Neutrino Telescope Array (NTA)

Towards Survey of Astro ν_τ Sources

George W.S. Hou (侯維恕)
National Taiwan University

March 20, 2014, Talk@VHEPA2014, Kashiwa

National Taiwan University

Neutrino Telescope Array

NTA

I. Intro: Earth-skimming ν_τ Method

II. "My" NuTel Effort

III. Ashra-1: 1st Search for GRB ν_τ

Courtesy Makoto Sasaki

IV. NTA: a New Collaboration

* Plan and "Size"
* Performance
* Organization

V. Collaborators Welcome!!

Sugiyama yesterday

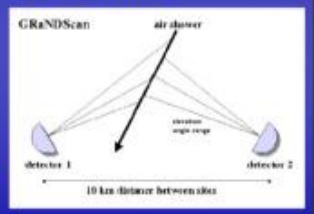
New Concepts from VHEPA-3

Future Searches for High Energy Galactic Cosmic Ray Sources

T. Adams
Florida State University
E. Loh
University of Utah
S. Westerhoff
Columbia University

Proposed Telescopes

- Telescopes
  - three 30°x30° cameras/mirrors
    - 30°x30° is largest size which doesn't need corrector plate
  - covers 30° in zenith and 90° in azimuth
  - 1° resolution
  - light-weight, easy to relocate
- Two telescopes
  - placed 10km apart
  - viewing same region of atmosphere



Future Searches for High Energy Galactic Cosmic Ray Sources
T. Adams ICRR March, 2003

The NuTel Project

Watching for Tau Neutrinos from a Mountain

George W.S. Hou (侯維恕)
National Taiwan University

March 22, 2003 @ VHEPA-3, ICRR, Tokyo

Hawaii Big Island

- Astronomer's dream site
  - Good weather
  - Less artificial light
- Mt. Hualalai: Good view of Mauna Loa On dryer west side
- Mauna Loa ~ 90 km x 4 km

3/22/2003 George W.S. Hou @ VHEPA-3

VHE Particle Astronomy with All-sky Survey High Resolution Air-shower detector (Ashra)

Ashra Collaboration
Makoto Sasaki

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

VHEPA2014

NTA

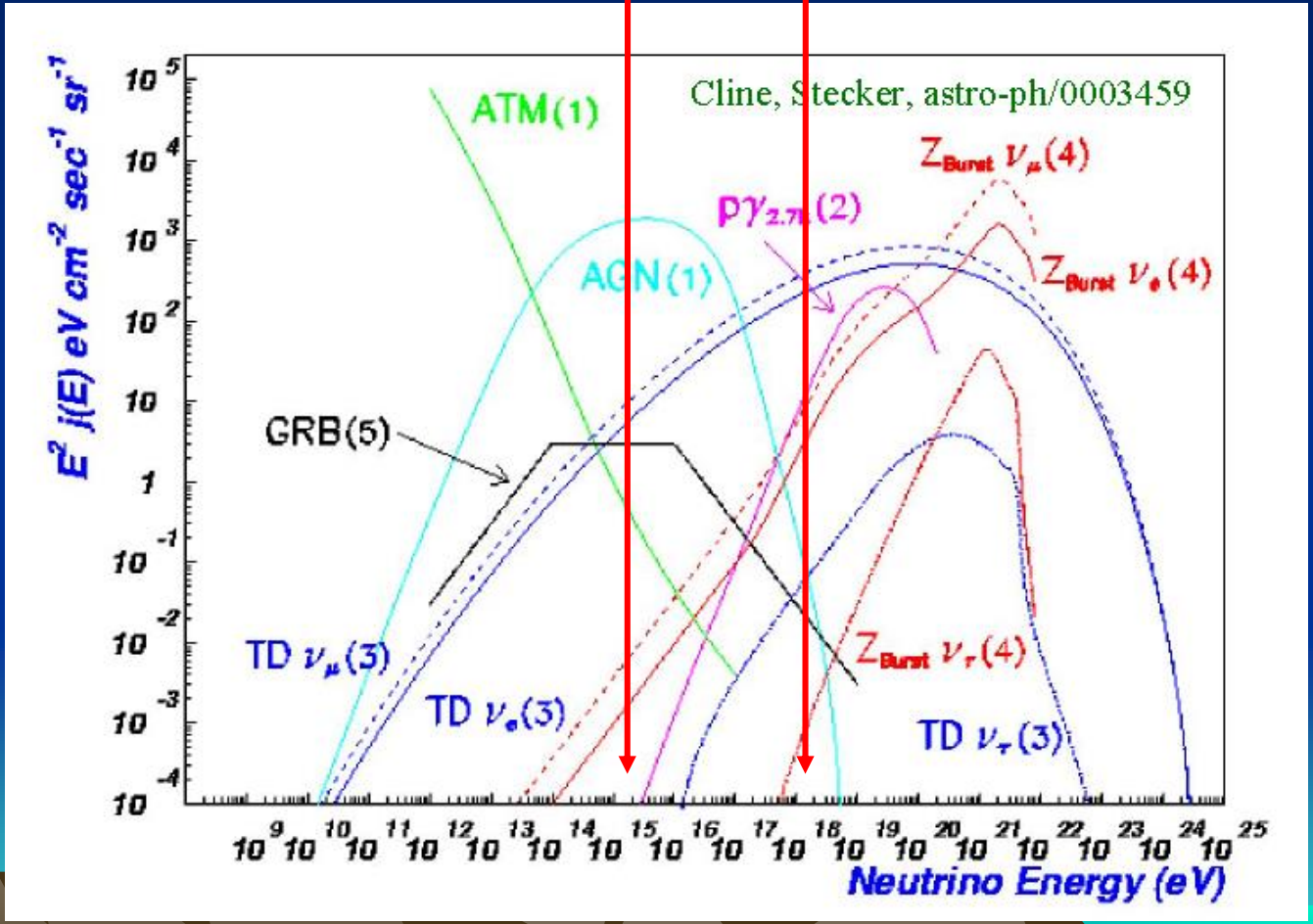
Ashra-1 + NuTel

Aim/Scientific Goal

Clear Discovery and Identification of Nonthermal Hadronic Processes in the Universe, be it Galactic, Extragalatic, or Cosmogenic.

Window of Opportunity

Conventional ν Detector | **?** | **UHECR ν Detector**

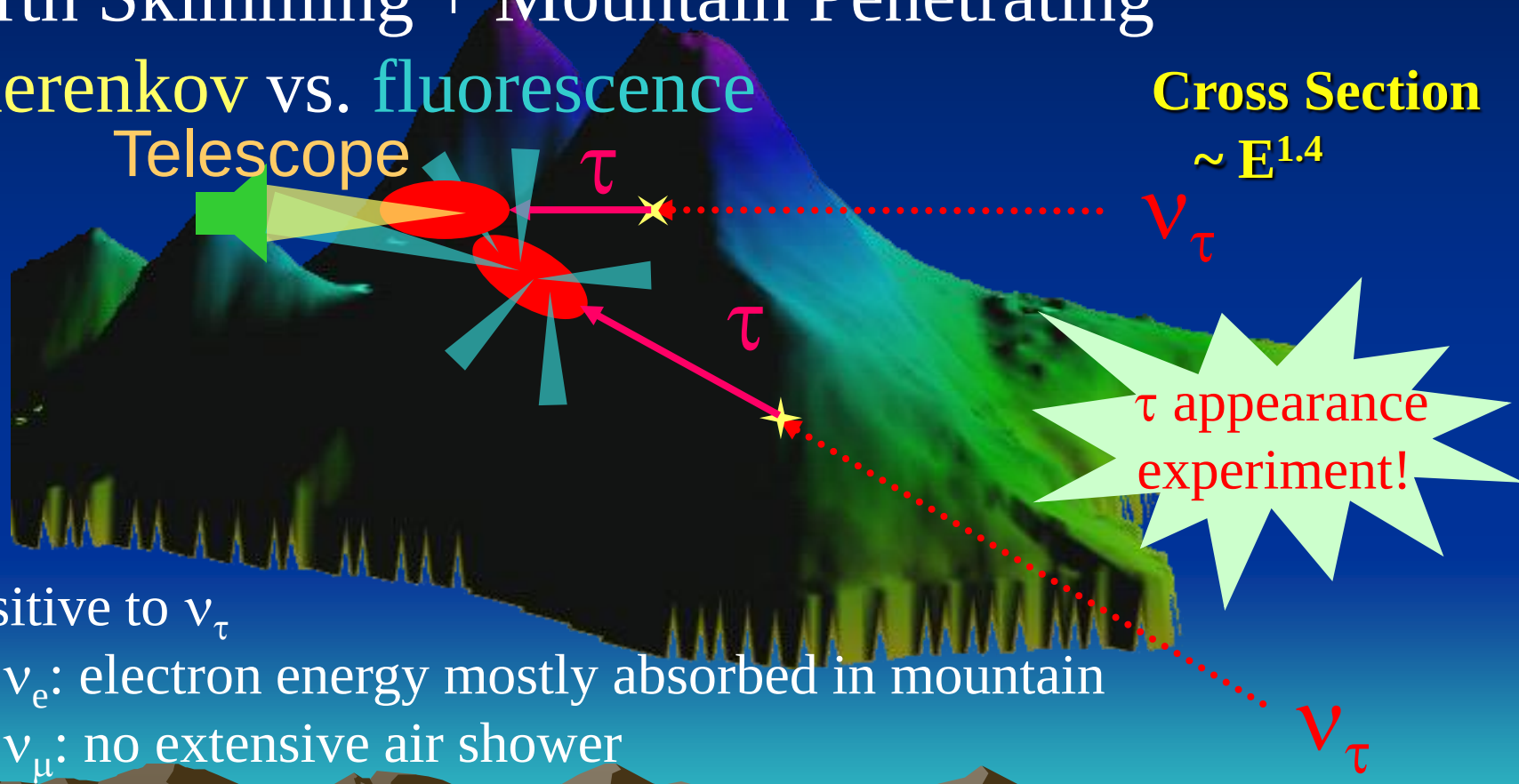


a plot I first used ~ 2002

Earth Skimming

Earth Skimming + Mountain Penetrating

Cherenkov vs. fluorescence



Cross Section

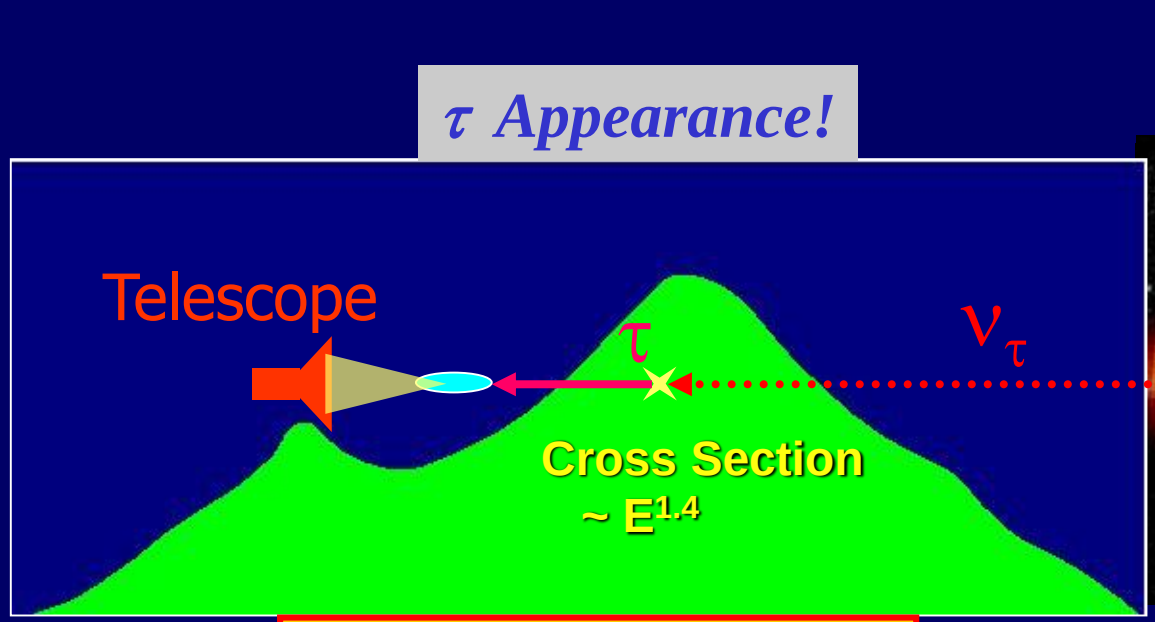
~ $E^{1.4}$

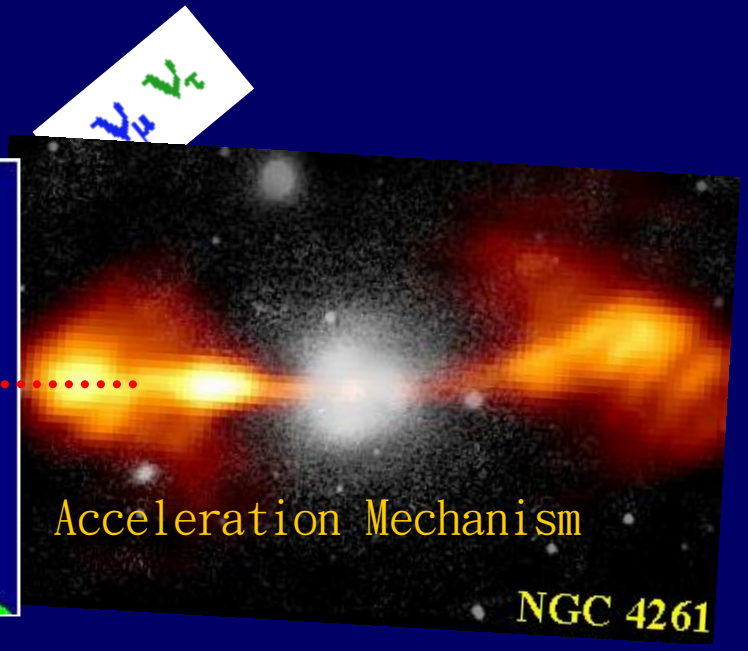
Sensitive to ν_τ

- ν_e: electron energy mostly absorbed in mountain
- ν_μ: no extensive air shower

Detection Mechanism

Earth-Skimming ν_τ Method





τ *Decay*: Air Shower → ns Cherenkov

What I learned 8/2001

▸ Vannucci Visit to NTU

- Earth Center Opaque for E > 10^{14} eV ν *!?*
- Mountain-Valley ν_τ Detection Concept

I asked whether he already had funding ...

after - checking literature (e.g. Fargion)

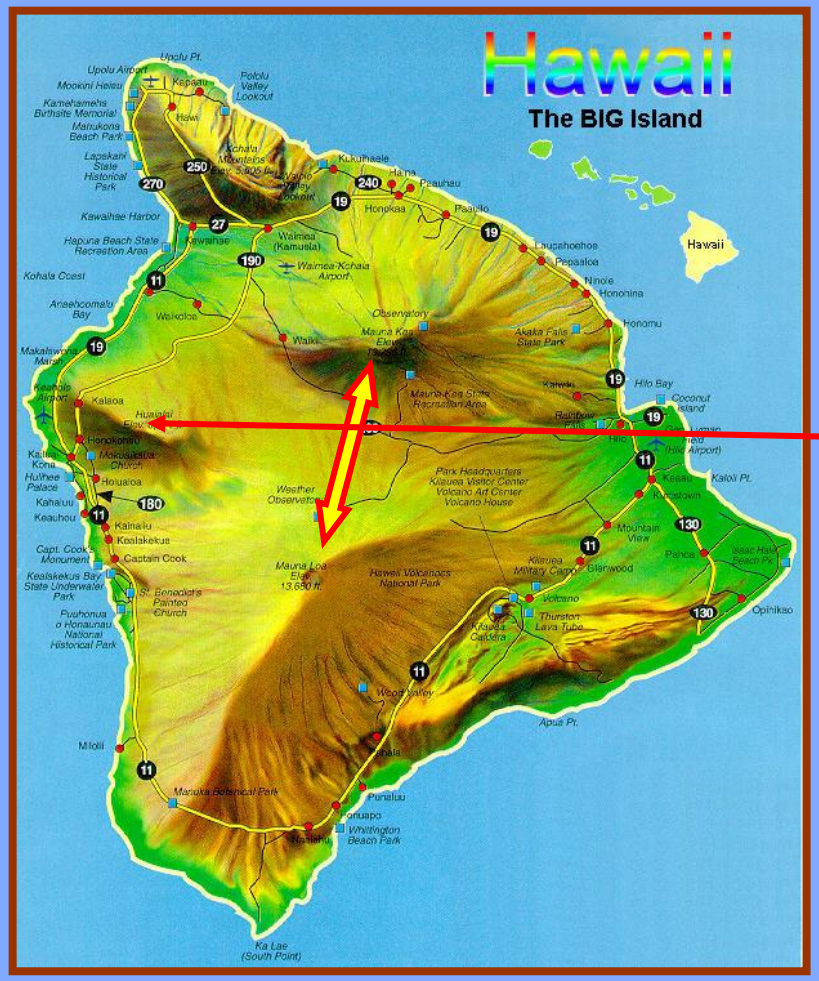
- passing it thru NTUHEP PIs

I hired Alfred Huang in Fall (start simulations)

(had to convince him ...)

