Lorentz Vector Manipulation and Histogram Handling

IRIS-HEP Future Analysis Systems & Facilities Workshop

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Boost-Histogram
What exists

- Fast, Pythonic histograms in Python
- Built on Boost.Histogram using cutting-edge pybind11 & cibuildwheel
- Int, Double, Weight, & “Profile” storages (and more)
- Can be filled in threads, merged, manipulated, and stored
- Already supported in Uproot 4, mplhep, and histoprint

Boost-histogram

Aside: Update to pybind11 2.6.0

- Python 3.9 support, PyPy 7.3.x (2.7, 3.6, and 3.7 alpha) support
- Fixed warnings on latest AppleClang
- 40% faster accumulator fills, simpler implementation
- Segfaults when passing an object with a throwing repr fixed
- kwargs replaced older workarounds (partially at the moment)
- Using new public py::type instead of pybind11::detail usage
- Enhanced CMake support, finds conda and venv now, uses pybind11_find_import
- Using setuptools support from pybind11 (previously vendored)

Boost-Histogram

What remains

- Most of the planned work for 1.0 was done in 0.10 through 0.11.1
- What makes 1.0?
  - Protocol for Histograms (at least plotting)
  - to_numpy normalization with other packages
  - Slightly more UHI support
  - Slightly better integer storage support
  - Will end Python 2.7 support

Hist

What exists

- Extends boost-histogram with user friendly features
  - Named axes (optionally enforced)
  - Fast histogram construction
  - UHI+: simpler slicing and manip, expecially in a notebook
  - Plotting: Simple adaptor to mplhep
  - Beautiful notebook reprs
- GSoC concluded, Python 3.6+ Hist 2.0 released

Hist
Examples

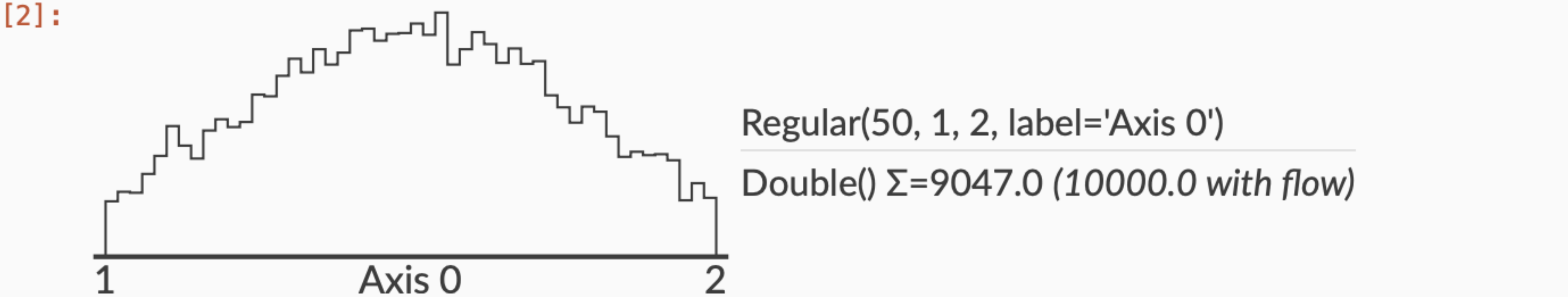
Reprs in Jupyter

Hist has custom reprs when displaying in a Jupyter.

```
[1]: from hist import Hist
     import numpy as np
```

```
[2]: Hist.new.Reg(50, 1, 2).Double().fill(np.random.normal(1.5, 0.3, 10_000))
```

[2]:

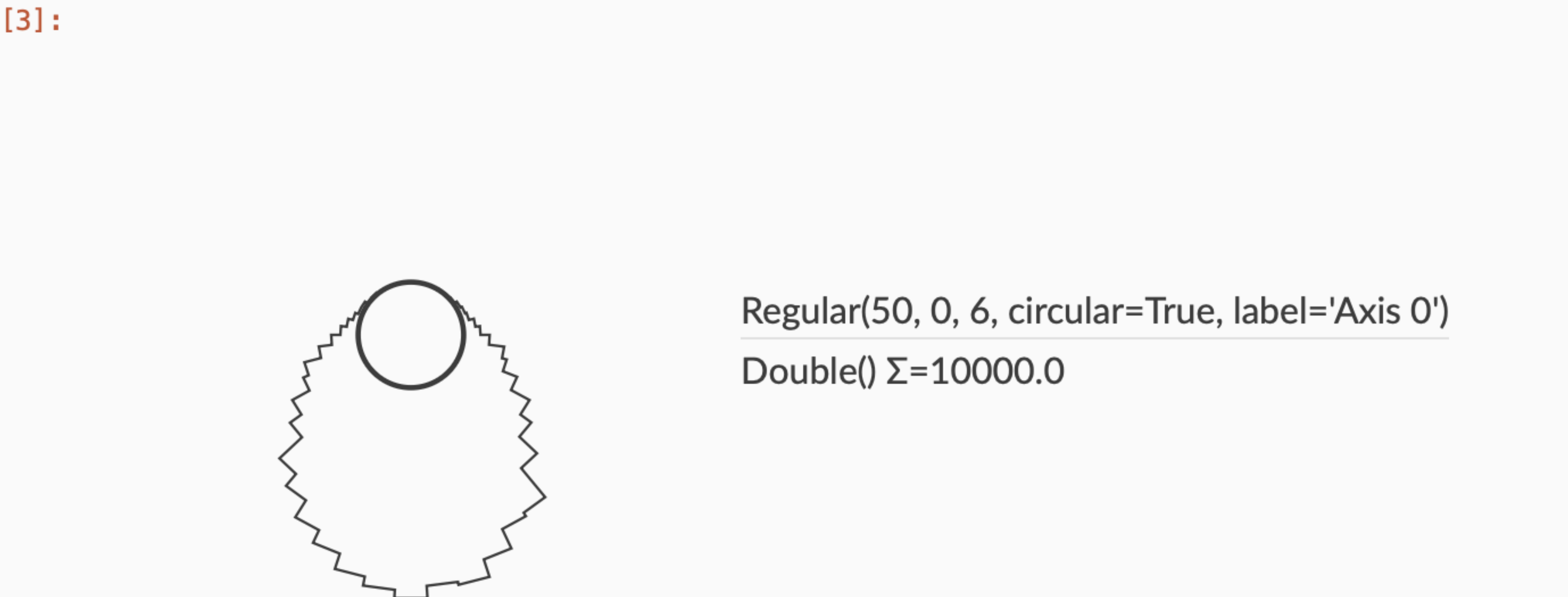


Regular(50, 1, 2, label='Axis 0')

Double() Σ=9047.0 *(10000.0 with flow)*

```
[3]: Hist.new.Reg(50, 0, 2 * 3, circular=True).Double().fill(np.random.normal(1.5, 0.7, 10_000))
```

[3]:

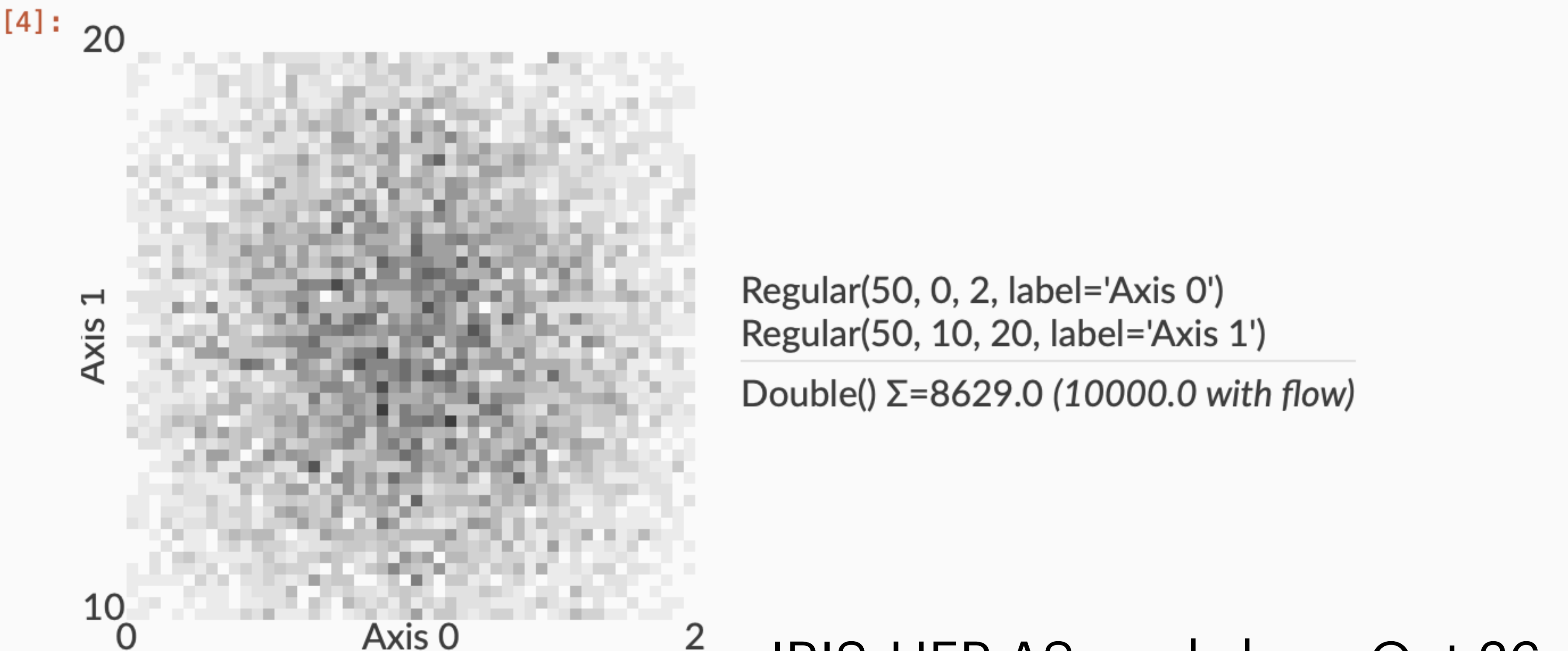


Regular(50, 0, 6, circular=True, label='Axis 0')

Double() Σ=10000.0

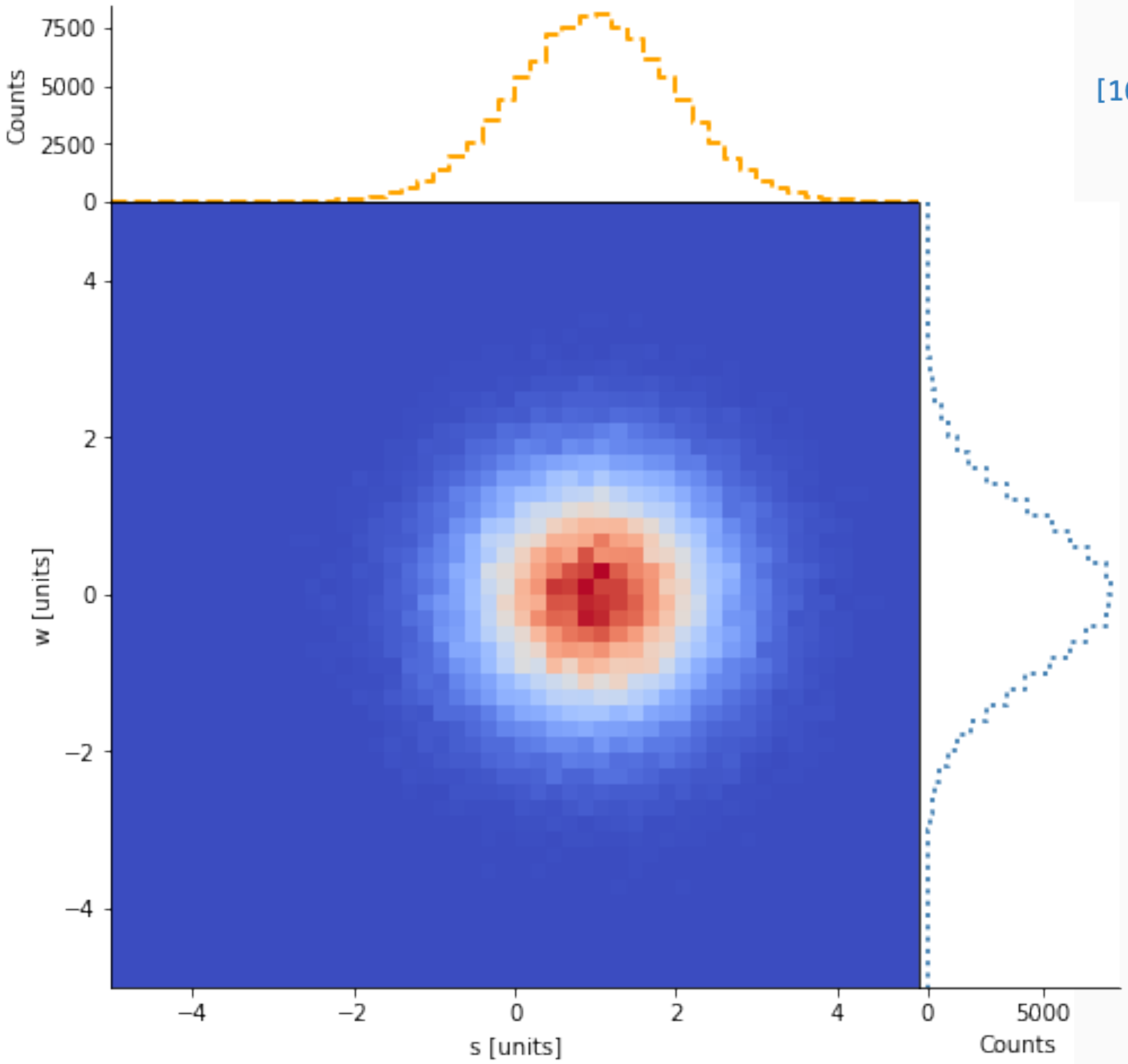
```
[4]: Hist.new.Reg(50, 0, 2).Reg(50, 10, 20).Double().fill(
         np.random.normal(1, 0.5, 10_000), np.random.normal(15, 3, 10_000)
     )
```

