Detecting UHE ν_τ's with the Auger Observatory

(if ν_μ oscillate ...)

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- Sources of Ultra High Energy Neutrinos
- The Auger Observatory
- Atmospheric Showers
- Atmospheric vs Terrestrial Neutrino Interactions
- Ingredients of the simulation
- Background rejection
- Acceptance and expectable rates

Neutrinos above 10^{17} eV

- **byproducts of acceleration mechanisms**
  (photoproduction of mesons)
  - Interaction with the medium of the source (AGN,...) :
    depends on model
  - Interaction with the CMBR ("GZK" neutrinos) :
    should exist if far sources

- **top-down processes**
  Decay of supermassive objects $\rightarrow$ fragmentation in hadrons
  speculative ; various models
  generally : relatively hard spectrum
  ν *and* γ *dominate*

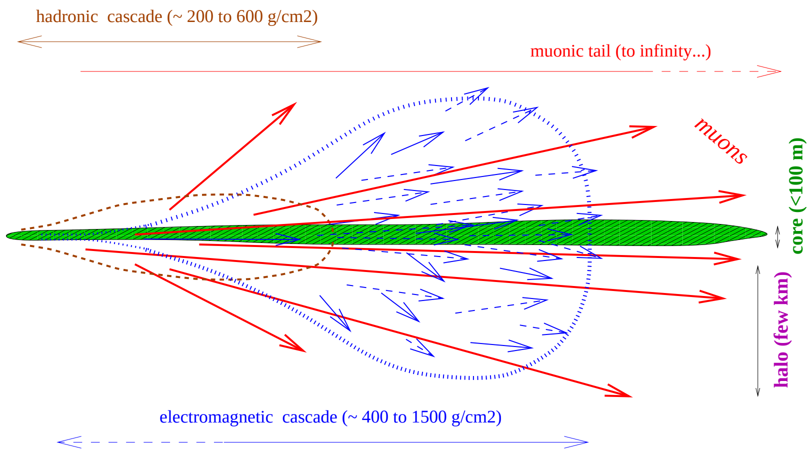
expected fluxes around 1 EeV (10^{18} eV)

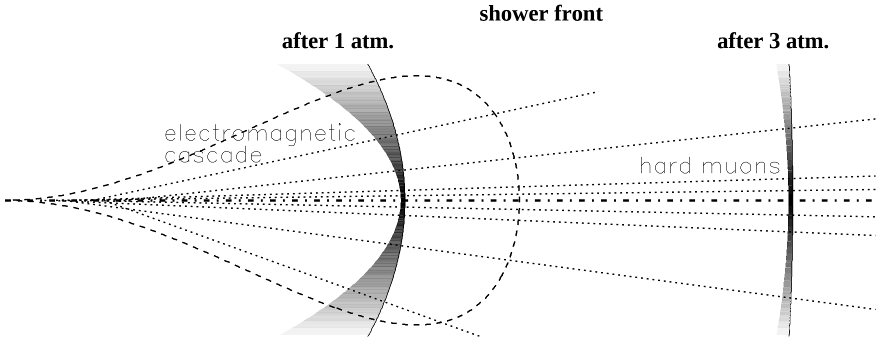
$E^2\, dI/dE =$ a few 10^{-8} GeV.cm^{-2}.s^{-1}.sr^{-1}

($\sim$ 10 EeV.km^{-2}.yr^{-1}.sr^{-1})

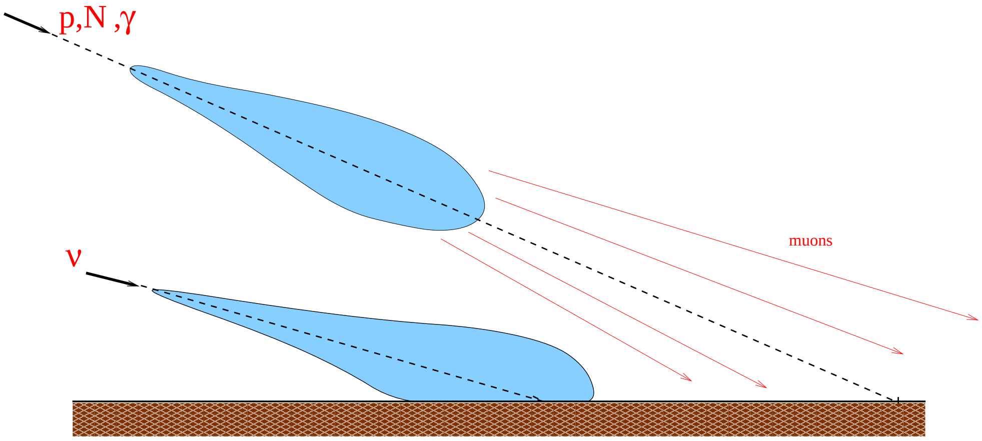
or more in speculative models...

