Snowmass EF05-07 LoI’s

α_s determination and non-perturbative modeling with energy-energy correlator

Jun Gao and Hua-Xing Zhu

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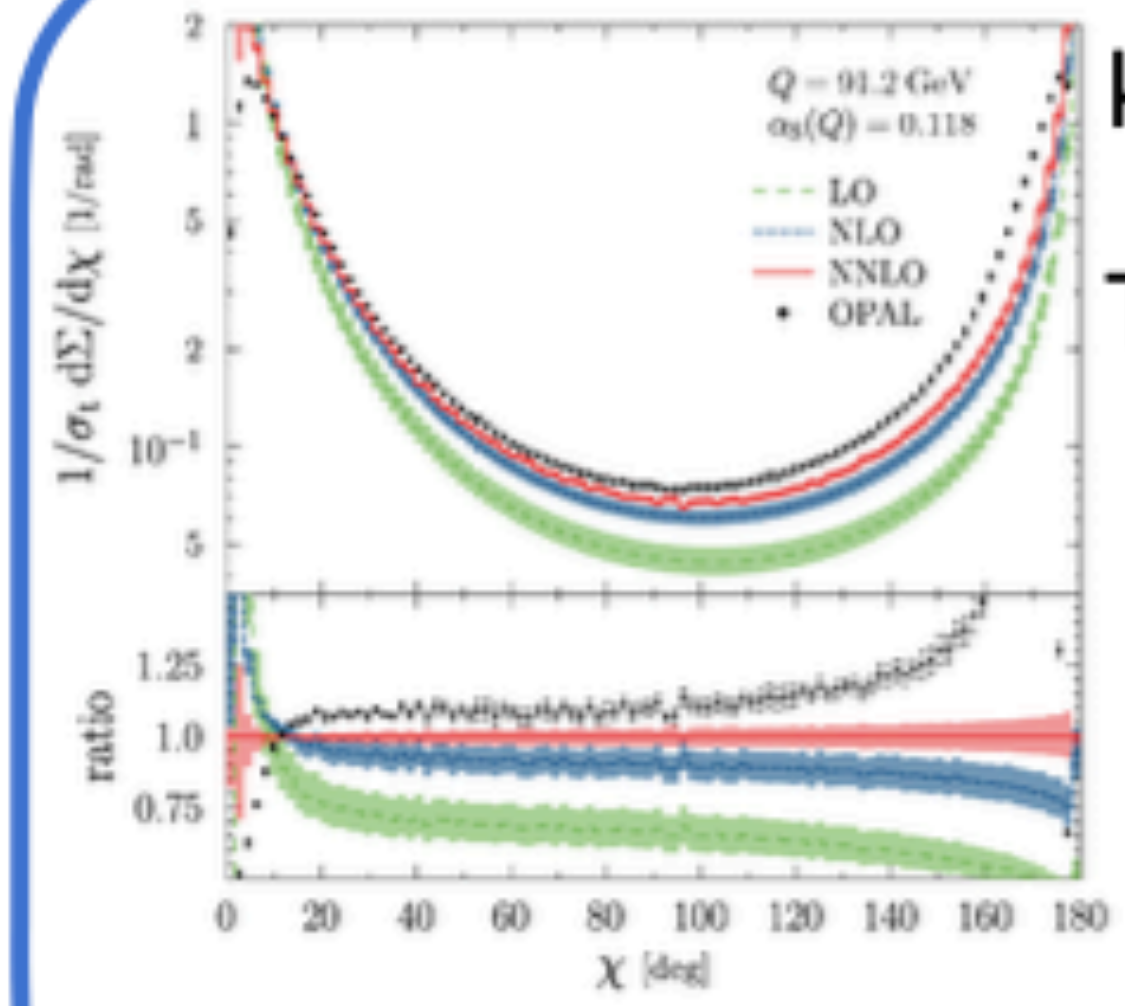


