Pille-ISS modernized sensors for EVA and radiation measurements in ISS compartments

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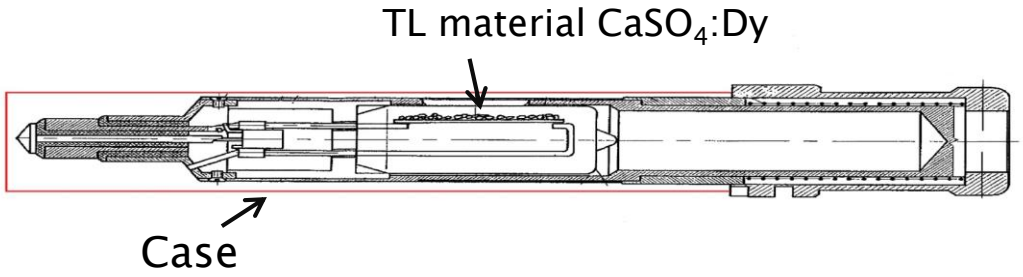
Shielding of sensor

There is some underestimation of the measured dose for EVA because of high shielding of TL material (different parts+protective case+spacesuit).



Considerable fraction of the electrons are shielded. According to MTA EK analyses electron dose might be underestimated from 4 to 5 times during EVAs (Hirn, 12th WRMISS, 2007)

During ESA EXPOSE-R2 mission the relativistic electron precipitation bands (PB) were discovered, that can increase EVA dose for astronauts. *

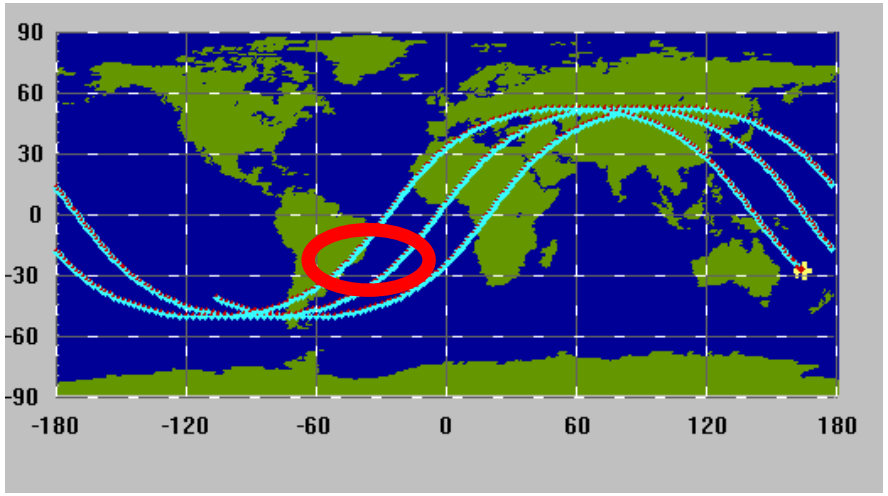
Pocket for Pille sensor in spacesuit

* Dachev et al., Journal of Atmospheric and Solar-Terrestial physics, 2017

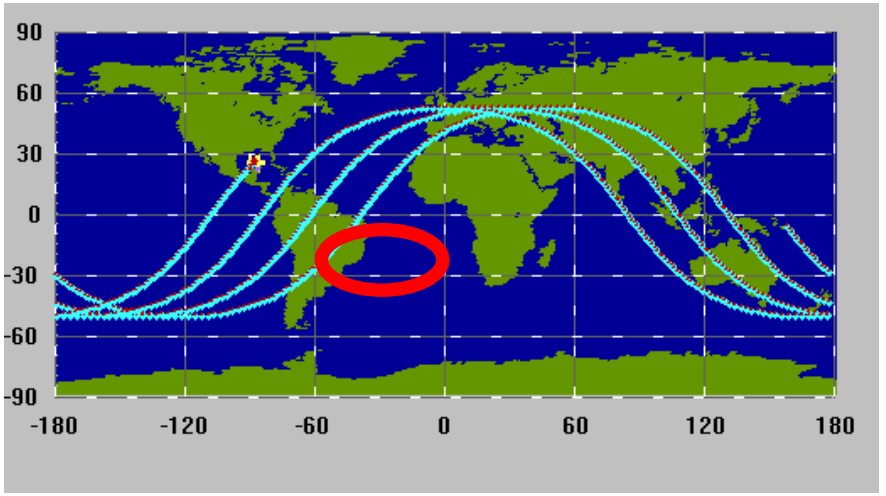
EVA doses

Typical EVA doses are from 10 μGy to 10^3 μGy depending on the ISS trajectory during EVA and radiation conditions.

