Space Radiobiology and
Precision Galactic Cosmic Ray Measurements
on how the AMS02 experiment on the International Space Station can help the radiation health hazard assessment in exploratory space missions

In the last two decades many experiments were built and deployed in space to produce a complete inventory of charged particles and nuclei in cosmic-ray (CR). The goals are the study of CR properties, search of Dark Matter and antimatter, but potentially can be used to evaluate the health hazard of astronauts due to the exposure to ionizing radiation in space missions.

We shall start with a detailed description of the AMS02 experiment, to which construction took part also INFN Roma and Sapienza University. AMS02 has collected up to now more than 146 billion CR events.

We shall then discuss the present and future research activities done by European Space Agency (ESA) for the radiation health hazard assessment in exploratory space missions.

Finally, the problem related to space ionizing radiation in design and build a space infrastructure will be presented, with particular attention to shielding solutions for manned lunar/mars missions.

Introduzione

Alessandro Bartoloni – INFN Roma

«High precision measurements of charged cosmic rays in space with the Alpha Magnetic Spectrometer.»

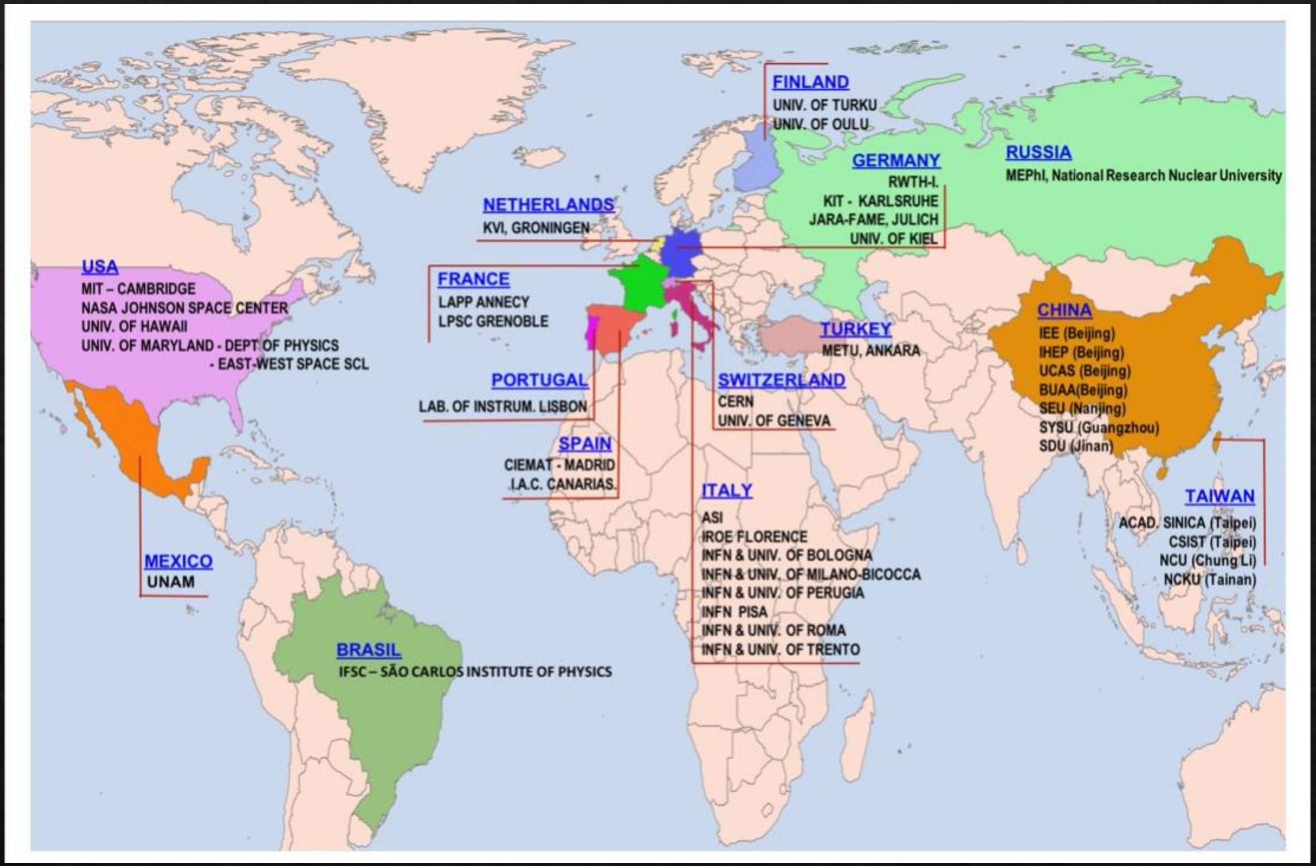
Mercedes Paniccia – Università di Ginevra

«ESA Human Spaceflight Radiation Research Programme activities"

L*eonardoSurdo – European Space Agency*

«Shielding design for long duration human exploratory space missions : issues and future perspective »

M.Giraudo – Thales Alenia Space



The AMS collaboration

(http://ams02.space)

An international collaboration made of 44 Institutes from America, Asia and Europe

Presents in 7 INFN departments (BO,MIB,PI,PG,RM1,RM2,TN)

AMS in Figures

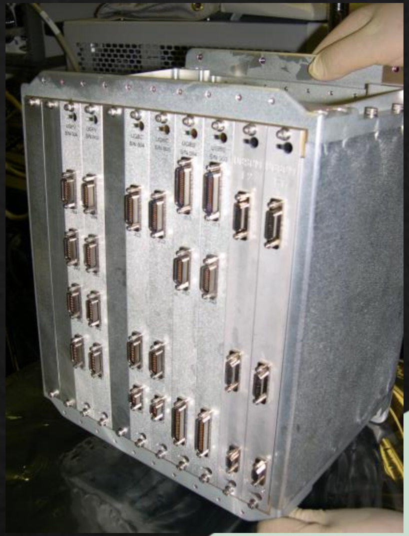
7.5 t Weight	**5×4×3 m³** Size	**0.14 T** Magnetic Field Intensity	**16/05/2011 08:56 AM EDT** Launched

