Resolving the spacetime structure of jets with medium

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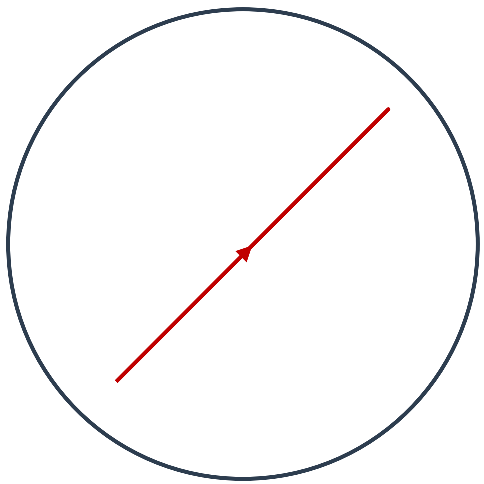
Resolving the spacetime structure of jets with medium

Outline:

1. Jets and parton showers in vacuum
2. Representation on the Lund plane
3. Results from our new parton shower
4. Quenching with a simplified medium

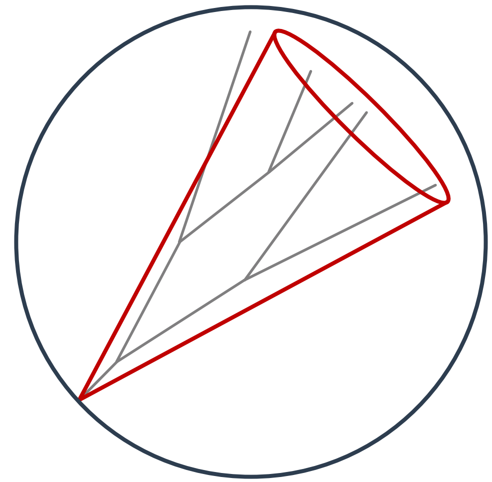
Why do we use jets?

single parton



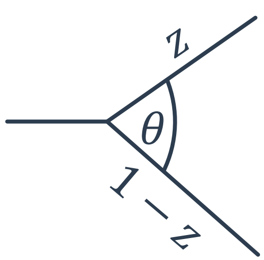
looks simple enough

jet



this object exists in QCD perturbation theory

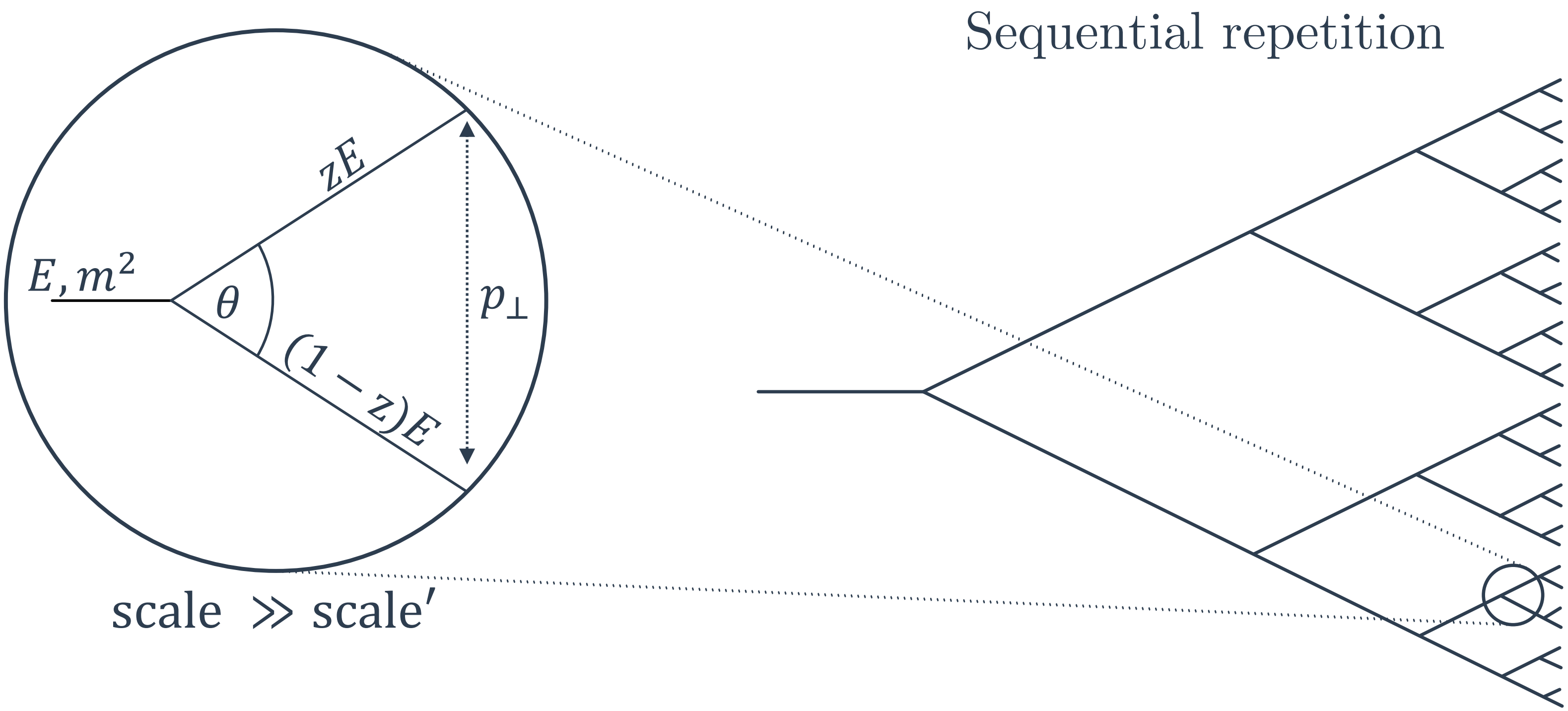
Why? QCD vertex IR-divergences!



$$\frac{\mathrm{d}N}{\mathrm{d}z\mathrm{d}\theta} \approx \frac{\alpha_s C}{\pi} \frac{1}{z} \frac{1}{\theta}$$

At high energies as LHC $N > 1$, there is no more single parton.

