

Evolution of the jet opening angle distribution in holographic plasma

Andrey V. Sadofyev

MIT

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based on PRL 116 (2016) 21 (arxiv: 1602.04187)
by AS, Rajagopal, van der Schee

- QGP is strongly interacting.
- Jets are main available probes of the plasma.
- A jet could be treated perturbatively (ignoring the first point).
- One could use holographic duals turning to the strongly coupled regime (ignoring everything else).
- I'll propose a new way to combine insights from both regimes.

AdS/CFT is a beautiful tool to deal with $N = 4$ SYM in the infinitely strong coupling limit which shares some properties with QCD (in a similar regime).

Using holography involves some caveats:

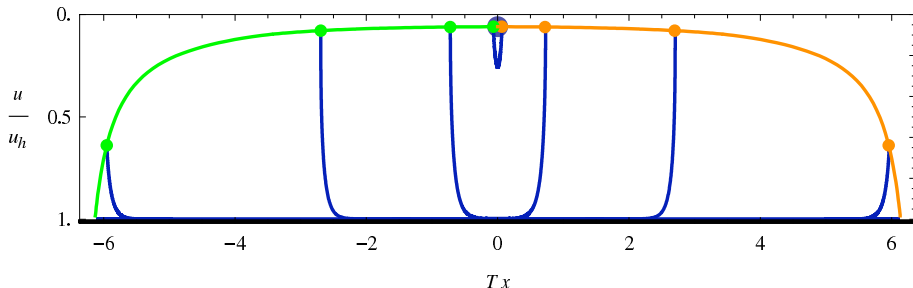
- Infinite coupling limit (while QCD is at an intermediate regime);
- No confinement in SYM (not a problem with plasma, but with notion of jet);

However it is useful in many aspects:

- A method to treat strongly interacting media;
- Could give intuition in the strong coupling limit;
- Allow improved models covering some aspects of pQCD;

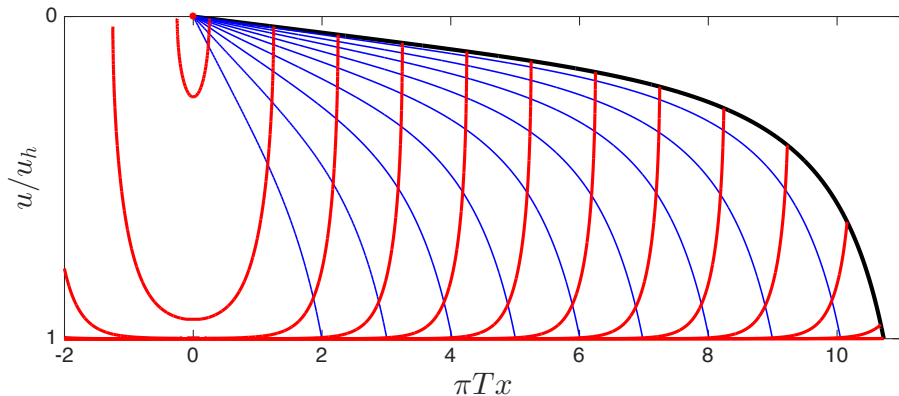
Jet production

A holographic massless quark corresponds to the end point of a string free-falling in the bulk¹.

