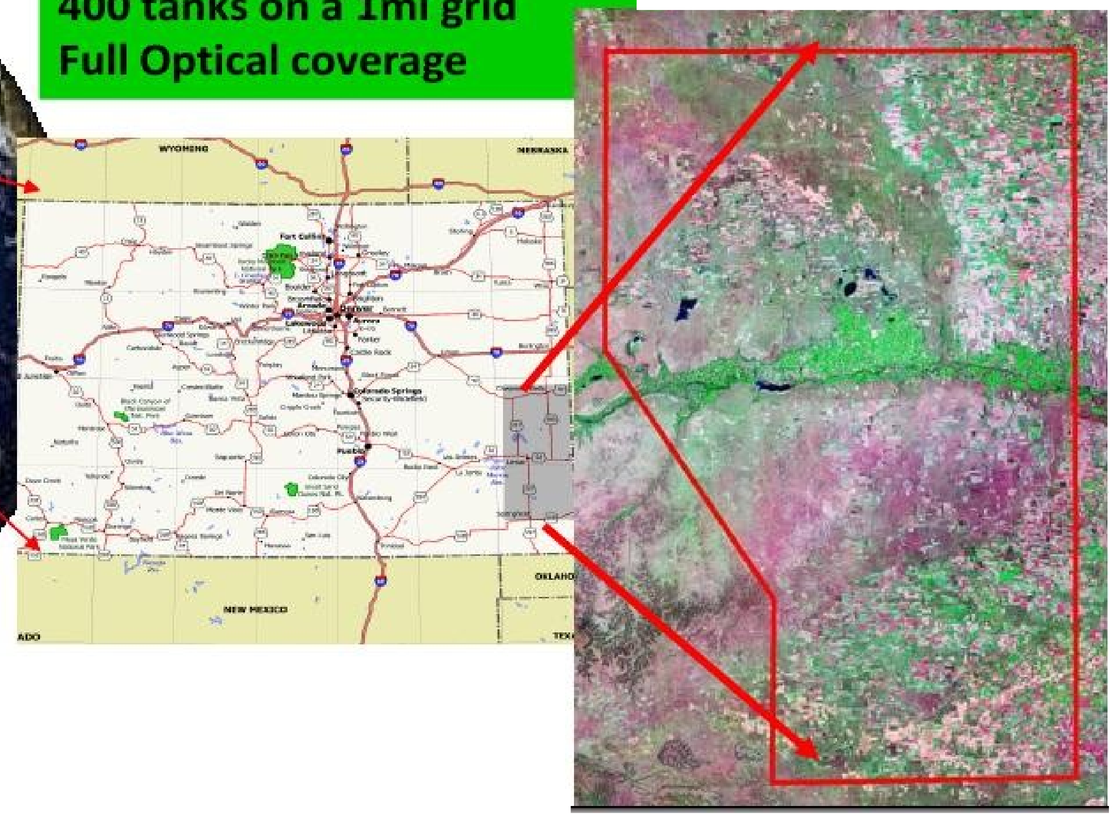
Atmospheric Monitoring R&D at the Auger North Site

Northern site
20 000 km^2

BASE DESIGN:
4000 tanks on a √2mi grid +
400 tanks on a 1mi grid
Full Optical coverage



Southern site
3 000 km^2

PIERRE AUGER OBSERVATORY

SCHOOL OF MINES 1874 COLORADO

David Starbuck
Colorado School of Mines

For the Pierre Auger Collaboration

Auger North Atmospheric R&D

·Institution	Country	Contribution
·Adelaide	Australia	Cloud Radiometers
·CSU	US	AMT-Calibration
·CSU-Pueblo	US	Site Prep
·CWRU	US	Firewall, GPS
·KIT	Germany	AMT-DAQ Radiosondes
Krakow	Poland	Molecular DB analysis
·L'Aquila	Italy	Raman LIDAR
·Madrid-Cmp	Spain	Laser Calibration
·Mines	US	AMT, Site Prep, NAILS-lite
·MTU	US	Weather Stations
·Napoli	Italy	AMT- DAQ analog
·Rosario	Argentina	Raman LIDAR

From Left to Right: Lawrence Wiencke (Faculty), Hans Klages (KIT guest), David Schuster (PhD student), John Claus (UG), Adam Botts (UG), Lucas Emmert (UG), Sarah Morgan (UG), Levi Hamilton (UG), Shay Robinson (UG), John Koop (UG-09), Eric Mayote (MS), Michael Coco (UG), Bryce Carande (UG) T.J. Heid (UG), Keri Kohn (UG), Mark Malinowski (UG), Martin Will (PhD student KIT), David Starbuck (MS),
Fred Sarazin (Faculty), Manoja Weiss (Faculty EE), Orlen Wolf (Staff)
Not shown: David Nitz (visiting from MTU), John Sherman (UG-09),
Michael Calhoun (UG)

Atmospheric Research and Development for the Pierre Auger Cosmic Ray Observatory

Adam Botts, Bryce Carande, Michael Calhoun, Michael Coco, John Claus, Lucas Emmert, Levi Hamilton, T.J. Heid, Sarah Morgan
Advisor: Lawrence Wiencke

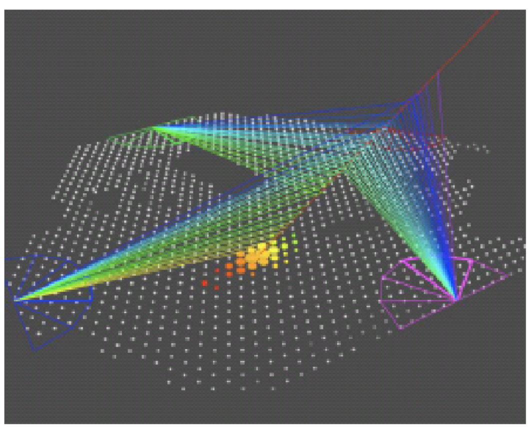
PIERRE AUGER OBSERVATORY

Ultra-High Energy Cosmic Rays

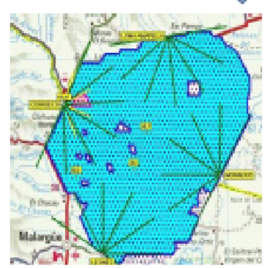
- Highest energy particles known (>10^{20} eV)
-Exact origins are unknown
- May be accelerated by super-massive black holes at center of galaxies
- Very rare (incident on the globe 23 times/day)
- Highest observed energy: 320 EeV

Atmospheric Research and Development

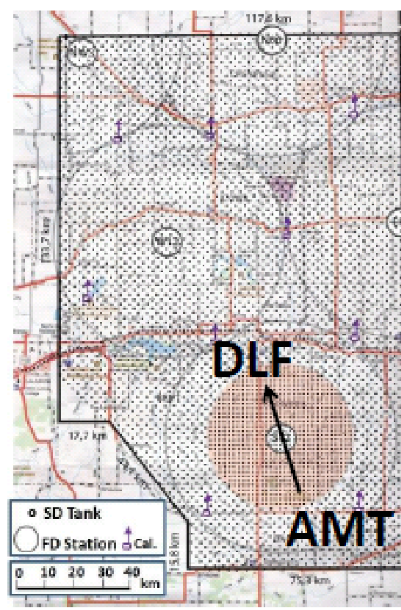
-Southern fluorescence detectors have 20 km view
- Northern detectors will have 40 km view
- Atmosphere is the largest correction factor and is most variable with time
- <u>Understanding atmospheric clarity is critical</u>



10^{19} eV Air Shower Measurement



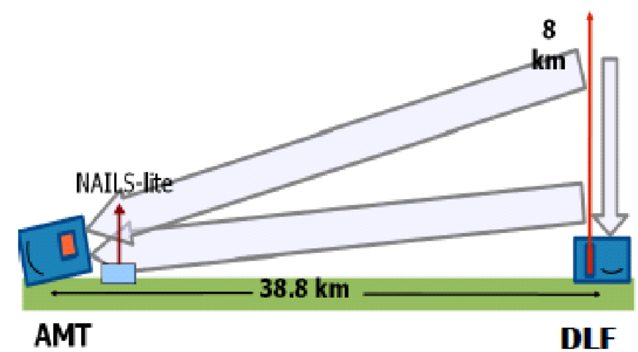
Southern Site: Argentina
Operational: 3000 km²



Northern Site: Colorado
Proposed: 21000 km²

Method

-Use pulsed, UV, vertically firing laser as test beam (DLF/NAILS)
- Laser produces scattered light equivalent to a 10^{19} eV cosmic ray
-Measure scattered light with a modified fluorescence detector (AMT)



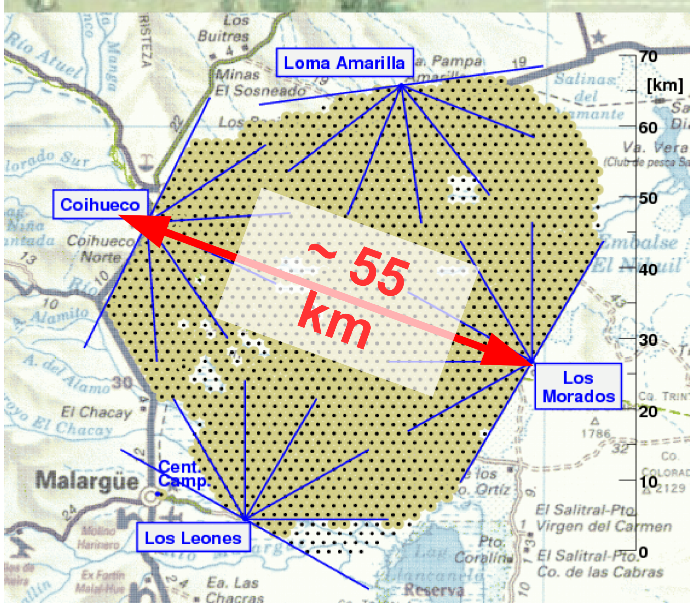
AMT – Atmospheric Monitoring Telescope
DLF – Distant Laser Facility
NAILS – Nitrogen Automated Integrated Laser System

Project Goal

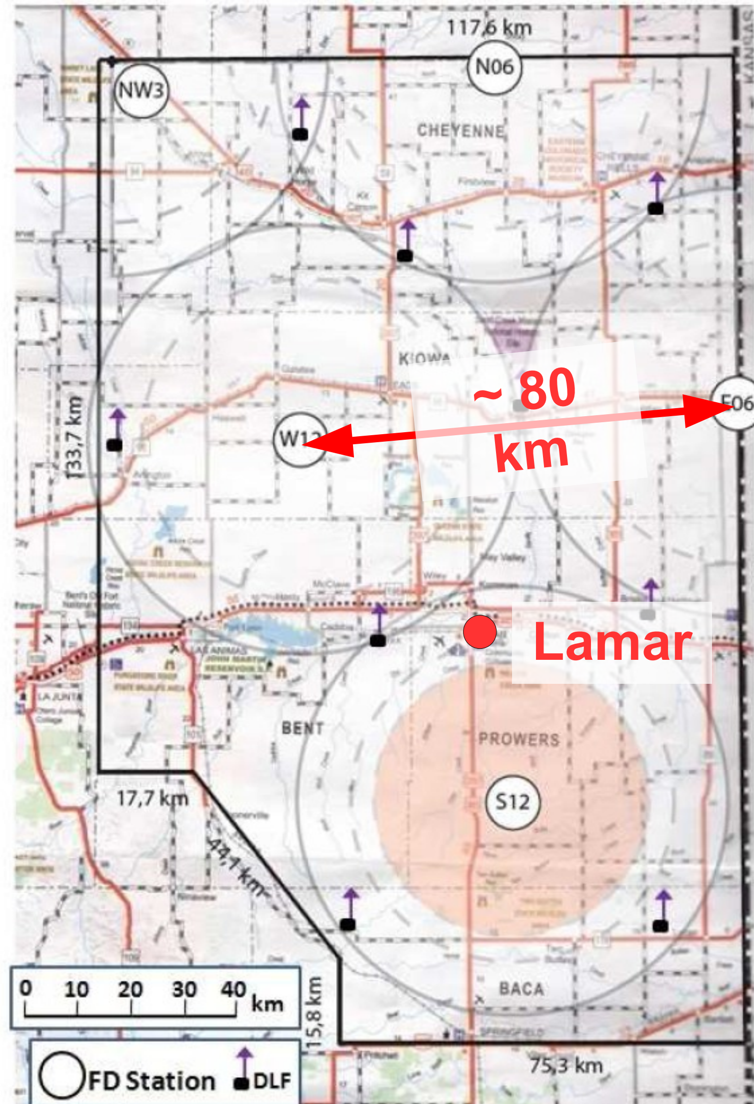
Design and implement a system to collect one year of atmospheric clarity measurements at a 40 km distance and up to 10 km in height

Auger North

Fort Collins
Boulder
Golden
Denver
Aurora
Colorado
Colorado Springs
Pueblo
Lamar

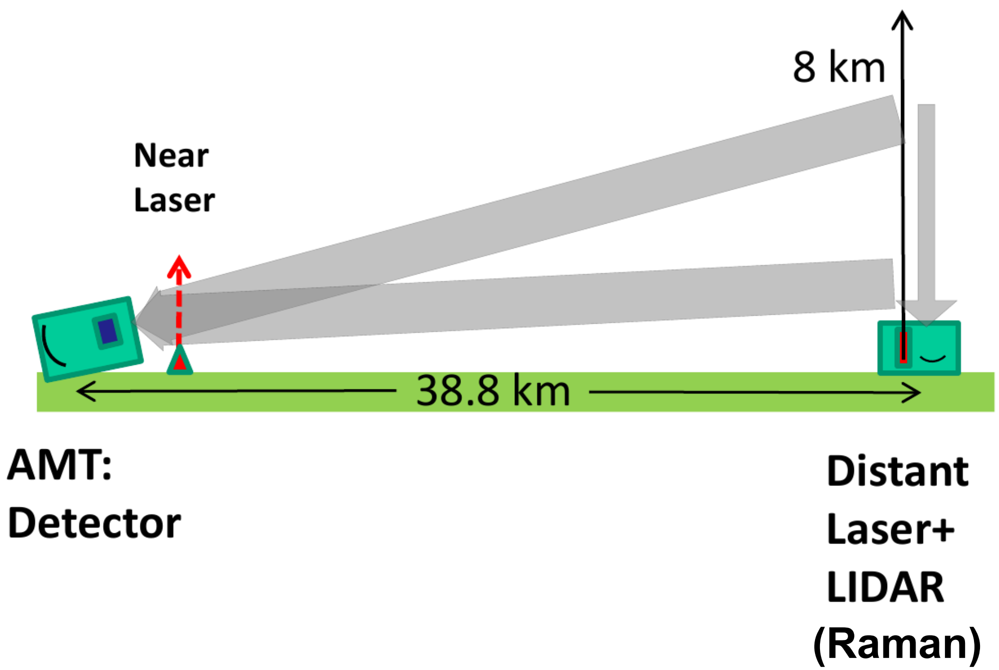


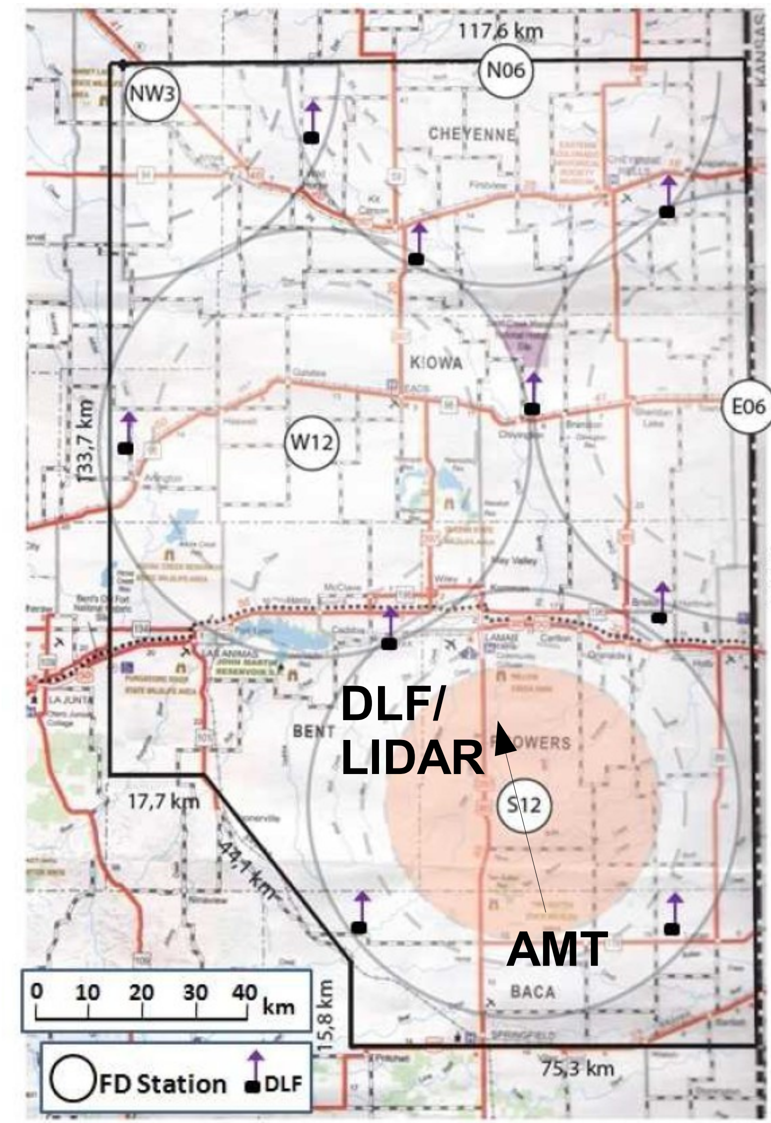
Loma Amarilla
Coihueco
Los Morados
Los Leones
Malargüe
Cent. Camp.
~ 55 km
[km]
70
60
50
40
30
20
10
0



117,6 km
N06
NW3
CHEYENNE
KIOWA
~ 80 km
E06
W11
133,7 km
184,5 km
Lamar
BENT
PROWERS
S12
17,7 km
44,1 km
BACA
0 10 20 30 40 km
15,8 km
75,3 km
FD Station
DLF

