

# Summary of FD Calibration Session

Auger Collaboration Meeting

Malargue, Argentina

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1. "All" the pieces
2. New results :
  - i)  $\langle PE/FADC \rangle$  "PMT/electronics" calibration
  - ii)  $\delta_s \leftrightarrow FADC$  "end to end" calibration
- ⊕ piece by piece efficiencies consistent w/ absolute FI calibration "already" at  $\approx 10\%$  precision!!
3. The "next" 5% !

# Fluorescence Detector Calibration

" $\delta$ "  $\rightarrow$  FADC  $i=1, 440$

$E(\lambda, i)$  Relative  
 4 reports using "all" techniques  
 $E(\lambda, i)$  end-to-end  
 2 reports using Rayleigh scattering

PMT/electronics  $i=1, 440$   
 P.E. statistics  
 ⊕ PMT, electronics characterization (or modelled)  
 2 reports using different analyses

⊗ "Fiber A" plus geometrical correction  
 $E'(\lambda, i)$

Optics

Drum Illuminator

✓ need drum absolute calibration

✓ need drum characterization  
 ⊕ ray trace fine tuning

Laser (M.S.) Light

✓ Rayleigh scattering

✓ laser intensity absolute calibration

⇓

$E(\lambda, i)$

⇕

✓ Piece by piece calibration ( $\lambda$ )  
 (P.E.'s/ $\delta$ )

