"Cosmogenic neutrinos detection"

P. Spillantini, INFN and University, Firenze

Round Table discussion
"Exciting neutrino: from Pauli, Fermi and Pontecorvo to nowadays prospect"
16°th Lomonov conference on Elementary Particle Physics, Moscow 22-28 August, 2013

Continued from:

Observation of Ultra High Energy neutrinos

Sergio Bottai, INFN, Firenze, Italy
Piero Mazzinghi, INOA, Firenze, Italy
Piero Spillantini, University and INFN, Firenze, Italy

11^{th} Lomonosov Conference on Elementary Particle Physics
Moscow, August 21-27, 2003

Continued from:

10th Lomonosov Conference on
Elementary Particle Physics,
Moscow, 23-29 August 2001

From the ‘Extreme Universe Space Observatory’
(EUSO)
to the ‘Extreme Energy Neutrino Observatory’

Cosmogenic neutrinos component

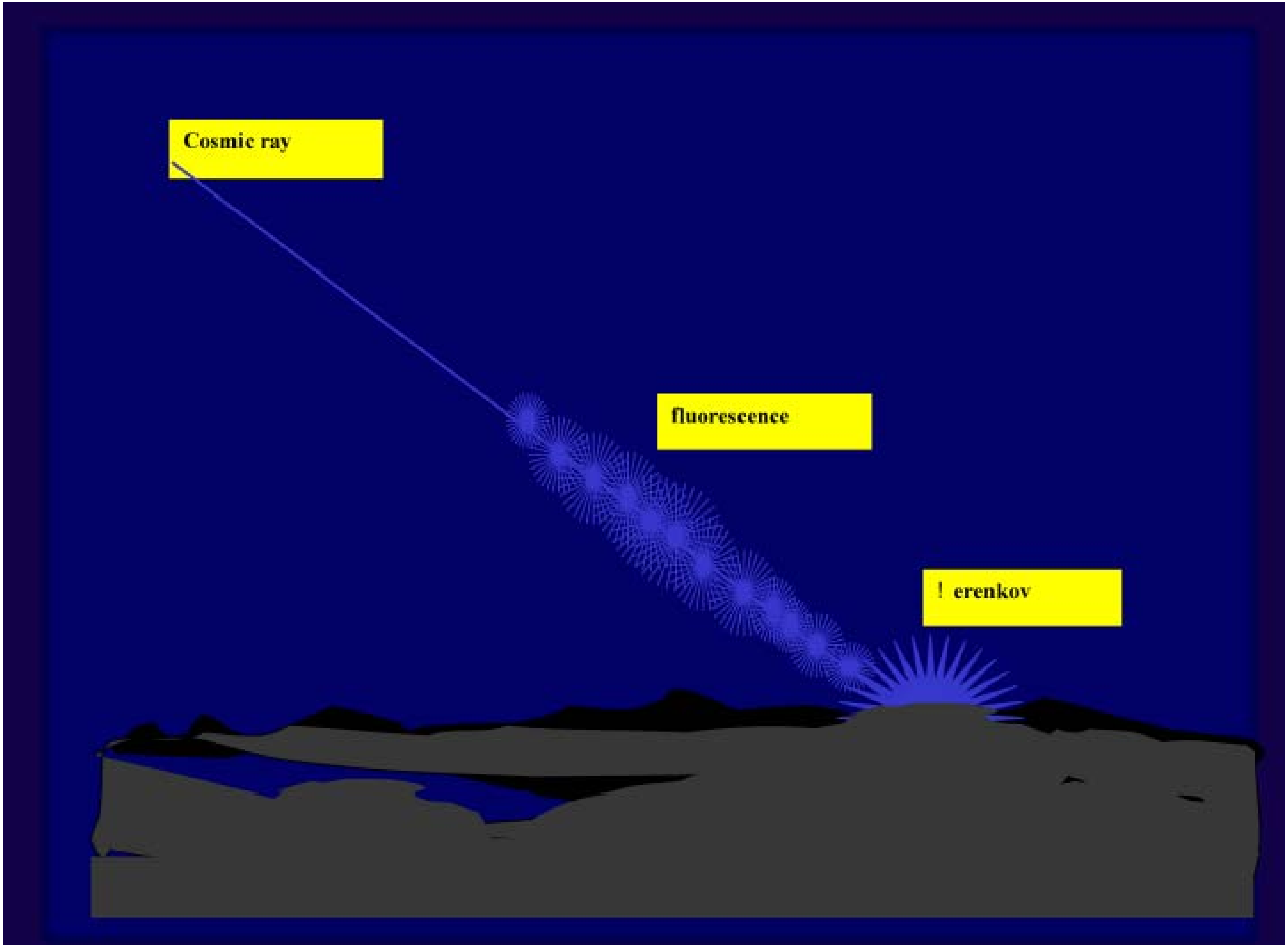
Protons coming from distances >20-50 Mpc interact with the CMB (GKZ effect) producing pions, and finally neutrinos.

Protons with $E>10^{20}$eV interact several times before degrading under the GKZ cut-off producing many ν_e and ν_μ neutrinos.

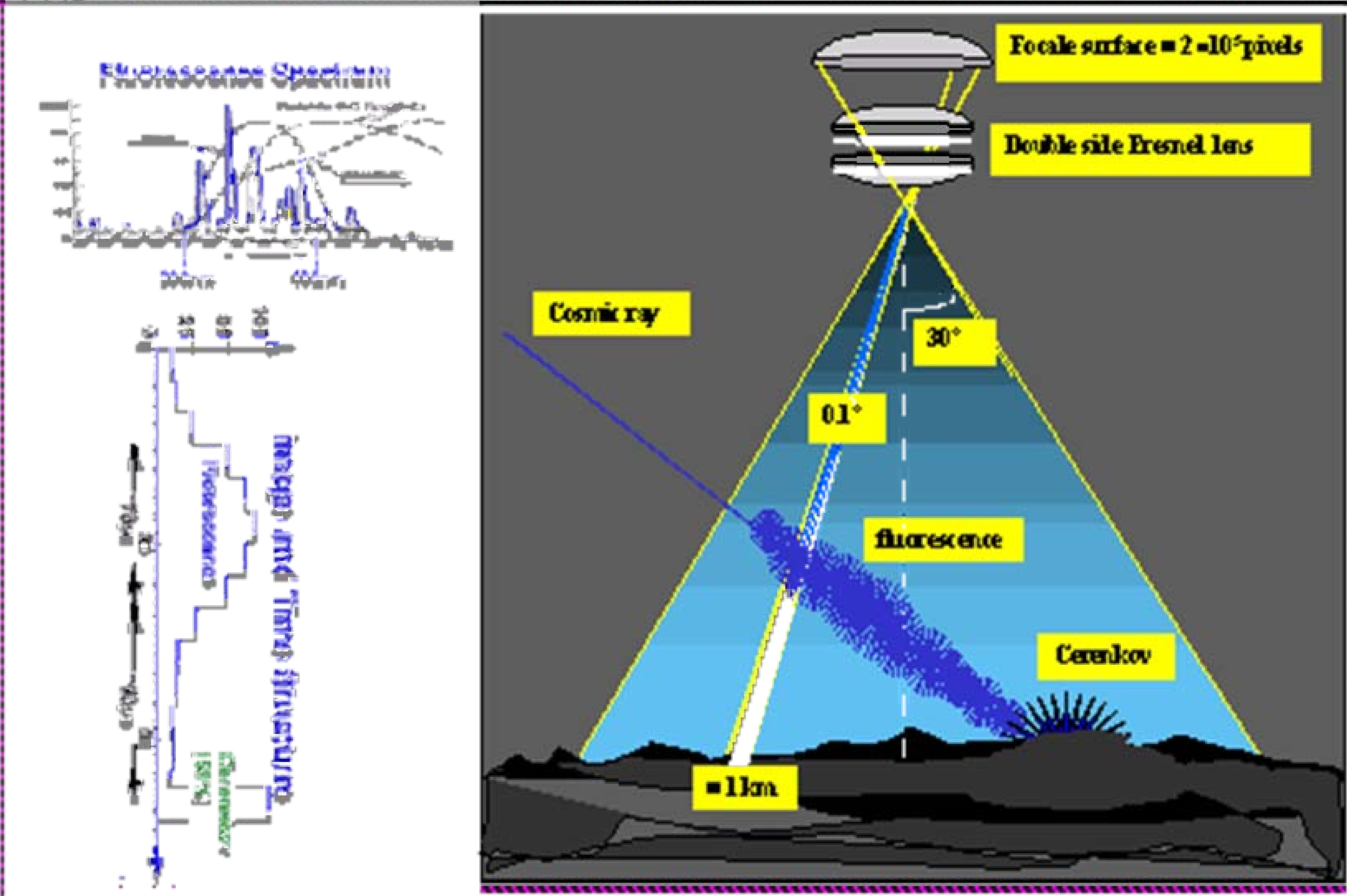
The energy of produced neutrinos is $\approx 10^{18}$eV or more

This is the “less unprobable” neutrino component expected at the extreme energies.

