Rivet overview

Robust Independent Validation of Experiment and Theory

David Grellscheid

2015-04-28

Rivet

Andy Buckley, Jon Butterworth, David Grellscheid, Hendrik Hoeth,
Leif Lönnblad, James Monk, Holger Schulz, Frank Siegert

+ dozens of analysis authors

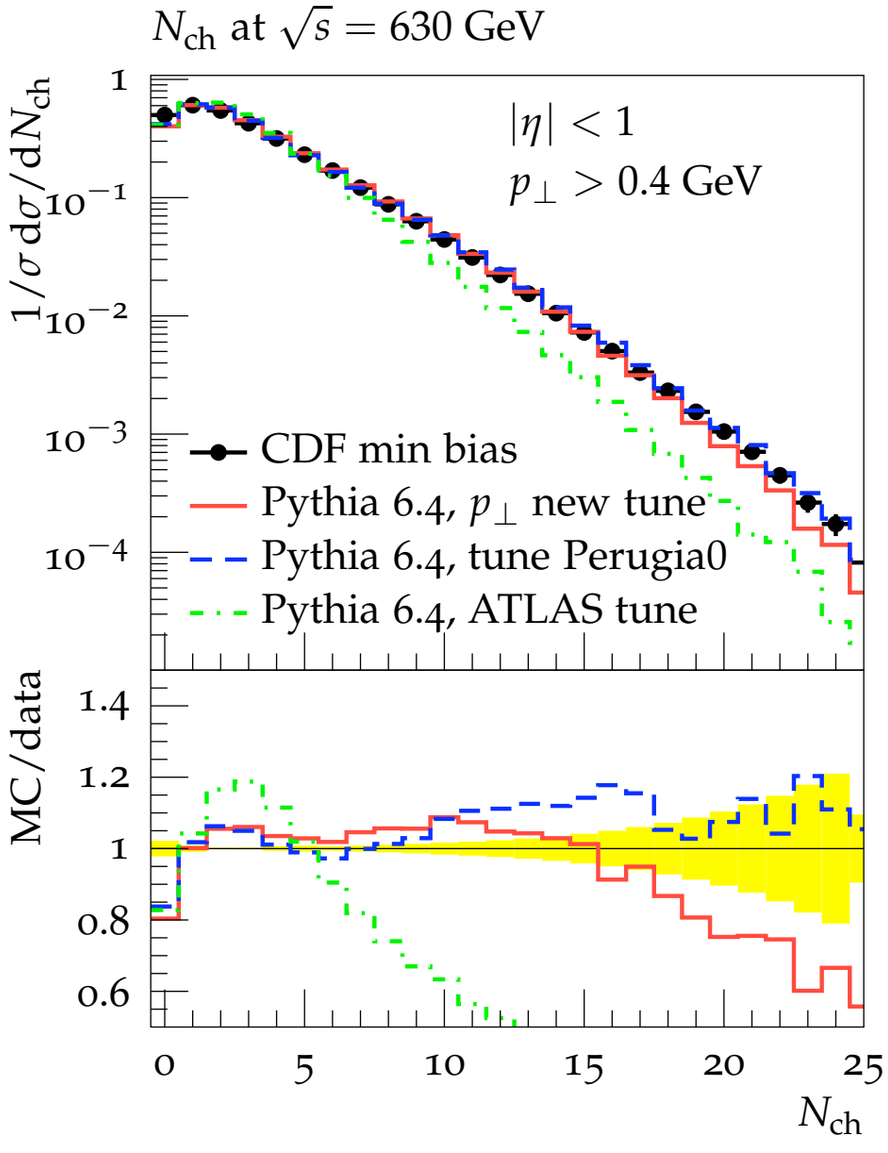
https://rivet.hepforge.org/

arXiv:1003.0694

Rivet (slide from 2009)

Tool for generator validation and comparisons with data:

- Analyses can be implemented in Rivet and applied to MC
- Uses HepMC ⇒ generator-independent, perfect for comparisons
- Many key analyses are already implemented; many more to come.
- Important for keeping your data alive: Publish your numbers corrected to hadron level and implement your analysis in Rivet.



Rivet analyses

```
$ rivet --list-analyses
ALEPH_1991_S2435284         Hadronic Z decay charged multiplicity measurement
ALEPH_1996_S3196992         Measurement of the quark to photon fragmentation function
ALEPH_1996_S3486095         Studies of QCD with the ALEPH detector.
ALEPH_1999_S4193598         Scaled energy distribution of $D^*$ at LEP
ALEPH_2001_S4656318         Study of the fragmentation of b quarks into B mesons at the Z peak
ALEPH_2002_S4823664         $\eta$ and $\omega$ Production in Hadronic $Z^0$ Decays
ALEPH_2004_S5765862         Jet rates and event shapes at LEP I and II
ALICE_2010_S8624100         Charged particle multiplicities at 0.9 and 2.36\;TeV in three different pseudorapidity
ALICE_2010_S8625980         Pseudorapidities at three energies, charged multiplicity at 7 TeV.
ALICE_2010_S8706239         Charged particle $\langle p_\perp \rangle$ vs. $N_\text{ch}$ in $pp$ collisions at 900 GeV
ALICE_2011_S8909580         Strange particle production in proton-proton collisions at $\sqrt{s} = 0.9$ TeV with ALICE
ALICE_2011_S8945144         Tranverse momentum spectra of pions, kaons and protons in pp collisions at 0.9 TeV
ALICE_2012_I1181770         Measurement of inelastic, single- and double-diffraction cross sections in proton--proton
ARGUS_1993_S2653028         Inclusive production of charged pions, kaons and protons in $\Upsilon(4S)$ decays.
ARGUS_1993_S2669951         Production of the $\eta'(958)$ and $f_0(980)$ in $e^+e^-$ annihilation in the Upsilon region.
ARGUS_1993_S2789213         Inclusive production of $K^*(892)$, $\rho^0(770)$, and $\omega(783)$ mesons in the upsilon
ATLAS_2010_S8591806         Charged particles at 900 GeV in ATLAS
ATLAS_2010_S8817804         Inclusive jet cross section and di-jet mass and chi spectra at 7 TeV in ATLAS
ATLAS_2010_S8894728         Track-based underlying event at 900 GeV and 7 TeV in ATLAS
[… skip 300 …]
UA5_1989_S1926373           UA5 charged multiplicity measurements
```

