Jet-medium interaction in dual models[1]

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[1] in collaboration with J. Brewer, K. Rajagopal, W. van der Schee (1704.05455)

- 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).
- We'll try 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:

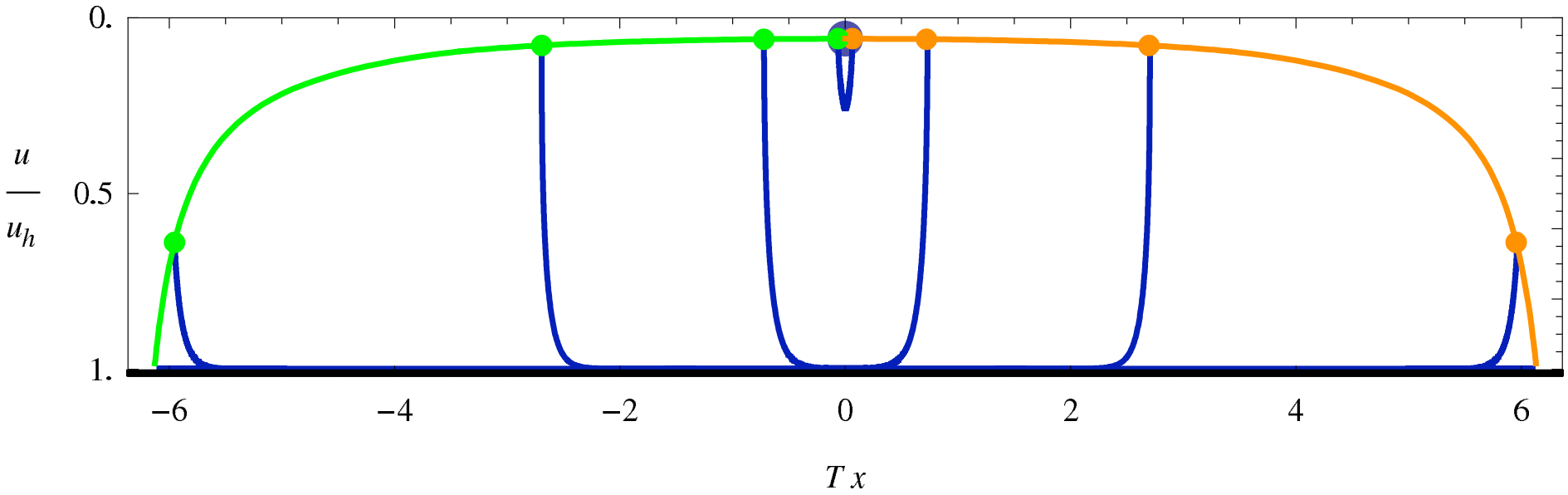
- Infinite coupling limit (while QCD is at an intermediate regime);
- No confinement in SYM (not a problem with plasma);

However it is useful in many aspects:

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

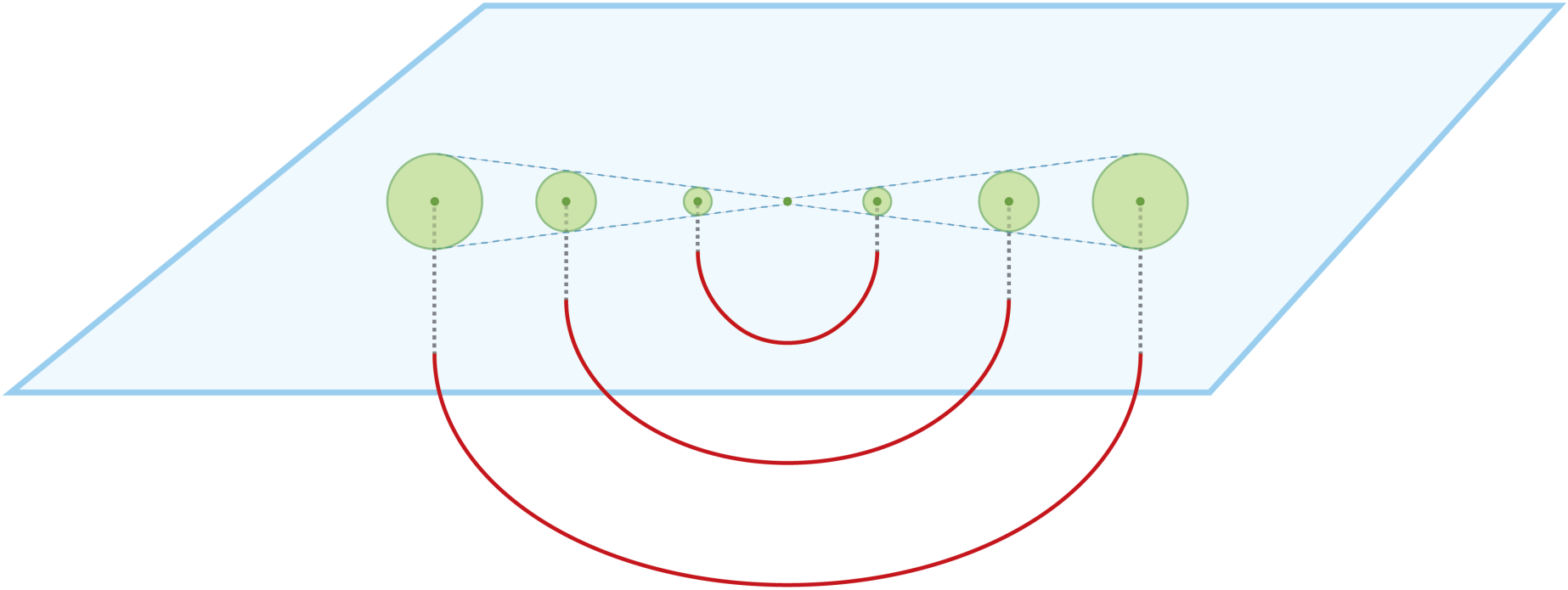
Jet production

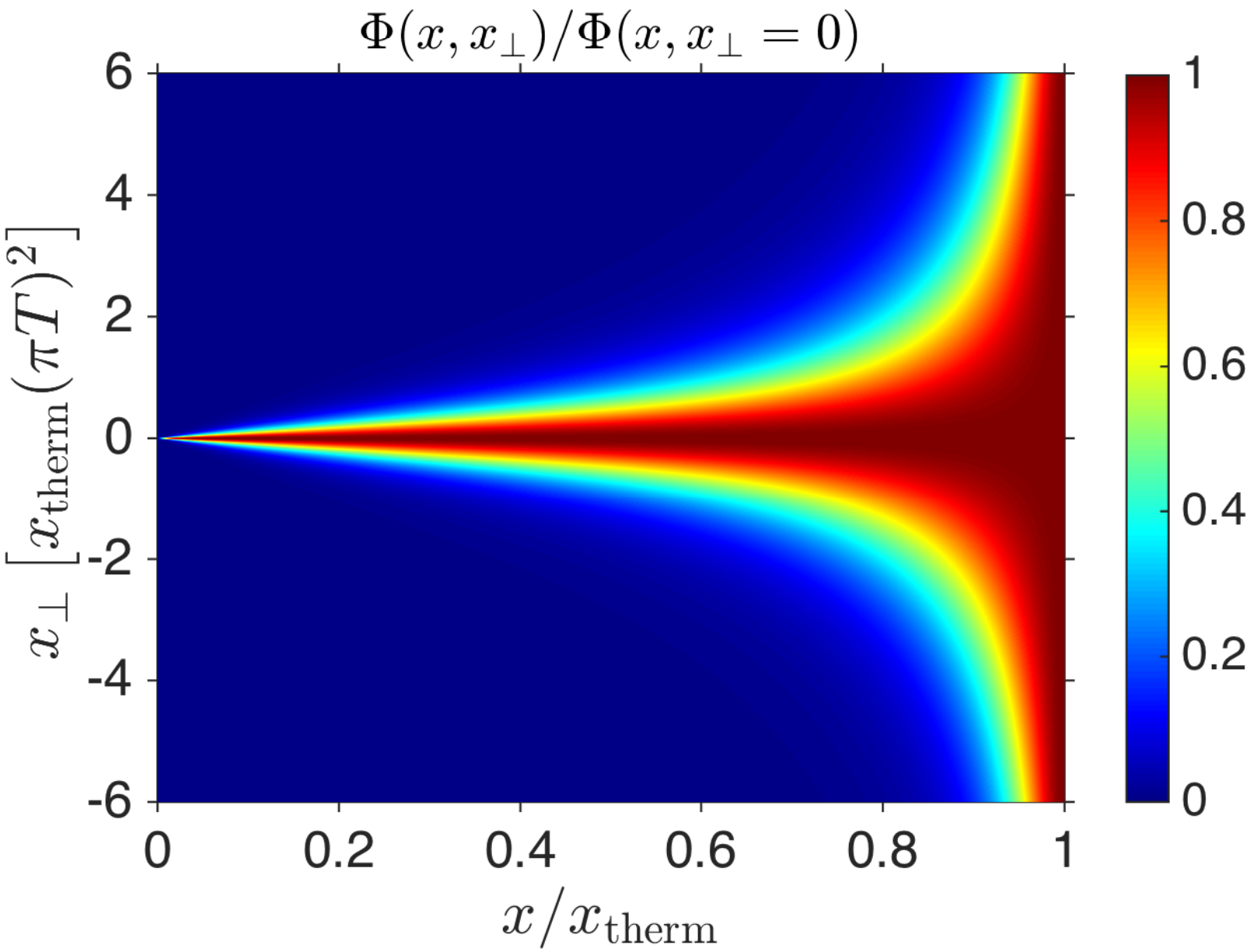
A quark is dual to the end point of a string in the bulk[2].



