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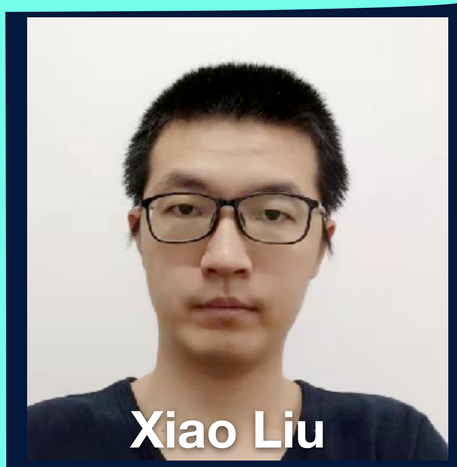

Xiao Liu


Federica Devoto


Giulio Gambuti


Fabrizio Caola


Jasmine Brewer


Silvia Zanoli


Radek Grabarczyk @ CERN/ATLAS


Javira Altmann


Peter Skands

Postdocs


Jack Helliwell

PhD students

visiting from Monash

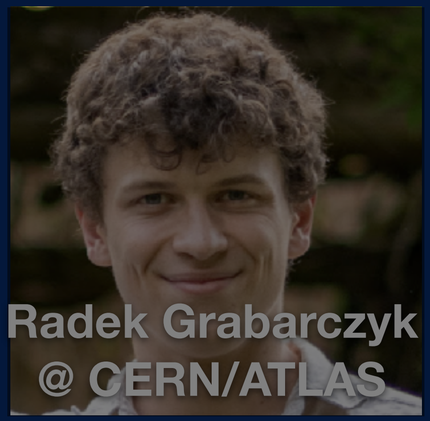

Gavin Salam

UNIVERSITY OF OXFORD

hadrons ⟷ partons
& everything in between
in vacuum or medium


Jasmine Brewer


Silvia Zanoli


Radek Grabarczyk
@ CERN/ATLAS


Javira Altmann


Peter Skands


Jack Helliwell


Gavin Salam

Gavin Salam

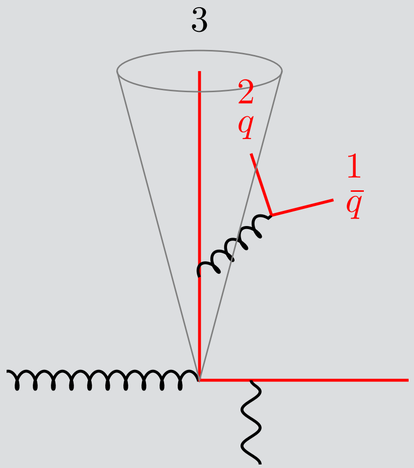
funded by
Royal Society Research Professorship,
All Souls College
ERC & STFC

Main interests

- Parton showers
  (PanScales project)
- Jet-physics
  (anti-kt algorithm, FastJet, flavour)
- Higgs studies
  (e.g. VBF @ NNLO, jet vetoes)
- Parton Distribution Functions
  (e.g. hoppet, LUXqed photons)
- BSM searches
  (jet substructure, ColliderReach)
- heavy-ion collisions
  (e.g. top-quarks as yoctosecond chronometer)
- What we learn from current colliders
  (2022: Nature perspective article)
- Motivations for future colliders

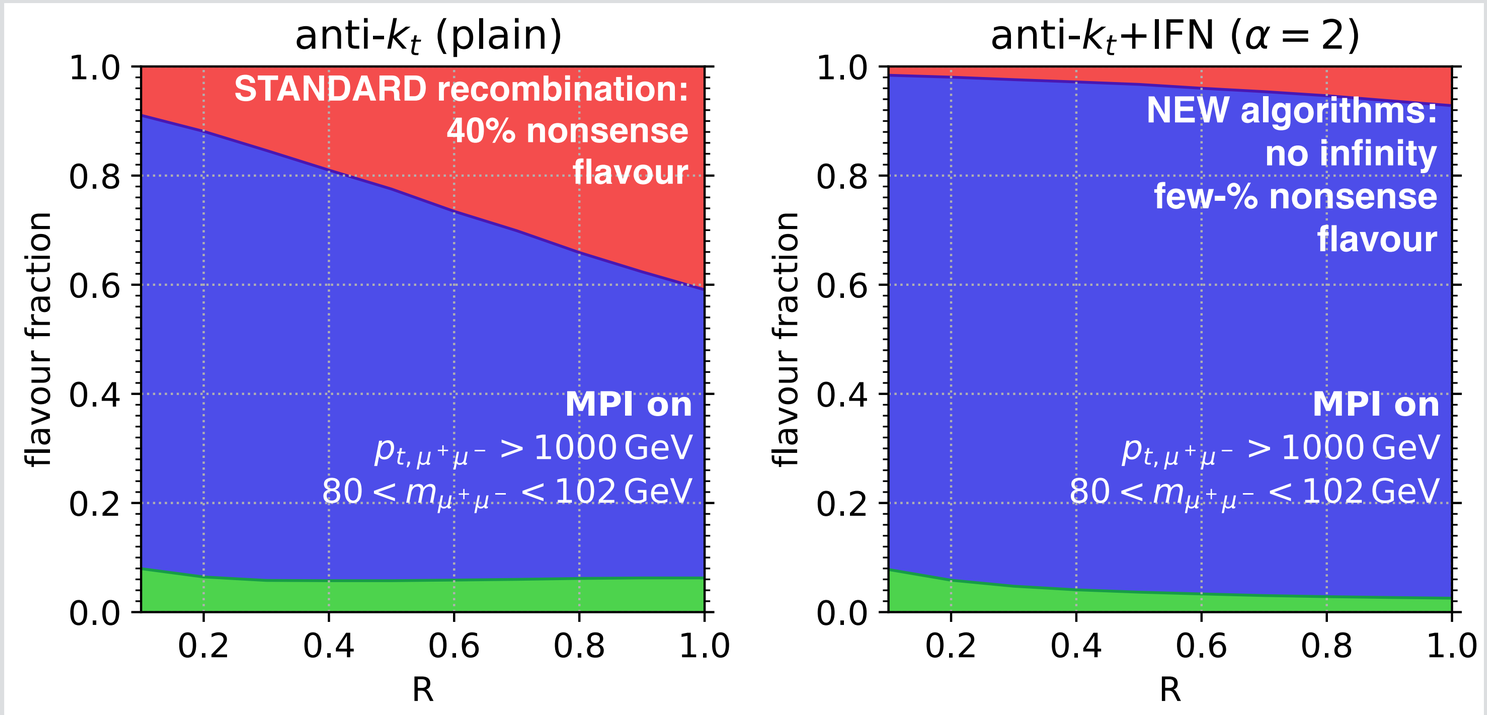
Jet flavour: making it IR safe for anti-kt jet algorithm

