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Nikhef

AZIMUTHAL DECORRELATION IN V+JET PRODUCTION WITH THE WTA AXIS

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QCD Evolution 13-05-21, UCLA

Based on [2005,12279] and WIP with
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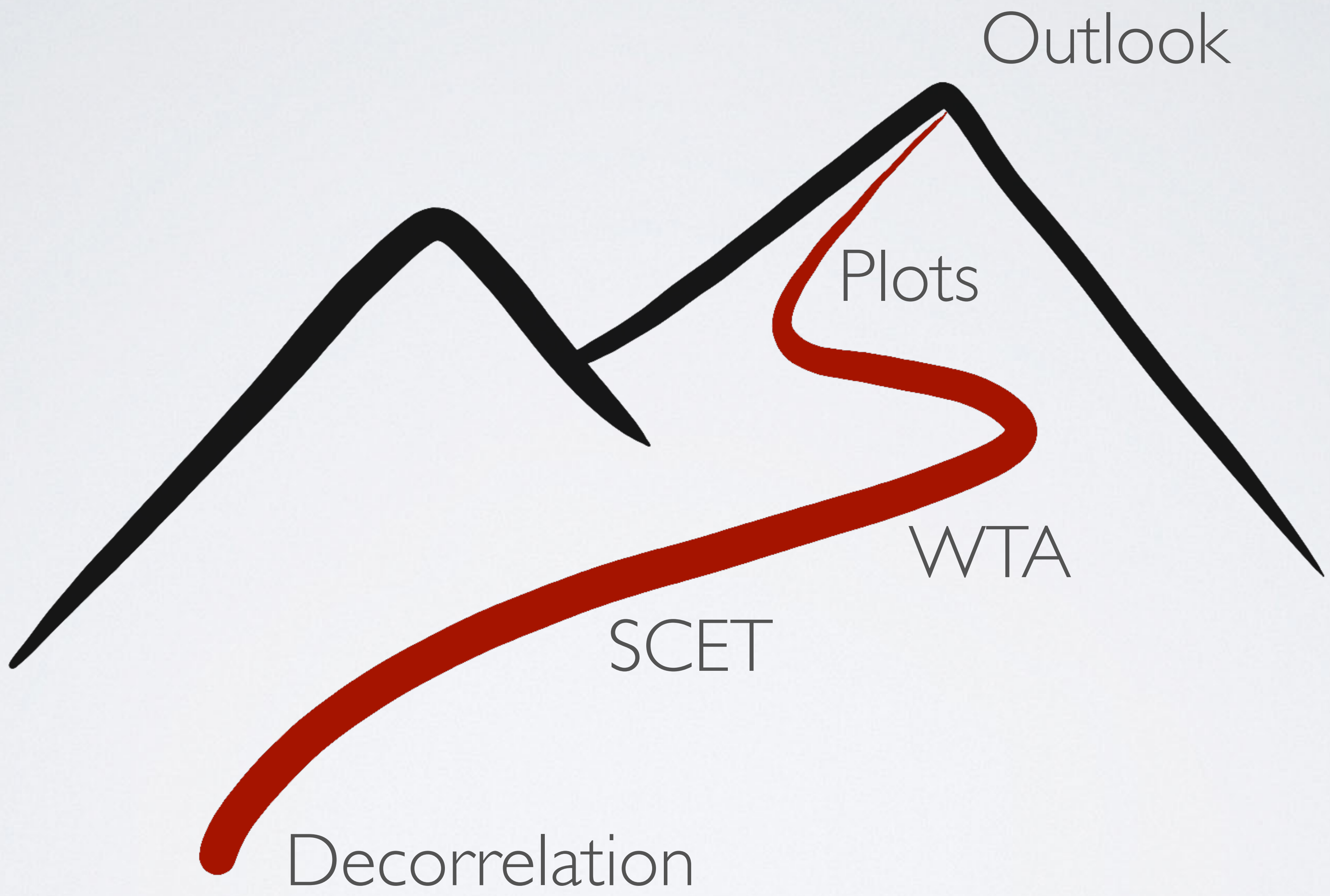
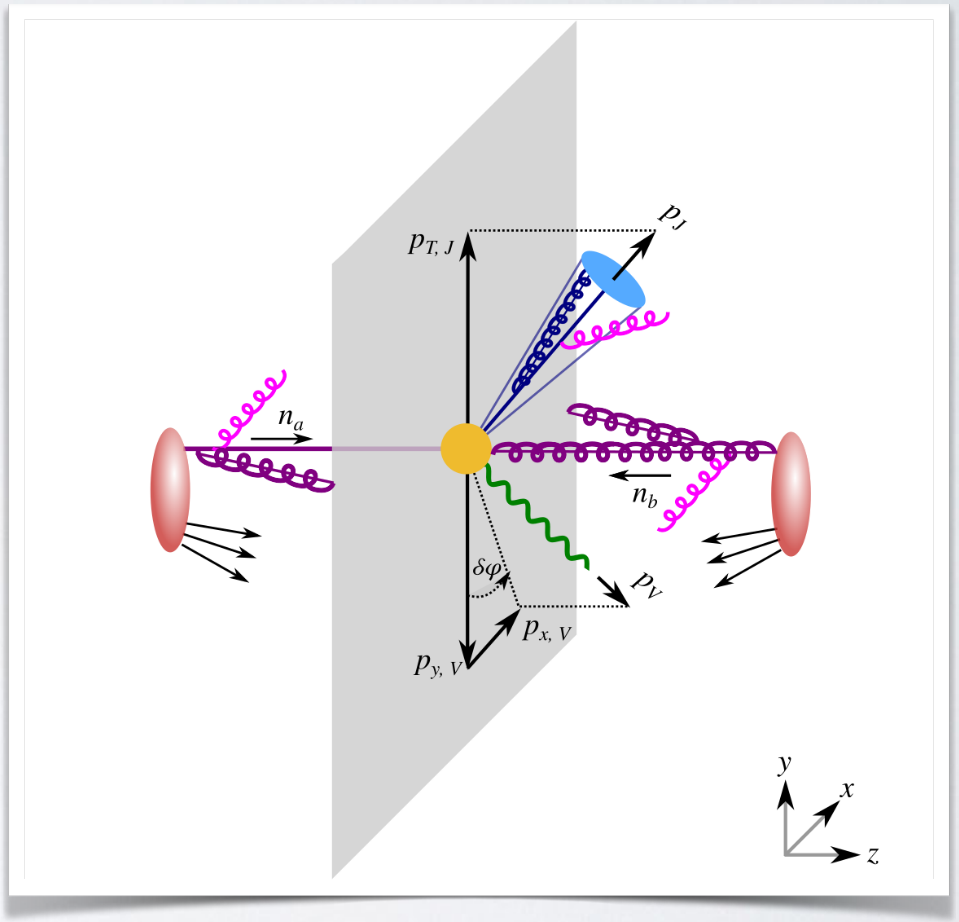
OUTLINE



