Neutrino Telescope Workshop
Venice, feb. 1999

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Neutrino Capability of AUGER

- Neutrino sources at ultra-high energy ($\gtrsim 10^{17}$ eV)
- Presentation of the Auger Observatory
- characterization of "deep" atmospheric showers
- simulation and selection of events
- evaluation of acceptance and event rate
- qualitative conclusions

UHE neutrinos

- Byproducts of **proton acceleration** (in AGN, GRB ...)

  photoproduction of mesons
  {in the accelerating site
  {on the CMBR

  then $\pi \to \mu \nu_\mu$, $\mu \to e \nu_\mu \nu_e$

  cannot exceed very much the flux of <u>protons</u> (except in specific models)

- Decay products of **topological defects** (hypermassive objects at GUT scale)

  → spectra extending above 10^{20} eV (relatively hard)

- In both cases: correlative production of <u>photons</u> → constraints

<u>Expected fluxes</u>:

$$E^2 \frac{dN}{dE} \lesssim \begin{cases} 10^{-6} \text{ GeV.cm}^{-2}.\text{s}^{-1}.\text{sr}^{-1} & (\text{"speculative"}) \\ 10^{-8} & (\text{"solid"}) \end{cases}$$

From Protheroe

(Neutrino 98, Takayama, june 98)