Hawaii Site also came out from Vannucci visit ...

Hawaii Big Island as Site: happened as *gotcha*



w/ Francois Vanucci

- Courtesy visit to CosPA-1
  [Fred Lo]
  - Hawaii is known good Astro Site
  - Stood together in front of Hawaii map
  - *Snap*: Big Mountains w/ 40 km sep.
- Mt. Hualalai: M. Alfred Huang

Good view of Mauna Loa

Situated at dryer west side

Mauna Loa provide long base line

~ 90 km wide and 4 km high

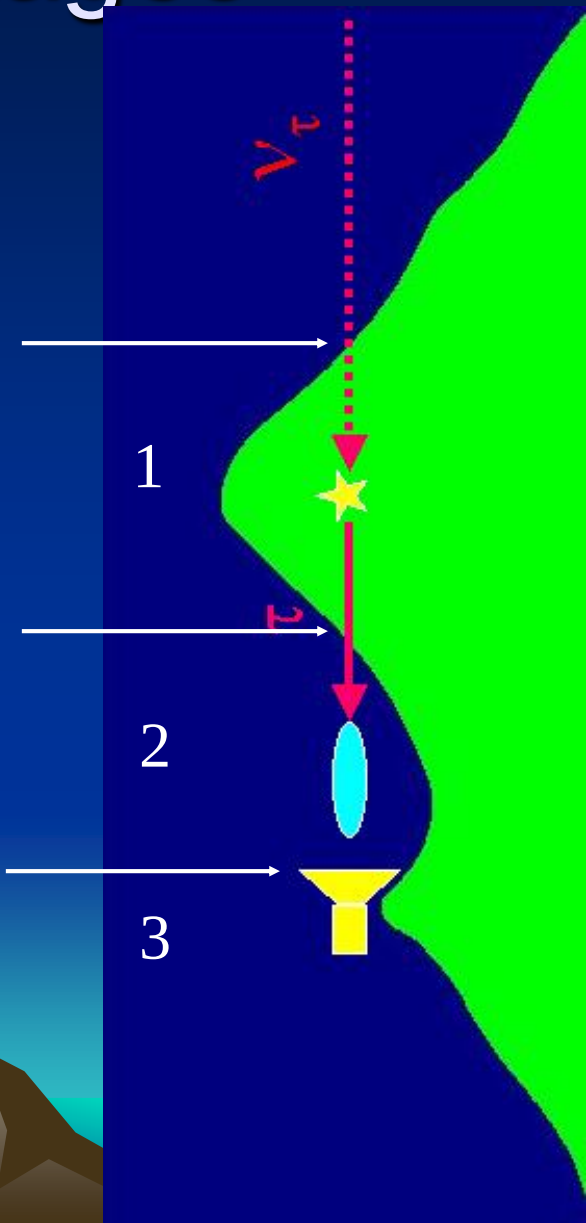
GWS Hou & MA Huang, astro-ph/0204145

P Yeh et al., MPLA 19 (2004) 1117 [CosPA 2003 WS]

from Colloquium 3/2004 @ KIAS

Three simulation stages

1. Mountain simulation: $\nu_\tau \rightarrow \tau$
   - ν + N cross-section
     - inelasticity
     - energy loss of tau
2. Air shower simulation:
   $\tau \rightarrow$ Cherenkov photons
   - τ decay mode
   - CORSIKA detailed air shower simulation vs. fast simulation
3. Detector performance simulation
   - light propagation + Q.E.
   - pixelization for triggers
   - reconstruction

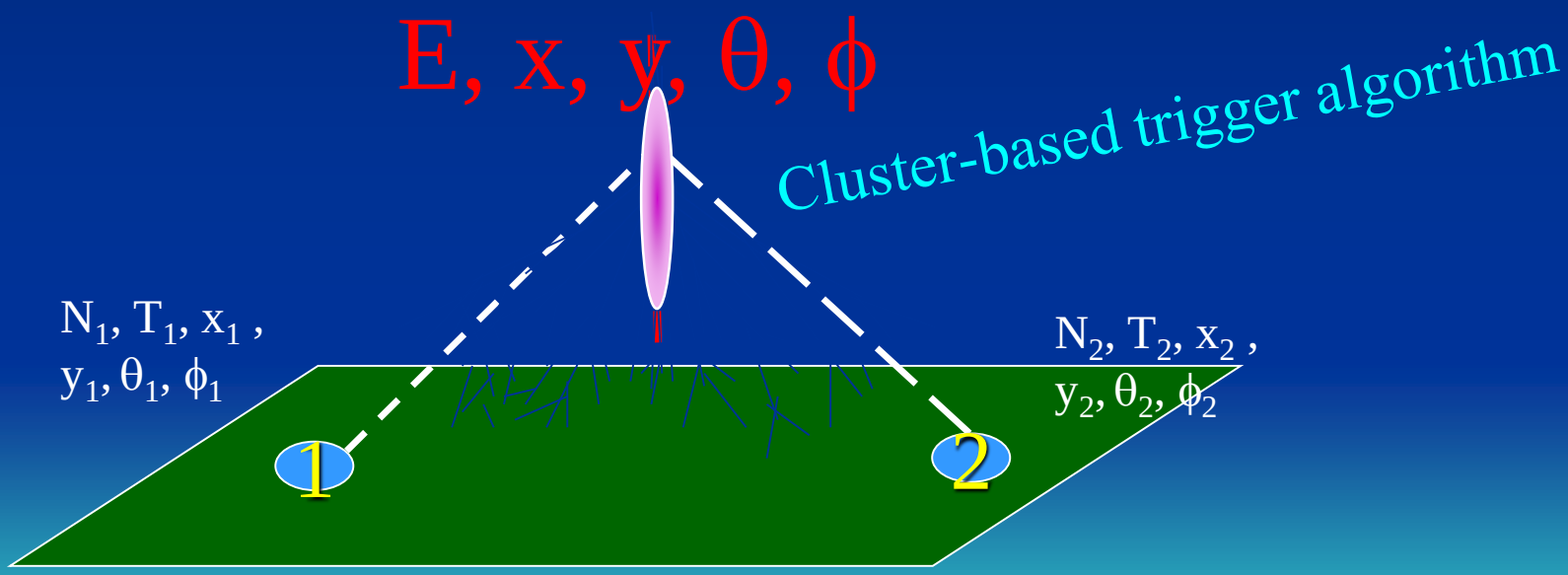


Preliminary Reconstruction

- Reconstruction: Minimize χ^2 for x,y,θ,ϕ,

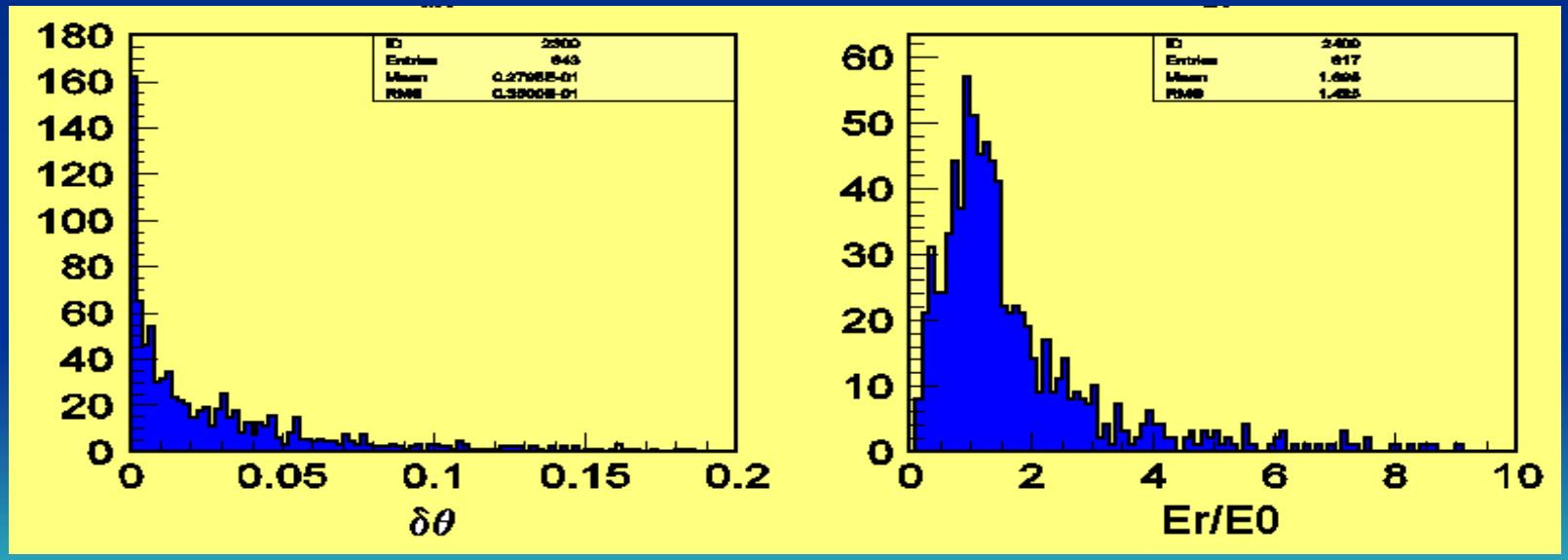
  and E

  – Two Detectors Separated by ~ 100 m ("stereo")

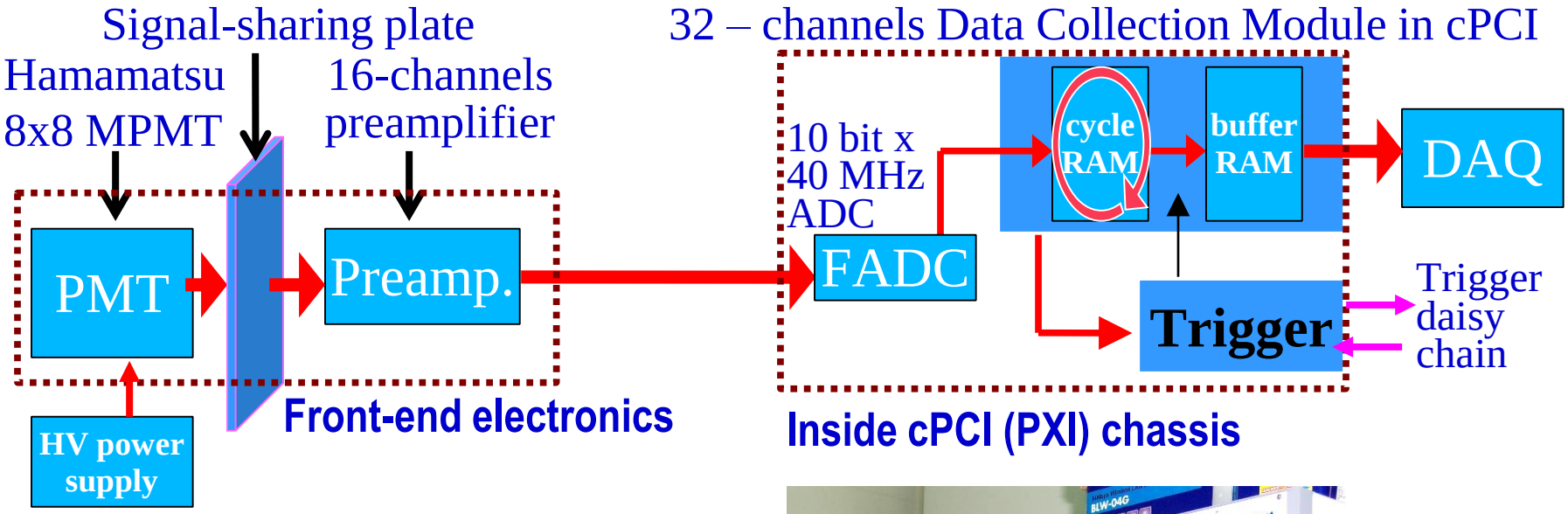


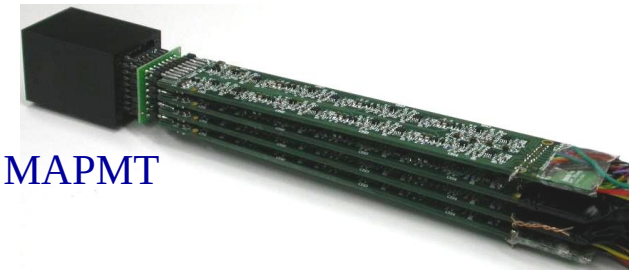
Possibility for Reconstruction

- Angular Error within 1°
- Energy Error ~ 40%
- Reconstruction Efficiency > 90% if triggered

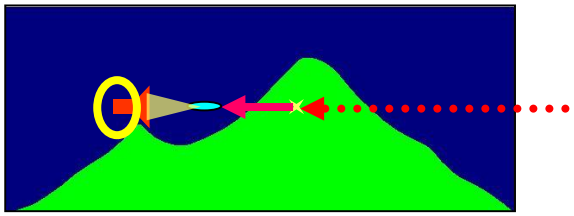


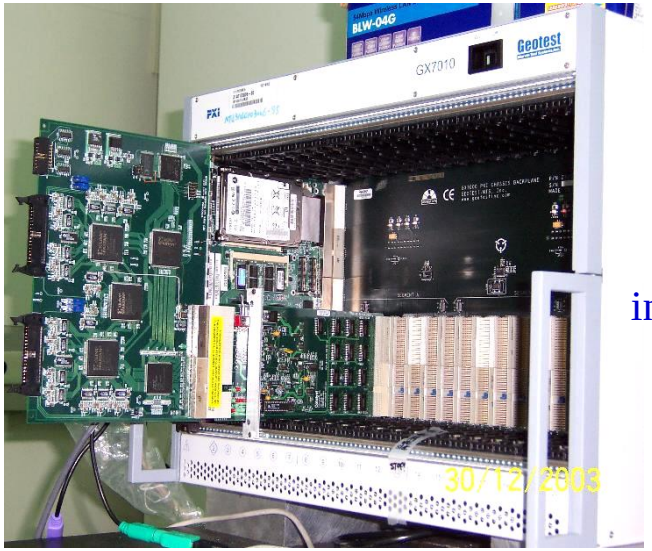
NuTel electronics (2002-2003)





