Evolving Rivet and MCPLOTS for Heavy Ions

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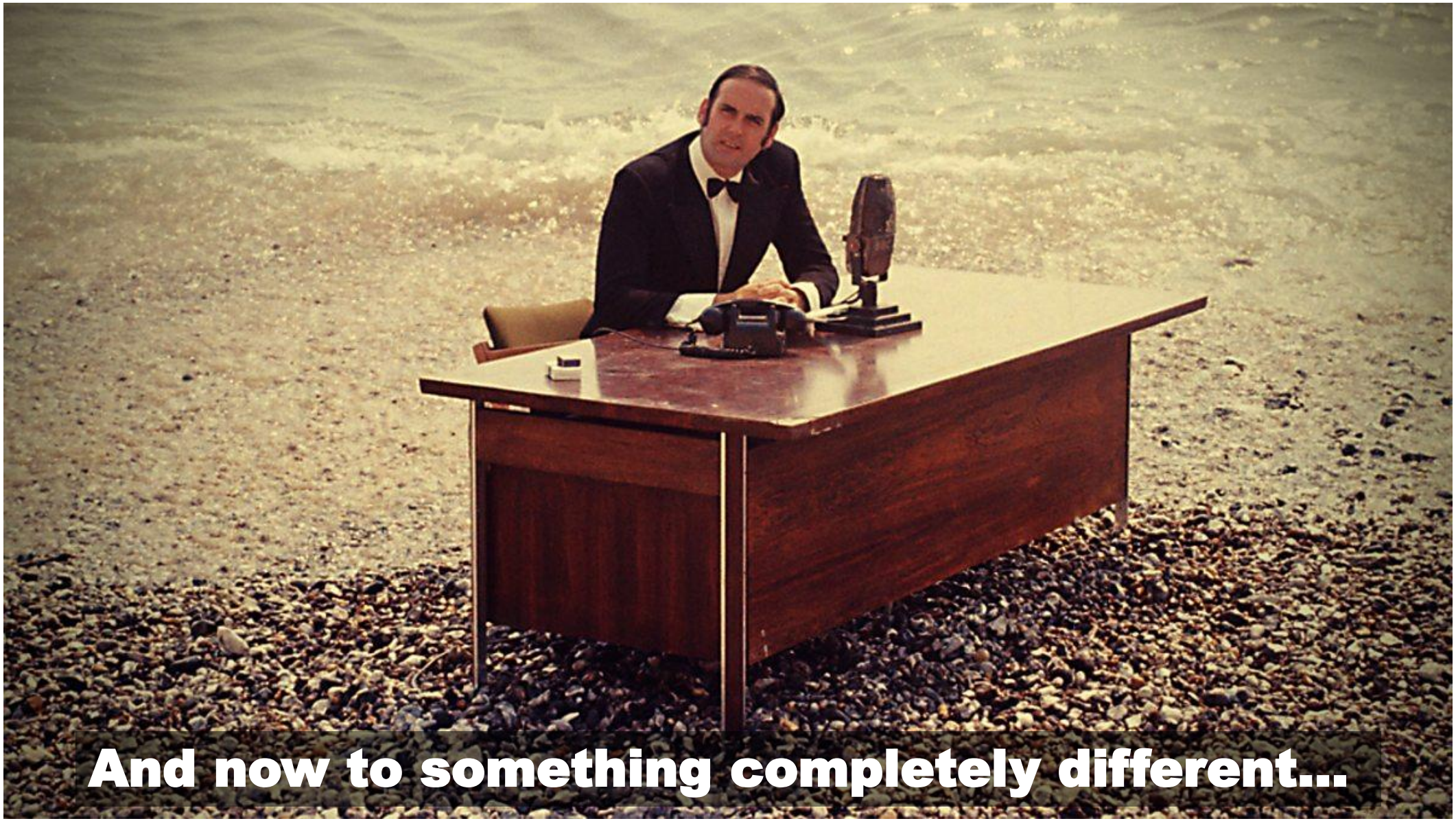
CERN TH Institute - Novel tools and observables for jet physics in heavy-ion collisions
21.08.17


And now to something completely different...

