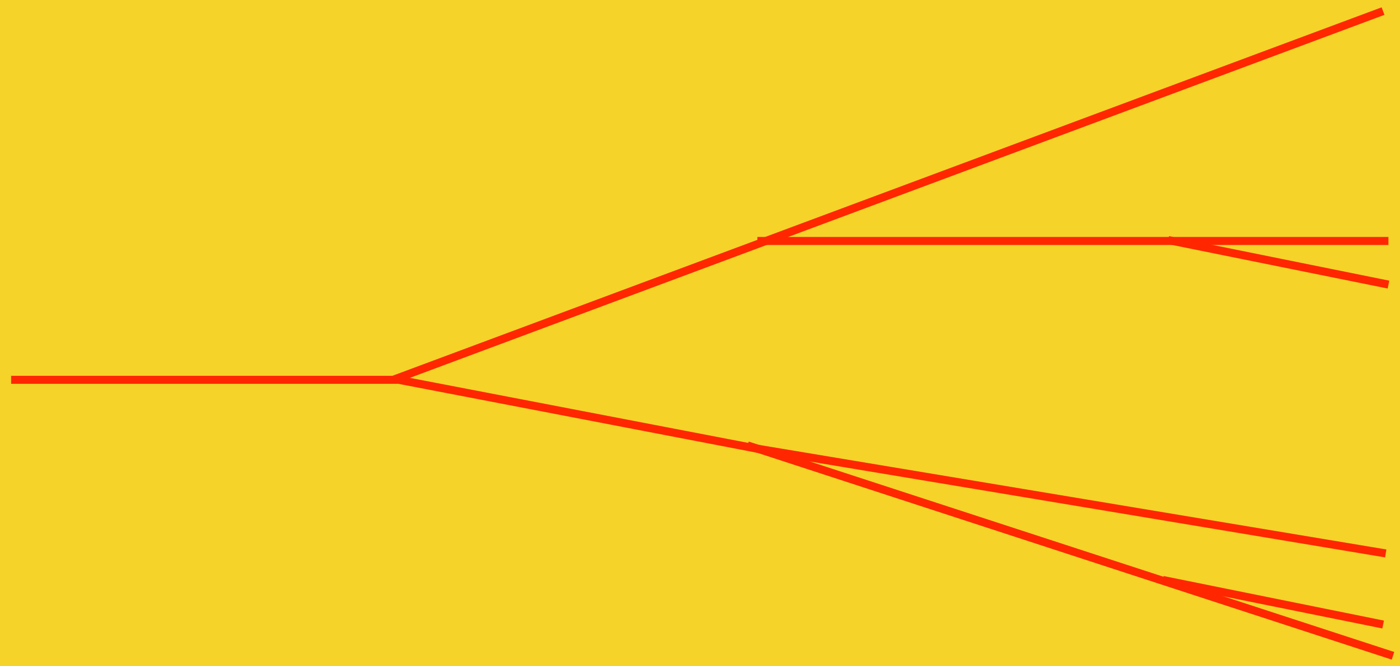
MEASURING MEDIUM-INDUCED GLUONS VIA JET GROOMING

Konrad Tywoniuk

Y. Mehtar-Tani, KT arXiv:1610.08930 [hep-ph]
Mehtar-Tani Session 6.4, Wed 8 11:40
(work in progress…)

Quark Matter 2017, 5-11 Feb 2017, Chicago

Jet quenching in 2017



how many sources are resolved by the medium?

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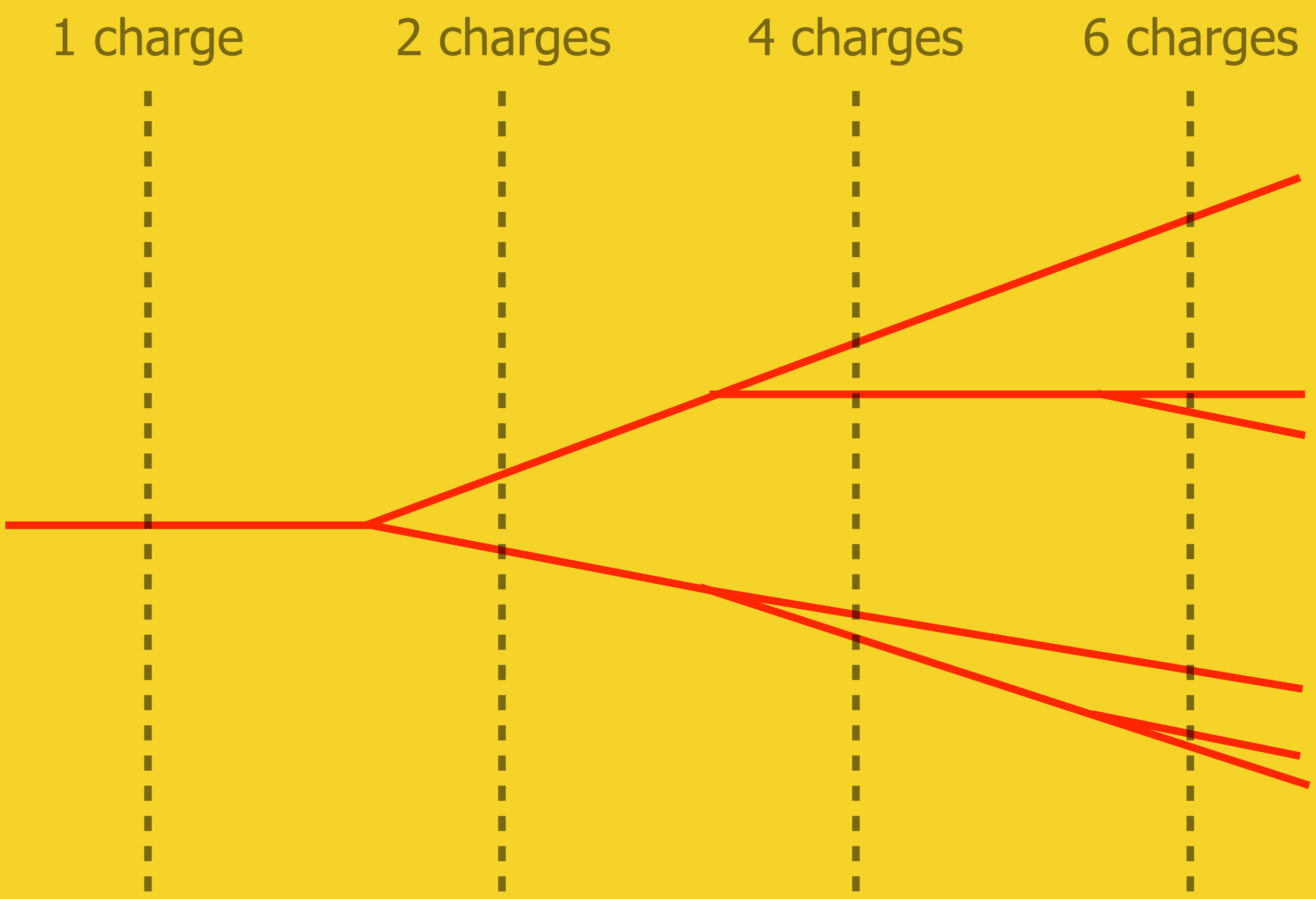

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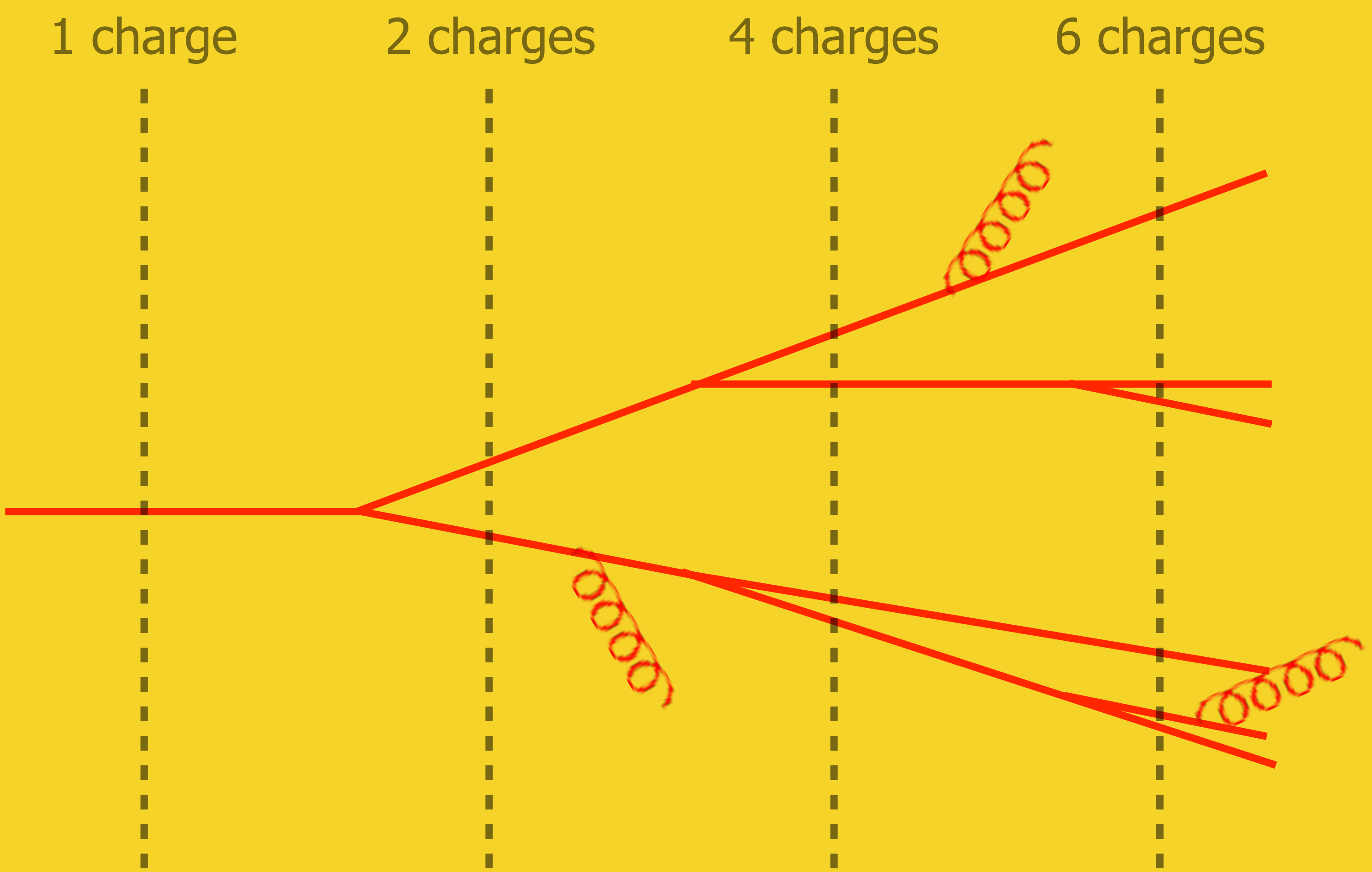
JET QUENCHING IN 2017



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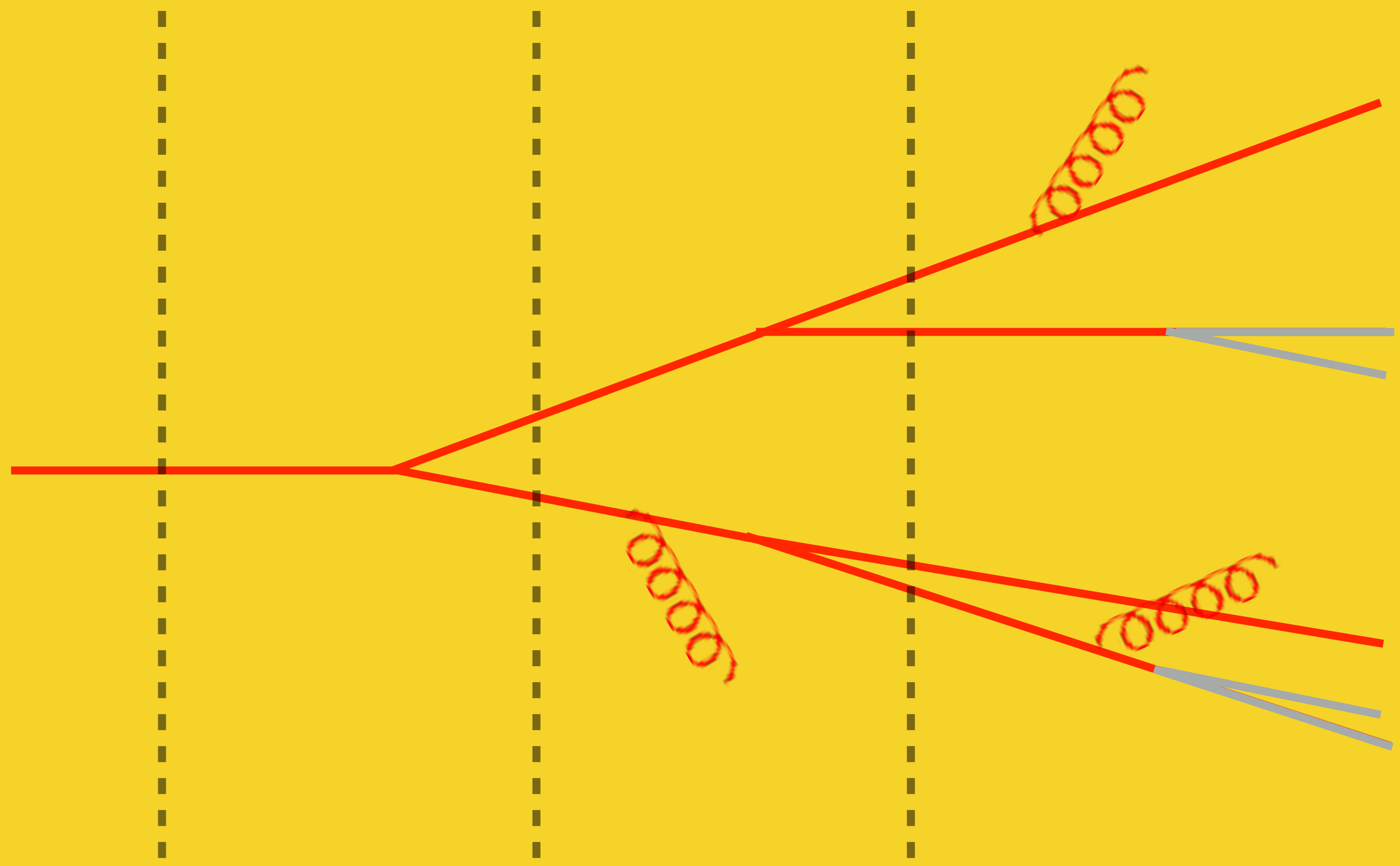

