INFN ROMA SAPIENZA
AMS GROUP
ACTIVITIES SPRB FOR ASI CONTRACT

27/03/2023

REPORT APPROVAL AND REVISION HISTORY

Version	Description of the Revision	Effective Date
V1.1	Modification for Table 1, reference added to Table 2	08/05/2023
V1.2	The AMS published data of particles flux with energy range in different time periods (Table 2) is updated with the new data published recently.	29/05/2023

AMS 4 SPACE RADIOBIOLOGY

1. Description and context of the project

The Alpha Magnetic Spectrometer (AMS-02) is a particle physics experiment that is mounted on the International Space Station (ISS) and is also a recognized CERN experiment. AMS-02 is a cosmic rays (CRs) detector able to measure all the charged components of the CRs. AMS-02 is the result of nearly two decades of effort of an international collaboration to design and build a state-of-the-art detector capable of performing high-precision CRs measurement. The AMS-02 will use the unique environment of space to advance knowledge of the Universe and lead to the understanding of its origin by searching for primordial antimatter, dark matter and measuring with great accuracy the CRs. So far, more than 218 billion CR events have been collected.

The INFN Roma and the Sapienza University AMS research group [1] joined the international AMS collaboration in 2001. Part of the AMS-02 experiment was built in Rome by the group, that has taken part in the construction of the Transition Radiation Detector (TRD), having as its 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. Current group members are:

Alessandro Bartoloni (INFN Roma)
Francesca Bisello (IRCCS AOUBo)
Bruno Borgia (INFN Roma & Sapienza University)
Aboma N. Guracho (INFN Roma)
Giulia Paolani (IRCCS AOUBo)
Sara Parsaei (Shahid Bahonar University of Kerman)
Mustafa M. Rafiei (Shahid Bahonar University of Kerman)
Miriam Santoro (IRCCS AOUBo)
Lorenzo Spagnoli (IRCCS AOUBo)
Lidia Strigari (IRCCS AOUBo)
Silvia Strolin (IRCCS AOUBo)
Klarisa Elena Szilagyi (IRCCS AOUBo)
Faith Tng (Space Generation Advisory Council)
Vincenzo Valente (GARR & INFN Roma)

After the installation of the AMS-02 on the International Space Station (ISS) in May 2011, the AMS Roma-Sapienza group is participating in the data-taking operations at CERN and the data analysis. In 2017 the group started to investigate some new potential use of the AMS-02 data for variable scientific research in space life sciences, space radiobiology (SPRB), and dosimetry. The AMS SPRB collaboration was created in 2017 by the synergy of the AMS INFN Roma Sapienza group headed by Alessandro Bartoloni with the medical physics research group headed by Lidia Strigari, currently at IRCCS Azienda Ospedaliero-Universitaria di Bologna (AOUBo) [2]. This collaboration was created to foster the synergy of the two research groups' complementary competencies, knowledge and skills. The expertise of INFN in the space radiation environment, CRs data analysis and AMS-02 detector were complemented with the ones in radiobiology, dosimetry and dose-effect models of AOUBo. In July 2017, this collaboration was announced to the INFN Roma Division Council and to the INFN National Scientific Committee 2 (CSN2) referees [3,4].

SPRB is an interdisciplinary science that examines the biological effects of ionizing radiation (IR) on humans involved in aerospace missions. Living things in the solar system are continuously exposed to Galactic Cosmic Ray (GCR) particles and rarely to more energetic particles emitted by the Sun named Solar Energetic Particles (SEP). The knowledge of the risk assessment of the health hazard related to human space exploration is crucial to reducing damages induced to astronauts from GCRs and SEP. GCRs have been identified as one of the primary sources of radiation exposure in space. Therefore, health risks associated with IR exposure play an essential role in space missions whose safety depends on detailed characterization of the space radiation environment. Table 1 evidence it by comparing the expected ionization doses for different expectation scenarios in space to what happens on the Earth's surface and in the clinical application exposition [5].

Exposure Scenario	Ratio#	Daily Absorbed Dose (mGy)	Daily Equivalent Dose (mSv)	Daily Effective Dose (mSv)
Earth's surface# (Background Radiation)	1.00		0.008	
Earth's surface (Cosmic radiation only)	0.13		0.001	
LEO-ISS (average)	51.37	0.41	0.41	0.41
Mars's surface (Solar maximum)	37.50	0.12	0.30	0.28
Mars's surface (Solar minimum)	76.25	0.25	0.61	0.54
Lunar surface (Solar maximum)	72.50	0.10	0.58	0.38
Lunar surface (Solar minimum)	195.00	0.27	1.56	0.84
Typical Radiation workers' Exposition	**Ratio#**	**Absorbed Dose (mGy)**	**Equivalent Dose (mSv)**	**Effective Dose (mSv)**
Aircrew flying polar routes (Per year)	2.05		6.00	
Diagnostic Radiologist (Per year)				0.9 [6]
Clinical Examples (diagnosis)	**Ratio#**	**Absorbed Dose (mGy)**	**Equivalent Dose (mSv)**	**Effective Dose (mSv)**
Whole Body CT (per exam.)	482.00			4.82
PET/CT (per exam.)	1840.00			18.4
Cardiac SPECT/CT (per exam.)	1270.00			12.7
Clinical Examples (treatment)	**Ratio#**	**Absorbed Dose (mGy)**	**Equivalent Dose (mSv)**	**Effective Dose (mSv)**
Proton therapy dose/fraction (typical)	220000.00		2200	

The ratio is calculated using the equivalent doses except for the CT, PET/CT and SPECT/CT cases in which the effective doses are used.

Table 1. Daily absorbed Dose, equivalent Dose, and effective Dose of ionization radiation in different exposure scenarios. Also, some IR doses typical of clinical use are reported.

The scope of this research is using the information of charged particle measurement of AMS to develop a new model on the ionization radiation damage on living things in the space regions that humans will explore in the following decades (LEO, Moon and Mars exploration). The research will produce new models of the expected damage of ionization radiation exposure in space using the AMS data to characterize the inputs to the model (spectra, fluences and doses) and the data presented in the existing relevant literature. The produced models will be helpful for the radiation health risk assessment for humans in space missions and design R&D activities for new dosimetry instrumentation for space.

Since 2018, after the approval of the research activities from INFN Scientific Committees, the group has collaborated with researchers and scientists to investigate the topic. The following paragraph will briefly describe the activities done up to the present.

2. Description of the previous years' project activities.

2018 - 2020

The first result of the research was a study of the capabilities and possibilities for using Cosmic Ray Detector (CRD) data to improve knowledge in the space radiobiology field, especially regarding the AMS-02. In particular, we elaborated a GCR sensitivity analysis showing that the AMS-02 detection capability includes all the elementary particles and nuclei of interest for the space radiobiology investigations and also covers the more significant part of the space radiation energy range of interest (>70%) [7].