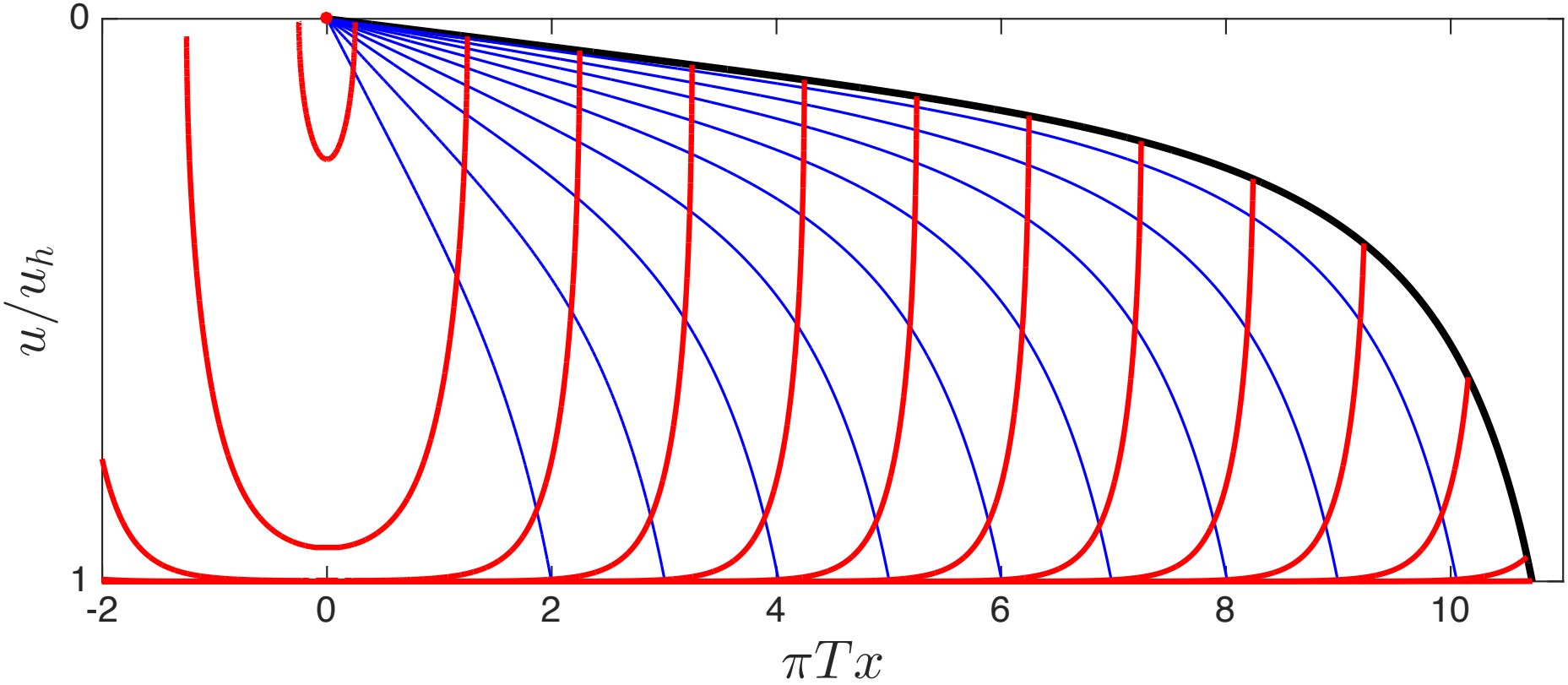
The depth in the bulk corresponds to **the size of the energy cloud** surrounding the quark. Equivalently there is a correspondence between the initial downward angle in the bulk and **the initial jet opening angle**.

[2] see e.g. K. Jensen et al., 2008; L. Yaffe et al., 2008.