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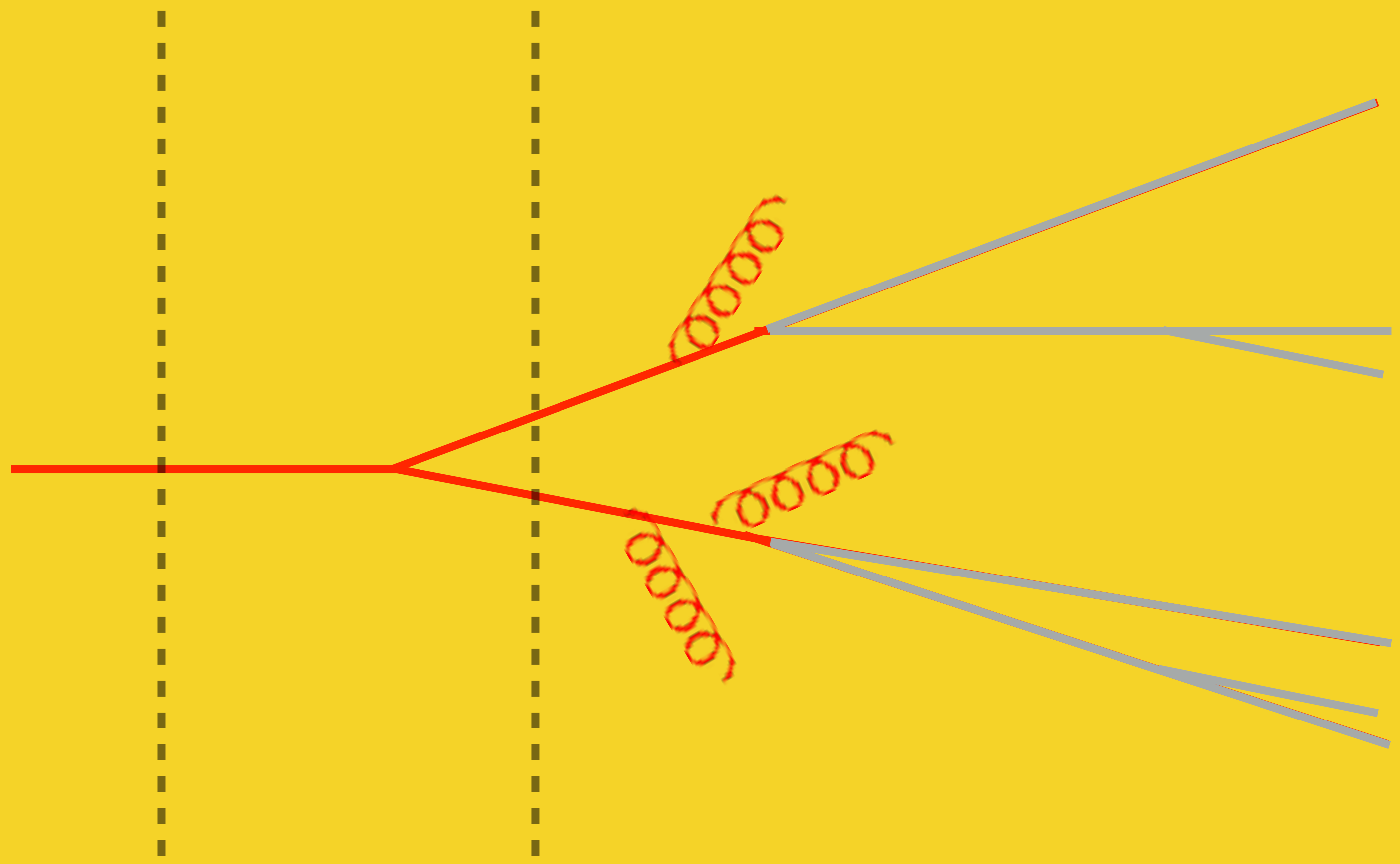


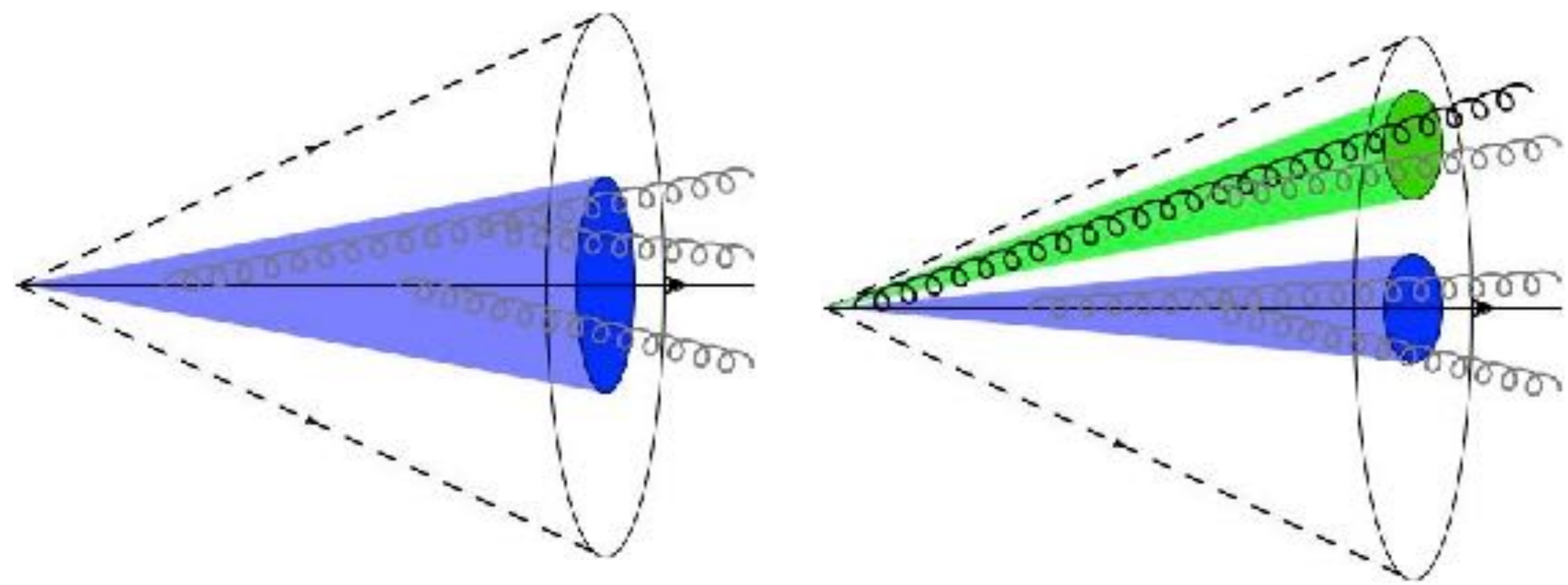
how many sources are resolved by the medium?

sources of radiation determine how intra-jet structure is modified

New picture of jets

Mehtar-Tani, Salgado, KT PRL (2011), PLB (2012), JHEP (2011-2012)
Casalderrey-Solana, Iancu JHEP (2012)
Casalderrey-Solana Mehtar-Tani, Salgado, KT PLB (2013)

number of medium-resolved substructures



critical angle (decoherence)	radiation as total charge	radiation as independent charges

vacuum-like fragmentation within each substructure

Grooming

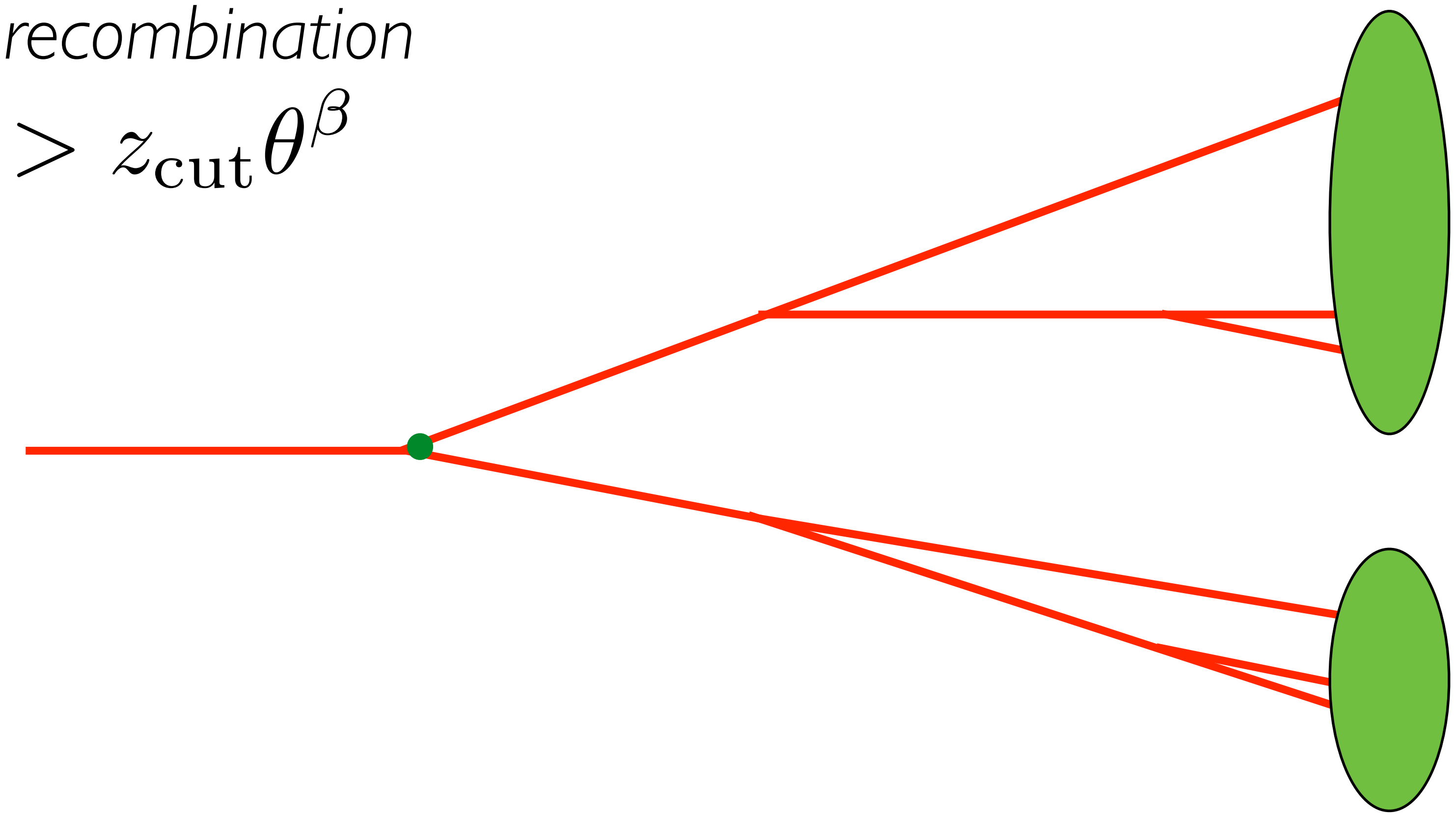
1. brush and clean the coat (of an animal)
2. prepare or train (someone) for a particular activity

JET GROOMING

Dasgupta, Fregoso, Marzani, Salam JHEP (2013)
Larkoski, Marzani, Soyez, Thaler JHEP (2014)
Larkoski, Marzani, Thaler PRD (2015)

C/A recombination

$$z > z_{\mathrm{cut}} \theta^{\beta}$$



SoftDrop procedure: looking for the first *acceptable* branching of an angular ordered tree

