Theory Summary 2025

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59th Rencontres de Moriond: QCD & High Energy Interactions, La Thuile, April 2025

Overview - 38 Theory Talks

Flavour Physics

EW/BSM
$Q \gtrsim M_{\mathrm{EW}}$

t, H, Z, W

Fixed-Order pQCD
Single-Scale $Q \gg \Lambda$

Matching

Resummed pQCD
Multi-Scale
$Q_i \gg Q_j \gg \Lambda$

b, Γ_{WZt}, c

Hadronization (&UE)
Powers, Strings, QGP
$Q \sim [\,\Lambda, 5\Lambda\,]$

Lattice

Hadrons
$Q \lesssim \Lambda$

QED

$g_\mu - 2$

Warning!

Omissions, biases, and misrepresentations may be encountered beyond this point

Higgs FLV & CPV

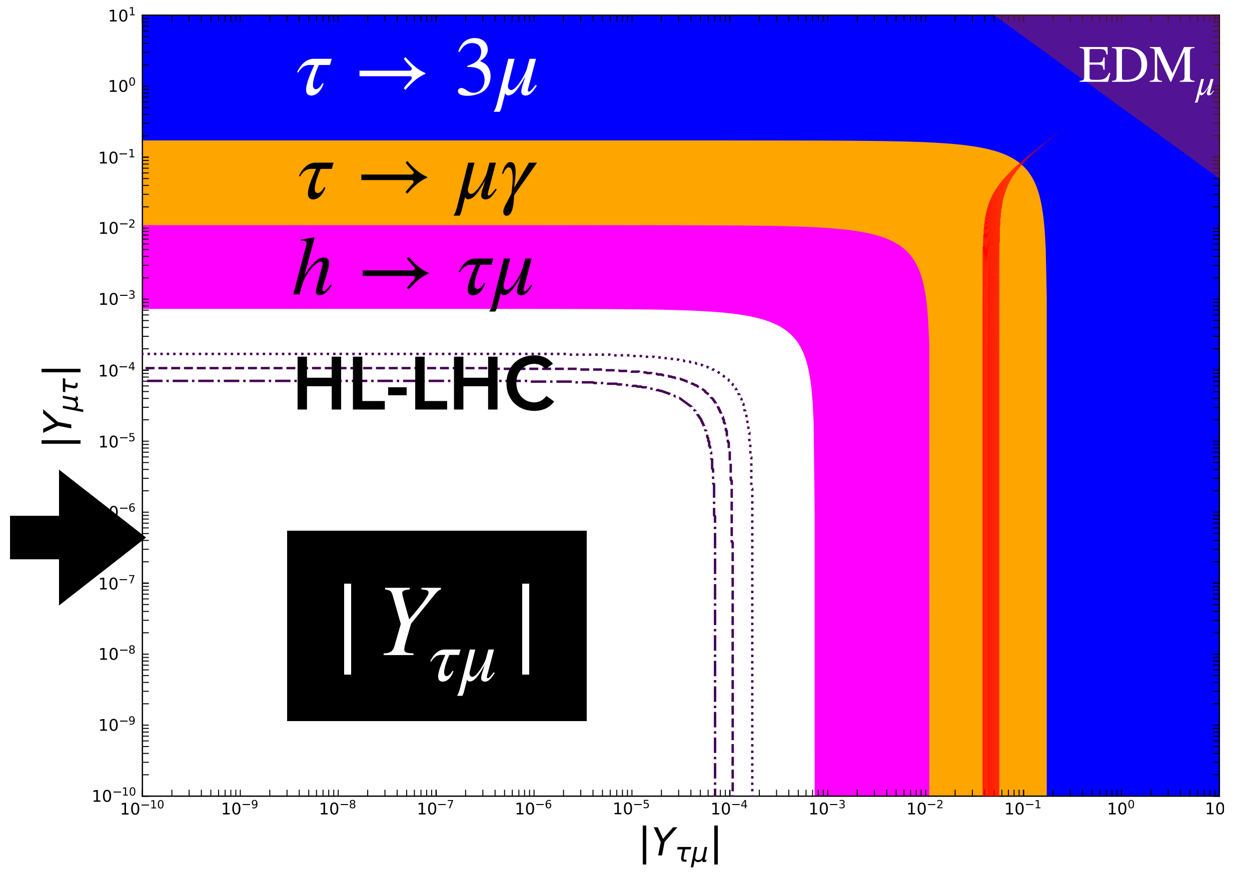
Vempati & Vryonidou

Vempati:

Allow for **FLV**

Higgs couplings

Updated constraints



+ FLV Di-Higgs:

$$\mathscr{L}^l_{\mathbf{FV}} \supset -\frac{1}{2\sqrt{2}v}\Big[C_{ee}\bar{e}e + C_{\mu\mu}\bar{\mu}\mu + C_{\tau\tau}\bar{\tau}\tau + C_{\mu e}(\bar{e}\mu + \bar{\mu}e) + C_{\tau\mu}(\bar{\mu}\tau + \bar{\tau}\mu) + C_{\tau e}(\bar{e}\tau + \bar{\tau}e)\Big]h^2$$

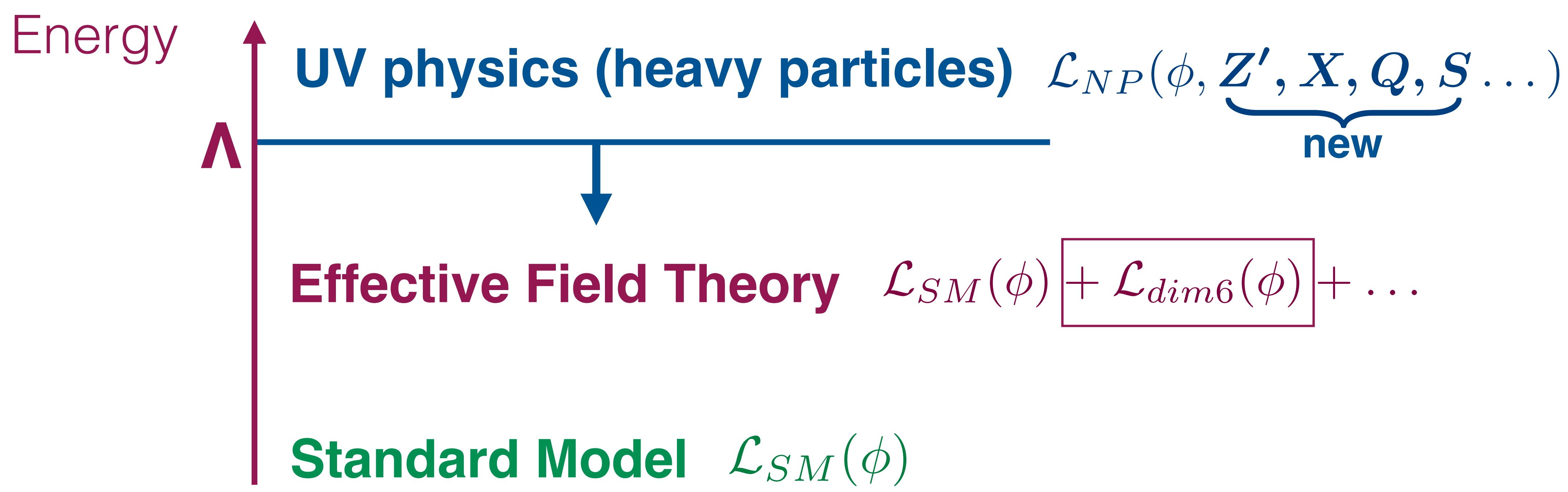
➜ Rich set of low-energy consequences:

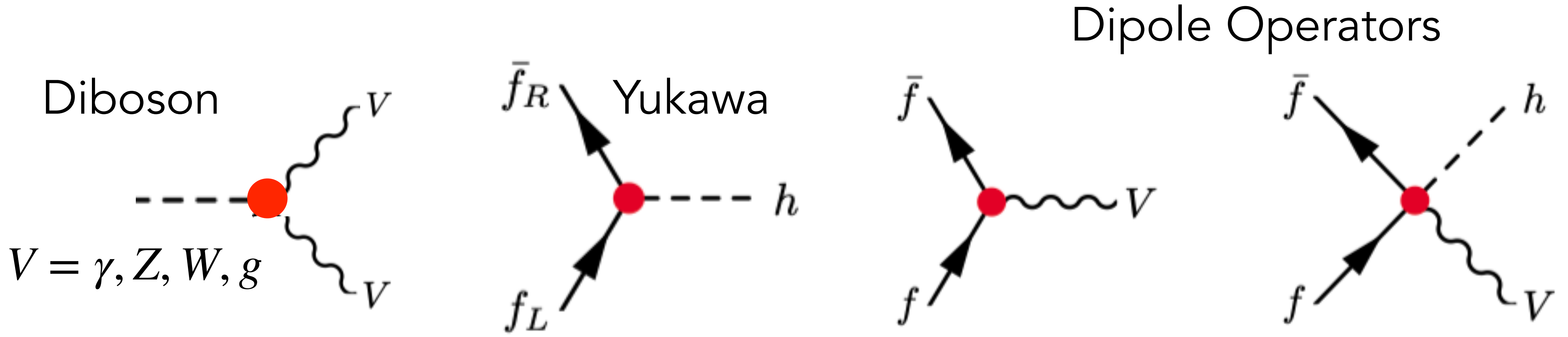
$\ell' \to \ell\ell\ell$, $\ell' \to \ell\gamma$, $\mu \to e$, muonium osc, …

$h \to \tau\ell$, $Z \to \ell'\ell$

B and K osc., R_K, …

Vryonidou: CPV in Higgs sector with SMEFT





➜ Comprehensive study of CPV effects in $t\bar{t}H$, tHq, VH (@NLO), loop-induced $gg \to hh$, hZ, WW, ZZ

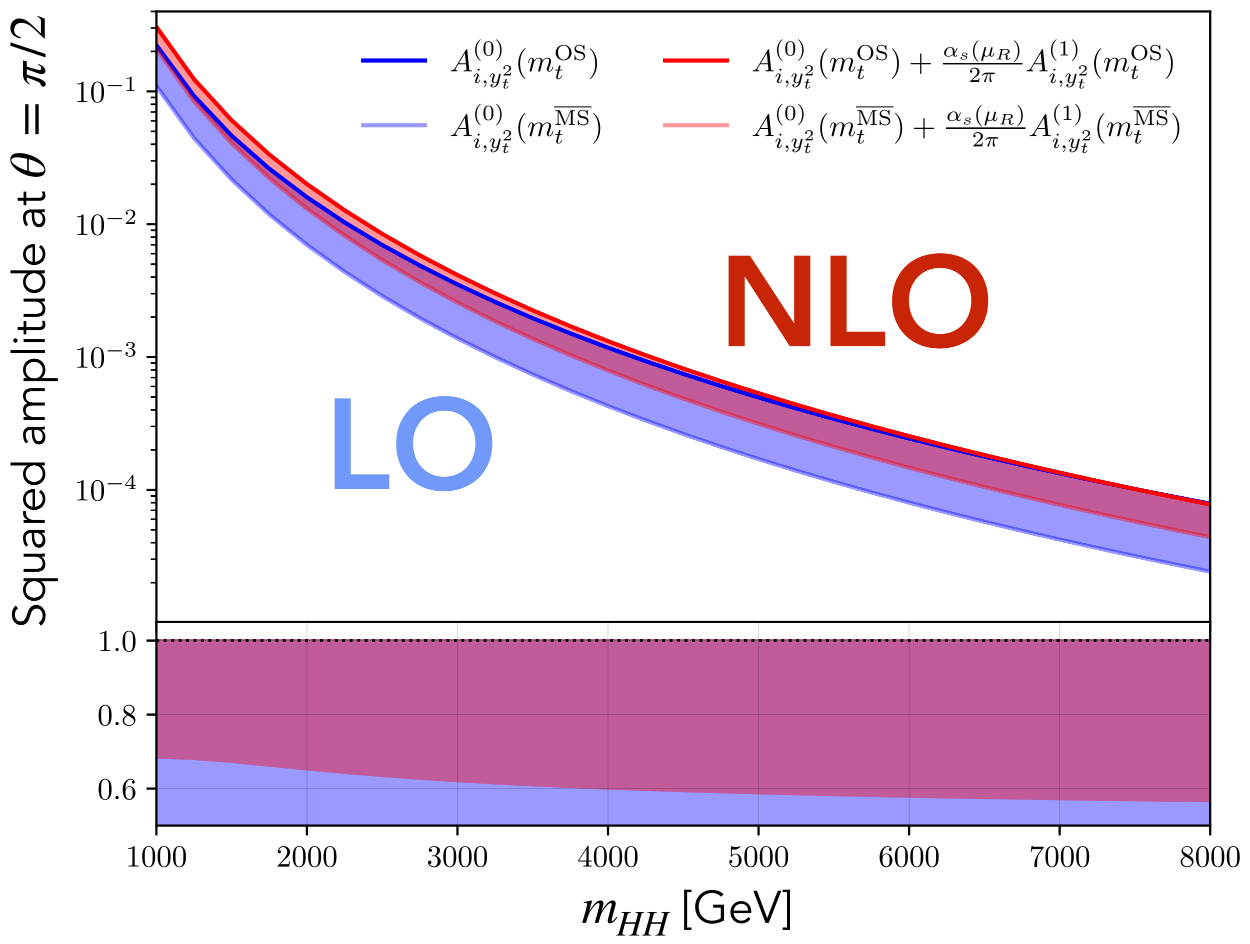
$t\bar{t}H$ and tHq complementary for **top Yukawa**

Angular obs. crucial for CPV gauge-Higgs couplings

HH & H + jet: finite m_t

Jaskiewicz: large TH uncertainty in **HH** due to top mass scheme (OS vs $\overline{\text{MS}}$)

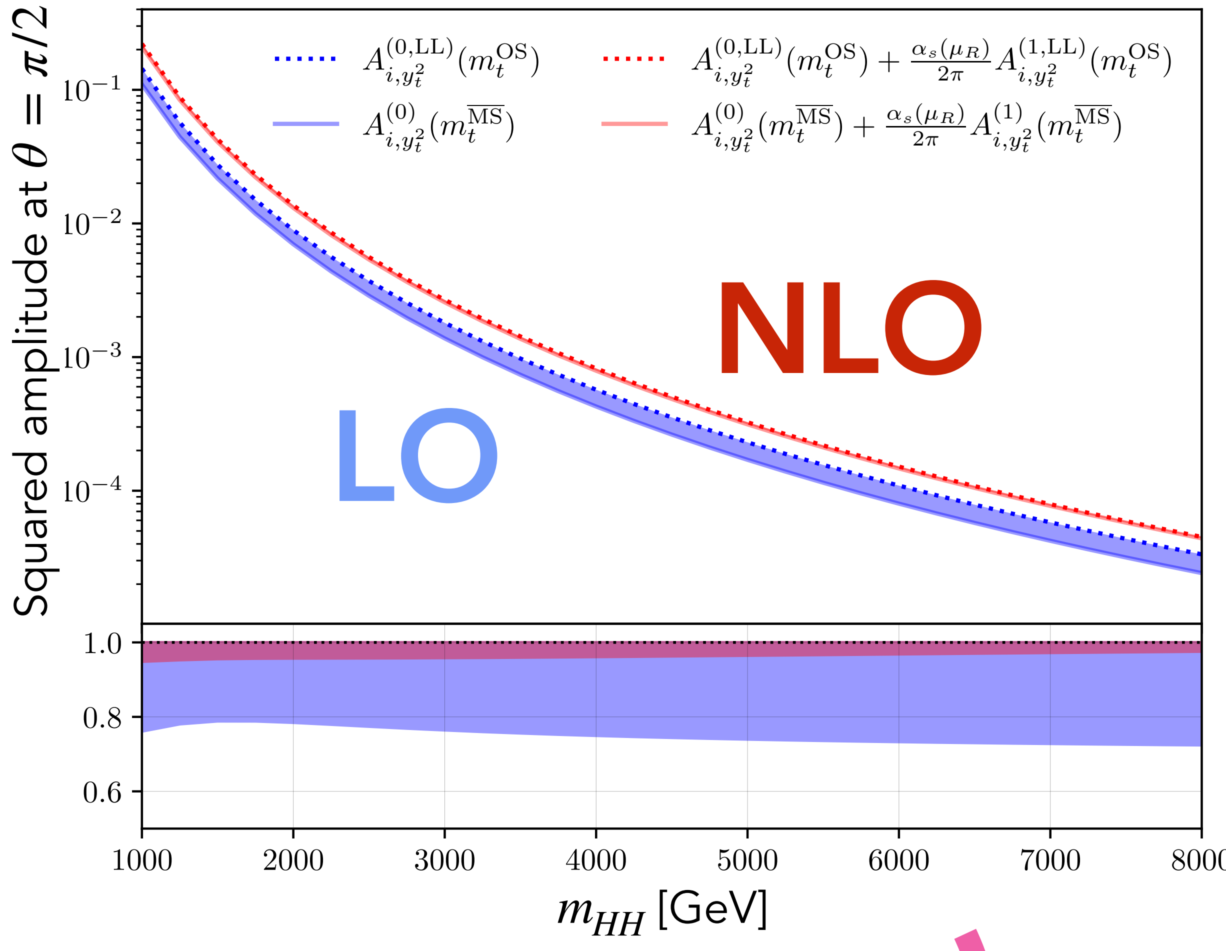
In H.E. limit, boils down to running m_{top}



Log structure known and universal.

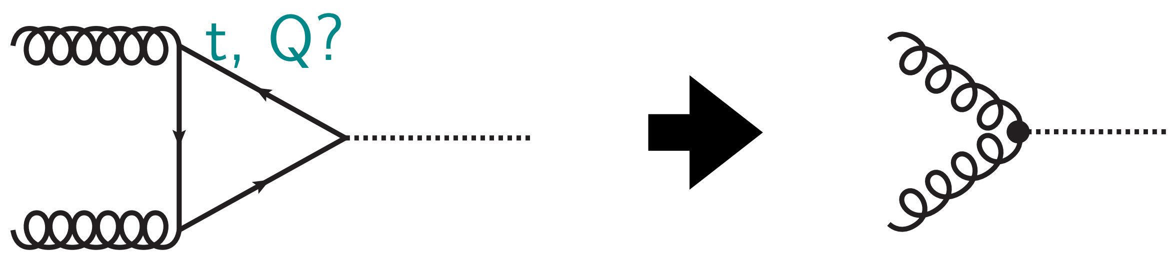
Truncation in OS scheme is artificial.

