Pierre Auger Project Note: GAP-2000-050

Fluorescence Detector Optical Calibration Source Test

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October 16, 2000

Abstract

A test of a small, portable version of the xenon light source, optical fiber distribution and Teflon diffuser proposed for the optical calibration system (for the Auger fluorescence detector) was made in June 2000. The test used the Auger fluorescence telescope prototype at U. of Roma2. The goals of the test were to measure the PMT signal(s) (at the center of the camera) to be sure that the final system will provide enough light to reach the high intensity end of the PMT dynamic range and to measure the azimuthal uniformity of the light diffused by simple Teflon diffusers.

1 Introduction

1.1 Auger Fluorescence Detector Relative Optical Calibration System

The Auger fluorescence detector (relative) optical calibration system will provide stable light pulses to monitor possible variations in the performance of the fluorescence telescopes with time. The design has one, central light source per 6 (or 12)-telescope fluorescence detector building. Light signals are distributed on optical fibers to 3 computer selectable destinations on each telescope:

1. the center of the mirror (light directed at camera)
2. the center of two sides of the camera (light directed at the mirror)
3. the rear center of camera (light directed at the UV filter/Schmidt entrance aperture of the telescope ... where it is reflected back into the telescope by a removable, reflective screen that is inserted just outside the UV filter during calibration runs).

The current design uses a separate xenon flash tube to provide light to each of the 3 destinations. The xenon flash tubes are simple, rugged sources with $\sim 1\mu$sec light pulses. These sources are very stable and nominally retain $> 50\%$ initial light output after 10^9 pulses. The light is rather uniform *versus* wavelength with $\sim 1\%$ of the light energy/10nm between 100nm $\sim$ 1100nm. Specific wavelengths are selected using (interference) filters. Specific intensities are selected using neutral density filters.

A schematic of the light source is provided in Fig. 1. The source includes: a xenon flash lamp [1] at the focus of a f/1.5 lens, a beam splitter (to a monitoring fiber), one or more filters [2] to select the wavelength and/or intensity of the light, and a f/2.4 lens focusing onto a 0.22 numerical aperture, 1:7 optical fiber splitter [3]. One leg of the optical fiber splitter is monitored; the other 6 legs distribute light to 6 telescopes at the fluorescence site. Quartz, 1" optics is used throughout.

At the time of the Roma2 test two major questions were unanswered: was the light (source) bright enough to cover the full dynamic range of the camera PMTs, and would a simple Teflon diffuser (at the output end of the fiber) provide a uniform distribution of light on the camera? To address these questions a small, portable version of the xenon light source, optical fiber distribution and Teflon diffuser was assembled and tested with the Auger fluorescence telescope camera prototype at U. of Roma2.

The camera prototype used in these measurements did *not* include the *Mercedes* light collectors. The portable light source used a low power xenon flash lamp, Perkin Elmer model RSL-2100-2 [1], f/1.5 and f/2.4 lenses as in Fig. 1, a Schott UG1 filter [4], a commercial 2m long, 200μm, UV transmitting optical fiber [5], and a 1mm (thick) Teflon diffuser. Photographs of the setup are provided in Fig. 2-5.

2 Measurements and Analysis

Pulse heights from three PMTs were recorded using the University of Roma2 DAQ system coupled to a digital sampling scope. The xenon flasher was operated at $\sim$ 1Hz. The scope was set on *averaging* mode. Pulses were accumulated for perhaps 30 seconds and the peak pulse height was recorded. Five configurations of the PMTs were used. In all configurations PMT channel 26 was held fixed (near the camera center). PMT channels 27 and 28 were moved in sequence around the four corners of the camera with a final measurement at the camera center. The raw data are summarized in Table 1.

