XSCRC2024: Cross sections for Cosmic Rays @ CERN

Wednesday 16 October 2024 - Friday 18 October 2024

CERN

Book of Abstracts

Contents

XS modelling / 3

Antinucleon-nucleus interactions with the INCL code

Author: Jean-Christophe David[None]

Corresponding Author: jean-christophe.david@cea.fr

The INCL intranuclear cascade code has been developed and used for a long time. Its aim is to simulate the interactions of light projectiles with all types of nuclei in an energy range from a few tens of MeV to 10-20 GeV. To do this, it has to be combined with a de-excitation code, and most of the time it is the ABLA code that is used. Both codes are also available in the Geant4 particle transport code. In addition, different versions of INCL are available in other codes (e.g. phits, genie).
The latest innovation in INCL is the ability to simulate antiproton-nucleus reactions, from at-rest to around 10 GeV (version available in Geant4). This is the subject that will be presented here, along with the way in which the implementations were made (hypotheses, ingredients) and the results that were obtained (comparisons with experimental data, and sometimes with other models). As the antineutron is currently being implemented, this subject could also be addressed. The next step will be to extend this to anti-deuterons, anti-tritons, etc.

Relevant XS reactions and precision for GCRs / 4

Measurement of proton spallation cross-sections of natCr and 55Mn between 0.2-2.5 GeV relevant to galactic cosmic ray propagation [10'+5']

Author: Priyarshini Ghosh[1]

Co-authors: Igor Moskalenko [2]; John Krizmanic [1]; Patrick Peplowski [3]; Jack Wilson [3]; Mauricio Unzueta [4]

[1] *NASA Goddard Space Flight Center*

[2] *Stanford University*

[3] *Johns Hopkins Applied Physics Lab*

[4] *Lawrence Berkeley National Lab*

Corresponding Authors: john.f.krizmanic@nasa.gov, mayllon@lbl.gov, patrick.peplowski@jhuapl.edu, jack.wilson@jhuapl.edu, ghoshp@umbc.edu, imos@stanford.edu

TIGERISS, the recently selected Pioneers mission, will look at elemental abundances across a wide Z range, from 5B up to 82Pb, for the first time with a single instrument, to further our knowledge of the way the galaxy redistributes elements. However, accurate cross section data is paramount to the accurate interpretation of this observed experimental data. High Z (>Z) proton spallation reaction channels and the sub-Fe region isotopes (which are crucial for constraining re-acceleration models) are lacking in cross-section data, especially at higher energies. To address this shortage, our team at NASA Goddard has established a collaboration with various institutes worldwide (Brookhaven National Laboratory, Facility for Rare Isotope Beams, NA61 at CERN) to perform a series of cross-section experiments for the reaction channels of utmost importance to the study of galactic cosmic ray propagation. The first of these experiments was performed in March 2024, at Brookhaven National Lab. Proton beams with energies between 0.2 to 2.5 GeV were irradiated upon a natural Cr and a monoisotopic Mn target, and the cross sections of several nat Cr(p,X) and Mn (p,X) reactions are currently being determined, using known gamma-ray lines of unstable daughter products. We will report upon the results of this experiment, and our future plans in this endeavour.

XS from space and XS for Ultra-high energy CRs / 5

Measuring the inelastic cross section of proton and helium-4 in space with DAMPE [10'+5']

Authors: Andrii Tykhonov[1]; Paul Coppin[1]

[1] *Universite de Geneve (CH)*

Corresponding Authors: paul.coppin@cern.ch, andrii.tykhonov@cern.ch

The Dark Matter Particle Explorer (DAMPE) is an ongoing space-borne experiment for the direct detection of cosmic rays (CR). Thanks to its large geometric acceptance and thick calorimeter, DAMPE is able to detect CR ions up to unprecedented energies of hundreds of TeV. Following by now more than 8 years of successful operation, DAMPE has amassed a large dataset of high-energy hadronic interactions in a regime that is often difficult to probe by accelerator experiments. In this contribution, we show how DAMPE data can be used to measure inelastic ion-nucleon cross sections, and present a cross section measurement of both proton and helium-4 on the BGO calorimeter. Our measurements are compared to previous results from accelerator experiments and current cross section models such as EPOS-LHC, QGSJETII-04, and DMPJET3.