EVA passing through South Atlantic Anomaly



EVA without South Atlantic Anomaly



Altitude=400 km, EVA time – 7 hours

Contribution from protons and electrons of radiation belts

Contribution from electrons, they can have variations (electron precipitation bands) **. Current sensor construction cuts off part of the EVA electron dose.**

Pille electron sensitivity can be increased by removing the protective metal case (Hirn, 12th WRMISS, 2007)

EVA dose control

Crew passive dosimeter ID3-ISS

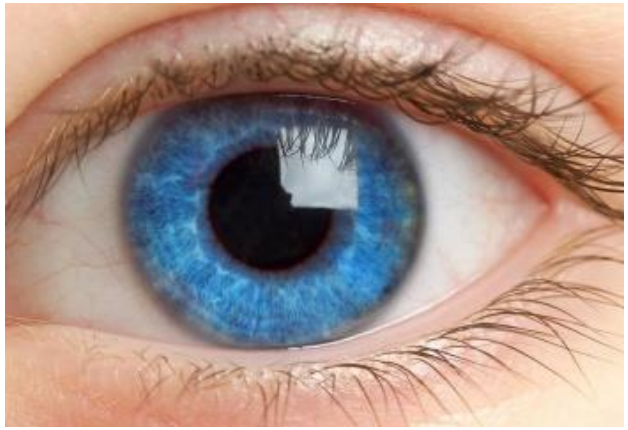
Dimensions, mm	40x42x13
Mass, kg	0.023
Tape of detector	Thermoluminescent

- ID3-ISS is used at EVA with Pille-ISS.
- It's placed in a chest pocket in a spacesuit under the cuirass
- Measures hematopoietic organs dose
- Absorbed dose range is from 0.04 to 0.5 Gy
- Developer dosimeters «ID3-ISS» - IBMP RAS

Skin and eye lens dose limits

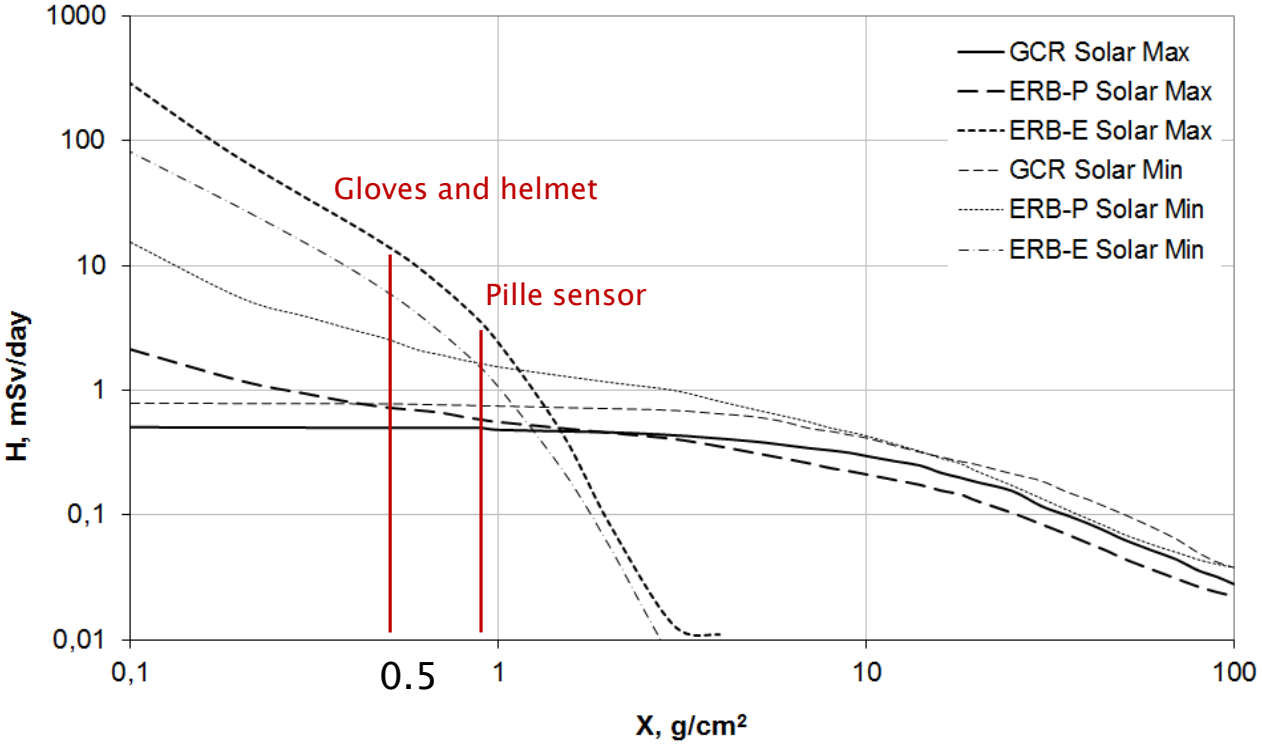
During EVA eye lens and skin are the most vulnerable because of their relatively thin selfshielding.

