

The UHE tail of the Cosmic Ray
Spectrum II:
Neutrinos and Composition

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Alicante Marzo 2004

Summary:

- Composition: Cosmic rays & ν
- Inclined Showers
 - ν detection
 - CR detection
- Radio Technique
 - Askary'an effect
 - Coherent pulses
 - Experiments

A *heavy* task : Composition SOURCES

reduced
fluctuations

• Xmax fluctuations 

• Xmax (elongation rate) 

• Time 

• Risetime 

• Lateral distribution (flatter)

• $\mu / (\gamma e)$ ratio 

• Inclined showers 

 Heavy

early

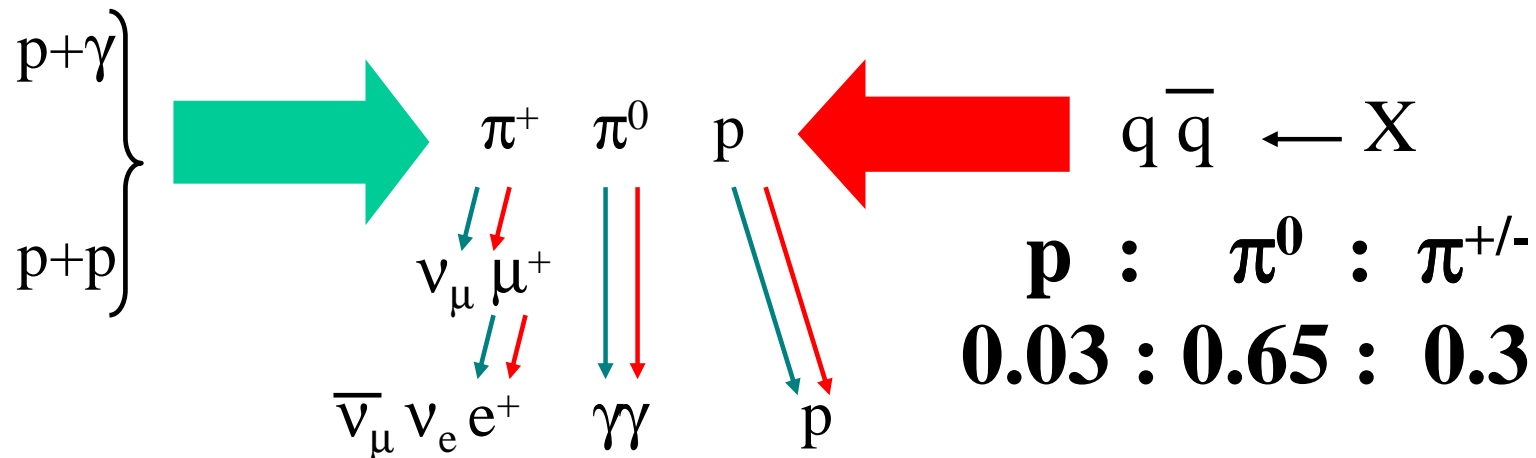
more μ

(Also includes γ)

v: UHECR source classification

- Acceleration

- Fragmentation



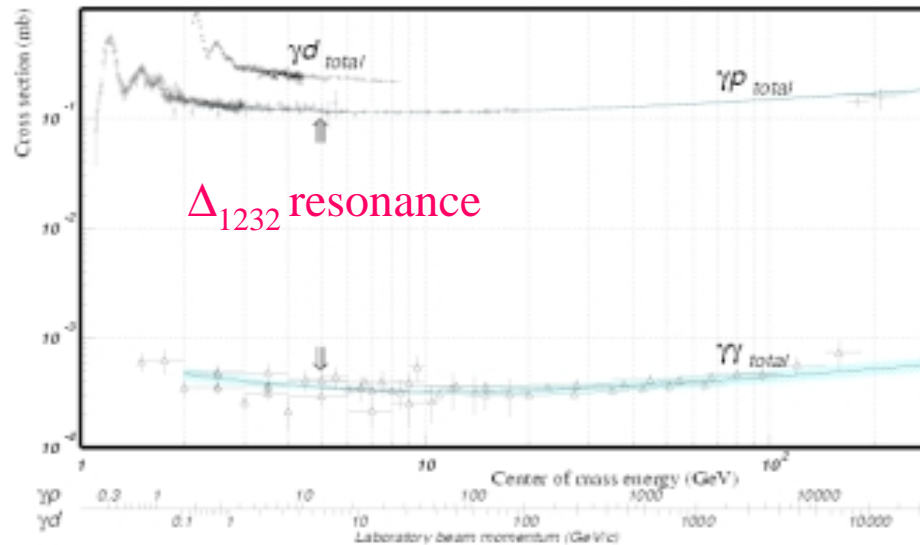
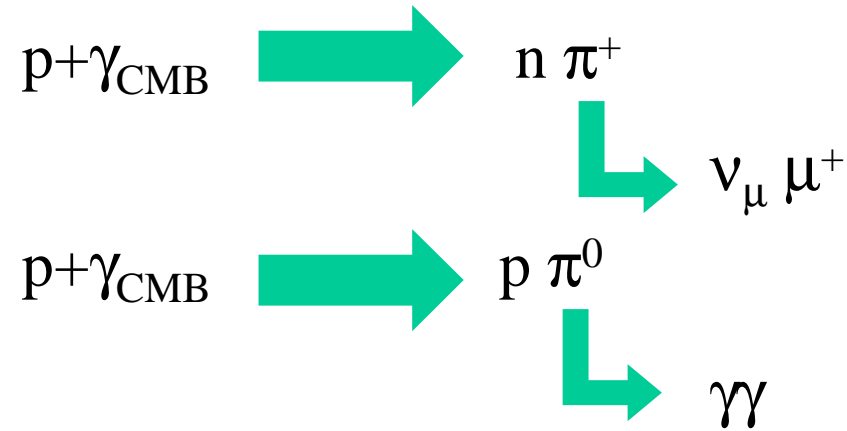
$p : \bar{\nu}_\mu$
1 : ~1

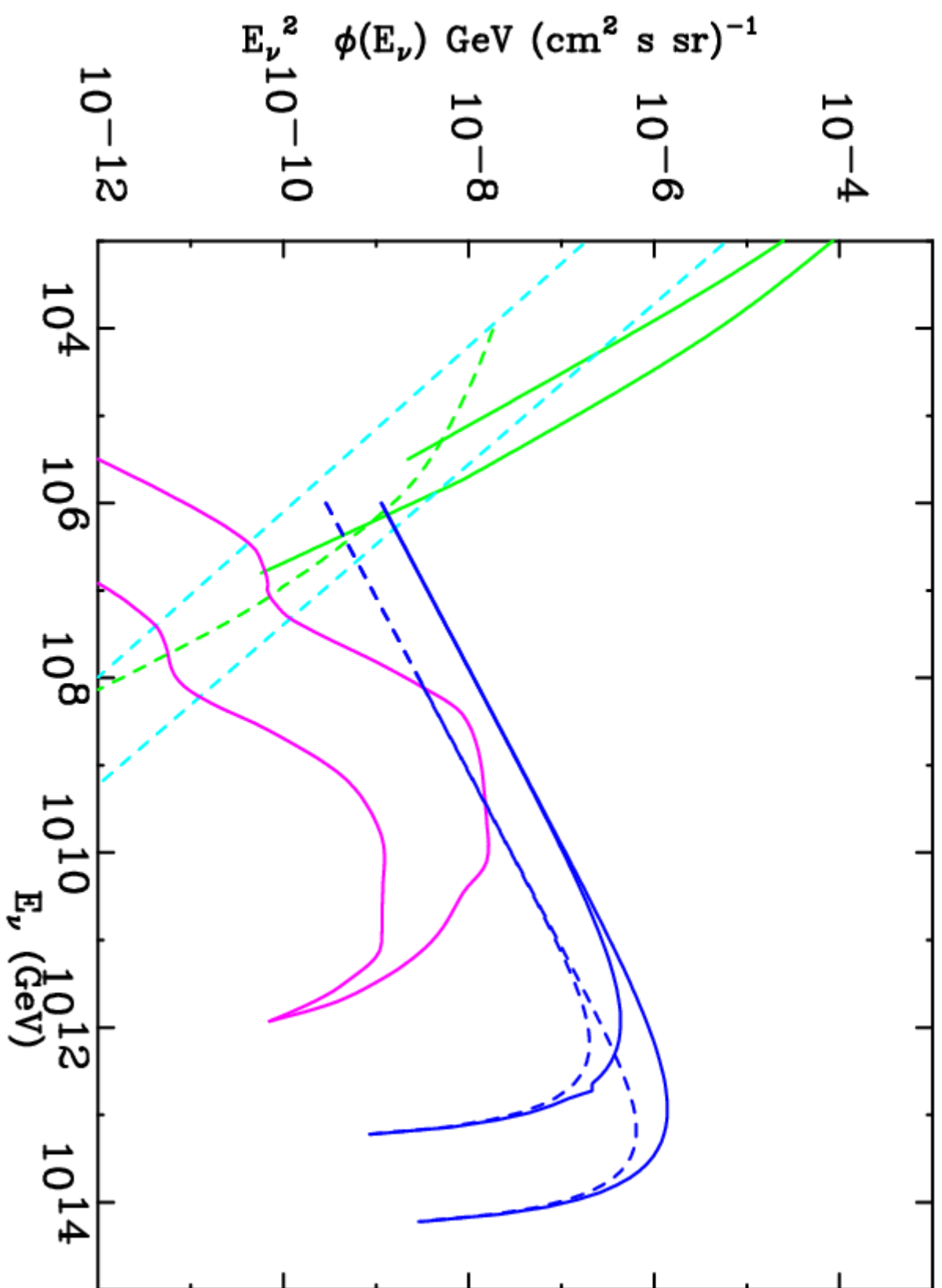
$\gamma : \bar{\nu}_\mu : \nu_e : \nu_\mu : \bar{\nu}_e$
2 : 2 : 1 : 2 : 1

Δ threshold

$p : \gamma : \nu$
0.09 : 2 : 6

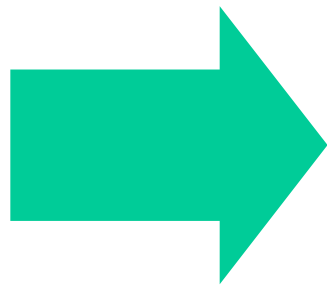
Neutrinos : Produced through GZK





Neutrinos : Can be identified in EAS

Large
fluctuations



at any depth

μ

- Xmax fluctuations ↑
- Xmax (elongation rate) ↑
- Time delay ↑
- Risetime? ↑
- Lateral distribution (steeper)
- Inclined showers (identify)
- $\mu / (\gamma e)$ ratio (cc/nc, flv)

Identification: inclined showers absorbed

- 36000 g cm^{-2} (sea level)
 - Electromagnetic part absorbed
 - “Only” Shower muons reach ground level
 - Electromagnetic part from muon decay, bremsstrahlung

What is the background?