"flat fielding" the camera

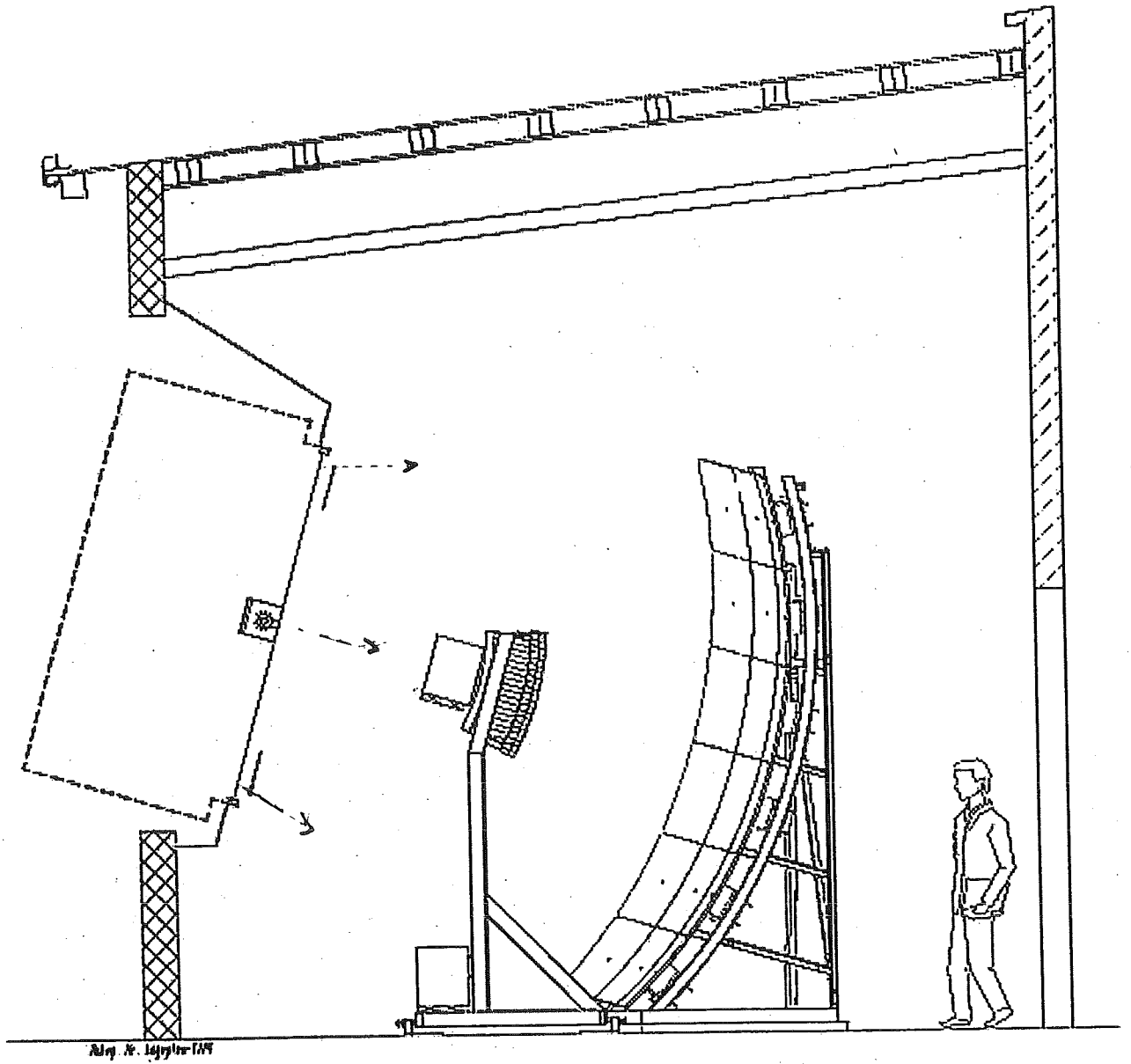