- According to Russian space radiation safety standards there are dose limits for critical organs:
  - for 30 days eye lens – 0.5 Sv, skin – 1.5 Sv
  - for 1 year eye lens – 1 Sv, skin – 3 Sv



As the current dosimeter construction does not allow the measurement of eye lens and skin doses during EVA, at the moment experts of the radiation safety service of IBMP RAS use only estimations.

Depth-dose curves for GCR and ERB protons and electrons at ISS orbit (400 km altitude, 51.6^0 inclination) in solar maximum and minimum*

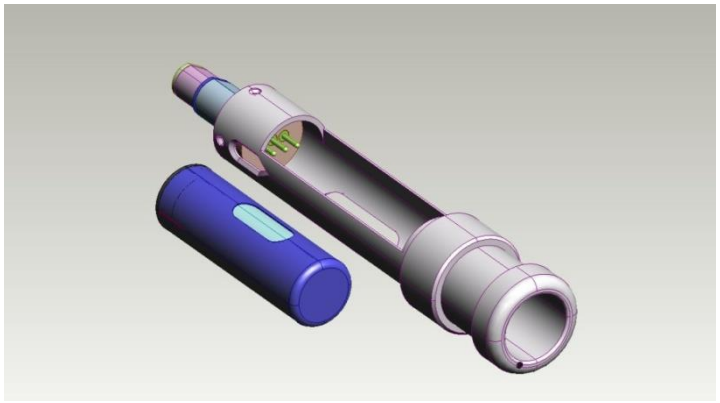


**Kartashov,Shurshakov Acta Astronautica 144, 2018.*

Skin and eye lens shielded ~0.4 and ~ 0.5 g/cm^2 thickness by spacesuit parts (gloves and helmet).
Pille sensor has ~0.9 g/cm^2 thickness.

Modernization

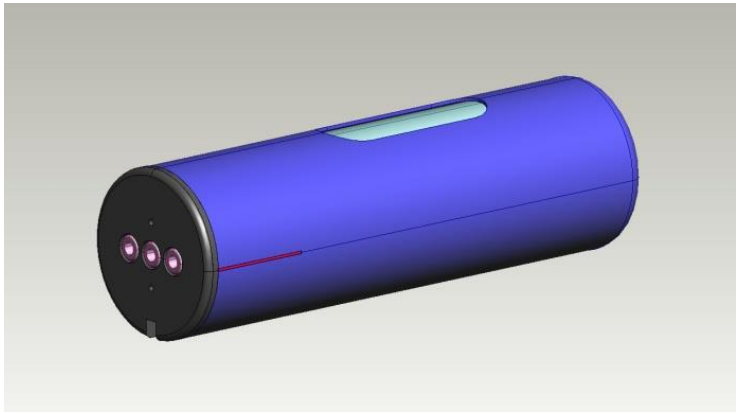
The modernized sensor is an aluminum capsule with TL-material. A special universal key is used for reading. Capsule must be placed into the key and then inserted in the reader.



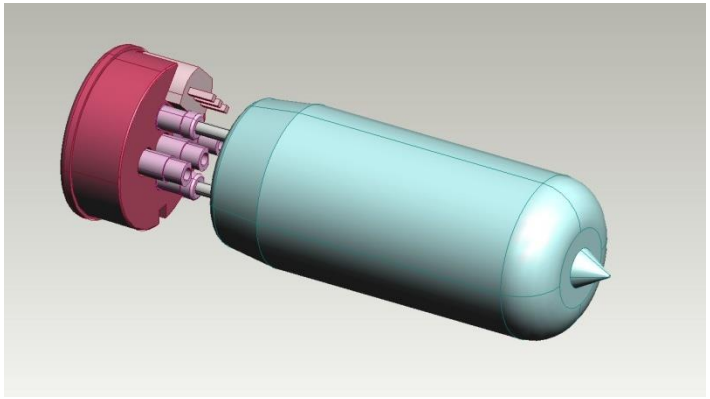
Modernized sensor (left) and Universal key (right)