EFT-like **restoration** $\Rightarrow$ much **smaller** Δ_{scheme}



Do similar to reduce Δ_{scheme}

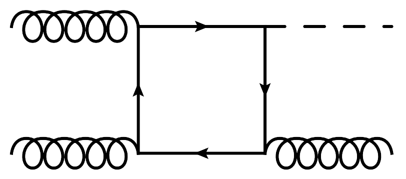
Kerner: want to distinguish BSM from top loops in $gg \to H$



$$\propto c_g \frac{\alpha_s}{8\pi}\frac{H}{v}|G|^2$$

But inclusive $\sigma_{gg\to H}$ only sensitive to sum $(c_t + \kappa_g)^2$

$\Longrightarrow$ NLO **H+jet with full m$_t$**

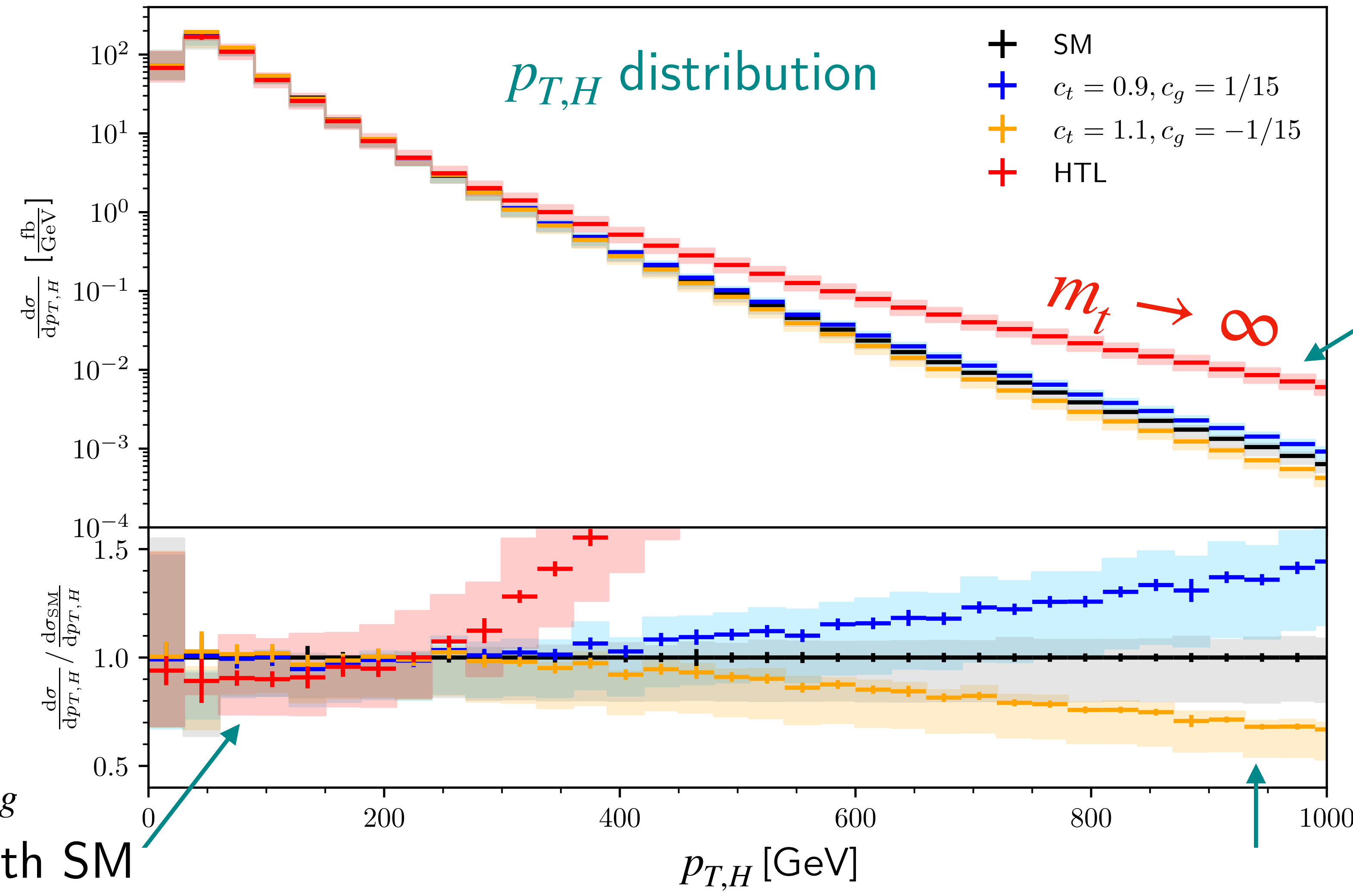


$$\frac{\sigma_{Hj}(p_{T,H}^{\min}, c_t, \kappa_g)}{\sigma_{Hj}^{\text{SM}}(p_{T,H}^{\min})} = (c_t + \kappa_g)^2 + \underline{\delta_1(p_{T,H}^{\min})\, c_t\, \kappa_g + \delta_2(p_{T,H}^{\min})\, \kappa_g^2}$$

at low $p_{T,H}$:

$\sigma \simeq (c_t + \kappa_g)^2$ with $\kappa_g = \frac{3}{2} c_g$

$\to$ both HEFT results agree with SM



$m_t \to \infty$ (HTL) not valid at high $p_{T,H}$

at high $p_{T,H}$ HEFT results can be distinguished from SM

Drell-Yan

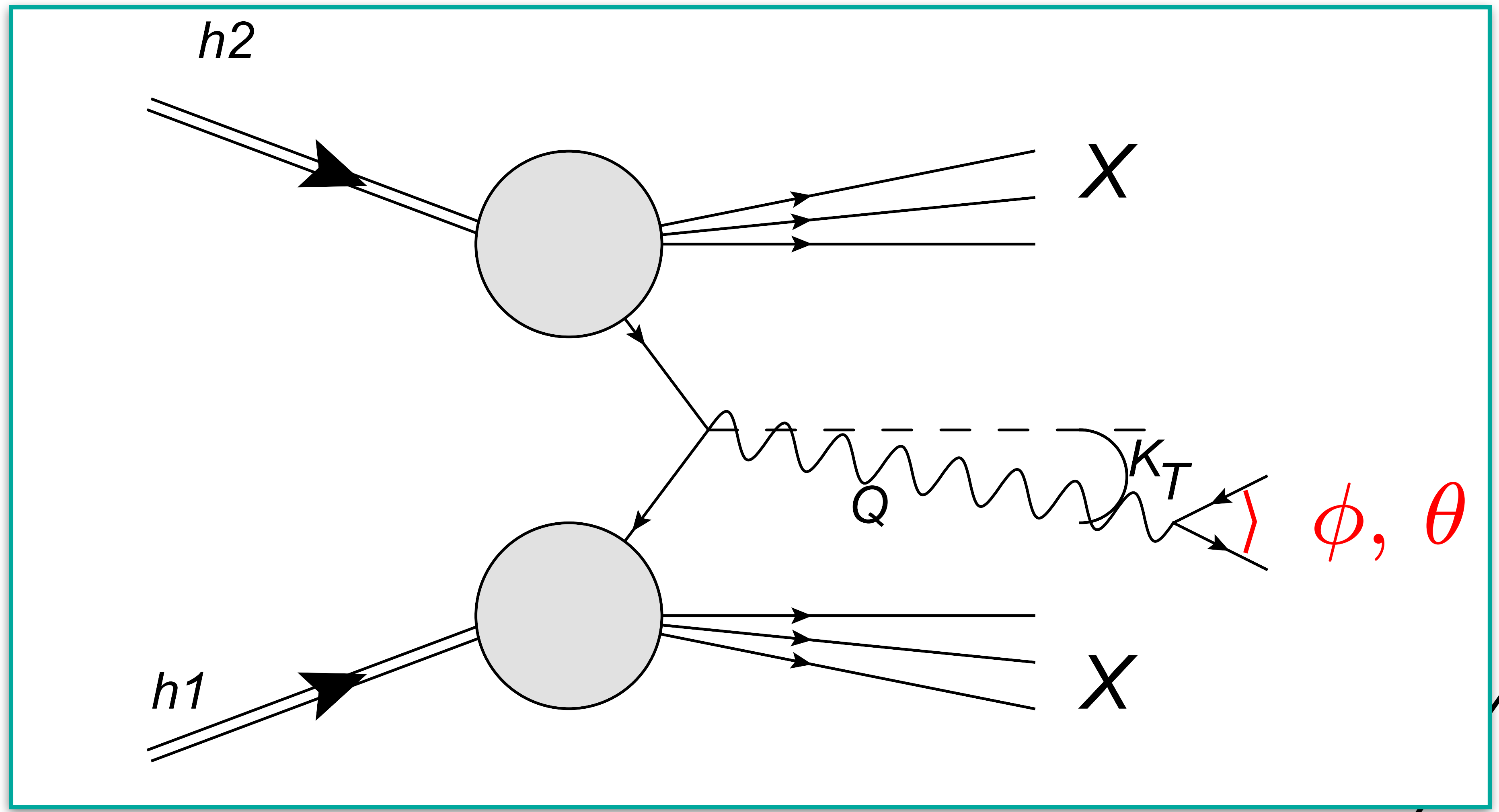
Vladimirov & Zhan

Zhan: Intrinsic DY pT

FOPT divergent for $p_T \to 0$, calls for **resummation**

TMD PDF framework allows to resum logs of (p_T/M_Z)

Use MC "parton branching method" to evolve TMD PDFs



Starting point: assume Gaussian **intrinsic component** k_T/q_s: only affects low-p_T part of spectrum

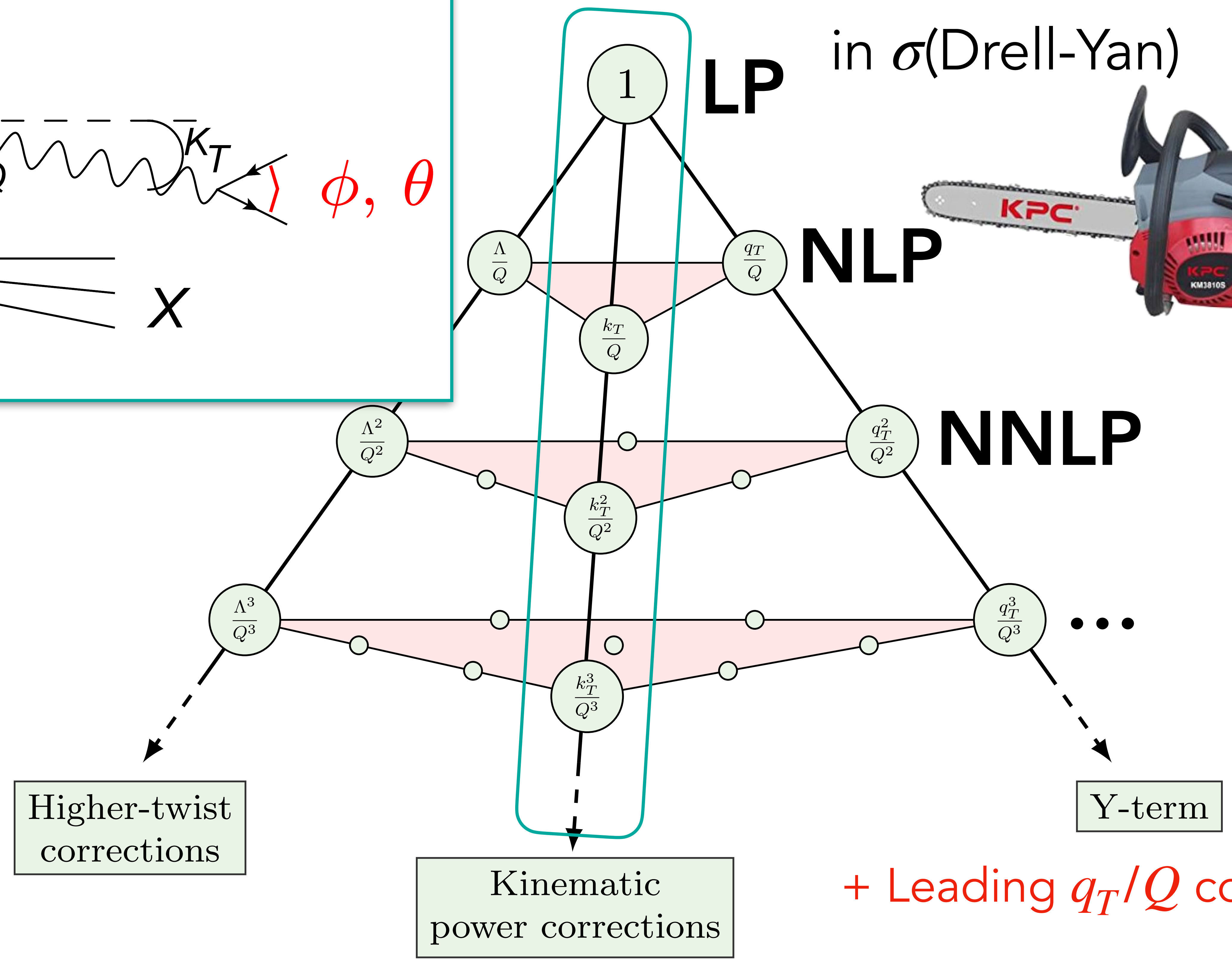
➜ Extract q_s from **ratio** between low and high p_T

Low $\sqrt{s} \lesssim 10\,\mathrm{GeV}$: $q_s \sim 1\,\mathrm{GeV}$

Higher $\sqrt{s}$: q_s **increases**

Vladimirov: TMD DY

Angular coefficients in σ(Drell-Yan)



KPC at all powers

+ Leading q_T/Q correction

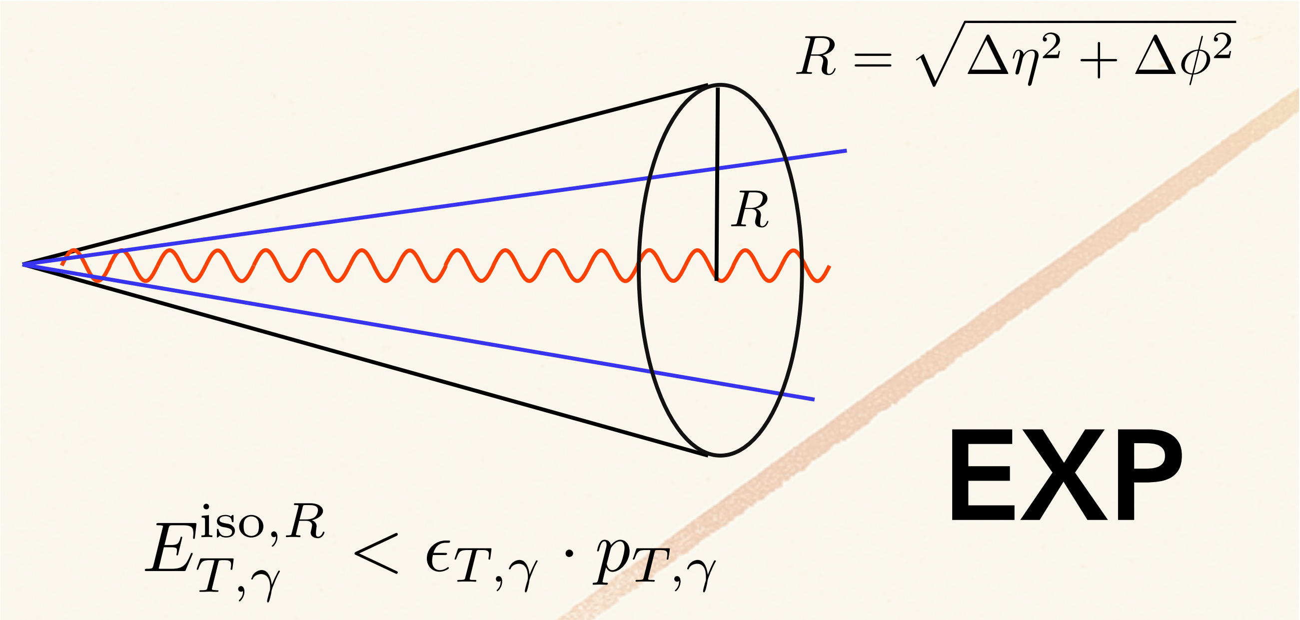
➤ Good agreement with measurements

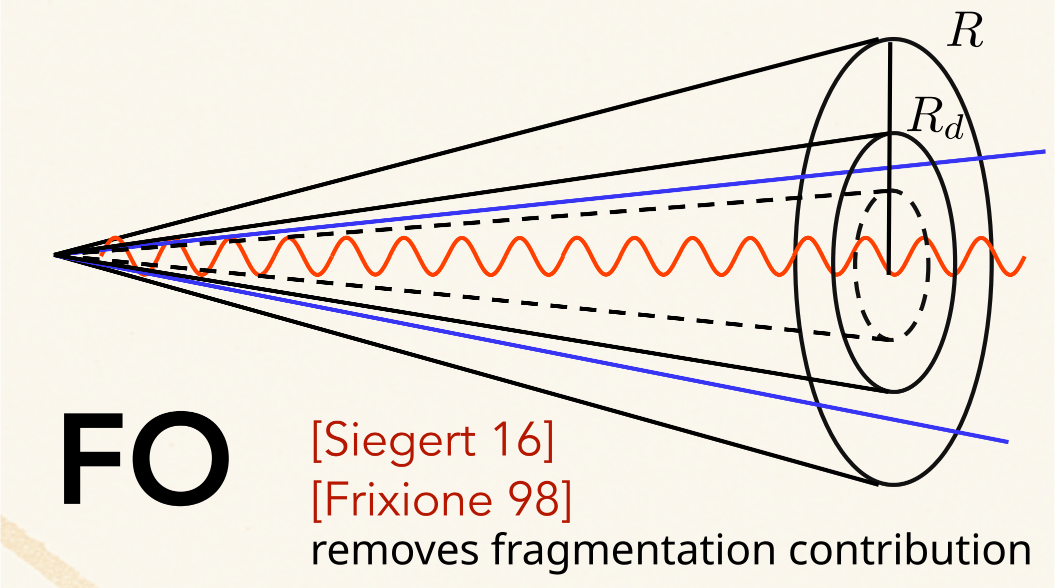
$pp \to \gamma\gamma + \text{jet}$ & $pp \to pp$

