

Ashra

Makoto SASAKI

ICRR External Review
2013.01.16

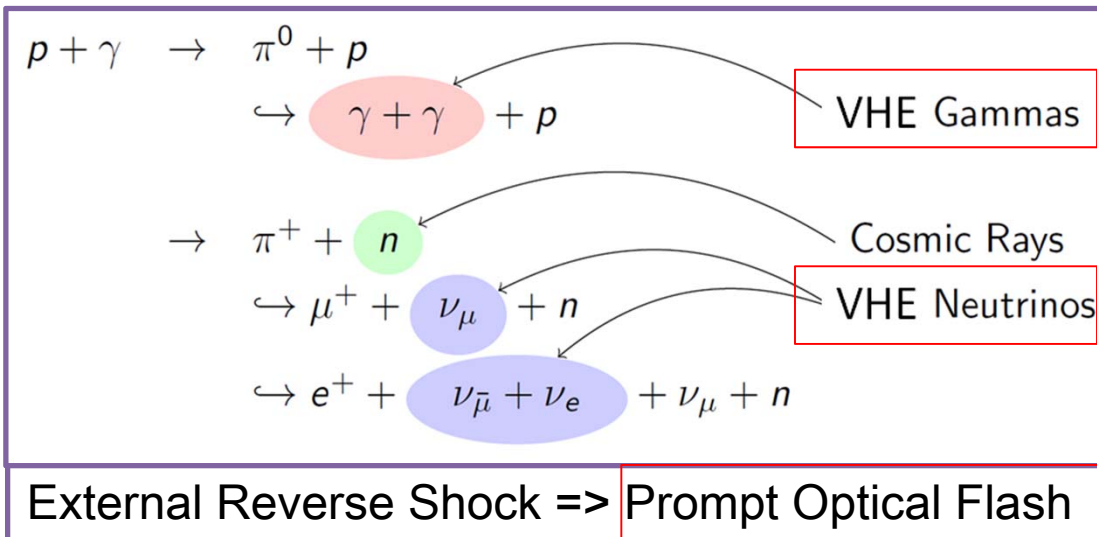
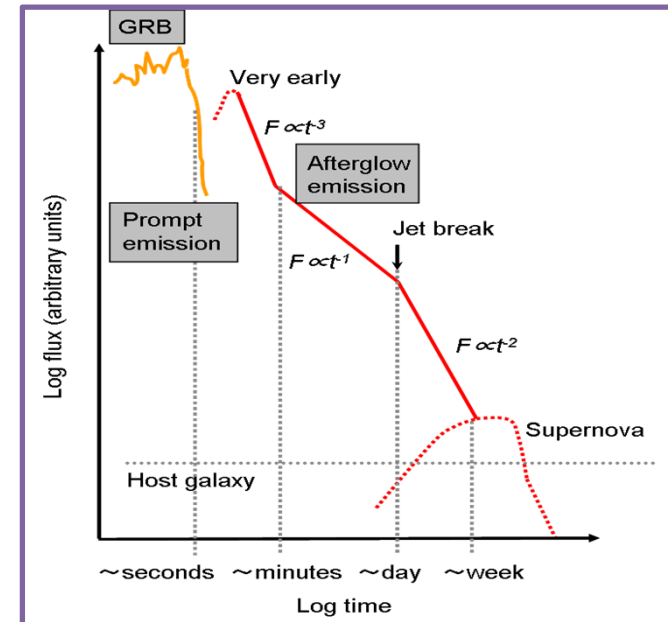
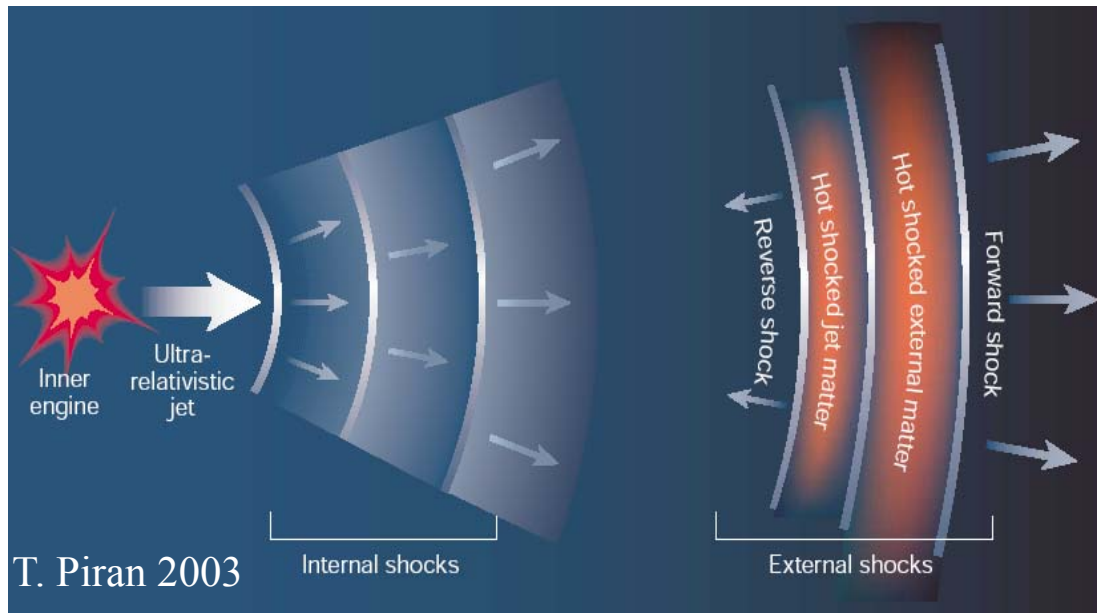
Outline

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

Scientific Goal

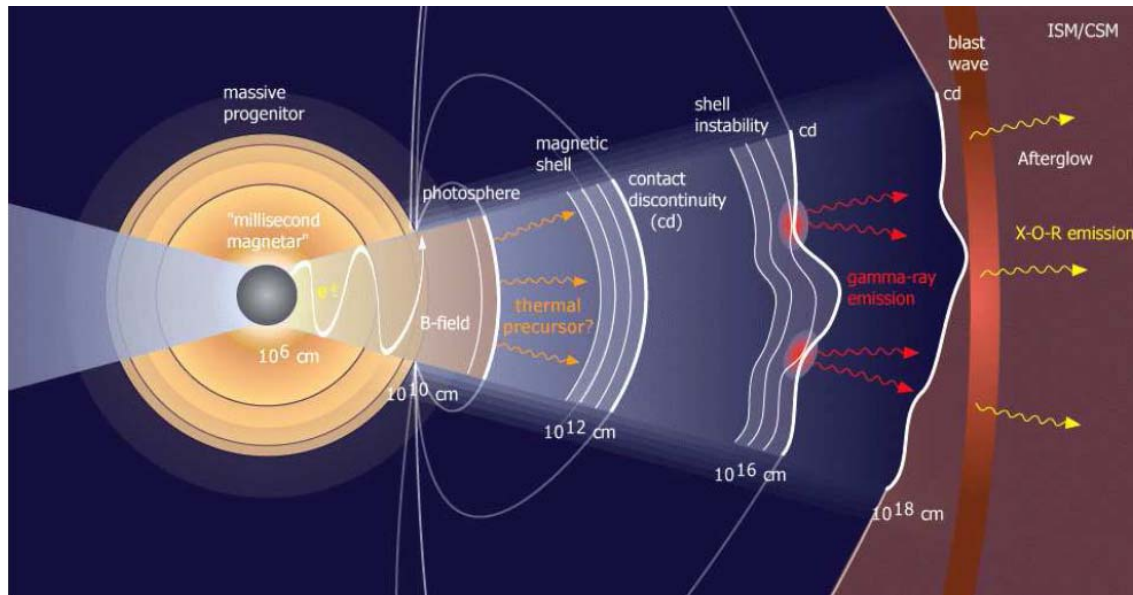
- “Multi-particle Astronomy”
 - Multiple probes into violent astro. objects (e.g. GRB)
 - PeV-EeV ν : hadronic model $\Rightarrow$ ES τ shower
 - TeV-PeV γ : leptonic model $\Rightarrow$ Atmospheric Cherenkov
 - Optical : reverse shock $\Rightarrow$ Optical transient
 - Distinguishable physics identification 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



Ashra

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

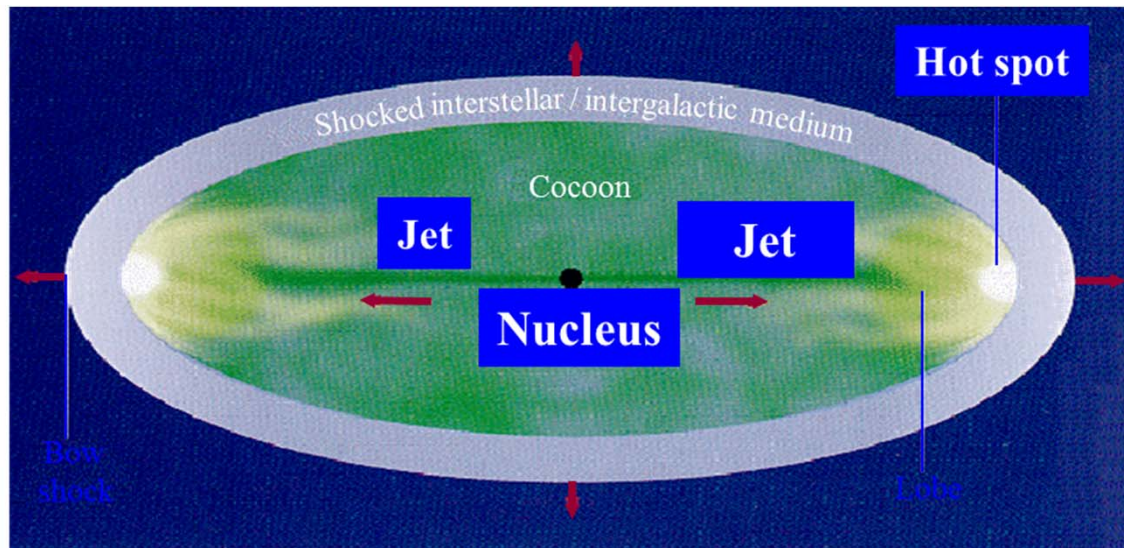


EMM

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

No EHECR $\Rightarrow$ VHE ν

No Optical Flash



Cocoon Model

(Zhang, Woosley, 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

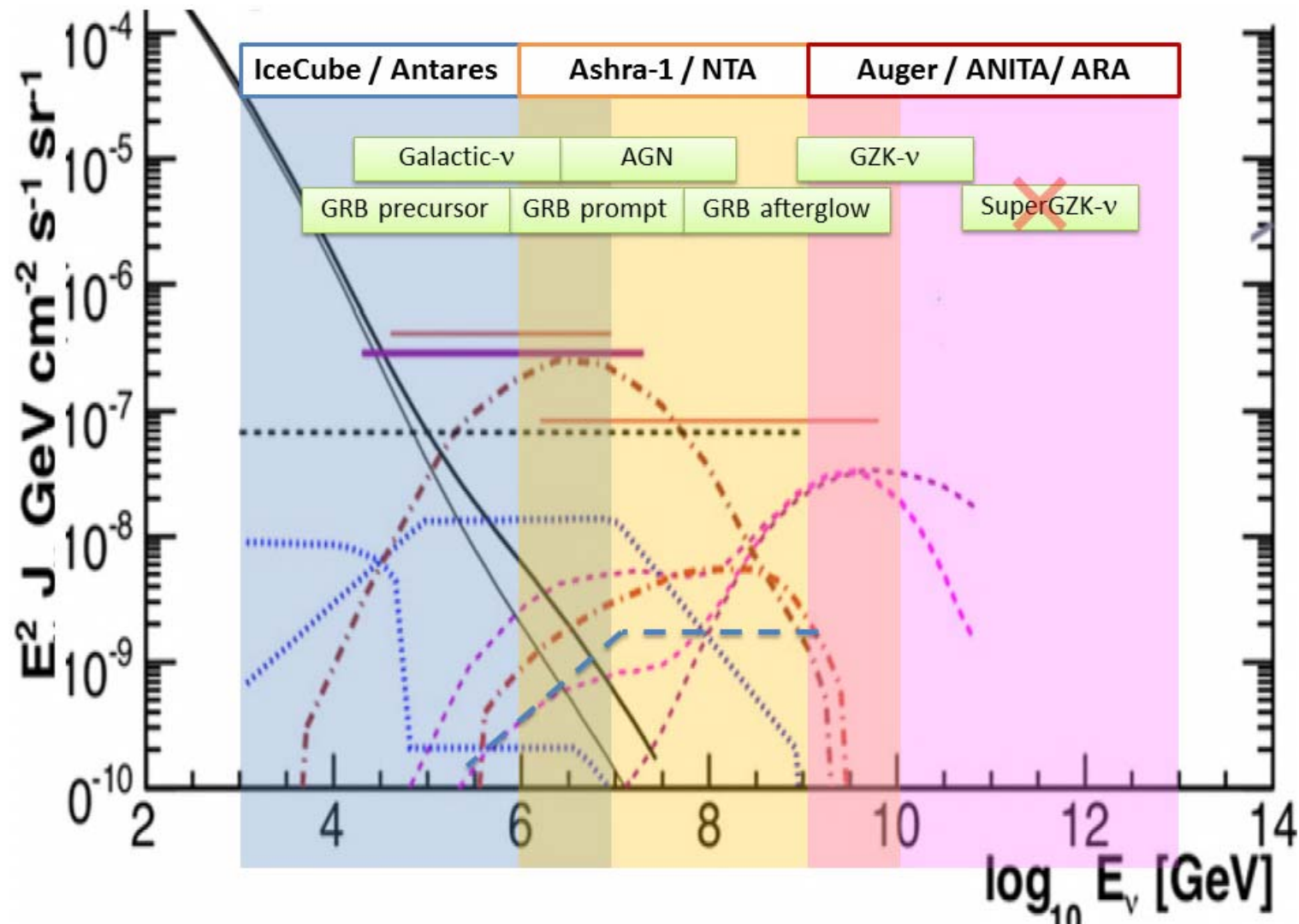
Galactic

- 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

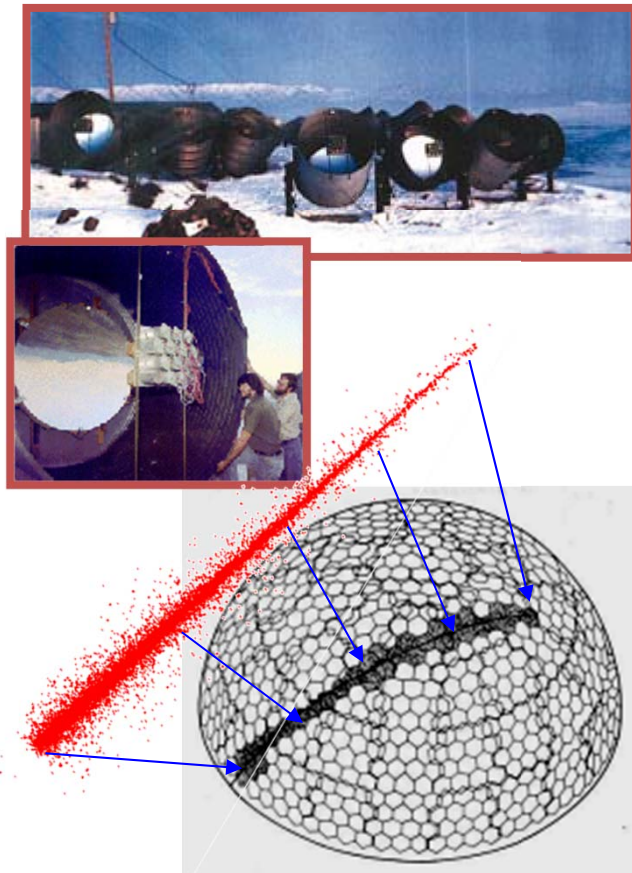


PeV-EeV $n \Rightarrow$ No Atm- ν & p Accelerator $\Rightarrow$ Clear Evidence

Optical Air-shower Detector

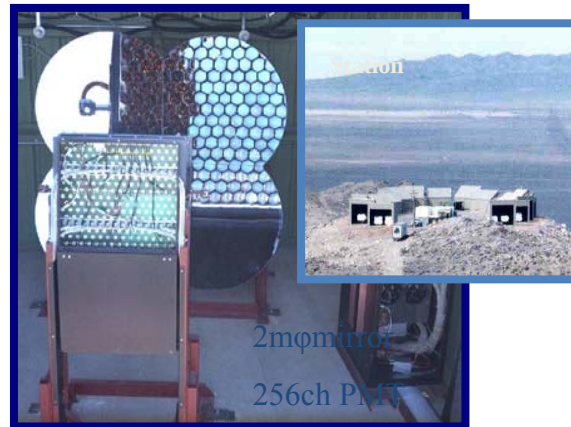
Progress of Resolution $\times$ FOV

Fly's Eye (1981-1993)



