From the Utah Desert
to the
International Space Station:

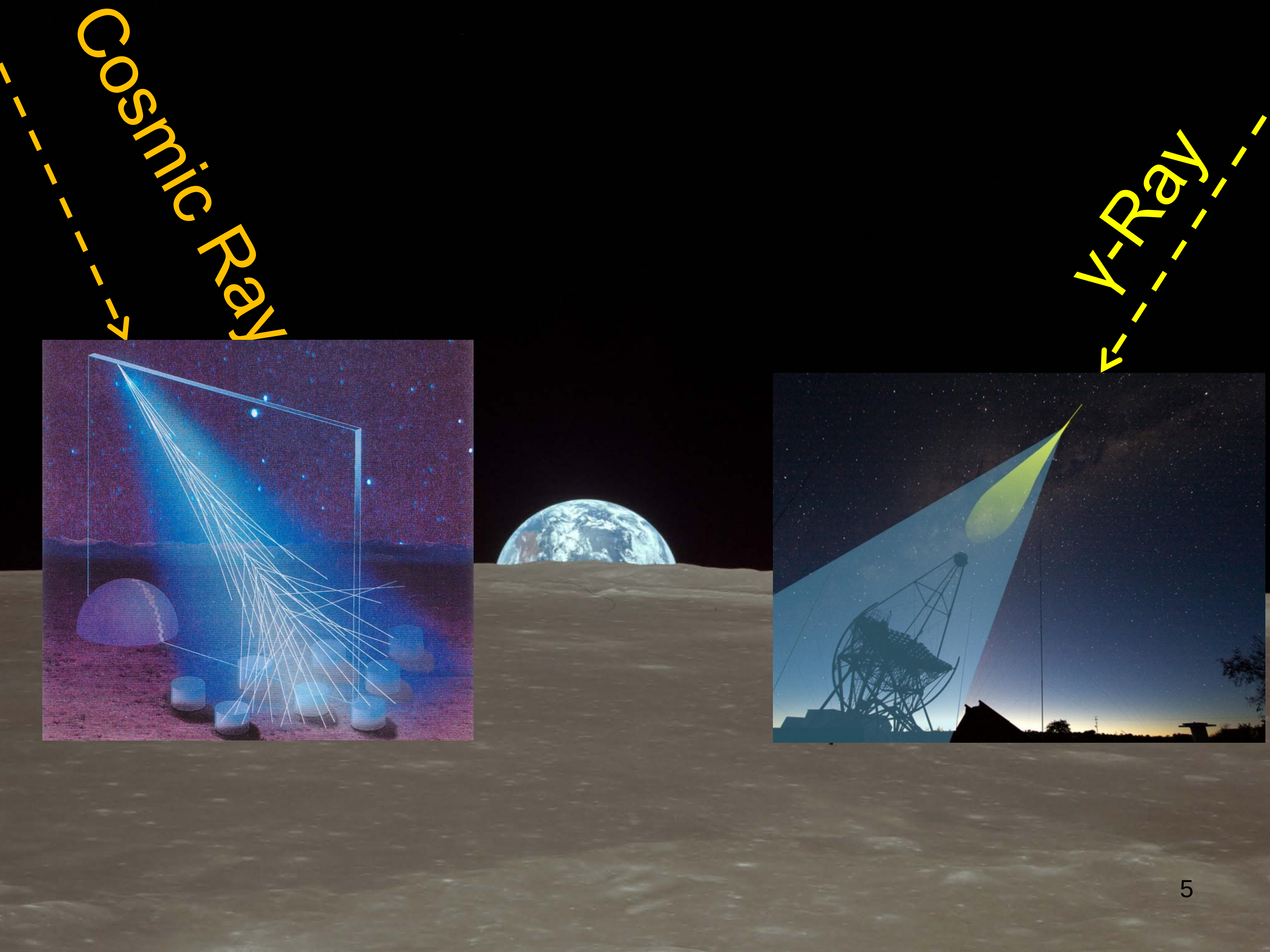
The evolution of atmospheric monitoring for astroparticle physics experiments

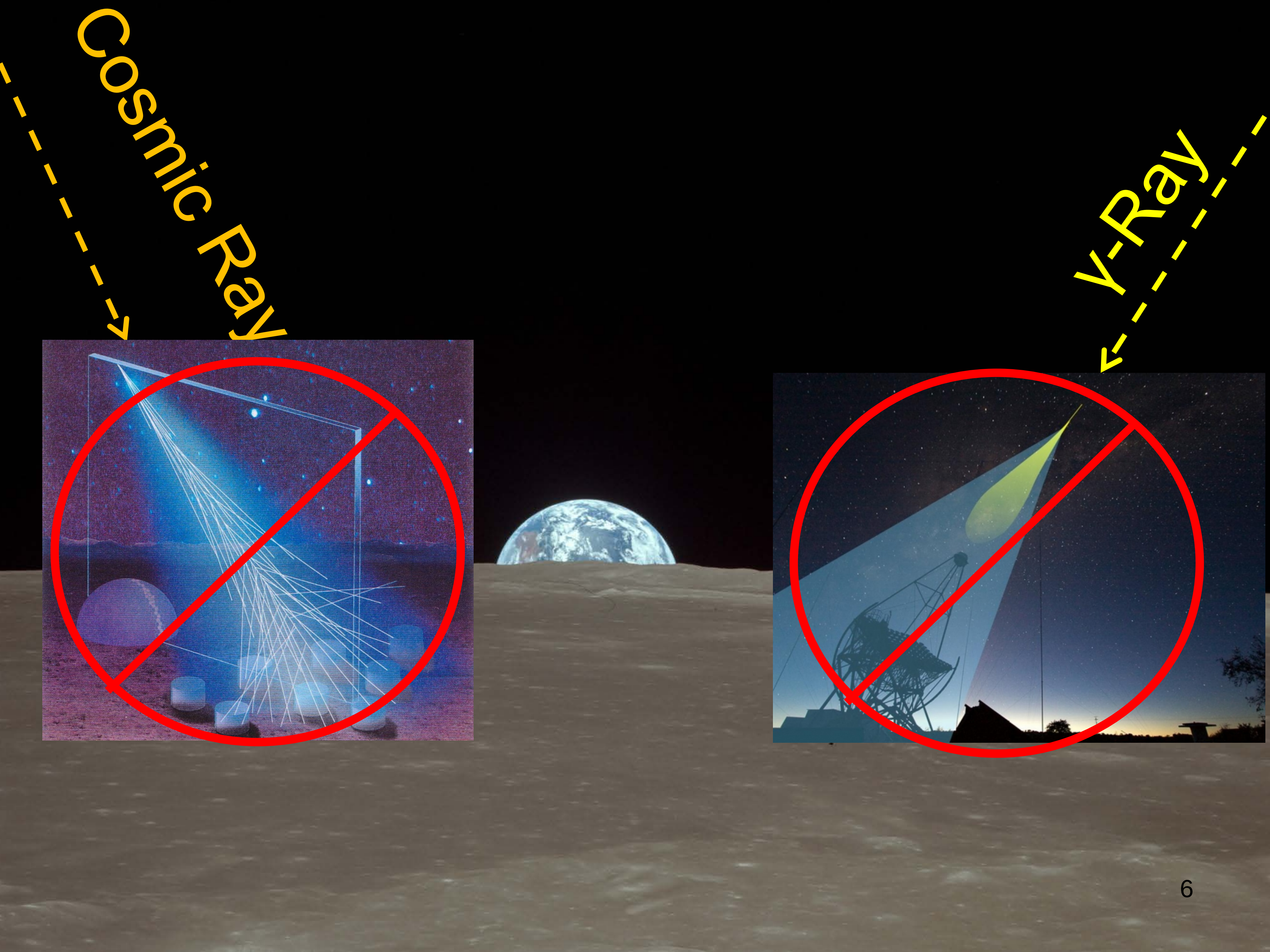
Lawrence Wiencke
Colorado School of Mines
June 10th 2013

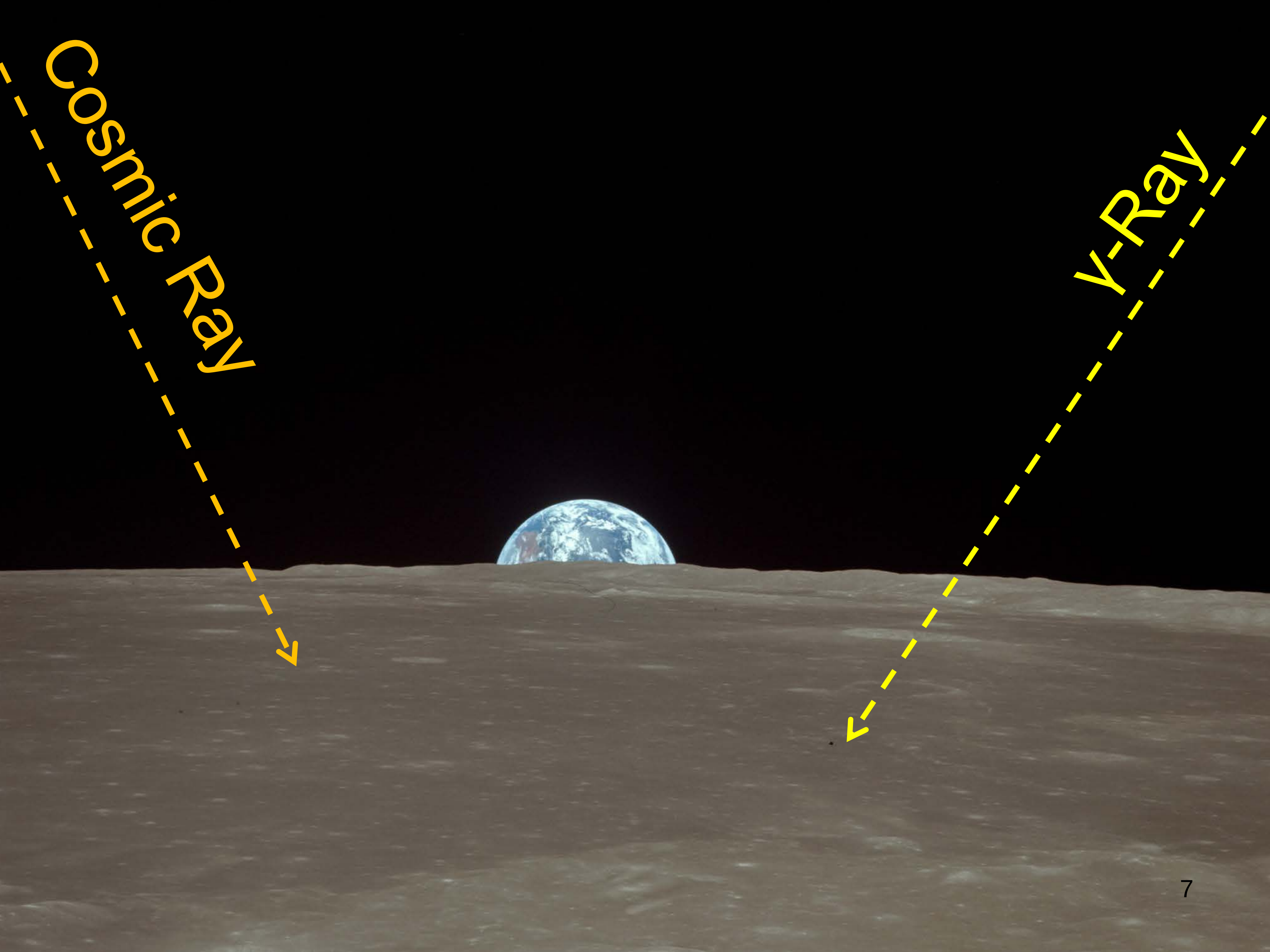
Near Moab Ut (USA) May 2012
Photo: J. Woeste

Earthrise Dec 24 1968 Bill Anders


Cosmic Ray
γ-Ray


Cosmic Ray
γ-Ray


Cosmic Ray
γ-Ray

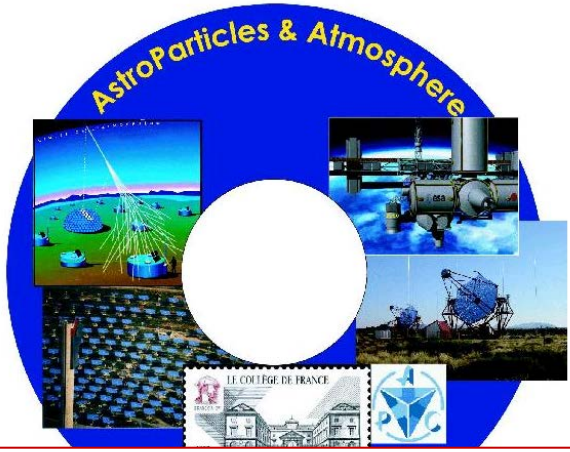

Cosmic Ray
γ-Ray

Earthrise Dec 24 1968 Bill Anders

Atelier ASTROPARTICULES et ATMOSPHÈRE

ASTROPARTICLES and ATMOSPHERE (AA) workshop

Paris, 26-28 May 2003



The group photo of the participants of the ASPERA days of the ATMON'08 conference in Prague:

2008

Atmospheric Monitoring for Astroparticle Physics, Prague, June 26 - July 4, 2008

ATMON'10: Madison, Wisconsin

Second Workshop on
Atmospheric Monitoring in Astroparticle Physics and Astronomy

Dates: from 13 September 2010 08:30 to 14 September 2010 18:00
Timezone: US/Central
Location: *UNIVERSITY OF WISCONSIN MEMORIAL UNION*
800 Langdon Street
Madison, WI USA

2010

AtmoHEAD

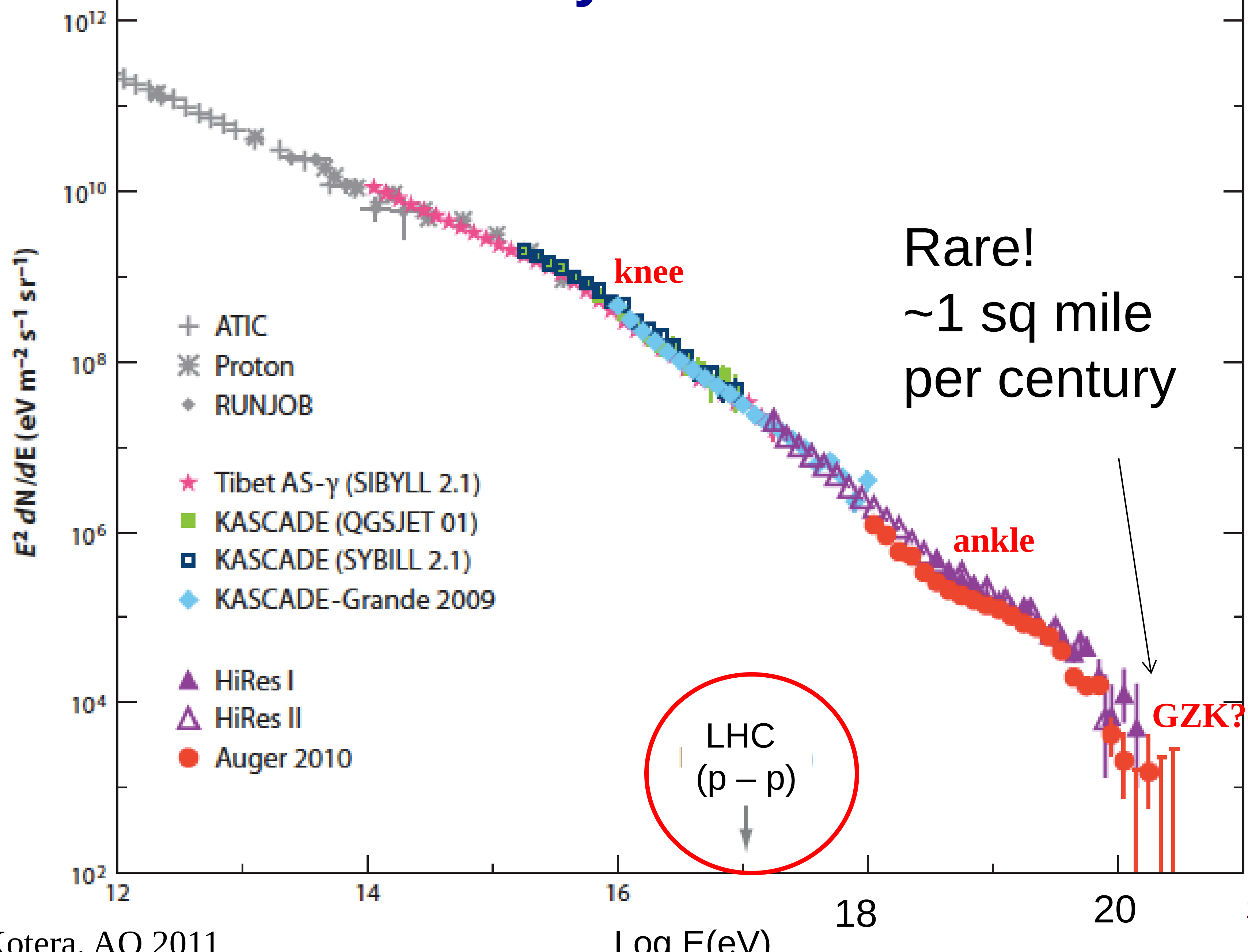
AtmoHEAD: Atmospheric Monitoring for High-Energy Astroparticle Detectors

10-12 juin 2013 *CEA Saclay*

Europe/Paris timezone

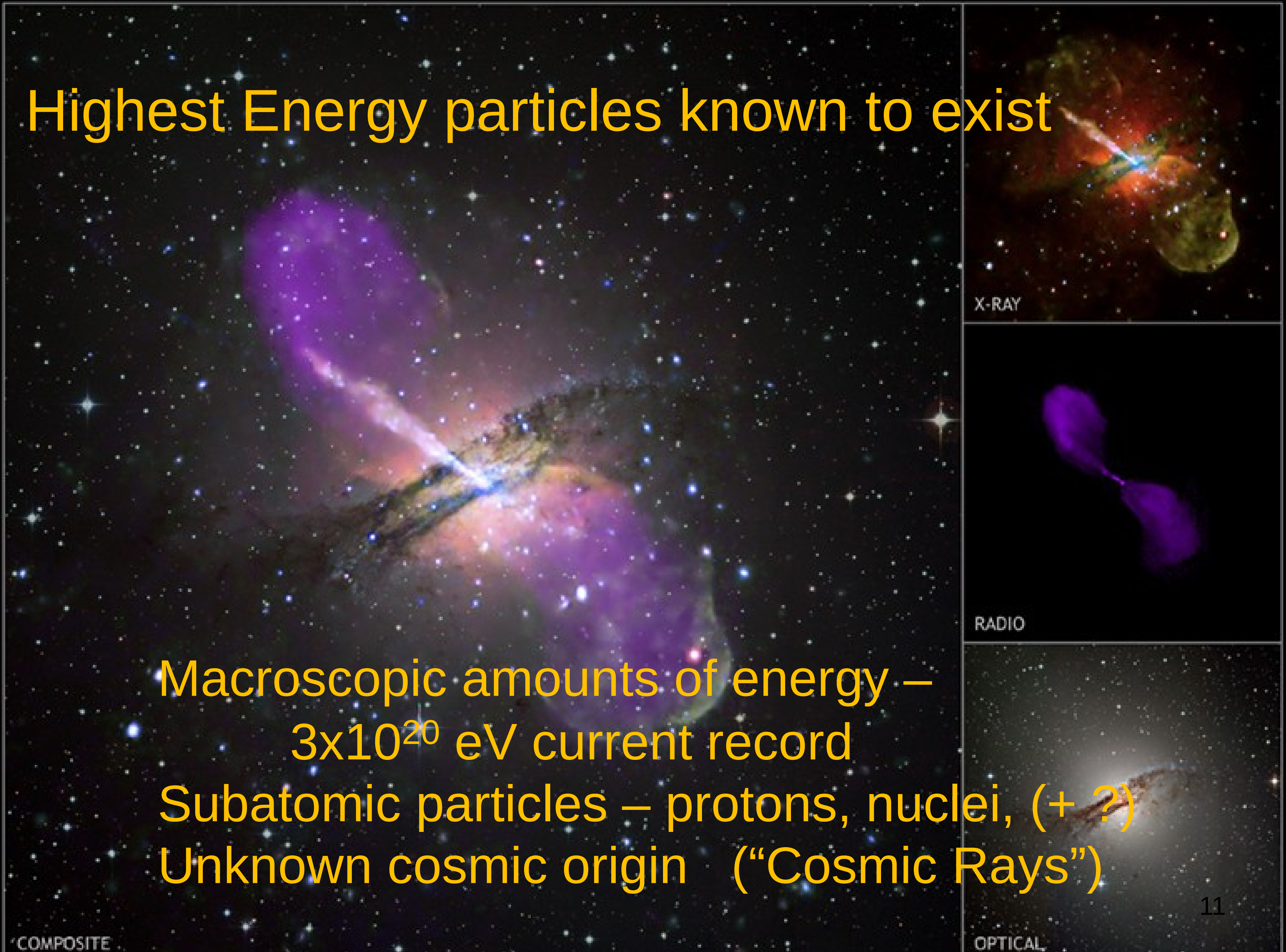
2013

Cosmic Ray Flux x E^2



Kotera, AO 2011

Highest Energy particles known to exist



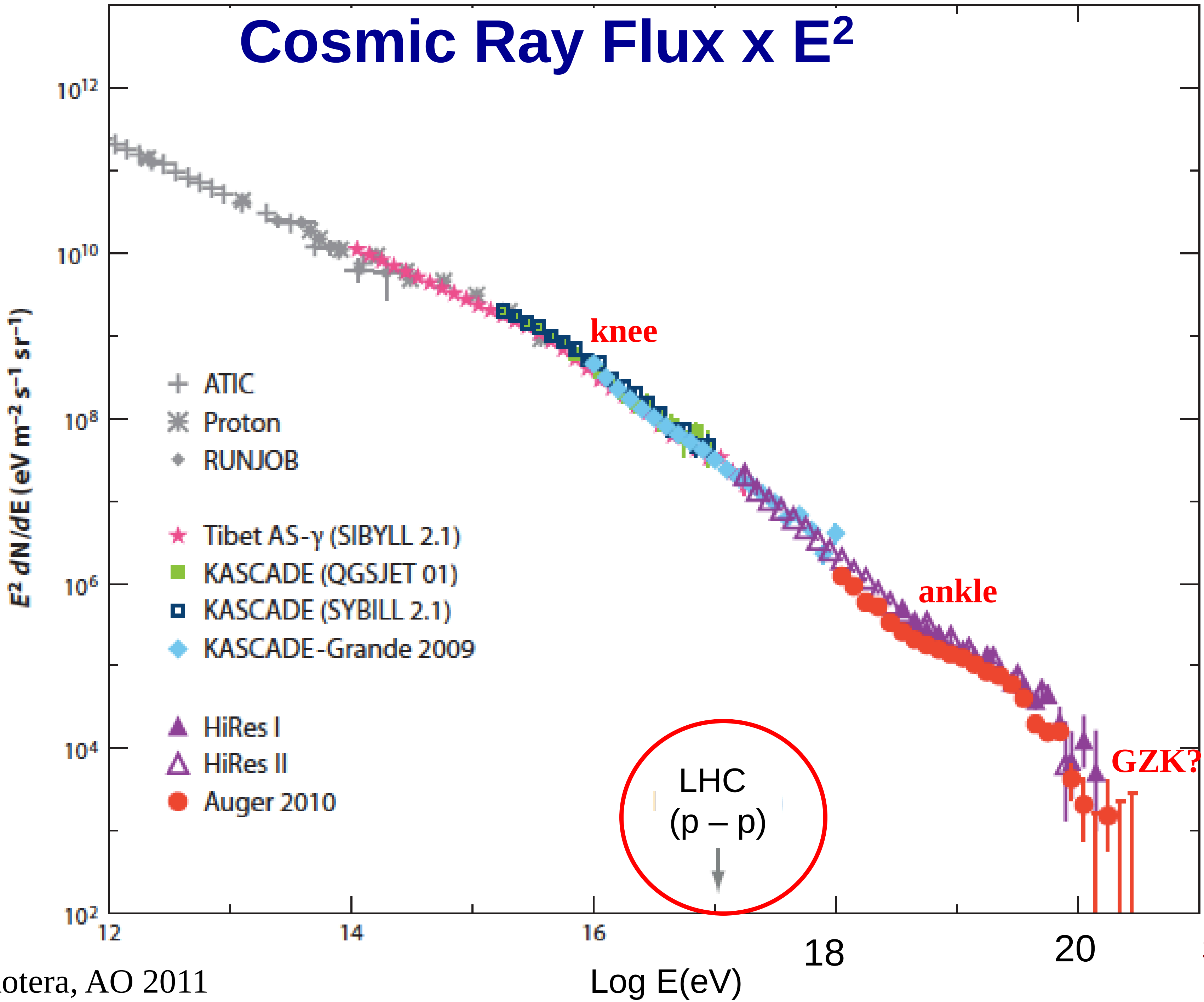
Macroscopic amounts of energy –
$3x10^{20}$ eV current record
Subatomic particles – protons, nuclei, (+ ?)
Unknown cosmic origin (“Cosmic Rays”)

Eleven Science Questions for the New Century*

Question 6: How Do Cosmic Accelerators Work and What Are They Accelerating?

***"Connecting Quarks with the Cosmos: Eleven Science Questions for the New Century Committee on the Physics of the Universe", National Research Council ,** ISBN: 0-309-50569-0 (2003)

Cosmic Ray Flux x E^2



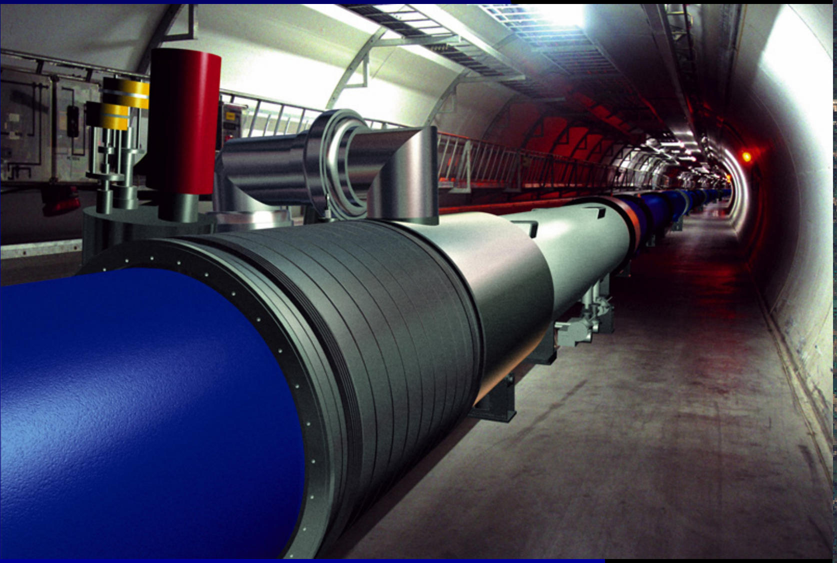
Kotera, AO 2011

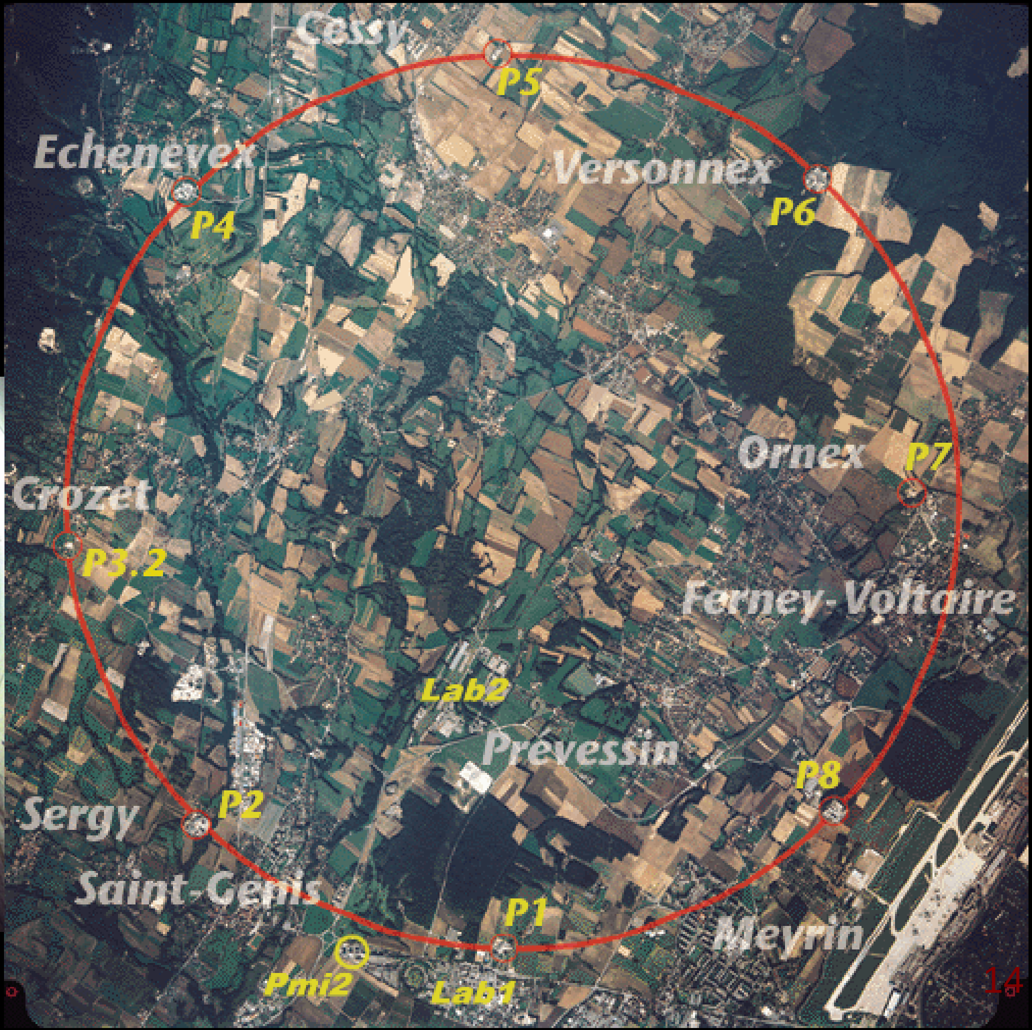
Challenging Accelerators

to reach 10^{20} eV

LHC magnetic field,
radius ~ 10^7 km (Sun - Mercury)

or 10 GT fields!



