Jet Substructure Measurements Sensitive to Soft QCD effects with the ATLAS Detector

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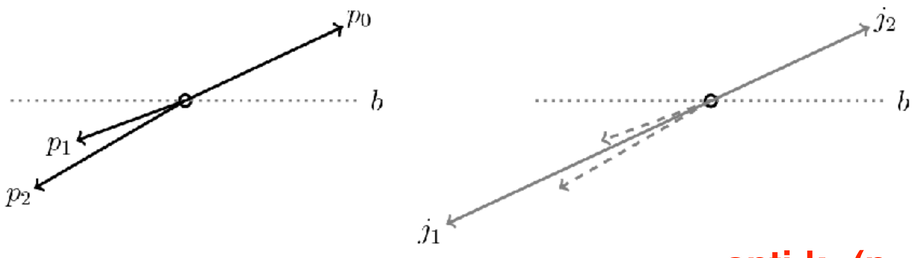
Relevance of energy flow study within the body of hadronic jets

- **Boosted heavy particles identification**
- **Perturbative QCD probe**
- **Soft QCD effects**

Data unfolded for detector effects and compared to QCD calculations and LL particle-level MC simulations

Sequential clustering algorithm for jets reconstruction



- **Infra-red and collinear-safe**
- **Cluster charged tracks and calorimeter energy deposits into collimated jets.**
- **Iteratively combine collimated jets pair with min. d_{ij} until $d_{ib} < d_{ij}$**

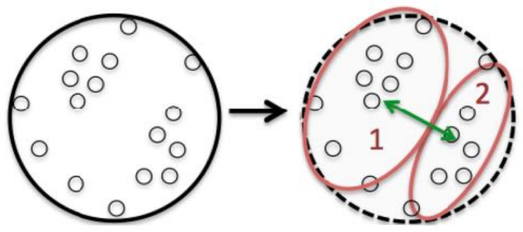
$$d_{ij} = \min(p_{T,i}^{n}, p_{T,j}^{n}) \times \frac{\Delta R_{ij}^{2}}{R^{2}}; \; d_{ib} = p_{T,i}^{n}$$

k_T (n=2)
- **Soft constituents pairs clustered first**
- **Follow IR and collinear splittings**

anti-k_T (n=-2)
- **Hard constituents clustered with closest neighbour**
- **Regularly shaped jets**

Cambridge-Aachen (n=0)
- **Close constituents pairs clustered first**
- **Follow angular-order of parton shower**

Measurement of kT splitting scales in Z(ℓℓ) + jets with charged particle tracks

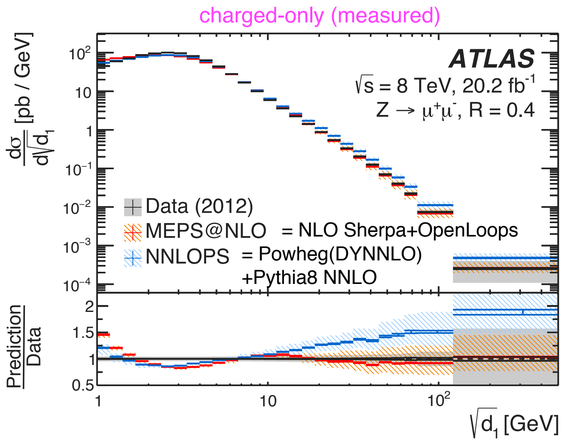


- **k_T clustering sequence in reverse**
- **k^{th} iteration splitting scale $d_k^{1/2} = \min(d_{ij}^{1/2}, d_i^{1/2})$**
- **small $d_k^{1/2}$ → soft/collinear splitting**
- **large $d_k^{1/2}$ → hard splitting**

