VHE Particle Astronomy with All-sky Survey High Resolution Air-shower telescope

(Ashra)

Ashra Collaboration
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One of Buddha's eight protectors to serve wisdom and harmony

Ashra Collaboration

under development

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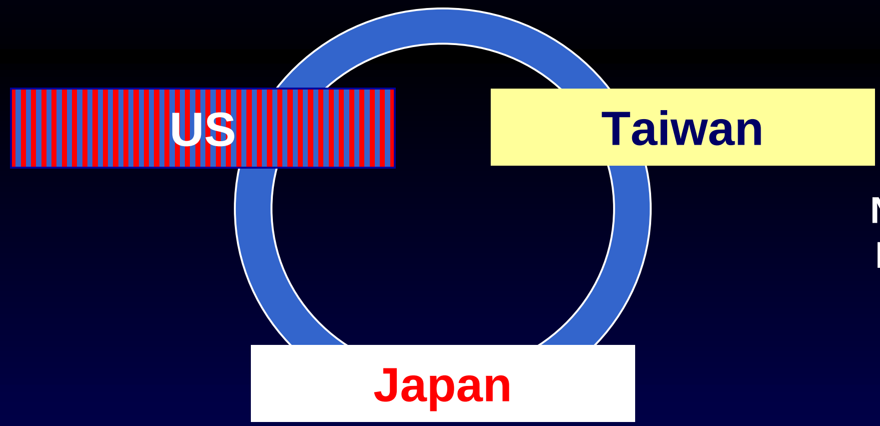


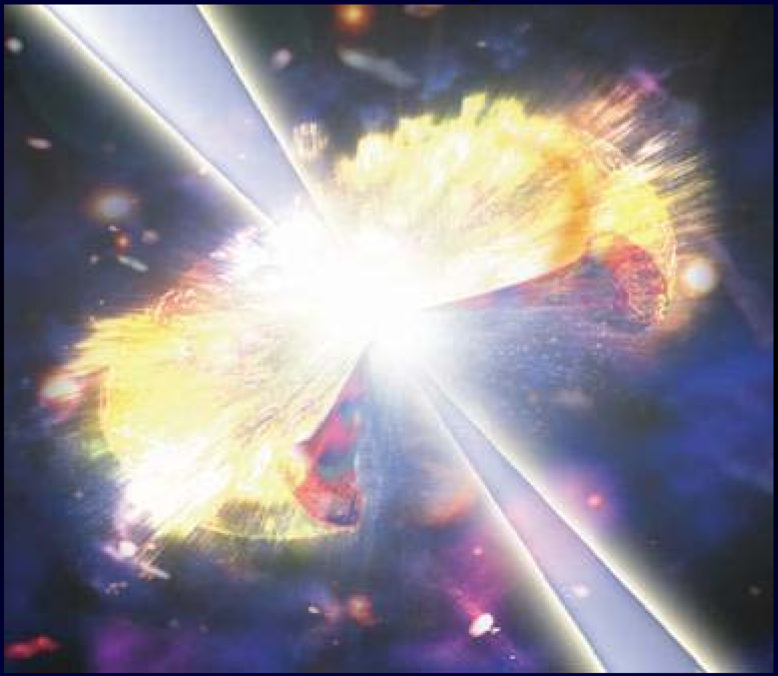
University of Hawaii

National Taiwan University
National United University

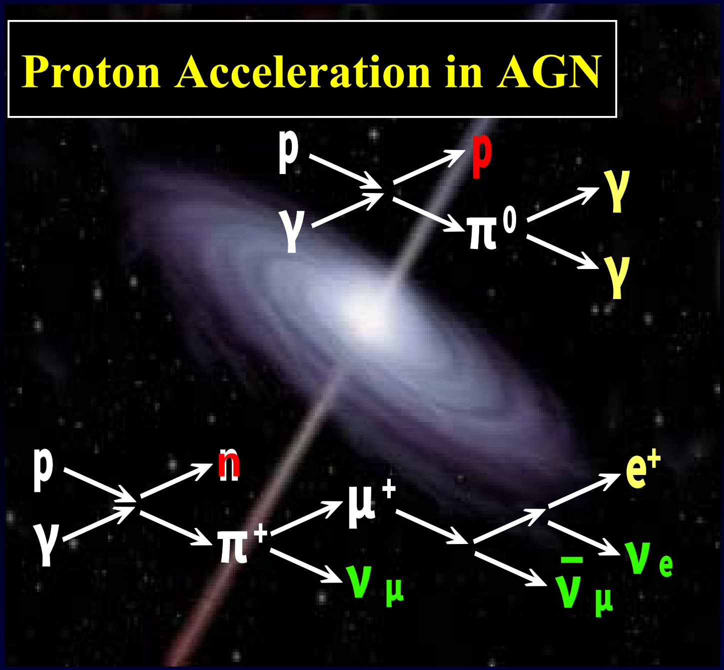
Institute for Cosmic Ray Research, Univ.Tokyo
High Energy Accelerator Research Organization
National Astronomical Observatory
Tokyo Institute of Technology
Tohoku University
Chiba University
Toho University

