Neutrino Telescope Array (NTA)

Towards Survey of Astro ν_τ Sources

このイメージは、現在表示できません。

July 25 KEK Seminar

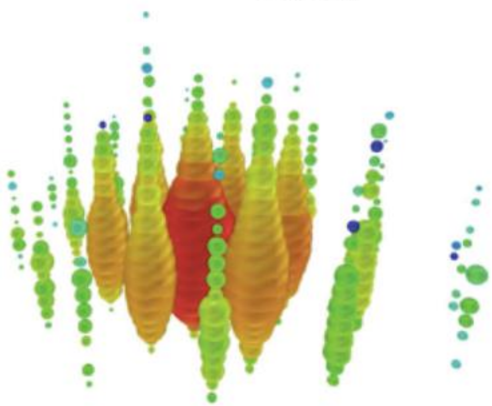
このイメージは、現在表示できません。

臺灣大學

IceCube PeV ν Events

PRL **111**, 021103 (2013)

"Ernie"

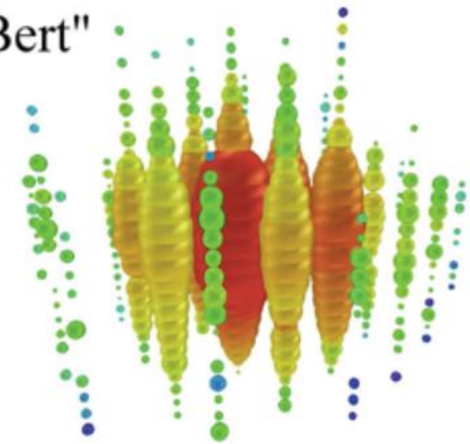


1.14±0.17 PeV

June 27, 2013

©2013 Sesame Workshop

"Bert"



1.04±0.16 PeV

Darren R. Grant - University of Alberta

What if one had better Sensitivity
and accurate Pointing Info ?

NTA

Ashra-1 + NuTel

Aim/Scientific Goal

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

NTA

I. Intro: Earth-skimming ν_τ Method

II. "My" NuTel Effort

III. Ashra-1: 1st Search for GRB ν_τ

IV. NTA: a New Collaboration

* Plan & "Size" * Performance * Organization
* Comparison: Auger/IceCube; GZK Quest

V. Conclusion: Call for Collaboration!!

Window of Opportunity

Still Survives

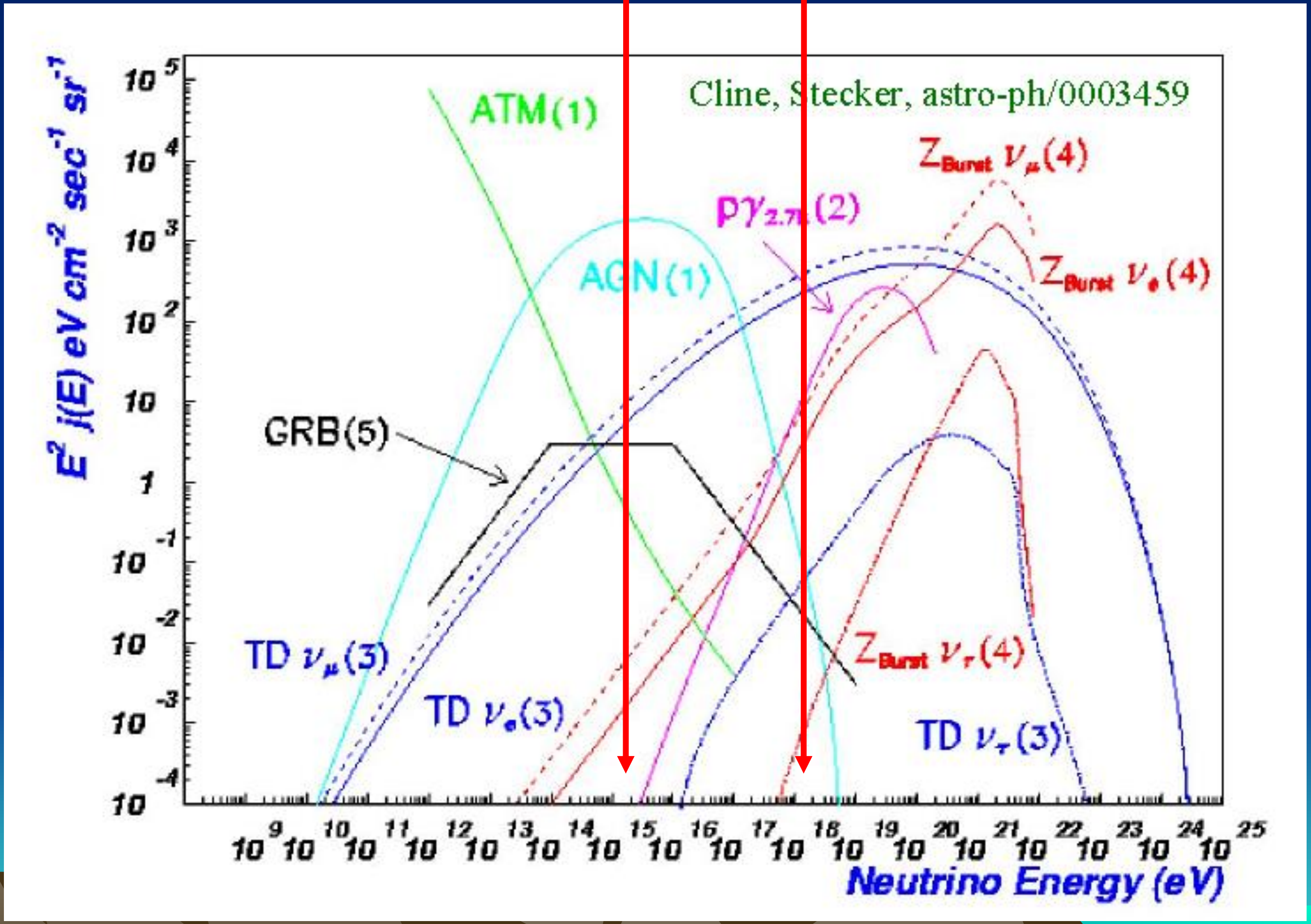
IceCube

Conventional ν Detector

?

UHECR ν Detector

Auger

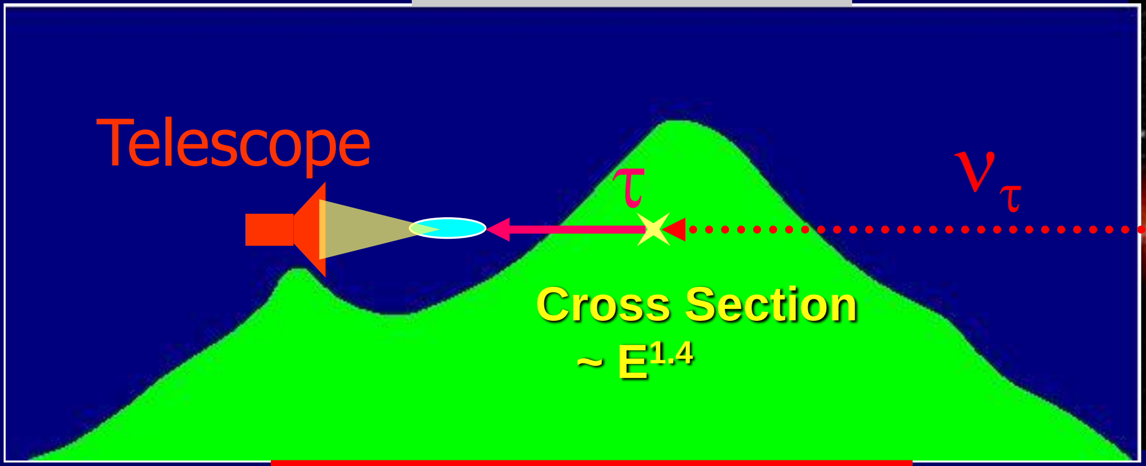


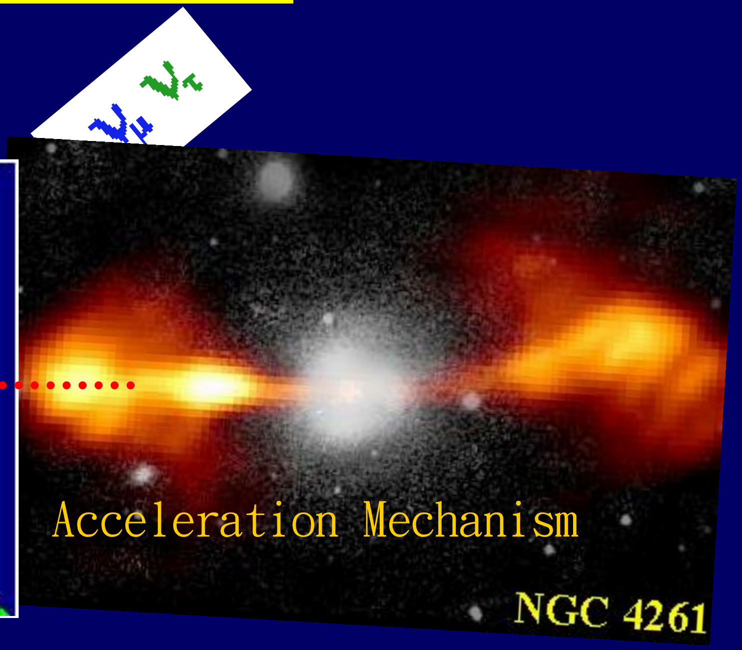
a plot I first used ~ 2002

Detection Mechanism

Earth-Skimming ν_τ Method

τ Appearance!





τ *Decay*: Air Shower
→ ns Cherenkov

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

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

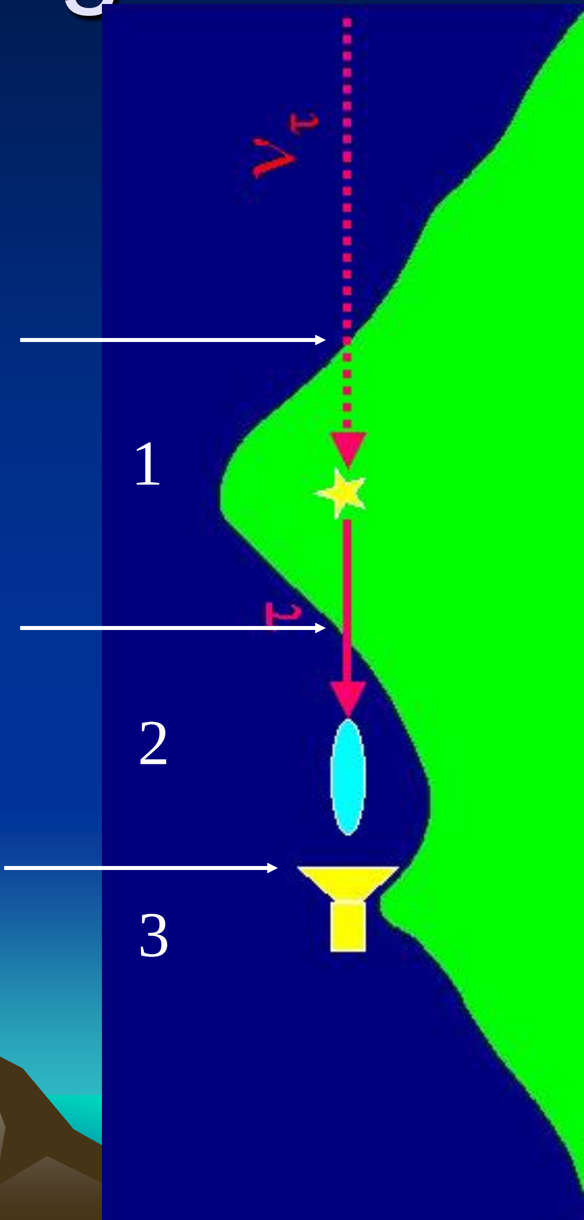
Mauna Loa provide long base line

~ 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]

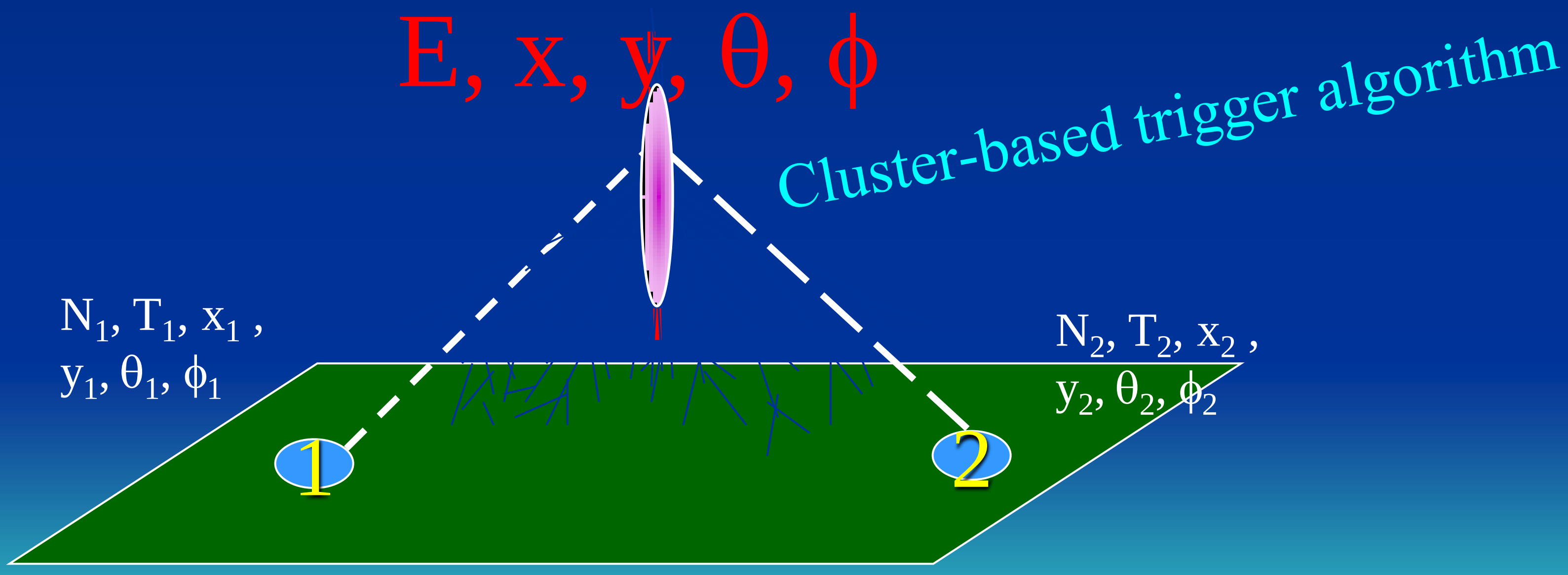
Three simulation stages

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



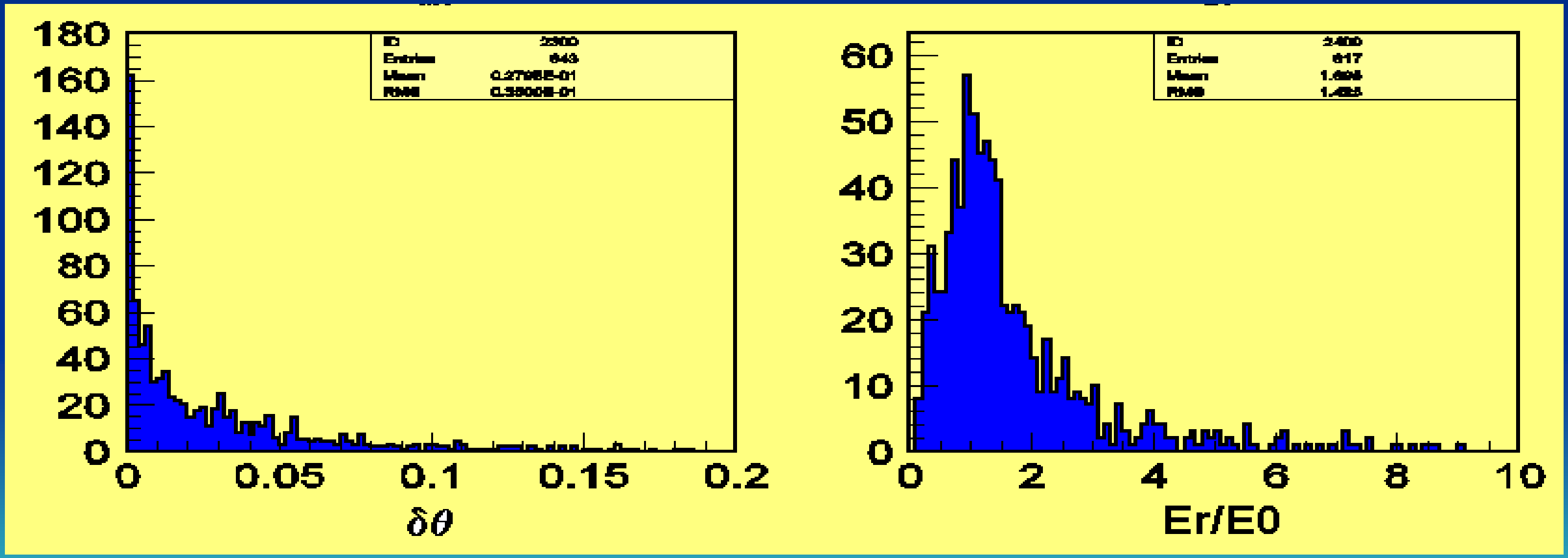
Preliminary Reconstruction

- Reconstruction: Minimize χ^2 for x, y, θ, ϕ, and E
  - <u>Two Detectors</u> Separated by ~ 100 m ("stereo")