The data analysis was straight forward. First the space (3D) coordinates of the front faces of the PMTs and the Teflon diffuser were determined. Two geometrical corrections were then evaluated. The first corrected for the variation of distance from the Teflon diffuser to the different possible PMT locations (on the camera face). This was labelled the $1/r^2$ factor. The other corrected for variations in the projected area of the PMT face, as viewed from the Teflon diffuser, for different possible PMT locations. This correction depended on the angle, θ, between the normal to the face of the PMT and the line joining the PMT and Teflon diffuser. This was labelled the $cos\theta$ factor. No (shadowing) correction was made for variations in the effective illuminated area of the Teflon diffuser (to different possible PMT locations). Because of a $\sim 2cm$ uncertainty in the horizontal position of the diffuser and of a small uncertainty in the orientation of the camera about the telescope axis, offsets were allowed to minimize variations in the corrected signal with PMT locations. The results are provided in Table 2.

Without any *alignment* corrections the geometrically corrected data were found to be uniform at the $\sim \pm 6\%$ level. With small alignment corrections, see Table 2, the geometrically corrected data were found to be uniform at the $\sim \pm 3\%$ level.

3 Source Intensity to Produce a Saturated PMT Signal

As noted above, one goal of the University of Roma2 test was to determine what light source intensity was required to produce a saturated PMT signal. The components of this estimate are as follows:

1. The intensity at the (optical fiber) output of the portable xenon light source, plus UG1 filter and 2m optical fiber, was measured at $\geq$ 8nJ/pulse at a nominal 365nm setting of the silicon energy probe/radiometer [6].

2. The PMTs were operated at a reduced voltage of 700V and thus at reduced gain. At the nominal operating voltage of 900V the PMT gain would be increased by a multiplicative factor of $(\frac{900}{700})^{5.9} = 4.4\times$.

3. Assuming the 3 PMT are representative of the 440 PMTs in the camera, typical (peak) signals for PMTs near the center of the camera should be > 200mv (with 1mm Teflon diffuser); see Table 1.

4. For the University of Roma2 DAQ a saturated PMT signal was 4V.

Thus the intensity (at the output of the optical fiber) to produce a 4V signal was estimated to be:

$$\frac{4V}{0.2V \times 4.4} \cdot 8nJ \ = \ 36nJ$$

To scale this result to the intensity required at the output of the 1:7 optical fiber splitter(s), see Fig. 1, we must include the ≥ 0.3 transmission efficiency of the optical coupler plus 40m of optical fiber. Thus the intensity output from the output of the 1:7 optical fiber splitters should be $\geq 36nJ/0.3 \ = \ 120nJ$ per pulse. The measured values, see Fig. 6, of one style of optical splitter (without fusion) meet this requirement; the optical fibers with fusion do not..

4 Summary

Measurements with a portable version of the (relative) optical calibration system light source plus simple 1mm Teflon diffuser at the University of Roma2 showed good signal uniformity over the camera. Furthermore the measured source light intensity should be adequate to cover the full dynamic range of the PMTs.

References

[1] Perkin Elmer Optoelectronics, 35 Congress St.,Salem, MA 01970

[2] Andover Corp., 4 Commercial Drive, Salem, NH 03079-2800

[3] InnovaQuartz Inc., 4420 South 32nd Street, Phoenix, AZ 85040

[4] Edmund Scientific Co., Industrial Optics Division, 101 East Gloucester Pike, Barrington, NJ 08007-1380

[5] CVI Spectral Products Division, 200 Dorado Place SE, P.O. Box 11308, Albuquerque, NM 87192

[6] We use a model RjP-465 silicon energy probe and model Rm-6600A radiometer from Laser Probe Inc., 23 Wells Ave., Utica, NY 13502

Table 1: PMT signal (peak) amplitudes *versus* position. PMT channel 26 was held fixed (near the camera center). PMT channels 27 and 28 were moved in sequence around the four corners of the camera with a final measurement at the camera center. When in the corners, channel 28 was always in the row furthest from the camera center with channel 27 one row closer to camera center.

Roving PMT position *View from Camera Rear* & (Teflon thickness)	Channel 26 (mV)	Channel 27 (mV)	Channel 28 (mV)
Top-left (1mm Teflon)	218	143	274
Top-right (1mm Teflon)	216	154	274
Bottom-right (1mm Teflon)	212	144	276
Bottom-left (1mm Teflon)	216	148	265
Center (1mm Teflon)	216	224	438
For reference: Center (0.6mm Teflon)	312	318	605

Table 2: PMT signal (peak) amplitudes and correction factors for the 4 camera *corner* positions of PMT channels 27 and 28. The *Ratio* column provides the ratio of the corrected signal to the (corrected) signal for the same PMT at the center of the camera. The results below include a 3cm offset in the horizontal and a 0.3° rotation about the telescope axis (consistent with alignment uncertainties ... see text).

