HP2024 NAGASAKI

Probing hadronization and quark-gluon plasma using collinear-drop jet observables at RHIC

Yang-Ting Chien

Georgia State University and Jefferson Lab Theory Center

In collaboration with Oleh Fedkevych

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U.S. DEPARTMENT OF ENERGY | Office of Science

Georgia State University

Jefferson Lab

Outline

- Soft drop and collinear drop
- Jet angularity and flattened jet angularity
- Factorization
- Hadronization and transfer matrix
- Medium modification
- Prediction for STAR

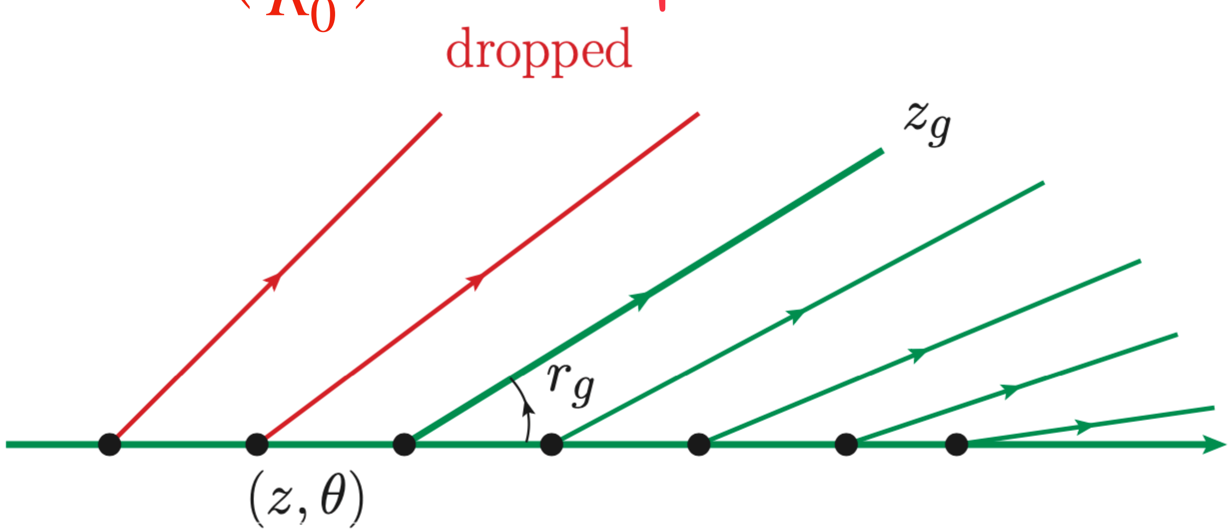
Soft drop

Larkoski, Marzani, Soyez, Thaler, JHEP05(2014)146

Recluster jet using Cambridge/Aachen (C/A) algorithm i.e. angular-ordering

$$z < z_{\mathrm{cut}} \left(\frac{\theta}{R_0}\right)^{\beta}$$

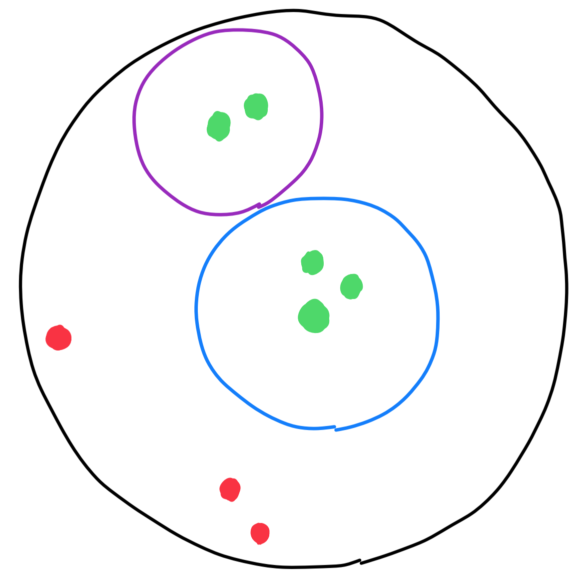
Soft drop condition

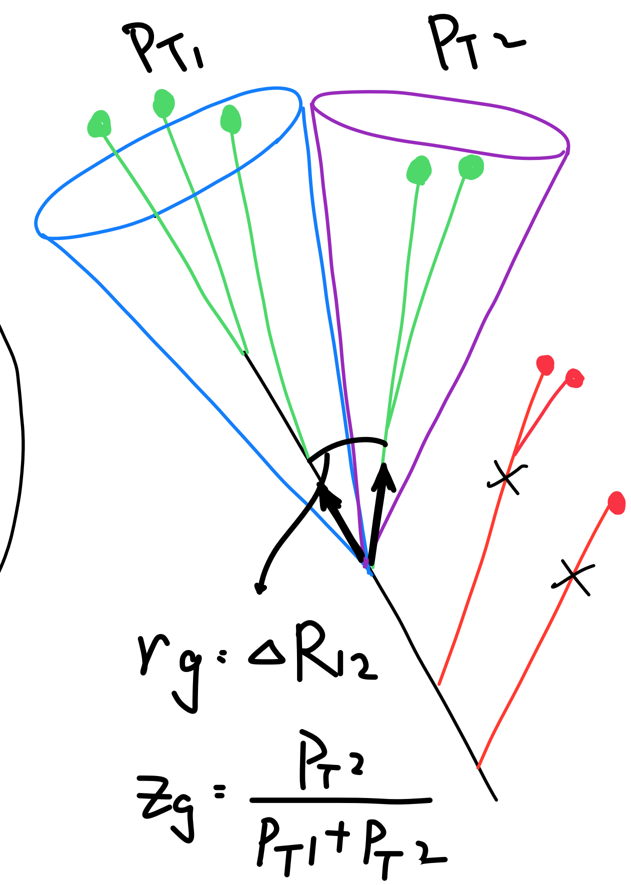


z : momentum fraction of the soft brand

θ : angle between two branches

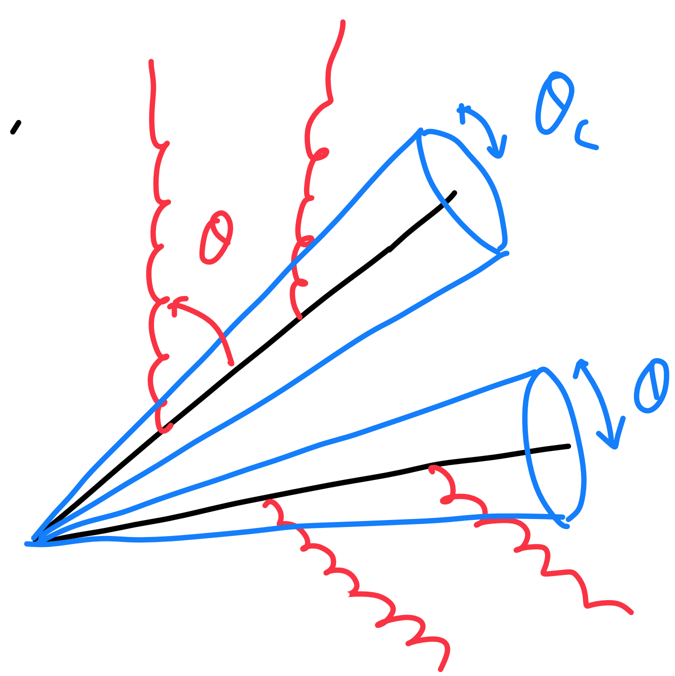
Essentially remove wide-angle, soft radiation





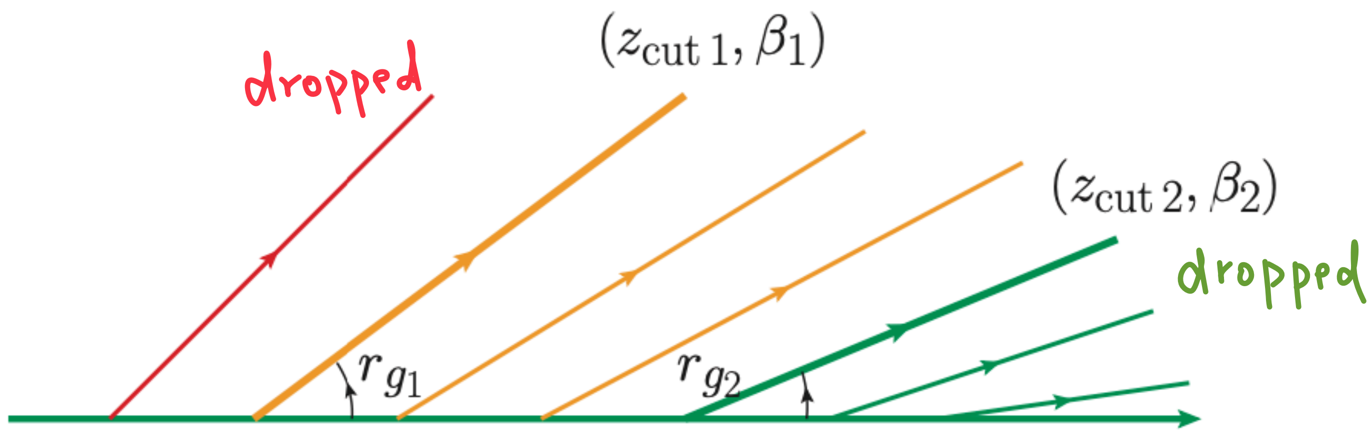
Medium-induced, color decoherent radiation may just has been dropped.