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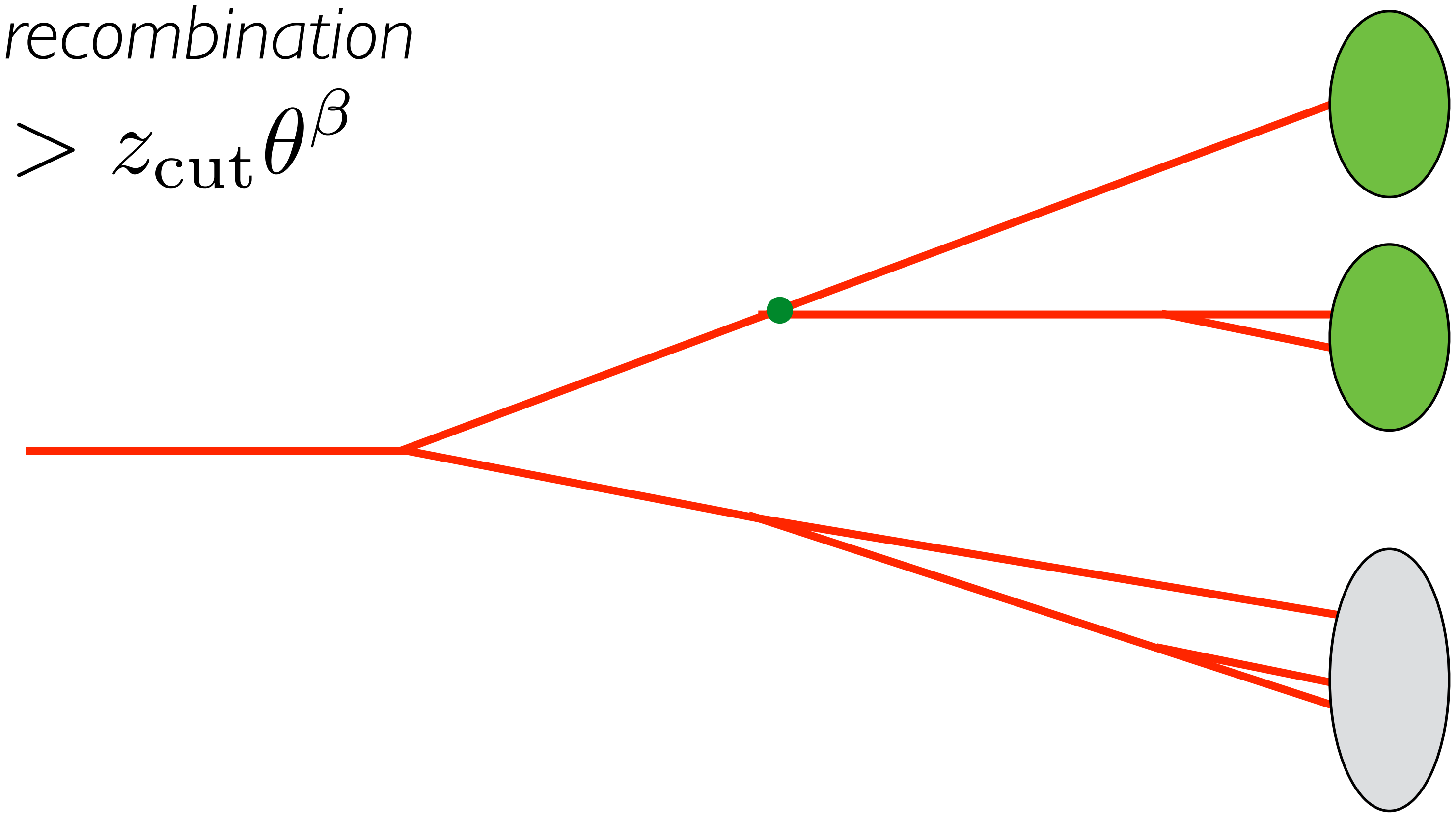

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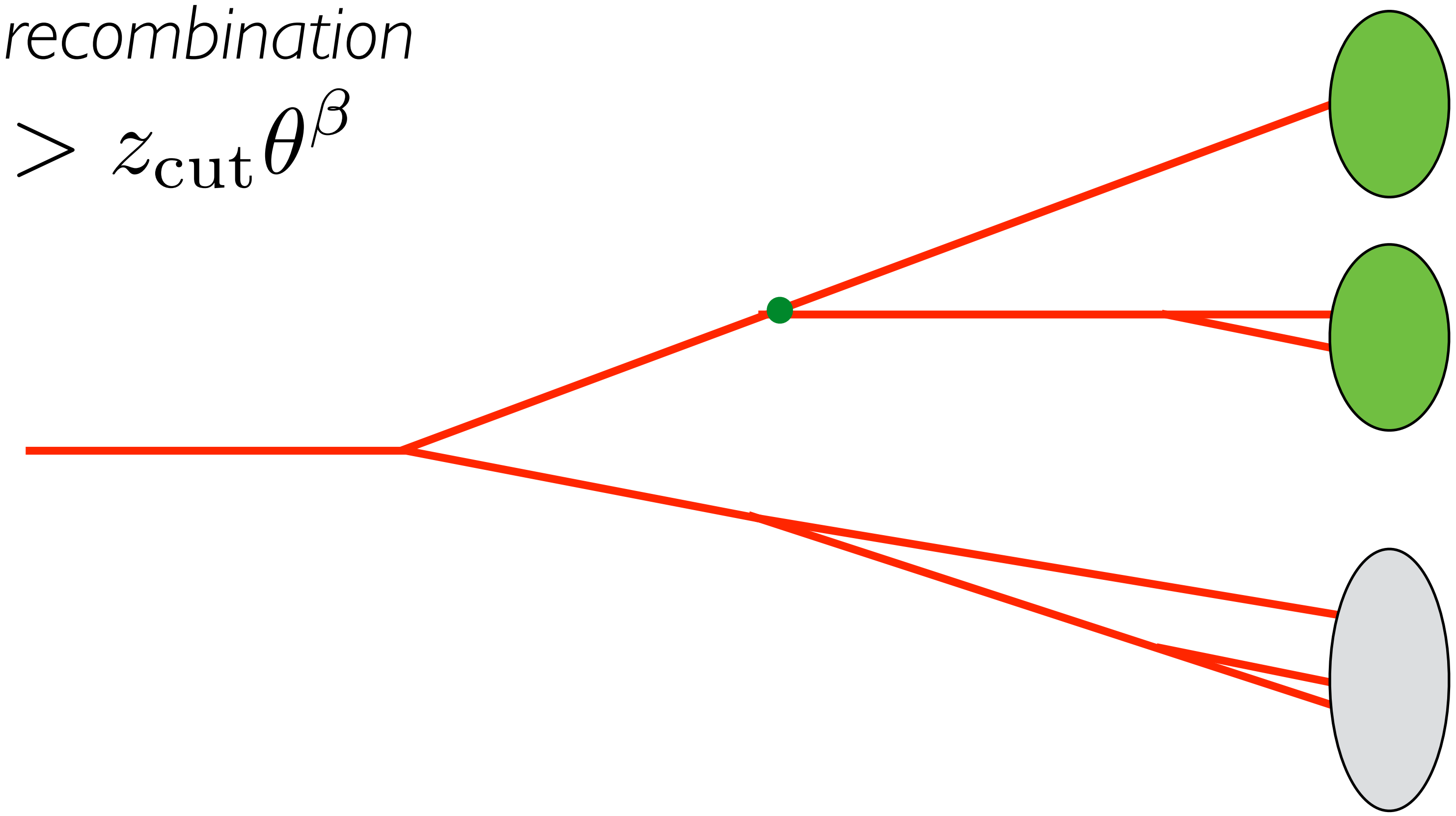

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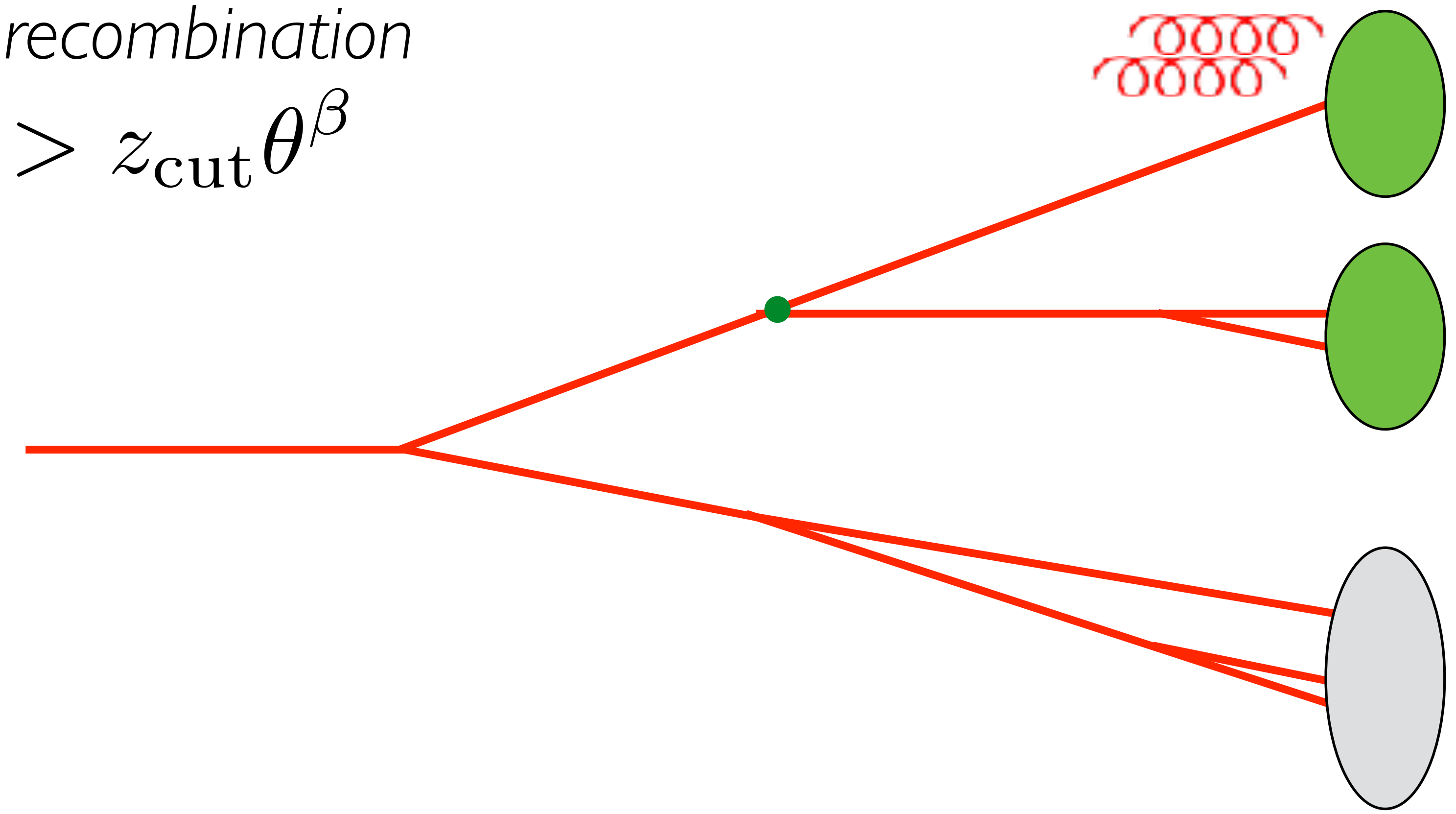

SoftDrop procedure: looking for the first *acceptable* branching of an angular ordered tree

…not always the case because of contamination

Dasgupta, Powling, Siodmok JHEP (2015)

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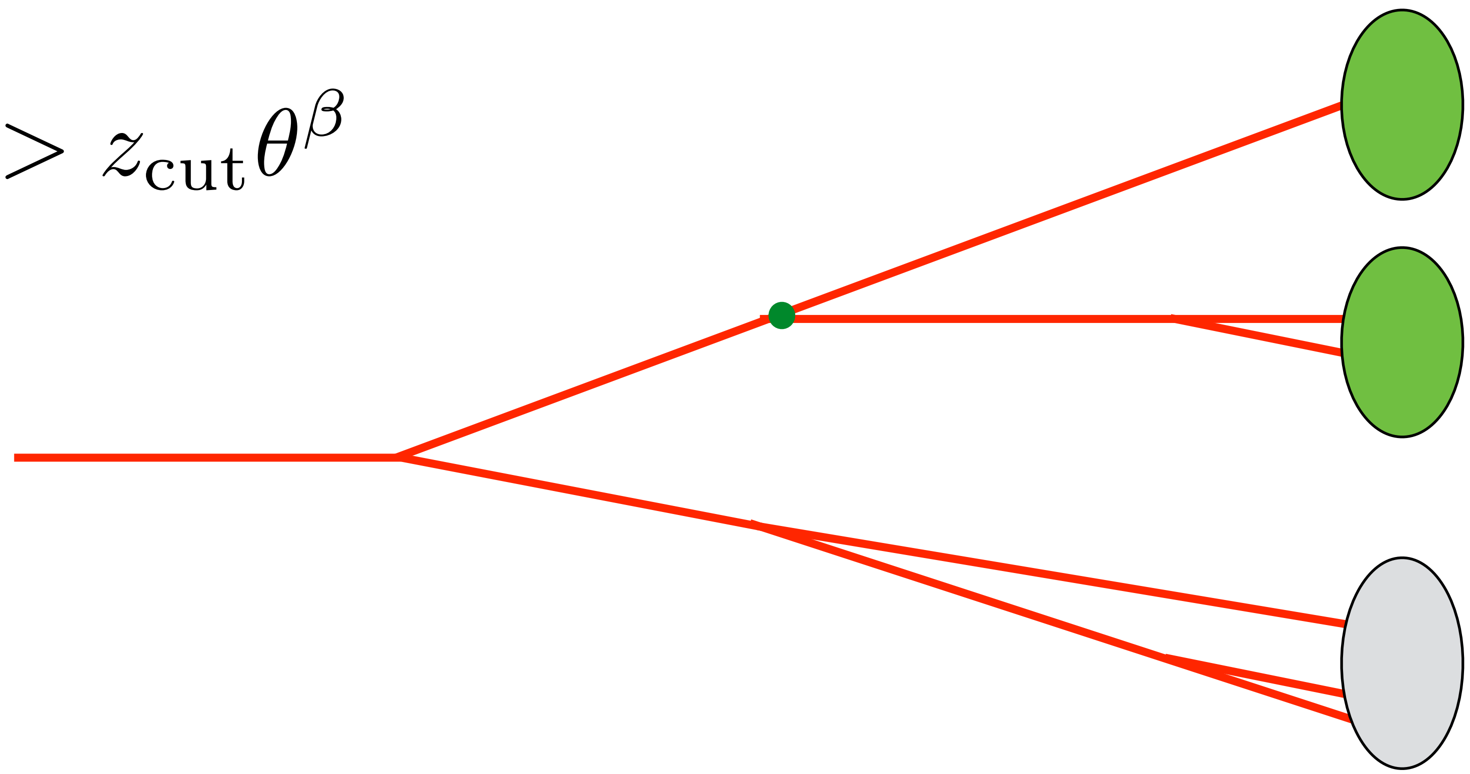

