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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Source Candidates of VHE Particles

Gamma Ray Burst

Active Galactic Nuclei

Proton Acceleration in AGN

Studying origin and propagation of VHE cosmic rays
Air Shower Detectors

$X_{\text{max}} = 800 \text{g/cm}^2$

$10^{18} \text{eV proton}$

$p, \text{Fe, } \overline{\text{p}}, \overline{\text{e}}, \overline{\text{e}}$

interaction

Fluorescence telecope

$\sim 5 \text{ UV } /e/m$

Cerenkov lights

1~2 km

Ground sampling detector

Air 1000 g/cm$^2$

= 28 rad. length

= 11 int. length

Cerenkov telescope

25 km

6 km

XX$_{\text{max}}$ = 800 g/cm$^2$
Ashra: Imaging Particle Detector

Key Technology

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

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

Pioneer Experiment for VHE Particle Astronomy: Ashra-1
protons, $\gamma$s $\rightarrow$ light emission after interaction with the air
neutrinos $\rightarrow$ light emission after interaction with and passing through the earth
**Design of Ashra Optics**

**Modified Baker-Nunn**

- 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*
Ashra Optics has a capability to achieve 1 arcmin resolution within the whole FOV of ± 25°.

Spot size = 0.0167° (1 arcmin)

from weighted sum of several wavelength

using ZEMAX by A. Okumura
Importance of Fine Image

1 deg. resolution

Virgo cluster

Traditional Fluo. Tele.

1 arcmin. resolution

Virgo cluster

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.**

- 4.6 Lp/mm => ~70 μm @ input surface
- magnification factor ~ 10

**Proximity focused I.I.**

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

- Photocathode
- Photon
- Photostimulated phosphor screen
  - φ 18-25mm
  - Gate pulse >5ns

**Commercial**

- Minimum modification of focal surface

**Our Lens I.I.**
Photoelectric Image Pipeline

Prototype
**MC performance for UHECR**

**Stereo Event Rate (duty10%)**

<table>
<thead>
<tr>
<th>Threshold</th>
<th>Events/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10^{19}$eV</td>
<td>1324</td>
</tr>
<tr>
<td>$10^{19.5}$eV</td>
<td>259</td>
</tr>
<tr>
<td>$10^{20}$eV</td>
<td>34</td>
</tr>
</tbody>
</table>

**Ashra-phase2**

- Auger $\geq 10$
**Capability of Charge Separation**

ASHRA

Angular Resolution

1 arcmin

- Charge ID with Magnetic Deflection
MC performance: TeV-

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

\( \sqrt{1.9} \) - like

\( p \)-like

source
Tau Neutrino Detection using Earth and Mountain

Earth Skimming Tau Neutrino

Fargion et al. (2003)
Sasaki, Asaoka and Jobashi (2002)
Giesel et al. (2003)*

Tau Appearance
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-$\nu$?

(Beacom et al, astro-ph/0307151)

by NuTel

Tau Cerenkov AS from Mountain
Flavor Dependence of Propagation Process in Rock

Tau dominates appeared leptons at VHE
- Range of tau ~ 10km
- Target Mass of Mauna Loa > 1000Km³-weq
Earth-skimming Tau Flux

(Tseng, et al. PR D68, 063003 (2003))

GRB- and GZK- events require 100km²/ as effective detection area.

=> km³-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 can keep the best sensitivity in the whole range $E>100\text{TeV}$

Great Chance of the first detection VHE Neutrinos
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

phase 0 Ashra Prototype Optical Flash obs.
R&D

phase 1 Pioneering

phase 2 High Statistics

sub-telescope

Expected Fluo. Event Rate for Earth-skimming \( \nu \)'s
- GRB : 2 /yr
- AGN : 26 /yr
- GZK : 2 /yr
(Cerenkov and Mountain effects not included)

prototype in labo. 2 Mt.s on the Hawaii Is. 3 Mt.s on the Hawaii Is.