Multi-dimensional measurements of the parton shower in p+p collisions at STAR

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Monika Robotková (robotkova@ujf.cas.cz),
Nuclear Physics Institute, Czech Academy of Sciences,
for the STAR Collaboration

Abstract

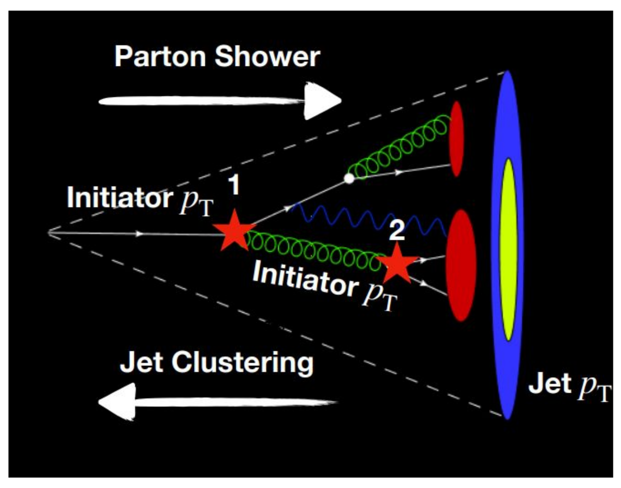
Jets are collimated sprays of hadrons and serve as an experimental tool for studying the fragmentation of quarks and gluons. In particular, differential measurements of jet substructure enable a systematic exploration of the parton shower evolution. The SoftDrop grooming technique utilizes the angular ordered Cambridge/Aachen reclustering tree and provides a correspondence between the experimental observables, such as the shared momentum fraction (z_g), groomed jet radius (R_g) or split opening angle, and the QCD splitting functions in vacuum. We present fully corrected correlations between z_g and R_g at the first split for jets of varying momenta and radii in p+p collisions at $\sqrt{s}$ = 200 GeV in STAR. To study the evolution along the jet shower, we also present the splitting observables at the first, second, and third splits along the jet shower for various jet and initiator prong momenta.

Motivation

- Our goal is to access and study the kinematics of the parton shower evolution via substructure observables

Two ways to study the parton shower:

1. **Correlation between substructure observables at the first split**
2. **Evolution of the substructure observables as we travel along the jet shower**



SoftDrop

- Grooming technique used to remove soft wide-angle radiation
- Connects parton shower and angular tree

Shared momentum fraction z_g

SoftDrop condition:

$$z_g = \frac{\min(p_{T,1}, p_{T,2})}{p_{T,1} + p_{T,2}} > z_{cut}\theta^{\beta},$$