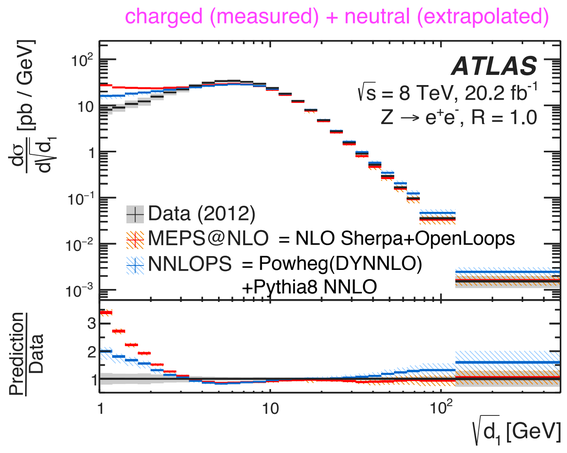
$\sqrt{d_0} = p_T$ of final jet

$\sqrt{d_1} = min(p_{T,1}, p_{T,2}) \times \frac{\Delta R_{12}}{R}$

charged-only (measured)

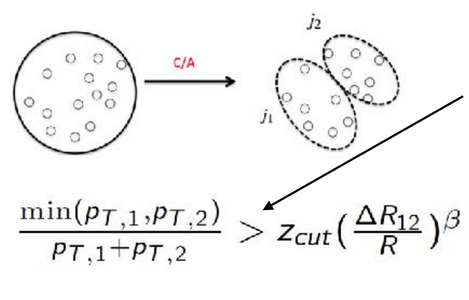


charged (measured) + neutral (extrapolated)



Large discrepancies of predictions at low values of $d_1^{1/2}$

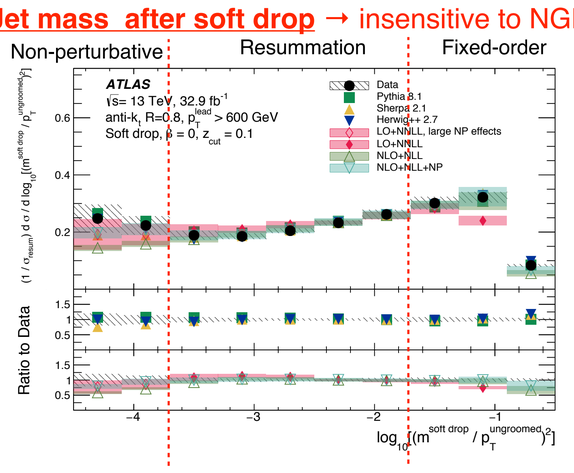
Measurement of soft drop jet mass in di-jet events

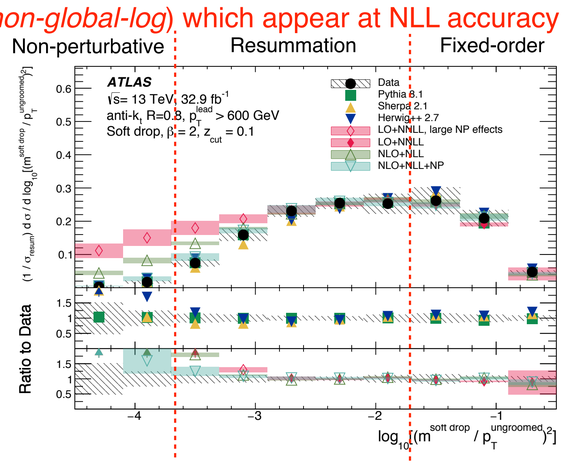


- **C/A clustering sequence in reverse**
- **Remove softer branch if criterion not satisfied**
- **Higher z_{cut} → more energy removed**
- **β → Tunes sensitivity to wide-angle radiation**

Jet mass → powerful tool for identifying boosted hadronically decaying massive particles

Jet mass after soft drop → insensitive to NGL (*non-global-log*) which appear at NLL accuracy