Understand inclined CR showers

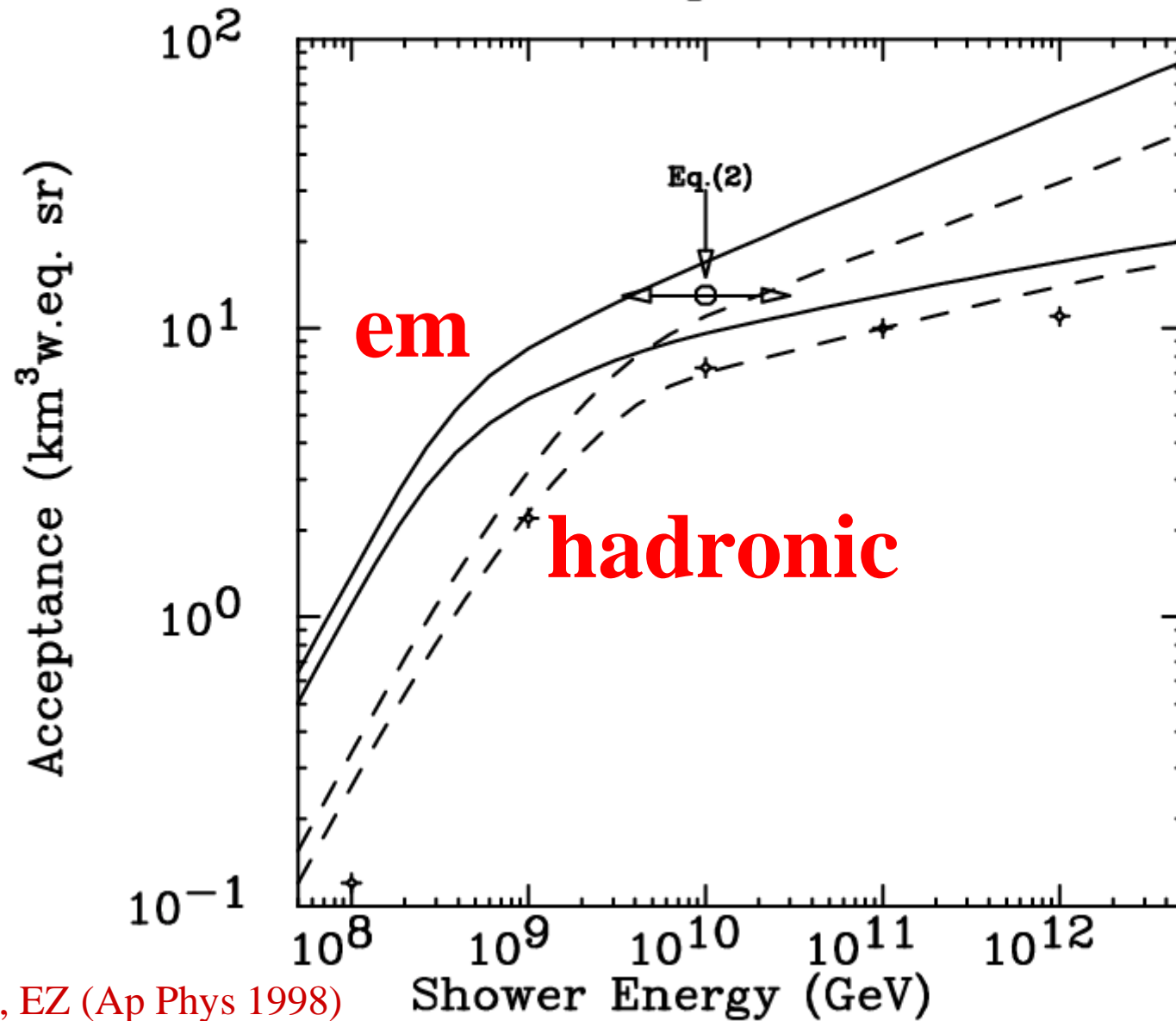
Assume identification: ν -Acceptance

Calculate **effective target volume**:

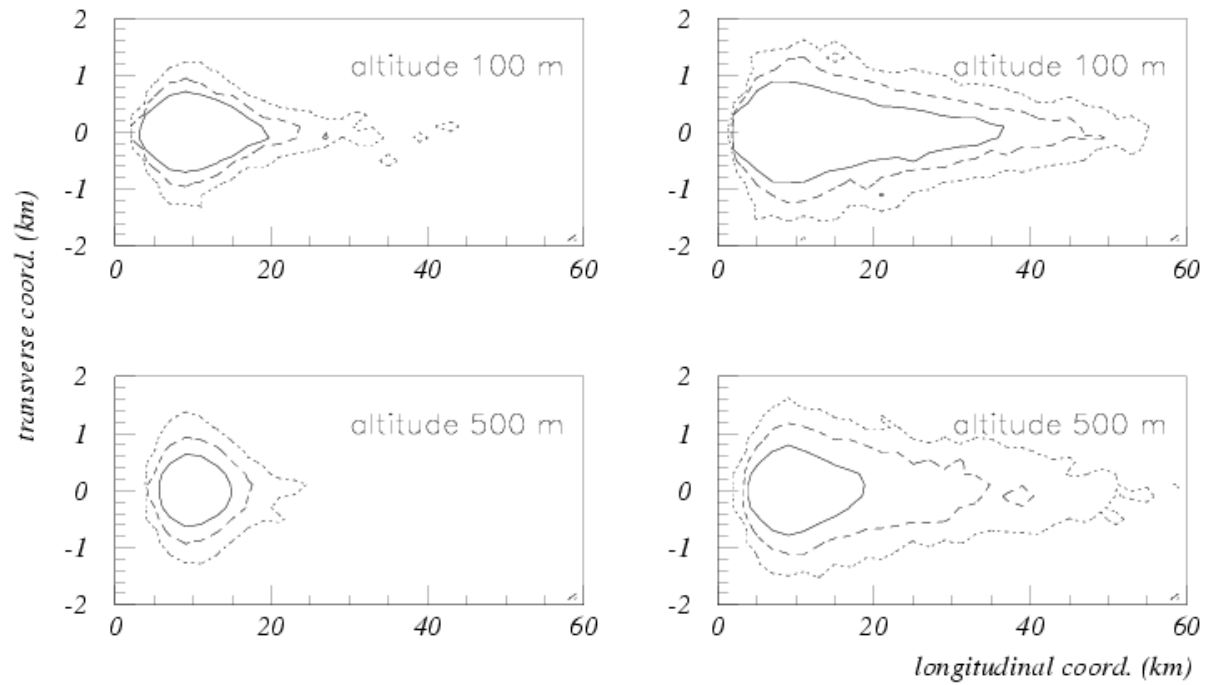
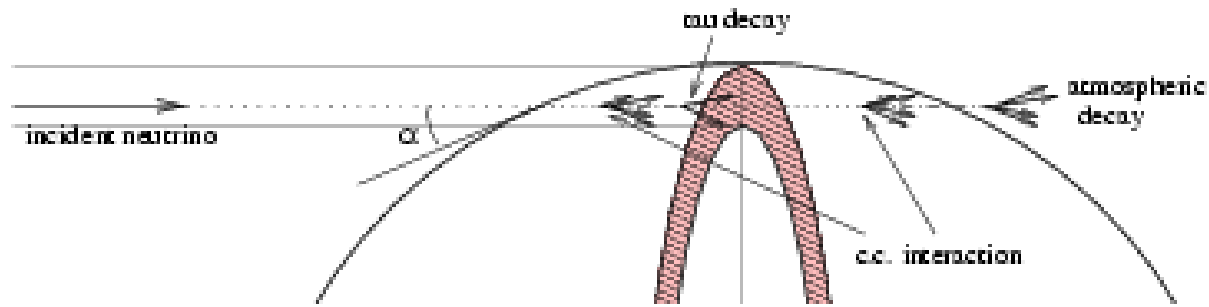
- **Neutral current**
- **Charged current (flavor ν τ)**
 - Hadronic showers (less particles)
- **Charged current (flavor e)**
 - Mixed showers

Auger ν -acceptance

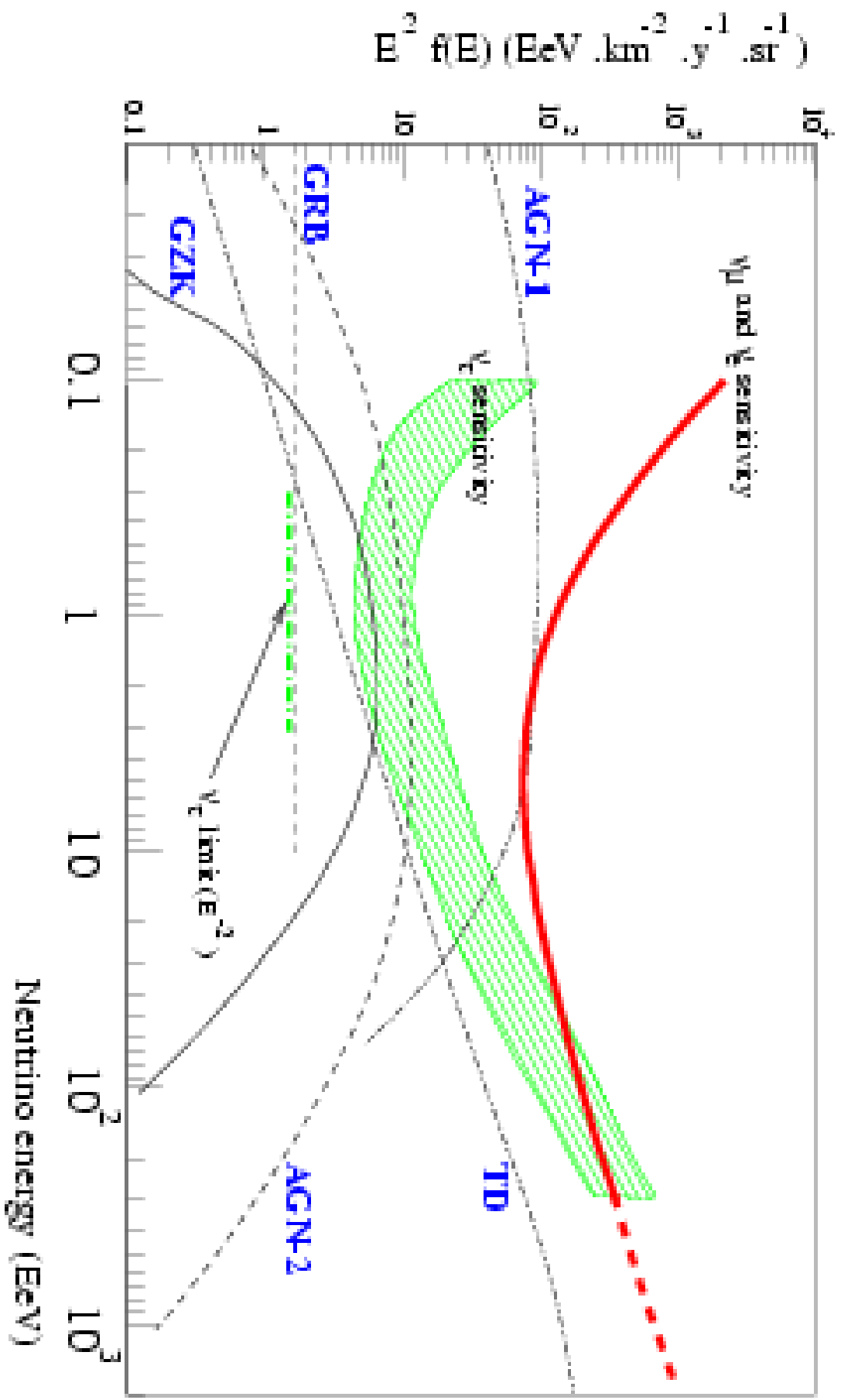
Fig. 4



Auger ν_τ -acceptance



P. Billoir et al, ApPhys(2002)



Need to separate CR “background”

understand

**Transverse
plane
pattern**

**Arrival times:
front curvature**

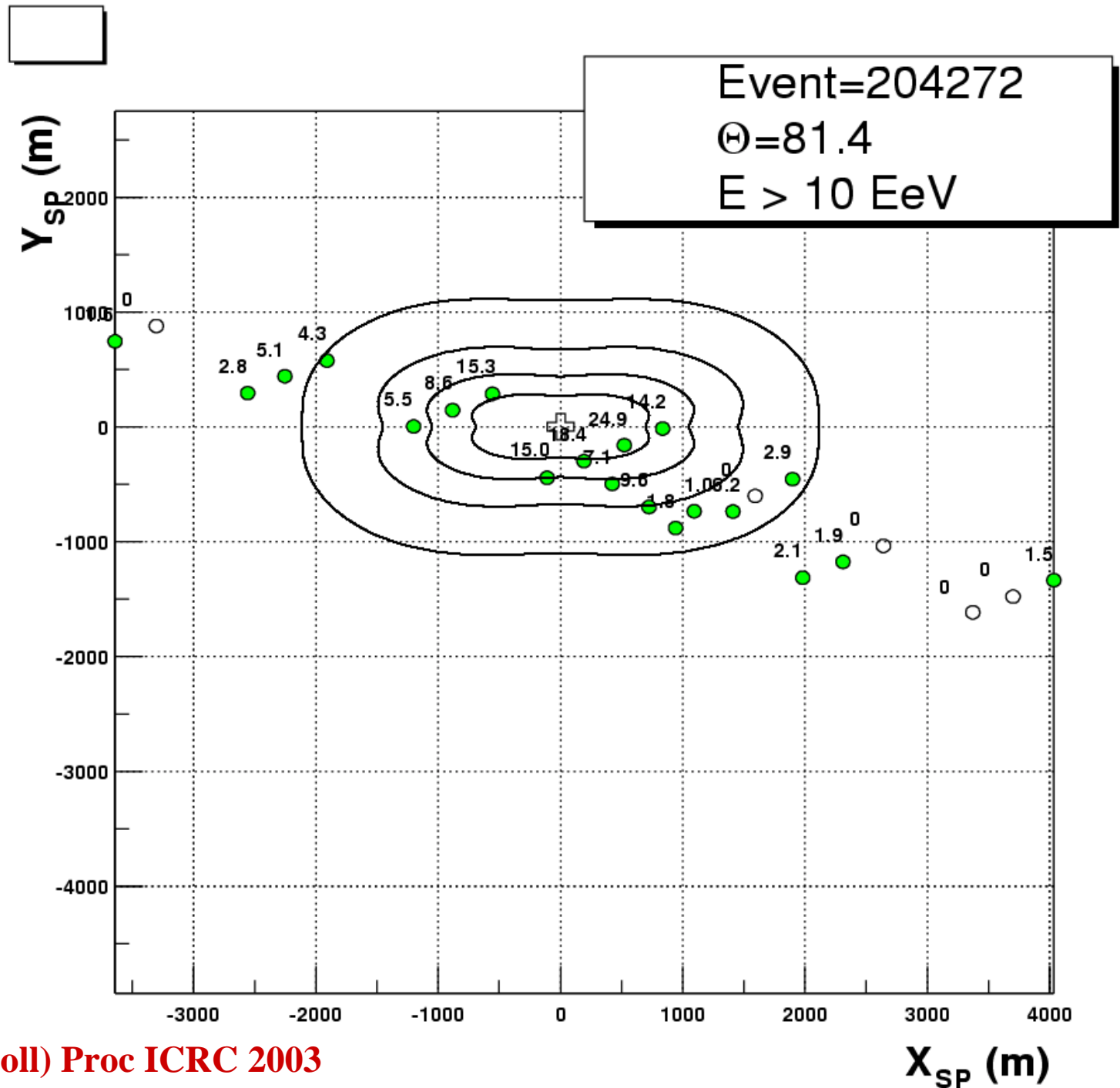
**Interesting Spinoff:
inclined shower rate
Composition**

