LUND UNIVERSITY

Rivet

Leif Lönnblad

Department of Astronomy
and Theoretical Physics
Lund University

JETSCAPE Winter Meeting
2020-03-19

Outline

- What is Rivet?
- What is an analysis?
- Rivet for Heavy Ions
- Rivet and JETSCAPE

What is Rivet?

Rivet is a framework for publishing *analyses* of *measurements* done by collider experiments.

"*But we already do that! Just read the paper!*"

What is Rivet?

Rivet is a framework for publishing *analyses* of *measurements* done by collider experiments.

"*But we already do that! Just read the paper!*"

Yes but . . .

- . . . which cuts were used?
- . . . was there a trigger?
- . . . how was that background subtracted?
- . . . was that *extrapolated* down to zero $p_\perp$?
- . . . which recombination scheme was used for the jets?
- . . . what exactly do you mean by a *primary particle*?
- . . . what did you divide with to get that R_{AA}?

How do we make an analysis useful for posterity?

- Description of analysis in code vs. in words
- Measurement vs. (model-dependent) interpretation
- Corrections for detector effects vs. extrapolation outside acceptance

If you can apply your analysis on simulated full events on particle level (i.e. using Event Generators) then your results can have a meaning outside of your interpretation in the paper.

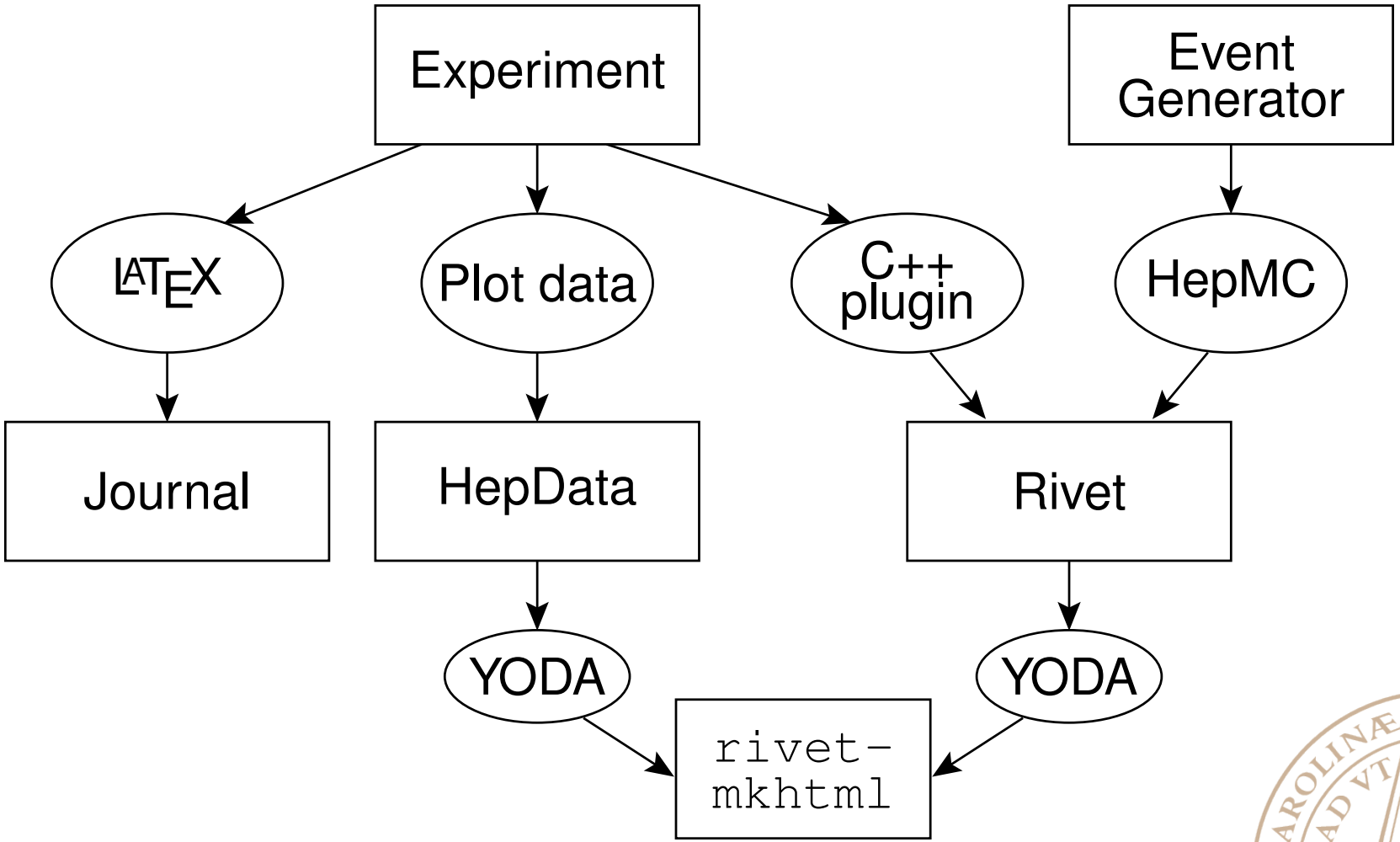
If someone says

- "*But my analysis is so complicated that it is impossible to implement in Rivet!*"

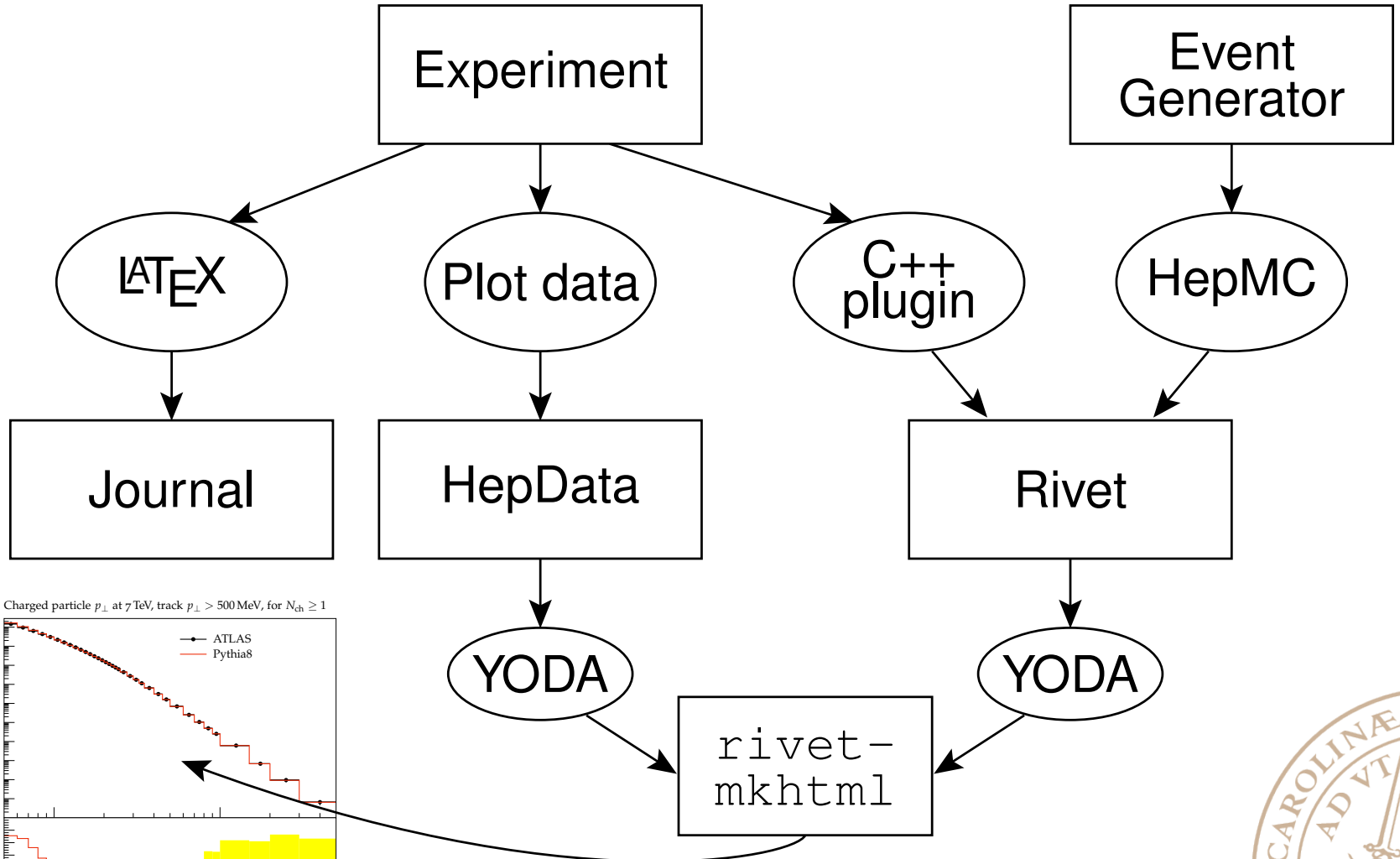
what I hear is

- "*My results are irreproducible!*"

The Rivet Model



The Rivet Model



The structure of a Rivet analysis

`void init()`

- book histograms and other analysis objects
- book *Projections*

`void analyze(const Event & event)`

- apply projections to the **`event`**
- fill histograms

`void finalize()`

- manipulate analysis objects to obtain the desired scaling, ratios, . . .