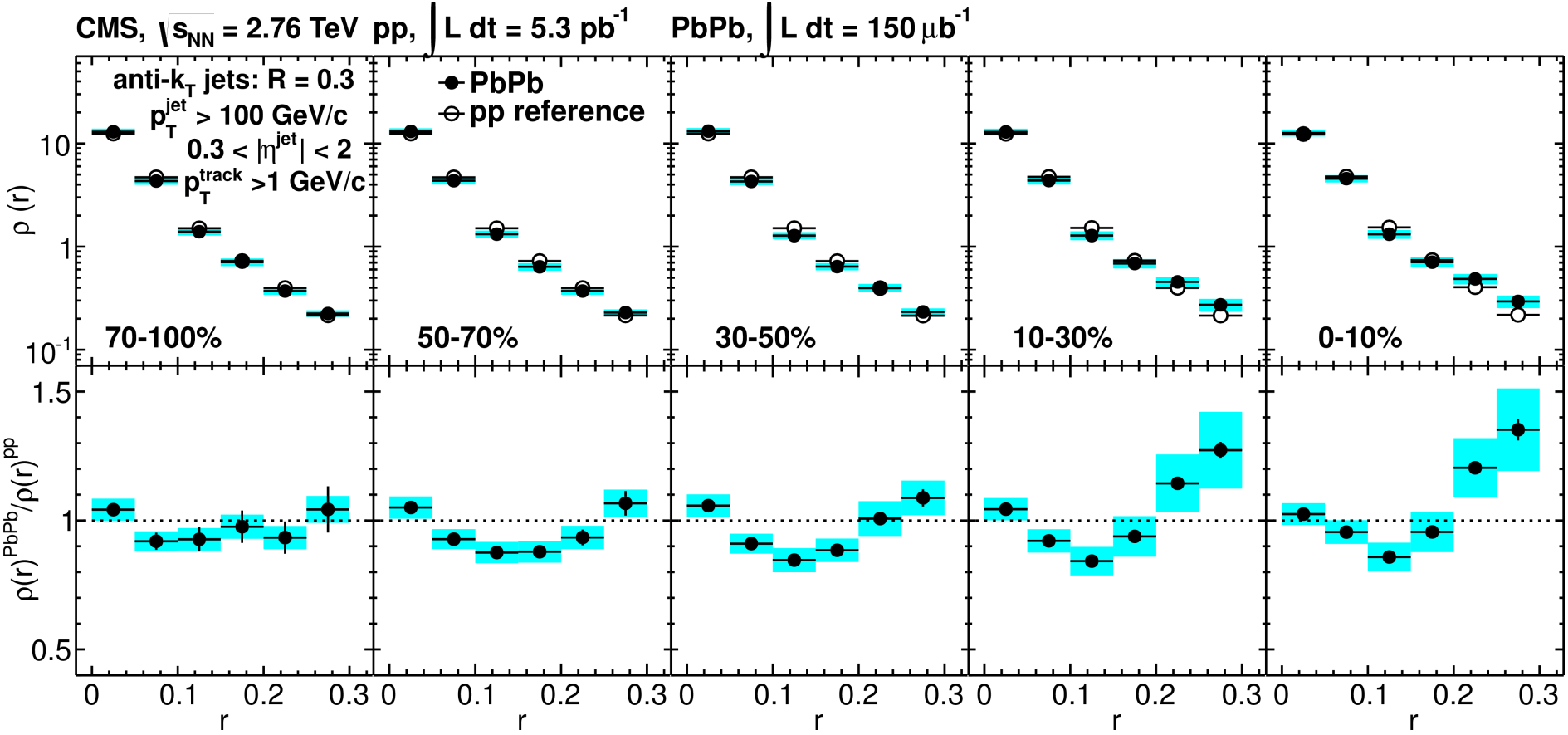


P. Chesler, K. Rajagopal, 2015



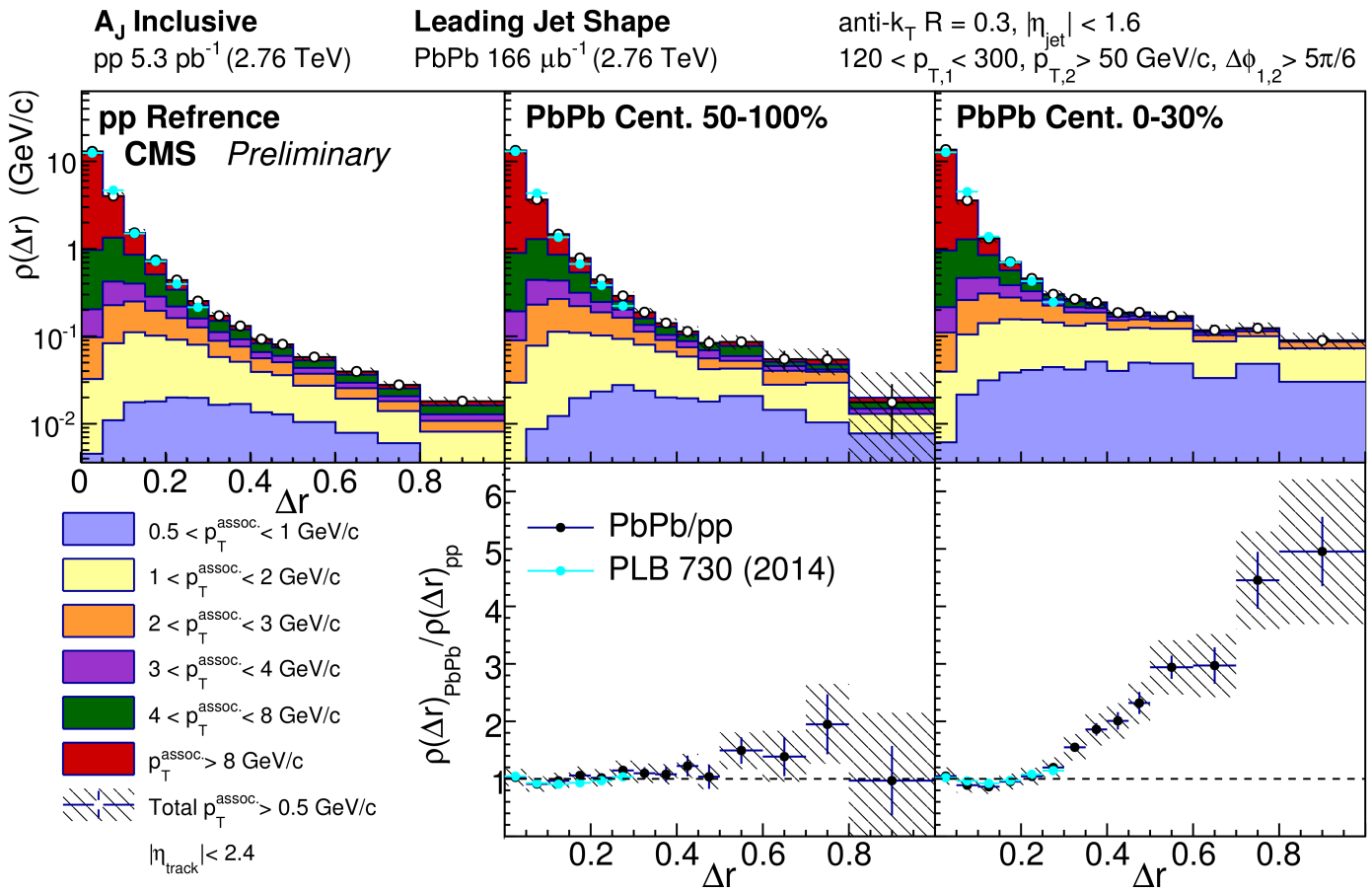
With this jet model energy propagates along null geodesics falling into the BH (production of the hydrodynamic wake by the light quark). Also one can see that **a jet with wider opening angle loses more energy**.

P. Chesler, K. Rajagopal, 2015



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

CMS, HIN-12-002



The narrowing is caused by the hard component of the jet while the broadening at large angles is in the soft particles.

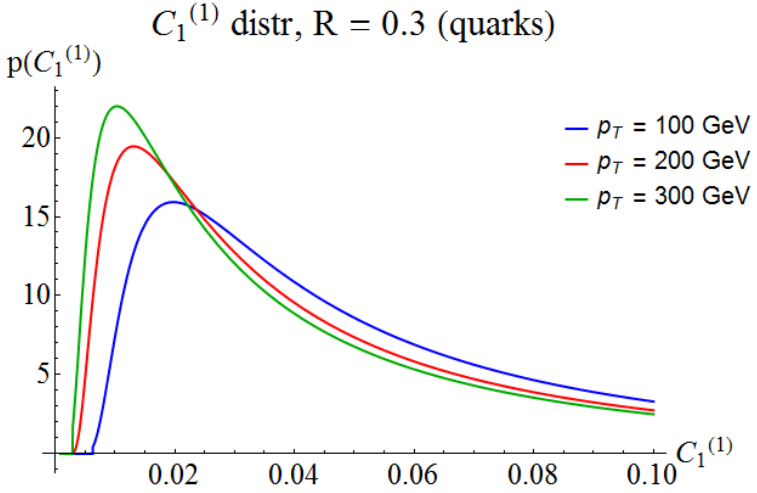
CMS, HIN-15-01

A simple model

To mimic pp collisions we choose the energy distribution E^{-6} and take the result from pQCD[3] for the angle distribution:

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

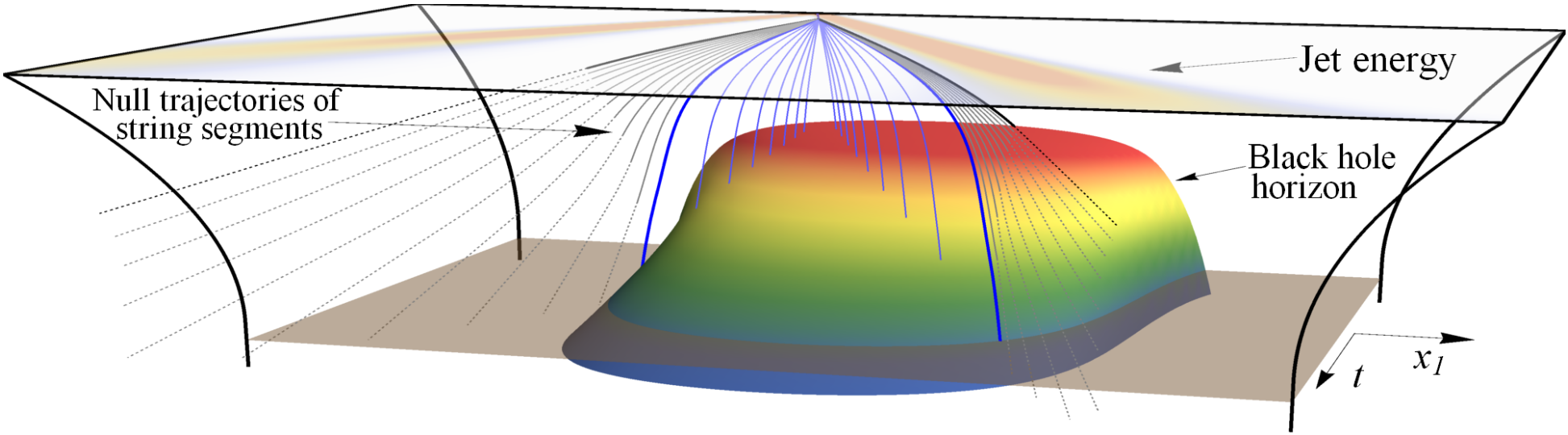
z_i-fraction of jet energy,
θ_{ij} - angle between particles,
R - jet radius parameter.