Parton showers



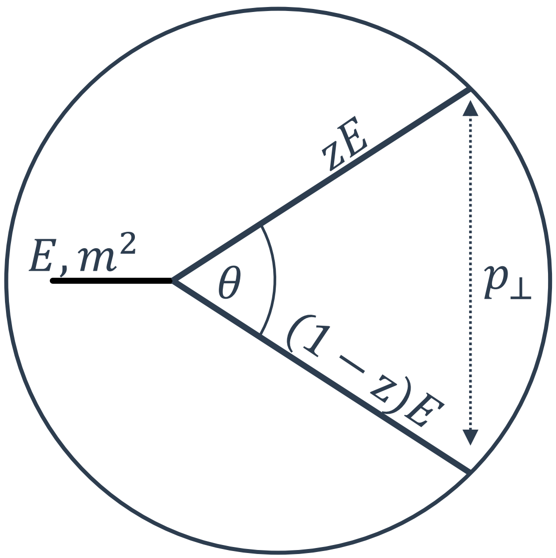
What can be the scale? (evolution variable)

m^2	$\gg$	m'^2	PYTHIA 6, SHERPA<1.2
$p_\perp^2$	$\gg$	$p'^2_\perp$	PYTHIA 8, SHERPA>1.2, DIRE, ARIADNE
θ	$\gg$	θ'	HERWIG

Almost equivalently good choices!

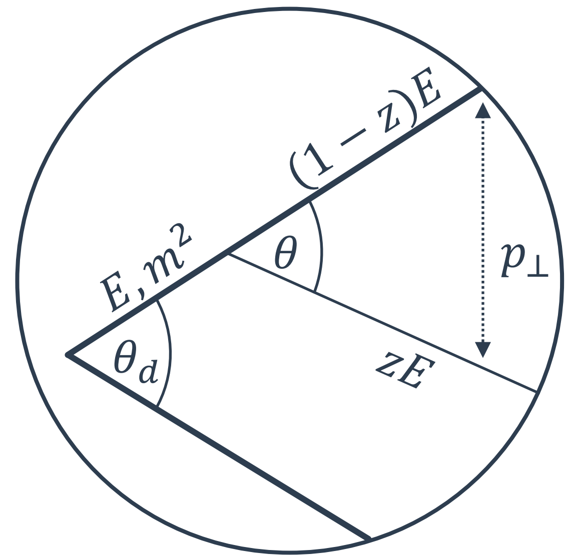
Parton showers: splitting schemes

$1 \to 2$ splitting



Altarelli-Parisi splitting function

$2 \to 3$ splitting (dipole/antenna*)



