PHOKHARA

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II Workshop on Muon Precision Physics 2023

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PHOKHARA MC generator

EVA: $e^+e^- \to \pi^+\pi^-\gamma$

- tagged photon ($\theta_\gamma > \theta_{cut}$)
- ISR at LO + Structure Function
- FSR: point-like pions

  [Binner et al.]

$e^+e^- \to 4\pi + \gamma$

- ISR at LO + Structure Function

  [Czyż, Kühn,2000]

F. Campanario, H.C., J. Gluza,

A. Grzelińska, M. Gunia, P. Kisza,

J. H. Kühn, E. Nowak-Kubat, T. Riemann,

G. Rodrigo, Sz. Tracz, A. Wapienik,

V. Yundin, D. Zhuridov

PHOKHARA 10.0: $\pi^+\pi^-, \mu^+\mu^-,$ $4\pi, \bar{N}N, 3\pi, KK, \Lambda\bar{\Lambda}, P\gamma$ $J/\psi, \psi(2S), \chi_{c_1}, \chi_{c_2}$

- **ISR at NLO:** virtual corrections to one photon events and two photon emission at tree level
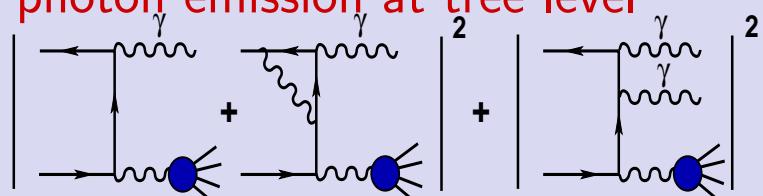
- FSR at NLO: $\pi^+\pi^-, \mu^+\mu^-, K^+K^-, \bar{p}p$
- tagged or untagged photons
- $e^+e^- \to hadrons\ (muons)$ ISR at NNLO
- Modular structure

http://ific.uv.es/~rodrigo/phokhara/

Complete NLO $e^+ e^- \to \mu^+ \mu^- \gamma$
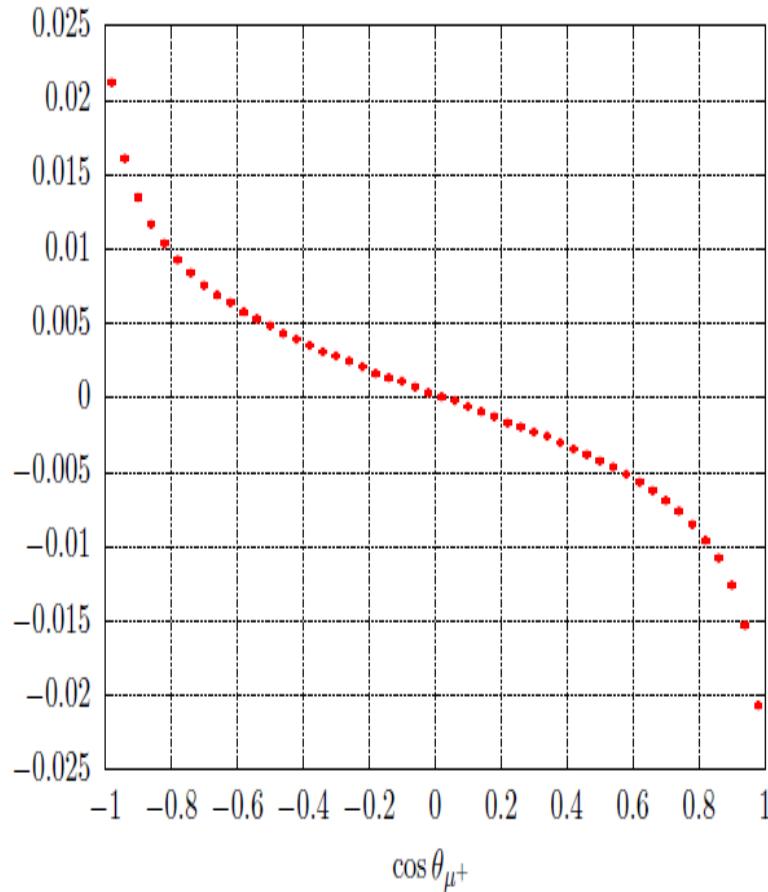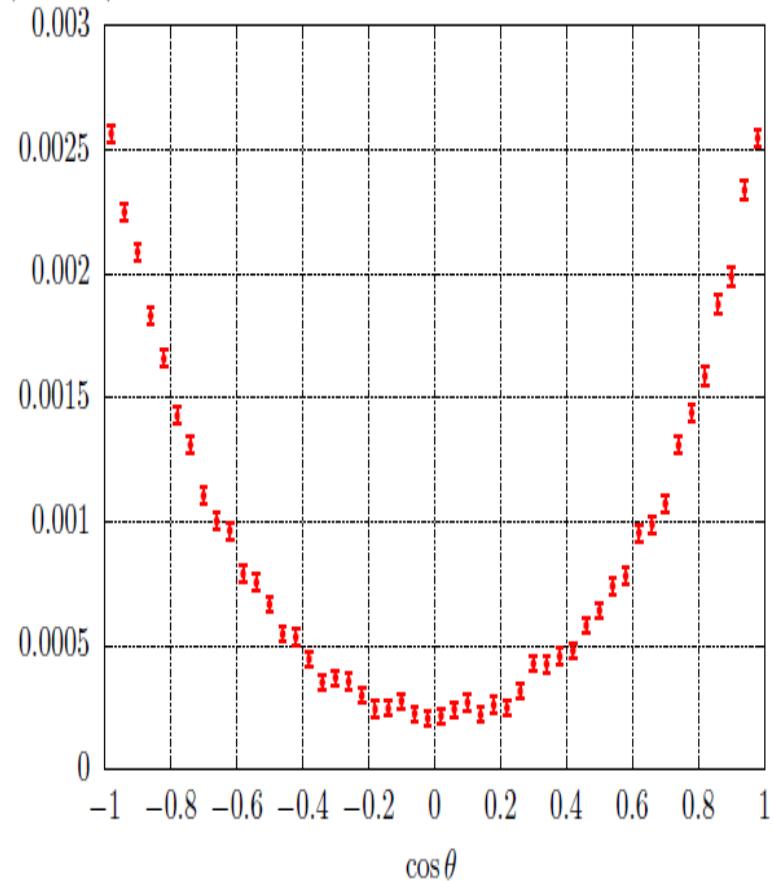
F. Campanario, HC, J. Gluza, M. Gunia, T. Riemann, G. Rodrigo,

