A brief introduction to RIVET for the EIC

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Day 2: RIVET

- Yesterday: went through PYTHIA8, and ran a RIVET analysis.
- Today: a more detailed introduction to RIVET.
- Prerequisites:
  - A working installation of the tutorial image.
  - A HEPMC *ep* sample (generated yesterday, or download later).
- Program:

  25' Introduction to RIVET.
  10' Questions and start group work.
  35' Groups: Write your own analysis (including small break).
  10' Follow-up on exercise & start next one (in plenary room).
  35' Groups: Advanced analysis features.
  5' End of day (in plenary room).
- This tutorial is also available as a lecture note, attached on Indico

Rivet

- Analysis system allowing for easy extraction of observables and plots from *any* Monte Carlo event generator.
- Requires only HepMC event output – no access to "unphysical" observables.
- Well suited for MC/data comparisons, with *many* analyses implemented.

Rivet analysis coverage

Rivet analyses exist for 917/5952 papers = 15%. 196 priority analyses required.

Total number of Inspire papers scanned = 10604, at 2020-07-02

Breakdown by identified experiment (in development):

Key	ALICE	ATLAS	CMS	LHCb	Forward	HERA	$e^+e^-(\geq 12$ GeV)	$e^+e^-(\leq 12$ GeV)	Tevatron	RHIC	SPS	Other
Rivet wanted (total):	259	311	411	222	44	520	800	690	1238	476	63	1
Rivet REALLY wanted:	36	45	82	9	0	13	1	3	6	1	0	0
Rivet provided:	**26**/285 = **9%**	**165**/476 = **35%**	**86**/497 = **17%**	**13**/235 = **6%**	**8**/52 = **15%**	**9**/529 = **2%**	**176**/976 = **18%**	**348**/1038 = **34%**	**59**/1297 = **5%**	**9**/485 = **2%**	**5**/68 = **7%**	**16**/17 = **94%**

- ...but also the tool of choice for communication between MC developers internally & to experiments.

Unphysical observables? What?

- Remember the event graph from yesterday?
  1. No experimental access to intermediate steps.
  2. (Many HERA analyses corrected to "Born level").
  3. Some steps cannot even be compared across generators!
- DIS physics adds other complications.
  1. The scattered lepton may not be uniquely determinable. Needs to mimic data analysis.
  2. Same problem for defining diffraction.
- And so does heavy ion physics & jets.
  1. HI: Measured centrality vs. "theoretical" centrality.
  2. Jets: Experimental jet definition vs. parton level jet.

RIVET is designed to mitigate

If you cannot put it in RIVET, it is not physical!

Tool of communication

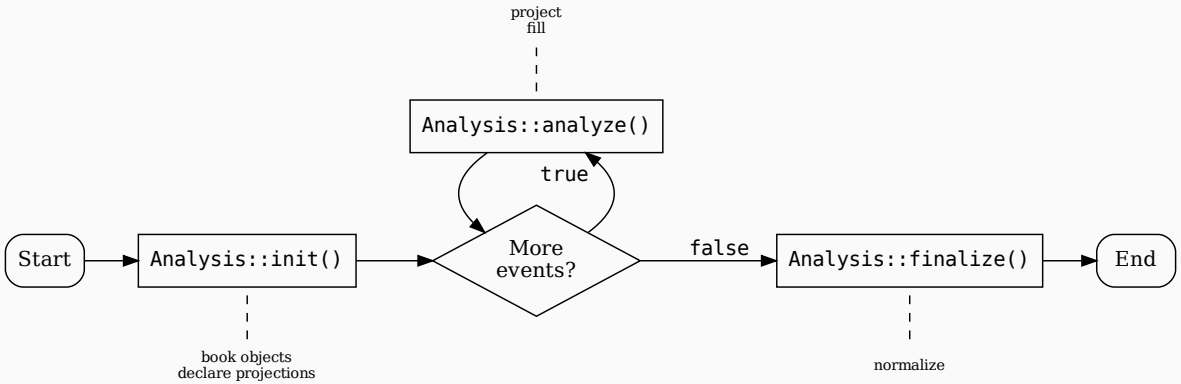
- For MC authors RIVET is also an invaluable tool of communication.
- Frequent use case: Compare observable across generators for prediction/validation.
- Two key features:
  1. Generator-agnostic analysis means rapid turn-around.
  2. Observables are physical *by design*.
- Also useful for MC/exp communication.
  1. Acceptances and trigger definitions encoded directly.
  2. EASY! No need for MC developers to install large exp. code frameworks.
  3. No ambiguity in definitions of observables.