Signal (mV)	$1/r^2$	$cos(\theta)$	Total Correction	Corrected Signal	Ratio to Camera Center
Channel 27					
143.	0.80680	0.78527	0.63356	223.639	0.998
154.	0.81881	0.81573	0.66793	230.563	1.029
144.	0.81459	0.81129	0.66087	222.007	0.991
148.	0.82004	0.80096	0.65682	225.330	1.006
Channel 28					
274.	0.80145	0.77948	0.62471	434.577	0.990
274.	0.79636	0.79006	0.62917	435.496	0.993
276.	0.80947	0.80494	0.65157	431.584	0.984
265.	0.79772	0.77471	0.61800	428.802	0.977

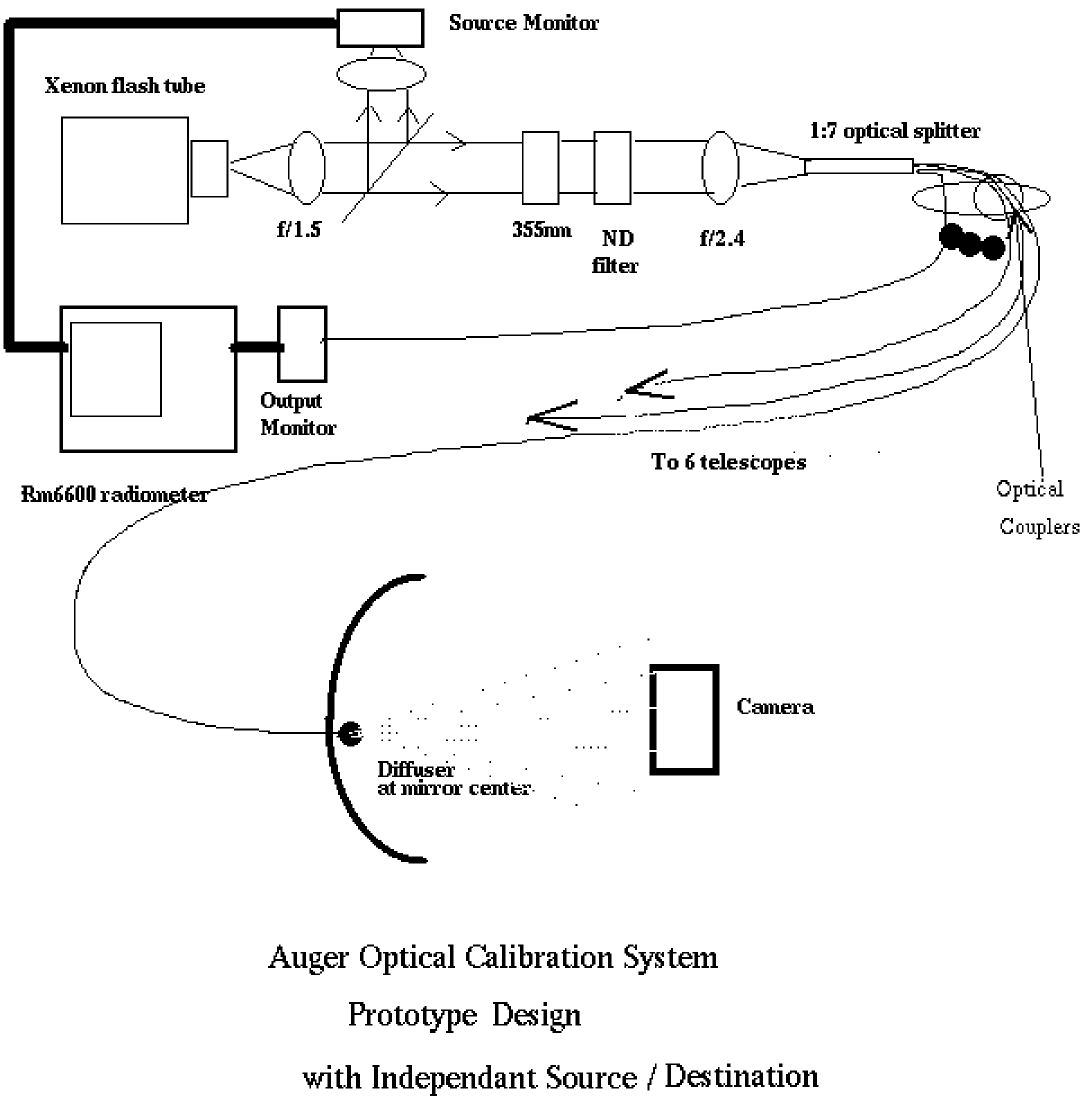

Fig. 1: Sketch of one channel of the xenon flash tube light source for the Auger fluorescence detector optical calibration system.

Fig. 2: Photograph of the University of Roma2 set-up: camera with three monitoring PMTs on the left and light source on the right. The light source was positioned at the nominal mirror center point.