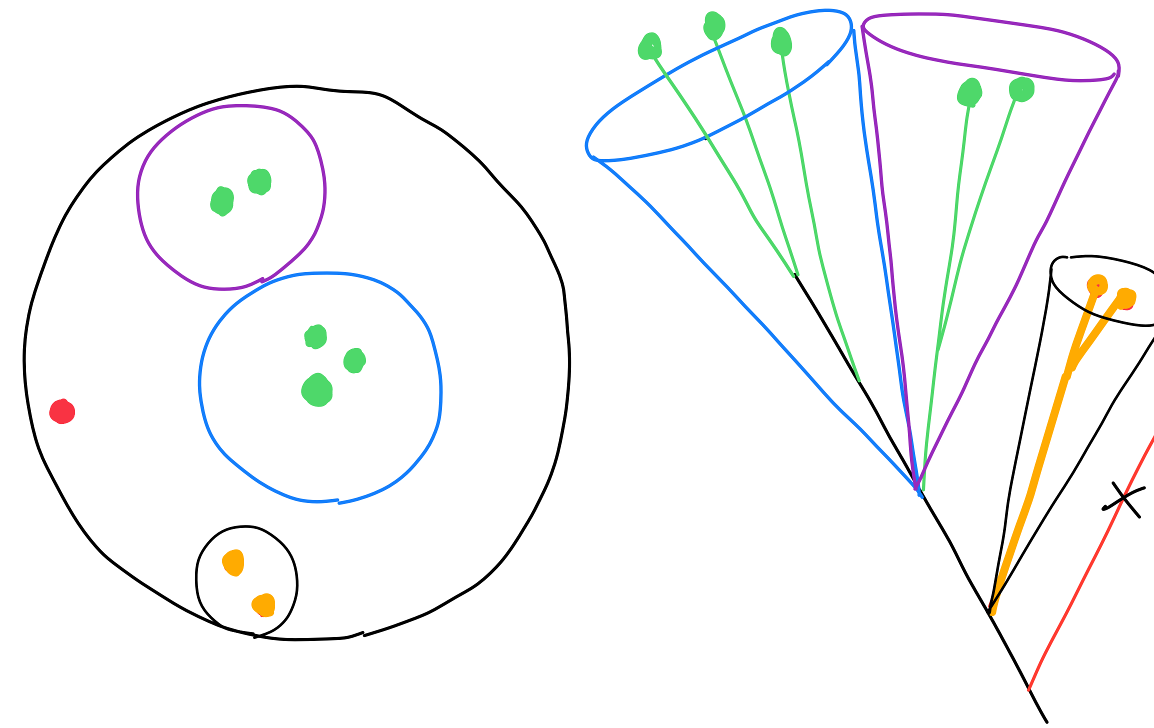
Oops!



Collinear drop

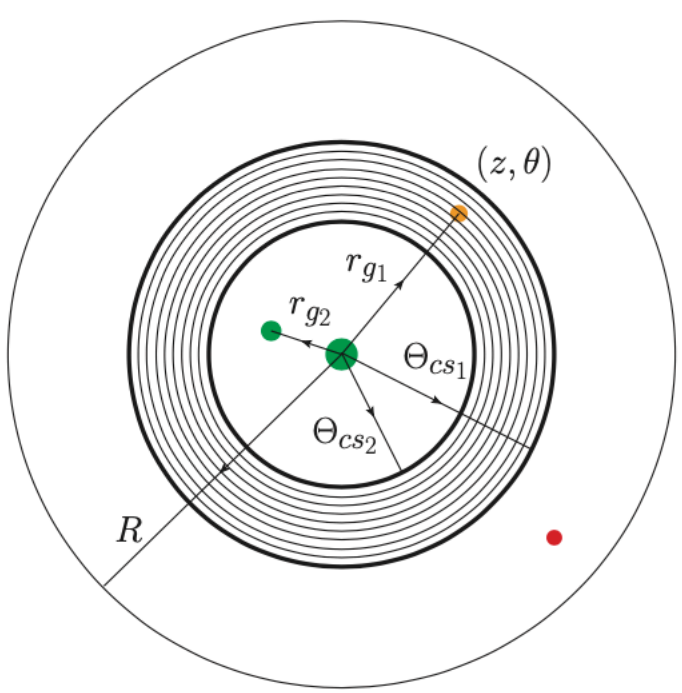
Chien, Stewart, JHEP06(2020)064





$$z_{cut_1}\left(\frac{\Delta R_{12}}{R_0}\right)^{\beta_1} < z < z_{cut_2}\left(\frac{\Delta R_{12}}{R_0}\right)^{\beta_2}$$

Collinear drop condition



- Conventionally only particles surviving soft drop are studied. However, one could study the dropped particles as well
- One could even pick out an intermediate branch with two soft drop conditions

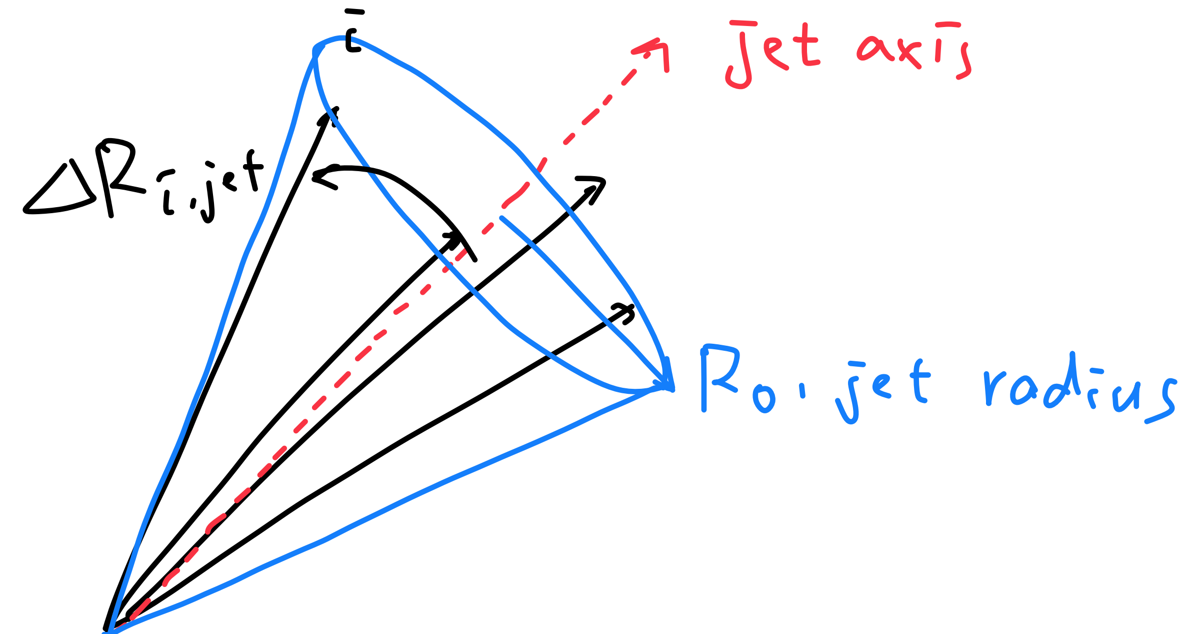
An extension of soft drop mass is the collinear drop mass

$$\Delta m^2 : m_{SD_1}^2 - m_{SD_2}^2$$

Jet angularity

Berger, Kucs, Sterman, PRD 68 (2003) 014012

Larkoski, Thaler, Waalewijn, arXiv: 1408.3122

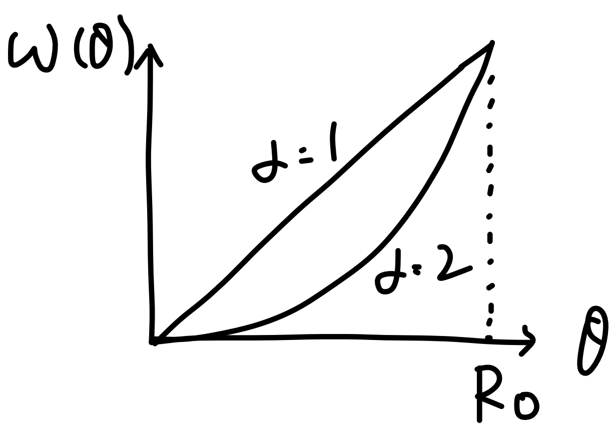


$$\lambda_\alpha^\kappa = \sum_{i\in \text{jet}} \Big(\underbrace{\frac{p_{t,i}}{p_{t,\text{jet}}}}_{z_i}\Big)^\kappa \Big(\frac{\Delta R_{i,\text{jet}}}{R_0}\Big)^\alpha$$