astroph/9809144

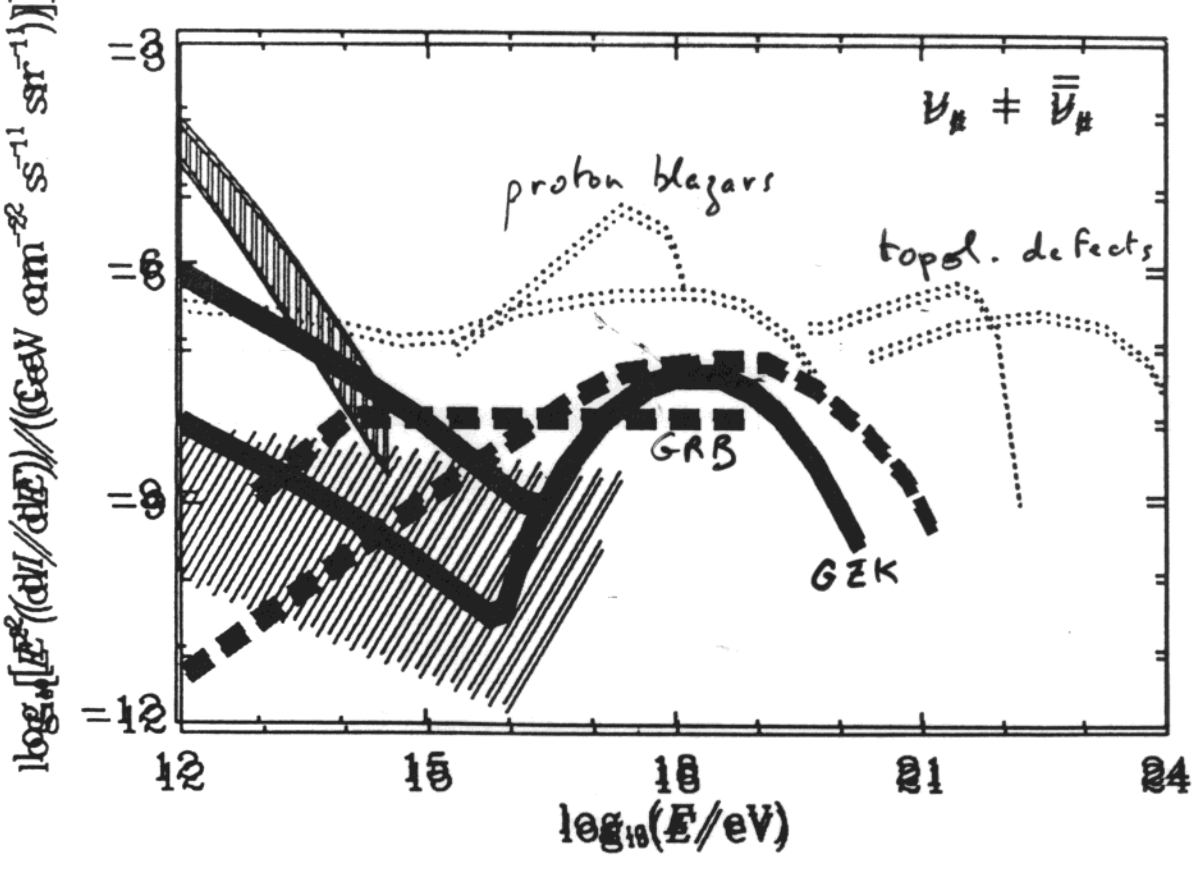


Figure 6. Grand Unified Neutrino Spectrum = a personal opinion about the predicted neutrino intensities: thick solid lines = certain; long dashed lines = almost certain; short dashed lines = speculative; dotted lines = highly speculative.

The Pierre AUGER Observatory

Hybrid detector of atmospheric showers

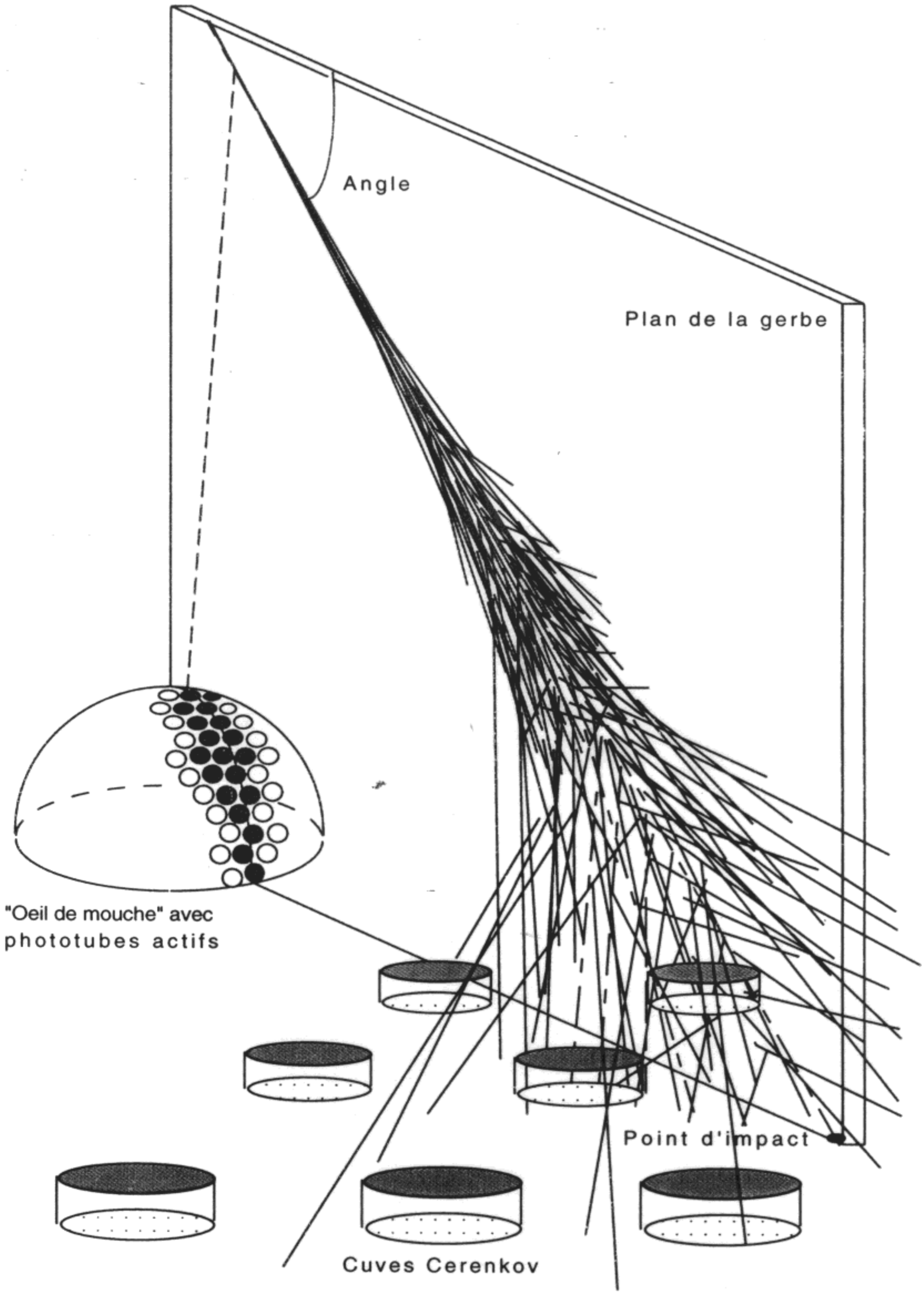
Fly's eye telescope	+	Ground array of stations
nitrogen fluorescence		Čerenkov light in water
↓		↓
longitudinal profile		lateral distribution + **time** structure (ADC @ 25 ns)

Aim: 100% efficiency above 10^{19} eV
(zenith angle $0 < \theta < 60$ deg.)