It is not “model dependent”
(i.e. it only depends from UHECR E_{max} and the proton source distribution)

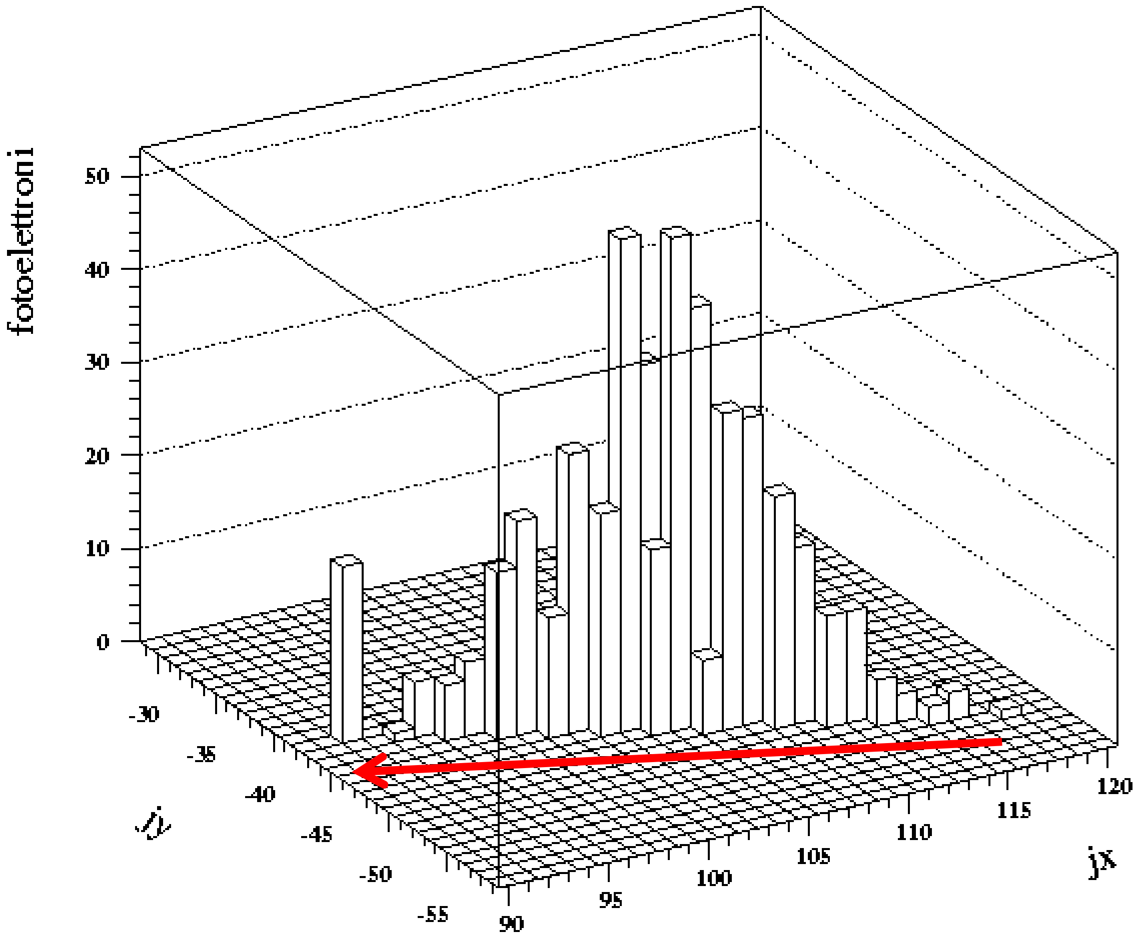

Cosmic ray
fluorescence
! erenkov

EUSO Approach



EUSO : Extreme Universe Space Observatory

Fig. 2.1 – Artist view of the ***EUSO*** concept. The shower development occurs in the atmosphere layers below 30-40 km a.s.l.; the isotopic fluorescence emission is proportional at any depth to the number of charged particles (mainly electrons) present in the shower front: $N_e \approx E_{eV} / (1.4x10^{9})$. The UV yield is ≈4 photons per meter of electron track, almost independent from air pressure and temperature.


fotoelettroni
50
40
30
20
10
0
-30
-35
-40
-45
-50
-55
jy
90
95
100
105
110
115
120
jx

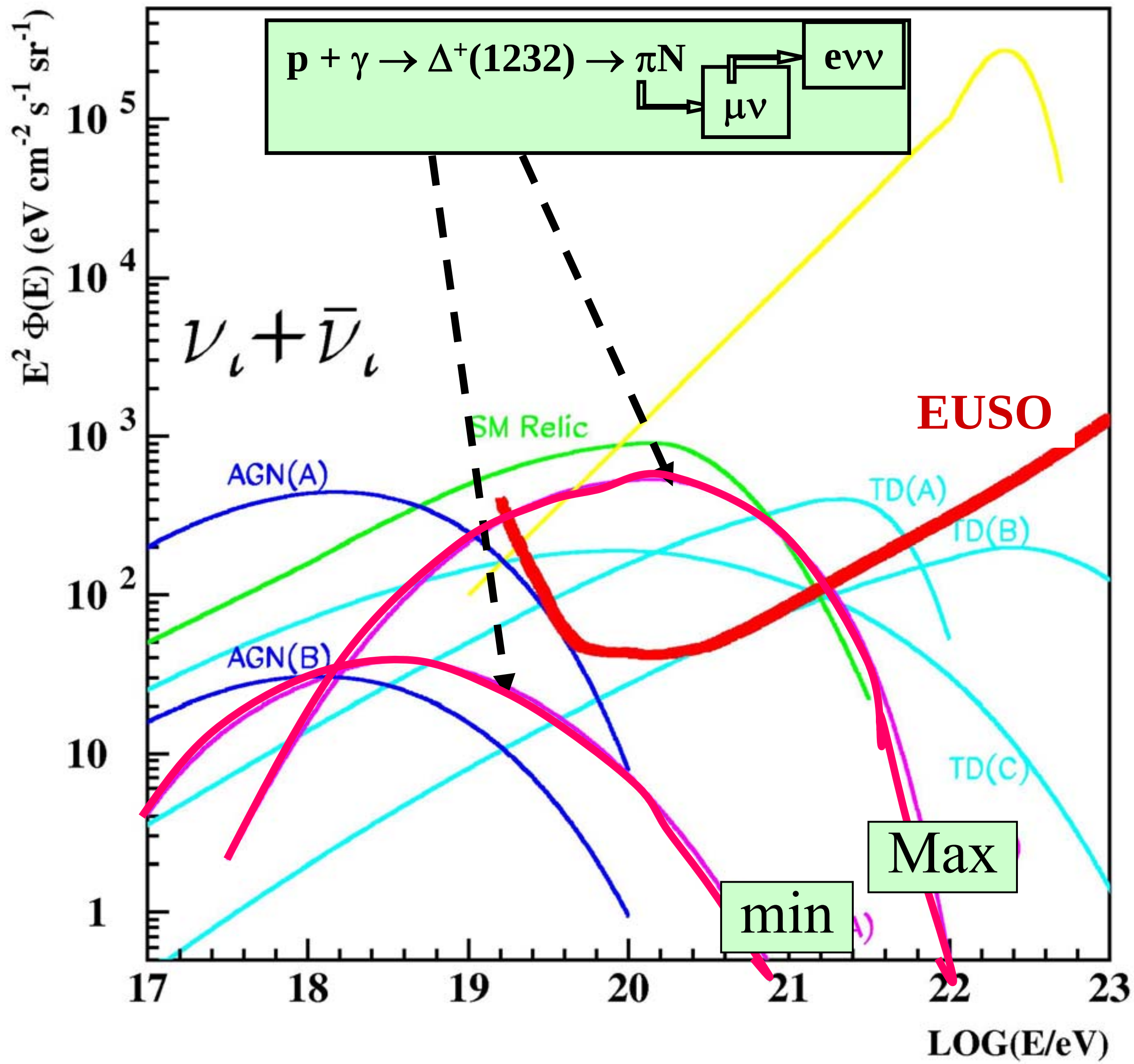
The most complete work was (@<2004)

"Ultra-High Energy Neutrino Fluxes and Their Constraints"

(Kalashek, Kuzmin, Semokov, Sigl)

[arXiv:hep-ph/0205050 v3 13 Dec 2002]

[Model consistent with gamma's and
UHECR data (Fly'sEye, Haverah Park, Yakytsk, AGASA)]


p + γ → Δ+(1232) → πN
μν
eνν
E2 Φ(E) (eV cm-2 s-1 sr-1)
10 5
10 4
10 3
10 2
10
1
ν + ν̄
SM Relic
AGN(A)
AGN(B)
TD(A)
TD(B)
TD(C)
EUSO
Max
min
17
18
19
20
21
22
23
LOG(E/eV)