Old sensor with case

Modernized sensors



Modernized sensor



Modernized sensor without aluminum cover (glass bulb)

Universal key

Advantages:

- ✓ more accurate dose measurements : eye lens and astronaut's skin in EVA
- ✓ taking into account the contribution of electrons from Van Allen radiation belts to the total dose
- ✓ ergonomic design

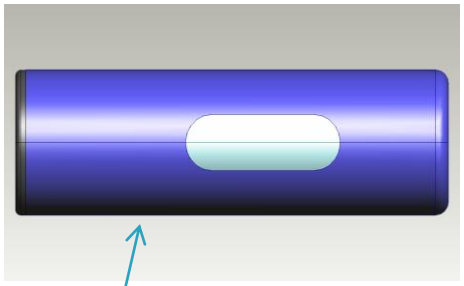
Qualification model

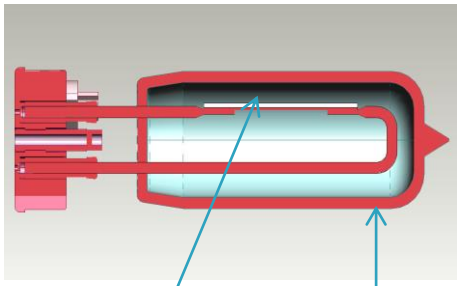
Aluminum case – 0.3 mm thickness

Sensor mass– 10 g
Key mass– 30 g

Sensor dimensions: ∅15 x 42 mm
Key dimensions: 110 x 23 x 23 mm

Comparison

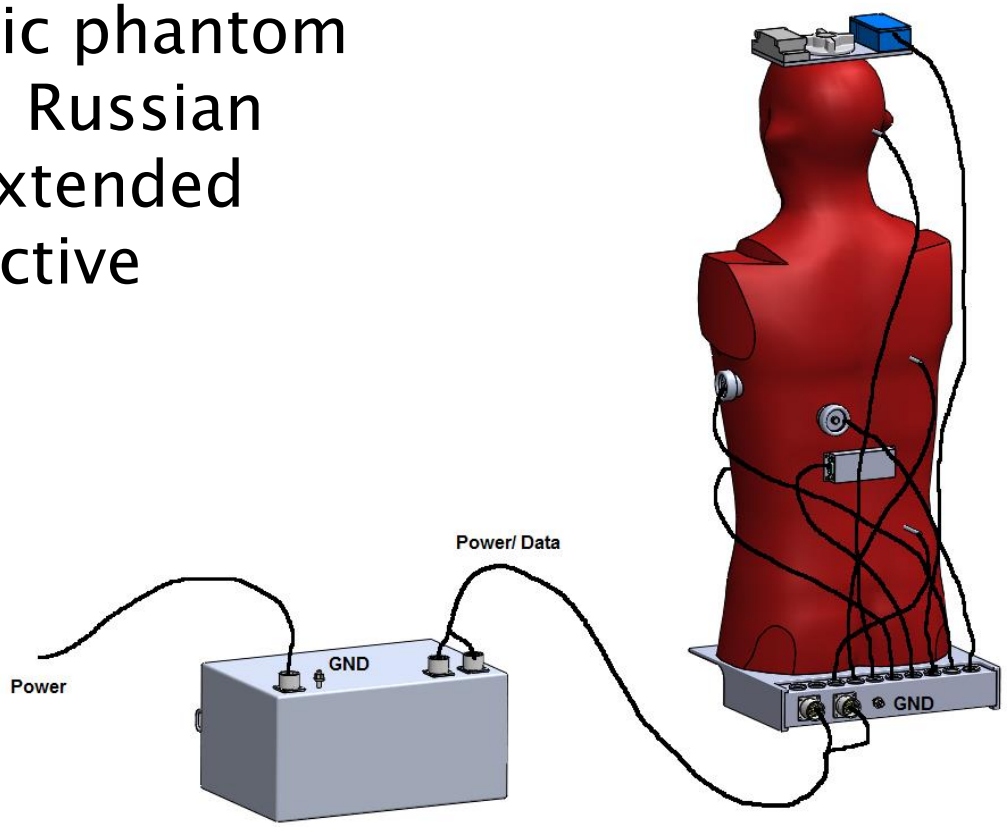




Old Pille sensor	Modernized Pille sensor
Vacuum bulb (glass) ~ 1.09 mm Al	Vacuum bulb (glass) ~ 1.09 mm Al
Cylindrical Al holder ~ 0.75 mm Al	Cylindrical Al holder ~ 0.25 mm Al
Stainless steel tube ~ 0.71 mm Al	
Protective Al case ~ 0.75 mm Al	
Total – 3.3 mm Al – 0.9 g/cm²	**Total – 1.34 mm Al – 0.4 g/cm²**

