Ashra

(*A*ll-sky *S*urvey *H*igh *R*esolution *A*ir-shower detector)

Aspen CR Physics WS 2007.04.16

Makoto Sasaki

ICRR, Univ.Tokyo

for Ashra Collaboration

Overview:
Efforts Toward More Astronomical Approach

- Ashra: 1.2 arcmin/pix × 80% all-sky
  - Consecutive exposure of star lights
  - Triggered exposure of air-shower Cherenkov and fluorescence lights

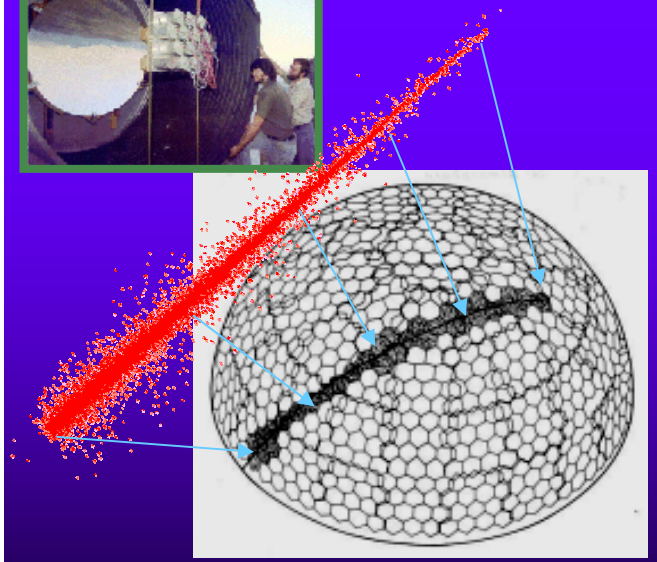
- Aims: Identify Sources in the VHE Universe
  - Probing transients like
    - Gamma Ray Bursts (GRBs)
    - Soft Gamma Ray Repeaters (SGR)
    - Core-collapse Supernovae (CC-SNs)

    => Strong candidates of CR sources
  - Evidence of Cosmic Accelerators with
    - VHE neutrinos (Test charged pions)
    - VHE gamma rays (Test neutral pions or/and EM)

Optical Air-shower Detector

Progress of Resolution × FOV

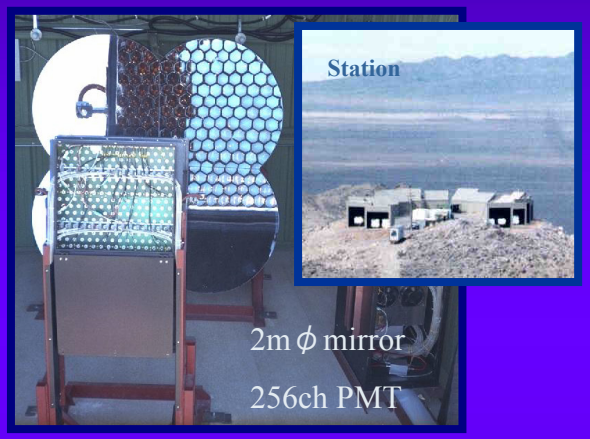
Fly's Eye (1981-1993)



5deg/pix × All-sky

PMT

HiRes (1994-2006)



1deg/pix × 28deg

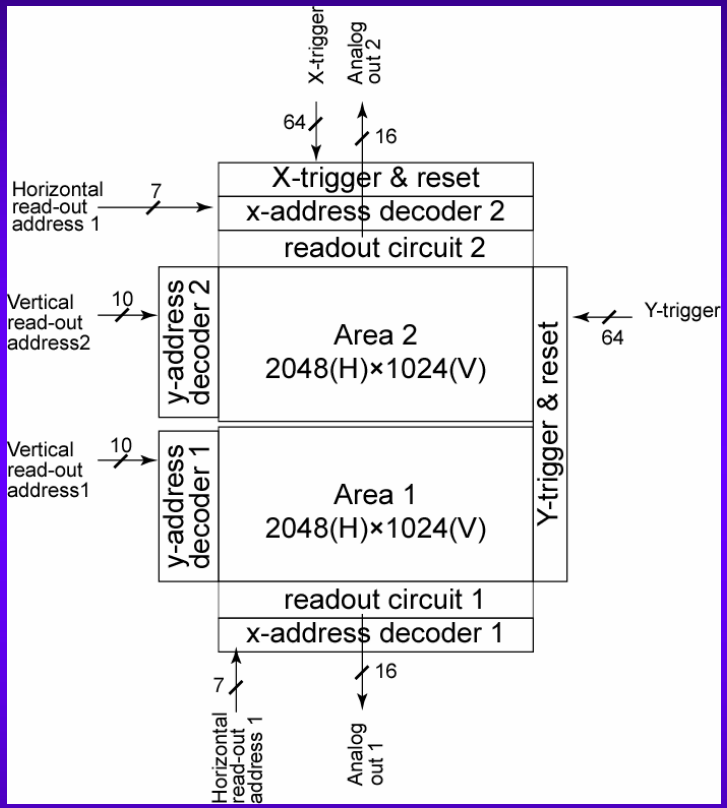
PMT

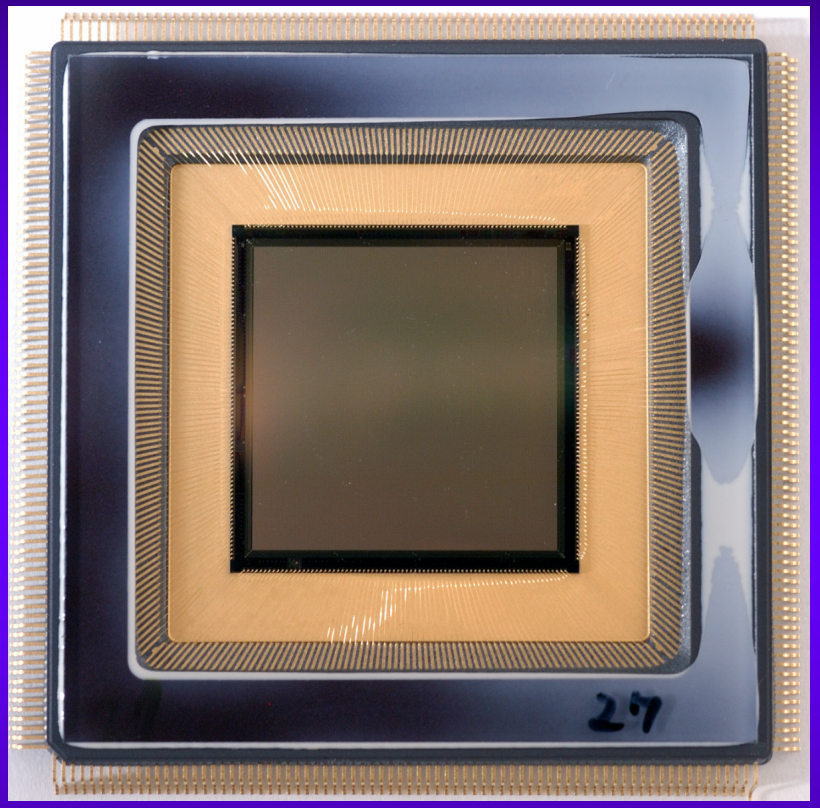
Ashra (2007-)

1.2min/pix × All-sky

Image Tube＋CMOS

Ashra CMOS Fine Sensor



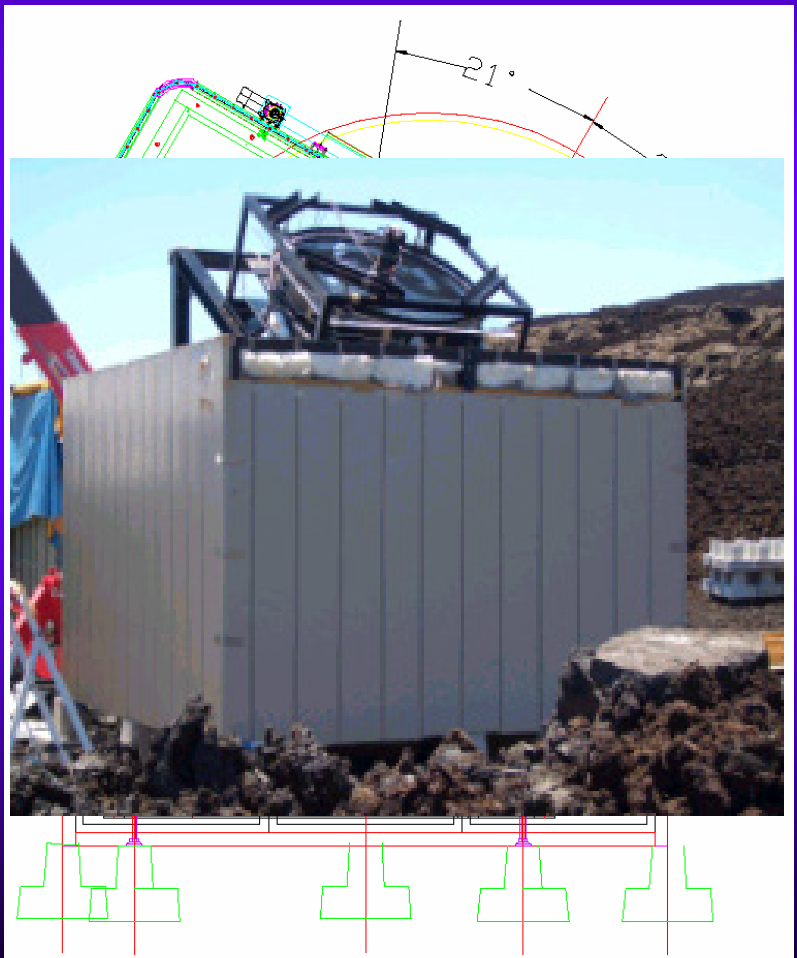


- Readout 2 directions independently
  - ⇒ Low parasitic capacitance
  - ⇒ Speed-up of readout
- Area is subdivided => 16 × 16 cells

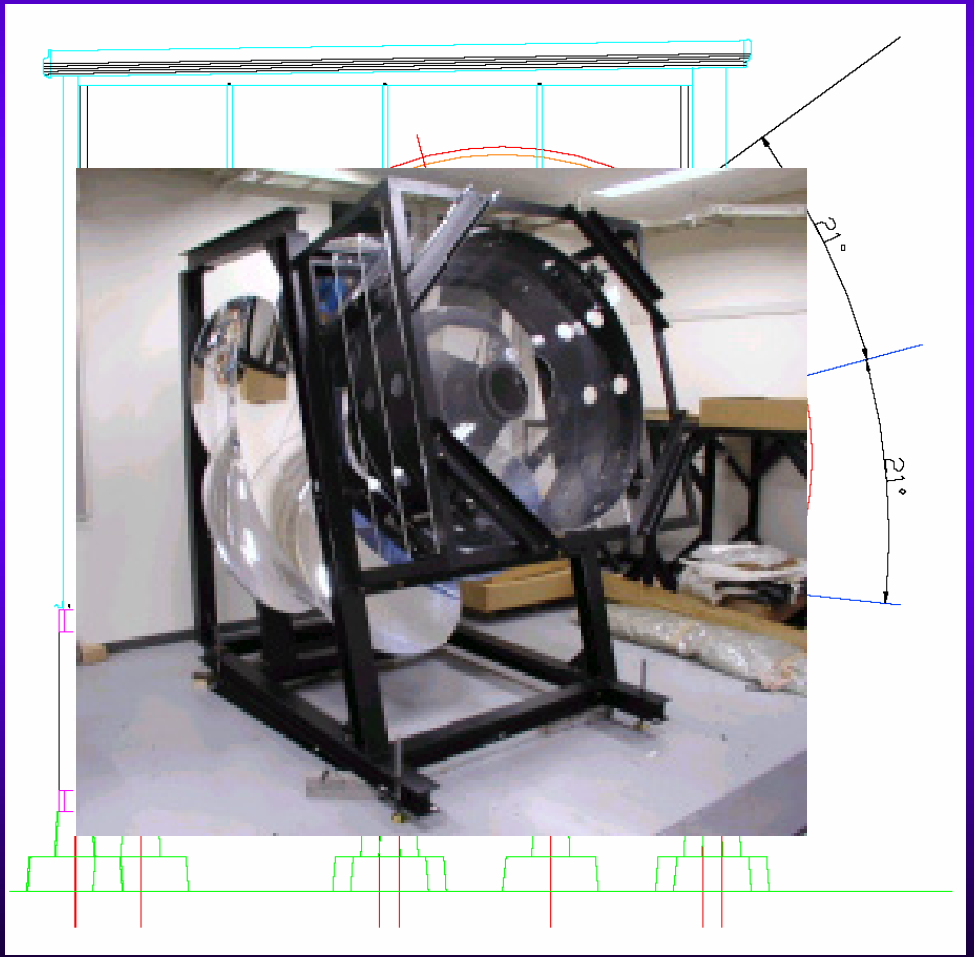
- 2-poly 3-metal 0.35μm Standard CMOS process
- 2048 × 2048 pixels（4.2Mpix）
- Chip size: 19 mm□

Light Collector

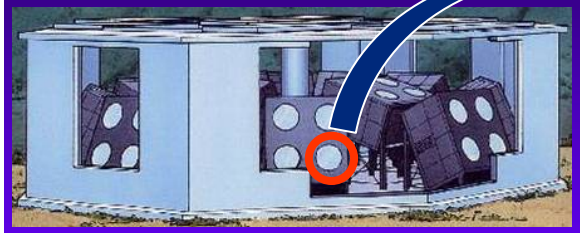
High Elevation (30deg.)