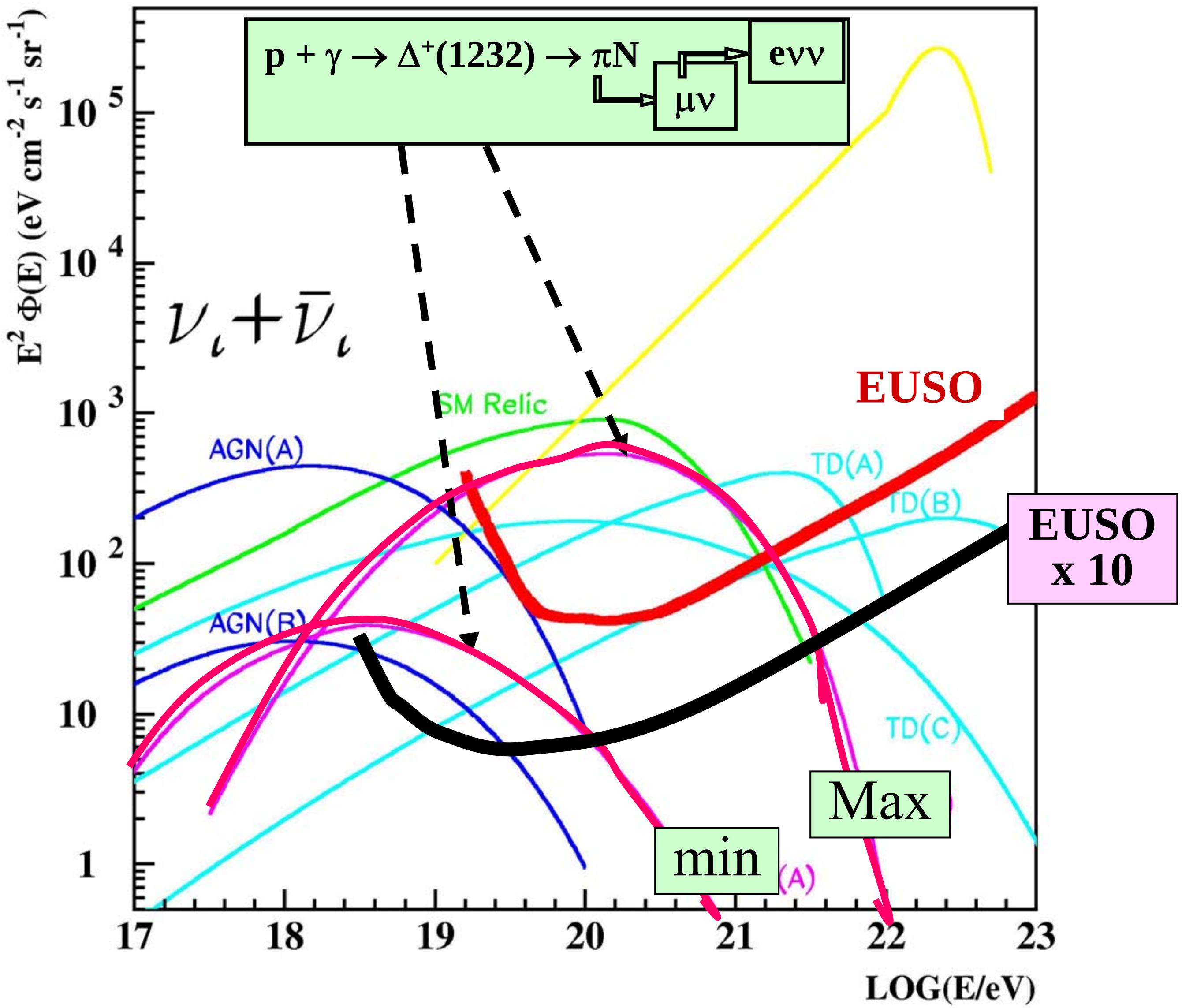
APS Neutrino Study:

Report of the Neutrino Astrophysics and Cosmology Working Group

(29 October 2004)

- We strongly recommend the development of experimental techniques that focus on the detection of astrophysical neutrinos, especially in the energy range above 10^{15} eV.

.... The technical goal of the next generation detector should be to increase the sensitivity by factor of 10, which may be adequate to measure the energy spectrum of the expected GZK (Greisen-Zatsepin-Kuzmin) neutrinos, produced by the interactions of ultra-high energy cosmic ray protons with the cosmic microwave background.



p + γ → Δ+(1232) → πN
eνν
μν
$\nu_\iota + \bar{\nu}_\iota$
SM Relic
AGN(A)
AGN(B)
TD(A)
TD(B)
TD(C)
(A)
EUSO
EUSO x 10
Max
min
E2 Φ(E) (eV cm-2 s-1 sr-1)
10 5
10 4
10 3
10 2
10
1
17
18
19
20
21
22
23
LOG(E/eV)

Is it possible to increase the number of detected neutrino events?

(EUSO-like from ISS)

-Decrease the energy threshold (5 x 10^{19}eV → 10^{18}eV)

by improving the sensor efficiency (0.20 → 0.50) x 1.5

by improving the light collection (pupil ∅ 2m → 6m) x 9

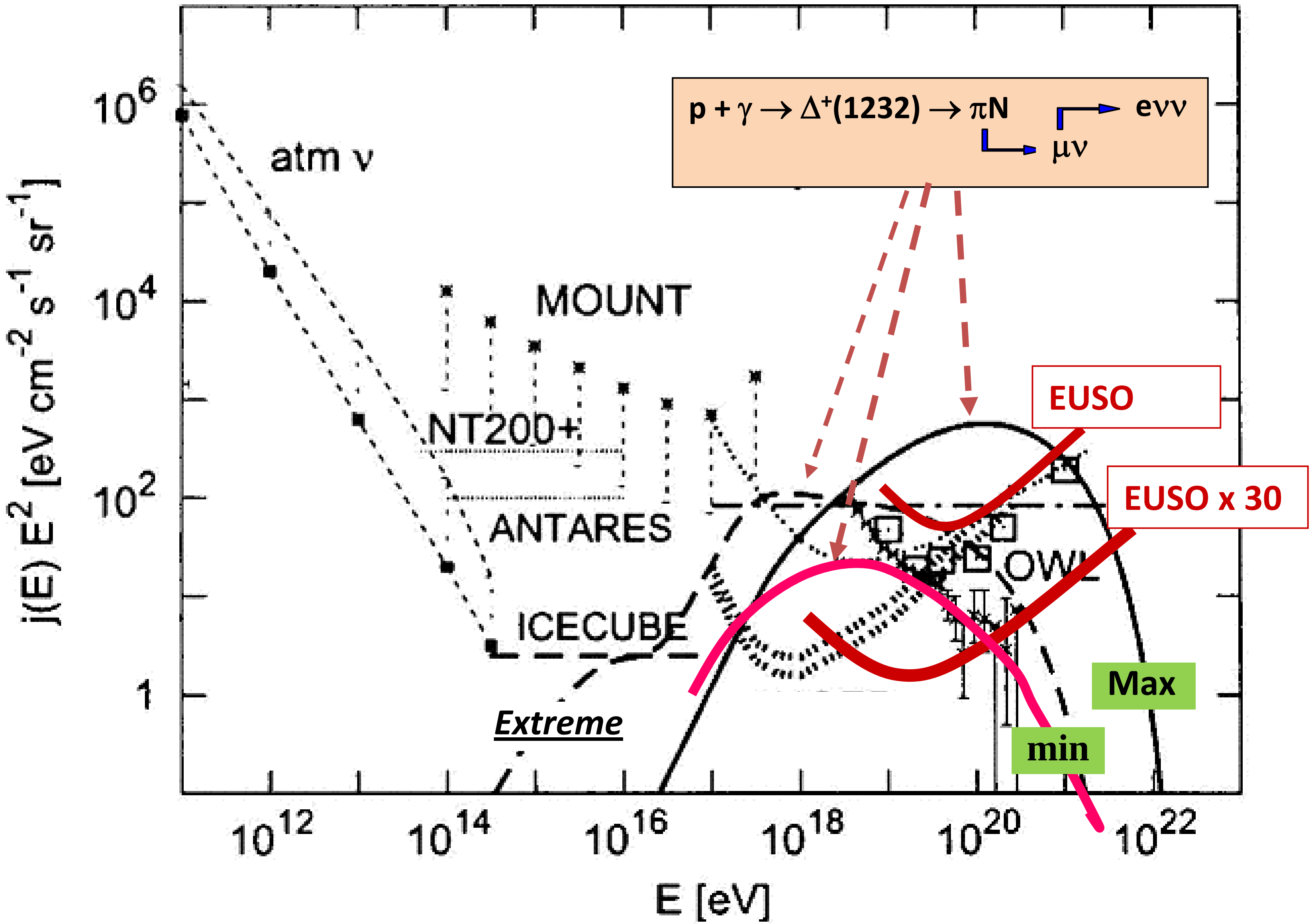
(what implies reflective systems and modularity)

-Increase the target volume

-by increasing the FOV (60° → 140.8°) (x 90)

but limited to ≅90º by attenuation by air and by distance x 3

....



