Neutrino Telescope Array (NTA)

Prospects towards Survey of Astronomical ν_τ Sources

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

July 31 @ ICRC015, Den Haag

Towards Survey of Astronomical ν_τ Sources

I. Intro: Towards ν-Astronomy

II. Earth-Skimming ν_τ Method

III. Ashra-1 & 1st Search for GRB ν_τ

- Ashra-1 talk by M. Sasaki in NU 06, Wed

IV. Neutrino Telescope Array (NTA)

* Site Plan
* Pointing Accuracy
* Performance & Sensitivity

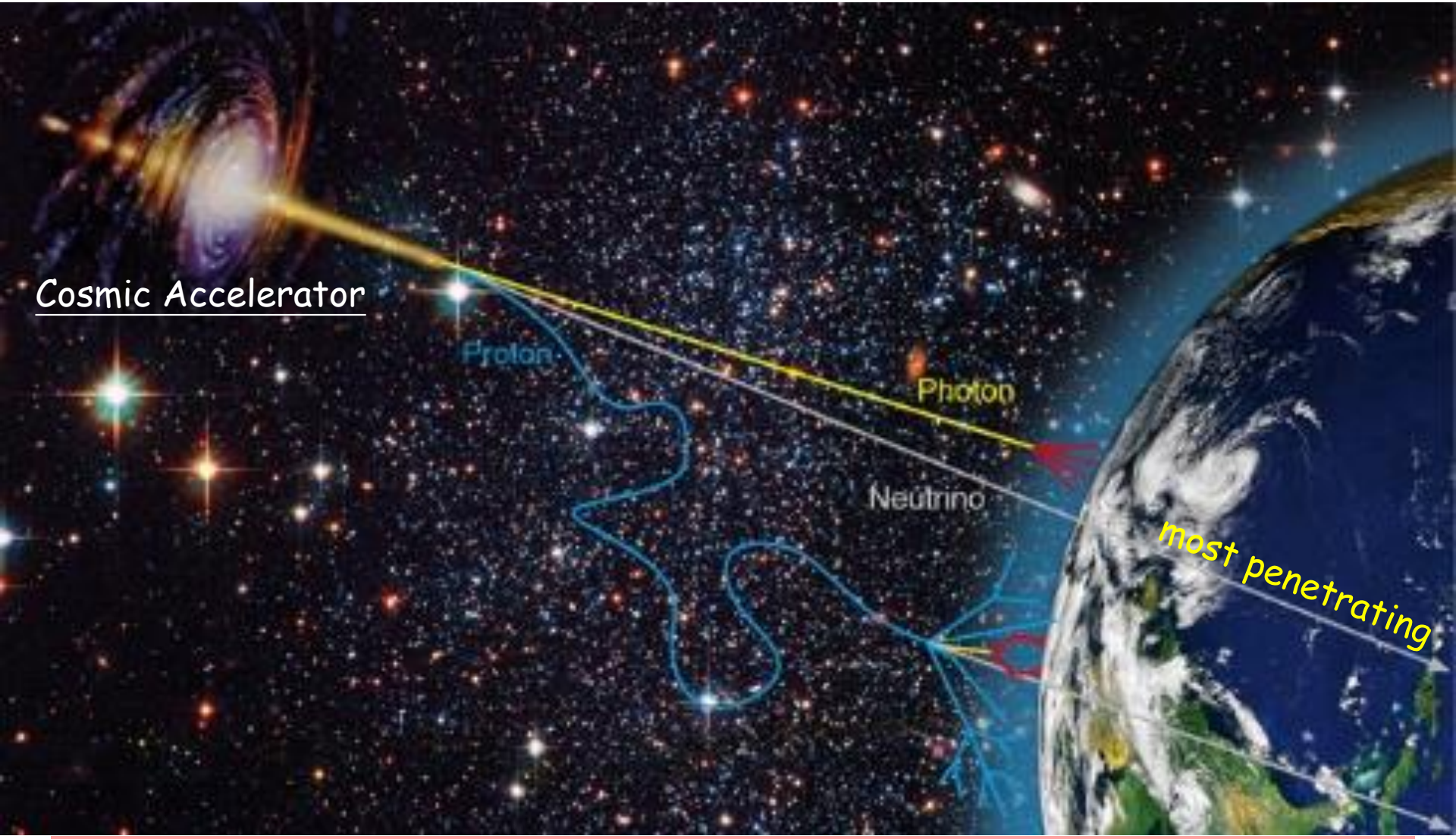
- NTA lunch "forum"
  1 Aug 12:45 @ Murray

Thanks to Ad, Aart
& Karl-Heinz
(and Alan & Francis)

V. Towards a New Collaboration

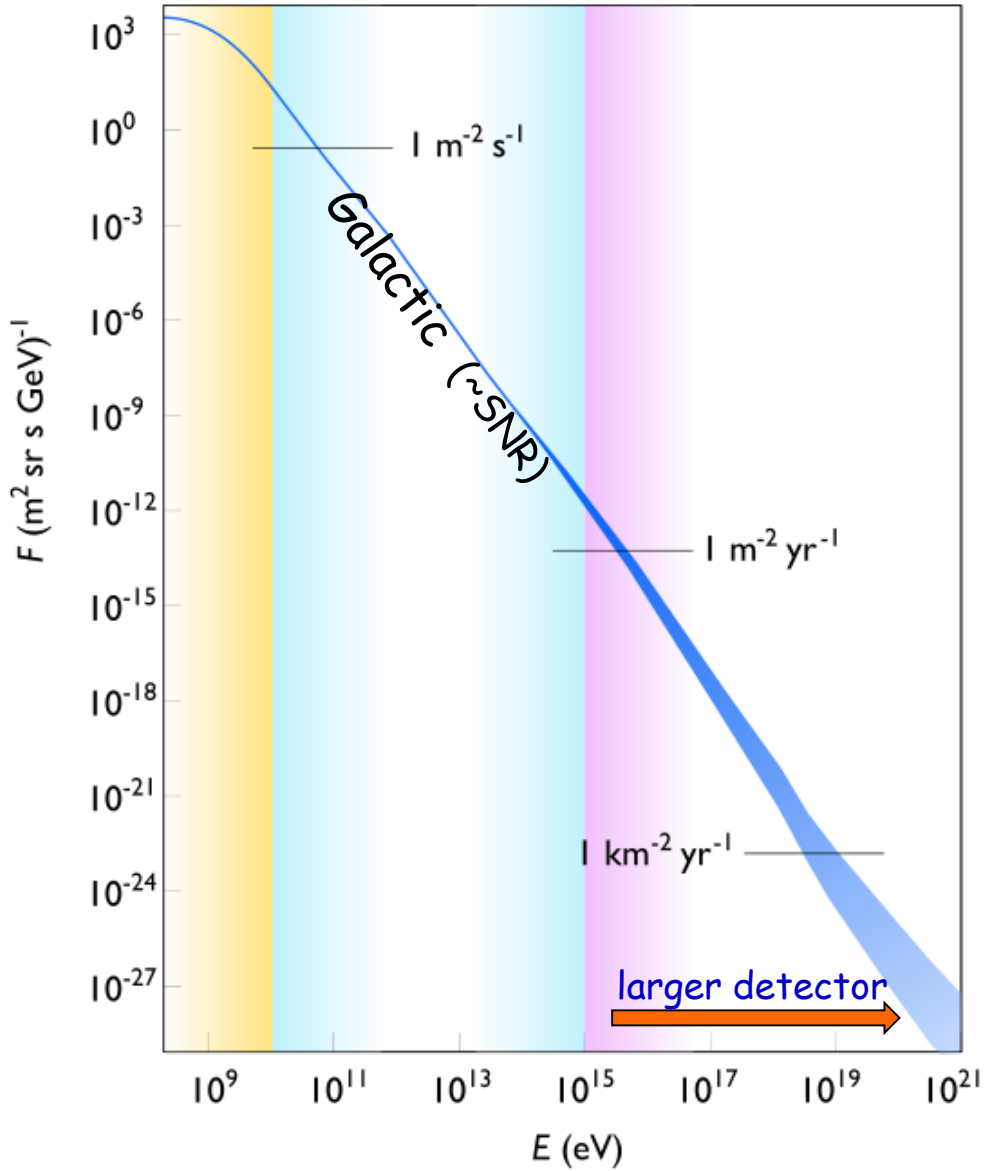
Apologies if I stole some slides from you without acknowledgement …

I. Intro: Towards ν-Astronomy

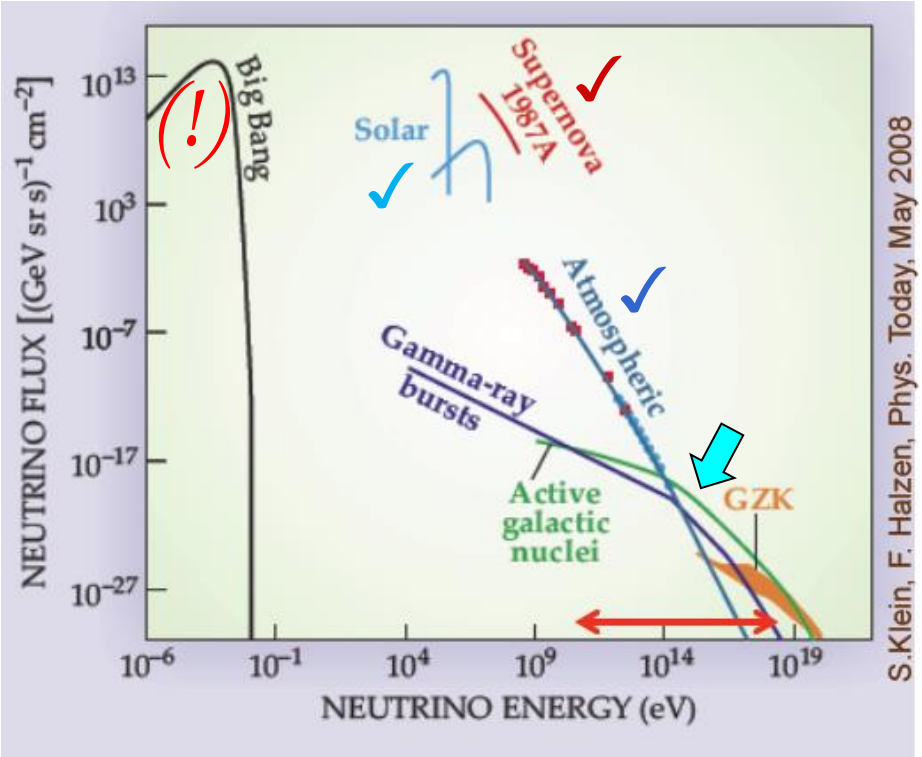


Neutrinos, chargeless and weakly interacting, point back to far away sources.

Cosmic Ray Flux



Neutrino Flux



Ernie

E = 1.1 PeV, θ = 23º

Bert

E = 1.0 PeV, θ = 62º

Big Bird

E = 2.0 PeV, θ = 34º

What if one had better Sensitivity and accurate Pointing Info?

Window of Opportunity

Still Survives

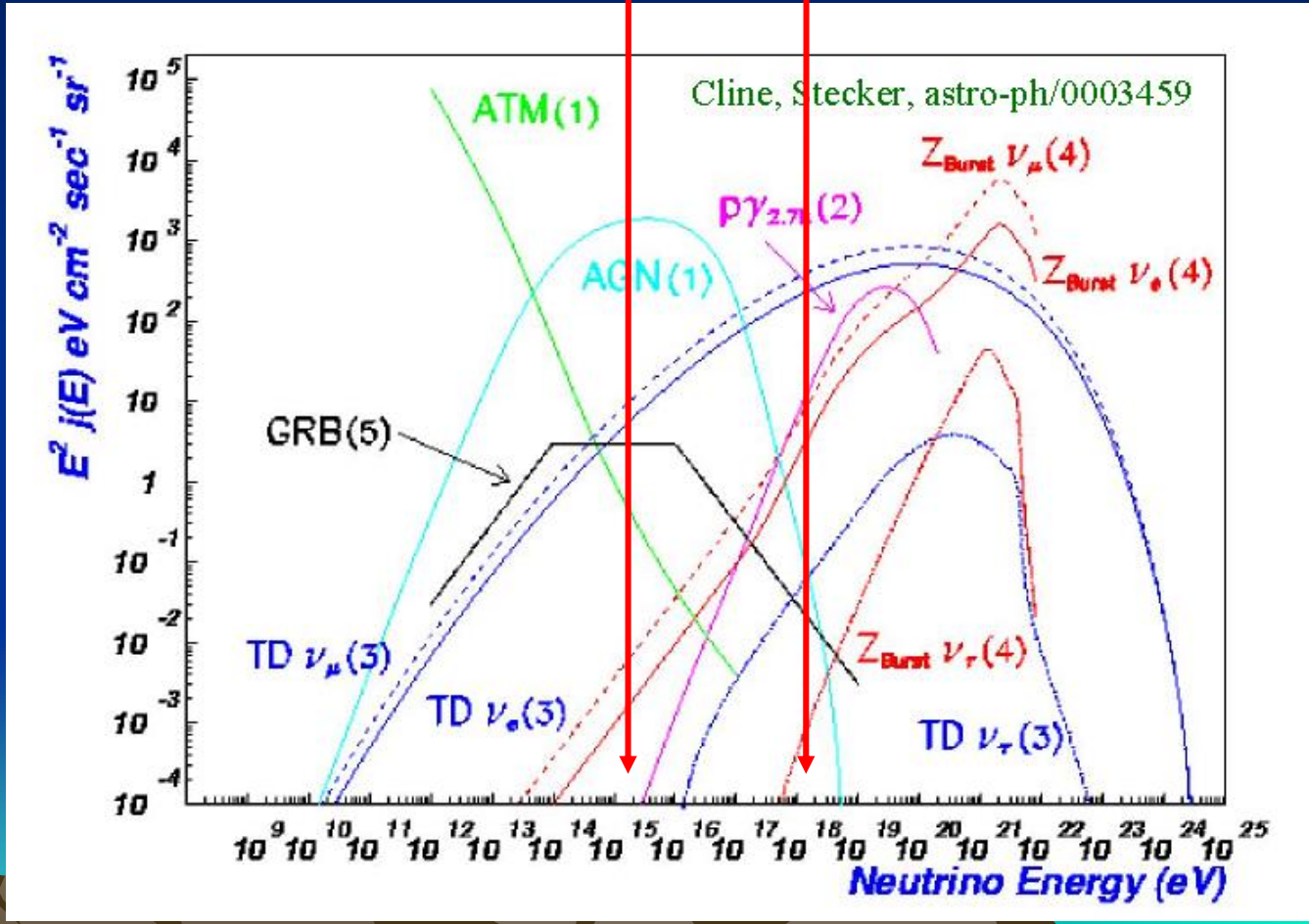
IceCube

Conventional ν Detector

?