With Fabrizio Caola, Radek Grabarzcyk, Max Hutt, Ludo Scyboz, Jesse Thaler, 2306.07314 → PRD editors' suggestion



To make jet flavour **collinear** safe: just add flavours at each recombination; but→ **infrared divergent**

To make it **collinear & IR** safe: at each kinematic recombination, examine and combine flavour globally



PanScales

Bringing
logarithmic accuracy
to parton showers

2018: principles of what a NLL shower should achieve

2020: proof of concept NLL e^+e^- shower

2022: proof of concept NLL pp shower

2023: first steps towards **NNLL – e^+e^- double soft**
(+ see Jack's slides for collinear work)

Double soft emission kernel + single-soft virtual

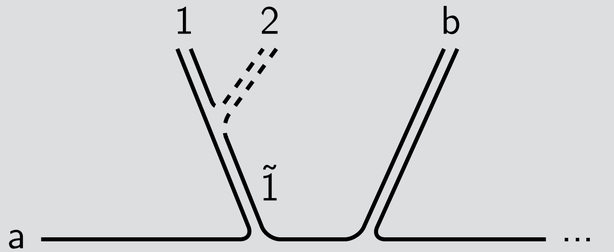
Iterated consistently within shower

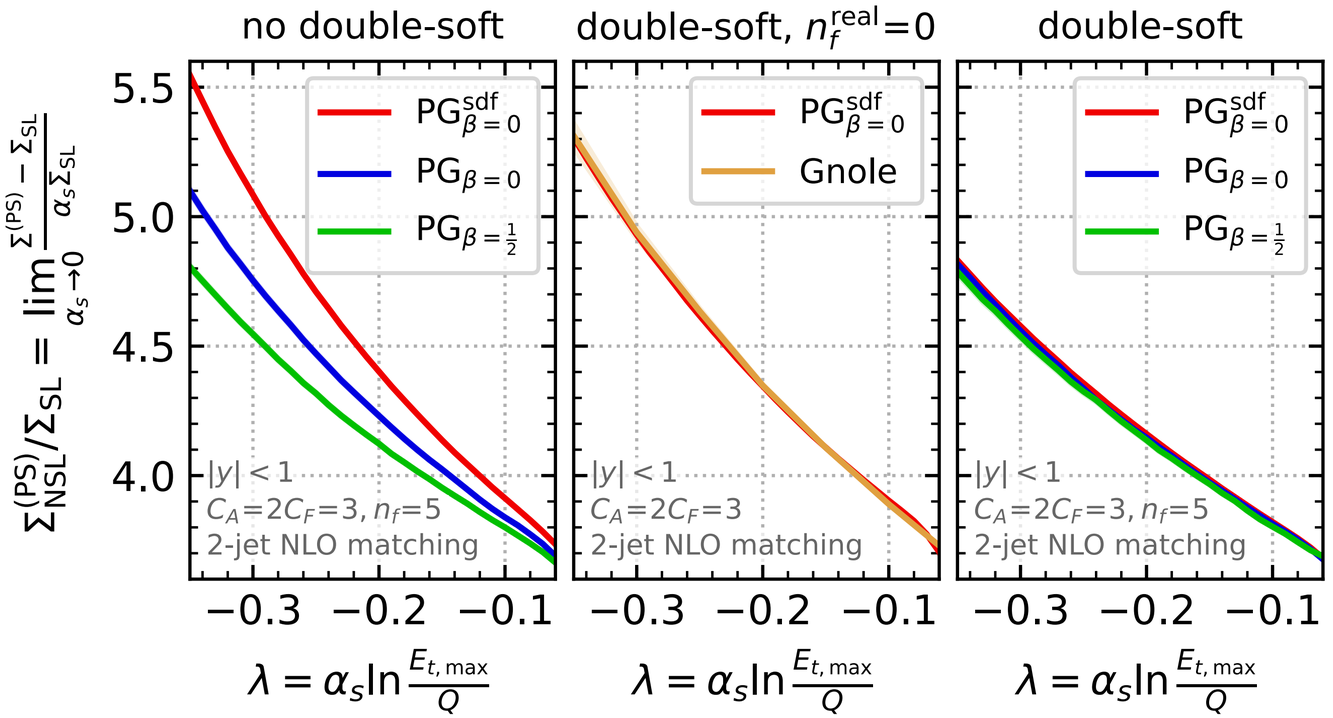
Achieves:

$\alpha_s^n L^{2n-2}$ for multiplicities (NNDL)

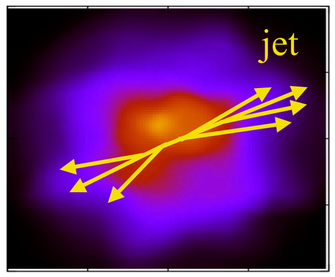
$\alpha_s^n L^{n-1}$ for non-global logarithms ("NSL")