QCD splitting function:
(soft & collinear divergences)

$$\mathcal{P}^{\rm vac}(z,\theta) = \alpha_s \frac{P_{gg}(z)}{\theta}$$

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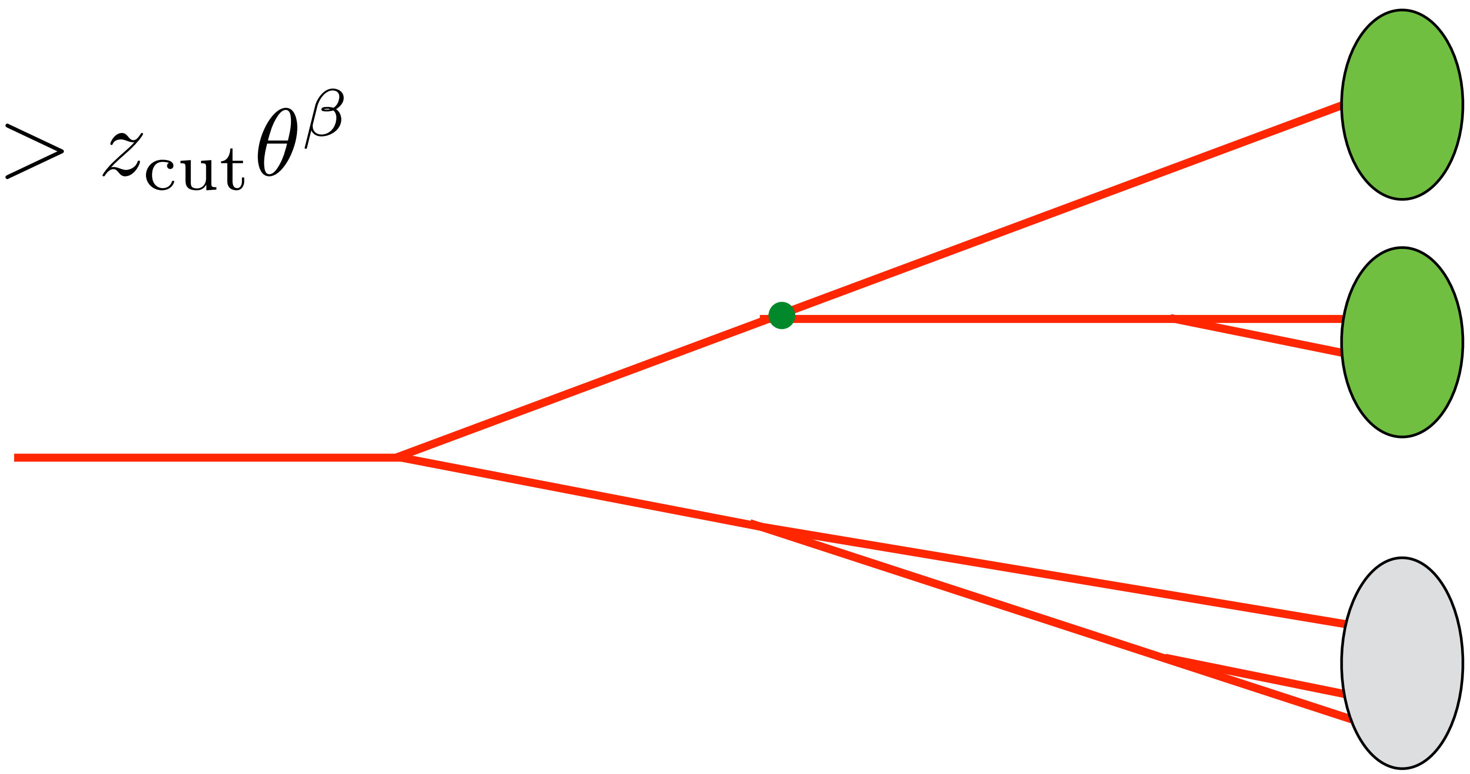

QCD splitting function:
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$$\mathcal{P}^{\rm vac}(z,\theta) = \alpha_s \frac{P_{gg}(z)}{\theta}$$

Probability: $$p(z_g) = \int_0^R {\rm d}\theta\, \Delta(R,\theta)\mathcal{P}^{\rm vac}(z_g,\theta)\Theta_{\rm cut}(z_g,\theta)$$

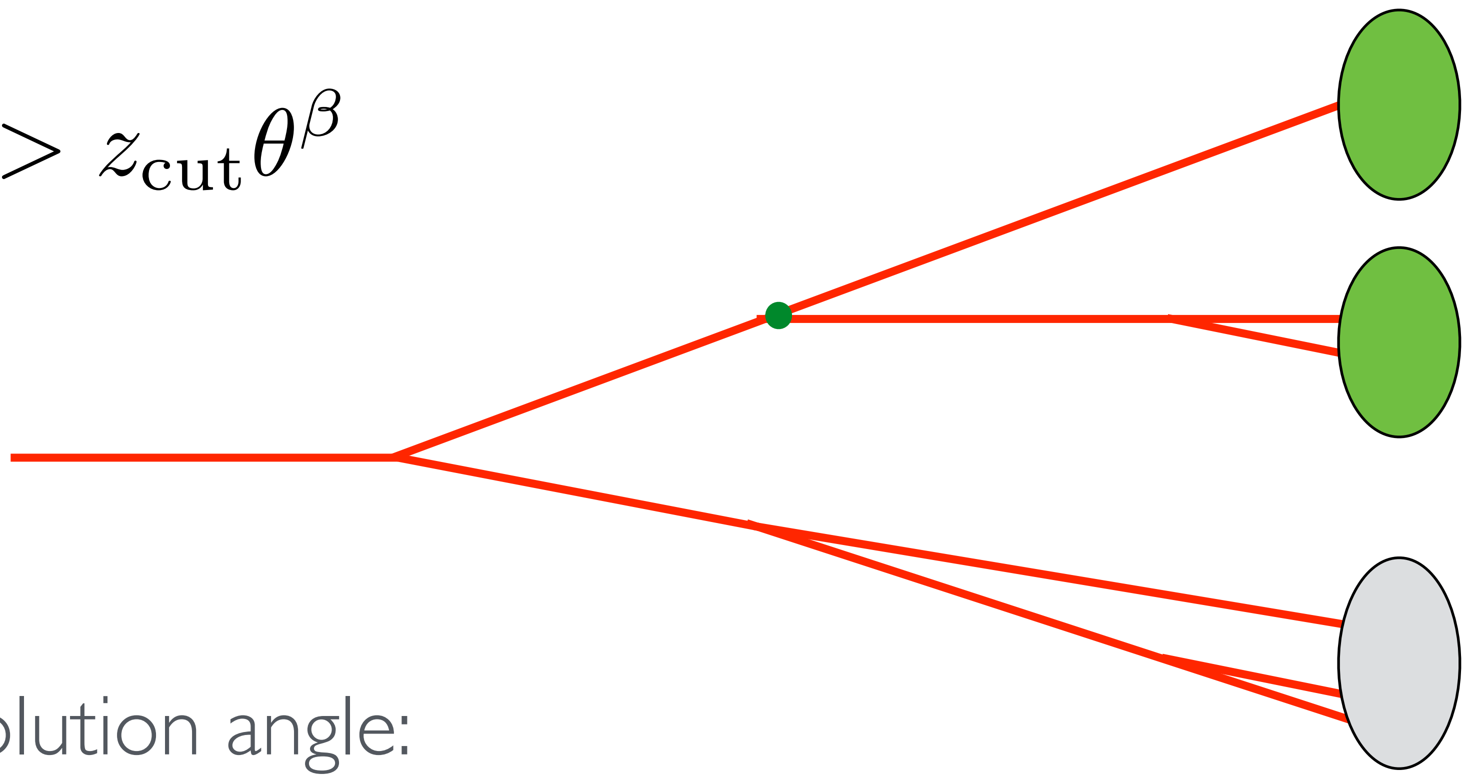
Sudakov form factor
accounts for groomed emissions

For β=0: splitting probability does not depend on α_s or flavour

$$p(z_g) \sim 1/[z(1-z)]$$

JET GROOMING

$$z > z_{\text{cut}}\theta^{\beta}$$



Finite resolution angle:

$$p_{\text{tot}}(z_g) = \int_{R_0}^{R} \mathrm{d}\theta\, \Delta(R,\theta)\mathcal{P}_{\text{vac}}(z_g,\theta)\Theta_{\text{cut}}(z_g,\theta) + \Delta(R,R_0)\delta(1-z)$$

JET GROOMING

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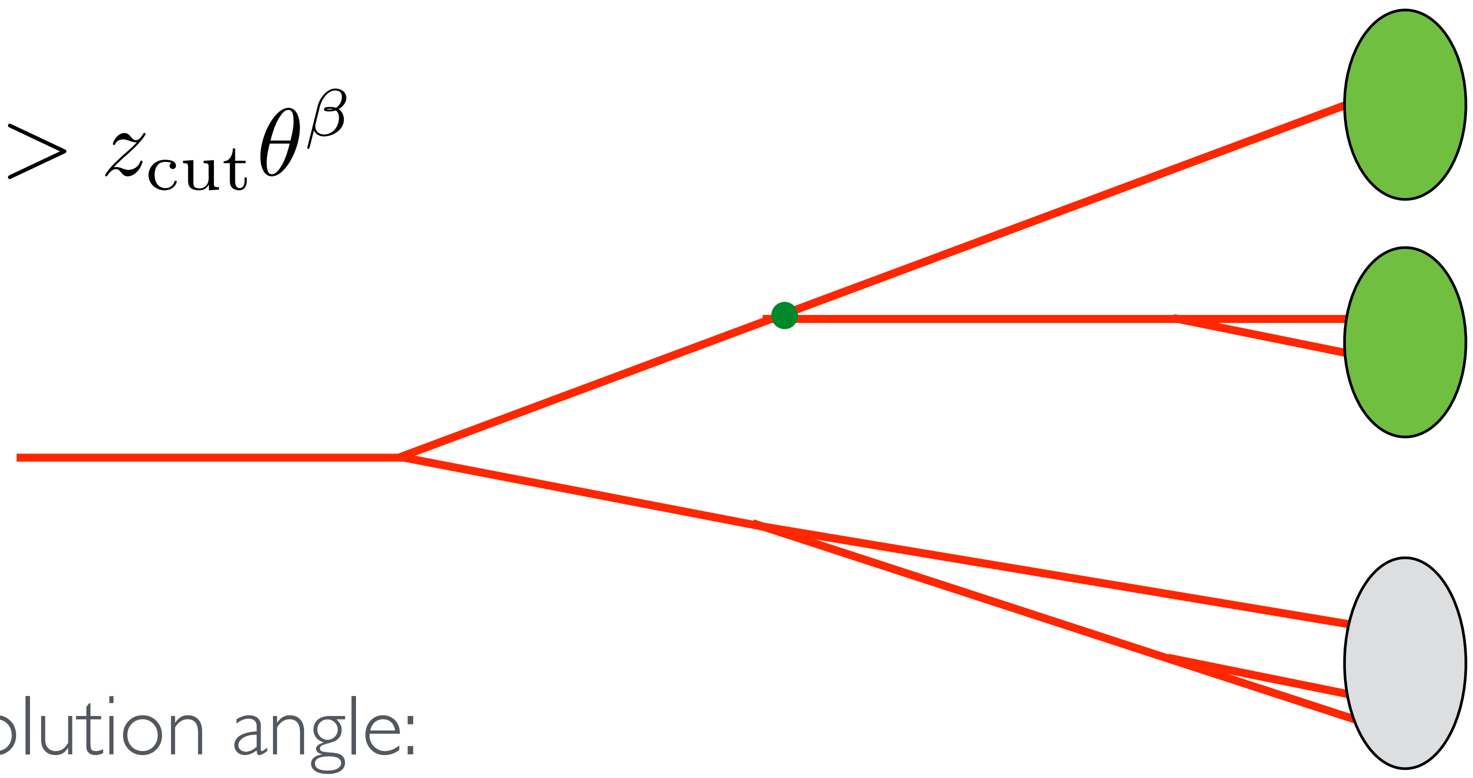

