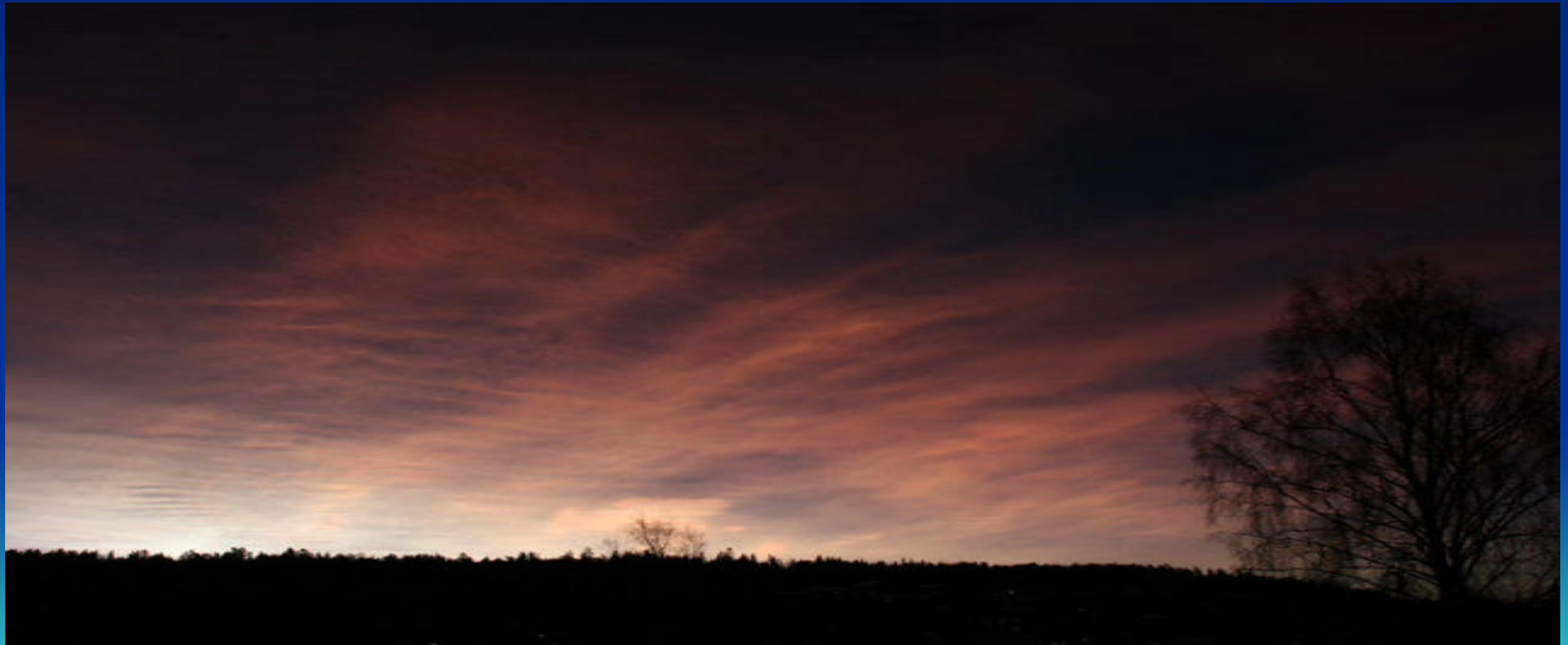
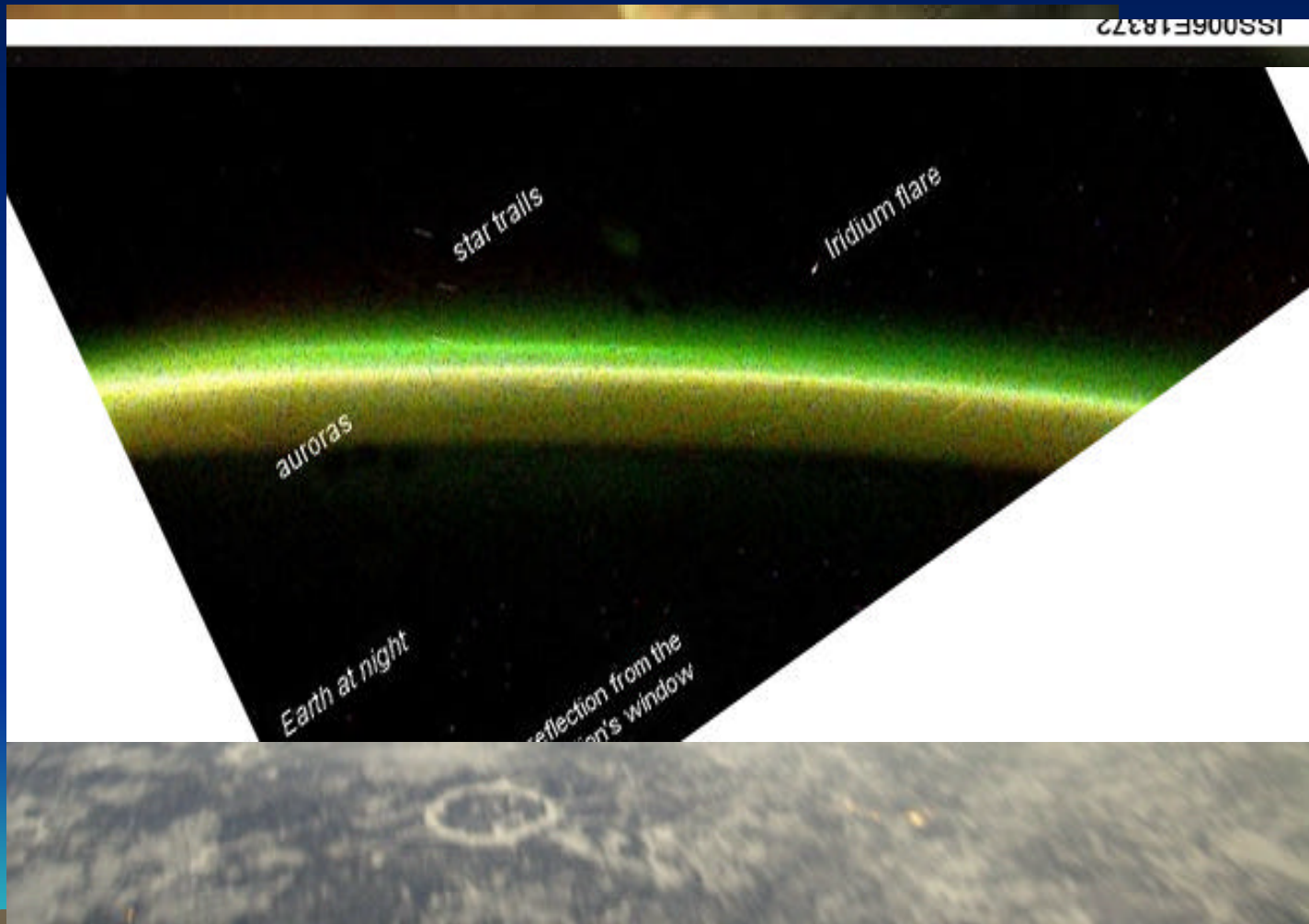


*Showers at Horizos and Array in Space*  
*for Neutrino Astronomy*  
*The rise of a New UHECR Spectroscopy and a New*  
*High Energy Neutrino Astronomy*

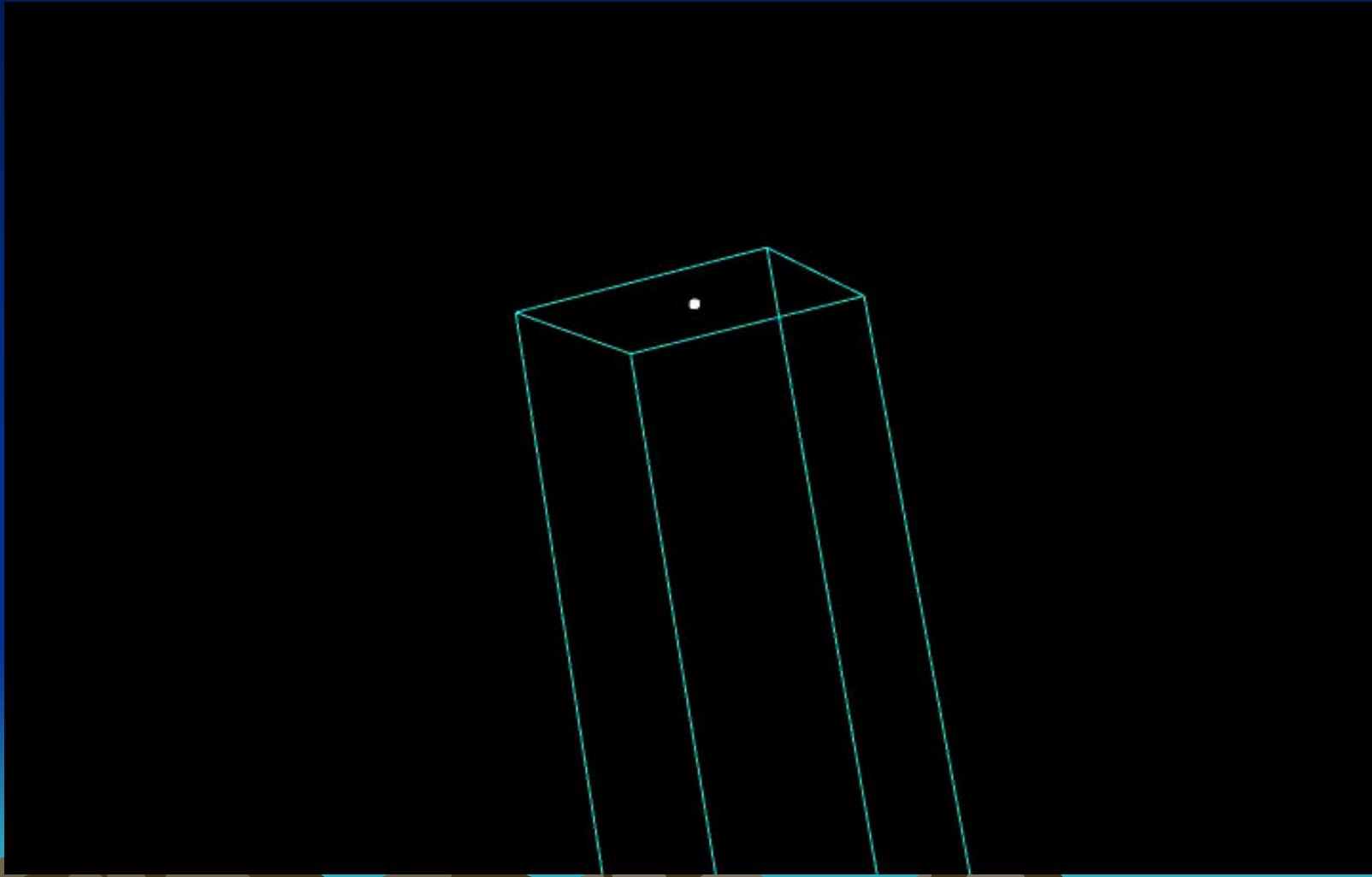


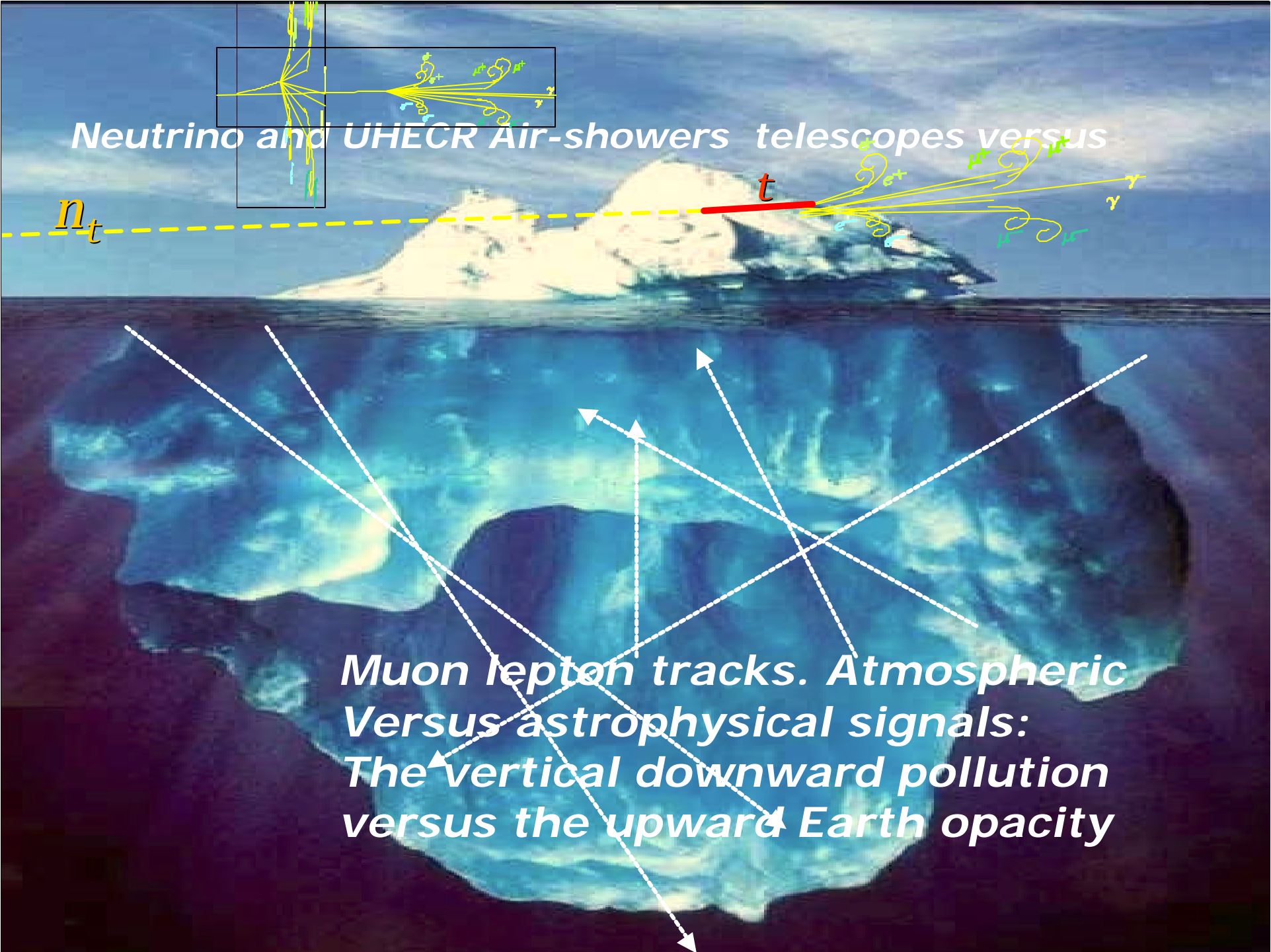
May we see Cosmic Rays by our eyes?  
**Yes , at least the non relativistic Solar wind  
raining on the Earth top atmosphere**



# *Why a new AIR-SHOWERS Spectroscopy ?*

## *Let us see a vertical one :Corsika simulation*





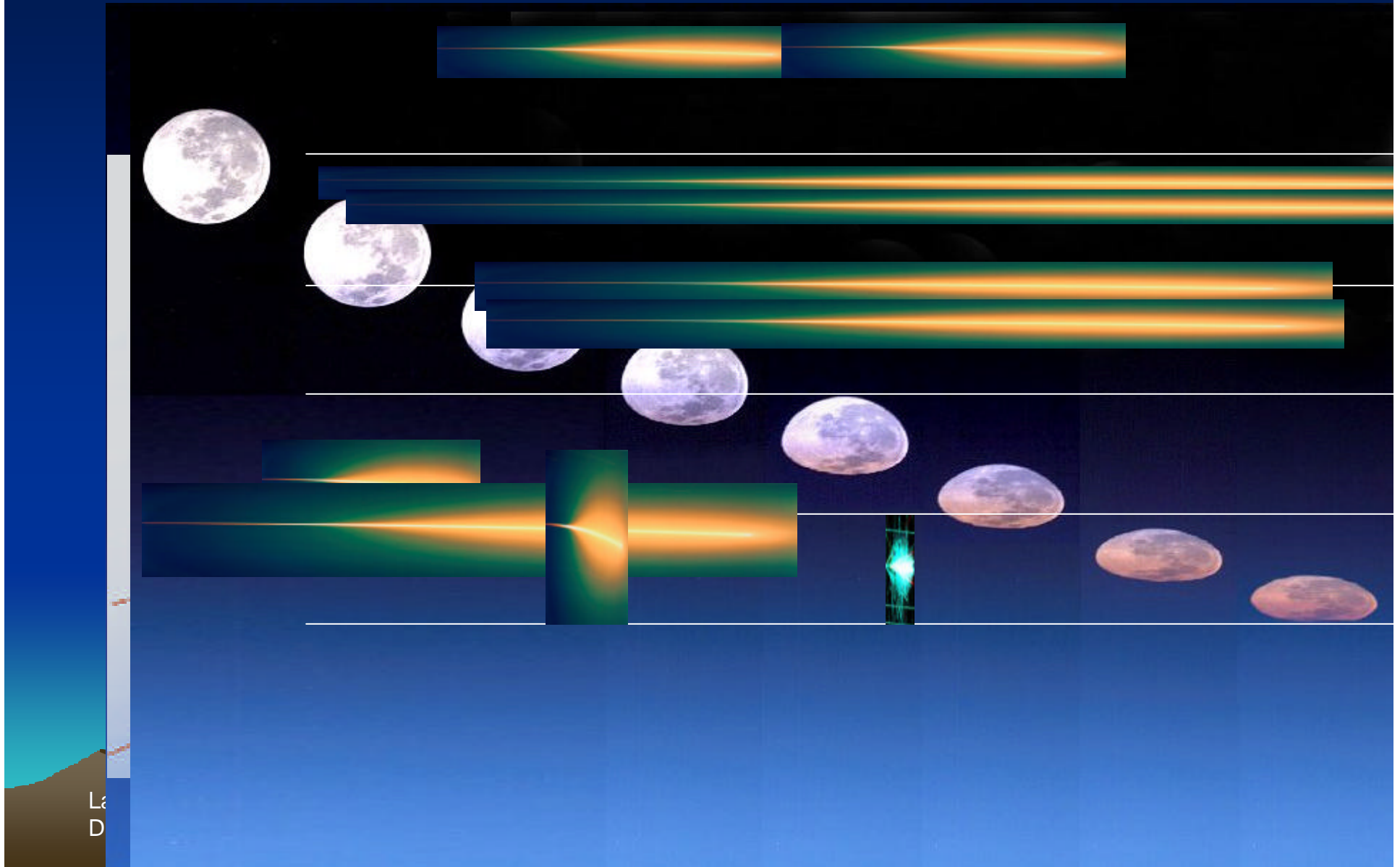
*Neutrino and UHECR Air-showers telescopes versus*

