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THE DESIGN FOR A NONINTERCEPTING PHOTON-BEAM MONITOR*

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ABSTRACT

We describe the design of a combination collimator-monitor used with the SLAC Compton-scattered photon beam facility. The beam is collimated to a half angle of 10^{-5} radians and the monitor is sensitive to changes in beam steering of 10^{-6} radians.

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I. INTRODUCTION

A laser induced, Compton-backscattered photon beam facility[1] for the LRL-SLAC 82" bubble chamber has been installed and operated at the Stanford Linear Accelerator Center. The instrument described here was designed to monitor and control the photon beam in conjunction with the electronic instrumentation described by A. Barna et al.[2] The shape of the beam permits monitoring the steering and flux without intercepting the central portion, which passes undisturbed into the bubble chamber.

II. THE PHOTON BEAM

The photon beam is produced by Compton scattering of light from a ruby laser (quantum energy K_i = 1.8 eV) clashing nearly head-on with the SLAC electron beam (energy E). The energy of a photon scattered at an angle θ from the electron beam direction is

$$K(\theta) = \frac{E(1-a)}{1 + a(\gamma\theta)^2}$$

where $\gamma = E/m$, m = electron mass, and $a = \left[1 + (4\gamma K_i/m)\right]^{-1}$. The backscattered photons ($\theta = 0$) have the maximum energy $K_{max} = E(1 - a)$. When the maximum scattering angle is limited by collimation, the energy spread of the collimated beam is correspondingly limited. With E = 16 GeV and $\theta_{max} = 10^{-5}$ radians, for example, the maximum energy is 4.87 GeV with an energy spread extending down to 4.53 GeV.

The maximum scattering angle is defined by a hole of radius r = 1 mm through the collimator, 100 meters from the scattering region. The electron beam must be steered to center the photon beam onto this hole within 10^{-6} radians.

The relative flux through an annulus at the monitor, as a function of the radius r from the axis of the photon beam, is shown in Fig. 1 (primary electron energy equals 16 GeV). For optimum steering sensitivity, it is desirable to detect the photons at a radius corresponding to the maximum rate of change of flux with position (r = 3 mm). The flux exhibits fourfold symmetry about the axis of the beam. The functional form is:

$$I(\theta, \phi) = A(\theta) + B(\theta) \sin^2\phi,$$

where I = intensity

θ = polar angle with respect to beam direction

ϕ = azimuthal angle with respect to the vertical

The scintillators described below are at $\phi = 0^\circ, 90^\circ, 180^\circ, 270^\circ$.

III. THE SHOWER PROCESS

High energy photons striking a material produce a shower of lower energy electrons, positrons and photons. The number of shower particles increases with depth, reaches a maximum, and then slowly decreases. The depth of the shower maximum in tungsten, as a function of the incident photon energy, is shown in Fig. 2.

IV. THE MONITOR

The beam is monitored by four Pilot B scintillators embedded 2.5 cm from the front surface (near the position of the shower maximum for 5 GeV photons) and 3 mm from the axis in a sintered tungsten* collimator. The tungsten following the scintillators completes the collimation of the beam to 2 mm (Fig. 3). The light produced in each scintillator is collected by a single photomultiplier (RCA 7767). The individual light pulses are not counted but the charge ($\sim 10^{-9}$ Coulombs) from each of the photomultipliers is integrated over the length of one photon pulse ($\sim$50 ns).

*Mallory 1000 (0.9 W, 0.04 Cu, 0.06 Ni by weight). Radiation length = 0.4 cm.

The balance of the photomultipler gains is checked by rotating the detector 180° about the beam axis. Once balanced, the signals are analyzed by the electronics.[2] The beam is centered by minimizing the left-right and up-down differences, a method sensitive to changes in beam direction of 10^{-6} radians. The beam intensity is monitored by summing the individual signals.

The sum of the individual photomultiplier outputs appears digitally on the bubble chamber film as well as at the beam control console. In addition, the analog left-right and up-down differences are displayed on meters[2] at the control console.

