Where, when and how SUSY is showering in the sky

D.Fargion,
ROME UNIV 1 and INFN

SUSY signals into sky

- ***Cosmic Rays and UHECR are reaching highest energy well above LHC ones. Because photopion production they might hide UHE GZK neutrino that may airshower at Earth Horizons. These Airshowers mostly are Tau induced ones.***

- ***SUSY traces might be also searched inside the same UHECR shower occuring on Earth. I ndeed UHE neutralino and other surprising SUSY secondaries may offer a novel Astronomy at the edge by inclined airshowering.***
- ***But also UHE SUSY and Neutrino traces maybe originated inside the sources and discovered in present Telescopes, as Magic one.***

Where, when and how SUSY traces maybe revealed and disentangled from Neutrino ?

- Assume a sharp event occur in the Universe, as the blazing of a BL Lac or of a GRB: it may be a trigger of a Gamma burst as well as of a UHE neutrino event. (Possibly its tau event may escape the earth and arise as a Tau Air-Showers)
- The same event may contain a rare neutral SUSY particle (UHE Neutralino, UHE gluino)

whose masses are above hundred GeV value. Being neutral it may flight in line and in time correlation.

The SUSY imprint

- The SUSY production is source of a signal ***delayed respect of the BL Lac- GRB event.***
- **Indeed an EeV (or 0.1 EeV) UHE Neutralino or Gluino**

  may reach the observer at a Lorents

  factor (10 or 1 million) and its delay (for a cosmic source at Universe edge) ranges from

  half and hour to a couple of days: Therefore

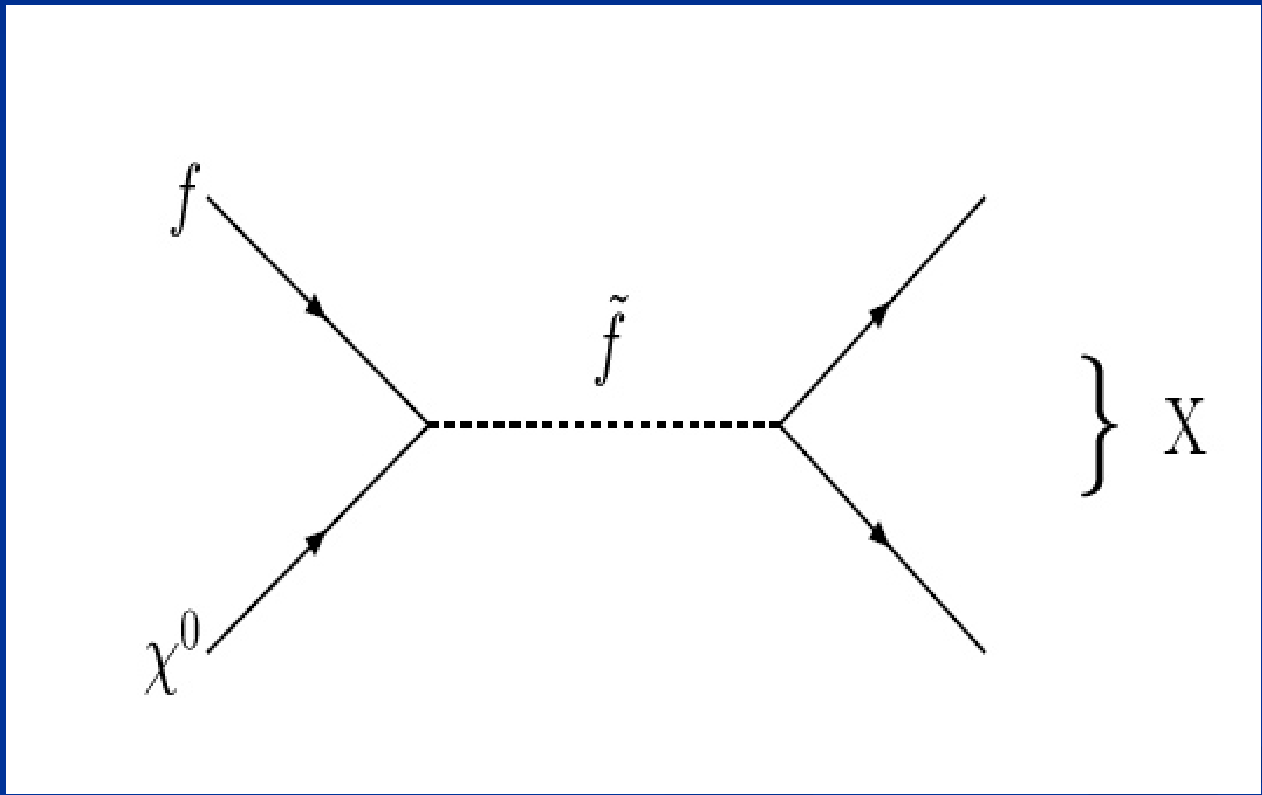
  SUSY rise as a Neutralino or Gluino BURST

  a day after..

The UHE SUSY versus UHE Neutrino air Showering

- The UHE Neutralino scattering on electron making s-electrons, behaves as a resonant PeVs Glashow anti-neutrino electron interacting via W boson:
- a difference, SUSY goes into electromagnetic air-showers always , while W has most hadronic channel decays

If UHECR hides (as most model require) SUSY secondaries than UHE Neutralino scattering with fermions in matter must occur: Selectrons-Squarks-Sneutrino Resonances



The simplest, the best

- The neutralino SUSY

resonance at UHE PeV-EeV energies

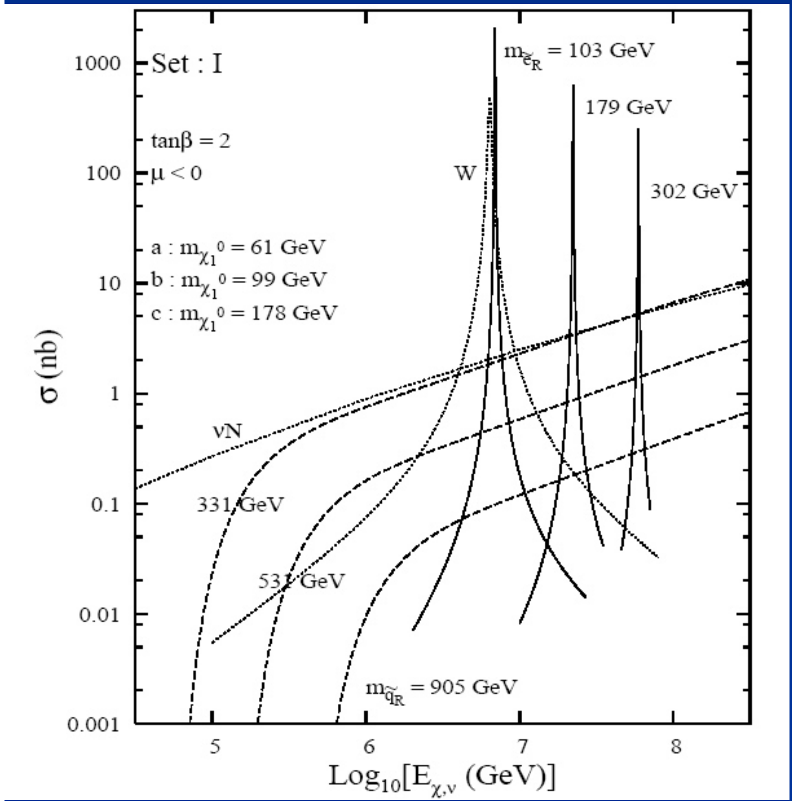
$$\chi_1^0 + e \to \tilde{e}_R \to \chi_1^0 + e \,,$$

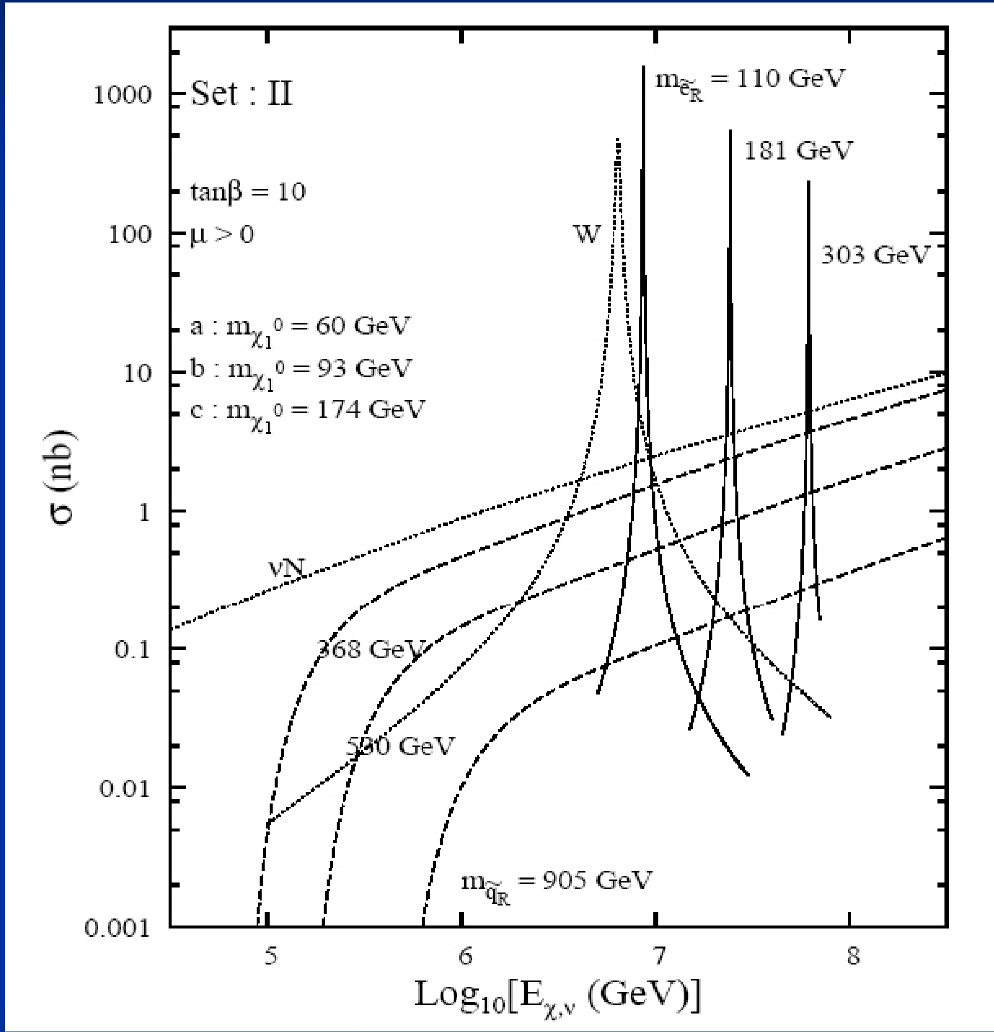
The Selectron resonance behave like the well known Glashow W one:

$$\bar{\nu}_e + e^- \to W^- \to X$$

$$E_\nu^{peak} = \frac{M_W^2 - m_\nu^2}{2m_e} \simeq \frac{M_W^2}{2m_e} \sim \; 6.3 \times 10^6 \text{ GeV} \,,$$

The Neutralino versus Neutrino cross sections for equal energies





Resonant Cross Section

$$\sigma^{peak} = \frac{8\,\pi}{m_{\tilde{f}}^2} \left(\frac{m_{\tilde{f}}^2}{m_{\tilde{f}}^2 - m_{\chi}^2} \right)^2 B(\tilde{f} \to f\ \chi_1^0)\ B(\tilde{f} \to X).$$