One analysis per publication, covering LEP, Tevatron, LHC, …

Most new analyses contributed directly by experiments

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UA5_1989_S1926373           UA5 charged multiplicity measurements
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$ rivet-findid 1211.6899
title       Measurement of angular correlations in Drell-Yan lepton
arxiv       1211.6899
arxiv_url   http://arxiv.org/abs/1211.6899
inspire     1204784
inspire_url http://inspirehep.net/record/1204784
rivet       ATLAS_2012_I1204784
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One analysis per publication, covering LEP, Tevatron, LHC, …

Most new analyses contributed directly by experiments

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$ rivet --show-analysis  ATLAS_2012_I1204784

ATLAS_2012_I1204784
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Measurement of angular correlations in Drell-Yan lepton pairs to probe $Z/\gamma^*$ boson transverse momentum

Status: VALIDATED

Inspire ID: 1204784
Inspire URL: http://inspire-hep.net/record/1204784
HepData URL: http://hepdata.cedar.ac.uk/view/ins1204784
Experiment: ATLAS (LHC)
Year of publication: 2012
Authors:
  Elena Yatsenko <elena.yatsenko.de@gmail.com>
  Kiran Joshi <kiran.joshi@cern.ch>

Description:
  A measurement of angular correlations in Drell-Yan lepton pairs via the
  $\phi^*$ observable is presented. This variable probes the same physics
  as the $Z/\gamma^*$  boson transverse momentum with a better experimental
  resolution. The $Z/\gamma^* \to ee$ and $Z/\gamma^* \to \mu \mu$ decays
  produced in proton--proton collisions at a centre-of-mass energy of
  $\sqrt{s} = 7\;\TeV$ are used. Normalised differential cross sections as
  a function of $\phi^*$ are measured separately for electron and muon
  decay channels. The cross-section is also measured double differentially
  as a function of $\phi^*$ for three independent bins of the $Z$ boson
  rapidity.

Beams: p+ p+
Beam energies: (3500.0, 3500.0) GeV
Run details:
  $Z/\gamma^*$ production with decays to electrons and/or muons.

References:
  arXiv:1211.6899 [hep-ex] - http://arxiv.org/abs/1211.6899
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AAD 2013 — Measurement of angular correlations in Drell-Yan lepton pairs to probe Z/gamma* boson transverse momentum at sqrt(s)=7 TeV with the ATLAS detector

Experiment: **CERN-LHC-ATLAS (ATLAS)**
Published in **PL B720,32** (DOI:10.1016/j.physletb.2013.01.054)
Preprinted as **CERN-PH-EP-2012-325**
Archived as: **ARXIV:1211.6899**
Record in: **INSPIRE**
Rivet Analysis: **ATLAS_2012_I1204784**

CERN-LHC. Measurements of the PHI* distributions of di-electron and di-muon Drell-Yan pairs produced in proton-proton collisions at a centre-of-mass energy of 7 TeV. The data sample has an integrated luminosity of 4.6 fb-1. Normalised differential PHI* distributions are presented within the fiducial region of the leptons corrected to three levels, Born, dressed and bare, for QED FSR. The data are presented for di-electron and di-muons separately as well as combined, and also in three regions of rapidity as well as overall. For details of the variables see the text of the article. UPDATE (05 JAN 2015): corrected columns 2,3,4 of Tables 2,3,5,6 due to a bug fixed for bare and dressed cross sections in y-ranges; Table 4, value of the very last bin of the born dimuon, y>1.6, phi*=2.522-3.277 corrected (typo error).

Table 1 (T 1.) HIDE DATA or as: input, plain text, AIDA, PyROOT, YODA, ROOT, mpl, ScaVis or MarcXML
The measured PHI* distributions for the dielectron events corrected back to the born level. The distributions are normalised to unity inidividually for each abs(yrap) bin and channel.

Additional systematic error: ± 0.3% (QED FSR uncertainty, not included in the plots)

