



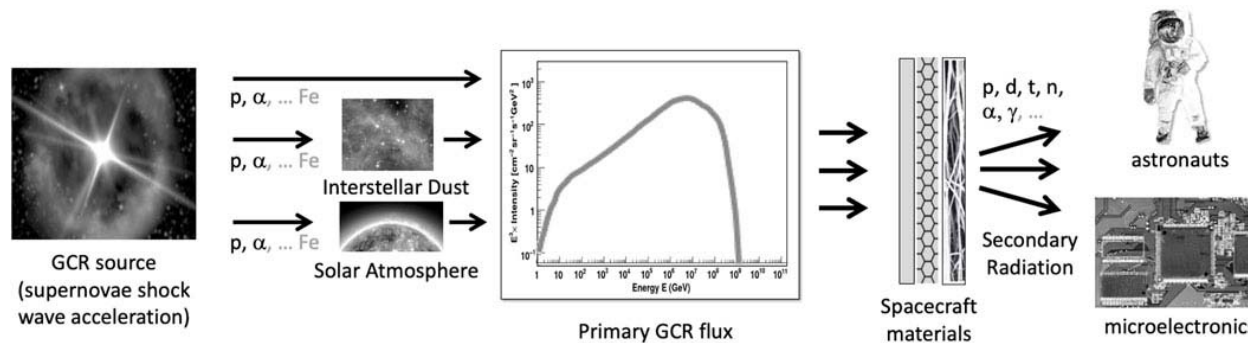
**International Atomic Energy Agency**

**EXFOR completeness for cross section data  
for space radiation protection**

**Naohiko Otsuka**  
**IAEA Nuclear Data Section**

# Needs of Experimental Database

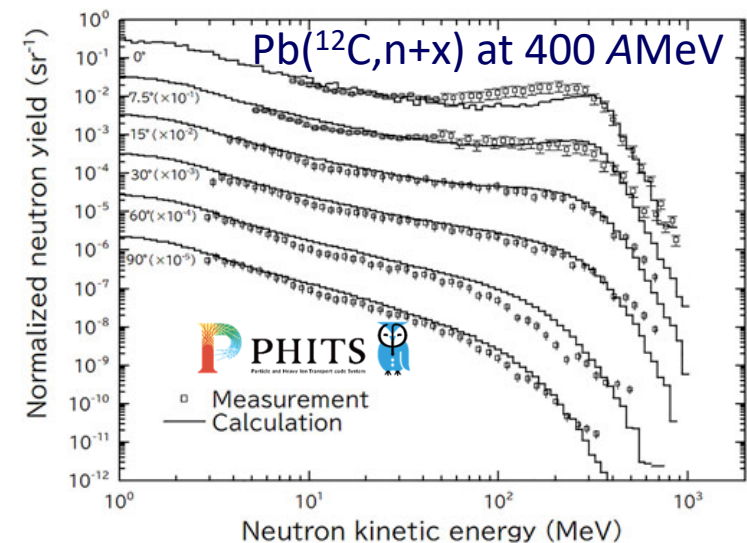
Particle transport simulation codes are essential tools to ensure radiation safety in space application.



M.S.Smith et al., Front. Astron. Space Sci. 10 (2023) 1228901

Codes must be validated against experimental database:

- microscopic experimental data (EXFOR)
- integral experimental data (SINBAD)



Y.Iwamoto et al., Front. Energy Res. 25 (2023) 1085264

# Scope of EXFOR Compilation

IAEA-NDS-0215  
Rev. 2018/06



INTERNATIONAL ATOMIC ENERGY AGENCY

**NUCLEAR DATA SERVICES**

DOCUMENTATION SERIES OF THE IAEA NUCLEAR DATA SECTION

NRDC Protocol defines three categories:

- **Category A** (*must* be in EXFOR)  
 $E_{inc} < 1 \text{ GeV}$  and  $A_{proj} \leq 12$

- **Category B** (*may* be in EXFOR)  
 $E_{inc} > 1 \text{ GeV}$  or  $A_{proj} \geq 13$

- **Not for EXFOR compilation**

Quantities not defined in the “EXFOR dictionary”  
(e.g., invariant cross section, transverse mass spectrum)