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2-prong probability

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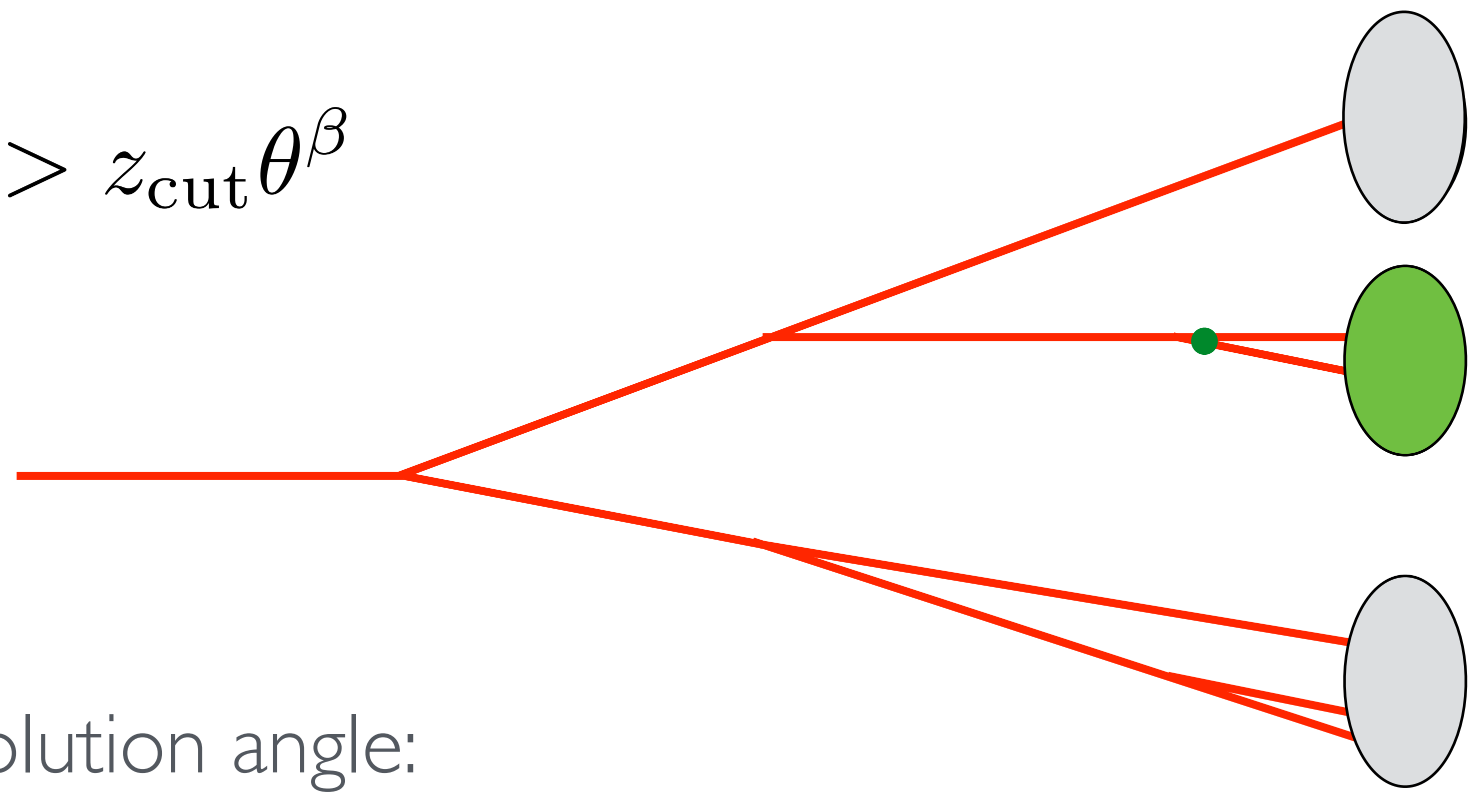

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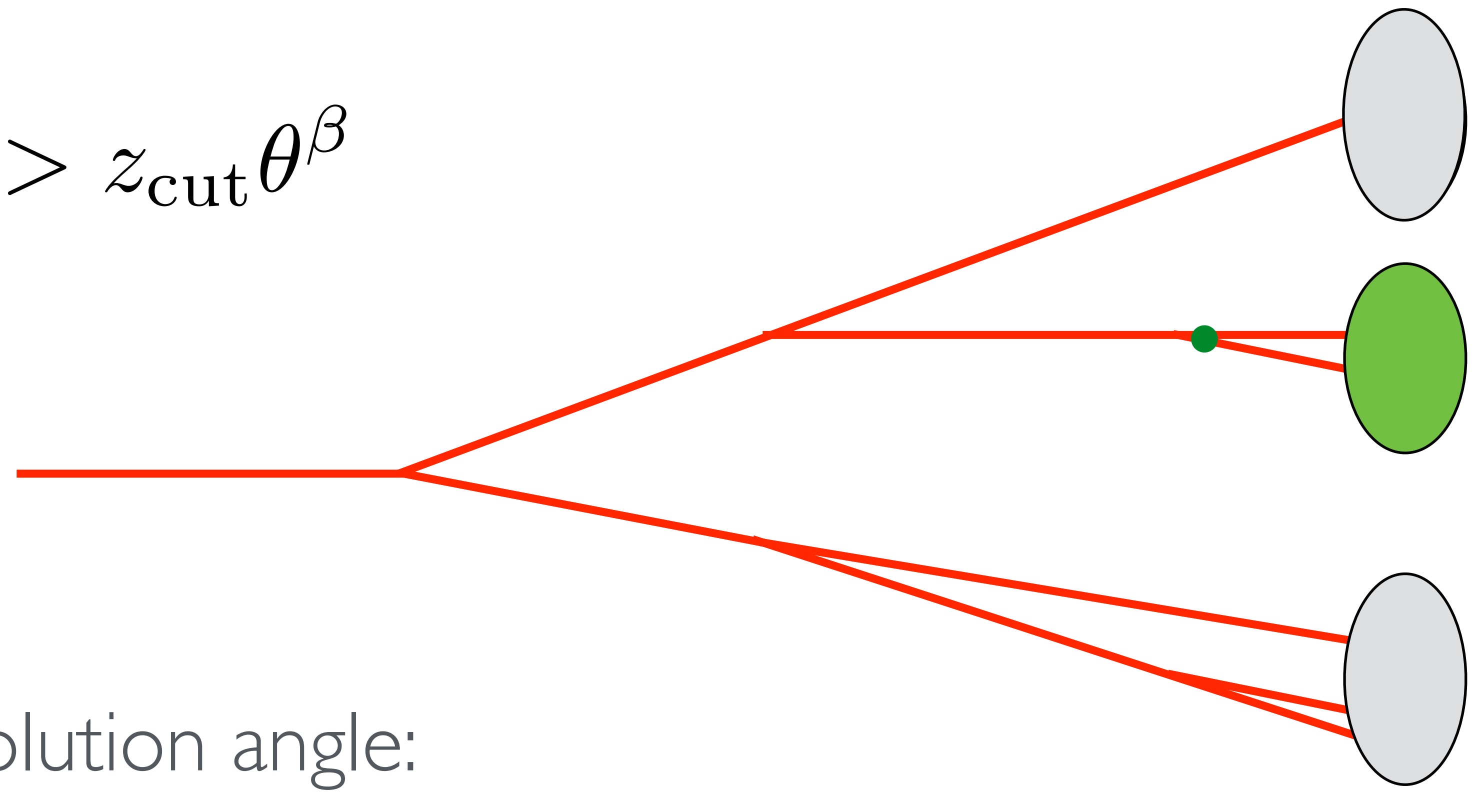

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2-prong probability

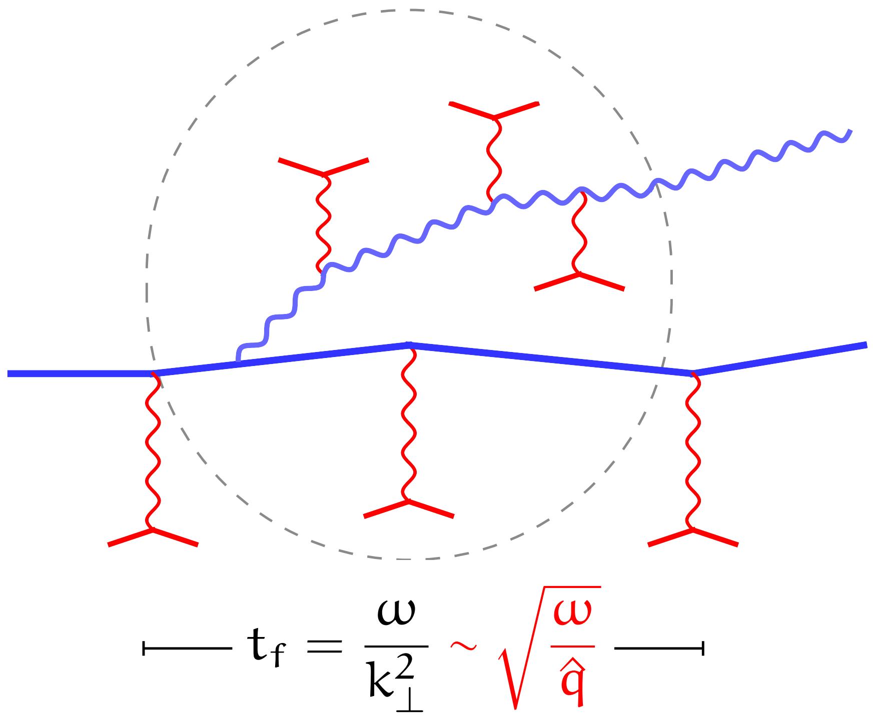
1-prong probability

$$\int \mathrm{d}z\, p_{\rm tot}(z) = 1 \quad \Rightarrow \quad \mathbb{P}_{\rm 2prong} = 1 - \Delta(R,R_0)$$

Medium-induced radiation

Baier, Dokshitzer, Mueller, Peigné, Schiff (1997-2000), Zakharov (1996), Wiedemann (2000), Gyulassy, Levai, Vitev (2000), Arnold, Moore, Yaffe (2001)

$$\omega \frac{\mathrm{d}N}{\mathrm{d}\omega} = \bar{\alpha}\sqrt{\frac{\omega_c}{\omega}}$$



$$\Delta E = \langle \omega \rangle \sim \bar{\alpha}\omega_c$$

mean energy loss dominated by maximal energy

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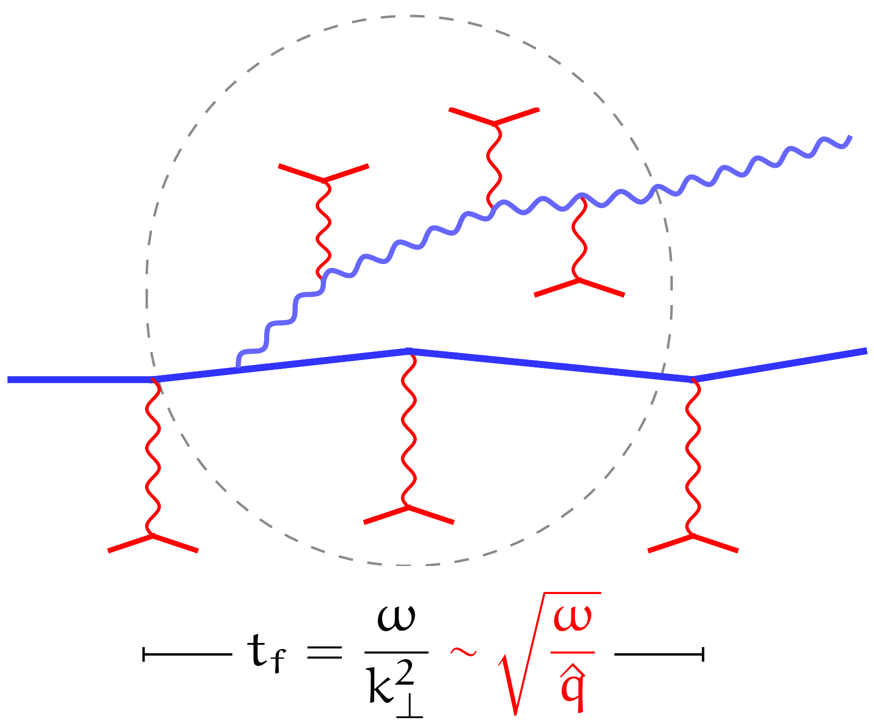

$$N(\omega) = \int_\omega^\infty \frac{\mathrm{d}N}{\mathrm{d}\omega} \sim \bar{\alpha}\sqrt{\frac{\omega_c}{\omega}}$$

multiplicity above a certain energy ω

$$N(\omega_c) \sim \mathcal{O}(\bar{\alpha})$$

rare emissions, hard BDMPS

$$N(\omega_s) \sim \mathcal{O}(1)$$

copious production, need for resummation, large fluctuations

Escobedo, Iancu JHEP (2016)
Escobedo Wed 8, 12:00

TWO REGIMES

$$t_{\rm br}(\omega) = \sqrt{\frac{\omega}{\hat{q}}}$$

$$t_{\rm br}(\omega_c) \sim \mathcal{O}(L)$$

takes a long time to form, emerge at *the end of the medium*

$$t_{\rm br}(\omega_s) \sim \bar{\alpha}\mathcal{O}(L)$$

produced rapidly, further branching highly probable

Blaizot, Mehtar-Tani, Iancu PRL (2013)

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$$\theta_{\rm br}(\omega) = \sqrt[4]{\frac{\hat{q}}{\omega^3}}$$

$$\theta_{\rm br}(\omega_c) \sim \sqrt{\frac{1}{\hat{q}L^3}} \equiv \theta_c$$

minimal angle!