R&D Configuration



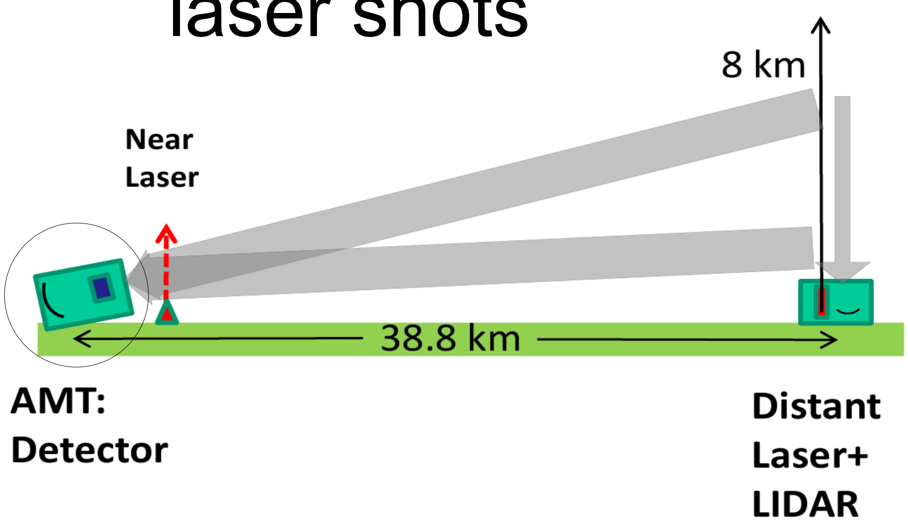


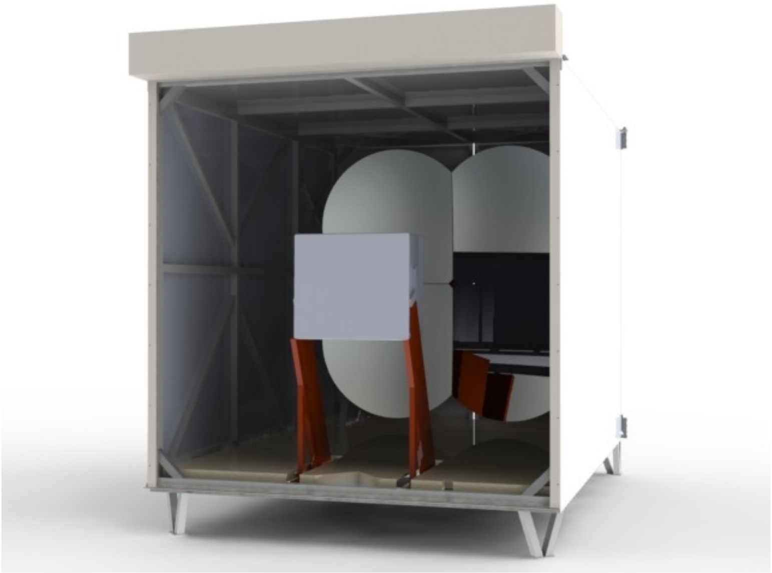
Auger North R&D Goals

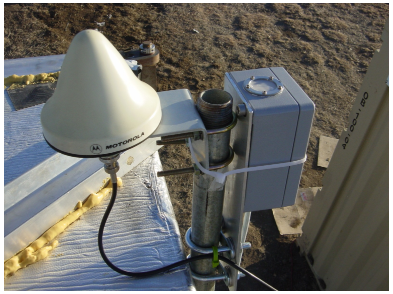
- Measure the Vertical Aerosol Optical Depth (VAOD or τ_a) using two methods
  - Inelastic Back Scattering – Raman LIDAR system
  - Elastic Side Scattering – Vertical laser shot + FD
- Measure molecular atmosphere with radiosonde balloons and test molecular models
- Test new equipment and procedures
  - High quantum efficiency photomultiplier tubes, Temperature controlled UV LED, GPS Timing, “Super Test Beam” for Auger South site

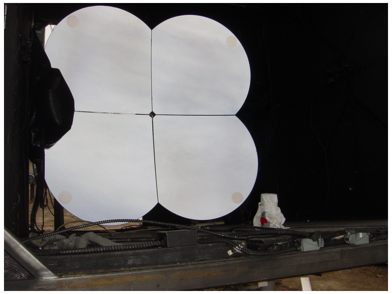
Auger North R&D Equipment

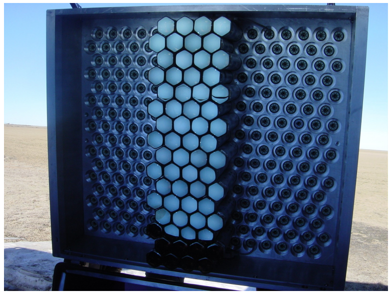
- Atmospheric Monitoring Telescope (AMT)
  - Fluorescence Detector used to measure vertical laser shots









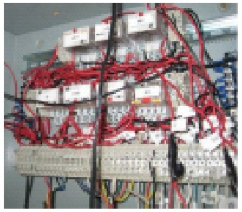


The Atmospheric Monitoring Telescope Mechanical Operation

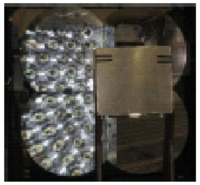
Levi Hamilton
with Adam Botts, Michael Calhoun, Bryce Carande, John Claus, Lucas Emmert, T.J. Heid, Sarah Morgan
Advisor: Lawrence Wiencke

Objective

- Automate and install AMT for daily operation under extreme weather conditions
- Measures light scattered from distant laser to measure aerosol content in atmosphere
- Part of Pierre Auger North Project



Relay logic circuitry controls doors



Four segment mirror optimized for UV light

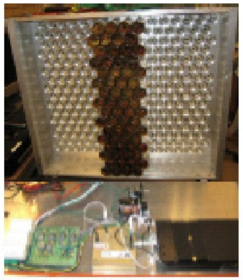
SBC is informational hub of AMT

Control and Sensing

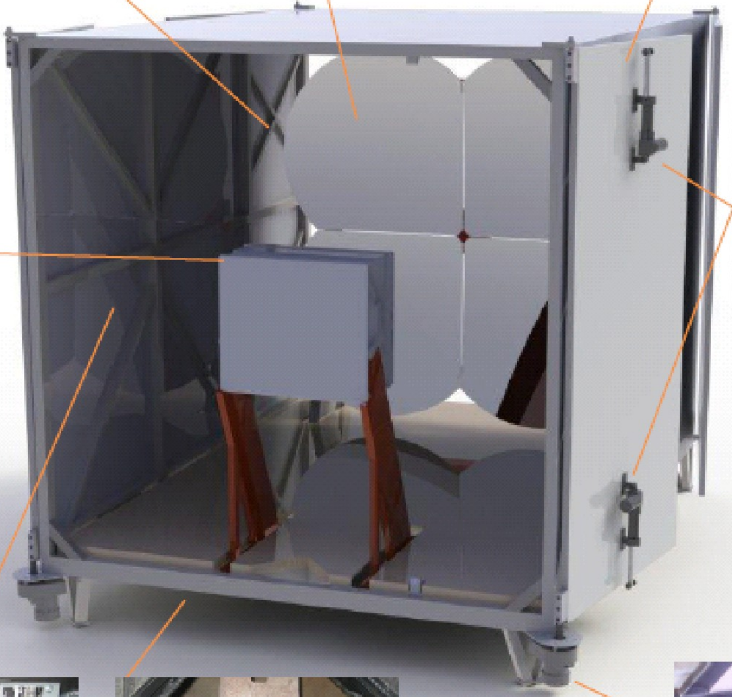
- Powered by rotary motors
- Actuator locking mechanism
- Limit switches sense and control position of door
- Operated by Single Board Computer (SBC)
- Weather station, cloud sensor
- Accessible from internet

Quick Facts:

- Modified Cosmic Ray Air Fluorescence Detector
- Four 1m² mirror segments
- PMT camera
- Dimensions: 12x8.5x8.5 ft
- Weight: > 5000 lb
- Location: SE Colorado
- Status: Operational



PMT camera and High Voltage Power Supply



Linear actuator

Future Work

New door design:

- Entire assembly housed in AMT
- Easy to retrofit existing system
- Holds the door firmly in position when power is off
- Expected installation: summer 2010

PMT Camera

- 48 PMTs
- UV filter
- Adjusted to focal point
- Variable High Voltage Power Supply

Limit switches sense door position

Rotary motors open/close doors

Before Installation

After Installation

Acknowledgements
Nevis Laboratories, Columbia University

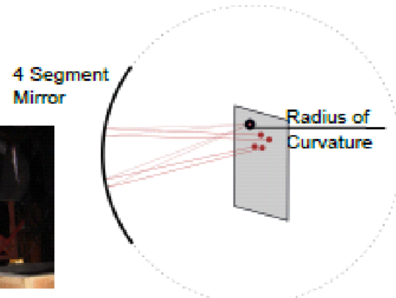
Alignment of the Atmospheric Monitoring Telescope

Lucas Emmert, with Adam Botts, Bryce Carande, Michael Calhoun, John Claus, Levi Hamilton, T.J. Heid, Sarah Morgan
Advisor: Lawrence Wiencke

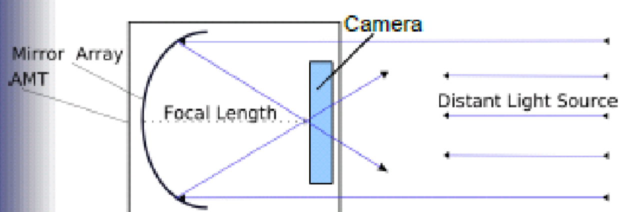
Internal Alignment

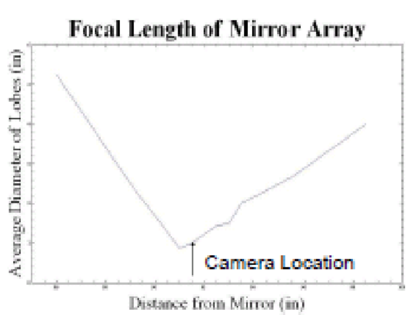
Mirror Alignment

- Set optical axis
- Aligned 4 spherical mirror segments along optical axis
  - Used point light source
  - Focused all mirror segments along optical axis
  - Focused at radius of curvature 477.5 cm (188 in)
- All of this done in the lab repeated in the field



Camera Placement





- Measured focal length of mirror array
  - Measured to be 231.1 cm (91 in)
- Calculate camera placement
  - Place camera slightly off focal point
  - Do not lose laser between PMTs
  - Placed at 232.4 cm (91.5 in)

Functional AMT

Goals

- Align AMT (Atmospheric Monitoring Telescope) with 0.1° of vertical laser 38.8 km away
- Detect laser with AMT

Challenges

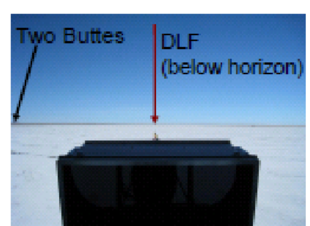
- DLF (Distant Laser Facility) is located below horizon with respect to AMT
- AMT direction must be adjustable with respect to azimuth and elevation
- AMT weighs 4500 lbs
- Installed in winter

Conclusions

- Aligned AMT within 0.11°±0.05 °of azimuthal angle with respect to DLF
- AMT aligned so that laser beam can be detected

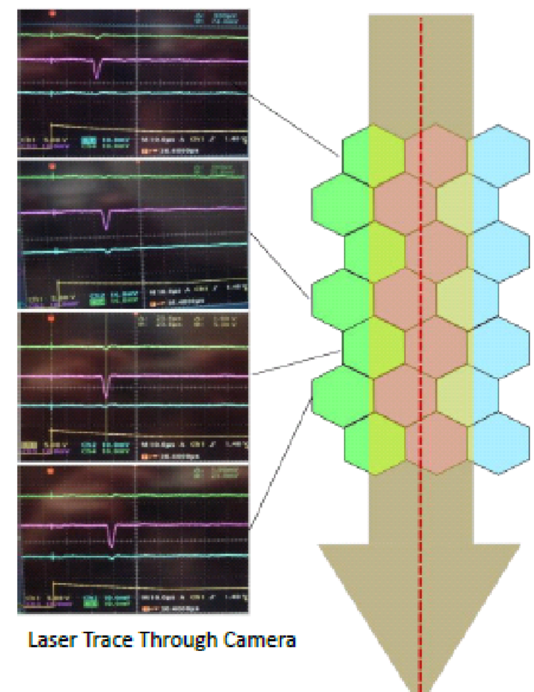
Using Theodolite

Adjustable Mounts



External Alignment

- Measured azimuthal angle from peak of Two Buttes
  - Used theodolite
  - Adjusted azimuth with come alongs and tow straps
  - Alignment is good to within 0.11° ±0.05 °over 38.8 km
- Angle of elevation from horizontal to center of camera
  - Final angle measured to be 8.72°
  - Allows us to see certain region of sky: Troposphere
    - 1 km to 10 km above the horizon
    - Most of the energy from UHECR is deposited in the region



Laser Trace Through Camera

- Checked alignment with laser traces centered on desired PMT column

The Atmospheric Monitoring Telescope Operation and Performance

Adam Botts

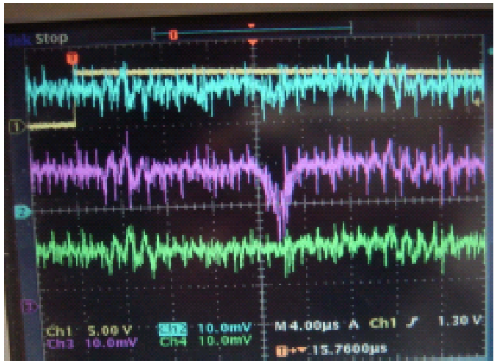
With Michael Calhoun, Lucas Emmert, Levi Hamilton, Bryce Carande, Michael Coco, John Claus, T.J. Heid, Sarah Morgan

Advisor: Lawrence Wiencke

Goal: measure atmospheric clarity over one year using Atmospheric Monitoring Telescope (AMT)
AMT is installed and has measured scattered light from two vertically firing lasers

Timeline of Measurement

Each instrument has GPS clock
DLF laser fires at 1 Hz and at time
GPS second + 0.250 000 000 100 ns
Laser light scatters and travels 40 km in 133 ns
DAQ begins measurement at
GPS second + 0.250 130 000 100 ns
DAQ records for
100 μs in 200, 50 ns bins



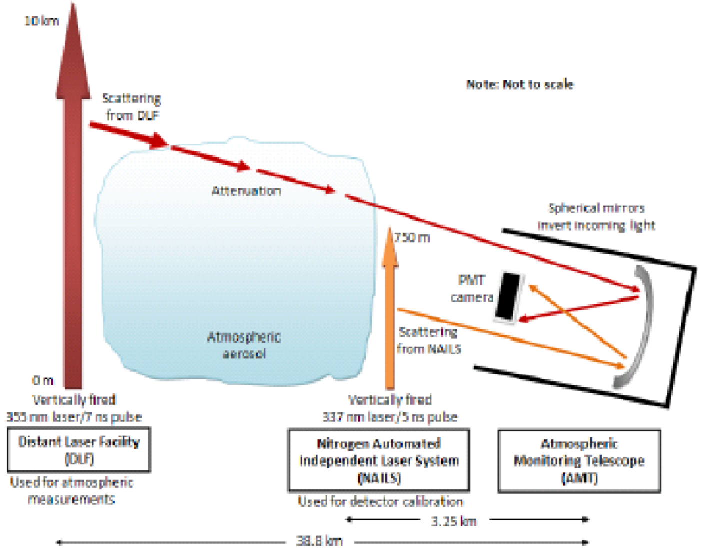
Single row of PMT captured on oscilloscope
Yellow is GPS trigger

NAILS laser fires at 1 Hz and at time
GPS second + 0.350 000 000 100 ns
Laser light scatters and travels 3 km in 10 ns
DAQ begins measurement at
GPS second + 0.350 000 000 100 ns
DAQ records for
100 μs in 200, 50 ns bins

Operation

Remote operation through Internet
Automated with C programming :
- checks weather conditions
- opens DLF hatch and AMT doors
- turns on laser and PMT camera
- synchronizes GPS timers

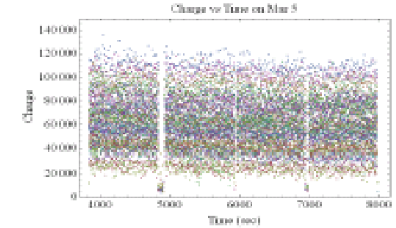
Measurements taken at night with no/low moonlight

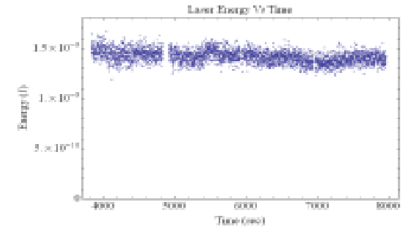


PMT camera sees an inverted trace of light
The scattered laser light travels <u>down</u> the camera
Time delay is longer as light travels further
Also attenuated more as it travels through more atmosphere

Data measured over 4000 laser shots measured by 16 PMTs

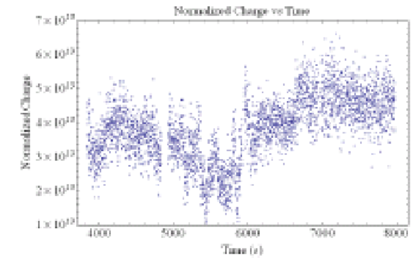
STABLE





Energy of received light (top) is variable with atmosphere and energy of laser pulse (bottom)
Each PMT is shown varying as the laser energy is changed
Charge deposited on each PMT as the laser trace moves through more aerosols is lower