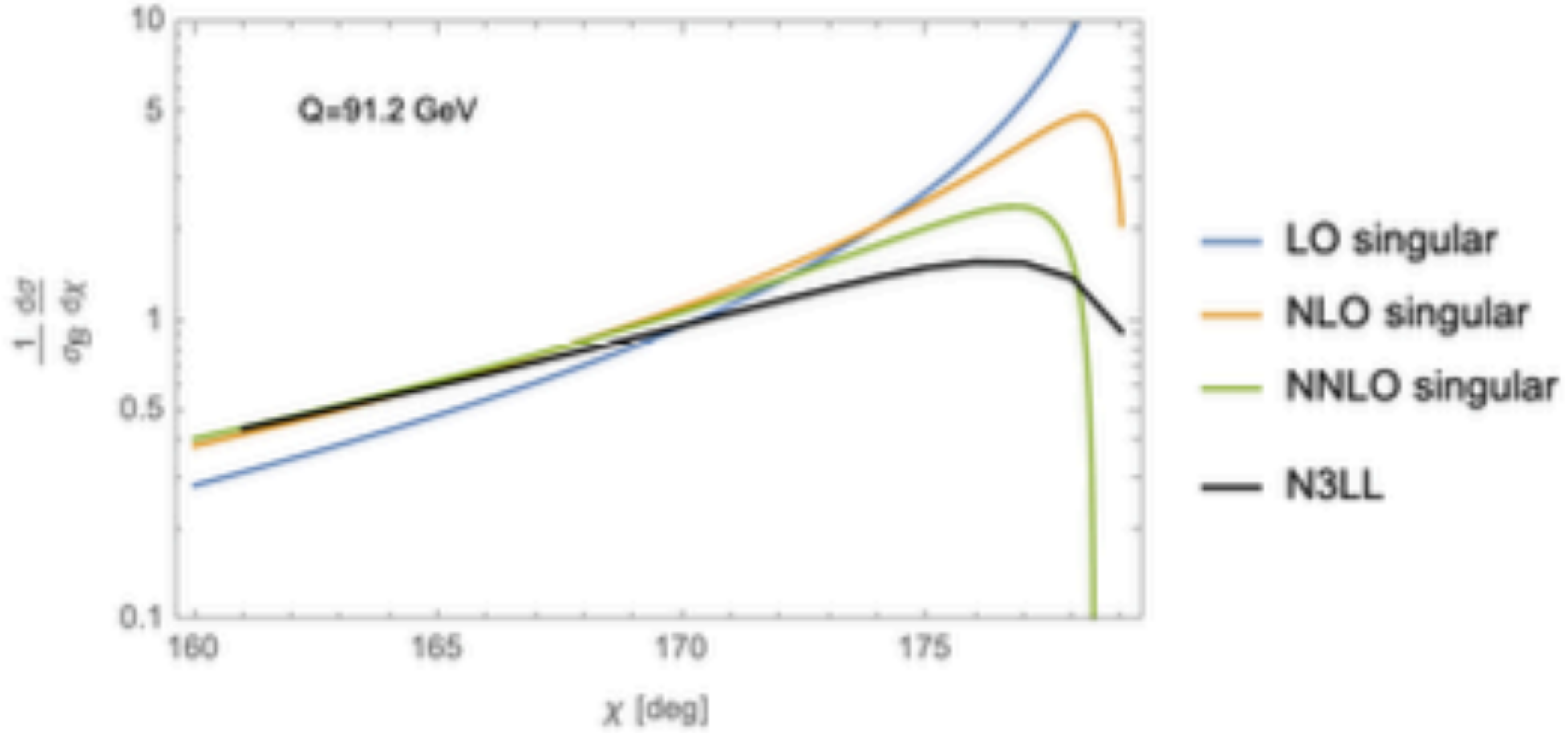
kardos, Kluth, Somogyi, Tulipant, Verbytskyi, 1804.09146

Theoretical accuracy: NNLO + NNLL (back-to-back)

Hadronization corrections:

non-perturbative modeling/Monte Carlo

$$\alpha_s(m_Z) = 0.11750 \pm 0.00018\,(exp.) \pm 0.00102\,(hadr.) \pm 0.00257\,(ren.) \pm 0.00078\,(res.),$$



Towards ultimate theory accuracy:

NNLO + N3LL resummation

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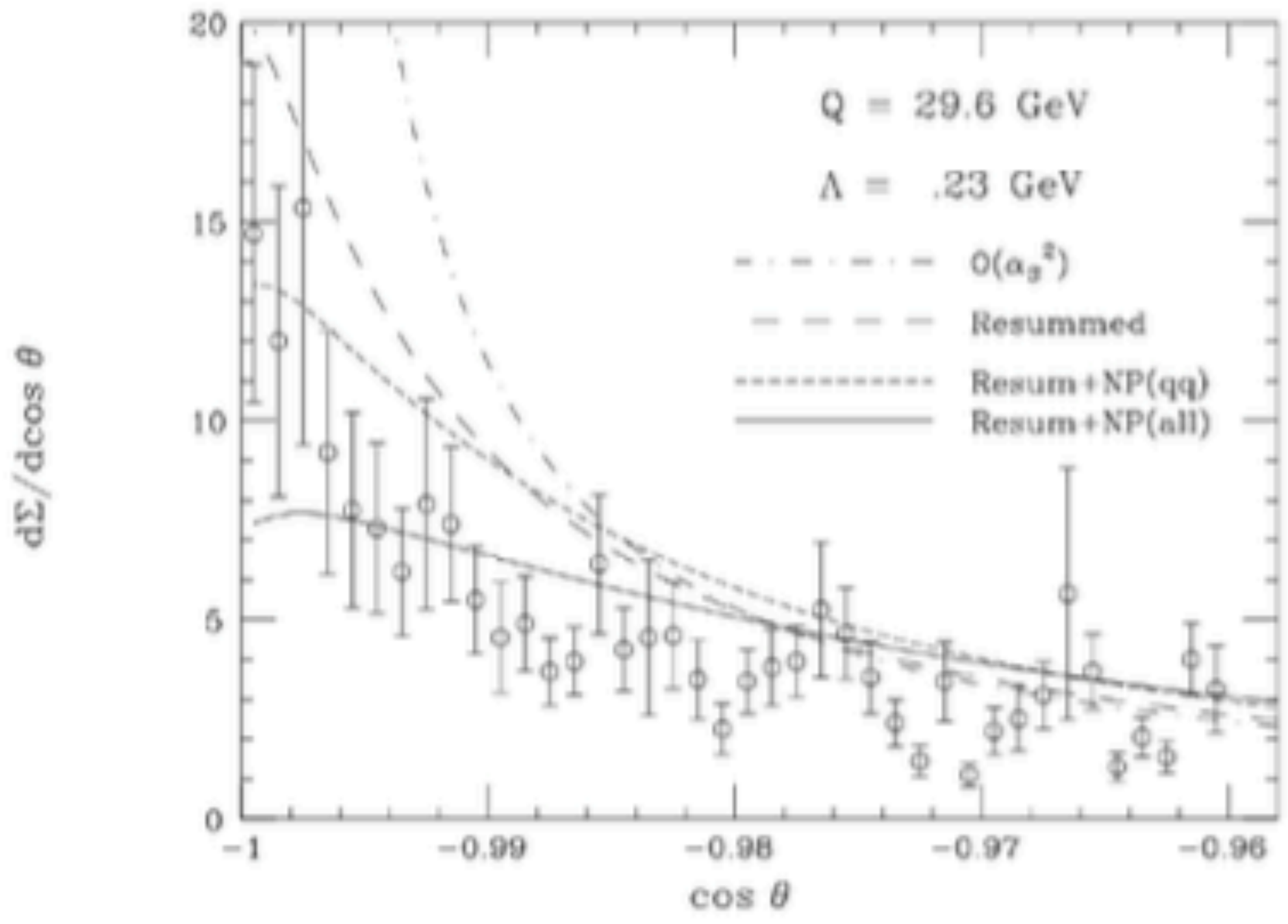


Sensitive to non-perturbative modeling in the back-to-back limit

Dokshitzer, Marchesini, Webber, hep-ph/9905339

log(Q) dependence from perturbative corrections

Power corrections in Q from non-perturbative hadronization

Goal: (a) Investigating better non-perturbative modeling of hadronization, with energy conservation sum rule incorporated;

(b) Disentangle perturbative and non-perturbative corrections with data from multiple Q: important to have energy scan in a wide range at CEPC

