Analysis preservation in heavy-ion collisions experiments

Reinterpretation of LHC Results for New Physics
Dec 13, 2022

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Outline

- **Analysis preservation**
  - **Why should I care?**
- **How to preserve analyses**
  - **Rivet, HepMC, and HepData**
- **Recent developments in heavy-ion collisions**

Analysis preservation

Analysis preservation

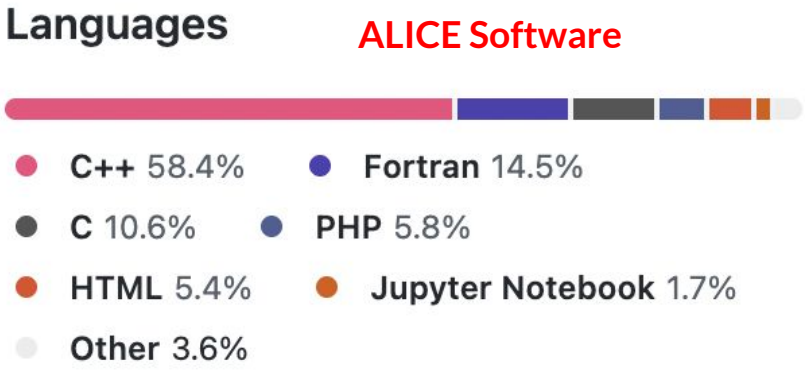
- **Recent heavy-ion experiments keep their codes in online repositories**
  - **Github, gitlab, etc**

- **10 years after “the end” of an experiment, a new heavy-ion collision model/Monte Carlo is released**

- **How likely will I be able to use this model/Monte Carlo to reproduce all the techniques and methods used by the experiment and make a comparison to the published data?**

Analysis preservation

- **Heavy-ion experiments have a large and complex software**



- **First commits are from March 2009**

- **C++ is backward compatible, but compilers implementing it are not!**
  - **Try to build 10 years old code from experiments… good luck!**

Analysis preservation

- **Papers have a great focus on results and data**
- **Complexity of analyses increases with time**
  - **Unfolding, machine learning, etc**
- **Tiny, but relevant details in analyses can be missing in the publication**
  - **Not always you can use as many pages as you want**
- **Even internal analysis notes can be incomplete**

Analysis preservation

- **Reproducing tiny details from papers can be very time consuming**
  - **Mistakes and be difficult to identify**

- **For people outside the experiment the situation is even more complicated**
  - **Even for theoreticians**
  - **Many observables or estimators definition are not clear**
  - **Centrality, multiplicity, etc**

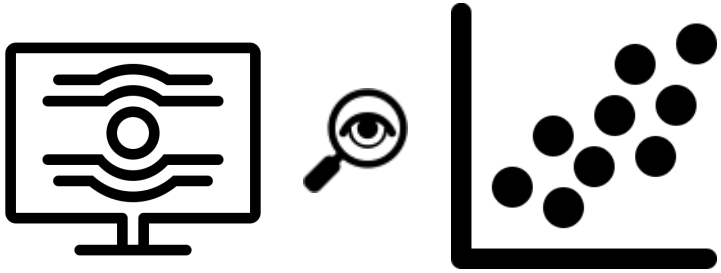
- **Reproducing comparison to models can be very challenging!**

Rivet, HepMC, and HepData

What's Rivet?

Robust Independent Validation of Experiment and Theory (Rivet)