ABS(YRAP)	> 0	< 0.8	0.8-1.6	> 1.6
QED FSR level	Born			
RE	P P --> Z0 < E+ E- > X + GAMMA* < E+ E- > X			
SQRT(S)	7000.0 GeV			
PHI*	(1/SIG)*D(SIG)/DPHI*			
0.0 – 0.004	9.77 ± 0.46% (stat) ± 0.35% (sys)	9.73 ± 0.67% (stat) ± 0.41% (sys)	9.75 ± 0.75% (stat) ± 0.4% (sys)	9.90 ± 1.23% (stat) ± 0.64% (sys)
0.004 – 0.008	9.68 ± 0.47% (stat) ± 0.26% (sys)	9.56 ± 0.67% (stat) ± 0.3% (sys)	9.80 ± 0.76% (stat) ± 0.4% (sys)	9.74 ± 1.23% (stat) ± 0.72% (sys)
0.008 – 0.012	9.42 ± 0.47% (stat) ± 0.28% (sys)	9.32 ± 0.68% (stat) ± 0.38% (sys)	9.47 ± 0.77% (stat) ± 0.37% (sys)	9.59 ± 1.24% (stat) ± 0.6% (sys)
0.012 – 0.016	9.14 ± 0.48% (stat) ± 0.35% (sys)	9.01 ± 0.69% (stat) ± 0.35% (sys)	9.21 ± 0.78% (stat) ± 0.46% (sys)	9.38 ± 1.26% (stat) ± 0.78% (sys)
0.016 – 0.02	8.82 ± 0.49% (stat) ± 0.24% (sys)	8.85 ± 0.7% (stat) ± 0.32% (sys)	8.81 ± 0.8% (stat) ± 0.37% (sys)	8.70 ± 1.31% (stat) ± 0.61% (sys)
0.02 – 0.024	8.48 ± 0.5% (stat) ± 0.25% (sys)	8.51 ± 0.71% (stat) ± 0.31% (sys)	8.42 ± 0.81% (stat) ± 0.45% (sys)	8.51 ± 1.33% (stat) ± 0.64% (sys)
0.024 – 0.029	7.97 ± 0.46% (stat) ± 0.26% (sys)	7.93 ± 0.66% (stat) ± 0.36% (sys)	8.00 ± 0.75% (stat) ± 0.33% (sys)	8.05 ± 1.21% (stat) ± 0.59% (sys)
0.029 – 0.034	7.57 ± 0.47% (stat) ± 0.22% (sys)	7.58 ± 0.67% (stat) ± 0.29% (sys)	7.61 ± 0.77% (stat) ± 0.35% (sys)	7.38 ± 1.26% (stat) ± 0.56% (sys)
0.034 – 0.039	7.02 ± 0.49% (stat) ± 0.29% (sys)	7.10 ± 0.7% (stat) ± 0.32% (sys)	6.96 ± 0.8% (stat) ± 0.42% (sys)	6.87 ± 1.31% (stat) ± 0.6% (sys)
0.039 – 0.045	6.55 ± 0.46% (stat) ± 0.22% (sys)	6.50 ± 0.66% (stat) ± 0.29% (sys)	6.66 ± 0.75% (stat) ± 0.33% (sys)	6.44 ± 1.24% (stat) ± 0.54% (sys)
0.045 – 0.051	5.93 ± 0.48% (stat) ± 0.22% (sys)	5.88 ± 0.69% (stat) ± 0.28% (sys)	5.94 ± 0.79% (stat) ± 0.34% (sys)	6.00 ± 1.28% (stat) ± 0.55% (sys)
0.051 – 0.057	5.52 ± 0.5% (stat) ± 0.22% (sys)	5.51 ± 0.72% (stat) ± 0.29% (sys)	5.54 ± 0.82% (stat) ± 0.35% (sys)	5.48 ± 1.34% (stat) ± 0.57% (sys)
0.057 – 0.064	5.04 ± 0.48% (stat) ± 0.22% (sys)	5.06 ± 0.69% (stat) ± 0.29% (sys)	5.05 ± 0.8% (stat) ± 0.34% (sys)	4.94 ± 1.3% (stat) ± 0.54% (sys)

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AAD 2013 — Measurement of angular correlations in Drell-Yan lepton pairs to probe Z/gamma* boson transverse momentum at sqrt(s)=7 TeV with the ATLAS detector

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Rivet Analysis

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ABS(YRAP	QED FSR lev	R	SQRT(S	PHI*				
				0.0 – 0.00				0.64% (sys)
				0.004 – 0.00				0.72% (sys)
				0.008 – 0.01				0.6% (sys)
				0.012 – 0.01				0.78% (sys)
				0.016 – 0.0				0.61% (sys)
				0.02 – 0.02				0.64% (sys)
				0.024 – 0.02				0.59% (sys)
				0.029 – 0.03				0.56% (sys)
				0.034 – 0.03				0.6% (sys)
				0.039 – 0.04				0.54% (sys)
				0.045 – 0.05				0.55% (sys)
				0.051 – 0.057	5.52 ± 0.5% (stat) ± 0.22% (sys)	5.51 ± 0.72% (stat) ± 0.29% (sys)	5.54 ± 0.82% (stat) ± 0.35% (sys)	5.48 ± 1.34% (stat) ± 0.57% (sys)
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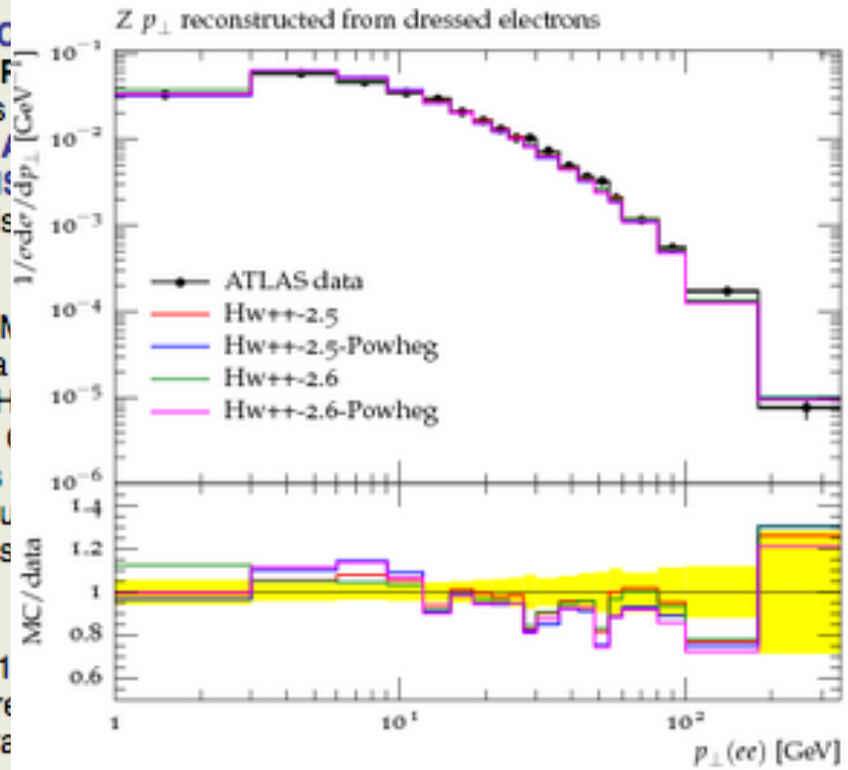
d01-x01-y02.pdf:



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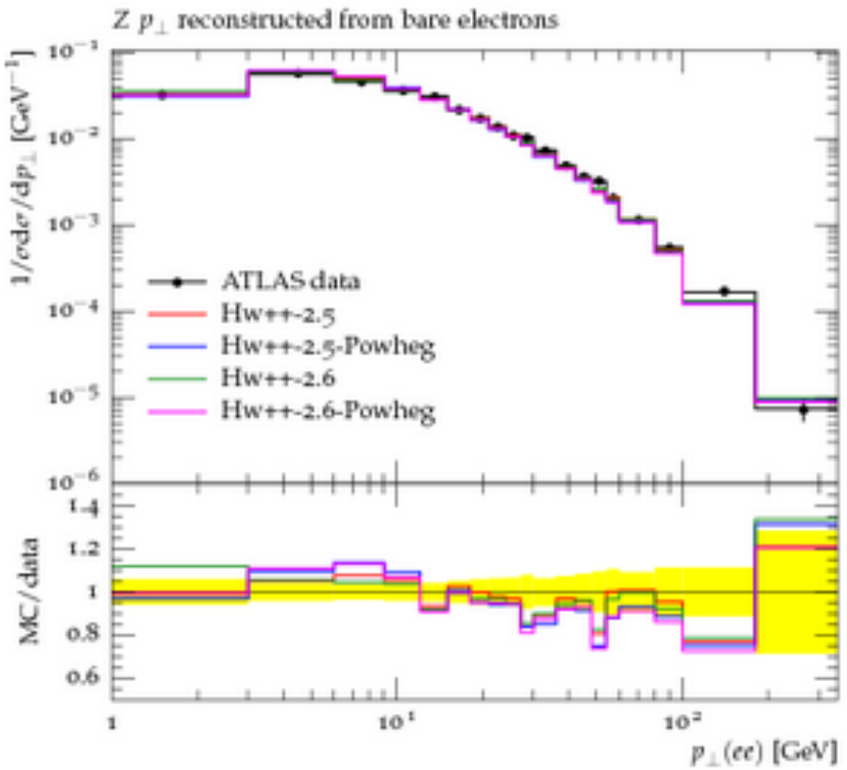

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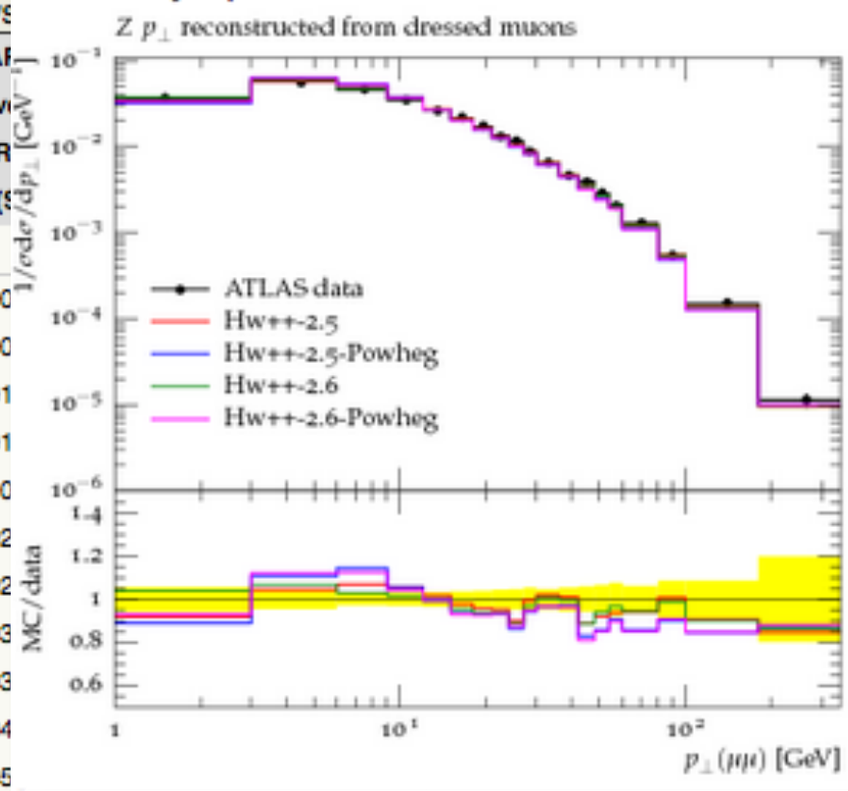

