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# DEVELOPMENT AND USE OF DATA ANALYSIS PROCEDURES FOR THE CRRES PAYLOADS AFGL-701-2/DOSIMETER AND AFGL-701-4/FLUXMETER AND APPLICATION OF THE DATA ANALYSIS RESULTS TO IMPROVE THE STATIC AND DYNAMIC MODELS OF THE EARTH'S RADIATION BELTS

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19 ABSTRACT (Continue on reverse if necessary and identify by block number)

Earth's magnetospheric radiation enviroment is a major hazard for spaceborne electronic systems. This report documents work aimed at providing the U. S. Air Force with accurate, time dependent radiation belt and cosmic ray environmental specifications. The data for this effort is obtained from two instruments to be flown aboard the Combined Realease and Radiation Satellite (CRRES). These instruments are the Energetic Particle Dosimeter and the High Energy Fluxmeter.

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Development & Use of Data Analysis Procedures for the CRRES Payloads AFGL-701-2/Dosimeter & AFGL-701-4/Fluxmeter & Application of the Data Analysis Results to Improve the Static & Dynamic Models of the Earth's Radiation Belts

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## 1. INTRODUCTION

The Earth's magnetospheric radiation environment is an important hazard for spacecraft electronic systems in the altitude range from several hundred km to several Earth radii. The Space Physics Division of the Geophysics Laboratory (GL) is engaged in a program to provide the USAF with accurate and time dependent radiation belt and cosmic ray environmental specifications. Much of the data for this effort will come from the Combined Release and Radiation Effects Satellite (CRRES), which is presently estimated to be launched in mid 1990. Two of the particle detection systems on CRRES have been designed, fabricated and calibrated by Panametrics, Inc.: the AFGL-701-2/Energetic Particle Dosimeter and the AFGL-701/High Energy Electron Fluxmeter (Refs. 1-3).

The general objective of this contract is for Panametrics to provide support to GL in analyzing the data from the Dosimeter and Fluxmeter and aid in GL's efforts to update and improve the radiation belt models. The specific objectives of the contract are:

(a) Prior to the launch of CRRES - provide support in developing the data analysis procedures for the AFGL-701-2/Dosimeter and the AFGL-701-4/Fluxmeter instruments.

(b) Following the launch of CRRES - apply these procedures to the CRRES data to provide the Dosimeter and Fluxmeter data in a reduced form in a timely manner.

(c) Use the obtained CRRES data to update and improve the static radiation belt and cosmic ray models and to provide inputs for dynamic radiation belt and magnetic storm models.

The program is split into two parts, Phase I, covering the period before the CRRES launch and Phase II, covering the post launch period. During Phase I a modest level of effort will be expended to develop the Dosimeter and Fluxmeter data analysis and data display procedures. A higher level of effort will be expended during Phase II to finalize the data handling procedures and use the data to update and improve the radiation belt and cosmic ray models.

## 2. PHASE I EFFORT

The work carried on during this period, as stipulated in the Technical Proposal, has been at a low level of activity. The primary reasons for this are the distant and uncertain CRRES launch date and the possibility of change of the parameters of the CRRES orbit. The count rates in the Dosimeter and Fluxmeter detectors are quite sensitive to the actual spacecraft orbit, so that at this time it is not feasible to construct the final algorithms for the analysis of CRRES data.

### 2.1 AFGL-701-2/Dosimeter

The CRRES Dosimeter measures electrons above 1 MeV and protons above 20 MeV in 4 channels (Domes), with both flux and dose being measured. Nuclear star events are also measured for each detector. The Dosimeter, shown in Fig. 2.1, is described in Ref. 1, and is similar to the DMSP/F7 Dosimeter described in Ref. 2. The primary detection characteristics of the CRRES Dosimeter are listed in Table 2.1. The flux and dose channel compression count characteristics are given in Table 2.2.

The dosimeter detectors have a $2\pi$ sr field-of-view and separate detected pulses into electron (LOLET = 50 to 1000 keV energy loss) and proton (HILET = 1 to 10 MeV energy loss). The star thresholds (40 or 75 MeV) are only sensitive to high energy proton nuclear interactions ("stars") or to heavy cosmic rays. Ref. 2 provides a detailed description of the basic operation of the Dosimeter, including energy loss curves for the four Al dome/detector sets.