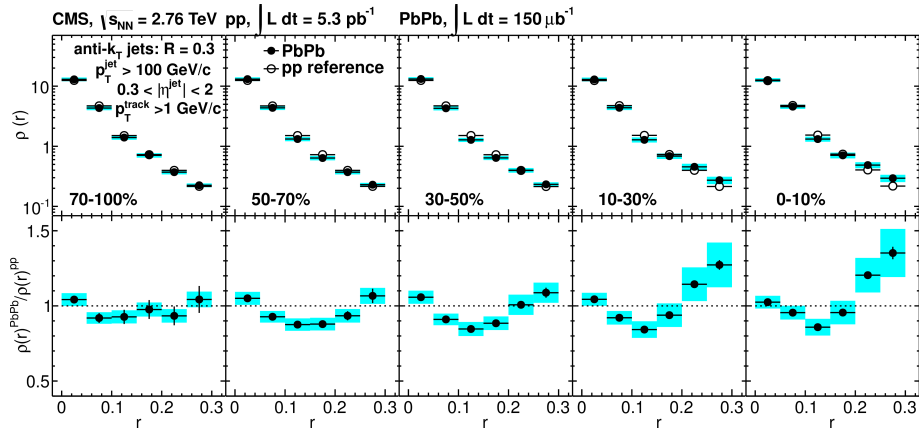


The depth in the bulk corresponds to **the size of the energy cloud** surrounding the quark. Equivalently there is a correspondence between the initial downward angle in the bulk and **the initial jet opening angle**.

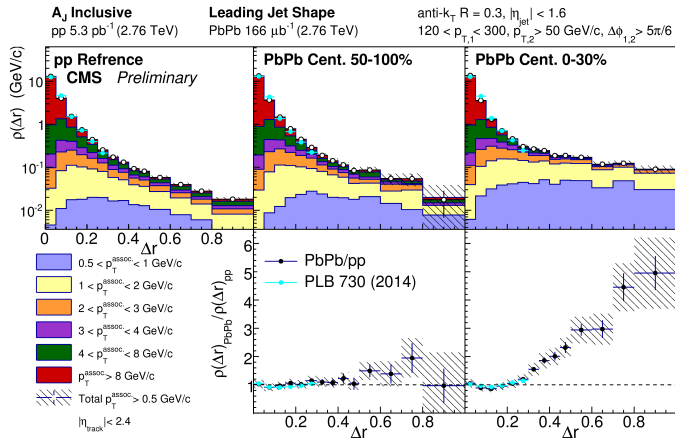
¹see e.g. K. Jensen et al., 2008; L. Yaffe et al., 2008.



With this jet model energy propagates along null geodesics falling into the BH (production of the hydrodynamic wake by the light quark). Also one can see that **a jet with wider opening angle loses more energy**.



Jets in PbPb appear to be narrower than jets with the same energy in pp for small angles.



The narrowing is caused by the hard component of the jet while the broadening at large angles is in the soft particles (likely coming from the wake).

Contradiction?

Indeed

- Each holographic jet gets wider propagating through the plasma;
- Jets in PbPb collisions may be narrower than jets in pp collisions;

On the other hand

- To compare quenched jets and unquenched jets with the same final energy one has to look at the evolution of an ensemble of jets;

To do so we need reasonable initial distributions of initial opening angle and initial energy (the distributions in the absence of plasma). The goal is to look for a direct contradiction and many things could be simplified.

A simple model

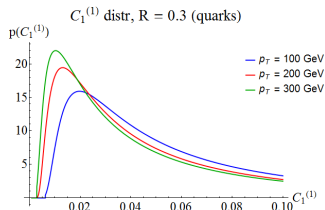
To mimic pp collisions we choose the energy distribution to be proportional E^{-6} and take the result from pQCD² for the angle distribution:

$$C_1^{(\alpha)} = \sum_{i,j} z_i z_j \left(\frac{|\theta_{ij}|}{R} \right)^\alpha$$

z_i - fraction of jet energy,

θ_{ij} - angle between particles,

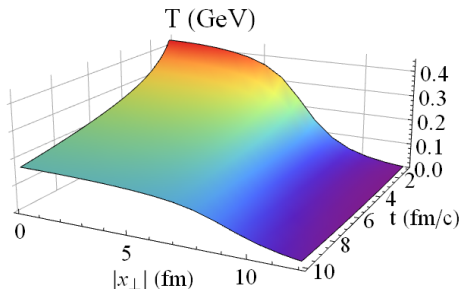
R - jet radius parameter.