2307.11142





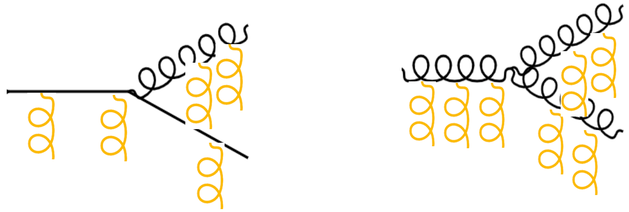
Silvia Ferrario Ravasio,[1] Keith Hamilton,[2] Alexander Karlberg,[1]
Gavin P. Salam,[3,4] Ludovic Scyboz,[3] and Gregory Soyez[1,5]



Jets as a probe of the quark-gluon plasma in heavy-ion collisions

Jasmine Brewer

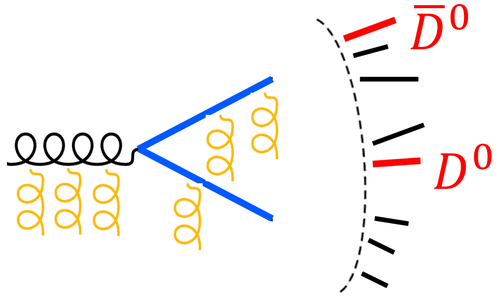
- Flavor dependence of jet modification



Separating quark and gluon substructure and their modification

JB, Jesse Thaler, Andrew Patrick Turner [2008.08596]; Ying, JB, Chen, Lee [2204.00641]

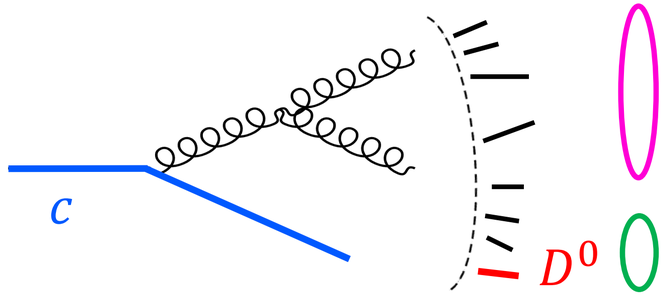
- Medium modification of $g \to c\bar{c}$ splitting



- Medium-enhanced production of $c\bar{c}$ pairs
- Signatures of momentum broadening and formation time dependence?

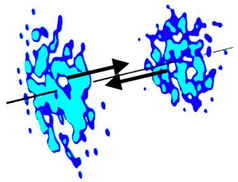
Attems, JB, Innocenti, Mazeliauskas, Park, van der Schee, Wiedemann [2203.11241], [2209.13600], and ongoing work

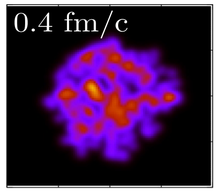
- New opportunities in heavy flavor substructure modification

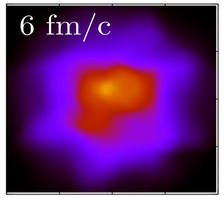


Leveraging different modification of quark and gluon substructure?

JB, Takacs, Zardoshti [*ongoing work*]

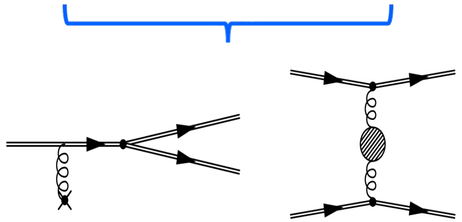






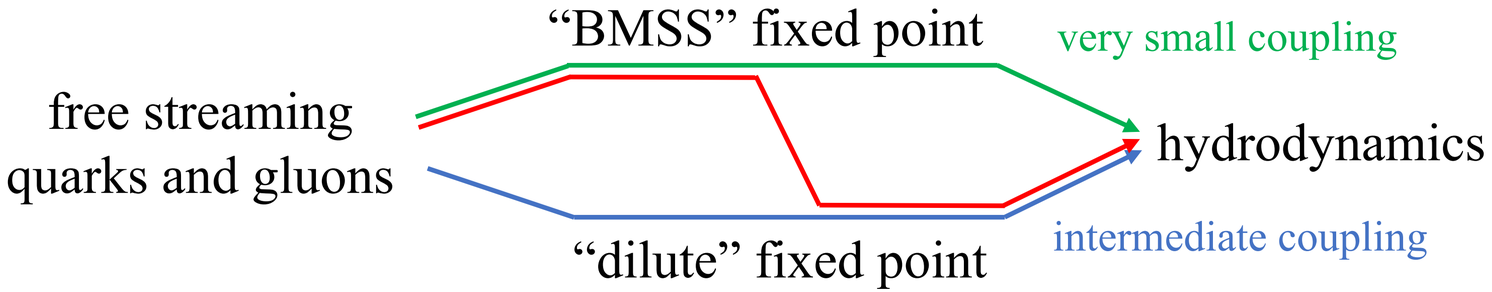
Thermalization in QCD and connection to jet physics

far from equilibrium | hydrodynamics



- Universal features of QCD equilibration

Fixed points of weak-coupling QCD: different paths to hydrodynamics



JB, Scheihing-Hitschfeld, Yin [2203.02427]

Slow decay of initial-state momentum anisotropies far-from-equilibrium

JB, Ke, Yan, Yin [2212.00820]