UHECR ν Detector

Auger

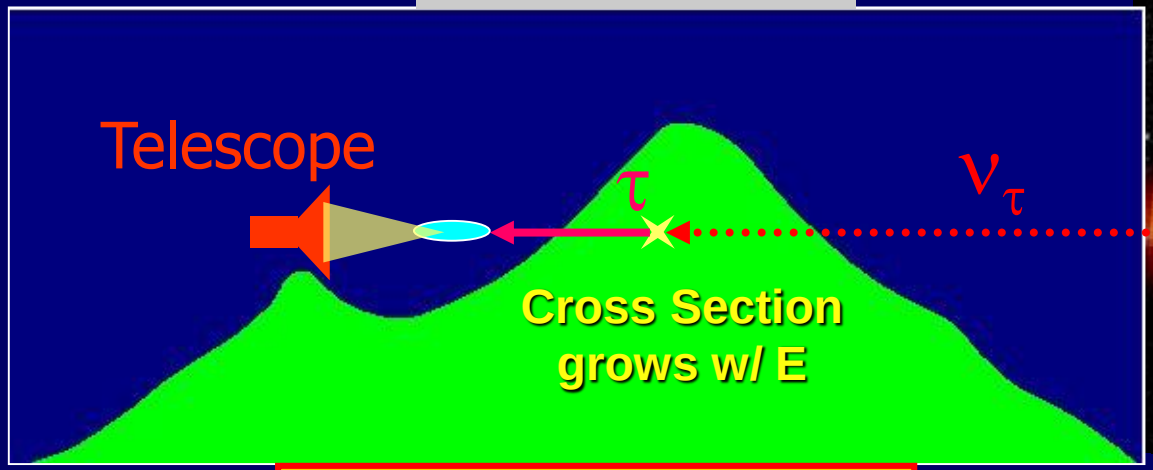


a plot I first used ~ 2002

Detection Mechanism

II. Earth-Skimming ν_τ Method

τ Appearance!



ν_μ ν_τ

θ_{23} ~ max. mix.

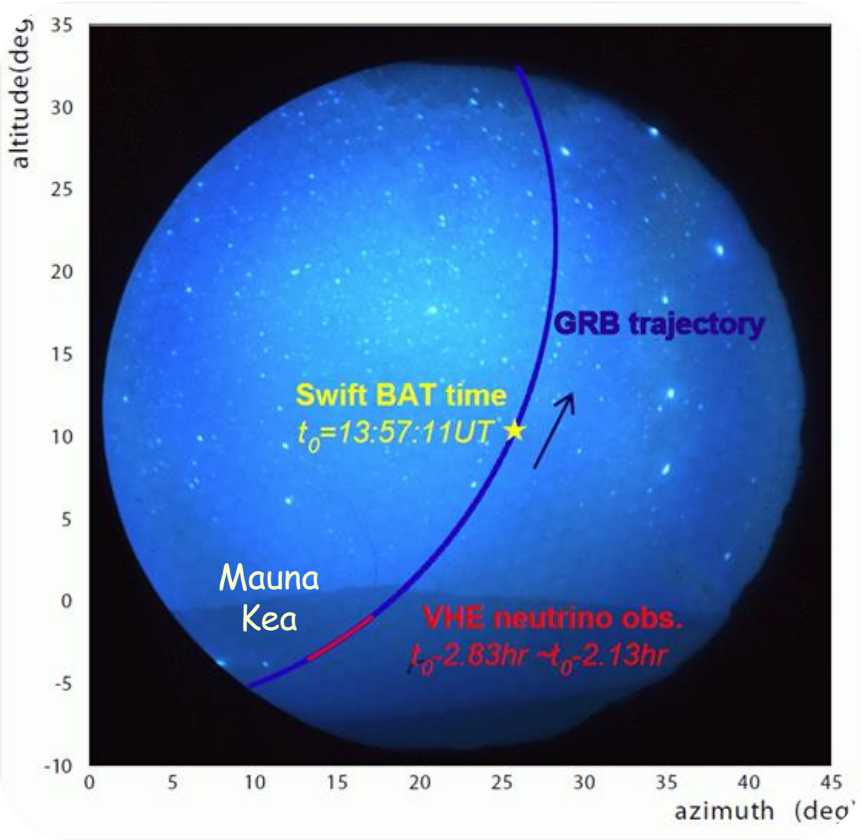
τ *Decay*: Air Shower
→ ns Cherenkov

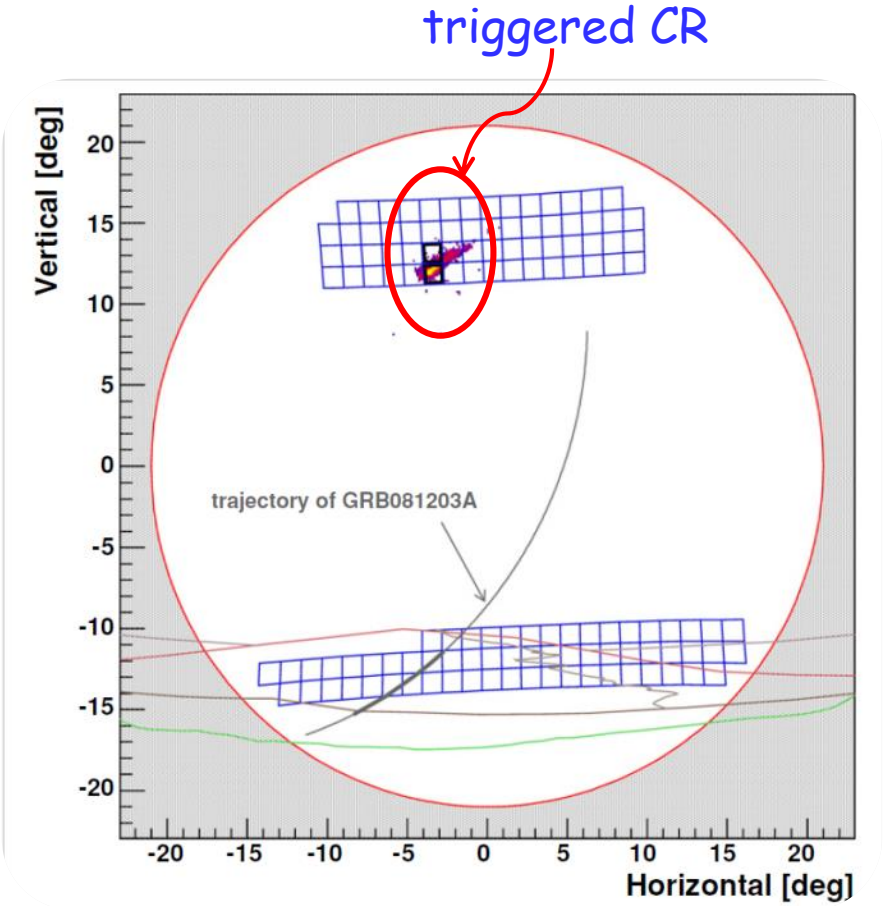
ν_e: electron energy mostly absorbed in mountain
ν_μ: no extensive air shower

"My" NuTel Effort

III. Ashra-1 & 1st Search for GRB ν_τ

GRB081209A





Swift GRB Alert during Ashra-1 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
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OBSERVATIONAL SEARCH FOR PeV–EeV TAU NEUTRINO FROM GRB081203A

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I'm not an author.

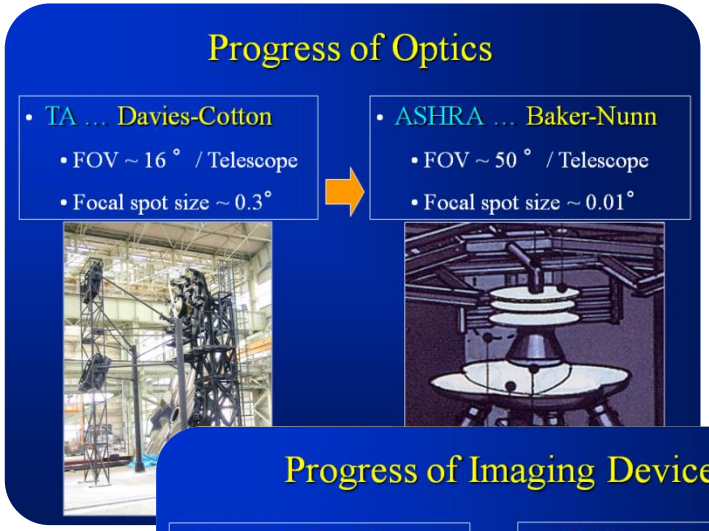
ABSTRACT

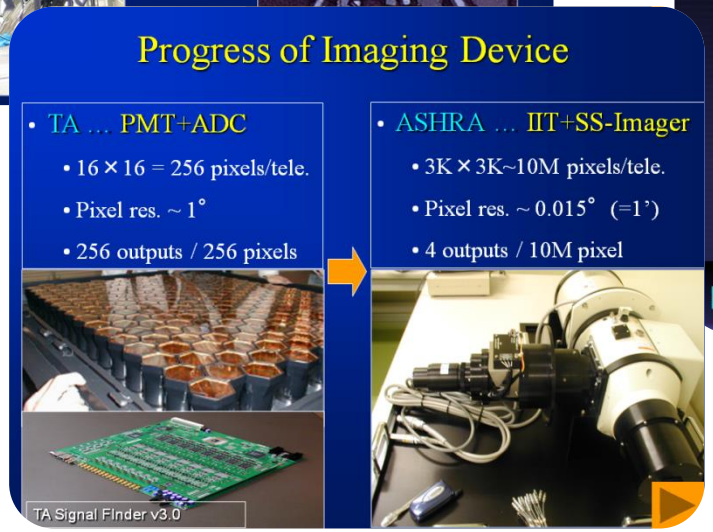
We report the first observational search for tau neutrinos (ν_τ) from gamma-ray bursts (GRBs) using one of the Ashra light collectors. The Earth-skimming ν_τ technique of imaging Cherenkov τ showers was applied as a detection method. We set stringent upper limits on the ν_τ fluence in PeV–EeV region 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.

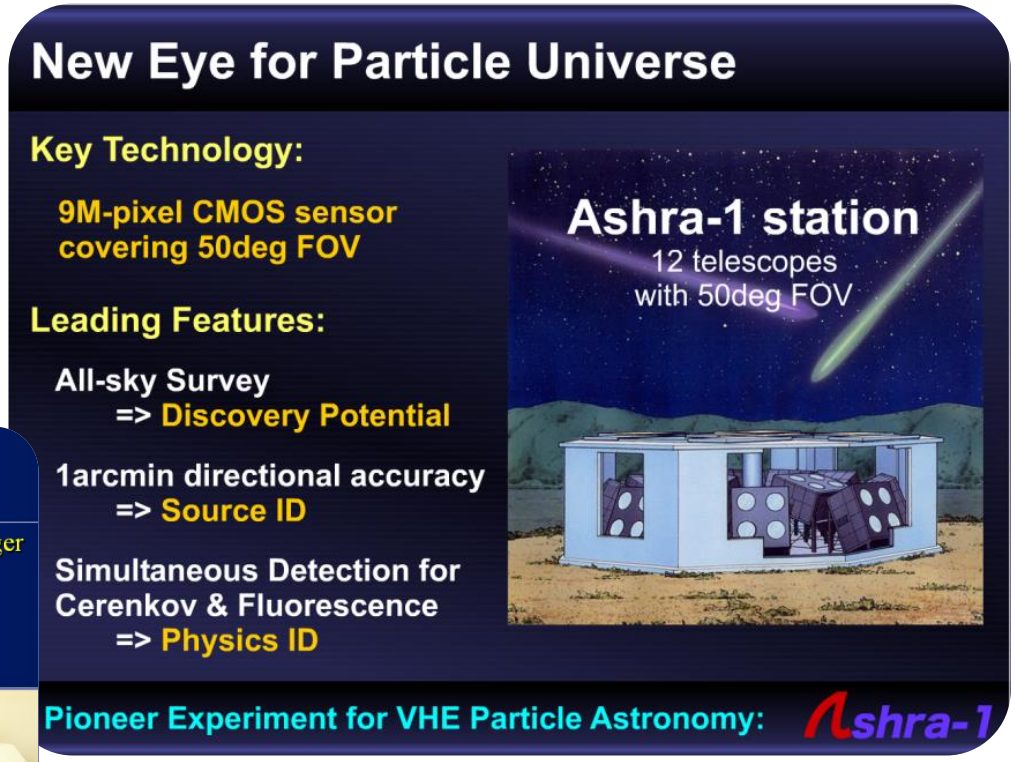
Focus of discussion tomorrow 1 Aug, Sat @ 12:45 in Murray. You Are Welcome!

Ashra-1

(Courtesy Makoto Sasaki)



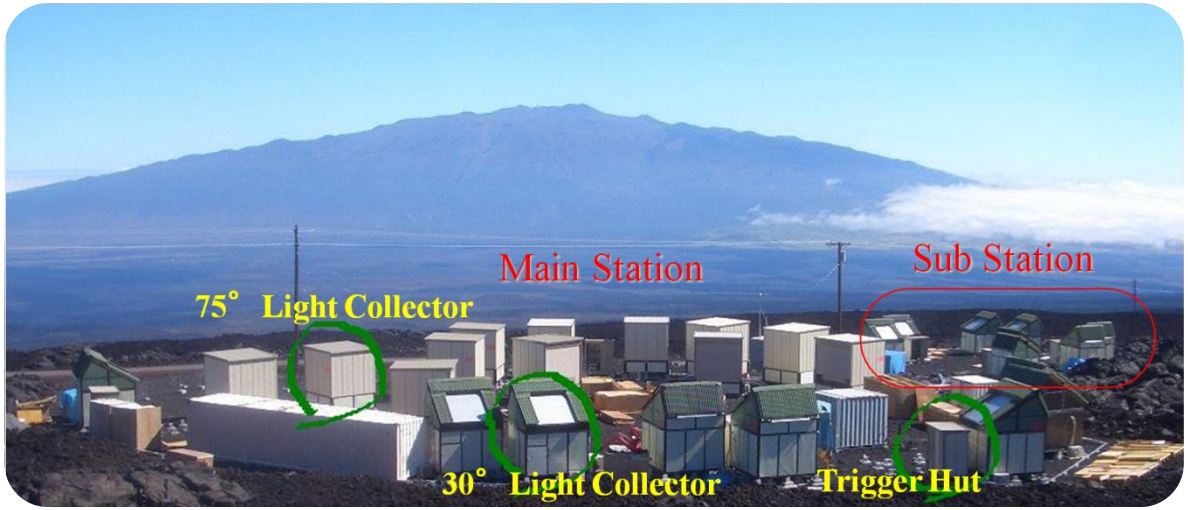




► Ashra-1 talk by M. Sasaki in NU 06, Wed 5 Aug.

