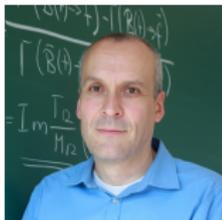


PRECISION QCD BEYOND FIXED-ORDER CALCULATIONS

[GUIDO BELL]



Who we are



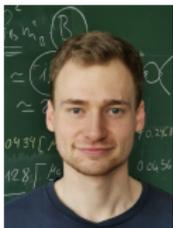
Guido Bell



Vladyslav Shtabovenko



Kevin Brune



Dennis Horstmann



Sebastian Edelmann



Tom Mockenhaupt

Research interests

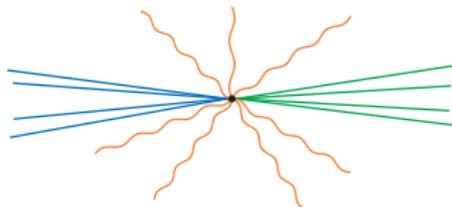
Our group works on different aspects of QCD:

- ▶ Precision resummations in Soft-Collinear Effective Theory
- ▶ Improving slicing techniques for NNLO QCD computations
- ▶ NNLO + PS calculations within the Geneva event generator
- ▶ Understanding factorisation at next-to-leading power
- ▶ Controlling non-perturbative effects to collider observables
- ▶ Development and maintenance of FeynCalc

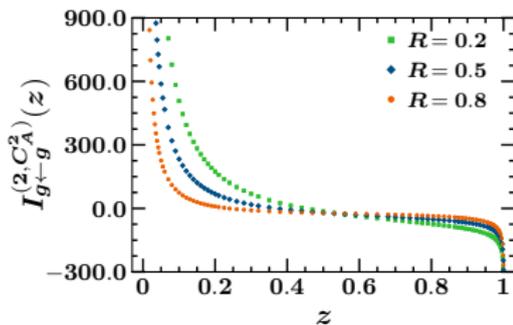
Precision resummations in SCET

QCD amplitudes factorise in soft and collinear limits

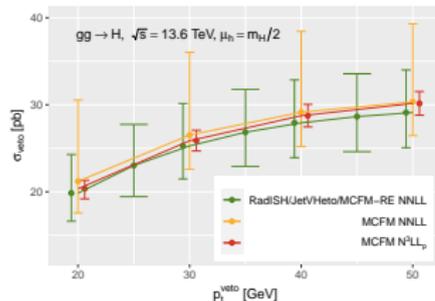
$$d\sigma \simeq H(\mu) \cdot B(\mu) \otimes B(\mu) \otimes S(\mu)$$



Automated framework to compute SCET ingredients



[Bell, Brune, Das, Shao, Wald 22,24]



[Campbell, Ellis, Neumann, Seth 23]

Slicing techniques

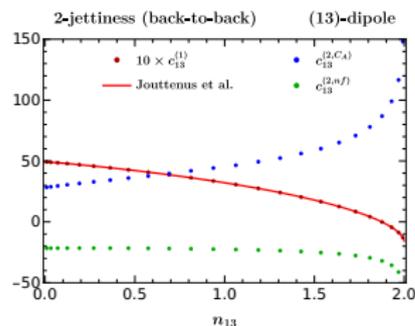
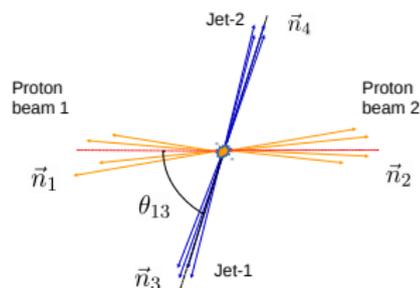
NNLO calculations based on phase-space slicing

$$d\sigma = \int_0^\delta d\tau_N \frac{d\sigma}{d\tau_N} + \int_\delta d\tau_N \frac{d\sigma}{d\tau_N}$$

$$\Big/ \delta \ll 1$$

$$\frac{d\sigma}{d\tau_N} = H \cdot B \otimes J \otimes \dots \otimes J \otimes S + \mathcal{O}(\tau_N)$$

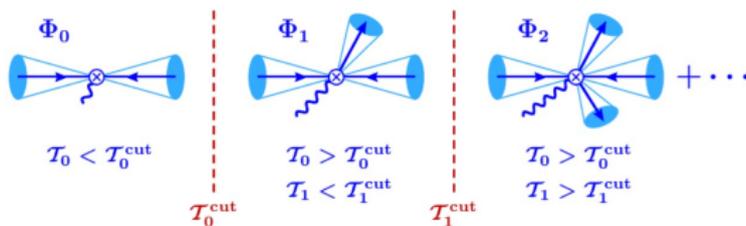
Extended jettiness-slicing to processes with two jets



[Bell, Dehnadi, Mohrmann, Rahn 23]