Marcoli: $pp \to \gamma\gamma + \text{jet}$ **at NNLO** + gg loop @ (N)LO

EXP done with **photon isolation**

TH sensitive to **fragmentation contribution**





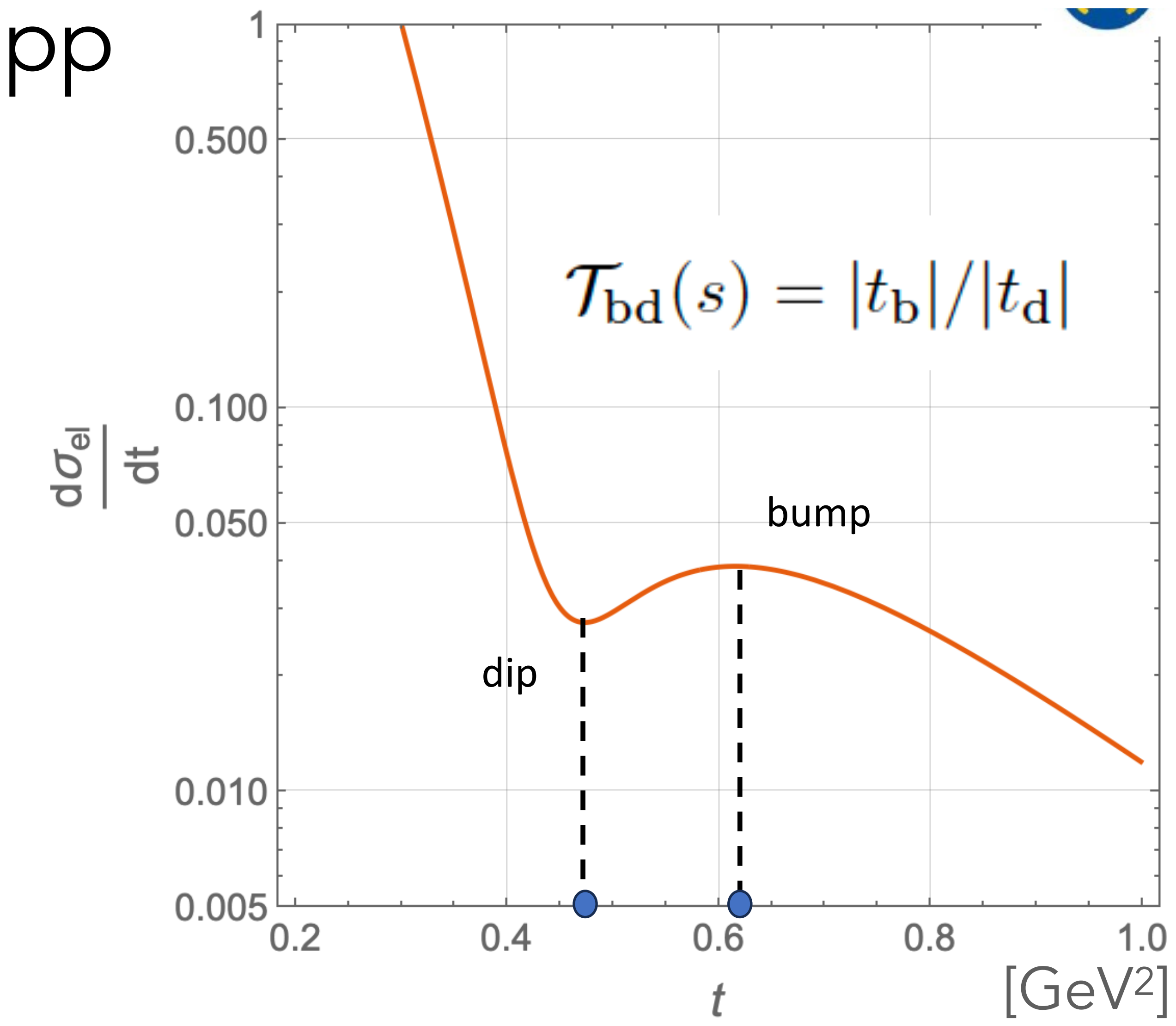
Calculation performed with **antenna subtraction** within the **NNLOJET** Monte Carlo framework

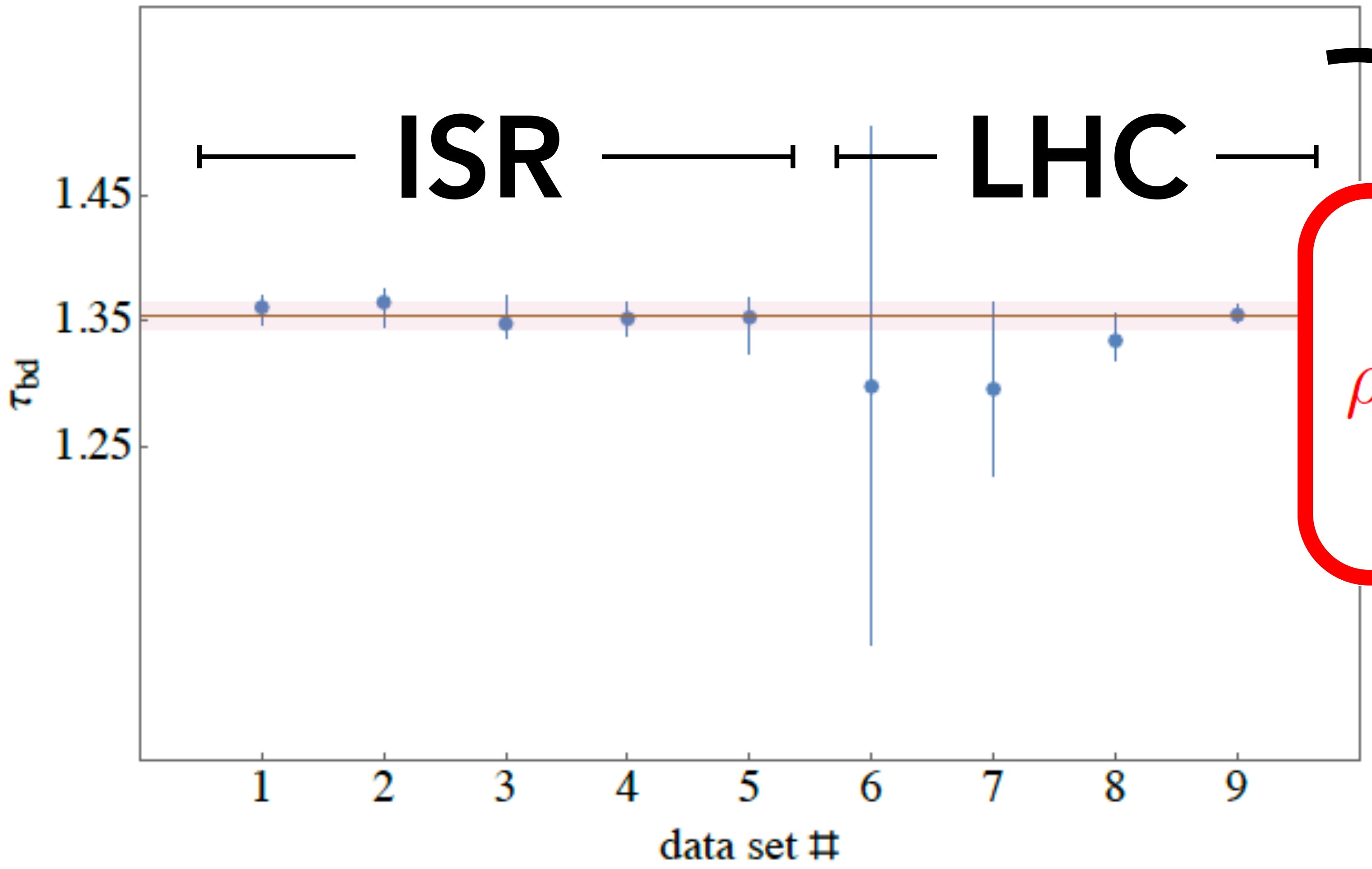
Improved agreement with data, but still systematic undershooting

→ **Isolation w realistic fragmentation, N3LO … ?**

Praszalowicz: elastic pp

Observation: dip-bump structure of $d\sigma_{\mathrm{elastic}}/dt$ appears to be **universal** between ISR & LHC energies





Geom. scaling + crossing

$$\boxed{\rho(y) = \frac{\pi}{2}\frac{dR^2(y)/dy}{R^2(y)}}$$

$$y = \ln(s)$$

$$\rho = \left.\frac{\mathrm{Re}[f_{\mathrm{el}}(t)]}{\mathrm{Im}[f_{\mathrm{el}}(t)]}\right|_{t\to 0}$$

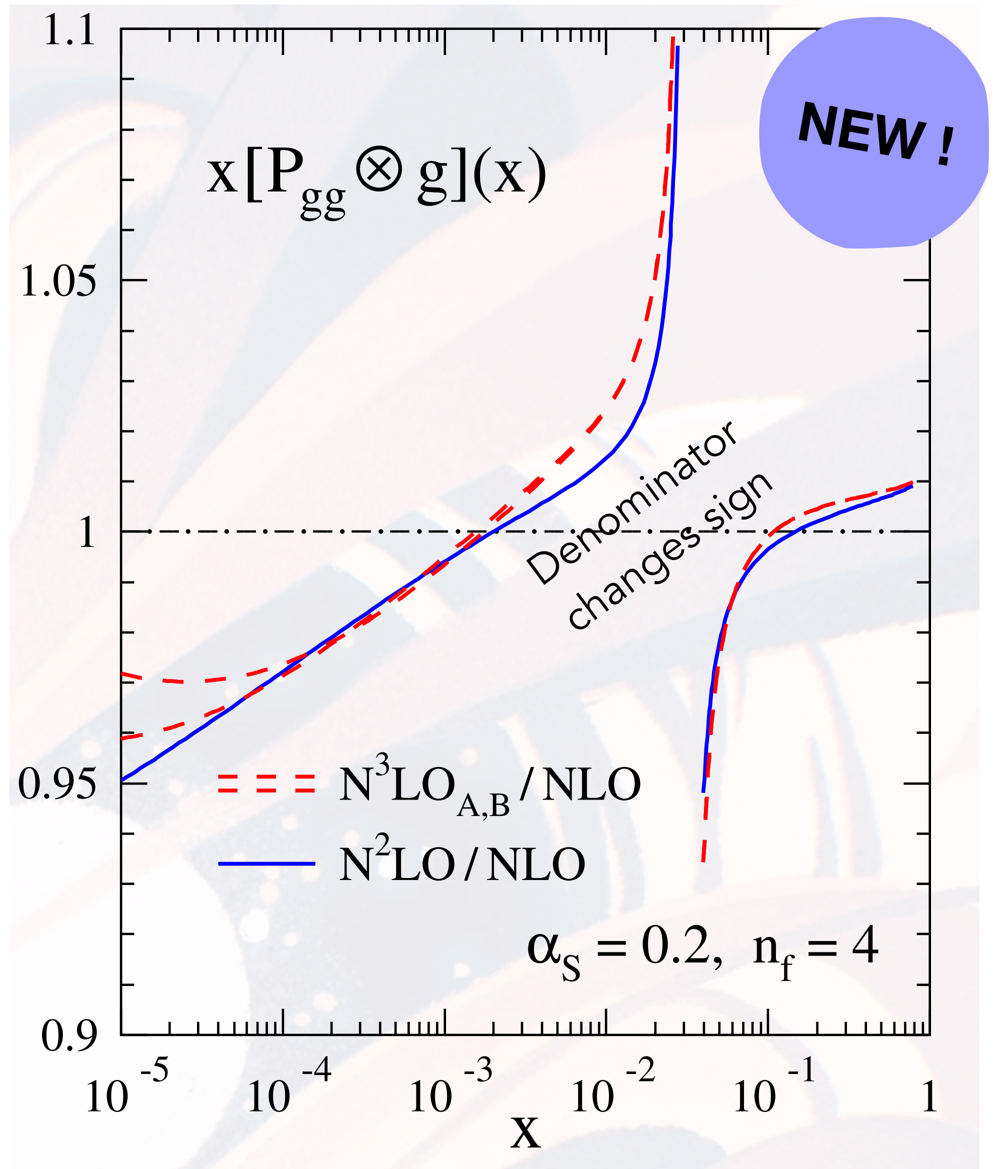
N3LO

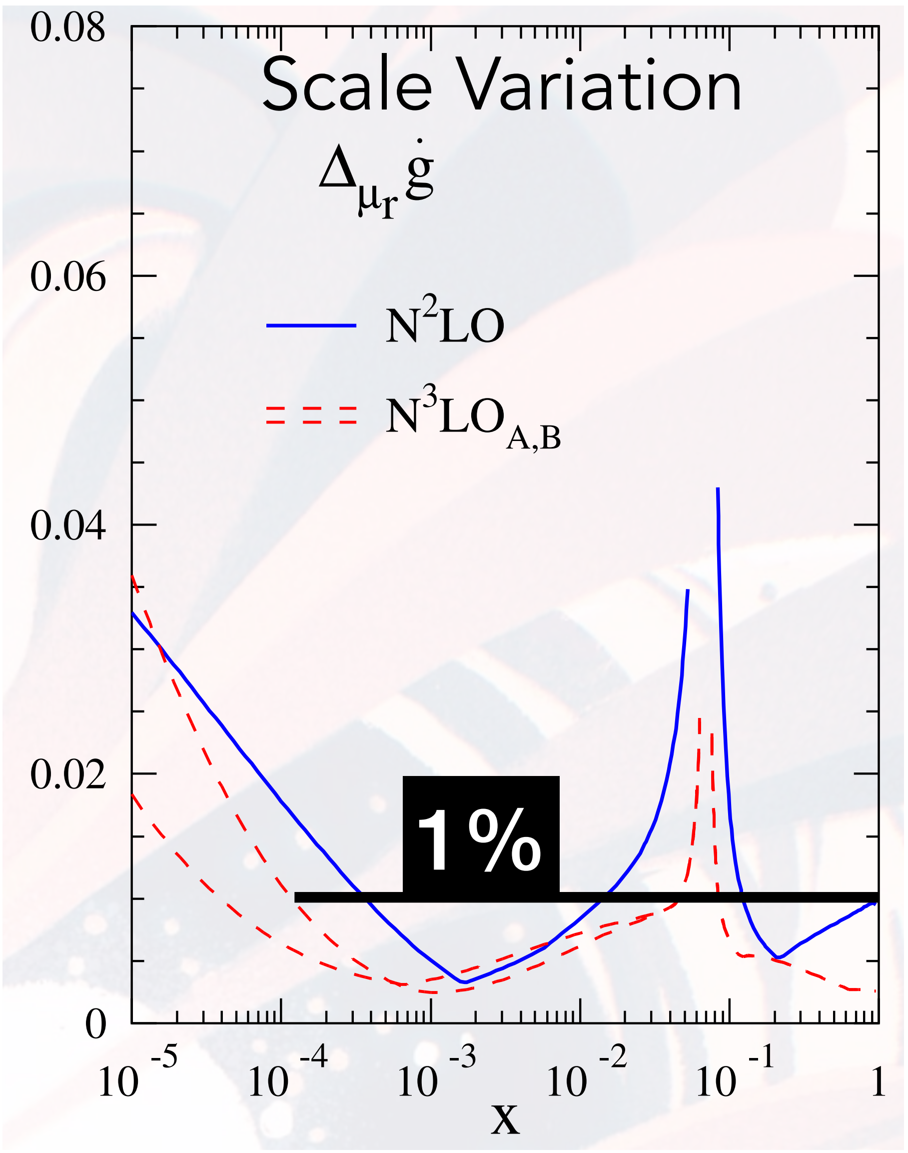
Pelloni: 4-loop gg splitting functions

$$\frac{d}{d\ln\mu^2}\begin{pmatrix} q_s \\ g \end{pmatrix} = \begin{pmatrix} P_{qq} & P_{qg} \\ P_{gq} & \boxed{P_{gg}} \end{pmatrix} \otimes \begin{pmatrix} q_s \\ g \end{pmatrix}$$

➜ Mellin space: anomalous dimensions $\sum_i \alpha_s^i \gamma_{gg}^{(i-1)}$

OPE approach ⇒ N ≤ 20 Mellin moments of $P_{gg}^{(3)}$
+ partial information on N ≥ 22



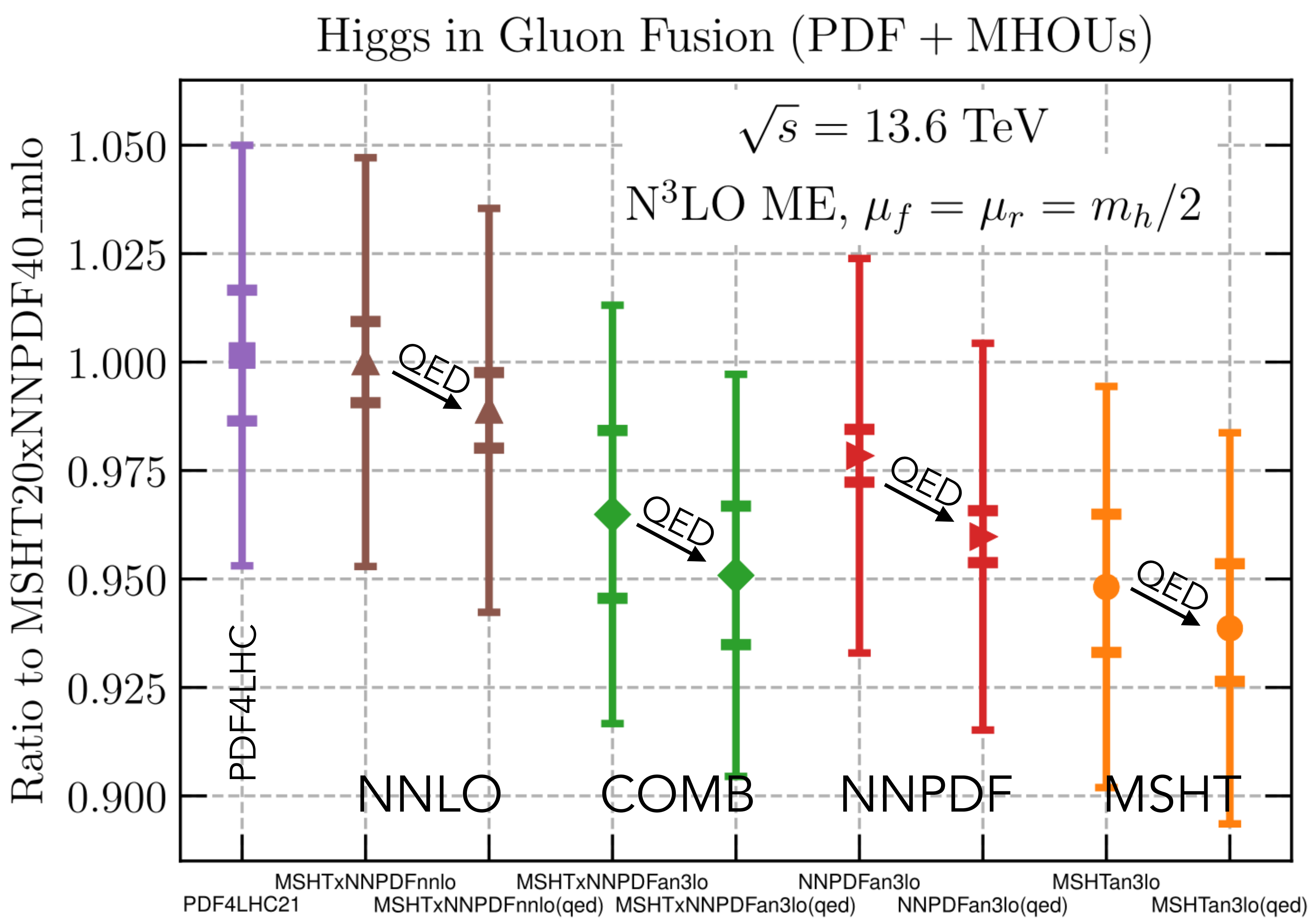


Hekhorn: aN3LO PDFs & Higgs Cross Sections

$$\sigma(Q^2) = \mathbf{C}(Q^2)\mathbf{E}^{(5)}(Q^2 \leftarrow m_b^2)\mathbf{A}^{(4)}(m_b^2)\mathbf{E}^{(4)}(m_b^2 \leftarrow Q_0^2)\mathbf{f}^{(4)}(Q_0^2)$$