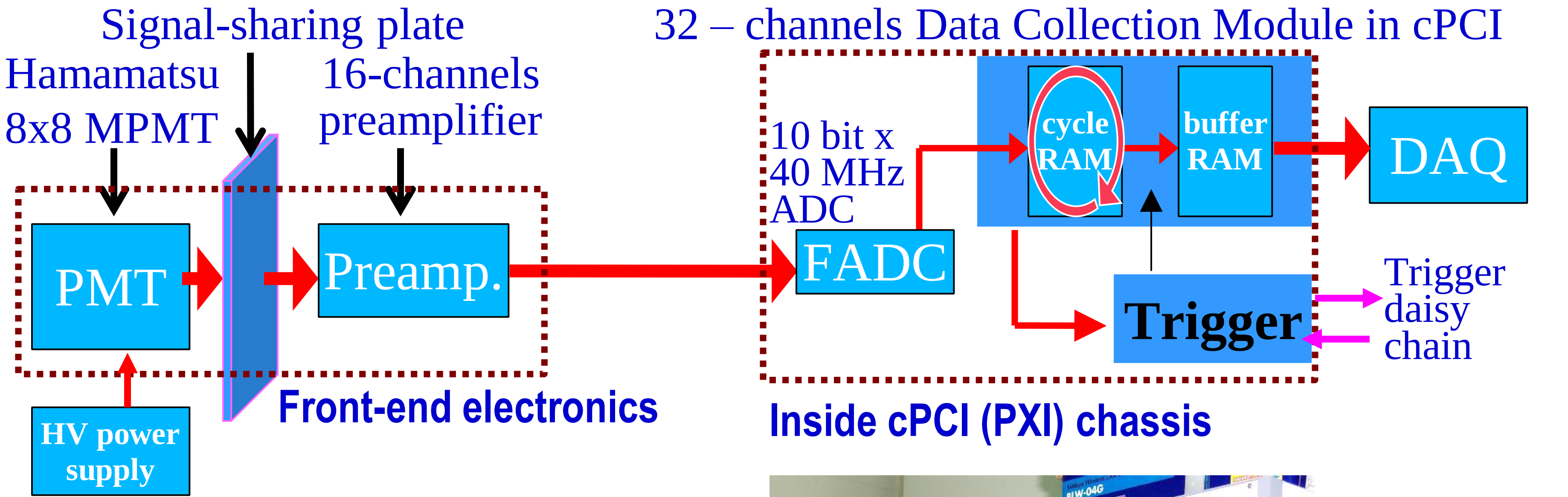


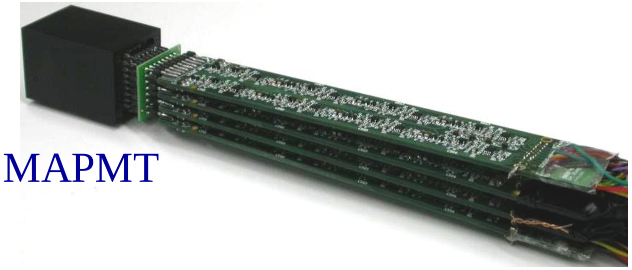
Possibility for Reconstruction

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

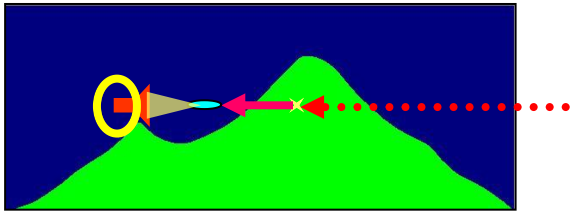


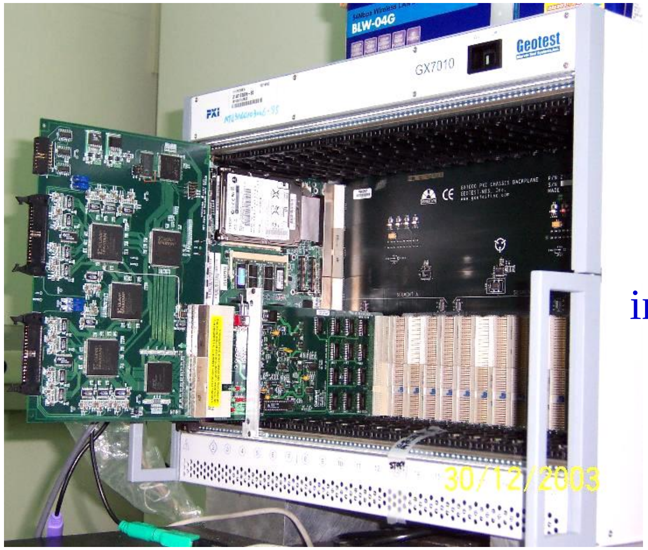
NuTel electronics (2002-2003)





MAPMT





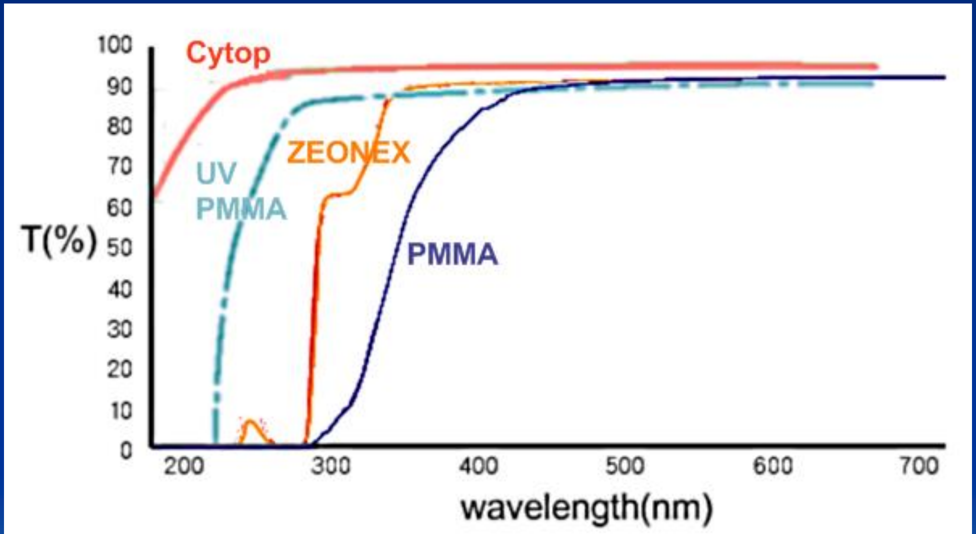
16 DCM boards
(512 channels)
inside PXI chassis

Contacts with Palermo (EUSO)

Fresnel lens system not good enough

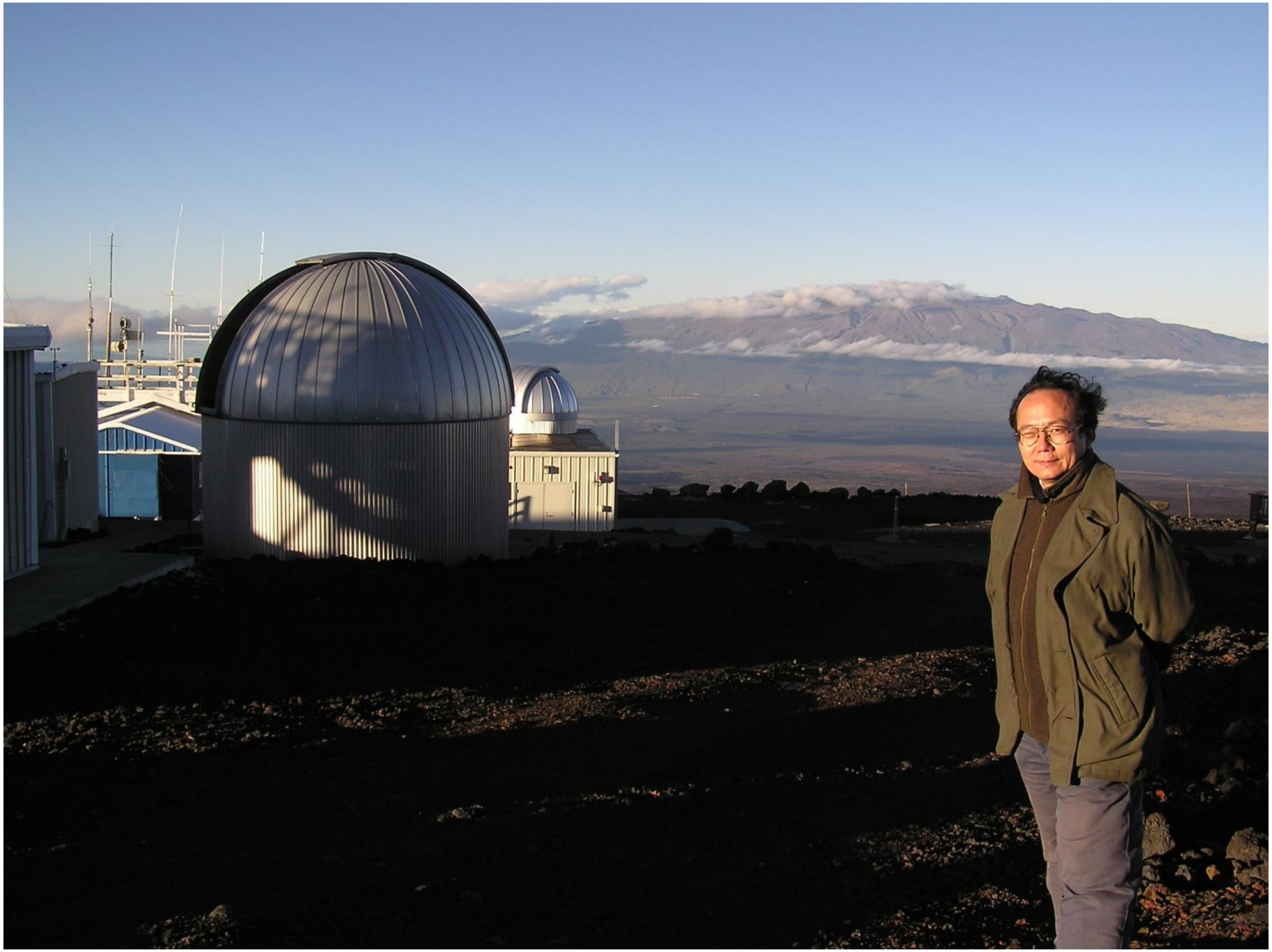
- The spot all isn't small, ~ 5mm. This is Chromatic issue.
  Spot with multi-wavelength is 2~3 times spot with single wavelength.
- The main way to lower the chromatic aberration is to use different material. However there are very few UV transparent material.
- Cytop is the best to eliminate dispersion (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.

Proposal for CosPA-1 Renewal (4 yr) filed 9/2013



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 ...

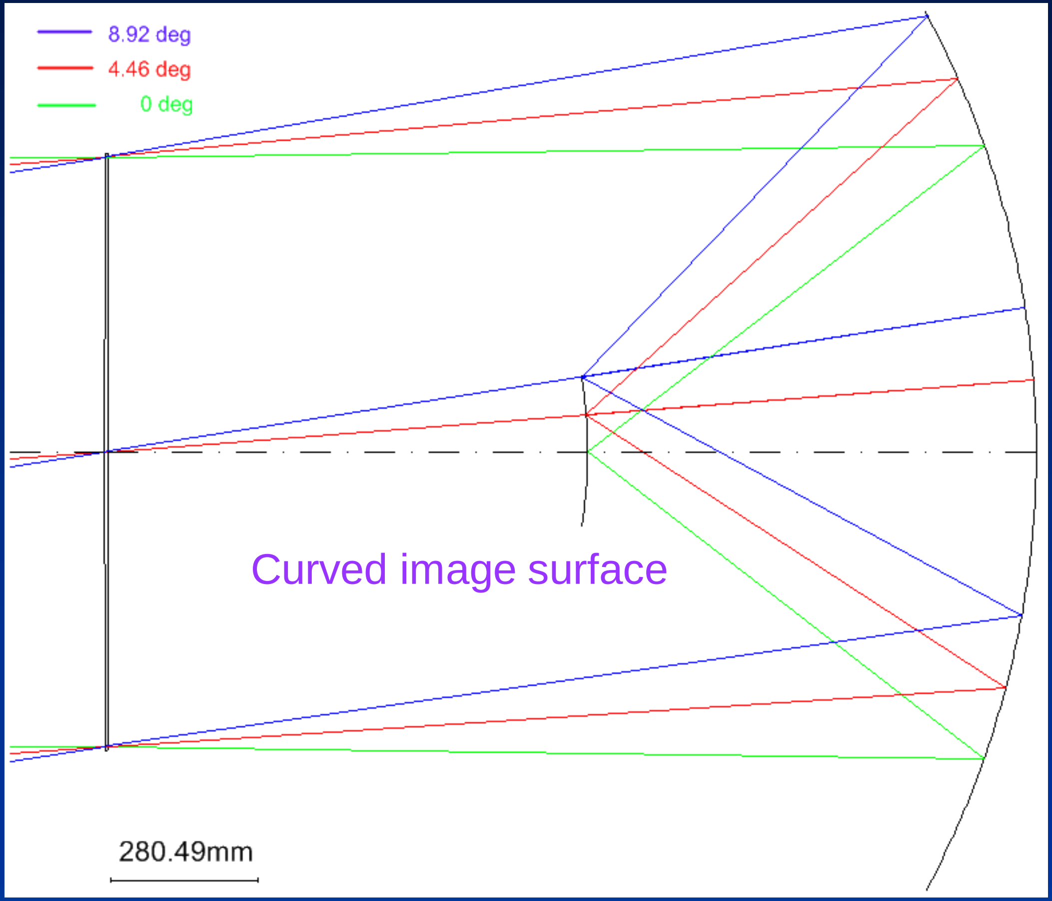
  and we could not restore it, after several tries ...

  so I continued it on a shoestring ...

Schmidt Mirror System

Aspherical Corrector Lens mainly eliminate spherical aberration.

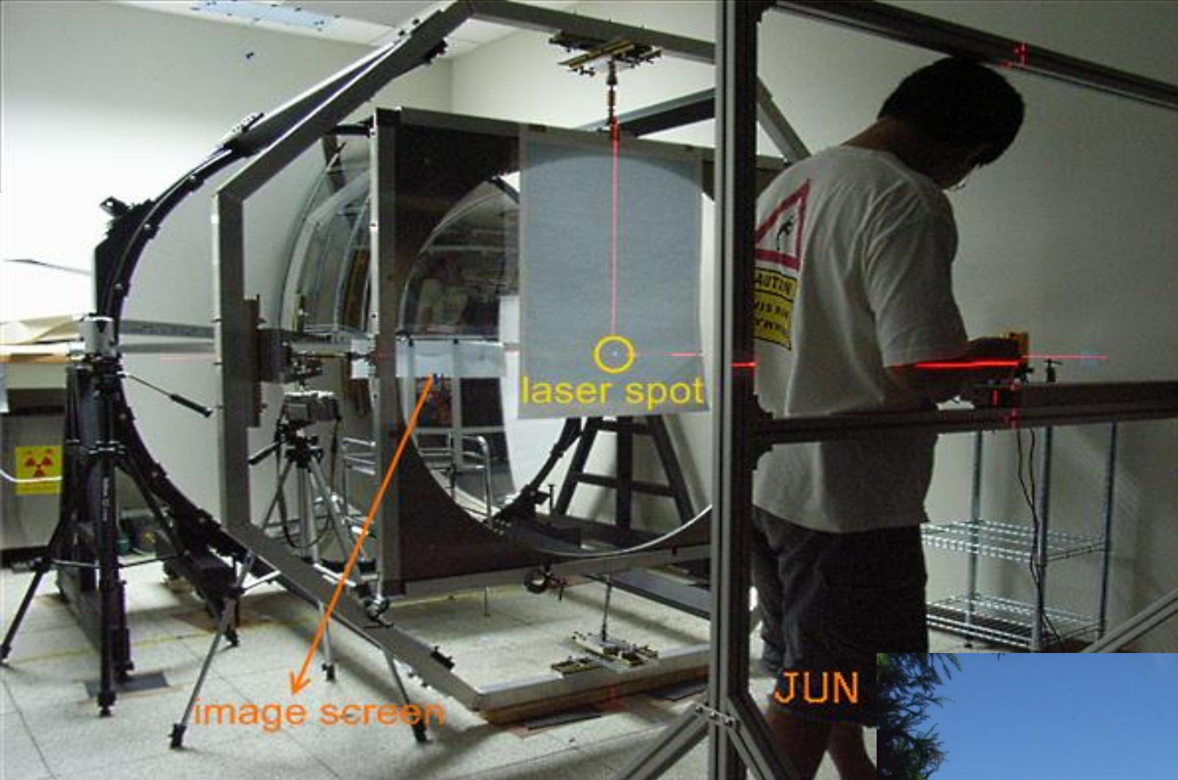
Help from KEK



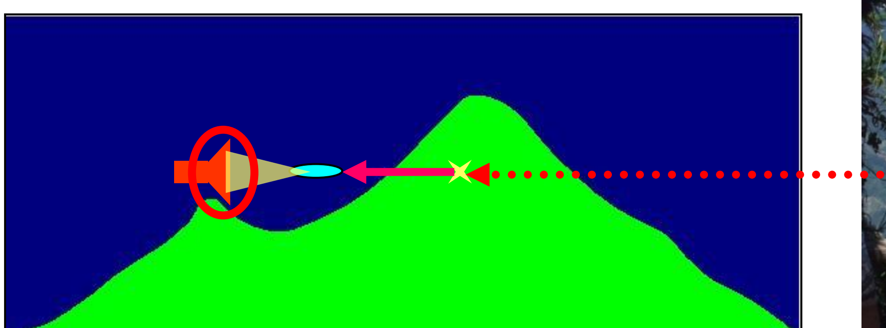
D:1.6 m, finally we made 1.8 m

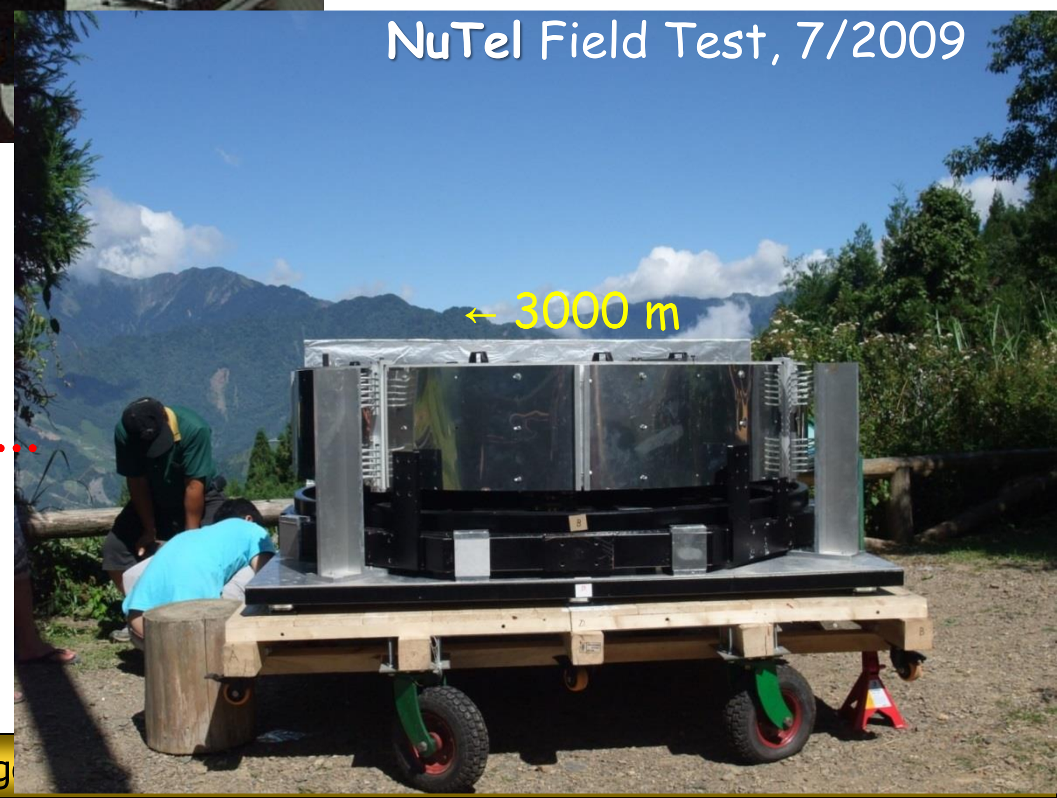
Surface #	Surface Name	Surface Type	Y Radius	Thickness	Glass	Refract Mode	Y Semi-Aperture
Object		Sphere	Infinity	Infinity		Refract	O
Stop		Asphere	14277.1987 V	8.0000	491755.573	Refract	570.0000 O
2		Sphere	Infinity	1797.4128 V		Refract	571.0183 O
3		Sphere	-1800.0000	-869.0192 V		Reflect	842.9845 O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