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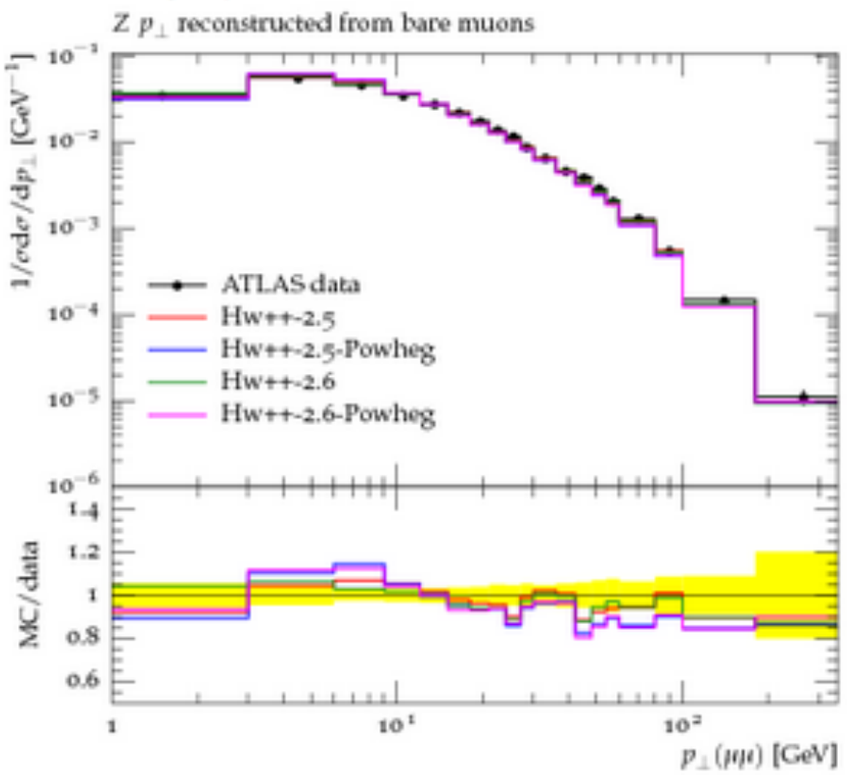
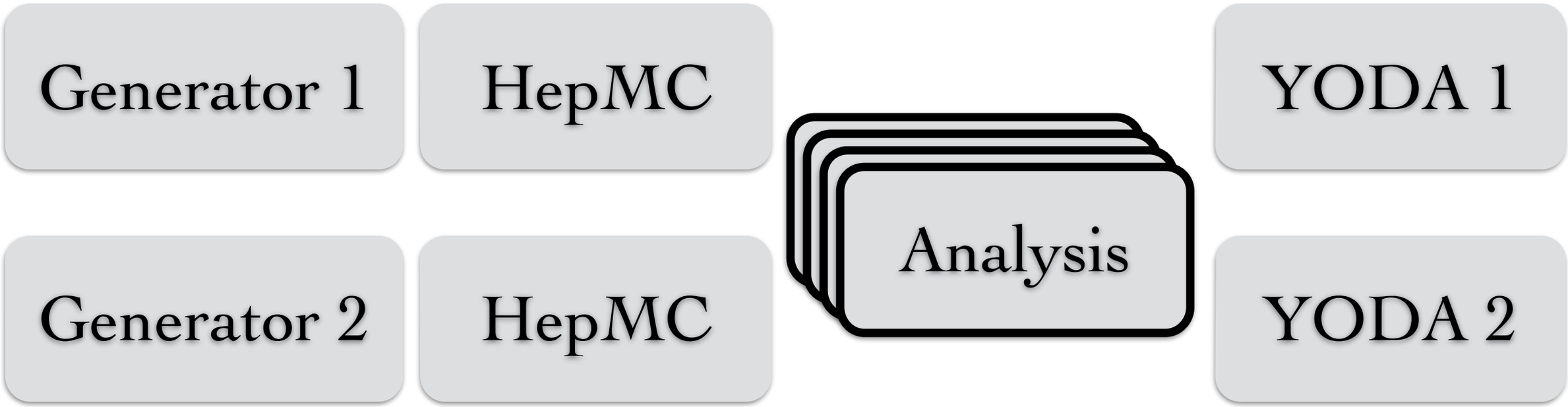


Rivet usage



Rivet usage

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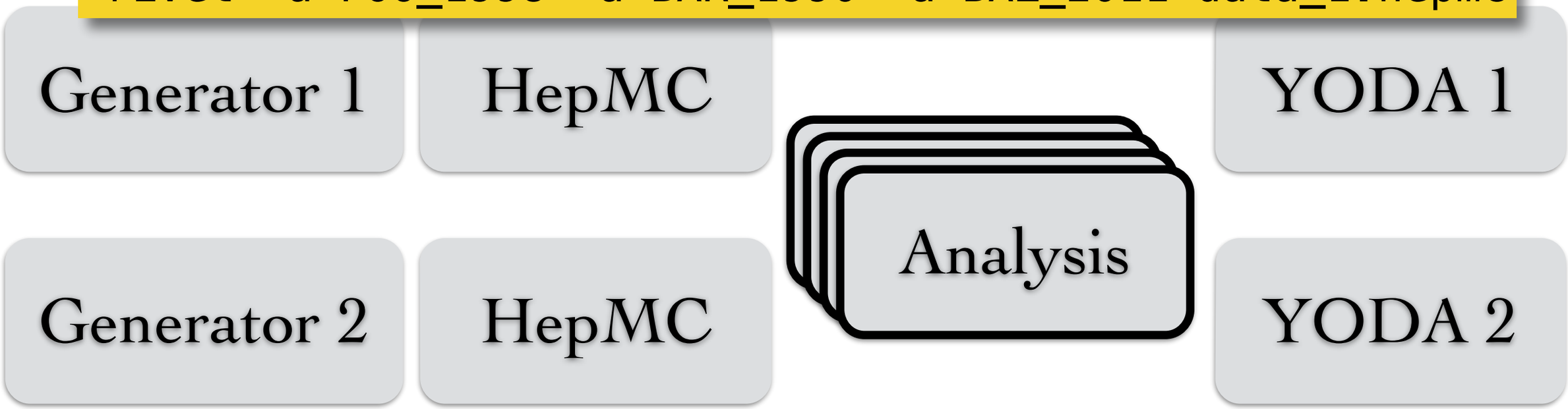