- **Geomagnetic separation**
- **Analytical model**
- **Event analysis possible**

- **v separation easy**
- **work in progress**

- **γ bound from HP**
- **Auger will improve it**

**>10¹⁹ eV
inclined
shower
detected
at Auger
EA 2002**

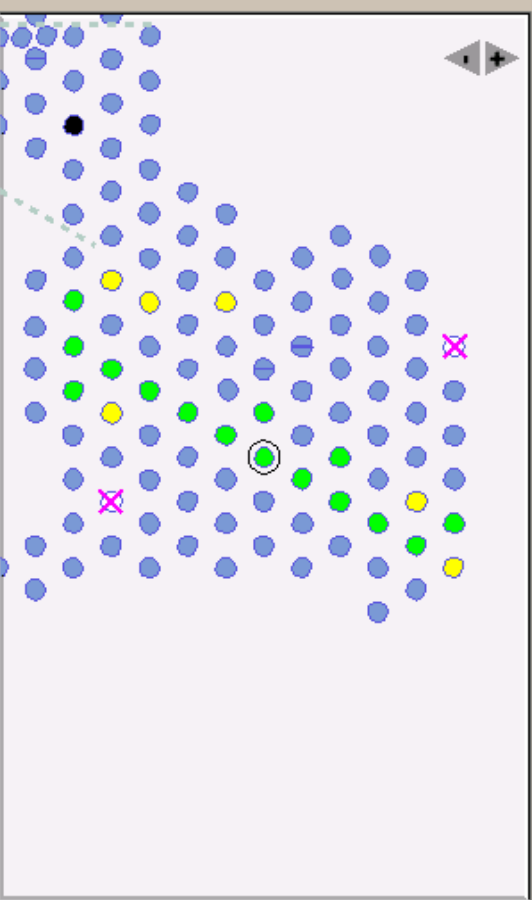


File Configure Experts only...

Reconstruct Previous Next Get # Update 5

#00602222, 15 stations, 3C2&4C4	0229 (24627 ns, 9.8 VEM)
#00602226, 5 stations, 3C2&4C4	0112 (26992 ns, 7.4 VEM)
#00602229, 6 stations, 3C2&4C4	0113 (29605 ns, 58.0 VEM)
#00602232, 6 stations, 3C2&4C4	0106 (34604 ns, 17.9 VEM)
#00602235, 23 stations, 3C2&4C4	0102 (36961 ns, 3.6 VEM)
#00602237, 7 stations, 3C2&4C4	0133 (39553 ns, 4.0 VEM)
#00602238, 5 stations, 3C2&4C4	0147 (42223 ns, 34.4 VEM)
#00602241, 5 stations, 3C2&4C4	0143 (44514 ns, 3.2 VEM)
#00602247, 5 stations, 3C2&4C4	0146 (44670 ns, 4.2 VEM)
#00602251, 5 stations, 3C2&4C4	0194 (47207 ns, 6.1 VEM)
#00602256, 5 stations, 3C2&4C4	0149 (49419 ns, 3.7 VEM)
#00602257, 6 stations, 3C2&4C4	0191 (49568 ns, 25.2 VEM)
#00602258, 5 stations, 3C2&4C4	0192 (52063 ns, 4.1 VEM)
#00602261, 5 stations, 3C2&4C4	0231, station deleted
#00602263, 7 stations, 3C2&4C4	0206, station deleted

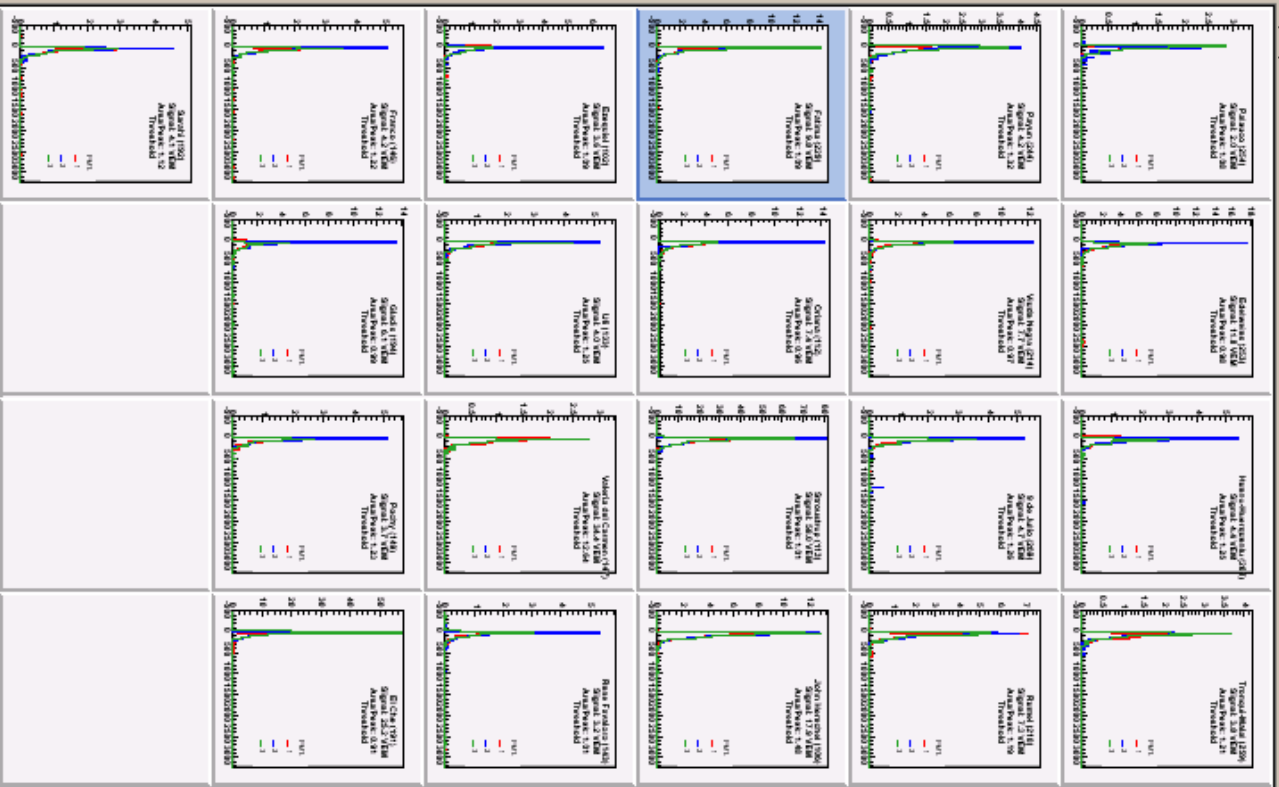
Array



Status

file selected: sd_2003_12_07_00h13.root
 Minimum number of triggered stations: 5
 Trigger selected: all of them, 44 events.
 Date of this event: Sun Dec 7 05:40:15 2003

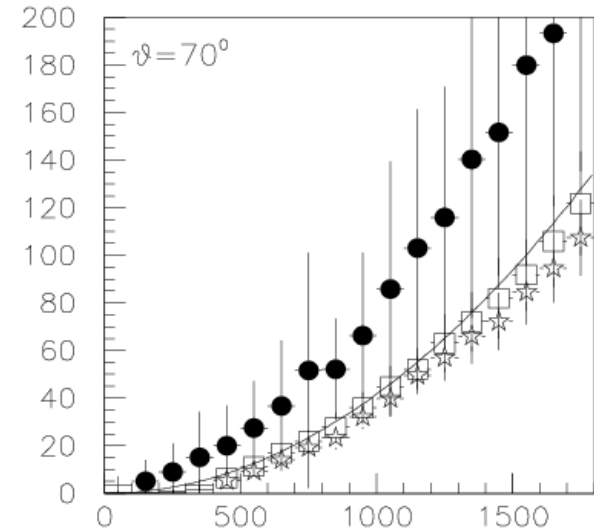
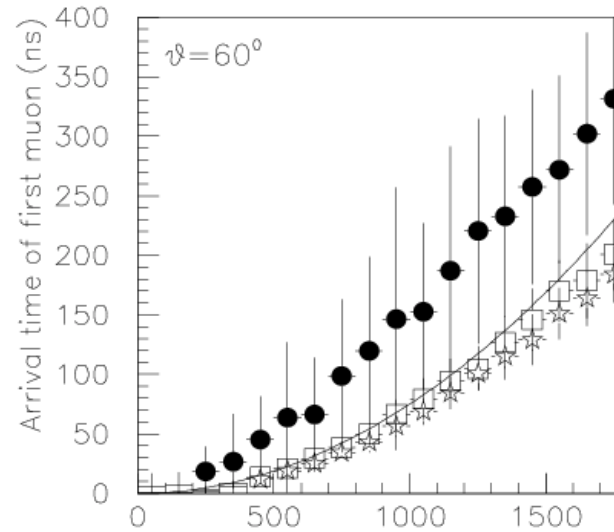
Display



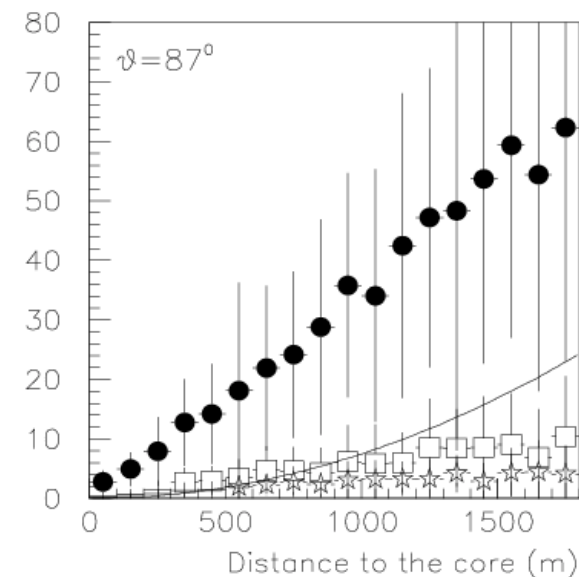
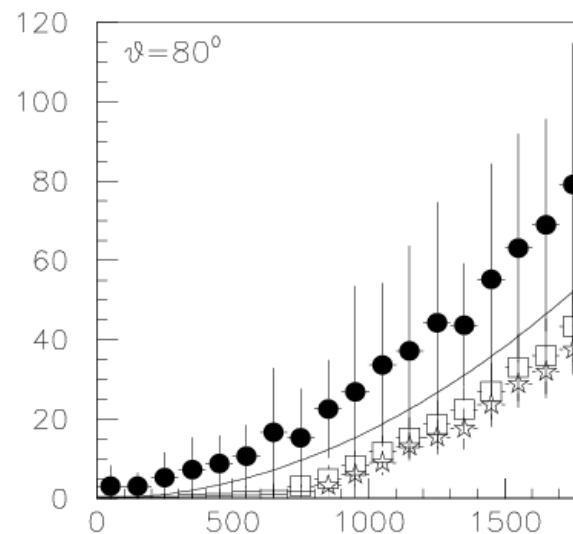
100%

