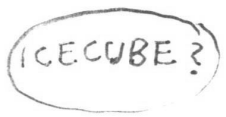
SIGNATURES OF SUPERSYMMETRY IN UNDEGROUND ν DETECTORS FROM UHECR ?



DESY THEORY WORKSHOP '04

D. FARGION
WITH B. MELE
(IN PREPARATION)

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- Observation of cosmic ray flux beyond GZK energies....
  AGASA ; Fly's Eye ...
  One of the greatest puzzles in physics to be solved....

- Many equally attractive models/proposals .....

  - Top-down models
  * primaries producing beyond GZK airshowers coming from decays of some supermassive "X" particles ....

    Important !!
    Decay life time & masses of these particles...

More on "X" particle decay.....

- Decay life time : comparable to the present age of universe...
- Masses of these heavy particles $\sim M_{GUT}$
  as they may be due to GUT symmetry breaking !!
- Density of "X" particles ....
- Distance from our universe ....
  as primaries of beyond GZK airshowers are mainly protons...
  protons have energy loss length $\sim$ 50 Mpc at these energies....

- Decays of supermassive "X" particles....
  - need of a dynamics which governs the decays (cascades....)
  - After long decay chains : end products p, γ, ν ... stable particles..

  Spectra : depends on "X" particle mass...
  (technique : Well Known; QCD fragmentation functions...)

  For SM : Sarkar, Toldra Nucl. Phys B621

Supersymmetry driven "X" decays ?
a well motivated extension of SM (do many important things...)
also provides a candidate for cold dark matter : neutralino

A natural end product with p, ν, γ of "X" decay is thus neutralino ($\tilde{\chi}_1^0$)
Berezinsky, Kachelriess PLB 422
• Barbot & Drees PLB 533

Detection of χ^0s in UHECR.....

$\chi^0 + q \rightarrow \tilde{q}_{L,R} \rightarrow q\,\chi^0$ Berezinsky & Kachelriess PLB 422 (1998)

q: from nucleons...

$\tilde{q}_{L,R}$: at resonance...

similar like $\nu N \rightarrow \nu X$, ν NC/DIS interaction...

final state hadrons have more energy....

- More recently in the context of EUSO..... Anchordoqui, Goldberg, Nath PRD 70 (2004)

  production of rather heavy (~ 1 TeV) $\tilde{q}_{L,R}$ resonances...

  → to get rid of ν-background...

Then what we want to do ?

$E_\chi^{peak} = \frac{m_r^2 - m_\chi^2}{2m_T}$

- Event rate at ICECUBE

In general : $\tilde{\chi}^0 + e^- \rightarrow \tilde{e}_{L,R} \rightarrow |f\rangle \rightsquigarrow m_T = m_e$

$\tilde{\chi}^0 + q \rightarrow \tilde{q}_{L,R} \rightarrow |f\rangle \rightsquigarrow m_T = m_p/m_n$

But remember : $\sigma_{peak} = \frac{8\pi}{m_r^2} \left(\frac{m_r^2}{m_r^2 - m_{\tilde{\chi}^0}^2}\right)^2 Br(\tilde{e},\tilde{q} \rightarrow e,q + \tilde{\chi}^0)\ Br(\tilde{e},\tilde{q} \rightarrow f)$

We stick to mSUGRA....

$Br(\tilde{e}_L, \tilde{q}_L \rightarrow \tilde{\chi}^0 + e,q)$ is considerably small compared to $\tilde{e}_R, \tilde{q}_R$ ....

$Br(\tilde{e}_R \rightarrow e\,\tilde{\chi}^0) \sim 1$ always.... mass ordering of $\tilde{e}_R$ / nature of $\tilde{\chi}^0$ ....

