STUDY OF EUSO SENSITIVITY

- Efficiencies and discrimination for P , ν (with cherenkov detection)
- Number of events expected from various models and event topology
- Upward τ neutrinos events and their observability with EUSO
- .....

Code : ELEP , UNISIM

BIBLIOGRAPHY

- http://hep.fi.infn.it/AIRWATCH/doc.html (2 thesis in Italian)
- F. Becattini, S. Bottai Astr. Phys. 15 (2001) 323
- ICRC 2001 he247 , he180
- INFN report (In preparation)

S. Bottai (INFN Florence)
Annecy 10/01

UNISIM GENERAL CHARACTERISTICS

- **FAST UNIDIMENSIONAL SHOWER SIMULATION**
- **HYBRID METHODS : FULL MC SIMULATION FOR E>Eth , PARAMETRIZATION FOR E<Eth. Good reproduction of fluctuations with Eth=10^{17}eV**
- **LPM EFFECT INCLUDED**
- **NEUTRINO SIMULATION OF EHE NEUTRINO INTERACTIONS**
- **SIMULATION OF EMISSION AND PROPAGATION OF FLUORESCENCE AND CHRENKOV LIGHT**

- **SIMPLE AND "IDEAL" DETECTOR SIMULATION WITH VARIABILITY OF DETECTOR PARAMETERS**

ELEP

(EXTREME ENERGY LEPTON PROPAGATION)

ELEP performs a Monte−Carlo propagation of neutrinos and charged leptons through the Earth. It can be used also as a MC tool for neutrino interactions and lepton propagation

- Neutrino cross sections (CC+NC) calculated from various parton distributions q(x) (now CTQE3−DIS) extrapolated for $x<10^{-5}$. Interactions stochastically simulated according to total and differential cross sections

- Muon and tau anergy loss from Bremm. , Pair Prod , Phonucl. Interactions. continuos loss for $dE/E < 10^{-3}$ and stochastic for $dE/E > 10^{-3}$

- TAU decay using TAUOLA library

UNISIM AND ELEP IN THE FUTURE OFFLINE SOFTWARE SCHEME

UNISIM → Use the fast alghoritm of shower development as parallel option to full MC

ELEP → Library for lepton interaction and propagation to be interfaced with UNISIM, CORSICA , AIRES , GILL , ...

(COMPLETELY NEW VERSION READY IN FEW WEEKS)

FOR PRESENT STUDY

DETECTOR (ideal) :

detector altitude = 380 km

FOV=60 deg

Dpupill = 2 m

Q.E. = 0.18

Detector total absorption = 0.5

pixels size at ground = 1 km^2

no point spread

ATMOSPHERIC TRANSPORT (ideal):

no clouds

only rayleigh + ozone (light absorption depending on single photon path)

TRIGGER :

≥4 P.E in 800 ns in 1 pixel −−> 1 hit

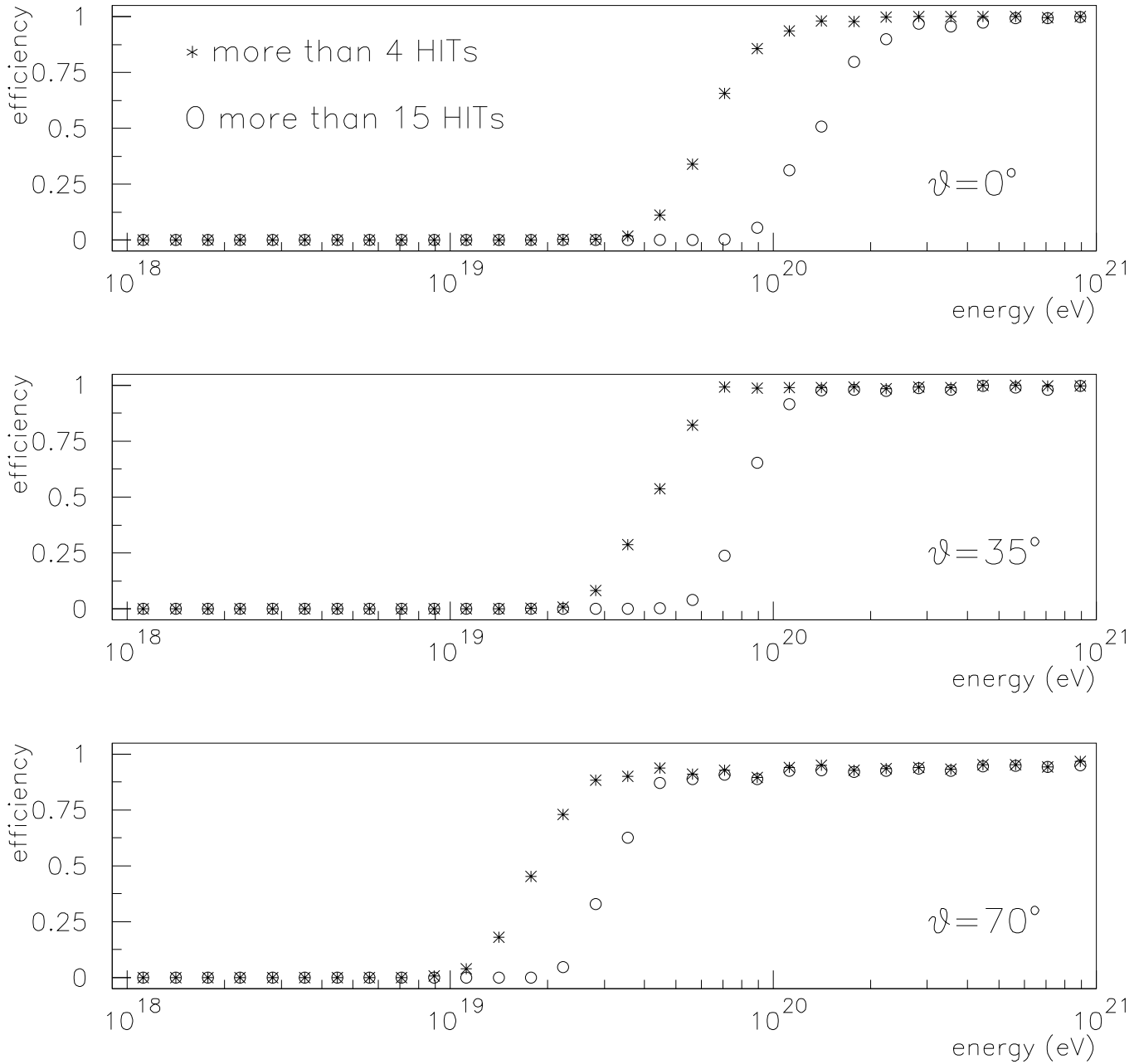
1 event −> ≥ 4 hit (15 hit)

CHERENKOV LIGHT

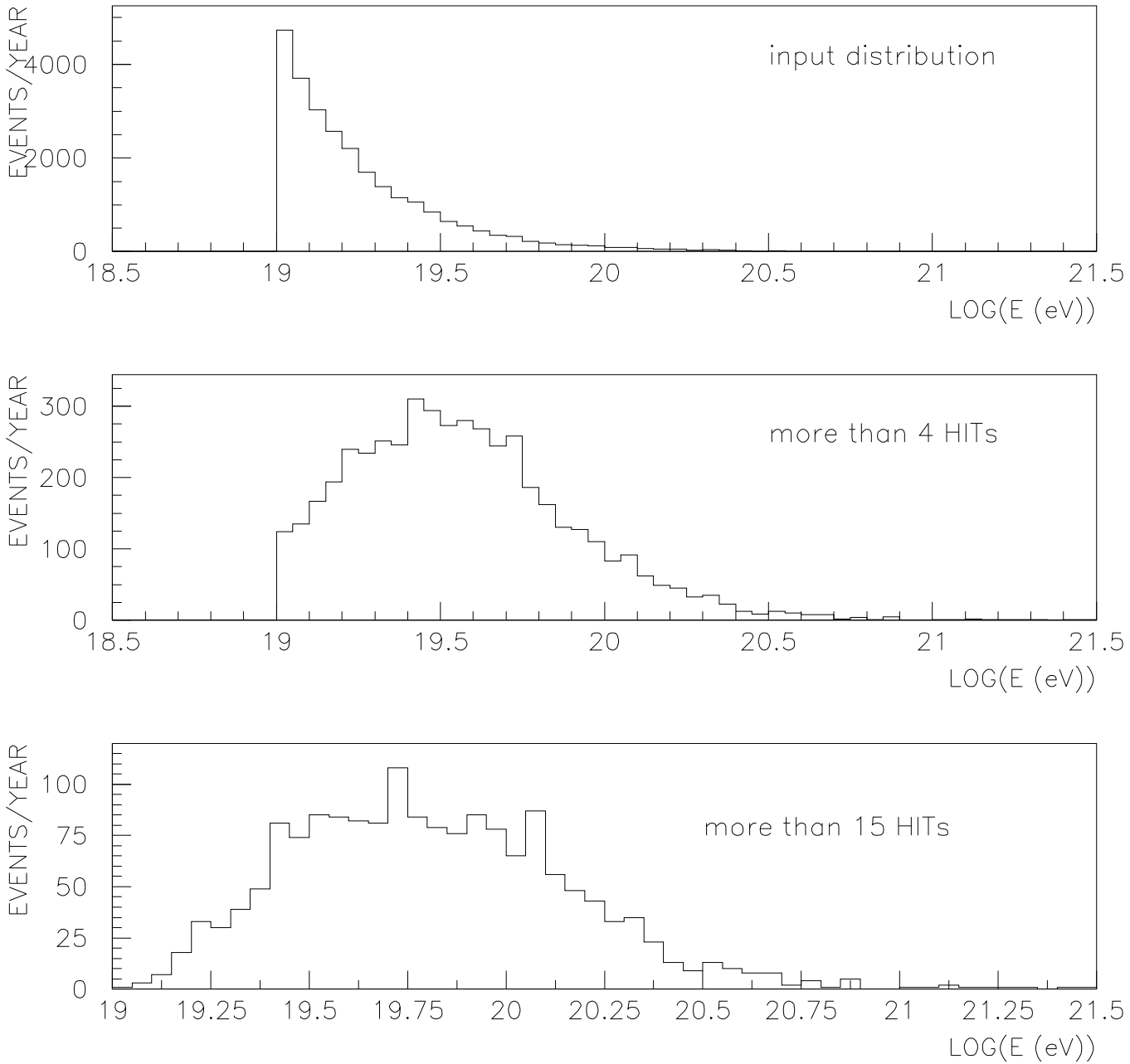
10% of light reaching ground is reflected isotropically

chrenkov light detection −> 4 P.E.