V. Yundin JHEP 1402 (2014) 114

NLO $e^+e^- \to \pi^+\pi^-\gamma$

Status - finished

PHYSICAL REVIEW D 100, 076004 (2019)

Francisco Campanario, Henryk Czyż , Janusz Gluza, Tomasz Jeliński, German Rodrigo, Szymon Tracz, and Dmitry Zhuridov

$\Rightarrow$ sQED + form factors:
FSR at NLO and pentaboxes ready and fully tested

$\Rightarrow$ Phokhara10.0
http://ific.uv.es/$\sim$ rodrigo/phokhara/

TVP(PB) for pions
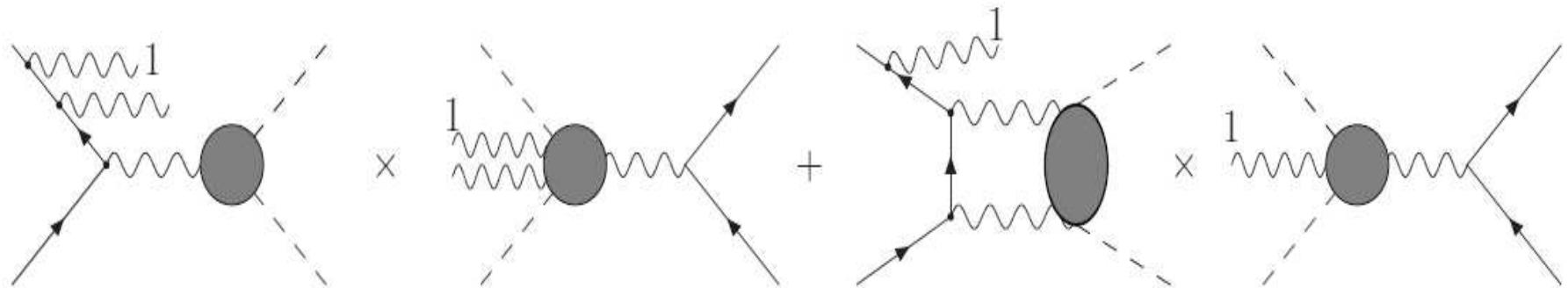
(E)
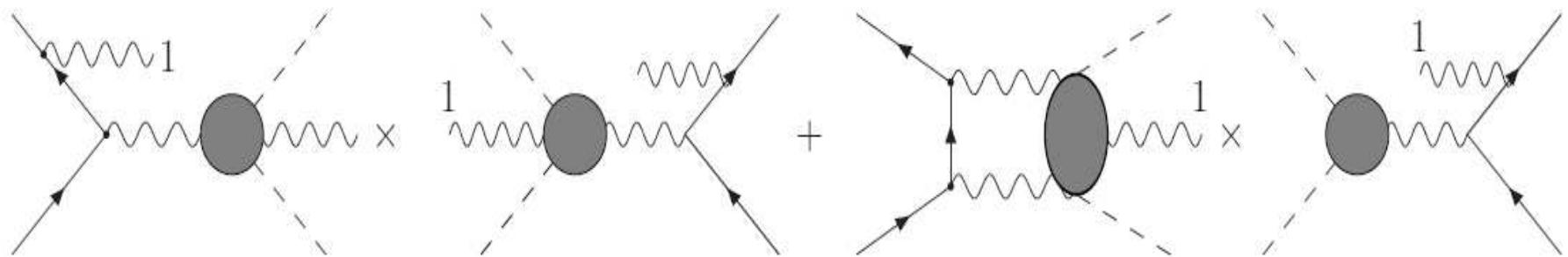
ETC.