$p + \gamma \rightarrow \Delta^+(1232) \rightarrow \pi N$
$e\nu\nu$
$\mu\nu$
atm ν
MOUNT
NT200+
ANTARES
ICECUBE
Extreme
OWL
EUSO
EUSO x 30
Max
min
10^6
10^4
10^2
1
10^{12}
10^{14}
10^{16}
10^{18}
10^{20}
10^{22}
E [eV]
$j(E)\,E^2\,[\mathrm{eV\,cm^{-2}\,s^{-1}\,sr^{-1}}]$

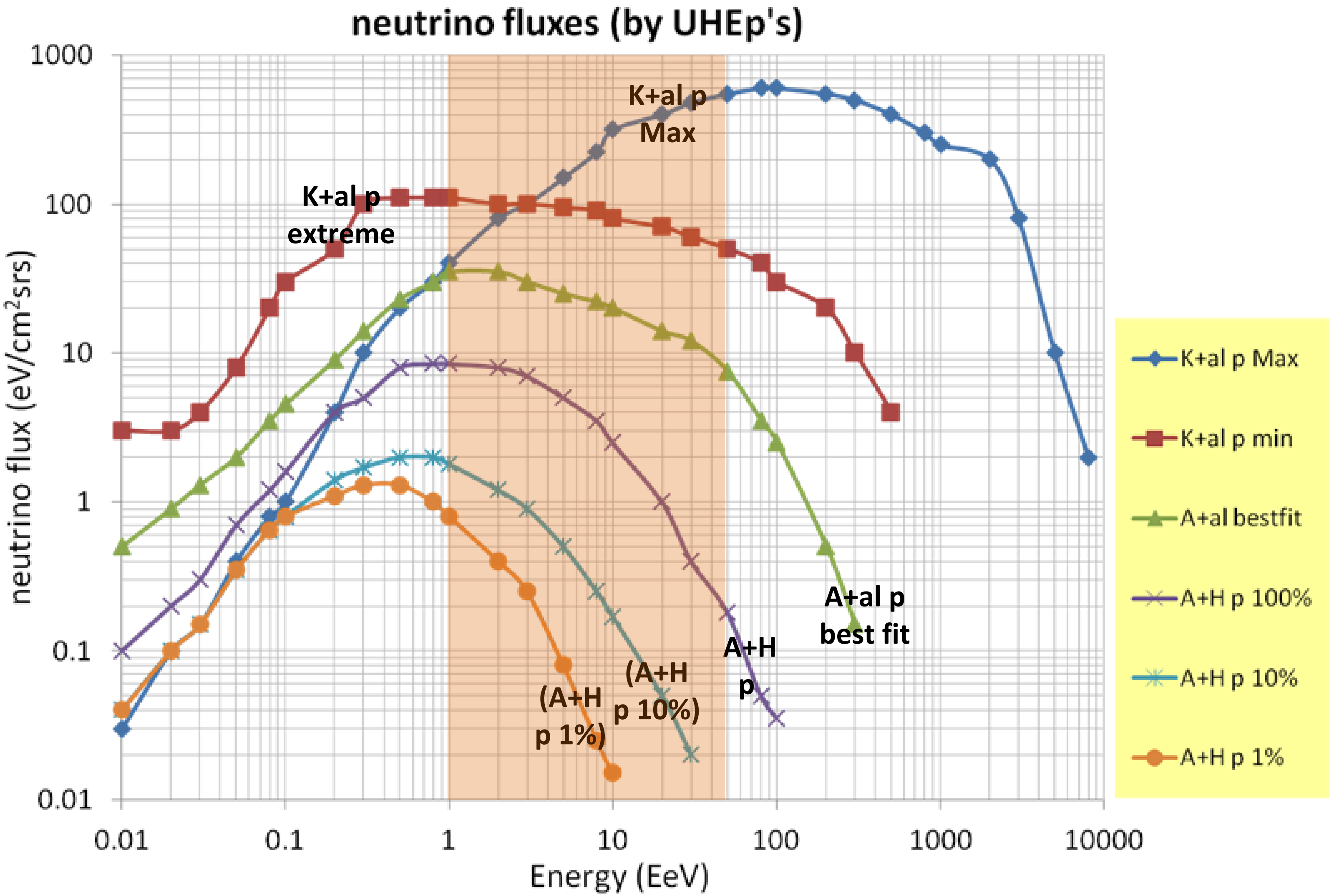
	One optical system (EUSO like)		Multi-mirror		
H (km)	400		400		
Total FoV (°)	60		90		
Radius on ground (km)	235		400		
Area on ground ($10^3 km^2$)	173		503		
Target volume (km^3)	1730		5030		
Pixel on ground (km * km)	0.8 x 0.8		0.8x0.8		
number of pixels) (.8x.8 km2)	270k		786k		
Pupil diameter (m)	2.0	2.0	4.0	6.0	10.0
Photo detection efficiency	20%	50%	50%	50%	50%
E threshold (EeV)	50	30	8	3	1.2
Proton events/year,					
GKZ + uniform source distrib.	1200	4000	35k	300k	2000k
with E_p >100 EeV)	100	100	290	290	290
Neutrino events per year (≈ min)	**0.2**	**0.4**	**1.5**	**4.5**	**10**
Neutrino events per year (≈ Max)	**4**	**6**	**12**	**14**	**18**

After 2004: new data:

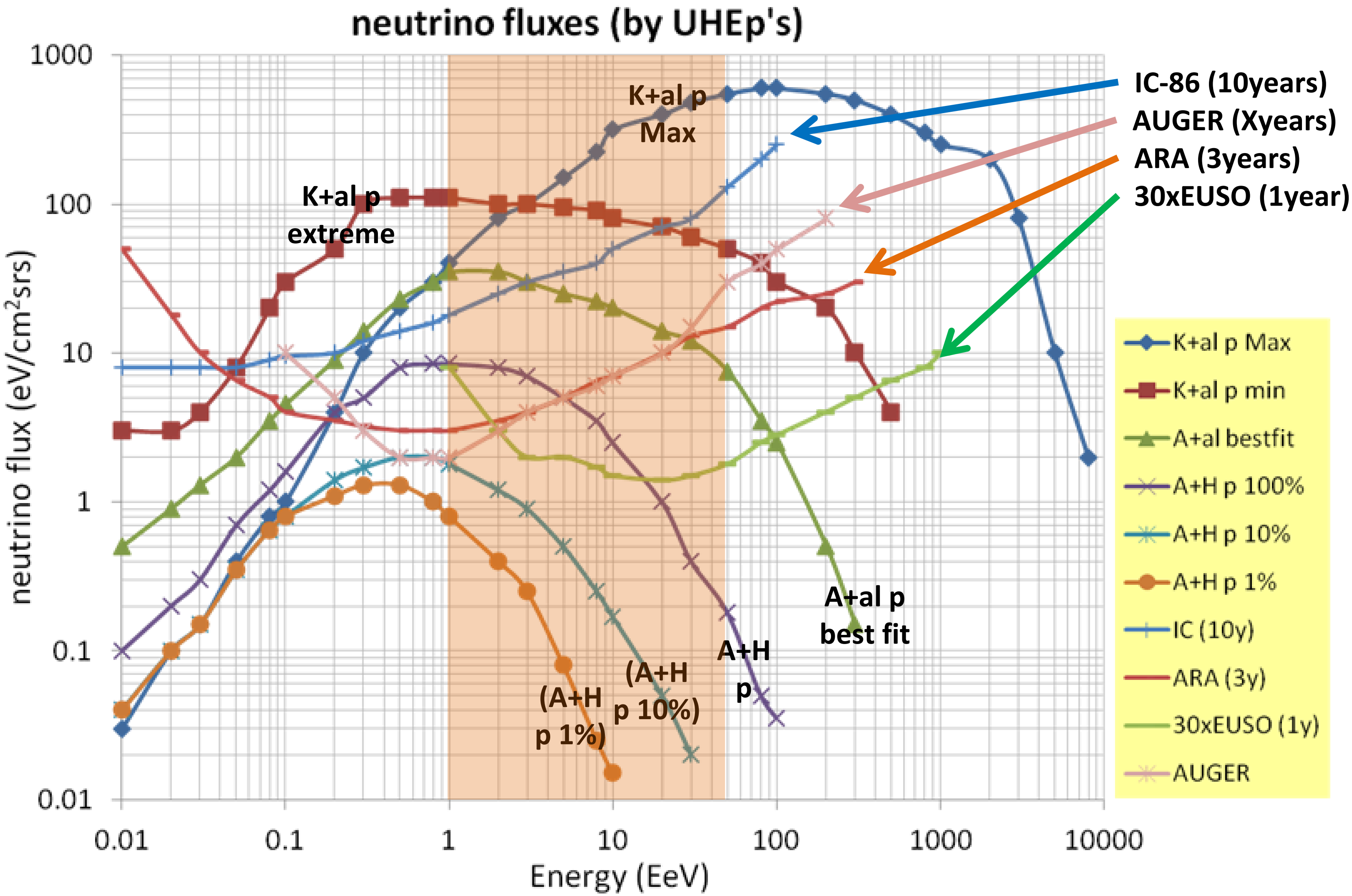
- GZK confirmed + (?) primary UHECR heavier than p (?)
- Fermi-LAT