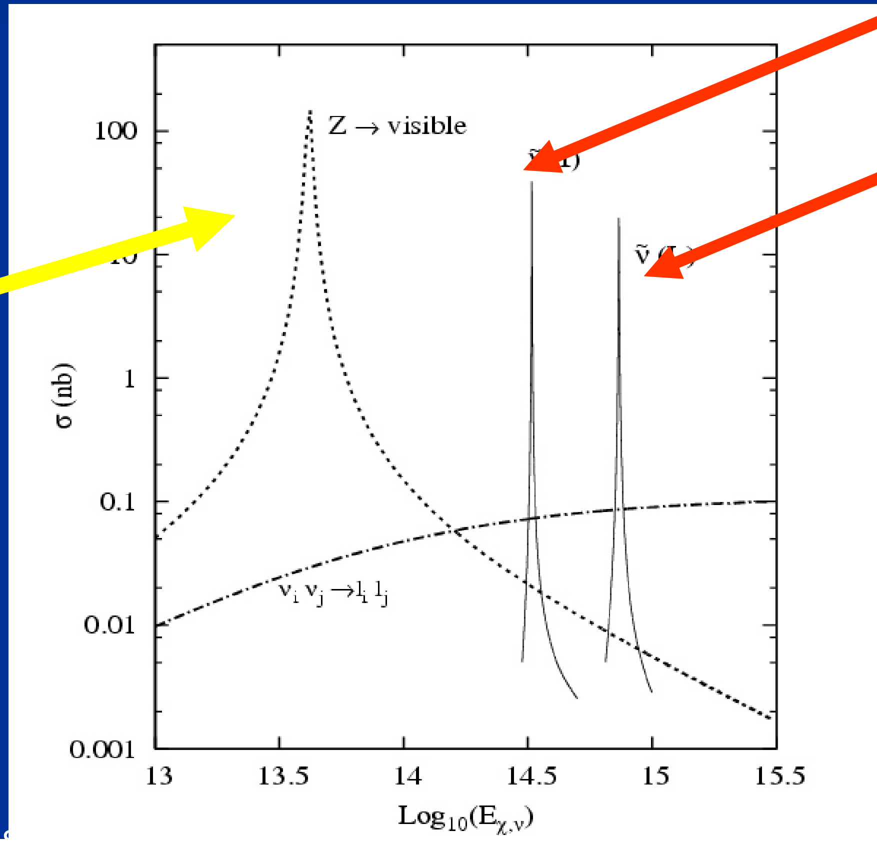
Different Squark –Selectron and Sneutrino masses →Different Neutralino UHE Resonant Energies

$$E_{\chi} \gtrsim \frac{m_{\tilde{q}}^2}{2m_p} \sim 10^5 \ \ \mathrm{GeV},$$

$$E_{\chi} \sim \frac{m_{\tilde{e}}^2}{2m_e} \simeq 10^7 \div 10^9 \ \ \mathrm{GeV}$$

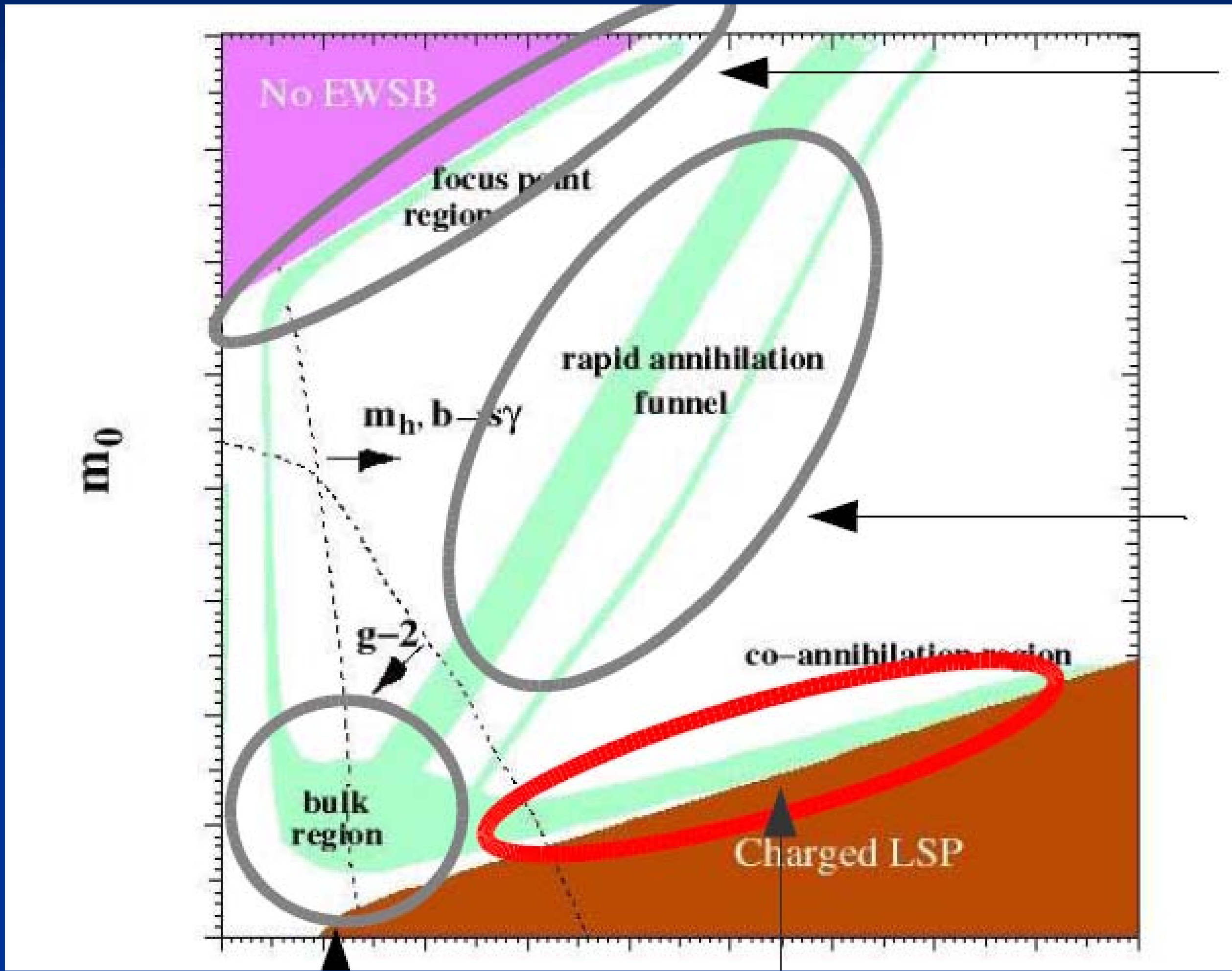
$$E_{\chi} \sim \frac{m_{\tilde{\nu}}^2}{2m_{\nu}} \simeq 10^{14} \ \ \mathrm{GeV}$$

UHE neutralino scattering onto relic light neutrino leading to Sneutrino Resonance channel, like Z-Burst

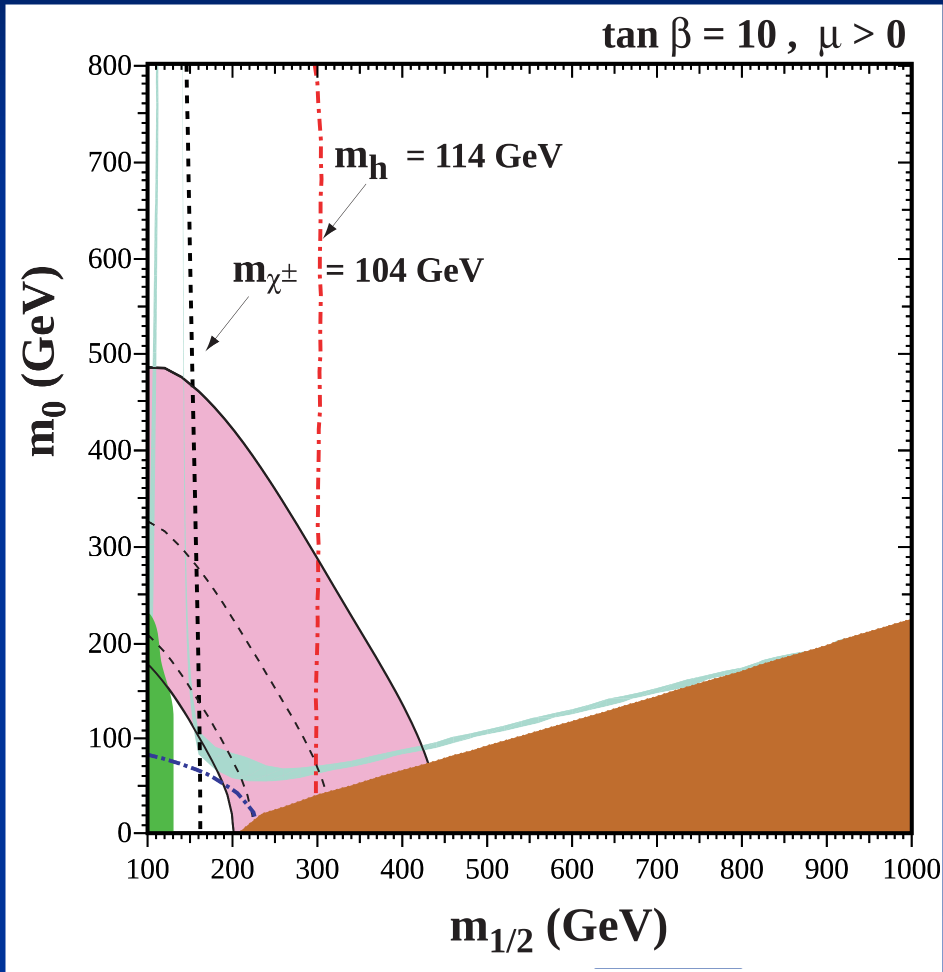


D. Fargion, B. Mele and A. Salis, Astrophys. J. **517** 725 (1999).

Range of SUSY parameters: Neutralino maybe among us making most of the dark matter



