

Update on Atmospheric Monitoring in Utah

Telescope Array Meeting

U. C. (Los Angeles)

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1. Introduction

Atmospheric Monitoring for Fluorescence Detector (FD) Experiments:

- Two broad categories of atmospheric monitoring:
 1. Detection and tracking of clouds
(*update from R. Clay and B. Dawson??*)
 2. Detailed characterization of the atmosphere for accurate reconstruction of the fluorescence signal
(*update from R. Grey and L. Wiencke??*)
(*update from M. Chikawa and N. Hayashida??*)
- There are two distinctly different corrections to the fluorescence data:

1. Transmission correction:

- (a) Light scattering in the atmosphere results in a finite transmission of light from the extensive air shower to the fluorescence telescopes
- (b) The observed light intensity, I , is related to the light intensity at the source, I_0 , as follows:

$$I \sim I_0 \cdot T^m \cdot T^a \cdot (1. + H.O.)$$

where T^m is the transmission based on Rayleigh scattering (on the molecular atmosphere), T^a is the

transmission based on Mie scattering (on aerosols in the atmosphere) and *H.O.* is a higher order correction (*aka* aureole).

- (c) The transmission corrections depend on the total number of scatterers between the source and the fluorescence detector and on the total cross sections.

2. Scattering of air Cherenkov background light into the fluorescence signal:

- (a) The observed light includes both air fluorescence signal plus some scattered air Cherenkov background.
- (b) The latter must be subtracted as part of the shower reconstruction/analysis.
- (c) This constitutes the second, *air Cherenkov*, correction to the fluorescence data.
- (d) The *air Cherenkov* correction depends on the local density of scatterers and on the differential scattering cross sections!

2. Overview of Recent Studies

- Dugway studies (mostly) use the HR2 steerable laser beam observed by HR1 or TA (at Cedar Mountain).
 1. Left *versus* Right symmetry?
 - Do we observe horizontal variations in the atmosphere transmission?
 - Learning pains from clouds and linearly polarized laser beams ...
 2. Detailed studies with linearly polarized laser light beams
 - Good progress ...
 - Q.: Should we continue polarization studies or move to circularly/randomly polarized laser beams?

3. Update on New Instrumentation

1. Steerable laser at HR1 (to be viewed by HR2 FADC system)

- Which laser (5mJ or 50mJ per pulse)?
- Which steering system (refurbish FE2 laser steering hardware or new commercial solution)?
- Goal is to work to a solution that could be used at future FD sites and with the roving laser **to minimize software development work load!**

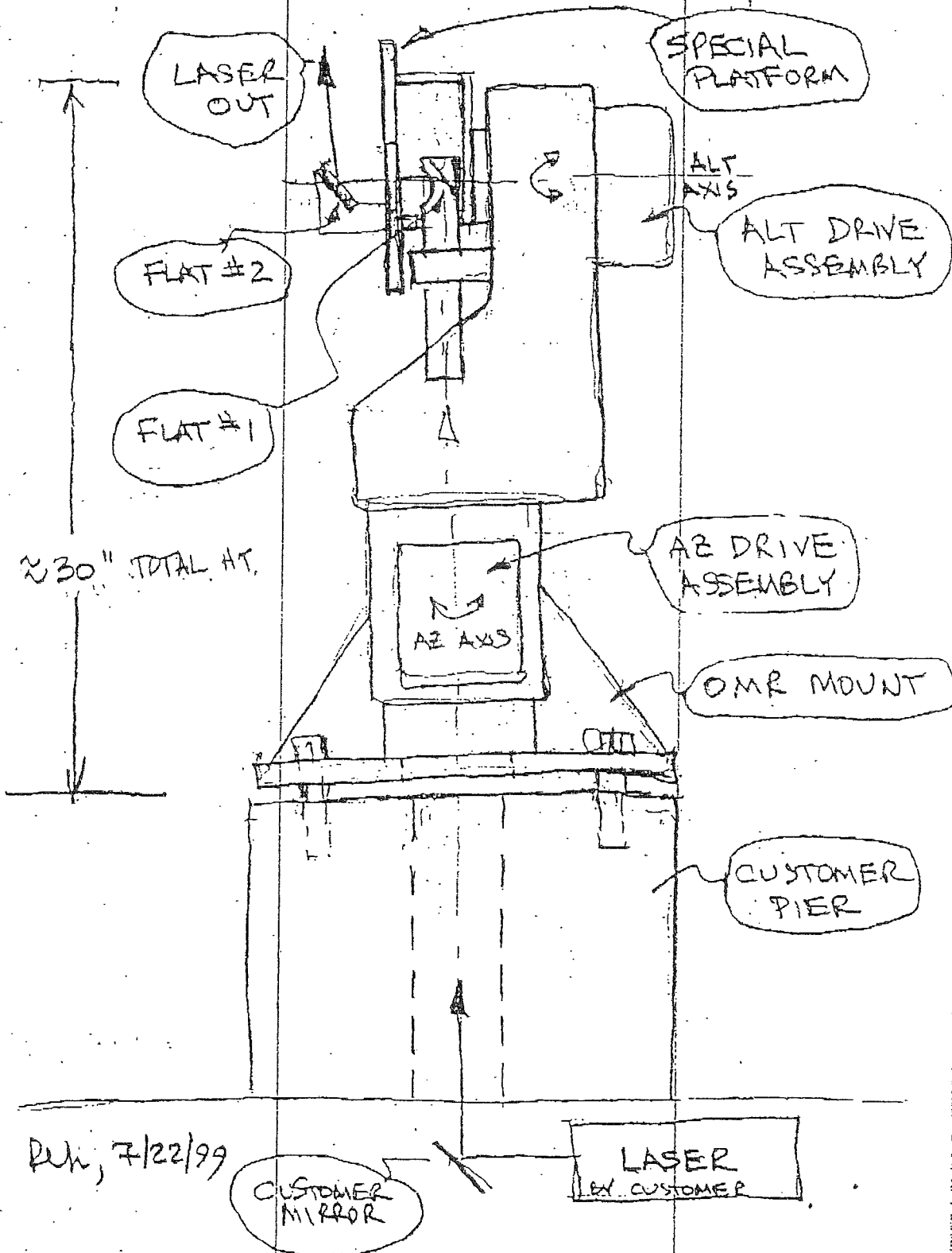
2. Horizontal attenuation length measurement at 5-wavelengths

- Inexpensive mercury vapor light source(s) ... start with one
- Meade ETX telescope
- Optec SSP-7 photometer

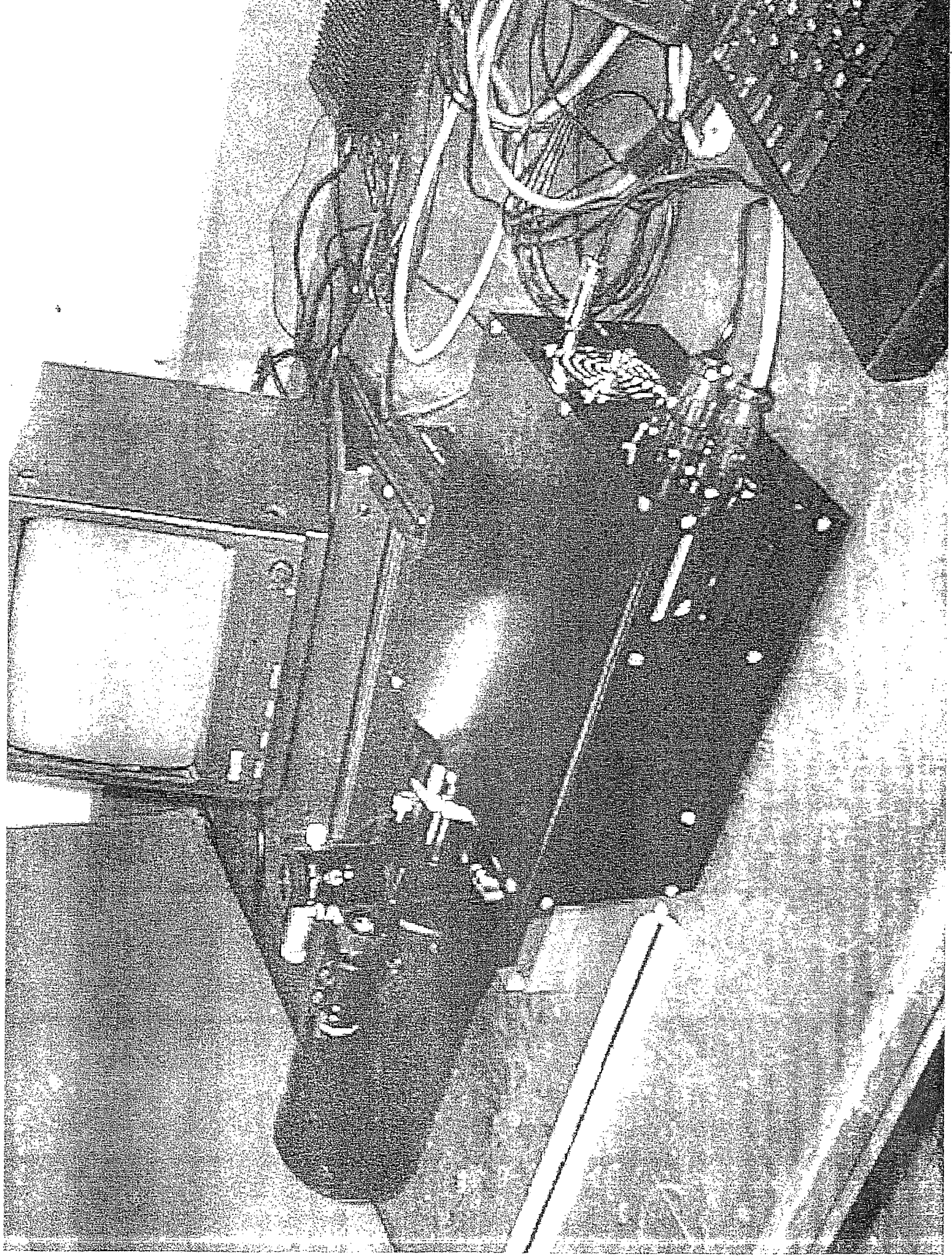
OPTOMECHANICS RESEARCH, INC.

