UNIVERSITY OF SUSSEX

MARIE CURIE ACTIONS

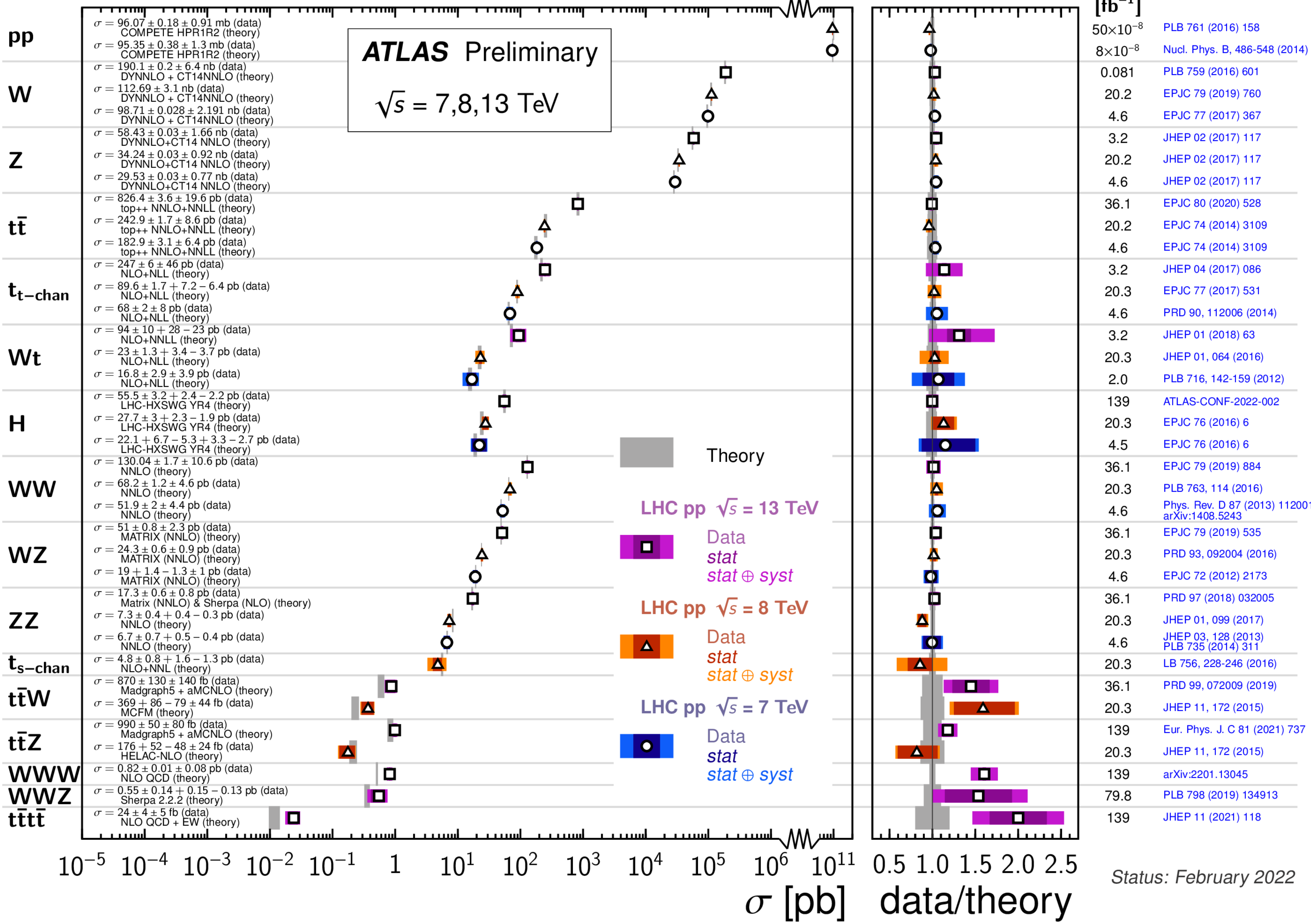
UK Research and Innovation

RECENT DEVELOPMENTS IN THE GENEVA FRAMEWORK

MATTHEW A. LIM

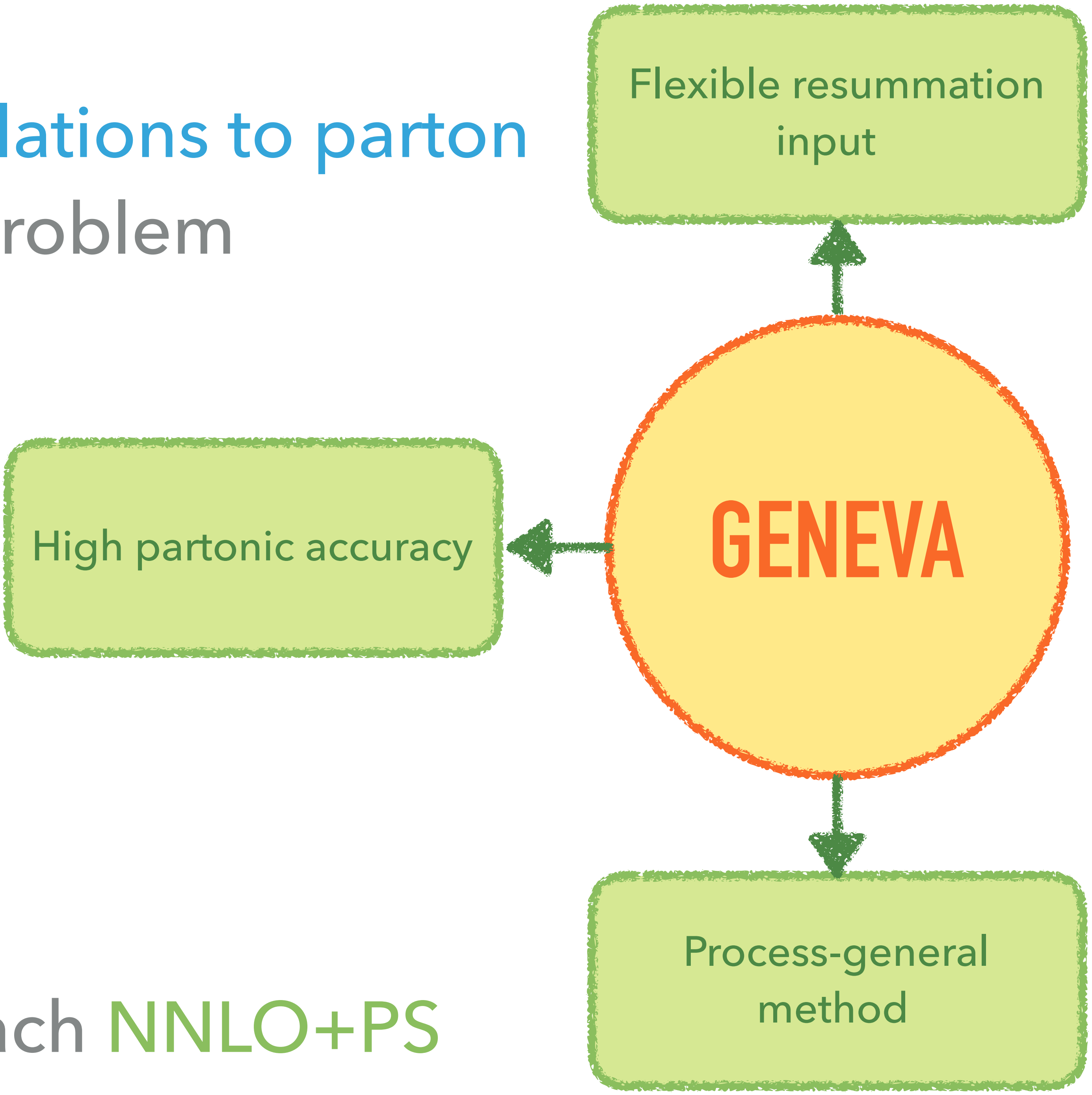
ICHEP 2024, PRAGUE

Standard Model Total Production Cross Section Measurements

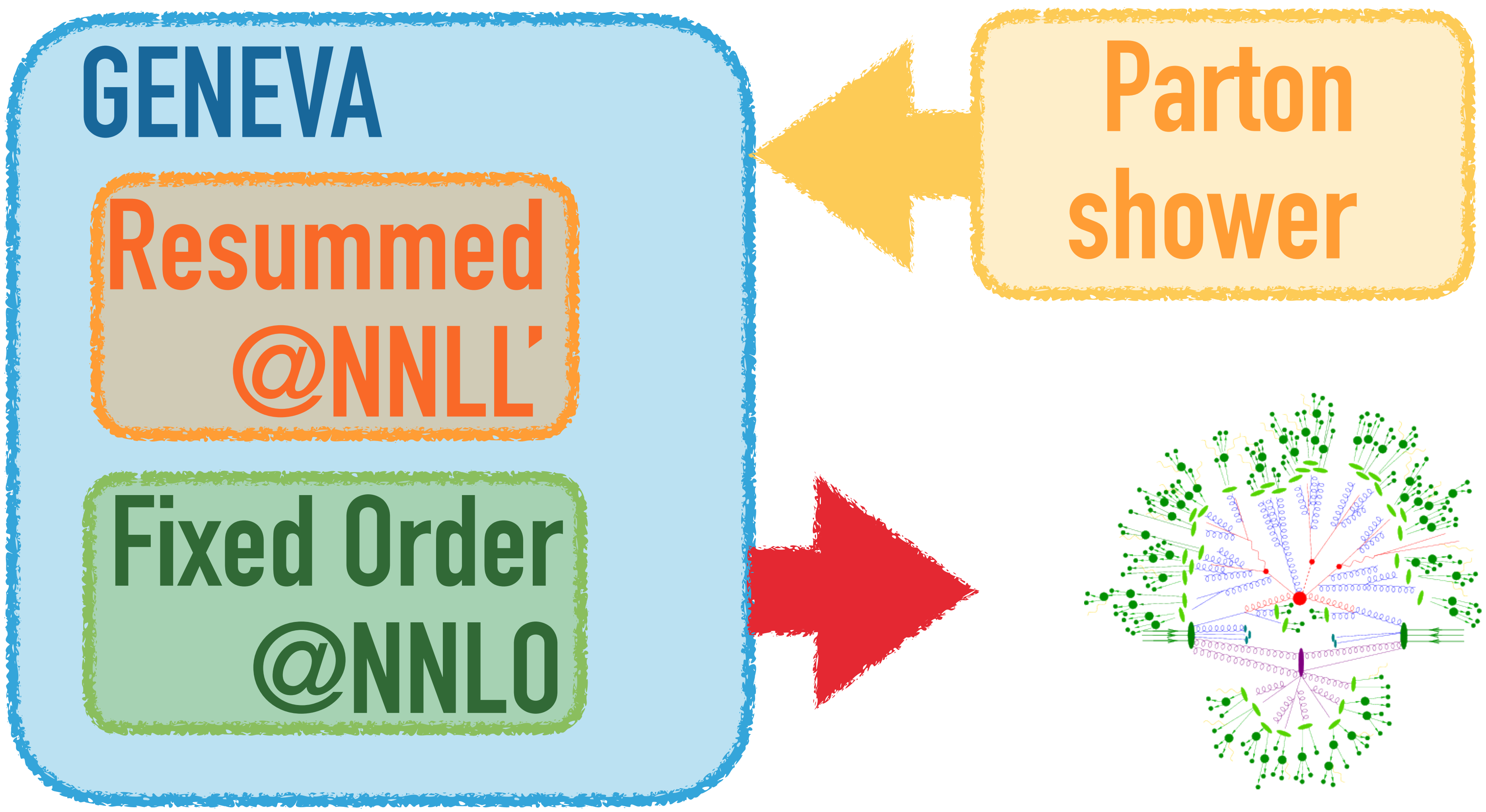