- Intersection of jets and equilibration

Equilibration of high-momentum partons in QCD kinetic theory

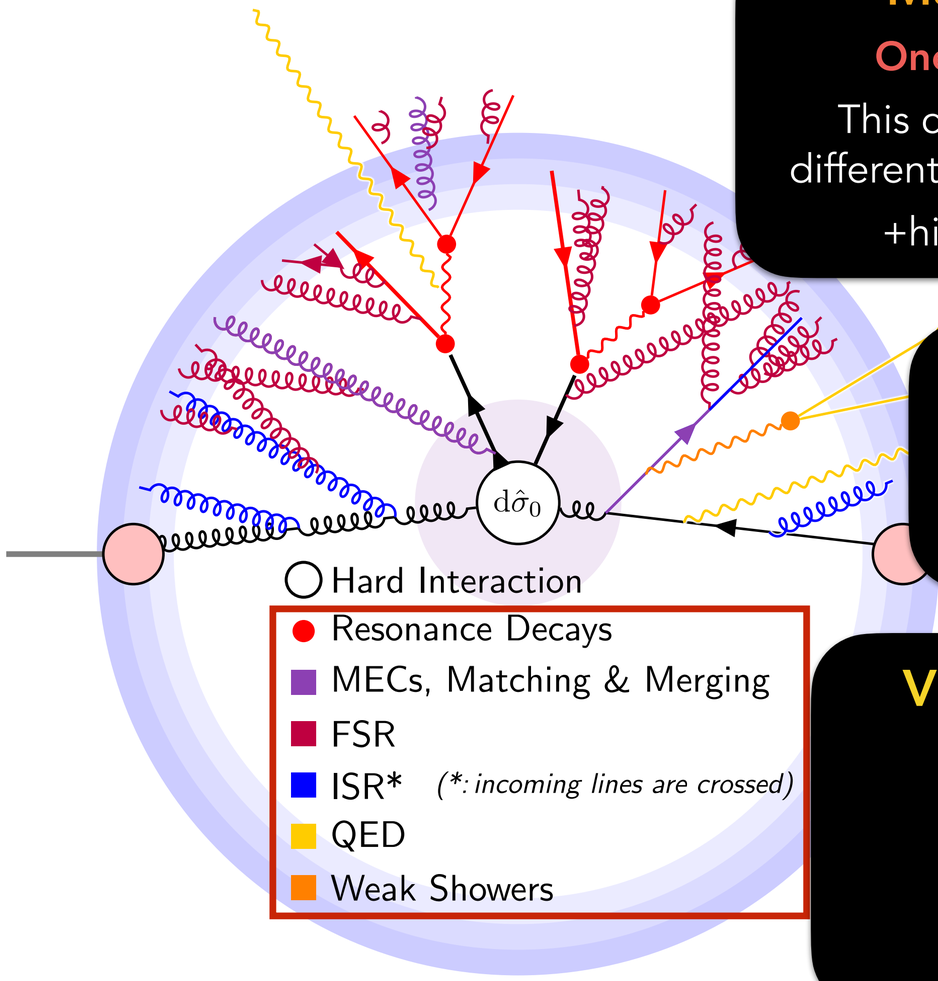
Zhou, JB, Mazeliauskas [2308.01177]

Peter Skands

RS Wolfson Visiting Fellow

U of Oxford / Monash U.

1: Parton-Level MC Models



Main Project: VINCIA sector showers [with C. Preuss]

One shower history instead of a factorial number [Villarejo & PS, '11]

This can be exploited to formulate comparatively simple and fully-differential ME+PS matching/merging strategies at LO, NLO, NNLO, …

+highly efficient: may even be ***faster than pure fixed order?***

VINCIA Resonance Decays [Brooks, PS, Verheyen, '19, '22]

New treatments of unstable particles: **Resonance-Final (RF) Showers** (initial-final coherence) and **Interleaved Resonance Decays** (decays as ~ shower branchings)

VINCIA QED (& Weak) Showers [Brooks, PS, Verheyen, '20, '22]