Ashra-1

Ashra Observational Site: Mauna Loa



<u>3300 m a.s.l.</u>, 35 km from MK

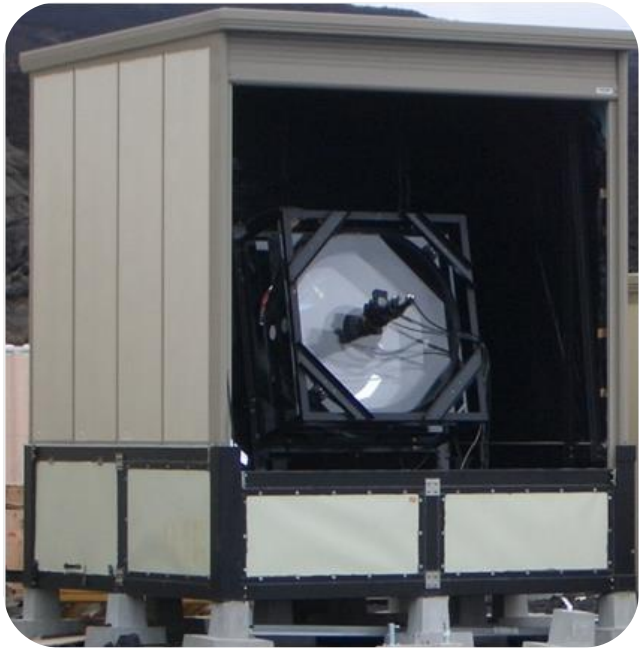
77% mono, 27% stereo

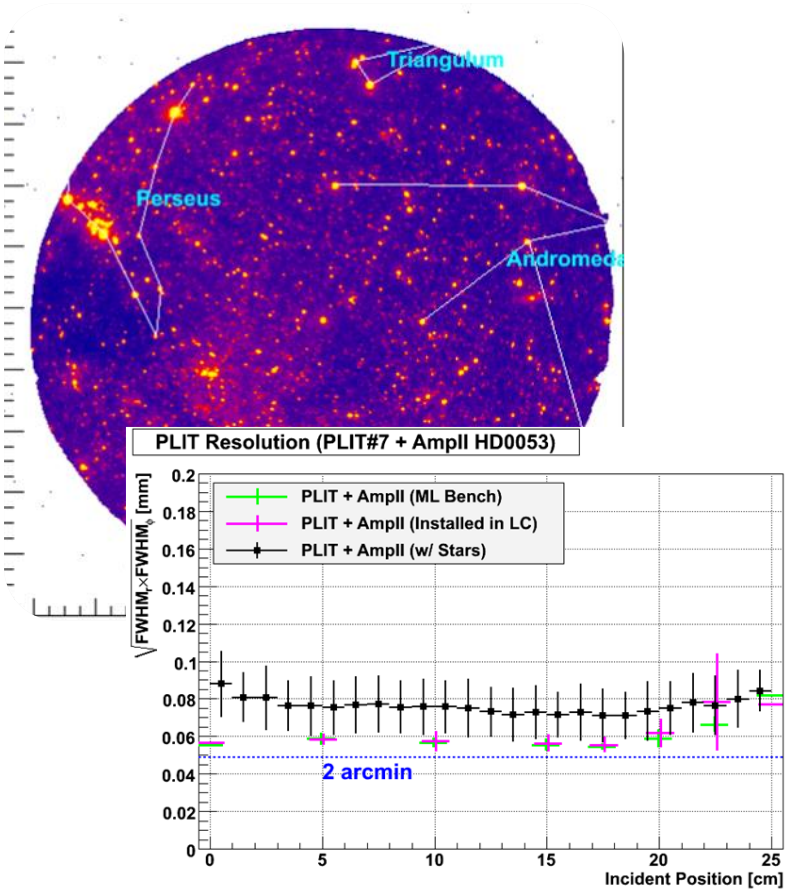
2~3 arcmin image

Nice Coverage and Precision as Particle Monitor

Ashra-1: Wide field Optics

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

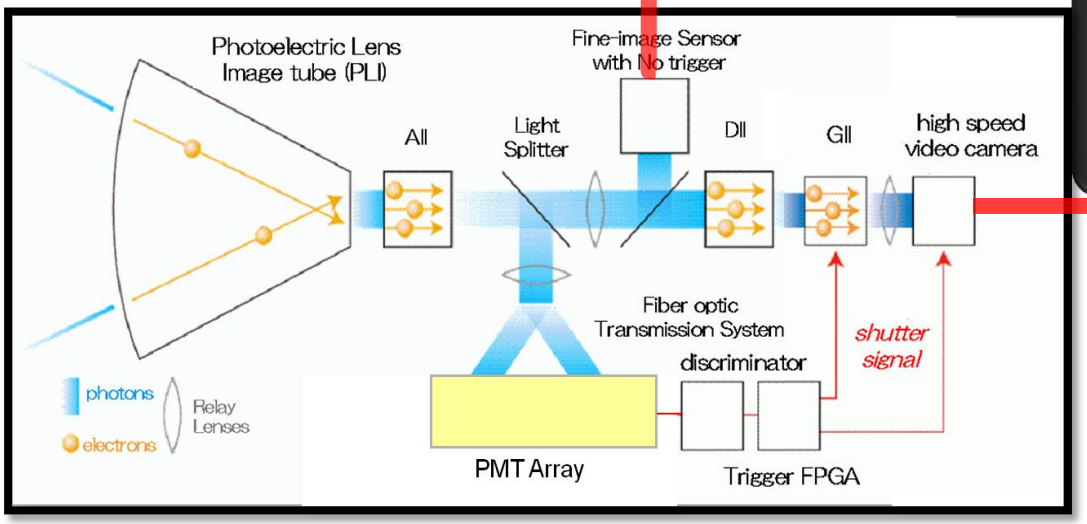
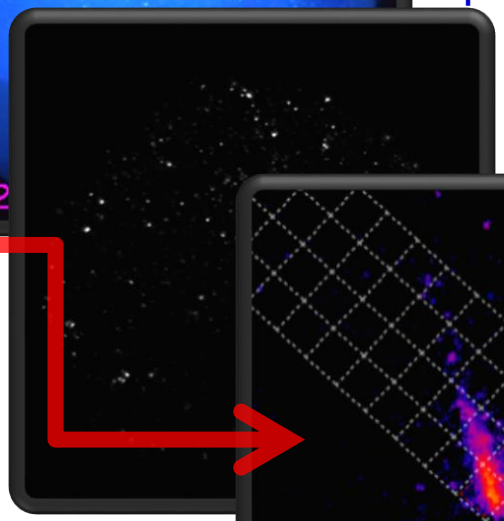
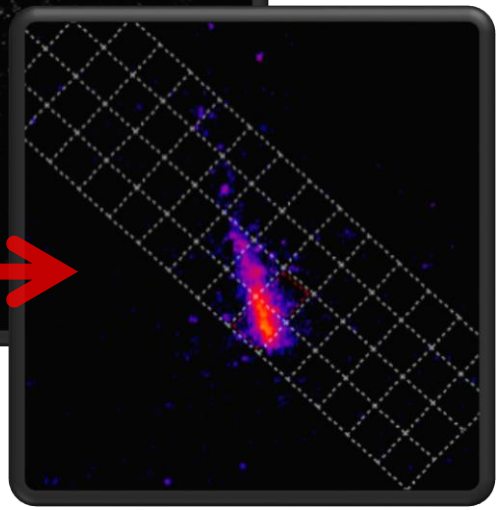


Photo-electric Image Pipeline (PIP)

Optical 4s



BG 200ns



CR 200ns

Multi-Messenger Approach with
One Detector System

High Pixelation w/ CMOS → Fine Resolution

1st imaging air-shower with self-trigger

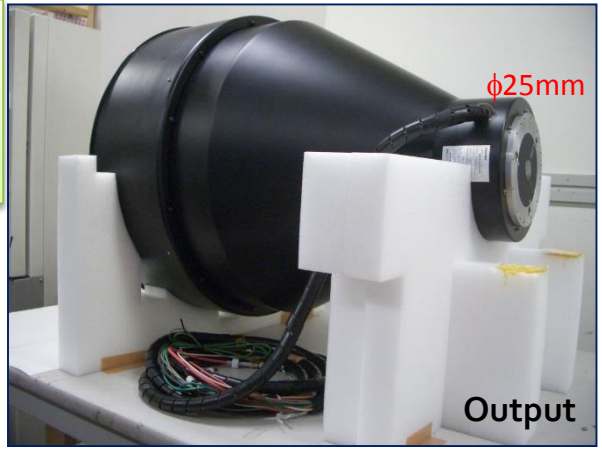
Imaging Tube + CMOS ("video camera")

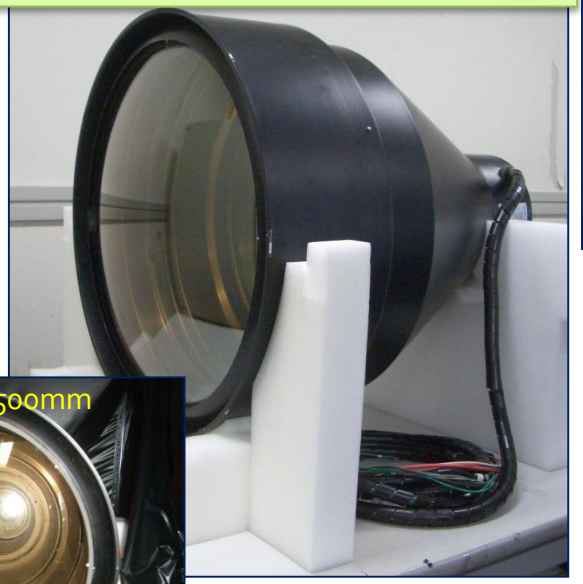
20" Photoelectric Lens Imaging Tube (PLI)

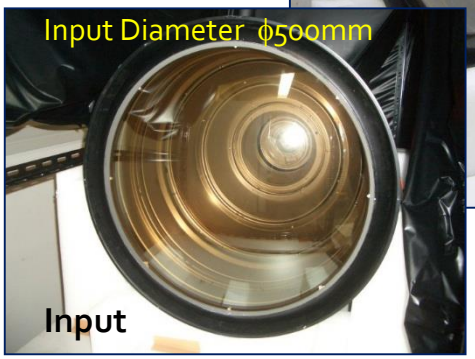
Large: World largest I.I.

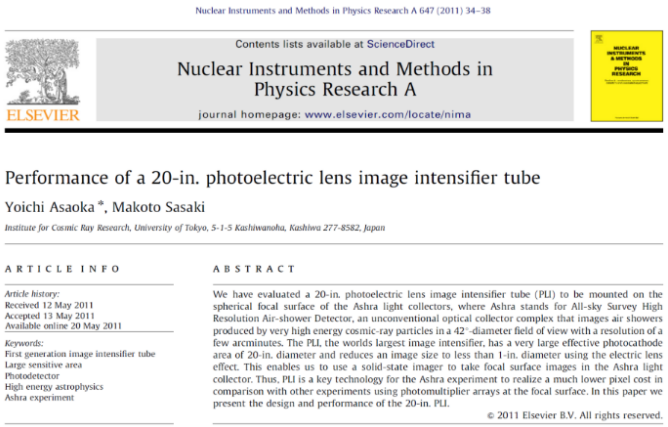
Fine: FWHM = 40-60μm @output window

Stable: No performance degradation for 3.5 years









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

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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.

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

High Pixelation w/ CMOS → Fine Resolution

Improved QE and Precision

IV. Neutrino Telescope Array (NTA)

Goal: The Clear Discovery and Identification of Non-thermal Hadronic Processes 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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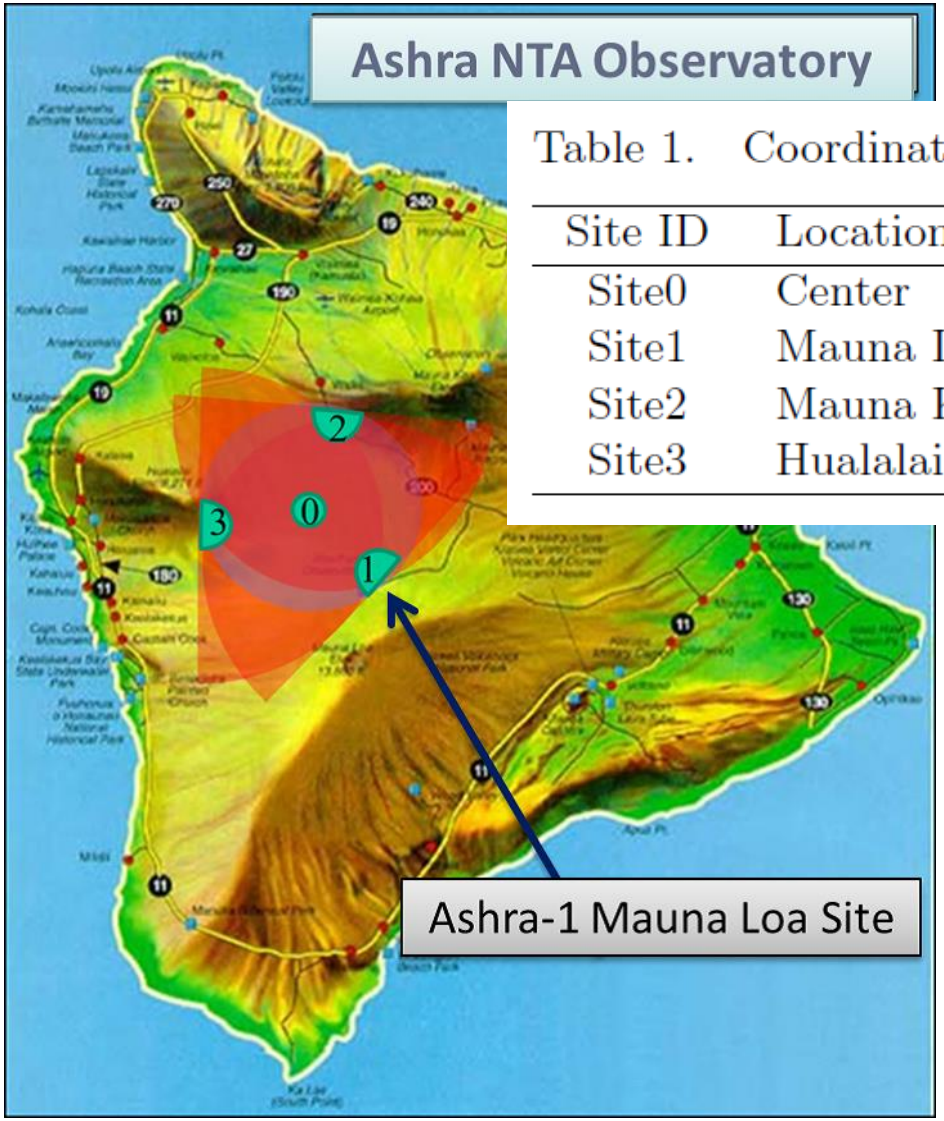
LoI at Hand