P.O. BOX 87 • VAIL, AZ. 85641 • 520-002/647-3332

LASER STEERING SYSTEM







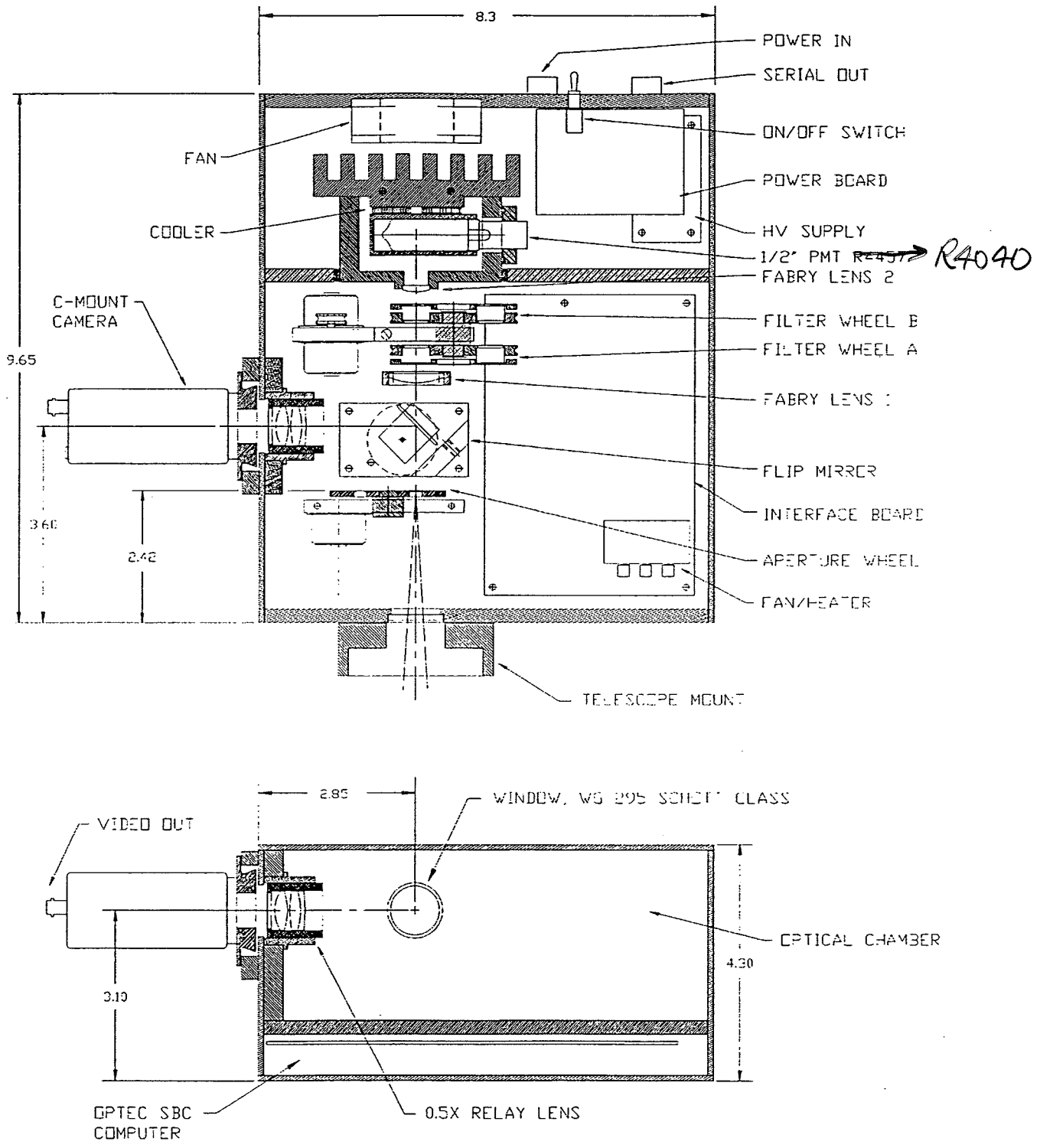
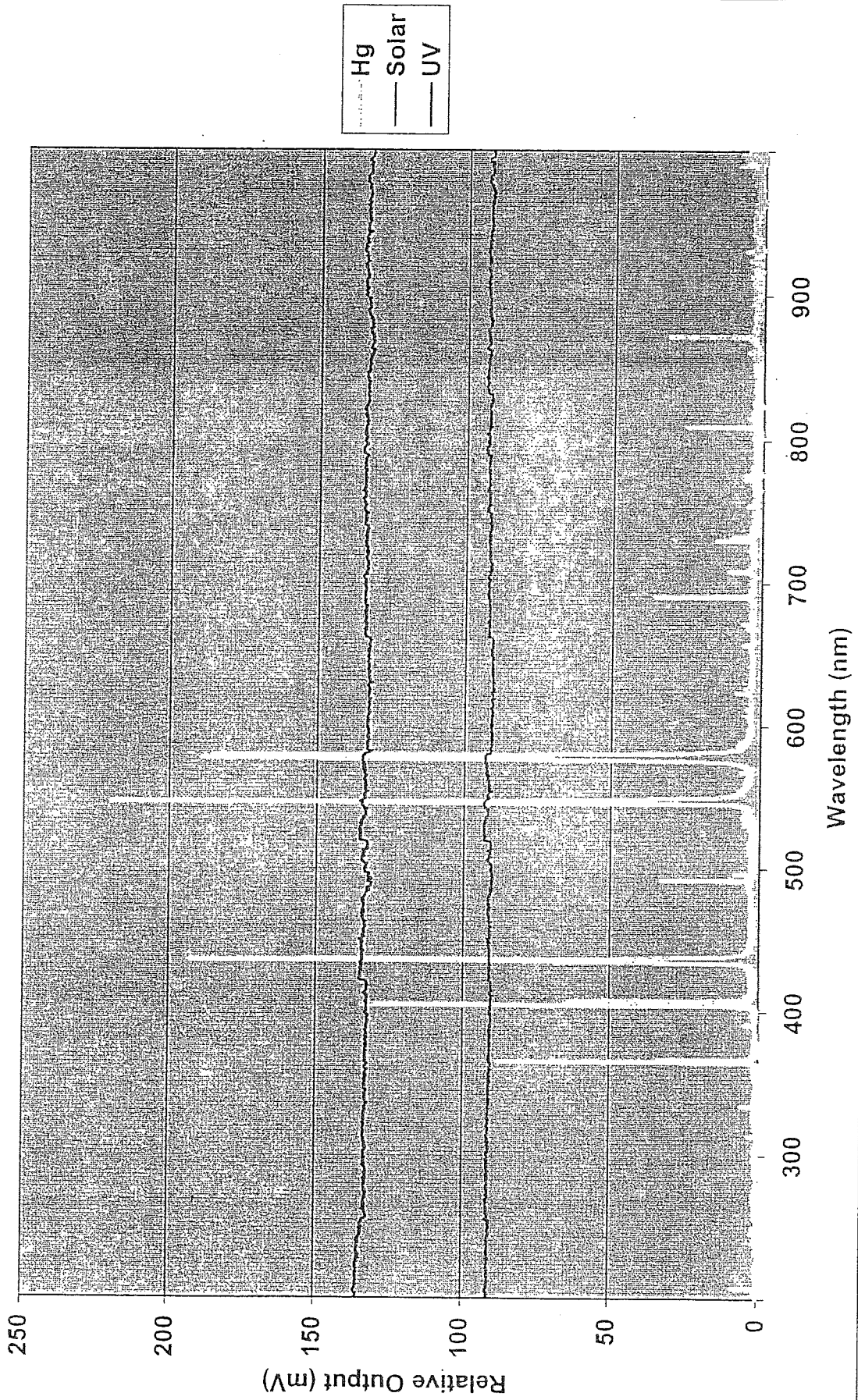
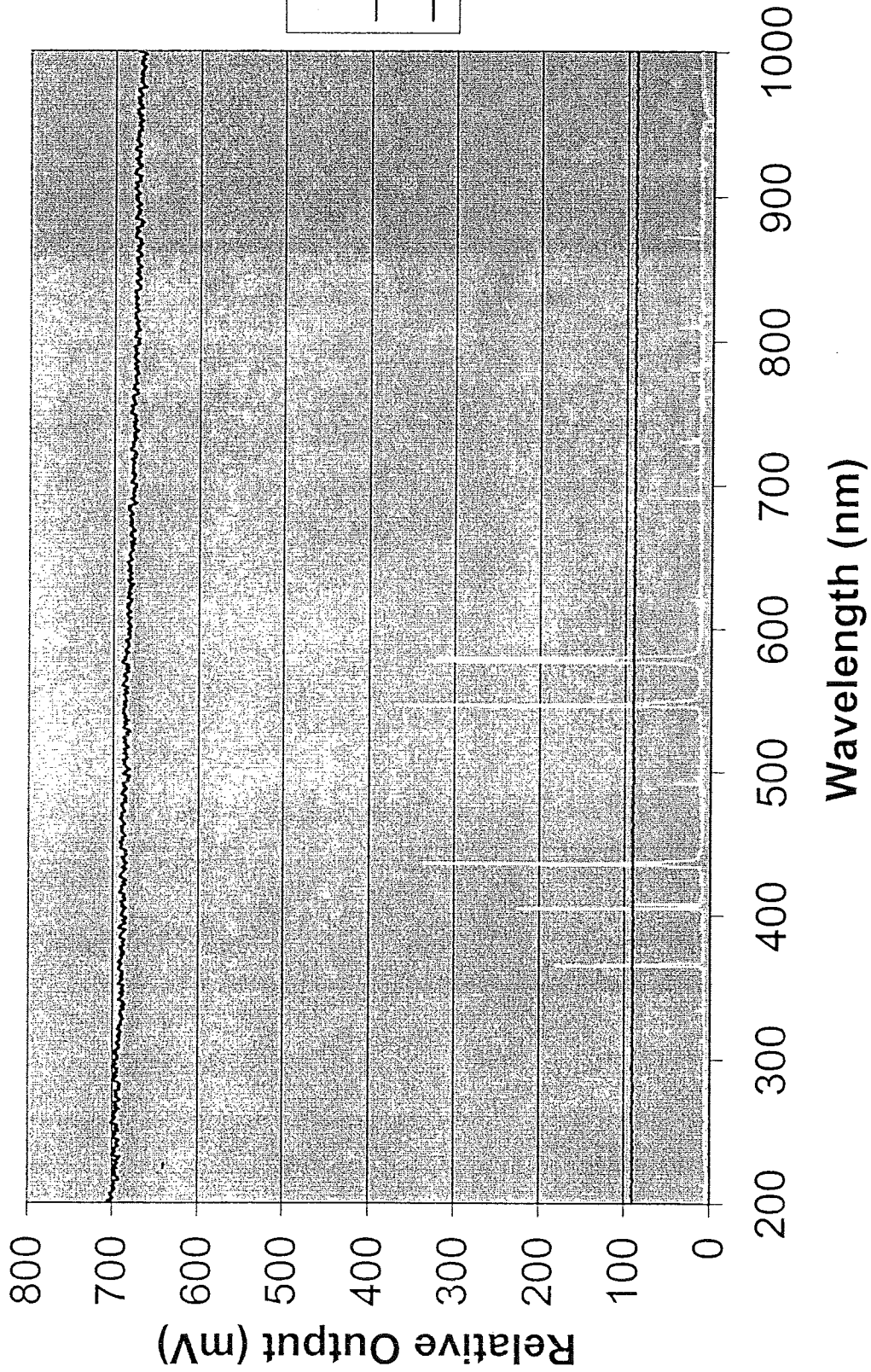


