# SPACE DOSIMETRY WITH A 3D SILICON DETECTOR TELESCOPE – THE ISS VERSIONS OF TRITEL

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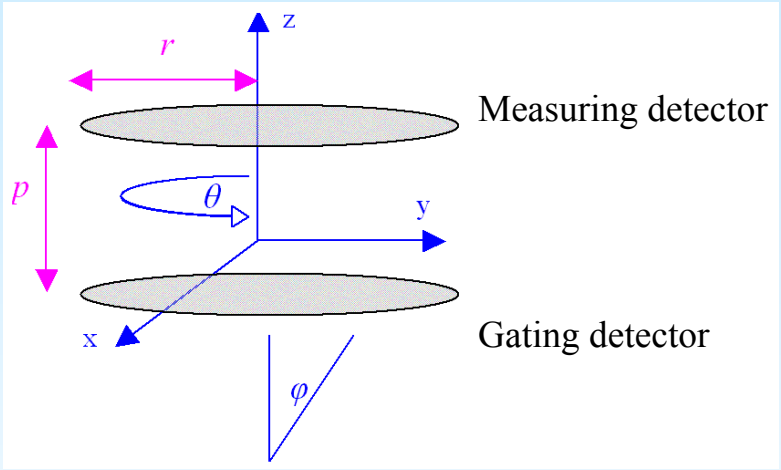
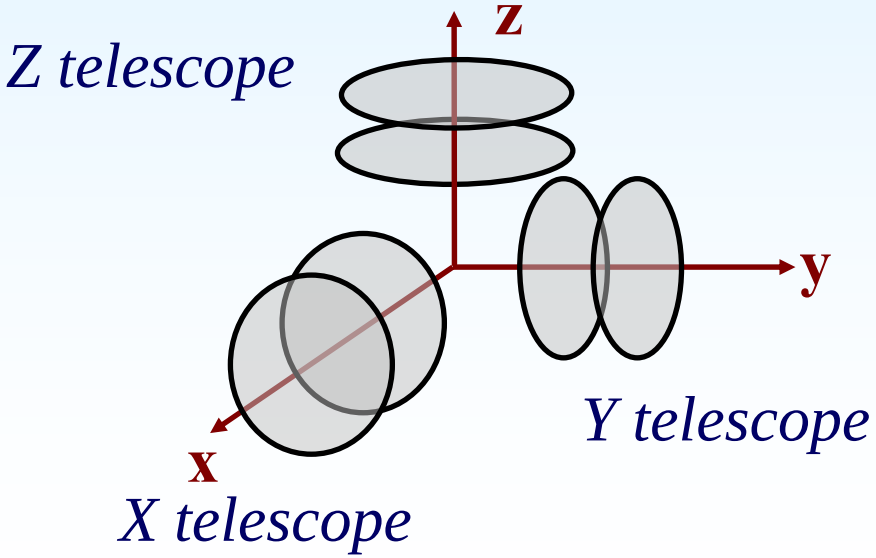
# Outline

- ISS versions of TriTel
  - 3D silicon detector telescope
  - Measurement ranges of the instrument
  - Construction
- Electron sensitivity of the Pille dosimeters (off-topic)
- Summary

# The TriTel 3D telescope



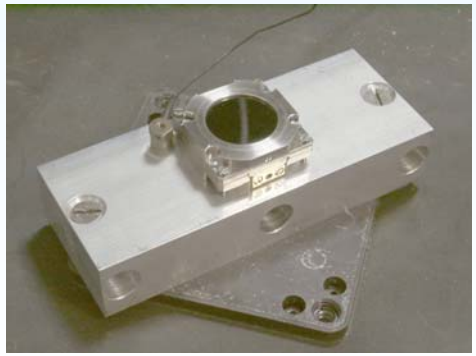




- **3 x 2 db 300 μm Si detector**
- **Detector chips of the telescope are connected as AND gate in coincidence**
- **D /from dep. energy spectra/**
- **LET spectra and Q /from the gated spectra/**