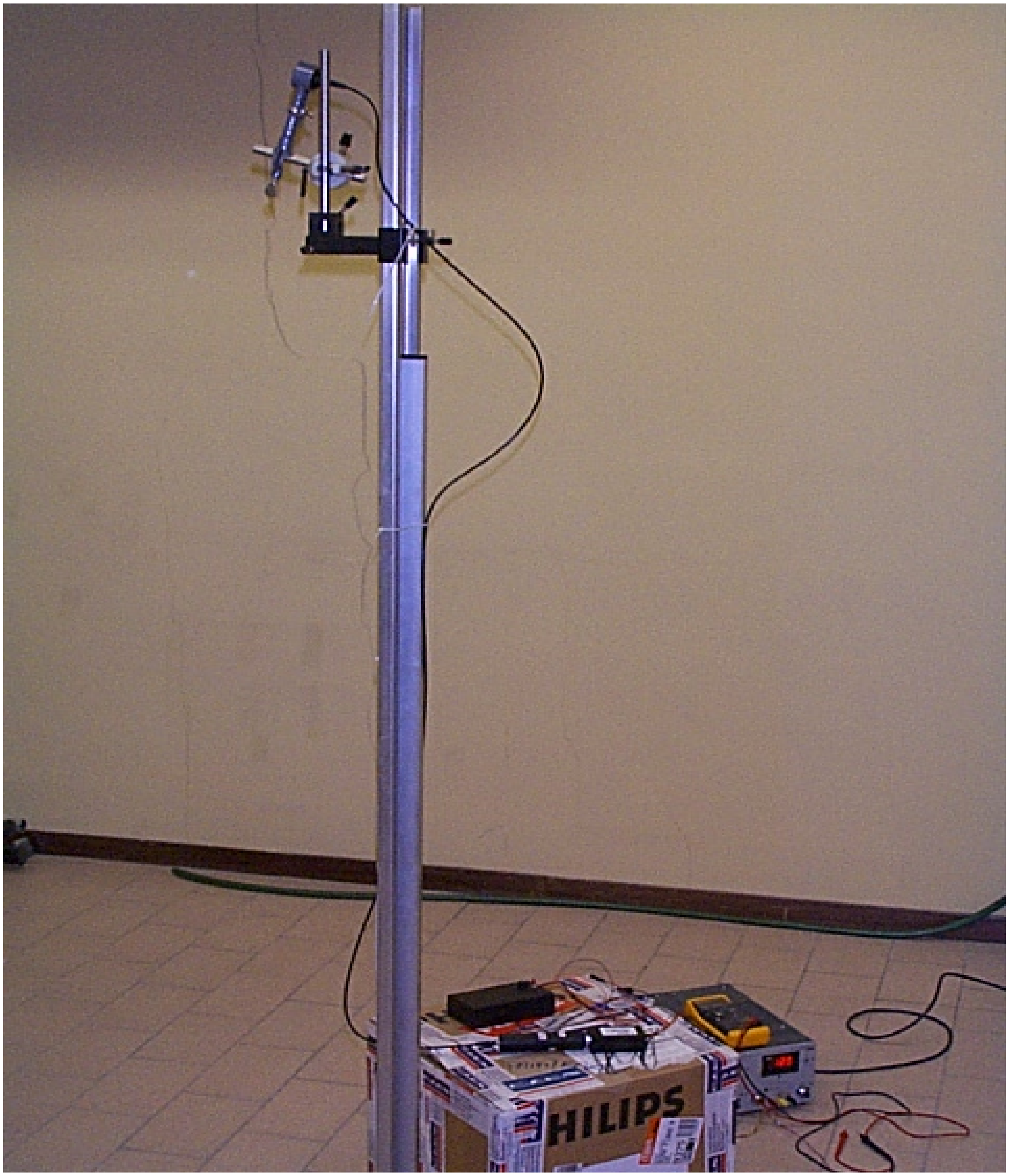

Fig. 3: *Portable* light source with xenon flasher (plus 12V power supply and TTL pulser), quartz, 1" optics, Schott UG1 filter, 0.22 NA, 200μm optical fiber and Teflon diffuser.