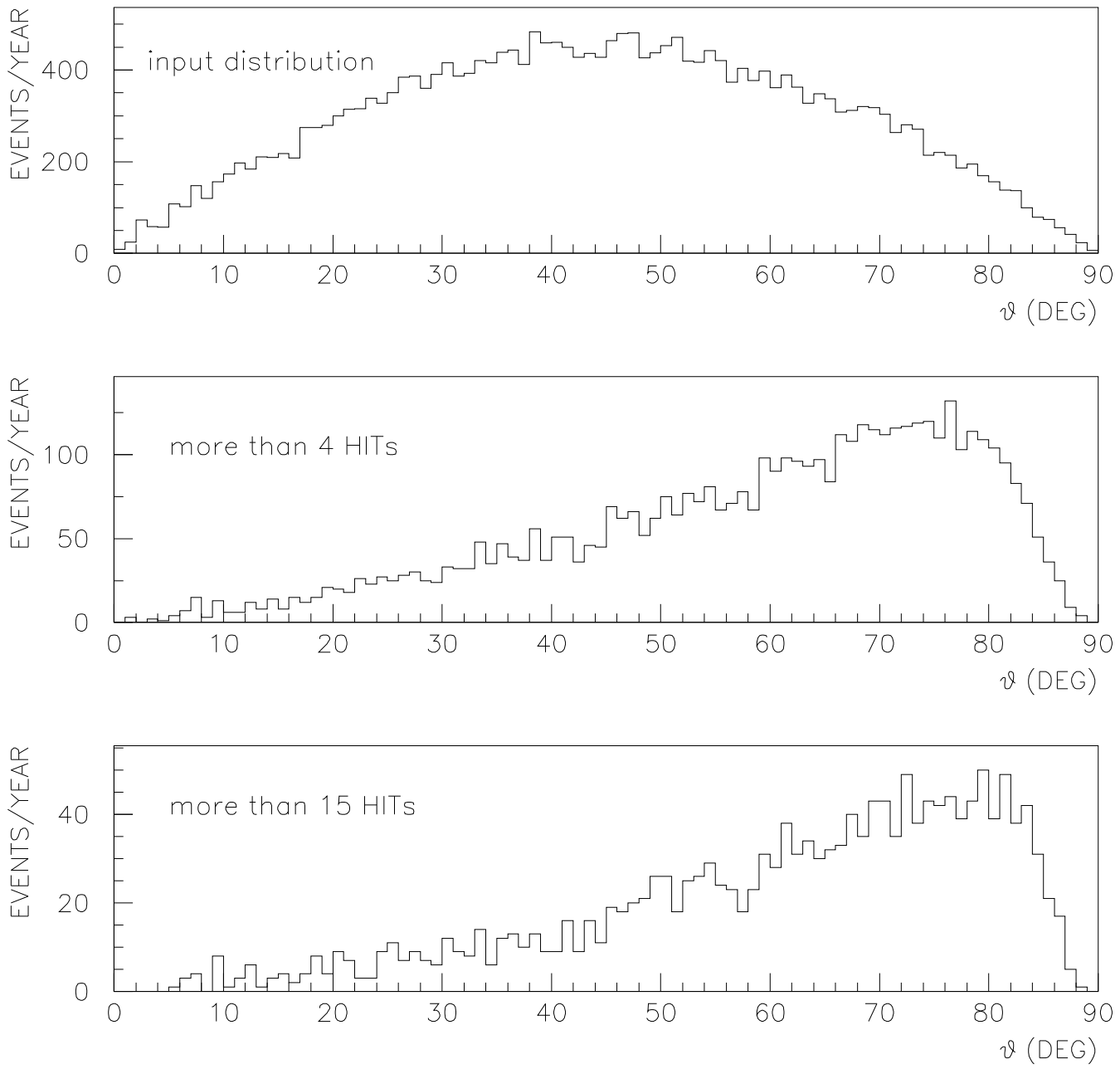
protons

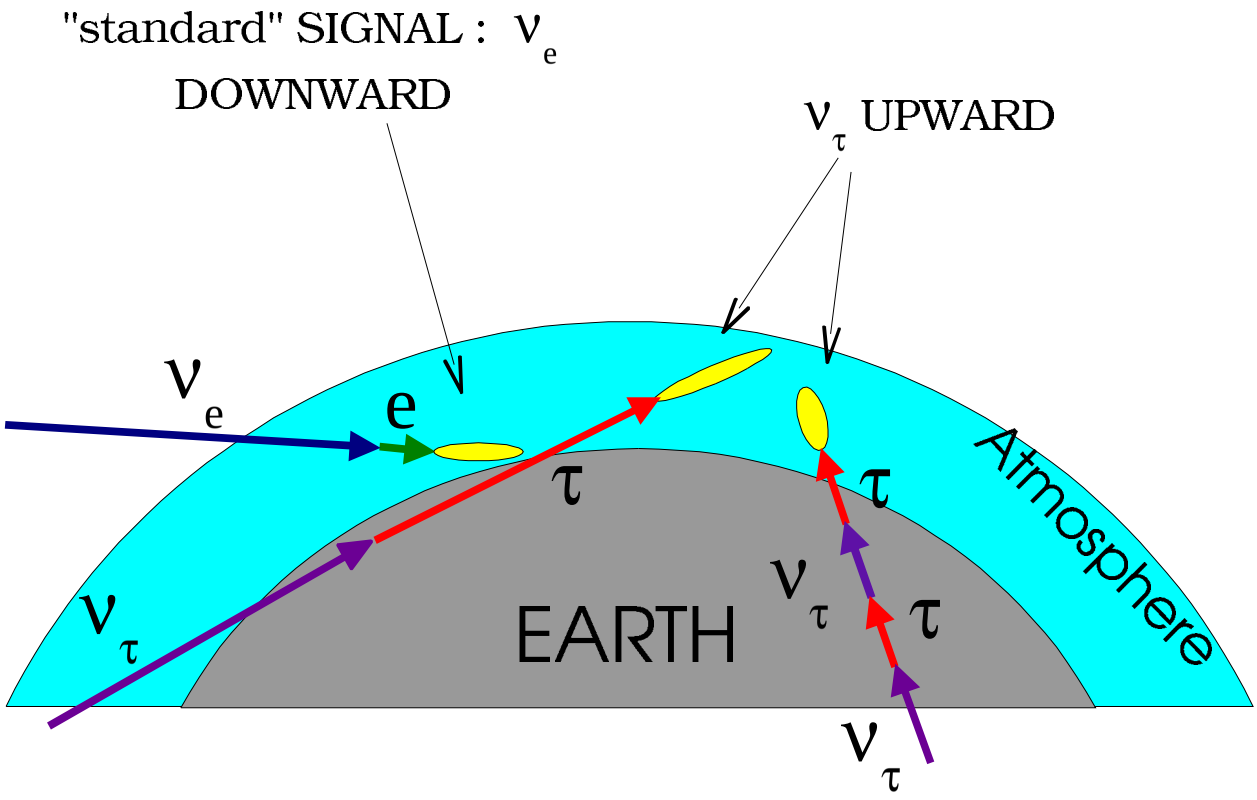

efficiency
1
0.75
0.5
0.25
0
* more than 4 HITs
O more than 15 HITs
$\vartheta = 0°$
10^{18}
10^{19}
10^{20}
10^{21}
energy (eV)
efficiency
1
0.75
0.5
0.25
0
$\vartheta = 35°$
10^{18}
10^{19}
10^{20}
10^{21}
energy (eV)
efficiency
1
0.75
0.5
0.25
0
$\vartheta = 70°$
10^{18}
10^{19}
10^{20}
10^{21}
energy (eV)

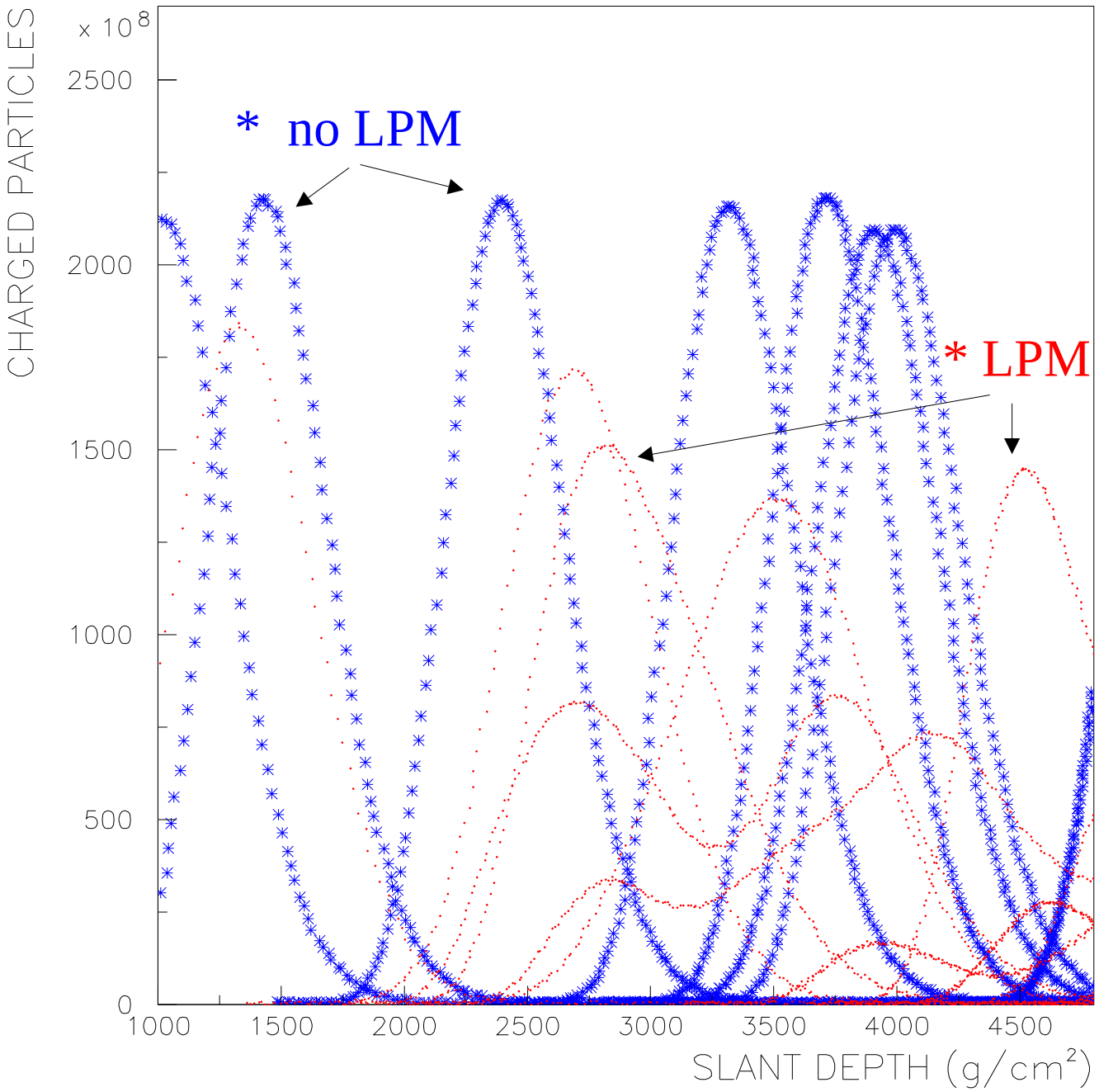
protons in one year (no gzk)