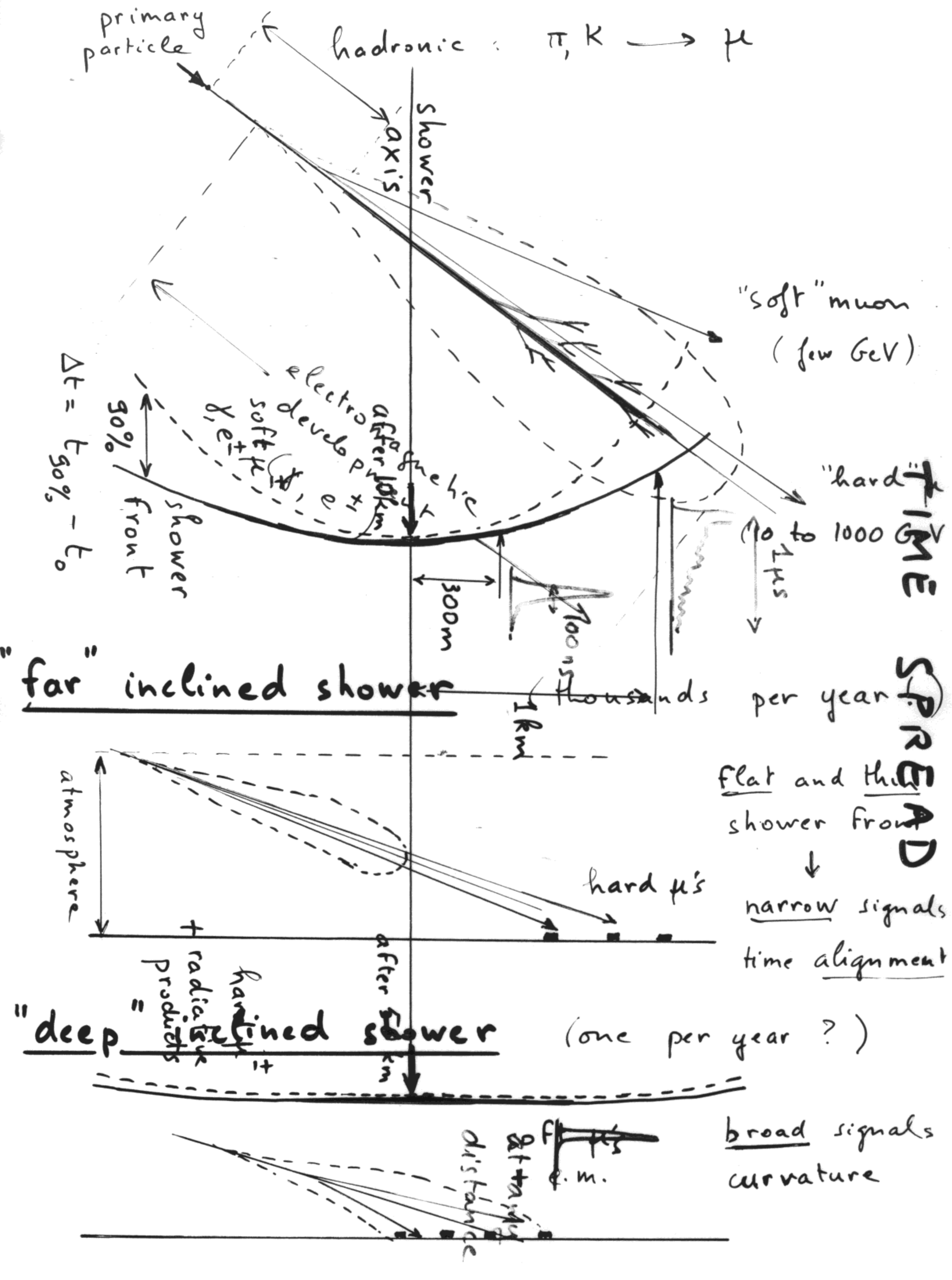
if interaction length $\ll$ atmosphere thickness
(nuclei, p, γ)