Analysis Code Repository



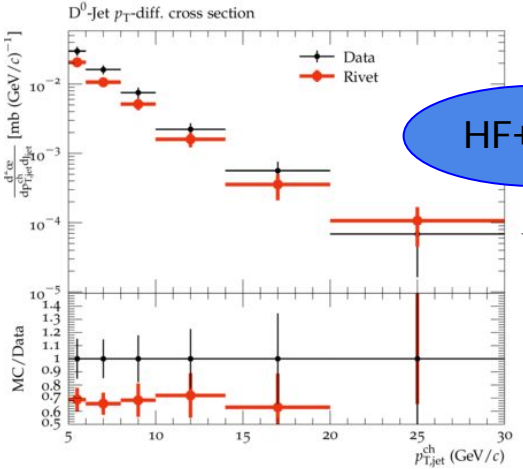
Comparison between theory and data

HEPData

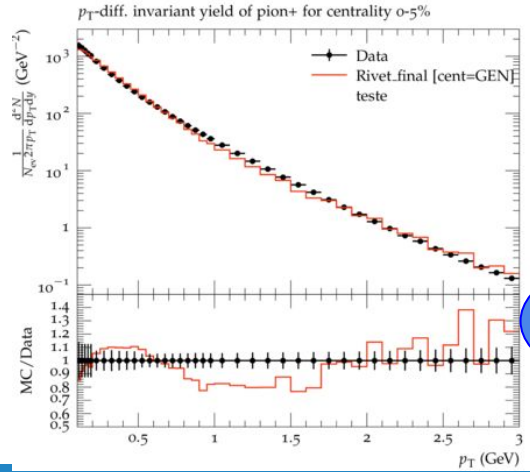
Search for data
EXPERIMENT_YEAR_I<InspireNumber>

Relatively easy to use

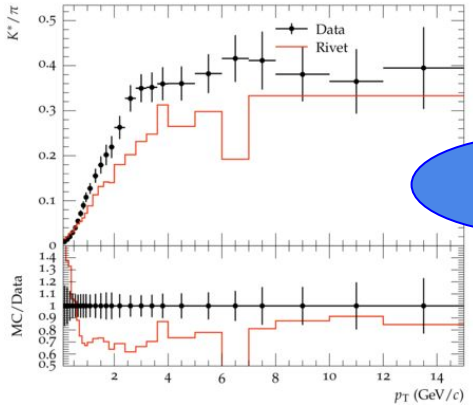
What's Rivet?



HF+Jets



Particle Spectra



Ratios

PYTHIA AMPT HIJING JETSCAPE

Monte Carlo Model

JEWEL EPOS smash

HepMC

HEPData

Rivet

What's Rivet?

Interface between MC and analysis
arxiv.org/abs/1912.08005

Preservation of scientific results

HepMC

HEPData

Rivet

Analysis repository
arxiv.org/abs/1003.0694

HepMC

- **Framework for recording high-energy physics simulations**
  - **Arxiv: https://arxiv.org/abs/1912.08005**
- **Available as direct output in most modern event generators**
- **Interface between Monte Carlo simulations and analyses**
- **Store information of final state particles. Compatible to HI**
- **See HepMC in heavy-ion collisions workshop**
  - **https://indico.bnl.gov/event/10966/**

HepData

- **Repository for published results**
- **Widely adopted by experiments**
  - **Part of the publication procedure**
- **It would be very useful if simulation points were also stored in the same way!**
  - **Comparison using Rivet analysis would be easier**

Rivet

- **Experiment independent framework**
- **MC analysis repository**
- **The ideal scenario → experiments implementing Rivet analyses**
  - **High fidelity in reproducing selections and methods**
  - **New projections (classes) can be implemented**
  - **Rivet analysis available as soon as paper is published**
- **See https://gitlab.com/hepcedar/rivet**

Analysis preservation

What Rivet can offer

- Generator-independent analysis preservation
- Validation/tuning of event generators
- Read outputs generated with HepMC framework (from file or in FIFO mode)
- Multiple analysis can be run over the same simulation at once
- A considerable (~1000) number of analyses already available
- Easy comparison between event generators and experimental data

Key	ALICE	ATLAS	CMS	LHCb	Forward	HERA	e^+e^- (≥ 12 GeV)	e^+e^- (≤ 12 GeV)	Tevatron	RHIC	SPS	Other
Rivet wanted (total):	269	331	446	253	17	496	715	558	1131	460	62	1
Rivet REALLY wanted:	36	38	85	8	0	12	1	0	5	1	0	0
Rivet provided:	**26**/295 = **9%**	**181**/512 = **35%**	**94**/540 = **17%**	**16**/269 = **6%**	**8**/25 = **32%**	**17**/513 = **3%**	**180**/895 = **20%**	**305**/863 = **35%**	**58**/1189 = **5%**	**8**/468 = **2%**	**4**/66 = **6%**	**112**/113 = **99%**

https://rivet.hepforge.org/rivet-coverage

What Rivet can already do

- ALICE primary particles definition (from https://cds.cern.ch/record/2270008/files/cds.pdf)

> A primary particle is a particle with a mean proper lifetime τ larger than 1 cm/c, which is either a) produced directly in the interaction, or b) from decays of particles with τ smaller than 1 cm/c, restricted to decay chains leading to the interaction.