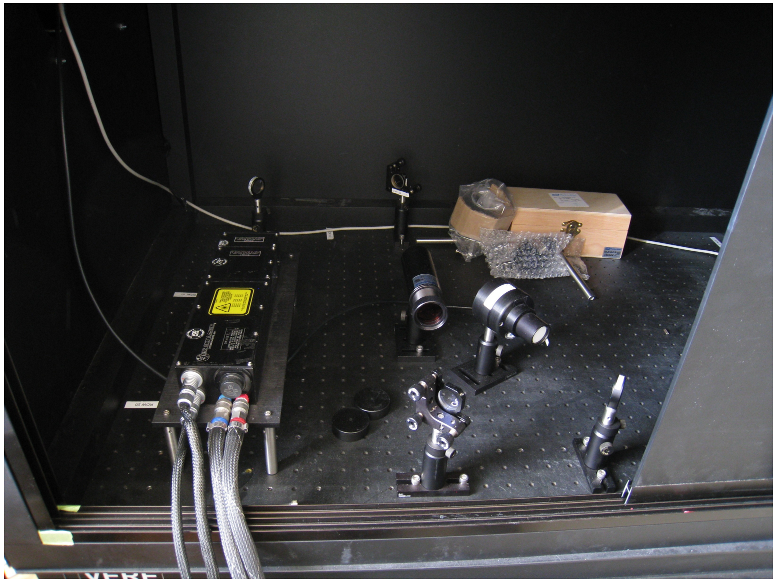
UNSTABLE

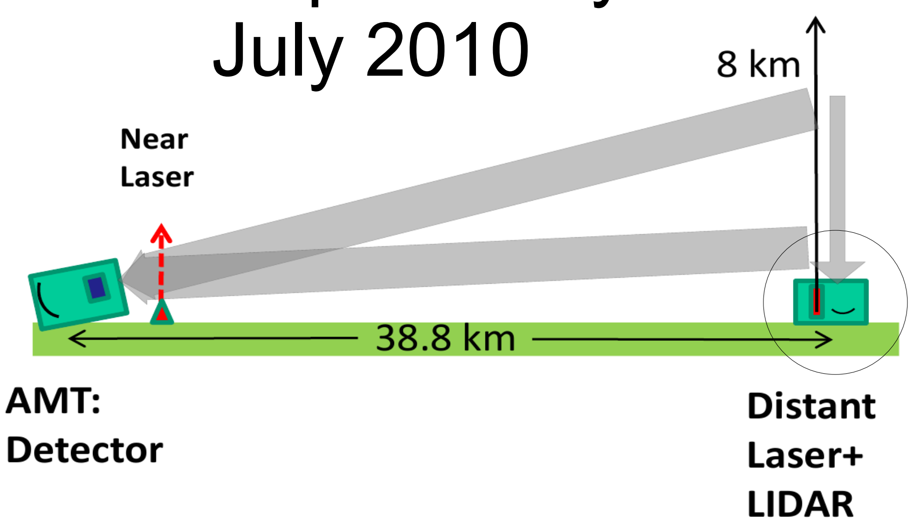


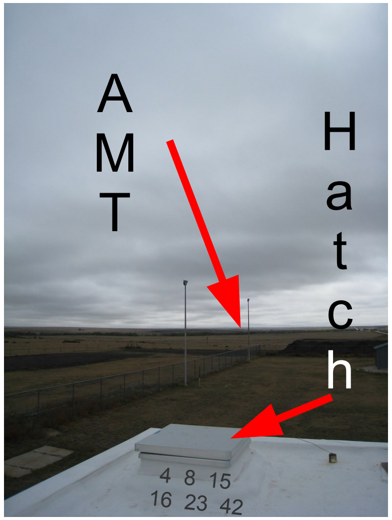
Example of unstable PMT assembly
This PMT will be replaced in debugging

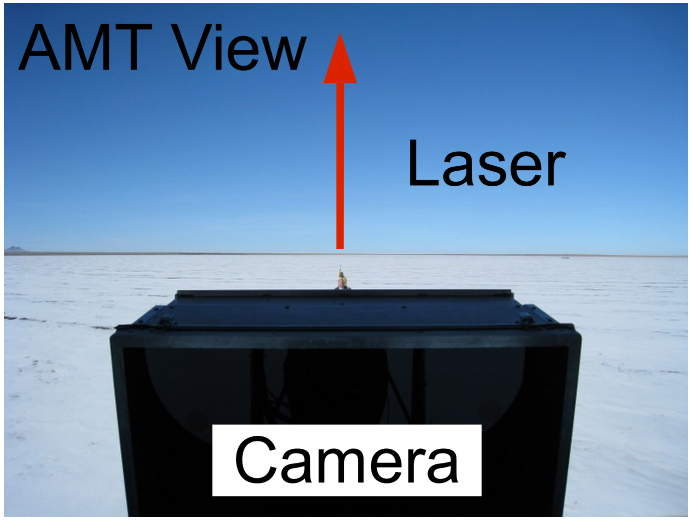
Auger North R&D Equipment

- Distant Laser Facility (DLF)
  - Laser system used to fire vertical laser shots
  - Replaced by DRLF July 2010









The Atmospheric Monitoring Telescope
Lasers as Cosmic Rays

Sarah Morgan
With John Claus, Adam Botts, Bryce Carande, Michael Calhoun, Lucas Emmert, Levi Hamilton, T.J. Heid
Advisor: Lawrence Wiencke

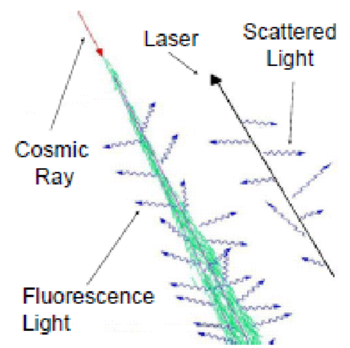
Lasers and Cosmic Rays

Differences

- Cosmic ray showers emit fluorescence light
- Laser light is scattered off the atmosphere
- Lasers travel up
- Cosmic rays travel down

Similarities

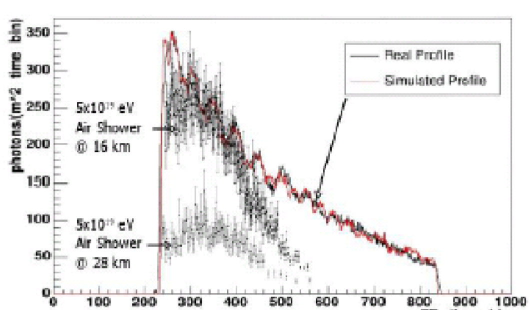
- Deposit most energy in troposphere
- Wavelength in middle of 300-400nm UV fluorescence spectrum
- Pulse length of 9ns



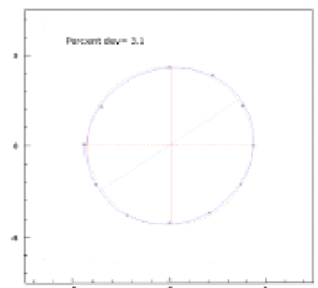
Cosmic ray and laser in the atmosphere

Advantages

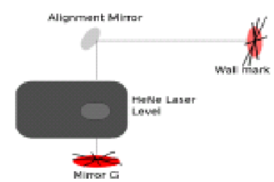
- Specify time, position, direction and measure energy
- Can fire 1000s of times
- Can fire laser as often as needed



Comparison of laser shot and cosmic ray shower



Depolarization plot showing light equally polarized over 360 degrees with a 3.1 percent deviation

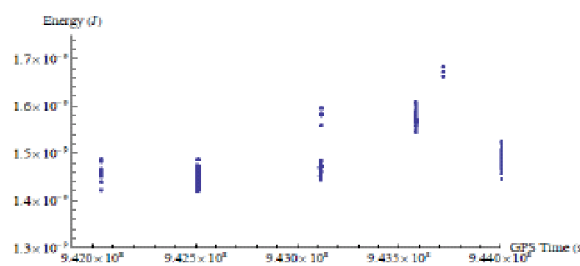


Vertical alignment setup

- Depolarize light for equal scattering in all directions
- A vertical beam is easiest to measure and simulate

Energy Stability

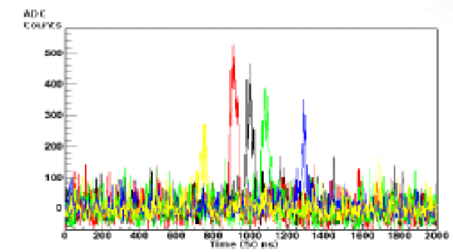
- Laser energy measured
- Laser energy varies over time
- Less than 10% variation in relative energy



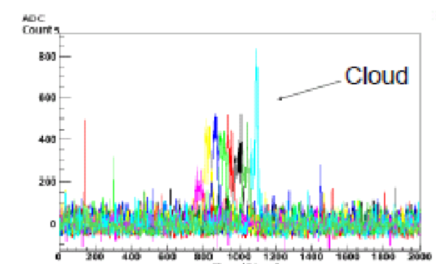
Laser energy over 3 weeks

Data Collection

- AMT camera output
- One pulse per PMT
- Increasing time = increasing height



Laser shot with clear sky



Laser shot hits a cloud

Future Work

- Ongoing gathering of atmospheric data
- Summer 2010, Raman-LIDAR (U. L'Aquila)
- Complete atmospheric model for Auger North

Pierre Auger North
Distant Laser Facility
Electronic Systems & Programming

Adam Botts, Bryce Carande, Michael Calhoun, John Claus, Lucas Emmert, Levi Hamilton, T.J. Heid, Sarah Morgan

Advisor: Dr. Lawrence Wiencke

Colorado School of Mines, 1500 Illinois Street, Golden, CO 80401

Background

- ***Integral part of Pierre Auger North Atmospheric Research & Development***
- ***Laser used in coordination with an Atmospheric Monitoring Telescope to measure side scattering of fluorescent light in the atmosphere***
- ***Laser at same frequency as light from high energy cosmic ray showers***

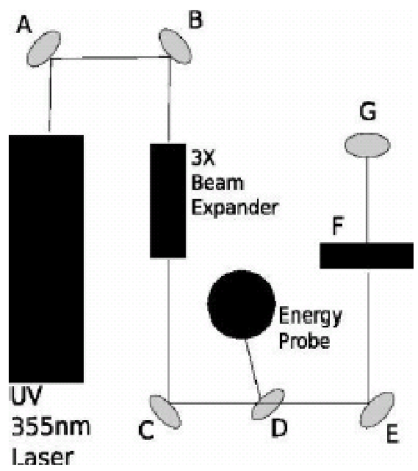
Location

- ***Located 2 miles south of Lamar, CO***
- ***Future site of Pierre Auger North Observatory***

Power System

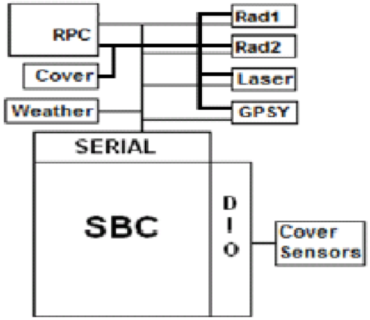
- ***System uses 120v 60 Hz AC power***
- ***Automatic controls of equipment through use of Remote Power Controller (RPC)***
- ***Weather Station and Single Board Computer (SBC) connected independent of RPC***
- ***All equipment including stand alone PC connected to UPS***
- ***Occasional power outages at site***
- ***Timer recycles power on router once per day***

Laser Setup



A BSR-35-1025
B BSR-31-1025
C Y3-1025-45UNP
D PW-1012-UV
E Y3-1025-45UNP
F CVI Optical Mounts 1100-10
G Y3-1025-45UNP
355nm Laser Big Sky Laser Technologies Model Ultra SN: 98041402
Beam Expander CVI Melles Griot
Energy Probe LaserProbe SN: 042-065-001

Single Board Computer



- ***TS-5500 Embedded Single Board Computer with 133Mhz 586 CPU***
- ***Compact Flash Drive used for as hard drive***
- ***Digital Input and Output (DIO) ports tied directly to memory locations***
- ***Additional serial connections from expansion cards***
- ***Connected via Ethernet LAN to Stand Alone PC***

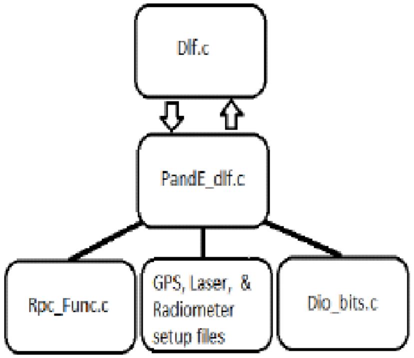
Serial Port Connections and Controls

- ***RPC controlled via serial connection with SBC***
- ***Power for Radiometers, Laser, and GPS controlled by RPC***
- ***Initialization and functionality control for laser, radiometers, and GPS through serial connection***
- ***Hatch cover operation controlled remotely through RPC***
- ***Weather Station independently tied and controlled through serial port.***
- ***Hatch cover sensors tied directly to DIO ports on SBC***

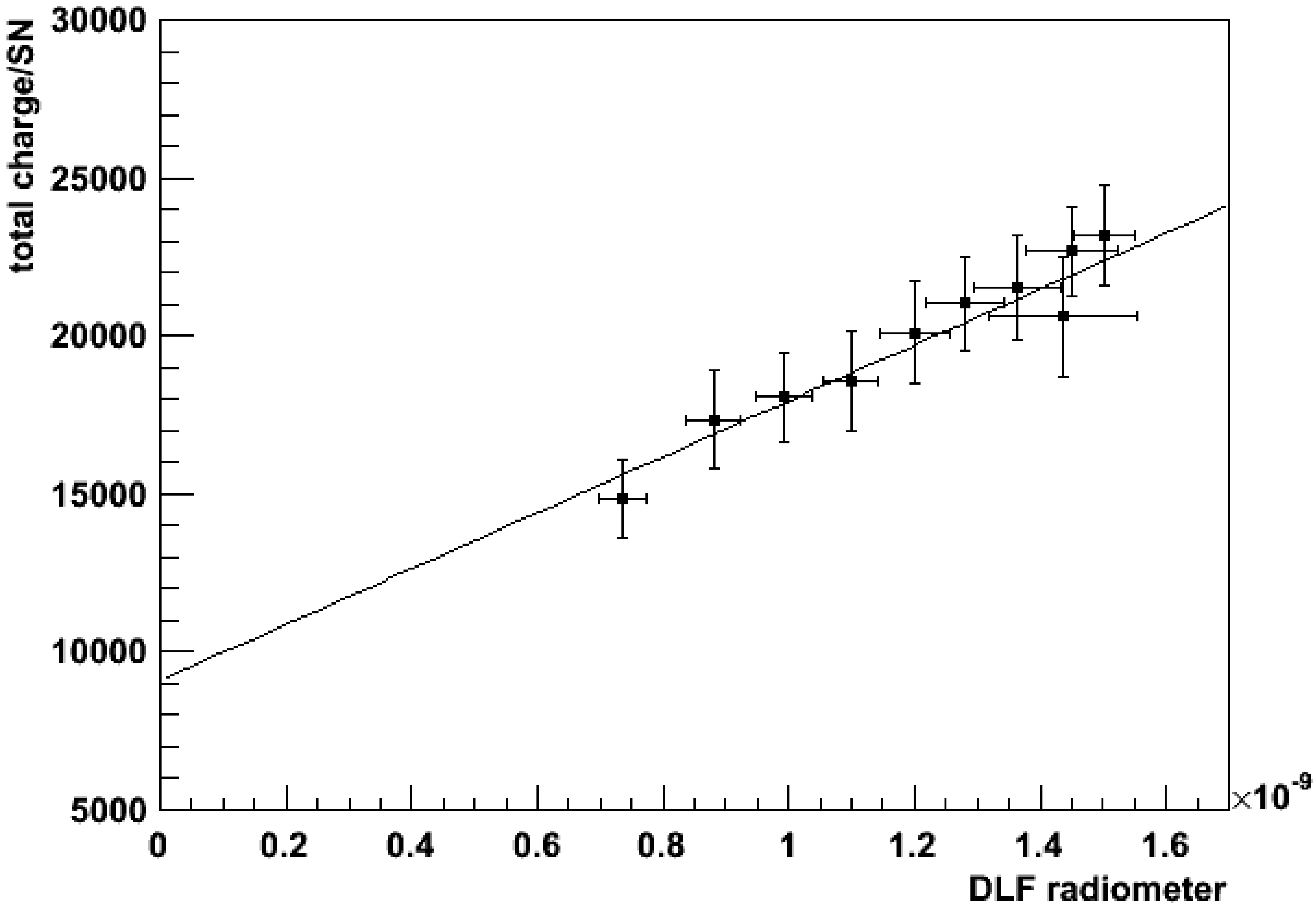
Hatch Control

- ***Automatically closes when weather station senses poor weather***
- ***Independent daemon controls automatic hatch functions***
- ***Manual control available***
- ***Hatch functions accessible within primary DLF program***