Also, we were focused on creating synergies within different scientific communities (radiobiology, medical physics, radiotherapy, and nuclear medicine) and institutions playing a crucial role in human space exploration (Universities, Research and National Space Agencies). To reach this purpose, in 2019, we organized at INFN Roma Sapienza a thematic workshop named "Space Radiobiology and Precision Galactic Cosmic Ray Measurements", on how the AMS-02 experiment on the International Space Station can help the radiation health hazard assessment in exploratory space missions. We invited people from the European Space Agency (ESA), Thales Alenia Space (TAS) and the AMS collaboration [8]. During the workshop addressed three main aspects starting with a detailed description of the AMS-02 experiment, followed by a discussion on the current and future research activities done by ESA for the radiation health hazard assessment in exploratory space missions and concluded with an overview of the problems related to space IR in design and build space infrastructures, with particular attention to shielding solutions for human-crewed lunar/mars missions. In the following days, a fruitful discussion led to the writing of a proposal for creating an ESA topical team on the subject forecast for the following years.

The second step was to deeply analyze how and where the CRD data can be used for the improvement of the risk assessment process for human health during space exploration in the near (LEO) and deep space (BLEO). The results of these studies were presented at different conferences and papers [9-11].

During this period, part of the activities was funded through an agreement between the Italian Space Agency (ASI) and the INFN (n. 2013-002-R.0). In October 2018, using the funding deriving from such agreement, two half-year contracts were activated for the study of possible applications of the data collected by AMS in the field of research activity in radiobiology of space and in particular of protons. The fellowships were attributed to Dr E. Solfaroli Camillocci and Dr E. Loi.

The research status and activities done in this period were presented to the ASI-INFN agreement review committee [12,13], INFN Roma council [14-16], INFN CNS2 referees [17-18], the INFN CNS2 council [19,20] and the international AMS collaboration in a general meeting at CERN [21].

2021 - 2022

During this period, the research focused on the dose-effect relationship (DER) and model (DEM) due to exposure to space radiation in exploratory space missions. Such mathematical models describe the correlation between the exposition to IR and the possible damage to the organs at risk. They are crucial to predicting the space radiation toxicity expected for astronauts/space workers. In particular, in 2021, we completed and published an extensive review of the existing literature we started in the previous year's [22]. DERs describe the observed damages to normal tissues or cancer induction during and after space flights. They are developed for the various dose ranges and radiation qualities characterizing the actual and forecast space missions. In this paper, based on a PubMed search including 53 articles reporting the collected dose-effect relationships after space missions or in-ground simulations, we identified seven significant DERs (e.g., eye flashes, cataracts, central nervous systems, cardiovascular disease, cancer, chromosomal aberrations, and biomarkers). The absorbed dose thresholds and the uncertainties/limitations of the developed relationships are summarized and discussed for each considered effect. The manuscript had a remarkable impact on the scientific community having about 4k views from all over the world and gained after 14 months from the publication a position in the 93rd percentile for download rank and 81st percentile for view rank of the papers published on the Frontiers editor journals [23]. Also, it was included in a collection published in 2022 [24]. After the publication, we presented this work at different conferences and continued to improve it [25-29].

Among the many ways that we identified in the paper to improve the DERs knowledge (e.g., computer simulation of interactions of IR with biological matter, synergy with the clinical field, quantitative meta-analysis, radioprotectors effects, individual radio-susceptibility, DEM integration platform, synergy with astroparticle experiments) we decided to focus our research activities on the development of a platform for the production of reliable DEM that will allow us to predict the possible risk due to radiation during space exploration including also all the information coming from cosmic ray detectors [30-33]. We also promoted a research topic initiative supported by the Frontiers Media SA publisher [34]. The research topic initiative was launched in November 2021 and supported by an interdisciplinary and international editorial team. This initiative was presented at different international conferences [35-38] and in a workshop organized by the United Nations [39].

Following this analysis, we started the development of an ad hoc software tool (NTE-DEM) to investigate one of the promising and not yet understood effects of ionization radiation, usually referred to as the non-targeted effect (NTE) of great relevance for space radiation. NTEs include bystander effects where cells traversed by heavy ions transmit oncogenic signals to nearby cells and genomic instability in the cell's progeny. The NTE-DEM aims to combine the existing experimental data (clinical, pre-clinical and in vitro), the cosmic ray fluences, as measured by the AMS detector and the cell survival probability function existing in the literature to produce reliable DEMs. We use the R-Studio integrated development environment to code it. The first NTE-DEM release (Fig. 1) comprises a main program and several libraries for>10K lines of code.

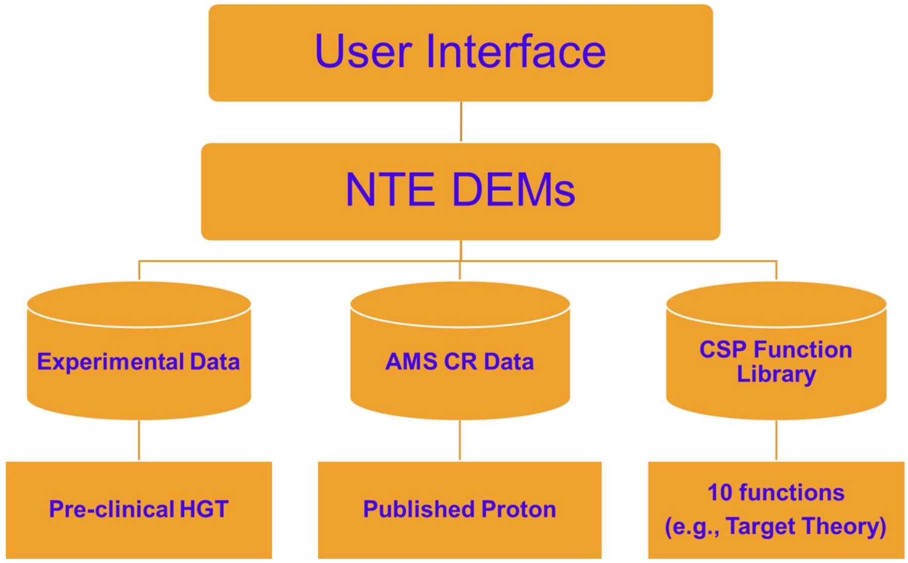

Fig.1 The NTE-DEM v1.0 architecture.

We use it to tune the DEM for the calculation of Tumor Prevalence (TP) in the NTE case induced by space radiation protons. We check the consistency of the results with a reliable dataset of pre-clinical in vivo experimental data related to the Harderian gland tumour (HGT) induced by radiation in rats [40-42]. Also, we check the model consistency by applying it to protons using the published data from the AMS collaboration of the fluxes of the GCRs protons components as an example (i.e., TP was calculated in terms of protons flux and exposition time for different bin energy ranges from 492.4±7 MeV to 1.46±0.335 TeV).

The software also used a software library of cell survival probability (CSP) functions in which we included all the models relevant to this kind of investigation.

We reported such results in an article [43] and presented them at an international meeting [44] and the international conference [45]. Both presentations aroused the interest of representatives of the scientific community of space sciences present in the audience (ASI, ESA and NASA).

For the Roma Sapienza division, this research project is also present in the DOE-INFN Summer Students Exchange Program 2023 Edition [46].

During this period, part of the activities was funded through an agreement between the ASI and the INFN (n. 2019-19-HH.0). In October 2021, using the funding deriving from such agreement, a year contract (art.22 Dlgs 240/2010) was activated for production and analysis of particle fluxes with the AMS-02 experiment to support studies in space radiobiology and dosimetry. The research grant was attributed to Dr A.N. Guracho. In November 2022, the grant was extended for a second year using INFN Roma Sapienza funds.