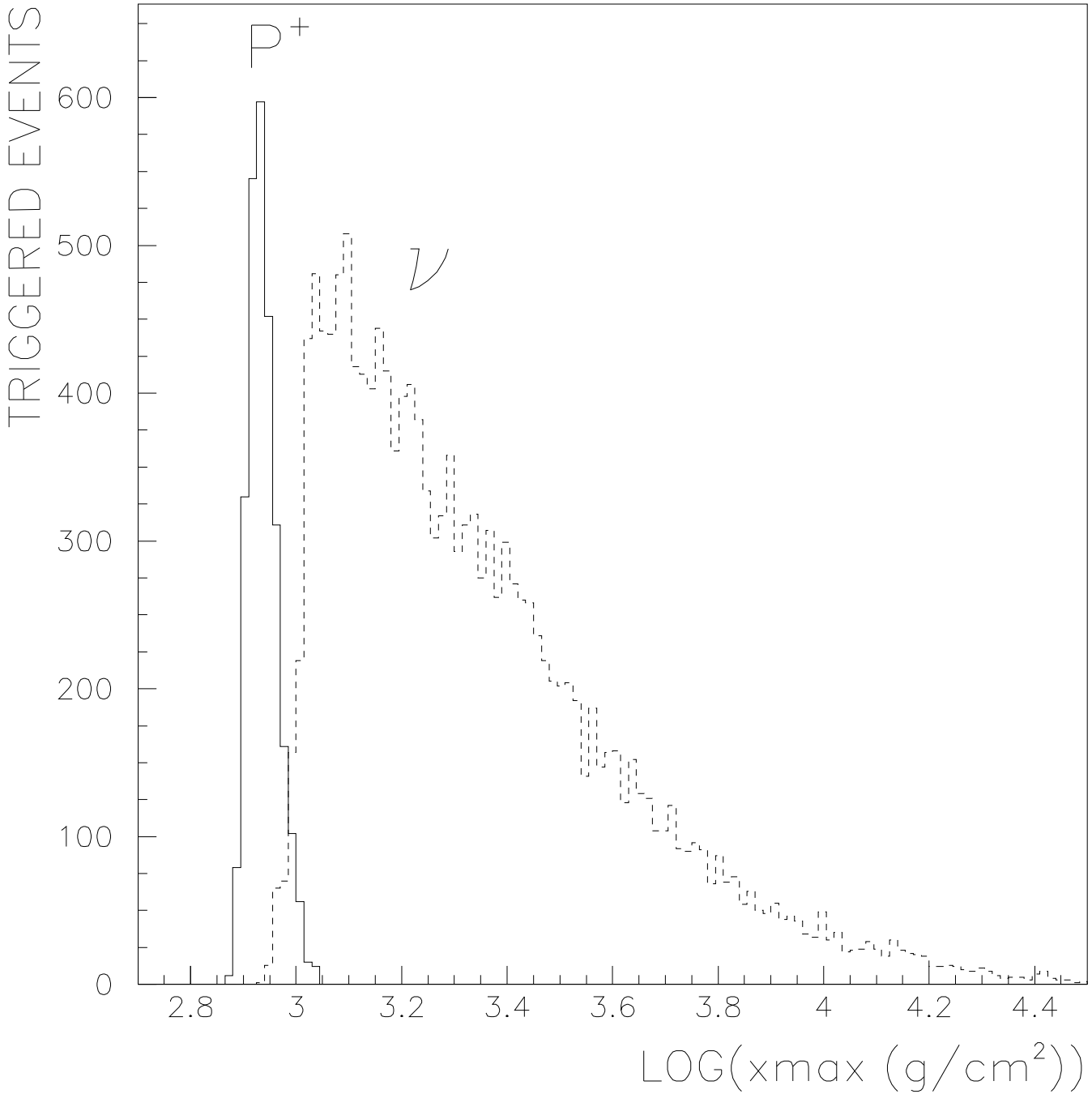


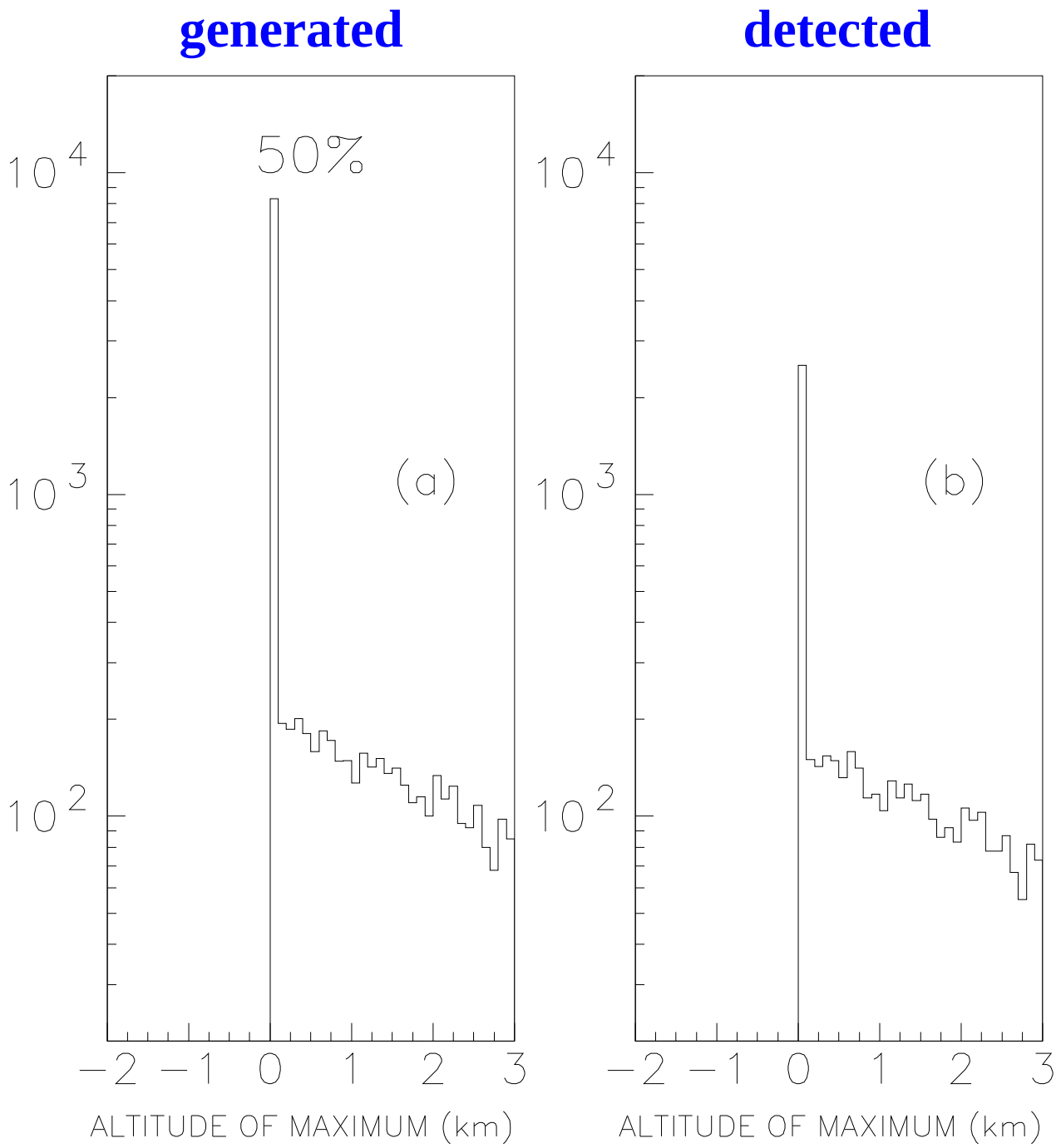
angular distribution of protons

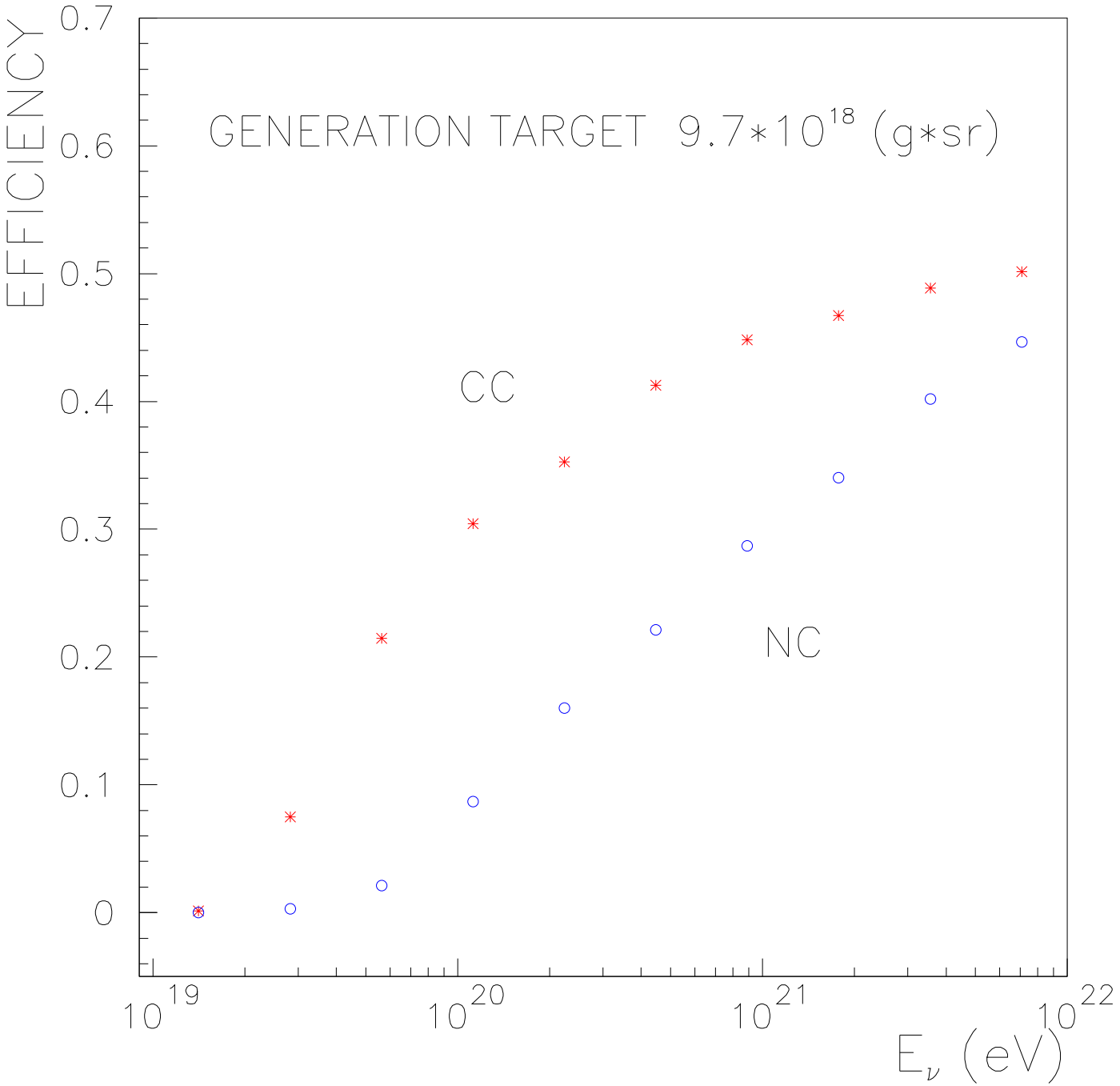


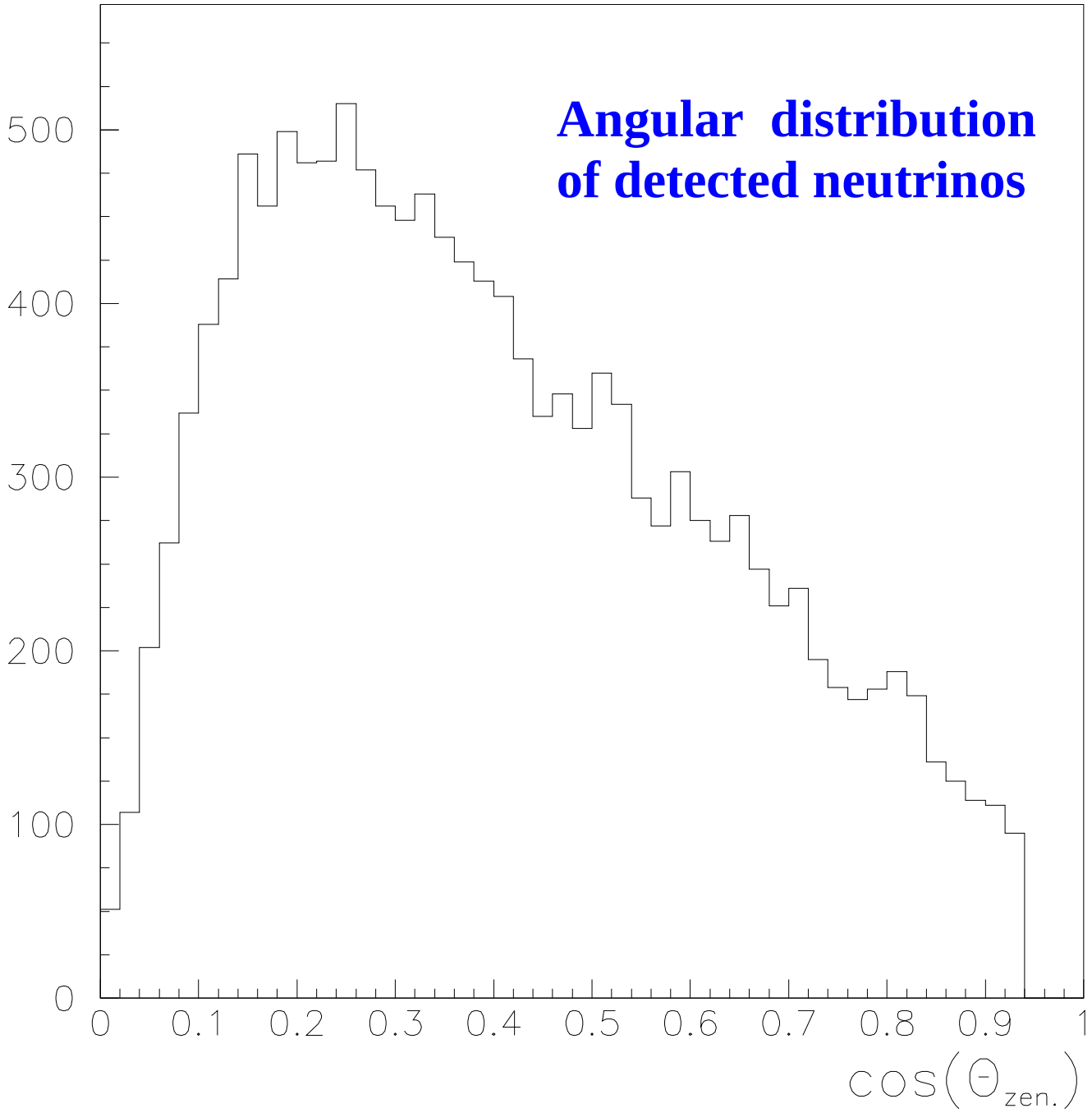

"standard" SIGNAL : ν_e
DOWNWARD
ν_τ UPWARD
ν_e
e
τ
τ
ν_τ
EARTH
ν_τ
τ
ν_τ
Atmosphere