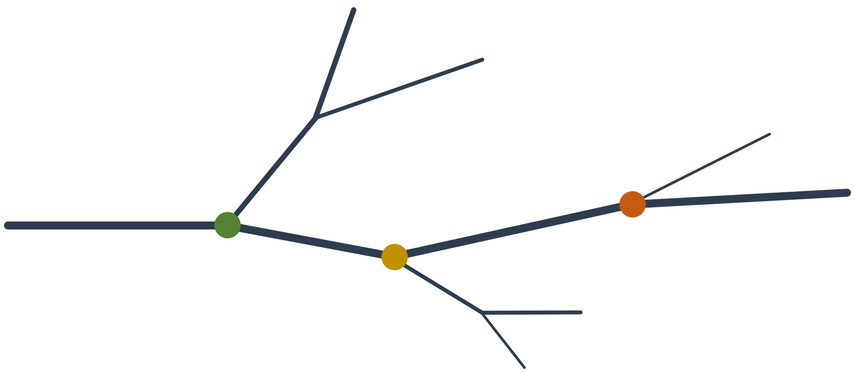
Catani-Seymour splitting function

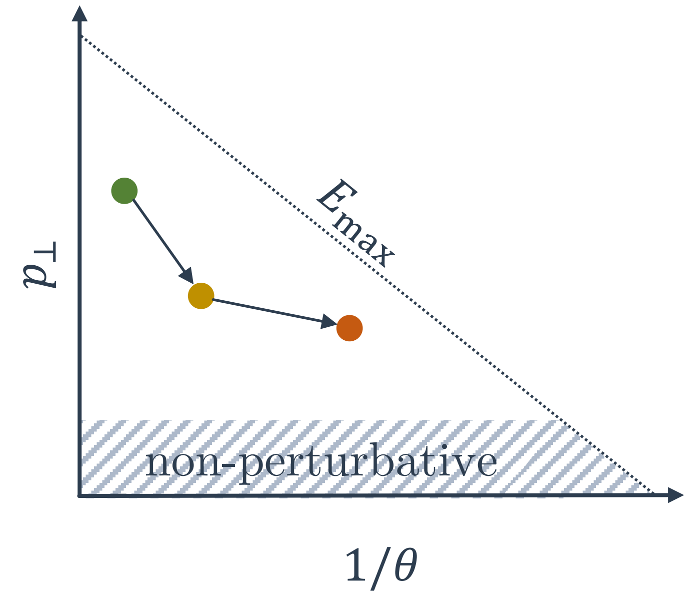
PYTHIA 6,
SHERPA<1.2,

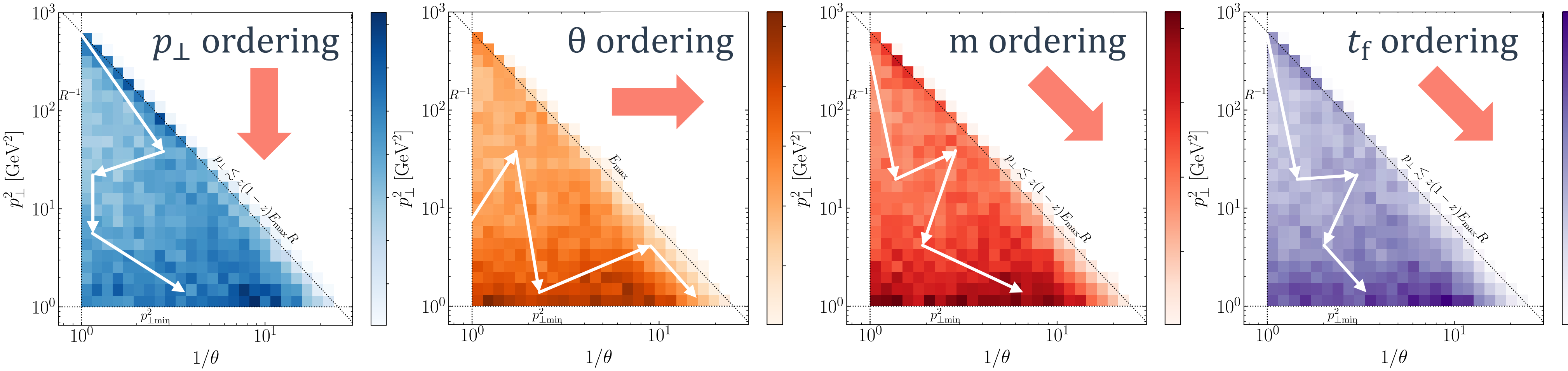
PYTHIA 8,

HERWIG,
DIRE,
ARIADNE*,
SHERPA>1.2

The Lund plane



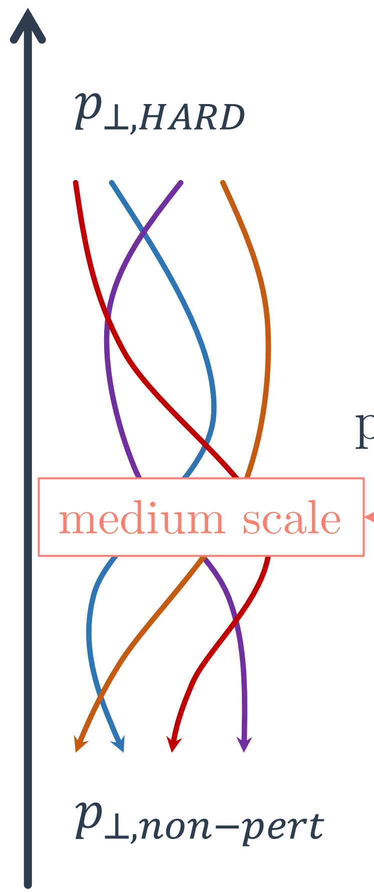




[A. Takacs QM2019 poster]

Why are there different orderings?

Highly excited partons



Ground state hadrons

parton showers with different orderings

medium scale ⟷ space-time structure of the medium ⟷ space-time structure of the jet

*Instead of the medium one could place the scale of MPI, hadronization relevant for vacuum studies.

Our 12 new parton showers

- All flavors and energy-momentum conversation

- Different ordering variables:

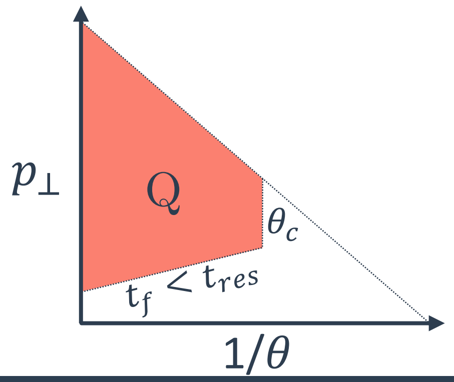
  $p_\perp$, m, t_f, θ

- Different splittings (momentum frame):

  Altarelli-Parisi (1→2) splitting: "PYTHIA6 like"
  Altarelli-Parisi (1→2) splitting with recoil: "PYTHIA8 like"
  Catani-Seymour dipole shower (2→3)

- Medium using quenching weights:

  energy shift of the particles,
  medium coherence effects.