HIGHER ORDER MONTE CARLO EVENT GENERATORS

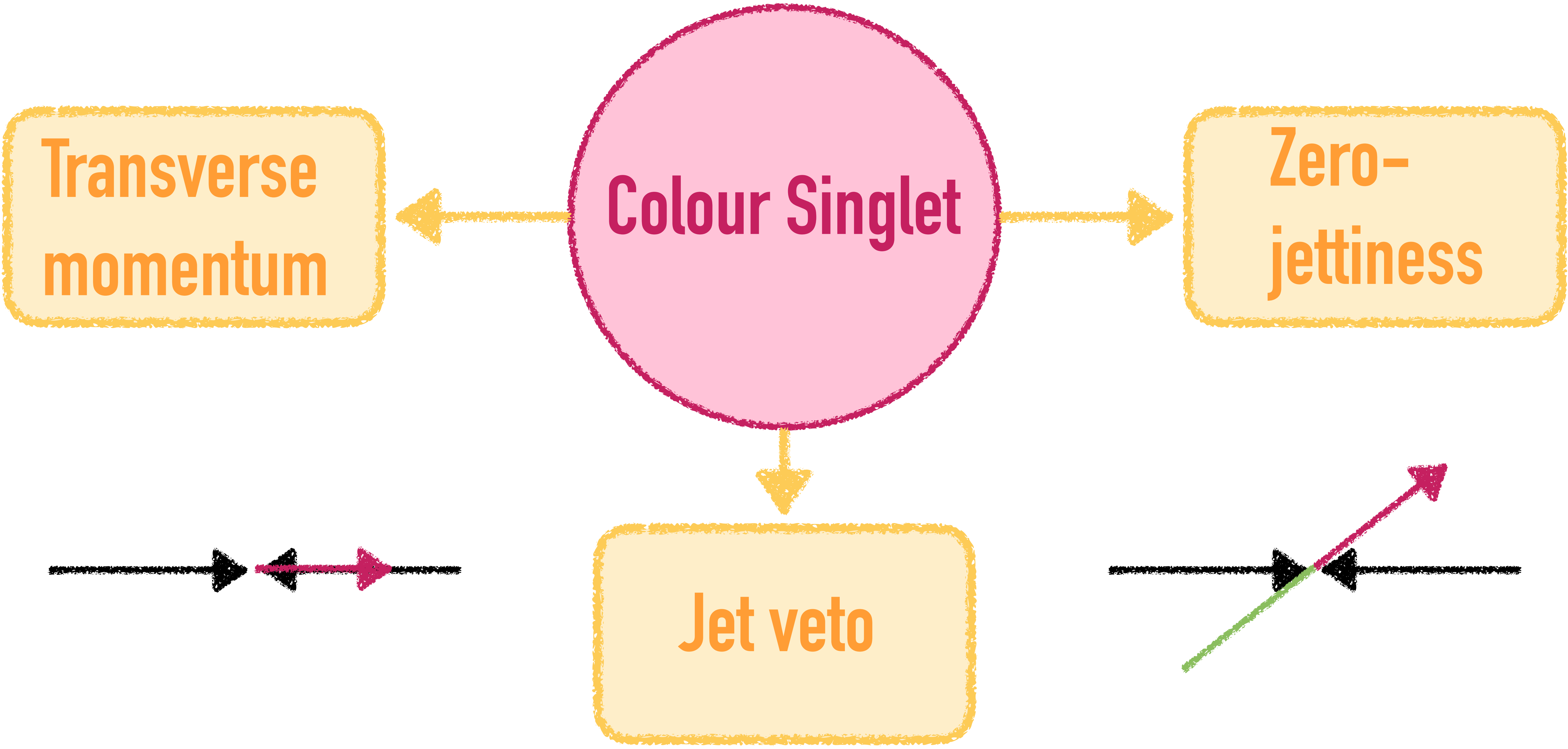
- Matching fixed order calculations to parton showers is a well-studied problem
- At NLO, several successful methods available - POWHEG, MC@NLO, KrkNLO, multiplicative-accumulative…
- GENEVA is a method to reach NNLO+PS accuracy