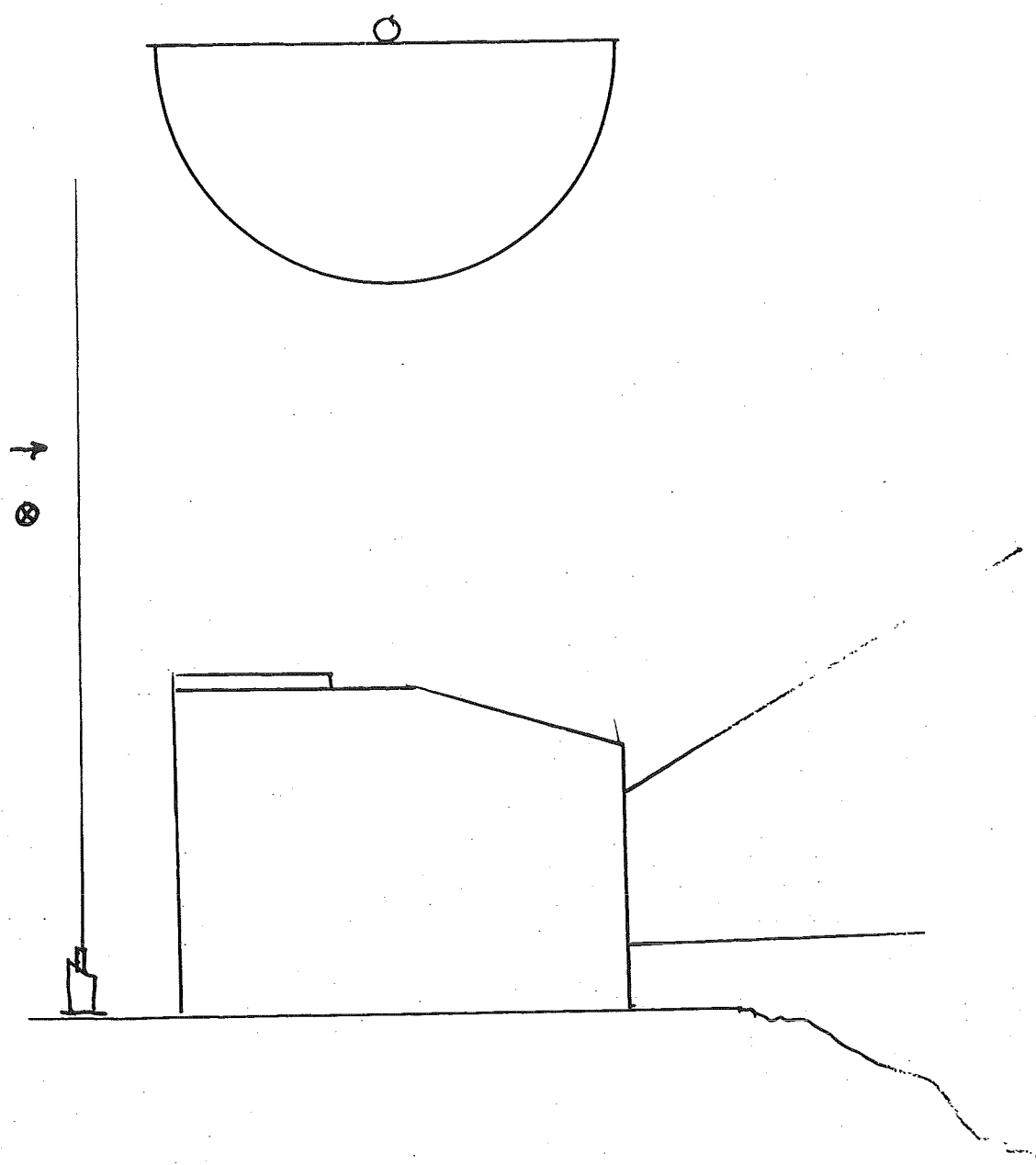
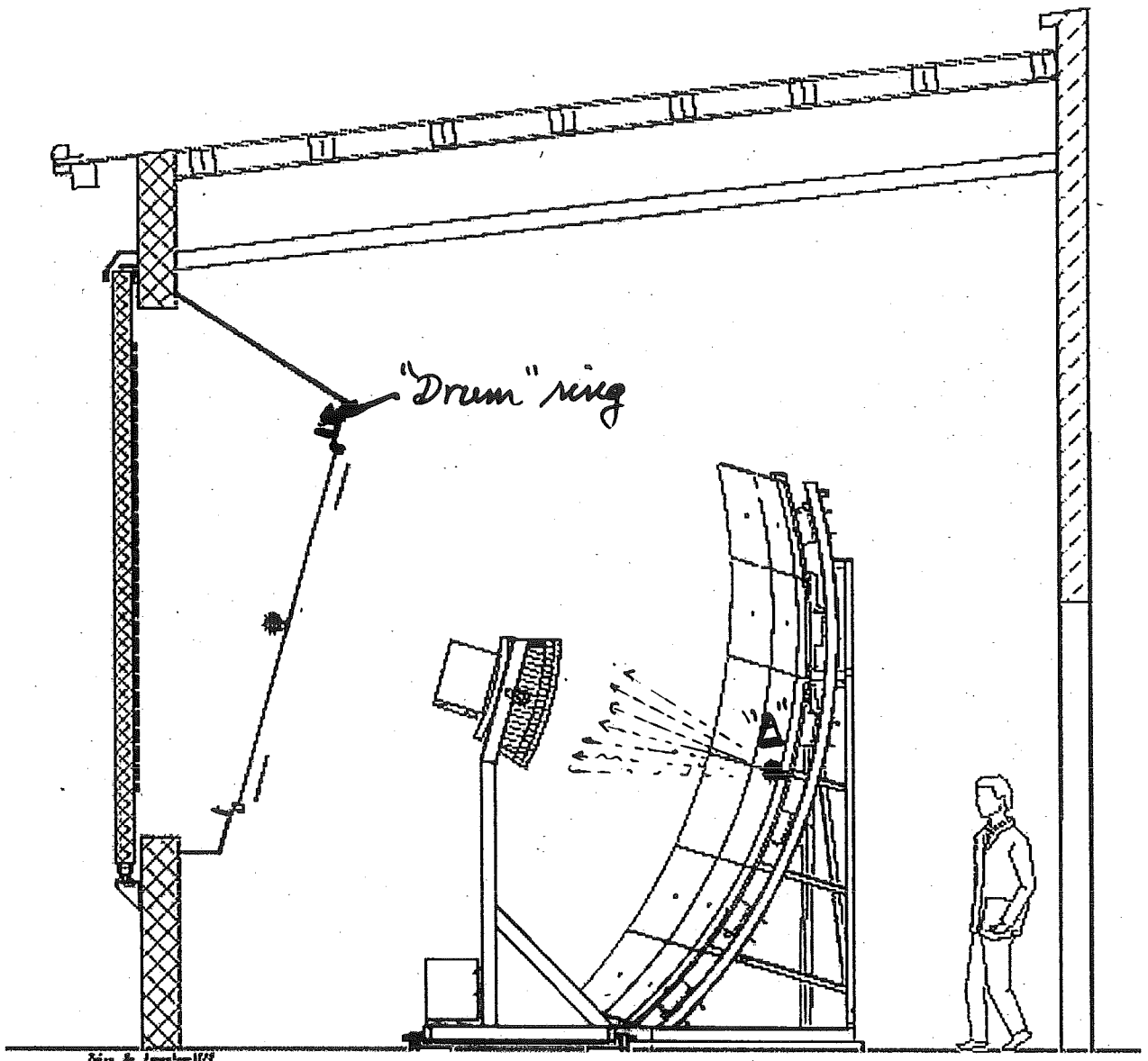


