Ashra

Makoto SASAKI

ICRR External Review
2013.01.16

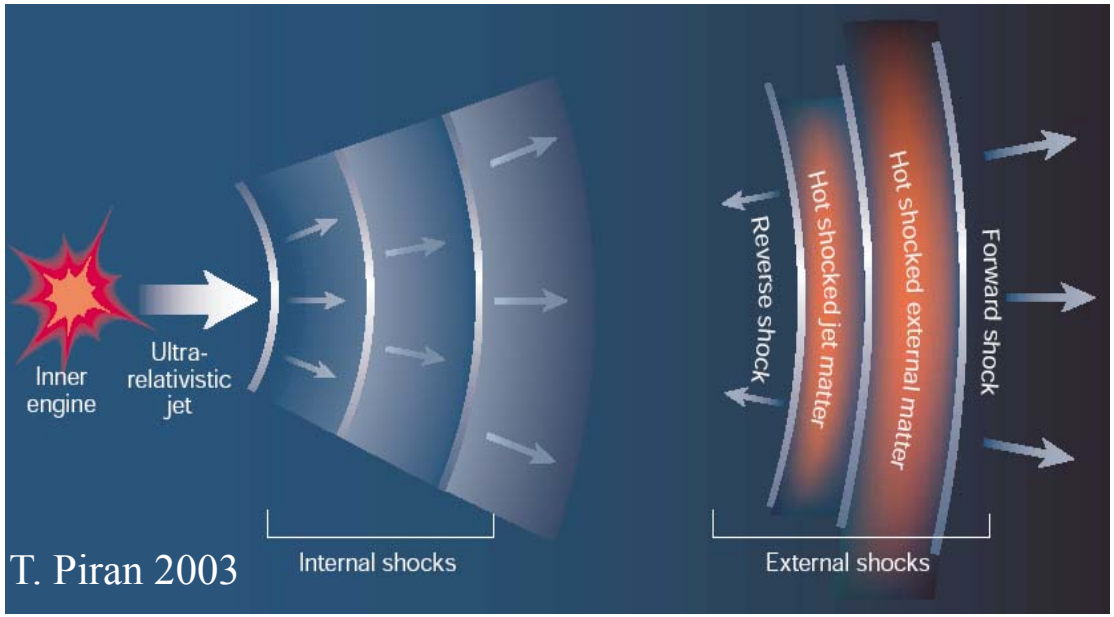
Outline

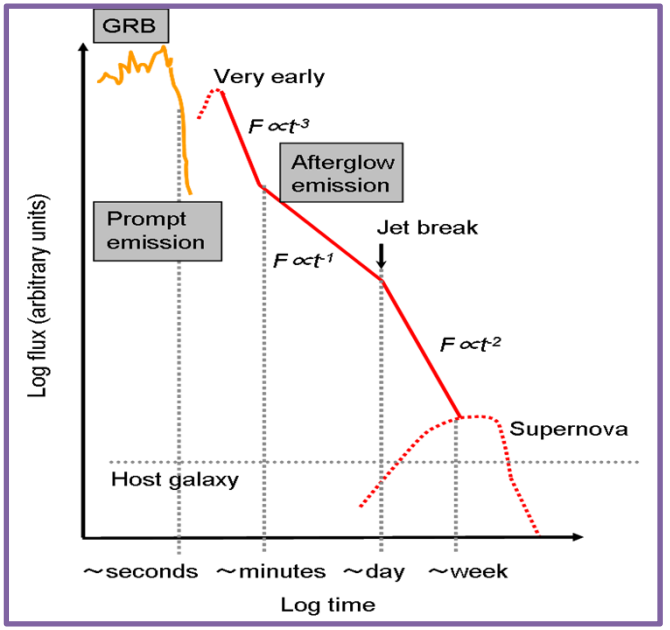
- Scientific Goal and Objectives
- Developments of Ashra-1 Detector
- Observation Status
- Collaboration
- Education Activities
- Future Prospects

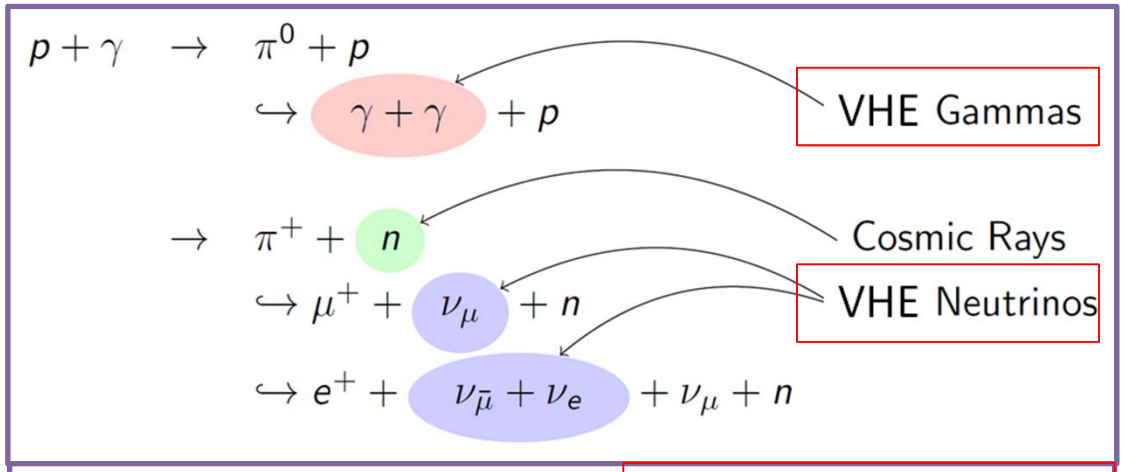
Scientific Goal

- "Multi-particle Astronomy"
  - Multiple probes into violent astro. objects (e.g. GRB)
    - PeV-EeV ν: hadronic model => ES τ shower
    - TeV-PeV γ: leptonic model => Atmospheric Cherenkov
    - Optical : reverse shock => Optical transient
  - Distinguishable physics identification on phenomena
  - Inescapable evidence of p acceleration i.e. "EHECR origin"
  - Required functions of detector
    - Wider field of view: toward all-sky coverage
    - Higher resolution: toward arc min resolution
    - Multiple self-trigger: opt./Cheren./fluo. simultaneous trigger

“Standard Model of GRB”: Internal External Shock



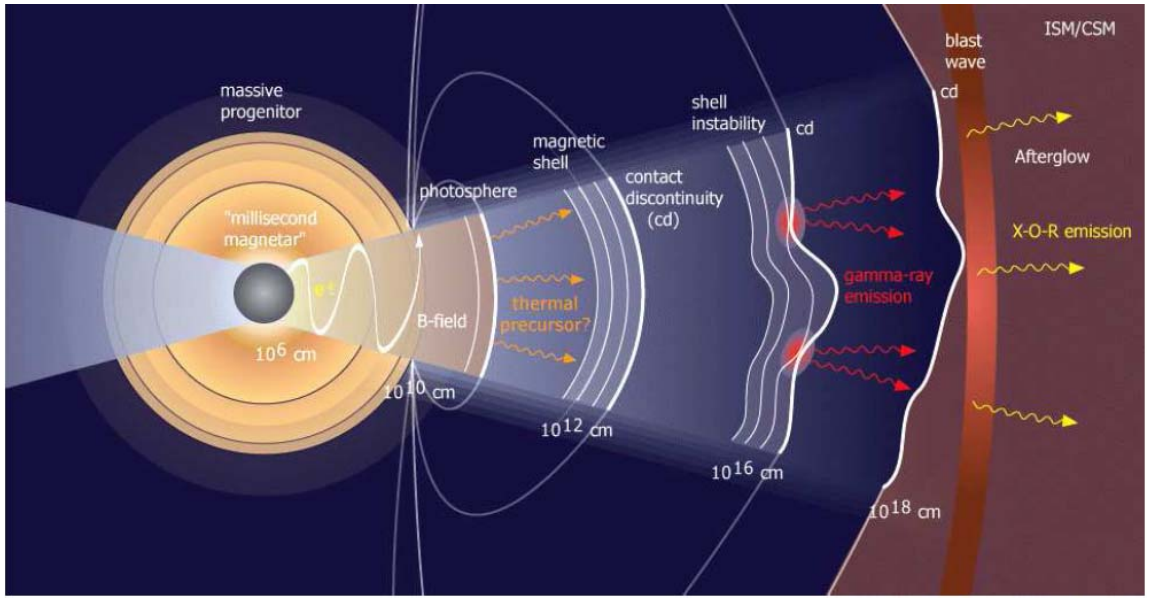




External Reverse Shock => Prompt Optical Flash

Ashra

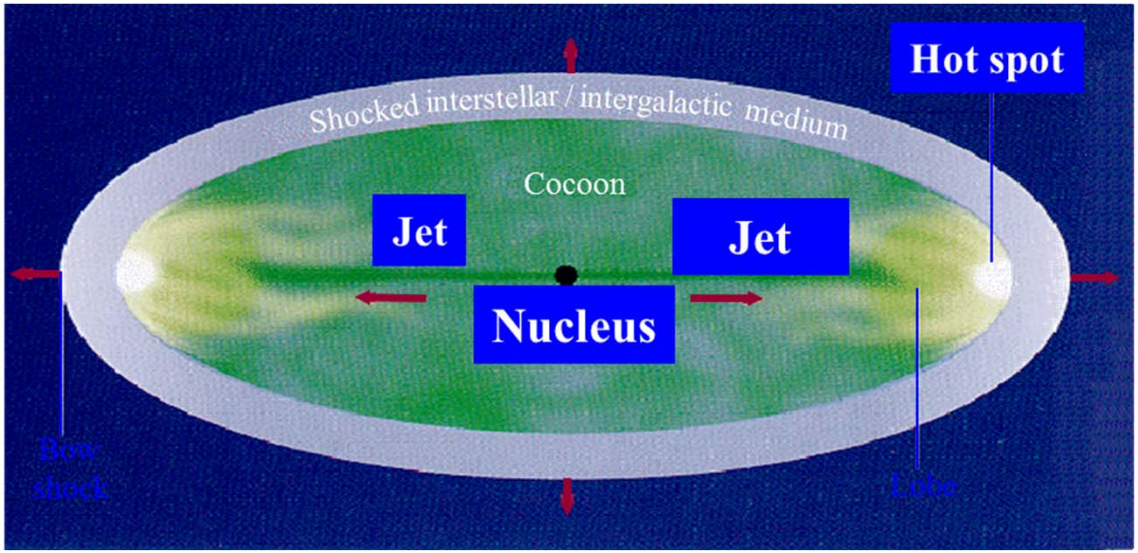
“Non-Standard Model of GRB”: EMM and Cocoon Model



EMM
(Lyutikov, Blandford, arXiv:astro-ph/0312347)

No EHECR => VHE ν

No Optical Flash



Cocoon Model
(Zhang,Woozley,Heger, ApJ 608: 365-377,2004)

Optically thick for γ
Low Luminosity of γ
Nearby X-ray flash?
Nearby VHE ν ?

Objects

Extragalactic

- Gamma-ray Bursts
- Flares of Active Galactic Nuclei
- Cosmogenic (GZK) ν

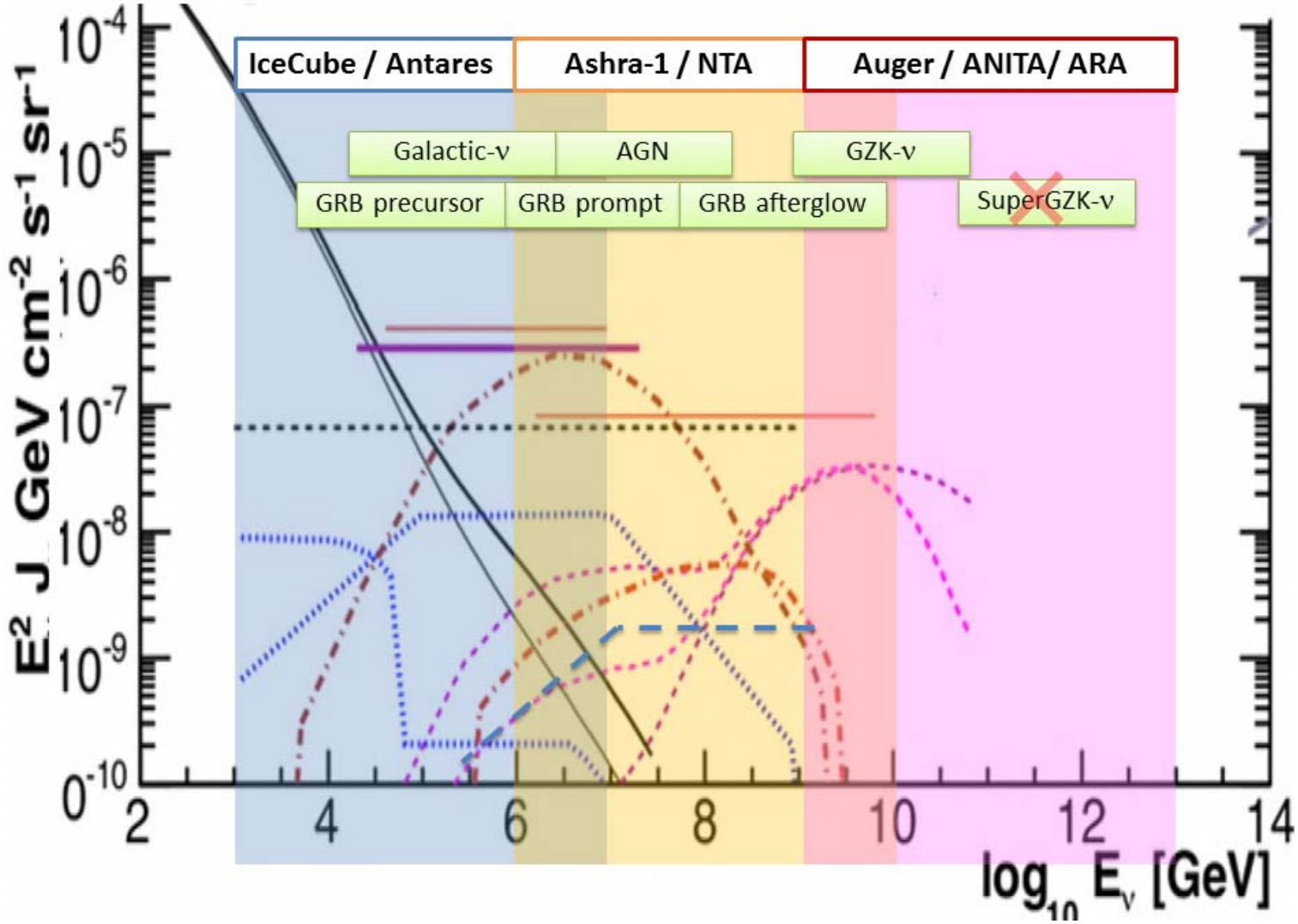
Galactic

- Soft Gamma-ray Repeaters
- Anomalous X-ray Pulsars
- Microquasars

Optical Thick LL Objects (VHE ν only)

- Nearby LL GRB
- Cocoon X-ray flash
- ….