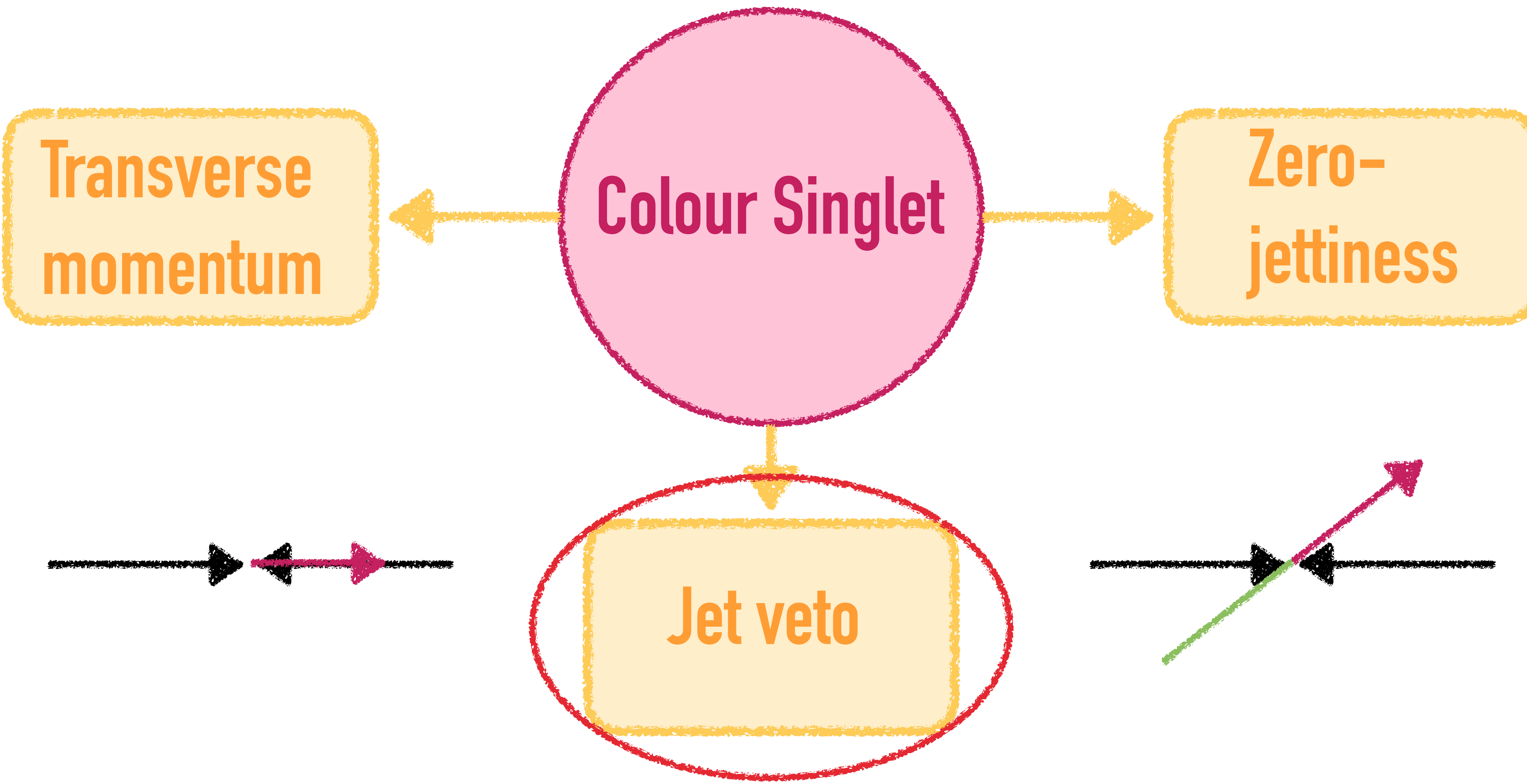
THE GENEVA METHOD



RESOLUTION VARIABLES

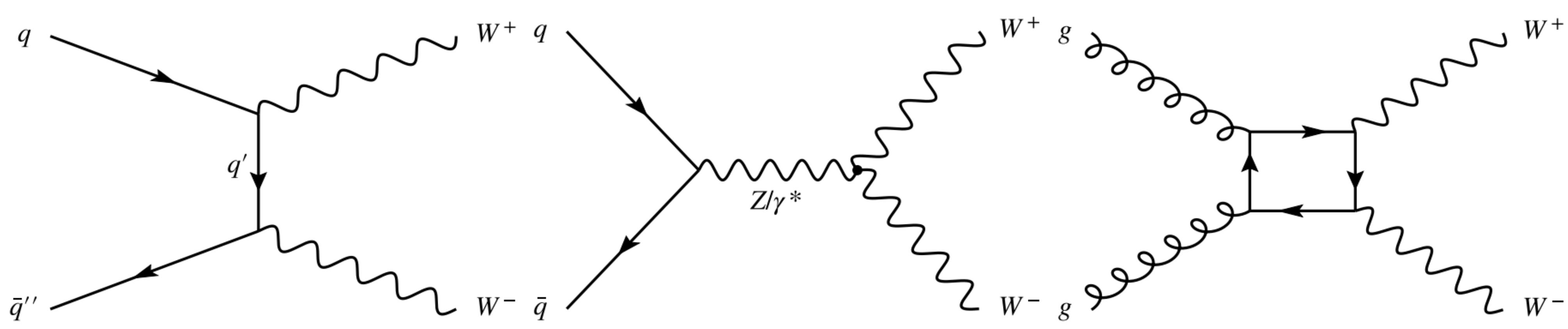


RESOLUTION VARIABLES



GENEVA USING JET VETO RESUMMATION

- W^+W^- production an interesting case study - jet vetoes used in analyses to reject $t\bar{t}$ background
- Aim to improve description of jet-vetoed cross section within an NNLO+PS event generator
- Combine NNLL′ resummation for WW + 0 jets with NLL′ resummation for WW + 1 jet to define events at NNLO



FACTORISATION WITH A JET VETO FOR COLOUR SINGLET

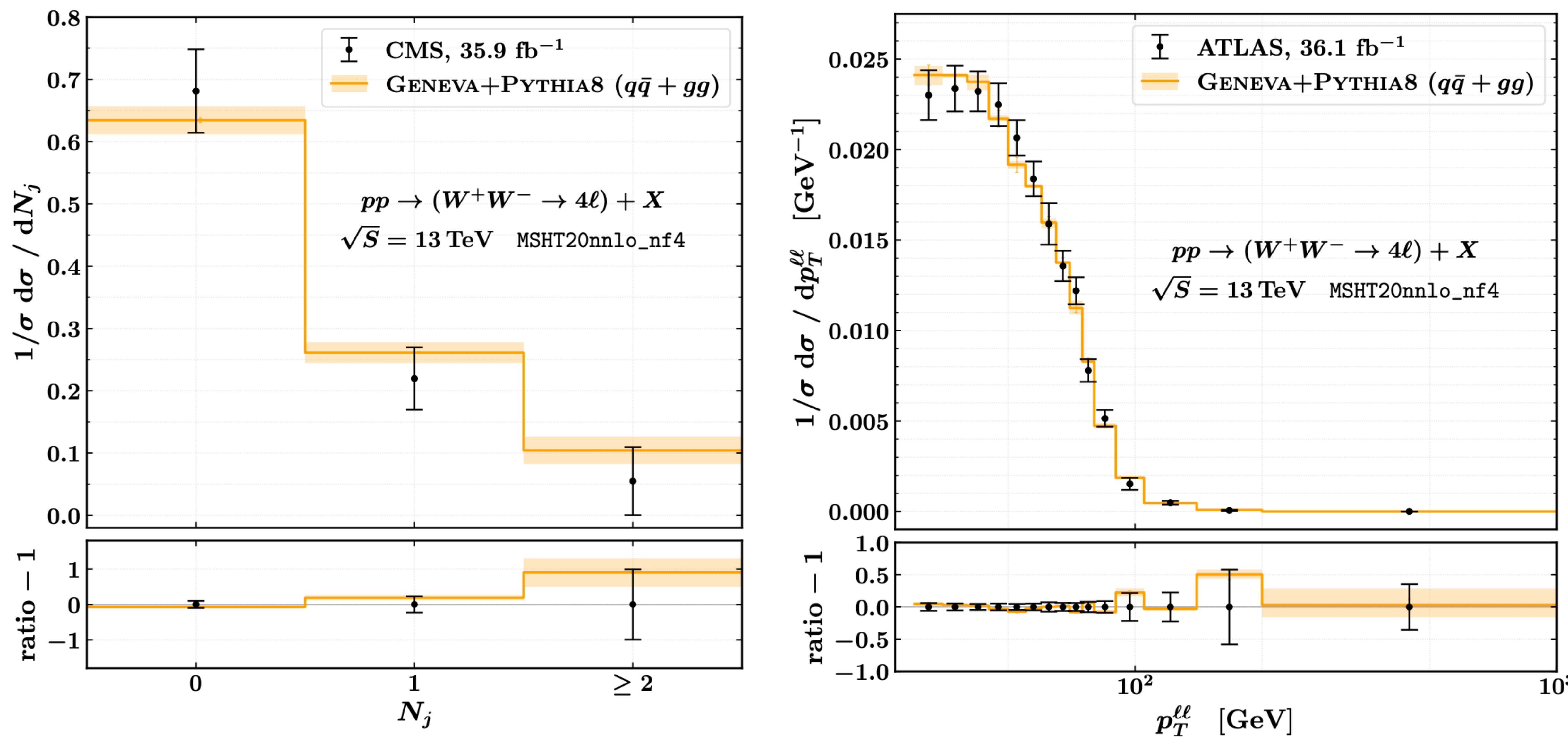
- Consider colour singlet production, vetoing all jets with $p_T > p_T^{\text{veto}}$. Resummation has been studied in both QCD and SCET. T. Becher, M. Neubert, 1205.3806, F. Tackmann, J. Walsh, S. Zuberi, 1206.4312, A. Banfi, G. Salam, G. Zanderighi, 1203.5773, I. Stewart, F. Tackmann, J. Walsh, S. Zuberi, 1307.1808, T. Becher, M. Neubert, L. Rothen, 1307.0025
- Factorisation into hard, beam and soft functions

$$\frac{\mathrm{d}\sigma(p_T^{\text{veto}})}{\mathrm{d}\Phi_0} = H(\Phi_0, \mu)\ [B_a \times B_b](p_T^{\text{veto}}, R, x_a, x_b, \mu, \nu)\ S_{ab}(p_T^{\text{veto}}, R, \mu, \nu)$$

- Radius of vetoed jets R
- Additional scale ν necessary to separate soft/collinear modes (SCET II)