Partonic dσ — 5-flav Evolution — Operator ME — 4-flav Evolution — PDF at Q_0

- ▶ N^{3}LO evolution is completed



- ▶ NB: N^{3}LO **cross sections** are a long term project …

Perturbative Uncertainties

Poncelet (+ EXP speakers)

Gocke (Mon): main uncertainties in top are ISR + FSR + "recoil" uncertainties (even with MiNNLOPS), JES (sens. to hadrochemistry), UE, and b-tagging

Grohsjean (Mon): main uncertainties for toponium η_t: bb4l (offsh, tt & tW int), FSR modelling

Poncelet (Thu): missing higher orders in fixed-order and resummed predictions (MHOU)

Generic perturbative expansion:

$$f(\alpha) = f_0 + f_1\alpha + f_2\alpha^2 + f_3\alpha^3 + \ldots$$

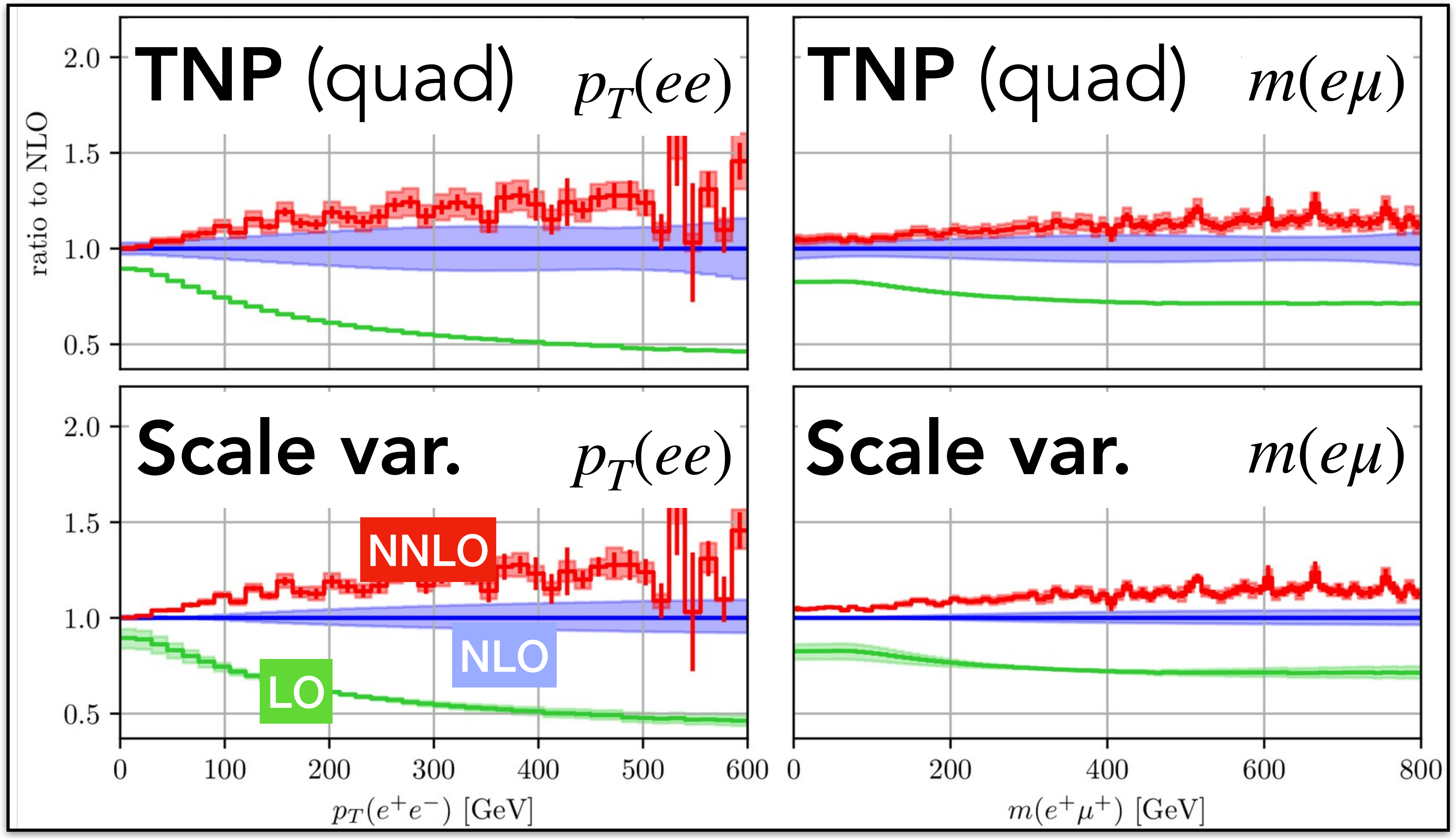
Introduce a parametrisation of unknown coefficients in terms of

"Theory nuisance parameters" θ

$$\frac{\mathrm{d}\bar{\sigma}^{(N+1)}_{\mathrm{TNP}}}{\mathrm{d}\bar{\sigma}^{(0)}} = \sum_{j=1}^{N} f_k^{(j)}\left(\vec{\theta}, x\right)\left(\frac{\mathrm{d}\bar{\sigma}^{(j)}}{\mathrm{d}\bar{\sigma}^{(0)}}\right)$$

E.g., Bernstein or Chebyshev polynomials

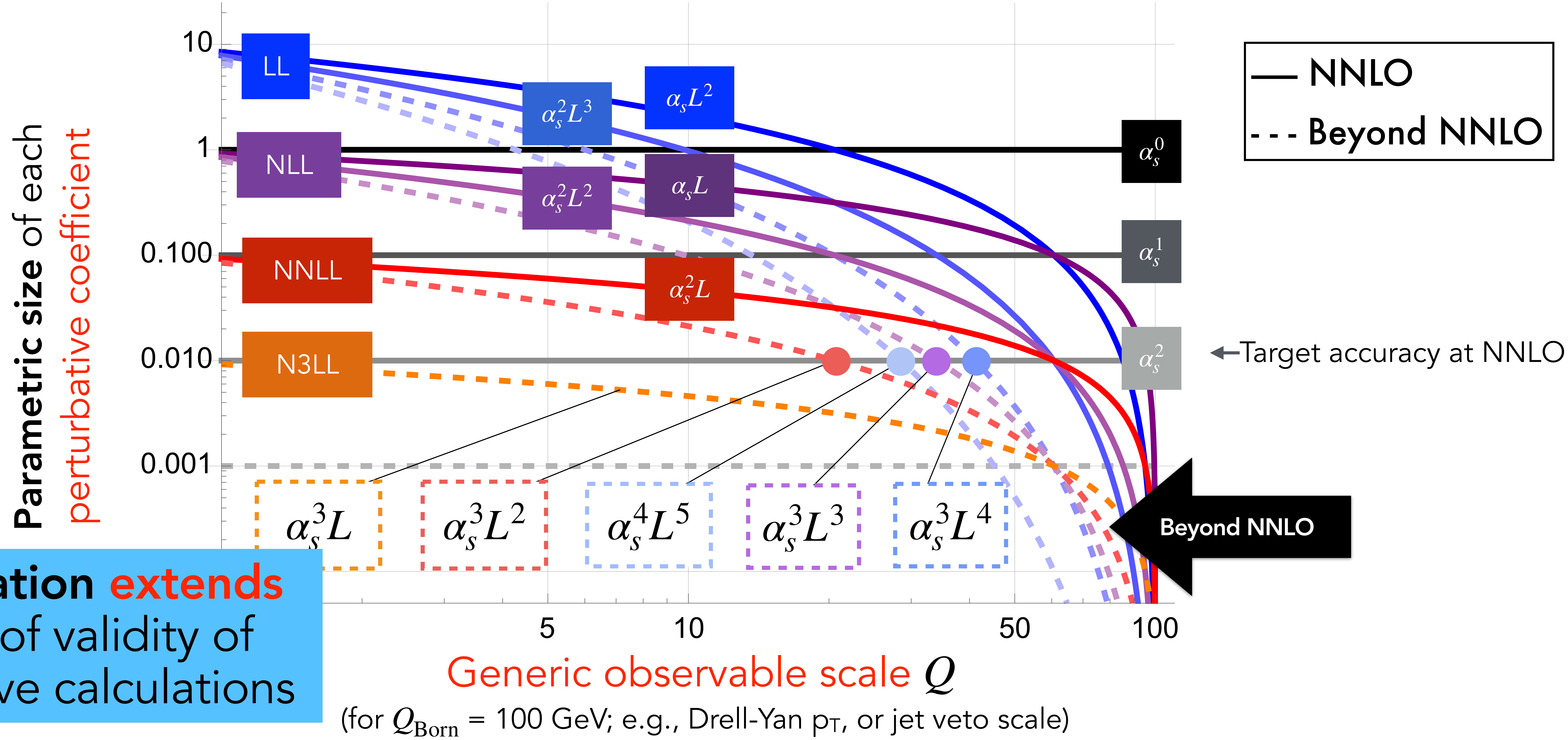
$pp \to ZZ^* \to ee\mu\mu$



Fixed Orders & Logs

Becher: In processes involving **disparate scales** $Q_i \gg Q_j$, higher-order corrections are enhanced by **large logarithms** $\alpha_s^n \ln^m(Q_i/Q_j)$, which can spoil fixed-order truncation. (Max log power $m \leq 2n$ depends on problem.)

Example: NNLO

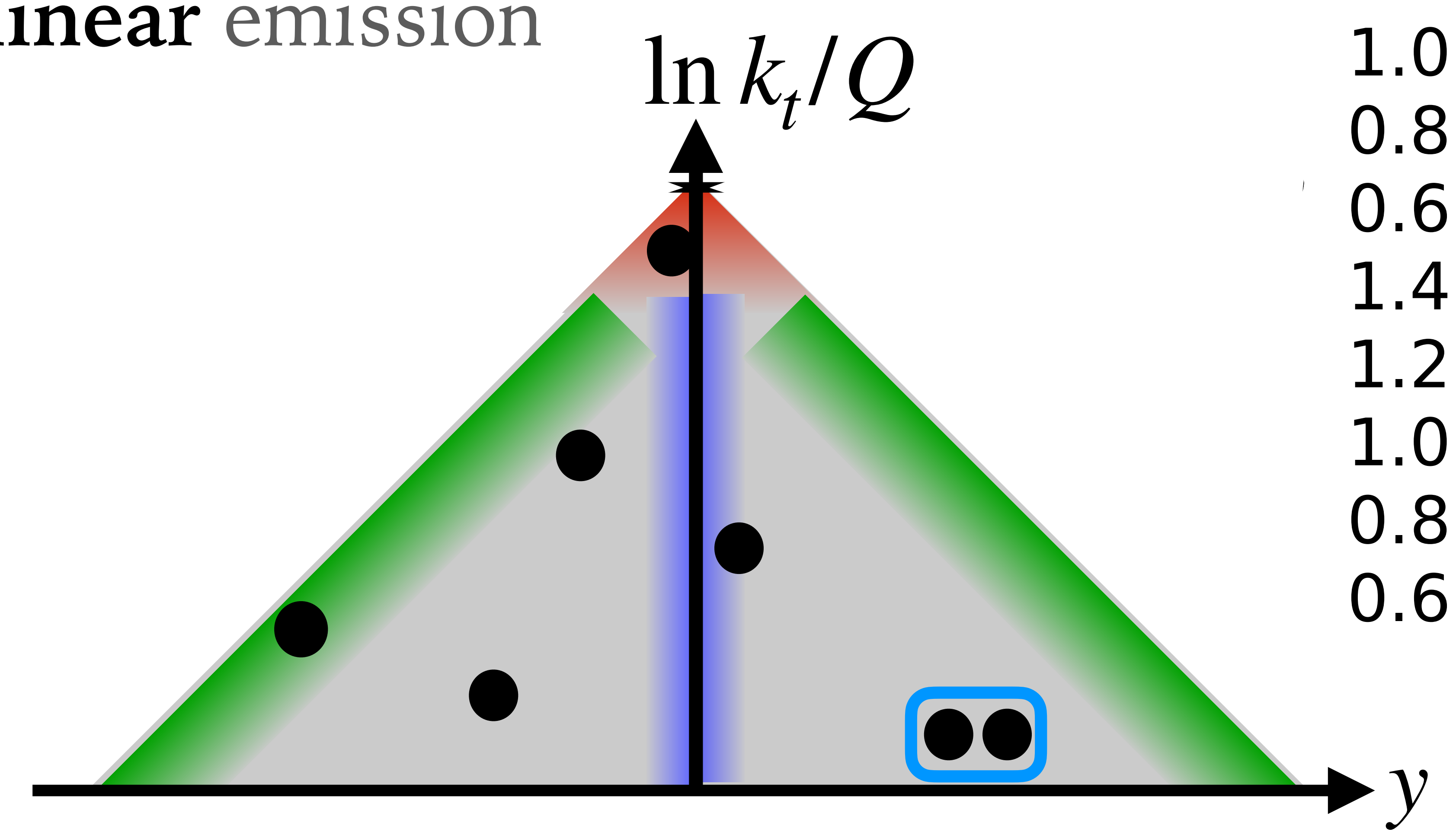


Resummation extends domain of validity of perturbative calculations

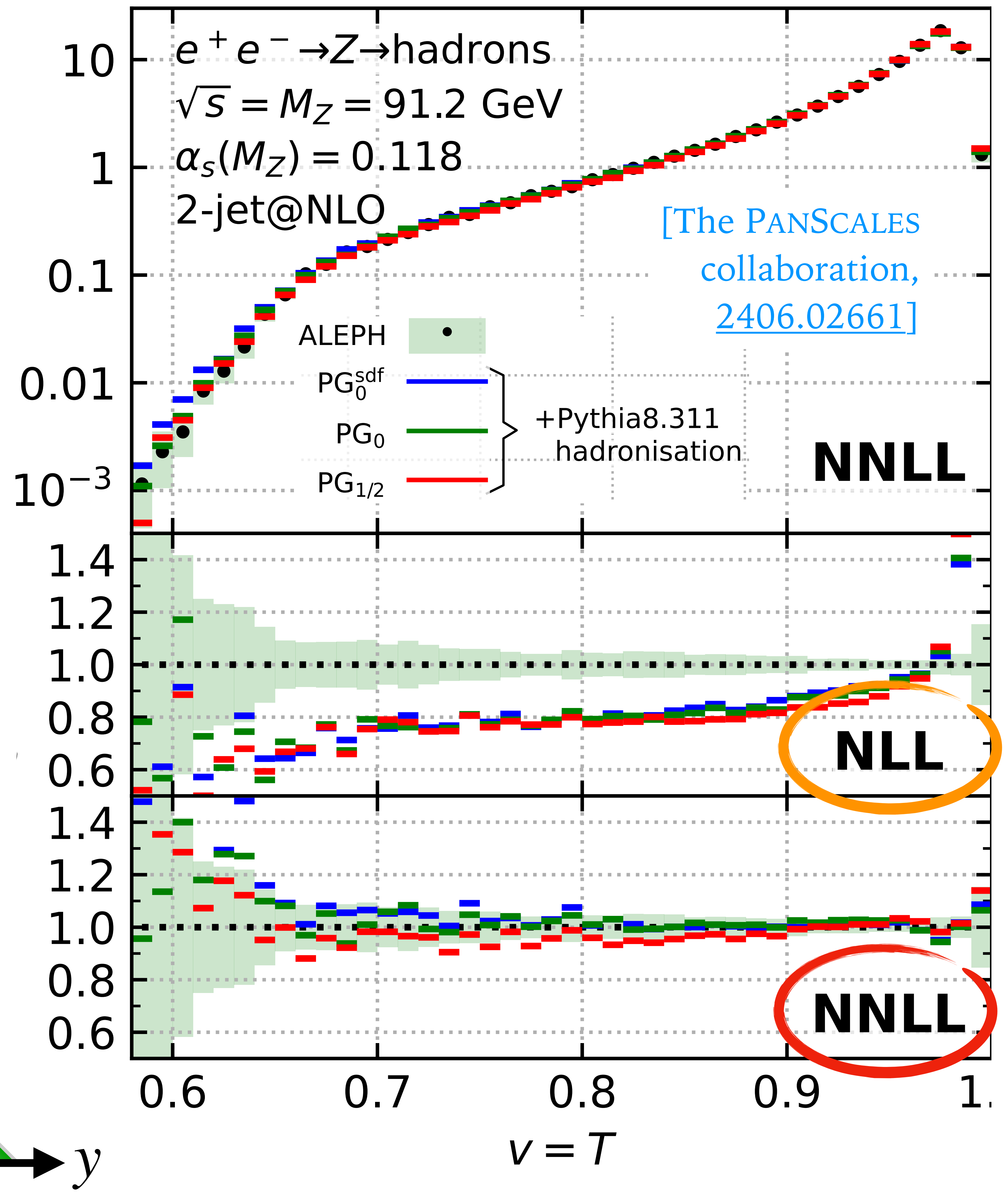
How to build an **NNLL accurate** parton shower