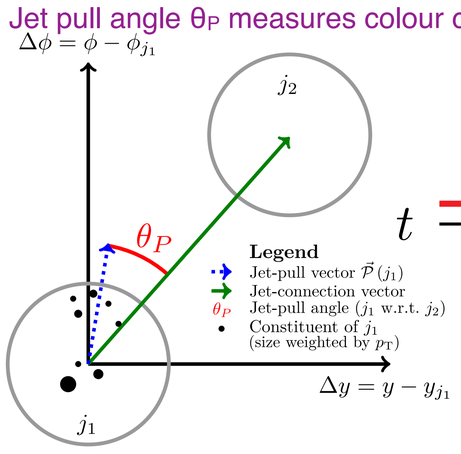


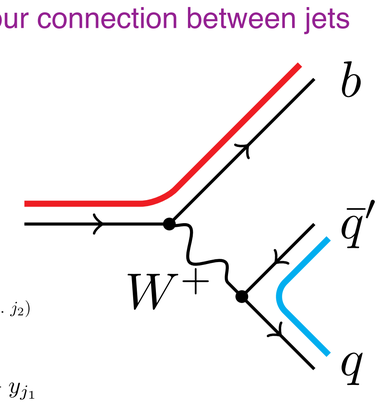


Discrepancies in non-perturbative region

Measurement of colour flow in $t+\bar{t} \rightarrow W^{+}+b+W^{-}+\bar{b}$

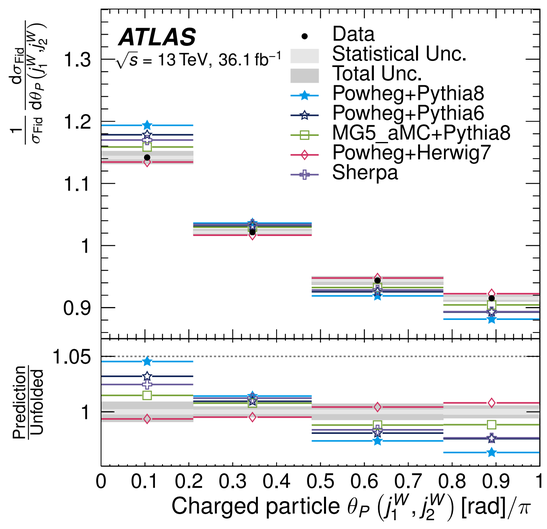
Jet pull angle θ_P measures colour connection between jets

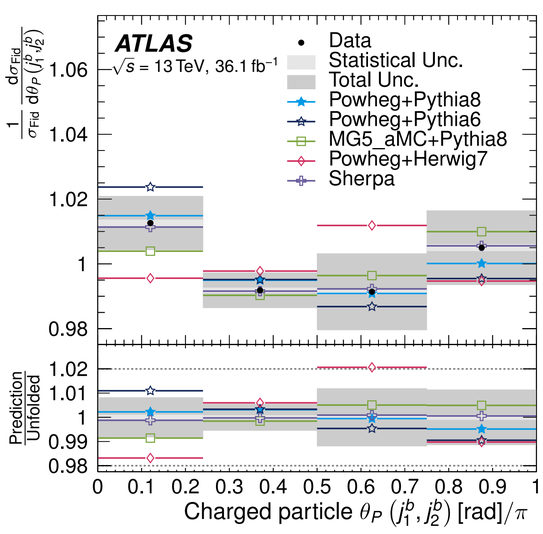




Uniform θ_P no colour connection: b-jets are not color connected

θ_P~0 for colour connected jets: color singlet W-jets





Color connection stronger in predictions than data

REFERENCE

Measurement of k_t splitting scales in Z→ℓℓ events in *pp* collisions at $s^{1/2}$=8 TeV with the ATLAS detector
JHEP08 (2017) 26

A measurement of the soft-drop jet mass in *pp* collisions at $s^{1/2}$=13 TeV with the ATLAS detector
arXiv:1711.08341

Measurement of colour flow using jet-pull observables in $t\bar{t}_{bar}$ events with the ATLAS experiment at $s^{1/2}$=13 TeV
arXiv:1805.02935

CONCLUSIONS

- **Measurements of soft QCD effects can constrain analytic calculations in perturbative regime and soft hadronic activity in non-perturbative region**
- **Useful for tuning of MC simulation of non-perturbative QCD**