Figure 1-1. Cross-sectional view of the SSP-7 Precision Photometer

Regent Bulb With Glass Envelope

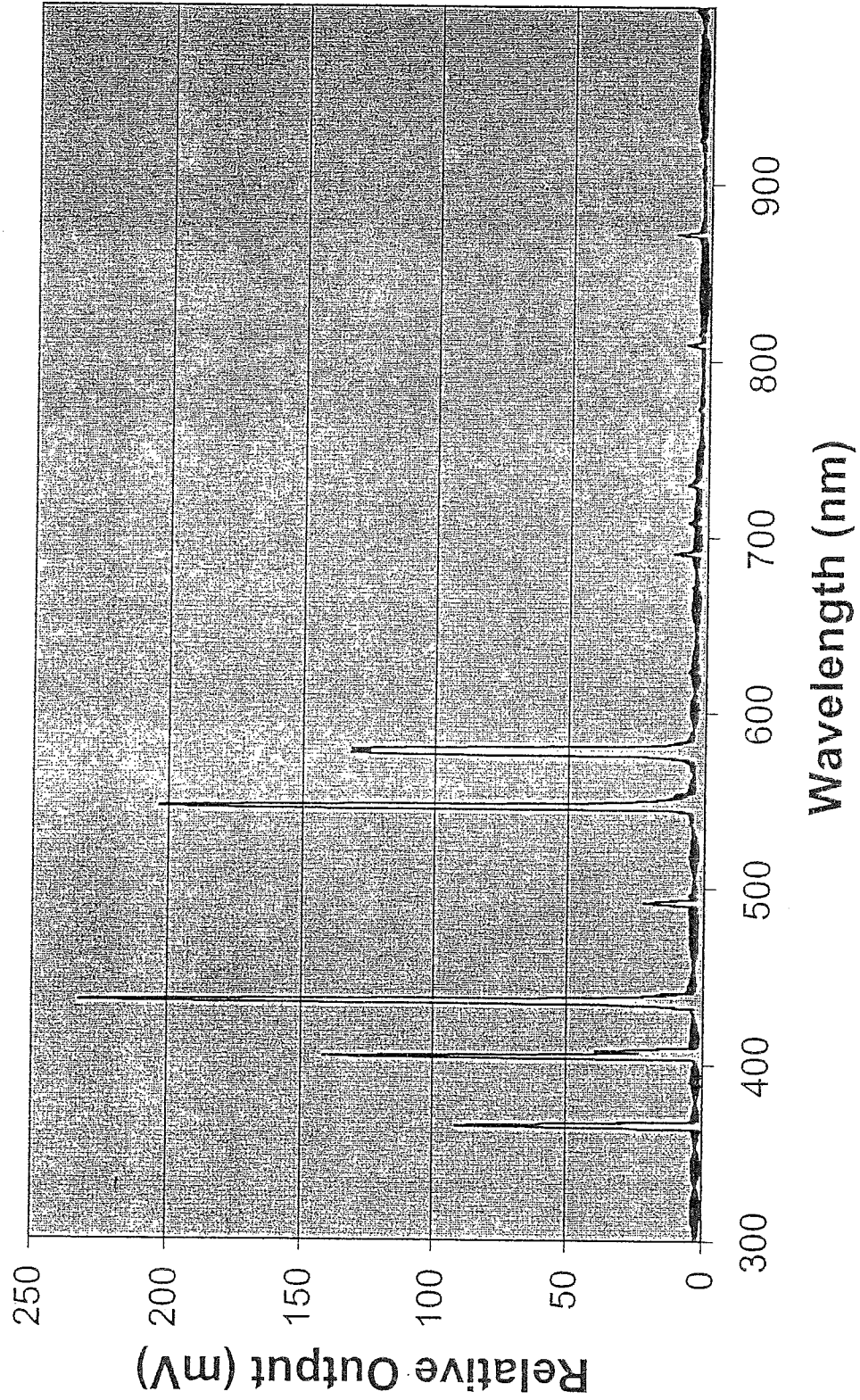


Philips Blub With Glass Envelope



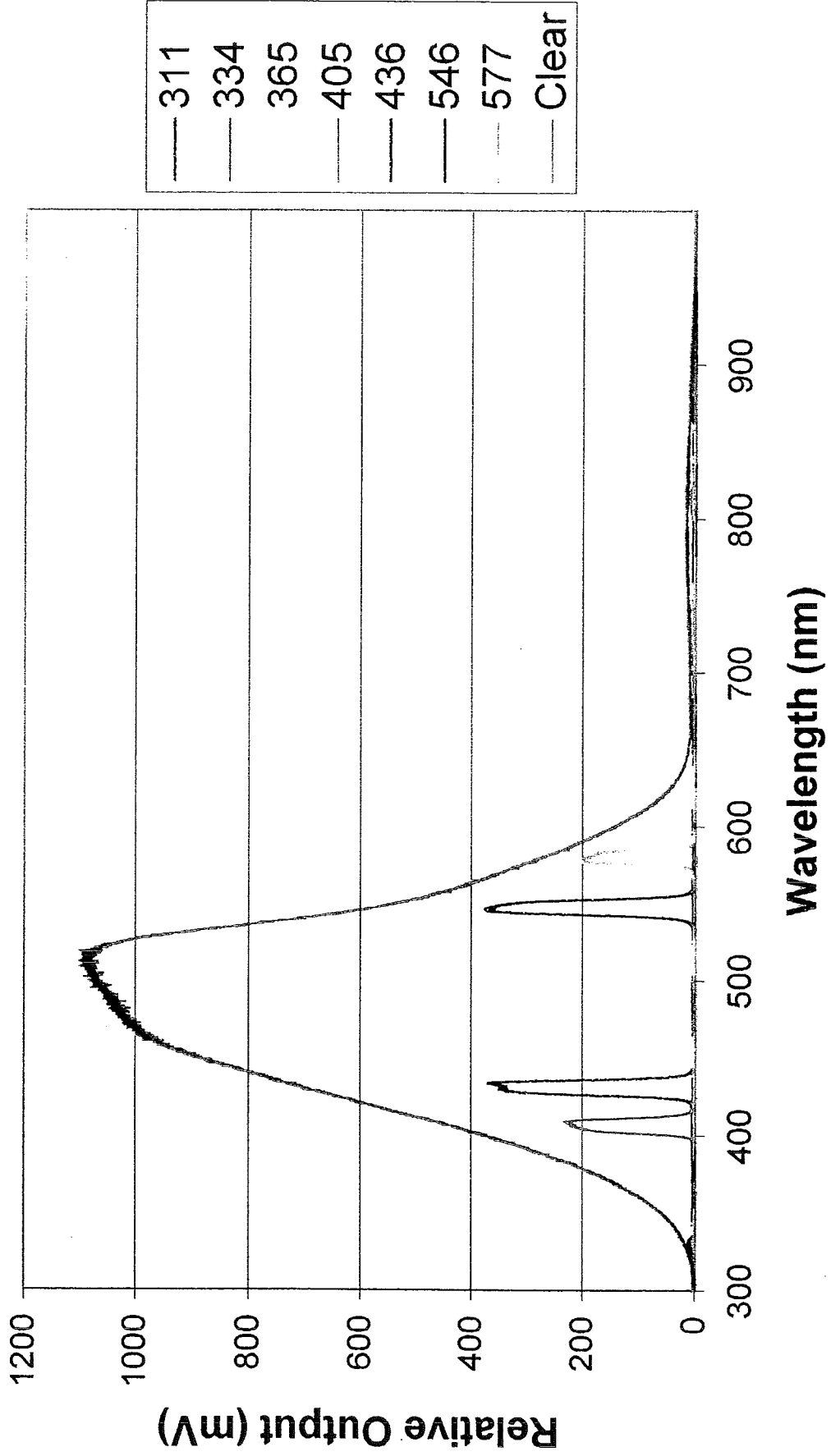
ETX TRANSMISSION

Normalized

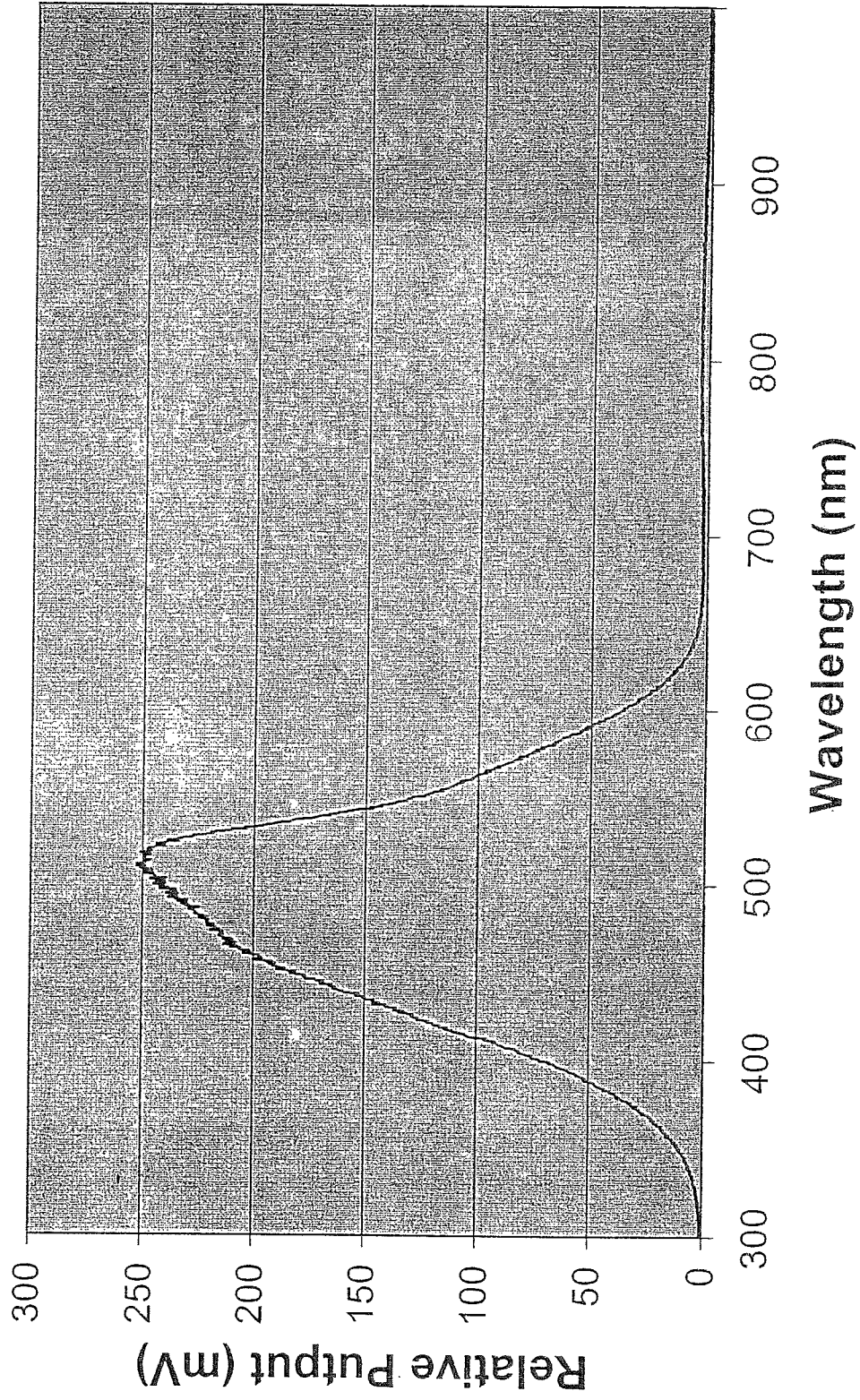


-ETX

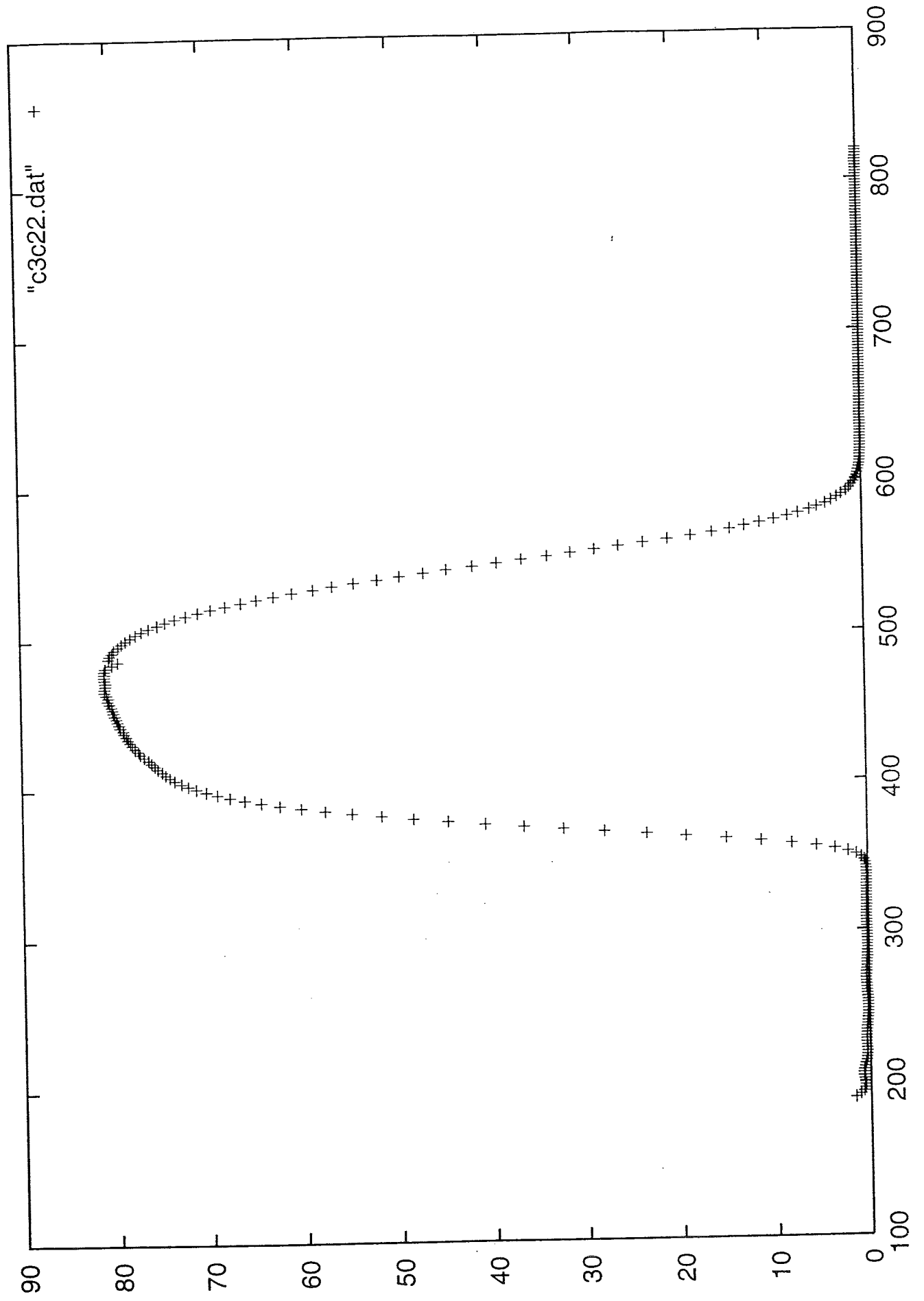
SSP7 FILTERS



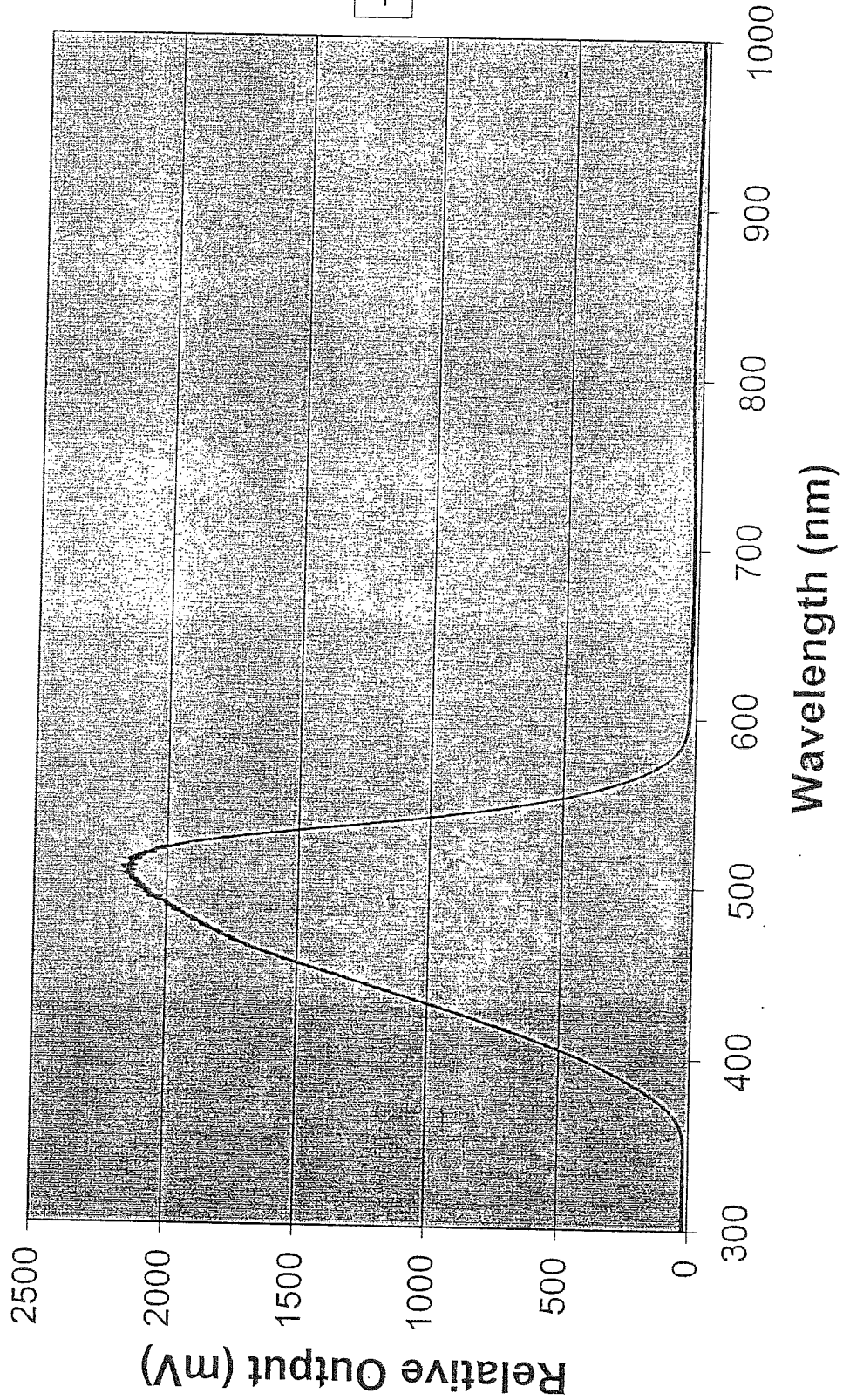
SSP-7 INCANDESCENT LAMP



— PMT



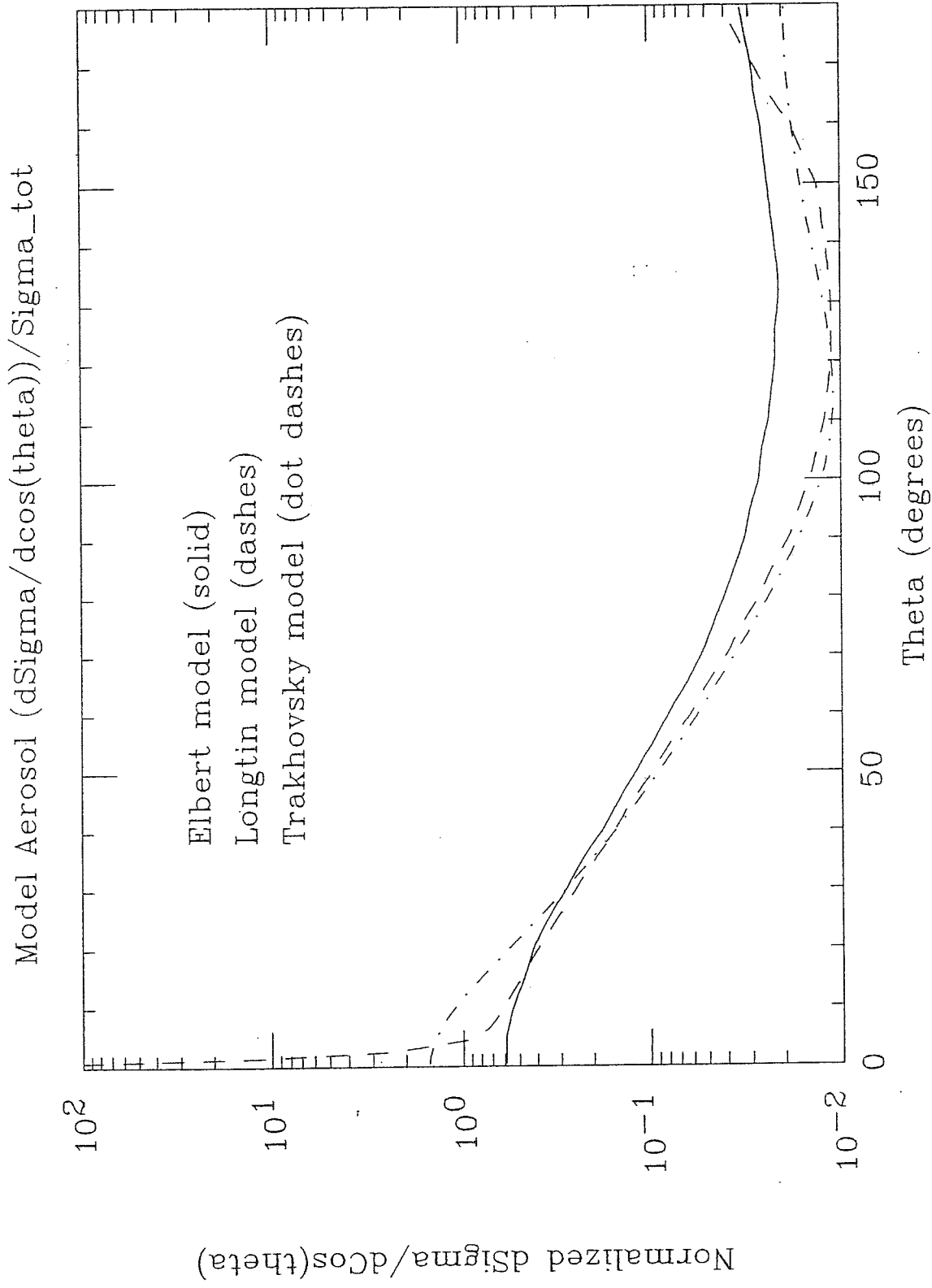
PMT Filter C3C22



— PMT

4. Small Angle Mie Scattering

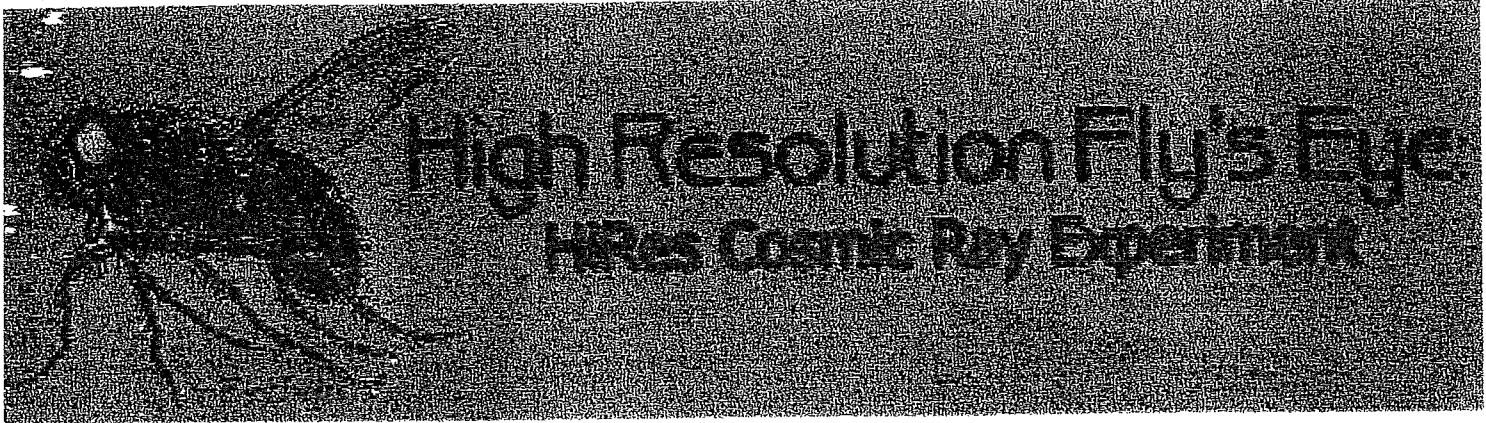
- The Mie scattering differential cross section is needed for the *air Cherenkov* correction and to estimate *H.O.* corrections:
 1. Variations in *existing* models:
 - Elbert parameterization
 - Longtin parameterization
 - *Other ... e.g.* Trakhovsky and Oppenheim
 2. Relevant when multiple scattering important:
 - *e.g.* $Source = Source + Aureole$
 - *e.g.* Atmospheric transmission, T , measurement
 3. M. Robert's suggestion to do a first measurement (at small angles)
 4. (More) motivation for a dedicated *aerosol phase function monitor*



Elbert & Longtin phase functions from HiRes Monte Carlo
 Trakhovsky from App. Opt., 22, 1635 (1983)

5. Molecular Atmosphere Study

1. Do we know the molecular atmosphere well enough?
 - The standard atmosphere *adiabatic model*, for use at elevations $< 11\text{km}$, is adequate for nearby showers.
 - For very distant showers we should use the Salt Lake City radiosonde data (*i.e.* the measured vertical profile of the atmosphere).
 - The agreement between Salt Lake City (Utah) and Reno (Nevada) radiosonde data is excellent. **This suggests that the Salt Lake City data can be used throughout the TA/HiRes experiment.**



High Resolution Fly's Eye HiRes Cosmic Ray Experiment

Time Variation of the Vertical Profile of the Atmosphere for Air Fluorescence Measurements

Georgianna Martin¹, John A.J. Matthews¹, Roger Clay²,

Bruce Dawson² for the HiRes Collaboration.