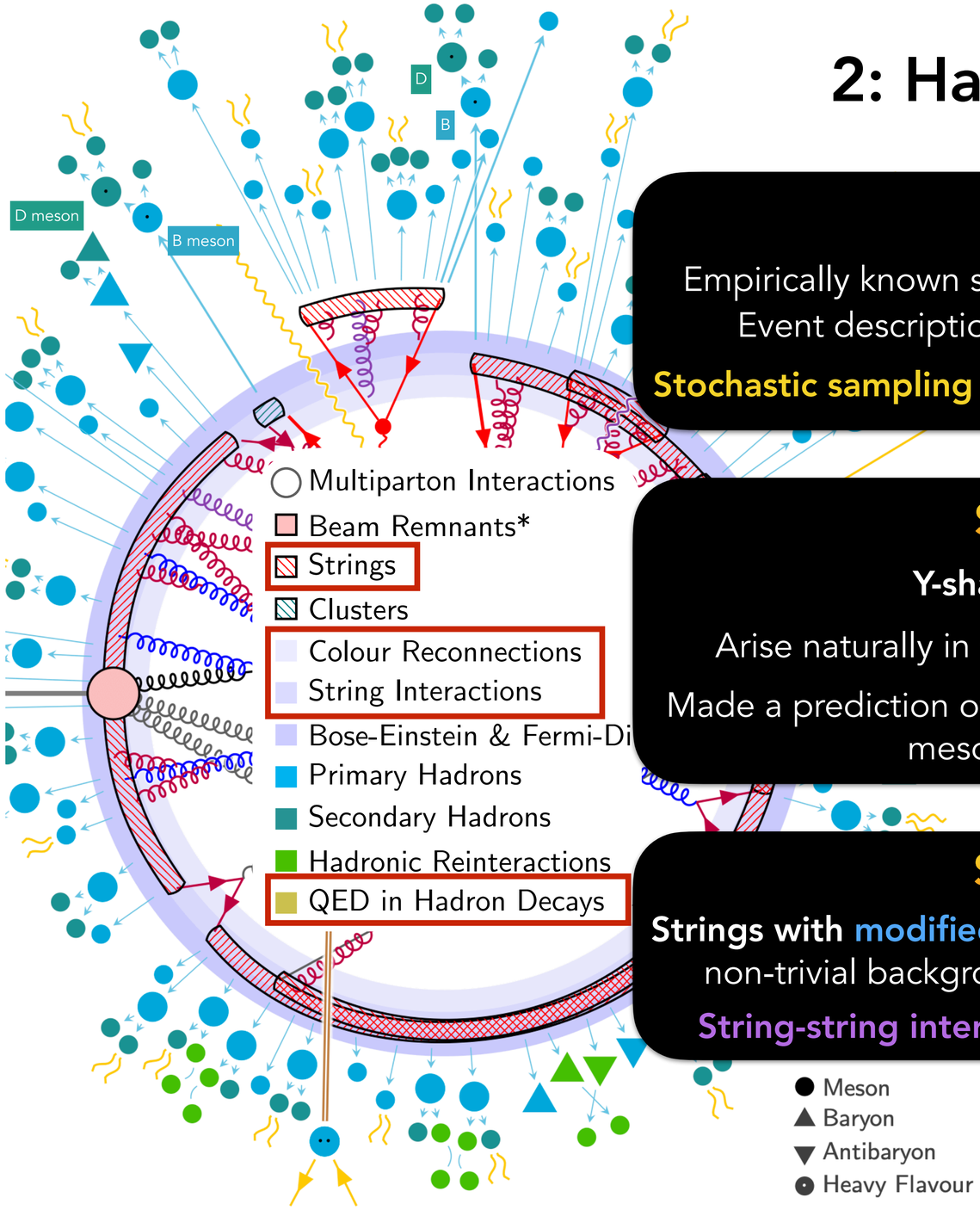
Unique **QED multipole** antenna shower [Verheyen & PS, '20]
(**all** soft & collinear limits whereas YFS captures only soft)

+ can be **interleaved** with QCD and/or resonance decays

Now considering applications to **QED in B decays**
[with LHCb / Warwick]

Australian Government
Australian Research Council

2: Hadron-Level MC Models



Colour Reconnections

Empirically known since ~ 80s to be important for Min-Bias/Underlying-Event description (*e.g.*, $\langle p_\perp \rangle (n_{\mathrm{ch}})$). Many models over the years.

Stochastic sampling of SU(3) correlations at end of shower [Christiansen & PS, '15]

String Junctions [with J. Altmann]

Y-shaped string topologies [Sjöstrand & PS, '02]

Arise naturally in QCD-CR model, e.g., according to $3 \otimes 3 = 6 \oplus \bar{3}$

Made a prediction of factor-10 enhancements in heavy-flavour baryon-to-meson ratios at LHC. Observed by ALICE!

String Dynamics [with J. Altmann]

Strings with modified tension: invariant-time dependence (cooling down), non-trivial backgrounds / higher-representations (Casimir scaling), …

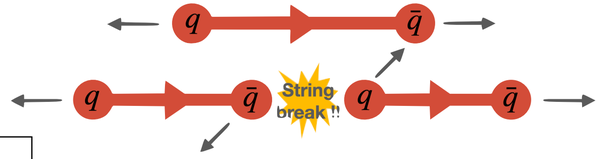
String-string interactions in momentum space: repulsion / attraction

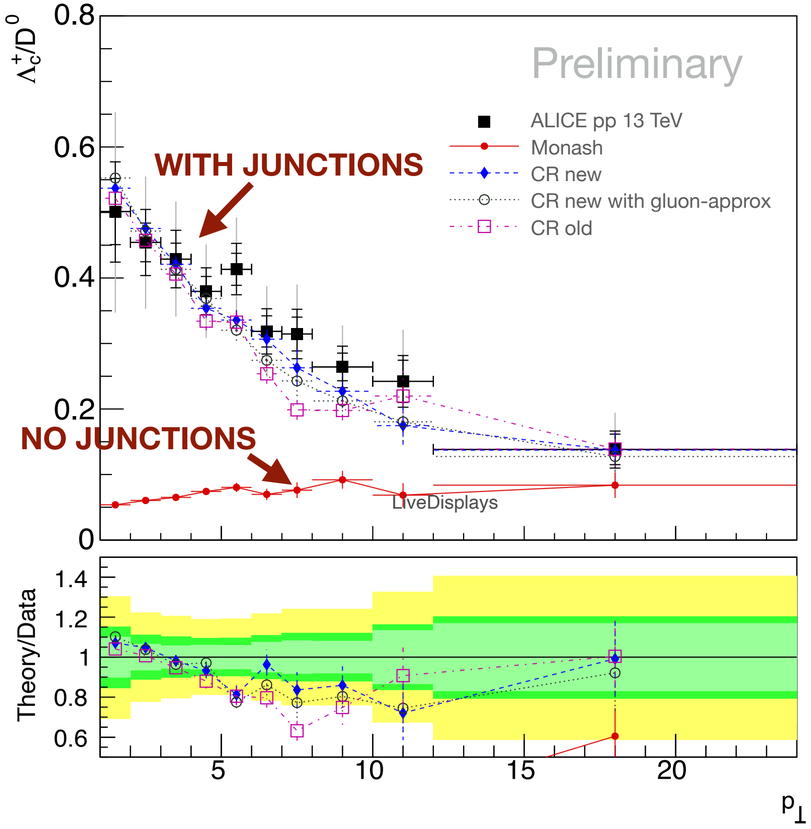
Javira Altmann

Junction Fragmentation Updates in PYTHIA

Hadronisation - The Lund String Model

- Maps partons to hadrons
- Uses **strings** to model the **colour confinement field,** *i.e.* stretched between colour-charged particles to form overall colour singlet
- Partons move apart and "break" the string, creating new quark-antiquark pair