- ➤ NLO matching
- ➤ Correct α_s^2 rate of **neighbouring pairs of soft-collinear emissions**
- ➤ Correct α_s^2 rate for a single **soft, large angle**, emission $\mathcal{O}(\alpha_s^2 L)$
- ➤ Correct α_s^2 rate for a single **collinear** emission
- ➤ Correct α_s^3 rate for a single **soft-collinear** emission $\mathcal{O}(\alpha_s^3 L^2)$

➜ PanScales v0.3
(+ Pythia 8 Hadronization)



Thrust



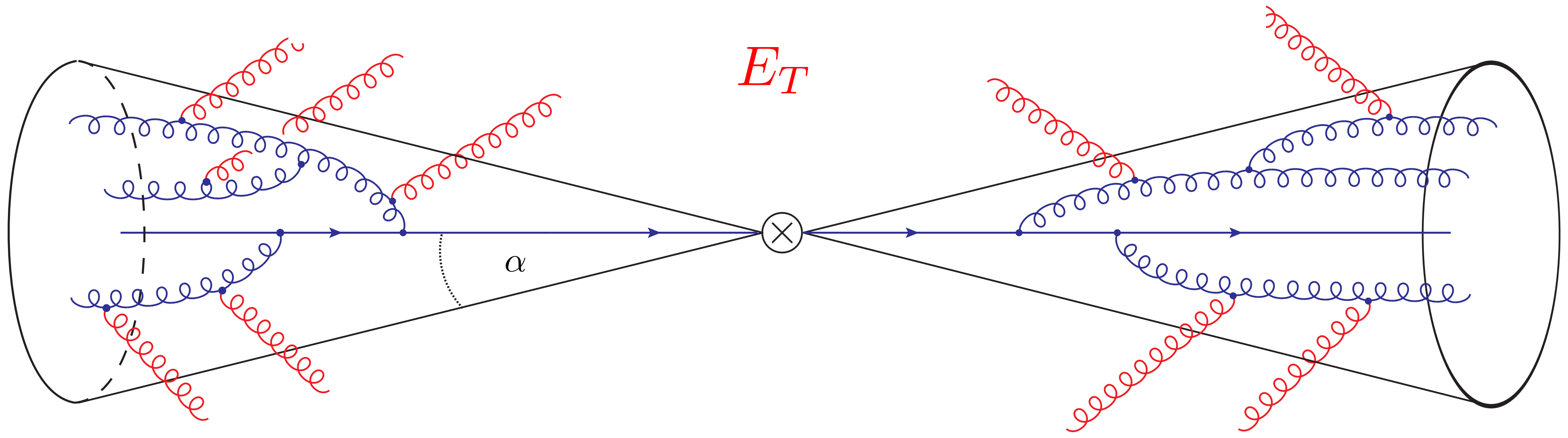
Gaps between jets

Schalch & Becher

Schalch: resummation of non-global logs

- Gap fraction: fraction of events with transverse energy E_T in gap below Q_0

$$R(Q_0) \equiv \frac{1}{\sigma_{\rm tot}} \int_0^{Q_0} dE_T \, \frac{d\sigma}{dE_T}$$



Resummation of **non-global logs** challenging

Solve complicated RGE equation ➜ **MC methods**
➜ shower-style evolution algorithm **MARZILI**

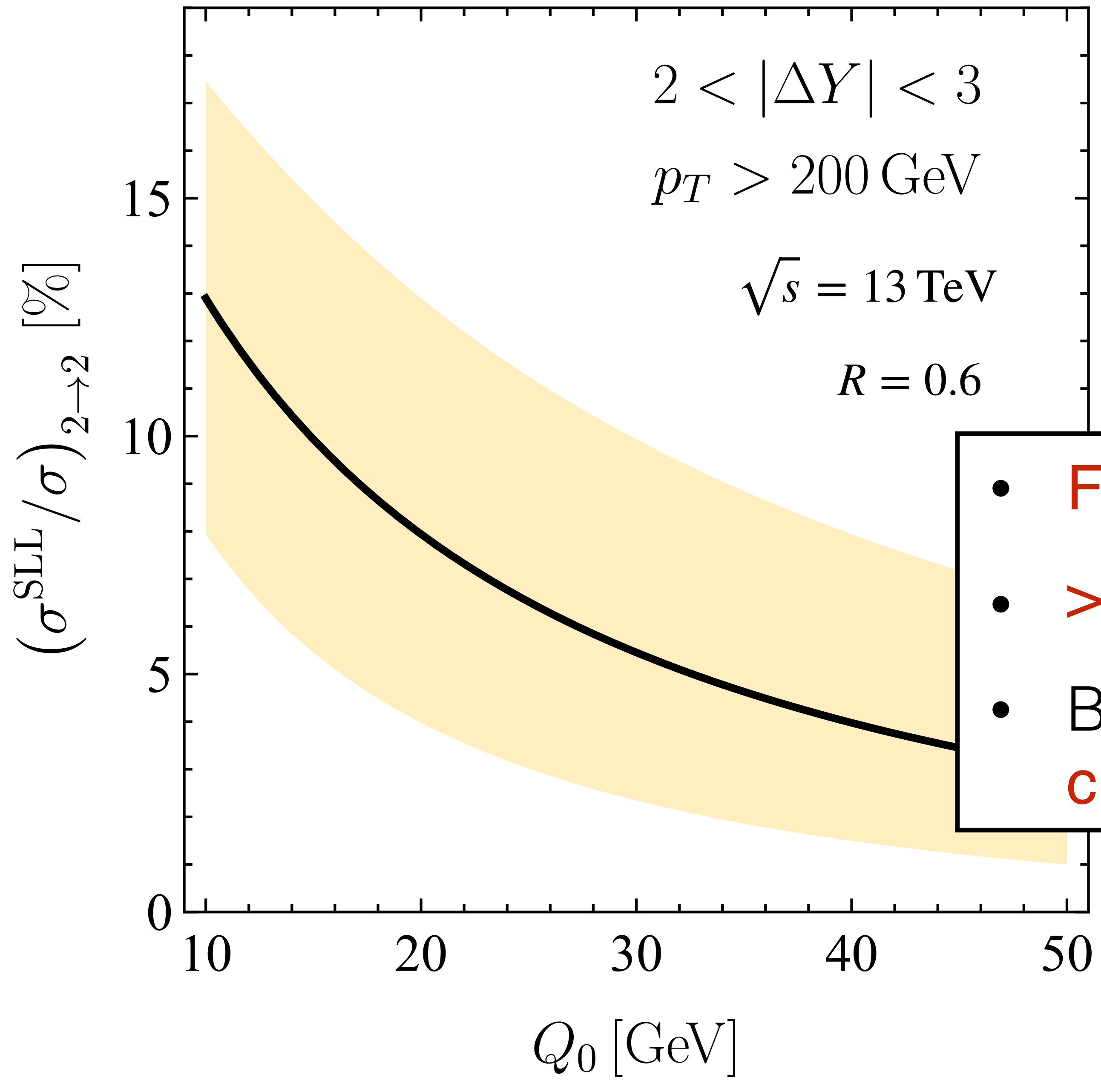
Careful insertion of $\Gamma^{(2)}$ (RR ⊕ RV ⊕ VV) ➜ **NLL**

$\mathcal{O}(1\%)$ agreement with GNOLE, PANSCALES

Next ➜ Gitlab
➜ LHC pheno

Becher: resummation of **super-leading logarithms**

SLLs: need **full-colour** result to see effect. Compute leading SLLs ***analytically***, order by order, sum up series



Glauber phase $\sim i\pi$

$$\sigma_{SLL} \sim \langle \mathcal{H} \, (\boldsymbol{\Gamma}^c)^{n-r} \, \boldsymbol{V}^G \, (\boldsymbol{\Gamma}^c)^r \, \boldsymbol{V}^G \, \overline{\boldsymbol{\Gamma}} \rangle$$

n insertions of cusp term

single emission into the gap

- First full SLL cross section
- $>$ 10% for small values of Q_0
- Biggest contribution from gluonic channels

Need to combine with NGLs (at N_c=3!) before comparing to ATLAS

Factorization Restoration

Neubert

Factorization expresses separation of scales

PDF Factorization: long-distance physics contained in universal PDFs ➤ used for all LHC processes — *but only proved for (inclusive) Drell-Yan [CSS]*

Relies on **collinear factorization**. Valid for timelike splittings. Broken for spacelike ones. How bad is it?

Factorization restoration through Glauber gluons:

Collinear factorization violation at $\mu \sim Q$ x Soft-collinear factorization violation by Glauber gluons at $\mu \sim Q_0$

= PDF factorization restored for $\mu < Q_0$

hard scale $Q \sim \sqrt{\hat{s}}$ — $\mathcal{H}_m$

double-logarithmic evolution (super-leading logs) & non-DGLAP *) collinear evolution

jet-veto scale Q_0 — $\mathcal{W}_m^{\text{pert}}$

single-logarithmic PDF evolution

OR: ~~*double-logarithmic evolution below Q_0 and breaking of PDF factorization?*~~

hadronic scale Λ_{QCD} — $f_{a/p}(\xi_1)\, f_{b/p}(\xi_2)$

OR: ~~*something more complicated, e.g. a combined two-proton distribution?*~~

Proof that factorization works at 3-loop order

α_s from hard processes

Pires: NNLO α_s from **dijets** at LHC and HERA

Sensitivity from cross section $\propto \alpha_s^2$ @ LO & PDFs

Used: NNLOJET w reduced scale dependence

+ SLC contributions for the first time for LHC α_s

Central scales: $\mu_{\mathrm{LHC}}^2 = m_{jj}^2$ & $\mu_{\mathrm{HERA}}^2 = Q^2 + \langle p_T \rangle_{1,2}^2$

Main Result: "LHC dijets":

$$\alpha_\mathrm{s}(m_\mathrm{Z}) = 0.1178\ (14)_{(\mathrm{fit,PDF})}\ (1)_{(\mu_0)}\ (17)_{(\mu_\mathrm{R},\mu_\mathrm{F})}$$

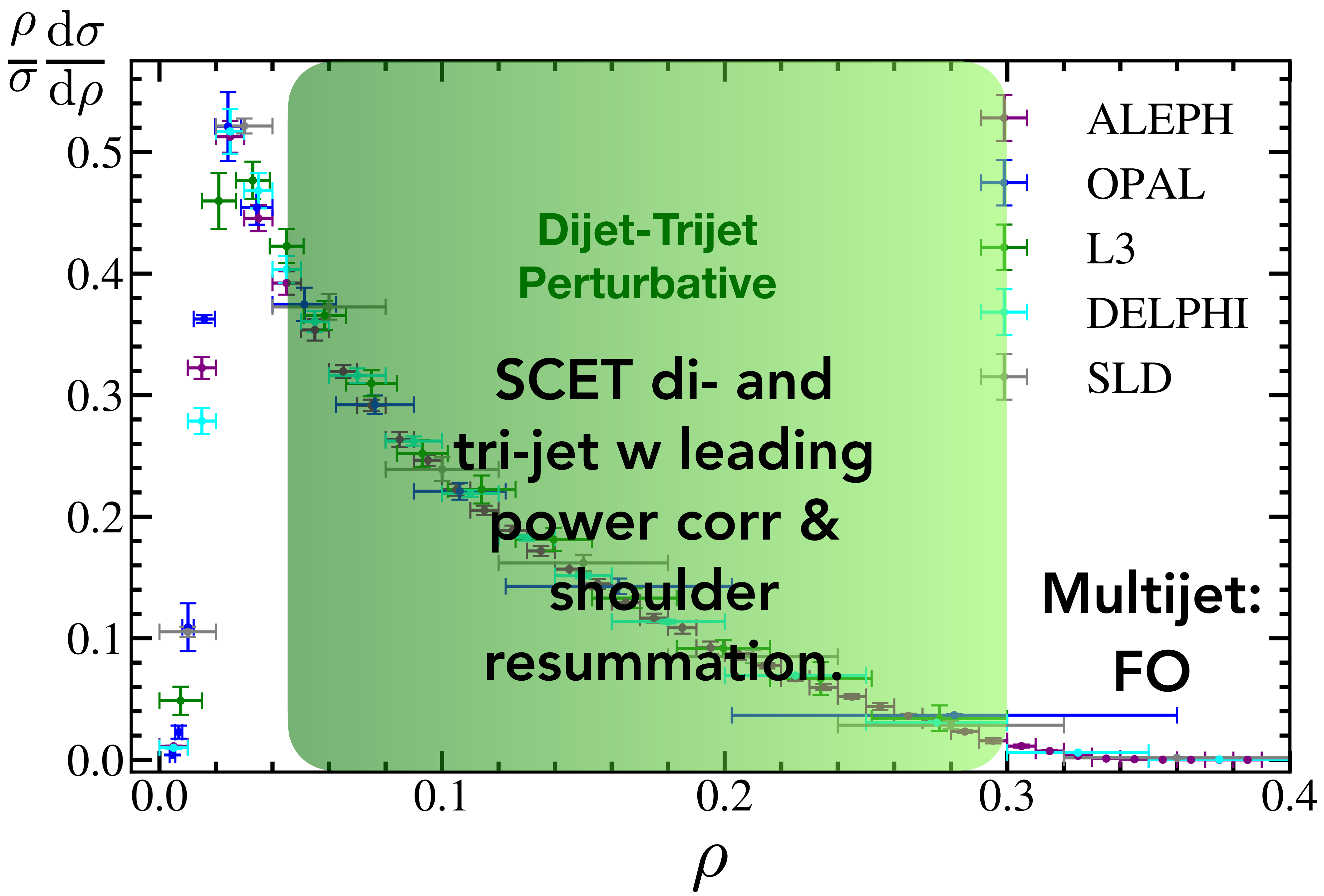
LHC + HERA

$$\alpha_\mathrm{s}(m_\mathrm{Z}) = 0.1180\,(10)_{(\mathrm{fit,PDF})}\,(1)_{(\mu_0)}\,(22)_{(\mu_\mathrm{R},\mu_\mathrm{F})}$$

+ Test of RGE running for 7 GeV < μ < 7 TeV

Benitez: α_s from $\rho = \max(s_1, s_2)/Q^2$ in $Z \to$ hadrons

Historically: low values. Significant HAD corrs.



Sophisticated treatment of EXP and TH **correlations**, & impact of fit range

$$\alpha_s(m_Z) = 0.1145^{+0.0021}_{-0.0019}$$

Compatible with T, C ✅

α_s from B and D decays

Che, Wu

Che: α_s from inclusive semileptonic B decays

HQE: $$\Gamma\left(B \to X_c \ell \bar{\nu}_\ell\right) = \Gamma_0 \left[C_0 - C_{\mu_\pi} \frac{\mu_\pi^2}{2m_b^2} + C_{\mu_G} \frac{\mu_G^2}{2m_b^2} + \dots \right]$$

$$C_0 = \mathbf{c}_0 + \mathbf{c}_1 \frac{\alpha_s}{\pi} + \mathbf{c}_2 \left(\frac{\alpha_s}{\pi}\right)^2 + \mathbf{c}_3 \left(\frac{\alpha_s}{\pi}\right)^3 + \mathcal{O}(\alpha_s^4)$$

(+ indirect sensitivity (?) from running quark masses)

Get $|V_{cb}|$, quark masses from other measurements (+ vary)

	Γ_{sl} prediction [%]	$\alpha_s(5\,\text{GeV})$ [%]
$\lvert V_{cb}\rvert = 0.0410 \pm 0.0007$	3.4 (1.4)	3.1 (1.3)
$\overline{m}_b(\overline{m}_b) = 4.18^{+0.03}_{-0.02}$ GeV	3.0 (1.1)	2.7 (1.0)
$\overline{m}_c(\overline{m}_c) = 1.27 \pm 0.02$ GeV	2.1 (1.4)	1.8 (1.2)
R-scale $\mu = 5^{+5}_{-2.5}$ GeV	4.4 (2.2)	4.0 (2.0)
High-order power corrections	0.5	0.5
$\tau_{B^\pm} = 1.638 \pm 0.004$ ps	-	0.2
$\mathcal{B}(B^\pm \to X_c \ell \nu) = 10.8 \pm 0.4$ %	-	2.4 (1.8)
Sum	6.7(3.2)	6.5 (3.4)

Competitive
$\Delta\alpha_s(M_Z) = 0.0018$
possible?

Wu: α_s from inclusive semileptonic D decays

Understand impact of spectator quark in semileptonic D decays

Different BRs and lifetimes:

D_i	$\mathcal{B}_{SL}$ (%)	$\tau\,(10^{-13}\,\text{s})$	$\Gamma_{SL}\,(10^{-15}\text{GeV})$
D^0	$6.46 \pm 0.09 \pm 0.11$	4.10 ± 0.01	104 ± 2
D^+	$16.13 \pm 0.10 \pm 0.29$	10.33 ± 0.05	103 ± 2
D_s^+	$6.30 \pm 0.13 \pm 0.10$	5.04 ± 0.04	82 ± 2

Same $\Gamma_{SL} \Rightarrow$ spectator impact isospin symmetric in semileptonic decays?