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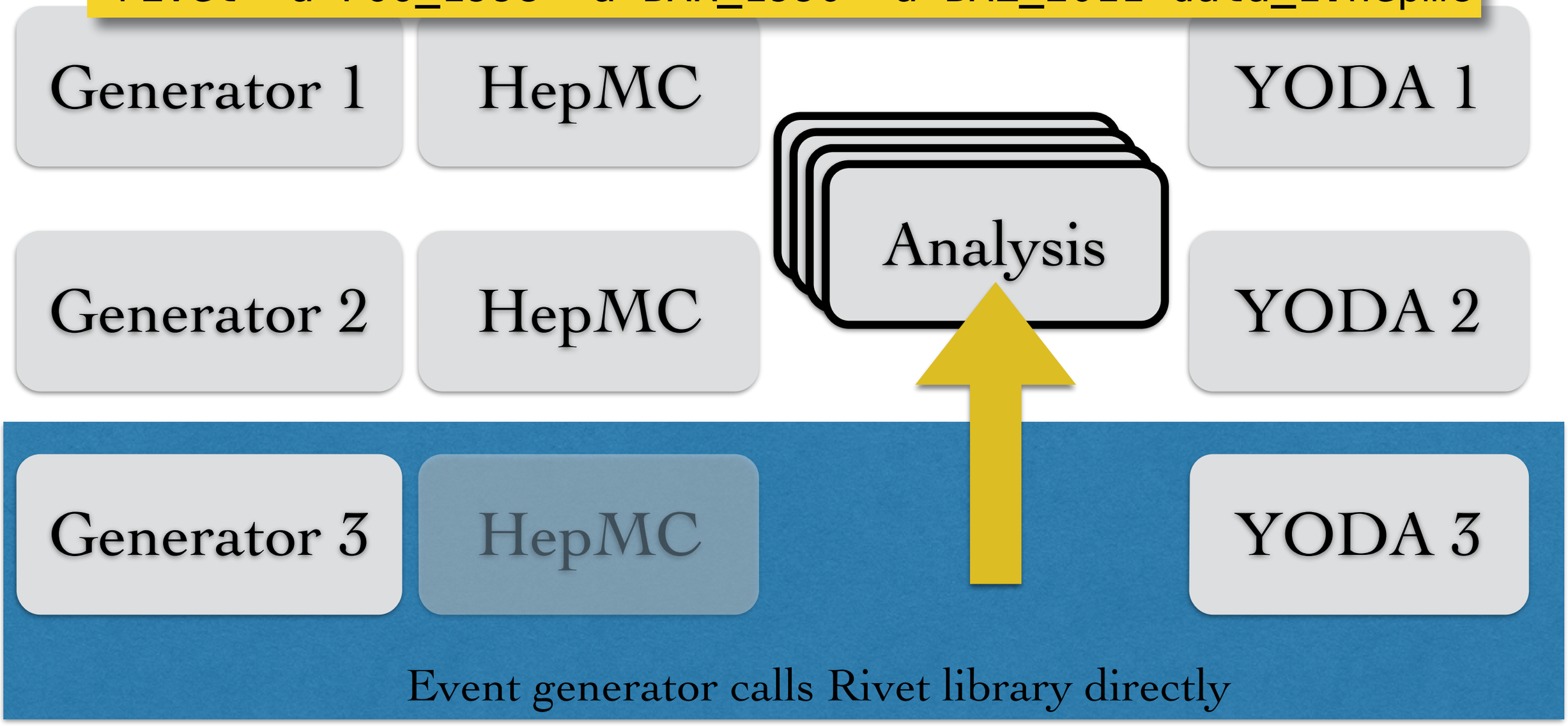

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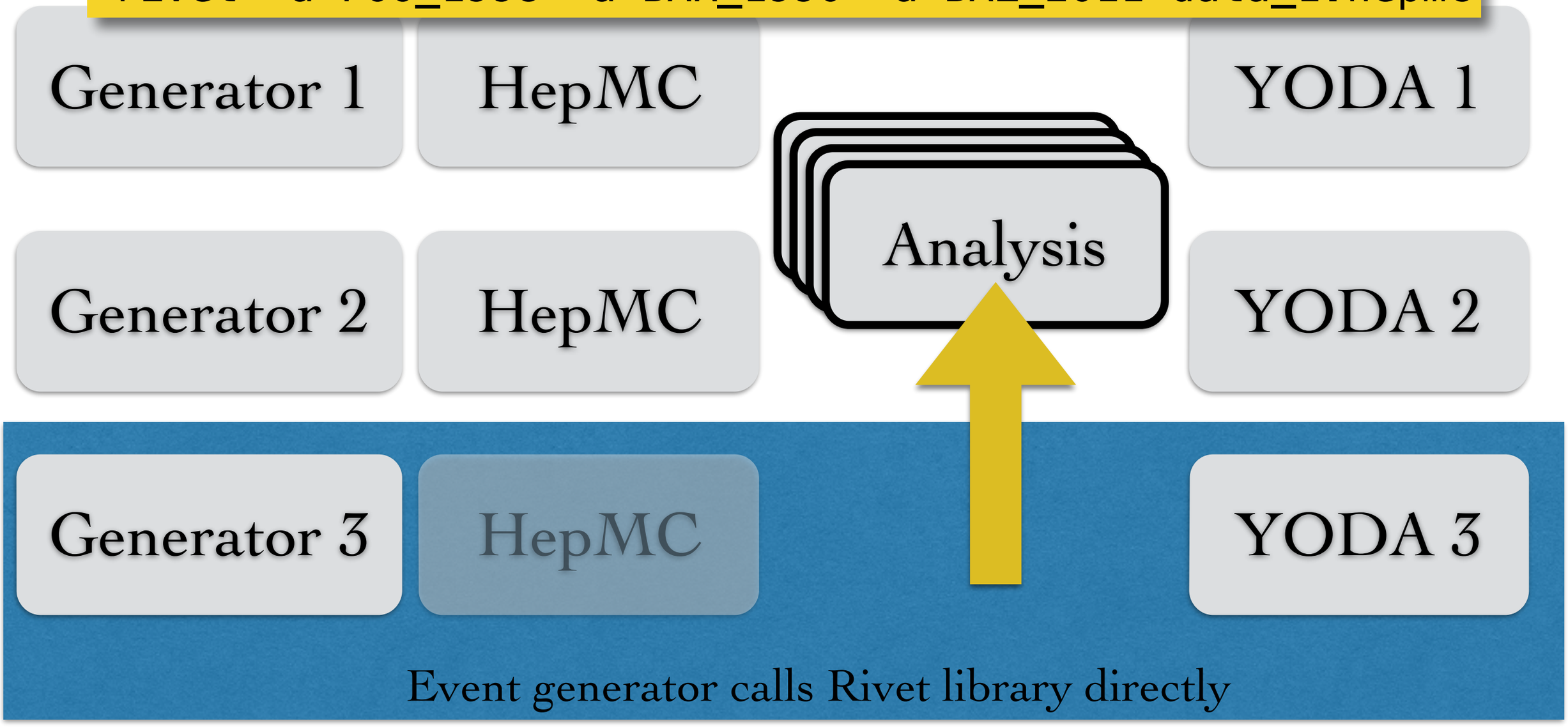