  **→ dose equivalent (H)**
- **3D sensitivity**

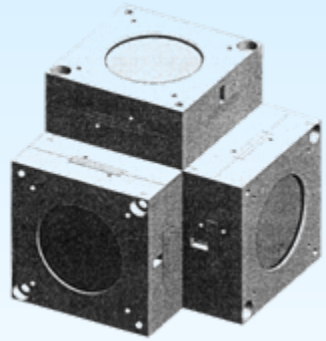
**- r = 6.9 mm**

**- p = 8.7 mm**



# LET and ΔE ranges

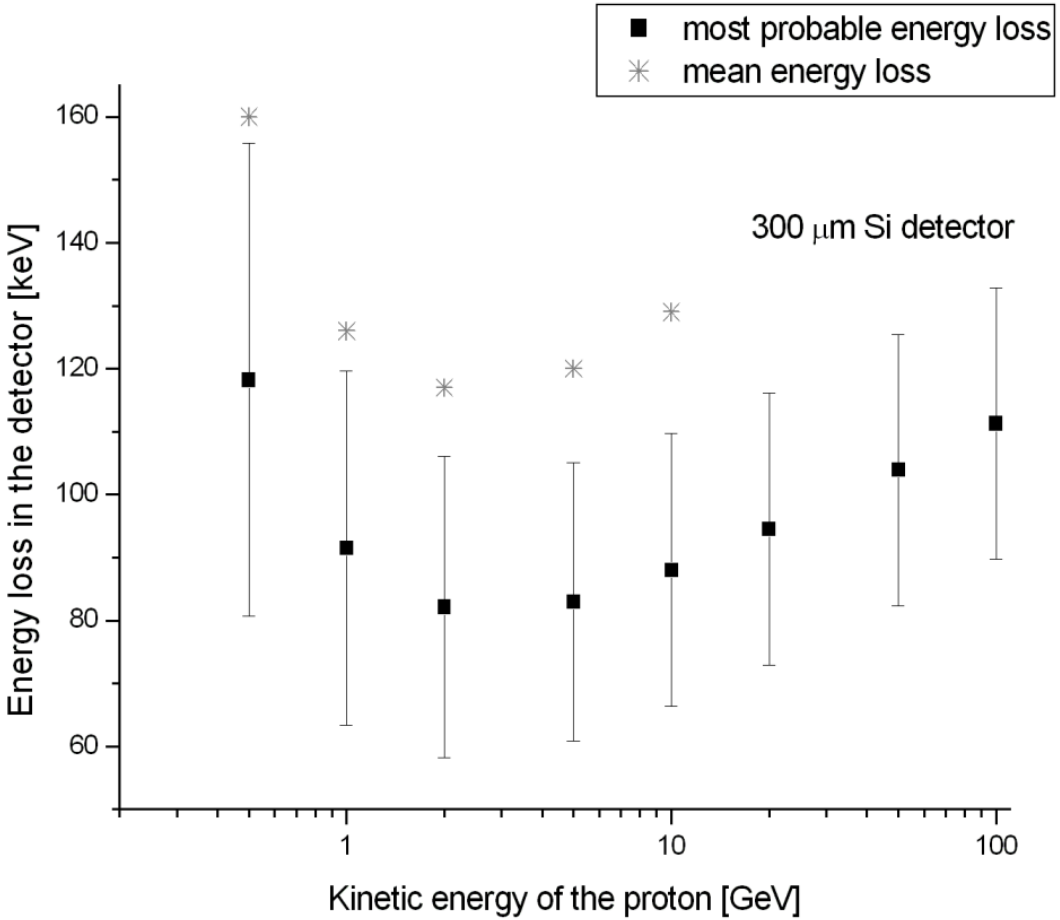
- Minimum deposited energy in the coincidence spectra:
  - By relativistic protons ($LET_{min,Si}$ = 0.4 keV/μm), 0° incidence
  - $\Delta E_{min,\ classical} = LET_{min} * w = 120$ keV
- But thin detectors! → Landau distribution
- Most probable energy loss:



$$\Delta_0 = \xi\left[\ln\frac{3000\beta^2\xi}{Z^2\left(1-\beta^2\right)}\right](eV); \quad \text{where} \quad \xi = \frac{1.54\cdot 10^5\,\rho}{\beta^2}\cdot\frac{Z}{A}$$

$$\text{and} \quad FWHM = \frac{4.0\xi}{\Delta_0}$$

# LET and ΔE ranges

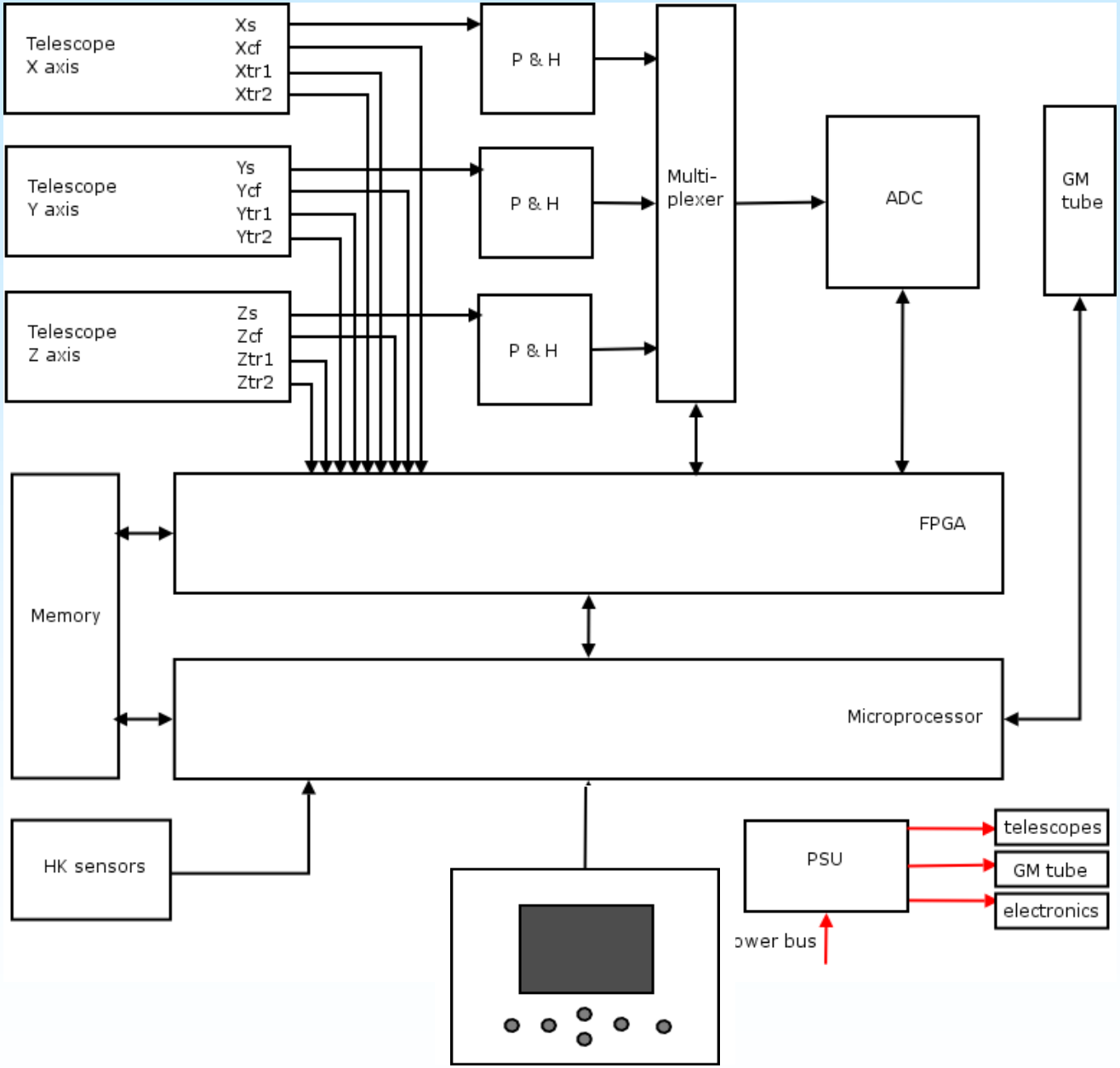



- Minimum @ 2-5 GeV
- $\Delta E_{min}$ = ~50-60 keV

- $LET_{max,Si}$ = = 230 keV/μm (120 keV/μm in water)
- → $\Delta E_{max}$ = ~85 MeV
- ΔE > 85 MeV → overflow bin