Projections

A *Projection* looks at the **`event`** and derives observable quantities from it and makes these available in the **`event`**.

The most common example is a **`FinalState`** projection produces a list of particles with given cuts.

Then we can us e.g. a **`FastJets`** projection that uses that **`FinalState`** to produce a list of jets

The same projection can be used in several different analyses and in several other projections. In that case the result of the projection is only calculated once for each event.

The ground rules

A Rivet analysis must not assume anything about the event generator that produced the HepMC file being analyzed!

Only the produced final state particles should be used in the analysis!

(but there are exceptions)

Rivet for Heavy Ions

Rivet was made with the LHC in mind, focusing primarily on pp physics.

Also old e^+e^- and ep analyses have been included.

But Heavy ion experiments have somewhat different needs

As of Rivet-2.7.x, there are a few additions for Heavy Ions

[arXiv:1912.05451 [hep-ph] (Rivet-3), arXiv:2001.10737 [hep-ph] (Heavy Ions)]

Centrality

In principle the Centrality is a simple projection.

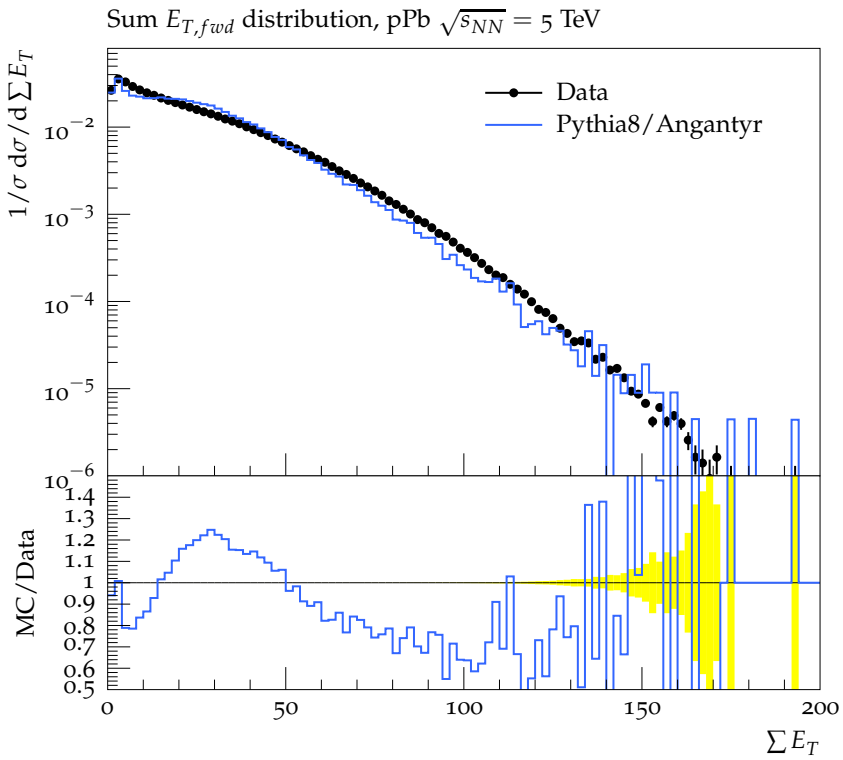
But there are caveats.

- Calibration: separate MinBias run needed to measure and bin centrality observable.
- Generator ambiguities: some generators cannot properly generate reasonable MinBias events.
- Experimental ambiguities: some experiments do not use a final-state particle based centrality observable.