Some free parameters:

$$C_1^{(1)} = a\sigma_0 \quad , \quad T_{SYM} = bT_{QCD}$$

[3] A.J. Larkoski, S. Marzani, G. Soyez, J. Thaler, 2014.


Null trajectories of
string segments
Jet energy
Black hole
horizon
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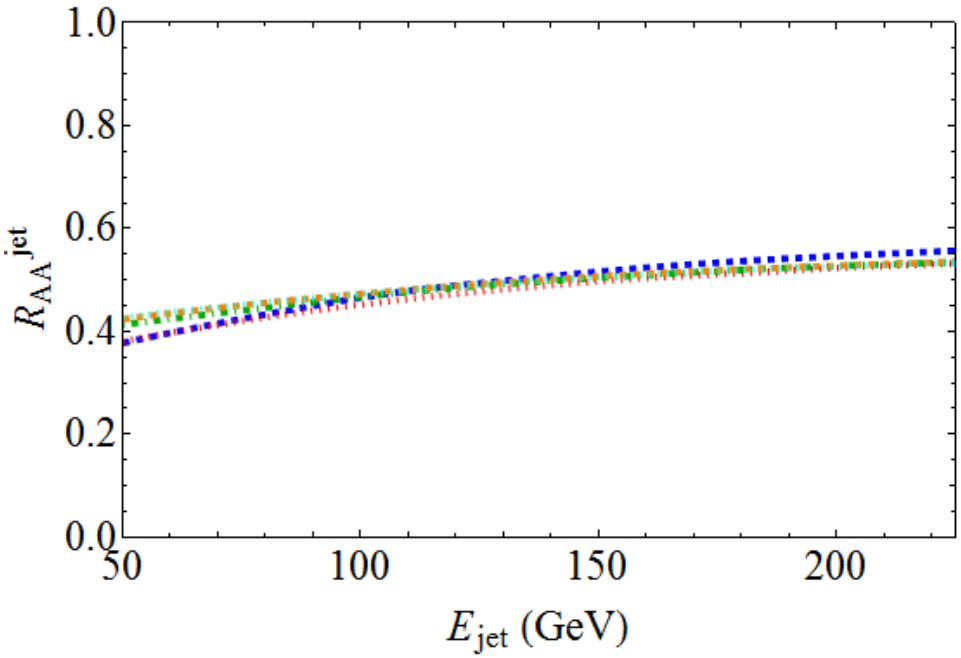
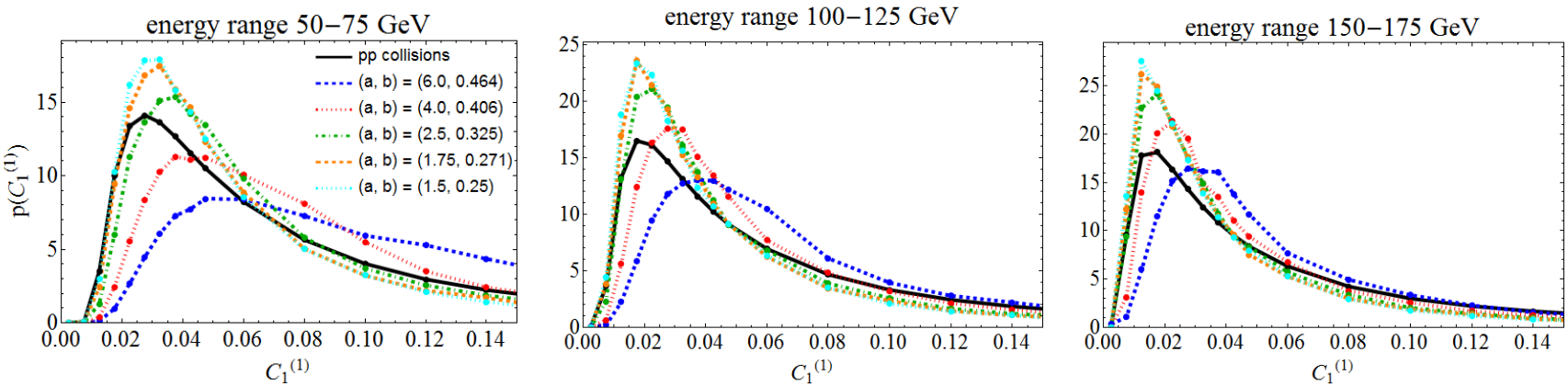
x_1



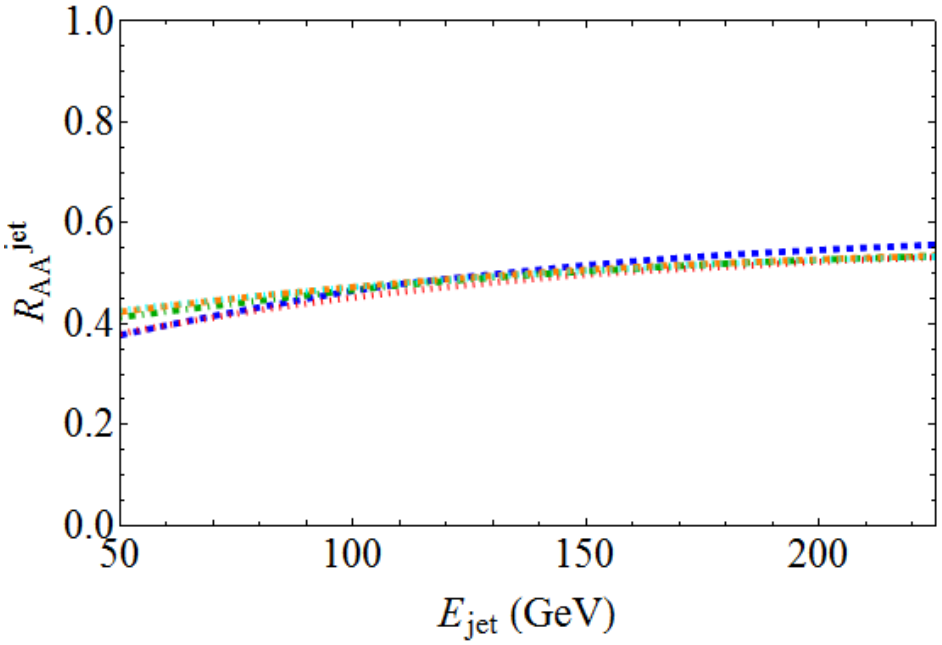
- Here R_{AA}^{jet} is the ratio of the number of jets with a given energy after propagation through the plasma to that in the initial ensemble.
- The combinations of (a, b) are chosen to keep R_{AA}^{jet} the same.

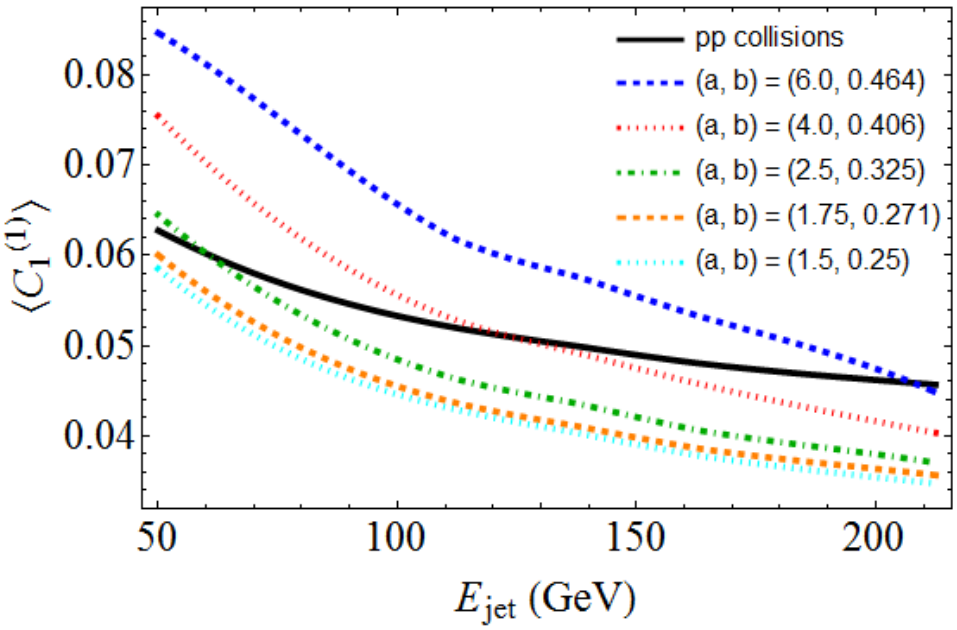
K. Rajagopal, AS, W. van der Schee, PRL, 2016



- The combinations of (a, b) are chosen to keep R_{AA}^{jet} the same.
- Colored curves show the distributions after an ensemble has propagated through the droplet of plasma for different a and b.