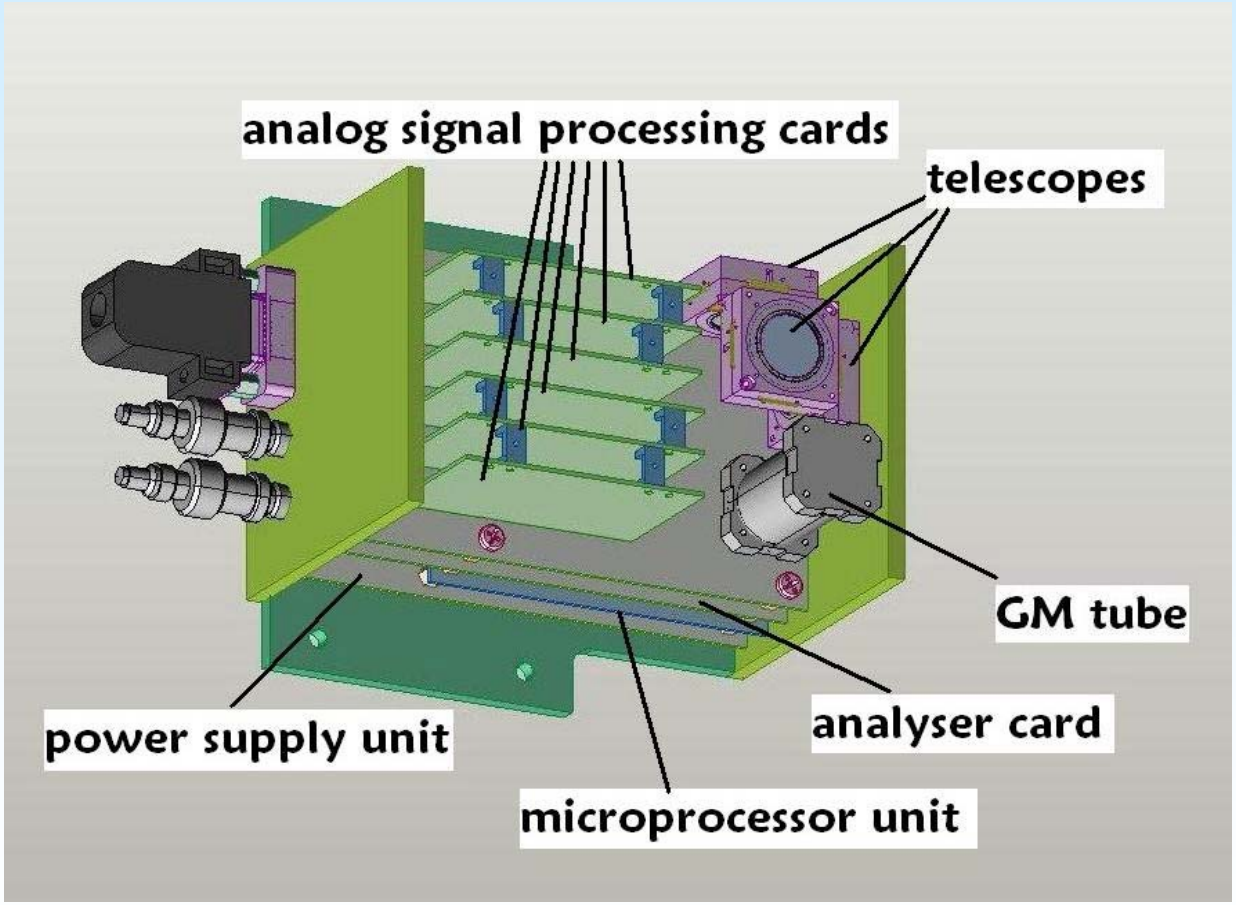
# TriTel measurement ranges

| Parts of the analog signal processing system | Physical quantity | Measurement (signal) ranges |
|---|---|---|
| Incoming particles: | LET in Si | 0.4 keV/μm – 230 keV/μm |
| Detector material: | Energy imparted to the detector material | 60-80 keV – 85 MeV |
| Output of the detectors: | Charge created by an incoming particle | 2.7-3.6 fC – 3.8 pC |