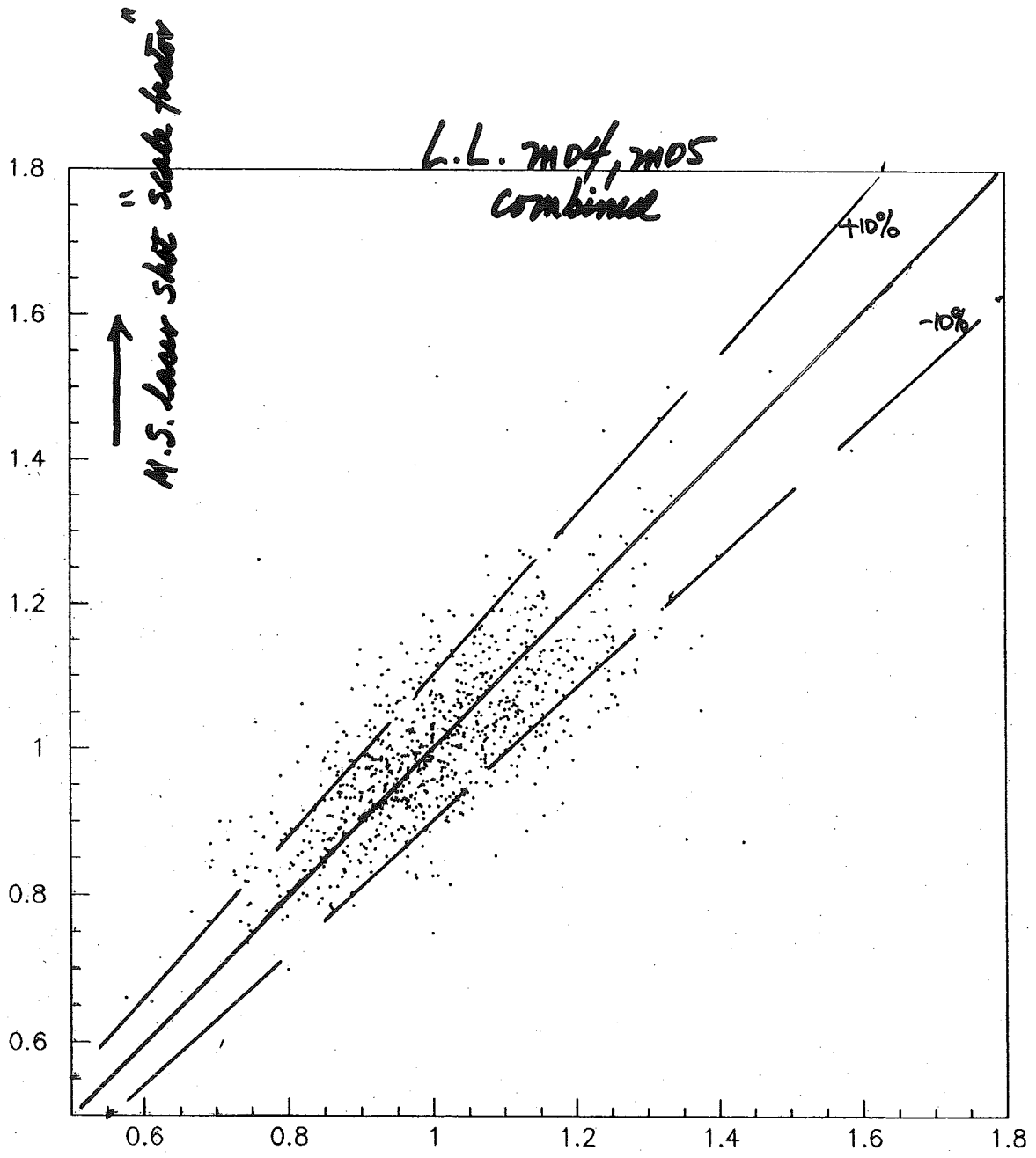
Fig. 147





"Drum" ring

Fig. 10. 1913



→  
 filter "A" "scale factor"  
 ("gain")