Rivet

rivet.hepforge.org

- RIVET = Robust Independent Validation of Experiment and Theory
- System for validation of Monte Carlo event generators
- Collection of experimental analyses, containing
  - Data (imported typically from HEPData)
  - Programmatic description of the analysis
  - Validated by the analysis authors
- A *RIVET analysis* converts event records with final-state particles (HepMC) into the published observable
  - Typically does not include detector effects
    (can be applied if experiment provides efficiencies and resolutions)

Buckley, Butterworth, Grellscheid, Hoeth, Lonnblad, Monk, Schulz, Siegert, arXiv:1003.0694

Link to Rivet tutorial

Rivet (2)

- Producing a RIVET analysis is part of publication process in ATLAS and CMS
- ALICE and LHCb have also produced a number of RIVET analysis
- These cover pp (as well as ppbar at Tevatron) and e^+e^-

- Several frameworks built on top of Rivet
  - Professor toolkit for MC tuning
  - MCPLOTS website presenting MC–data comparisons
  - CONTUR framework for BSM-limit setting

MCPLOTS

mcplots.cern.ch

- Web site presenting MC–data comparisons
  - Large number of available analysis (uses analysis available in Rivet)
  - Large number of MC generators

Generator Group: General-Purpose MCs | Soft-Inclusive MCs | Alpgen | Herwig++ | Pythia 6 | Pythia 8 | Sherpa | Vincia | Epos | Phojet
Subgroup: Defaults | LHC Tunes | C++ Generators | Tevatron vs LHC tunes

- Uses volunteering computing infrastructure (LHC@home, Test4Theory)

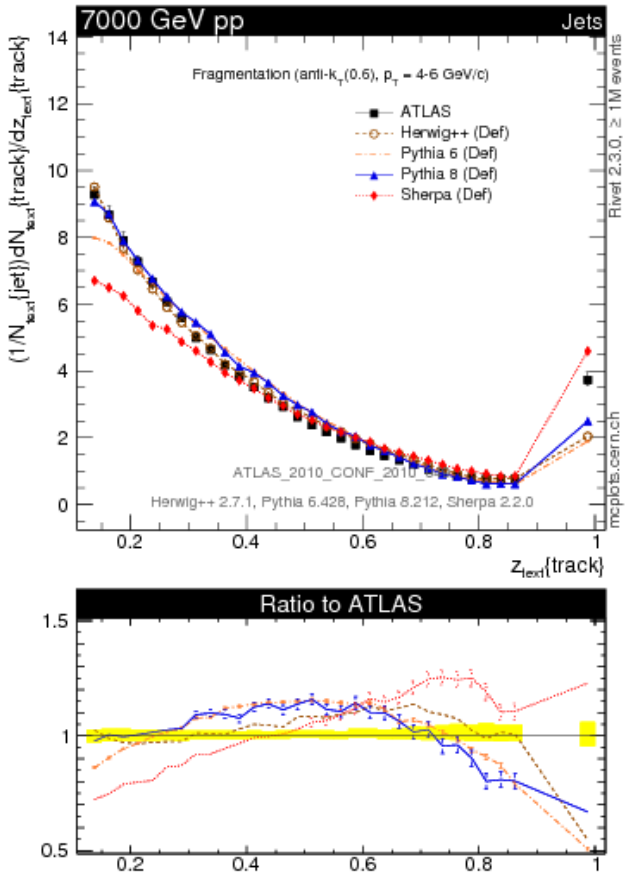
Skands, Charalimpidis, Karneyeu, Konstantinov, Mangano, Mijovic, Prestel, Eur Phys J C74 (2014) 1 (arXiv:1306.3436)

MCPLOTS (2)

mcplots.cern.ch

pp @ 7000 GeV **Jet fragmentation function**

ATLAS 4 < pT < 6 [akt4]