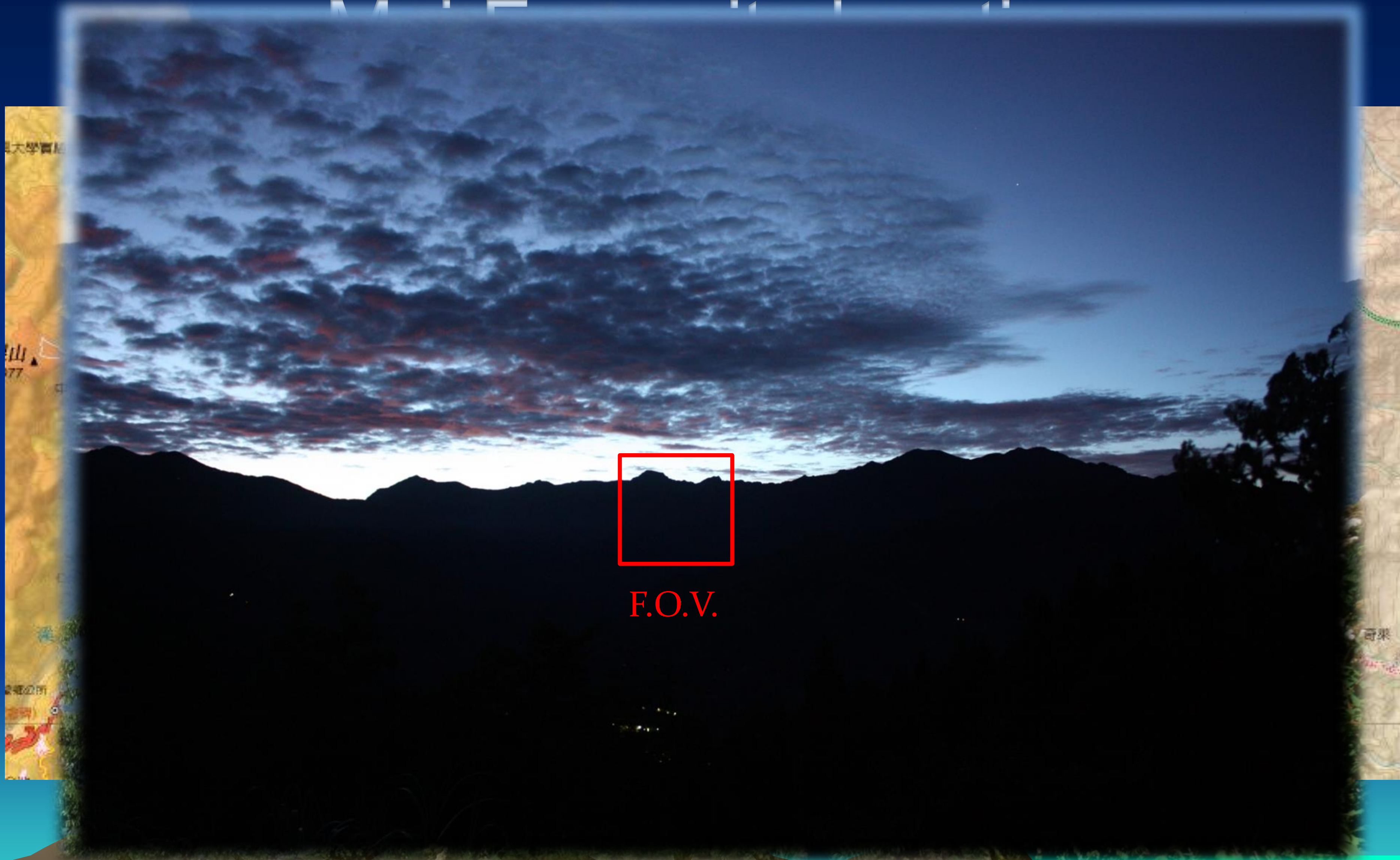
	conic const (k)	4th order	6th order	8th order
surf 1(Stop) aspherical parameters	0	-7.033e-011	-2.904e-017	-2.607e-023



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

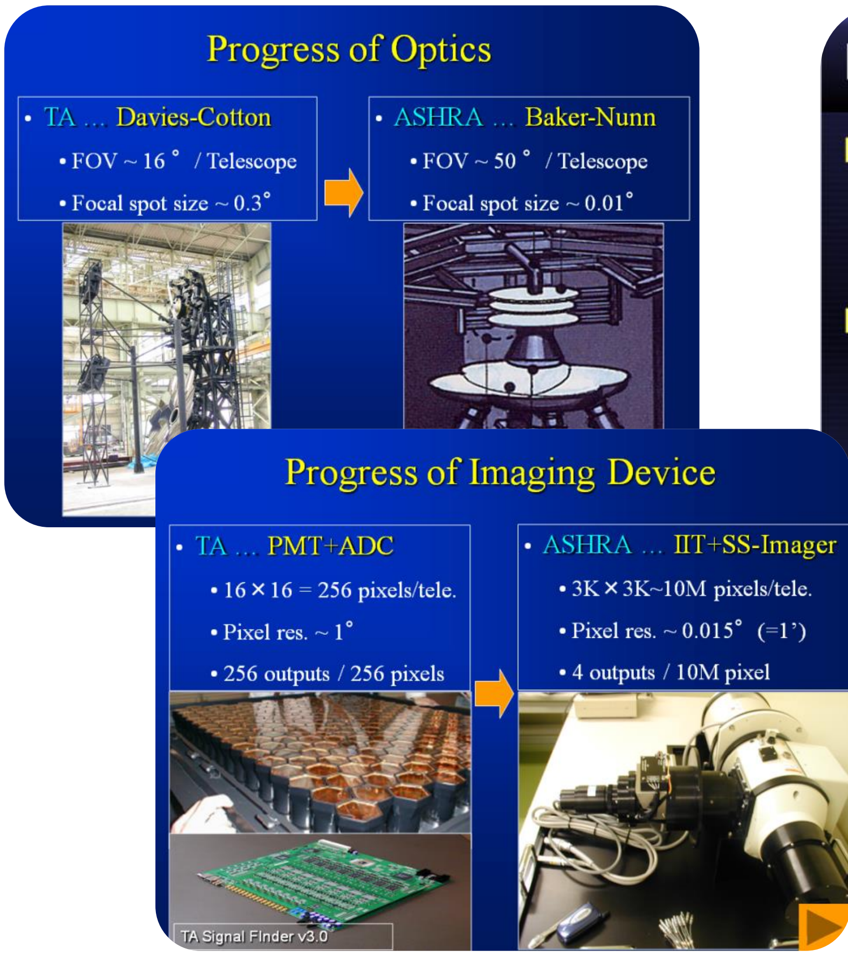
- NuTel is the first experiment *dedicated* to earth skimming for τ appearance
- PeV cosmic ν_τ rate is ~~~ 0.5 event/year~~
- ~~First set of~~ two telescopes ready
- VHECR observation in Taiwan: prototype deployment in 2009 indicates high light background at Mei-Fong
- We learned challenge of mountain operation

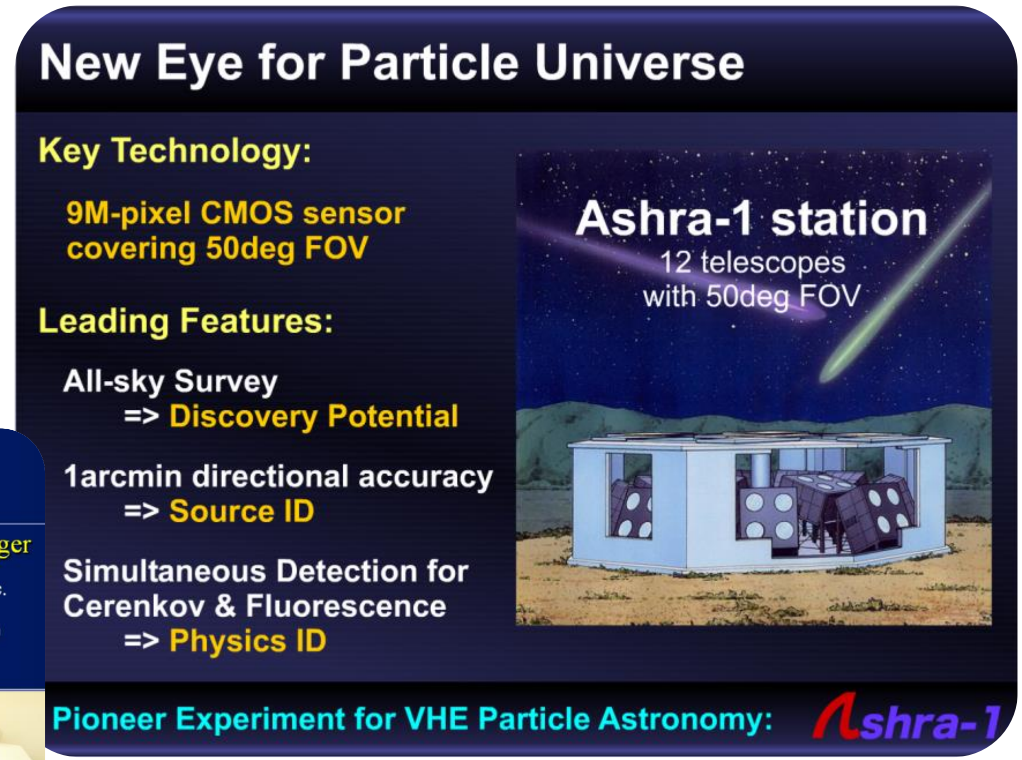
  → Tried pair up with CRTNT (曹臻) … they evolved …
- Synergy w/ Ashra-1 (reconnect 9/2012) → (Ashra) NTA

Ashra-1

- Ashra-1 succeeded in demonstrating power of <u>Earth-Skimming ν_τ Method</u>

(Courtesy Makoto Sasaki)



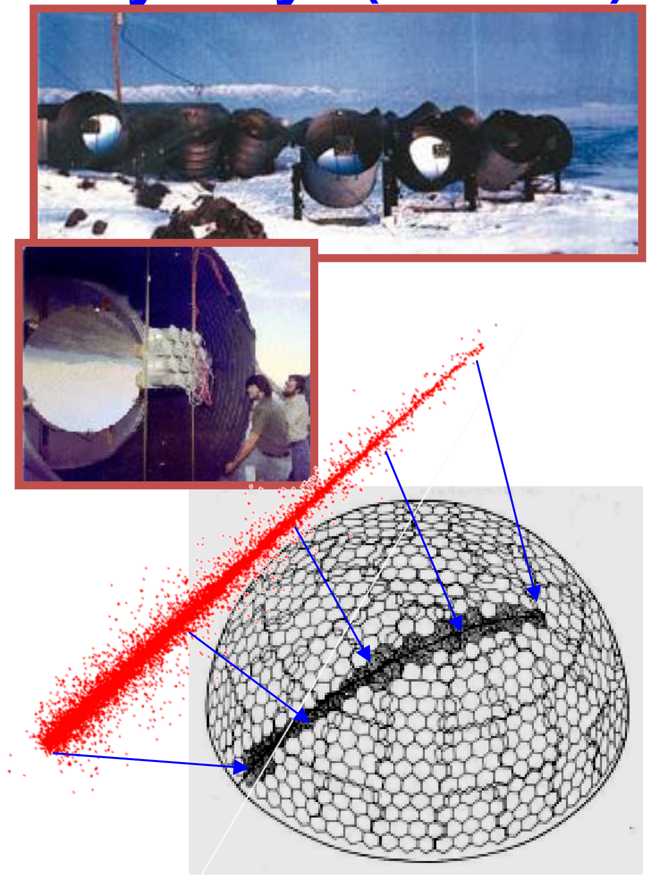


[Sasaki's Presentation @ <u>CosPA 2003-NTU</u>]

Aim now for NTA

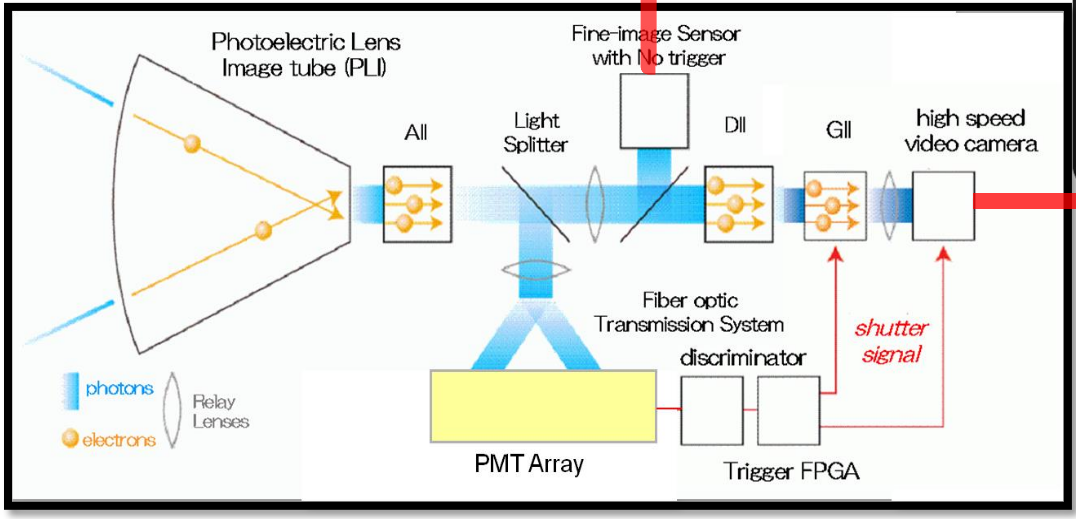
Optical Air-shower Detector

Progress of Resolution × FOV

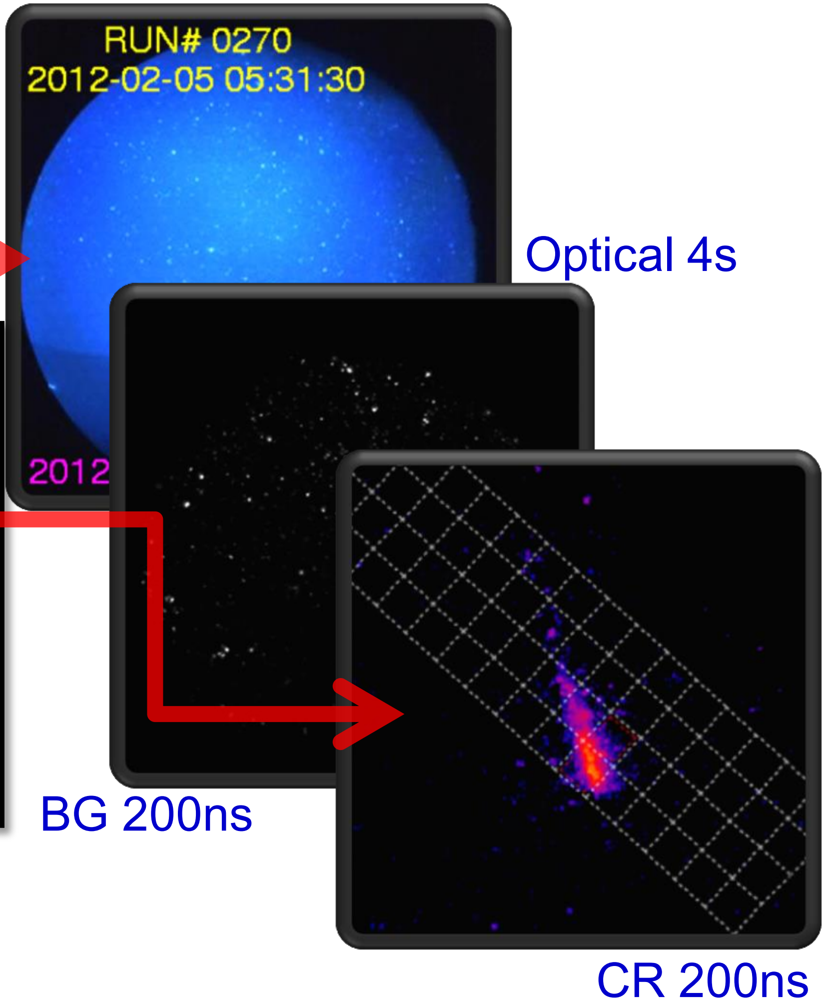
Fly's Eye (1981-1993)	HiRes (1994-2006)	Ashra-1
		
		
4deg/pix × All-sky	1deg/pix × 28deg	1.2min/pix × All-sky
PMT	PMT	**Image Tube＋CMOS**

demonstrated

Same Fine Image to Multiple Triggers



Photoelectric Image Pipeline (PIP)

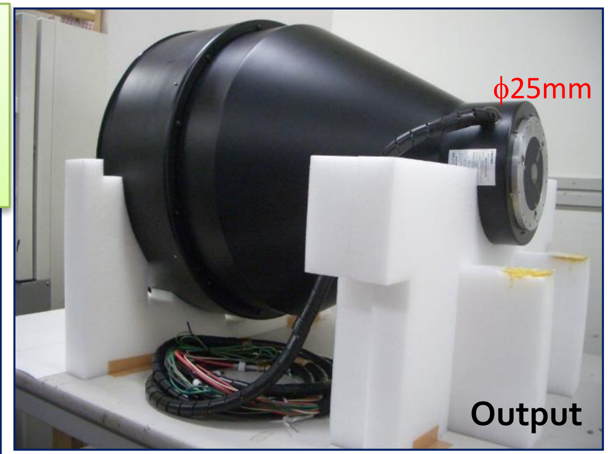


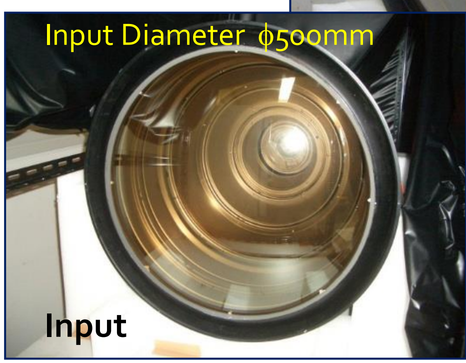
Multi-Messenger Approach with
One Detector System

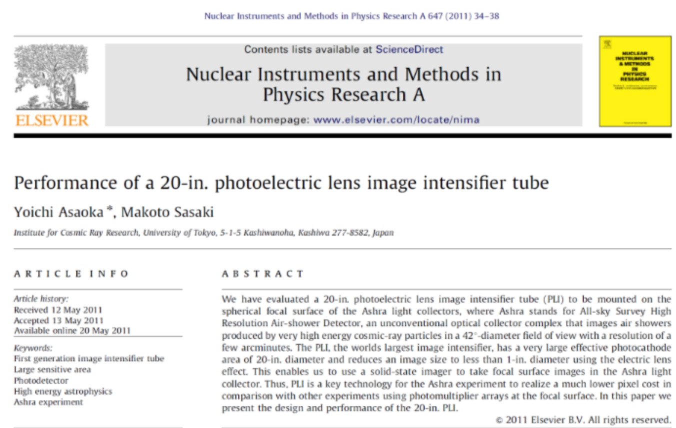
1st imaging air-shower with self-triggered I.I.

20” Photoelectric Lens Imaging Tube (PLI)

Large: World largest I.I.
Fine: FWHM = 40-60μm @output window
Stable: No performance degradation for 3.5 years







Nuclear Instruments and Methods in Physics Research A 647 (2011) 34–38

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journal homepage: www.elsevier.com/locate/nima

ELSEVIER

Performance of a 20-in. photoelectric lens image intensifier tube

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ARTICLE INFO

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Large sensitive area
Photodetector
High energy astrophysics
Ashra experiment

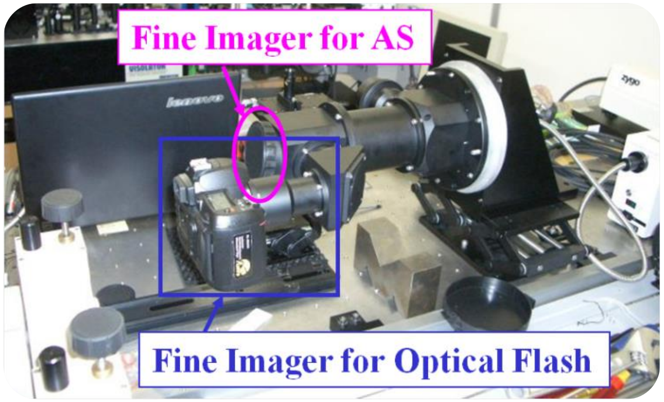
ABSTRACT

We have evaluated a 20-in. photoelectric lens image intensifier tube (PLI) to be mounted on the spherical focal surface of the Ashra light collectors, where Ashra stands for All-sky Survey High Resolution Air-shower Detector, an unconventional optical collector complex that images air showers produced by very high energy cosmic-ray particles in a 42°-diameter field of view with a resolution of a few arcminutes. The PLI, the worlds largest image intensifier, has a very large effective photocathode area of 20-in. diameter and reduces an image size to less than 1-in. diameter using the electric lens effect. This enables us to use a solid-state imager to take focal surface images in the Ashra light collector. Thus, PLI is a key technology for the Ashra experiment to realize a much lower pixel cost in comparison with other experiments using photomultiplier arrays at the focal surface. In this paper we present the design and performance of the 20-in. PLI.