de Capoa  
U. of Turin

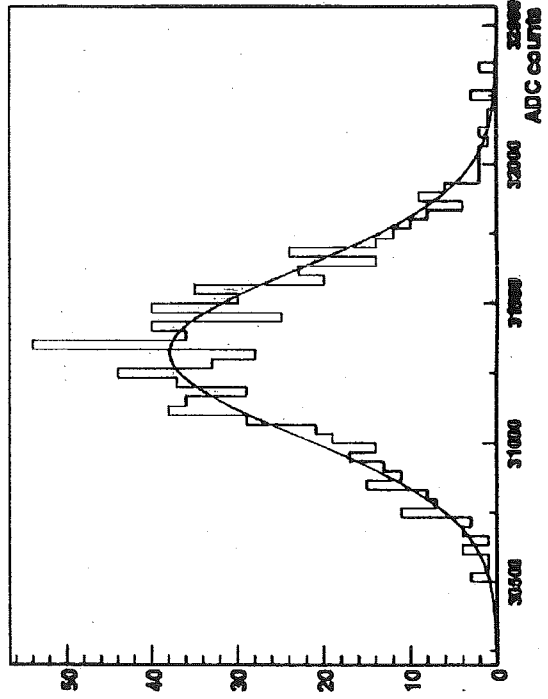
## ABSOLUTE CALIBRATION

Conversion ADC counts/ n photoelectrons

$$K = \frac{S_i}{\sigma_i^2} \cdot V^n \rightarrow 1.413$$

$V_m$  from PMT simulation  
in agreement w/ manufacturer

pin 367

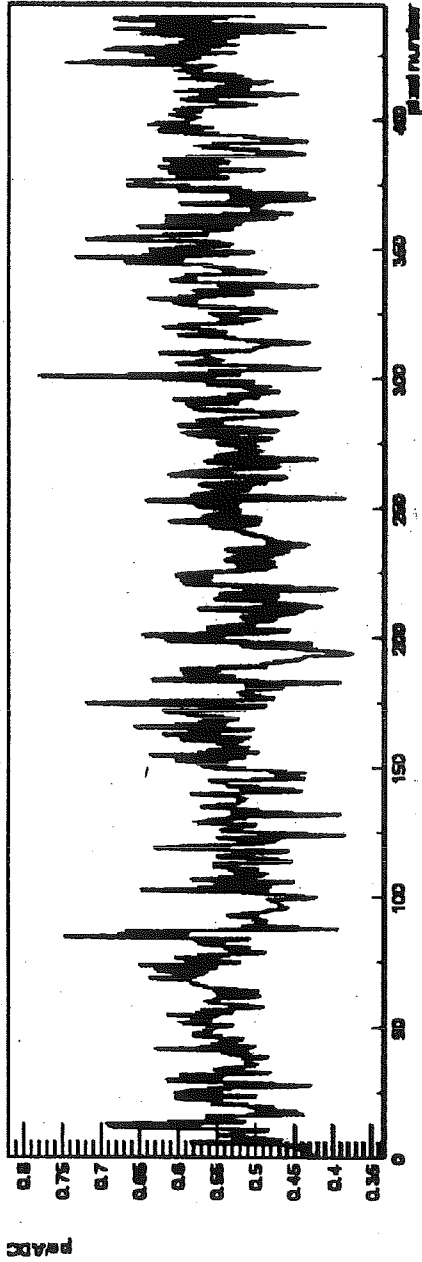


Assumes that only contribution to  $\sigma$  is from p.e. statistics and multiplication.

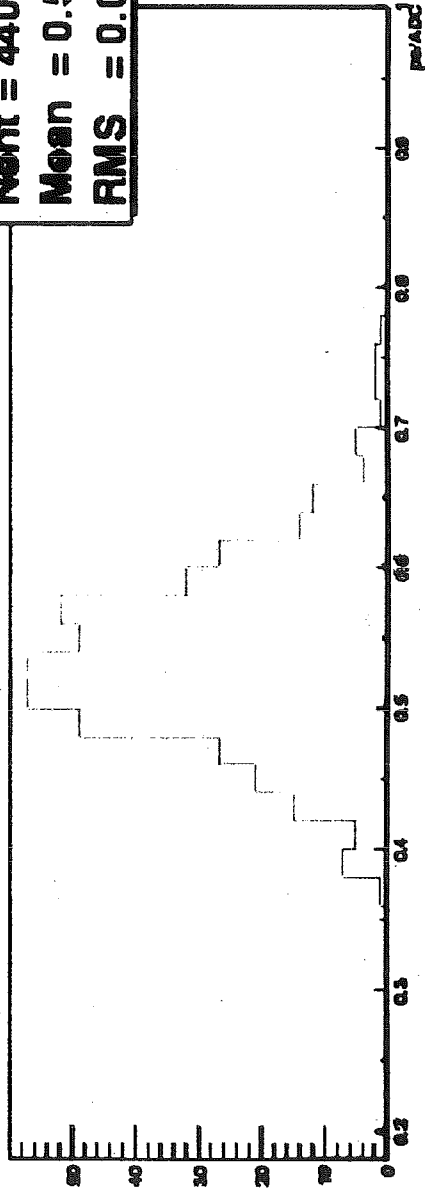
Other possible sources of broadening

- Integral calibration
- Baseline calibration
- Noise

absolute calibration



channel distribution



Count = 440  
Mean = 0.5367  
RMS = 0.06527

← PE's/FADC  
"electrons/PMT"  
calibration



# Fluorescence Detector Calibration

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$E(\lambda, i)$

✓ Piece by piece calibration ( $\lambda$ )  
(P.E.'s/ $\delta$ )

"Fiber A"  
plus geometrical correction

$E'(\bar{\lambda}, i)$

"flat filling"  
The camera

PMT/electronics  $i=1,440$

P.E. statistics  
⊕ PMT, electronics characterization (or modeled)