For each pulse, a bubble chamber picture is permitted only if the left-right and up-down differences are sufficiently small[2] and the total intensity lies within a predetermined range.*

The entire system has performed well for over 10^{6} pulses.

ACKNOWLEDGEMENTS

The inspired electronics design by Dr. Arpad Barna and Mr. John Saarloos was basic to our success. We are indebted to Mr. Robert Gurney and Mr. Robert Vetterlein for the mechanical design.

*Electronic design of this unit by J. Saarloos, UCLRL, Berkeley.

REFERENCES

1. J. J. Murray and P. R. Klein, "A Compton scattered laser beam for the 82" bubble chamber," Technical Note No. SLAC-TN-67-19, Stanford Linear Accelerator Center, Stanford University, Stanford, California (1967).

2. A Barna, E. L. Cisneros, C. Dale and A. Johnson, "Electronic instrumentation for a nonintercepting gamma-beam monitor," Report No. SLAC-PUB-590, Stanford Linear Accelerator Center, Stanford University, Stanford, California (1969).

LIST OF FIGURES

1. Radial distribution of a 5 GeV photon beam at the monitor. The scintillator is embedded in the tungsten near the position of maximum rate of change in intensity with respect to the radial position.

2. Depth of the shower maximum in tungsten. Results are from a Monte Carlo computer calculation.

3. Schematic of the mechanical assembly. The tungsten discs can be rearranged, varying the effective depth of the scintillators.