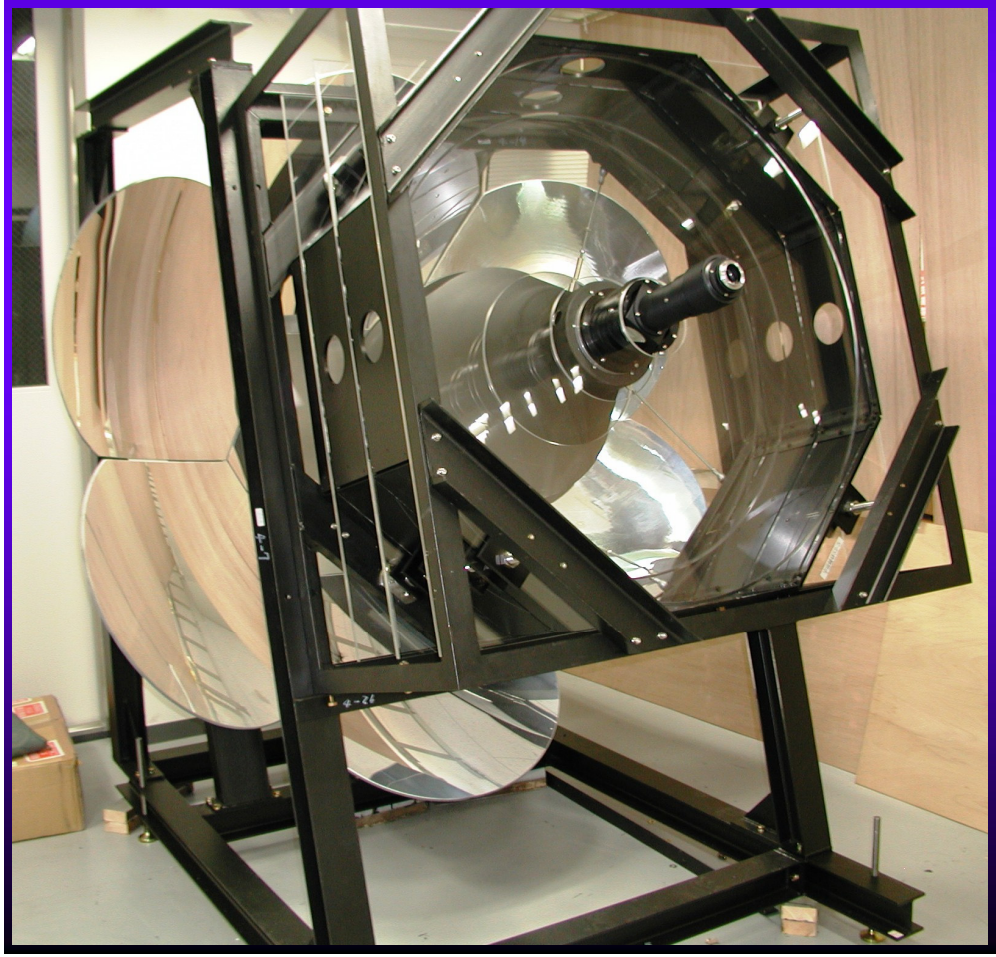


Low Elevation (75deg.)



Light Collector



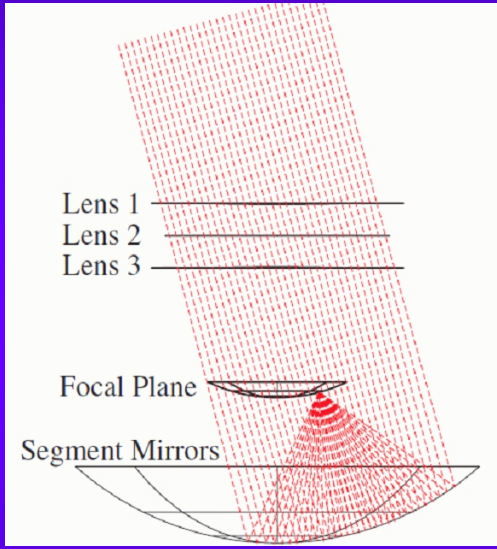


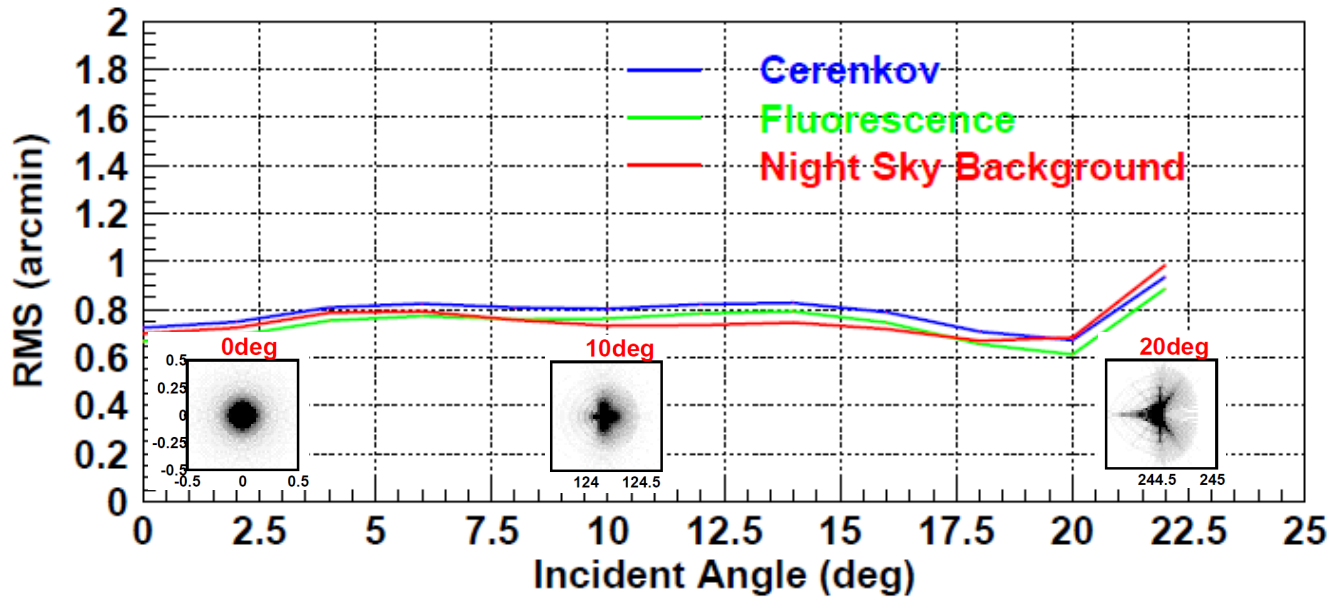
- Optics:
  - **Modified Baker-Nunn**
- Components:
  - **Correcting lens** (1.0~1.2mϕ) with 3 acrylic cut plates
  - **Spherical mirror** (2.2mϕ) with 7 curved glass plates on adjustable tables.
  - **Photoelectric lens IT** (0.5mϕ) on focal sphere suspended with Stewart platform mechanism
  - **Mount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

=> arcmin. resolution over 42deg FOV

=> Affordably cost-effective

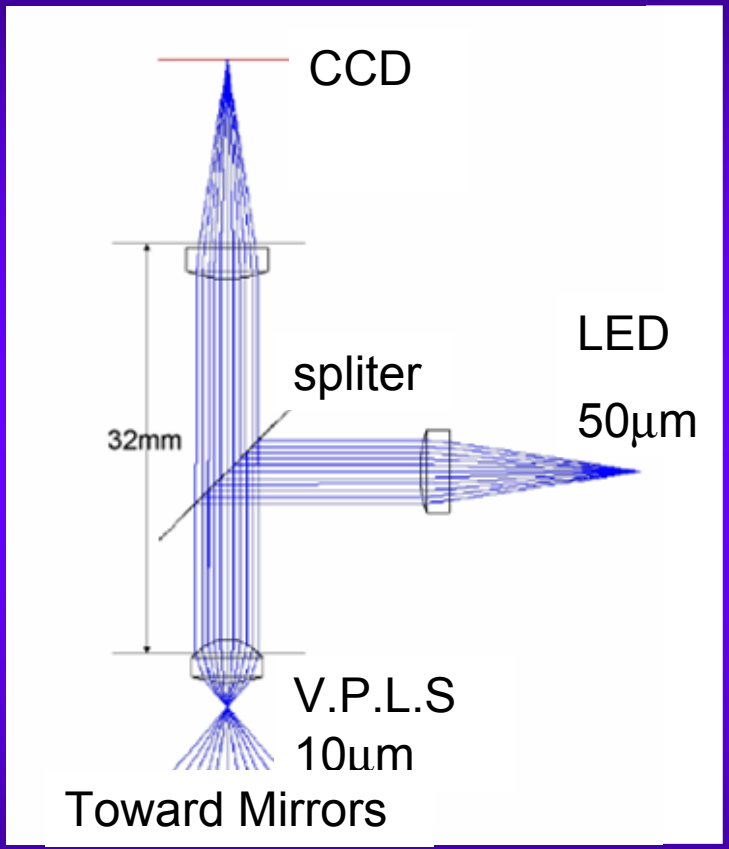
Modified Baker-Nunn Optics

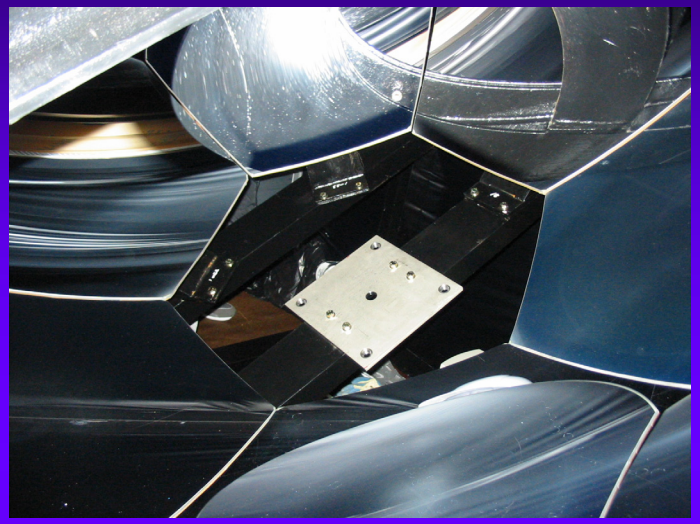


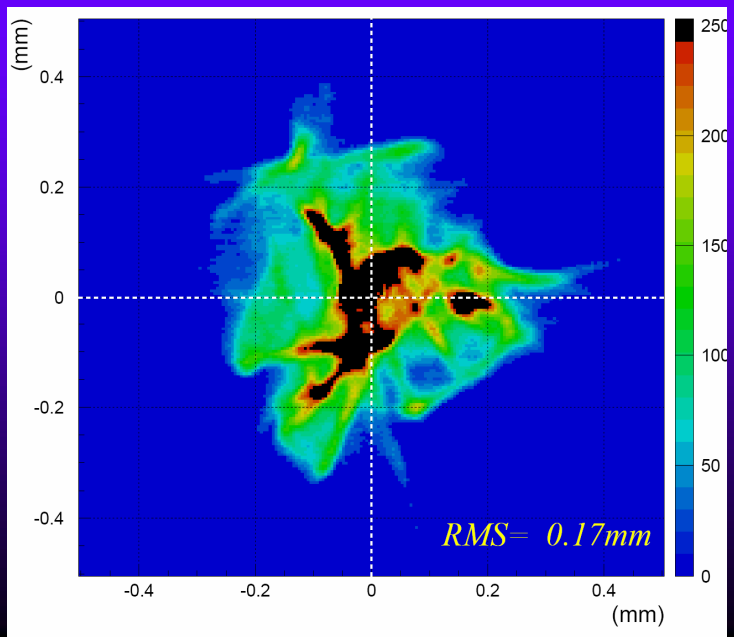


- 0.8 arcmin. RMS (design) resolution is stable over all FOV
- Spherical, Coma, and Chromatic aberrations are well controlled.