The activities done in this period were presented to the ASI-INFN agreement review committee [47], INFN Roma council [48,49], INFN CNS2 referees [50,51], to the INFN CNS2 council [52] and at the AMS-Italy Collaboration meeting [53].

3. Project future activities

In the future, we will extend our investigations and studies and the NTE-DEM software in three different main directions, that will regard (see Fig.2):

- The experimental data includes the other diseases expected from space radiation exposure.
- The AMS-02 detector measures the CRs components (electrons, heavy nuclei).
- The Radiobiology Mathematical models' library addresses specific NTE biologic mechanisms and AI-based data analysis technique.

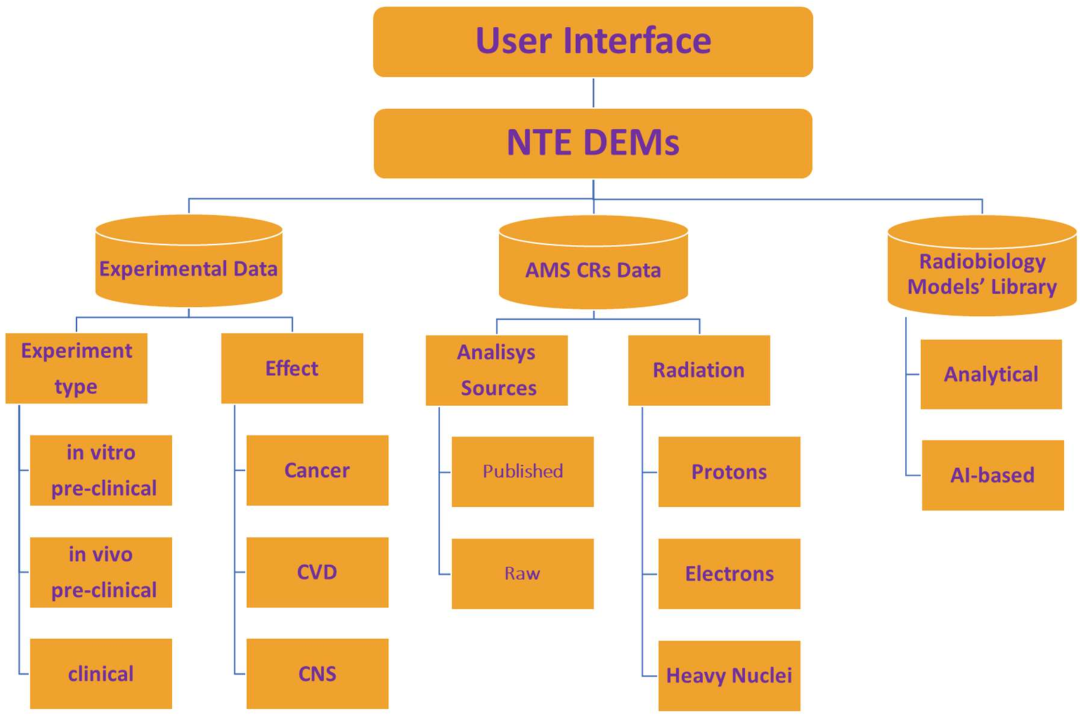

Fig.2 The NTE-DEM software architecture

Experimental data

We will also extend our tools to generate NTE DEMs for other possible effects. As identified in [26], three are the effects resulting crucial for space exploration from the point of view of the risk to human health and, at the same time, requires substantial improvements in the DEMs to forecast in a precise way the impact of radiation exposure.

- radiation-induced cancer
- radiation-induced effects on the central nervous system (CNS)
- radiation-induced cardiovascular disease (CVD)

Further, not only for cancer, there is a clear understanding of the importance of NTEs, but also of CVD and CNS [54-57]. The extension will include the experimental data available in the literature from different existing stages of studies (i.e., pre-clinical in vitro, pre-clinical in vivo and clinical) referred to these effects starting from the ones we previously identified in the scientific literature [58-99].

A database will be generated and updated.

A database will be generated and updated to enable the training, test and validation of proposed Artificial Intelligence-based models.

AMS data analysis

We will extend our studies of NTEs, including the effects due to electrons and nuclei (Z>=2). In table 2 are represented the actual published AMS data, which are and will be part of the NTE-DEM tool, with also reported some information and characteristics about the published data analysis (particle type, rigidity ranges, time period, …).

Particle	Ref.	Rigidity Range (GV), [bins]	Measurement Type	Time Period	Number of Events
Electron (e^+, e^-)	[100]	1.0 – 350 [19]	Absolute Flux	2011/2012	Over $6.8x10^6$
Electron (e^++ e^-)	[101]	0.5 – 1000 [74]	Absolute Flux	2011/2013	$10.1x10^6$
Electron (e^+ + e^-)	[102]	0.5 – 1400 [75]	Absolute Flux	2011/2017	$28.1x10^6$
Electron (e+ + e-)	[103]	1 - 41.9 [10]	Time Variation (4015d)	2011/2021	$2.0x10^8$
Electron (e^+ + e^-)	[104]	0.5 – 49.33 [52]	Time Variation (79)	2011/2017	$23.5x10^6$
Proton (p^+ + p^-)	[105]	1 – 1800 [72]	Absolute Flux	2011/2013	
Proton (p^+ + p^-)	[112]	1 – 450 [57]	Absolute Flux	2011/2015	2.8 $x10^9$
Proton (p^+ + p^-)	[107]	1 – 100 [30]	Time Variation (114)	2011/2019	5.5 $x10^9$
Helium (He)	[108]	1.92 – 60 [40]	Time Variation (79)	2011/2017	$112x10^6$
Helium (He)	[109]	1.92 – 3000 [68]	Absolute Flux	2011/2013	$50x10^6$
Helium (He)	[106]	1.92 – 3000 [68]	Absolute Flux	2011/2016	$90x10^6$
Helium (He)	[110]	1.71 – 100 [26]	Time Variation (2824d)	2011/2019	$7.6x10^8$
Lithium (Li)	[111]	1.92 – 3300 [67]	Absolute Flux	2011/2016	$1.9x10^6$
Beryllium (Be)	[111]	1.92 – 3300 [67]	Absolute Flux	2011/2016	$0.9x10^6$
Boron (B)	[111]	1.92 – 2600 [67]	Absolute Flux	2011/2016	$2.6x10^6$
Boron (B)	[118]	2.15 – 3300 [66]	Absolute Flux	2011/2021	
Carbon (C)	[112]	1.92 – 3000 [68]	Absolute Flux	2011/2016	$8.4x10^6$
Carbon (C)	[118]	2.15 – 3000 [48]	Absolute Flux	2011/2021	
Nitrogen (N)	[113]	2.15 – 3300 [66]	Absolute Flux	2011/2016	$2.2x10^6$
Oxygen(O)	[112]	2.15 – 3000 [67]	Absolute Flux	2011/2016	$7.0x10^6$
Oxygen(O)	[118]	2.15 – 3000 [48]	Absolute Flux	2011/2021	
Oxygen(O)	[118]	2.15 – 3300 [66]	Absolute Flux	2011/2021	
Fluorine (F)	[116]	2.15 – 2900 [48]	Absolute Flux	2011/2019	$0.29x10^6$
Fluorine (F)	[118]	2.15 – 3000 [48]	Absolute Flux	2011/2021	
Neon (Ne)	[114]	2.15 – 3000 [66]	Absolute Flux	2011/2018	$1.8x10^6$
Neon (Ne)	[118]	2.15 – 3000 [48]	Absolute Flux	2011/2021	