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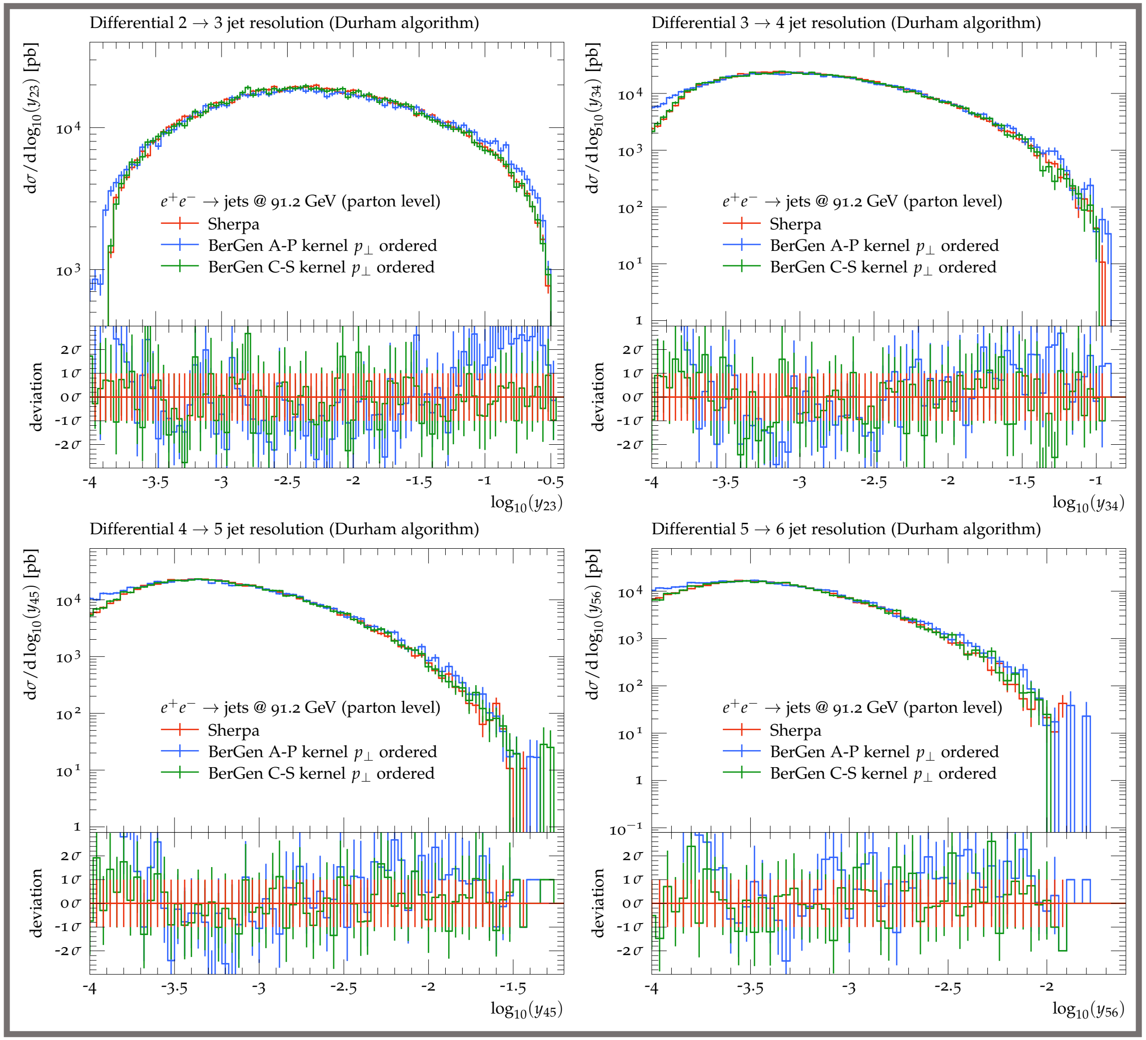
Validation in e⁻e⁺→jets