Check of Reflective Mirror
with Virtual Point Light Source Module







- Light source is required to be very accurate.
- Point spread at curvature center = 0.17mm
- Parallel light spot size => 0.4 arcmin.
  Error come from adjustment of mirrors

Resolution after all adjustments

Assembly and install

- Shelter
- Mount
- Correcting lens

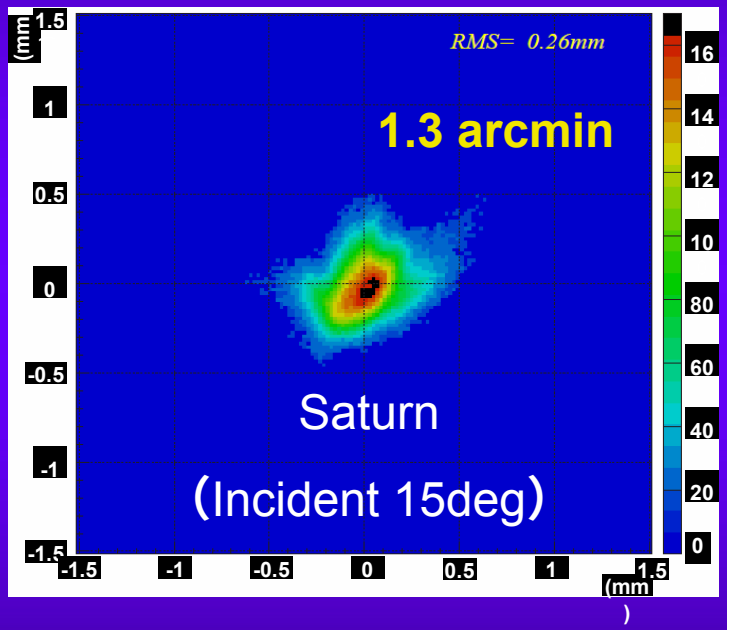
+

Assembly and install

- Mirror
- Stewart platform

Adjusting all

=



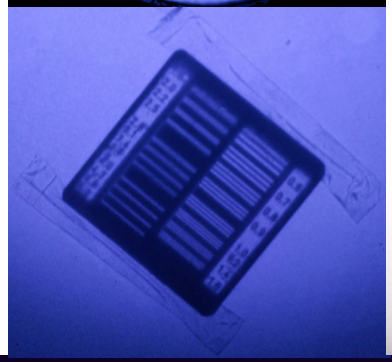
- CCD image on focal sphere
- Total resolution:
  1.3 arcmin

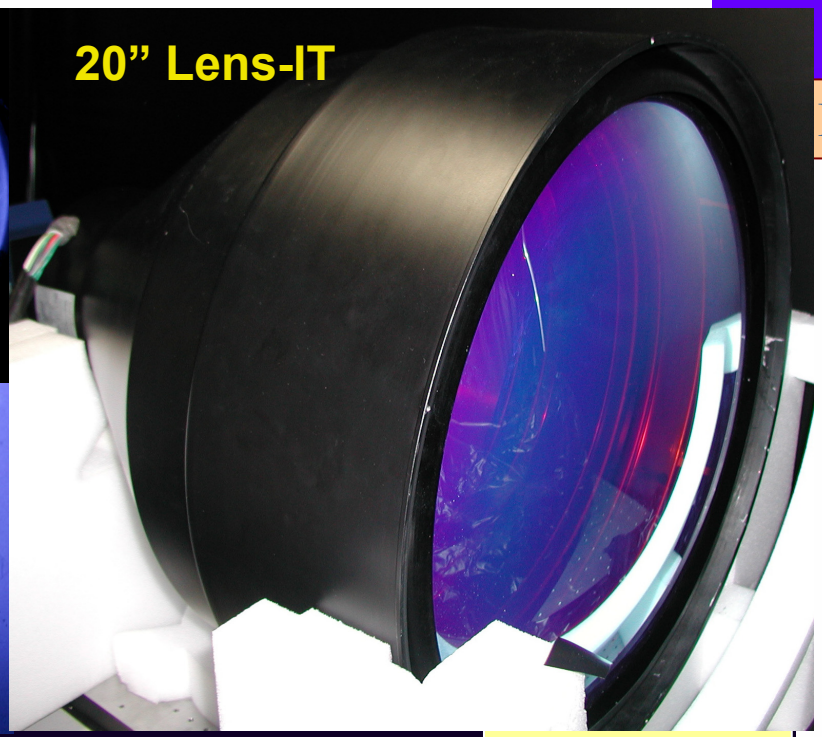
- Satisfies our requirement

Photoelectric Lens Image Tube

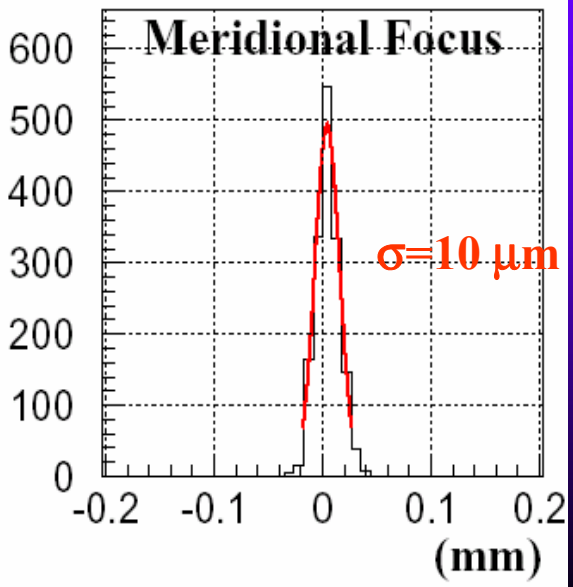
Key technology for the uniqueness of the Ashra optics

- Makes input images scaled to the 25 mm diameter of the output FOP window with the electrostatic lens effect.
- The cathode sphere is aligned to be combined with the surface of the sharp focus in the layout of the optical system.



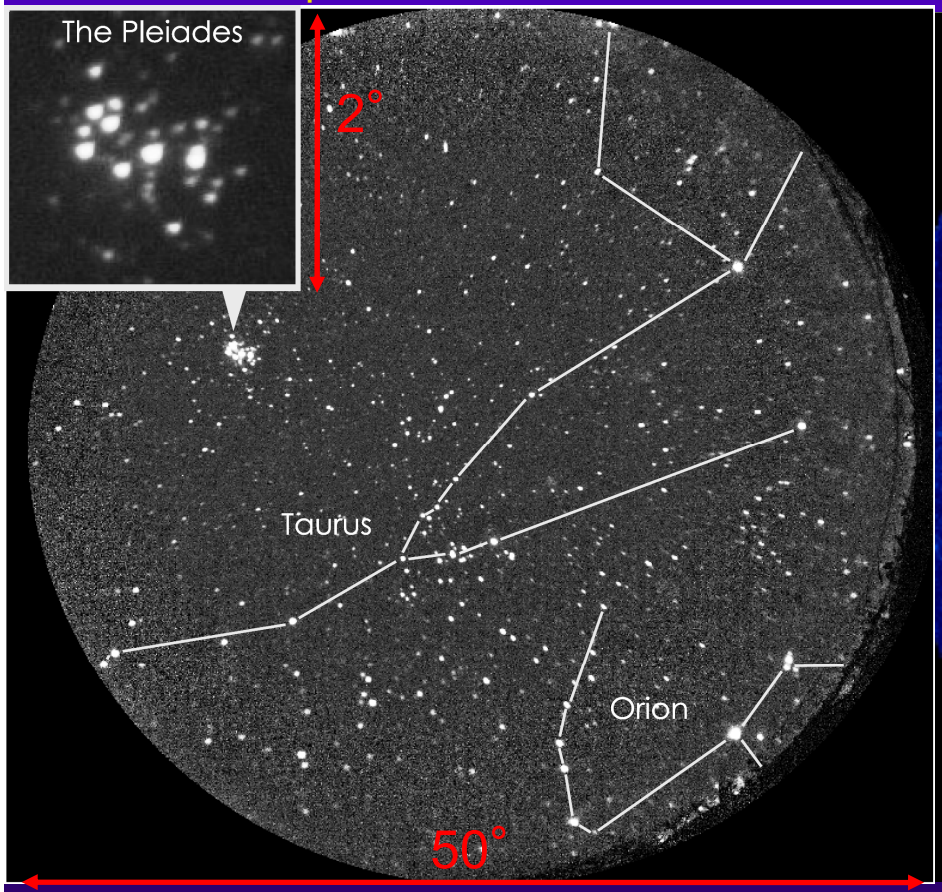


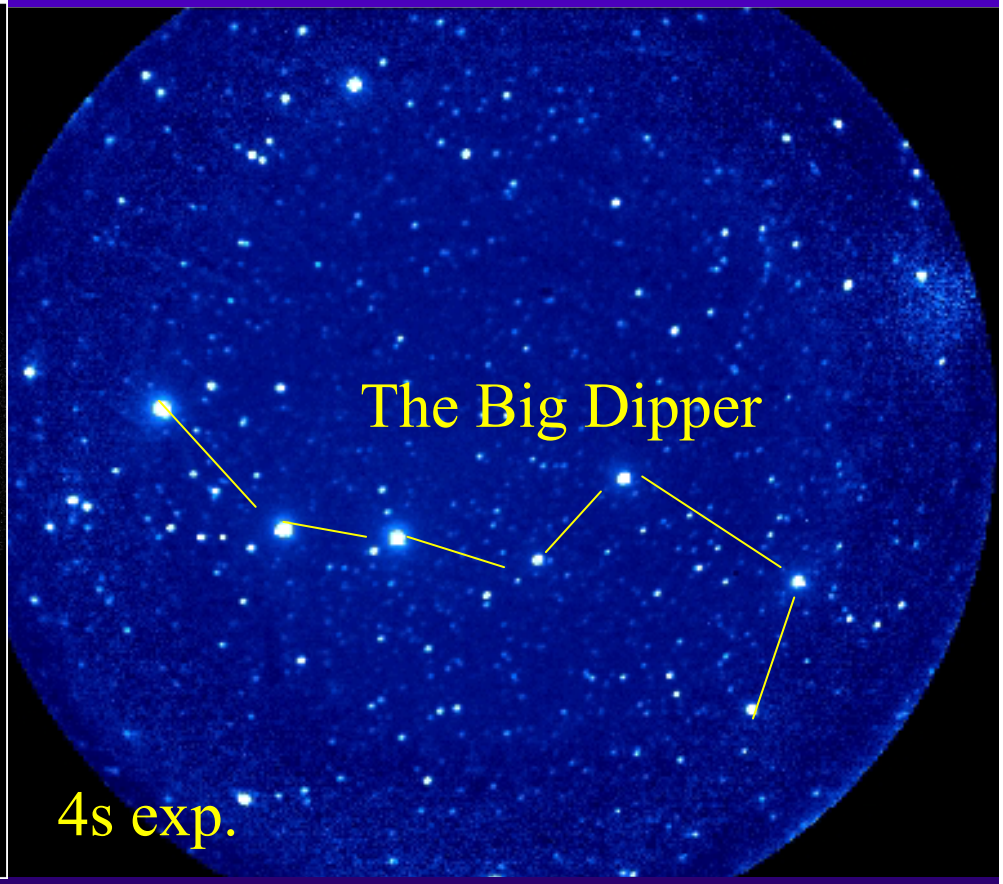
Point Spread



Star Images

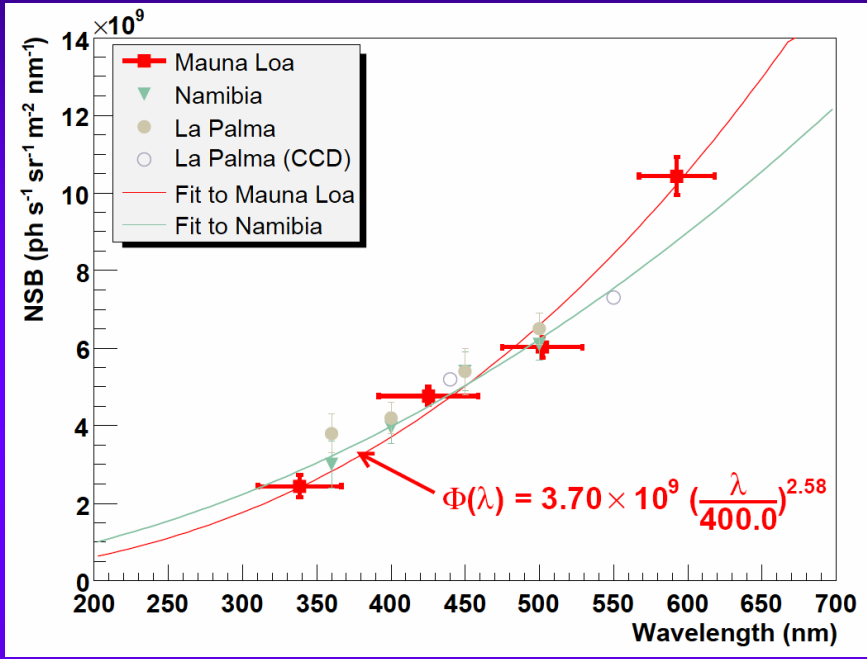
Constellations Taurus and Orion &
close-up view of the Preades