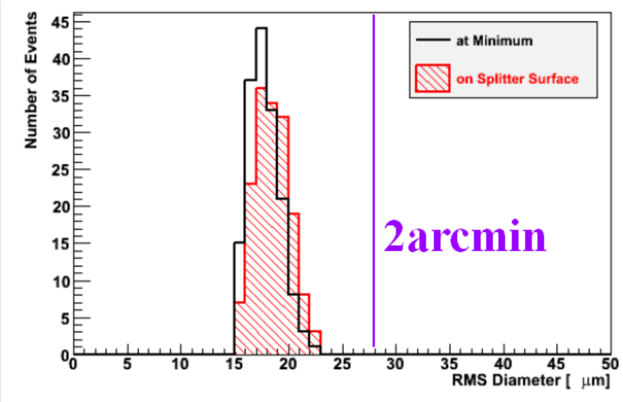
Y.Asaoka, M.Sasaki NIMA 647 (2011) 34

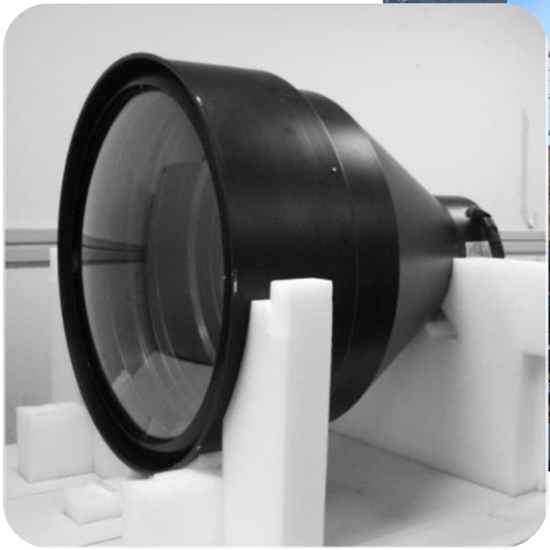
Improving QE and Precision

PIP & PLI Installation @ Mauna Loa



Test of PIP

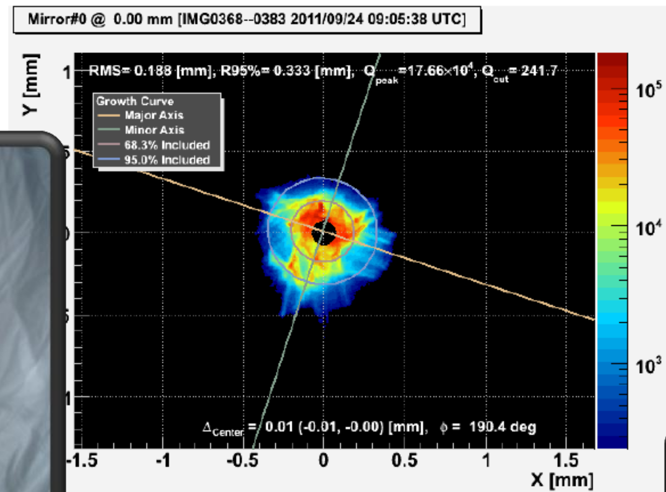




Installation of PLIs

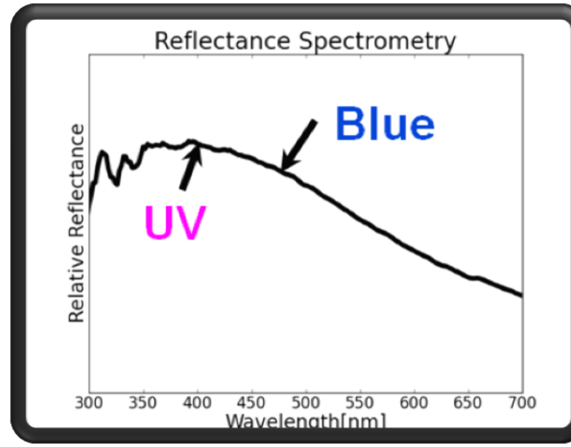
20-in Photoelectric Lens Image Intensifier (PLI)
[Y. Asaoka & M. Sasaki, NIM, A647 (2011) 34]

Segment Mirror Installation @ Mauna Loa

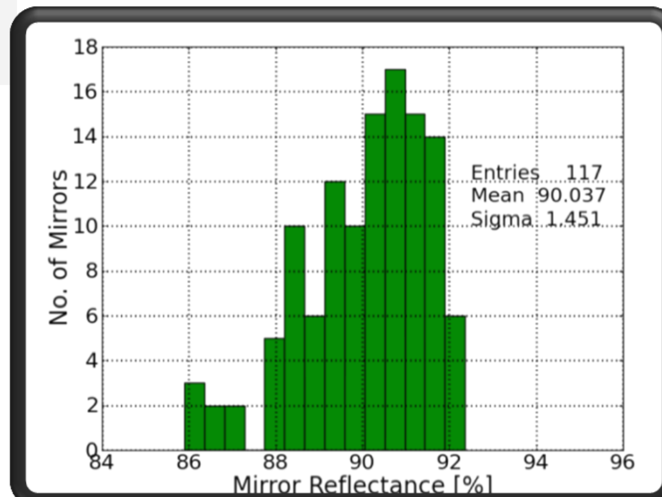


Mount Seg. Mirrors

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

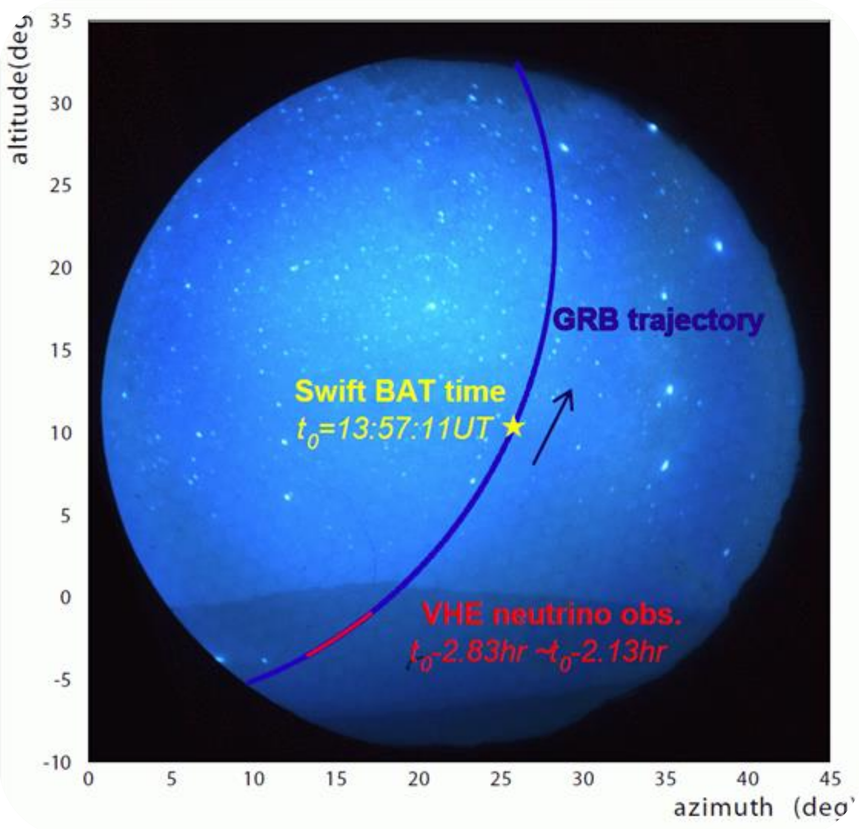
77% mono, 27% stereo

2~3 arcmin image

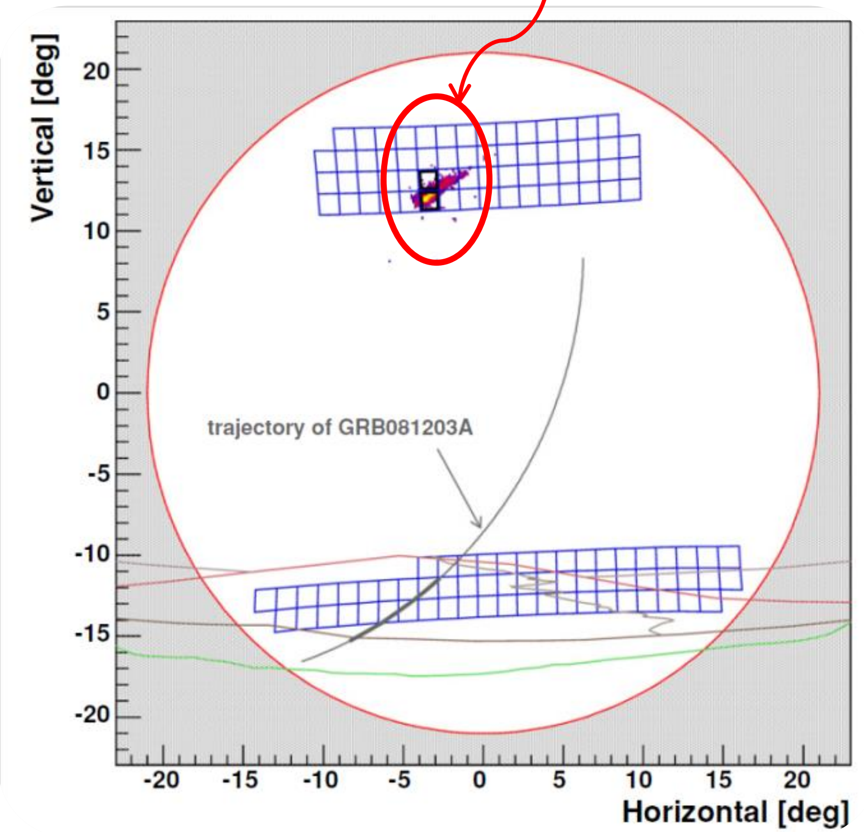
Nice Coverage and Precision as Particle Monitor

Ashra-1: 1^{st} 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

Y. AITA[1], T. AOKI[1], Y. ASAOKA[1], T. CHONAN[1], M. JOBASHI[1], M. MASUDA[1], Y. MORIMOTO[1], K. NODA[1], M. SASAKI[1], J. ASOH[2], N. ISHIKAWA[2], S. OGAWA[2], J. G. LEARNED[3], S. MATSUNO[3], S. OLSEN[3], P.-M. BINDER[4], J. HAMILTON[4], N. SUGIYAMA[5], AND Y. WATANABE[6]

(ASHRA-1 COLLABORATION)

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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.

The Clear Discovery and Identification of Non-thermal Hadronic Process in the Universe

Air Shower Imaging Detector for Neutrinos

Neutrino Telescope Array Letter of Intent:

A Large Array of High Resolution Imaging Atmospheric Cherenkov and Fluorescence Detectors for Survey of Air Showers from Cosmic Tau Neutrinos in the PeV-EeV Energy Range

Makoto Sasaki[1], George Wei-Shu Hou[2]

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[*] *E-mail: sasakim@icrr.u-tokyo.ac.jp, wshou@phys.ntu.edu.tw*

LoI at Hand

VHEPA 2014: Start forming collab. → VHEPA 2015: Design & Proposal

NTA Site Plan

(LOI at Hand)

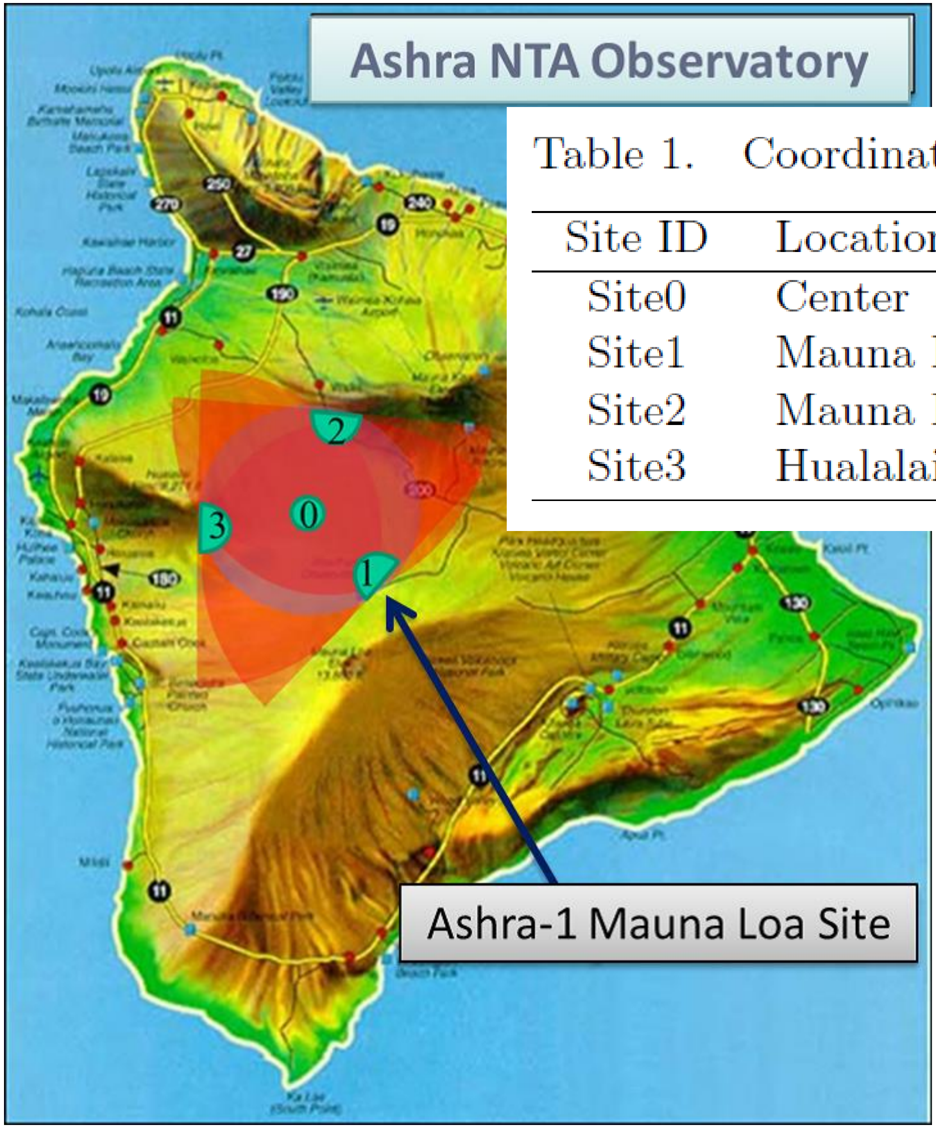
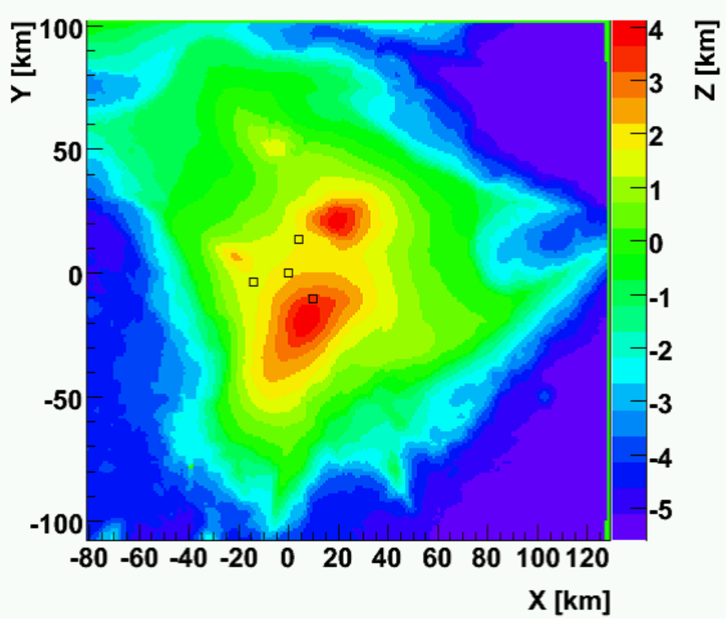
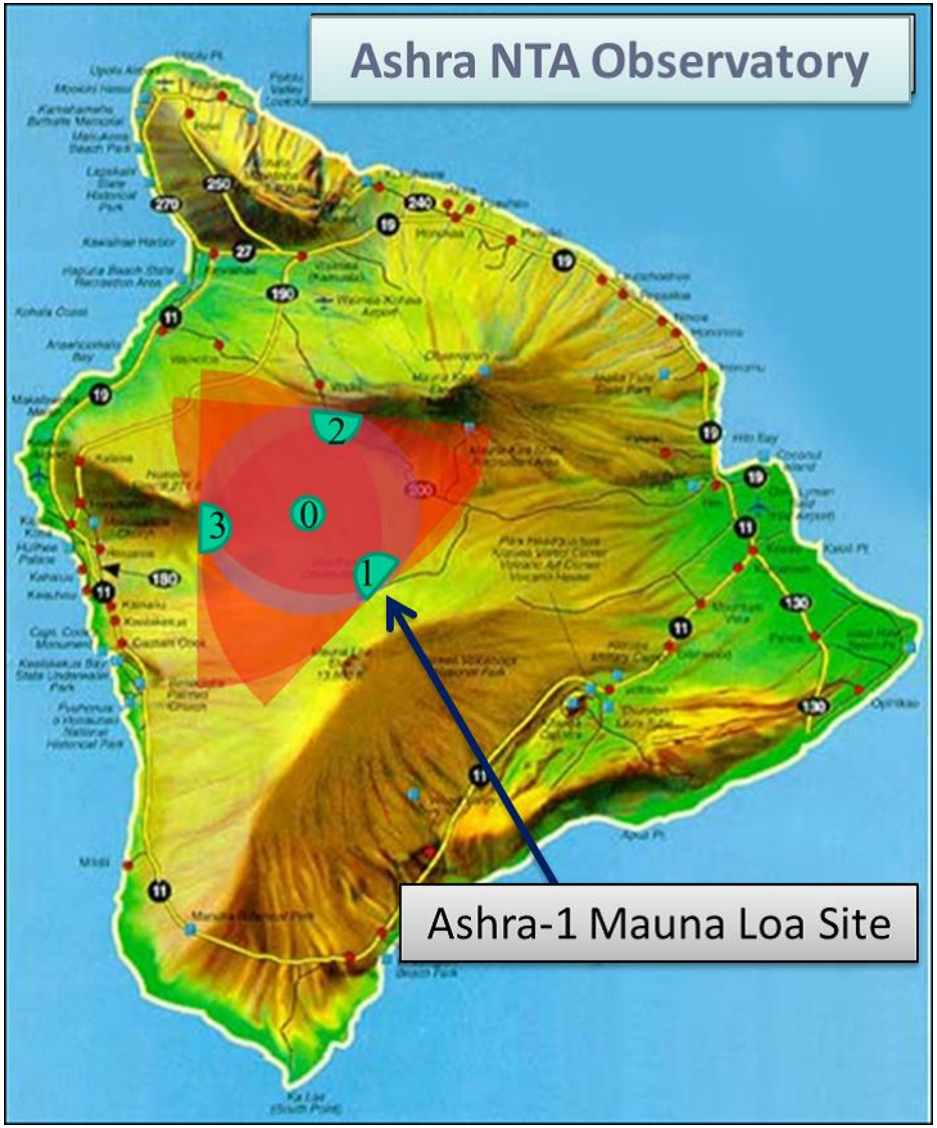
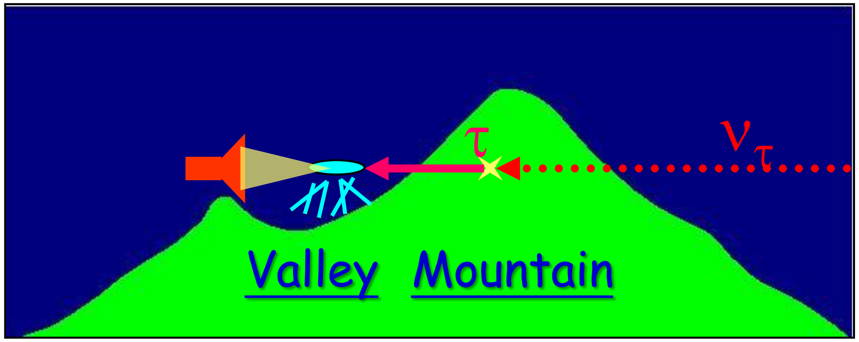


Table 1. Coordinates and FOV coverage of the Ashra NTA sites.

