Brookhaven National Laboratory

U.S. DEPARTMENT of ENERGY

# x4i Update

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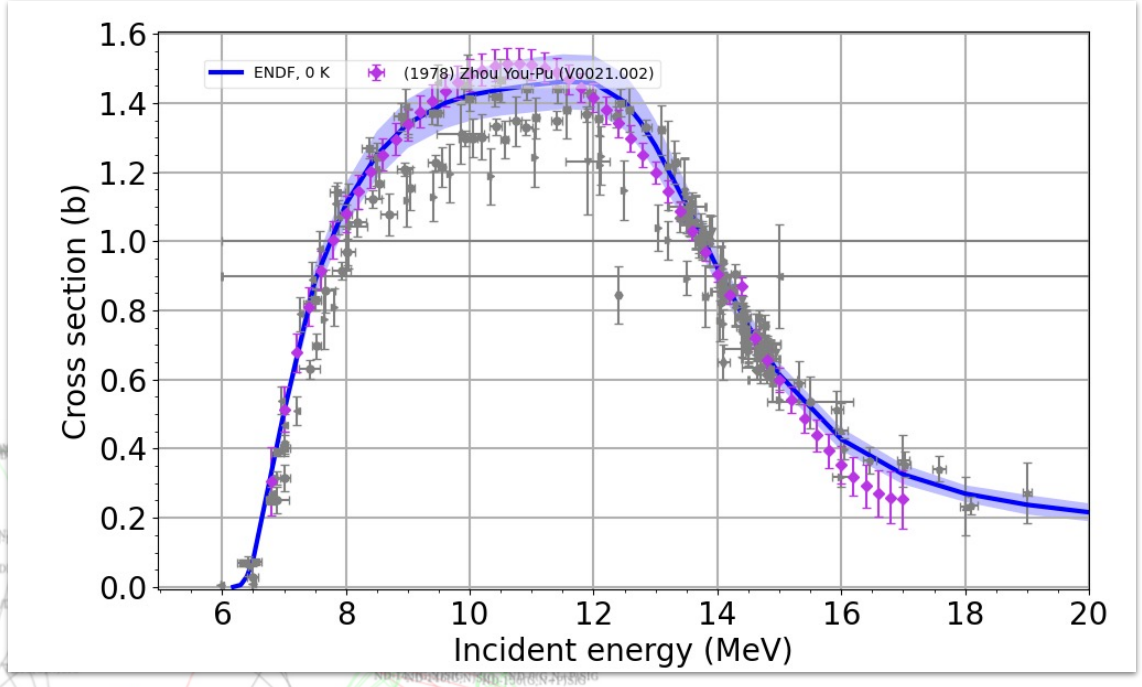
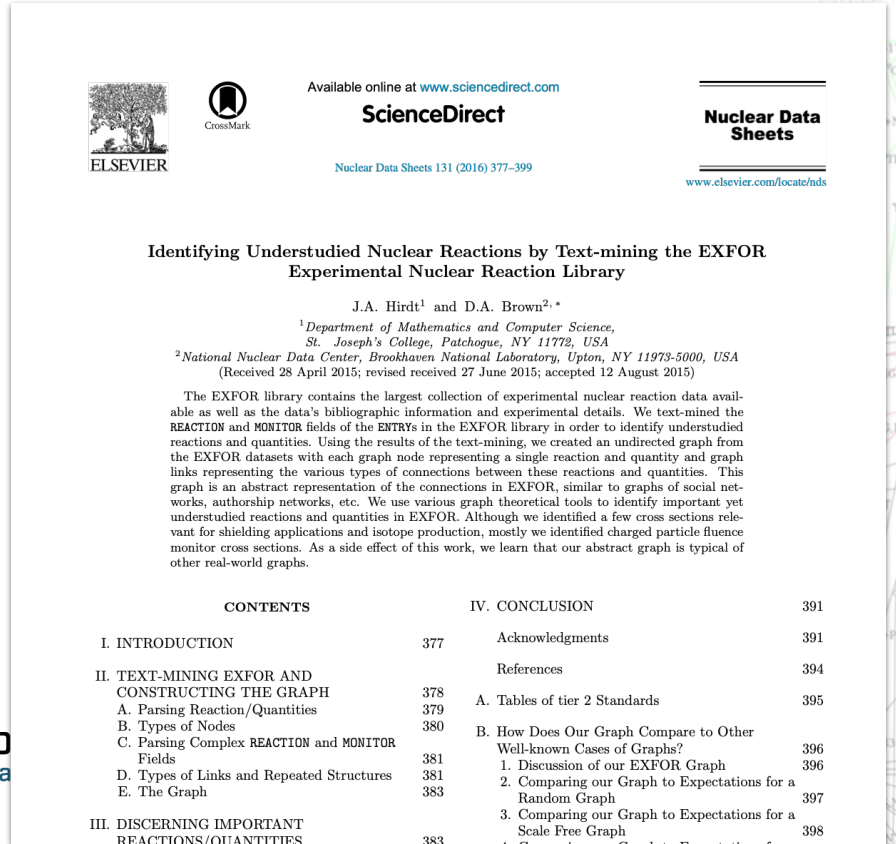
# x4i Backstory