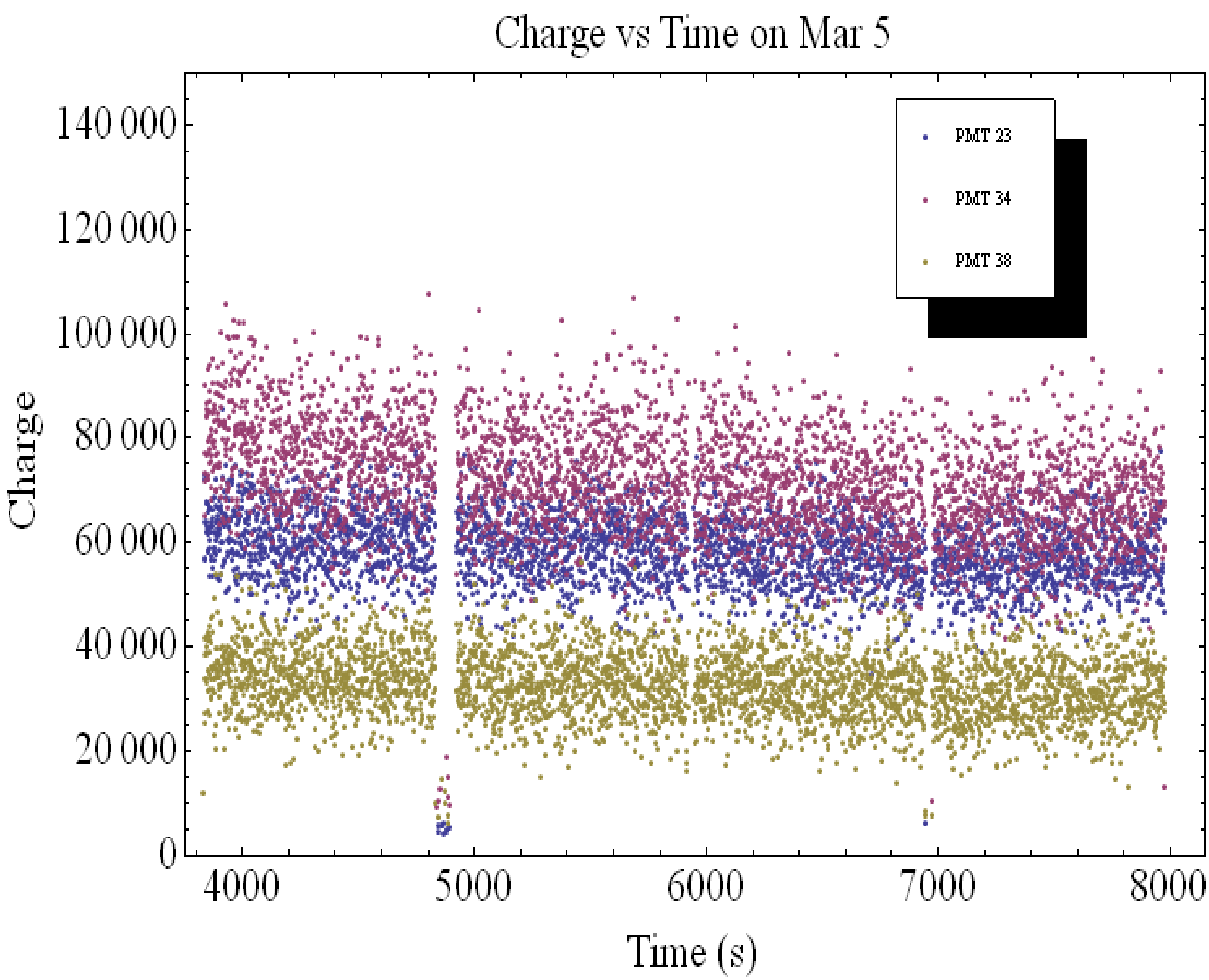
Programming



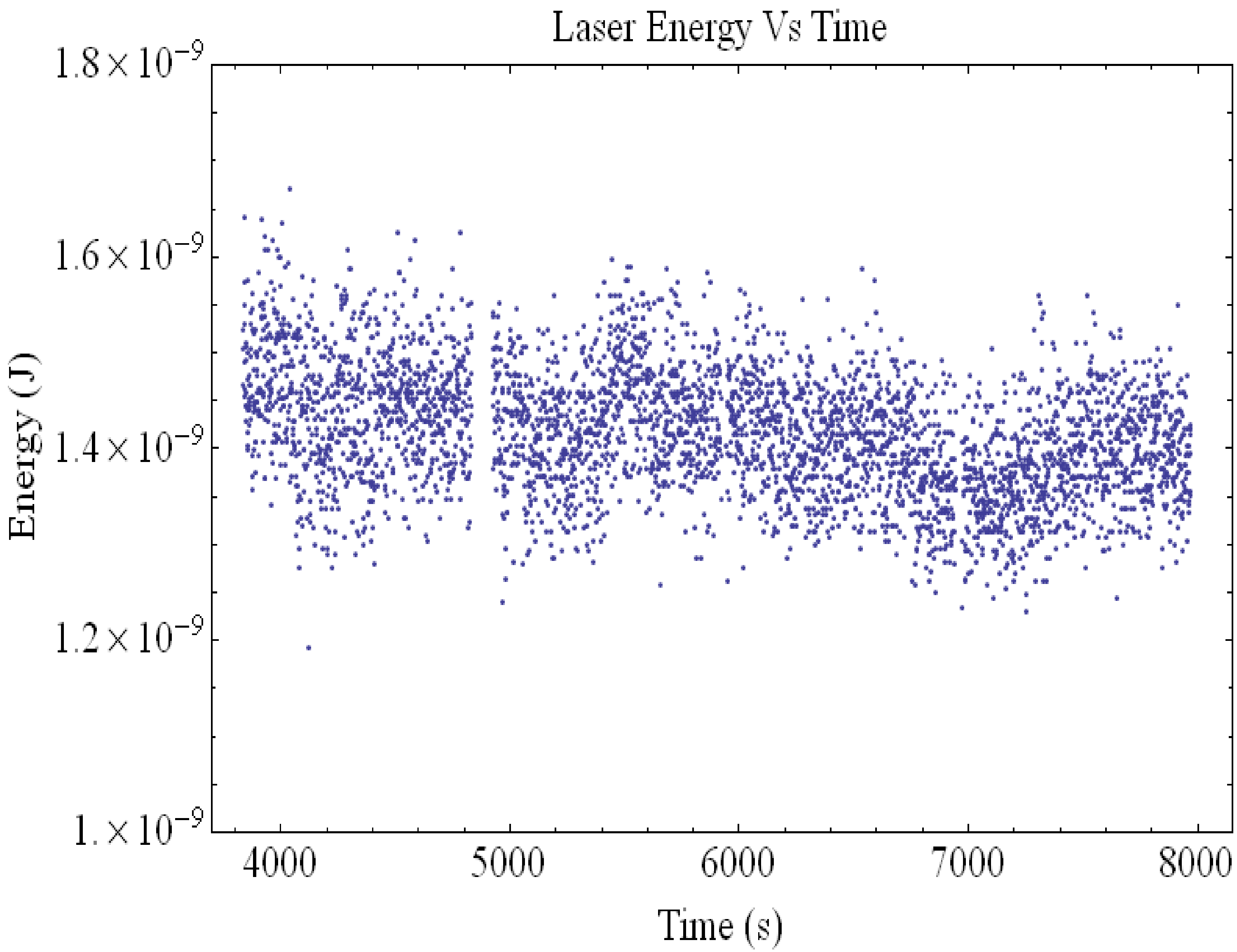
Linearity test with DLF (40 km)



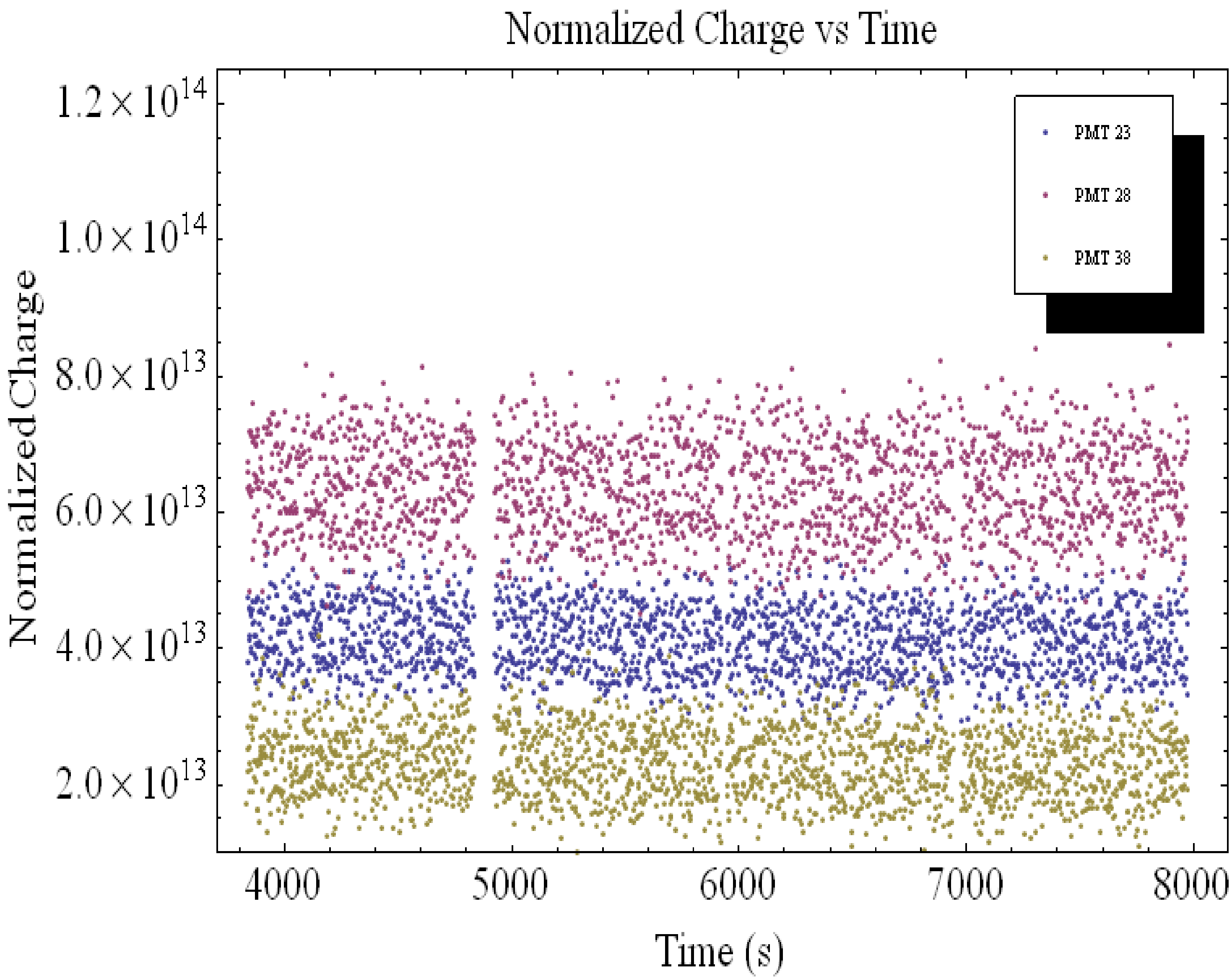
DLF Pulse Measurement vs Time



DLF Laser Energy vs Time



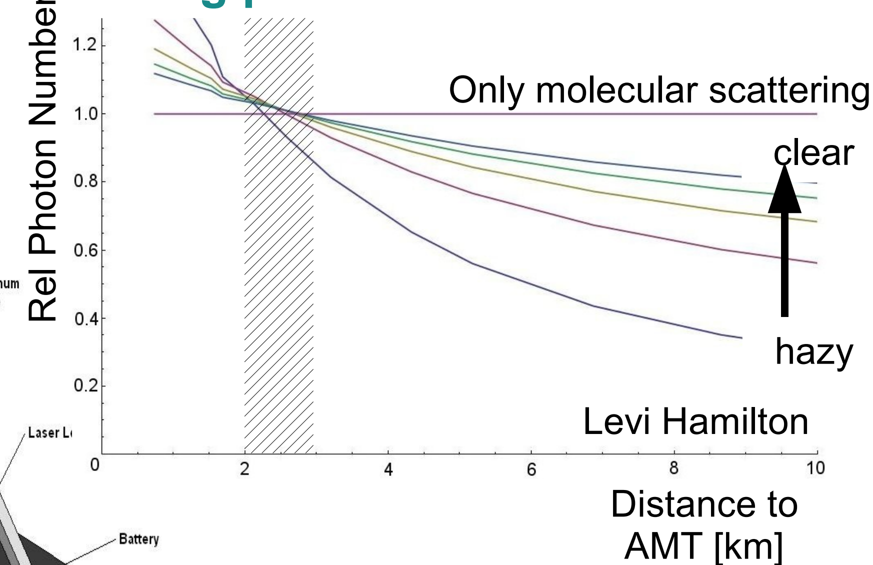
Normalized DLF Pulse Measurement vs Time

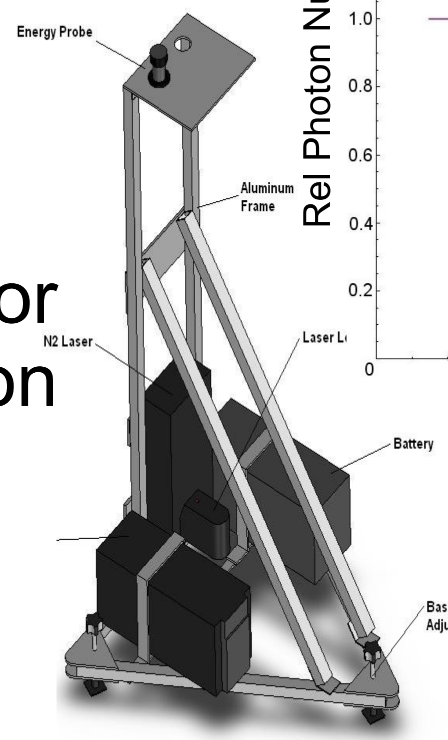


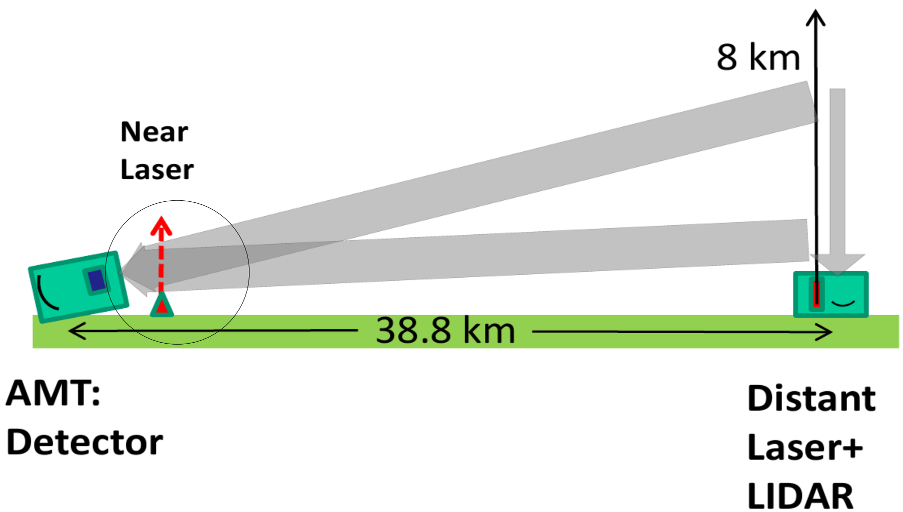
Auger North R&D Equipment

- Nitrogen Automated Integrated Laser System (NAILS)
  - Portable laser used for photometric calibration

Monte Carlo Simulations using parametric VAOD models







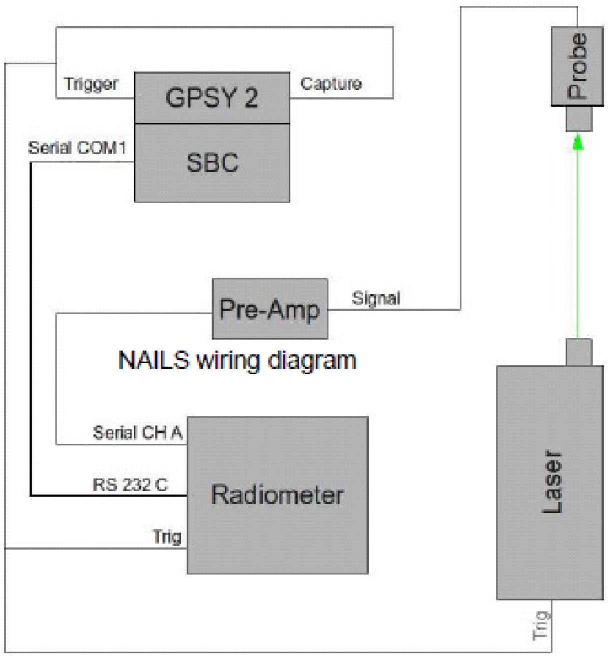
The Nitrogen Automated Integrated Laser System

Advisor: Lawrence Wiencke

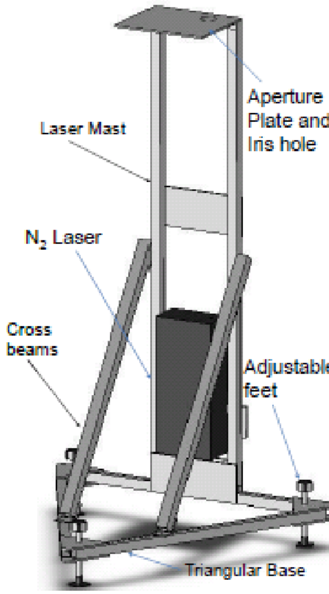
Adam Botts, Bryce Carande, Michael Calhoun, Michael Coco, John Claus, Lucas Emmert, Levi Hamilton, **T.J. Heid**, Sarah Morgan

Background

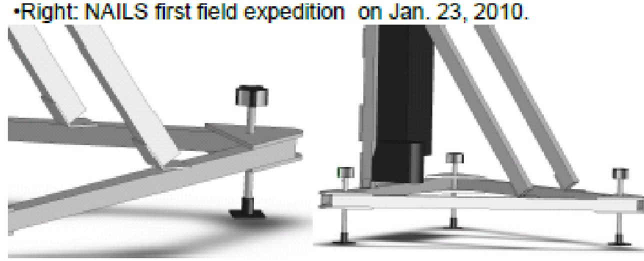
The (NAILS) is a portable roving laser system used to provide absolute photometric calibration for the AMT used at the future site of the Northern Pierre Auger Observatory. The observatory is looking for ultra high energy cosmic rays by observing the resultant shower of secondary particles that arise from the interaction of the ray with the atmosphere. The laser simulates a cosmic ray by scattering off aerosols in the atmosphere like the ray's shower of particles would.



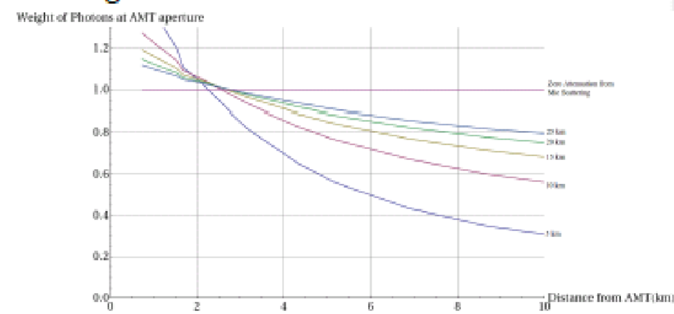
- All electronics powered by uninterruptable power supply
- The Single board computer (SBC) sends a trigger signal to the radiometer and the laser timed of the GPS clock.
- Probe readings are sent through the calibrated pre-amp then to the analog input on the radiometer.
- The radiometer gives the digital reading to the SBC over an RS232 serial cable where the data is stored in the log files.



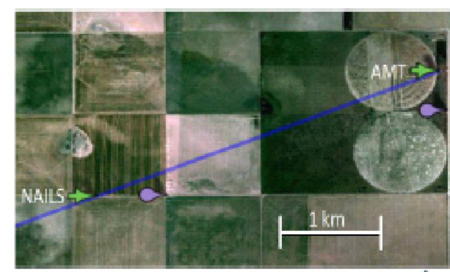
- Left: the NAILS design modeled in solid works.
- Right: NAILS first field expedition on Jan. 23, 2010.

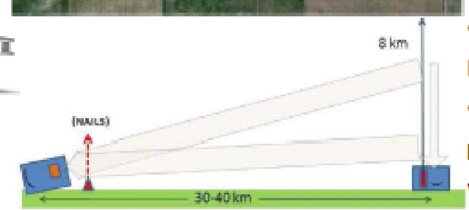


- Adjustable feet at each corner for vertical alignment.
- Two ¾" X ¾" aluminum cross beams for added stability.
- Energy probe and adjustable iris mounted on aperture plate.
- Leveling laser aligns with pre-calibrated target on aperture plate to provide vertical alignment.
- Adjustable iris provides attenuation of output energy and eliminates beam halo.



- Weight of Photons at AMT aperture vs. Distance from AMT (km) from simulation of scattering and attenuation effects.
- NAILS is operated at the point where effects cancel.
- The spot is located approximately 2.5 km from the AMT.
- NAILS coordinates: 37' 38.566" LAT -102 deg 27' 21.033" LONG





- Satellite view of the AMT and NAILS sites.
- NAILS site picked to be on Co-Rd. 34.
- DLF located 30 km northeast of AMT
- AMT – NAILS – DLF configuration.
- AMT tilted up 7° provides 13° field of view

References

[1] The Pierre Auger Collaboration, *The Fluorescence Detector of the Pierre Auger Observatory*. May 25, 2009, pp. 31 – 40.
[2] L. Wiencke, *Atmospheric Monitoring R&D plan for Auger North*. Feb. 4, 2009.
[3] J. Abraham et al., Atmospheric effects on extensive air showers observed with the surface detector of the Pierre Auger observatory, Astropart. Phys. (2009), doi:10.1016/j.astropartphys.2009.06.004

NAILS: Performance and Calibration

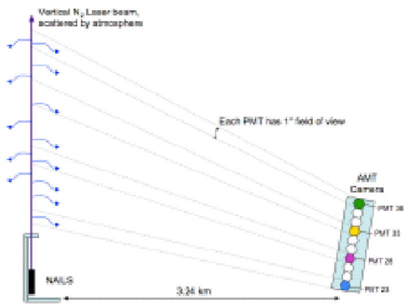
Bryce Carande

With Adam Botts, Michael Calhoun, Michael Coco, John Claus, Lucas Emmert, Levi Hamilton, T.J. Heid, Sarah Morgan

Advisor: Lawrence Wiencke

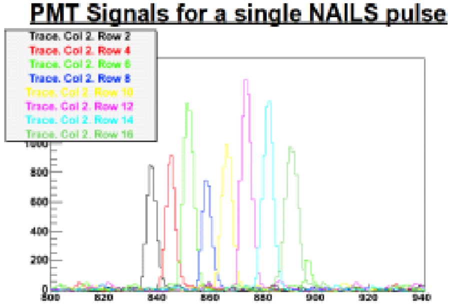
Background

The Nitrogen Automated Independent Laser System (NAILS) is a portable, self-powered laser system for use in the atmospheric R&D of the Pierre Auger North site. NAILS fires a laser pulse vertically into the sky, and scattered light from this pulse is observed 3.24 km away by the AMT.