ν−Objects, Experiments, Energy

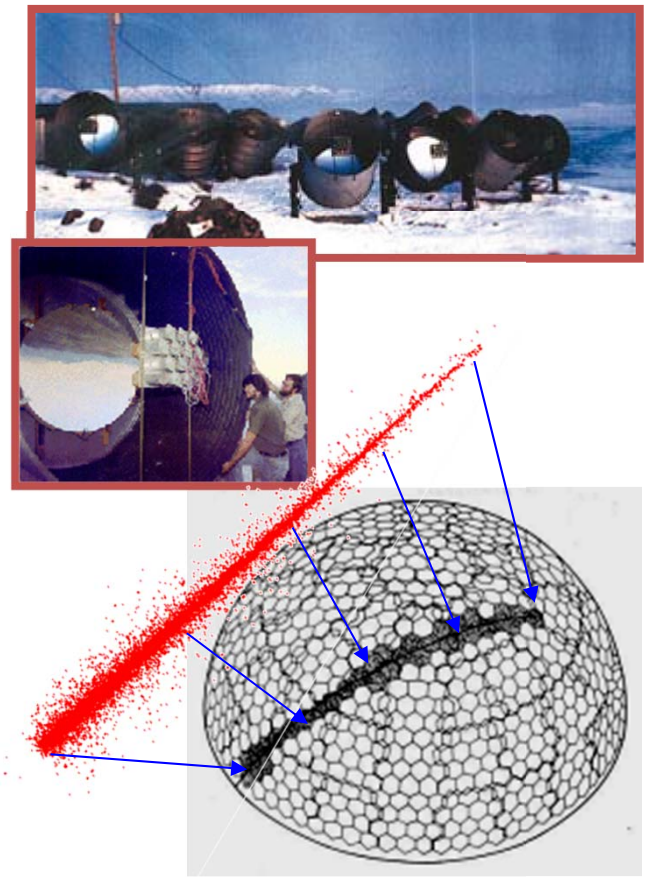


PeV-EeV n ⇒No Atm-ν＆p Accelerator ⇒Clear Evidence

Optical Air-shower Detector

Progress of Resolution × FOV

Fly's Eye (1981-1993)



4deg/pix × All-sky

P M T

HiRes (1994-2006)

1deg/pix × 28deg

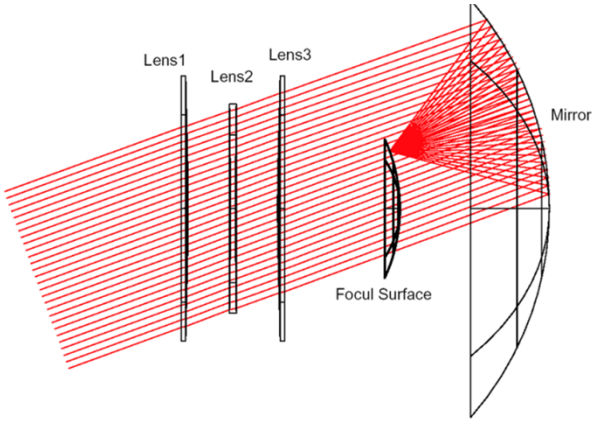
P M T

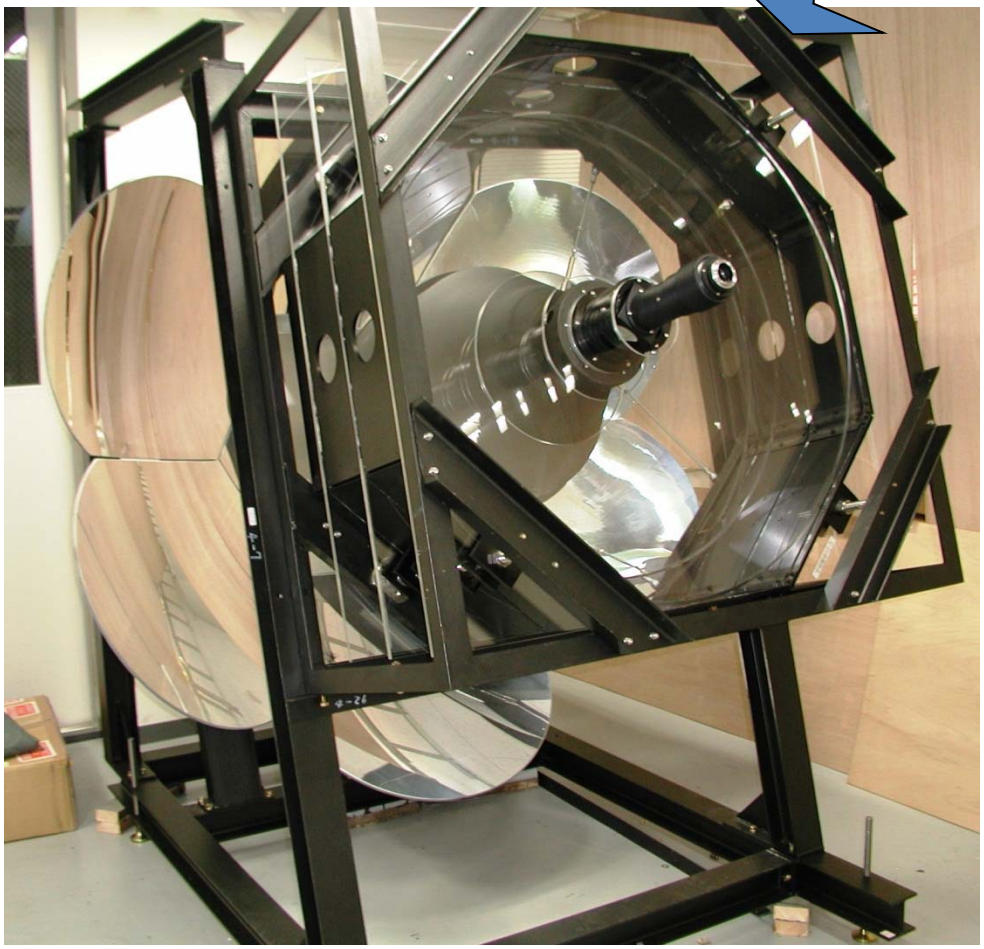
Ashra-1

1.2min/pix × All-sky

Image Tube＋CMOS

Light Collector



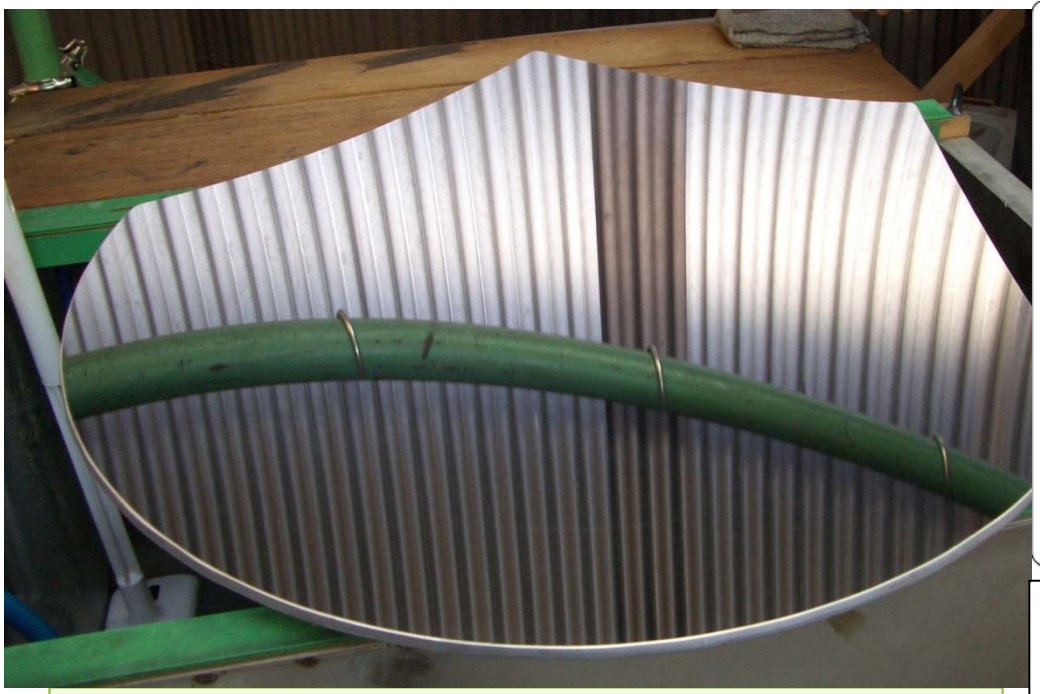


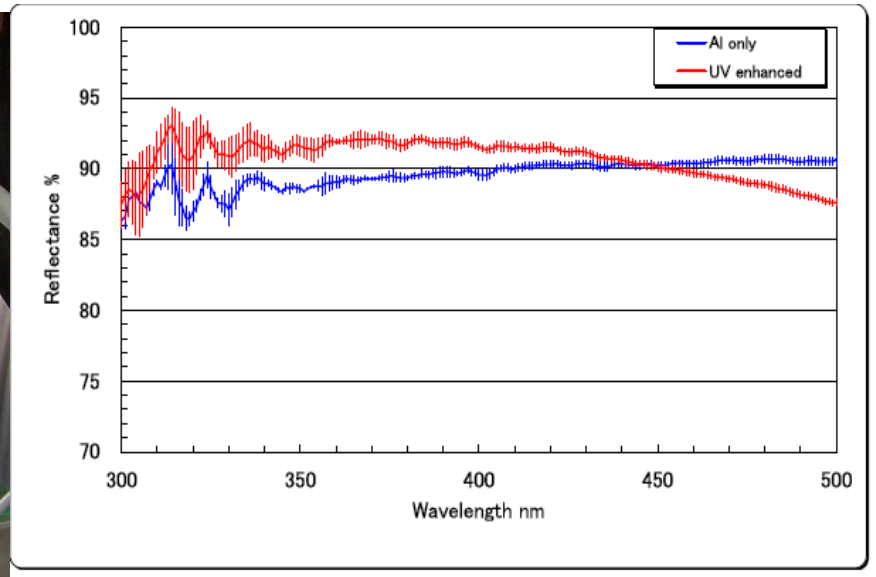
- Optics:
  - **Modified Baker-Nunn**
- Components:
  - **Correcting lens** (1.0~1.2mϕ) with 3 acrylic cut plates
  - **Spherical mirror** (2.2mϕ) with 7 curved glass plates on adjustable tables.
  - **Photoelectric lens IT** (0.5mϕ) on focal sphere suspended with Stewart platform mechanism
  - **Mount structure** with steel channels for easy assembly

=> arcmin. resolution over 42deg FOV

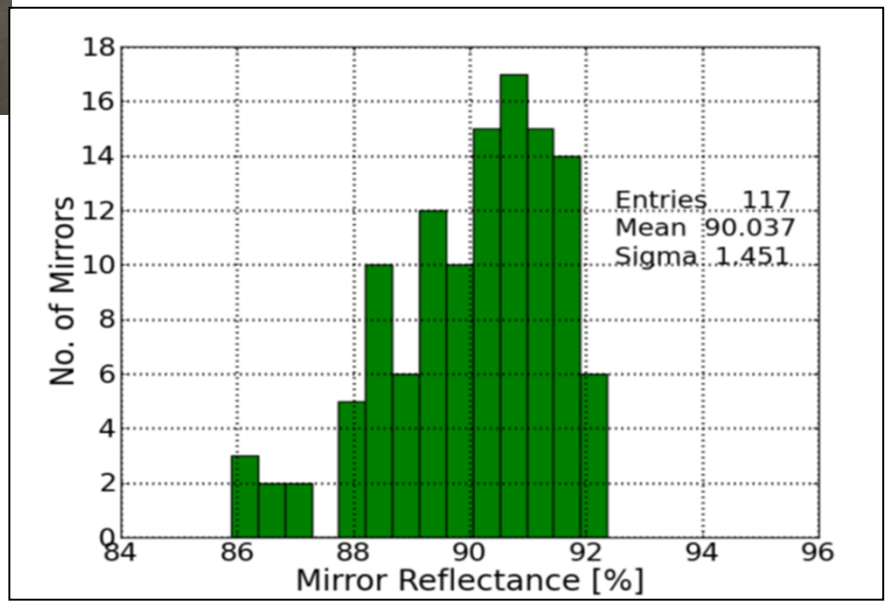
=> Affordably cost-effective

Segment Mirror

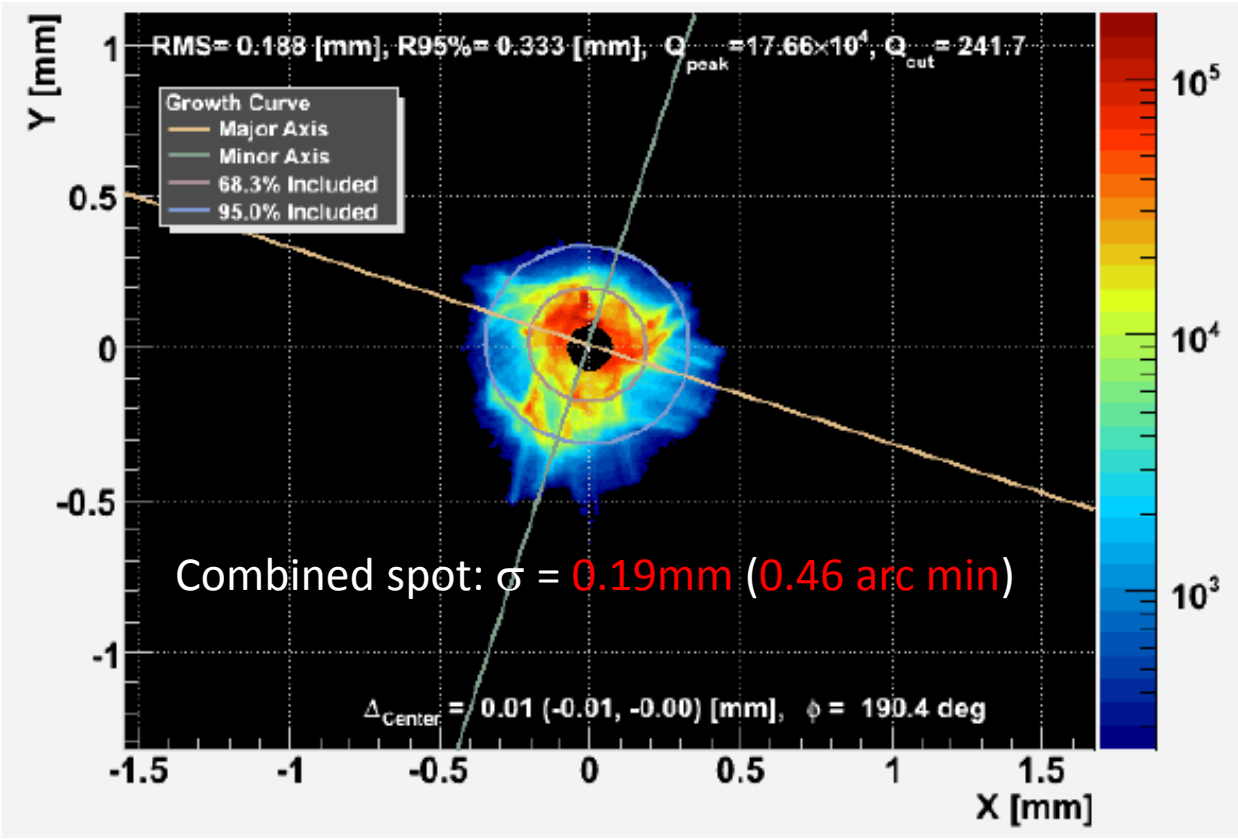




1. Float glass curved mirror:
   ϕ850 x t8 Cut => 10 kg / seg . piece
   Total 7seg / LC => ϕ2.2m & ~70kg.
2. Evaporation of Al + Al_2O_3 coating
   => UV enhanced
3. On-site test just before installation:
   all segments (~200 pieces) OK:
   >85% @ 470nm => >88% @ <400nm



Mirror Adjustment



- Installation of Segment Mirror on Mount @ Ashra Mauna Loa Site

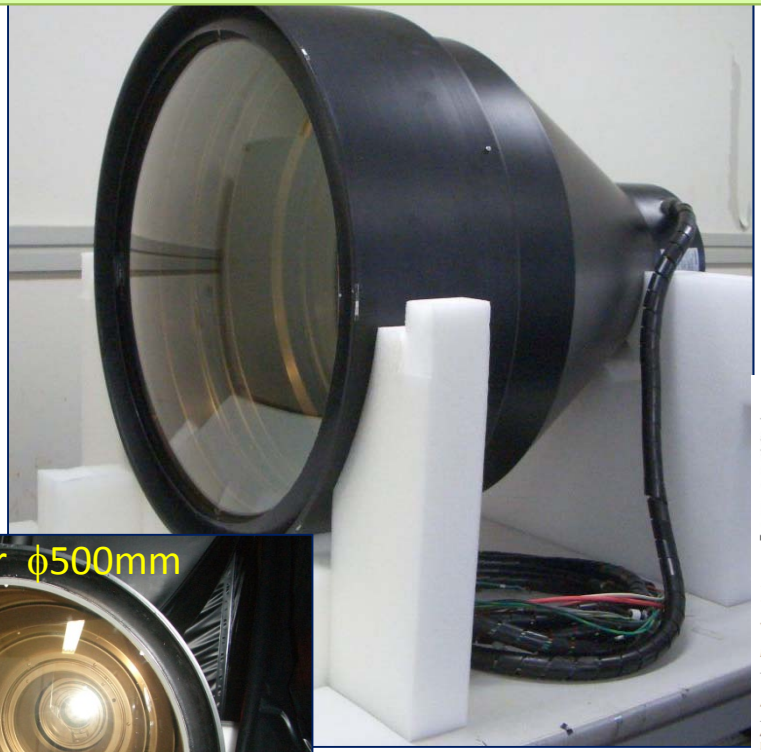
- Total spot size measured after adjusting 6 segment mirrors on mount:
  => Combined spot σ = 0.19mm
  => corresponding to 0.46 arc min

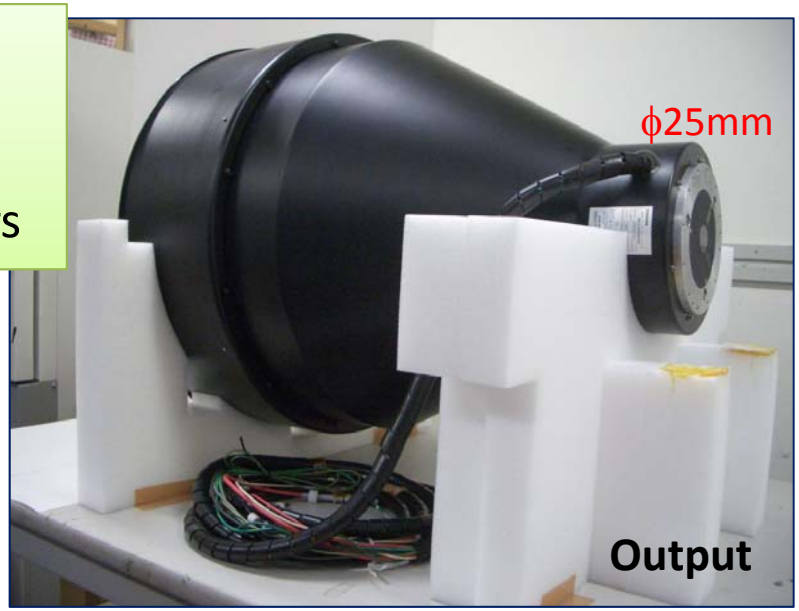
20” Photoelectric Lens Imaging Tube (PLI)

Large : World largest I.I.