Possibility (without any addition, except trigger software)

"deep" showers with $\theta \sim 90$ deg, $E \gtrsim 10^{17}$ eV
(larger ground crossing surface)



Représentation schématique de la détection d'une gerbe atmosphérique par un détecteur hybride. Reproduit avec la permission de E.Zas, d'après un article dans la Revista Española de Física.



primary particle
hadronic : π, K → μ
shower axis
electromagnetic development
after 10 km
soft γ, e±
"soft" muon
(few GeV)
"hard" μ
(10 to 1000 GeV)
1 μs
90%
Δt = t90% − t0
shower front
300m
100 ns
1 km
TIME SPREAD
"far" inclined shower
thousands per year
flat and thin shower front
↓
narrow signals
time alignment
atmosphere
hard μ's
after 1 km
"deep" inclined shower
(one per year ?)
broad signals
curvature
e.m.
distance

First approach

Ground array

- area ~ 3000 km^2
- solid angle ~ 2 sr
- useful shower length ~ 15 km (10^{18} eV)
  → useful depth ~ 0 to 5 km
  (θ = 90 to 70 deg)

acceptance ~ 15 000 $km^3.sr$ at 10^{18} eV

above 10^{18} : increases smoothly (shower length)

below 10^{18} : decreases rapidly (favourable position needed w.r.t. array)

Fluorescence :

- only 10 (15?) % duty time
- limited range below 10^{19} eV

→ low rate of hybrid events !

monocular view : ambiguous position

not yet studied

Simulation of "neutrino" showers

AIRES package : accepts { <u>one</u> input particle at a time
{ not a neutrino

- <u>c.c. interaction of ν_e</u> (E) $\equiv$ { e (0.8 E)
{ p (0.2 E)

(independent check : hadronic fragments give ~ the same shower as an unique proton)

- n.c. interact. of ν_e }
c.c. or n.c. interact. of ν_μ } hadronic part only

(AUGER does not see a single UHE muon!)

<u>Rem</u>: hadronic induced showers are <u>broader</u> and contain more <u>muons</u> → important role!

- <u>Data samples</u>:
(zenith angle $70 < \theta < 90$ deg
(different injection altitudes h

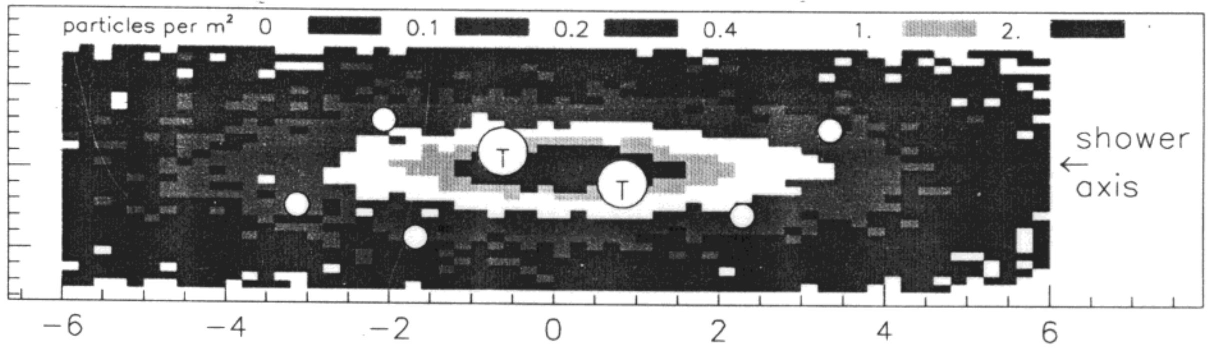
each sample : list of (weighted) ground particles

<u>then</u> : random position w.r.t. array
→ local sampling of ground particles in stations
→ ADC trace