- AMT camera composed of PMT array
- Each PMT sees laser pulse at different angle
- PMT array tracks laser pulse as it travels upwards

PMT Signals for a single NAILS pulse

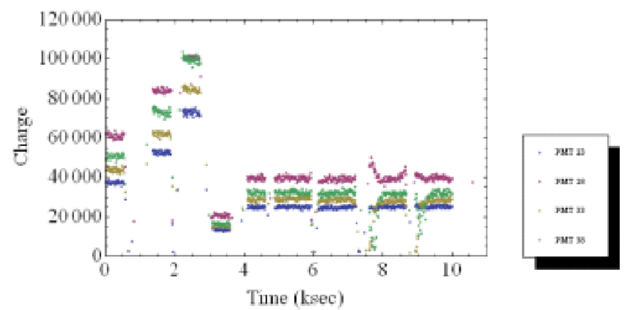


Goals

- Provide nearby laser system (insensitive to aerosol condition)
- Measure stability of system and atmosphere over multi-hour duration
- Calibrate relative PMT gains
- Relate energy level of laser pulses to observed signal →**Photometric calibration of AMT detector**

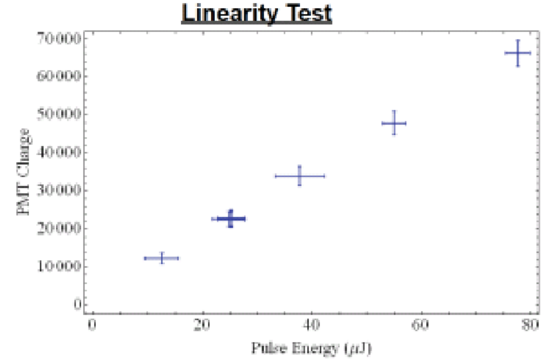
Stability and Linearity

AMT Measurements over multiple energy sets



- Many pulses fired at varied energy levels
- Energies above 70 μJ saturate detector
- Measurements very stable during good weather conditions
- Cloud cover strongly affects measurements

Linearity Test

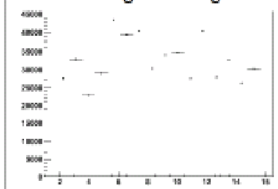


- Averaged measurements of each energy group
- Used data from PMT 23 – least likely to see clouds
- Related pulse energy (measured at NAILS) to PMT charge (observed at AMT)
- Linearity in laser energy and observed PMT charge

Relative Calibration of AMT

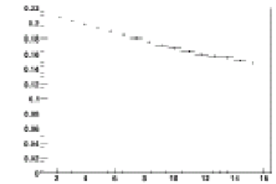
Observed

PMT Charge vs. Angle



Simulated

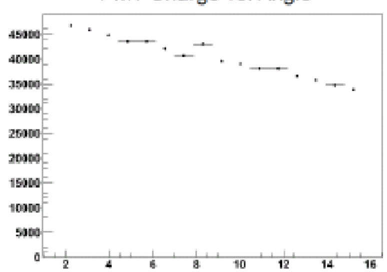
Normalized Photons vs. Angle



- PMTs operate at slightly different efficiencies
- Data recorded from NAILS pulse compared to simulation
- Individual PMT gains adjusted to match observed and theoretical data (camera 'flat-fielded')

Corrected

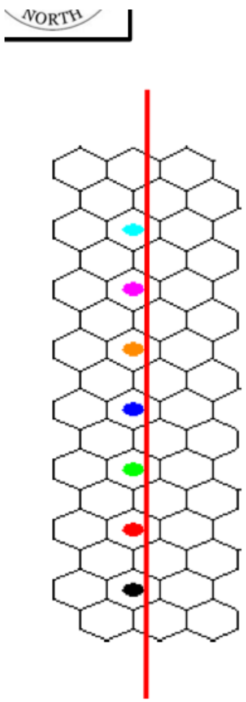
PMT Charge vs. Angle



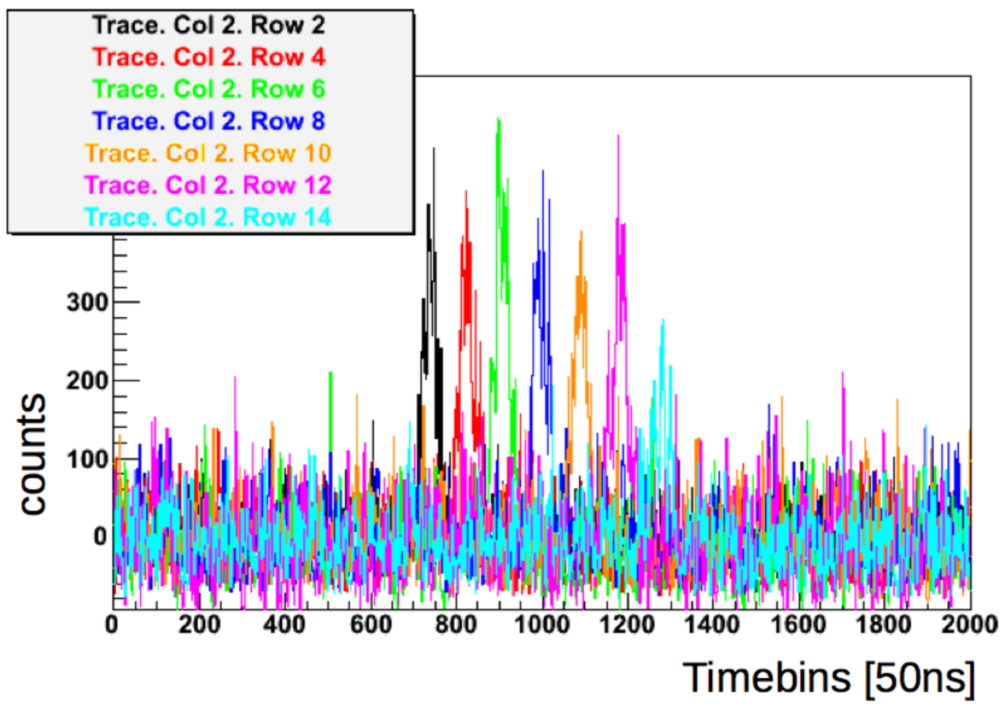
Conclusions

- NAILS provides nearby calibration laser for AMT
- Observed signal stable over many hours
- Observed signal increases linearly with pulse energy
- Accumulated results allow relative calibration of AMT camera
- NAILS will continue to provide AMT with means of absolute photometric calibration

DLF vs NAILS Pulses

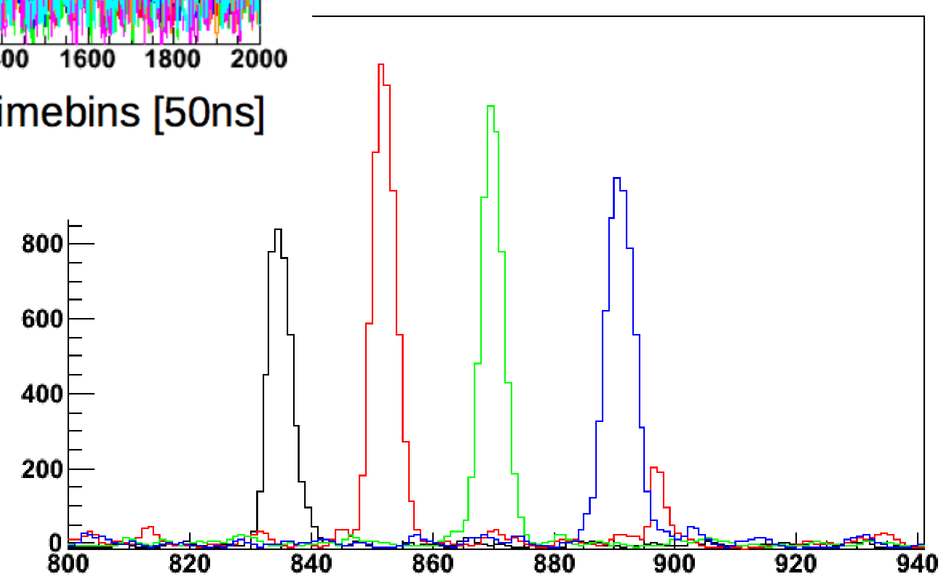


Lasers on Camera

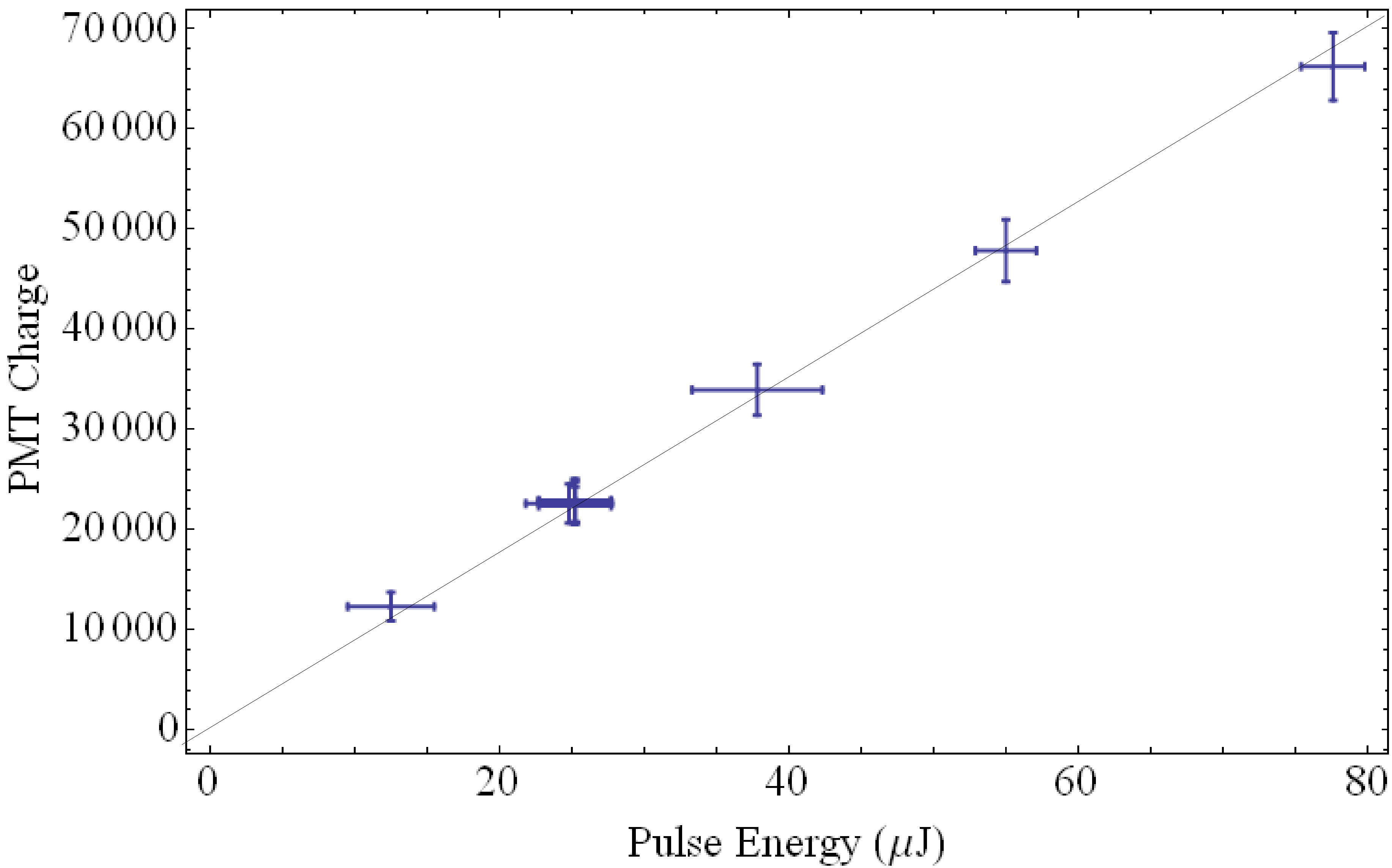


DLF- 40 km (7 mJ)

NAILS- 3 km (0.07 mJ)

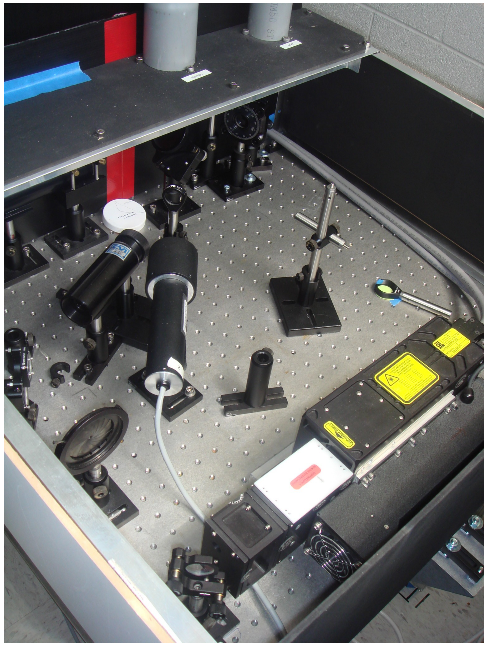


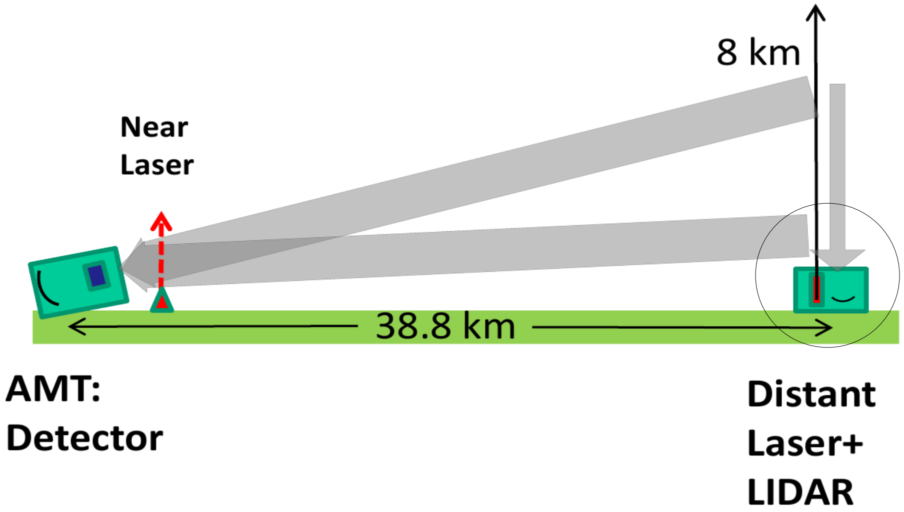
Linearity test with NAILS (3 km)

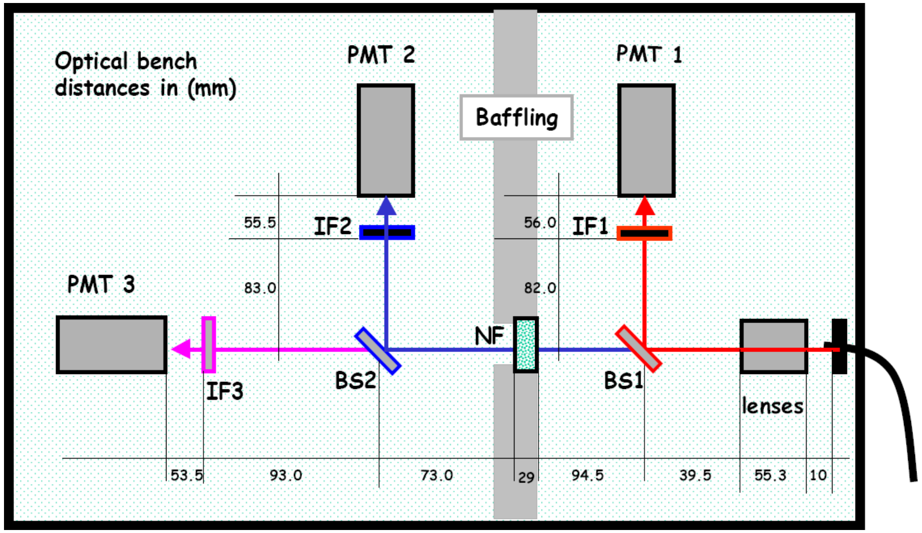


Auger North R&D Equipment

- Distant Raman Laser Facility (DRLF)
  - Laser system used to fire vertical laser shots
    - Raman LIDAR measures VAOD from backscattering
    - AMT measures VAOD from side scattering

