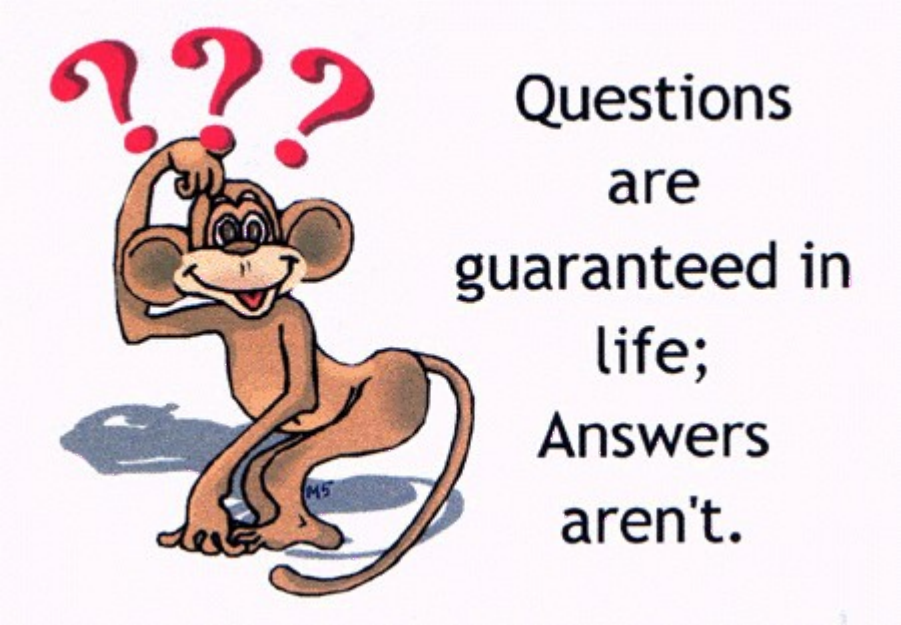
Variances

What is it?

and what for?



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ADC signal

- Allow control quality of measurement
- Fluctuations of ADC signal in PMTs is proportional to background
- Background: brightness of sky + intrinsic and electronic noise of PMT

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Fluorescence detector

- Short introduction
- Pierre Auger Observatory is HYBRID detector
- Operates during “clear”, “moonless” nights
- How it looks like...

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FD - day

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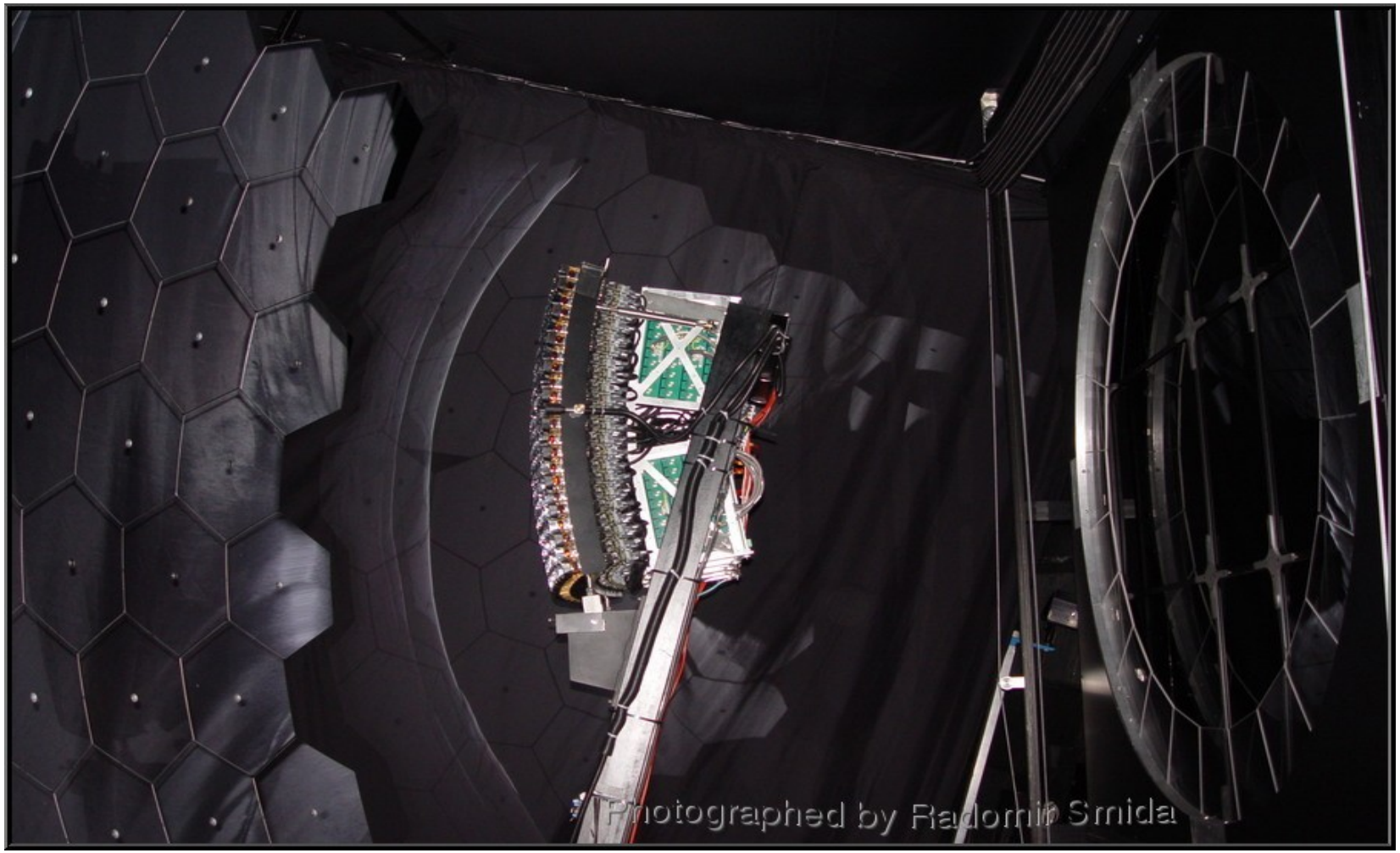
Cloudy night, w Moon

Radomír Šmída, smida@fzu.cz

Bay of FD



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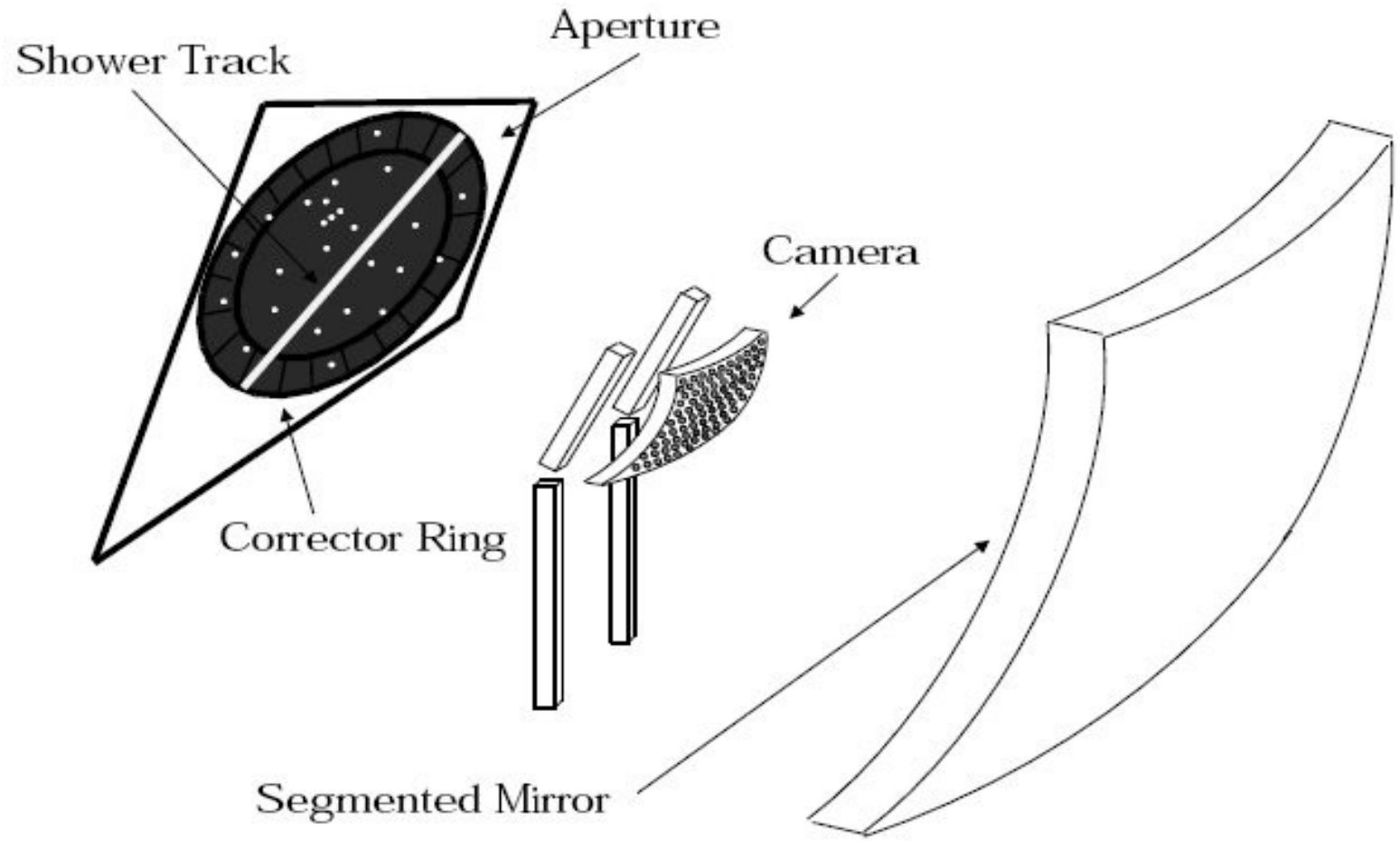
Scheme of FD



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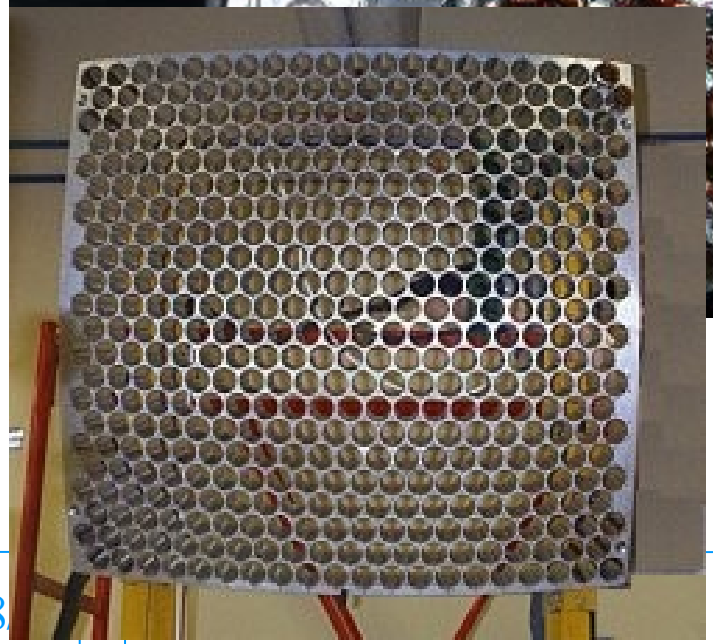
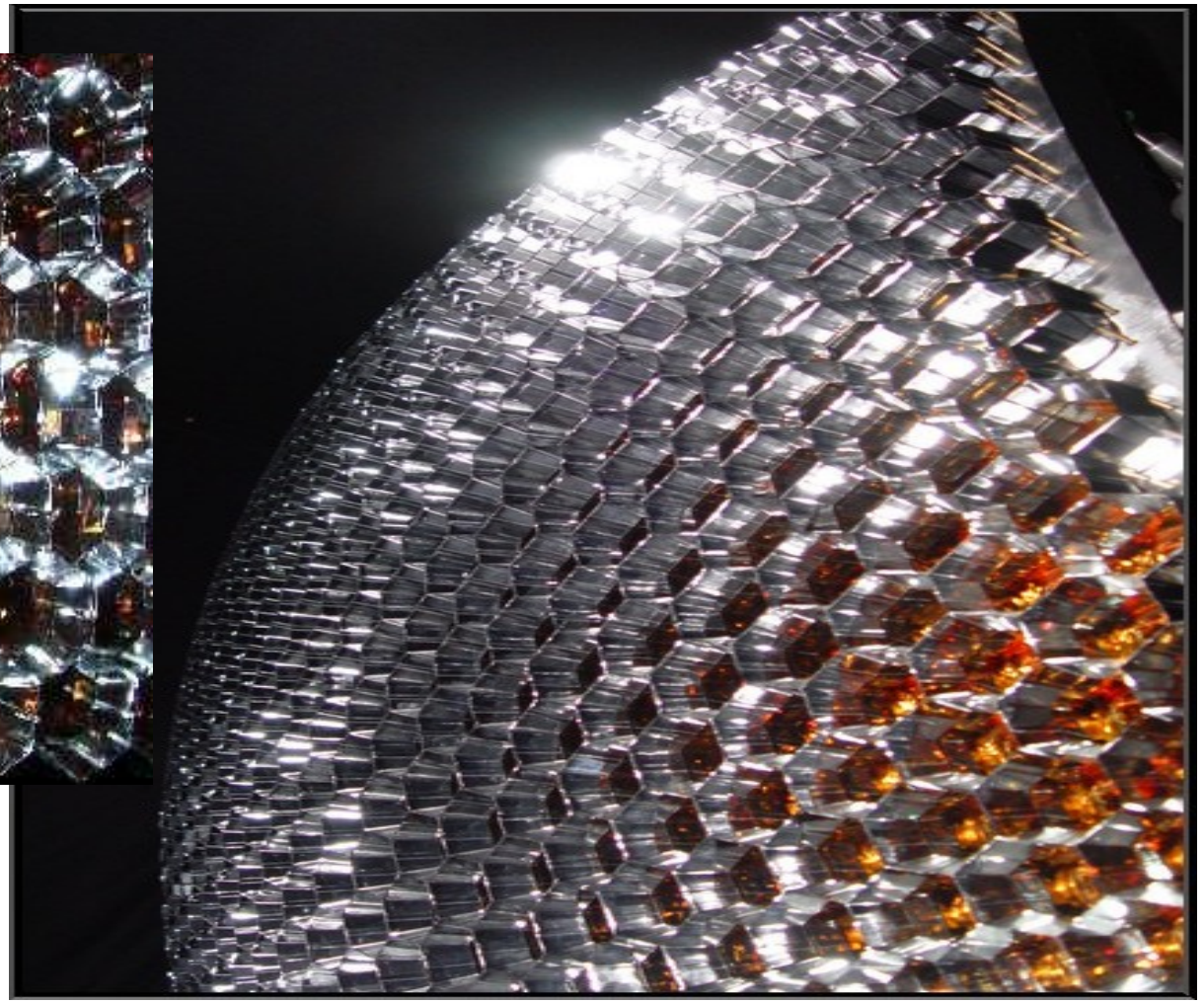
FD camera





