Jet modification by Multiple Parton Interactions

and determining the characteristic jet size based on multiplicity dependent jet shape analysis

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Role of multiplicity in pp collisions

Experimental indications: high-multiplicity pp collisions are non-trivial and similar to HI collisions

- Collectivity: flow coefficients are substantial [1]
- Relative enhancement of heavy flavor, attributed to multiple-parton interactions (MPI) [2]

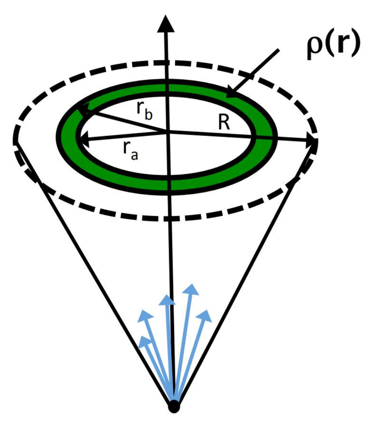
Jets in high-multiplicity pp collisions

- One does not expect soft effects such as jet quenching
- However, QCD mechanisms in the semi-hard regime, such as MPI, should in principle influence jet development
- This influence depends on MPI and Color Reconnection (CR) models
- **Jet structure may be a sensitive tool to study the semi-hard regime** [3]
- Also provide baseline for jet structure studies in HI collisions

Jet structure vs. multiplicity

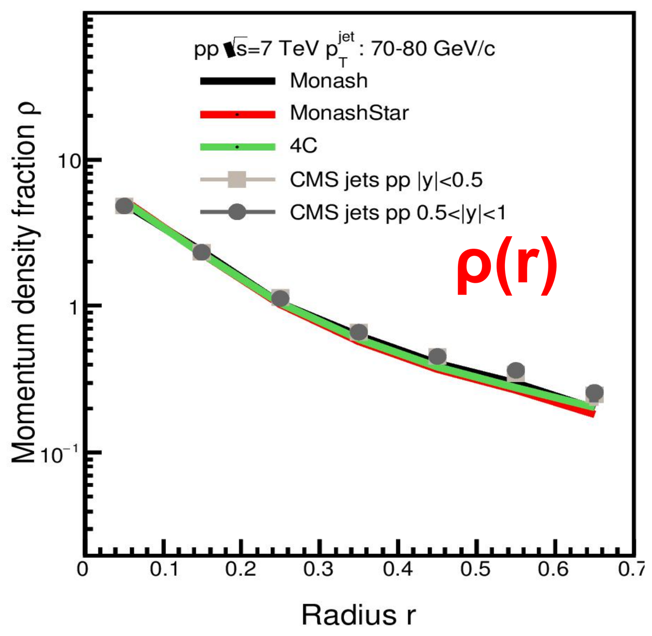
Jet structure at LHC

- CMS data at $\sqrt{s}=7$ TeV pp collisions [4]
- PYTHIA 8 [5] simulations reproduce data with different tunes: Monash 2013, 4C, Monash* (all different ingredients)