The CRRES dosimeter dose channels have been adjusted to overflow in approximately 2 to 40 orbits so that more detailed dose increment data can be obtained. (The DMSP dosimeter required months to overflow.) The overflow intervals for each of the four electron and proton dose channels are listed in Table 2.3. The electron flux used in the calculations was AE4 (Ref. 4) and the proton flux was AP8 MIN. A comparison of flux and dose increment allows the average particle energy loss to be calculated, and can be used to separate protons and electrons in the LOLET channels. Note that LOLET (Low Linear Energy Transfer) and HILET (High Linear Energy Transfer) are actually better descriptions for the electron and proton channels.

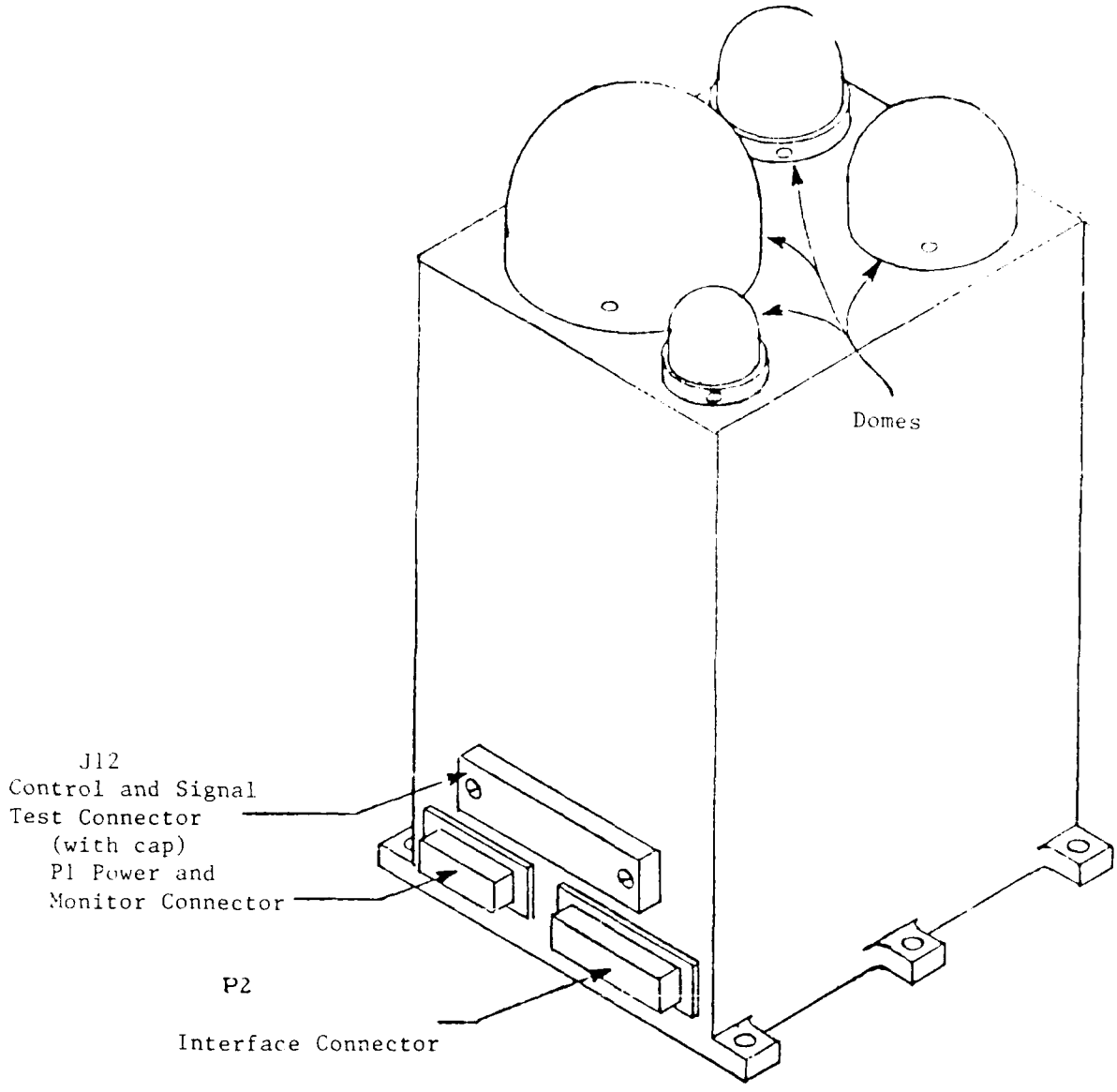


Fig. 2.1 Isometric View of the CRRES Dosimeter.

