

Recent developments in the Awkward Array world

Peter Fackeldey¹, Iason Krommydas², Ianna Osborne¹, Jim Pivarski¹, Andres Rios-Tascon¹

Princeton University¹, Rice University²



Named axis for Awkward Arrays

You can now add named axis (or algebraic shapes) to `ak.Array`, use them with awkward's operations, and leverage a new named axis based indexing syntax:

```
1 import awkward as ak
2
3 array = ak.Array([[1, 2], [3], [], [4, 5, 6]], named_axis=("x", "y"))
4
5 ak.sum(array, axis="y")
6 # <Array [3, 3, 0, 15] x:0 type='4 * int64'>
7
8 array[{"y": np.s_[0:1]}]
9 # <Array [[1], [3], [], [4]] x:0,y:1 type='4 * var * int64'>
```

Named axis provide more safety and readability for array manipulations with Awkward Array. For more details, check out the [named axis documentation](#).



Virtual Arrays for Awkward Array

Awkward Array does support virtual arrays, i.e. representing not-yet-loaded arrays in memory. These arrays are loaded on-demand when Awkward Arrays needs them to perform an operation. An example of virtual arrays in the scope of the coffea 2025 project is shown in the following:

```
1 import awkward as ak
2 from coffea.nanoevents import NanoEventsFactory
3
4 # construct a coffea.NanoEvents collection without reading!
5 events = NanoEventsFactory.from_root(
6     {"nanoaod.root": "Events"},
7     mode="virtual",
8     access_log=(log := []),
9 ).events()
10
11
12 print(events.Jet.pt)
13 # [??, ??, ??, ??, ..., ??, ??, ??, ??]
```

?? indicates that the values are not yet loaded into memory. You can access the values of these virtual arrays in two ways.

1. Explicitly load them into memory using `ak.materialize()`:

```
14 print(ak.materialize(events.Jet.pt))
15 # [[50.1, 47.3], ..., [62.4, ..., 16]]
```

2. Implicitly through any operation that needs the values:

```
16 print(events.Electron.pt)
17 # [??, ??, ??, ??, ..., ??, ??, ??, ??]
18 print(events.Electron.pt > 40.)
19 # [[True, True], ..., [True, False]]
```

Finally, let's make sure we only loaded the columns we need from the file:

```
20 print(log)
21 # ['nJet', 'Jet_pt', 'nElectron', 'Electron_pt']
```

The new virtual arrays in Awkward Array v2 have been carefully implemented at the lowest level enabling highly granular laziness. This integrates well with modern file formats like ROOT's RNTuple that allows reading data at the same high granularity.



RNTuple support in Uproot (reading and writing)

ROOT's RNTuple format is a modern file format for columnar data storage. Uproot supports reading (since [v5.5.1](#)) and writing (since [v5.6.0](#)) [RNTuple v1.0.0.0](#) files.

An example of inspecting an RNTuple file with Uproot is shown in the following:

```
1 import uproot
2
3 file = uproot.open("staff_rntuple_v1-0-0-0.root")
4 print(file.classnames())
5 # {'Staff;1': 'ROOT::RNTuple'}
```

Reading the RNTuple's contents is as easy as reading TTrees with Uproot:

```
6 rntuple = file["Staff"]
7
8 print(rntuple["Age"].array())
9 # [58, 63, 56, 61, 52, 60, 53, ..., 38, 26, 51, 25, 35, 28, 43]
10 print(rntuple.arrays(["Age", "Cost", "Nation"]))
11 # [{Age: 58, Cost: 11975, ...}, ..., {Age: 43, Cost: 12716, ...}]
```

(full link to this rntuple file can be found [here](#).)



Performance gains in Awkward Array and Vector

Several performance improvements have been made in Awkward Array and Vector. For example, the [trijet mass reconstruction of the Analysis Grand Challenge \(AGC\)](#) runs ~15-20% faster since Awkward Array [v2.7.3](#). This is achieved by reducing the metadata overhead on the Python side of Awkward Array for any `ak.layout.RecordArray`, see the improvements for the trijet mass reconstruction with 100.000 events below:

CPU backend:	Relative improvement
• Runtime: 29.3 ms ± 434 µs → 25.1 ms ± 126 µs	14.3%
• Allocations: 3691 → 2633	39.3%