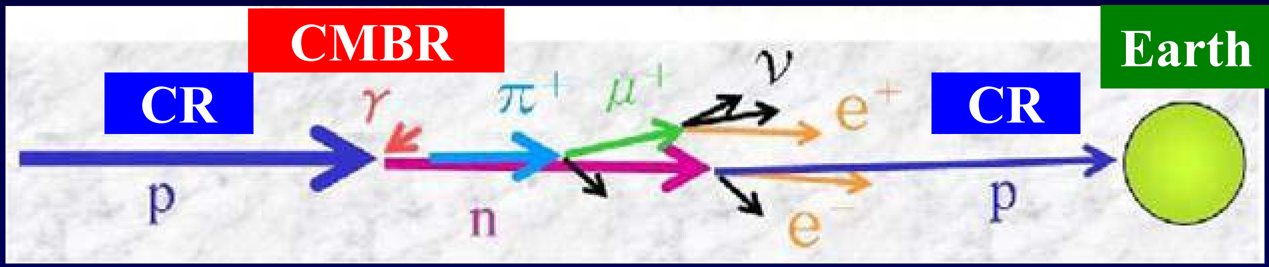
Source Candidates of VHE Particles

Gamma Ray Burst



Active Galactic Nuclei

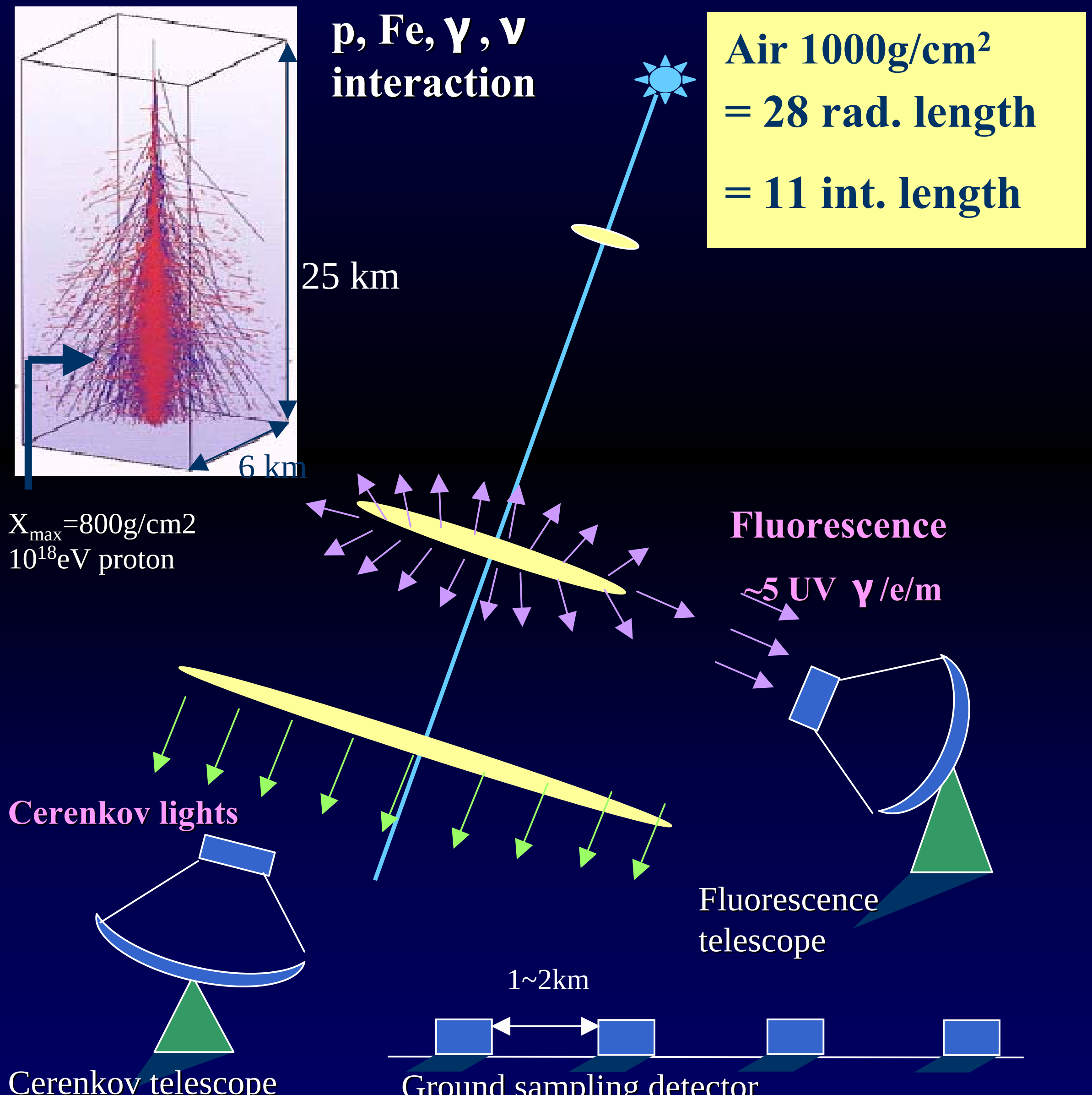




GZK Mechanism

Studying origin and propagation of VHE cosmic rays

Air Shower Detectors

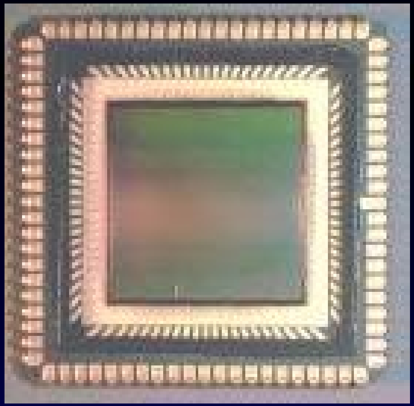


Ashra:
Imaging Particle Detector

Key Technology

9M-pix. CMOS Sensor Covering 50deg-FoV

PMT-array Camera



CMOS Sensor Chip

4,500x3,000 (14M) pix.
Commercial CMOS Camera

Pixel Cost Reduction
by $O(10^4)$

New Eye for Particle Universe

Key Technology:

9M-pixel CMOS sensor covering 50deg FOV

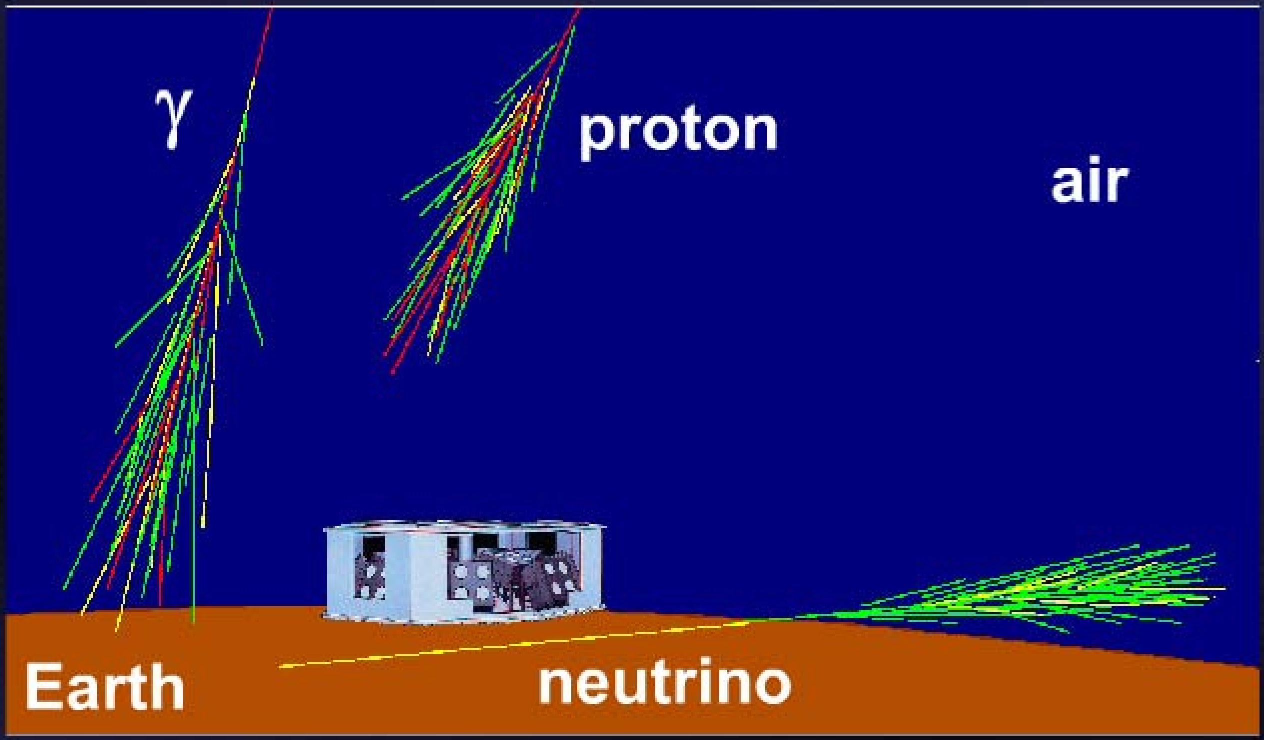
Leading Features:

All-sky Survey
=> Discovery Potential

1arcmin directional accuracy
=> Source ID

Simultaneous Detection for Cerenkov & Fluorescence
=> Physics ID

Air-shower Detection by Ashra

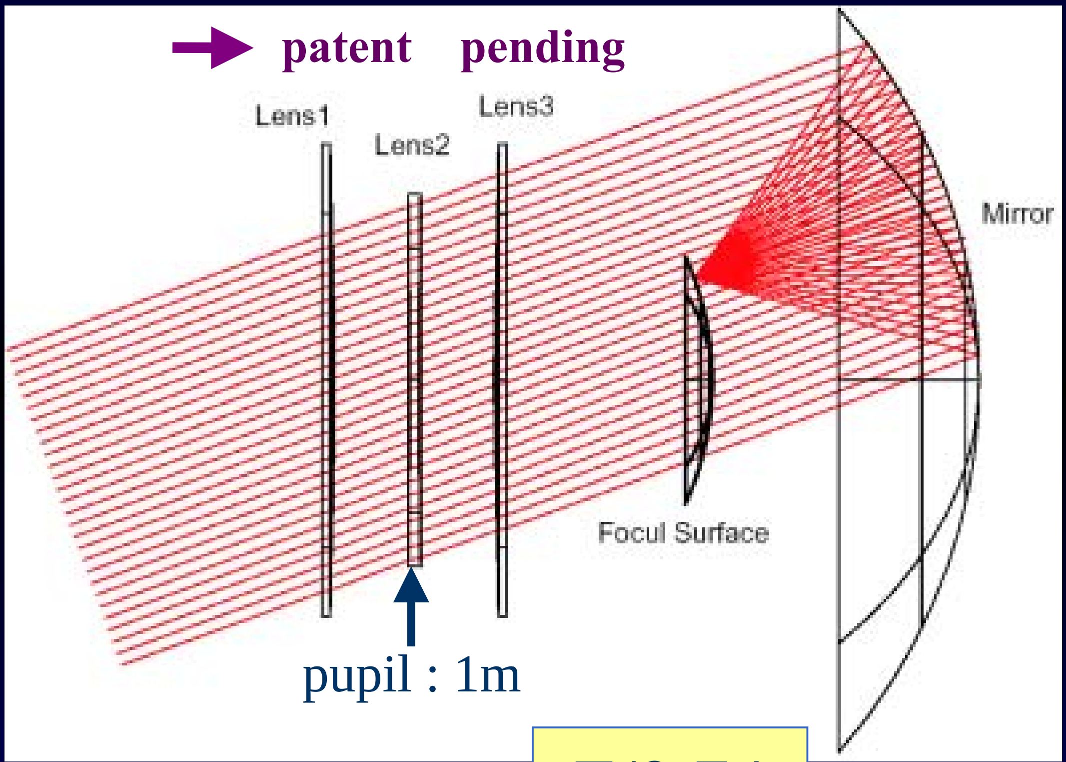


protons, γs => light emission after interaction with the air
neutrinos => light emission after interaction with and passing through the earth