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NM 87131, USA*

²*Physics Department, University of Adelaide, South Australia, 5005*

Outline:

- Analysis motivation
- Radiosonde Data Analysis
 - Atmospheric model
 - * time independent
 - * time dependent
 - Radiosonde model
 - * site dependence
- Conclusions

Rayleigh Transmission, T^m Correction :

Calculation - Fractional uncertainty in T^m is:

$$\frac{\Delta T^m}{T^m} \approx \left(\frac{1}{\cos(\theta)} \right) \cdot \frac{\Delta(\delta P(\Delta z))}{g * \Lambda^m(\lambda)} \quad (1)$$

where,

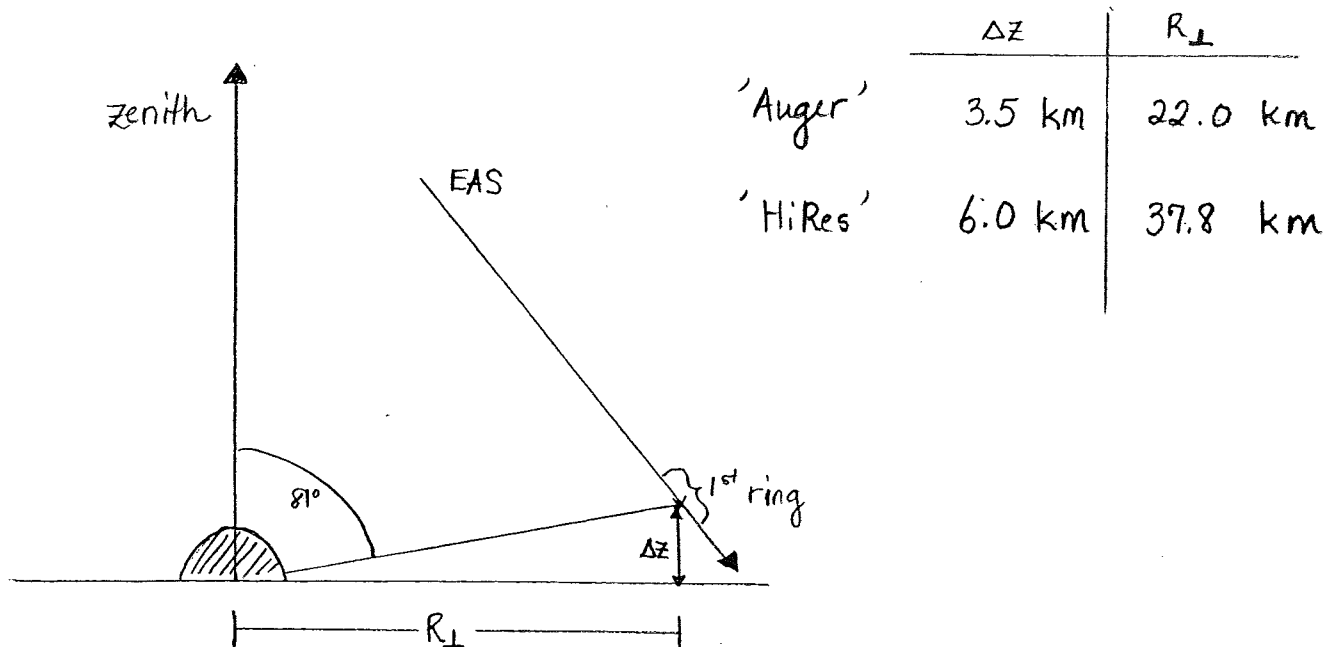
$$\Lambda(\lambda) = 2970 \frac{gm}{cm^2} * \left(\frac{\lambda}{400 \text{ nm}} \right)^4 \quad (2)$$

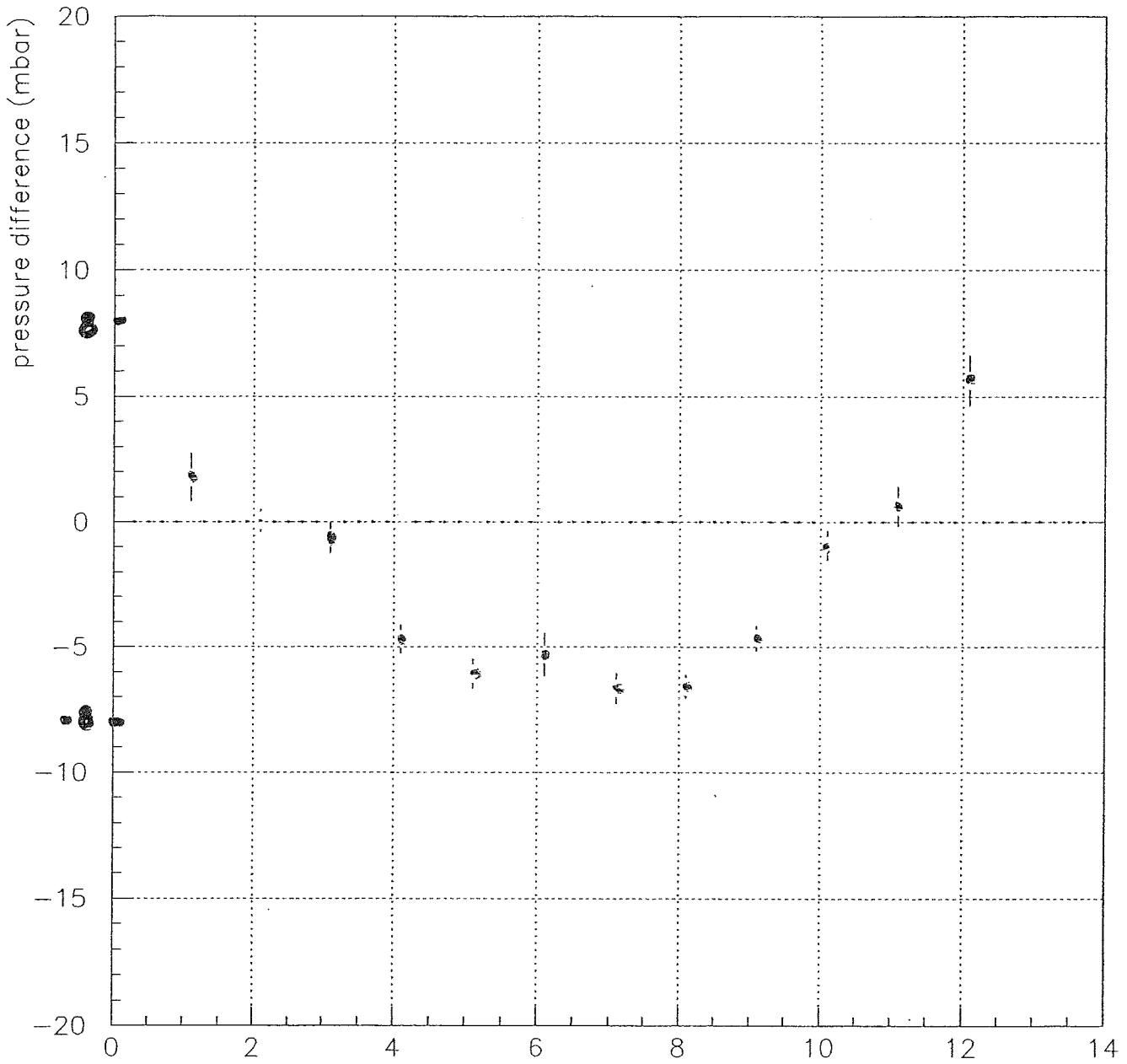
$$\delta P(\Delta z) \sim \int_0^{\Delta z} \rho(z) * g dz \quad (3)$$

If $\frac{\Delta T^m}{T^m} < n\%$ at 350nm, near the center of the HiRes wavelength acceptance, then:

$$\Delta(\delta P) \leq n(\%) \cdot \frac{17 \text{ mbar}}{(1/\cos(\theta))} \quad (4)$$