COMPARISON TO ATLAS/CMS

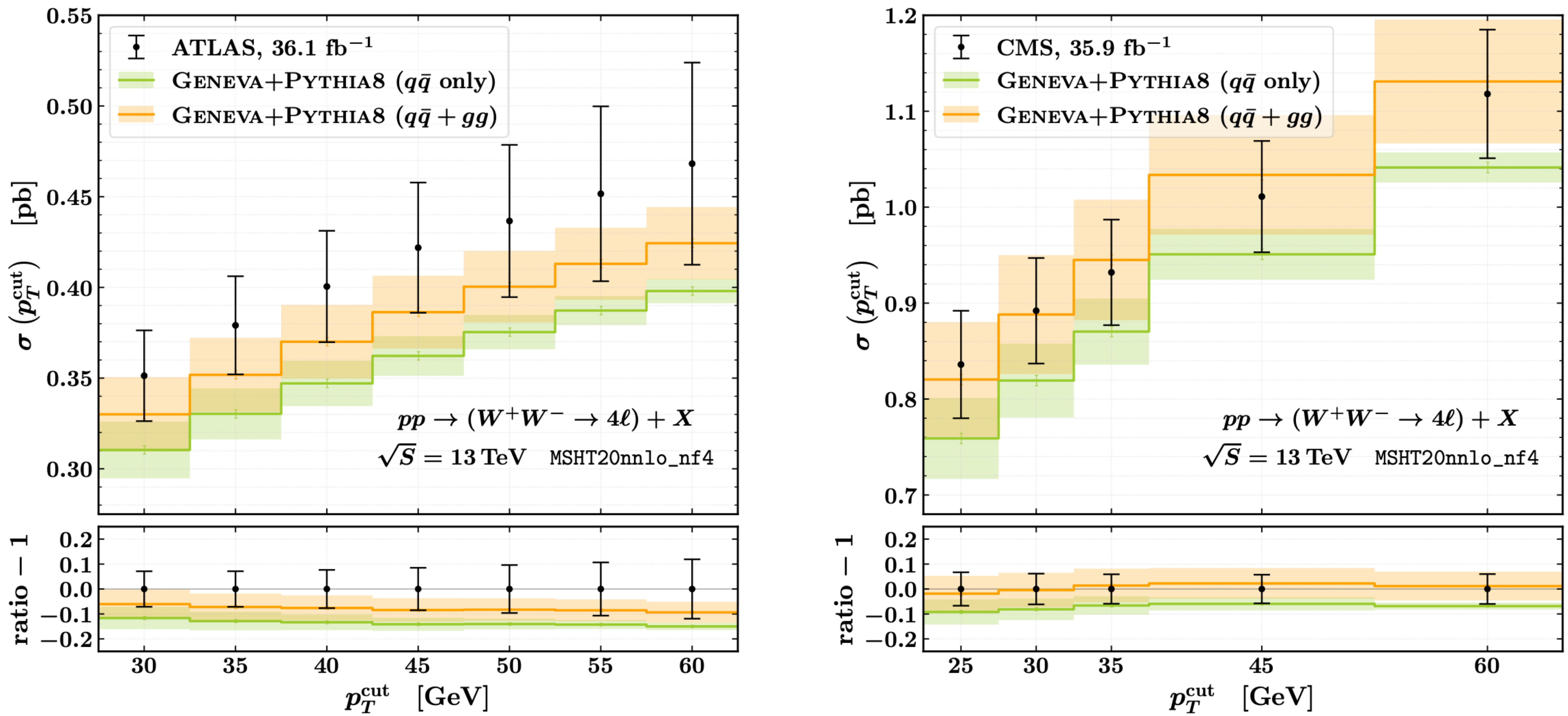
- Compared with ATLAS/CMS measurements



2308.11577 A. Gavardi, MAL, S. Alioli, F. Tackmann

COMPARISON TO ATLAS/CMS

- Vetoed cross section measurements



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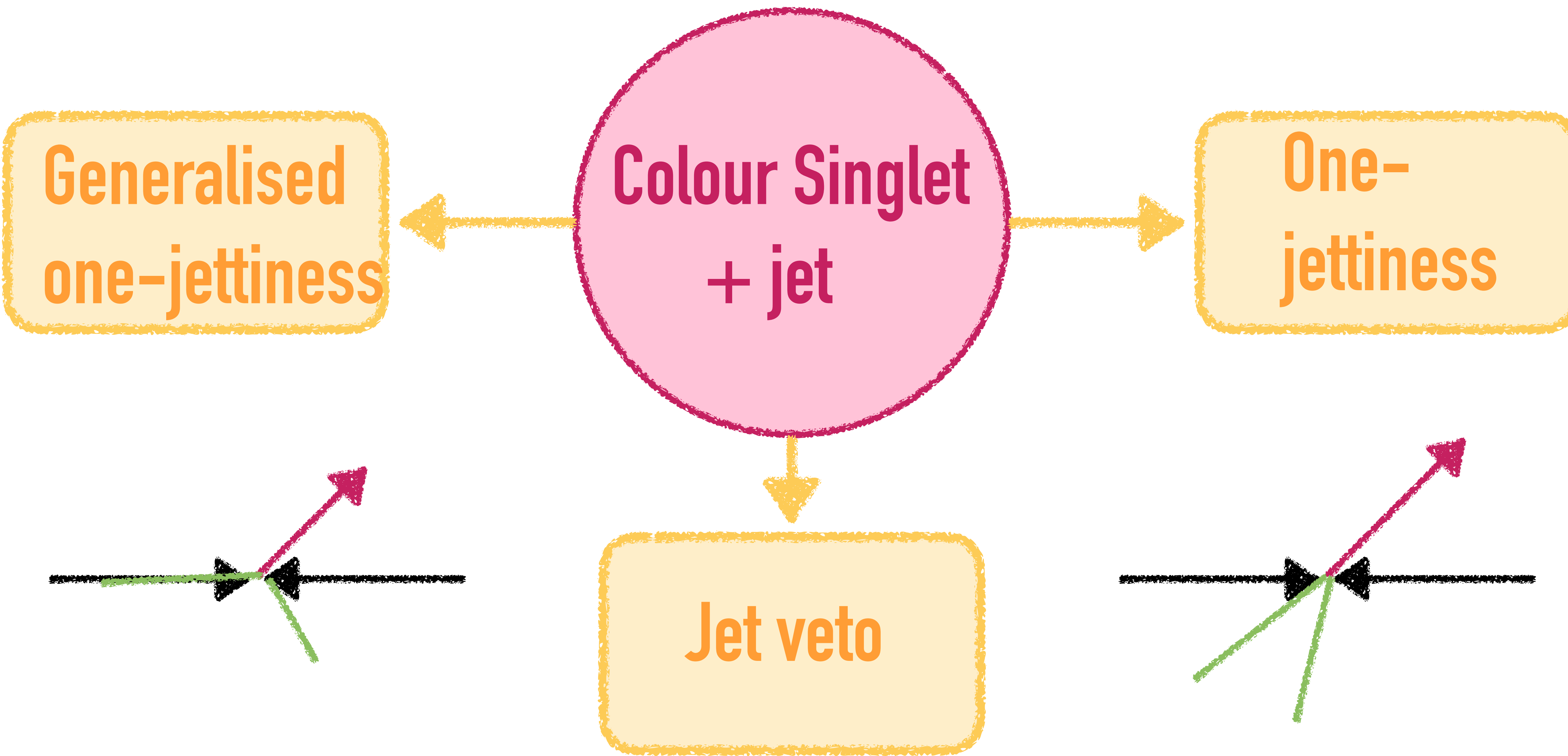
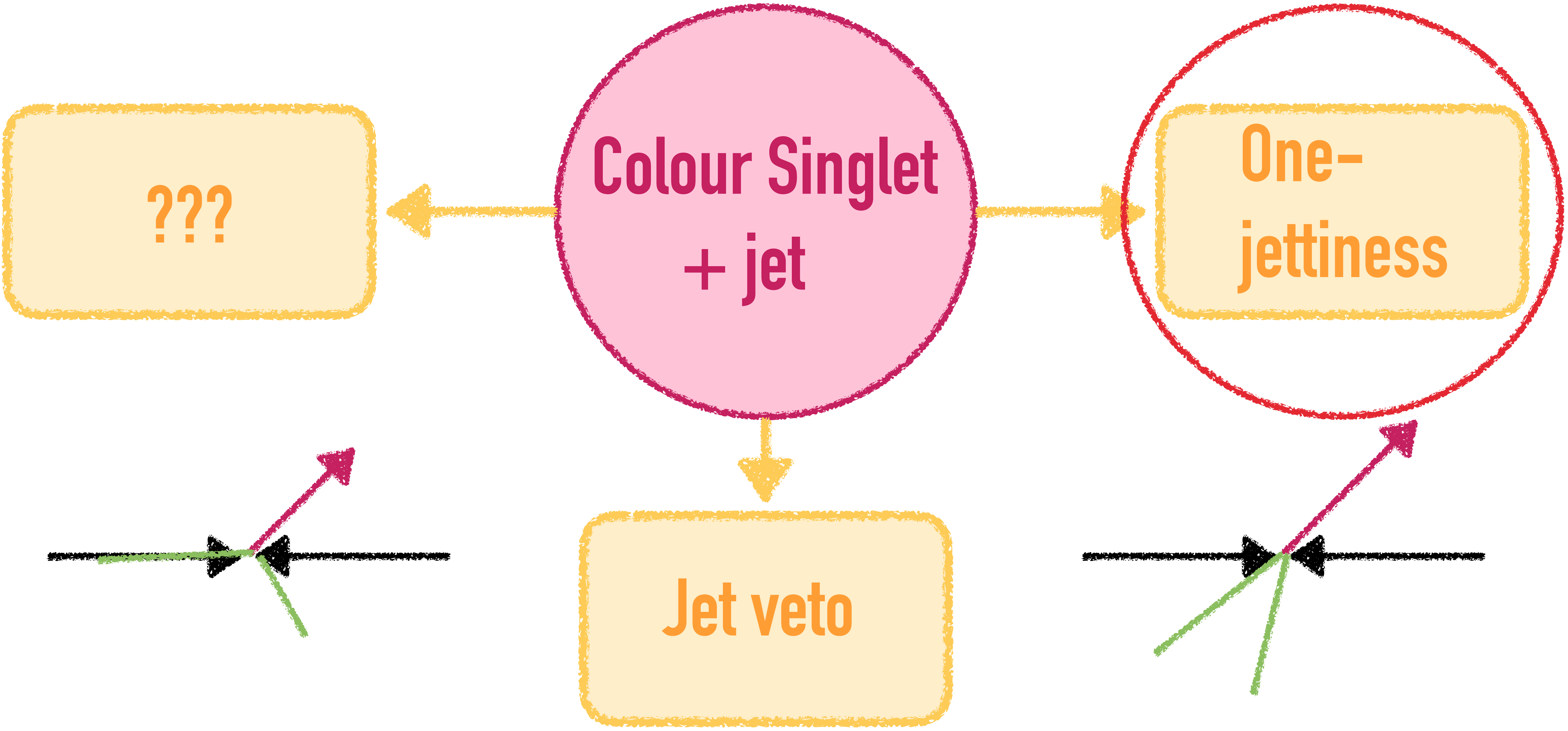
RESOLUTION VARIABLES