Atmospheric Showers





discrimination of deep showers



Atmospheric vs terrestrial

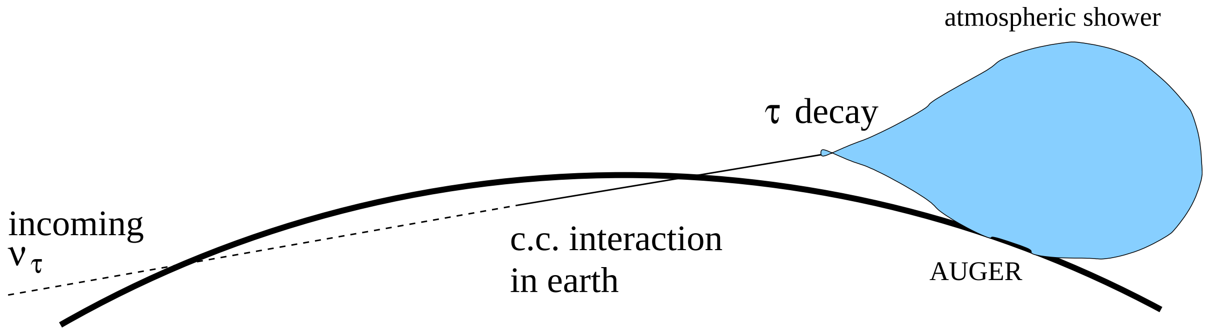
at the source : very few ν_τ $\nu_e : \nu_\mu \simeq 1 : 2$

atmospheric interactions : probability 10^{-5} to 10^{-4}
detection of the *hadronic* shower ($\simeq 1/4$ of initial energy)
$+$ *electromagnetic* if c.c. interaction of ν_e
$\rightarrow$ *poor sensitivity* $(E^2 \times flux \sim 100$ EeV.km^{-2}.yr^{-1}.sr$^{-1})$

if $\nu_\mu \leftrightarrow \nu_\tau$ oscillations with maximal mixing

$\nu_e : \nu_\mu : \nu_\tau \simeq 1 : 1 : 1$

the channel $\tau \rightarrow \nu_\tau \rightarrow$ *decay* is competitive!



at 1 EeV :

$L_{int} \simeq 500$ km $L_{dec} \simeq 50$ km $L_{Eloss} \simeq 30$ km (or less ?)

$++$ much higher probability of interaction

$-$ acceptance limited to $\simeq 2$ degrees above horizon

Globally : **more** events expected
(mainly up-going, plus a few down-going from the Andes)

not yet studied : detection of fluorescence
probably less efficient (10% duty time, limited visibility at low energy)

Ingredients for simulation

- τ **decay** into
  $e^{\pm}$ / $\mu^{\pm}$ / $\pi^{\pm}$ /$\pi^{\pm}\pi^{0}$/$\pi^{\pm}\pi^{+}\pi^{-}$/$\pi^{\pm}2\pi^{0}$/$\pi^{\pm}\pi^{+}\pi^{-}\pi^{0}$/$\pi^{\pm}3\pi^{0}$
  18 / 17 / 11 / 25 / 10 / 10 / 6 / 3 %
  simplified "realistic" kinematics, but : no polarization effects

- **interactions** in earth ($< A >= 22$, $\rho = 2.15$ g.cm^{-2})
  $\sigma_{cc} = 10^{-32}\,\mathrm{cm}^2 \times {E_{18}}^{0.363}$; $\sigma_{nc} = 0.4\,\sigma_{cc}$
  tabulated distribution in y ($< y >= 0.24$)

  continuous **Energy loss** $dE/dx = -b.E$ with 3 options :
  (uncertainty on DIS in photonuclear interaction at UHE)
  – Brems + pair production : $b = 1.5 \times 10^{-7}\,\mathrm{cm}^2.\mathrm{g}^{-1}$
  – B + PP + "low" ph-nucl DIS : $b = 2.5 \times 10^{-7}$
  – B + PP + "high" ph-nucl DIS : $b = (1.5 + 6\,{E_{18}}^{0.2}) \times 10^{-7}$
  (cf Iyer Dutta et al., Phys. Rev. D63 (2001))