Sodium (Na)	[115]	2.15 – 3000 [48]	Absolute Flux	2011/2019	$0.46x10^6$
Magnesium (Mg)	[114]	2.15 – 3000 [66]	Absolute Flux	2011/2018	$2.2x10^6$
Magnesium (Mg)	[118]	2.15 – 3000 [48]	Absolute Flux	2011/2021	
Silicon (Si)	[114]	2.15 – 3000 [66]	Absolute Flux	2011/2018	$1.6x10^6$
Silicon (Si)	[118]	2.15 – 3000 [48]	Absolute Flux	2011/2021	
Sulfur (S)	[118]	2.15 – 3000 [48]	Absolute Flux	2011/2021	0.38×10^6
Iron (Fe)	[117]	2.65 – 3000 [46]	Absolute Flux	2011/2019	$0.62x10^6$

Table 2. The AMS published data of particles flux with energy range in different time periods.

Further, we will extract information from the AMS raw data by ad hoc data analysis that will allow improving our understanding of radiobiology aspects related to:

- isotopes not included in the published one,
- period still needs to be published,
- specific space weather event (SEP, CME, …),
- monoenergetic fluences (narrow statistical bin ranges).

We will use it for the risk assessment of NTE induced by IR in different exposure scenarios for the risk assessment of the health hazard related to human space exploration to reduce the damages caused to astronauts from GCRs and sun-generated radiation in a more precise way.

Radiobiology mathematical models' library

In the first version of the tool was developed a software library including all the relevant cell survival probability (CSP) models both for the gamma-ray and charged particles relevant for radiobiology and in particular for space radiation; we coded 10 different mathematical models [119] to be used for the dose-effects relationships description and development:

- Target Theory - n-Targets N-Hits Model - nTNH
- Cellular Track Structure Theory (TST) for charged particles.
- Linear Quadratic Model- LQ
- Linear Quadratic Hyper-RadioSensitivity Model - LQ-HRS
- Linear Quadratic Cubic Model - LQC
- Sublesions Theory Linear Eurepair- Quadratic Misrepair (phi = 1) Model - LE-QM
- Sublesions Theory Linear Eurepair-Linear & Quadratic Misrepair (phi =1) Model- LE
- Sublesions Theory Lethal-Potentially Lethal Model - LPL
- Sublesions Theory Saturable Repair Model- SR-D
- Sublesions Theory Saturable Repair Model- SR-RT

In the future, we will extend such part to include radiobiological mathematical models deeply describing the phenomenology of the NTE biological behaviours (e.g., gap junction intercellular communications) [120]. In addition, artificial intelligence-based models will be developed using the database as mentioned above necessary for their training, testing and validation [121-124].

4. References

[1] INFN Roma Sapienza AMS group wiki site: (wiki.infn.it/strutture/roma1/experiments/ams2/home)

[2] *A. Bartoloni, B. Borgia, G.Bossi G., L. Strigari,.(2017) Space Radiobiology Investigation using AMS-02 experiment on the International Space Station (ISS) , INFN Roma Sapienza Internal Note, AMS INFN Referee meeting . 07/10/2017*

[3] *INFN Roma Division Council "preventivi 2018" 28/6/2017 (wiki.infn.it/strutture/roma1/experiments/ams2/home)*

[4] *AMS INFN Referee meeting, Roma 20/07/2017 (wiki.infn.it/strutture/roma1/experiments/ams2/home)*

[5] *John R. A., David R. F., Joseph I. M., Jonathan A. P., Alonso H. V., (2022). Safe Human Expeditions Beyond Low Earth Orbit (LEO). NASA/TM-20220002905 NESC-RP-20-01589*

[6] *Shubayr N., Alashban Y., Almalki M., Aldawood S., Aldosari A., Occupational radiation exposure among diagnostic radiology workers in the Saudi ministry of health hospitals and medical centers: A five-year national retrospective study, Journal of King Saud University – Science, 27 November 2020*

[7] *A.Bartoloni, L.Strigari, (2019), AMS02 e Radiobiologia nello spazio, - Annual Conference of the Italian Physical Society (SIF) L'Aquila 27/09/2019, https://en.sif.it/*

[8] *Half-day workshop on 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, INFN Rome and La Sapienza University, 04-11-2019, https://agenda.infn.it/event/20462/*

[9] *A Bartoloni, S Strolin, L Strigari (2020) Radiobiology with the Alpha Magnetic Spectrometer (AMS02) experiment on the International Space Station in proceedings of RAD 8 - 8th International Conference on radiation in different fields of research June/2020*

[10] *Bartoloni A, Strolin S, Strigari L, N-30-228 – Can high energy particle detectors be used for improving risk models in space radiobiology? The 2020 Virtual IEEE Nuclear Science Symposium and Medical Imaging Conference, 2020, N-30 - NSS Poster Session III https://wiki.infn.it/_media/strutture/roma1/experiments/ams2/ieee-nss-mic_bartoloni5.pdf (accessed on 23 May 2023)*

[11] *Bartoloni A, Strigari L, Can high energy particle detectors be used for improving risk models in space radiobiology? On proceedings of the Global Exploration Conference 2021 — IAF Digital Library (iafastro.directory), 62186, International Astronautical Federation.*

[12] *Final report of ASI contract 31/5/2019 (Agreement INFN-ASI n. 2013-002-R.0)*

[13] *ASI-AMS Agreement INFN-ASI n. 2013-002-R.0 meeting, Bologna 19/07/2019, Presentation Slides: (wiki.infn.it/strutture/roma1/experiments/ams2/home)*

[14] *INFN Roma Division Council "preventivi 2019" 28/6/2018 (wiki.infn.it/strutture/roma1/experiments/ams2/home)*

[15] *INFN Roma Division Council "preventivi 2020" 28/6/2019 (wiki.infn.it/strutture/roma1/experiments/ams2/home)*

[16] *INFN Roma Division Council "preventivi 2021" 08/07/2020 (wiki.infn.it/strutture/roma1/experiments/ams2/home)*

[17] *AMS INFN Referee meeting, Roma 20/07/2018 (wiki.infn.it/strutture/roma1/experiments/ams2/home)*

[18] AMS INFN Referee meeting, Roma 6/09/2019 (wiki.infn.it/strutture/roma1/experiments/ams2/home)

[19] AMS INFN Referee meeting, Roma 4/09/2020 (wiki.infn.it/strutture/roma1/experiments/ams2/home)

[20] CNS2 Committee meeting September 2019, https://web.infn.it/csn2/index.php/it/riunioni

[21] CNS2 Committee meeting September 2020, https://web.infn.it/csn2/index.php/it/riunioni

[22] AMS Collaboration general meeting @CERN 07/02/2019 (wiki.infn.it/strutture/roma1/experiments/ams2/home)

[23] Strigari, L., Strolin, S., Morganti, A. G., Bartoloni A. (2021). Dose-Effects Models for space radiobiology: an overview on dose effect relationships, Front. Public Health 9, 733337. 10.3389/fpubh.2021.733337.