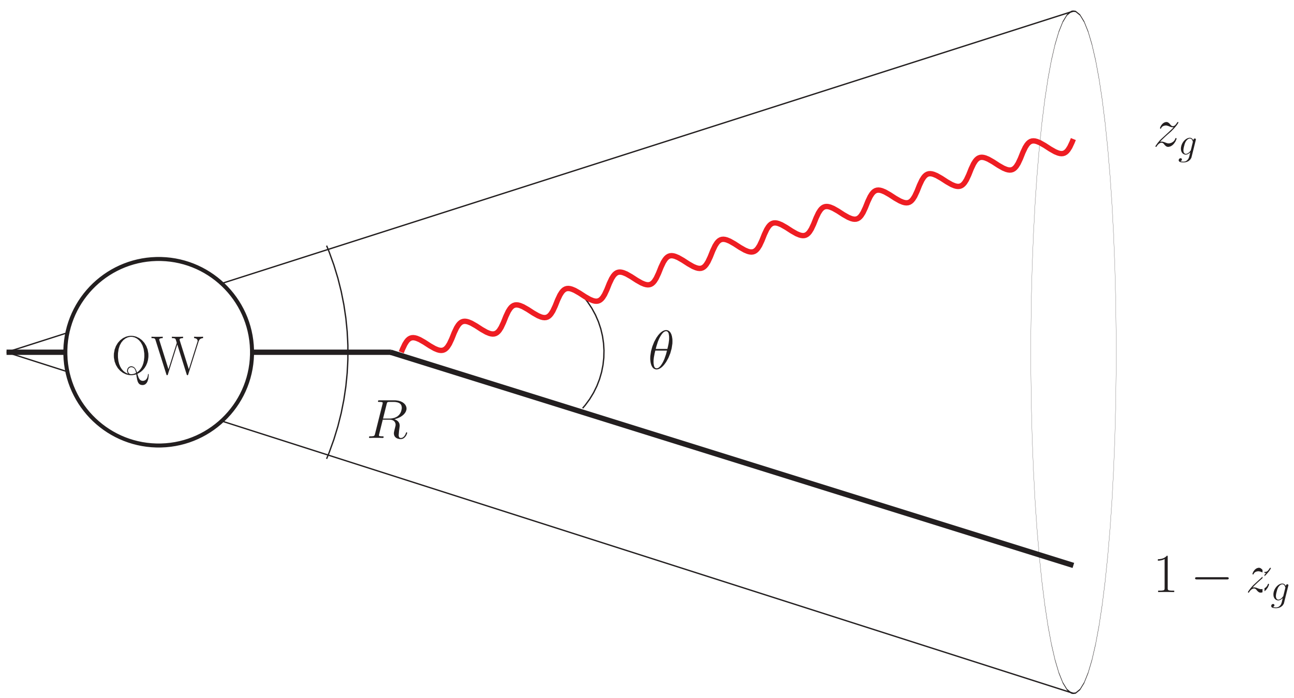
$$\theta_{\rm br}(\omega_s) \sim \frac{1}{\bar{\alpha}^{3/2}}\theta_c$$

energy transported to parametrically large angles

Blaizot, Fister, Mehtar-Tani NPA (2015); Kurkela, Wiedemann PLB (2015); Iancu, Wu JHEP (2015);...

IN-CONE	hard medium-induced radiation
OUT-OF-CONE	multiple-soft radiation, energy loss

PROBING BDMPS IN SUBSTRUCTURE



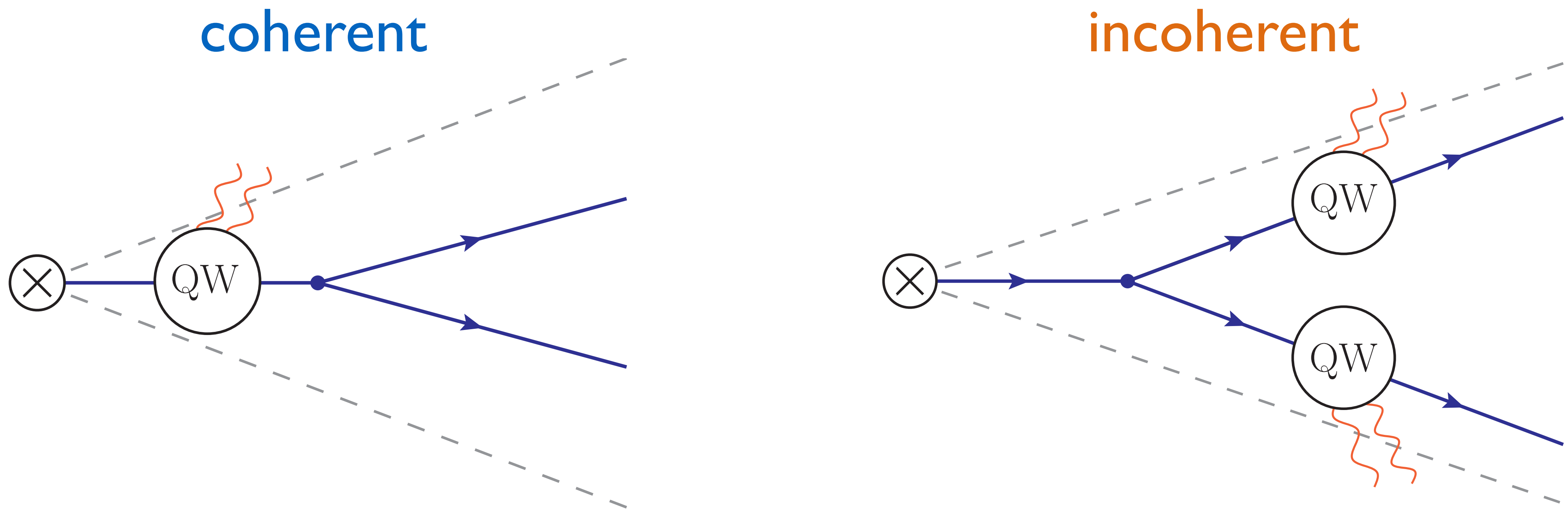
BDMPS-Z spectrum:

$$d\sigma_{\rm LPM} \sim \frac{\alpha_s}{z^{3/2}} \sqrt{\frac{\hat{q} L^2}{E_{\rm jet}}}$$

- semi-hard bremsstrahlung can be emitted into the cone!
  - changes intra-jet structure
- no collinear enhancement: add to probability at leading-order
- jet spectrum reduced by quenching

See also N=1 calculation: Vitev, Chien arXiv:1608.07283

ELOSS: CRUCIAL INGREDIENT



- internal structure of jet affected only if resolved: infrared behaviour regularised
- grooming & total e-loss: depend on the number of resolved jet substructures
- assume that jets are mostly coherent ($\theta_c \sim R$): jet spectrum suppressed by quenching factor

$$\frac{\mathrm{d}N}{\mathrm{d}p_{\mathrm{T}}^2} = \int \mathrm{d}\epsilon\, \mathcal{D}_{\mathrm{QW}}(\epsilon) \frac{\mathrm{d}N_{(0)}(p_{\mathrm{T}}+\epsilon)}{\mathrm{d}p_{\mathrm{T}}^2}$$

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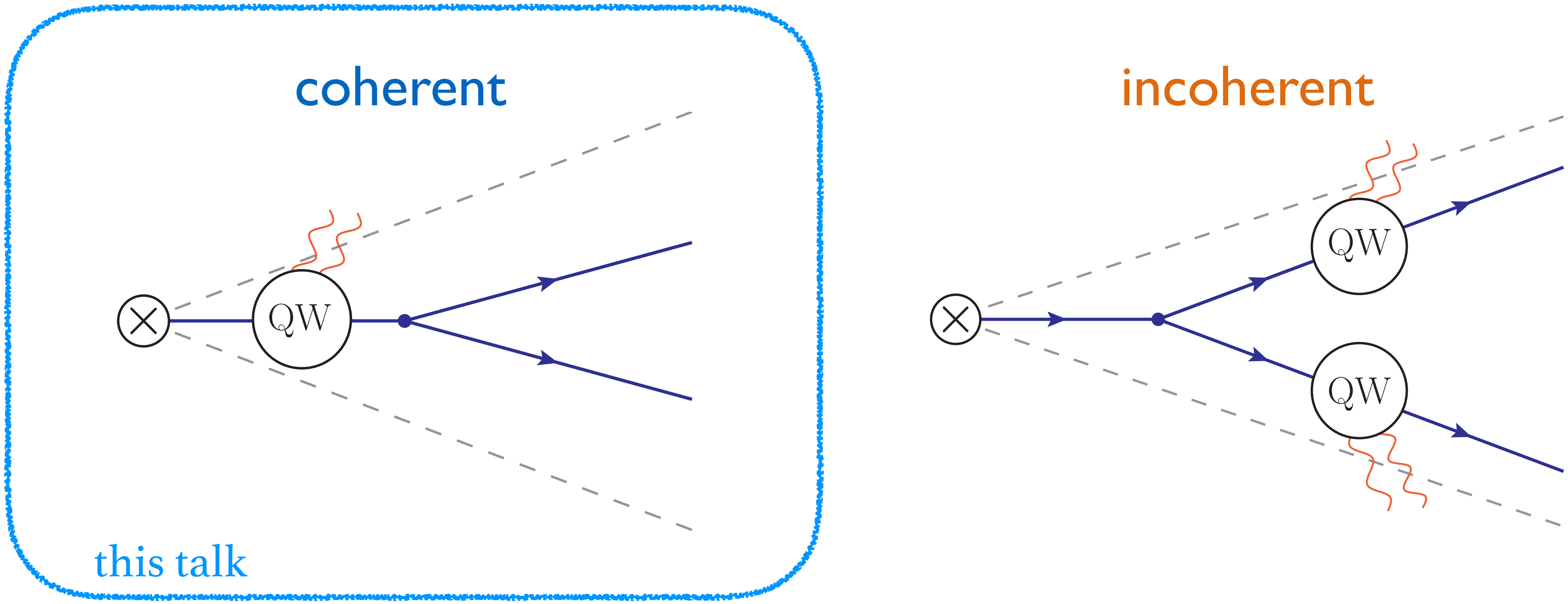

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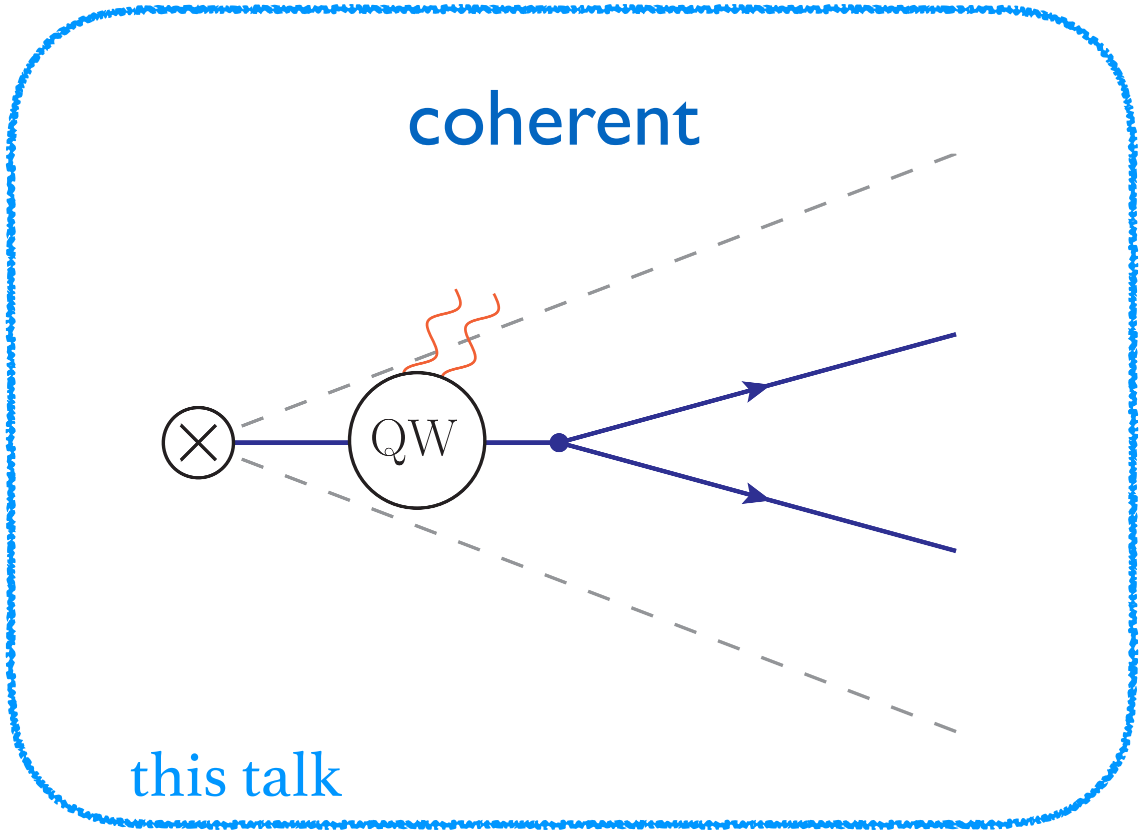