CHARGED PARTICLES
x 10^8
2500
2000
1500
1000
500
0
* no LPM
* LPM
1000
1500
2000
2500
3000
3500
4000
4500
SLANT DEPTH (g/cm²)


TRIGGERED EVENTS
0
100
200
300
400
500
600
2.8
3
3.2
3.4
3.6
3.8
4
4.2
4.4
LOG(xmax (g/cm^2))
P$^+$
ν


generated
detected
50%
(a)
(b)
10^4
10^3
10^2
−2 −1 0 1 2 3
ALTITUDE OF MAXIMUM (km)
ALTITUDE OF MAXIMUM (km)


EFFICIENCY
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
GENERATION TARGET 9.7*10^18 (g*sr)
CC
NC
10^19
10^20
10^21
10^22
E_ν (eV)

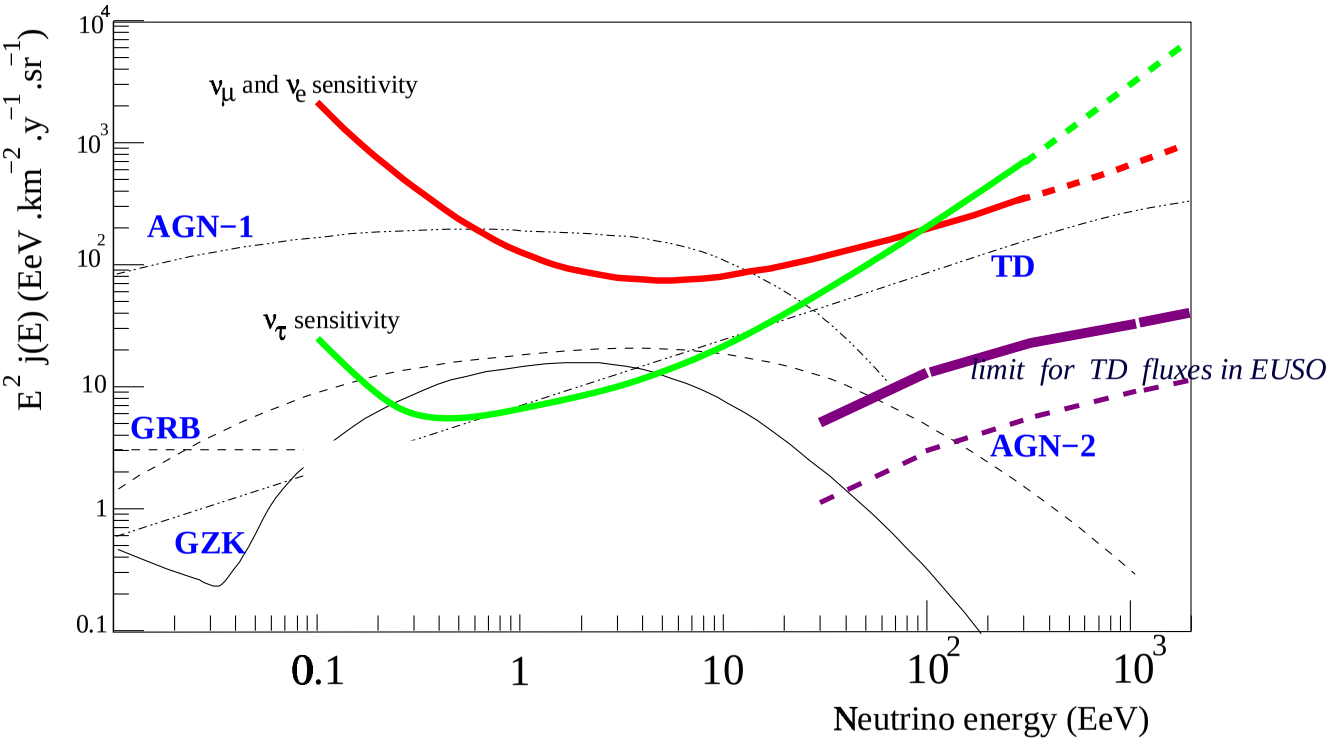

Angular distribution
of detected neutrinos
500
400
300
200
100
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
cos(Θzen.)

NEUTRINOS FROM TOP DOWN MODELS

3 years	TD1	TD2	TD3	TD4	MR
INTERACTIONS INSIDE TARGET *0.1	98	94	22	816	396
EVENTS DETECTED	21	15	6	188	61

NEUTRINOS FROM GZK AND AGN

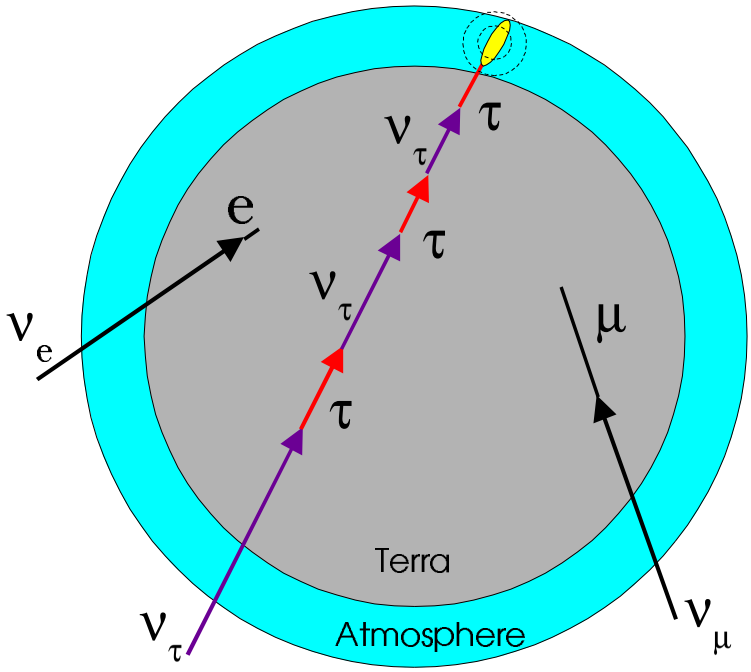
3 years	GZK1	GZK2	GZK3	AGN1	AGN2
INTERACTIONS INSIDE TARGET *0.1	0.5	4.6	26	1	11
EVENTS DETECTED	0.1	0.7	3.4	0.16	2


E^2 j(E) (EeV .km^{-2} .y^{-1} .sr^{-1})
10^4
10^3
10^2
10
1
0.1
ν_μ and ν_e sensitivity
AGN−1
ν_τ sensitivity
GRB
GZK
TD
limit for TD fluxes in EUSO
AGN−2
0.1
1
10
10^2
10^3
Neutrino energy (EeV)

τ INDUCED BY ν_τ IN THE EARTH: NEW OBSERVATIVE CHANNEL FOR COSMIC NEUTRINOS ?

$$E_\nu = 10^{15}\ \text{eV} \qquad \mathcal{L}_{intCC} \sim R_T$$

ν_e e ν_μ ARE PRATICALLY ABSORBED AFTER ONE CC



regeneration mechanism due to τ decay in flight

$$\nu_\tau \rightarrow \tau \rightarrow \nu_\tau \rightarrow \ldots$$

NEUTRINO INTERACTRIONS

ANELASTIC SCATTERING ON NUCLEONS

NEUTRAL CURRENT (NC)

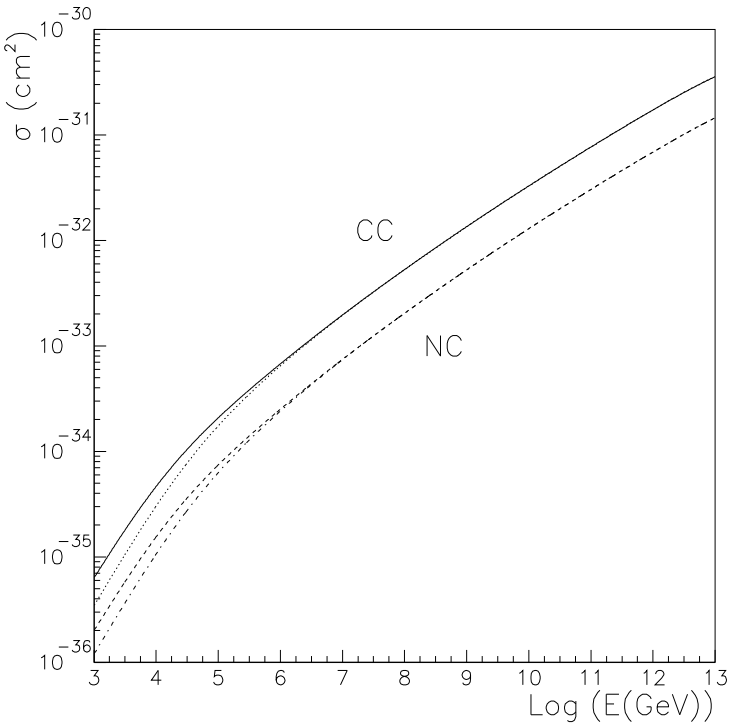
$$\nu_{e,\mu,\tau} + N \longrightarrow \nu_{e,\mu,\tau} + \text{adrons}$$

CHARGED CURRENT (CC)

$$\nu_e + N \longrightarrow e + \text{adrons}$$

$$\nu_\mu + N \longrightarrow \mu + \text{adrons}$$

$$\nu_\tau + N \longrightarrow \tau + \text{adrons}$$



τ energy loss

Radiative processes

- Bremstrahlung $\tau + Z \rightarrow \tau + Z + \gamma$
- direct pair production $\tau + Z \rightarrow \tau + Z + e^{+}e^{-}$
- photonuclear interaction $\tau + Z \rightarrow \tau + \text{adroni}$

Bremsstrahlung $\sigma_{brems} \sim \left(\frac{m_e}{m_L}\right)^2$

direct pair production $\sigma_{dpp} \sim \frac{m_e}{m_L}$

photonuclear $\sigma_{phnuc} \sim \frac{1}{m_L}$

radiation lenght for τ :