FSR for pions
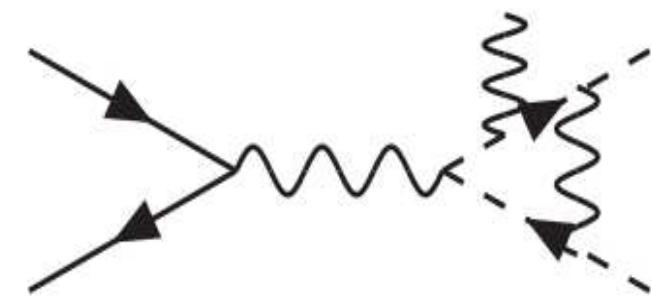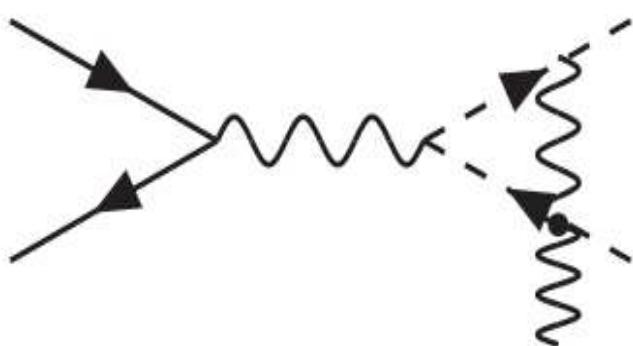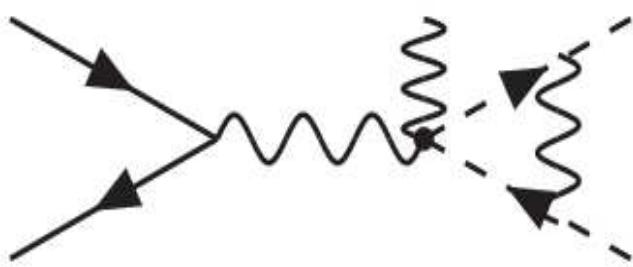
ETC.

Model assumptions
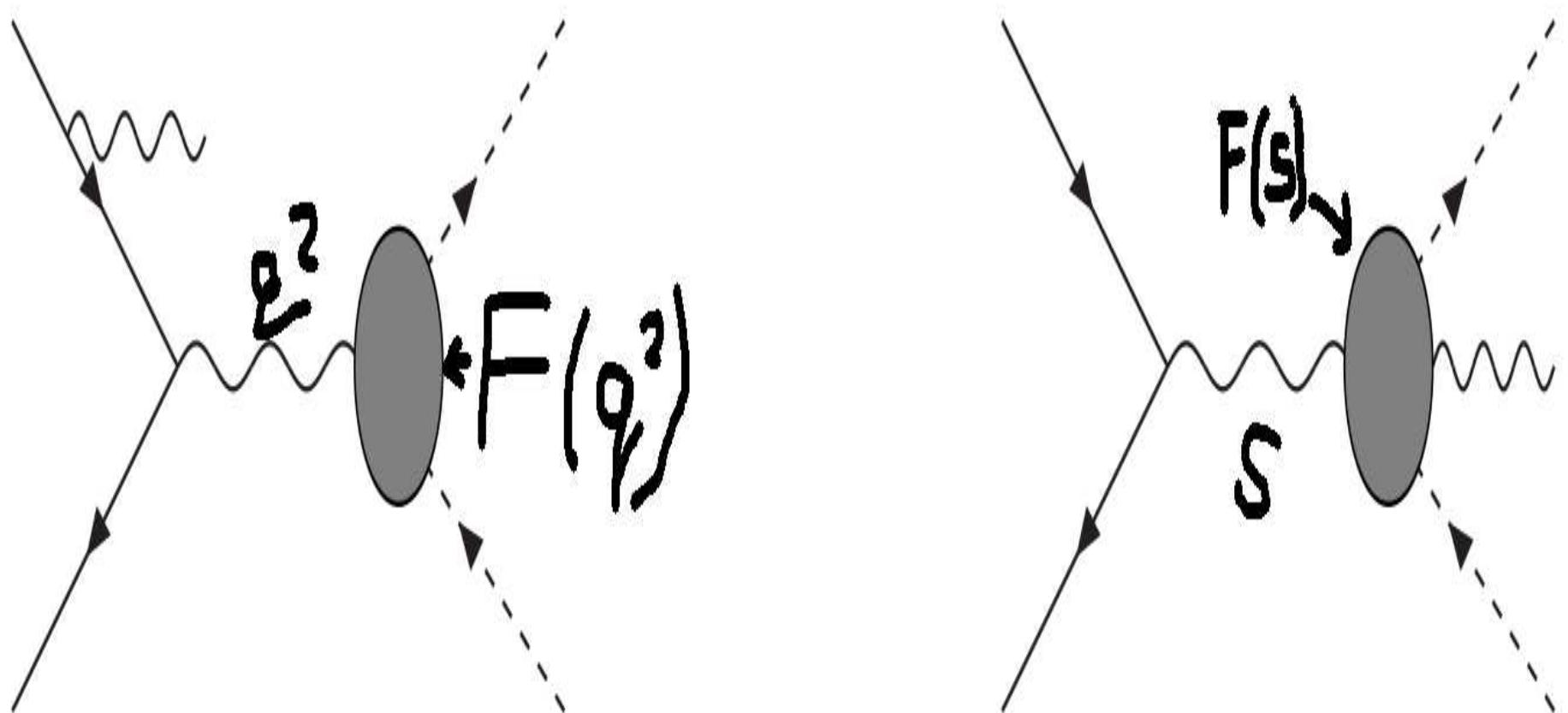
a)

b)