Up dated narrow Neutralino allowed Areas

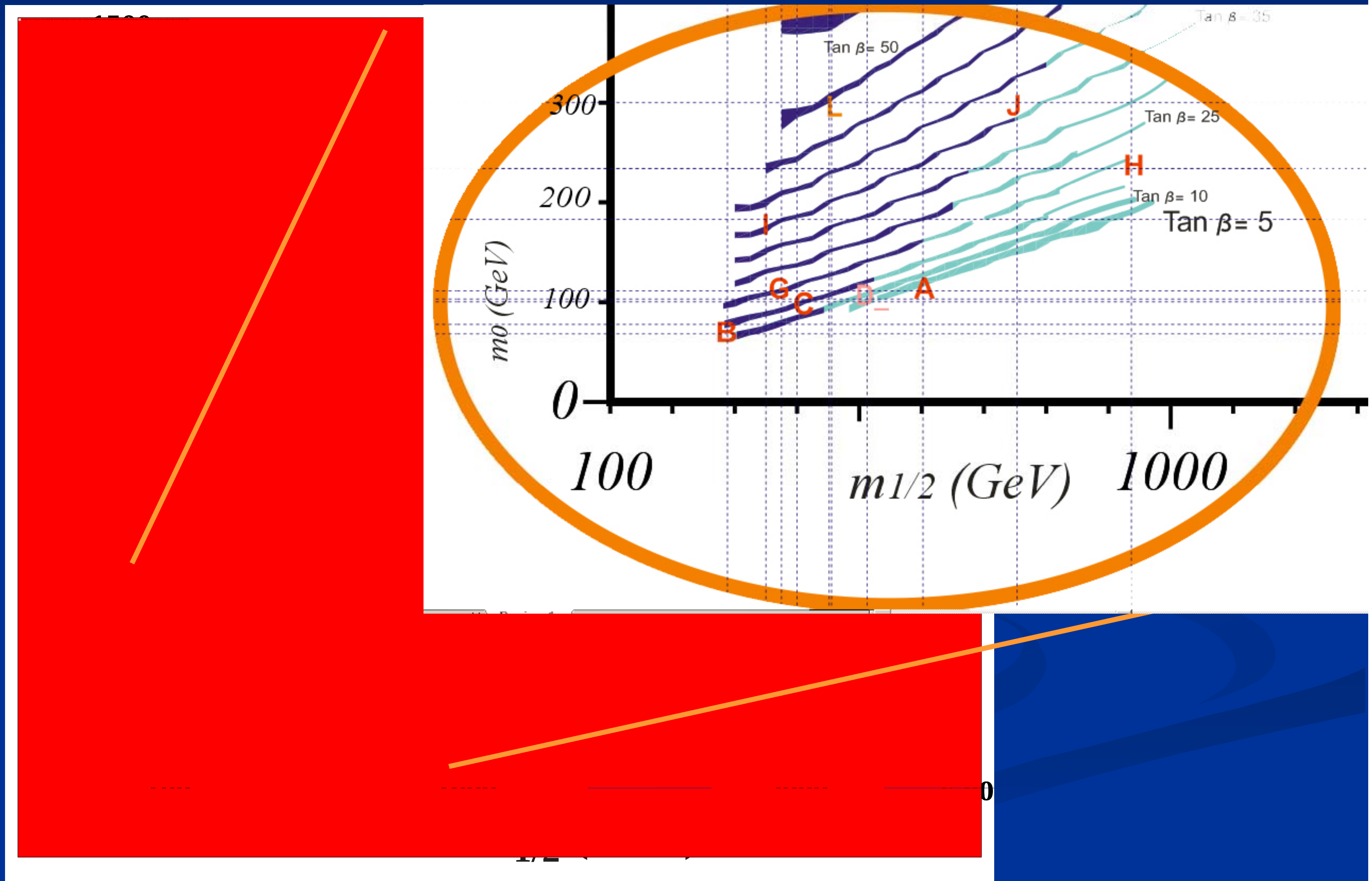


Olive 2005

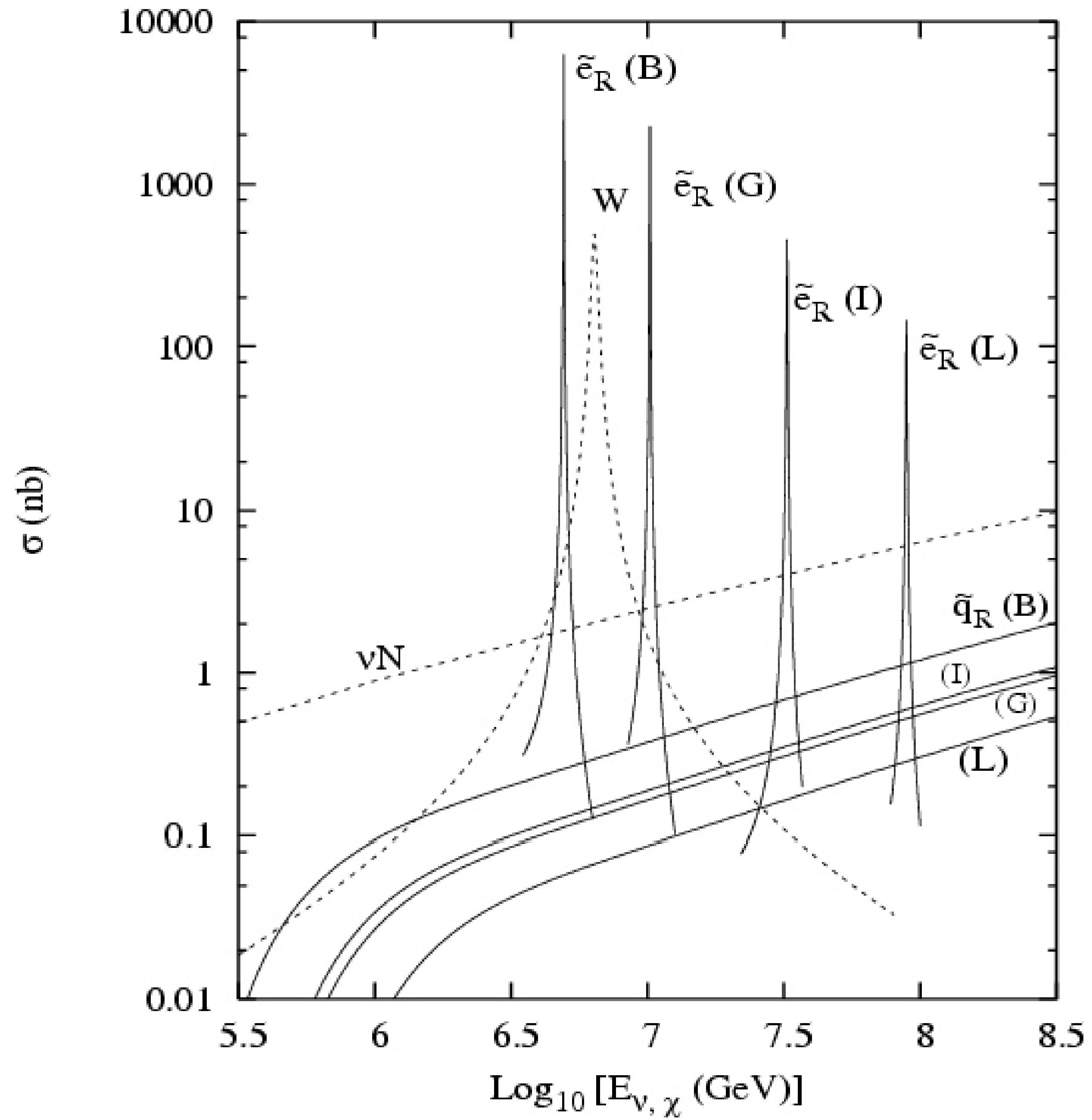
mSUGRA Benchmark Scenario : the test points (J.Ellis et all 2003)

Model	A'	B'	C'	D'	E'	F'	G'	H'	I'	J'	K'	L'	M'
$m_{1/2}$	600	250	400	525	300	1000	375	935	350	750	1300	450	1840
m_0	107	57	80	101	1532	3440	113	244	181	299	1001	300	1125
$\tan\beta$	5	10	10	10	10	10	20	20	35	35	46	47	51
sign(μ)	+	+	+	−	+	+	+	+	+	+	−	+	+
m_t	175	175	175	175	171	171	175	175	175	175	175	175	175
Masses													
$\lvert\mu(m_Z)\rvert$	773	339	519	663	217	606	485	1092	452	891	1420	563	1940
h	116	113	117	117	114	118	117	122	117	121	123	118	124
H	896	376	584	750	1544	3525	525	1214	444	888	1161	480	1623
A	889	373	580	745	1534	3502	522	1206	441	882	1153	477	1613
$H^{\pm}$	899	384	589	754	1546	3524	532	1217	453	892	1164	490	1627
χ	242	95	158	212	112	421	148	388	138	309	554	181	794
χ_2	471	180	305	415	184	610	286	750	266	598	1064	351	1513
χ_3	778	345	525	671	229	622	492	1100	459	899	1430	568	1952
χ_4	792	366	540	678	302	858	507	1109	475	908	1437	582	1959
$\chi_1^{\pm}$	469	178	304	415	175	613	285	750	265	598	1064	350	1514
$\chi_2^{\pm}$	791	366	541	679	304	846	507	1108	475	908	1435	582	1956
$\tilde{g}$	1367	611	940	1208	800	2364	887	2061	835	1680	2820	1055	3884
e_L, μ_L	425	188	290	376	1543	3499	285	679	304	591	1324	434	1660
e_R, μ_R	251	117	174	224	1534	3454	185	426	227	410	1109	348	1312
ν_e, ν_μ	412	167	274	362	1539	3492	270	665	290	579	1315	423	1648
τ_1	249	109	167	217	1521	3427	157	391	150	312	896	194	796
τ_2	425	191	291	376	1534	3485	290	674	312	579	1251	420	1504
ν_τ	411	167	273	360	1532	3478	266	657	278	558	1239	387	1492
u_L, c_L	1248	558	859	1103	1639	3923	814	1885	778	1554	2722	1001	3670
u_R, c_R	1202	542	830	1064	1637	3897	787	1812	754	1497	2627	969	3528
d_L, s_L	1250	564	863	1107	1641	3924	818	1887	783	1556	2723	1004	3671
d_R, s_R	1197	541	828	1059	1638	3894	786	1804	752	1491	2615	967	3509
t_1	958	411	653	860	1052	2647	617	1477	584	1207	2095	753	2857
t_2	1184	576	837	1048	1387	3373	792	1753	748	1428	2366	920	3231
b_1	1147	514	789	1015	1375	3356	737	1719	677	1377	2297	844	3149
b_2	1181	535	816	1043	1602	3816	770	1761	725	1423	2349	904	3217

Narrower range of Neutralino mass parameters following W-Map, LEP and g-2 constrains



Consequent resonant Neutralino electron-Selectron cross sections along the main SUSY points



Neutralino Fluxes in agreement with WB flux

- Assumed Spectra
- Comparable with the Neutrino power law

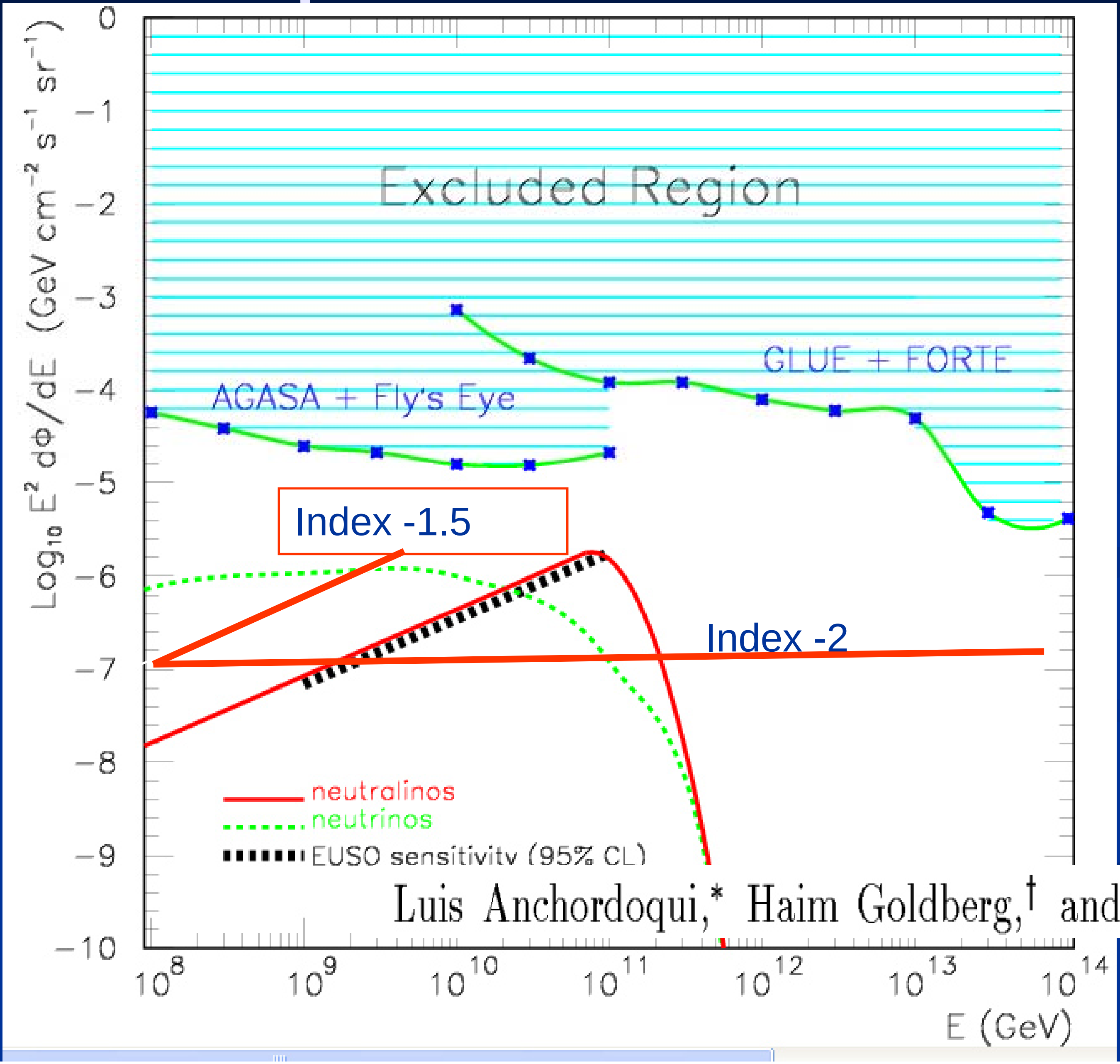
one at exponent -1.5 for Fragmentation:

$$E_\chi^2 \frac{dN}{dE_\chi} = 10^{-7}\ \mathrm{GeV\ cm^{-2}\ s^{-1}\ sr^{-1}} \left[\frac{E_\chi}{10^7\ GeV}\right]^{0.5}$$