Junctions

Red, **green** and **blue** colour singlet state

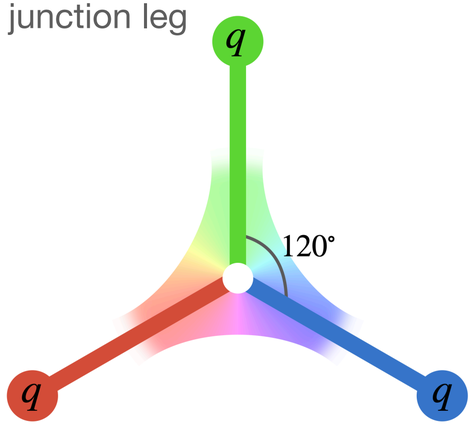
- Mechanism for **baryon production**
- Perform fragmentation in junction rest frame (JRF)
  - In practice, use an **average junction rest frame**
- ~40% of baryons are from junctions in PYTHIA

~70% of heavy baryons are from junctions in PYTHIA

Junction Rest Frame

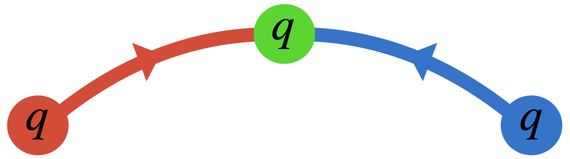
Mercedes frame

120° between each junction leg



Pearl-on-a-string

NEW



If Mercedes frame isn't possible, **junction gets "stuck"** to the quark

- More likely to occur for heavy quark endpoints

For a junction to make a **heavy baryon**, the junction leg with the heavy quark can't fragment (*i.e.* a "soft" junction leg) **= pearl-on-a-string!**

Updates to junction fragmentation:

- New iterative procedure without reliance on convergence
- Includes pearl-on-a-string
- Approximates light pearls as a gluon kink

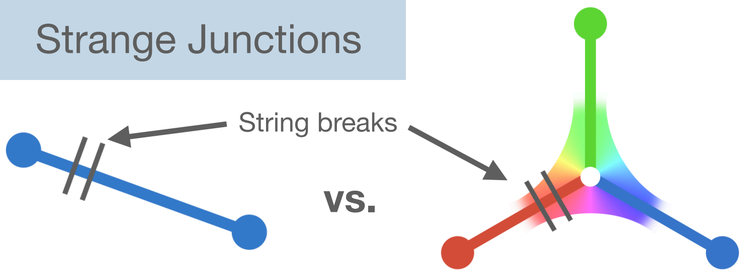
Collective Effects

Strangeness Enhancement

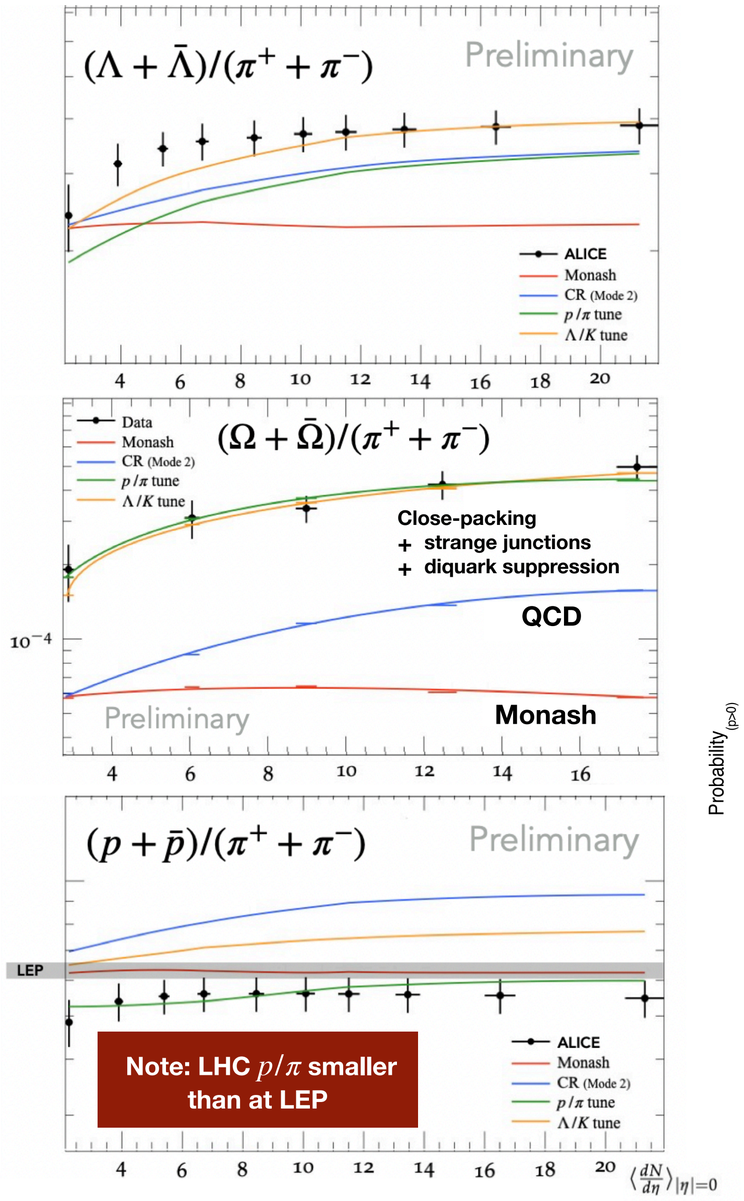
Close-packing

Dense string environments
→ Casimir scaling of effective string tension
→ Higher probability of strange quarks

