

Rivet for Heavy Ions

latest developments

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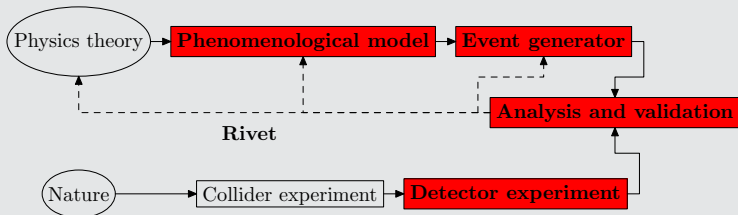
Lund University

December 10 2018, MPI@LHC Perugia



- Analysis system for Monte Carlo events. (Buckley *et. al.*: arXiv:1003.0694.)
 1. Data preservation.
 2. Monte Carlo validation.
- Generator independent, HepMC events.
- C++ library with analyses as "plugins", optimally written by the analyser.

The bigger picture



LHC Coverage

- Main LHC pp and LEP analyses.
- Standard tool @ LHC, fair coverage...

Rivet LHC analysis coverage

Rivet analyses exist for 240/1790 papers = 13%. 119 priority analyses required.

Total number of Inspire papers scanned = 2895, at 2018-10-12

Breakdown by identified experiment (in development):

Key	ALICE	ATLAS	CMS	LHCb	Other
Rivet wanted (total):	205	279	338	155	573
Rivet REALLY wanted:	23	26	60	10	0
Rivet provided:	11/216 = 5%	141/420 = 34%	69/407 = 17%	11/166 = 7%	8/581 = 1%

LHC Coverage

- Main LHC pp and LEP analyses.
- Standard tool @ LHC, fair coverage...
- ...but not for heavy ions! (<http://rivet.hepforge.org>)

Rivet LHC analysis coverage (heavy ion only)

Rivet analyses exist for 0/239 papers = 0%. 28 priority analyses required.

Total number of Inspire papers scanned = 270, at 2018-10-12

Breakdown by identified experiment (in development):

Key	ALICE	ATLAS	CMS	LHCb	Other
Rivet wanted (total):	153	21	61	4	0
Rivet REALLY wanted:	18	1	9	0	0
Rivet provided:	0/153 = 0%	0/21 = 0%	0/61 = 0%	0/4 = 0%	0

Why no heavy ions?

- Heavy Ions have not been prioritized.
 - Lack of common interest (few MCs for HI).
 - Lack of specialized functionality → High threshold.

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That has changed!

- ◇ Experimental community:
pilot project lead by J. F. Grosse-Oetringhaus, P. Karczmarczyk, J. Klein (ALICE: CERN).
- ◇ MC community:
efforts by C. Bierlich, L. Lönnblad (Pythia, DIPSY: Lund).
- ◇ Efforts joined 2018:
supported by Rivet core group and University of Copenhagen,
resulting in this release.

This talk

1. Centrality selection → analysis options.
2. Comparing to pp → re-entrant finalize.
3. Flow observables → generic framework.
4. Perspectives.

Centrality selection

- Centrality is ubiquitous, but not directly measurable.
- Experiment: Forward particle production/energy flow as proxy.
Cannot always be unfolded.
- MC: Not always feasible to fold prediction with "forward central" correlation.

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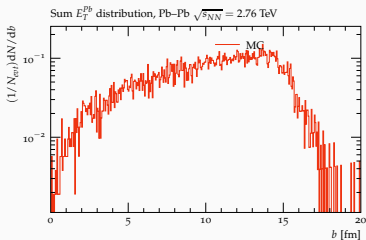
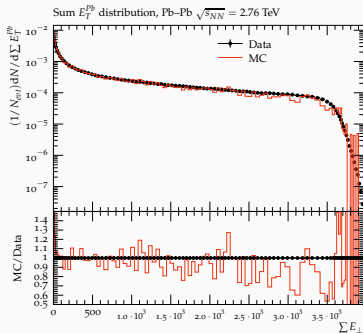
Solution: Users' choice between several options

1. Experimental measure (if existing).
2. Generated version of experimental measure.
3. Impact parameter distribution.
4. MC supplies centrality number.

- Three letter requires a "calibration run".