K. Rajagopal, AS, W. van der Schee, PRL, 2016





- The combinations of (a, b) are chosen to keep R_{AA}^{jet} the same.
- Still, the mean of the opening angle distribution vary significantly.

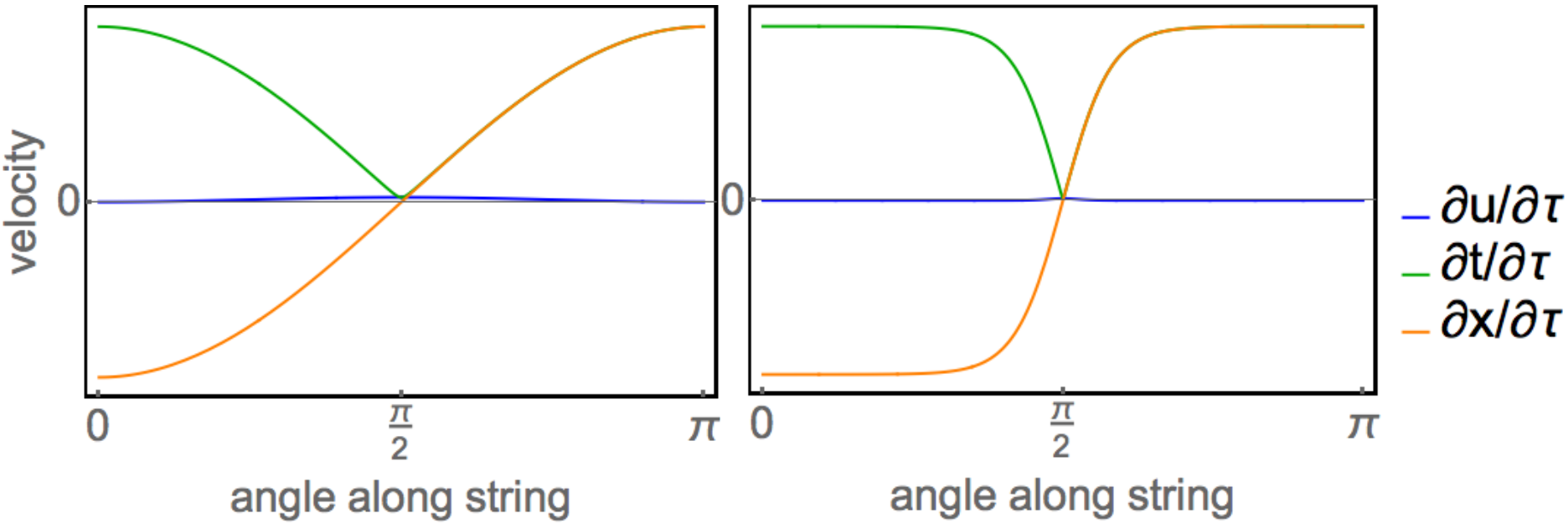
K. Rajagopal, AS, W. van der Schee, PRL, 2016

What can we improve?

- Consider the full string dynamics in the bulk and relate it to the full jet shape.
- Construct an ensemble based on the relation above - remove one of model parameters.
- Study the modification of the whole jet shape in the plasma (just the mean opening angle previously).
- Consider the modification of more involved characteristics and we start with dijet asymmetry.

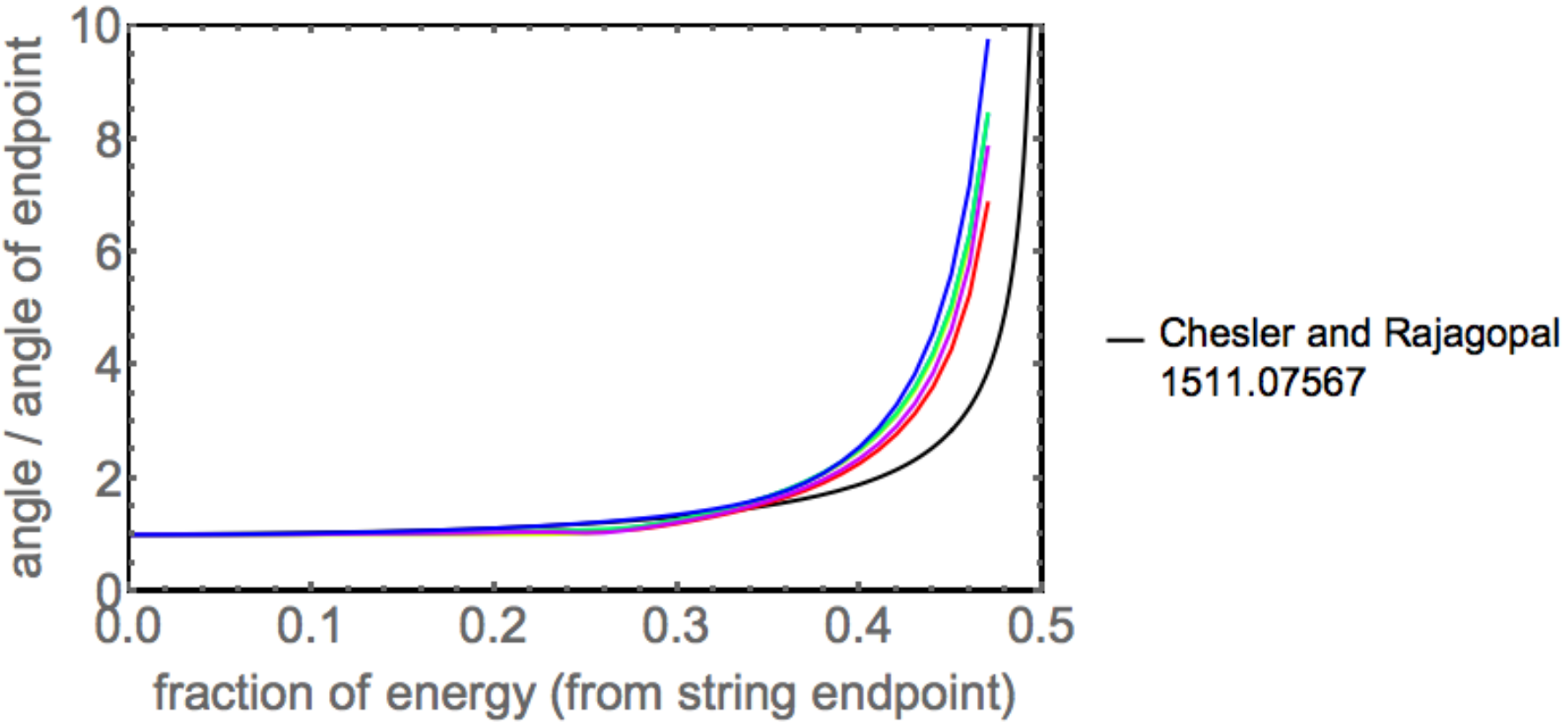
Full string dynamics

What's about fixing a setup?