[4]:



Regular(50, 0, 2, label='Axis 0')
Regular(50, 10, 20, label='Axis 1')

Double() Σ=8629.0 *(10000.0 with flow)*

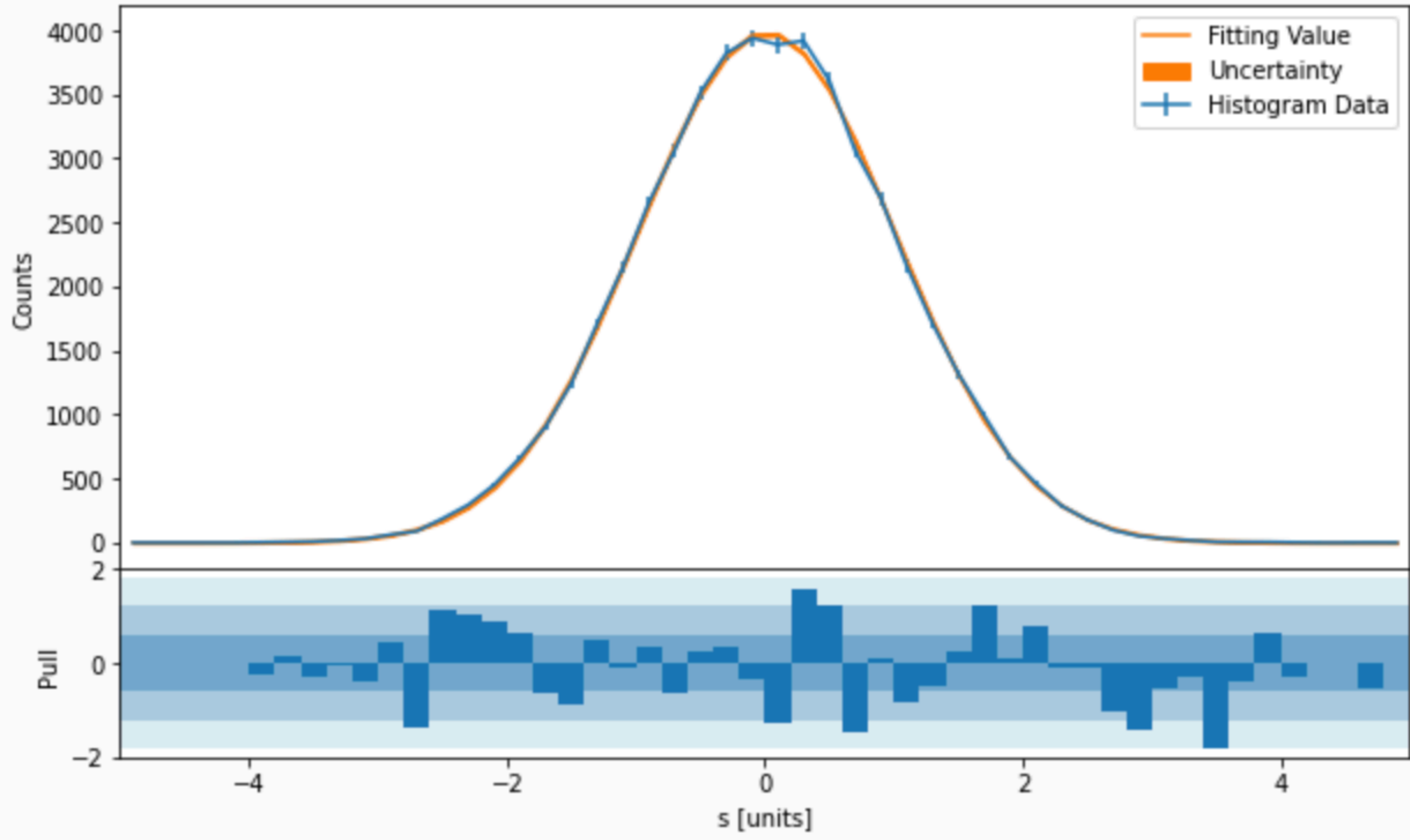


This is an example of a pull plot:

```
[15]: from uncertainties import unumpy as unp


      def pdf(x, a=1 / np.sqrt(2 * np.pi), x0=0, sigma=1, offset=0):
          exp = unp.exp if a.dtype == np.dtype("O") else np.exp
          return a * exp(-((x - x0) ** 2) / (2 * sigma ** 2)) + offset
```

(The uncertainty is non-significant as we filled a great quantities of observation points above.)

```
[16]: plt.figure(figsize=(10, 6))

      h.project("S").plot_pull(pdf)

      plt.show()
```



Hist

What remains

- Anything that doesn’t fit in boost-histogram
  - Statistical functions
  - Bayesian blocks algorithm
- Design a cool logo

Histogram
Ecosystem

- Developing a Plotting Protocol
  - Next iteration coming soon
  - Feedback welcome, will help broaden and shape (exp. for fitters!)
    - https://github.com/scikit-hep/boost-histogram/issues/423

Vector

What exists

- Basic examples of Lorentz vectors:
  - Core - standalone functions (usable by Numba)
  - Common - class structure, basis for others
    - NumPy - Holds arrays
    - Awkward - Usable in Awkward 1
    - Single (free) - useful for Numba
    - Numba - Works in Numba functions

Vector

What exists - 2

- Lorentz
  - Coordinate free (all) (can be overridden)
  - xyzt
- Alternate coordinate properties, like pt, eta, phi
- A few single values, like mag and mag2
- A vector-returning function, __add__ (vector - scalar __mul__ mostly done)

Vector

Working example

```
@numba.njit
def do_cool_stuff(input, output):
    for muons in input:
        output.begin_list()

        for i in range(len(muons)):
            output.begin_list()

            for j in range(i + 1, len(muons)):
                zboson = muons[i] + muons[j]

                output.begin_tuple(2)
                output.index(0)
                output.append(zboson)
                output.index(1)
                output.append(zboson.mag)
                output.end_tuple()

            output.end_list()

        output.end_list()
```

Vector

What remains

- Filling out the remaining scalar and vector functions
- Adding a Protocol to verify an implementation is complete
- Redesigning unit tests to share between impl and coord sys
- Filling out more coordinate systems
- Adding 2D & 3D vectors, handling rotations
  - Interactions between vectors, like boosting
- TensorFlow impl

Vector

Questions

- Clean, “one way to do it”, with optional mix-ins for “momentum”, etc?
- Selecting best names for core methods/properties
  - Protocol will be a good place to get feedback!
- Balance of “sharing code” with simple, separate implementations
  - Protocol can help with the latter!
- ROOT compatibility layer/mix-in
  - Already testing against ROOT using Conda-Forge ROOT