Karlsruher Institut für Technologie

Particle Physics Phenomenology
after the Higgs Discovery

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PRECISION COLLIDER PHYSICS

Annual meeting of the Collaborative Research Center, Siegen, 29.09.2026-01.10.2026

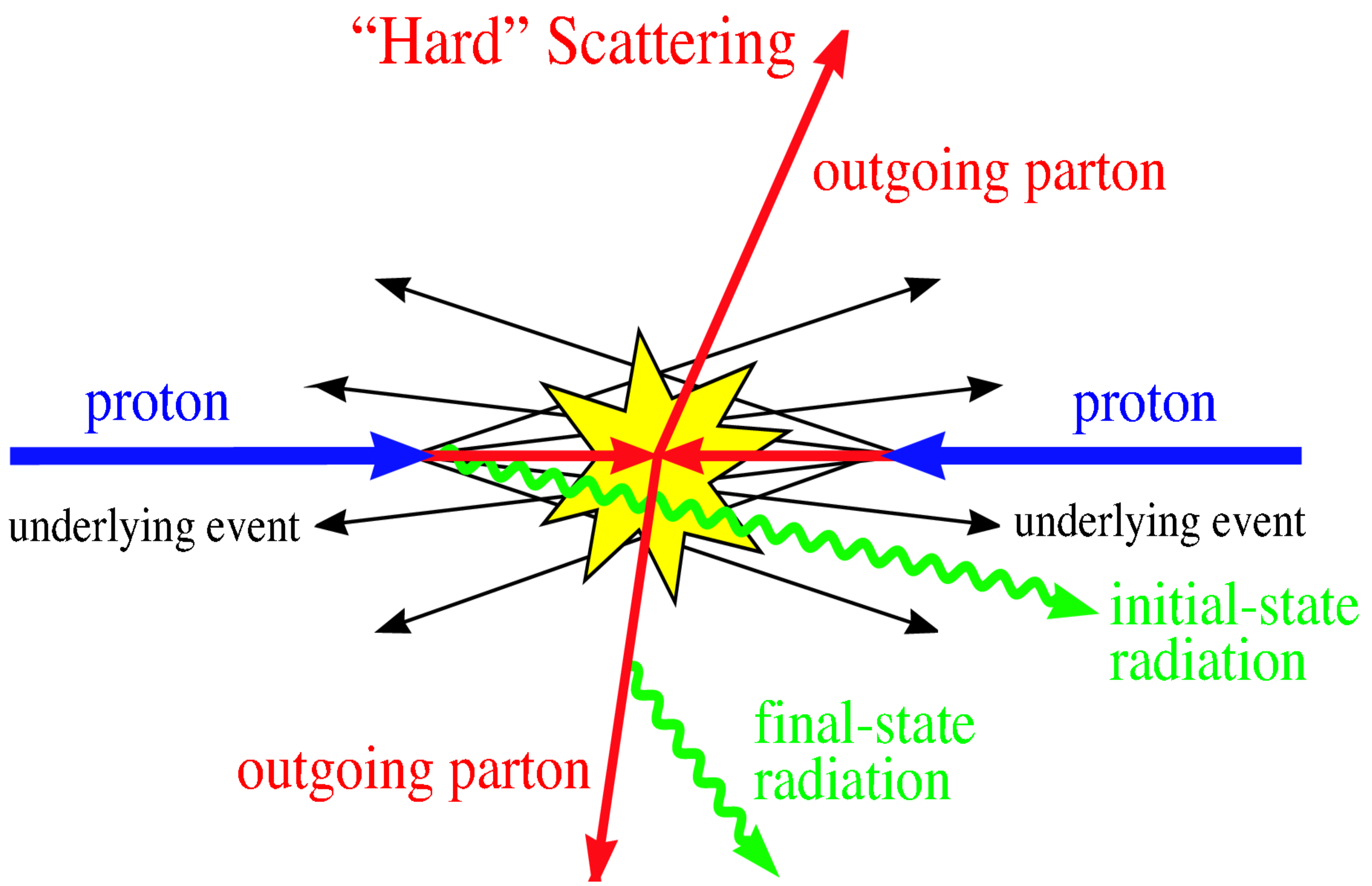
This annual meeting is not an ordinary one, since the second funding period is coming to an end, and we need to prepare the application for the third one.

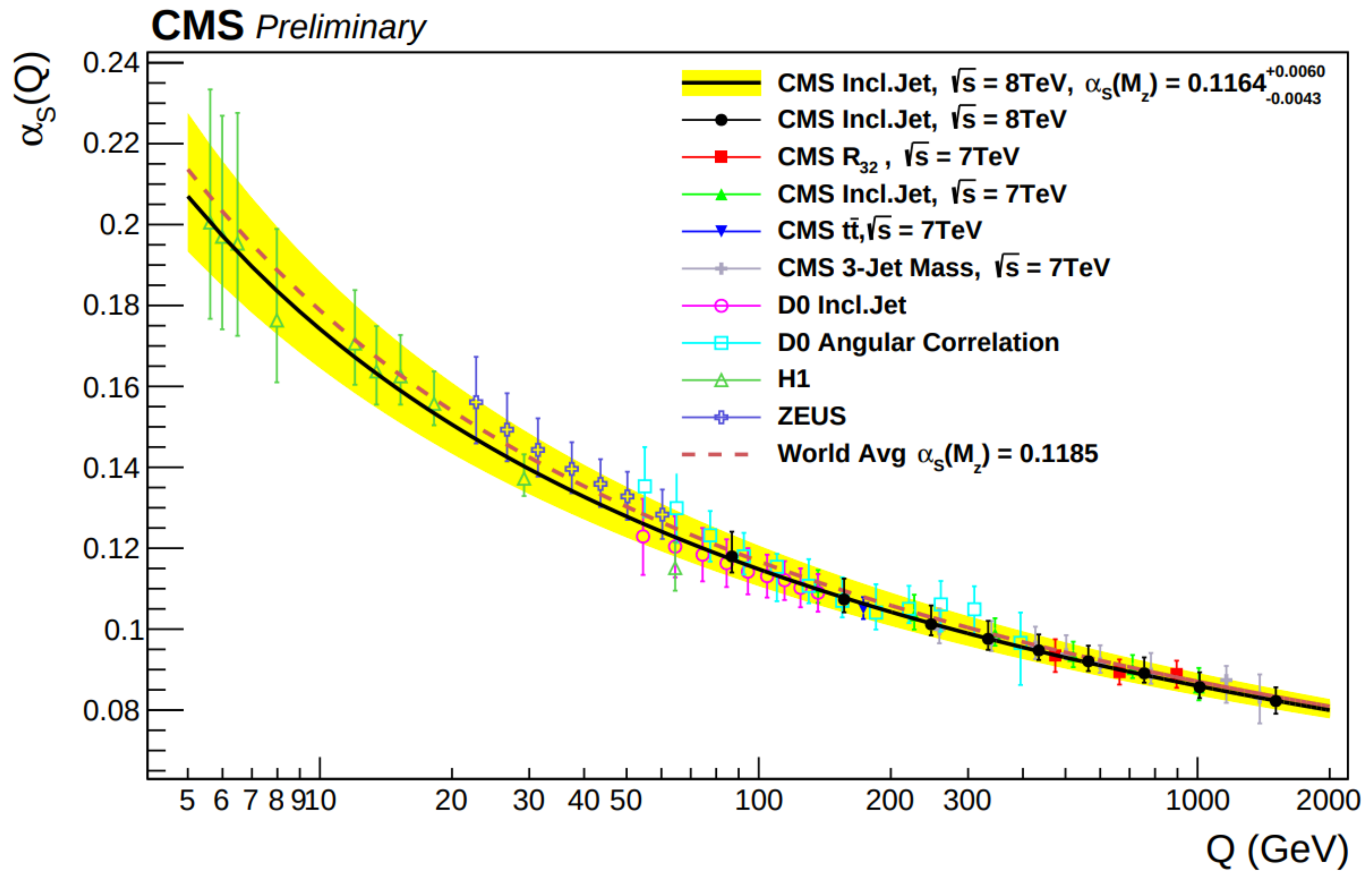
Will research in precision collider physics remain important in the near future (few years) ?

Can we (the CRC) claim to be world-leading in (at least) some aspects of the precision collider physics?

Any physics question becomes a precision physics questions if answering it relies on the detailed understanding of the underlying theory. For this reason alone, precision physics studies will be at the focus of the LHC experiments in the foreseeable future.

$$\mathcal{L}_{\rm QCD} = \sum \bar{q}_j \left(i\hat{D} - m_j \right) q_j - \frac{1}{4} G^a_{\mu\nu} G^{a,\mu\nu}$$





$$d\sigma_{\rm hard} = \sum_{ij \in \{q,g\}} \int dx_1 \, dx_2 f_i(x_1) f_j(x_2) \, d\sigma_{ij}(x_1, x_2), \{p_{\rm fin}\}) \, O_J(\{p_{\rm fin}\}).$$

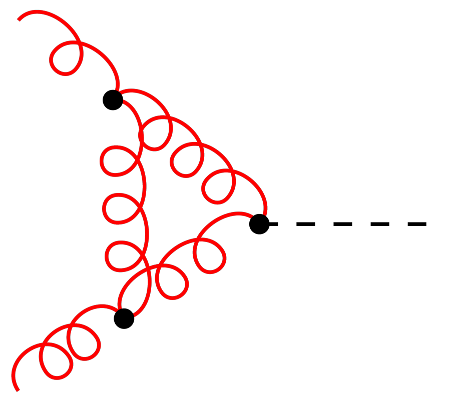
$$d\sigma_{ij} = d\sigma_{ij,{\rm LO}} \left(1 + \alpha_s \, \Delta_{ij,{\rm NLO}} + \alpha_s^2 \, \Delta_{ij,{\rm NNLO}} + \ldots \right)$$

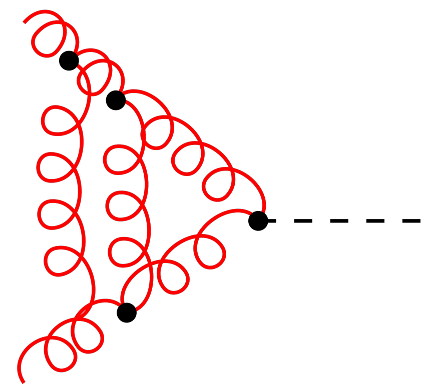
To be a global player in the precision collider physics, one needs to either advance collider theory, or (and) use these advances to do insightful phenomenology. The research in the CRC has examples of both.

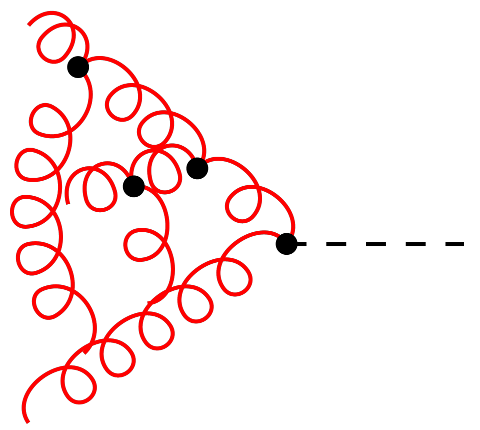
Loops	Radiation	Resummation	Matching	Parton Showers	Power corrections
✓	✓	✓			✓
A1a, A1b, A3b, B1b	A1c,B1a, B1b, B2a	B2a			B1e

A1a: quark-mass effects in the Higgs boson production in gluon fusion were studied; a unique result of the CRC which removes the last remaining N3LO uncertainty beyond the PDFs and the strong coupling.

$$\sigma = 48.58\,\text{pb}^{+2.22\,\text{pb}\,(+4.56\%)}_{-3.27\,\text{pb}\,(-6.72\%)}\ (\text{theory}) \pm 1.56\,\text{pb}\,(3.20\%)\ (\text{PDF}+\alpha_s)\,.$$





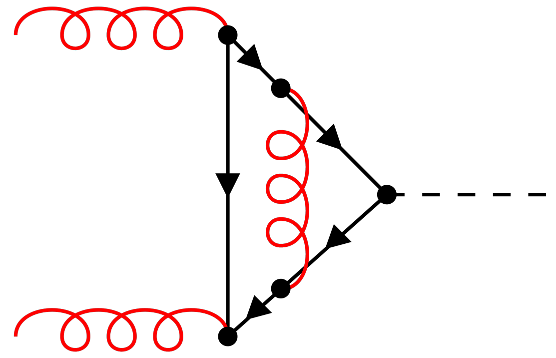


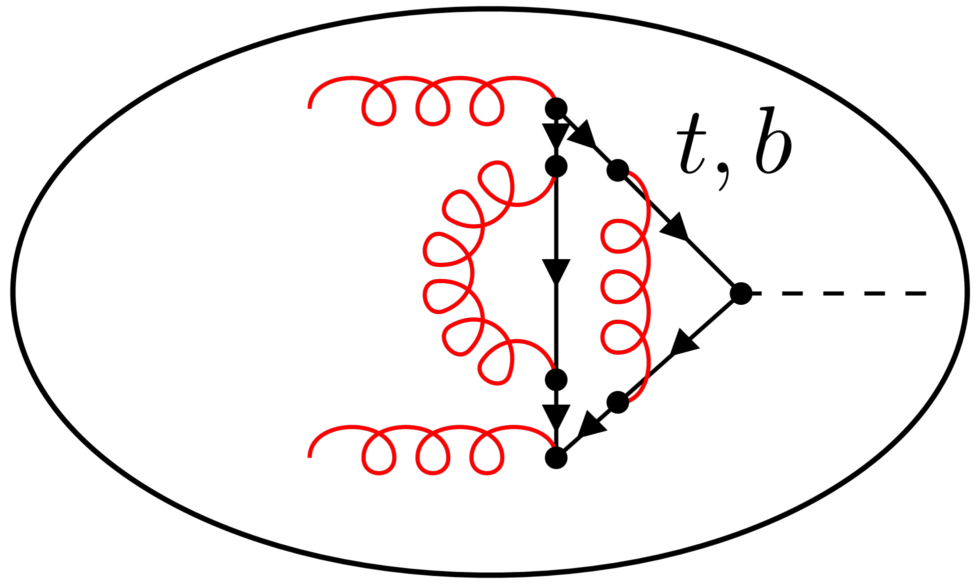
48.58 pb =	16.00 pb	(+32.9%)	(LO, rEFT)
	+ 20.84 pb	(+42.9%)	(NLO, rEFT)
	− 2.05 pb	(−4.2%)	((t, b, c), exact NLO)
	+ 9.56 pb	(+19.7%)	(NNLO, rEFT)
	+ 0.34 pb	(+0.7%)	(NNLO, $1/m_t$)
	+ 2.40 pb	(+4.9%)	(EW, QCD-EW)
	+ 1.49 pb	(+3.1%)	(N^3LO, rEFT)