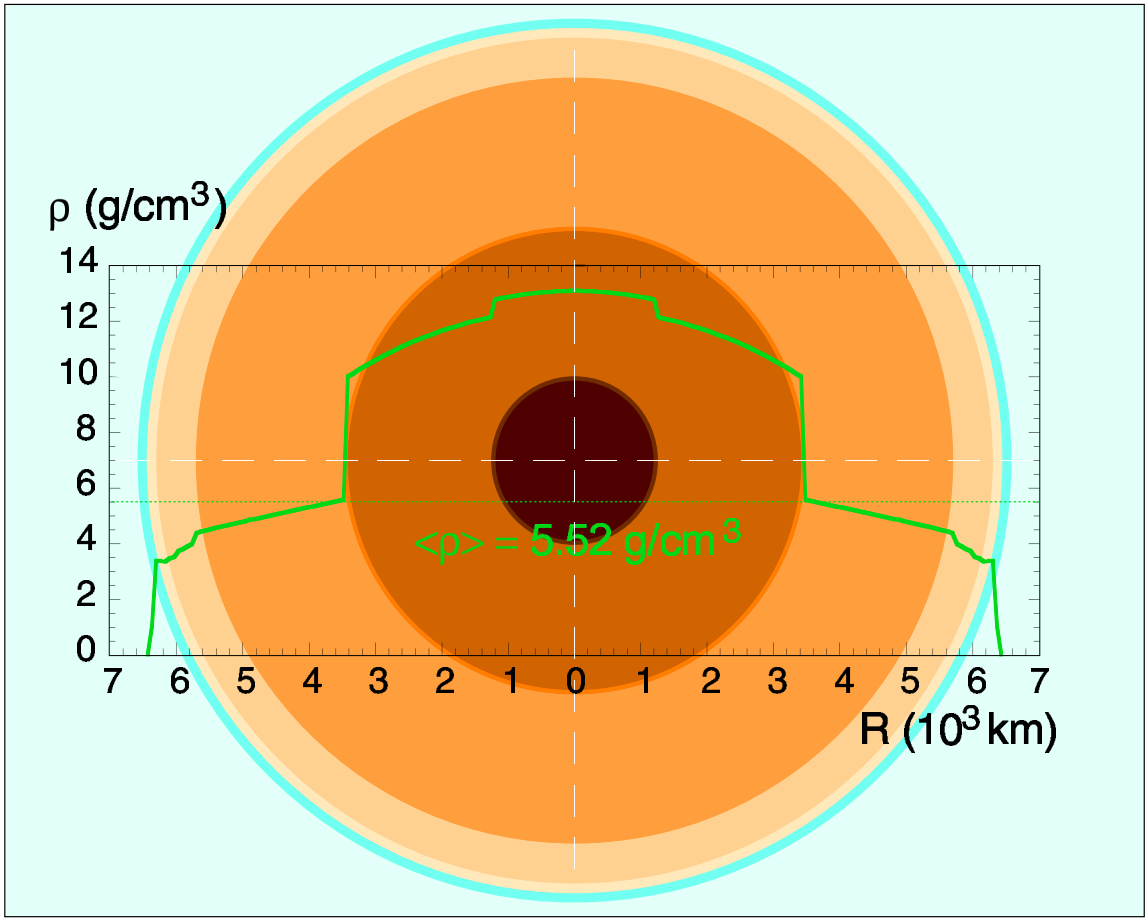
$$R_{nuc} \sim R_{pair} \ll R_{brems}$$

DECAY

$\tau \rightarrow \nu_{\tau} + \ldots$ TAUOLA library

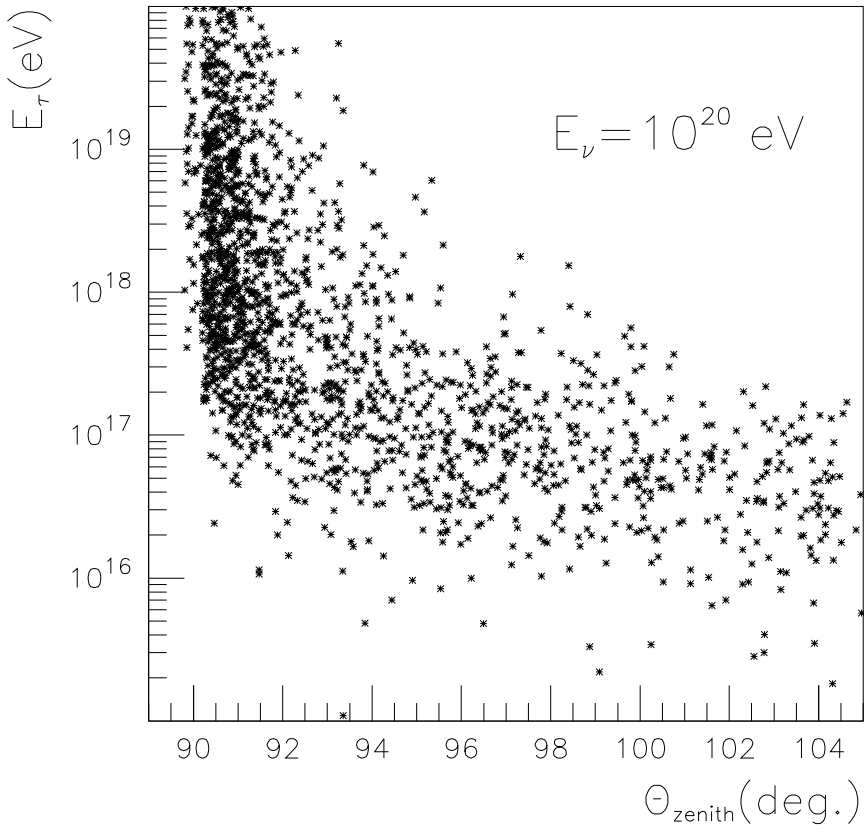
EARTH MODEL

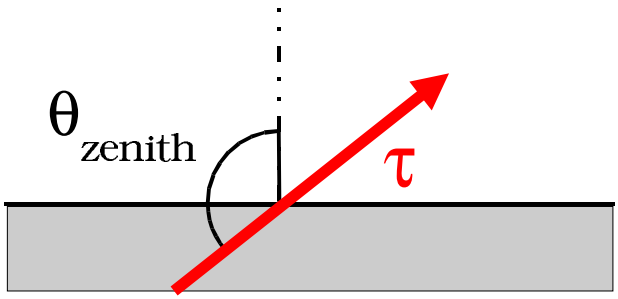
Dziewonski – Anderson



SIMULATION OF PROPAGATION THROUGH THE EARTH

$$10^{14}\text{eV} \leq E_\nu \leq 10^{22}\text{eV}$$





DEFINTION OF EFFECTIVE APERTURE

IT CONTAINS ONLY AND COMPLETELY THE PHYSICS OF PROPAGATION THROUGH THE EARTH

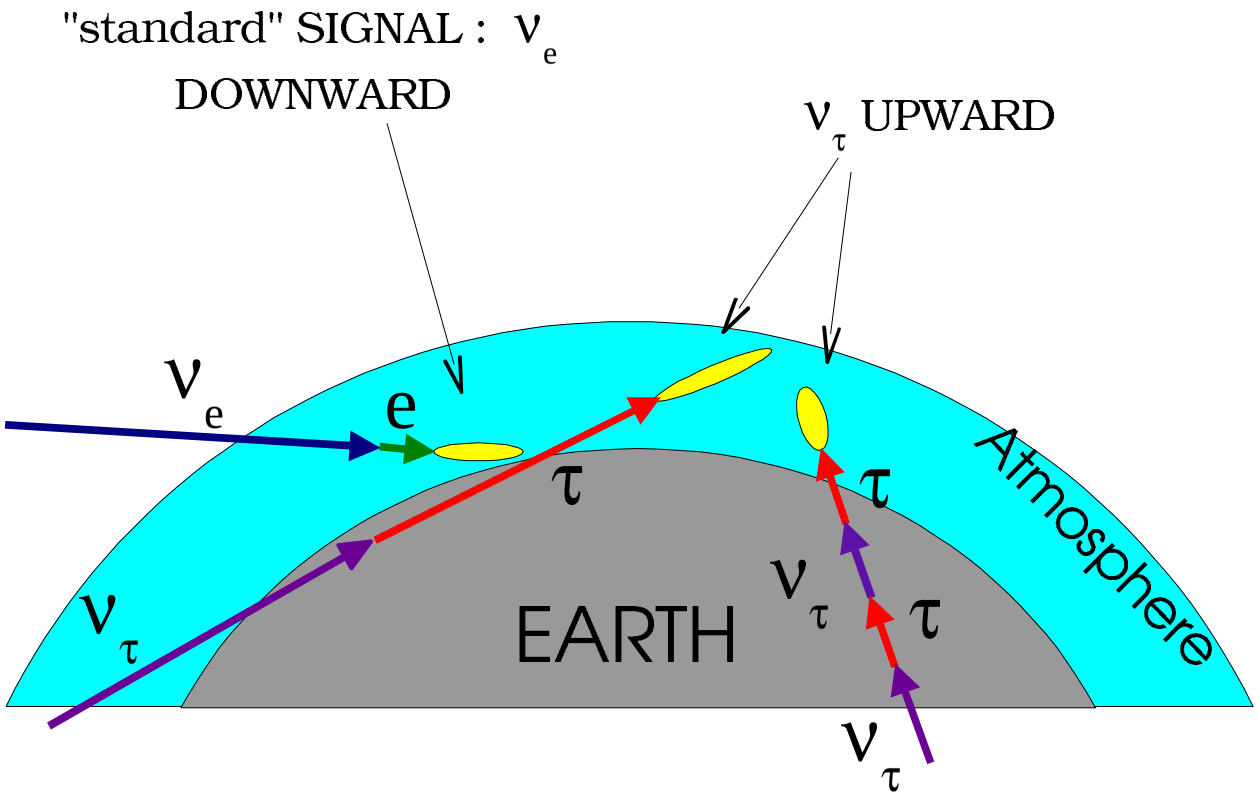
FOR ISOTROPIC FLUXES:

EFFECTIVE APERTURE (sr) $\mathbf{A_{eff}\,(E_\nu, E_{thr})}$

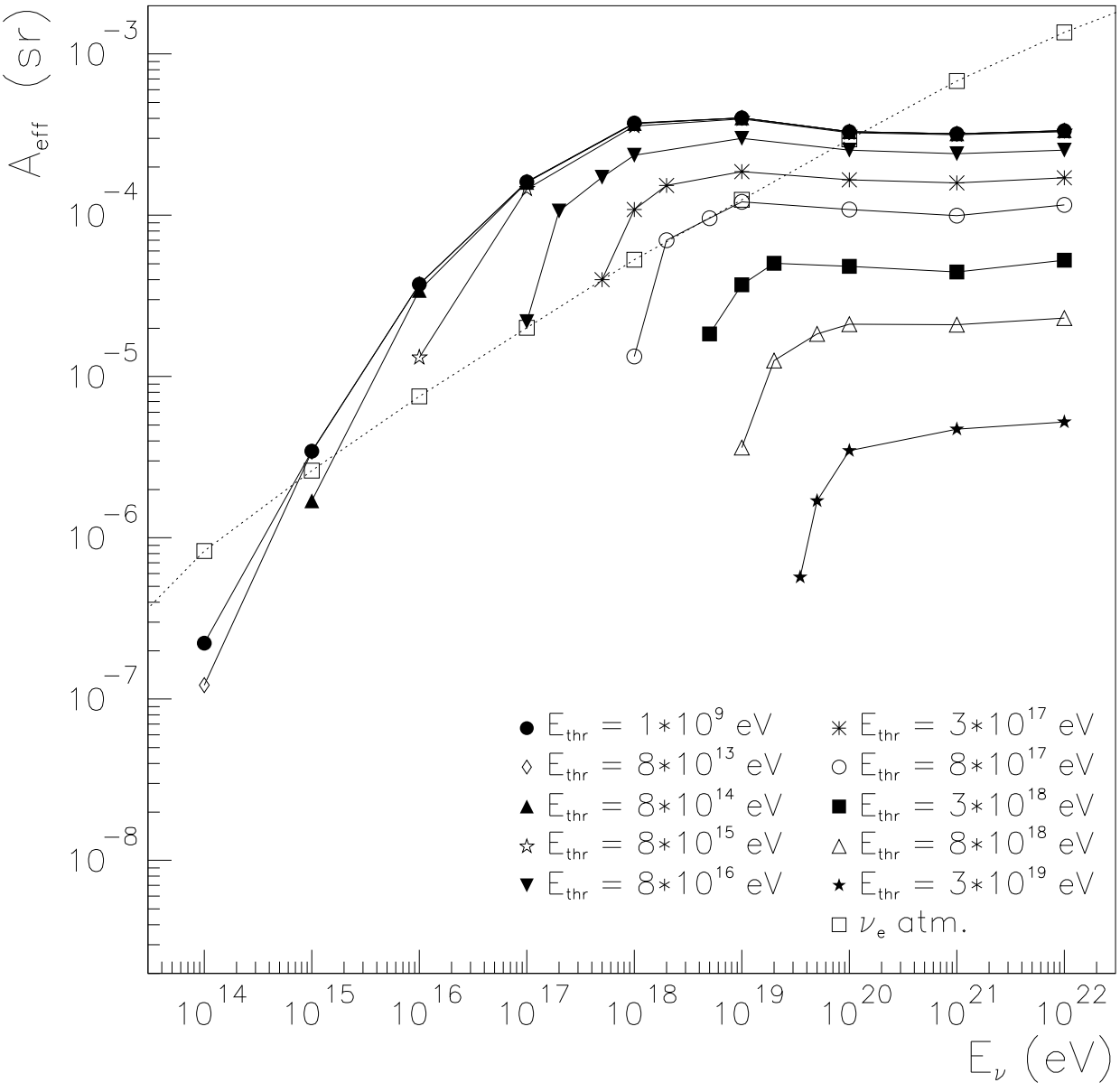
$$A_{eff}(E_\nu, E_{thr}) = \int_\Omega P_{\nu_\tau \to \tau}(\vartheta_{zenith}, E_\nu, E_{thr}) \left|\cos(\vartheta_{zenith})\right| d\Omega$$

