Probing Hadronization and Jet Substructure with Leading Particles in Jet at H1

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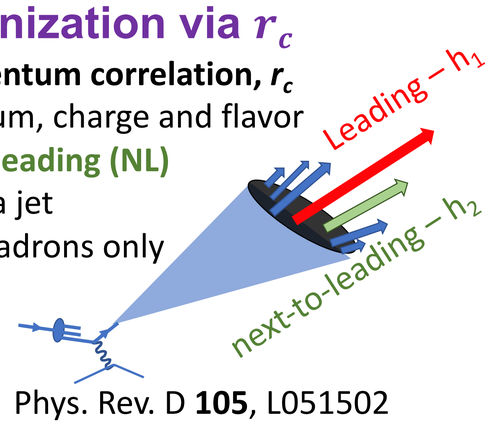
Abstract : A momentum charge correlation ratio observable r_c, generalized from the balance function [1], is measured using data recorded with the H1 experiment at HERA during 2003 to 2007. This variable distinguishes between same-sign and opposite-sign charged particle pairs[2] in a jet. The average r_c is studied for two configurations (prongs) of the leading particles in the jet, defined with the help of declustering in a recursive soft drop technique. When resolved as as a function of other kimenatic variables, such as the formation time, this probes the transition from non-perturbative to perturbative aspects of QCD. This sets the path for a novel way of studying jet substructure and the evolution of partons in a jet. The data of rc at different prongs reveal differences between the first and subsequent splits. Data are confronted with predictions from various event generators.

Motivation : Hadronization via r_c

Observable : charge-momentum correlation, r_c

- Correlations in momentum, charge and flavor
- **Leading(L)** and **next-to-leading (NL)** momentum particles in a jet
- h1 and h2 are charged hadrons only



$$r_c \equiv \frac{N_{CC} - N_{C\bar{C}}}{N_{CC} + N_{C\bar{C}}}$$

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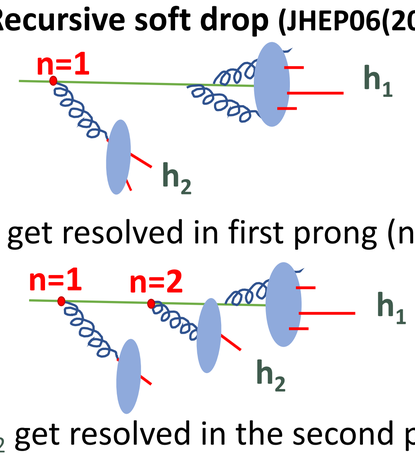
N_{CC} : h_1, h_2 have same sign charges

$N_{C\bar{C}}$: h_1, h_2 have opposite sign charges

r_c for Subjets : Partonic Proxies

Using Recursive soft drop (JHEP06(2018)093)



h_1, h_2 get resolved in first prong (n_R = 1)

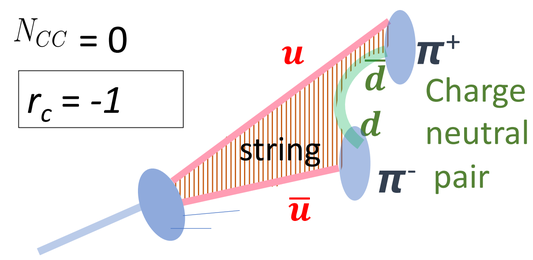
h_1, h_2 get resolved in the second prong (n_R = 2)

Significance of r_c

"**alternating**" picture :

N_{CC} = 0

r_c = -1



"**random**" picture : no charge correlation

$N_{CC} = N_{C\bar{C}}$

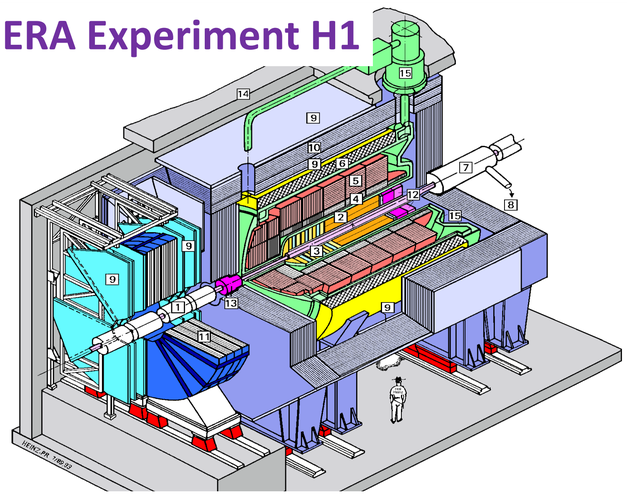
r_c = 0

Partonic final state : u and $\bar{u}$

Combine charge-neutral pair : $\bar{d}$ and d

r_c is a measure of the fraction of "string-like hadronization"