- Developed at LLNL, open sourced in 2011
- Used by FUDGE, ADVANCE, mainly for plotting and some ENDF data QA
- Modest use in SG-30 for checking EXFOR
- Development stalled while BNL figured out whether I could work on the code
- In the meantime, code forked: https://github.com/afedynitch/x4i3

# In addition to use in ENDF QA, there are at least two (non-conference proceedings) papers that used x4i

**J.A. Hirdt and D.A. Brown**
**Nuclear Data Sheets 131 (2016) 377–399**



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Nuclear Data Sheets 131 (2016) 377–399

Nuclear Data Sheets

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## Identifying Understudied Nuclear Reactions by Text-mining the EXFOR Experimental Nuclear Reaction Library

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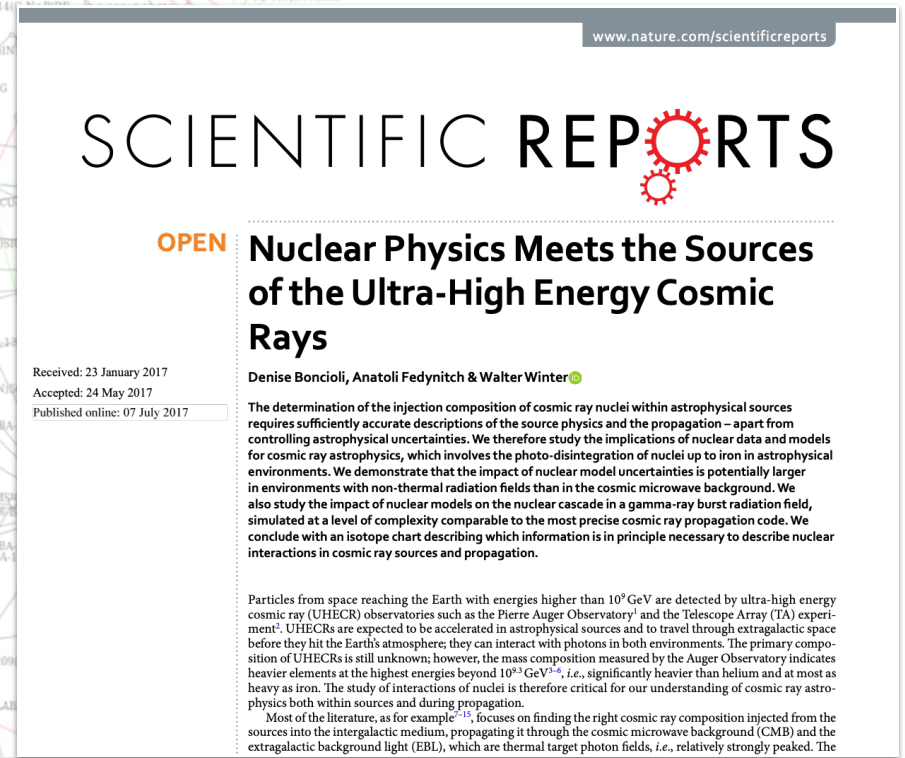
The EXFOR library contains the largest collection of experimental nuclear reaction data available as well as the data's bibliographic information and experimental details. We text-mined the REACTION and MONITOR fields of the ENTRYs in the EXFOR library in order to identify understudied reactions and quantities. Using the results of the text-mining, we created an undirected graph from the EXFOR datasets with each graph node representing a single reaction and quantity and graph links representing the various types of connections between these reactions and quantities. This graph is an abstract representation of the connections in EXFOR, similar to graphs of social networks, authorship networks, etc. We use various graph theoretical tools to identify important yet understudied reactions and quantities in EXFOR. Although we identified a few cross sections relevant for shielding applications and isotope production, mostly we identified charged particle fluence monitor cross sections. As a side effect of this work, we learn that our abstract graph is typical of other real-world graphs.