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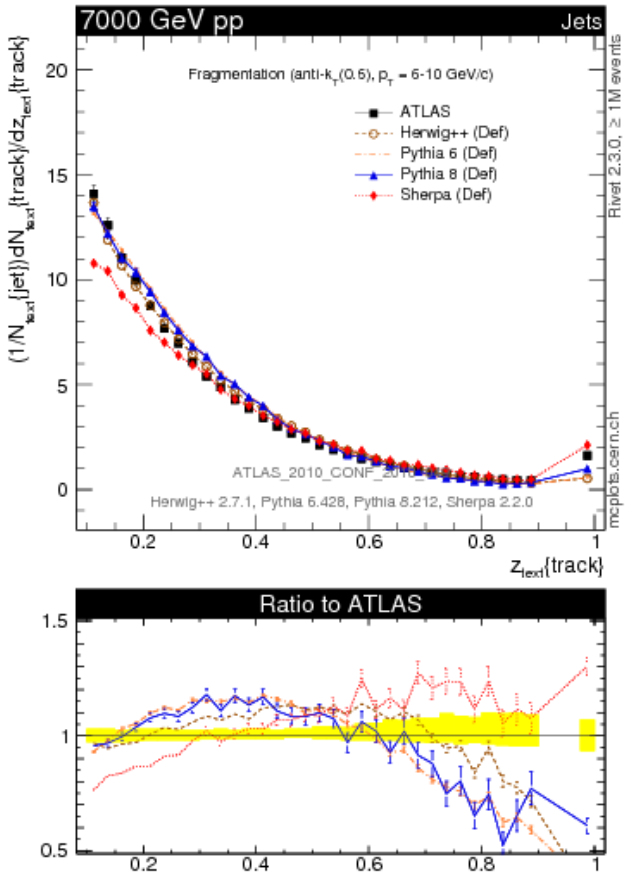
ATLAS 6 < pT < 10 [akt4]



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MCPLOTS (3)

mcplots.cern.ch

- Displayed comparisons customizable

Generator Group: General-Purpose MCs Soft-Inclusive MCs Alpgen Herwig++ Pythia 6 Pythia 8 Sherpa Vincia Epos Phojet Custom

herwig++	2.4.2	☐ default
	2.5.0	☐ default
	2.5.1	☐ default ☐ LHC-UE-EE-2-1800 ☐ LHC-UE-EE-2-2760 ☐ LHC-UE-EE-2-7000 ☐ LHC-UE7-2
	2.5.2	☐ default ☐ LHC-UE-EE-2-1800 ☐ LHC-UE-EE-2-2760 ☐ LHC-UE-EE-2-7000 ☐ LHC-UE-EE-3-7000 ☐ LHC-UE7-2
	2.6.0	☐ default ☐ LHC-UE-EE-4 ☐ LHC-UE-EE-4-CTEQ6L1 ☐ LHC-UE-EE-SCR-CTEQ6L
	2.6.1a	☐ default ☐ LHC-UE-EE-4 ☐ LHC-UE-EE-4-CTEQ6L1 ☐ LHC-UE-EE-SCR-CTEQ6L
	2.6.2	☐ default ☐ LHC-UE-EE-4 ☐ LHC-UE-EE-4-CTEQ6L1 ☐ LHC-UE-EE-SCR-CTEQ6L
	2.6.3	☐ default ☑ LHC-UE-EE-4 ☐ LHC-UE-EE-4-CTEQ6L1 ☐ LHC-UE-EE-SCR-CTEQ6L
	2.7.0	☐ default ☐ LHC-UE-EE-4 ☐ LHC-UE-EE-4-CTEQ6L1 ☐ LHC-UE-EE-SCR-CTEQ6L
	2.7.1	☐ default ☐ LHC-UE-EE-4 ☐ LHC-UE-EE-4-CTEQ6L1 ☐ LHC-UE-EE-SCR-CTEQ6L
phojet	1.12a	☐ default
pythia6	6.423	☐ a ☐ d6t ☐ default ☐ dw ☐ dwt ☐ p0 ☐ p2010 ☐ p6 ☐ pnocr ☐ pro-q2o
	6.424	☐ a ☐ ambt1 ☐ d6t ☐ default ☐ dw ☐ dwt ☐ p0 ☐ p2010 ☐ p6 ☐ phard ☐ pnocr ☐ pro-q2o ☐ psoft ☐ z1
	6.425	☐ 350 ☐ 351 ☐ 352 ☐ 353 ☐ 354 ☐ 355 ☐ 356 ☐ 357 ☐ 358 ☐ 359 ☐ 360 ☐ a ☐ ambt1 ☐ atlas-csc ☐ d6t ☐ default ☐ dw ☐ dwt ☐ p0 ☐ p2010 ☐ p6 ☐ phard ☐ pro-q2o ☐ psoft ☐ z1 ☐ z1-lep ☐ z2 ☐ z2-lep
	6.426	☐ 350 ☐ 351 ☐ 352 ☐ 353 ☐ 354 ☐ 355 ☑ 356 ☐ 357 ☐ 358 ☐ 359 ☐ 360 ☐ a ☐ ambt1 ☐ atlas-csc ☐ d6t ☐ default ☐ dw ☐ dwt ☐ p0 ☐ p2010 ☐ p3 ☐ p6 ☐ ph ☐ pro-q2o ☐ psoft ☐ px ☐ z1 ☐ z1-lep ☐ z2 ☐ z2-lep
	6.427	☐ 345 ☐ 346 ☐ 347 ☐ 348 ☐ 349 ☐ 350 ☐ 351 ☐ 352 ☐ 353 ☐ 354 ☐ 355 ☐ 356 ☐ 357 ☐ 358 ☐ 359 ☐ 360 ☐ 361 ☐ 362 ☐ 363 ☐ 364 ☐ 365 ☐ 370 ☐ 371 ☐