- **shower** development : program AIRES
  (including upgoing particles, LPM effect)
  $\rightarrow$ set of weighted ground particles (*thinning* algorithm)

- **detector** response : regeneration of particles, Cherenkov emission and collection in water tanks

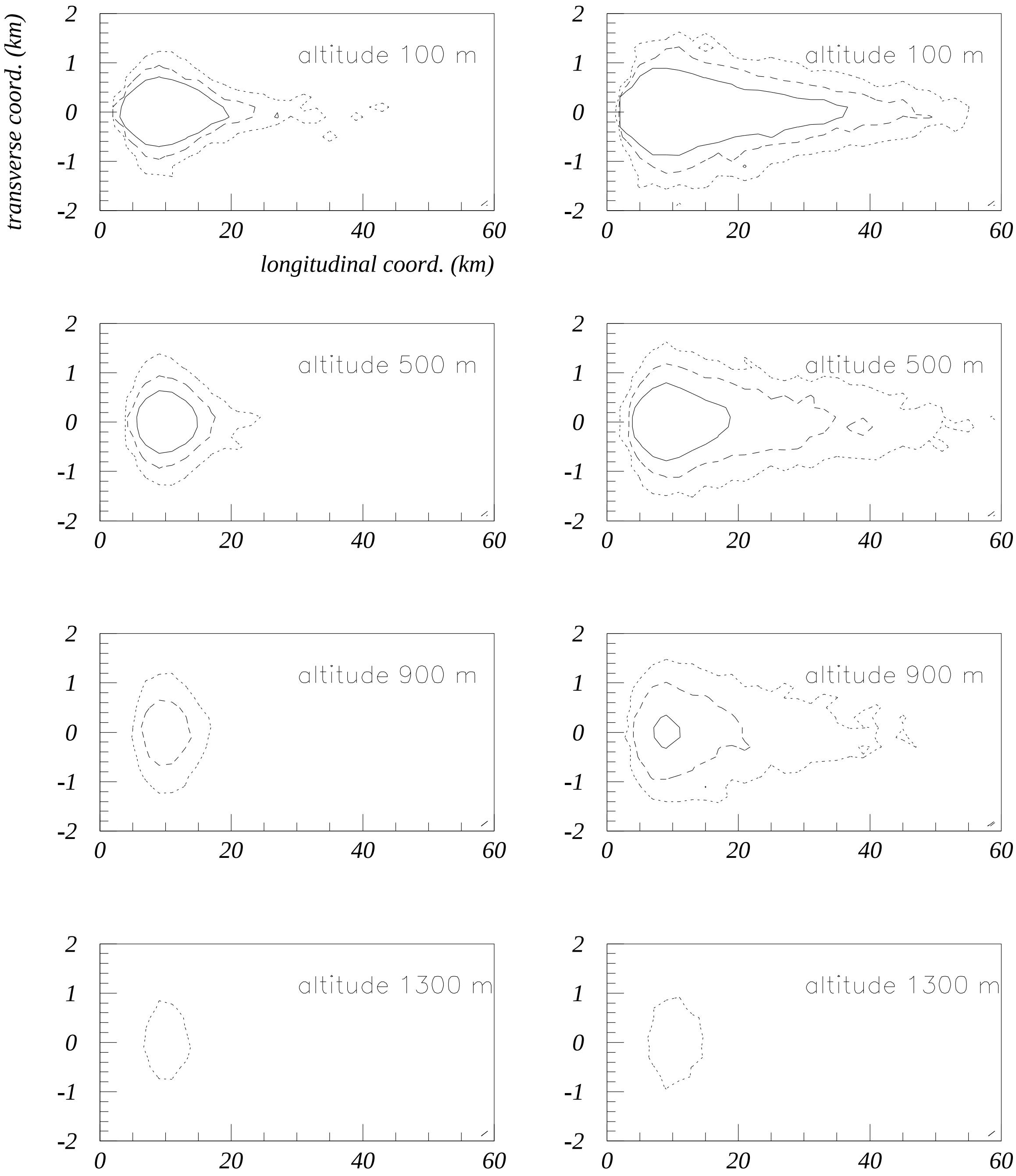
- **local trigger** (*standard*) : signal > 4 vertical equivalent muons ($\simeq$ 1 GeV deposited)