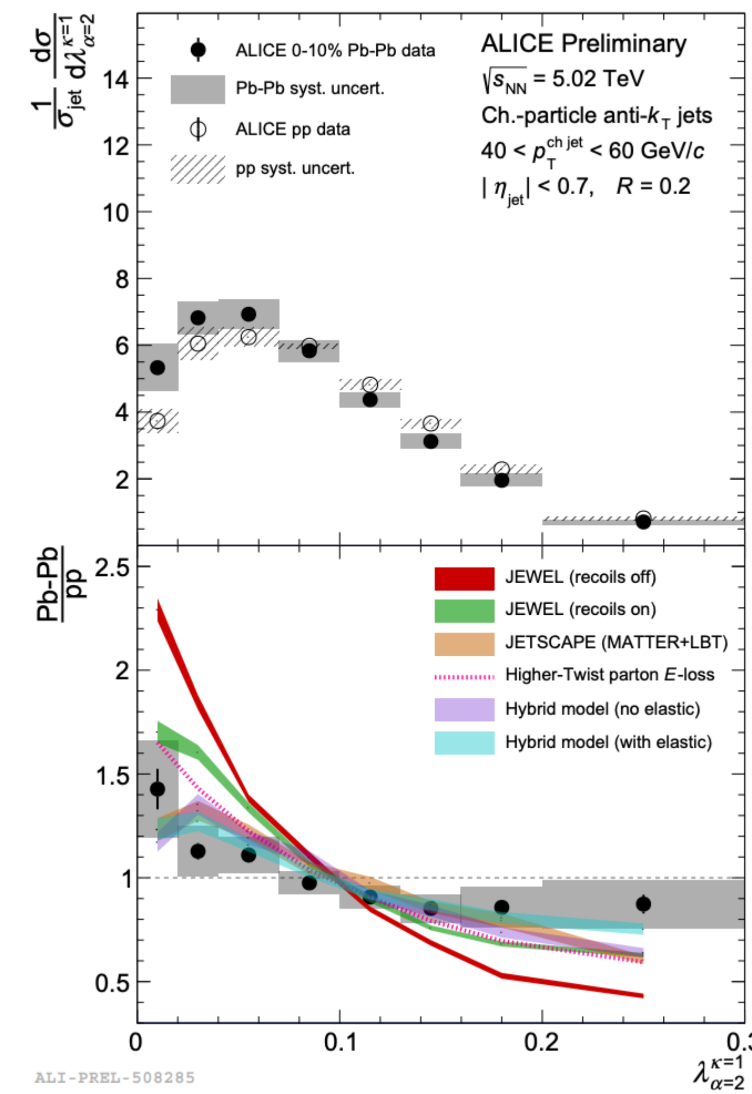
$\alpha > 0$, $\kappa = 1$ for IRC safety

$$\rightarrow \sum_{i\in \text{jet}} z_i \underbrace{\omega(\theta)}_{\text{some angular weight}}$$

$$\omega(\theta) = \left(\frac{\theta}{R_0}\right)^\alpha$$



Weighing wide-angle radiation heavily.

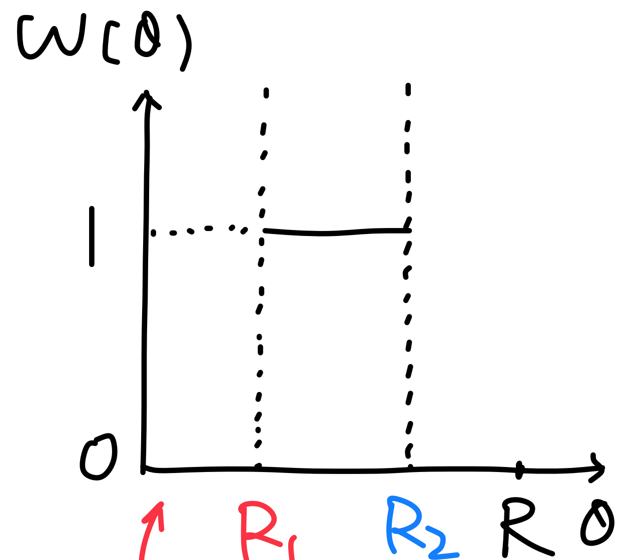


Flattened jet angularity

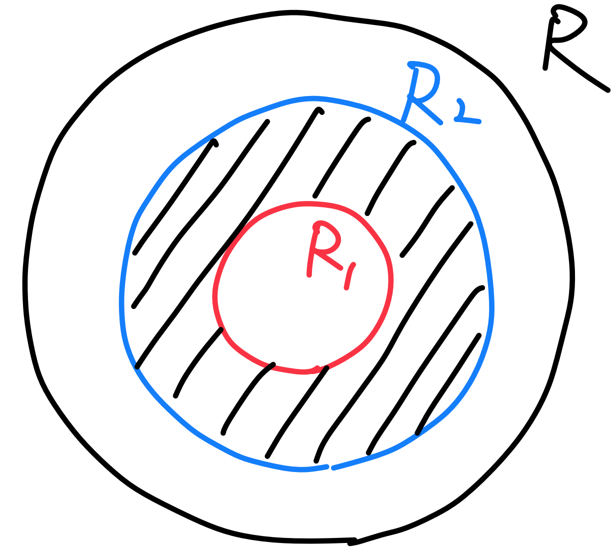
Flatten jet angularity generalize the functional form of $w(\theta)$