1408.6244v2

Towards Initiation Funds & Beyond

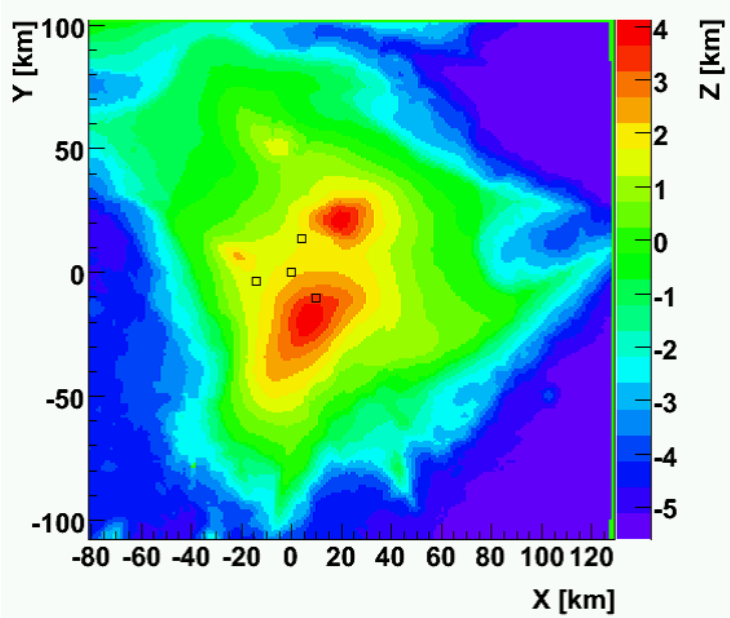
NTA Site Plan



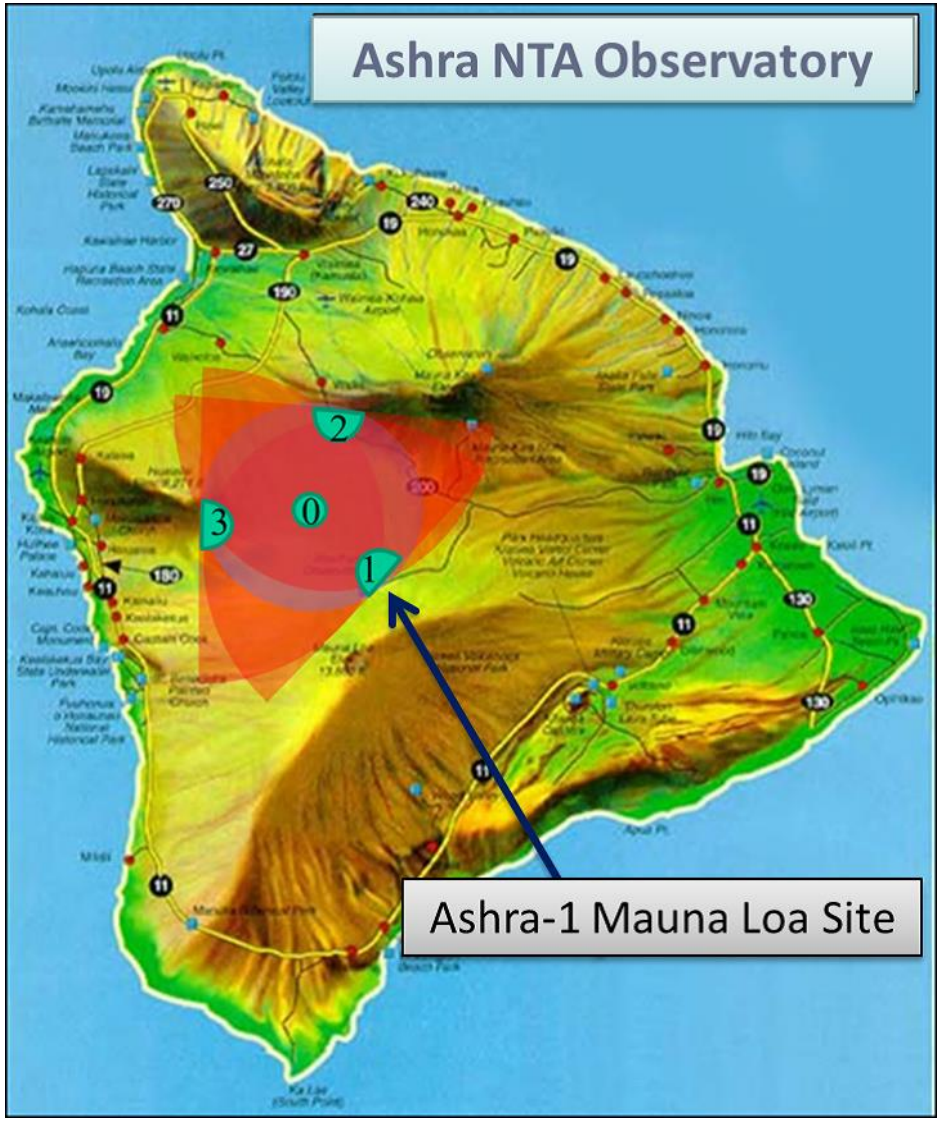
(LOI at Hand)

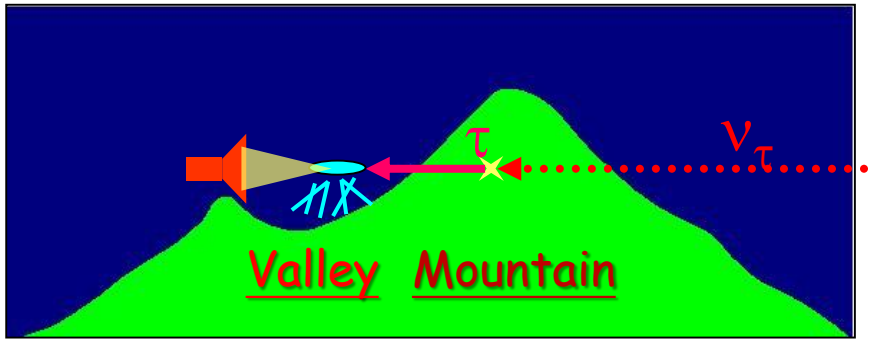
Table 1. Coordinates and FOV coverage of the Ashra NTA sites.

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	$\pi/2$



NTA "Charm" Recap

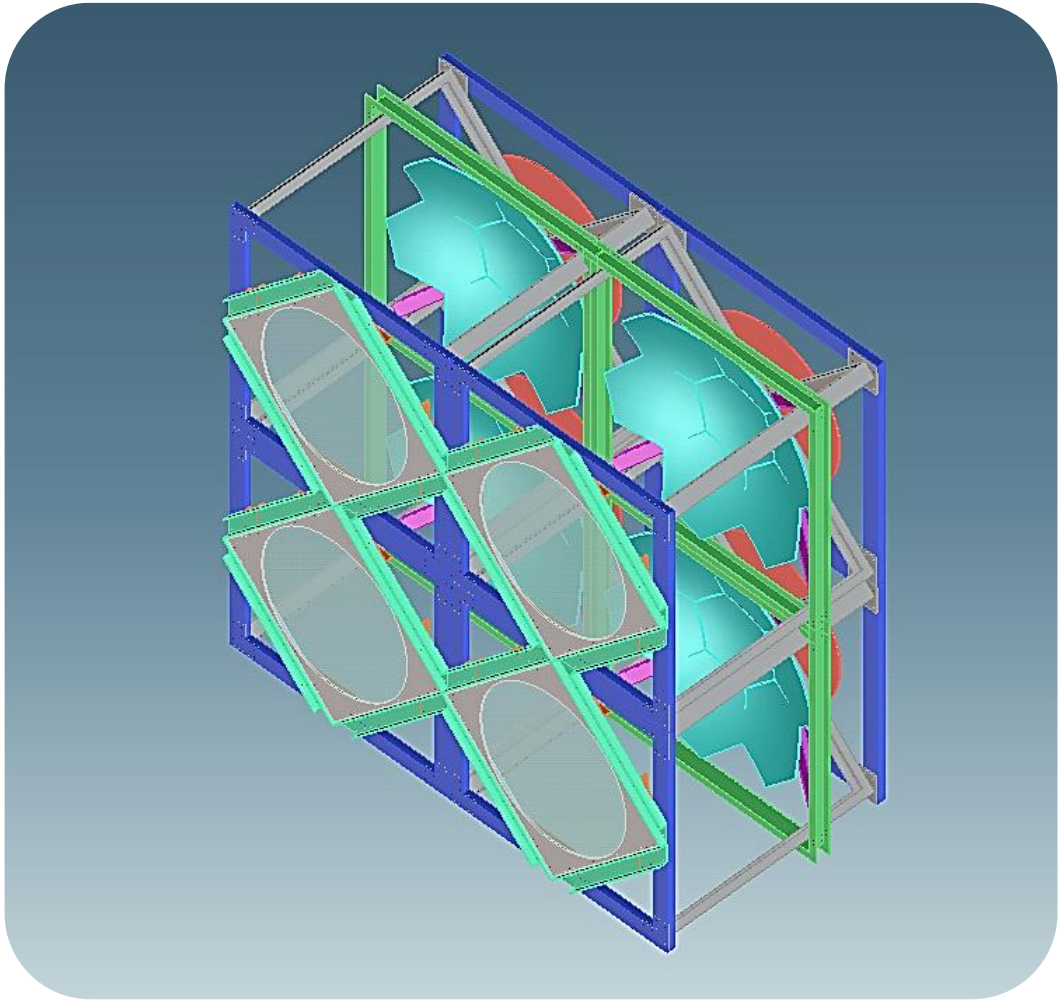




Separation of
Conversion vs **Shower**

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

NTA Dector Unit (DU)



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

12 DU's per π coverage

Need at least 30 DU's for Coverage

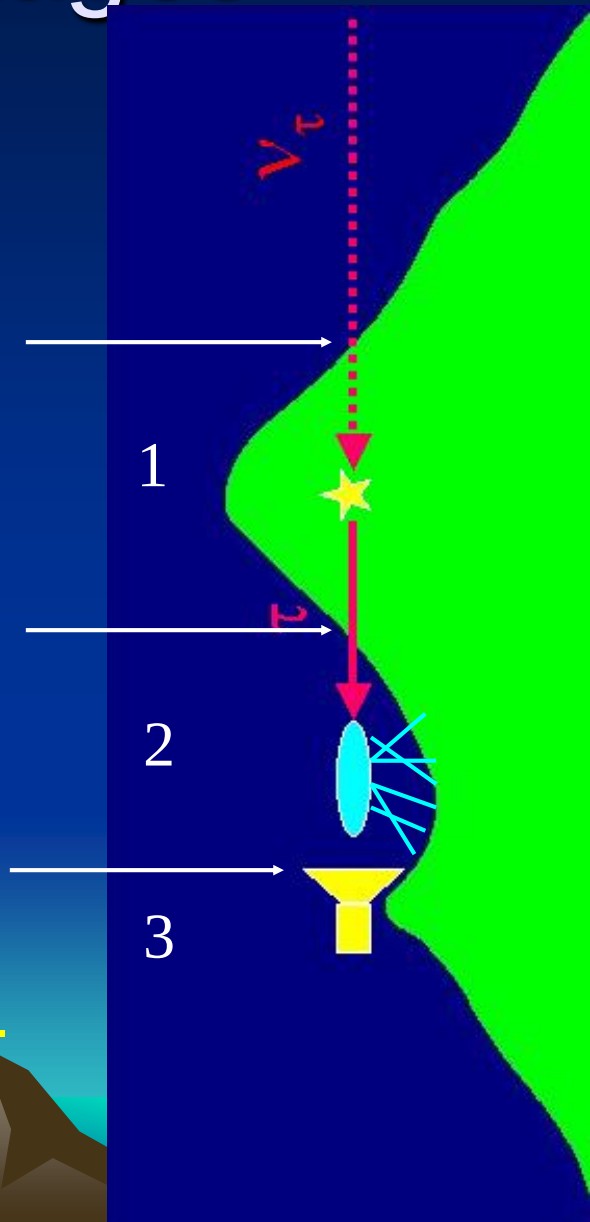
¥¥¥¥

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

Three simulation stages

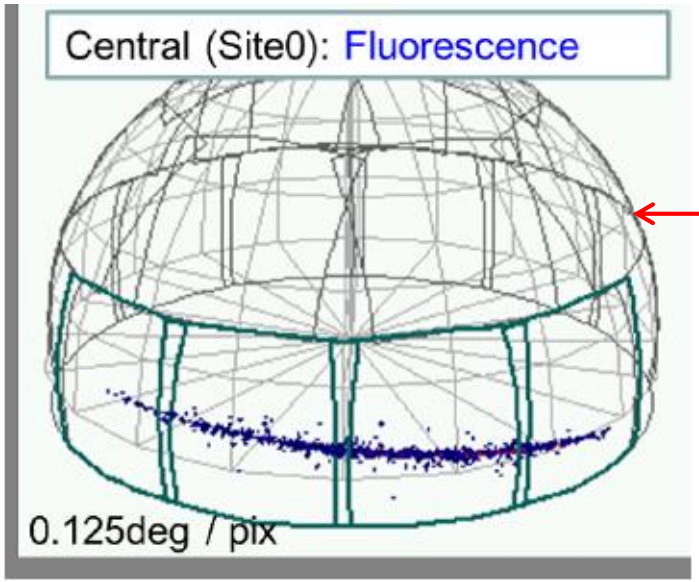
1. Mountain simulation: $\nu_\tau \rightarrow \tau$
   - ν+N cross-section
   - inelasticity
   - energy loss of tau
2. Air shower simulation:
   $\tau \rightarrow$ Cherenkov photons / fluorescence
   - τ decay mode
   - CORSIKA detailed air shower simulation vs. fast simulation
3. Detector performance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

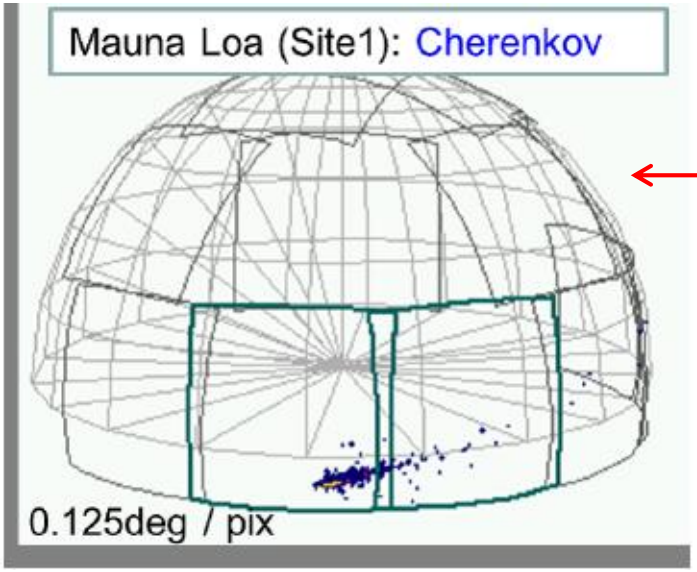
sophisticated "Ashra-1" det.