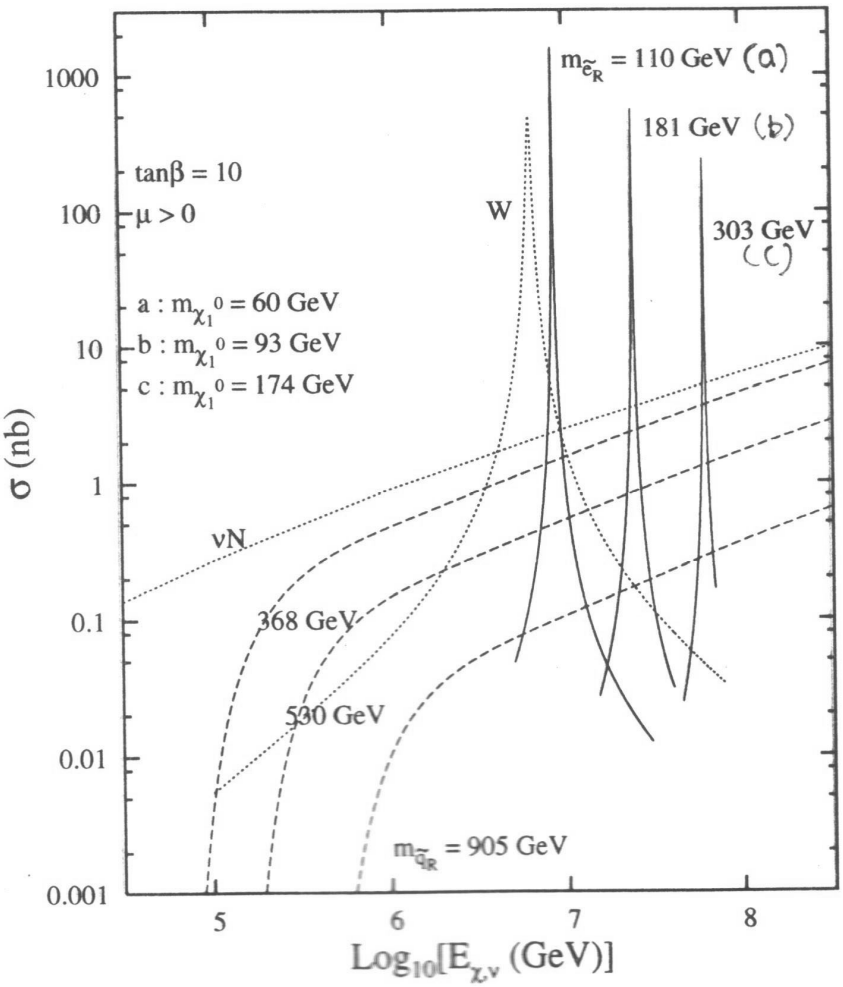
$Br(\tilde{q}_R \rightarrow q\,\chi^0) \sim 1$ $m_{\tilde{q}} < m_{\tilde{g}}$ (not a very unrealistic choice....)

