Integrating the RIVET analysis tool into EPOS 4

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in collaboration with

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Dr. Damien VINTACHE - Subatech / CNRS

Event generators in HEP

Event generators are codes engineered to compute models in order to simulate collisions on an event-by-event basis, using Monte-Carlo sampling techniques.

Advantage: perfect knowledge of the whole event history

Caveats: underlying-model dependence + requires parametrisation

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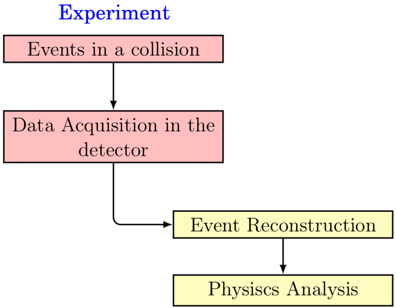

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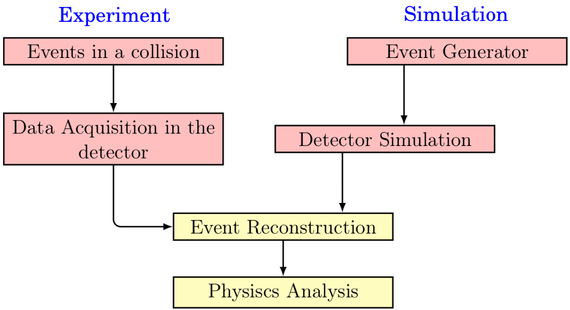

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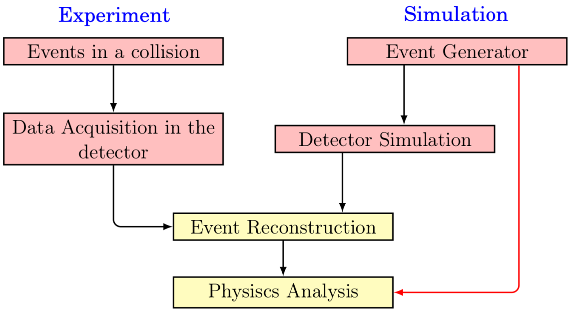
Essential to bridge the gap between theory and experiment, being used for data interpretation and model validation.



Energy conservation + **P**arallel scattering + fact**O**rization + **S**aturation

General-purpose event generator (simulates every steps of the collision) for hadronic physics, like Pythia [1] or HIJING++ [2] *(see Tuesday's talk)*.

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Based on a multiple scattering approach, the parton-based Gribov-Regge Theory (PBGRT)[3], and a hybrid evolution of matter including 3+1D hydrodynamics[4] to reproduce the fluid behaviour of the QGP.

Developed to simulate any type of collision, from $\sqrt{s} \propto$ GeV, with the same formalism:

$$e^+ + e^- \qquad e^\pm + p \qquad p + p \qquad p + A \qquad A + A$$

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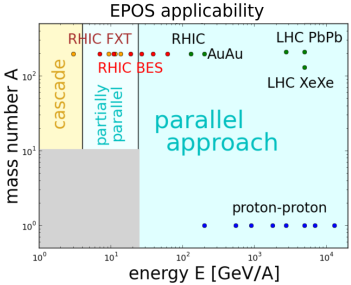
Includes some new developments about the physics:



EPOS 4 - latest public release

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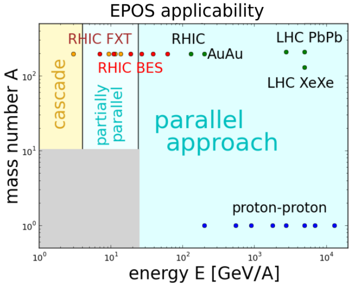

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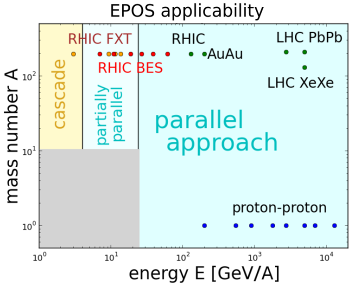