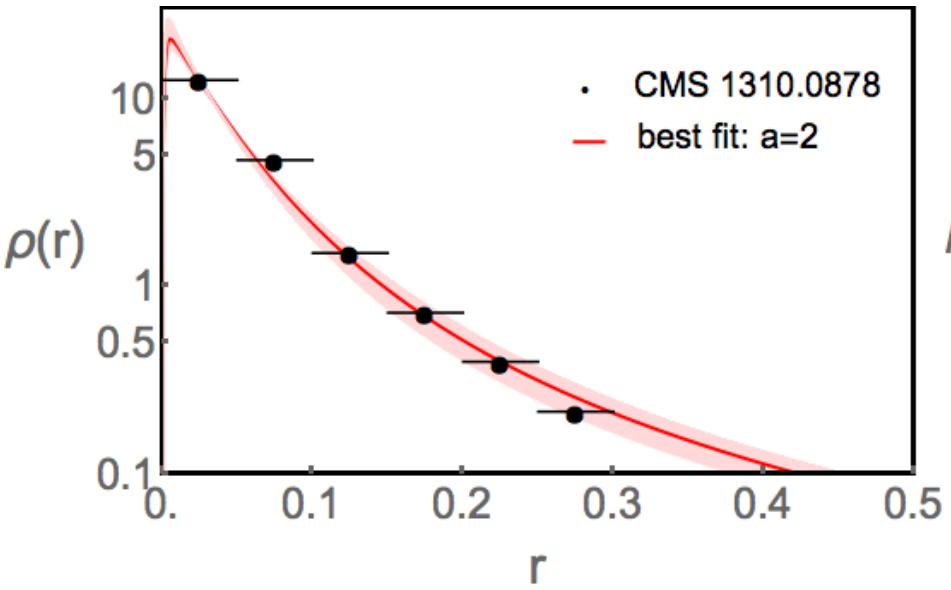


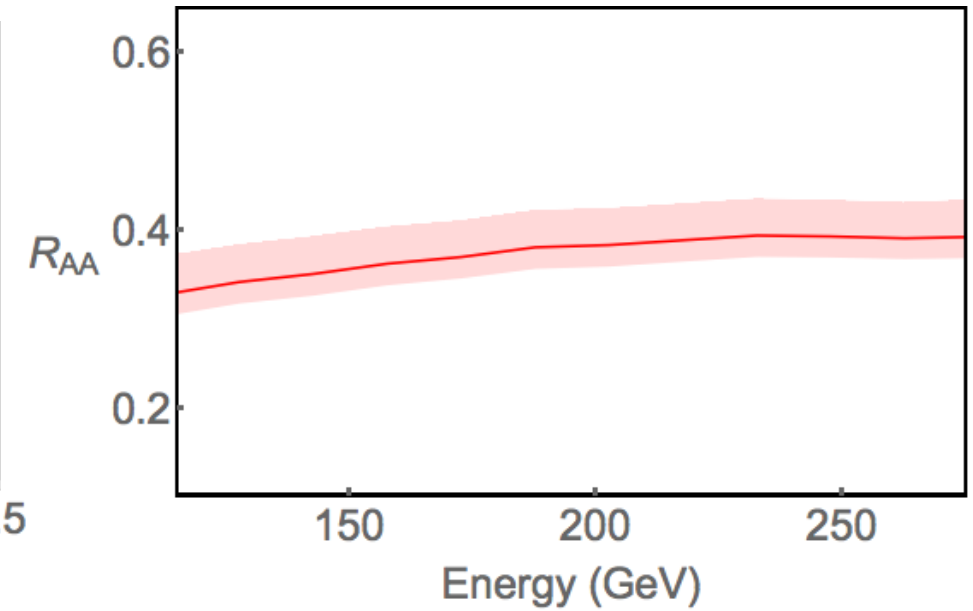
There is a lot of freedom and one has to motivate the choice. Particularly, even after nullification the space of unfixed parameters is large.

Some "universality" in the simplest limit



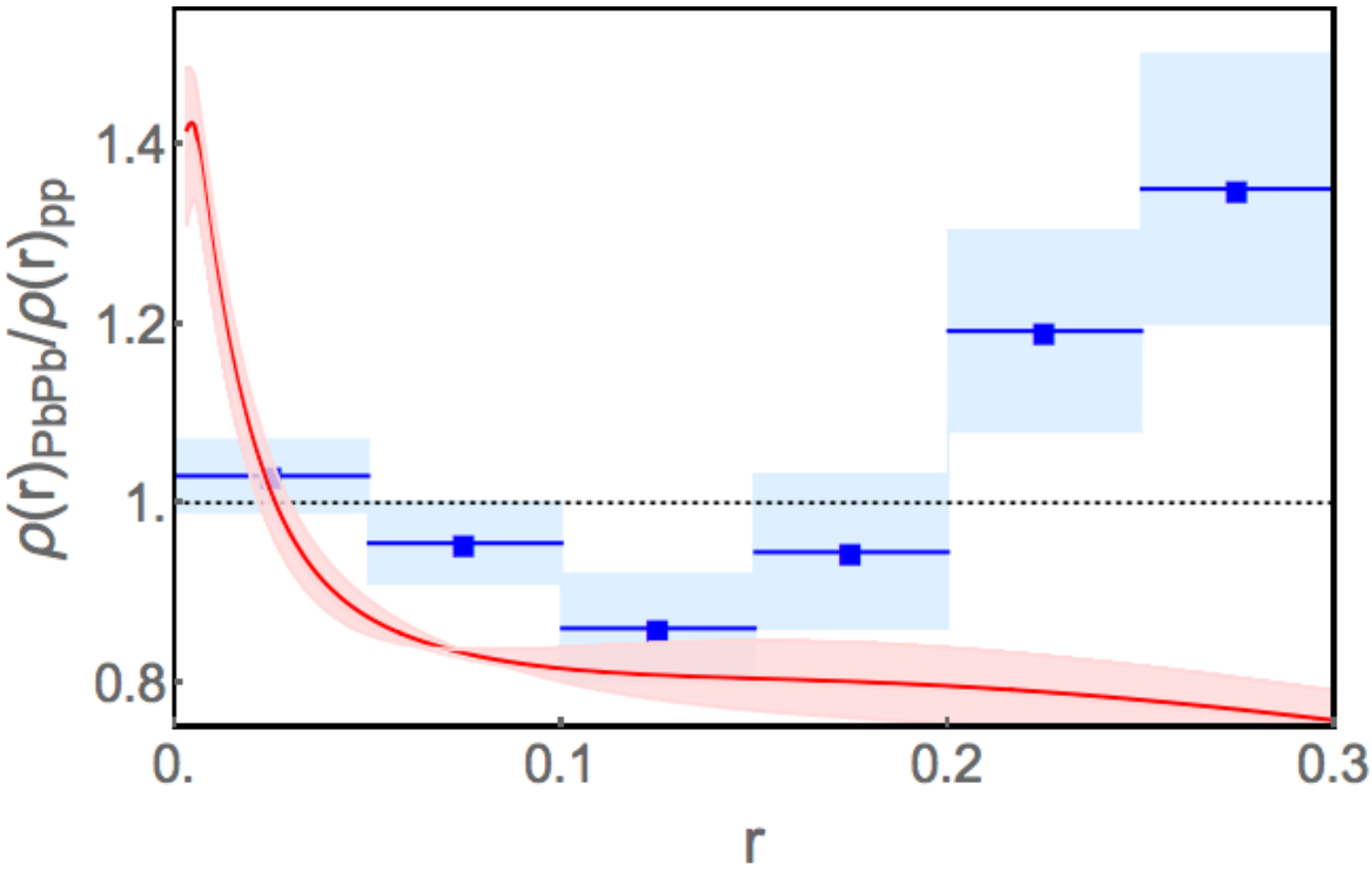
Fitting pp-shape and R_{AA} by the free parameters