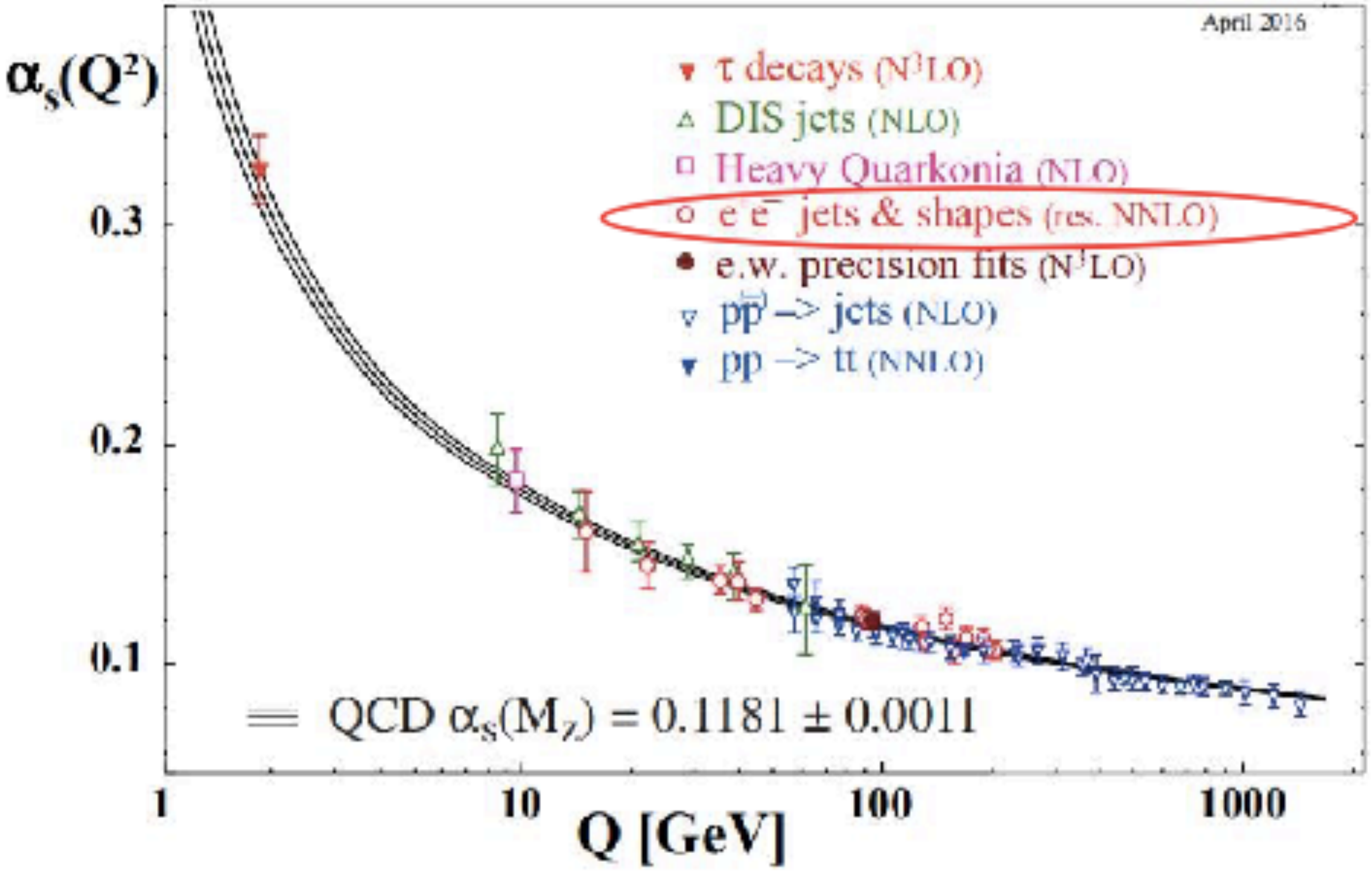
高俊，朱华星，in progress

Event shape variables and the extraction of QCD coupling constant at the CEPC

Sheng-Quan Wang, Xing-Gang Wu, Stanley J. Brodsky

Event shape variables:

thrust T, the normalised heavy jet mass, the wide and total jet broadenings B_W and B_T, the C-parameter..., are extensively measured by e^+e^- annihilation, such as LEP, SLD...experiments. One often extract the QCD coupling constant for these shape variables



Exclusive Z decays

Qin Qin
Huazhong University of Science and Technology

CEPC as a Tera-Z factory

- **Exclusive** channels will be discovered and measured:

Decay mode	Branching ratio	CEPC Uncertainty
$Z \to J/\psi\gamma$	8.02×10^{-8} [29]	$\sim 1.8\%$
$Z \to \Upsilon(1S)\gamma$	5.39×10^{-8} [29]	$\sim 3.4\%$
$Z \to \rho^0\gamma$	4.19×10^{-9} [29]	$\sim 1.8\%$
$Z \to \omega\gamma$	2.82×10^{-8} [29]	$\sim 0.8\%$
$Z \to \phi\gamma$	1.04×10^{-8} [29]	$\sim 1.6\%$
$Z \to \pi^0\gamma$	9.80×10^{-12} [29]	$< 3.4 \times 10^{-8}$
$Z \to \eta\gamma$	$0.1 - 1.7 \times 10^{-10}$ [30]	$\sim 12\% - 50\%$
$Z \to \eta'\gamma$	$3.1 - 4.8 \times 10^{-9}$ [30]	$\sim 2.7 - 3.4\%$

[Grossman,Konig,Neubert,1501.06569]
[Alte,Konig,Neubert,1512.09135]

$$\mathcal{B}(Z \to \pi^+\pi^-) = (0.83 \pm 0.06) \times 10^{-12}$$

$$\mathcal{B}(Z \to K^+K^-) = (1.74 \pm 0.06) \times 10^{-12}$$

[Cheng,Qin,1810.10524]

Are they important?