PYTHIA8 like and dipole shower

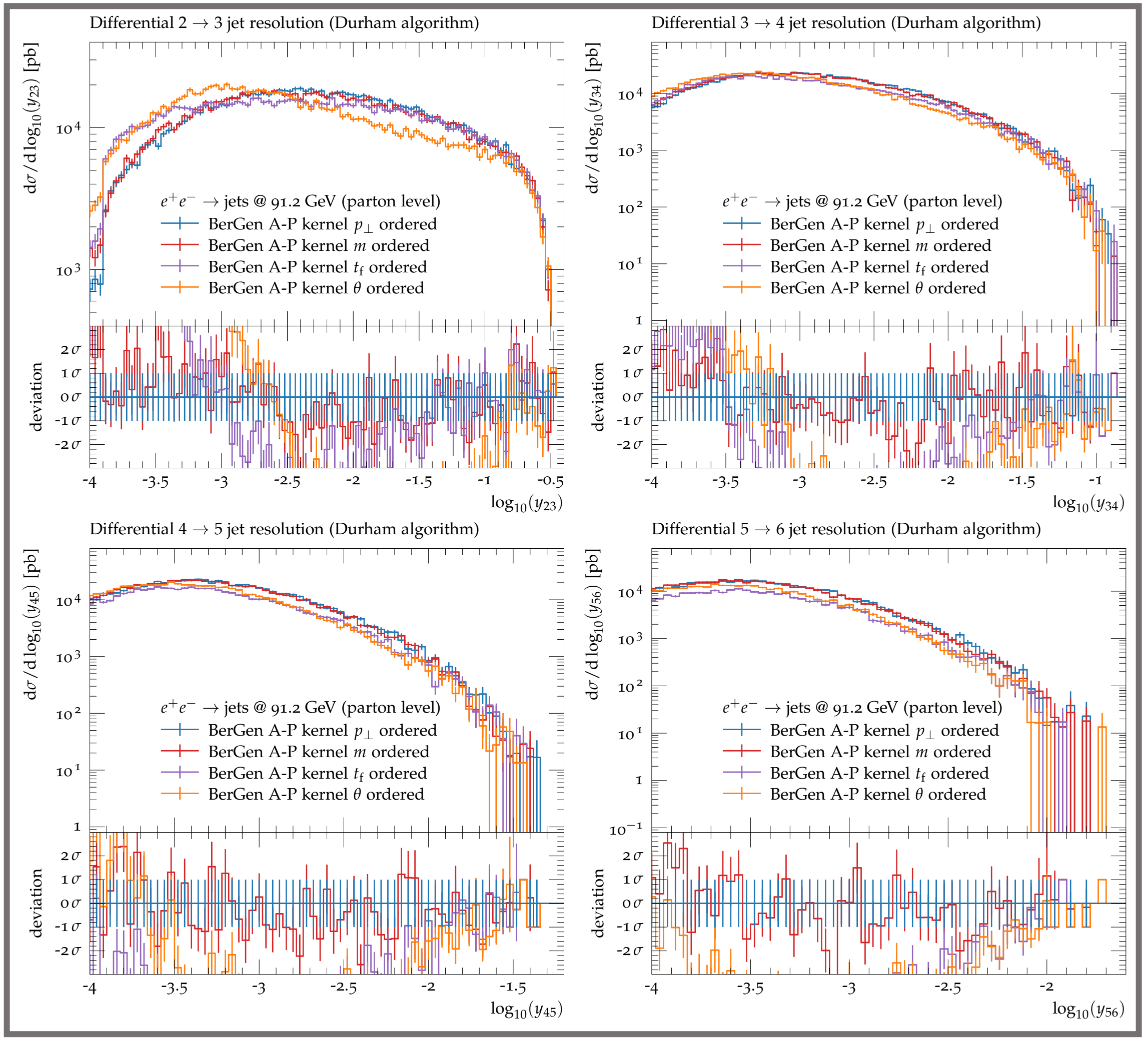


Very good agreement with Sherpa.

Dipole shower does a bit better job.

Validation in e⁻e⁺→jets

PYTHIA8 like

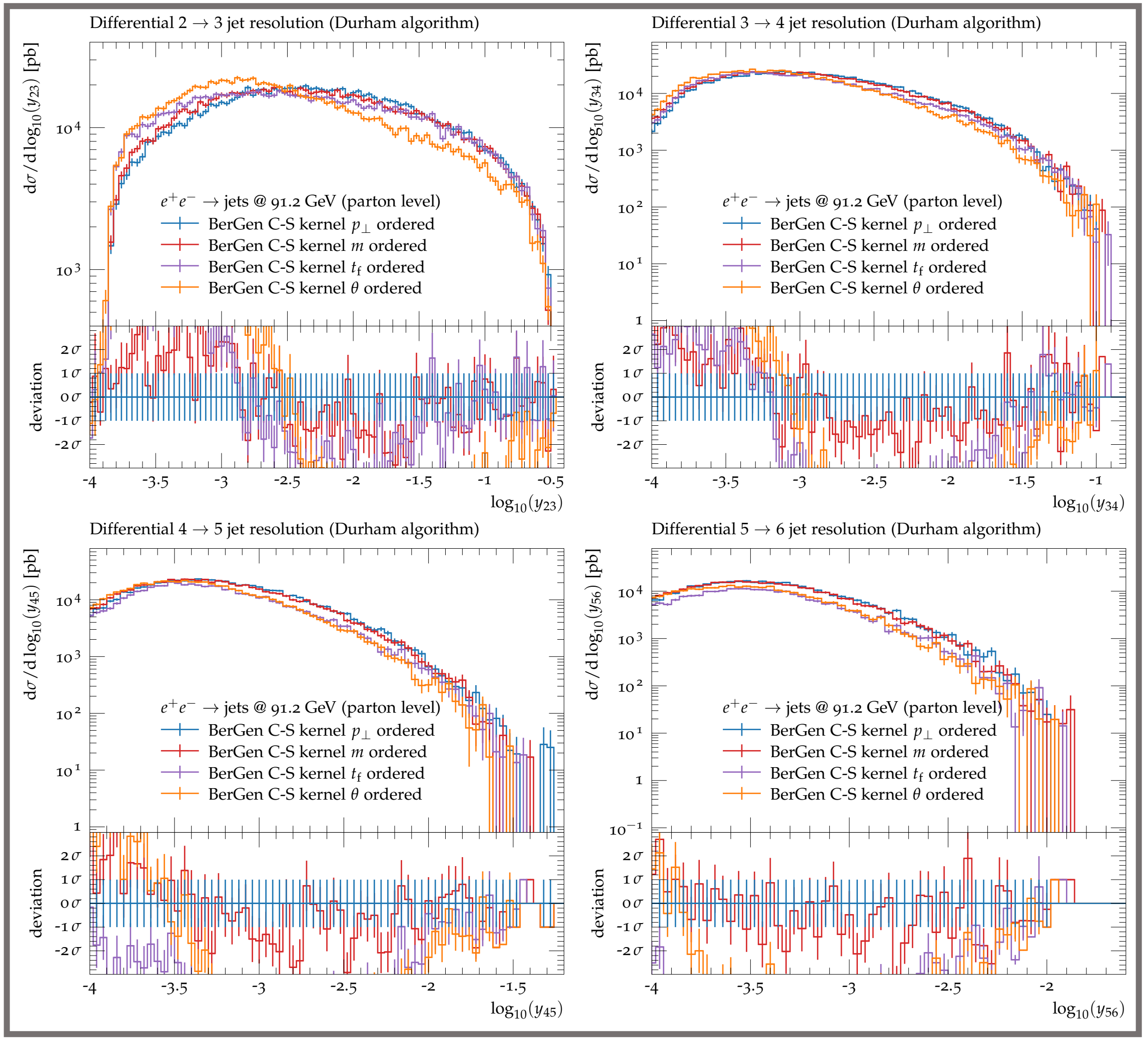


Different orderings are very similar.

θ and t_f are a bit different.