| Output of the preamplifiers: | Voltage step | 1.3-1.8 mV – 1.9 V |
| Output of the amplifier and pulse shaping circuits: | Amplitude of the signal to be processed by the ADC | 2 mV – 2 V |

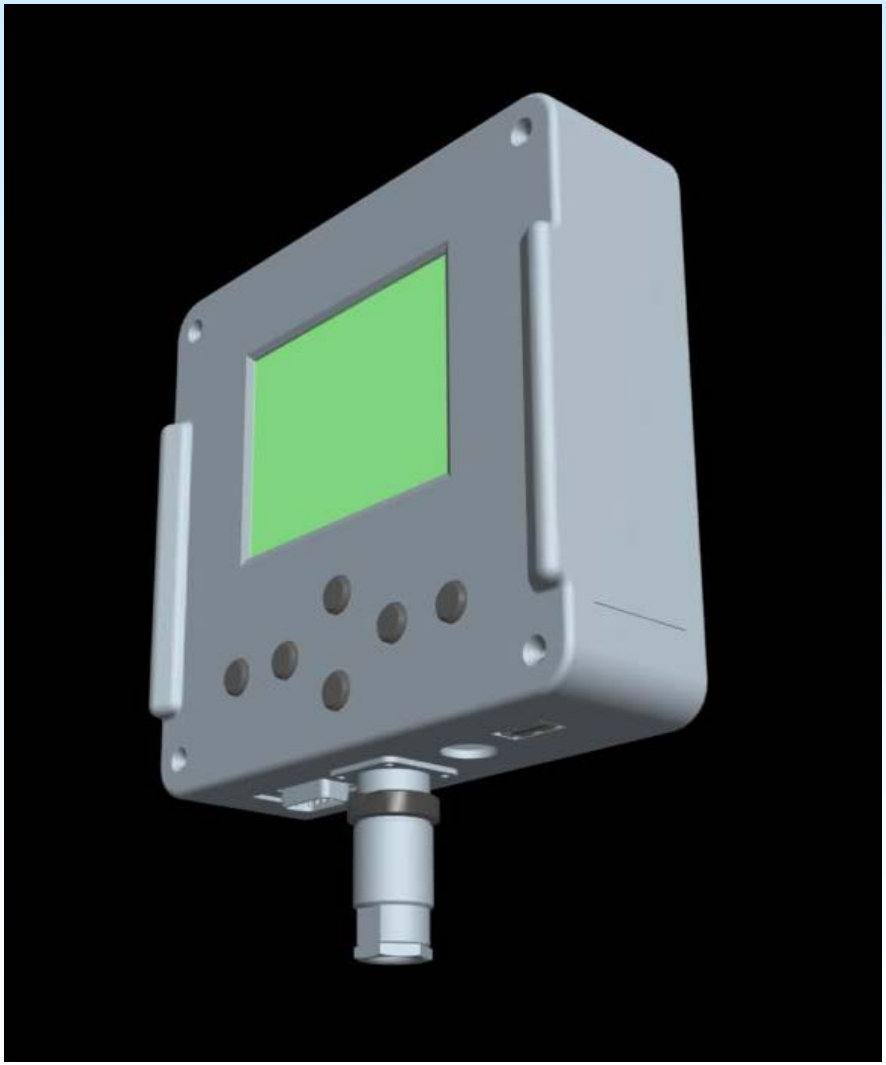



- 12-bit ADC
- LUT→ 4096 channel spectra
- 3 x 2 x 2 deposited energy spectra per day
- 3 time spectra (10 s resolution + SAA flag)