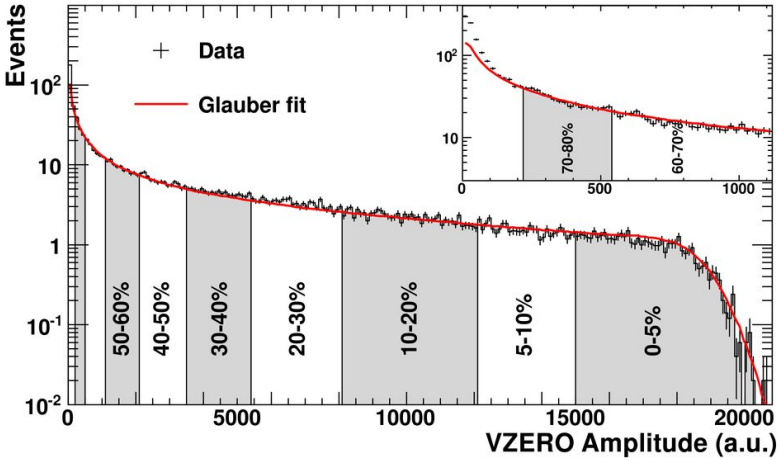
  - The definition of primary particles is experiment-dependent
- Other experiments could have their own primary particle definitions
- Useful in special for people outside the collaborations

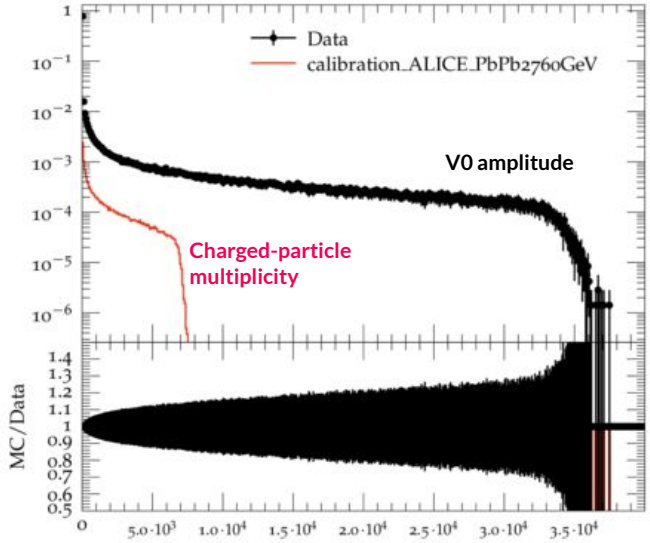
What Rivet can already do

Centrality determination in Rivet

- A calibration file has to be produced before running the analysis
  - Each event generator needs a different calibration
  - A dedicated plugin is used to create the calibration files

- The calibration creates a probability density of number of charged particles per event in the acceptance of the V0 detector
  - $2.8 < \eta_{V0A} < 5.1$ and $-3.7 < \eta_{V0C} < -1.7$

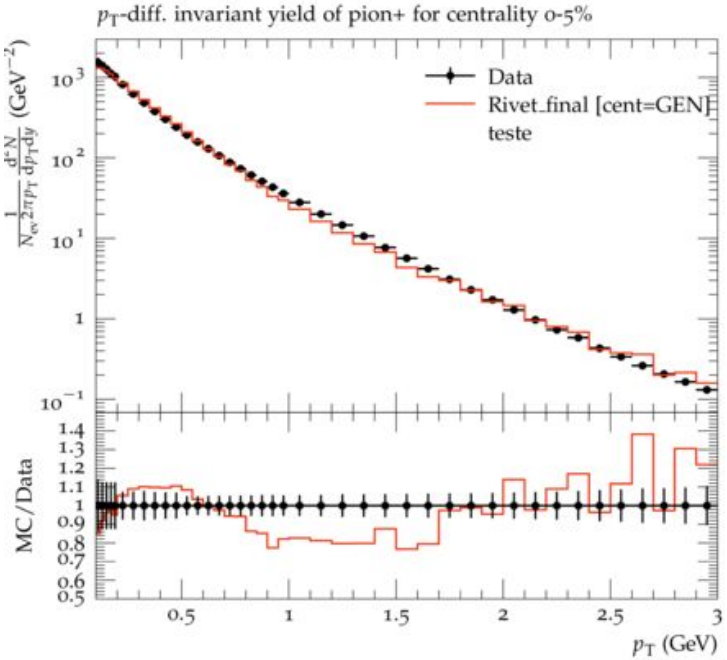




What Rivet can already do

Centrality determination in Rivet

- The calibration file is given to Rivet as a pre-load
- During the analysis run, the centrality is calculated in each event