Ashra-1

Design of Ashra Optics

Modified Baker-Nunn



F/0.74

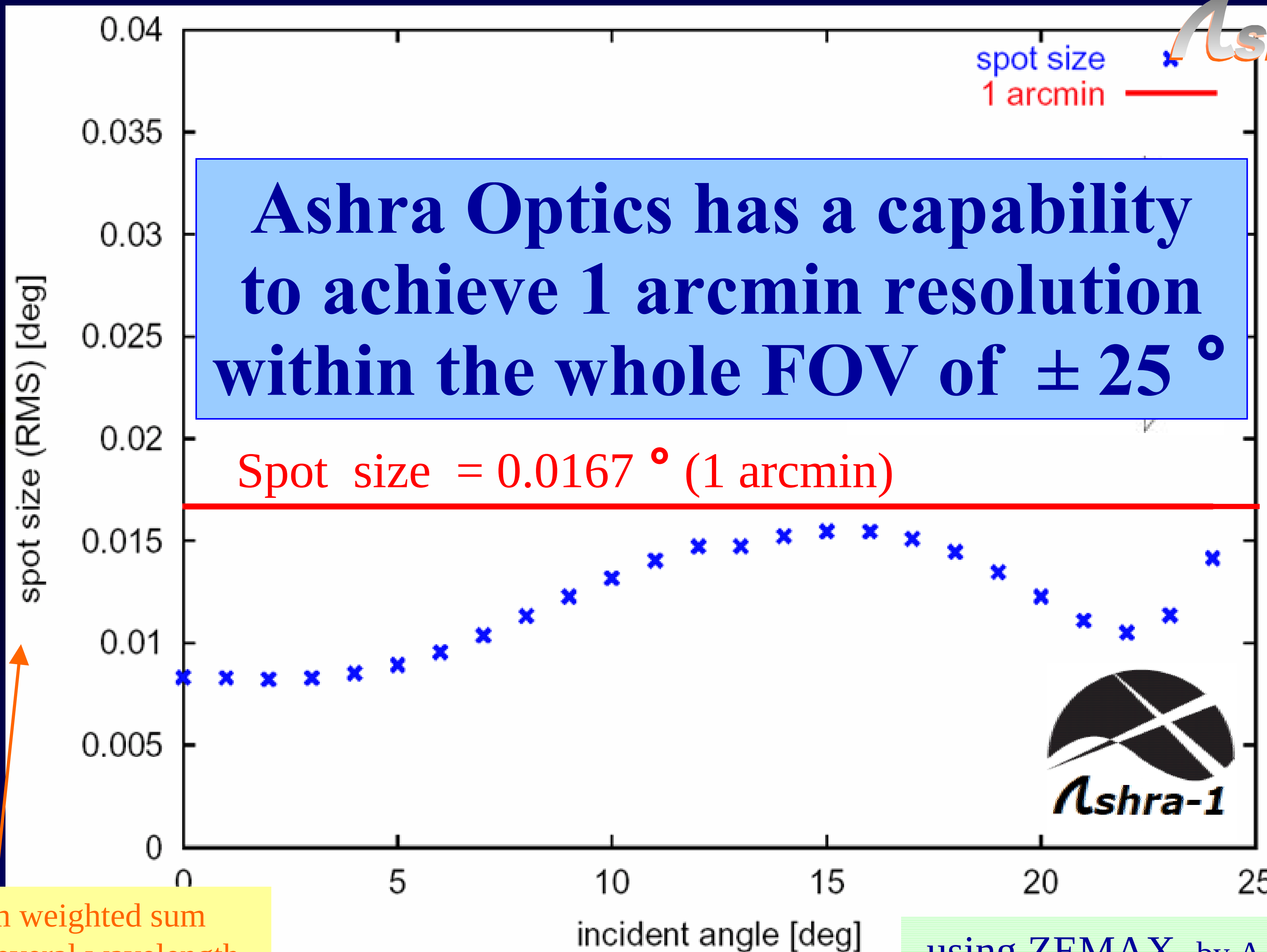
- Schmidt-type optics
- Spherical segment mirror
- Spherical focal surface
- 3-element corrector lens

Advantage: a large degree of freedom for optimization of lens surface shape to cancel

1. spherical aberration
2. chromatic aberration.

Details can be found in
M.Sasaki et al, NIM A492 (2002) 49

performance of Ashra Optics



from weighted sum of several wavelength

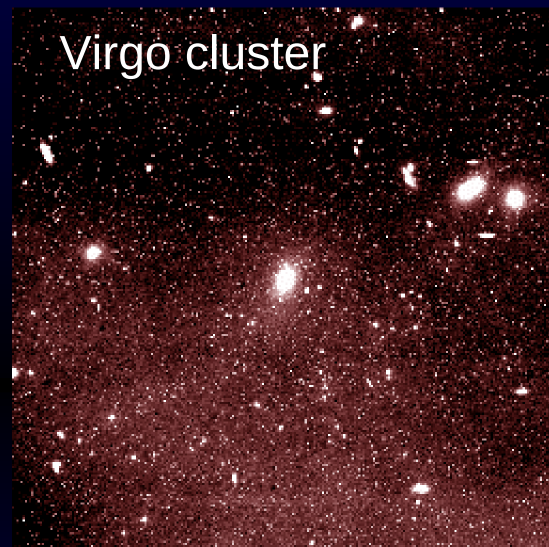
using ZEMAX by A.Okumura

Importance of Fine Image

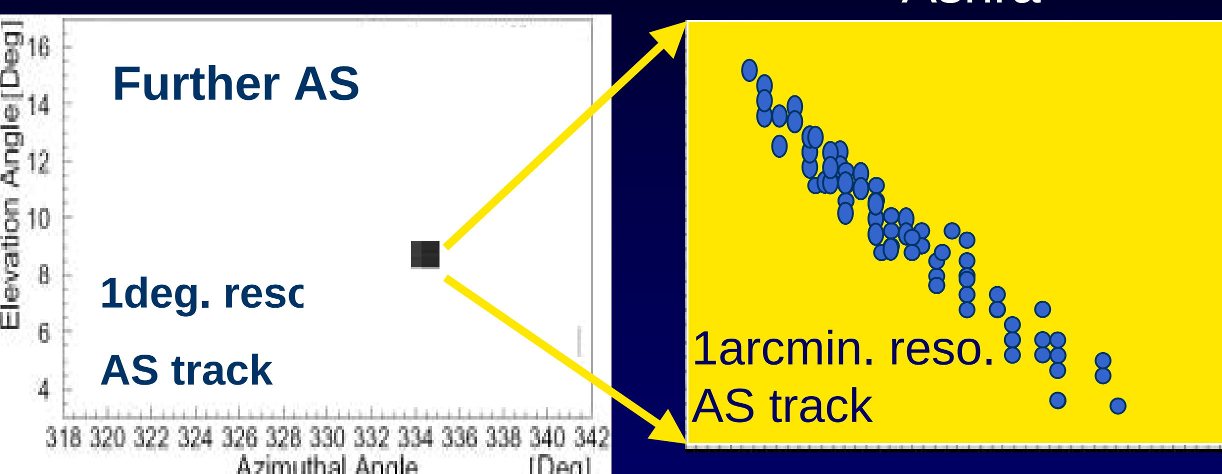
1deg. resolution

Traditional Fluo. Tele.

1arcmin. reslution



Ashra



- **Source Location**

⇒ Real astronomy

⇒ Reliable ID for Earth-skimming and Mt. Neutrinos

- **Higher Sensitivity**

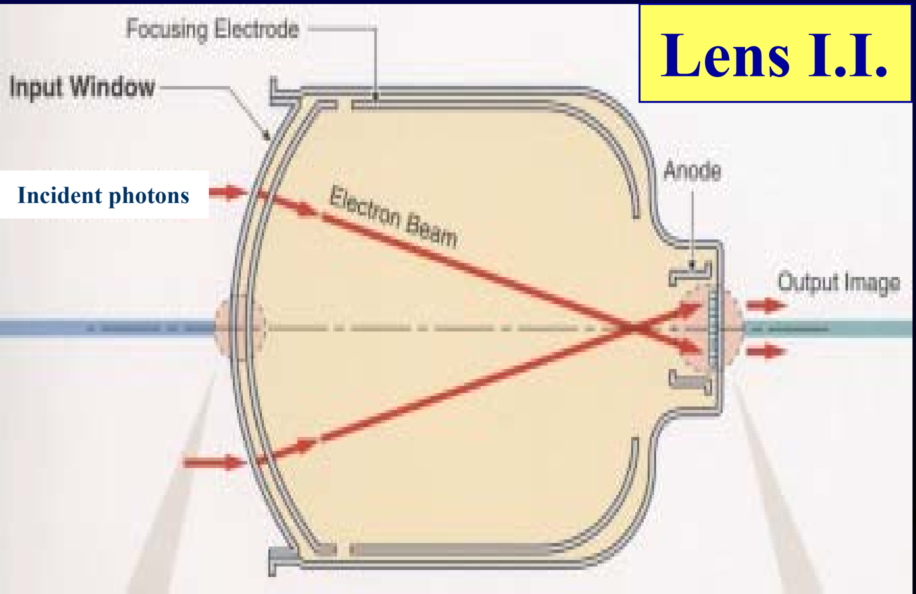
=> Imaging for further AS

Focal sphere =>

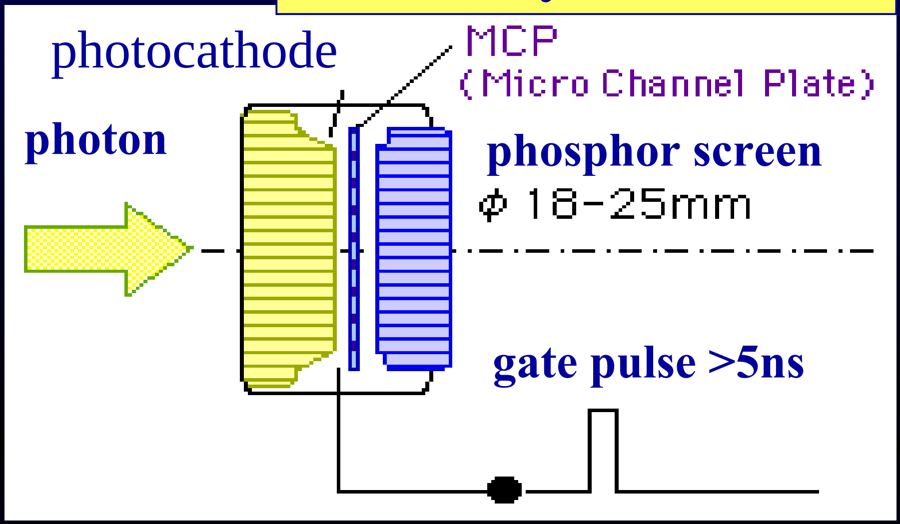
Image Intensifier Pipeline

=> CMOS Sensor

Lens I.I.