# Construction of the detector unit



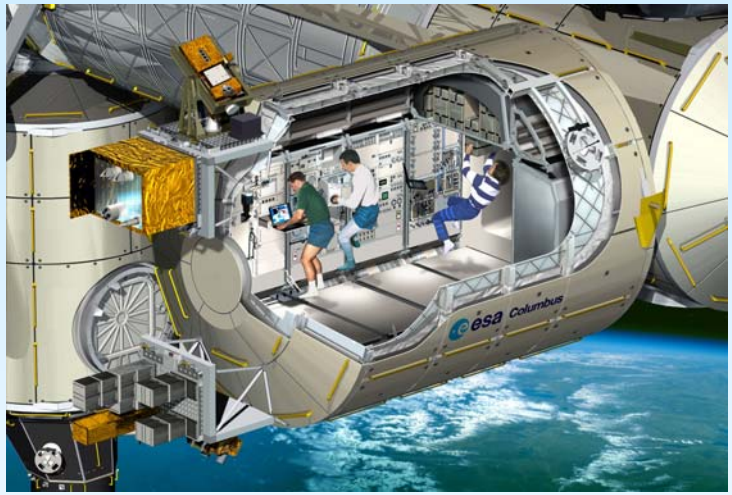
# User interface unit

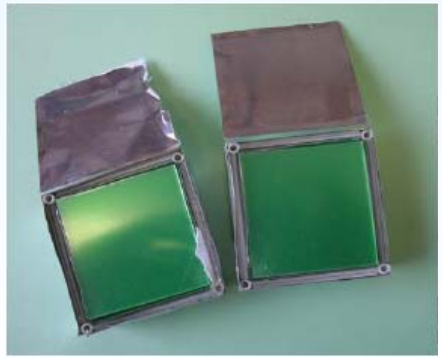


- PC104 module with graphical display, 6 menu buttons, 1 Ethernet and 2 USB ports
- Parameters can be changed manually
- Data written to memory card
- Displaying the results of the preliminary data analysis
- Possible software updates

# SURE TriTel

- Upload expected in 2009 (Increment 19)
- Operation for 6 months
- Comprises
  - TriTel 3D silicon detector telescope
  - Palfalvi's passive detector stacks (3 stacks with axes coincident with the axes of TriTel) consisting
    - several layers of SSNTDs (plastics and converter layers) and
    - $Al_2O_3$ TL detectors (integral absorbed dose measurement)

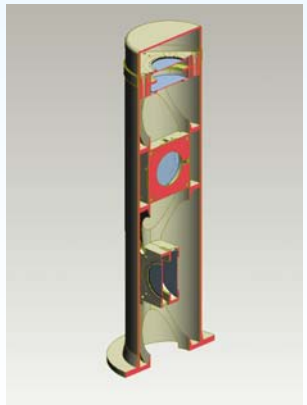


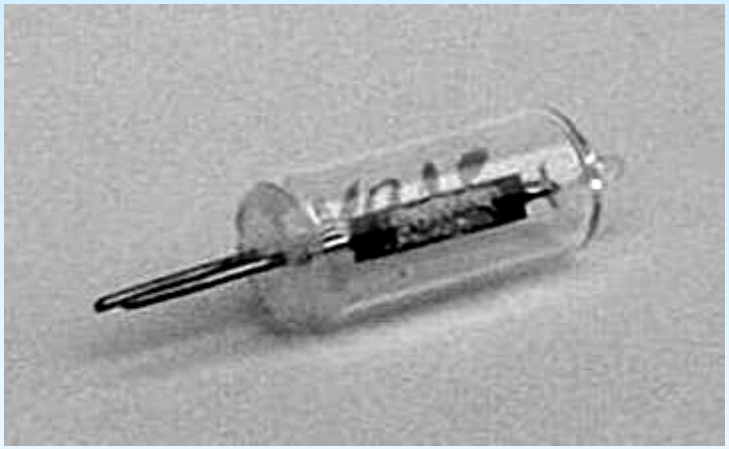
25 mm x 55 mm x 20 mm

# ISS TriTel

- In the Russian segment of the ISS
- In cooperation with IBMP
- Upload expected in 2009
- Operation for at least 6 months
- Comparing the results with SURE TriTel
- Later on → external unit →