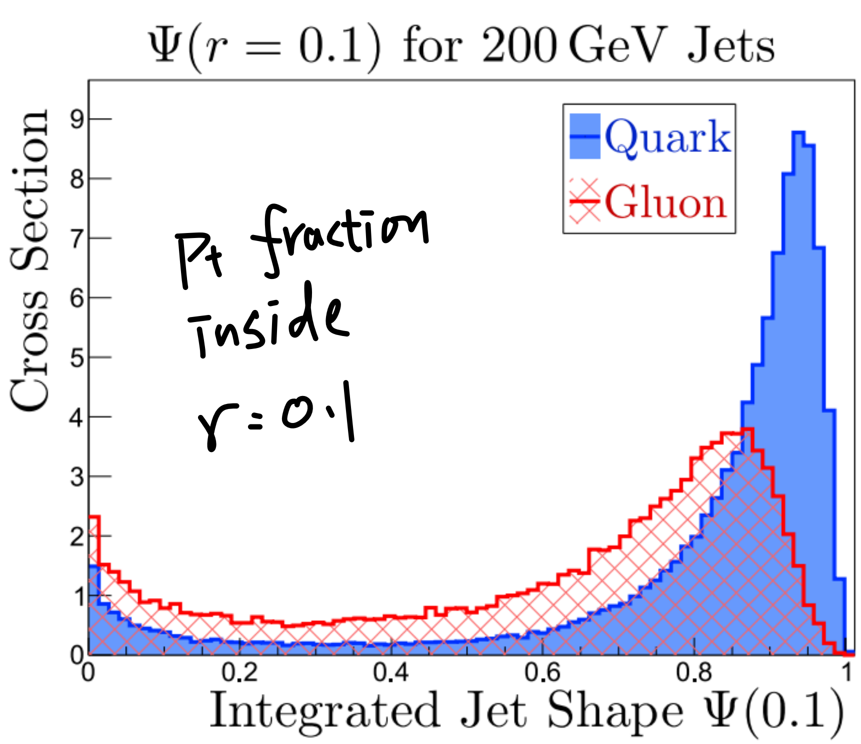
$$\sum_{i \in jet} z_i\, w(\theta)$$

In this talk we focus on annulus p_t fraction χ



another implementation of collinear drop





Gallicchio, Schwartz
PRL 107 (2011) 172001

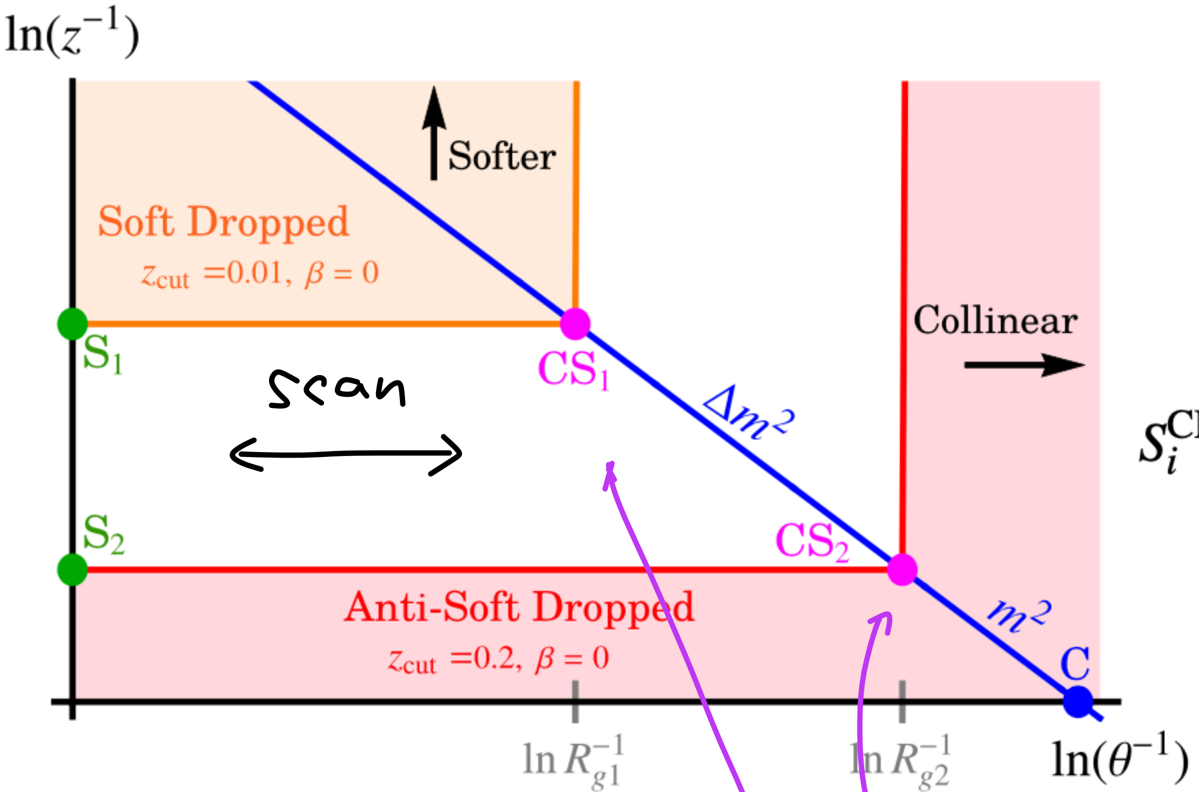
Instead of the average quantity, which is the conventional jet shape, this jet-by-jet distribution is shown to be sensitive to quark/gluon differences

Factorization

Chien, Stewart, JHEP06(2020)064

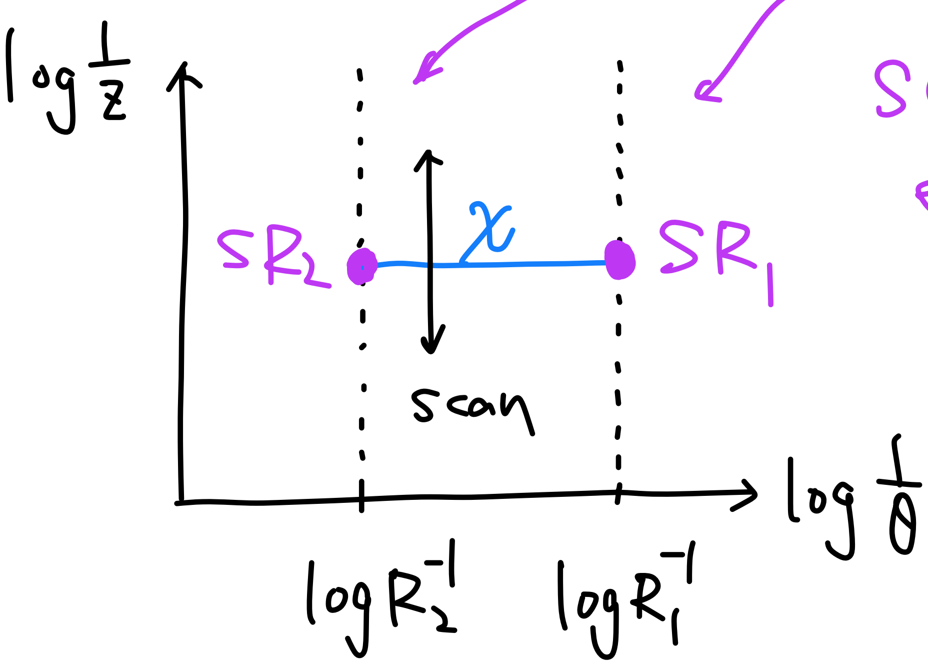
$$\frac{d\sigma}{d\Delta m^2} = \sum_{i=q,g} N_i(\mu) J^{\rm SD}_{{\rm un},i}(z_{{\rm cut}\,2},\beta_2,\mu) S_i^{\rm CD}(\Delta m^2, z_{{\rm cut}\,i}, \beta_i,\mu)$$

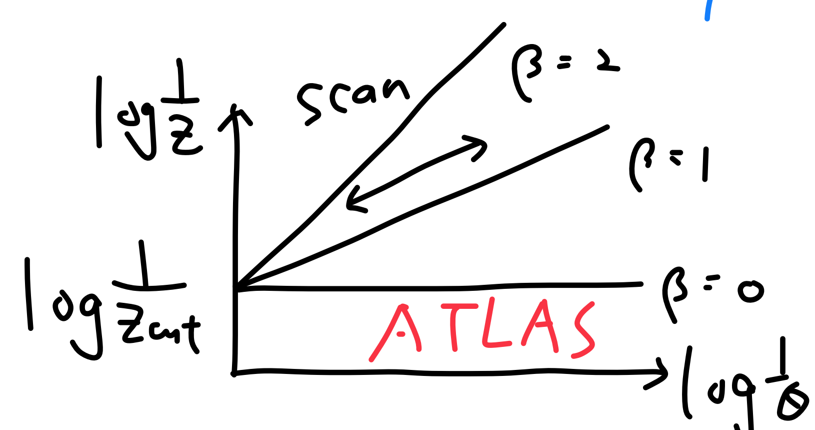
$$S_i^{\rm CD}(\Delta m^2,\mu) = \int dk_i \overline{S_{C_2,i}}(k_2,\mu) S_{C_1,i}(k_1,\mu)\delta(\Delta m^2 - 2E_J(k_1+k_2))$$



Using Soft-Collinear Effective Theory, Collinear drop and flatten jet angularity can be resummed at NLL accuracy

relevant modes in SCET factorization expressions.

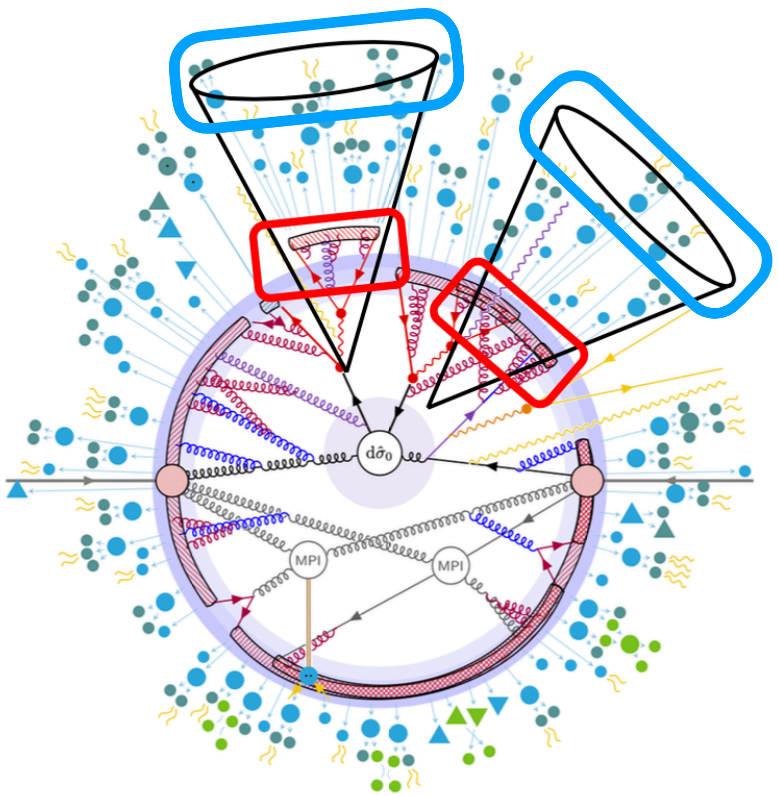




$$P_i^{\rm FA}(x,R_1,R_2) = \int dx_1 dx_2\; S_{\overline{R}_1 i}(x_1,\mu)\; S_{R_2 i}(x_2,\mu)\delta(x-x_1-x_2)$$