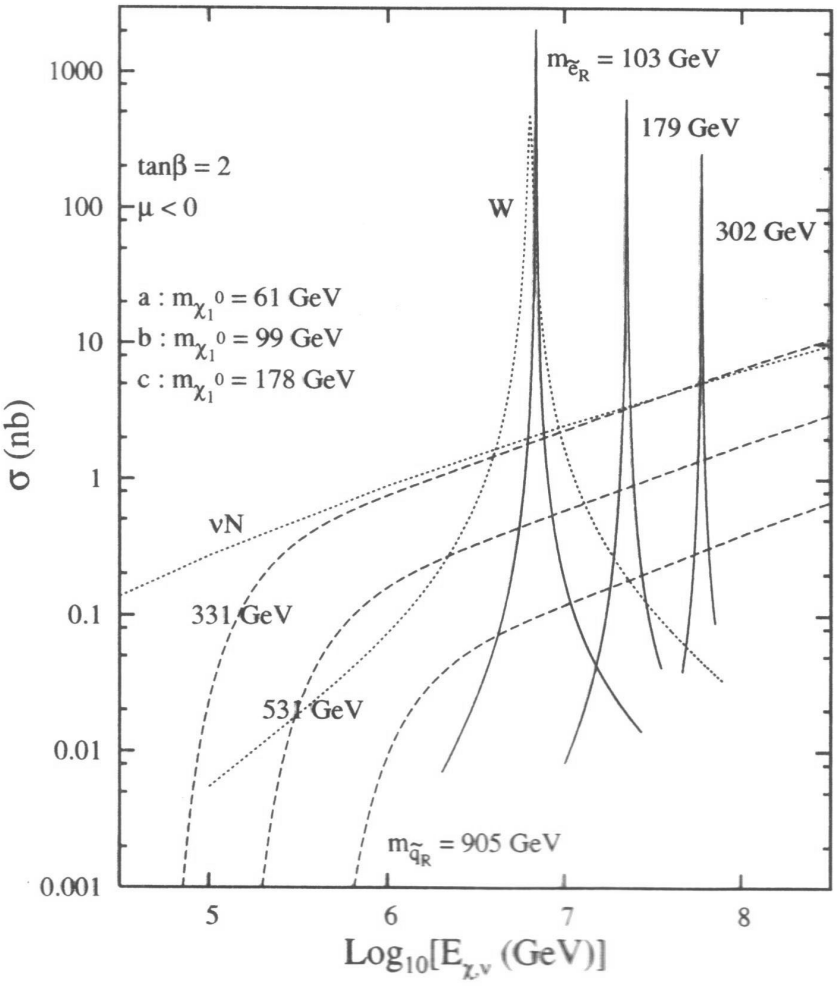
So our estimate of # of events are conservative side...

Let us look at some results...

- Height of the peaks are not only important qty.
- $\bar{\nu}_e + e^- \rightarrow W^- \rightarrow$ visible
  $\nu + N \rightarrow \nu, l + X$
  } backgrounds ....

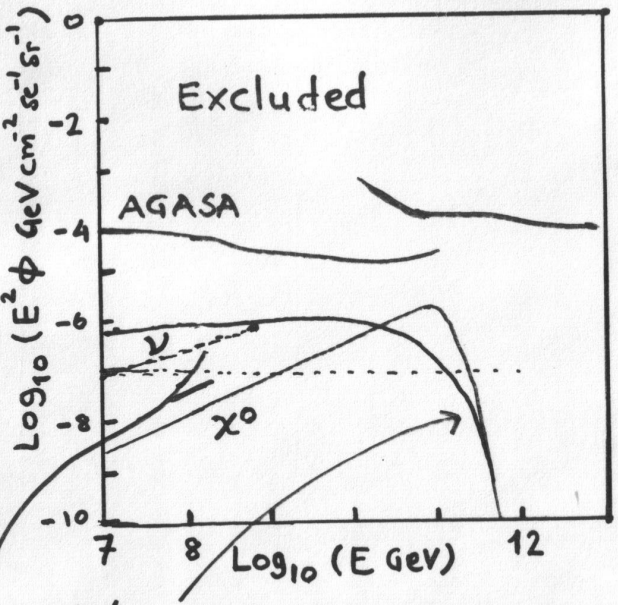
  $\rightarrow \sigma_\nu (NC + CC) = 8 \times 10^{-3}$ nb $\left(\frac{E_\nu}{1\,GeV}\right)^{0.36}$ Gandhi et al.




1000
100
10
1
0.1
0.01
0.001
σ (nb)
tanβ = 2
μ < 0
a : m$_{\chi_1^0}$ = 61 GeV
b : m$_{\chi_1^0}$ = 99 GeV
c : m$_{\chi_1^0}$ = 178 GeV
m$_{\tilde{e}_R}$ = 103 GeV
179 GeV
302 GeV
W
νN
331 GeV
531 GeV
m$_{\tilde{q}_R}$ = 905 GeV
5
6
7
8
Log$_{10}$[E$_{\chi,\nu}$ (GeV)]

➡ <u>One caveat concerning $\tilde{x}^0$-flux.....</u>

no existing experimental bound on $\tilde{x}^0$-flux...