CONTENTS



**D. Boncioli, A. Fedynitch & W. Winter**
**Scientific Reports 7: 4882 (2017)**
**DOI:10.1038/s41598-017-05120-7**



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## Nuclear Physics Meets the Sources of the Ultra-High Energy Cosmic Rays

Received: 23 January 2017
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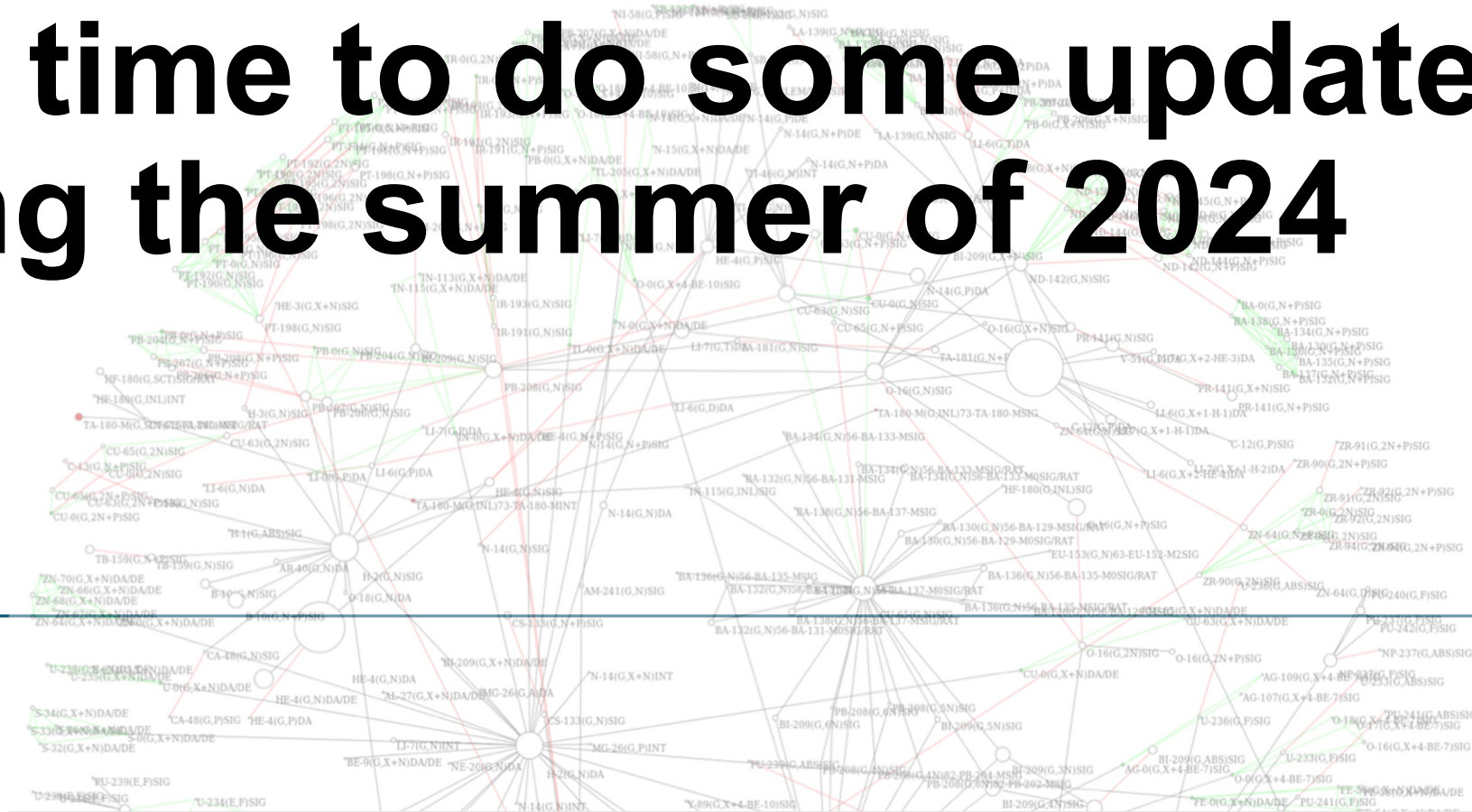
Denise Boncioli, Anatoli Fedynitch & Walter Winter