## NRDC Protocol

(Protocol for Cooperation between Nuclear Reaction Data Centres)

last version edited by

Naohiko Otuka  
IAEA Nuclear Data Section, Vienna, Austria

on behalf of the  
International Network of Nuclear Reaction Data Centres

June 2018

IAEA Nuclear Data Section, Vienna International Centre, A-1400 Vienna, Austria



# Space Application Data and EXFOR

frontiers | Frontiers in Astronomy and Space Sciences

TYPE Review  
PUBLISHED 08 September 2023  
DOI 10.3389/fspas.2023.1228901

M.S.Smith et al., Front. Astron. Space Sci. 10 (2023) 1228901

Check for updates

## Nuclear data for space exploration

Michael S. Smith<sup>1\*</sup>, Ramona L. Vogt<sup>2,3</sup> and Kenneth A. LaBel<sup>4</sup>

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### OPEN ACCESS

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“The wide range of energies (up to  $\sim$ TeV) and species ( $Z \sim 1-28$ ) of GCRs (galactic cosmic rays) make it very challenging to determine all of their potential effects on spacecraft and astronauts.”



Such data *can* be added in EXFOR if the quantities are defined in EXFOR Dictionary. **(Category B)**



# Comparison of EXFOR with GSI-ESA-NASA DB

IOP Publishing New J. Phys. 23 (2021) 10 1201 <https://doi.org/10.1088/1367-2630/ac27e1>

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The open access journal at the forefront of physics

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IOP Institute of Physics

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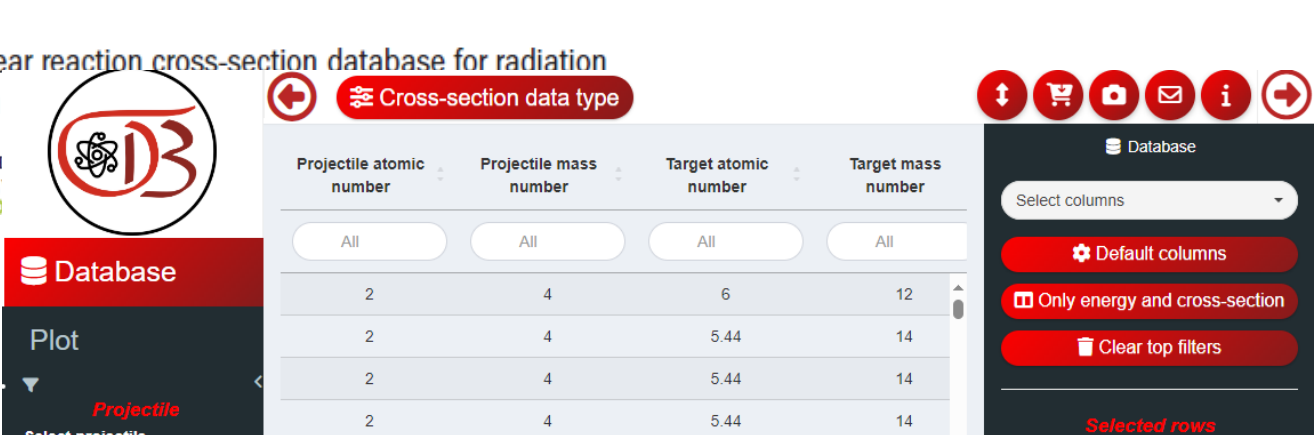
**Total reaction cross section**  
**Total charge/mass changing cross section**

**TOPICAL REVIEW**  
CrossMark

**OPEN ACCESS**  
RECEIVED 14 July 2021  
REVISED 7 September 2021

**Total nuclear reaction cross-section database for radiation protection**

F Luoni<sup>1,2</sup>, F H R B Norman<sup>4</sup>, M Durante<sup>1,2,3\*</sup>



The screenshot shows a web interface for the 'Total nuclear reaction cross-section database for radiation protection'. It features a table with columns for 'Projectile atomic number', 'Projectile mass number', 'Target atomic number', and 'Target mass number'. The table contains four rows of data. To the right of the table is a sidebar with a 'Database' section containing a 'Select columns' dropdown, 'Default columns', 'Only energy and cross-section', and 'Clear top filters' buttons. There are also social media icons at the top right of the sidebar.

Projectile atomic number	Projectile mass number	Target atomic number	Target mass number
All	All	All	All
2	4	6	12
2	4	5.44	14
2	4	5.44	14
2	4	5.44	14

Compilation from 103 publications. Download of full data possible!