- **global trigger** (*standard*) : at least 4 stations (in a relatively compact topology)

Ground spot of horizontal showers

with $E_\tau = 0.8$ EeV (averaged on 10 decays)

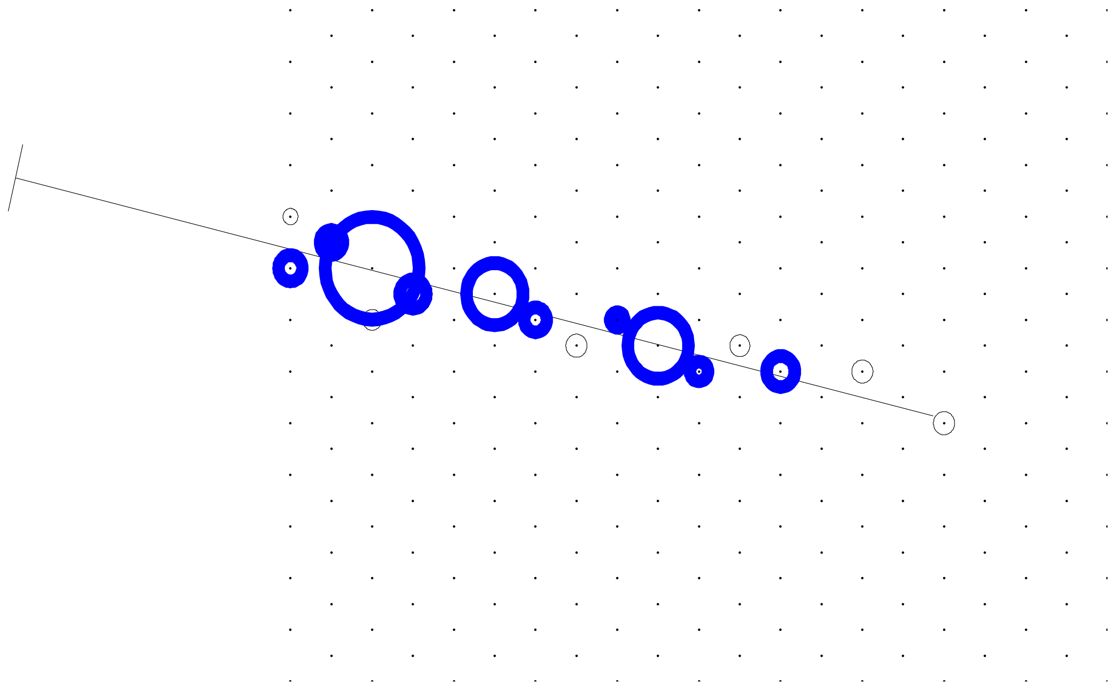
$\tau^\pm \to e^\pm \nu\nu$ $\tau^\pm \to \pi^\pm \nu$



Levels of averaged signal in tanks :

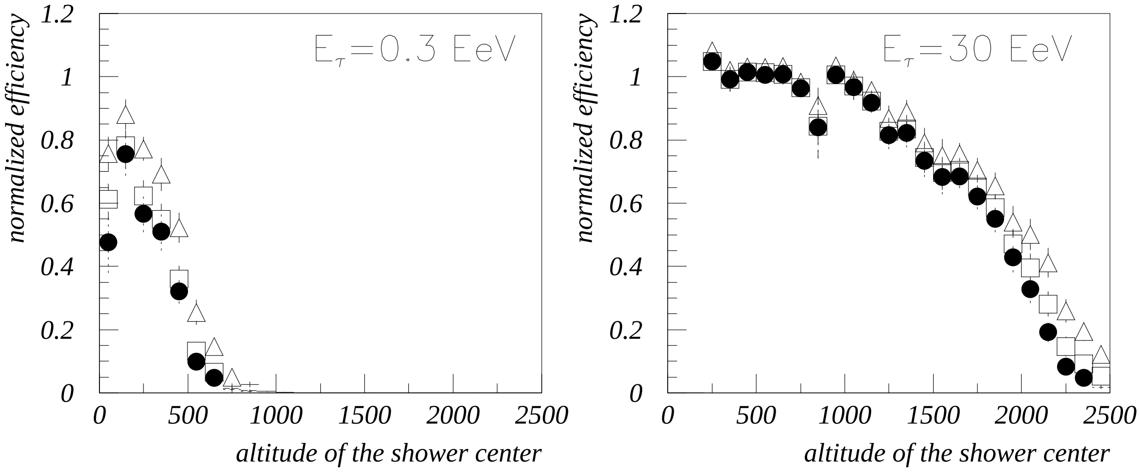
solid : local trigger ; dashed : 1/3 ; dotted : 1/10