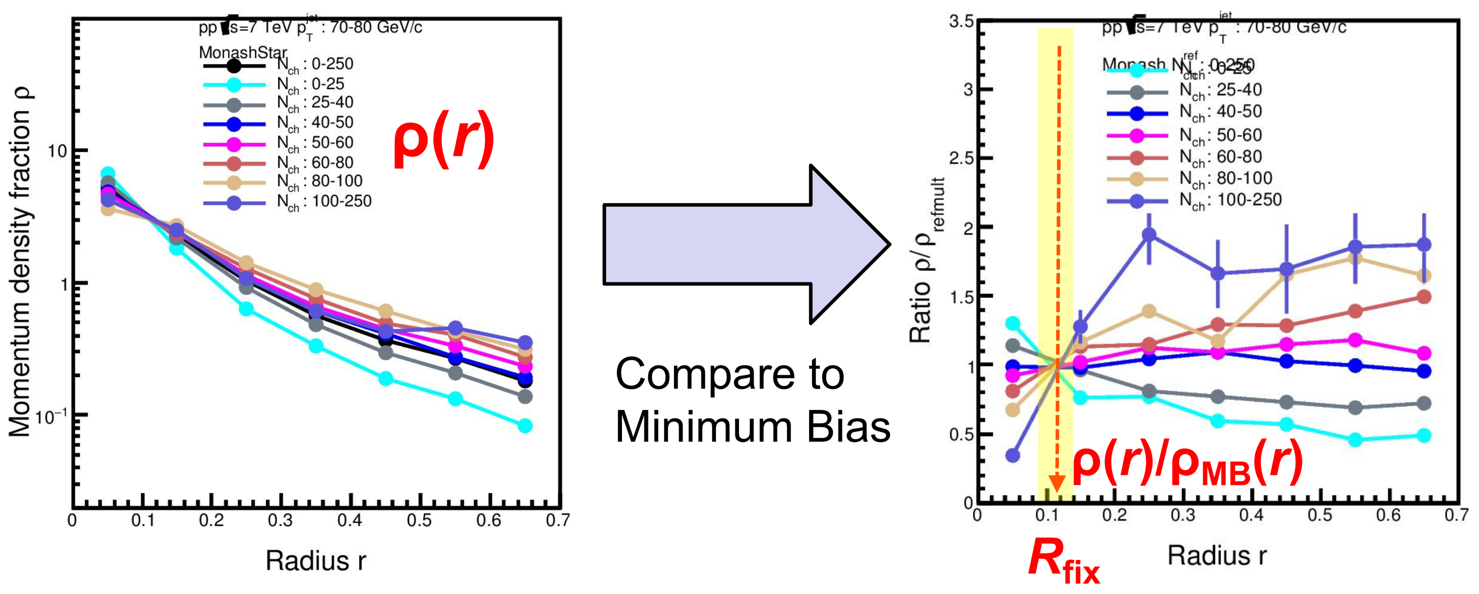
$$\rho(r) = \frac{1}{\delta r}\frac{\sum_{r_a<r_i<r_b} p_{T,i}}{\sum_{r_i<R} p_{T,i}}$$