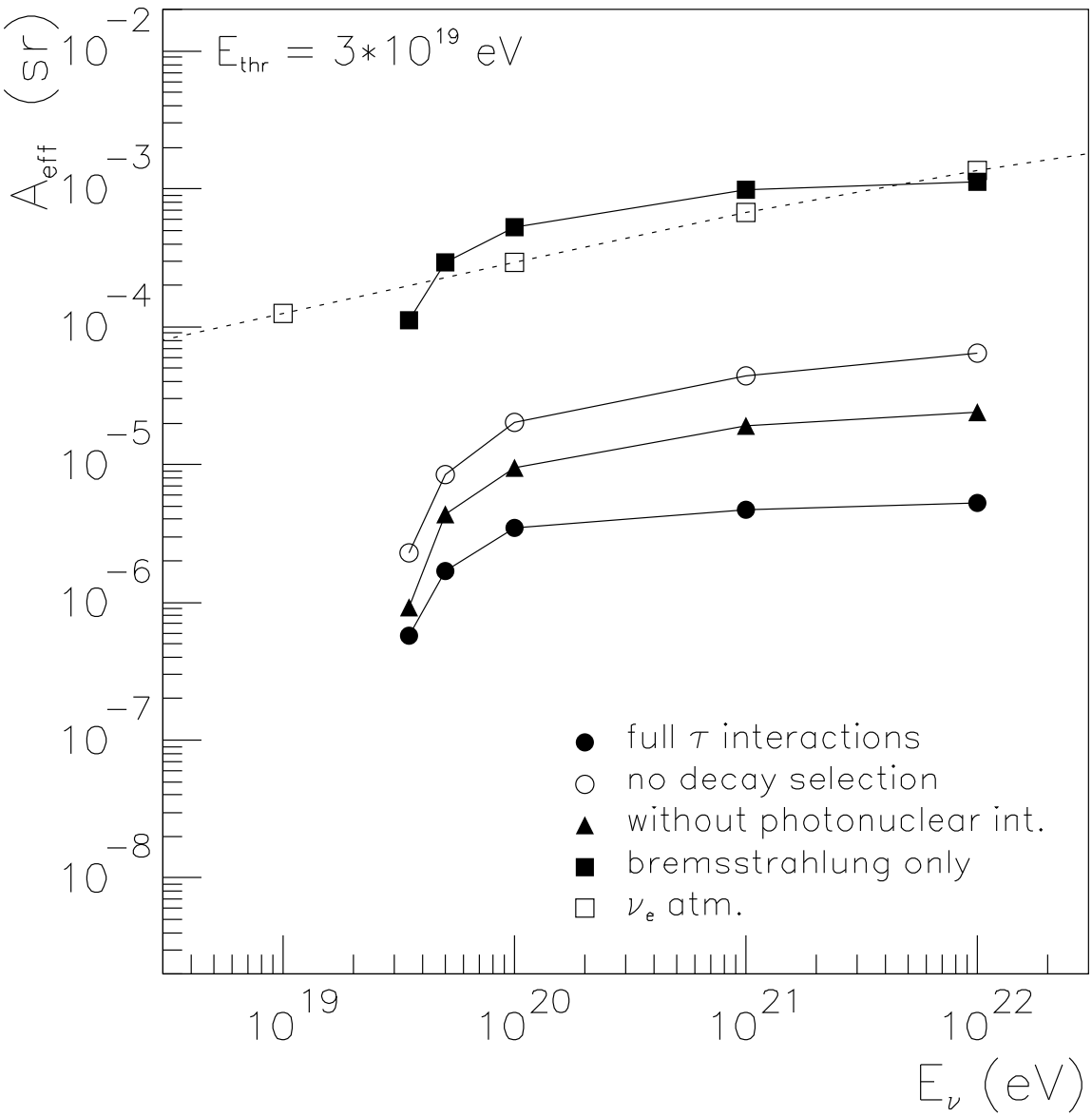
NUMBER OF EMERGING τ FOR UNIT EARTH SURFACE :

$$N_\tau(E_\tau > E_{thr}) = \int_{E_\nu} A_{eff}(E_\nu, E_{thr}) \frac{d^2 N_\nu}{dE_\nu\, d\Omega} dE_\nu$$

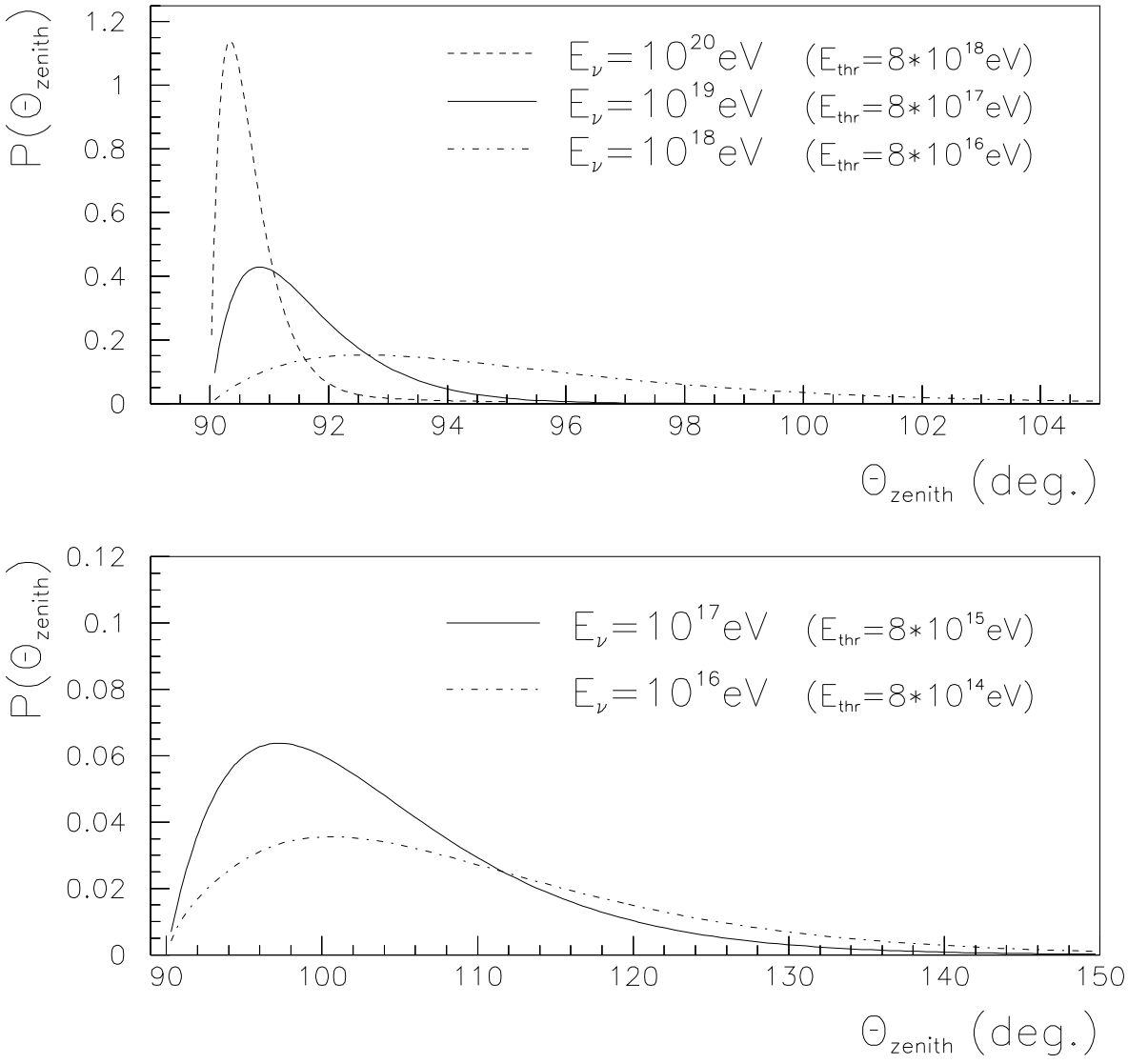

"standard" SIGNAL : ν_e
DOWNWARD
ν_τ UPWARD
ν_e
e
τ
τ
ν_τ
EARTH
ν_τ
τ
ν_τ
Atmosphere

EFFECTIVE APERTURE




A_{eff} (sr)
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
$E_{thr} = 3*10^{19}$ eV
full τ interactions
no decay selection
without photonuclear int.
bremsstrahlung only
ν_e atm.
10^{19}
10^{20}
10^{21}
10^{22}
E_ν (eV)