one horizontal event at low altitude



straight line : shower axis (first 20 km after the decay)
blue circles : stations locally triggered
(area proportional to the integrated signal)

probability of detection vs altitude



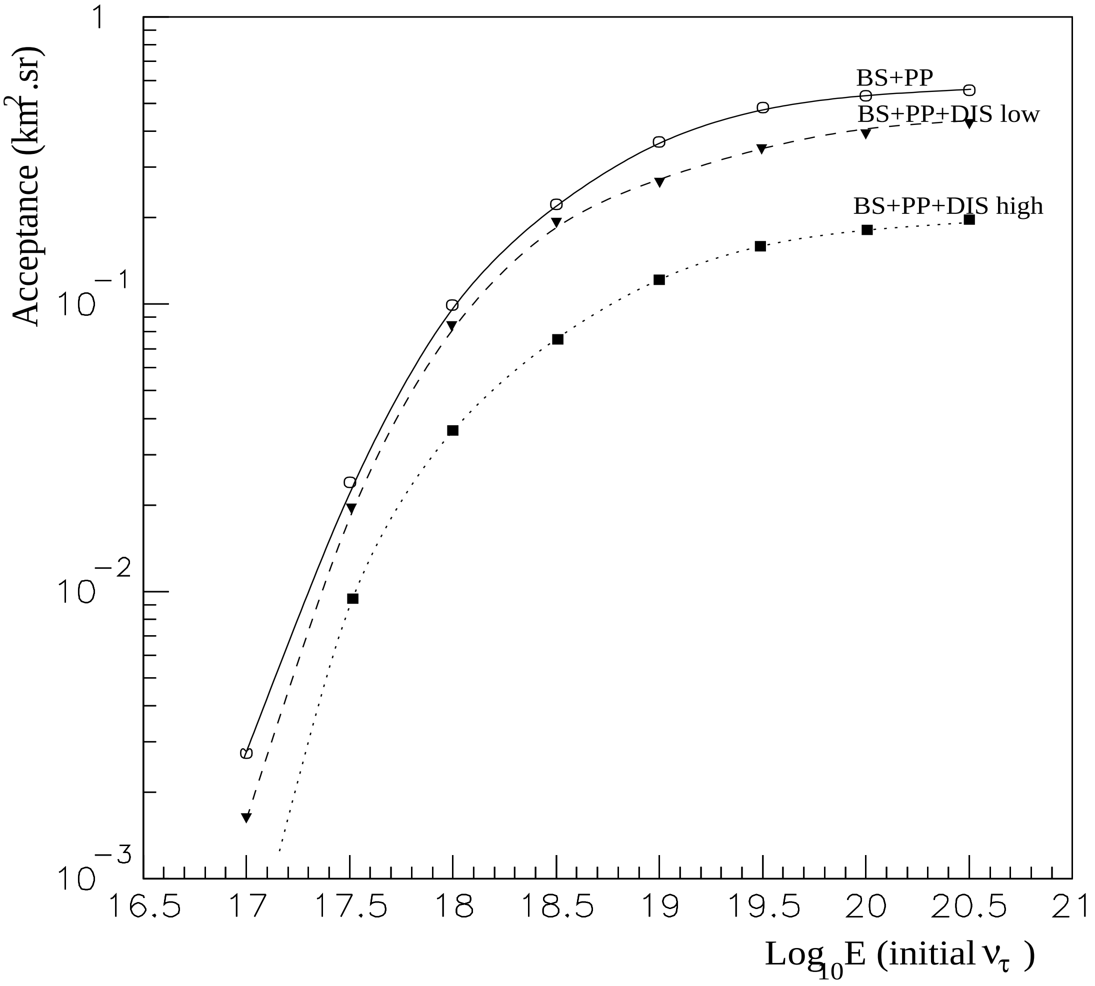
(shower center : 10 km after the decay)

