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IN COLLABORATION WITH

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NONPERTURBATIVE CORRECTIONS TO GROOMED OBSERVABLES

BOOST, JULY 2018, PARIS

universität wien

FWF

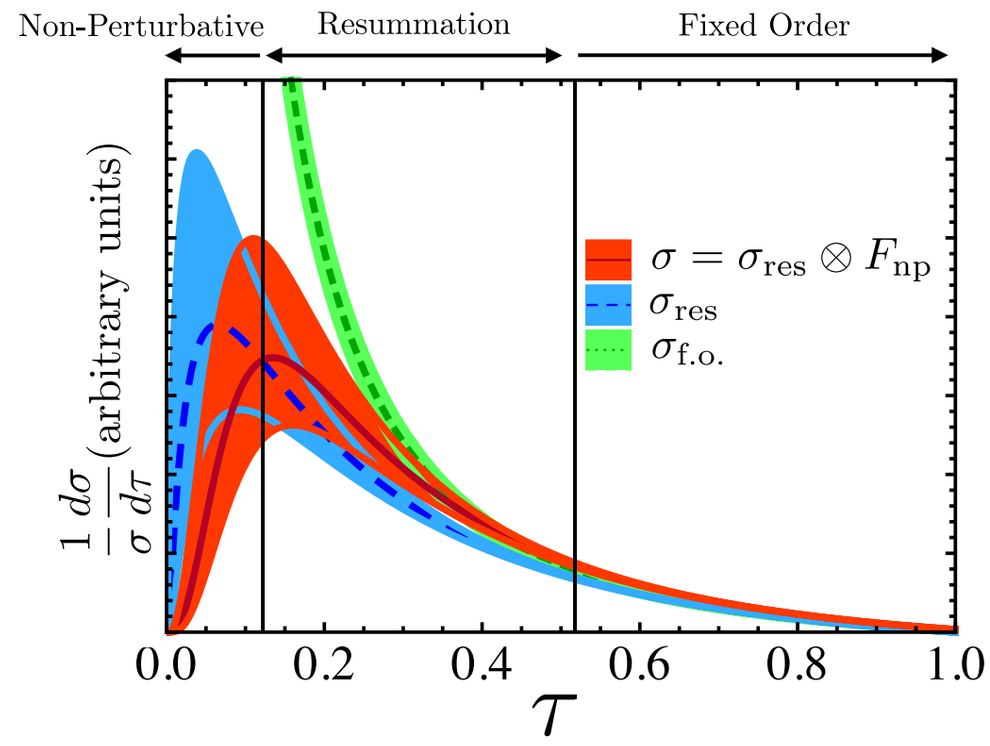
Der Wissenschaftsfonds.

REGIONS OF JET MASS SPECTRUM

- Perturbation theory allows us to describe the resummation and the fixed order regions.

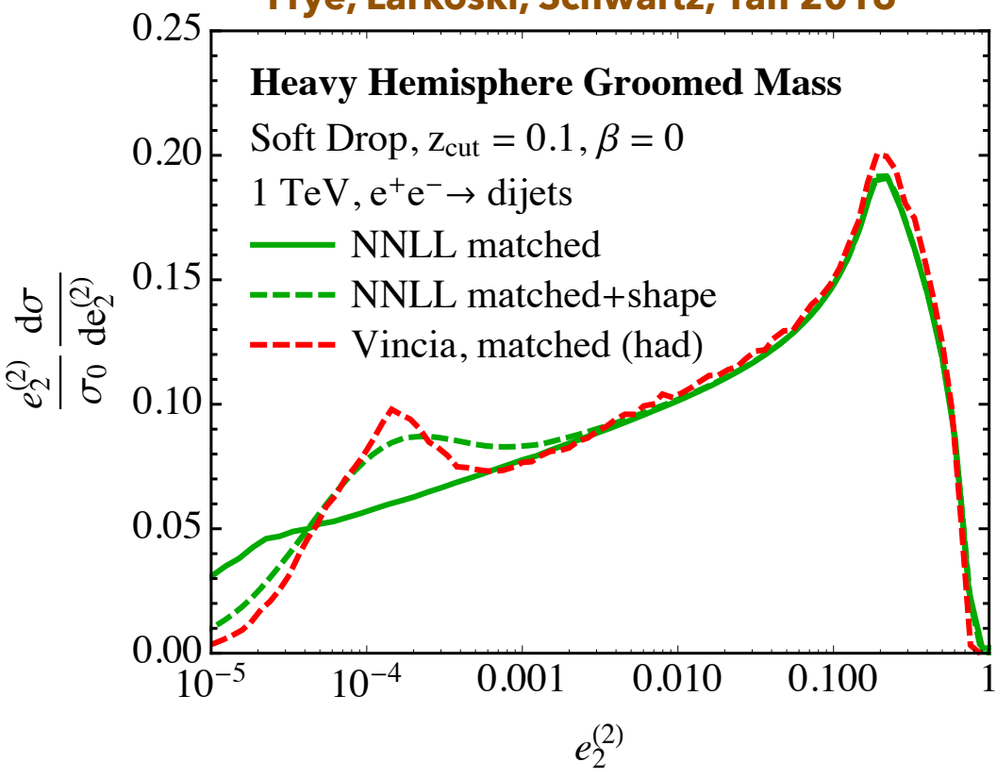
- Treat the Non perturbative region via **analytic shape function**

$$\frac{d\sigma_{\rm had}}{de_2^{(\alpha)}} = \int d\epsilon \, \frac{d\sigma_{\rm pert}\left(e_2^{(\alpha)} - \left(\frac{\epsilon}{z_{\rm cut} Q}\right)^{\frac{\alpha-1}{1+\beta}} \frac{\epsilon}{Q}\right)}{de_2^{(\alpha)}} F_{\rm shape}(\epsilon)$$



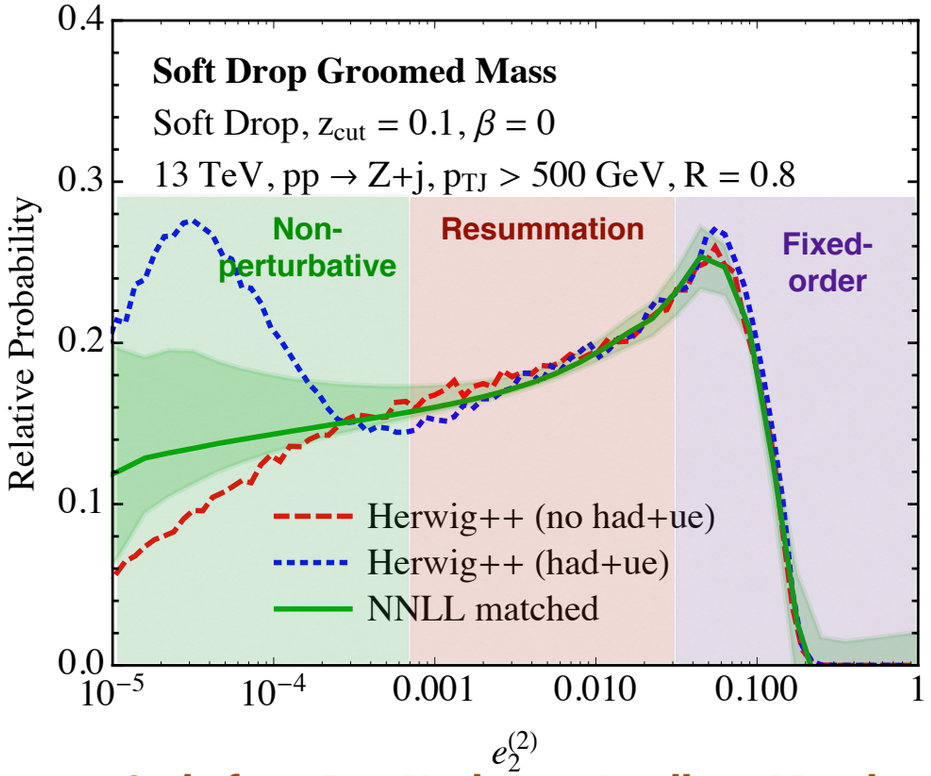
Plot from Larkoski, Moult, Nachmann 2017

Frye, Larkoski, Schwartz, Yan 2016



$$e_2^{(\alpha)} = \frac{m_J^2}{E_J^2}$$

$$e_2^{(\alpha)} \ll z_{\rm cut} \ll 1$$



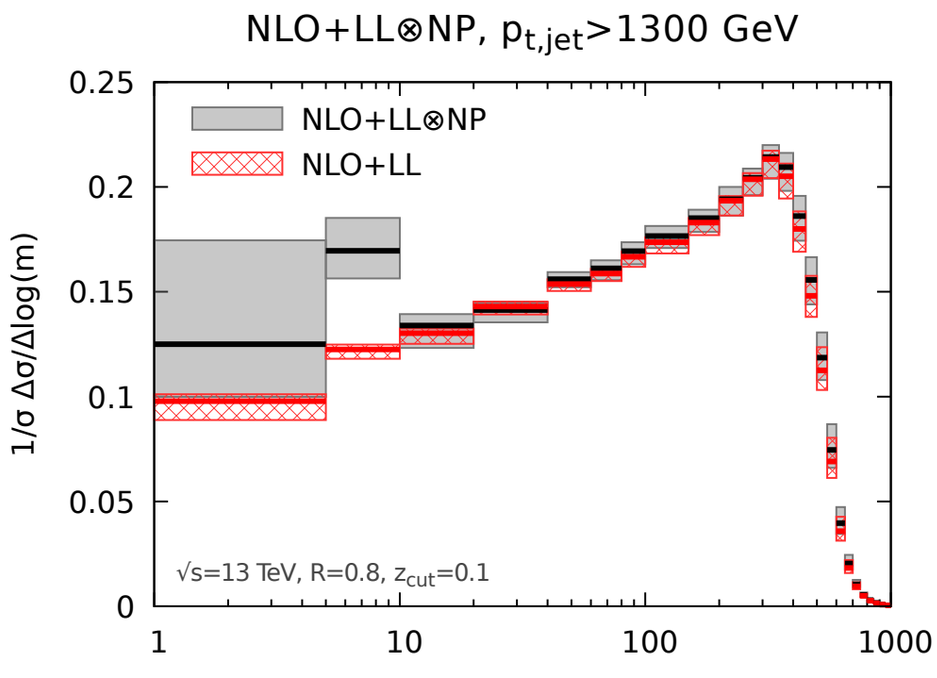
Stole from Ben Nachmann's talk on Monday