Arrival Time of first muon (& average)

**ν -like delay
large**

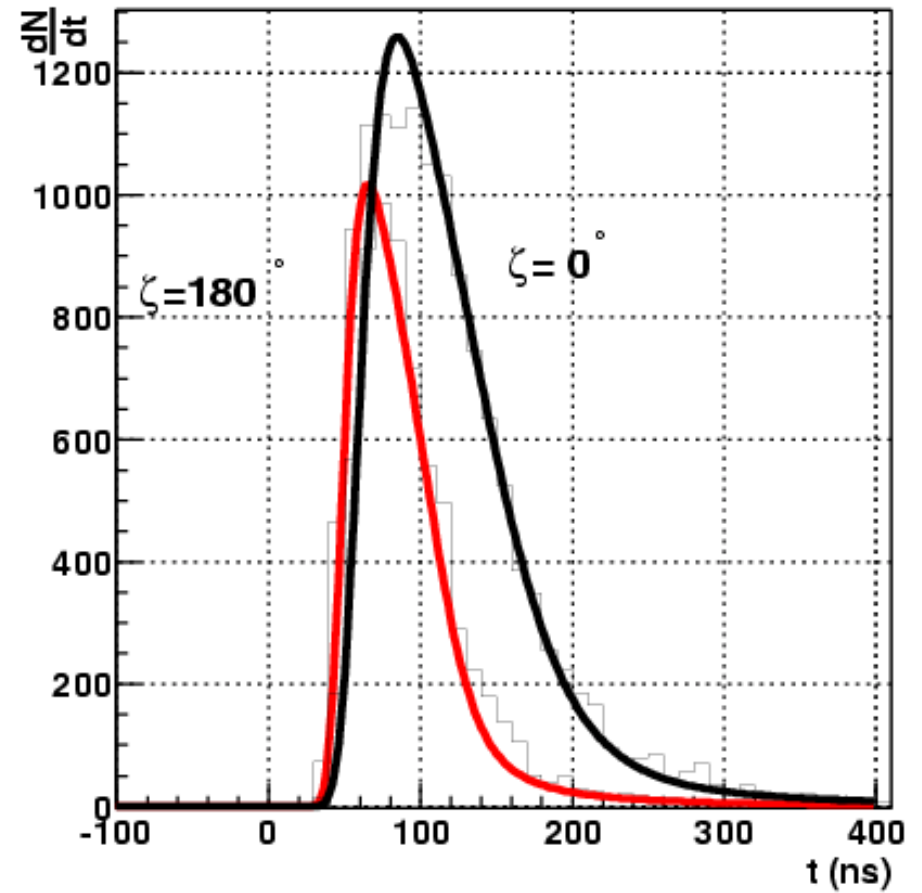
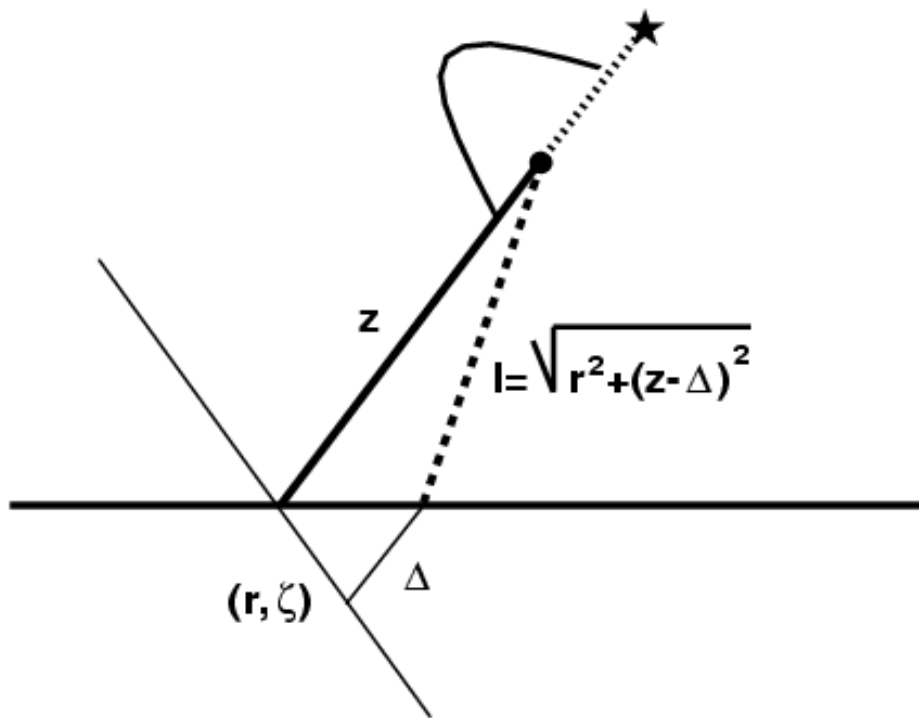


**μ -like delay:
small (flat)**



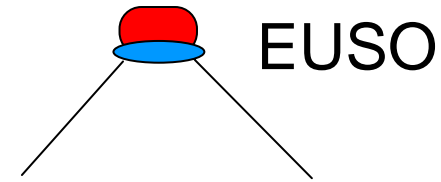
Cazon, RAV, EZ (in prep)

A model for muon times:



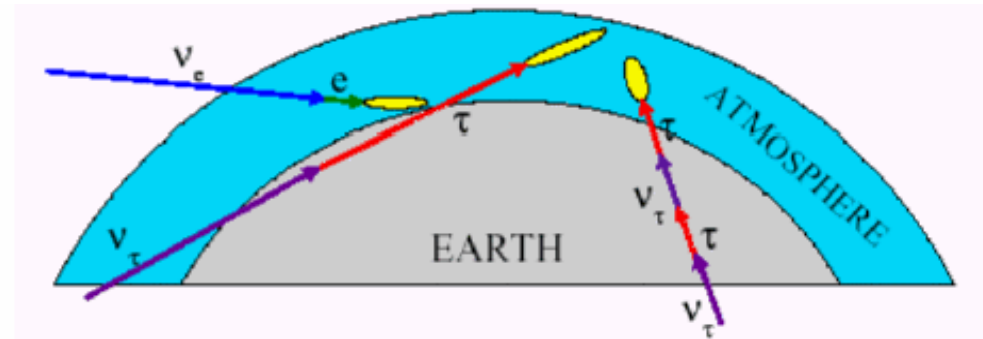
L Cazon, RAV, AAW, EZ (Ap Phys 2004)

Neutrinos in EUSO

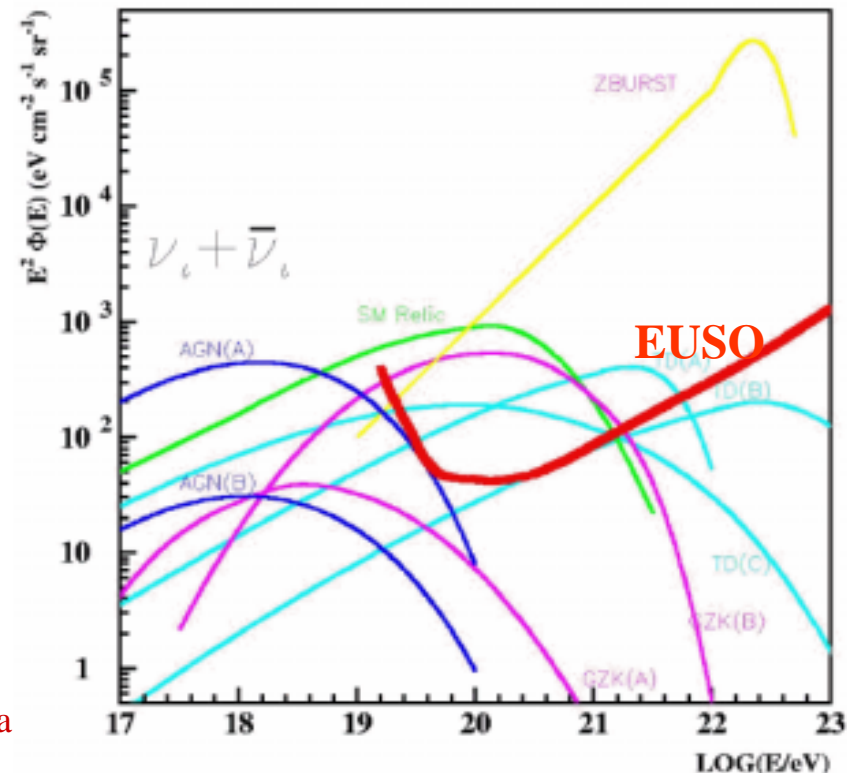


quasi- horizontal ν
 energy threshold $\approx 10^{20}$ eV

upgoing ν_τ
 energy threshold $\approx 4 \cdot 10^{15}$ eV



EUSO Flux sensitivity
 (1event/year/energy decade)
 compared to theoretical
 expected fluxes




Diagramas from M. Pimenta

Radio pulses from showers

Cherenkov in radio

- “Askary’an effect” (1961) : $N_e > N_{e+}$
Dense medium: \dim_{SHOW}
Coherent $\longleftrightarrow \lambda > \dim_{\text{SHOW}}$
- Simulation code 90 (GEANT00)
- Checked at SLAC (2000)

Power 
 $\propto \omega^2$
 $\propto E_{\text{SHOW}}^2$

New generation of UHE ν -experiments

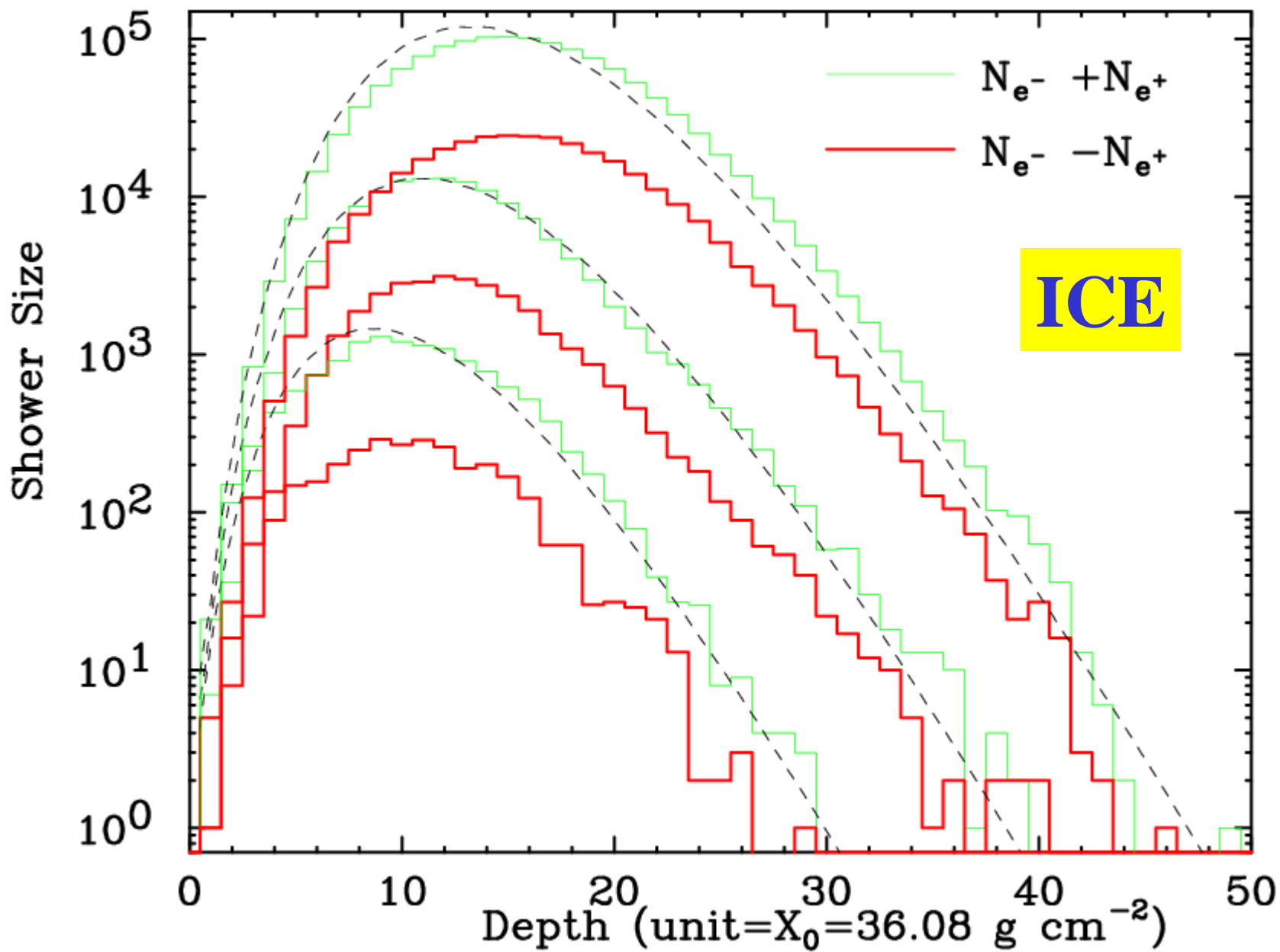
JAlvarez Muñiz,EMarques,FH,TS,RAV,EZ, PRD(91-99-00-01)PLB(97-98)