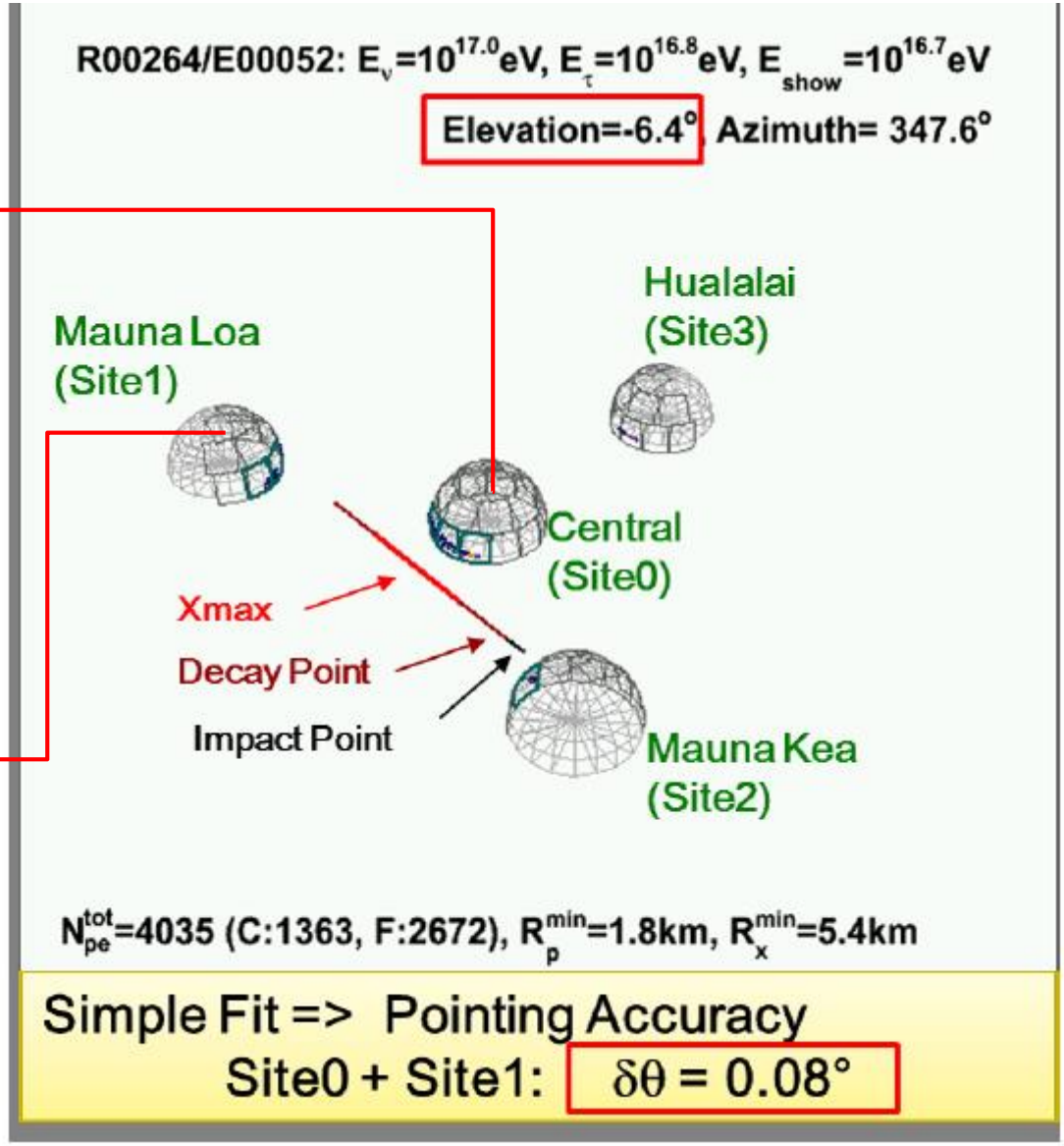


LOI at hand (submitted to PTEP)

NTA Simulated Event: 0.1° Pointing



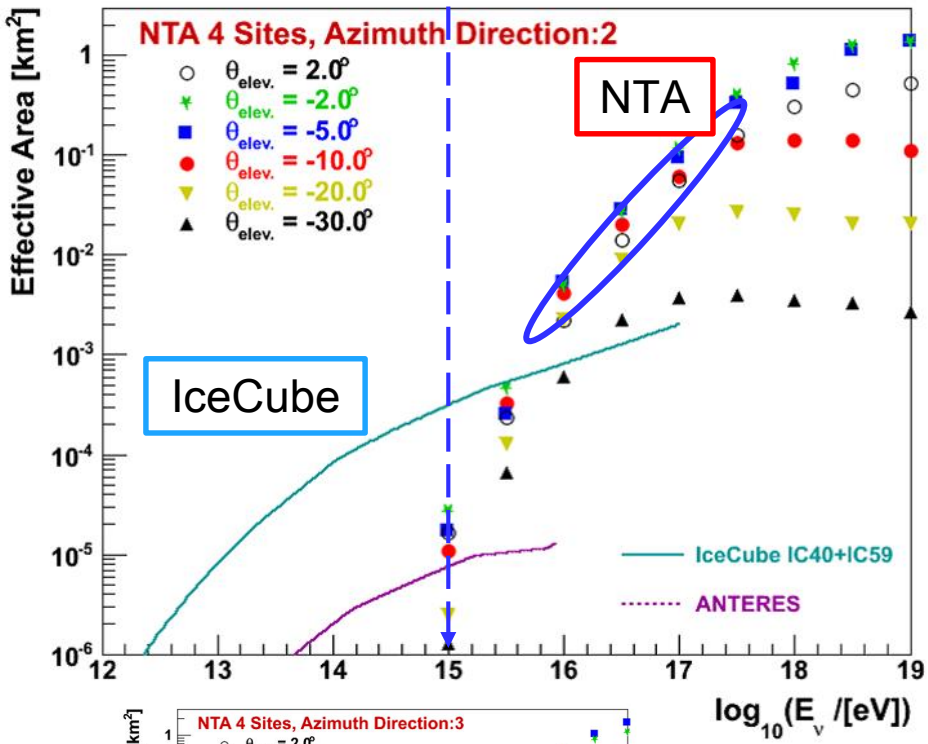


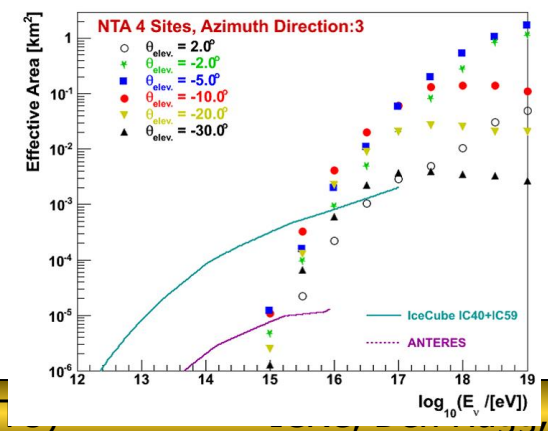


Acceptance: Air & Tau vs Water & Muon

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].

Ernie

E = 1.1 PeV, θ = 23º

Bert

E = 1.0 PeV, θ = 62º

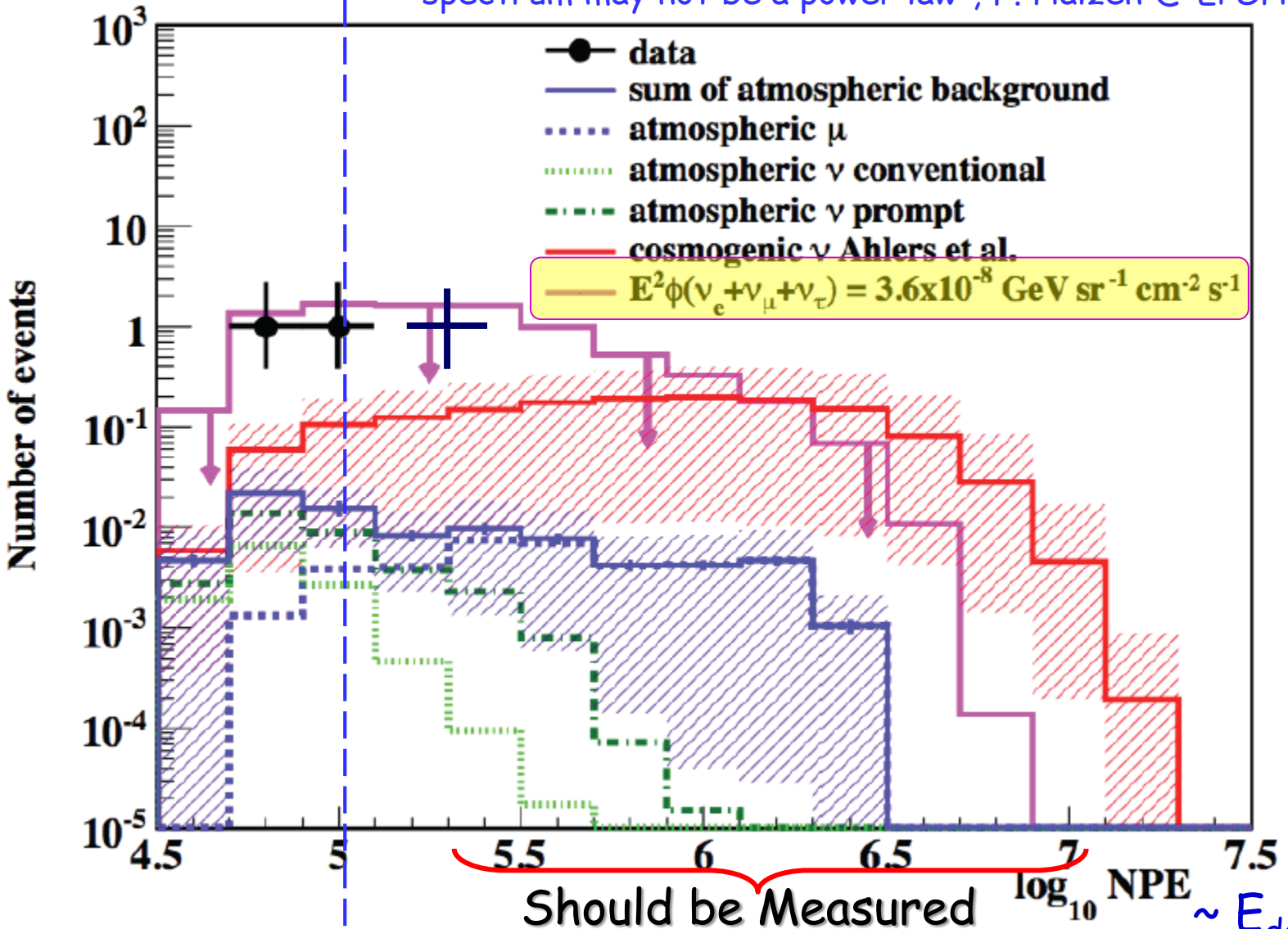
Big Bird

E = 2.0 PeV, θ = 34º

What if one had better Sensitivity and accurate Pointing Info?