AZIMUTHAL DECORRELATION I

- V+jet at pp collisions
- Leading partonic: planar
- Soft/Collinear emissions: $\delta\varphi \neq 0$
- Large logarithms $\alpha_s^n \ln^{2n} \delta\varphi$

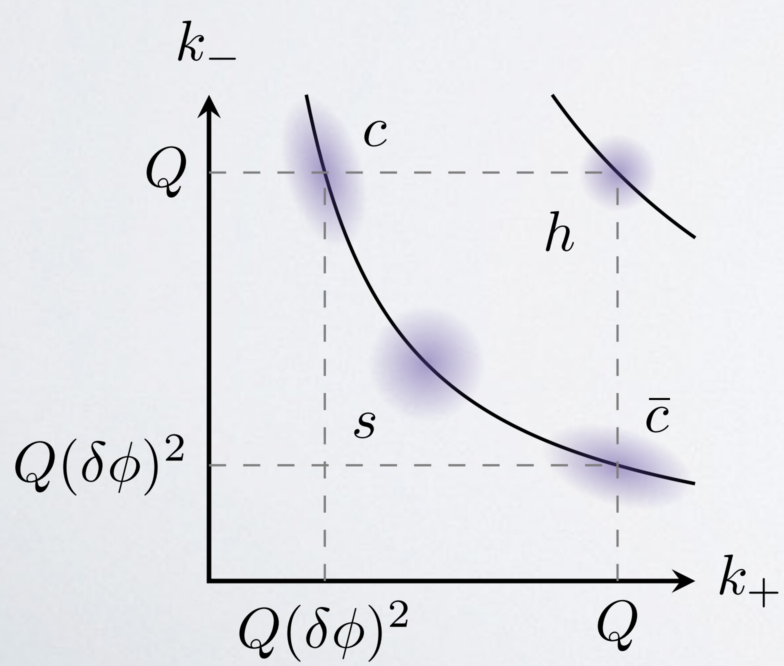


  - Resum using SCET

SOFT-COLLINEAR EFFECTIVE THEORY

[Bauer, Fleming, Pirjol, Stewart, Rothstein, '01/'02]
[Beneke, Chapovsky, Diehl, Feldmann, '02]

- Dominant contributions from select phase space regions
- Represent them by dedicated fields
- Power counting of EFT $\Leftrightarrow$ large logarithm argument



		$(k_+, k_-, k_\perp)$
Azimuthal decorrelation:	Soft:	$Q(\delta\varphi, \delta\varphi, \delta\varphi)$
	Beam:	$Q(\delta\varphi^2, 1, \delta\varphi)$
	Beam:	$Q(1, \delta\varphi^2, \delta\varphi)$
	Jet:	$Q(1, \delta\varphi^2, \delta\varphi)_J$