$$r = \sqrt{(\varphi-\varphi_{jet})^2 + (\eta-\eta_{jet})^2}$$



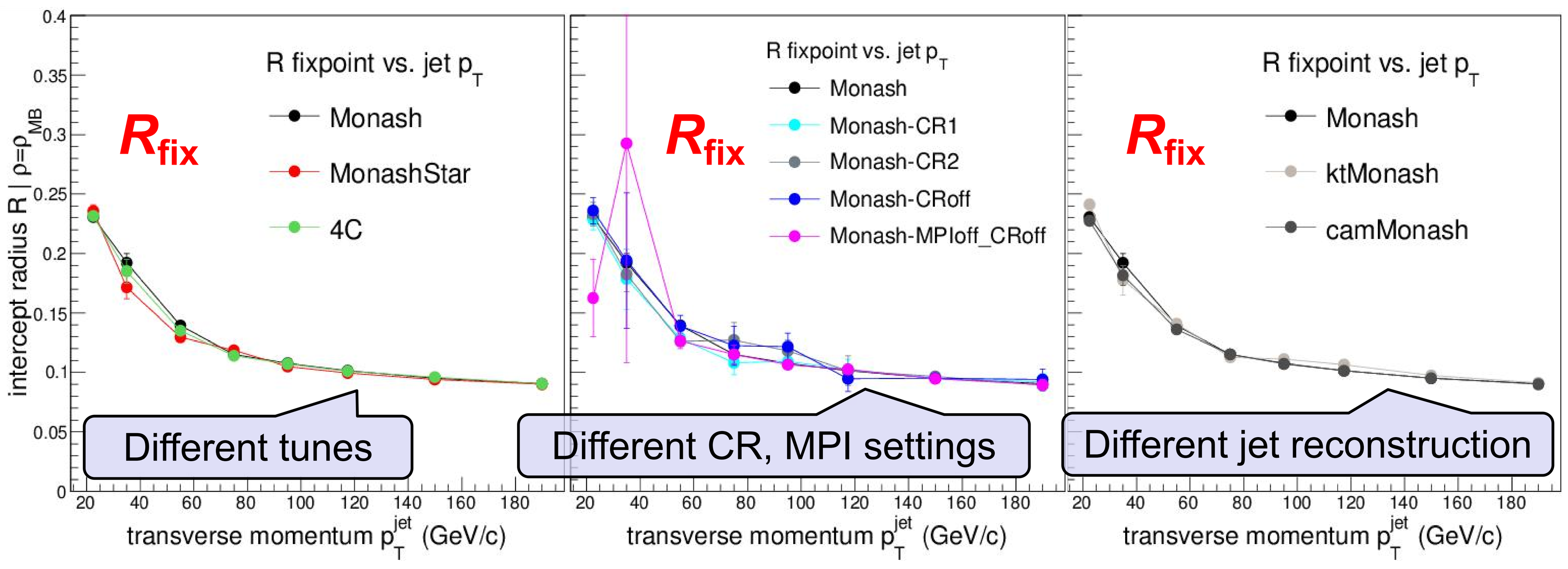
Multiplicity-differential simulations

- Several charged-hadron multiplicity (N_{ch}) classes



- Jets generally narrower in low-N_{ch} events: expected bias (jets tend to be more compact in events with less particles)
- However, all ρ(r) curves intersect at a given $r = R_{fix}$

Is there a characteristic jet size?



- **We find a well-defined R_{fix} for any given p_T**
- **Regardless of the chosen tune, setup, or even of the jet reconstruction algorithm**
- $R_{fix}(p_T)$ is qualitatively similar to a Lorentz-boost curve

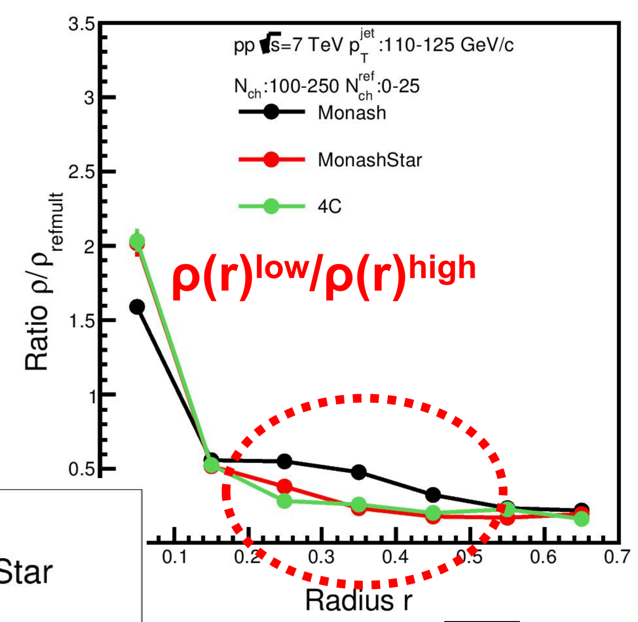
A sensitive model test: $\rho(r)$ vs. N_{ch}