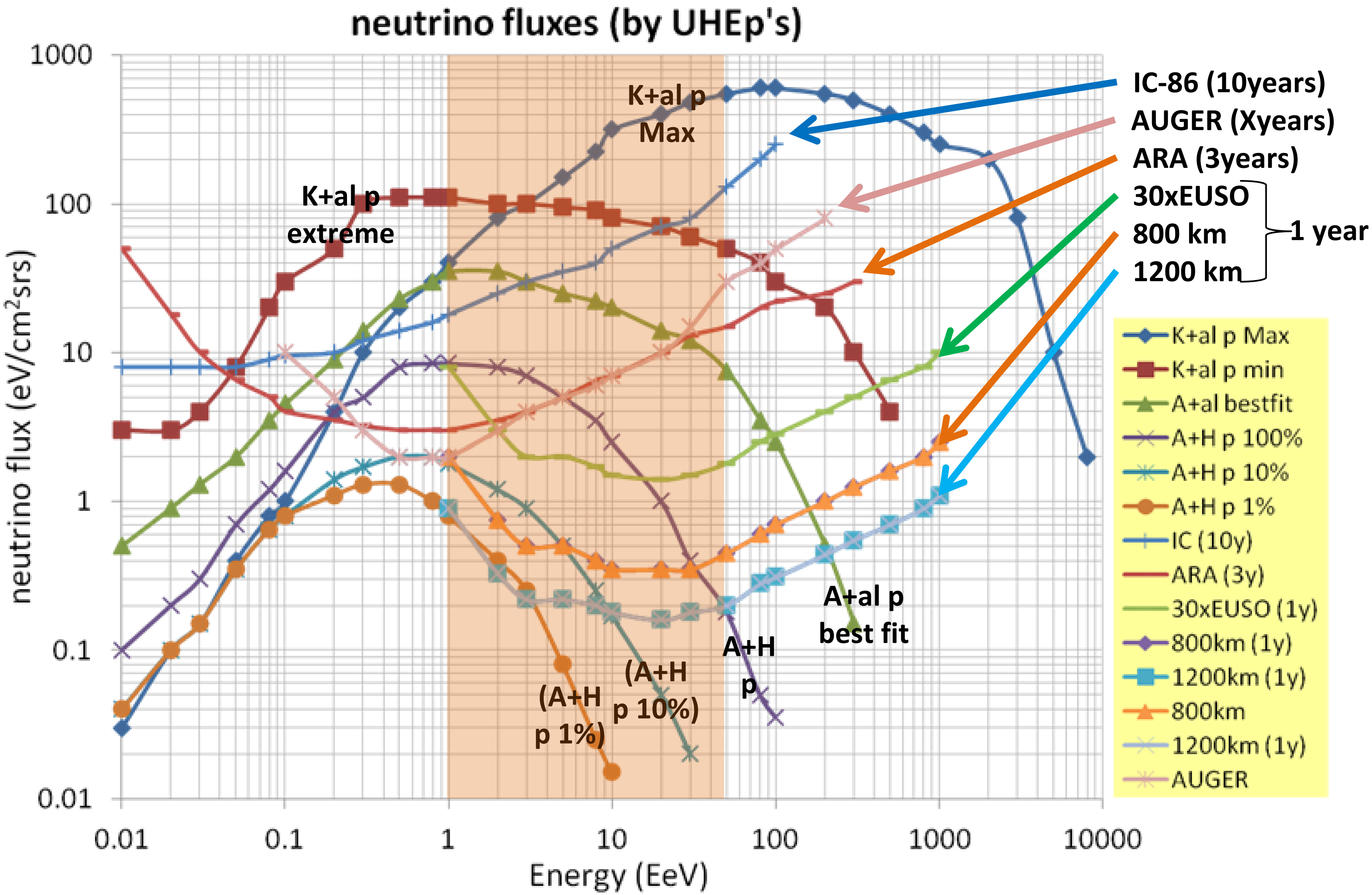
Ahlers et al. bestfit, consistent with HiRes spectrum and Fermi-LAT diffuse gamma's
'GZK neutrinos after Fermi-LAT diffuse photon flux measurement'
M.Ahlers et al., Astropart. Phys. 34, 106 (2010)

Ahlers and Halsen updates of lower limits (normalization to Auger data)
'Minimal Cosmogenic Neutrinos' arXiv:1208.4181v1, 21 Aug 2012

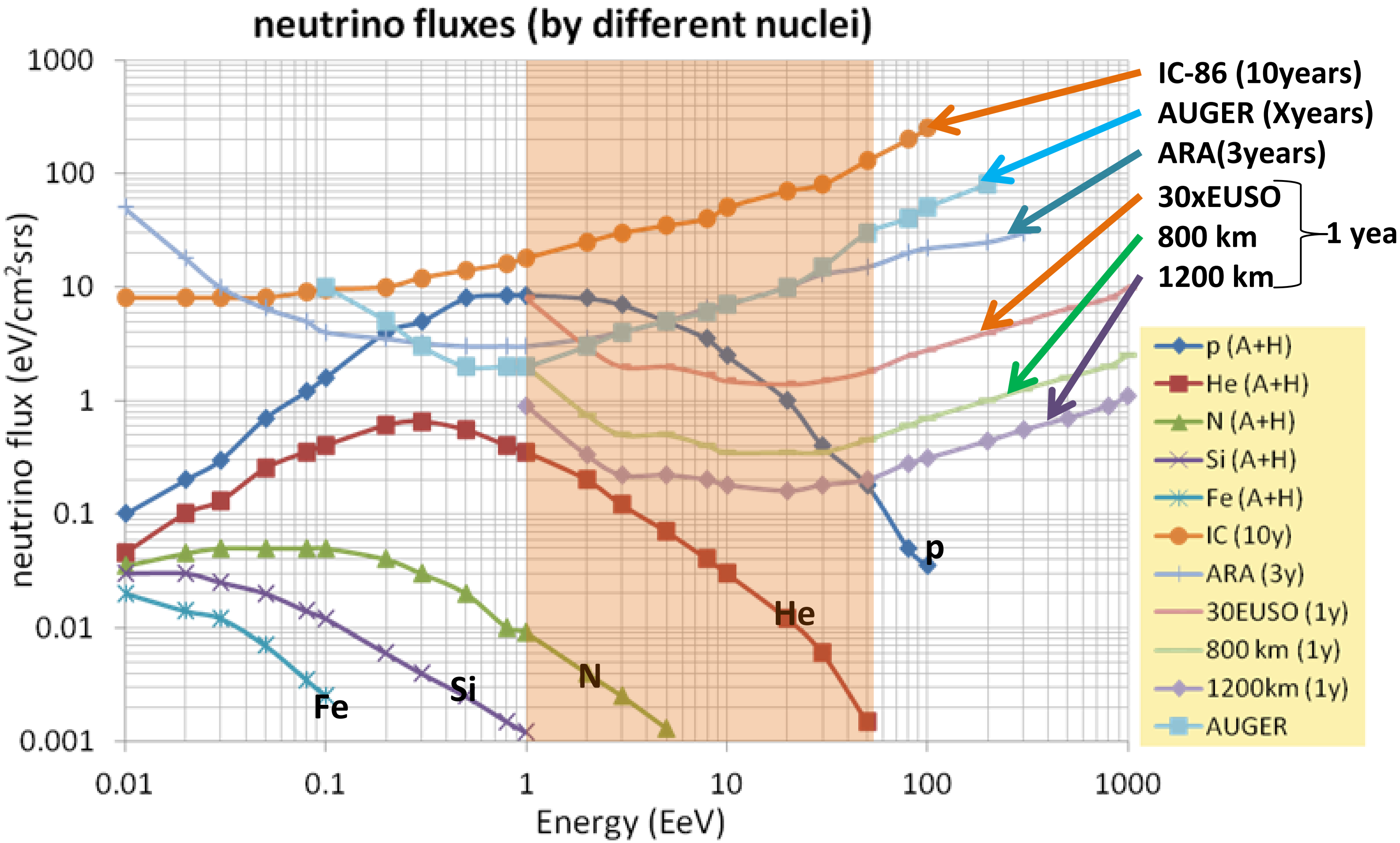


neutrino fluxes (by UHEp's)
neutrino flux (eV/cm²srs)
1000
100
10
1
0.1
0.01
0.01
0.1
1
10
100
1000
10000
Energy (EeV)
K+al p Max
K+al p extreme
A+al p best fit
A+H p
(A+H p 10%)
(A+H p 1%)
K+al p Max
K+al p min
A+al bestfit
A+H p 100%
A+H p 10%
A+H p 1%


neutrino fluxes (by UHEp's)
neutrino flux (eV/cm²srs)
Energy (EeV)
1000
100
10
1
0.1
0.01
0.01
0.1
1
10
100
1000
10000
K+al p Max
K+al p extreme
A+al p best fit
A+H p
(A+H p 10%)
(A+H p 1%)
IC-86 (10years)
AUGER (Xyears)
ARA (3years)
30xEUSO (1year)
K+al p Max
K+al p min
A+al bestfit
A+H p 100%
A+H p 10%
A+H p 1%
IC (10y)
ARA (3y)
30xEUSO (1y)
AUGER