Fine : FWHM = 40-60μm @output window

Stable: No performance degradation for 2 years





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

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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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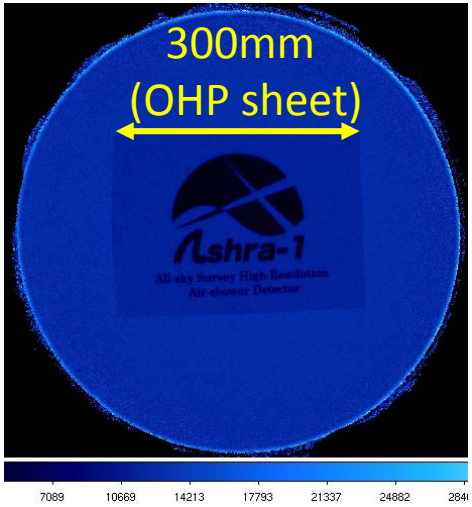
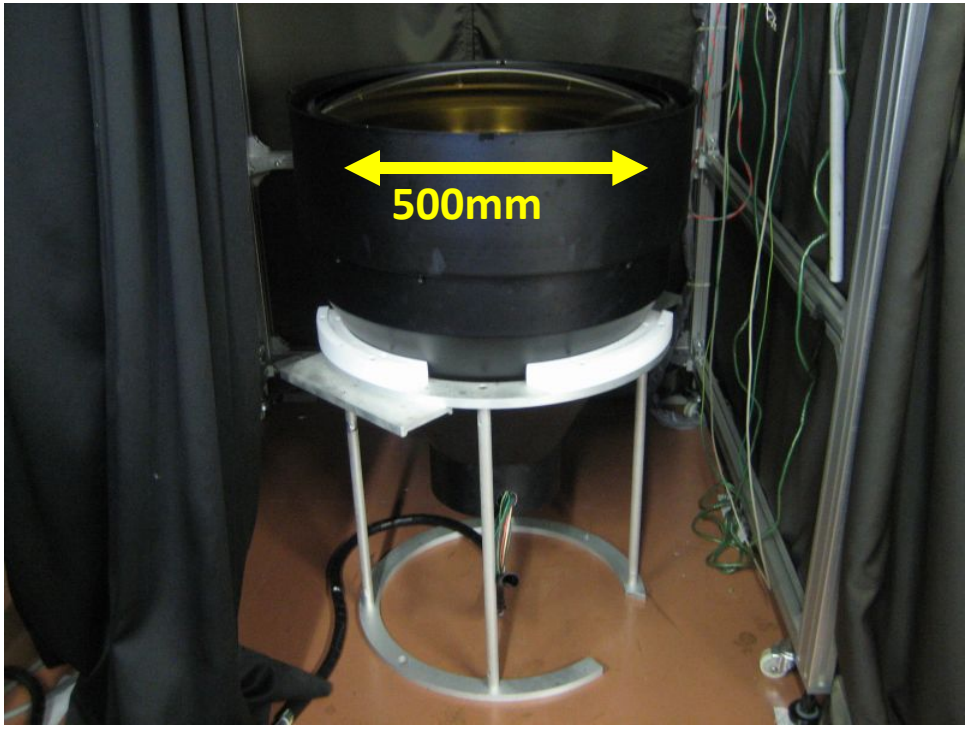
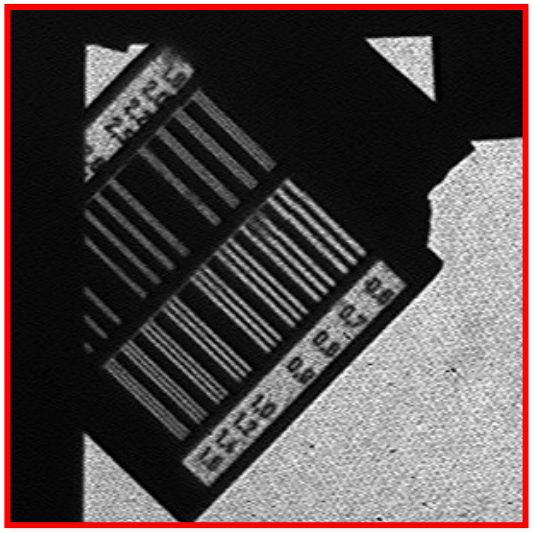
Imaging Test of 20” PLI

Output Image Example





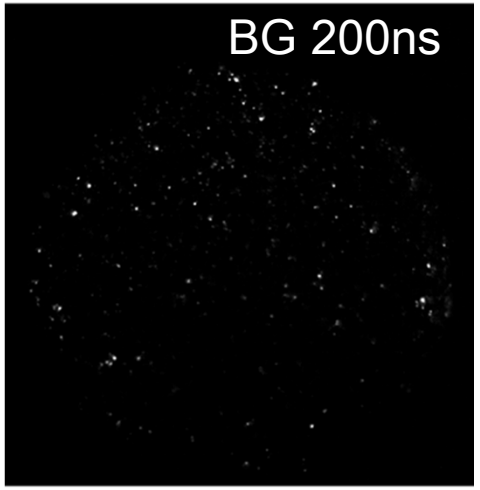


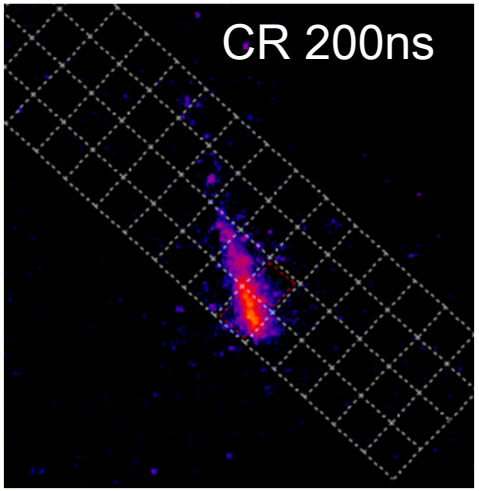
Imaging Resolution Chart on Input Window

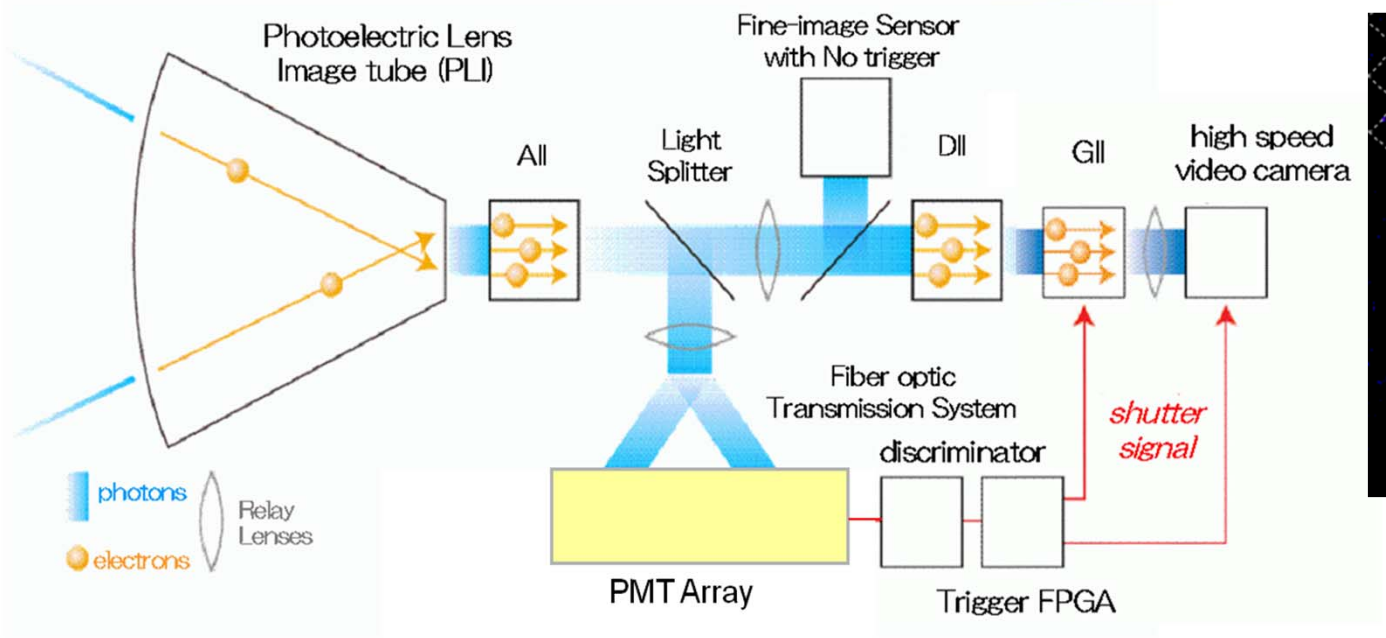
Pipeline Trigger & Readout

Multiple trigger is realized

Optical 4s

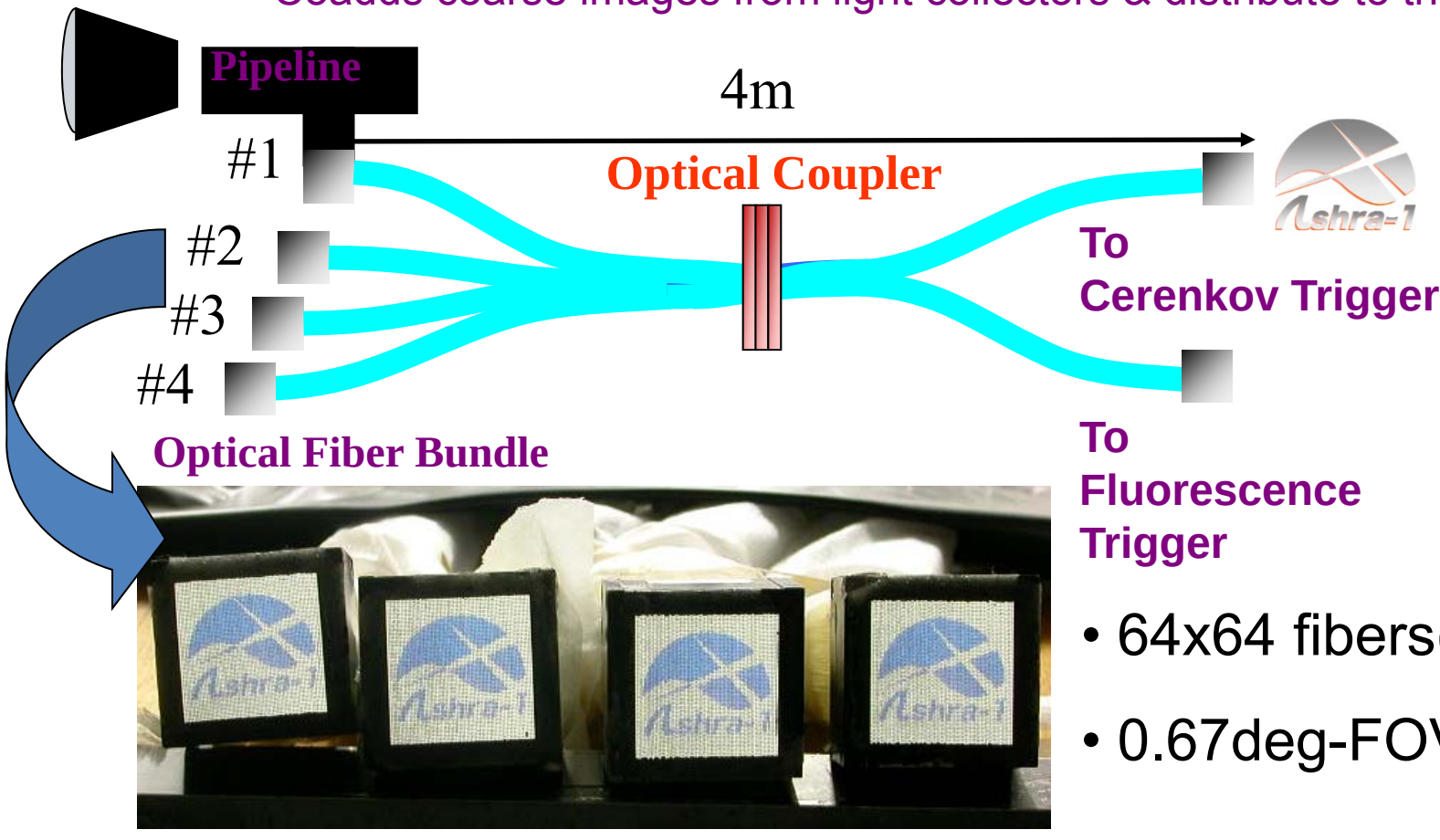


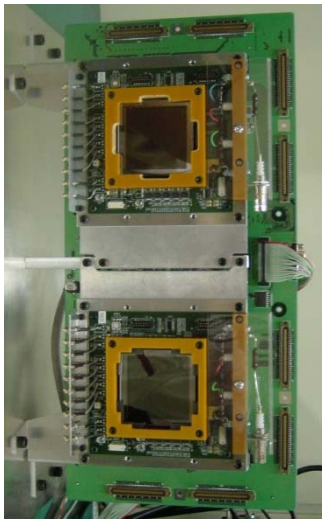




Optical Fiber Transmission System

Coadds coarse images from light collectors & distribute to trigger sensors





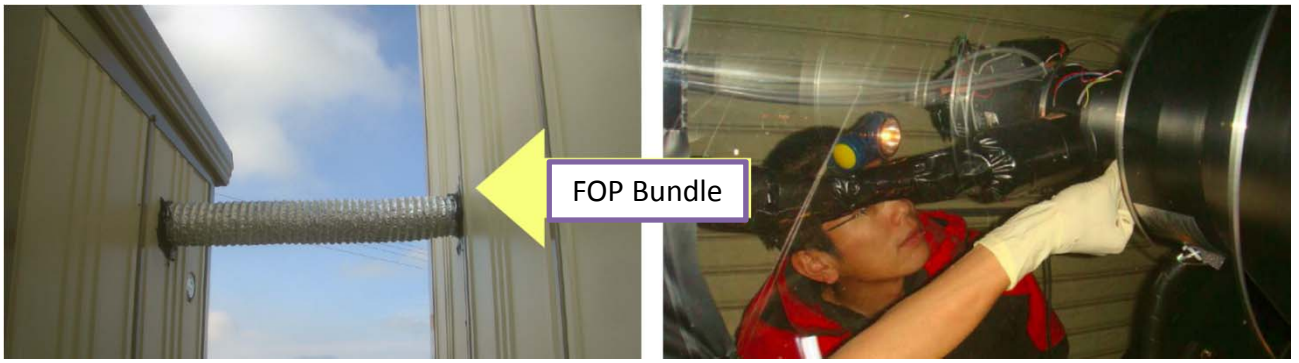
64 × 64 MAPMT

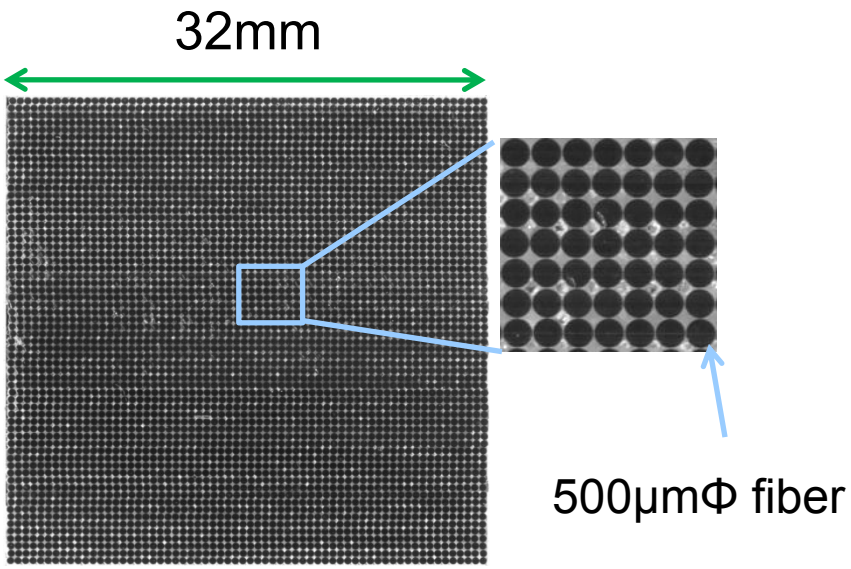
- 64x64 fibers(0.5mmf)
- 0.67deg-FOV / fiber

Light collectors can be easily appended to the trigger.

Sensitivity can be reinforced when more budget is available.