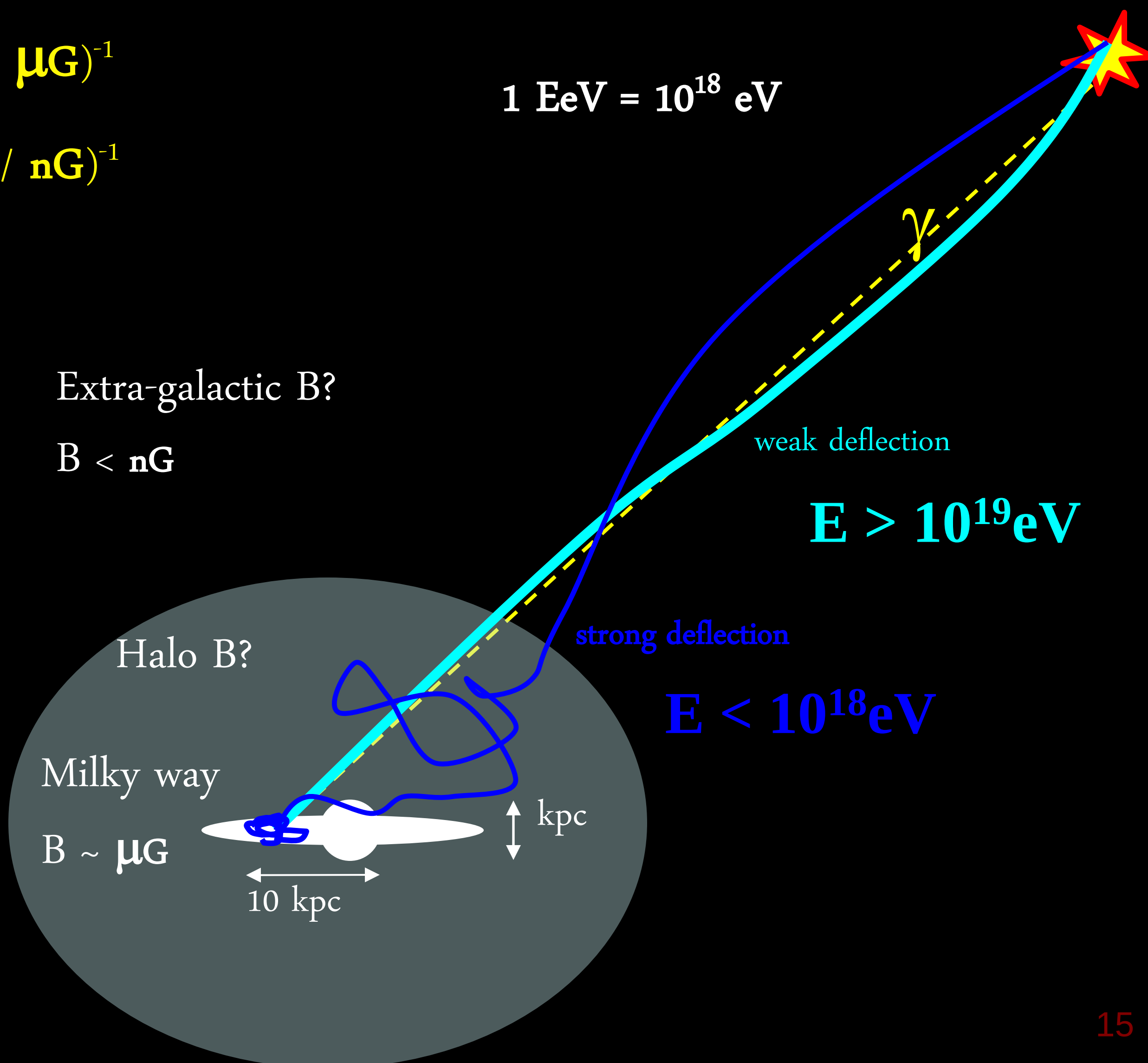


"Known unknown"

Cosmic Magnetic Fields

R_L = **kpc** Z^{-1} (E / EeV) (B / **μG**)$^{-1}$

R_L = **Mpc** Z^{-1} (E / EeV) (B / **nG**)$^{-1}$



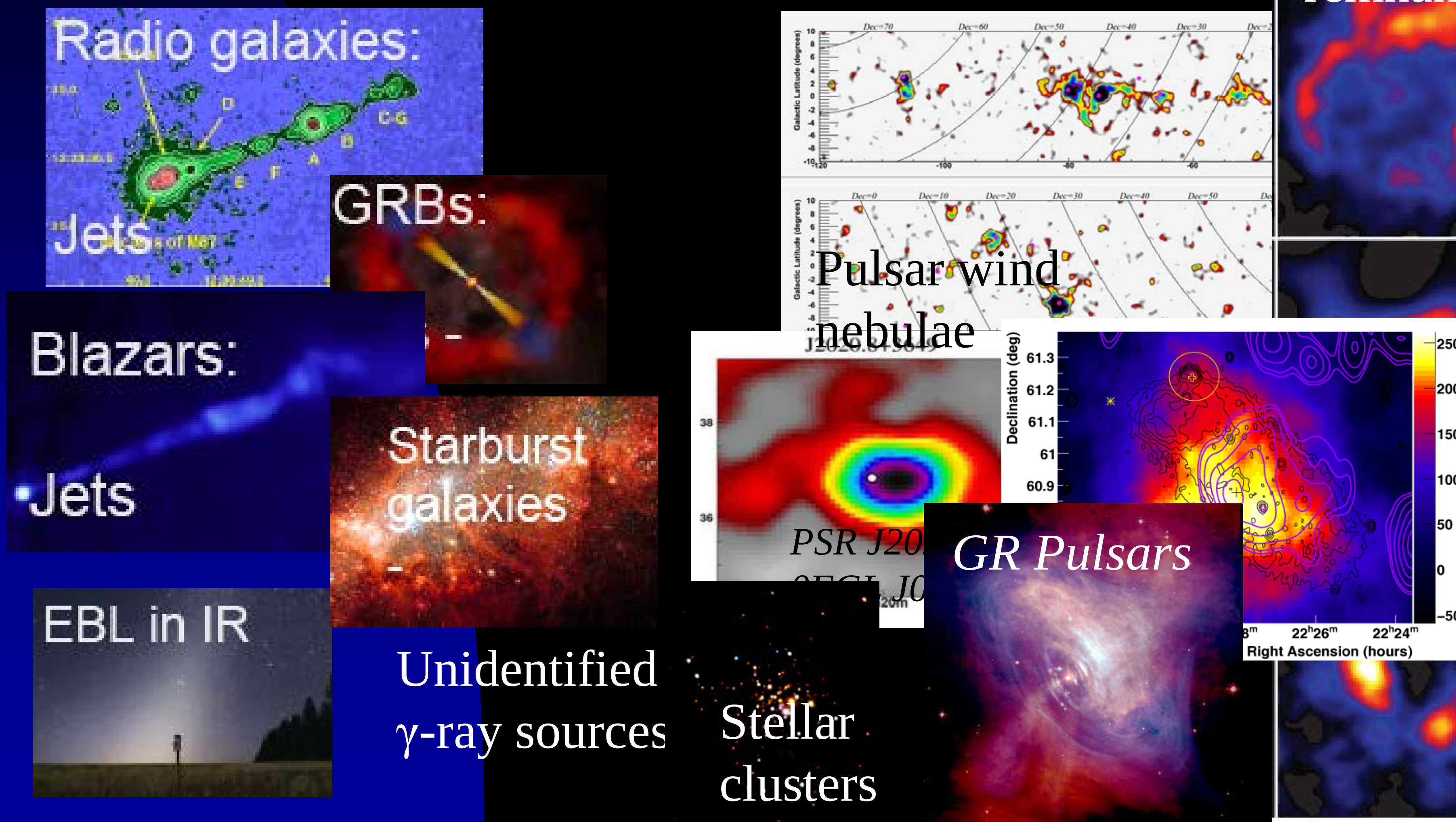
Galactic B deflection
<< 10^o Z (40 EeV/E)
anisotropic in sky

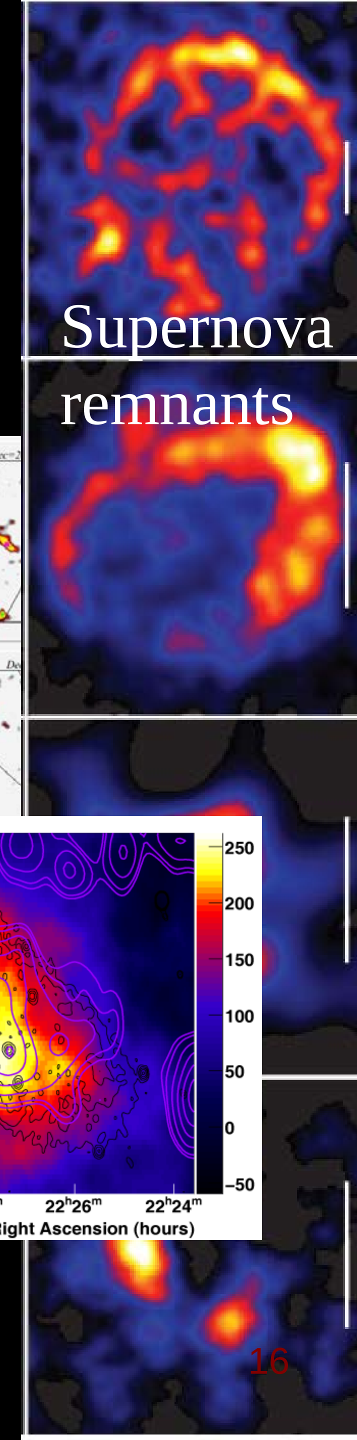
Astrophysical

High Energy Accelerators

Extragalactic

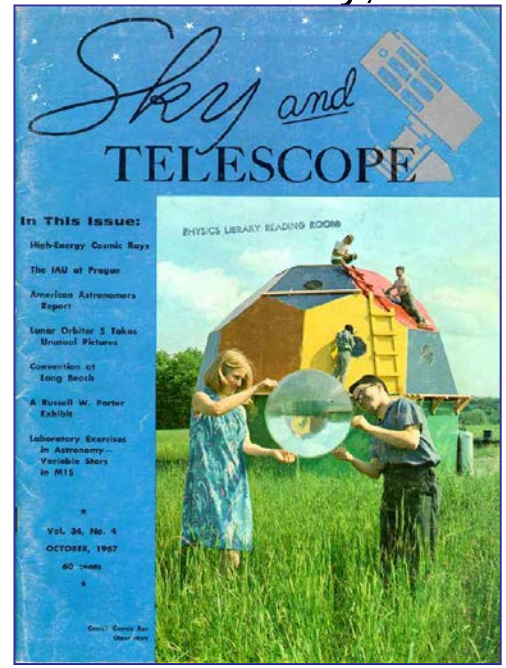
Galactic





The Fluorescence Technique has a colorful history

Cornell University, 1967



LA-3409-MS Supplement
UC-34, PHYSICS
TID-4500

RELEASED FOR ANNOUNCEMENT
IN NUCLEAR SCIENCE ABSTRACTS

H.C. $ 3.00; MN .75

LOS ALAMOS SCIENTIFIC LABORATORY
of the
University of California
LOS ALAMOS • NEW MEXICO

Report written: September 1965
Report distributed: May 4, 1966

Prompt Air Fluorescence Excited by
High Altitude Nuclear Explosions

Original Fly's Eye 1981-93

Atmosphere Components

Molecular *(Nitrogen, Oxygen, Argon + traces)*

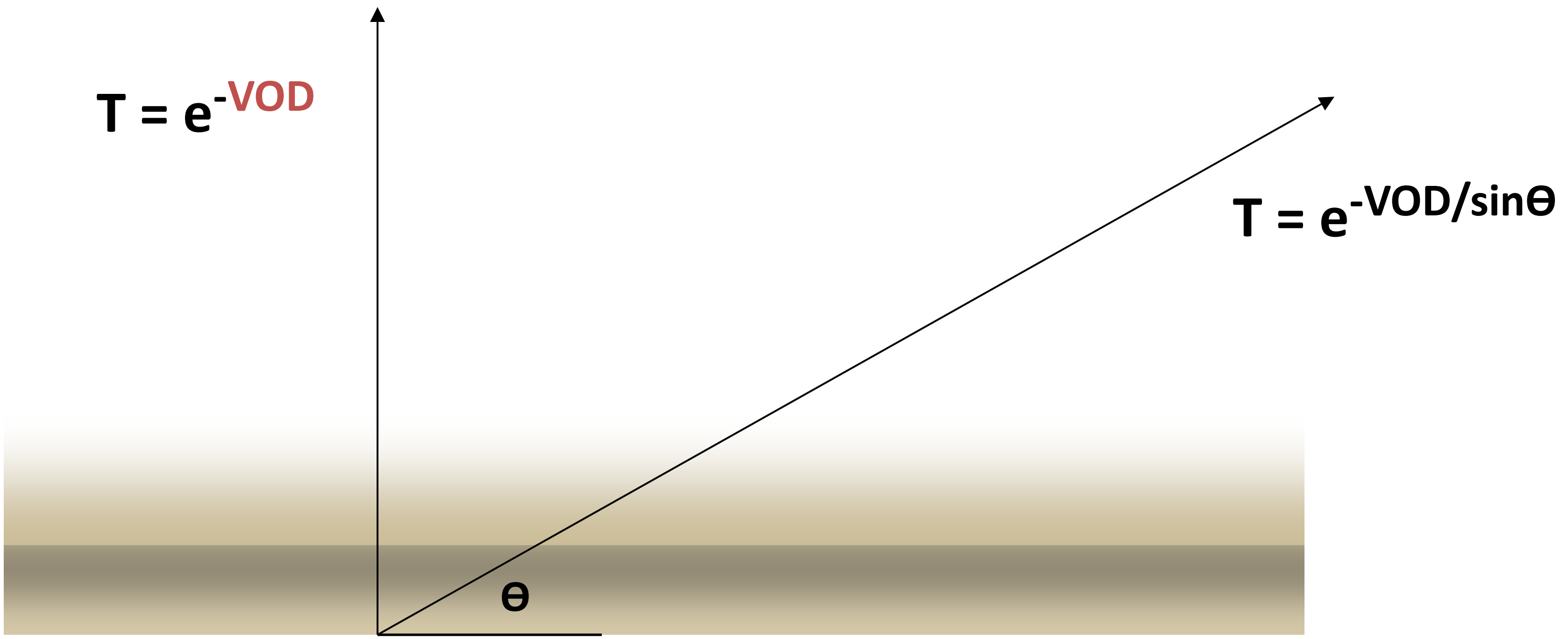
Described by Molecular Scattering
Density(z) from Radiosonde Balloon Data (P,T,z)
Global Data Asymillation System (GDAS)

Aerosols *(Haze, Dust)*

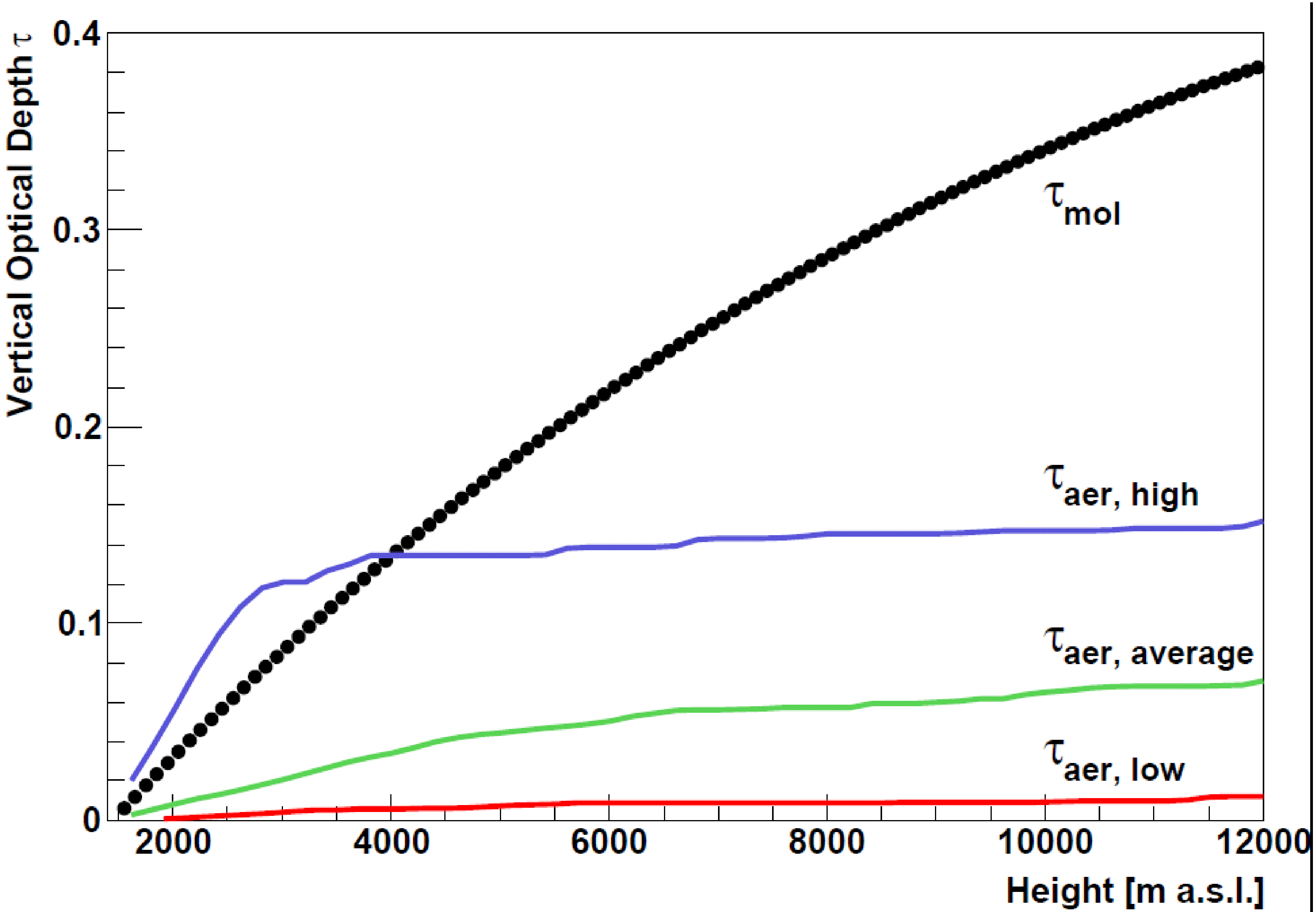
Clouds

(Ozone) *Not a factor for Fluorescence*

What is Vertical Optical Depth?

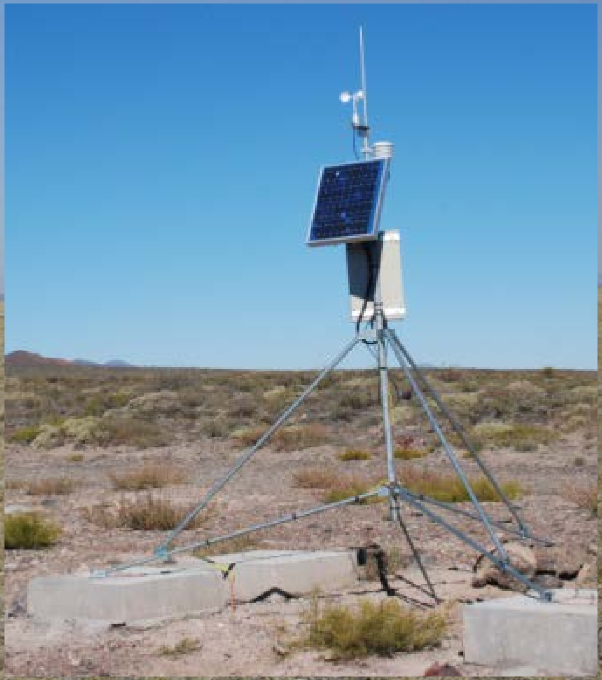


VAOD - Vertical Optical Depth of Aerosol Component



Techniques for measuring aerosol attenuation using the Central Laser Facility at the Pierre. Auger Observatory **...** 2013 *JINST* 8 P04009.

Molecular



Weather Stations (1/5)
Wind, temperature, humidity, Pressure

Radiosonde Launches
temperature, pressure, humidity (x,y,z,t)

NOAA NATIONAL CLIMATIC DATA CENTER
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

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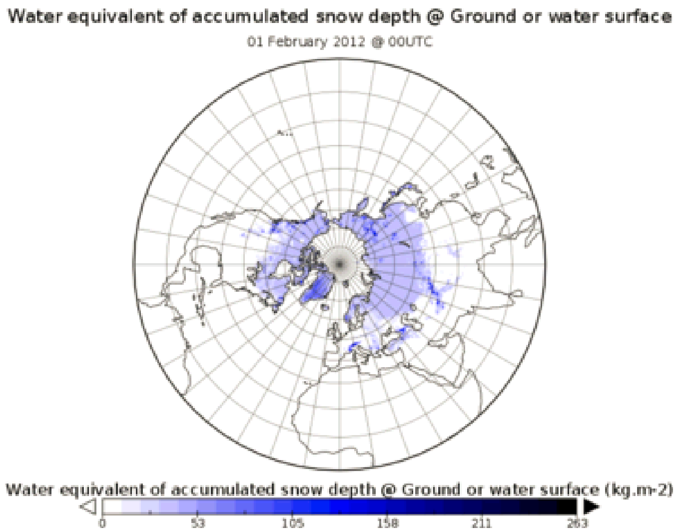
    - GEFS
    - GFS
    - NAM
    - RAP
    - RUC
    - CM2.X
    - CMIP5

HOME > DATA ACCESS > MODEL > DATASETS

Global Data Assimilation System (GDAS)

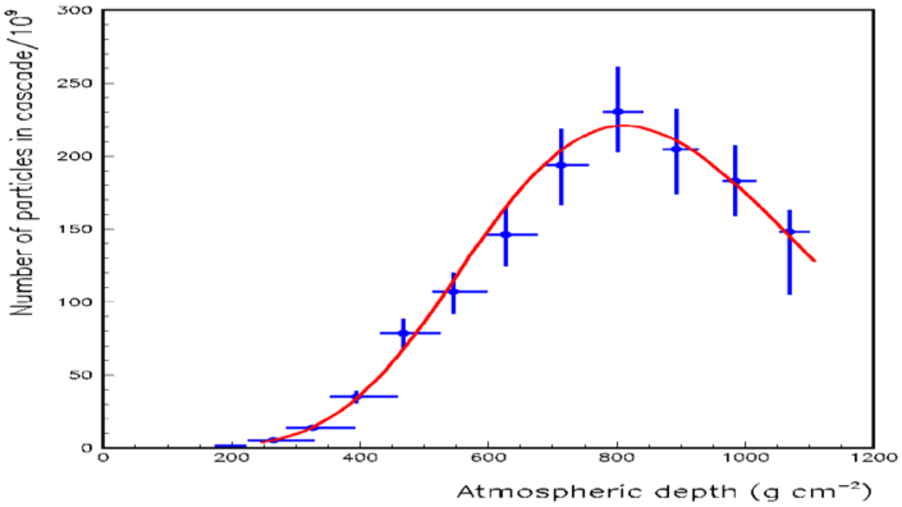
The Global Data Assimilation System (GDAS) is the system used by the Global Forecast System (GFS) model to place observations into a gridded model space for the purpose of starting, or initializing, weather forecasts with observed data. GDAS adds the following types of observations to a gridded, 3-D, model space: surface observations, balloon data, wind profiler data, aircraft reports, buoy observations, radar observations, and satellite observations. GDAS data are available through NOMADS as both input observations to GDAS and gridded output fields from GDAS. Gridded GDAS output data can be used to start the GFS model. Due to the diverse nature of the assimilated data types, input data are available in a variety of data formats, primarily Binary Universal Form for the Representation of meteorological data (BUFR) and Institute of Electrical and Electronics Engineers (IEEE) binary. The GDAS output is World Meteorological Organization (WMO) Gridded Binary (GRIB).

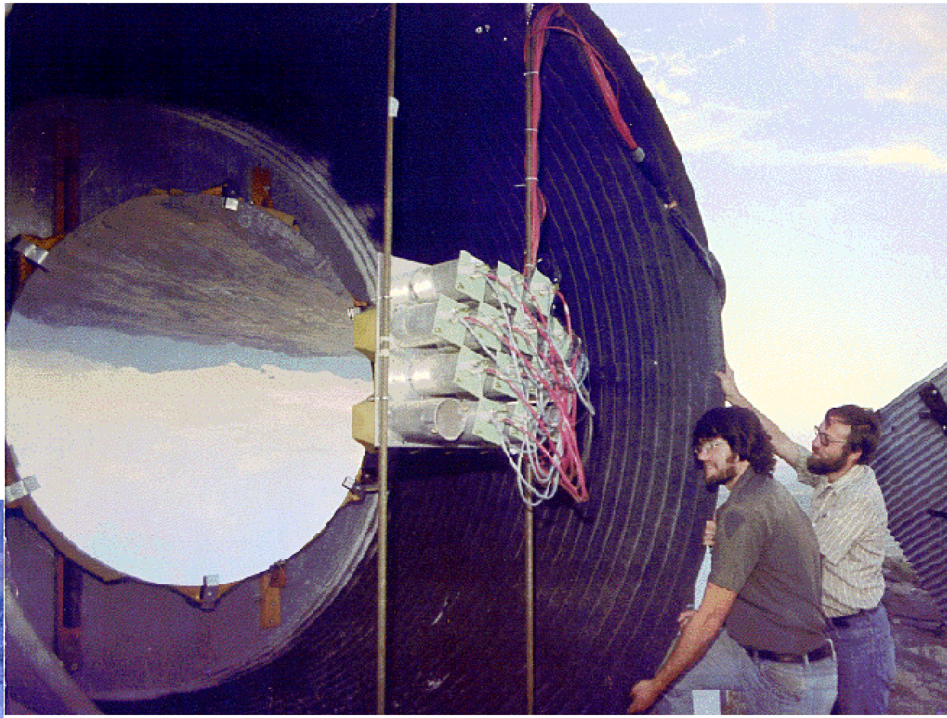


A plot of GDAS output showing the amount of water in snow covering the ground on February 1st, 2012 at 00UTC. This image was produced by visualizing GDAS output data with NASA's Panoply visualization tool.