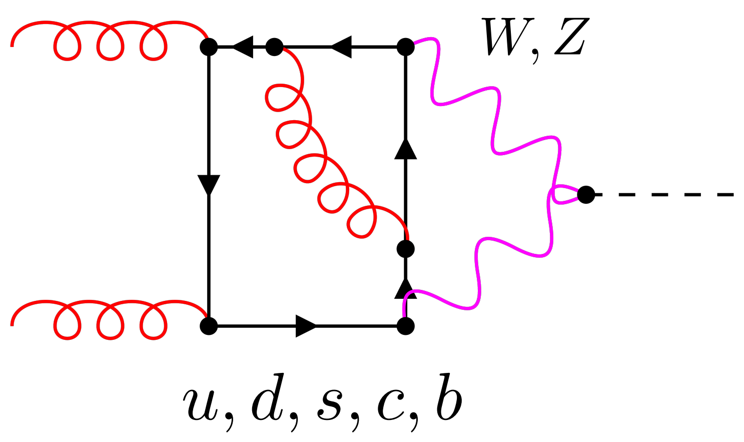
Anastasiou, Duhr, Dulat, Furlan, Gehrmann, Herzog, Lazopoulos, Mistlberger

δ(scale)	δ(trunc)	δ(PDF-TH)	δ(EW)	$\delta(t, b, c)$	$\delta(1/m_t)$
$^{+0.10\text{ pb}}_{-1.15\text{ pb}}$	±0.18 pb	±0.56 pb	±0.49 pb	±0.40 pb	±0.49 pb
$^{+0.21\%}_{-2.37\%}$	±0.37%	±1.16%	±1%	±0.83%	±1%

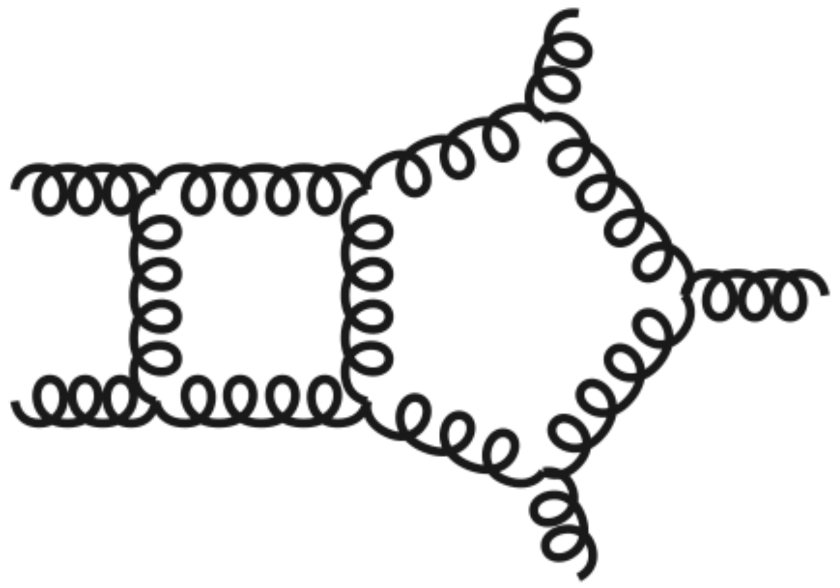
Czakon, Eschment, Schellenberger , Niggetiedt, Poncelet



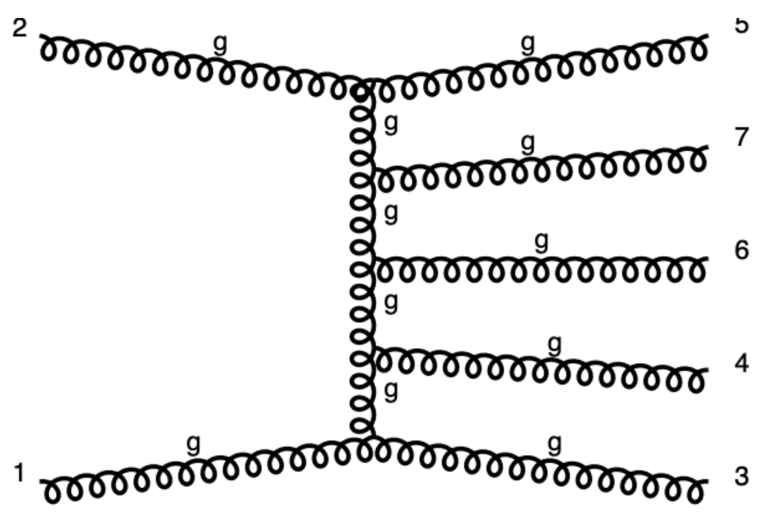




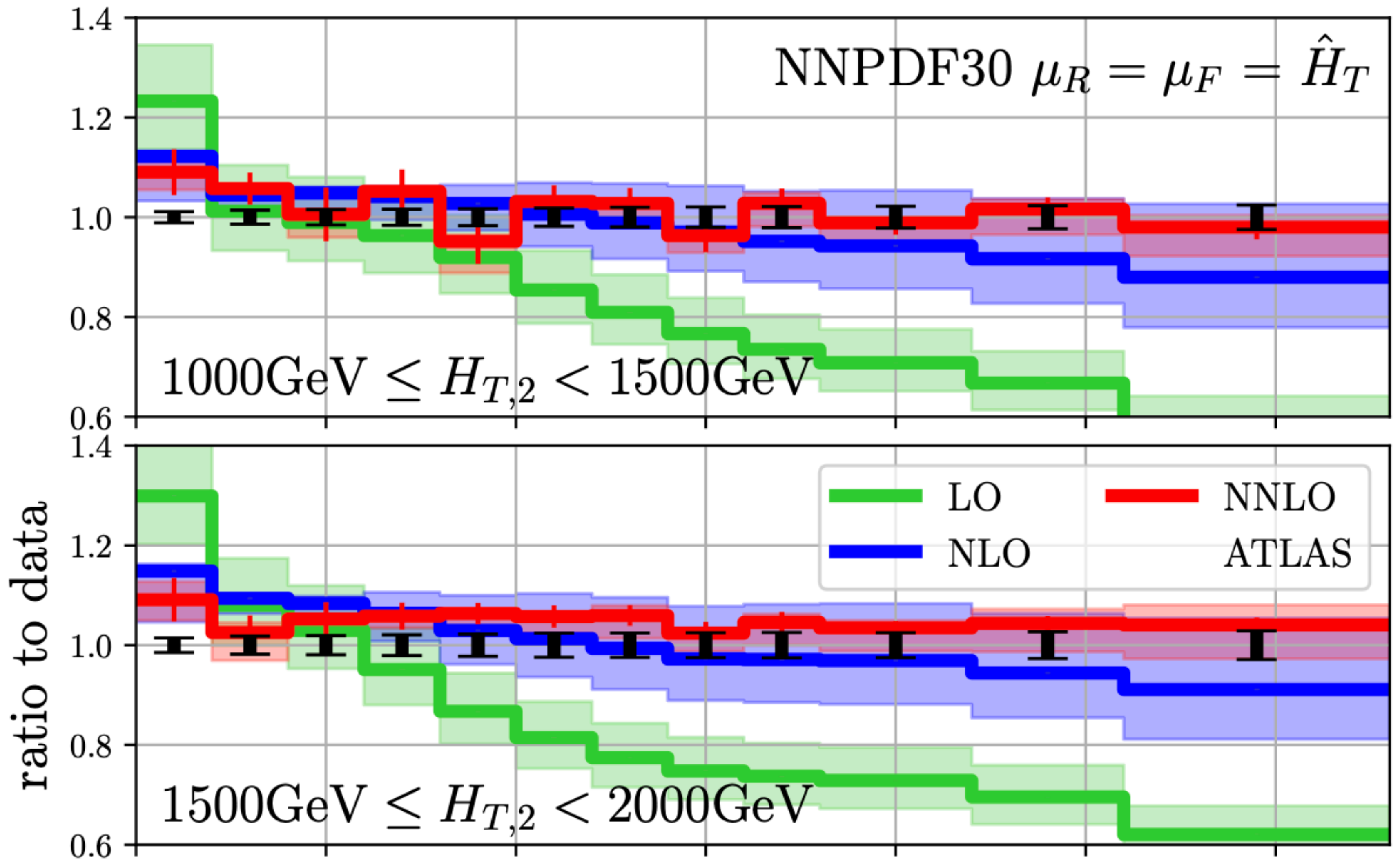
B1a: Pioneering calculations of NNLO QCD corrections to 2 ➞ 3 processes at the LHC: 3 jet production, a prompt photon and two jets etc.



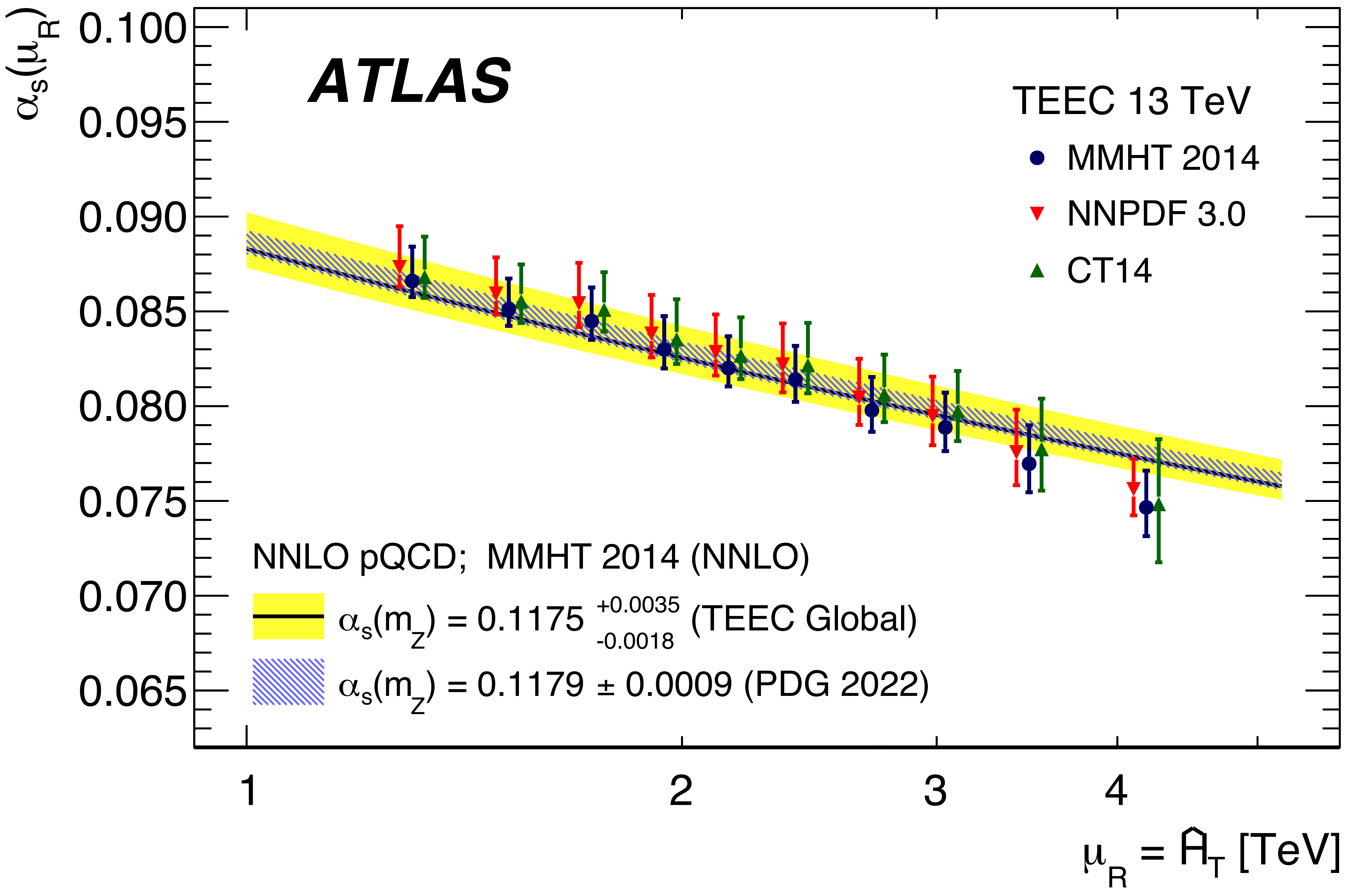
Two-loop amplitudes: Chicherin, Sotnikov, Gehrmann, Zhang, Henn, Wasser, Zola, Abreu et al.