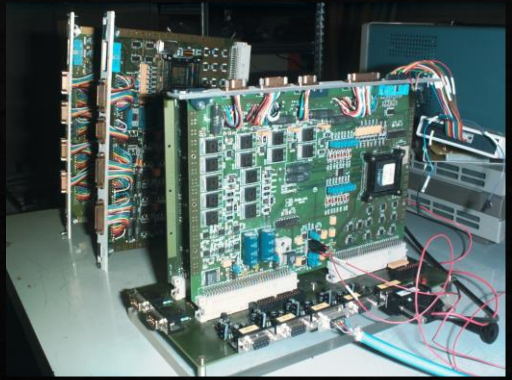
Part of the AMS02 experiment was built at Rome (INFN & Sapienza)

The INFN Roma and the Sapienza university joined the AMS collaboration in 2001.

The group has taken part to the construction of the Transition Radiation Detector (TRD), having as main task the responsibility to develop the slow control electronics of the GAS System of the TRD (UG-Crate).

The UG-CRATE was part of a safety-critical system and the group took care of all the phases of the development (Design–Test-Integrate-Fly) following the NASA requirements.





Design – Test – Integrate – Fly

2001-2003
- Engineering Modules to test system functionalities

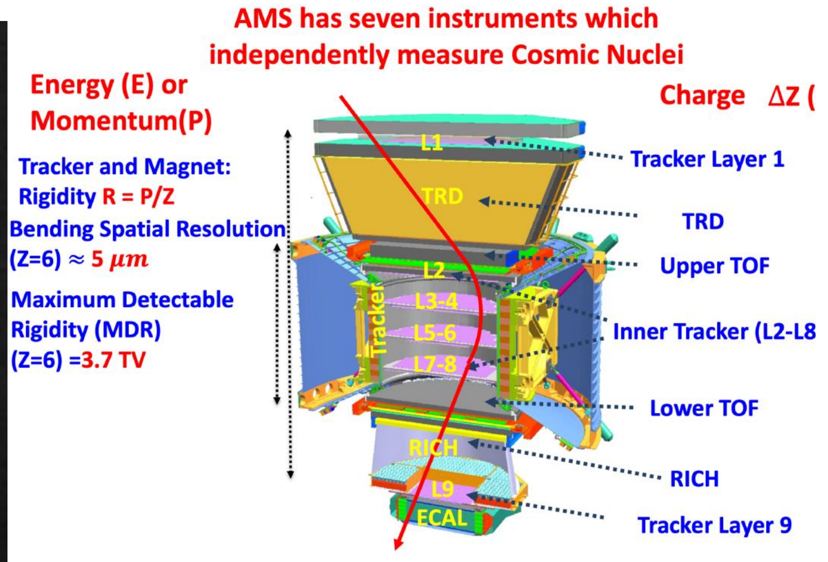
2004-2005
- Qualification Modules to space qualify (EMC-Thermo/Vacuum-Vibration Test)

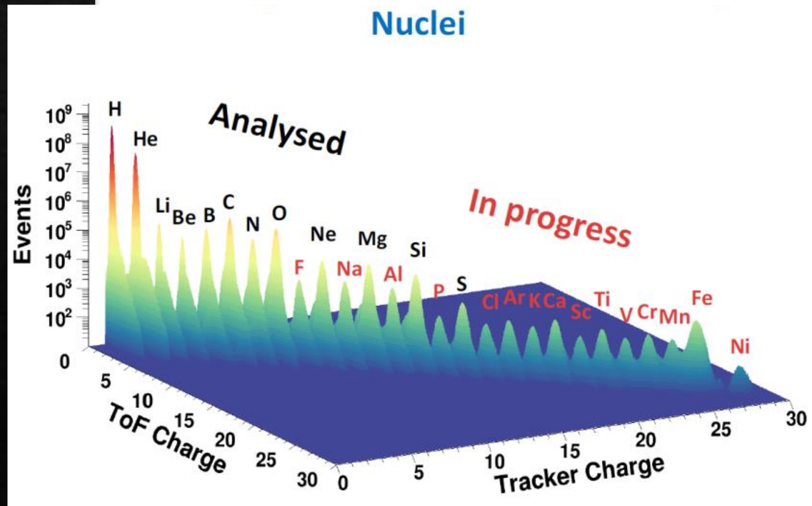
2006-2008
- Flight & Spare Modules Production and qualification of electronics now installed on the ISS

2009-2011
- UGPD-Crate Assembly in AMS02 and Space Qualification at ESA-ESTEC
- Launch ops at NASA-MSFC