Model assumptions

Model assumptions

$$= F(q^2) \cdot sQED$$

$$= F(s) \cdot sQED$$
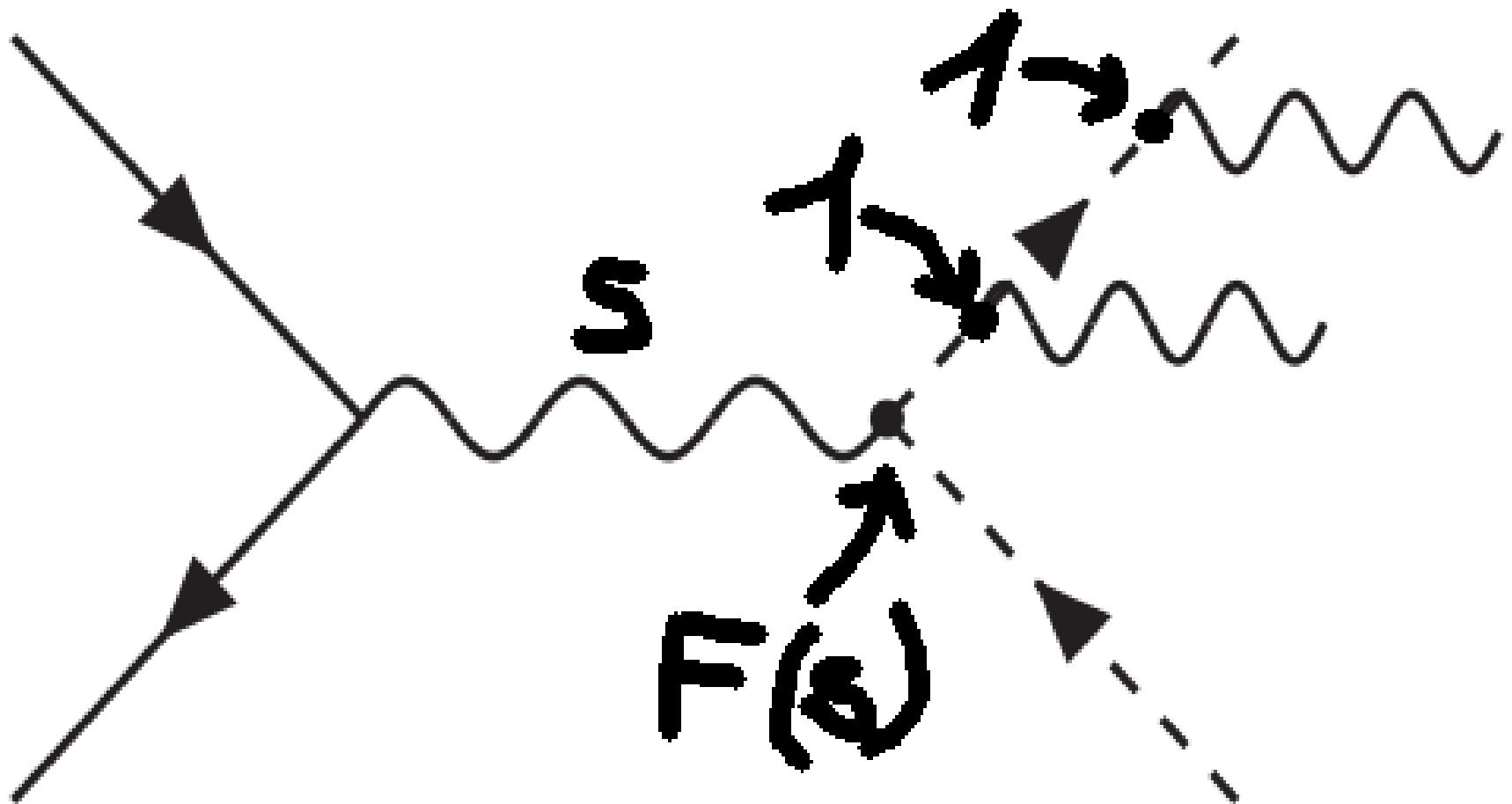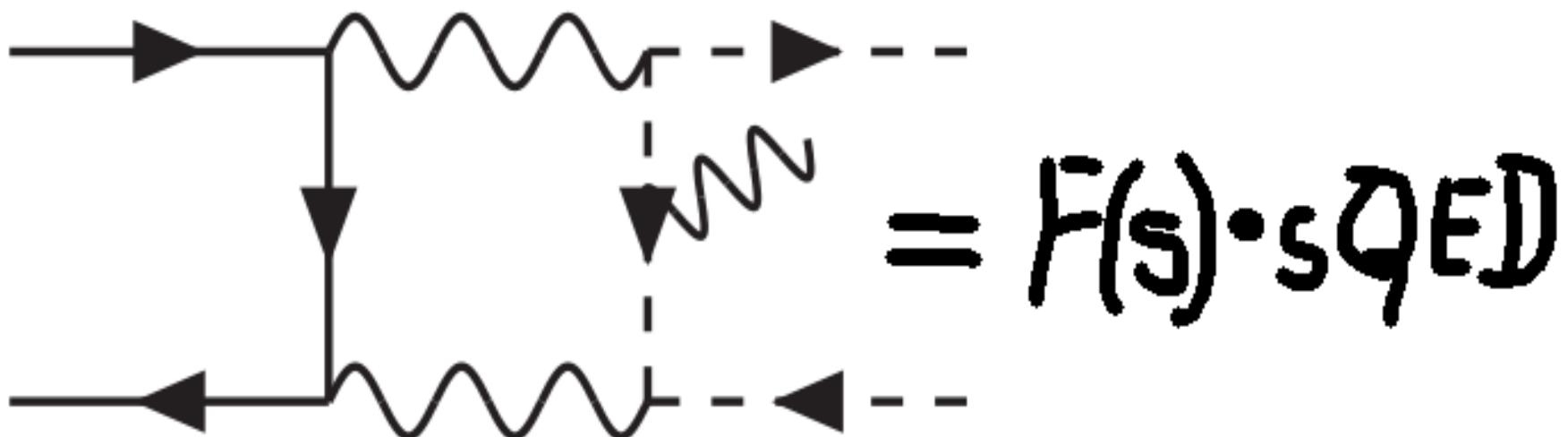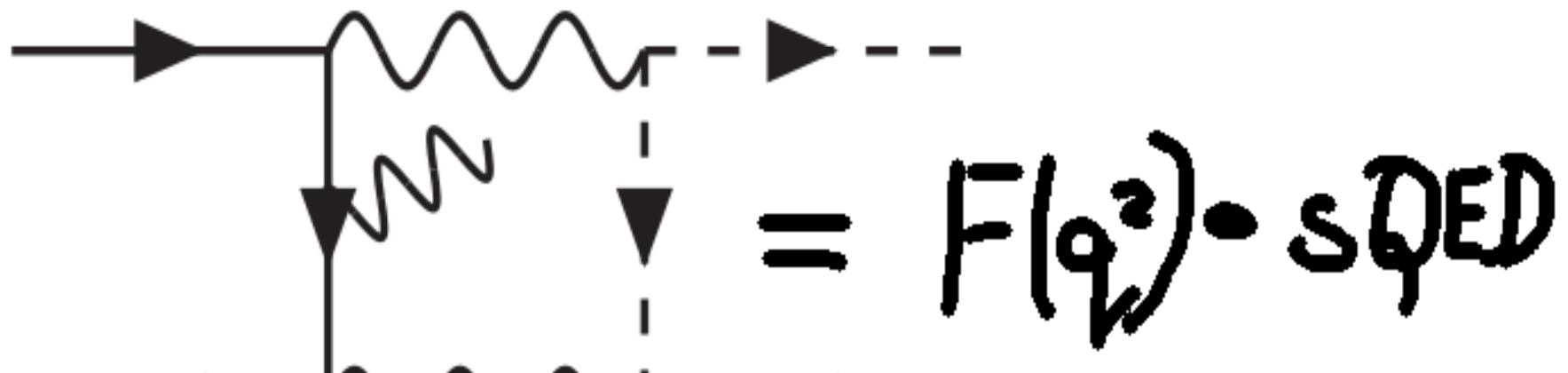