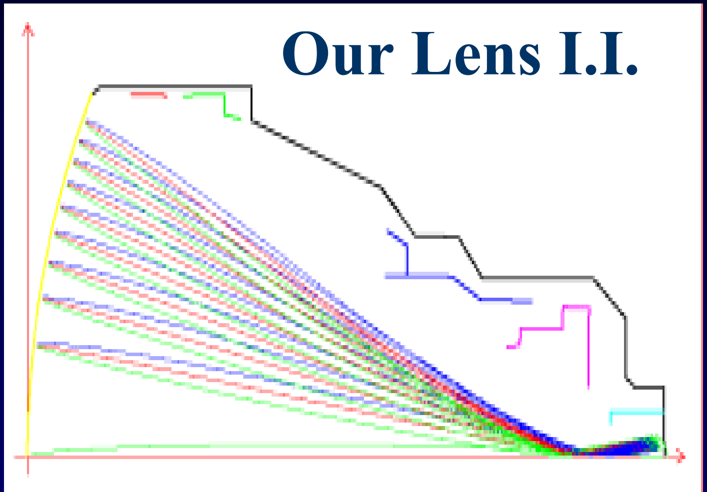
Proximity focused I.I.



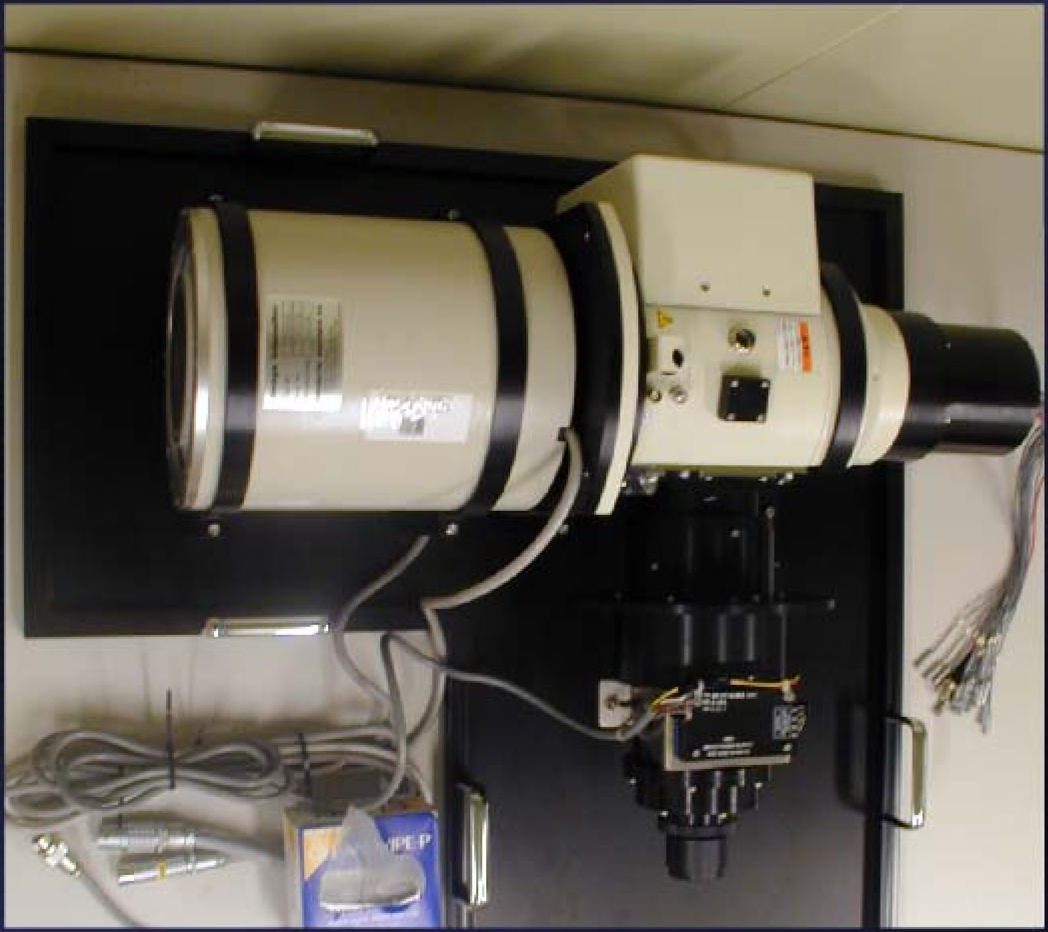
- 4.6 Lp/mm => σ ~70 μ m @ input surface
- magnification factor ∼ 10

