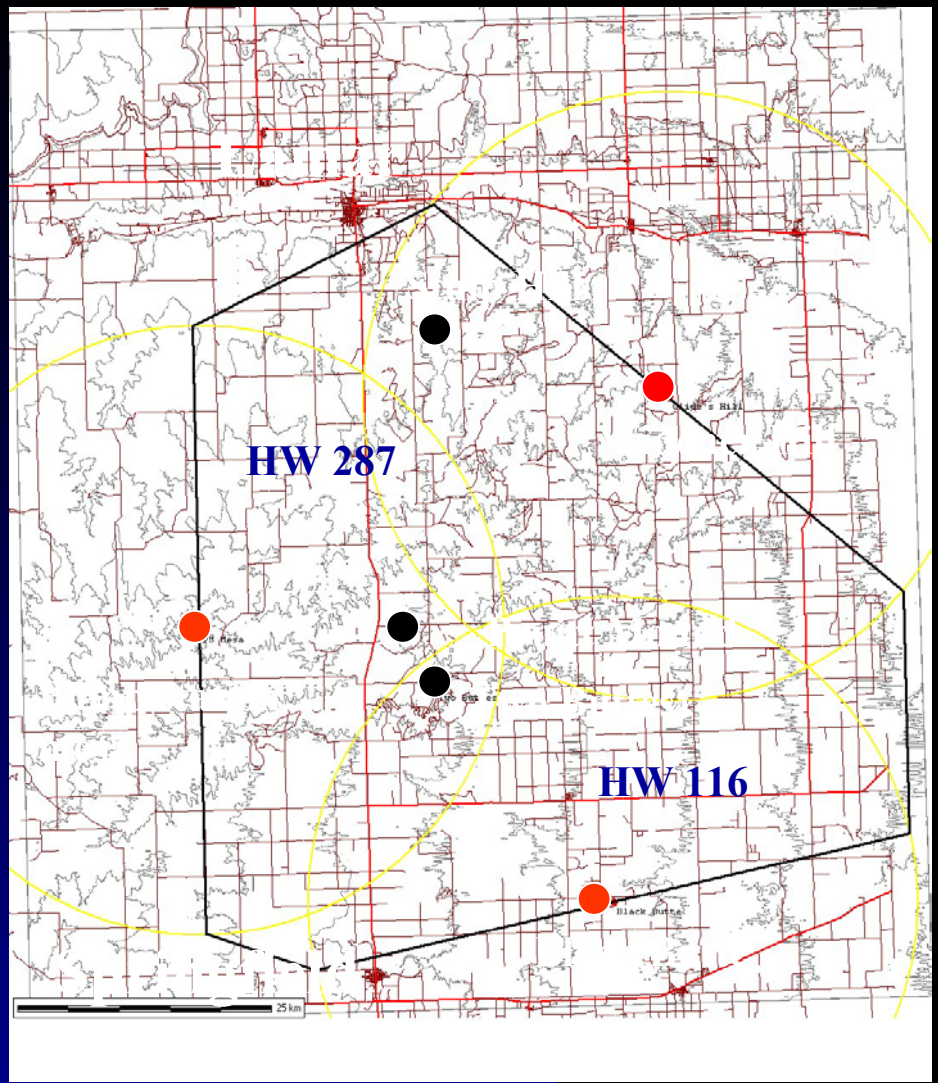
Possible Expansion of Northern Auger Site