Chien, Fedkevych, in preparation

Hadronization and transfer matrix (TM)

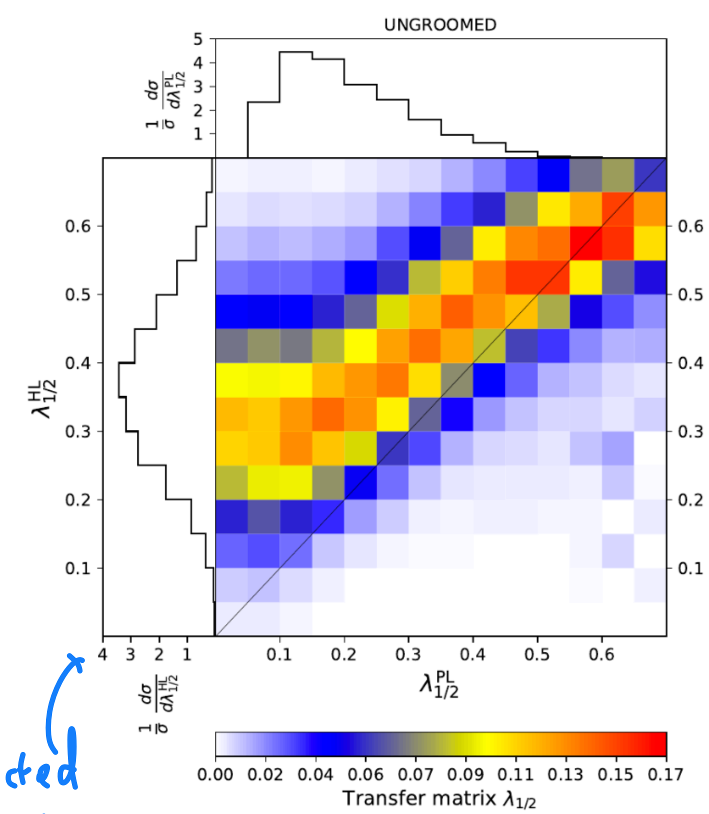


Transfer matrix extracted from Monte Carlo (Pythia 8 in this talk)

- The information on correlation between partons and hadrons in each event is embedded
- The clearly visible off-diagonal structures indicate strong bin-migration caused by non-perturbative effects
- Unlike the approach of the shape functions the TM are not bounded to any particular functional form

Korchemsky, Sterman, 99'