Subtraction scheme: Czakon, Czakon, Heymes

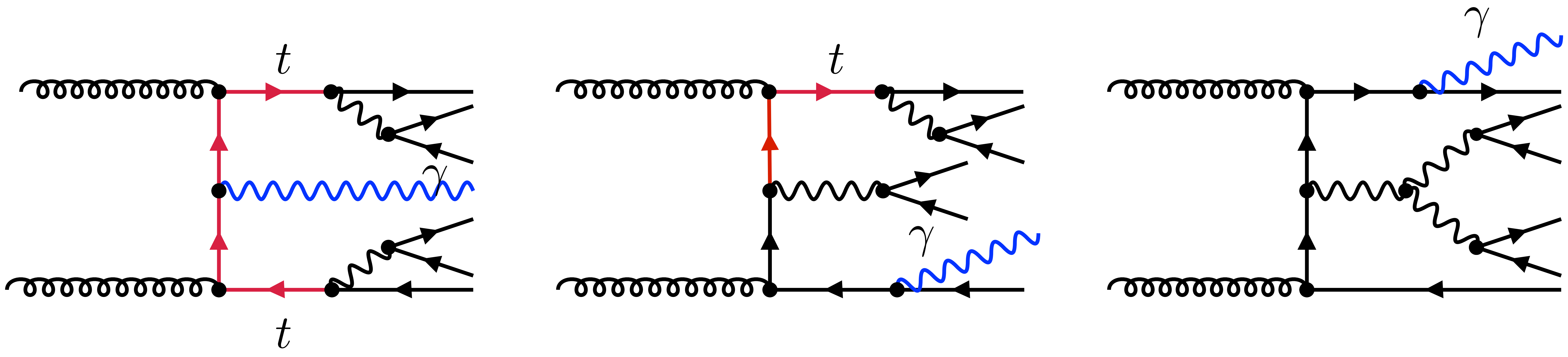


Alvarez, Cantero, Czakon, Lorente, Mitov, Poncelet



The ATLAS collaboration used these calculations to measure the running of the strong coupling constant at the O(TeV) scales.

B1b: world-leading advances in NLO QCD computations for high-multiplicity processes at the LHC.



$$pp \to t\bar{t}\gamma \quad \Rightarrow \quad pp \to e^+\nu_e\mu^-\bar{\nu}_\mu b\bar{b}\gamma$$

1) Much more complicated diagrams (pentagons vs. heptagons, in the above example);

1) resonance and non-resonance diagrams are included, with all interferences between them;

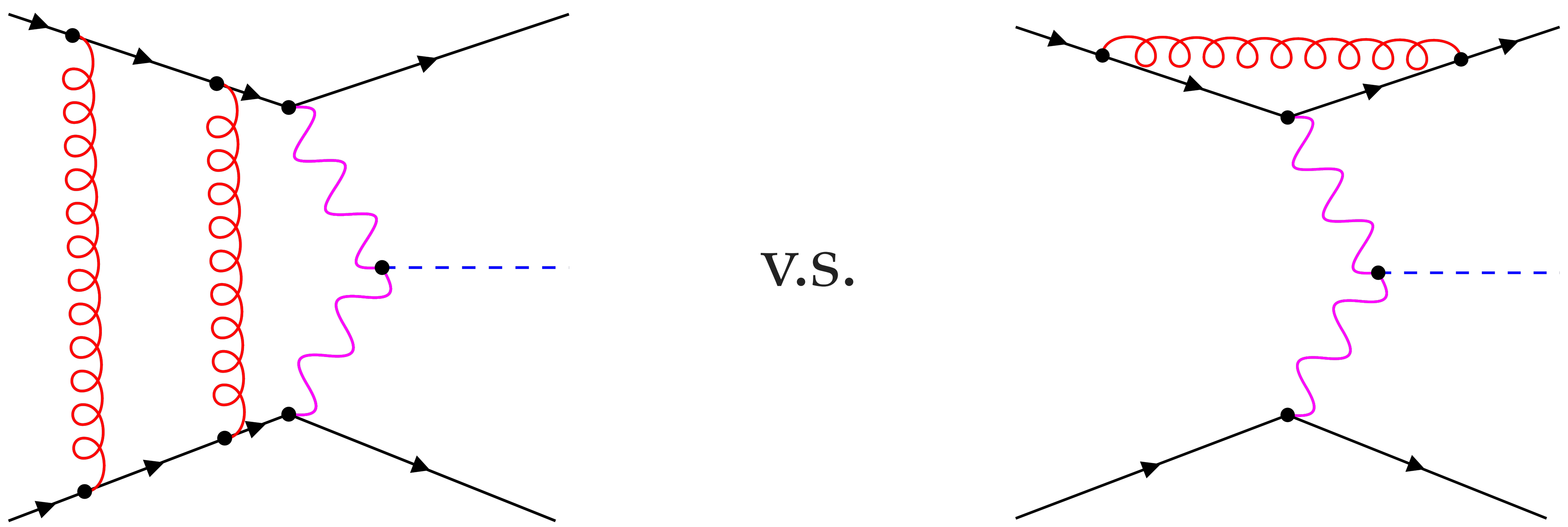
2) finite width effects are accounted for;

3) the $t\bar{t}\gamma$ signal is identified through selection cuts rather than by identifying diagrams with top quarks lines; allows for meaningful comparison with experiment.

μ_0	$\sigma^{\rm LO}$ [fb]	$\sigma^{\rm NLO}$ [fb]	$\mathcal{K} = \sigma^{\rm NLO}/\sigma^{\rm LO}$
$E_T/4$	$17.512(8)^{+30.9\%}_{-22.1\%}$	$21.50(2)^{+1.4\%}_{-5.0\%}$	1.23
$H_T/4$	$19.409(9)^{+31.9\%}_{-22.6\%}$	$21.38(2)^{+1.4\%}_{-7.5\%}$	1.10
m_t	$15.877(7)^{+30.1\%}_{-21.6\%}$	$21.13(2)^{+1.4\%}_{-6.4\%}$	1.33

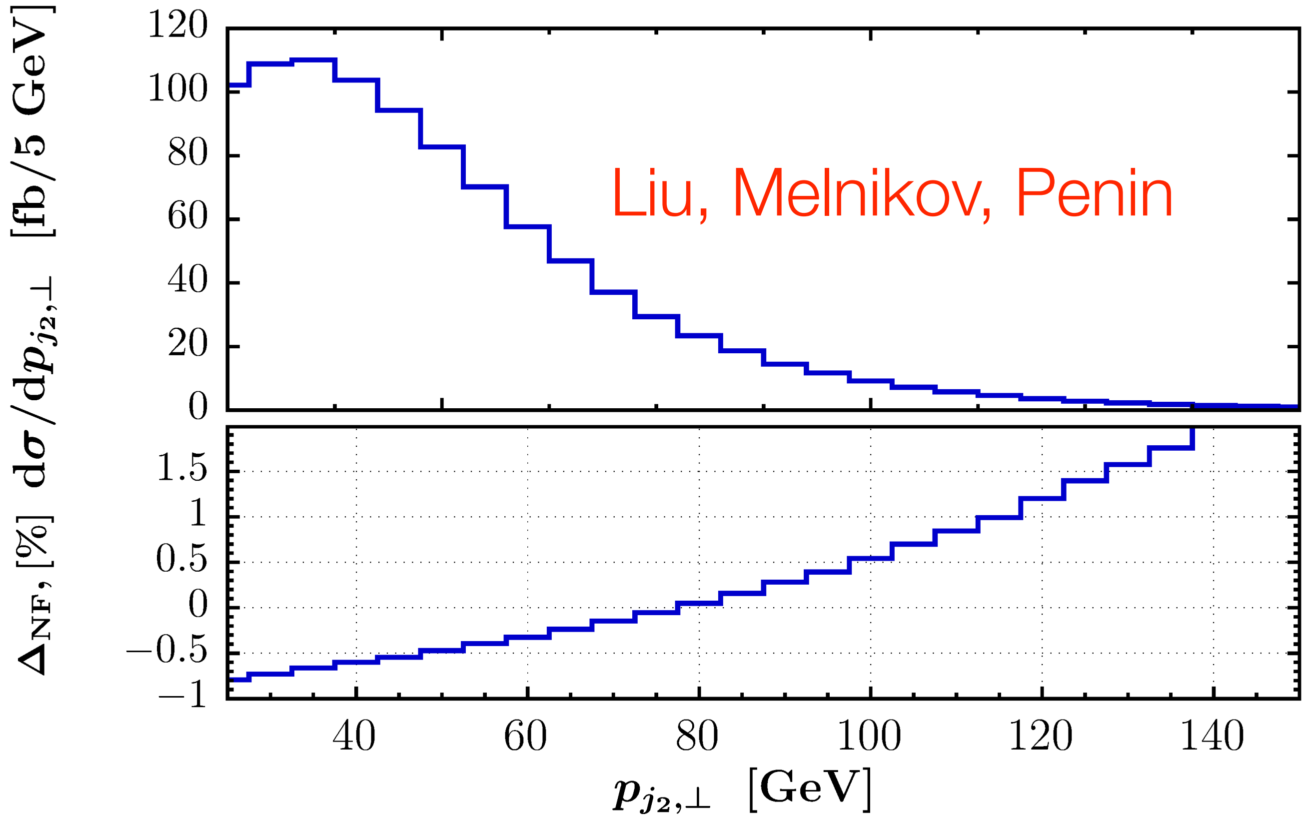
D. Stremmer, M. Worek

A1c: impact of non-factorizable effects, and QCD corrections to Higgs decays to bottom quarks on the Higgs boson production cross section in weak boson fusion.



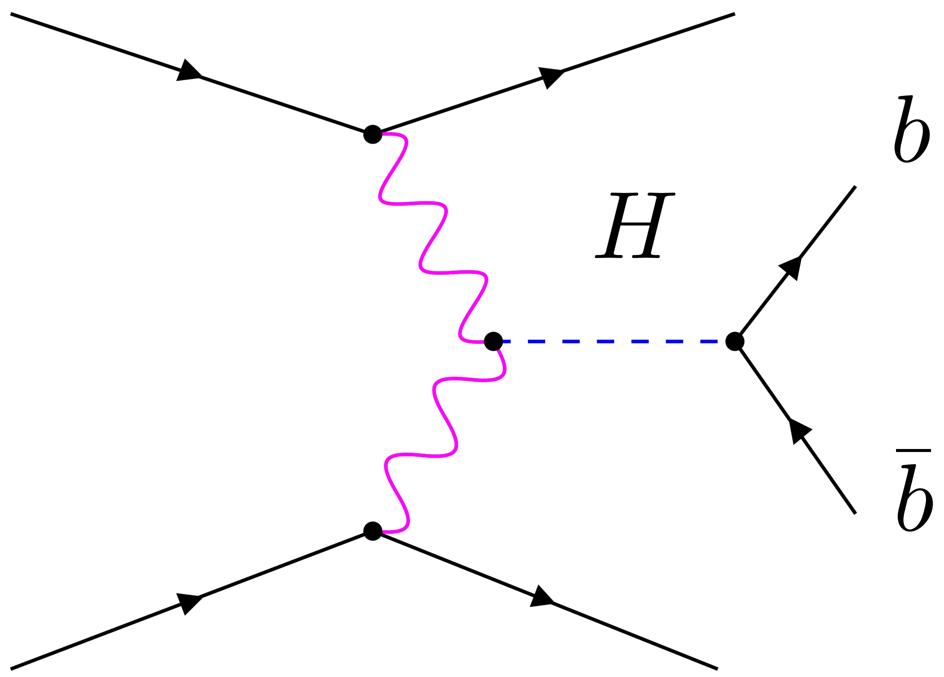
$$\mathcal{M}^{(2)} = -\frac{\tilde{\alpha}_s^2}{2!}\chi^{(2)}(\boldsymbol{q}_3, \boldsymbol{q}_4)\mathcal{M}^{(0)}$$

$$\chi^{(2)}(\boldsymbol{q}_3, \boldsymbol{q}_4) = \frac{1}{\pi^2}\int\left(\prod_{i=1}^{2}\frac{\mathrm{d}^2\boldsymbol{k}_i}{\boldsymbol{k}_i^2+\lambda^2}\right) \times \frac{\boldsymbol{q}_3^2+M_V^2}{(\boldsymbol{k}_1+\boldsymbol{k}_2-\boldsymbol{q}_3)^2+M_V^2}\,\frac{\boldsymbol{q}_4^2+M_V^2}{(\boldsymbol{k}_1+\boldsymbol{k}_2+\boldsymbol{q}_4)^2+M_V^2}$$



Ch. Bronnum-Hansen, M.M. Long, K.M. J. Quarroz

$$\sigma_{\mathrm{nf}}^{\mathrm{NNLO}} = (-3.1 + 0.53)\ \mathrm{fb}$$



σ/fb	fixed order	LO+PS	MiNNLO+PS
LO	75.6	46.6	45.2
NLO	52.4	43.6(1)	42.3
NNLO	44.6(1)	43.1(1)	41.4(1)

(number in parenthesis indicates Monte-Carlo uncertainty)

K. Asteriadis, A. Behring, K.M., I. Novikov, R. Roentsch

A. Behring, K.M., I. Novikov, G. Zanderighi

A1c: in the context of the soft-collinear subtraction scheme, finite remainders for arbitrary processes with massless partons at NNLO QCD, for both lepton and a hadron colliders, have been derived.

1) Color correlations are handled globally, with the help of the generalization of Catani's operator I_1 , that combines color-correlated contributions from virtual, soft and soft-collinear terms;

2) Collinear contributions through NNLO are shown to factorize leg-by-leg (as it should be), enabling generalization to arbitrary processes in a relatively straightforward manner;

3) Cancellation of 1/ep divergencies at NNLO has been demonstrated for the very first time in a process-independent way.

4) These results put the understanding of NNLO QCD subtractions on par with the understanding of NLO QCD subtractions, at least inasmuch as their generality is concerned.