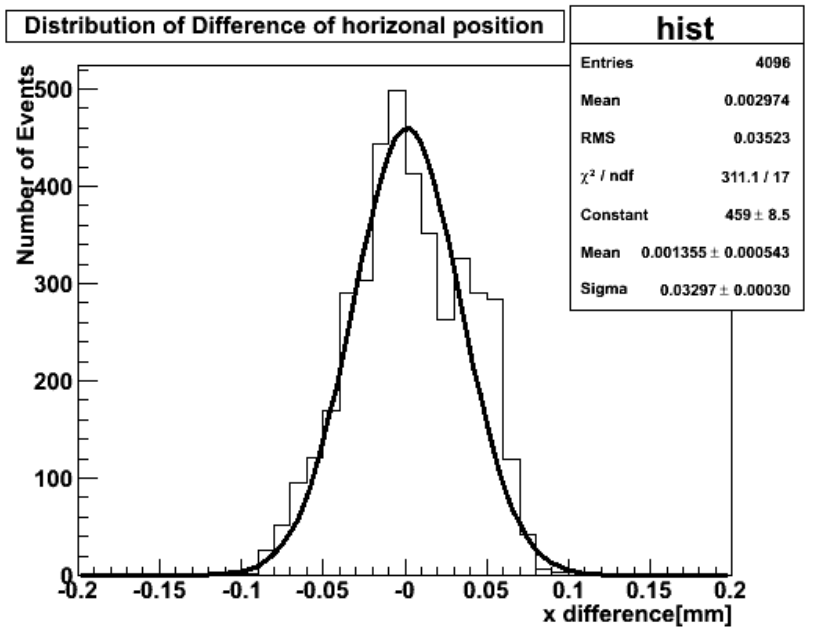
FOP Bundle





Cross sectional view

64x64 acrylic FOP bundle

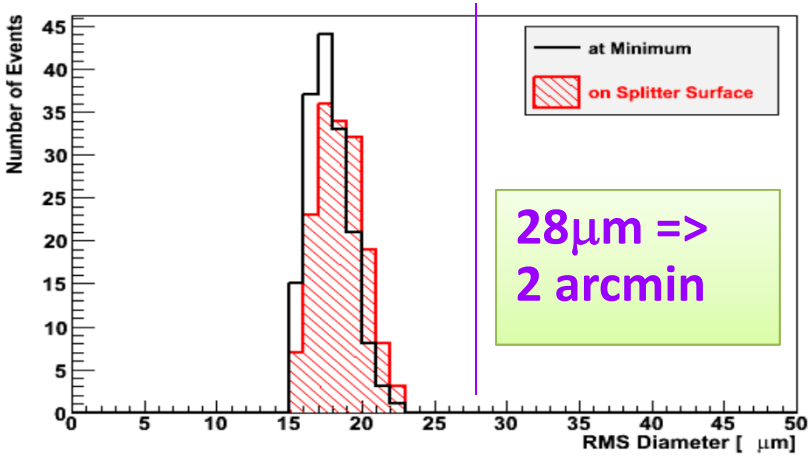


Alignment Errors from Expected Position

Developed by Prof.Ogawa group in Toho University

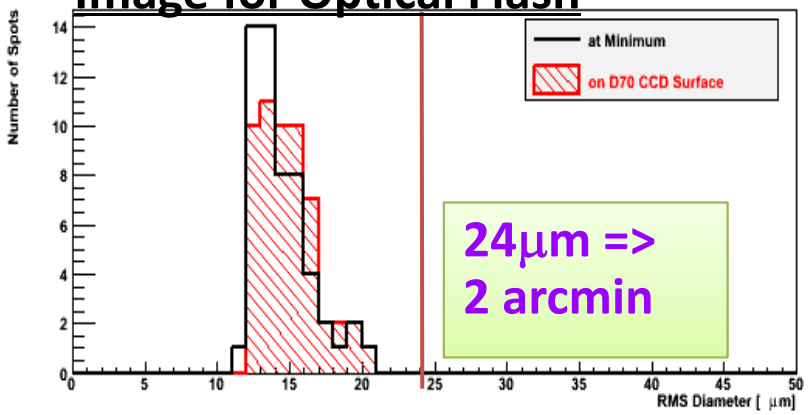
Photoelectric Image Pipeline (PIP)

Image for AirShower



28μm =>
2 arcmin

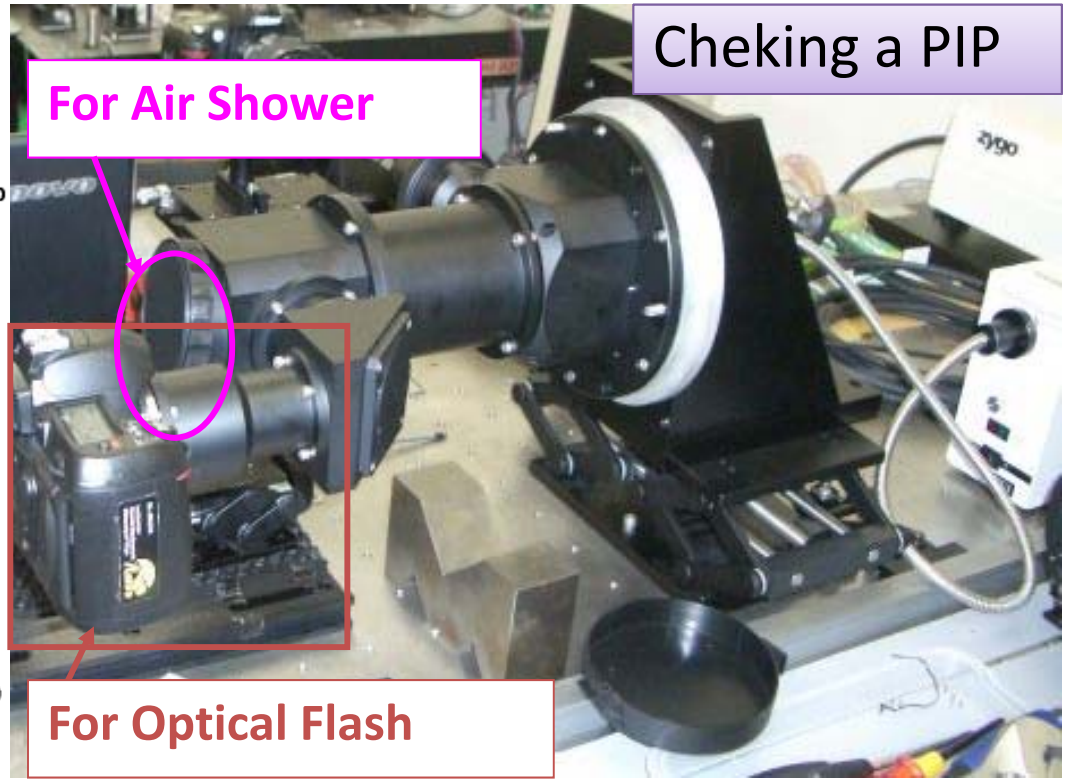
Image for Optical Flash



24μm =>
2 arcmin

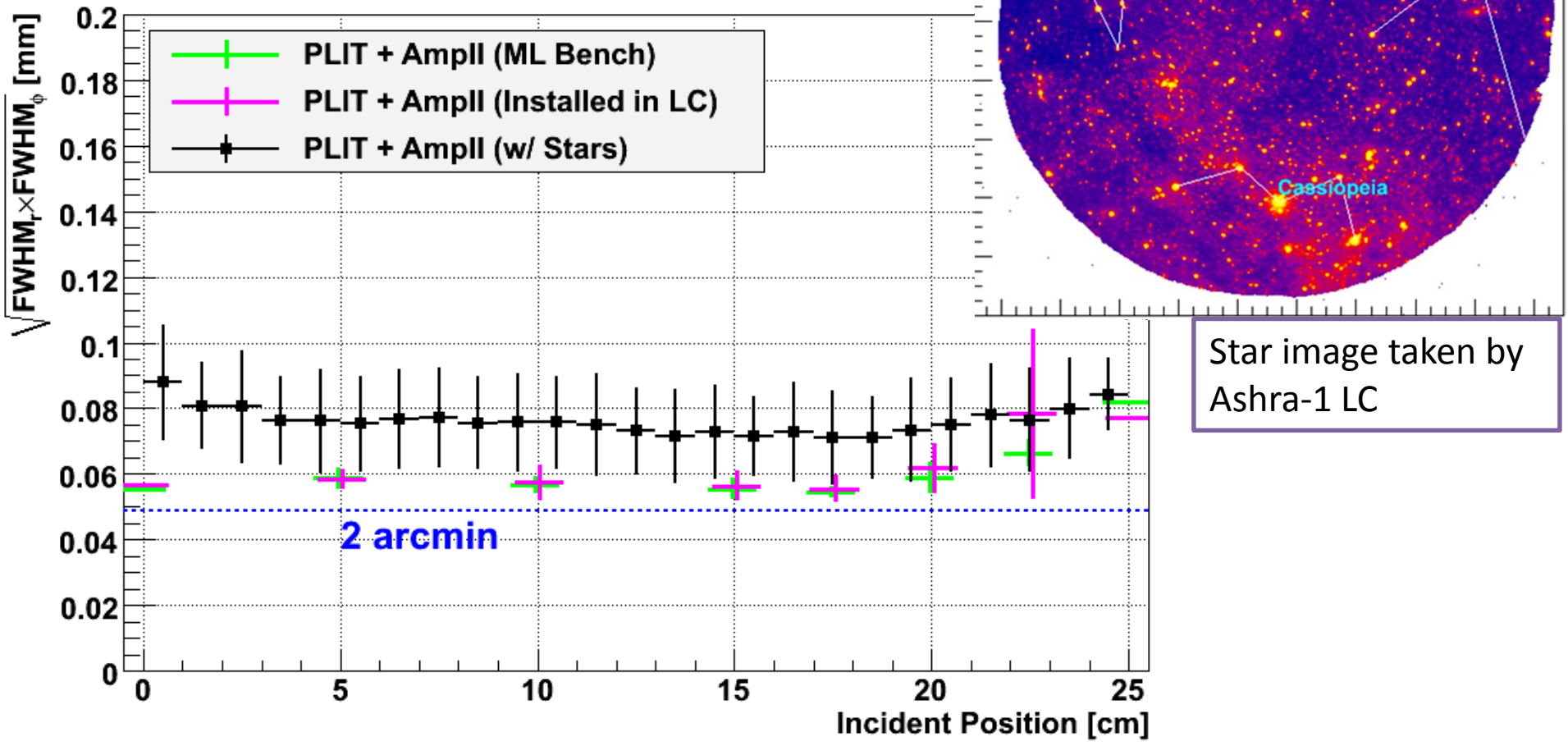
Results on Checking Incoming PIPs

Focus Point Accuracy: 10μm
Imaging Resolution ~1.5 arc min



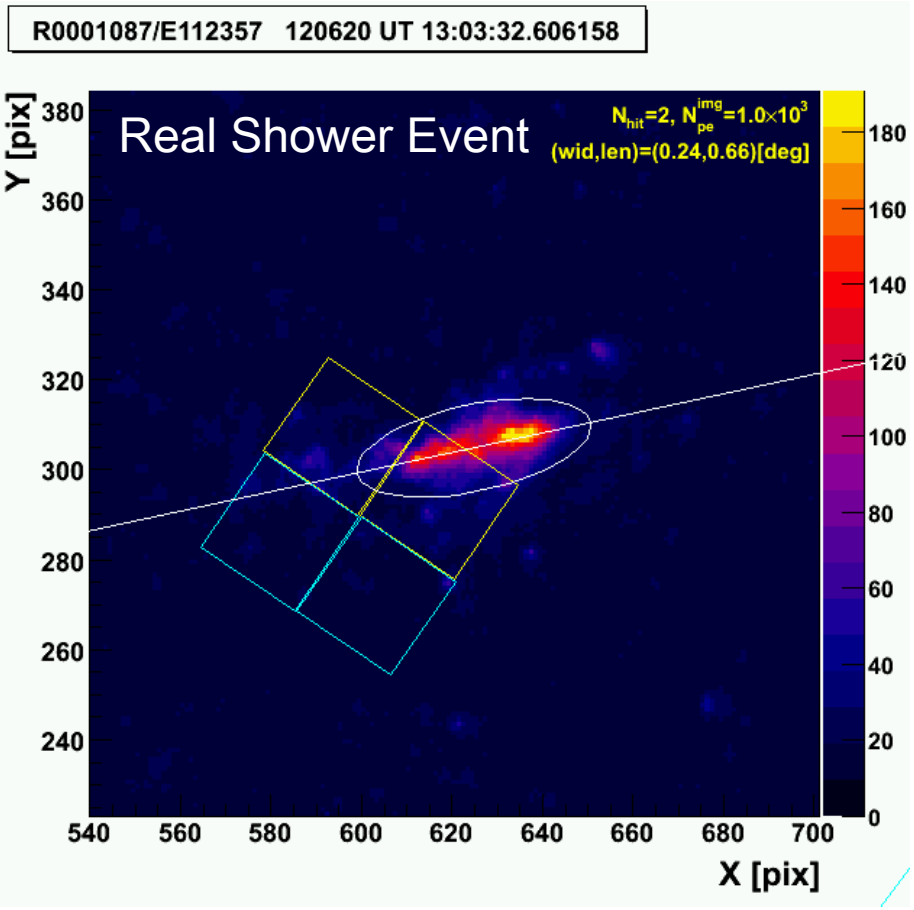
Total Star Resolution (Opt.Sys+PLI+PIP)

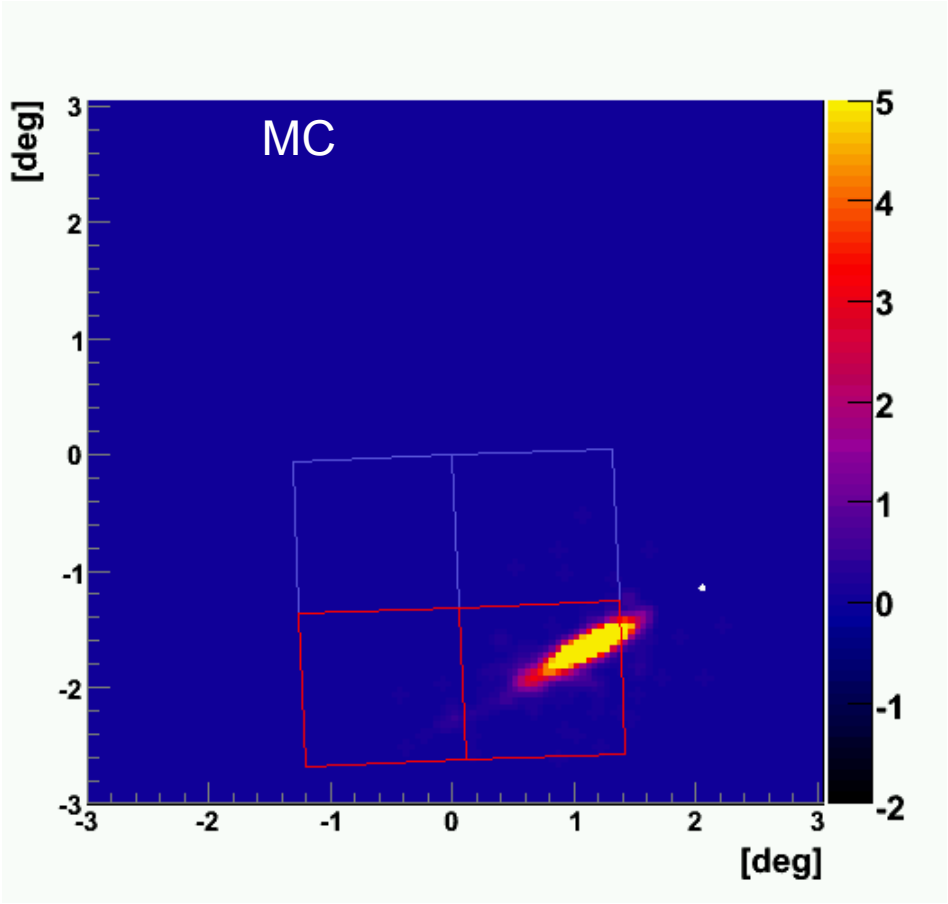
~3 arc min over 42 deg FOV after all adjustments



Star image taken by Ashra-1 LC

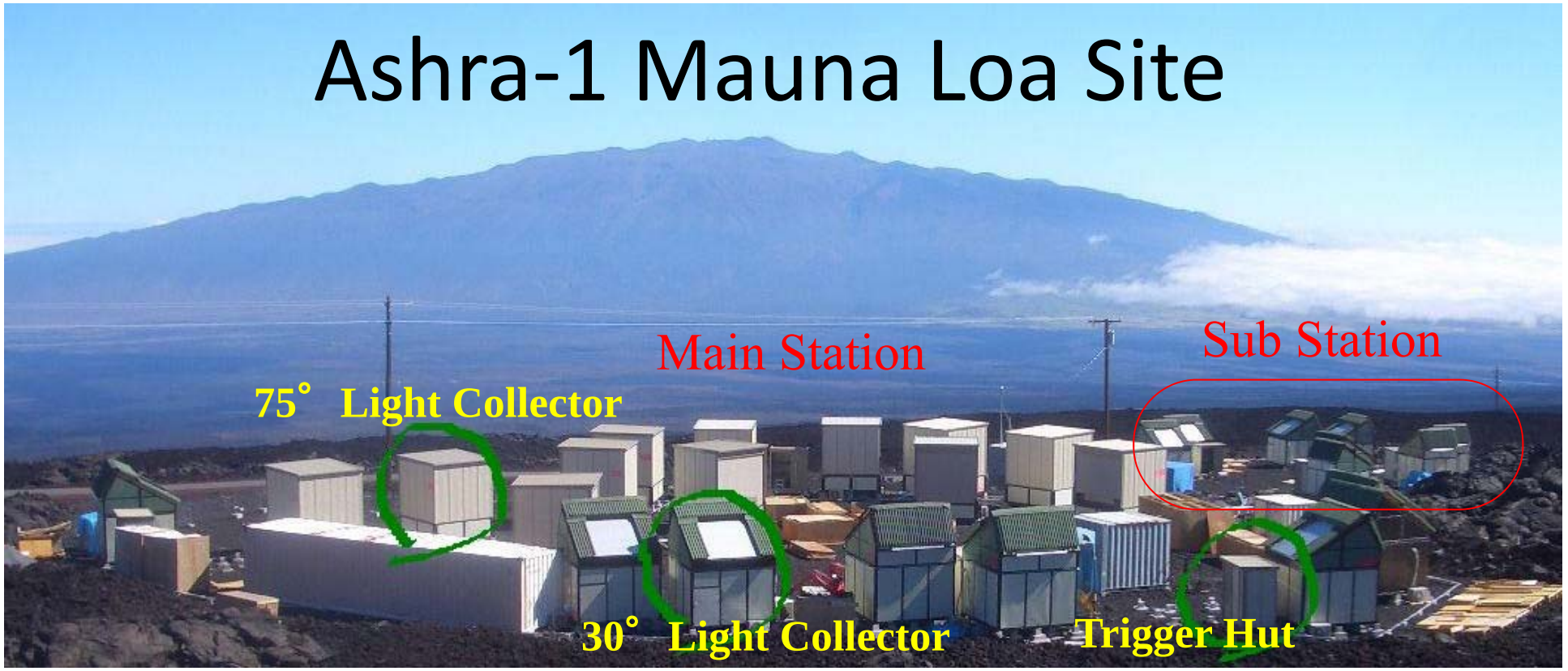
Ashra-1 R0000941/E115513 Triggered Real Shower Event vs MC