Articles	<b>Total</b>	USA	JPN	EUR	Rest
in GSI DB	<b>103</b>	38	22	34	9
in EXFOR	<b>48</b>	14	16	13	5
Coverage (%)	<b>47</b>	37	73	38	56

# Comparison of EXFOR with NASA NUCDAT Collection

Radiation Measurements 47 (2012) 315–363



Contents lists available at SciVerse ScienceDirect

Radiation Measurements

journal homepage: [www.elsevier.com/locate/radme](http://www.elsevier.com/locate/radme)

NASA/TP-2011-217179



Nuclear data for space radiation

John W. Norbury<sup>a,\*</sup>, Jack Miller<sup>b</sup>, Anne M. Adamczyk<sup>c</sup>, Lawrence H. Heilbrunn<sup>c</sup>, W. Townsend<sup>c</sup>, Steve R. Blattnig<sup>a</sup>, Ryan B. Norman<sup>a</sup>, Stephen B. Guetersloh<sup>c</sup>

Review of Nuclear Physics Experiments for Space Radiation

*John W. Norbury  
Langley Research Center, Hampton, Virginia*

Collection of 50,000 “entries”. (Is this a database? data index?)

Articles	<b>Total</b>	USA	JPN	EUR	Rest
in NUCDAT	<b>398</b>	178	53	123	44
in EXFOR	<b>270</b>	102	47	84	38
Coverage (%)	<b>68</b>	57	89	68	86



# Relativistic Heavy Ion Collision Data

Data published in 7 articles by AGS E802 were compiled by NNDC in “area H” EXFOR entries(<https://nds.iaea.org/nrdc/file/rhic.html>).

Y. Nara et al., Phys.Rev.C61(1999)024901

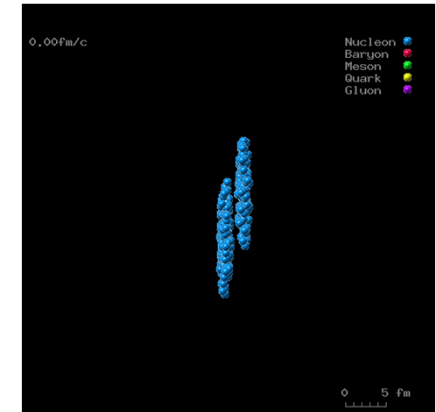
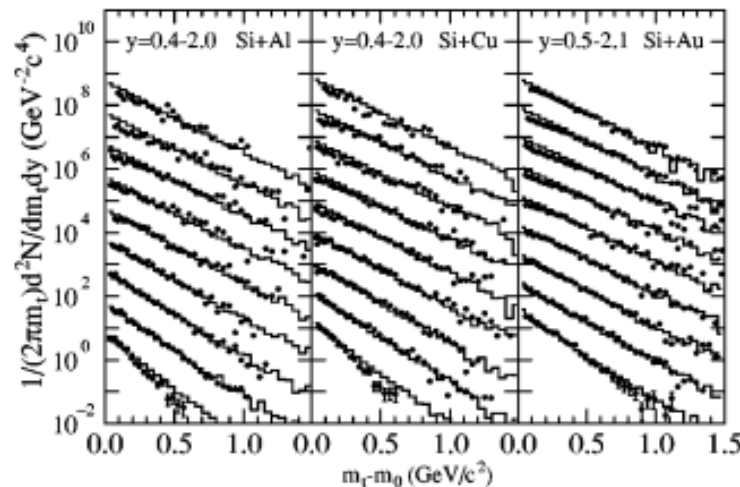
## Relativistic nuclear collisions at 10.4 GeV energies from $p + \text{Be}$ to $\text{Au} + \text{Au}$ with the hadronic cascade model

Y. Nara,<sup>1,2</sup> N. Otuka,<sup>3</sup> A. Ohnishi,<sup>3</sup> K. Niita,<sup>4</sup> and S. Chiba<sup>1</sup>

<sup>1</sup>Advanced Science Research Center, Japan Atomic Energy Research Institute, Tokai, Naka, Ibaraki 319-1195, Japan

<sup>2</sup>Physics Department, Brookhaven National Laboratory, Upton, New York 11973

Al/Cu/Au(Si,p+x) from AGS in EXFOR entry “H0002” compared with INC model (“JAM”)



JAM on Web (JoW)  
[www.jcprg.org/jow/](http://www.jcprg.org/jow/)

Now HEPData takes care compilation of data from RHIC and LHC.

# Summary

- Majority of GCR related reaction data ( $A > 12$  or  $E/A > 1$  GeV) are being compiled in EXFOR **on a voluntary basis** (i.e., no guarantee on completeness)
- EXFOR coverage of articles in GSI-ESA-NASA DB and NASA NUCDAT are 47 and 68%, respectively (not so bad).
- I registered all missing articles in the EXFOR Article Allocation List. They could be compiled by us as time permits.
- NRDC leaves compilation of relativistic heavy ion collision data from RHIC and LHC to the HEPData coordinators.





**Thank you!**



Vienna International Centre (VIC) Buildings from Kaiserwasser