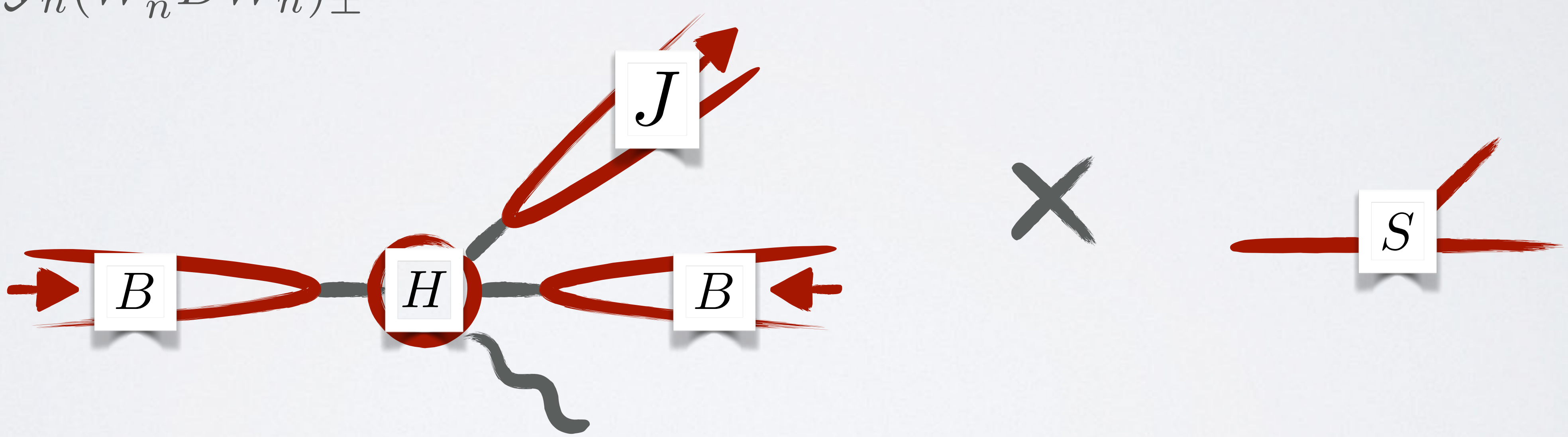
SOFT-COLLINEAR EFFECTIVE THEORY

- Crucial advantage: EFT modes decouple

- Only effective operator joins them

$$\mathcal{O} \sim C_\pm \cdot \mathcal{B}_{a,\pm}\,(\bar{\chi}_J\,\Gamma\,\chi_b)_\pm$$

$$\mathcal{B}_{n,\pm} \sim \mathcal{Y}_n (W_n^\dagger D W_n)_\pm$$



$$\mathrm{d}\sigma = H \otimes B_a \otimes B_b \otimes J \otimes S$$

- Resummation via RG equations

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Only if the observable plays along!

$$\mathrm{d}\sigma = H \otimes B_a \otimes B_b \otimes J \otimes S$$

- Resummation via RG equations

AZIMUTHAL DECORRELATION II

- Starting point: momentum conservation

$$\vec{p}_{T,a} + \vec{p}_{T,b} + \vec{p}_{T,S} + \vec{p}_{T,c} + \vec{p}_{T,V} = 0$$

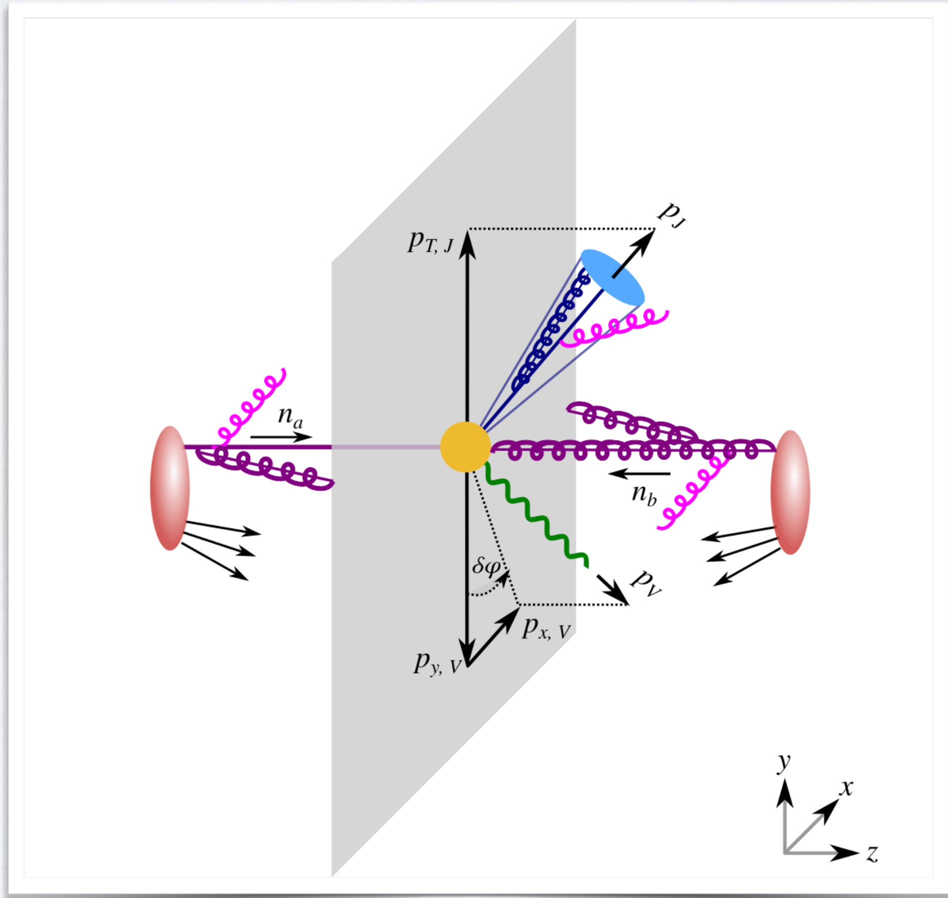
- For WTA axis $\vec{p}_{T,c} \neq \vec{p}_{T,J}$, and rearrange

$$\begin{aligned} \vec{q} &:= \vec{p}_{T,V} + \vec{p}_{T,J} \\ &= \vec{p}_{T,J} - \vec{p}_{T,c} - \vec{p}_{T,a} - \vec{p}_{T,b} - \vec{p}_{T,S} \end{aligned}$$

