Jet overlap in heavy ion collisons

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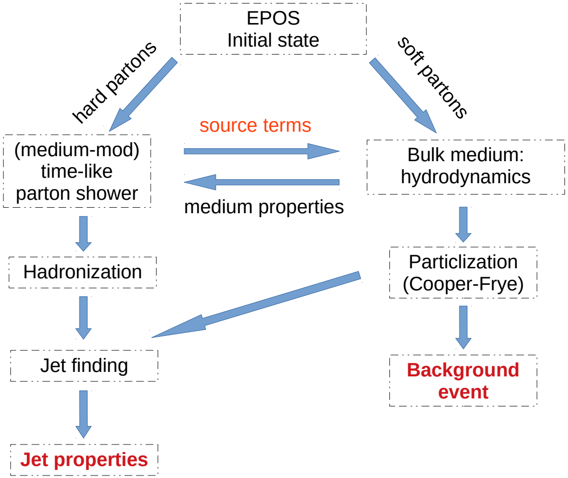
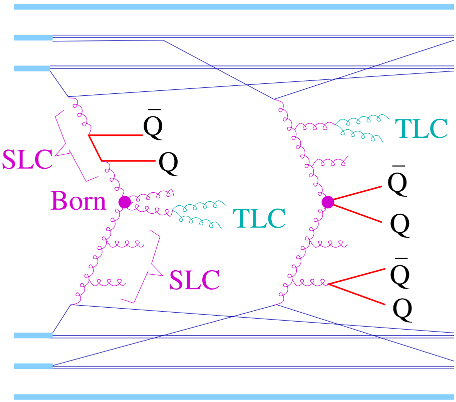
Our project

Our project

To get both hydrodynamic IS and initial hard partons from EPOS3 (currently), make hydrodynamic and jet parts talk to each other, add hadronization scheme and jet finding.



EPOS initial state



Parton-Based Gribov-Regge Theory

H. J. Drescher, M. Hladik, S. Ostapchenko, T. Pierog, K. Werner, Phys. Rept. 350, 93, 2001

Pomeron = parton ladder, treated as a kinky string.

Spacelike cascades including Born process in the EPOS IS provide partons with all p_T which are further separated into core and corona.

The IS produces multiple hard partons in each (central) Pb-Pb collision!

Hydrodynamic background

Event-by-event initial state from EPOS.

Equation of state: Laine & Schroeder '06, compartible with s95p-v1.2 EoS.
M. Laine, Y. Schroeder Phys. Rev. D73 (2006) 085009

3+1 dimensional viscous hydrodynamics:

$$T^{\mu\nu} = (\varepsilon + p) u^\mu u^\nu - p \cdot g^{\mu\nu} + \pi^{\mu\nu}$$

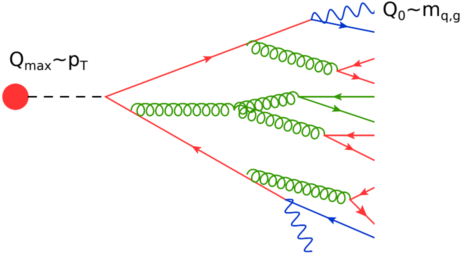
$$\partial_{;\nu} T^{\mu\nu} = 0, \quad \partial_{;\nu} N^\nu = 0$$

$$< u^\gamma \partial_{;\gamma} \pi^{\mu\nu} > = -\frac{\pi^{\mu\nu} - \pi^{\mu\nu}_{\text{NS}}}{\tau_\pi} - \frac{4}{3} \pi^{\mu\nu} \partial_{;\gamma} u^\gamma$$

solved with vHLLE code, Comput. Phys. Commun. 185 (2014), 3016
`https://github.com/yukarpenko/vhlle`

Time-like parton shower

- Monte Carlo simulation of DGLAP equations for a parton shower between virtuality scales $Q_\uparrow$ (from Born process in EPOS) and $Q_\downarrow = 0.6$ GeV. Core algorithm made by **Martin Rohrmoser**



- Medium modified radiation (splittings) a là YaJEM: $\frac{dQ^2}{dt} = +\hat{q}_R(t,x)$
- Collisional energy loss: longitudinal drag $\frac{dp_\parallel}{dt} = -A(t,x)$
- Collisional energy loss: transverse kicks $\Delta p_\perp = n_\perp \sqrt{\hat{q}_C \cdot \Delta t}$
- Mean lifetime of a parton between the branchings is $\Delta t = E/Q^2$.