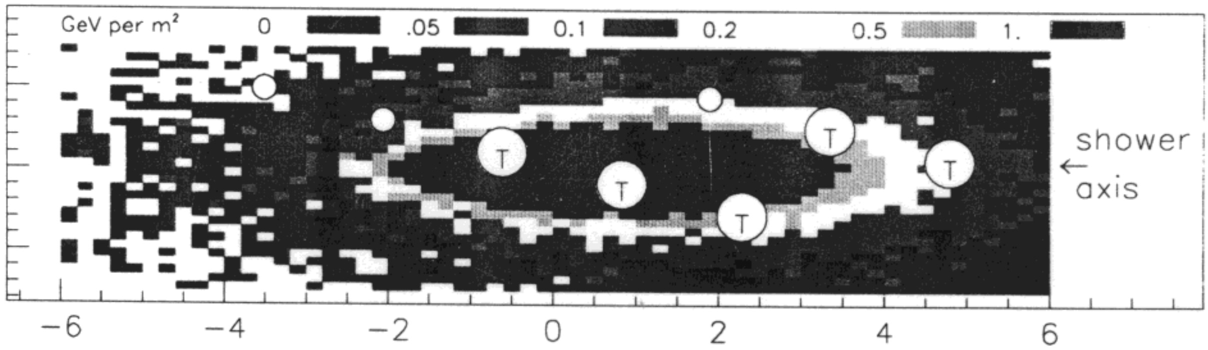
ν_e c.c. interaction

ground densities

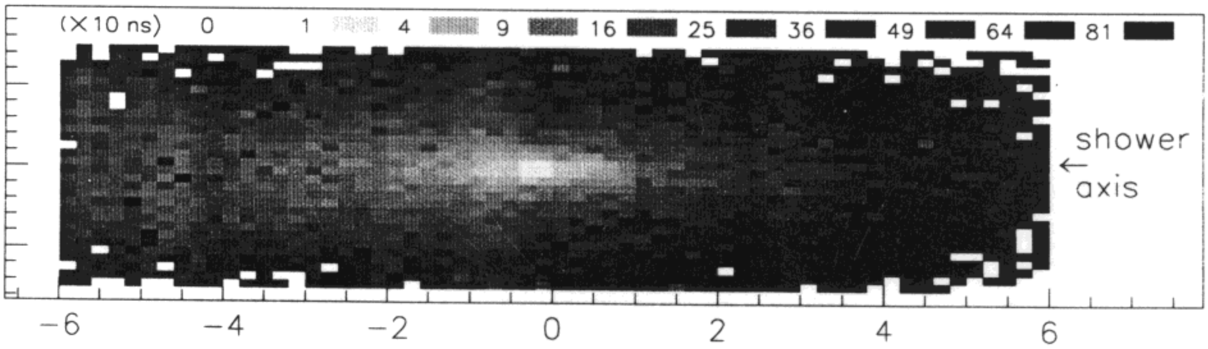
neutrino 10^{18}eV – injection altitude 2.1km – zenith angle 80 deg.