where $\theta = \frac{\Delta R_{12}}{R}$

Grooming radius R_g

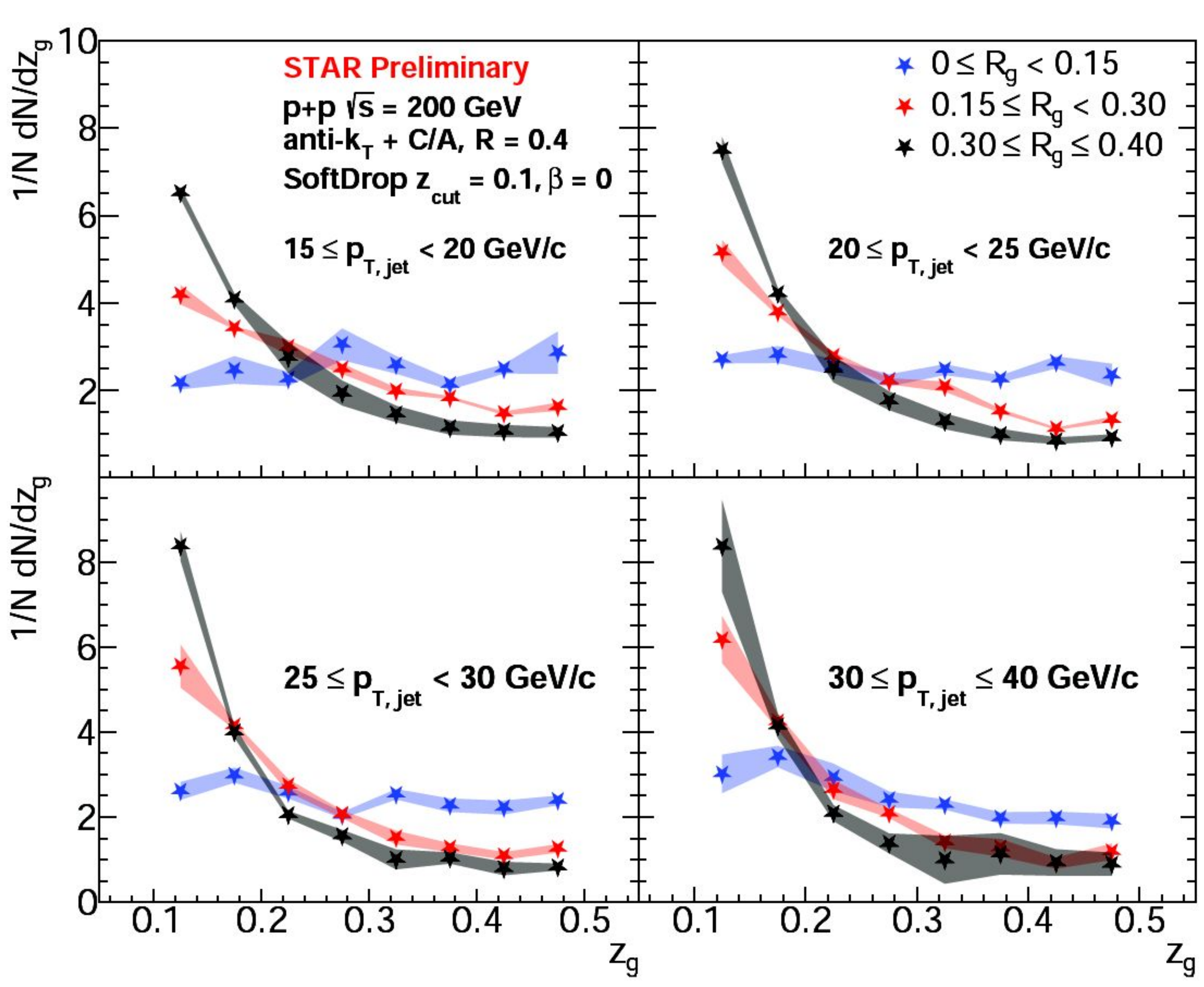
- First ΔR_{12} that satisfies SoftDrop condition

$p_{T,1}, p_{T,2}$ - transverse momenta of the subjets
z_{cut} - threshold (0.1)
β - angular exponent (0)
ΔR_{12} - distance of subjets in the rapidity-azimuth plane

SoftDrop: Larkoski, Marzani, Soyez, Thaler, *Journal of High Energy Physics,* 146, (2014)

Correlation between observables at the first split

- z_g for different R_g and different jet transverse momentum ($p_{T,jet}$) bins
- Distributions change mildly with varying $p_{T,jet}$
- **R_g is the driving factor for the change in shape of z_g distributions**