$n_t$

$t$

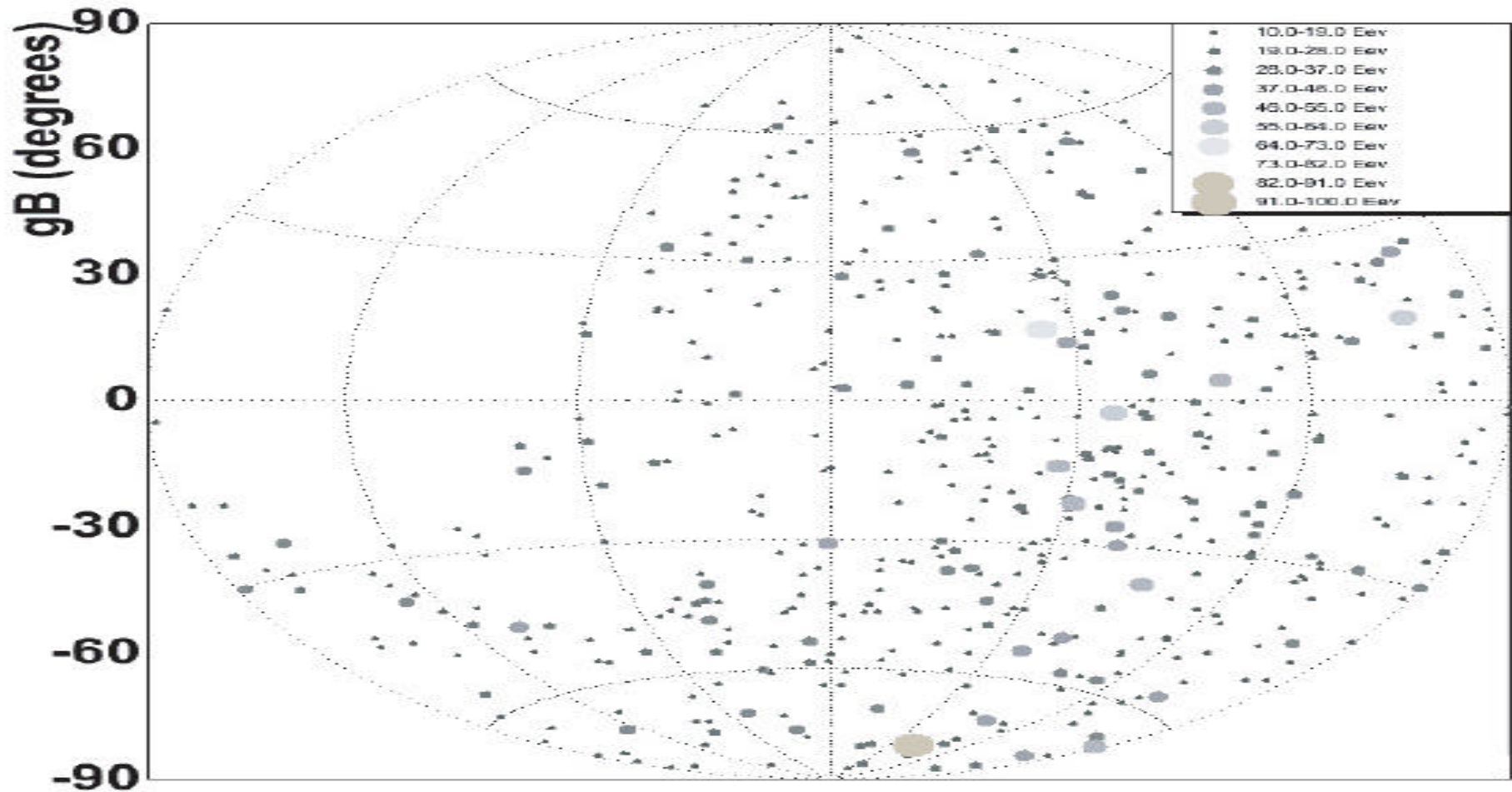
*Muon lepton tracks. Atmospheric  
Versus astrophysical signals:  
The vertical downward pollution  
versus the upward Earth opacity*

# Tuning to Air Showers by atmosphere filter at different angles and altitudes



# Why Neutrino astronomy? For New Universe Windows

Real Sky RunID 055

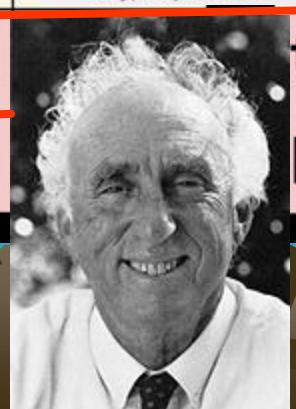
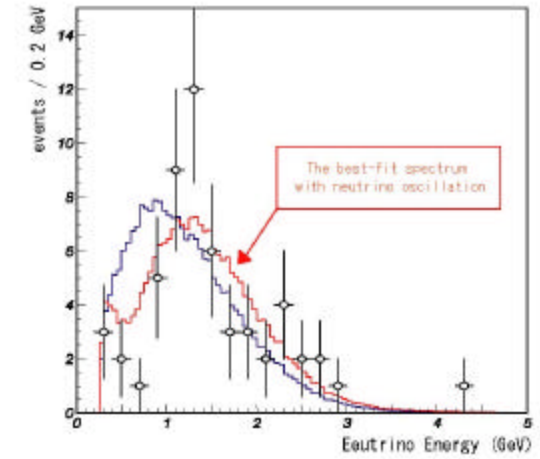
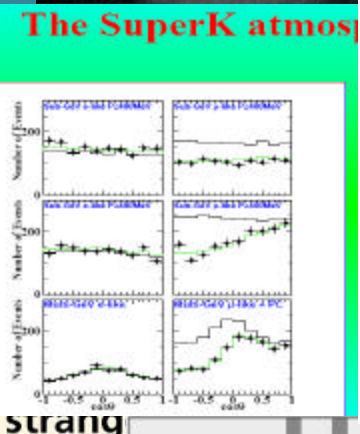
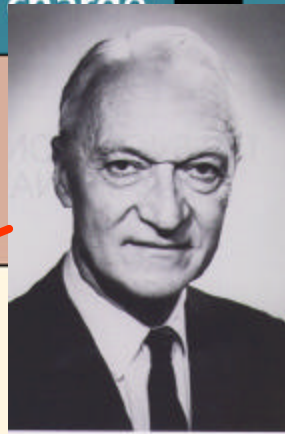


# 6 Neutrinos in search of an Author and an Astronomy

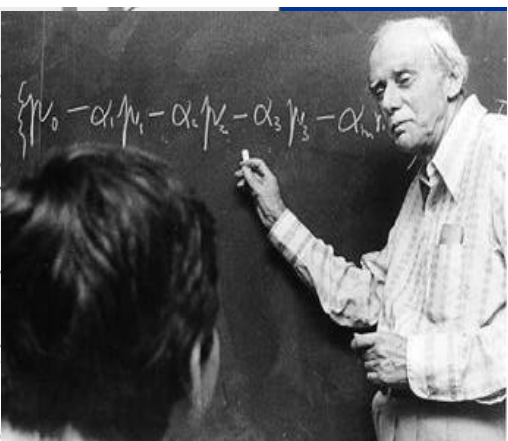
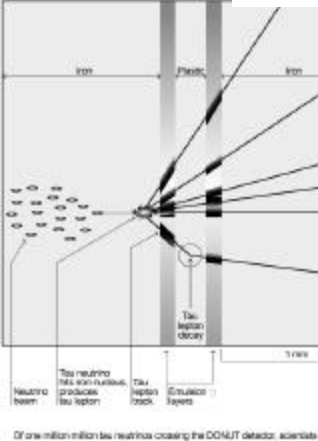


Flavor

- $\nu_e$  electron neutrino
- $\nu_\mu$  muon neutrino
- $\nu_\tau$  tau neutrino

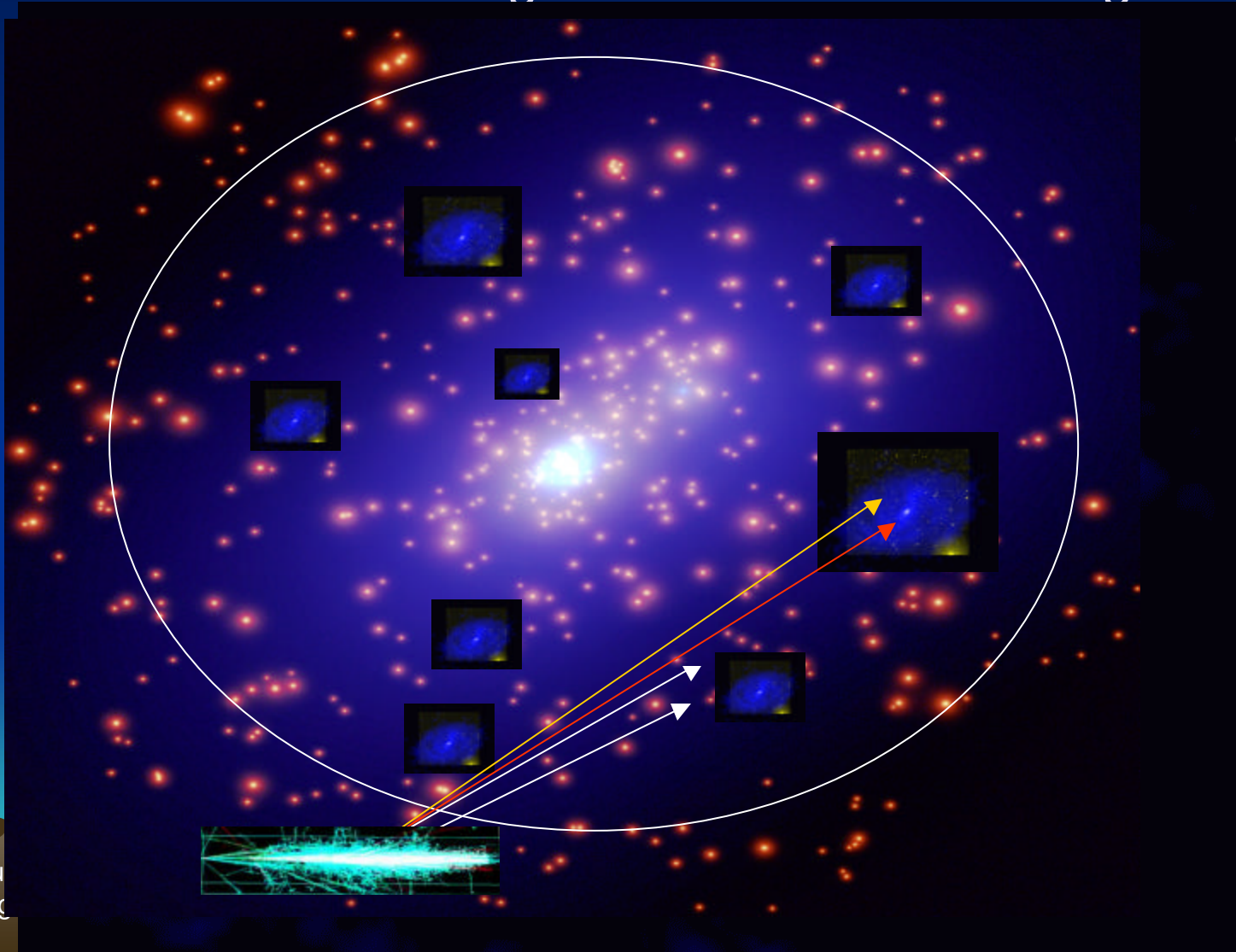


t top  
b bottom



LaThuile-07M  
D.Fargion@r

*Relic Neutrinos: a hot dark-matter candidate cloud target for  
UHE neutrinos: the Z-Burst Model  
like GZK cut off : Lighter neutrino mass-Larger Halos*



2°

October 1997

astro-  
ph/9710029

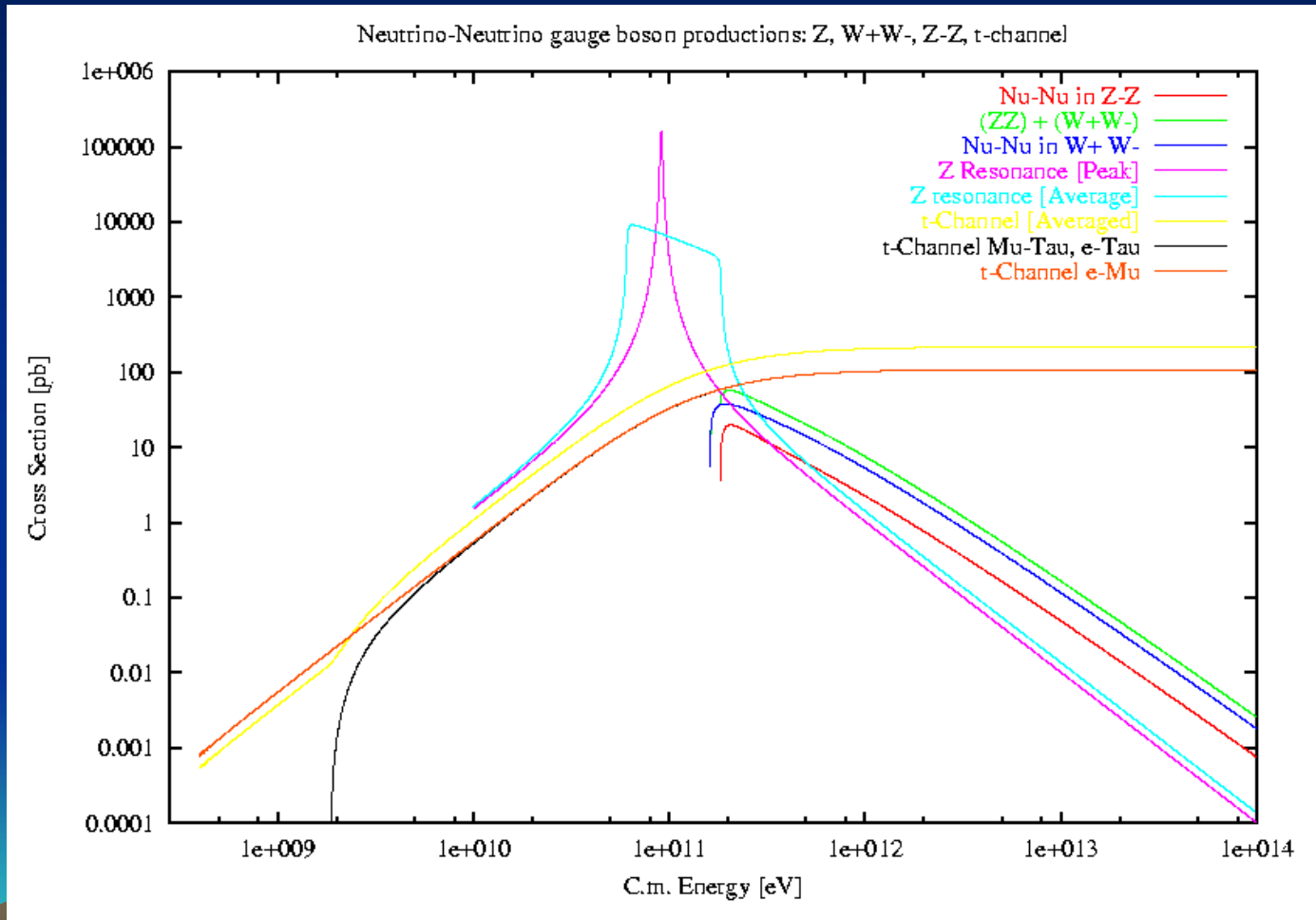
[D.Fargion,](#)  
[B.Mele,](#)  
[A.Salis](#)

Astrophys.J.  
517 (1999)  
725-733

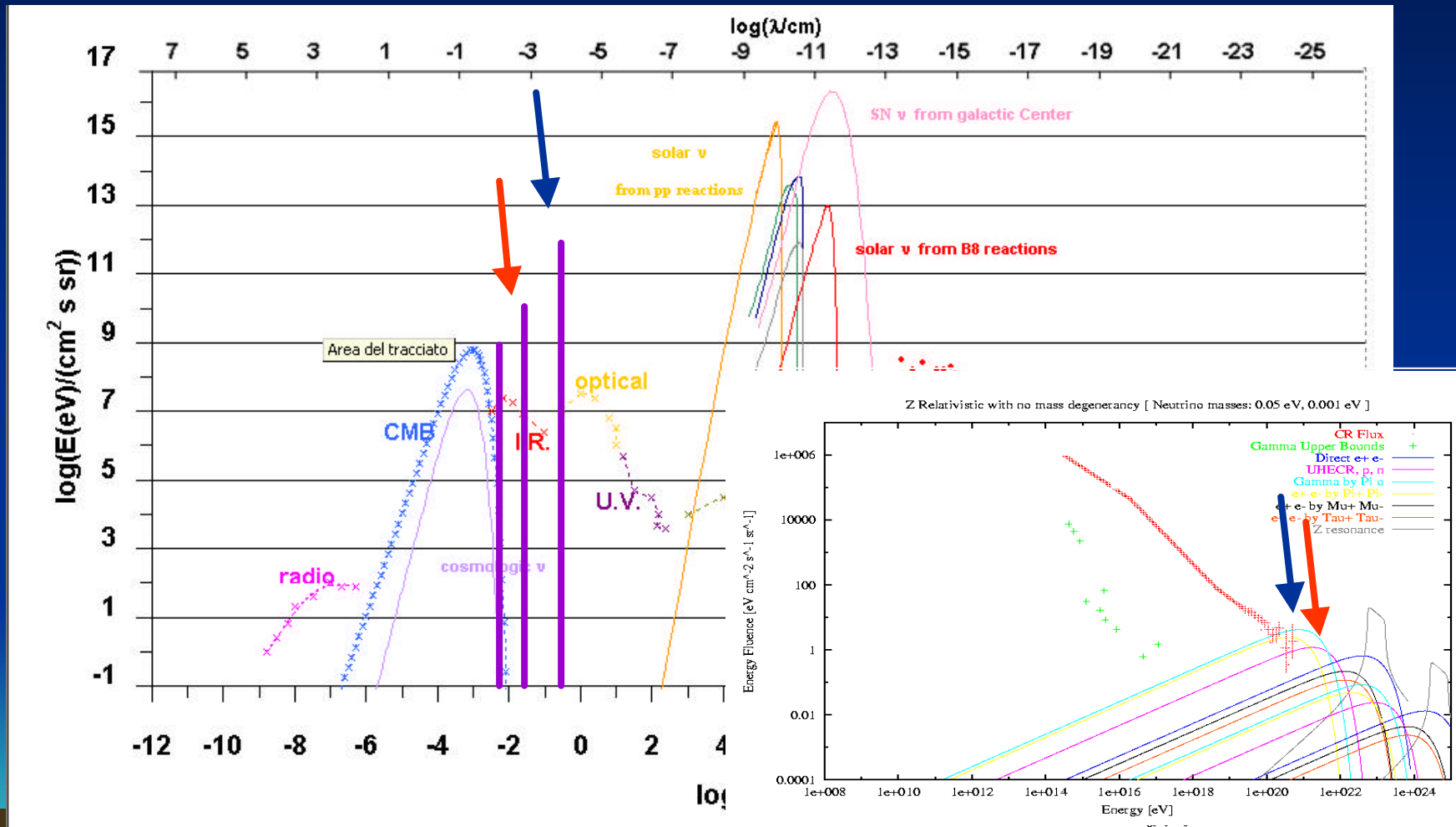
LaThu  
D.Farg



# Z-Burst by Z bosons in neutrino pair scattering



$(dN/(dA dE dt d\Omega) * E^2) : \text{Differential Flux Energy}$   
 For a minimal 0.05 eV mass one may foresee a bump of UHECR at ZeV



