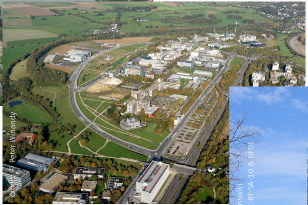
Arnd Behring

Particle physics on long-distance trains

My academic journey so far



Undergrad: TU Dortmund

PhD: DESY Zeuthen

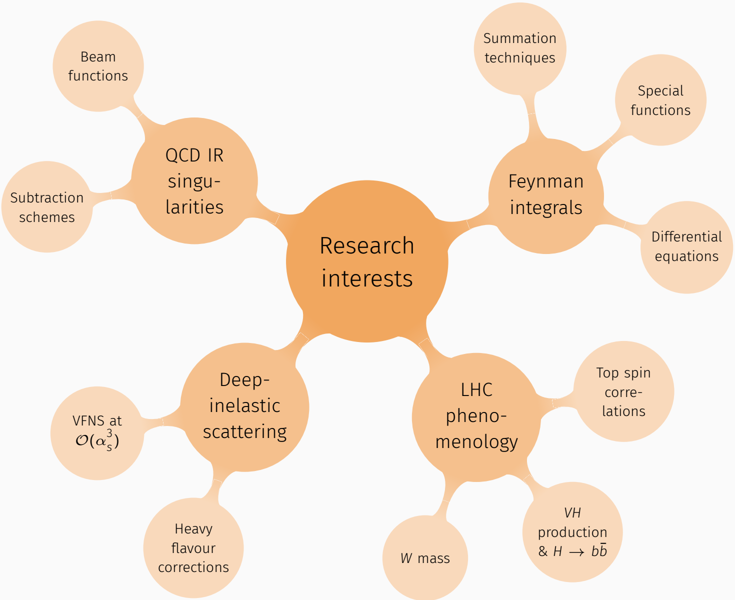
1st postdoc: RWTH Aachen

Karlsruher Institut für Technologie

2nd postdoc: KIT Karlsruhe

3rd postdoc: CERN

My research interests



Variable flavour number scheme at $O(\alpha_s^3)$

b quarks in initial state

massless u, d, s, c and massive b

- u, d, s, c PDFs
- b only produced perturbatively
- potentially large $\ln\left(Q^2/m_b^2\right)$

massless u, d, s, c and b

- u, d, s, c and b PDFs
- DGLAP equations resum collinear singularities

- Appropriate description depends on relevant scales of the process
- Match PDFs in both schemes at a matching scale, e.g.,

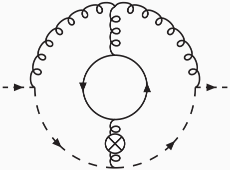
$$f_Q(n_f+1) + f_{\bar{Q}}(n_f+1) = A_{Qq}^{PS} \otimes \sum_k [f_k(n_f) + f_{\bar{k}}(n_f)] + A_{Qg} \otimes G(n_f)$$

Variable flavour number scheme at $O(\alpha_s^3)$ (cont.)

Matching coefficients A_{ij} can be calculated perturbatively:
Massive operator matrix elements (OMEs)

$$A_{ij} \sim \langle j|O_i|j\rangle$$

Until recently: 5 of 7 OMEs known to $O(\alpha_s^3)$
$\rightarrow$ Important, e.g., for N^{3}LO PDFs



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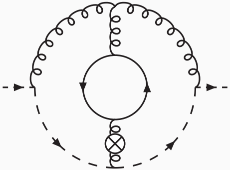

Many of the results in this project were obtained while on the train between Berlin $\leftrightarrow$ Dortmund/Bielefeld during my PhD

Variable flavour number scheme at $O(\alpha_s^3)$ (cont.)

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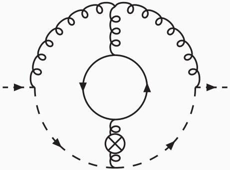
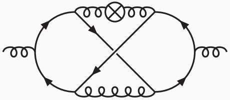


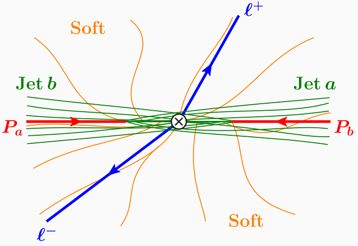
New progress in past few weeks: Finished $\mathrm{A}_{gg,Q}^{(3)}$
Enters matching relation for gluons:

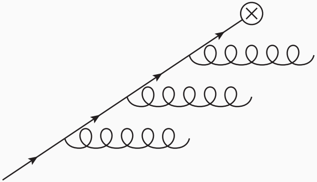
$$G(n_f+1) = A_{gq,Q}(n_f) \otimes \sum_k [f_k(n_f) + f_{\bar{k}}(n_f)] + \mathrm{A}_{gg,Q} \otimes G(n_f)$$



Paper (CERN-TH-2022-179) on arXiv later this week:
[J. Ablinger, AB, J. Blümlein, A. De Freitas, A. Goedicke, A. von Manteuffel, C. Schneider, K. Schönwald '22]

Beam functions for N-jettiness at N^{3}LO





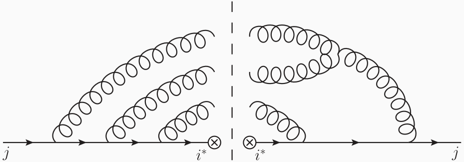
Long-running project to calculate the beam functions for N-jettiness (τ_N) at N^{3}LO
[Melnikov, Rietkerk, Tancredi, Wever '18] [Melnikov, Rietkerk, Tancredi, Wever '19]
[AB, Melnikov, Rietkerk, Tancredi, Wever '19]

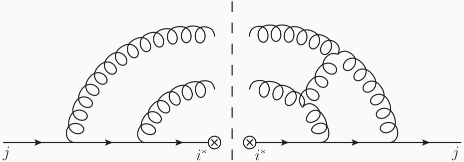
- Appear in factorisation theorem for $\tau_0 \to 0$

$$\lim_{\tau_0 \to 0} \sigma = B \otimes B \otimes S \otimes H \otimes \sigma_{\mathrm{LO}} + O(\tau)$$

- Describe collinear emissions off the initial state
- Building block for
  - Slicing scheme $\to$ differential description of colour singlet production at N^{3}LO
  - Resummation

Beam functions for N-jettiness at N^{3}LO (cont.)