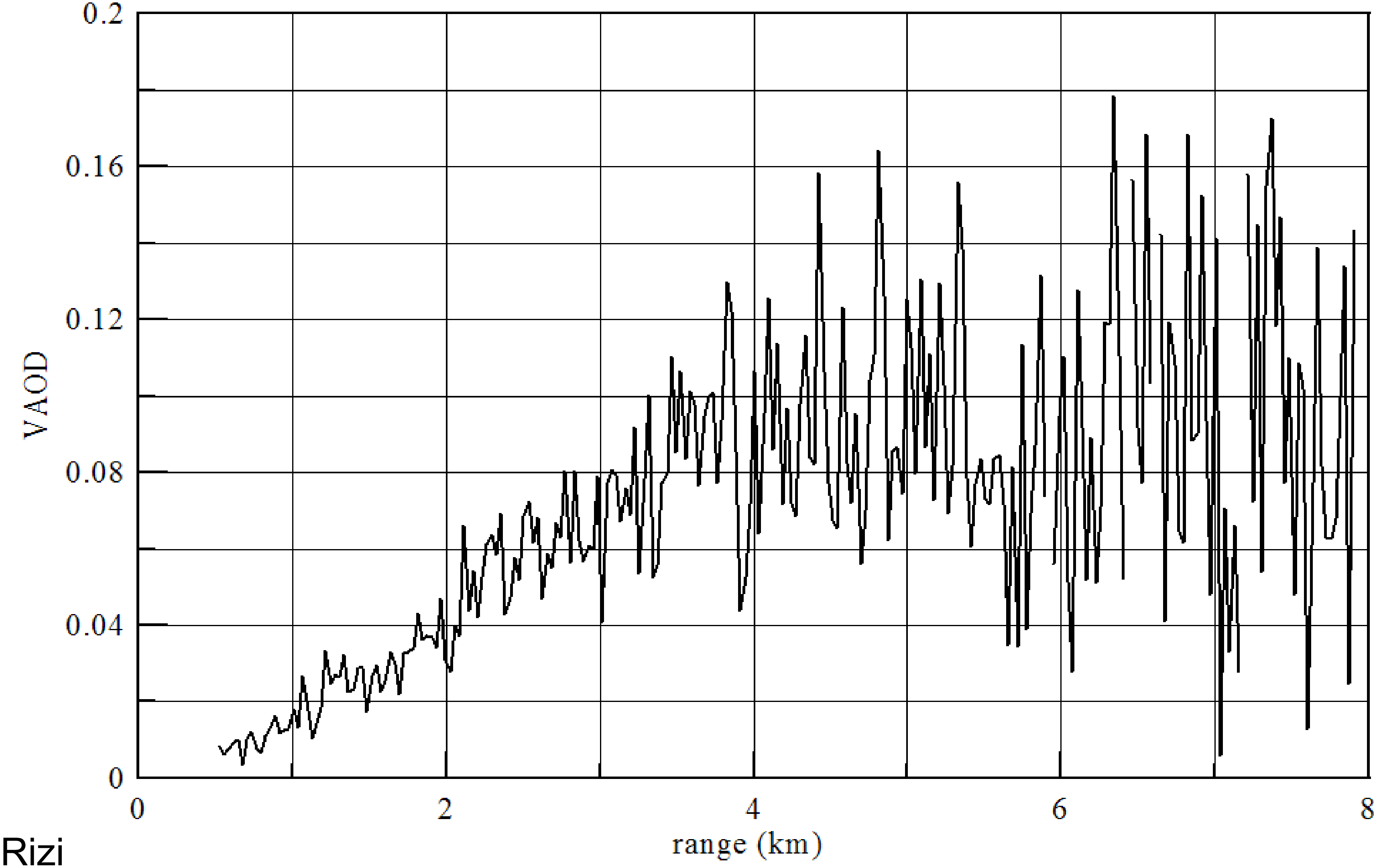






Raman LIDAR VAOD Measurement

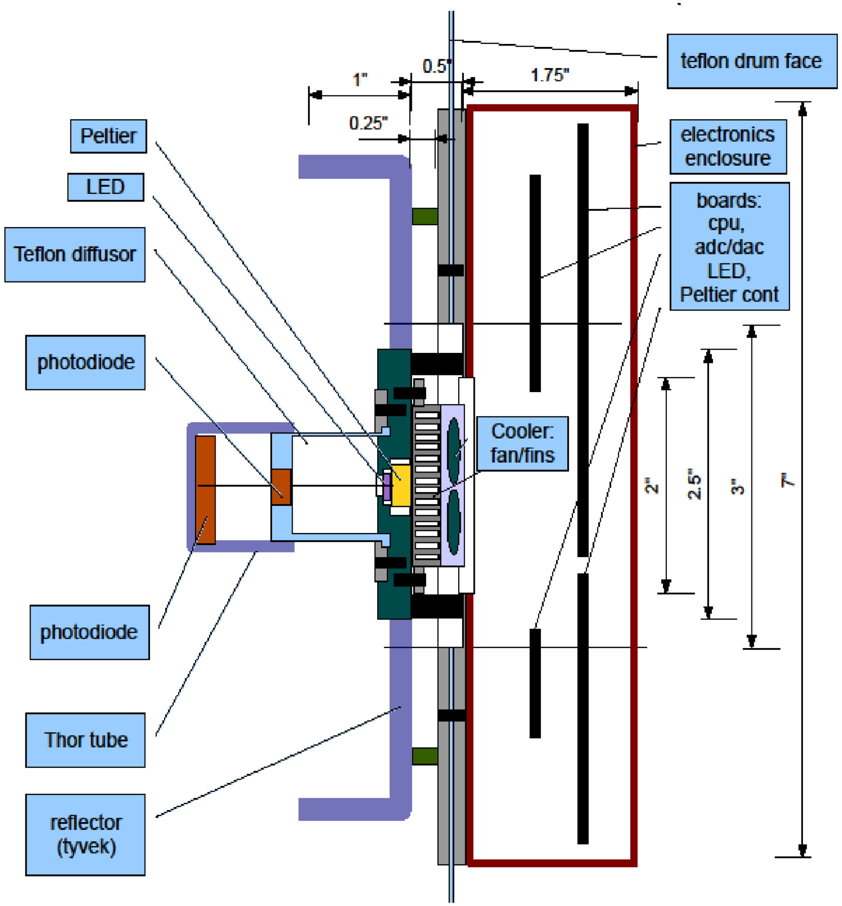
LAMAR 06_08_2010-041719-042656 (10min) **vertical aerosol optical depth**



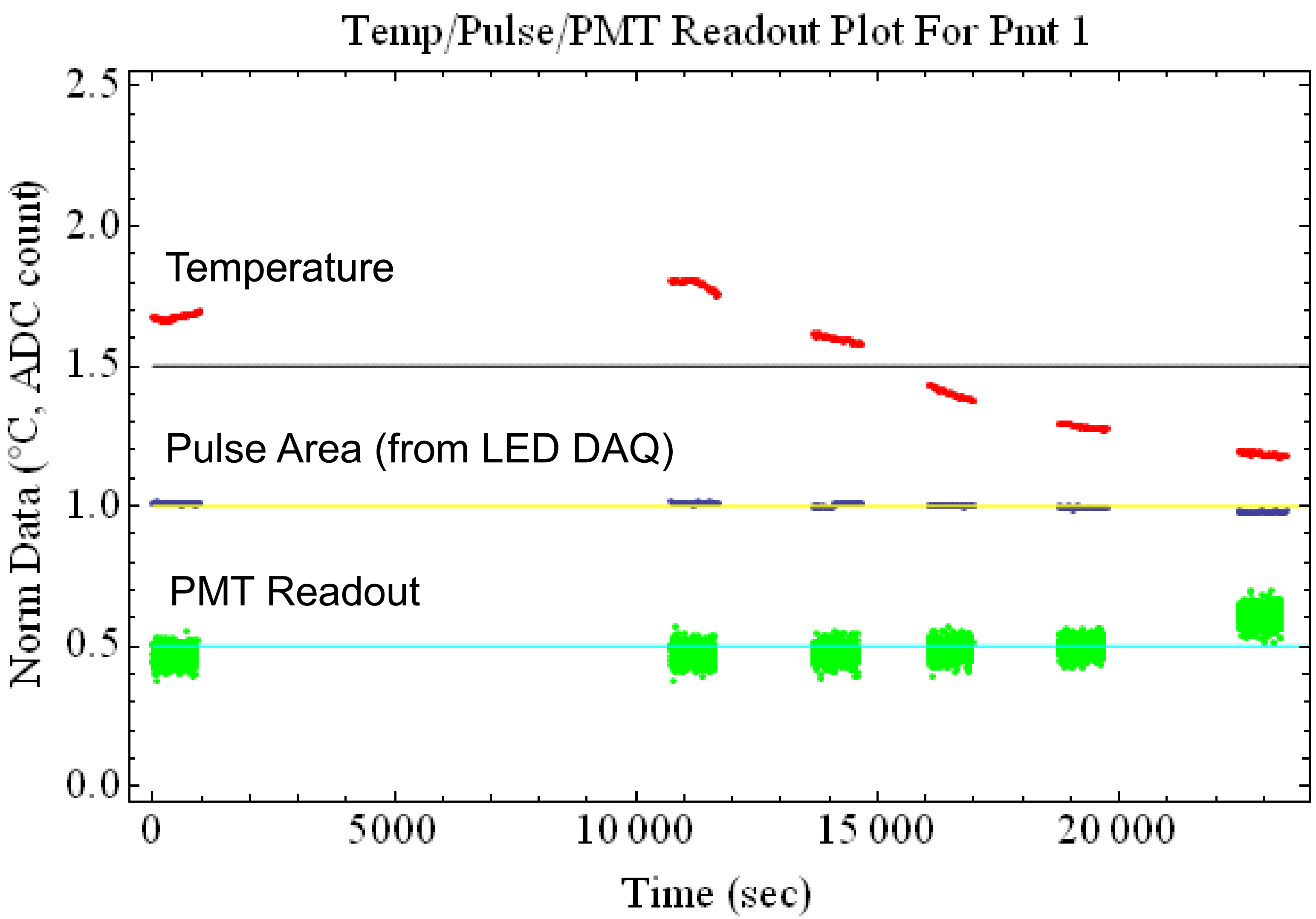
V.Rizi

Auger North R&D Equipment

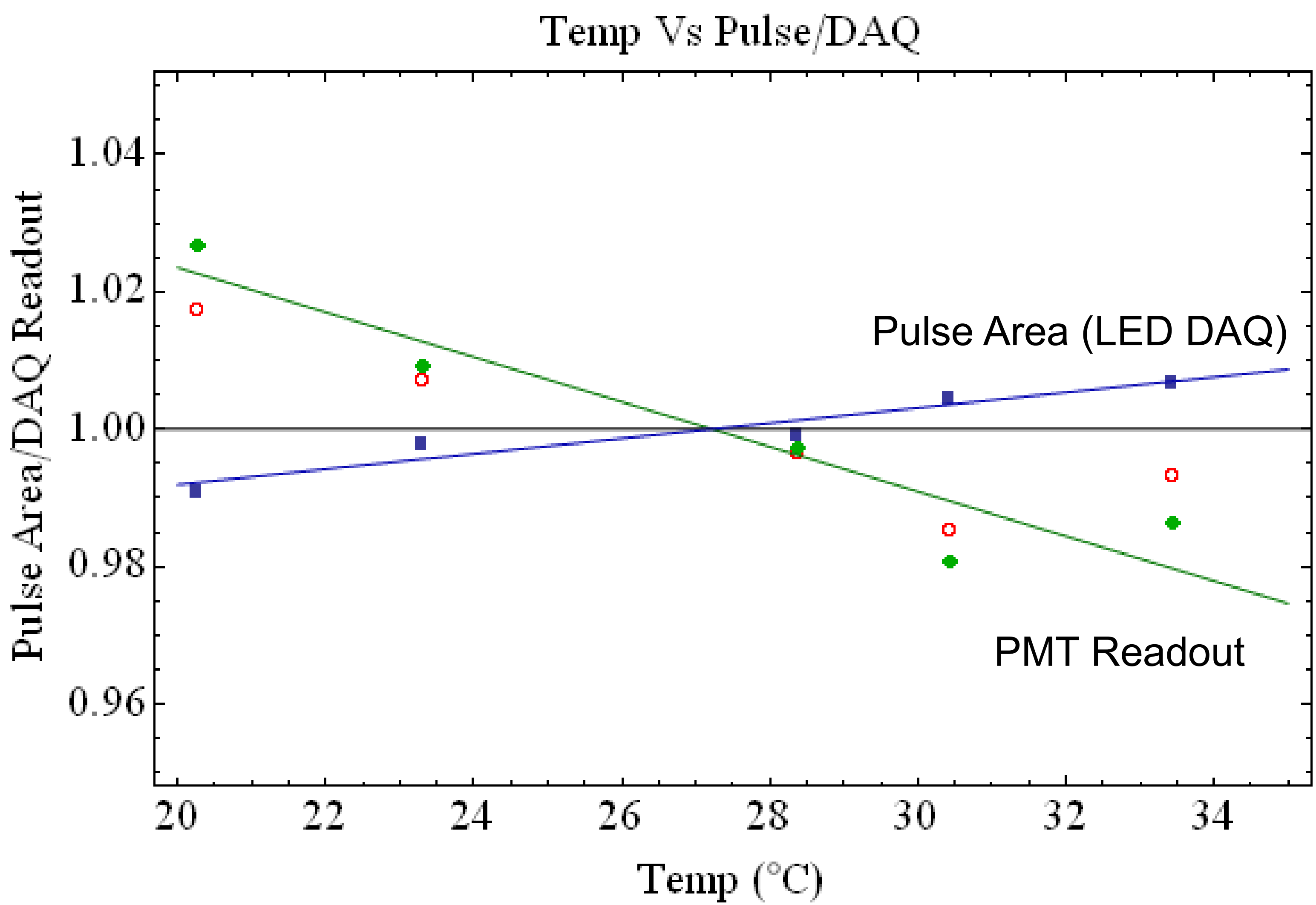
- Temperature controlled UV LED
  - Fires UV light inside the AMT
  - Used for PMT calibration
  - Located at center of AMT mirrors



UV LED Time/Temperature Stability



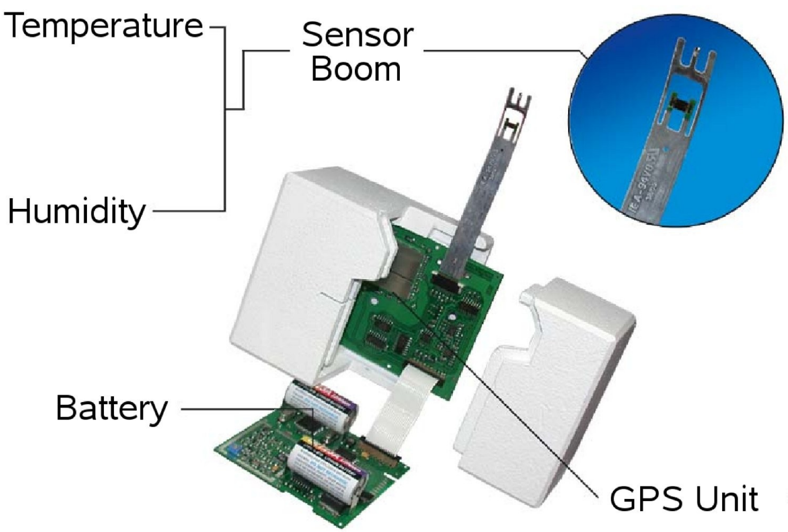
UV LED Temperature Stability



Red Dots- ADC counts   Green Dots- ADC/PulseArea

Auger North R&D Equipment

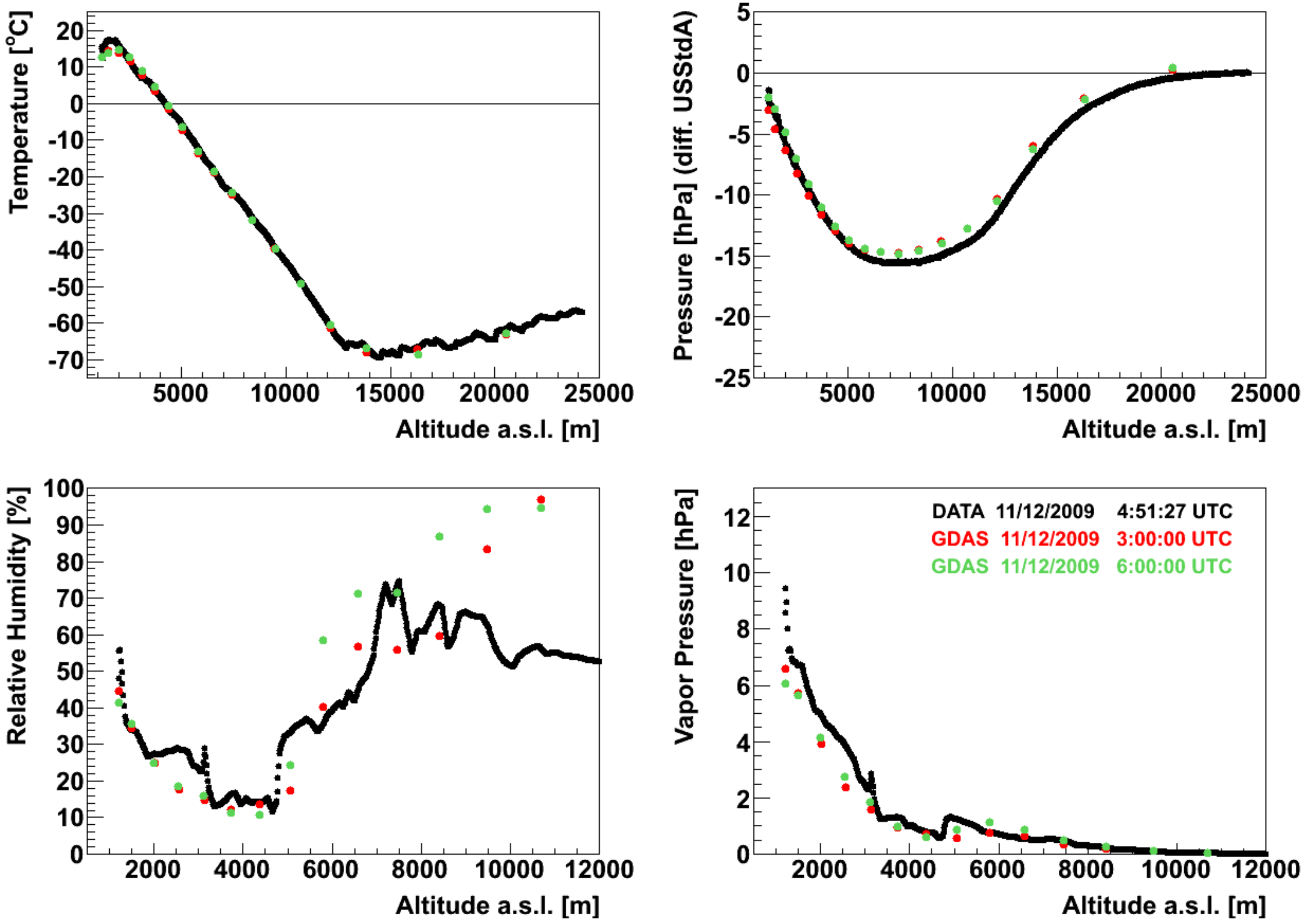
- Radiosonde Balloons
  - Measures temperature, pressure, rel. humidity, wind
  - Used to characterize molecular atmosphere



First Launch Oct 14, 2010

GDAS Auger North

- •Global Data Assimilation System (GDAS)
- Good agreement with measured data



M.Will

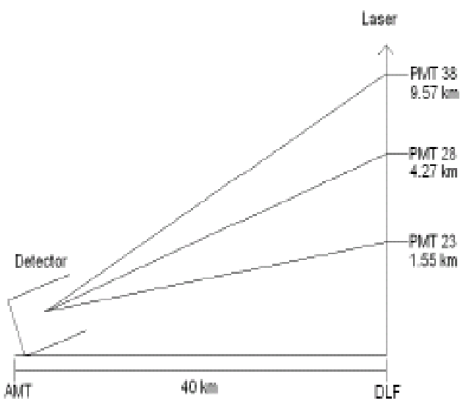
Atmospheric Monitoring Telescope: Characterizing Different Atmospheric Conditions