Communication with the EICUG

MC authors prefer to communicate analyses with RIVET.
If you don't use it, expect long answer times!

Analysis structure

- You already ran an analysis yesterday.
- Let's take a look at the general structure.



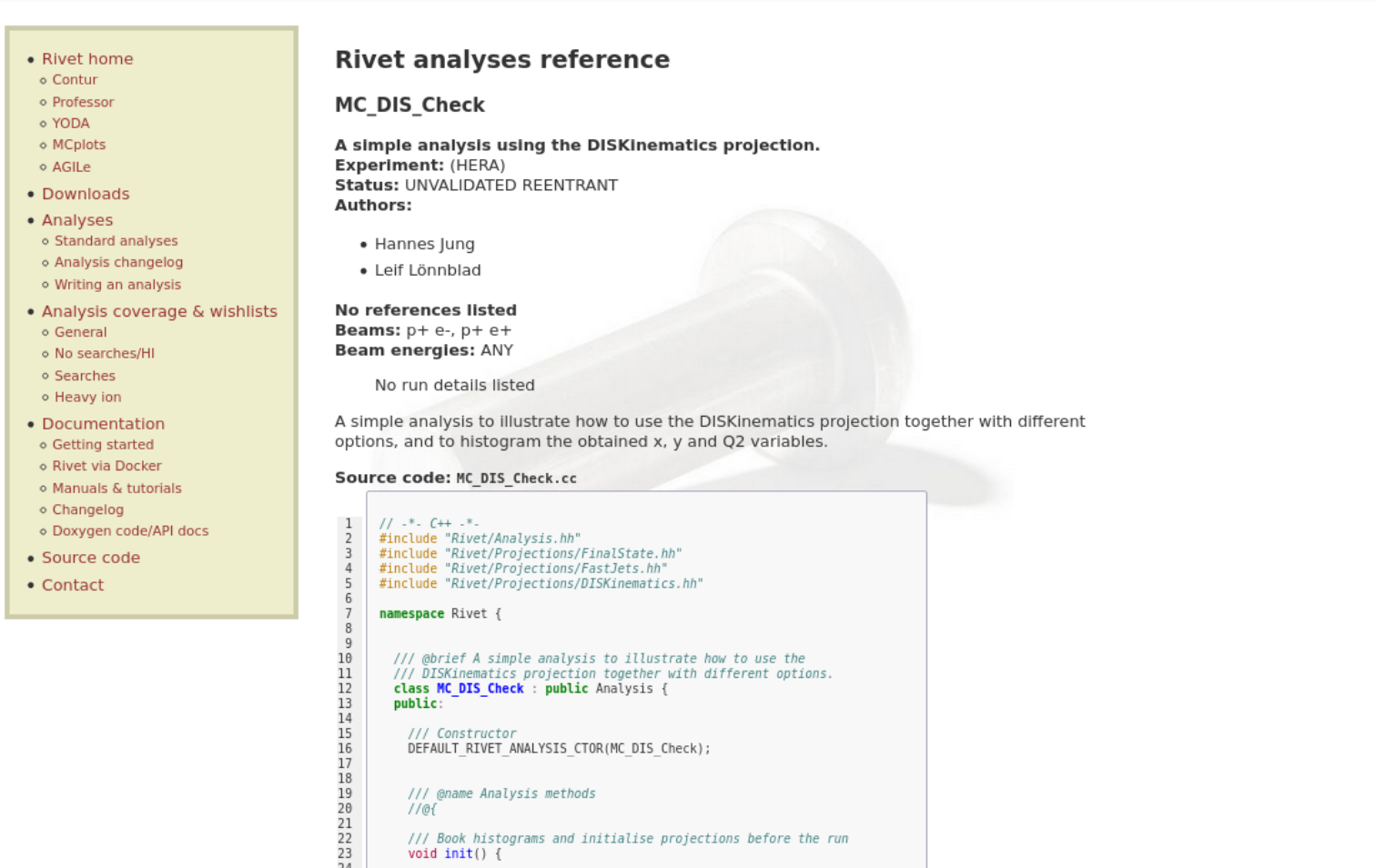
Initialization: `init()` is called once per analysis, used to declare ("book") histograms and projections.