[24] Loop | Publication Impact | Dose-Effects Models for Space Radiobiology: An Overview on Dose-Effect Relationships https://loop-impact.frontiersin.org/impact/article/733337

[25] Medical Application and Radiobiology Research of Particle Radiation e-book, edited by: Fei Ye, Chao Sun, yi Xie, Lu cai and Bing Wang, Published in: Frontiers in Public Health.26/08/2022.

[26] L. Strigari, A.N. Guracho, S. Strolin, A.G. Morgan A. Bartoloni Dose-Effects Models for Space Radiobiology: An Overview on Dose-Effect Relationship in proceedings of the 10th International Conference on Radiation in Various Field of Research, July 25-29, 2022, Herceg Novi Montenegro, https://doi.org/10.21175/rad.sum.abstr.book.2022.25.1

[27] L. Strigari, A.N. Guracho, S. Strolin, A.G. Morganti and A.Bartoloni, Dose-Effects Models for Space Radiobiology: An Overview on Central Nervous System Dose-Effect Relationship by in proceedings of the 3rd International Congress on Future of Neurology & Neurosurgery June 2022, Future neurology, page 53, Peers Alley Media.

[28] A. Bartoloni (speaker), A.N. Guracho, A.G. Morganti, S.Strolin,L. Strigari, COSPAR2022-44th Scientific Assembly, July 2022 Atene, Grecia, Poster, Dose-Effects Models for Space Radiobiology: An Overview on Dose-Effect Relationship.

[29] A. Bartoloni (speaker), G. Della Gala, A.N. Guracho, A.G. Morganti, G. Paolani, M. Santoro, L. Strigari, S. Strolin, IAC2022 – 73th International Astronautical Conference, IAF/IAA Space Life Sciences Symposium (A1), Dose-Effects Models for Space Radiobiology: an overview on Dose-Effect Relationship.

[30] A. Bartoloni (speaker), A.N. Guracho, A.G. Morganti, S.Strolin,L. Strigari, RAD-10 Summer Edition - 10th International Conference on Radiation in Various Fields of Research, July 2022, Herceg Novi, Montenegro, Presentazione Orale, Dose-Effects Models for Space Radiobiology: An Overview on Dose-Effect Relationship.

[31] A. Bartoloni, G. Della Gala, A.N. Guracho G. Paolani, M. Santoro L. Strigari, S. Strolin. Space Radiation Field Characterization Using the Astroparticle Operating Detectors. Proceedings of the 72nd International Astronautical Congress (IAC 2021), Dubai, United Arabian Emirates, 25 – 29 October 2021 - IAF Library reference -(IAC-21. A1.5.1 (ID:63116).

[32] A. Bartoloni, G. Della Gala, A.N. Guracho G. Paolani, M. Santoro L. Strigari, S. Strolin. High energy Physics Astro Particle Experiments to Improve the Radiation Health Risk Assessment for Humans in Space Missions, in Proceedings of the European Physical Society Conference on High Energy Physics EPS-HEP2021 (2022), vol. 398, p.106, DOI:10.22323/1.398.0106, Sissa Medialab.

[33] A. Bartoloni (Presenter), A. N. Guracho, G. Della Gala, G. Paolani, M. Santoro, L. Strigari, S. Strolin, IAC2022 – 73th International Astronautical Conference, IAF Symposium on Ongoing and Near Future Space Astronomy and Solar-System Science Missions (A7) – Presentazione Orale Interattiva, Astroparticle Experiments to Improve the Radiation Health Risk Assessment for Humans in Space Missions.

[34] A.Bartoloni (invited speaker) [25th WRMISS –25th workshop on radiation Monitoring on the International Space Station, 6-8 September, Mons-Belgium September, Presentazione Orale, Astroparticle Experiments to Improve the Radiation Health Risk Assessment for Humans in Space Missions.

[35] Research topic initiative web page, (2021), https://www.frontiersin.org/research-topics/28918/astroparticle-experiments-to-improve-the-biological-risk-assessment-of-exposure-to-ionizing-radiation-in-the-exploratory-space-missions

[36] A.Bartoloni (speaker), N.Ding, G. Cavoto, C. Consolandi, L.Strigari, (2022), Astroparticle Experiments to Improve the Biological Risk Assessment of Exposure to Ionizing Radiation in the Exploratory Space Missions: The research topic initiative. PM2021 15th Pisa Meeting on Advanced Detectors- Edition, Maggio 2022, Biodola Italia.

[37] A. Bartoloni (speaker), N. Ding, G. Cavoto, C. Consolandi, L. Strigari, RAD10 Spring Edition-10th International Conference on Radiation in Various Fields of Research. June 2022, Herceg Novi, Montenegro, Presentazione Orale, Astroparticle Experiments 4 Space Radiobiology: The Research Topic Initiative.

[38] A.Bartoloni (speaker), N.Ding, G. Cavoto, C. Consolandi, L.Strigari, Astroparticle Experiments to Improve the Biological Risk Assessment of Exposure to Ionizing Radiation in the Exploratory Space Missions:The research topic initiative ICHEP2022 XLI International Conference on High Energy Physics Luglio 2022, Bologna Italy, Poster,

[39] A. Bartoloni (speaker), N. Ding, G. Cavoto, C. Consolandi, L. Strigari, COSPAR2022- 44th Scientific Assembly, July 2022 Athens, Greece, Astroparticle Experiments to Improve the Biological Risk Assessment of Exposure to Ionizing Radiation in the Exploratory Space Missions:The research topic initiative. by A. Bartoloni (speaker).

[40] A. Bartoloni, (2022), Astroparticle Experiments to Improve the Biological Risk Assessment of Exposure to Ionizing Radiation in the Exploratory Space Missions: A Research Topic Initiative Participation in the United Nations/China 2nd Global Partnership Workshop on Space Exploration and Innovation. Workshop Program in the Prospects and Challenges in Space Science Session, November 2022.

[41] XXII ICMMB in Italy, Bologna, September 19-21, 2022, giving a talk on "Target Effects vs. Non-Target effects in Estimating the Carcinogenic risk due to Galactic Cosmic Rays in Exploratory Space Missions", https://eventi.unibo.it/icmmb2022/

[42] A. Bartoloni (speaker), A.N. Guracho, L. Strigari, IAC2022 – 73th International Astronautical Conference, IAF/IAA Space Life Sciences Symposium (A1), Target Effects vs. Non-Target Effects in Estimating the Carcinogenic risk due to Galactic Cosmic Rays in Exploratory Space Missions.

[43] A. Bartoloni on behalf of AMS INFN Roma Research group, (2022), Dose-effects Model Lunar Space Missions Risk Assessment, 6th Global Moon Village workshop & Symposium, November 8, 20222, Los Angeles, USA.