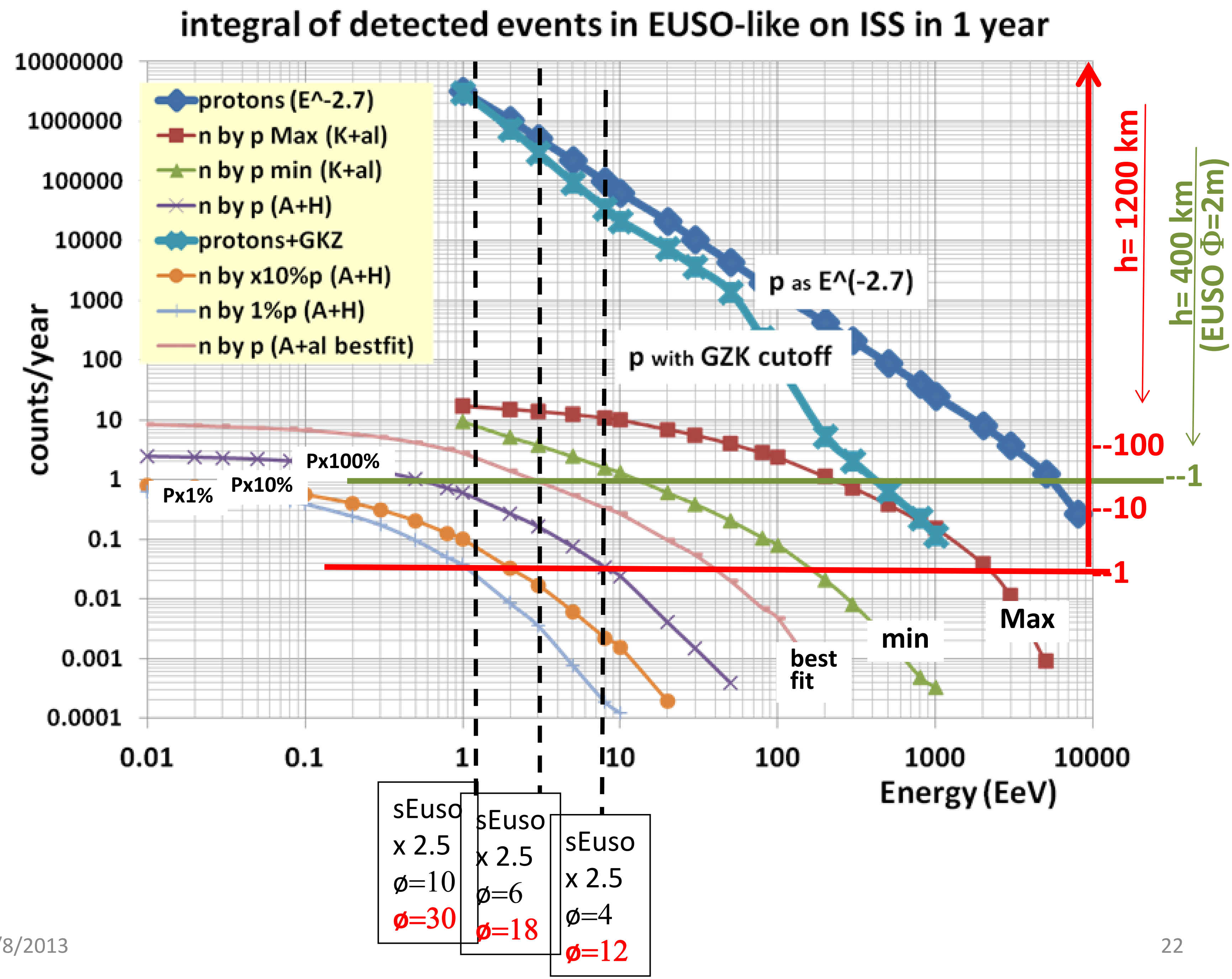


neutrino fluxes (by UHEp's)
1000
100
10
1
0.1
0.01
neutrino flux (eV/cm²srs)
0.01
0.1
1
10
100
1000
10000
Energy (EeV)
K+al p Max
K+al p extreme
A+al p best fit
A+H p
(A+H p 10%)
(A+H p 1%)
IC-86 (10years)
AUGER (Xyears)
ARA (3years)
30xEUSO
800 km
1200 km
1 year
K+al p Max
K+al p min
A+al bestfit
A+H p 100%
A+H p 10%
A+H p 1%
IC (10y)
ARA (3y)
30xEUSO (1y)
800km (1y)
1200km (1y)
800km
1200km (1y)
AUGER



neutrino fluxes (by different nuclei)
1000
100
10
1
0.1
0.01
0.001
neutrino flux (eV/cm²srs)
0.01
0.1
1
10
100
1000
Energy (EeV)
Fe
Si
N
He
p
IC-86 (10years)
AUGER (Xyears)
ARA(3years)
30xEUSO
800 km
1200 km
1 year
p (A+H)
He (A+H)
N (A+H)
Si (A+H)
Fe (A+H)
IC (10y)
ARA (3y)
30EUSO (1y)
800 km (1y)
1200km (1y)
AUGER

	One optical system (EUSO like)	Multi-mirror				
H (km)	400		400		800	1200
Total FoV (°)	60		90		90	90
Radius on ground (km)	235		400		≅ 800	≅ 1200
Area on ground ($10^3 km^2$)	173		503		≅ 2000	≅ 4500
Target volume (w.e. km^3)	1730		5030		≅ 20000	≅ 45000
Pixel on ground (km x km)	0.8 x 0.8		0.8x0.8		0.8x0.8	0.8x0.8
number of pixels) (.8x.8 km^2)	270k		786k		≅ 3000k	≅ 7000k
Pupil diameter (m)	2.0	4.0	6.0	10.0	12	18
Photo detection efficiency	50%	50%	50%	50%	50%	50%
E threshold (EeV)	30	8	3	1.2	3	3
Proton events/year,						
GKZ + uniform source distrib.	4000	35k	300k	2000k	1200K	2700k
with E_p >100 EeV)	100	290	290	290	1180	2600
Neutrino events per year (≈ min)	**0.4**	**1.5**	**4.5**	**10**	**18**	**40**
Neutrino events per year (≈ Max)	**6**	**12**	**14**	**18**	**56**	**126**
Neutrino events per year (bestfit)	**0.05**	**0.3**	**1**	**2.5**	**4**	**9**
Neutrino events per year (px100%)	**0.002**	**0.035**	**0.15**	**0.5**	**0.6**	**1.3**
Neutrino events per year (px10%)	**-**	**0.0025**	**0.015**	**0.08**	**0.06**	**0.13**
Neutrino events per year (px1%)	**-**	**0.0002**	**0.003**	**0.025**	**0.012**	**0.027**



integral of detected events in EUSO-like on ISS in 1 year
protons (E^-2.7)
n by p Max (K+al)
n by p min (K+al)
n by p (A+H)
protons+GKZ
n by x10%p (A+H)
n by 1%p (A+H)
n by p (A+al bestfit)
p as E^(-2.7)
p with GZK cutoff
Px100%
Px10%
Px1%
best fit
min
Max
counts/year
Energy (EeV)
h= 1200 km
h= 400 km
(EUSO Φ=2m)
--100
--10
-1
--1
sEuso x 2.5 ø=10 ø=30
sEuso x 2.5 ø=6 ø=18
sEuso x 2.5 ø=4 ø=12

Conclusions:

Cosmogenic neutrino detection is crucial for the neutrino entering the scene as a new instrument for Astrophysics, Cosmology and Particle Physics

New data have diminished their foreseen flux by at least 2 orders of magnitude

If the p component in UHECR is abundant, complex large optical systems can observe cosmogenic neutrinos from space, but high altitude orbits could be necessary

If the heavy nuclei component prevails its ‘daugter’ cosmogenic neutrino flux is out of reach for any system.
(also because the neutrino energy becomes too small for detection by radio-systems)

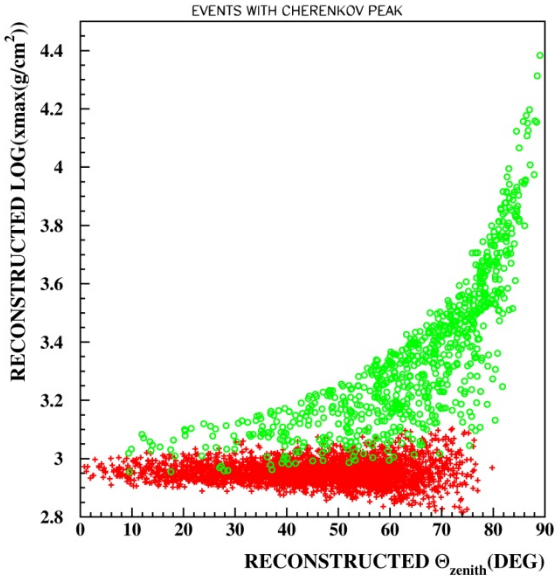
In next few years the increase of UHECR statistics and the definition of their charge should help in clarifying the situation.