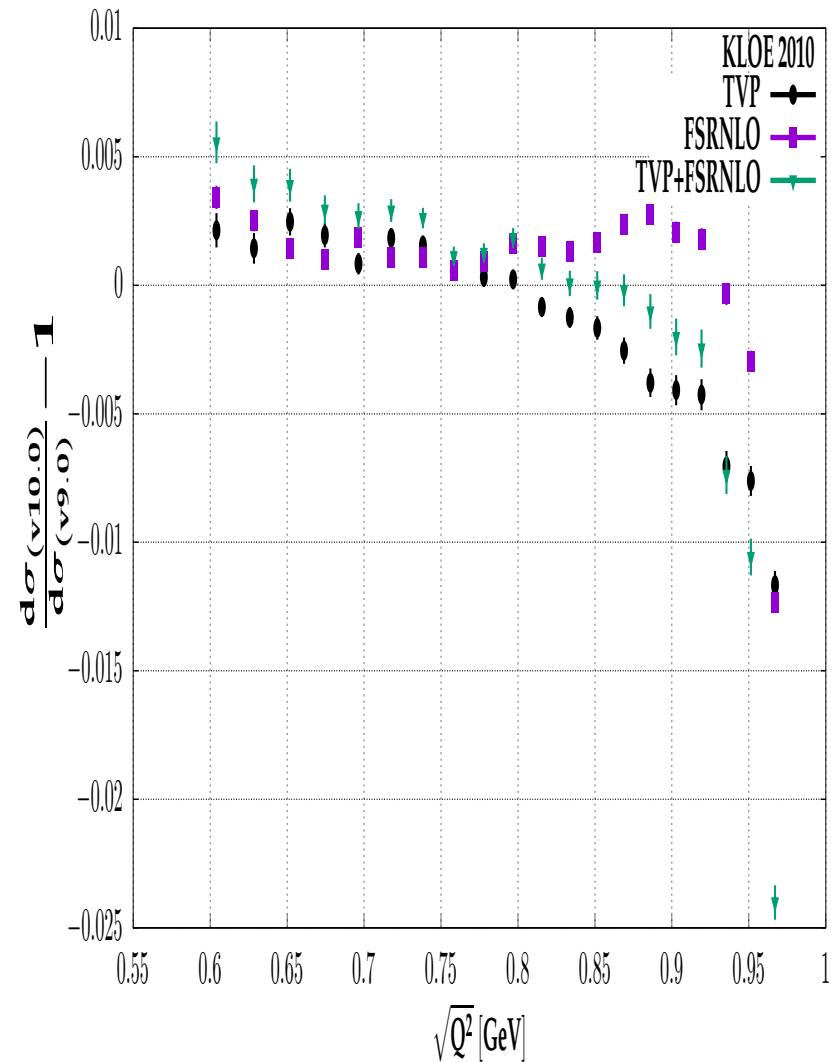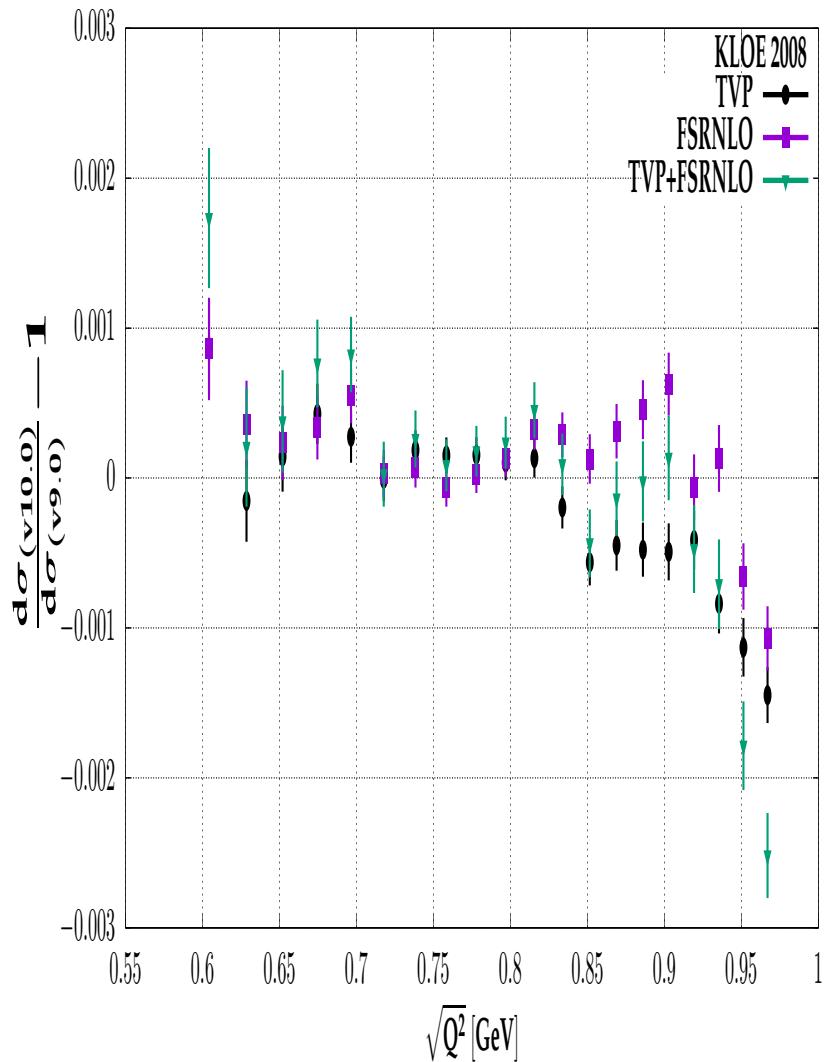
Complete NLO: KLOE