Table 2.1

Characteristics of the CRRES Dosimeter

| Dome No. | Al shield ($g/cm^2$) | Det. area ($cm^2$) | G ($cm^2$-sr) | Star threshold (MeV) |
|---|---|---|---|---|
| 1 | 0.55 | 0.00815 | 0.0256 | 40 |
| 2 | 1.55 | 0.051 | 0.160 | 40 |
| 3 | 3.05 | 0.051 | 0.160 | 40 |
| 4 | 5.91 | 1.000 | 3.14 | 75 |

| Dome No. | Proton flux prescale | Dose channel calibration Rads (Si)/(output dose count) | |
|---|---|---|---|
| | | Electron (LOLET) | Proton (HILET) |
| 1 | 1 | $1.16 \times 10^{-2}$ | $3.44 \times 10^{-3}$ |
| 2 | 1 | $1.85 \times 10^{-3}$ | $2.05 \times 10^{-3}$ |
| 3 | 1 | $1.85 \times 10^{-3}$ | $1.10 \times 10^{-3}$ |
| 4 | 8 | $1.94 \times 10^{-4}$ | $8.78 \times 10^{-4}$ |

| Dome No. | Electron channel range (MeV) | | Proton channel range (MeV) |
|---|---|---|---|
| | Electrons | Protons | Protons |
| 1 | > 1 | > 130 | 20-130 |
| 2 | > 2.5 | > 135 | 35-135 |
| 3 | > 5 | > 140 | 51-140 |
| 4 | > 10 | > 155 | 75-155 |

Table 2.2

CRRES Dosimeter Compression Counter Characteristics

Flux Counters: Output counts

Minimum count = $M \times 2^E$

Electron Channel: E x M = 4 x 4 bits/overflow at 524288

Proton Channel: E x M = 3 x 5 bits/overflow at 4096

Notes: Proton Channel No. 4 has a prescale $K_{pf} = 8$, so input count = $K_{pf} \times M \times 2^E$

Dose Counters: Output counts used with Dose calibration factors

Counters: = R + E x M

= 4 + 4 x 4 bits

Modified counter version: output counts are

$D = 16n + R + 16M \times 2_E$, $E \leq 7$ (or $E < 8$)

where $0 \leq n \leq 2^E - 1$, $\Delta = 2^E \times 16$ (for $\Delta M = 1$)

$D = 16n + R + 16 (M + 8 (E - 7)) 128$, $E > 7$ (or $E \geq 8$)

where $0 \leq n \leq 127$, $\Delta = 128 \times 16$ (for $\Delta M = 1$)

D at overflow = 16 x 10,240

Table 2.3

Typical Number of CRRES Orbits Required for an Overflow

| Channel | Dose | |
|---|---|---|
| | Electrons | Protons |
| 1 | 1.4 | 23.4 |
| 2 | 2.58 | 41.5 |
| 3 | 245.0 | 39.6 |
| 4 | 35.6 | 35.7 |

## 2.2 AFGL-701-2/Fluxmeter

The CRRES Fluxmeter measures primarily electrons in the 1 to 10 MeV range in ten intervals. Secondary data provide some information on high energy proton fluxes. The Fluxmeter, illustrated in Fig. 2.2, is designed to measure electrons in the presence of high energy protons. Two solid state detectors and a BGO (Bismuth Germanate) scintillator form the primary triple-coincidence electron detection scheme. A cylindrical anti-coincidence plastic scintillator around the BGO scintillator is used to reject electrons which scatter out of the side of the BGO crystal, to reject edge-cutting proton for some coincidence configurations, and to reduce interference from side-entry high energy protons. The Fluxmeter can have any coincidence or anti-coincidence requirement set by ground command, so there are eight (8) possible operating configurations. The nominal electron channel geometric factors and particle detection energy ranges are given in Table 2.4. A more detailed discussion of the Fluxmeter design and operation is given in Ref. 3.