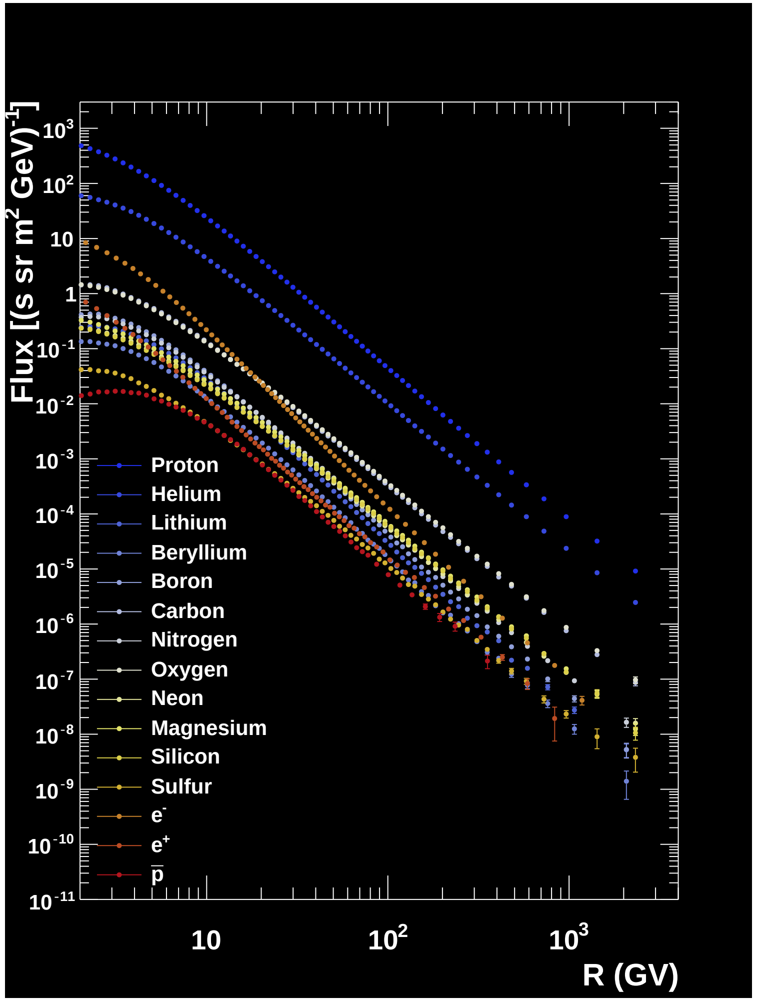
AMS02 Detector

- Multiple instruments detector
  - Tracker Layer 1
  - TRD
  - ECAL
  - Upper TOF
  - Tracker (L2-L8)
  - Lower TOF
  - RICH
  - Tracker Layer 9





AMS02 Nuclei Events (2019)



AMS02 Latest Results (Flux)

High precision measurements of charged cosmic rays in space with the Alpha Magnetic Spectrometer

Dr. Mercedes Paniccia – Università di Ginevra

The Alpha Magnetic Spectrometer (AMS) is the most powerful and sensitive cosmic-ray detector ever deployed in space to produce a complete inventory of charged particles and nuclei in cosmic rays near Earth in the rigidity (momentum/charge) range from GV to few TVs. Its physics goals are the study of cosmic-ray properties, indirect search for Dark Matter and direct searches for primordial antimatter and exotic form of matter. The improvement in accuracy over previous measurements is made possible through its long duration time in space, large acceptance, built-in redundant systems and its thorough pre-flight calibration in the CERN test beam. These features enable AMS to analyse the data to an accuracy of ~1%. Since its installation on the International Space Station in May 2011, AMS has collected more than 146 billion cosmic-ray events and has produced precision measurements of electron, positron, proton, antiproton, and helium to oxygen nuclei fluxes in cosmic rays of rigidity ranging from GV to few TVs, as well as the helium isotopic composition in the 2.1 GV to 21 GV rigidity range. The percent precision of the AMS results challenges the current understanding of the origin and of the acceleration and propagation mechanisms of cosmic rays in the galaxy and thereby requires new theories to be developed by the physics and astrophysics community. In this talk, after a brief introduction to cosmic-ray physics, I will present the latest AMS results, pointing out their implication for cosmic-ray modelling and for Dark Matter searches.

UNIVERSITÉ DE GENÈVE
FACULTÉ DES SCIENCES
Département de physique nucléaire et corpusculaire