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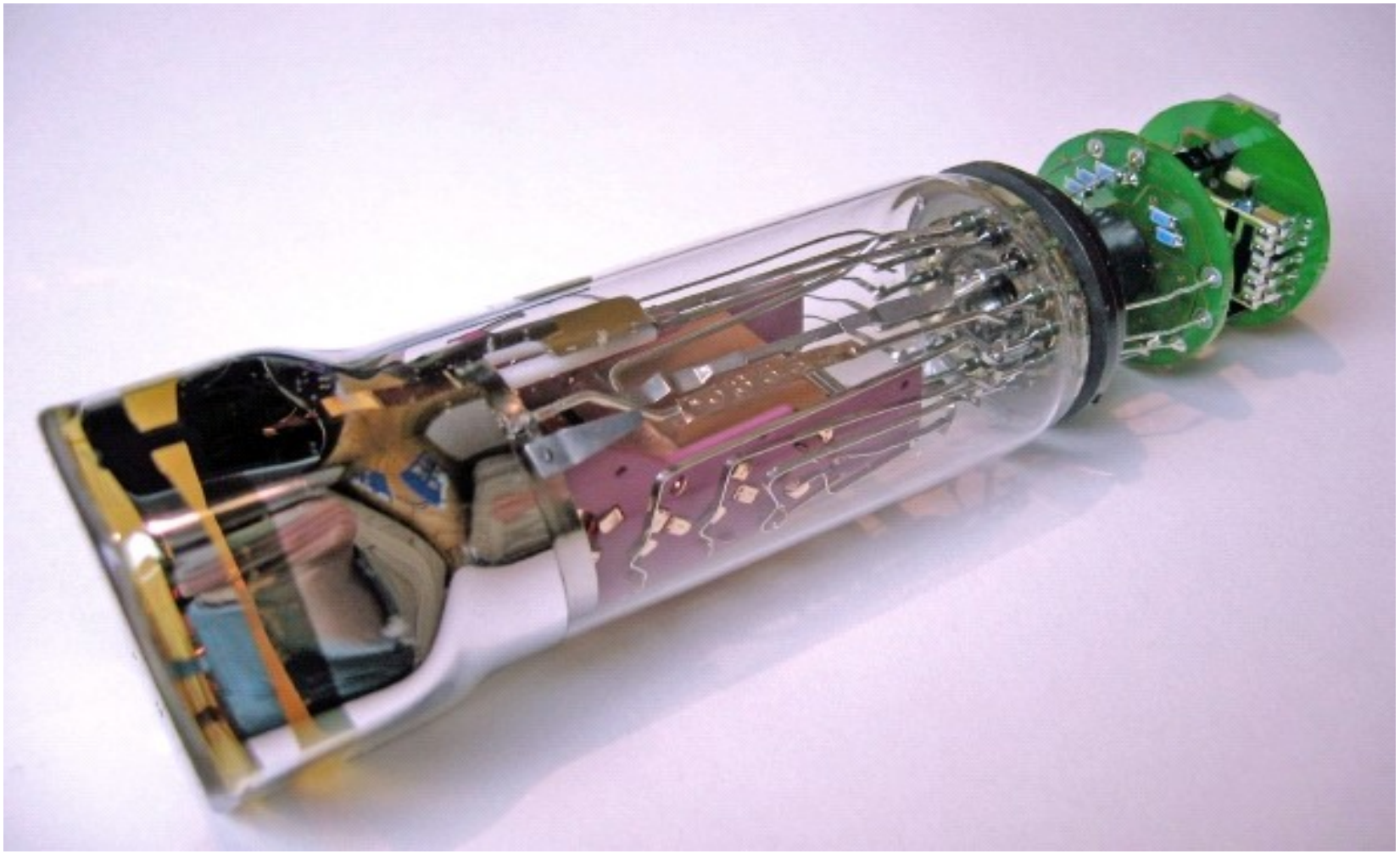
Photonis XP 3062



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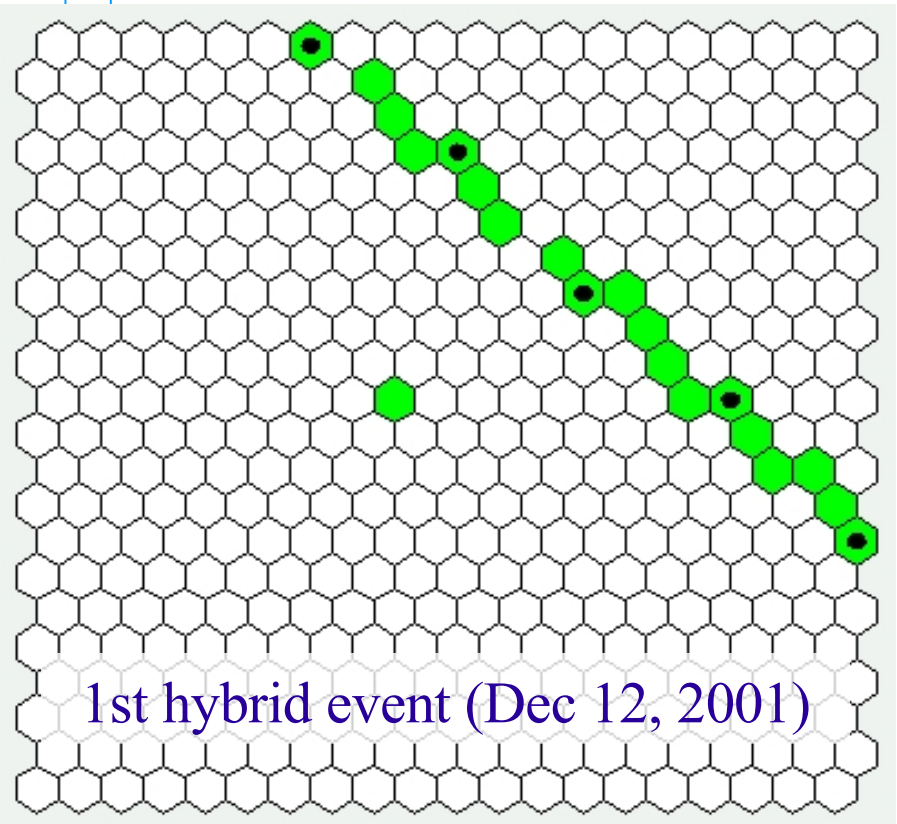
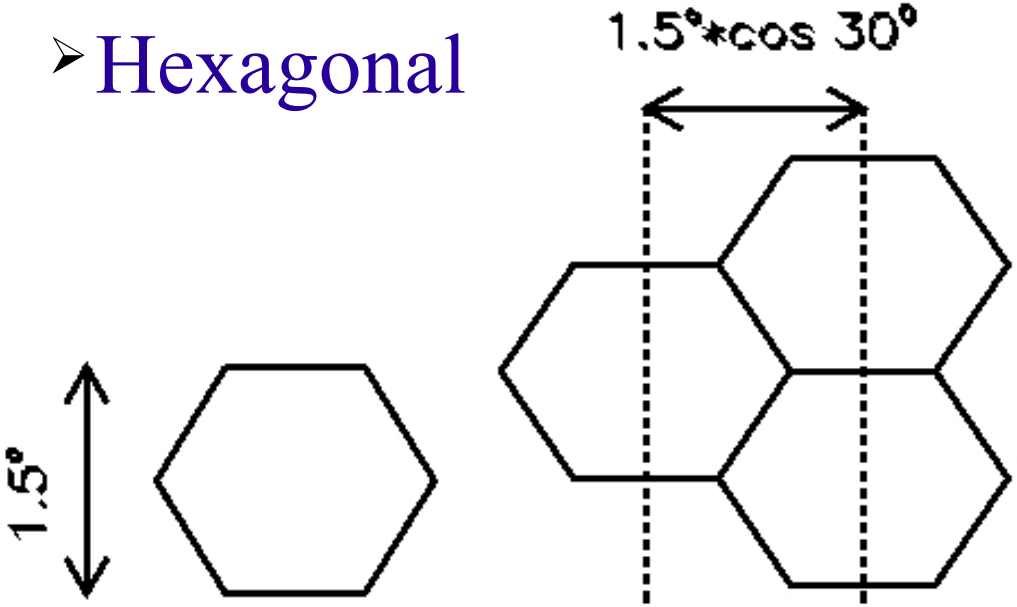
FD PMT



- 440 PMTs / camera
- Photonis XP 3062
- Hexagonal



- 1.5 deg (40 mm)

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Constraints on PMT

- properly respond to pulses of variable time width (100 ns to few mu sec)
- signals up to 100k p.e. should not saturate
- constant gain over large background current
- The most energetic shower: 1e21 eV (120k p.e.)

=> Na = G*Np.e., G = 100k

Ia = e*Na/100 ns = 20 mA

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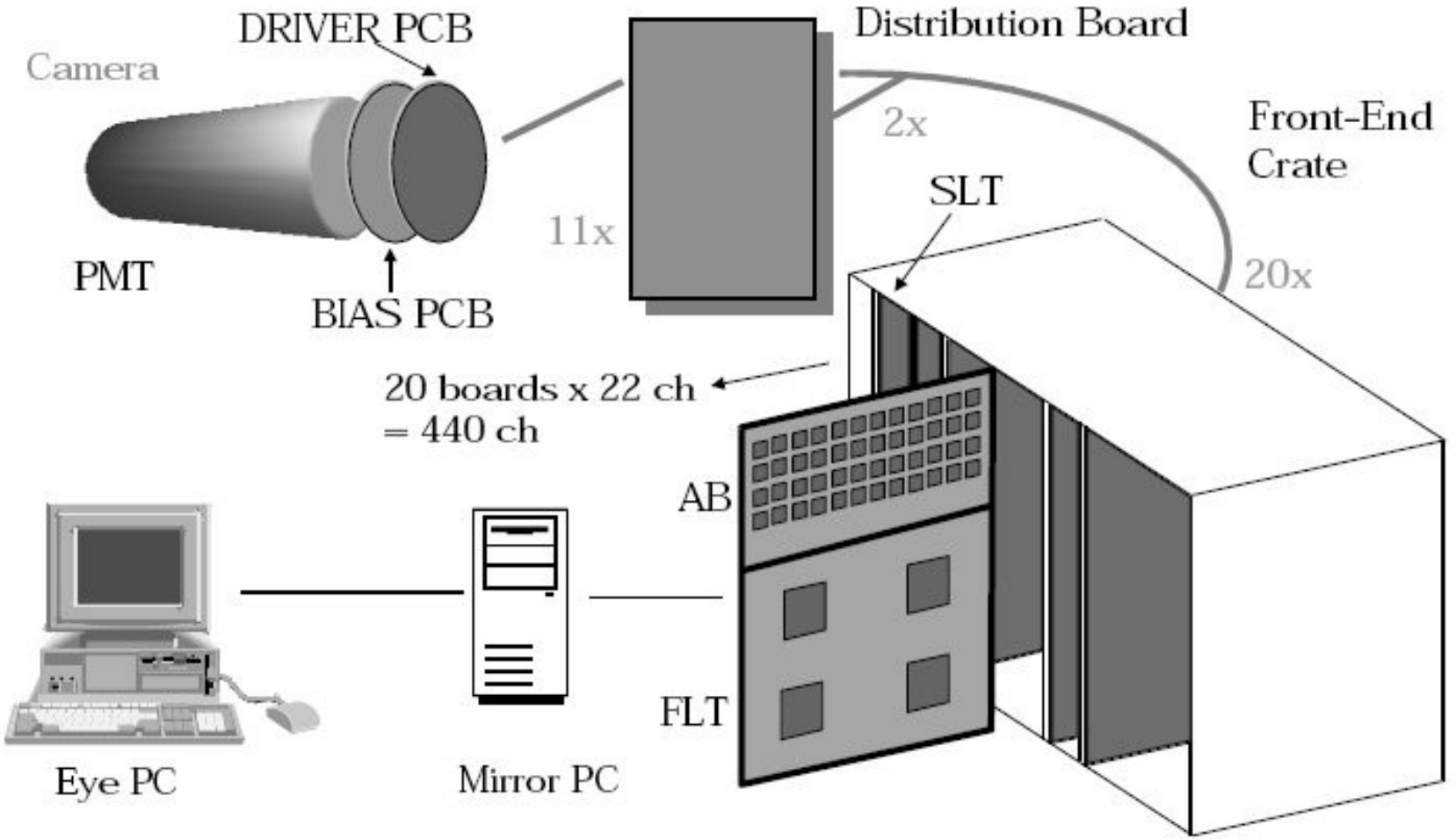
Readout scheme



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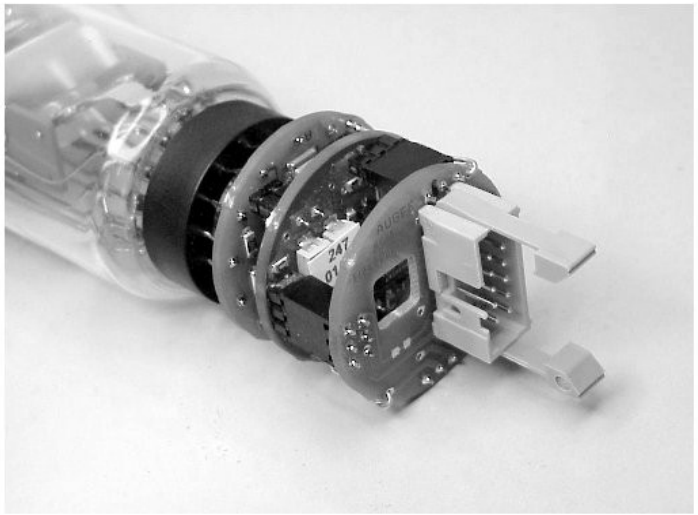
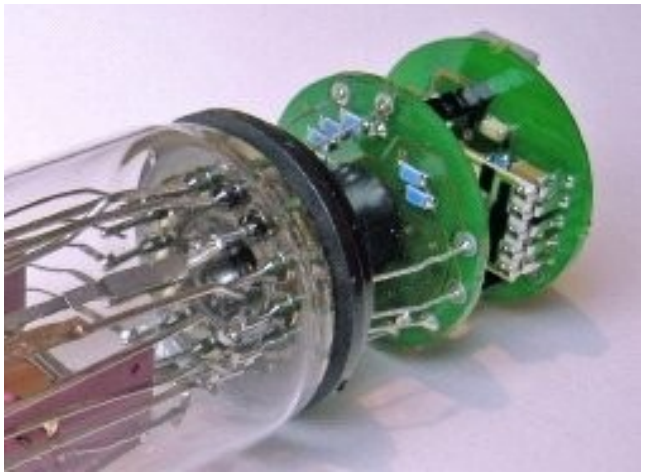
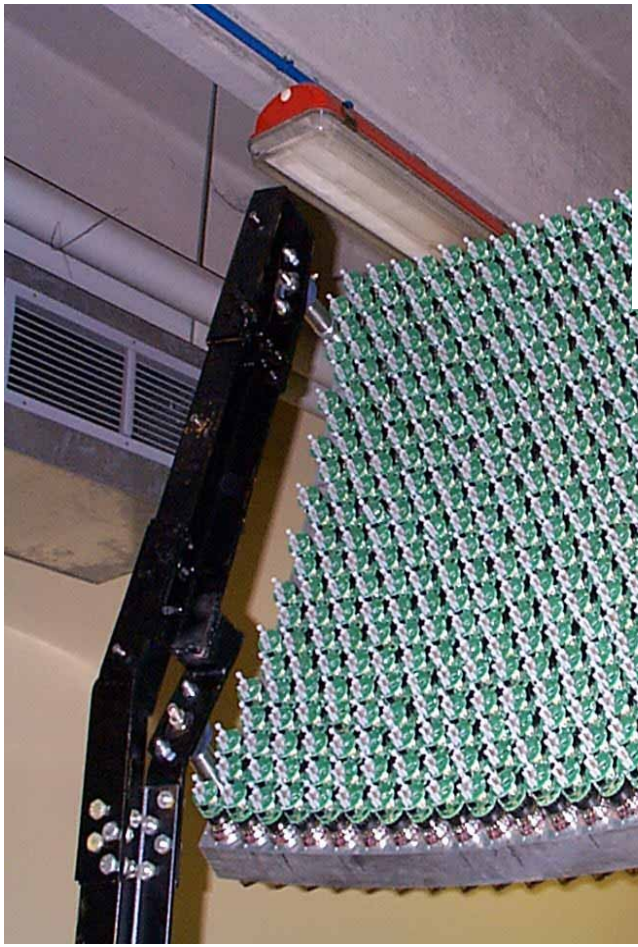
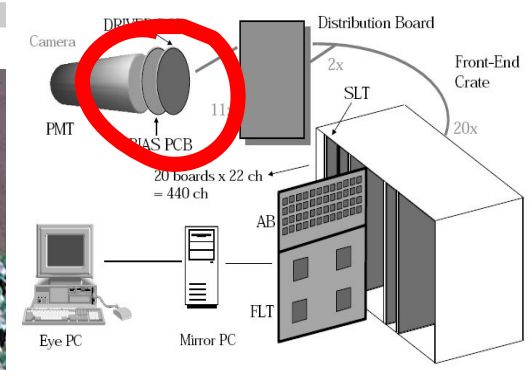
Head electronics unit