MAPMT





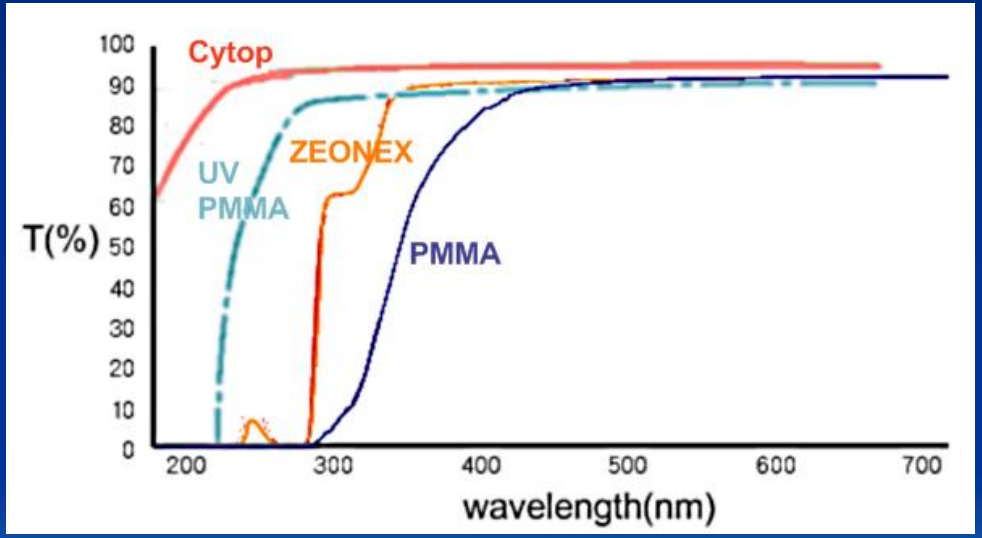
16 DCM boards
(512 channels)
inside PXI chassis

Contacts with Palermo (EUSO)

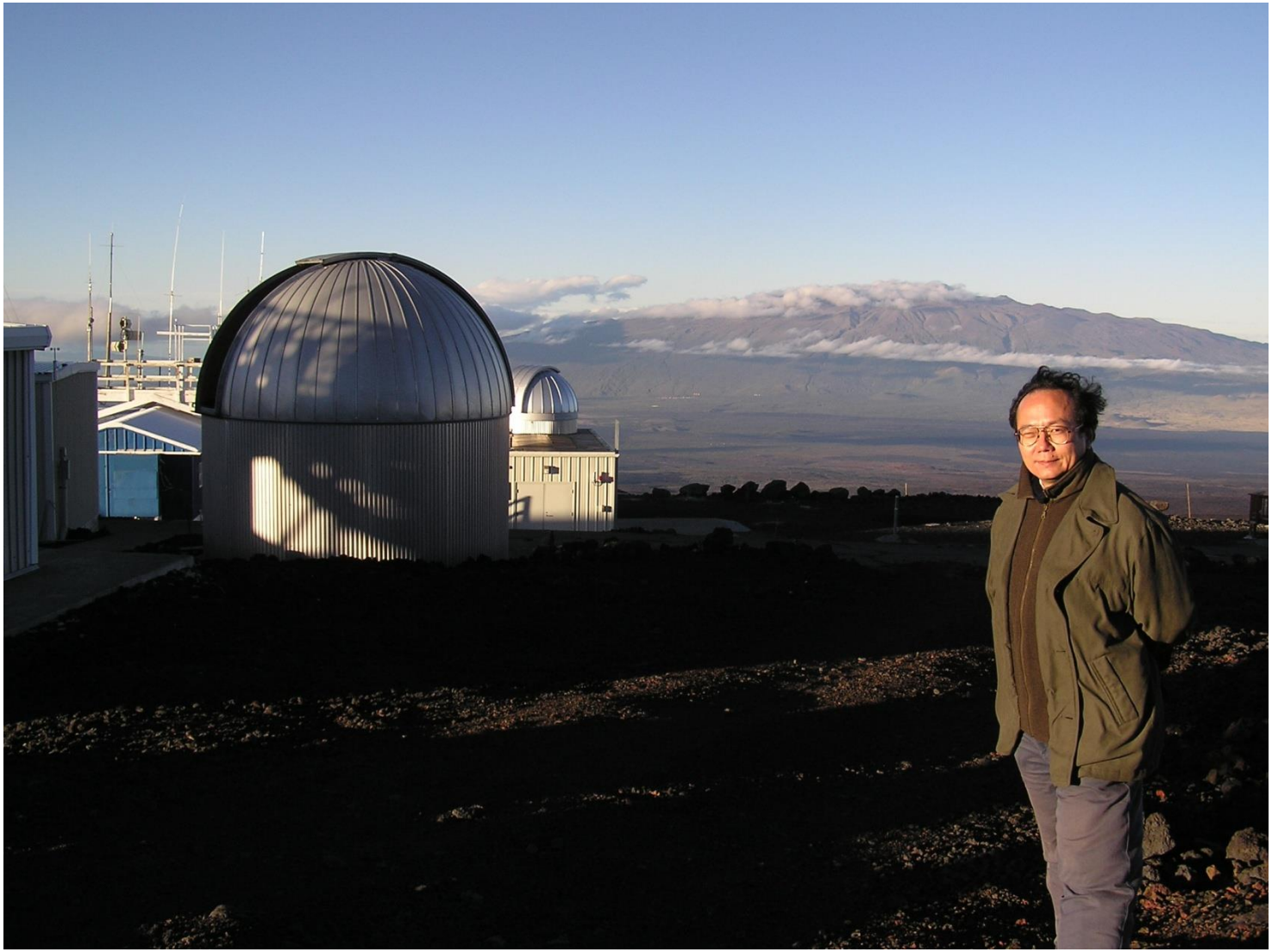
Fresnel lens system not good enough

- The spot all isn't small, ~ 5mm. This is Chromatic issue.
  Spot with multi-wavelength is 2~3 times spot with single wavelength.
- The main way to lower the chromatic aberration is to use different material. However there are very few UV transparent material.
- Cytop is the best to eliminate dispersion (high Abbe no.), also high T(%)
  its spot size ~3mm, but it is expensive and
  lens will become fatter due to low index.

	Cytop	PMMA
Refraction index (n_d)	1.34	1.49
Abbe's number	90	55



- To sum up, all spot size are less than the channel size of MAPMTs,
  it meets the threshold but not good enough. Any possible errors can make spots larger.
  So we changed to other design.



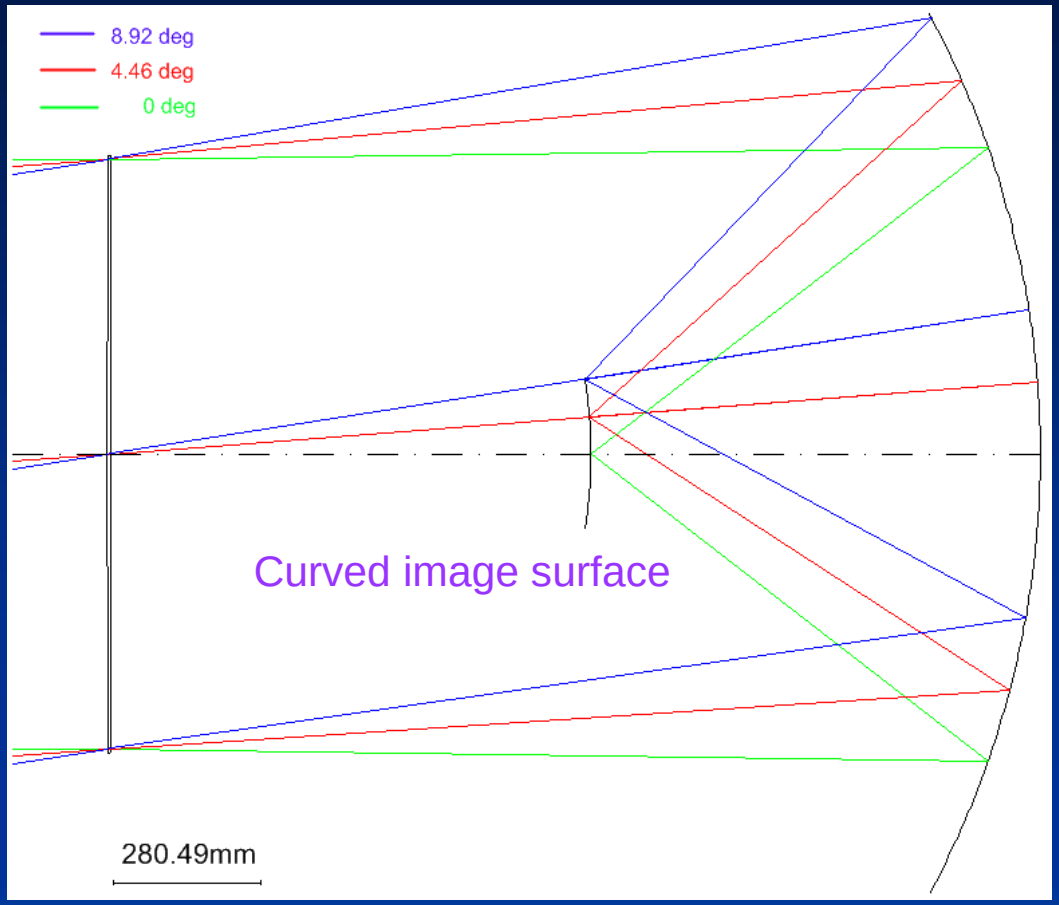
1/2004 up Mauna Loa

NuTel

- **NuTel is the first experiment *dedicated* to earth skimming for τ appearance**
- **PeV cosmic ν_τ rate is ~ 0.5 event/year**
- **First set of two telescopes ready**
- **VHECR observation in Taiwan: prototype deployment in 2009 indicates high light background at Mei-Fong**
- **But it got cut out in CosPA II in Spring 2004 ... and we could not restore it, after several tries ... so I continued it on a shoestring ...**

Schmidt Mirror System

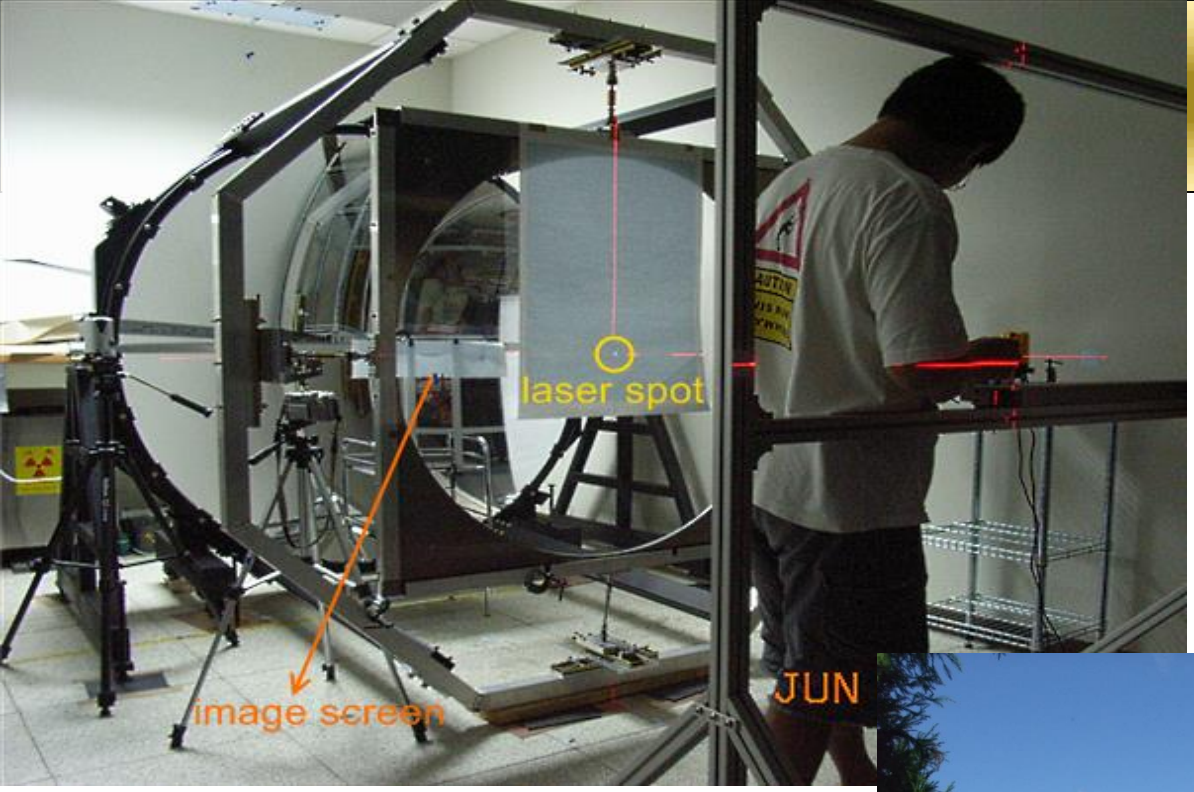
Aspherical Corrector Lens mainly eliminate spherical aberration.



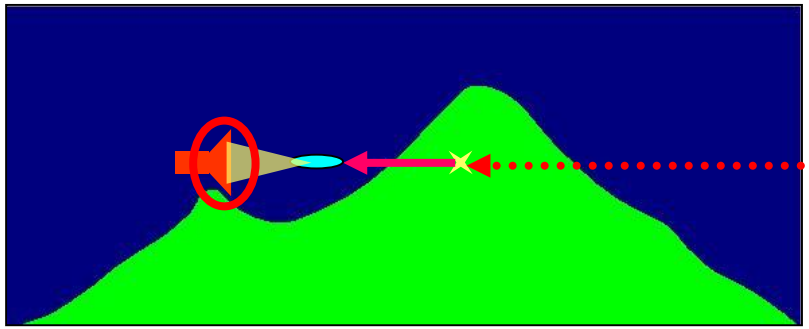
D:1.6 m, finally we made 1.8 m

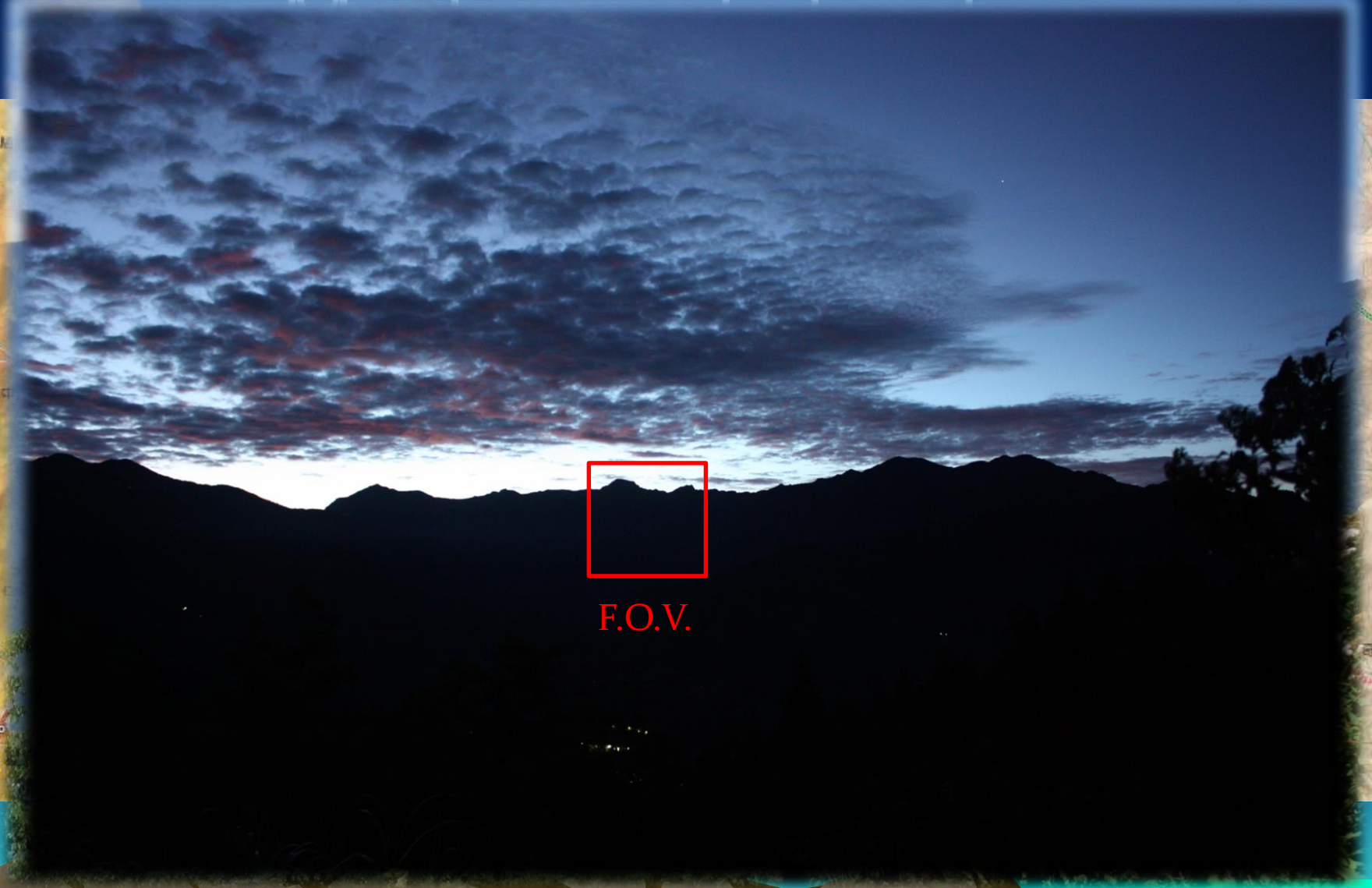
Surface #	Surface Name	Surface Type	Y Radius	Thickness	Glass	Refract Mode	Y Semi-Aperture
Object		Sphere	Infinity	Infinity		Refract	
Stop		Asphere	14277.1987 V	8.0000	491755.573	Refract	570.0000
2		Sphere	Infinity	1797.4128 V		Refract	571.0183
3		Sphere	-1800.0000	-869.0192 V		Reflect	842.9845
Image		Sphere	-914.3269 V	0.0000		Refract	144.9557

	conic const (k)	4th order	6th order	8th order
surf 1(Stop) aspherical parameters	0	-7.033e-011	-2.904e-017	-2.607e-023



NuTel went on a shoestring budget since 2004 …




F.O.V.