Health Hazard for Astronauts

Visual Impairments

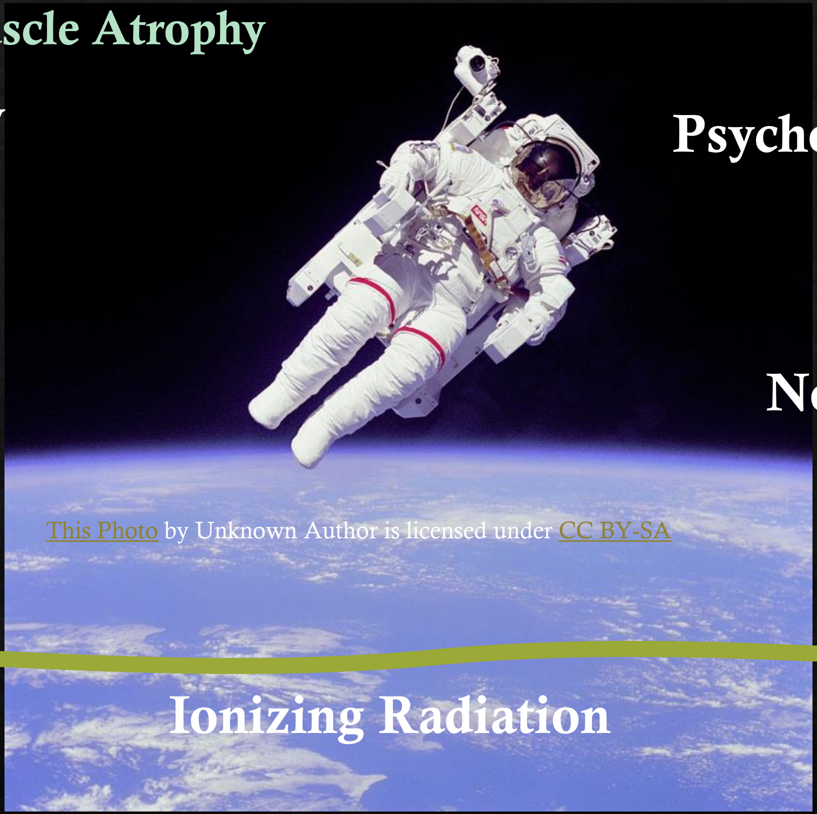
Muscle Atrophy

Fluid Distribution

Microgravity

Osteoporosis

Motion sickness



Circadian

Psychological Stress

Isolation

Dietary Limitation

Noise Background

Confined Space

Ionizing Radiation

Eye Flashes

Cardiovascular disease

Cataract

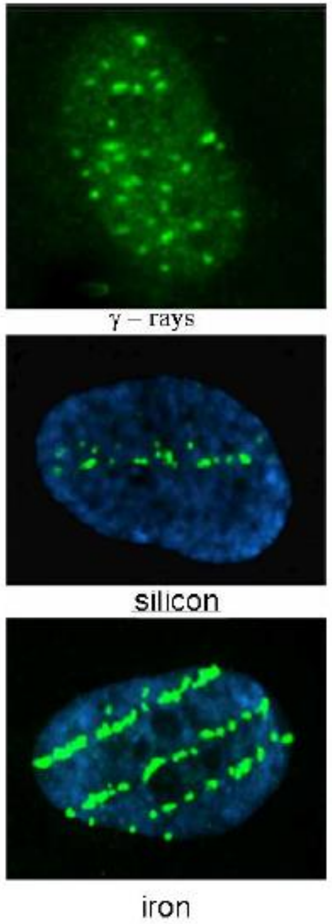
Central nervous system effects

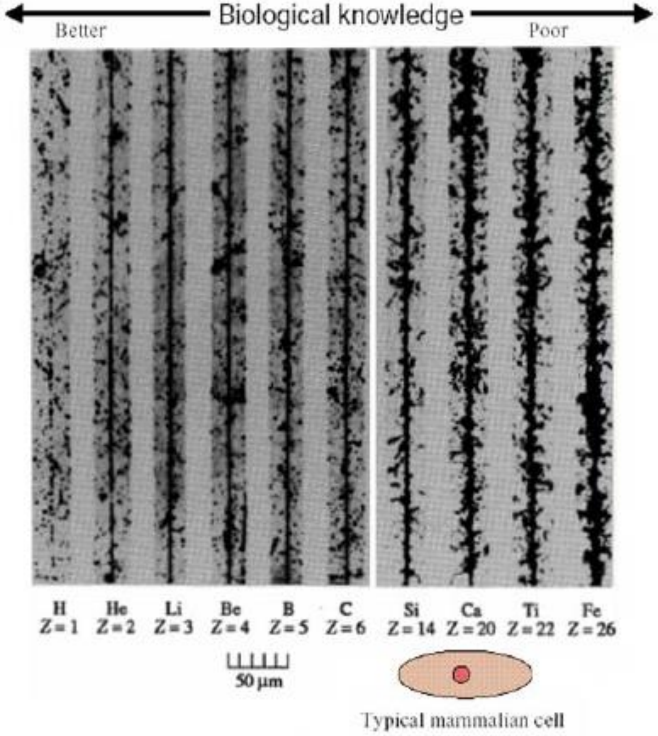
Acute radiation syndromes

Immune dysfunction

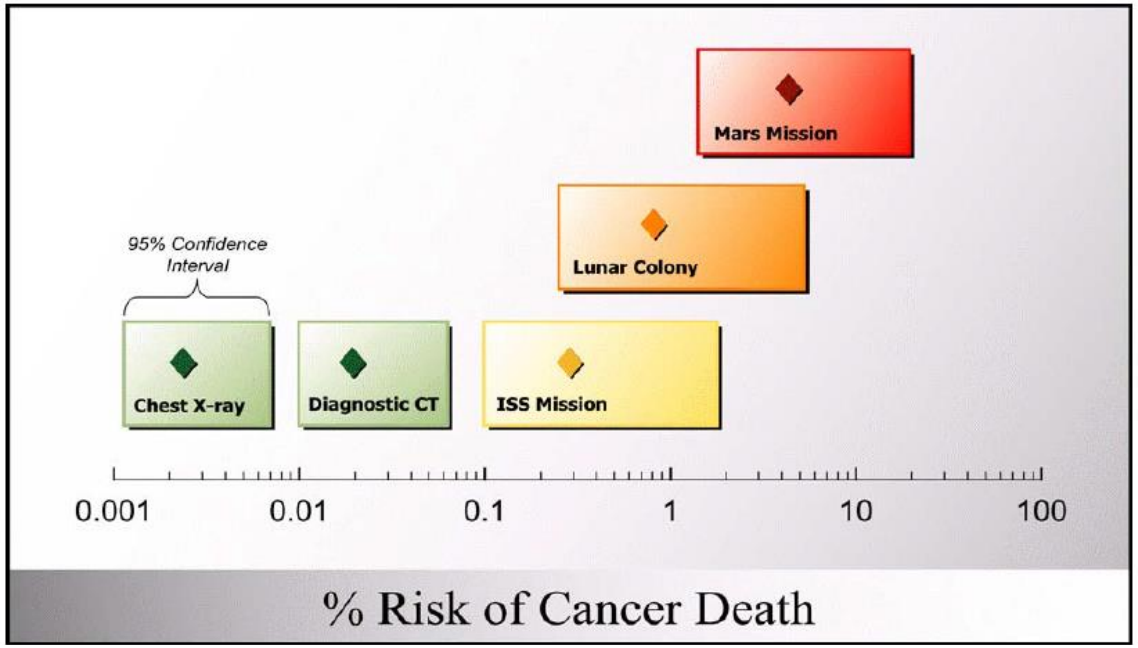
Cancer

Radiation Quality





(Cucinotta, Durante 2008)[1]