Coherent pulses:

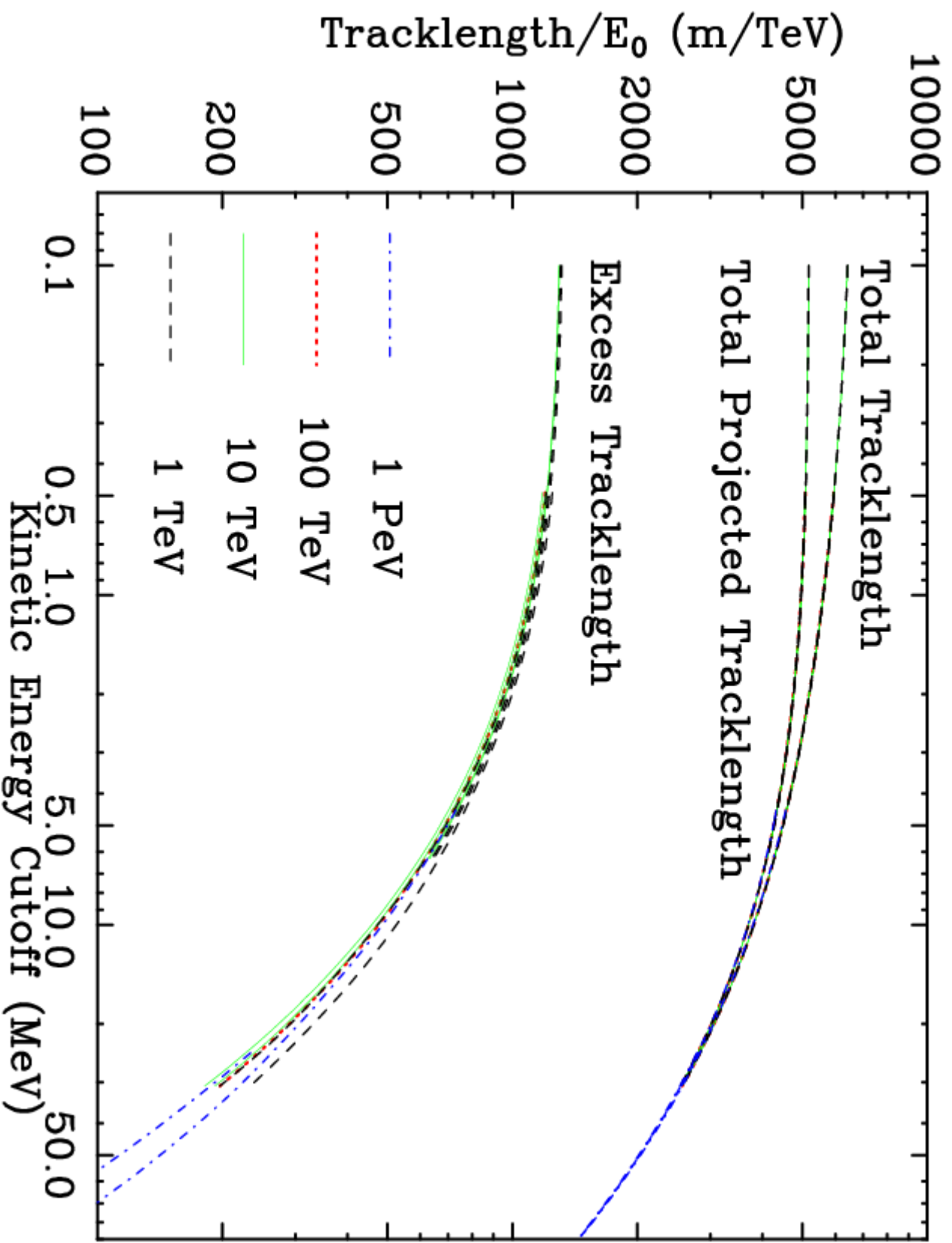
- $\lambda > \text{dim}_{\text{SHOW}}$
- e^- and e^+ cancel $N_{e^-} - N_{e^+}$
- $|\mathbf{E}| \propto N_{e^-} - N_{e^+}$
- $N_{e^-} - N_{e^+} \propto E_{\text{SHOW}}$
- **Shower information is preserved**

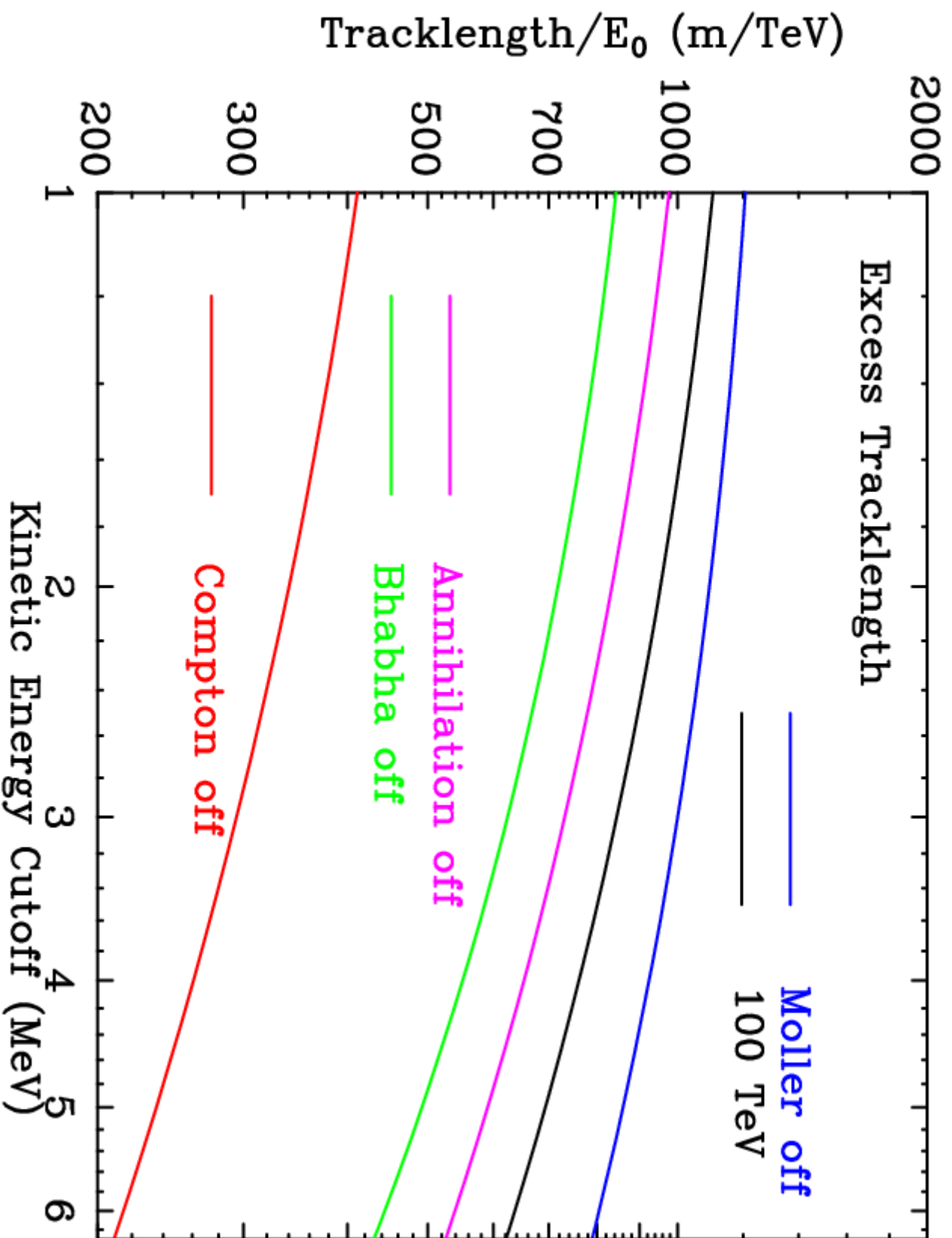
Analogy to a slit diffraction pattern

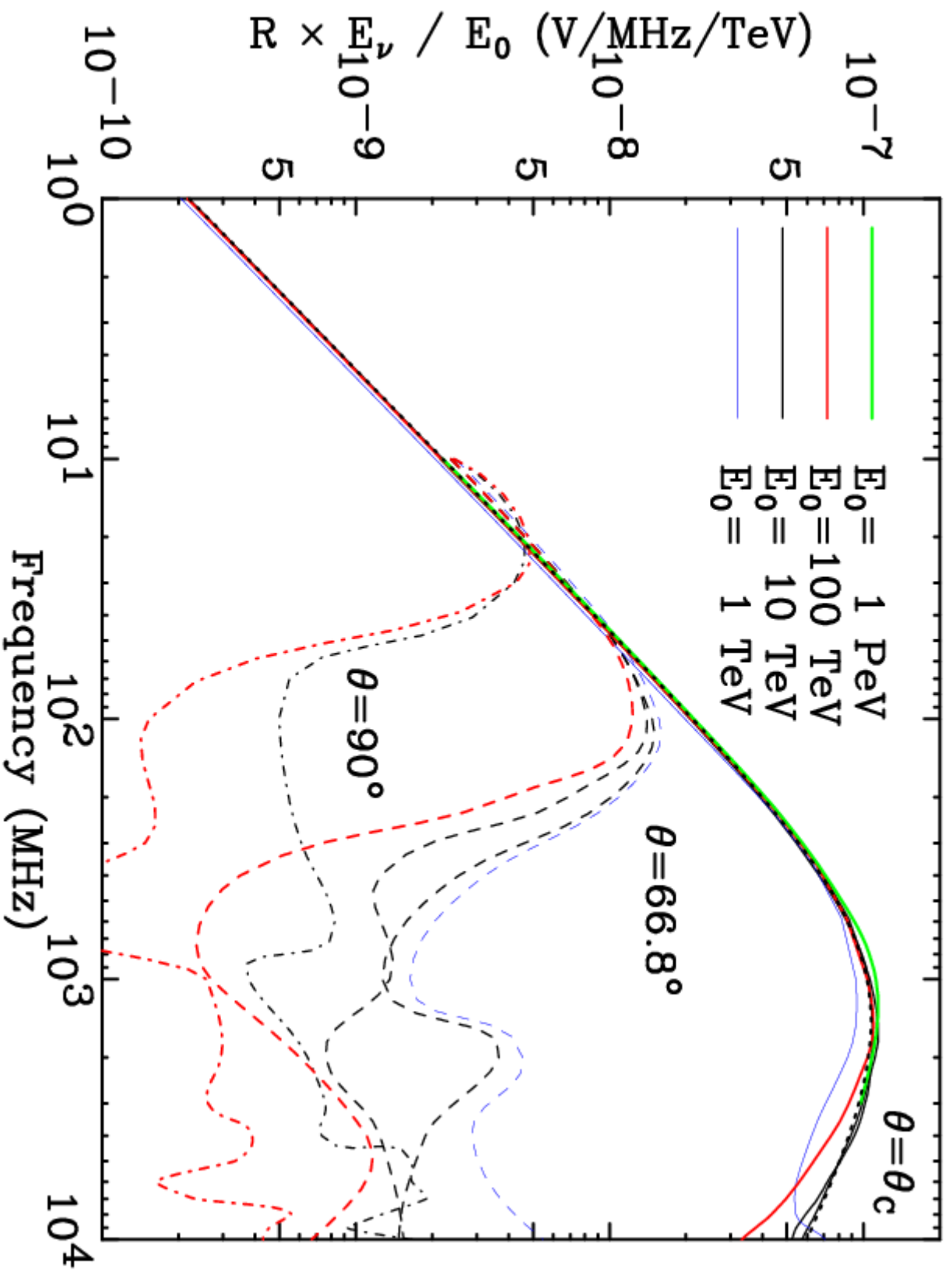
Radio Pulse Power $\propto |\mathbf{E}|^2 \propto E_{\text{SHOW}}^2$