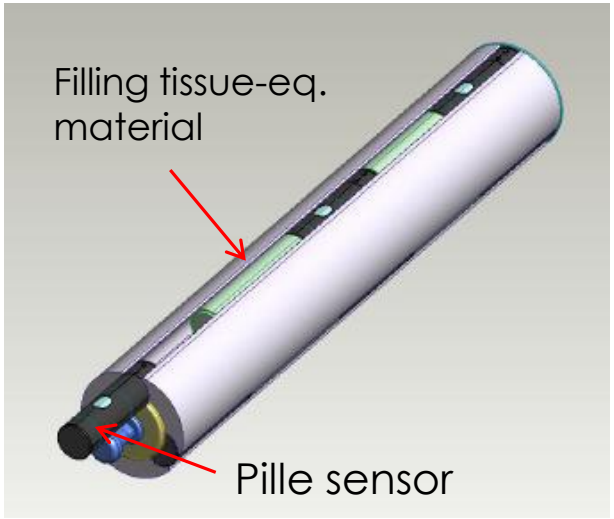
MATROSHKA-III experiment

Anthropomorphic phantom will be placed in Russian segment for a extended exposure with active detectors

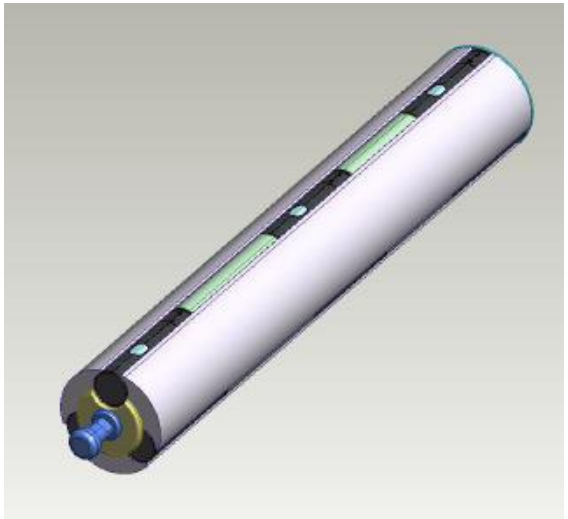


Using in MATROSHKA-III experiment

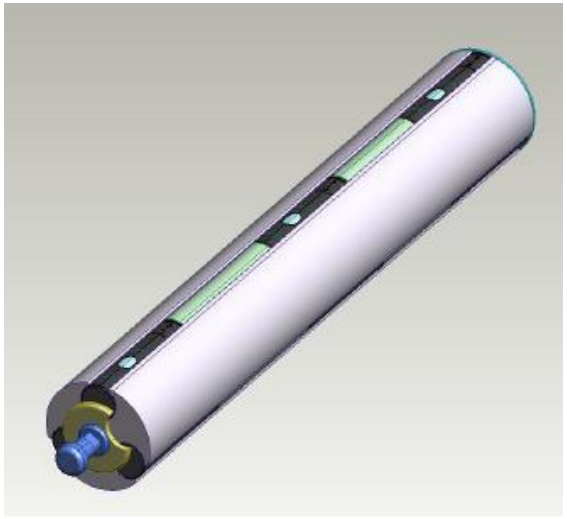
New type sensors can be used inside the phantom. Special holder from tissue equivalent material was developed. The structure is capable of housing 1 to 9 sensors (3 pieces at three different locations).



1 – Inserting sensor in the holder



2 – After inserting: cells are not fixed



3 – After inserting: cells are fixed after rotating the knob of the holder

Holder printed by a 3D printer

Summary

- There is some EVA dose underestimation measured by Pille sensors, it caused by high shielding of different parts.
- Modernization developed by MTA EK and IBMP RAS reduces shielding
- It becomes possible to measure eye lens and skin doses and increase sensitivity to electron contribution to the dose during EVA
- The qualification model of modernized sensor have been developed in 2018

Following work:

- qualification tests of qualification model (2018), calibration with gamma and proton flux included
- developing of flight samples and further on-ground tests (2019)
- flight tests aboard the ISS during IVA and EVA (2020)
- usage in Matroshka-R space experiment (2021)

Thank you!