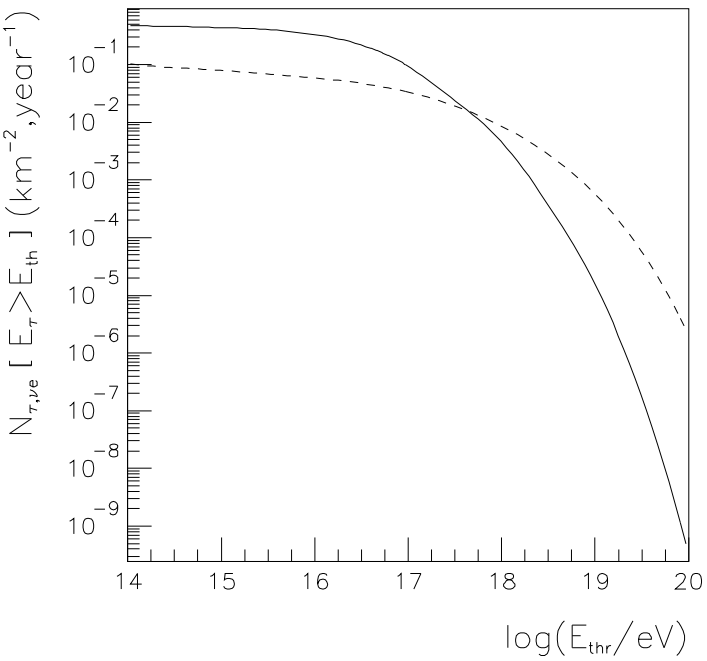
ANGULAR DISTRIBUTION FOR EMERGING τ



FLUXES OF EMERGING τ

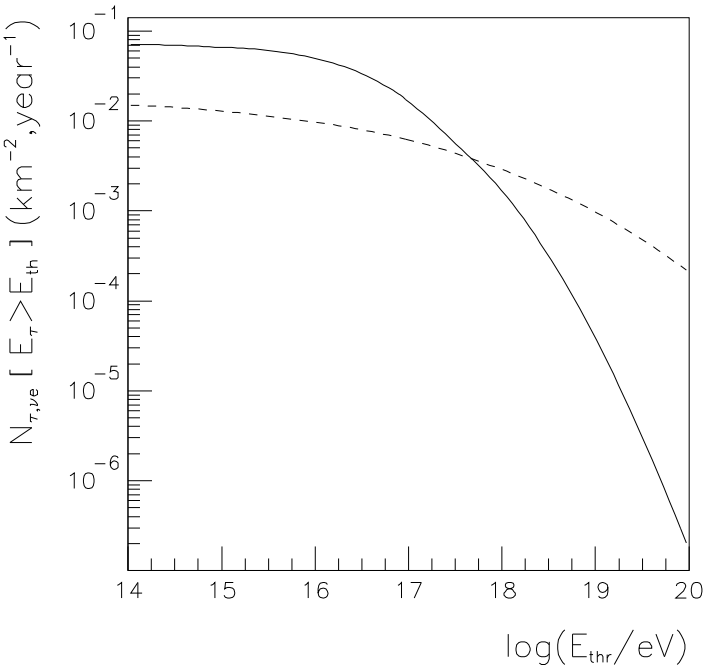
BOTTOM-UP

AGN



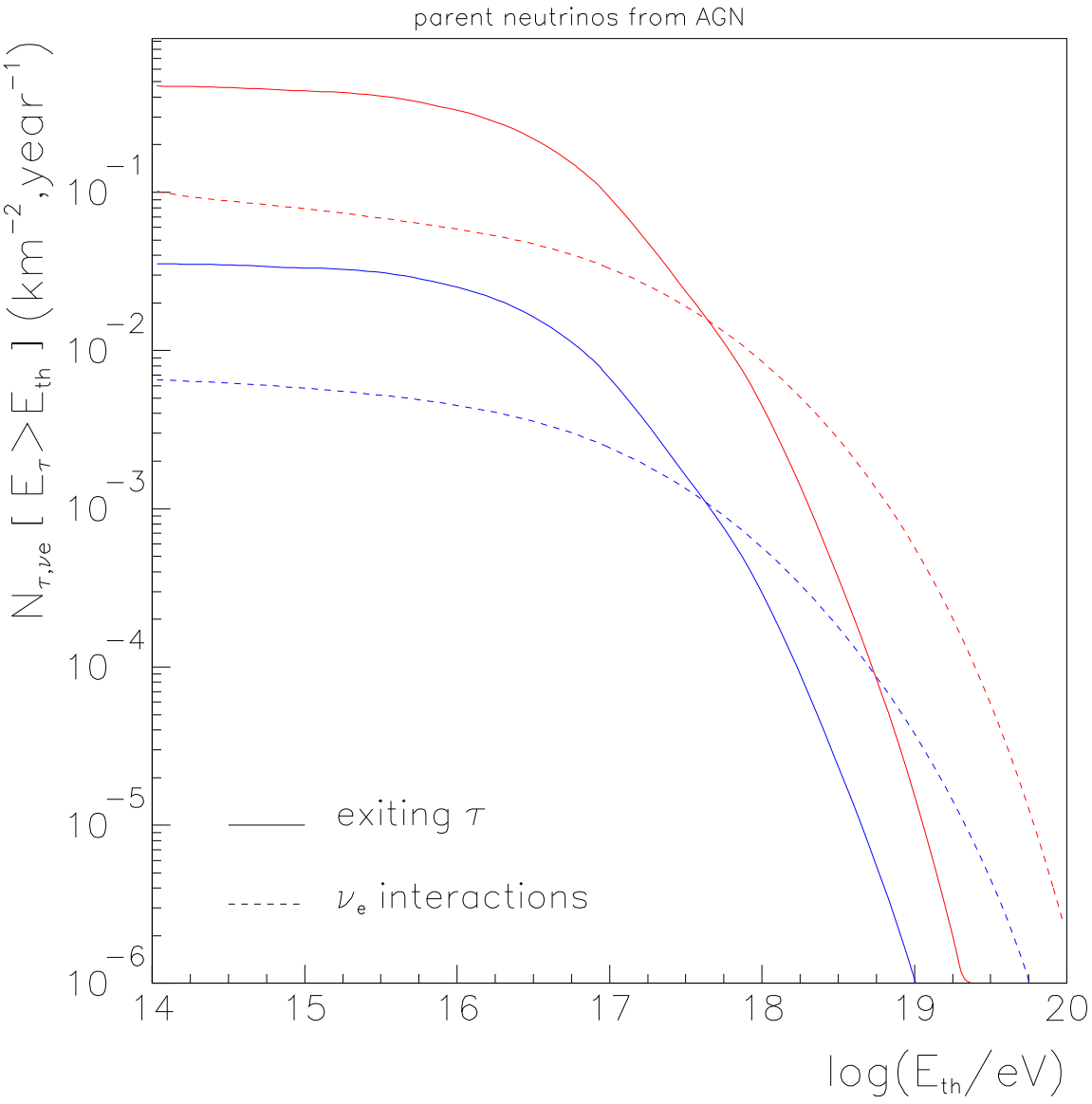
TOP-DOWN

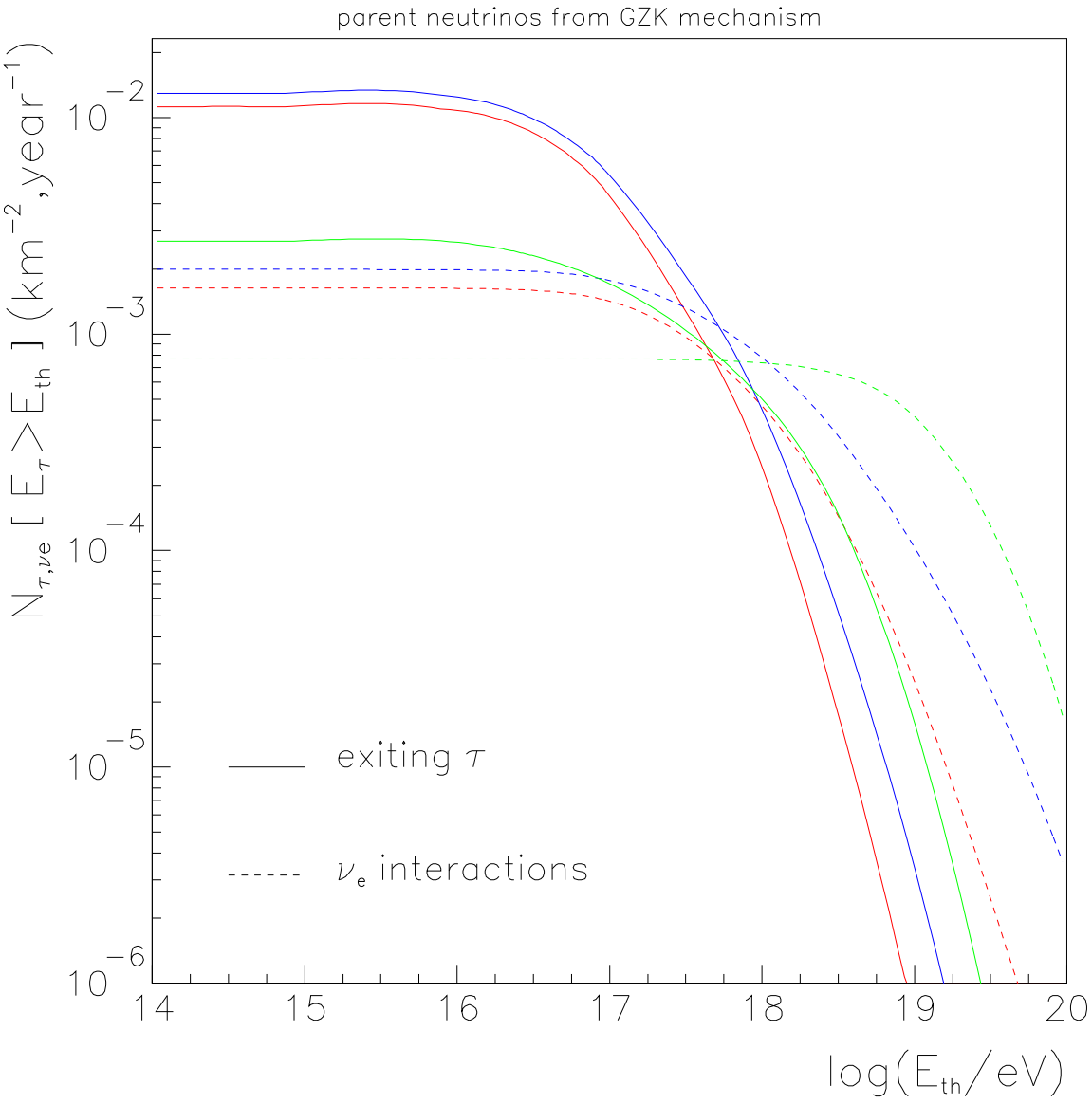
TOP. DEF.

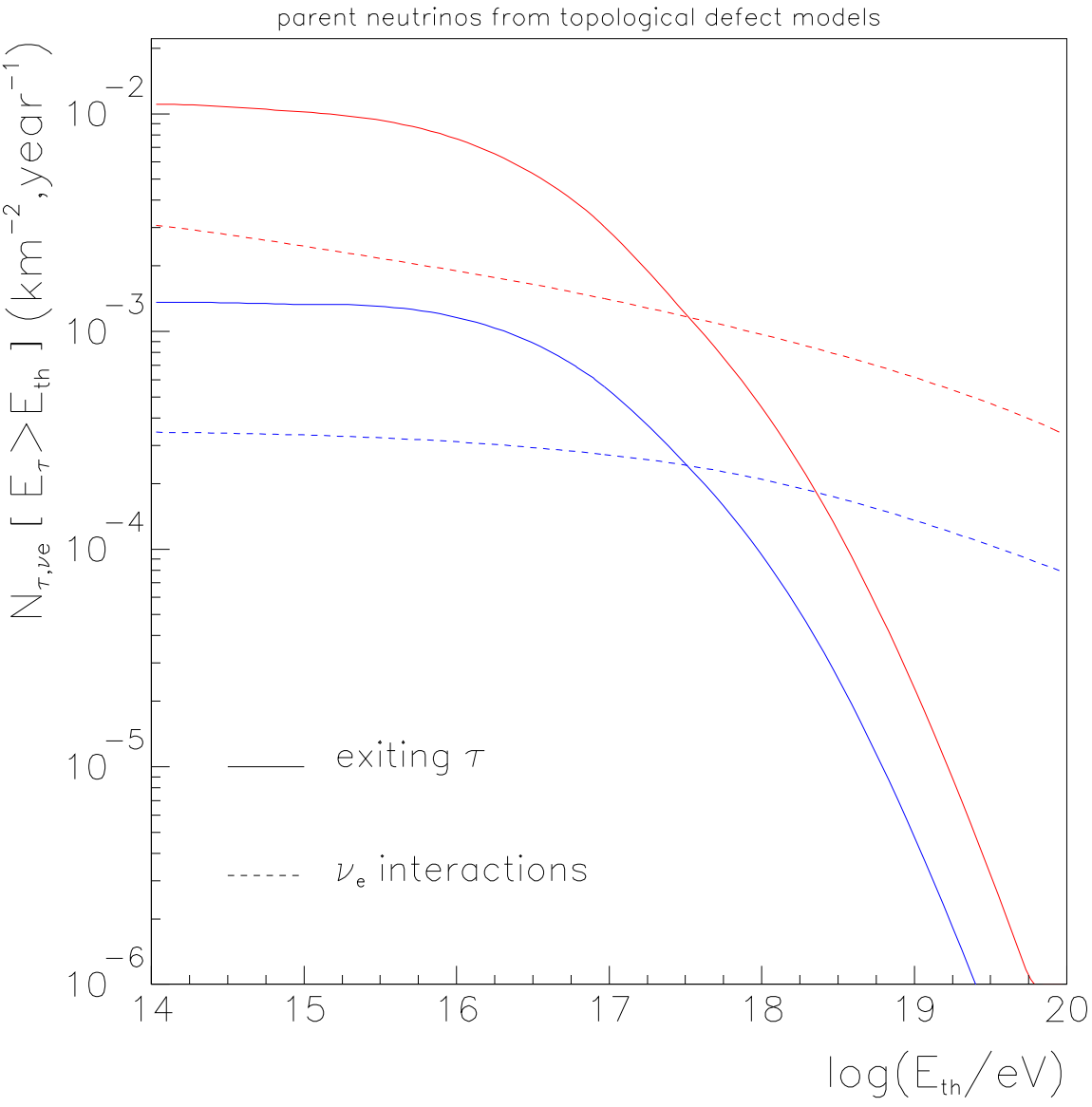


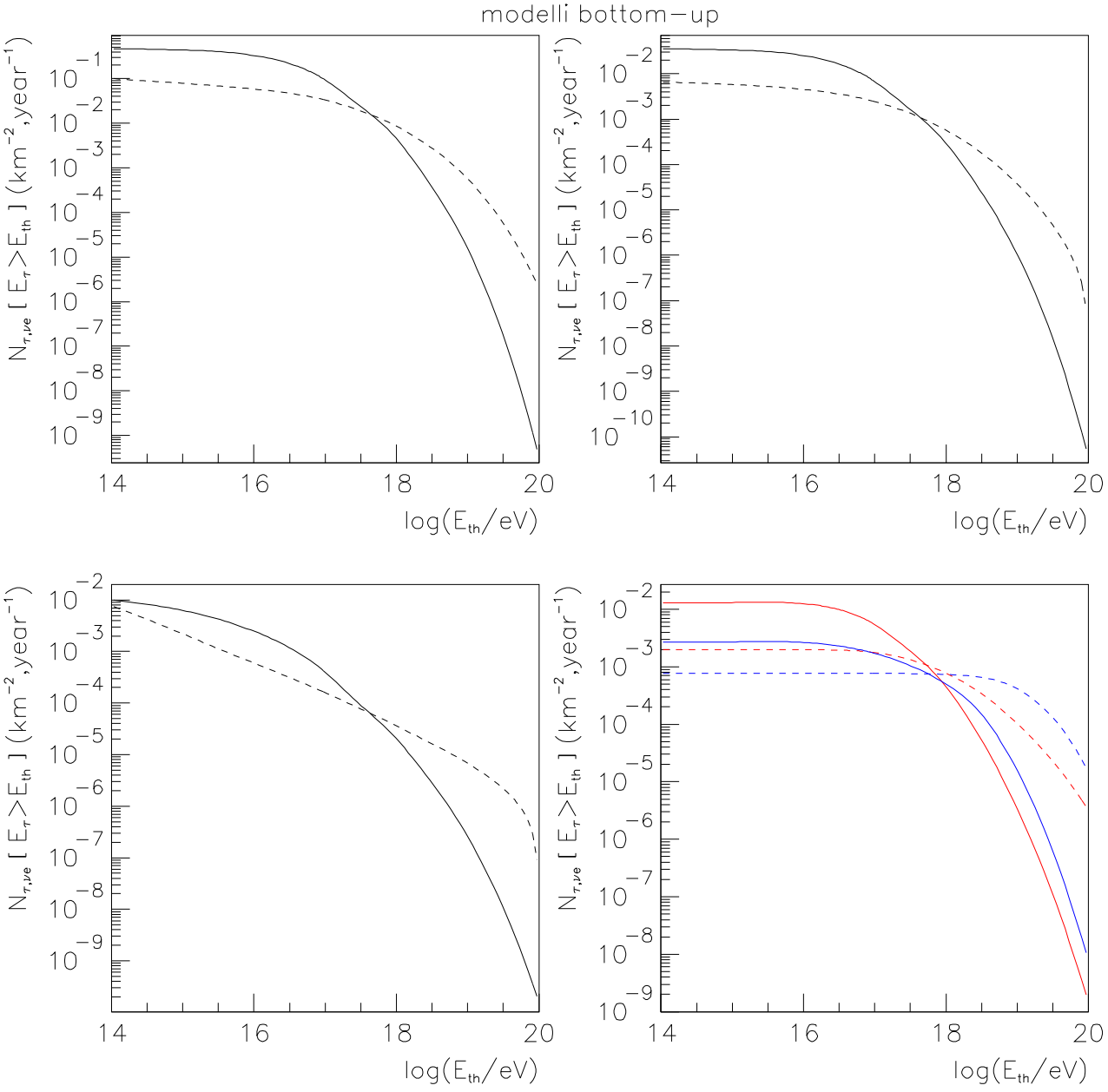
CONDITION FOR DETECTION :