An Amazing Event:

1980-1993 Fly's Eye Experiment (Dugway Proving Ground)

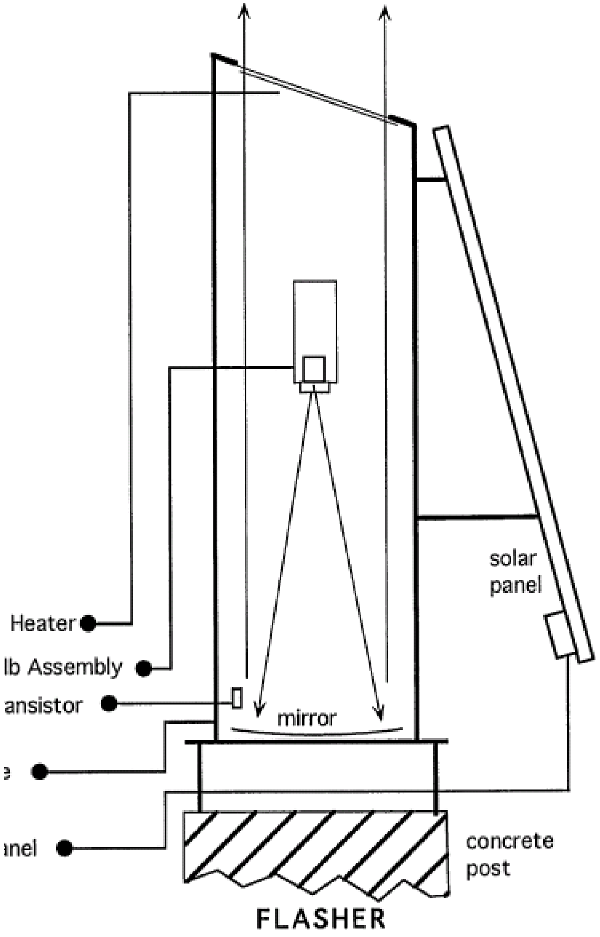




November 1991:
Event reconstructs at
320 EeV +/- 93 EeV ≈ 50 J

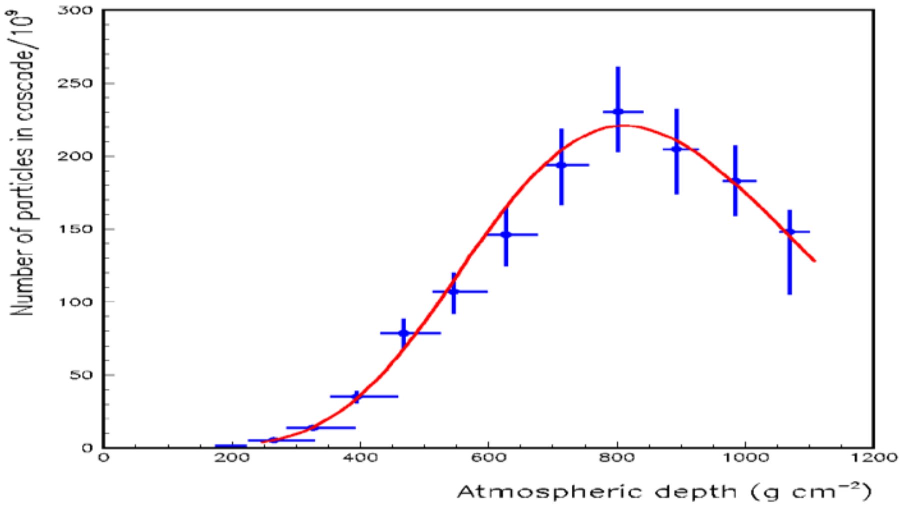
“Flashers”


Cosmic Ray Research
UNIVERSITY OF UTAH
18


Heater
lb Assembly
ansistor
e
anel
mirror
solar
panel
concrete
post
FLASHER

The 320 EeV Event Revisited

- Still the Highest Energy "Record"



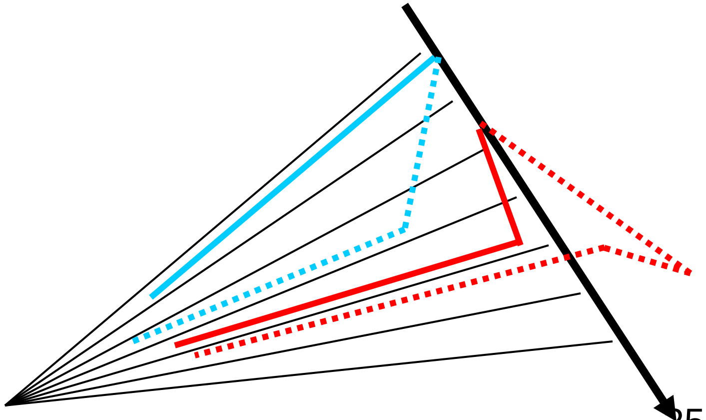
Original Fly's Eye

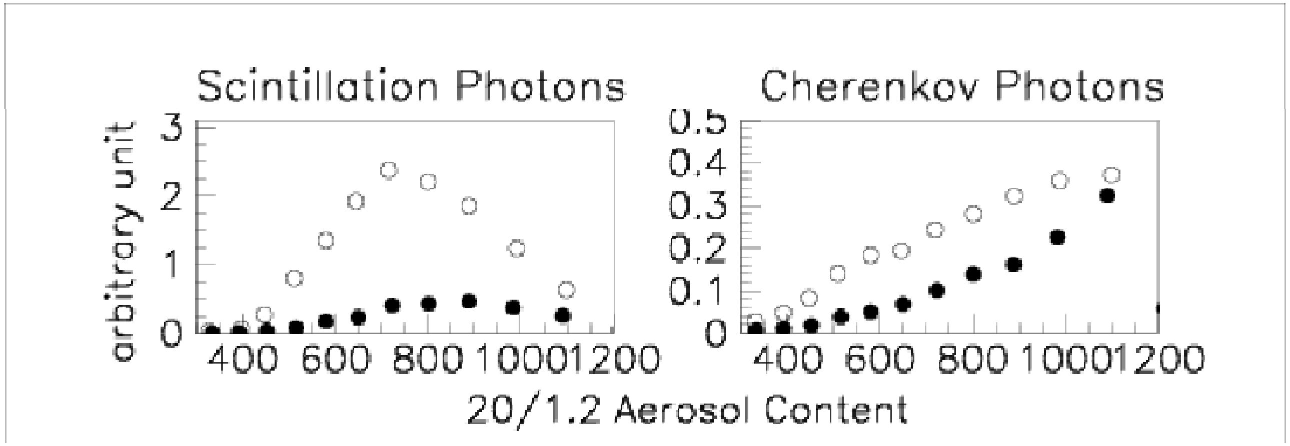
5 degree pixels

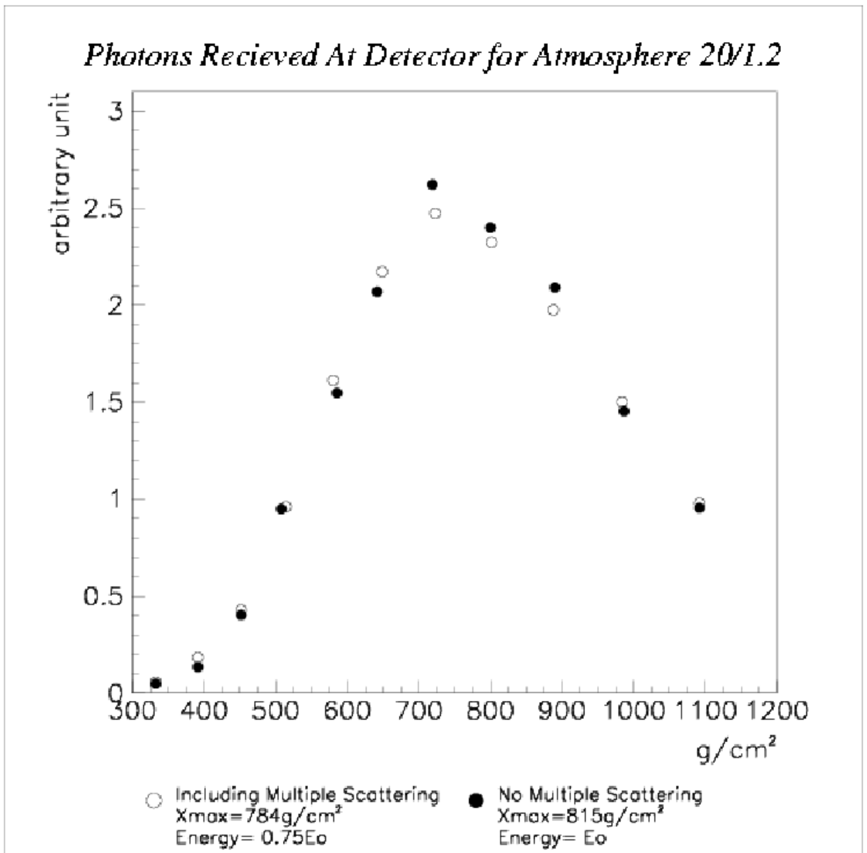
25 uS integration gate used

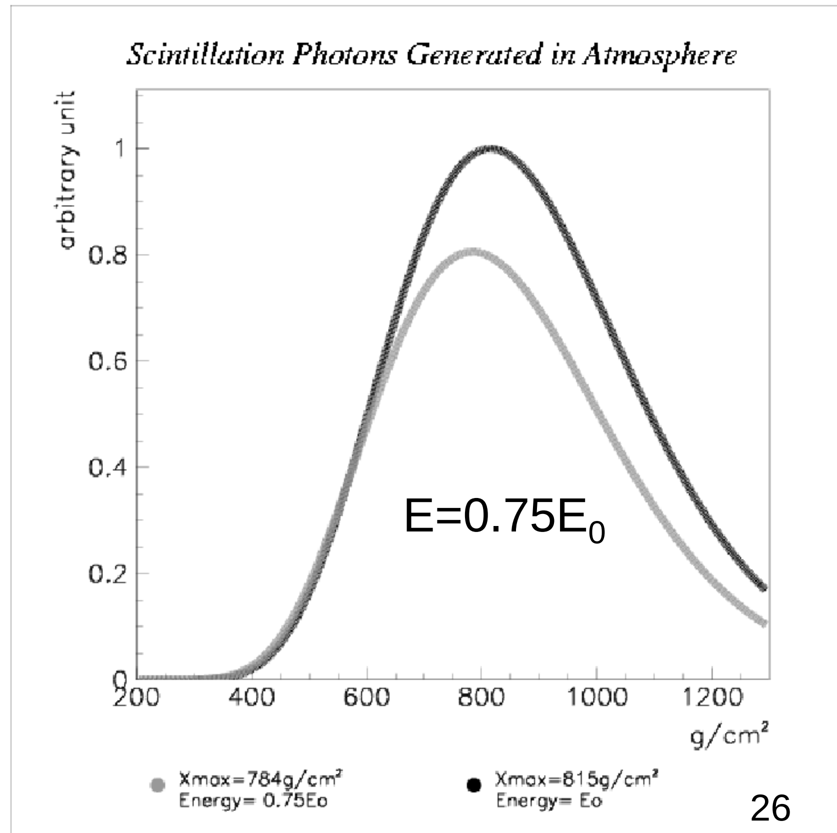
Room for extra light to be "counted"

- multiple scattering



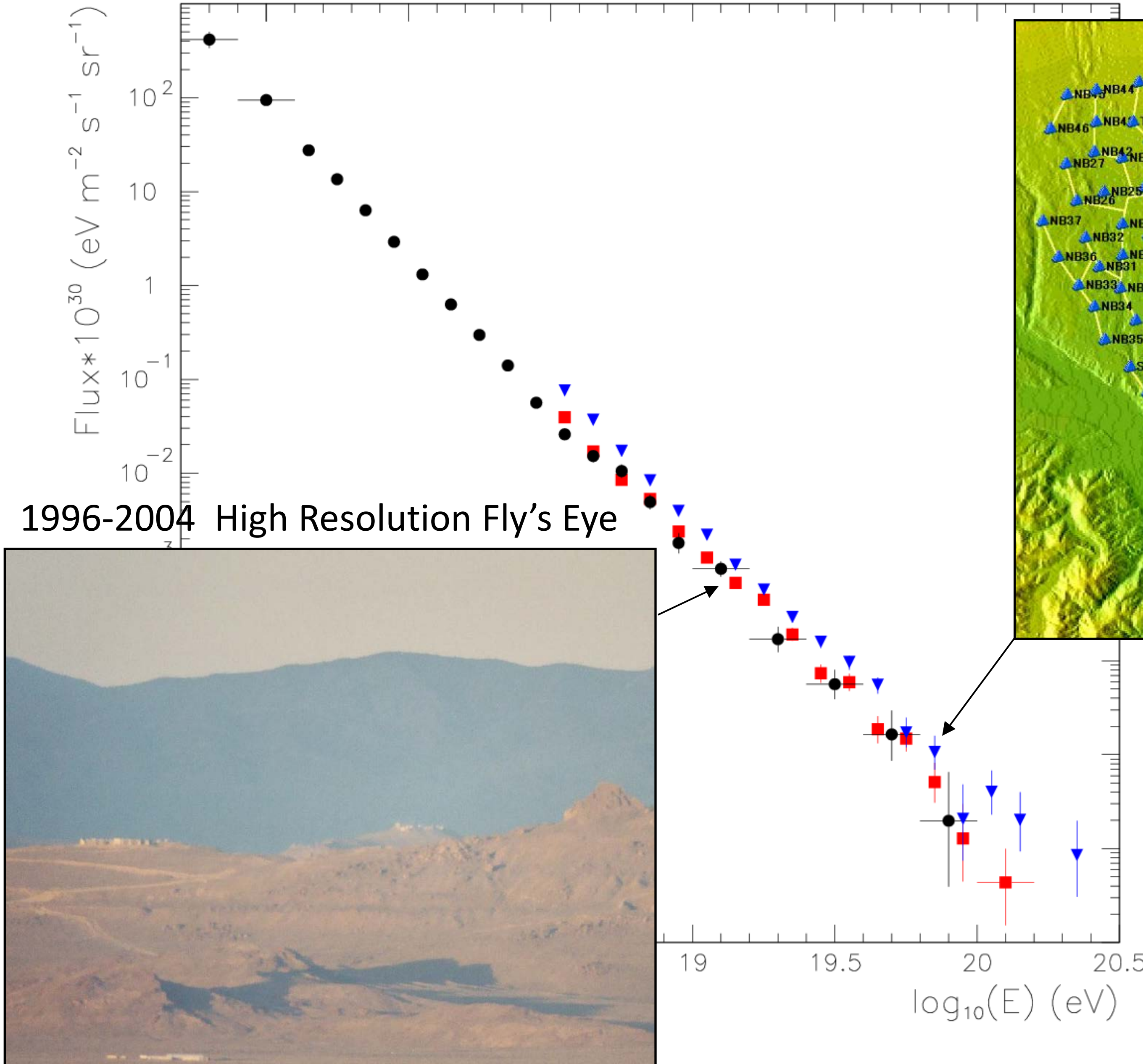


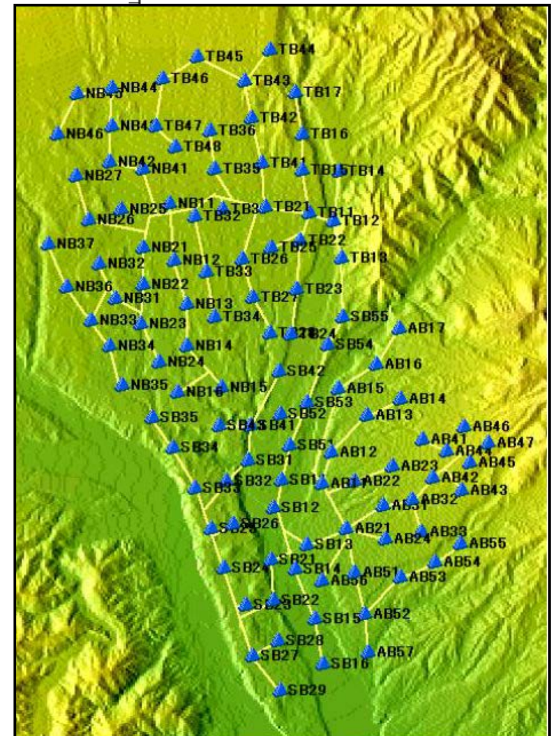




L. Wiencke, R. Grey

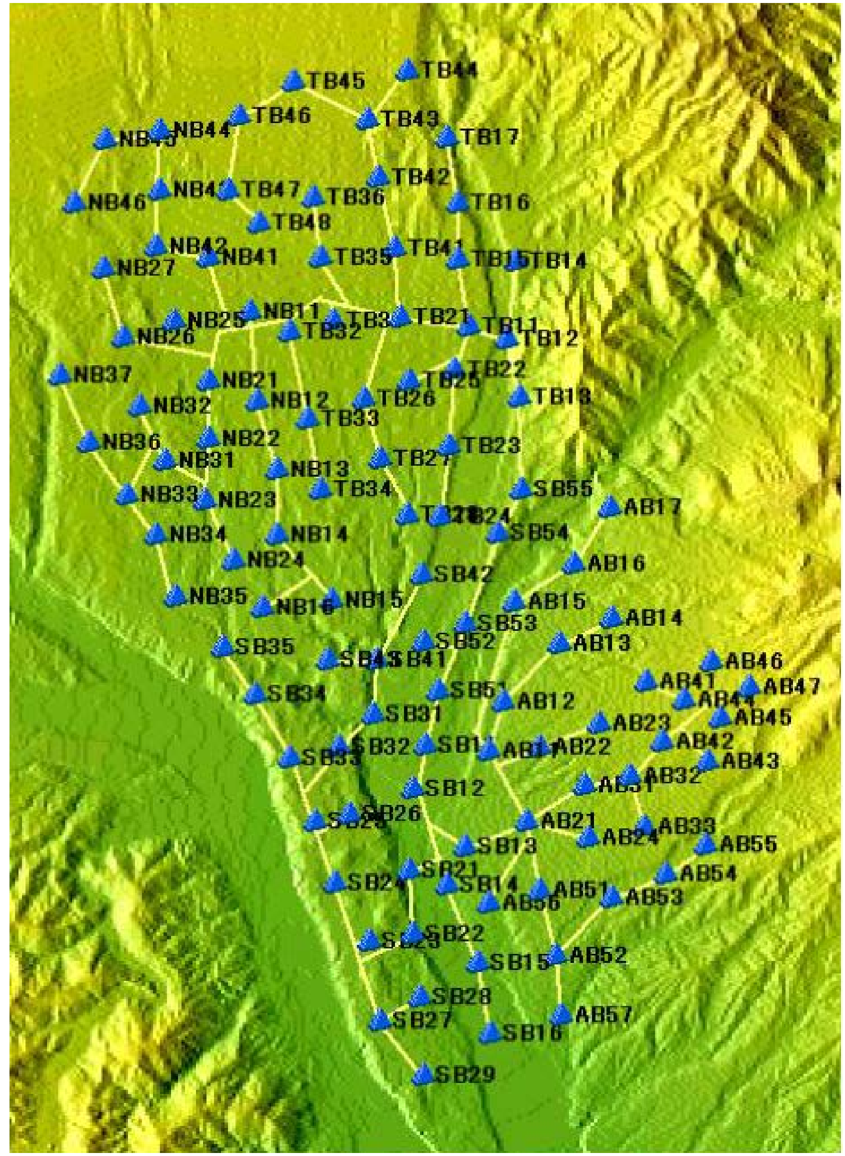
1990's (AGASA ground Array)





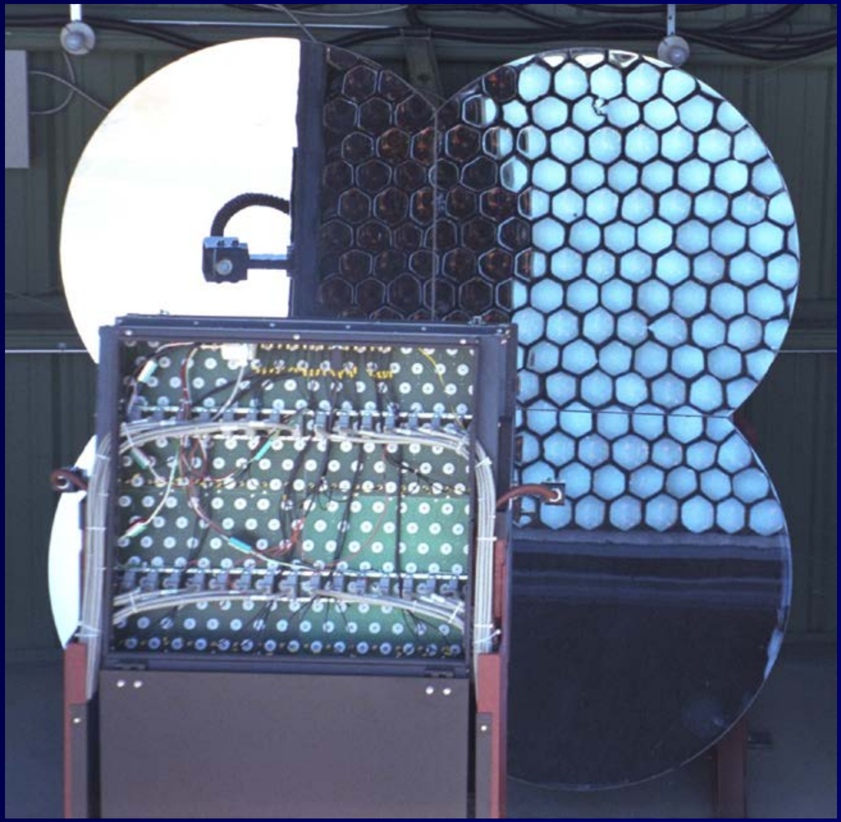
1996-2004 High Resolution Fly's Eye

AGASA (Akeno Giant Air Shower Array)

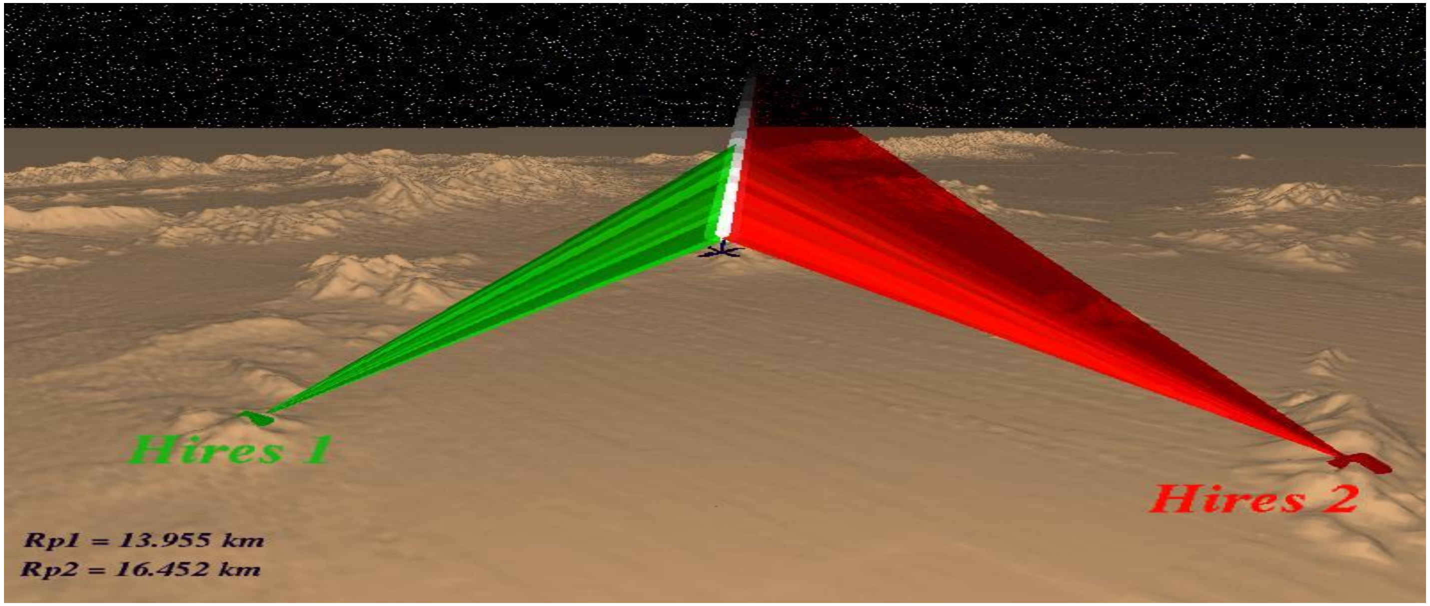


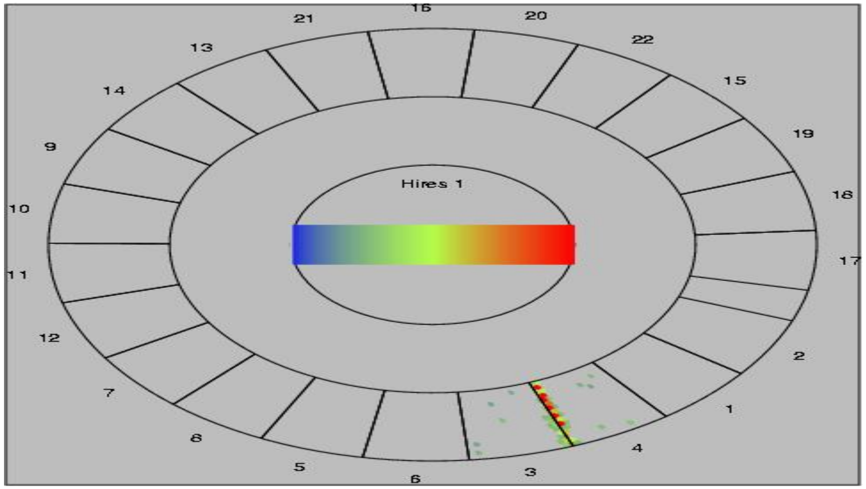
- 100 km^2 scintillators + muon detectors

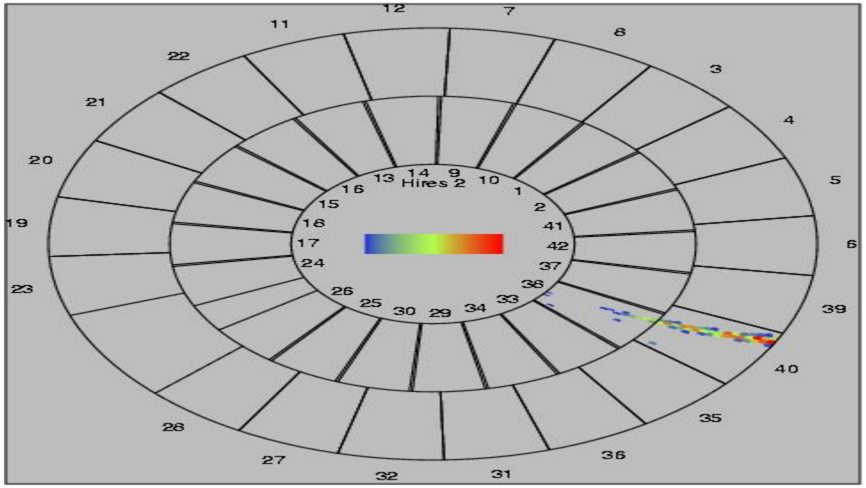
High Resolution Fly's Eye
1999-2004



High Resolution Fly's Eye Stereo Event E ~50 EeV







HiRes1

HiRes2

- At 1999 ICRC - Preliminary results from monocular measurement of CR energy spectrum ~6 super GZK candidates

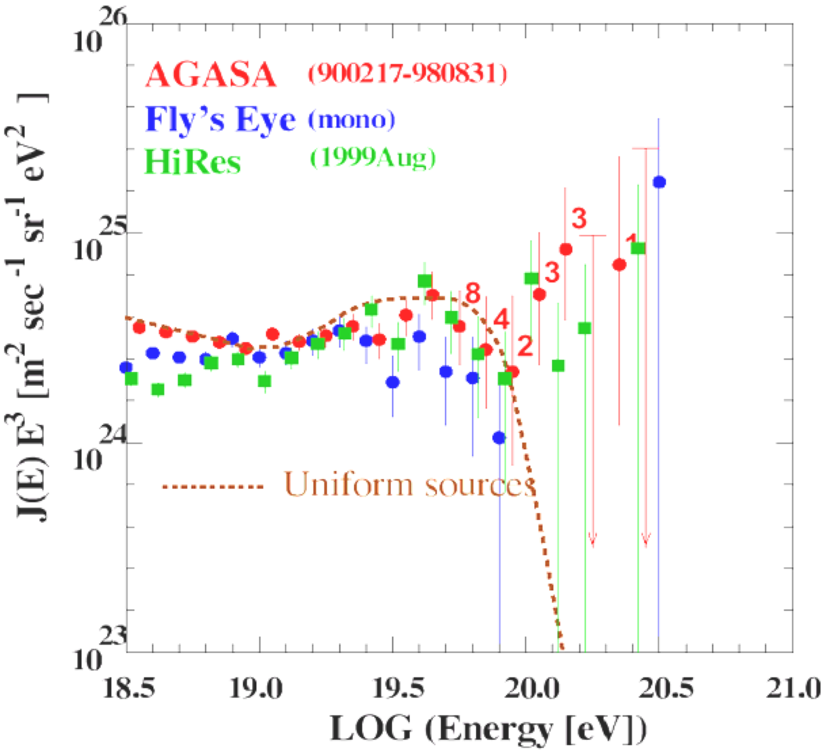
- At 2001 ICRC - HiRes reported monocular measurement of CR energy spectrum

~2x statistics, but ~2 super GZK candidates

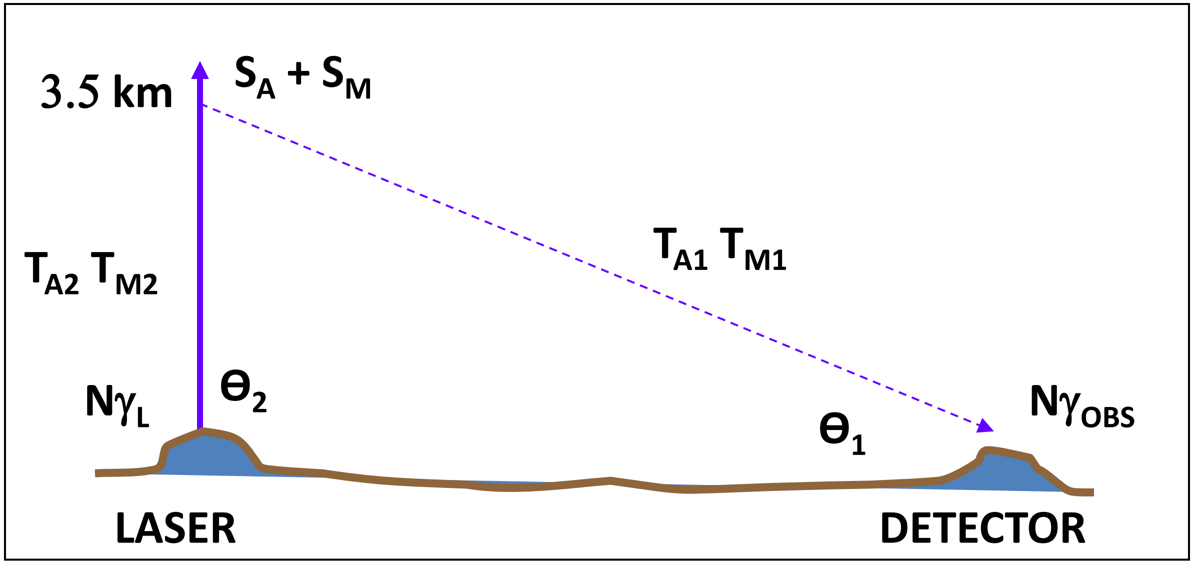
What Happened?