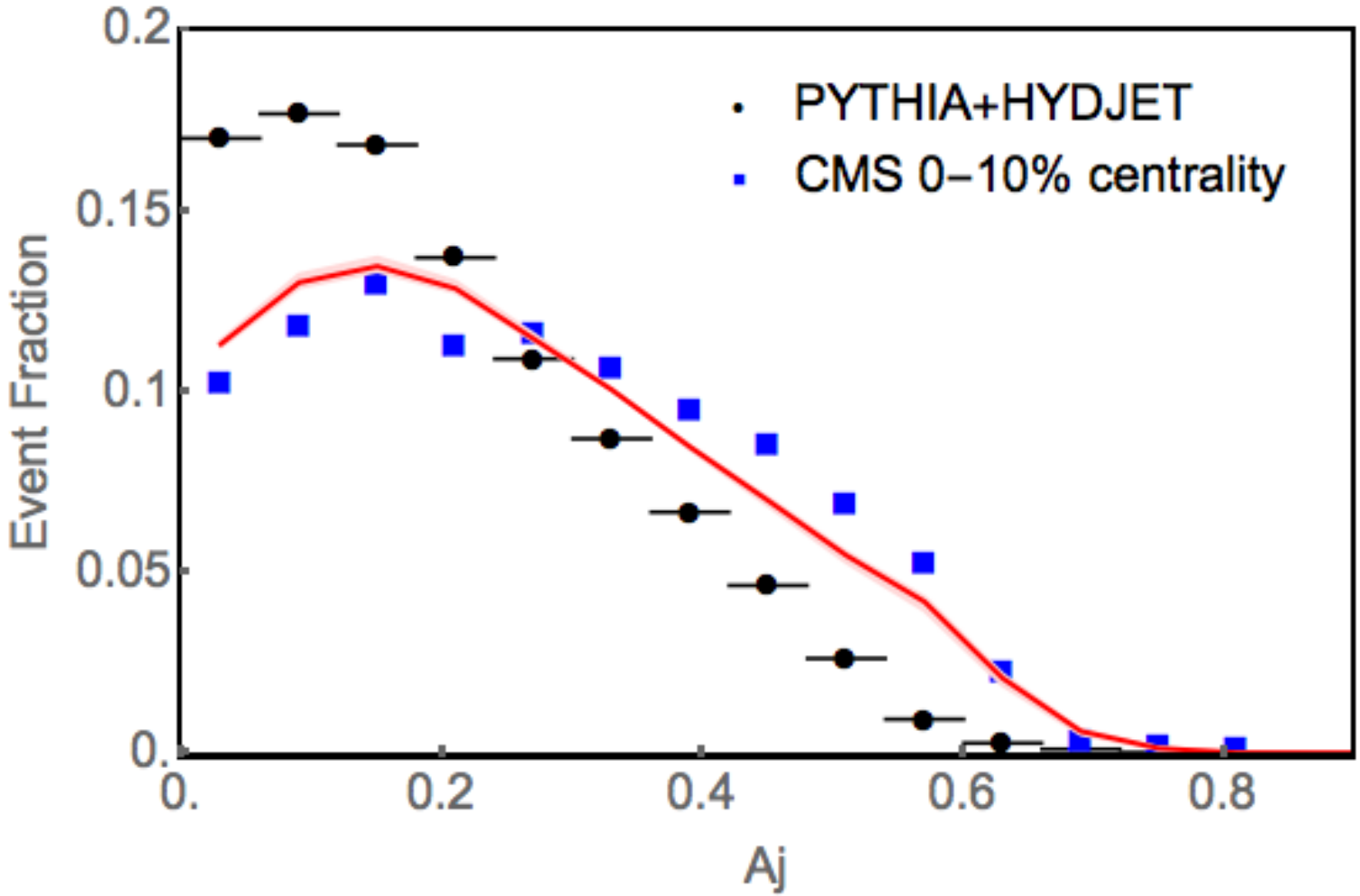
$$p_T > 100\text{GeV} \quad , \quad 0.3 < |\eta| < 2 \quad , \quad R = 0.3$$
$$a = 2 \quad , \quad b = 0.203$$

The jet shape modification



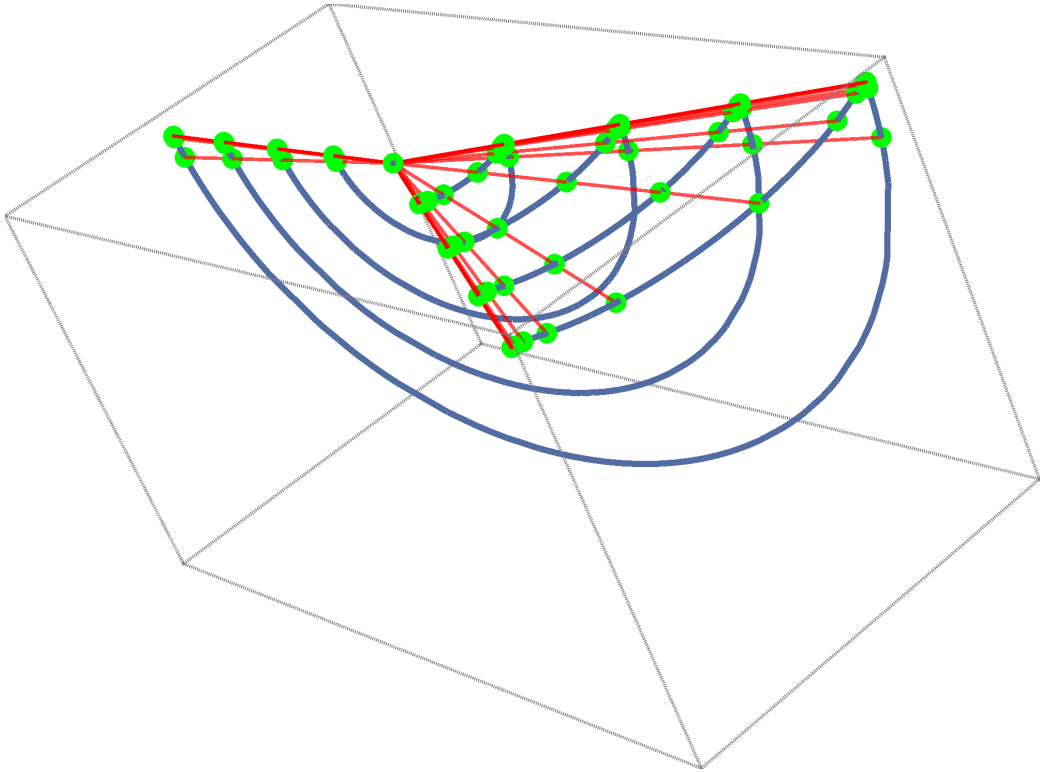
Large r behavior requires study of the medium backreaction.

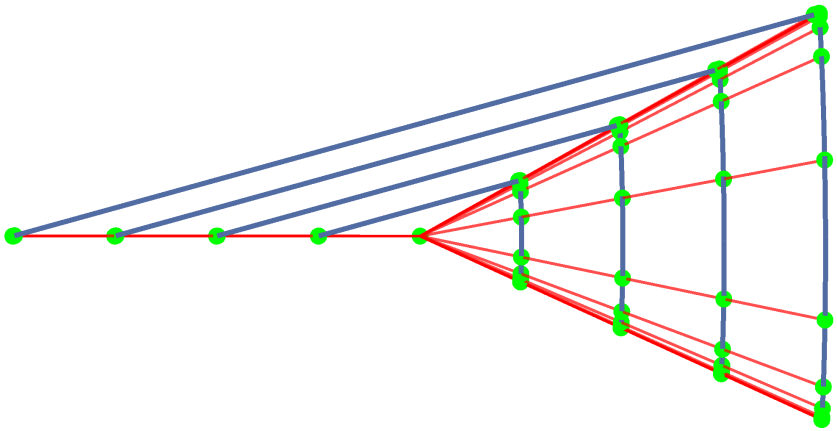
The preliminary dijet asymmetry modification

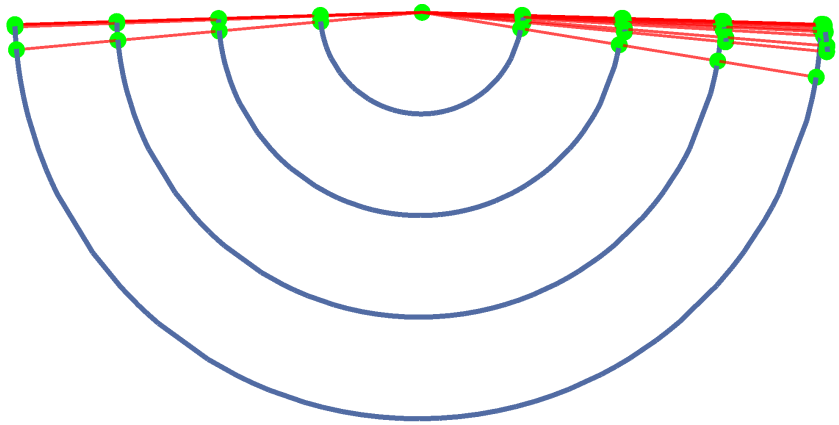


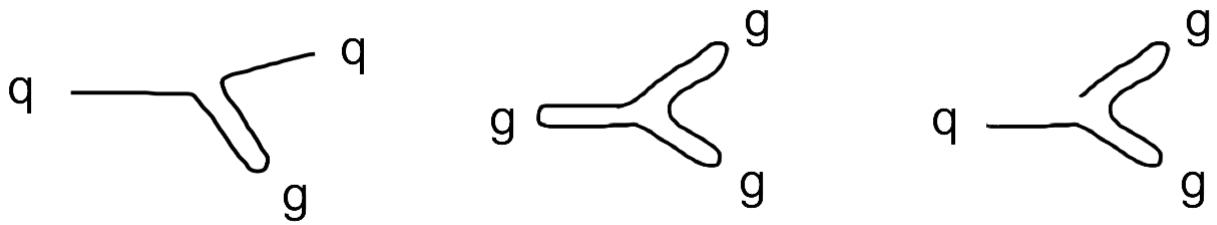
Data points and PYTHIA+HYDJET: CMS 1202.5022