	D^+, D^0	D_s^+
m_c[GeV]	$\mathbf{1.3701 \pm 0.0338}$	1.3699 ± 0.0340
$\alpha_S(m_c^2)[10^{-3}]$	$\mathbf{445 \pm 9 \pm 114}$	$400 \pm 14 \pm 113$

α_s from lattice

Petreczky

Review of Flavour Lattice Averaging Group (FLAG 2024)

Overview of α_s determinations:

- Determination using physical quantities

  Window problem: Syst. errors dominate

  $$\mu a \ll 1,\ L = N_s a > 1\ \text{fm} \Rightarrow \mu = 1 - 3\ \text{GeV}$$

  Reasonable resolution for big box Cannot go higher than this

- Comparison with lattice perturbation theory

  $$\Rightarrow \alpha_s^{\overline{\rm MS}}(\mu = 1/a)$$

  Limited by accuracy of lattice perturbation theory

- Lattice QCD in "femto boxes" and special schemes

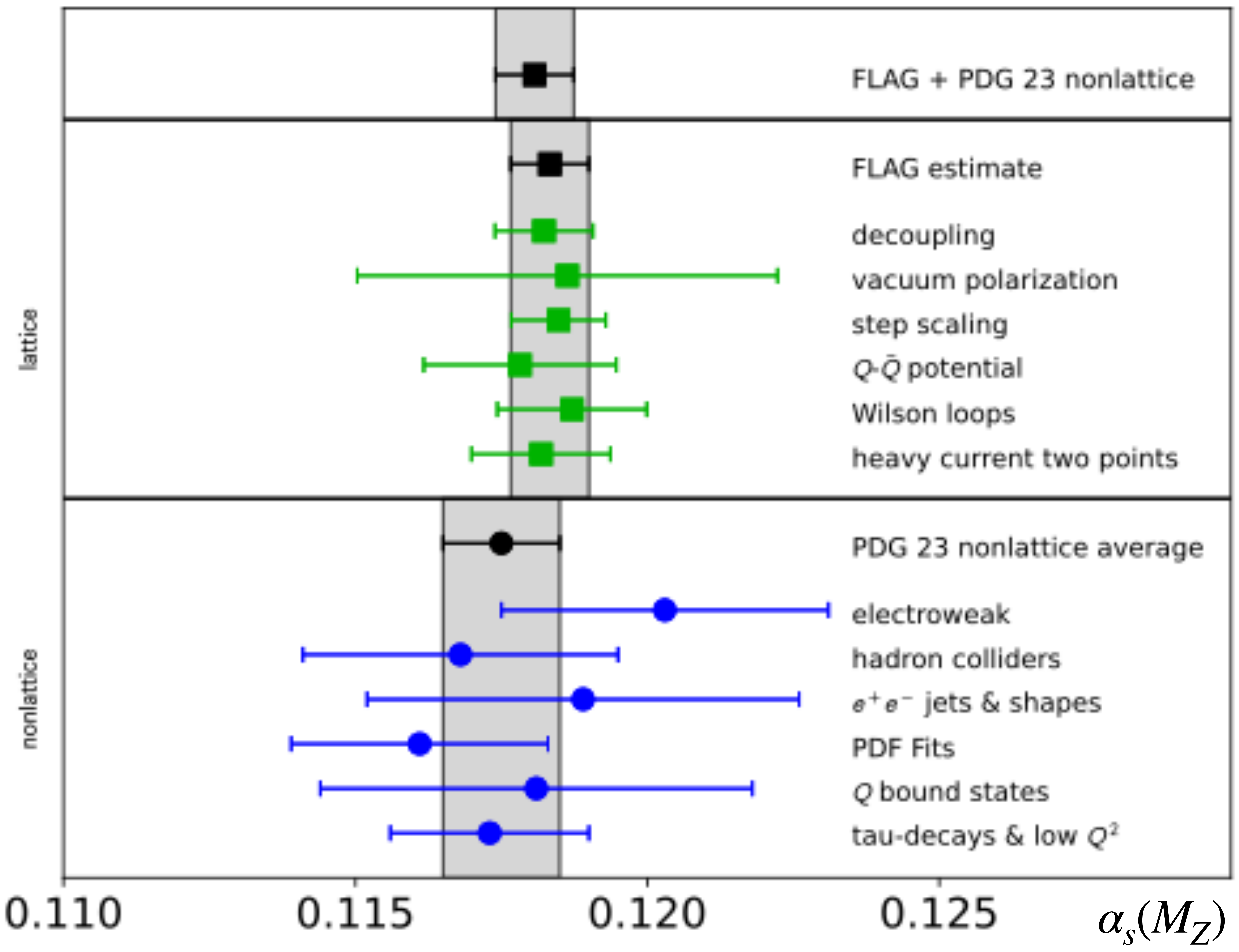
  $$\mu = 70\ \text{GeV},\ \mu a \ll 1,\ L = N_s a \ll 1\ \text{fm}$$

  "Femto box"

  Connect calculations for L ≪ 1 fm to physical calculations using "step scaling"

FLAG 2024: $\alpha_s^{(5)}(M_Z) = 0.1183(7)$

FLAG+PDG 2024: $\alpha_s^{(5)}(M_Z) = 0.1181(7)$



PDFs from lattice

Zafeiropoulos

The natural ab-initio method to study QCD non-perturbatively is on the **lattice**. But …

PDFs ≡ expectation values of bilocal operators evaluated along **light-like** lines.

Cannot evaluate this on a Euclidean setup
➜ Traditional lattice studies were limited to first few (three) Mellin moments of a local ME.

Breakthrough (Ji 2013): put quarks some distance apart. Then boost them to heck ➜ almost lightlike separation (in proton frame).

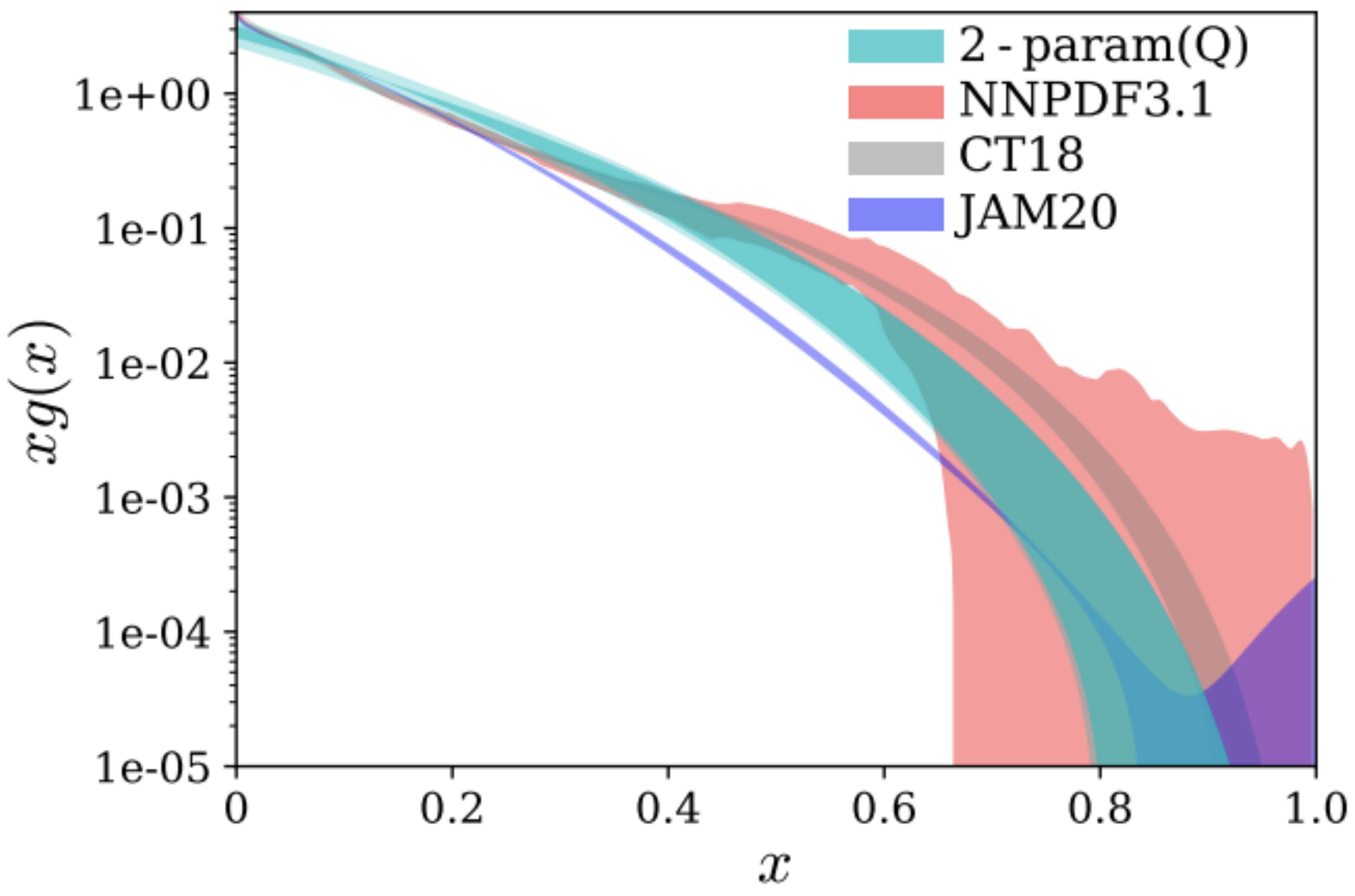
➜ Use **perturbative matching** from finite to infinite momentum (and deal with divergencies)

Only a handful of lattice data

"Ioffe Time PDFs

$$\mathfrak{M}_R(\nu,\mu^2) \equiv \boxed{\int_0^1 dx\ \cos(\nu x)}\ q_v(x,\mu^2)$$

Cosine not orthogonal in $[0,1]$

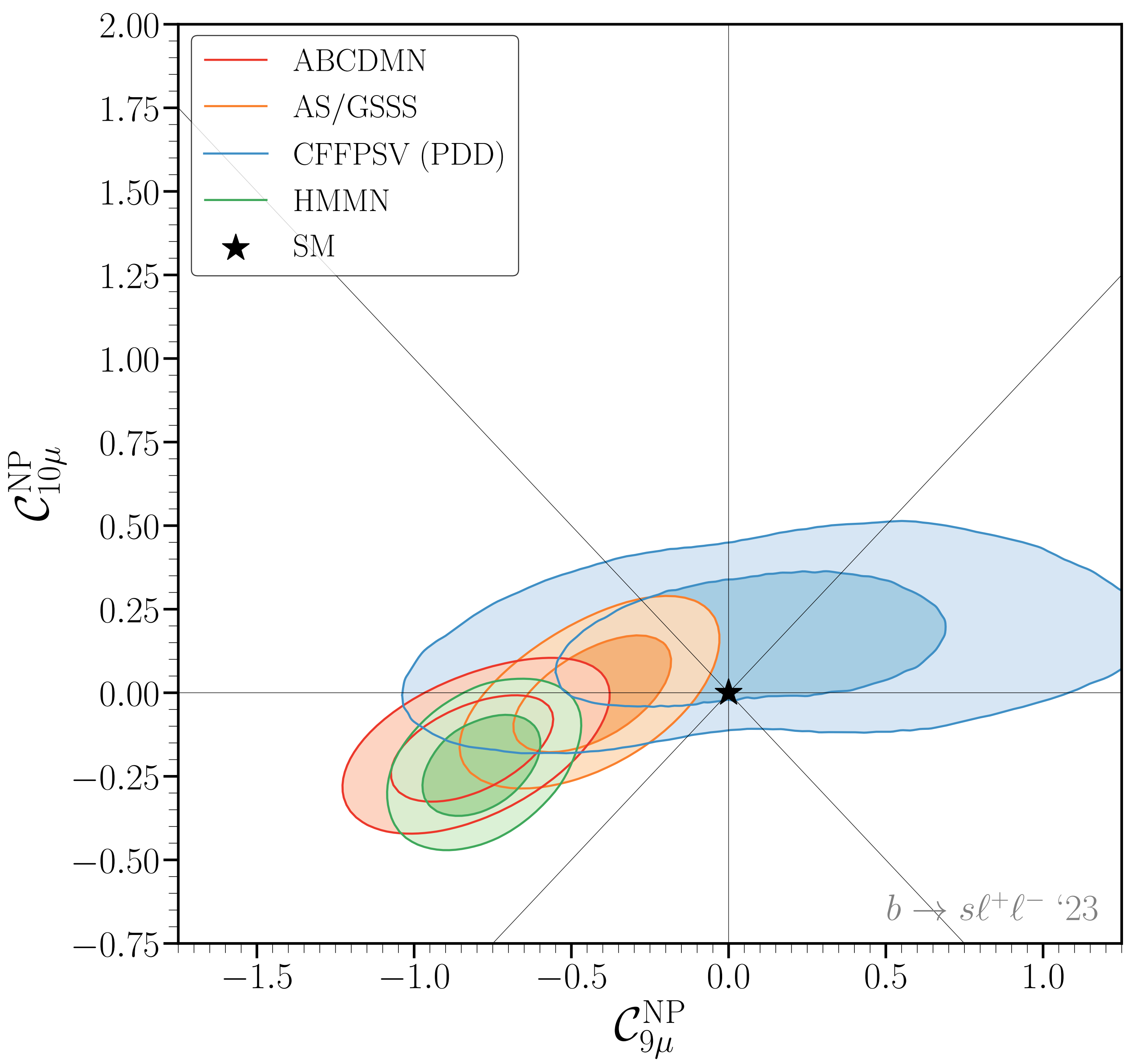


Also: can get helicity & transversity PDFs

Take-home: Lattice can by now provide **ab-initio PDF determinations** without theoretical obstructions

Inclusive $b \to s\mu^+\mu^-$

- Exclusive $b \to s\mu\mu$ subject to potentially large and uncontrolled power corrections



- Up to power corrections the inclusive rate is free of hadronic uncertainties:

$$\Gamma[B \to X_s \ell\ell] = \Gamma[b \to X_s \ell\ell] + O\left(\frac{\Lambda^2_{QCD}}{m_b^2}, \cdots\right)$$

- The OPE breaks down at large $q^2 = m^2_{\mu\mu}$ but not for the ratio:

$$\mathscr{R}(q_0^2) = \frac{\int_{q_0^2}^{m_b^2} dq^2 \frac{\mathrm{d}\Gamma(\bar{B} \to X_s \ell^+\ell^-)}{dq^2}}{\int_{q_0^2}^{m_b^2} dq^2 \frac{\mathrm{d}\Gamma(\bar{B}^0 \to X_u \ell\nu)}{dq^2}}$$

- LHCb has already measured enough high-q^2 modes to reconstruct the BR:
  $\mathscr{B}[>15]_{\rm LHCb} = (2.65 \pm 0.17) \times 10^{-7}$

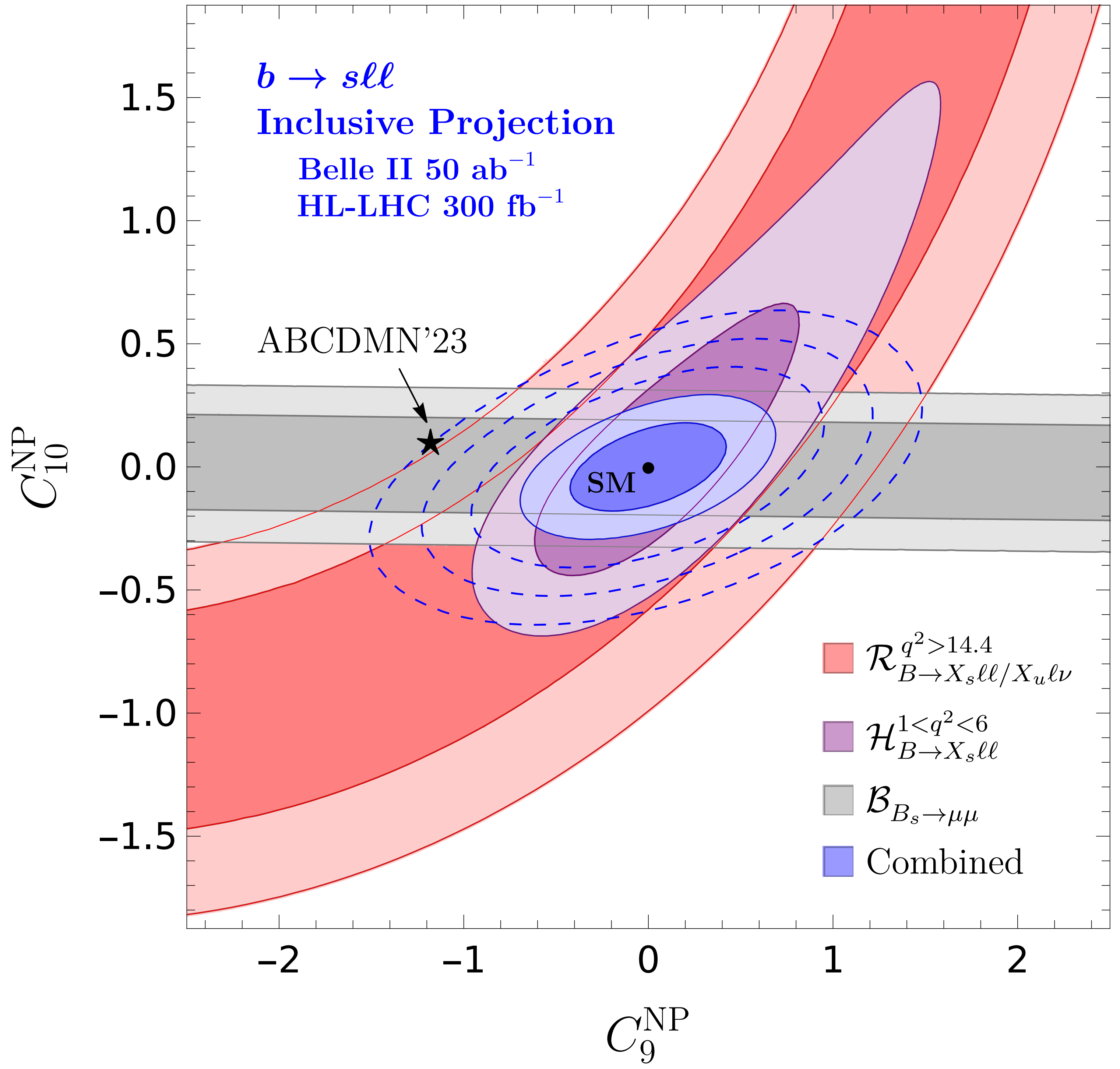
- LHCb should produce a proper combination of these modes taking into account correlations and for $q^2 > 14.4$ GeV^2

- Using differential Belle semileptonic data the high-q^2 and the theory prediction for $\mathscr{R}$:

  $\mathscr{B}[>15]_{\rm SM+Belle} = (4.10 \pm 0.81) \times 10^{-7}$

- Inclusive modes are currently in agreement with data

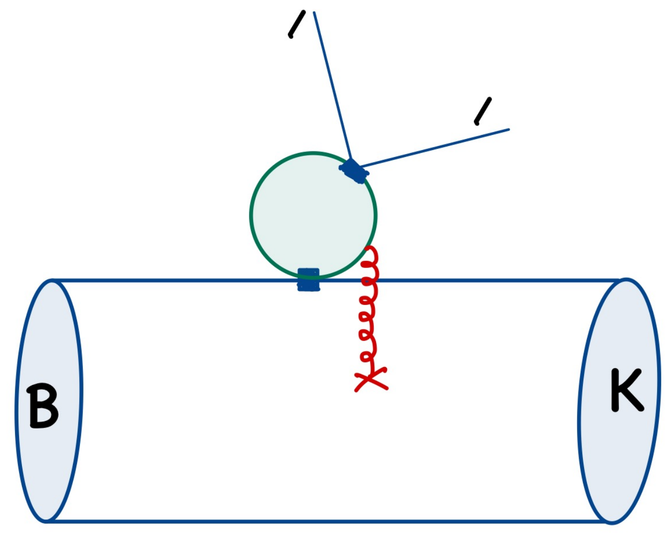
- Future LHCb + Belle II data can confirm the exclusive anomalies at 5σ if central values do not change:



Hadronic Transitions & Form Factors

Mishra: $B \to K$ FFs from LCSR

Measured BR(B→K$\mu\mu$) lower than predictions.
Tensions between different theory predictions.