IceCube PeV Events

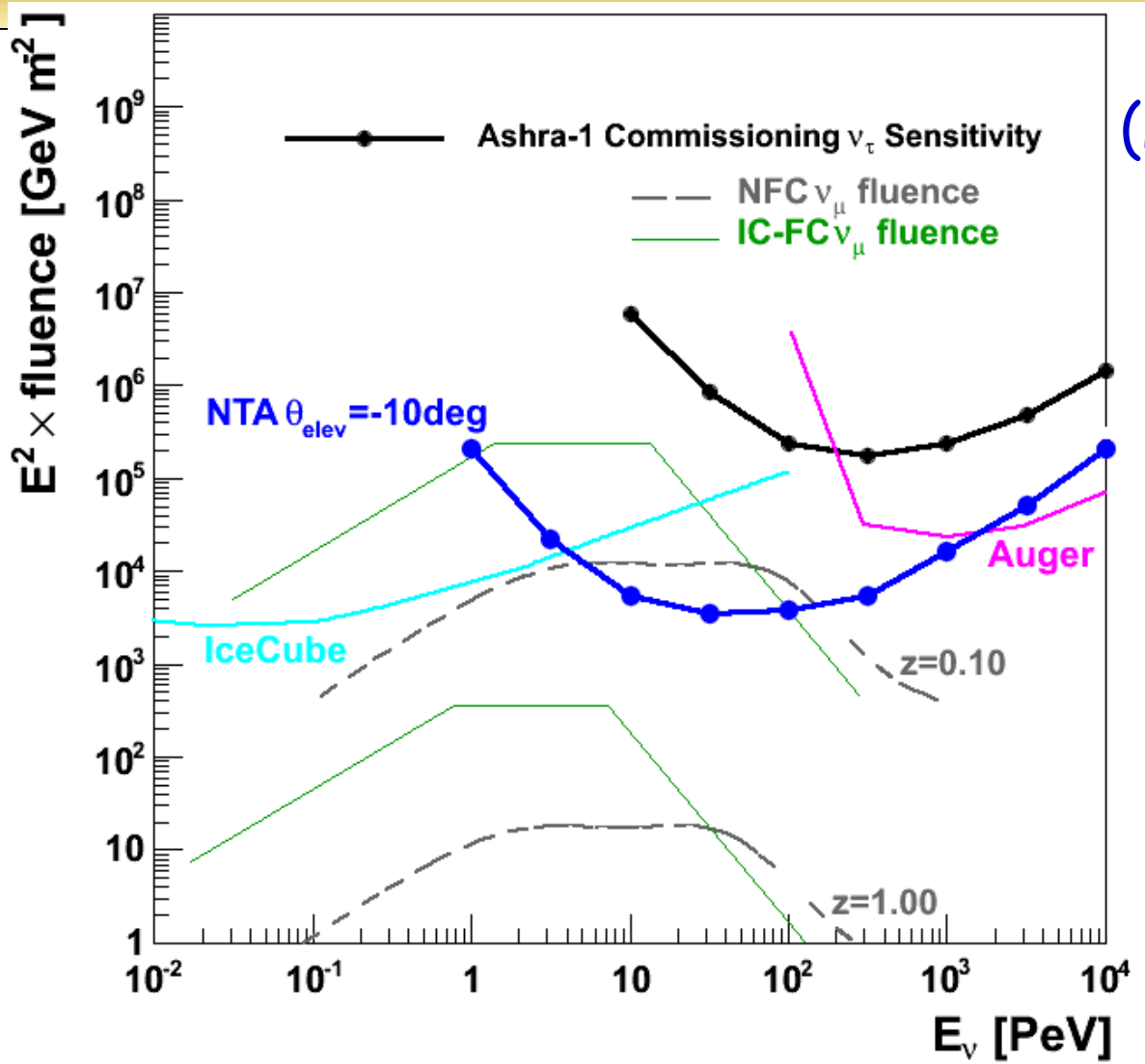
"spectrum may not be a power law", F. Halzen @ EPSHEP, Tue



Should be Measured

~ E_{dep}

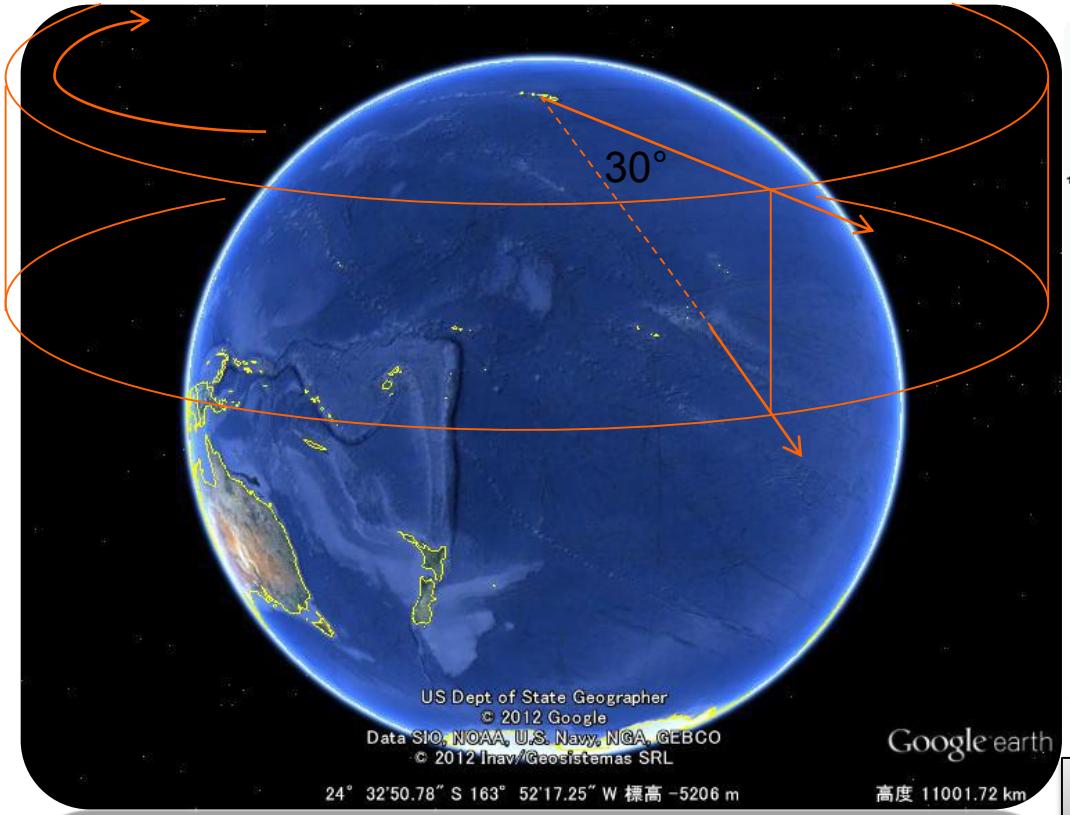
NTA Differential Sensitivities

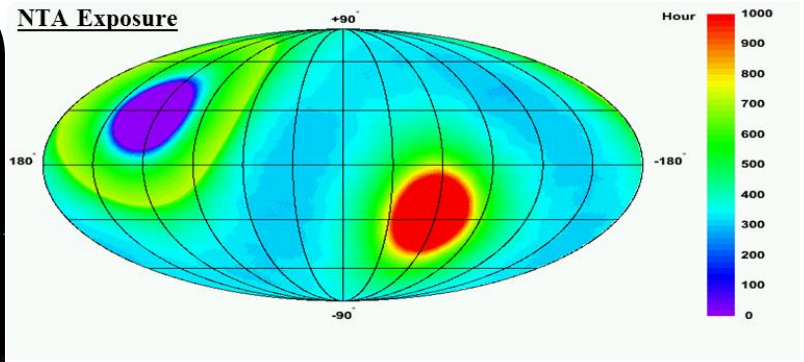


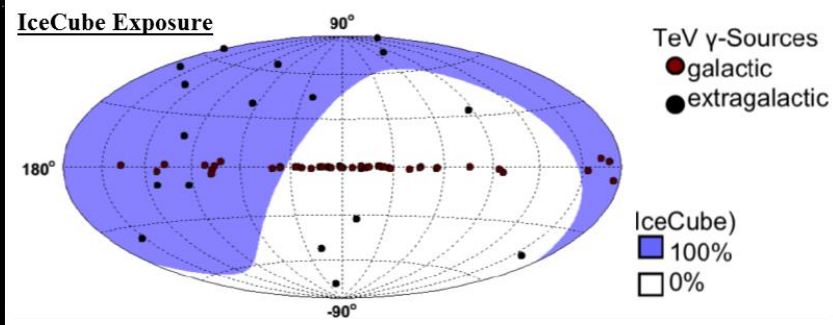
(LOI at hand)

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

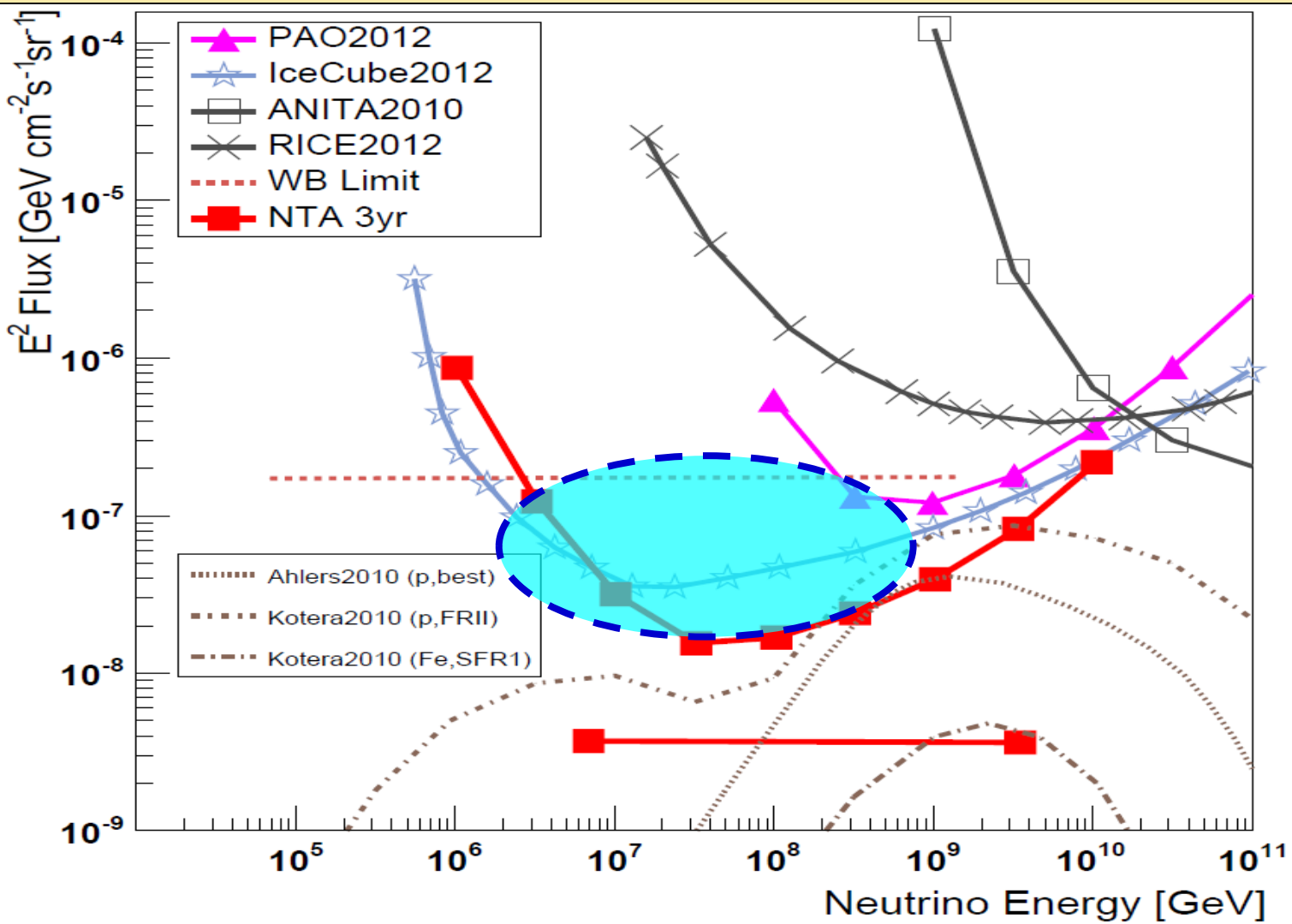
Duty 10-20% from Ashra-1

ν pointing accuracy < 0.2°

FOV Elevation 30° × Azimuth 360°

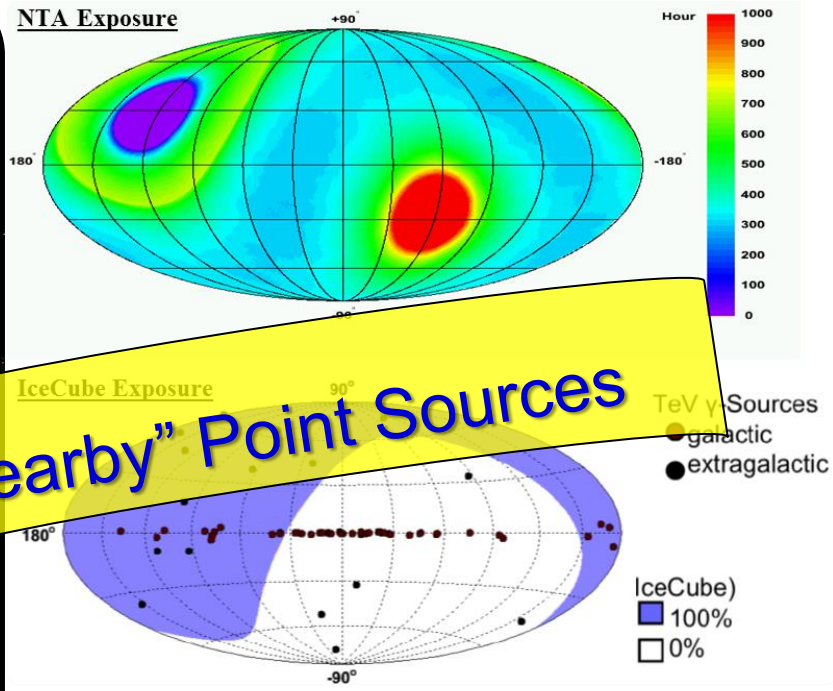
For GRBν
Survey Depth z < 0.15 (2 Glyr)

NTA Diffuse Sensitivity (3 yr)



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

NTA ν_τ Survey Performance

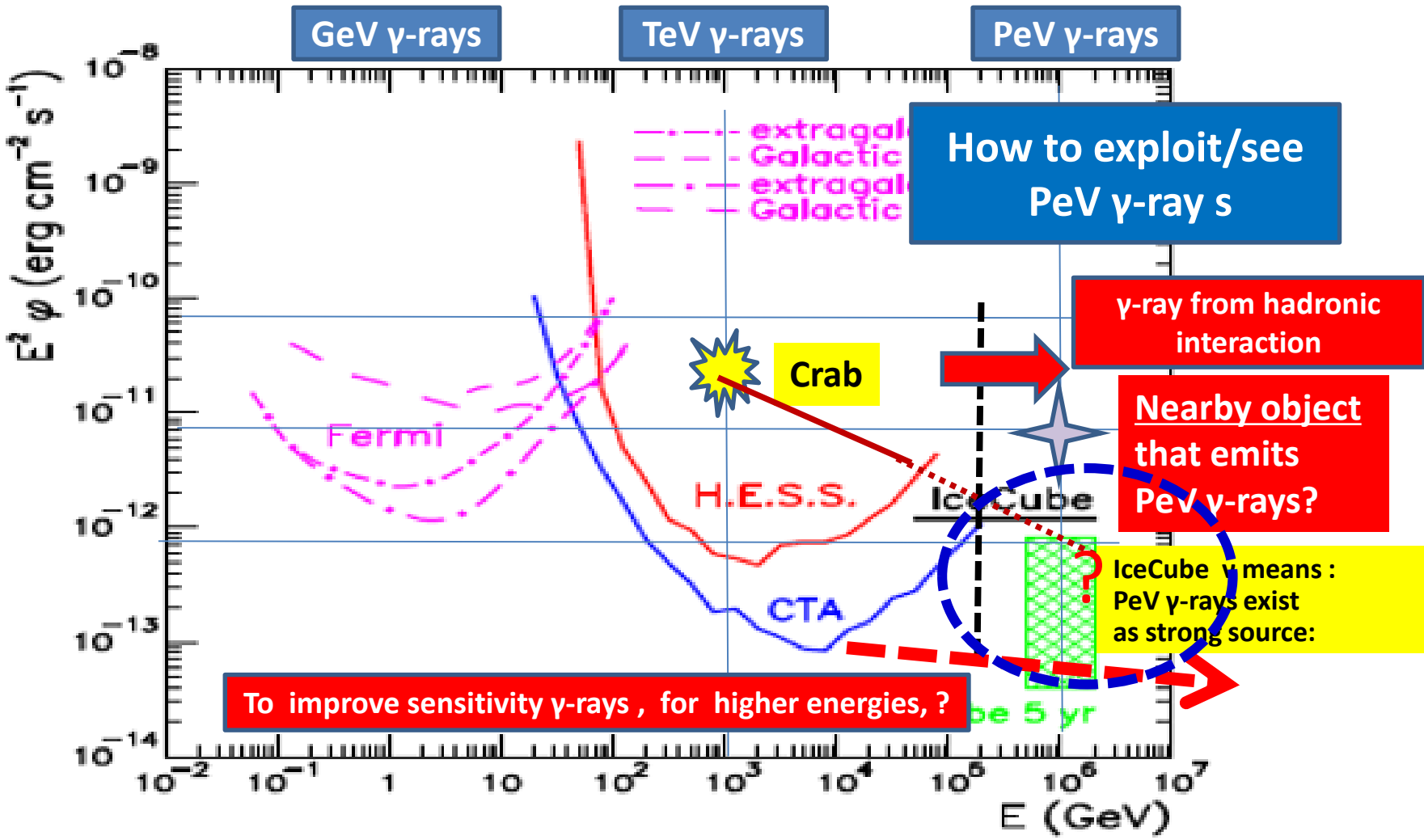


Target is not Diffuse, but "nearby" Point Sources

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)

Shed Light on PeV Gamma?