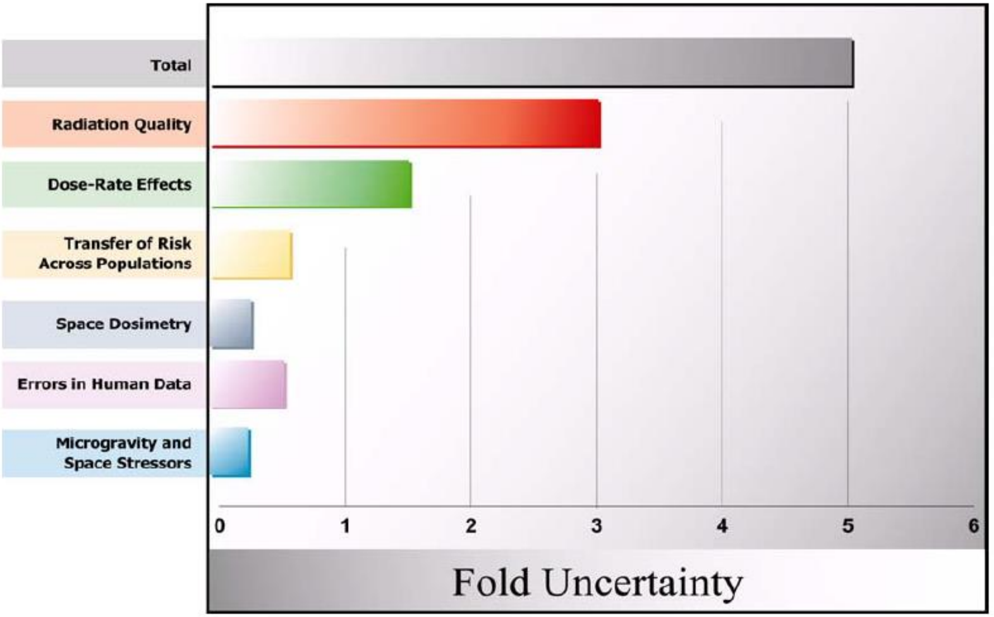
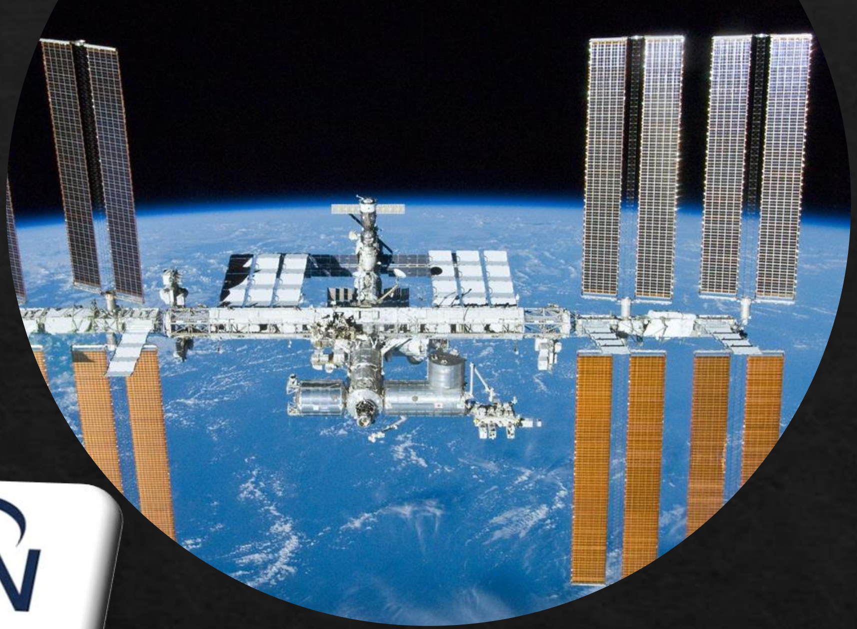


Figure 4-1. *Estimates of fold uncertainties from several factors that contribute to cancer risk estimates from space radiation exposures. The uncertainties are larger for astronauts who are in space as compared to typical exposures on Earth, as illustrated.*



Misure di precisione di raggi cosmici con l'Alpha Magnetic Spectrometer e radiobiologia nello spazio.

A.Bartoloni et al (2019)

"Dose-Effects Models for space radiobiology: an overview"

Study Reference	Model	Dose range/threshold or LET	Experimental Validation
7-10	Eye flashes	LET> 5 – 10 keV/μm	Yes
11-17	Chromosomal aberrations	5 - 150 mGy	Yes
18-24	Cataract Risk	8 mSv	Yes
26-27	CNS Risk	100-200 mGy	No
28-29	Oral mucositis	2000 mGy	No
30-32	Cardiovascular disease (CVD)	*1000 mGy*	in Japan atomic bomb survivors
28, 32-34, 36,38	Cancer	*<100 mGy*	Yes

Table 1: investigated model for predicting dose effect relationship in humans involved in space missions.

We carried out a review of the dose effect patterns derived from the biological effects observed as a result of space missions.

Many of the effects occur at doses of hundreds of mGy and are typical doses of diagnostic investigations so a synergy between knowledge arising from clinical trials and those of Space Radiobiology is desirable to increase the robustness and prediction of current models.

A.Bartoloni et al (2019)

bando tesi n.33

"ESA Human Spaceflight Radiation Research Programme activities"