Could you follow me?

Thank you!

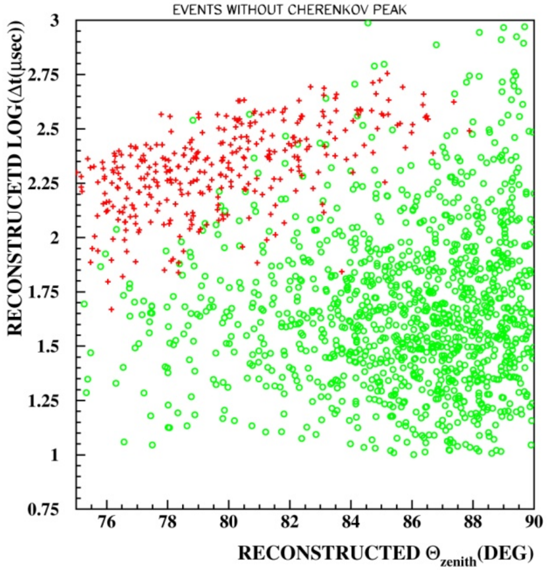
golden

Xmax Select.



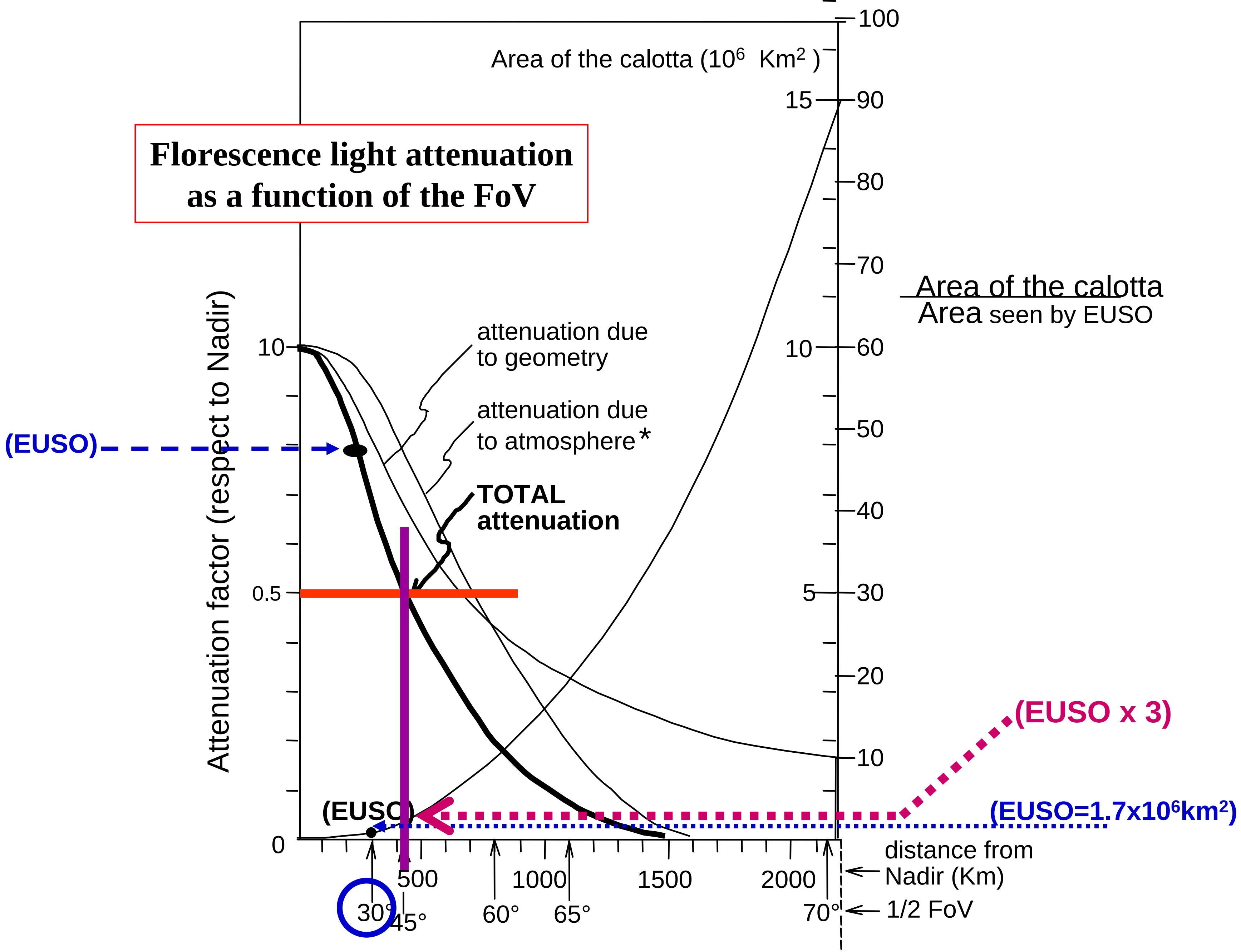
Fluorescence only

Shape Select.



Rejection > 10^{-4}

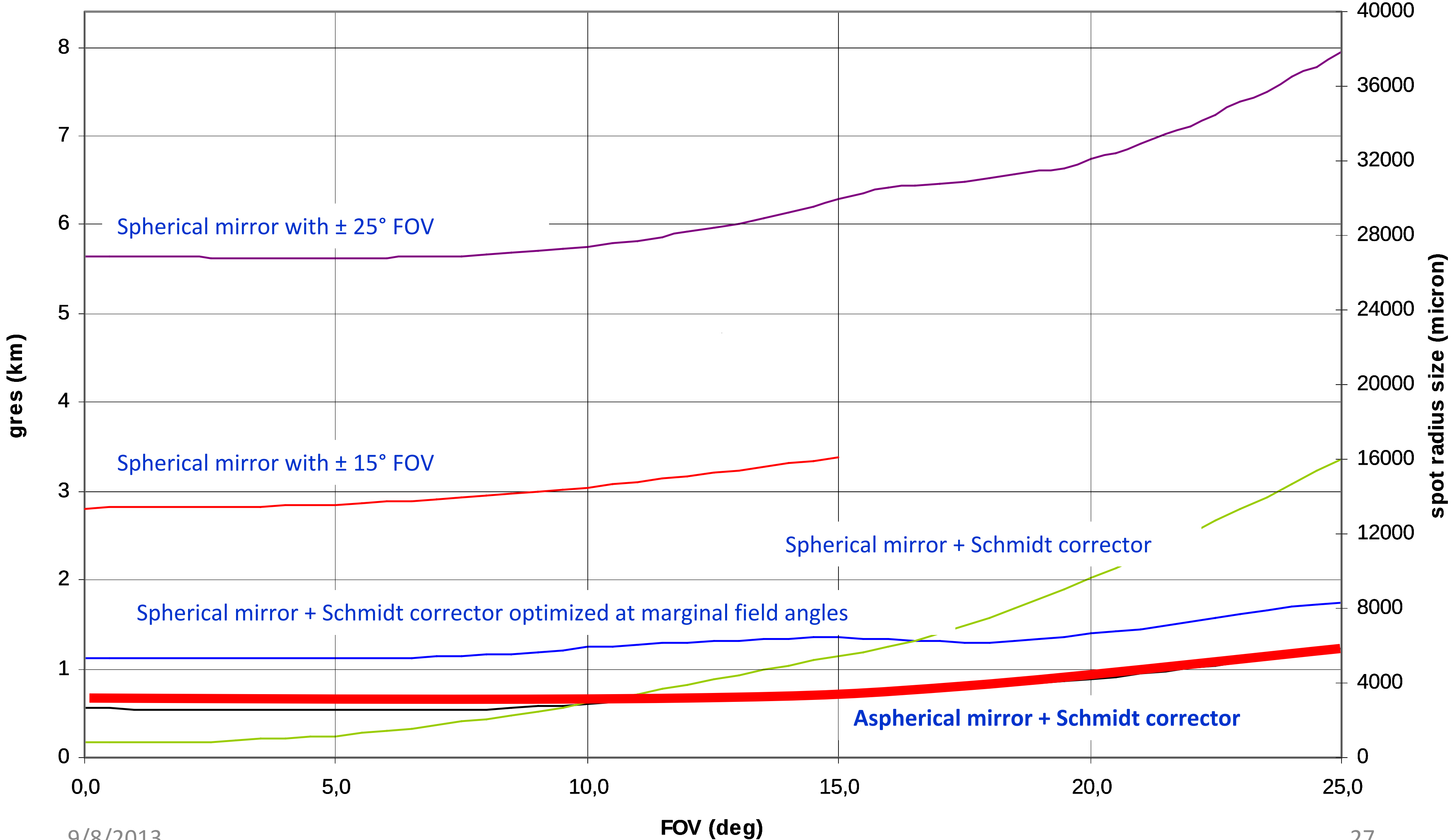
Florescence light attenuation as a function of the FoV