Strange Junctions

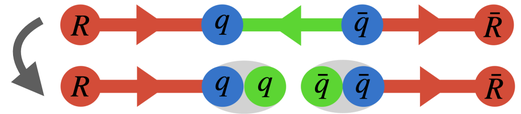


String tension could be different from the vacuum case compared to near a junction

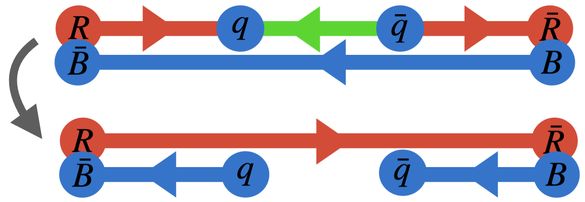


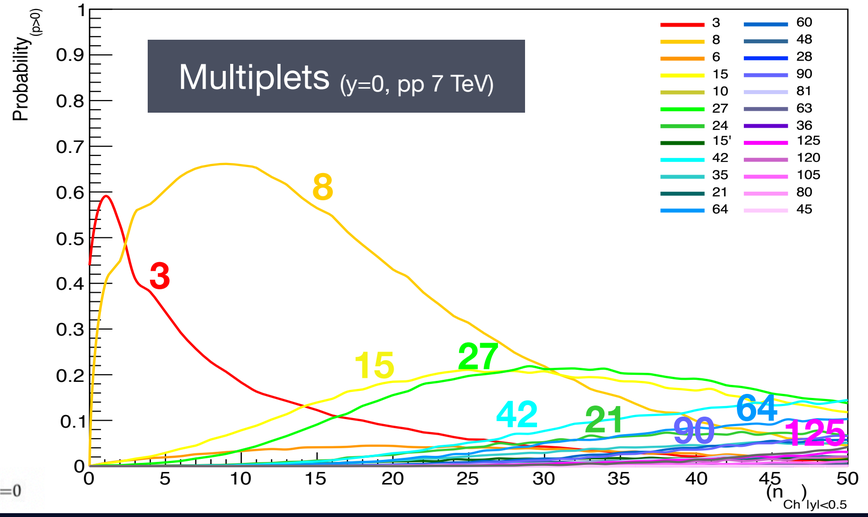
Diquark Suppression

Diquark formation via successive colour fluctuations (popcorn mechanism)



What if we allow the blue fluctuation to break a nearby string?





Jack Helliwell
Postdoctoral research assistant
University of Oxford

UNIVERSITY OF OXFORD

Specific interests: Resummation, Parton Showers, Jet Substructure

Today: collinear logarithms at NNLL ($\exp(\alpha_s^n L^{n-1})$)

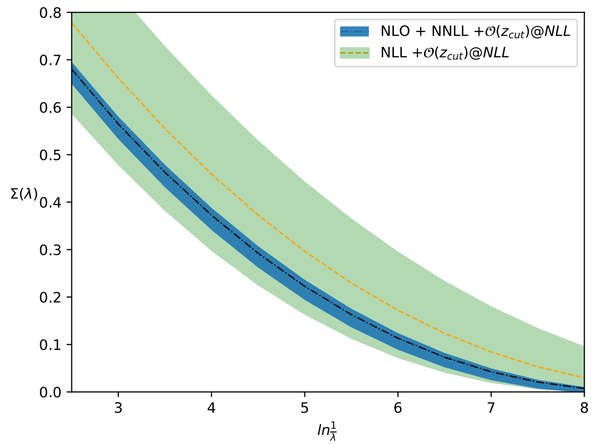
$$S = \exp\left[-\int_{b_0^2/b^2}^{Q^2} \frac{\mathrm{d}q^2}{q^2}\left(A(\alpha_s(q^2))\ln(Q^2/q^2) + B\big(\alpha_s(q^2)\big)\right)\right]$$

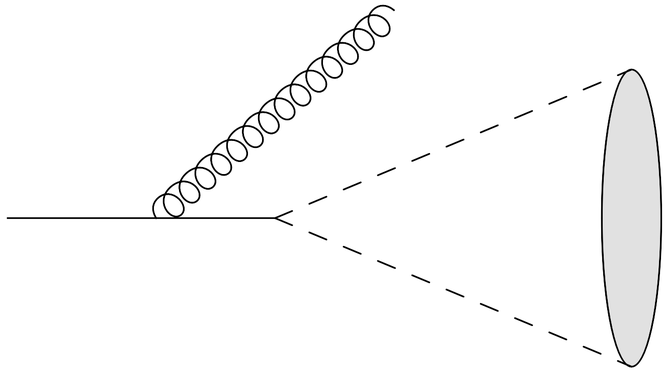
$$B(\alpha_s(q^2)) = \sum_n \left(\frac{\alpha_s(q^2)}{2\pi}\right)^n B_n$$

collinear logarithms at NNLL $\rightarrow$ B_2 (which is observable dependent)

NNLL Collinear Logarithms

- Can extract B_2 from a fixed order calculation in the collinear limit (Anderle, Dasgupta, El-Menoufi, JH, Guzzi, 2007.10355)
- Can be used e.g. in resummation of groomed angularities (see plot) (Dasgupta, El-Menoufi, JH, 2211.03820)
- Can define a more differential object - $B_2(z)$(Dasgupta, El-Menoufi 2109.07496) Calculated for gluons in (van Beekveld, Dasgupta, El-Menoufi, JH, Monni, 2307.15734)
- $B_2(z)$ can be used with generating functionals to address a wide class of collinear resummation problems (van Beekveld, Dasgupta, El-Menoufi, JH, Monni, 2307.15734)
- Also an ingredient for NNLL parton showers