Can safely neglect non-fact. soft-gluon contributions to c loop

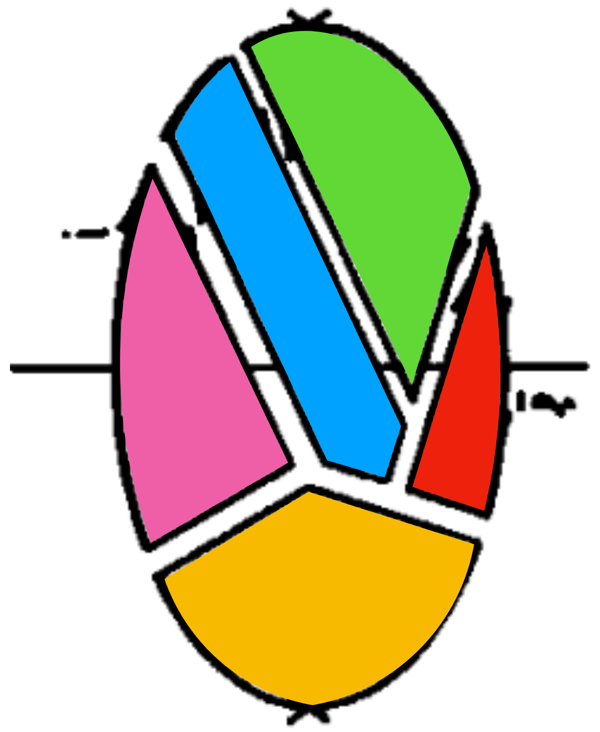
+ Re-analysis of hadronic ME ➜ **tension persists**

d'Ambrosio: $K \to \pi\ell^+\ell^-$

Dominated by **long distances**

LC ⇒ Sum of 1-meson poles

⇒ VMD-like ansatz for γ^*



$$\langle J(q)J(-q)\rangle = \sum_n \frac{a_n^2}{q^2 - m_n^2} \underset{q^2\to\infty}{\sim} \log q^2$$

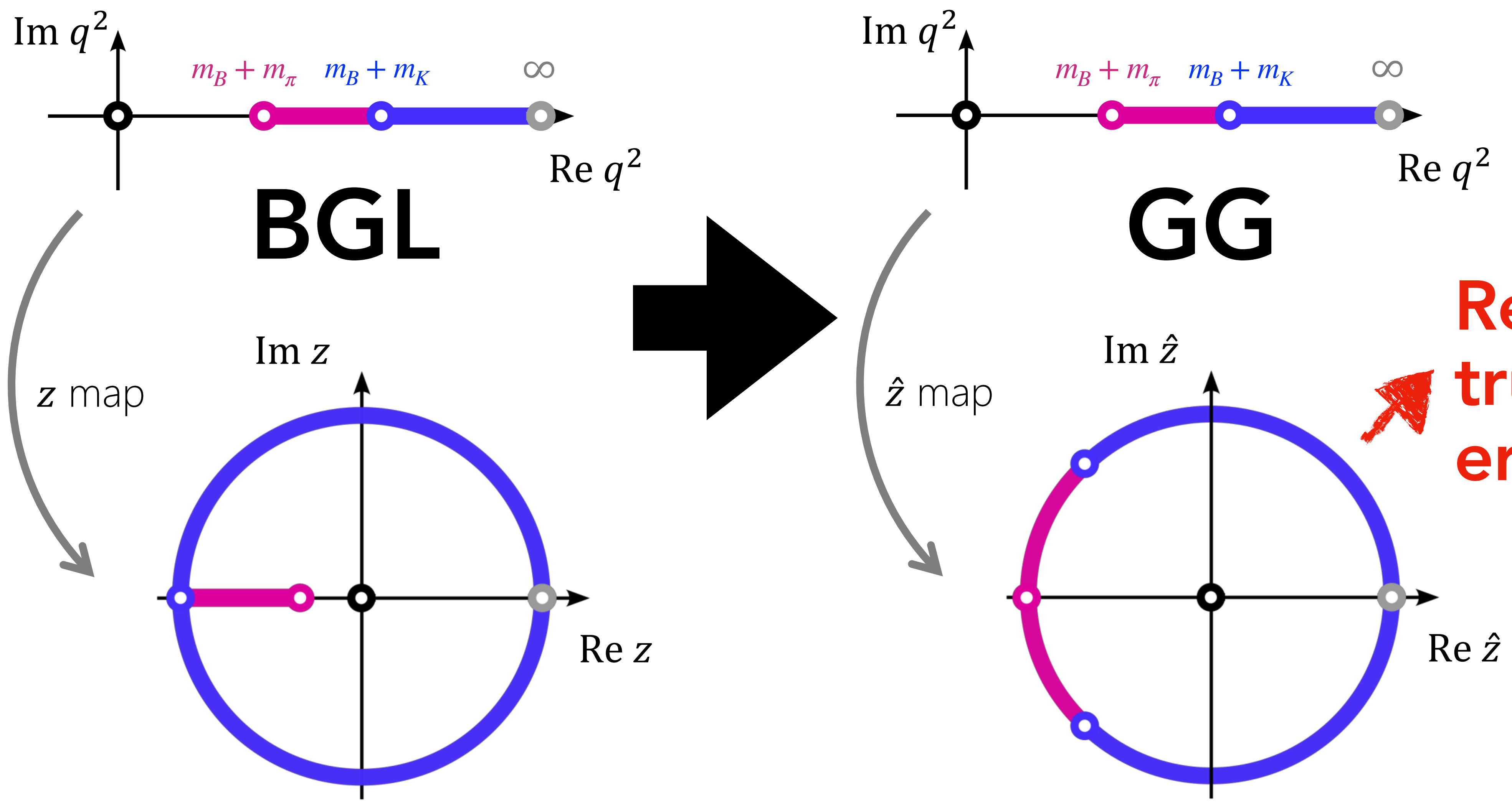
Gubernari: improving FF parametrisations

Conventional approach: BGL

⇒ **divergent series in presence of branch cuts**

Problem for $B \to K$, $B \to D^{(*)}$, $\Lambda_b \to \Lambda$
(Also: truncation error meaningless)

Analytic structure suggests **an alternative parm:**



Reliable truncation error!

(+ extension to rescattering)

FFs for B_c & HF hadrons from recombinations?

Nandi: FFs for $B_c \to$ charmonium

Tests of **Lepton Flavour Universality** analogous to those in $B \to D^{(*)}$ (R_D, R_{D^*}) can be done with $B_c \to \eta_c$, $B_c \to J/\psi$, and $B_c \to P(=\chi_c^0, \chi_c^1, h_c)$

For $B_c \to J/\psi$, there are FFs from lattice

Heavy Quark Spin Symmetry $\Rightarrow B_c \to \eta_c$

Estimate symmetry-breaking correction ~ 30%

➜ $R(\eta_c) = 0.290 \pm 0.017$

Also compute $B_c \to$ P- and S-wave FFs in both NRQCD ($q^2 \to 0$) & pQCD (high q^2)

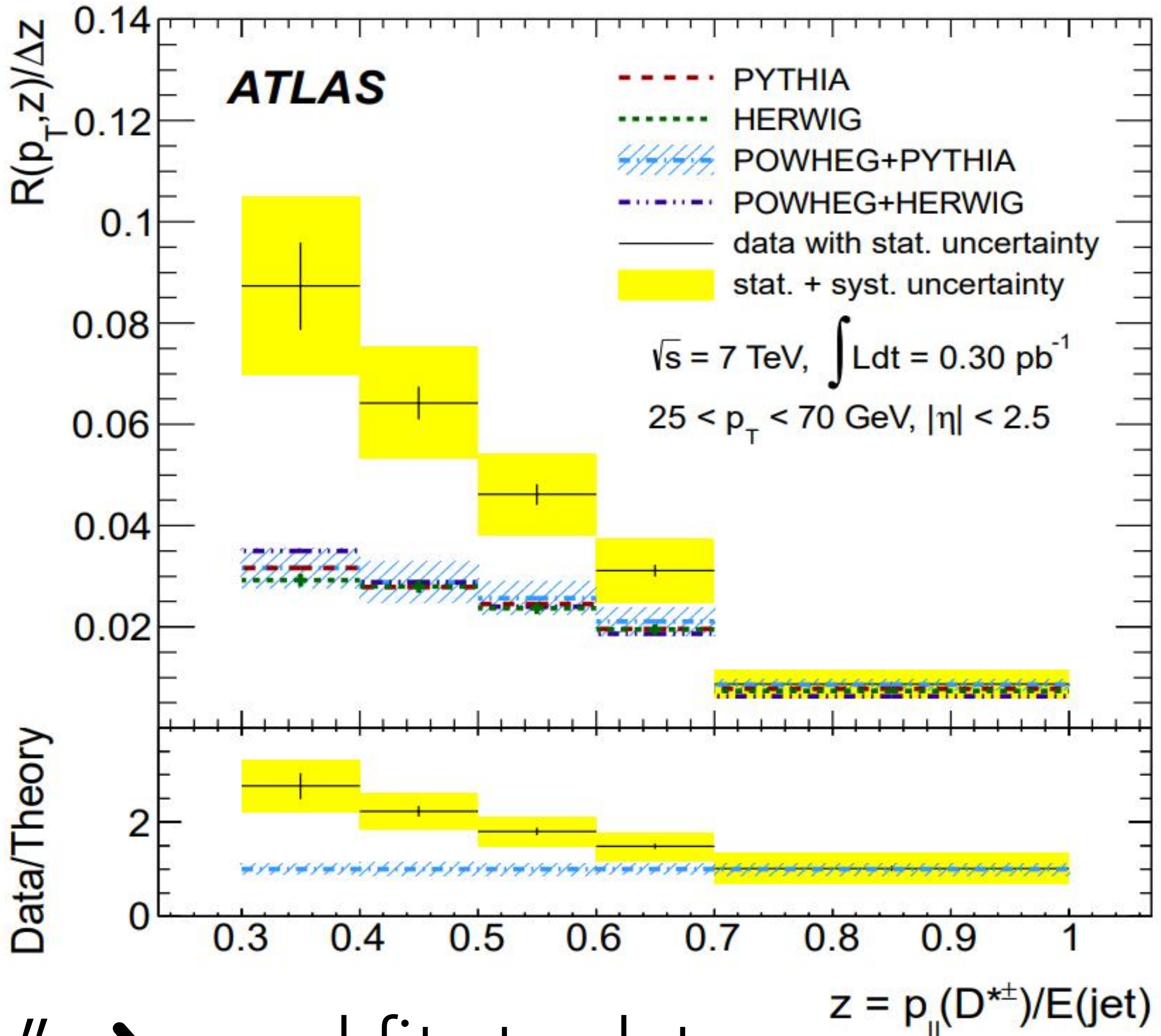
In: B_c-> J/ψ FFs, decay consts, and measured charmonium radiative decay rates ⇒ LFU $R(\ldots)$

Li:

Observation: more low-z D* in data than in baseline MCs

Could originate from **recombination** of c with quark from UE?

Similar to coalescence?



Assumptions for "UE sea" ➜ good fits to data

Also: more HF baryons at low p_T than at LEP

Diquark-style recombinations? ⟷ **(Note: similar phenomena modelled in event generators: QCD Colour Reconnections)**

➜ can also make predictions for tetra-quarks

Pion Holography?

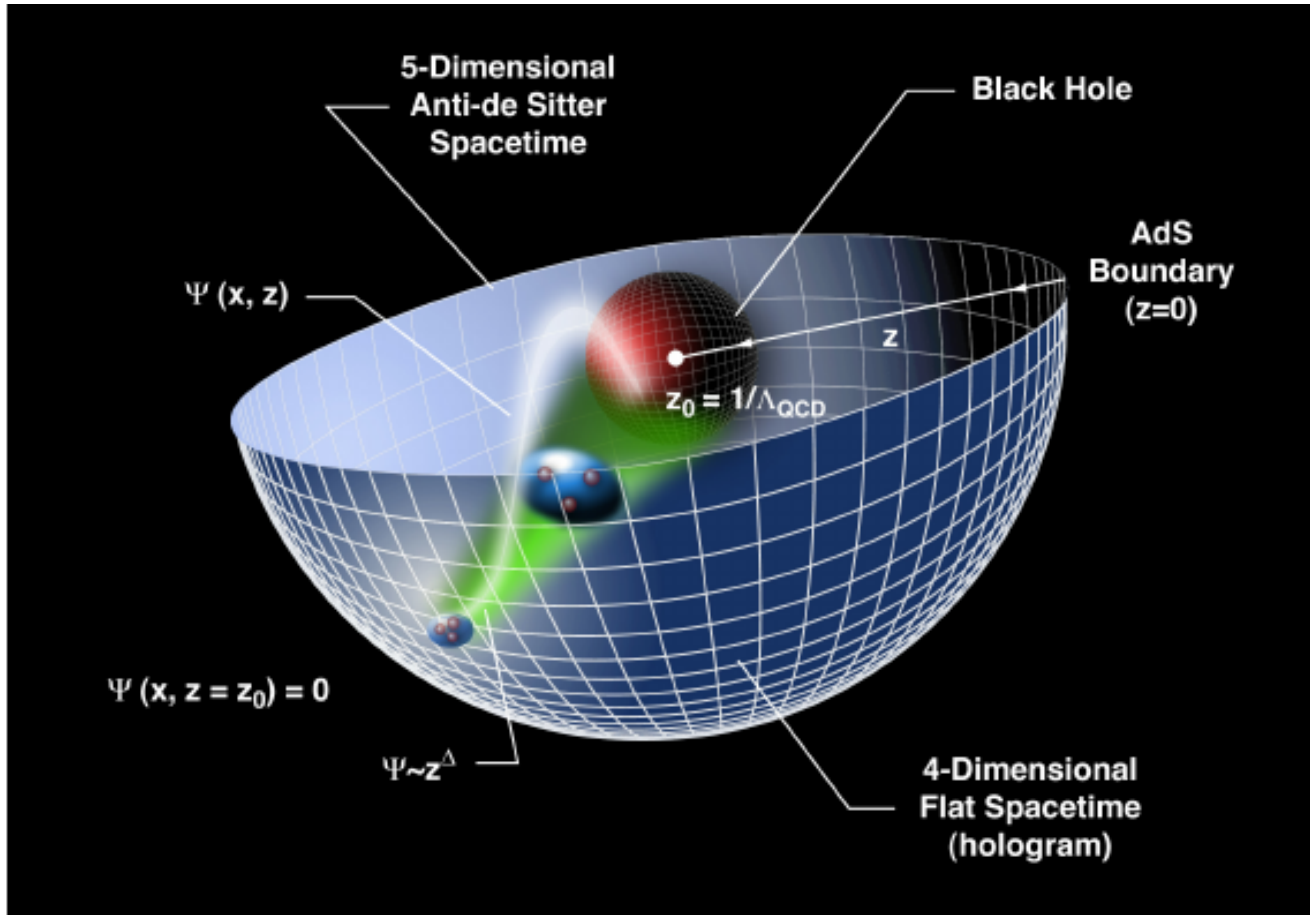
Holography = formal equivalence beween two theories, said to be each other's **holographic duals:**

- A **strongly-coupled** scale-invariant (conformal) gauge theory in flat 4D space-time
- A **weakly-coupled** 5D gravity (string) theory in a curved space (AdS)

⇒ **can do calculations** in the weakly coupled theory and **relate them** to the strongly-coupled one!

Problems:

- QCD ≠ scale invariant
- Longitudinal dofs neglected in "light-front quantisation" ⇒ massless pion



Sandapen: restoring conformal-symmetry breaking longitudinal potential $U_{||}$ ➜ correct m_π

Three Different forms of $U_{||}$ ⇒ **same** m_π, f_π, r_π, low-Q2 form factors, and $\Gamma_{\gamma\gamma}$ = 7.0, 7.2, and 7.4 eV

PDG: 7.82 ± 0.22 eV

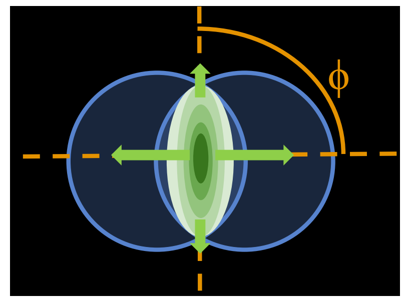
Form "C" with $\Gamma_{\gamma\gamma}$ = 7.4 eV also exhibits quantitative agreement with holographic prediction in limit of weak coupling

Work in progress: holographic pion distribution amplitude & pion PDFs

Heavy Ions

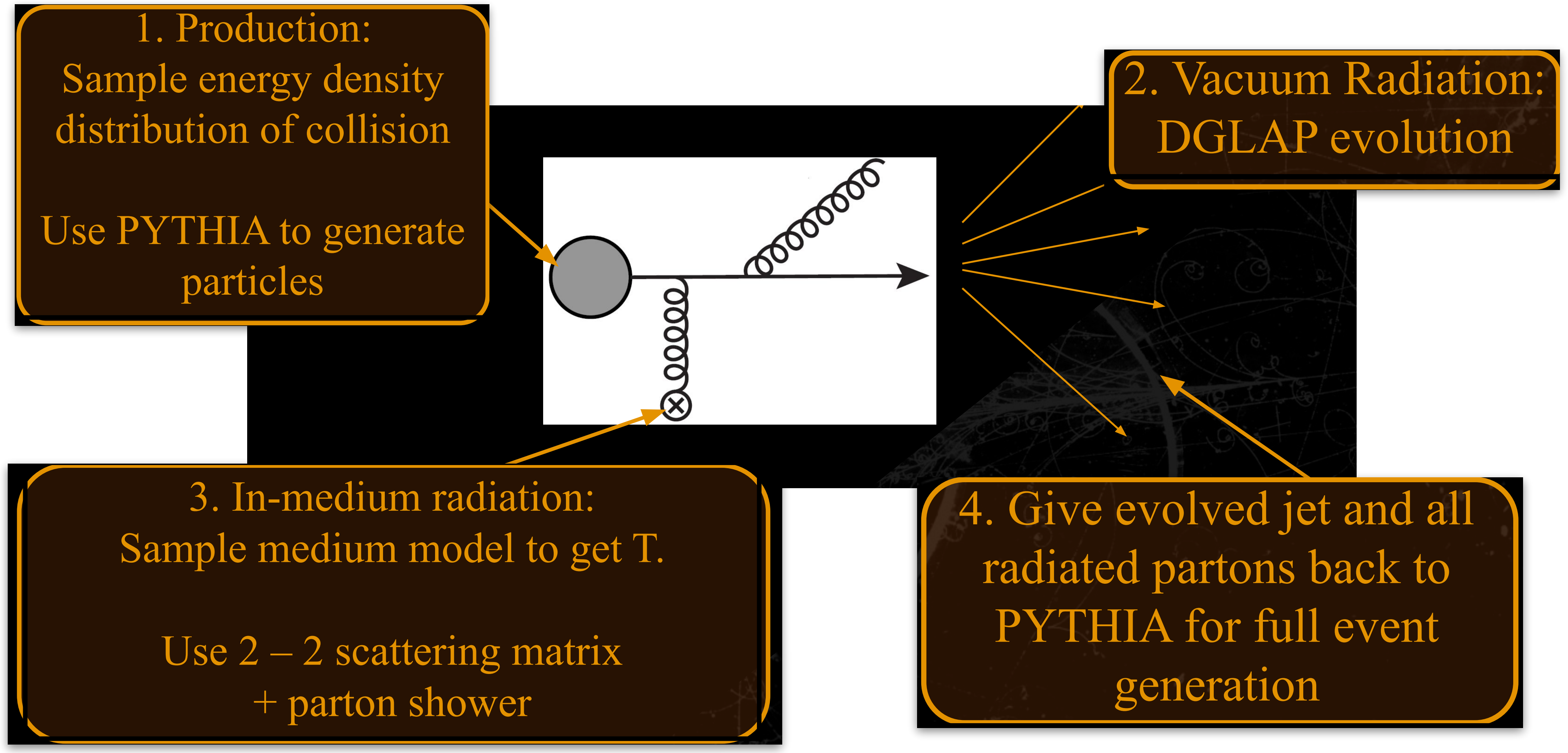
Kolbé, Speranza

Kolbé: Simulating jets in medium



Nonzero $\mathbf{v_2}$ **at high p_T** not well understood

Hydro interface for JEWEL: **J**et **E**volution **W**ith **E**nergy **L**oss



➜ Careful hydro with **Trajectum**

Agrees well with **jet pT spectrum in central PbPb**

But nonzero $\mathbf{v_2}$ **at high p_T** still not well understood

Speranza: Initial-state-driven spin correlations in HI

Huge angular momentum in peripheral HI may be converted to angular momentum ➜ polarisation?