The CRRES Fluxmeter is designed to measure 1-10 MeV electrons in ten channels, in the presence of large fluxes of high energy (> 100 MeV) protons. This is particularly necessary for measuring these electrons in the inner radiation belt. It is expected that the normal mode of operation will have the two solid state detector coincidences and the plastic scintillator anti-coincidence all enables. However, in-orbit data will be used to verify that this mode provides the most reliable results. The Fluxmeter has a $7.5^{o}$ half-angle detection cone, so pitch angle distributions will be measured. The nominal geometric factor is 0.012 $cm^2$-sr, so that low flux pitch angle distributions may have to be averaged over several spins. Much of the 1-10 MeV electron flux measurements will be the first reliable measurements of this component of the earth's trapped radiation environment.

# 3. SUMMARY

We are developing algorithms that utilize the known Dosimeter and Fluxmeter responses and various trapped radiation models to estimate the expected on orbit count rates. The preliminary calculation of Dosimeter count rate is complete. Data analysis to determine the Fluxmeter response to electrons is currently under way.

As soon as a firm launch date for CRRES is determined, the Dosimeter and Fluxmeter instruments will be refurbished in preparation for satellite integration. At that time, the effort devoted to this program will increase to insure that all required data analysis algorithms are completed by launch time.

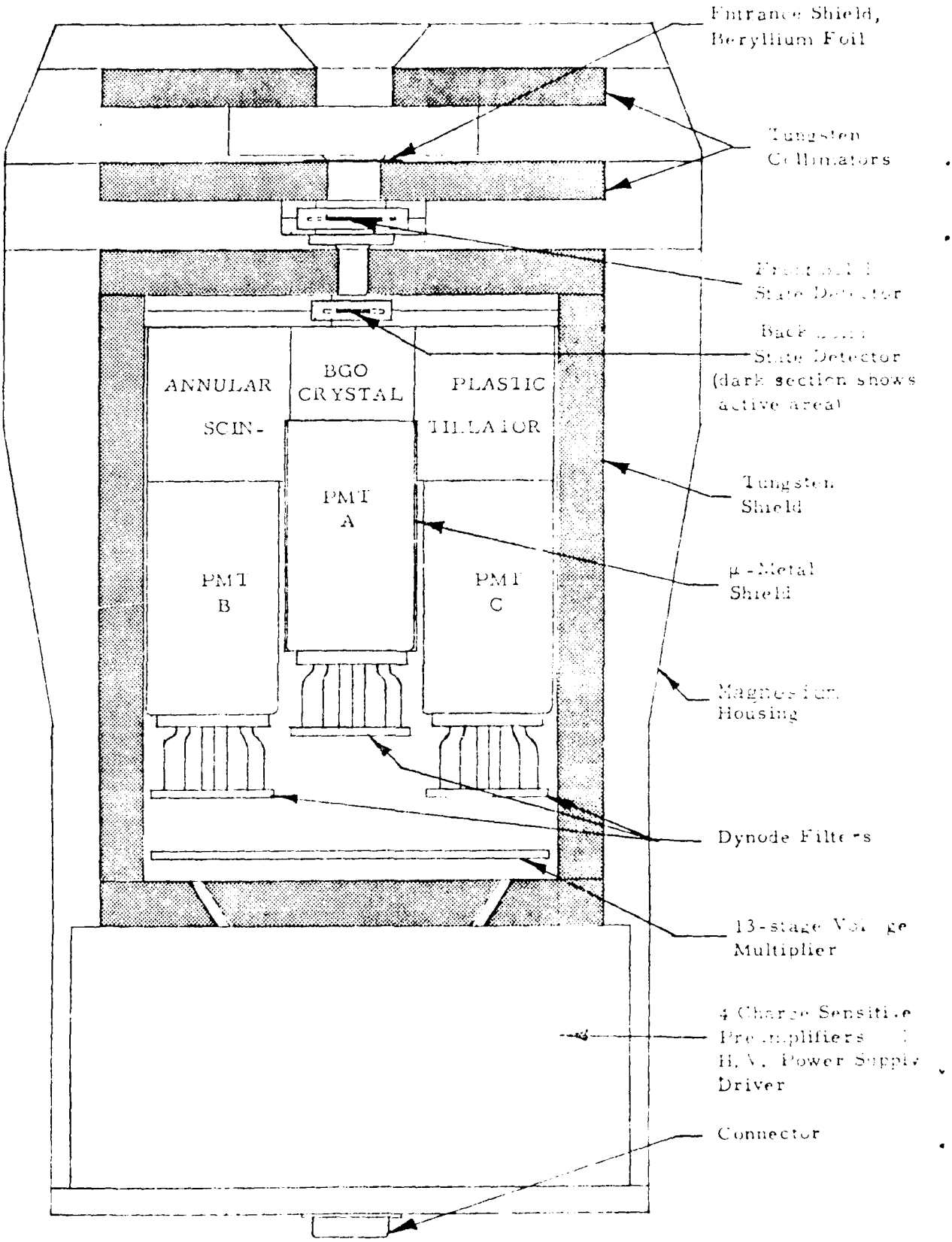


Figure 2.2 Cross Section of the CRRES Fluxmeter

Table 2.4
CRRES Fluxmeter
Channel Geometric Factors and Particle Detection Ranges