- For azimuthal decorrelation, pick q_x

$$\boxed{q_x = -p_{x,c} - p_{x,a} - p_{x,b} - p_{x,S}}$$

$$= p_{T,V} \sin \delta\varphi$$



THE WINNER-TAKES-ALL AXIS

[Salam, unpublished]
[Bertolini, Chan, Thaler, '14]

- Recluster a jet, pairwise: pair emissions i,j with $p_{T,i}, \hat{n}_i$ & $p_{T,j}, \hat{n}_j$

$$\boxed{p_{T,i+j} = p_{T,i} + p_{T,j}}$$

$$\boxed{\hat{n}_{i+j} = \begin{cases} \hat{n}_i & \text{if } p_{T,i} > p_{T,j} \\ \hat{n}_j & \text{if } p_{T,i} < p_{T,j} \end{cases}}$$

- Combine with SCET: $p_{T,c} \sim Q, \; p_{T,S} \sim Q\delta\varphi$
  - Direction purely a collinear affair: $\boxed{\max(p_{T,c}, p_{T,S}) = p_{T,c}}$
  - Soft subleading in magnitude: $\boxed{p_{T,c} + p_{T,S} \approx p_{T,c}}$

$\Rightarrow$ No soft recoil, no non-global logarithms*

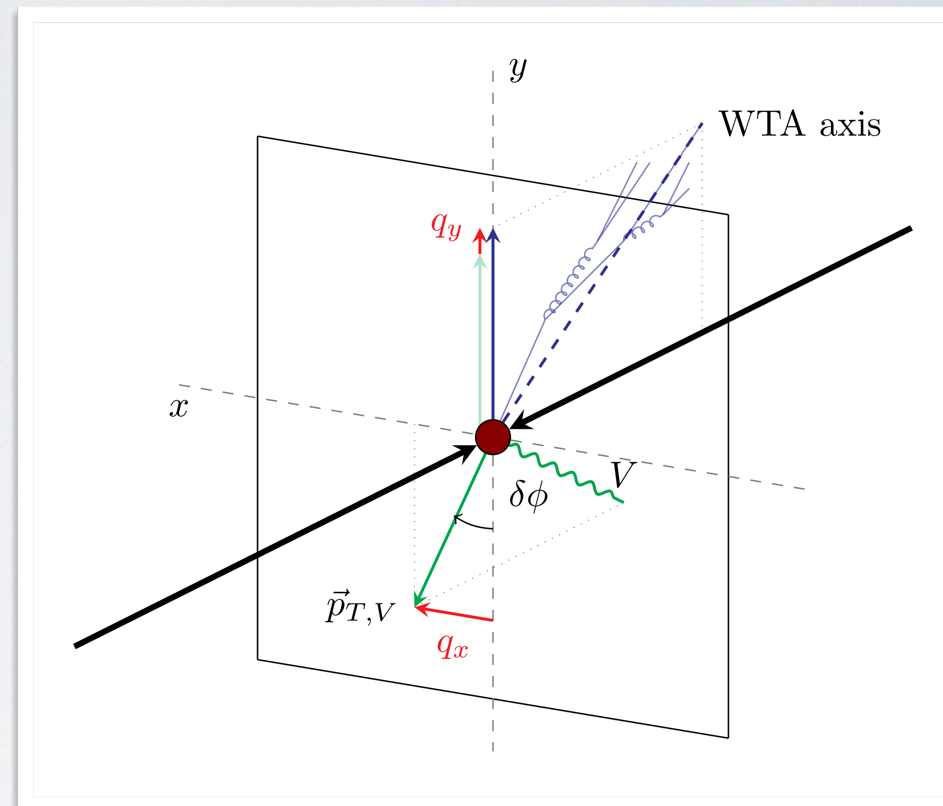
[Larkoski, Neill, Thaler, '14]

WHY SO SIMPLE?

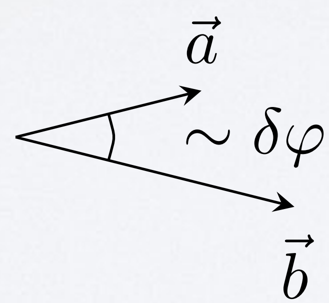
- Compare: *radial* decorrelation

$$q_x = p_{T,V} \sin\delta\varphi$$
$$\sim \delta\varphi$$

$$q_y = p_{T,J} - p_{T,V} \cos\delta\varphi$$
$$\sim (\delta\varphi)^2$$



- Scalar vs. vector sum:



$$\Rightarrow \quad (|\vec{a}| + |\vec{b}|) - |(\vec{a} + \vec{b})| \sim \delta\varphi^2$$