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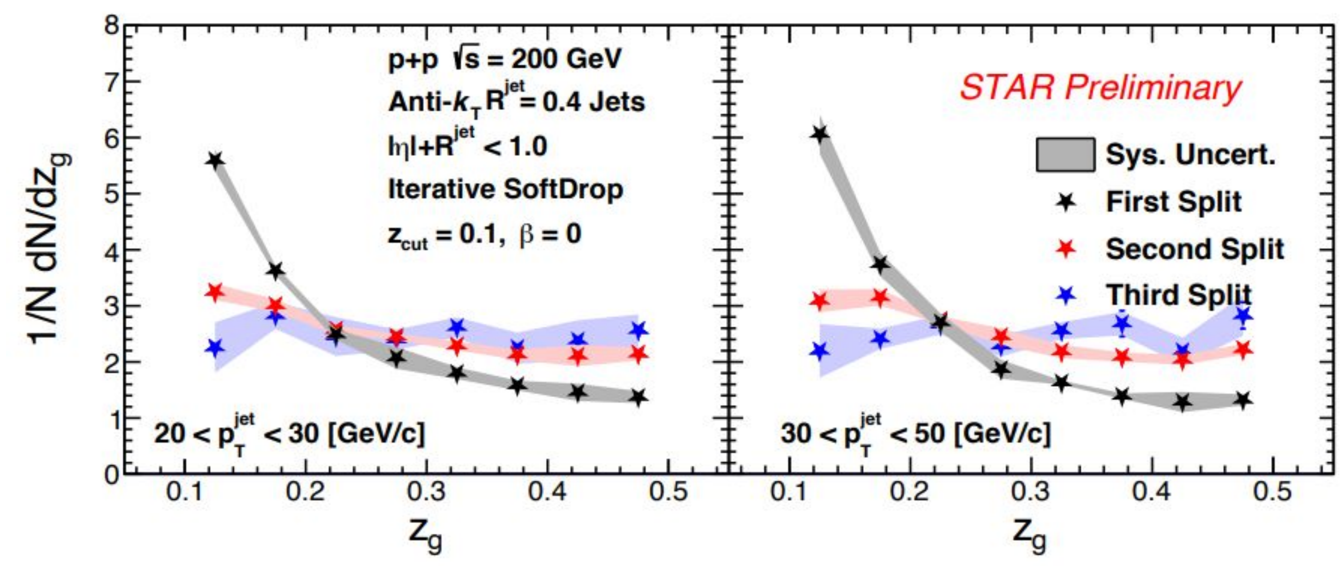
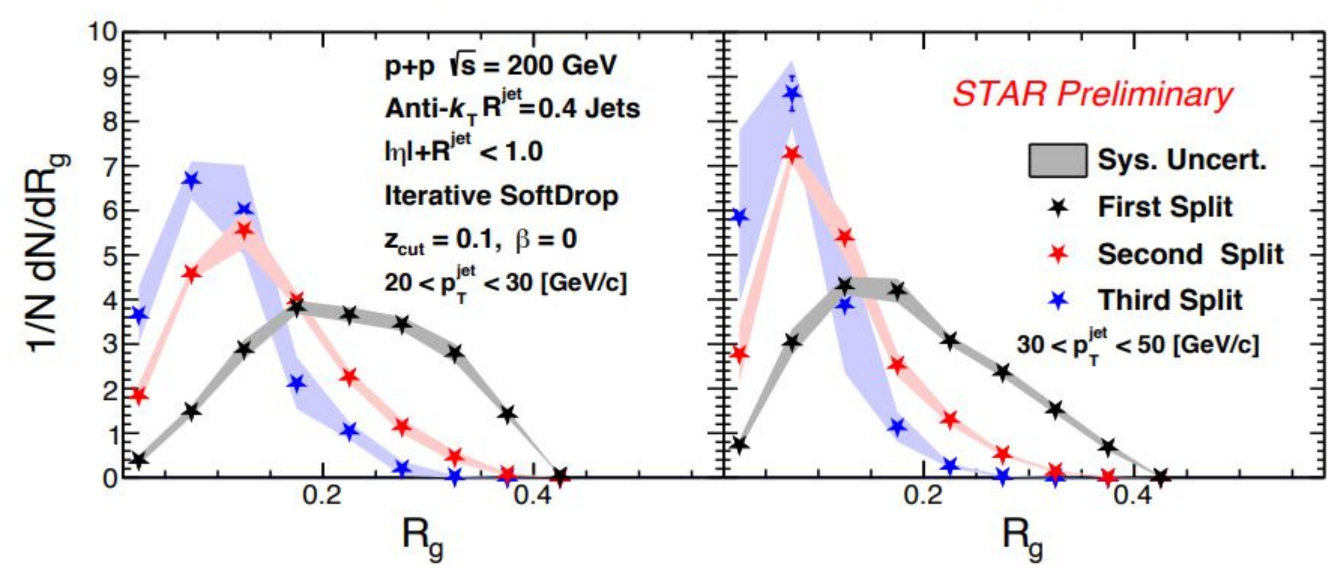
First, second and third split