Centrality selection, calibration

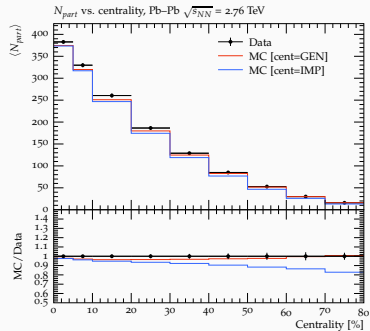
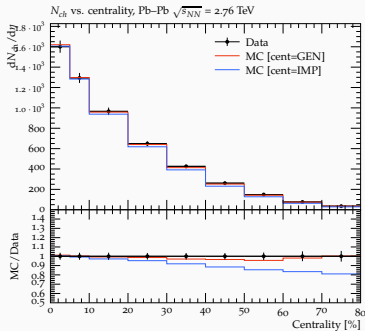
- Example calibration: ATLAS_PBPB_CENTRALITY.
- (data points extracted from paper, not unfolded).



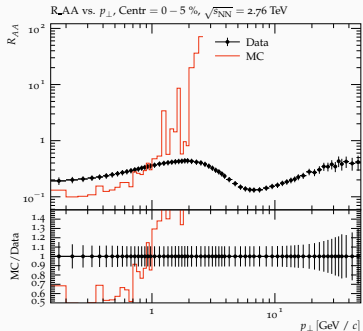
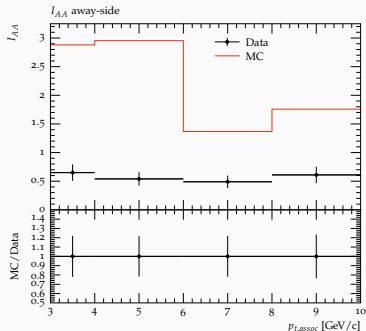
- Generated histograms are preloaded into Rivet: new preload option.

Centrality and Rivet options

- New Rivet functionality: Analysis options, selected at run time.
- Run the same analysis, with different options.
- Example: ALICE_2010_I880049



Ratios to pp – "nuclear modification factors"



ALICE_2012_I930312, ALICE_2012_I1127497.

New feature: rivet-merge

1. Read in histogram files, and re-generate analysis objects (must be .yoda streamable).
2. Run `void finalize()` again.

Flow observables – generic framework

- Piecewise inclusion of HI observables, first: Flow coefficients and cumulants.
- Generic framework (the flow equivalent of FastJet!) and add-ons implemented. ([1010.0233](#), [1312.4572](#)).
- Functionality, calculate any $\langle\langle M \rangle\rangle_{m,n}$.
- Automatic subtraction of lower orders and error calculation.