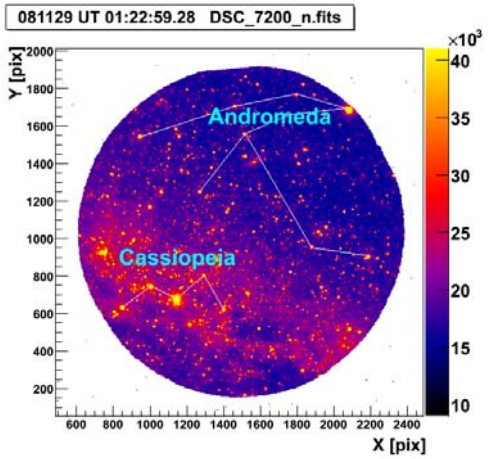


MC reproduce real event

Ashra-1 Mauna Loa Site

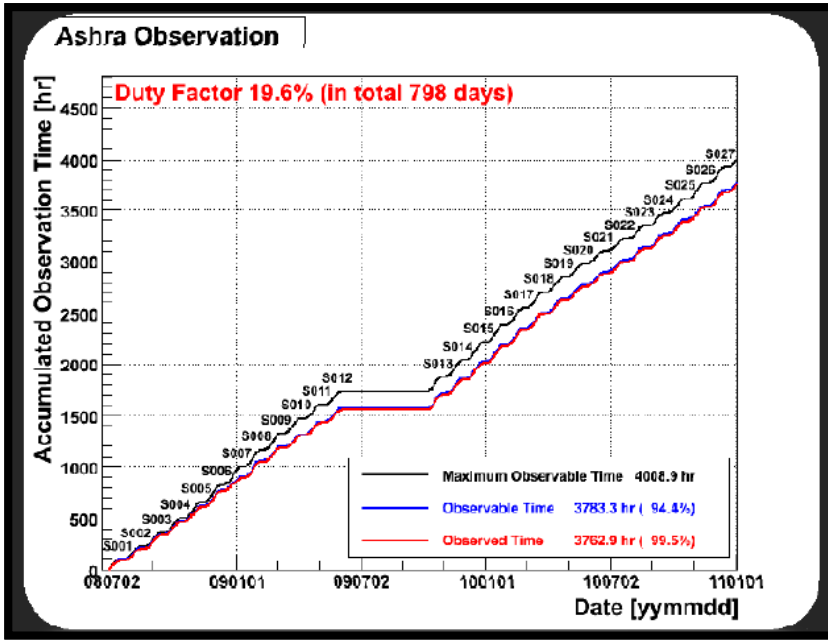


2003	Funded
2005	Observational site use permit
2007	Intensive installation
2008	Obs01 started
	– Optical flash observation
	– VHE neutrino commissioning observation
2009	Obs02 started.
2011	Extension of the site use permit
2012	Obs03 has been started.



Optical Flash Obs.

Observation 01,02, and 03 (on going)



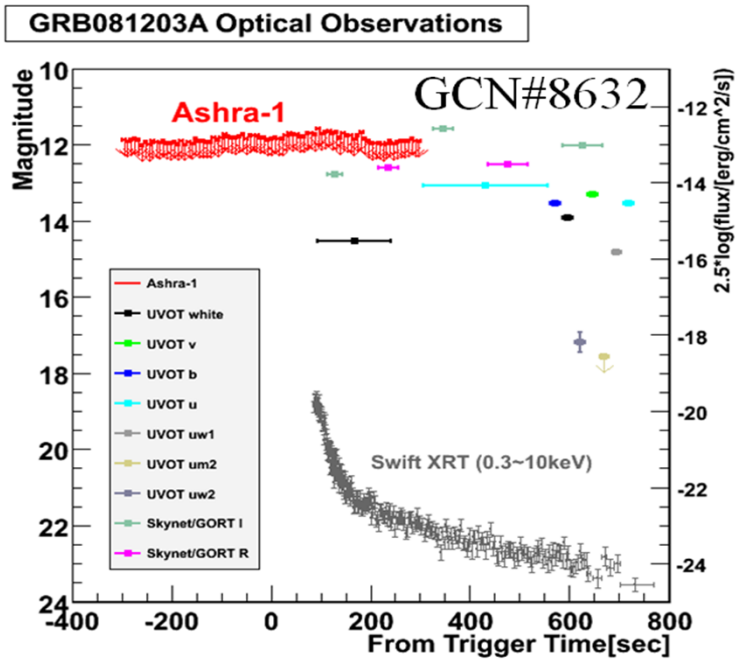
	Obs01	Obs02	Total
Period	080628-090605	091007-110104	798 days
Obs. Time	1551 hr	2212 hr	3763 hr
Good Weather	90.6%	97.3%	94.4%
Efficiency	99.1%	99.7%	99.5%
Duty Factor	18.8%	20.3%	19.6%

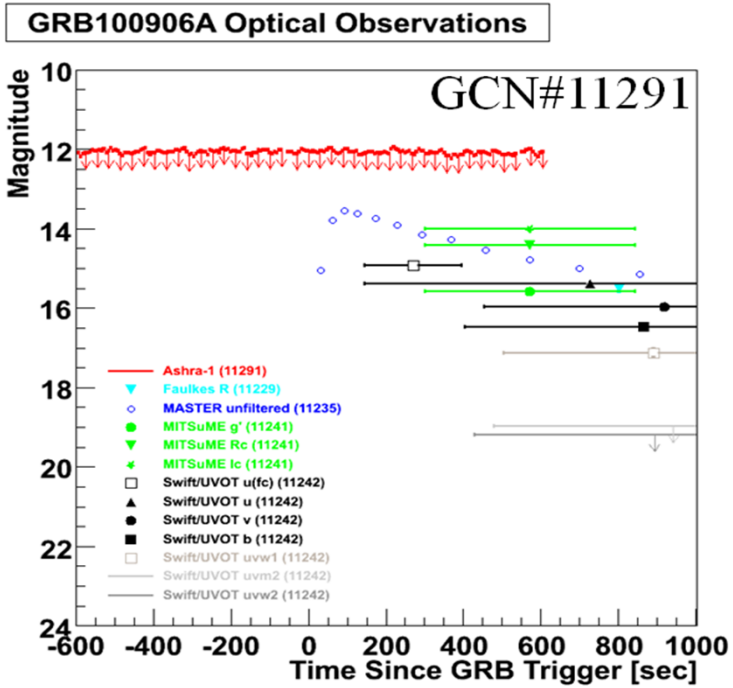
One of Best Sites for Astronomy

Observation 03 on going
(Statistics: **2012.01-2012.11**)

	ν_τ	Opt. Flash
Obs. Time	1291.8 hr	1311.9 hr
Good Weather	98.0%	98.3%
Efficiency	93.8%	96.0%
Duty Factor	18.2%	18.5%

Optical Search Limits



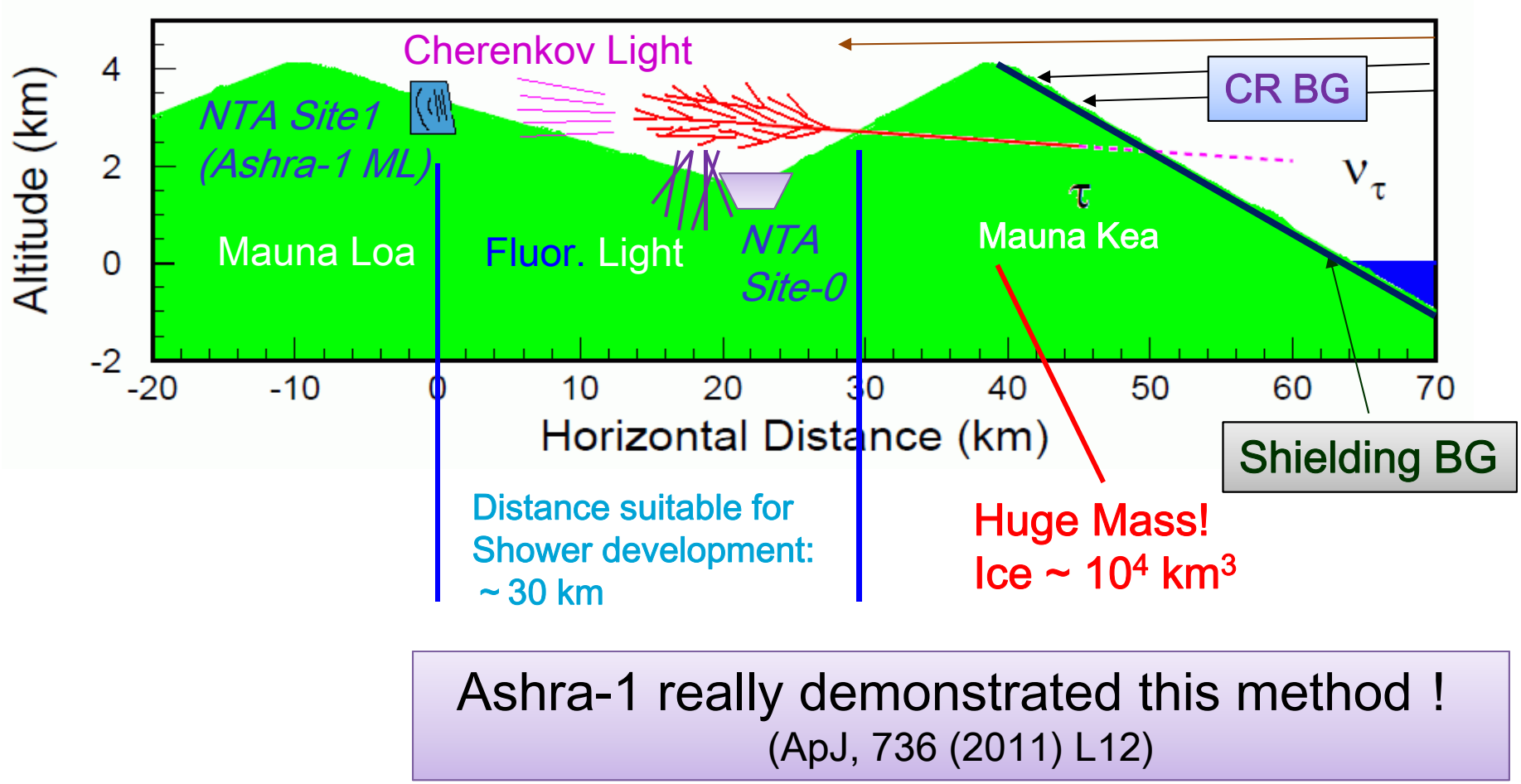


$Z = 2.05\ ^{+}/_{-}\ 0.01$ (Kuin et al., 2009)
$E_{iso} = (3.5\ ^{+1.8}/_{-1.0}) \times 10^{53}$ [erg] (Kann et al, 2010)
T_{90} (15-350 keV) = 294 $^{+}/_{-}$ 71 [sec] (GCN#8599)

$Z = 1.73$ (GCN#11230)
$E_{iso} = (2.2\ ^{+}/_{-}\ 0.4) \times 10^{53}$ [erg] (GCN#11251)
T_{90} (15-350 keV) = $114.4^{+}/_{-}$ 1.6 [sec] (GCN#11233)

- Unique Limits before Satellite Alert (T=0)
- ~10 GRBs coincided with Ashra-1 LC FOV
  => Limit the Init. Loretz factors and some peculiar GRB precursor models
  => independent GRB and SN search without using satellite trigger

Earth-Skimming τ Shower Imaging Method

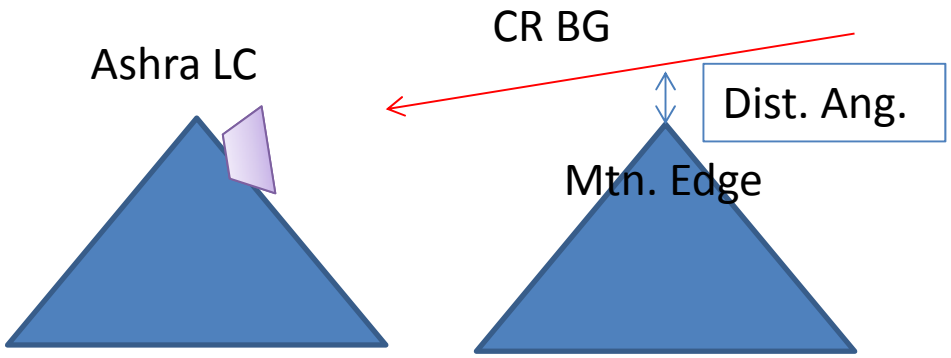


Ashra-1 really demonstrated this method !
(ApJ, 736 (2011) L12)

BG Condition for VHE ν

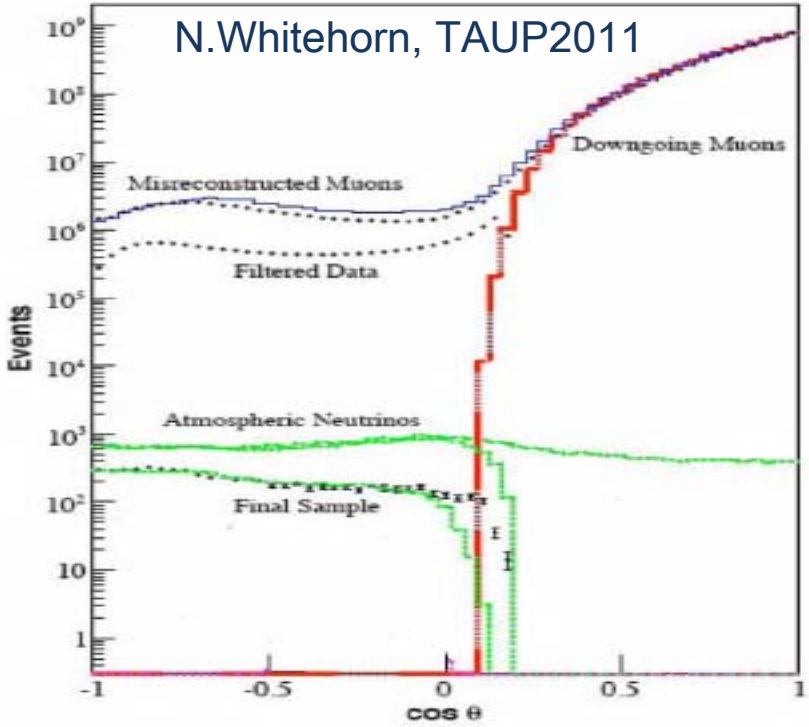
Ashra NTA BG Condition

Dist. Ang. w.r.t. Mountain Edge	Expected BG Contamination
0.1 deg	0.08 /yr
0.3 deg	0.55 /yr
1.0 deg	4.3 /yr
3.0 deg	39 /yr



Enjoy **BG Free!**
with High Precision Directional Measurement
by Ashra NTA

IceCube BG Condition (Reduction)