and Heavy Ions?

- Rivet and MCPLOTS well established in the HEP/pp community

- Heavy ion community can profit from such concepts
  - Programmatic comparisons allow more complete model validation
  - Avoid mistakes in understanding the experimental method
  - Use MCPLOTS as a source of comparison plots

What is needed to use Rivet and MCPLOTS for heavy ions?

Challenges from Heavy Ion Community

- Event classification
  - Centrality, based on some experimental quantity
  - Event-plane calculation (from initial state, final state)
  - Event mixing
  - …
- Comparison of several collision systems or centrality classes
  - R_{AA} ~ Pb-Pb / pp R_{CP} = Central / Peripheral
- Characterization of distributions
  - Yield extraction of invariant mass distributions
  - Parameter extraction through fitting of correlation functions (e.g. HBT)
- Event generators very computing intense (~10s/event)

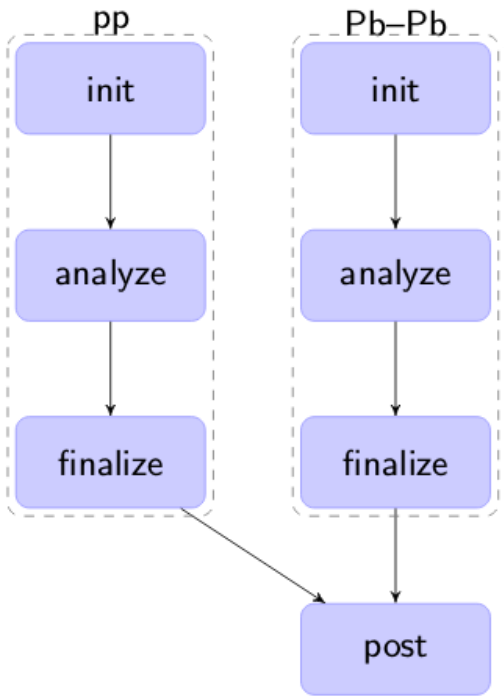
Project

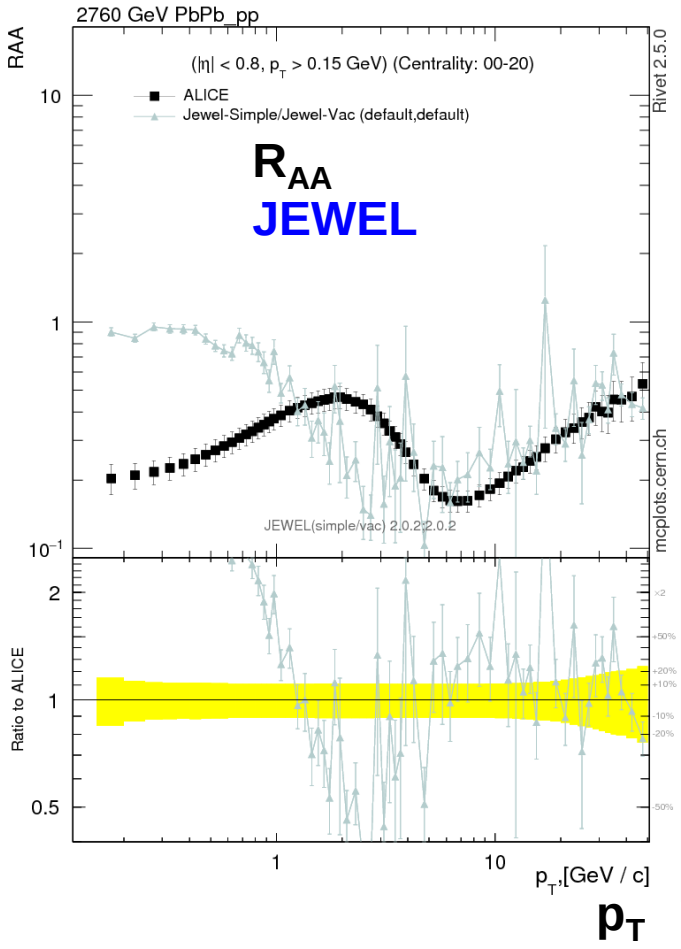
- ALICE started a project last summer to evolve Rivet and MCPLOTS for our needs
  - since October backed up by a CERN doctoral student
- Prototype implementations (see next slides)
- Regular interactions with Rivet team
  - Discussion of proposed solutions
  - Feeding code back to Rivet core repository (avoid having Rivet “HI” as a permanent fork)