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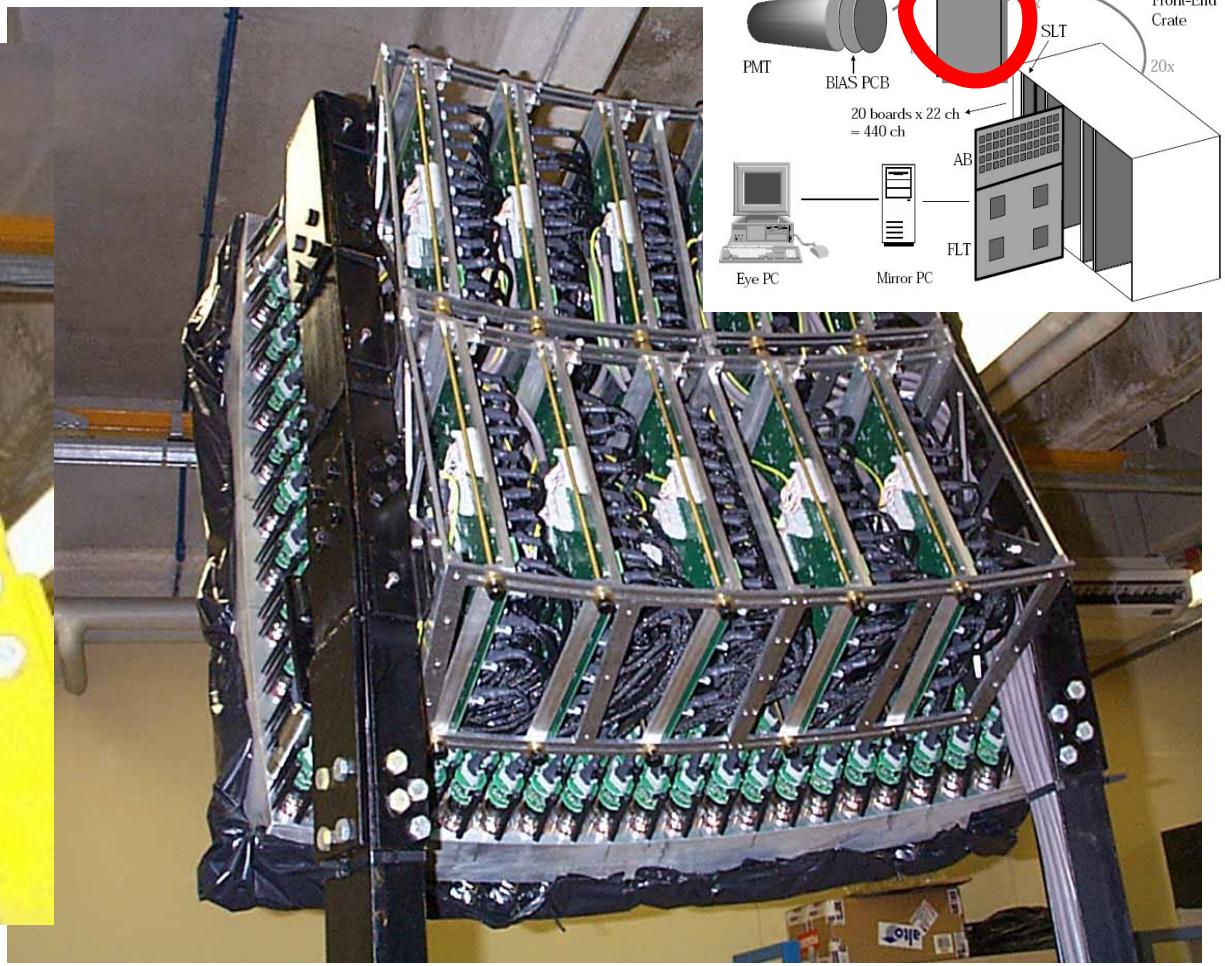
Distribution boards



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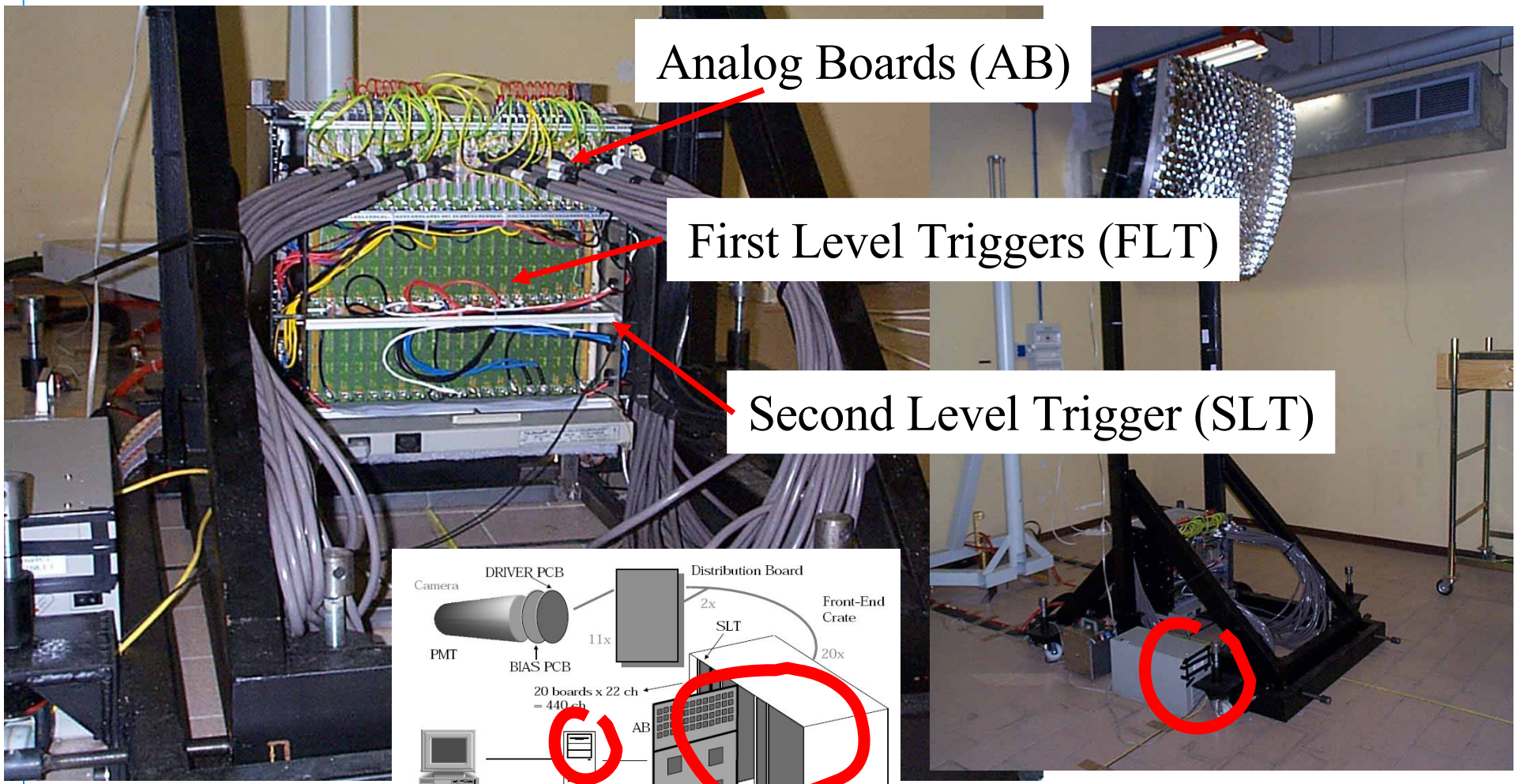
Front-end crate



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DC anode current

- to avoid dust deposition (due to electrostatic attraction) cathodes of PMT are grounded
- Therefore PMT signals are AC coupled to analog electronics (static DC components from input signal to amplifier are removed, leaving quickly variating signal with time)
- DC anode current varies with background light (!)
- Indirect method: statistical analysis of ADC counts

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of photoelectrons

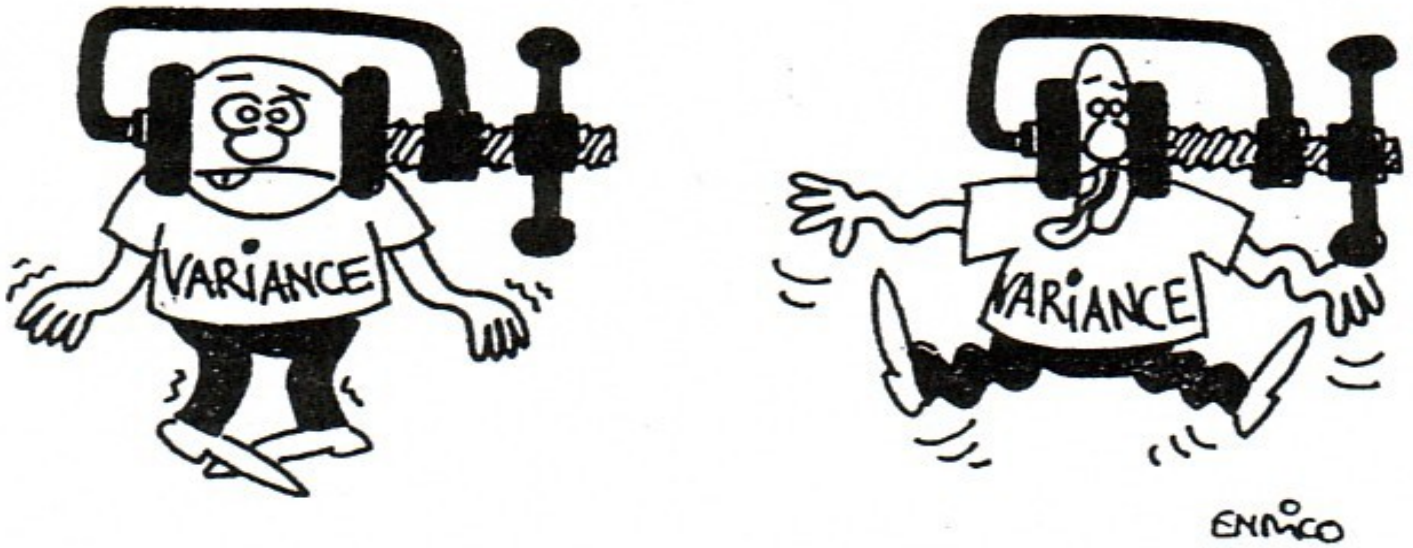
Assuming random processes at the PMT dynodes it is possible to derive the cathode DC current (as the number N_{phel} of photoelectrons per 100 ns) from the variance σ^2 to [5]

$$N_{phel} = \frac{\sigma^2 \times 10}{G^2 \times (1 + \upsilon_g) \times 2 \times F}$$

M.Kleifges+, IEEE-TNS 50, 4 (2003)

Here G is the gain (in ADC counts per photoelectron), υ_g is the gain variance of the PMT of around 0.4 and F is the noise equivalent bandwidth of 2.69 MHz from the complete analog signal chain used in October 2001 [5]. The value of υ_g varies from PMT to PMT within a batch in the 10 % range, which induces an error of 2.5 % in the number of photoelectrons. However, this variation is determined by the annual absolute calibration using an external light source of known brightness [6].

Variances



- Variance Reduction...
- What in our case?