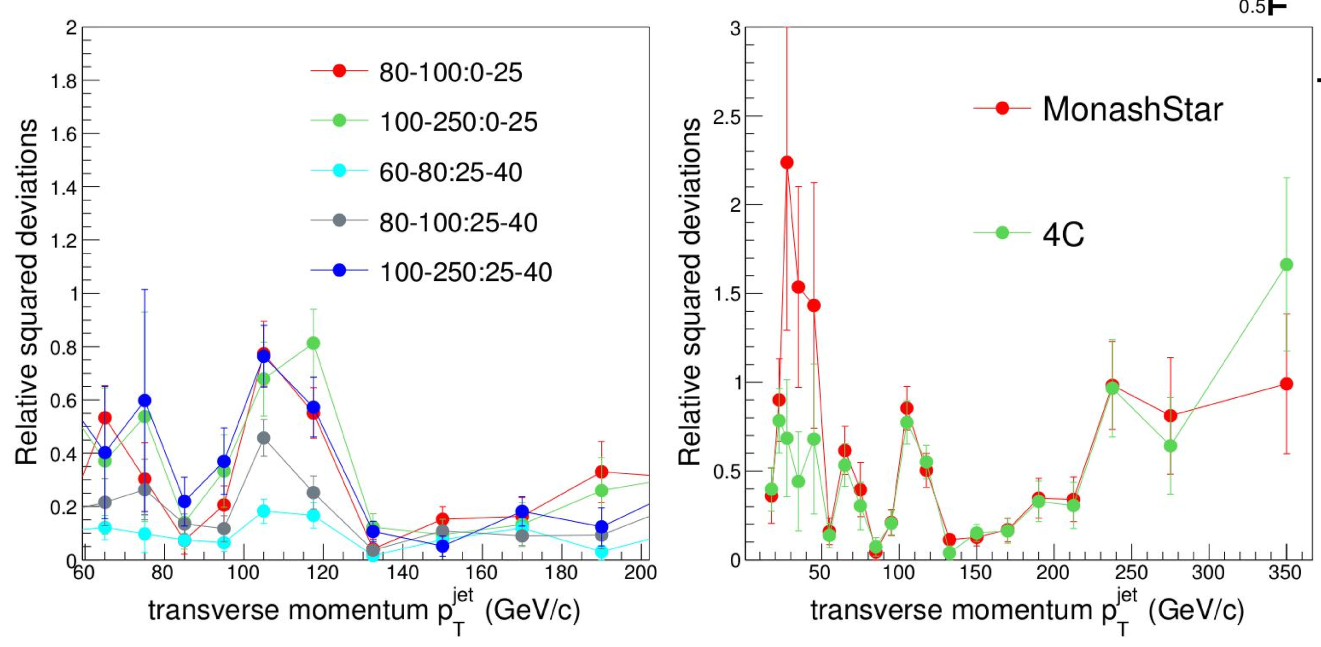
Tunes contain different MPI, x-section,

- Used Monash 2013, 4C, Monash* models
- All describe minimum bias jet structure well, but...
- Multiplicity-differential predictions are different

Ratio of structures in different multiplicity classes

- Trivial dependence (selection bias)
- But: **difference between tunes** on top of that