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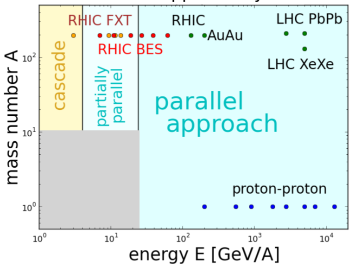
EPOS applicability



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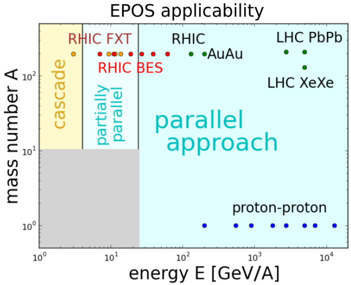

+ some user-oriented upgrades: more documentation, modularisation, simplified running mode...

Motivations

New version of an event generator requires intensive testing to find the **best parameters tuning**, covering as much system sizes and widest energy range as possible.

$\Rightarrow$ **computationally consuming!** (*210Mh of CPU-time in 2022*)

Hence the motivation to integrate RIVET into EPOS on-stream analysis system to help us optimising the process.

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2. For users:
   - an independent analysis tool which is easy to handle

Robust Independant Validation of Experiment and Theory (RIVET)

RIVET is a system for validation of MC event generators, based on a C++ framework for analysis algorithms.

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$\Rightarrow$ **RIVET fulfills all the condition we're seeking**

Adding the HepMC output

In addition to the **ROOT** format (only standard output so far), implemented the **ASCII standard HepMC** output format.

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   - Default Mode: records complete decay history for particles with $\tau > 10^{-20}$s (+ some exception like quarkonia)
     $\rightarrow$ necessary for feed-down corrections + reconstructed particles + jets...

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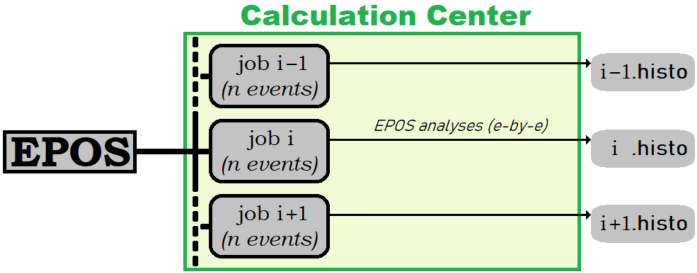

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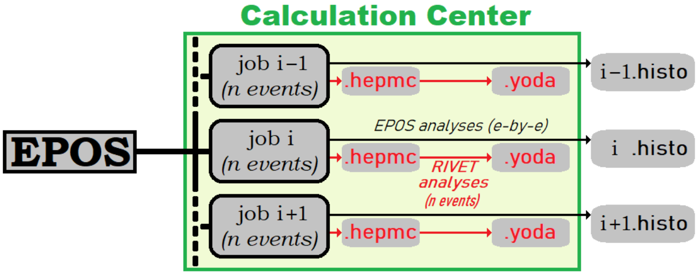

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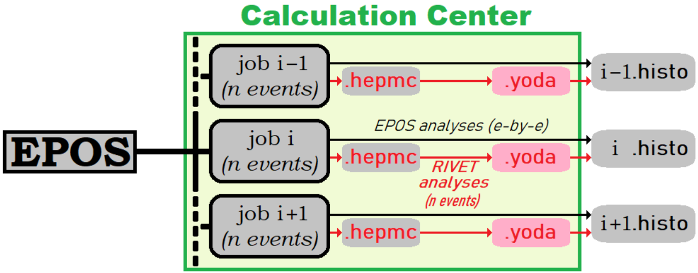

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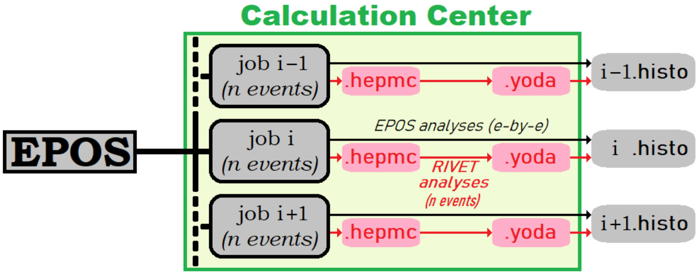