*Why Horizontal – Upward Tau Showering is so much linked to neutrino mass and mixing ?*

**Because mixing, even for minimal masses guarantee the flavour transformation from Muon Neutrinos to the Tau Neutrinos.**

**Galactic and cosmic distances are huge respect oscillation lengths.**

$$L_{\nu_{\mu}-\nu_{\tau}} = \boxed{8.3 \text{ pc}} \left( \frac{E_{\nu}}{10^{19} \text{ eV}} \right) \left( \frac{\Delta m_{ij}^2}{(10^{-2} \text{ eV})^2} \right)^{-1}$$

# *Why Horizontal – Upward Tau air-showers are easier to be revealed than muon tracks ?*

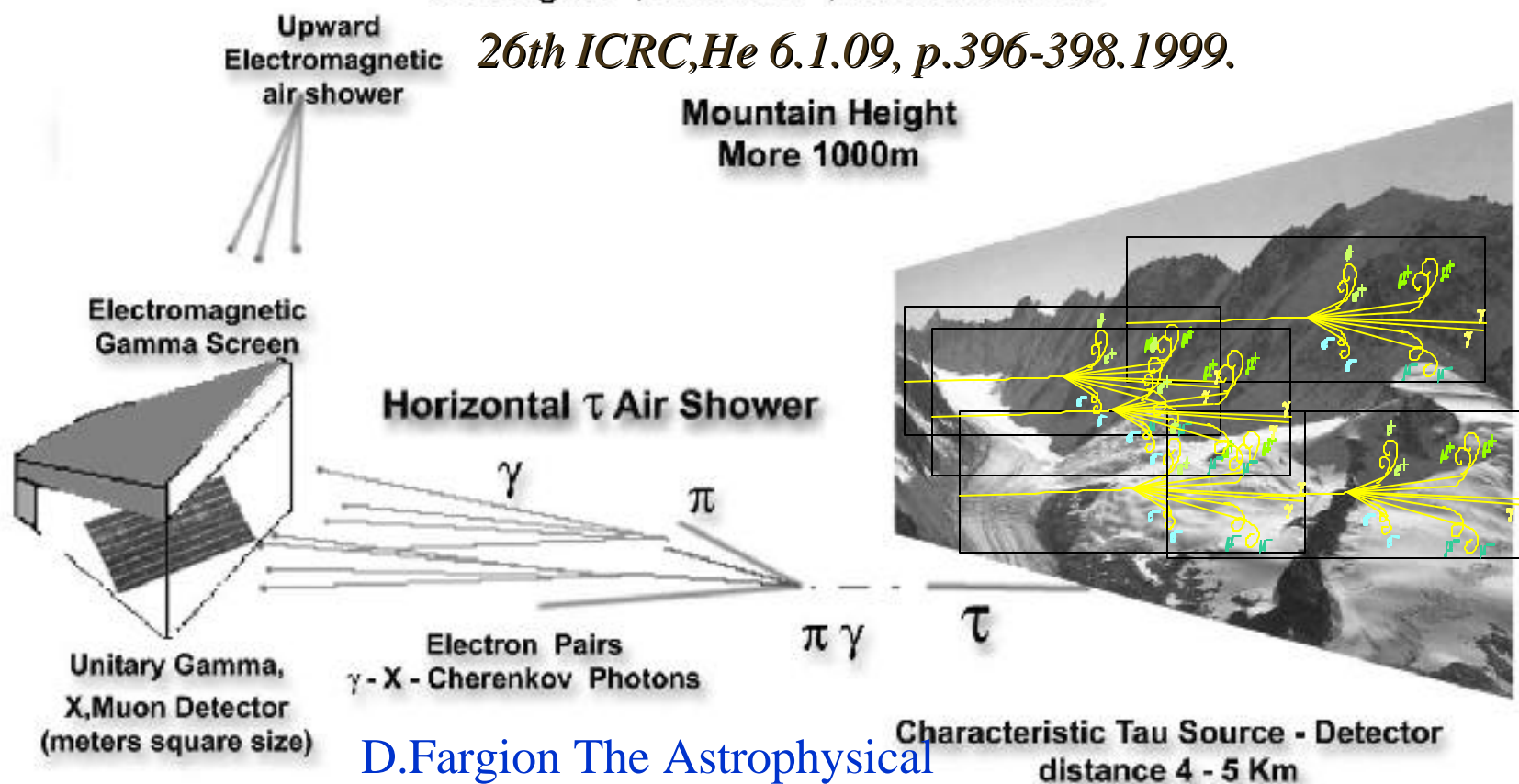
Because an air- shower is amplified  
By its huge secondary number.  
Millions muons, billions gamma and e-pairs  
trillions or more Cerenkov photons.

Muon is single, alone and shine little.

# Horizontal Tau air showers from mountains in deep valley: Traces of UHECR neutrino tau

D. Fargion<sup>1</sup>, A. Aiello<sup>2</sup>, R. Conversano

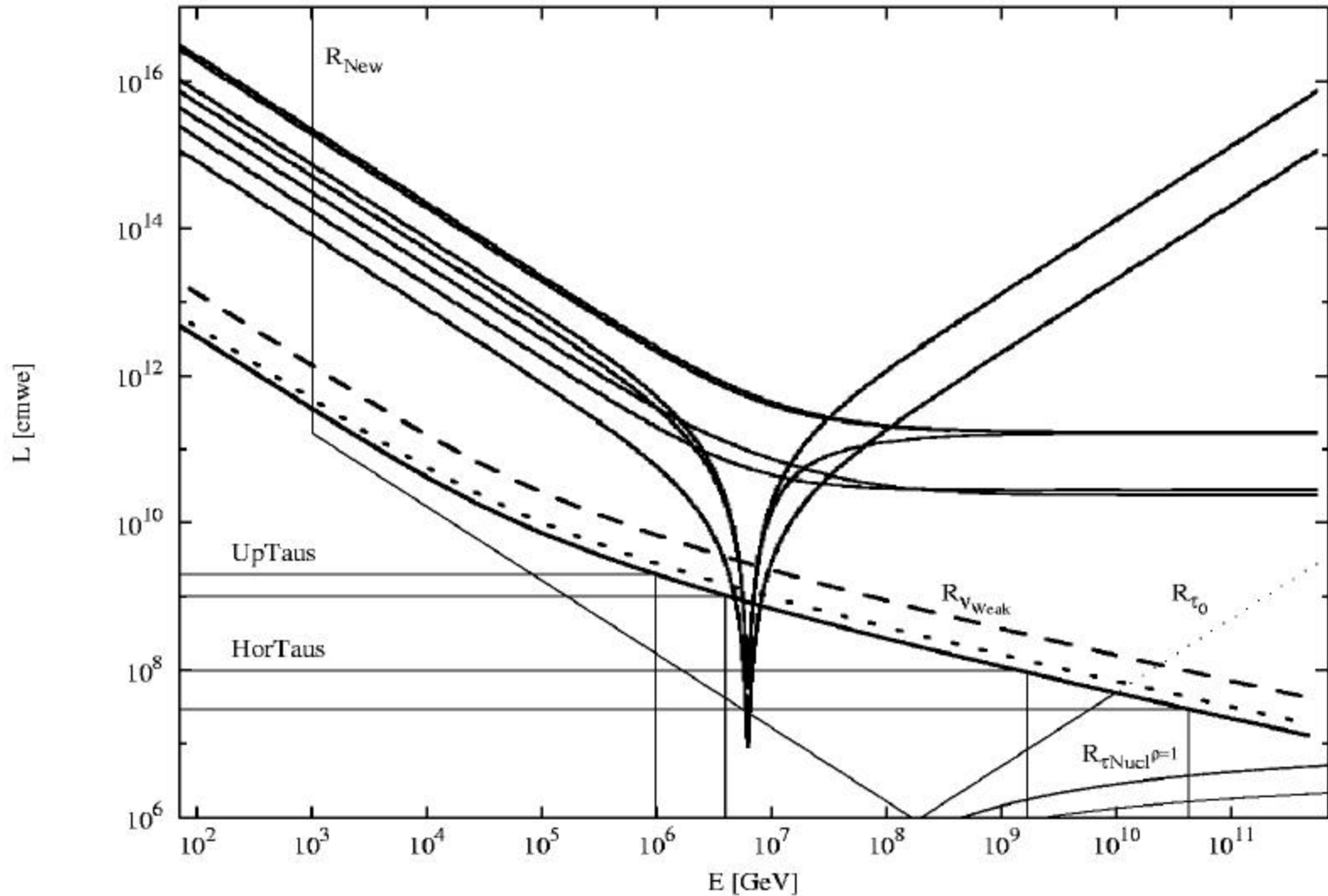
*26th ICRC, He 6.1.09, p.396-398.1999.*



D.Fargion The Astrophysical Journal, 570, p.909. 2002

D. Fargion, The role of tau neutrino... [astro-ph/9704205](https://arxiv.org/abs/astro-ph/9704205)  
ApJ 619, 1285-1301, 2004

*The Earth act as a beam dump  
and the atmosphere as a calorimeter  
to amplify the Tau Air-Shower*

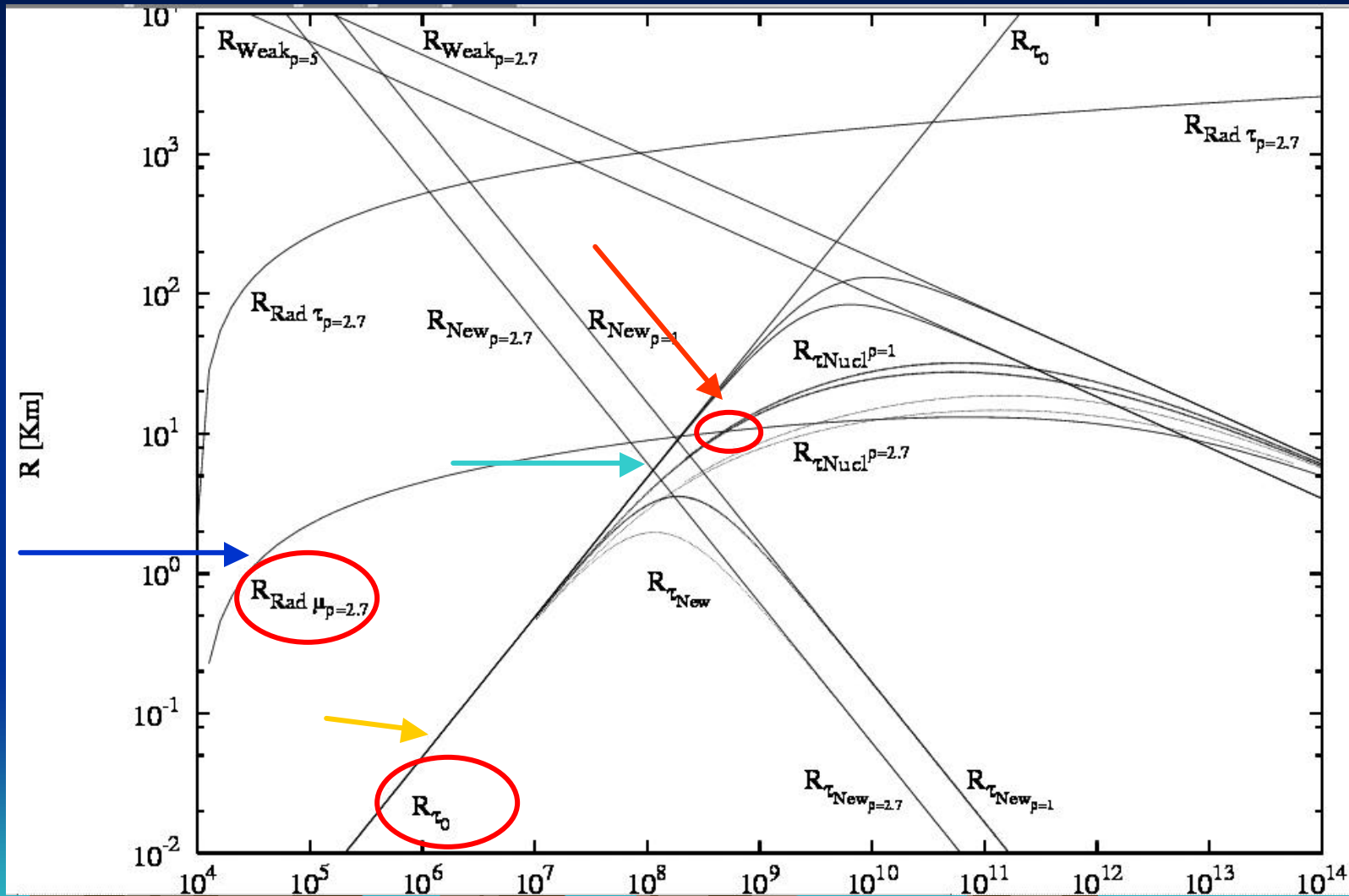


# Tau Air-Showers: Astronomy versus Elementary Particle Tau Channels Modes

TABLE 1  
TAU AIR SHOWER CHANNELS

Decay	Secondaries	Probability	Air-shower
$\tau \rightarrow \mu^- \bar{\nu}_\mu \nu_\tau$	$\mu^-$	$\sim 17.4\%$	Unobservable
$\tau \rightarrow e^- \bar{\nu}_e \nu_\tau$	$e^-$	$\sim 17.8\%$	1 Electromagnetic
$\tau \rightarrow \pi^- \nu_\tau$	$\pi^-$	$\sim 11.8\%$	1 Hadronic
$\tau \rightarrow \pi^- \pi^0 \nu_\tau$	$\pi^-, \pi^0 \rightarrow 2\gamma$	$\sim 25.8\%$	1 Hadronic, 2 Electromagnetic
$\tau \rightarrow \pi^- 2\pi^0 \nu_\tau$	$\pi^-, 2\pi^0 \rightarrow 4\gamma$	$\sim 10.79\%$	1 Hadronic, 4 Electromagnetic
$\tau \rightarrow \pi^- 3\pi^0 \nu_\tau$	$\pi^-, 3\pi^0 \rightarrow 6\gamma$	$\sim 1.23\%$	1 Hadronic, 6 Electromagnetic
$\tau \rightarrow \pi^- \pi^- \pi^+ \nu_\tau$	$2\pi^-, \pi^+$	$\sim 10\%$	3 Hadronic
$\tau \rightarrow \pi^- \pi^+ \pi^- \pi^0$	$2\pi^-, \pi^+, \pi^0 \rightarrow 2\gamma$	$\sim 5.18\%$	3 Hadronic, 2 Electromagnetic