4deg/pix $\times$ All-sky
P M T

HiRes (1994-2006)



1deg/pix $\times$ 28deg
P M T

Ashra-1

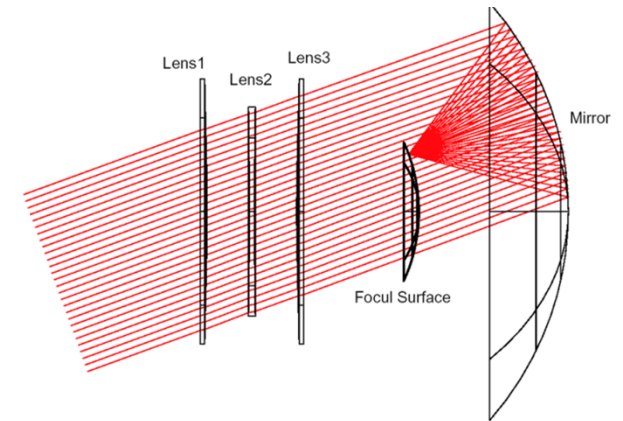
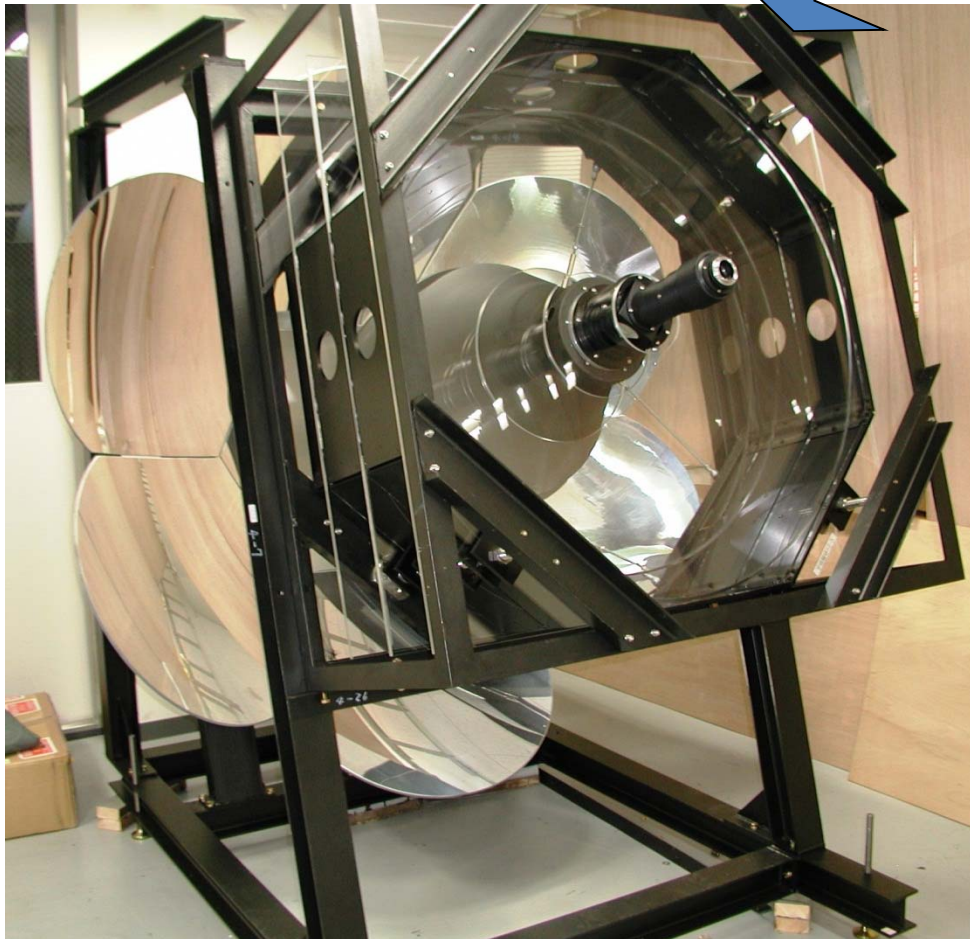


1.2min/pix $\times$ All-sky
Image Tube + CMOS

Light Collector



Ashra @ Mauna Loa

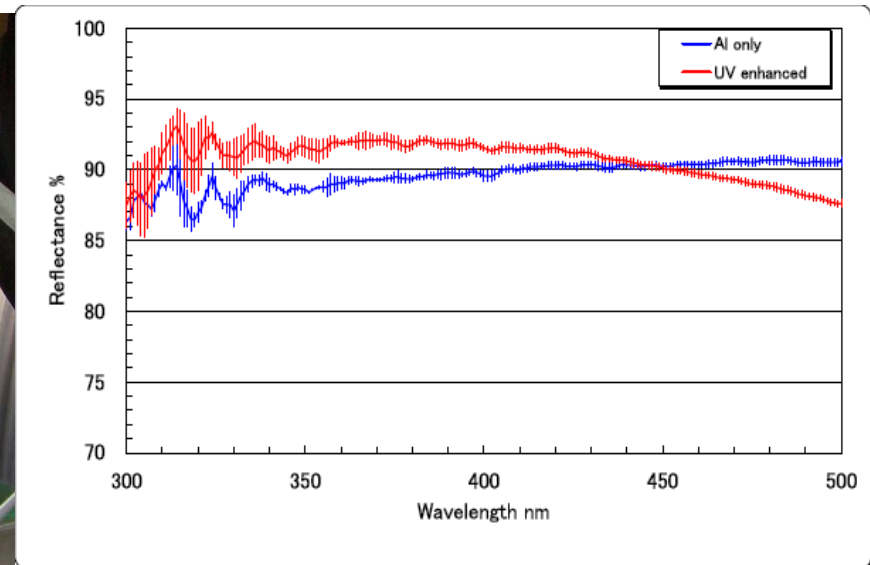
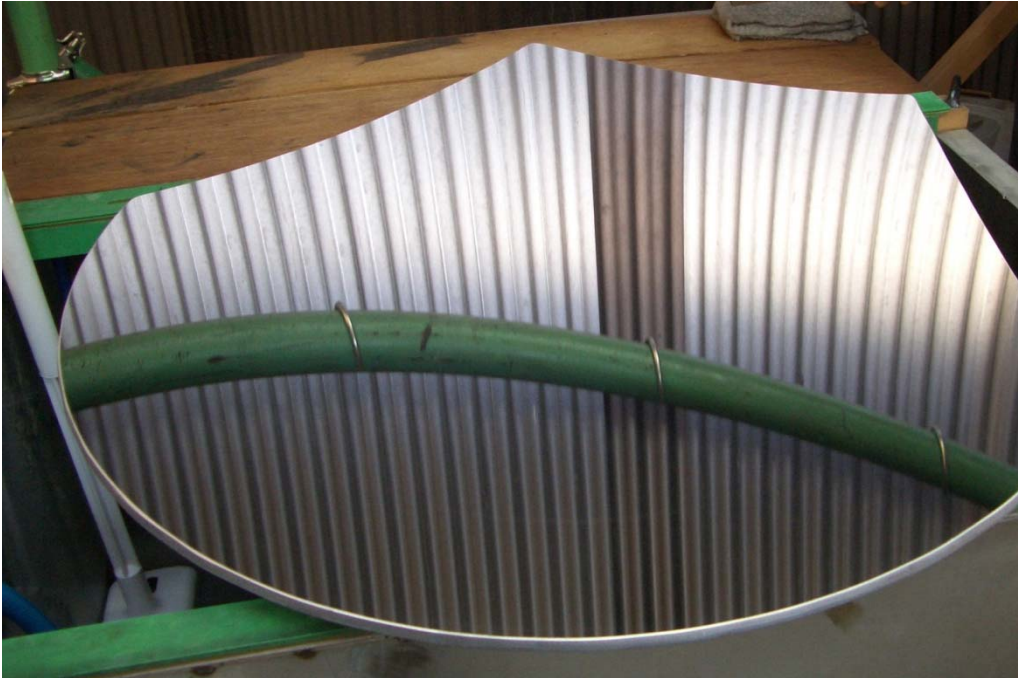


- Optics:
 - **Modified Baker-Nunn**
- Components:
 - **Correcting lens** (1.0~1.2m ϕ) with 3 acrylic cut plates
 - **Spherical mirror** (2.2m ϕ) with 7 curved glass plates on adjustable tables.
 - **Photoelectric lens IT** (0.5m ϕ) on focal sphere suspended with Stewart platform mechanism
 - **Mount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

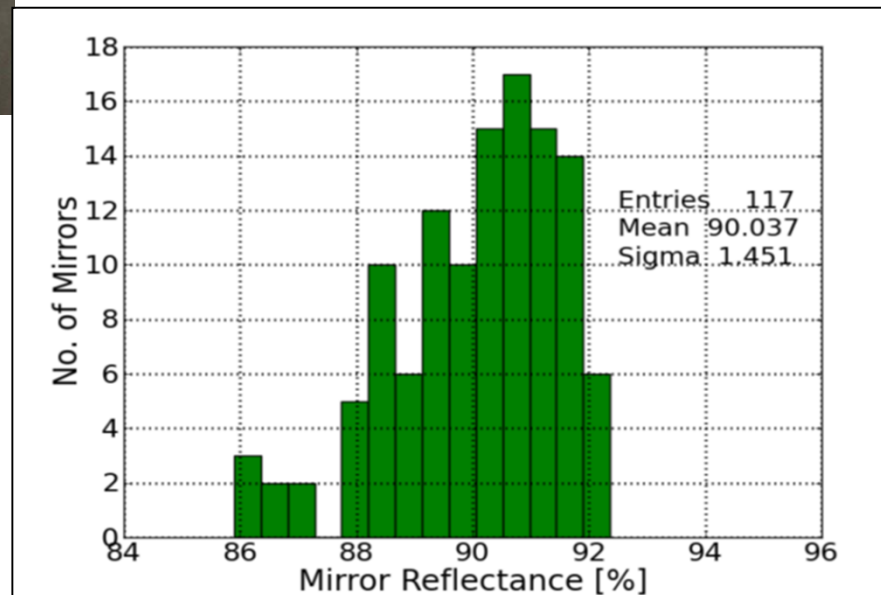
=> arcmin. resolution over 42deg FOV

=> Affordably cost-effective

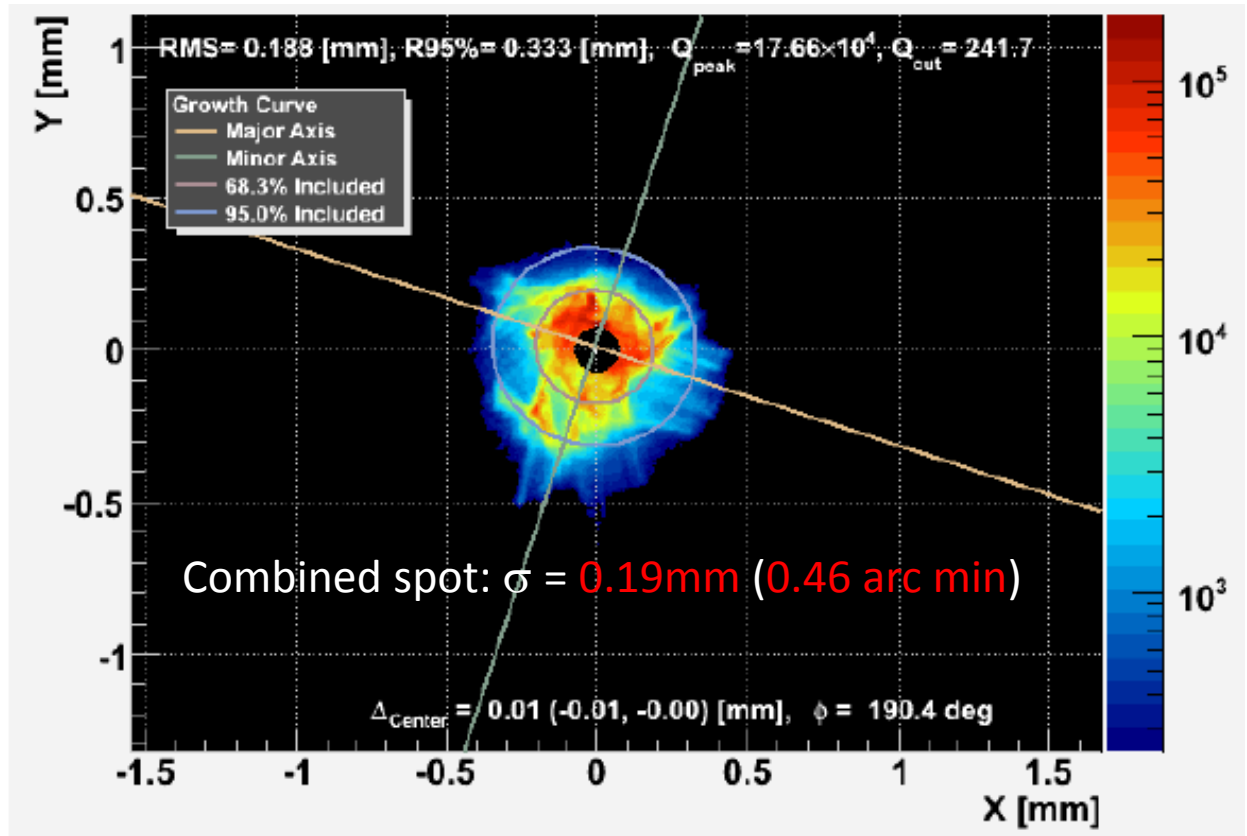
Segment Mirror



1. Float glass curved mirror:
 $\phi 850 \times t8$ Cut $\Rightarrow$ 10 kg / seg . piece
Total 7seg / LC $\Rightarrow \phi 2.2\text{m}$ & $\sim 70\text{kg}$.
2. Evaporation of Al + Al_2O_3 coating
 $\Rightarrow$ UV enhanced
3. On-site test just before installation:
all segments (~ 200 pieces) OK:
 $>85\%$ @ 470nm $\Rightarrow >88\%$ @ $<400\text{nm}$



Mirror Adjustment



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

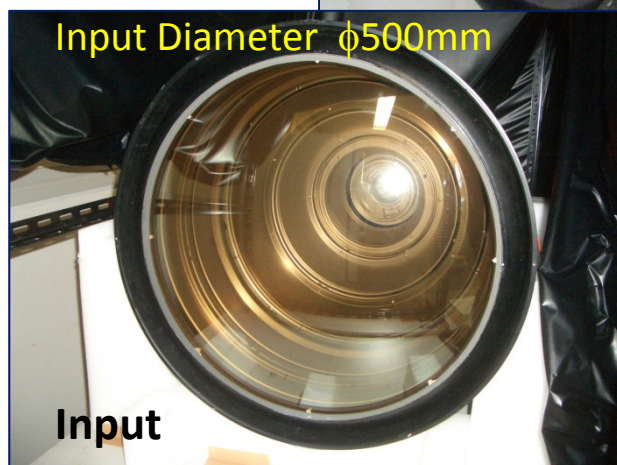
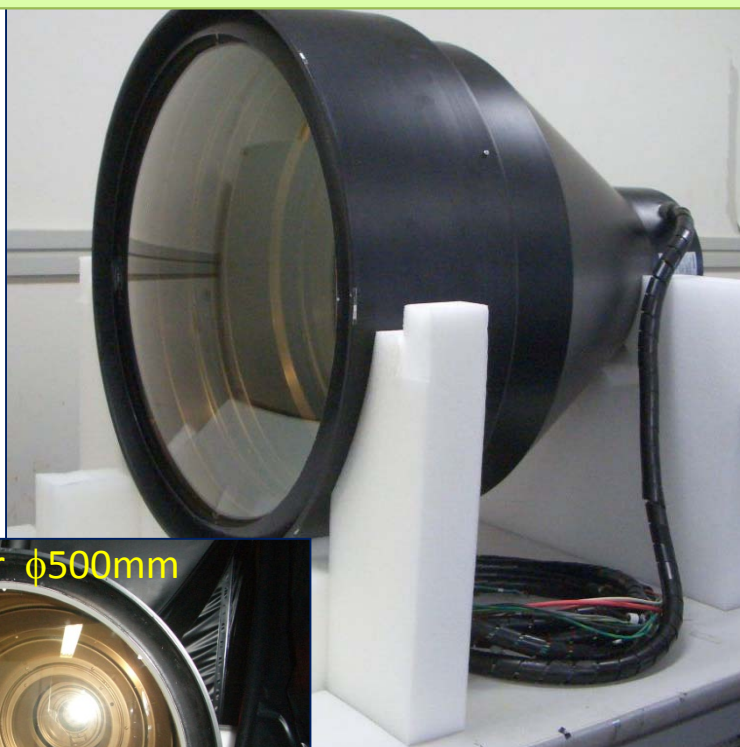
- Total spot size measured after adjusting 6 segment mirrors on mount:
 - => Combined spot $\sigma = 0.19\text{mm}$
 - => corresponding to 0.46 arc min

20" Photoelectric Lens Imaging Tube (PLI)

Large : World largest I.I.