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Measur. of variances

- sky background measurement is an average of (2^16 – 1) = 65.535 variances
- each obtained during 100 ns light (16-bit) ADC chip integration period
- => background light measurement for one pixel can be obtained during 6.5 ms
- recorded only every 30 sec

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Data storage

- ASCI files: bg_run_coihueco_070109_a.txt.gz
- transferred to Lyon database

  (.../FD-Coihueco/eyepc/2007/01/09/aux)
- golias: /raid3_alice/auger/Fd/
- GPS time, Telescope, Timer (5 or 30 sec),

  Variations, Thresholds, Hit rates,...
- SW provided by Michael Prouza

before run bg_coih... el. noise

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Application of variances

- Photon flux
- Brightness of sky
- Star tracking
- Lifetime of PMT

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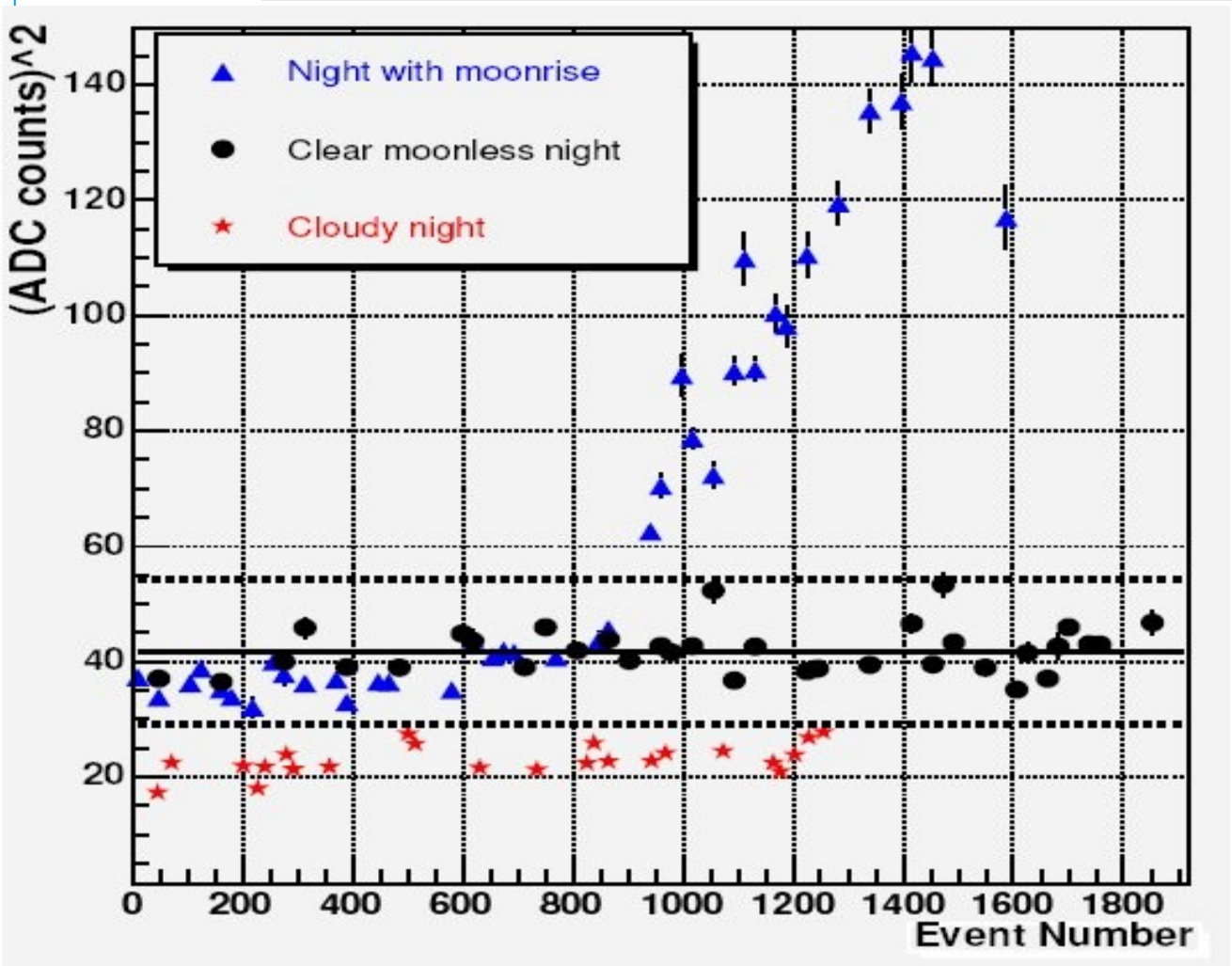
Typical values



- closed shutters
  ~ 4
- cloudy night
  ~ 20
- clear moonless
  ~ 40
- moonrise
  ~ 80

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Photon flux

Conversion from photoelectrons to photon flux:

$$\Phi_\gamma = \frac{n_{phe}}{Q \cdot f \cdot \mathcal{A} \cdot \Delta t} \quad ,$$

where f is the optical factor, $\mathcal{A}$ is the pixel aperture and Δt the sampling time slot (100 ns). f is the product of the telescope transmissions:

$$f = F \cdot LT \cdot R \cdot M$$

with F the filter transmission @370 nm, L the corrector ring lens transmission @370 nm, T the camera shadow factor calculated by Ray Tracing simulation, R the mirror reflectivity @370 nm and M the mercedes collection efficiency.

GAP-2004-072

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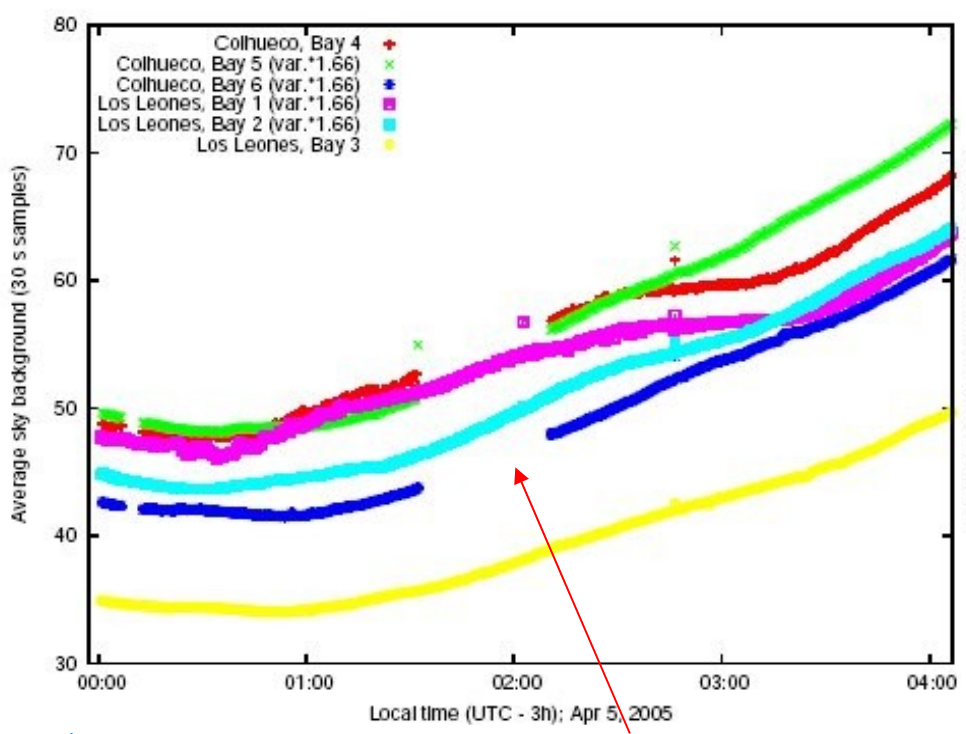
Brigthness of sky

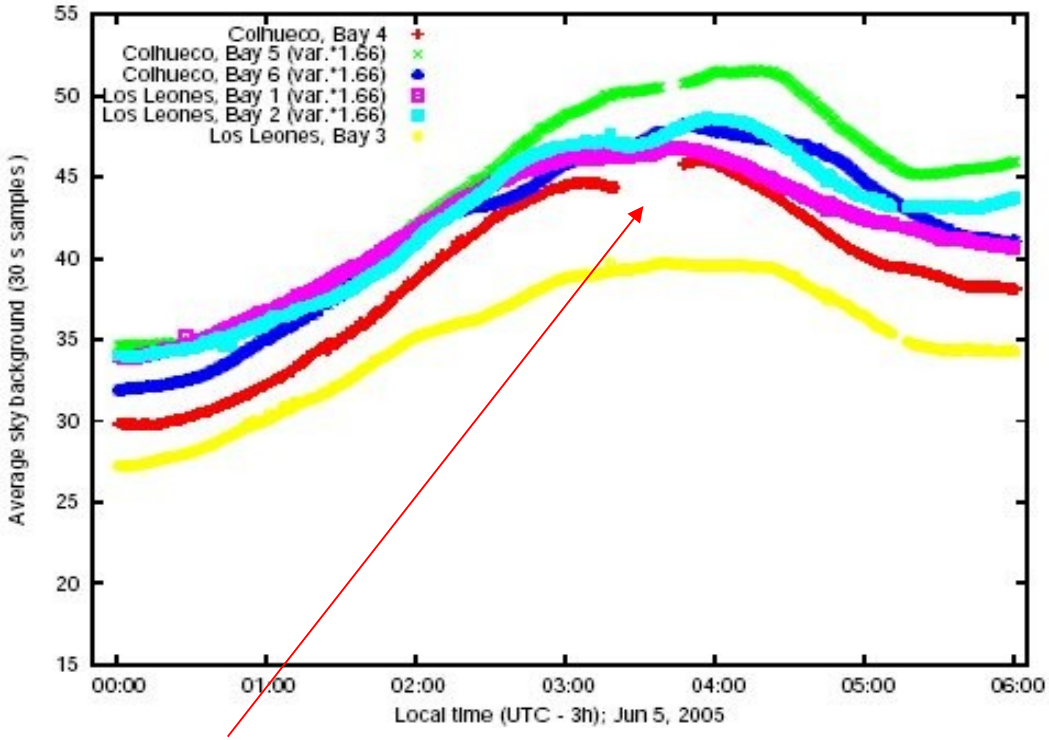
Contribution	Relative brightness (%)	Note
Airglow	60%	varies between 50% – 70% during 11-yr solar cycle
Zodiacal light	30%	dependent on Galactic latitude
Starlight scattered by interstellar dust	4%	mostly along Galactic plane
Unresolvable faint stars	∼2%	
Extragalactic light	< 1%	
Aurorae	0%	
Light pollution	< 4%	at "dark" site

GAP-2006-090

- airglow = emission of light by Earth's atmosphere (ionized by Sun and CR, chemical processes)
- van Rhijn layer (altitude of 130 km)

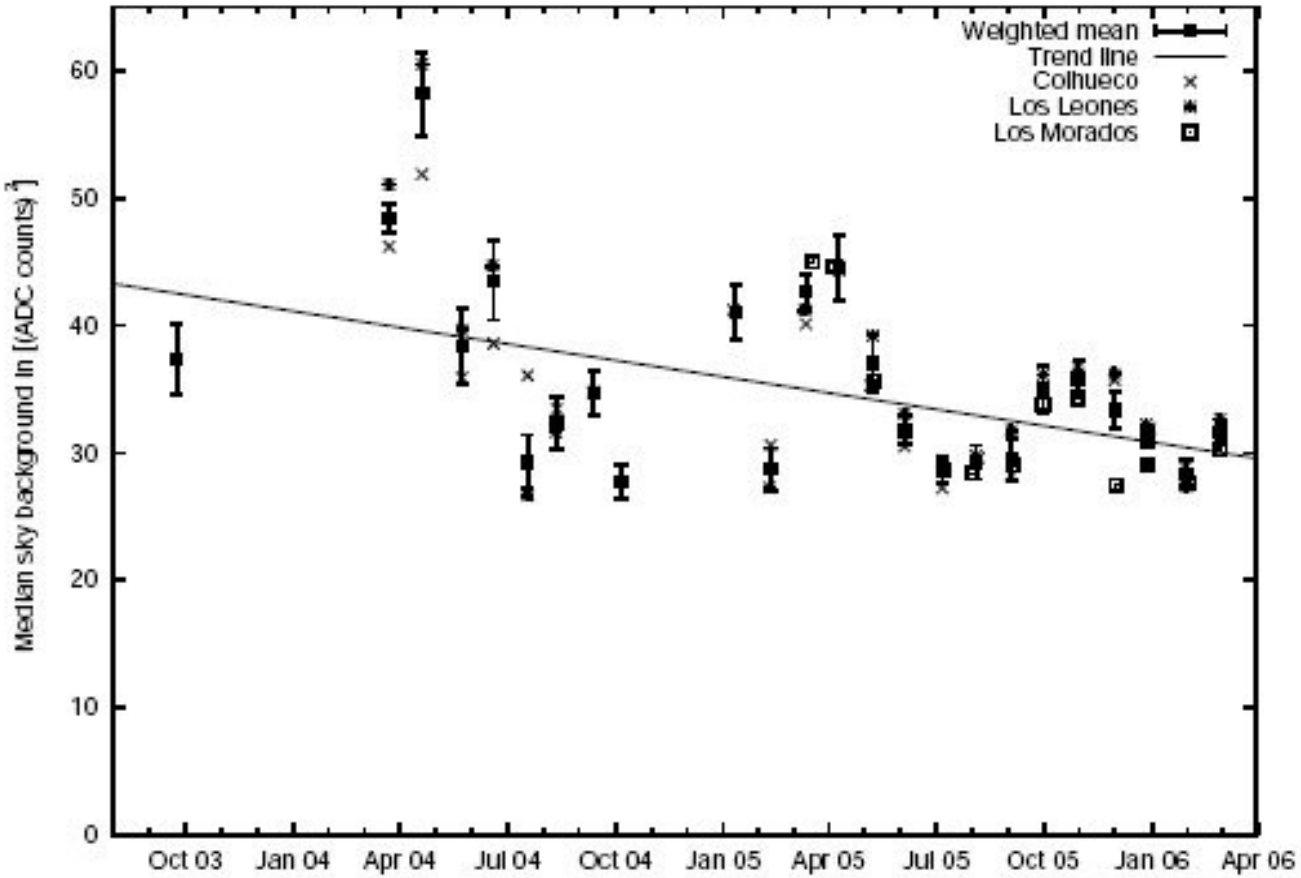
Nightly variances





- it is not an instrumental effect
- fluctuations of airglow intensity (alt. 130 km)
- none correlation with aerosol data from CLF
- cannot provide much info for shower recon. (10 km)

Long-term variances



- 2.5 yr data
- clear, moonless
- trend line slope is 5.1/yr
- seasonal effect (?)
- ~ solar activity