x^0/ν flux from Drees, Barbot

$M_X = 10^{12}$ GeV

Only existing bound on UHE-ν flux ----

assuming : $\sigma(\nu N) \sim \sigma(x^0 N)$

Limits on $\phi_\nu \rightarrow \phi_{x^0}$

Apart from that :

ν-flux (e.g. Drees) : Highly model dependent...

e.g. <u>assumes no relevant physics between m_X & 1 TeV</u>

$$E^2\phi_x = \underline{10^{-6}\ \text{GeV cm}^2\ \text{sec}^{-1}\ \text{sr}^{-1}\left(\frac{E_x}{10^9\ \text{GeV}}\right)^{0.5}} \leftarrow$$

$$= \underline{10^{-7}\ \text{GeV cm}^2\ \text{sec}^{-1}\ \text{sr}^{-1}} \leftarrow$$

We do not strictly follow Drees flux....

• Number of events ..... $N = N_T \Delta t \int \sigma_{\tilde{f}}(E_\chi) \frac{dN}{dE_\chi} dE_\chi$

(Km^3 ICE / 1 year)

$N_{\tilde{e}} = N_\bullet \sigma^{e_R}_{peak} \Gamma \left(\frac{m_{\tilde{e}_R}}{2m_e}\right) E^{-\beta}_{peak}$

$N_{\tilde{q}} = \tilde{N}_\bullet \int_{E_{min}} \sigma^{q_R}(E)\, E_\chi^{-\beta}\, dE_\chi$

$\phi_\chi = 10^{-7}$ GeV cm^2 sec^{-1} sr^{-1}

$\phi_\chi = 10^{-6}$ GeV cm^2 sec^{-1} sr^{-1} $\left(\frac{E_\chi}{10^9 GeV}\right)^{0.5}$

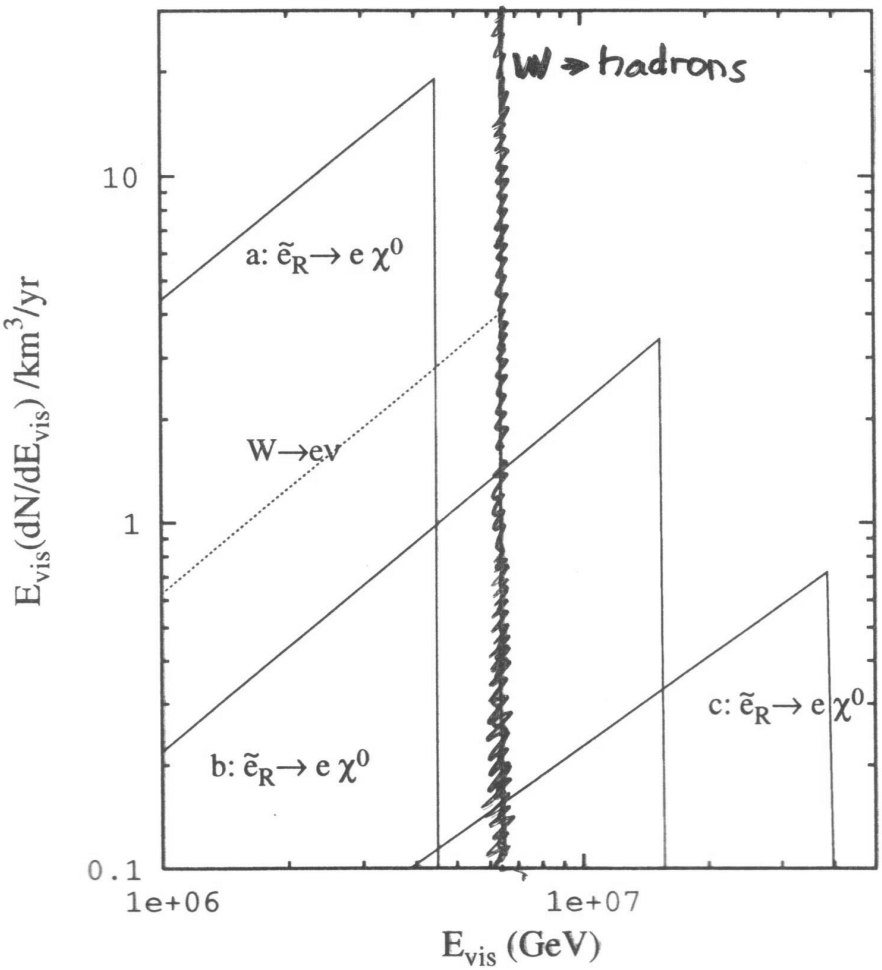
$m_{\tilde{e}_R}$	$m_{\tilde{q}_R}$	$m_{\chi_\bullet}$	$N_{\tilde{e}_R}$	$N_{\tilde{q}_R}$
103	331	61	23	4
			19	2.3
179	531	99	2.3	0.6
			3.4	0.5
302	905	178	0.3	0.07
			0.8	0.1
260	432	69	0.28	1.45
			0.7	1
363	611	100	0.08	0.37
			0.26	0.33