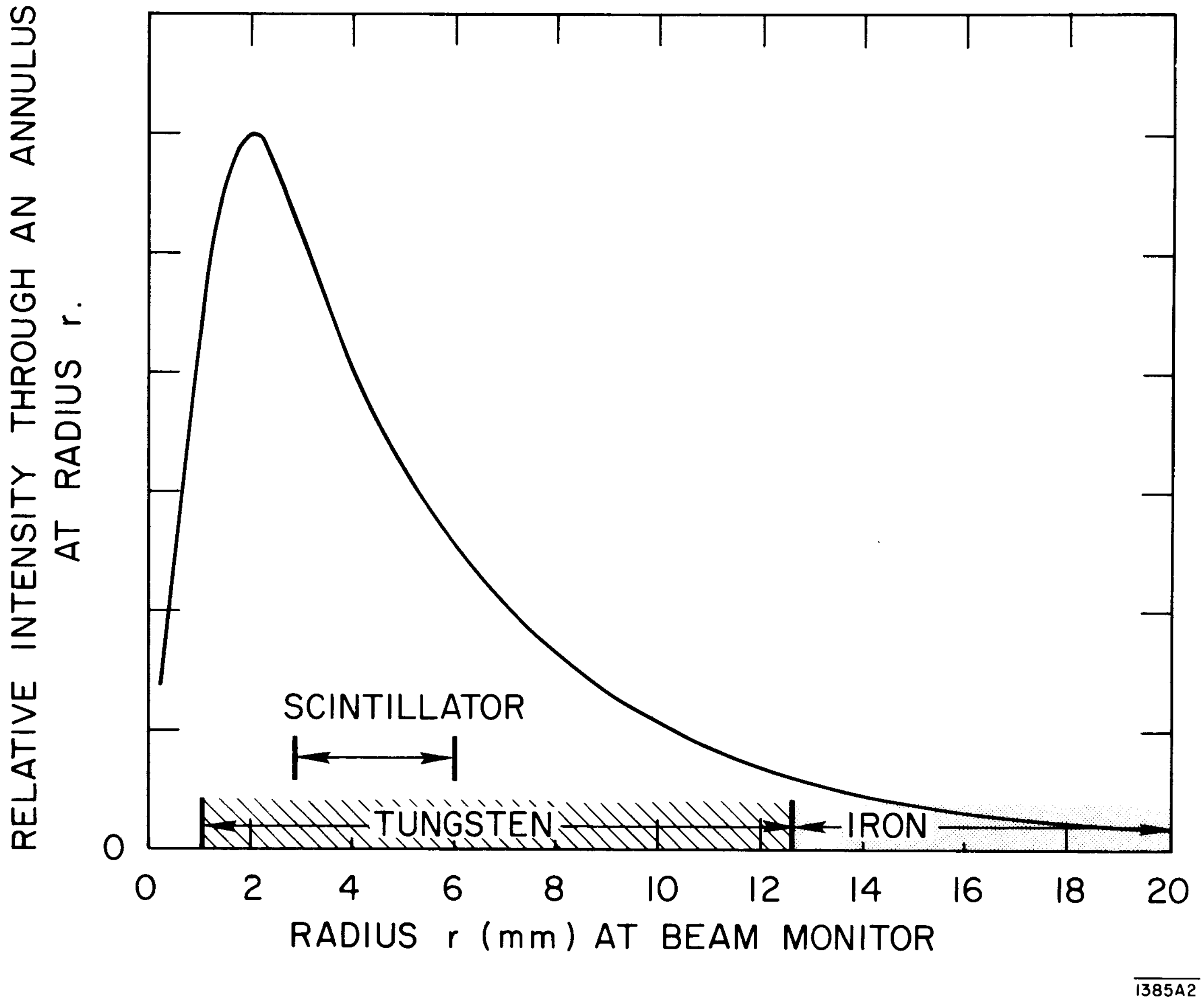
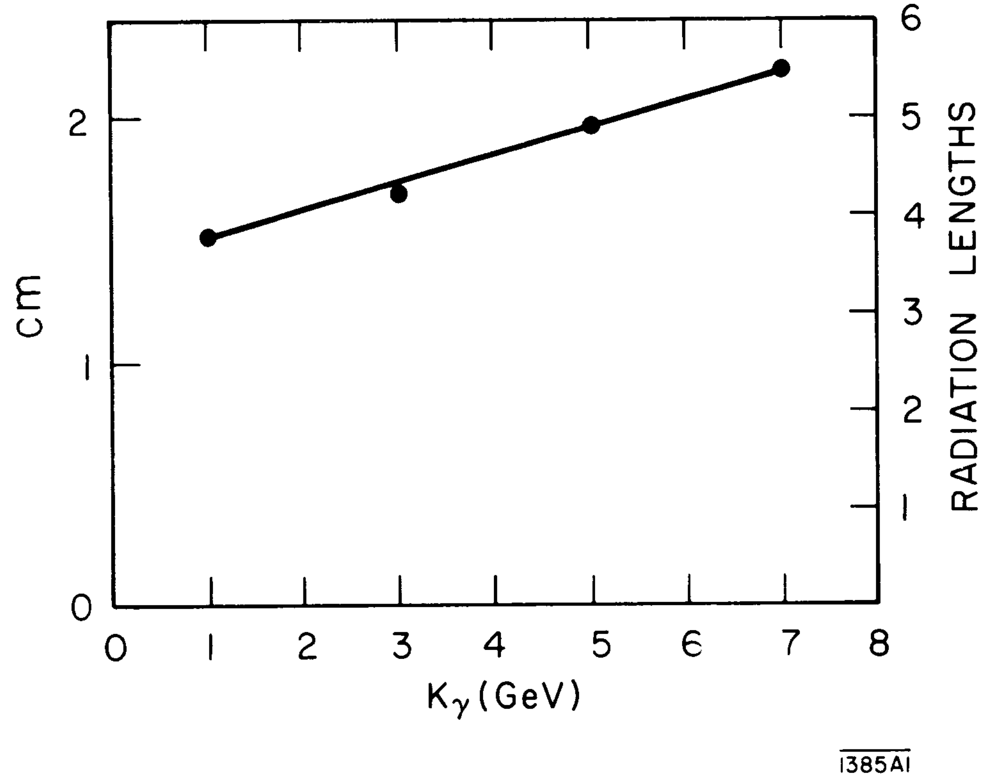
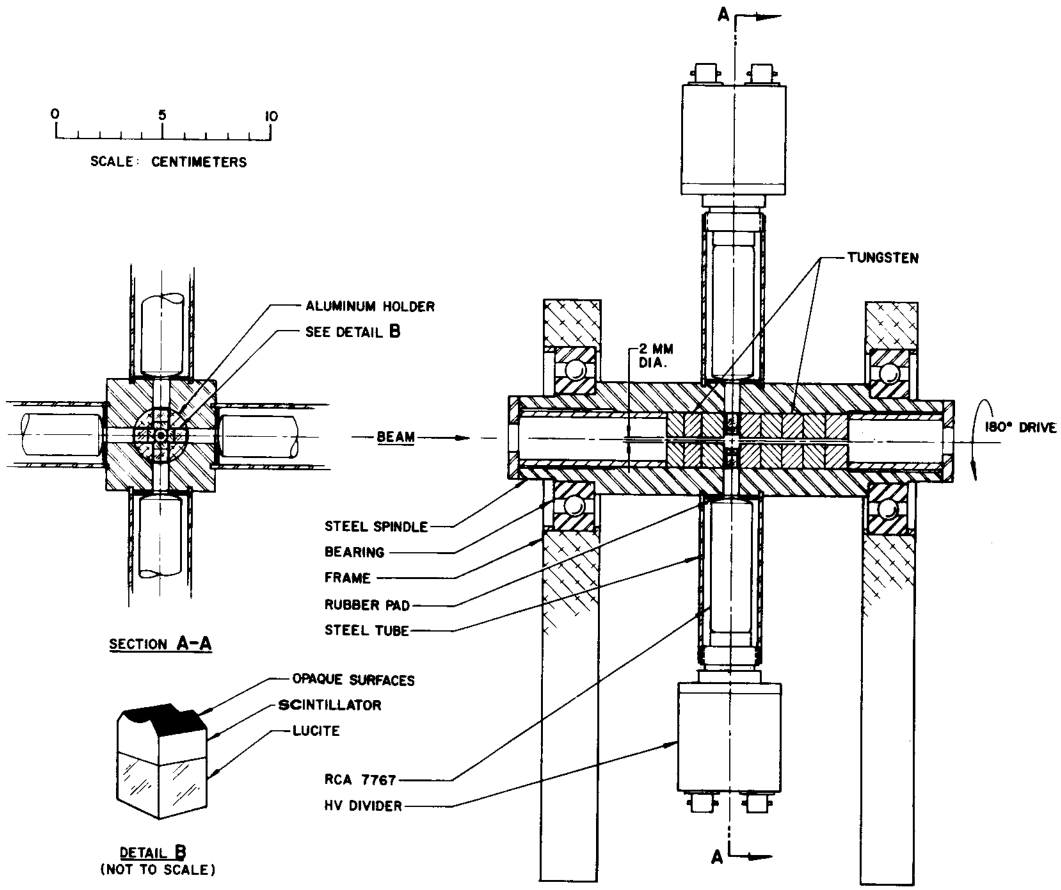

RELATIVE INTENSITY THROUGH AN ANNULUS AT RADIUS r.
SCINTILLATOR
TUNGSTEN
IRON
0
0
2
4
6
8
10
12
14
16
18
20
RADIUS r (mm) AT BEAM MONITOR
1385A2

Fig. 1



cm
0
1
2
RADIATION LENGTHS
1
2
3
4
5
6
0
1
2
3
4
5
6
7
8
K_γ (GeV)
1385A1

Fig. 2


0
5
10
SCALE: CENTIMETERS
ALUMINUM HOLDER
SEE DETAIL B
SECTION A-A
OPAQUE SURFACES
SCINTILLATOR
LUCITE
DETAIL B
(NOT TO SCALE)
A
TUNGSTEN
2 MM
DIA.
BEAM
180° DRIVE
STEEL SPINDLE
BEARING
FRAME
RUBBER PAD
STEEL TUBE
RCA 7767
HV DIVIDER
A

1385A3

Fig. 3