muon density



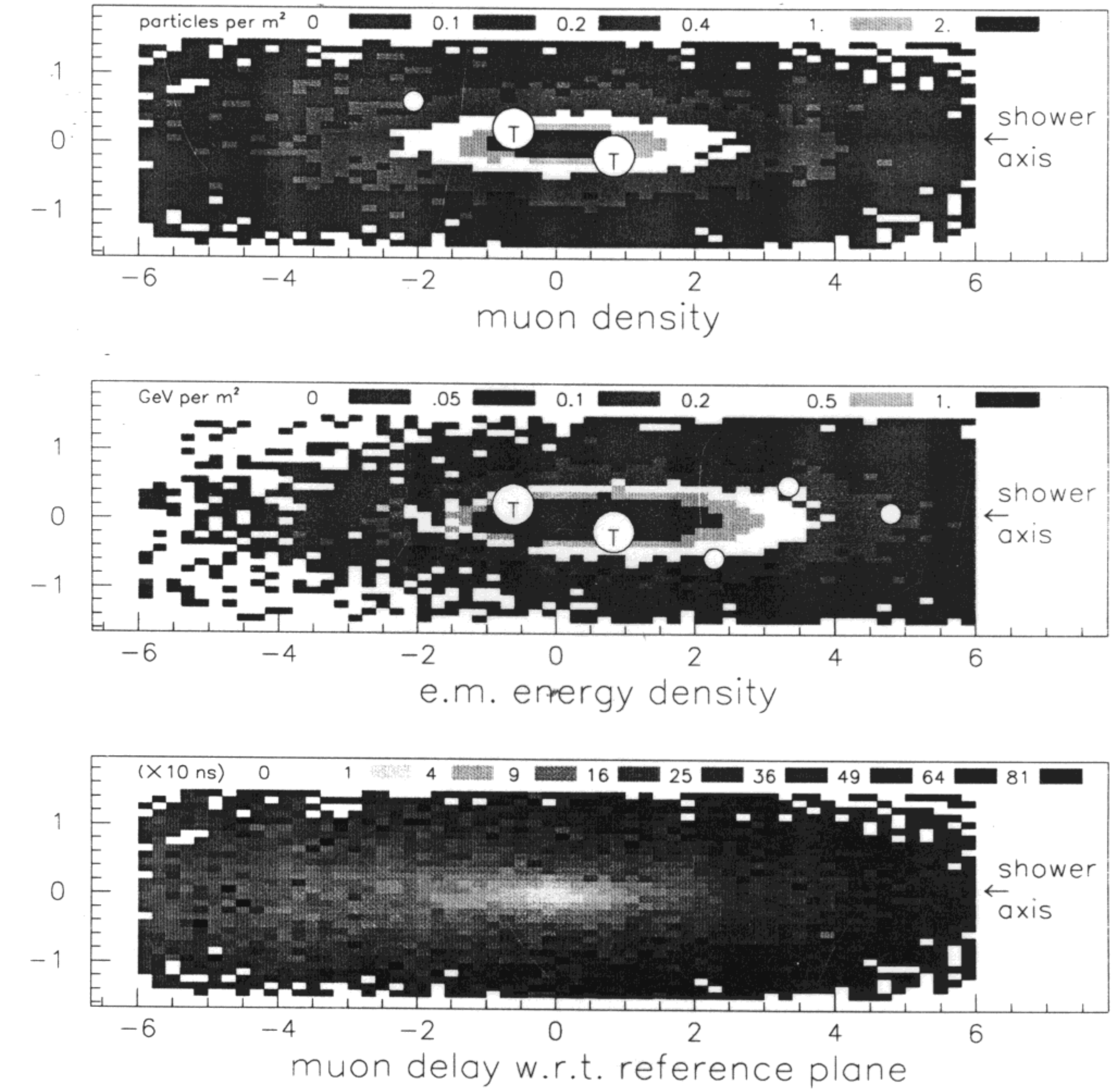
e.m. energy density



muon delay w.r.t. reference plane

ν_e (n.c.) or ν_μ interaction
ground densities

proton $10^{17.4}$ eV – injection altitude 2.1 km – zenith angle 80 deg.



Background ; selection of events

Random coincidences

estimation in progress
(prototype data + simul.)
rejection :
integral ⊗ time spread

critical if events with
$n_{stat} = 3$ are wanted

Extended events

- muonic tail of far showers
  time spread

- energetic τ ?
  negligible unless large heavy Flavour prod.

- **Local trigger condition :**

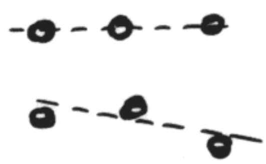
  in this study : sum > 8 vertical equiv. muons
  or : sum > 4 v.e.m **and** $\Delta t > 100\,ns$

  (to be tuned ; rate should be < 20 Hz)

- **Global condition :**

  - n (local trigger) ≥ 3
  - at least 2 with $\Delta t > 100\,ns$
  - time align^t (t_0's) within 200 ns

  if only 3 stations :

  etc...

  t_0 compatible with
  dotted line within 20 deg

→ no acceptance below 10^{17} eV (time spread)
problematic below 3.10^{17} eV

Acceptance ; event rate

$$\mathcal{A}(E) = \underbrace{S}_{\substack{\text{area} \\ \sim 3000\,\text{km}^2}} \int 2\pi \sin\vartheta \, d\vartheta \int dh \, \mathcal{P}(E, \vartheta, h)$$

$\mathcal{A}$ = (volume of air × solid angle)

assuming $\sigma_{\nu ee} = 10^{-32} \left(\frac{E}{10^{18}\,eV}\right)^{0.4} \; cm^2$

($L_{int} \sim 10^8\, g.cm^{-2}$ at $10^{18}\,eV$)