XS measurements at CERN / 6

Antihelium production at LHC and in Space [10'+5']

Author: Valery Zhukov[1]

[1] *Rheinisch Westfaelische Tech. Hoch. (DE)*

Corresponding Author: vzhukov@physik.rwth-aachen.de

The production of prompt antihelium in pp and pA collisions, as well as displaced antihelium from hypertriton and Lb decays have been recently studied with the LHCb detector. Recent results are presented and the implication to Cosmic Rays are discussed.

Relevant XS reactions and precision for GCRs / 7

Data-driven constraints on cosmic-ray diffusion: Probing self-generated turbulence in the Milky Way [10'+5']

Author: Alessandro Cuoco[None]

Corresponding Author: alessandro.cuoco@unito.it

The AMS-02 experiment has provided high-precision measurements of several cosmic-ray (CR) species. We exploit the AMS-02 data to investigate CR propagation in the Galaxy, and provide updated constraints on reacceleration, convection, and the spatial and rigidity dependence of the diffusion coefficient. We explicitly consider the impact of the uncertainties in the nuclear production cross-sections of secondaries. Our findings favor models with a smooth behavior in the diffusion coefficient, indicating a good qualitative agreement with the predictions of self-generated magnetic turbulence models. Instead, the current cosmic-ray data do not exhibit a clear preference for or against inhomogeneous diffusion, which is also a prediction of these models.

Galactic Cosmic Ray data / 8

Nine years of charged cosmic ray measurements with CALET on the International Space Station [15'+10']

Author: Paolo Maestro[1]

[1] *Universita degli studi di Siena (IT)*

Corresponding Author: paolo.maestro@cern.ch

The CALorimetric Electron Telescope (CALET) is a high-energy cosmic-ray detector that has been in continuous operation on the International Space Station (ISS) since October 2015. Developed by JAXA in collaboration with ASI and NASA to study the origin of cosmic rays (CR), their acceleration and propagation mechanisms in the Galaxy, and to search for dark matter and the presence of potential nearby astrophysical sources of high-energy electrons, CALET has so far detected more than 2 billion events with an energy >10 GeV. The analysis of these data allowed to measure the energy spectra of electron+positron and individual CR nuclear species up to the multi-TeV region, revealing spectral features such as a sharp break in the electron flux around 1 TeV, the hardening of the proton, He, C, O fluxes at a few hundred GeV/n and the softening of the proton and He spectra around 10 TeV/n.
In addition, the measurement of the B/C and B/O flux ratios up to a few TeV/n indicates the possible presence of a residual propagation length compatible with the hypothesis that a fraction of secondary B nuclei can be produced in the vicinity of the cosmic ray source.
I will summarise these results obtained with CALET, highlight similarities and discrepancies with measurements from other recent experiments, and discuss the main sources of systematic uncertainties affecting the spectra.

Relevant XS reactions and precision for GCRs / 9

Refining predictions of Galactic secondary cosmic rays [10'+5']

Author: Pedro De la Torre Luque[1]

Co-author: Nicola Mazziotta [2]

[1] *Institute of theoretical physics (IFT-UAM)*

[2] *Universita e INFN, Bari (IT)*

Corresponding Authors: pedro.delatorre@uam.es, mario.nicola.mazziotta@cern.ch

Despite the simplicity of our phenomenological models of CR propagation, we have been able to explain with very good accuracy the fluxes of the main secondary CRs, including antiprotons. In this talk, we show new cross sections of CR interactions in the Galaxy computed with FLUKA, covering from light secondaries, such as deuterium, tritium or 3He, to gamma rays and neutrinos. In addition, we show how some assumptions, such as the head-on approximation, can affect our predicted fluxes of light secondary CRs.