Validation in e⁻e⁺→jets

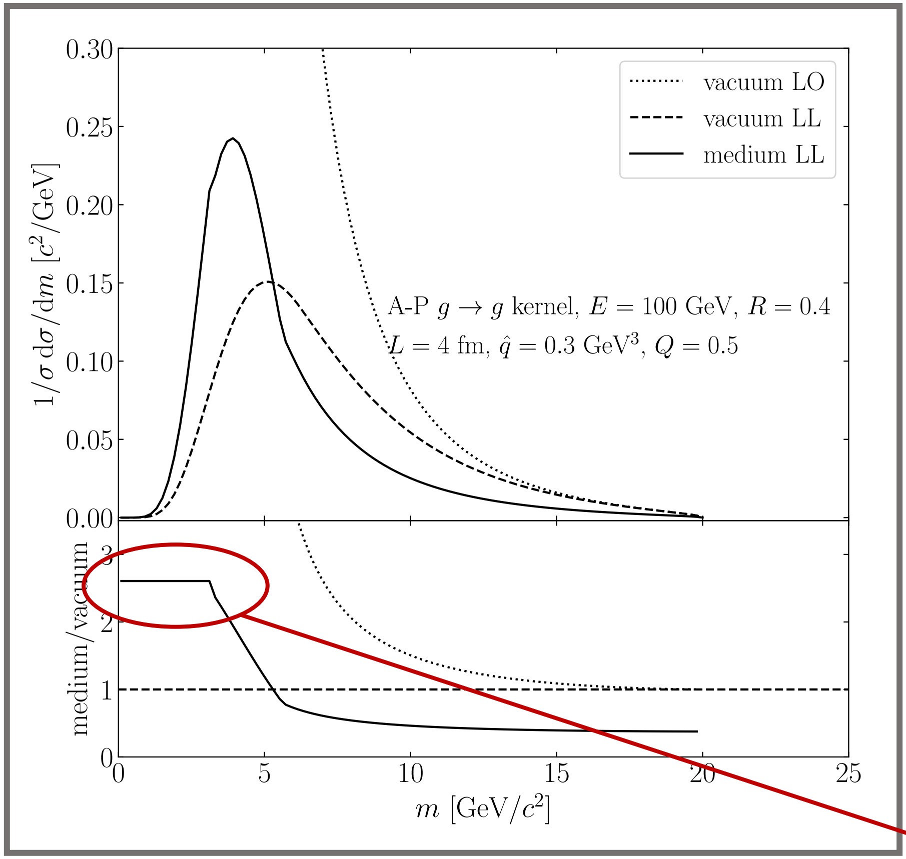
Dipole shower



Different orderings are very similar.

θ and t_f are a bit different.

Jet mass (at Leading Logarithm)



LO and LL good agreement at high m.

LL captures the peak.

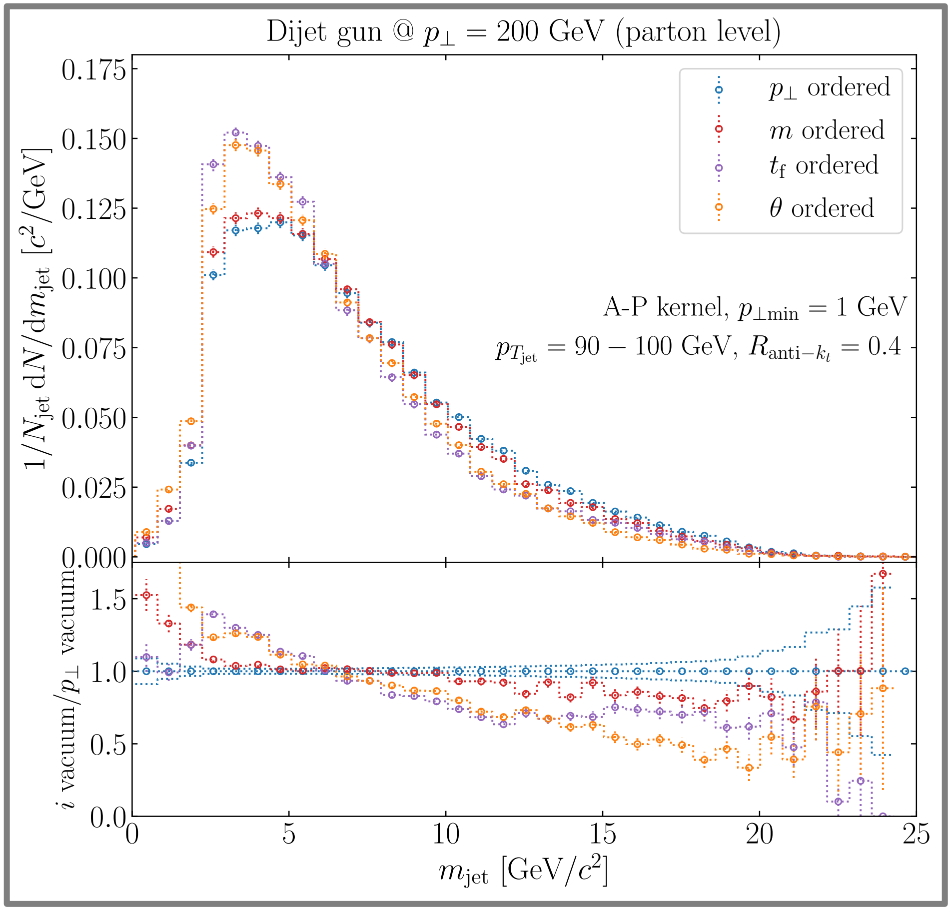
Medium suppresses high m.

Medium shifts the peak.