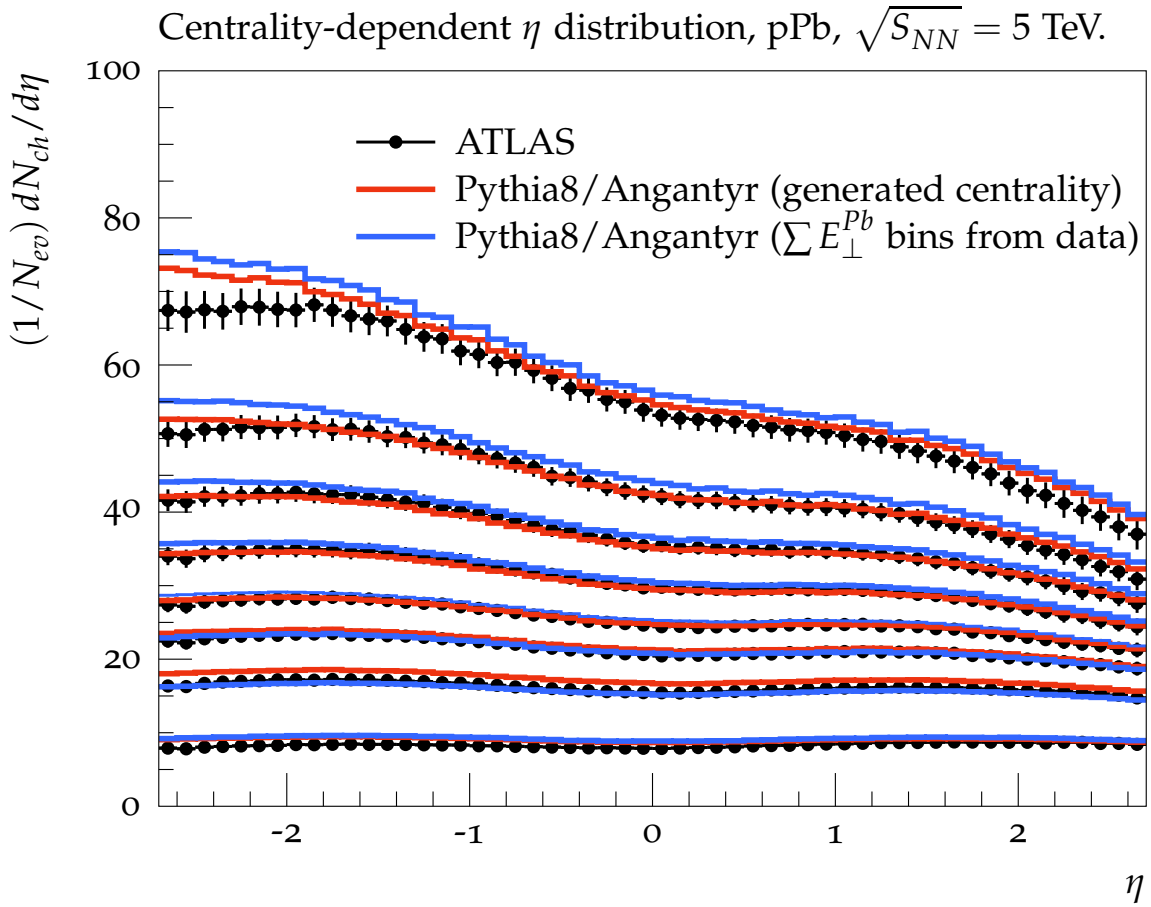
In rivet all this is handled by *options* and *preloading*.