Or a Fermi-like power law at exponent -2 :

$$E_\chi^2 \frac{dN}{dE_\chi} = 10^{-7}\ \mathrm{GeV\ cm^{-2}\ s^{-1}\ sr^{-1}}$$

Spectra Fluxes



Luis Anchordoqui,* Haim Goldberg,† and Pran Nath‡

Constrained best Neutralino parameters

Model	A	B	C	D	G	H	I	J	L
$m_{1/2}$ (GeV)	600	280	400	525	375	935	350	750	450
m_0 (GeV)	107	57	77	101	110	233	180	298	303
$\tan\beta$	5	10	10	10	20	20	35	35	47
sign(μ)	+	+	+	−	+	+	+	+	+
Ωh^2	0.128	0.123	0.122	0.116	0.110	0.123	0.117	0.119	0.113
m_χ (GeV)	243	107	158	212	148	388	138	309	181
$m_{\tilde{e}_R}$ (GeV)	254	128	175	226	184	423	227	412	349
$\Gamma_{\tilde{e}_R}$ (MeV)	9.13	57.2	29.7	16.3	103	53.4	448	396	931
$\sigma^{peak}_{\tilde{e}_R}$ (μb)	21.1	6.58	9.34	13.3	2.57	2.17	0.477	0.301	0.150
$\mathcal{N}_{\tilde{e}_R}$	28	32	26	23	8.5	2.3	1.9	0.55	0.42
(km^{-3} yr^{-1})	37	45	34	30	7.7	1.4	1.1	0.20	0.14
$m_{\tilde{q}_R}$ (GeV)	1194	596	825	1057	781	1798	748	1487	961
$\Gamma_{\tilde{q}_R}$ (GeV)	2.45	1.23	1.70	2.17	1.61	3.65	1.55	3.04	1.99
$\sigma^{peak}_{\tilde{q}_R}$ (nb)	7.43	28.6	15.3	9.46	17.1	3.32	18.5	4.81	11.3
$\mathcal{N}_{\tilde{q}_R}$	0.35	3.0	1.1	0.52	1.3	0.08	1.5	0.17	0.70
(km^{-3} yr^{-1})	0.22	2.6	0.89	0.36	1.1	0.04	1.2	0.09	0.51

Table 1: Definition of different mSUGRA scenarios and corresponding event-number expectations $\mathcal{N}_{\tilde{e}_R,\tilde{q}_R}$, for resonant neutralino scattering in ice. In all scenarios, we assume $A_0 = 0$. The resonance decay widths and peak cross sections for the right selectron and right squark are also shown. The upper of the two entries in the $\mathcal{N}_{\tilde{e}_R,\tilde{q}_R}$ raws corresponds to the event number calculated by the neutralino flux in eq. (4) ($\beta_0 = 1.5$), while the lower entry refers to eq. (5) ($\beta_0 = 2$). When computing the squark event rates, an incident neutralino energy threshold of 1 PeV is assumed. The relic DM density Ωh^2 corresponding to each scenario is also shown.

Number of events expected for Cubic Km/ year

Model	A	B	C	D	G	H	I	J	L
$m_{1/2}$ (GeV)	600	280	400	525	375	935	350	750	450
m_0 (GeV)	107	57	77	101	110	233	180	298	303
$\tan\beta$	5	10	10	10	20	20	35	35	47
sign(μ)	$+$	$+$	$+$	$-$	$+$	$+$	$+$	$+$	$+$
Ωh^2	0.128	0.123	0.122	0.116	0.110	0.123	0.117	0.119	0.113
m_χ (GeV)	243	107	158	212	148	388	138	309	181
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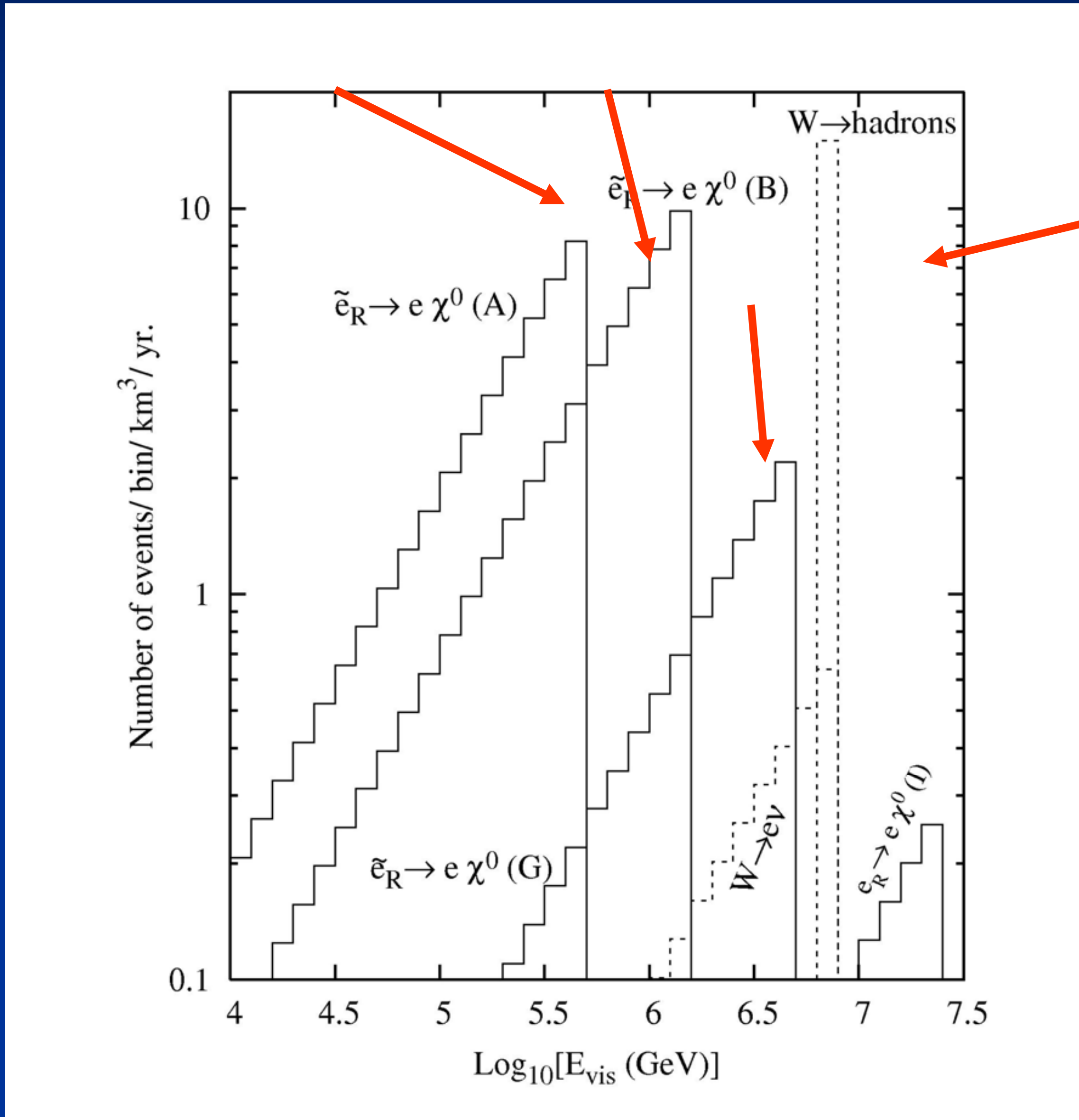
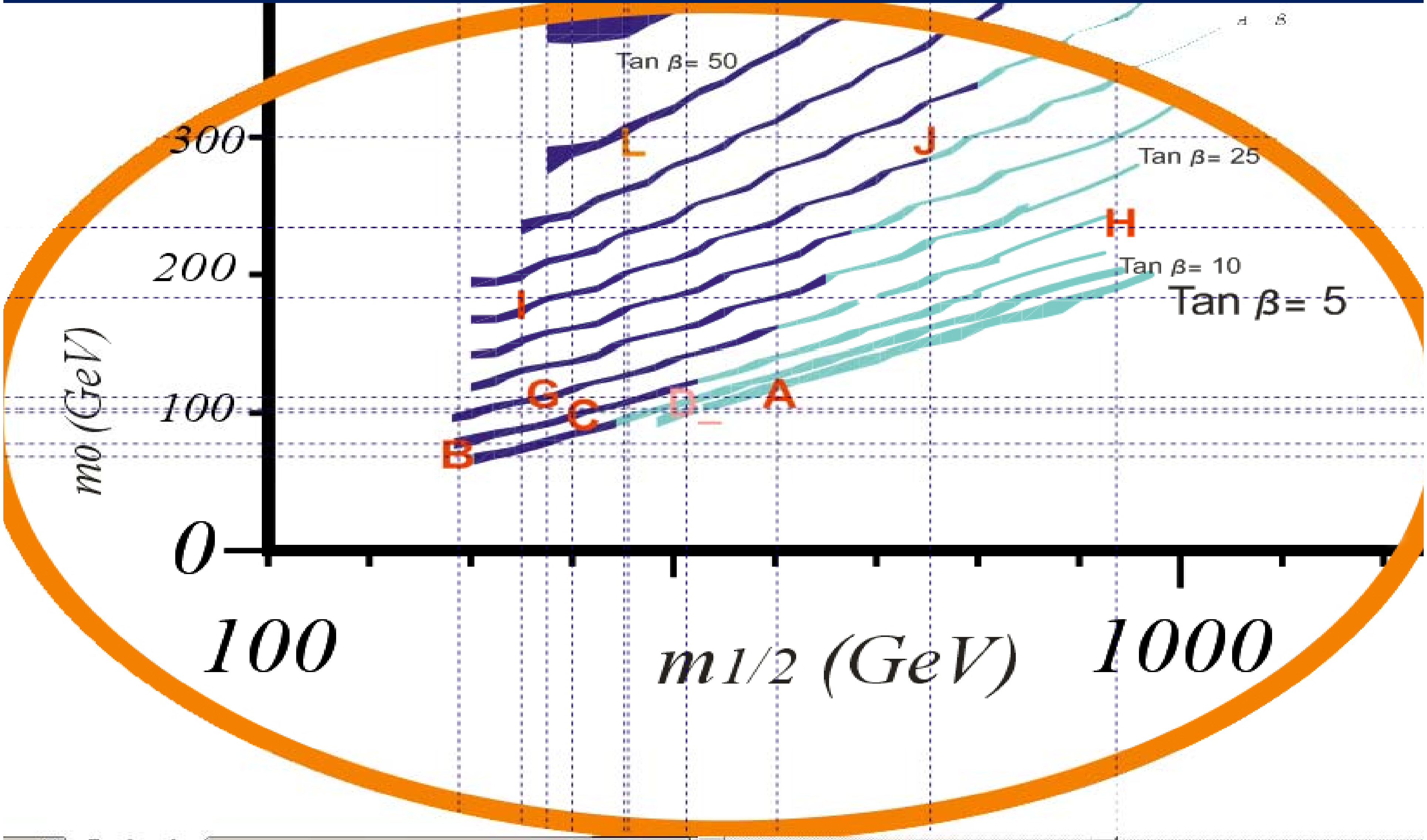
Real Energy released per SUSY Showers: Imprint of Selectrons (and Squark) mass in Cubic Km. Similar Consequences in Horizontal Air-Showers



SUSY Points of interest



SUSY S-electron may air-shower at Horizons

- In air the s-electron may arise as a Glashow resonant event. At best at Horizons
- In air also Gluino may air shower at best.
- The UHE Neutrino Tau must also appear and airshower at greater rate. Therefore we show a brief summary of UHE Neutrino tao astronomy at the Earth edge.