$C_1^{(1)}$ is linked to the AdS angle σ_0 via a free parameter: $C_1^{(1)} = a\sigma_0$

Jets are not made of particles; no R (put $R = 0.3$), no fragmentation function, no z_i , etc.

²A.J. Larkoski et al, 2014.



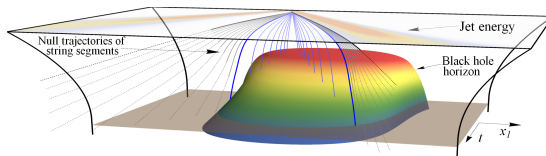
For the temperature profile $T(x_{\mu})$, we assume boost invariant longitudinal expansion and use a simplified blast-wave expression for the transverse expansion³. Thus we need to analyze only jets with zero rapidity.

Temperature is rescaled by an extra parameter $b < 1$ to get reasonable energy loss (fit couplings and the number of dof).

Thus we have two parametric model (a, b) with input from pQCD

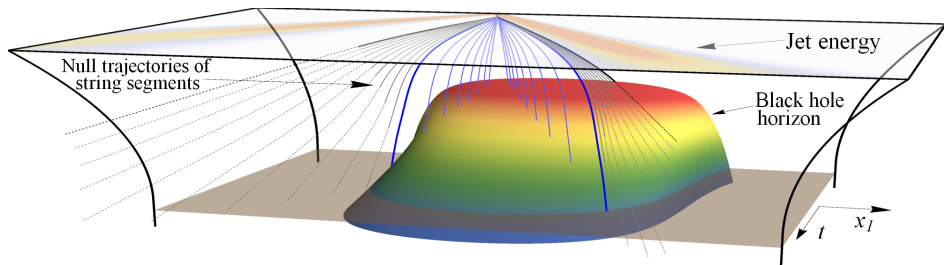
³A. Ficnar, 2014.

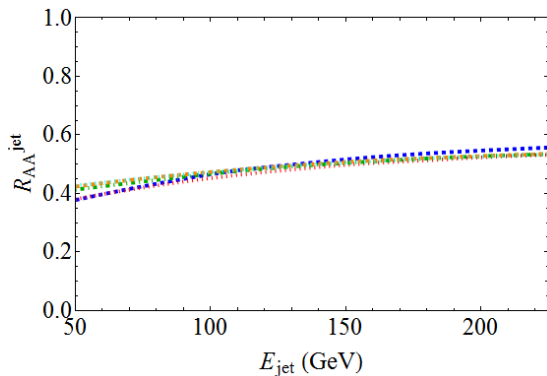
The procedure



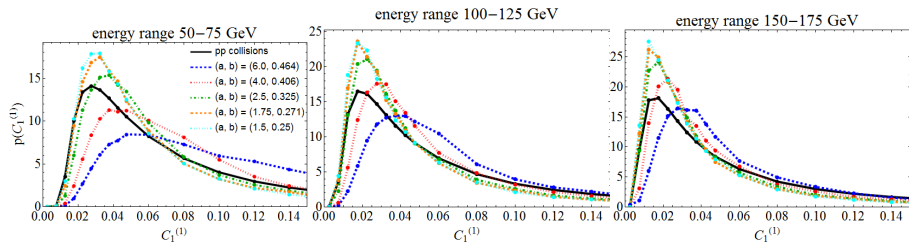
- Generate an initial set of opening angles and energies (pQCD);
- Generate an initial set of transverse positions;
- Let each jet to propagate through the prepared plasma droplet;
- Find the energy loss and the opening angle for each jet at the moment of freeze-out (region with $T = 175\text{MeV}$);
- Scan the parameter space sorting energies/angles;
- Compare initial and final distribution;