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rivet-mkhtml Gen1.yoda Gen2.yoda Gen3.yoda
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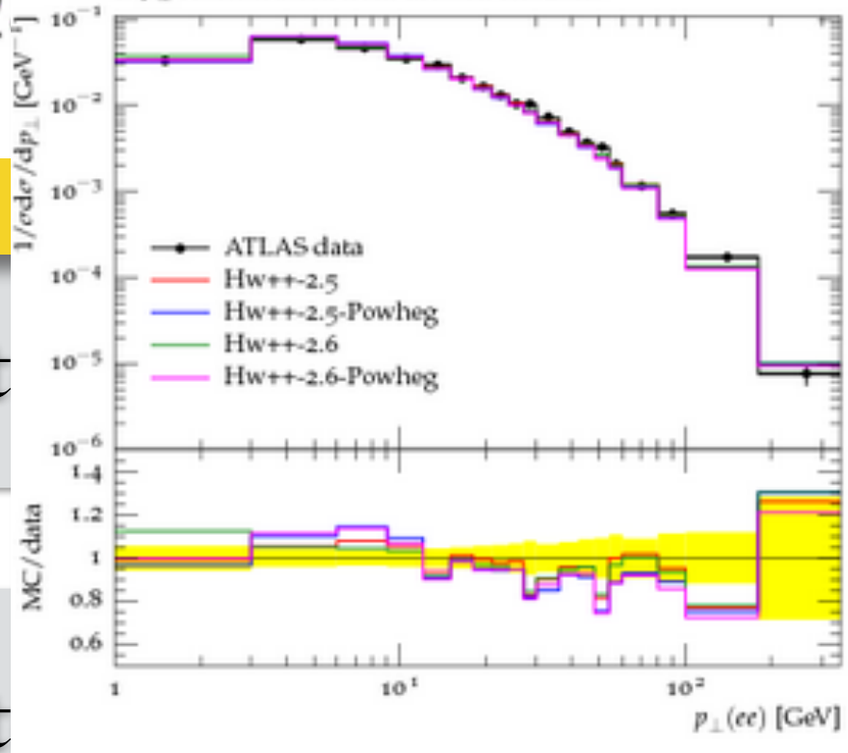
d01-x01-y02.pdf:



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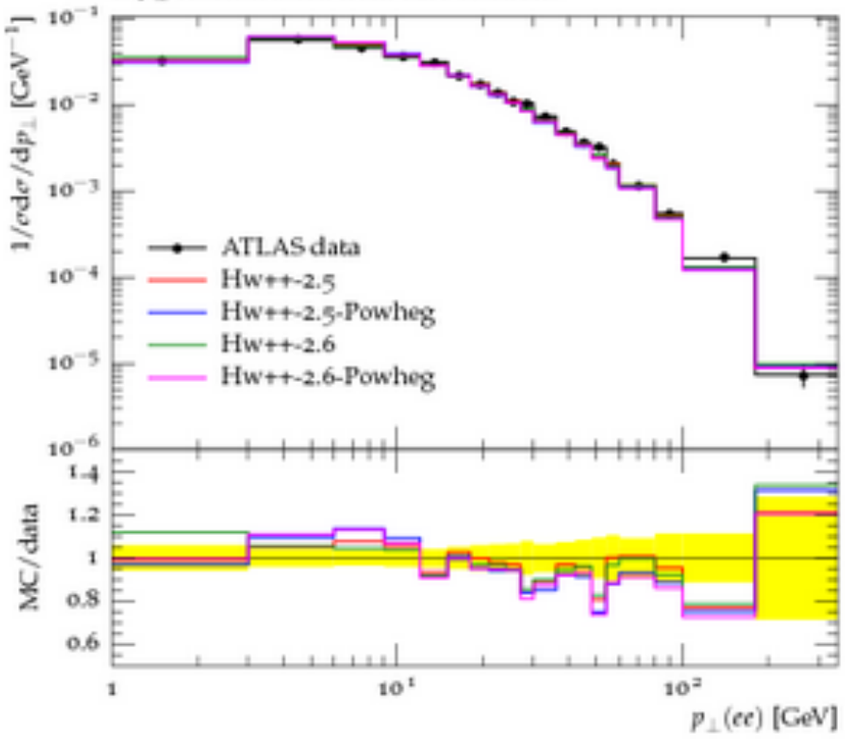