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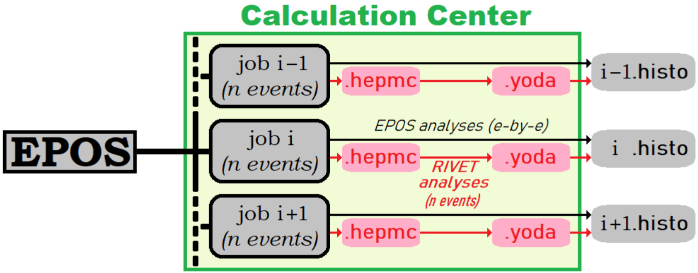
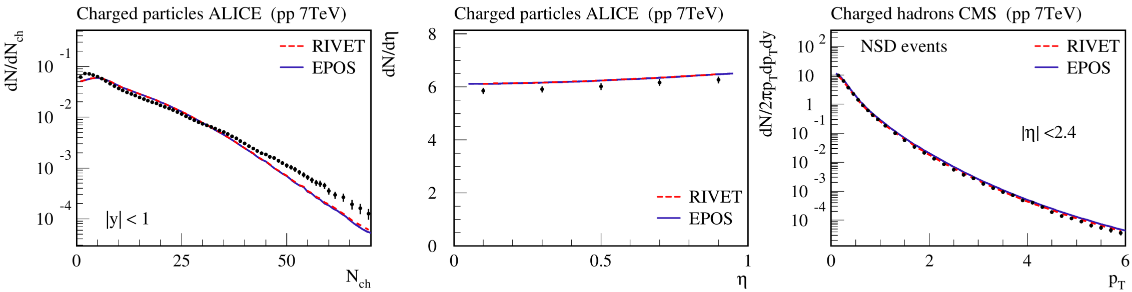


Still room for improvements:

- give more freedom to the user regarding particle species recorded in the HepMC format
- use FIFO pipes to run RIVET, to avoid temporary storage of HepMC files

See J. Jahan's Ph.D. thesis for more technical details.

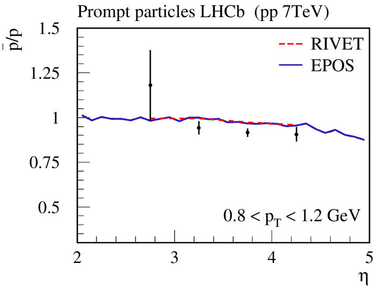
RIVET / EPOS analyses comparisons

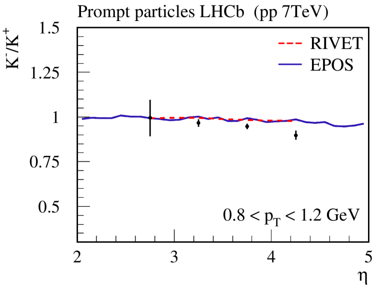


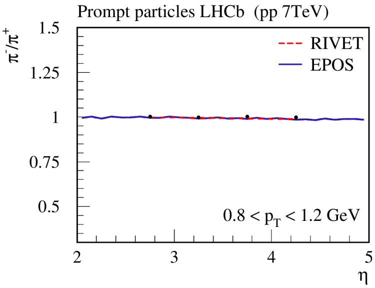
Physics level: data are well reproduced at mid-rapidity overall

Analysis level: RIVET and EPOS analyses give identical results

(except for some cases because of normalisation)







Physics level: common particles production is well reproduced at forward rapidity