2 reports using different analyses  
• 47

• 0.547E? PE/FADC  
• 0.625E? PE/FADC

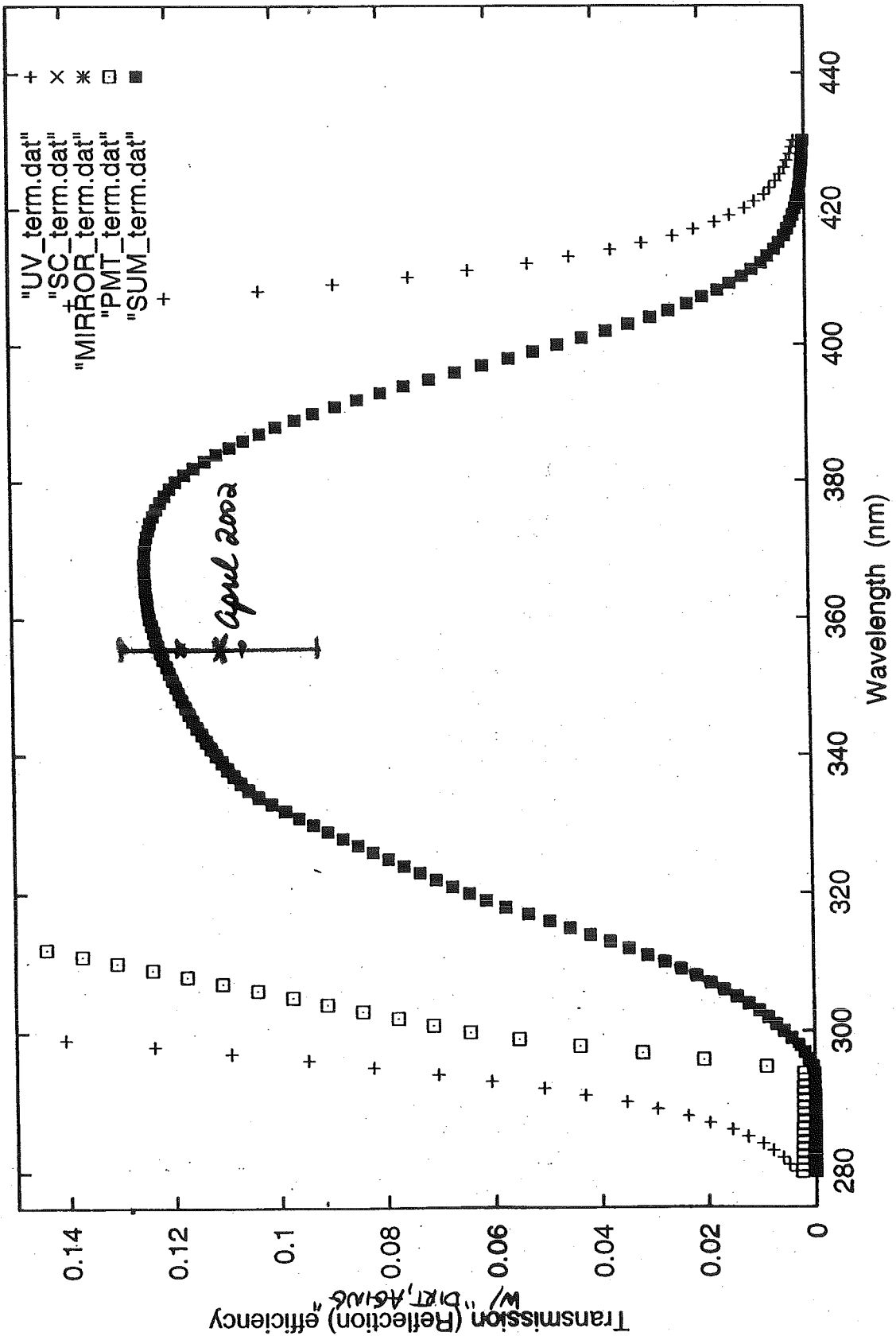
$E(\lambda, i)$  Relative  
4 reports using "all" techniques

$E(\lambda, i)$  end-to-end  
2 reports using Rayleigh scattering

• 5.09  $\pm$  0.09?  
• 4.9  $\pm$ ?  $\delta \rightarrow \Delta$

106  $\sim$  .128 PE's/ $\delta$   
• 097

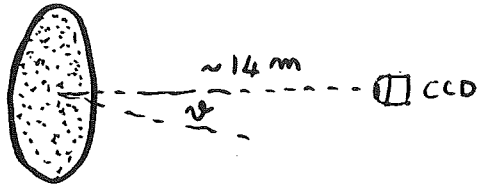
# Cumulative Fluorescence Detector Efficiency



The "next" 5%:

- ① Calibrated and characterized drum illuminator(s)
- ② Better characterized and calibrated (ranging) laser ⊕ simultaneous atmospheric monitoring
- ③ Tuned ray tracing programs:
  - i) match drum illuminator signals
  - ii) " diffuse laser "δ" signals
  - iii) " fiber "A" signals⊕ data base of transmission/reflection vs  $\lambda$  for all (new) telescope components
- ④ Stable camera response ⊕ Time dependent  
PEs/FADC |<sub>i = all channels</sub>

\* STARTING POINT:  
 DRUM CCD PICTURES AT DIFFERENT  $\nu$  (J. Barck)  
 Ric.



\* FROM CCD PICTURE TO DRUM AT THE APERTURES  
 CCD PIXEL  $\rightarrow d\varphi_x d\varphi_y$

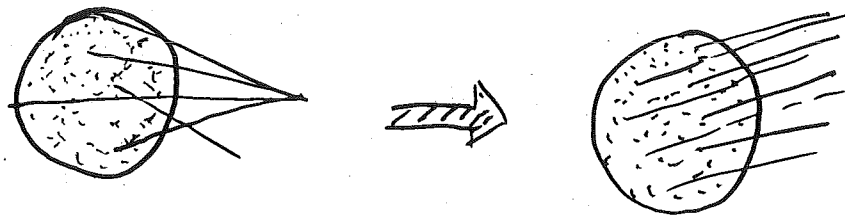
$\nu$ , CCD TO DRUM DISTANCE, DRUM RADIUS ARE KNOWN  
 MINIMIZE TO FIND  $d\varphi_x d\varphi_y$