C. Frye, A. Larkoski, M. Schwartz, K. Yan, JHEP 07 (2016) 064

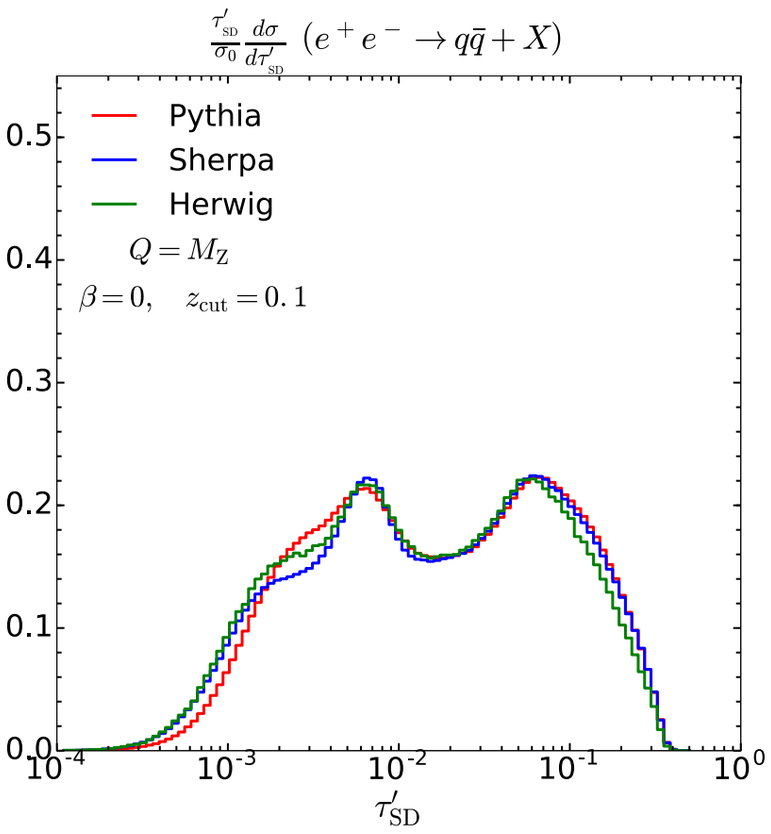
STRATEGIES FOR INCLUDING NP CORRECTIONS

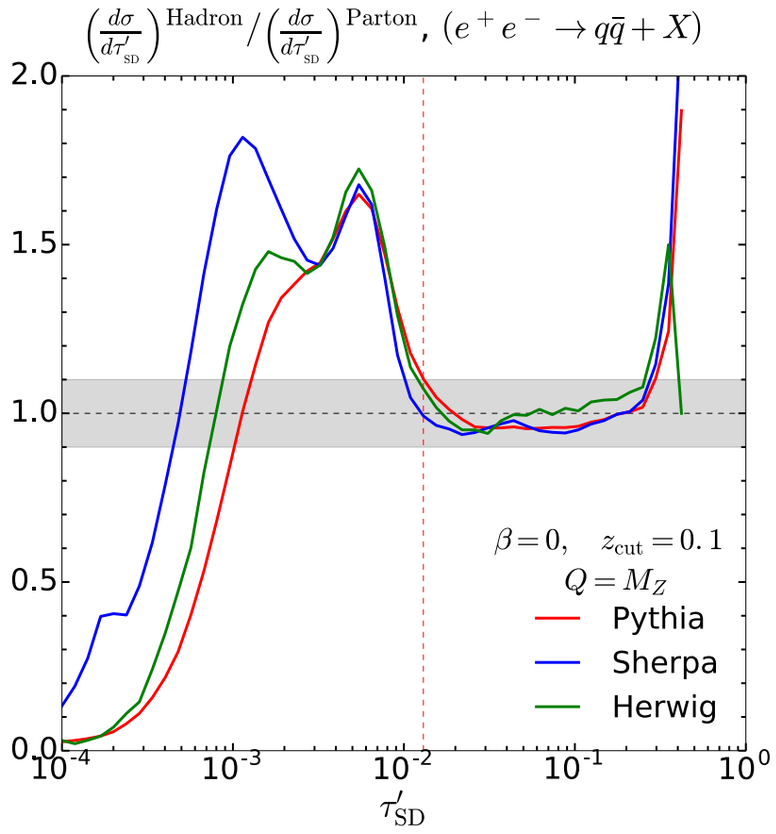
- Perturbation theory allows us to describe the resummation and the fixed order regions.
- Describe the non perturbative region via **Monte Carlos**
- Soft drop jet mass shows robustness against hadronization in the resummation region

Marzani, Schunk, Soyez 2017



Baron, Marzani, Theeuwes 2018





NP CORRECTIONS TO PLAIN JET MASS

Stewart, Tackmann, Waalewijn 2015

$$\frac{d\sigma}{dm_J^2 d\Phi_2} = \sum_{\kappa,a,b} H_\kappa(\Phi_2) \int dk_s dk_B \, (\mathcal{I}_{\kappa_a a}\mathcal{I}_{\kappa_b b} \otimes f_a f_b)(k_B)$$
$$\times J_{\kappa J}(m_J^2 - 2p_T^J k_s)\, S_\kappa(k_S, p^{\rm cut} - k_B, y_J, R)$$

- Consider an example of pp-> H/Z + 1 jet:
- SCET allows us to understand these aspects of the interface between NP function and the perturbative cross section:
  - The form of the convolution
  - Boundary of the NP region
  - Universality - Power corrections only dependent on R
  - Operator definition of the first moment.

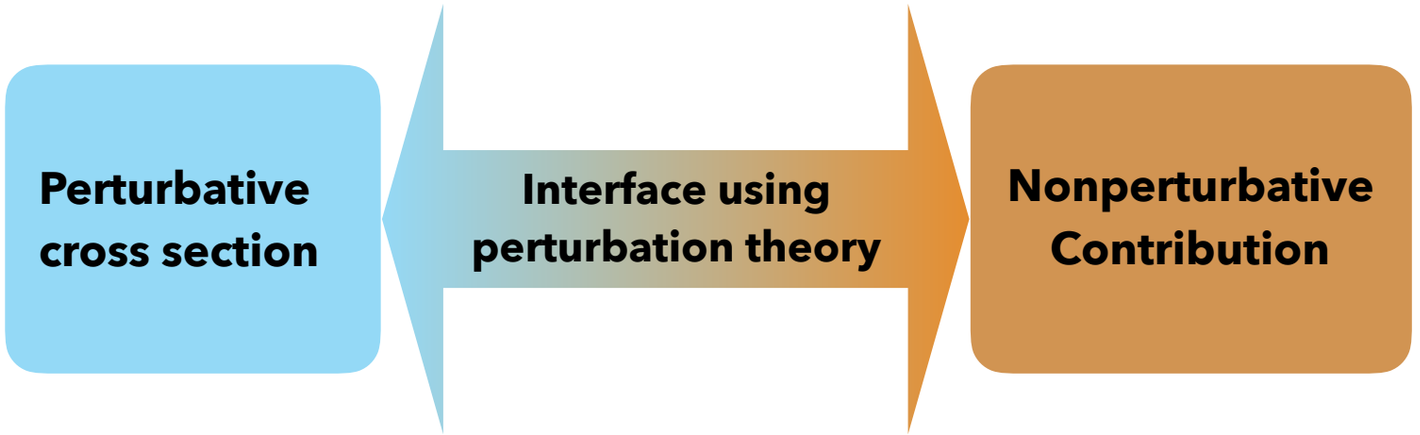
$$S_\kappa(k_S, k_B, y_J, R) = \int dk \; S_\kappa^{\rm pert}\big(k_S - k, k_B, y_J, R\big)$$
$$\times F_\kappa(k, R)\big[1 + \mathcal{O}(\Lambda_{\rm QCD}/k_B)\big]$$

$$\frac{d\sigma_\kappa}{dm_J^2} = \int dk \frac{d\sigma_\kappa^{\rm partonic}}{dm_J^2}(m_J^2 - 2p_T^J k) F_\kappa(k, R)$$

$$\Phi_2 = \{p_T^J, y_J, Y\}$$

$$m_J^2 = \big(m_J^2\big)^{\rm pert} + 2p_T^J \, \Omega_\kappa(R)$$

$$m_J^2 \gg \Lambda_{\rm QCD} \, p_T^J$$



INTERFACE BETWEEN PERTURBATIVE AND NP COMPONENTS

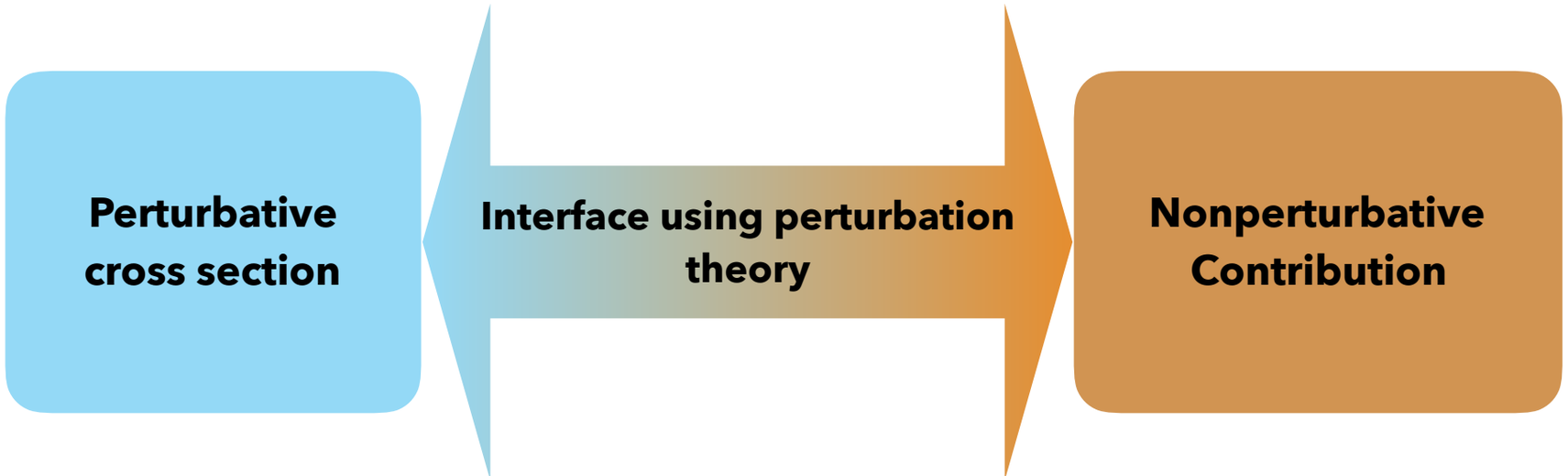
In what way is the groomed jet mass different?

- Universality: dependence on zcut? beta?
- NP catchment area: no longer determined by the jet radius: no fixed geometric region.
- C/A clustering: NP corrections could depend on perturbative branching history.

Goal of this work is to deepen our understanding of the interface for groomed jet mass via field theory calculations

Work in the limit:

$$\frac{m_J^2}{Q^2} \ll z_{\rm cut} \ll 1$$



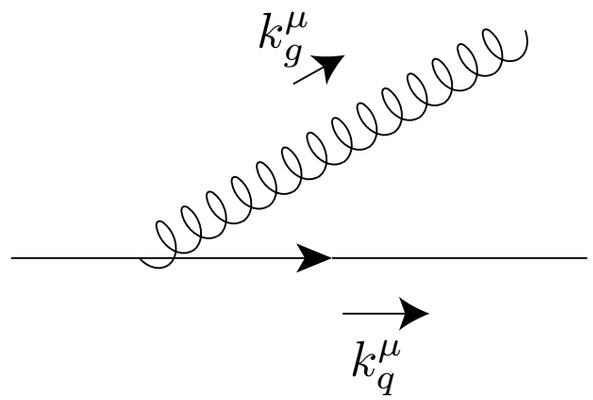
NP CORRECTIONS FOR SOFT DROPPED JET MASS

1. SCALE OF NP CORRECTIONS FROM EFFECTIVE THEORY MODES
2. EFFECTS OF C/A CLUSTERING AND NLL APPROXIMATION
3. UNIVERSALITY OF NP CORRECTIONS
4. HADRON LEVEL CROSS SECTION

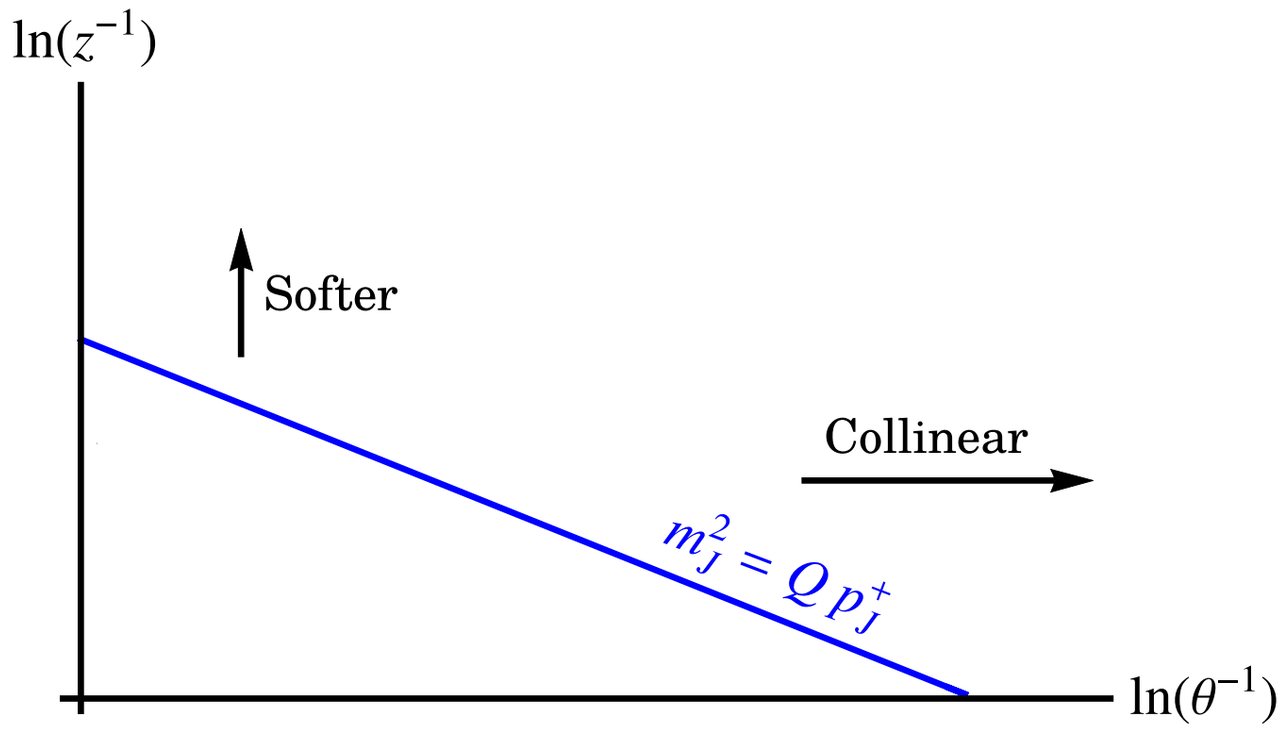
EFT MODES FOR PLAIN JET MASS

- Consider the case of plane jet mass.