Results



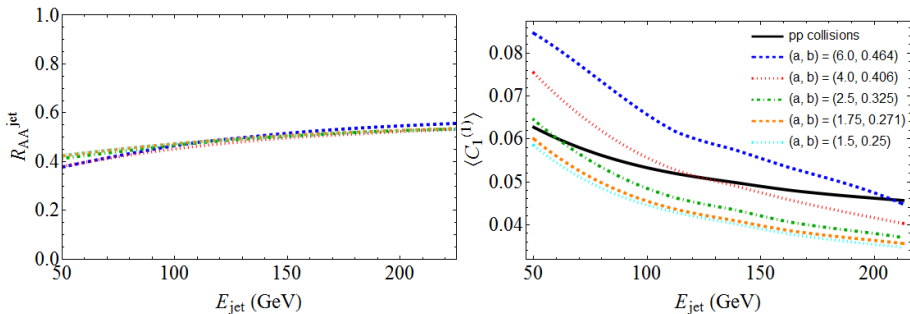


- Here R_{AA}^{jet} is the ratio of the number of jets with a given energy after propagation through the plasma to that in the initial ensemble (shouldn't be directly compared to the experimental curves).
- The combinations of (a, b) are chosen to keep R_{AA}^{jet} the same and close to the experimental value for jets at LHC heavy-ion collisions.

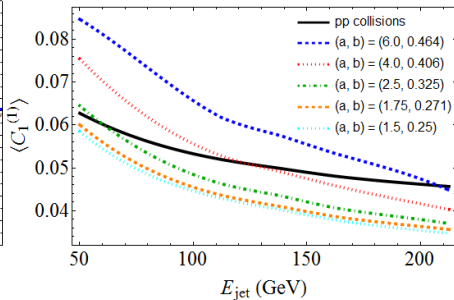
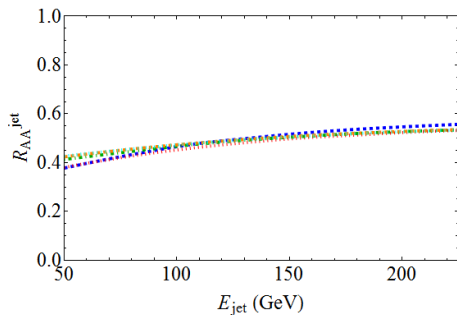
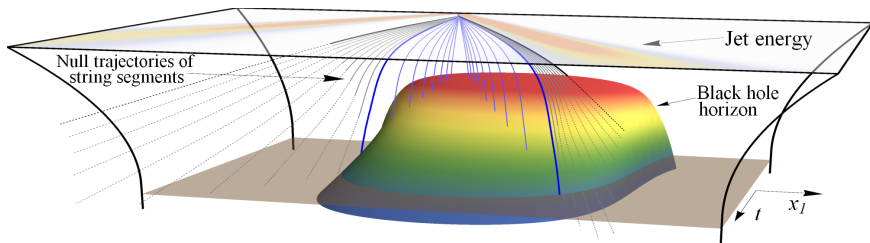


We observed two competing effects:

- Each separate jet gets wider traveling through plasma thus pushing the pick of distributions to the right.
- Wide jets are lost and can't be compensated by jets coming from higher energies (E^{-6}) resulting in distributions pushed down for large angles.



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- The combinations of (a, b) are chosen to keep R_{AA}^{jet} the same and close to the experimental value for jets at LHC heavy-ion collisions.
- **One can see that despite of similar R_{AA}^{jet} the mean values are pretty different.**



Discussions

Results:

- Energy loss highly depends on the opening angle.
- Each jet gets wider resulting in the loss of narrow jets in final distribution.
- Widest jets get lost resulting in the suppression of the large angle tail.
- However the mean opening angle could go both up and down depending on the initial distributions.

To do list:

- Improve the model in one of many possible ways;
- Analyze the distribution of jet opening angles along with its mean in other models for jet quenching, in Monte Carlo calculations of jet quenching at weak coupling, and in analyses of data.