# Why Highest Energy unstable Tau are more penetrating than H.E. muons?

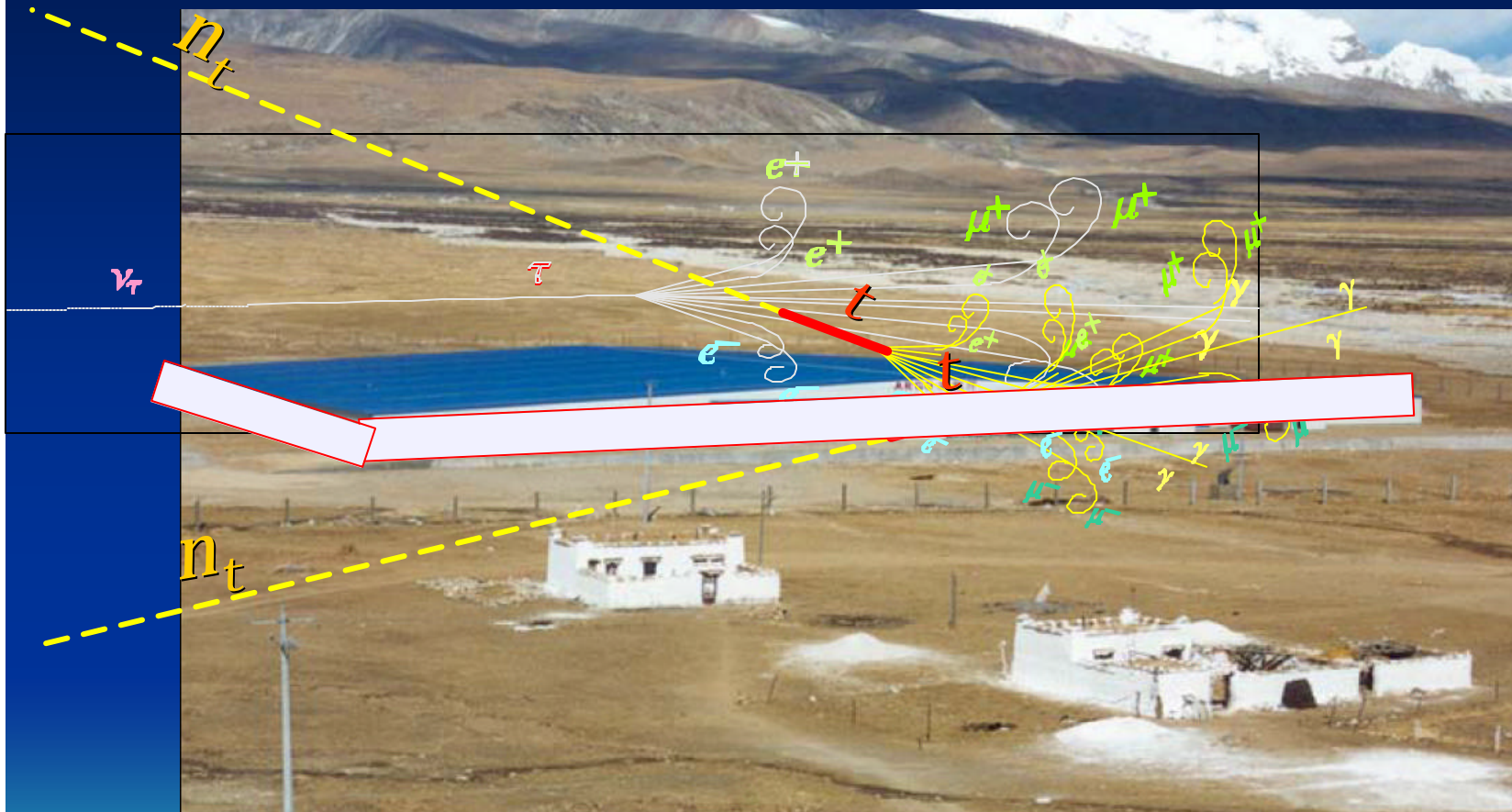




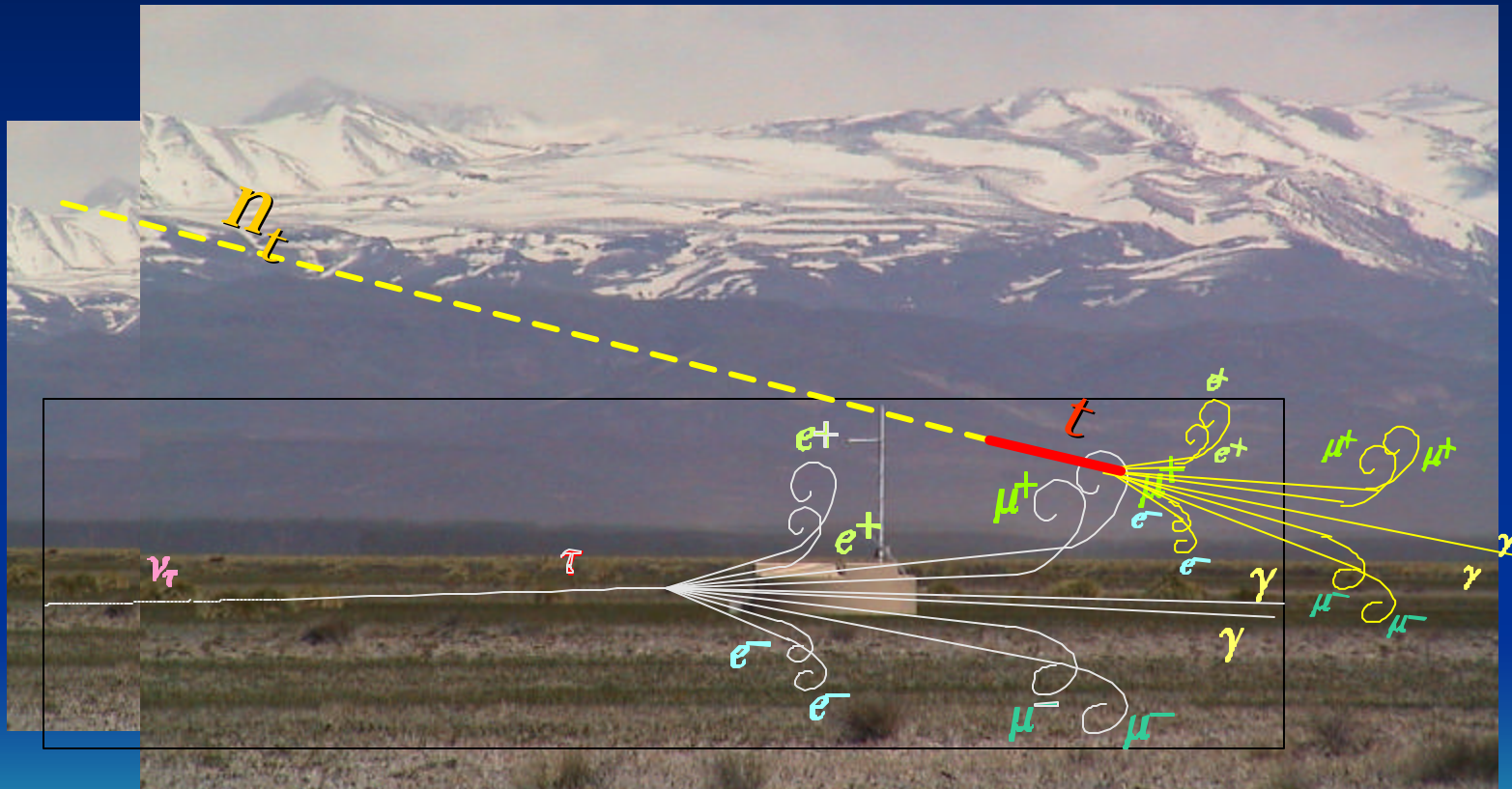
# Muons are old , Taus are young.

- More than 54 paper on Taus,600 references
- Feng,Wilzeck,Reno,Yoshida,Zas,Cao...
- Many on going experiment can or may test Taus:
- AUGER- MAGIC-EUSO-MILAGRO-ARGO-ASHRA-NEVOD-ICRUS-FLARE- SHALON and future CROWN ARRAYS

# Detectors extended in deep valley : ARGO-Tibet

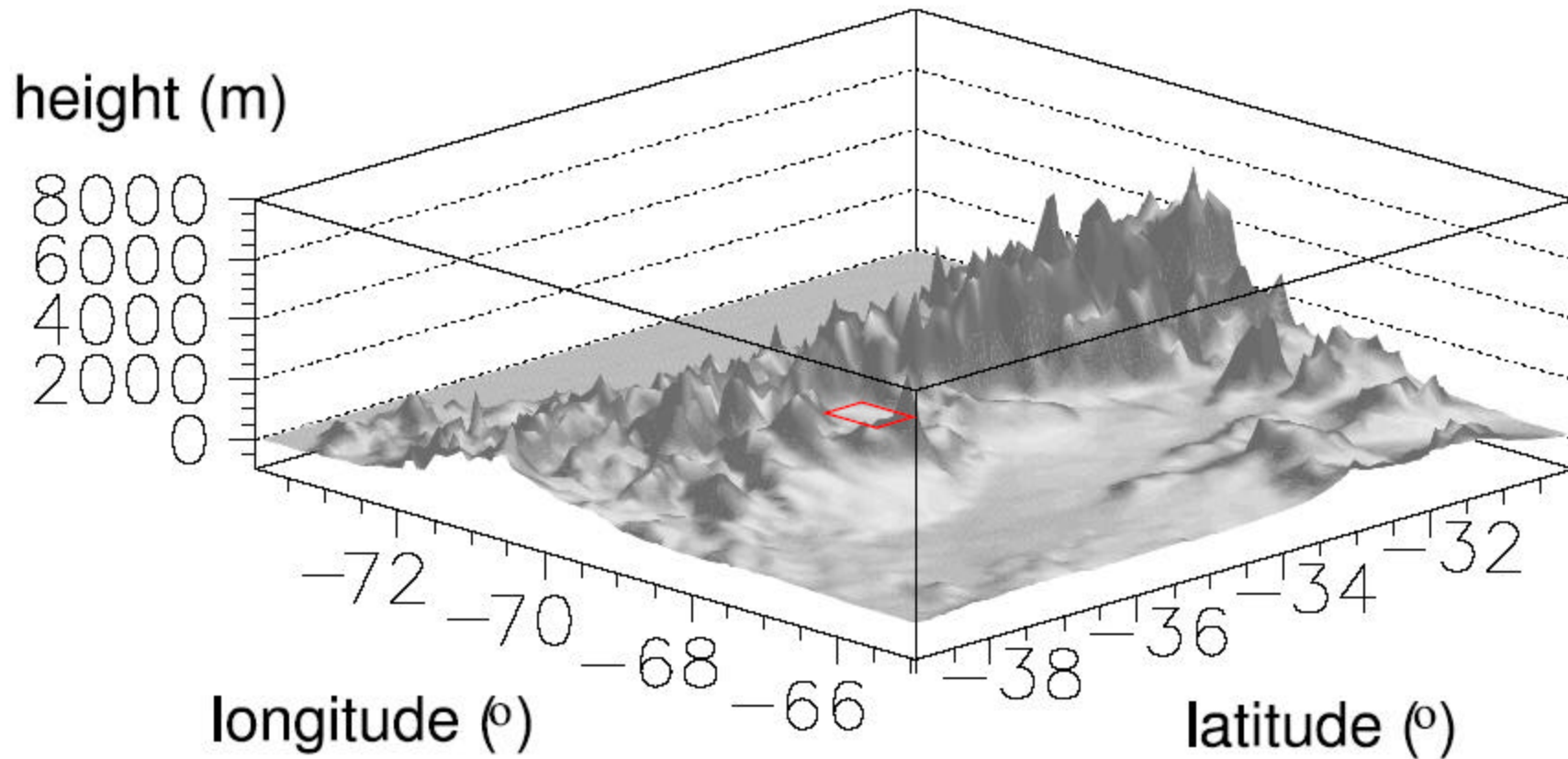


# The Ande Mountains as a target for detecting UHE neutrino tau by Horizontal Air-Showers at AUGER: ANDE SHADOWS on GZK Cosmic Rays from West and Young Horizontal Tau Air-Showers at EeVs



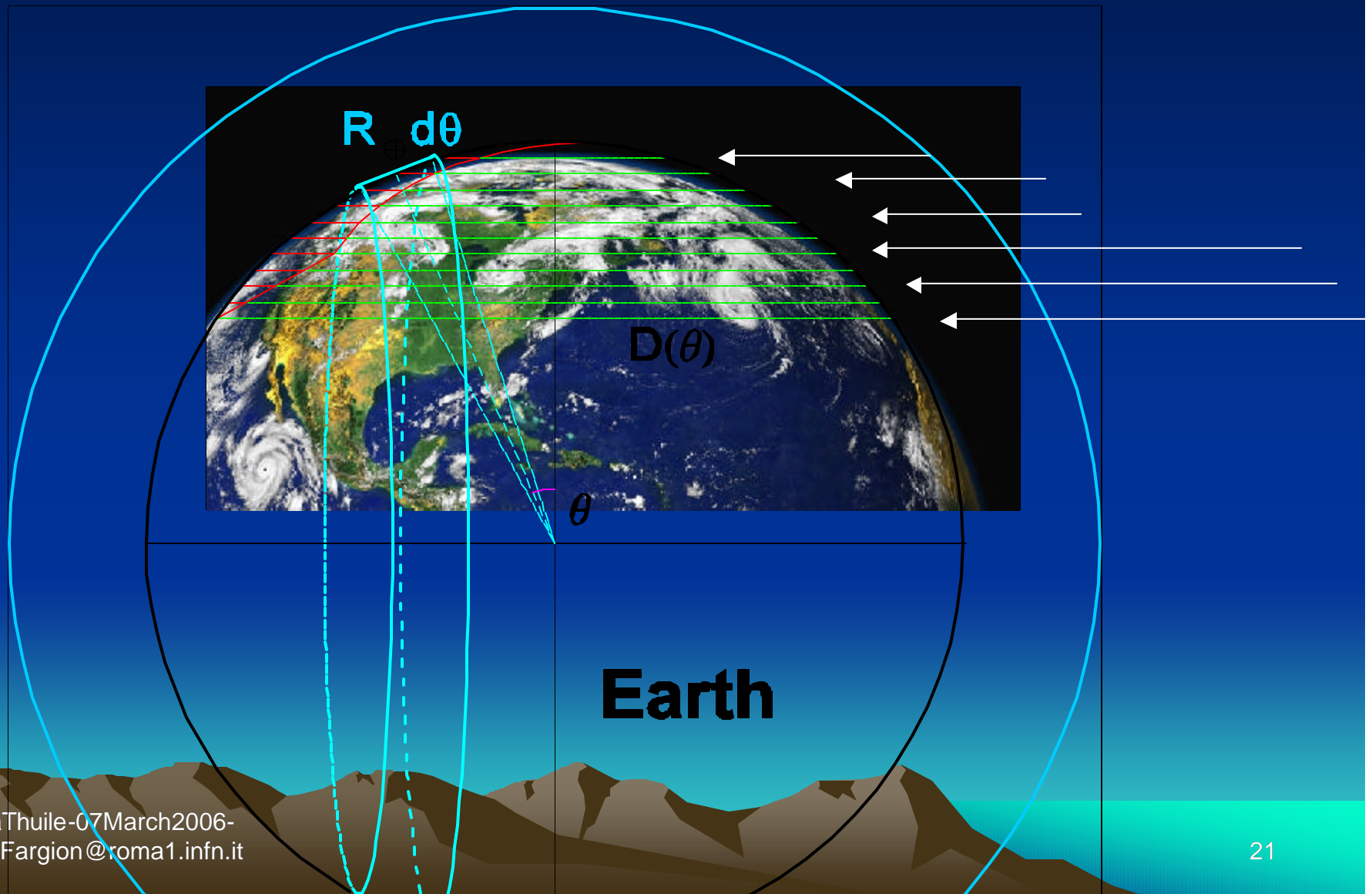
D.Fargion The Astrophysical Journal,570,p.909. 2002

# The Ande Shadows on AUGER

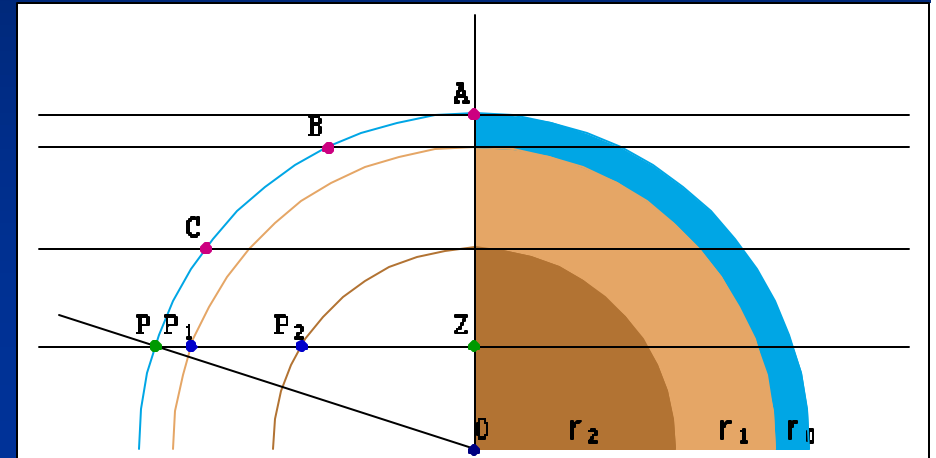
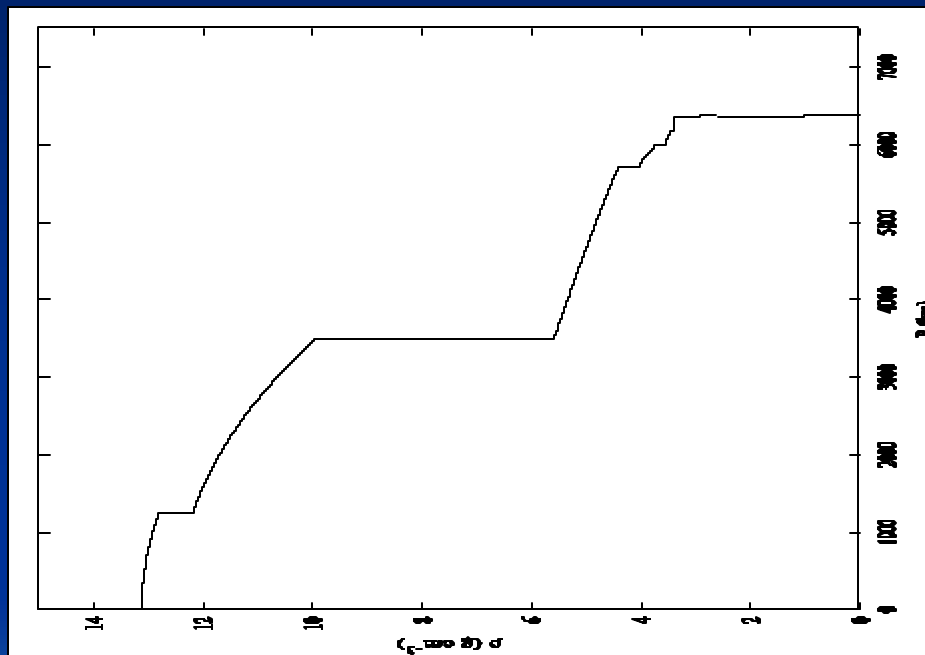


Pastor et. Al 2005

# Effective Volume Areas for Uptaus



# Earth Opacity by Inner Earth Density Structures



[astro-ph/0501033](https://arxiv.org/abs/astro-ph/0501033)

[astro-ph/0409460](https://arxiv.org/abs/astro-ph/0409460)