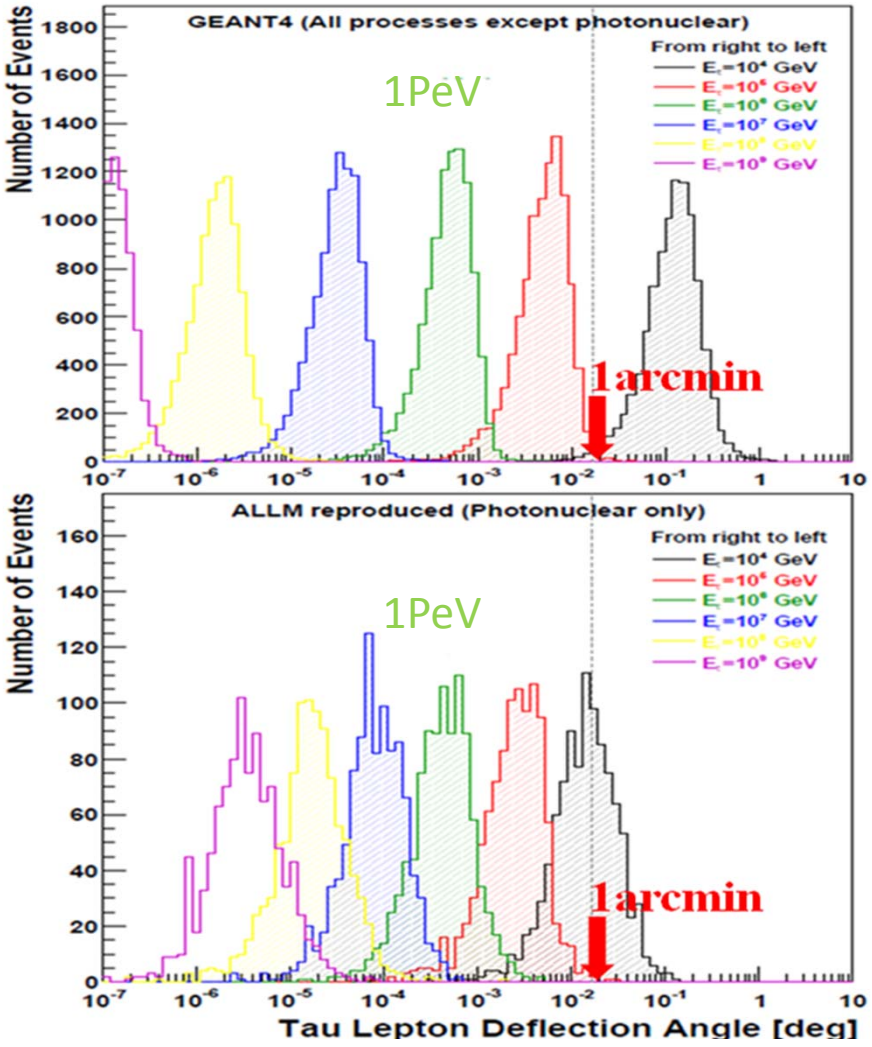


Surface: 1 cm^{-2} $minute^{-1}$

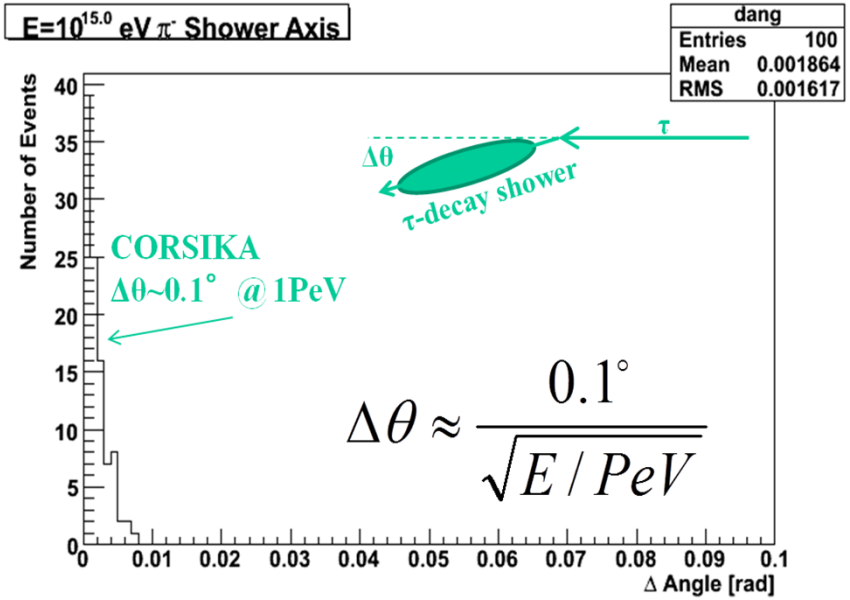
In ice: 2800 Hz μ
compared to 1 neutrino
per 10 minutes
atm. ν

→ requires 10^6 background rejection

Tau Propagation Deflection in Rock



Possible Deflection << 1 arcmin



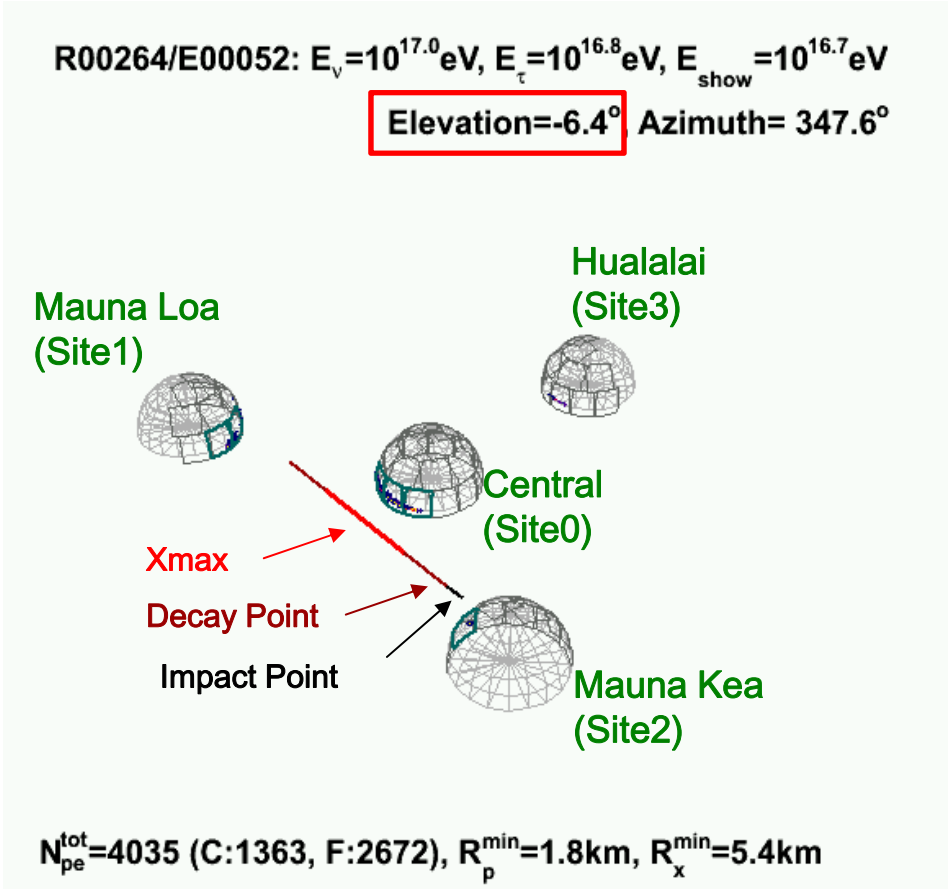
Pointing ν with τ Shower < 0.1 deg

Higher Energy Better Accuracy Due to

1. Highly Boosting
2. Shower Size Statistics

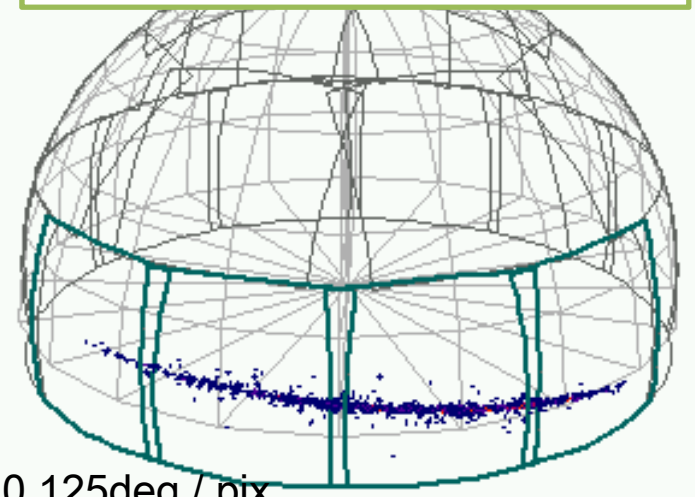
τ Shower Can Remember the Original ν Direction Very Well

100PeV Neutrino Fluo.+Cheren. Event Simulated with Ashra NTA



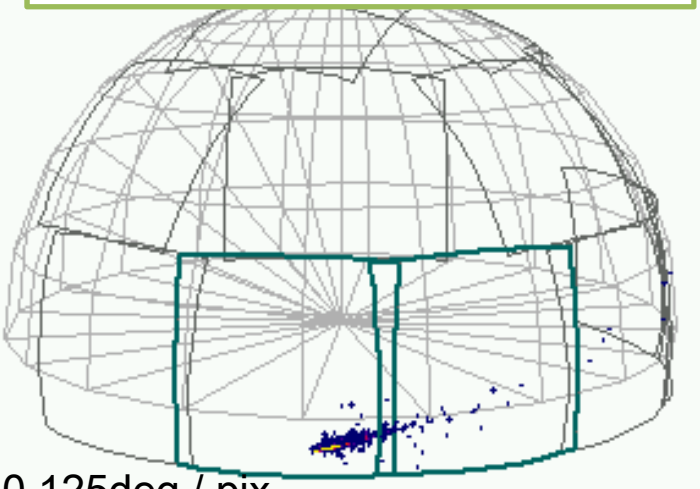
Simple Fit =>
Site0 + Site1: 方向精度: 0.08°

Central (Site0): Fluorescence



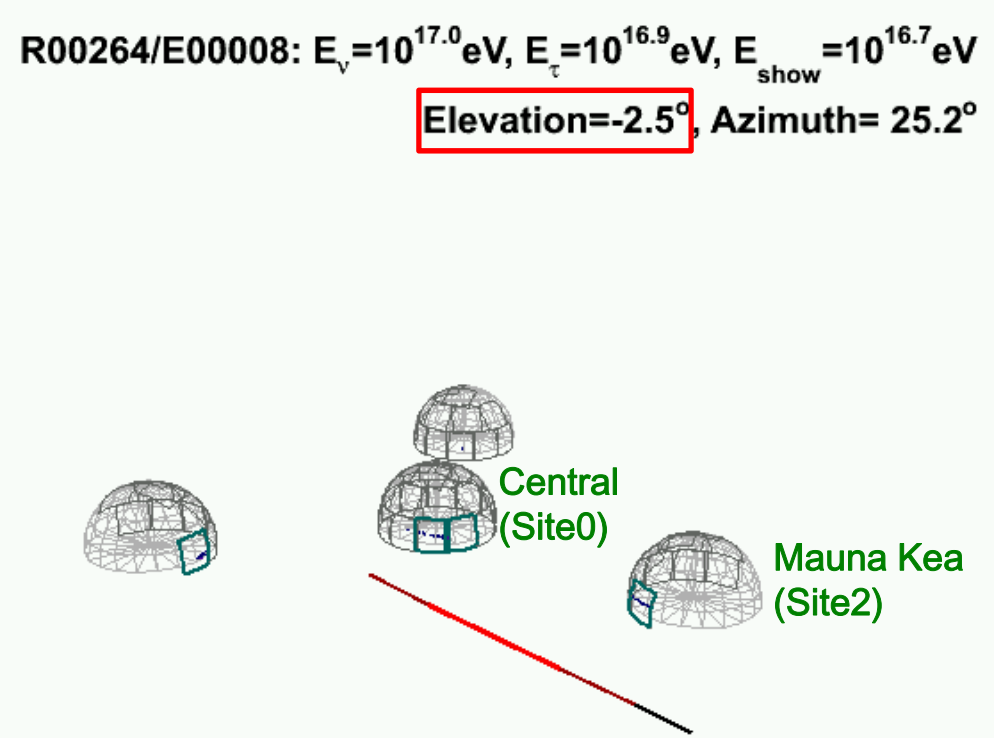
0.125deg / pix

Mauna Loa (Site1): Cherenkov

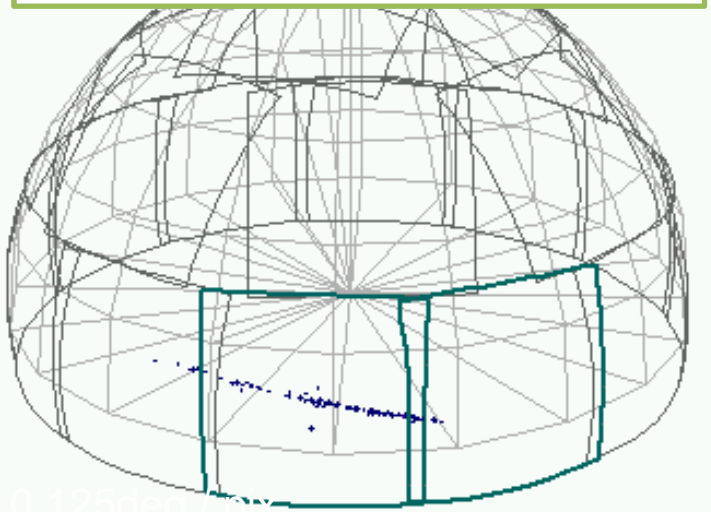


0.125deg / pix

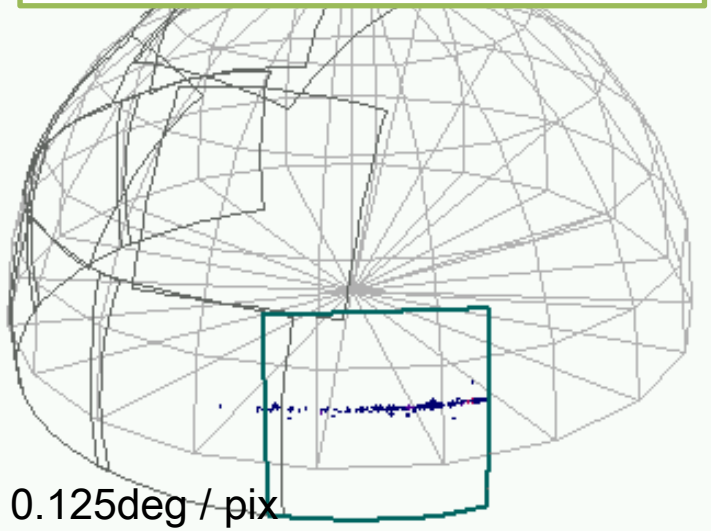
100PeV Neutrino Fluo.+Fluo. Event
Simulated with Ashra NTA



Central (Site0): Fluorescence

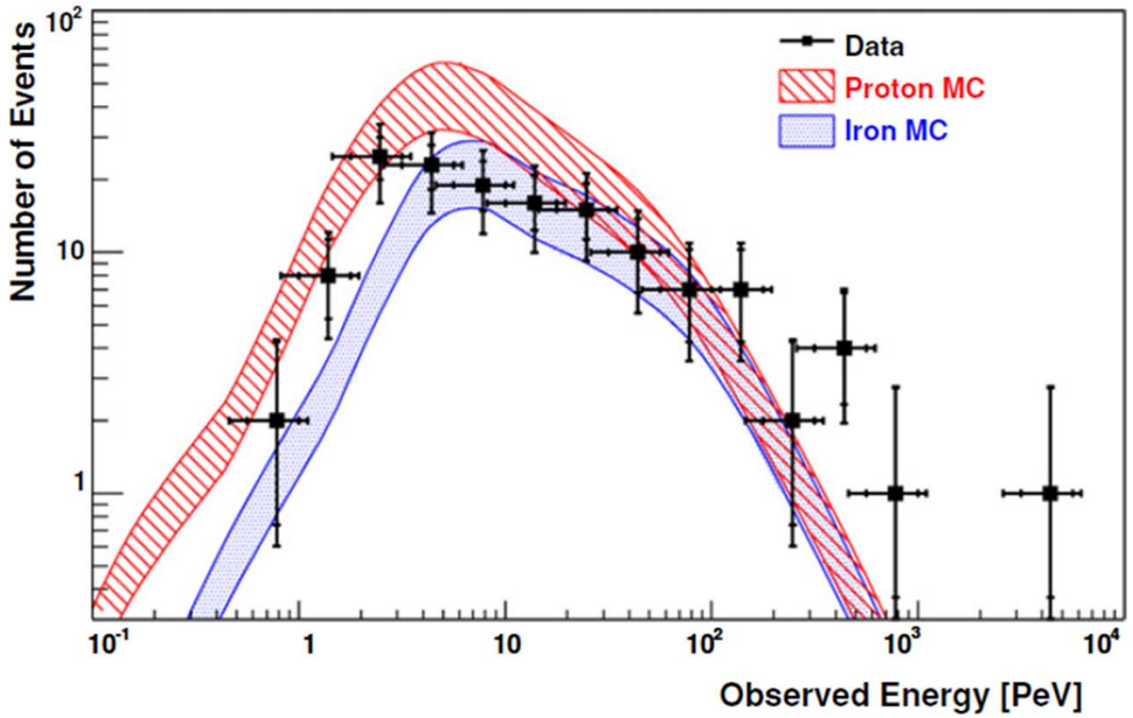


Mauna Kea (Site2): Fluorescence



Simple Fit =>
Site0 + Site1: 方向精度: 0.007°

(Comissioning) Observed CR Spectrum

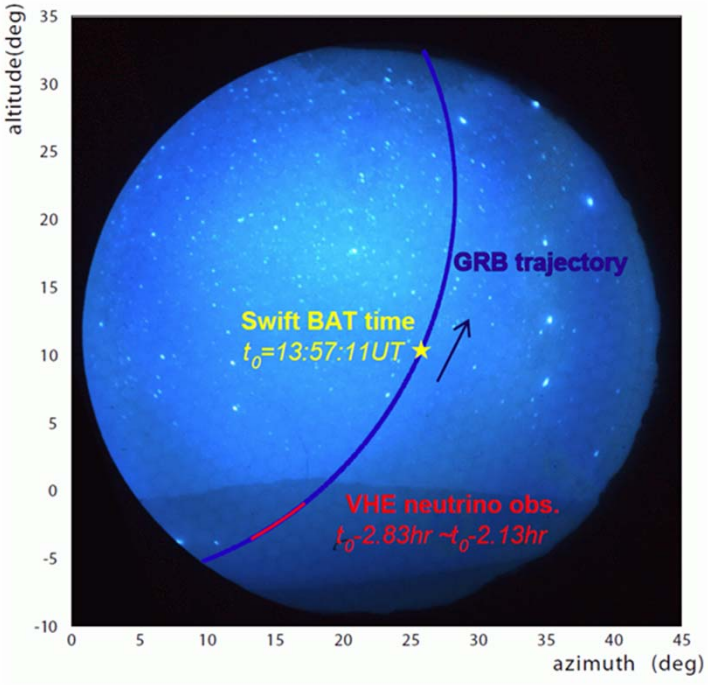


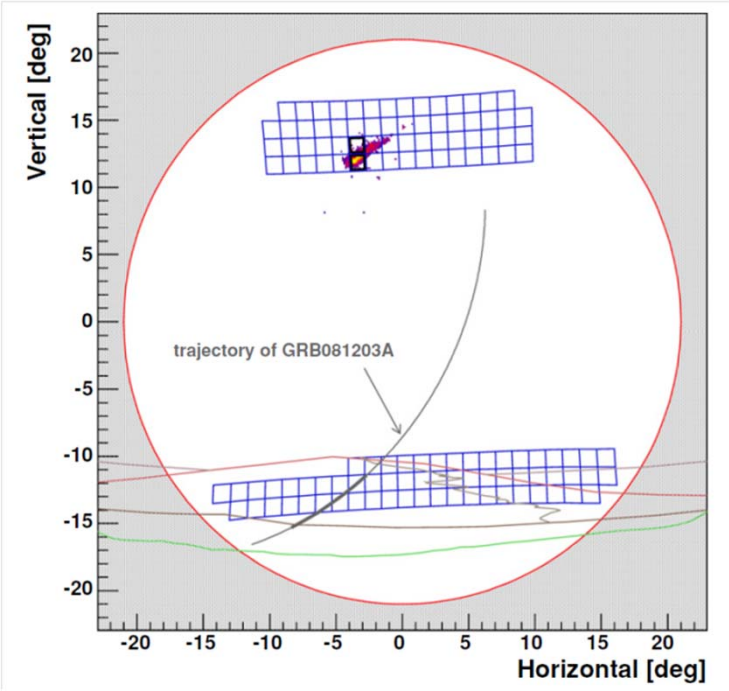
Validation of Sensitivity and Reconstruction