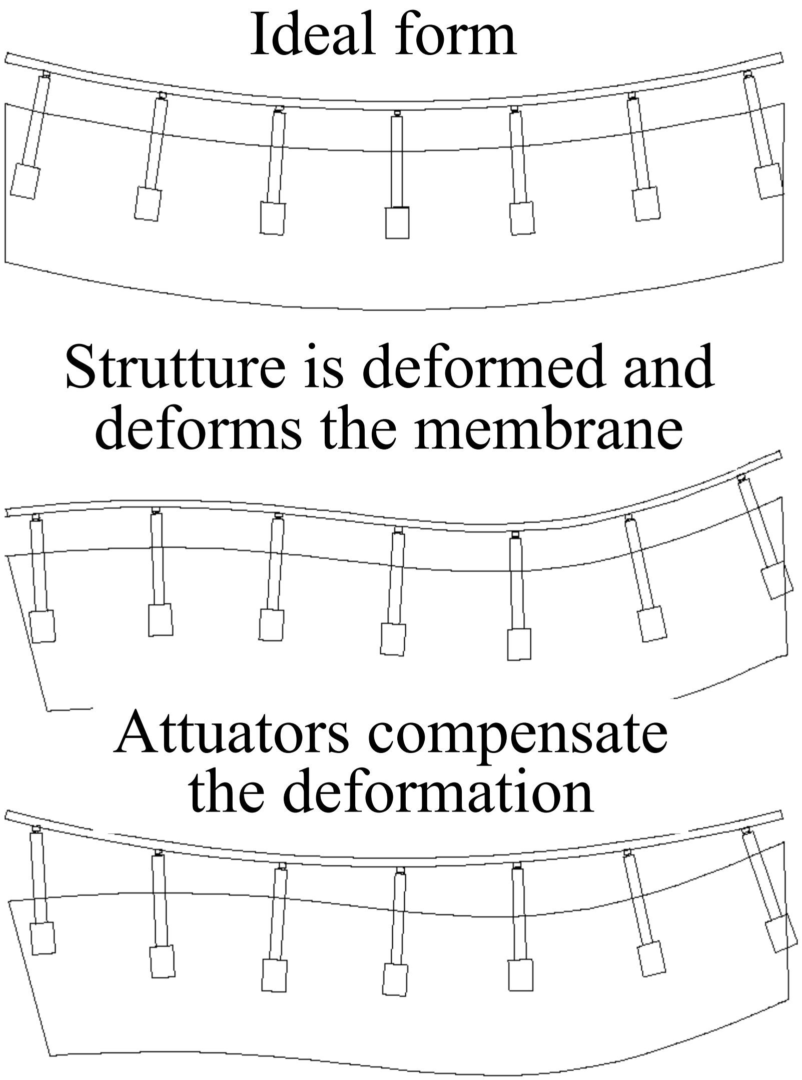
*Considered from the sea level

Resolution of 5 m EDP reflecting system

INOA

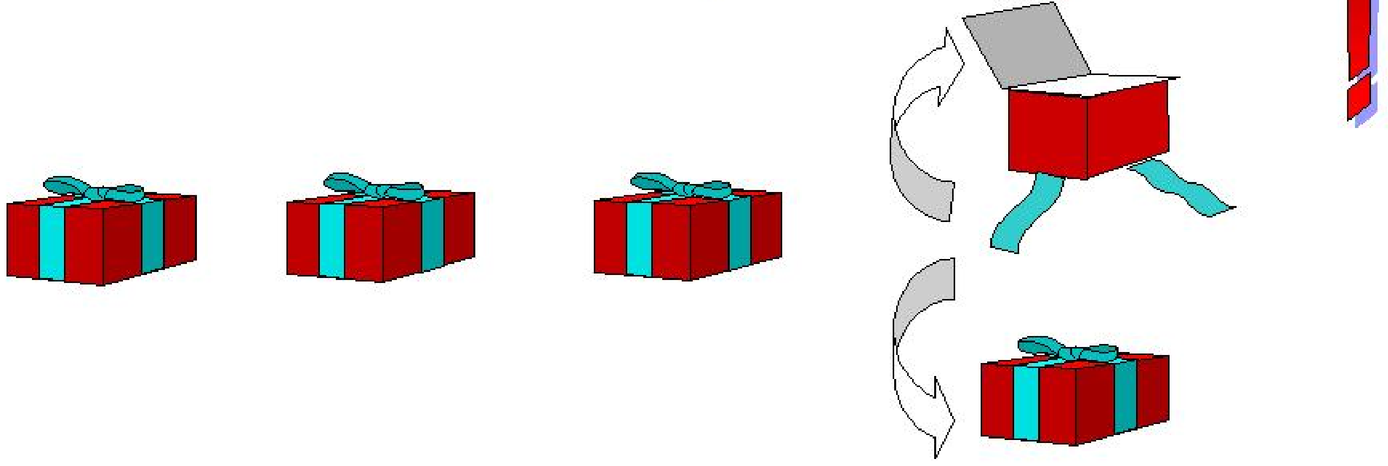


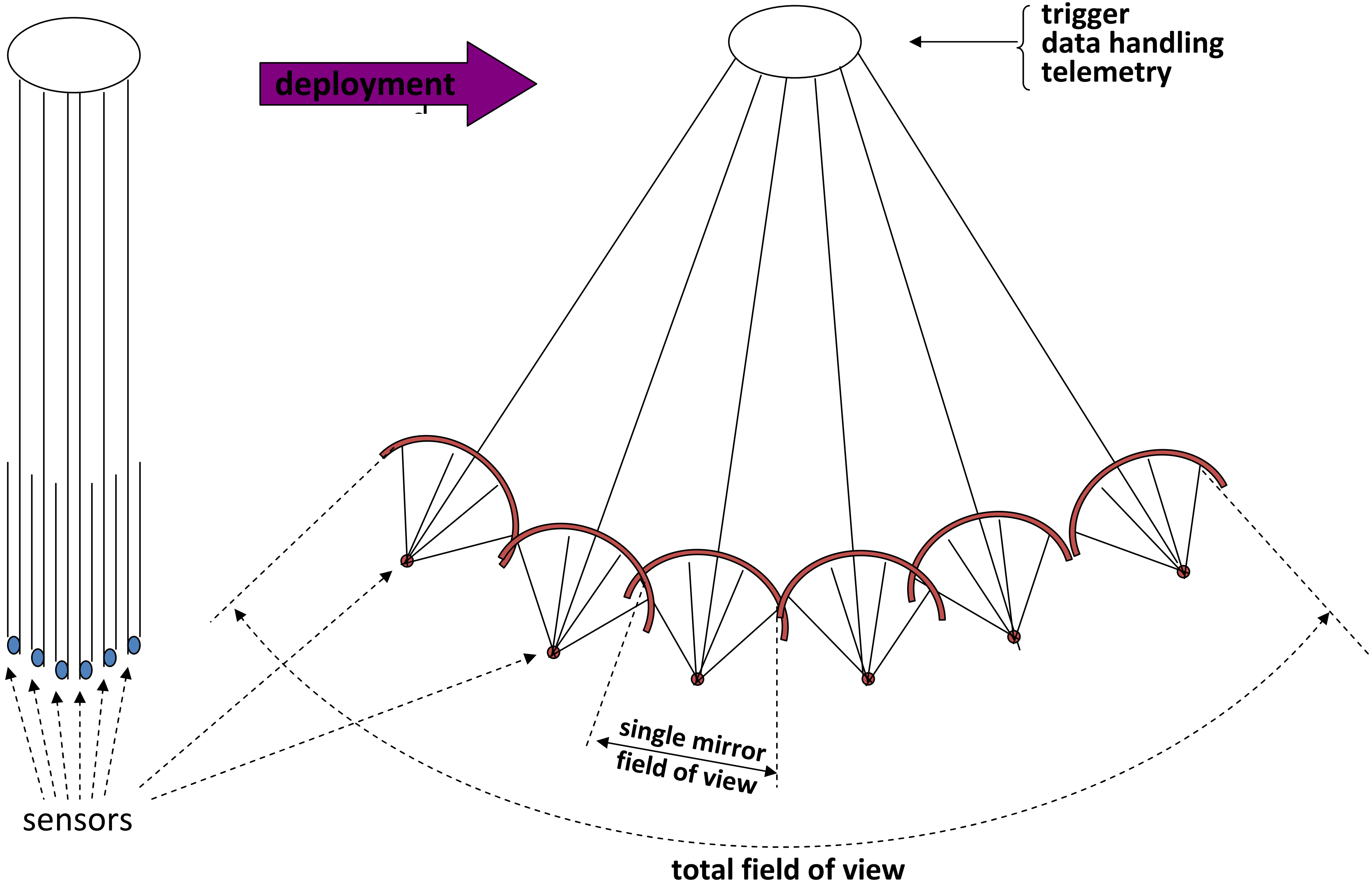
Active thin mirror concept



The optical surface is coupled to a structure of light rigid supports by a matrix of actuators, adjusted on the measurements of the wave front

	AGASA	HI-RES	AUGER	*EUSO*
EECR ($\geq 10^{20}$ eV) Events/year	1	10	10^2	10^3
ν				!




deployment
trigger
data handling
telemetry
sensors
single mirror
field of view
total field of view