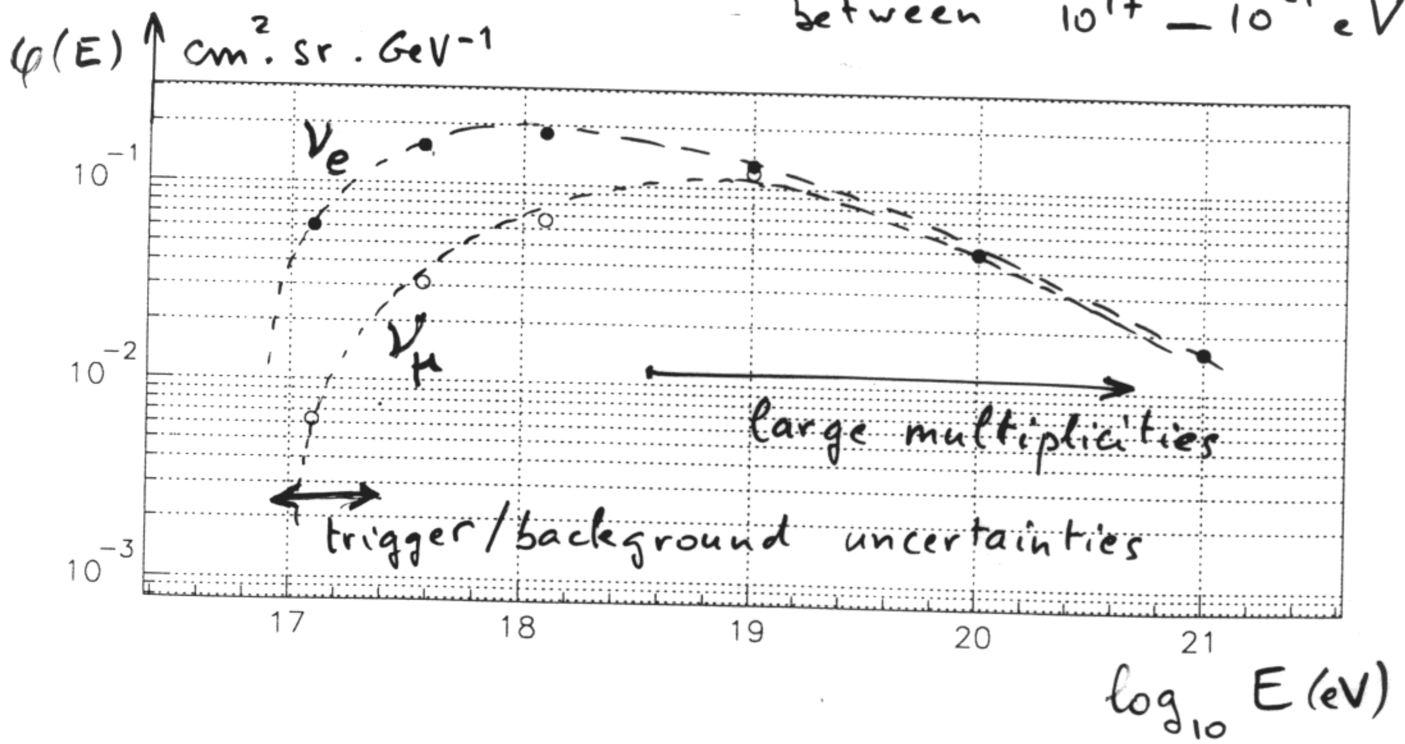
→ event rate :

$$\int_{E_{min}}^{E_{max}} \mathcal{A}(E)\, \sigma(E) \underbrace{n}_{6.10^{20}\,cm^{-3}} \underbrace{I(E)}_{\text{incident flux}} dE$$