NNLO + PS

Geneva event generator uses N-jettiness to classify events into jet bins



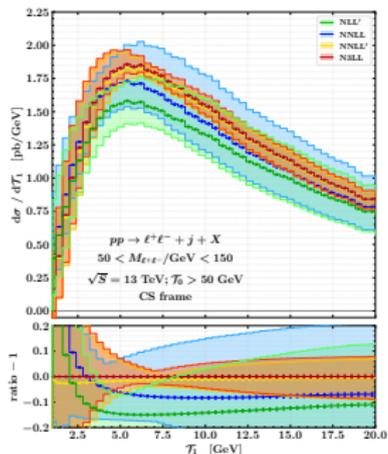
Extended scope of Geneva to

colour-singlet plus jet production

► N³LL resummation for 1-jettiness

in $pp \rightarrow (\gamma^*/Z \rightarrow \ell^+\ell^-) + \text{jet}$

[Alioli, Bell, Billis, Broggio, Dehnadi, Lim, Marinelli,
Nagar, Napoletano, Rahn 23]



Next-to-leading power

Factorisation at next-to-leading power highly non-trivial

$$\frac{d\sigma}{d\tau_N} = H \cdot B \otimes B \otimes J \otimes \dots \otimes J \otimes S + \mathcal{O}(\tau_N)$$

Very active field in SCET community

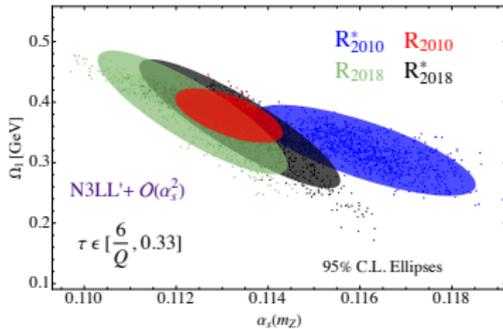
- ▶ threshold resummation [Beneke et al 18-23]
- ▶ bottom-quark contribution to $H \rightarrow \gamma\gamma$ and $gg \rightarrow H$ [Neubert et al 19-22]
- ▶ thrust distribution [Stewart et al 18, Beneke et al 22]
- ▶ **muon-electron backward scattering** [Bell, Böer, Feldmann 22]
- ▶ virtual Compton scattering [Schoenleber, Szafron 25]
- ▶ **exclusive B decays** (\rightarrow RA2) [Bell, Böer, Feldmann, Horstmann, Shtabovenko 24]

Non-perturbative effects

Precision determination of α_s from e^+e^- event shapes

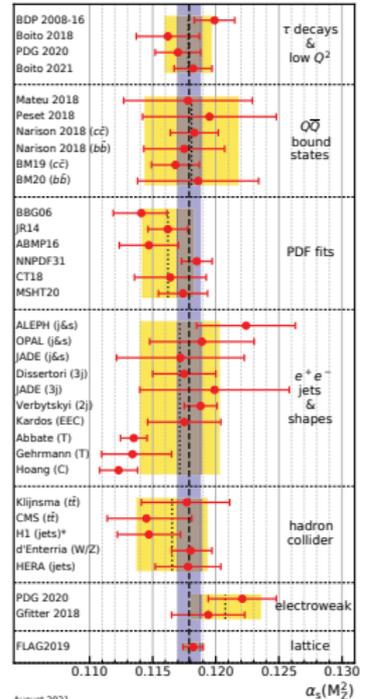
$$\alpha_s(M_Z) = \begin{cases} 0.1179 \pm 0.0009 & \text{PDG world average} \\ 0.1135 \pm 0.0011 & \text{Thrust} \end{cases} \quad [\text{Abbate et al 10}]$$

Requires robust understanding of non-perturbative effects



[Bell et al 23]

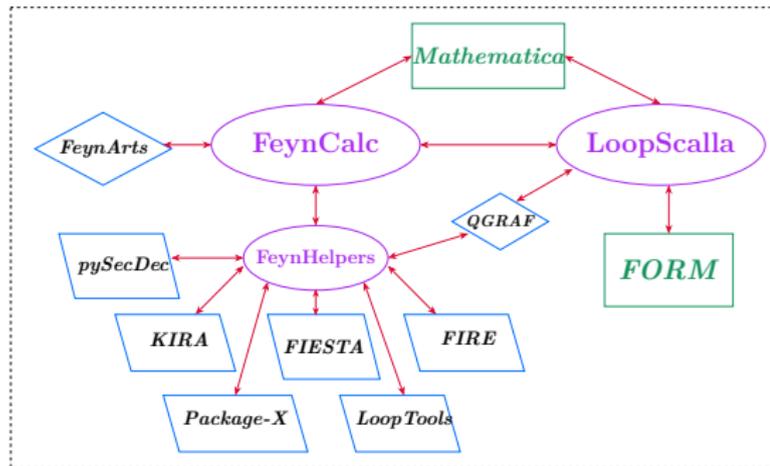
⇒ sign of underestimated theory uncertainties?



FeynCalc 10

General-purpose framework for multi-loop calculations

[Shtabovenko, Mertig, Orellana 23]



- ▶ interface to popular tools
- ▶ user-friendly input via Mathematica
- ▶ new LoopScalla framework
- ▶ efficient manipulations in FORM

Synergies in RA3

We are currently extending the Geneva framework to top-quark processes

- ▶ NNLO + PS predictions for $t\bar{t}$ and $t\bar{t}X$ production

Connection to precision phenomenology group in Bonn

- ▶ multi-loop and slicing / resummation technology is complementary

Analytic understanding of non-perturbative effects

- ▶ α_s from Z-boson p_T spectrum in ATLAS, top-mass determination, . . .

Happy to learn about further connections