Axial gauge calculation

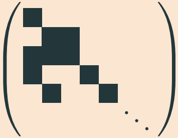
$$D^{\mu\nu}(k) = \frac{1}{k^2}\left(-g^{\mu\nu} + \frac{k^\mu \bar{p}^\nu + k^\nu \bar{p}^\mu}{k \cdot \bar{p}}\right)$$

Partial fraction rel. between MI

$$\frac{1}{(k_1 \cdot \bar{p})(k_2 \cdot \bar{p})} = \frac{2}{s\bar{z}}\left[\frac{1}{k_1 \cdot \bar{p}} + \frac{1}{k_2 \cdot \bar{p}}\right]$$

Canonical bases with square roots

$$\frac{\mathrm{d}}{\mathrm{d}z}\begin{pmatrix} I_1 \\ I_2 \\ \vdots \end{pmatrix} = \varepsilon$$

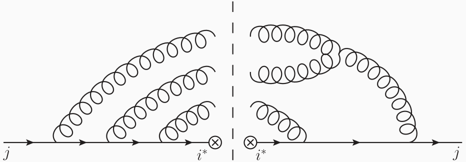


$$\begin{pmatrix} I_1 \\ I_2 \\ \vdots \end{pmatrix}$$

Iterated integrals with square roots

$$\int_0^z \frac{\mathrm{d}z'}{\sqrt{z'}\sqrt{4-z'}} \int_0^{z'} \frac{\mathrm{d}z''}{\sqrt{4+z''^2}} \int_0^{z''} \ldots$$

Beam functions for N-jettiness at N^{3}LO (cont.)



There are 5 independent matching coefficients:

- $q_j \to q_i$: Finished in Karlsruhe
- $g \to q$:
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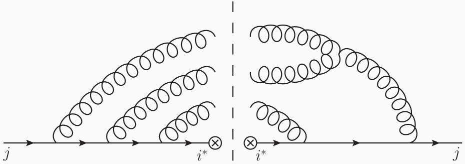
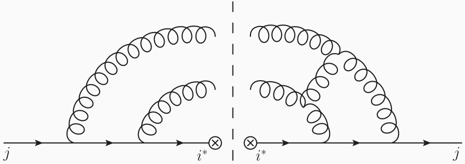
- $\bar{q}_j \to q_i$:

Beam functions for N-jettiness at N^3LO (cont.)





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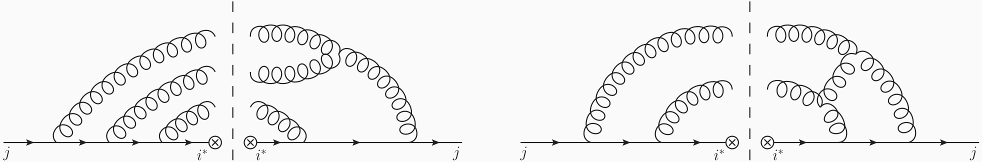

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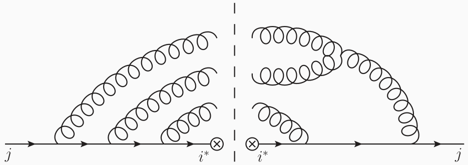

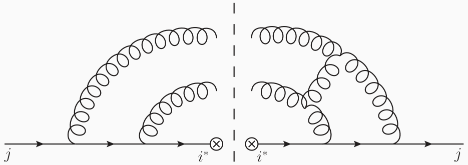

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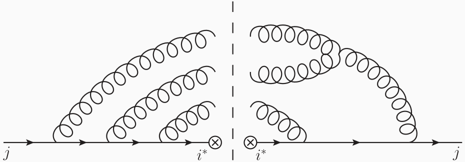

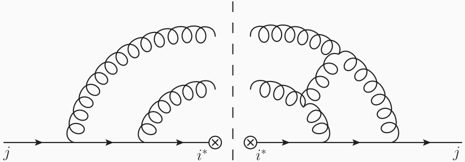

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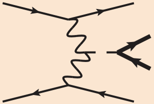
Paper (CERN-TH-2022-178) on arXiv later this week:
[D. Baranowski, AB, K. Melnikov, L. Tancredi, C. Wever '22]

Future directions

VBF & $h \to b\bar{b}$ @ NNLO with $m_b \neq 0$

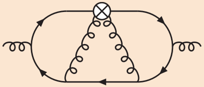
with K. Asteriadis, F. Caola, K. Melnikov, R. Röntsch



Effects from $m \neq 0$?
Flavour jet alg.?

Massive OME $A_{Qg}^{(3)}$

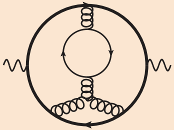
with J. Blümlein, A. De Freitas, C. Schneider, K. Schönwald



Last missing OME
New functions?

Four-loop ρ parameter

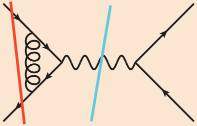
with S. Abreu, A. McLeod, B. Page



Two-mass contributions (m_b & m_t)
New functions?

Local unitarity for the LHC

with V. Hirschi, B. Ruijl, Z. Capatti



Deal with hadronic initial states