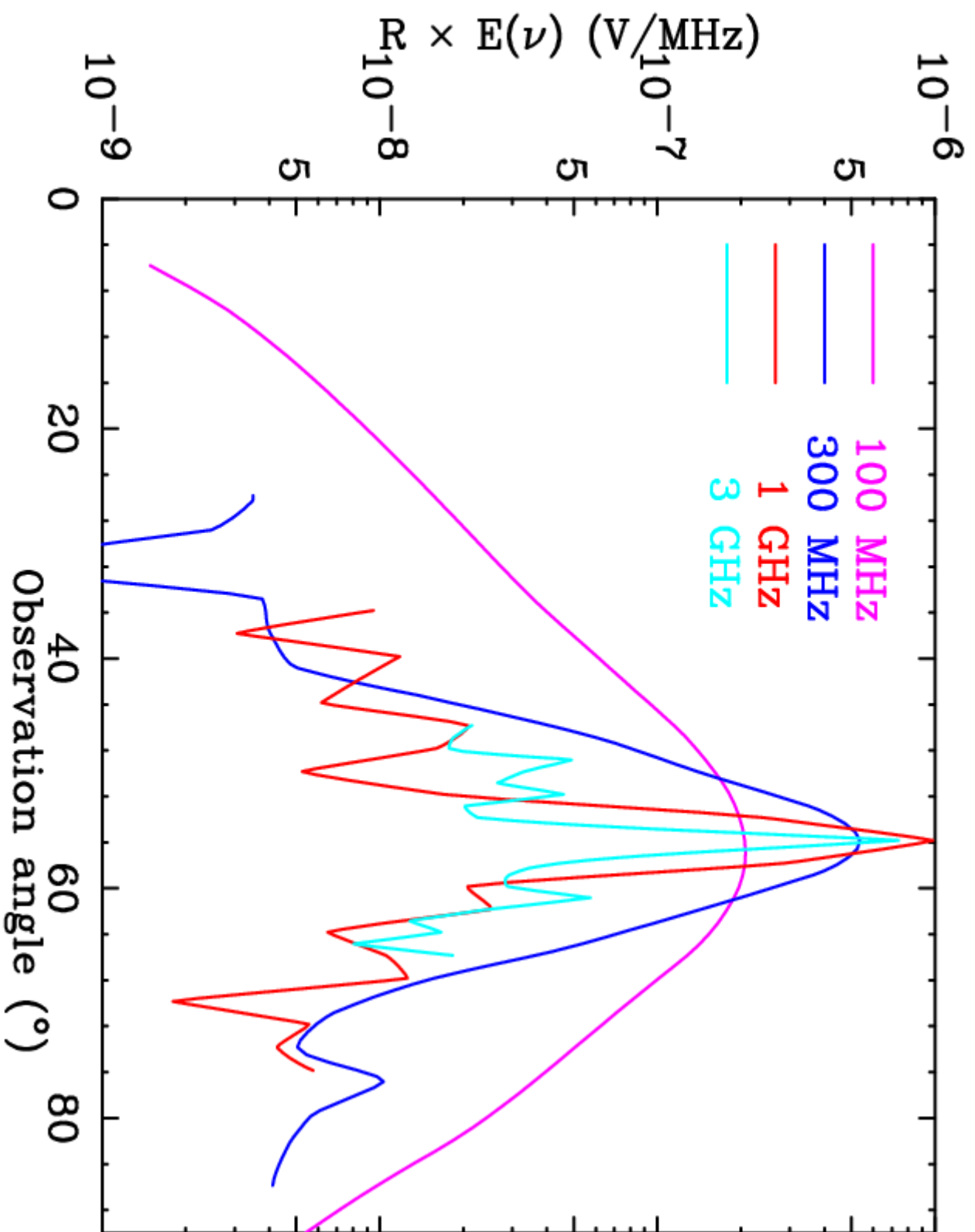


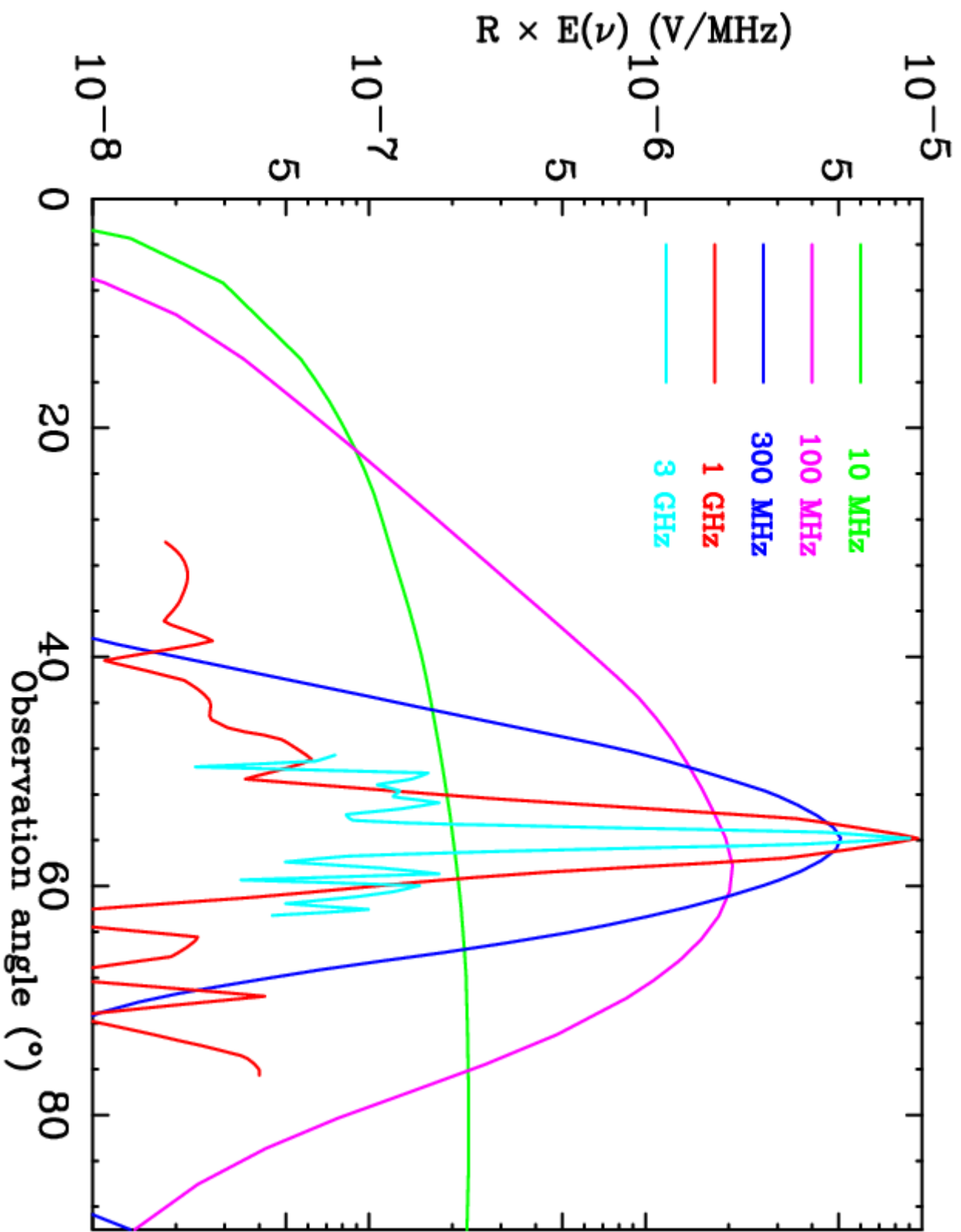
ZHS code: FH, TS, EZ, PRD(91)