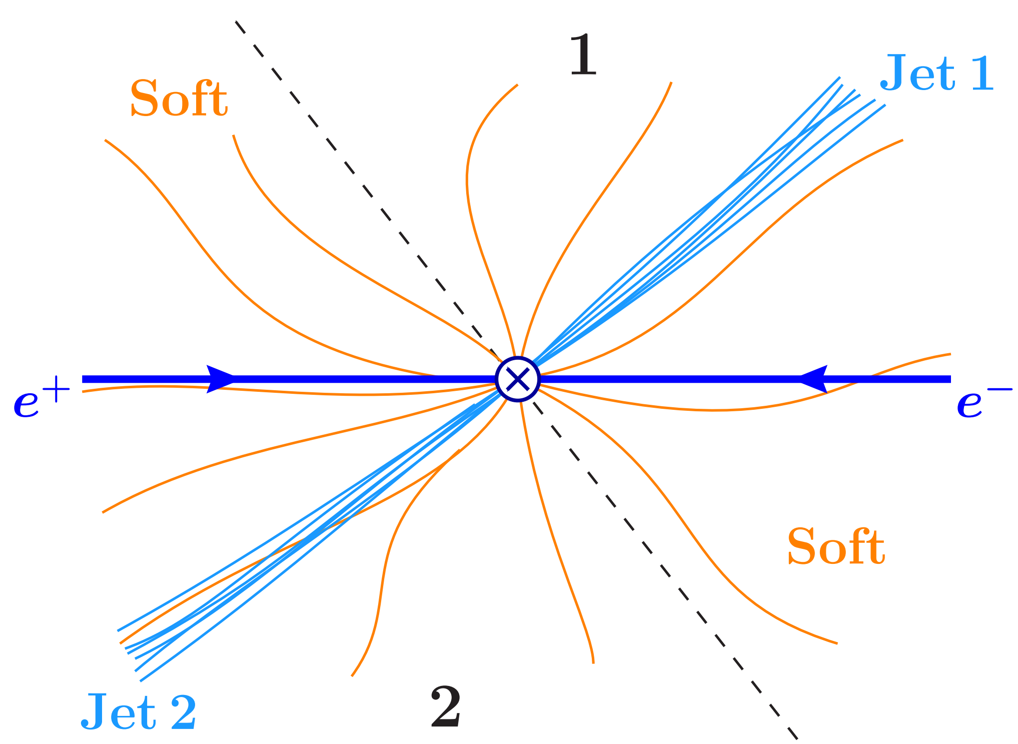
RESOLUTION VARIABLES

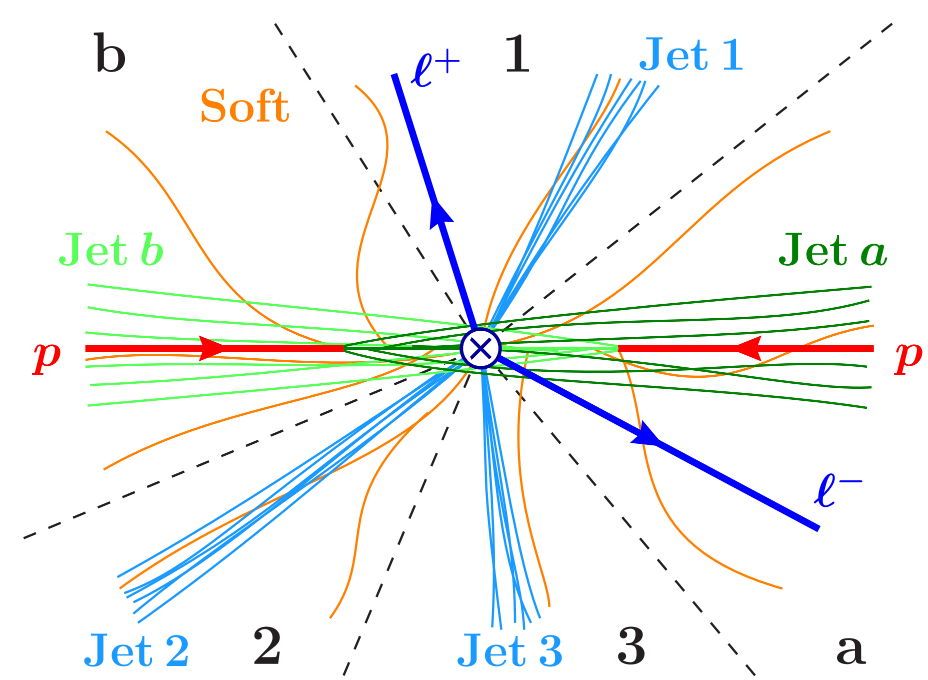


THE N-JETTINESS OBSERVABLE

- $\mathcal{T}_N = 0$ implies there are exactly N pencil-like jets
- Large $\mathcal{T}_N$ implies a spherical distribution of radiation

$$\mathcal{T}_N = \frac{2}{Q} \sum_k \min\{q_a \cdot p_k, q_b \cdot p_k, q_1 \cdot p_k, \ \ldots, q_N \cdot p_k\}$$





ONE-JETTINESS RESUMMATION FOR COLOUR SINGLET + JET

Similar factorisation to zero-jet case:

$$\frac{\mathrm{d}\sigma^{\mathrm{resum}}}{\mathrm{d}\Phi_1 \mathrm{d}\mathcal{T}_1} = \sum_{ijk} \int \mathrm{d}t_a \mathrm{d}t_b \mathrm{d}s_J \;\; B_i(t_a, x_a, \mu_B)\, B_j(t_b, x_b, \mu_B)\, J_k(s_J, \mu_J)\, \mathrm{Tr}\left\{ \mathbf{H}_{ij}(\Phi_1, \mu_H) \;\; \mathbf{S}\left(\mathcal{T}_1 - \frac{t_a}{Q_a} - \frac{t_b}{Q_b} - \frac{s_J}{Q_J}, \Phi_1, \mu_S \right) \right\}$$