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	$\pi/2$





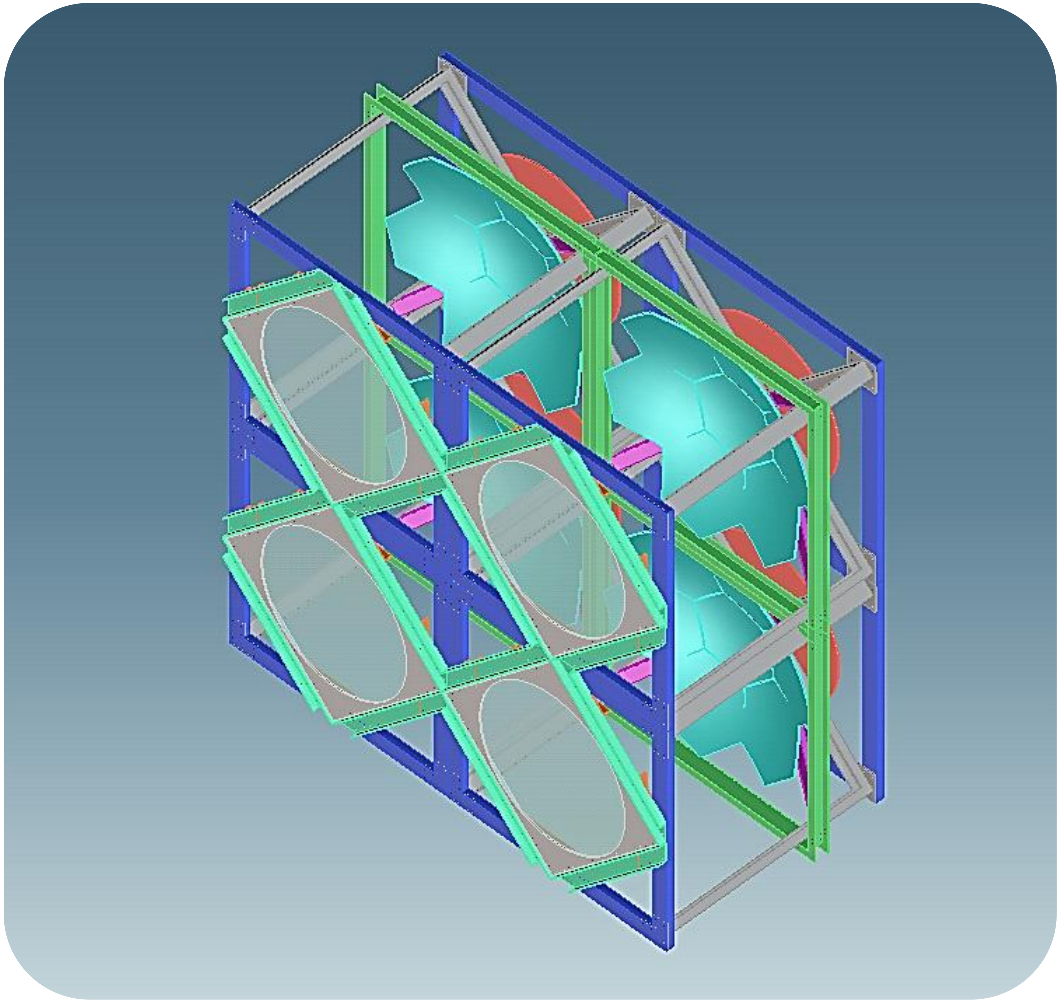


Separation of
Conversion vs **Shower**

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

→ Need Collaboration

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
$\Rightarrow$ Effective pupil size = ϕ3m

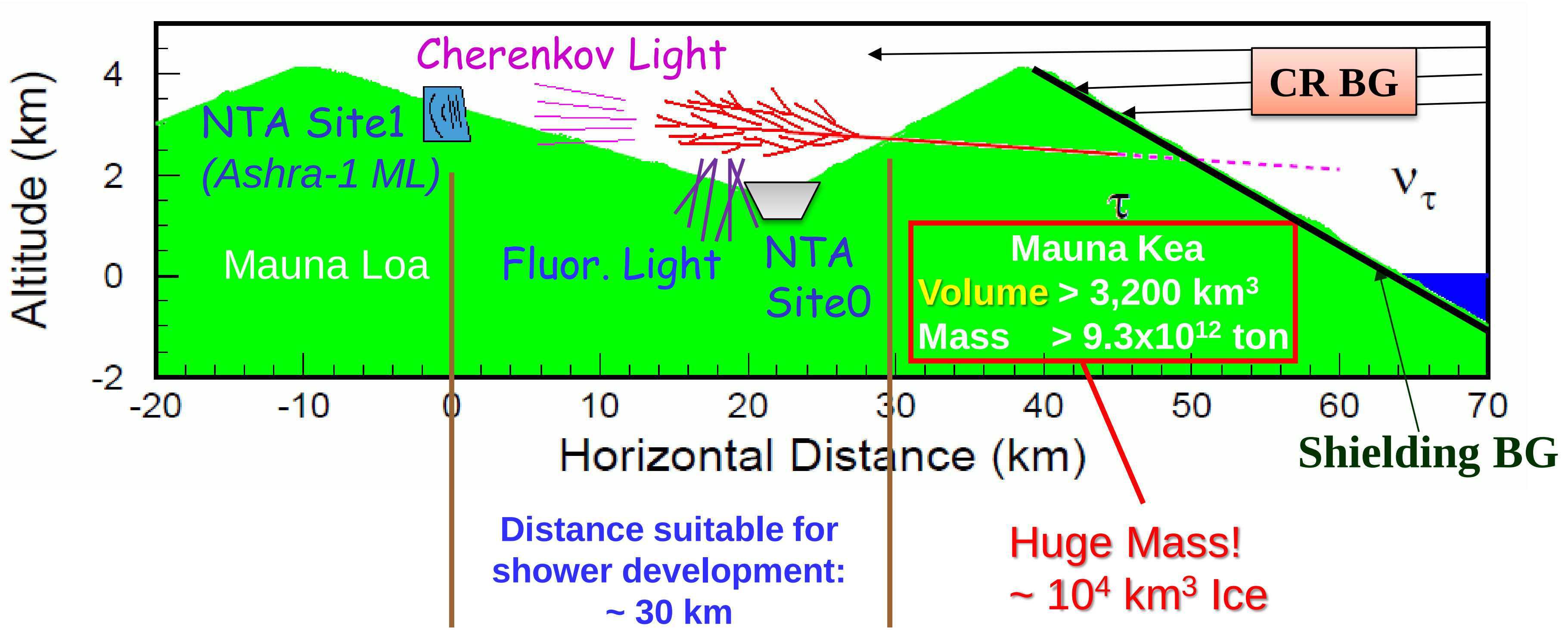
Need at least 30 DU's for Coverage

Need Collaboration

$\Rightarrow$ Concept:
Ashra-1 x 1.5 scaled-up + same trigger & readout

Earth-skimming τ Shower Imaging Method

reminder



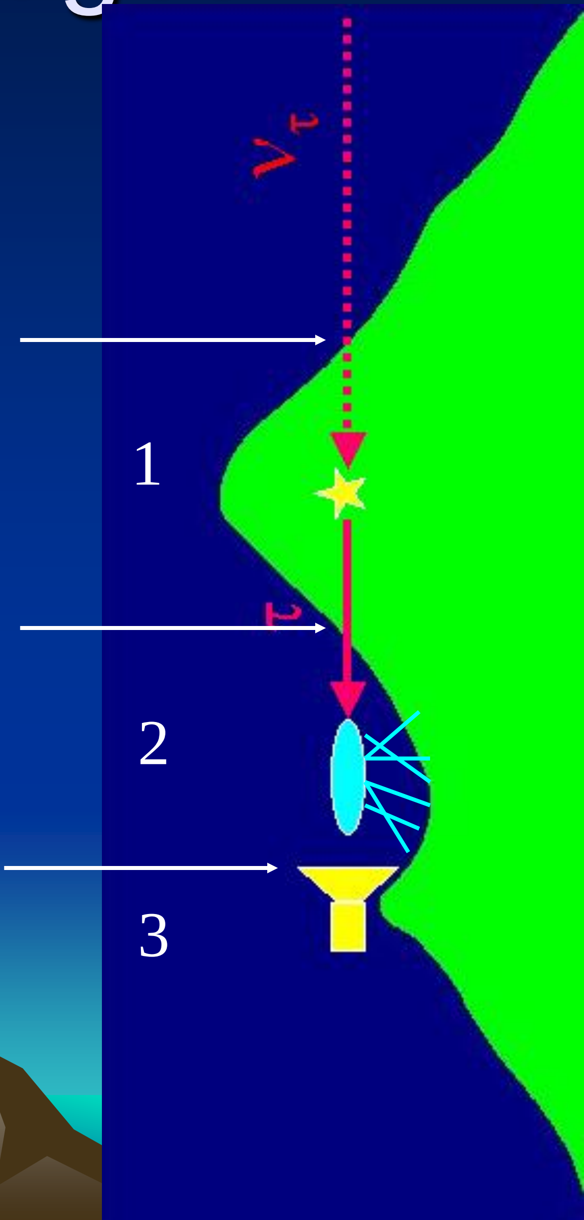
Ashra-1 already demonstrated this method !

ApJ, 736 (2011) L12

Three simulation stages

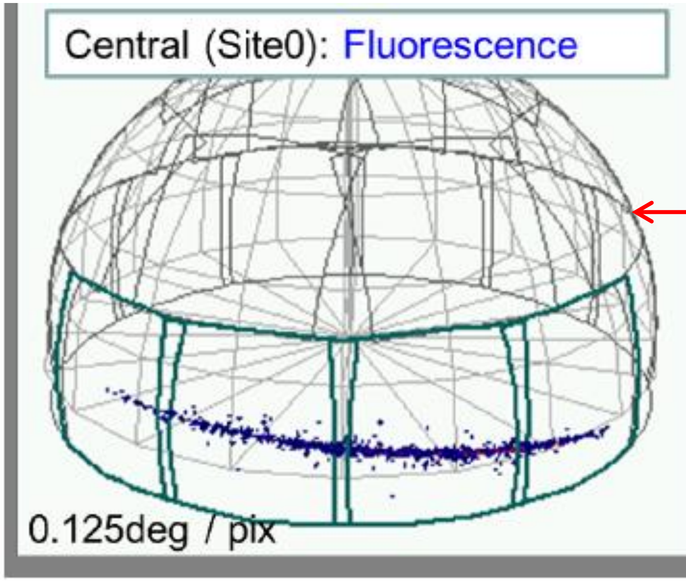
1. Mountain simulation: $\nu_\tau \rightarrow \tau$
   ν+N cross-section
   – inelasticity
   – energy loss of tau
2. Air shower simulation:
   $\tau \rightarrow$ Cherenkov photons / fluorescence
   – τ decay mode
   – CORSIKA detailed air shower simulation
     vs. fast simulation
3. Detector performance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

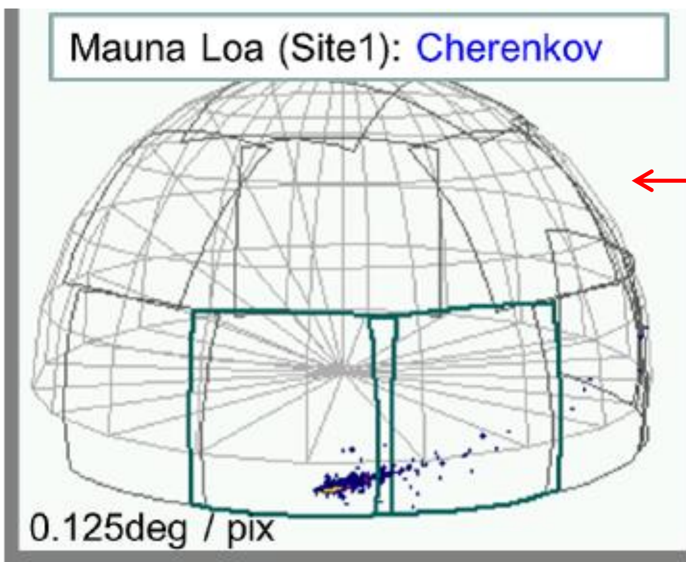
sophisticated "Ashra-1" det.



LOI at hand (submit soon)

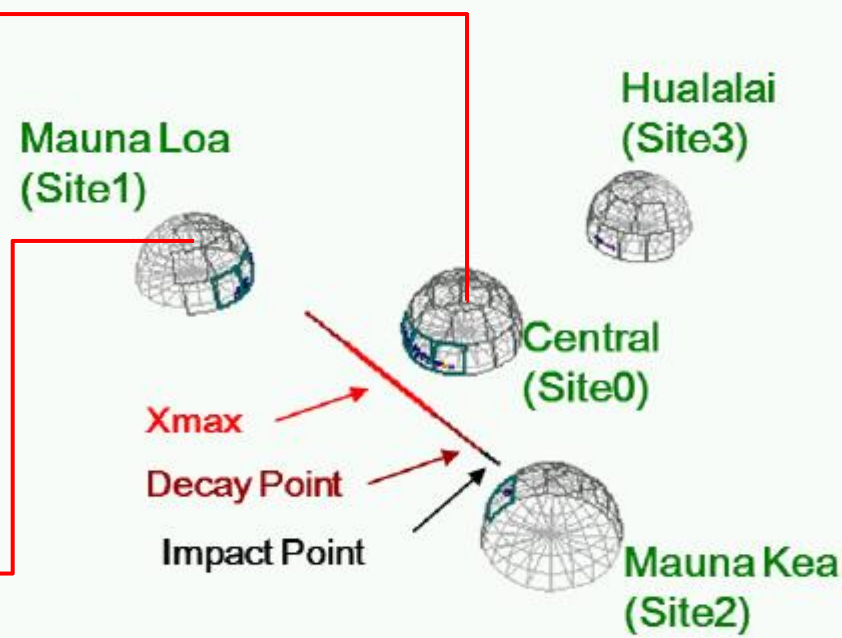
NTA Simulated Event





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

$\boxed{\text{Elevation}=-6.4^\circ}$, Azimuth= 347.6°



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

Simple Fit => Pointing Accuracy

Site0 + Site1: $\boxed{\delta\theta = 0.08^\circ}$

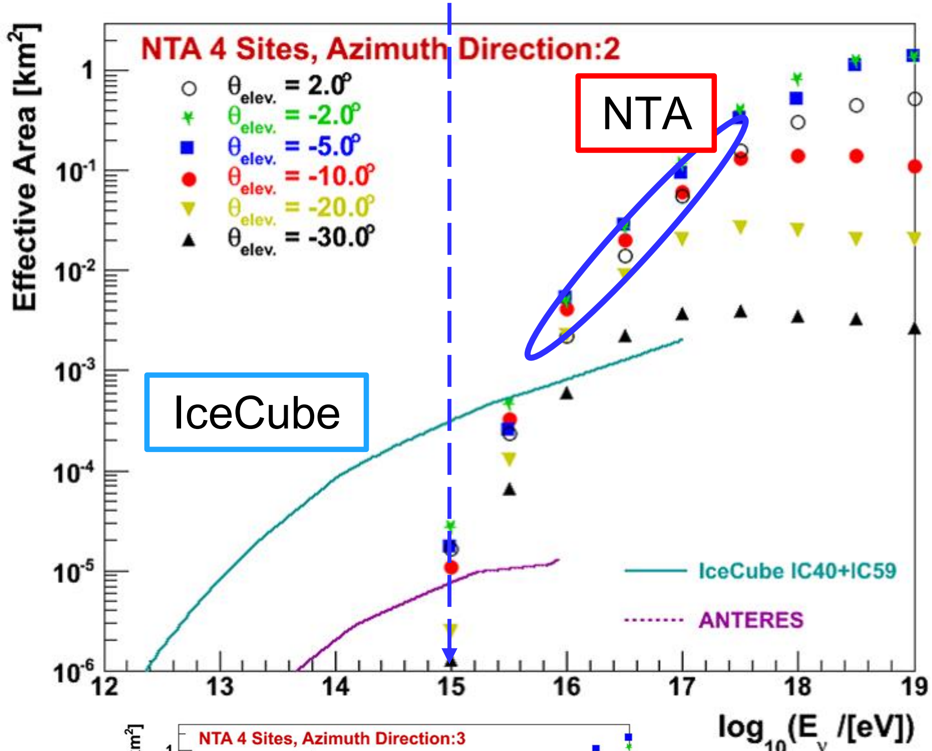
Acceptance: Air & Tau vs Water & Muon

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].

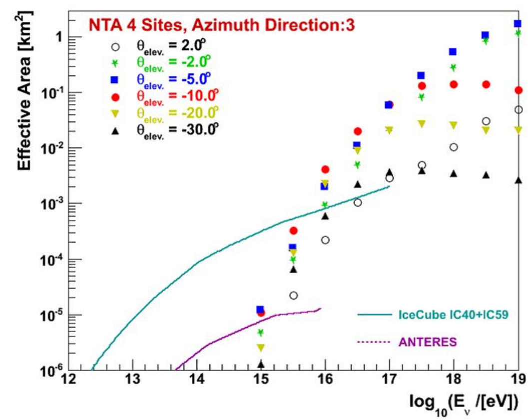
3. For detector simulation, we incorporate light collection and throughput with simplified triggering logic. Event reconstruction is not yet implemented.