Fine : FWHM = 40-60 μ m @output window

Stable: No performance degradation for 2 years



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



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Physics Research A

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

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Large sensitive area
Photodetector
High energy astrophysics
Ashra experiment

ABSTRACT

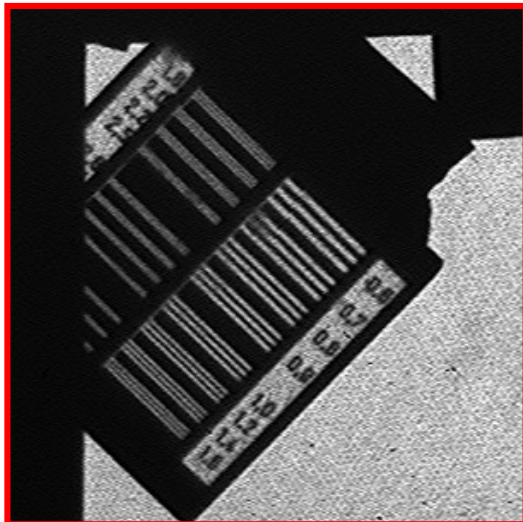
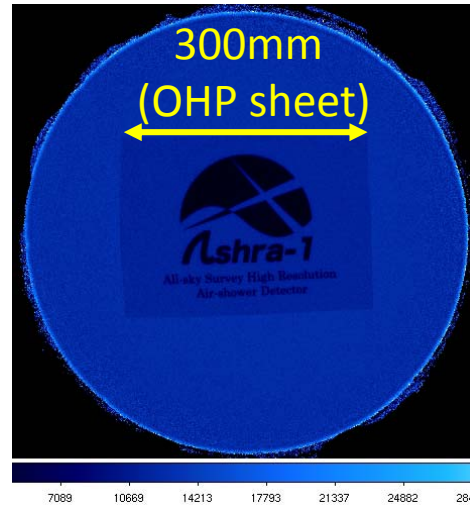
We have evaluated a 20-in. photoelectric lens image intensifier tube (PLI) to be mounted on the spherical focal surface of the Ashra light collectors, where Ashra stands for All-sky Survey High Resolution Air-shower Detector, an unconventional optical collector complex that images air showers produced by very high energy cosmic-ray particles in a 42-m-diameter field of view with a resolution of a few arcminutes. The PLI, the world's 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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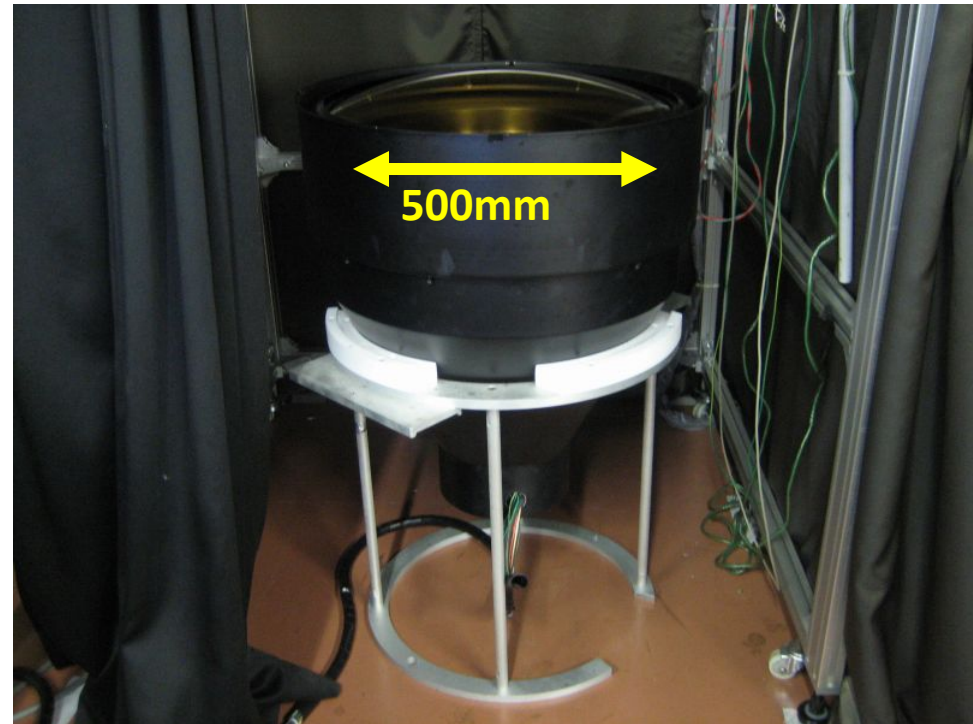
Y.Asaoka, M.Sasaki NIMA 647 (2011) 34

Imaging Test of 20" PLI

Output Image Example



Imaging Resolution Chart on Input Window



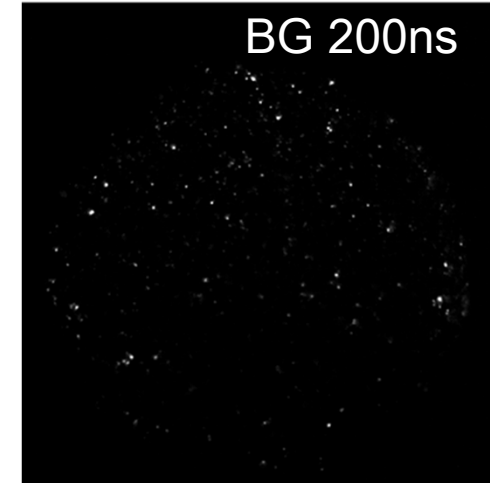
Pipeline Trigger & Readout

Multiple trigger is realized

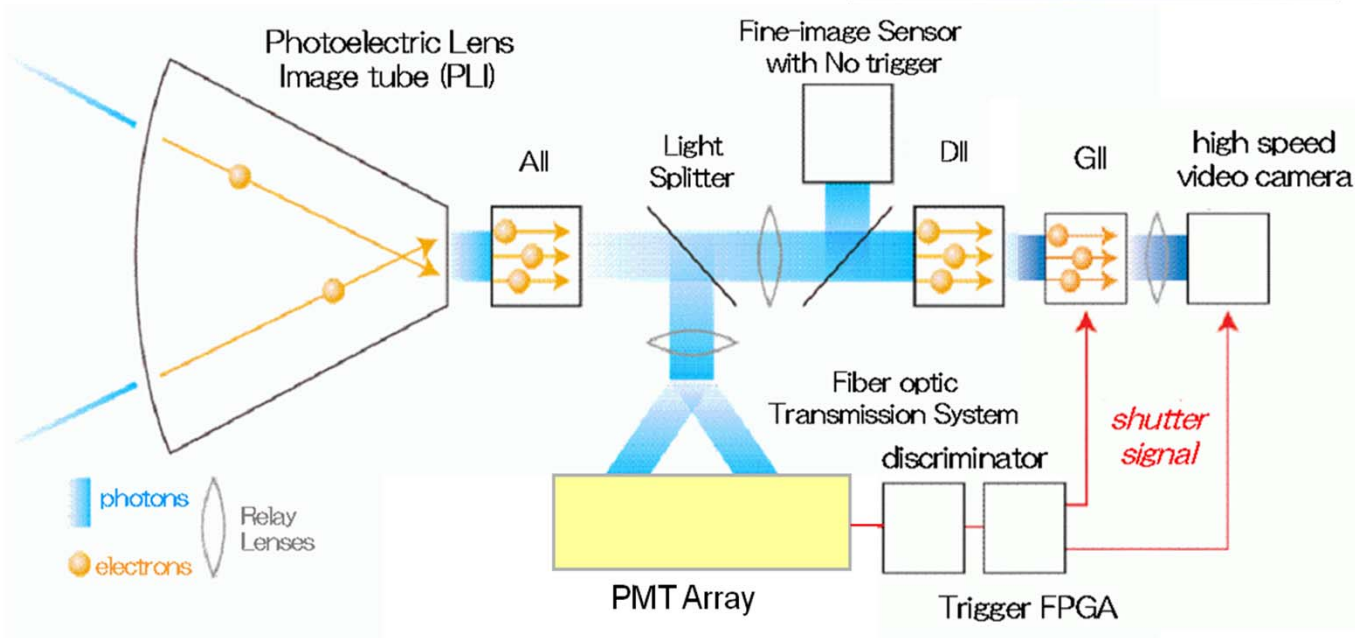
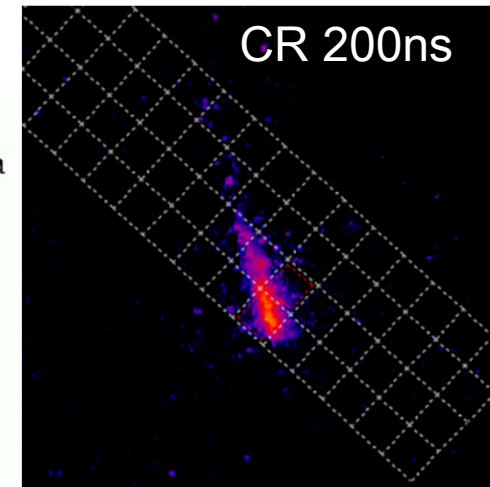
Optical 4s



BG 200ns

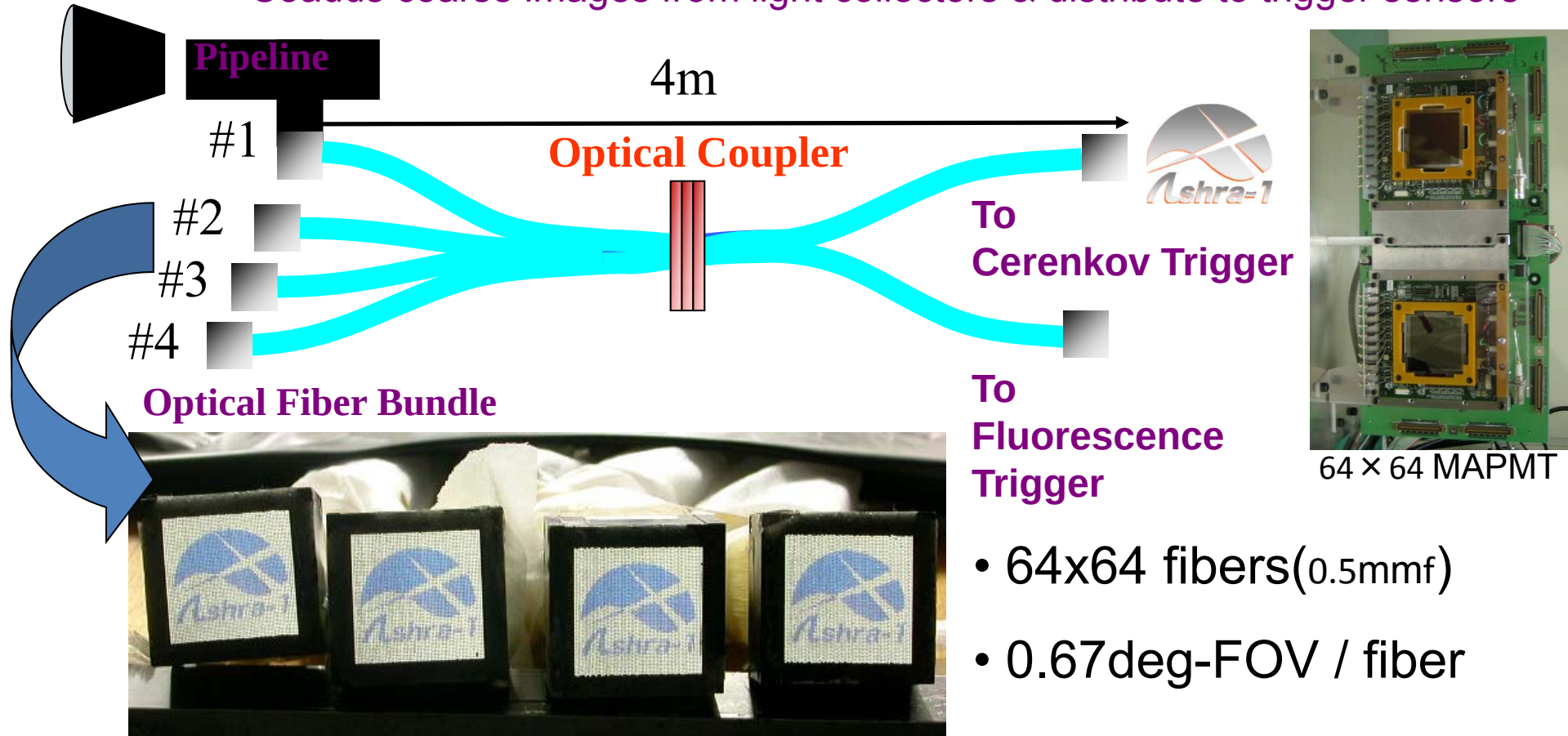


CR 200ns



Optical Fiber Transmission System

Coadds coarse images from light collectors & distribute to trigger sensors



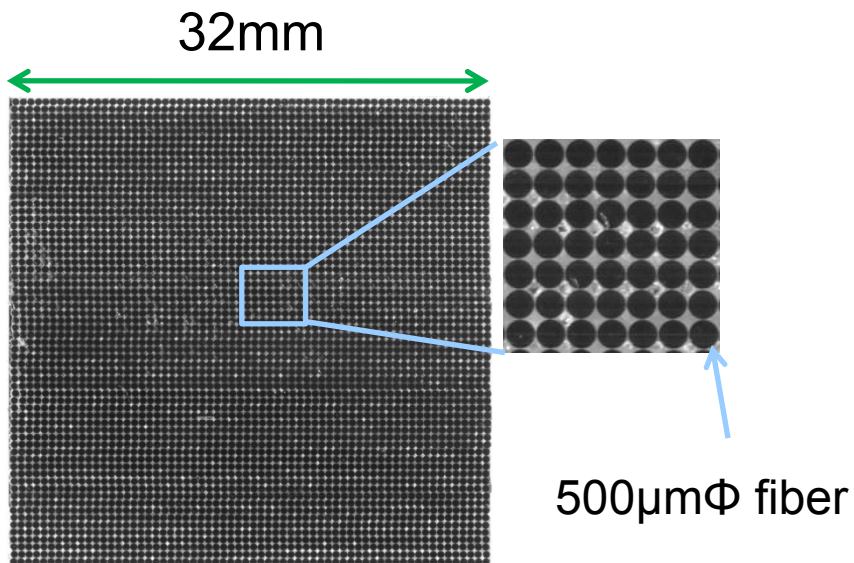
Light collectors can be easily appended to the trigger.