~7200km²



By Brian Fick

The Lamar site in southeast Colorado

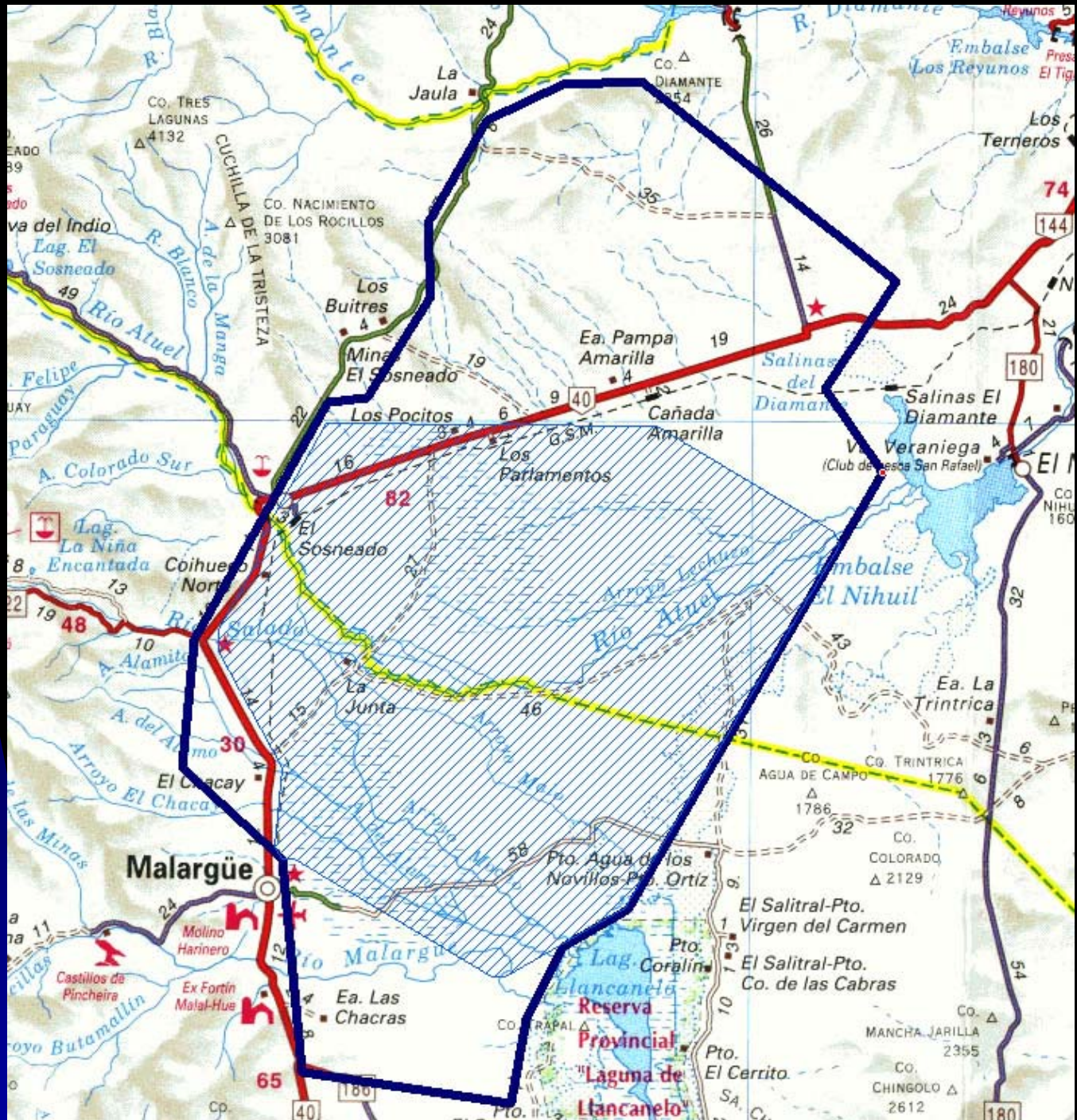


J. Harton (CSU)

Possible Expansion of Southern Auger Site

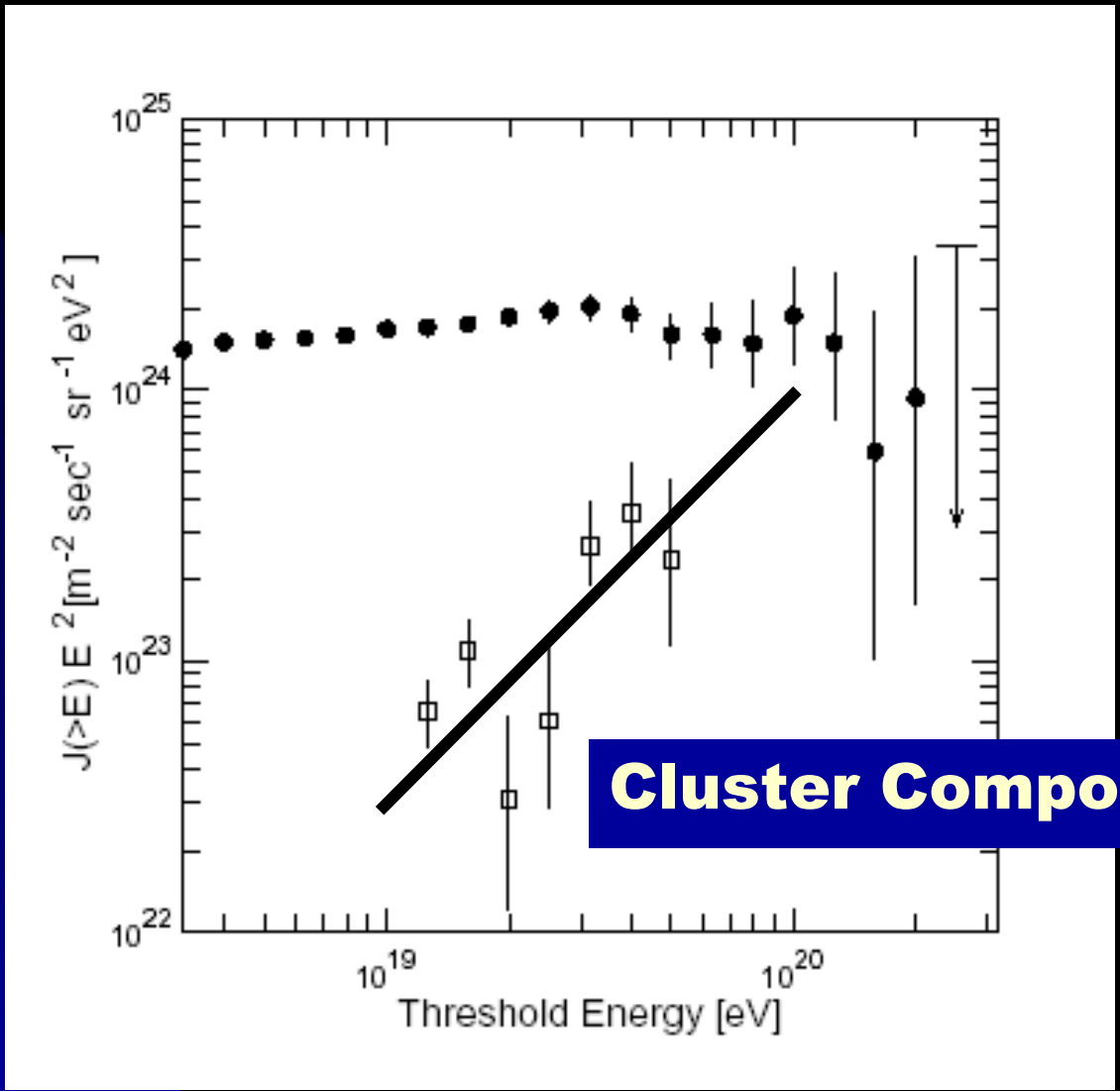
~7000km²