[44] Aboma N. Guracho, L. Strigari, G. Della Gala, G. Paolani, M. Santoro, S. Strolin, and A. Bartoloni, (2023), Space radiation-induced bystander effect in estimating the carcinogenic risk due to galactic cosmic rays, Journal of Mechanics in Medicine and Biology (JMMB), https://doi.org/10.1142/S0219519423400237

[45] A. Bartoloni on behalf of AMS INFN Roma Research group, (2023), Space Radiation Characterization for Safe Human Space Exploration and Settlements, The 17th International Conference on Space Operation, 6-10 March 2023, Dubai, UAE.

[46] A. Bartoloni on behalf of AMS INFN Roma Research group, (2023), AMS@INFN Roma-Sapienza: Current Activities and Future Perspectives; Elicsir Project final Symposium, 27 January 2023, Nis, Serbia.

[47] DOE-INFN Summer Students Exchange Program 2023 Edition, "*Non-Target Effects induced Galactic Cosmic Rays in Exploratory Space Missions: Improvements using the AMS detector data*" *https://wiki.infn.it/_media/strutture/roma1/experiments/ams2/bando_doe_25272.pdf*

[48] ASI-AMS Agreement ASI-INFN n. 2019-19-HH.0 meeting, 28/10/2022, Presentation Slides: (wiki.infn.it/strutture/roma1/experiments/ams2/home)

[49] INFN Roma Division Council "preventivi 2022" 02/7/2021 (wiki.infn.it/strutture/roma1/experiments/ams2/home)

[50] INFN Roma Division Council "preventivi 2023" 07/7/2022 (wiki.infn.it/strutture/roma1/experiments/ams2/home)

[51] AMS INFN Referee meeting, Roma 07/09/2021 (wiki.infn.it/strutture/roma1/experiments/ams2/home)

[52] AMS INFN Referee meeting, Roma 8/09/2022 (wiki.infn.it/strutture/roma1/experiments/ams2/home)

[53] CNS2 Committee meeting September 2021, https://web.infn.it/csn2/index.php/it/riunioni

[54] A. Bartoloni on behalf of AMS INFN Roma Research group, (2022), Dose-Effect Models for Biological Risk Assessment of Exposure to Space Radiation, AMS-Italy Collaboration Meeting 11 March 2021, Virtual. (https://agenda.infn.it/event/26127/)

[55] F.A. Cucinotta, E. Cacao (2017) Non-Targeted Effects Models Predict Significantly Higher Mars Mission Cancer Risk than Targeted Effects Models. Sci Rep. May 12;7(1):1832. doi: 10.1038/s41598-017-02087-3. PMID: 28500351; PMCID: PMC5431989.

[56] J.E. Baker, J.E. Moulder, and J.W. Hopewell. (2011) Radiation as a Risk Factor for Cardiovascular Disease.Antioxidants & Redox Signaling.Oct 2011.1945-1956.http://doi.org/10.1089/ars.2010.3742

[57] G. Yanan, M. Hong, L. Changyin, L. Fei, W. Yunfeng, D. Yulin (2021) Exosomes and exosomal microRNA in non-targeted radiation bystander and abscopal effects in the central nervous system,Cancer Letters,Volume 499, Pages 73-84 ISSN 0304 https://doi.org/10.1016/j.canlet.2020.10.049.

[58] C. Feiock, M. Yagi, A. Maidman, A. Rendahl, S. Hui, D. Seelig (2016) Central Nervous System Injury - A Newly Observed Bystander Effect of Radiation. PLoS One. 2016 Sep 30;11(9): e0163233. doi: 10.1371/journal.pone.0163233. PMID: 27690377; PMCID: PMC5045183.

[59] NCRP. Radiation Protection Guidance for Activities in Low-Earth Orbit. Bethesda, MD: National Council on Radiation Protection and Measurements (2000). p. 132.

[60] Cucinotta FA, Kim MY, Chappell L. Space Radiation Cancer Risk Projections and Uncertainties. Washington, DC: National Aeronautics and Space Administration (2012).

[61] UNSCEAR. United Nations Scientific Committee on the Effects of Atomic Radiation Effects of Ionizing Radiation UNSCEAR Report to the General Assembly, With Scientific Annexes. United Nations, NY. (1993).

[62] International Commission on Radiological Protection. ICRP Publication 103: the 2007 recommendations of the international commission on radiological protection. Ann ICRP. (2007) 37:1–332. doi: 10.1016/j.icrp.2007.10.003

[63] 44. NCRP. Health Effects of Low Doses of Radiation: Perspectives on Integrating Radiation Biology and Epidemiology, NCRP Commentary No. 24 (2015).

[64] McLean AR, Adlen EK, Cardis E, Elliott A, Goodhead DT, Harms-Ringdahl M, et al. A restatement of the natural science evidence base concerning the health effects of low-level ionizing radiation. Proc Biol Sci. (2017) 284:20171070. doi: 10.1098/rspb.2017.1070

[65] Weber W, Zanzonico P. The controversial linear no-threshold model. J Nucl Med. (2017) 58:7–8 doi: 10.2967/jnumed.116.182667

[66] Scott BR. A critique of recent epidemiologic studies of cancer mortality among nuclear workers. Dose Response. (2018) 16:155932581877870. doi: 10.1177/1559325818778702

[67] Walenta S, Mueller-Klieser W. Differential superiority of heavy charged-particle irradiation to X-rays: studies on biological effectiveness and side effect mechanisms in multicellular tumour and normal tissue models. Front Oncol. (2016) 6:30. doi: 10.3389/fonc.2016.00030

[68] Cucinotta FA, To K, Cacao E. Predictions of space radiation fatality risk for exploration missions. Life Sci Space Res. (2017) 13:1–11. doi: 10.1016/j.lssr.2017.01.005

[69] Cucinotta FA. Review of NASA approach to space radiation risk assessments for Mars exploration. Health Phys. (2015) 108:131–42. doi: 10.1097/HP.0000000000000255

[70] Cucinotta FA, Alp M, Sulzman FM, Wang M. Space radiation risks to the central nervous system. Life Sci Space Res. (2014) 2:54–69. doi: 10.1016/j.lssr.2014.06.003

[71] Britten RA, Davis LK, Johnson AM, Keeney S, Siegel A, Sanford LD, et al. Low (20 cGy) doses of 1 GeV/u 56Fe-particle radiation led to a persistent reduction in the spatial learning ability of rats. Radiat Res. (2012) 177:146–51. doi: 10.1667/RR2637.1

[72] Hienz RD, Davis CM, Weed MR, Guida PM, Gooden VL, Brady JV, et al. Neurobehavioral effects of space radiation on psychomotor vigilance and reaction time tests. In: Proceedings of the 18th Biannual Meeting of the International Academy of Astronautic's Humans in Space Symposium. Houston, TX (2011) p.11–5.