Concept of the optics = "Wide & High resolution"
Demonstrated well

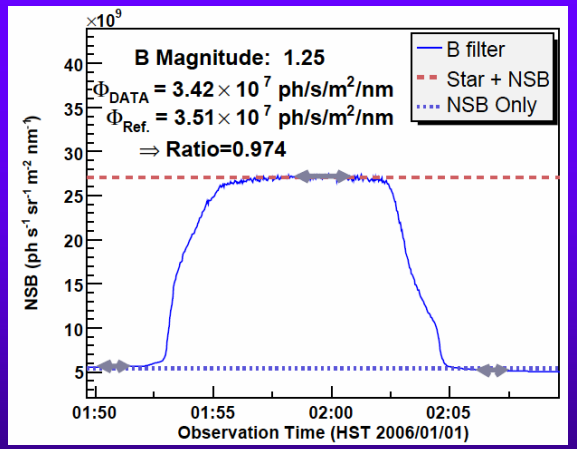
Night Sky BG on Mauna Loa

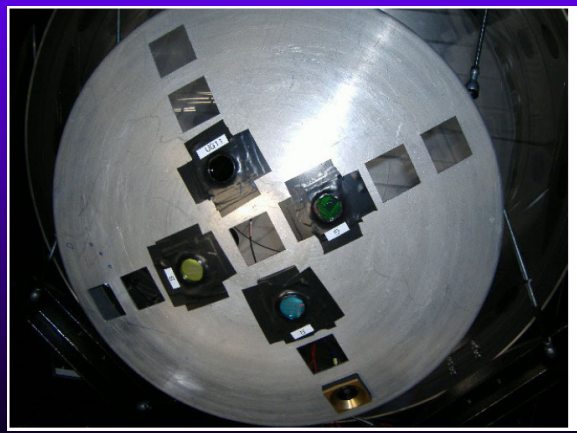


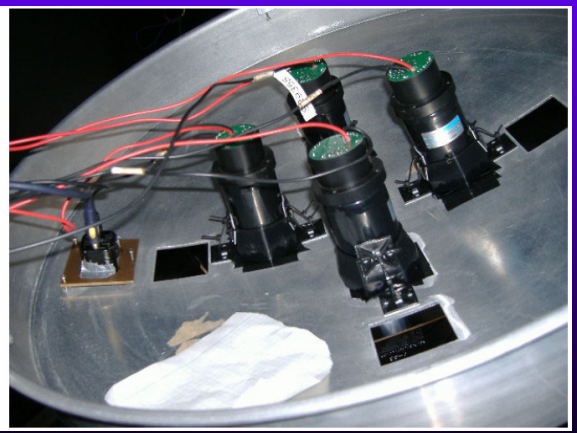
Night Sky BG Flux Spectrum

Fairly consistent with NSB measurements on Namibia and La Palma by the H.E.S.S. group (Preuβ, et al., NIM A481 (2002) 229).

Understanding of total light collection efficiency is checked well with stars crossing PMT FOVs within 5% accuracy.







<= How to fix R, G, B, U optical filters on PMTs and CCD on the focal sphere.

Ashra Potential for Opt. Tran.

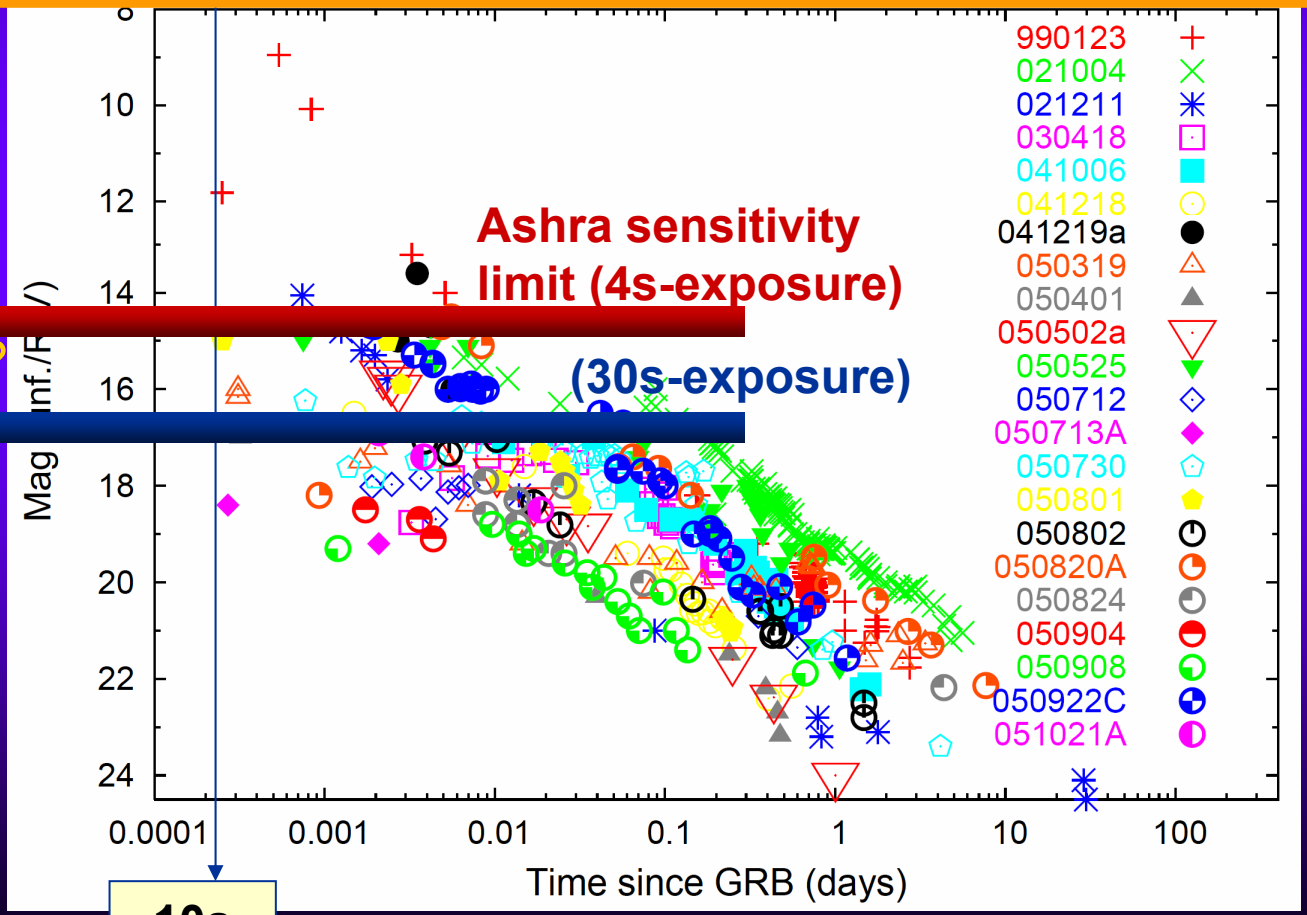
Ashra Unique Point:

Prompt Opt. Flash (<10s), Precursors, and Orphan

Precursor?

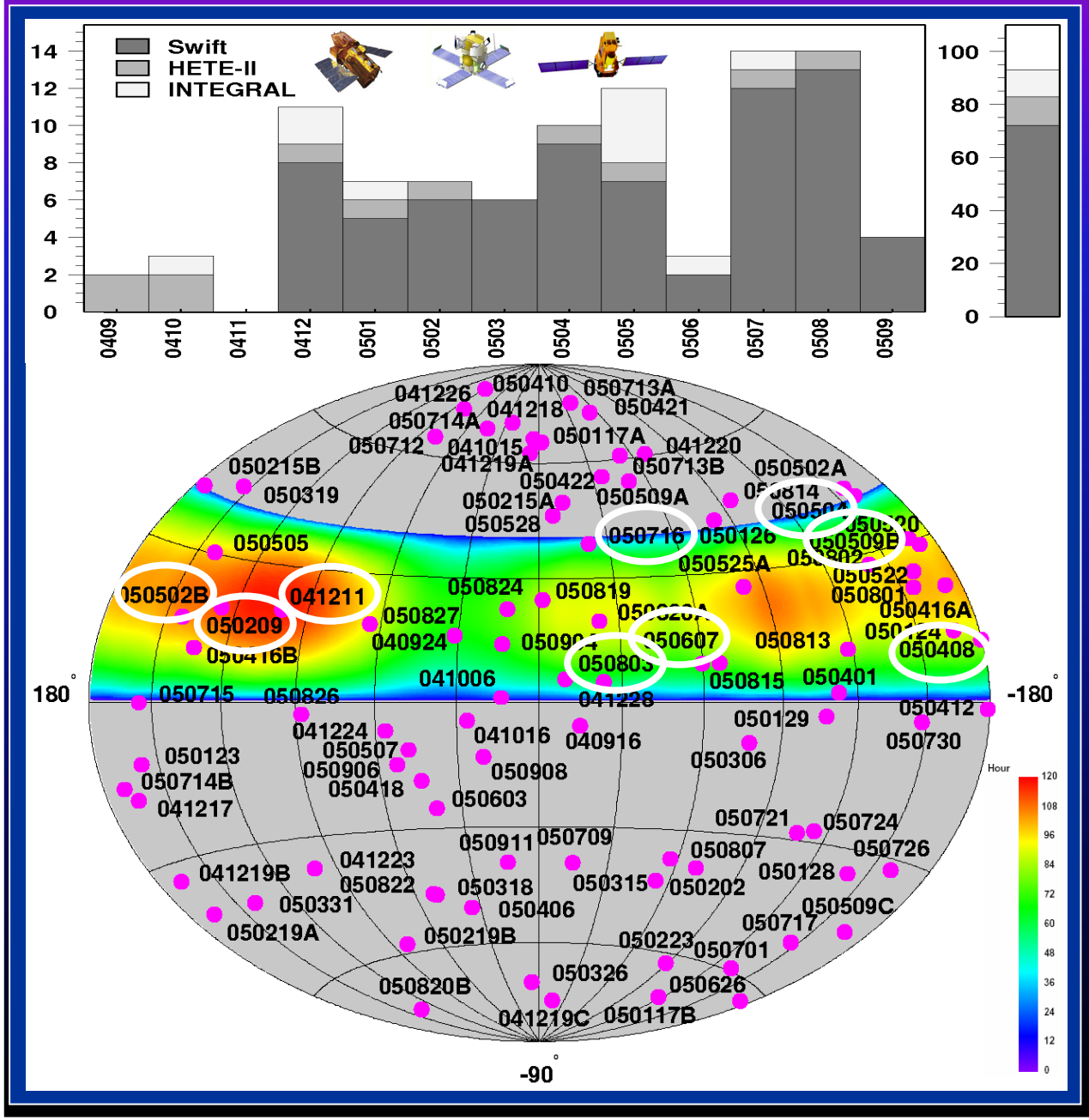
Orphan?