- Large cancellation: $\boxed{p_{T,c} + p_{T,S} \approx p_{T,c}}$

$\Rightarrow$ Sensitive to in-jet soft $\Rightarrow$ NGL

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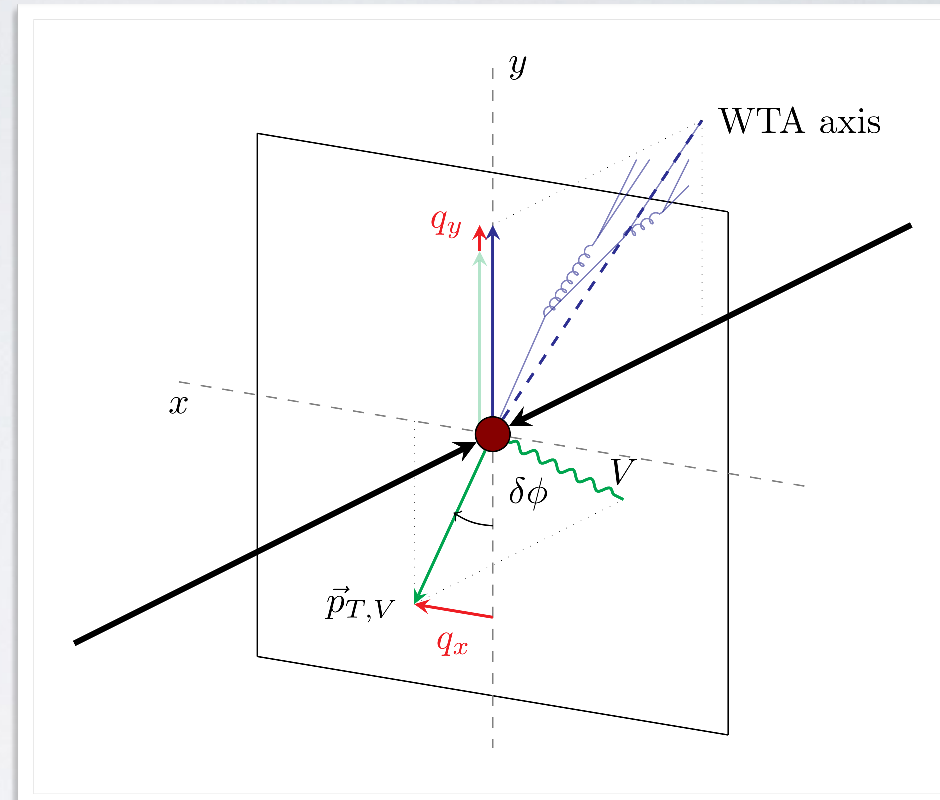

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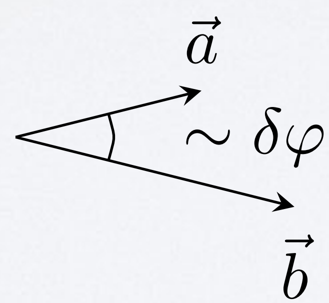


$\Rightarrow$ $(|\vec{a}| + |\vec{b}|) - |(\vec{a} + \vec{b})| \sim \delta\varphi^2$

- Large cancellation: $\cancel{p_{T,c}} + p_{T,S} = p_{T,S}$

$\Rightarrow$ Sensitive to in-jet soft $\Rightarrow$ NGL

CALCULATION

$$\frac{\mathrm{d}\sigma}{\mathrm{d}p_{x,V}\,\mathrm{d}p_{T,J}\,\mathrm{d}y_V\,\mathrm{d}\eta_J} = \int \frac{\mathrm{d}b_x}{2\pi}\, e^{\mathrm{i}p_{x,V}b_x} \sum_{i,j,k} B_i(x_a,b_x)B_j(x_b,b_x)S_{ijk}(b_x,\eta_J) \times \mathcal{H}_{ij\to Vk}(p_{T,V},y_V-\eta_J)\,\mathscr{J}_k(b_x)\Big[1+\mathcal{O}\Big(\frac{p_{x,V}^2}{p_{T,V}^2}\Big)\Big]$$

- NNLL resummation
  - 3-loop $\Gamma_{\rm cusp}$, 2-loop γ_i, 1-loop finite H,J,S,B

[Arnold, Reno, '89]
[Becher, Lorentzen, Schwartz, '12]
[Moch, Vermaseren, Vogt, '04/'05]
[Becher, Neubert, '09]
[Gehrmann, Luebbert, Yang, '14]
[Echevarria, Scimemi, Vladimirov, '16]
[Luebbert, Oredsson, Stahlhofen, '16]

- Most known, only minor recalculations:
  - S at NLO via boost (non-)invariance:

$$S_{ij}^{(1)}(b_x,\eta_J,\mu,\nu) = -\sum_{i<j} \mathbf{T}_i\cdot\mathbf{T}_j S^{(1)}\Big(b_x,\mu,\nu\sqrt{n_i\cdot n_j/2}\Big)$$

  - TMD jet function with η-regulator and large jet radius

[Gutierrez-Reyes, Scimemi, Waalewijn, Zoppi, '18/'19]
[Chiu, Jain, Neill, Rothstein, '12]

LINEAR POLARISATION

- Two Lorentz structures in gluon beam function

$$B_g^{\mu\nu}(\vec{b}_\perp,\mu,\nu) = \frac{-g_\perp^{\mu\nu}}{d-2} B_g^{(1)}(\vec{b}_\perp,\mu,\nu) + \left(\frac{g_\perp^{\mu\nu}}{d-2} + \frac{b_\perp^\mu b_\perp^\nu}{b_T^2}\right) B_g^{(2)}(\vec{b}_\perp,\mu,\nu)$$