Centrality

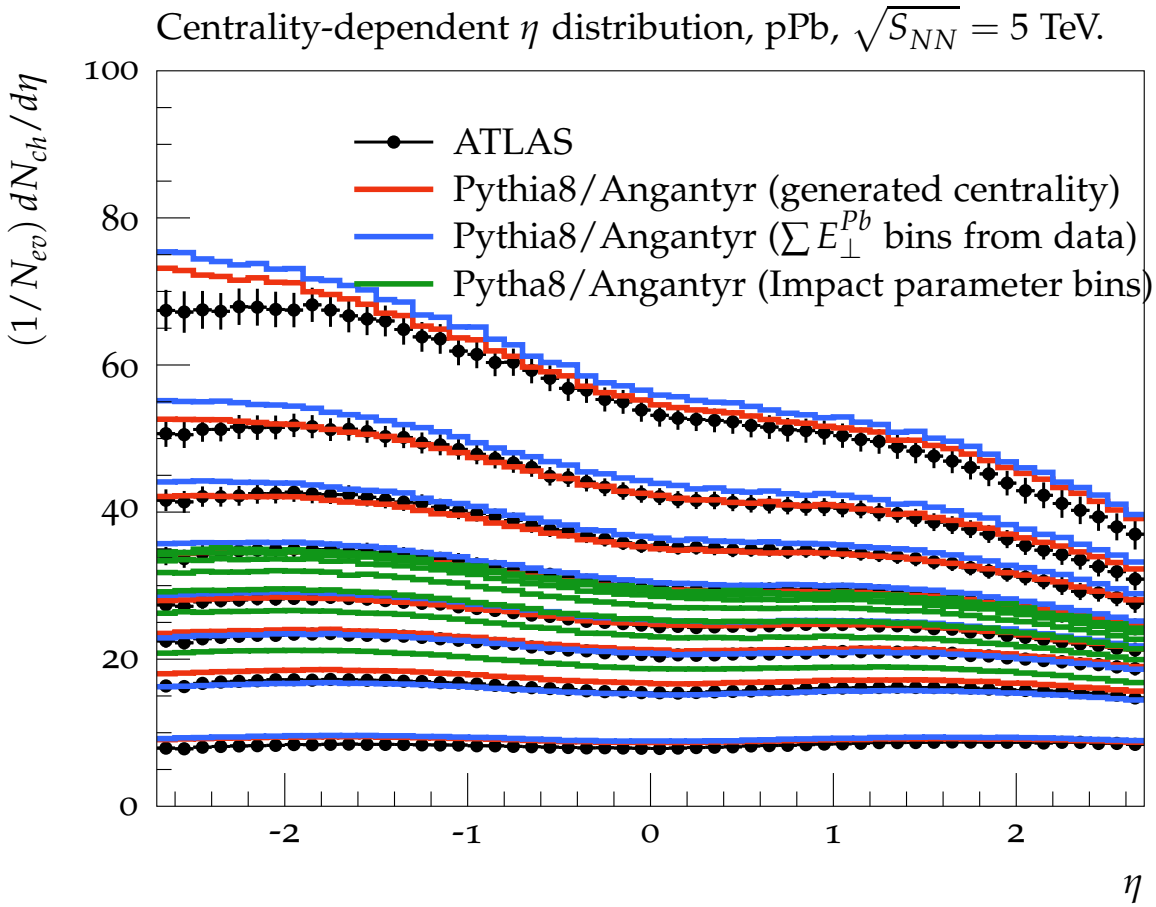
ATLAS uses the sum of transverse energy in the forward direction. This is a simple final-state observable, that can be measured.



Should we bin it the measured $\sum E_\perp$? The generated $\sum E_\perp$?



Should we bin it the measured $\sum E_\perp$? The generated $\sum E_\perp$?
Or maybe we should bin in the generated impact parameter?



First run the centrality calibration

```
> rivet pPbMinBias5TeV.hepmc \
    -a ATLAS_pPb_Calib \
    -o centcalib.yoda
```

Then run the binned analysis with several options for the preloaded centrality calibration

```
> rivet pPbMinBias5TeV.hepmc \
    -p centcalib.yoda \
    -a ATLAS_2015_I1386475:cent=REF \
    -a ATLAS_2015_I1386475:cent=GEN \
    -a ATLAS_2015_I1386475:cent=IMP \
    -o etadist.yoda
```

Other new Rivet stuff for Heavy Ions

- Event mixing
- Correlator framework for flow analyses
- Re-entrant `finalize()` and `rivet-merge`

Re-entrant `finalize()`

Run with PbPb

```
> rivet PbPb-run.hepmc -a My_RAA_Analysis \
    -o PbPb-run.yoda
```

then with pp

```
> rivet pp-run.hepmc -a My_RAA_Analysis \
    -o pp-run.yoda
```

then merge the output files

```
> rivet-merge PbPb-run.yoda pp-run.yoda \
    -o RAAplots.yoda
```

`finalize()` will be run in all steps, but only in **`rivet-merge`** will it find that both PbPb and pp histograms are filled and will then perform the R_{AA} ratios.