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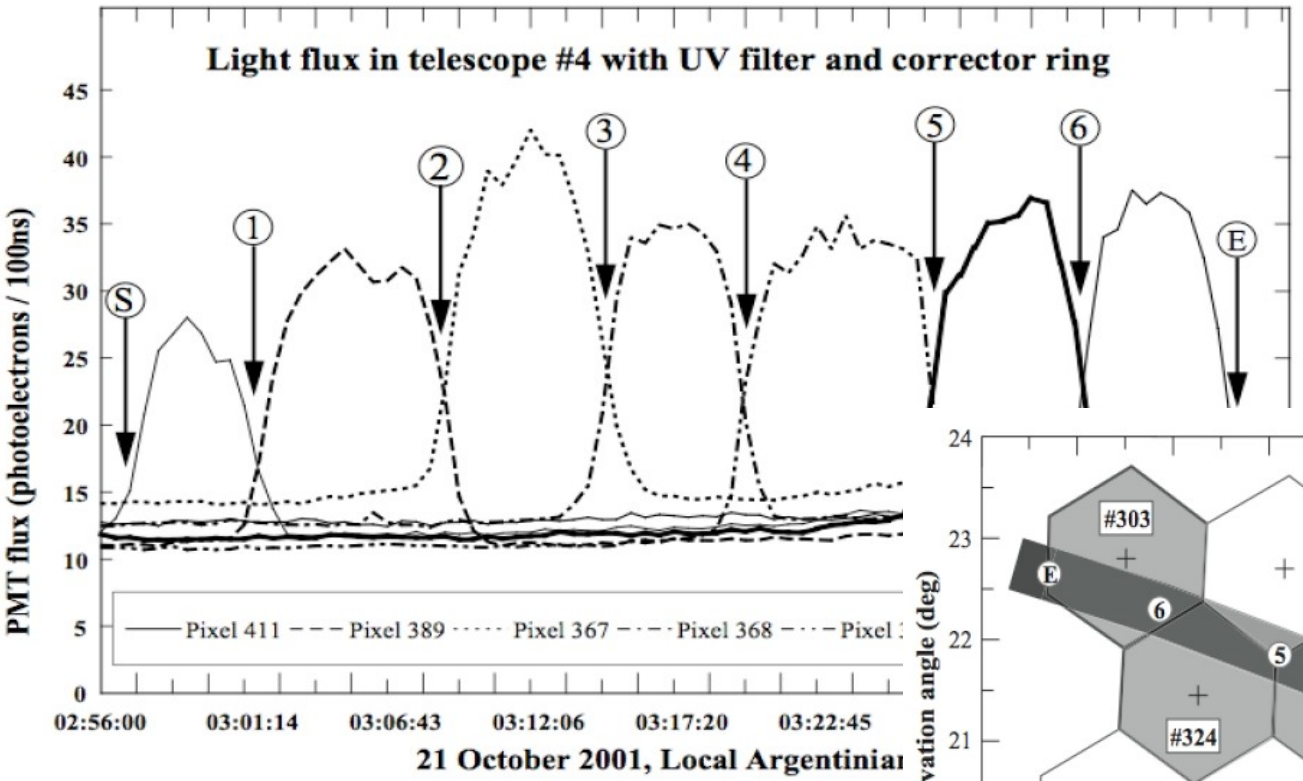
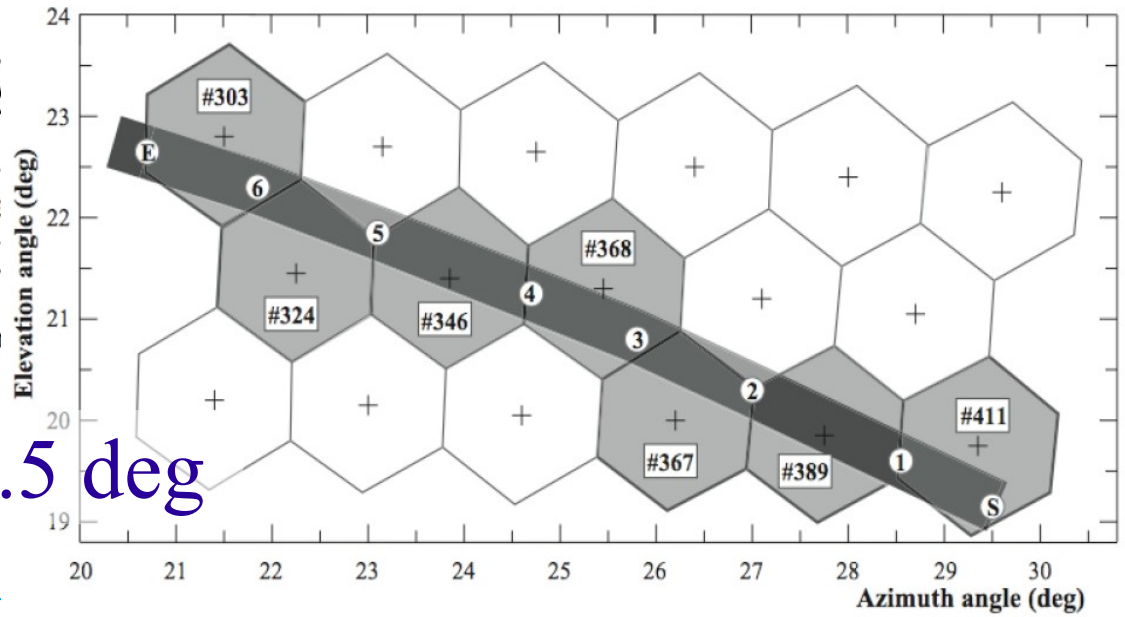
Star tracking



- UV-bright stars
- mag < 4



angular diameter of star 0.5 deg

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Offsets of cameras

- Milan group GAP-2005-008
- Prague (M. P.) GAP-2005-041
- catalogue of UV-bright stars
- calculated positions + corrections
- Offset of cameras for elevation and azimuth (~ tenths of deg)
- also uniformity of photocathodes

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Life-time of PMT

- expected life-time ~ 20 yr
- cuts on variances during measurement !!
- What is an optimal value??
- Phase of the Moon
- What we could loose with cuts?

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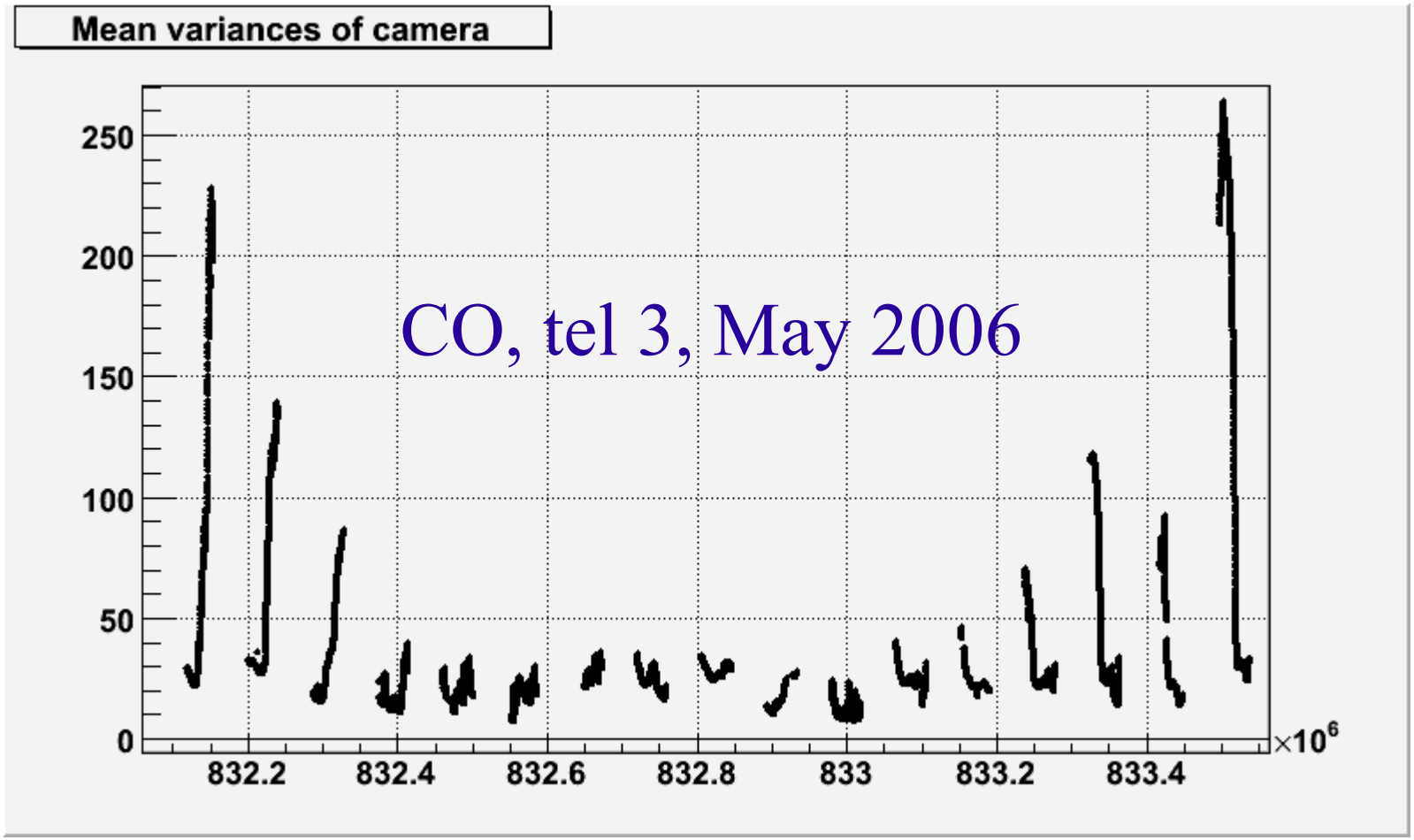
FD shift



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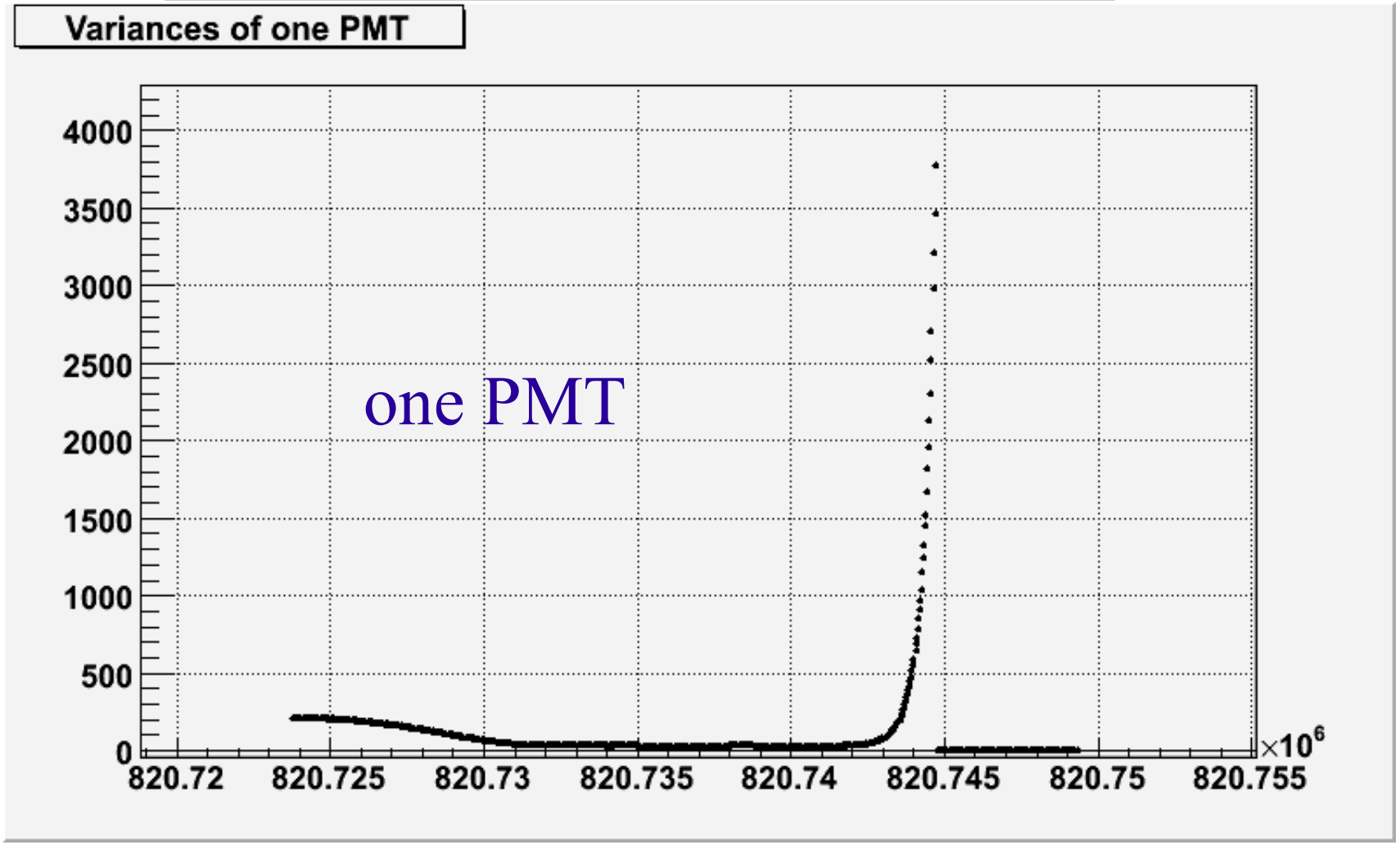
Moonrise



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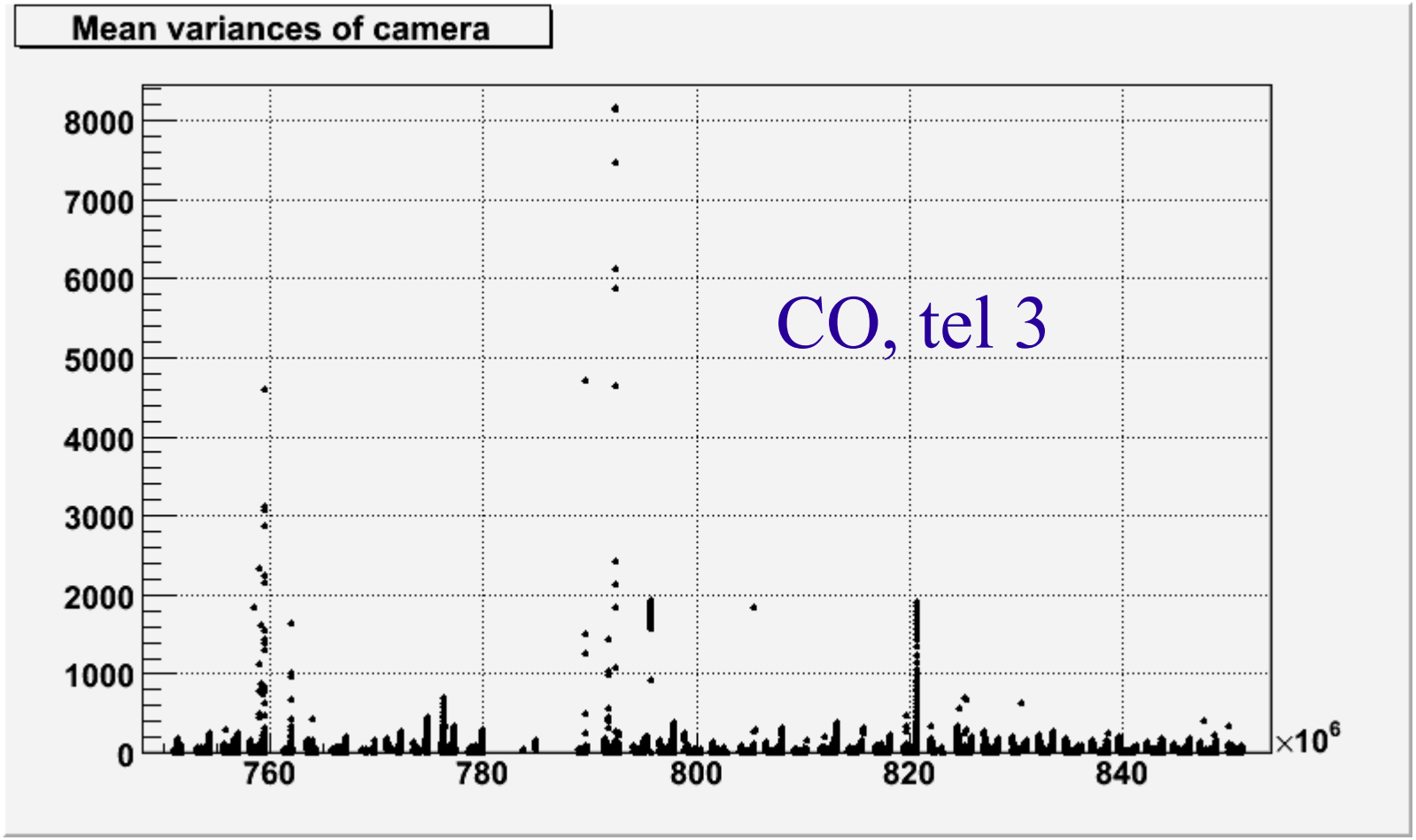
High variances