! Medium effects in the model will be updated soon.

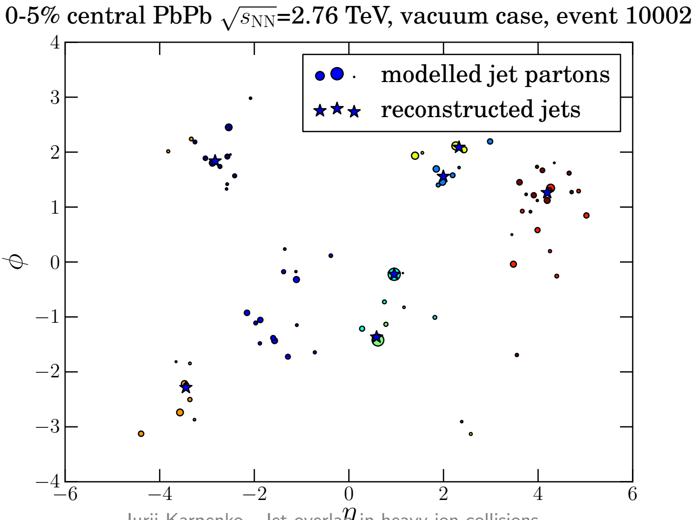
Jet reconstruction and jet overlap

In the rest of the talk:

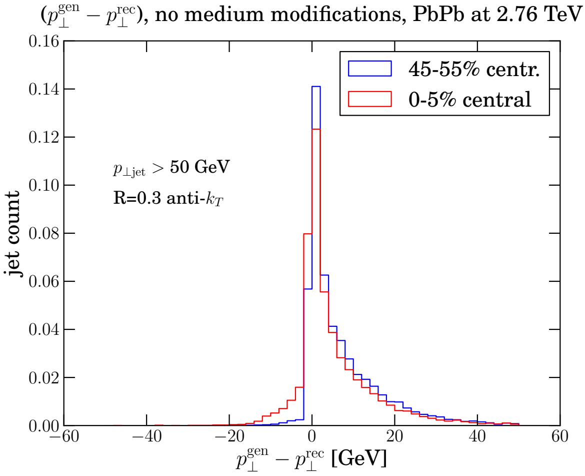
- medium effects are switched off
- there are no medium partons/hadrons

Jet reconstruction

A current shortcut:
Final state of a jet (partons) $\rightarrow$ **no** hadronization $\rightarrow$ jet finding.
Jet finding: vanilla FASTJET 3.3, anti-k_T algorithm



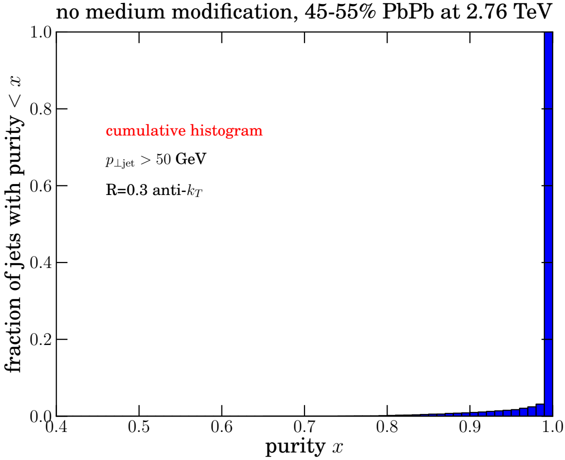
The artefacts



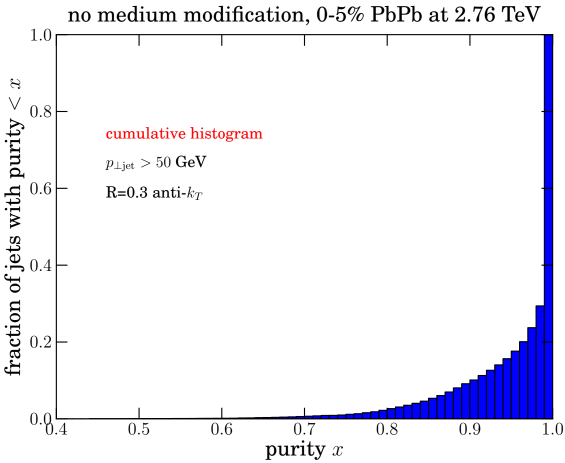
- ‘runaway’ jet partons are not clustered with the rest (loss, $\Delta p_\perp < 0$)
- partons from neighbouring jets are clustered together (gain, $\Delta p_\perp > 0$)

"Jet purity", noncentral PbPb

We define it as a leading fraction of reconstructed jet momentum coming from an underlying simulated jet.