- Plots in energy fraction (z) and angle are helpful.

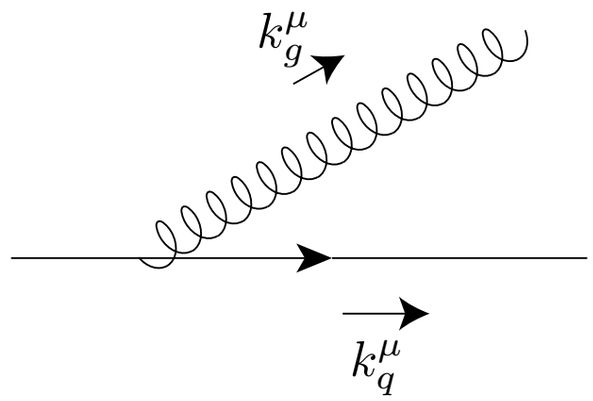


$$m_J^2 = (k_q + k_g)^2 = 2E_q E_g (1 - \cos\theta_{qg})$$



EFT MODES FOR PLAIN JET MASS

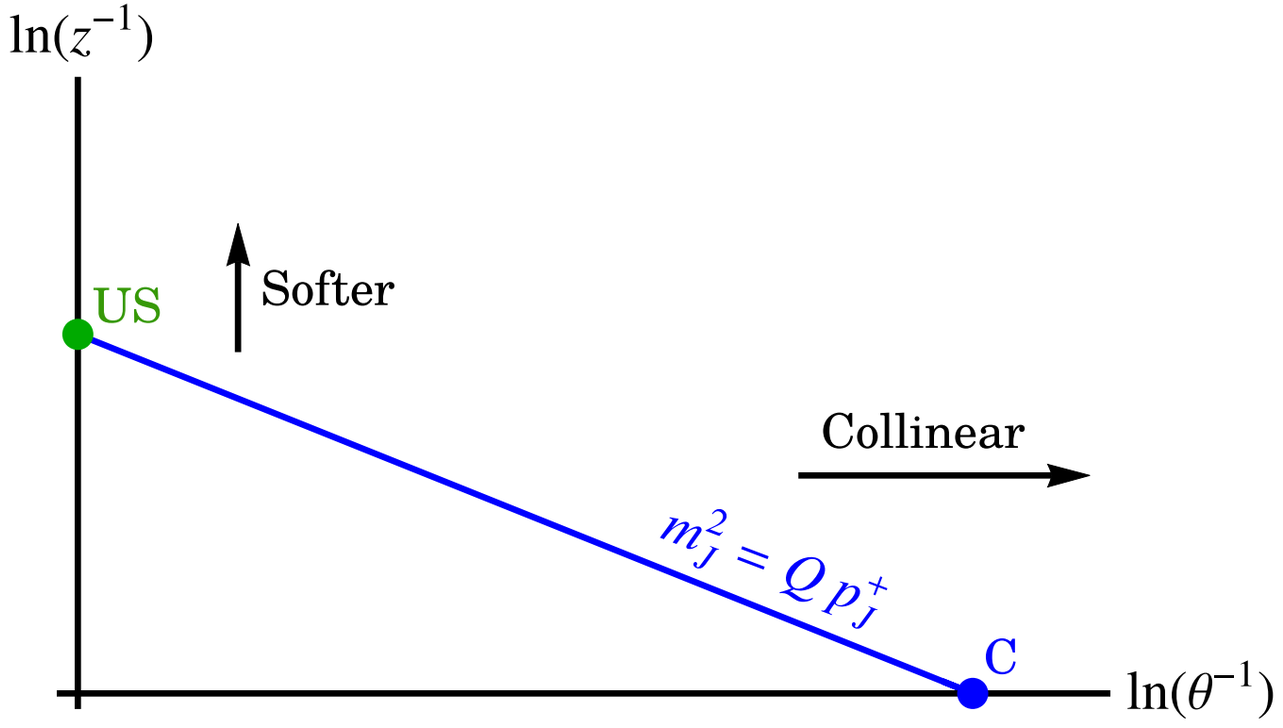
- Consider the case of plane jet mass.
- Plots in energy fraction (z) and angle are helpful.
- Resummation region can be described via the ultrasoft and collinear modes.



$$m_J^2 = (k_q + k_g)^2 = 2E_q E_g (1 - \cos\theta_{qg})$$

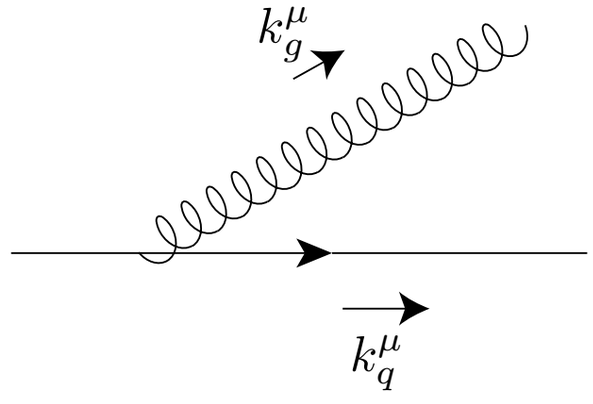
$$m_J^2 \simeq Q\, p^+_{\text{coll, usoft}} \qquad p^\pm = E \pm \vec{p}\cdot\hat{n}$$

$$z_{us} \sim \frac{m_J^2}{Q^2}, \theta_{us} \sim 1 \qquad z_c \sim 1, \theta_c \sim \frac{m_J}{Q}$$



EFT MODES FOR PLAIN JET MASS

- Consider the case of plane jet mass.
- Plots in energy fraction (z) and angle are helpful.
- Resummation region can be described via the ultrasoft and collinear modes.
- We imagine a background of NP emissions at all angles.
- US becomes nonperturbative first - hence include power corrections in the soft function.



$$m_J^2 = (k_q + k_g)^2 = 2E_q E_g (1 - \cos\theta_{qg})$$

$$m_J^2 \simeq Q\, p^+_{\text{coll, usoft}} \qquad p^\pm = E \pm \vec{p}\cdot\hat{n}$$

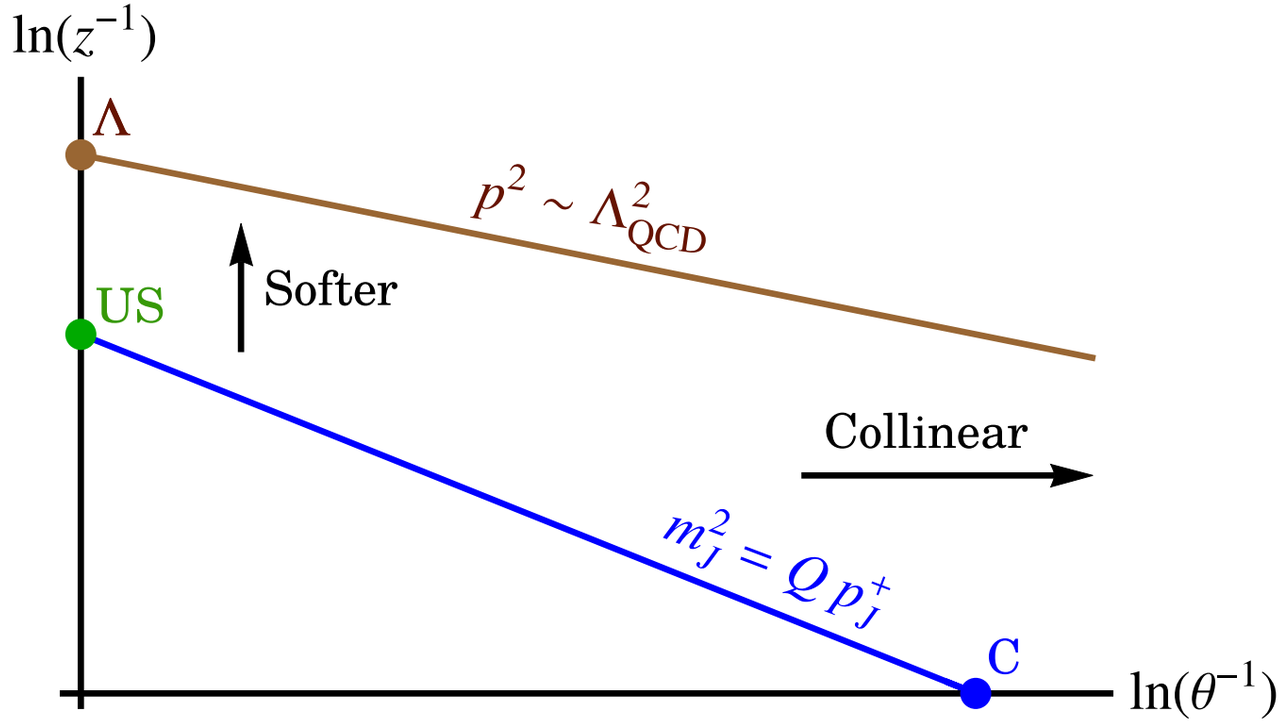
$$z_{us} \sim \frac{m_J^2}{Q^2},\ \theta_{us} \sim 1 \qquad z_c \sim 1,\ \theta_c \sim \frac{m_J}{Q}$$

$$p_\Lambda^+ p_\Lambda^- - p_{\Lambda\perp}^2 \sim \Lambda_{\text{QCD}}^2 \qquad z_\Lambda(\theta_\Lambda) = \frac{2\Lambda_{\text{QCD}}}{Q\,\theta_\Lambda}$$

$$\text{collinear NP} \to \Lambda_{\text{QCD}}\left(\frac{\theta_\Lambda}{2}, \frac{2}{\theta_\Lambda}, 1\right)$$

$$\text{wide angle NP} \to \Lambda_{\text{QCD}}(1, 1, 1)$$

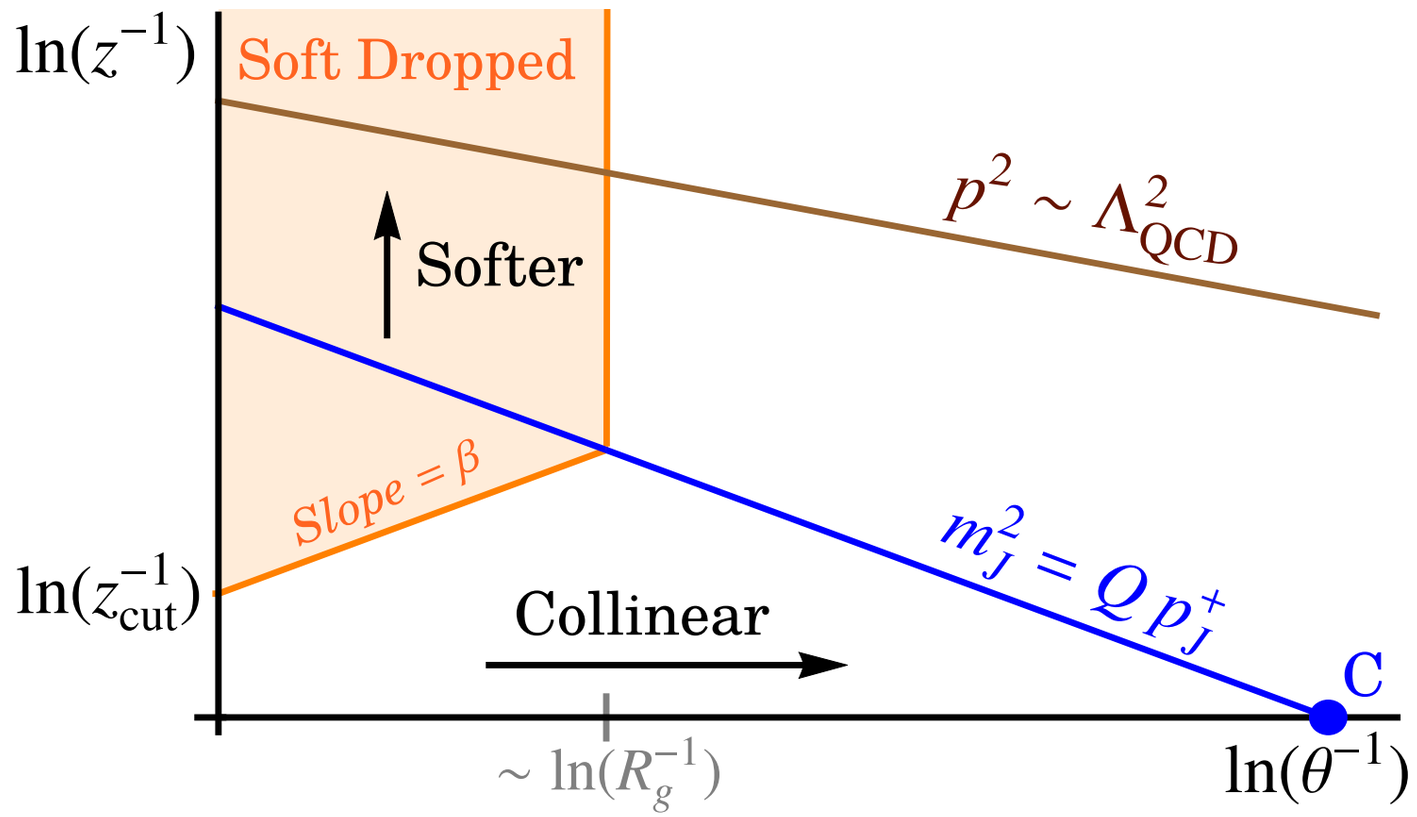
$$S_\kappa = S_\kappa^{\text{pert}} \otimes F_\kappa$$