Hadron level results

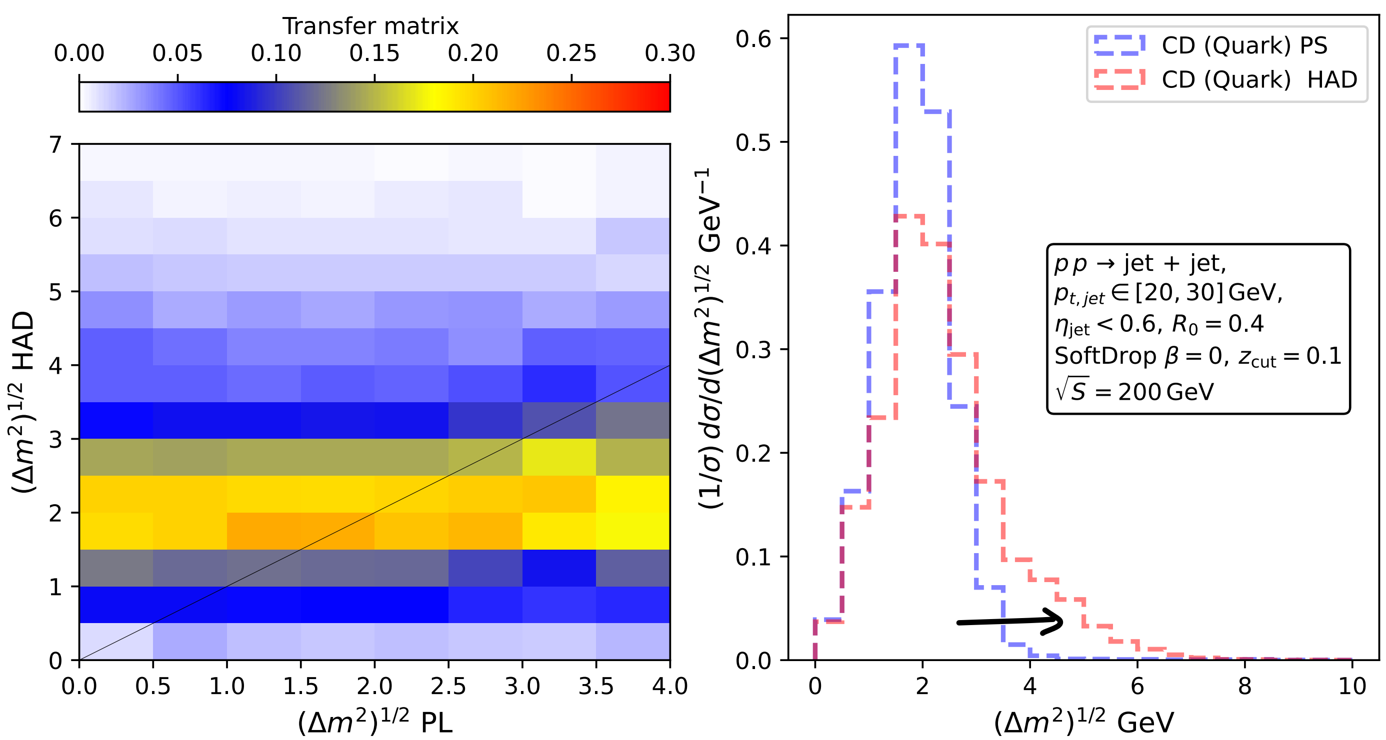


extracted from Sherpa

Parton level results

Chien, Fedkevych, Reichelt, Schumann, JHEP06(2020)064

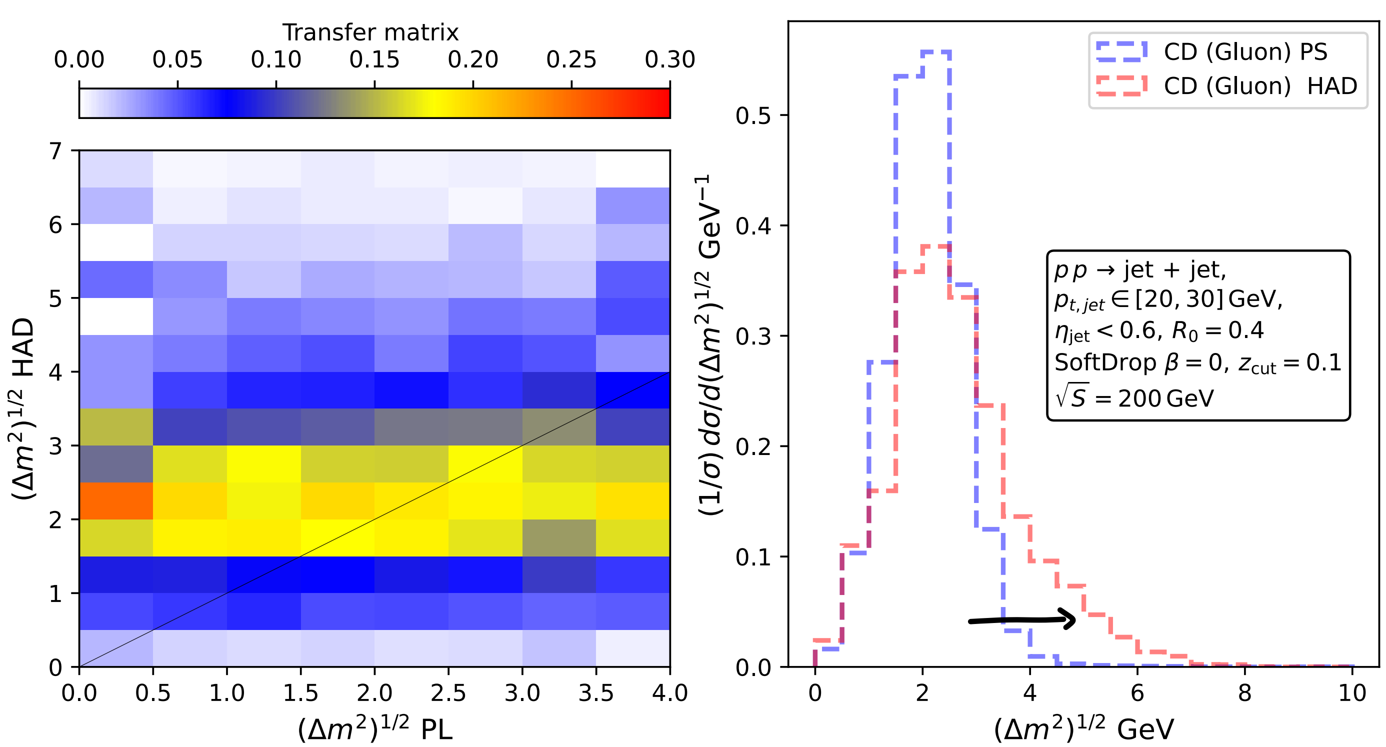
TM for collinear drop



Hadronization effect is of $\mathcal{O}(1)$ effect for collinear drop observable

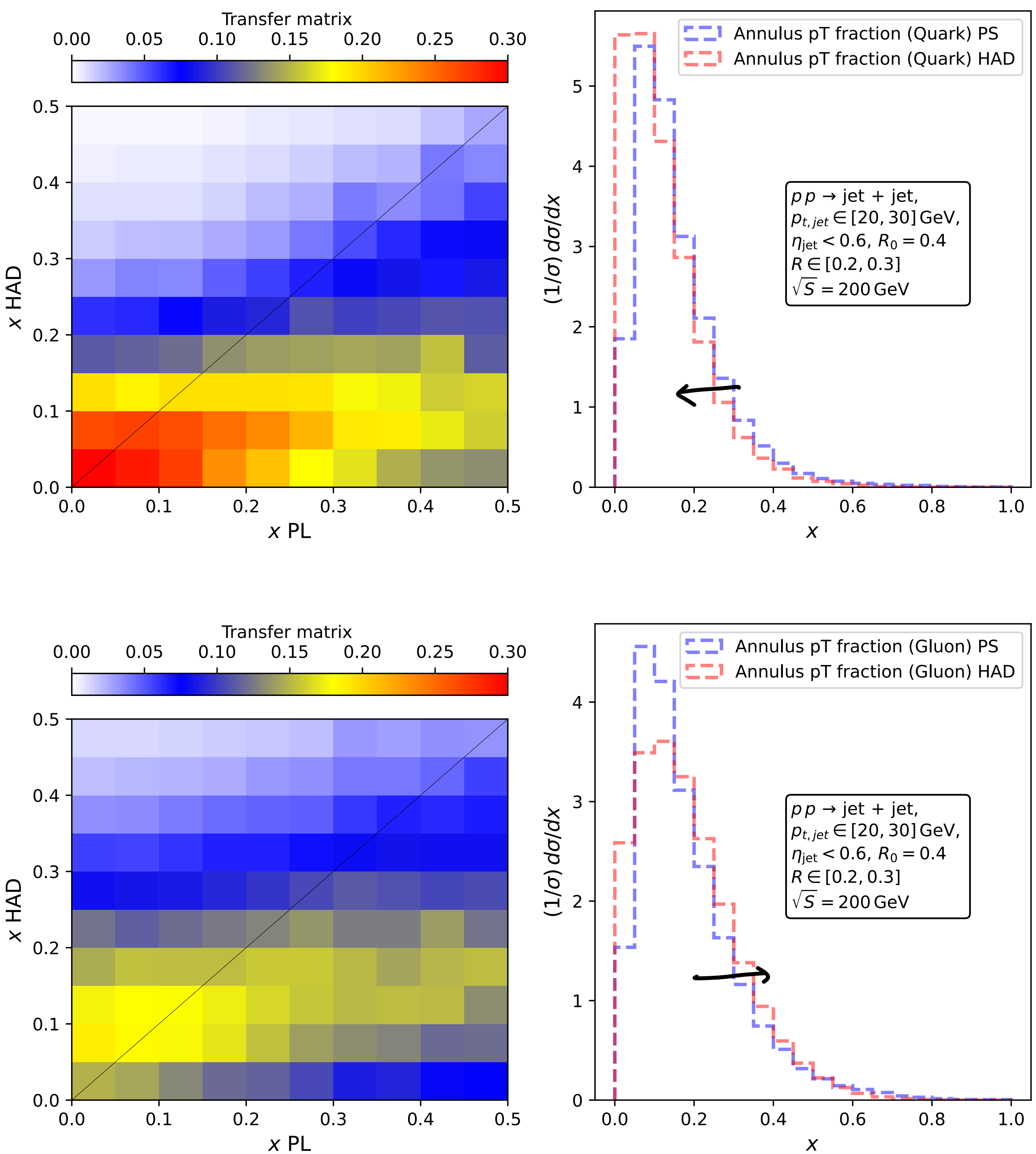
$$\Delta m^2 = m^2_{ungroomed} - m^2_{SD}$$

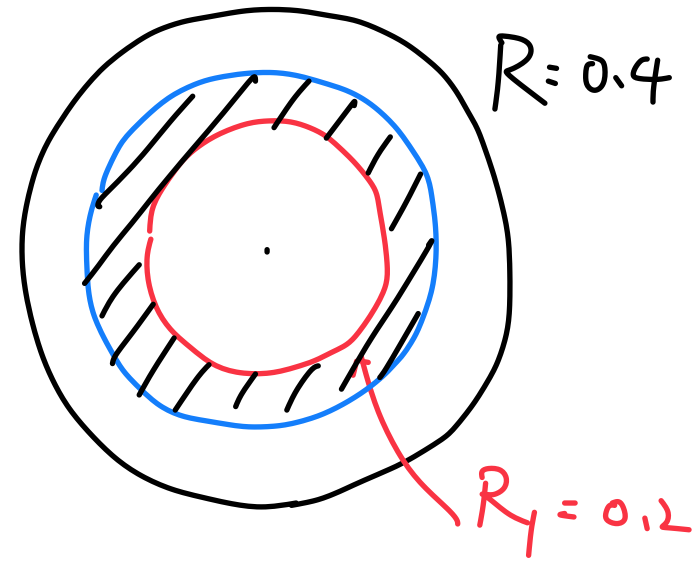
with $z_{cut} = 0.1$, $\beta = 0$



Transfer matrices for quark and gluon jets being extracted from Pythia8 and studied. Hadronization effect different in peak and tail regions.