Analysis: `analyze(const Event&)`is called once per event, analyze events and fill histograms.

Finalization: `finalize()` is called once, at the end of each analysis, apply normalizations, fill histograms with all-event averages, construct ratios.

A closer look

- We'll take a closer look at the analysis MC_DIS_Check.
- All analyses can be studied in the online documentation.
- Keywords: class structure, projections: booking, projections: using, histograms: booking, filling and scaling.



- Rivet home
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Rivet analyses reference

MC_DIS_Check

A simple analysis using the DISKinematics projection.
Experiment: (HERA)
Status: UNVALIDATED REENTRANT
Authors:

- Hannes Jung
- Leif Lönnblad

No references listed
Beams: p+ e-, p+ e+
Beam energies: ANY

No run details listed

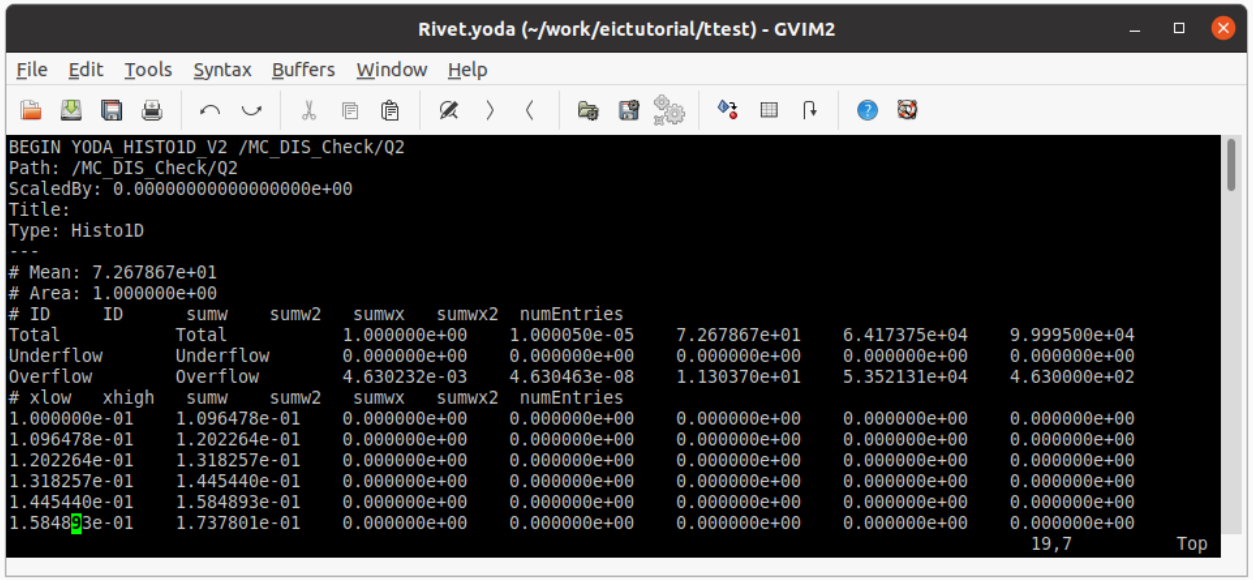
A simple analysis to illustrate how to use the DISKinematics projection together with different options, and to histogram the obtained x, y and Q2 variables.