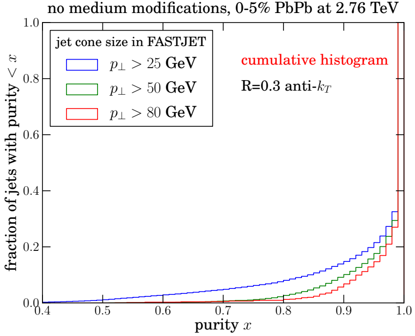
"Jet purity", central PbPb



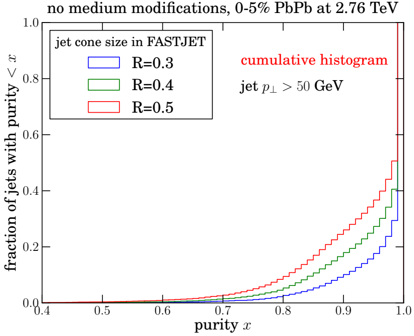
- about 1/3 of the reconstructed jets (or simply jets) have various contrbutions to their momentum from jet overlap.

"Jet purity", jet $p_\perp$ and R dependencies

Left: $P(\text{purity} > x)$ at different jet $p_\perp$

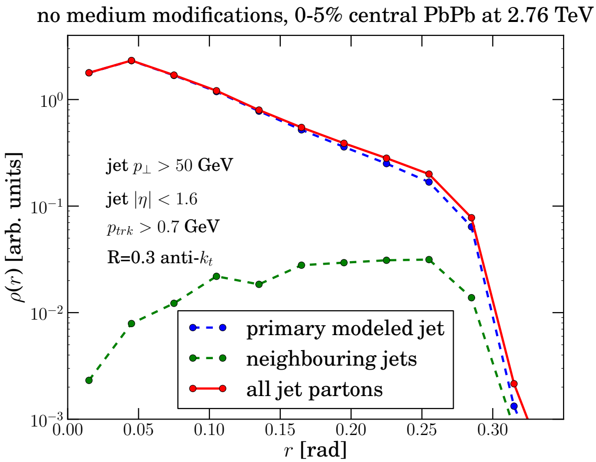


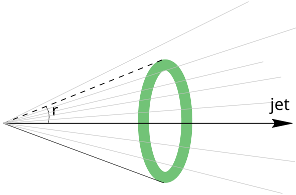
Right: $P(\text{purity} > x)$ for different R



- harder jets are more collimated, so less overlap with neighbours
- with larger jet cone one picks up more neighbouring partons

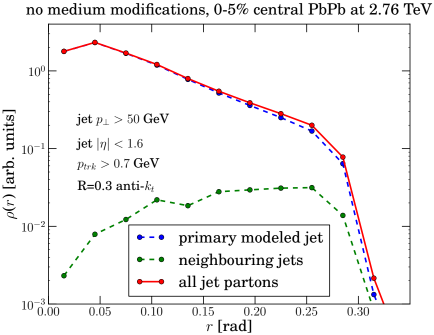
Jet shape



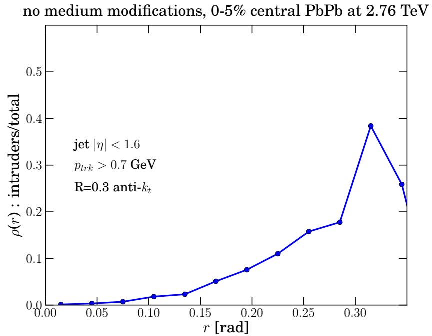


- The core of the jet $(r < 0.2)$ has negligible contribution from the jet overlap.
- For the periphery of the jet the jet overlap starts to be important.