Test of Factorization

❖ **Factorization for inclusive processes**

- well tested (e.g. DIS and LHC processes)

❖ **Factorization for exclusive processes**

- extensively applied in B meson decays
- but not tested well, owing to unknown and large power corrections $\sim \mathcal{O}(\Lambda_{\rm QCD}^n/m_b^n)$ in calculation
- expected to be well tested in Z decays, whose power corrections $\sim \mathcal{O}(\Lambda_{\rm QCD}^n/M_Z^n)$ are negligible

Test of Factorization

Comparing (1) precise CEPC measurements of the exclusive Z decays and (2) clear theoretical calculation free of dirty power corrections, the factorization theorem for exclusive processes will be well tested.

Extract distribution amplitude

proton PDF	✓	meson DAs	✗

- Practically, exclusive Z decays can be used to determine meson DAs, free of power corrections
- also test DA evolution comparing to low-energy case

$a_2^M(\mu)$	Theoretical value	CEPC precision
ρ^0	0.17 ± 0.07	± 0.02
ω	0.15 ± 0.12	± 0.01
ϕ	0.23 ± 0.08	± 0.02

<u>Plans</u>

- ❖ from **theoretical** side
  - calculation of <u>more channels</u>
  - with <u>higher precision</u>
- ❖ from **experimental** side
  - precision requirement => resolution requirement

Identification of multi-jet events at the CEPC (240 GeV)

Manqi Ruan and Zhu Yongfeng

Contents:

Discrimination variables (Event-shape):

- thrust
- heavy mass
- wide and total broadening
- C and D parameter
- energy-energy correlation
- jet transition variable

Main result: separation power

Summary

Motivation

final state	process	cross section (fb) / number
2 jets	$e^+e^- \to q\bar{q}$	54106.86 / 3.0*10^8
4 jets	$e^+e^- \to WW \to 4quarks$ $e^+e^- \to ZZ \to 4quarks$ $e^+e^- \to ZH \to 4quarks$	4436.77 / 2.5*10^7
6 jets	$e^+e^- \to ZH$ $Z \to q\bar{q}, H \to WW^*(ZZ^*) \to 4quarks$	15.13 / 8.5*10^4

NNLO EW corr. to $e^+e^- \to HZ$

Zhao Li, Yefan Wang
IHEP-CAS

$\sqrt{s}$ (GeV)	$\sigma_{\rm LO}$ (fb)	$\sigma_{\rm NLO}$ (fb)	$\sigma_{\rm NNLO}$ (fb)	$\sigma^{\rm exp.}_{\rm NNLO}$ (fb)
240	256.3(9)	228.0(1)	230.9(4)	230.9(4)
250	256.3(9)	227.3(1)	230.2(4)	230.2(4)
300	193.4(7)	170.2(1)	172.4(3)	172.4(3)
350	138.2(5)	122.1(1)	123.9(2)	123.6(2)
500	61.38(22)	53.86(2)	54.24(7)	54.64(10)

TABLE I. Total cross sections at various collider energies in the $\overline{\rm MS}$ scheme.

$\sqrt{s}$ (GeV)	$\sigma_{\rm LO}$ (fb)	$\sigma_{\rm NLO}$ (fb)	$\sigma_{\rm NNLO}$ (fb)	$\sigma^{\rm exp.}_{\rm NNLO}$ (fb)
240	252.0	228.6	231.5	231.5
250	252.0	227.9	230.8	230.8
300	190.0	170.7	172.9	172.9
350	135.6	122.5	124.2	124.0
500	60.12	54.03	54.42	54.81

TABLE II. Total cross sections at various collider energies in the $\alpha(m_Z)$ scheme.

Future: one of CEPC/FCC-ee/ILC/CLIC…

NLO EW correction about 10%

What about NNLO EW?

More than 1% correction for mixed EW-QCD

Feynman diagrams @ NNLO EW

- Feynman Gauge: 25377 two-loop diagrams.
- All two-loop diagrams can be classified into 179 categories.
- Some of the two-loop diagrams involves multiple scales.
- Challenges: amplitude reduction, reduction to master integrals, evaluation of master integrals, efficiency of the numerical calculations.
- Very likely it would be a mission of international collaboration.