Michael Calhoun, Adam Botts, Bryce Carande, Michael Coco, John Claus, Lucas Emmert, Levi Hamilton, T.J. Heid, Sarah Morgan
Advisor: Lawrence Wiencke

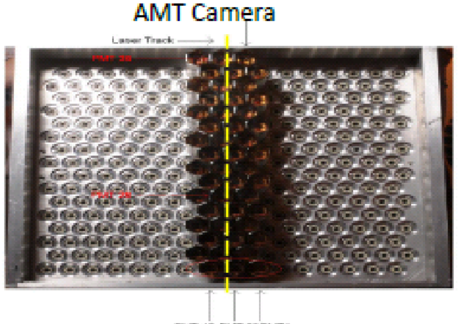
First Atmospheric Measurements at Auger North Site

- Measurements taken from 40 km away
- Clouds
  - Measure time and height
- System response
  - Stability
  - Laser and AMT gain stable
  - Small changes in VAOD can be seen

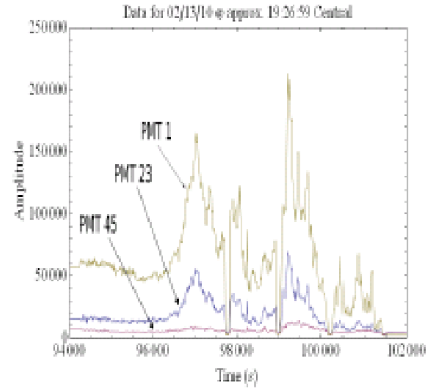
- AMT: Atmospheric Monitoring Telescope
- PMT: Photomultiplier Tube
- VAOD: Vertical Aerosol Optical Depth
  - Transmission of light through Atmosphere
  - Scattering from molecules and aerosols
  - Function of Height



AMT Camera

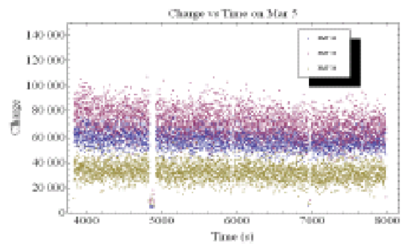


Clouds: February 13, 2010

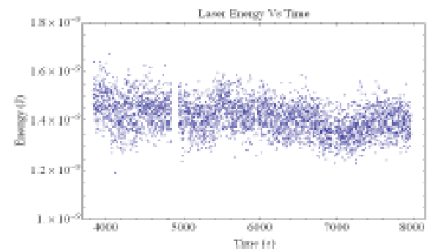


- Clouds scatter more light
- Early in the night no cloud
- Later in the night cloudy
  - Clouds above DLF will increase the PMT signal
  - A cloud in between the DLF and AMT will reduce the signal

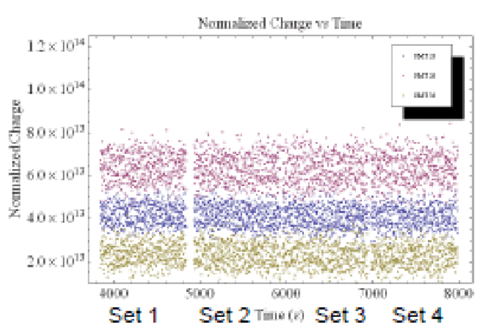
No clouds: March 5, 2010



- Point is a single laser shot
- PMT signals drop over the night
  - Aerosols? Laser? PMT's?



- Relative laser energy drops over the night



- Signals normalized to relative laser energy
- Detector and atmosphere stability
  - To 3 % below 4 km
  - To 10% at 10 km

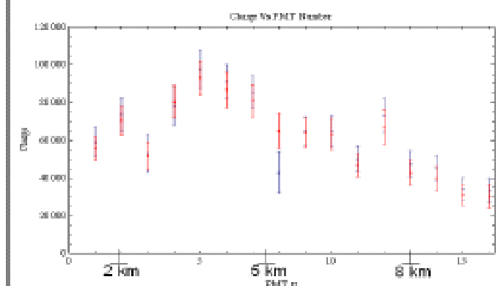
	PMT 23 1.5 km	PMT 28 4.3 km	PMT 38 9.6km
Set 1	1.00	1.00	1.00
Set 2	1.02	1.00	0.96
Set 3	0.99	0.99	0.93
Set 4	0.99	0.99	0.91

- A set is an average of 1000 shots
- Each set is normalized to set 1

Instrument Sensitivity

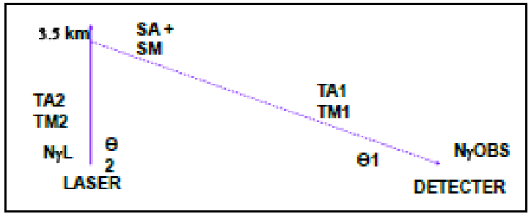
- See changes for three reasons
  - Laser energy
  - AMT gain
  - Atmosphere
    - Largest and most variable

Laser Light Profile: March 5, 2010



- Points Represent 10 min average
  - Can be used to calculate VAOD at specific height.
- Error bars are the Standard deviation of each set
- Two samples: 1 hour apart

Measurement of Vertical Aerosol Optical Depth



$$N\gamma_{OBS} = N\gamma_L T_{M1} T_{A1} (S_M + S_A) T_{M2} T_{A2}$$

$$N\gamma_{MOL} = N\gamma_L T_{M1} S_M T_{M2} \qquad T_A = e^{-(VAOD/\sin\theta)}$$

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

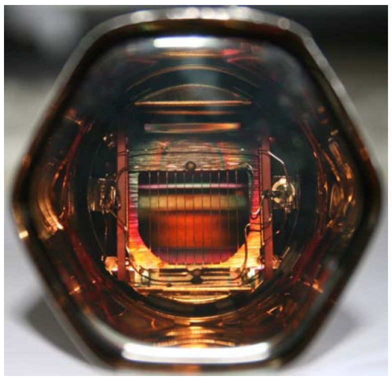
Conclusions

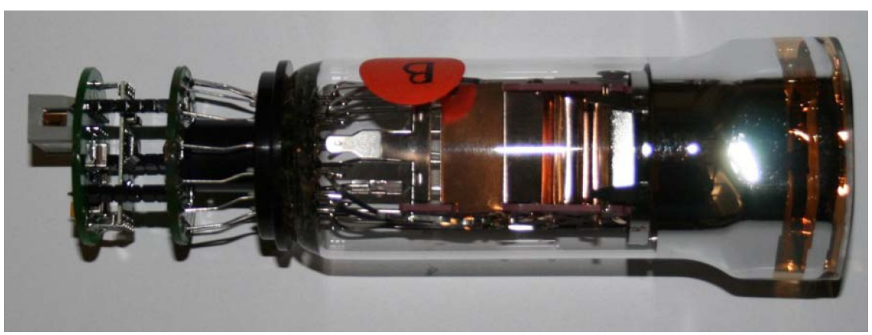
- System is working and stable over time
- Is photometrically stable to a level better than 10%
- Can see significant changes in VAOD with small changes in transmission
  - 0.005 change in VAOD with expected average of 0.05 to 0.1 for site

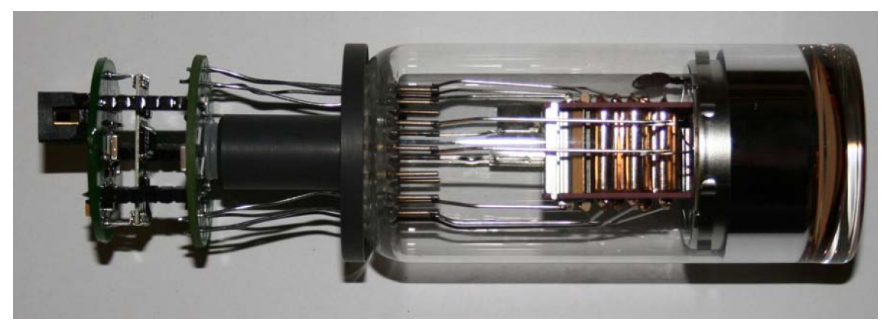
Planned PMT Upgrade

Old PMT

High QE PMT

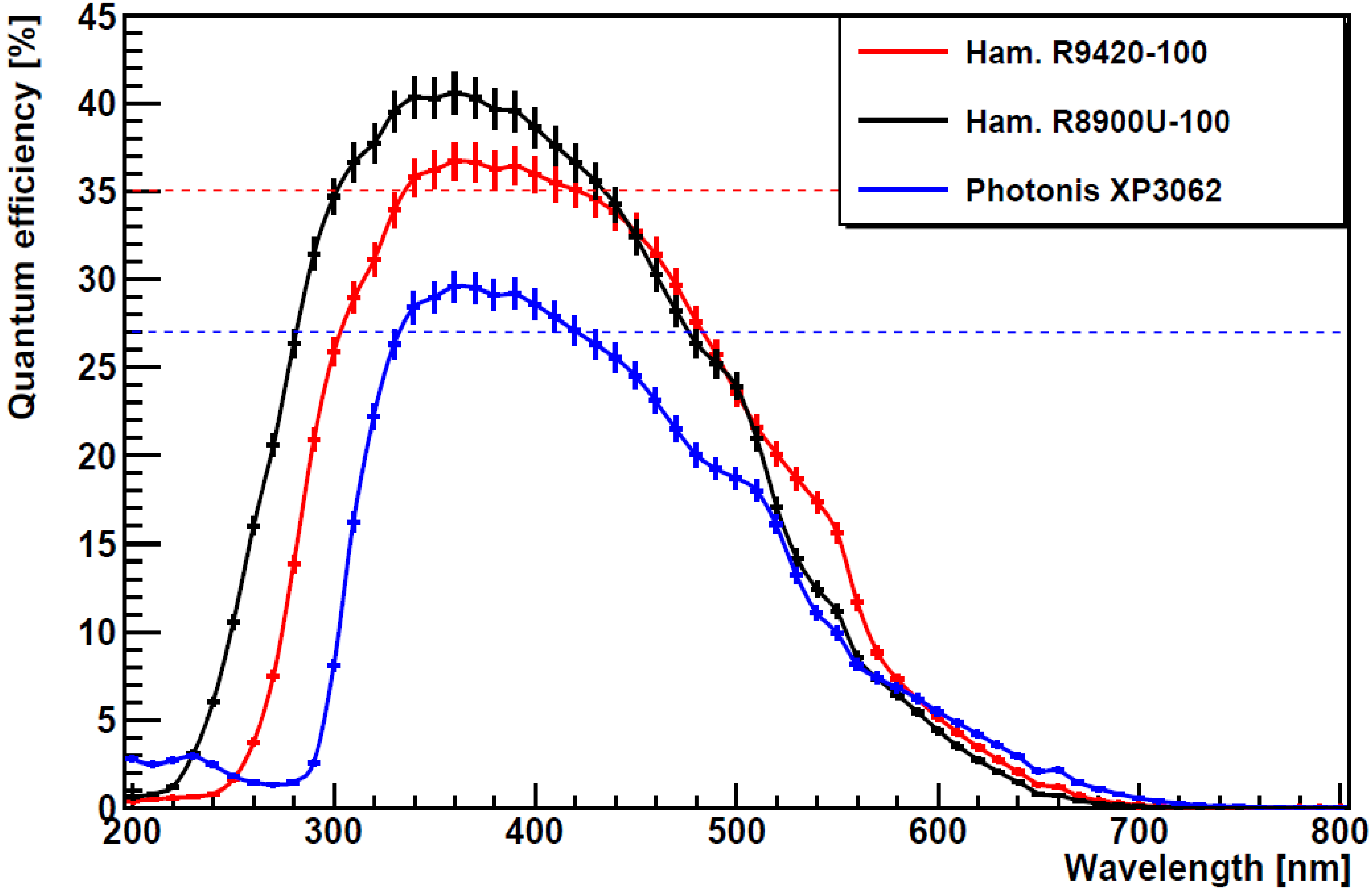






Will soon upgrade to PMTs higher quantum efficiency at AMT.

PMT QE Comparison

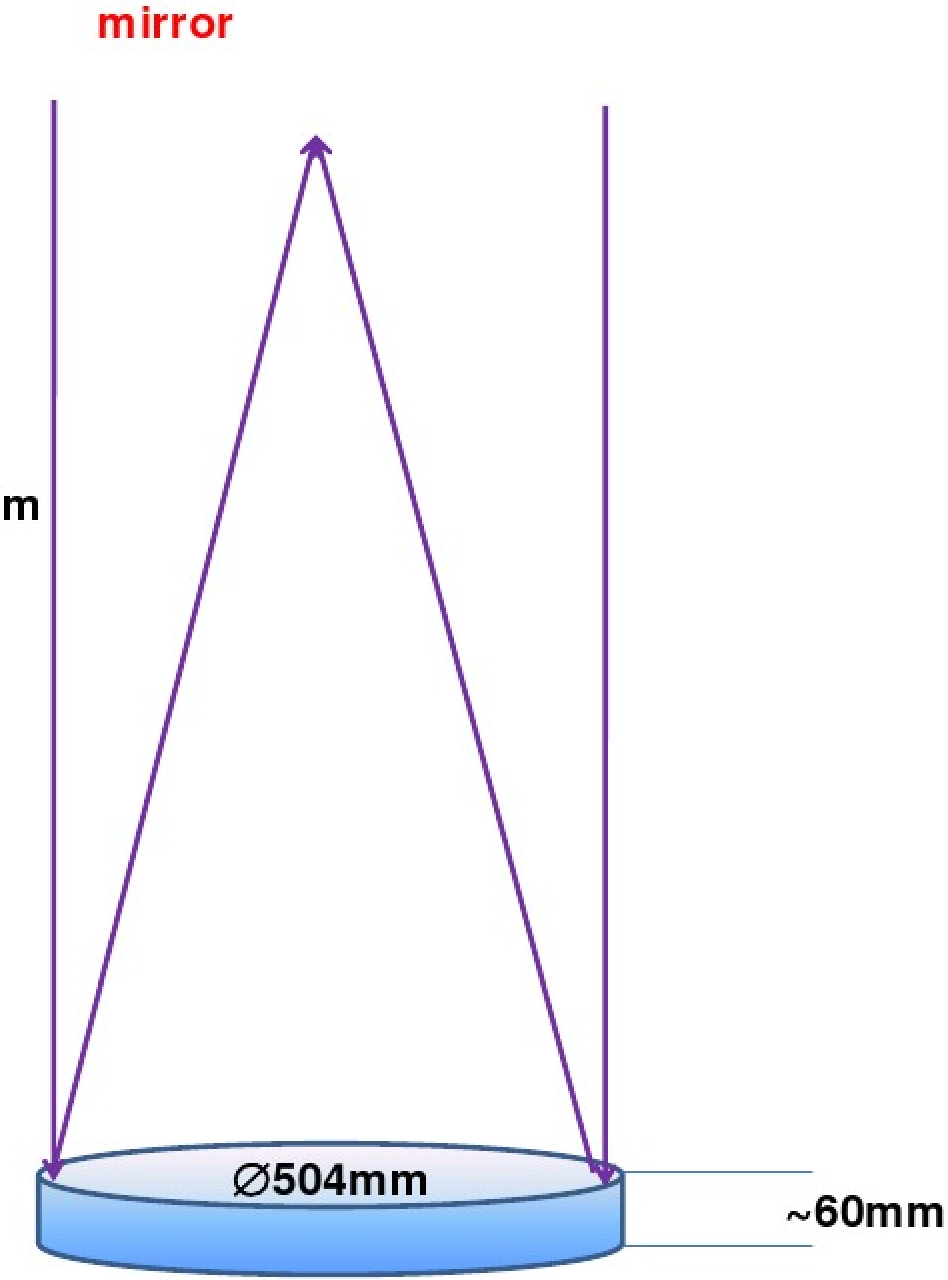


Sven Querchfeld, Wuppertal

Conclusion

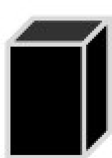
- Very active group for Auger North R&D
- On track to measure atmospheric clarity at AN
  - Raman LIDAR installed July 2010
  - Most equipment can be operated remotely
- Great test bench for Auger South
  - Temperature controlled UV LED, GDAS models, Roving Laser, "Super Test Beam"