Supranova?



Guidorzi et al. 2005

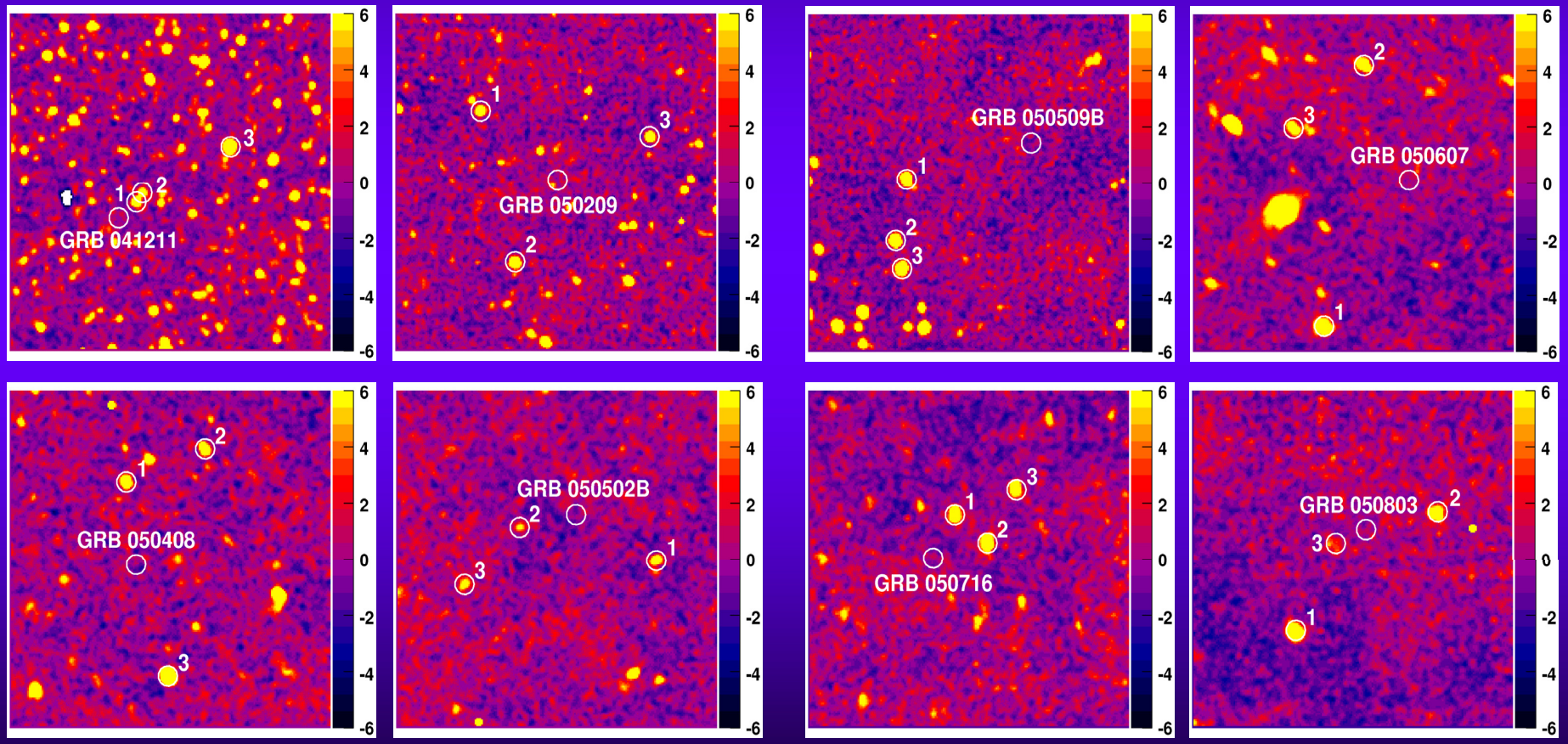
First Optical Precursor Search



- 9 possible GRB counterparts passed through the FOV within 24 hours before GRB
- First systematic search for GRB optical precursors
- GRB 041211
- GRB 050209
- GRB 050408
- GRB 050502B
- GRB 050504
- GRB 050509B
- GRB 050607
- GRB 050716
- GRB 050803

First Optical Precursor Search

Publish the limits soon.



Optical Transient Observation Network

Ashra @ Mauna Loa

MAGNUM
@Haleakala

Alert

Alert

Big Telescopes
@Mauna Kea

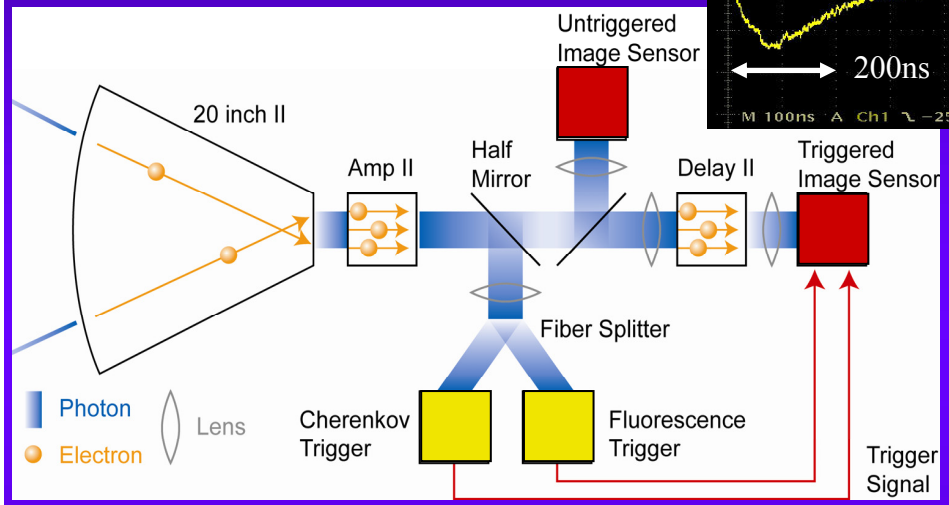
Ashra: 1mϕ pupil
All-sky Monitor
⇒ Optical&Particle Alert
⇒ Test Particle Emission

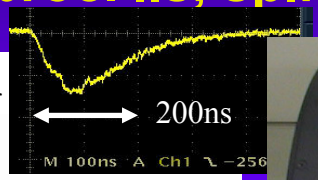
Middle-class
Telescope: ～2mϕ
Rapid follow-up
⇒ Precise pointing to the afterglow

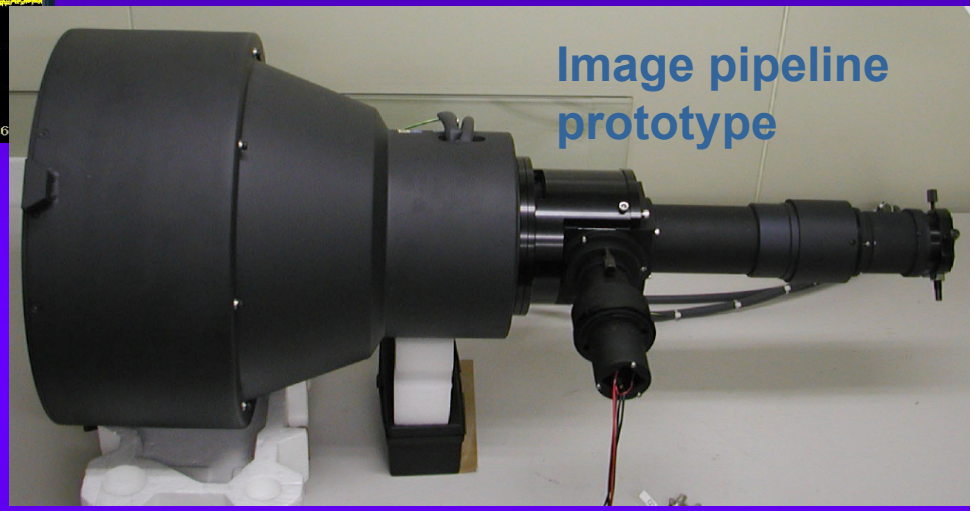
Big Telescopes：～8mϕ
⇒ Spectroscopy
⇒ metal. in host gal.
z estimate

Trigger & Readout
Attached to Image Pipeline

Distributes same image to 4 sensors keeping good resolution and brightness with proc. IIs, splitters, and relay lenses

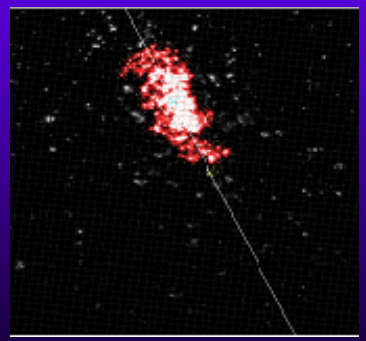






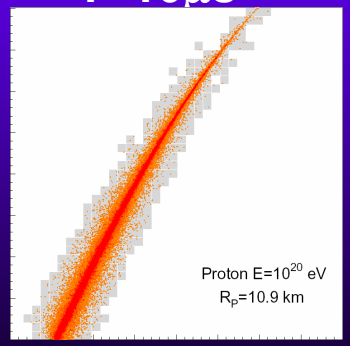
- **3 types of images with different exposure times:**