Silvia Zanoli

Postdoctoral Research Assistant

Fulford Junior Research Fellow at Somerville College

- **PhD at Max Planck Institute for Physics** - supervision of Giulia Zanderighi
- **Postdoc at University of Oxford** - joint position between Fabrizio Caola's and Gavin Salam's groups

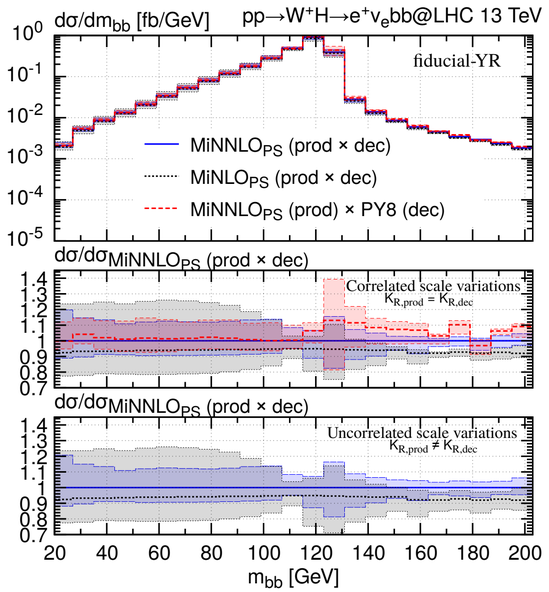
PhD research: matching between fixed-order computations and parton showers (LL) at NNLO accuracy in QCD using the MiNNLO$_{\mathrm{PS}}$ method. [Monni, Nason, Re, Wiesemann, Zanderighi '19]

$$\mathrm{d}\sigma^{\mathrm{MiNNLO_{PS}}} = \bar{\mathrm{B}}^{\mathrm{MiNNLO_{PS}}}\,\mathrm{d}\Phi_{\mathrm{FJ}}\left\{\Delta_{\mathrm{pwg}}(\Lambda) + \Delta(\mathrm{p_T})\frac{\mathrm{R}(\Phi_{\mathrm{F}},\Phi_{\mathrm{rad}})}{\mathrm{B}(\Phi_{\mathrm{F}})}\mathrm{d}\Phi_{\mathrm{rad}}\right\}$$

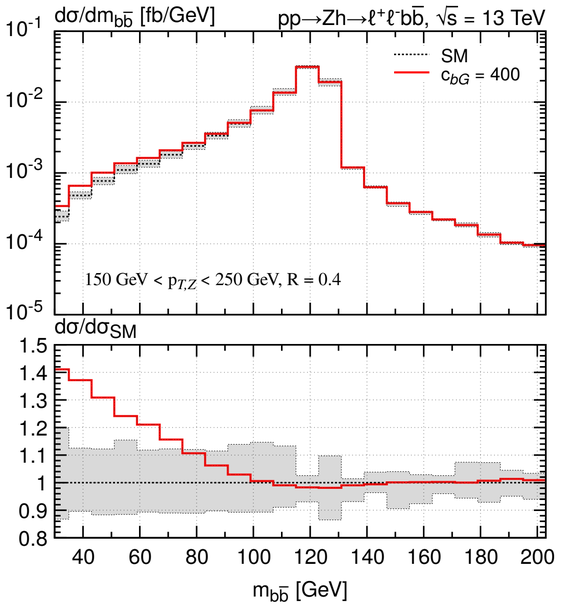
$$\bar{\mathrm{B}}^{\mathrm{MiNNLO_{PS}}} \sim \mathrm{e}^{-\mathrm{S}}\left\{\mathrm{d}\sigma^{(1)}_{\mathrm{FJ}}\left(1+\mathrm{S}^{(1)}\right) + \mathrm{d}\sigma^{(2)}_{\mathrm{FJ}} + \left(\mathrm{D}-\mathrm{D}^{(1)}-\mathrm{D}^{(2)}\right)\right\}$$

2019	H/Z	[1908.06987]
2020	$Z\gamma$	[2010.10478]
	tt	[2012.14267]
	W	[2006.04133]
2021	WW	[2103.12077]
	ZZ	[2108.05337]
	VH (H→bb)	[2112.04168]
2022	VH (H→bb) (SMEFT)	[2204.00663]
	$\gamma\gamma$	[2204.12602]
	WZ	[2208.12660]
2023	bb	[2302.01645]

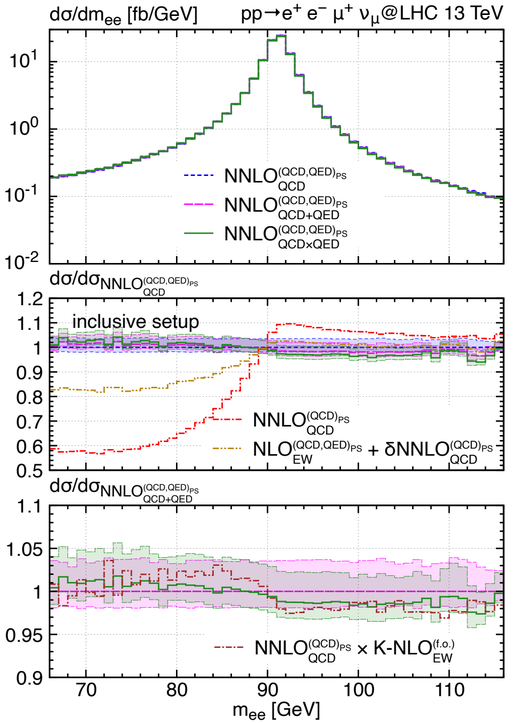
Precision Higgs physics



Possible SMEFT effects in Higgs sector



Inclusion of NLO EW effects



Ongoing projects:

- Inclusion of NLO EW effects without a-posteriori reweighting
- Extension to F+1jet processes

Current research:

NNLO+PS(LL) → NLO+PS(NLL)