Sensitivity can be reinforced when more budget is available.

FOP Bundle

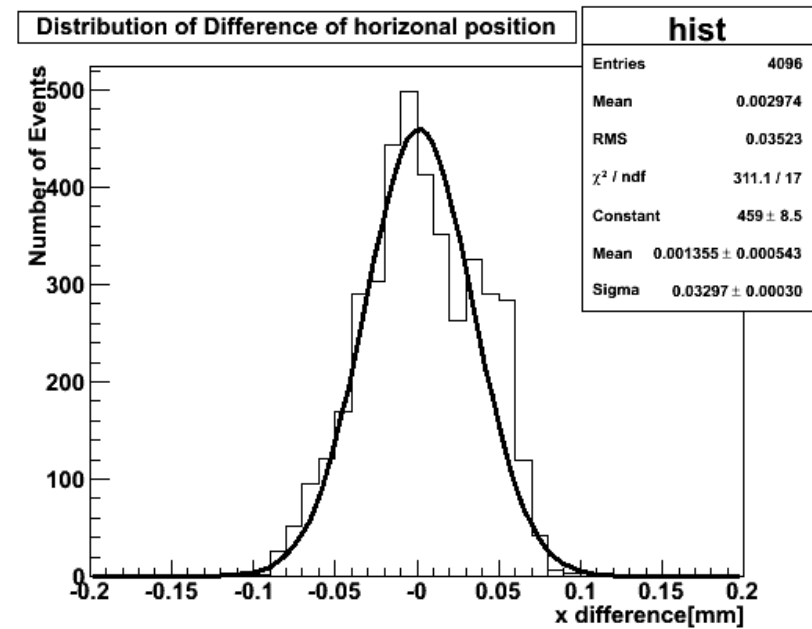


FOP Bundle



Cross sectional view

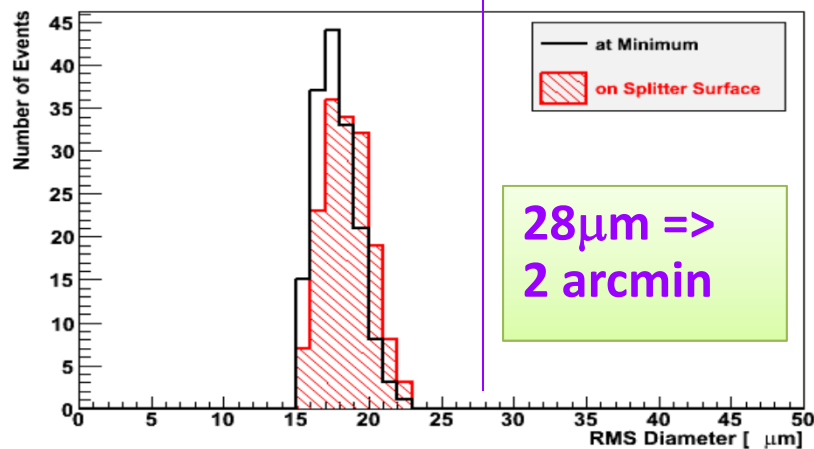
64x64 acrylic FOP bundle



Alignment Errors from Expected Position

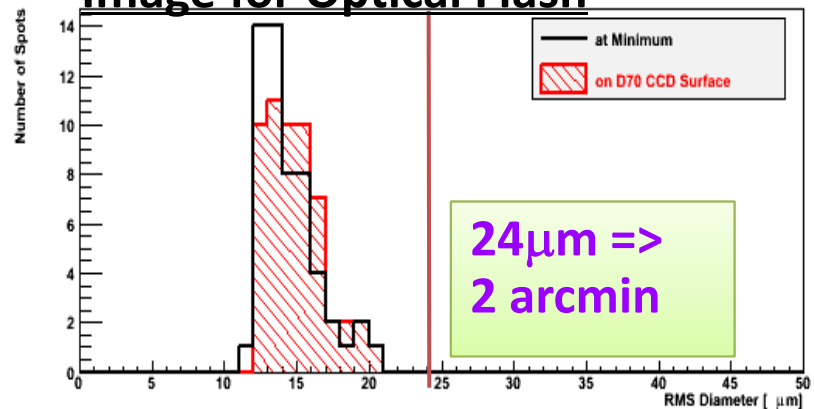
Photoelectric Image Pipeline (PIP)

Image for AirShower

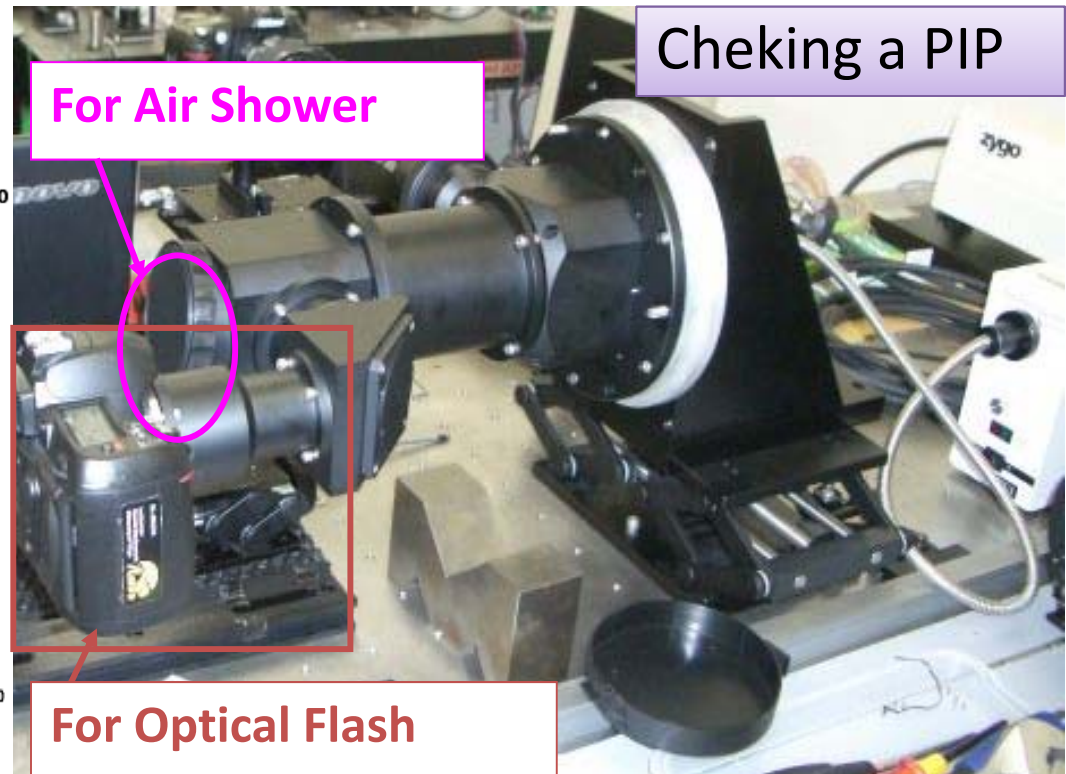


Focus Point Accuracy: 10 μm
Imaging Resolution ~ 1.5 arc min

Image for Optical Flash

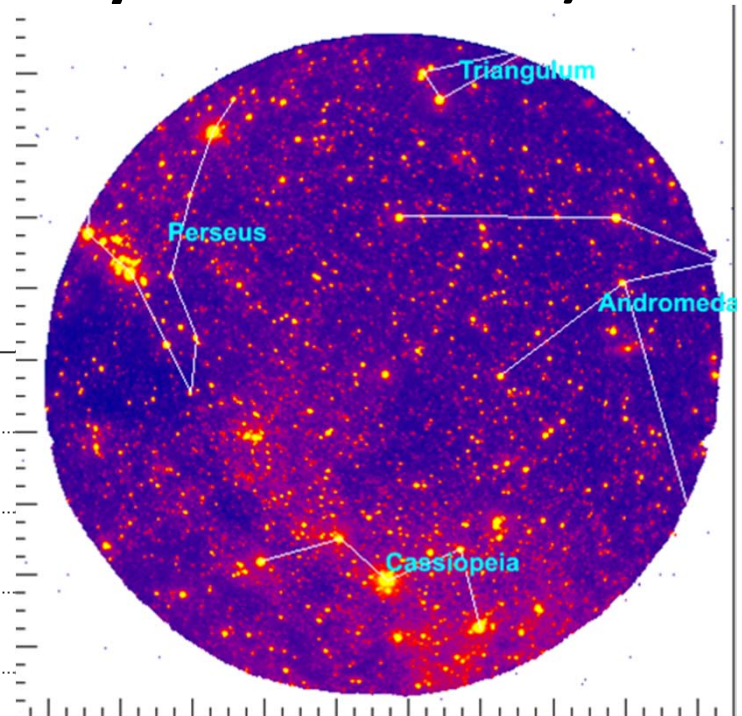
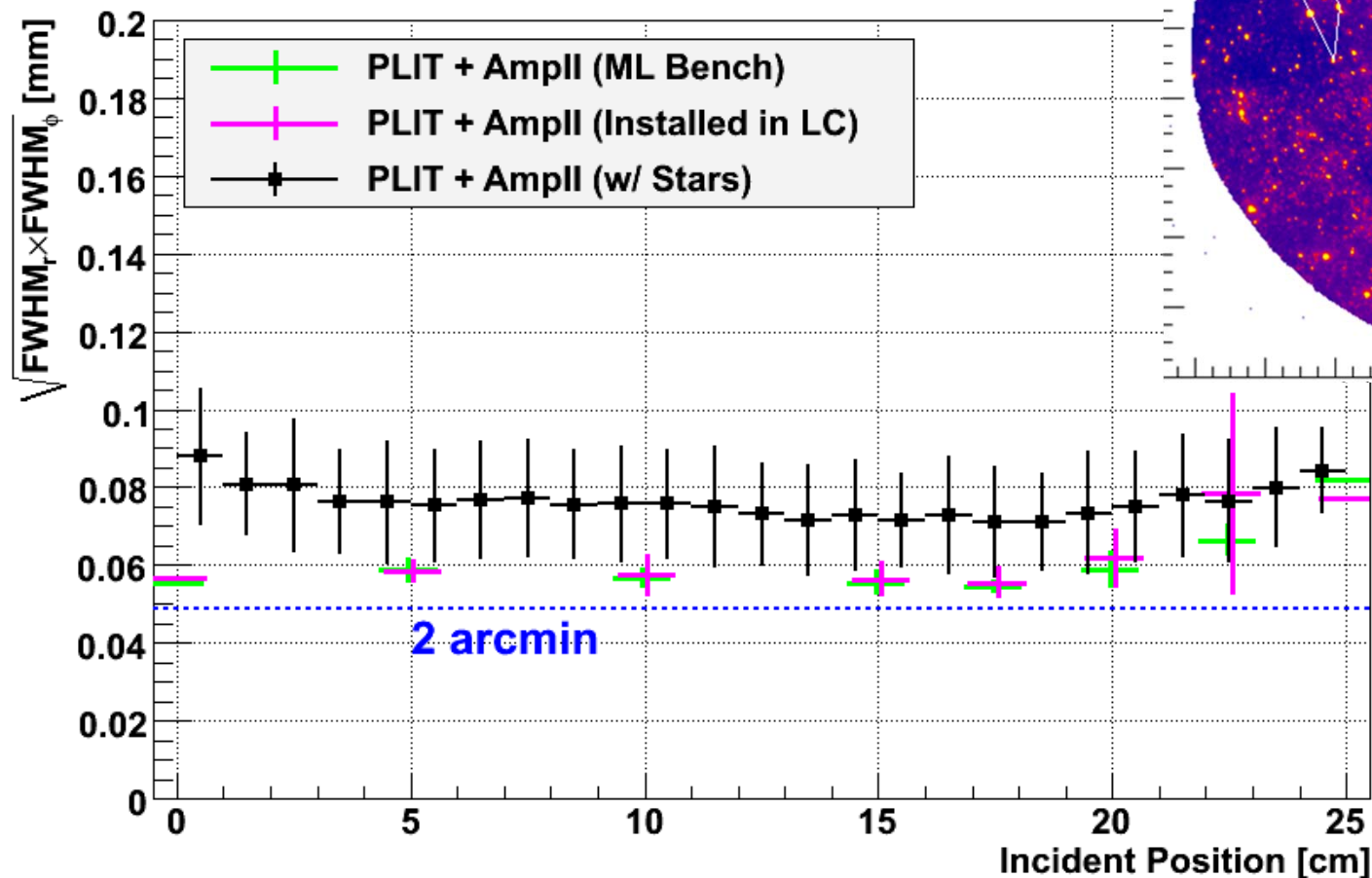


Results on Checking Incoming PIPs



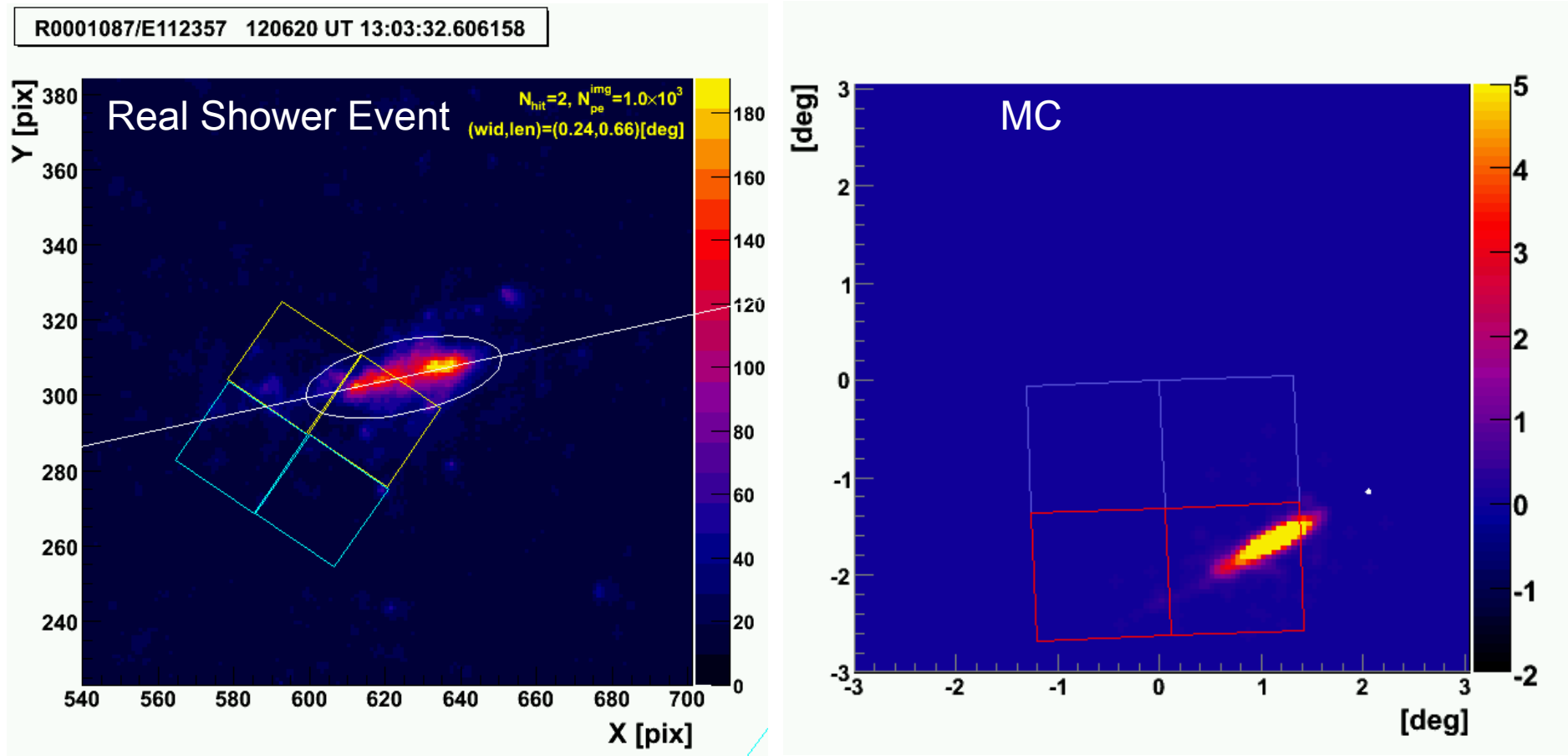
Total Star Resolution (Opt.Sys+PLI+PIP)