<100ns



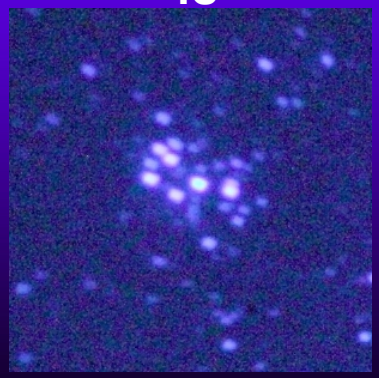
Cherenkov triggered Image

1~10μs



Fluorescence MC triggered Image

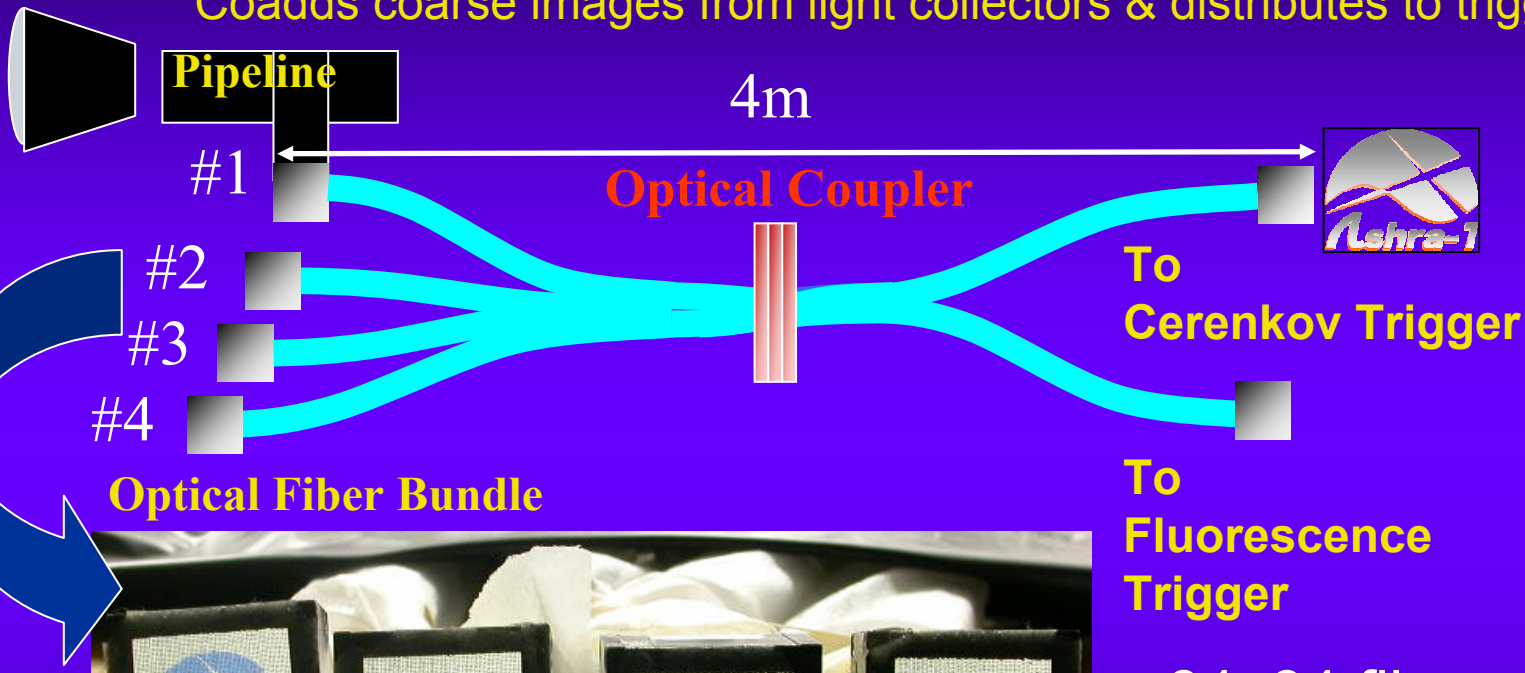
4s

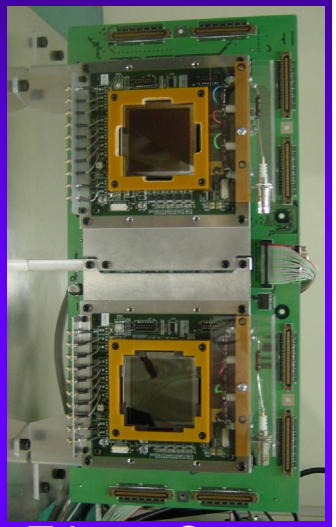


Untriggered Image

Optical Fiber Transmission System

Coadds coarse images from light collectors & distributes to trigger sensors





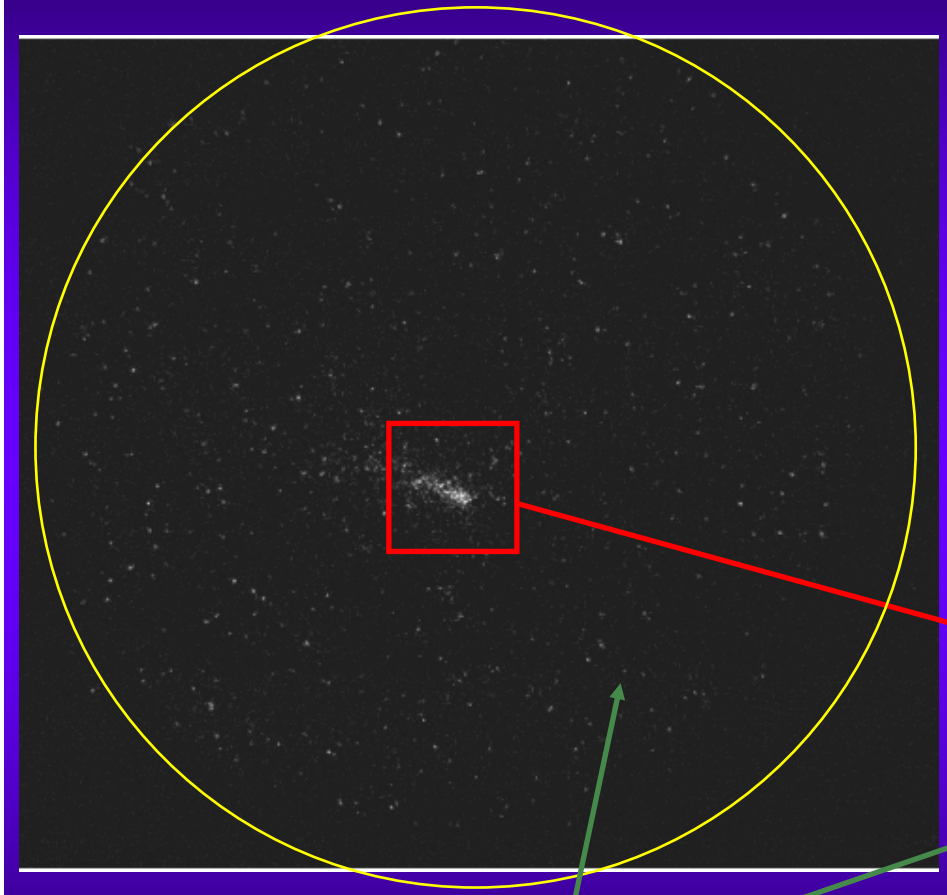
Trigger Sensor

- 64x64 fibers ($0.5\text{mm}\phi$)
- 0.67deg-FOV / fiber

Light collectors can be easily appended to the trigger.

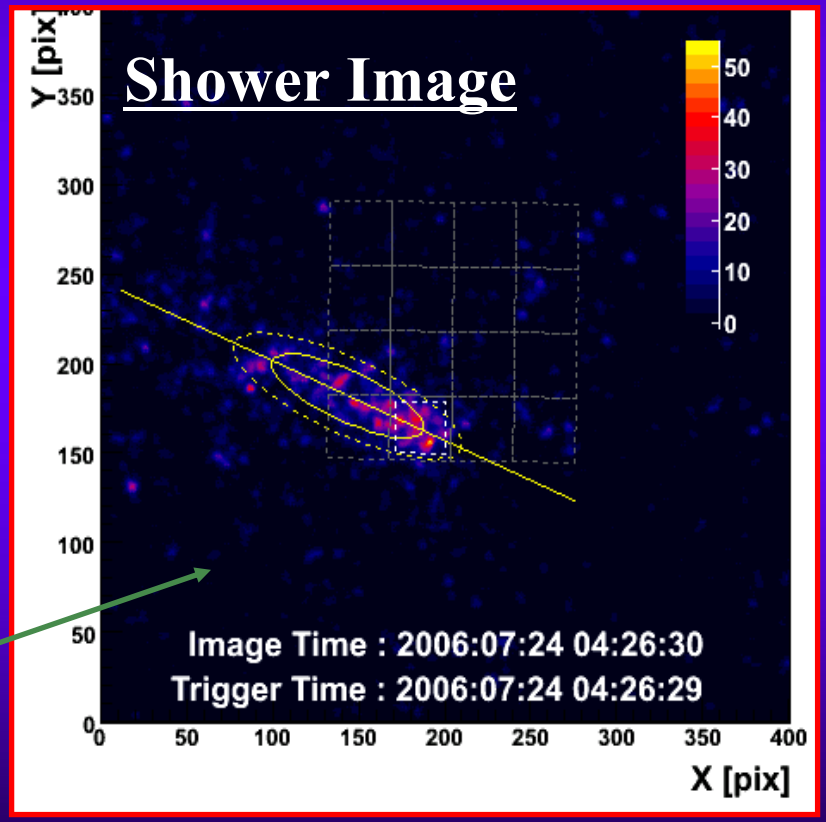
Sensitivity can be reinforced when more budget is available.

Pilot Observation of Cherenkov Showers



Exposure: 200ns

Succeeded in self-triggering with almost final setup

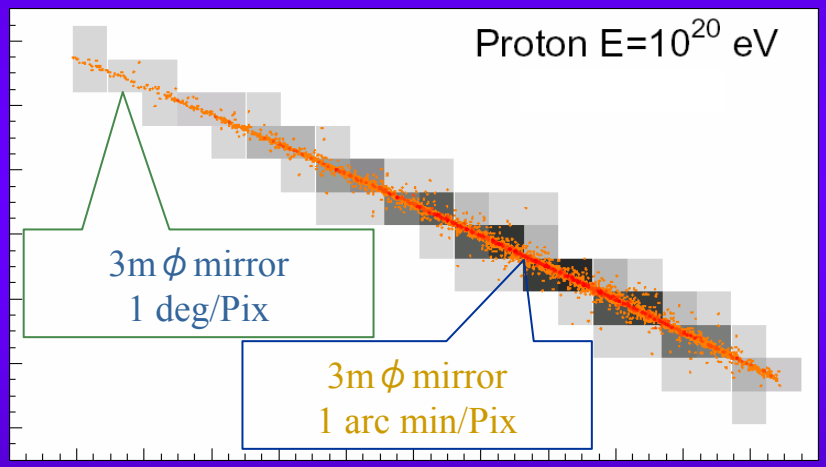


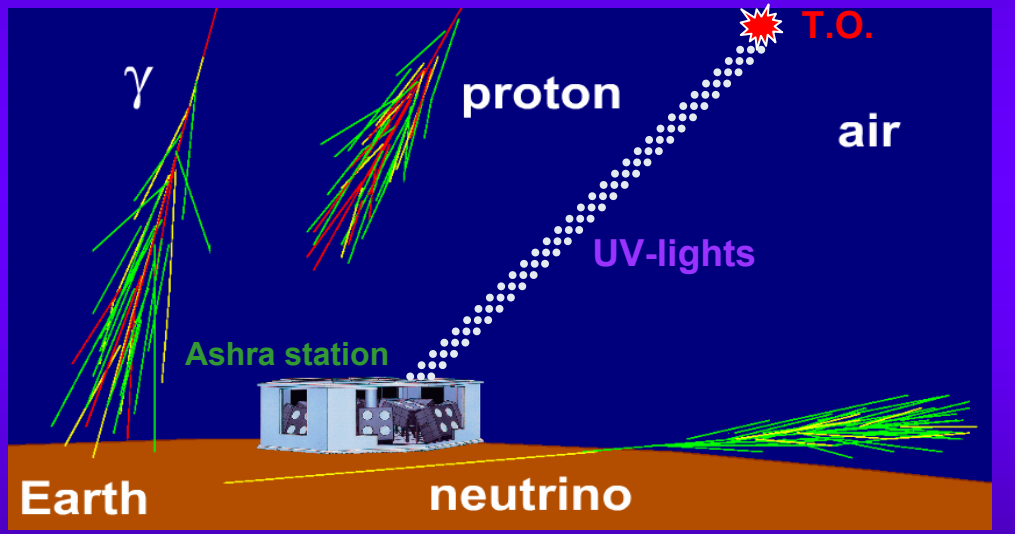
Each spot corresponds to individual incoming photon.

Ashra Station

Advantage of High Resolution & Wide FOV

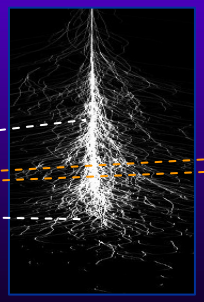
Main Station = “compound eye” with 12 “eye segments”