Example: R_{AA} in Rivet

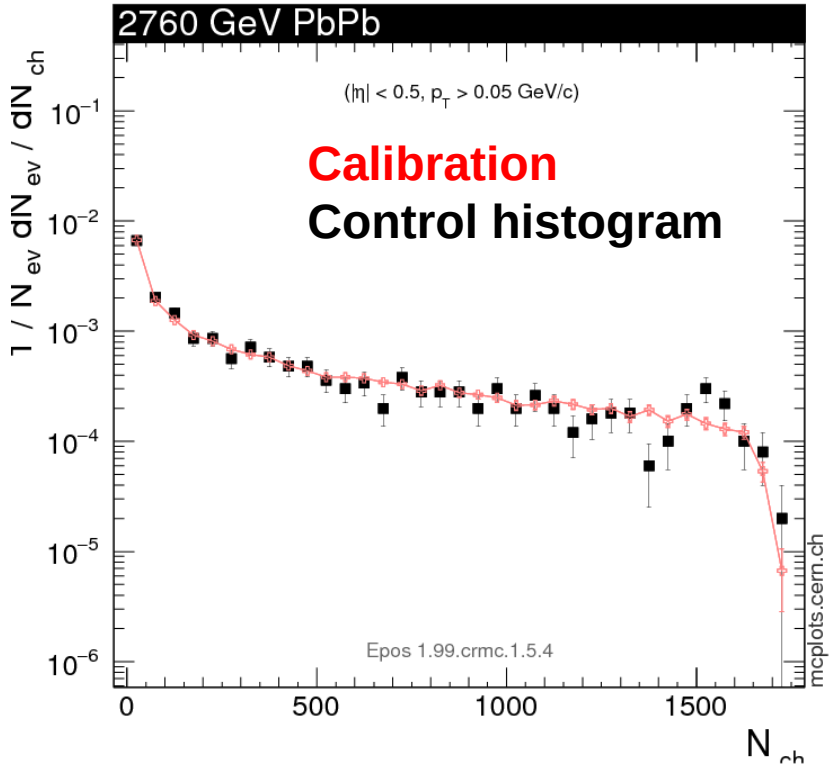
$$R_{AA} = \frac{dN_{AA}/dp_T}{\langle N_{coll} \rangle dN_{pp}/dp_T}$$

- New developments
  - Read results from previous Rivet run
  - Postprocessing functionality
  - Two Rivet runs: pp + PbPb
- Solution implemented and working
  - Will be further evolved using *reentrant finalize functionality* which is planned in core Rivet development





Centrality in Rivet



- Only few generators provide centrality
- Important to (also) reproduce experimental selection
- Use final-state projection to define phase space for centrality measure (e.g. tracks in certain η region)
- New developments
  - Centrality calibration files
    - Multiplicity → centrality
    - Impact parameter → centrality
  - Centrality determination
    - Two implementation flavors: 1) projection; 2) heavy-ion analysis base class
- Centrality calibration is generator and tune specific, but can be shared between different analysis