- 46 Lp/mm => σ ~7 μ m ~ CCD pix. size
- magnification factor = 1

Minimum modification of focal surface



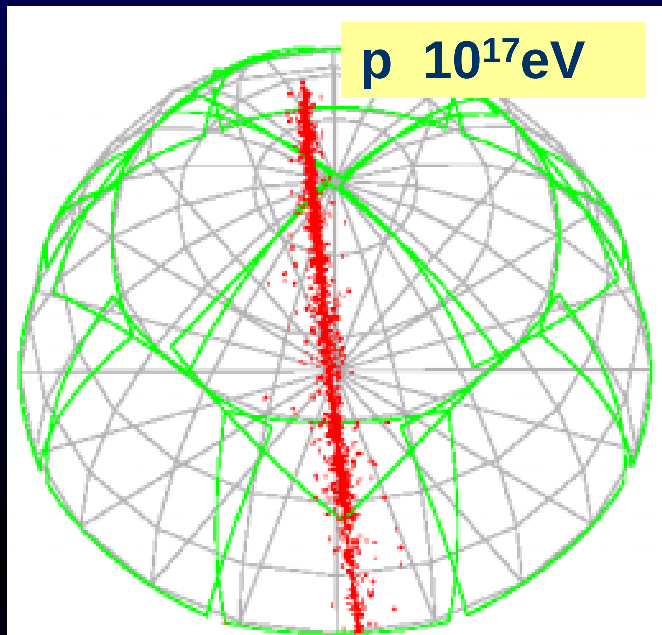
Photoelectric Image Pipeline

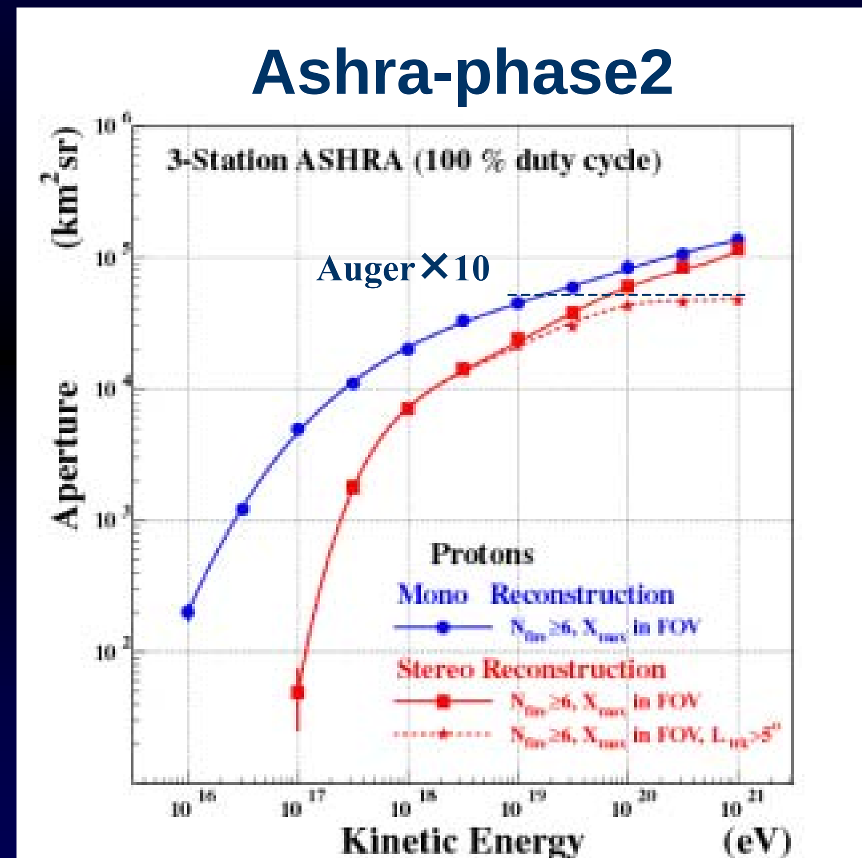


Prototype

Ashra-1

MC performance for UHECR

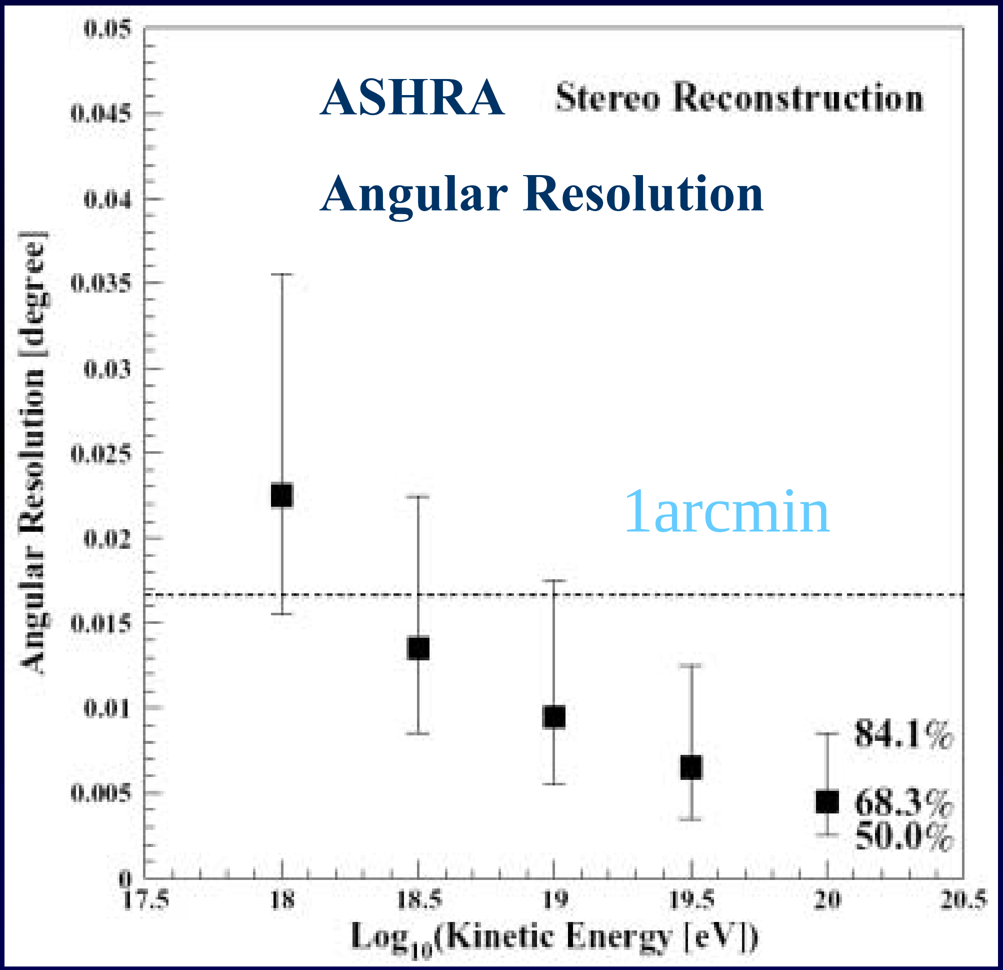


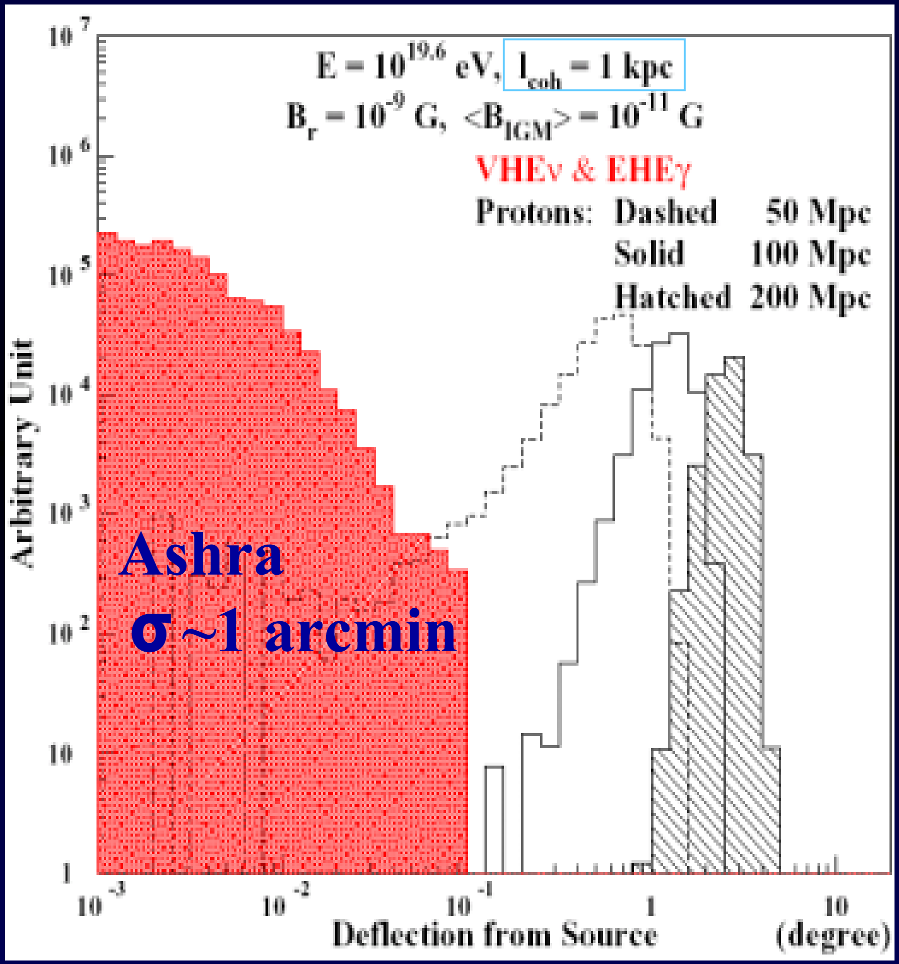


Stereo Event Rate (duty10%)