HERA Experiment H1



Liquid Ar Calorimeter

$\sigma/E \approx 11\%/\sqrt{E_e} \oplus 1\%$ (electromagnetic)

$\sigma/E \approx 50\%/\sqrt{E_h} \oplus 3\%$ (hadronic)

CTD: Single Track resolution

$\sigma p_T / p_T = 0.2\%\ p_T/\text{GeV} \oplus 1.5\%$

σ_θ = 1 mr

(magnetic field = 1.16 T)

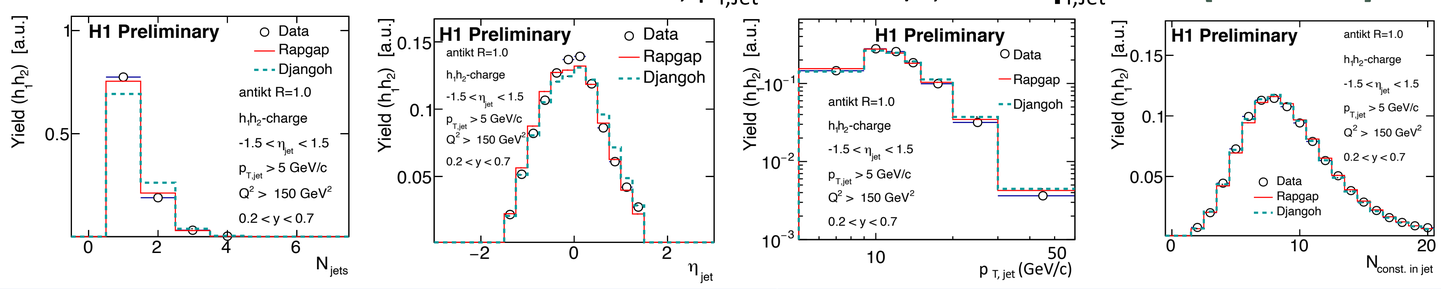
Data : 2004-2007

$\sqrt{s}$ =319 GeV, $\mathcal{L}$ = 361 pb^{-1}

Event and Jet Selection

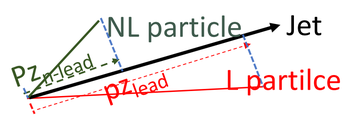
-30 cm < zVertex < 30 cm, 45 GeV< E-pz < 65 GeV, Q^2 > 150 GeV^2, 0.2< y < 0.7

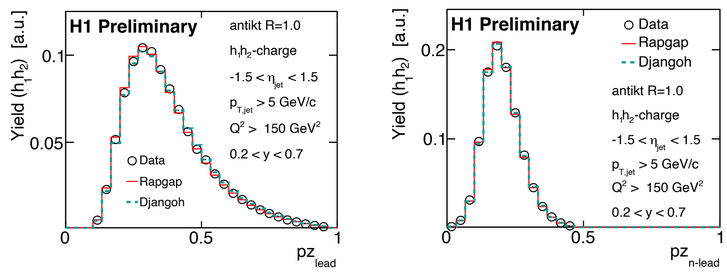
anti-kt R = 1.0 , $p_{T,Jet}$ > 5.0 GeV/c, -1.5 < $\eta_{T,Jet}$ < 1.5. [LAB frame]



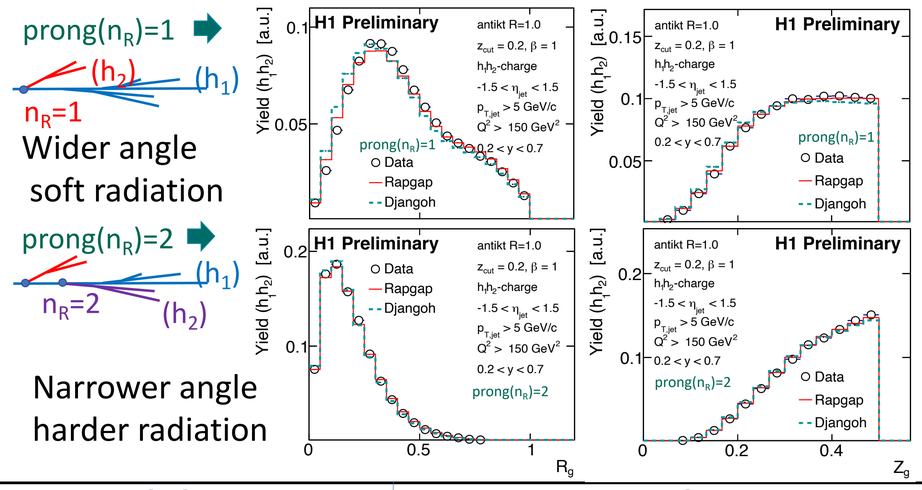
Djangoh and Rapgap reproduce the DATA distributions well (reconstruction level)