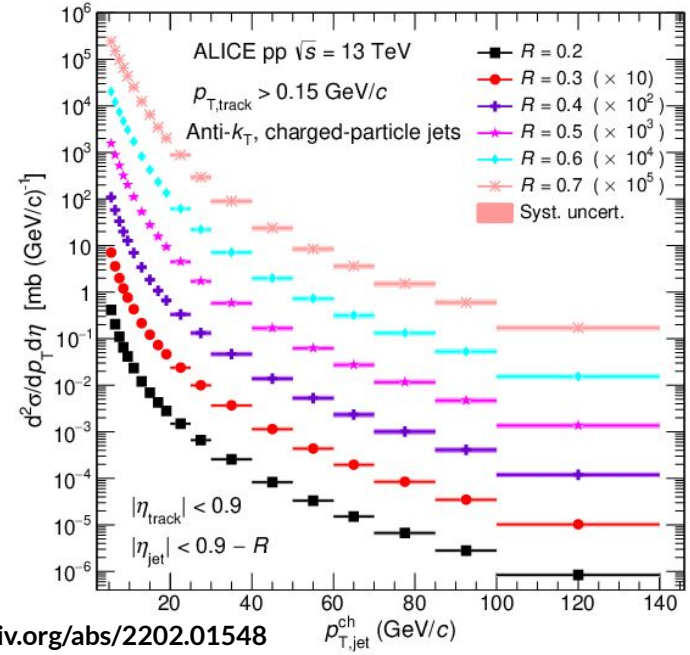
- Centrality is calculated in a way analogous to what is done in the experiment
- Simple implementation
- Previous knowledge of experimental methods is not necessary
- Not a black box! Code is open and methods can be understood

Recent developments in Rivet for heavy ions

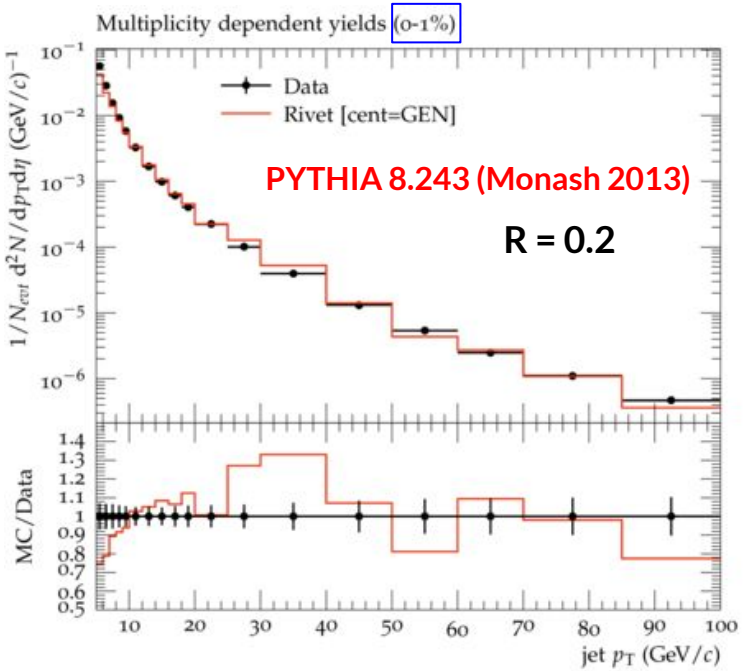
Multiplicity

Analysis using V0M/<V0M>

- Multiplicity dependence of charged-particle jet production in pp collisions at 13 TeV
- Rivet plugin for this analysis is under development