Analysis level: RIVET and EPOS analyses give identical results again

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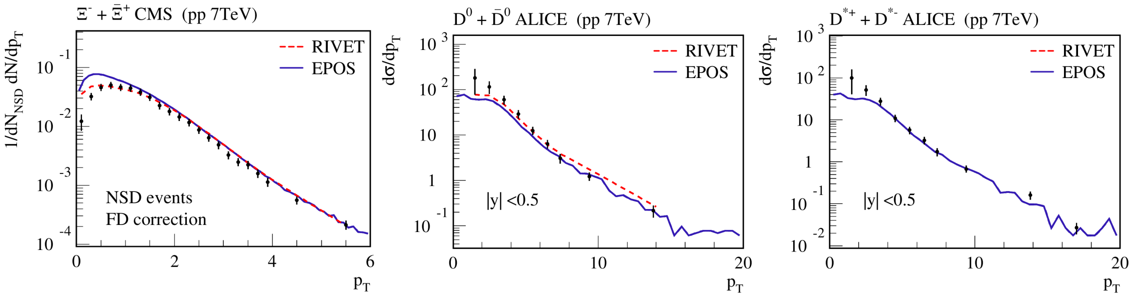

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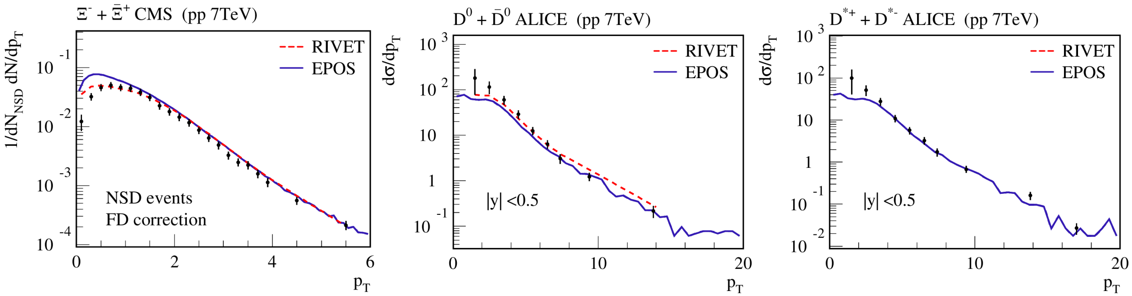

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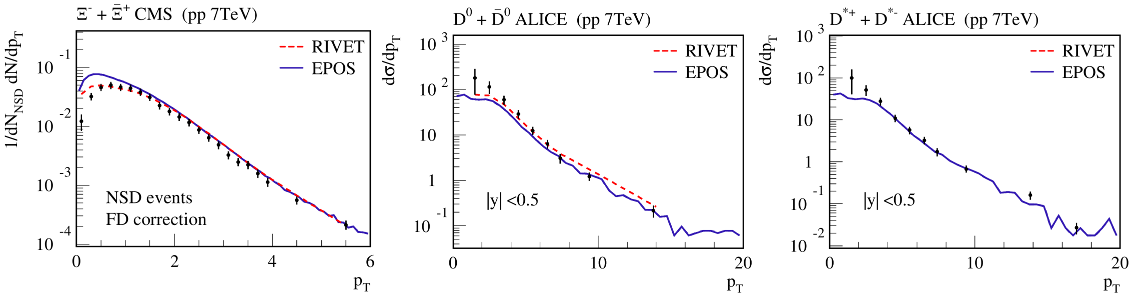

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- Feed-down corrections? Normalisation? Event selection?

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- to go futher: RIVET integrated into the online EPOS4 analysis system

  (saves memory space + enables cross-check with pre-existent analyses)

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BUT...

- further improvement might be necessary + some tricky questions regarding event recording

  $\longrightarrow$ **user's feedback**

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- made EPOS 4 compatible with RIVET, useful for both users and developers
- to go futher: RIVET integrated into the online EPOS4 analysis system

  (saves memory space + enables cross-check with pre-existent analyses)

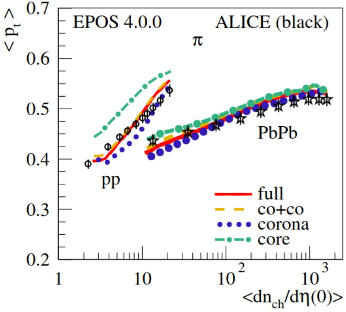
BUT...