[73] Chancellor JC, Scott GB, Sutton JP. Space radiation: the number one risk to astronaut health beyond low earth orbit. Life. (2014) 4:491–510. doi: 10.3390/life4030491

[74] Cucinotta FA, Kim MY, Chappell LJ, Huff JL. How safe is safe enough: radiation risks for a human mission to Mars. PLoS ONE. (2013) 8: e74988. doi: 10.1371/journal.pone.0074988

[75] Batmunkh M, Aksenova SV, Bayarchimeg L, Bugay AN, Lkhagva O. Optimized neuron models for estimating charged particle energy deposition in hippocampus. Phys Med. (2019) 57:88–94. doi: 10.1016/j.ejmp.2019.01.002

[76] Alp M, Cucinotta FA. Biophysics model of heavy-ion degradation of neuron morphology in mouse hippocampal granular cell layer neurons. Radiat Res. (2018) 189:312–25. doi: 10.1667/RR14923.1

[77] Alp M, Cucinotta FA. Track structure model of microscopic energy deposition by protons and heavy ions in segments of neuronal cell dendrites represented by cylinders or spheres. Life Sci Space Res. (2017) 13:27–38. doi: 10.1016/j.lssr.2017.03.004

[78] Britten RA, Mitchekk S, Johnson AM, Singletary SJ, Keeney SK, Nyalwidhe JO, et al. The identification of serum biomarkers of high-LET radiation exposure and biological sequel. Health Phys. (2010) 98:196–203. doi: 10.1097/HP.0b013e3181acff7c

[79] Lonart G, Parris B, Johnson AM, Miles S, Sanford LD, Singletary SJ, et al. Executive function in rats is impaired by low (20 cGy) doses of 1 GeV/u 56Fe particles. Radiat Res. (2012) 178:289–94. doi: 10.1667/RR2862.1

[80] Cacao E, Cucinotta FA. Modeling heavy-ion impairment of hippocampal neurogenesis after acute and fractionated irradiation. Radiat Res. (2016) 186:624–37. doi: 10.1667/RR14569.1

[81] Cacao E, Cucinotta FA. Meta-analysis of cognitive performance by novel object recognition after proton and heavy ion exposures. Radiat Res. (2019) 192:463–72 doi: 10.1667/RR15419.1

[82] 28. Delp MD, Charvat JM, Limoli C.M., Globus RK, Ghosh, P. Apollo lunar astronauts show higher cardiovascular disease mortality: possible deep space radiation effects on the vascular endothelium. Sci. Rep. (2016) 6:29901. doi: 10.1038/srep29901

[83] Cucinotta FA, Hamada N, Little MP. No evidence for an increase in circulatory disease mortality in astronauts following space radiation exposures. Life Sci Space Res. (2016) 10:53–56. doi: 10.1016/j.lssr.2016.08.002

[84] Elgart SR, Little MP, Chappell LJ, Caitlin MM, Shavers MR, Huff JL, et al. Radiation exposure and mortality from cardiovascular disease and cancer in early NASA astronauts. Sci Rep. (2018) 8:8480. doi: 10.1038/s41598-018-25467-9

[85] NCRP. Second Primary Cancers and Cardiovascular Disease After Radiotherapy. Bethesda, MD: National Council on Radiation Protection and Measurements (2011). p. 170. Google Scholar

[86] Wakeford R. Does low-level exposure to ionizing radiation increase the risk of cardiovascular disease? Hypertension. (2019) 73:1170–1. doi: 10.1161/HYPERTENSIONAHA.119.11892

[87] Shimizu Y, Kodama K, Nishi N, Kasagi F, Suyama A, Soda M, et al. Radiation exposure and circulatory disease risk: Hiroshima and Nagasaki atomic bomb survivor data, 1950-2003. BMJ. (2010) 340: b5349. doi: 10.1136/bmj. b5349

[88] Azizova T, Briks K, Bannikova M, Grigorieva E. Hypertension incidence risk in a cohort of Russian workers exposed to radiation at the Mayak Production Association over prolonged periods. Hypertens. (2019) 73:1174–84. doi: 10.1161/HYPERTENSIONAHA.118.11719

[89] Gillies M, Richardson DB, Cardis E, Daniels RD, O'Hagan JA, Haylock, et al. Mortality from circulatory diseases and other non-cancer outcomes among nuclear workers in France, the United Kingdom and the United States (INWORKS). Radiat Res. (2017) 188:276–290. doi: 10.1667/RR14608.1

[90] McGeoghegan D, Binks K, Gillies M, Jones S, Whaley S. The non-cancer mortality experience of male workers at British nuclear fuels PLC, 1946-2005. Int J Epidemiol. (2008) 37:506–518. doi: 10.1093/ije/dyn018

[91] Kashcheev VV, Chekin SY, Maksioutov MA, Tumanov KA, Menyaylo AN, Kochergina EV, et al. Radiation-epidemiological study of cerebrovascular diseases in the cohort of Russian recovery operation workers of the Chernobyl accident. Health Phys. (2016) 111:192–7. doi: 10.1097/HP.0000000000000523

[92] Kashcheev VV, Chekin SY, Karpenko SV, Maksioutov MA, Menyaylo AN, Tumanov KA, et al. Radiation risk of cardiovascular diseases in the cohort of Russian emergency workers of the Chernobyl accident. Health Phys. (2017) 113:23–9. doi: 10.1097/HP.0000000000000670

[93] Ozasa K, Takahashi I, Grant EJ, Kodama K. Cardiovascular disease among atomic bomb survivors. Int J Radiat Biol. (2017) 93:1145–1150. doi: 10.1080/09553002.2017.1290849

[94] NASA. (1998), Strategic Program Plan for Space Radiation Health Research. NASA Headquarters, Washington DC.

[95] Durante, M., Kraft, G., O'Neill, P., Reitz, G., Sabatier, L., Schneider, U., (2007). Preparatory study of a ground-based space radiobiology program in Europe. Adv. Sp. Res. 39, 1082–1086. https://doi.org/10.1016/j.asr.2006.10.007.

[96] Cucinotta, FA; Durante, M (2006). "Cancer risk from exposure to galactic cosmic rays: implications for space exploration by human beings" (PDF). Lancet Oncol. **7** (5): 431–435. doi:10.1016/S1470-2045(06)70695-7. PMID 16648048.

[97] Cucinotta, FA; Kim, MH; Willingham, V; George, KA (Jul 2008). "Physical and biological organ dosimetry analysis for international space station astronauts". Radiation Research. 170 (1): 127–38. doi:10.1667/RR1330.1.

[98] National Aeronautics and Space Agency (NASA). (2007), Nasa space flight humans' system standard, volume 1: Crew health. In Space-Permissible Exposure Limit (SPEL) for Space Flight Radiation Exposure Standard; NASA: Washington, DC, USA.

[99] Robert MZ., David AB., and Owen G., (1998), Mars Direct: A Simple, Robust, and Cost-Effective Architecture for the Space Exploration Initiative, NASA Ames Research Center, Moffett Field, CA 94035, AIAA-91-0328, January 1998.