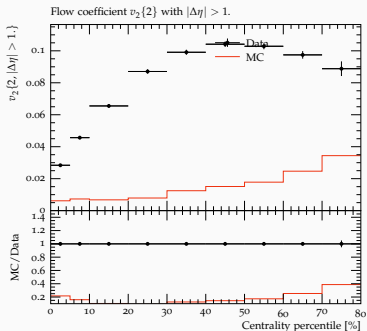
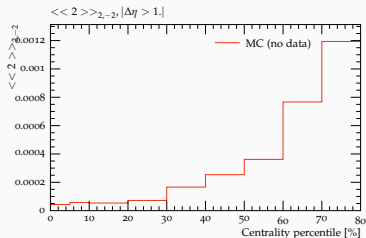
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```
1      hc24 = bookScatter2D("c24",120,0,120);
2      ec22 = bookECorrelator<2,2>("ec22",hc22);
3      ec24 = bookECorrelator<2,4>("ec24",hc24);
4      ...
5      ec22->fill(...);
6      ec24->fill(...);
7      ...
8      // c_n{4} = <<4>>_{n,-n} - 2 * <<2>>_{n,-n}
9      cnFourInt(hc24, ec22, ec24);
```

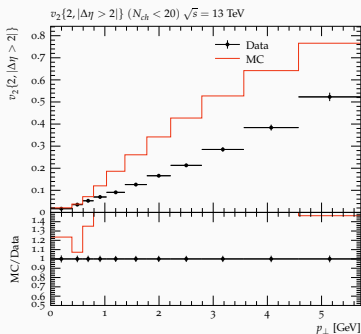
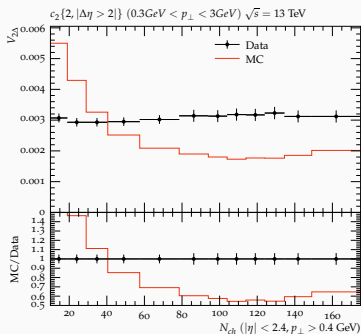
Sample results

- Some HI analyses implemented, here: ALICE_2016_I1419244.
- Correlators and cumulants can be plotted, also without data.
- Data not well reproduced by this MC.



Perspective: HI methods in pp (CMS: Evidence for collectivity in pp collisions at the LHC)

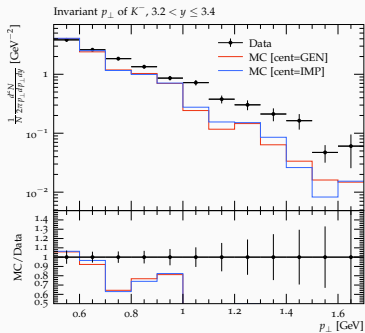
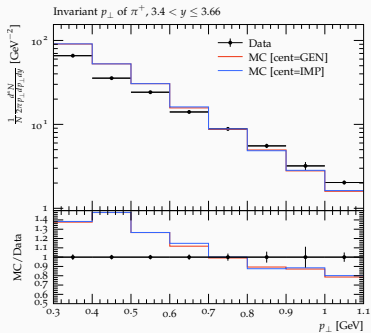
- Heavy ion methods also available for pp analyses.
- Allows for new types pp analyses in Rivet.
- Example: CMS_2017_I1471287.



- (subtraction procedures still unclear – analyser help needed!)

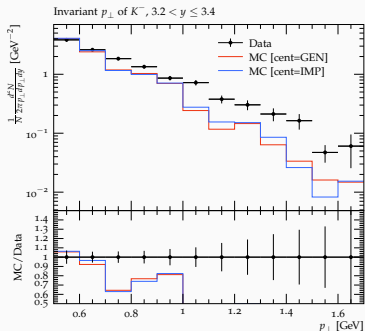
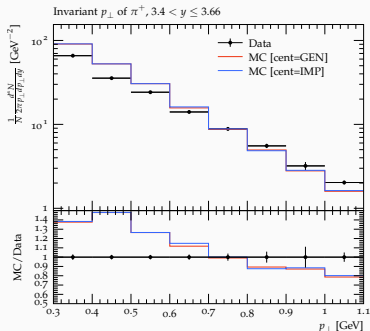
Perspective: Data preservation, RHIC

- Older data still exist – but not forever!
- Example: BRAHMS_2004_I647076, 200 GeV/nn Au–Au collisions with PID at large y_{\perp} .



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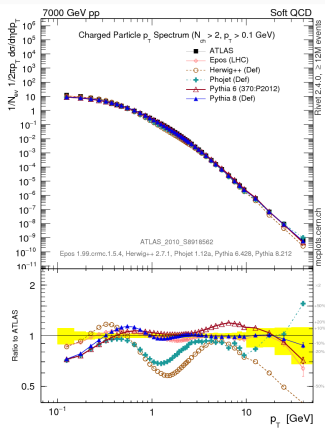
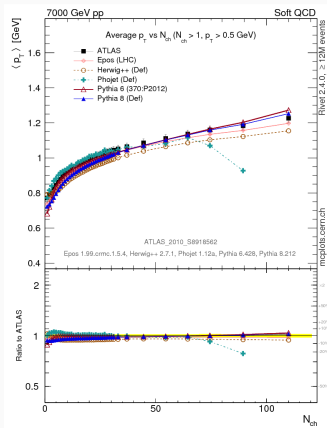


WANTED: Other RHIC collaborations!

Correlation measurements from STAR already in pipeline.

Perspective: <http://mcplots.cern.ch> for Heavy Ions

- Browsable repository of Rivet analyses and MC results.
- Excellent to search for tensions between generators.
- Development of HI support ongoing in parallel. (CERN ALICE group)



A collaborative effort

Current contributors

J. Bellm (Herwig), C. Bierlich (Pythia), A. Buckley (ATLAS), C.H. Christensen (ALICE), P. Christiansen (ALICE), C. Duncan (Pythia), P. Karczmarczyk (ALICE), P. Kirchgaesser (Herwig), J. Klein (ALICE), L. Lönnblad (Pythia), J. Monk (ATLAS), J. F. Grosse-Oetringhaus (ALICE), R. Preghenella (ALICE), V. Pacik (ALICE), C. O. Rasmussen (Pythia), M. Stefaniak (EPOS + STAR), F. Thoresen (ALICE), V. Vislavicius (ALICE).

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You can contribute too!

- We need your analyses!
- Rough alpha release can be downloaded and tested at:
<https://rivet.hepforge.org/downloads/>.

Summary

- Several heavy ion features have been added to Rivet.
- Focus mainly on soft observables so far, ≈ 15 analyses in release.
- Possible to add new and old analyses.

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Have: Framework, Need: Users!

First tutorial planned for COST Workshop in Lund, Sweden, Feb. 25th - Mar. 1st 2019.

<https://indico.lucas.lu.se/event/1065/>