F. Devoto, K.M., R. Röntsch, C. Signorile-Signorile, D.M. Tagliabue, M. Tresoldi

We started extending the nested soft-collinear subtraction scheme to accommodate massive color-charged partons: semi-analytic results for the integrated NNLO eikonal function for massless-massive emitters, and massive-massive emitters with momenta at an arbitrarty angle have been obtained.

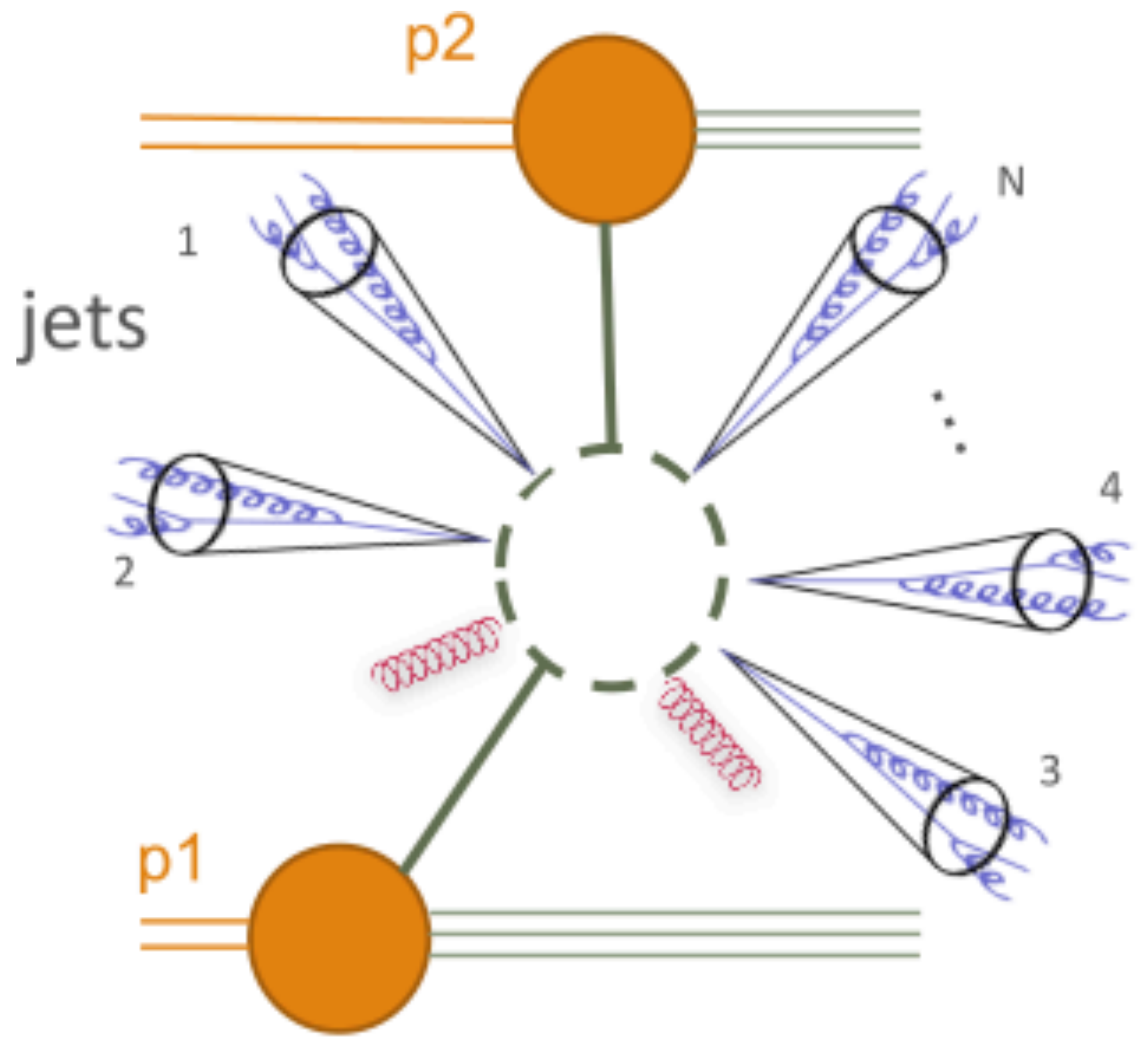
D. Horstmann, M.M. Long, K.M., A. Pikelner
M.M. Long, K.M., A. Pikelner

B1a, B2a & B1e: slicing schemes with the N-jettiness variable were explored from various perspectives; groundbreaking results have been achieved.

$$\int |\mathcal{M}|^2 \; F_J \; \mathrm{d}\phi_d = \int_0^\delta \left[|\mathcal{M}|^2 \; F_J \; \mathrm{d}\phi_d\right]_{\text{simp}} + \int_\delta^1 |\mathcal{M}|^2 \; F_J \; \mathrm{d}\phi_4 + \mathcal{O}(\delta)$$

$$\mathcal{T}_N = \sum_{i=1}^{N_{\text{part}}} \min\left[\frac{2k_i p_{J_1}}{Q_1}, \frac{2k_i p_{J,2}}{Q_2}, \cdots, \frac{2k_i p_{J_N}}{Q_N}\right]$$

$$\lim_{\tau\to 0} \int_0^\tau \frac{\mathrm{d}\sigma}{\mathrm{d}\mathcal{T}_N} \, \mathrm{d}\mathcal{T}_N = \int B_a \otimes B_b \otimes S \otimes H \otimes J.$$



Double real

B2a & B1a: the N-jettiness soft function for arbitrary N was computed by two CRC groups independently of each other, with different motivations.

$$\mathcal{T}_N = \sum_{i=1}^{N_{\rm part}} \min\left[\frac{2k_i p_{J_1}}{Q_1}, \frac{2k_i p_{J,2}}{Q_2}, \cdots, \frac{2k_i p_{J_N}}{Q_N}\right] \quad \Rightarrow \quad \mathcal{T}_N = \min\left[\frac{2p_1 p_m}{Q_1}, \frac{2p_2 p_m}{Q_2}, \cdots \frac{2p_N p_m}{Q_N}\right]$$

In the traditional approach, that goes back to papers where the N-jettiness variable was introduced, one resolves the minimum condition for the jettiness function by partitioning the phase space. This approach was used earlier for calculations with N=0,1,2; it is hard to imagine how it can be used for arbitrary number of jets.

$$1 = \theta(x_1 - x_2)\theta(x_2 - x_3) + \theta(x_1 - x_2)\theta(x_3 - x_2)$$

B2a: Can one design a robust numerical code (SoftServe) to compute arbitrary soft functions, including the N-jettiness one?

G. Bell, B. Dehnadi, T. Mohrmann, R. Rahn

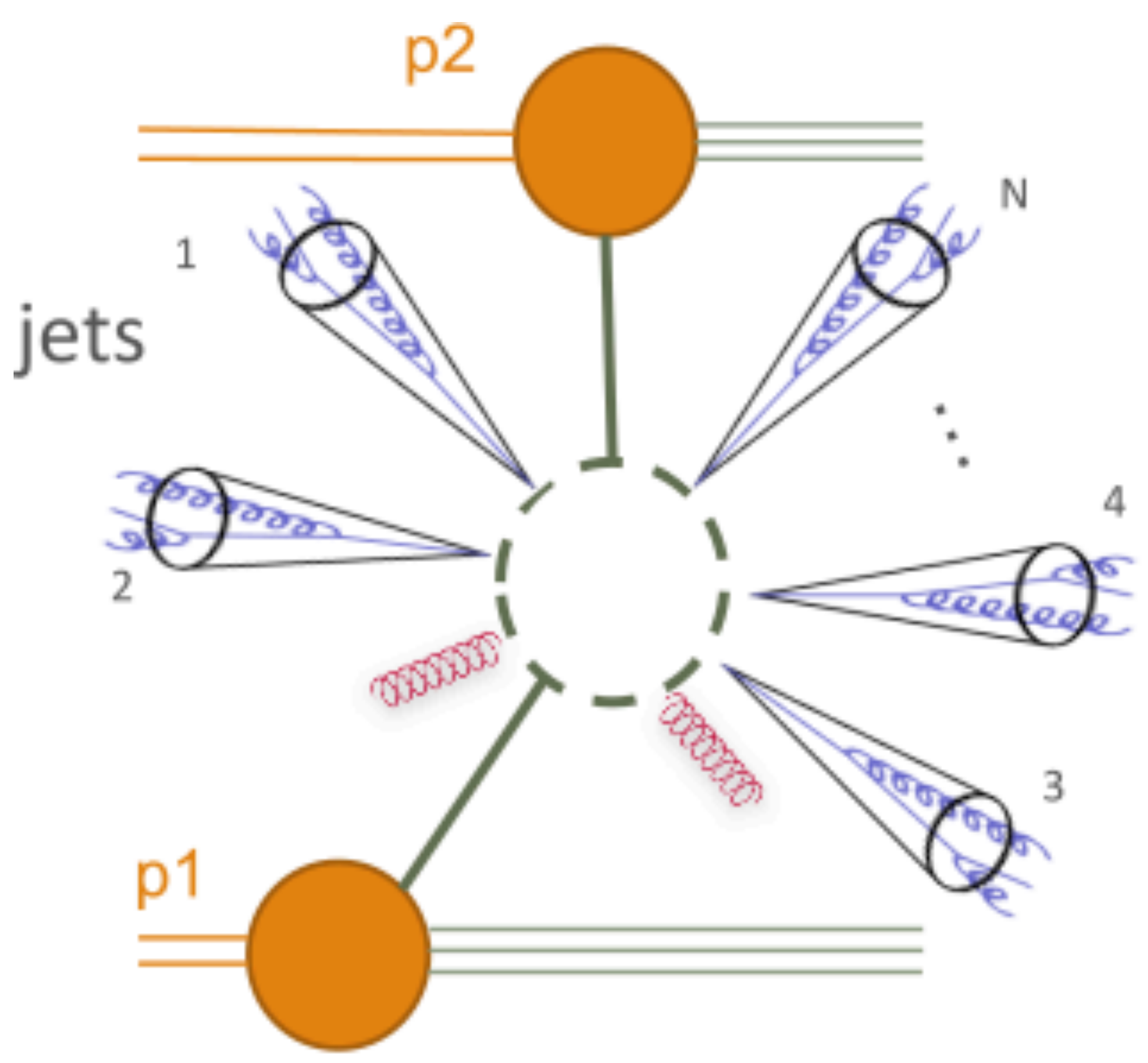
B1a: Can one use a local subtraction, treat N-jettiness as an infra-red safe variable, extract analytically the 1/ep poles and compute the rest in an efficient numerical way?

P. Agarwal, K.M., I. Pedron

B2a & B1a: calculation of the NNLO soft function for arbitrary N is a step beyond the state-of-the-art in this field.

$$\tilde{S} = 1 + \tilde{S}_1 + \tilde{S}_2 + \mathcal{O}(\alpha_s^3)$$

$$\tilde{S}_1 = a_s \sum_{(ij)} \mathbf{T}_i \cdot \mathbf{T}_j \left[2L_{ij}^2 + \mathrm{Li}_2(1-\eta_{ij}) + \frac{\pi^2}{12} + \left\langle L^{\psi}_{ij,\mathfrak{m}} \frac{\rho_{ij}}{\rho_{i\mathfrak{m}}\rho_{j\mathfrak{m}}} \right\rangle_{\mathfrak{m}} \right] \qquad \tilde{S}_2 = \frac{1}{2}\,\tilde{S}_1^2 + a_s^2 C_A \sum_{(ij)} \mathbf{T}_i \cdot \mathbf{T}_j\, G_{ij} + a_s^2\, n_f\, T_R \sum_{(ij)} \mathbf{T}_i \cdot \mathbf{T}_j\, Q_{ij} + a_s^2 \pi \sum_{(kij)} F^{kij}\, \kappa_{kj} G_{kij}^{\text{triple}}$$



Comparison of the results of the two independent calculations (G. Bell et al. and P. Agarwal et al.) performed within the CRC.