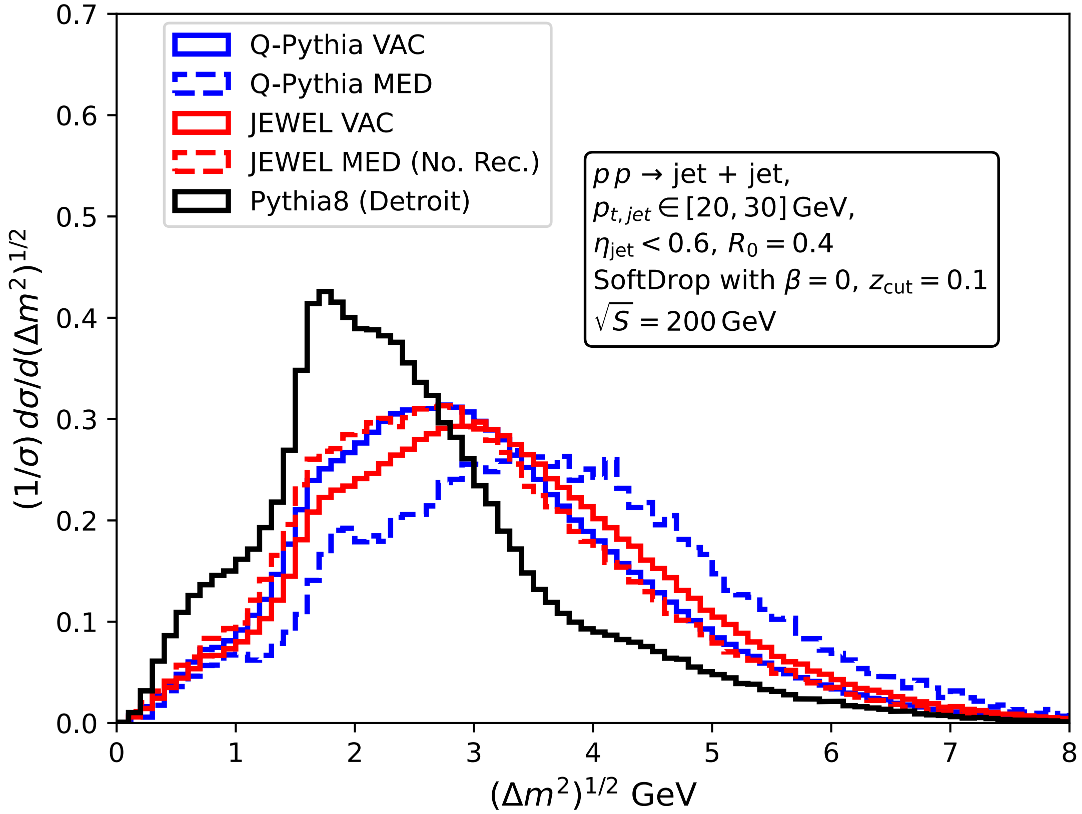
TM for annulus pt fraction

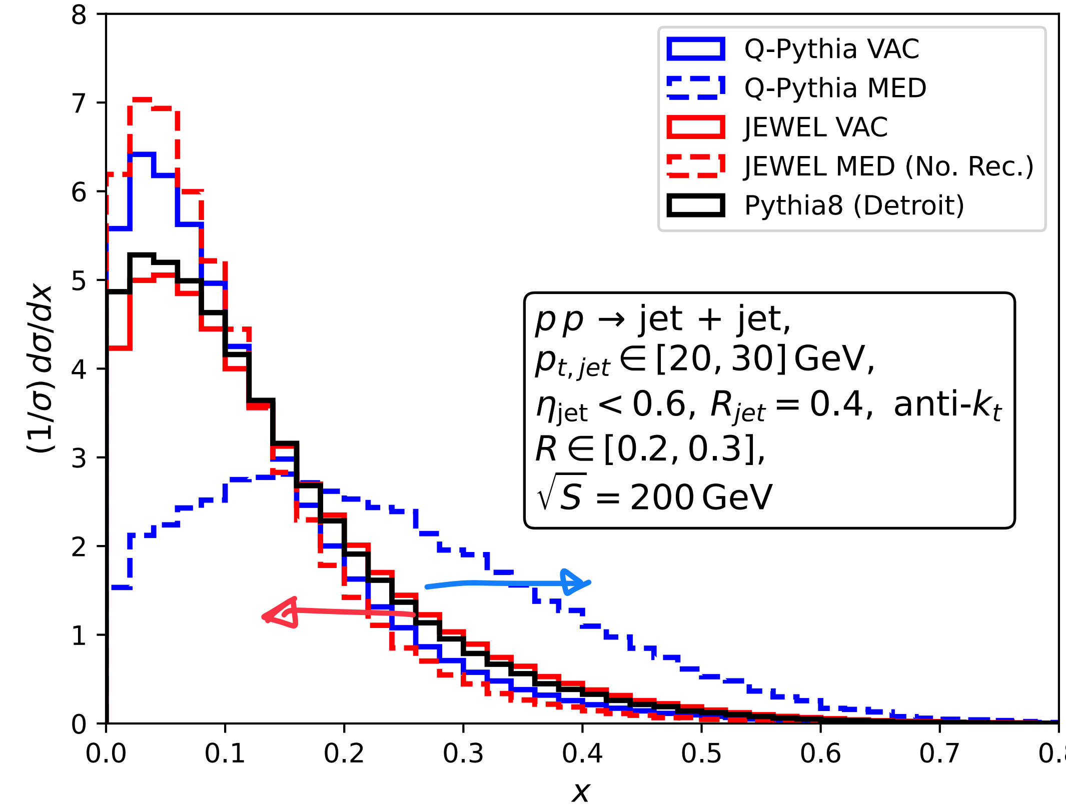




Surprisingly, hadronization effect is moderate for annulus pt fraction. However, effect is opposite for quark and gluon jets.