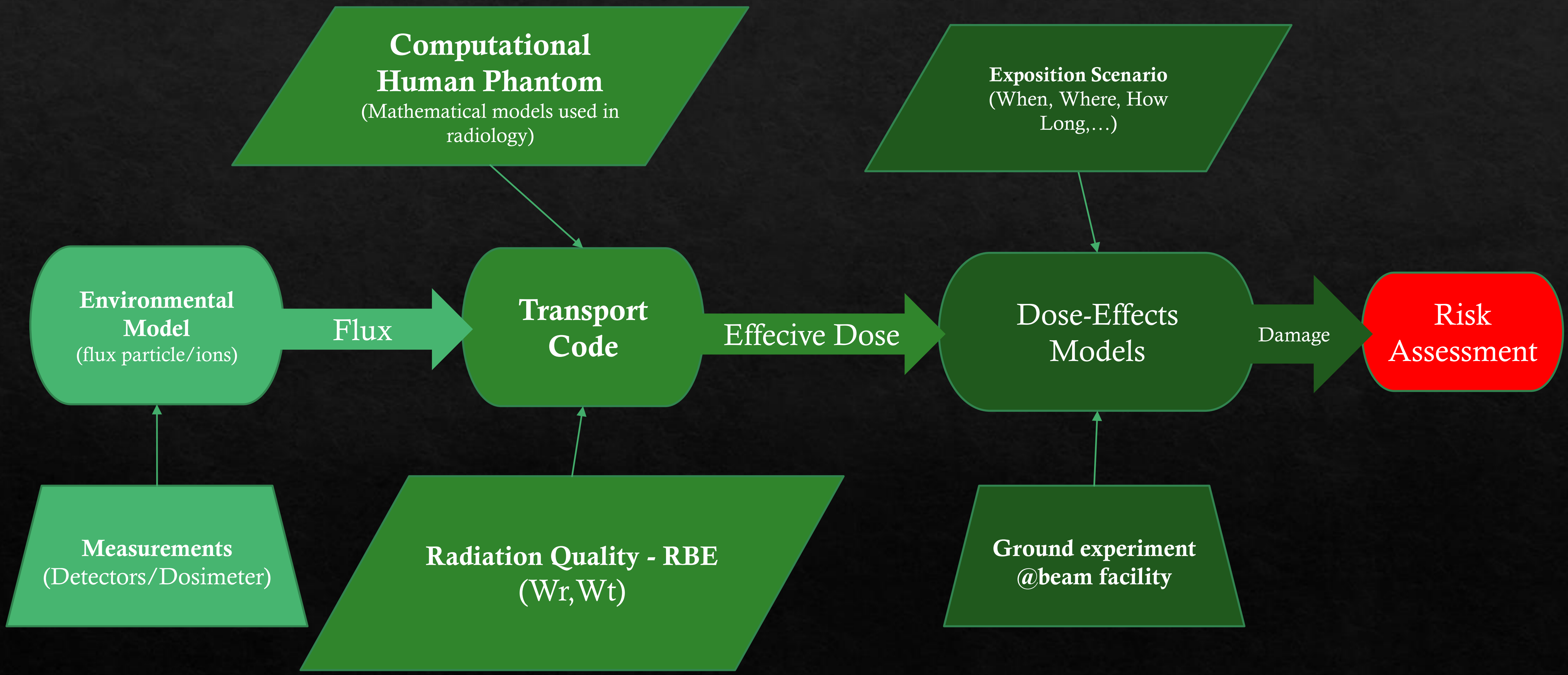
Dr. Leonardo Surdo – European Space Agency

Space radiation has long been recognized as a potential showstopper for long duration human exploration missions: crewmembers will be exposed to different doses and qualities of radiation, threatening life quality and individual survivability, thereby disrupting mission success. When assessing the risks related to radiation in human exploration scenarios, high uncertainty remains about the biological effects of this space radiation. To support research enabling safe and stable human space exploration with acceptable risk from exposure to space radiation, the European Space Agency has intensified its efforts to advance knowledge on quantifying the risks and actual exposures to radiation in space to allow developing effective countermeasure strategies to protect crewmembers from the damaging effects of space radiation.

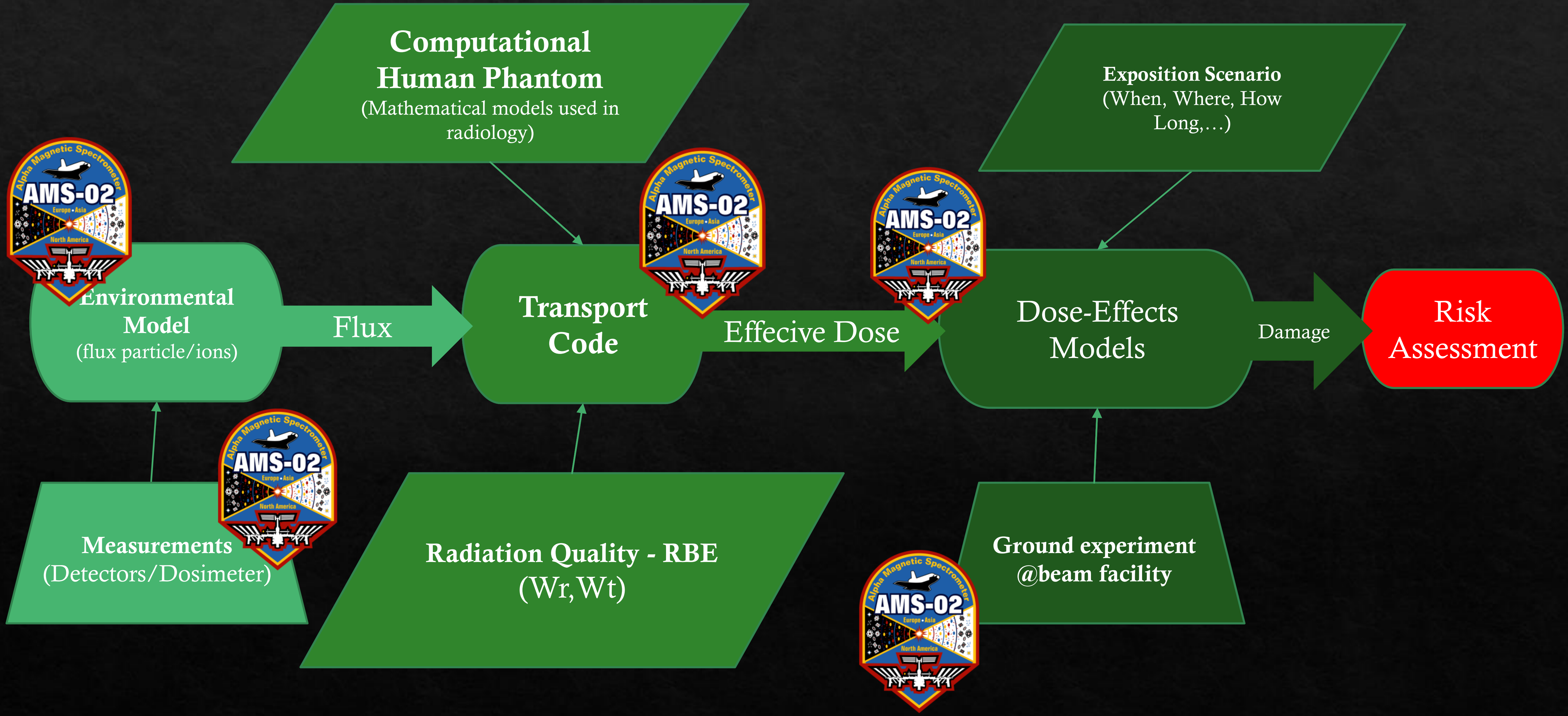
esa

European Space Agency
Agence spatiale européenne

Adattato da «Research plans in Europe for radiation health hazard assessment in exploratory space missions», Life Sciences in Space Research (2019)[2]