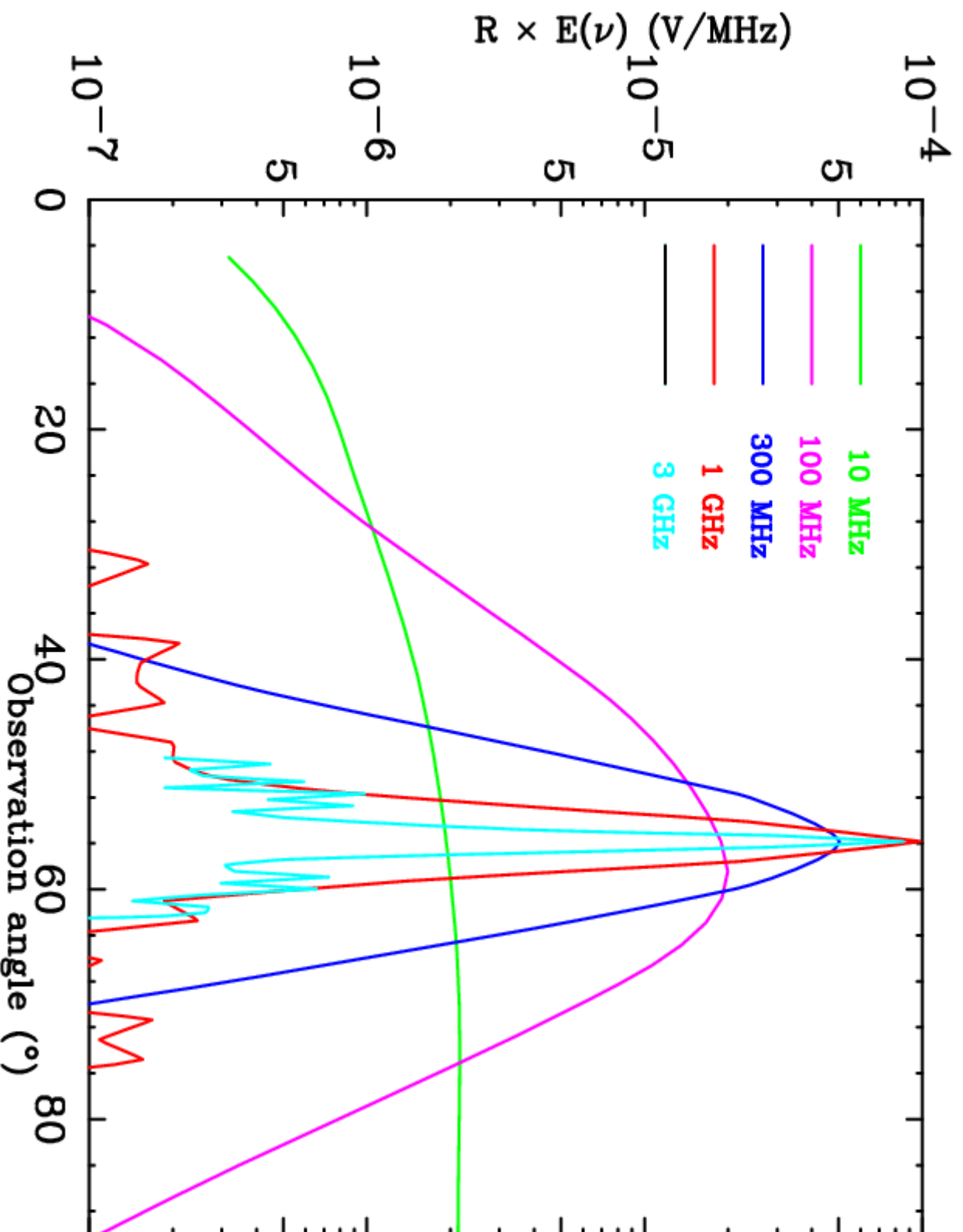










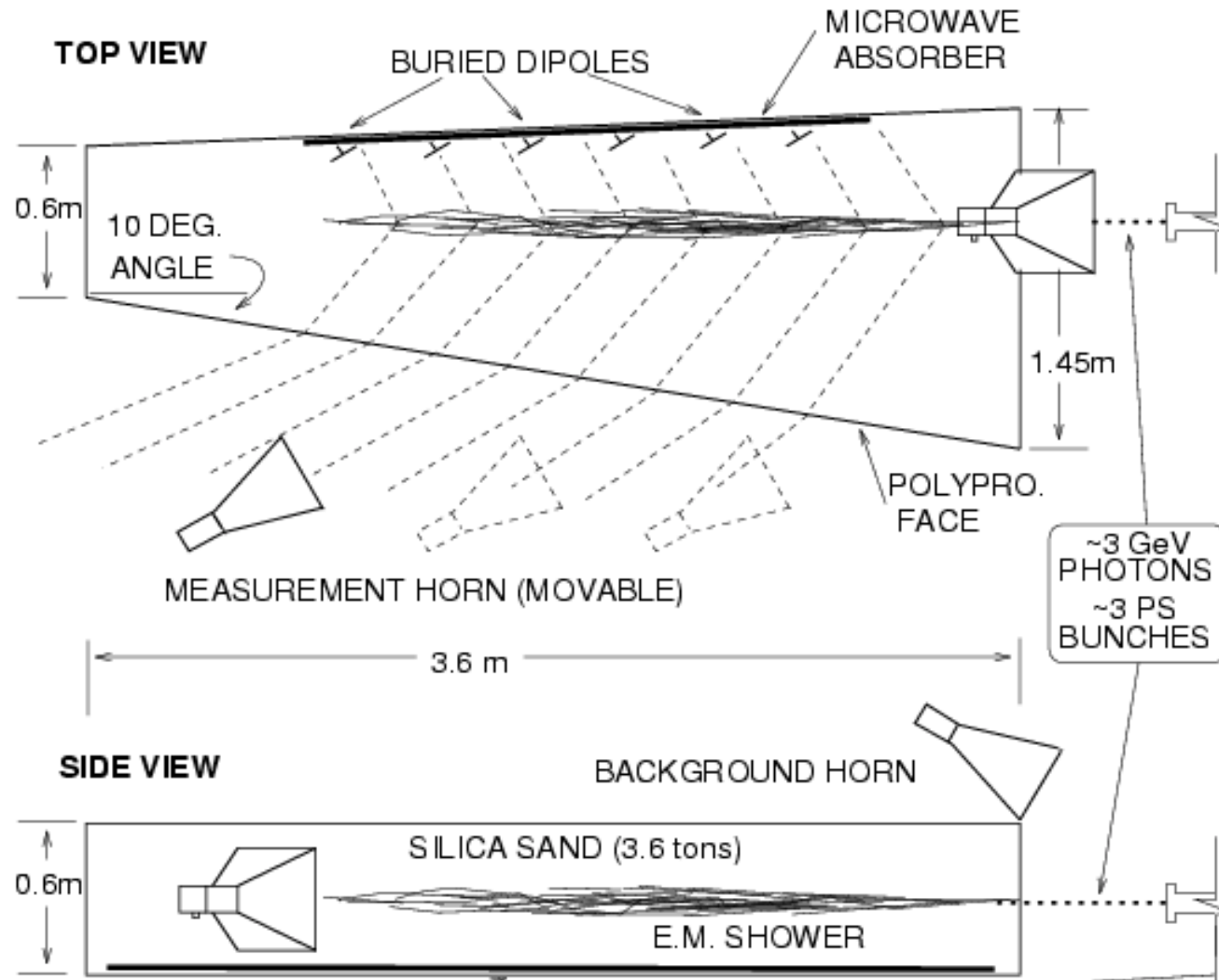


Coherent radio detection: ν -experiments

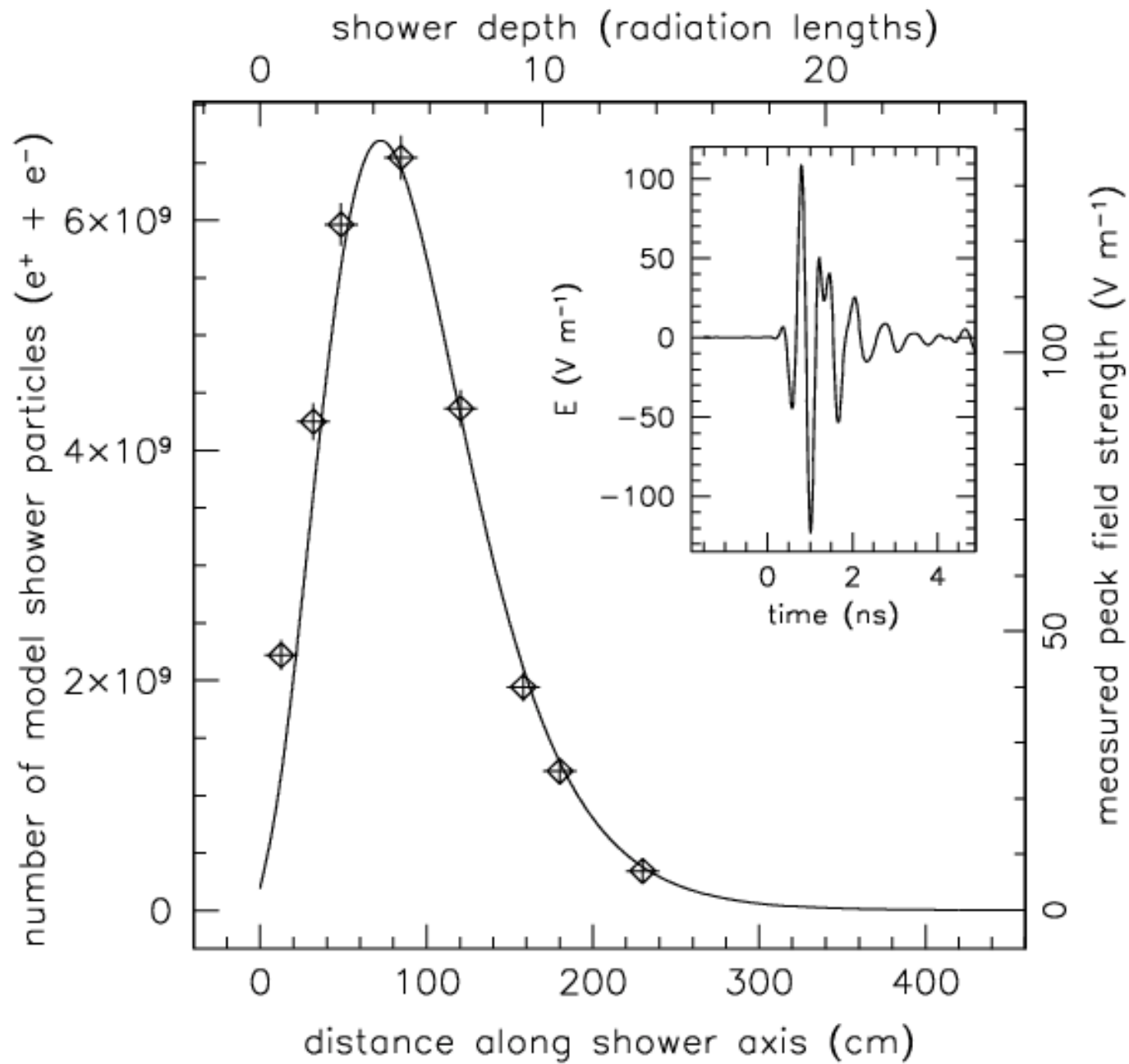
Natural transparent media

- **ICE:**
 - **Antarctica**
 - RICE (array buried)
 - ANITA (balloon)
 - **Greenland**
 - FORTE (satellite)
- **SALT:**
 - **Domes explored**
 - SALSA
- **MOON REGOLITH:**
 - **Radiotelescopes**
 - GLUE
 - **Radiotelescope array**
 - LUNASKA (ska)
- **ATMOSPHERE:**
 - **Antenna array**
 - LOFAR

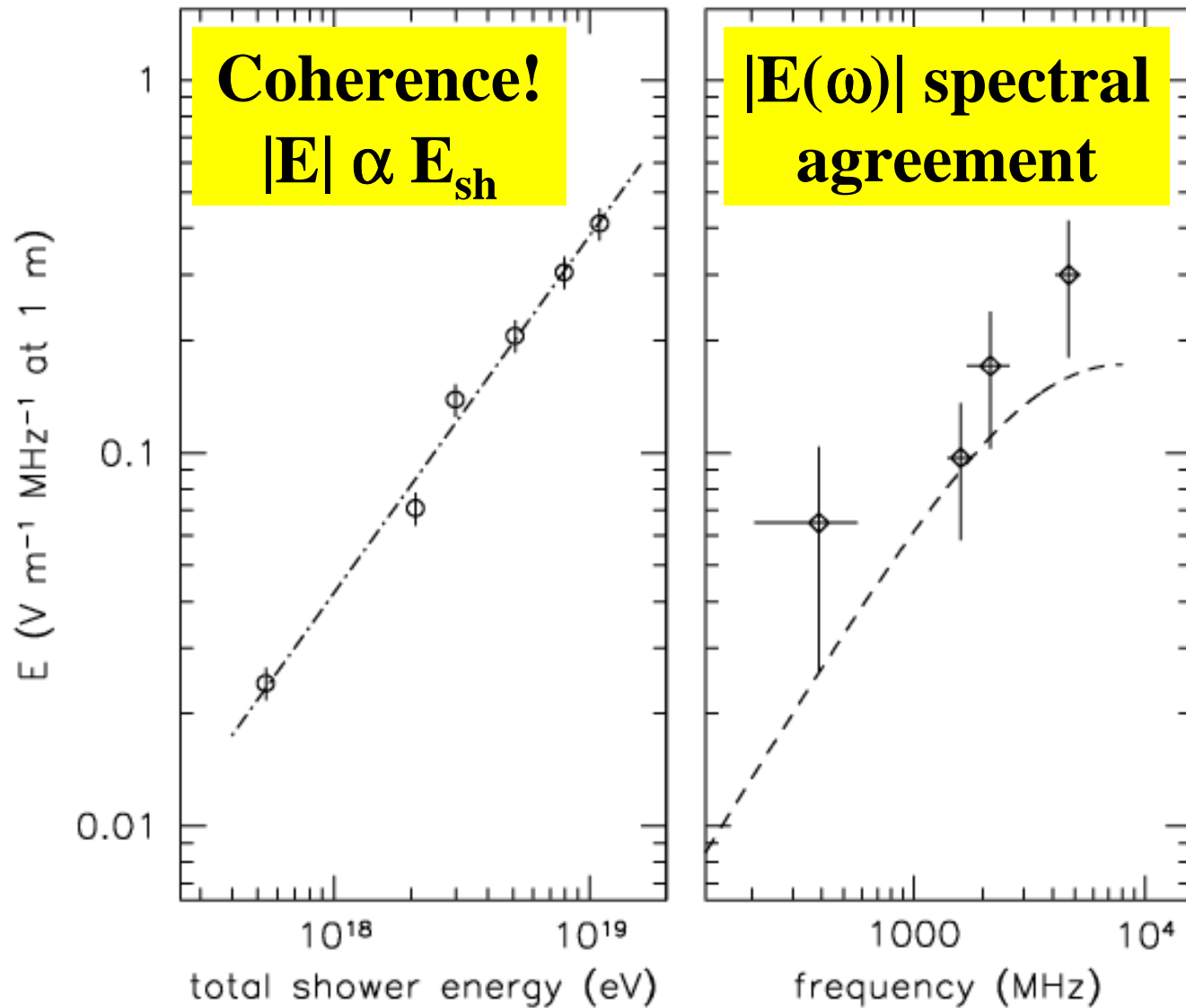
Askarian effect confirmed at SLAC



D.Saltzberg et al. PRL86, 2802 (2001)



D.Saltzberg et al. PRL86, 2802 (2001)



D.Saltzberg et al. PRL86, 2802 (2001)