Background rejection

- alignment : t_{start} in the stations is compatible with a front plane moving at speed c, within 100 ns $\rightarrow$ rejection of random coincidences
- time spread : e.g. requesting $t_{10\rightarrow 90} > 150$ ns removes **both** the uncorrelated signals (single muons or mini-showers) **and** the muonic tail of "normal" showers

hopefully : background reduced well below 1 event/year

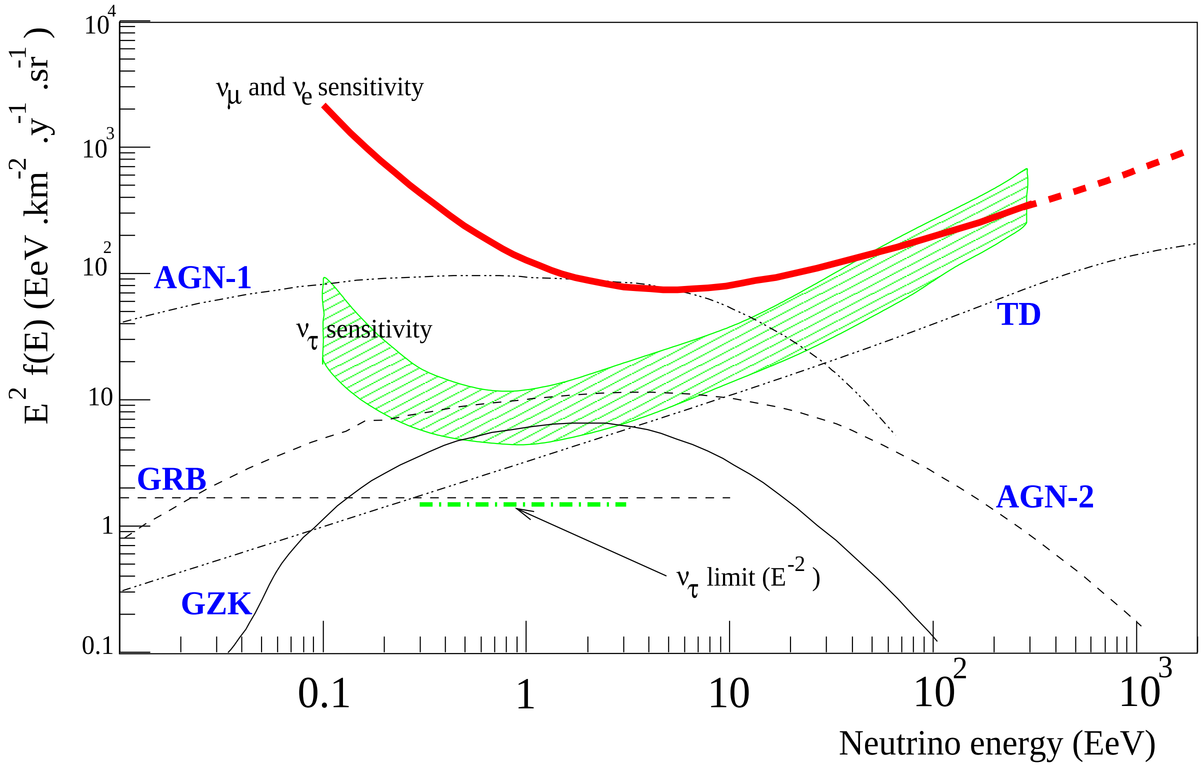
Acceptance



Sensitivity

(Isotropic flux giving 1 event / year / energy decade)

models extracted from Protheroe (astro-ph/9809144)



lower edge : B + PP ; upper edge : B + PP + ph-nucl(high)

dash-dotted : upper limit (90% C.L.) after 5 years, with a flux in $1/E^2$ ("low edge" option)

Annual rates

	AGN-1	TD	GRB	GZK	AGN-2
no ph-nucl	27.0	2.3	0.5	1.7	2.9
low	24.0	1.8	0.4	1.5	2.5
high	10.0	0.8	0.2	0.6	1.1

Conclusions

- if $\nu_\mu \leftrightarrow \nu_\tau$, improvement of neutrino sensitivity around 1 EeV (10^{18} eV) by a factor 10 to 30
- $\sim$ 1 event/year expected from "almost sure" sources (esp. GZK)
  crucial test for speculative models
- large sky coverage : $\simeq$ 80 % with northern+southern sites
  (not included : polar regions)
- direction may be reconstructed (precision $\sim$ 1 deg)
  $\rightarrow$ search for *correlation to clusters of UHECR* (if they are confirmed...)
- there are still theoretical uncertainties...