PERTURBATIVE MODES FOR SOFT DROP GROOMED JET MASS

- Turning on soft drop removes emissions in the shaded region.

$$z > z_{\rm cut}\,\theta^{\beta}$$



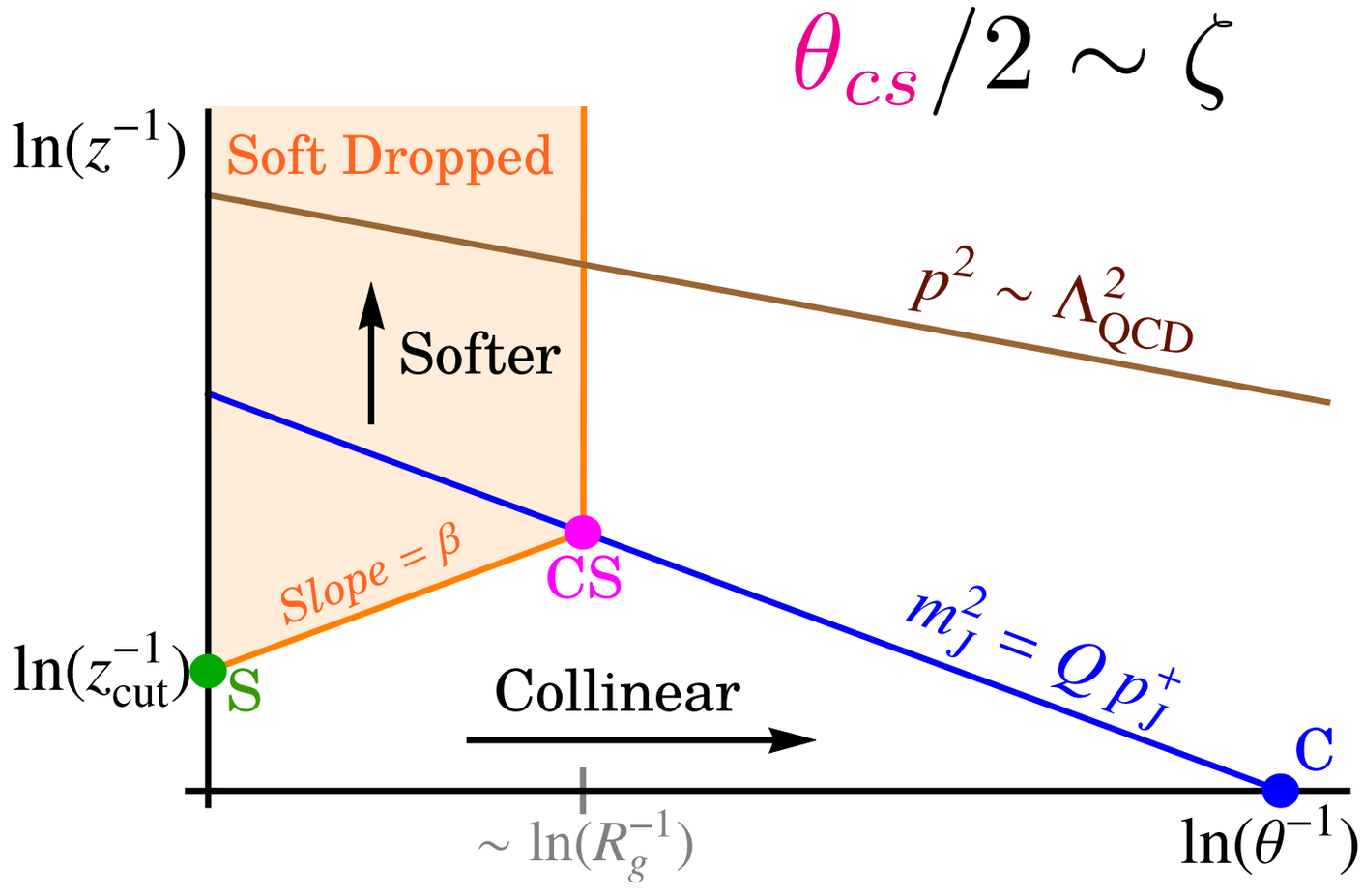
PERTURBATIVE MODES FOR SOFT DROP GROOMED JET MASS

- Turning on soft drop removes emissions in the shaded region.
- CS denotes the emission at widest angle that satisfies the soft drop condition.

$$z \;>\; z_{\rm cut}\,\theta^{\beta}$$

$$p_{CS}^{\mu} \sim \frac{m_J^2}{Q\,\zeta}\left(\zeta,\,\frac{1}{\zeta},\,1\right) \qquad p_{C}^{\mu} \sim \left(\frac{m_J^2}{Q}, Q, m_J\right)$$

$$\zeta \equiv \left(\frac{m_J^2}{Q\,Q_{\rm cut}}\right)^{\frac{1}{2+\beta}} \qquad Q_{\rm cut} \equiv 2^{\beta} Q\, z_{\rm cut}$$



LEADING NON PERTURBATIVE MODE FOR SD JET MASS

- Turning on soft drop removes emissions in the shaded region.
- CS denotes the emission at widest angle that satisfies the soft drop condition.
- Leading non-perturbative corrections have the largest plus component - hence the same angle as the CS modes

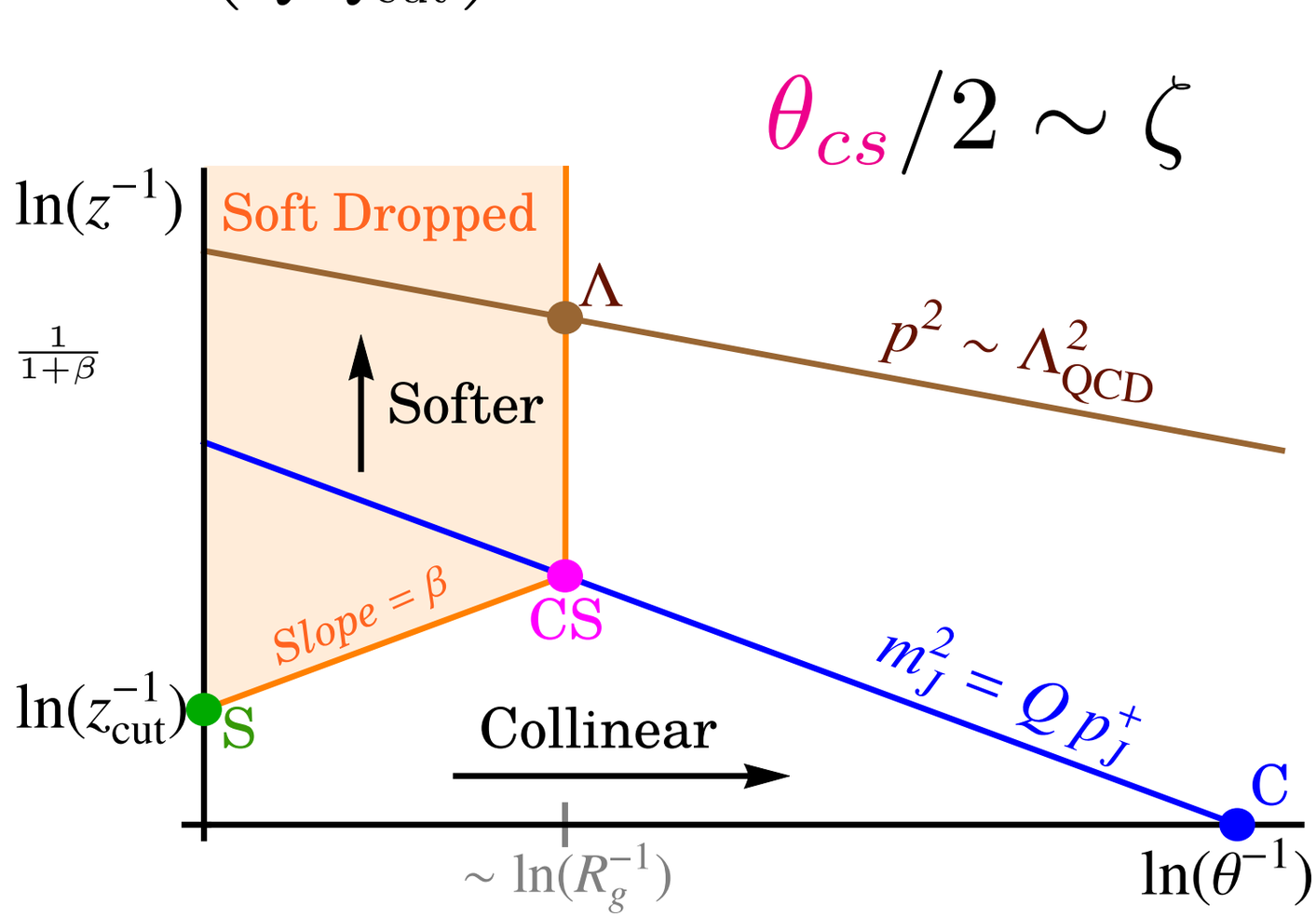
$$z > z_{\rm cut}\,\theta^{\beta}$$

$$p_{CS}^{\mu} \sim \frac{m_J^2}{Q\,\zeta}\left(\zeta,\,\frac{1}{\zeta},\,1\right) \qquad p_C^{\mu} \sim \left(\frac{m_J^2}{Q}, Q, m_J\right)$$

$$\zeta \equiv \left(\frac{m_J^2}{Q\,Q_{\rm cut}}\right)^{\frac{1}{2+\beta}} \qquad Q_{\rm cut} \equiv 2^{\beta} Q\, z_{\rm cut}$$

$$p_{cs}^{+} \gg p_{\Lambda}^{+} \Rightarrow m_J^2 \gg Q\,\Lambda_{\rm QCD}\left(\frac{\Lambda_{\rm QCD}}{Q_{\rm cut}}\right)^{\frac{1}{1+\beta}}$$

$$p_{\Lambda}^{\mu} \sim \Lambda_{\rm QCD}\left(\zeta,\,\frac{1}{\zeta},\,1\right)$$



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3. UNIVERSALITY OF NP CORRECTIONS

4. HADRON LEVEL CROSS SECTION

PERTURBATIVE SD JET MASS CROSS SECTION

$$\frac{d\hat{\sigma}}{dm_J} = \sum_{\kappa=q,g} D_\kappa(\Phi_J, z_{\rm cut}, \beta, \mu) \int d\ell^+ J_\kappa\left(m_J^2 - Q\ell^+,\, \mu\right) S_C^\kappa\left[\ell^+ Q_{\rm cut}^{\frac{1}{1+\beta}}, \beta, \mu\right]$$

$$S_C^\kappa\left[\ell^+ Q_{\rm cut}^{\frac{1}{1+\beta}}, \beta\right] \equiv \frac{Q_{\rm cut}^{\frac{-1}{1+\beta}}}{n_\kappa} \,\mathrm{tr}\langle 0|T X_{n\kappa}^\dagger V_{n\kappa} \delta\left(\ell^+ - \widehat{\bar{\Theta}}_{SD}\, \hat{p}_{cs}^+\right) \bar{T} V_{\kappa n}^\dagger X_{n\kappa}|0\rangle$$