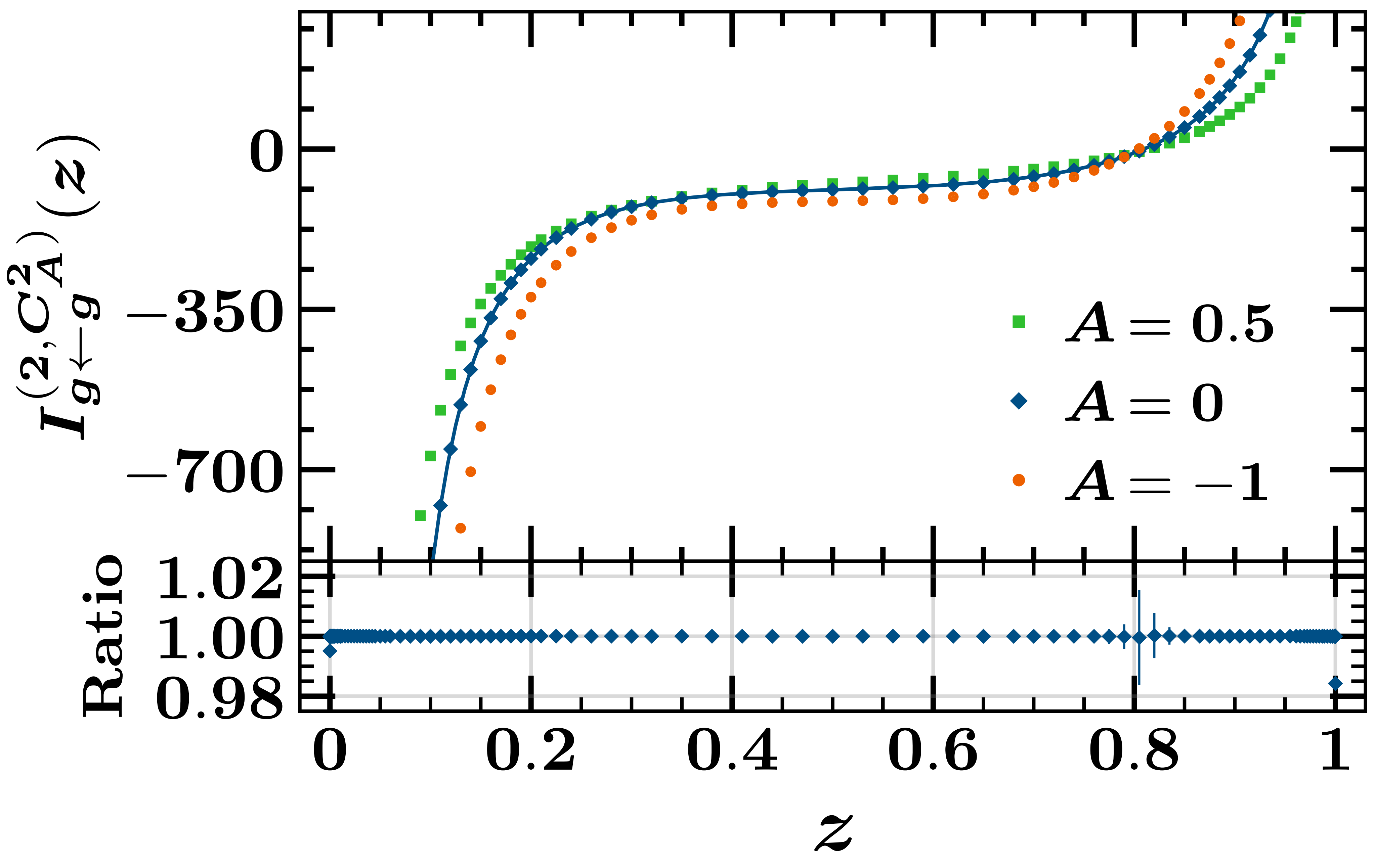
Ref [37] = Bell et

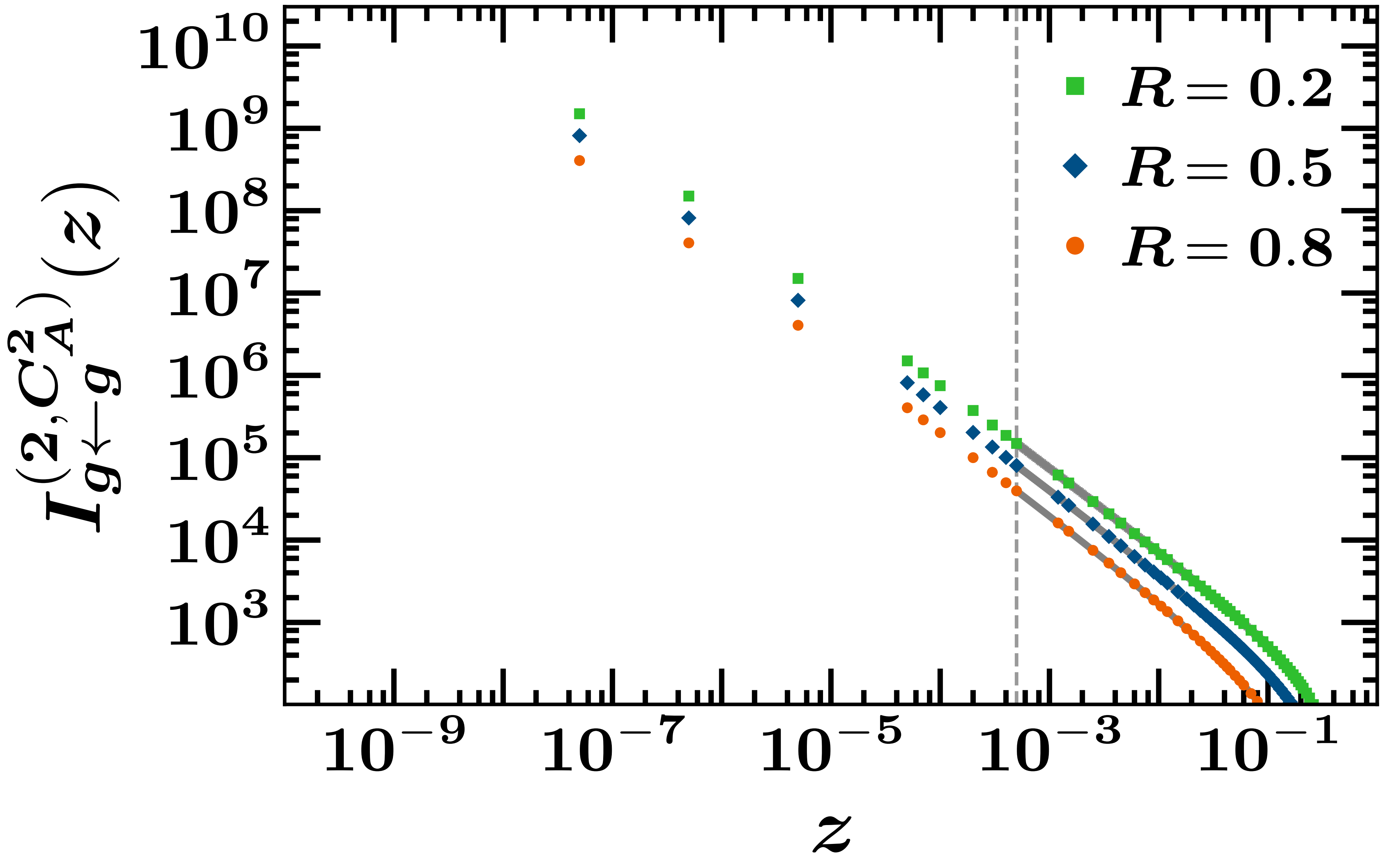
$$n_1 = (0,0,1), \quad n_2 = (0,0,-1),$$
$$n_3 = (\sin\theta_{13}, 0, \cos\theta_{13}), \quad n_4 = (\sin\theta_{14}\cos\phi_4, \sin\theta_{14}\sin\phi_4, \cos\theta_{14})$$
$$n_5 = (\sin\theta_{15}\cos\phi_5, \sin\theta_{15}\sin\phi_5, \cos\theta_{15})$$
$$\theta_{13} = \frac{3\pi}{10}, \quad \theta_{14} = \frac{6\pi}{10}, \quad \theta_{15} = \frac{9\pi}{10}, \quad \phi_4 = \frac{3\pi}{5}, \quad \phi_5 = \frac{6\pi}{5}$$

Dipoles	Gluons		Quarks	
	G_{ij}^{nl}	Ref. [37]	Q_{ij}^{nl}	Ref. [37]
12	116.20 ± 0.01	116.20 ± 0.16	-36.249 ± 0.001	-36.244 ± 0.009
13	38.13 ± 0.03	37.63 ± 0.03	-21.717 ± 0.007	-21.732 ± 0.005
14	63.63 ± 0.01	63.66 ± 0.06	-25.189 ± 0.003	-25.192 ± 0.006
15	107.17 ± 0.01	106.99 ± 0.12	-35.268 ± 0.001	-35.256 ± 0.009
23	97.11 ± 0.01	96.97 ± 0.10	-32.875 ± 0.002	-32.872 ± 0.008
24	67.36 ± 0.02	67.51 ± 0.08	-26.821 ± 0.003	-26.815 ± 0.007
25	30.87 ± 0.03	30.73 ± 0.04	-21.561 ± 0.009	-21.561 ± 0.005
34	69.43 ± 0.01	69.24 ± 0.07	-25.854 ± 0.002	-25.861 ± 0.006
35	106.13 ± 0.02	105.97 ± 0.13	-34.799 ± 0.002	-34.796 ± 0.008
45	74.45 ± 0.02	74.36 ± 0.09	-28.247 ± 0.004	-28.251 ± 0.007

	$\tilde{c}^{(2,124)}_{\text{tripoles}}$	$\tilde{c}^{(2,125)}_{\text{tripoles}}$	$\tilde{c}^{(2,145)}_{\text{tripoles}}$	$\tilde{c}^{(2,245)}_{\text{tripoles}}$
$\tilde{c}_{\text{tripoles}}$	-683.25 ± 0.01	-2203.3 ± 0.2	-6.324 ± 0.004	-0.837 ± 0.008
Ref. [37]	-683.23 ± 0.04	-2203.5 ± 0.1	-6.325 ± 0.04	-0.830 ± 0.039

B2a: continuous development of a numerical code for calculating soft, beam and jet functions in SCET, including complex observables. The code is a unique framework for computing SCET ingredients with the NNLO accuracy.



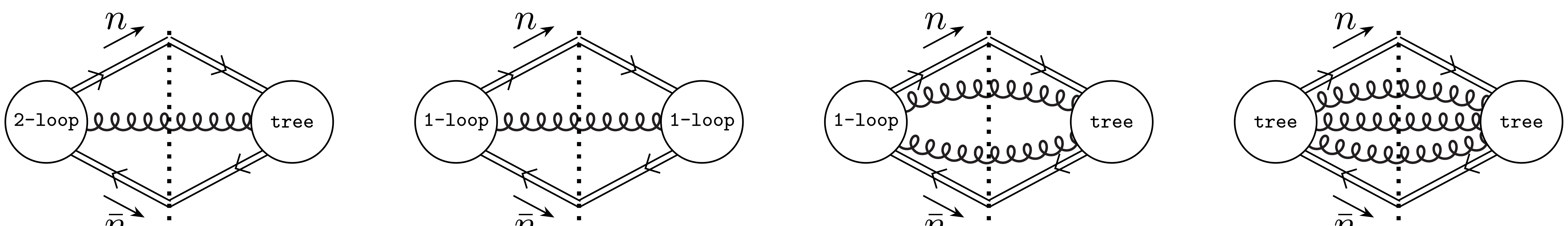


Matching beam-function coefficients at NNLO for a maximally non-abelian color factor for three angularities (left) and three values of jet radius R for the jet-veto case.

G. Bell, K. Brune, G. Das. M. Wald

G. Bell, K. Brune, G. Das. D.Y. Shao, M. Wald

B1a: the pioneering computation of the zero-jettiness soft function at N3LO QCD was completed in the second funding period.



$$\mathcal{T}_N = \min\left[\frac{2p_1 p_m}{Q_1}, \frac{2p_2 p_m}{Q_2}, \cdots \frac{2p_N p_m}{Q_N}\right]$$

$$\tilde{s}(L_S) = \log\left[\tilde{S}(L_S)\right] = \sum_{i=1}^{\infty} a_s^i \sum_{j=0}^{i+1} C_{i,j} L_S^j \,.$$

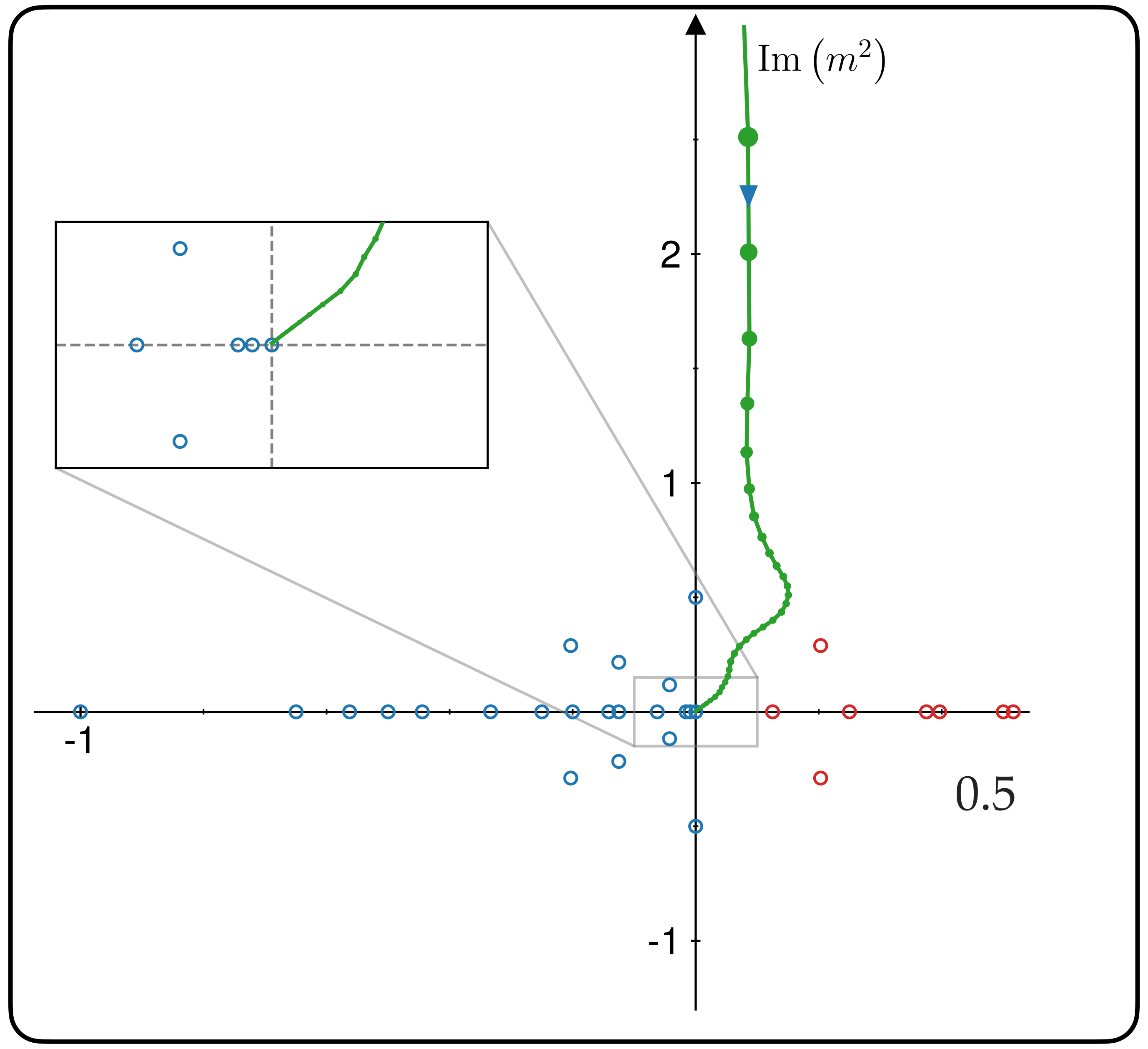
$$C_{1,0} = -C_R \pi^2$$

$$C_{2,0} = C_R\left[n_f T_F\left(\frac{80}{81} + \frac{154\pi^2}{27} - \frac{104\zeta_3}{9}\right) - C_A\left(\frac{2140}{80} + \frac{871\pi^2}{54} - \frac{286\zeta_3}{9} - \frac{14\pi^4}{15}\right)\right],$$