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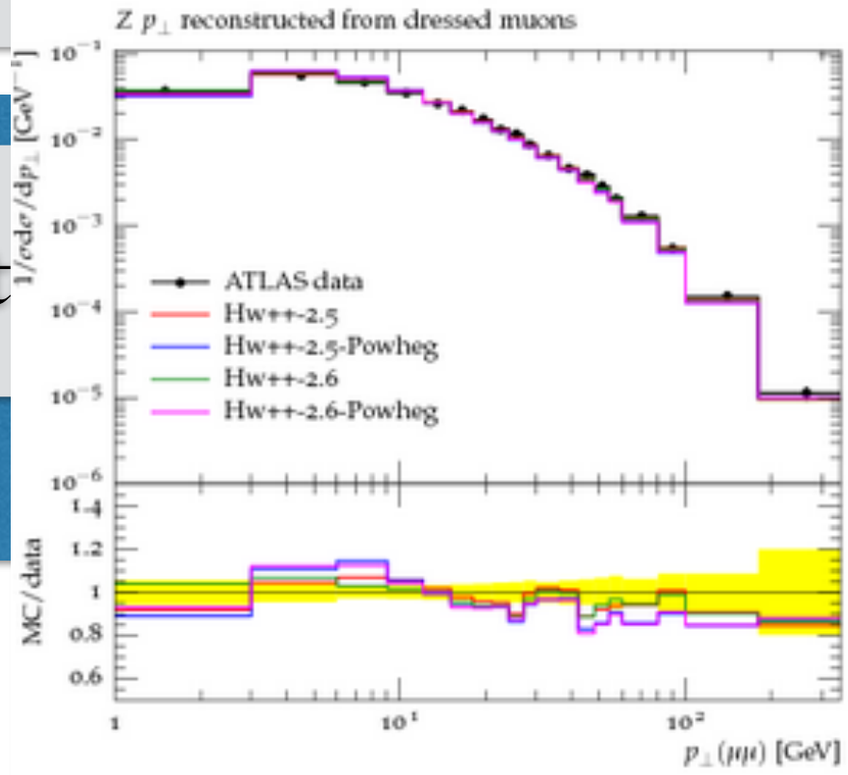

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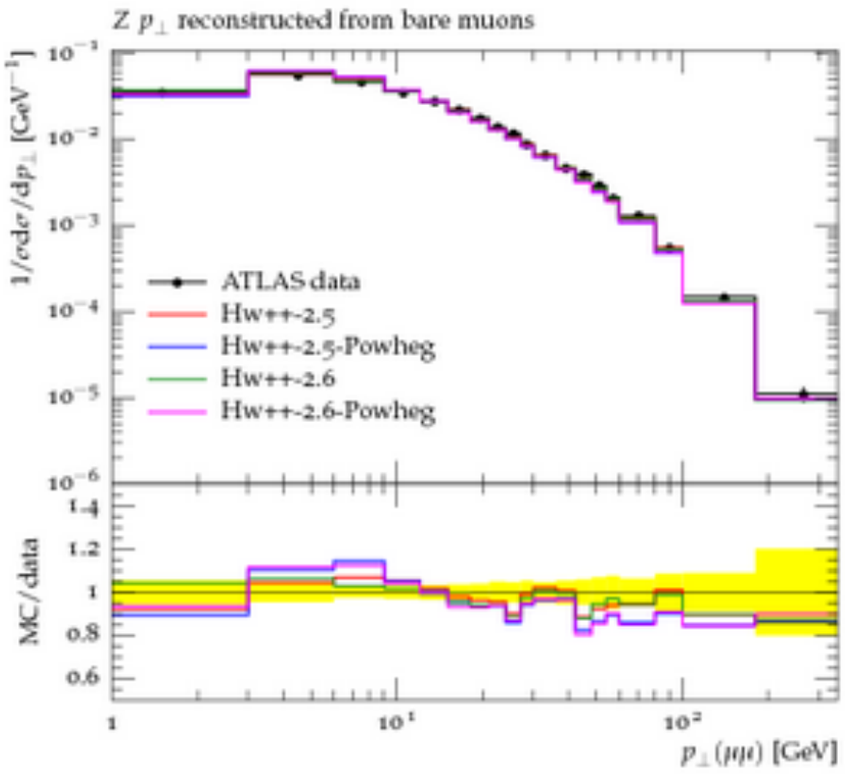

Rivet, David Grellscheid 2015-04-28

Analysis code

Main design principle: make it easy to contribute analyses

Strongly encourages physically meaningful,
generator-independent choices:

no direct access to unstable particles,
certainly nothing before hadronization

e.g. Z p_t cannot be read from MC truth,
need to reconstruct from leptons, just as in the actual data

Encoding analysis selections programmatically protects against information loss over time. Papers often missed out vital points!

Rivet FAQ: Why no detector sim?

Wrong for modern SM results, the results are published already corrected to hadron-level

Turns out also not needed for BSM searches, hadron-level works well enough in vast majority of cases

Fast detector sim can give misleading confidence:

> If observable is robust against detector effects:
> OK either way
>
> If observable is *not* robust against detector effects:
> problem shifted: need to validate fast sim specifically

Rivet today

Standard analysis record, used by all expt. SM groups

Analyses contributed directly from experiments

implements event selection criteria directly from each published paper (~320 so far), compares to HepData

enforces explicit statement of event selection, in the past often missing from publication write-ups

Carefully made generator-independent

Objects are hadron-level jets, leptons, E_miss, …
efficiency and mistagging rates can be applied if analysis requires