[Catani, Grazzini, '11]

- $B_g^{(2)}$ contributes, with $\mathcal{H}^{(L)}_{qg\to Vq} \sim \dfrac{\hat{u} m_V^2}{\hat{s}\hat{t}}$

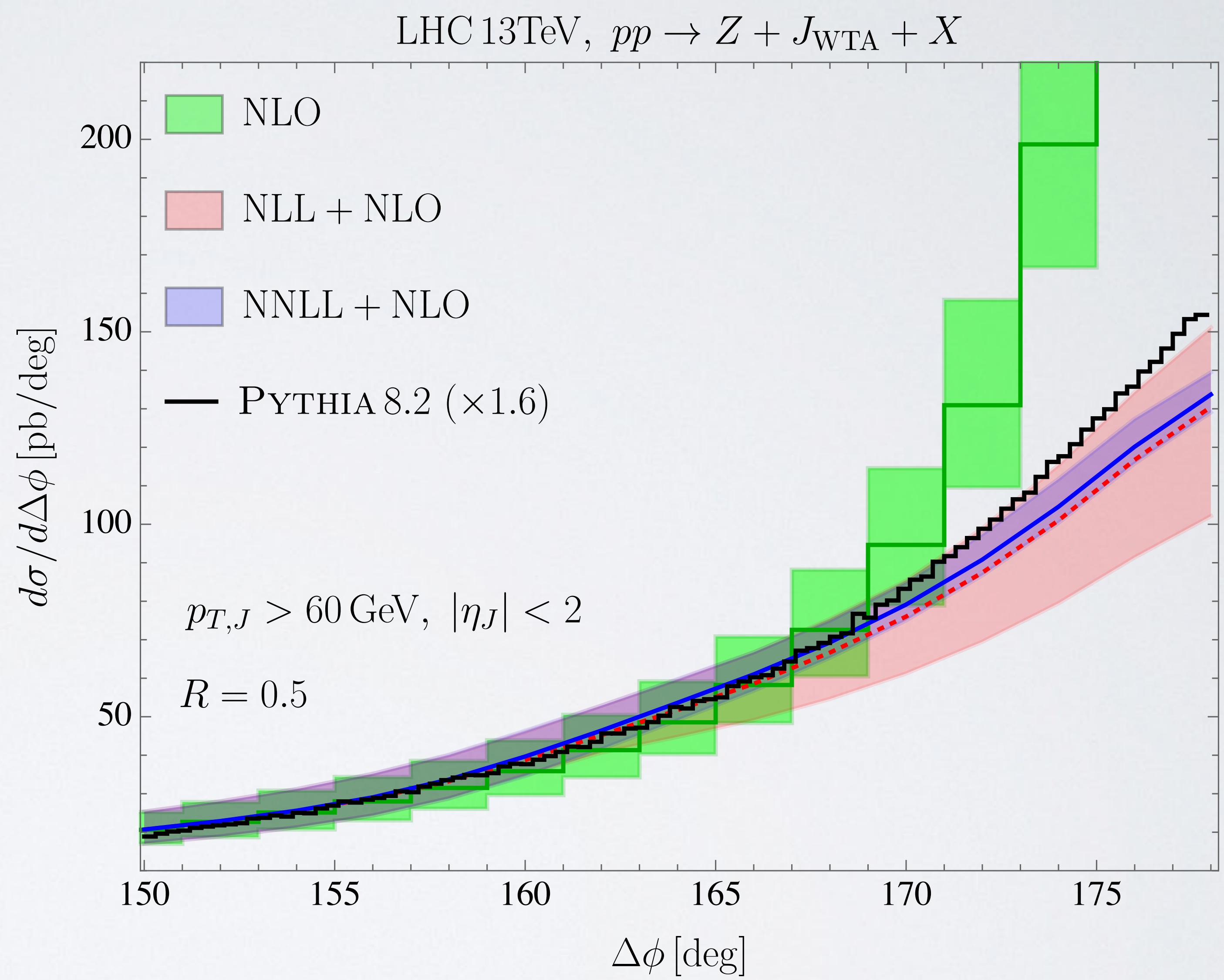
- Somewhat surprising, only one gluon

- Identically for gluon jet!

$$\mathscr{J}_g^{L(1)}(\vec{b}_\perp,\mu,\nu) = -\frac{1}{3}C_A + \frac{2}{3}T_F n_f$$

PLOTS I

- Using CT14nlo
- NLO from MCFM
- No difference Pythia hadron/parton
- Matching via transition function