Source code: `MC_DIS_Check.cc`

```
// -*- C++ -*-
#include "Rivet/Analysis.hh"
#include "Rivet/Projections/FinalState.hh"
#include "Rivet/Projections/FastJets.hh"
#include "Rivet/Projections/DISKinematics.hh"

namespace Rivet {


  /// @brief A simple analysis to illustrate how to use the
  /// DISKinematics projection together with different options.
  class MC_DIS_Check : public Analysis {
  public:

    /// Constructor
    DEFAULT_RIVET_ANALYSIS_CTOR(MC_DIS_Check);


    /// @name Analysis methods
    //@{

    /// Book histograms and initialise projections before the run
    void init() {
```

Analysis output

- You will run the analysis from command line in a minute.
- The output file is in the YODA format.
- YODA is light-weight, and optimized for hep usage.



But... ROOT?

ROOT is too heavy weight to include as a dependency for MC developers. You can convert YODA histograms to ROOT with `yoda2root` (see online docs).

Setting up RIVET

- Installation instructions and standard tutorials can be found on gitlab.

Local installation

Mostly harmless to install, using the installation script.
Requires C++14.

- For this tutorial, we use the same docker image as yesterday (with RIVET 3.1.2 installed).

Docker setup

```
docker pull electronioncollider/pythia-eic-tutorial
```

- See next page for further setup.

Further setup

- Navigate to the working directory from yesterday.
- Expose relevant RIVET commands from the container.

```
$> alias rivet='docker run -i  --rm  -u `id -u $USER`:`id -g` \
    -v $PWD:$PWD -w $PWD electronioncollider/pythia-eic-tutorial rivet'
$> alias rivet-mkanalysis='docker run -i  --rm  -u `id -u $USER`:`id -g` \
    -v $PWD:$PWD -w $PWD electronioncollider/pythia-eic-tutorial \
    rivet-mkanalysis'
$> alias rivet-build='docker run -i  --rm  -u `id -u $USER`:`id -g` \
    -v $PWD:$PWD -w $PWD electronioncollider/pythia-eic-tutorial \
    rivet-build'
$> alias rivet-mkhtml='docker run -i  --rm  -u `id -u $USER`:`id -g` \
    -v $PWD:$PWD -w $PWD electronioncollider/pythia-eic-tutorial \
    rivet-mkhtml'
```

- You can now run RIVET from the command line, as if it was installed on your own machine.

Try this:

```
$> rivet --help # Display the Rivet help menu
$> rivet --list-analyses # List available analyses on your system
```

Exercises: Run analyses & writing your first analysis

- It is time to get to work!
- I will first show you how to run analyses on the command line, using your pre-generated HepMC file, following the tutorial sheet.
- You will then be divided into smaller groups, and should follow the attached tutorial sheet, where you will:
  1. Study the analyses.
  2. Write your own analysis, which adds more observables.
- Start from section 4 in the tutorial sheet, and work through until section 7 (More advanced analysis techniques), or however far you get.
- I will visit all the breakout rooms, and answer questions.
- We reconvene in 35 minutes (including a short break).

Have fun!

Follow-up on first exercise

- The tutorial sheet includes a possible solution to the exercise.

Advanced analysis features

- For the next exercise, you can choose between three features.
  1. Interact with an analysis using `options`.
  2. Percentile binning of observables.
  3. Jet finding with FastJet.
- The instructions in the sheet are a bit more fast paced.
- Make sure you have a working ex. 1 analysis before moving on!
- We reconvene in 35 minutes.

The end

- You can now write a RIVET analysis, run it and produce figures.
- Most useful to preserve existing analyses and communication with MC authors.
- More functionality: detector simulation, multi-weights, NLO counter-events, multi-particle cumulants, event mixing...
- Need more?
  Documentation: rivet.hepforge.org.
  Mailing list: rivet-developers@cern.ch.
  Contribute? exp: Implement your analysis,
  ph: Make your generator HEPMC compatible.
  Tutorial at $MY_LAB: Get in touch. Also with different focus.
- Feedback and questions always welcome!

Thank you!