Threshold	Events/yr
10^{19}eV	1324
$10^{19.5}$eV	259
10^{20}eV	34

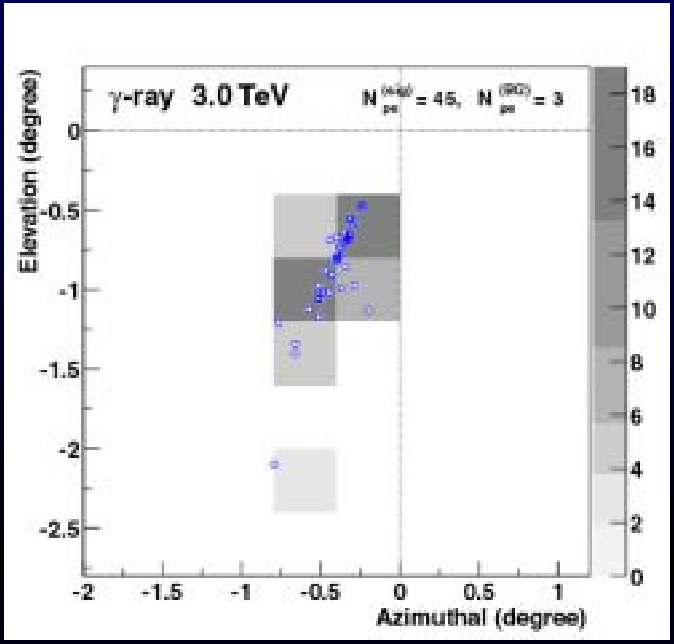
Capability of Charge Separation

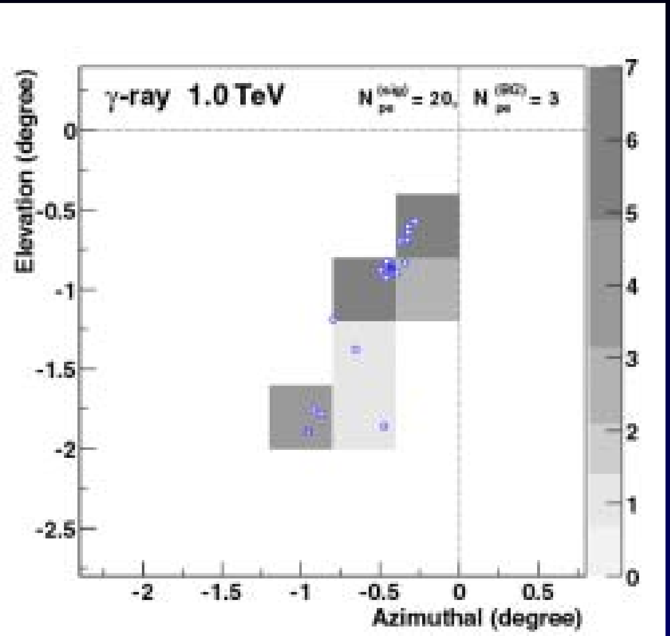


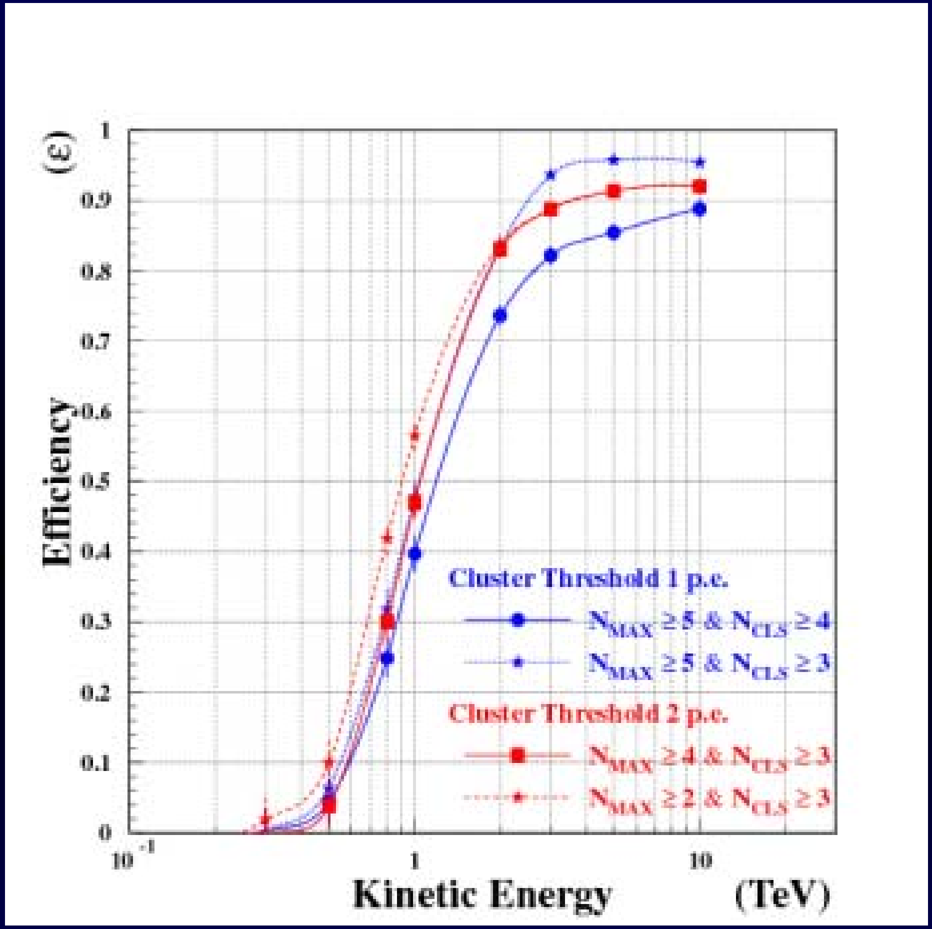


- Charge ID with Magnetic Deflection

MC performance: TeV- γ



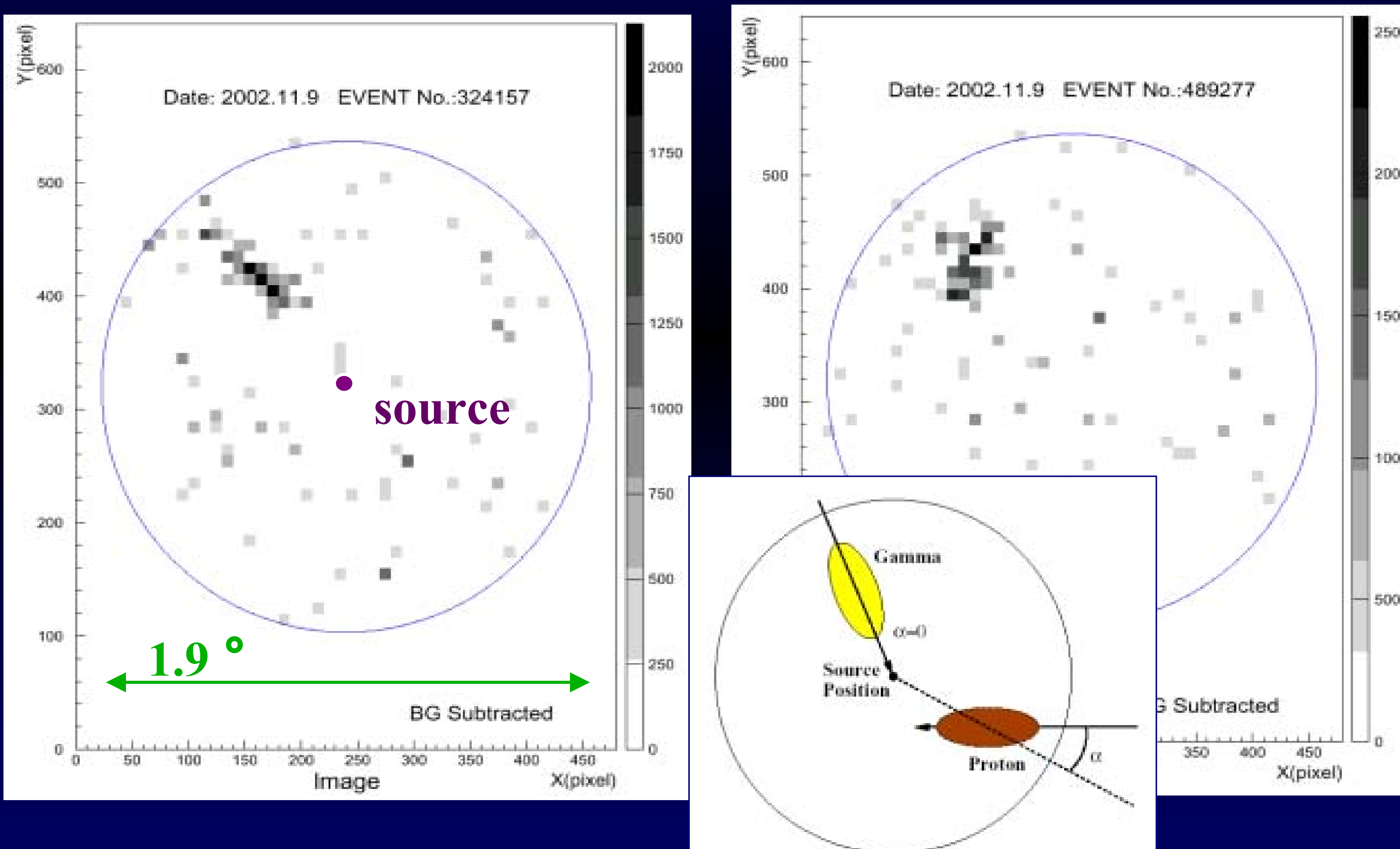




- Energy threshold ~ 1 TeV @ 1600m alt
- Not need to share the observation time => Higher statics => Better dir. accuracy.