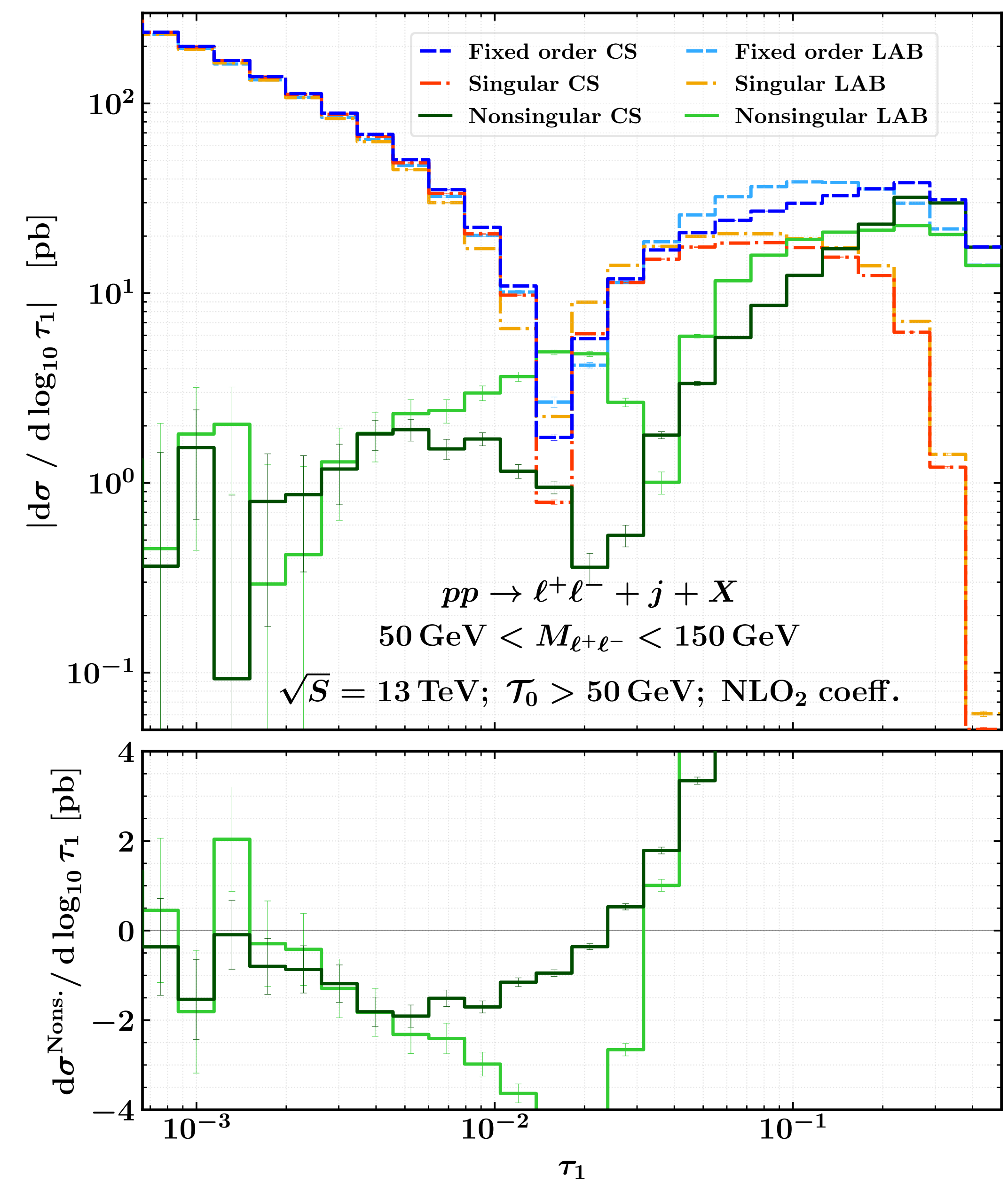
New jet function

- Only three coloured legs - colour algebra is diagonal
- Ingredients for N^{3}LL all known, we use new numerical of two-loop soft function from SoftSERVE
- One-jettiness definition requires choice of frame - can evaluate energies in lab or in CS centre-of-mass

0910.0467, 1302.0846, T. Jouttenus, I. Stewart, F. Tackmann, W. Waalewijn

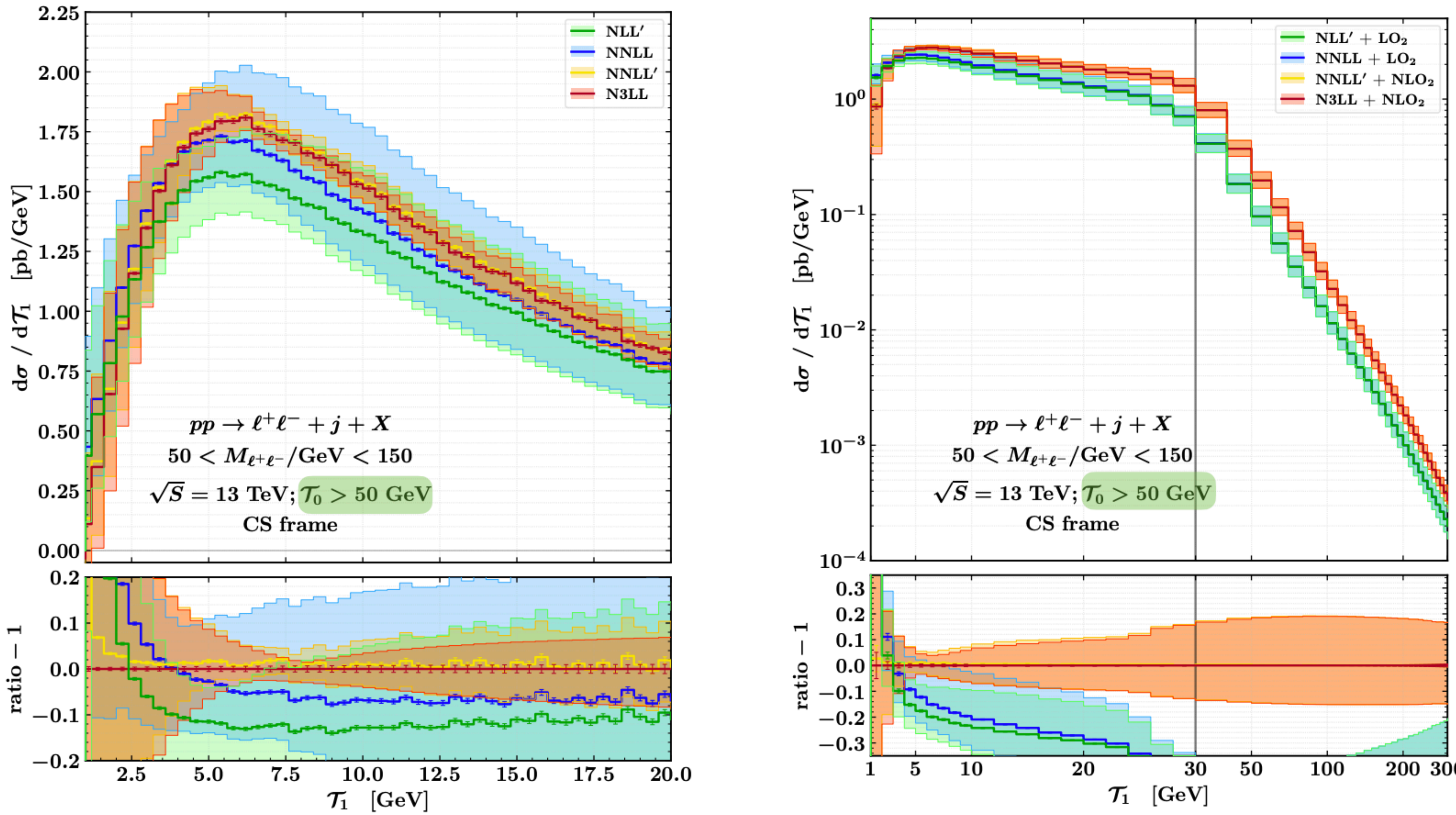
FIXED-ORDER VALIDATION OF ONE-JETTINESS FACTORISATION

- Factorisation theorem must reproduce result of fixed order in the small $\tau_1 = \mathscr{T}_1/Q$ limit
- Size of nonsingular difference has implications for numerical accuracy of slicing calculations



2312.06496, S. Alioli, G. Bell, G. Billis, A. Broggio, B. Dehnadi, MAL, G. Marinelli, R. Nagar, D. Napoletano, R. Rahn