~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

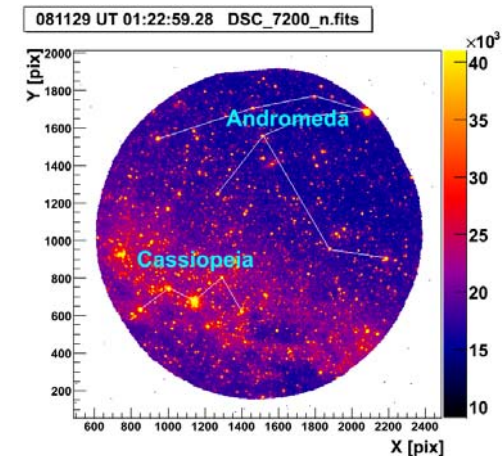


MC reproduce real event

Ashra-1 Mauna Loa Site

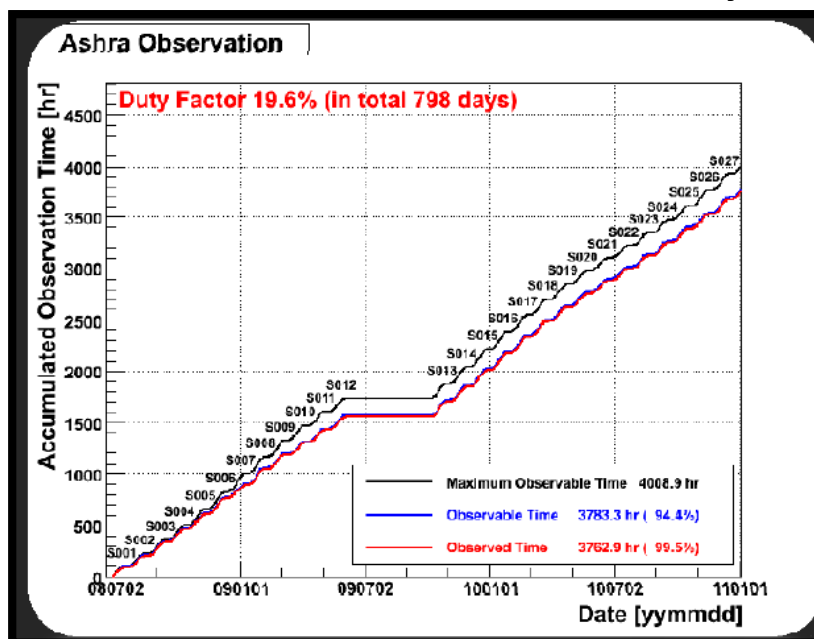


- | | |
|------|--|
| 2003 | Funded |
| 2005 | Observational site use permit |
| 2007 | Intensive installation |
| 2008 | Obs01 started <ul style="list-style-type: none">– Optical flash observation– VHE neutrino commissioning observation |
| 2009 | Obs02 started. |
| 2011 | Extension of the site use 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%

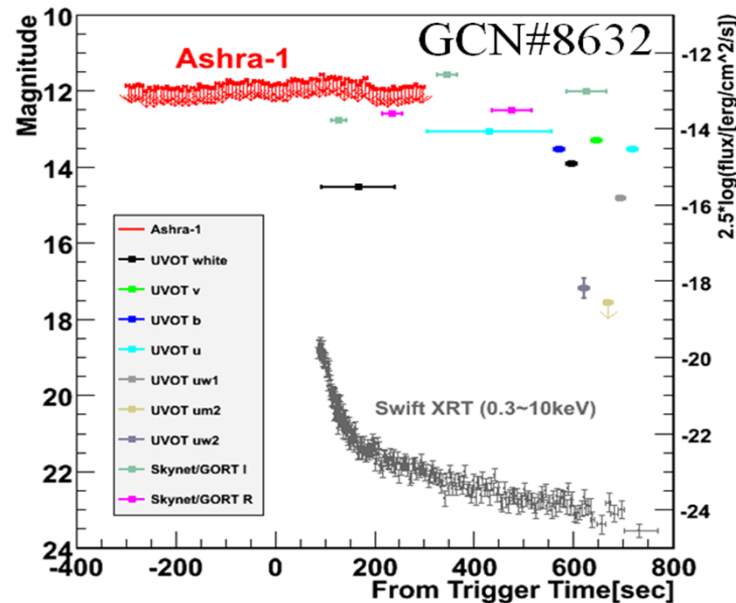
One of Best Sites for Astronomy

Observation 03 on going
(Statistics: 2012.01-2012.11)

	v_{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%

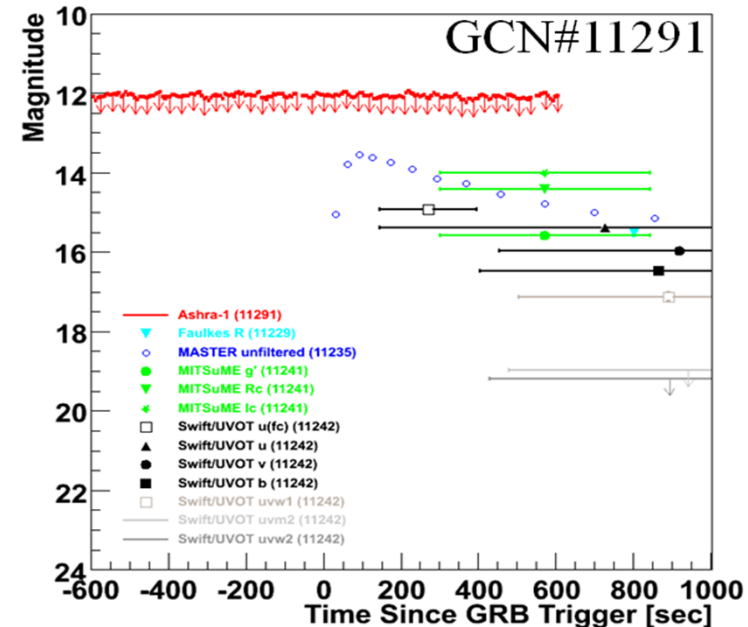
Optical Search Limits

GRB081203A Optical Observations



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

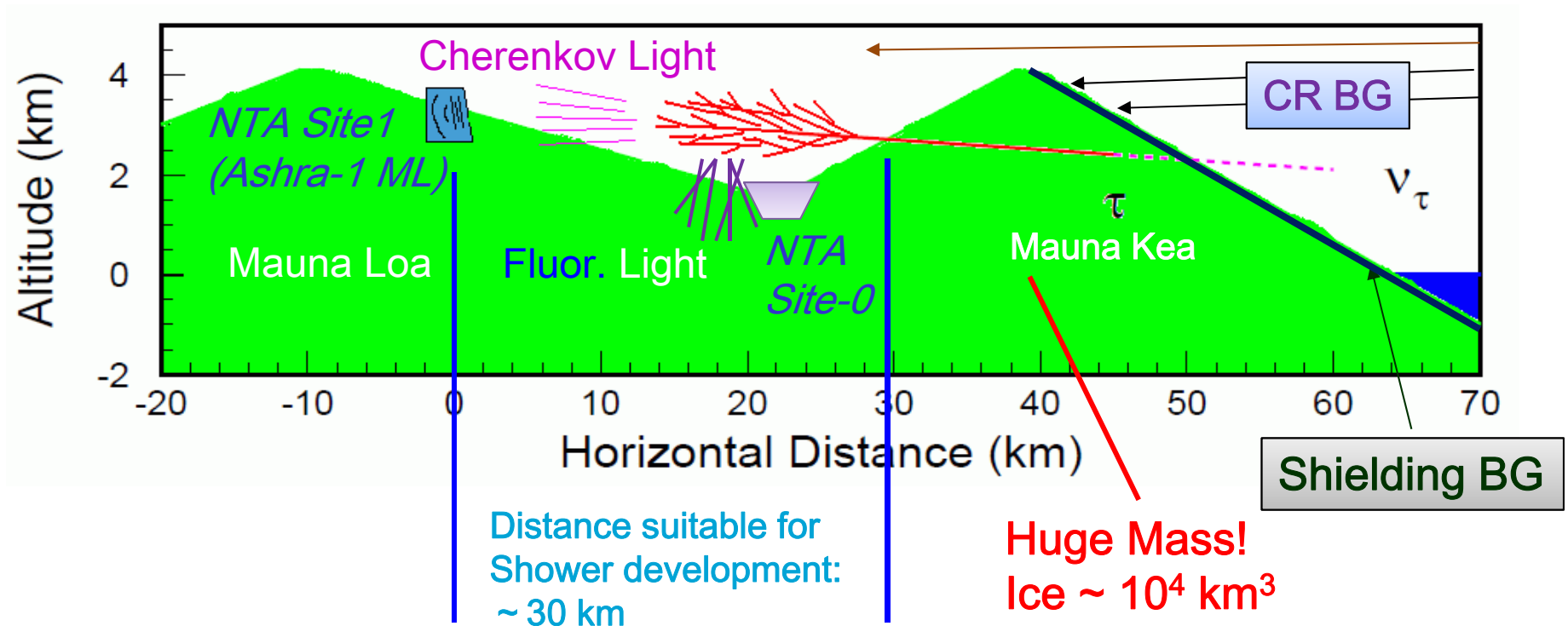
GRB100906A Optical Observations



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

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

Earth-Skimming τ Shower Imaging Method

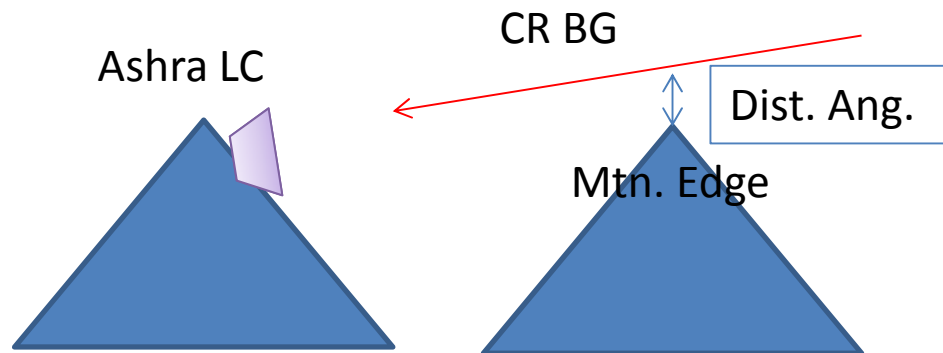


Ashra-1 really demonstrated this method !
(ApJ, 736 (2011) L12)

BG Condition for VHE ν

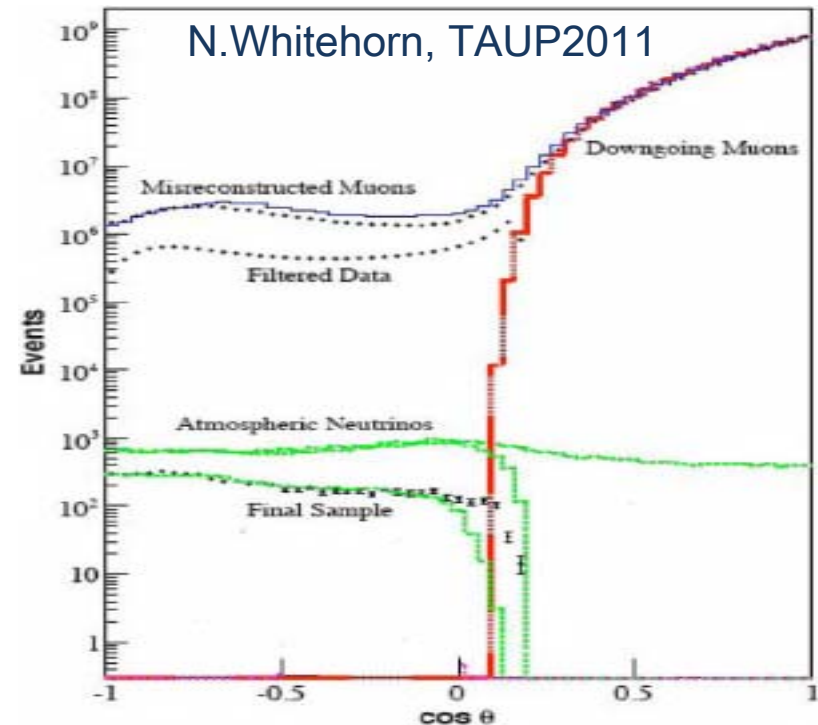
Ashra NTA BG Condition

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)