Why the Atmosphere Matters

1999 **(Desert Aerosol Model)**



Measurement of Vertical Aerosol Optical Depth



$$T_A = e^{-(VAOD/\sin\theta)}$$

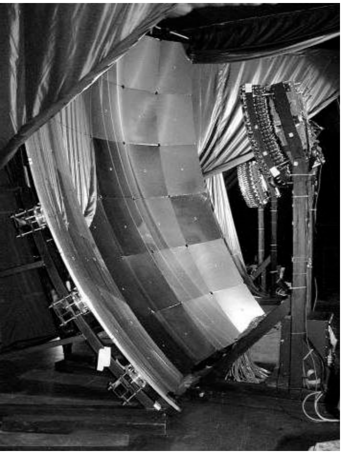
$$\mathrm{N}\gamma_{\mathrm{OBS}} = \mathrm{N}\gamma_{\mathrm{L}} \mathrm{T}_{\mathrm{M1}} \mathrm{T}_{\mathrm{A1}} (\mathrm{S}_{\mathrm{M}} + \mathrm{S}_{\mathrm{A}}) \mathrm{T}_{\mathrm{M2}} \mathrm{T}_{\mathrm{A2}}$$

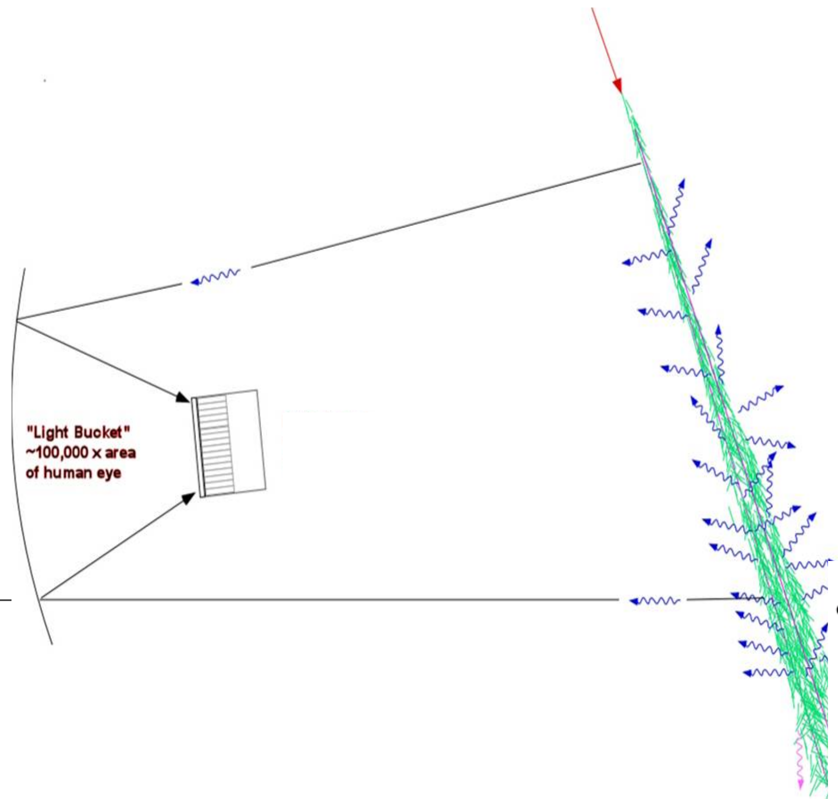
$$\mathrm{N}\gamma_{\mathrm{MOL}} = \mathrm{N}\gamma_{\mathrm{L}} \mathrm{T}_{\mathrm{M1}} \mathrm{S}_{\mathrm{M}} \mathrm{T}_{\mathrm{M2}}$$

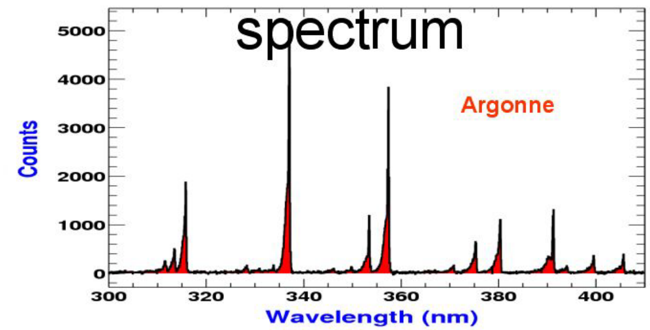
Then for $S_A << S_M$

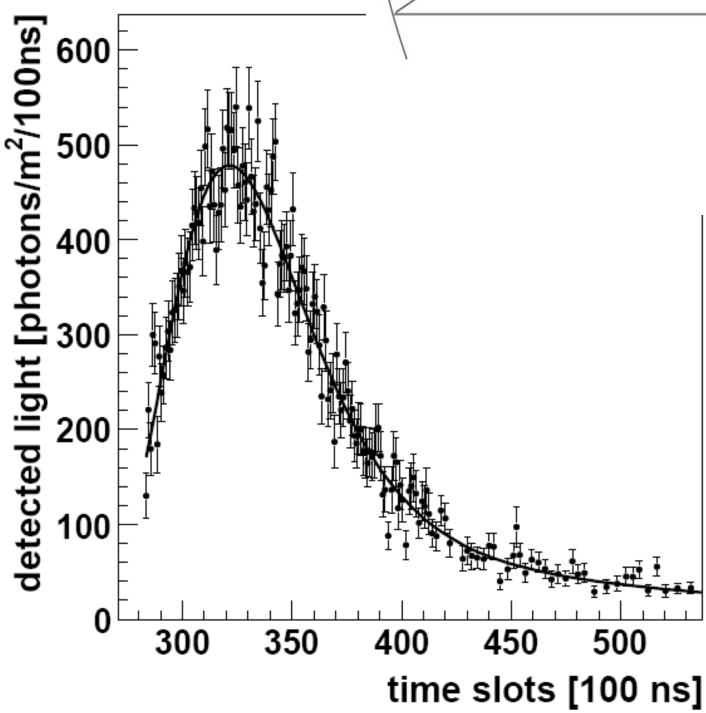
$$\boxed{\mathrm{VAOD} = \frac{-1}{1/\sin\theta_1 + 1/\sin\theta_2} \ln\left(\frac{\mathrm{N}\gamma_{\mathrm{OBS}}}{\mathrm{N}\gamma_{\mathrm{MOL}}}\right)}$$

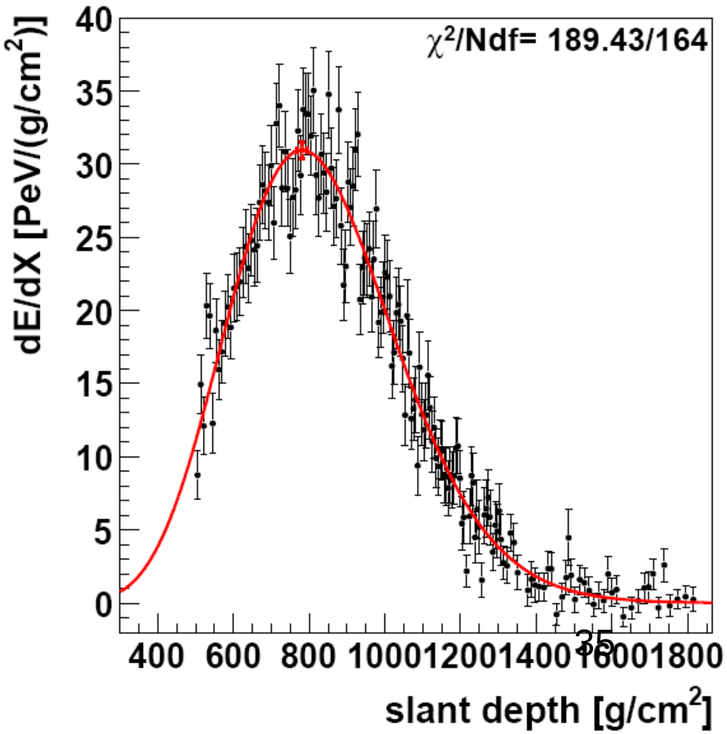
Role of the atmosphere in the Fluorescence Technique





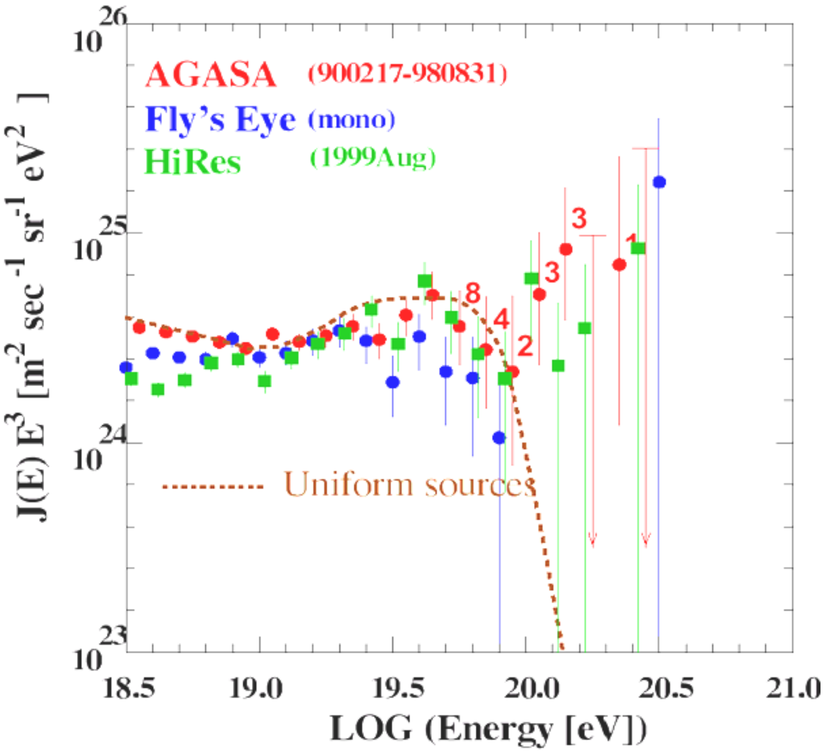




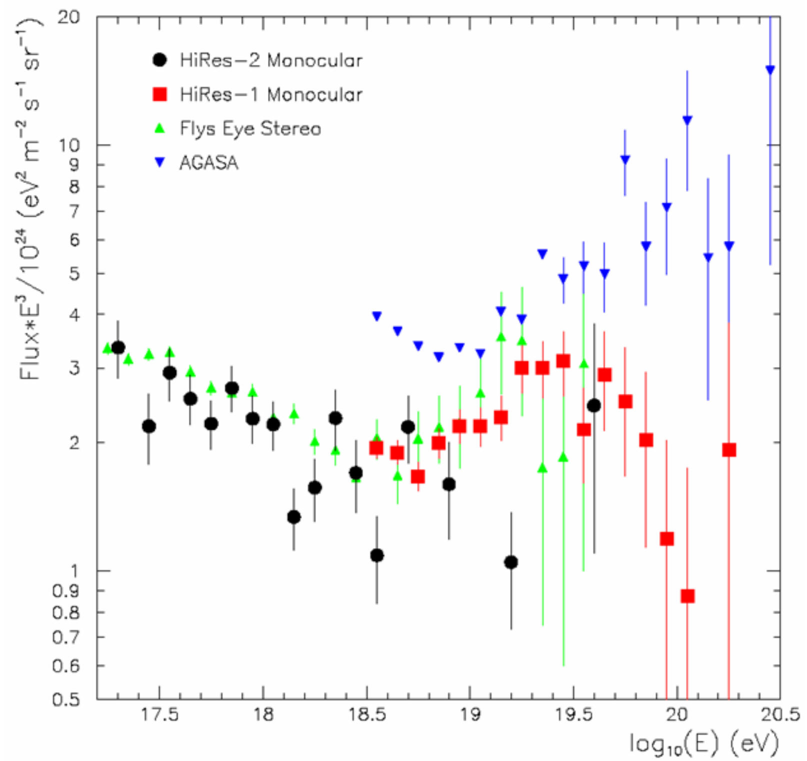


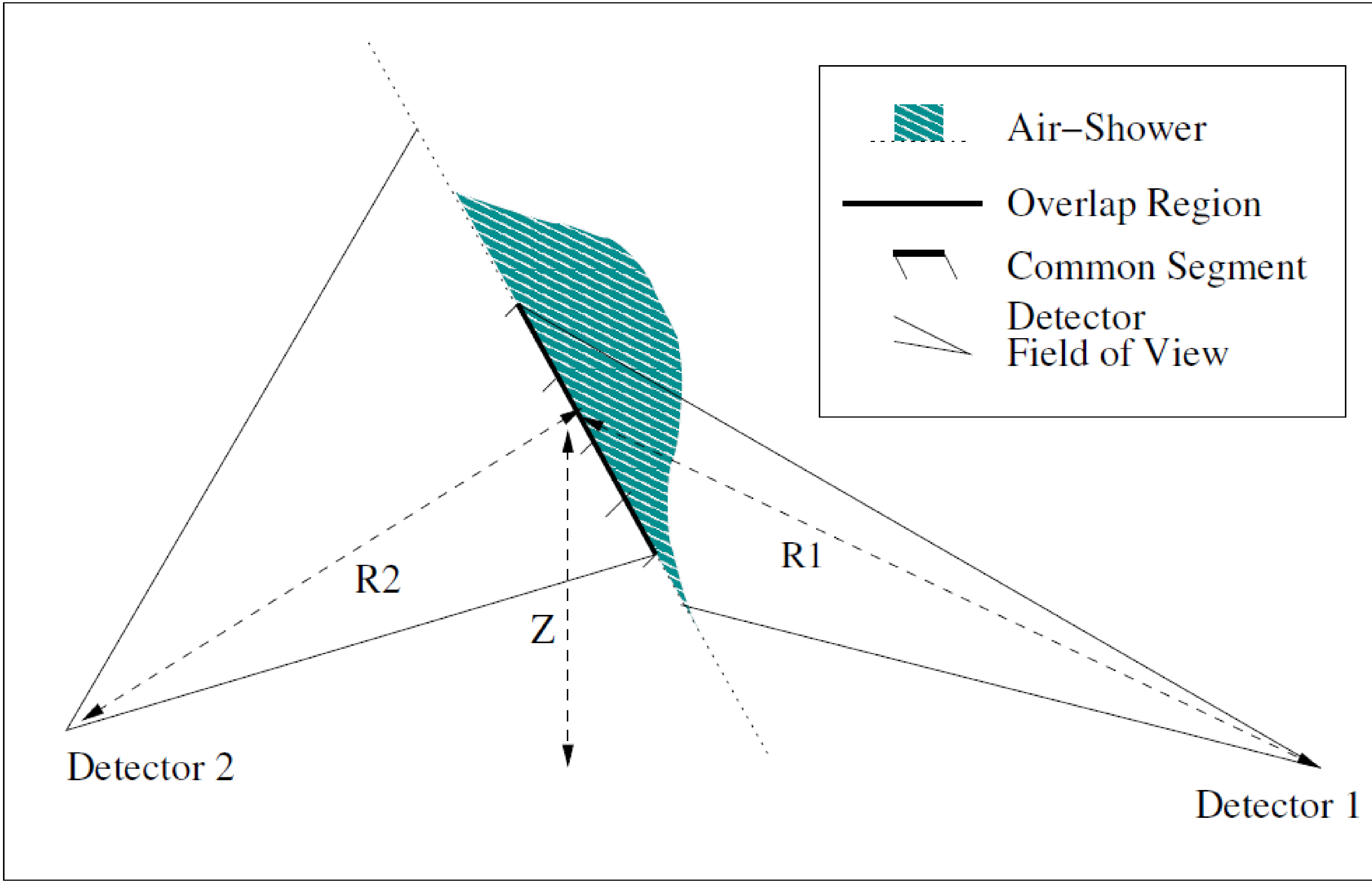
Why the Atmosphere Matters

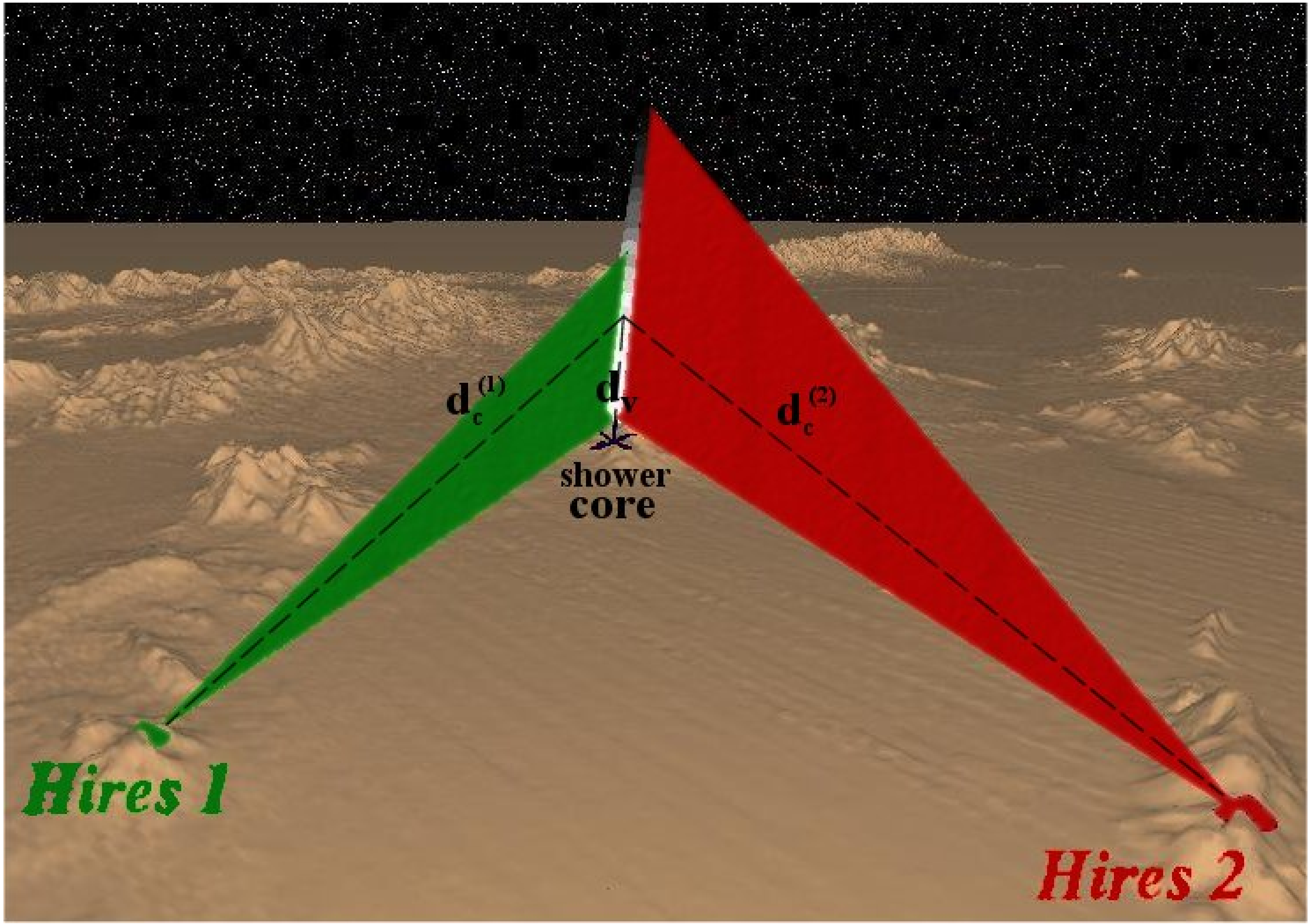
1999 **(Desert Aerosol Model)**



2001 **(2 x statistics and** **<u>Measured</u> Atmosphere)**




Air–Shower
Overlap Region
Common Segment
Detector
Field of View
R2
R1
Z
Detector 2
Detector 1

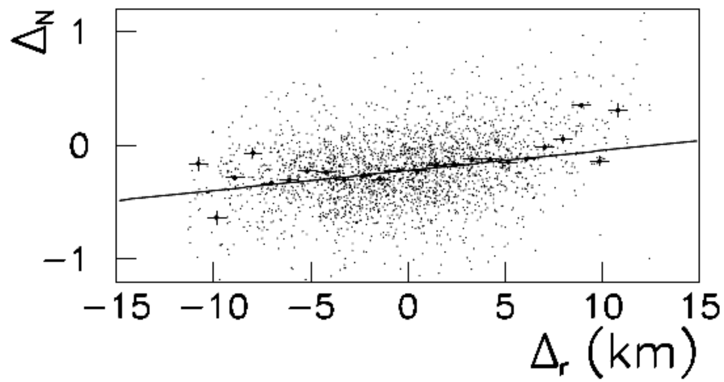


$d_c^{(1)}$
d_v
$d_c^{(2)}$
shower
core
Hires 1
Hires 2

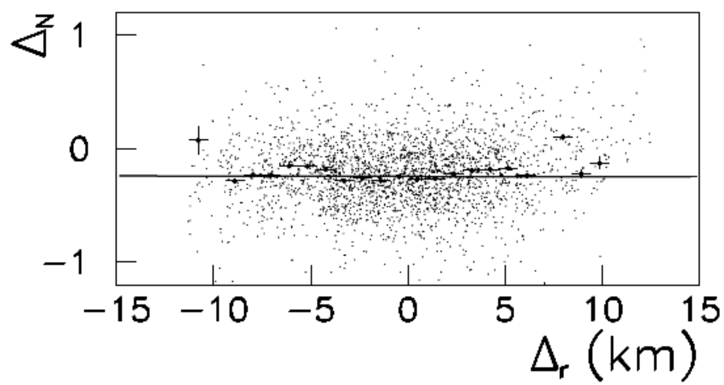
The "Goldilocks" Plot

Plot Δ_N vs Δ_R using Data and different corrections

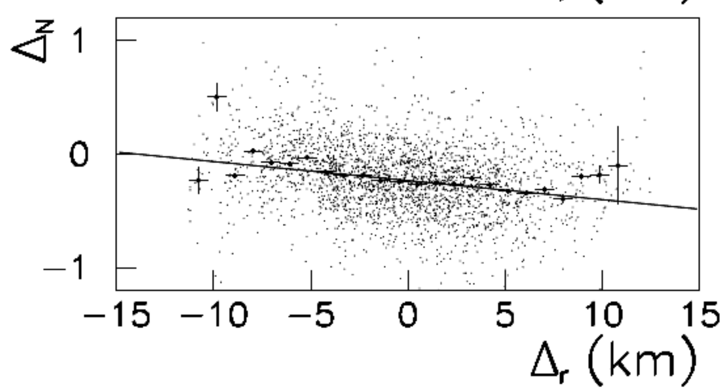
τ_A(model)=0.001
Slope=0.0176
±0.0027



τ_A(model)=0.040
Slope=−0.0004
±0.0039



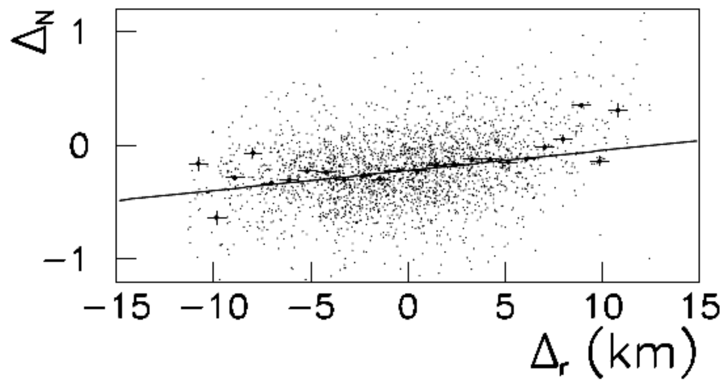
τ_A(model)=0.100
Slope=−0.0168
±0.0023



The “Goldilocks” Plot

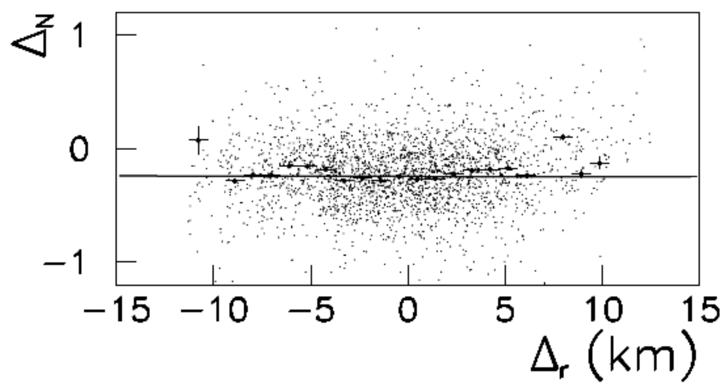
Plot Δ_N vs $\Delta_{\mathbf{R}}$ using <u>Data</u> and different corrections

τ_A(model)=0.001
Slope=0.0176
±0.0027



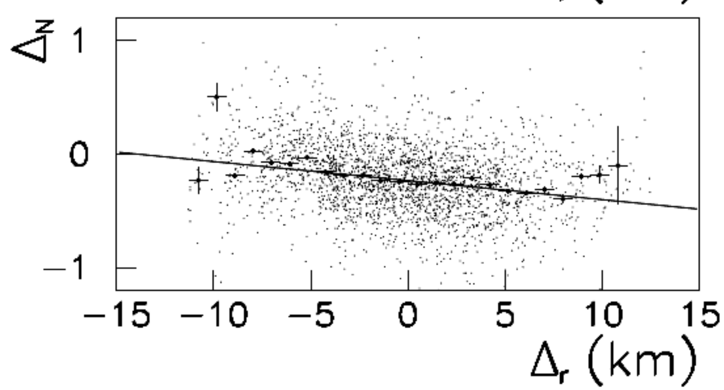
Too Clear

τ_A(model)=0.040
Slope=−0.0004
±0.0039



“Just Right”

τ_A(model)=0.100
Slope=−0.0168
±0.0023



Too Hazy

Conclusions

We used EeV cosmic rays to measure the atmosphere.

1200 air showers over 4 years.

$$\tau_A \text{ of } (0.042 \pm 0.006(stat) \pm 0.014(sys))$$

Added confidence we were not making a large mistake in the atmospheric corrections for the HiRes experiment (1999-2004)

Is this an application of EeV cosmic rays??? Yes

works at night, global, through out troposphere

Is it a <u>practical</u> application?

seems unlikely

Astroparticle Physics 25 (2006) 93-97

A Measurement of Time-Averaged Aerosol Optical Depth using Air-Showers Observed in Stereo by HiRes

R.U. Abbasi,[1] T. Abu-Zayyad,[1] J.F. Amann,[2] G. Archbold,[1] R. Atkins,[1] K. Belov,[1] J.W. Belz,[3] S. BenZvi,[5] D.R. Bergman,[6] J.H. Boyer,[4] C.T. Cannon,[1] Z. Cao,[1] B.M. Connolly,[5] Y. Fedorova,[1] C.B. Finley,[5] W.F. Hanlon,[1] C.M. Hoffman,[2] M.H. Holzscheiter,[2] G.A. Hughes,[6] P. Hüntemeyer,[1] C.C.H. Jui,[1] M.A. Kirn,[3] B.C. Knapp,[4] E.C. Loh,[1] N. Manago,[7] E.J. Mannel,[4] K. Martens,[1] J.A.J. Matthews,[8] J.N. Matthews,[1] A. O'Neill,[5] K. Reil,[1] M.D. Roberts,[8] S.R. Schnetzer,[6] M. Seman,[4] G. Sinnis,[2] J.D. Smith,[1] P. Sokolsky,[1] C. Song,[5] R.W. Springer,[1] B.T. Stokes,[1] S.B. Thomas,[1] G.B. Thomson,[6] D. Tupa,[2] S. Westerhoff,[5] L.R. Wiencke,[1] A. Zech[6]
(The High Resolution Fly's Eye Collaboration)
Corresponding author email: ~~wiencke@cosmic.utah.edu~~
lwiencke@mines.edu

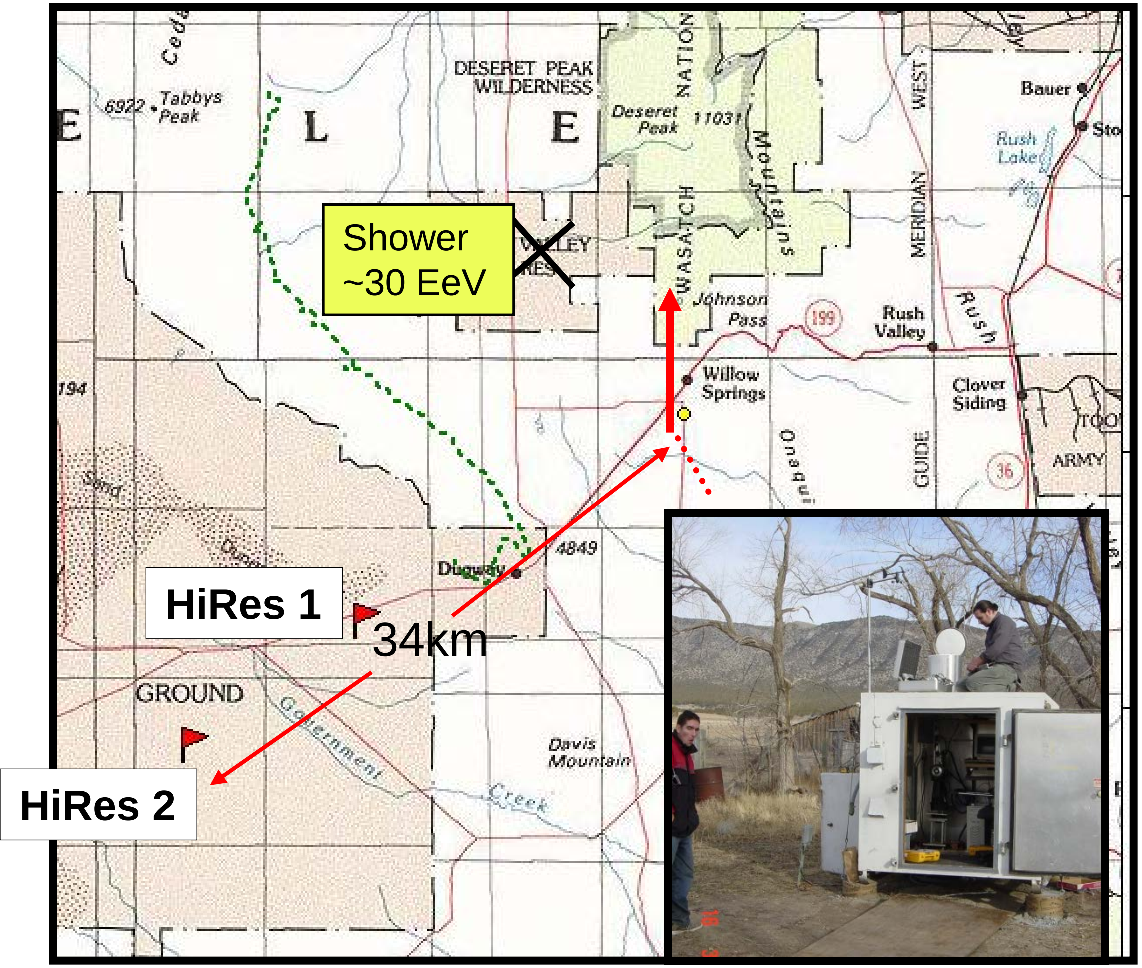
January 4, 2006

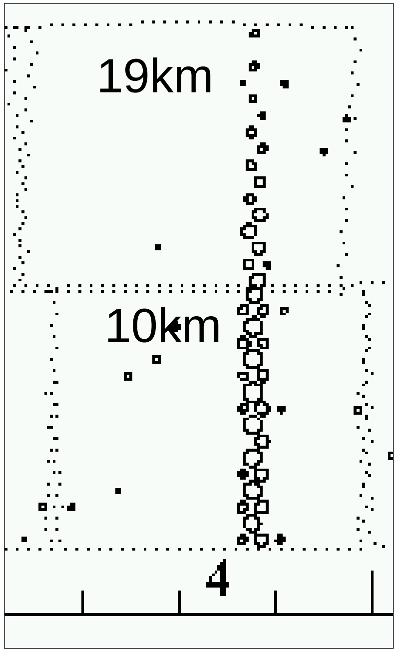
ABSTRACT

Air fluorescence measurements of cosmic ray energy must be corrected for attenuation of the atmosphere. In this paper we show that the air-showers themselves can yield a measurement of the aerosol attenuation in terms of optical depth, time-averaged over extended periods. Although the technique lacks statistical power to make the critical hourly measurements that only specialized active instruments can achieve, we note the technique does not depend on absolute calibration of the detector hardware, and requires no additional equipment beyond the fluorescence detectors that observe the air showers. This paper describes the technique, and presents results based on analysis of 1258 air-showers observed in stereo by the High Resolution Fly's Eye over a four year span.