Tau first,UHE neutralino after GRB probing UHE Neutrino and SUSY Astronomy

- The near future detection of prompt neutrino maybe correlated with GRB activities:

however the SUSY masses may induce delayed events: **half an hour for z=1 and EeV event**

and a SUSY 100-200 GeV Gluino mass. A coincidence?

THE SUSY VERSUS UHE NEUTRINO SIGNAL at HORIZONS

The UHECR Ultra High Energy Cosmic Ray airshower in peculiar way at the horizons with splitting signature due to geomagnetic fields.

This offer a novel spectroscopy of UHECR.

- Neutrino Astronomy may arise by upward-horizontal airshowers :

anti- ν_e Glashow resonance and-or by Tau Neutrino Earth Skimming Air showers may split into sky. The τ airshower are mostly GZK guaranteed and oscillated neutrinos at EeV energy.

- Magic is already looking for Horizontal Tau Air Showers at PeVs-EeV.
- AUGER may look Neutrino Showering by three ways:
- 1) τ airshower by Young Airshowers signature
- 2) τ airshower in Ande Shadows
- 3) τ airshower inside AUGER (cloudy) skies.

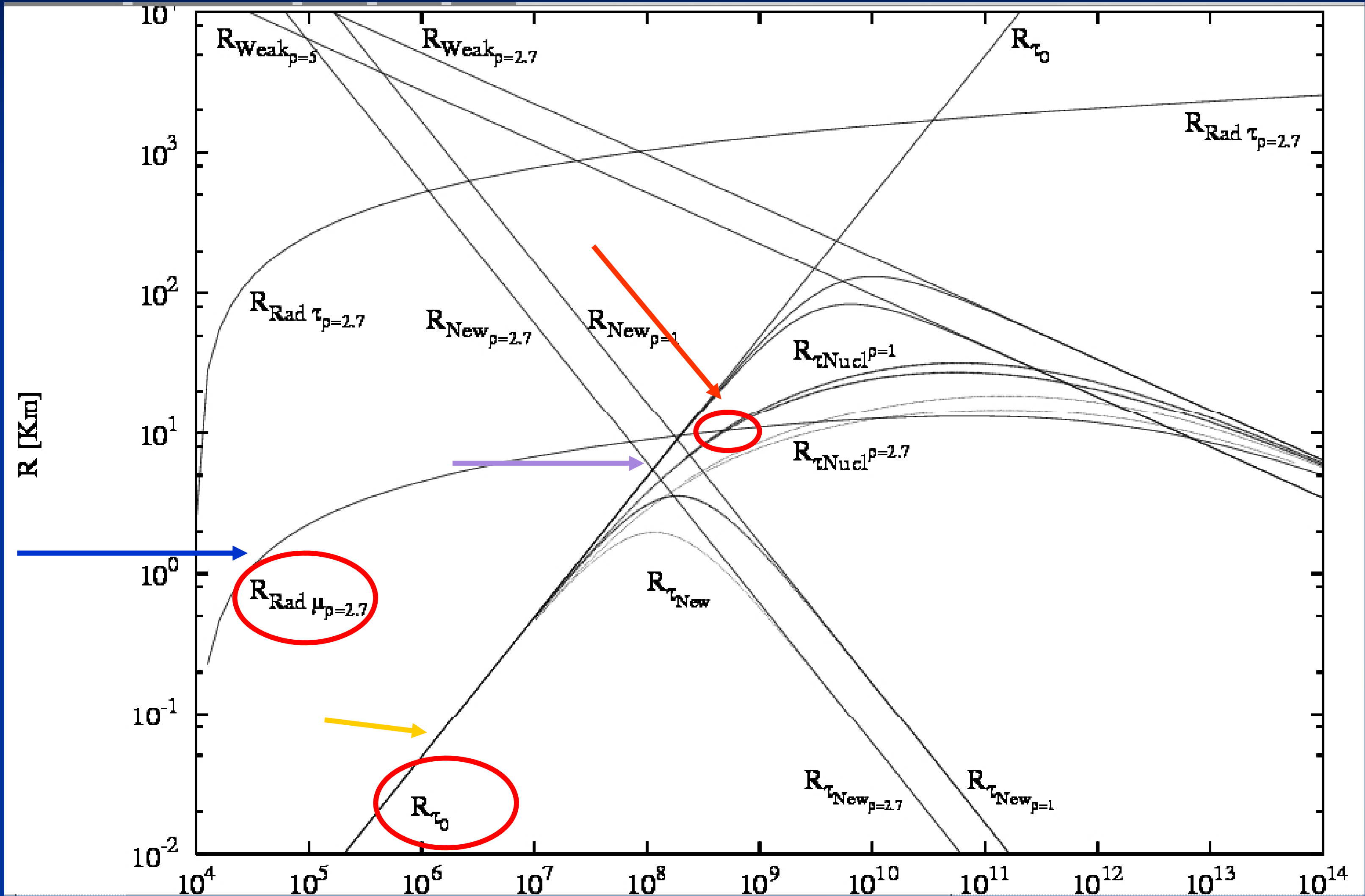
May UHE Neutrinos trace UHECR and solve the never ending puzzles of UHECR?

There is not just 1 neutrino but
3*2 = 6 different Neutrino
Astronomies

Electrons are very dissipating and short.
Muons are very penetrating ones.
BUT
<u>**Tau are the most penetrating, short at small, but longest at highest energies**</u>

Unstable tau versus muons at highest energy

D.Fargion ApJ 2002 and ApJ 2004



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 and in large area
Millions muons, billions gamma , e-pairs,
trillions or more Cerenkov photons.

An Unique Muon is single and shine little.

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 (otherwise very difficult to produce) Tau Neutrinos.

Galactic and cosmic distances are huge respect the neutrino oscillation lenghts. Even at UHE energies

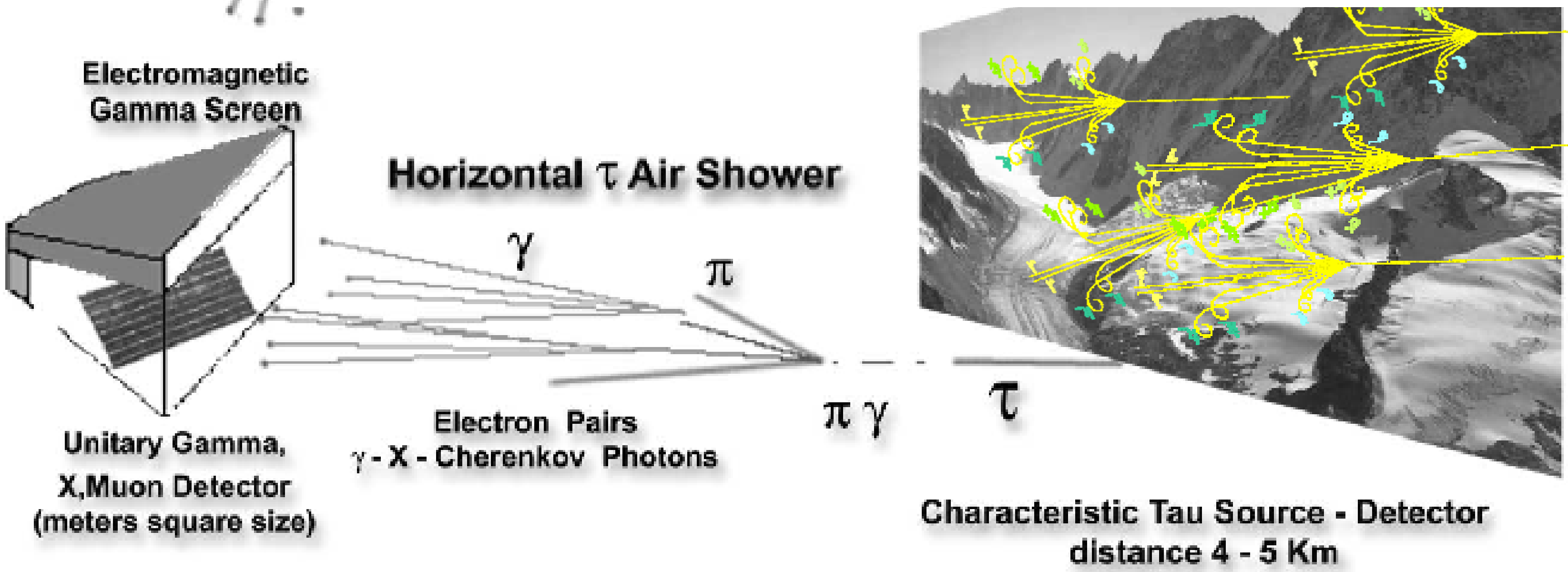
$$L_{\nu_\mu - \nu_\tau} = \boxed{8.3\,\text{pc}} \left(\frac{E_\nu}{10^{19} eV} \right) \left(\frac{\Delta m_{ij}^2}{(10^{-2} eV)^2} \right)^{-1}$$

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

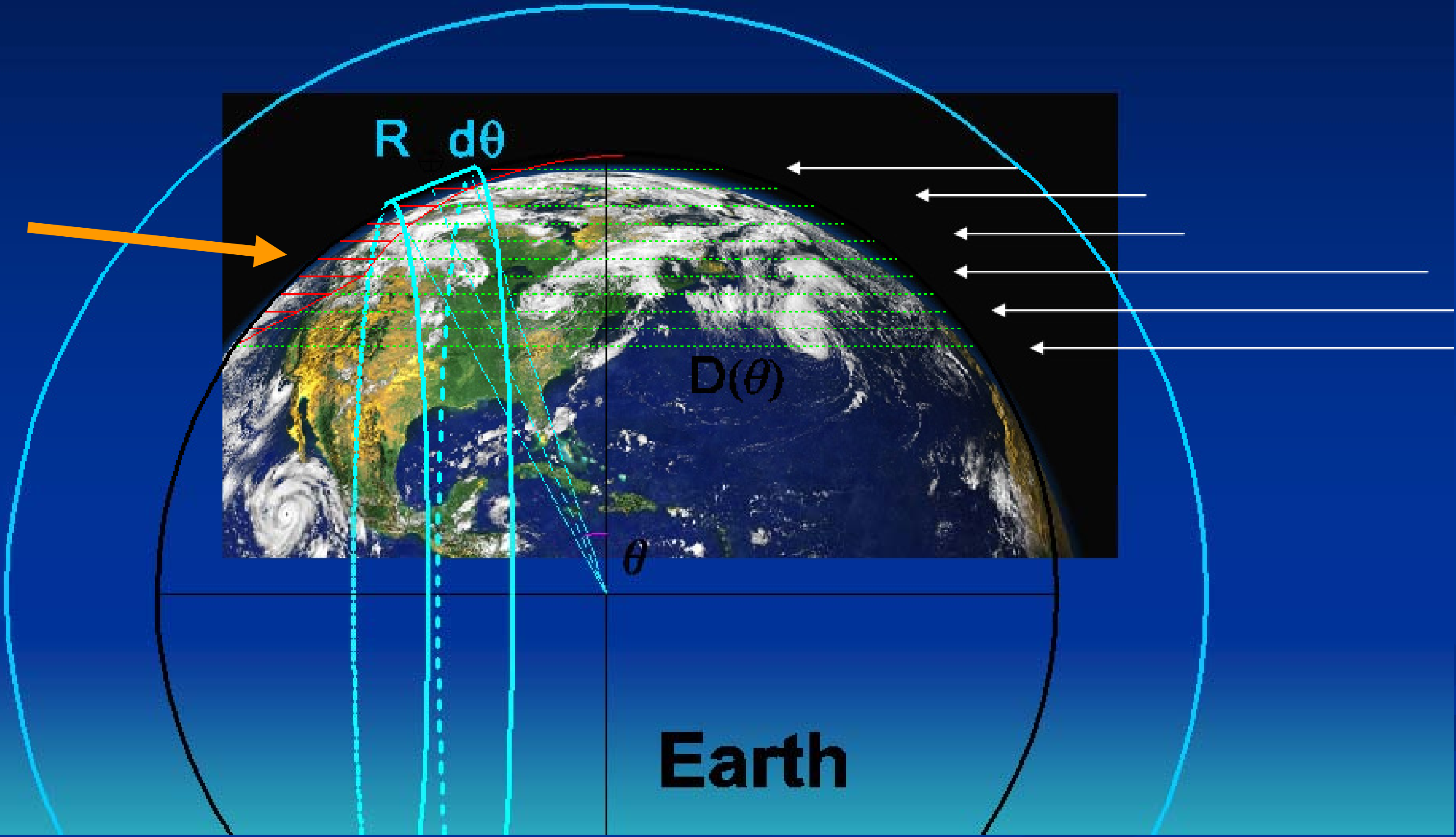
The Astrophysical Journal, 613:1285–1301, 2004 October 1