1. Compare to reference tune
2. Take relative squared deviance

Deviation quantified

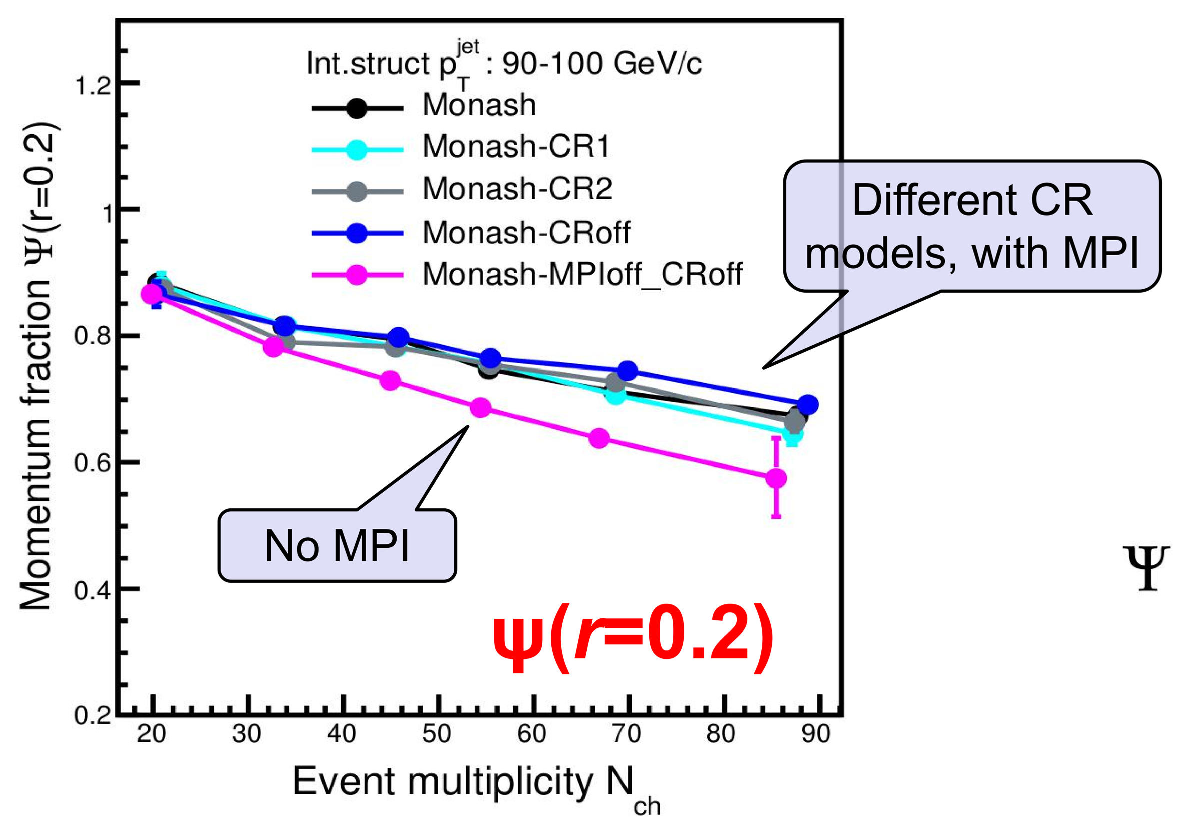
- Reference tune: Monash 2013
- Non-trivial structure in p_T
- Persistent through statistically independent N_{ch} classes
- **Great model discrimination power**

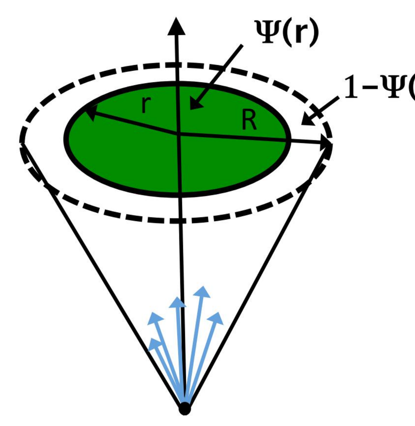
$$RSD = \sqrt{\sum_{r_i}\left(1-\frac{\rho^{low}(r)/\rho^{hi}(r)}{\rho^{low}_{ref}(r)/\rho^{hi}_{ref}(r)}\right)^2}$$

Integral structure: Clear effect of MPI

Structure at given radius, vs. multiplicity

- Generally less sensitive to subtleties
- However: multiplicity distributions different if MPI is OFF → will introduce a bias into the r-dependent distribution.
- No such bias in $\psi(N_{ch})$





$$\Psi(r) = \frac{\sum_{r_i<r} p_{T,i}}{\sum_{r_i<R} p_{T,i}}$$

- **A significant difference in $\psi(N_{ch})$ provides clean evidence that MPI influences jet structure at high N_{ch}**

Conclusion

- We give predictions on multiplicity-differential jet structures in $\sqrt{s}=7$ TeV pp collisions, using PYTHIA8. We show that multiplicity-differential jet-structure studies have strong discriminative power among well-established tunes.
- We define a characteristic jet-size measure R_{fix} that is found to be independent of the chosen simulation settings or jet reconstruction method.
- We demonstrate the influence of Multiple-Parton Interactions (MPI) on jet structure in high-multiplicity events

References:
[1] L. Yan, J. Y. Ollitrault, PRL 112, 082301 (2014).
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[5] T. Sjöstrand *et al.*, JHEP 05, 026 (2006).

Further Information:
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