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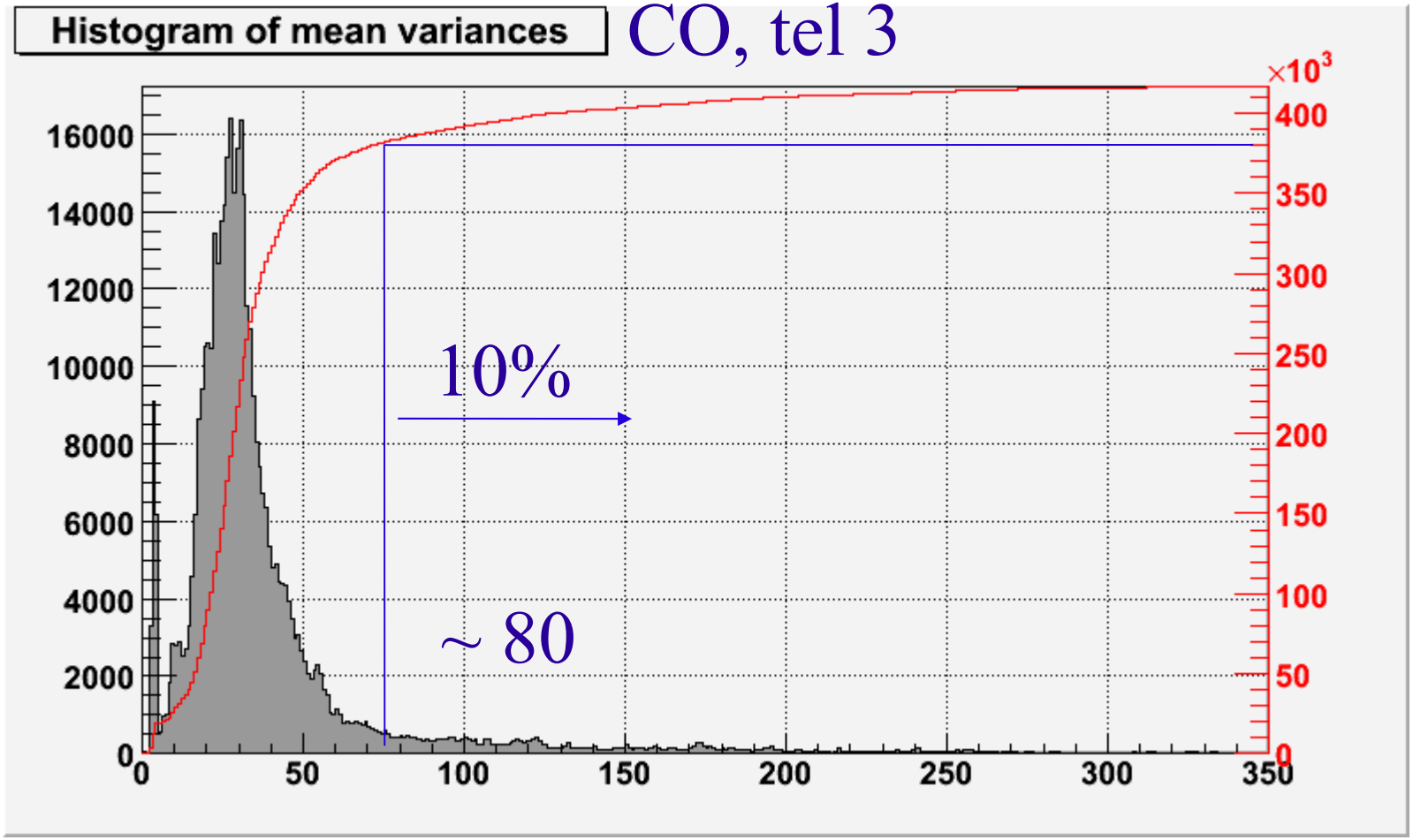
Histogram of variances



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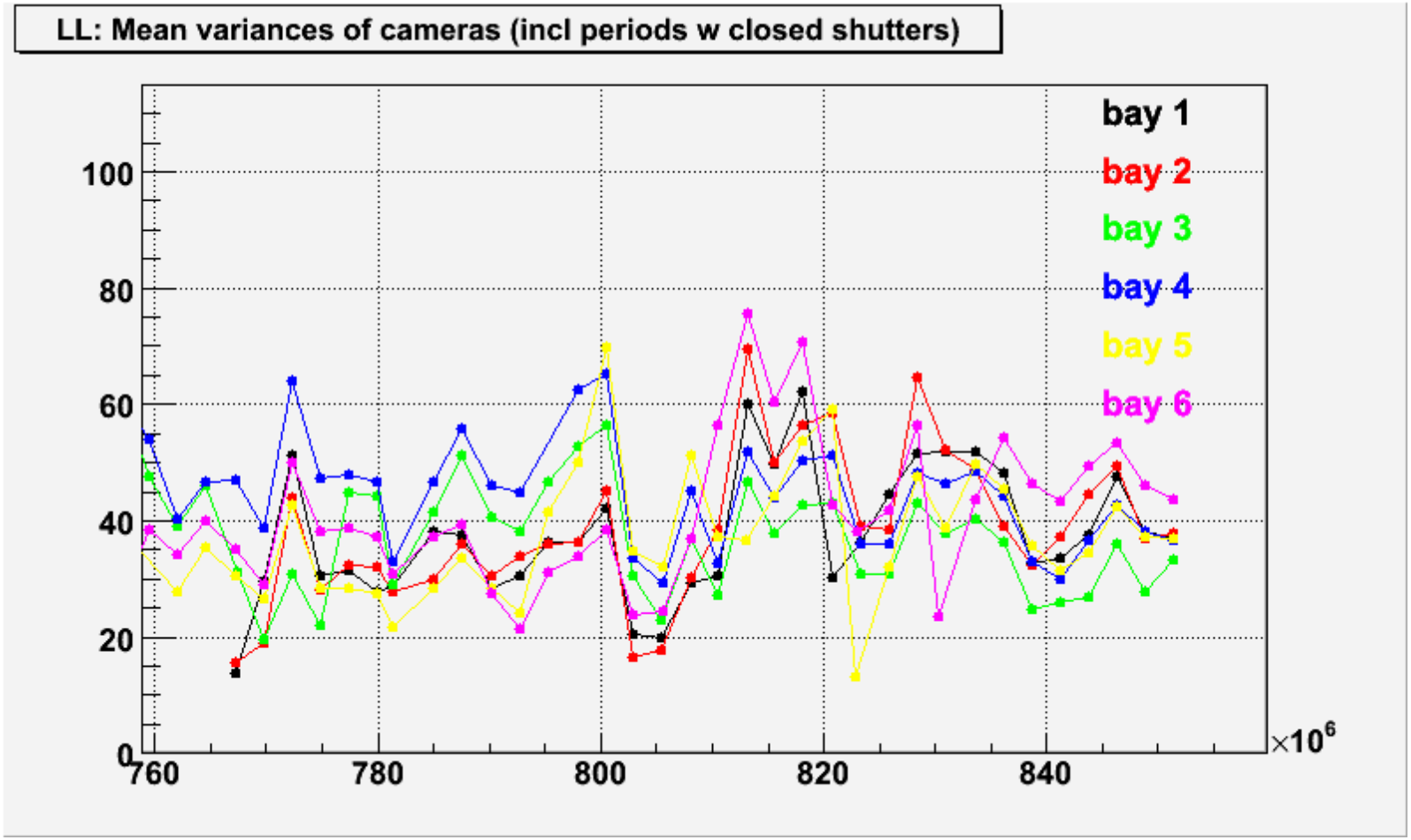
LL, mean camera var.



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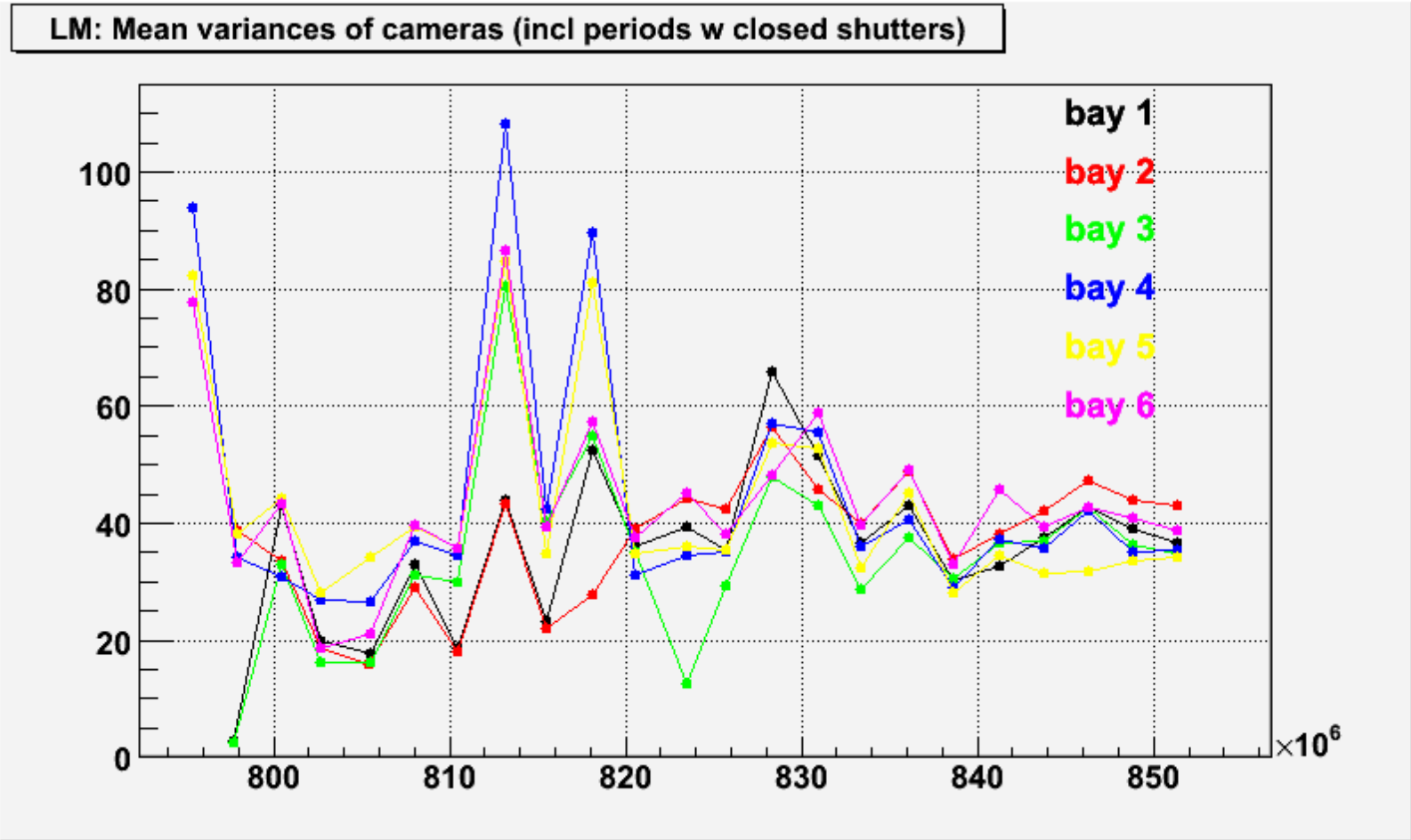
LM, mean camera var.



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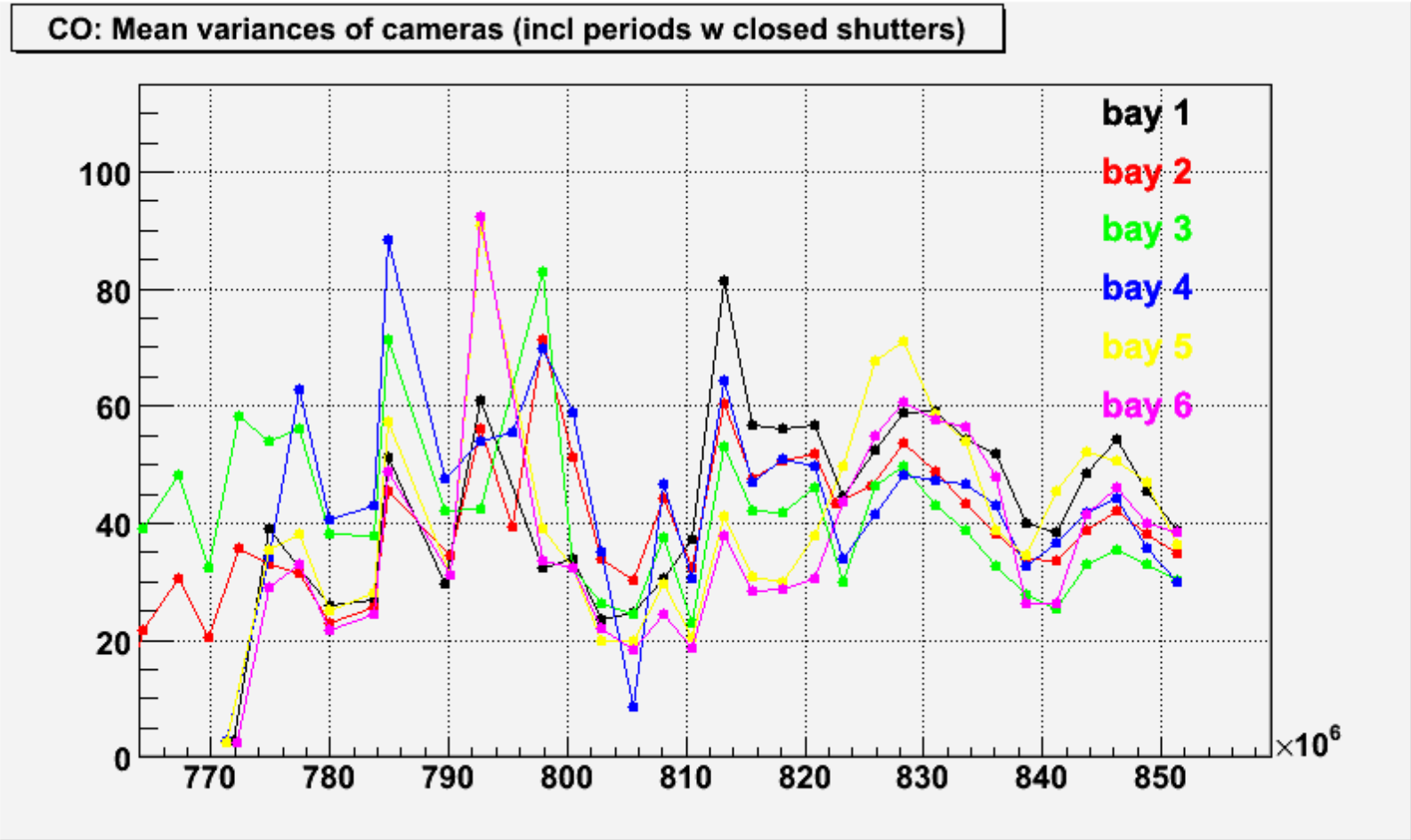
CO, mean camera var.