RESUMMED AND MATCHED ONE-JETTINESS SPECTRA



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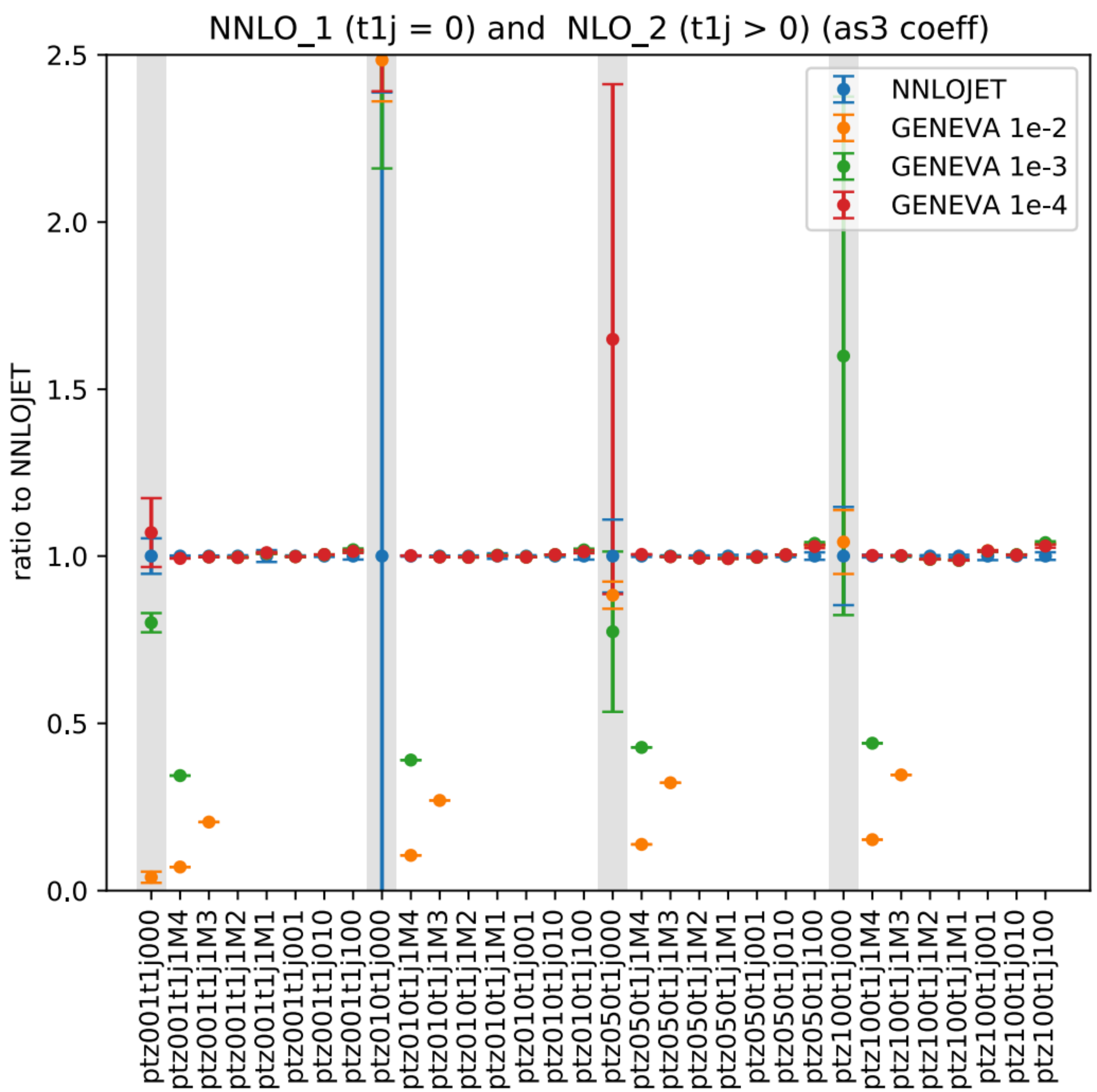
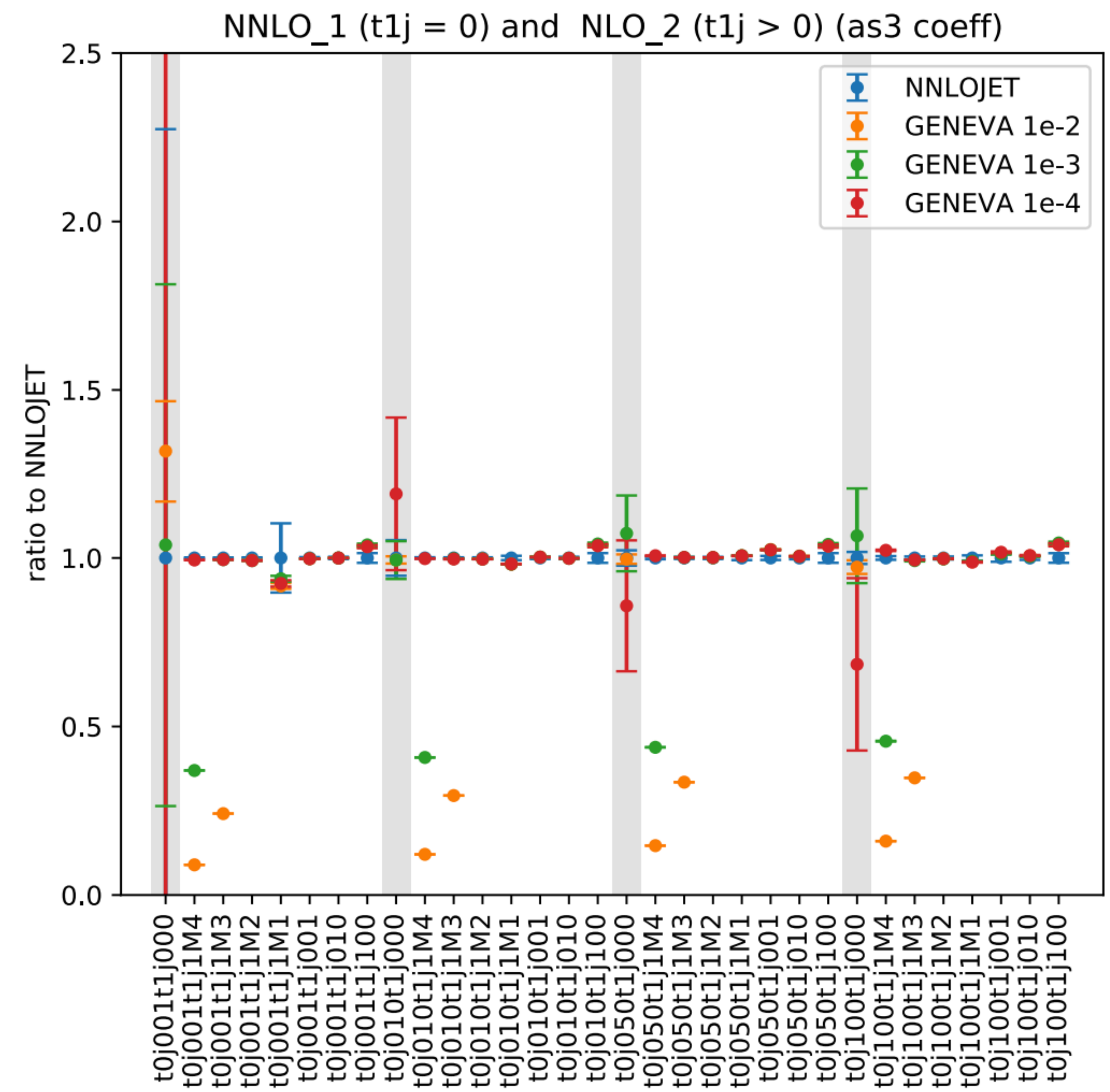
NNLO CROSS SECTIONS (VERY PRELIMINARY!)





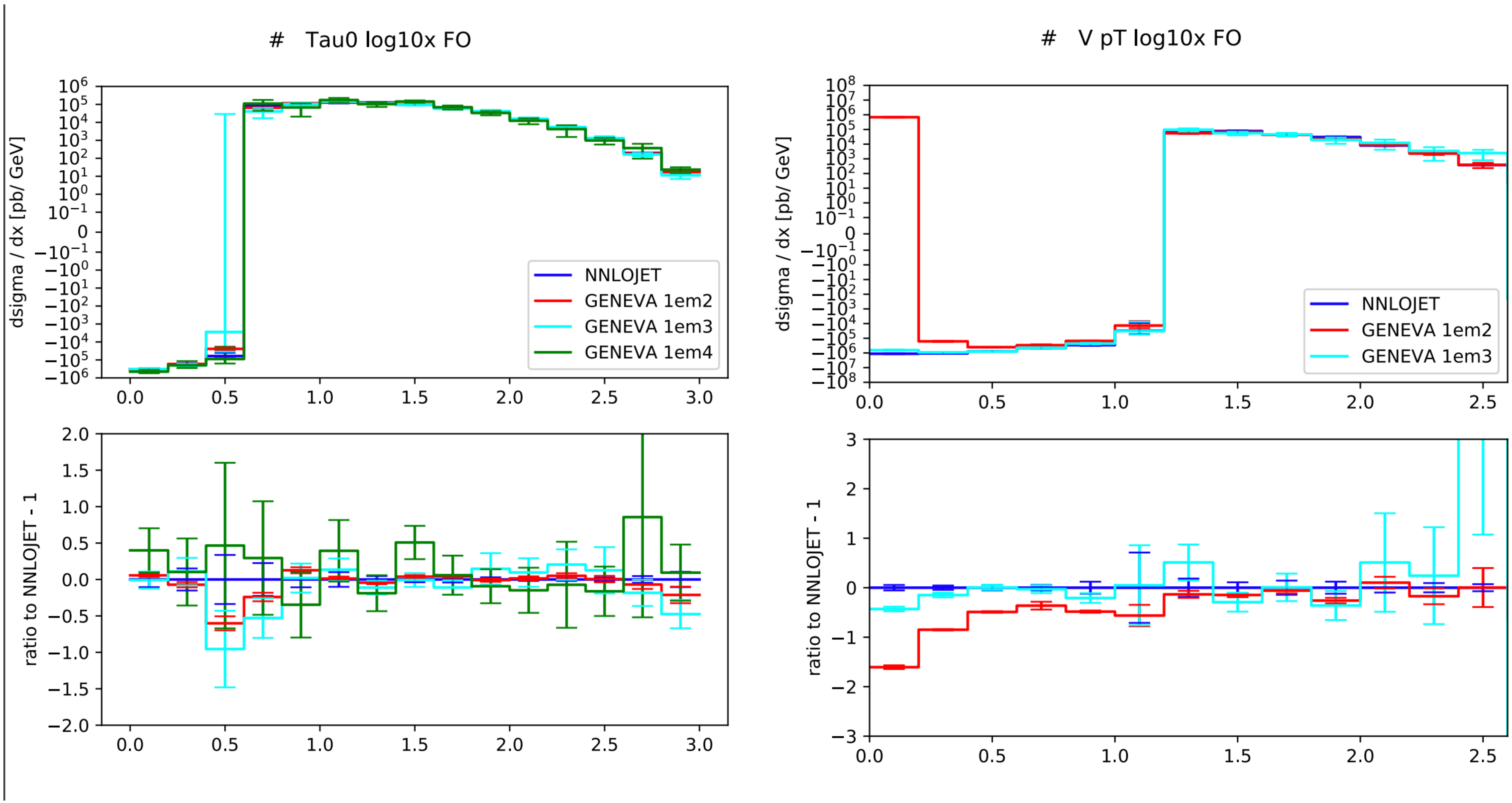
GENEVA ~48k CPU

q_T cuts

$\mathcal{T}_0$ cuts

NNLOJET ~80k CPU

NNLO DIFFERENTIAL DISTRIBUTIONS (VERY PRELIMINARY!)