TAU AIR SHOWERS FROM EARTH

D. Fargion,[1,2] P. G. De Sanctis Lucentini,[1] M. De Santis,[1] and M. Grossi[1]
Received 2003 May 11; accepted 2004 May 21

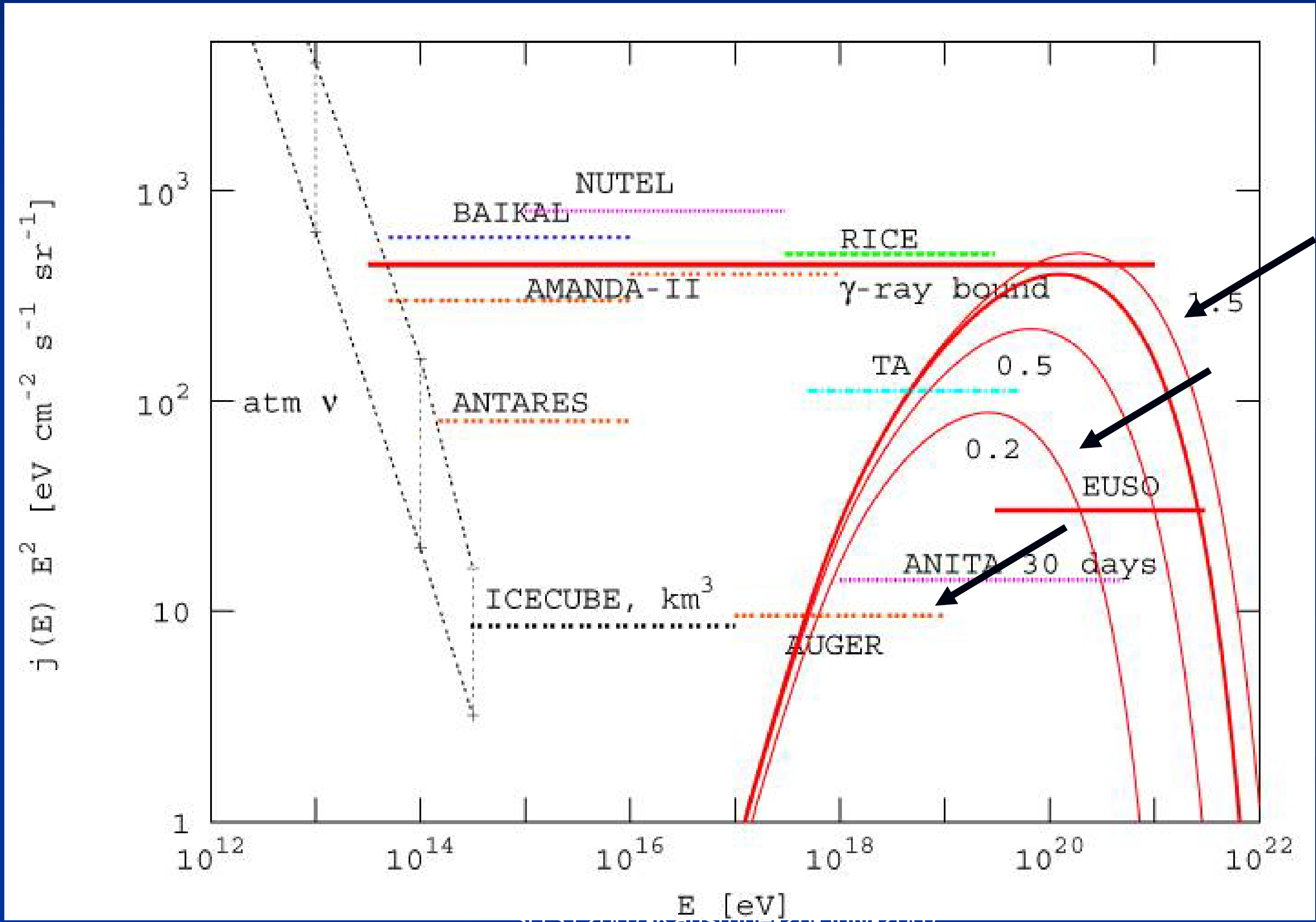


Effective Volume Areas for Uptaus

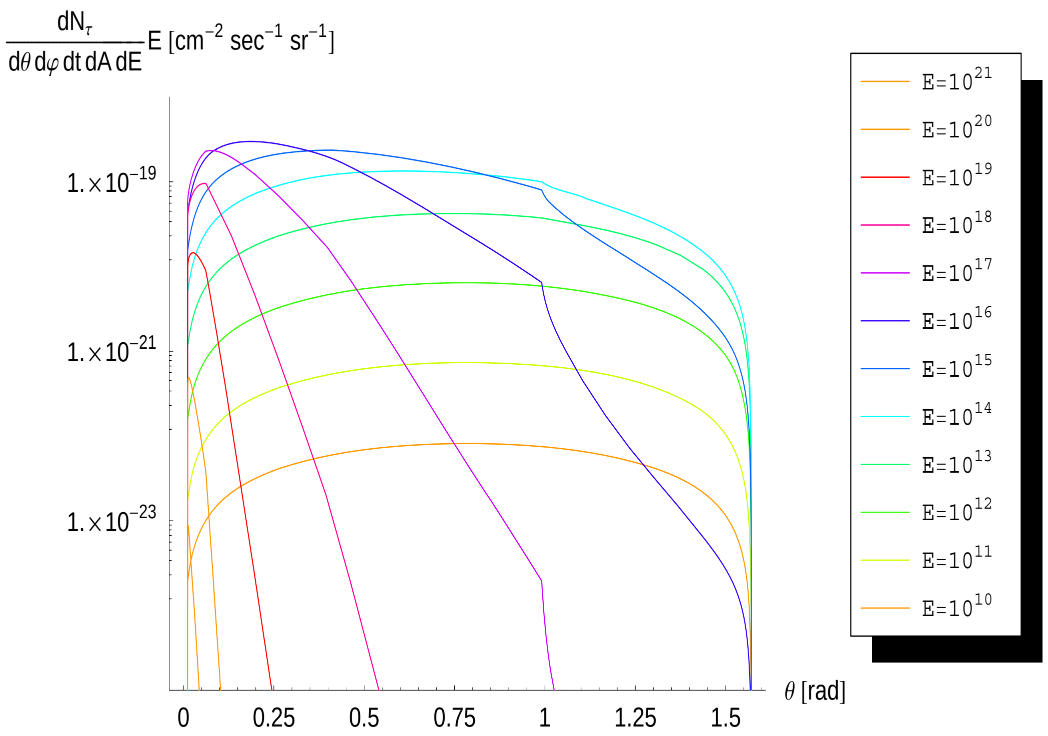


Expected GZK neutrino flux

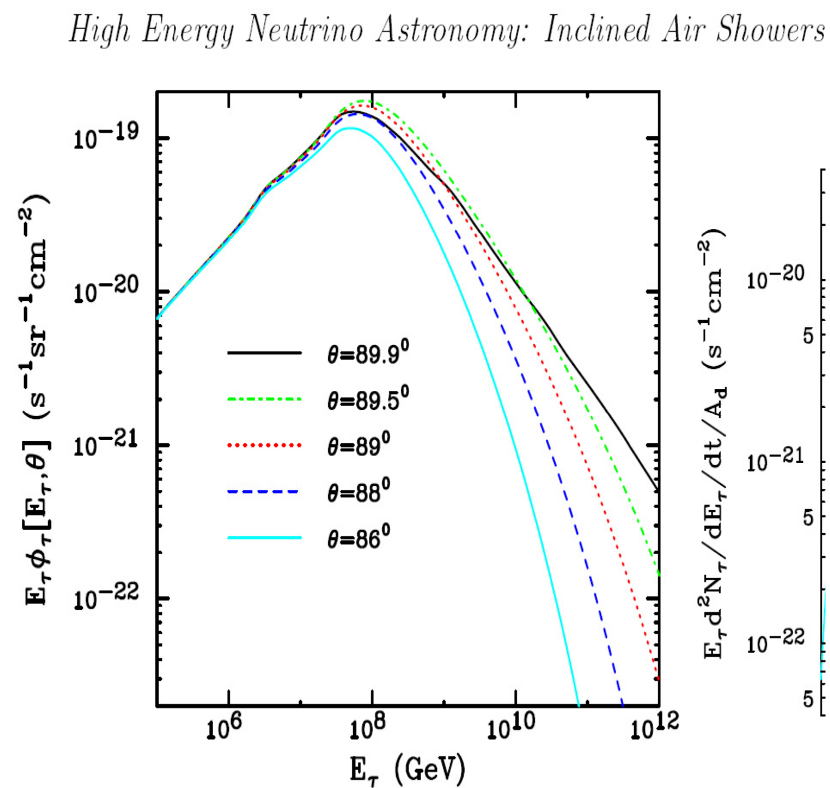
following most authors (Semikoz,Sigl..)



GZK neutrino and Upward Tau



Following Fargion et all 2004



Following Zas 2005

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^3 NEUTRINO TELESCOPE

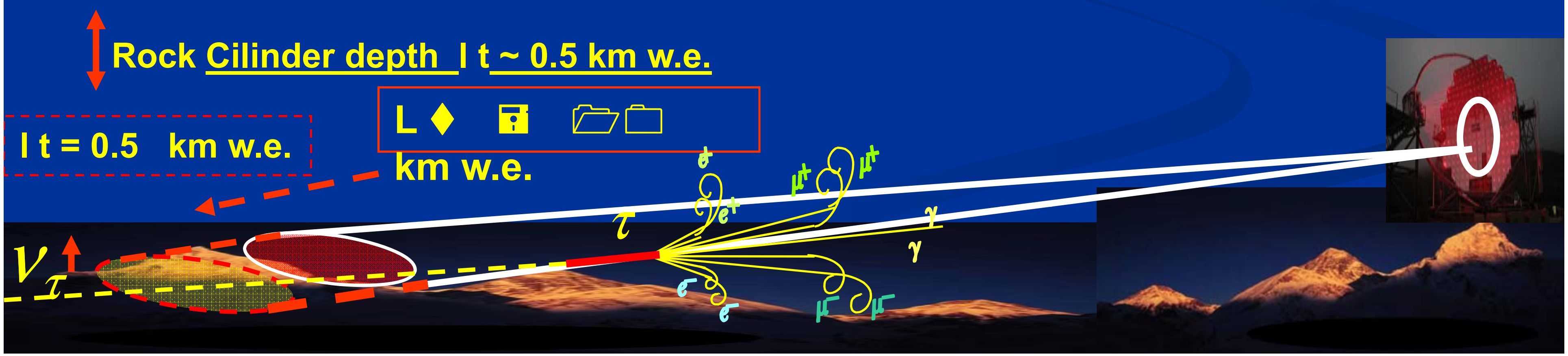
astro-ph/0511597
D. Fargion
Progh.Part.Nucl.Phys.57 (2006) 384-393.

Horizons distance d= 167 km √(h/2.2 km) Cerenkov Shower opening angle ~ 0.3°

Inclined Conic Rock Base Area A ~ 3*50 =150 km^2

Inclined Rock Cilinder depth L ♦ ~ 10 km

Rock Cilinder depth l t ~ 0.5 km w.e.