Some Hint for Composition

First GRB ν_τ Search

GRB081209A

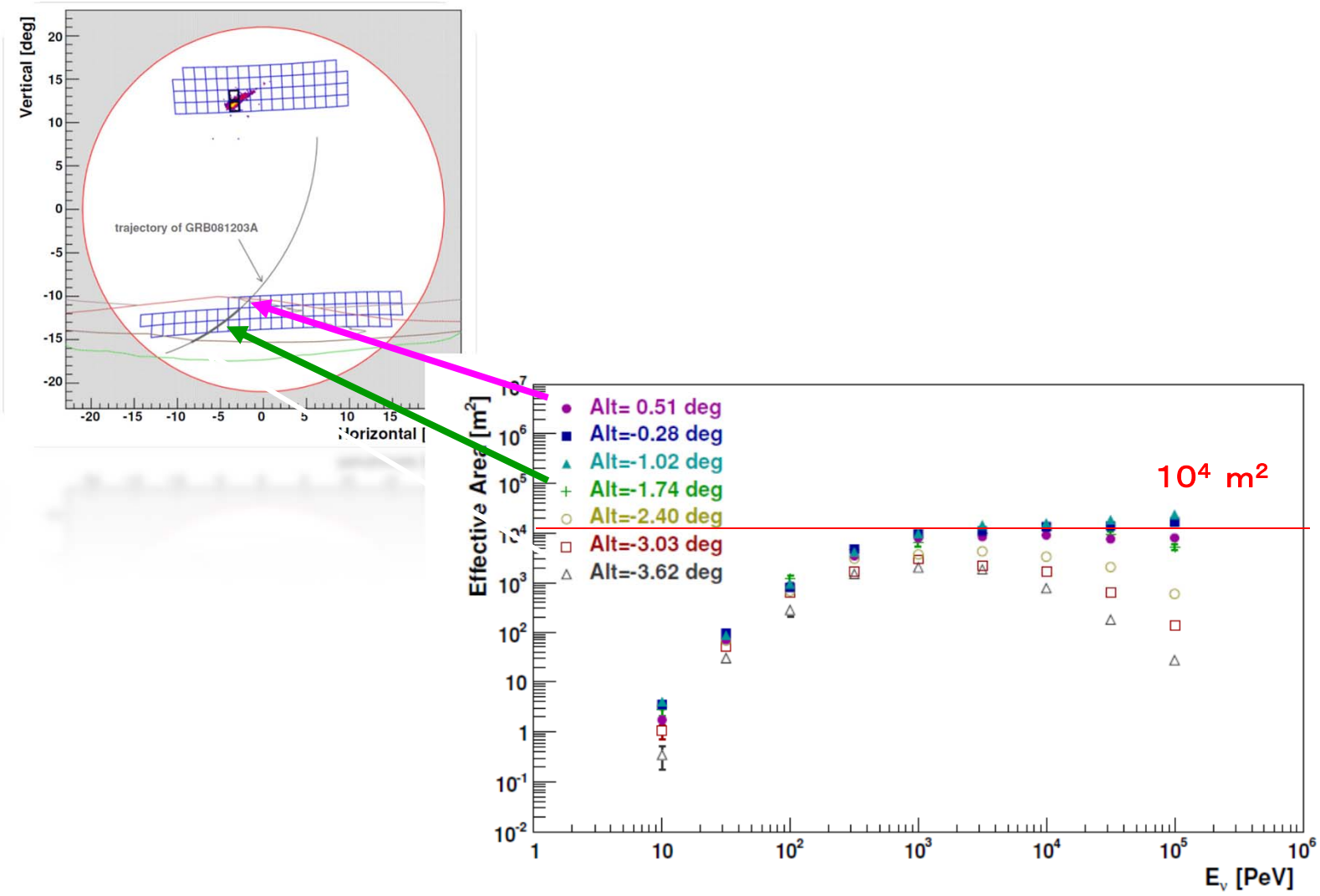




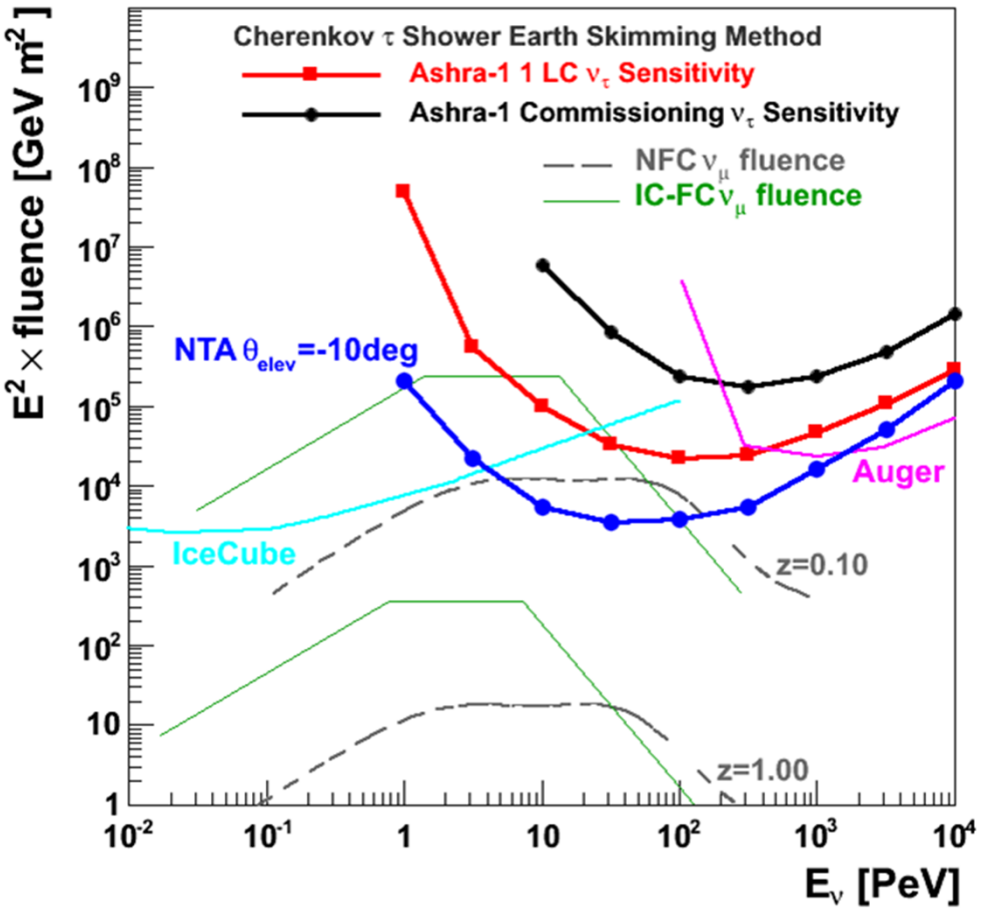
Swift GRB Alert during Commissioning in 2008

First Check for PeV-EeV Tau Neutrino from a GRB (ApJ, 736 (2011) L12)

Effective Aperture along GRB Trajectory



GRB Neutrino Search Comparison



0. Auger, PRD 79 (2009) 102001

Complement IceCube:
- Methodology
- Energy
- Self-trigger for Tau Neutrino

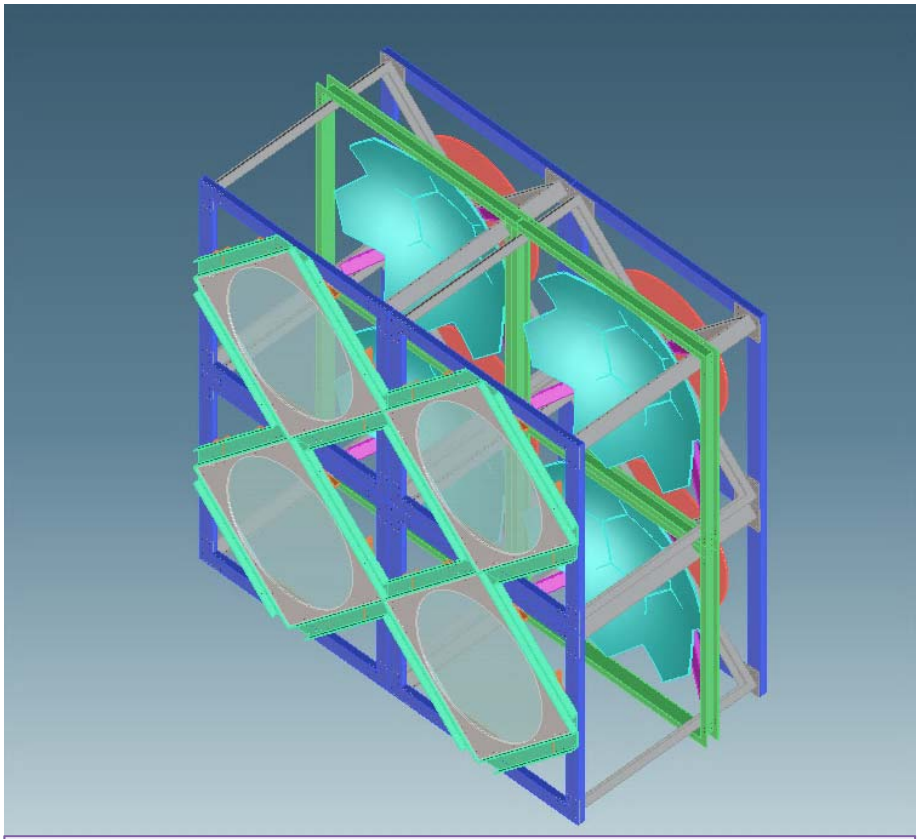
1. IceCube, Nature 484 (2012) 351
- IC40+IC59 stacked 117+181GRBs
- Very strong bias for time window (28s) around Satellite Triggers to suppress huge BG

2. Murase et al. ApJ 651 (2006) L5
- Nearby Low luminosity (LL) GRB (ex. GRB 060218/SN 2006aj) dominate total neutrino fluxes at Earth
- X or γ Satellites cannot detect

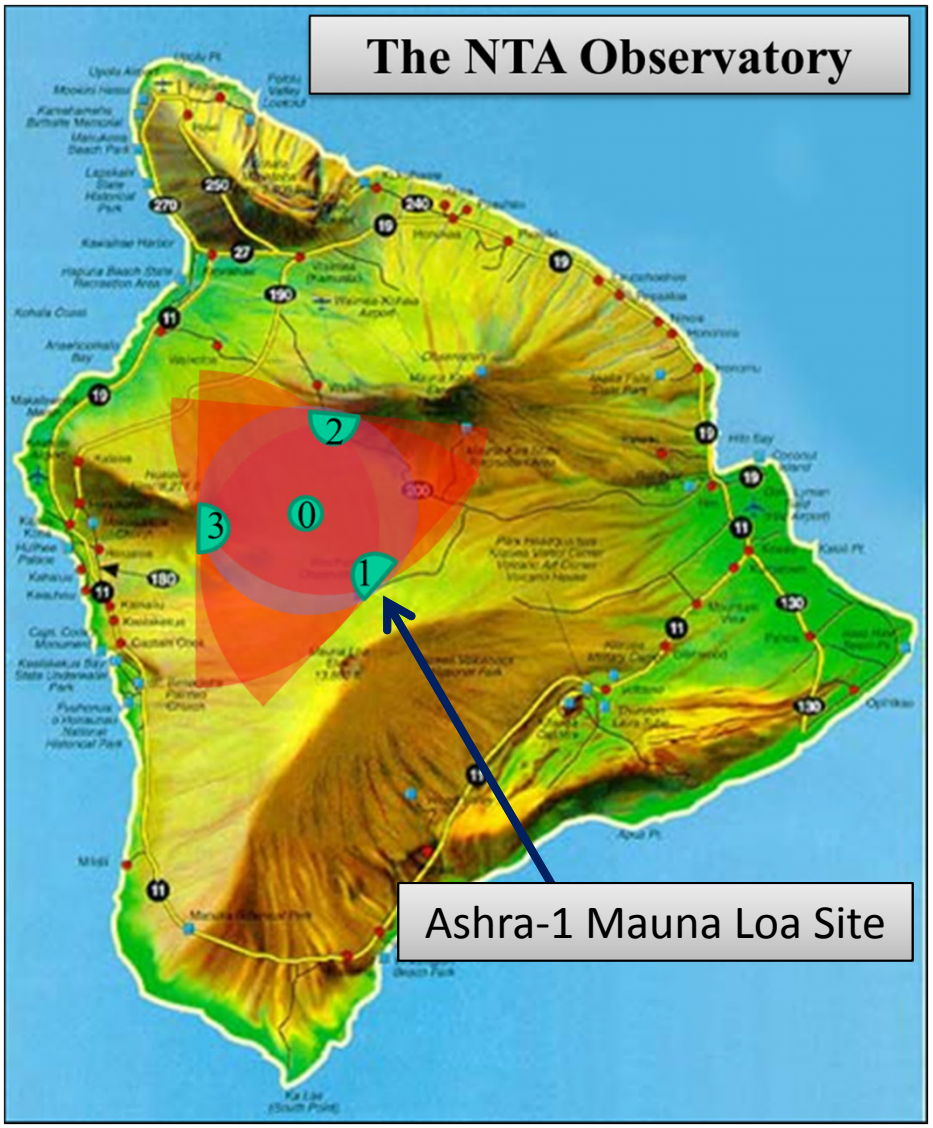
3. Hummer et al. PRL 108 (2012) 231101
- Recalculated neutrino flux => Ashra Energy Region more important

Ashra can Survey Depth: z ~ 0.1 (~400Mpc) for GRBν flux (by Hummer et al.)