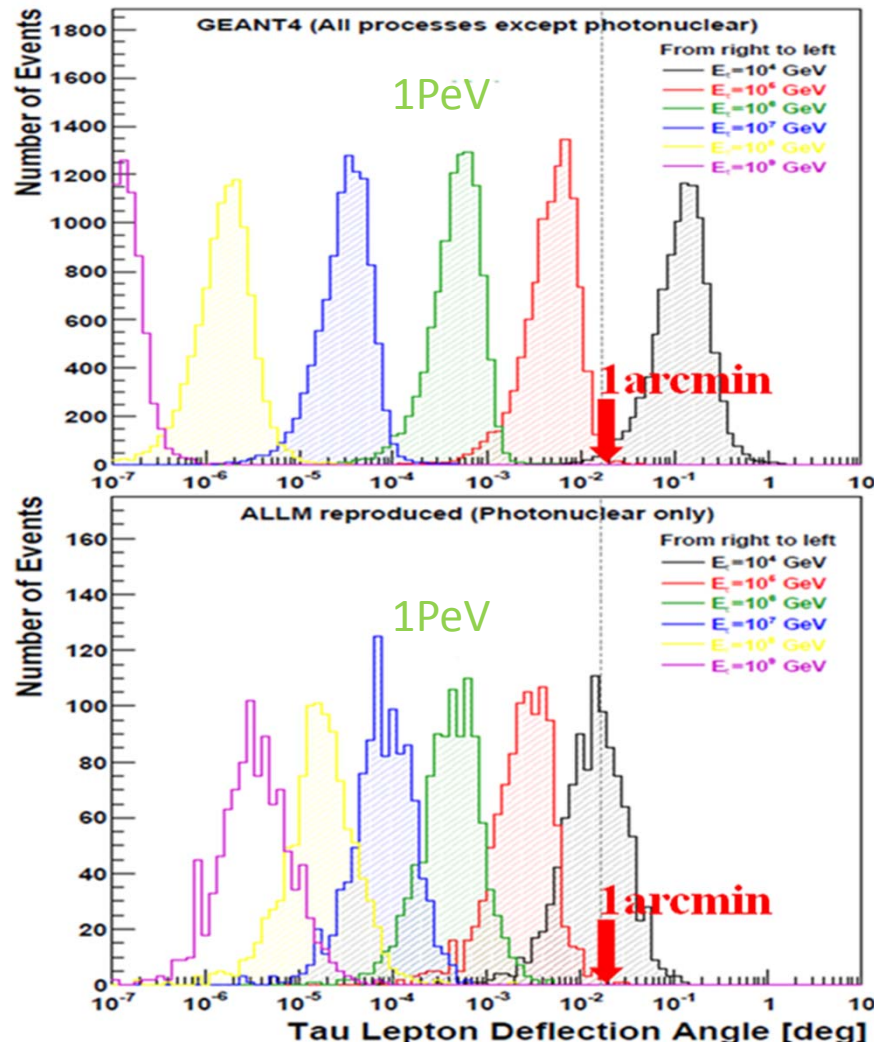


Surface: $1 \text{ cm}^{-2} \text{ minute}^{-1}$

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

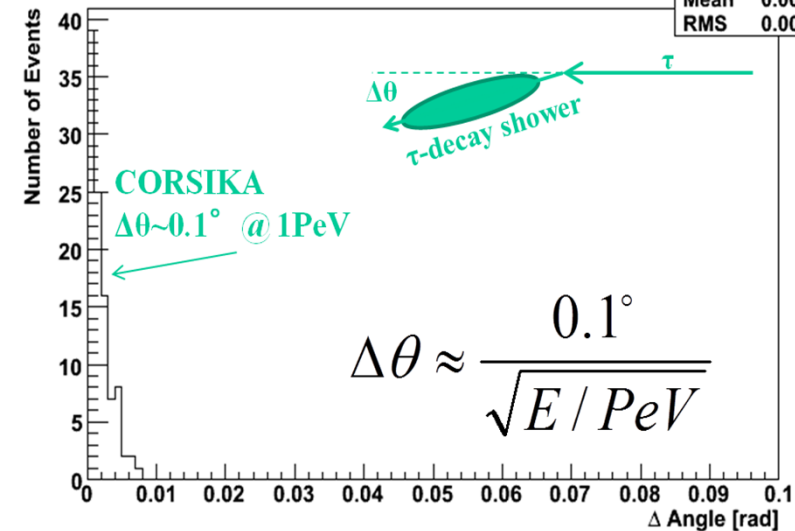
→ requires 10^6 $\text{atm. } \nu$
background rejection

Tau Propagation Deflection in Rock



Possible Deflection $\ll$ 1 arcmin

$E=10^{15.0}$ eV π Shower Axis



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

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

Elevation=-6.4° Azimuth= 347.6°

Mauna Loa
(Site1)

Hualalai
(Site3)

Central
(Site0)

Mauna Kea
(Site2)

Xmax

Decay Point

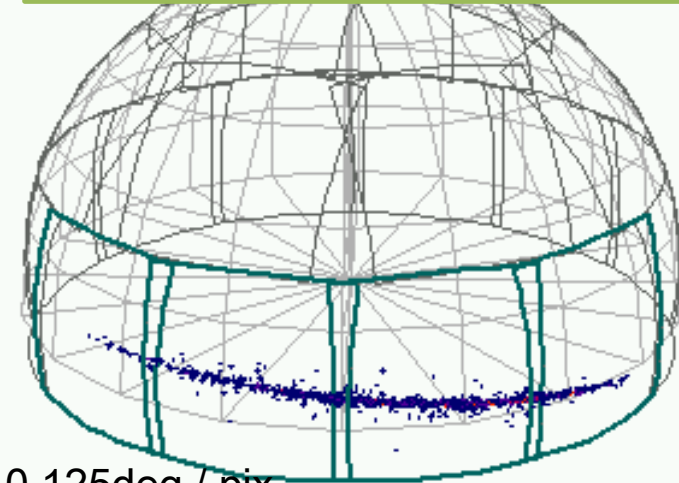
Impact Point

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

Simple Fit =>

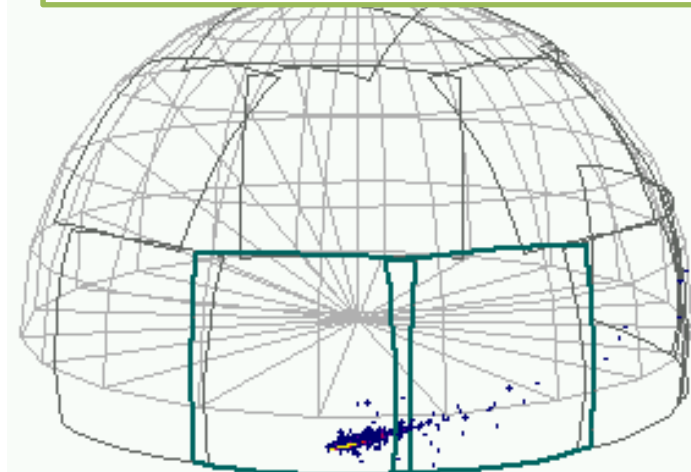
Site0 + Site1: 方向精度: 0.08°

Central (Site0): Fluorescence



0.125deg / pix

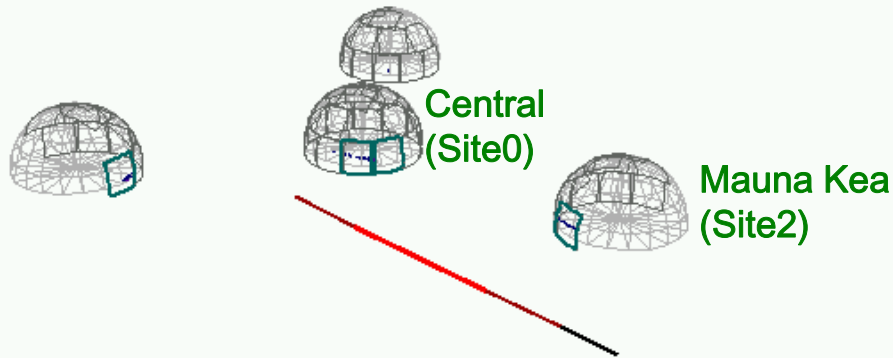
Mauna Loa (Site1): Cherenkov



0.125deg / pix

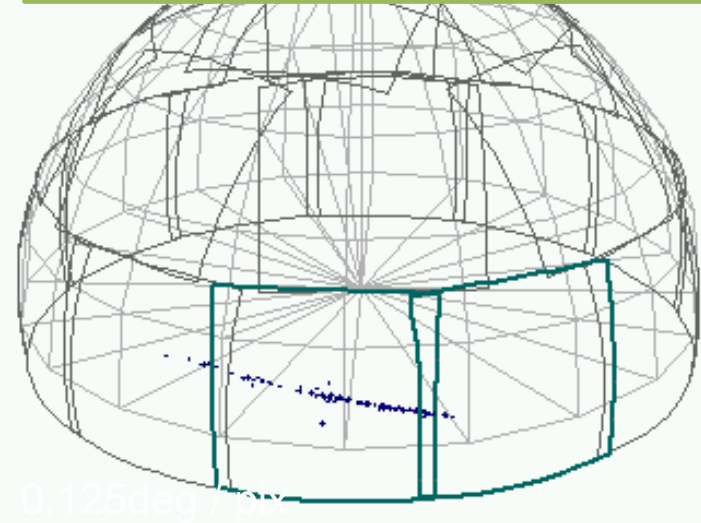
100PeV Neutrino Fluo.+Fluo. Event Simulated with Ashra NTA

R00264/E00008: $E_\nu=10^{17.0}\text{eV}$, $E_\tau=10^{16.9}\text{eV}$, $E_{\text{show}}=10^{16.7}\text{eV}$
Elevation=-2.5°, Azimuth= 25.2°

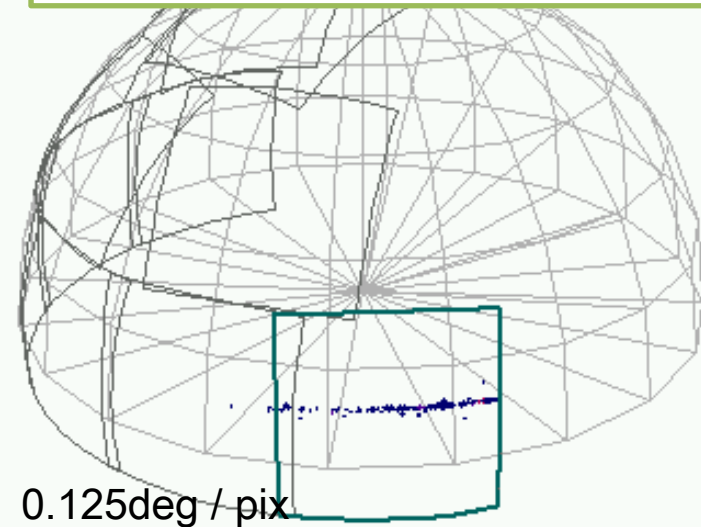


Simple Fit =>
 Site0 + Site1: **方向精度: 0.007°**

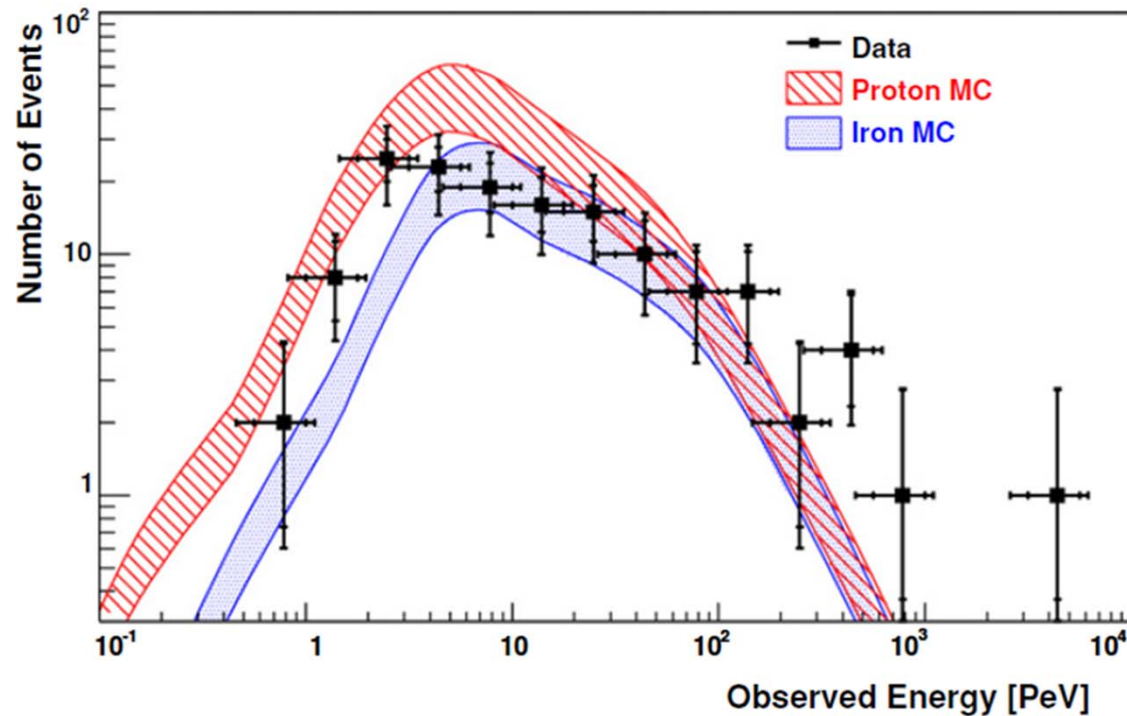
Central (Site0): Fluorescence



Mauna Kea (Site2): Fluorescence



(Commissioning) Observed CR Spectrum

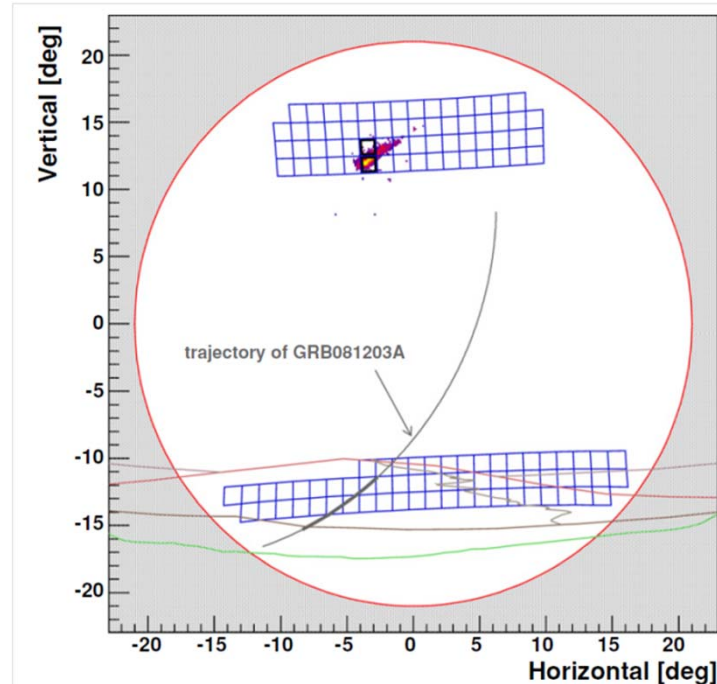
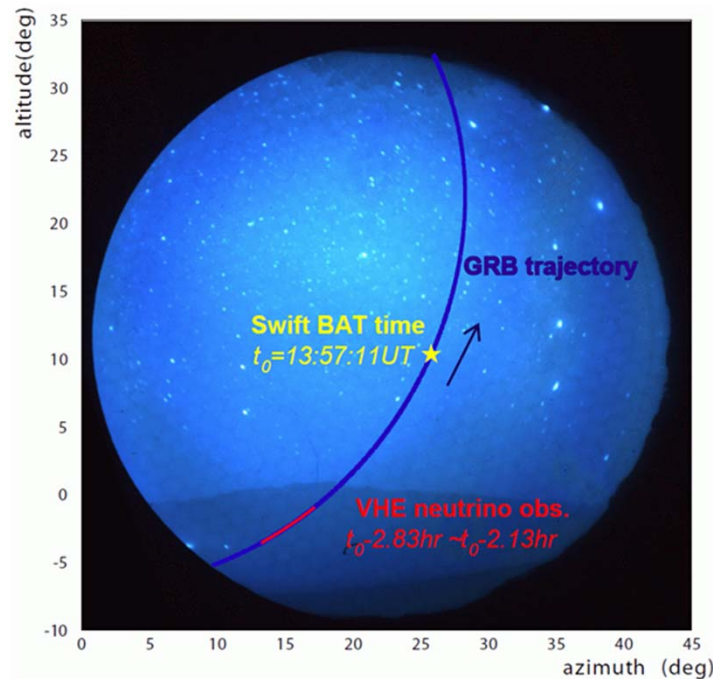