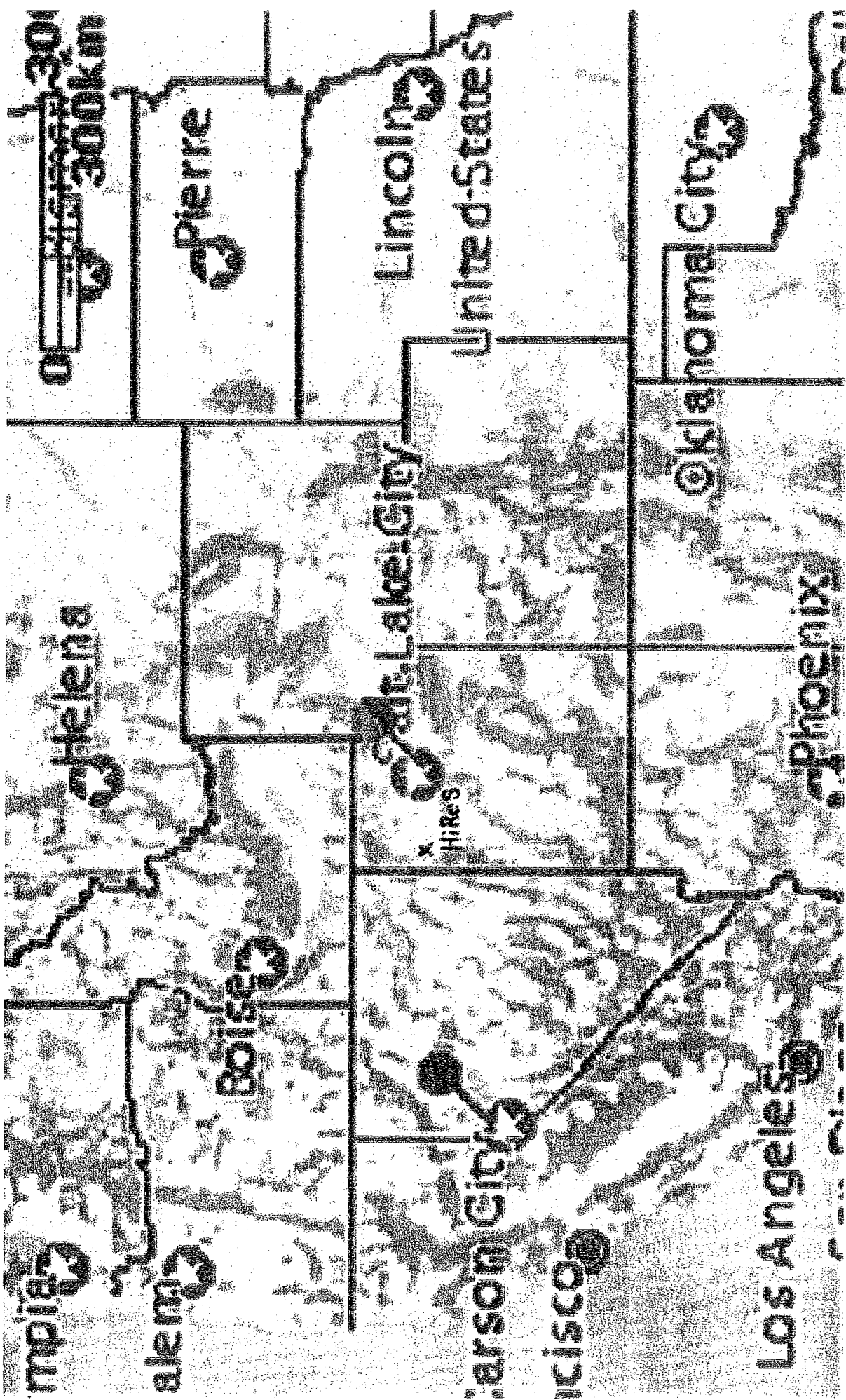
Fortunately δP must be known most precisely at small viewing angles, *i.e.* near the ground. As an example with $n = 3(\%)$ and $\theta = 81^\circ$ (middle of HiRes ring one mirrors) then we require that $\Delta(\delta P) \leq 8 \text{ mbar}$.





pres - pres adiabatic(time dependent) del z = 6.0 km, R perp.= 37.8 km - 1998

time(months)