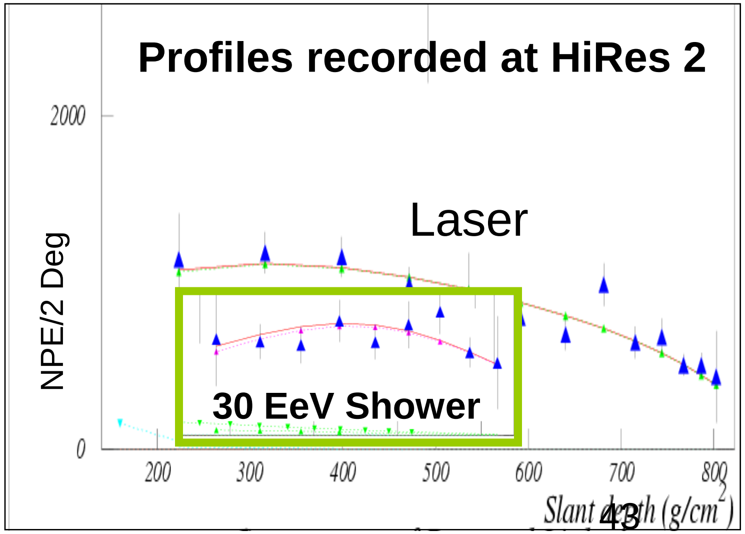
Subject headings: HiRes, extensive air-showers, atmosphere, aerosols, aerosol optical depth

Installed a laser 34 km from HiRes2 Detector.
Equivalent light production to ~20-100 EeV shower
"GZK Test Beam"





Laser recorded at HiRes 2



PRL 100, 101101 (2008) PHYSICAL REVIEW LETTERS week ending 14 MARCH 2008

First Observation of the Greisen-Zatsepin-Kuzmin Suppression

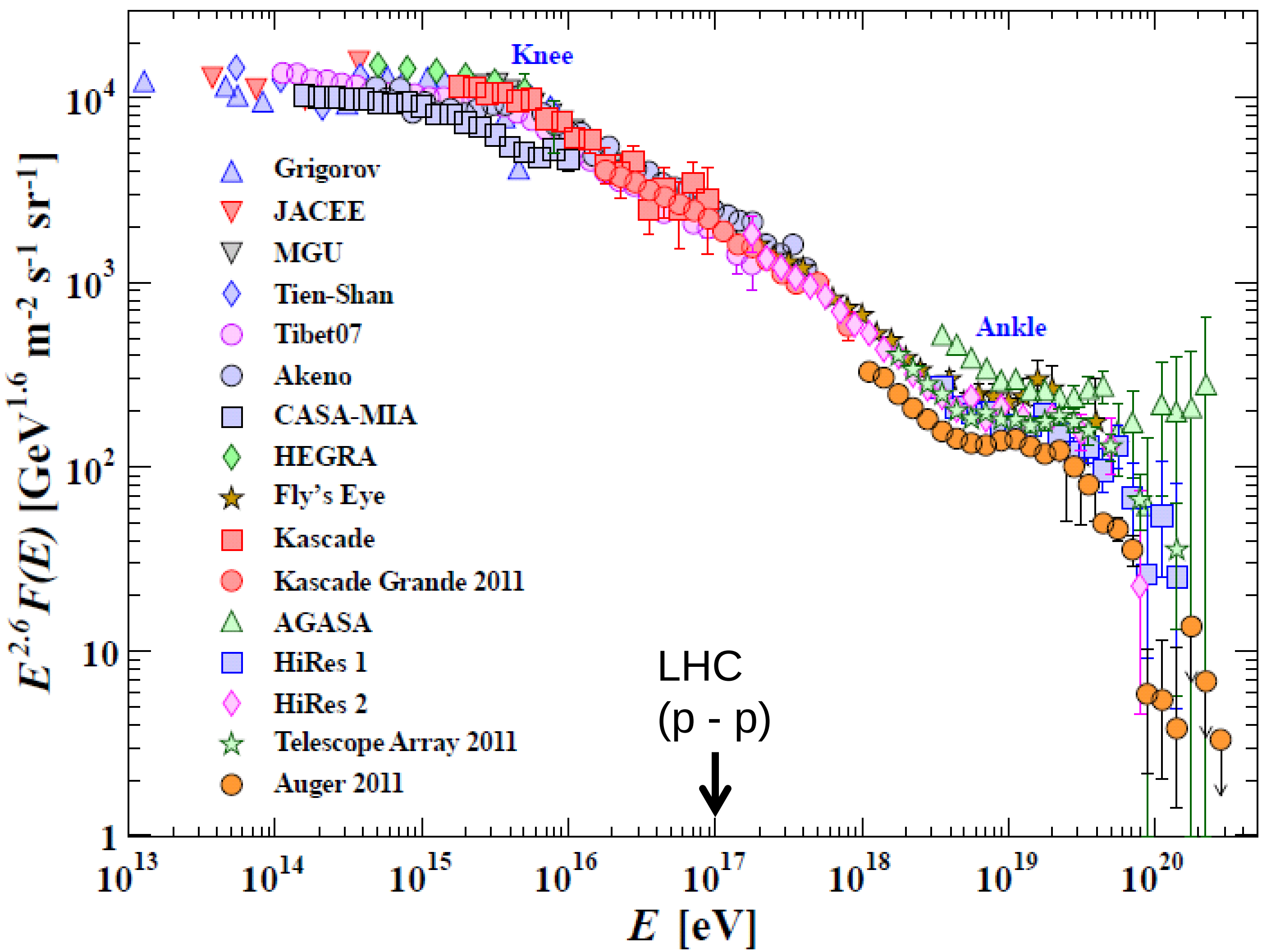
R. U. Abbasi,[1] T. Abu-Zayyad,[1] M. Allen,[1] J. F. Amman,[2] G. Archbold,[1] K. Belov,[1] J. W. Belz,[1] S. Y. Ben Zvi,[3] D. R. Bergman,[4,*] S. A. Blake,[1] O. A. Brusova,[1] G. W. Burt,[1] C. Cannon,[1] Z. Cao,[1] B. C. Connolly,[3] W. Deng,[1] Y. Fedorova,[1] C. B. Finley,[3] R. C. Gray,[1] W. F. Hanlon,[1] C. M. Hoffman,[2] M. H. Holzscheiter,[2] G. Hughes,[4] P. Hüntemeyer,[1] B. F Jones,[1] C. C. H. Jui,[1] K. Kim,[1] M. A. Kirn,[5] E. C. Loh,[1] M. M. Maestas,[1] N. Manago,[6] L. J. Marek,[2] K. Martens,[1] J. A. J. Matthews,[7] J. N. Matthews,[1] S. A. Moore,[1] A. O'Neill,[3] C. A. Painter,[2] L. Perera,[4] K. Reil,[1] R. Riehle,[1] M. Roberts,[7] D. Rodriguez,[1] N. Sasaki,[6] S. R. Schnetzer,[4] L. M. Scott,[4] G. Sinnis,[2] J. D. Smith,[1] P. Sokolsky,[1] C. Song,[3] R. W. Springer,[1] B. T. Stokes,[1] S. B. Thomas,[1] J. R. Thomas,[1] G. B. Thomson,[4] D. Tupa,[2] S. Westerhoff,[3] L. R. Wiencke,[1] X. Zhang,[3] and A. Zech[4]

(High Resolution Fly's Eye Collaboration)

Phys Rev Lett. 2008 Aug 8;101(6):061101. Epub 2008 Aug 4.

Observation of the suppression of the flux of cosmic rays above 4 x 10 (19) eV.

P. Abreu et al. (The Pierre Auger Collaboration)

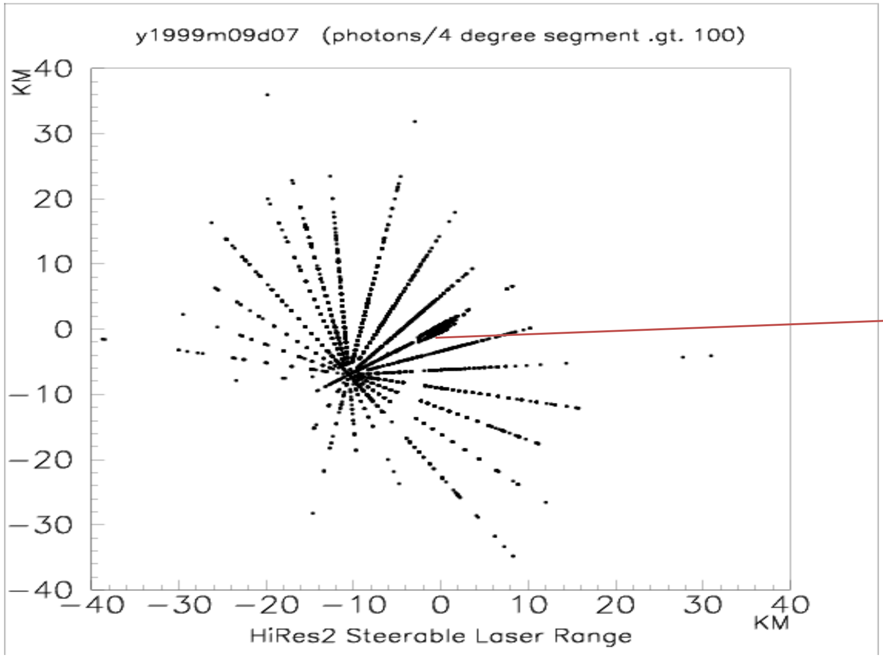


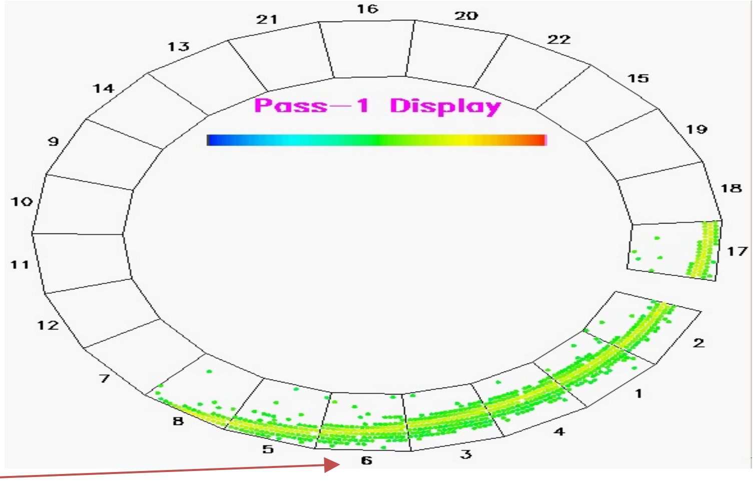
Knee
Ankle
Grigorov
JACEE
MGU
Tien-Shan
Tibet07
Akeno
CASA-MIA
HEGRA
Fly's Eye
Kascade
Kascade Grande 2011
AGASA
HiRes 1
HiRes 2
Telescope Array 2011
Auger 2011
LHC
(p - p)
$E^{2.6}F(E)$ [GeV$^{1.6}$ m^{-2} s^{-1} sr^{-1}]
E [eV]
10^{13}
10^{14}
10^{15}
10^{16}
10^{17}
10^{18}
10^{19}
10^{20}
1
10
10^2
10^3
10^4

PDG 2011

Sample Laser Shot recorded at HiRes1

Pattern of laser shots





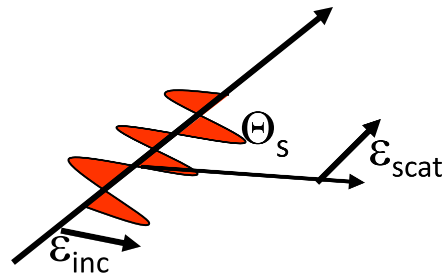
The pattern of light in the detector depends on the laser direction and atmospheric clarity.

Can we see molecular effects?

From Rayleigh Scattering theory

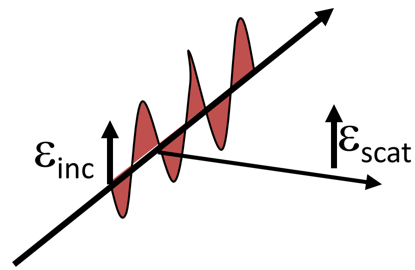
$$\frac{d\sigma}{d\Omega} \propto \left| \varepsilon_{inc} \bullet \varepsilon_{scat} \right|^2$$

Polarization II to Scattering Plane



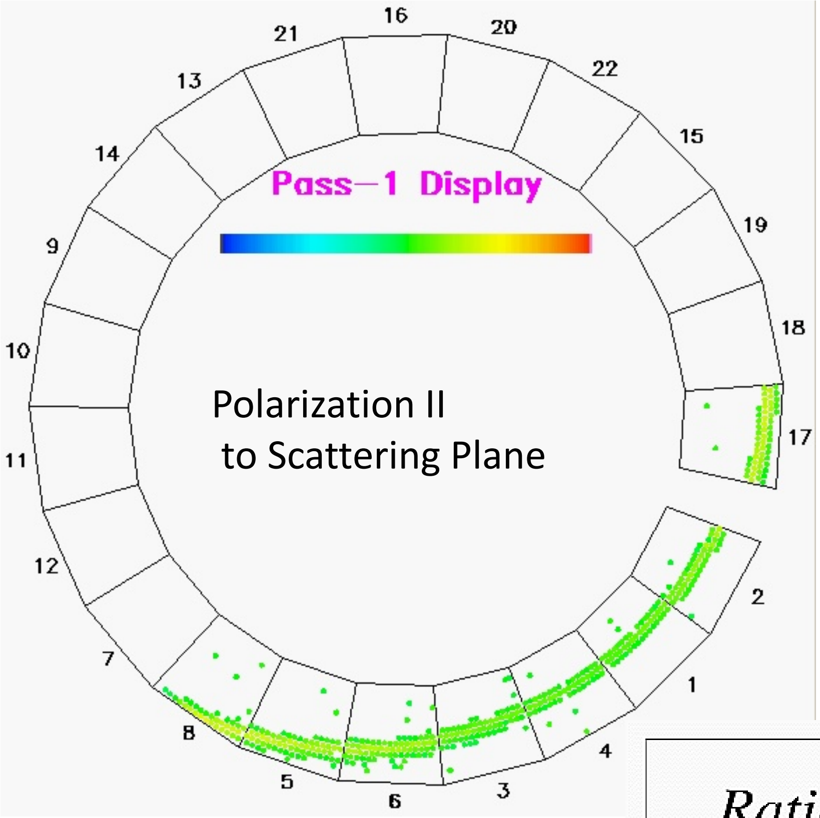
$$\frac{d\sigma}{d\Omega} \propto \cos^2 \Theta_s$$

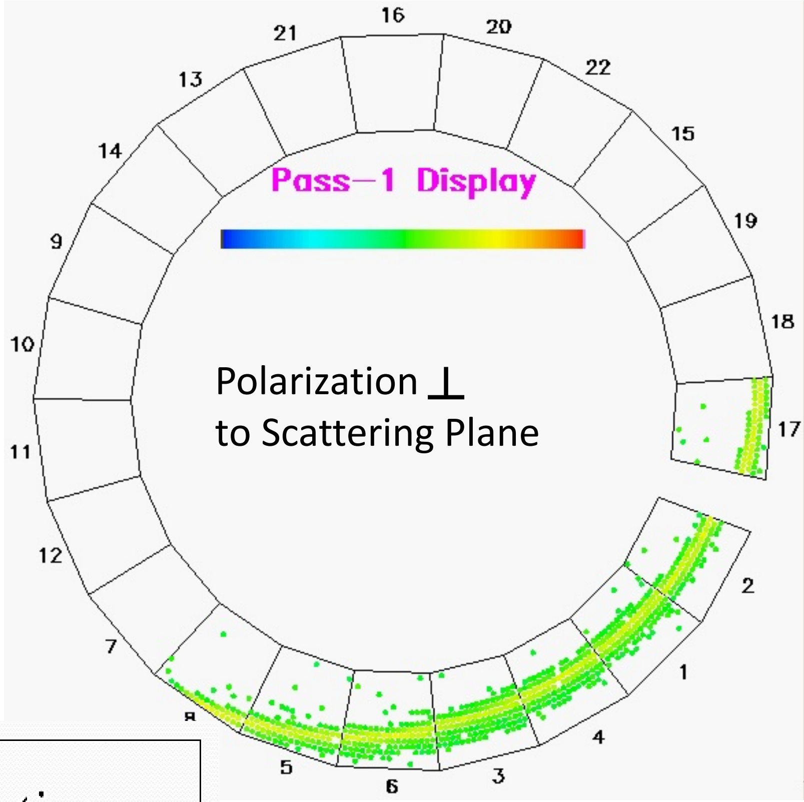
Polarization $\perp$ to Scattering Plane

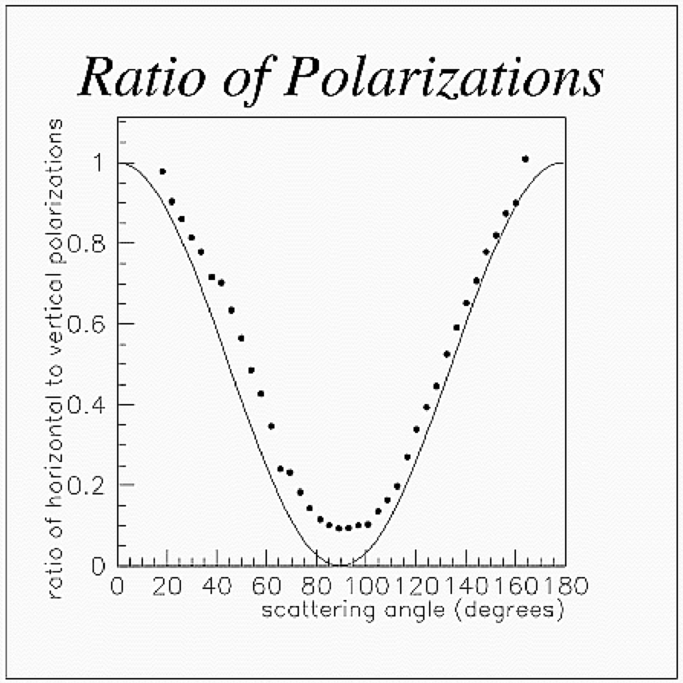


$$\frac{d\sigma}{d\Omega} \propto 1$$

Ratio should be ~ $\cos^2\Theta$

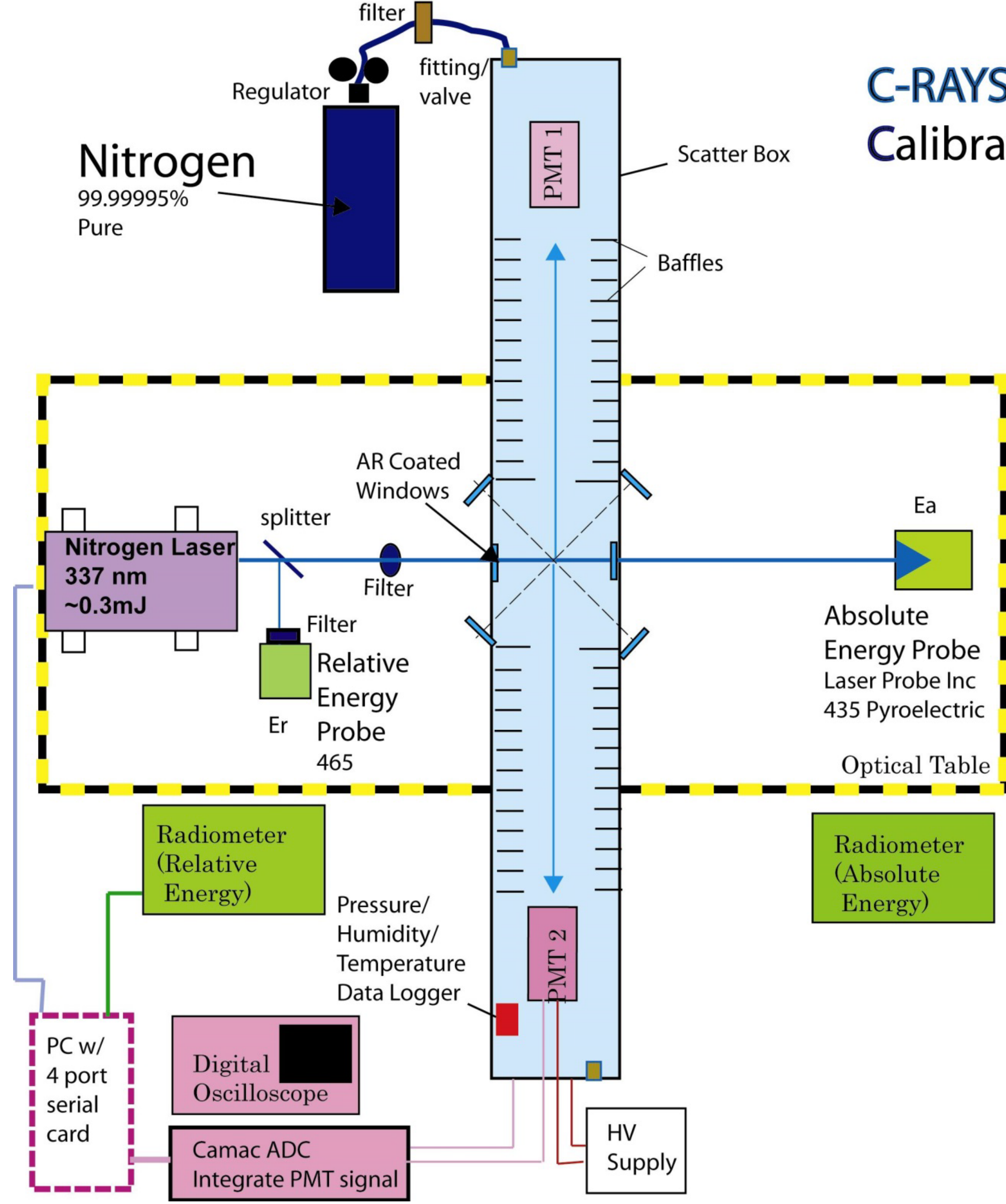

Pass–1 Display
Polarization II
to Scattering Plane
16
20
22
15
19
18
17
2
1
4
3
6
5
8
7
12
11
10
9
14
13
21


Pass–1 Display
Polarization ⊥
to Scattering Plane
16
20
22
15
19
18
17
2
1
4
3
6
5
7
12
11
10
9
14
13
21


Ratio of Polarizations
ratio of horizontal to vertical polarizations
1
0.8
0.6
0.4
0.2
0
0 20 40 60 80 100 120 140 160 180
scattering angle (degrees)

C-RAYS Experiment 6/01/2002
Calibration by RAYleigh Scattering

M. Fukushima
N. Sakurai
L. Wiencke



3x10-4J
1J=1.6x10+19eV
337nm= 3.6eV

1.3x10+15 photons

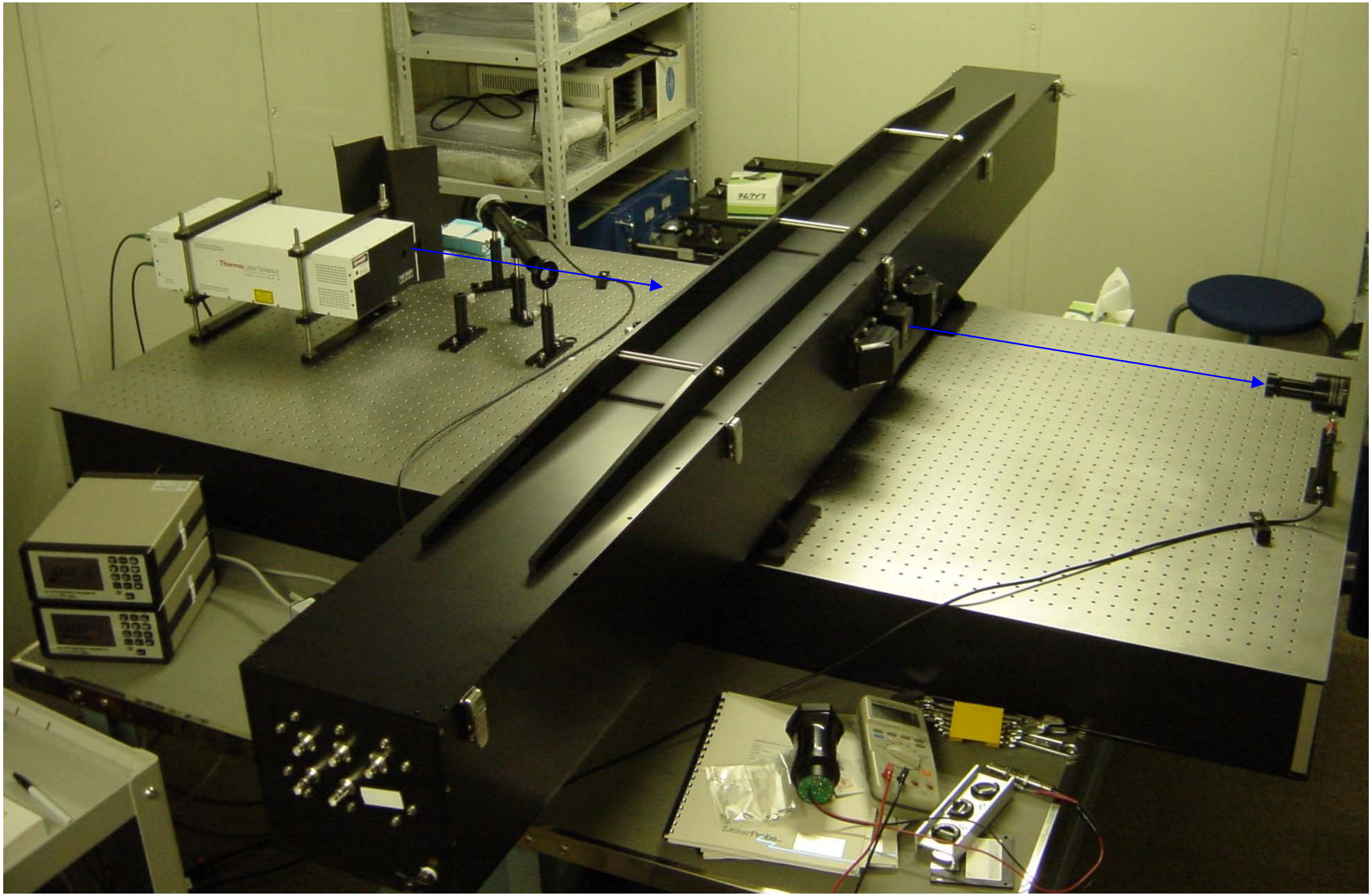
dl/L=10cm/10km=10-5

aperture/4πM^2
7.9x10-6 per cm^2 of aperture

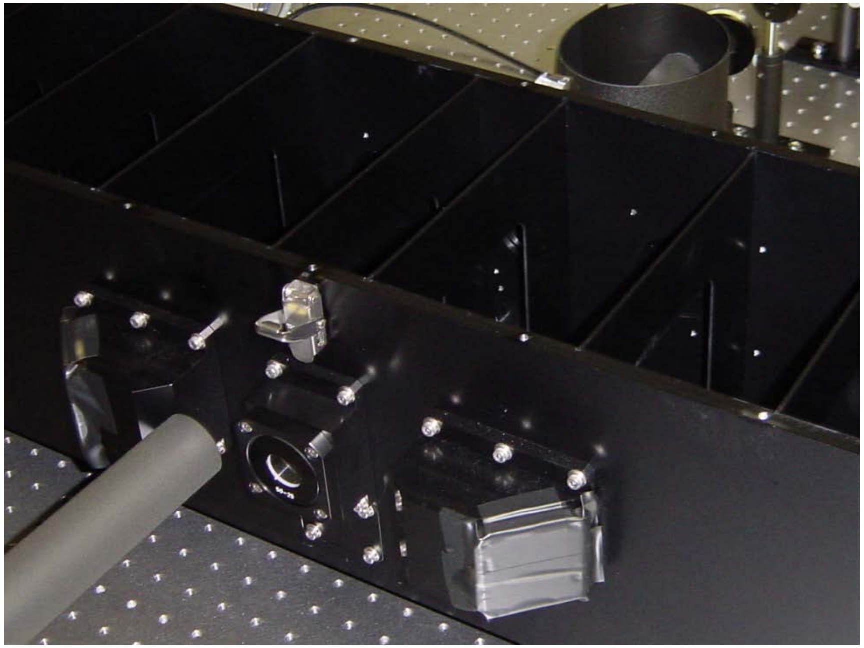
fraction of beam scattered
into 1cm^2 is 8x10^-11