Potentialities of AMS02 in the research plan context



“Shielding design for long duration human exploratory space missions : issues and future perspective”

Dr. Martina Giraudo - Thales Alenia Space

“As manned spaceflights Beyond Low Earth Orbits (BLEO) are in the agenda of space agencies, concerns related to the astronaut space radiation exposure are still under discussion and without conclusive solutions.

In BLEO missions, outside the protection provided by Earth’s atmosphere and magnetic field, the astronauts will be exposed to the full spectrum of space radiation.

Many uncertainties characterize indeed the radiobiological effects and the nuclear interactions with the spacecraft materials of this high energy radiation found in space, in particular when the Galactic Cosmic Rays (GCR) are concerned, and no definitive shielding solution has been found. For this reason risk assessment of long-term detrimental health effects for a deep-space mission is a difficult task.

A long term space exploration mission requires to mitigate the effects of GCR and, at the same time, emergency countermeasures must be planned to avoid the short-term consequences of exposure to Solar Particle Events (SPE), able to impair mission success and to endanger astronauts’ life.

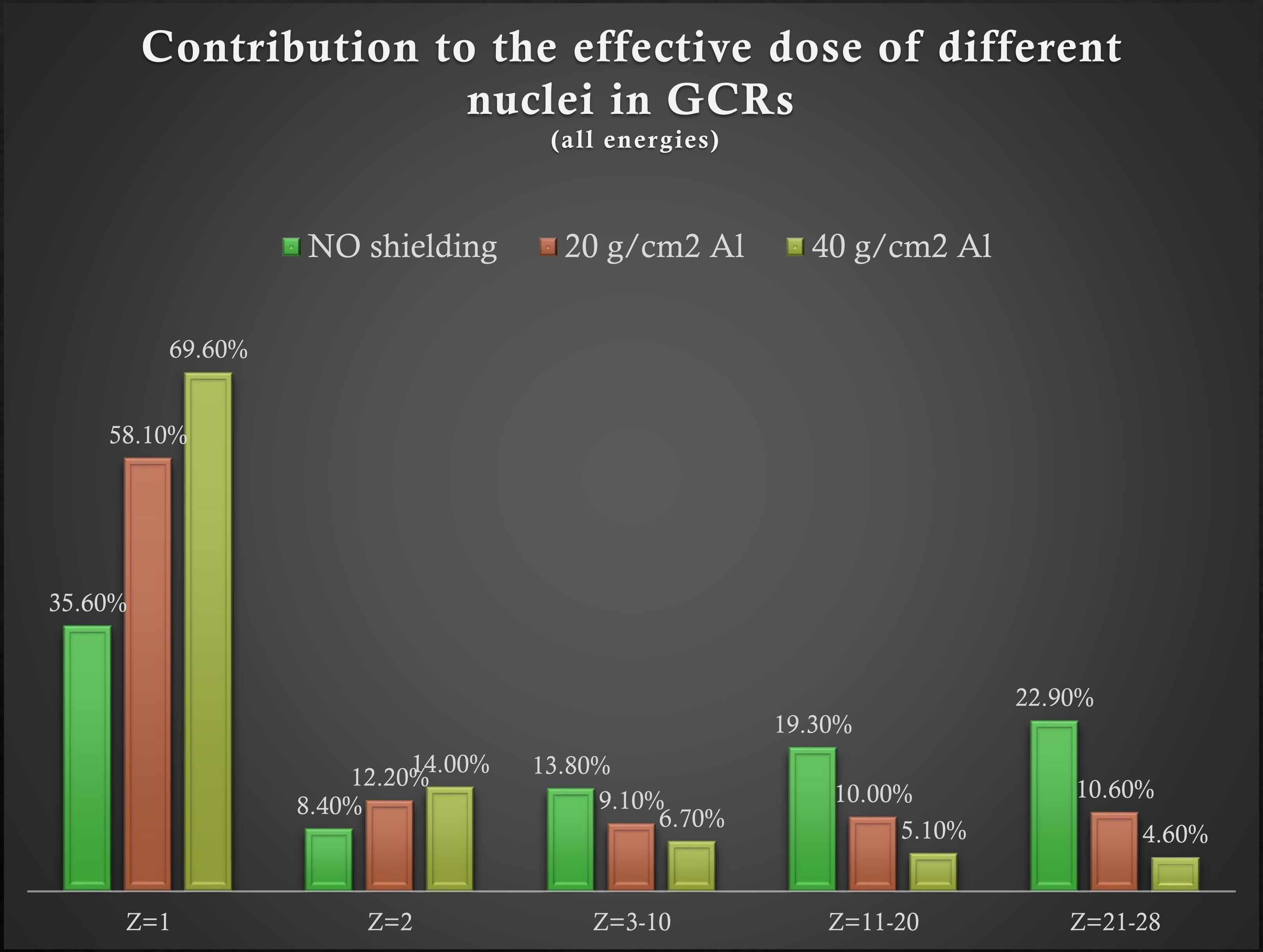
The various themes related to the design of shielding for deep space human missions will be presented and discussed, focusing on the work done in Thales Alenia Space and discussing possible developments. “