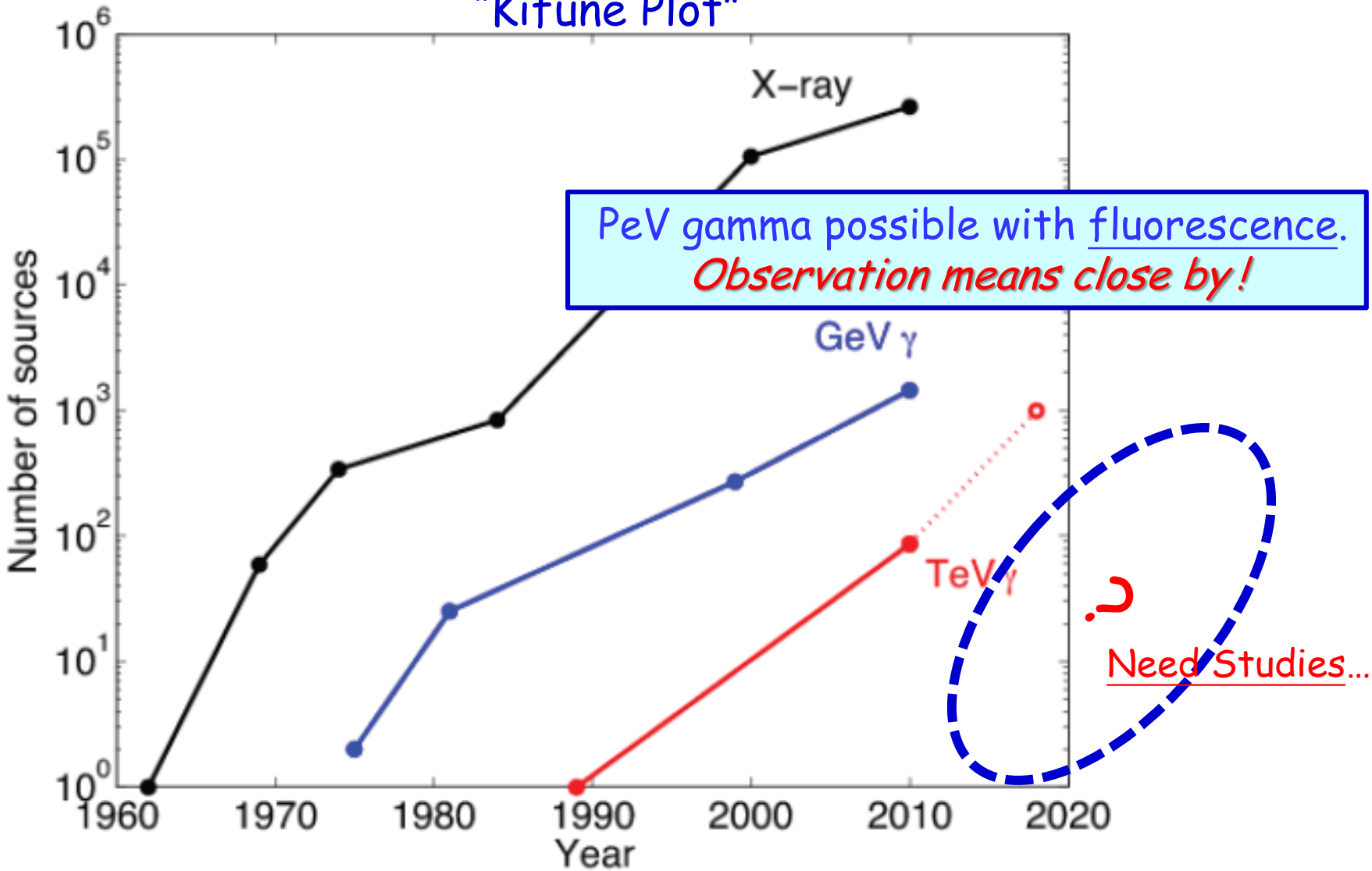


Courtesy T. Kifune.

LA. Anchordoqui et al./Journal of High Energy Astrophysics 1-2 (2014) 1-30.

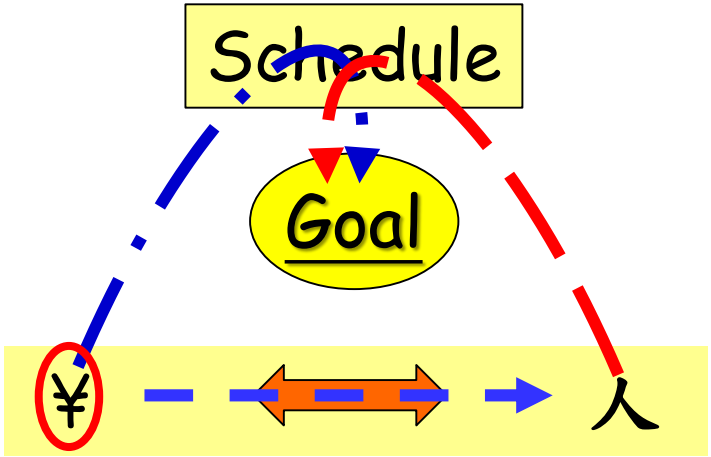
Shed Light on PeV Gamma?

"Kifune Plot"



PeV gamma possible with fluorescence.
Observation means close by!

V. Towards a New Collaboration



40-50M USD

NTA Projected: ~ 7 countries

Call for Collaboration

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

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.

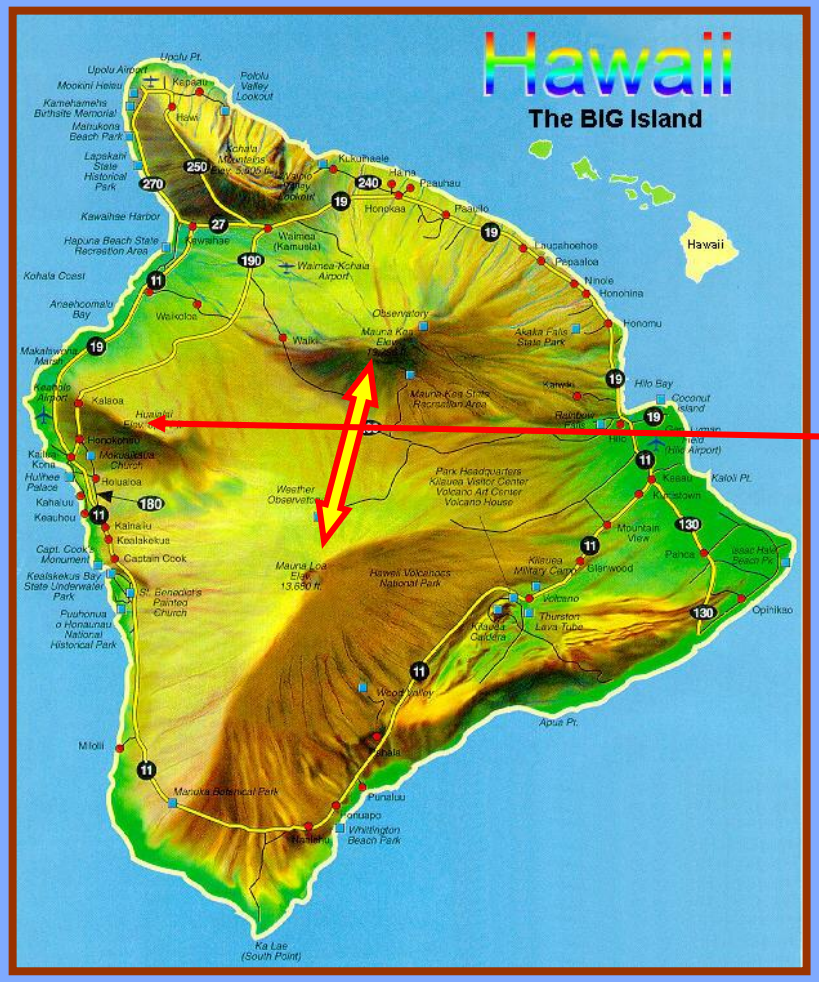
Call for Collaboration

Let's Go to Hawaii !!

- NTA lunch "forum"
  1 Aug 12:45 @ Murray

You Are Welcome!

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

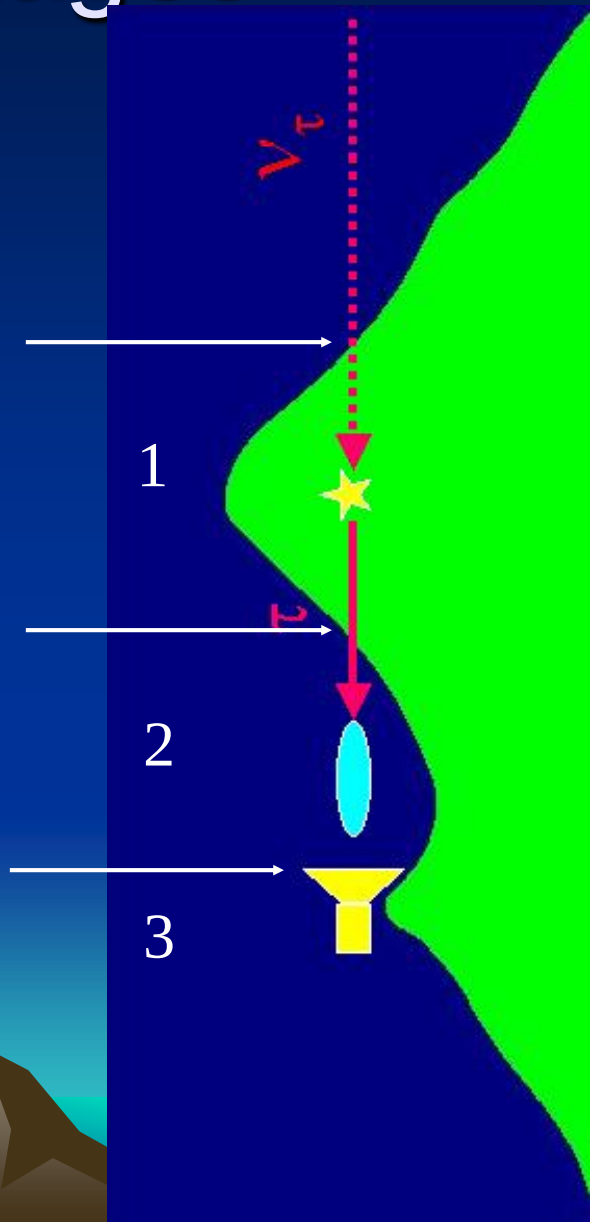
GWS Hou & MA Huang, astro-ph/0204145

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

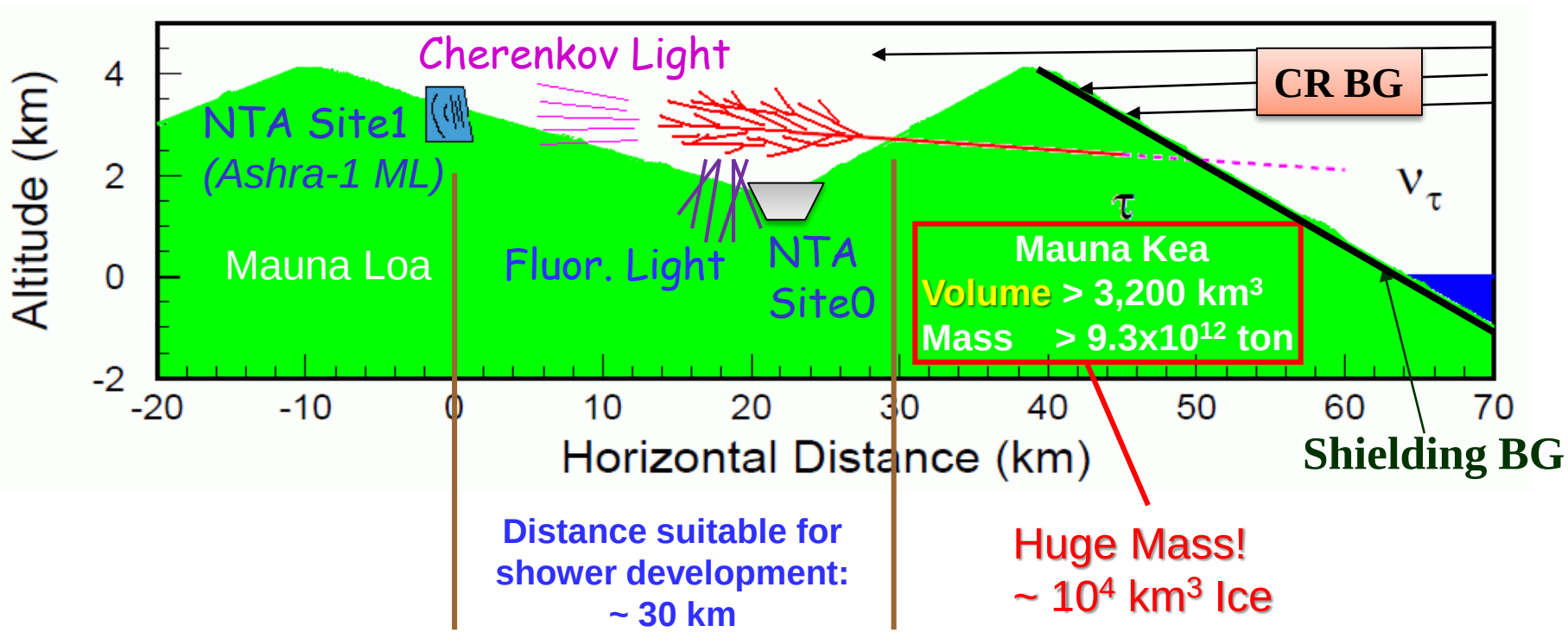


NuTel

- NuTel is the first experiment *dedicated* to earth skimming for τ appearance, but was terminated ...
- 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