Set-up of Observational Tent

Image around the focal plane

Waiting for sunrise before leaving

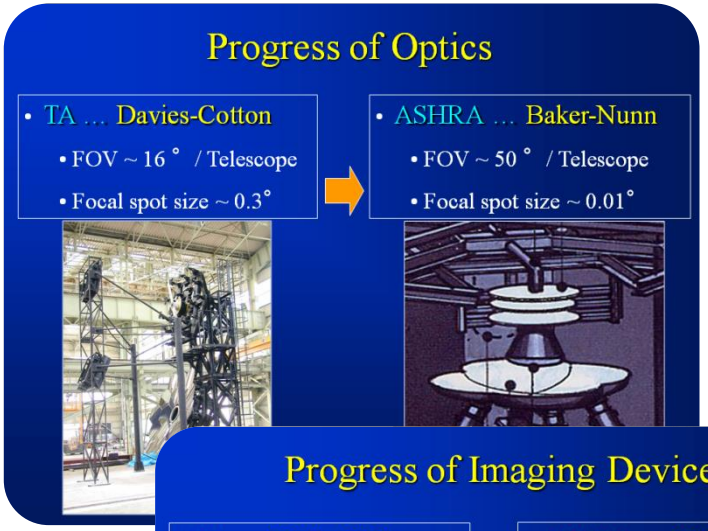
NuTel

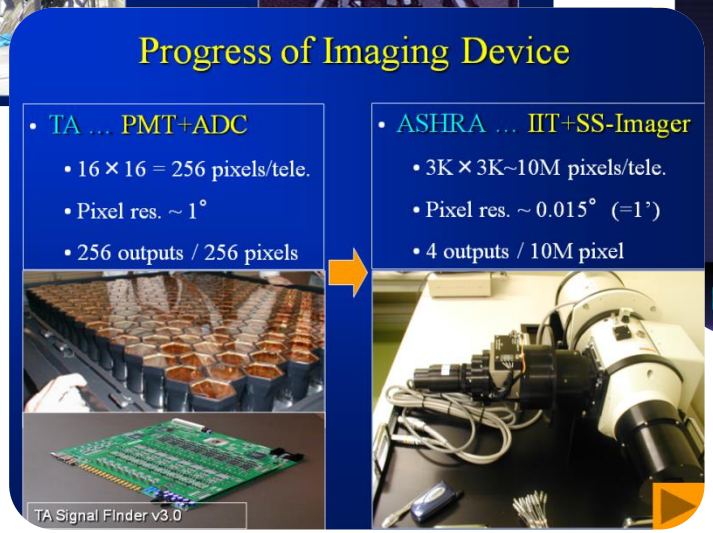
- NuTel is the first experiment *dedicated* to earth skimming for τ appearance
- PeV cosmic ν_τ rate is ~ 0.5 event/year
- ~~First set of~~ two telescopes ready
- VHECR observation in Taiwan: prototype deployment in 2009 indicates high light background at Mei-Fong
- We learned challenge of mountain operation
  - ➔ Tried pair up with CRTNT ... they evolved ...
- Synergy w/ Ashra-1 (reconnect 9/2012) ➔ (Ashra) NTA

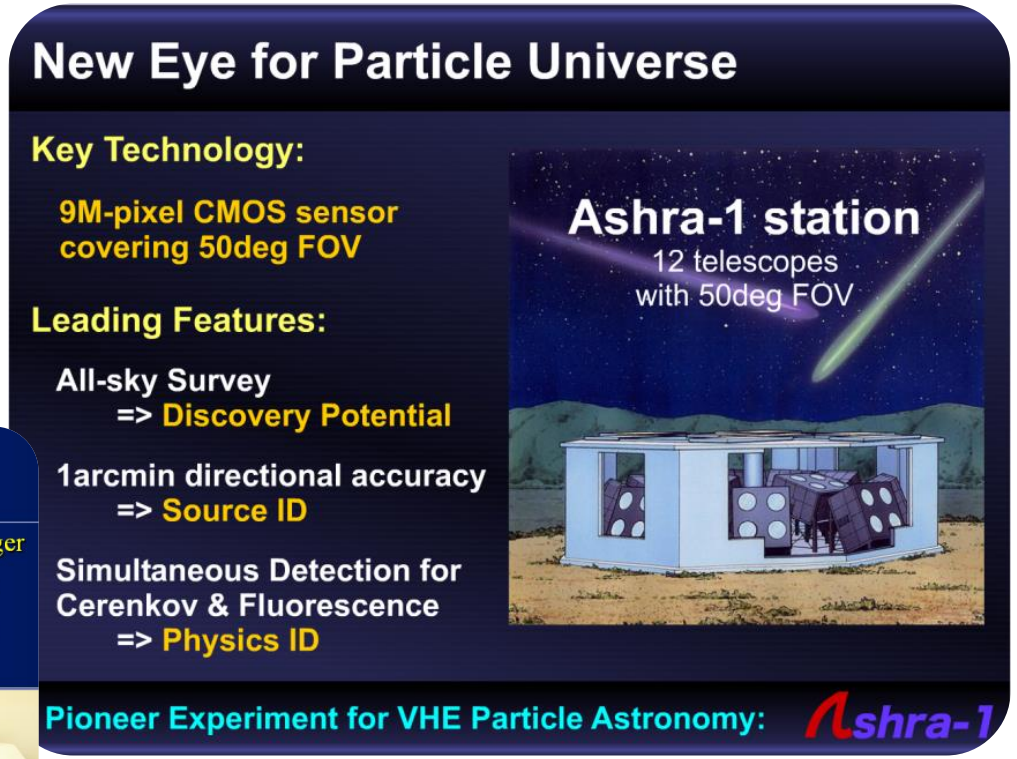
Ashra-1

- Ashra-1 succeeded in demonstrating power of Earth-Skimming ν_τ Method

(Courtesy Makoto Sasaki)





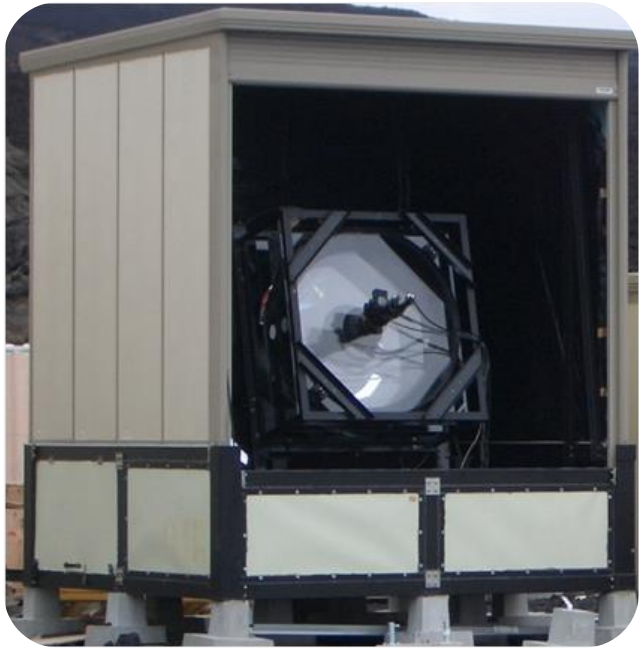


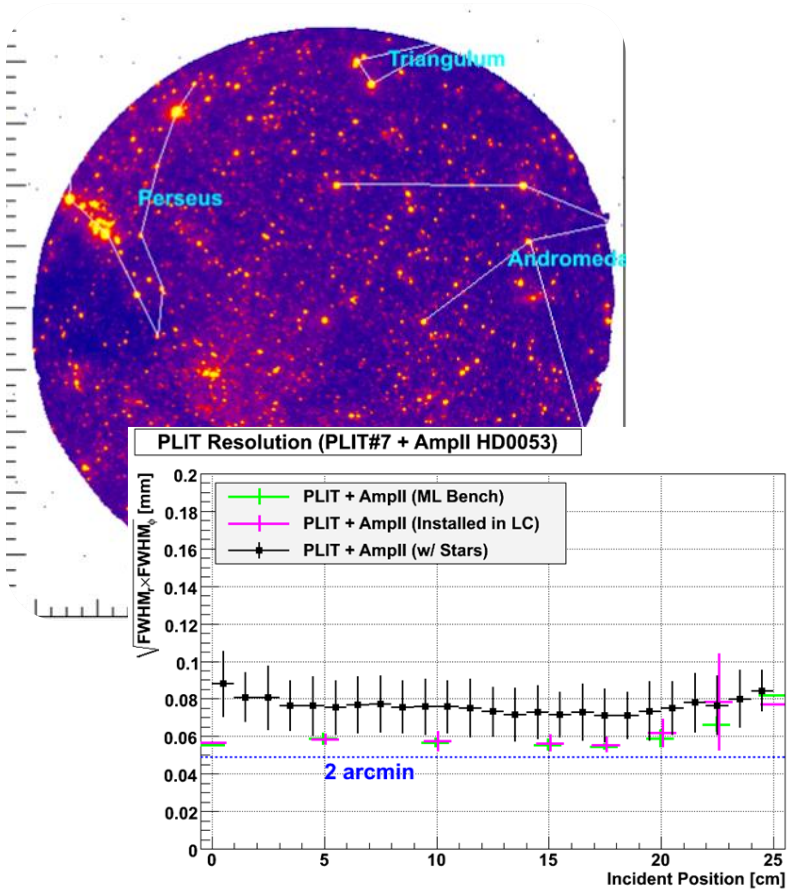
[Sasaki's Presentation @ CosPA 2003-NTU]

Aim now for (Ashra) NTA

Ashra-1

Ashra-1 Light Collector





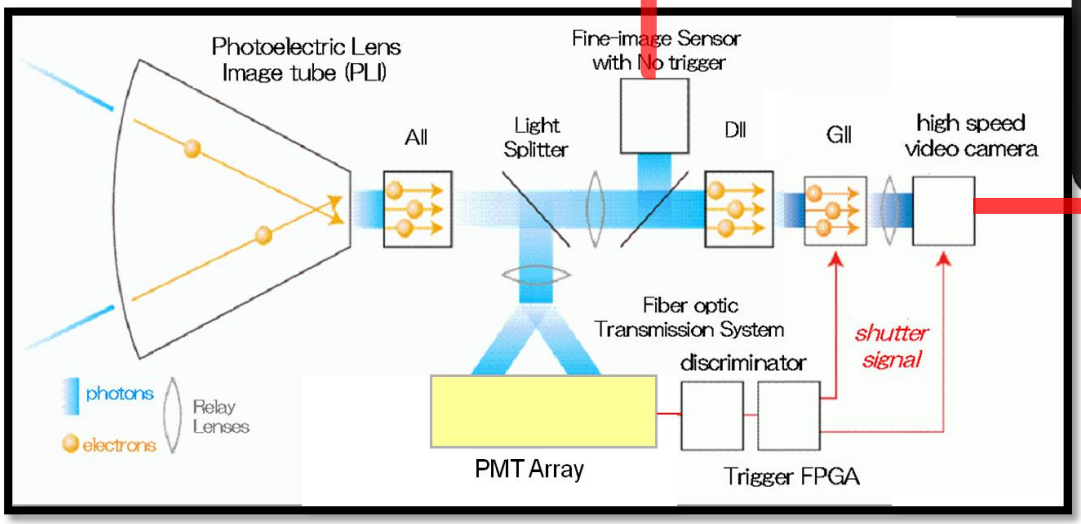
Total Resolution: ~3 arcmin image in 42° FOV

Can cover Mauna Kea surface at 35 km distance

Ashra-1 Pipeline Trigger & Readout

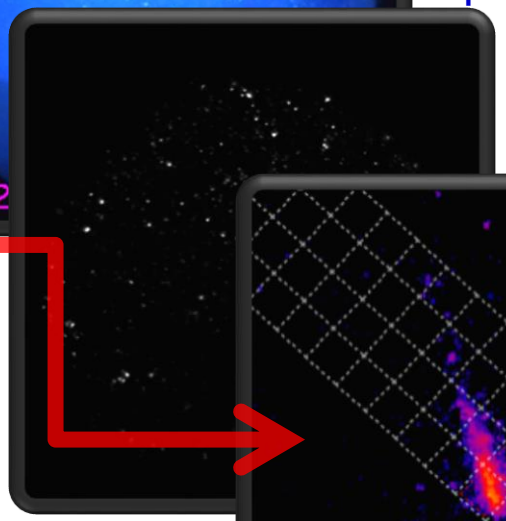
demonstrated

Same Fine Image to Multiple Triggers

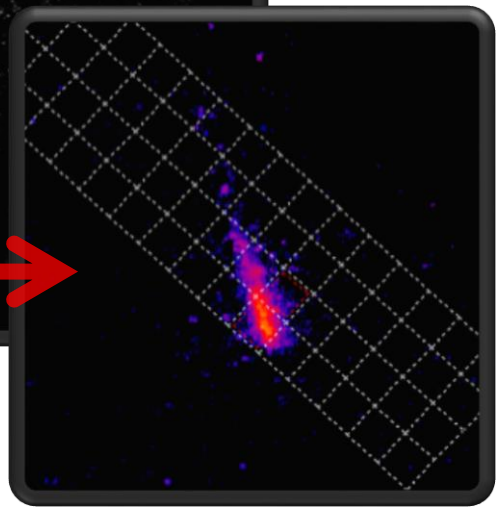


Photoelectric Image Pipeline (PIP)

Optical 4s



BG 200ns



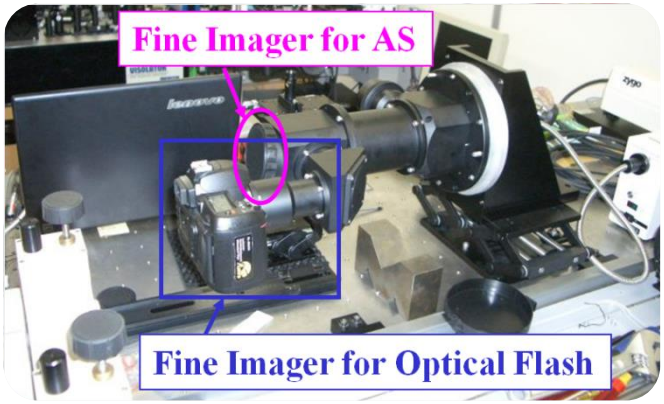
CR 200ns

Multi-Messenger Approach with
One Detector System

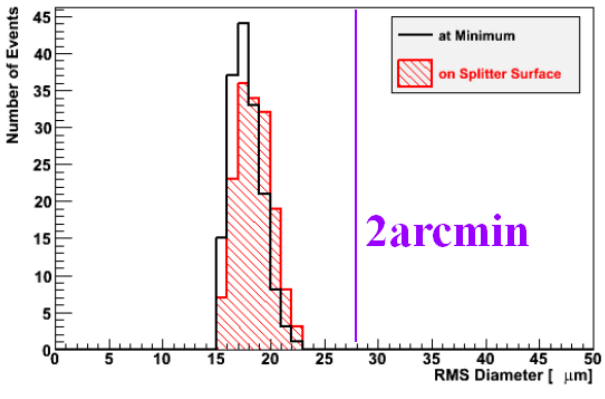
1st imaging air-shower with self-triggered I.I.