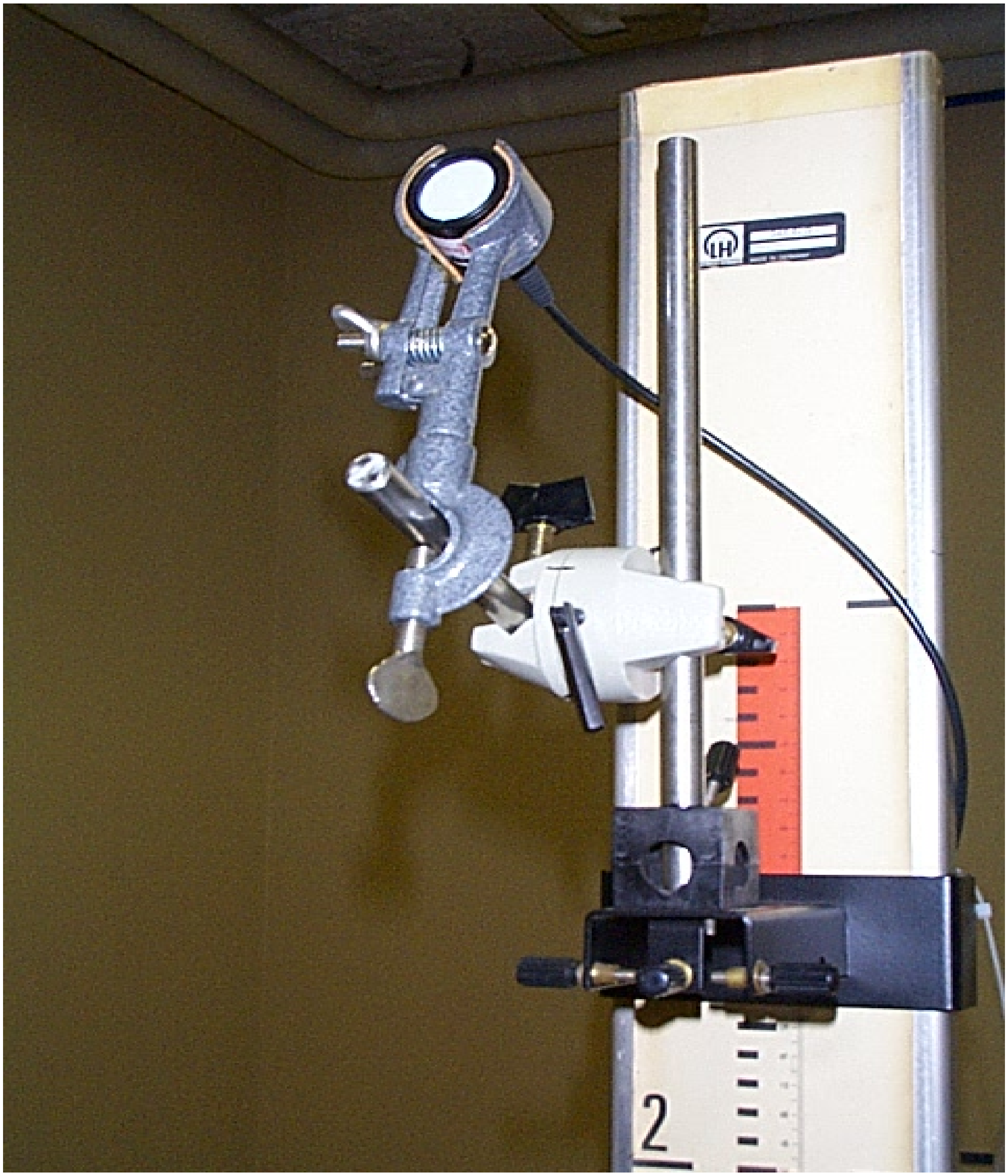

Fig. 4: Close-up of the Teflon diffuser (a 1mm thick, 1" diameter Teflon disk in standard 1" optics.