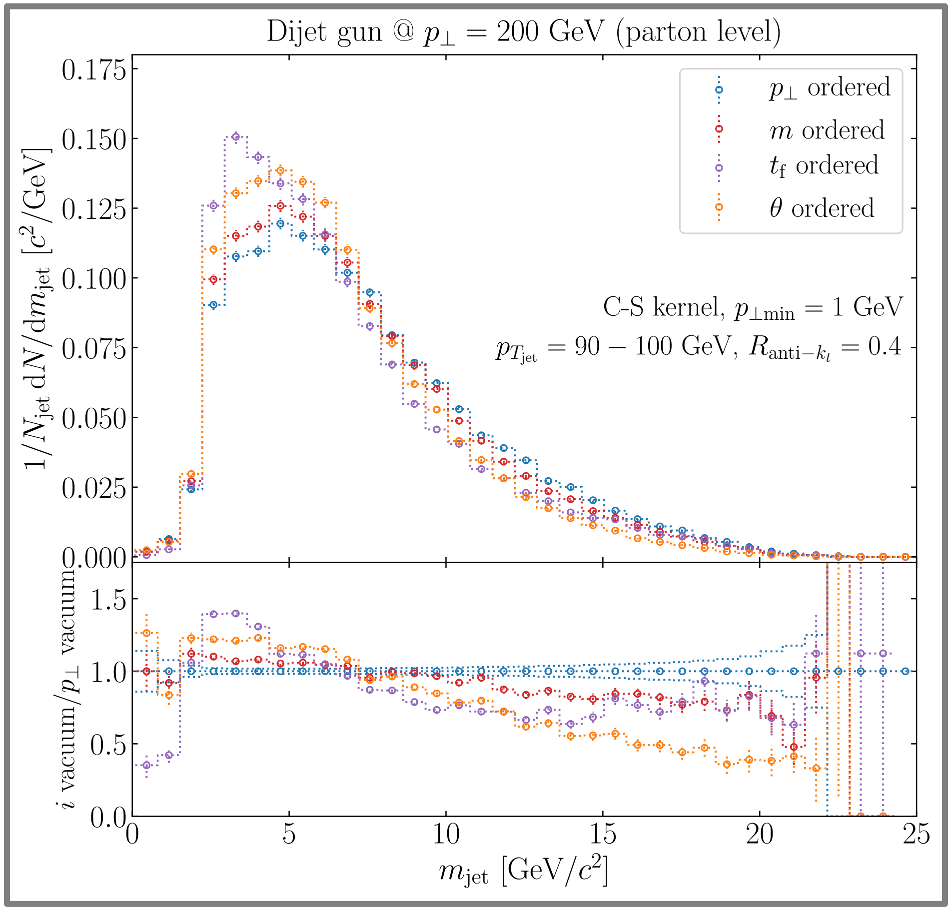
Ratio gets flat for unresolved masses.

Jet mass (vacuum)