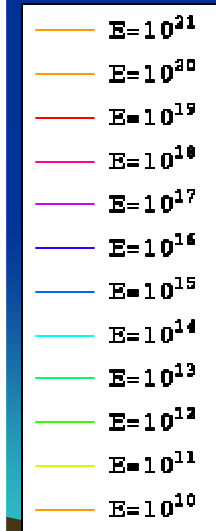
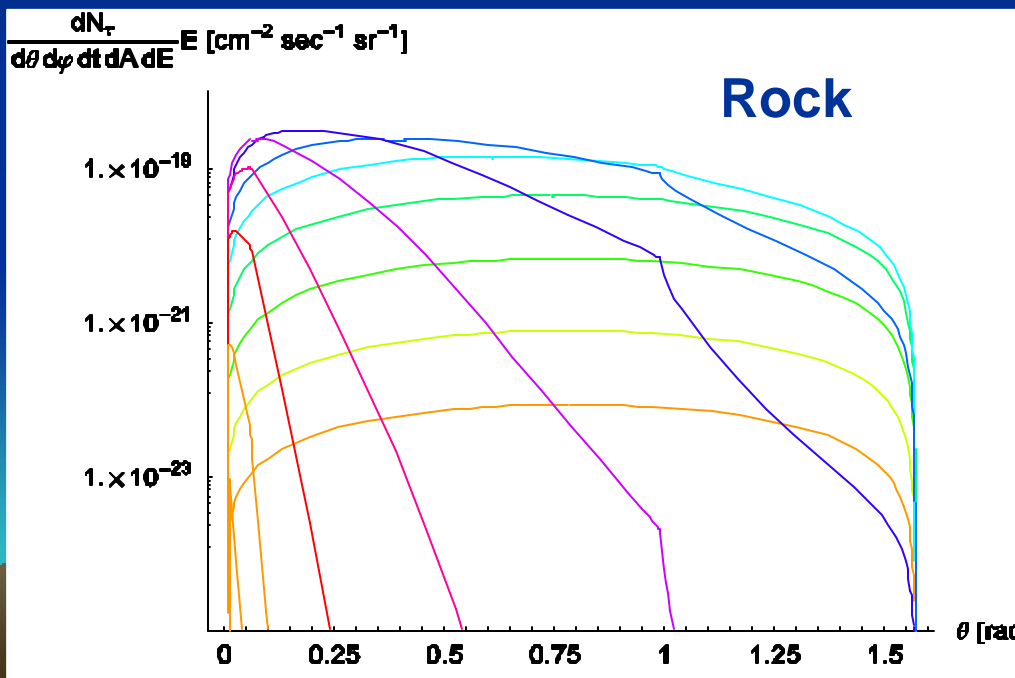
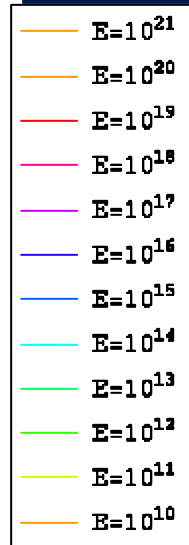
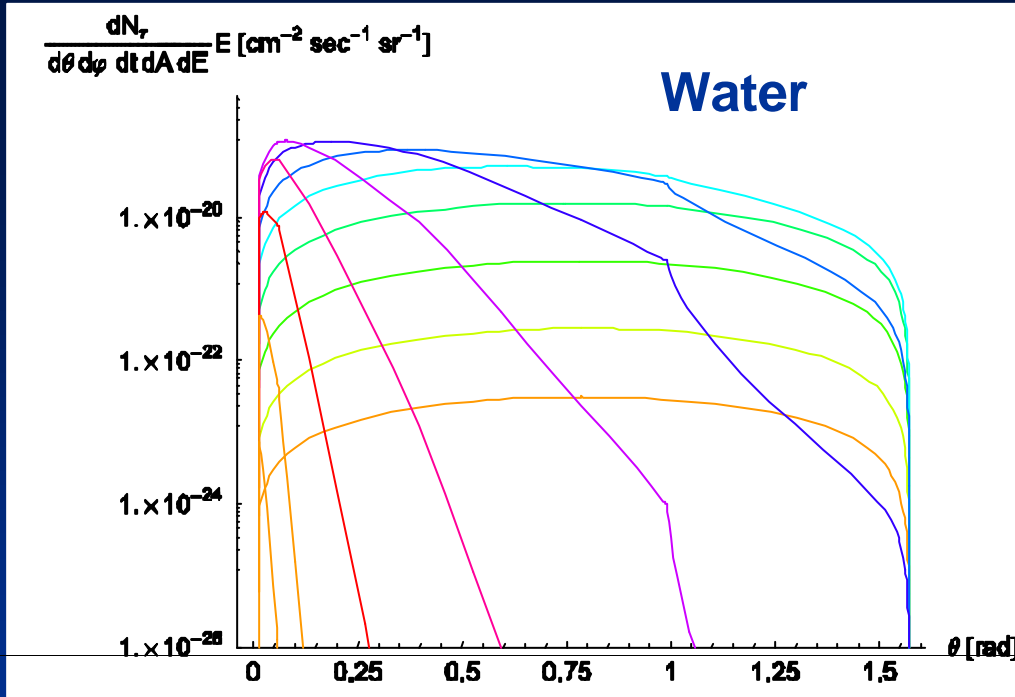
[Nucleare Phys B](#)

[D.Fargion, M.Grossi,](#)

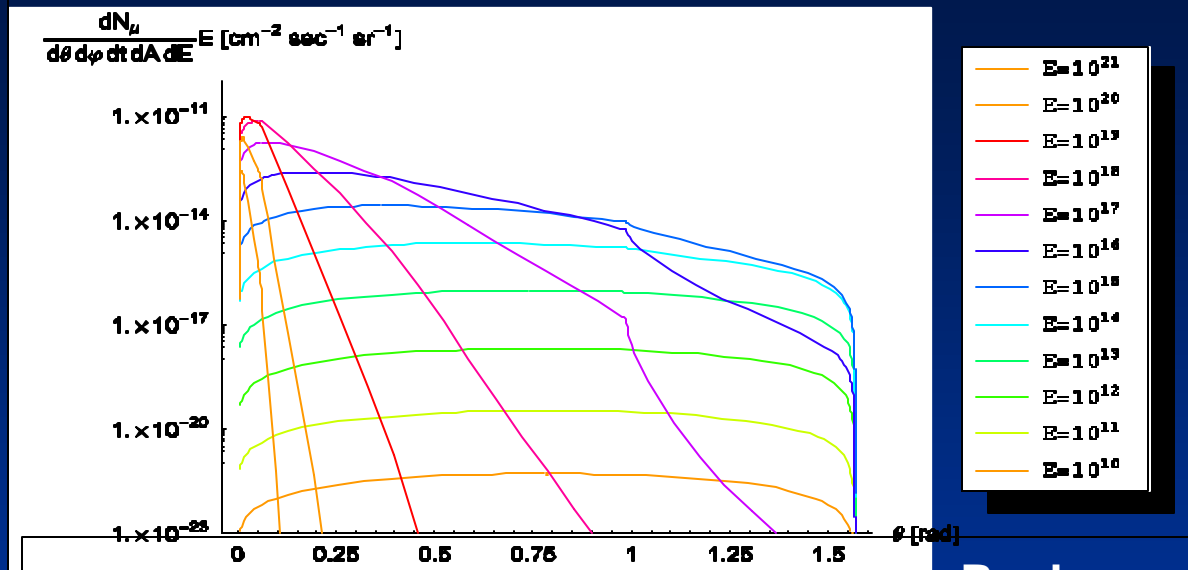
[M.De Santis,](#)

[P.G. de Sanctis Lucentin](#)

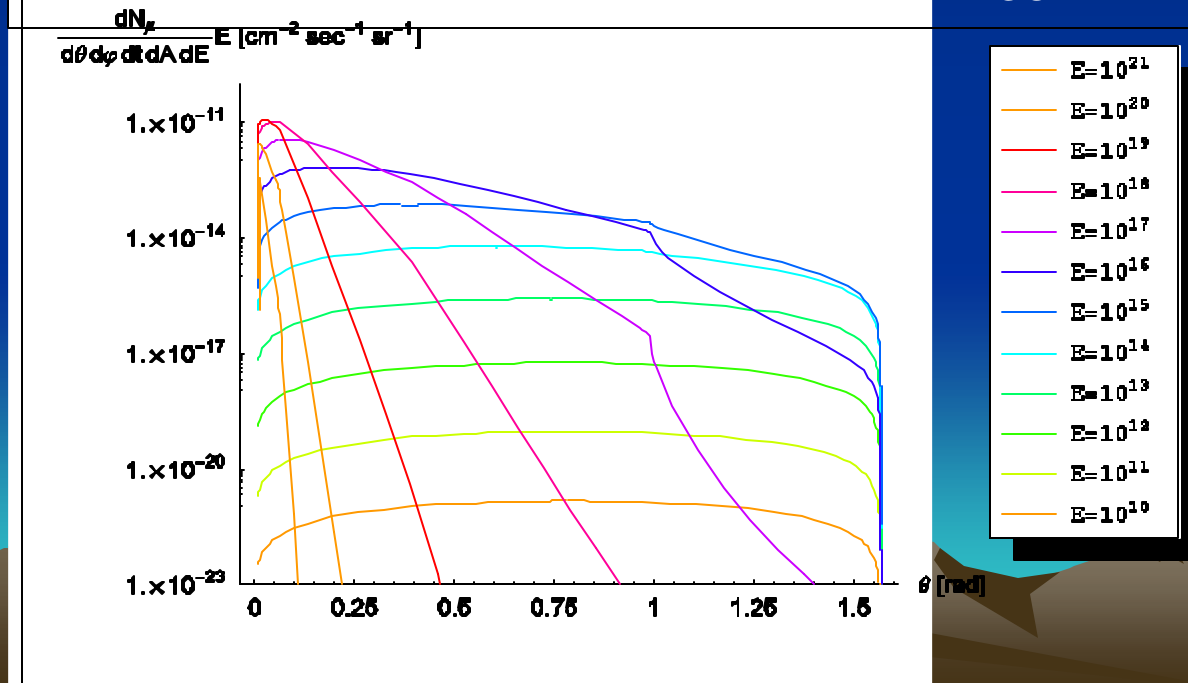
Expected Tau  
events at  
different angles.  
GZK input  
neutrino flux



## Water



## Rock



[astro-ph/0501033](#)

[astro-ph/0409460](#)

**Nucleare Phys B**

**[D.Fargion](#), [M.Grossi](#),**

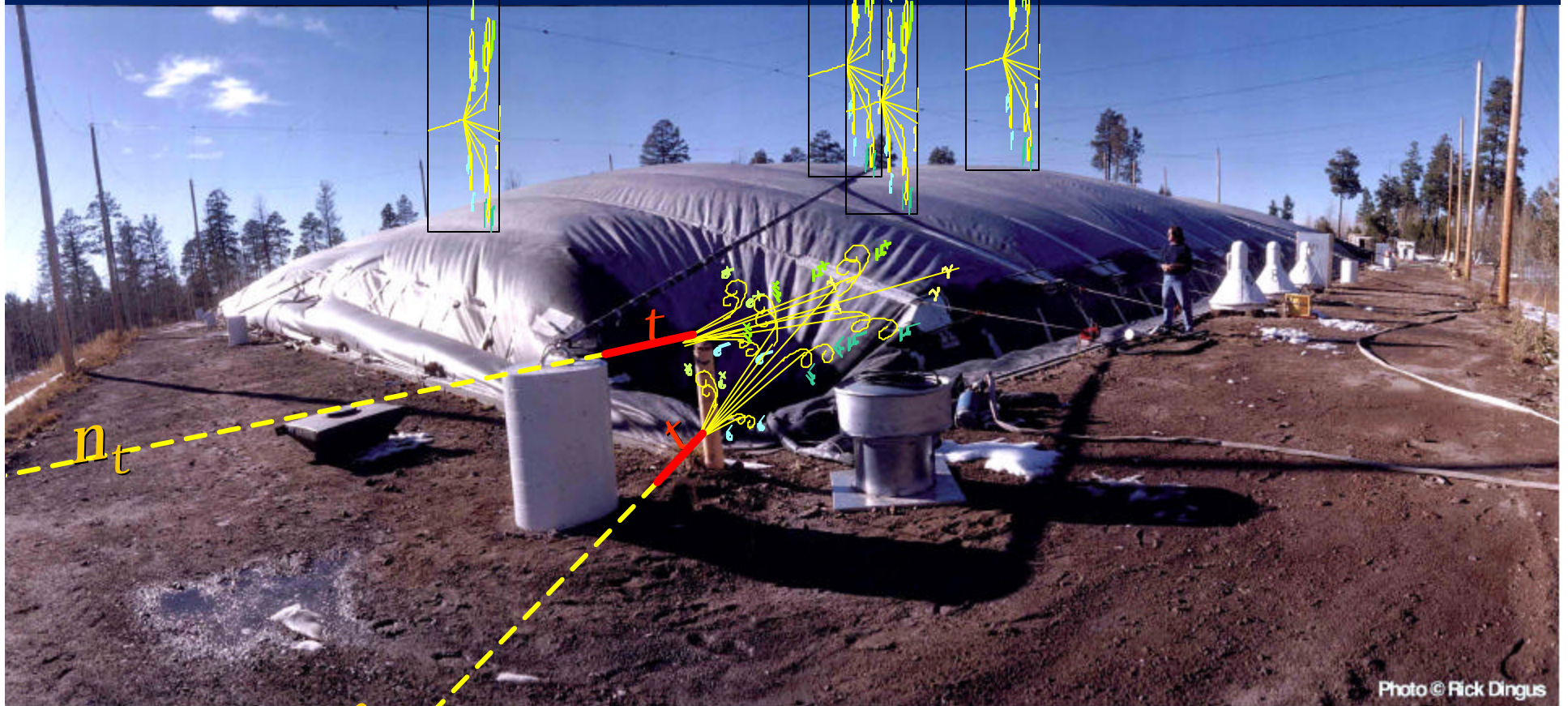
**[M.De Santis](#),**

**[P.G. de Sanctis Lucentin](#)**

**Expected  $\mu^\pm$   
events by  
Tau Air  
Showers  
(Hortaus)  
GZK input  
neutrino flux.**

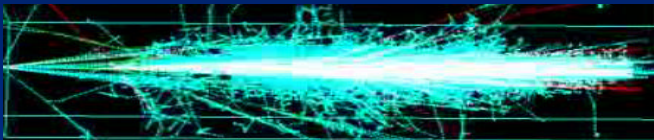


# Milagro: TeV gamma on vertical and Muon bundle by tau on horizons



# Jungfrauoch , the top of Europe

## A crown array around



M.Iori,A.Sergi,D.Fargion  
Astro-ph 0602108, 2006

LaThuile 07March2006-  
D.Fargion@roma1.infn.it

# SOFIA airplane Infrared Lab. searching for Cherenkov flashes at Earth edges

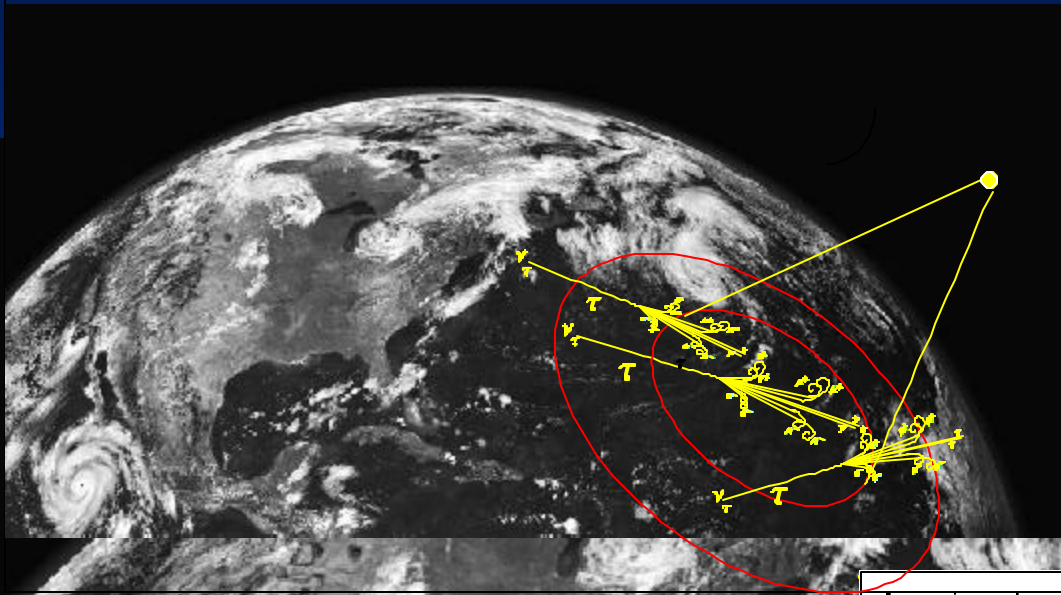


# Where to go to look at best for Upward Tau Air-Showers ?



LaThuile-07March2  
D.Fargion@roma1.