~~DRUM~~  $R_{\text{DRUM}}$  CORRECTLY RECOVERED WITHIN 1 cm

\* PIXEL INTENSITY MUST BE CORRECTED FOR THE SOLID ANGLE

$\rightarrow I(x, y)$

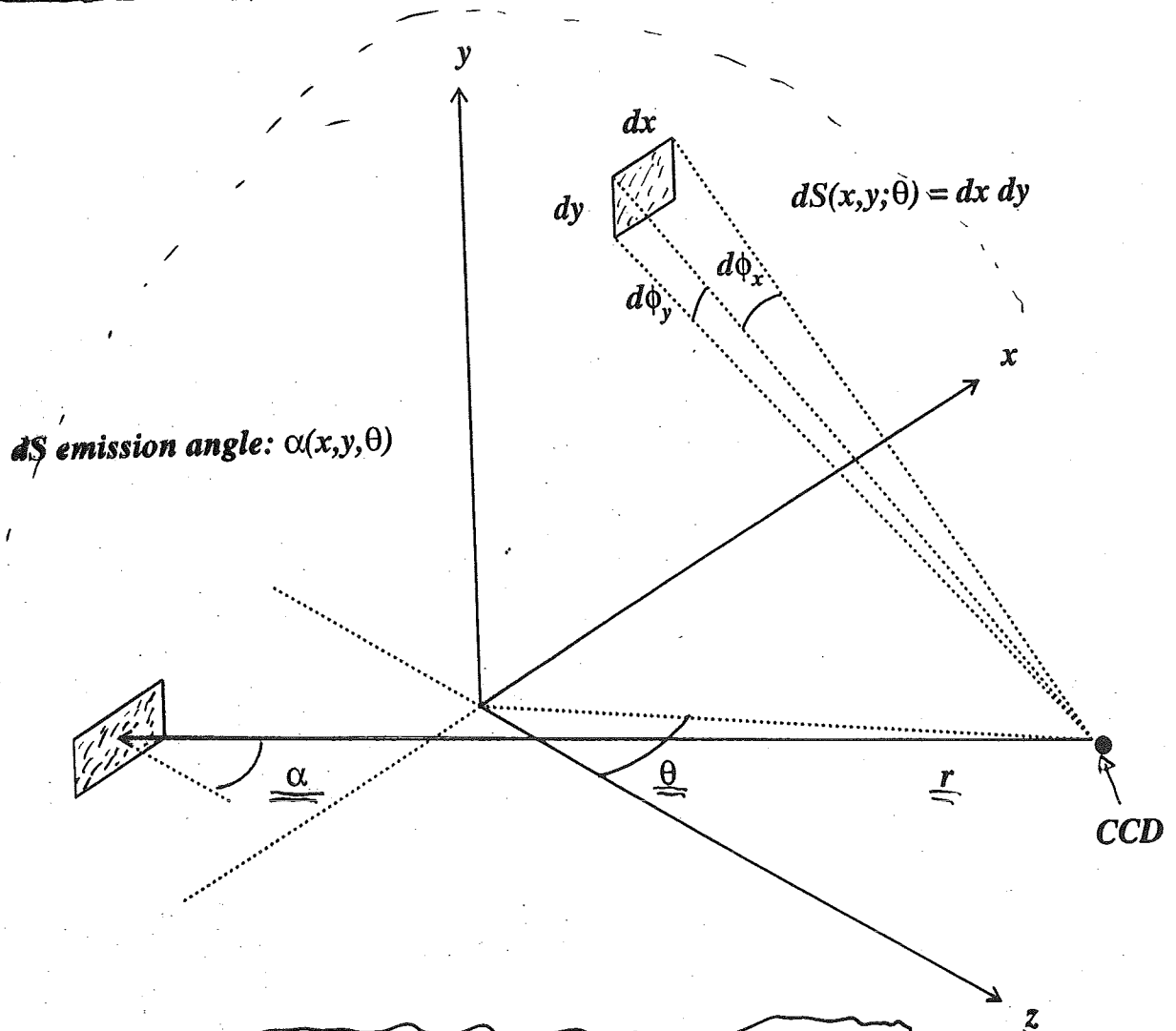
\* FROM DRUM IMAGES TO  $I_{\text{DRUM}}(\nu)$