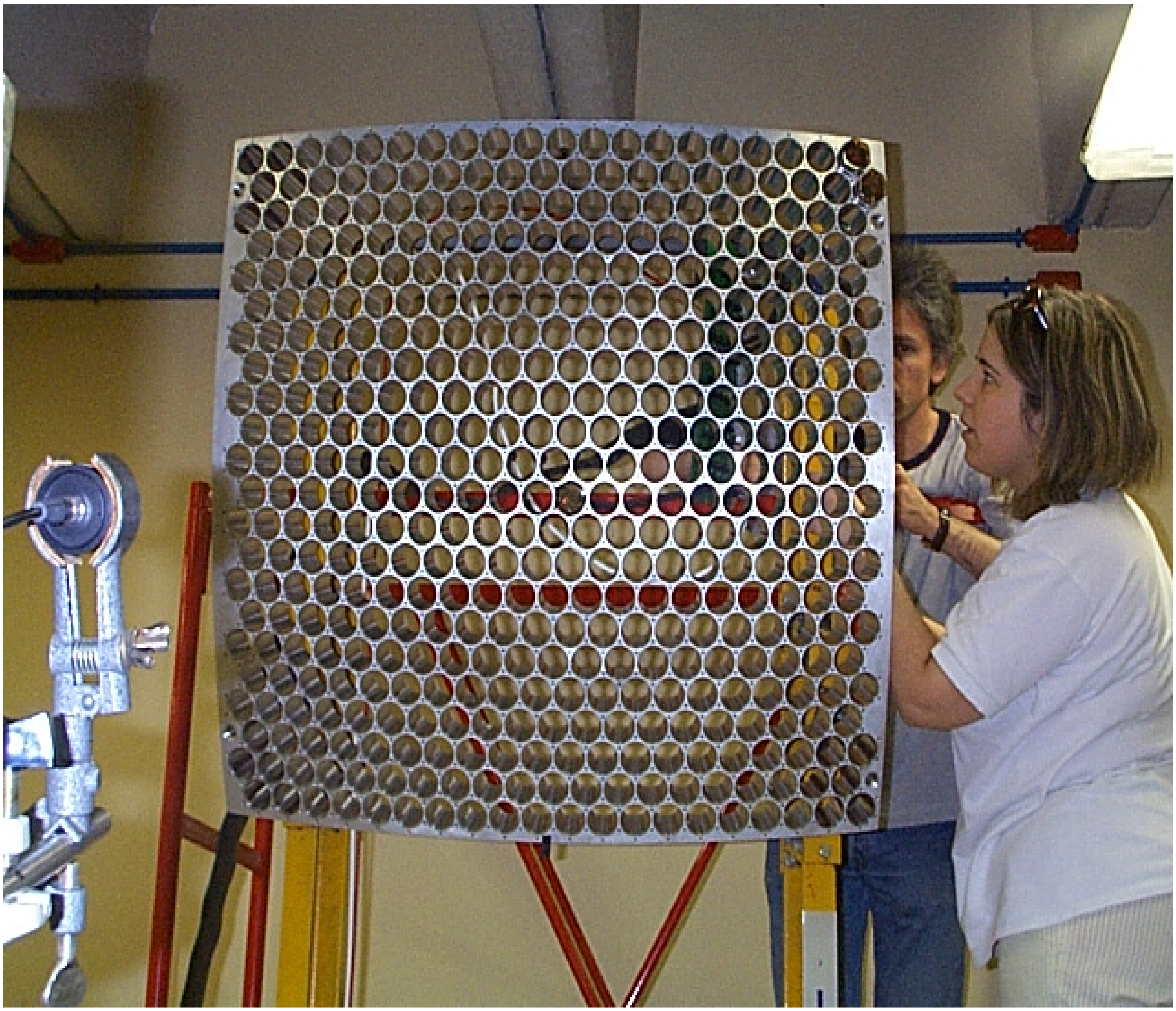

Fig. 5: Teflon diffuser view of the camera. Of the three monitoring PMTs, one was fixed near camera center and the other two were placed (in sequence) near the camera center or in the camera corners.

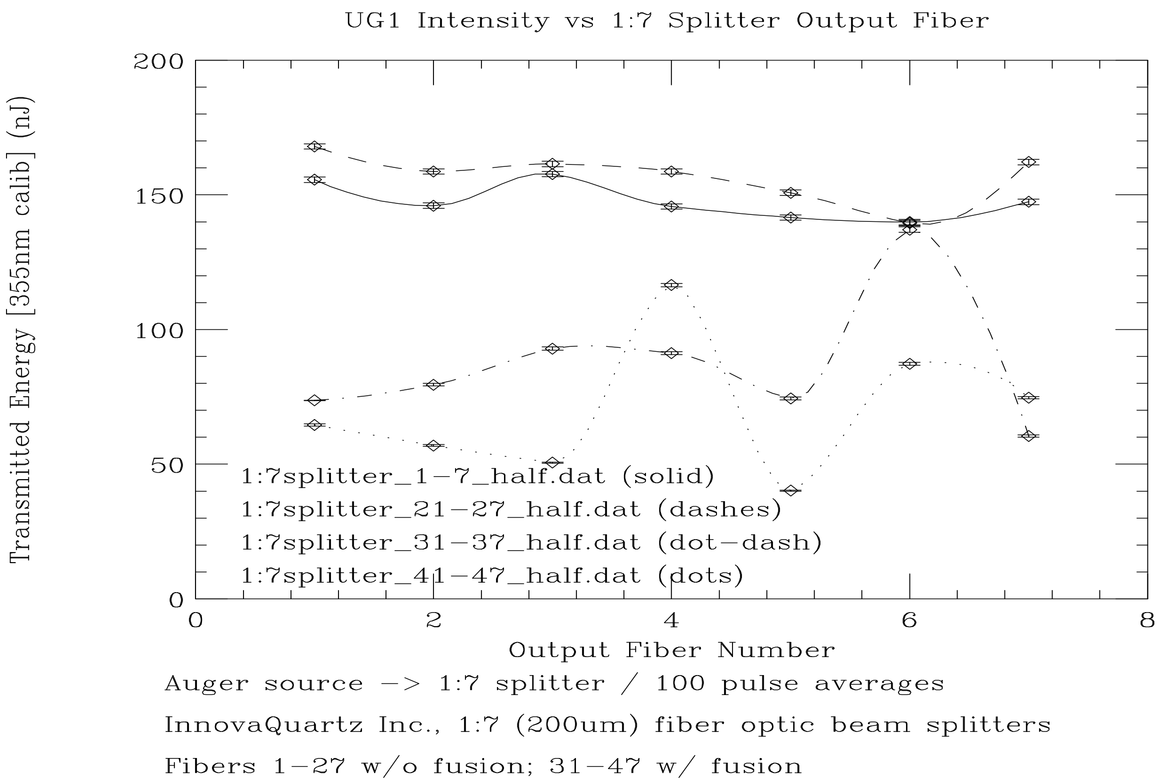

Fig. 6: Light intensities (in nJ/pulse), with a Schott UG1 wavelength filter, measured at the output of four prototype 1:7 splitters from InnovaQuartz [3]. The simple splitters (without fusion in the common leg) meet the intensity requirement from the U. of Roma2 test.