# The EUSO telescope seeing Hortaus in wide FOV: tens of events in three years



The Effective Air Mass  
obtained for the EUSO  
telescope:  $1000 \text{ km}^3$

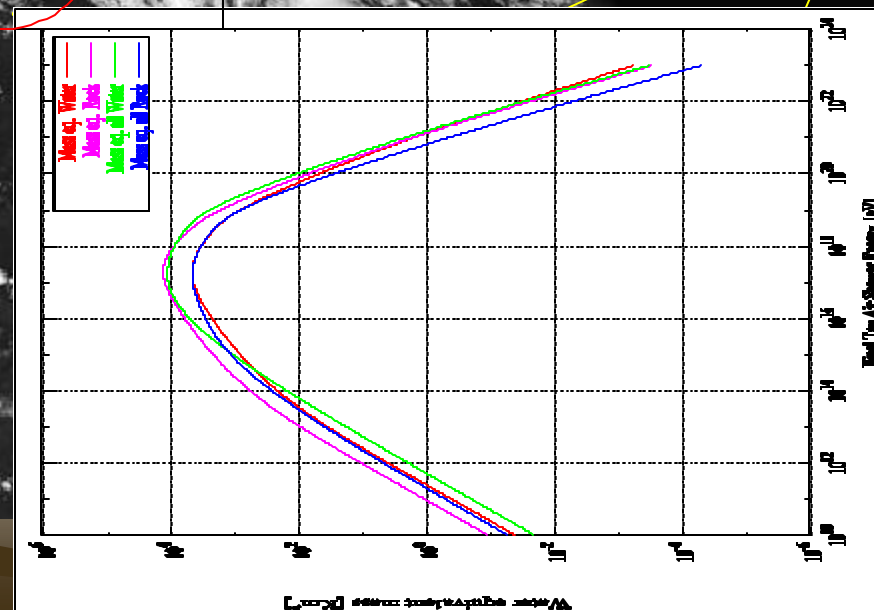
ApJ 613, 1285-1301, 2004

D. Fargion, P. De Sanctis  
Lucentini, M. De Santis, M.

Grossi ; [hep-ph/0305128](https://arxiv.org/abs/hep-ph/0305128)

La Misure 07 March 2000

D.Fargion@roma1.infn.it



# Array detectors in Space Station to track Horizontal Air-Showers



LaThuile-07March2006-Arrays in Space to detect Upward Tau and Highest Altitude Showers

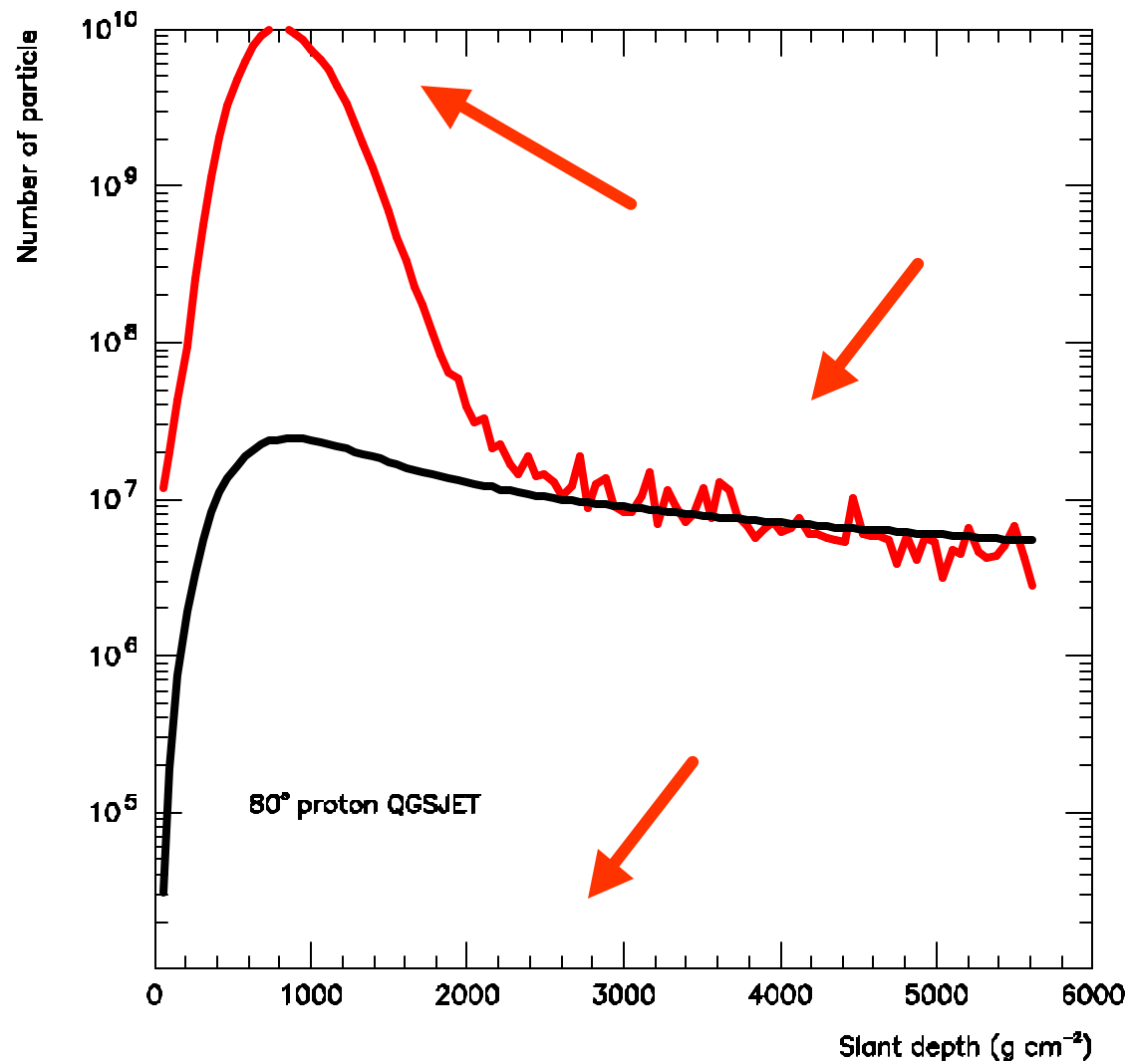
D.Fargion@roma1.infn.it

[D. Fargion](#)

27th ICRC 2001, HE1.8, Vol-2, Germany, Pag. 903-906, 2001

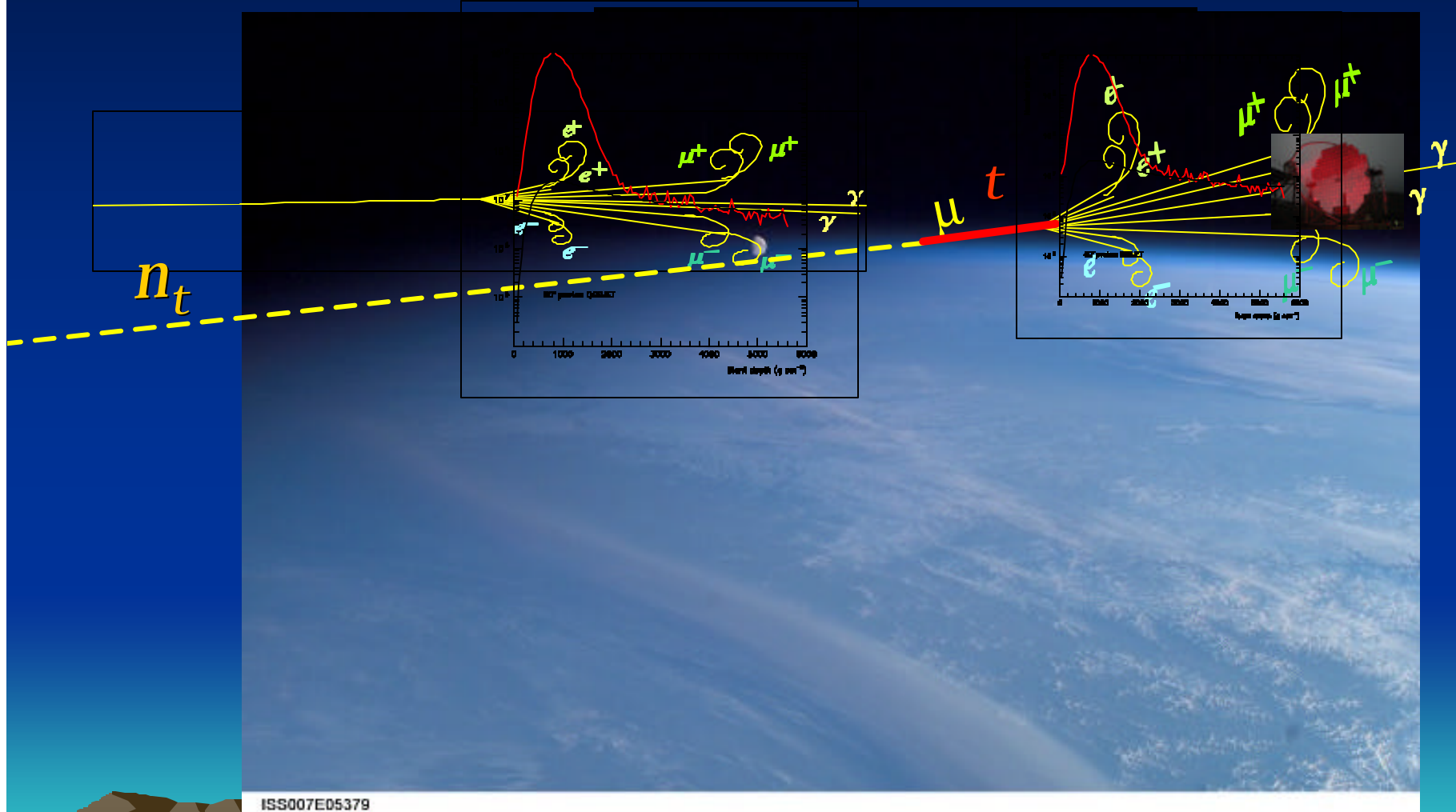
30

# Electro-magnetic Shower profile



*Cillis et al.2001*

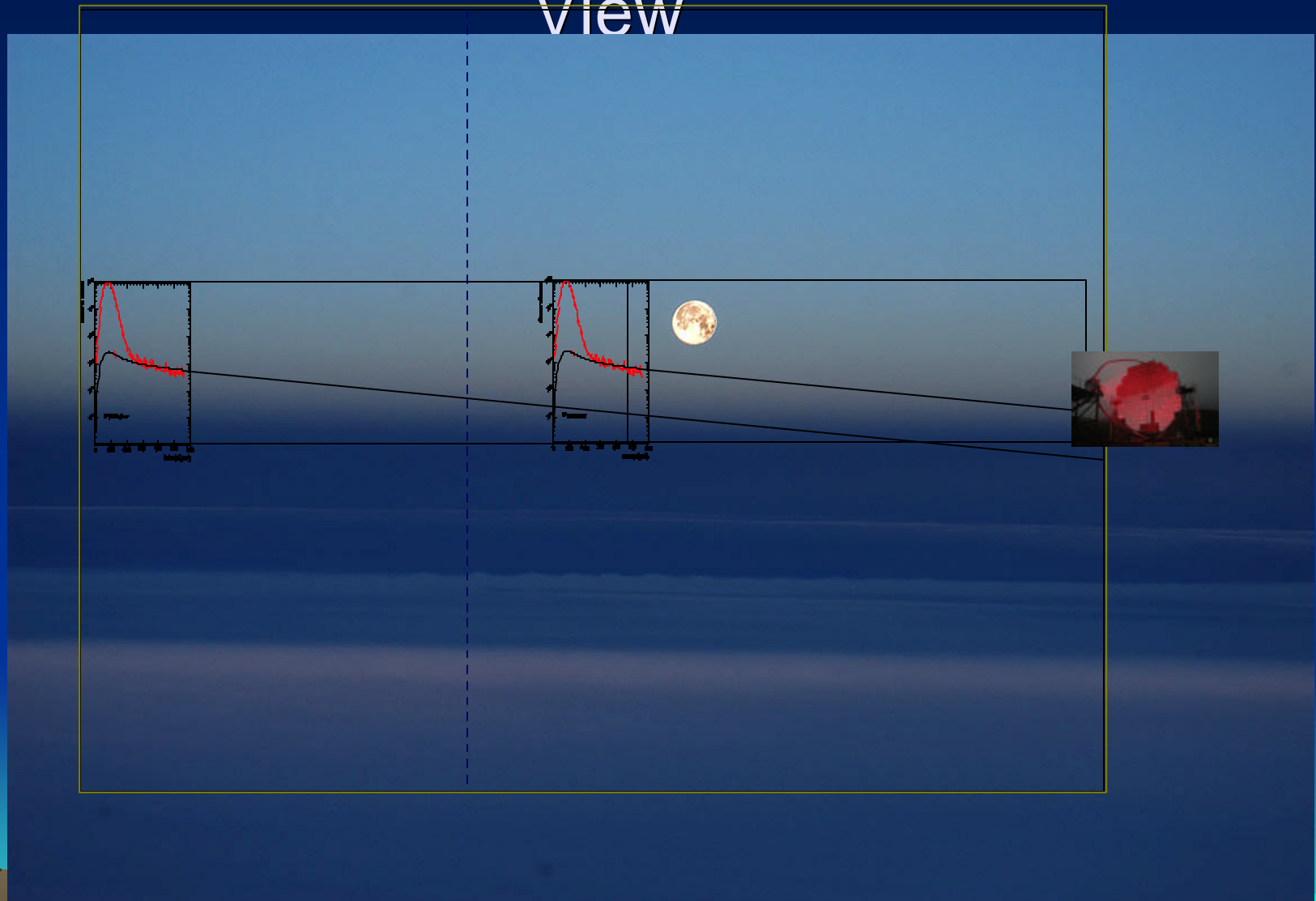
# Where and how to see Horizontal Air-Showers



ISS007E05379



# Old and Young Showers Imprint in a Magic View

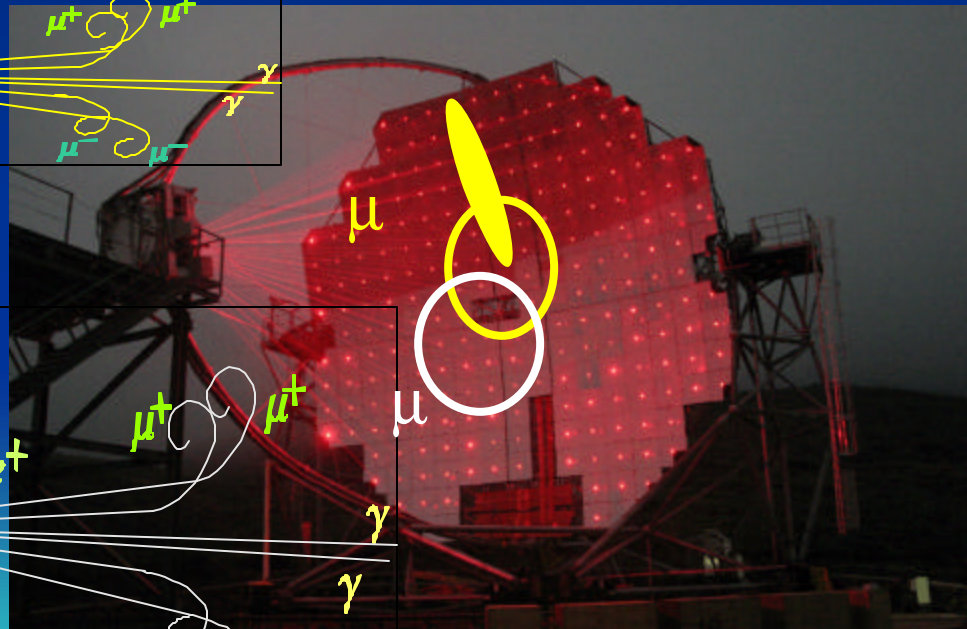
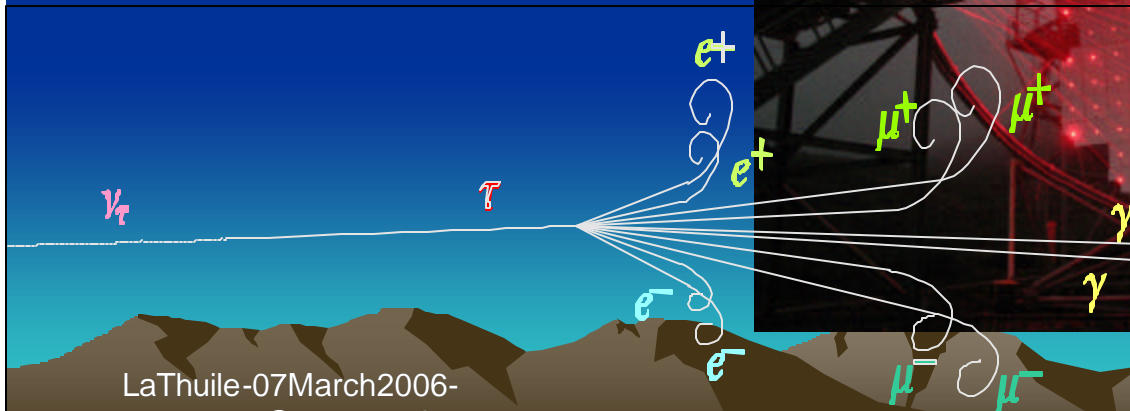
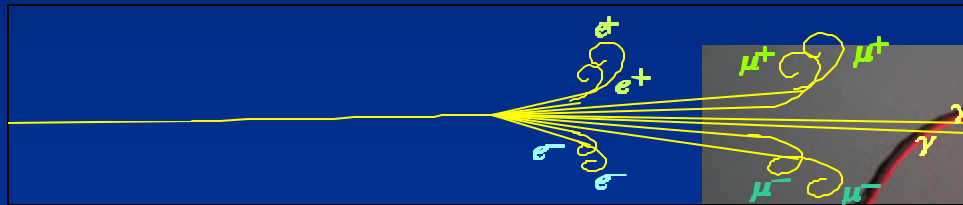
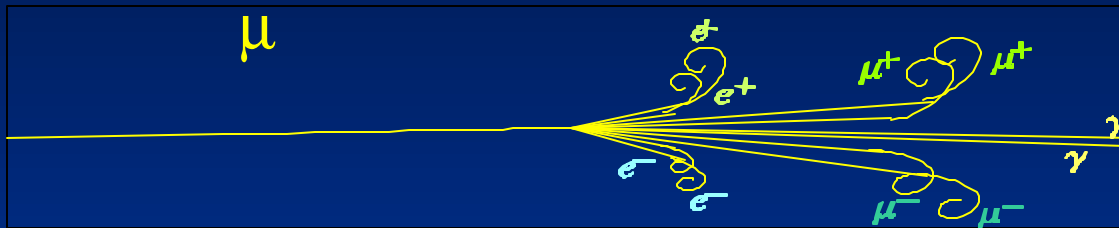


# What is Magic ?

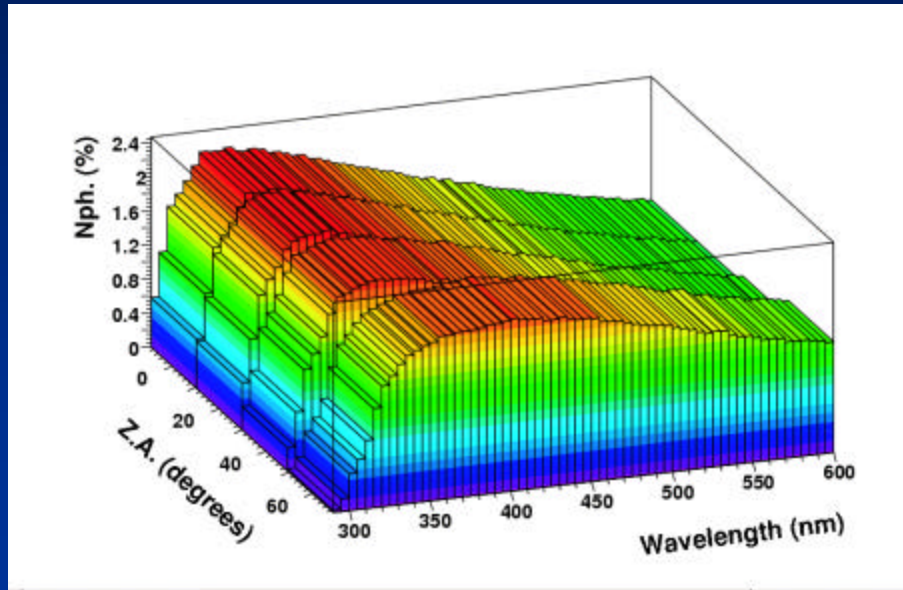


La Mole di Roma 2000  
D.Fargion@roma1.infn.it

Showering Up - Down on MAGIC Horizons :  
Cosmic Rays at PeVs –EeVs energy versus  
Glashow Resonant 6.3 Pevs and Tau EeVs Air-Showers  
Muon' s Rings and Arcs, Gamma Lateral Traces:  
Fan -like Horizontal Shower