Point source, arrival dir. Mauna Loa



Assumed FOV

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



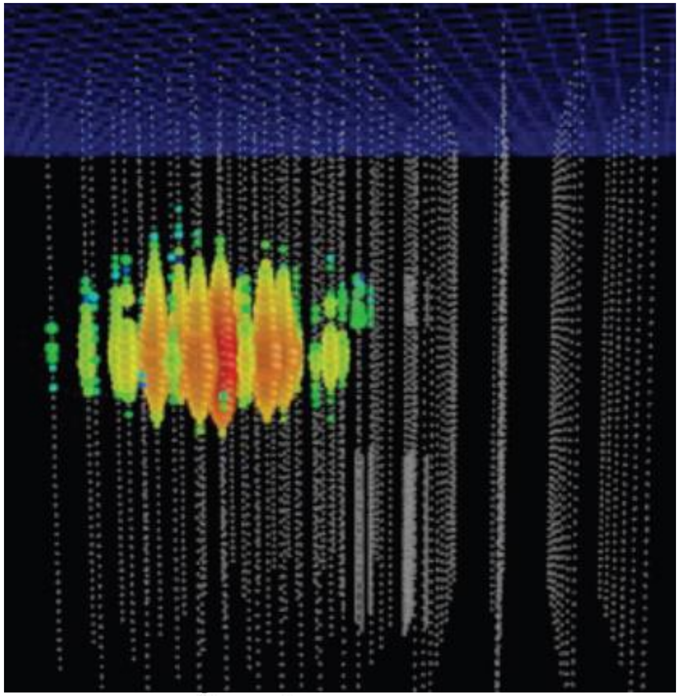
dir. Hualalai

trigger conditions:

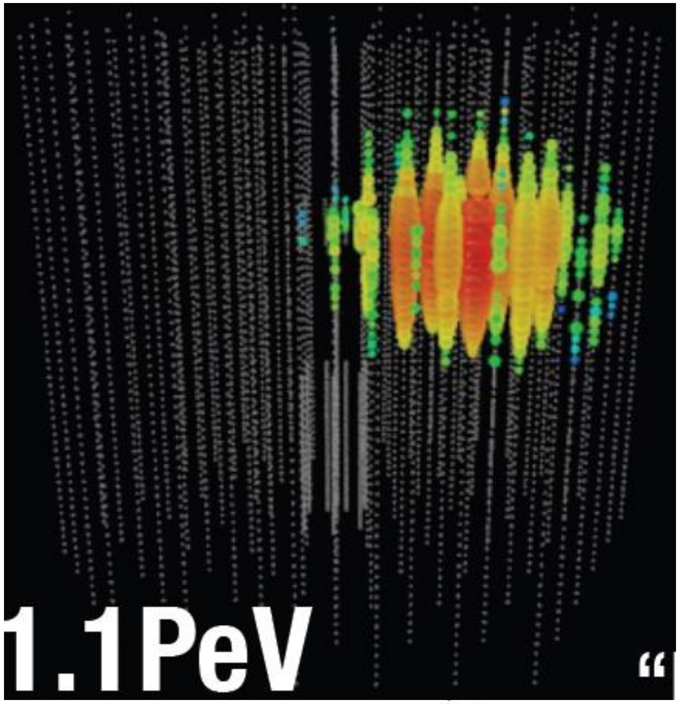
- Number of detected photoelectrons per LC > 61.
- S/N estimated in track-associated 4 pixels × 64 pixels box (air-shower track included) > 4 [17].

IceCube PeV ν Events

PRL **111**, 021103 (2013)

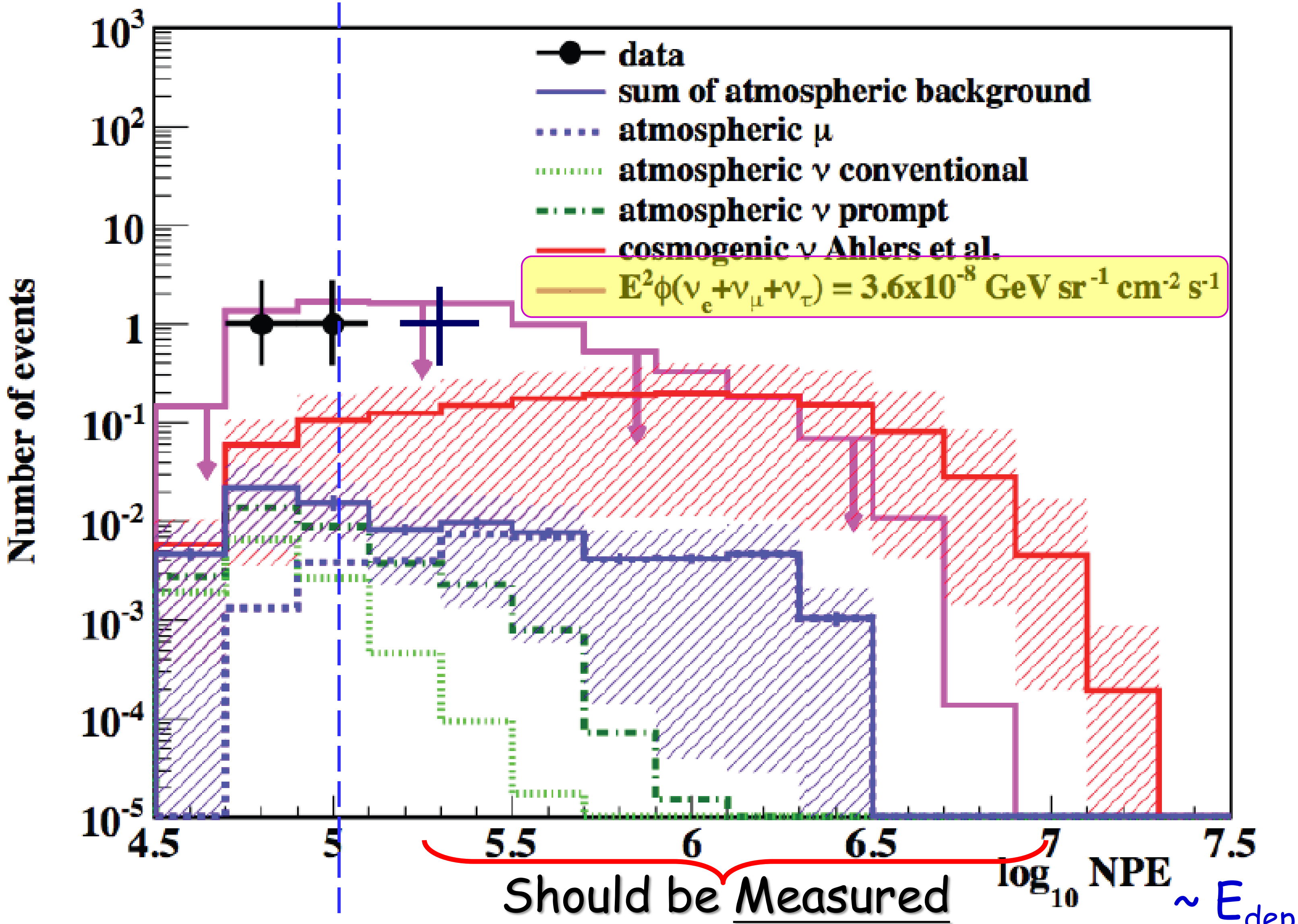


©2013 Sesame Workshop



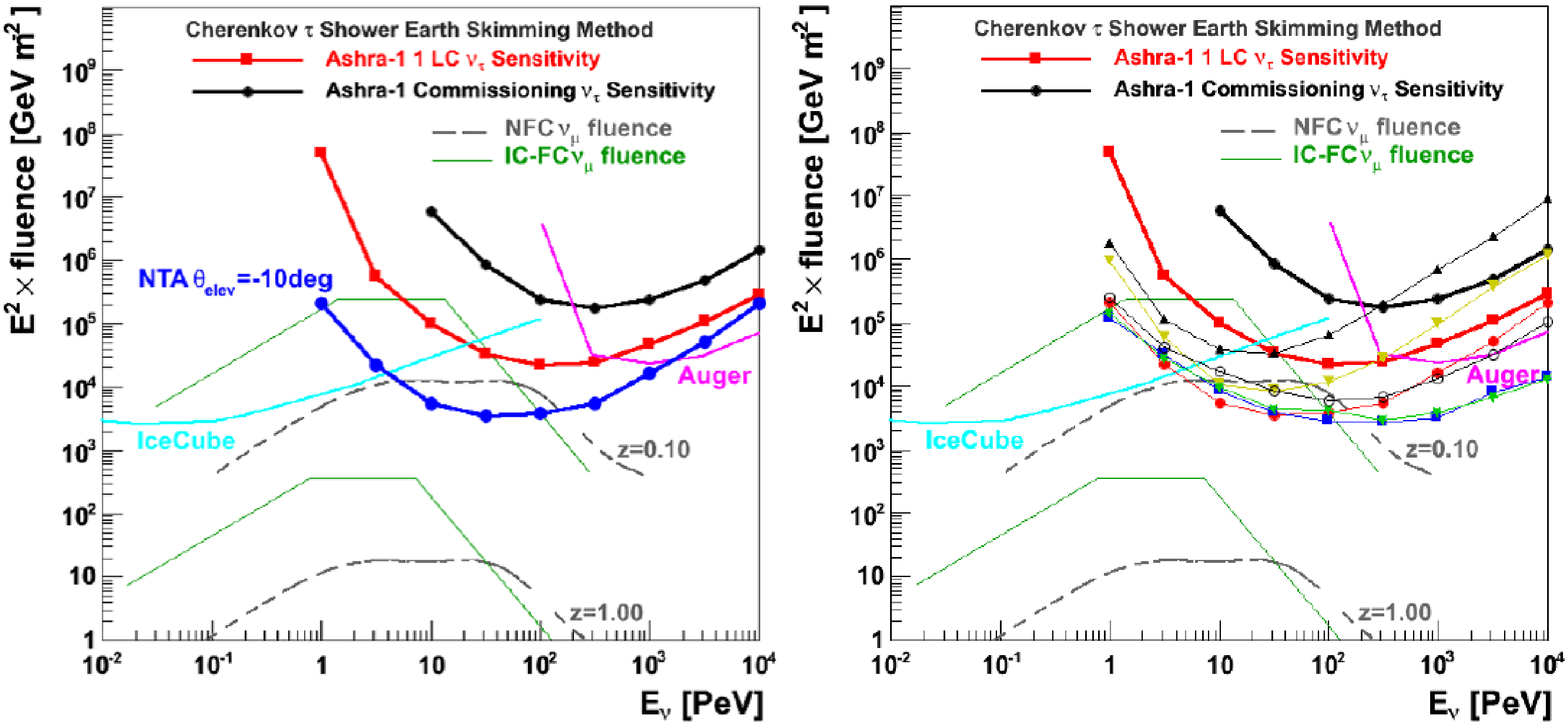
What if one had better Sensitivity and accurate Pointing Info ?

IceCube PeV Events



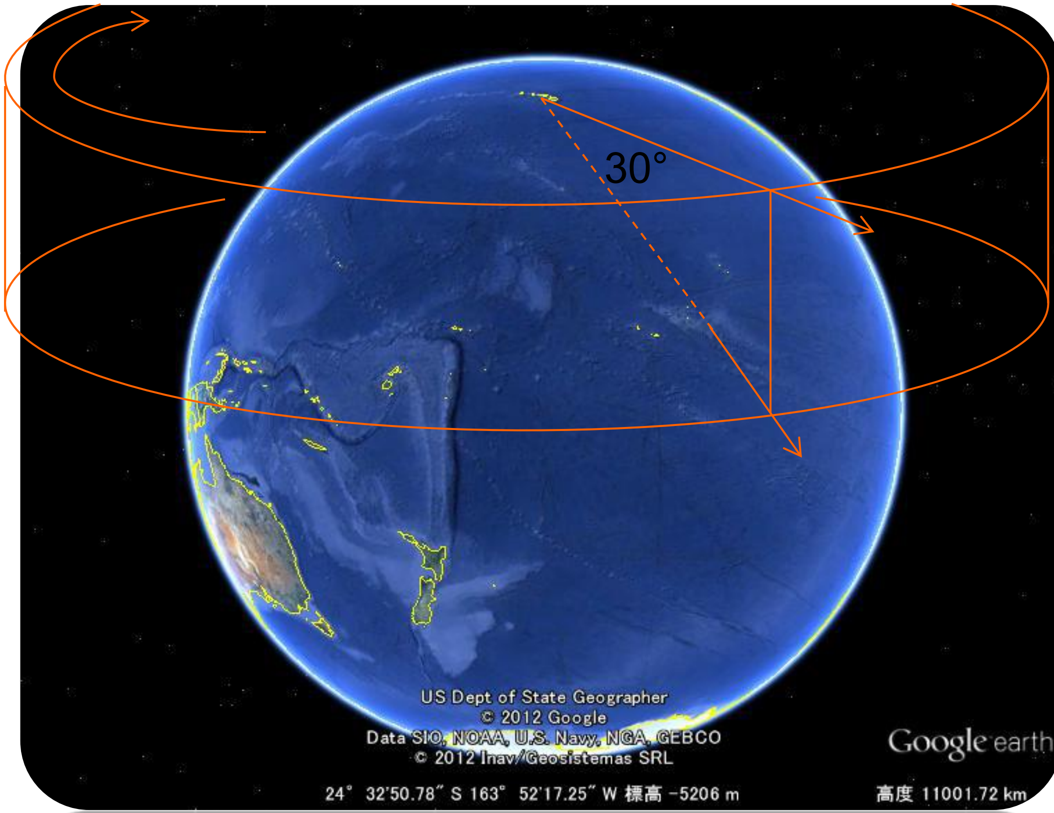
NTA Differential Sensitivities

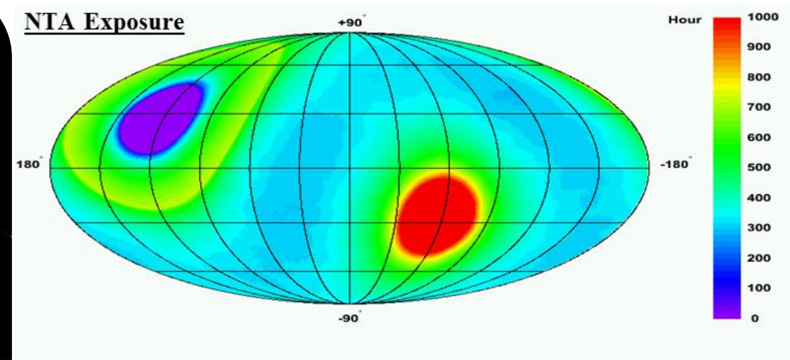
(LOI at hand)

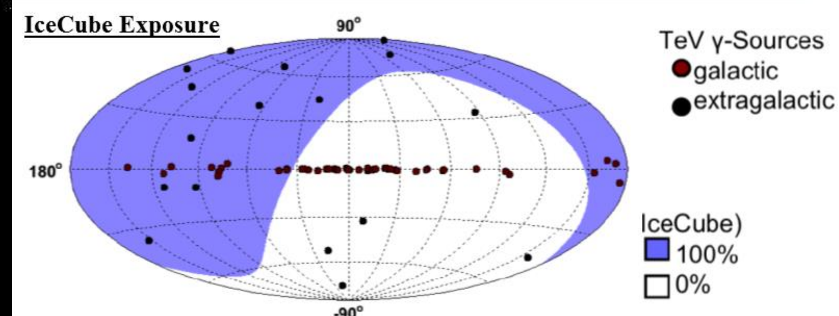


NTA Survey Depth: z ~ 0.15 (2 Glyr) for GRBν flux (Hümmer et al., 2012)