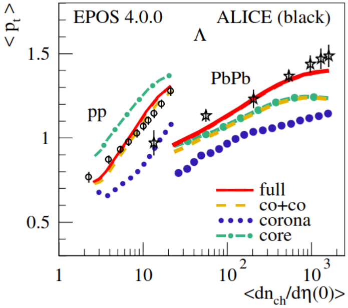
- further improvement might be necessary + some tricky questions regarding event recording

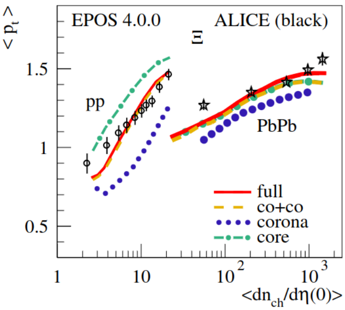
  $\rightarrow$ **user's feedback**
- limited catalogue (**VERY** limited for heavy-ions) restrain use of systematic tuning tools (*e.g.* Professor)

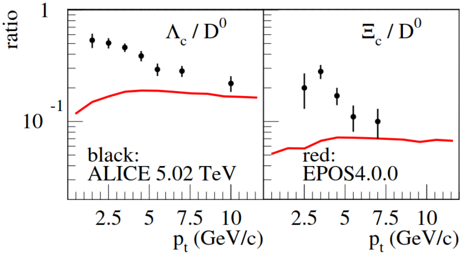
Key	ALICE	ATLAS	CMS	LHCb	Forward	HERA	e^+e^- (≥ 12 GeV)	e^+e^- (≤ 12 GeV)	Tevatron	RHIC	SPS	Other
Rivet wanted (total):	278	334	447	269	17	479	703	560	1131	469	64	2
Rivet REALLY wanted:	36	37	89	8	0	12	1	0	5	1	0	0
Rivet provided:	26/304 = 9%	189/523 = 36%	103/550 = 19%	17/286 = 6%	8/25 = 32%	34/513 = 7%	192/895 = 21%	325/885 = 37%	58/1189 = 5%	8/477 = 2%	4/68 = 6%	112/114 = 98%

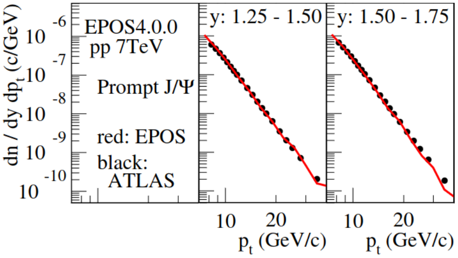
EPOS 4 selected results









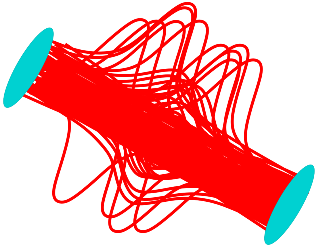


Complementary material

Event generation with EPOS

Primary interactions treated with PBGRT

Exchange of multiple Pomerons $\equiv$ parton ladders in parallel



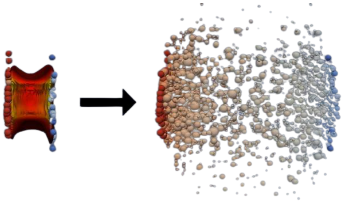
K. Werner (2018)

Core-corona separation

Dynamical separation of the system into 2 parts at early time of evolution [a]:

- core = high energy-density region ($> \varepsilon_c$)
- corona = low energy-density region ($< \varepsilon_c$)

[a] K. Werner, *Phys.Rev.Lett.* **98** (2007) 152301



MADAI collaboration

Core evolution

Viscous 3+1D hydrodynamics expansion based on a cross-over transition Equation of State (EoS)

Corona evolution

Strings evolution following dynamics of a gauge invariant Lagrangian + string fragmentation

Hadronic cascades

Re-scatterings between formed hadrons simulated using UrQMD[b].

[b] M. Bleicher et al., *J.Phys.G* **25** (1999) 1859-1896

EPOS + RIVET infrastruture