**The determination of the injection composition of cosmic ray nuclei within astrophysical sources requires sufficiently accurate descriptions of the source physics and the propagation – apart from controlling astrophysical uncertainties. We therefore study the implications of nuclear data and models for cosmic ray astrophysics, which involves the photo-disintegration of nuclei up to iron in astrophysical environments. We demonstrate that the impact of nuclear model uncertainties is potentially larger in environments with non-thermal radiation fields than in the cosmic microwave background. We also study the impact of nuclear models on the nuclear cascade in a gamma-ray burst radiation field, simulated at a level of complexity comparable to the most precise cosmic ray propagation code. We conclude with an isotope chart describing which information is in principle necessary to describe nuclear interactions in cosmic ray sources and propagation.**

Particles from space reaching the Earth with energies higher than $10^9$ GeV are detected by ultra-high energy cosmic ray (UHECR) observatories such as the Pierre Auger Observatory[1] and the Telescope Array (TA) experiment[2]. UHECRs are expected to be accelerated in astrophysical sources and to travel through extragalactic space before they hit the Earth's atmosphere; they can interact with photons in both environments. The primary composition of UHECRs is still unknown; however, the mass composition measured by the Auger Observatory indicates heavier elements at the highest energies beyond $10^{9.3}$ GeV[3–6], *i.e.*, significantly heavier than helium and at most as heavy as iron. The study of interactions of nuclei is therefore critical for our understanding of cosmic ray astrophysics both within sources and during propagation.

Most of the literature, as for example[7–15], focuses on finding the right cosmic ray composition injected from the sources into the intergalactic medium, propagating it through the cosmic microwave background (CMB) and the extragalactic background light (EBL), which are thermal target photon fields, *i.e.*, relatively strongly peaked. The