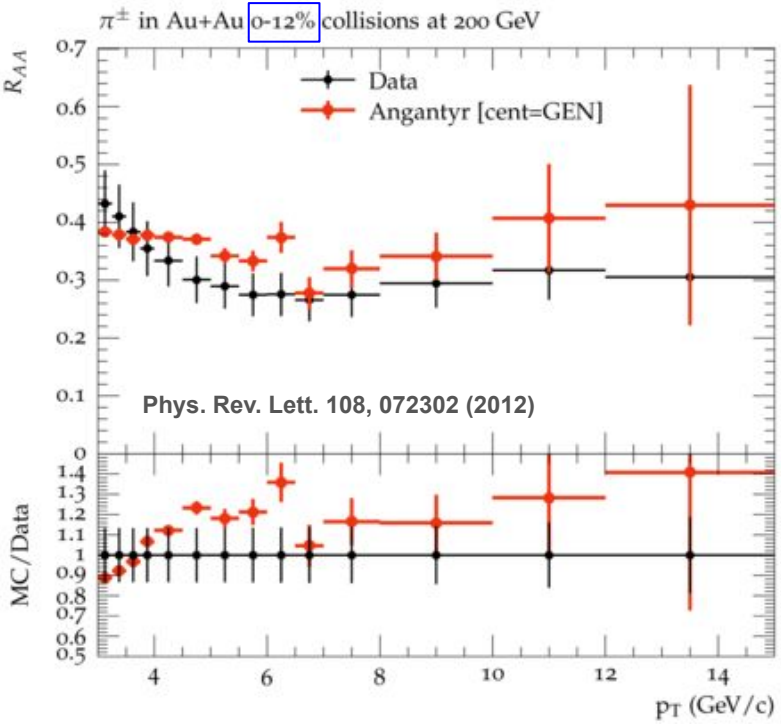


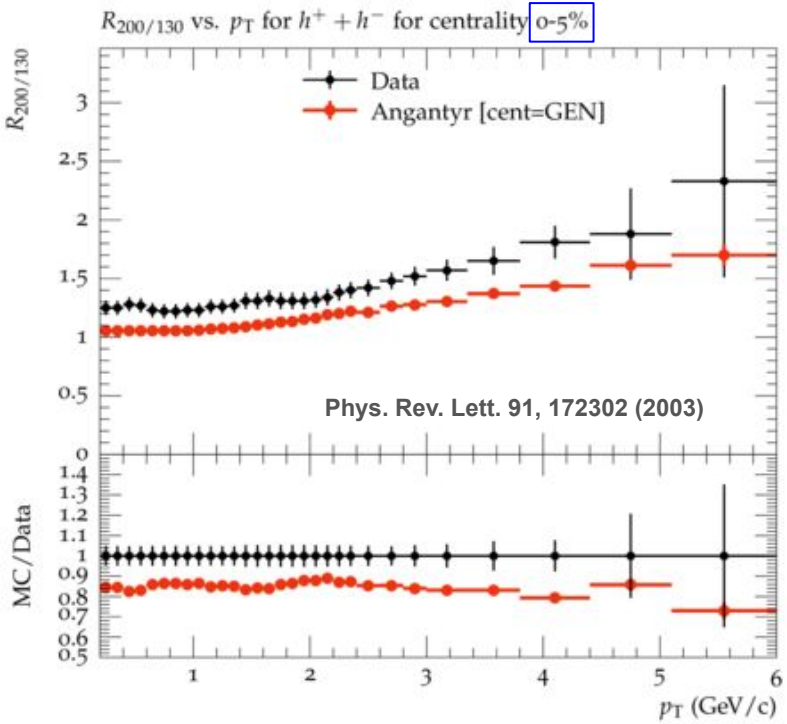
arxiv.org/abs/2202.01548



Centrality for STAR and PHENIX

- **The centrality determination in Rivet is based on the same methods used by the respective experiments**
- **Critical feature for the implementation of heavy-ion analyses in Rivet**
- **Not yet endorsed by the experiment**