# Cerenkov Color Filtering: A test of the Column Depth



Cerenkov Parental Showering Timing versus  
Muon and-or Gamma mini-flashes : Additional meter  
on column depth

MAGIC , while pointing a GRB or a SGR Burst at Horizons (~ 3% of the GRB-SGRs events ) behave as a km<sup>3</sup> NEUTRINO TELESCOPE

Horizons distance d= 167 km v(h/2.2 km)  
Cerenkov Shower opening angle  $\theta \sim 1^\circ$

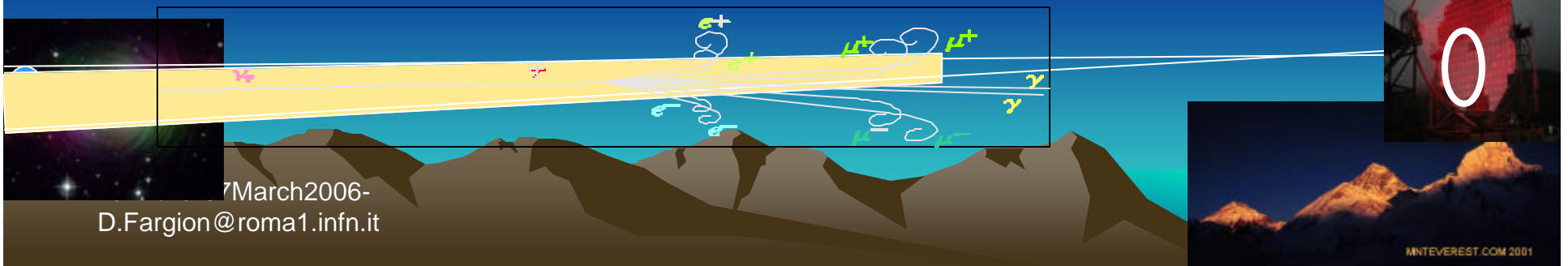
Conic Air Base Area  $A \sim 30 \text{ km}^2$

Truncate Air Cone height h ~ 100 km

Truncate Air Cone Volume V ~ 1000 km<sup>3</sup>

Truncate Cone Mass M ~ 1 km<sup>3</sup>

astro-ph/0505459  
Neutrino Astronomy beyond  
and beneath the Horizons  
: [D. Fargion](#)



MAGIC, while pointing a GRB, SGR or BL Lac  
Below The Horizons (~ 1% of the GRB-SGRs  
events) on rock behave (near EeV ■ ◆  
energy) as a 75 km<sup>3</sup> NEUTRINO TELESCOPE

astro-ph/0511597  
[D. Fargion](#)

Horizons distance  $d = 167 \text{ km}$   $v(h/2.2 \text{ km})$  Cerenkov  
 Shower opening angle  $\sim 0.3^\circ$

Inclined Conic Rock Base Area  $A \sim 3 \cdot 50 = 150 \text{ km}^2$

Inclined Rock Cilinder depth  $L$  ◆  $\sim 10 \text{ km}$

Rock Cilinder depth  $l$   $\sim 0.5 \text{ km w.e.}$

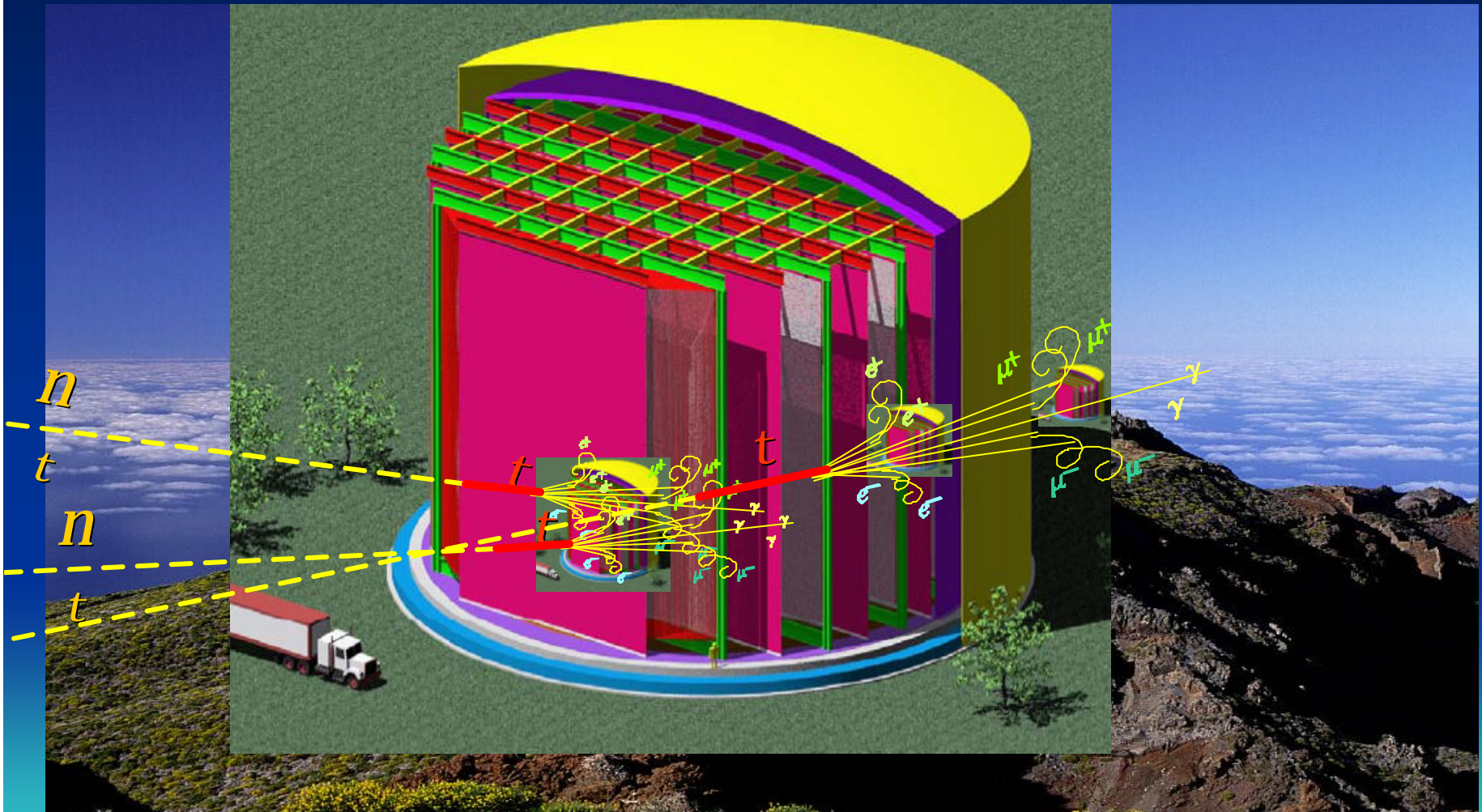
$l = 0.5 \text{ km w.e.}$   $L$  ◆ ■ □ km w.e.



# An Array of Magic Crown Arrays on the top



We also propose today: NEVOD, ICARUS, **FLARE** or UNO  
in crown arrays on peak mountains tracing Upward  
Horizontal AirShowers





# Neutrino and Showering in A

$$\bar{n}_e + e^- \longrightarrow W^- \longrightarrow l + \bar{\nu}_l$$

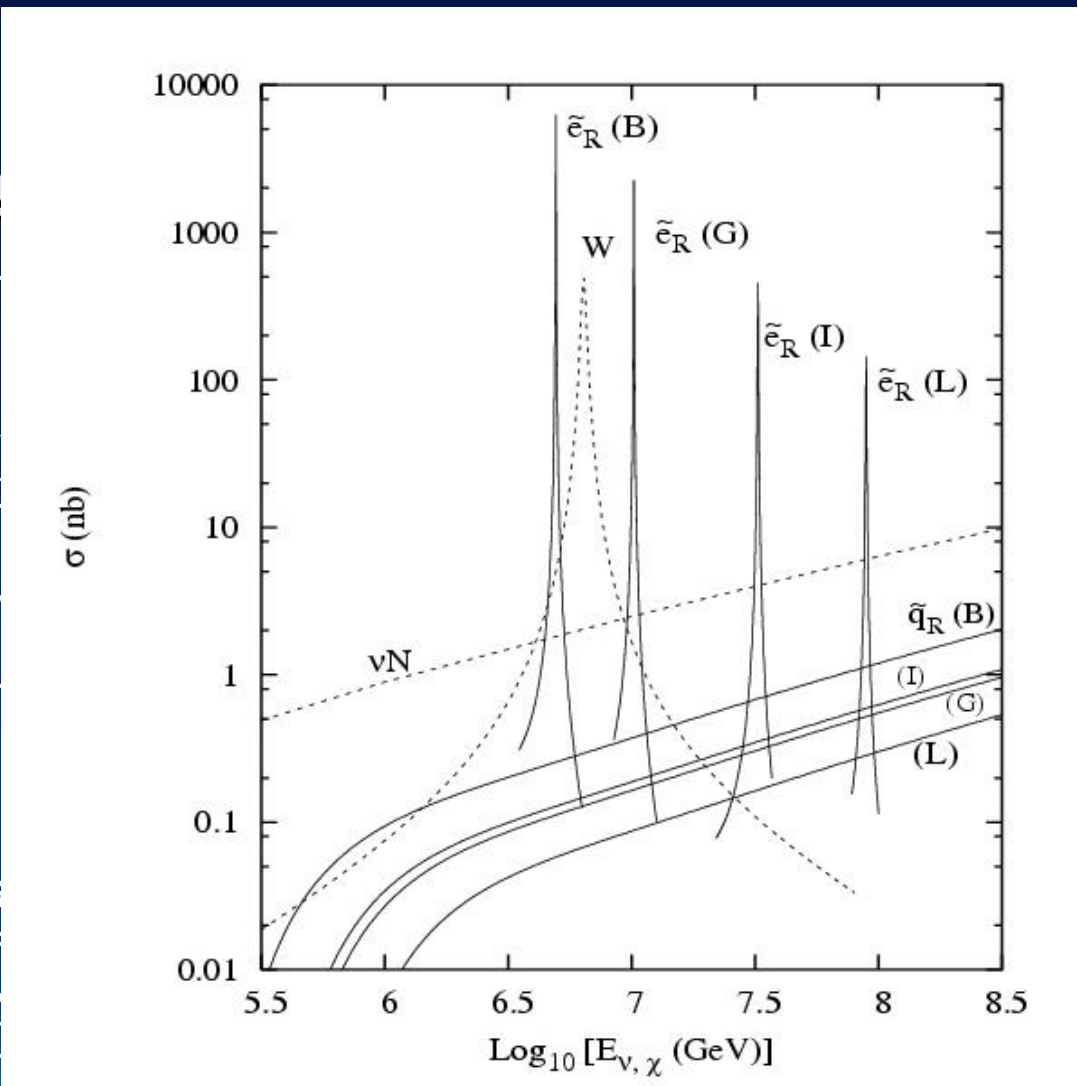
$$n_l + ? \longrightarrow l + X \quad \text{Char}$$

$$n_t + ? \longrightarrow t + X, t + \bar{t}$$

*Tau Air-Showers and Double Ba*

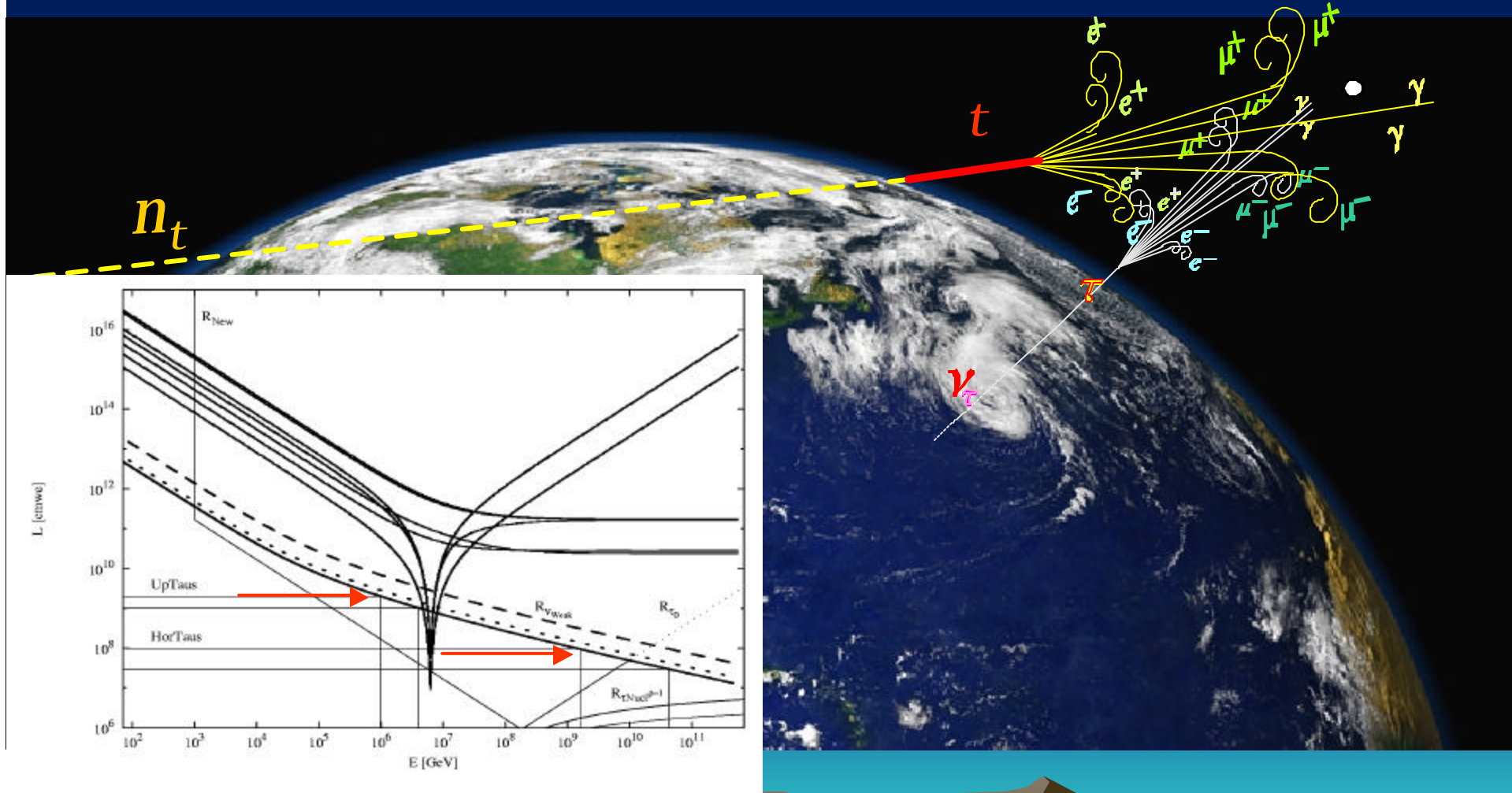
$$C_0 + e^- \longrightarrow ?_L^- \longrightarrow C$$

$$n_l + ? \longrightarrow \tilde{l} + \tilde{q}$$

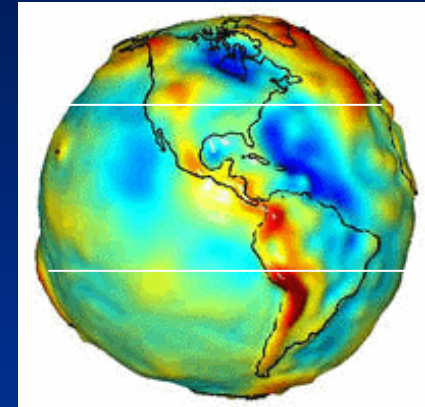
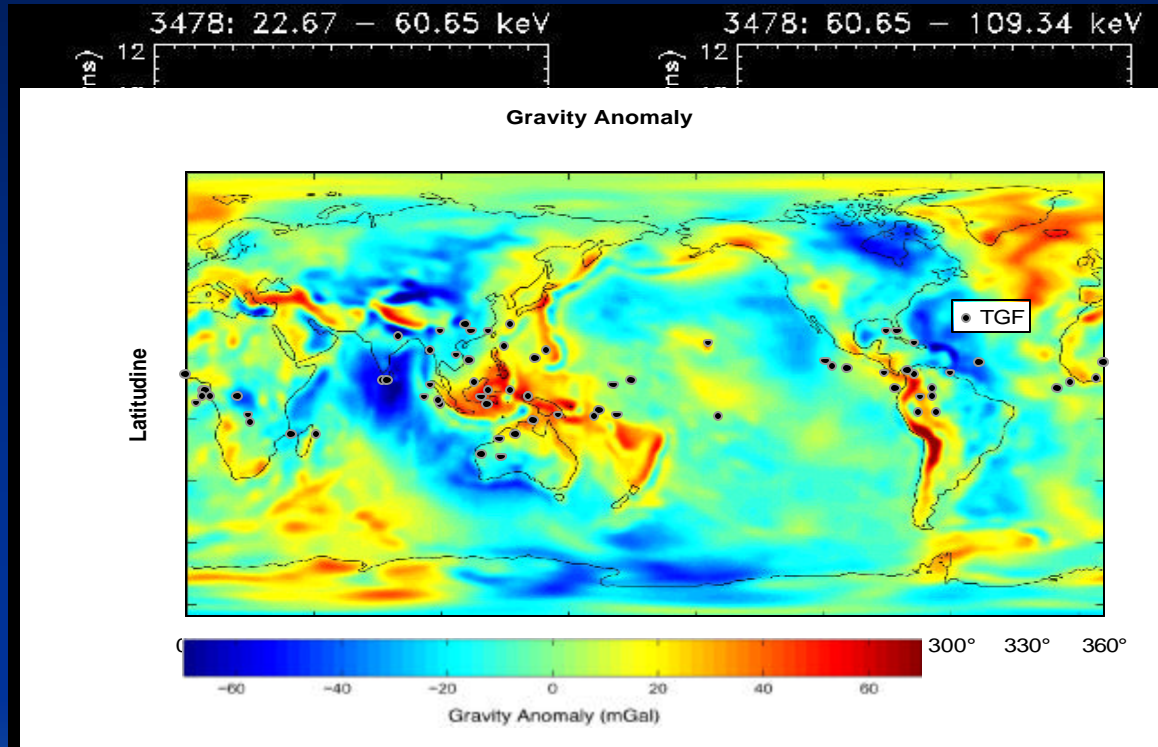


*hadronic or electromagnetic Stau Air showers : see hep-ph/0312197, by I. Albuquerque, G. Burdman, Z. Chacko*