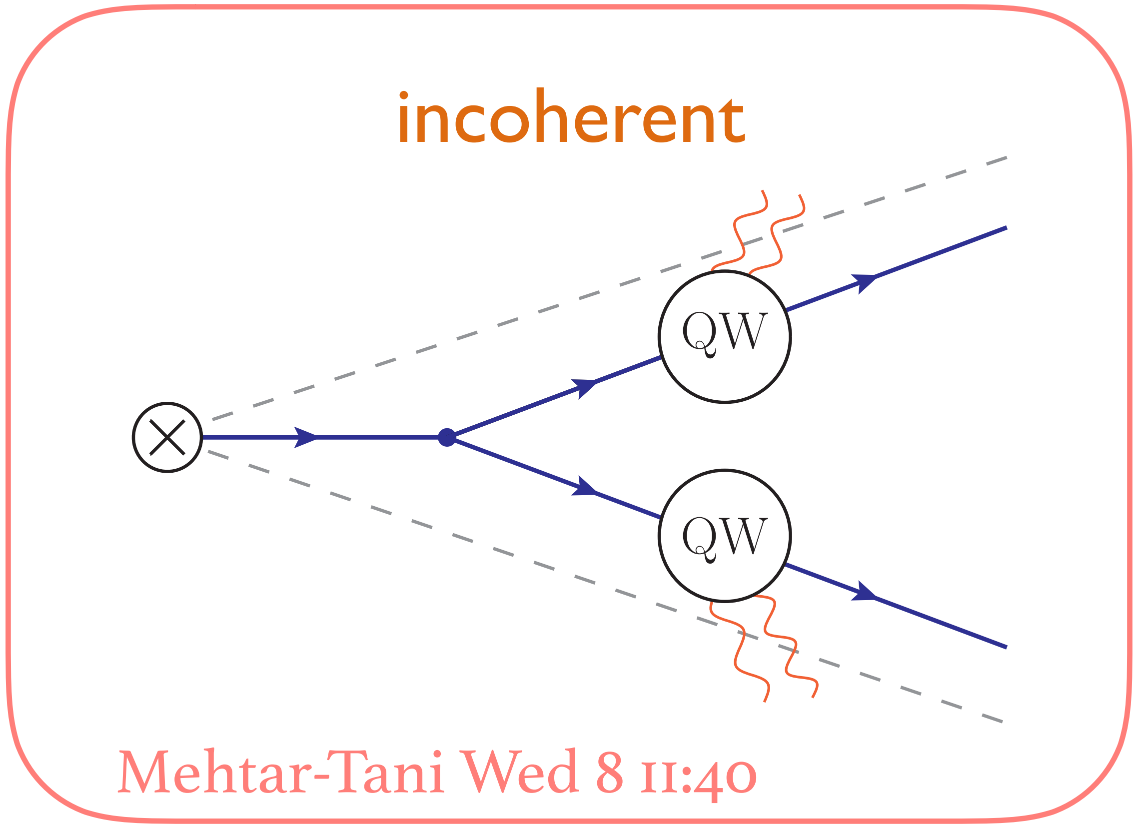

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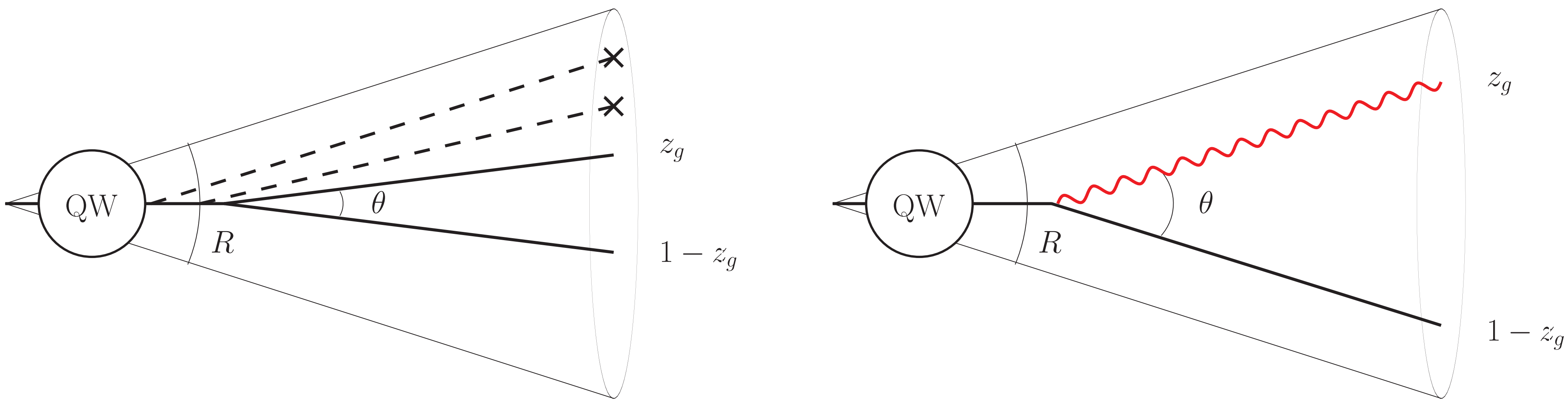
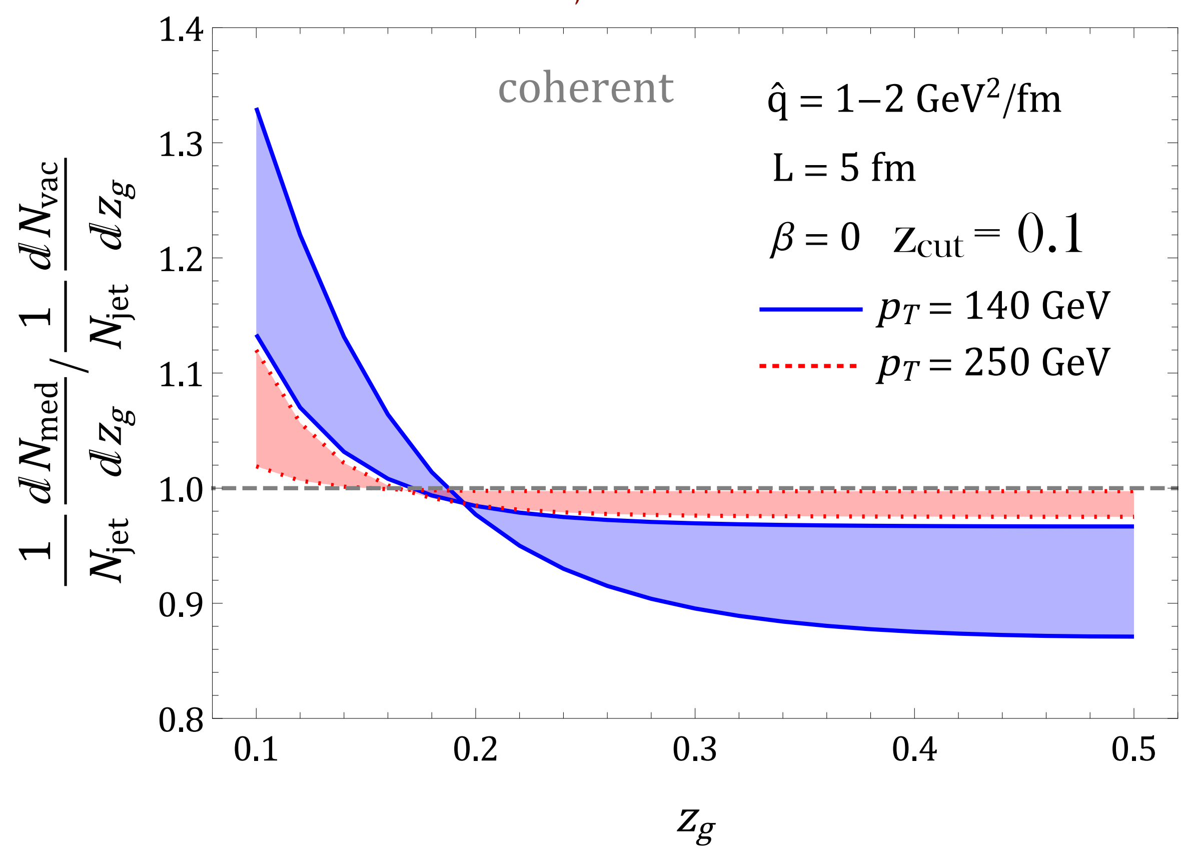
SPLITTING PROBABILITY IN AA



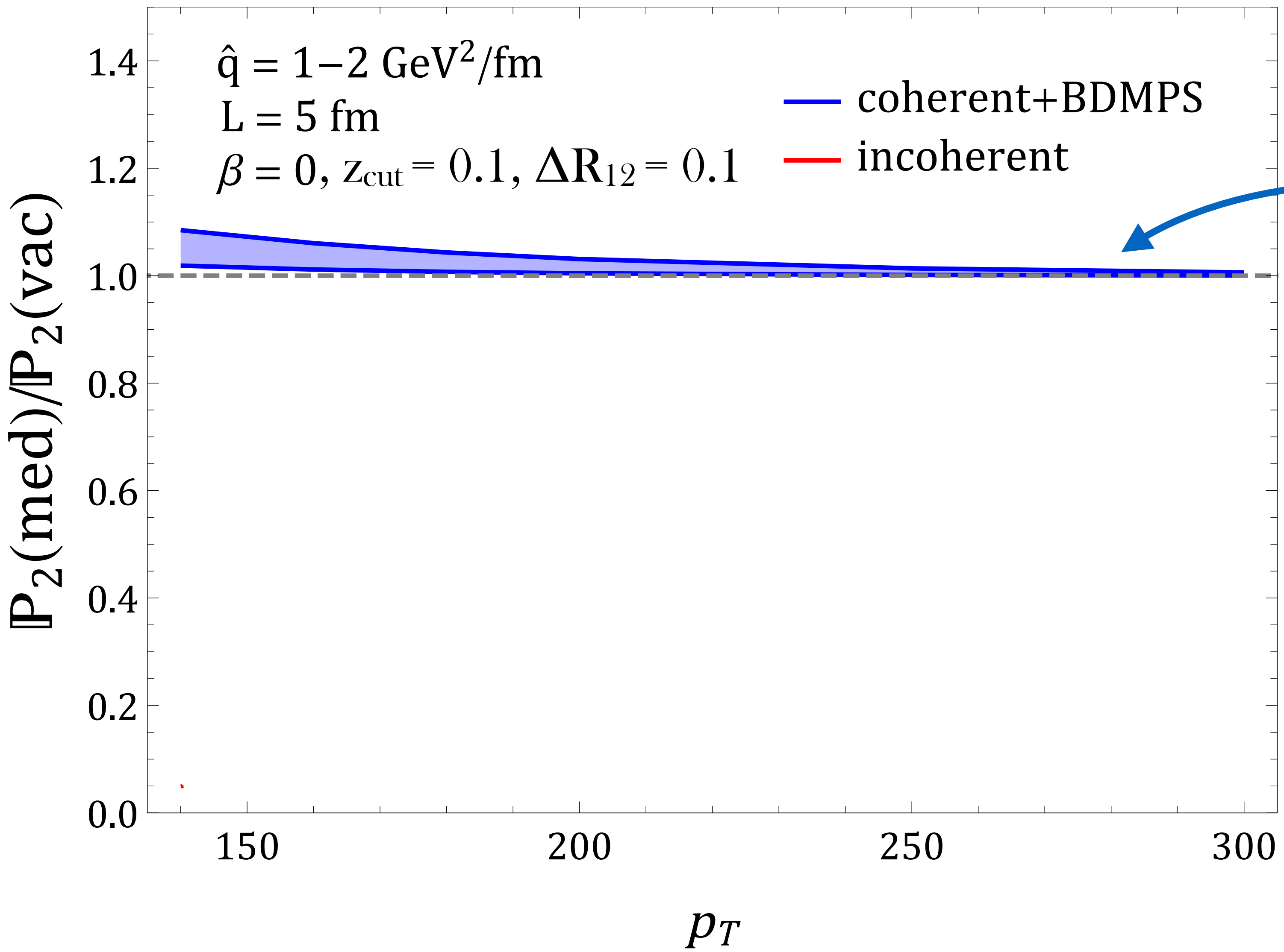
- enhancement of the z_g-spectrum at small energies
- possibility to pin-point details of the enhancement
  - measure *direct* medium-induced bremsstrahlung