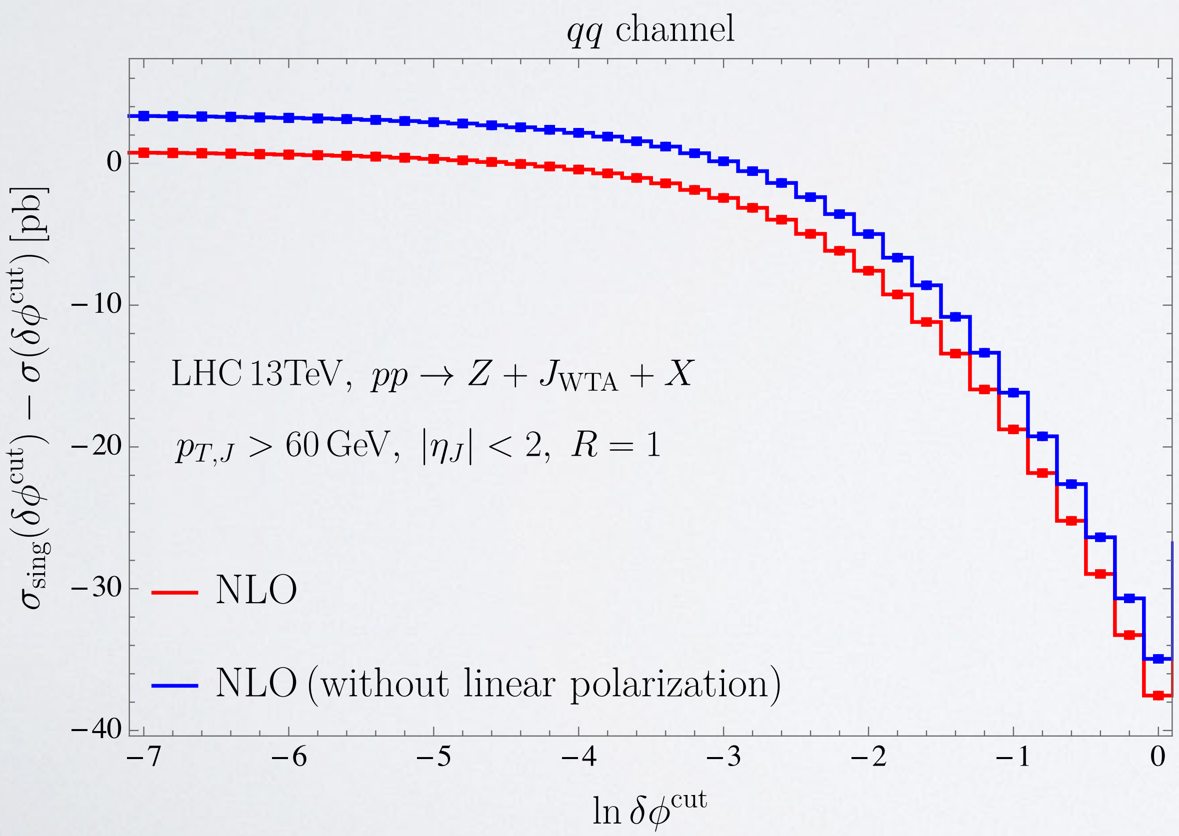


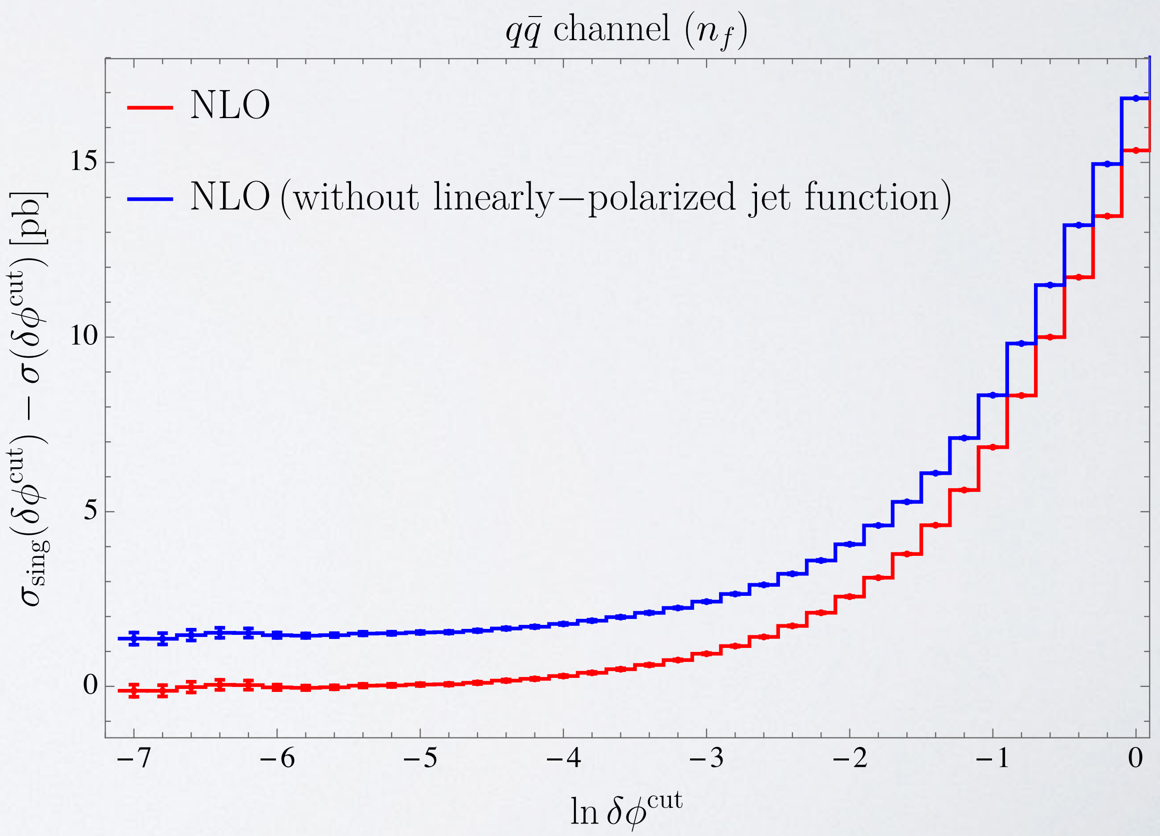
$$\mu_H = \sqrt{p_{T,V}^2 + m_V^2},\ \nu_S = \mu_B = 2e^{-\gamma_e}/|b_x|,\ \nu_{B_{a,b}} = x_{a,b}\sqrt{s},\ \nu_J = 2p_{T,J}\cosh\eta_J$$