[100] Aguilar M., et al., (AMS Collaboration), First Result from the Alpha Magnetic Spectrometer on the International Space Station: Precision Measurement of the Positron Fraction in Primary Cosmic Rays of 0.5–350 GeV, PRL 110, 141102 (2013), DOI: 10.1103/PhysRevLett.110.141102

[101] Aguilar M., et al., (AMS Collaboration), Precision Measurement of the ðeþ þ e−Þ Flux in Primary Cosmic Rays from 0.5 GeV to 1 TeV with the Alpha Magnetic Spectrometer on the International Space Station, PRL 113, 221102 (2014), DOI: 10.1103/PhysRevLett.113.221102

[102] Aguilar M., et al., (AMS Collaboration), Towards Understanding the Origin of Cosmic-Ray Electrons, Physical Review Letters 122, 101101 (2019), DOI: 10.1103/PhysRevLett.122.101101

[103] Aguilar M., et al., (AMS Collaboration), Temporal Structures in Electron Spectra and Charge Sign Effects in Galactic Cosmic Rays, Physical Review Letters 130, 161001 (2023), DOI: 10.1103/PhysRevLett.130.161001

[104] Aguilar M., et al., (AMS Collaboration), Observation of Complex Time Structures in the Cosmic-Ray Electron and Positron Fluxes with the Alpha Magnetic Spectrometer on the International Space Station, Physical Review Letters 121, 051102 (2018), DOI: 10.1103/PhysRevLett.121.051102

[105] Aguilar M., et al., (AMS Collaboration), Precision Measurement of the Proton Flux in Primary Cosmic Rays from Rigidity 1 GV to 1.8 TV with the Alpha Magnetic Spectrometer on the International Space Station, PRL 114, 171103 (2015), OI: 10.1103/PhysRevLett.114.171103

[106] Aguilar M., et al., (AMS Collaboration), Antiproton Flux, Antiproton-to-Proton Flux Ratio, and Properties of Elementary Particle Fluxes in Primary Cosmic Rays Measured with the Alpha Magnetic Spectrometer on the International Space Station, PRL 117, 091103 (2016), DOI: 10.1103/PhysRevLett.117.091103

[107] Aguilar M., et al., (AMS Collaboration), Periodicities in the Daily Proton Fluxes from 2011 to 2019 Measured by the Alpha Magnetic Spectrometer on the International Space Station from 1 to 100 GV, Physical Review Letters 127, 271102 (2021), DOI: 10.1103/PhysRevLett.127.271102

[108] Aguilar M., et al., (AMS Collaboration), Observation of Fine Time Structures in the Cosmic Proton and Helium Fluxes with the Alpha Magnetic Spectrometer on the International Space Station, Physical Review Letters 121, 051101 (2018), DOI: 10.1103/PhysRevLett.121.051101

[109] Aguilar M., et al., (AMS Collaboration), Precision Measurement of the Helium Flux in Primary Cosmic Rays of Rigidities 1.9 GV to 3 TV with the Alpha Magnetic Spectrometer on the International Space Station, PRL 115, 211101 (2015), DOI: 10.1103/PhysRevLett.115.211101

[110] Aguilar M., et al., (AMS Collaboration), Properties of Daily Helium Fluxes, Physical Review Letters 128, 231102 (2022), DOI: 10.1103/PhysRevLett.128.231102

[111] Aguilar M., et al., (AMS Collaboration), Observation of New Properties of Secondary Cosmic Rays Lithium, Beryllium, and Boron by the Alpha Magnetic Spectrometer on the International Space Station, Physical Review Letters 120, 021101 (2018), DOI: 10.1103/PhysRevLett.120.021101

[112] Aguilar M., et al., (AMS Collaboration), Observation of the Identical Rigidity Dependence of He, C, and O Cosmic Rays at High Rigidities by the Alpha Magnetic Spectrometer on the International Space Station, PRL 119, 251101 (2017), DOI: 10.1103/PhysRevLett.119.251101

[113] Aguilar M., et al., (AMS Collaboration), Precision Measurement of Cosmic-Ray Nitrogen and its Primary and Secondary Components with the Alpha Magnetic Spectrometer on the International Space Station, Physical Review Letters 121, 051103 (2018), DOI: 10.1103/PhysRevLett.121.051103

[114] Aguilar M., et al., (AMS Collaboration), Properties of Neon, Magnesium, and Silicon Primary Cosmic Rays Results from the Alpha Magnetic Spectrometer, PHYSICAL REVIEW LETTERS 124, 211102 (2020), DOI: 10.1103/PhysRevLett.124.211102

[115] Aguilar M., et al., (AMS Collaboration), Properties of a New Group of Cosmic Nuclei: Results from the Alpha Magnetic Spectrometer on Sodium, Aluminum, and Nitrogen, Physical Review Letters 127, 021101 (2021), DOI: 10.1103/PhysRevLett.127.021101

[116] Aguilar M., et al., (AMS Collaboration), Properties of Heavy Secondary Fluorine Cosmic Rays: Results from the Alpha Magnetic Spectrometer, Physical Review Letters 126, 081102 (2021), DOI: 10.1103/PhysRevLett.126.081102

[117] Aguilar M., et al., (AMS Collaboration), Properties of Iron Primary Cosmic Rays: Results from the Alpha Magnetic Spectrometer, Physical Review Letters 126, 041104 (2021), DOI: 10.1103/PhysRevLett.126.041104

[118] Aguilar M., et al., (AMS Collaboration), Properties of Cosmic-Ray Sulfur and Determination of the Composition of Primary Cosmic-Ray Carbon, Neon, Magnesium, and Sulfur: Ten-Year Results from the Alpha Magnetic Spectrometer, Physical Review Letters 130, 211002 (2023), DOI: 10.1103/PhysRevLett.130.211002

[119] Guracho A.N., et al., Supplementary fille for : Space radiation induced bystander effect in estimating the carcinogenic risk due to galactic cosmic rays, 2022, https://wiki.infn.it/_media/strutture/roma1/experiments/ams2/bystander_effect_appendices.pdf

[120] M. Sinyuk, E.E.Mulkearns-Hubert, O. Reizes and J. Lathia (2018) Cancer Connectors: Connexins, Gap Junctions, amdn Communications Frontiers in Oncology 8:646 doi:103389/fonc.2018.00646

[121] Manco L, N Maffei N, Strolin S, Vichi S, Bottazzi L, Strigari L. Basic of machine learning and deep learning in imaging for medical physicists. Phys Med. 2021 Mar; 83:194-205. doi: 10.1016/j.ejmp.2021.03.026. Epub 2021 Apr 4. PMID: 33826964.

[122] Spagnoli, L.; Morrone, M.F.; Giampieri, E.; Paolani, G.; Santoro, M.; Curti, N.; Coppola, F.; Ciccarese, F.; Vara, G.; Brandi, N.; Golfieri, R.; Bartoletti, M.; Viale, P.; Strigari, L. Outcome Prediction for SARS-CoV-2 Patients Using Machine Learning Modeling of Clinical, Radiological, and Radiomic Features Derived from Chest CT Images. Appl. Sci. 2022, 12, 4493. https://doi.org/10.3390/app12094493

[123] Paolani, G.; Spagnoli, L.; Morrone, M.F.; Santoro, M.; Coppola, F.; Strolin, S.; Golfieri, R.; Strigari, L. LASSO-Cox Modeling of Survival Using High-Resolution CT-Based Radiomic Features in a Cohort of COVID-19 Patients and Its Generalizability to Standard Image Reconstruction. Appl. Sci. 2022, 12, 12065. https://doi.org/10.3390/app122312065p12

[124] Santoro, M.; Strolin, S.; Paolani, G.; Della Gala, G.; Bartoloni, A.; Giacometti, C.; Ammendolia, I.; Morganti, A.G.; Strigari, L. Recent Applications of Artificial Intelligence in Radiotherapy: Where We Are and Beyond. Appl. Sci. 2022, 12, 3223. https://doi.org/10.3390/app12073223