Medium effects in heavy ion



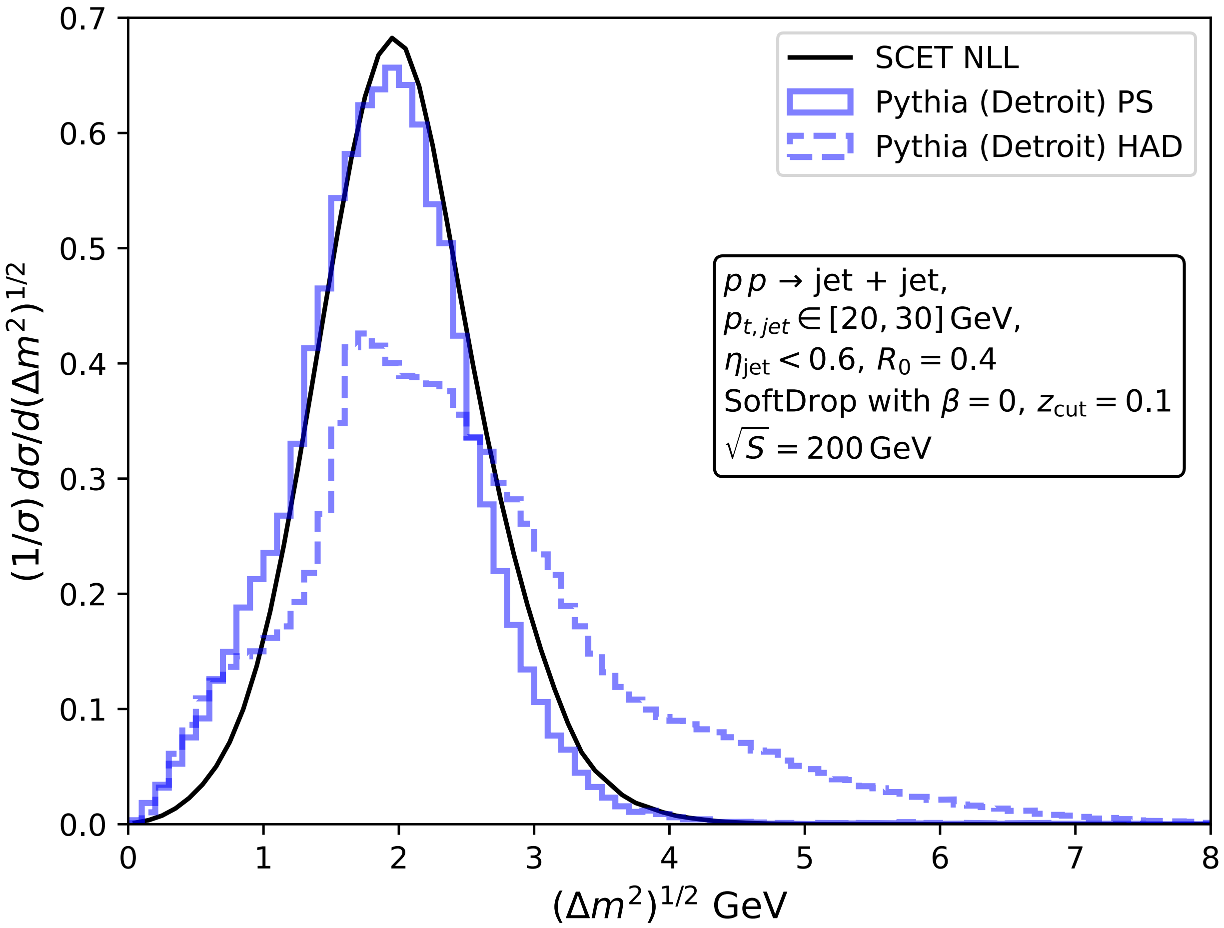


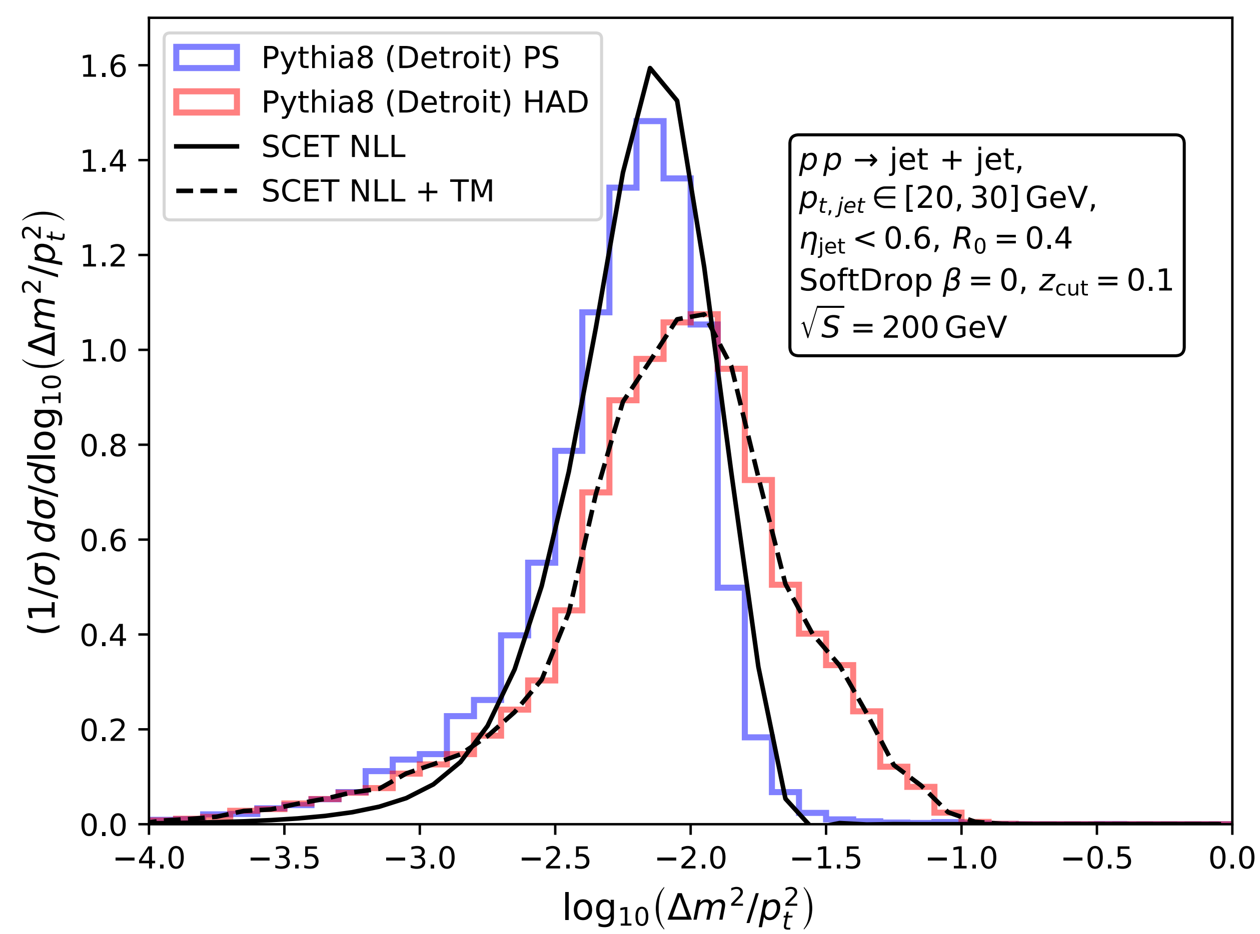
Q-pythia and Jewel are used to estimate the medium effect.

O(1) discrepancy between pp baseline from Pythia 8 and Q-pytha/ Jewel (based on Pytha 6) for collinear drop.

Opposite trends for medium effect in Jewel and Q-pythia

Prediction for STAR

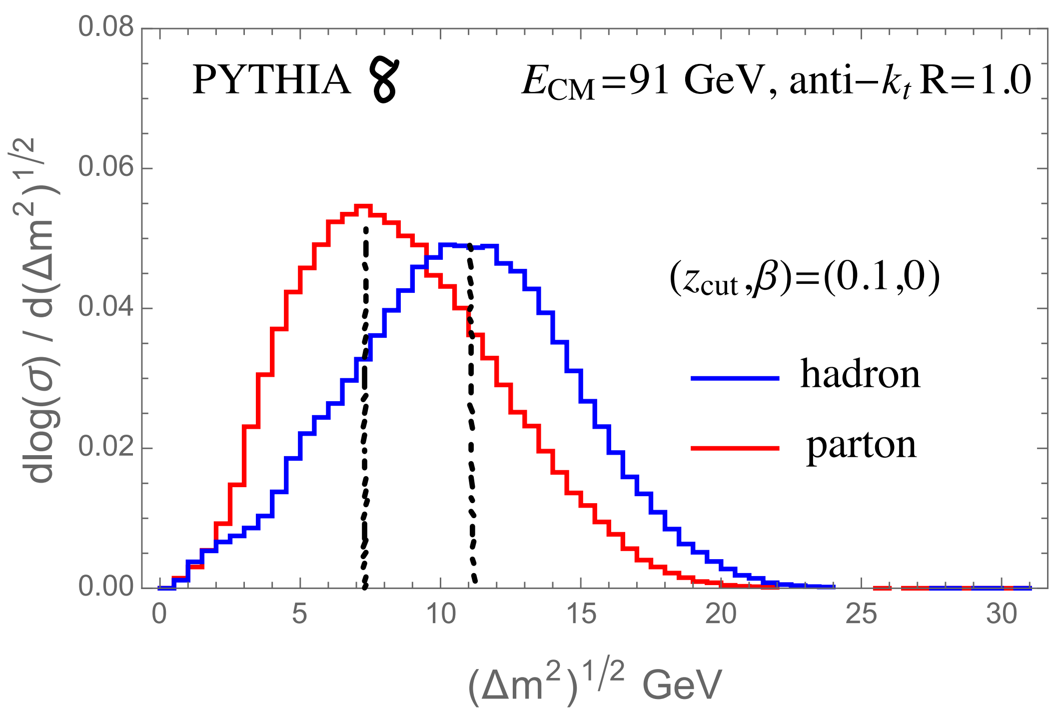


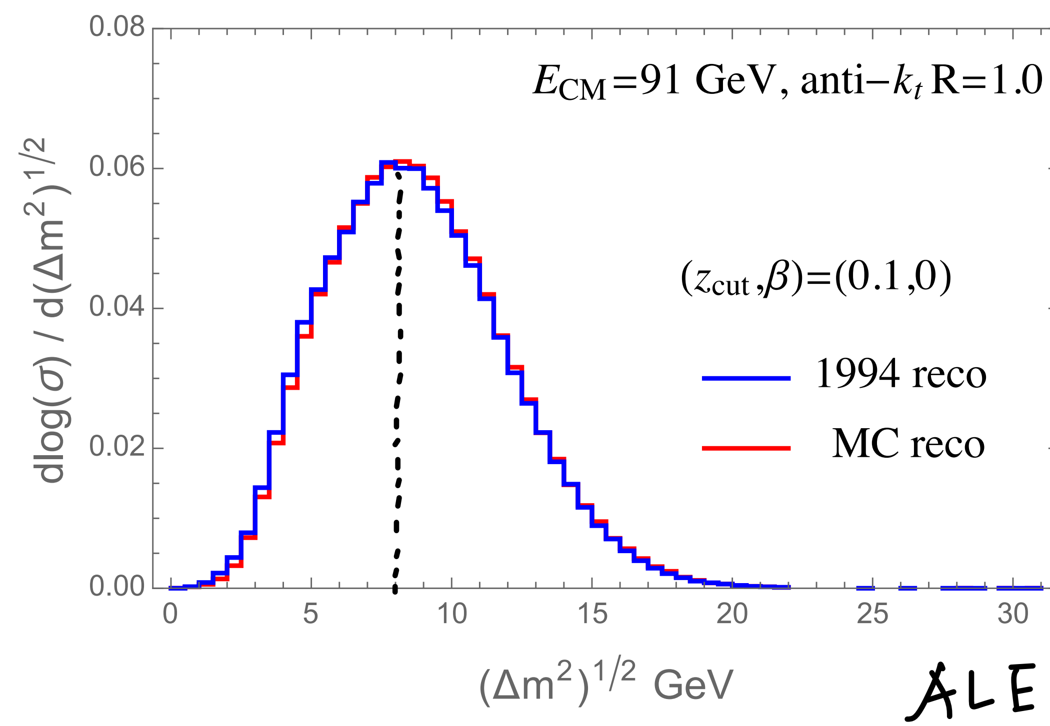


Summary

- Collinear drop observables enhances the sensitivity to intermediate, soft radiation, targeting physics goals in heavy ion
- Flattened jet angularity is introduced which give a difference approach to probe QCD phase space
- These observables receive significant/intriguing hadronization corrections in pp collisions. Further studies using the transfer matrix approach are necessary to establish the baseline
- Prediction of collinear drop jet mass for STAR is provided

Collinear drop @ LEP





ALEPH
open data & MC

$$\Delta m^2 = m_{total}^2 - m_{SD}^2$$

- Hadronization effect is significant throughout the whole region
- At the reco level, data and MC agree quite well
- Detector effect is significant