Other new Rivet stuff

Rivet in principle demands that all measurements should be *unfolded* for detector effect to measurements of final-state particles

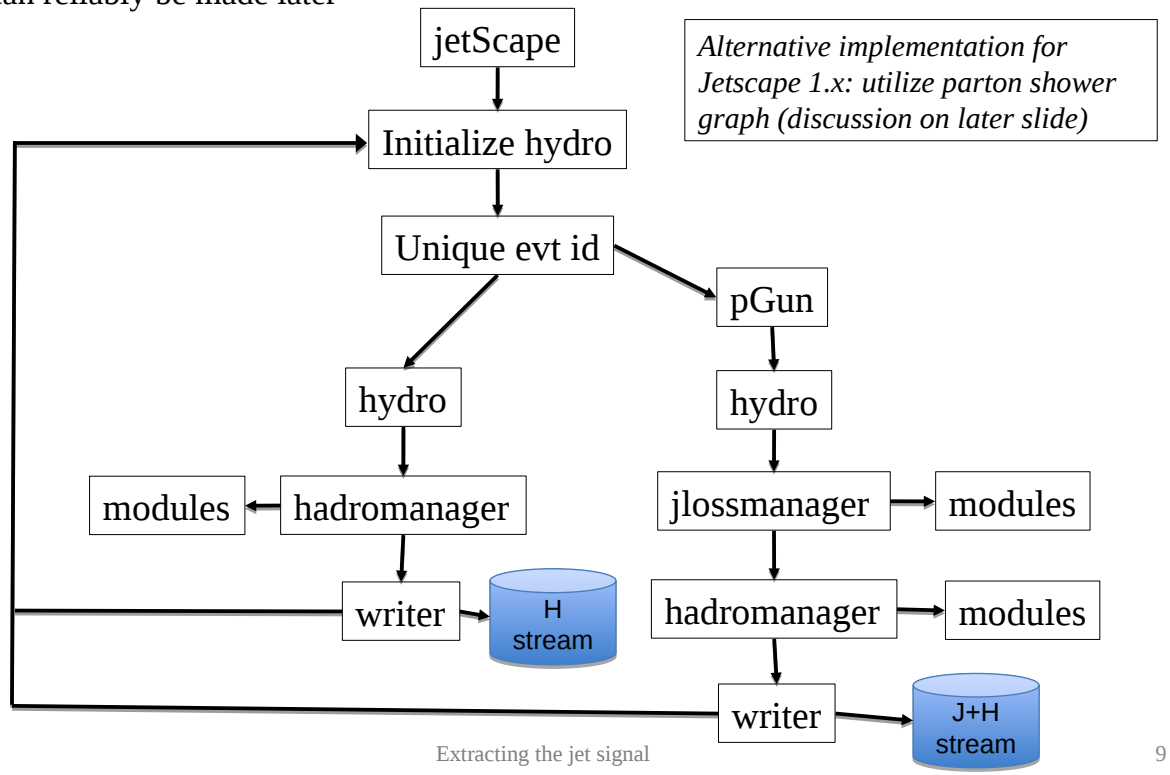
But the demand, mainly from the BSM community to make their measurements reusable, has forced us to cave in and now allow for basic detector simulations in terms of *smearing* and *efficiencies* ($\sim$ DELPHES).

Rivet and JETSCAPE

Rivet and JETSCAPE

Proposal: modified program flow

Most general implementation: separate event generation from subtraction
→write two separate event streams with unique event ID so association can reliably be made later



[From talk by Peter Jacobs]

- Major change of Rivet structure
  (but doable)
- Against the philosophy of Rivet
  (but c.f. BSM concessions)
- Event Generator dependent
  (Cannot be used with Pythia/Angantyr)

Generalization of centrality calibration

Start by running the subtraction calibration with MinBias events

```
> rivet H-stream.hepmc -a MySubtractionCalib \
   -o subtractcal.yoda
```

Then preload the calibration to be used for subtraction

```
> rivet H+J-stream.hepmc -p subtractcal.yoda \
   -a MyJetAnalysis -o JETSCAPE.yoda
```

Generalization of centrality calibration

Start by running the subtraction calibration with MinBias events

```
> rivet H-stream.hepmc -a MySubtractionCalib \
   -o subtractcal.yoda
```

Then preload the calibration to be used for subtraction

```
> rivet H+J-stream.hepmc -p subtractcal.yoda \
   -a MyJetAnalysis -o JETSCAPE.yoda
```

We can use options to run the same analysis for generators without background

```
> rivet JEWEL.hepmc -p subtractcal.yoda \
   -a MyJetAnalysis:subt=NONE \
   -o JEWEL.yoda
```

Conclusions

Rivet has re-defined the way we think about measurements in the HEP community, encouraging experiments to publish results in a *model-indepent* and *reinterpretable* way.

We would like the NP community to follow.

LUND UNIVERSITY

Rivet

Leif Lönnblad

Department of Astronomy
and Theoretical Physics
Lund University

JETSCAPE Winter Meeting
2020-03-19