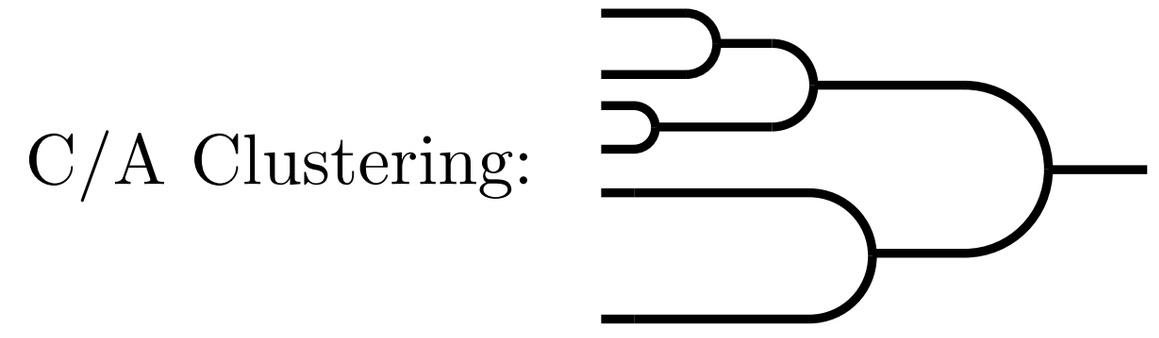
$$V_{n\kappa} = V_{n\kappa}[\bar{n}\cdot A_{cs}],\; X_{n\kappa} = X_{n\kappa}[n\cdot A_{cs}]$$

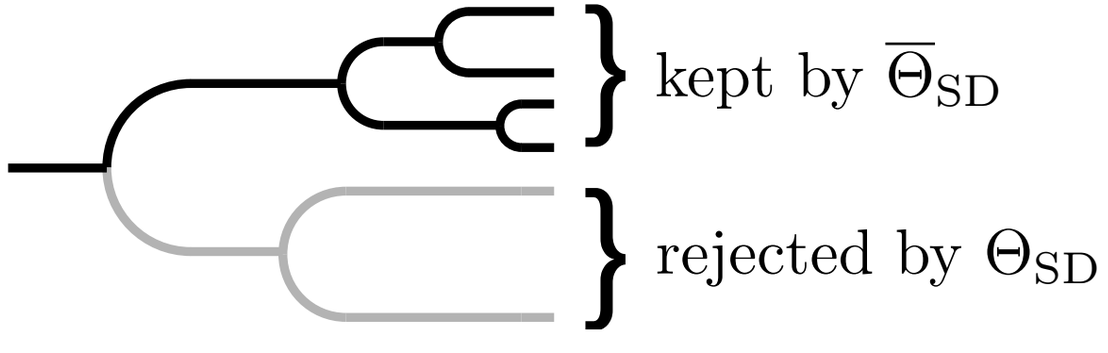
- Leading power corrections come from the collinear-soft function.

$$S_C^\kappa \supset \alpha_s^n \log^m \left(\frac{\mu^2}{\left(\ell^+ Q_{\rm cut}^{\frac{1}{1+\beta}}\right)^{\frac{2(1+\beta)}{2+\beta}}} \right)$$

- The soft drop operator in the measurement includes C/A clustering and hence cannot be written in a simple form.

C/A Clustering:





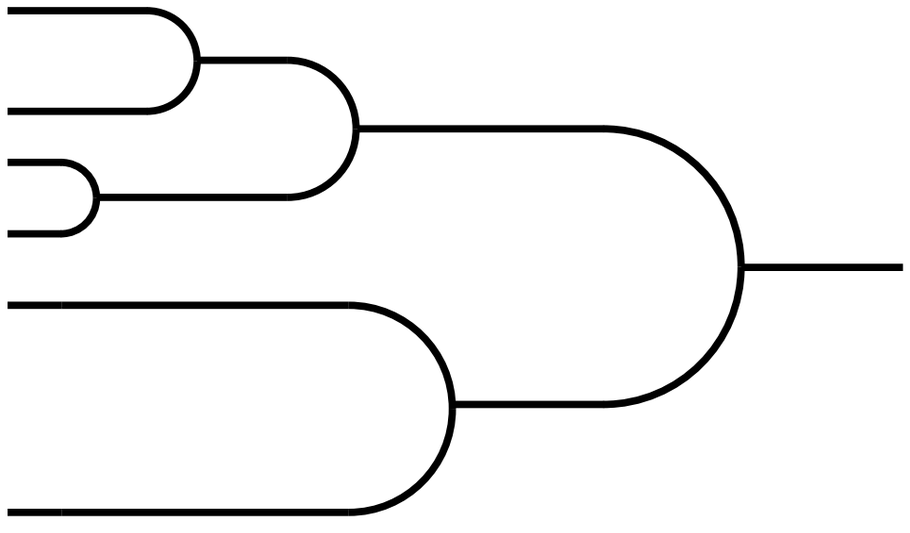
POWER CORRECTIONS IN THE TAIL REGION

$$S_C^{\kappa}\left[\ell^+ Q_{\text{cut}}^{\frac{1}{1+\beta}}, \beta\right] \equiv \frac{Q_{\text{cut}}^{\frac{-1}{1+\beta}}}{n_\kappa} \operatorname{tr}\left\langle 0\middle| T X_{n\kappa}^\dagger V_{n\kappa} \delta\left(\ell^+ - \widehat{\overline{\Theta}}_{sd}\, \hat{p}_{cs}^+\right) \bar{T} V_{\kappa n}^\dagger X_{n\kappa}\middle|0\right\rangle$$

C/A clustering could prevent factorization of non-perturbative corrections. But we can make some approximations …

$$\begin{aligned}\mathcal{M}_{S_C} &= \delta\left(\ell^+ - \widehat{\overline{\Theta}}_{\text{SD}}\left(\hat{p}_{cs}^+ + \hat{p}_\Lambda^+\right)\right) \\ &= \delta\left(\ell^+ - \widehat{\overline{\Theta}}_{\text{SD}}\left(p_{c,i}^\mu,\, p_{s,i}^\mu,\, p_{cs,i}^\mu,\, p_{\Lambda,i}^\mu\right)\left(\hat{p}_{cs}^+ + \hat{p}_\Lambda^+\right)\right)\end{aligned}$$

$$\widehat{\overline{\Theta}}_{\text{SD}}\left(p_{c,i}^\mu,\, p_{s,i}^\mu,\, p_{cs,i}^\mu,\, p_{\Lambda,i}^\mu\right)$$



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- Collinear particles clustered in the core of the jet do not their change direction.

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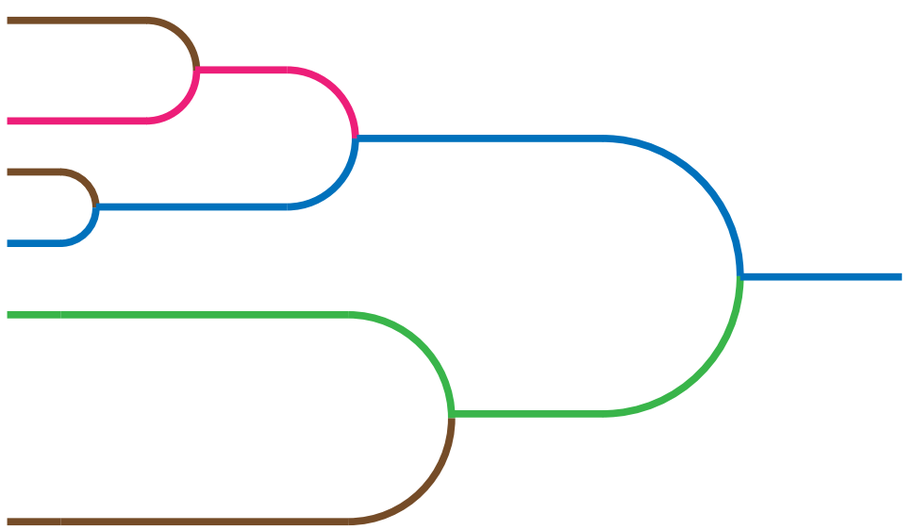

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- NP emissions do not change angles of energetic perturbative emissions

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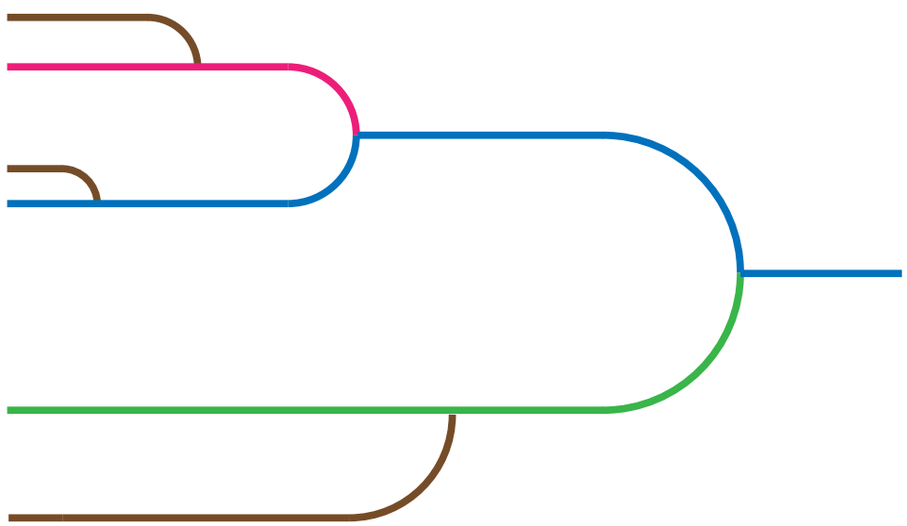

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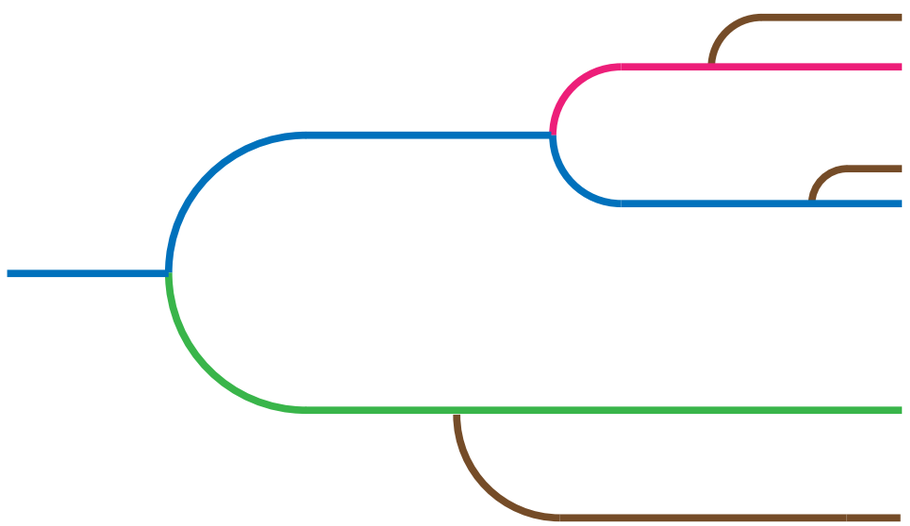

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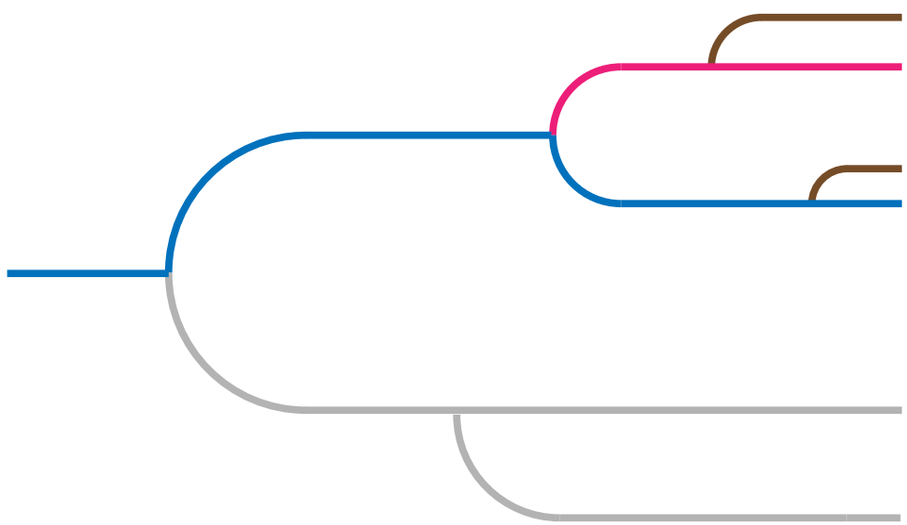
- Collinear particles clustered in the core of the jet do not their change direction.
- NP emissions do not change angles of energetic perturbative emissions
- CS mode defined as the first emission that satisfies soft drop - hence wide angle soft modes do not affect the C/A clustering

$$\widehat{\Theta}_{\text{SD}}\left(p_{c,i}^\mu,\, p_{s,i}^\mu,\, p_{cs,i}^\mu,\, p_{\Lambda,i}^\mu\right)$$



