# **Features of HDF5**

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## Key features of HDF5

- Hierarchical data format = like a file system
- Metadata + data together
- Cross-platform: Linux, Windows, Mac
- Multi-language: Fortran, C, C++, Java, Python, Julia, etc..; thread-safe Architectures (official): x86, amd64, ppc64; (community): arm64
- Open-source: BSD 3-clause license



#### Example MCEq database layout

- Used official tool to view file "HDFView"
- MCEq stores all data in one file
- File is opened/closed many times
- Only data requested by program flow is read from disk



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# HDF group

- Element to organize hierarchy
- Contains groups and datasets
- Can have many "properties"



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## HDF dataset

- Is like a "datatype"
- Can be a primitive array of floats, into, etc
- Can have many "properties"



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## HDF dataset

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## HDF dataset

- Is like a "datatype"
- Can be a primitive array of floats, into, etc
- Can have many "properties"
- Customization options (Filters) for read/write



	$ \Box$ $\times$
evel\git\MCEq\MC	Eq\data\mceq_db_lext_dpm191_v13.h5
_v13.h5 ^	Object Attribute Info General Object Info
	Name: EPOSLHC
	Path: /hadronic_interactions/air/
	Type: HDF5 Dataset
	Object Ref: (27121647) = line UUID in MAS
dptrs	Dataset Dataspace and Datatype
ndptrs	No. of Dimension(s): 2
r0	Dimension Size(s): 2 x 2189686
15	Max Dimension Size(s): 2 x 2189686
lptrs	Data Type: 64-bit floating-point
ptrs	Show Data with Options
ptrs	Miscellaneous Dataset Information Handle data in Blocks of 85546
S	Storage Layout: CHUNKED: 1 X 8554 The over I/O, cach, etc
otrs	Filters:       SHUFFLE: Nbytes = 8, USERDEFINED Izf(32000): 4, 261, 68432         Storage:       SIZE: 15966085, allocation time: Incremental         Fill value:       NONE
otrs	
S	Filfers: applied during sericlization. Here LZF-compression (MI) + SHEFL, improves comp.
v S	

#### **Reading and writing to parts of a dataset**

- The HDF library can read parts of dataset defined by:
  - Ranges
  - Sequence of points
  - Block selections
  - Periodic selections, etc...
- One can think of a method to read particles only at the coordinates of detectors, for example...





#### Multi-file and nested structures



Figure 4-2. A file with a circular reference



Figure 3-3. Two separate files

The figure below shows the two files after File2 has been mounted File1 at the group that is the target of the B link.



Figure 3-4. File2 mounted on File1



## Low-level file drivers

- Splitting I/O into multiple files can be handled by the lowlevel driver
- Split (subset of Multi) can write metadata and data into separate files
- MPI driver for control and comms
- Fine-grained control over interaction with file system



Figure 3-2. I/O path from application to VFL and low-level drivers to storage

![](_page_9_Picture_7.jpeg)

#### Very easy to use in user applications

In [1]:
<pre>1 import matplotlib.pyplot as plt 2 import numpy as np 3  4 import h5py</pre>
In [2]:
<pre>1 hdf_file = h5py.File("//MCEq/MCEq/data/mceq_db_lext_dpm191_v13.h5", "r")</pre>
In [3]:
<pre>1 print(hdf_file['cross_sections']['air']['EPOSLHC'])</pre>
<hdf5 "<f8"="" "ep0slhc":="" (140,="" 3),="" dataset="" shape="" type=""> In [4]:</hdf5>
<pre>1 assert hdf_file['cross_sections/air/EPOSLHC'] == hdf_file['cross_sections']['air']['EPOSLHC'] In [5]:</pre>
<pre>1 #Access attributes of group or dataset, another dictionary 2 hdf_file['common'].attrs.keys()</pre>
Out[5]:
<keysviewhdf5 'e_dim',="" 'e_grid',="" 'widths']="" ['e_bins',=""></keysviewhdf5>

![](_page_10_Figure_2.jpeg)

#### Summary

- HDF5 is a widely adopted, high-performance, open-source file format.
- The features to organize structured data and meta data should be well suited for CORSIKA8.
- In my experience it is smooth to interact with. Speed is good and optimization is possible, but quite technical job.
- Binaries can be bundled with CORSIKA.
- It is very easy to read and write with standard options. In my experience multi-TB single files were handled without issues.
- No experience with MPI, multi-file, etc. -> no explicit recommendation