$\tan\beta = 2$ (not very important !)

Backgrounds from W^- : 30 (24) hadronic channel 5 (4) in electronic channel...

from νN (CC+NC) : 70 (50) events $E_\chi > 10^{5.5}$ GeV

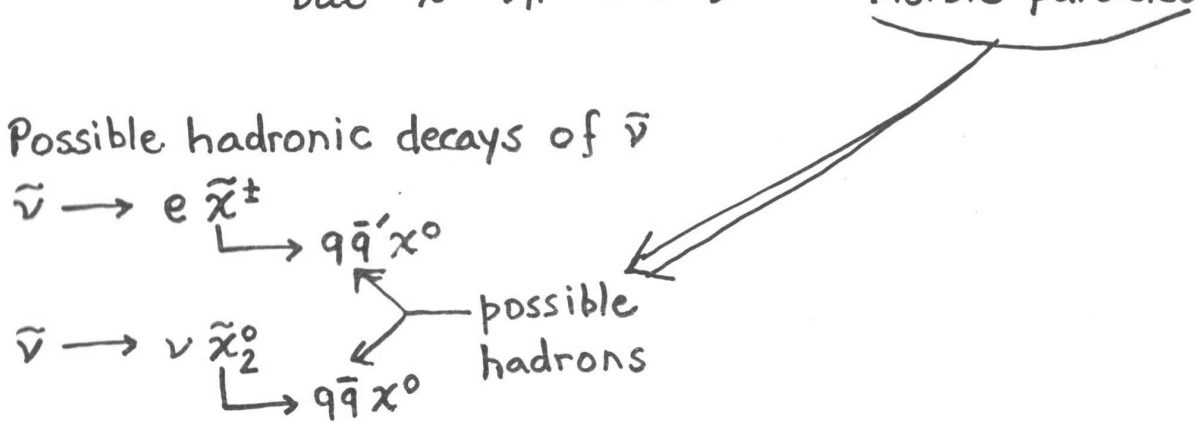
How the visible spectra look like . . .
typical two-body decay . . . .



Beyond GZK : A possible $\tilde{\nu}$-burst ?

- Similar to Z-burst :

but $x^0 \nu_r \longrightarrow \tilde{\nu} \longrightarrow$ visible particles



Possibly less energetic than hadrons from Z-decay....
(depends on masses of the particles in cascade)

Z-burst vis-a-vi $\tilde{\nu}$-burst ...