XS from space and XS for Ultra-high energy CRs / 10

Ultra-heavy nuclei and ultra-high-energy cosmic rays [10'+5']

Author: Denise Boncioli[1]

[1] *University of L'Aquila*

Corresponding Author: denise.boncioli@univaq.it

Thanks to the experimental advancements in the field of ultra-high-energy cosmic rays (UHECRs), recent results about their mass composition indicate that, as the energy increases, the mean mass of these nuclei first decreases, reaching its lightest point around 2 EeV, and then afterward, increases significantly.

These results motivated several studies for modelling the interactions suffered by UHECR particles in their travel from the sources to the edge of the Milky Way, to compute the nuclear cascades induced by their interactions with the background photons in the extragalactic space.

Nuclear species with atomic mass A<=56 are treated in the most common codes used in the UHECR community to simulate the extragalactic propagation. In this talk, I will motivate why heavier nuclei should be considered as well, in the light of the highest energy events detected at the UHECR observatories. In addition, I will discuss how to possibly include the corresponding cross sections in SimProp, a simulation code for the simulation of UHECR interactions in the cosmic microwave background and extragalactic background light.

Relevant XS reactions and precision for GCRs / 11

Deuteron and Helium-3 production cross sections and propagation in the Galaxy [10'+5']

Author: Diego Mauricio Gomez Coral[1]

[1] *Universidad Nacional Autonoma (MX)*

Corresponding Author: diegomez.87@cern.ch

The AMS collaboration has published recent results on deuteron-over-helium-4 ($d/^4$He) and helium-3-over-helium-4 (^{3}He/^{4}He) cosmic rays flux ratios with unprecedented precision and covering a wider energy range than previous experiments. Both $d/^4$He and ^{3}He/^{4}He ratios are important to understand the propagation of cosmic rays in the Galaxy and the heliosphere, complementing observations with heavier nuclei like the boron-to-carbon ratio. Interestingly, the AMS has found that deuterons have a sizeable primary-like component, instead of being mostly secondary as expected. To better interpret such revealing observations is necessary to understand in more detail the secondary component that depends on production cross sections, propagation parameters in the transport model, and their uncertainties.
In this work, we revisit the deuterons and helium-3 production cross sections through fragmentation of heavier nuclei, as well as their uncertainties, and we study their propagation in the Galaxy comparing the resulting flux ratios to AMS measurements.

XS from space and XS for Ultra-high energy CRs / 12

Measurement of the proton-proton cross section at ultra-high energies with the Pierre Auger Observatory [10'+5']

Author: Olena Tkachenko[1]

[1] *Institute of Physics of the Czech Academy of Sciences*

Corresponding Author: tkachenko@fzu.cz

The energies of cosmic rays significantly exceed the range of the existing human-made particle accelerators. The analysis of the air shower data makes it possible to infer the particle production cross sections - one of the most fundamental properties of soft QCD interactions at the highest energies. The depth at which the number of particles in a shower reaches its maximum is linked to the depth of the first interaction in the atmosphere, which is determined by the cross section of the particle initiating the shower in the air. In this contribution, we discuss the estimation of the proton-proton cross section from the depth of shower maxima observed with the Pierre Auger Observatory. The results are compared with standard extrapolations from low-energy accelerator data and are in good agreement. The systematic uncertainties of the analysis and the integrity of the underlying assumptions are evaluated and summarized. The interplay of the production cross section with mass composition and the possibility of the corresponding simultaneous measurement of both quantities is outlined.

13

Relevance of cross sections for indirect dark matter detection

Author: Mattia Di Mauro[1]

[1] *INFN Torino*

Corresponding Author: dimauro.mattia@gmail.com

The origin of dark matter remains one of the most puzzling open problems in physics. Understanding its particle nature is a central focus of theoretical research and a primary objective for several experimental efforts. Among the various strategies for dark matter detection, indirect detection stands out as one of the most promising. This approach seeks to identify signals in flux data of the rarest cosmic particles (such as neutrinos, photons, or antimatter) originating from dark matter beyond the known astrophysical sources and mechanisms.