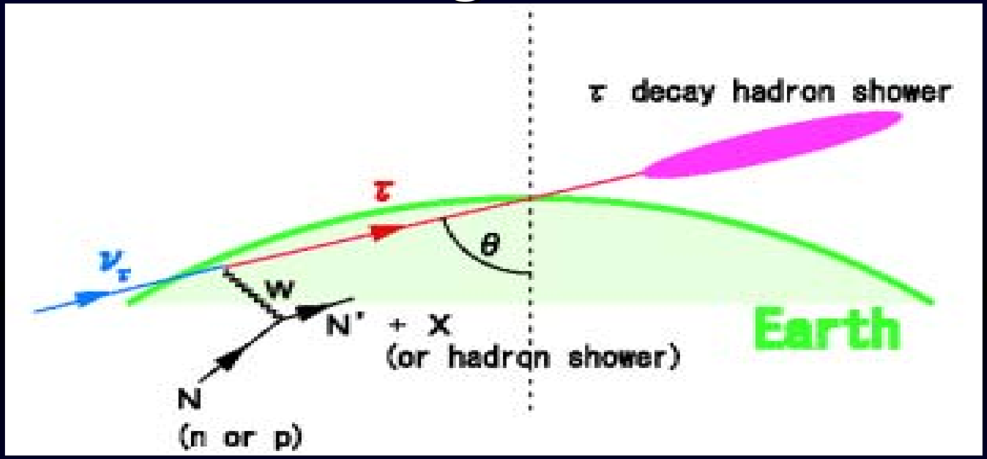
Shower Event Examples

γ - like　　　　　　　　p- like

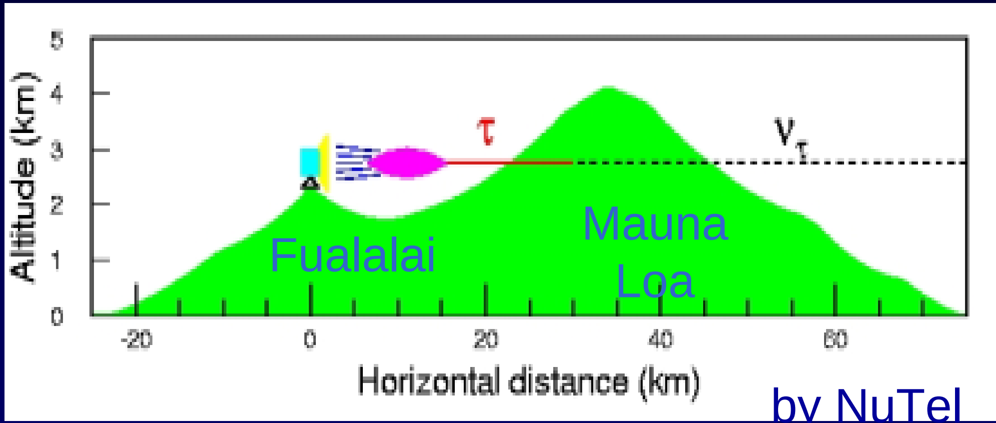


Tau Neutrino Detection using Earth and Mountain

Earth Skimming Tau Neutrino



Tau Cerenkov AS from Mountain



by NuTel

Feng, Fisher, Wilczek and Yu (2002)
Fargion et al. (2003)
Sasaki, Asaoka and Jobashi (2002)
Gupta (2003)
Giesel et al. (2003)*

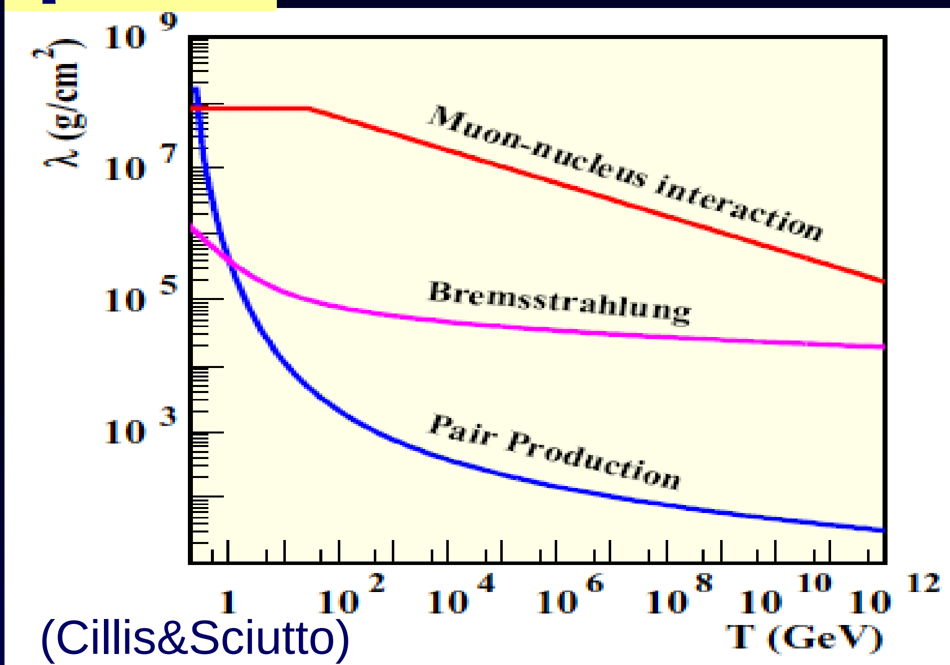
Tau Apperance
Vacuum Oscillation Experiment with Super-long Baseline

- $\nu_e : \nu_\mu : \nu_\tau = 1:1:1$
- Search $\delta m^2 > 10^{-17} eV^2$
- pseudo-Dirac-ν?

(Beacom et al, astro-ph/0307151)

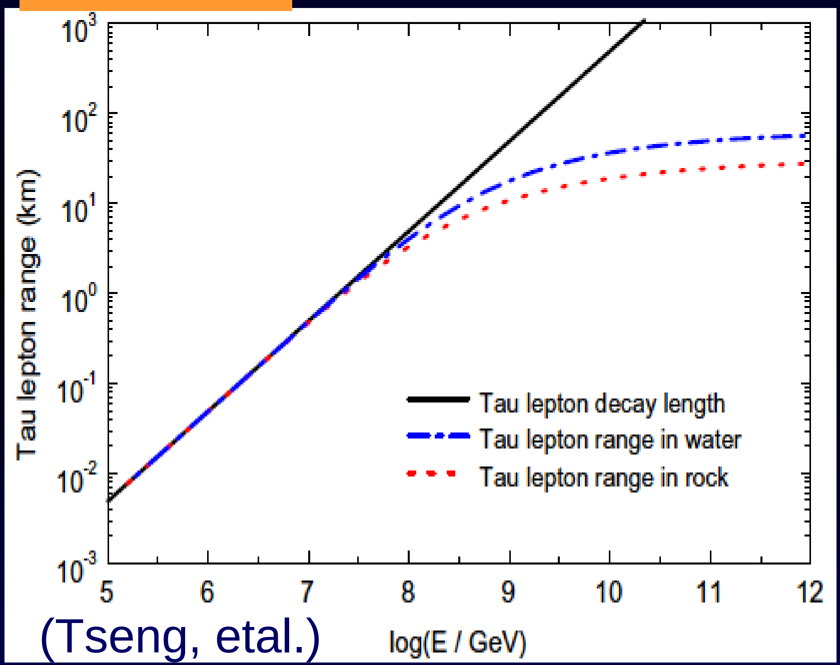
Flavor Dependence of Propagation Process in Rock

μ



(Cillis&Sciutto)

τ



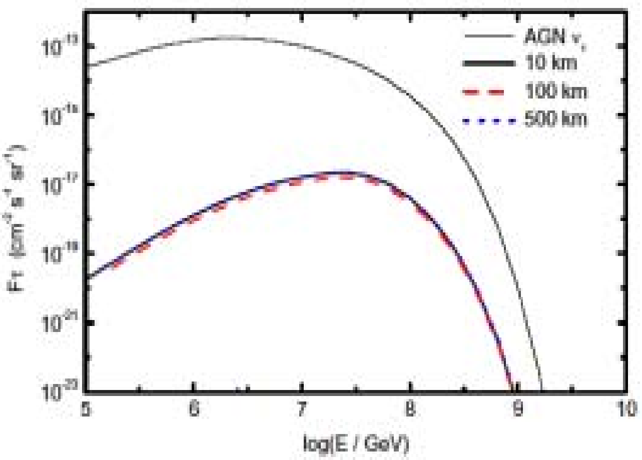
(Tseng, etal.)

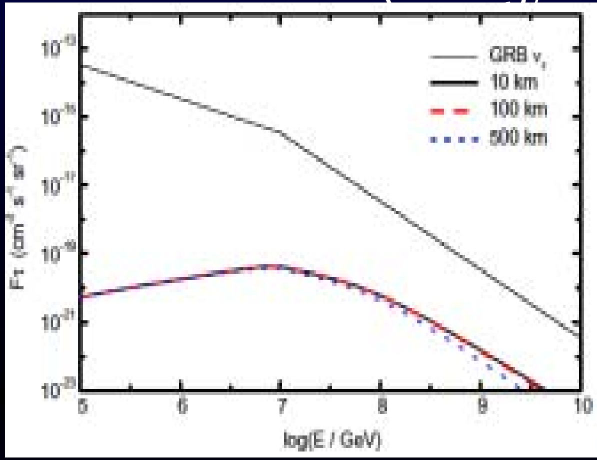
Tau dominates appeared leptons@VHE

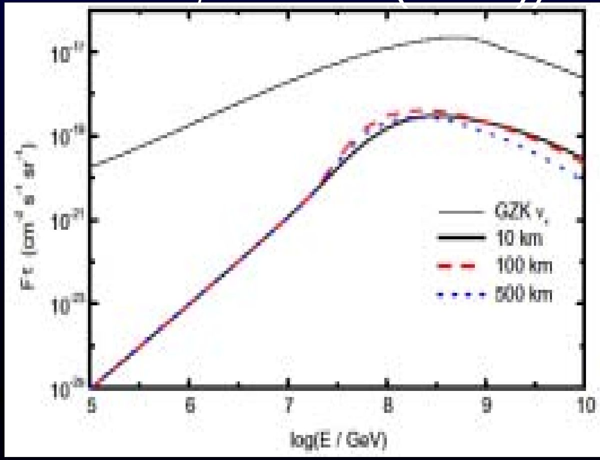
- Range of tau ~ 10km
- Target Mass of Mauna Loa > 1000Km^3-weq