# Upward Tau Air-Shower or Horizontal at PeVs and EeVs



*Earth skimming neutrino and Tau AirShowering:  
Are there correlations between Earth Crust Contrast and  
birth place of Terrestrial Gamma Flashes?*



**Batse data TGF: 1991-2000: 78 Upward gamma flashes**

***RHESSI 2005:...Counter-intuitively, these strong gamma outbursts also seem to precede associated lightning discharges by a split second...Tau trigger?***

# Upward Neutrino Tau Flux derived by BATSE TGF data 1991-2000

Research Signpost  
37/661 (2), Fort P.O., Trivandrum-695 023, Kerala, India



Recent Res. Devel. Astrophys., 1(2003): 395-454 ISBN: 81-271-0004-8

15

## Ultra High Energy Particle Astronomy, neutrino masses and Tau airshowers

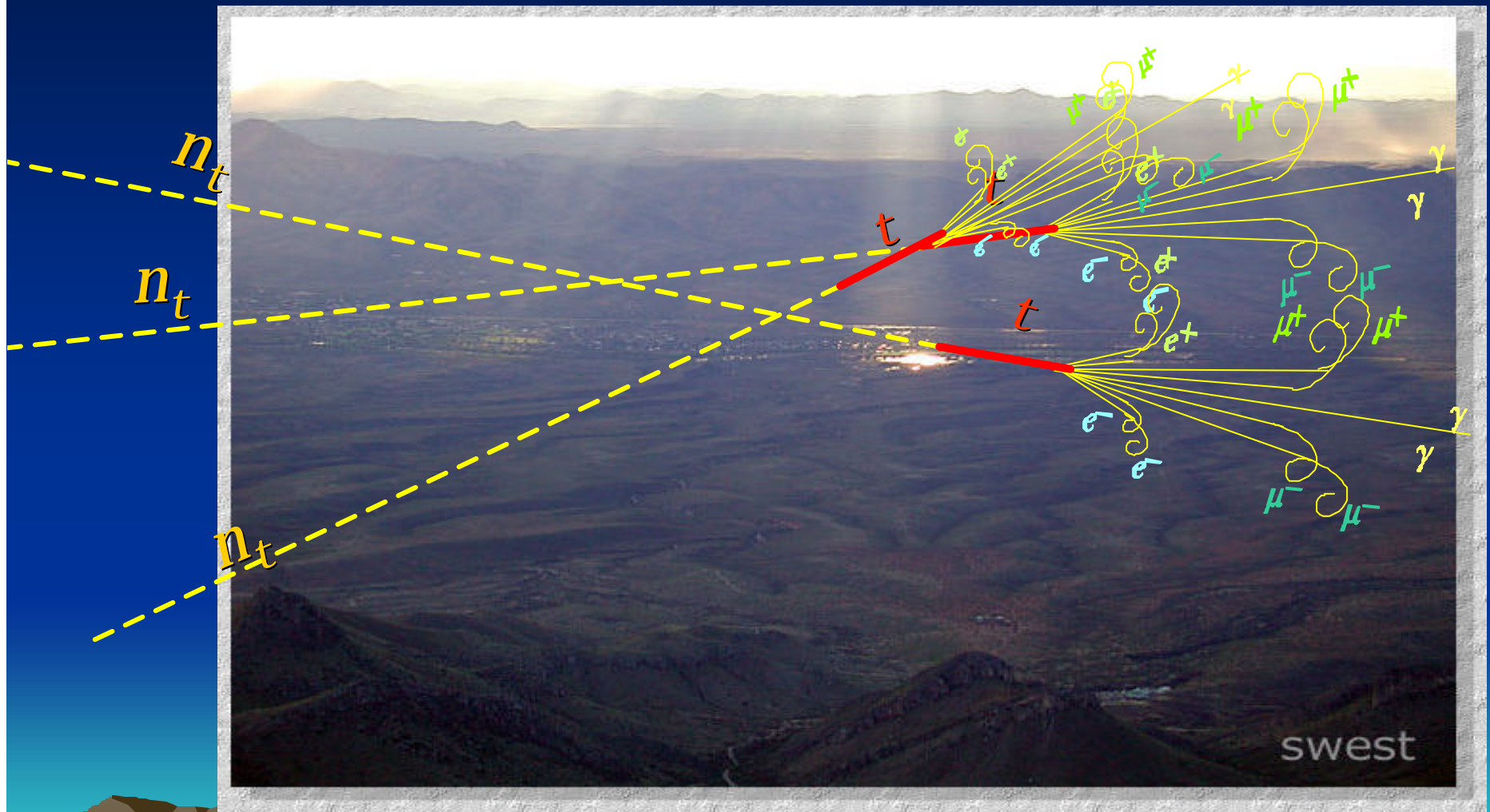
D. Fargion<sup>1,2</sup>, M.Khlopov<sup>1,3</sup>, R.Konoplich<sup>4</sup>, P.G. De Sanctis Lucentini<sup>2</sup>  
M. De Santis<sup>2</sup> and B. Mele<sup>2</sup>

<sup>1</sup>Physics Department, Rome University "La Sapienza", Ple.A.Moro 2,00185, Rome, Italy

# Conclusions

1. Horizontal High Energy Cosmic Rays are well observable at Magic Horizons at a rate of hundred (ten PeV) or a few (0.2 EeV) a night offering first CR Spectroscopy.
2. Neutrino Astronomy at Glashow resonance at sight by Crown array: experiment in progress (Italy-China-USA)
3. Tau Air-Showers observable in West Side Story Shadows at Auger now days.. Shadows 2006- Tau 2008?
4. Dozens of Tau Air Showers by GZK neutrinos from Earth observable by EUSO and OWL .
5. EeV Tau and Glashow showers in present Magic Upward Horizons during BL Lac, GRB or SGR : Already a  $\text{km}^3$   $n$  cube detector for Glashow resonance and  $75 \text{ km}^3$  at EeV.
6. SUSY Resonant Showering on the edge as well
7. Enhancement of TeV gravity to expected Nu event rate
8. Are TGF triggered by Up-Taus and Hor-Taus already testing and already recording GZK and WB neutrino fluxes?

# In summary: The Neutrino Sky is just the Sky of the Sky.. Our Earth



# Thank you for the attention



LaThuile-07March  
D.Fargion@roma1.infn.it

# END

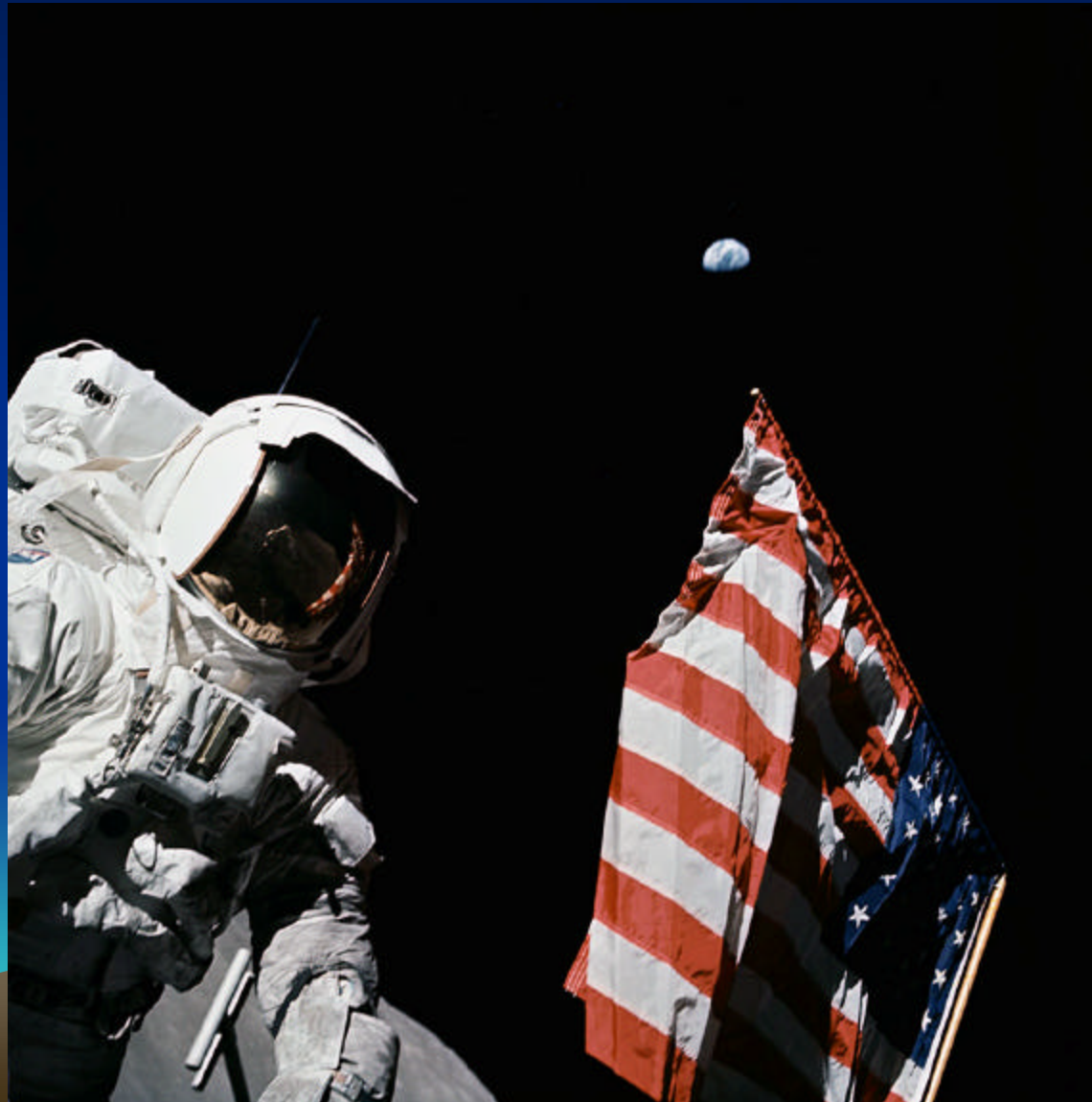


# Earth Skimming = Tau AirShowers



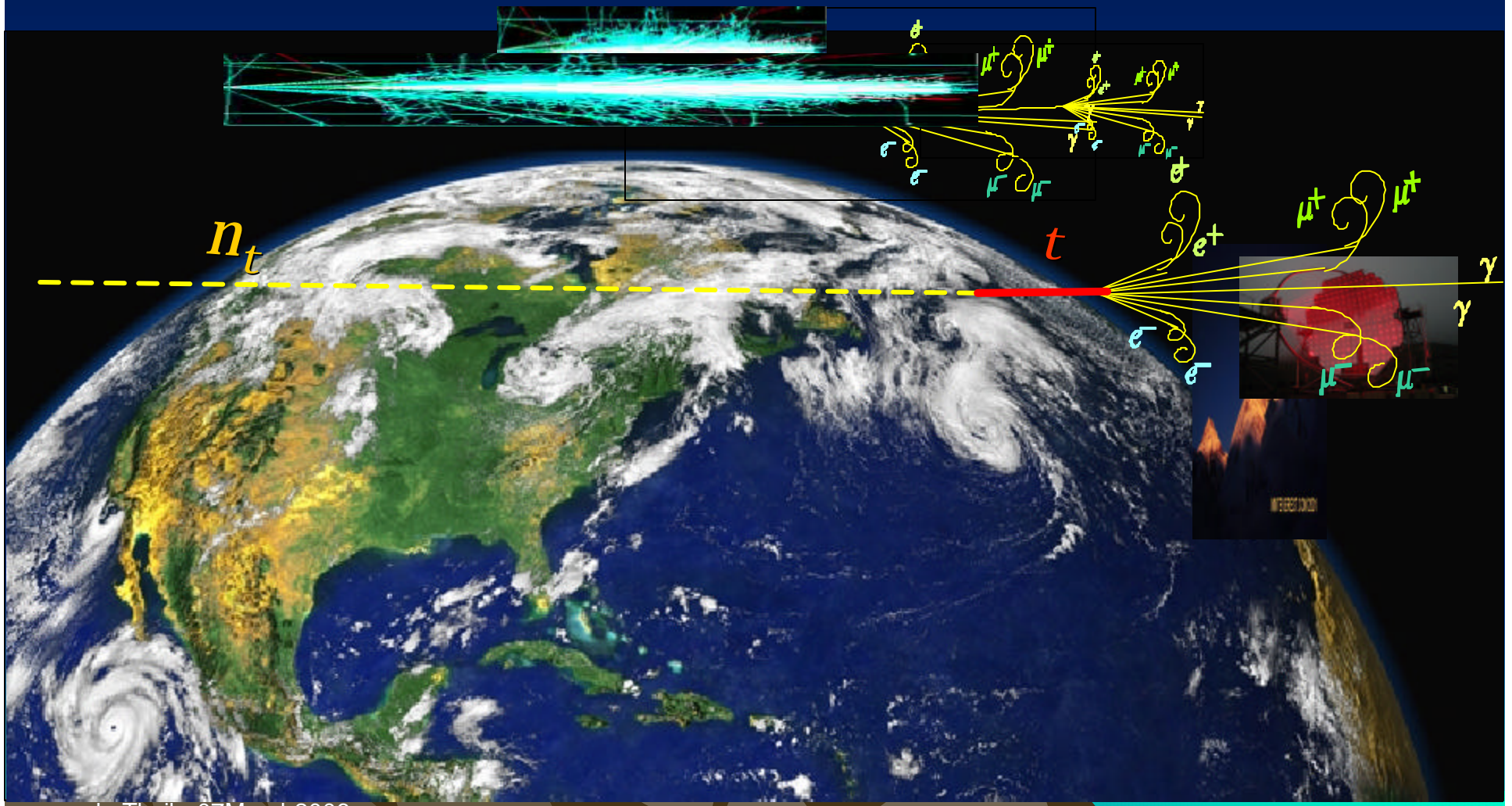


# Where **not** to go for search for air-showers Not Air..No.. Showers

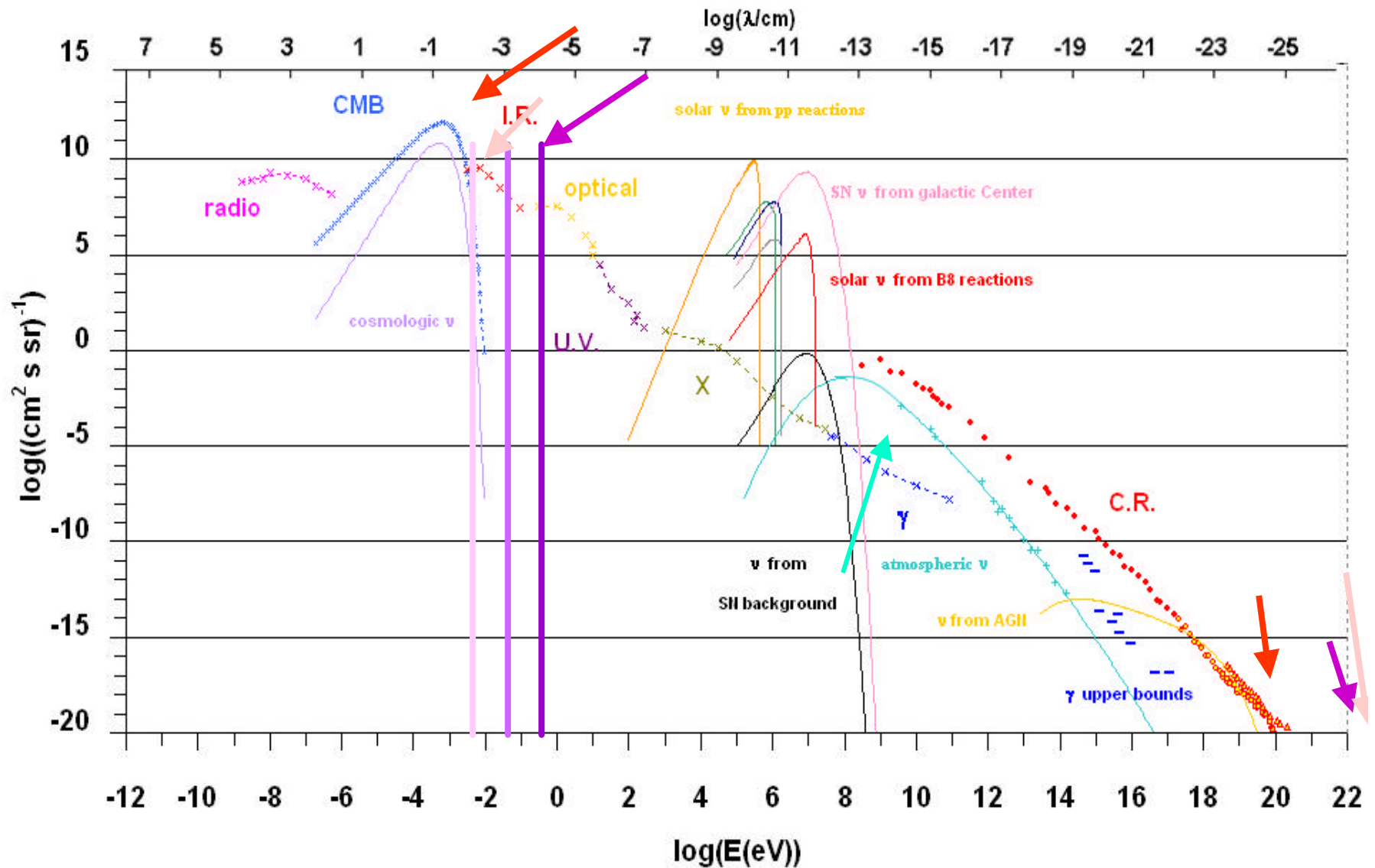


LaThuile-07March2006-  
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# Multi Showers Signatures: Shadows of Horizontal Astronomies from the top



# All particle flux ( $dN/dA dE dt dW * E$ ): Photons versus C.R. and Neutrinos Astronomy



# High Energy Neutrino Astronomy are a Must just behind the corner

- Solar, Supernovae Neutrino Astronomy are probed.
- Cosmic rays flux as rich as BBR, being charged, are bent and smeared, blinding most CR astronomy.
- UHECR are direct, but BBR cut them, GZK cut, locally.
- UHECR themselves must produce GZK- EeV neutrinos.
- AGN, GRBs, Star Burst Galaxy must also produce PeV neutrinos.
- UHE neutrinos must emerge above atmospheric neutrino noises: muons tracks and tau showers by their decay in flight (double bang) are their best trace.

# Solving UHECR and GZK puzzle by Z-Burst and relic neutrino mass: 0.4 eV