Momentum Sharing of Leading Particles in Jet





Prong Kinematics : β=1, z_{cut} = 1 at Resolved Prongs

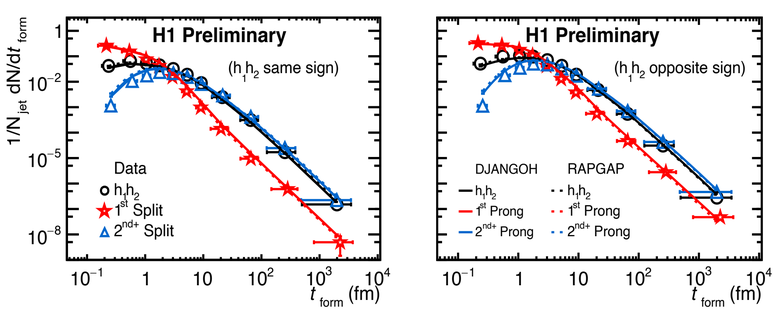


Result and Conclusion: Formation Time

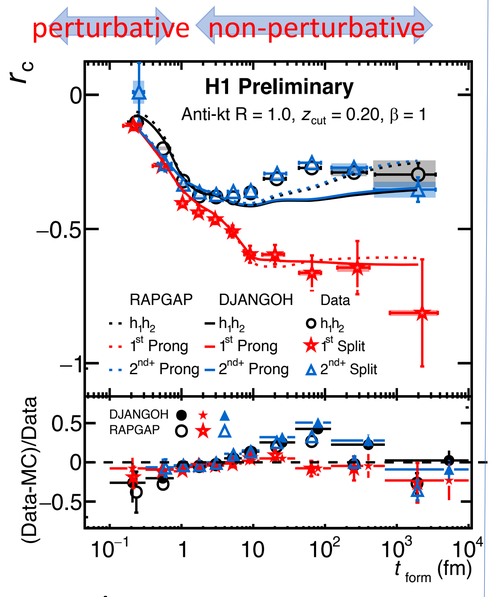
P total momentm, z momentum fraction of h2

K_{perp}^2 = relative transverse momentum

Formation time, t_{form} = [2z(1-z) P] / k_{perp}^2

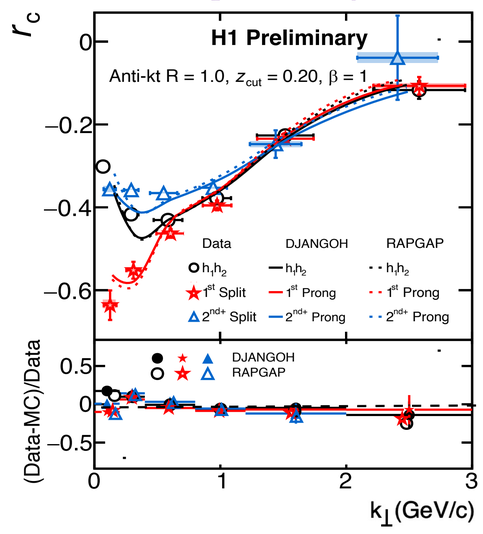


perturbative non-perturbative



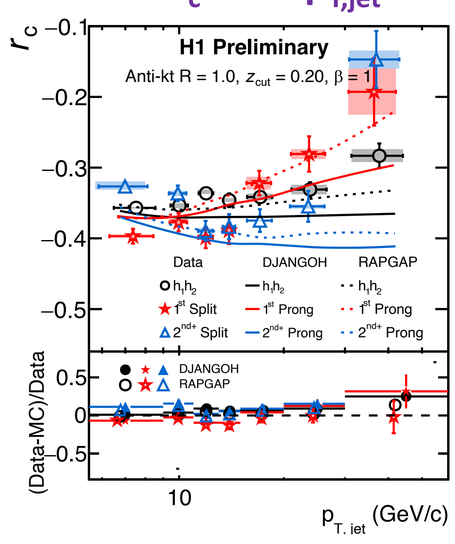
- ✓Density of leading pairs in small formation time is much large in the 1st split compared to that of later splits.
- ✓Large decorrelations is seen in r_c at small formation time (< 1 fm)
- ✓At large formation time r_c is stronger for 2nd+ splits compared to that of 1st split
- ✓Rapgap and Djangoh values are comparable to data

r_c with k_T



- ✓Small $k_\perp$ belong mostly in nonperturbative domain and r_c is large. Large $k_\perp$ are related mostly to early gluon splits and r_c is approaching to zero

r_c with $p_{T,jet}$



- ✓MC shows extraordinary scaling except 1st Prong
- ✓Data shows decorrelations in r_c with jet transverse momentum

References: [1] S. A. Bass, P. Danielewicz and S. Pratt, Phys. Rev. Lett. 85 (2000) [2] Y. T. Chien, A. Deshpande, M. M. Mondal and G. Sterman, *Phys.Rev.D* 105 (2022) 5, L051502

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