- Crucial $m_\nu = 0.1$ eV

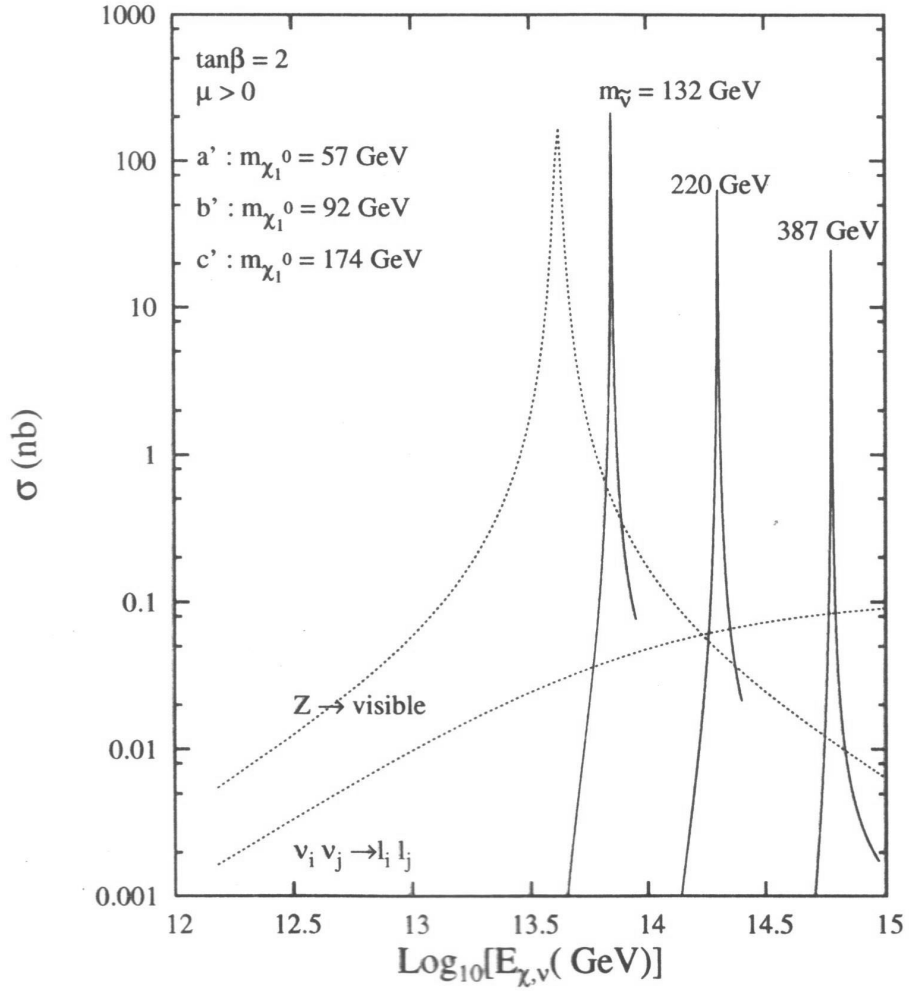
$m_{\tilde{\nu}}$	m_{χ^0}	σ^{peak}	$\Gamma_{\tilde{\nu}}$	B^{vis}
132	57	212 nb	0.37 GeV	0.46
220	92	64	0.60	0.47
387	174	25	0.59	0.42
269	170	22	2.53	0.72
383	93	11	3.29	0.70

For Z-decay

$\sigma^{peak} = 200$ nb

$\Gamma_Z = 2.5$ GeV

$B^{vis} = .80$



$$E_\chi^{peak} = \frac{m_{\tilde{\nu}}^2 - m_{\chi^0}^2}{2m_\nu}$$

$$E_\nu^Z = \frac{m_Z^2}{2m_\nu}$$

To summarise.....

- UHE neutralinos are natural end products of superheavy particle decay models of UHECR beyond GZK-energies...
- We have calculated events rate corresponding to $\tilde{e}_R$ and $\tilde{q}_R$ production at resonance from UHE-$\tilde{\chi}_0$ interaction in underground ν-detector like ICECUBE
- Events rates are small unless the $\tilde{e}_R$-masses are close to their present expt. limits... (only shadows of SUSY ?)
- UHE-χ^0 can produce $\tilde{\nu}$-resonances interacting with relic-ν... a similar process like Z-burst..
- Again $\tilde{\nu}$-burst events are small compared to Z-burst, producing less energetic visible particles on the average.....