NTA ν_τ Survey Performance







NTA can observe
Galactic Center

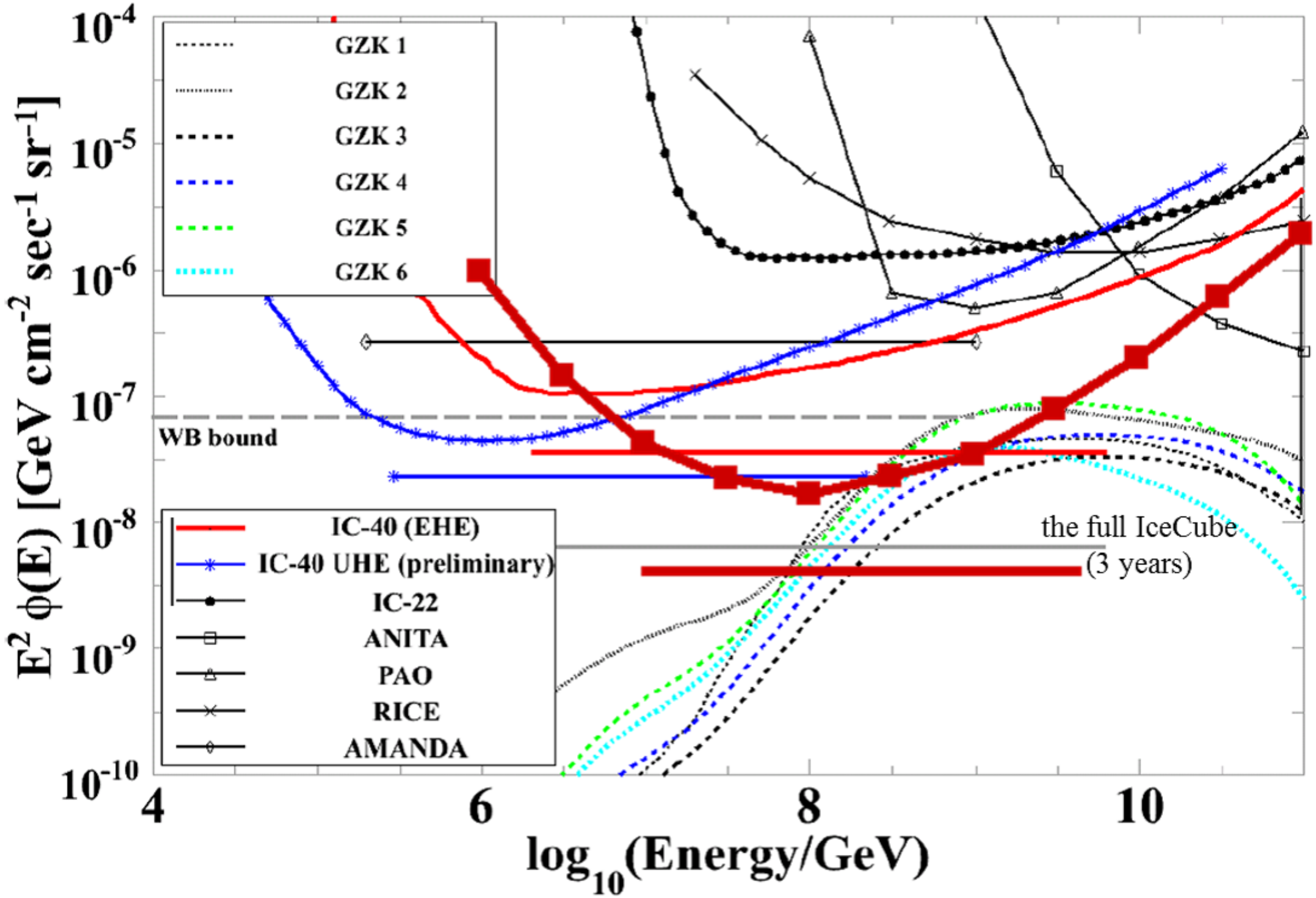
Duty 10-20% from Ashra-1

ν pointing accuracy < 0.2°

FOV Elevation 30° × Azimuth 360°

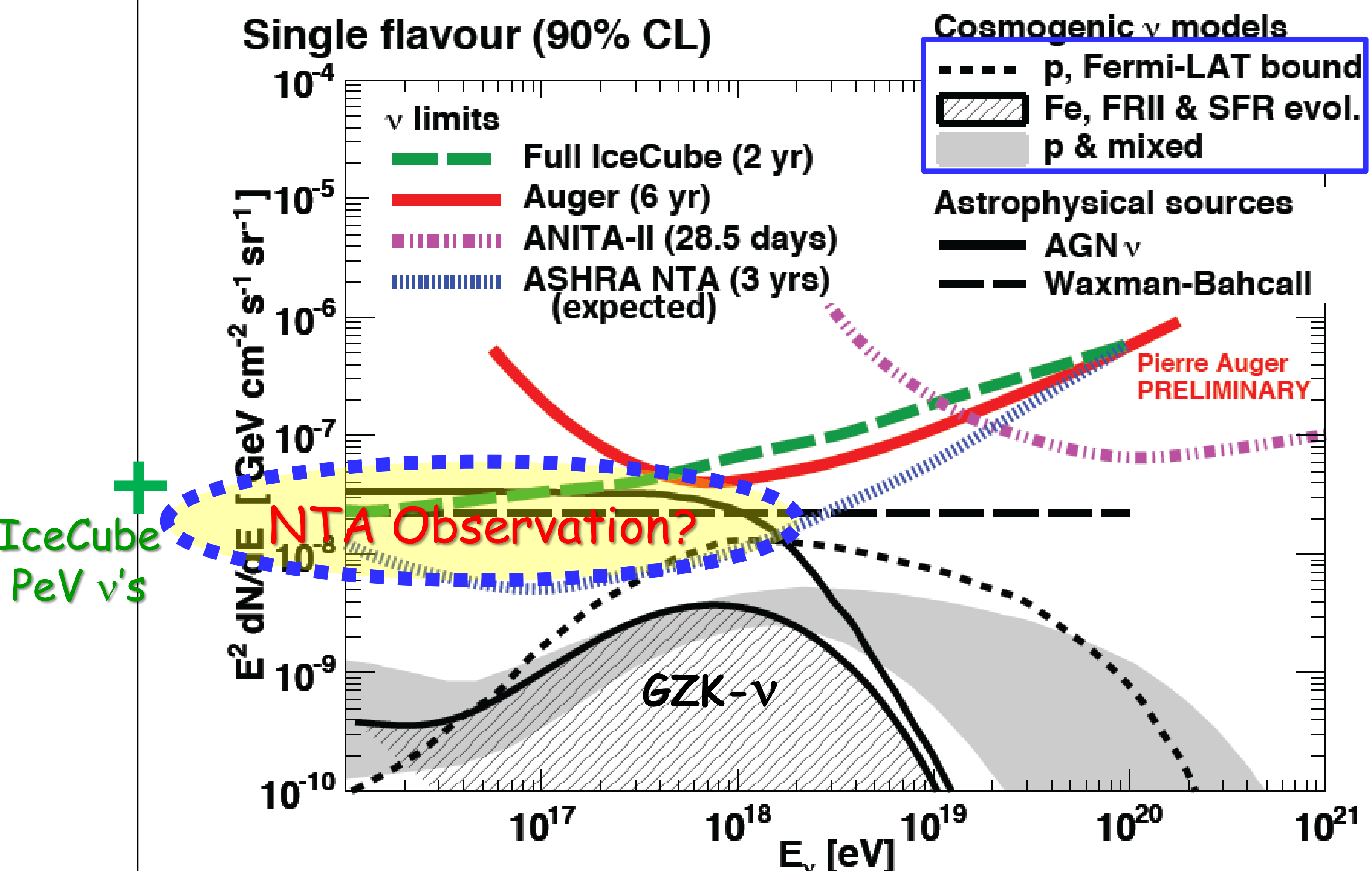
For GRBν
Survey Depth $z < 0.15$ (2 Glyr)

NTA Diffuse Sensitivity (3 yr)



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

Differential limits to diffuse flux of UHEν

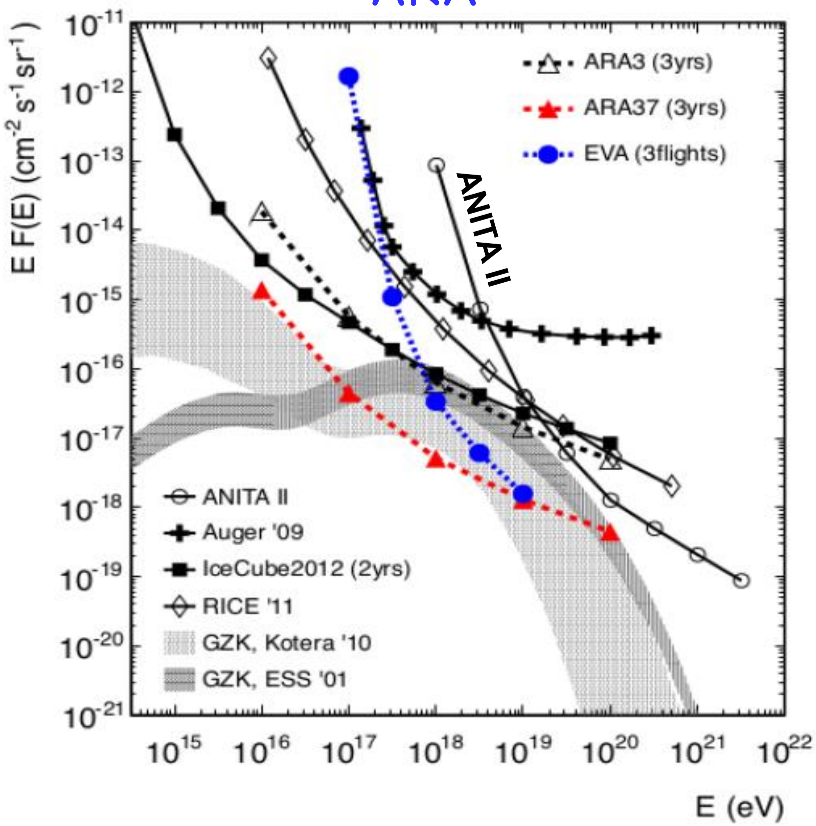


The Quest for GZK Neutrino

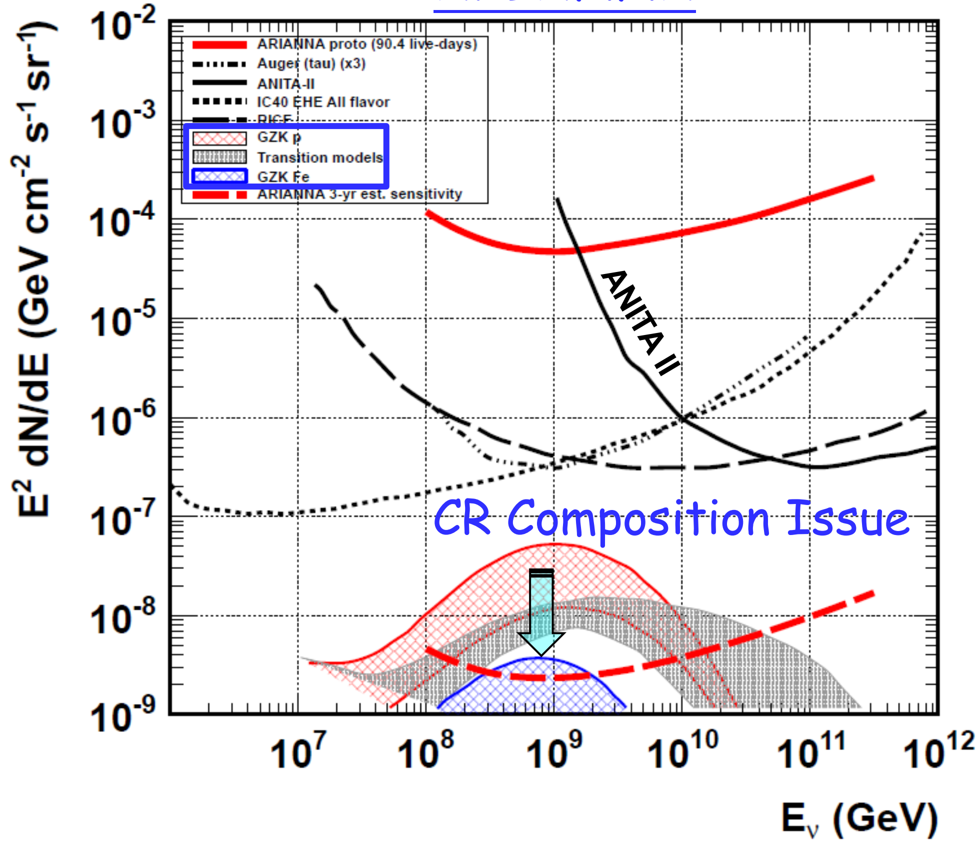
Jordan Hanson @ VHEPA2014
March 2014 @ Kashiwa, Tokyo Univ.

$$p^+ + \gamma_{CMB} \rightarrow \Delta^+ \rightarrow n + \pi^+$$
$$\pi^+ \rightarrow e^+ + \bar{\nu_\mu} + \nu_\mu + \nu_e$$

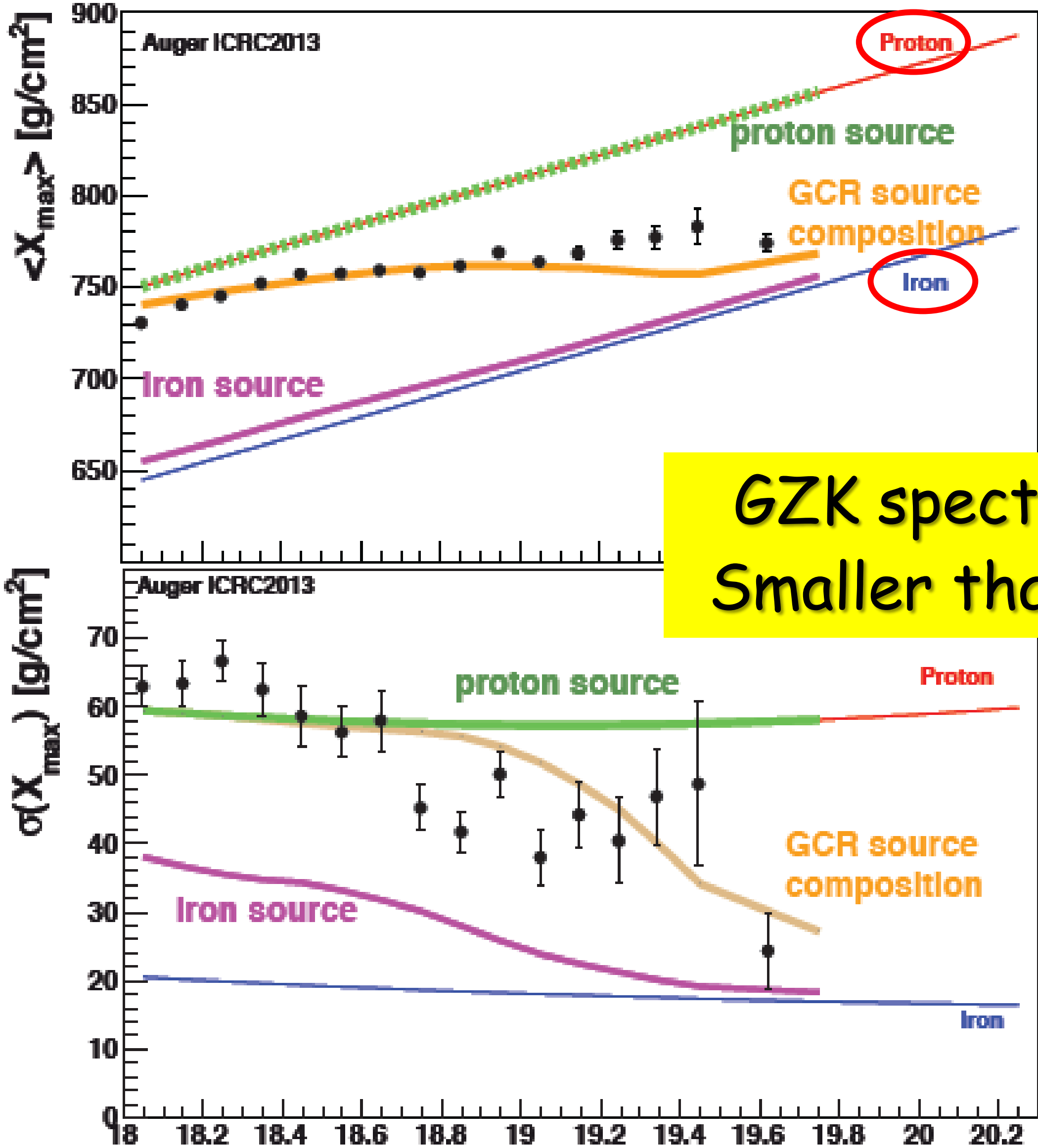
ARA

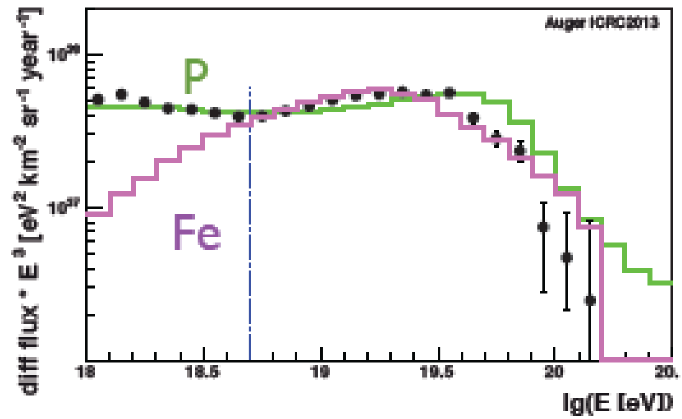


ARIANNA

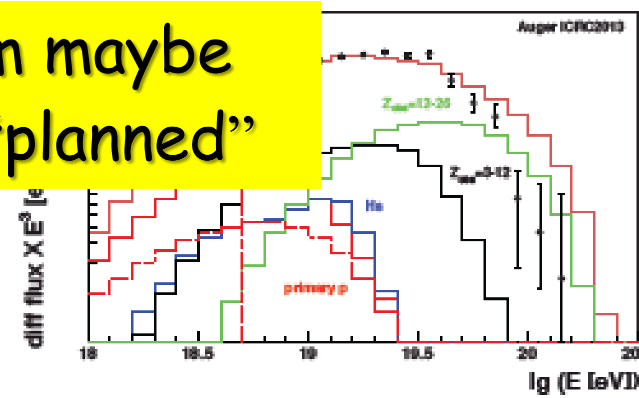


Composition compared with astrophys. scenarios





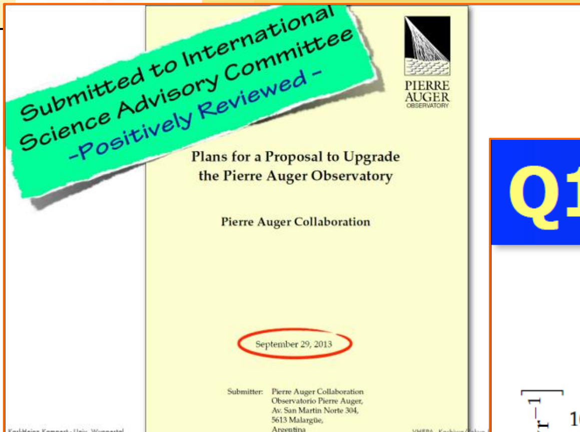
GZK spectrum maybe Smaller than "planned"



Limiting energy of sources combined with GZK describes composition data best

Karl-Heinz Kampert (SP of Auger) @ VHEPA2014

Auger Upgade Target



Submitted to International Science Advisory Committee -Positively Reviewed -

PIERRE AUGER OBSERVATORY

Plans for a Proposal to Upgrade the Pierre Auger Observatory

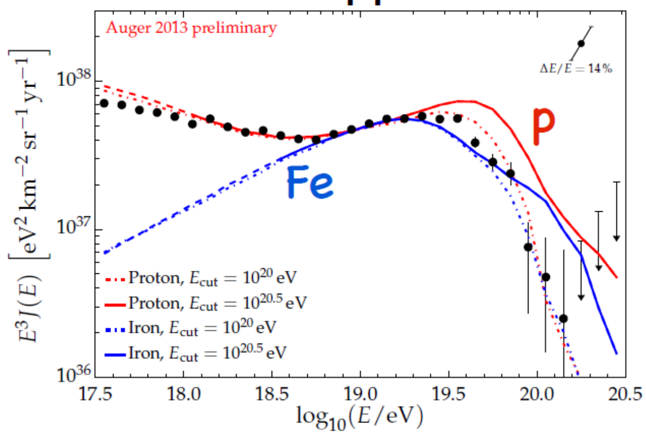
Pierre Auger Collaboration

September 29, 2013

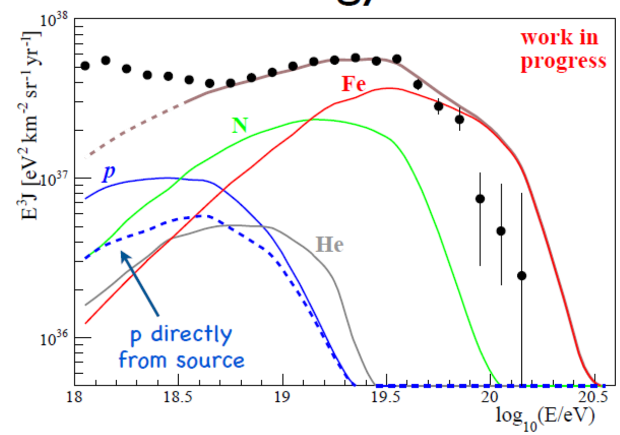
Submitter: Pierre Auger Collaboration
Observatorio Pierre Auger,
Av. San Martin Norte 304,
5613 Malargüe,
Argentina

Q1: GZK effect or Exhausted Sources ?