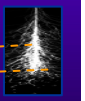


=> Astrometory for CR sources
Mag. Field & Charges

Require
5pix=5deg track length

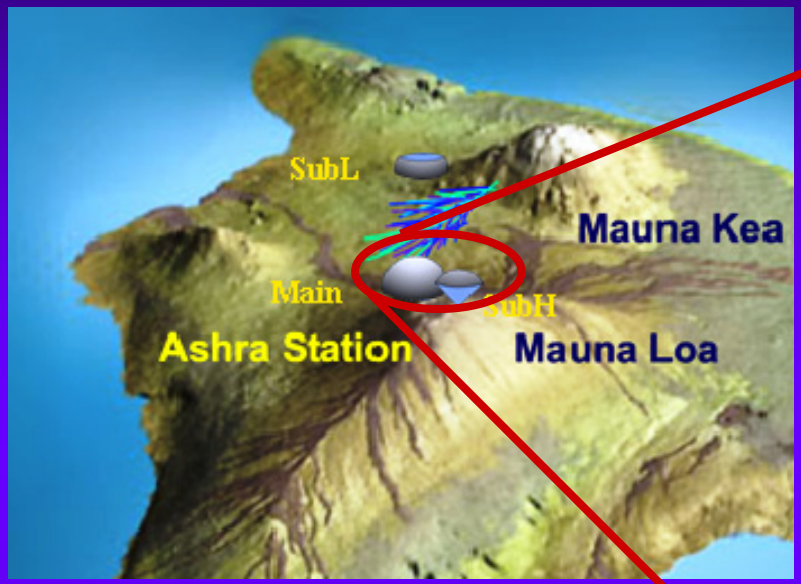


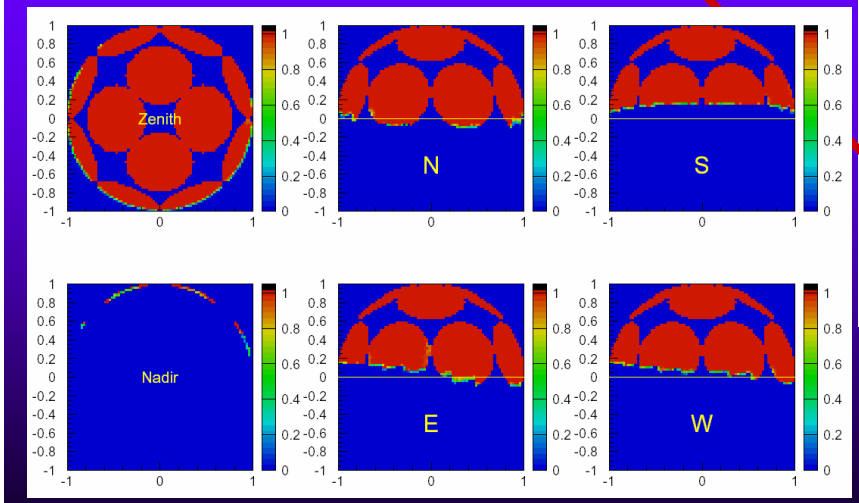
Require
5pix=6min track length



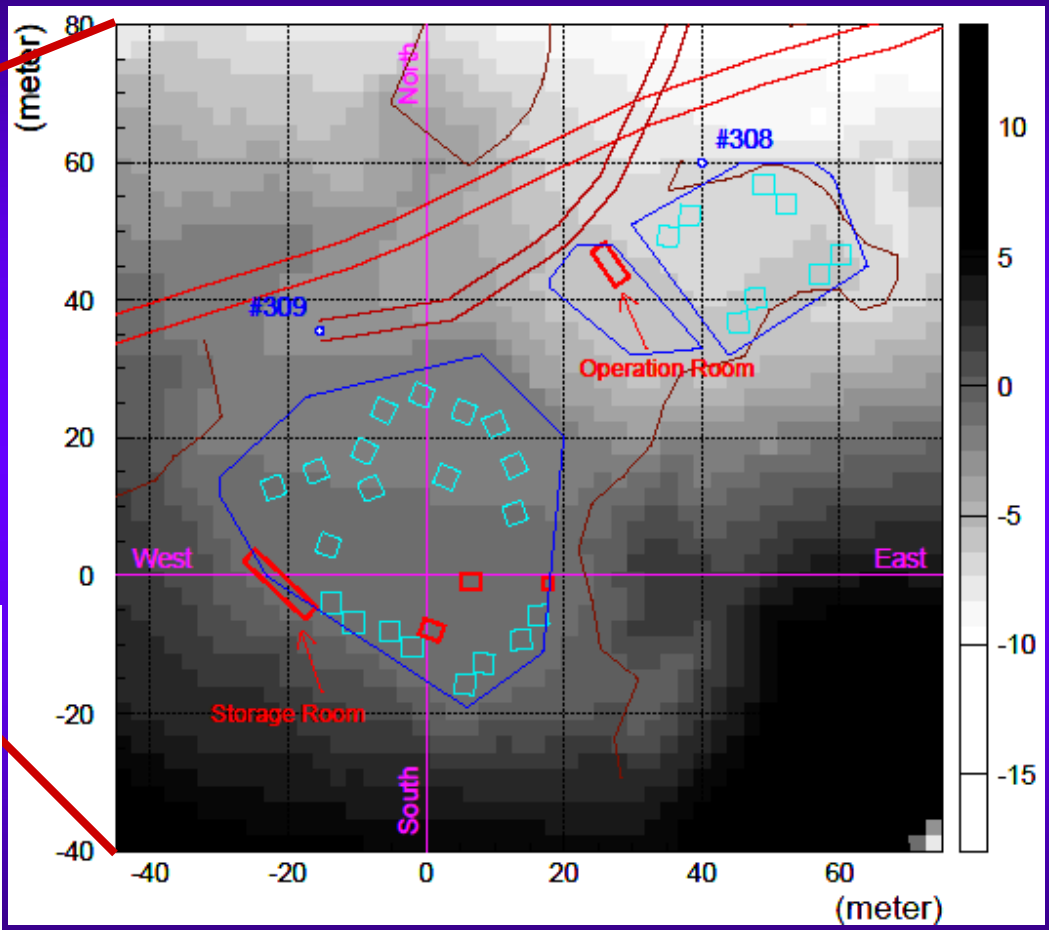
=> Large effective aperture

Phase-1 Layout





77% 2π str. 89% of sky 70% Mauna Kea



High Elevation Angle : 4 Detec. Units
=> Stereo for TeVγ
Low Elevation Angle: 8 Detec. Units

Ashra Mauna Loa Site

Ashra Site, May 2005
untrodden lava field

LINDA LINGLE
GOVERNOR OF HAWAII

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
OFFICE OF CONSERVATION AND COASTAL LANDS
POST OFFICE BOX 621
HONOLULU, HAWAII 96809

PETER T. YOUNG
CHAIRPERSON
BOARD OF LAND AND NATURAL RESOURCES
COMMISSION ON WATER RESOURCE MANAGEMENT

ROBERT K. MASUDA
DEPUTY DIRECTOR - LAND

DEAN NAKANO
ACTING DEPUTY DIRECTOR - WATER

AQUATIC RESOURCES
BOATING AND OCEAN RECREATION
BUREAU OF CONVEYANCES
COMMISSION ON WATER RESOURCE MANAGEMENT
CONSERVATION AND COASTAL LANDS
CONSERVATION AND RESOURCES ENFORCEMENT
ENGINEERING
FORESTRY AND WILDLIFE
HISTORIC PRESERVATION
KAHOOLAWE ISLAND RESERVE COMMISSION
LAND
STATE PARKS

REF:OCCL:TM

FILE NO.: HA-3221

JUL - 5 2005

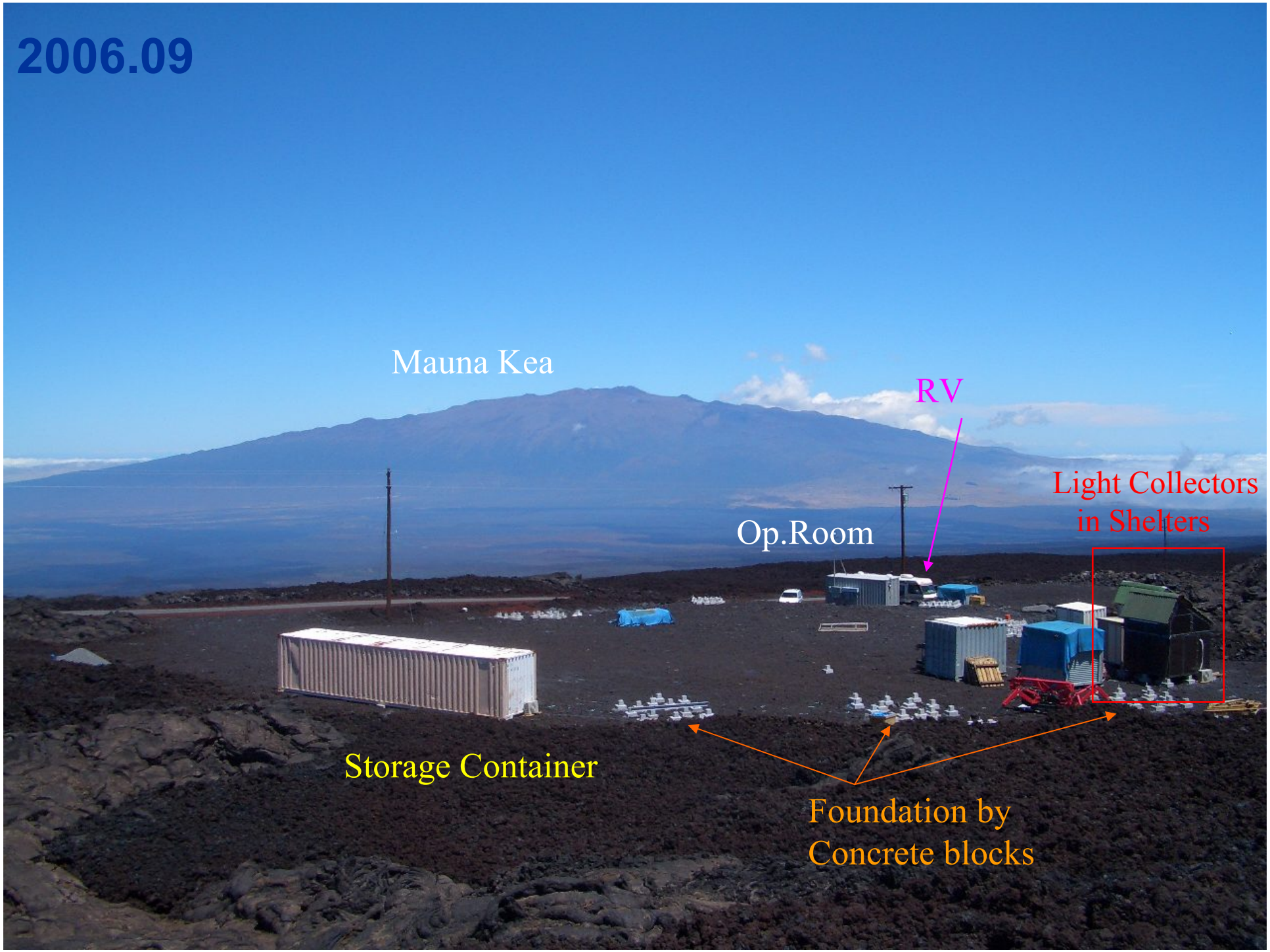
John Hamilton
Department of Physics & Astronomy
Natural Science Division
University of Hawaii-Hilo
200 West Kawili Street
Hilo, Hawaii 96720

2005.07.01:
Permission of Land Usage

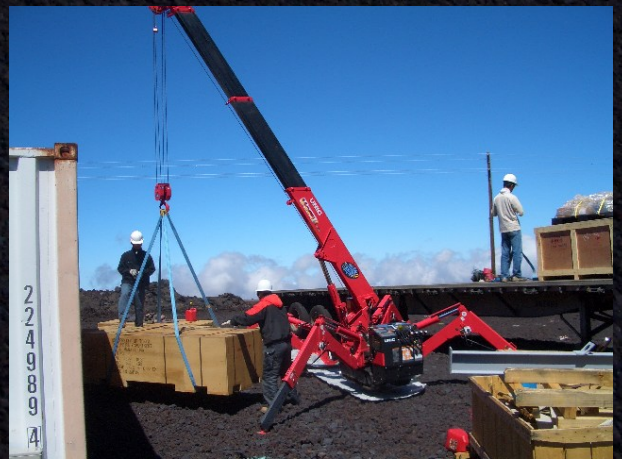
Dear Mr. Hamilton;

SUBJECT: Conservation District Use Permit (CDUP) HA-3221 All-sky Survey High Resolution Air-shower Detector (Ashra) Project Located at Kaohe V, Island of Hawaii, TMK

2005.07.27 **Started up Grading Work**


2006.09
Mauna Kea
RV
Op.Room
Light Collectors
in Shelters
Storage Container
Foundation by
Concrete blocks

2006.10



Construction of Detector and Shelter

- Cost Effective and Quick Construction
  - Human size steel materials with little welding points
- Getting Ready for 0.5TB Data/Light Collector/Month
  - Copy to 0.5TB-HDDs and transport them to ICRR by air