# Complete NLO: BaBar,BES
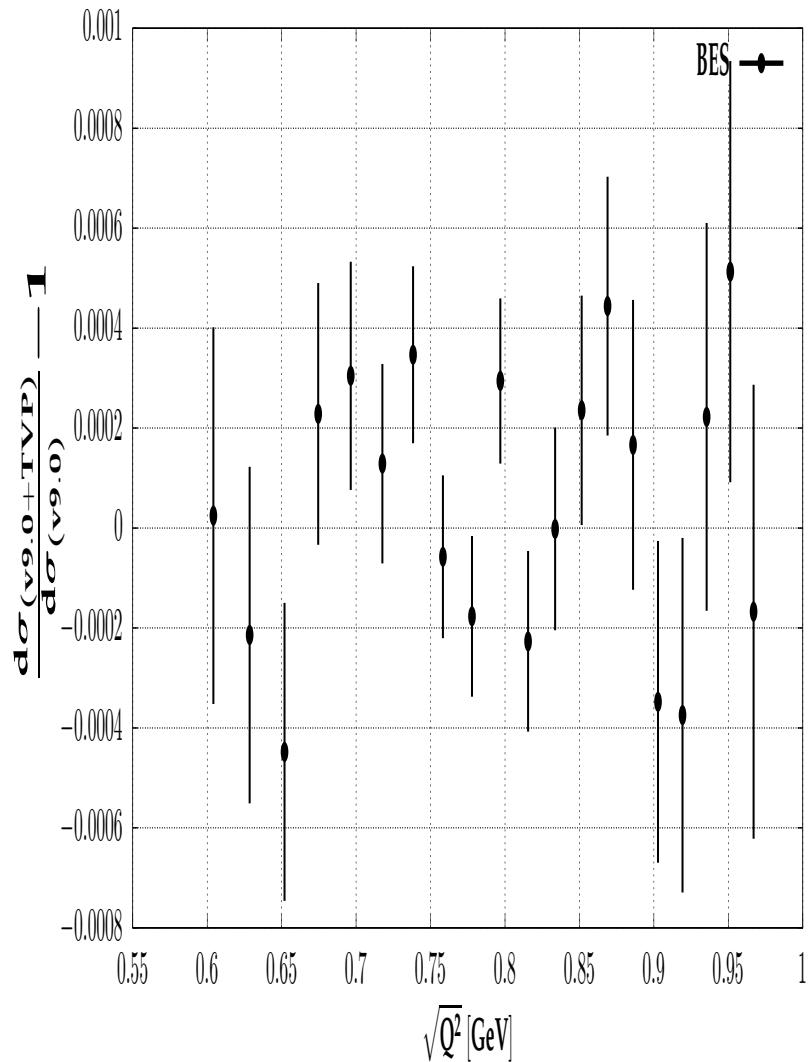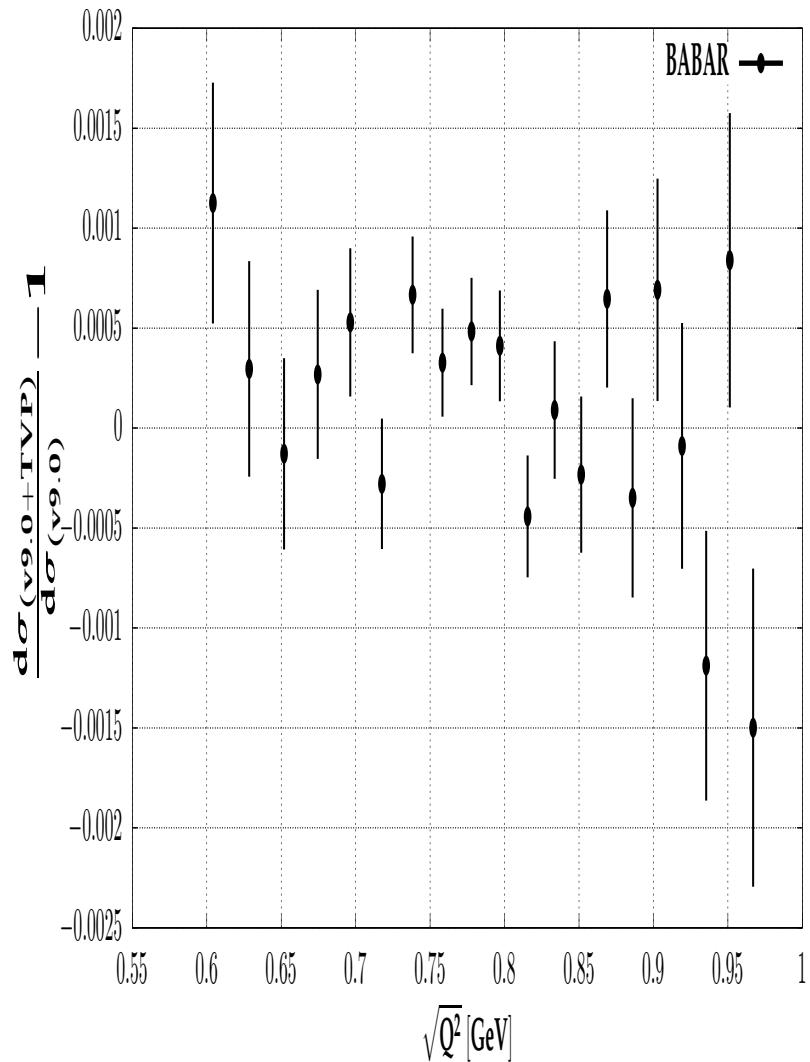
Conclusions

$\Rightarrow$ PRD 100, 076004 (2019) and JHEP 1402 (2014) 114

show that missing NLO radiative corrections

cannot be the source of the discrepancies between

the different extractions of the pion form factor

performed by BaBar, BES and KLOE

Few remarks on BaBar arXiv:2308.05233

$\Rightarrow$ The event selections used the that preprint require
to have at least 2 hard photons in the final state