POWER CORRECTIONS IN THE TAIL REGION

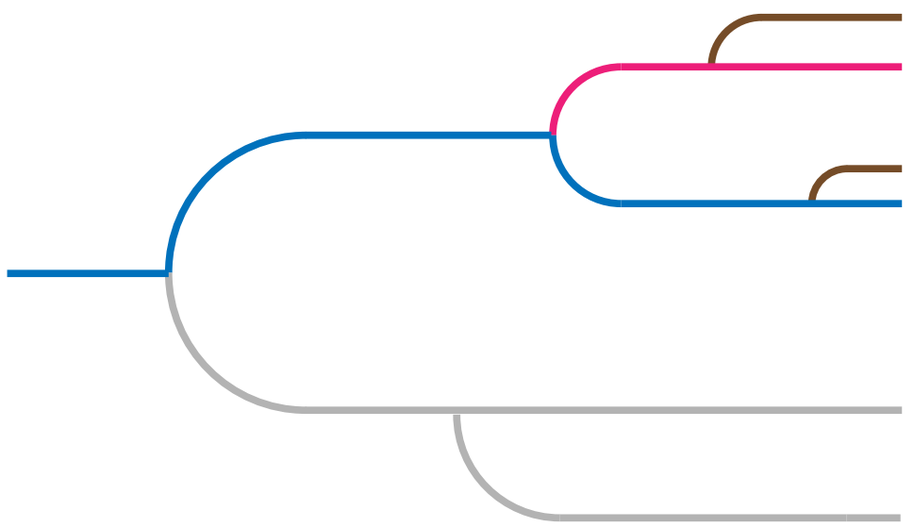
$$S_C^{\kappa}\left[\ell^+ Q_{\text{cut}}^{\frac{1}{1+\beta}}, \beta\right] \equiv \frac{Q_{\text{cut}}^{\frac{-1}{1+\beta}}}{n_\kappa} \operatorname{tr}\left\langle 0\middle| T X_{n\kappa}^\dagger V_{n\kappa} \delta\left(\ell^+ - \widehat{\overline{\Theta}}_{sd}\, \hat{p}_{cs}^+\right) \bar{T} V_{\kappa n}^\dagger X_{n\kappa}\middle|0\right\rangle$$

C/A clustering could prevent factorization of non-perturbative corrections. But we can make some approximations:

- Collinear particles clustered in the core of the jet do not their change direction.
- NP emissions do not change angles of energetic perturbative emissions
- CS mode defined as the first emission that satisfies soft drop - hence wide angle soft modes do not affect the C/A clustering

$$\mathcal{M}_{S_C} = \delta\left(\ell^+ - \widehat{\overline{\Theta}}_{\text{SD}}\left(p_{cs,i}^\mu\right)\left(\hat{p}_{cs}^+ + \hat{p}_\Lambda^+\right)\right)$$

$$\widehat{\overline{\Theta}}_{\text{SD}} = \widehat{\overline{\Theta}}_{\text{SD}}\left(p_{cs,i}^\mu\right)$$



The soft drop operator depends only on the perturbative CS emissions (up to NLL).

HADRON LEVEL FACTORIZATION

Ansatz for hadron level factorization:

- Convolution between the shape function and the collinear-soft function depends on the order of perturbation theory!

$$\frac{d\sigma}{dm_J} = \sum_{\kappa=q,g} D_\kappa(\Phi_J, z_{\rm cut}, \beta, \mu) \int d\ell^+ \, J_\kappa\left(m_J^2 - Q\ell^+, \, \mu\right)$$
$$\times \int dp_\Lambda^+ \int [dr_{cs}^i] \, S_C^\kappa \left[\ell^+ - p_\Lambda^+, Q_{\rm cut}, \beta, \{r_{cs}^i\}, \mu\right]$$
$$\times \, \tilde{F}_{\rm SD}^\kappa(p_\Lambda^+, \, Q_{\rm cut}, \, \beta, \{r_{cs}^i\})$$

$$\int [dr_{cs}^i] \, S_C^\kappa \left[\ell^+, Q_{\rm cut}, \beta, \{r_{cs}^i\}\right] = S_C^\kappa \left[\ell^+ Q_{\rm cut}^{\frac{1}{1+\beta}}, \beta\right]$$

HADRON LEVEL FACTORIZATION – NLL APPROXIMATION

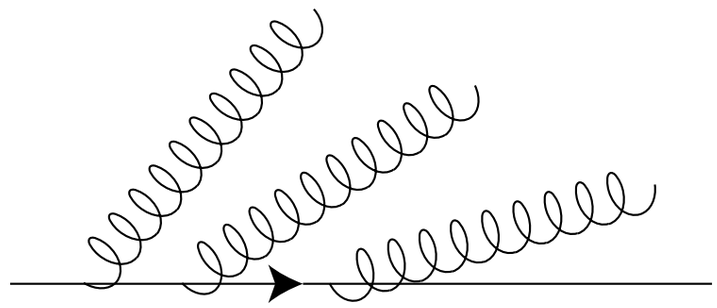
Ansatz for hadron level factorization:

$$\frac{d\sigma}{dm_J} = \sum_{\kappa=q,g} D_\kappa(\Phi_J, z_{\rm cut}, \beta, \mu) \int d\ell^+ \, J_\kappa\left(m_J^2 - Q\ell^+, \, \mu\right)$$
$$\times \int dp_\Lambda^+ \int [dr_{cs}^i] \, S_C^\kappa \left[\ell^+ - p_\Lambda^+, Q_{\rm cut}, \beta, \{r_{cs}^i\}, \mu\right]$$
$$\times \, \tilde{F}_{\rm SD}^\kappa(p_\Lambda^+, \, Q_{\rm cut}, \, \beta, \{r_{cs}^i\})$$

- Convolution between the shape function and the collinear-soft function depends on the order of perturbation theory!

$$\int [dr_{cs}^i] \, S_C^\kappa \left[\ell^+, Q_{\rm cut}, \beta, \{r_{cs}^i\}\right] = S_C^\kappa \left[\ell^+ Q_{\rm cut}^{\frac{1}{1+\beta}}, \beta\right]$$

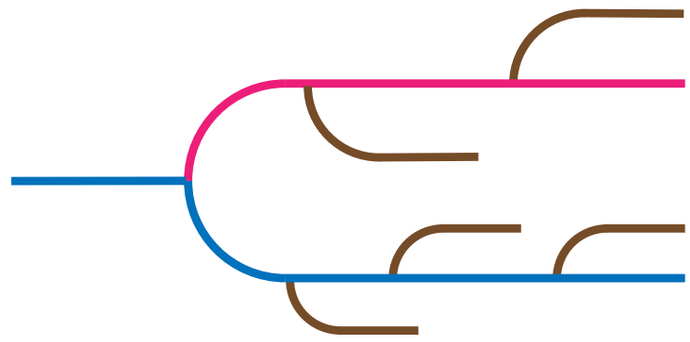
- At NLL one can assume angular ordering of the CS emissions
  - the widest emission sets the angle of the CS subjet



$$\widehat{\overline{\Theta}}_{\rm SD}(p_{cs,i}^\mu)\hat{p}_\Lambda^+ \to \overline{\Theta}_{\rm NP}(\theta_{cs}, \phi_{cs})\hat{p}_\Lambda^+$$

NLL APPROXIMATION

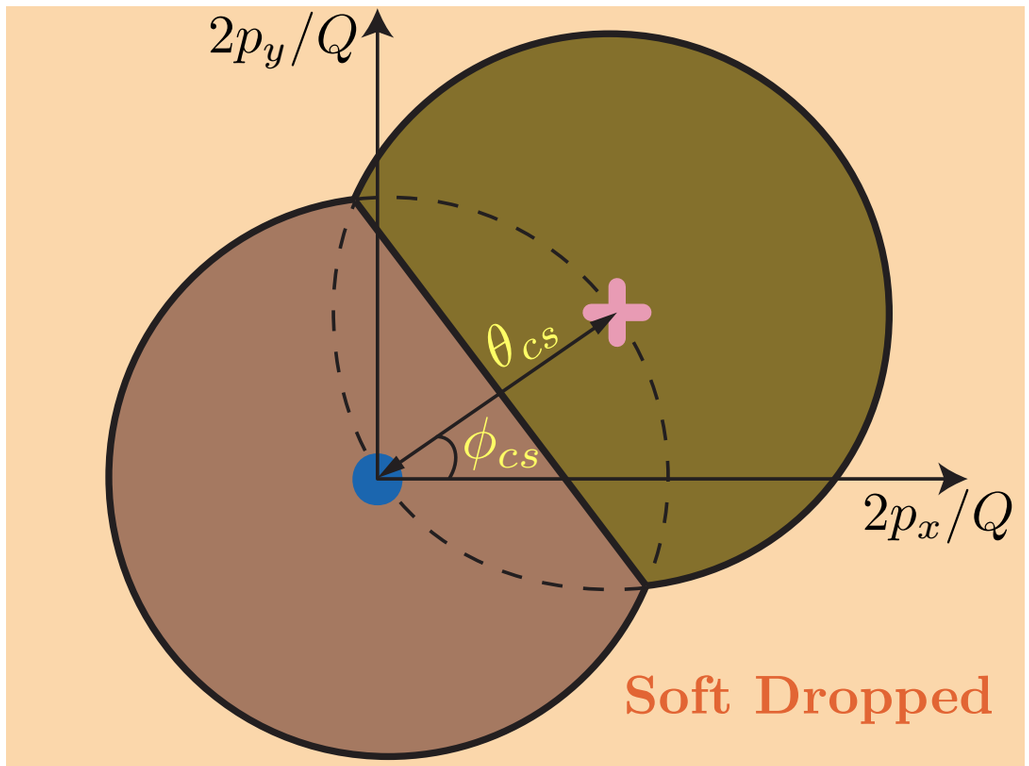
$$\widehat{\overline{\Theta}}_{\rm SD}(p^{\mu}_{cs,i})\hat{p}^{+}_{\Lambda} \to \overline{\Theta}_{\rm NP}(\theta_{cs},\phi_{cs})\hat{p}^{+}_{\Lambda}$$



$$\tilde{F}^{\kappa}_{\rm SD}(p^{+}_{\Lambda},\{\theta_{cs},\phi_{cs}\})$$
$$= \frac{1}{n_\kappa}\mathrm{tr}\Big\langle 0\Big|TY^{\dagger}_{n\kappa}Y_{\bar{n}\kappa}\,\delta\Big(p^{+}_{\Lambda}-\widehat{\overline{\Theta}}_{\rm NP}(\theta_{cs},\phi_{cs})\,\hat{p}^{+}_{\Lambda}\Big)\,\bar{T}Y^{\dagger}_{\bar{n}\kappa}Y_{n\kappa}\Big|0\Big\rangle$$

The NP emission can get clustered with either collinear or the collinear-soft subjet.

At NLL the catchment area of NP emissions is determined by the location of the CS radiation.



NP CORRECTIONS FOR SOFT DROPPED JET MASS

1. SCALE OF NP CORRECTIONS FROM EFFECTIVE THEORY MODES
2. EFFECTS OF C/A CLUSTERING AND NLL APPROXIMATION
3. UNIVERSALITY OF NP CORRECTIONS
4. HADRON LEVEL CROSS SECTION

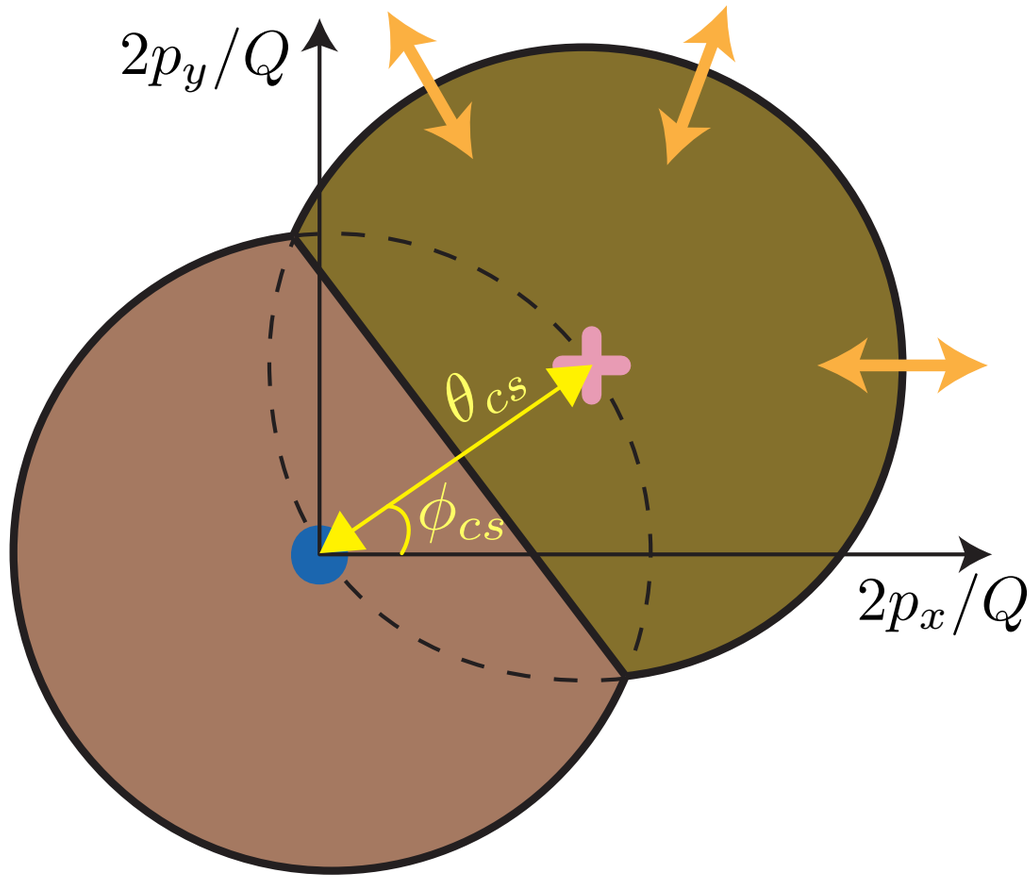
TWO TYPES OF POWER CORRECTIONS

- Here we revisit our assumption about the effect of NP emissions on clustering and soft drop condition.