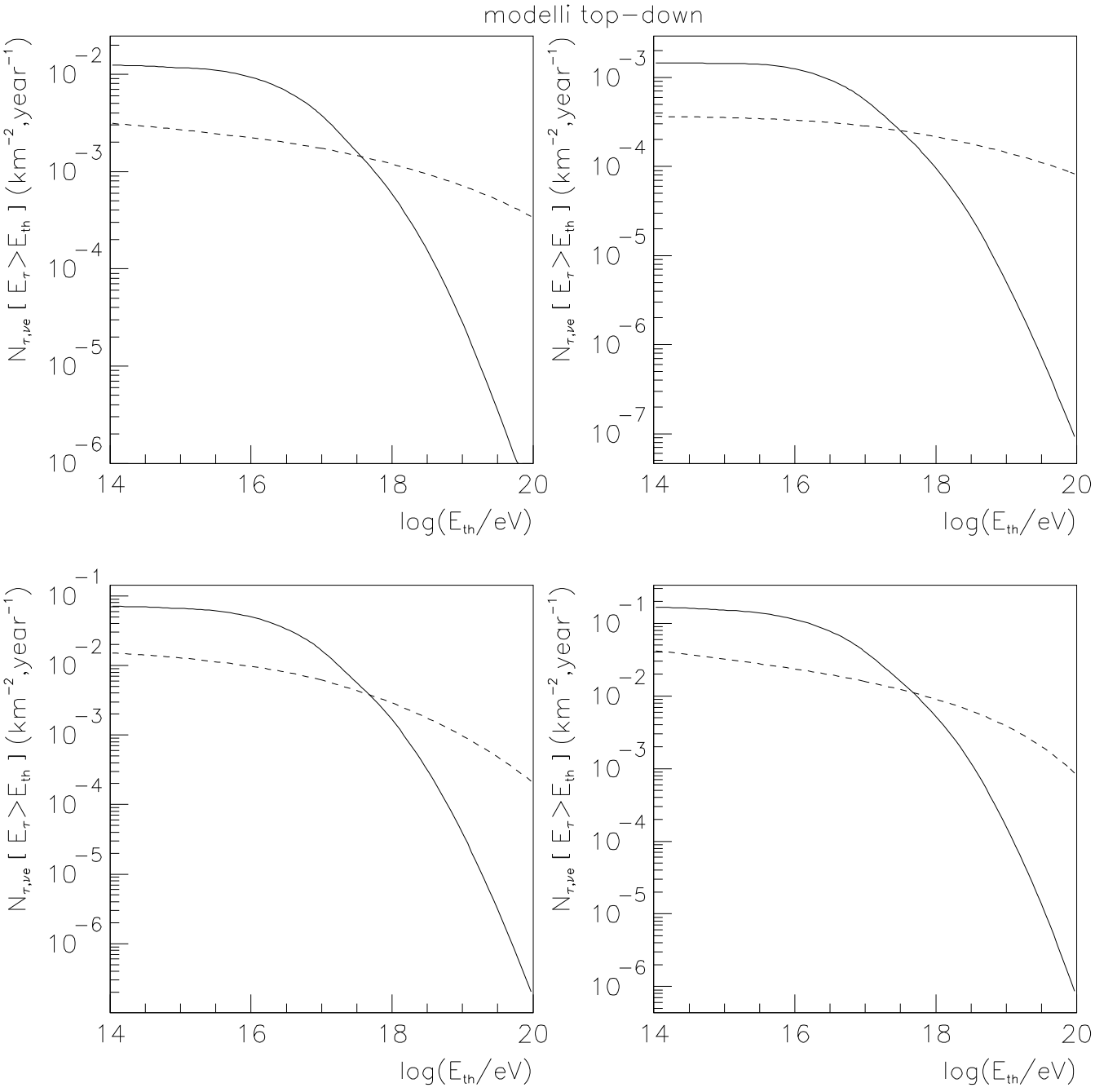
$E_{thr} < 10^{18}$ eV $S > 10^3$ km^2


parent neutrinos from AGN
$N_{\tau,\nu e}$ [$E_\tau > E_{th}$] (km^{-2},$year^{-1}$)
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
14
15
16
17
18
19
20
log(E_{th}/eV)
exiting τ
ν_e interactions

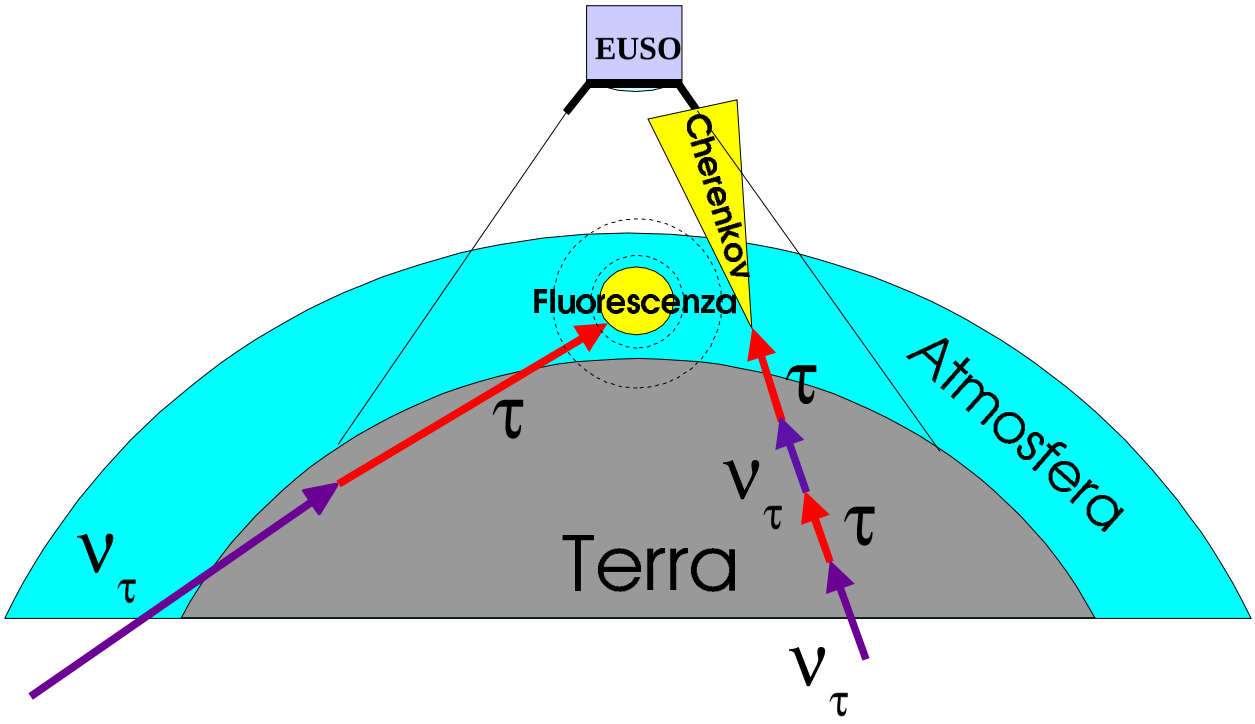

parent neutrinos from GZK mechanism
$N_{\tau,\nu e}$ [$E_\tau > E_{th}$] (km^{-2},$year^{-1}$)
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
14
15
16
17
18
19
20
log(E_{th}/eV)
exiting τ
ν_e interactions


parent neutrinos from topological defect models
$N_{\tau,\nu e}$ [$E_\tau > E_{th}$] (km^{-2}, $year^{-1}$)
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
14
15
16
17
18
19
20
log(E_{th}/eV)
exiting τ
ν_e interactions


modelli bottom−up
$N_{\tau,\nu e}$ [$E_\tau > E_{th}$] (km^{-2},$year^{-1}$)
log(E_{th}/eV)
14
16
18
20


modelli top−down
$N_{\tau,\nu e}\ [\ E_\tau > E_{th}\ ]\ (km^{-2},year^{-1})$
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
14
16
18
20
$\log(E_{th}/eV)$
$N_{\tau,\nu e}\ [\ E_\tau > E_{th}\ ]\ (km^{-2},year^{-1})$
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
14
16
18
20
$\log(E_{th}/eV)$
$N_{\tau,\nu e}\ [\ E_\tau > E_{th}\ ]\ (km^{-2},year^{-1})$
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
14
16
18
20
$\log(E_{th}/eV)$
$N_{\tau,\nu e}\ [\ E_\tau > E_{th}\ ]\ (km^{-2},year^{-1})$
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
14
16
18
20
$\log(E_{th}/eV)$

DIRECT CHERENKOV LIGHT DETECTION ?



DIRECT CHERENKOV LIGHT (very preliminar) :

$\theta_{cher} = 1.3°$

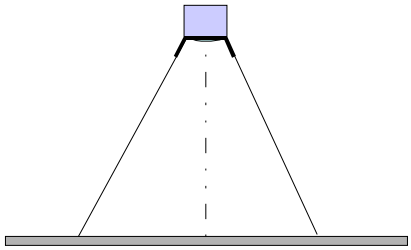
DETECTION IN ONE PIXEL

threshold energy (4 pe): ~ $2 \cdot 10^{15}$ eV

EFFECTIVE AREA ~ AREA OF CHERENKOV CONE

~ 250 km^2

standard configuration

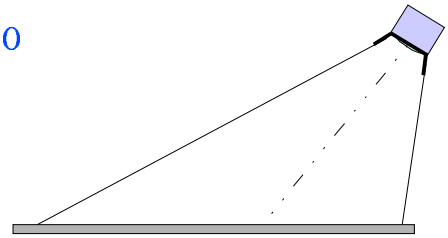


events selected only near the vertical

↓

no detection

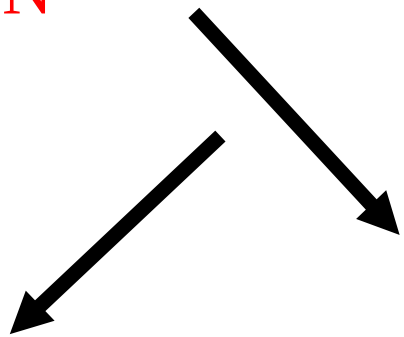
inclined configuration ~ 40^0



from optimistic AGN flux ~ 10 events/year

NEXT STEPS

- INCLUDE REAL DETECTOR SIMULATION
- INCLUDE EFFECT OF DEVELOPED RECONSTRUCTION
- INCLUDE REALISTIC ATMOSPHERIC TRANSPORT SIMULATION



VALIDATE THE THECNIQUE

WE MUST KNOW THE FUTURE UNCERTAINTY ON ONLINE MEASURE OF LOCAL ATMOSPHERIC TRANSPORT PARAMETERS

ENERGY RESOLUTION