Earth-skimming Tau Flux

(Tseng, etal. PR D68, 063003 (2003))







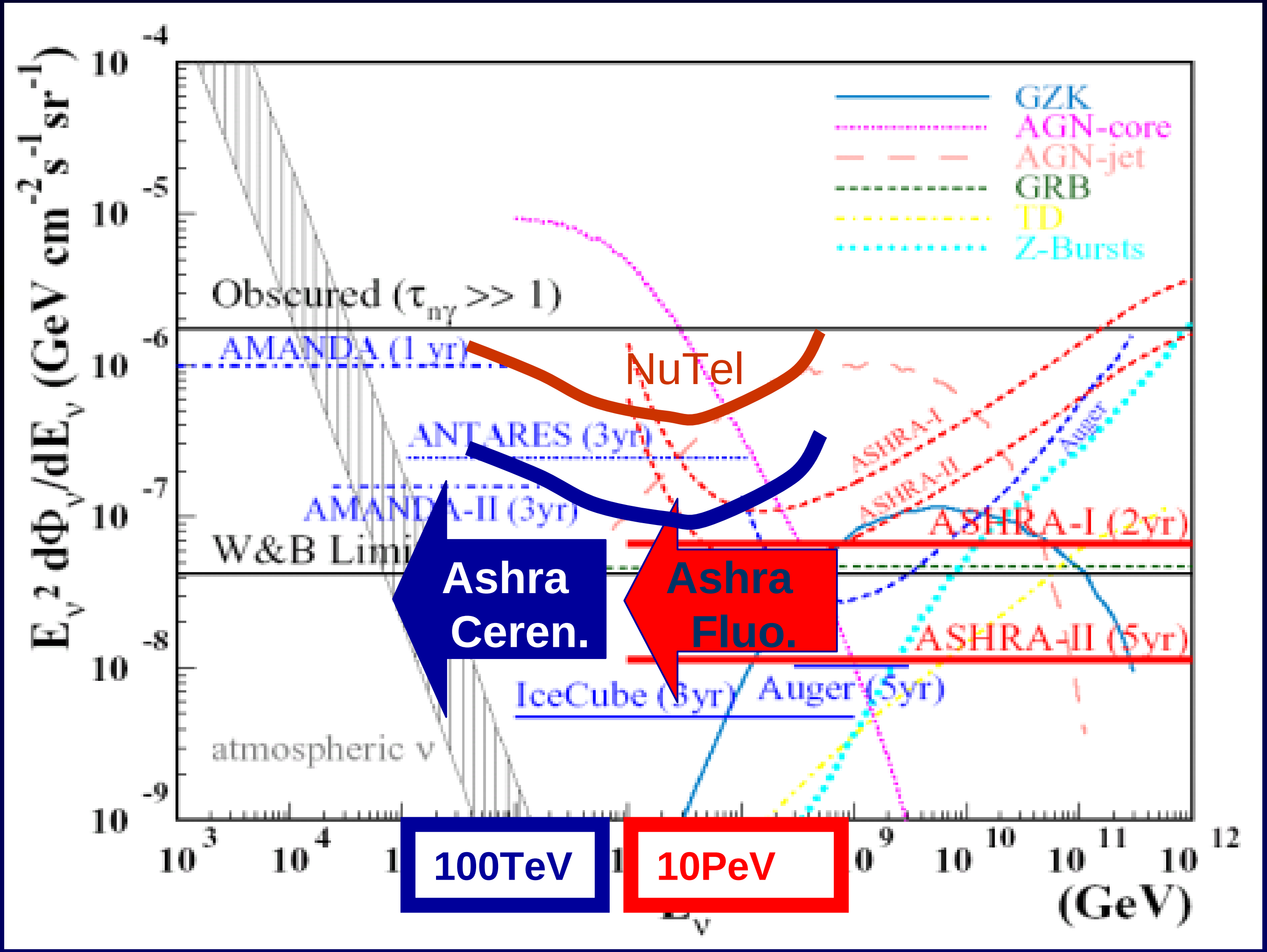
$(km^{-2}\ yr^{-1}\ sr^{-1})$	AGN		GRB		GZK	
Energy interval	Full	Approx	Full	Approx	Full	Approx
$10^6 \le E/\mathrm{GeV} \le 10^7$	2.23	2.12	9.63×10^{-3}	1.05×10^{-2}	7.38×10^{-5}	2.08×10^{-5}
$10^7 \le E/\mathrm{GeV} \le 10^8$	4.89	5.12	7.12×10^{-3}	6.82×10^{-3}	1.14×10^{-2}	1.90×10^{-2}
$10^8 \le E/\mathrm{GeV} \le 10^9$	1.95×10^{-1}	1.52×10^{-1}	5.39×10^{-4}	4.63×10^{-4}	8.17×10^{-2}	8.47×10^{-2}
$10^9 \le E/\mathrm{GeV} \le 10^{10}$			1.13×10^{-5}	1.24×10^{-5}	3.31×10^{-2}	3.52×10^{-2}

GRB- ν_τ, GZK- ν_τ require $100km^2/\varepsilon$ as effective detection area.

=> km^3-water detector is difficult. => advantage of air-light detector

Neutrino Sensitivity

- 1 event/year/decade of energy (curve)
- 90% upper limit assuming E^{-2} flux (horizontal line)



Ashra

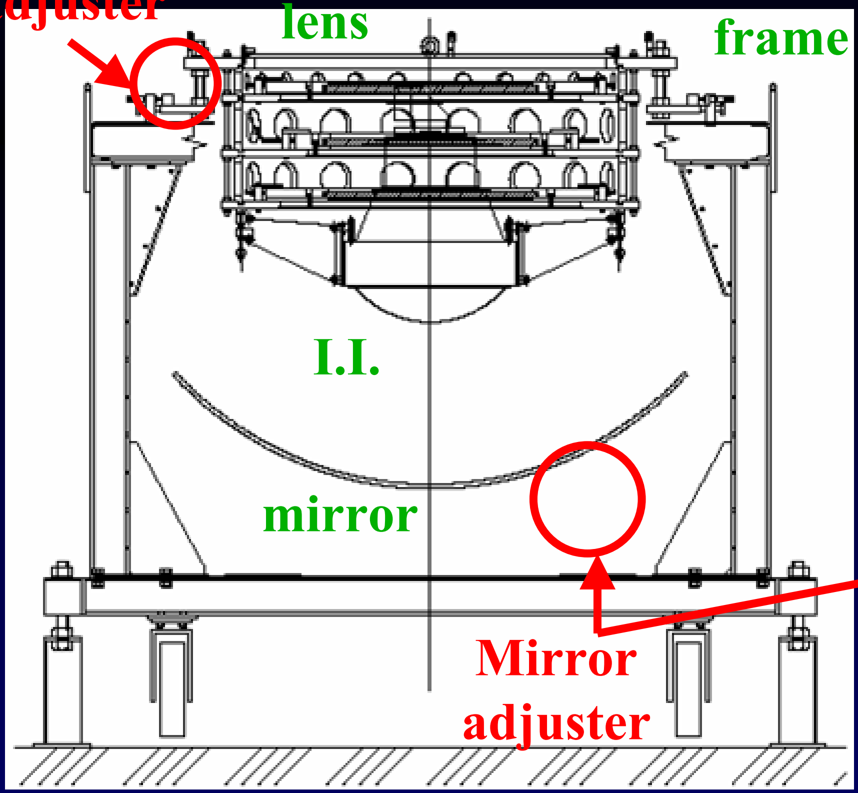
Cerenkov + Fluo.

Ashra can keep the best sensitivity in whole range E>100TeV

Great Chance of the first detection VHE Neutrinos

R&D Status : Sub-Telescope

Integration test of optical system
- Achieve 1 arcmin resolution
- Develop fabrication processes



2 mirrors have been adjusted.

Ashra Project Plan

2002	2003	2004	2005	2006	2007

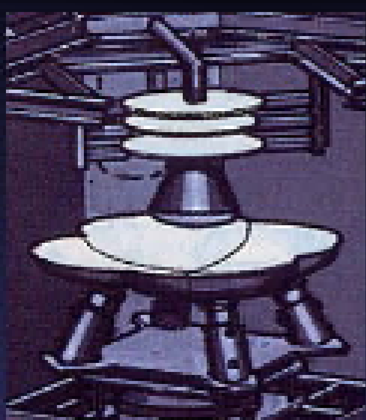
Ashra Prototype
Optical Flash obs.

phase 0
R&D

phase 1
Pioneering

phase 2
High Statistics

sub-telescope



Expected Fluo. Event Rate for Earth-skimming ν's
- GRB : 2 /yr
- AGN : 26 /yr
- GZK : 2 /yr

(Cerenkov and Mountain effects not included)

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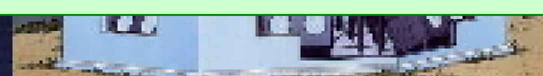

prototype in labo.

2 Mt.s on the Hawaii Is.

3 Mt.s on the Hawaii Is.