# Electron sensitivity of Pille during EVAs (1)

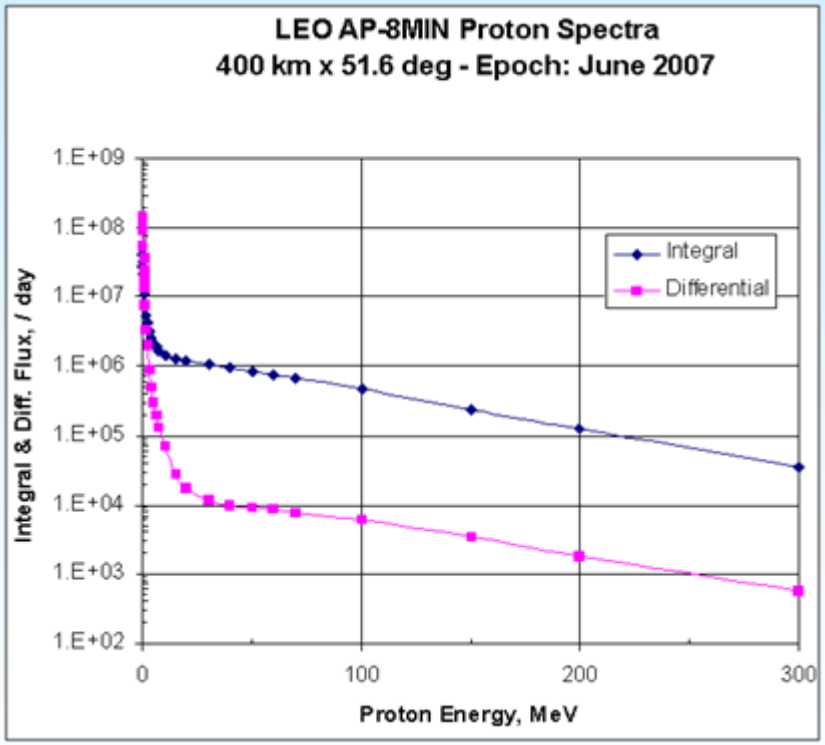


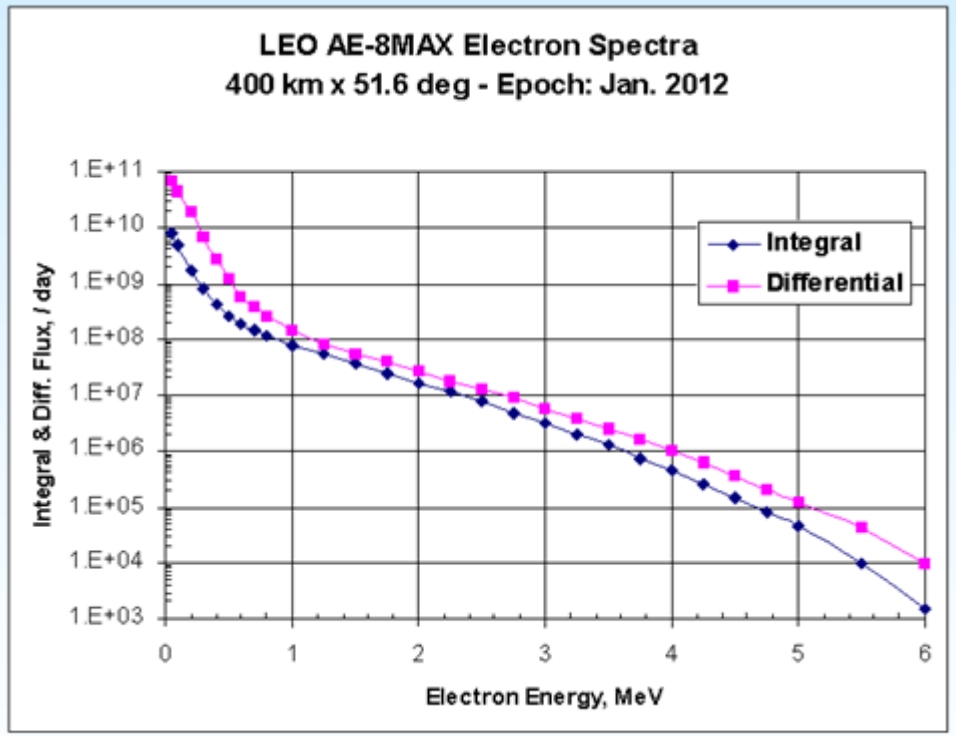
- EVA → astronauts are protected by the Orlan-M spacesuit
- ~ 1.2 mm Al(eq.) shielding
- Pille dosimeter:
  - Vacuum bulb (glass) ~ 1.09 mm Al
  - Cylindrical Al holder ~ 0.75 mm Al
  - Stainless steel tube ~ 0.71 mm Al
  - ***Protective Al case ~ 0.75 mm Al***
  - ***Polyamid insert ~ 0.89 mm Al***
- ~ 4.2 mm Al(eq.) shielding provided by the different parts of the Pille dosimeter
- → considerable fraction of the electrons are shielded → underestimate of the electron dose