Use b* prescription [Collins, Soper, Sterman, '85]

PLOTS II

- Linearly polarised beam and jet functions needed
- MCFM vs. Our singular:

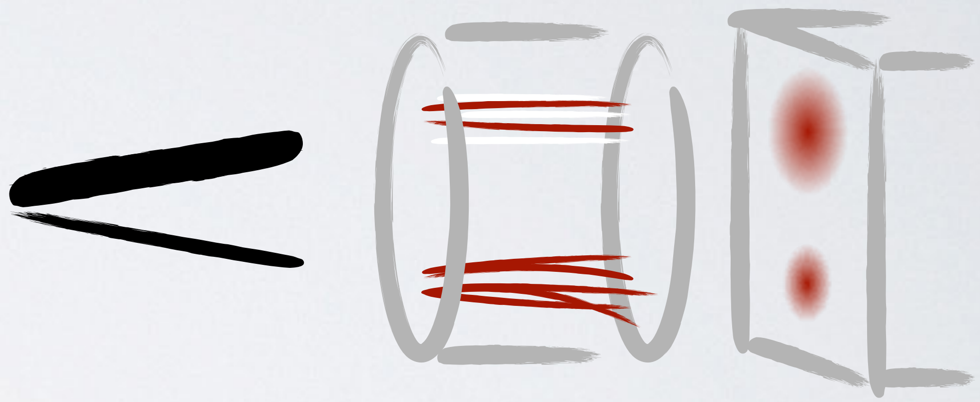




TRACKS

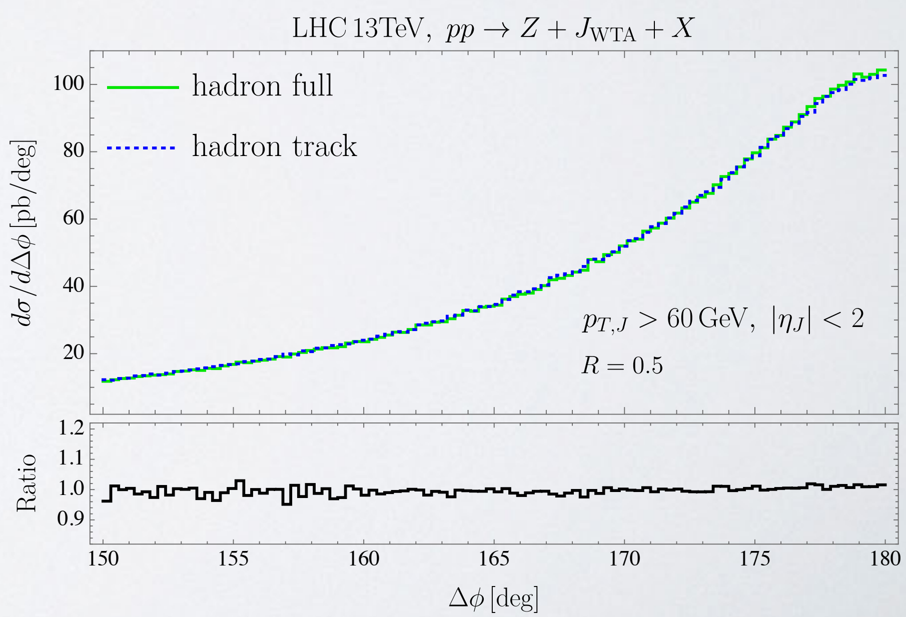
- Angular resolution of calorimetry could be a problem

⇒ Use charged particle tracks



- Only affects Jet function finite term

$$\bar{\mathscr{J}}_q^{(1)} = \mathscr{J}_q^{(1)} + 4C_F \int_0^1 \mathrm{d}x \, \frac{1+x^2}{1-x} \ln \frac{x}{1-x} \int_0^1 \mathrm{d}z_1 \, T_q(z_1,\mu) \times \int_0^1 \mathrm{d}z_2 \, T_g(z_2,\mu) [\theta(z_1 x - z_2(1-x)) - \theta(x - \tfrac{1}{2})]$$



- Track function T ⇒ after the break

[Chang, Procura, Thaler, Waalewijn, '13]

OUTLOOK / CONCLUSION

- Resummation for azimuthal decorrelation in V+jet
  - Surprisingly simple (WTA+SCET)
  - Surprisingly rich (linear polarisation)
  - Surprisingly flexible (Tracks)
- Still some work to do (Glauber contribution,…)