Validation of Sensitivity and Reconstruction

Some Hint for Composition

First GRB ν_τ Search

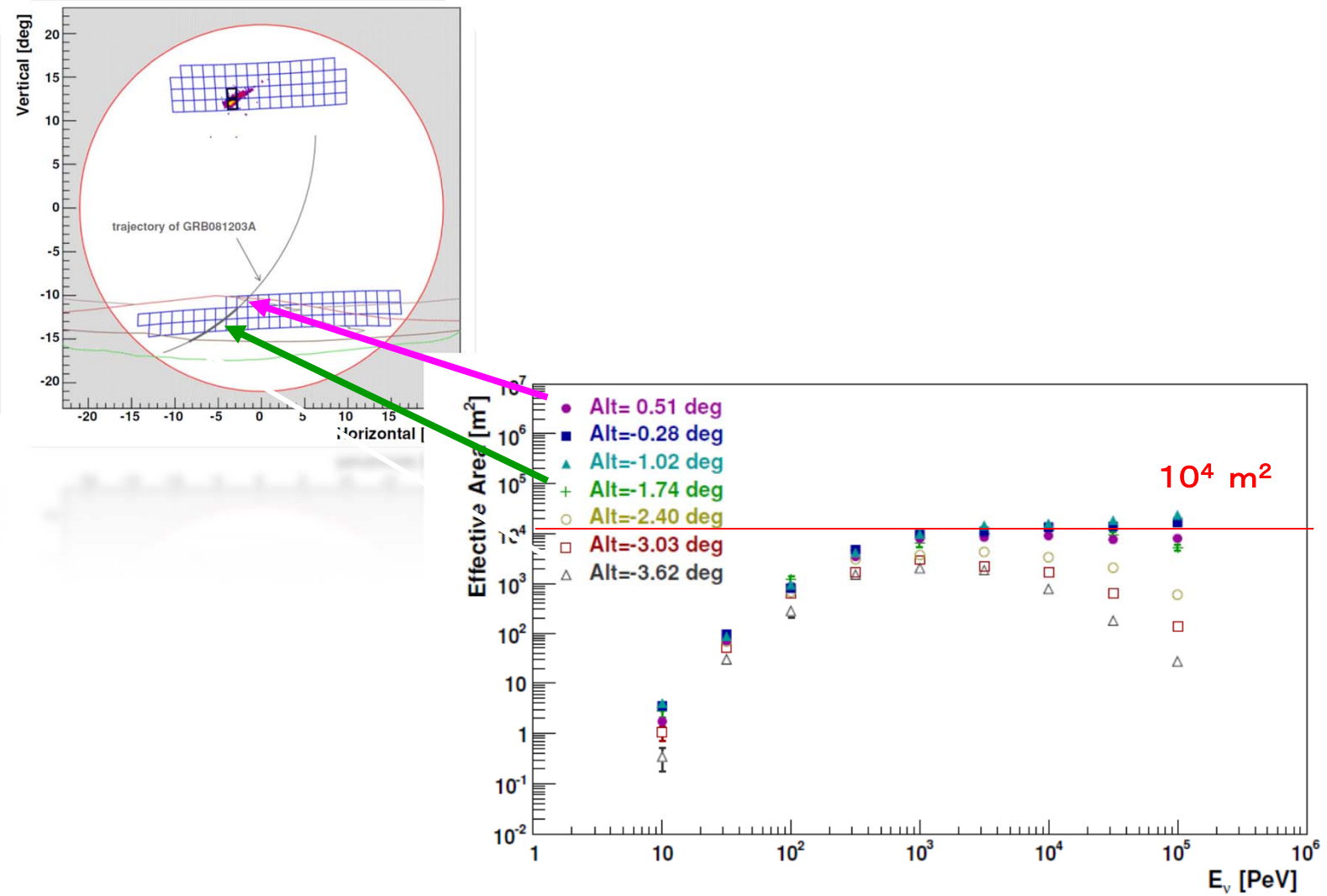
GRB081209A



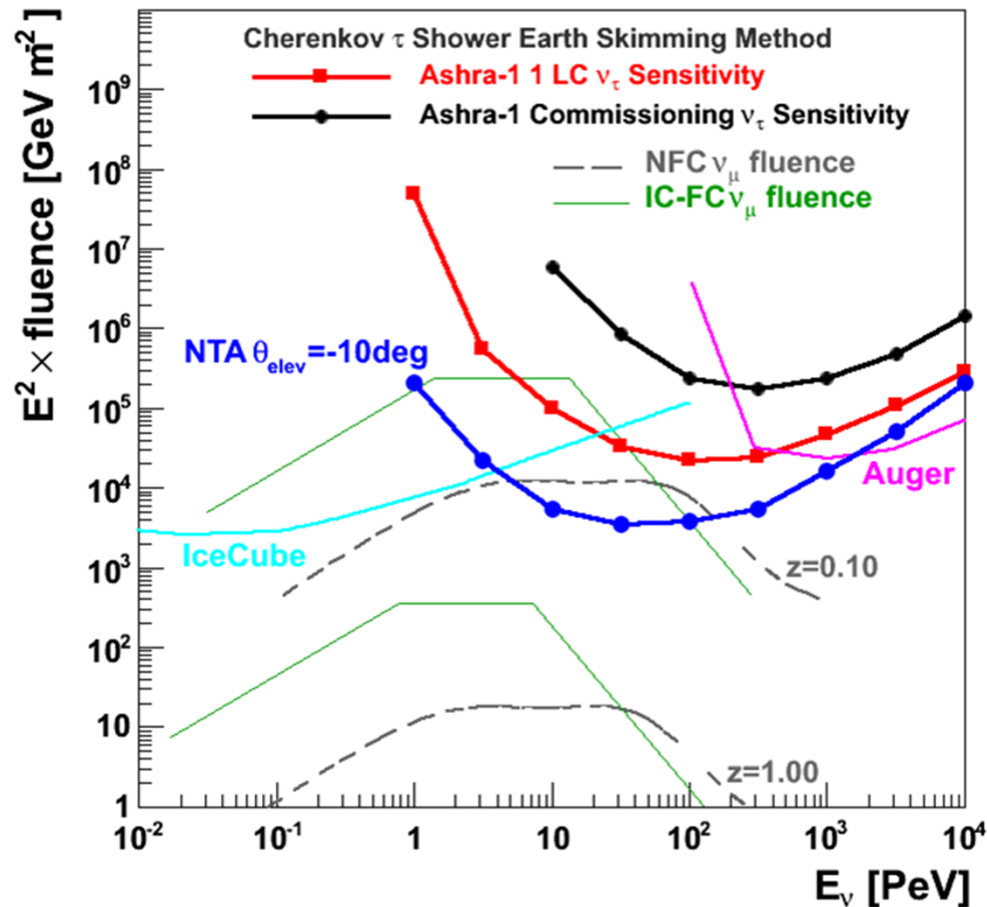
Swift GRB Alert during Commissioning in 2008

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

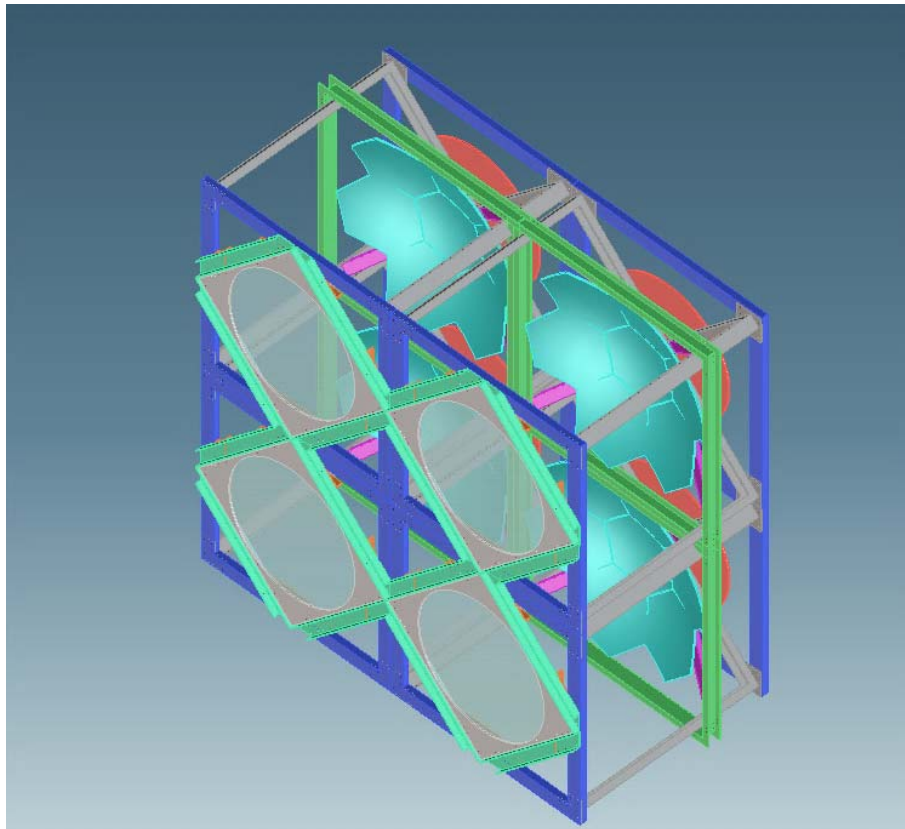
- Nearby Low luminosity (LL) GRB (ex. GRB 060218/SN 2006aj) dominate total neutrino fluxes at Earth
- X or γ Satellites cannot detect

3. Hummer et al. PRL 108 (2012) 231101

- Recalculated neutrino flux => Ashra Energy Region more important

Ashra can Survey Depth: $z \sim 0.1$ ($\sim 400\text{Mpc}$) for GRB ν flux (by Hummer et al.)

Prospect: Ashra NTA



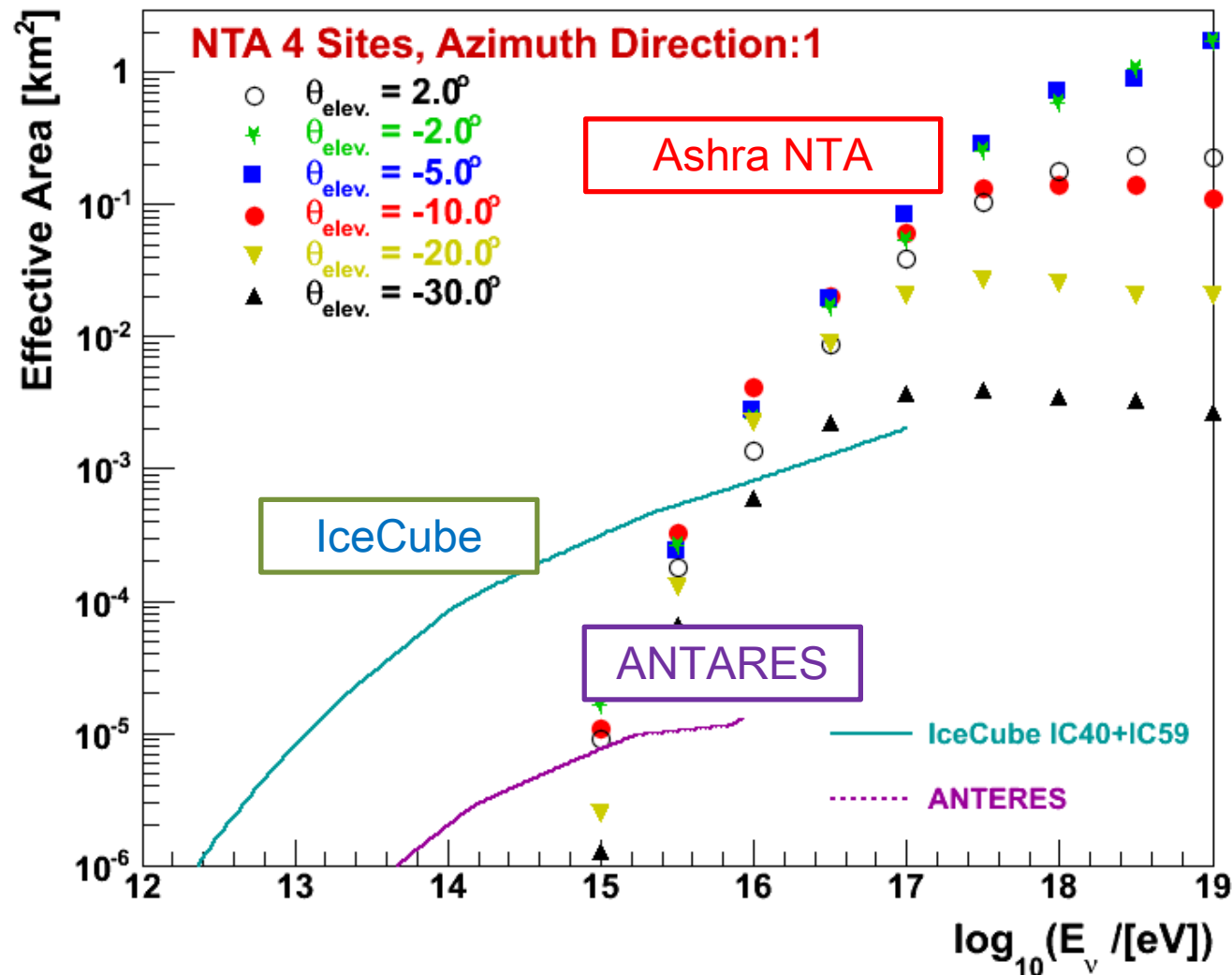
=> Concept of NTA Detector Unit with
Ashra-1 LC x 1.5 scaled-up x 4
+ same trigger & readout
=> Effective input pupil size: $\phi 3m$



The NTA Observatory

Ashra-1 Mauna Loa Site

Ashra NTA Effective Area



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

References

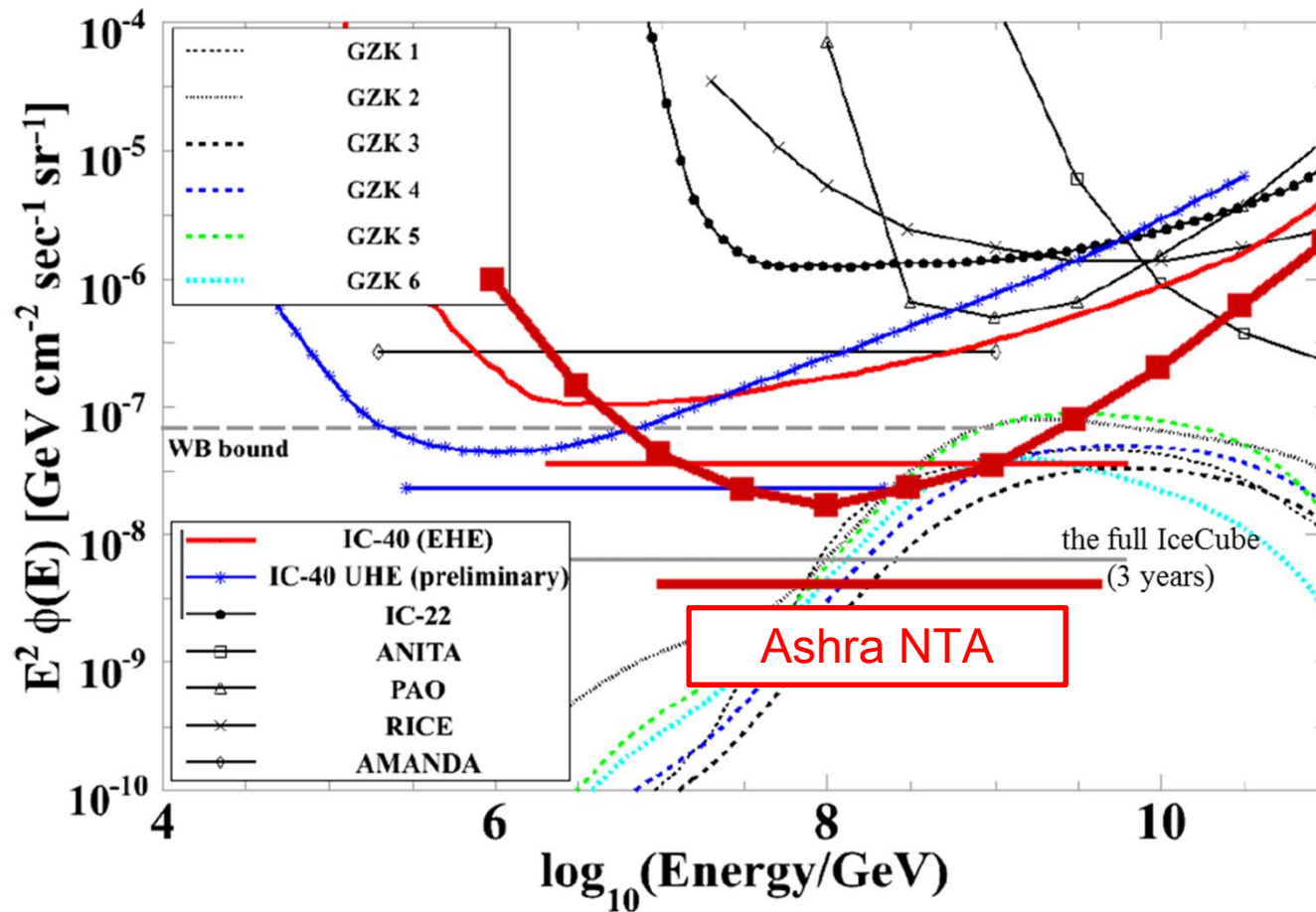
IceCube:

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

ANTARES:

ApJ 743 (2011) L14 Fig.2 (Right)
Declination Range $-90 < \delta < -45$ deg

Ashra NTA Diffuse Sensitivity (3yrs)

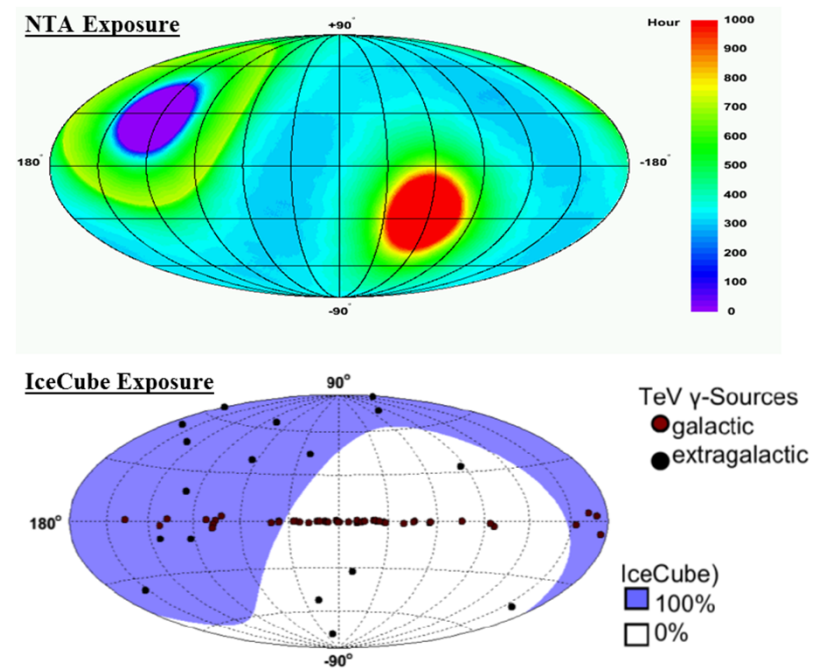
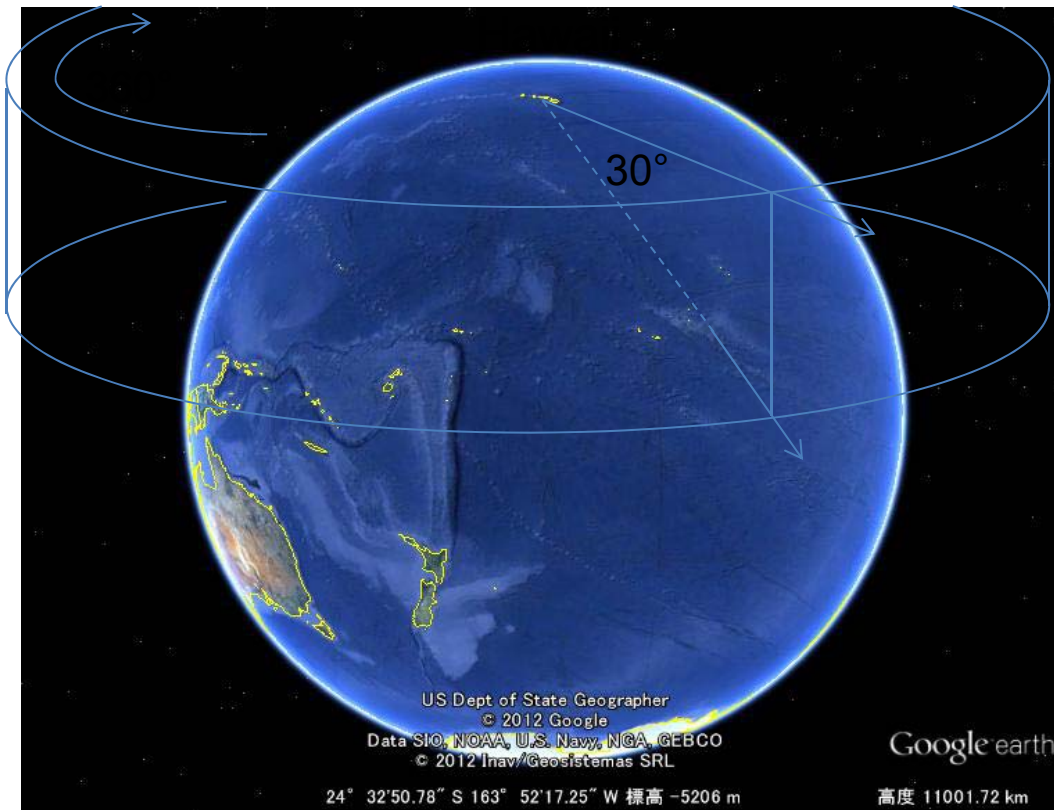


$$\text{Diff. Limit} = 2.3E/(\text{Aperture} \cdot \Delta T)$$

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

3 year Observation can resolve Cosmogenic ν

Ashra NTA ν Pont Source Survey Search Performance



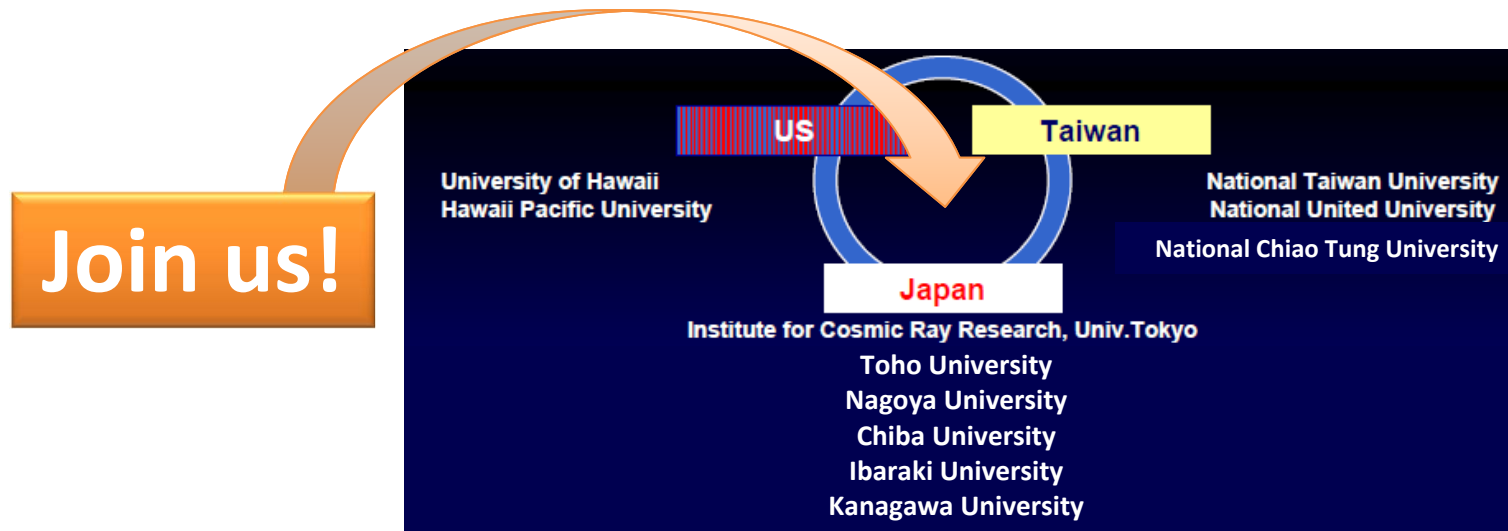
Duty 10-20% from Ashra-1

ν pointing accuracy $< 0.2^\circ$
(Cheren. Mono $\Rightarrow$ worst case)

FOV Elevation $30^\circ \times$ Azimuth 360°

Assuming Hammer's GRB ν fluence
Survey Depth $z < 0.1$ (400Mpc)

Expanding Ashra NTA Collaboration



Research Staffs of ICRR

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



Yoichi ASAOKA
Assistant Professor



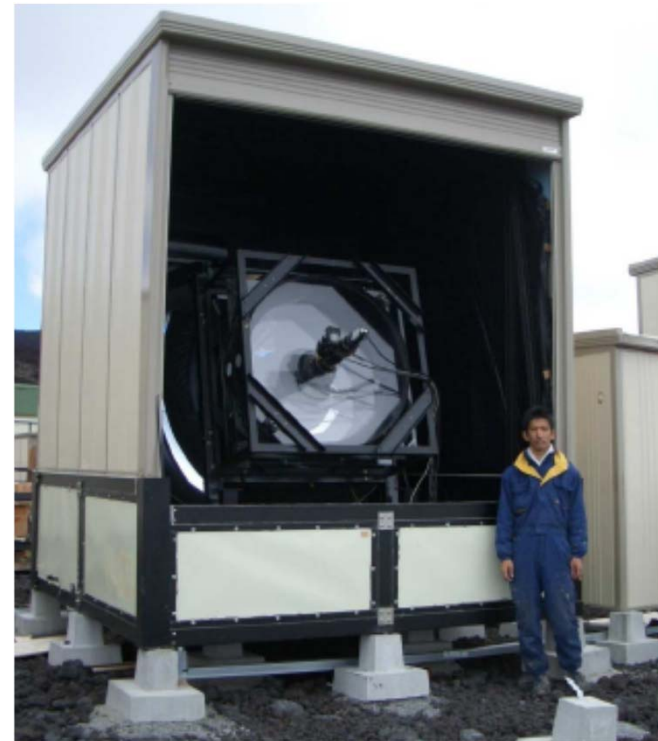
Holger Martin Motz
Research Associate

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



James Ah Heong
Hawaii Community College
University of Hawaii at Hilo
2006 Internship:
Institute for Astronomy, Hilo

Go for it!
If you are thinking of applying, you are obviously looking for an adventure this summer. The Akamai internship is well run and very rewarding. I've lost count of the times I've thought "this task is so much easier now! it's because I learned how during the internship."

[I've gained] confidence, foresight, and friends. The people you meet will enlighten you. Just being in the same room with these people; I learned how to approach situations avoid setbacks and get my money's worth out of college.

**The Akamai Internship Program
Maui and Hawaii Island**

The Akamai Internship Program was developed by the Center for Adaptive Optics (CAO) to advance Hawaii students in science, engineering and technology careers. Interns are placed in full-time summer positions to complete a research or technology project. Interns receive guidance from a mentor and extensive support from the Akamai Program itself.

Past interns placed in the Maui Akamai Internship have worked at Akimeka, Boeing, the Institute for Astronomy, the Maui High Performance Computing Center, Maui Scientific Research Center, Northrop Grumman, Oceanic, the Pacific Disaster Center, Techron and Trex Enterprises. Past interns placed in the Hawaii Akamai Internship have worked at Canada-France-Hawaii Telescope, Gemini Observatory, the Institute for Astronomy, Subaru Telescope, Submillimeter Array, University of Hawaii at Hilo, the Aha Project and W.M. Keck Observatory.

The Akamai Programs require a full-time, 8-week commitment to all program components. Interns are paid a stipend and also receive college credit.

All community college and university undergraduates in Hawaii – and kama'aina studying on the mainland – are encouraged to apply.

For more information on the Akamai Internship Program components, and how to apply, please visit:
<http://cfao.ucolick.org/EO/internshipsnew/akamai/>
or Google "Akamai Internships"

The Akamai Internship Program was developed by the Center for Adaptive Optics (CAO). Maui Island partners include CAO, Maui Community College, UH Institute for Astronomy, and Maui Economic Development Board. Hawaii Island partners include CAO, W.M. Keck Observatory, and Hawaii Community College. Many other organizations across the state of Hawaii participate in the Akamai Program. The Akamai Program is currently funded by the National Science Foundation (NSF), the Space Office of Scientific Research, NXP Center for Adaptive Optics, and the University of Hawaii.

AKAMAI

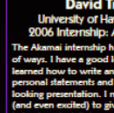


Suzanne Burns
Maui Community College
2006 Internship:
Trex Enterprises

I came into the program with wide eyes, and no experience in programming, my mentors guided me through each step of writing a program in C++.

The CAO/MCC staff and faculty helped me create my first Power Point presentation and an award winning poster. I have been offered several jobs in the Maui tech community since the internship, and I haven't even graduated yet.

I have been able to meet and worked with scientists, engineers, educators and company owners and managers in workshops and seminars. The program staff are still there for me if I need anything.



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.



Glenda Ramos
Maui Community College
2006 Internship: Akimeka

The Akamai program boosted my morale/confidence.

It opened a lot of opportunities for me in the tech field here on Maui and it helped me to know the right people to talk to if you want to really work on high tech job here on Maui.

It may seem daunting to know that you're going to be presenting to a lot of people at the end of the internship but it's quite rewarding to know how much you've accomplished in just a short span of time.

The Akamai program is not only for people who are exceptionally gifted but also for those people who are willing to excel in the technical area of their choice by being hardworking, persistent, and focused individuals.

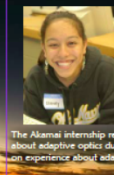


Chad Sithar
Maui Community College
2007 Internship: Hnu Photonics

I would tell someone wanting to apply to DO IT ... :) The internship gave me a much needed boost in confidence in a lot of areas, one of them being speaking in front of groups.

It gives good work experience in your desired field of interest. Leads to a lot of opportunities after the internship.

Before I was just going through the motions of school and now I feel I have the drive, focus and desire to go further than just graduating with an associates degree and for that I am truly grateful to you and every one at the CAO. I got to have dinner with the Mayor and Senator Inouye, my NEW job (Hnu), other job opportunities/offers, I've done several "Green" conferences, and SACNAS (a national undergraduate science and tech conference) was an awesome experience, and my "people" skills have gotten A LOT better.



Shamuty Kishenschmidt
University of Hawaii at Manoa
2007 Internship: Trex Enterprises

The Akamai internship really helped me to improve my knowledge about adaptive optics during the first week. It was fun getting hands-on experience about adaptive optics and the different concepts.

Interning at an engineering-based company allowed me to learn and get hands-on experience about the different applications of engineering in the real world.

It also taught me that engineering is not just based on one particular topic but it can be applied to many technologies like satellites, solar cells, computer programs, researching for future projects, etc. And it's not too bad living at one of the most beautiful islands either. It was definitely one of the most enjoyable and enlightening internships that I had where I learned more than just engineering.



Eric Dela Rosa
Hawaii Community College
2007 Internship: Canada France Hawaii Telescope

This internship has been a major stepping stone for me. It made me grow more as a student, as well as a person and gave me the courage to pursue anything I want to. If you're looking for an internship that provides more than just experience, you'll find it in the Hawaii Island Akamai Internship Program. The amount of things I've gained from the internship is enormous. I've gained real life experience that I can use in the future.

I've gained courage in myself and believing that I can do anything I set my mind to. I've gained a whole new family, from the coordinators and mentors from the Akamai Program as well as the other students and other staff at my internship site. I've gained new insight of how technology will be in the future and what to look forward to when I graduate from College. And, I've gained a renewed love for the field of science and technology.

what akamai interns say

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.



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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 VHE ν , 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 VHE ν , γ , optical flash have been well demonstrated
- Observation Status:
 - Experimental proof for VHE ν , 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 VHE ν