Jet shape

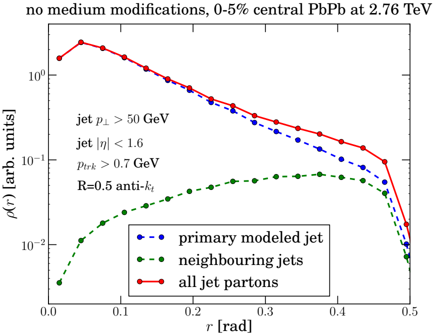


Right: ratio of neighbours/principal

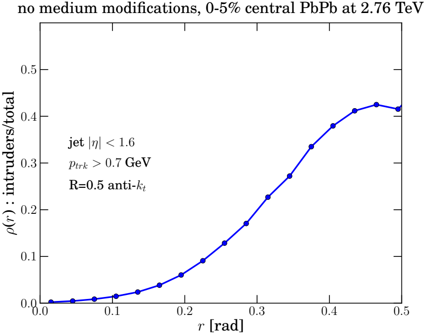


- The effect goes up to 20% at the boundary of the jet cone.

Same thing for $R = 0.5$ cone size

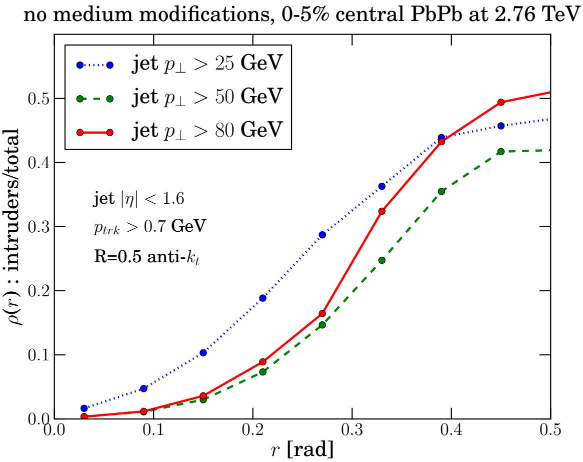


Right: ratio of neighbours/principal



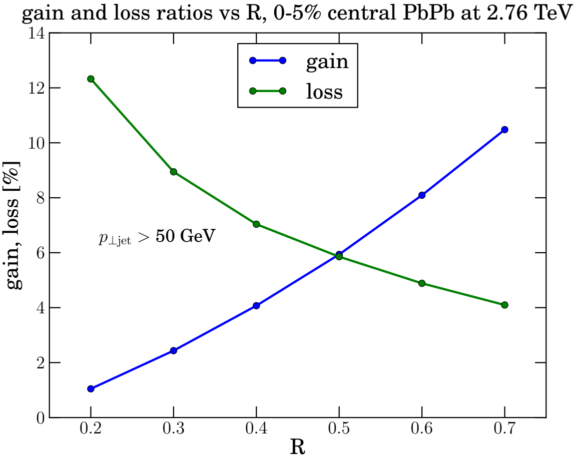
- As the jet cone extends further in r, the contrbution from jet overlap grow further.

Jet $p_\perp$ dependence of the effect



- The jet shape contamination by overlapping jets persists as jet $p_\perp$ increases!

Gain and loss to the reconstructed jet $p_\perp$



- For smaller R, more jet momentum is lost (outside of the cone).
- The larger R, more jet momentum is gained (from the neighbouring jets).

How do the experiments deal with it

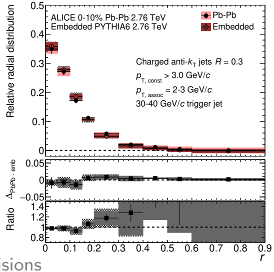
- CMS performs a background subtraction in a statistical way based on PYTHIA+HYDJET simulations - which also removes the jet overlap effects.
  $\Rightarrow$ It should remove the overlap effect as the background jets are not correlated with the jet of interest.

  CMS Collaboration, JHEP 1805 (2018) 006

- ALICE reports the ratio of actual jet shape in PbPb events relative to the shape of (vacuum) PYTHIA jets embedded into actual PbPb events, as a proxy for the PbPb/pp ratio.
  $\Rightarrow$ It should remove the overlap effect as well, provided that PYHIA gives correct shape of vacuum jets.

  ALICE Collaboration, Phys.Lett. B796 (2019) 204-219

  - In order to have apple-to-apple comparison with the experiment, we should:
    - Either degrade the model so that we have solitary jets
    - Or keep all jets together but add all the machinery (medium hadrons, background subtraction)



Summary

- EPOS3 initial state produces multiple hard partons = jet seeds in each **central** Pb-Pb event at the LHC energies
- This creates the effect of jet overlap in momentum space once we attempt to find all of the jet at once with FASTJET
- The effect influences the apparent jet shape.
- As experiments correct for that, the most practical solution is to treat the modelled jets separately.