$\Rightarrow$ The matrix elements in Phokhara for
$e^+e^- \to \pi^+\pi^-\gamma\gamma$ and $e^+e^- \to \mu^+\mu^-\gamma\gamma$
are calculated at LO , so no surprise the accuracy is not high

$\Rightarrow$ Does it affect the pion FF measurement???
1: Babar claims they are not affected
2: Right now BES and KLOE can address that question only
by comparing Phokhara with KKMC for their event selections

S.Jadach: KKMC

PHOKHARA **included in the game, μ-pairs again**
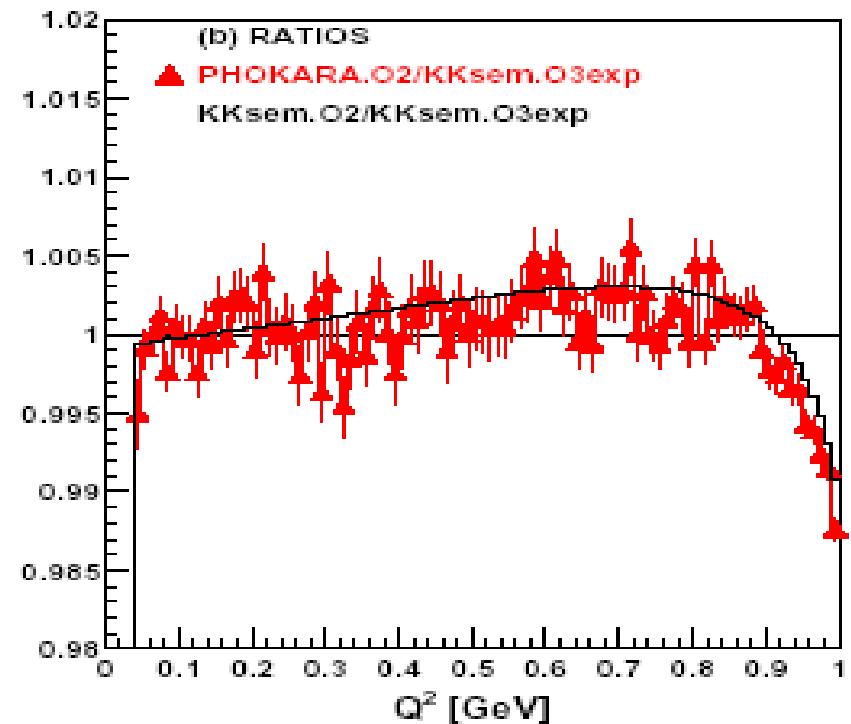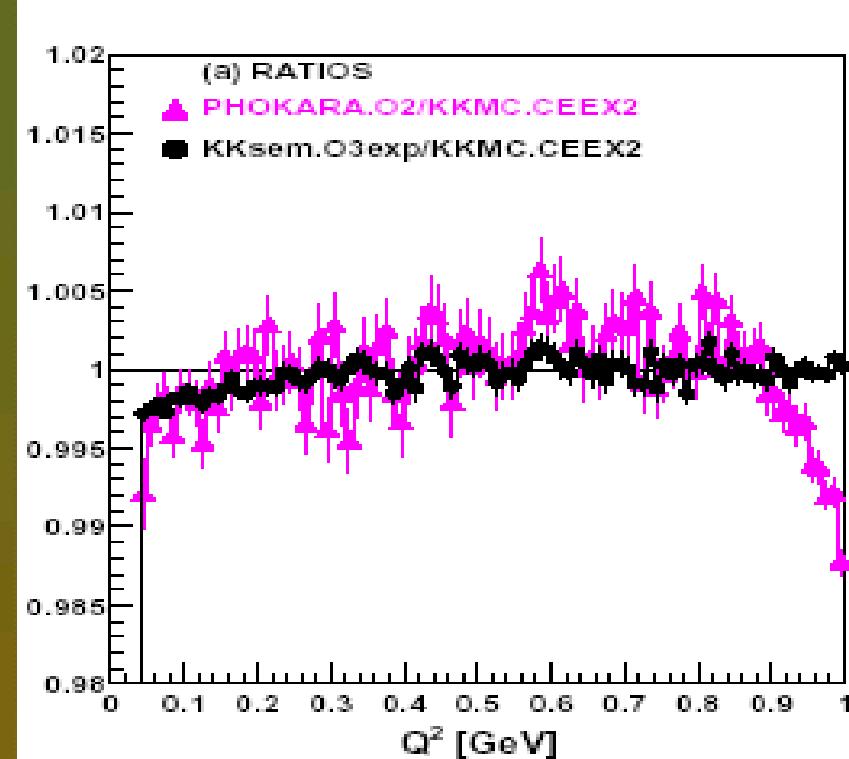
PHOKHARA agrees to within 0.3% with KKMC and KKsem.

Discrepancy at high Q^2 reflects lack of exponentiation in PHOKHARA

Acta Phys.Polon.B 36 (2005) 2387

Outlook

$\Rightarrow$ Whatever the outcome of the KKMC - Phokhara comparison is, the direct calculation of the NNLO corrections (at least ISR) is necessary

$\Rightarrow$ Let's hope that the young generation of physicist will do it and in addition sort out the mess of $g - 2$ discrepancies we observe right now