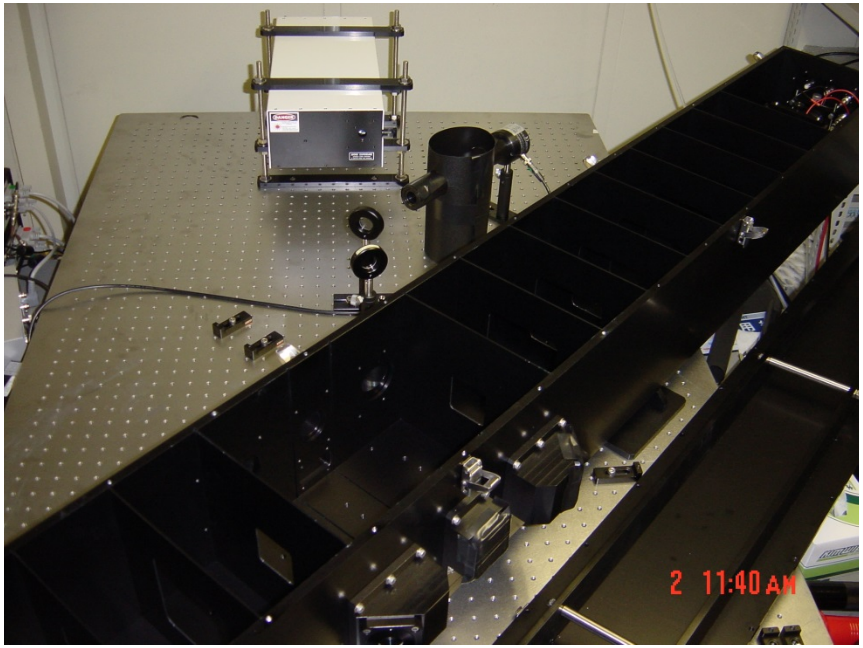
for 300uJ get
10^+5 photons/cm^2

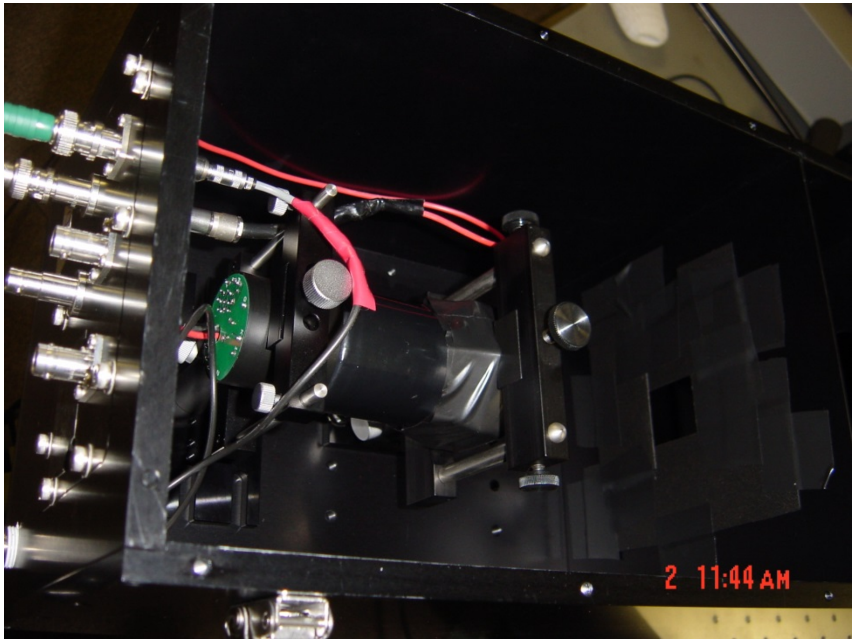
C-RAYS Experiment at ICRR

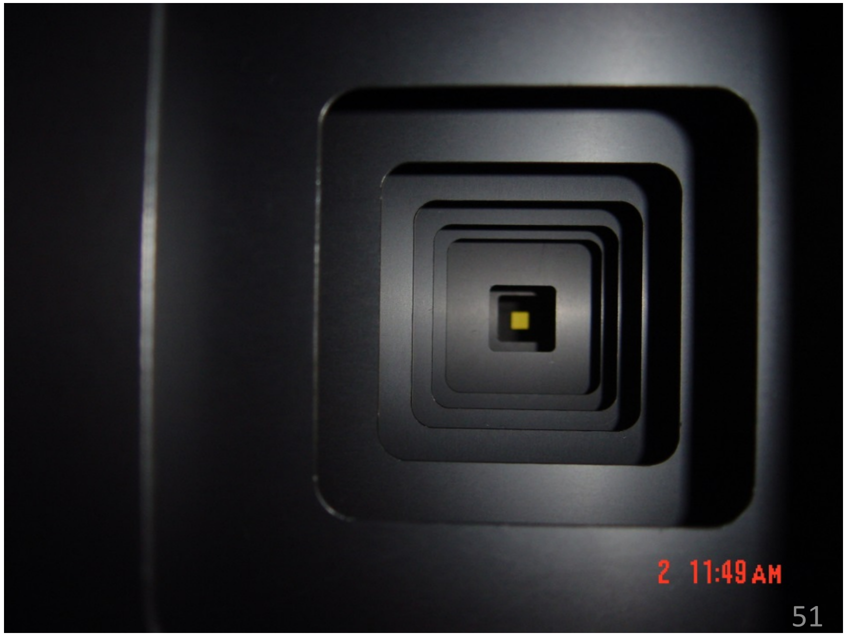


C-RAYS Experiment at ICRR




2 11:40 AM

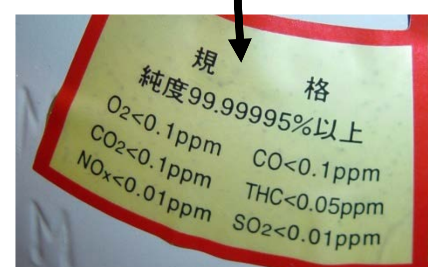

2 11:44 AM


2 11:49 AM

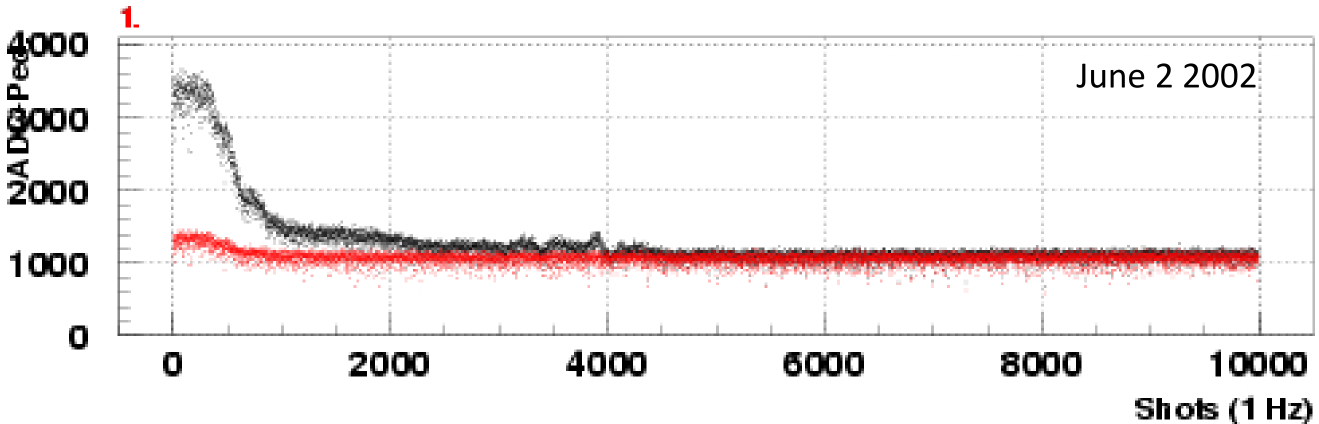
Change the Atmosphere

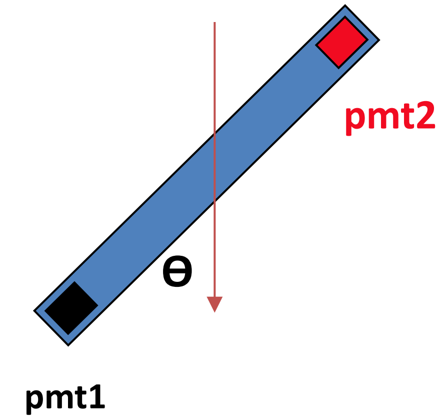
Kashiwa Air (May 30-June 2)

Pure Nitrogen

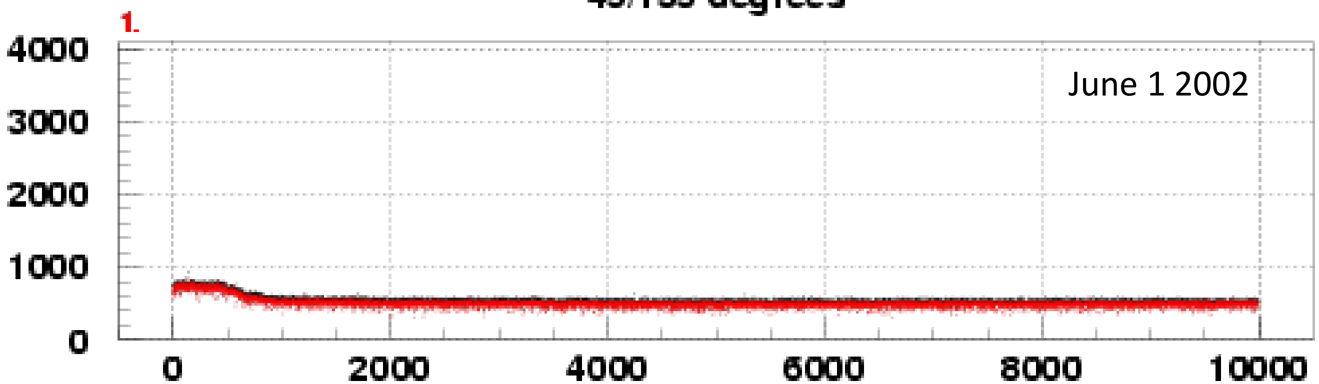


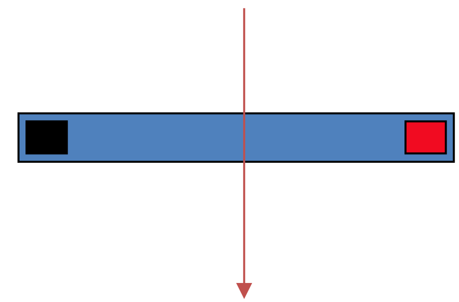
Scattering (Kashiwa Air replaced by Pure Nitrogen)



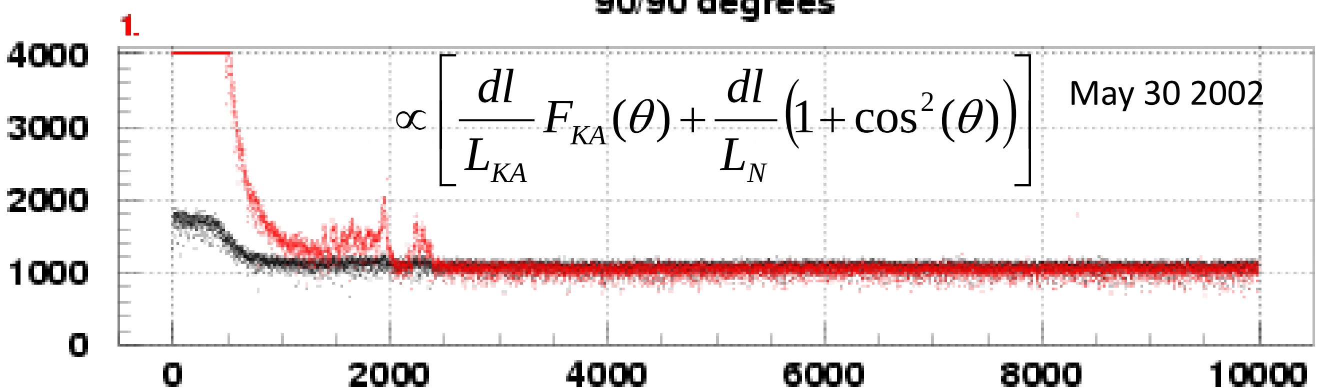


45/135 degrees

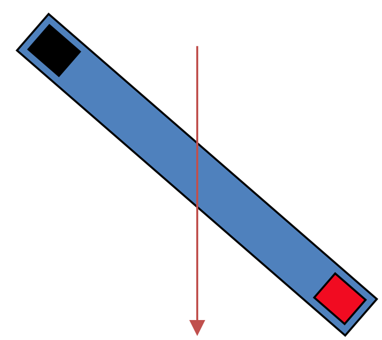




90/90 degrees



$$\propto \left[\frac{dl}{L_{KA}} F_{KA}(\theta) + \frac{dl}{L_N} \left(1 + \cos^2(\theta)\right) \right]$$



135/45 degrees

Calibration of Photomultiplier Tubes for the Fluorescence Detector of Telescope Array Experiment using a Rayleigh Scattered Laser Beam

Shingo Kawana[a,*], Nobuyuki Sakurai[b], Toshihiro Fujii[b],
Masaki Fukushima[c,d], Naoya Inoue[a], John N. Matthews[e], Shoichi Ogio[b],
Hiroyuki Sagawa[c], Akimichi Taketa[c,f], Masato Takita[c], Stan B. Thomas[e],
Hisao Tokuno[g,h], Yoshiki Tsunesada[g], Shigeharu Udo[i],
Lawrence R. Wiencke[j]

arXiv:1202.1934
[astro-ph.IM]

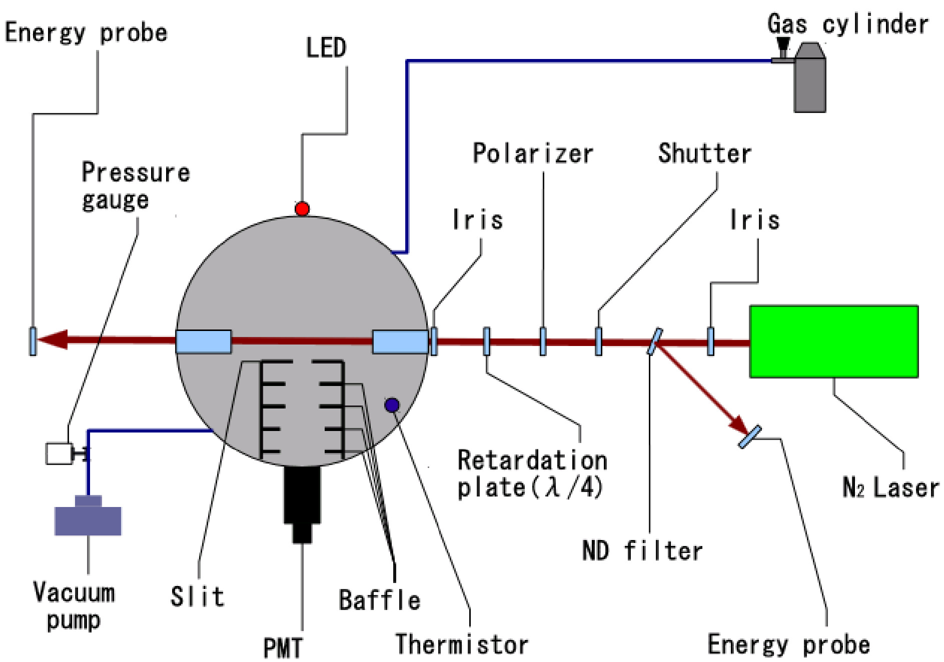


Table 1: Systematic uncertainties of the CRAYS calibration.

	Error
Cross-section (σ_R, $d\sigma_R/d\Omega$ and polarization)	2.8%
Molecular density (T and P)	1.3%
Measurement of laser energy	5.0%
Geometric aperture calculation	3.0%
Signal integration (Σ_{ADC})	2.0%
Background and noise subtraction (Σ_{ADC})	1.9%
Effect of geomagnetism	1.0%
Total (quadratic sum of above)	7.2%

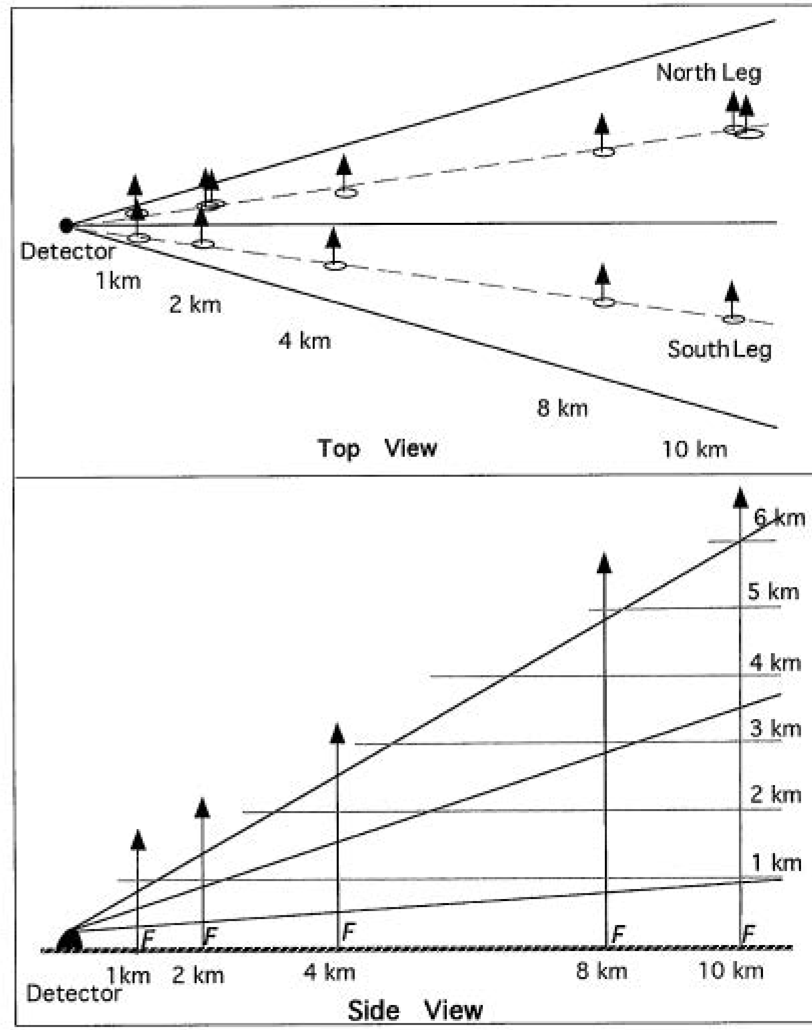


Fig. 10. Geometry of the radio-controlled flasher array. The solid lines in the top panel denote the field of view in azimuth of two HiRes mirrors.

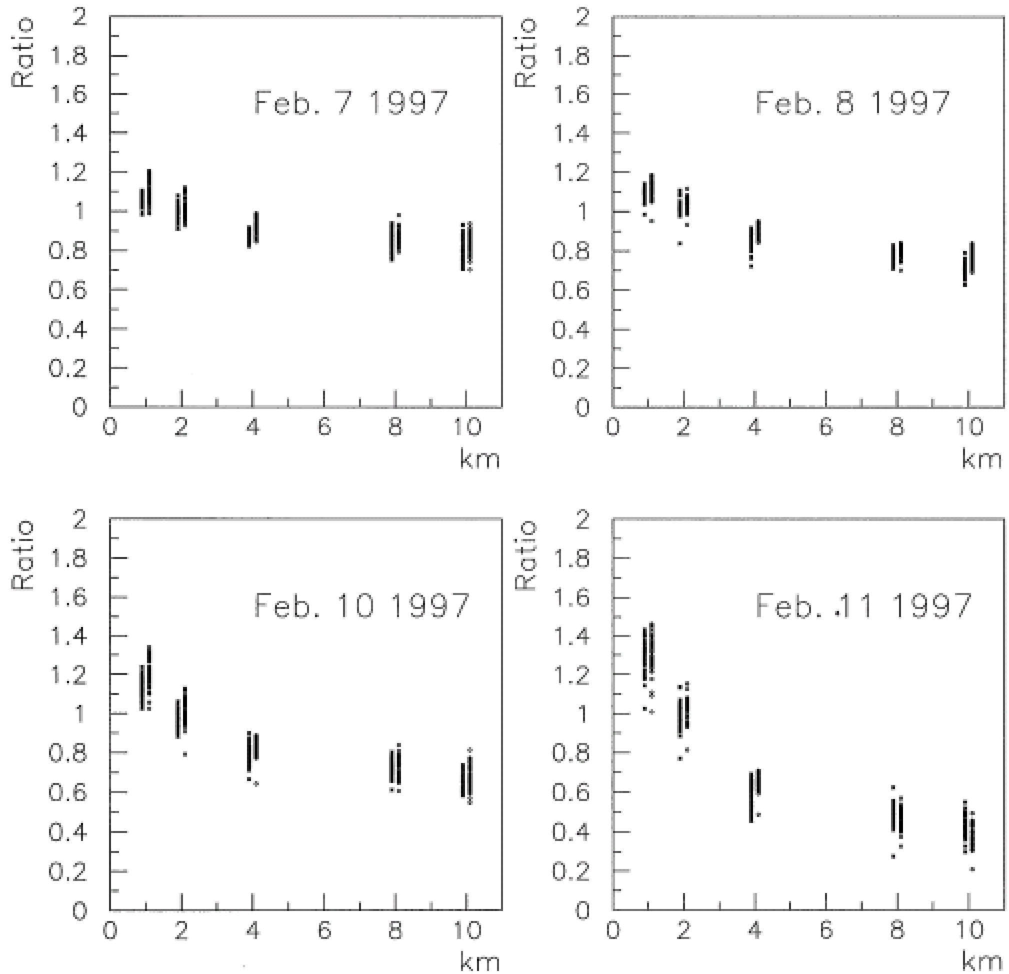
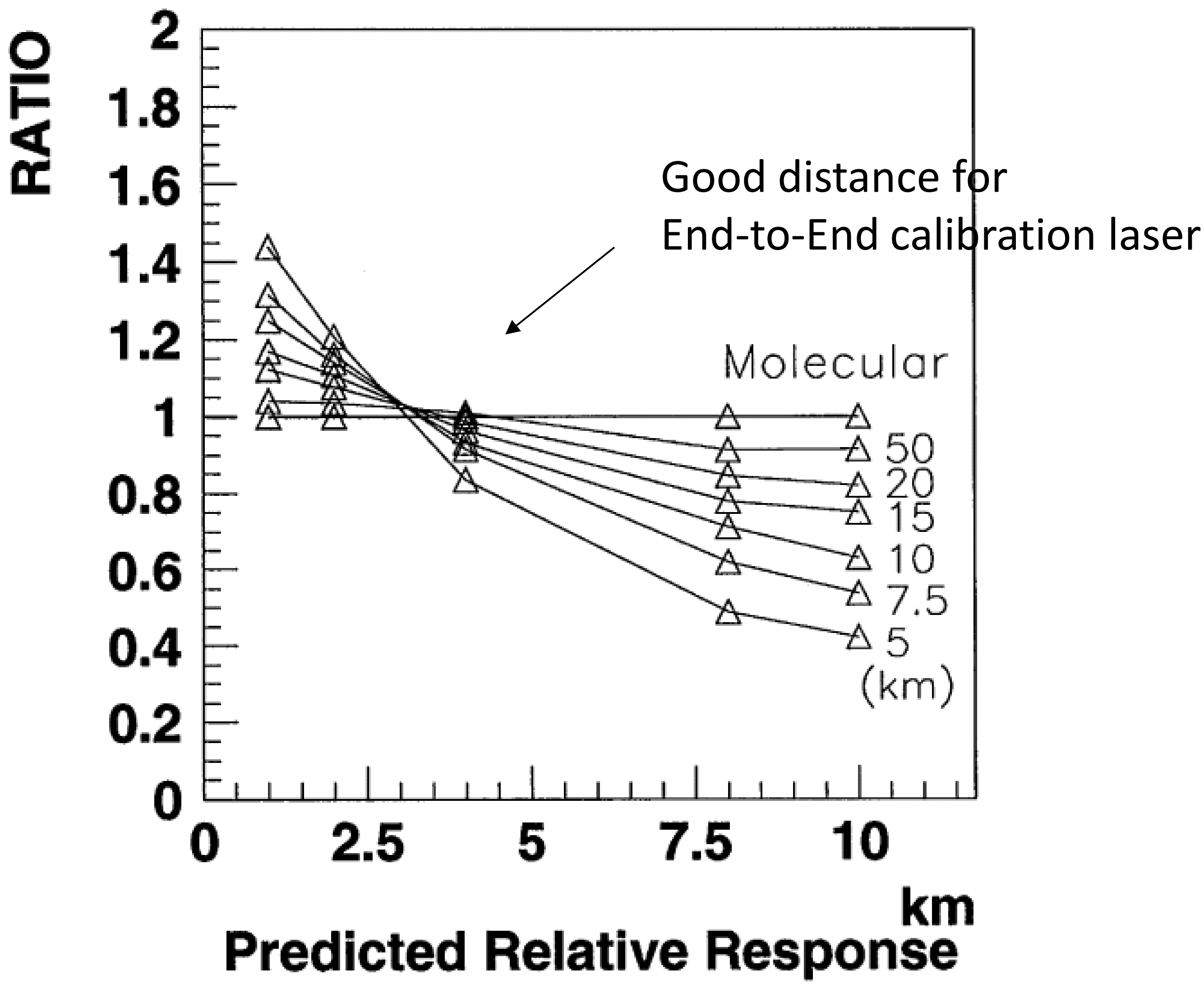


Fig. 12. HiRes detector measurements of 10 vertical flashers vs horizontal distance. These measurements are normalized to those for a relatively haze-free night. Adjacent bands of points correspond to two flashers at the same distance from the detector but separated by 16° in azimuth.

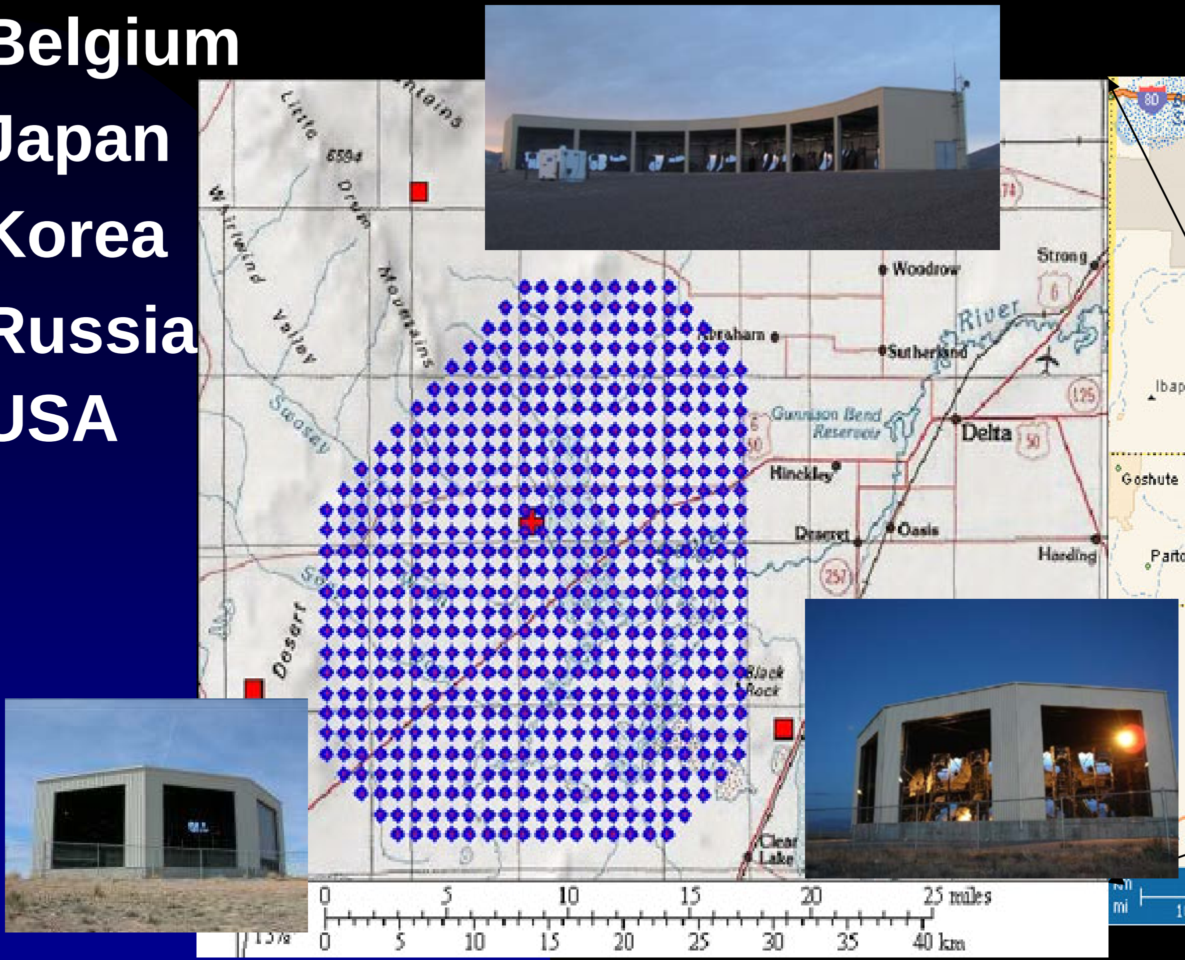


RATIO
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Good distance for
End-to-End calibration laser
Molecular
50
20
15
10
7.5
5
(km)
0
2.5
5
7.5
10
km
Predicted Relative Response

Telescope Array

Area: 680 km^2

Belgium
Japan
Korea
Russia
USA



3 FD stations overlooking an array of

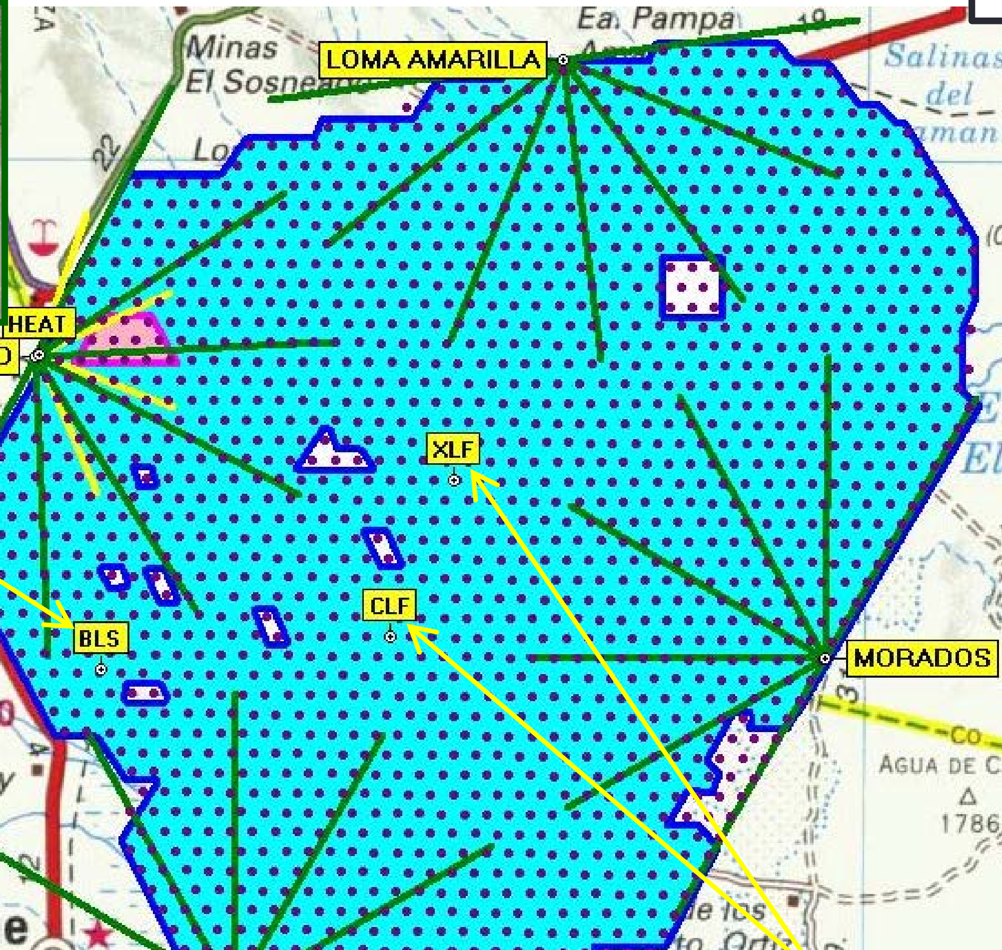
507 scintillator surface detectors (SD)

complete and operational as of ~1/2008.