UHECR Mirror air-showers and their polarization: an Useful test for UHECR meter

- **Reflection on the Sea of UHECR air-Showers Cherenkov lights**

MAGIC , while pointing a GRB or a SGR Burst at Horizons (~ 3% of the GRB-SGRs events) behave as a km^3 NEUTRINO and

SUSY NEUTRALINO and GLUINO TELESCOPE

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

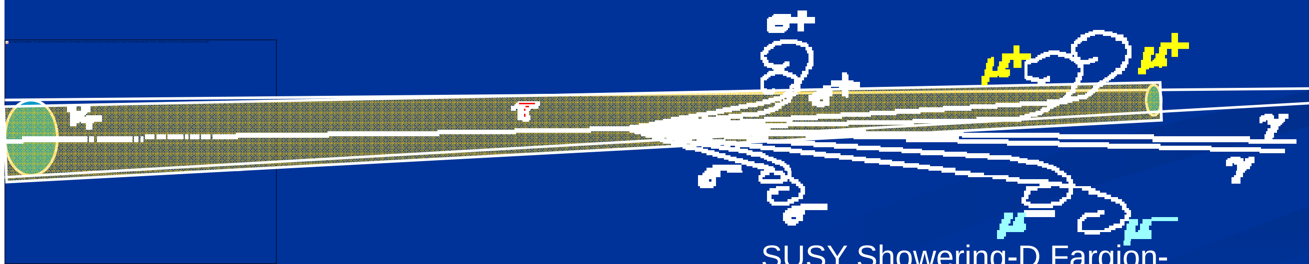
astro-ph/0505459
Neutrino Astronomy beyond and beneath the Horizons
: D. Fargion

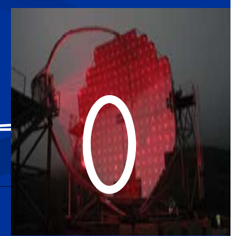
Conic Air Base Area A ~ 30 km^2

Truncate Air Cone height h ~ 100 km

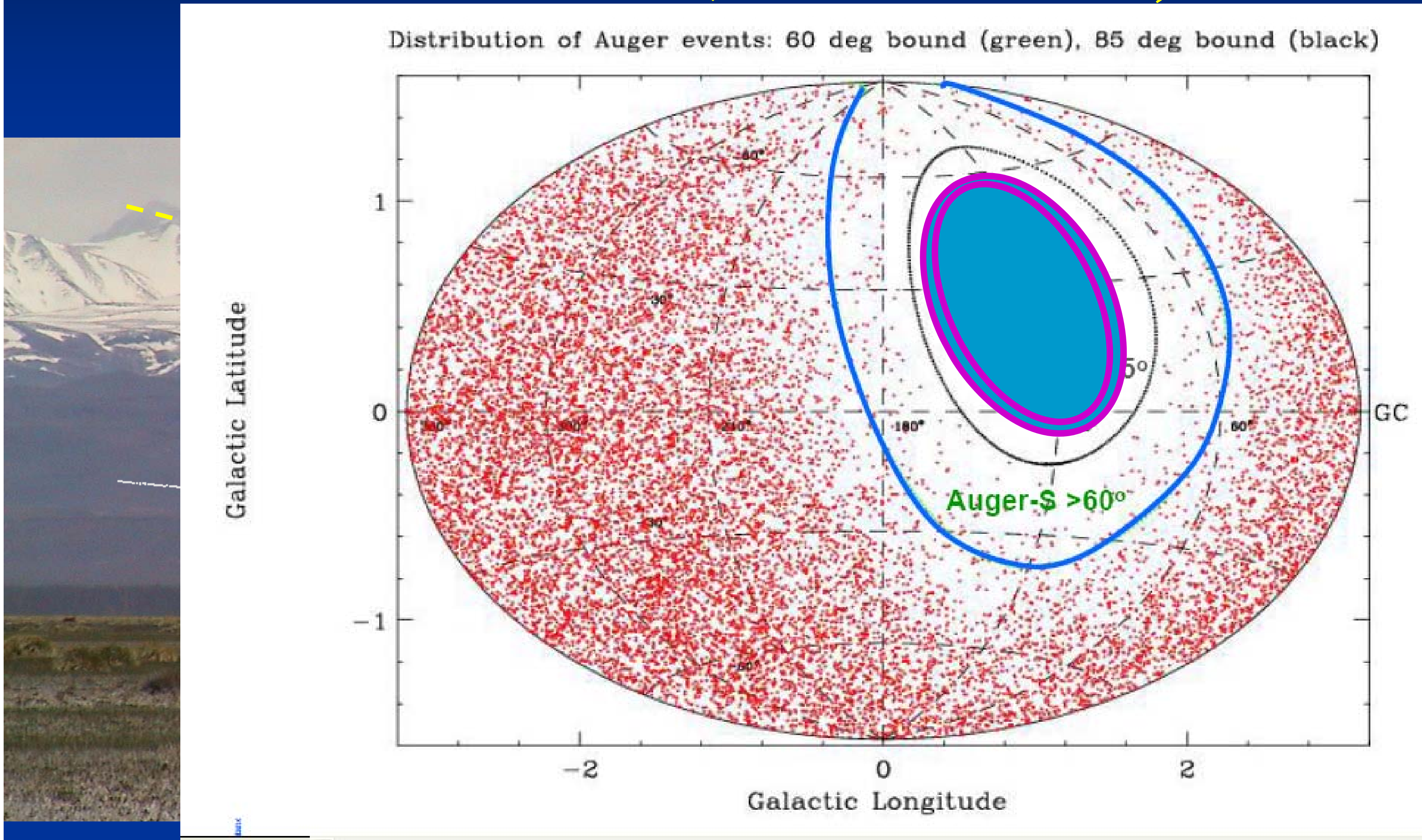
Truncate Air Cone Volume V ~ 1000 km^3

Truncate Cone Mass M ~ 1 km^3

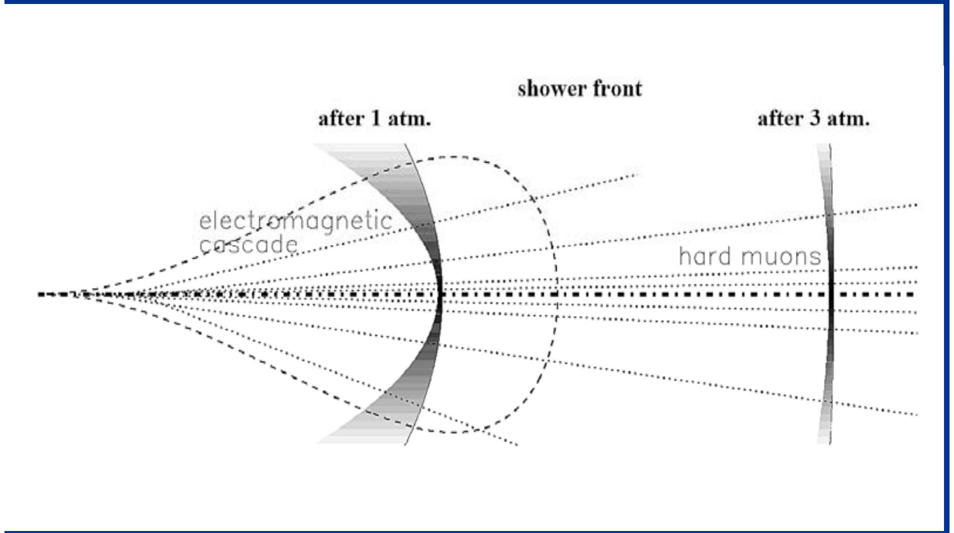


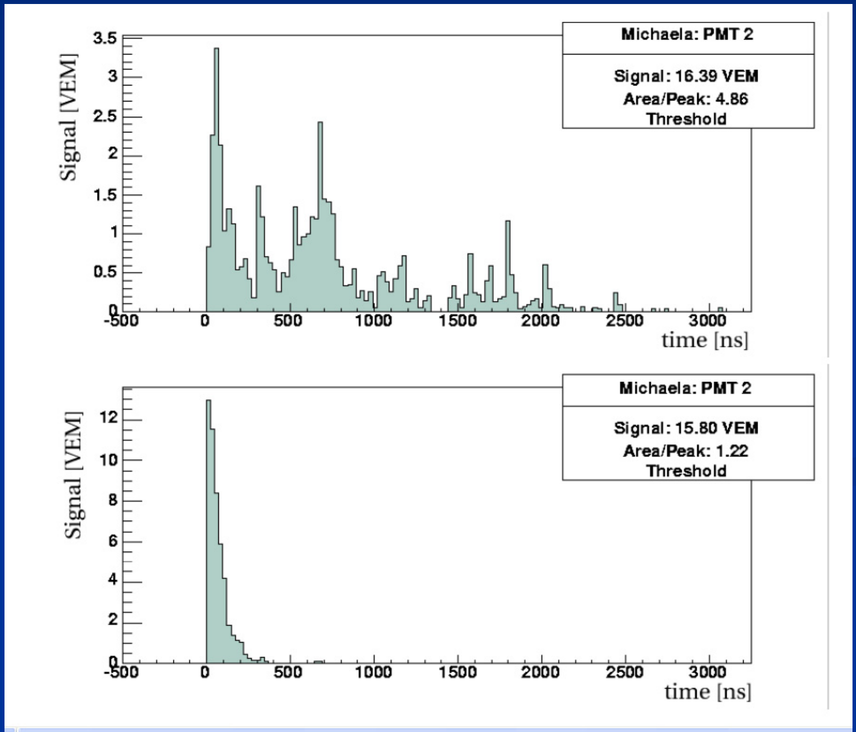


The Ande Mountains as a target for detecting UHE neutrino tau by Horizontal Tau Air-Showers at AUGER: MOON AND SUN Shadows difficult to observe- ANDE SHADOWs must be OBSERVED (within the 2008 ?)



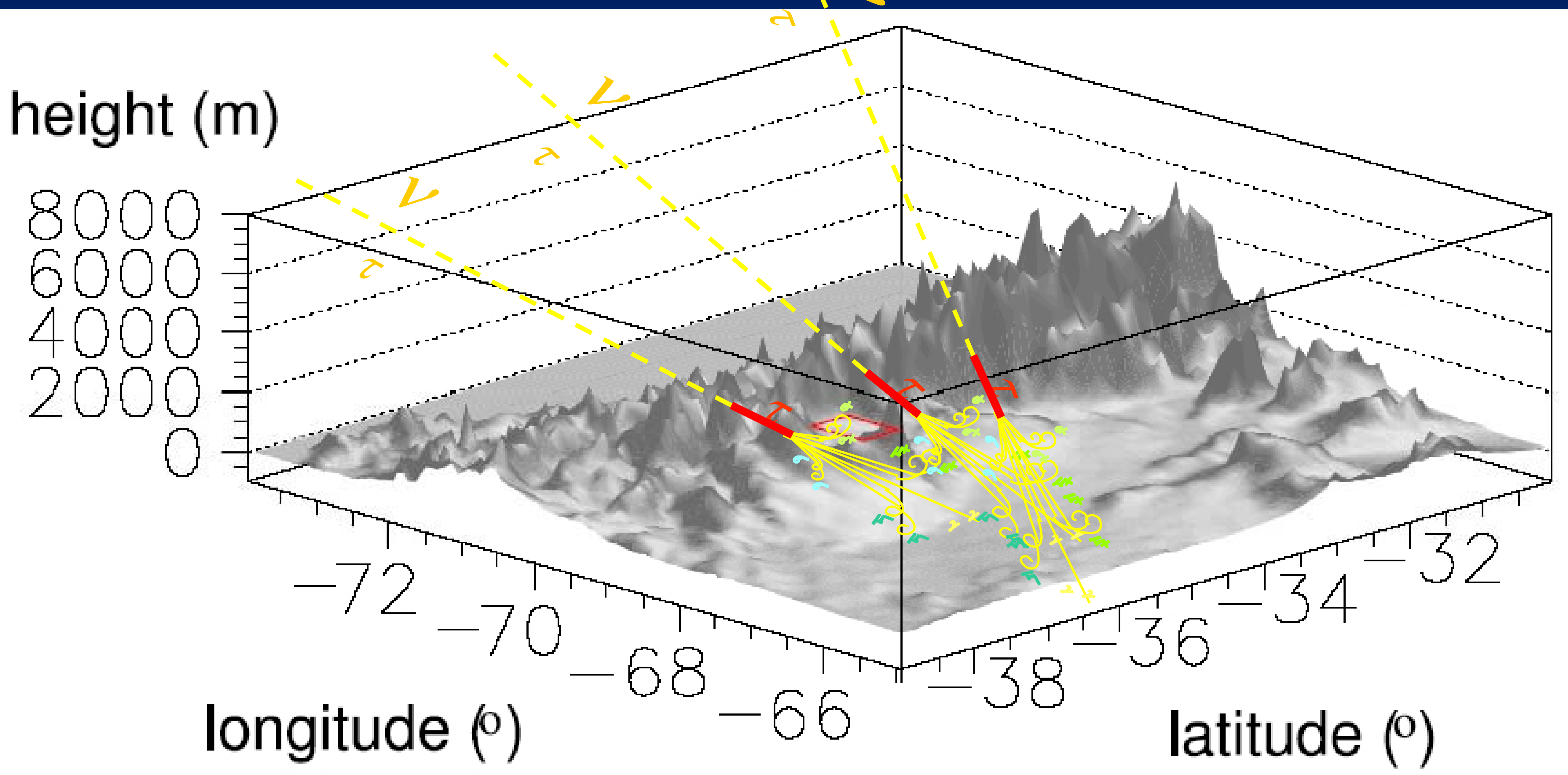
Tau Young Air-Showers versus Hadron Old ones in AUGER