In this talk, I will review the current status of dark matter indirect detection, with a particular emphasis on the crucial role of cross-section measurements relevant for astroparticle physics. I will demonstrate how achieving the discovery potential for dark matter is contingent upon obtaining precise measurements of these cross sections.

Welcome / **14**

Welcome to CERN

Welcome / **15**

Organisation of the workshop

Author: Fiorenza Donato[1]

Co-authors: David Alain Maurin [2]; Saverio Mariani [3]

[1] *Torino University*

[2] *Centre National de la Recherche Scientifique (FR)*

[3] *CERN*

Corresponding Authors: dmaurin@lpsc.in2p3.fr, saverio.mariani@cern.ch, donato@to.infn.it

Introduction and motivation: astrophysics and dark matter / **16**

Galactic Cosmic Ray transport and XS [20'+10']

Corresponding Author: carmelo.evoli@gssi.infn.it

Introduction and motivation: astrophysics and dark matter / **17**

Indirec dark matter detection and relevant XS [20'+10']

Corresponding Author: mattia.dimauro@to.infn.it

Galactic Cosmic Ray data / **18**

Selected results from AMS-02 [15'+10']

Corresponding Author: mercedes.paniccia@cern.ch

XS measurements at CERN / **23**

AMBER [15+10]

Corresponding Author: davide.giordano@cern.ch

XS measurements at CERN / **24**

ALICE [15'+10']

Corresponding Author: laura.serksnyte@cern.ch

Relevant XS reactions and precision for GCRs / **26**

Desired reaction for nuclear production XS [15'+10']

Corresponding Author: dmaurin@lpsc.in2p3.fr

Relevant XS reactions and precision for GCRs / **27**

XS for e+, e-, and gamma rays [15'+10]

Corresponding Author: luca.orusa@edu.unito.it

XS measurements at other facilities / 28

XS nuclear fragmentation at GANIL and GSI [15'+10']

Corresponding Author: audouin@ijclab.in2p3.fr

XS measurements at other facilities / 29

XS for hadrontherapy and space studies with the FOOT project [15'+10']

Corresponding Author: m.vanstalle@gsi.de

XS modelling / 30

EPOS [15'+10']

Corresponding Author: tanguy.pierog@kit.edu

XS modelling / 31

Antinuclei coalescence [15'+10']

Corresponding Author: maximilian.horst@tum.de

XS modelling / 32

Antinucleon-nucleus interactions with the INCL code [10'+5']

Corresponding Author: jean-christophe.david@cea.fr

XS measurements at CERN / 33

LHCf [15'+10']

Corresponding Author: eugenio.berti@cern.ch

XS measurements at CERN / 34

LHCb [15'+10']

Corresponding Author: chiara.lucarelli@cern.ch

XS measurements at CERN / 35

NA61 and nuclear production XS [15'+10']

Corresponding Author: michael.unger@cern.ch

Brainstorming on a roadmap: preparing a white paper (TBC) / 36

Roadmap for production XS for nuclei (panel discussion)

Brainstorming on a roadmap: preparing a white paper (TBC) / 37

Roadmap for anti-nuclei XS (panel discussion)

Brainstorming on a roadmap: preparing a white paper (TBC) / 38

Roadmap for other XS and models (panel discussion)

Galactic Cosmic Ray data / 39

Selected DAMPE results [15'+10']

Corresponding Author: andrii.tykhonov@cern.ch

Galactic Cosmic Ray data / 40

Future CR precision experiments (Aladino, AMS100, HERD) [15'+10']

Corresponding Author: adriani@fi.infn.it

Brainstorming on a roadmap: preparing a white paper (TBC) / 45

2-slide summary of the 3 panel discussion [3x10']

Brainstorming on a roadmap: preparing a white paper (TBC) / 46

Organisation to write white paper - TBC [20']

Corresponding Authors: donato@to.infn.it, saverio.mariani@cern.ch, dmaurin@lpsc.in2p3.fr

Brainstorming on a roadmap: preparing a white paper (TBC) / 47

Concluding remarks [5']

Corresponding Author: donato@to.infn.it