- NP emissions contribute to the power corrections in two ways:

  - Add to the plus momentum in the bulk.

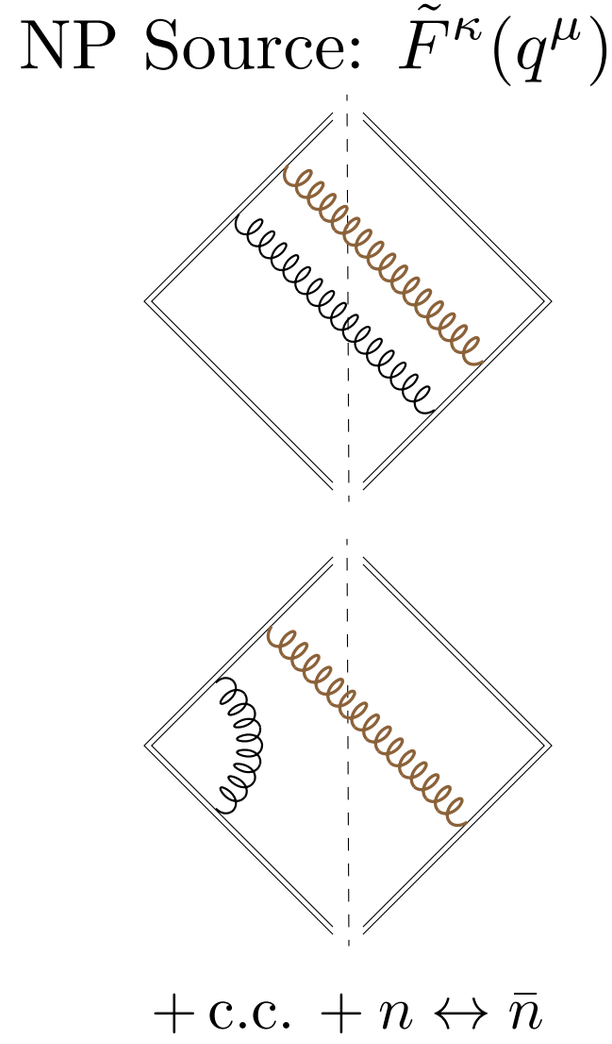
  - Shift the boundary of the catchment area.



COLLINEAR-SOFT FUNCTION WITH A NP SOURCE

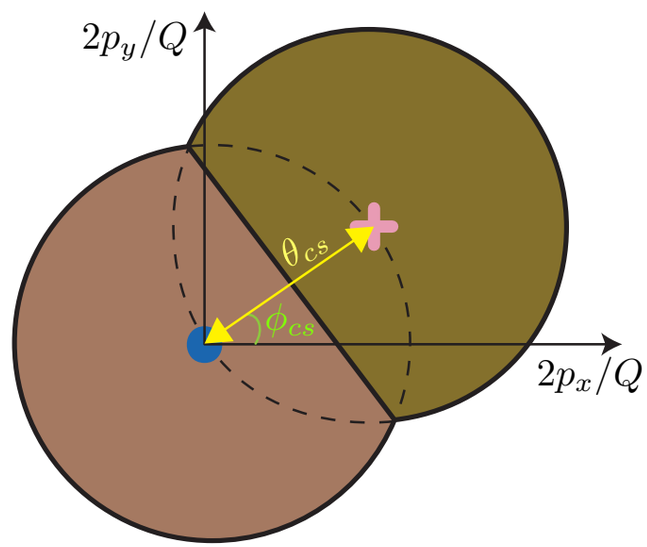
In order to understand the universality of the NP corrections and how they ought to be combined with the perturbative cross section we open the black box:

- Consider the one-loop collinear soft function.
- Include an NP emission sourced externally.
- Source is agnostic about the perturbative physics, soft drop parameters and C/A Clustering: included explicitly via the catchment area selection operator.



$$\widehat{\overline{\Theta}}_{\text{SD}}(p^{\mu}_{cs,i})\,\hat{p}^{+}_{\Lambda} \to \widehat{\overline{\Theta}}_{\text{NP}}(\theta_{cs},\,\phi_{cs})\,\hat{p}^{+}_{\Lambda}$$

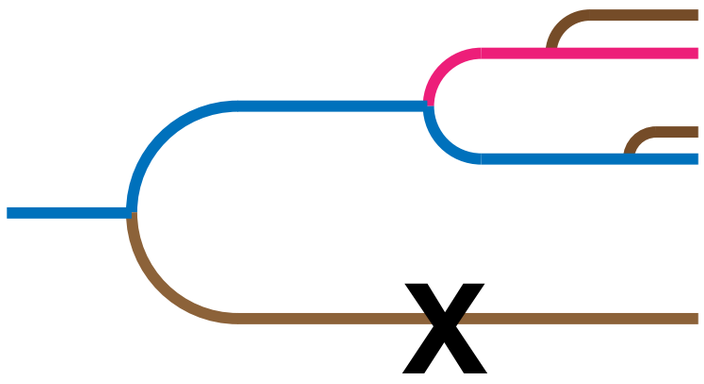
$$\mathcal{M}^{\text{full}}_{S_C} = \left(\overline{\Theta}_{\text{NP}}\overline{\Theta}^{p}_{\text{SD}} + \Theta_{\text{NP}}\overline{\Theta}^{q}_{\text{SD}}\right)\delta(\ell^{+} - p^{+} - q^{+}) + \ldots$$



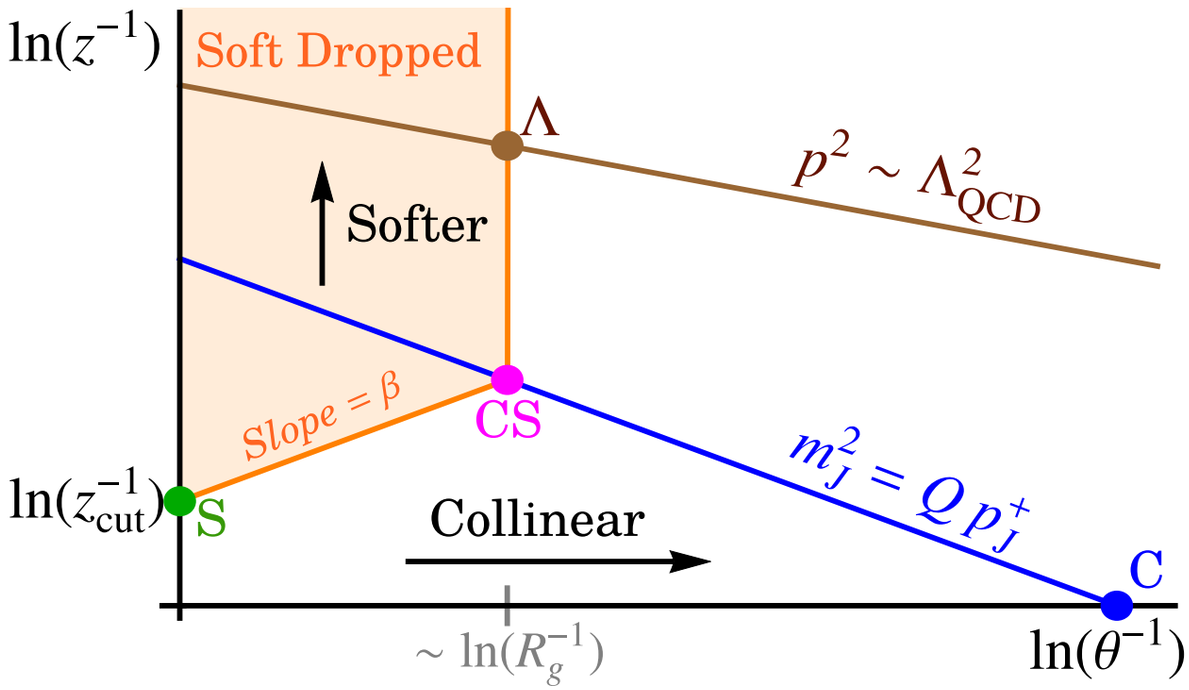
COLLINEAR-SOFT FUNCTION WITH A NP SOURCE

$$\mathcal{M}_{S_C}^{\text{full}} = \left(\overline{\Theta}_{\text{NP}}\overline{\Theta}_{\text{SD}}^{p} + \Theta_{\text{NP}}\overline{\Theta}_{\text{SD}}^{q}\right)\delta(\ell^+ - p^+ - q^+) + \dots$$

Simplification: in the resummation region the NP emission cannot stop soft drop.



Set terms with $\overline{\Theta}_{\text{SD}}^{q} = 0$



Power correction from the bulk:

$$\Delta S_C^{\kappa,\,\text{bulk}}(\ell^+, q^\mu, Q_{\text{cut}}, \mu) \simeq q^+\overline{\Theta}_{\text{NP}}\left(\theta_\Lambda, \theta_{cs},\, \Delta\phi\right)\frac{d}{d\ell^+}S_C^{\kappa,\,\text{pert}}\left(\ell^+ Q_{\text{cut}}^{\frac{1}{1+\beta}}, \mu\right)$$

COLLINEAR-SOFT FUNCTION WITH A NP SOURCE

$$\Delta S_C^{\kappa,\,\mathrm{bulk}}(\ell^+, q^\mu, Q_{\mathrm{cut}}, \mu) \simeq q^+ \overline{\Theta}_{\mathrm{NP}}\left(\theta_\Lambda, \theta_{cs},\, \Delta\phi\right) \frac{d}{d\ell^+} S_C^{\kappa,\,\mathrm{pert}}\left(\ell^+ Q_{\mathrm{cut}}^{\frac{1}{1+\beta}}, \mu\right)$$

Since the source is constructed from soft Wilson lines we can boost the NP momentum to scale out any dependence on collinear-soft variables:

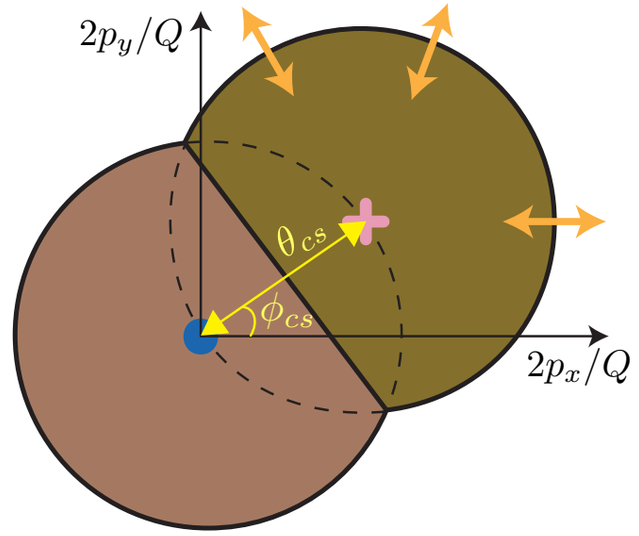
$$q^\mu \xrightarrow{\text{boost}} k^\mu \qquad k^+ \sim k^- \sim k^\perp \sim \Lambda_{\mathrm{QCD}}$$

$$\overline{\Theta}_{\mathrm{NP}}\left(\theta_\Lambda, \theta_{cs},\, \Delta\phi\right) \to \overline{\Theta}_{\mathrm{NP}}\left(k^\mu,\, \Delta\phi\right)$$

$$\int d^d q \tilde{F}^\kappa(q^\mu)\, \Delta S_C^{\kappa,\,\mathrm{bulk}}(\ell^+, q^\mu, Q_{\mathrm{cut}}, \mu) = \Omega^\kappa \left(\frac{\ell^+}{Q_{\mathrm{cut}}}\right)^{\frac{1}{2+\beta}} \frac{d}{d\ell^+} S_C^{\kappa,\,\mathrm{pert}}(\ell^+ Q_{\mathrm{cut}}^{\frac{1}{1+\beta}}, \mu)$$

$$\Omega^\kappa = \int d^d k\; k^+ \tilde{F}^\kappa(k) \int \frac{d\Delta\phi}{2\pi}\, \overline{\Theta}_{\mathrm{NP}}\left(k^\mu, \Delta\phi\right)$$

POWER CORRECTION TO THE NP CATCHMENT AREA



We can also take into account the effect of NP emission on the soft drop condition and the boundary:

$$\overline{\Theta}_{\mathrm{SD}}^{p+q} = \overline{\Theta}_{\mathrm{SD}}^{p} + \Theta_{\mathrm{NP}}^{(i)}(q^{\mu})\,\Delta\Theta_{\mathrm{SD}} + \mathcal{O}(\Lambda_{\mathrm{QCD}}^{2})$$

Leads to an additional beta dependent term:

$$S_C^{\kappa\,\mathrm{full}}(\ell^+, Q_{\mathrm{cut}}, \mu) = S_C^{\kappa,\,\mathrm{pert}}\left(\ell^+ Q_{\mathrm{cut}}^{\frac{1}{1+\beta}}, \mu\right)$$
$$- \Omega^{\kappa}\left(\frac{\ell^+}{Q_{\mathrm{cut}}}\right)^{\frac{1}{2+\beta}} \frac{d}{d\ell^+} S_C^{\kappa,\,\mathrm{pert}}(\ell^+ Q_{\mathrm{cut}}^{\frac{1}{1+\beta}}, \mu) - \tilde{\Omega}^{\kappa}(\beta)\frac{d}{d\ell^+}\left(\frac{\ell^+}{Q_{\mathrm{cut}}}\right)^{\frac{1}{2+\beta}} S_C^{\kappa,\,\mathrm{pert}}(\ell^+ Q_{\mathrm{cut}}^{\frac{1}{1+\beta}}, \mu)$$

Hence inclusion of NP effects is consistent with the shape function treatment, up to the boundary term.