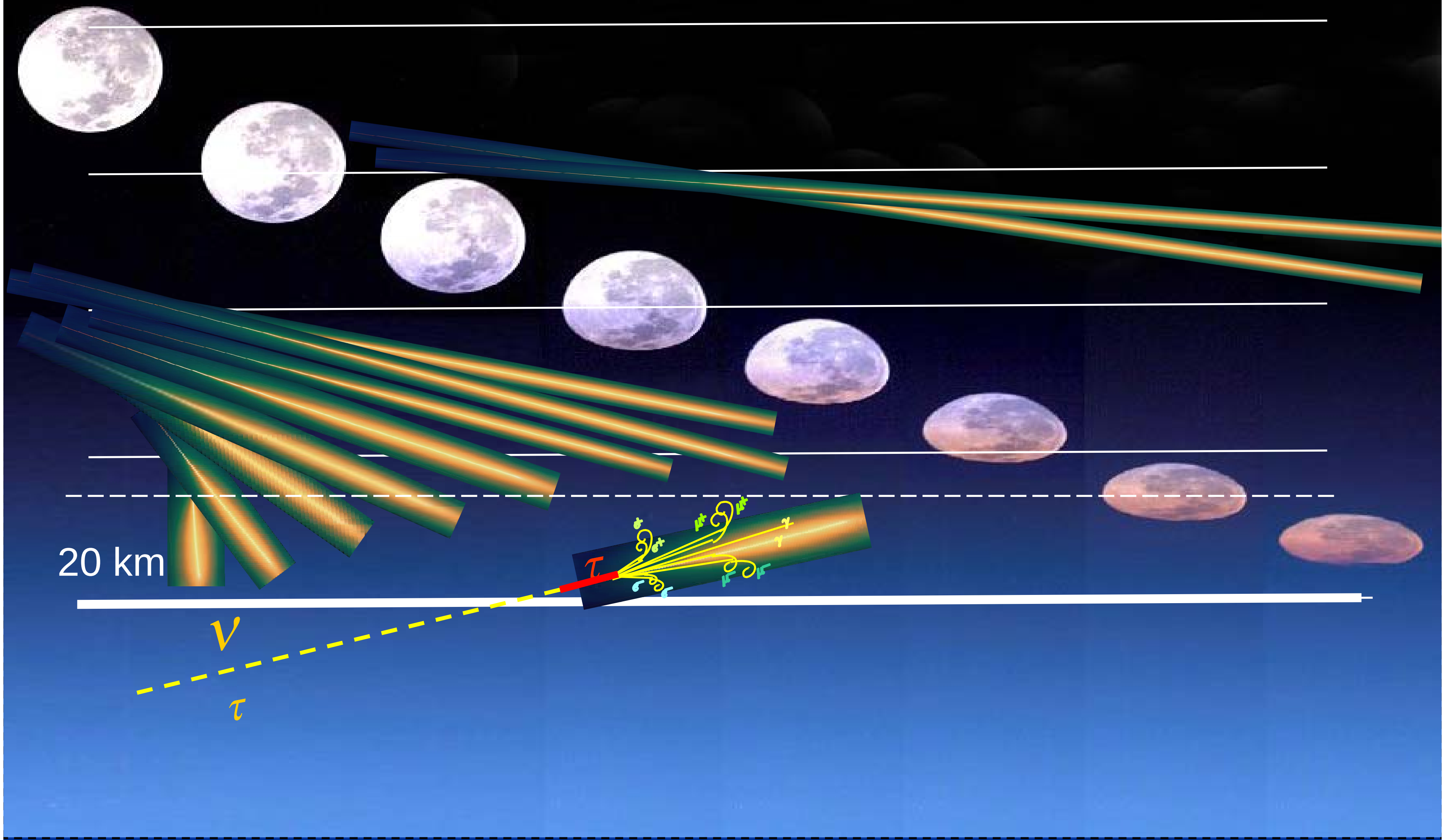
Pierre Billoir, AUGER 2006 NOW

The Ande Shadows on AUGER



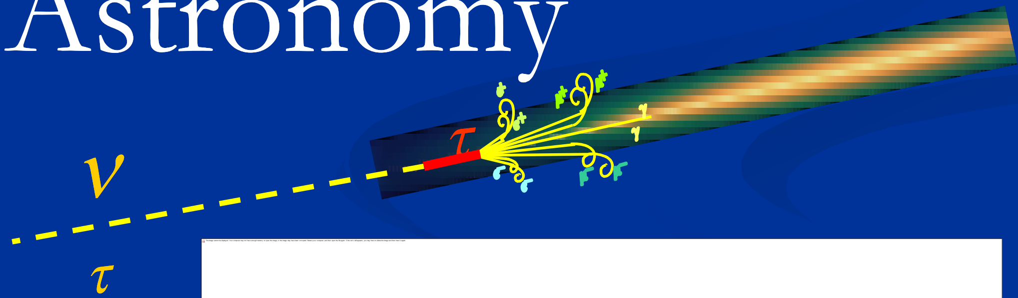
Pastor et. All 2005

AUGER SKY EDGES and THRESHOLDS

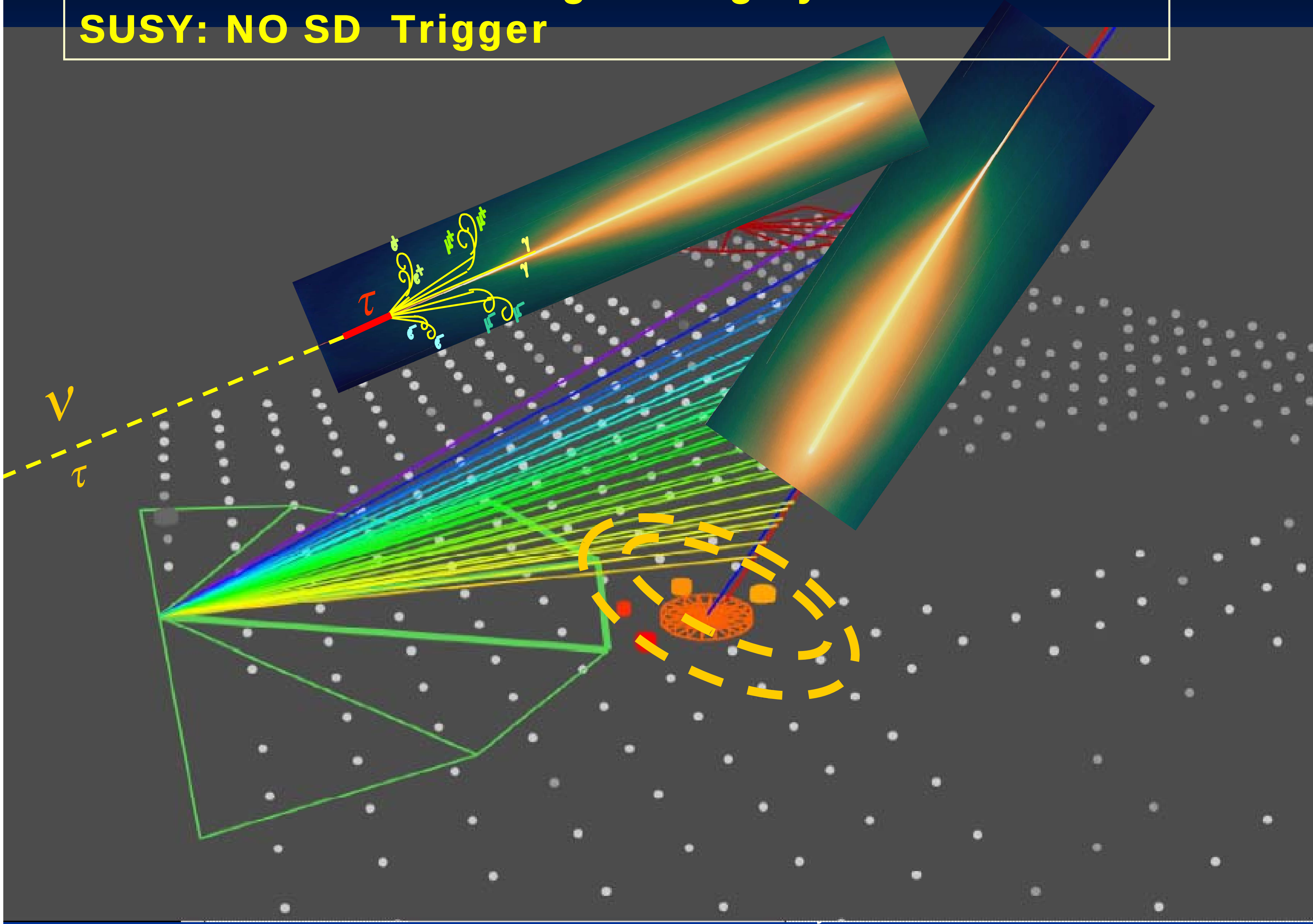


Long life Horizontal AirShowers with no Surface Detector event

- A Novel way to Neutrino and SUSY Astronomy



THE FLUORESCENCE lightening by TAU and SUSY: NO SD Trigger



Predictions

- Auger tracing Ande Shadows may reveal there an event in two years. Both Tau, Glashow and SUSY may be born

- Auger detector fine-tuned to EeV may see

Fluorescent air-showers at ten km altitude and
Should reveal Tau Air-showers at 1-2
Event a year. ALSO a few Cherenkov flash
On Clouds in Auger Sky-ALSO by SUSY sources

AUGER showering into clouds:
Tau and SUSY a few event a year

Conclusions

1. ***τ Neutrino Earth Skimming Astronomy is at the edges within the Earth horizons and within our lives.***

2. ***MAGIC and Veritas and Hess might discover taus within horizons tracing active GRB- BL Lac sources***
3. ***AUGER may and MUST.. find τ GZK in inclined events WITHIN 1-2 years from NOW:***
4. ***A DIFFERENT TRIGGER for fotopluorescent UPTAUS and HORTAUS with NO Surface Detector event : 1-2 event a year. Just beyond a corner***
5. ***SUSY may arise at Tens PeVs on MAGIC-HESS*** ***pointing at horizons or at a few degrees below the edge.***

Tau Neutrino and SUSY sky lay just beyond our own sky …the EARTH

Thank you DF