Relativistic Spin Hydrodynamics

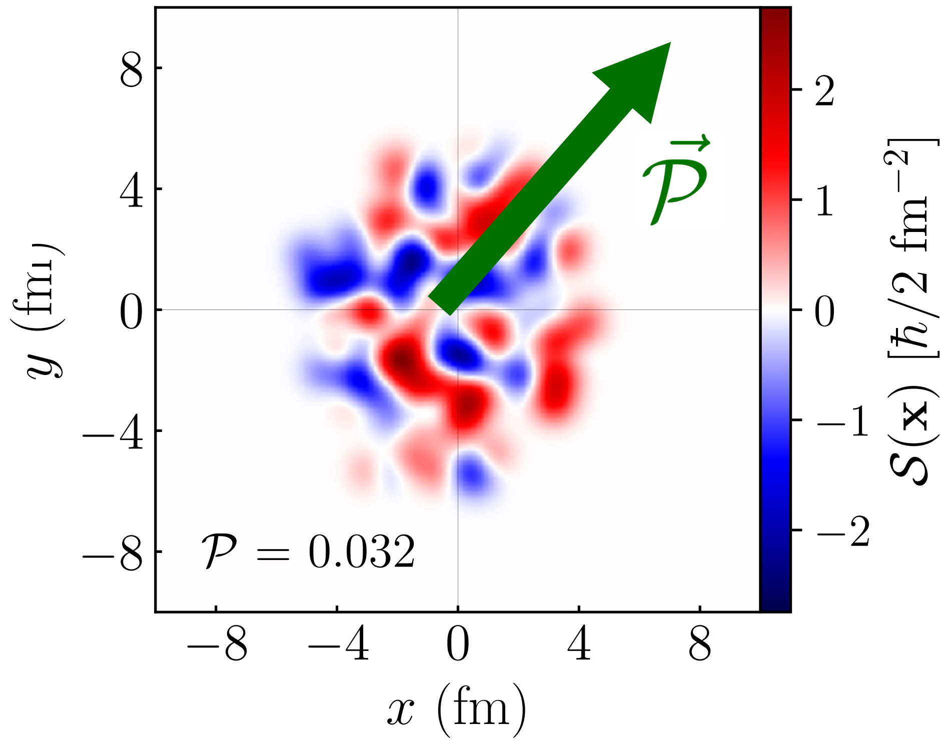
Hydro with spin as additional degree of freedom

$$\boxed{\partial_\mu T^{\mu\nu} = 0}$$

(E,p) cons.

$$\boxed{\partial_\lambda S^{\lambda,\mu\nu} = T^{\nu\mu} - T^{\mu\nu}}$$

Cons of angular momentum

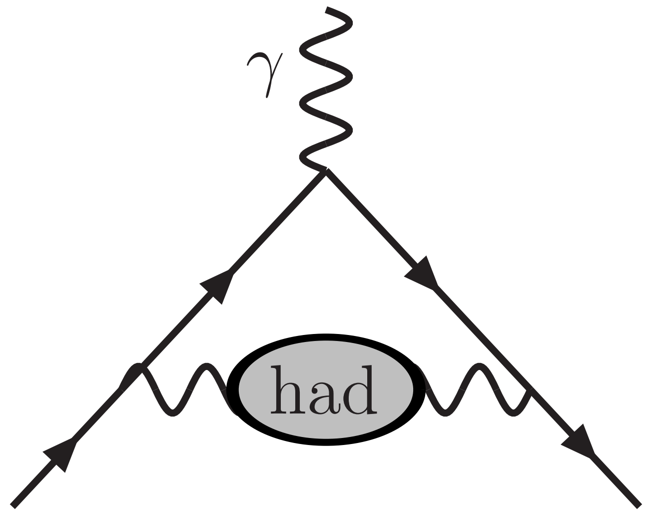


Initial-state spin fluctuations can be **much larger** than those induced by **final-state vorticity**

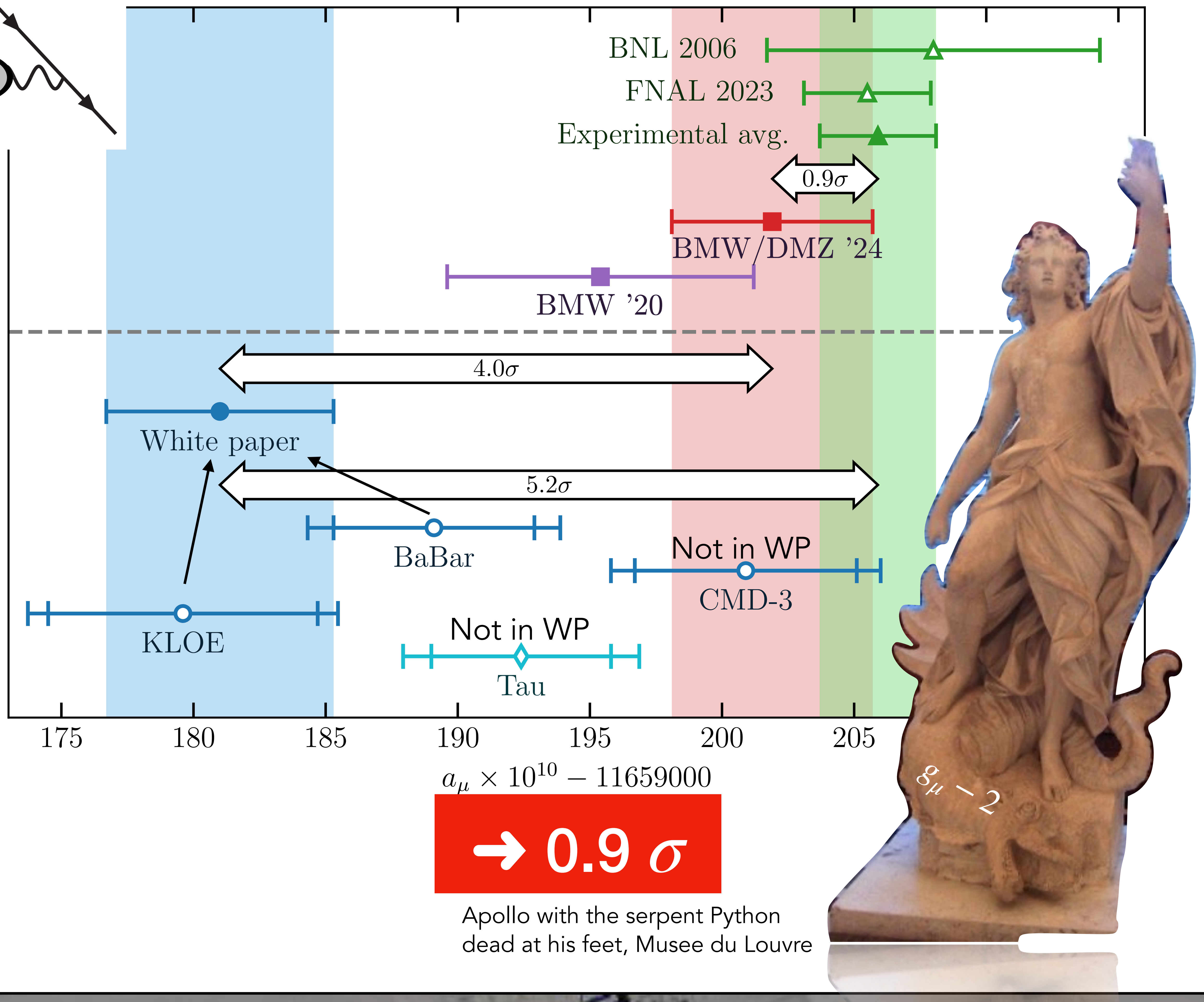
Observable: $\Lambda\Lambda$ spin corr

g_μ - 2

Largest TH uncertainty: **hadronic vacuum polarisation (HVP)**

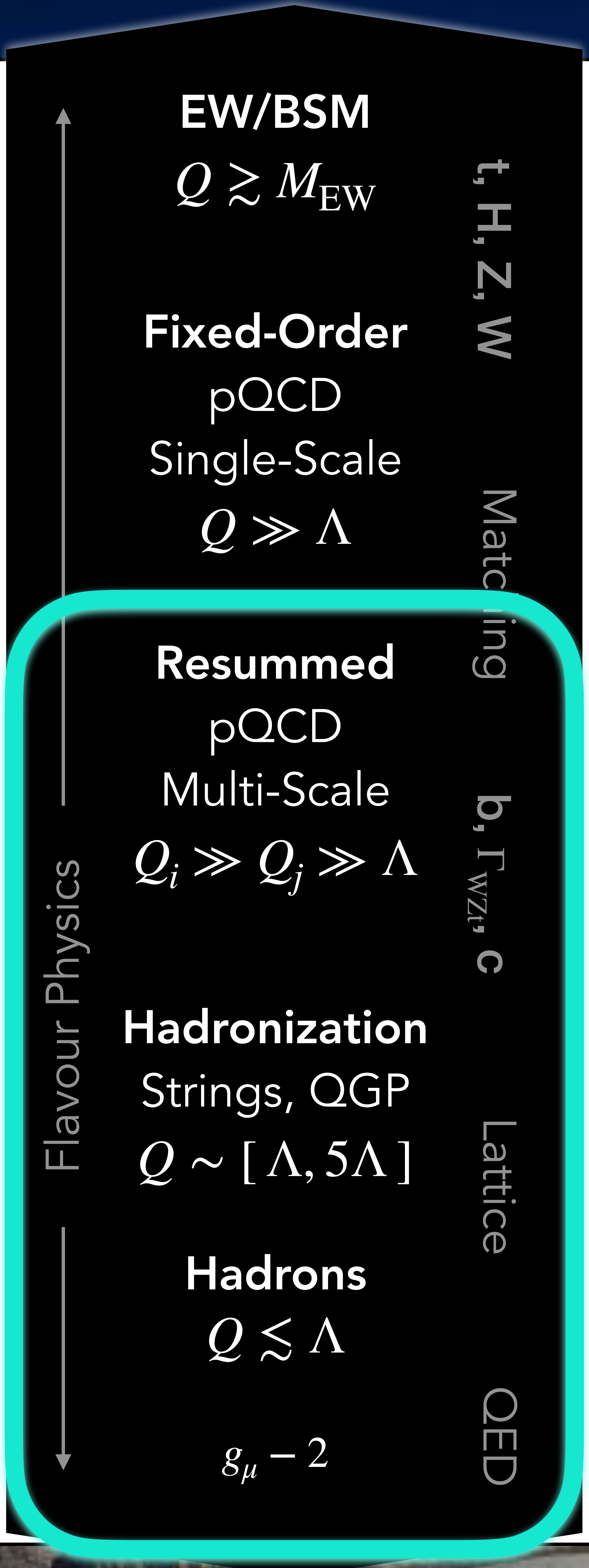


1. **Data driven** (from R-ratio)
   - $e^+e^- \to \mathrm{had}$ + optical theorem
   - But note some tensions among data sets!
2. **Lattice QCD** (10^{10}-dim integral)
   - Community agreement on intermediate (simpler) benchmark: **window observable** (restrict correlator to 0.4-1fm)
   - Finer lattice spacings (page 10)
3. **Frankenfit**
   - **Lattice** for 0-2.8fm window
   - **Data driven** for 2.8-∞fm tail (5% of total result, avoids ρ peak, good agreement).



→ 0.9 σ

Apollo with the serpent Python dead at his feet, Musee du Louvre



Apologies: a few **speakers** not yet mentioned in these slides

Quark Flavour Physics

- S. Nandi ($B_c \to X_{c\bar{c}}$ FFs)
- E. Lunghi ($b \to s\mu^+\mu^-$)
- N. Gubernari ($B \to K$ FFs)
- D. Mishra ($B \to K$ LCSR)
- G. d'Ambrosio (LC $K \to \pi\ell^+\ell^-$)

Non-perturbative QCD

- S. Li (Hadrons from recombination)
- S. Zafeiropoulos (Lattice PDFs)
- B. Tóth (Lattice $g_\mu - 2$)
- M. Praszalowicz (Elastic pp)
- R. Sandapen (Pion Holography)

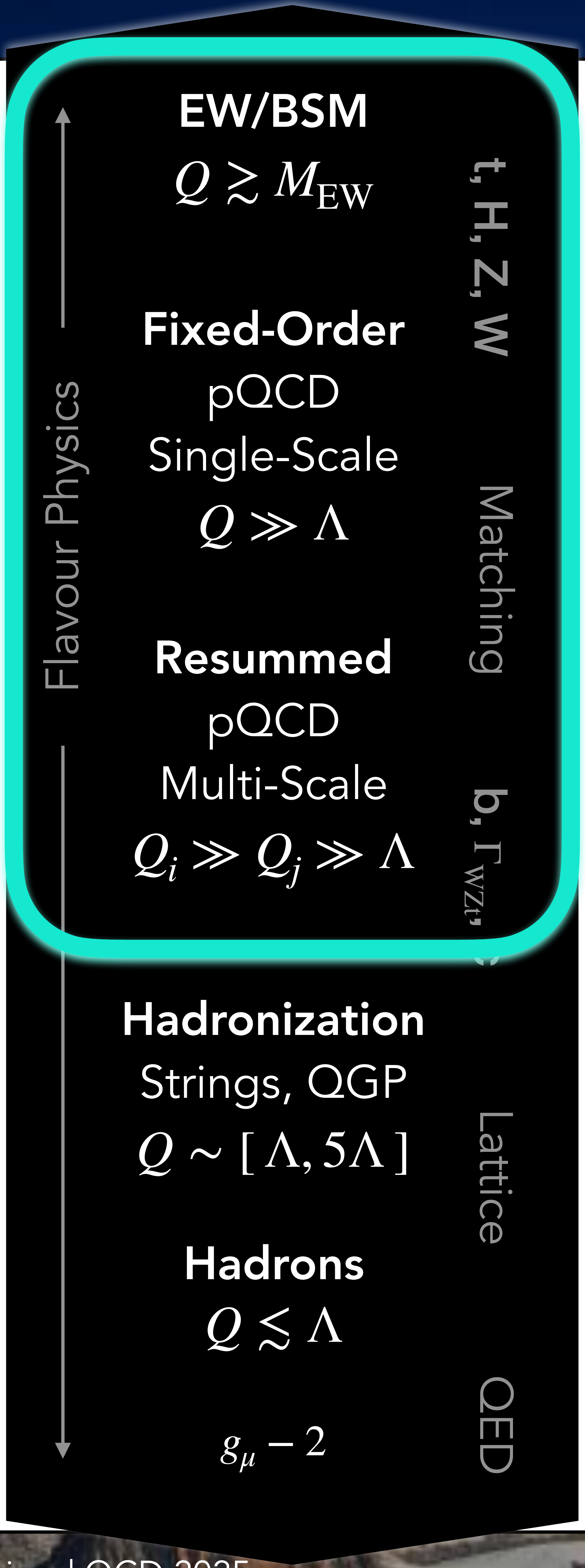
Heavy Ions

- **N. Zardishti (HI Overview)**
- I. Kolbé (Jets in Medium)
- E. Speranza (Spins in HI)
- **W. Schee (QCD ↔ Gravity?)**

Methodology

- R. Poncelet (σ_{th})
- **M. White (Q. Advantage in $t\bar{t}$)**

Theory Speakers 2 — **Hard/Partonic**



Hard Processes

- S. Jaskiewicz (m_t in HH)
- M. Kerner (m_t in $H + j$)
- M. Marcoli (pp $\to \gamma\gamma$)
- **D. d'Enterria (Rare H decays)**

BSM

- S. Vempati (Higgs FLV)
- E. Vryonidou (Higgs CPV)
- **M. Baker (Heavy Vectors)**
- **S. Balan (Dark-Matter Fits)**
- **M. Fedele (Sterile ν in $b \to c\ell^+\ell^-$)**

Splittings, Resummation, Factorization

- A. Pelloni (N3LO splittings)
- F. Hekhorn (aN3LO PDFs & Higgs)
- S. Ferrario Ravasio (Shower Logs)
- N. Schalch (Non-global Logs)
- T. Becher (Super-Leading Logs)
- M. Neubert (Factorization)
- A. Vladimirov (DY TMD)
- W. Zhan (DY intrinsic p_T)

Strong Coupling

- J. Pires (α_s from Dijets)
- M. Benitez (α_s from M_H)
- Y. Che (α_s from B)
- J. Wu (α_s from D)
- P. Petreczky (α_s from lattice)

Theory Summary 2025

59th Rencontres de Moriond: QCD & High Energy Interactions, La Thuile, April 2025