Laser/telescope optical bench

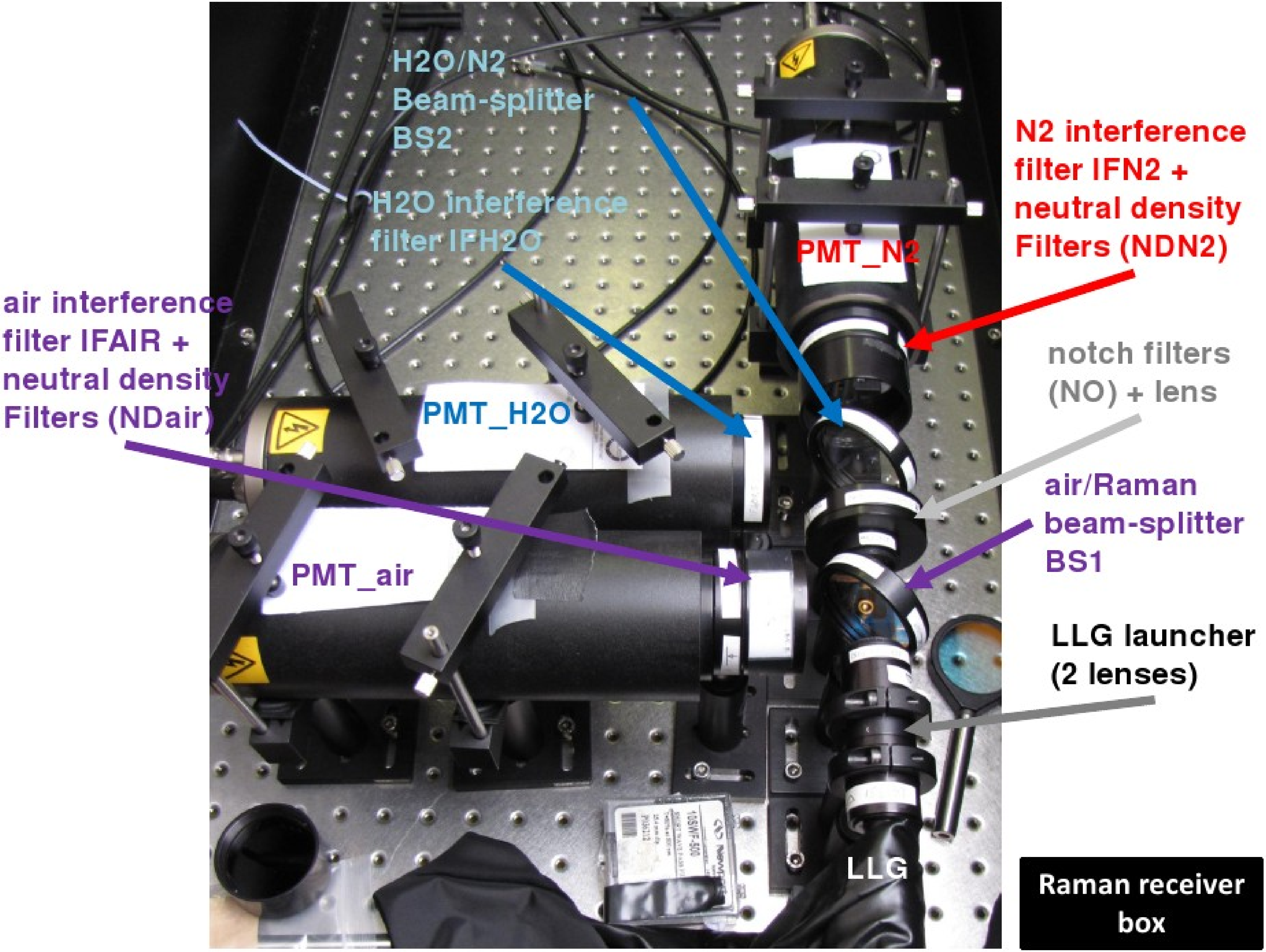


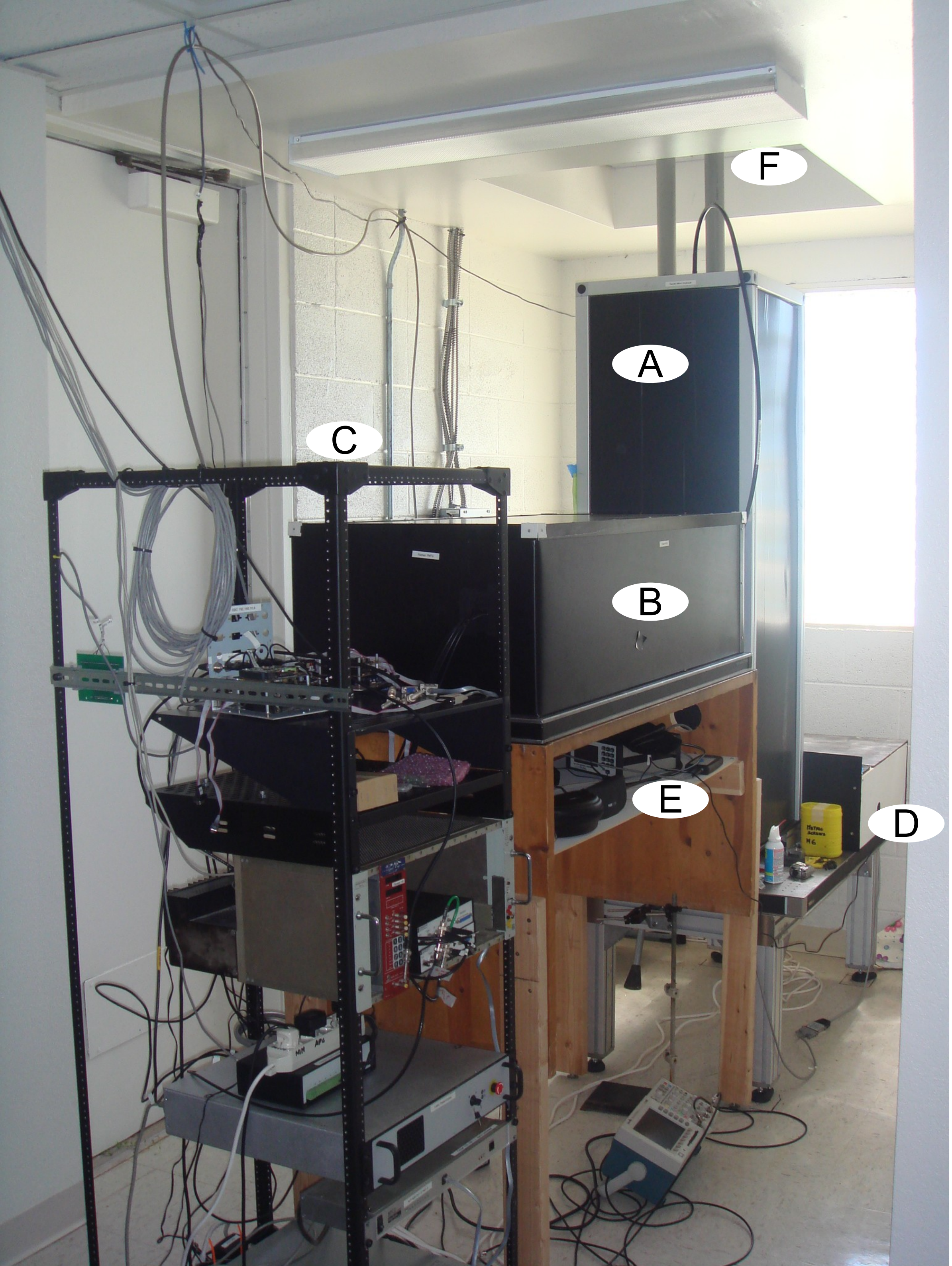
focal length 1500mm
f/number 3
MgF_2 coating
Al protection

weight ~30kg



telescope system


H2O/N2
Beam-splitter
BS2
N2 interference
filter IFN2 +
neutral density
Filters (NDN2)
PMT_N2
H2O interference
filter IFH2O
air interference
filter IFAIR +
neutral density
Filters (NDair)
PMT_H2O
notch filters
(NO) + lens
air/Raman
beam-splitter
BS1
PMT_air
LLG launcher
(2 lenses)
LLG
Raman receiver
box



DRLF System

A. Mirror Enclosure

B. Receiver Box

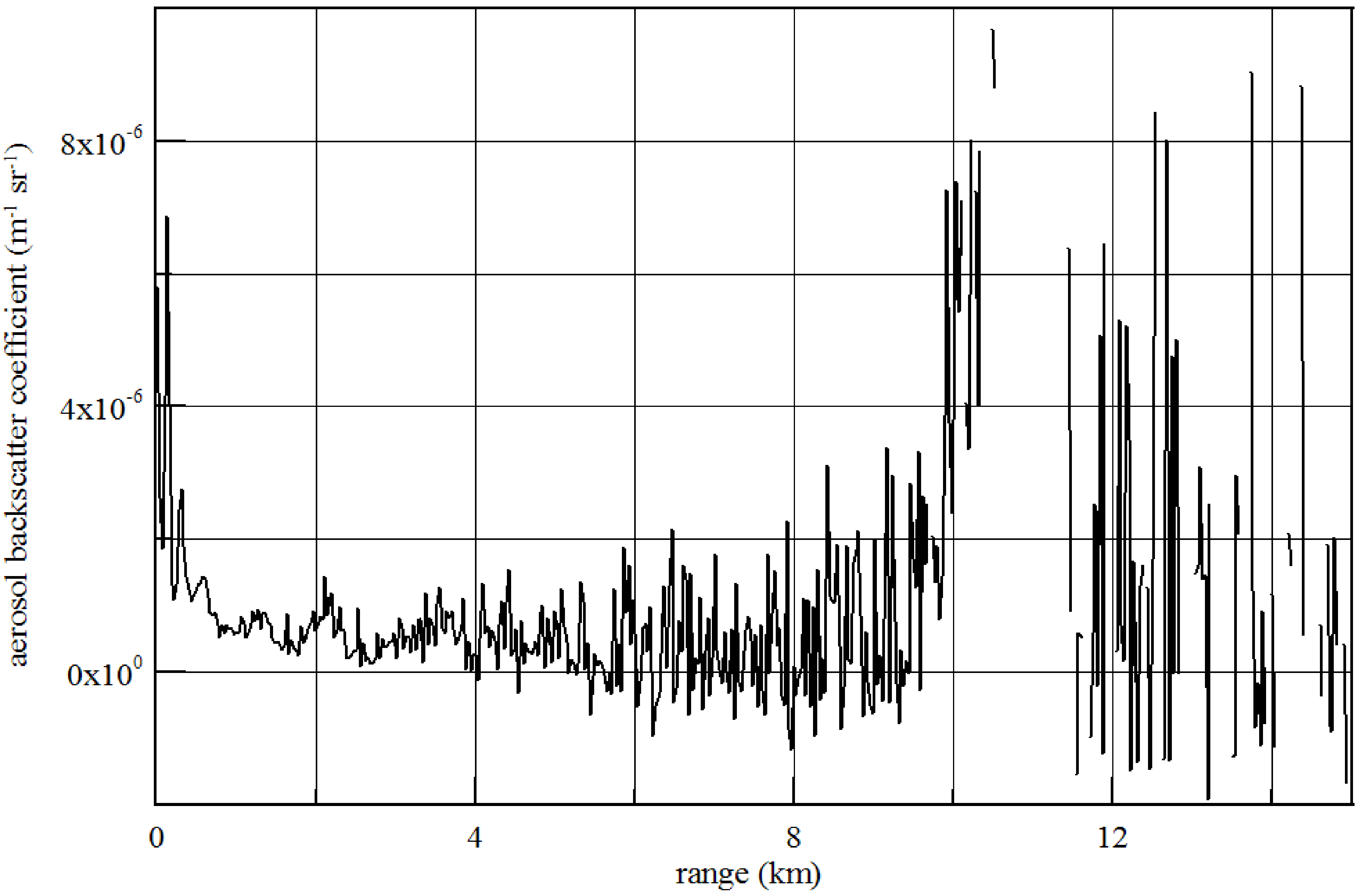
C. Rack- SBC, HVPS, DAQ, RPCs, Weather Station

D. Laser/Optics Box

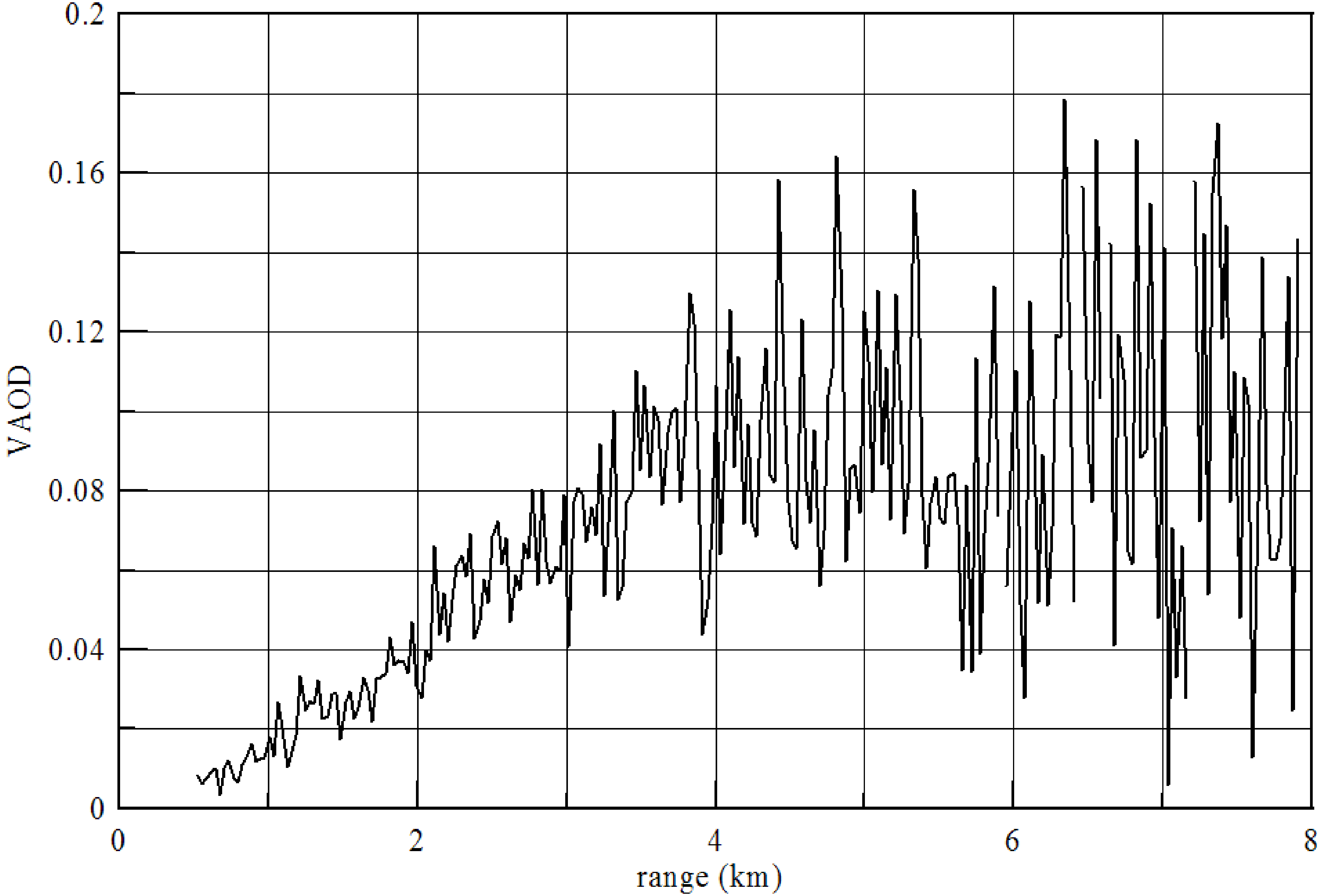
E. Radiometer

F. Window/Hatch

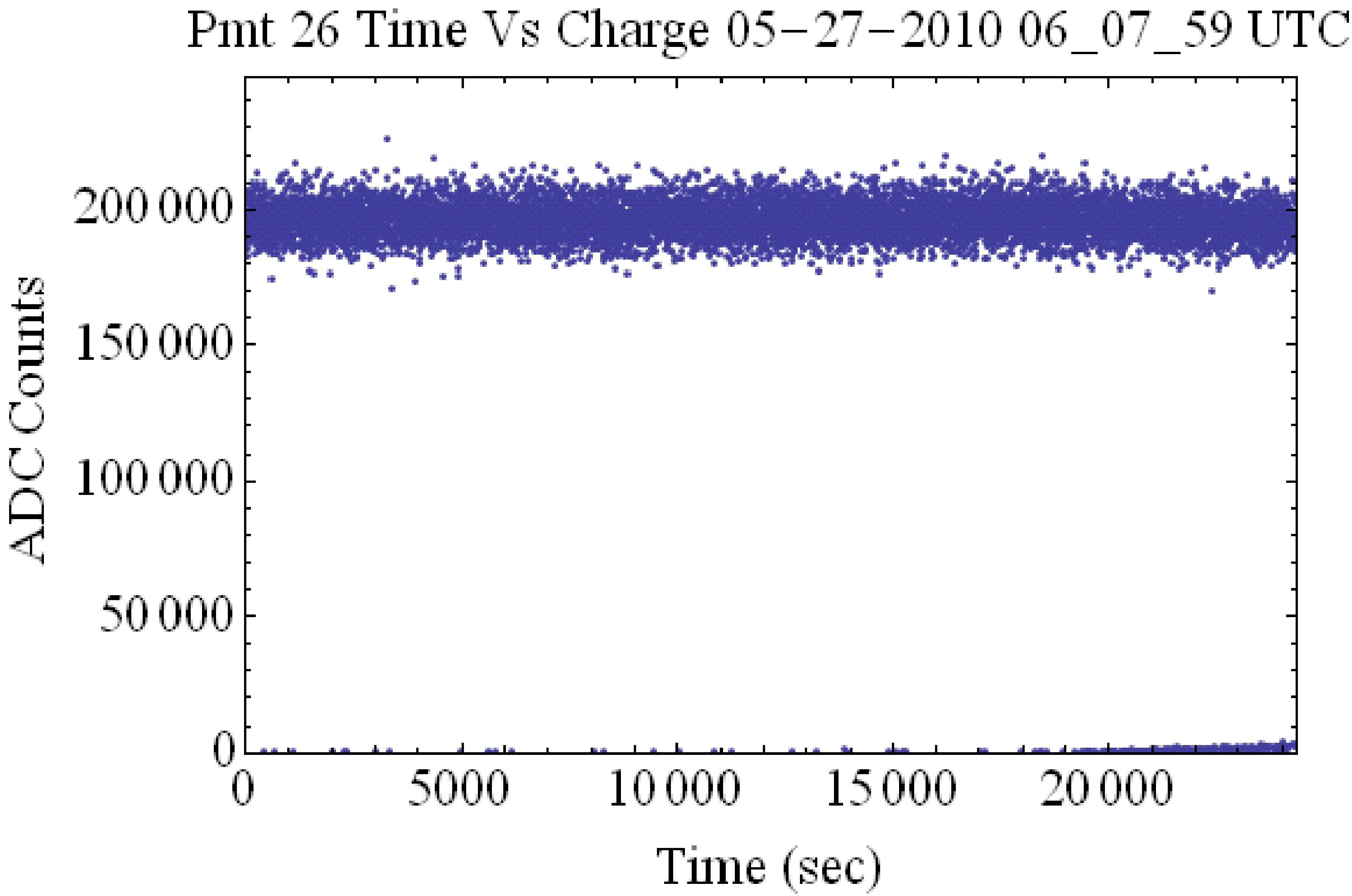
LAMAR 06_08_2010-041719-042656 (10min) aerosol backscatter coefficient



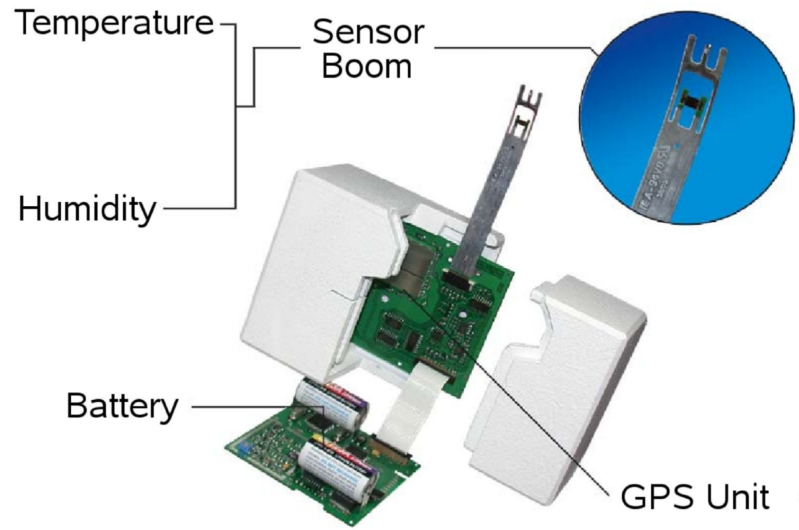
LAMAR 06_08_2010-041719-042656 (10min) **vertical aerosol optical depth**



UV LED First Data



Radiosonde Balloon Launches



- **Measured**

- Temperature
- Pressure
- Rel. Humidity
- Wind

- **Derived**

- Vapor Pres.
- Density
- Atm. Depth