Pierre Auger

4 Fluorescence Detectors
(24 telescopes total)

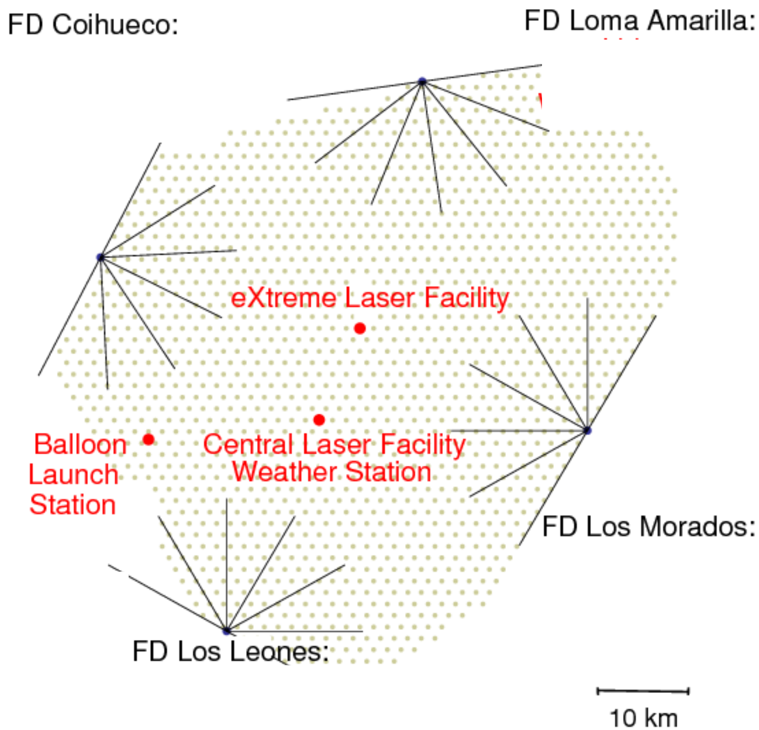
1600 surface detectors
Water-Cherenkov Tank
1.5 km spacing

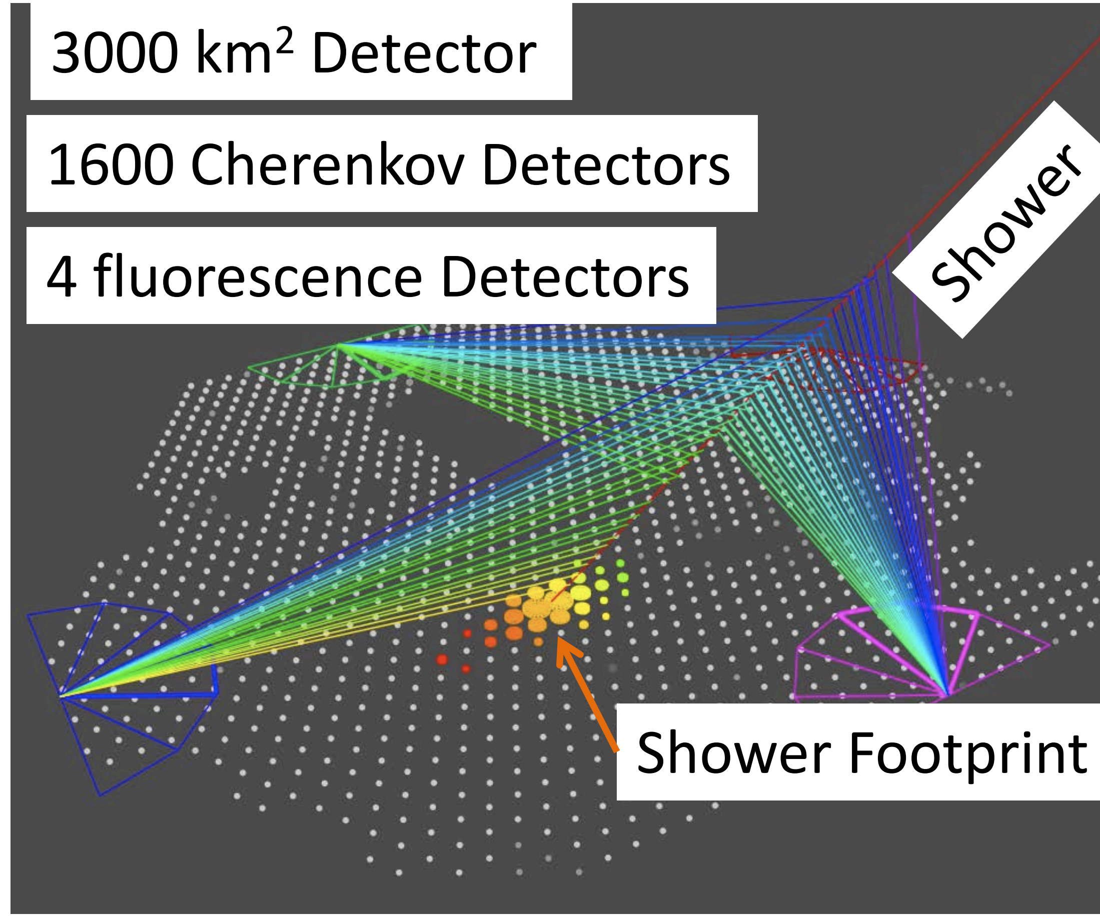


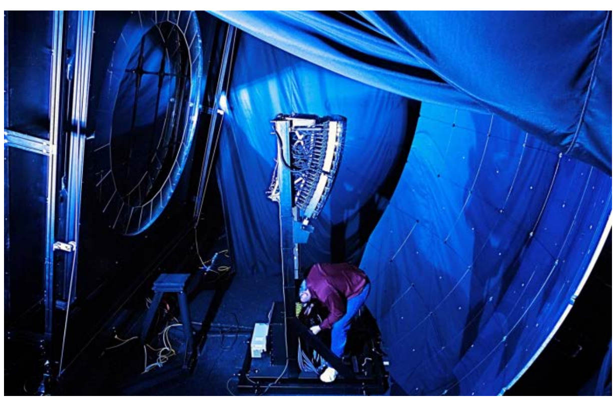
Balloon Station

4 Elastic LIDARs

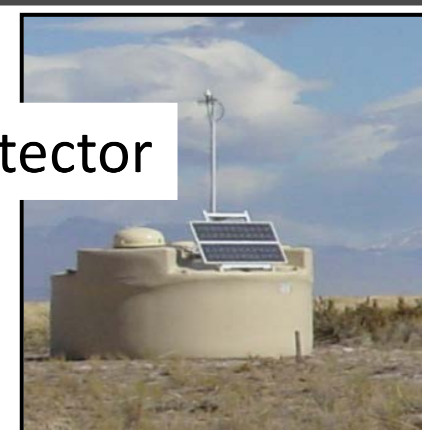
2 Laser Facilities
(100 EeV Optical Equivalent)





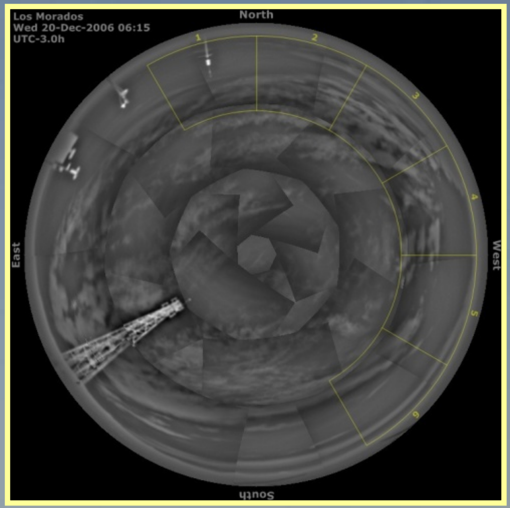


Fluorescence Detector



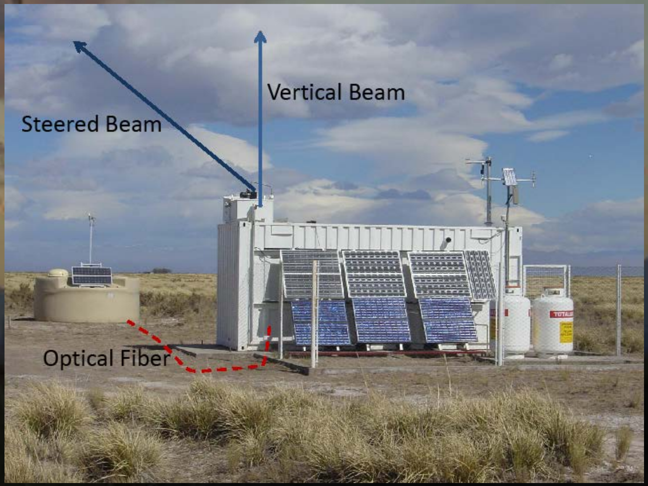
Cherenkov Detector

Clouds



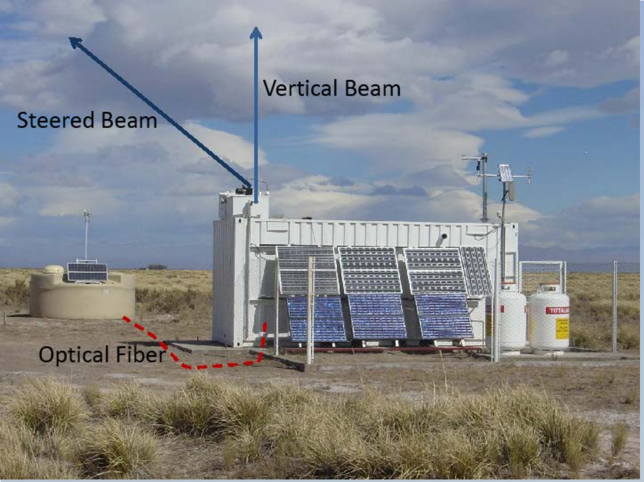
Cloud Camera (1/4)

LIDAR (1/4)



Central Laser Facility 1/2

Aerosols



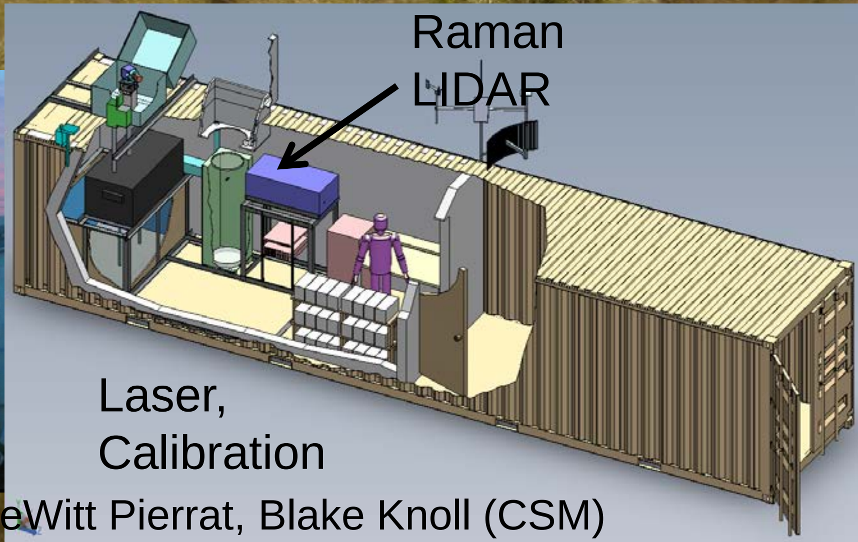
Central Laser Facility

LIDAR (1/4)

XLF

Phase Function Monitor

FRAM



Nev DeWitt Pierrat, Blake Knoll (CSM)

XLF (eXtreme Laser Facility)


2007 10 23

Some References

Techniques for measuring aerosol attenuation using the Central Laser Facility at the Pierre Auger Observatory Pierre Auger Collaboration *JINST* 8 P04009 (2013).

Atmospheric Super Test Beam for the Pierre Auger Observatory, L. Wiencke for the Pierre Auger Collaboration et al Proc 32nd ICRC(August, 2011).

The Rapid Atmospheric Monitoring System of the Pierre Auger Observatory, The Pierre Auger Collaboration, JINST 7 (2012) P09001

Description of Atmospheric Conditions at the Pierre Auger Observatory using the Global Data Assimilation System (GDAS) The Pierre Auger Collaboration, Astroparticle Physics, 35 (2012), 591-607

A study of the effect of molecular and aerosol conditions in the atmosphere on air fluorescence measurements at the Pierre Auger Observatory, The Pierre Auger Collaboration, Astroparticle Physics 33, 108 (2010).

The Fluorescence Detector of the Pierre Auger Observatory, The Pierre Auger Collaboration, NIMA, 620 p227 (2010).

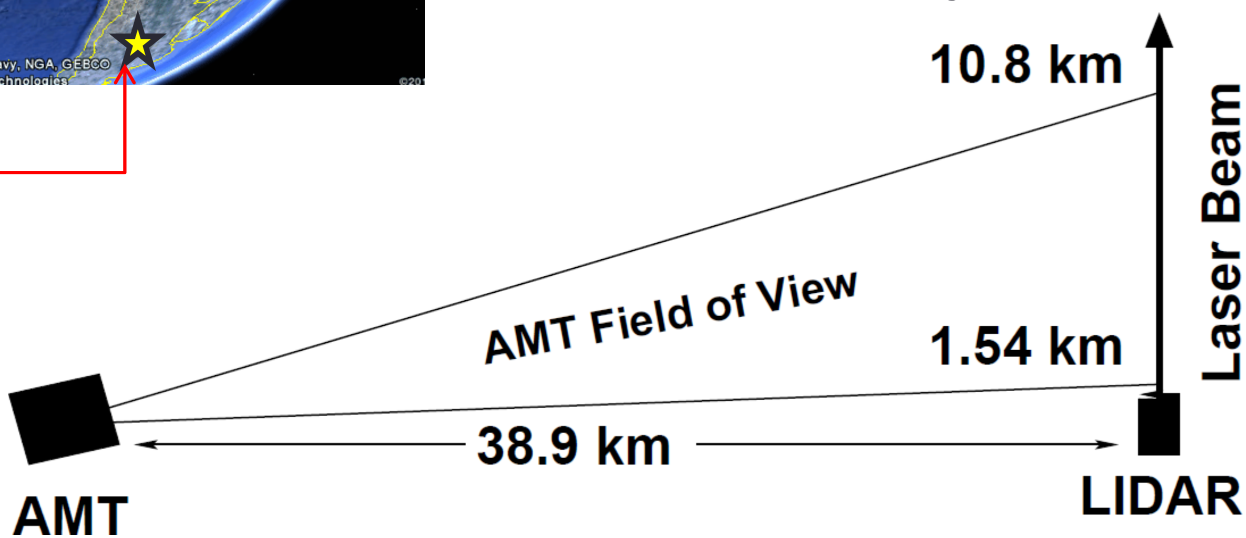
The Central Laser Facility at the Pierre Auger Observatory, B. Fick et al., JINST 1, p11003 (2006).

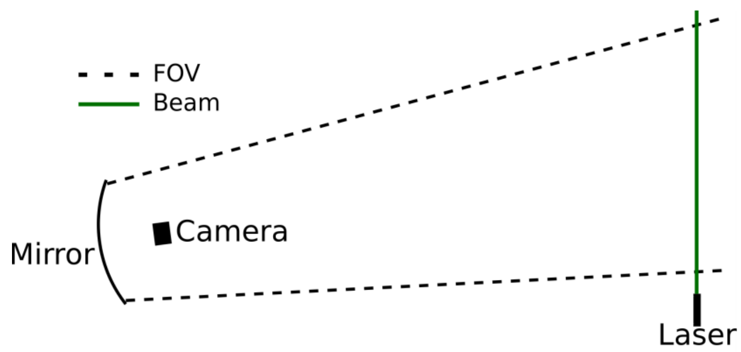
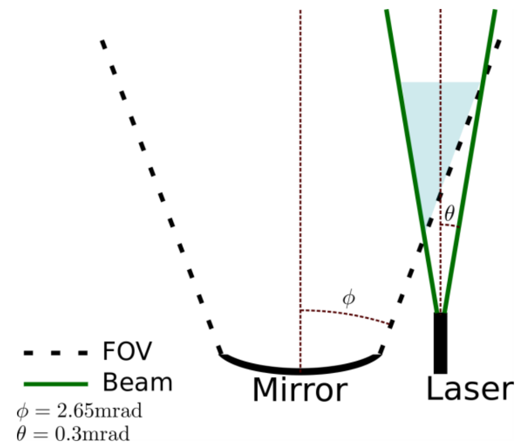
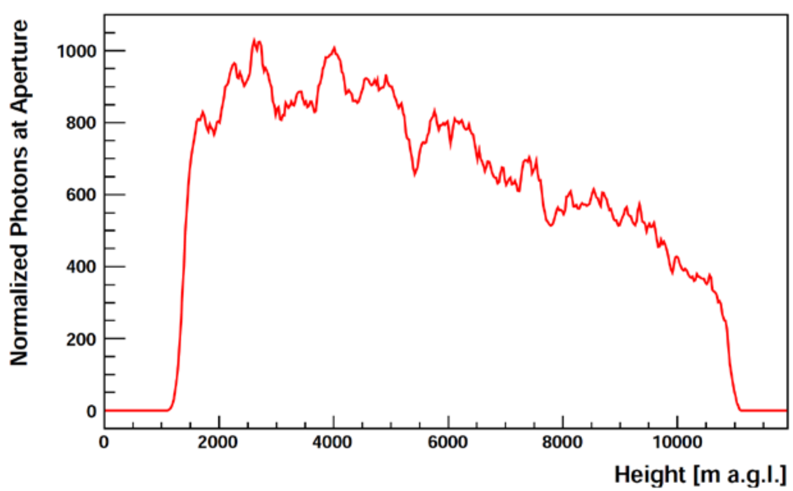
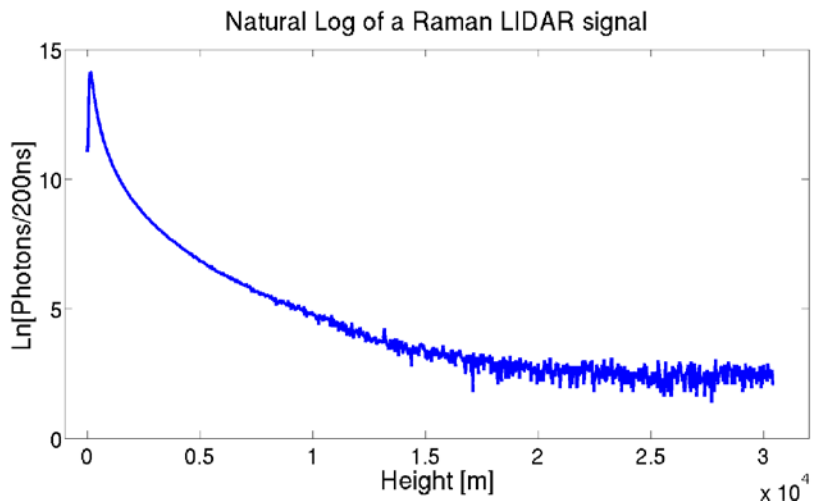
R&D Site

Pierre Auger

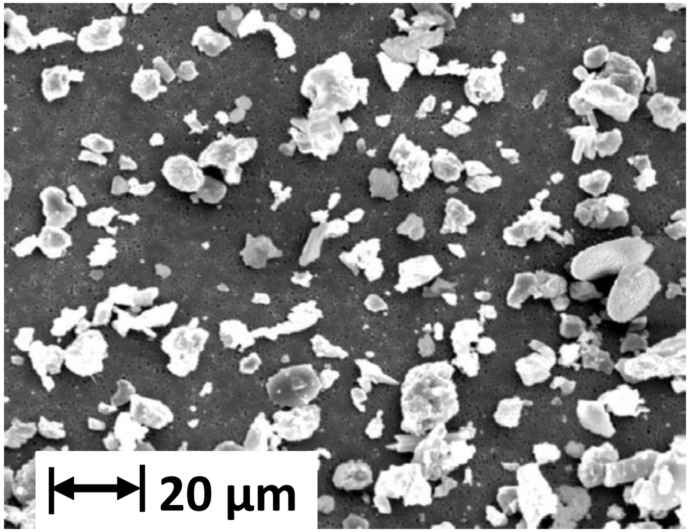
To better understand the bi-static LIDAR, we designed an experiment at the Pierre Auger Research and development site to compare the bi-static LIDAR with a Raman LIDAR.

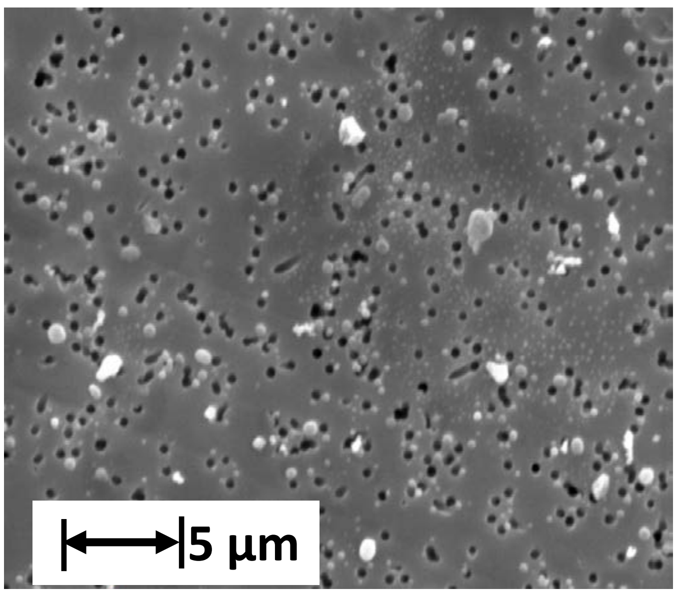
Combined System



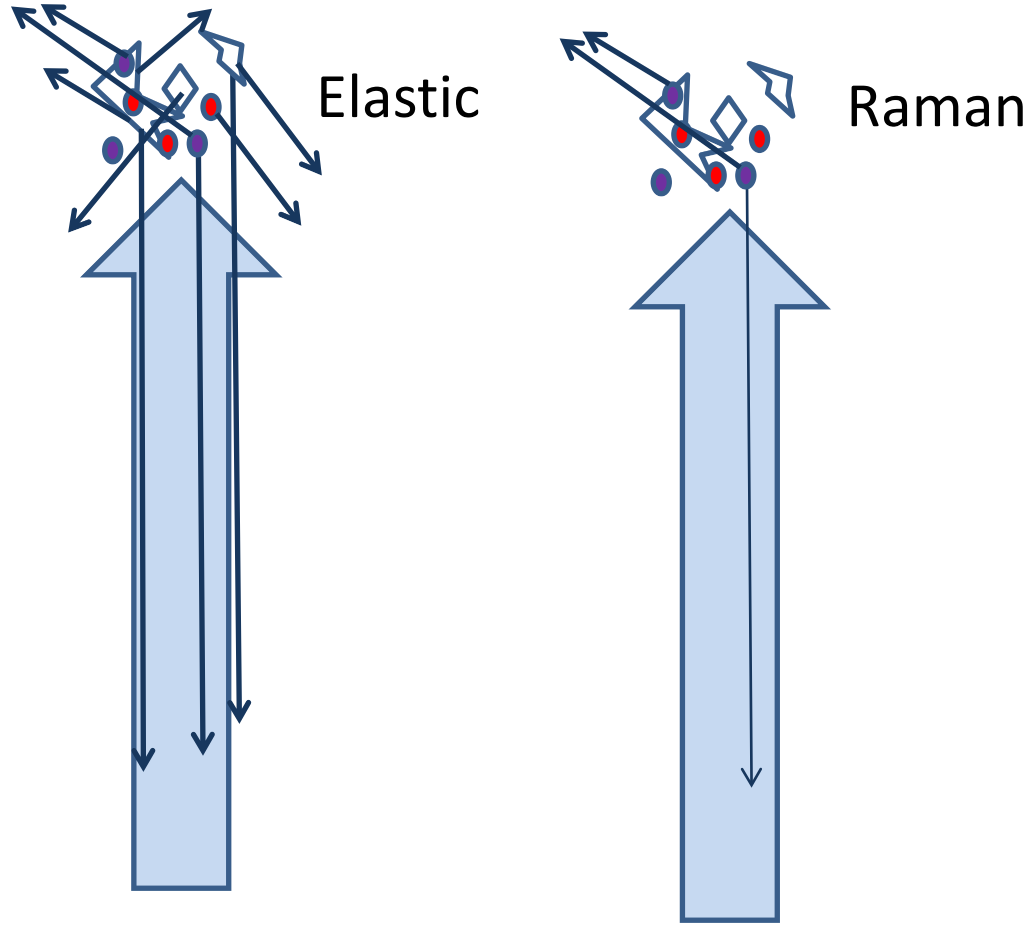
	Elastic Bi-Static LIDAR	Raman LIDAR
Field of View		
Dynamic Range		
	Dynamic range ≈ 600	Dynamic range ≈ 10^6

Why Raman LIDAR?





Electron Scanning Images of Aerosol Particles from Pierre Auger Observatory (M. Micheletti)

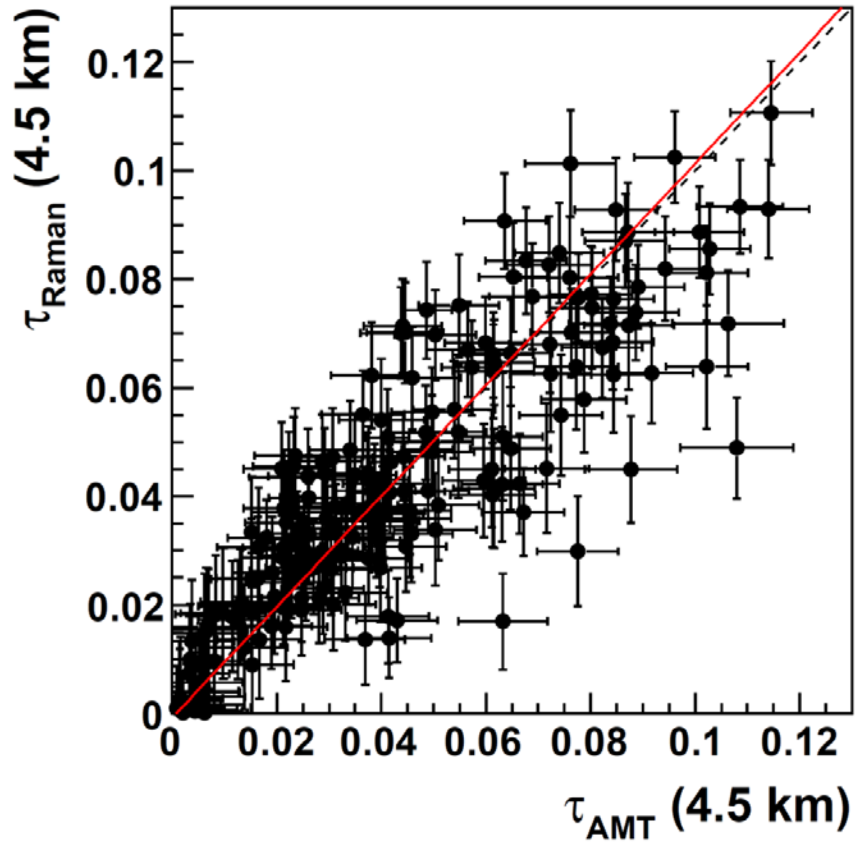


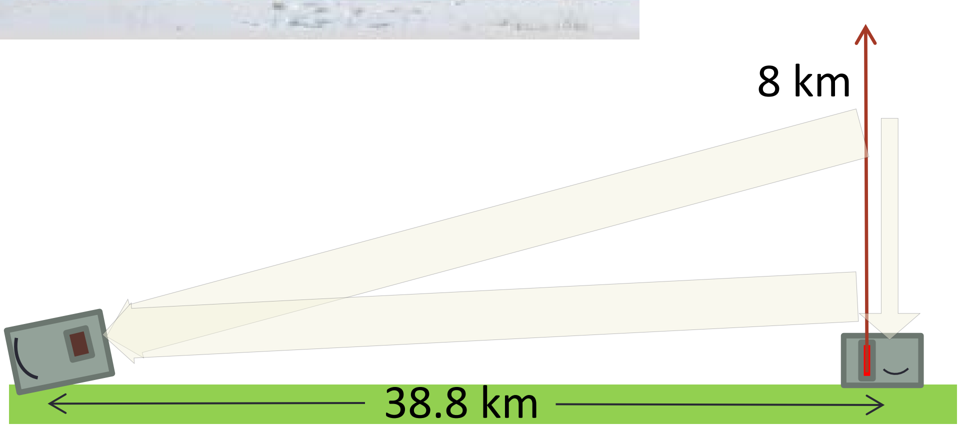
2 Unknowns
Transmission
Scattering

1 Unknown
Transmission

Elastic Side-Scatter vs Raman LIDAR techniques

Aerosol Optical Depth @ 4.5 KM

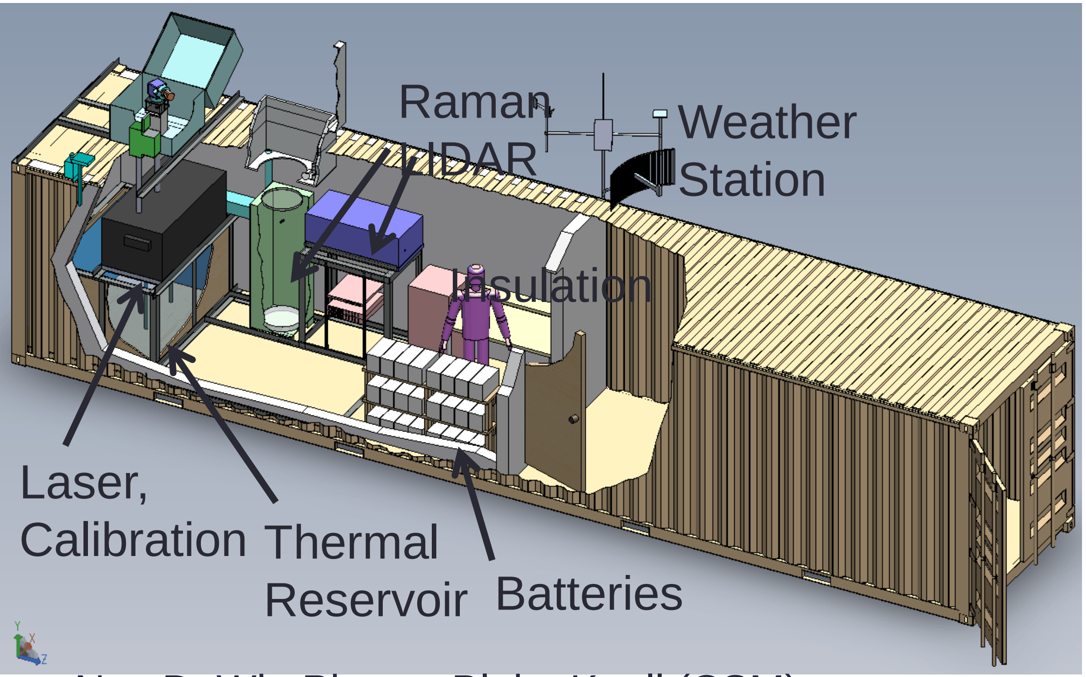




AMT:
Detector

Laser/
Raman
LIDAR

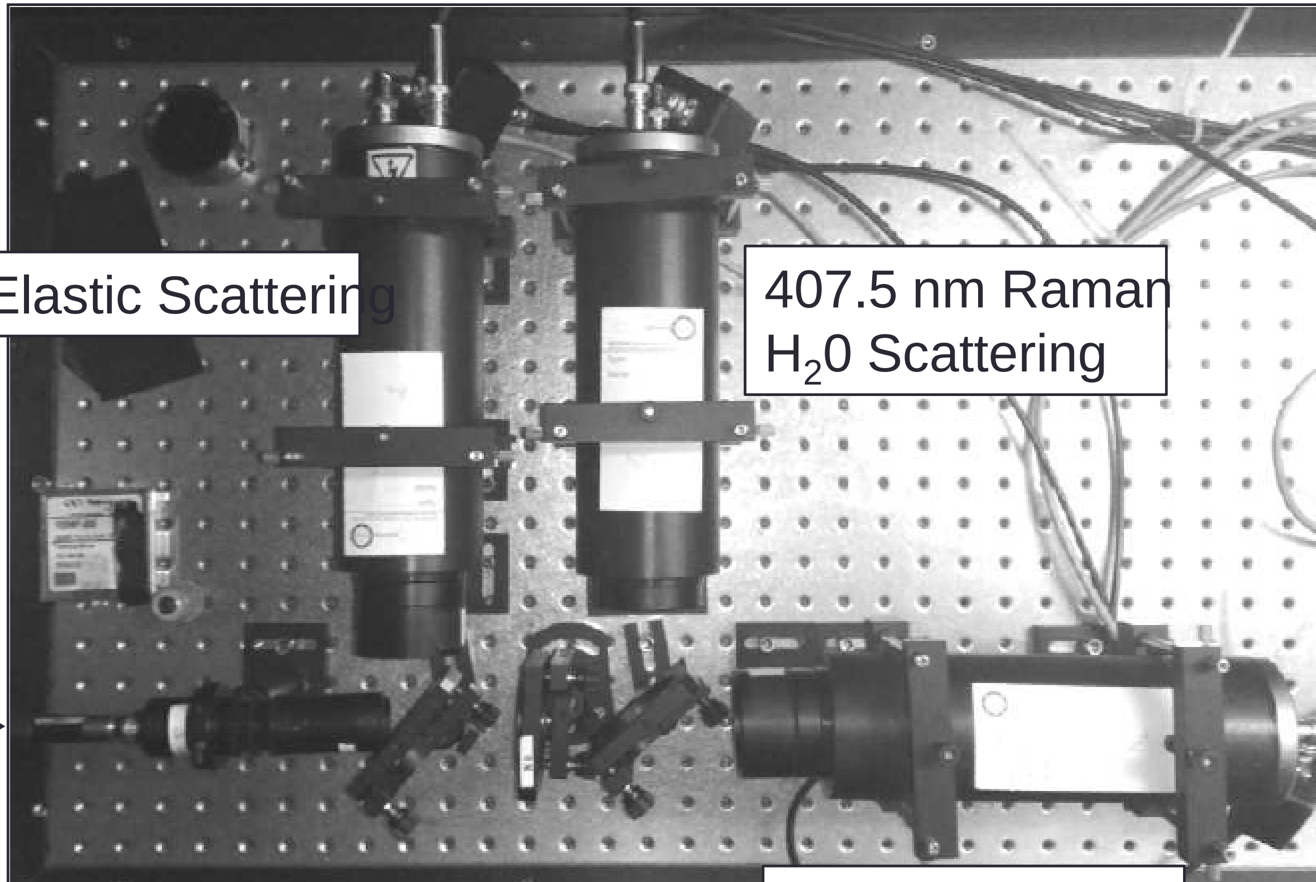
Pierre Auger Atmospheric Super Test Beam - Status