# I had time to do some updates during the summer of 2024



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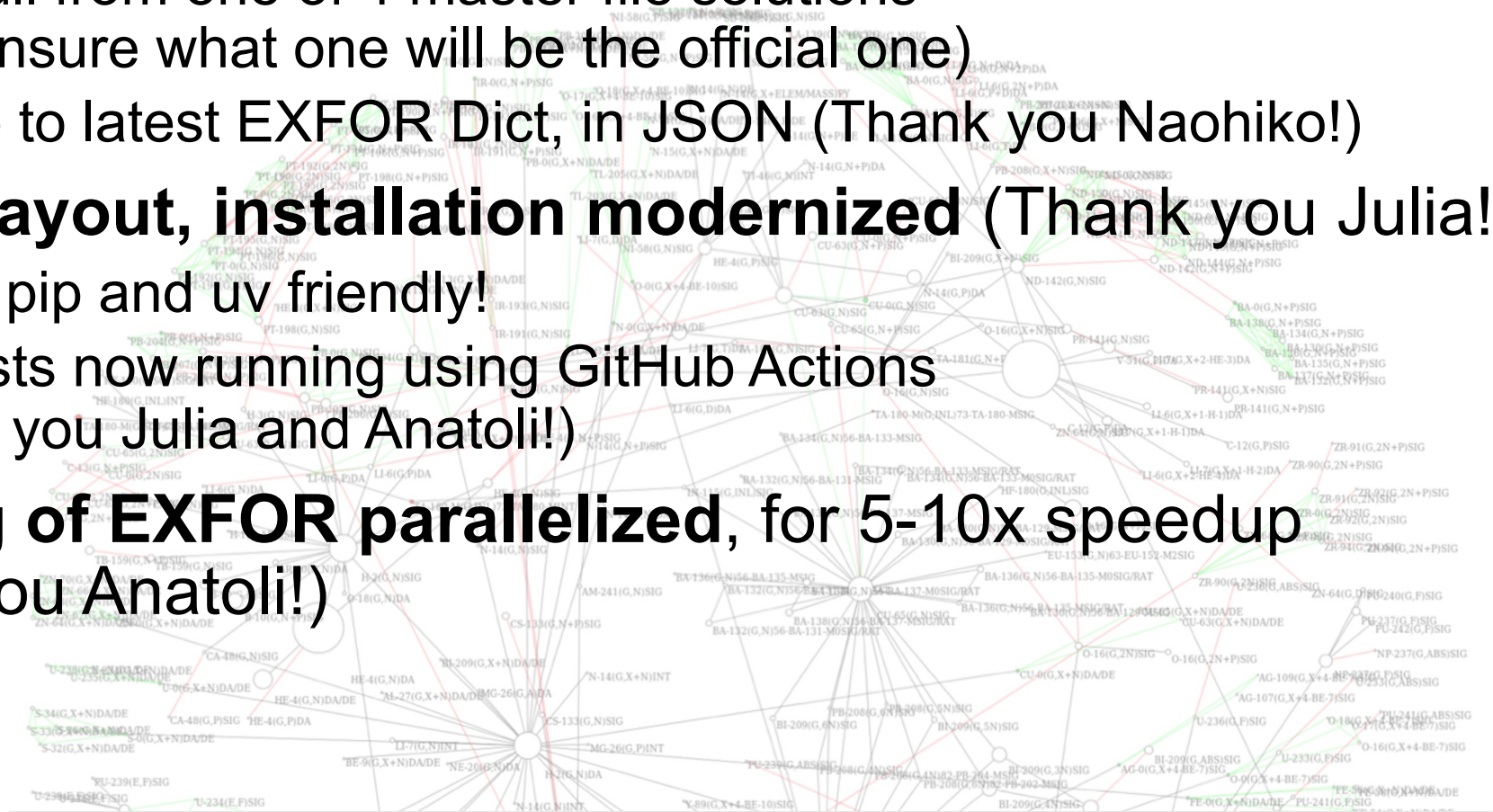
# There are no big visible change, but there are a lot of behind-the-scenes things

- **Update with latest IAEA offerings**
  - Now pull from one of 4 master file solutions
    (I am unsure what one will be the official one)
  - Update to latest EXFOR Dict, in JSON (Thank you Naohiko!)
- **Project layout, installation modernized** (Thank you Julia!)
  - Now is pip and uv friendly!
  - Unit tests now running using GitHub Actions
    (Thank you Julia and Anatoli!)
- **Indexing of EXFOR parallelized**, for 5-10x speedup
  (Thank you Anatoli!)



# There are no big visible change, but there are a lot of behind-the-scenes things (cont.)

- **Redid DATA and COMMON section processing**
  - Now use `pandas` dataframes, leading to substantial code simplifications, speedups and stability improvements. This also enables trivial CSV output
  - Use `pint` and `pint-pandas` to manage units, leading to even more simplifications, speedups and stability improvements
  - Use `tabulate` for table formatting.

| EN (MeV) | EN-ERR (MeV) | DATA (mb) | DATA-ERR (mb) |
|---|---|---|---|
| 6.49 | 0.085 | 24 | 63 |
| 7.01 | 0.08 | 49 | 50 |
| 7.52 | 0.075 | 54 | 58 |
| 8.03 | 0.075 | 177 | 70 |
| 8.54 | 0.07 | 275 | 54 |
| 9.04 | 0.065 | 249 | 41 |
| 9.55 | 0.065 | 354 | 56 |
| 10.06 | 0.06 | 415 | 39 |
| 10.56 | 0.06 | 411 | 70 |
| 11.07 | 0.055 | 356 | 79 |
| 11.57 | 0.055 | 418 | 49 |
| 12.08 | 0.055 | 455 | 76 |
| 12.58 | 0.05 | 318 | 132 |
| 13.09 | 0.05 | 588 | 148 |

# What's next

- readthedocs.io integration (needs improved documentation though)
- Better logging so can implement EXFOR checking
- PyPy
- Various administrative things (license reup, etc.)
- More column transformers for more datatypes used in ENDF preparation and checking
- Hybrid JSON + CSV export - I don't like EXFOR-JSON output for DATA and COMMON since they make more sense as CSV
- Unfork x4i3?
- Import EXFOR data via github EXFOR scheme or master file