Paolo Pruntera  
 et al

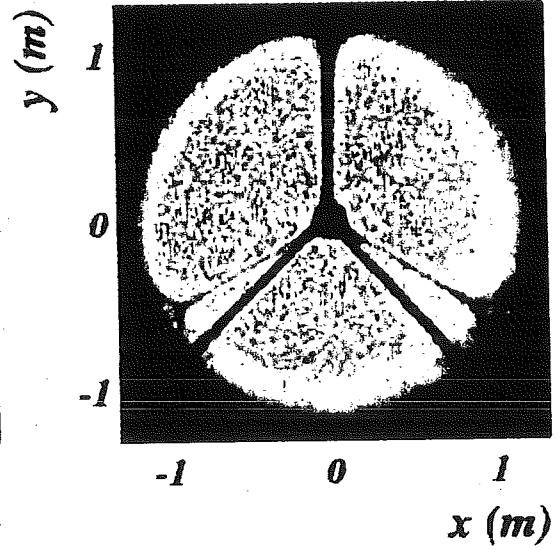
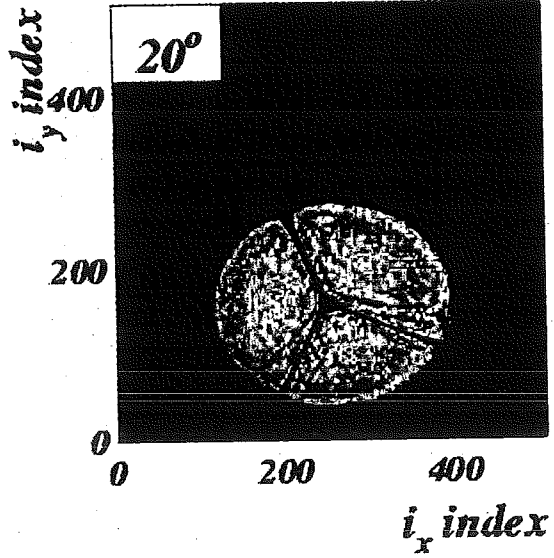
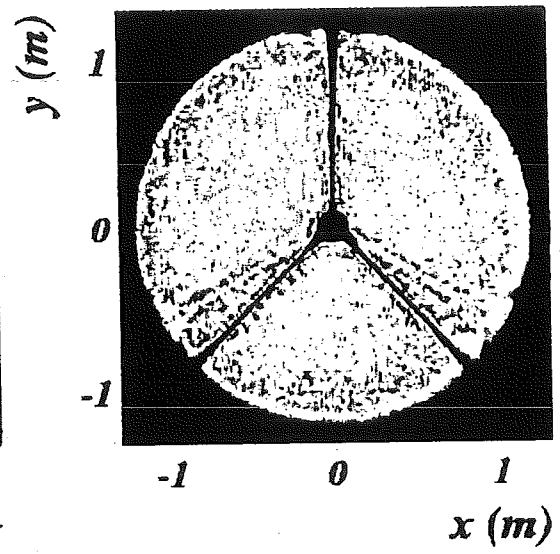
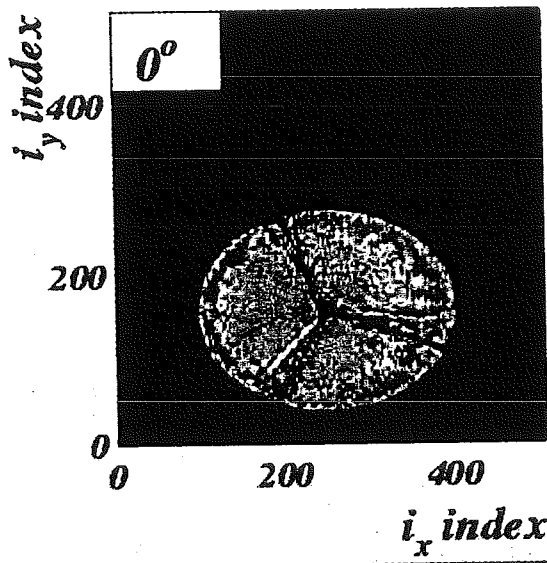
Drum plane:  $(x,y)$

CCD pixel aperture:  $(d\phi_x, d\phi_y)$



$$I_{CCD}(x,y;\theta) = I_{Drum}(x,y;\theta) \frac{dS(x,y;\theta)}{dS(0,0;0)} \frac{r^2(0,0;0)}{r^2(x,y;\theta)}$$

# CCD Drum images



## \* FROM APERTURE TO PIXEL

- CAMERA SHADOW
  - CORRECTOR RING
  - MIRROR
  - MERCEDES
  - PMT E VS RAY ANGLE
- OK  
IN  
APERTURE
- } RAY TRACING



PREDICTION OF PIXEL SIGNAL

## \* COMPARISON OF DRUM DATA AND SIMULATION

$$\left( \frac{N_{ADC}}{\sigma_{ADC}} \right)^2 \sim \frac{(1+V_G) m_x}{\rho_{PMT}}$$

BAY 4: LEFT-RIGHT ASYMMETRY      QUALITATIVE AGREEMENT  
UP-DOWN ...

BAY 5: ~ FLAT

\* NOTE: FROM PMT TEST BOX MEASUREMENTS

$$\sigma^2 \sim \underline{(1+V_G) G \cdot S}$$

2001 BAY4