CONCLUSIONS

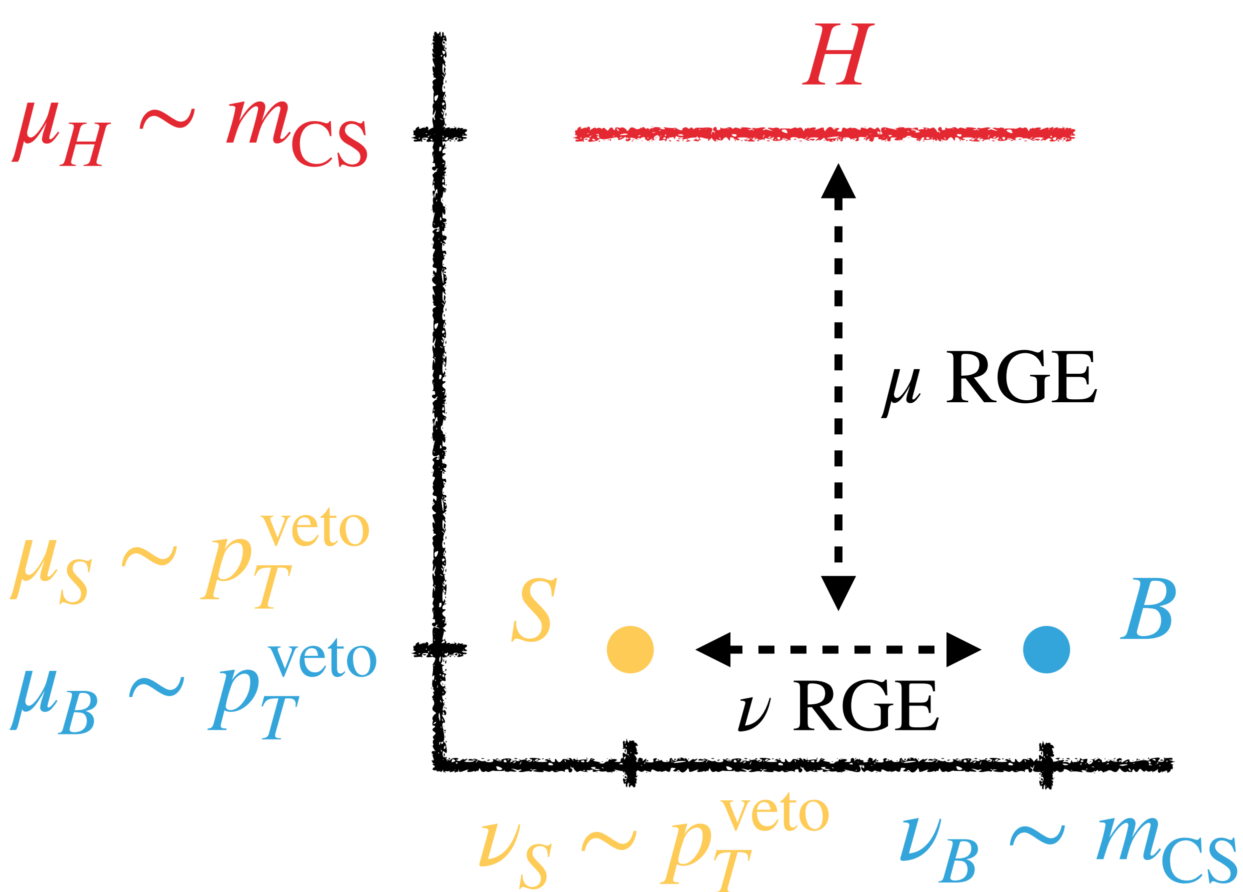
- GENEVA allows matching of NNLO calculations to parton shower algorithms using NNLL′/N3LL resummation
- Ongoing work aims to extend this to processes with jets
- Main limitation is availability of suitable resummed calculation
- Recent N3LL resummation of one-jettiness will allow an NNLO+PS event generator for Z/H+jet in the near future

BACKUP SLIDES

RESUMMATION OF JET VETO LOGS FOR COLOUR SINGLET

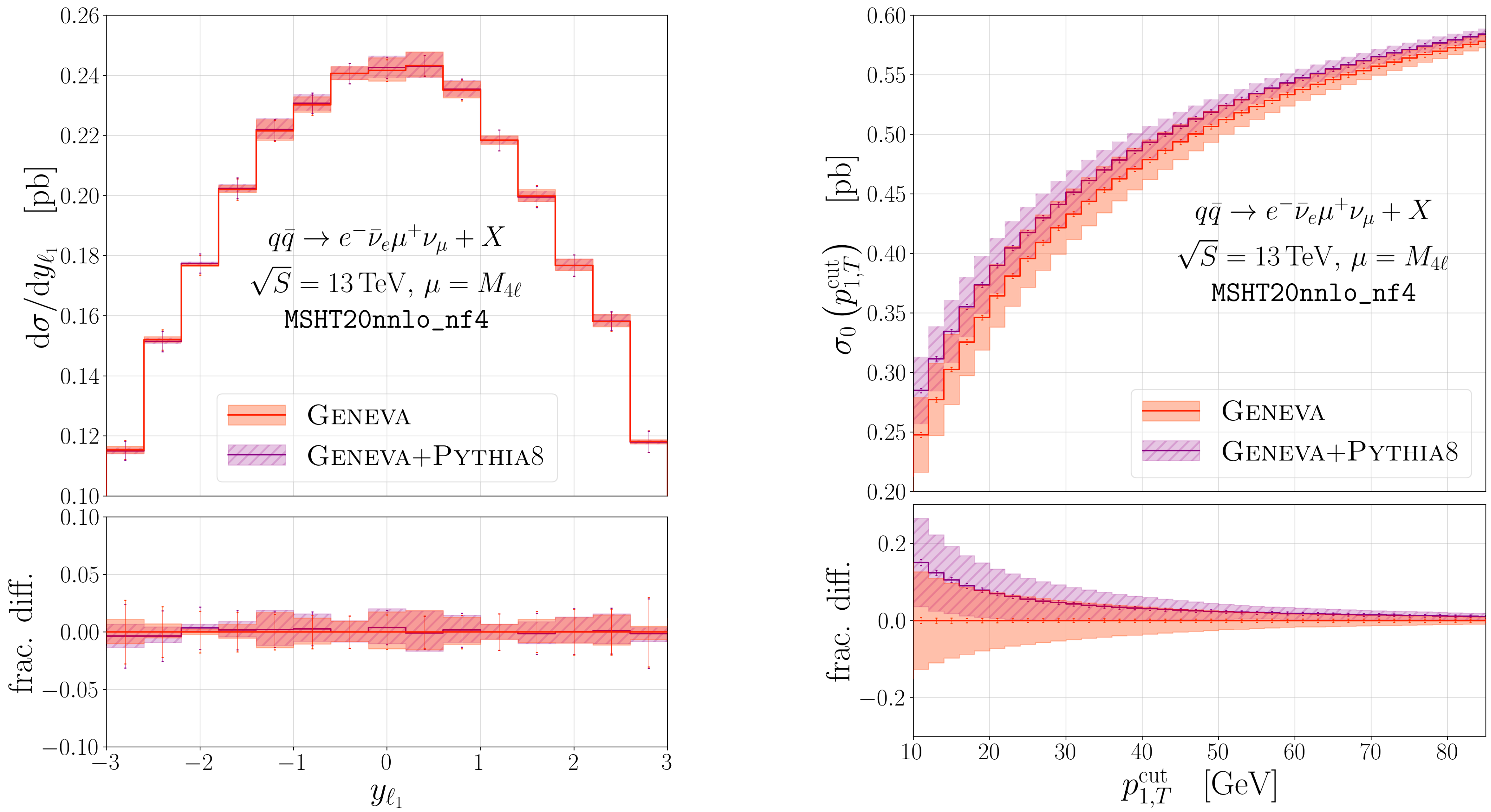
- Rapidity scale ν requires two-dimensional evolution

$$\frac{\mathrm{d}}{\mathrm{d}\ln\mu}\ln S(p_T^{\mathrm{cut}}, R, \mu, \nu) = 4\Gamma_{\mathrm{cusp}}\ln\frac{\mu}{\nu} + \gamma_S \qquad \frac{\mathrm{d}}{\mathrm{d}\ln\nu}\ln S(p_T^{\mathrm{cut}}, R, \mu, \nu) = \gamma_\nu$$



SHOWERED RESULTS

- Numerically examine effect of shower on accuracy



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