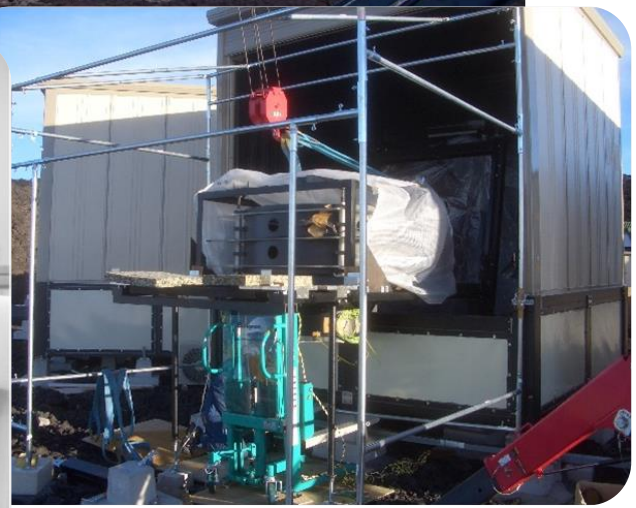
Ashra-1

PIP & PLI Installation @ Mauna Loa



Test of PIP





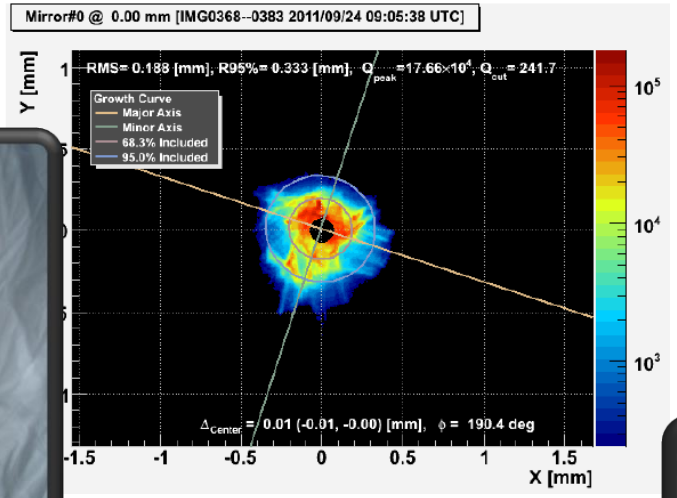
Installation of PLIs

20-in Photoelectric Lens Image Intensifier (PLI)
[Y. Asaoka & M. Sasaki, NIM, A647 (2011) 34]

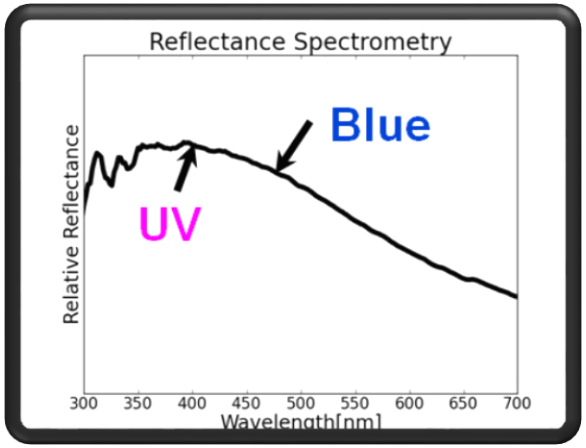
Ashra-1

Segment Mirror Installation @ Mauna Loa

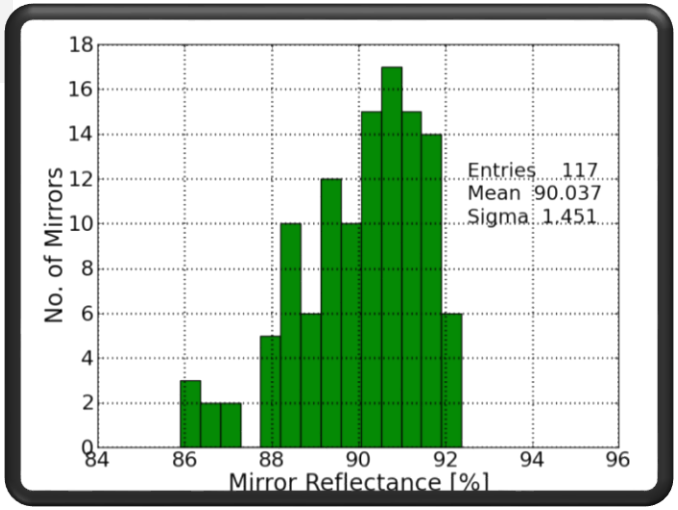
Mount Seg. Mirrors



Spot Size RML 0.19 mm
Corresponds to 0.46 arcmin after adjusting all segments



Al+Al_2O_3-coat:
UV enhanced

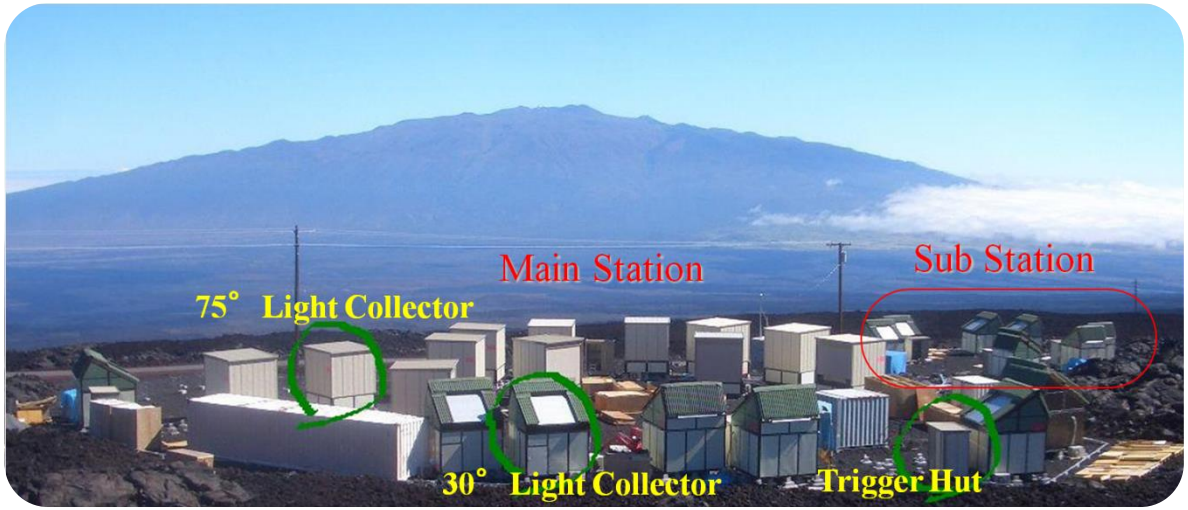


Reflection > 85%

All Light Collector Optical System on ML Ready

Ashra-1

Ashra Observational Site: Mauna Loa



3300 m a.s.l., 35 km from MK

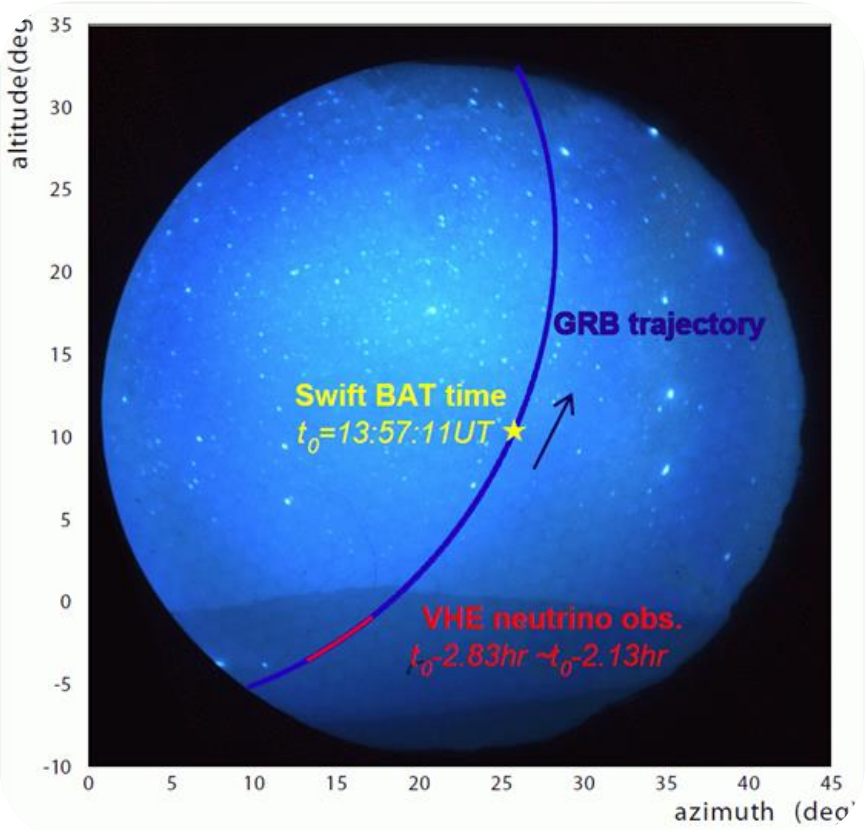
77% mono, 27% stereo

2~3 arcmin image

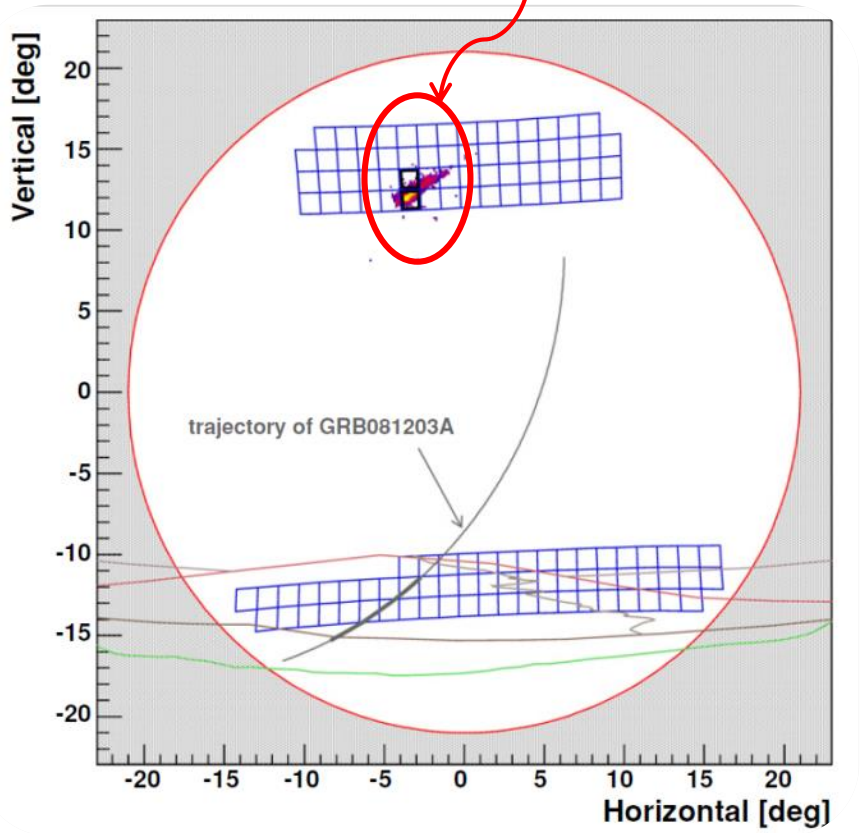
Nice Coverage and Precision as Particle Monitor

Ashra-1: 1st Search for GRB ν_τ

GRB081209A



triggered CR



Swift GRB Alert during Commissioning

First Check for PeV-EeV Tau Neutrino from a GRB

Y. Aita et al., ApJ 736 (2011) L12

Ashra-1: 1st Search for GRB ν_τ

THE ASTROPHYSICAL JOURNAL LETTERS, 736:L12 (5pp), 2011 July 20 doi:10.1088/2041-8205/736/1/L12

OBSERVATIONAL SEARCH FOR PeV–EeV TAU NEUTRINO FROM GRB081203A

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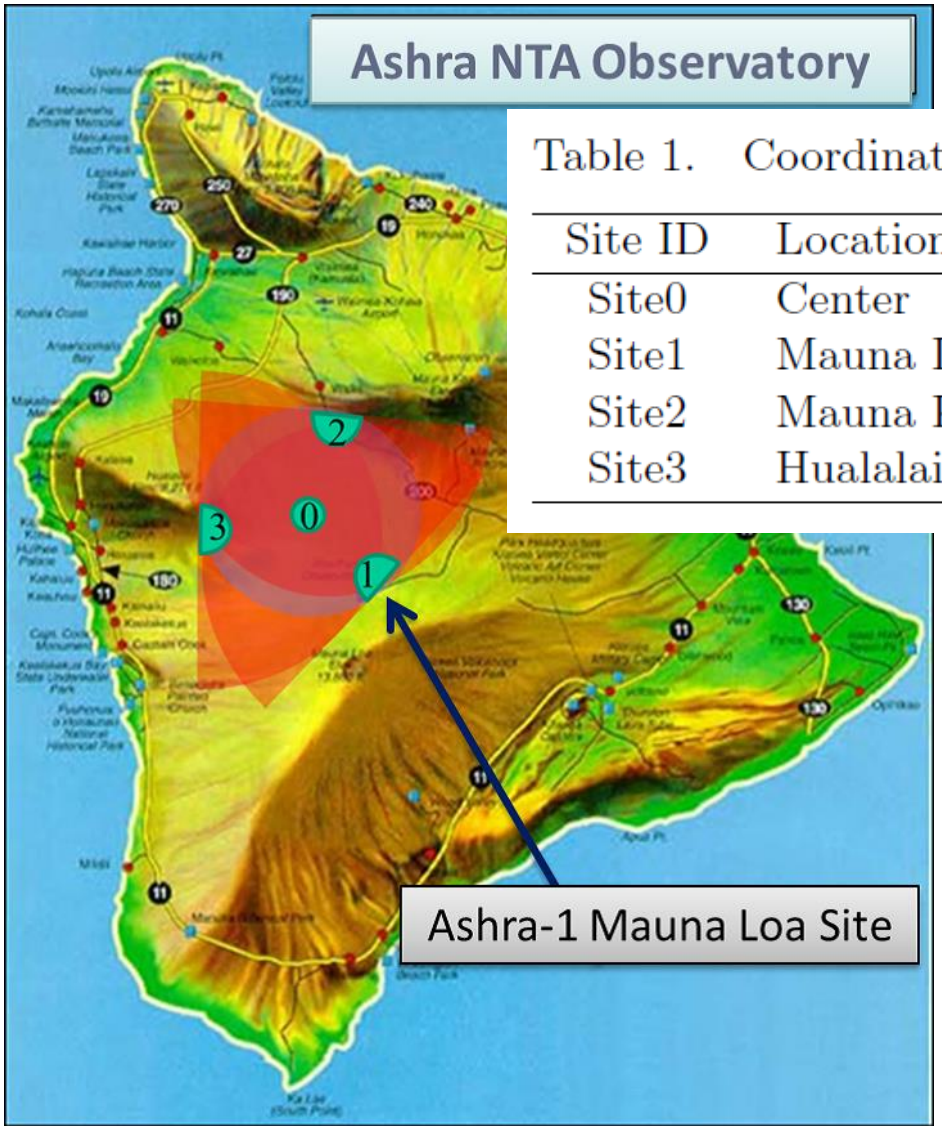
ABSTRACT

We report the first observational search for tau neutrinos (ν_τ) from gamma-ray bursts (GRBs) using one of the Ashra light collectors. The Earth-skimming ν_τ technique of imaging Cherenkov τ showers was applied as a detection method. We set stringent upper limits on the ν_τ fluence in PeV–EeV region for 3780 s (between 2.83 and 1.78 hr before) and another 3780 s (between 21.2 and 22.2 hr after) surrounding GRB081203A triggered by the *Swift* satellite. This first search for PeV–EeV ν_τ complements other experiments in energy range and methodology, and suggests the prologue of "multi-particle astronomy" with a precise determination of time and location.