Both Cosmic Ray & ν -detector

Different
geometries

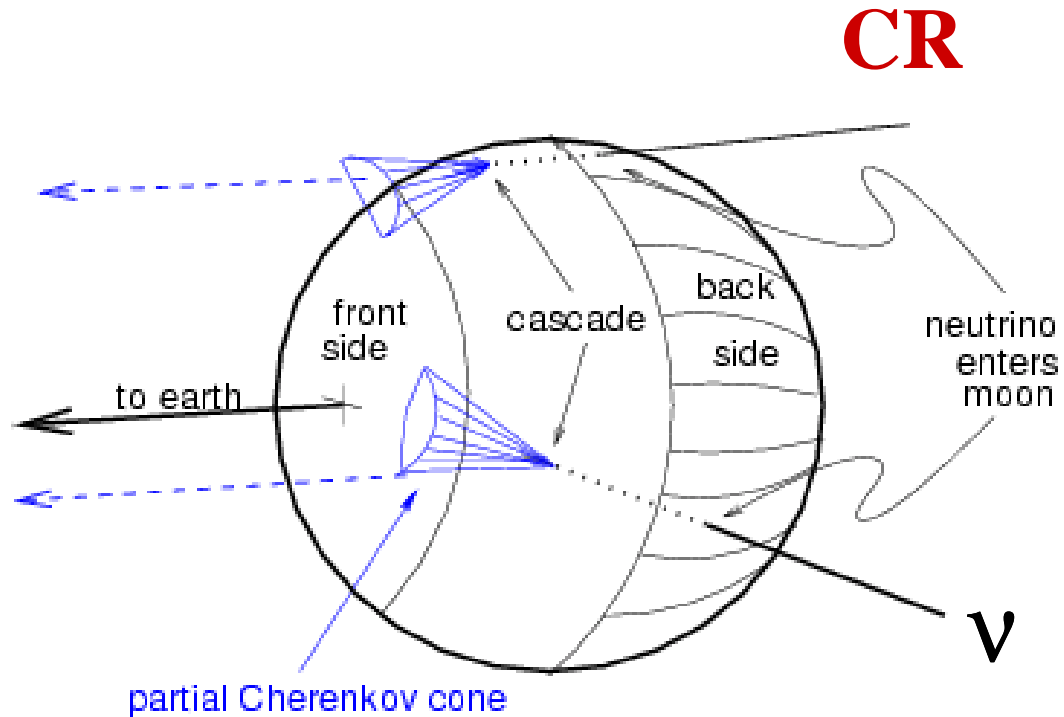
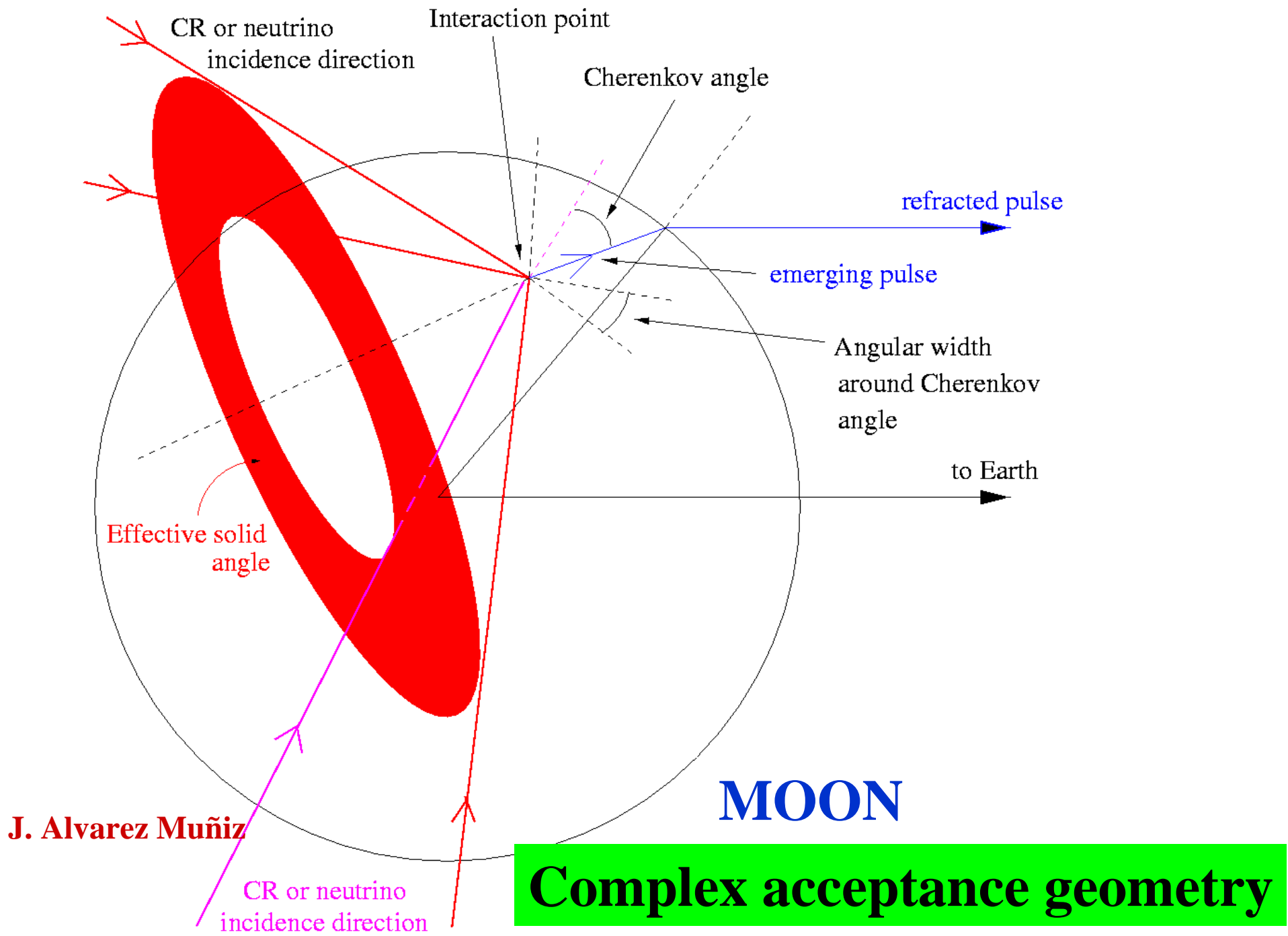


Diagram from P.Gorham



FORTE low frequency search system for transients

(weather measurements)

central ν : 20-300 MHz

bandwidth: 22 MHz

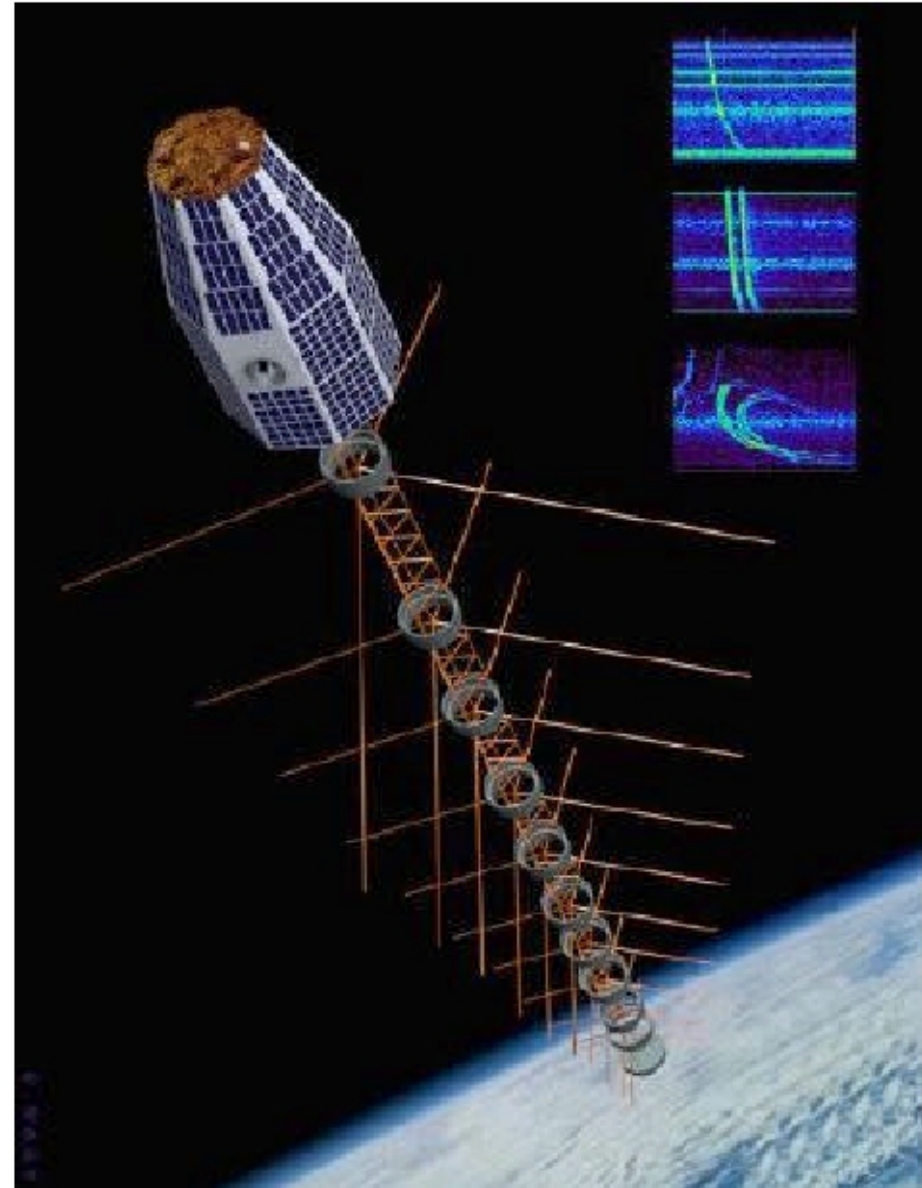
5 subbands coincidences

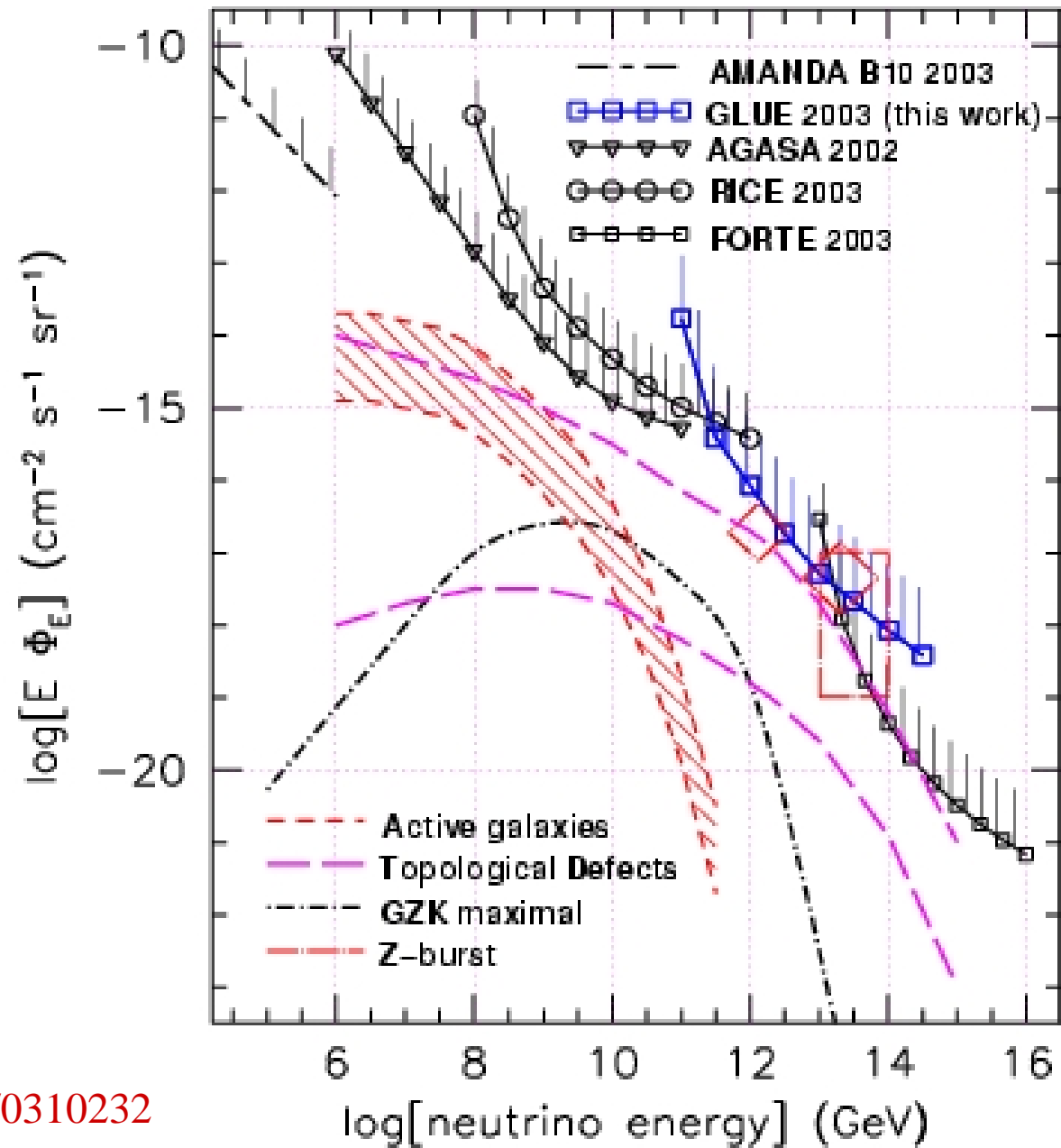
Data Sep 97-Dec 99



2003 BOUND

Lehtinen, PG et al. astro-ph/0309656





P. Gorham, et al. astro-ph/0310232

Conclusion:

**A detectable UHE sky
is open to observation**

- UHE Cosmic rays & ν interrelated
- Inclined Showers have important potential
- Radio Technique is possibly the future
 - See UHE pulses: CR?
 - Calibrate with UHE: EUSO?
 - Expand its potential