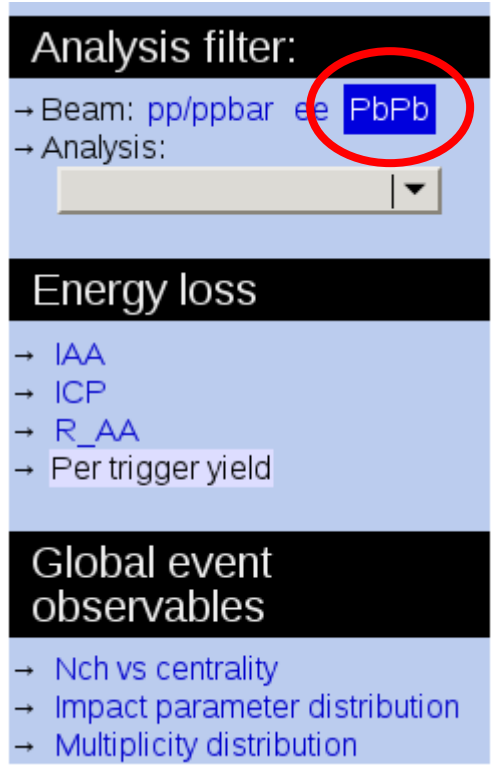
What is next?

- Ongoing integration of generators
  - HIJING, AMPT
  - VISHNU with UrQMD
- Event mixing (prototype exists by Christian Bierlich)

- Analysis which need fitting code
- Models which do not produce final-state particles
  - E.g. hydrodynamic codes which stop with freeze-out surface

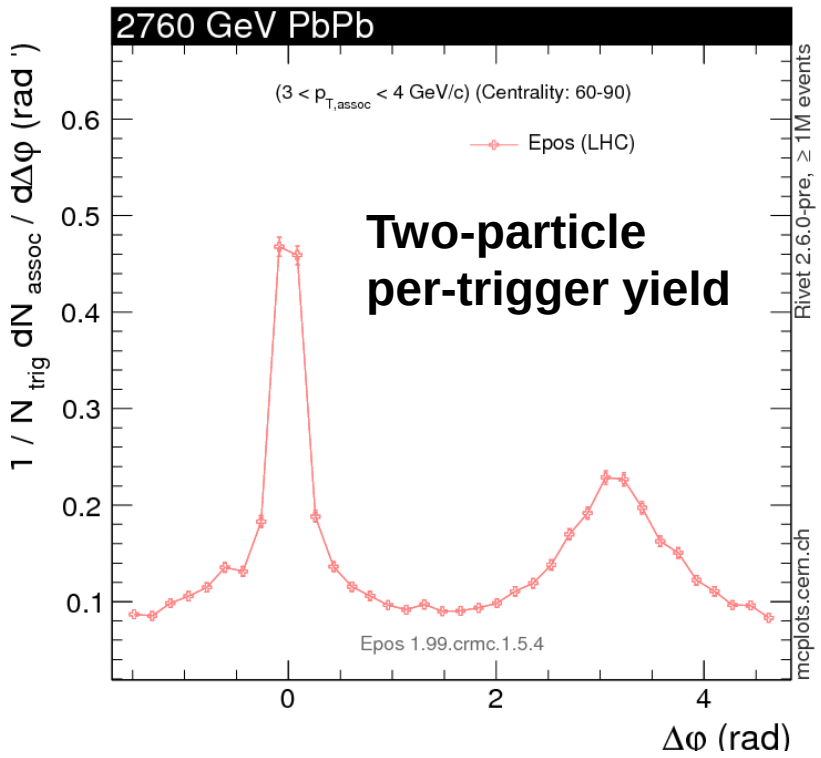
MCPLOTS Status

- Development web site (accessible only within CERN):
  - mcplots-alice-dev2.cern.ch
- New developments
  - Event classifiers displayed and selectable (centrality, etc.)
  - Adaptation of steering macros for post processing, centrality calibration, etc.
- Usage of volunteering computing infrastructure to be evaluated