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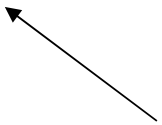
Accumulated charge

Cam	Los Leones	Los Morados	Coihueco
1	15.30 C (# 401651)	9.14 C (# 240276)	15.21 C (# 350567)
2	15.74 C (# 408459)	8.90 C (# 234538)	16.74 C (# 416784)
3	18.32 C (# 486784)	9.32 C (# 255512)	17.01 C (# 417778)
4	21.39 C (# 480853)	10.37 C (# 244586)	14.41 C (# 334175)
5	17.50 C (# 465186)	9.84 C (# 244964)	14.30 C (# 348180)
6	18.38 C (# 447330)	10.41 C (# 244396)	12.83 C (# 346975)



# of 30 sec intervals

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LL 2006

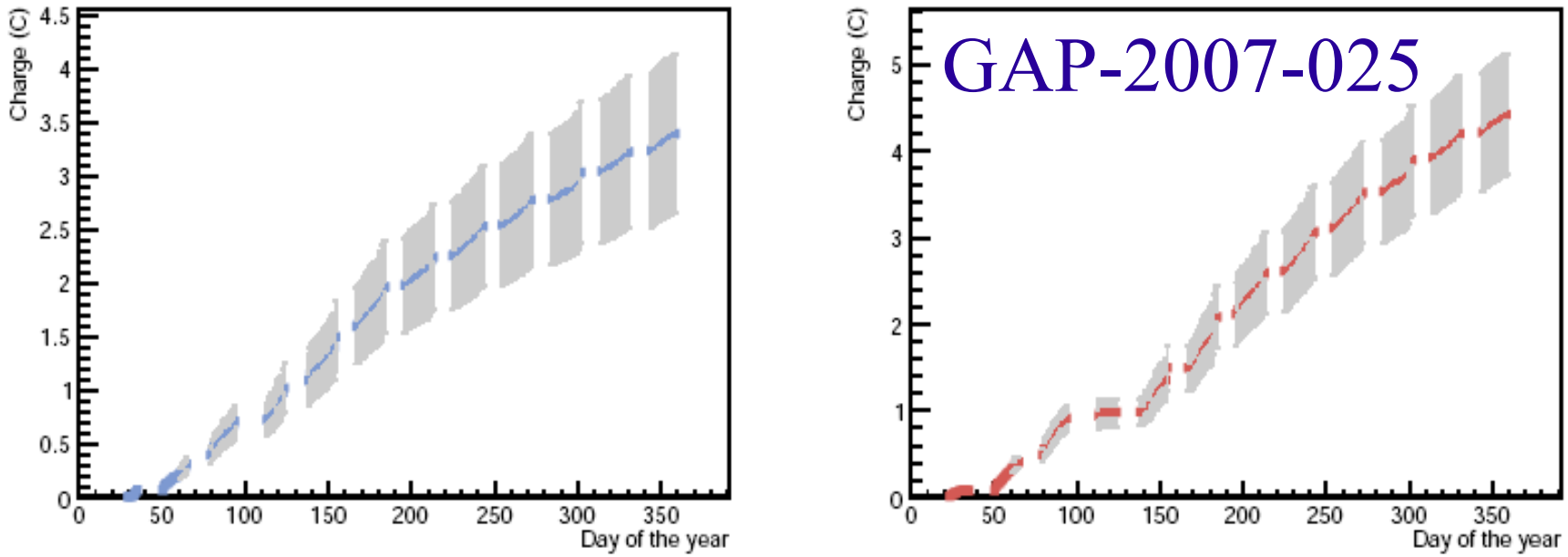

Figure 4. Integrated charge for bay 3 (left) and bay 6 (right)

- our results (2006): 5.61 C (LL03)
  7.39 C (LL06)

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Gain drop

$$G(t) = e^{-0.693 \frac{qa \cdot t}{Q_{1/2}}}$$

- Q(1/2) = 500 C half-life of PMT
- qa charge accum. by PMT anode

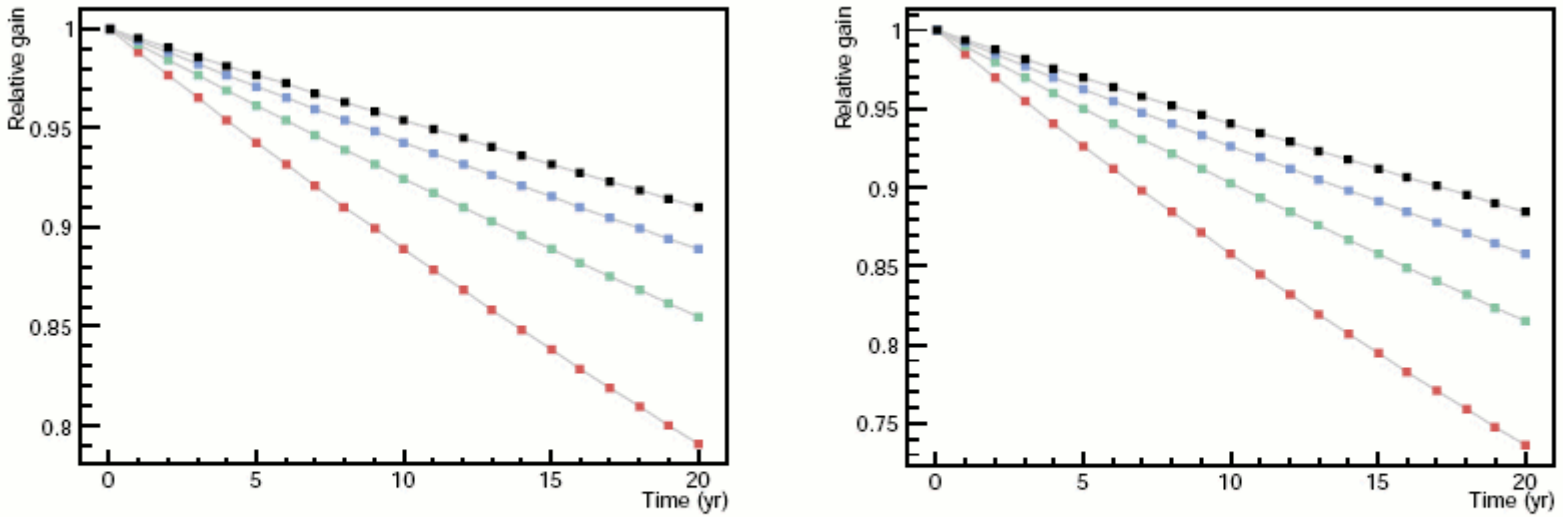
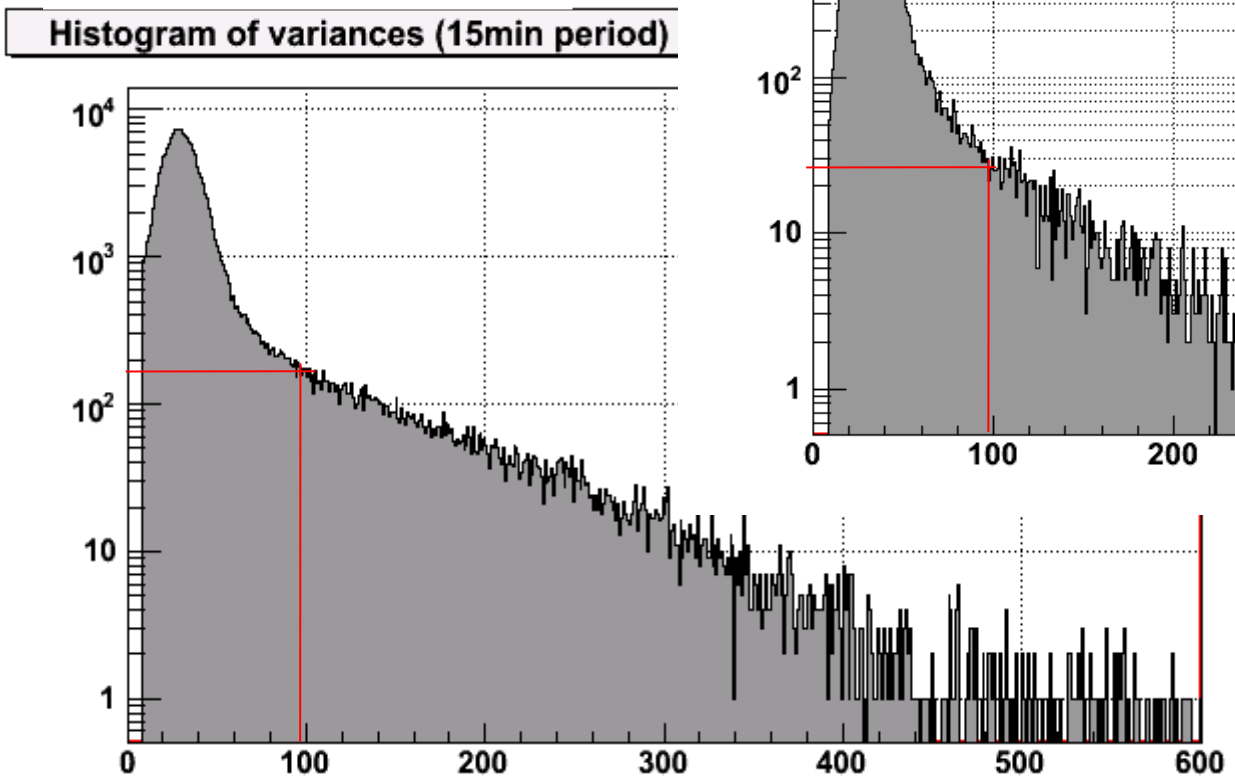
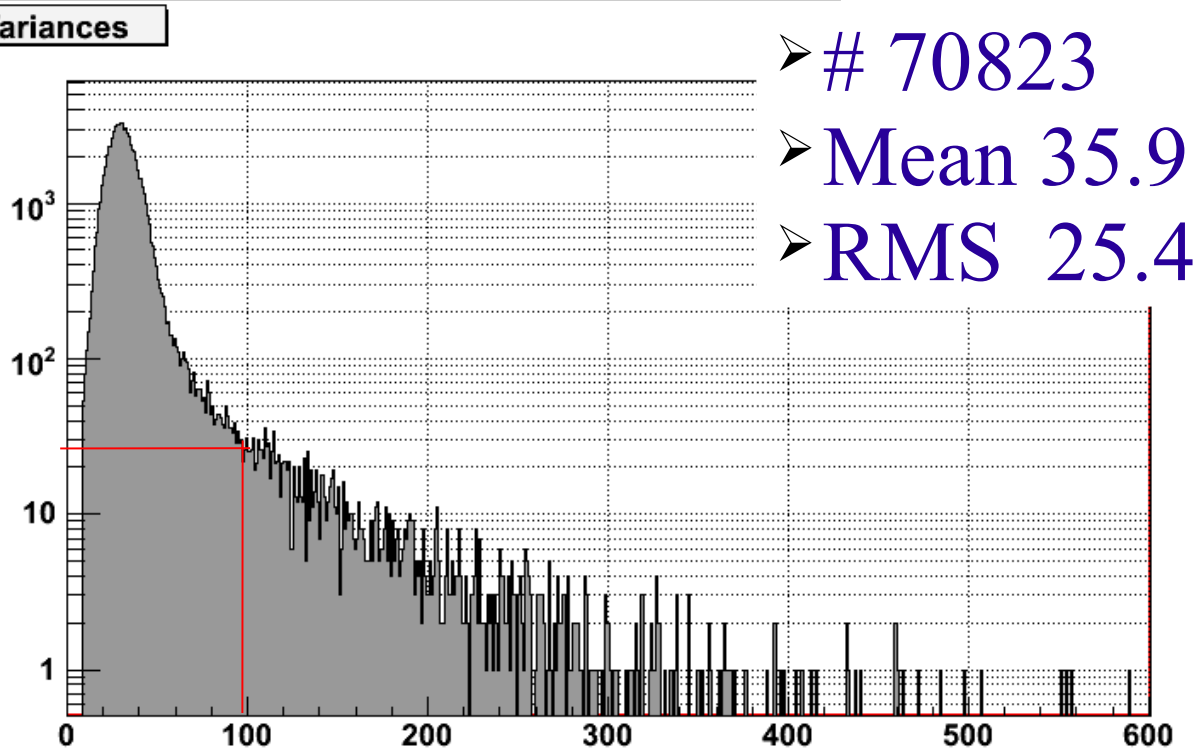


Figure 6. Mean decrease in gain for camera 3 (left) and 6 (right) for $Q_{1/2}$ of 200 C (black), 300 C (blue), 400 C (green) and 500 C (red)

Var and var for data

- # 204580
- Mean 43.0
- RMS 44.0





- # 70823
- Mean 35.9
- RMS 25.4

- FD data: Observer

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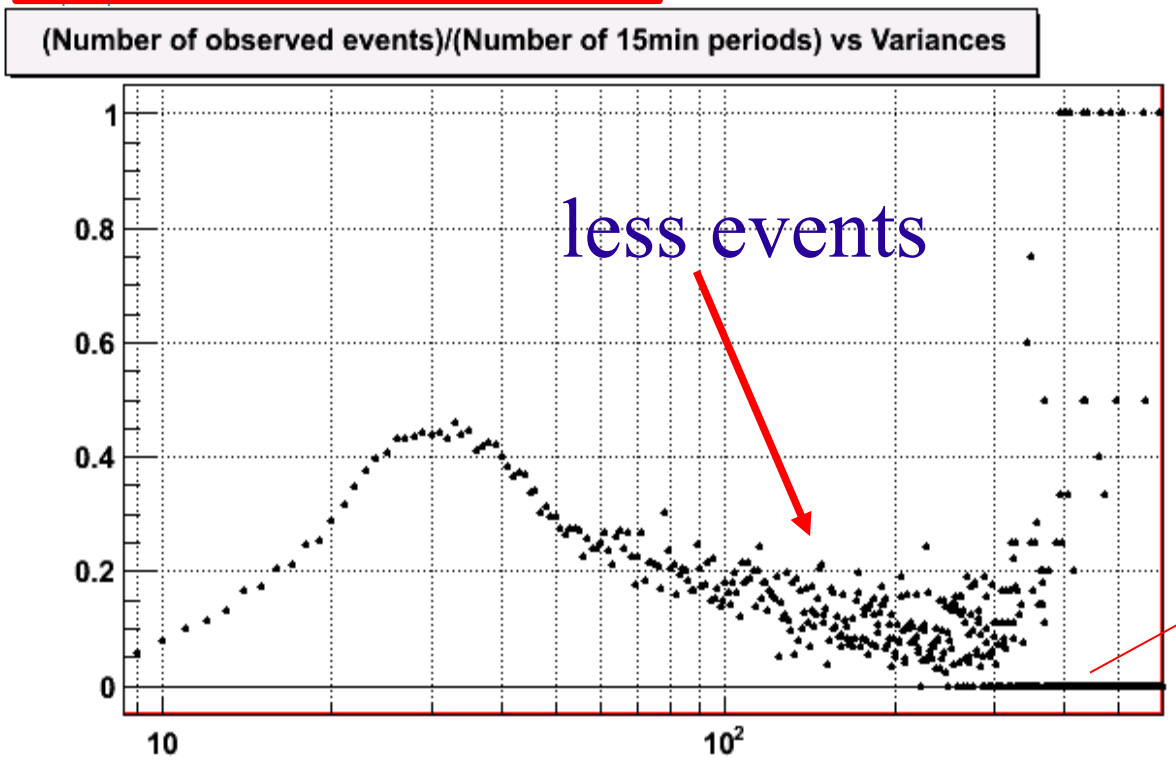
Variances / Gain drop