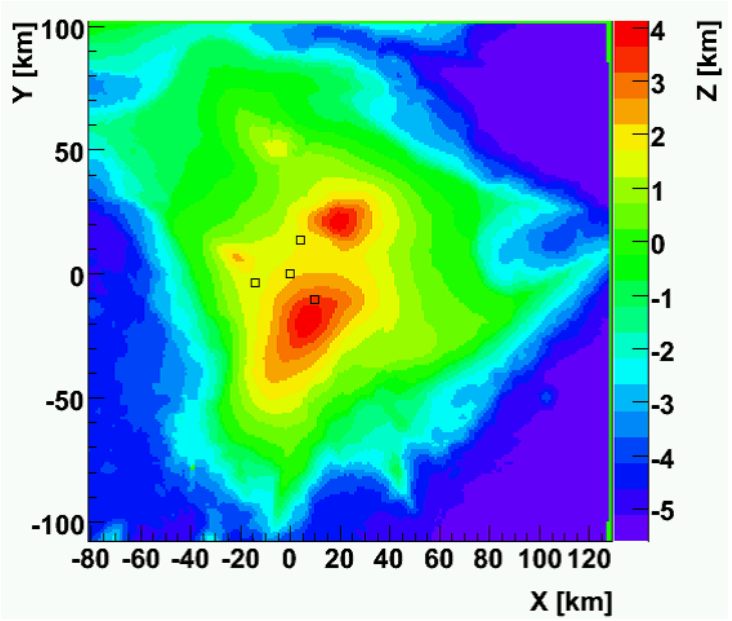
NTA Site Plan



(LOI at hand)

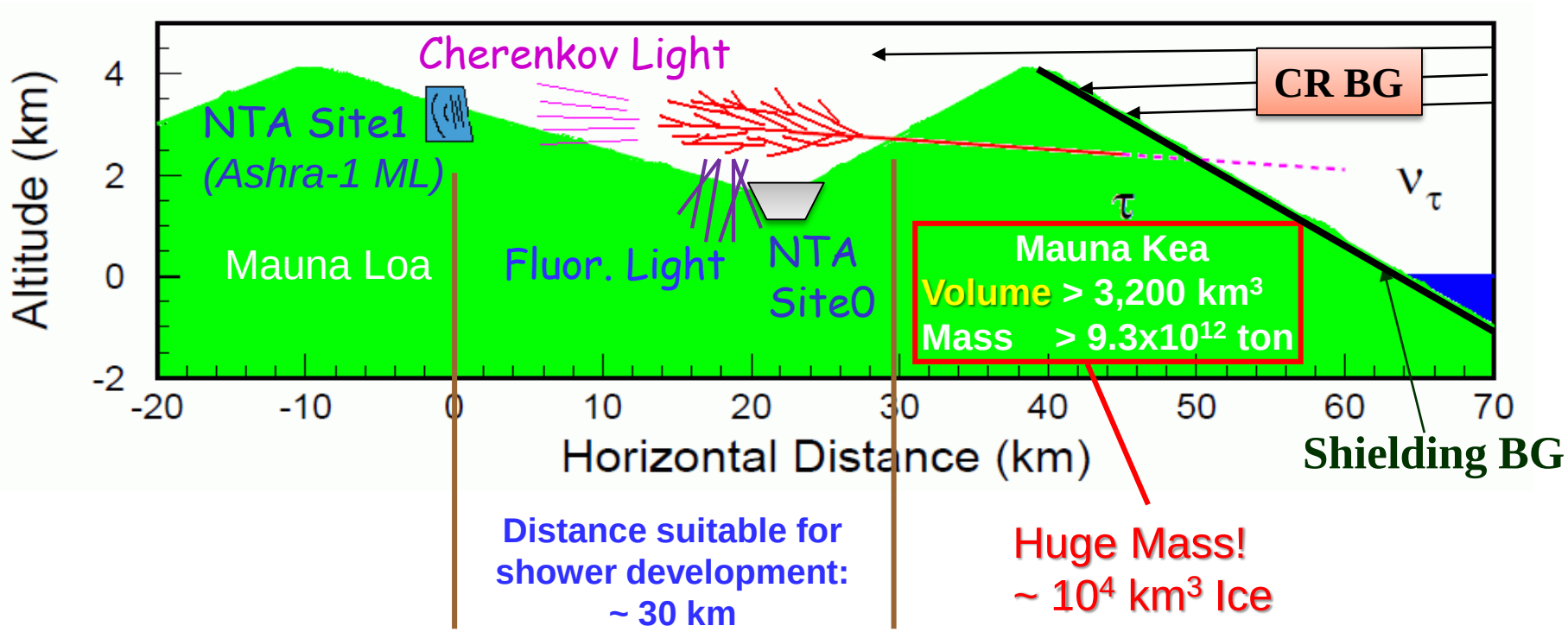
Table 1. Coordinates and FOV coverage of the Ashra NTA sites.

Site ID	Location	X [km]	Y [km]	Z [km]	FOV [sr]
Site0	Center	0.000	0.00	2.03	π
Site1	Mauna Loa	9.91	-10.47	3.29	$\pi/2$
Site2	Mauna Kea	4.12	13.82	1.70	$\pi/2$
Site3	Hualalai	-14.02	-3.35	1.54	$\pi/2$



Earth-skimming τ Shower Imaging Method

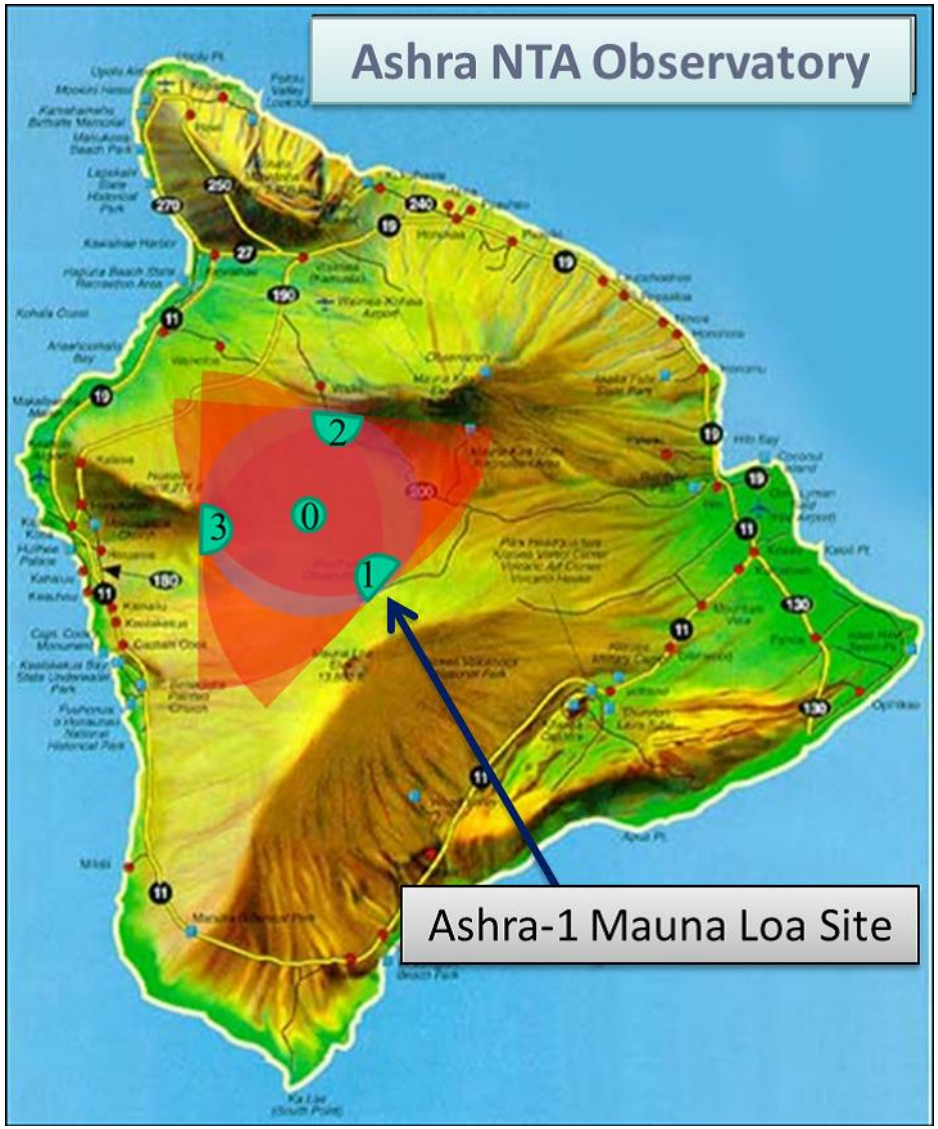
reminder

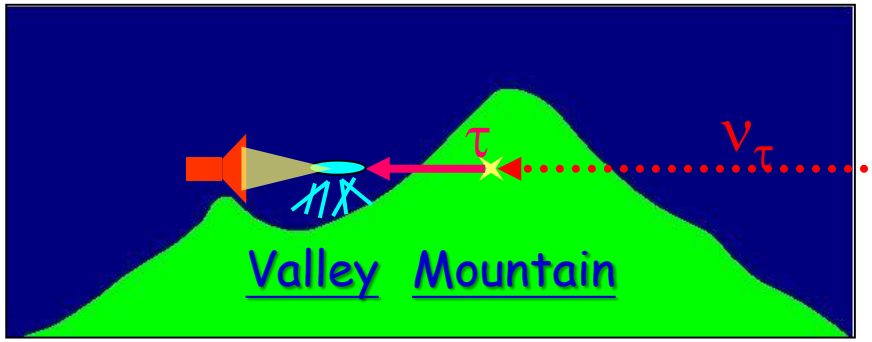


Ashra-1 already demonstrated this method !

ApJ, 736 (2011) L12

NTA "Size"



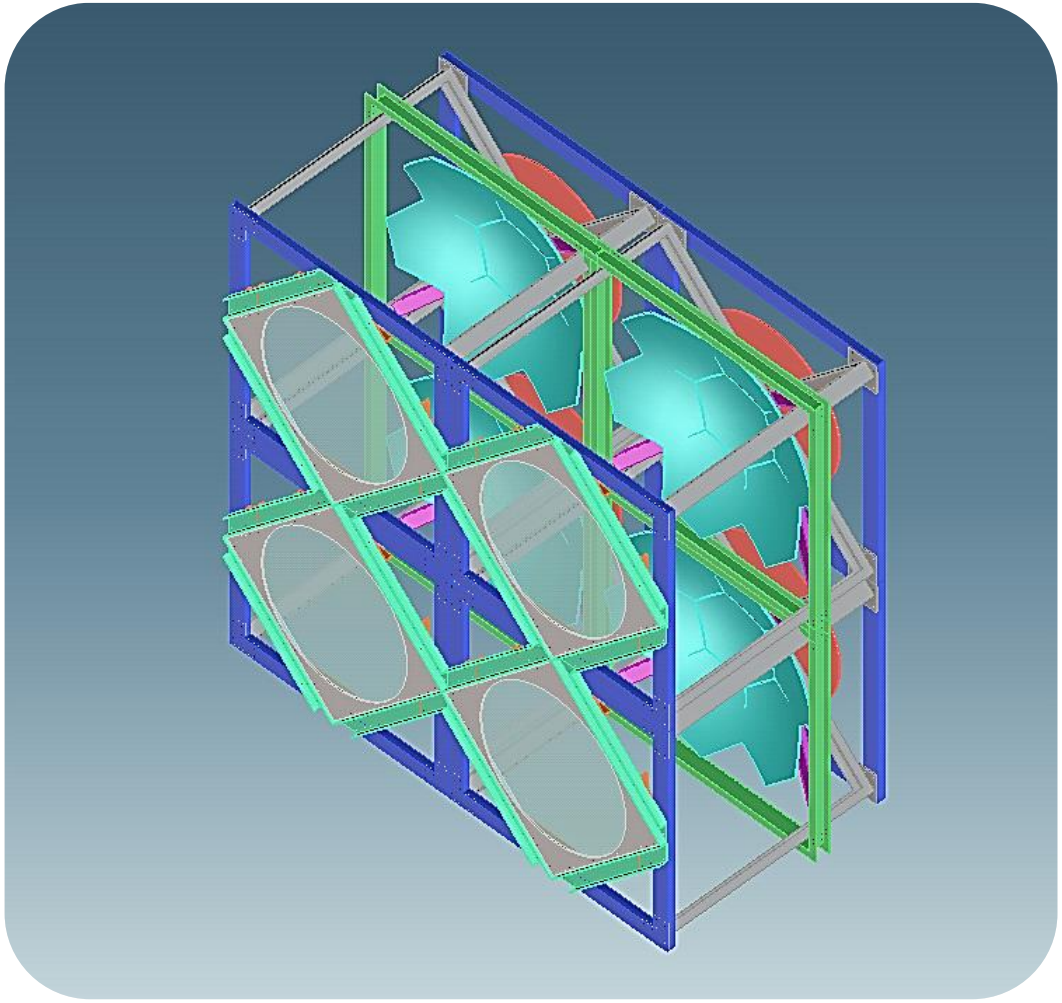


Separation of
Conversion vs **Shower**

- Huge **Target** Mass
  (> 100 km^3-weq)
- Huge **Atmos.** Mass
  (area **> 1000 km^2**)
- Mountains Shield BG

Collaboration Needed

NTA Light Collector (LC)



12 DU's per π coverage

Light Collector (LC)
Schmidt Optics with ϕ1.5m pupil
FOV 28° = focal sphere ϕ50cm

Detector Unit (DU)
4 LCs watching same FOV
Superimposed 4 images
⇒ Effective pupil size = ϕ3m

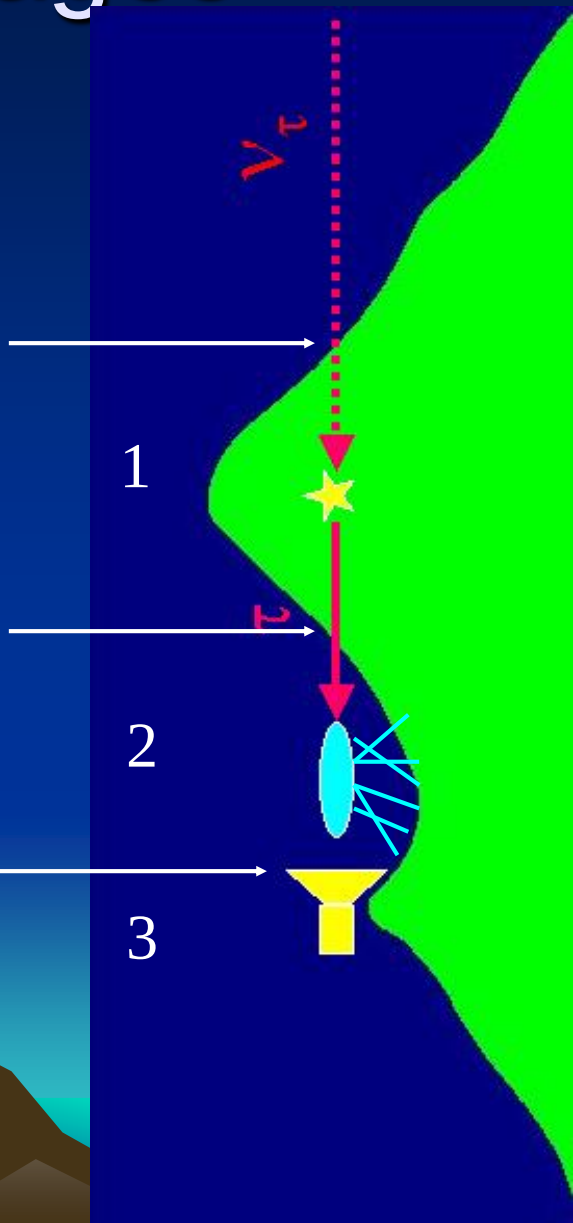
Need at least 30 DU's for Coverage

⇒ Concept:
Ashra-1 x 1.5 scaled-up + same trigger & readout

Collaboration Needed

Three simulation stages

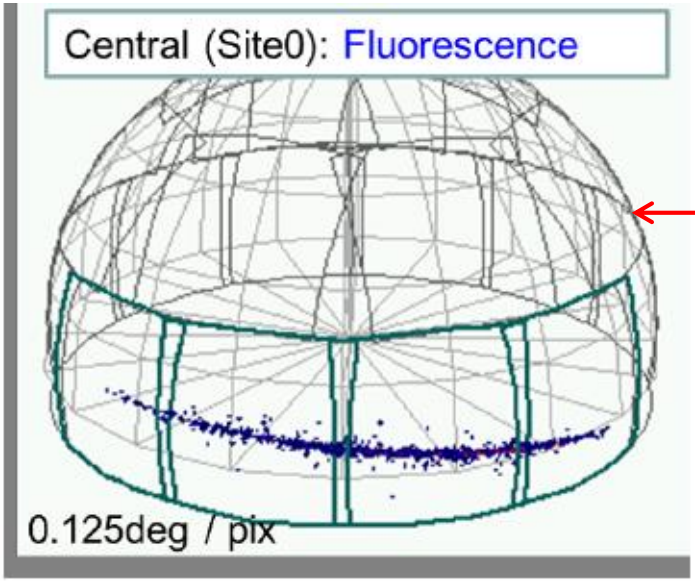
1. Mountain simulation: $\nu_\tau \rightarrow \tau$
   - ν+N cross-section
   - inelasticity
   - energy loss of tau
2. Air shower simulation:
   $\tau \rightarrow$ Cherenkov photons / fluorescence
   - τ decay mode
   - CORSIKA detailed air shower simulation vs. fast simulation
3. Detector performance simulation
   - light propagation + Q.E.
   - pixelization for triggers
   - reconstruction