Empire

Alabama

Boise

Helena

San Francisco

San Jose

Salt Lake City

X Hires

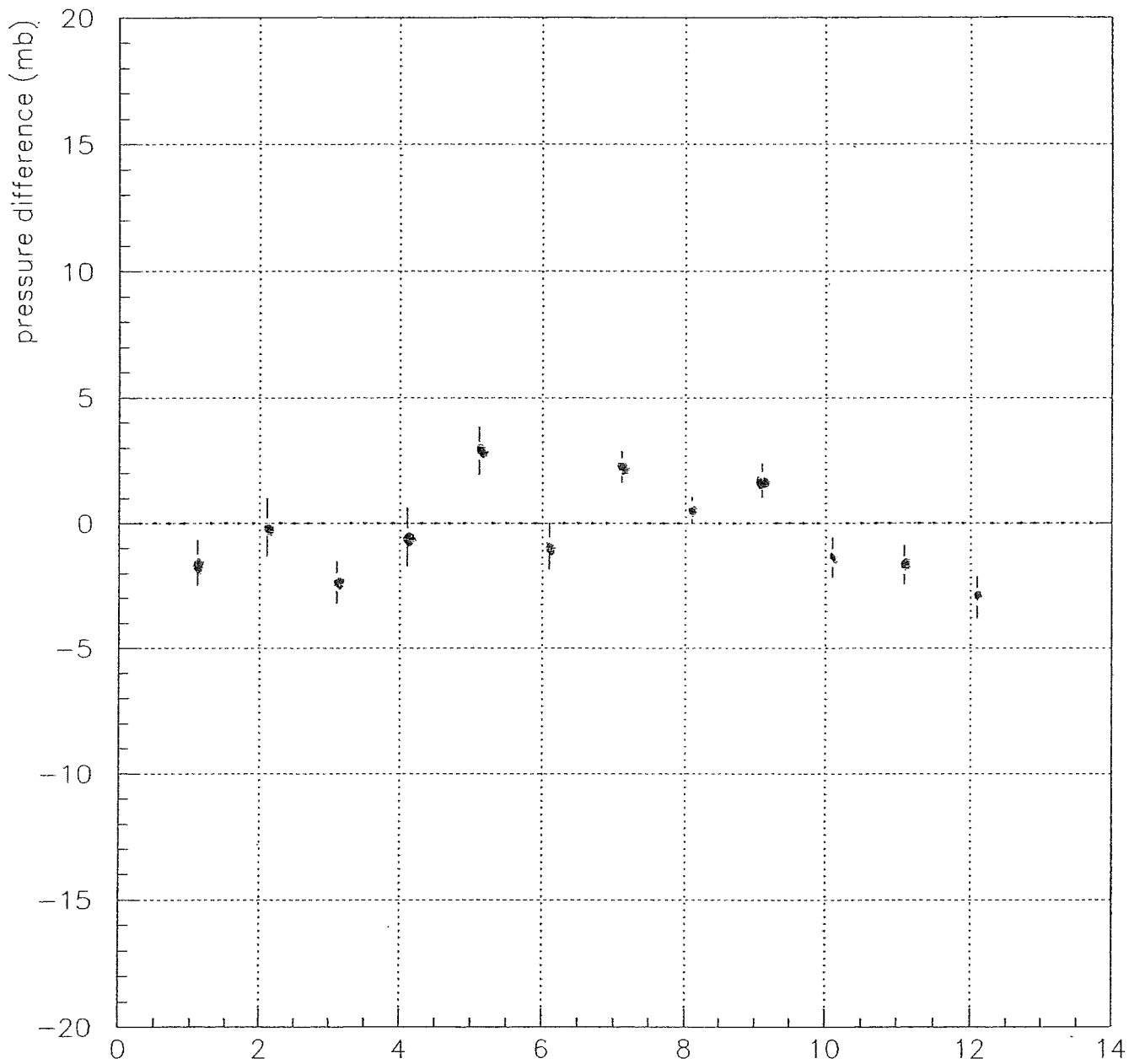
Phoenix

Lincoln

United States

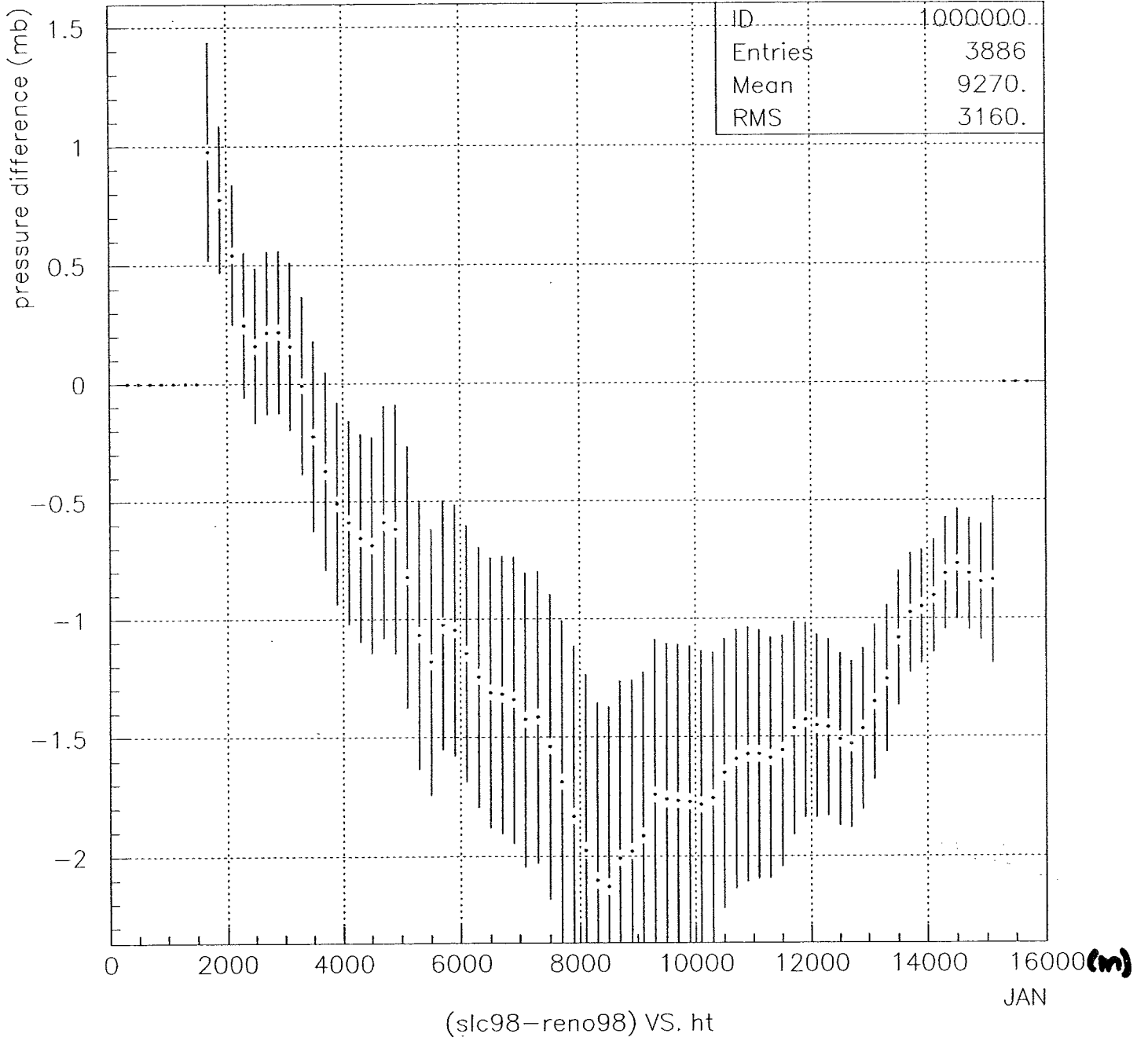
Oklahoma City

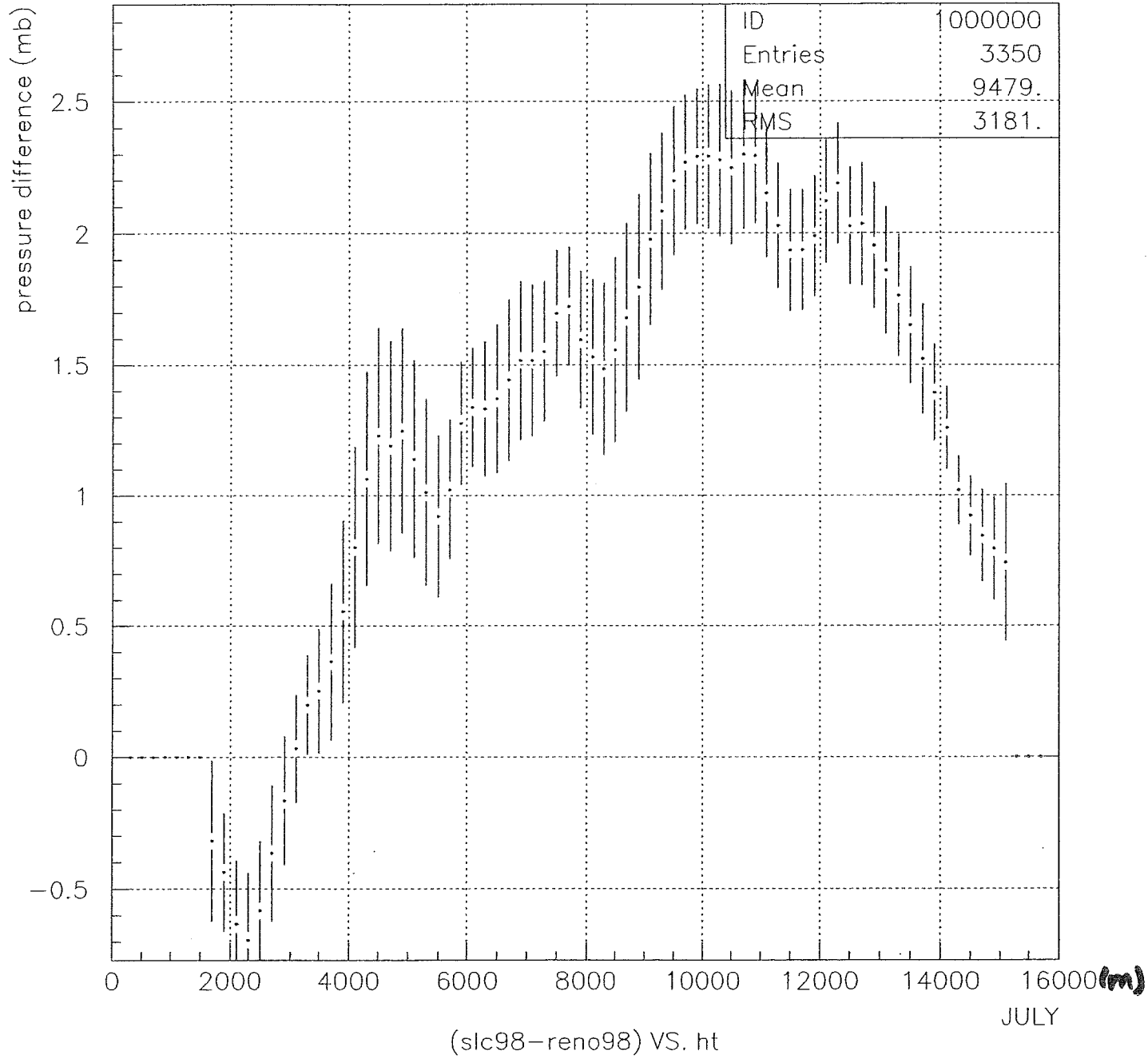
Los Angeles



del z = 6.0 km, R perp = 37.8 km (slc98-reno98)

time (months)





6. *Related* FD Studies using Light Beams

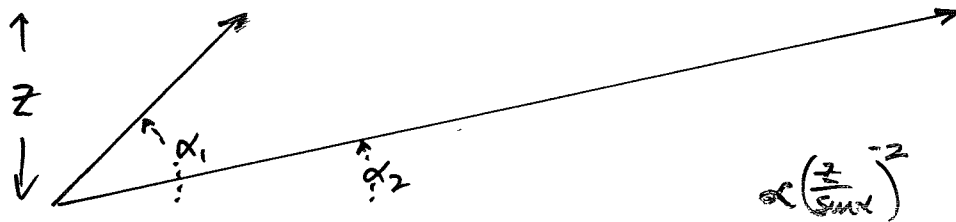
1. Light scattered out of (laser) beams provides a good cross-check on FD stereo reconstruction, absolute pointing accuracy, telescope cracks/inefficiencies, ...
 - June and July *laser safari* data from Simpson Springs, 45km site, and Black Rock
(see <http://www-hep.phys.unm.edu/fun5.html>)
 - Q.: Would a vertical flasher midway between FD sites provide a good, continuous monitor of relative energy calibrations (between the adjacent sites)?

7. Opportunity for Joint Auger/HiRes/TA Atmospheric Monitoring R&D?

1. M. Chikawa has requested one of the TA steerable telescopes for atmospheric monitoring R&D
2. SAGENAP committee was interested in atmospheric monitoring R&D
3. Are there topics that would benefit all three collaborations?
 - Development of back-scattered LIDAR technology?
 - Development of significantly brighter xenon vertical flashers?
 - Development of a *flying flasher* ... *e.g.* a xenon flash bulb plus diffusing ball mounted on a robotic helicopter?
 - **Plus** items already requested but not (fully) funded for use in HiRes:
 - (a) Hardware for laser safaris
 - (b) Aerosol phase function monitor (including new interest to extend down to small angle scattering)
 - *Other* ...

LIDAR geometry

The analysis to extract the optical depth, $\tau(z)$:



$$I(\alpha)_{obs} \propto I_0 (T^m(z) T^a(z))^{z/\sin\alpha} \left\{ \frac{1}{N(z)} \left(\frac{d\sigma}{d\Omega} \right)^m_{180^\circ} + \frac{1}{N(z)} \left(\frac{d\sigma}{d\Omega} \right)^a_{180^\circ} \right\} \Delta\Omega \Delta S$$

$\propto \left(\frac{z}{\sin\alpha} \right)^2$
 \downarrow
 cat

Take ratios:

$$\frac{I(\alpha_1)}{I(\alpha_2)} = (T^m(z) T^a(z))^{(z/\sin\alpha_1 - z/\sin\alpha_2)} \left(\frac{\sin\alpha_1}{\sin\alpha_2} \right)^2$$

Writing $T(z) = e^{-\tau(z)}$ and taking ln's:

$$\tau^m(z) + \tau^a(z) = \frac{\frac{1}{2} \ln \left[\left(\frac{\sin\alpha_2}{\sin\alpha_1} \right)^2 \frac{I(\alpha_1)}{I(\alpha_2)} \right]}{\left\{ \frac{1}{\sin\alpha_2} - \frac{1}{\sin\alpha_1} \right\}}$$

and $\delta(\tau^m(z) + \tau^a(z)) = \frac{1}{2 \left\{ \frac{1}{\sin\alpha_2} - \frac{1}{\sin\alpha_1} \right\}} \left\{ \frac{\delta I(\alpha_1)}{I(\alpha_1)} \oplus \frac{\delta I(\alpha_2)}{I(\alpha_2)} \right\}$

molecular part that is "well known"

(need P, T at $z=0$)

\oplus standard atmos. model)

Best to measure at $\alpha_1 \approx 90^\circ$ and $\alpha_2 \approx 5-6^\circ$
 unknown aerosol (optical depth)