$$C_{3,0} = C_R\left[n_f^2 T_F^2\left(\frac{265408}{6561} - \frac{400\pi^2}{243} - \frac{51904\zeta_3}{243} + \frac{328\pi^4}{1215}\right) + n_f T_F\left(C_F X_{FF} + C_A X_{FA}\right) + C_A^2 X_{AA}\right]$$

$$X_{FF} = 68.9425849800376, \qquad X_{FA} = 839.7238523813981,$$

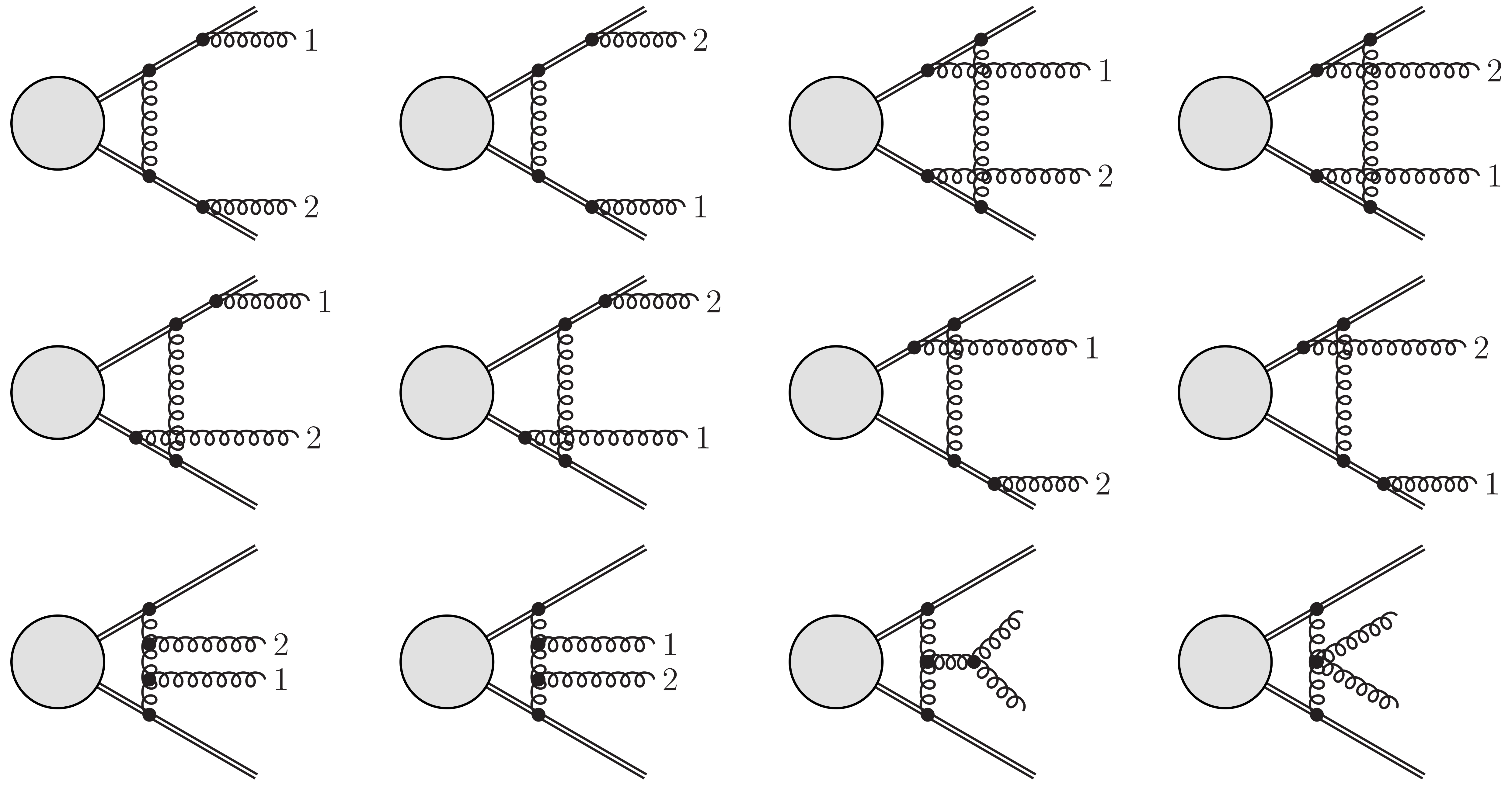
$$X_{AA} = -753.7757872704537.$$



A typical path in the complex plane that was used to compute some of the master integrals

D. Baranowski, C.Y. Chen, M. Delto, K.M., A. Pikelner

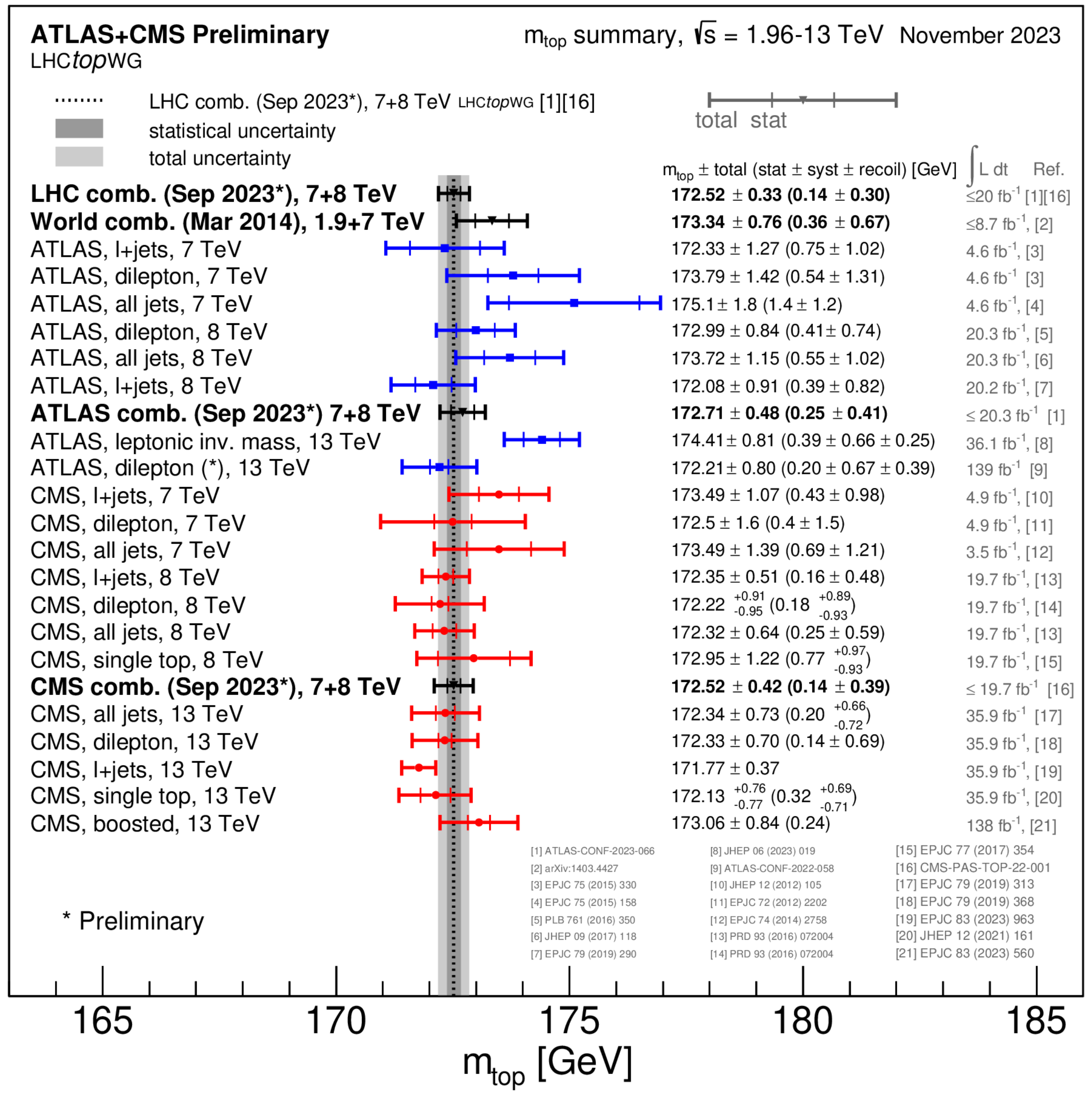
B1a: extending the zero-jettiness soft function calculation to the one-jettiness one is a tall order. One important ingredient for this step — the one-loop correction to the double-soft current for arbitrary number of hard emitters was also obtained as part of the CRC research effort.

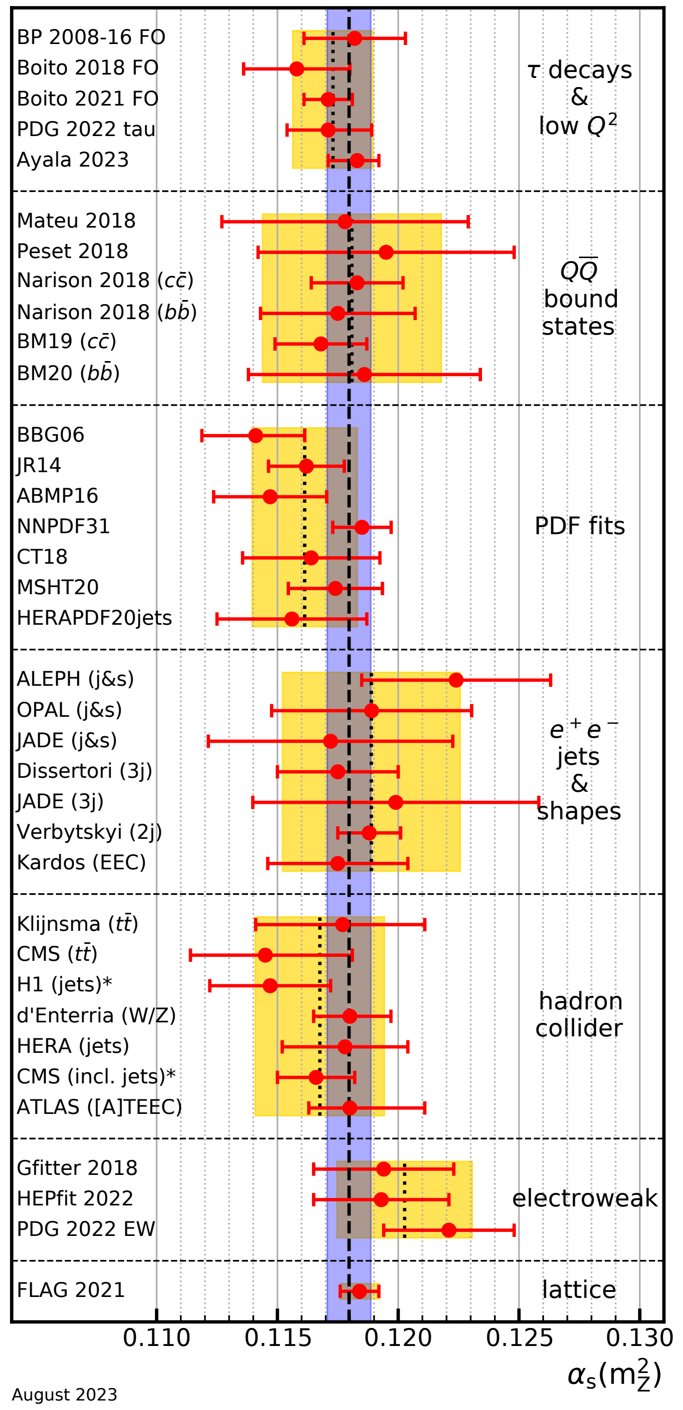


$$\mathbf{J}^{(1)a_1a_2}_{\alpha_1\alpha_2}(q_1,q_2) = \left(\mathbf{J}^{(1)a_1}_{\alpha_1}(q_1)\mathbf{J}^{(0)a_2}_{\alpha_2}(q_2) + \mathbf{J}^{(1)a_2}_{\alpha_2}(q_2)\mathbf{J}^{(0)a_1}_{\alpha_1}(q_1)\right) + \Delta\mathbf{J}^{(1)a_1a_2}_{\alpha_1\alpha_2}(q_1,q_2)\ .$$

M. Czakon, F. Eschment, T. Schellenberger

B1e: Power corrections in collider processes: commonalities between perturbative and non-perturbative aspects of the problem.