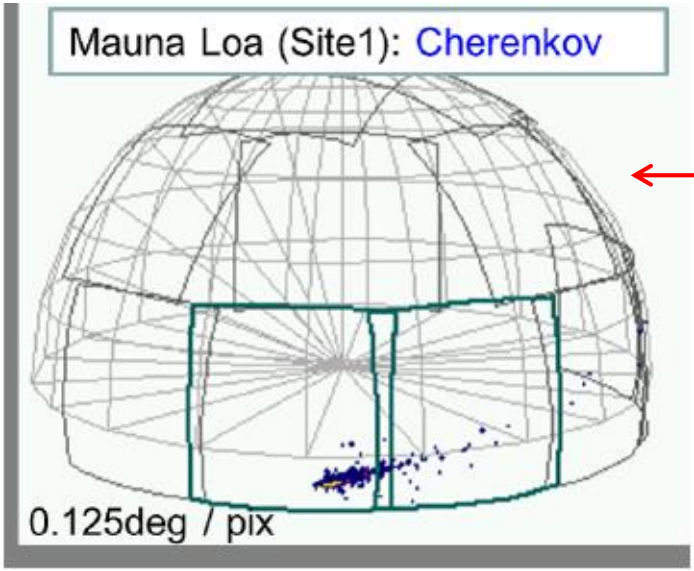


sophisticated “Ashra-1” det.

LOI at hand (submit soon)

NTA Simulated Event





R00264/E00052: $E_\nu = 10^{17.0}$eV, $E_\tau = 10^{16.8}$eV, $E_{show} = 10^{16.7}$eV

Elevation=-6.4° Azimuth= 347.6°

Mauna Loa (Site1)

Hualalai (Site3)

Central (Site0)

Xmax

Decay Point

Impact Point

Mauna Kea (Site2)

N_{pe}^{tot}=4035 (C:1363, F:2672), R_p^{min}=1.8km, R_x^{min}=5.4km

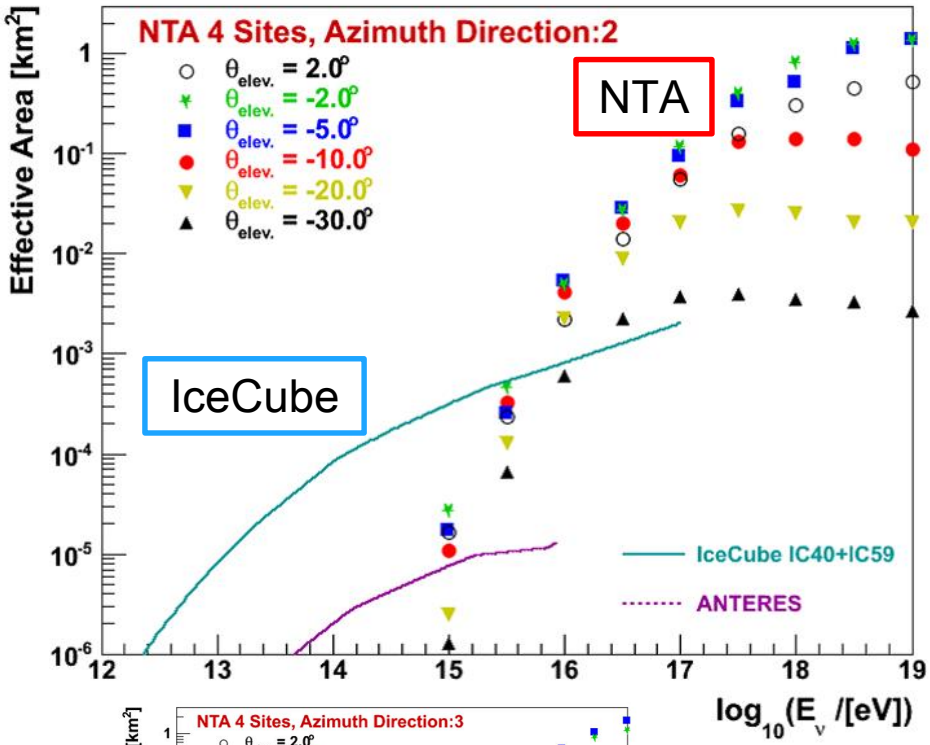
Simple Fit => Pointing Accuracy

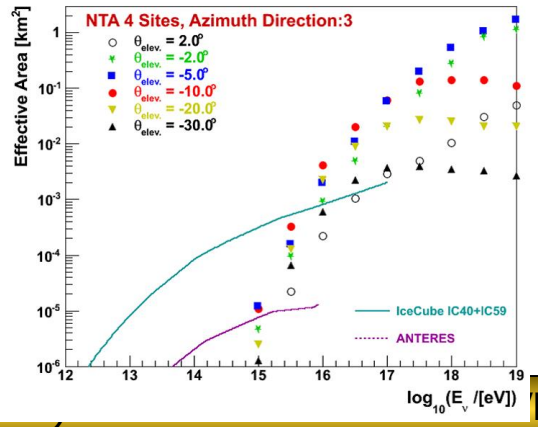
Site0 + Site1: $\delta\theta = 0.08°$

Acceptance: Air & Tau vs Water & Muon

1. We use the ν_τ distribution from CTEQ4 [14], inelasticity parameter from [13], and parameterize energy loss in Earth by [12, 15].
2. We use τ decay from TAUOLA and air-shower generation of Gaisser-Hillas + NKG [16].
3. For detector simulation, we incorporate light collection and throughput with simplified triggering logic. Event reconstruction is not yet implemented.

Point source, arrival dir. Mauna Loa





dir. Hualalai

Assumed FOV

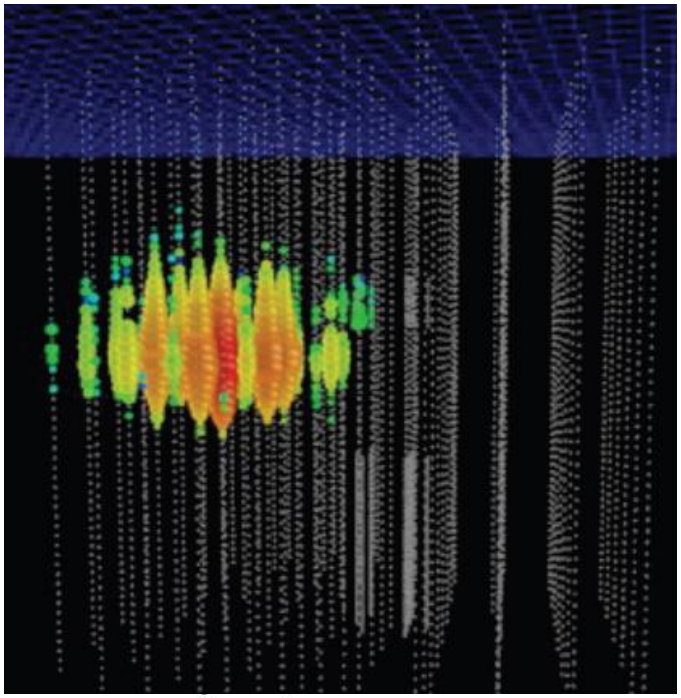
LC:	32° X 32°
Trigger Pixel:	0.5° X 0.5°
Sensor Pixel:	0.125° X 0.125°

trigger conditions:

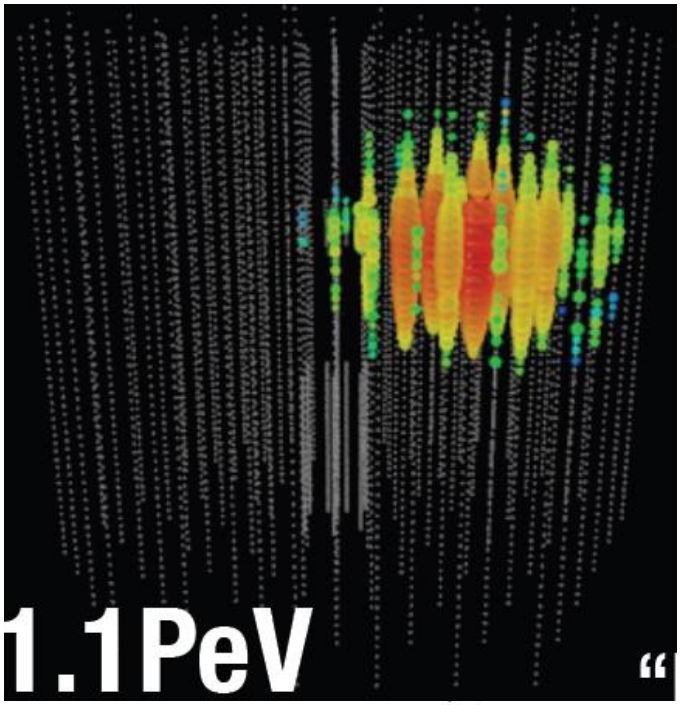
- Number of detected photoelectrons per LC > 61.
- S/N estimated in track-associated 4 pixels × 64 pixels box (air-shower track included) > 4 [17].

IceCube PeV Events

PRL **111,** 021103 (2013)

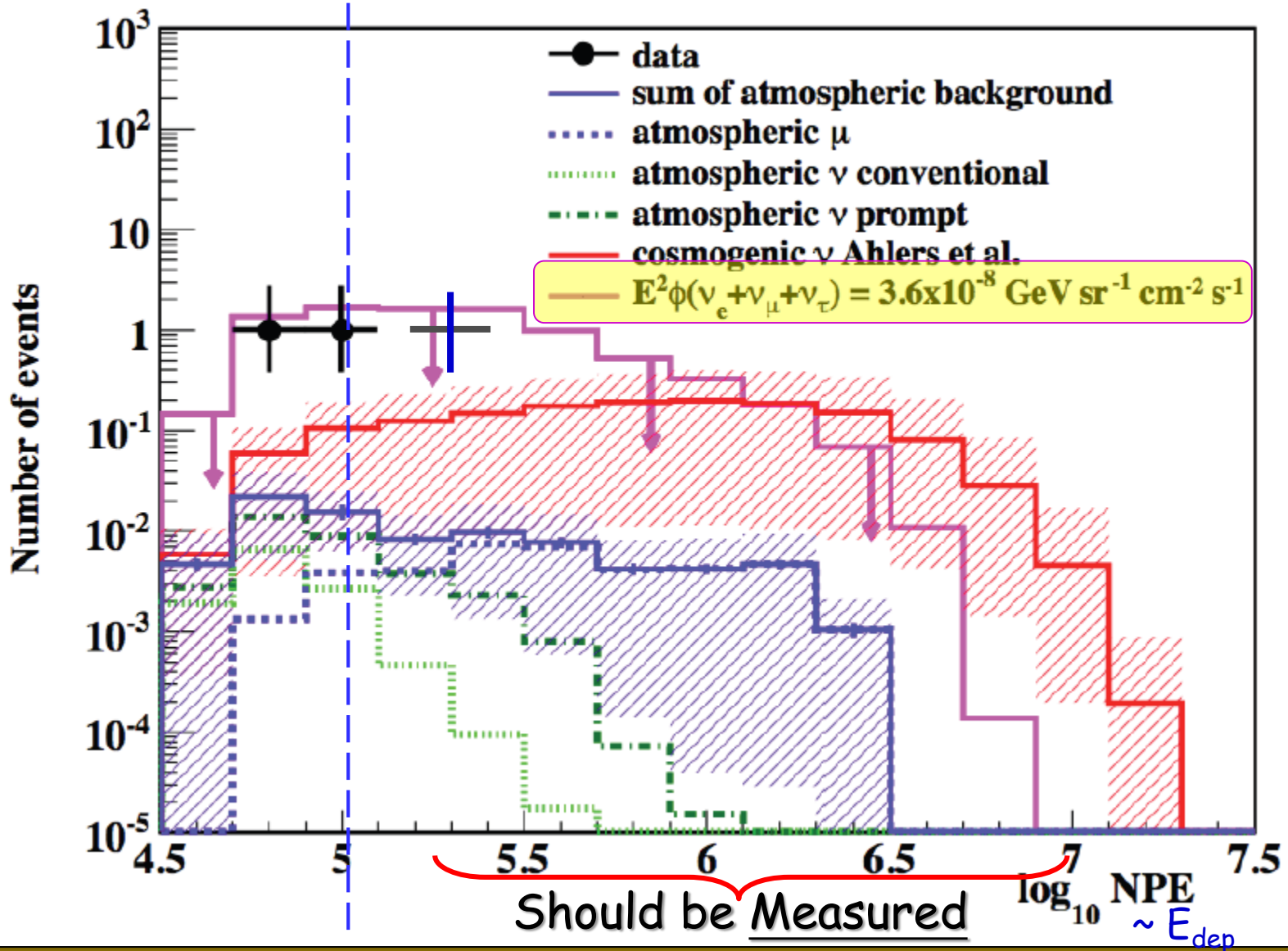


©2013 Sesame Workshop



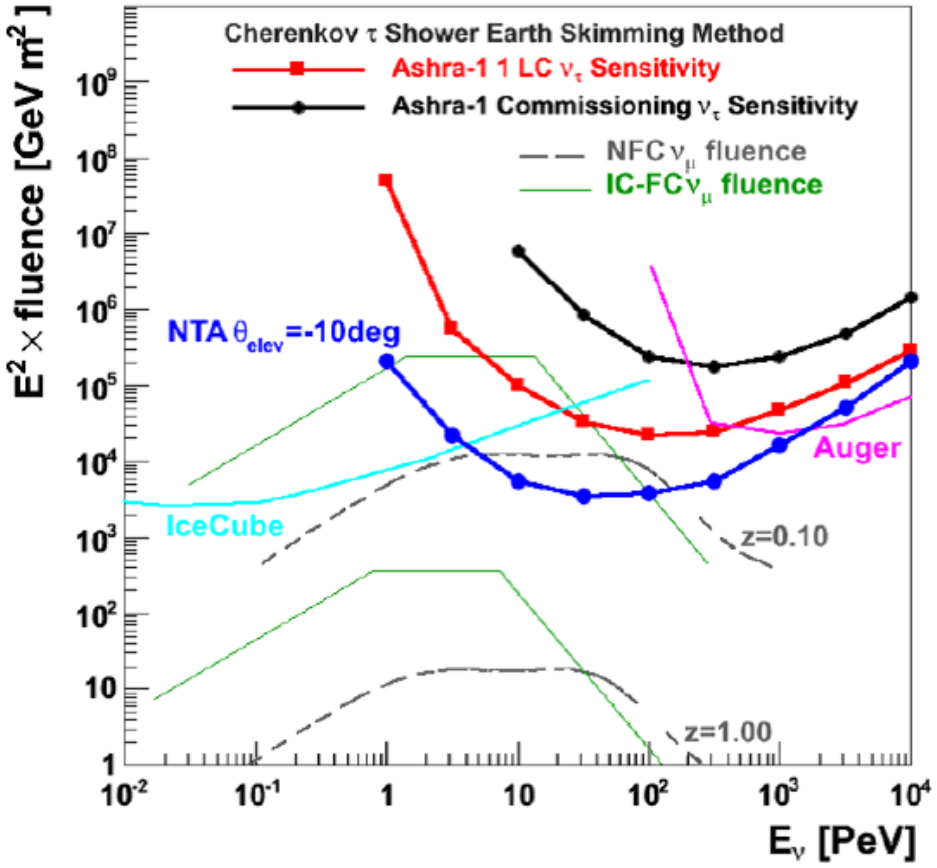
What if one had better Sensitivity and accurate Pointing Info ?