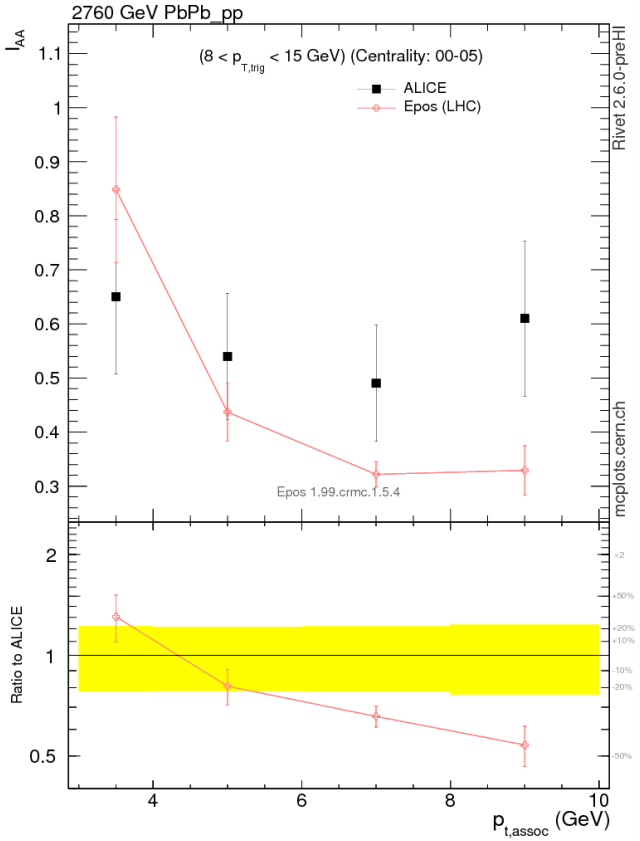


Implemented “Test Case” Analyses

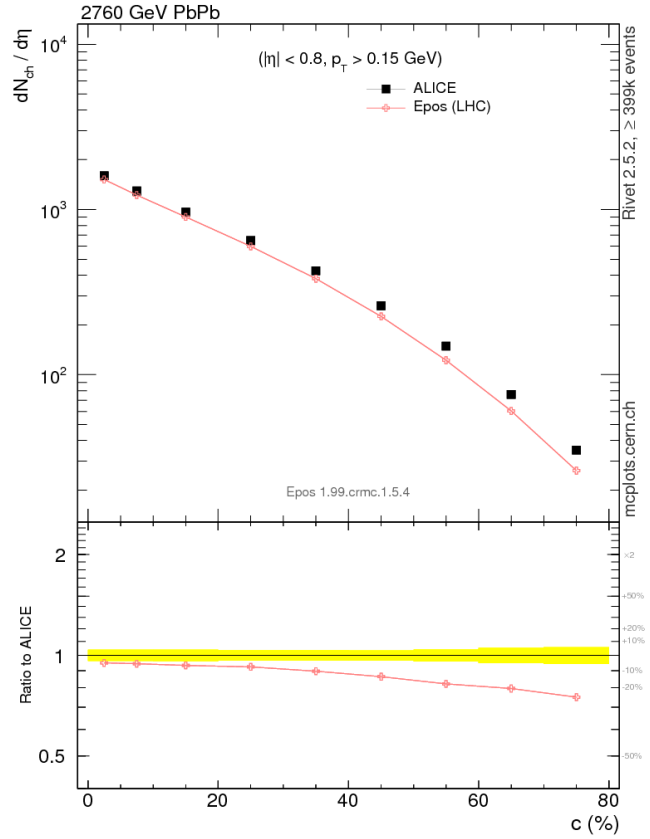
- R_{AA}, I_{AA}, $dN_{ch}/d\eta$ vs. centrality
  - Here compared to EPOS (LHC)



I_{AA} (away side)



$dN_{ch}/d\eta$ vs. centrality



$$I_{AA} = \frac{\text{Yield(Pb} - \text{Pb)}}{\text{Yield(pp)}}$$

Summary

- Project ongoing to evolve Rivet and MCPLOTS to support the needs of the heavy-ion community
  - Several test case analyses (R_{AA}, I_{AA}, $dN_{ch}/d\eta$ vs. centrality) implemented
  - Rivet developments to support centrality and processing of several collision systems done
    - Not yet in central Rivet repository
  - MCPLOTS heavy ion development web site available here
  - Many thanks to Andy, Chris, Leif (Rivet) and Anton, Peter (MCPLOTS)
- Your input is highly appreciated !
- We plan to have a usable prototype by the end of the year