$$m_t = 172.52 \pm 0.33 \text{ GeV}$$

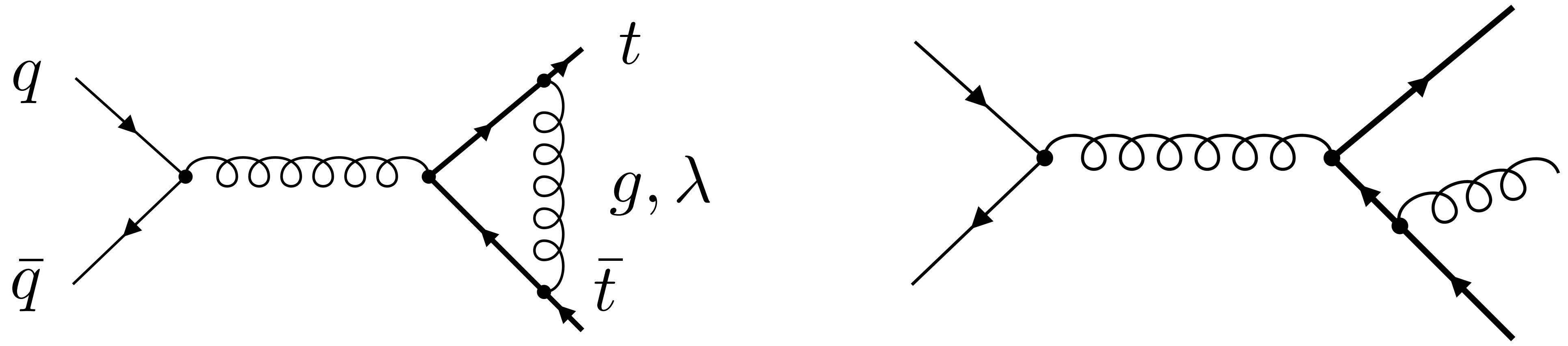
$$\alpha_s(M_z) = 0.118 \pm 0.001$$

$$\mathrm{d}\sigma_{\text{hard}} = \int \mathrm{d}x_1\, \mathrm{d}x_2 f_i(x_1) f_j(x_2)\, \mathrm{d}\sigma_{ij}(x_1, x_2, \{p_{\text{fin}}\})\, O_J(\{p_{\text{fin}}\}) \left(1 + \mathcal{O}(\Lambda^n_{\text{QCD}}/Q^n)\right)$$

B1e: studies of linear non-perturbative corrections for collider observables were significantly advanced in the second funding period.

$$\int \mathrm{d}k\; k^{p-1}\alpha_s(\mu)\; F(k) \Rightarrow \int \mathrm{d}k\; k^{p-1}\alpha_s(k)F(k)$$

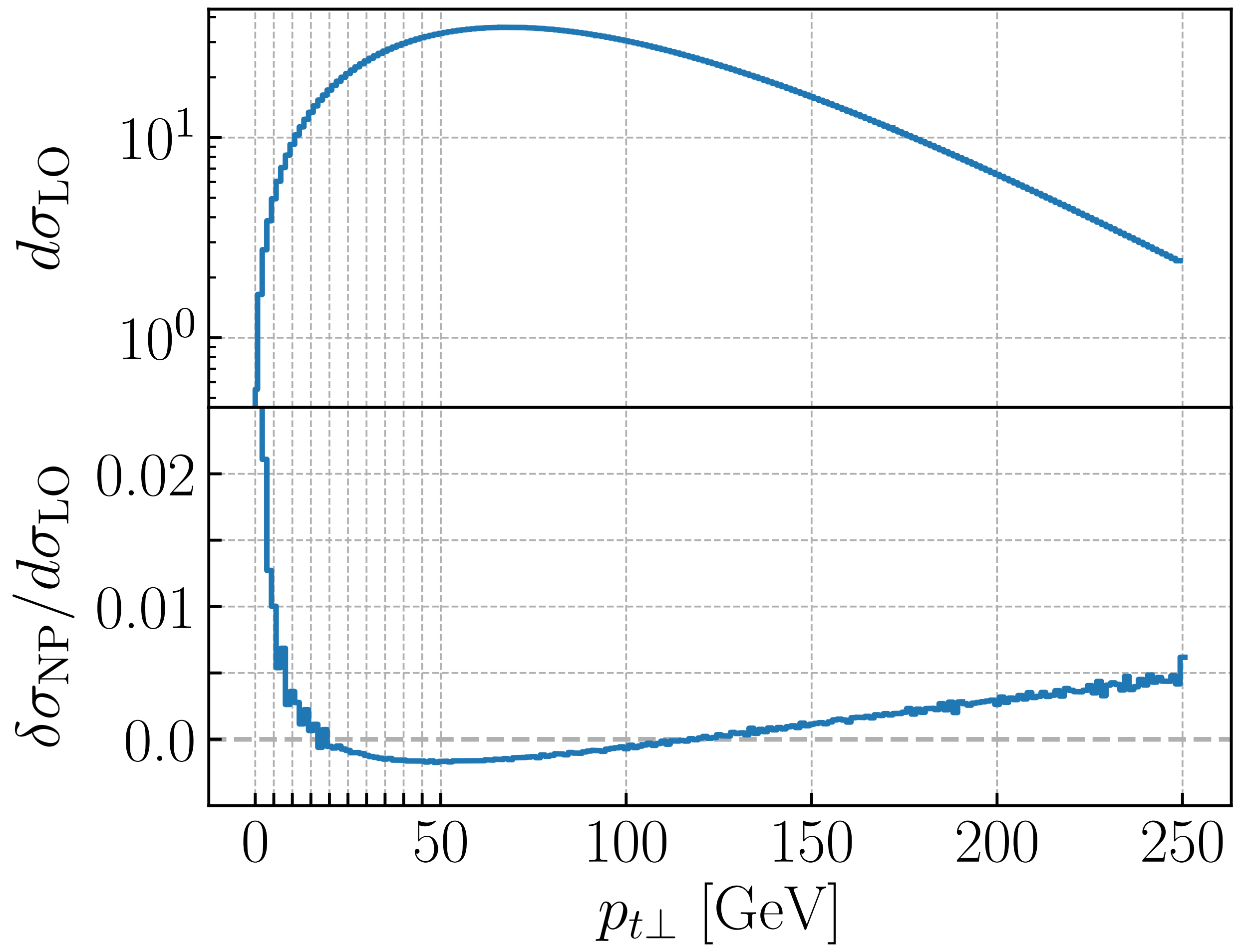
$$\alpha_s(k^2) \approx \frac{1}{2\beta_0}\frac{\Lambda^2_{\mathrm{QCD}}}{k^2-\Lambda^2_{\mathrm{QCD}}}, \qquad k^2 \approx \Lambda^2_{\mathrm{QCD}}$$

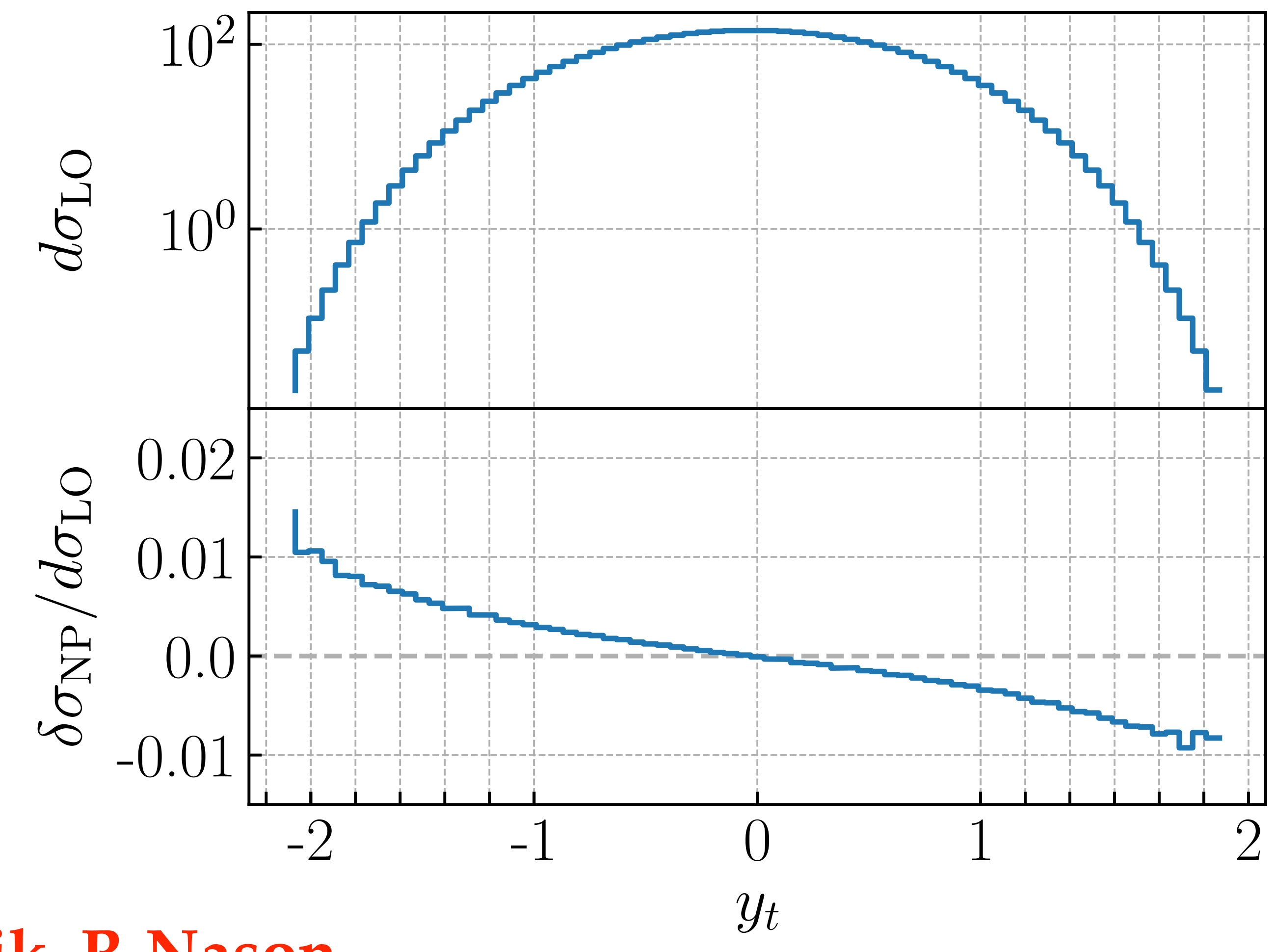


$$\sigma_{t\bar{t}} = \sigma_0\left[1 + c\,\frac{\lambda}{m_t} + \mathcal{O}(\lambda^2)\right] \qquad \lambda \to \Lambda_{\mathrm{QCD}}$$

$$\frac{\delta_{\mathrm{NP}}\left[p_{t\perp}\right]}{p_{t\perp}} = \frac{\alpha_s}{2\pi}\frac{\pi\lambda}{m_t}\frac{(2C_F - C_A\tau)}{2(1-\tau)}$$

$$\delta_{\mathrm{NP}}\left[y_t\right] = \frac{\alpha_s}{2\pi}\frac{\pi\lambda}{m_t}\left[(3C_A - 8C_F)\,\tau\cosh^2 y_t - (C_A - 2C_F)\,\frac{\tau(2-\tau)}{4(1-\tau)}\sinh(2y_t)\right]$$