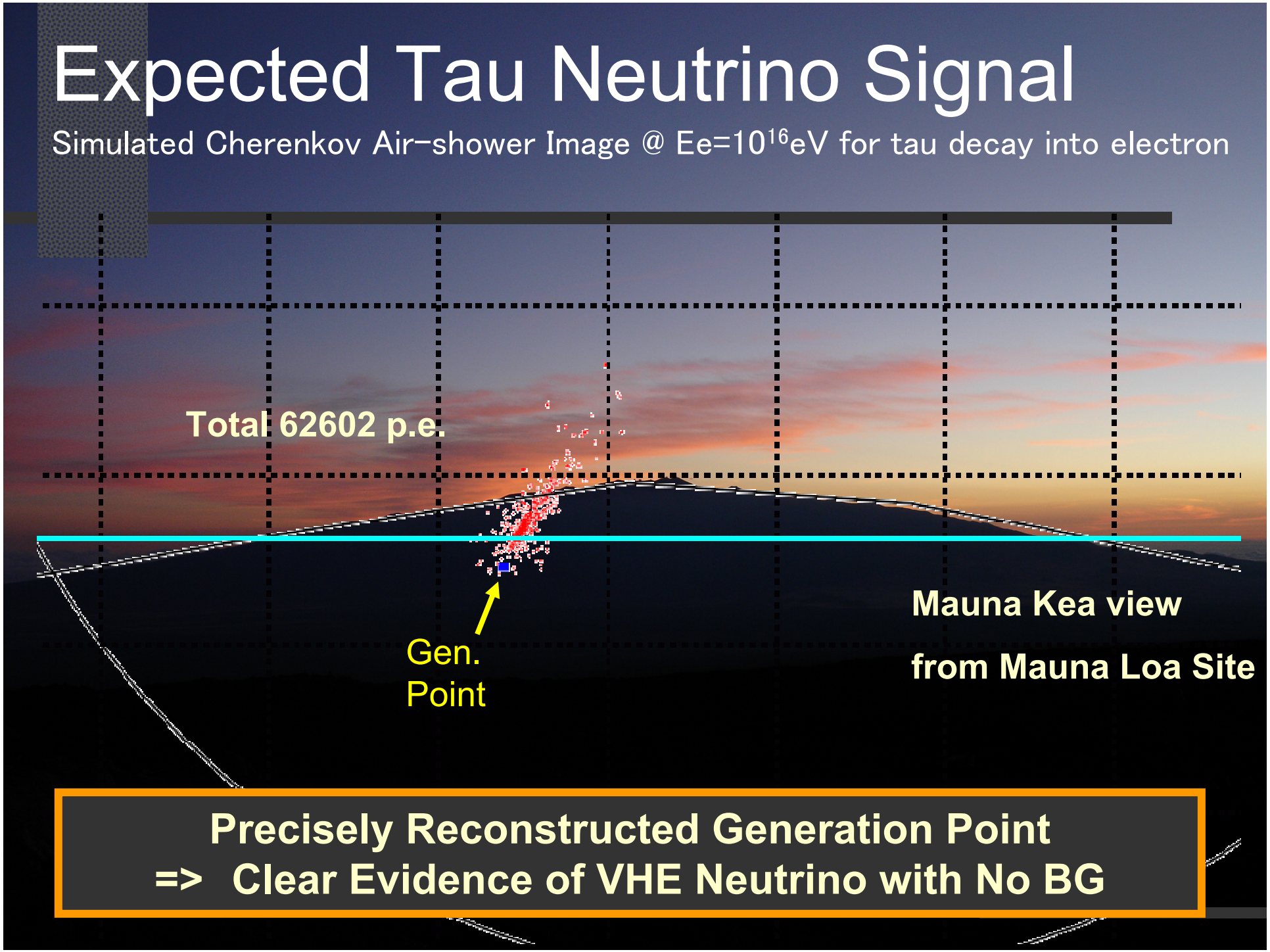
2007.01
High-ele.-ang. Light Collectors Watches 4 Directions

Light Collector with Lower Elevation FOV

Covering 70% of the View of Mauna Kea

Expected Tau Neutrino Signal

Simulated Cherenkov Air-shower Image @ Ee=10^{16}eV for tau decay into electron

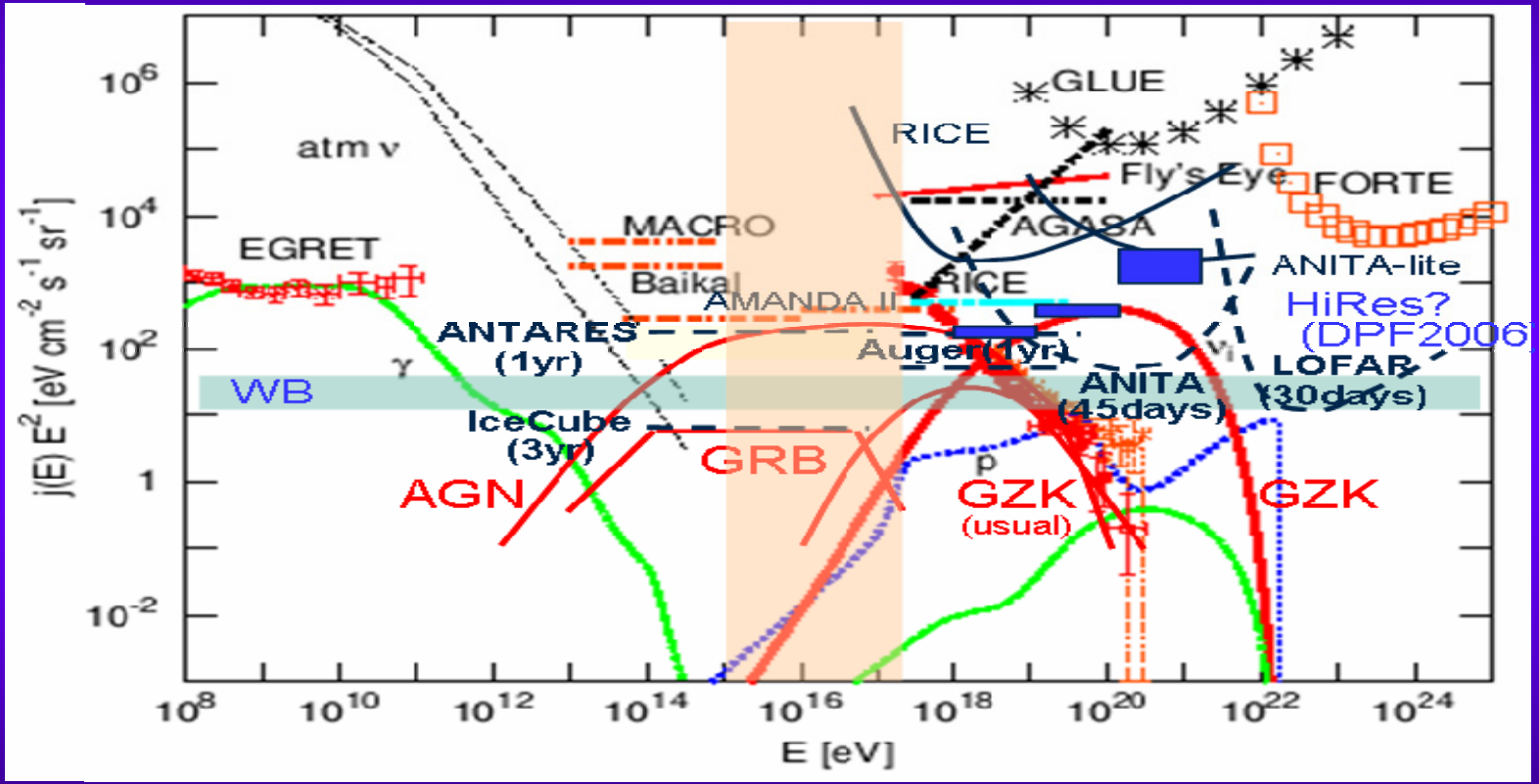


Precisely Reconstructed Generation Point
=> Clear Evidence of VHE Neutrino with No BG

Sensitivity of VHE Neutrino Detector

Semikoz & Sigl, J. of Cosmology and Astroparticle Phys., 04 (2004) 003
Cazon & Bigas (from Olinto's talk @DPF2006)

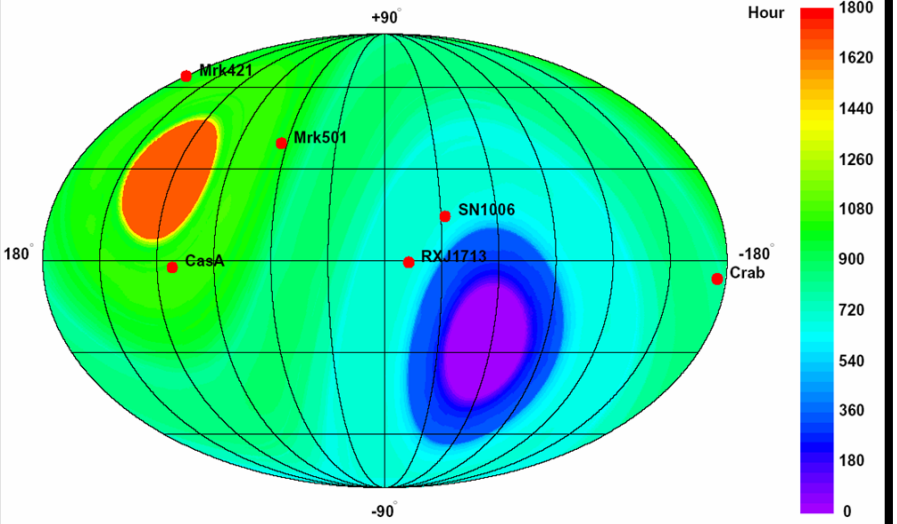
Halzen, Eur. Phys. J., C 46 (2006) 669
Murase et al., ApJ. 651 (2006) L5



- Several experiments have used earth-skimming method.
- Window ($10^{15\text{-}18}$eV) between Cherenkov & Fluo. Techniques
- Advantage of Ashra simultaneous detection with fine images

Cosmic Ray Renaissance

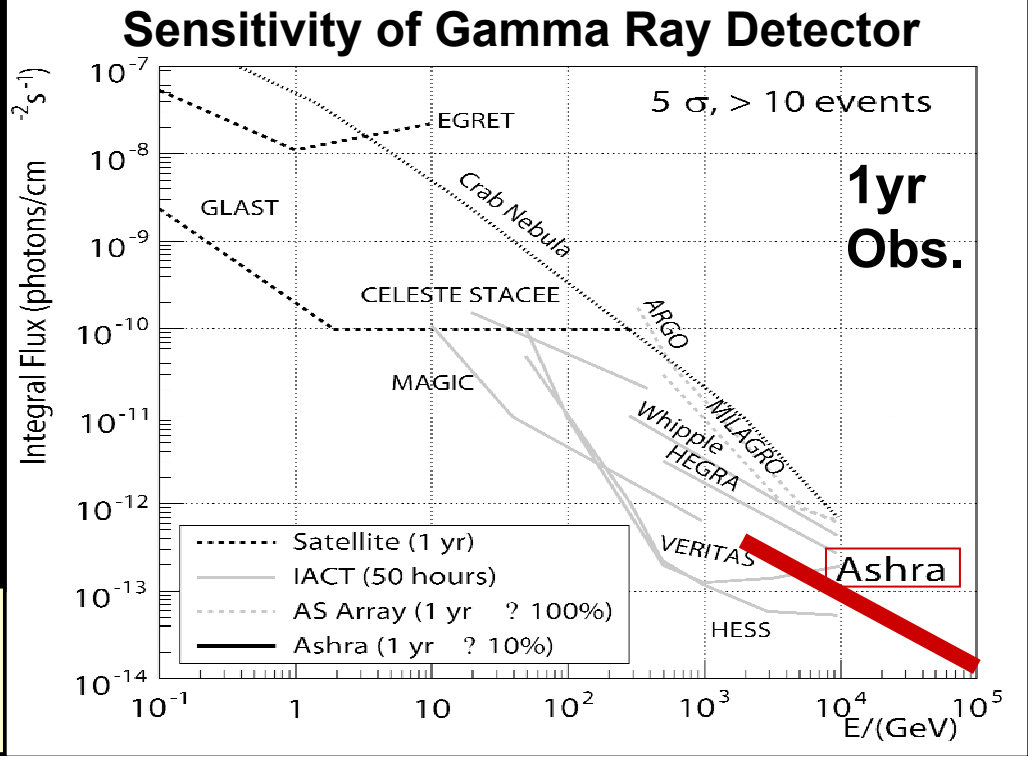
- **Discovery of Ultra High Energy Cosmic Ray?**
  - AGASA discovery vs HiRes denial => Auger resolution
- **New Step of Gamma Ray Astronomy**
  - Fascinating Gamma Ray Bursts
  - H.E.S.S. IACT Activity (Morphology, Survey, …)



Observation Time / 2yr (Duty=10%)

Low Ene. => Poor Light =>Big Mirror

High Ene.=> Poor Flux =>Long Obs.



Near Future Plan (Revised)

- FY2005 Started construction at site on Mouna Loa

Budget Problem in FY2006!

- FY2007 Optical assembly & adjustment
  => Start Optical transient monitor
- FY2008 Cherenkov Trigger & Readout assembly
  => Start VHEγ monitor
  => Start VHEν Search (Mountain)
- FY2009 Fluorescence Trigger & Readout assembly
  => Start VHEν Search (Earth)