Nev DeWitt Pierrat, Blake Knoll (CSM)

Installed at CLF site First Light May 24th 2013

3-Channel LIDAR Receiver

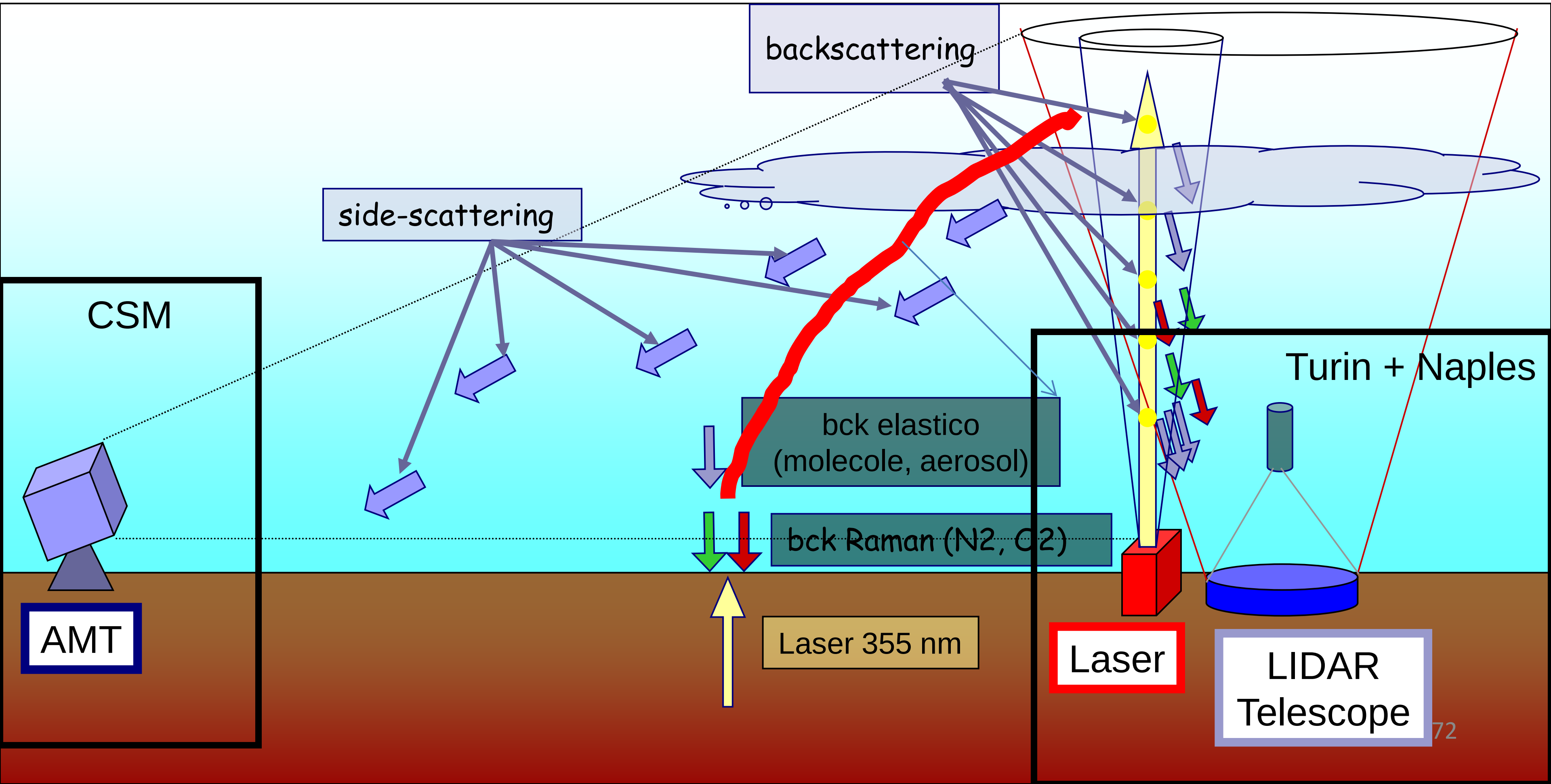


L. Valore, A. Tonachini, et al.

ARCADE: Atmospheric Research for Climate and Astroparticle Detection

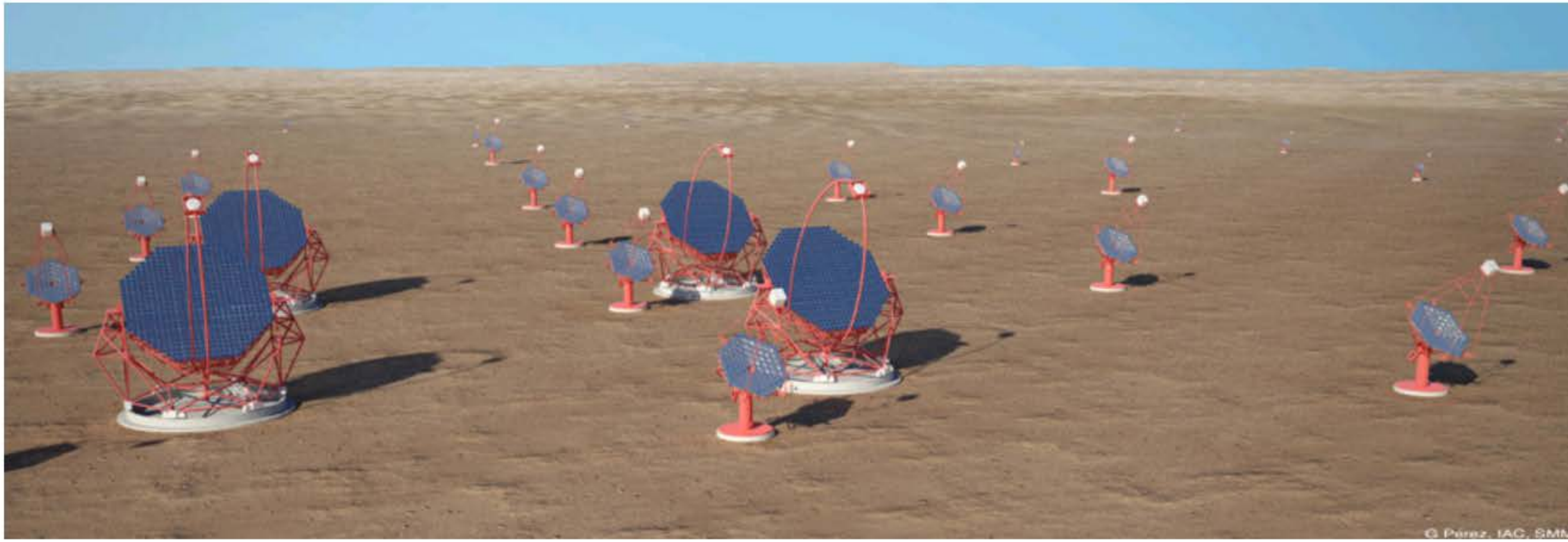
LIDAR (elastic + Raman) and telescope for side-scattering measurements (Atmospheric Monitoring Telescope). The laser source is common.

LASER and LIDAR Can Tilt Toward The AMT



Looking Ahead…..

An observatory for ground-based gamma-ray astronomy



CONTENT

- Home
- CTA Instrument
- CTA Science
- The CTA Consortium
- The Preparatory Phase

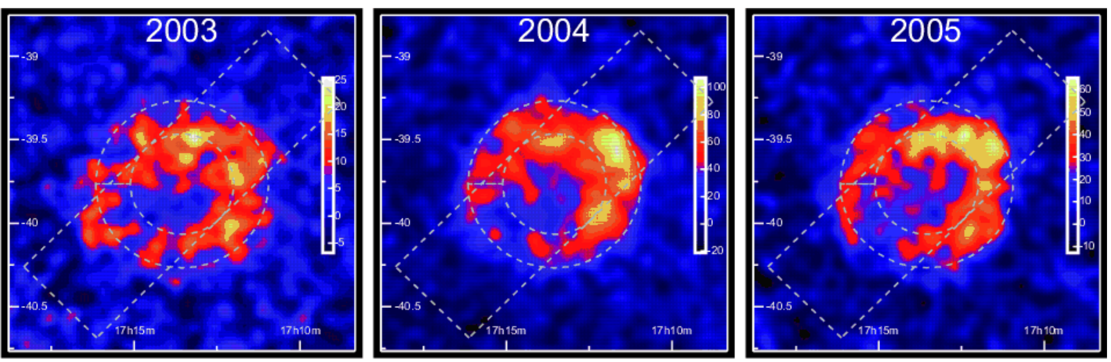
Atmospheric Monitoring And Calibration

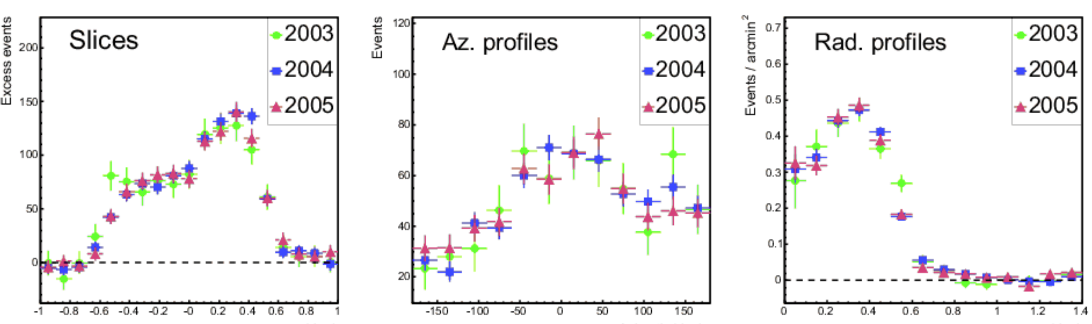
Atmospheric monitoring and calibration is focused towards atmospheric monitoring, associated science and instrument calibration with the goal of better understanding the atmosphere as part of the detector and the calibration of the optical properties of the telescopes. This will result in the reduction of systematic uncertainties, which could be a limiting factor given the high sensitivity of CTA, and in an increase of the effective livetime of the telescopes. Significant development is underway by participants to develop Lidar systems and analysis methods to monitor the aerosol and molecular atmosphere, with very promising results.

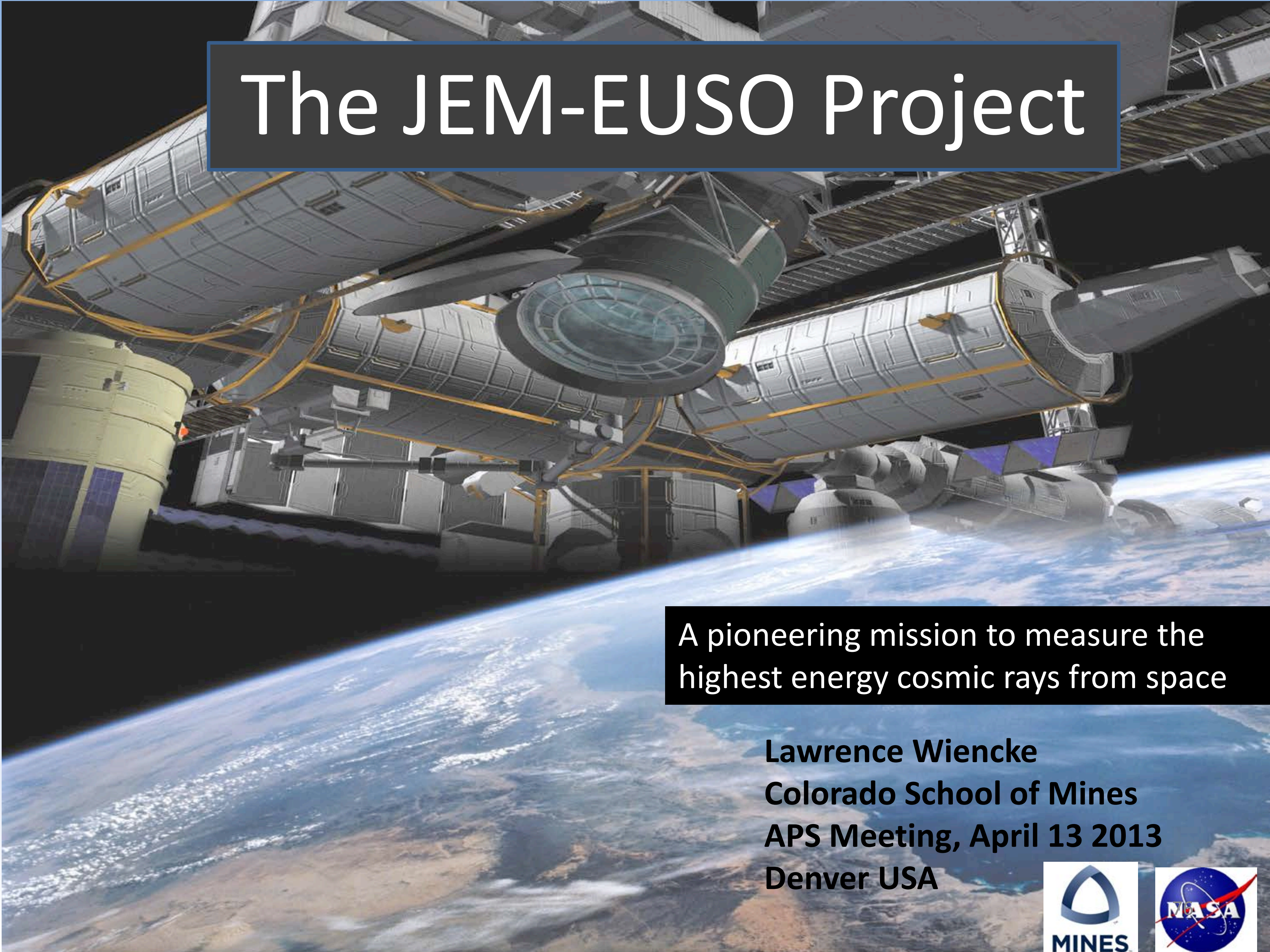
Atmospheric monitoring and calibration …. will result in the reduction of systematic uncertainties, which could be a limiting factor given the high sensitivity of CTA, and in an increase of the effective livetime of the telescopes.

A&A 464, 235-243 (2007)
DOI: 10.1051/0004-6361:20066381

Primary particle acceleration above 100 TeV in the shell-type supernova remnant RX J1713.7-3946 with deep HESS observations







The JEM-EUSO Project

A pioneering mission to measure the highest energy cosmic rays from space

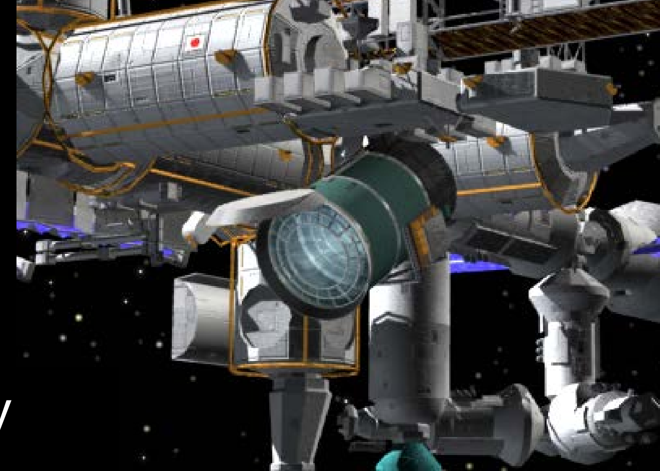
Lawrence Wiencke
Colorado School of Mines
APS Meeting, April 13 2013
Denver USA

Nadir (2 yrs)

35º tilt (3 yrs)

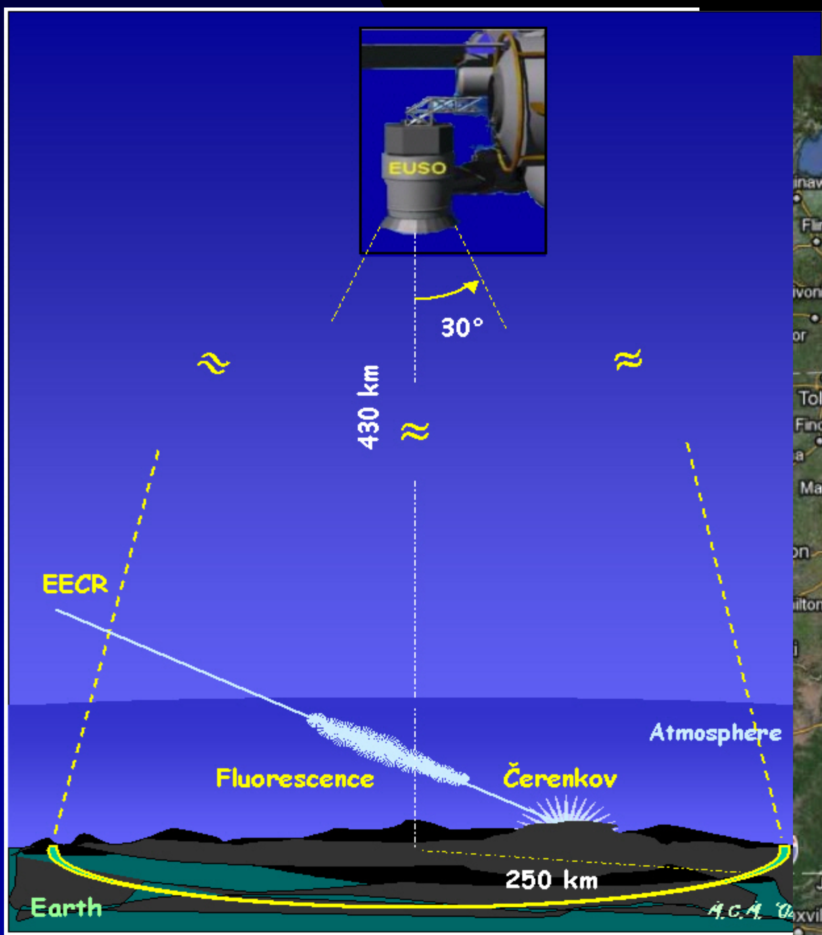
- 3 x area

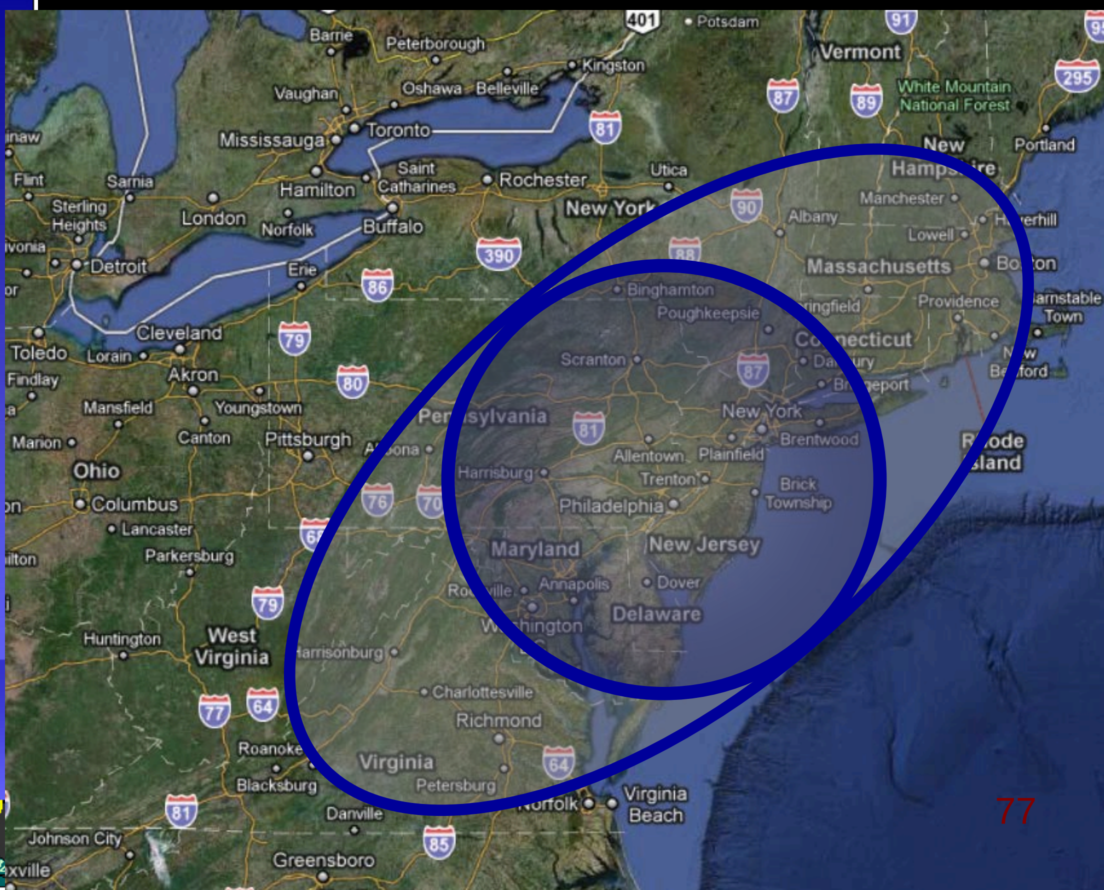
$E_{th} \sim 10^{20}$ eV



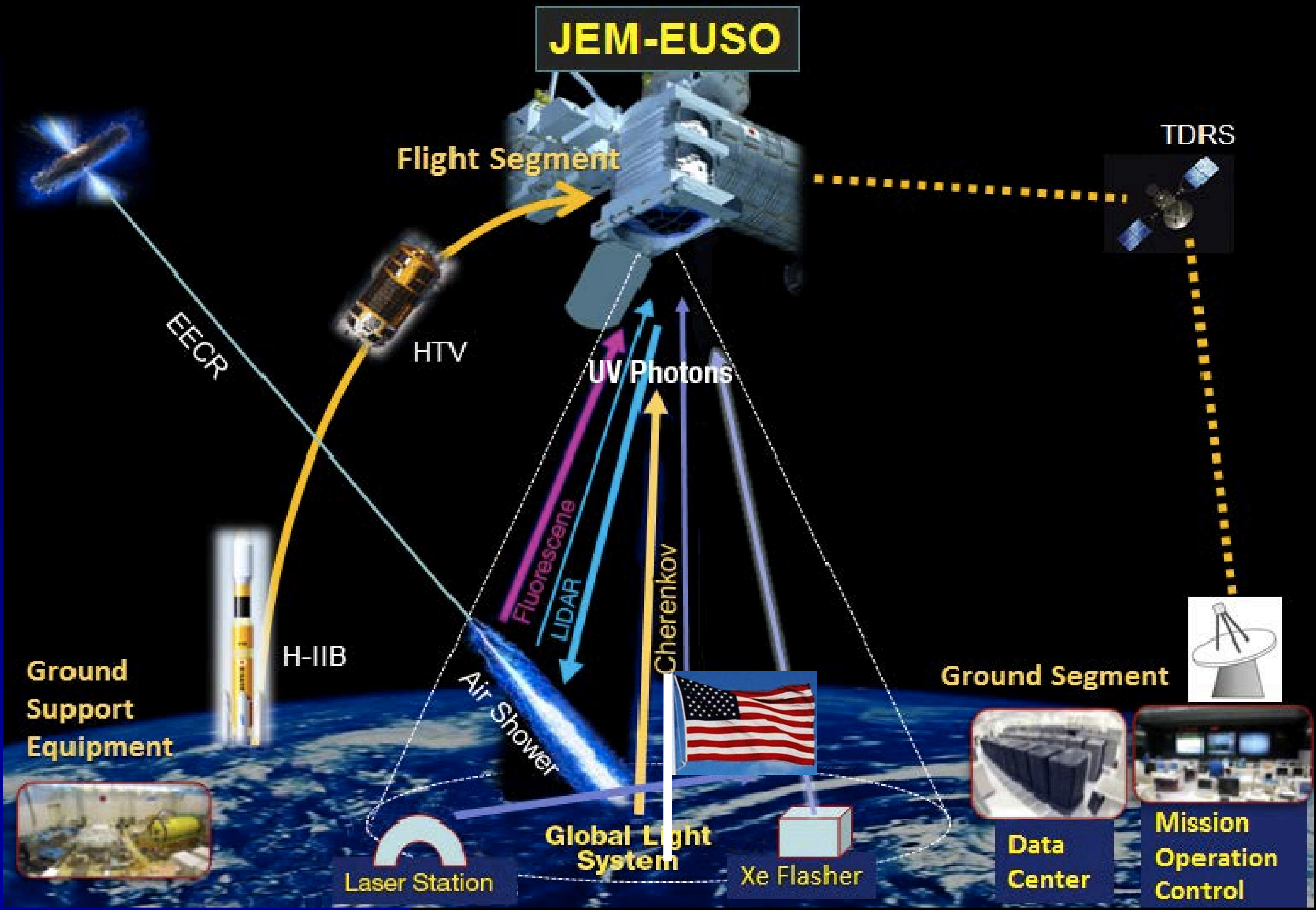
Fluorescence only

~ 20% duty cycle





Exposure History


JEM-EUSO
Flight Segment
TDRS
EECR
HTV
UV Photons
Fluorescene
LIDAR
Cherenkov
H-IIB
Air Shower
Ground
Support
Equipment
Ground Segment
Laser Station
Global Light
System
Xe Flasher
Data
Center
Mission
Operation
Control

Optical Test Beams and Optical Cosmic Ray Detectors

Fly's Eye
(1980-1993)

2 km

Calibration
Atmospheric Clarity

High Resolution
Fly's Eye
1992-2004

13 km

Aerosol Optical Depth
Clouds, Diagnostics

Pierre Auger
Observatory
2003-Present

27-40 km

Aerosol Profiles, Clouds,
Timing, Calibration ……

JEM-EUSO
2017->

350-400 km

GLS

Pointing, Timing,
Calibration tests ….

How many UHECRs > 60 EeV?

Auger w/ 3,000 km^2

(annual exposure of 6,000 km^2 sr

~20 events > 55 EeV/ yr

Telescope Array w/ 700 km^2

(annual exposure of ~ 1,400 km^2

~4.6 events > 55 EeV/ yr

5 o-o-m to go!

Earth – land ~1.5 10^8 km^2 = 5 10^4 Auger

10^6 events/yr

- full surface ~5.1 10^8 km^2 = 1.7 10^5 Auger

3.4 10^6 events/yr

Some Concluding Remarks

Atmospheric Monitoring has an established a history of critical contributions to UHECR

Also atmospheric science results and methods are interesting (and can be published) on their own!

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To those working on atmospheric monitoring..

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A) atmospheric monitoring program and

B) the gamma-ray and/or cosmic-ray science

and write it down. Figure out what really matters!

Consider the interdisciplinary uses for your system, and how to report results

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Looking ahead:

Next generation instruments pose interesting atmospheric challenges

CTA (atmospheric precision frontier)

JEM-EUSO (atmospheric global frontier)