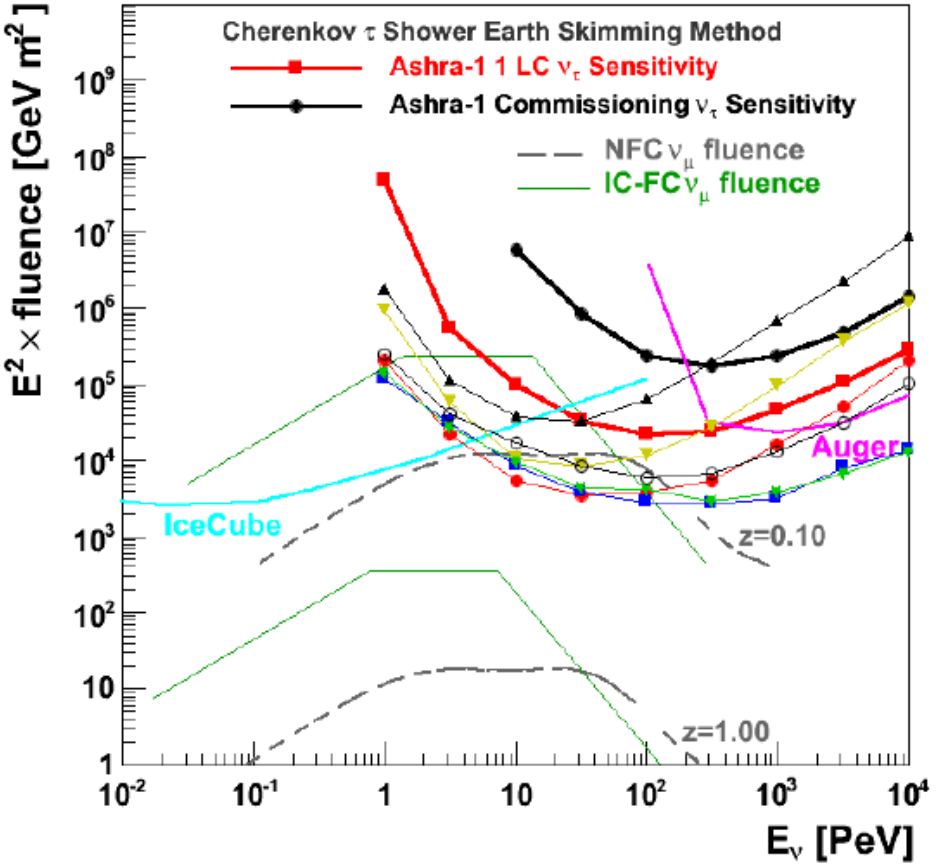
IceCube PeV Events



NTA Differential Sensitivities

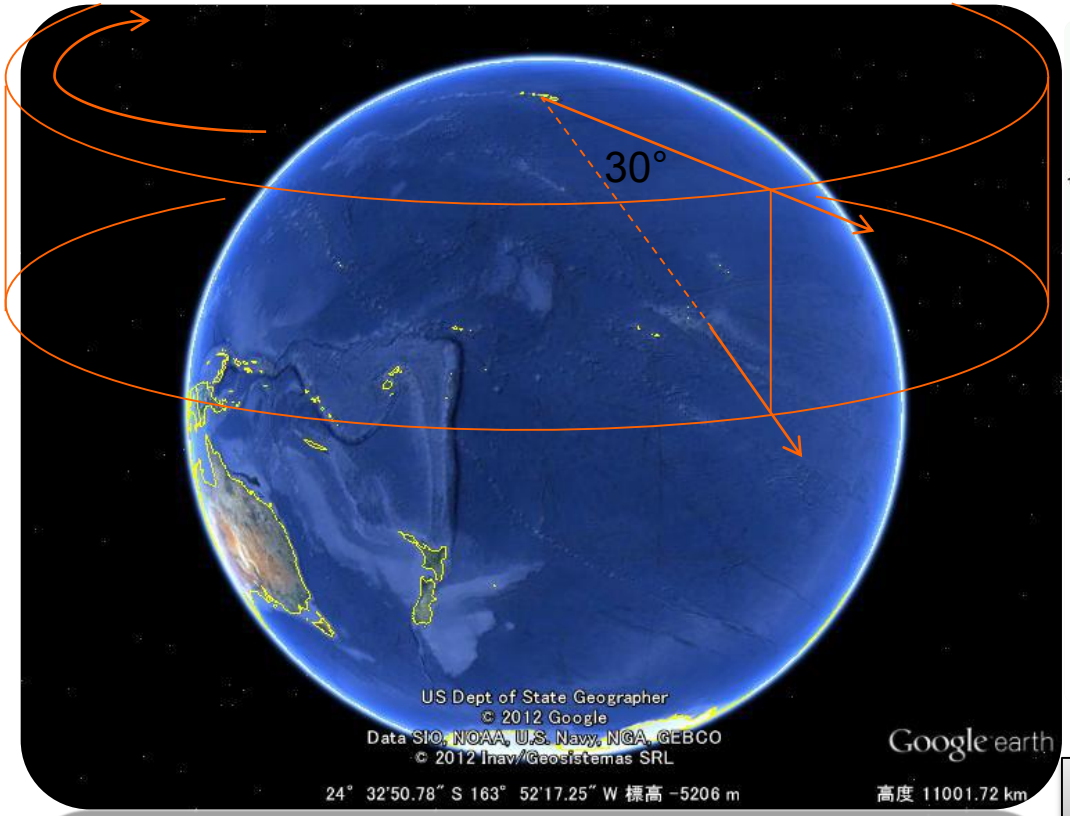
(LOI at hand)

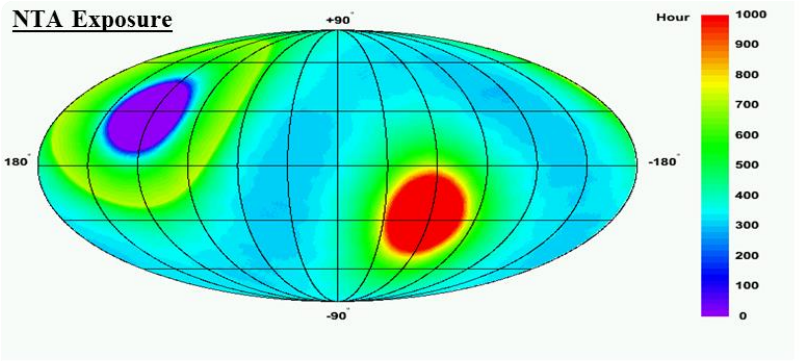


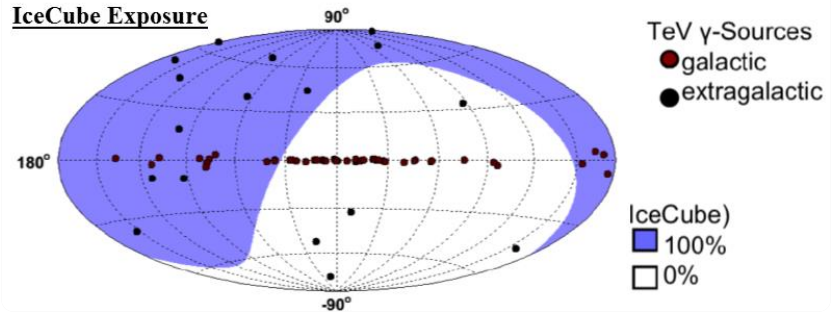


NTA Survey Depth: z ~ 0.15 (2 Glyr) for GRBν flux (Hümmer et al., 2012)

NTA ν_τ Survey Performance



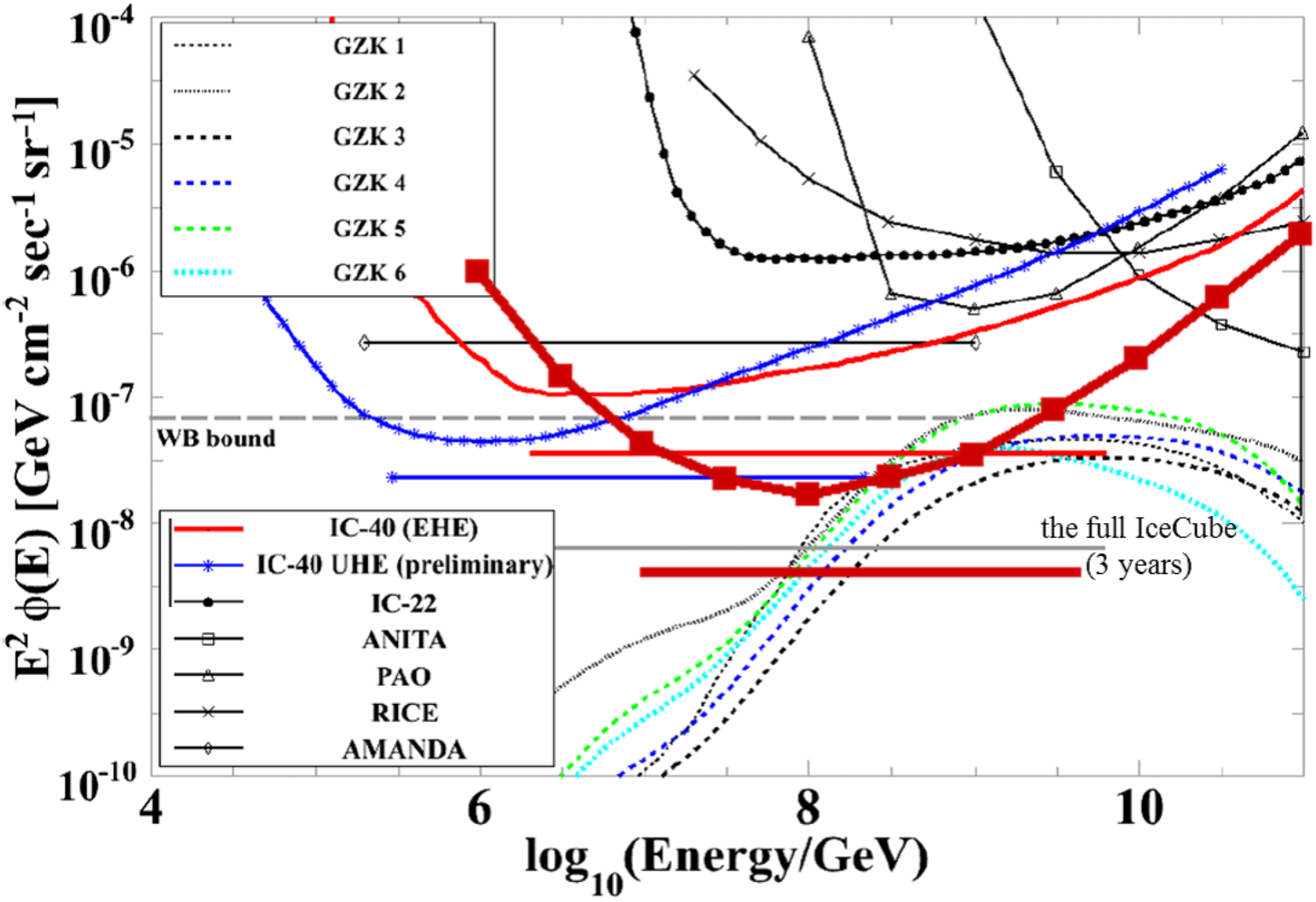




NTA can observe
Galactic Center

- Duty 10-20% from Ashra-1
- ν pointing accuracy < 0.2°
- FOV Elevation 30° × Azimuth 360°
- For GRBν
  Survey Depth z < 0.15 (2 Glyr)

NTA Diffuse Sensitivity (3 yr)



NTA Survey Depth: z ~ 0.15 (2 Glyr) for GRBν flux (Hümmer et al., 2012)

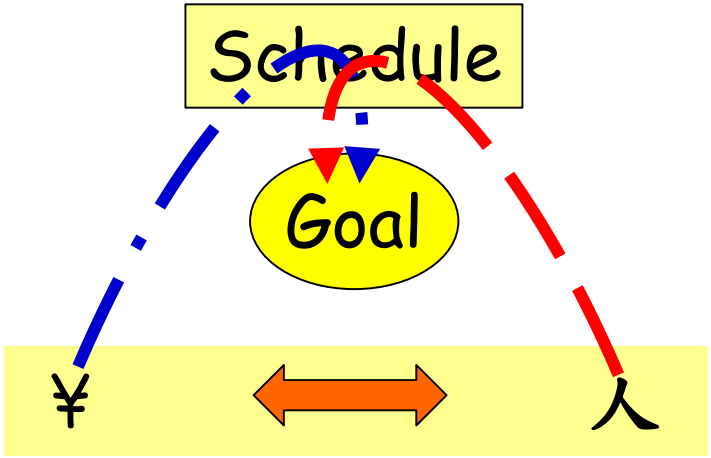
Organization

250 people, 39 institutions, 11 countries

490 people, 18 countries

NTA Projected: ≤ 10 countries

Organization



NTA Projected: ≤ 10 countries

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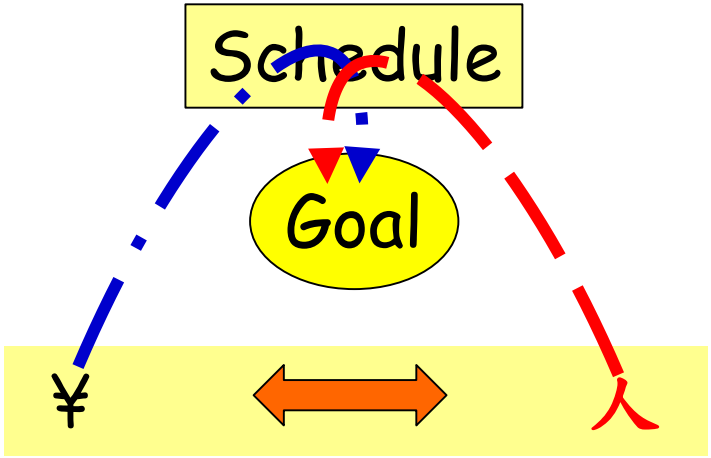
At least 30 DUs for Coverage, 100 Myen each

12 DU's per π coverage

Organization



NTA Projected: ≲ 10 countries

Collaboration Needed

Currently: IEB [3: N, T, (US)A] ⇔ LIB (Local I.B.)

Initial Meeting 11/2012

Near-term Timeline } LOI at hand (submit soon) → VHEPA2014 (Now) Call for Collaboration → Proposal/TDR "2014"

funding ~ 2 yrs; construction ~ 5 yrs

use Ashra-1 for test/sci

Conclusion

Neutrino Telescope Array (NTA)

Aim/Scientific Goal

Clear Discovery and Identification of
Nonthermal Hadronic Processes in the Universe,
be it Galactic, Extragalatic, or Cosmogenic.

Help spread the word.

Collaboration Needed

Collaborators Welcome !!

send mail to wshou@phys.ntu.edu.tw
if interested to join mailing list