GZK suppression



maxium energy scenario



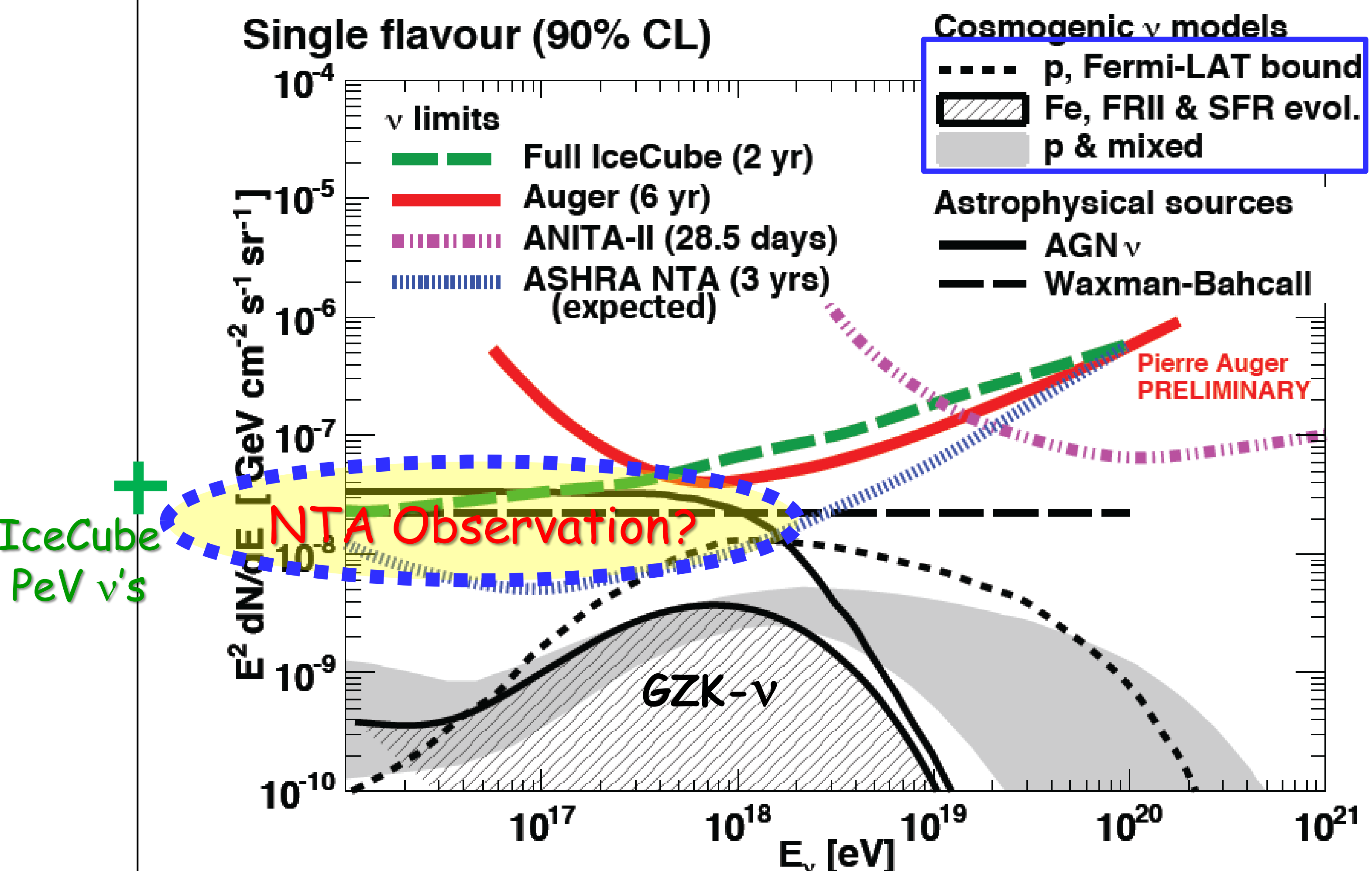
$E_{max}^{P} \sim 10^{18.6}$ eV → $E_{max}^{Fe} \sim 10^{20}$ eV

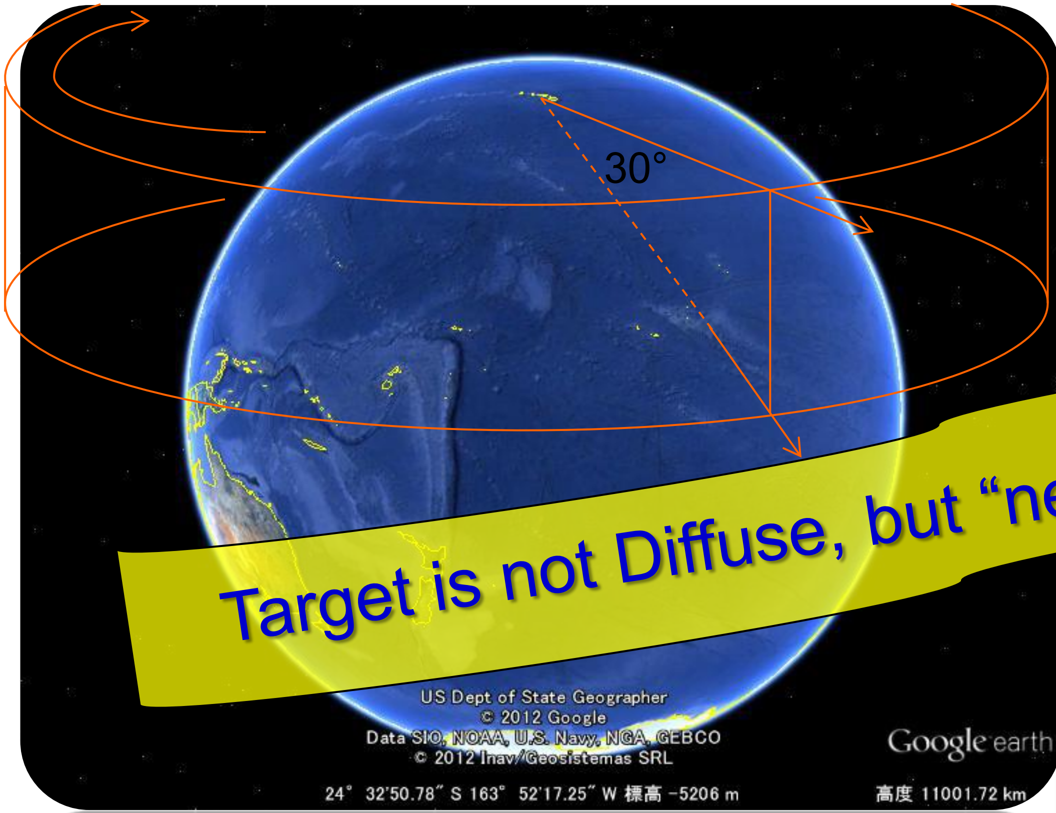
Of fundamental astrophysical importance:
E_{max} of sources ? Standard Fermi acceleration ?

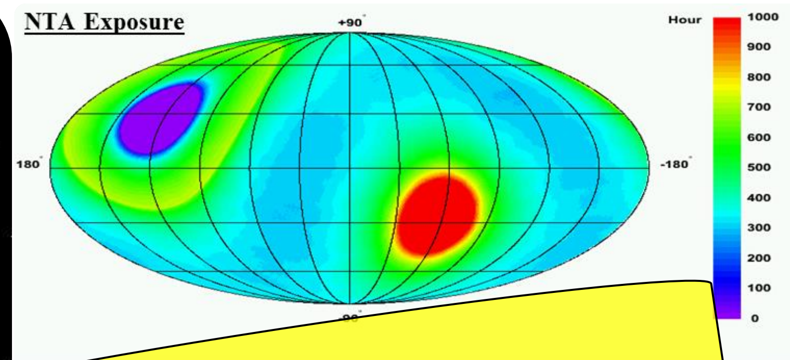
Karl-Heinz Kampert - Univ. Wuppertal 43 VHEPA, Kashiwa/Tokyo (Japan), March 19-20, 2014

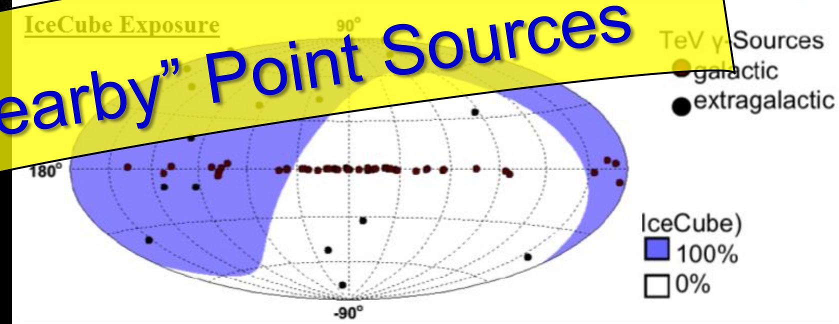
Karl-Heinz Kampert @ VHEPA, March 2014 , Kashiwa, Tokyo Univ.

Differential limits to diffuse flux of UHEν









Target is not Diffuse, but “nearby” Point Sources

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 Organization

ICECUBE
SOUTH POLE NEUTRINO OBSERVATORY

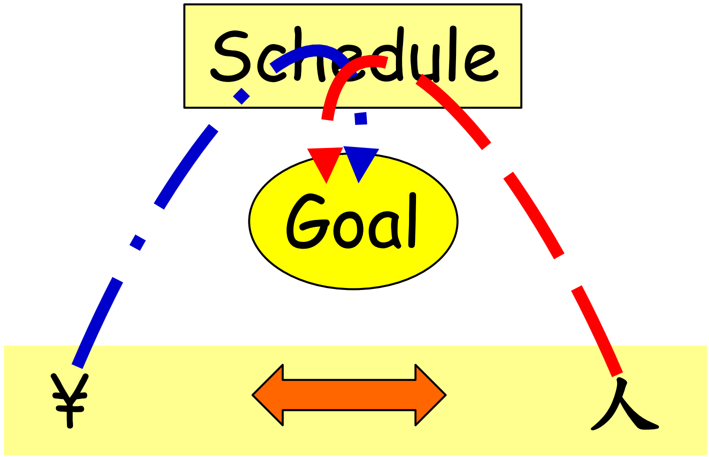
250 people, 39 institutions, 11 countries

Pierre Auger Observatory
the universe's highest energy particles

490 people, 18 countries

NTA Projected: $\lesssim$ 10 countries

NTA Organization



NTA Projected: $\lesssim$ 10 countries

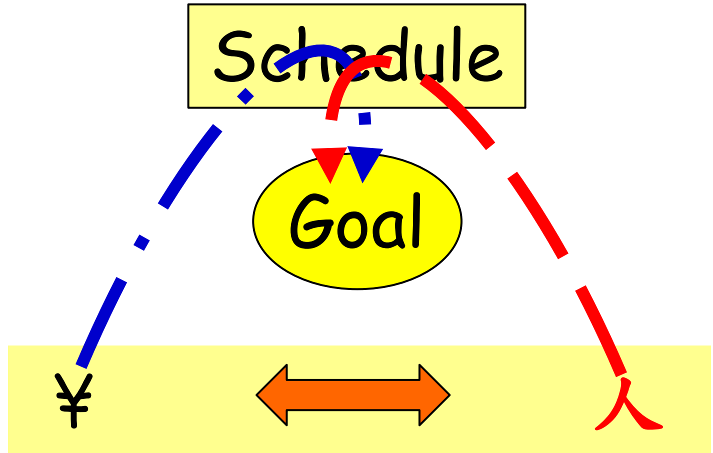
Collaboration Needed

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	$\pi/2$

At least 30 DUs for Coverage, 100 Myen each

12 DU's per π coverage

NTA Organization



NTA Projected: $\lesssim$ 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 (submitted) → VHEPA2014 (March) Call for Collaboration → Proposal/TDR "2015"

funding ~ 2 yrs; construction ~ 5 yrs

use Ashra-1 for test/sci

萬 事 具 備，

只 欠 東 風。 ¥

Conclusion

Neutrino **T**elescope **A**rray (**NTA**)

Aim/Scientific Goal

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

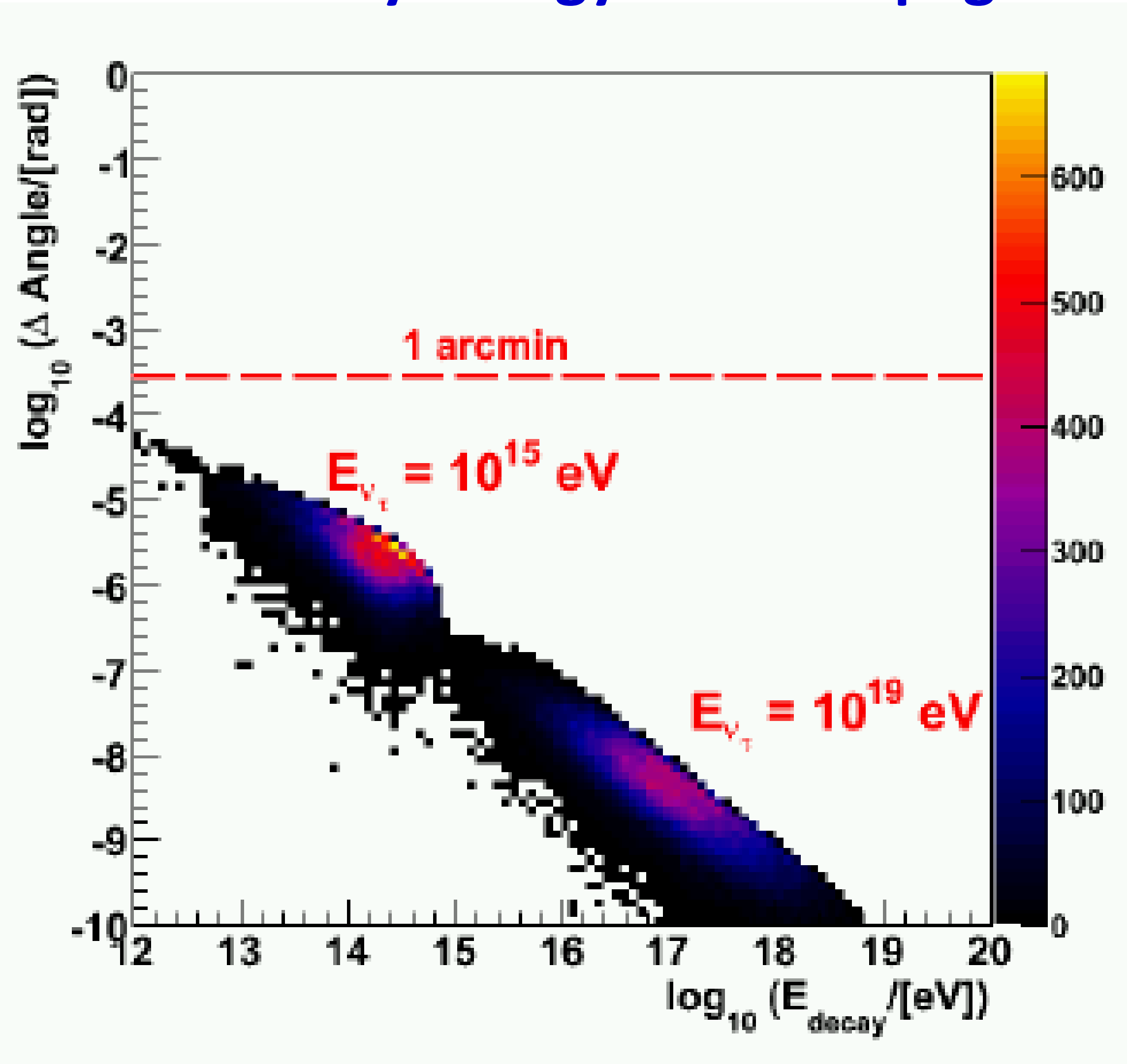
Help spread the word.

Call for Collaboration

Collaborators Welcome !!

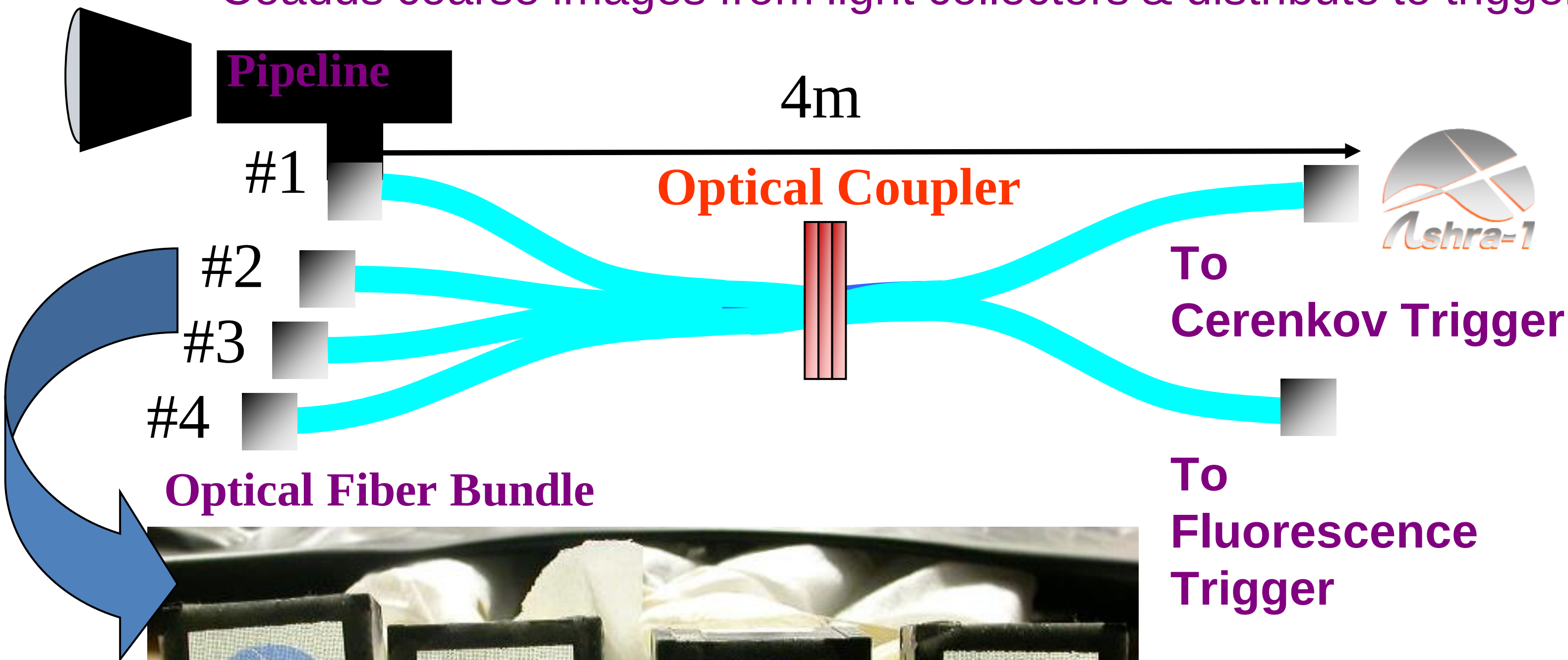
send mail to wshou@phys.ntu.edu.tw
if interested to join mailing list

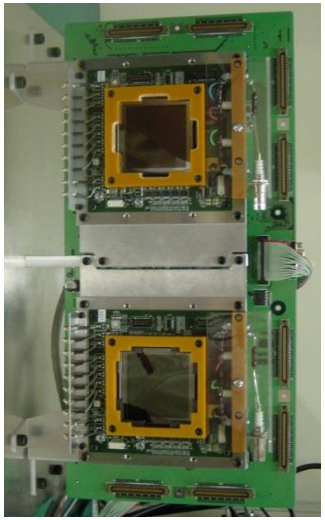
Tau Deflection & Decay Energy After Propagation in Rock



Optical Fiber Transmission System

Coadds coarse images from light collectors & distribute to trigger sensors





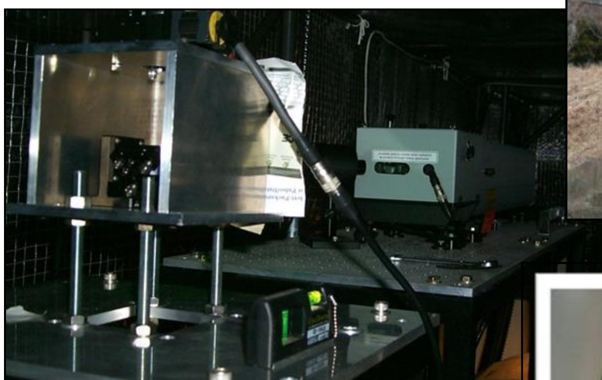
64 × 64 MAPMT

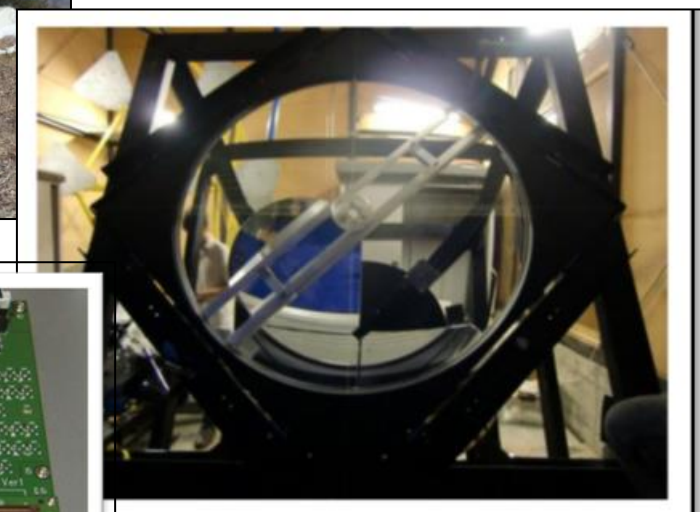
- 64x64 fibers(0.5mmf)
- 0.67deg-FOV / fiber

Light collectors can be easily appended to the trigger.

Sensitivity can be reinforced when more budget is available.

Now Test for Fluor. Trigger @ Akeno





Trigger FPGA Board