# Electron sensitivity of Pille during EVAs (2)

- Substituting the protective case (and the polyamid insert) with a thin Kapton foil (~ 0.05 mm Al)
- $\rightarrow$ 2.6 mm Al(eq.) shielding
- Expected doses behind the shielding were estimated using the Geant4 based Multi-Layered Shielding Simulation Software (MULASSIS)
- Simulations were run in planar geometry
- Proton and electron spectra taken from AP8 and AE8 model for ~ISS orbit (altitude of 400 km and an inclination of 51.6°) [Redell and Atwell, 2005]

# Electron sensitivity of Pille during EVAs (3)




Redell & Atwell

# Electron sensitivity of Pille during EVAs (4)

- Absorbed doses in skin tissue relative to doses behind Orlan-M:

| | $D/D_{Orlan}$ (0°, parallel) | $D/D_{Orlan}$ (cosine law) |
|---|---|---|
| Orlan-M | 100% | 100% |
| Pille with metal case | 5% | 4% |
| Pille without metal case | 21% | 18% |

# Electron sensitivity of Pille during EVAs (5)

- Absorbed doses in skin tissue relative to doses behind Orlan-M (cont'd):

| 0°parallel | $D_{electr}/D_{Orlan}$ | $D_{proton}/D_{Orlan}$ | $D_{total}/D_{Orlan}$ |
|---|---|---|---|
| Orlan-M | 4.5% | 95.5% | 100% |
| Pille w/o metal case | 0.9% | 66.6% | 67.6% |
| Pille w/ metal case | 0.2% | 55.0% | 55.3% |

| **Cos law** | $D_{electr}/D_{Orlan}$ | $D_{proton}/D_{Orlan}$ | $D_{total}/D_{Orlan}$ |
|---|---|---|---|
| Orlan-M | 2.4% | 97.6% | 100% |
| Pille w/o metal case | 0.4% | 72.5% | 72.9% |
| Pille w/ metal case | 0.1% | 58.7% | 58.8% |

# Summary

- Measurement range of TriTel in terms of deposited energy will be 60 keV – 85 MeV
- $\Delta E > 85$ MeV $\rightarrow$ overflow bin
- SURE TriTel: TriTel + 3 passive detector stacks
  - LET spectra (0.2 keV/μm – 120 keV/μm in water), absorbed dose, average Q, dose equivalent (separately in SAA)
  - Integrated absorbed dose for the mission (TL)
  - LET spectra, and directional information (SSNTDs)
- ISS TriTel in the Russian Segment of ISS
- Pille electron sensitivity can be increased by a factor of ~ 4-5 by removing the protective metal case

# Acknowledgements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# *Thank you for your attention*

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