TypeTracer backend:	
• Runtime: 30.3 ms ± 145 µs → 24.4 ms ± 195 µs	19.5%
• Allocations: 2882 → 1816	36.9%

The Vector library has also seen performance improvements with [v1.6.1](#) and newer. By bypassing metadata overhead and grouping operations, the performance of the *whole* Vector library is often improved by factors of 2 and more, see the p_T calculation of a four-vector below:

```
1 import vector
2 vector.register_awkward()
3
4 vec = vector.awk([{"x": 1.0, "y": 2.0, "z": 3.0, "t": 4.0}])
5
6 # pip install --upgrade "vector>1.6.0"
7 %timeit vec.rho
8 # 305 µs ± 659 ns
9
10 # pip install --upgrade "vector<1.6.0"
11 %timeit vec.rho
12 # 731 µs ± 2.26 µs
```

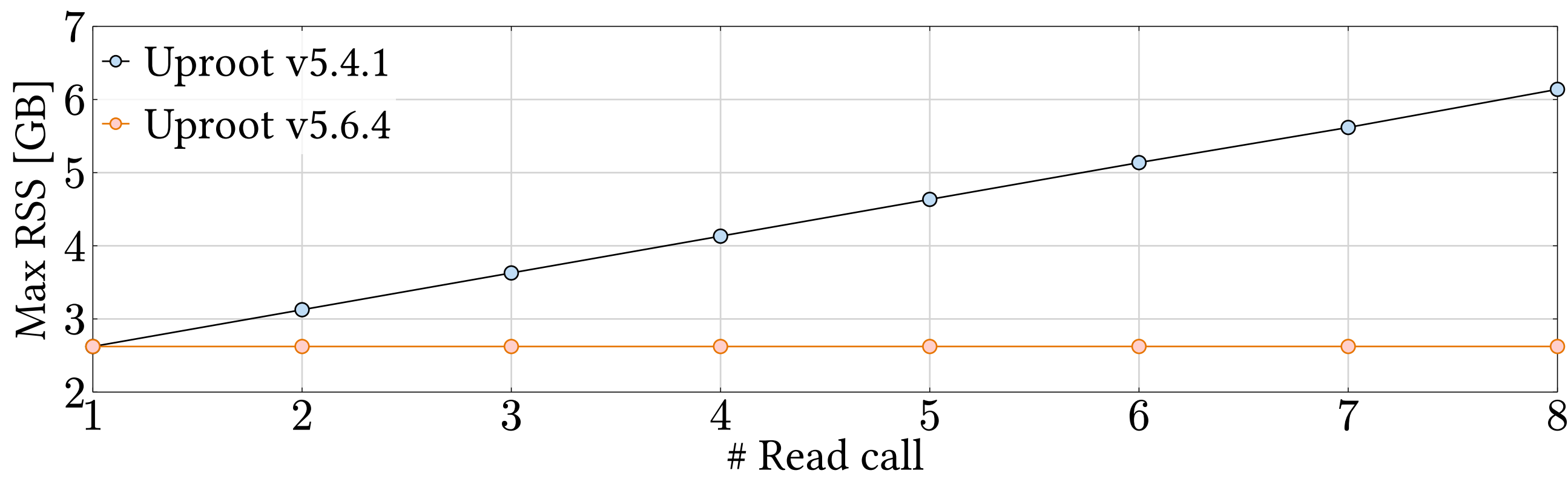
These Vector improvements further bring down the runtime of the trijet mass reconstruction of the AGC with 100.000 events to **19.1 ms ± 203 µs** (**18.2 ms ± 49.6 µs**) in the CPU (TypeTracer) backend.



Memory improvements in Awkward Array and Uproot

Several memory improvements have been made in Awkward Array and Uproot resolving cyclic references on the Python side. This allows for more efficient memory management and thus usually reduces the memory footprint of physics analyses.

Especially, the memory footprint of performing multiple reads of the same file with Uproot has been improved significantly since [v5.4.1](#), essentially eliminating growing memory usage, see the following figure:



Additional Information and Tips

- Checkout the new features and improvements in the Awkward Array world!
- If you're already a coffea user: coffea v2025.7 (July, CalVer) release (and newer) includes all of these improvements.
- Stay up-to-date and join us on the IRIS-HEP Slack workspace at [iris-hep.slack.com](#).