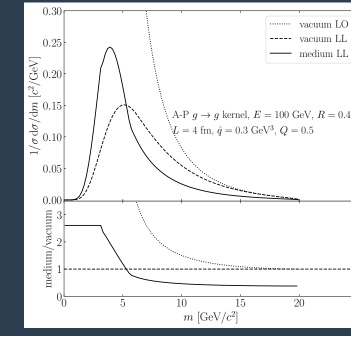
PYTHIA8 like



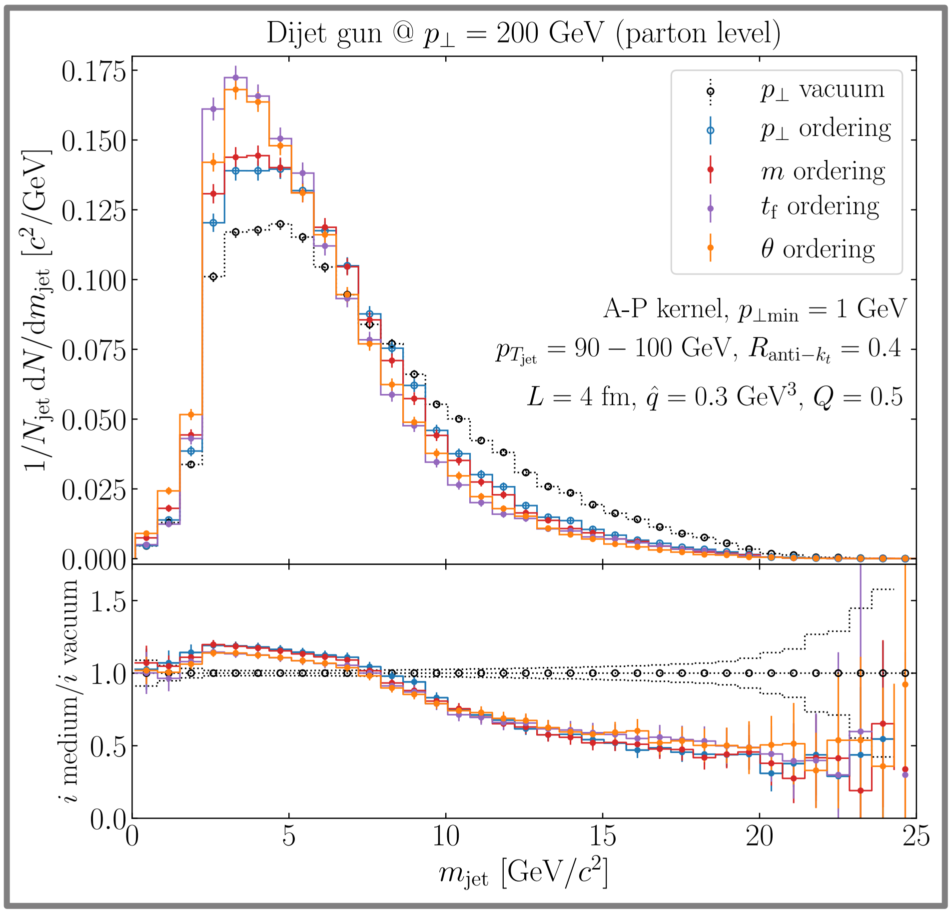
Dipole shower



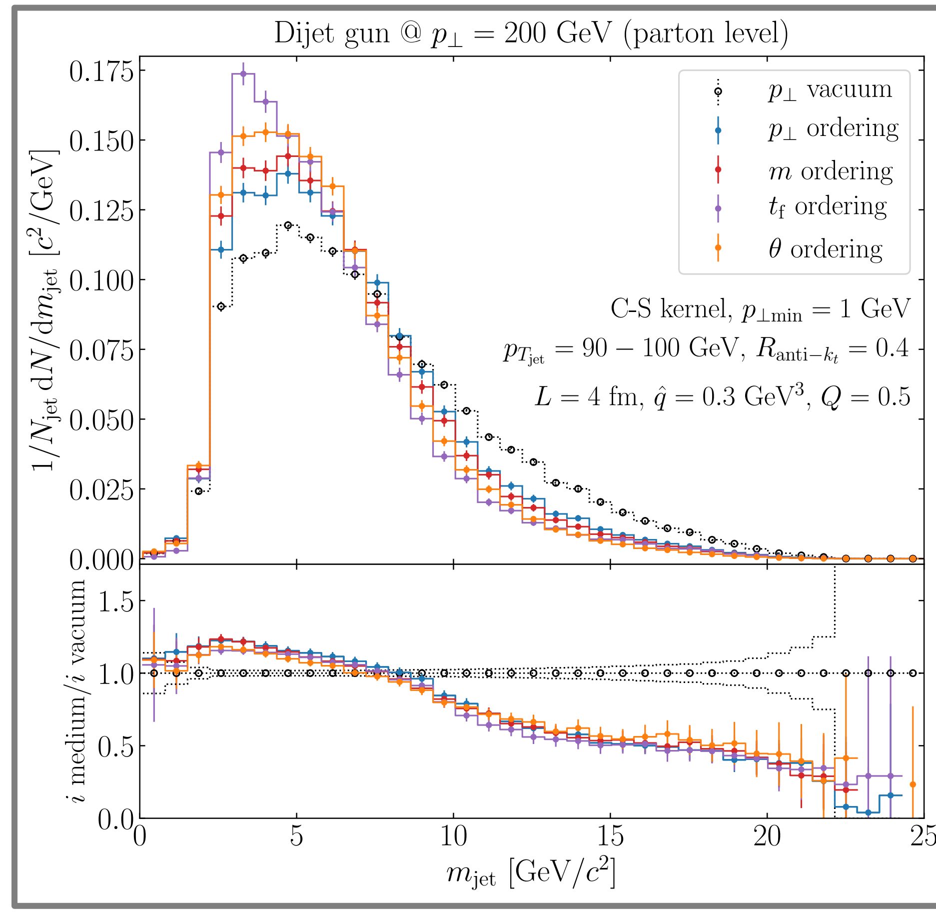
Jet mass (medium)



PYTHIA8 like



Dipole shower



Summary

MCnet is going to support our investigations.

1. Introduction of parton showers uncertainties:
   choice of ordering variables and splitting schemes.

2. Systematic study of parton shower uncertainties:
   12 implemented parton showers.

3. E-loss and coherence are implemented by quenching weights:
   analytic and MC comparison.

+ Future:
  ready for other observables: $z_{\rm g}$, $r_{\rm g}$, $n_{\rm SD}$, $m_{\rm jet}$, Lund plane,
  include more medium effects.

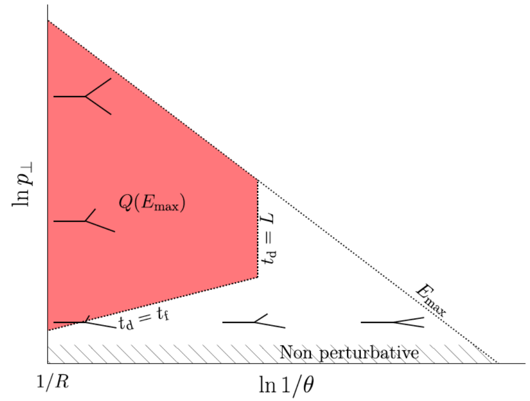
Thank you for your attention!

Quenching weight

The momentum radiated out of the jet cone is described by the quenching factor Q of each parton, resulting for n particles [1]

$$\frac{\mathrm{d}^n\sigma_{\mathrm{med}}(p_{\mathrm{jet}})}{\mathrm{d}p_1 \cdot \ldots \cdot \mathrm{d}p_n} = Q^n(p_{\mathrm{jet}}) \frac{\mathrm{d}^n\sigma_{\mathrm{vac}}(p_{\mathrm{jet}})}{\mathrm{d}p_1 \cdot \ldots \cdot \mathrm{d}p_n}, \quad (1)$$

assuming that all branchings are affected by energy loss. However, a **branch is quenched only if the medium resolves its color** [2]. This takes time t_{d}, thus the branching formation has to be long enough, and placed inside the medium $t_{\mathrm{d}} < t_{\mathrm{f}} < L$. This implies a separation of time-scales of vacuum and medium-induced processes. The branches and the **quenched region** are illustrated on the Lund plane below.



Quenching is implemented by the following procedure (see Fig. 1.):

1. Generate a vacuum jet.
2. Count the splittings inside the region and forbid jump-backs.
3. Reweight the whole jet by the quenching factor (extracted from data).

[1] R. Baier, Y. L. Dokshitzer, A. H. Mueller and D. Schiff, JHEP **0109**, 033 (2001).
[2] Y. Mehtar-Tani and K. Tywoniuk, Phys. Rev. D**98**, 051501 (2018).

[A. Takacs QM2019 poster]