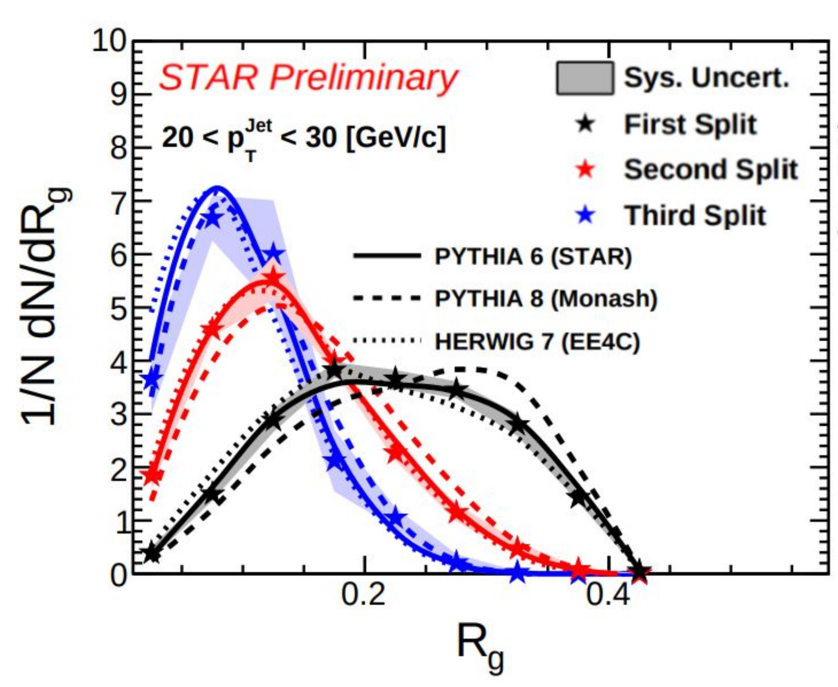
- z_g and R_g distributions at the 1st, 2nd and 3rd split for various $p_{T,jet}$
- z_g distribution becomes flatter and R_g distribution becomes narrower with the split → **collinear emissions are enhanced**

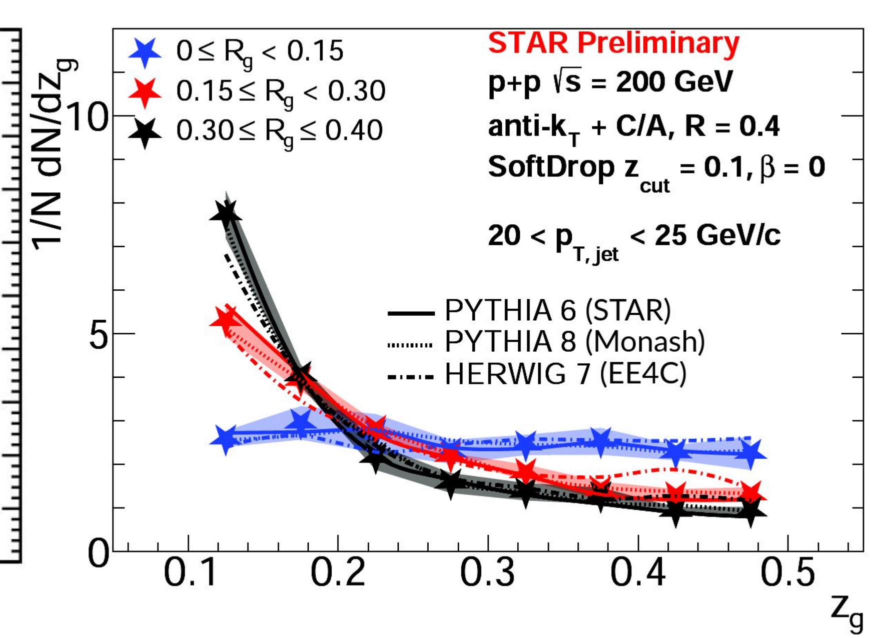




Comparison with different MC generators

- Leading-order MC models describe the trend of the data





Conclusions

Correlation at the first split

- z_g has a **weak** dependence on $p_{T,jet}$ and a **strong** dependence on R_g
- We can select significantly **softer splits** by selecting **wider angle** splits

Splits along the shower

- Observed significantly **harder/more symmetric** splitting at the third/narrow split compared to the first split

z_g distributions can be controlled either by selecting on R_g at the first split or by selecting on the split number

Jet substructure measurements at RHIC energies allow to disentangle perturbative and mostly non-perturbative dynamics of jet evolution

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The STAR Collaboration
https://drupal.star.bnl.gov/STAR/presentations