by Mariano Berisso
& Ingo Allekotte

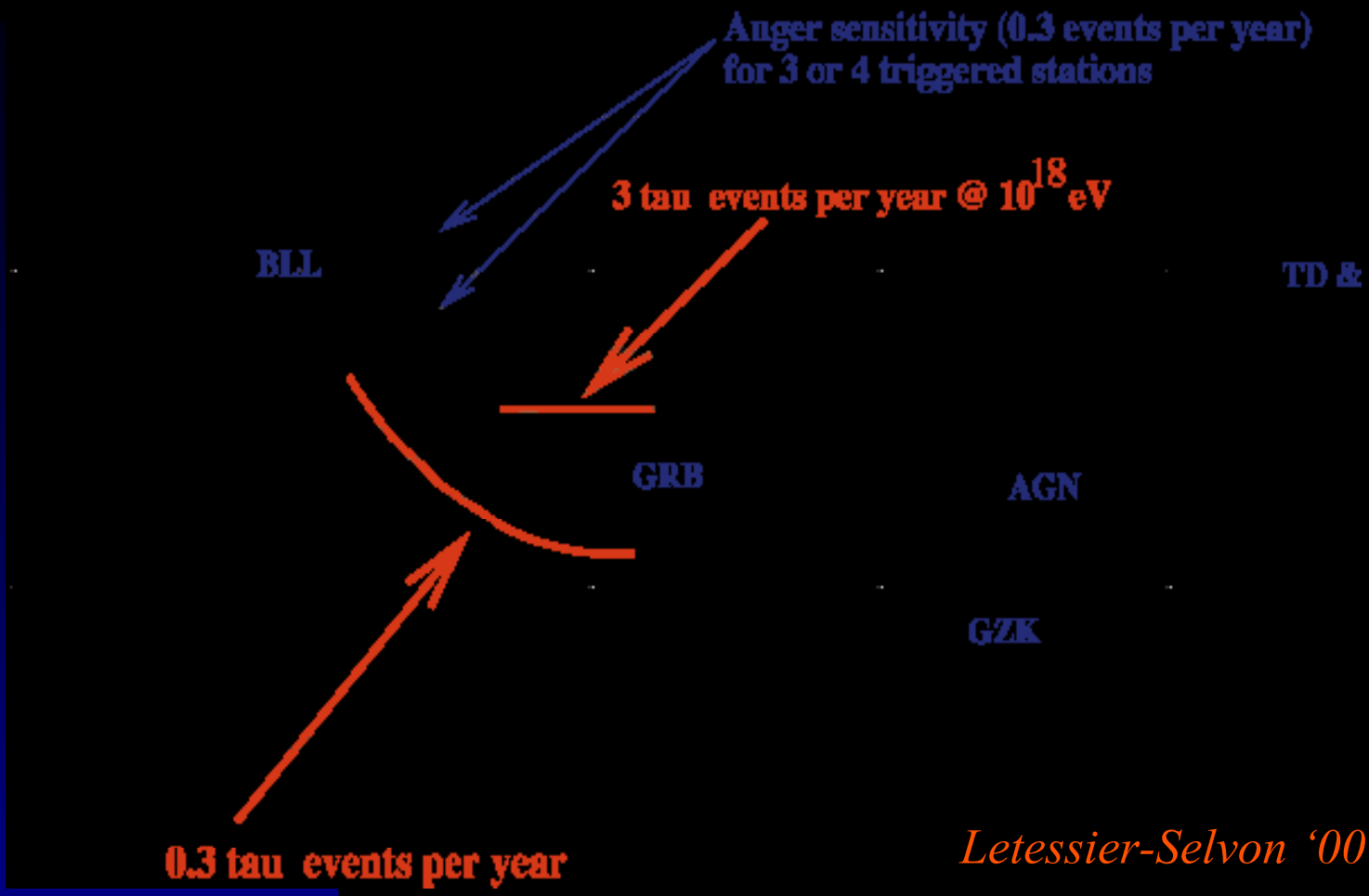


Energy spectrum of Cluster events

$E^{-1.8 \pm 0.5}$

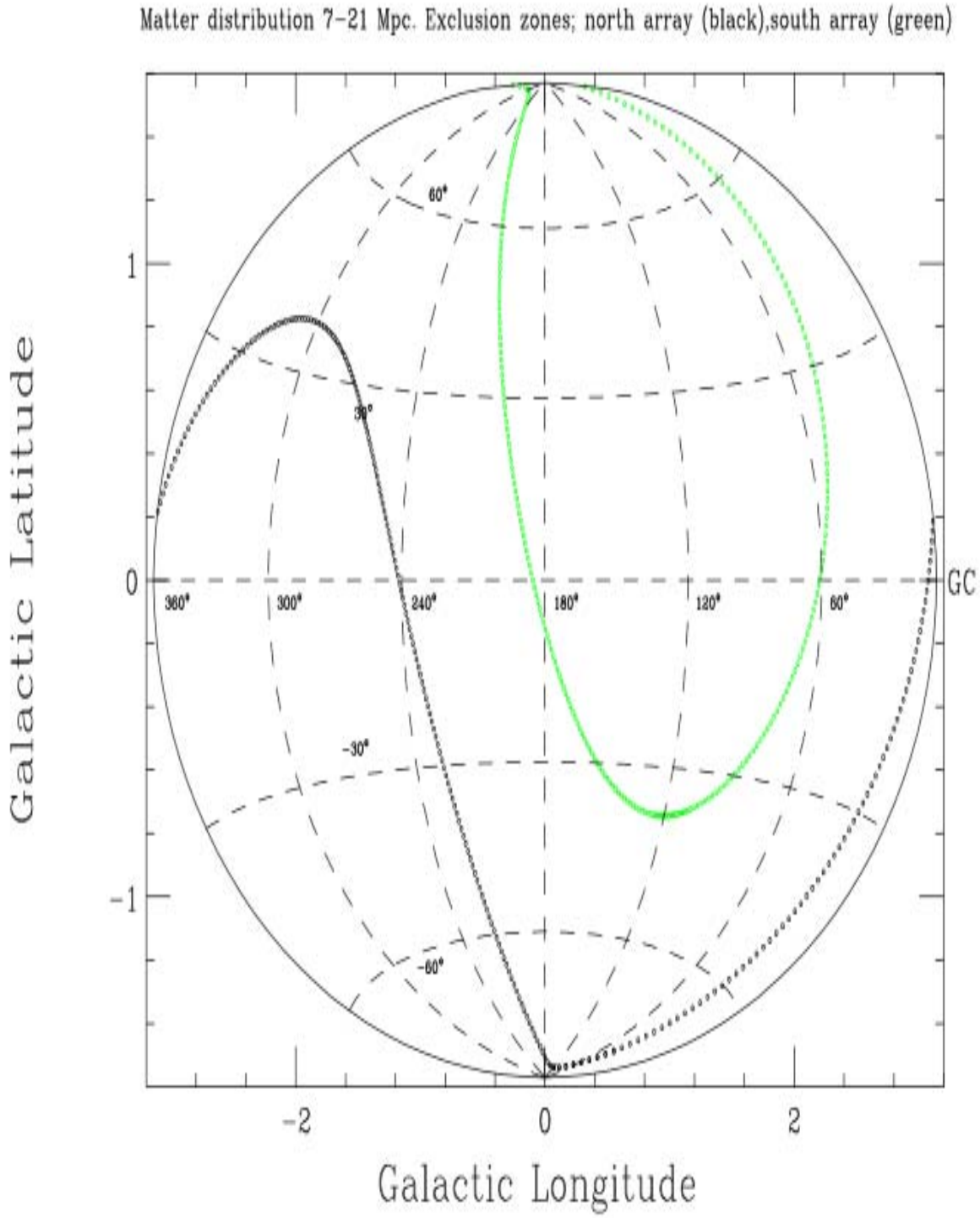


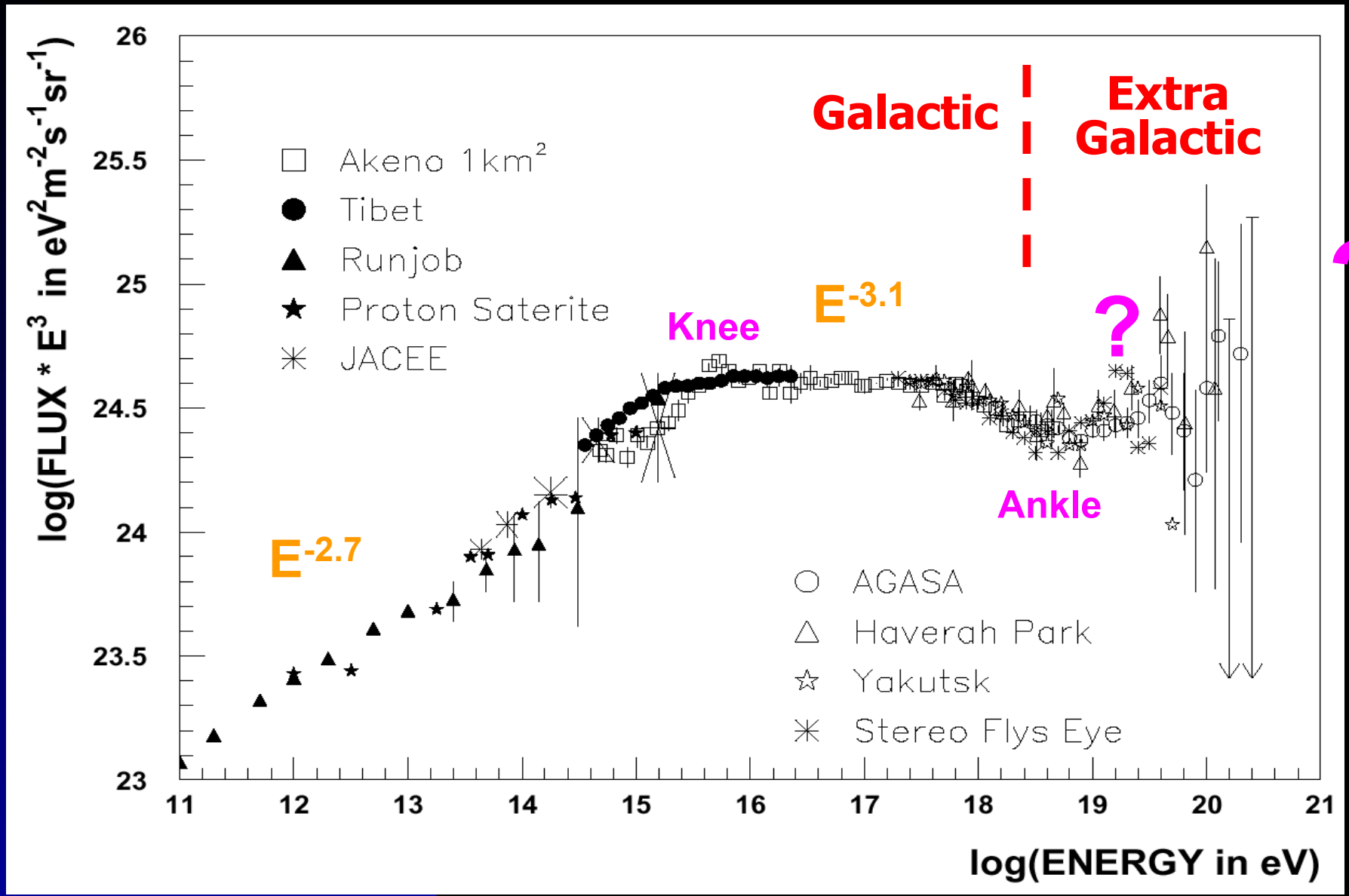
Neutrinos at Auger I



Letessier-Selvon '00

Plans to increase by factor of 5 - 15 neutrinos/year


Matter distribution 7-21 Mpc. Exclusion zones; north array (black),south array (green)
Galactic Latitude
Galactic Longitude
60°
30°
-30°
-60°
360°
300°
240°
180°
120°
60°
GC
1
0
-1
-2
0
2


log(FLUX * E^3 in eV^2 m^-2 s^-1 sr^-1)
log(ENERGY in eV)
Akeno 1km^2
Tibet
Runjob
Proton Saterite
JACEE
AGASA
Haverah Park
Yakutsk
Stereo Flys Eye
Galactic
Extra Galactic
Knee
Ankle
E^-2.7
E^-3.1
?
?

Model Uncertainties

Santadard SIMULATION codes to be used across experiments

An extreme comparison in composition studies with QGSJet…

J. Knapp ICRC03