Cut on variances during measurement



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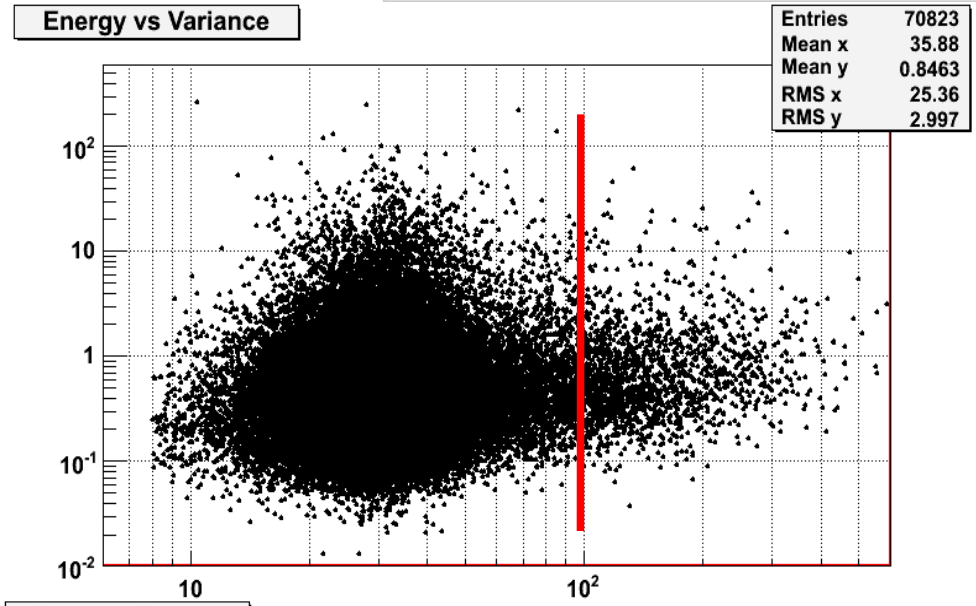
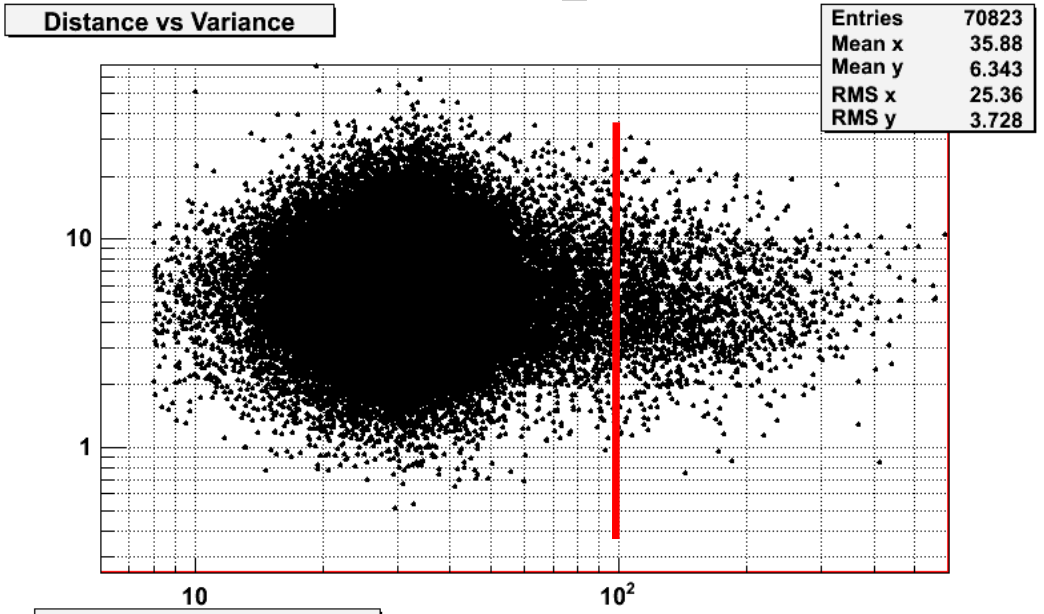
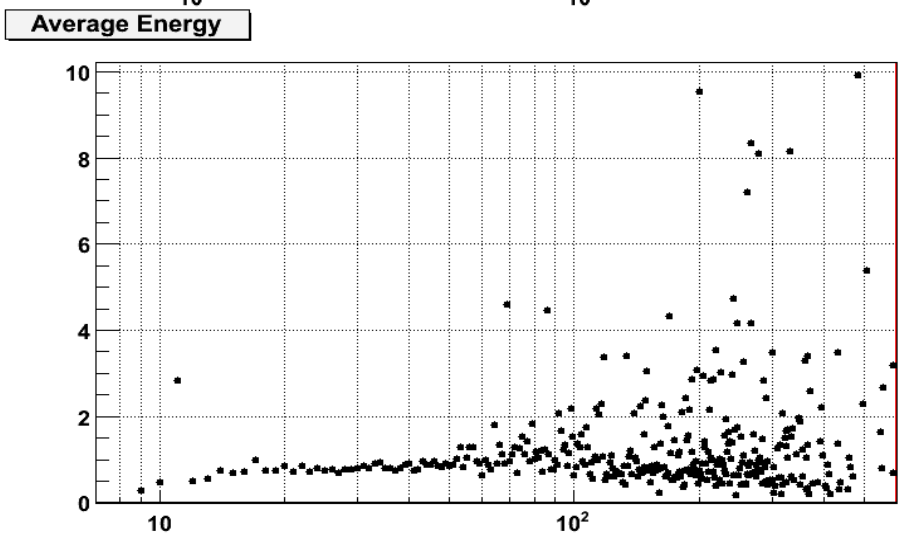
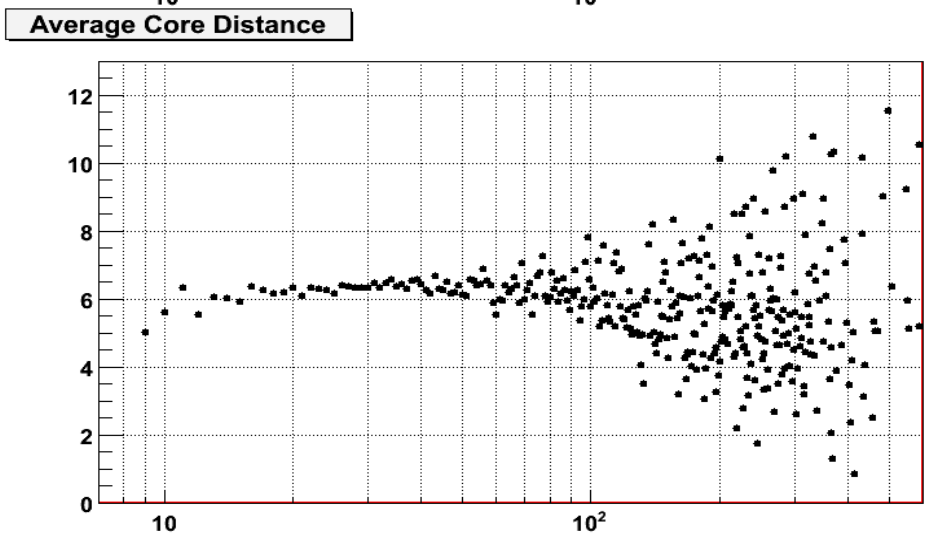
Energy, core distance

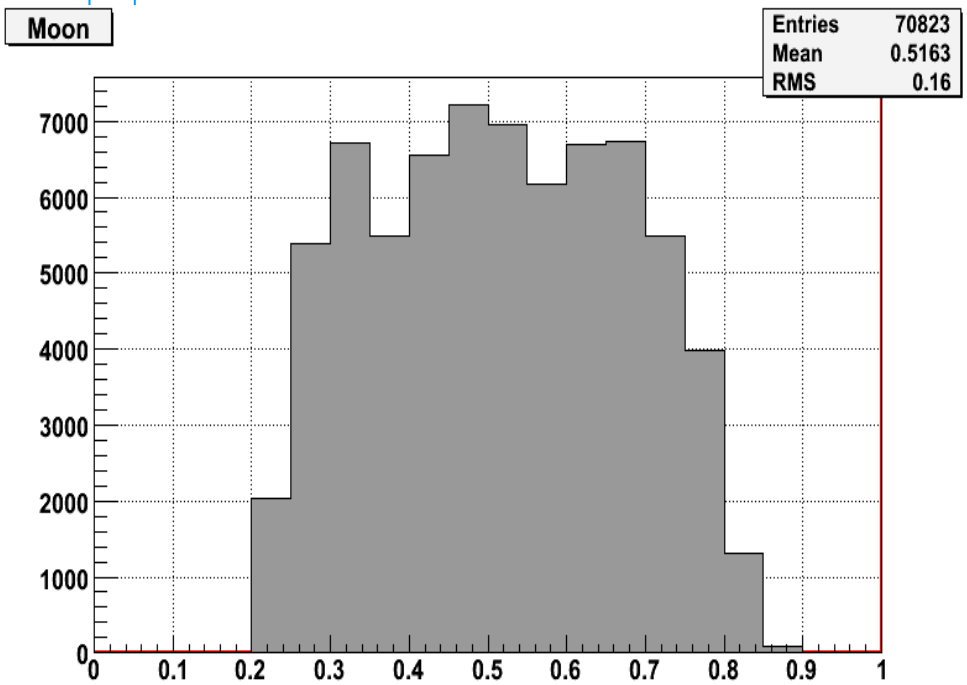


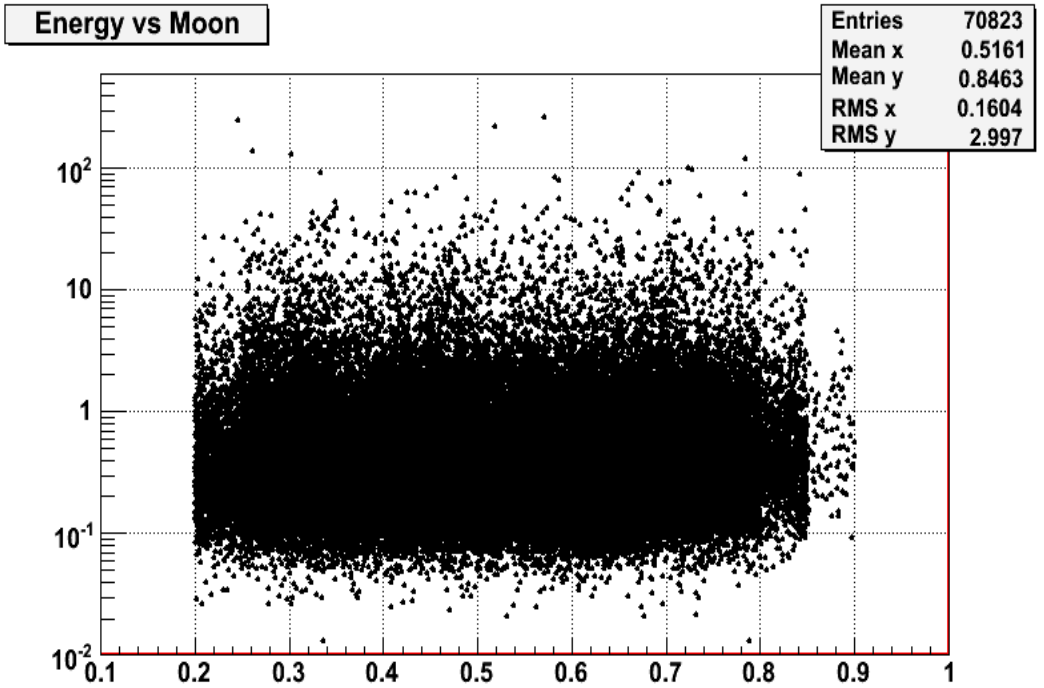






Moon vs variance





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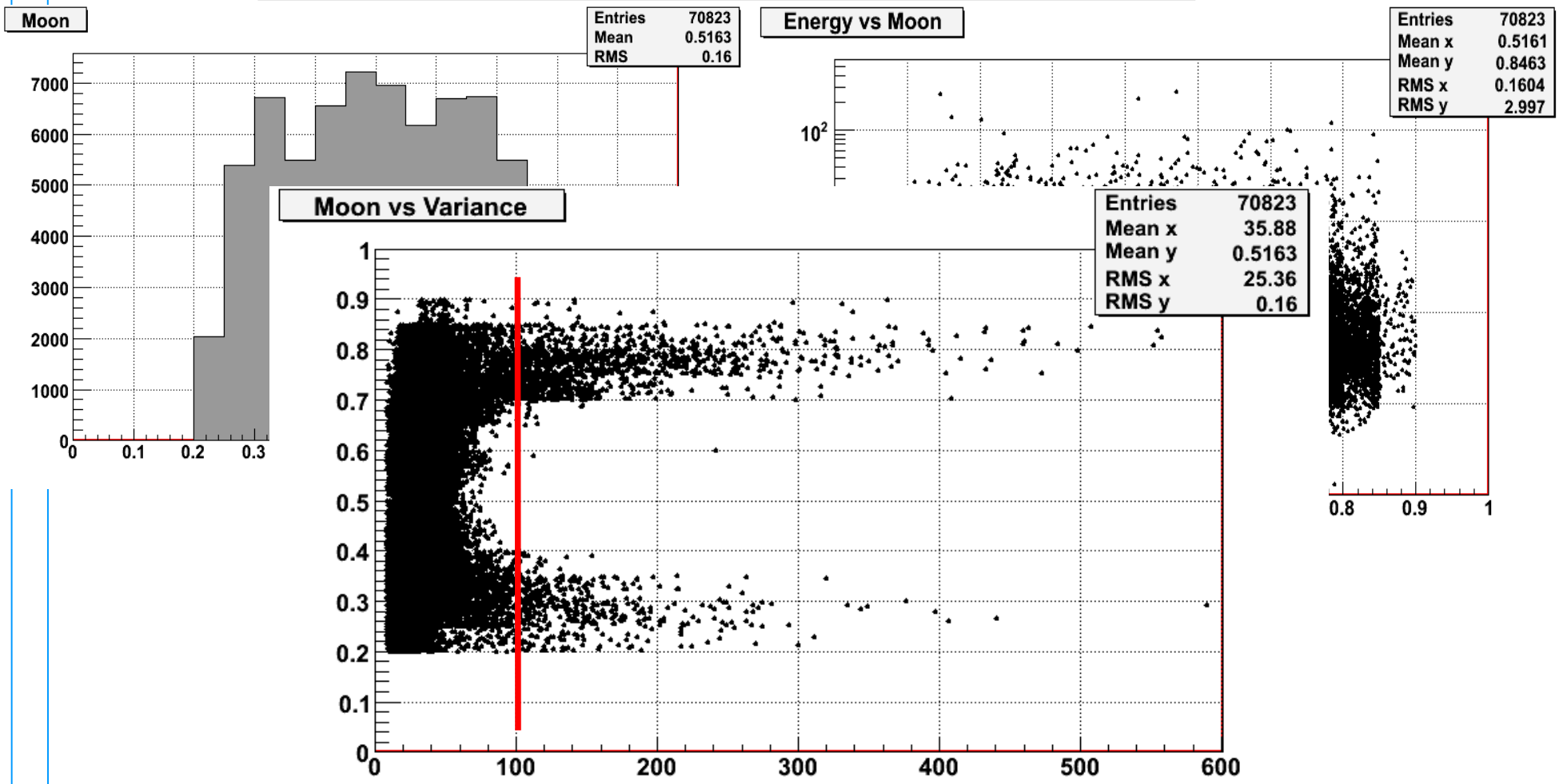
Moon vs variance



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