- There is no dijet asymmetry in pp without 3-jets and they should be included.
- 3-jets provide a toy model to access R-dependence and simplest reconstruction procedures.
- One may think about an ambitious project - to introduce hard splittings by hands up to some energy scale.
- Opportunity to study correlations inside a jet in the strongly coupled regime.





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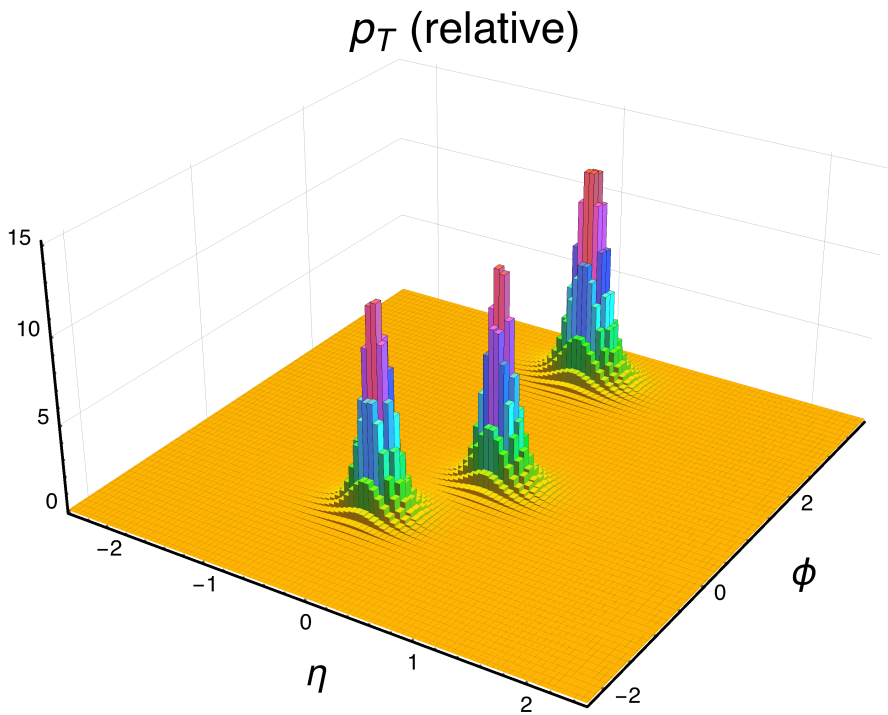
p_T (relative)
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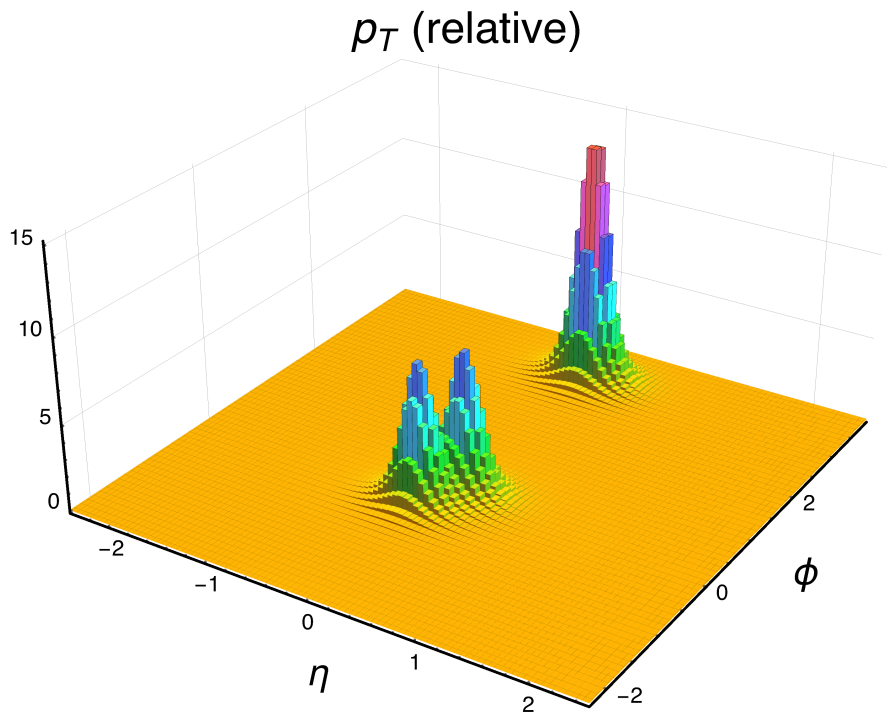
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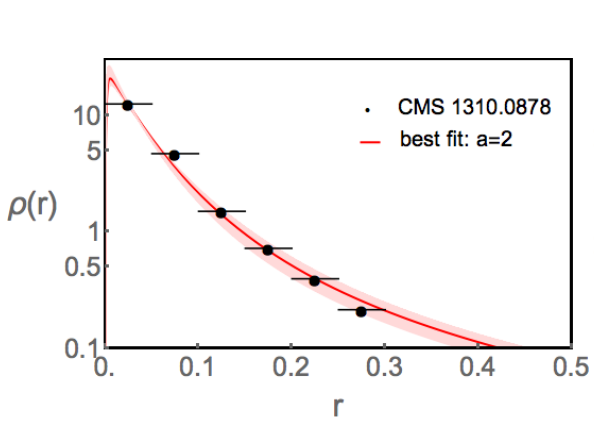

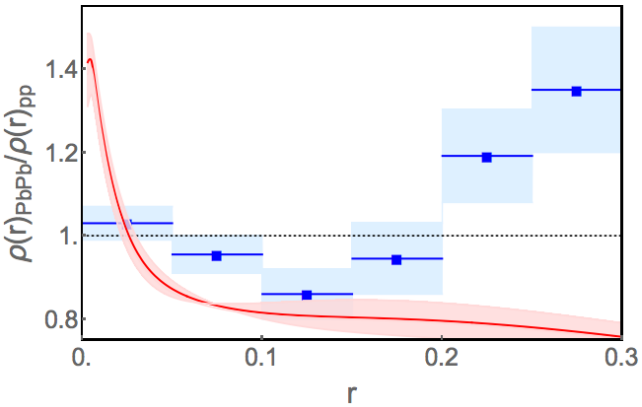

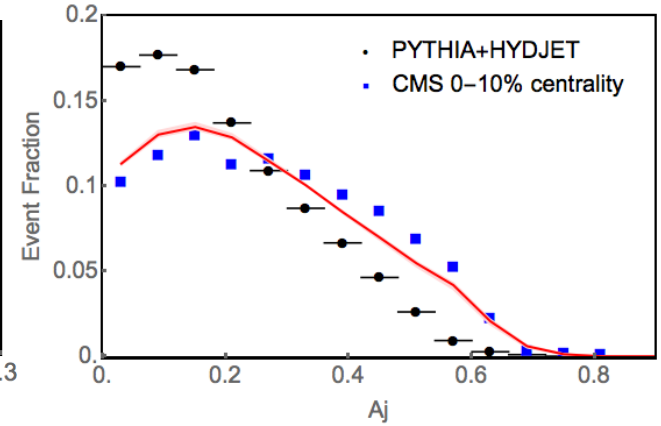

Results:

- Jet shape from full string dynamics.
- Jet shape modification.
- Dijet asymmetry modification.

To do list:

- Include the medium backreaction (wake, etc).
- Complete the model by 3-jets.