ThalesAlenia Space
a Thales / Leonardo company

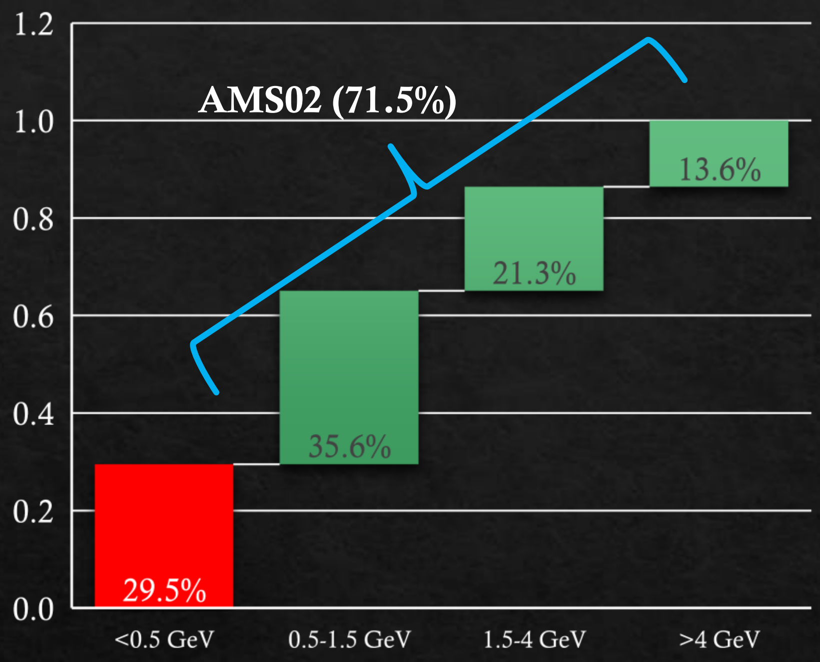
AMS02 is able to measure 100% of the particles and heavy ions of interest

As the thickness of the protective shielding increases (in the Aluminum study) the heavier ions are stopped and the contribution of the lighter ones becomes prevalent.

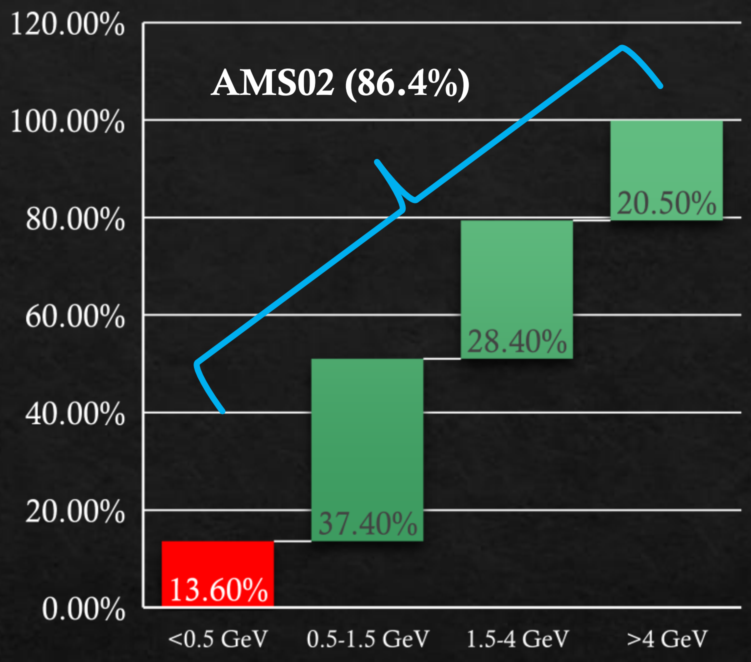
Protons contribute for 50% of the effective dose



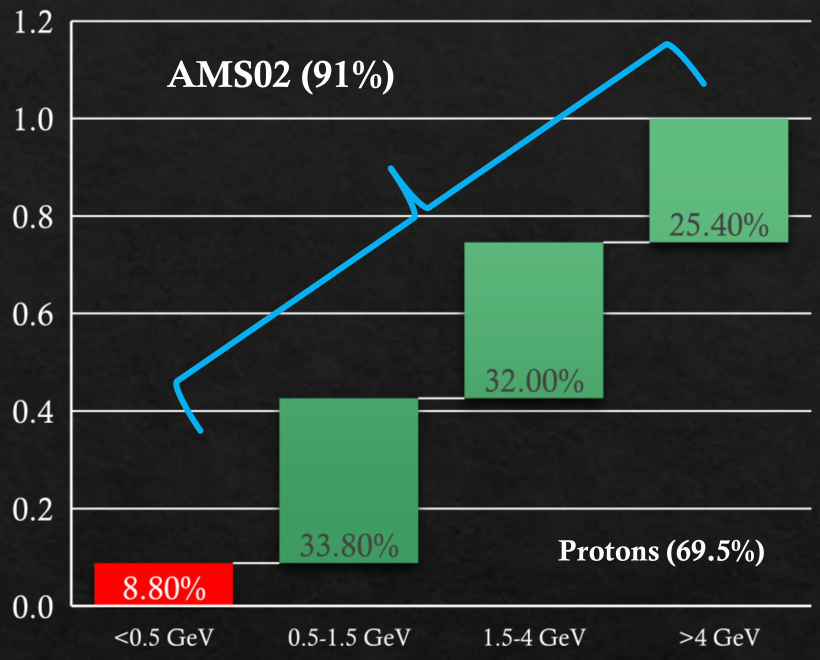
Dati elaborati da (Slaba2014)



No Shielding



Al Shielding 20g/cm2



Al Shielding 40g/cm2

AMS02 measures the flux and properties of most GCRs charged particles that contribute to the effective dose

Dati elaborati da (Slaba2014)

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