Mehtar-Tani, KT arXiv:1610.08930



2-PRONG PROBABILITY

Mehtar-Tani, KT arXiv:1610.08930



vacuum+medium:
enhanced splitting probability because of more radiation

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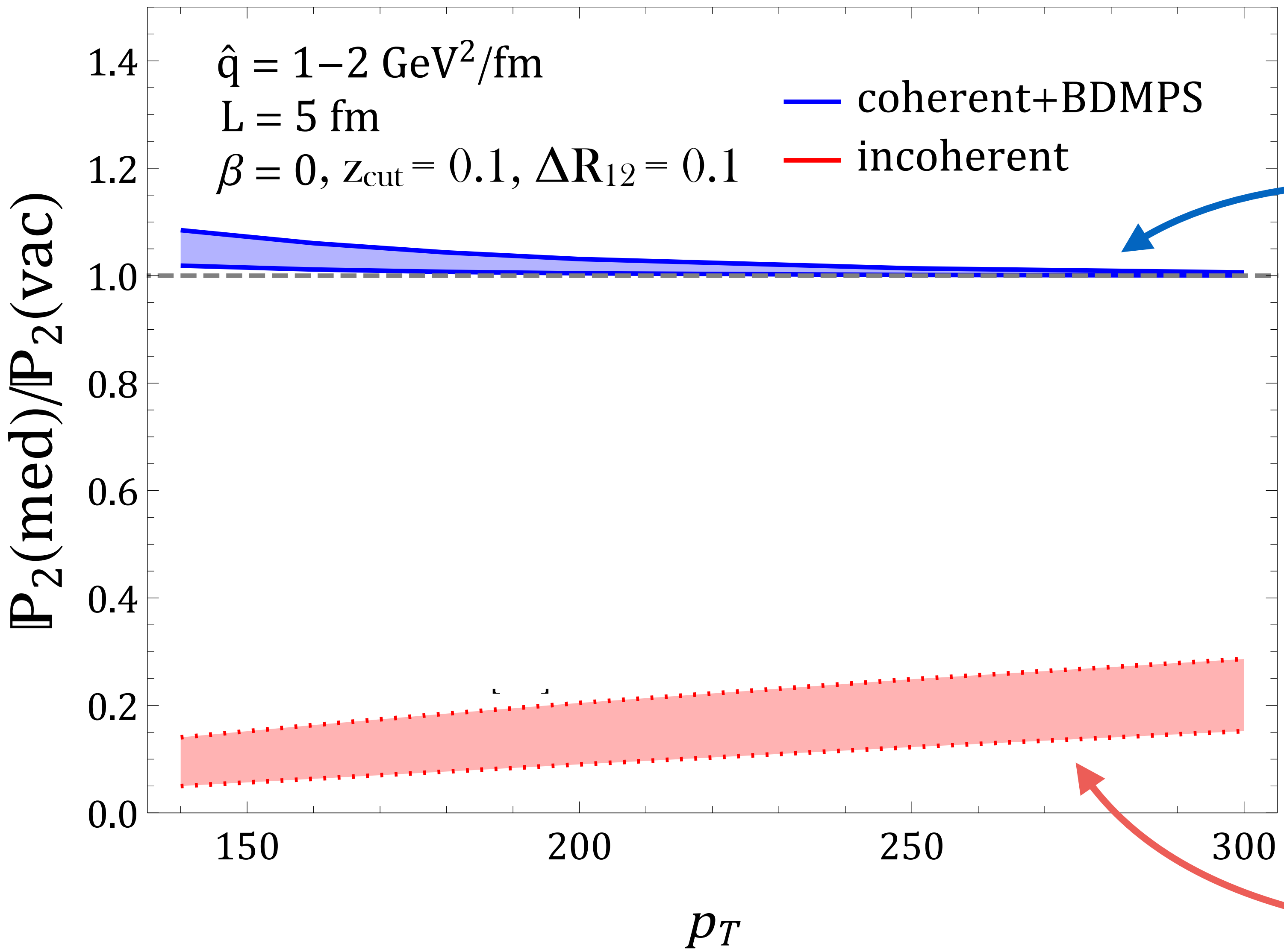

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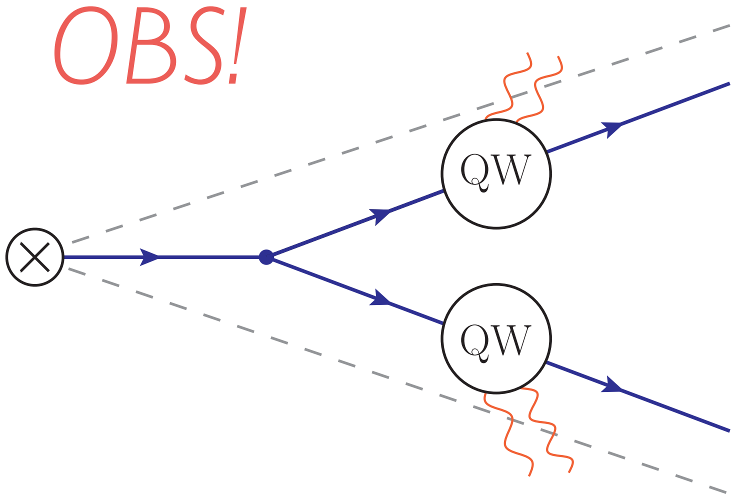
OBS!

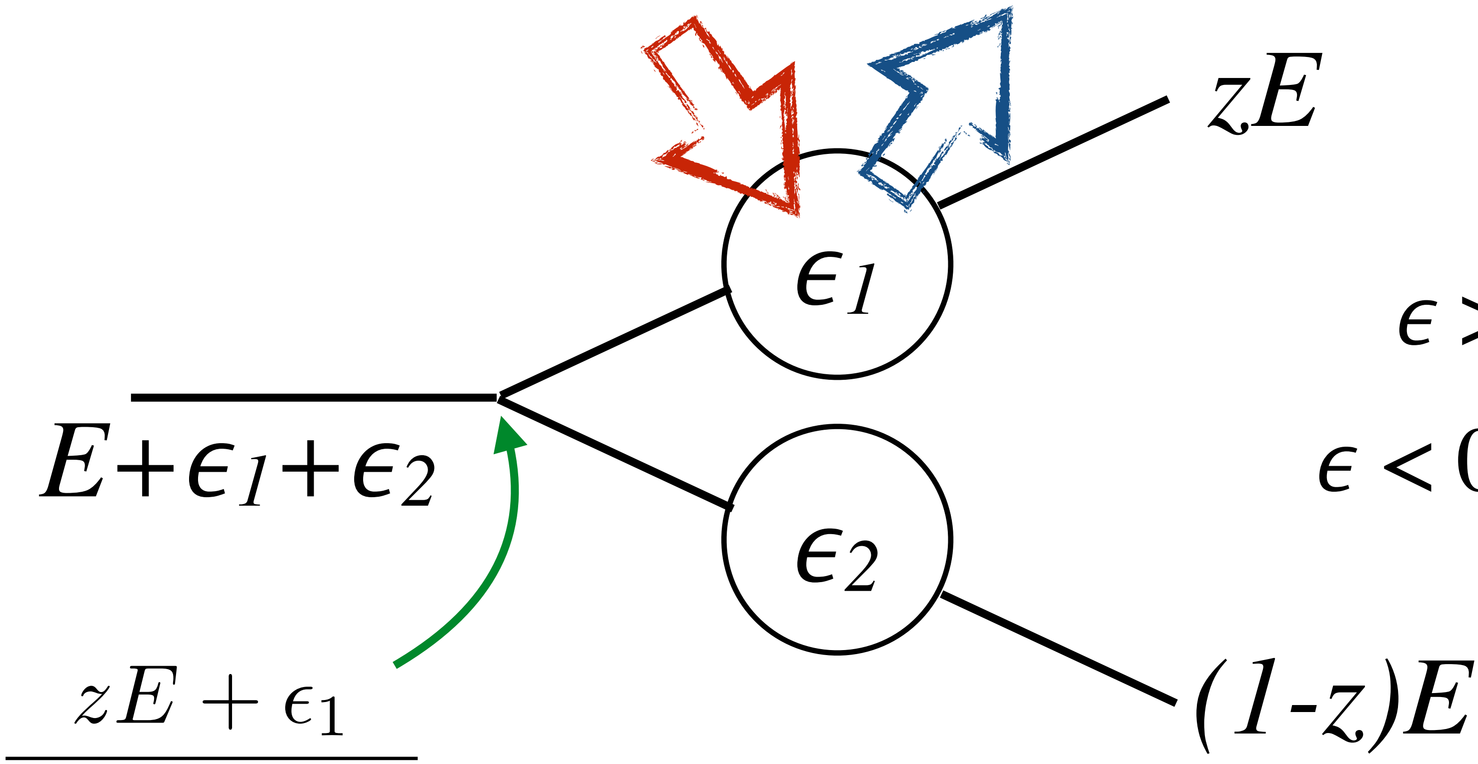


Outlook

- new observables: jet substructure
  - importance of coherence effects
  - potentially a *direct* probe of a new type of radiation generated in the medium
  - analytical tools & insight valuable for qualitative features
  - z_g-distribution first of many possible observables
- *challenges:* sensitivity to background contamination, vacuum+medium interference

BACK-UP

MODIFIED SPLITTING



$\epsilon > 0$: quenching

$\epsilon < 0$: recombination

$$z_{\mathrm{v}} = \frac{zE + \epsilon_1}{E + \epsilon_1 + \epsilon_2}$$

Splitting function

$$\frac{1}{z_{\mathrm{v}}(1 - z_{\mathrm{v}})} = \frac{(E + \epsilon_1 + \epsilon_2)^2}{[zE + \epsilon_1][(1 - z)E + \epsilon_2]}$$

Parametric estimates

- For example: $L = 4\ fm$, $\hat{q} = 2\ GeV^2/fm$, $\bar{\alpha} = 0.3$
  - $\omega_c = 80\ GeV$, $\omega_s = 7\ GeV$
  - $\theta_{BDMPS} = k_T/\omega \sim \sqrt{(\hat{q}L)}/\omega$
  - $0.025 < \theta_{BDMPS} < 0.28$

typical vacuum radiation

$$t_f = \frac{1}{zE\theta^2}$$

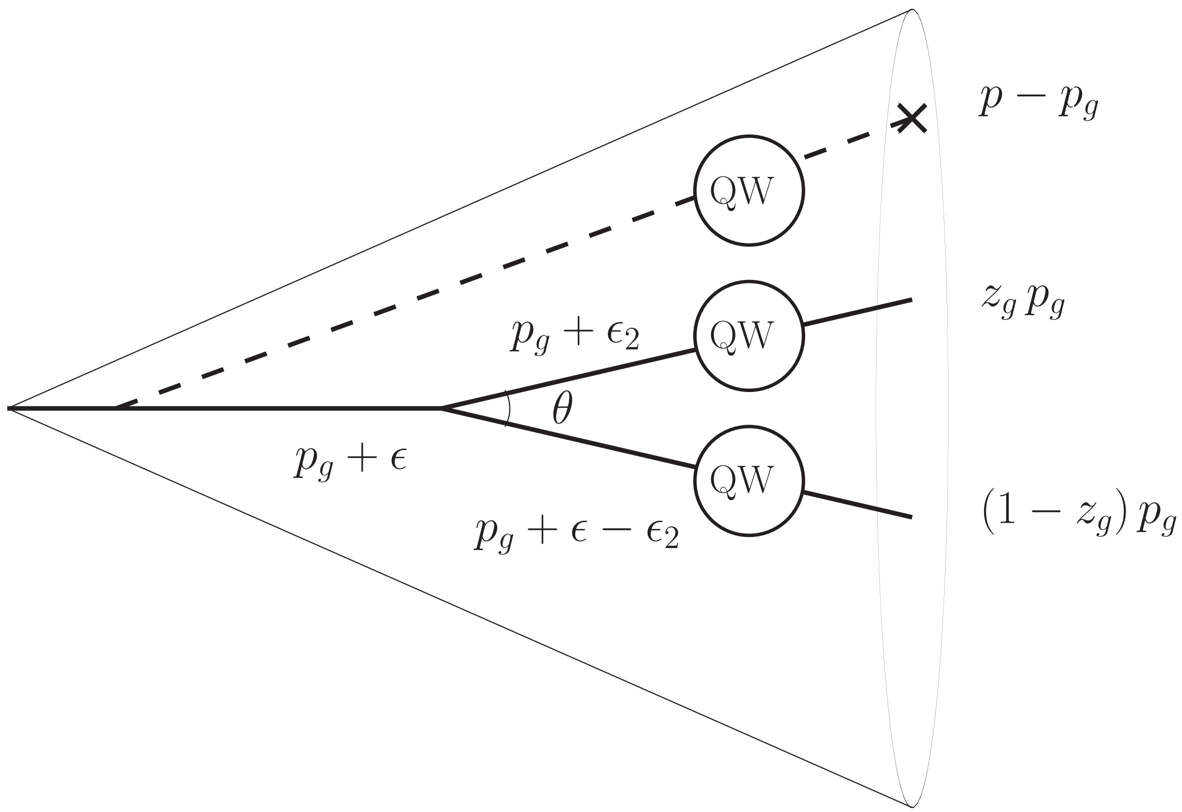
~10-2-1.5 fm

$$t_f = \sqrt{\frac{zE}{\hat{q}}}$$

typical medium radiation

~0.5-2.5 fm

Decoherent eloss



$$\frac{\mathrm{d}N_{\mathrm{jet}}}{\mathrm{d}p_{\mathrm{T}}^2}\, p(z_g) = \int_0^R \mathrm{d}\theta \int_0^\infty \mathrm{d}\epsilon \int_0^{(1/2-z_g)p_{\mathrm{T}}} \mathrm{d}\epsilon'\, \Delta(R,\theta|p_{\mathrm{T}})\Theta(z_g - z_{\mathrm{cut}}\theta^\beta)$$
$$\times D_{\mathrm{QW}}(\epsilon) D_{\mathrm{QW}}(\epsilon') \mathcal{P}_{\mathrm{vac}}\left(z_g + \frac{\epsilon'}{p_{\mathrm{T}}}, \theta\right) \frac{\mathrm{d}N_{\mathrm{jet}(0)}(p_{\mathrm{T}}+\epsilon)}{\mathrm{d}p_{\mathrm{T}}^2}\,,$$

$$\Delta(R,R_0|p_{\mathrm{T}}) = \exp\left[-\int_{R_0}^R \mathrm{d}\theta \int_{z_{\mathrm{cut}}\theta^\beta}^{1/2} \mathrm{d}z \int_0^{(1/2-z)p_{\mathrm{T}}} \mathrm{d}\epsilon\, D_{\mathrm{QW}}(\epsilon)\, \mathcal{P}_{\mathrm{vac}}\left(z + \frac{\epsilon}{p_{\mathrm{T}}}, \theta\right)\right]$$

Mehtar-Tani, KT arXiv:1610.08930