| Channel Designation | Energy Loss (MeV) | Geometric Factors ($cm^2$-sr) Telescope | Omni | Telescope Energy Ranges (MeV) Electrons | Protons | Omnidirectional Energy Ranges (Me Protons |
|---|---|---|---|---|---|---|
| **Solid State Detectors** | | | | | | |
| $> S_2$, Front | > 0.80 | 0.167 | 6.06 | - | 4.2-130 | 116-265 |
| $> S_1$, Front | > 0.50 | 0.167 | 6.06 | - | 4.1-269 | 116-588 |
| $W_1$, Front | 0.13-0.50 | 0.167 | 6.06 | > 0.20 | 3.97-4.12/269-∞ | 115.51-115.65/588-∞ |
| $W_2$, Front | 0.13-0.80 | 0.167 | 6.06 | > 0.20 | 3.97-4.24/130-∞ | 115.51-115.76/265-∞ |
| $> S_2$, Back | > 0.80 | 0.0120 | 3.11 | - | 11.2-130 | 116-265 |
| $> S_1$, Back | > 0.50 | 0.0120 | 3.11 | - | 11.1-270 | 116-588 |
| $W_1$, Back | 0.13-0.50 | 0.0120 | 3.11 | > 0.52 | 11.00-11.13/270-∞ | 115.51-115.65/588-∞ |
| $W_2$, Back | 0.13-0.80 | 0.0120 | 3.11 | > 0.52 | 11.00-11.23/130-∞ | 115.51-115.76/265-∞ |
| **BGO Crystal** | | | | | | |
| $> L_{10S}$ | > 9.40 | 0.0120 | 78.6 | > 10 | 19.3-∞ | 117-∞ |
| $> L_{10C}$ | > 9.40 | 0.0120 | 78.6 | > 10 | 19.3-∞/(270-∞)* | 117-∞ |
| $L_9 - L_{10}$ | 7.41-9.40 | 0.0120 | 78.6 | 8 - 10 | 18.5-19.3 | 116.29-116.51 |
| $L_8 - L_9$ | 5.42-7.41 | 0.0120 | 78.6 | 6 - 8 | 17.7-18.5 | 116.07-116.29 |
| $L_7 - L_8$ | 4.43-5.42 | 0.0120 | 78.6 | 5 - 6 | 17.3-17.7 | 115.96-116.07 |
| $L_6 - L_7$ | 3.44-4.43 | 0.0120 | 78.6 | 4 - 5 | 16.9-17.3 | 115.84-115.96 |
| $L_5 - L_6$ | 2.95-3.44 | 0.0120 | 78.6 | 3.5-4 | 16.7-16.9 | 115.79-115.84 |
| $L_4 - L_5$ | 2.45-2.95 | 0.0120 | 78.6 | 3-3.5 | 16.5-16.7 | 115.73-115.79 |
| $L_3 - L_4$ | 1.96-2.45 | 0.0120 | 78.6 | 2.5-3 | 16.3-16.5 | 115.68-115.73 |
| $L_2 - L_3$ | 1.46-1.96 | 0.0120 | 78.6 | 2-2.5 | 16.1-16.3 | 115.62-115.68 |
| $L_1 - L_2$ | 0.96-1.46 | 0.0120 | 78.6 | 1.5-2 | 15.9-16.1 | 115.57-115.62 |
| $LL - L_1$ | 0.44-0.96 | 0.0120 | 78.6 | 1-1.5 | 15.7-15.9 | 115.51-115.57 |
| Any BGO (> LL) | > 0.44 | 0.0120 | 78.6 | > 1 | 15.7-∞ | 116-∞ |
| **Plastic Shield Scintillator** | | | | | | |
| Ls | > 1. | - | 525 | - | - | 98-∞ |

*For coincidence operation.

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