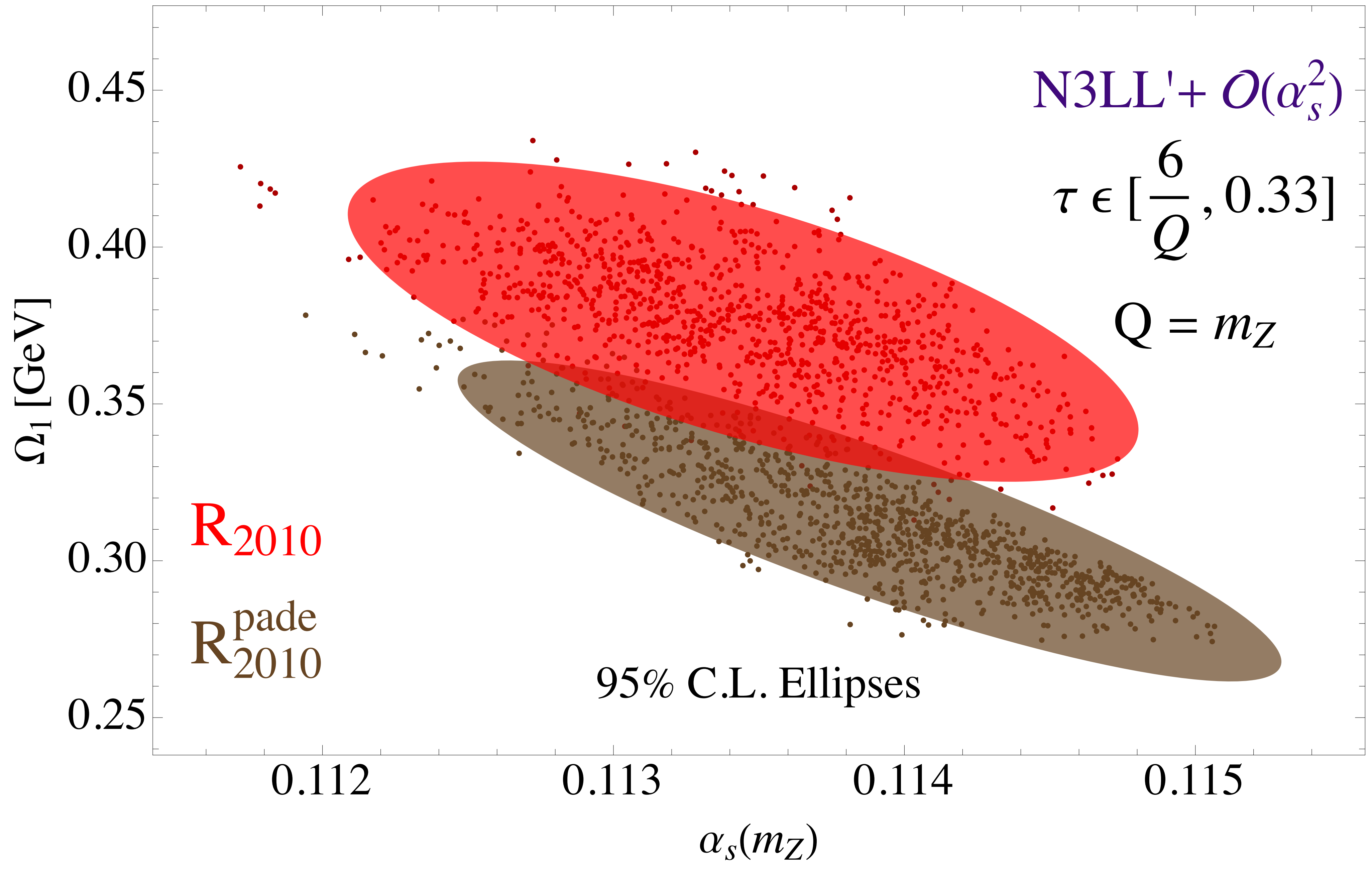


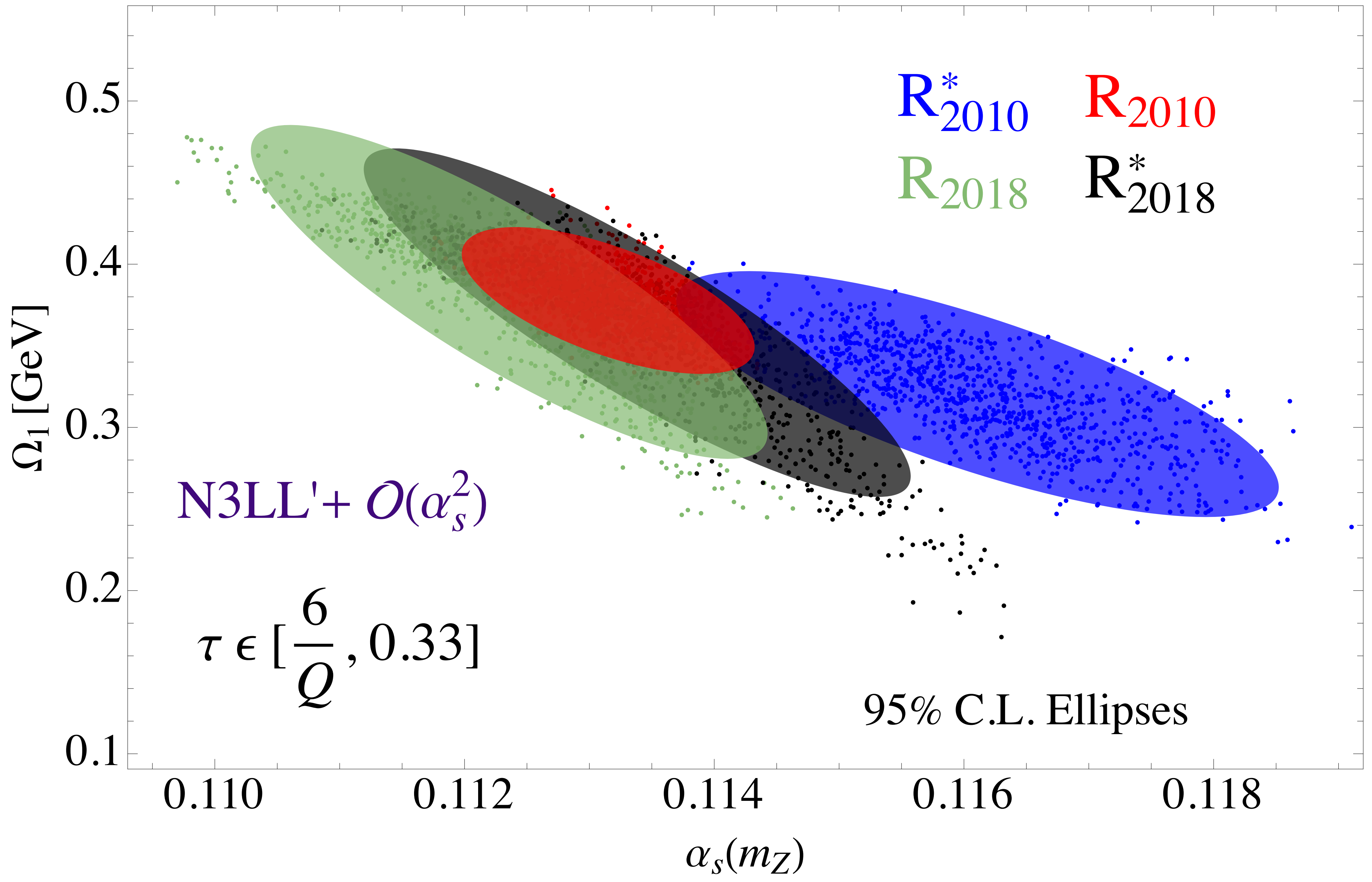


$$\alpha_s\lambda = \frac{0.4\ \mathrm{GeV}}{C_F} = 0.3\ \mathrm{GeV}$$

S. Makarov, K.M., M. Ozcelik, P. Nason

B1e: Tests of the stability of the extracted value of the strong couplling constant from the thrust distribution for different renormalon subtraction schemes.





Red: the soft function coefficient is -19988 ± 5440

Green: the soft function coefficient is 691 ± 1000

The correct soft function coefficient is -1000

The comparison of different renormalon subtraction schemes on the extracted value of the strong coupling constant and the non-perturbative shift parameter

G. Bell, C. Lee, Y. Makris, J. Talbert, B. Yan

B1e: next-to-soft contribution of one-loop amplitudes & next-to-collinear at tree level in QCD.

Next-to-soft contribution for one-loop amplitudes in QCD admits a nearly factorized representation which generalizes the tree-level next-to-soft theorems (the analog of Burnett-Kroll-Low in QED).

$$\left|M_g^{(1)}(\{p_i+\delta_i\},q)\right\rangle = \mathbf{S}^{(0)}(\{p_i\},\{\delta_i\},q)\left|M^{(1)}(\{p_i\})\right\rangle$$
$$+\mathbf{S}^{(1)}(\{p_i\},\{\delta_i\},q)\left|M^{(0)}(\{p_i\})\right\rangle + \int_0^1 \mathrm{d}x \sum_i \mathbf{J}_i^{(1)}(x,p_i,q)\left|H_{g,i}^{(0)}(x,\{p_i\},q)\right\rangle$$
$$+\sum_{i\neq j}\sum_{\substack{\tilde{a}_i\neq a_i\\ \tilde{a}_j\neq a_j}} \tilde{\mathbf{S}}^{(1)}_{a_i a_j\leftarrow \tilde{a}_i\tilde{a}_j,\,ij}(p_i,p_j,q)\left|M^{(0)}(\{p_i\})\Big|_{\substack{a_i\to\tilde{a}_i\\ a_j\to\tilde{a}_j}}\right\rangle + \int_0^1 \mathrm{d}x \sum_{\substack{i\\ a_i=g}} \tilde{\mathbf{J}}_i^{(1)}(x,p_i,q)\left|H_{\bar{q},i}^{(0)}(x,\{p_i\},q)\right\rangle$$
$$+\mathcal{O}(\lambda)\,.$$

M. Czakon, F. Eschment, T. Schellenberger

An example of an operator:

$$\mathbf{P}_g(\sigma,c)\,\mathbf{S}^{(1)}(\{p_i\},\{\delta_i\},q)+\mathcal{O}(\lambda) = \frac{2\,r_{\mathrm{Soft}}}{\epsilon^2}\sum_{i\neq j} i f^{abc}\mathbf{T}_i^a\mathbf{T}_j^b \otimes \left(-\frac{\mu^2 s_{ij}^{(\delta)}}{s_{iq}^{(\delta)}s_{jq}^{(\delta)}}\right)^{\epsilon}\Bigg[\mathbf{S}_i^{(0)}(p_i,\delta_i,q,\sigma)$$
$$+\frac{\epsilon}{1-2\epsilon}\frac{1}{p_i\cdot p_j}\left(\frac{p_i^\mu p_j^\nu - p_j^\mu p_i^\nu}{p_i\cdot q}+\frac{p_j^\mu p_j^\nu}{p_j\cdot q}\right)F_{\mu\rho}(q,\sigma)\left(J_i-\mathbf{K}_i\right)_\nu{}^\rho\Bigg]$$

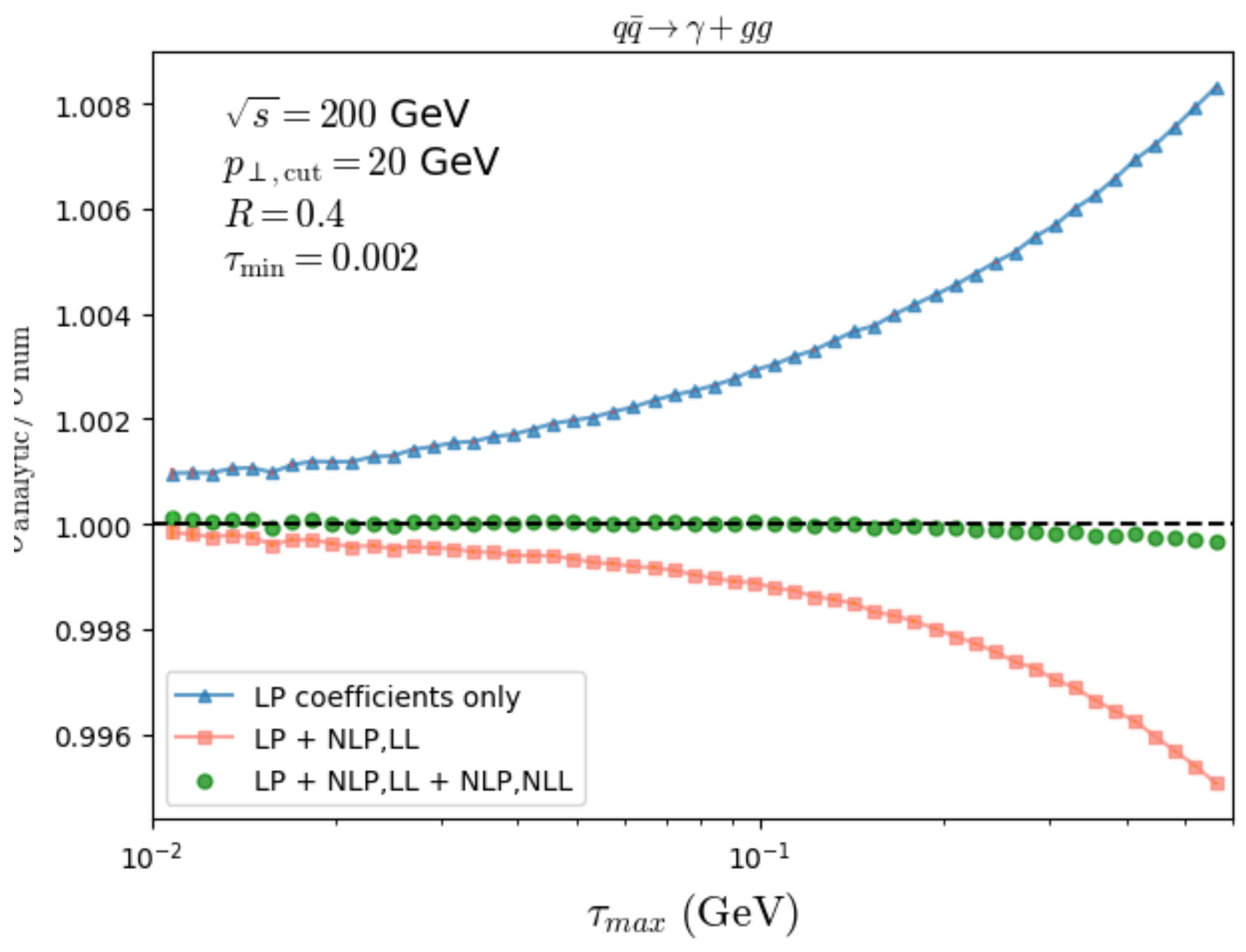
B1e: exploration of power corrections to N-jettiness slicing scheme at NLO QCD.

$$\int |\mathcal{M}|^2 \, F_J \, \mathrm{d}\phi_d \;\Rightarrow\; \underbrace{\int_0^\delta \left[|\mathcal{M}|^2 \, F_J \, \mathrm{d}\phi_d\right]_{\rm simp}}_{\log\delta} + \underbrace{\int_\delta^1 |\mathcal{M}|^2 \, F_J \, \mathrm{d}\phi_4}_{\log\delta,\, \delta\log\delta,\, \delta,\, \cdots} = \mathcal{O}(1) + \mathcal{O}(\delta)$$

Until earlier this year, no results for power corrections in the N-jettiness variable were known, except for the production of a single vector boson in hadron collisions. Methodology used to obtain them was not generalizable to more complex cases.

A combination of Lorentz transformations and momenta redefinitions, familiar from the subtraction methodology, allowed us to factorize phase spaces and matrix elements with sub-leading power accuracy.

We have obtained N-jettiness power correction to the production of
1) an arbitrary colorless final state in hadron collisions;
2) a prompt photon and a jet in collisions of a quark and an antiquark, for a fully realistic jet algorithm.



P. Agarwal, K.M., I. Pedron

Conclusions

1) Not only will research in precision collider physics remain important in the near future, but its relevance will certainly increase. It will largely define the scientific legacy of the LHC.

2) The CRC is world-leading in several aspects of precision collider physics.

3) The CRC has been at the forefront of both technological developments for collider theory, and insightful phenomenology, that has significantly impacted Higgs physics, top quark physics and jet physics.