Earth-skimming τ Shower Imaging Method

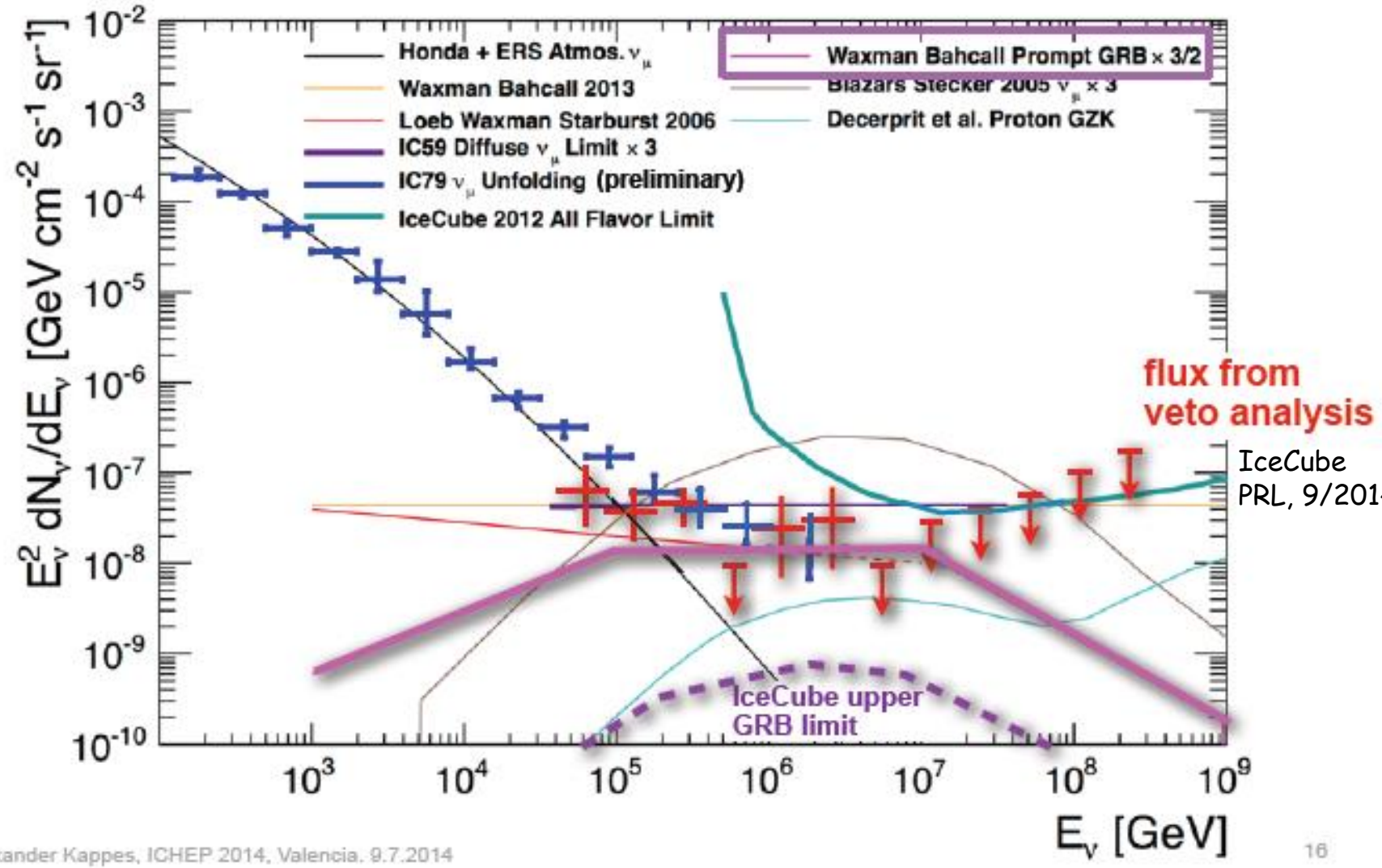
reminder



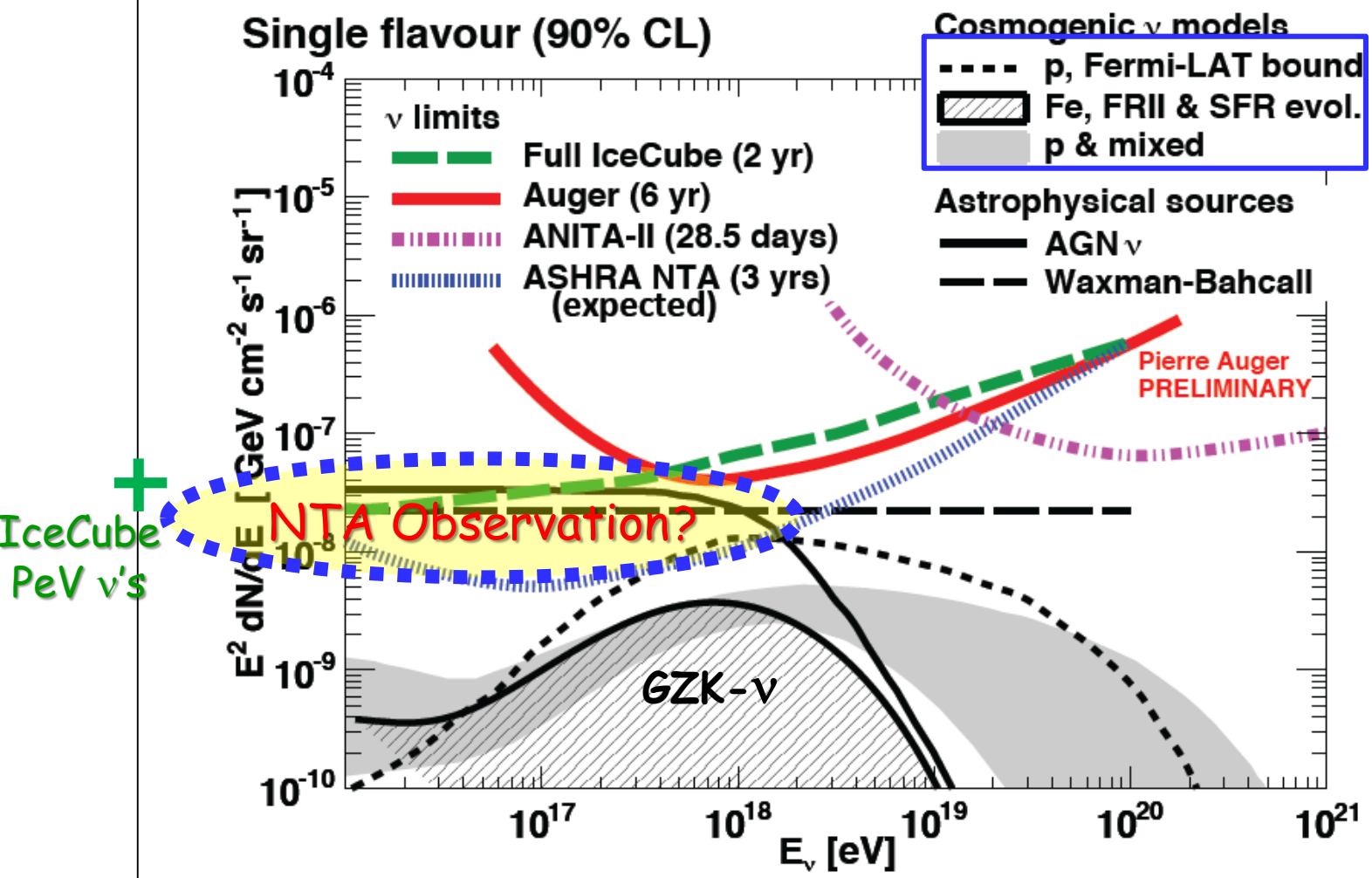
Ashra-1 already demonstrated this method !

ApJ, 736 (2011) L12

Source candidates



Differential limits to diffuse flux of UHEν



NTA Organization

ICECUBE SOUTH POLE NEUTRINO OBSERVATORY

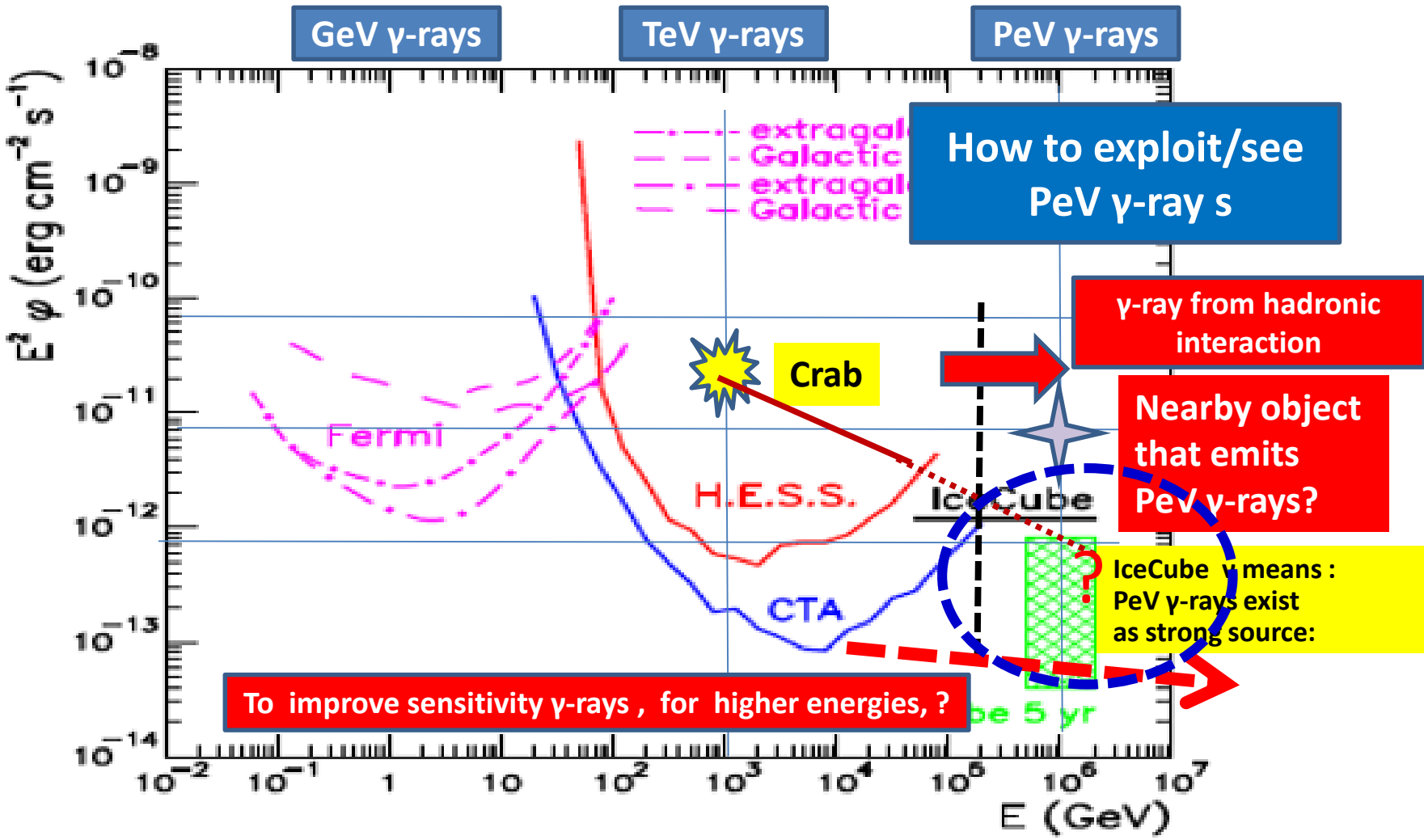
250 people, 39 institutions, 11 countries

Pierre Auger Observatory
the universe's highest energy particles

500 people, 18 countries

NTA Projected: $\lesssim$ 10 countries

Shed Light on PeV Gamma?



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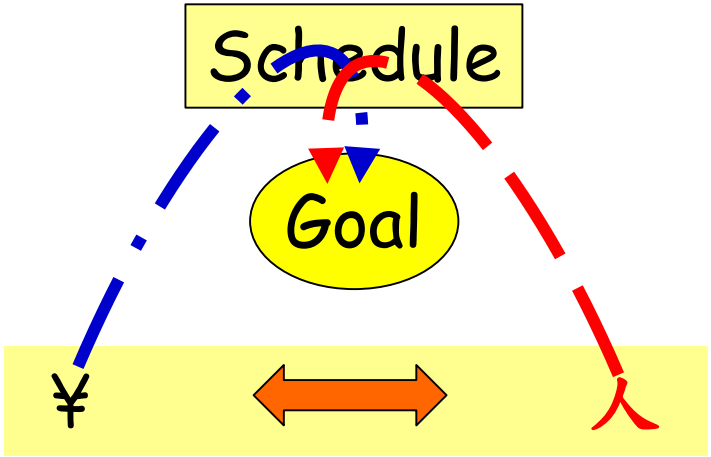
NTA Organization



NTA Projected: ~ 7-ELEVEN countries

Call for Collaboration

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

Initial Meeting 11/2012

Near-term Timeline } LOI at hand (submitted 2014) ⇒ VHEPA2015 (April) Call for Collaboration ⇒ Community Disc.? ICRC 2015

funding ~ 2 yrs; construction ~ 5 yrs

use Ashra-1 for test/sci