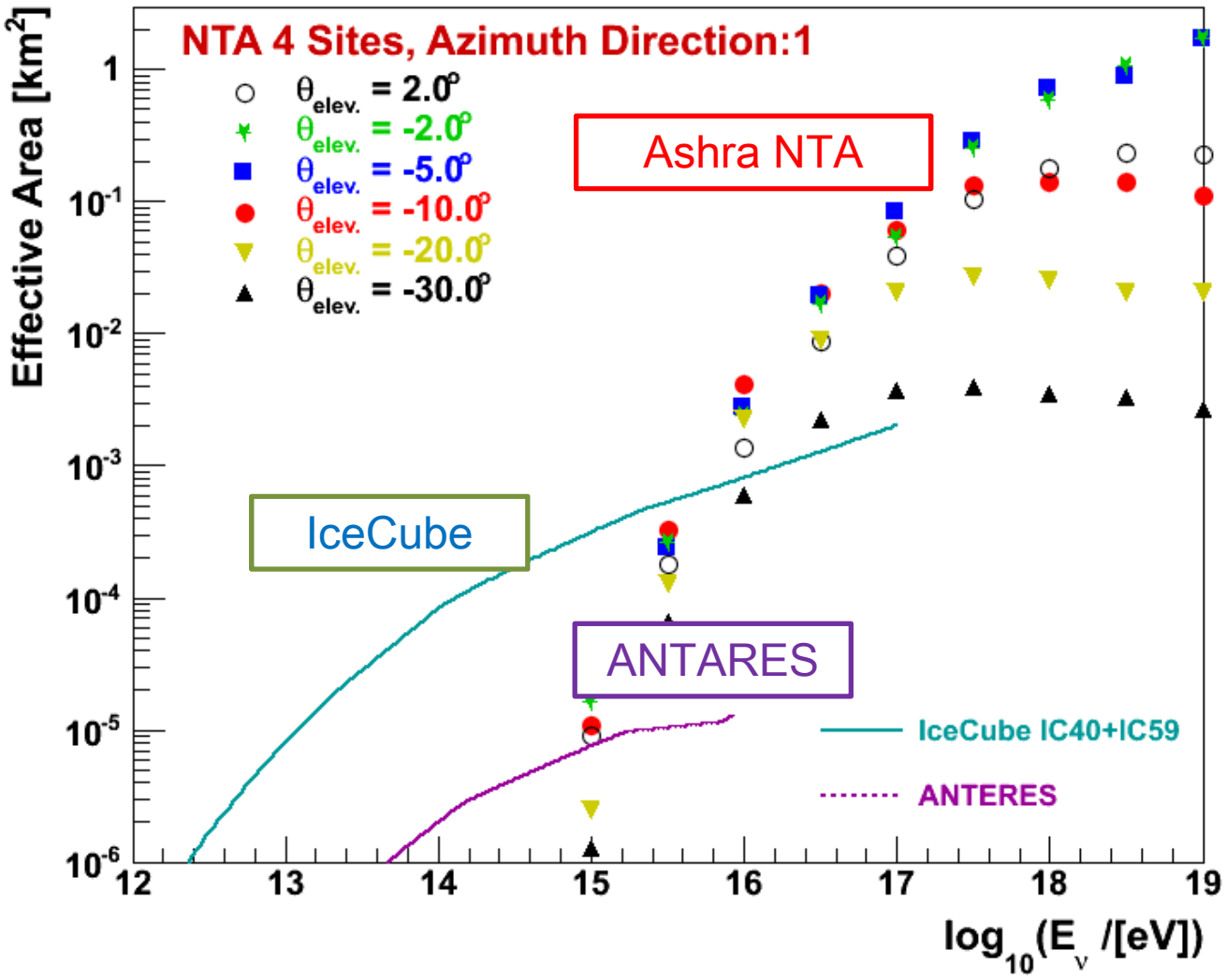
Prospect: Ashra NTA



=> Concept of NTA Detector Unit with
Ashra-1 LC x 1.5 scaled-up x 4
+ same trigger & readout
=> Effective input pupil size: ϕ3m



Ashra NTA Effective Area



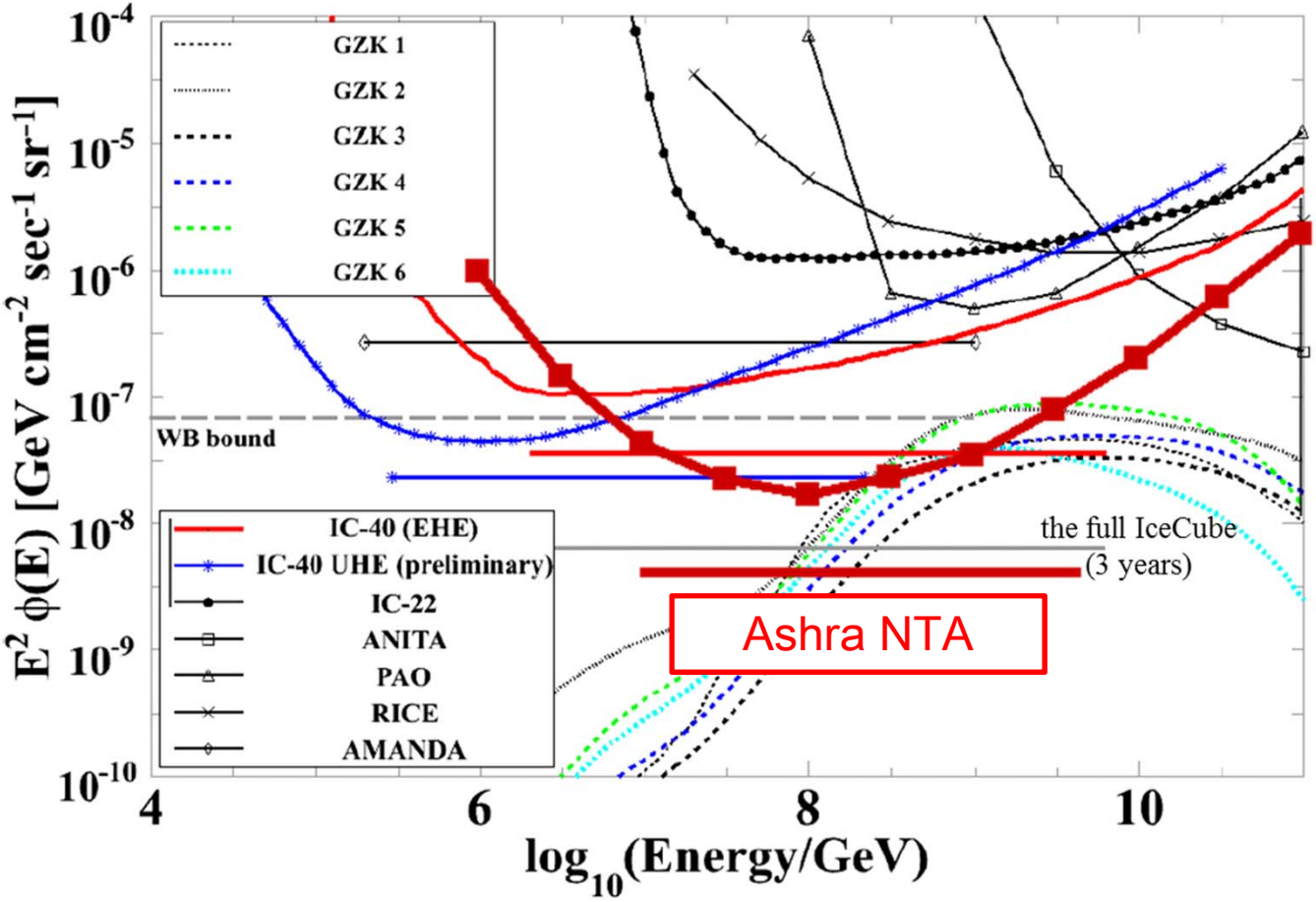
Azimuth-1 :
Assuming a point source in the dir. of azimuth of Mauna Kea summit from Site0 (center).

References

IceCube:
Nature 484 (2012) 351 Suppl. Info. Fig.S2 Model Independent

ANTERES:
ApJ 743 (2011) L14 Fig.2 (Right)
Declination Range -90<δ<-45 deg

Ashra NTA Diffuse Sensitivity (3yrs)

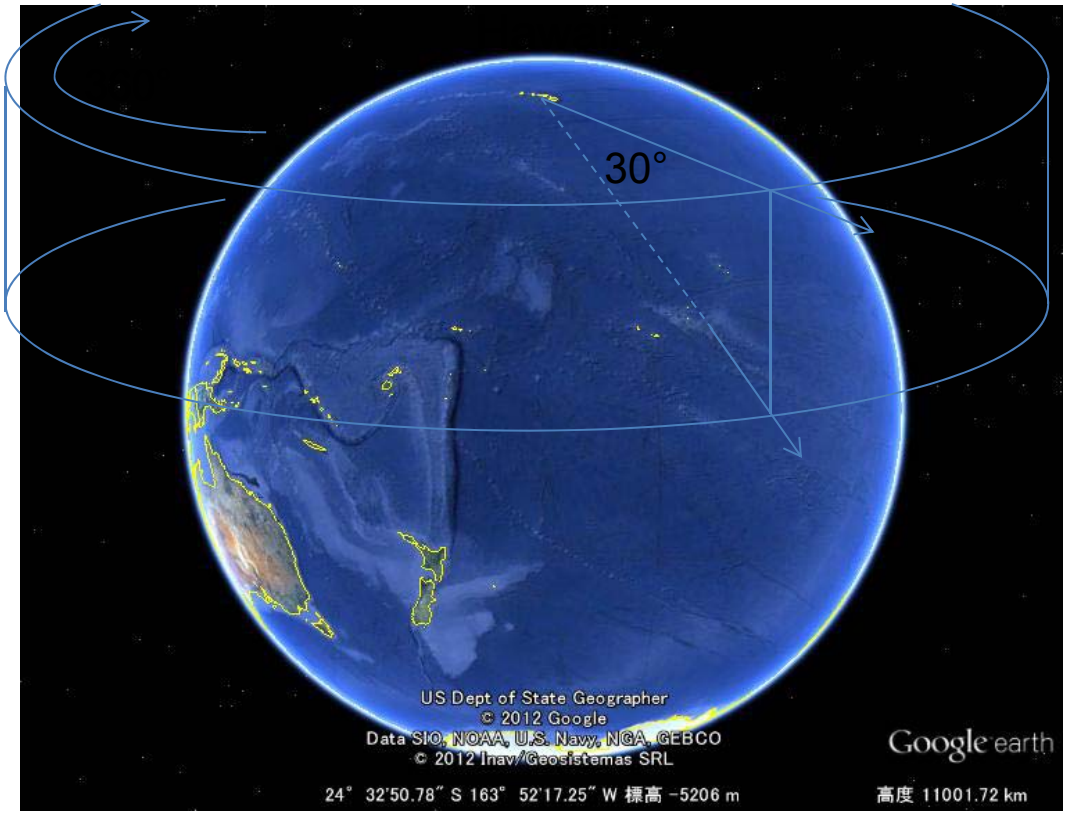


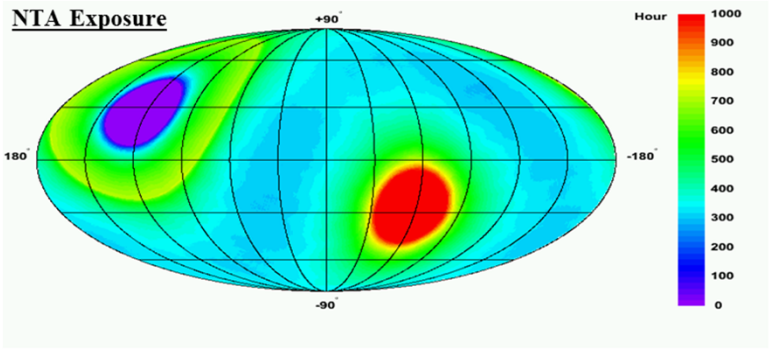
Diff. Limit
= 2.3E/(Aperture・ΔT)

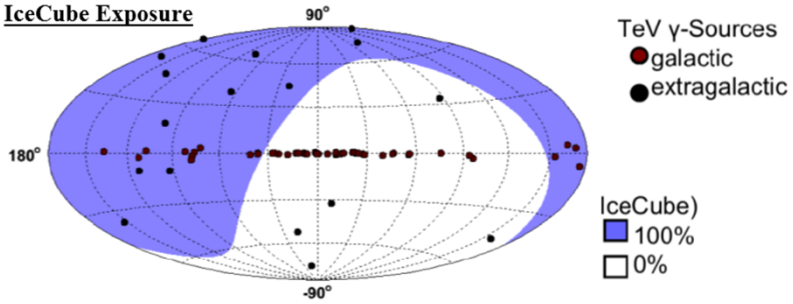
Duty 10% is assumed
($\Delta T = 9.5 \times 10^6$ sec)

3 year Observation can resolve Cosmogenic ν

Ashra NTA ν Pont Source Survey Search Performance



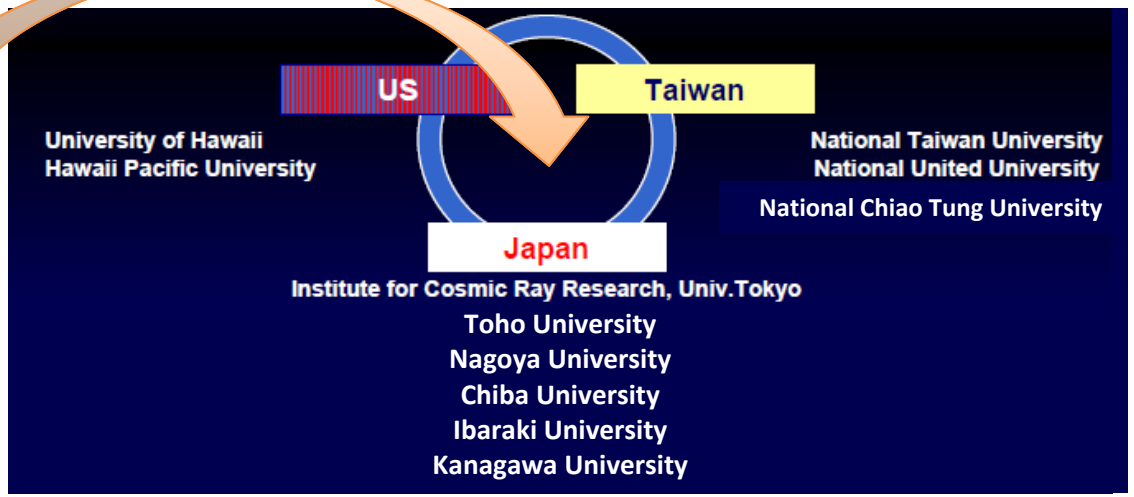




Duty 10-20% from Ashra-1
ν pointing accuracy < 0.2° (Cheren. Mono => worst case)
FOV Elevation 30°× Azimuth 360°
Assuming Hammer's GRBν fluence Survey Depth z < 0.1 (400Mpc)

Expanding Ashra NTA Collaboration

Join us!



Ashra Collaboration Meeting In 2004

Research Staffs of ICRR

Both are now on shift for observation at Ashra Mauna Loa site.

Yoichi ASAOKA
Assistant Professor

Holger Martin Motz
Research Associate

Students and supporting staffs

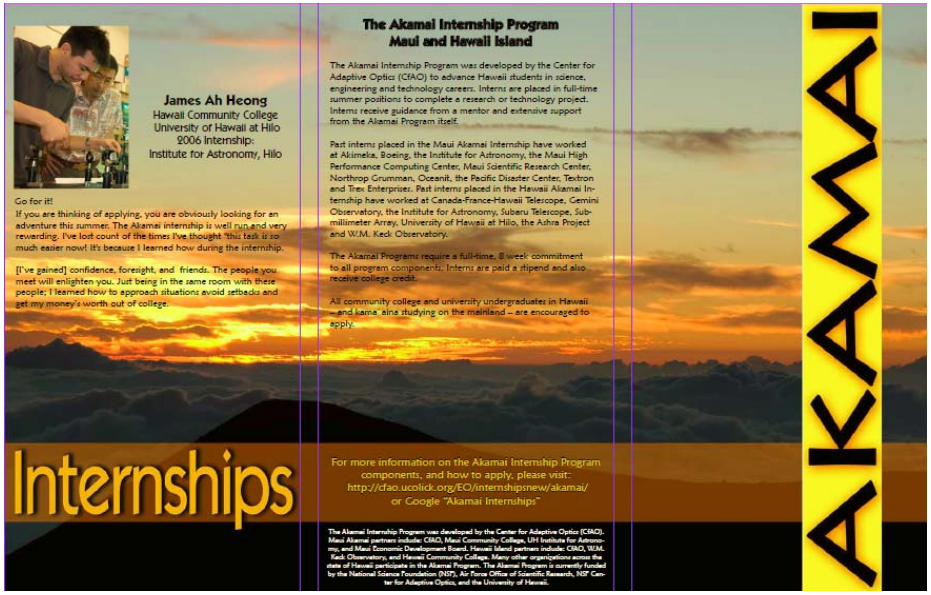
Excursion in Nikko in 2005 Summer

Starting Observation in 2008

Since 2006:
1 Ph.D => Post. Doc.
6 MD => Industrial

Educational Activity

- Taught undergrads at UHH as affiliate prof.
- Joined Akamai Internship Program in Hawaii
  - Provided several students field works for instruments



Akamai Internship

David Trang

University of Hawaii at Hilo

2006 Internship: Ashra Project

The Akamai internship helped me in a lot of ways. I have a good looking resume, learned how to write an abstract, write personal statements and make very good looking presentation. I now feel confident (and even excited) to give presentations. It helped me to talk to graduate schools and put together a pretty good list of schools that I want to apply to.

Thanks to Akamai, applying for grants and internship have become easier because of the practice we got with Akamai and it helped me become more confident in applying. The internship even pushed me to find other internships and to sign up because I discovered how fun research really is.

I think it's the Akamai Internship that made me really want to be a scientist and I think it's what really got my life and career started.

Conclusions

- Scientific Goal and Objectives:
  - Clear ID for EHECR Origin with VHEν, γ, optical flash
  - Complementary and competitive methodology and energy range
- Developments of Ashra-1 Detector:
  - Wide angle, high resolution, multiple trigger have been developed
  - Observation for VHEν, γ, optical flash have been well demonstrated
- Observation Status:
  - Experimental proof for VHEν, CR, optical flash observation
  - Search observation for physics aims with good statistics is continued
- Collaboration:
  - Now forming expanded Ashra NTA Int. national collaboration
- Education Activities:
  - Educational contributions for students of collaborated institutes
- Future Prospects:
  - Ashra-1 => Ashra NTA as full scale project enhancing clear ID of VHEν