Universality: We observe that the power corrections depend only on beta and the parton channel, and no other parameters.

COMPARISON WITH PREVIOUS WORK

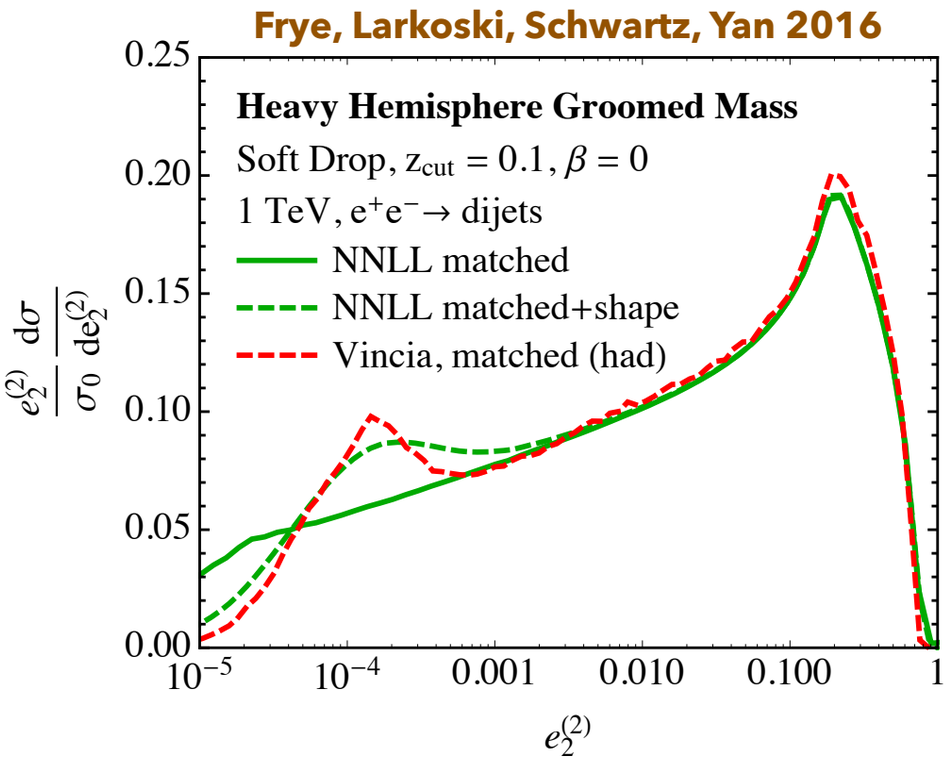
$$S_C^{\kappa\,\text{full}}(\ell^+, Q_{\text{cut}}, \mu) = S_C^{\kappa,\,\text{pert}}\left(\ell^+ Q_{\text{cut}}^{\frac{1}{1+\beta}}, \mu\right)$$
$$- \Omega^\kappa \left(\frac{\ell^+}{Q_{\text{cut}}}\right)^{\frac{1}{2+\beta}} \frac{d}{d\ell^+} S_C^{\kappa,\,\text{pert}}\left(\ell^+ Q_{\text{cut}}^{\frac{1}{1+\beta}}, \mu\right) - \tilde{\Omega}^\kappa(\beta) \frac{d}{d\ell^+} \left(\frac{\ell^+}{Q_{\text{cut}}}\right)^{\frac{1}{2+\beta}} S_C^{\kappa,\,\text{pert}}\left(\ell^+ Q_{\text{cut}}^{\frac{1}{1+\beta}}, \mu\right)$$

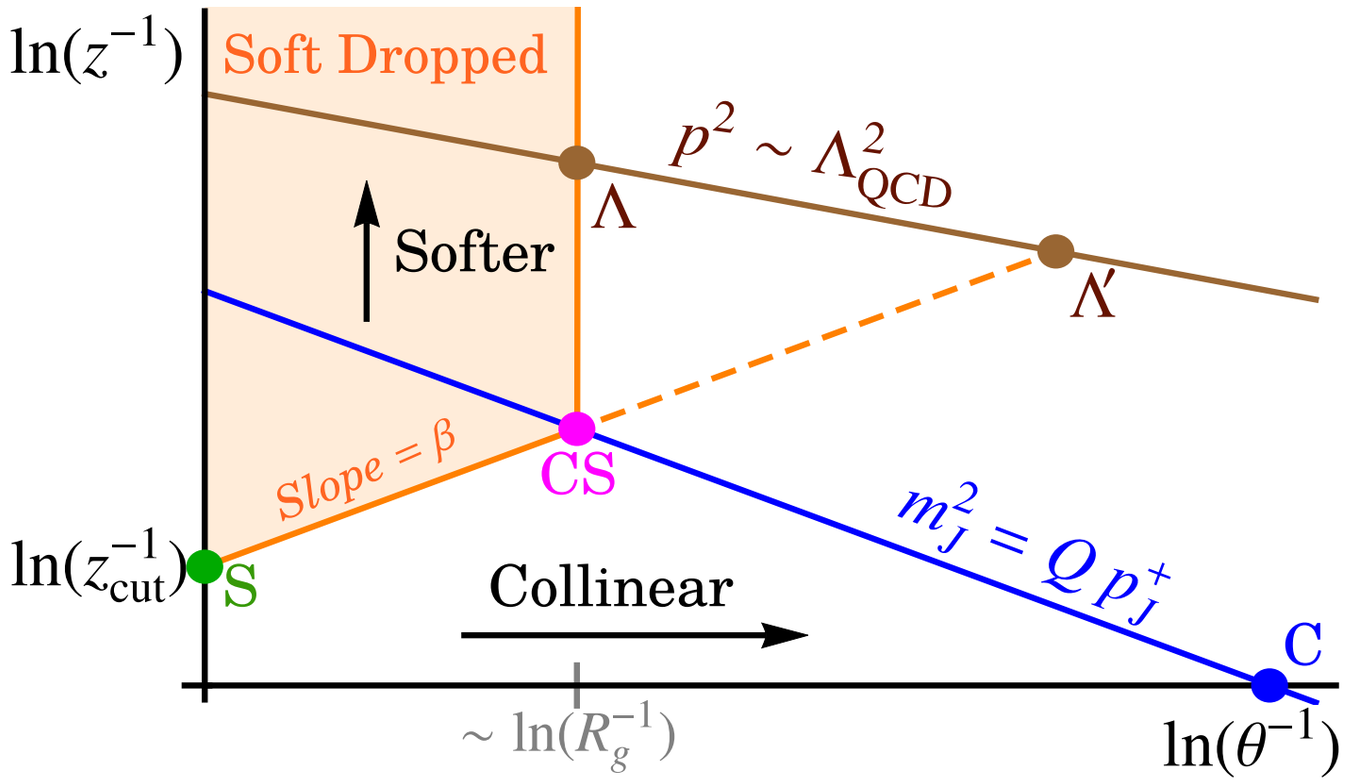
- We can compare the result with the shape function convolution used earlier

- Numerically these things are not far apart in the np region.

$$\int dk^+ \, S_C^\kappa \left[\left(\ell^+ - \left(\frac{k^+}{Q_{\text{cut}}}\right)^{\frac{1}{1+\beta}} k^+\right) Q_{\text{cut}}^{\frac{1}{1+\beta}}, \beta, \mu\right] F_{\text{model}}(k^+)$$

- Close to the peak triangle collapses to a point and they merge.

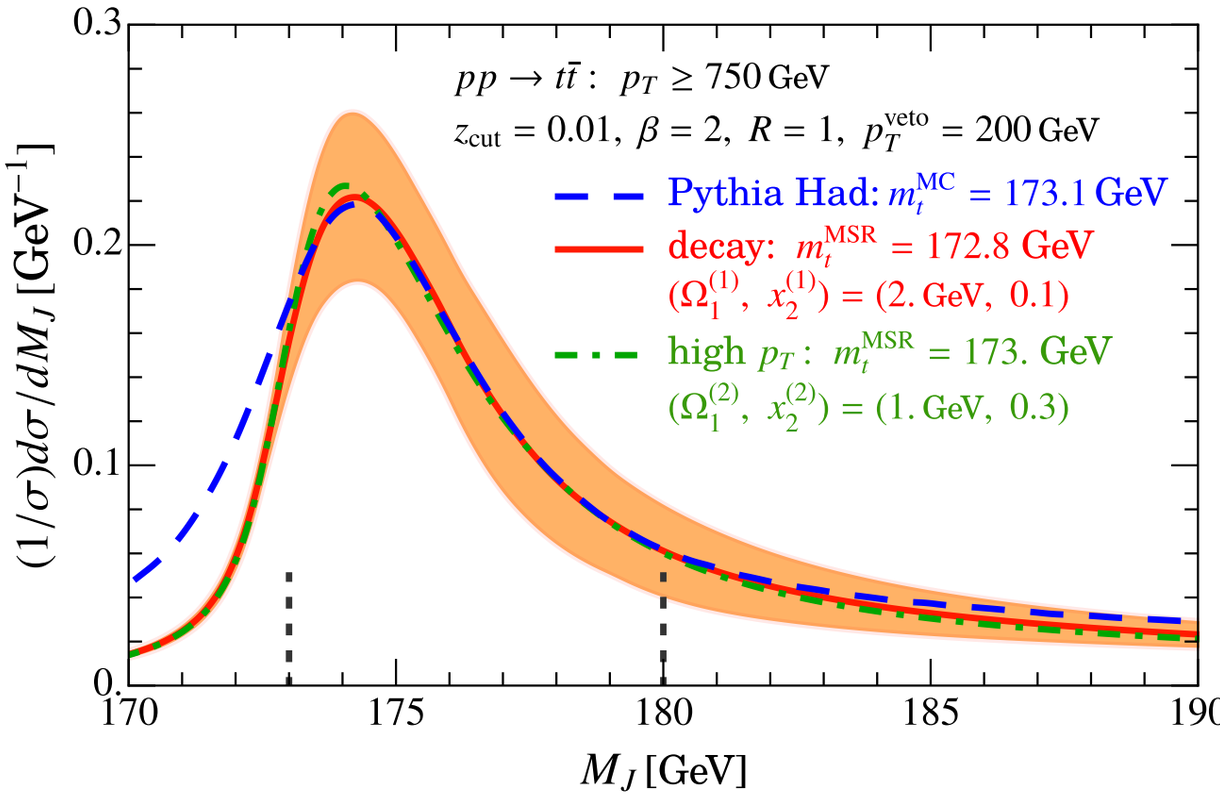




SUMMARISING WHAT WE LEARNED

- Field theory analysis of the interface between partonic and non-perturbative cross section
- Power corrections to soft drop jet mass exhibit universality: only depend on beta and the partonic channel.
- Beta dependence induced through a boundary term
- This is also applicable for groomed top-jet mass analysis - universality extends to massive quarks as well.
- Analysis useful for other groomed observables as well, eg. “collinear drop” (see Yang-Ting’s talk)

Hoang, Mantry, AP, Stewart 2017



THANK YOU