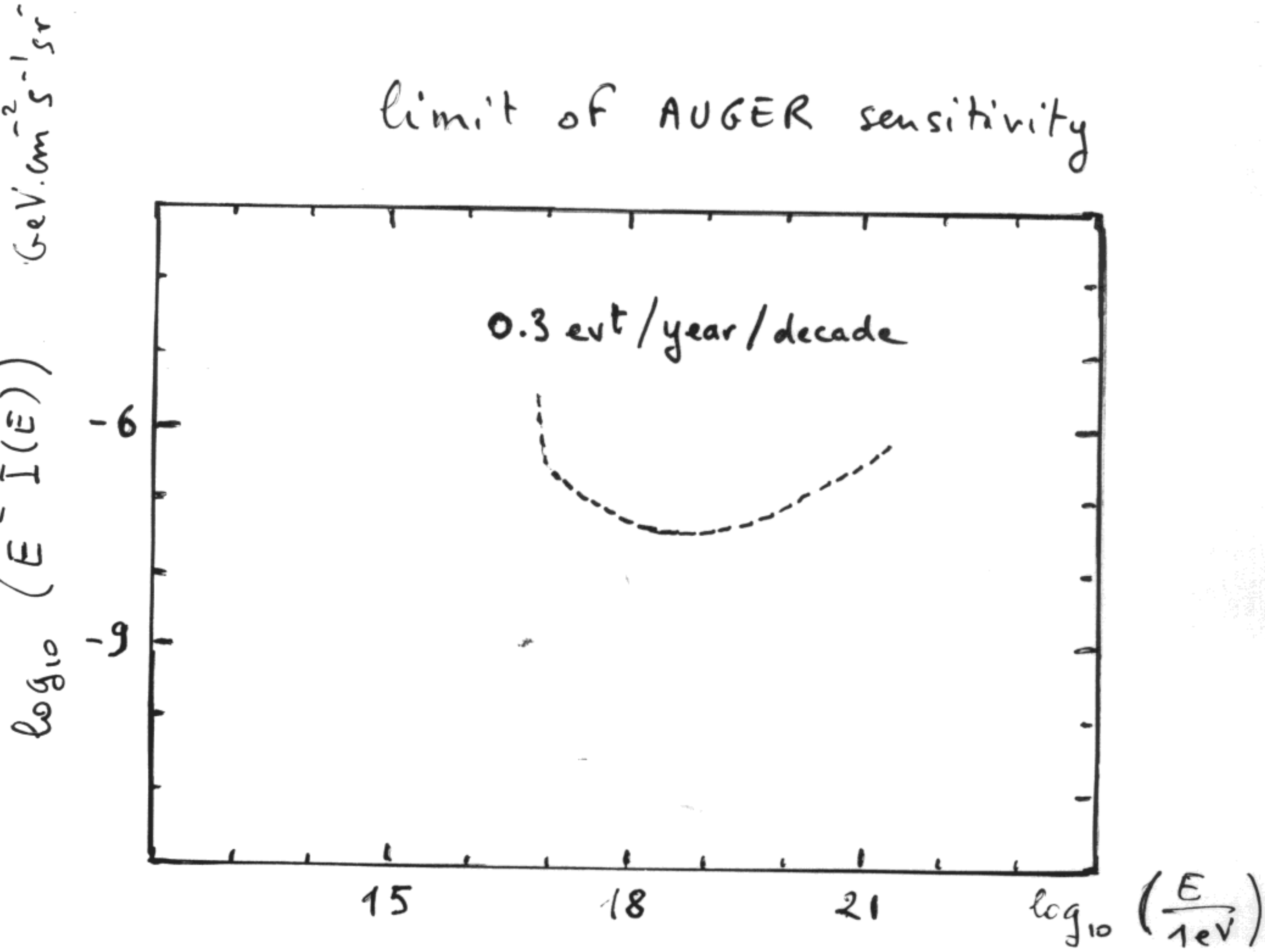
event rate per E decade (1 site)

$$\underbrace{\frac{2.3\, n\, \sigma(E)\, \mathcal{A}(E)}{E}} \times E^2 I(E)$$

$\varphi(E)$: smooth Function between 10^{17} – 10^{21} eV



limit of AUGER sensitivity



Shower reconstruction

Individual measurements:

3/4 stations:
- poor angular precision (a few deg, depending on configuration)
- nothing about energy

$\gtrsim 10$ stations:
- angles (~ 1 deg)
- lower bound on energy (depth is unknown ...)
- hadronic / electronic (muon content)

with luck: fluorescence $\longrightarrow$ full reconstruction

Statistical studies (if possible ...)

multiplicity
topology (aligned / not aligned) } $\longrightarrow$ spectrum

ν_e / ν_μ counting ?

compatibility with pointlike sources ?

time coincidences with GRB ?

Conclusions

- AUGER opens a window in the neutrino spectrum above 10^{17} eV

  no other experiment can do it in a near future

- A few events are expected from almost sure sources

- Clear yes/no answer to more or less speculative models. Constraints on TD

To be combined with <u>photon</u> identification