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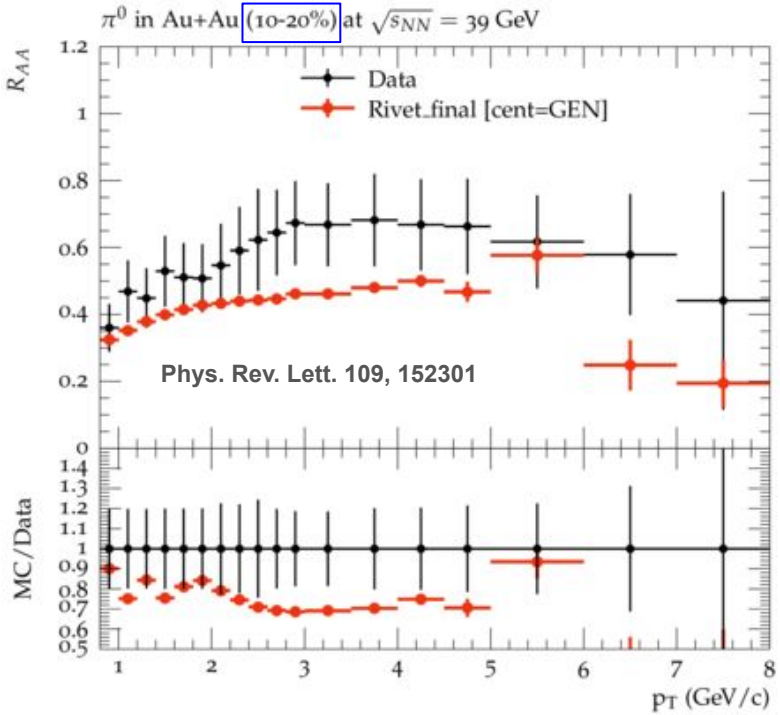

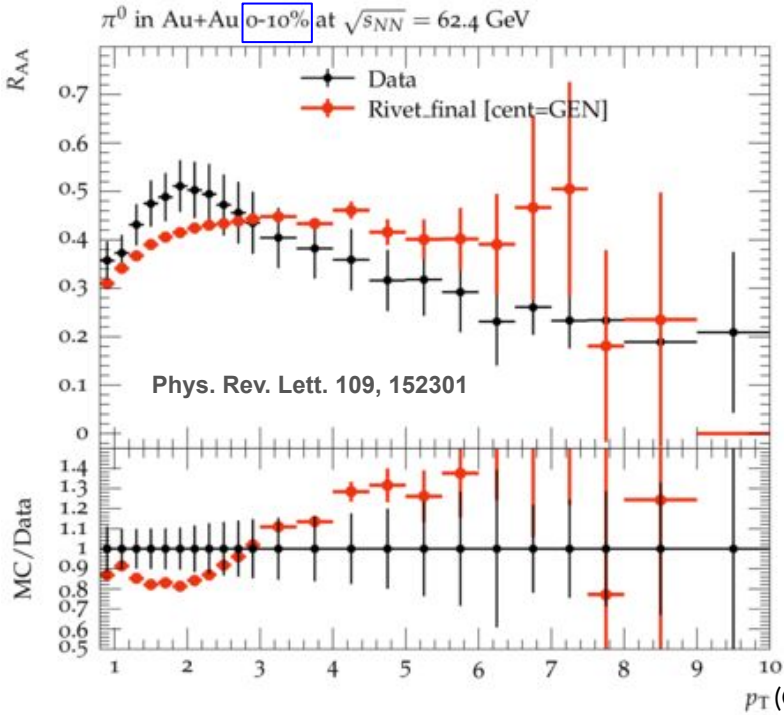

Rivet workshops and classes

Course-based Undergraduate Research Experience

Instructors: Dr. Christine Nattrass and Antonio Silva

- The course is in its 4th semester
- 17 undergraduate students
- Good source of workers for implementing analyses in Rivet

CBE Life Sci Educ. Summer 2016;15(2):ar20. doi: 10.1187/cbe.16-03-0117.

Early Engagement in Course-Based Research Increases Graduation Rates and Completion of Science, Engineering, and Mathematics Degrees

Stacia E Rodenbusch [1], Paul R Hernandez [2], Sarah L Simmons [3], Erin L Dolan [4]

Affiliations + expand

PMID: 27252296 PMCID: PMC4909342 DOI: 10.1187/cbe.16-03-0117

Free PMC article

Rivet workshop focused on RHIC publications

Rivetizing Heavy Ion Collisions at RHIC 2020

30 November 2020 to 4 December 2020
Online
US/Eastern timezone

Summary

- **Rivet** → **Experimental analysis for MC repository**
- **HepData** → **Repository of data**
- **HepMC** → **Interface between MC and analyses**

- Data and analysis preservation
- Easy comparison of data and theory

- **High-energy experiments are expensive!**
  - **We should preserve as much as possible!**
- **Heavy-ion community needs to preserve the power to reproduce analyses**
- **Analysis preservation could be incorporated as part of the publication process**