UNIVERSITY OF LIVERPOOL

LEVERHULME TRUST

Soft Photon Exponentiation

and its implementation in Phokhara

KLOE meeting

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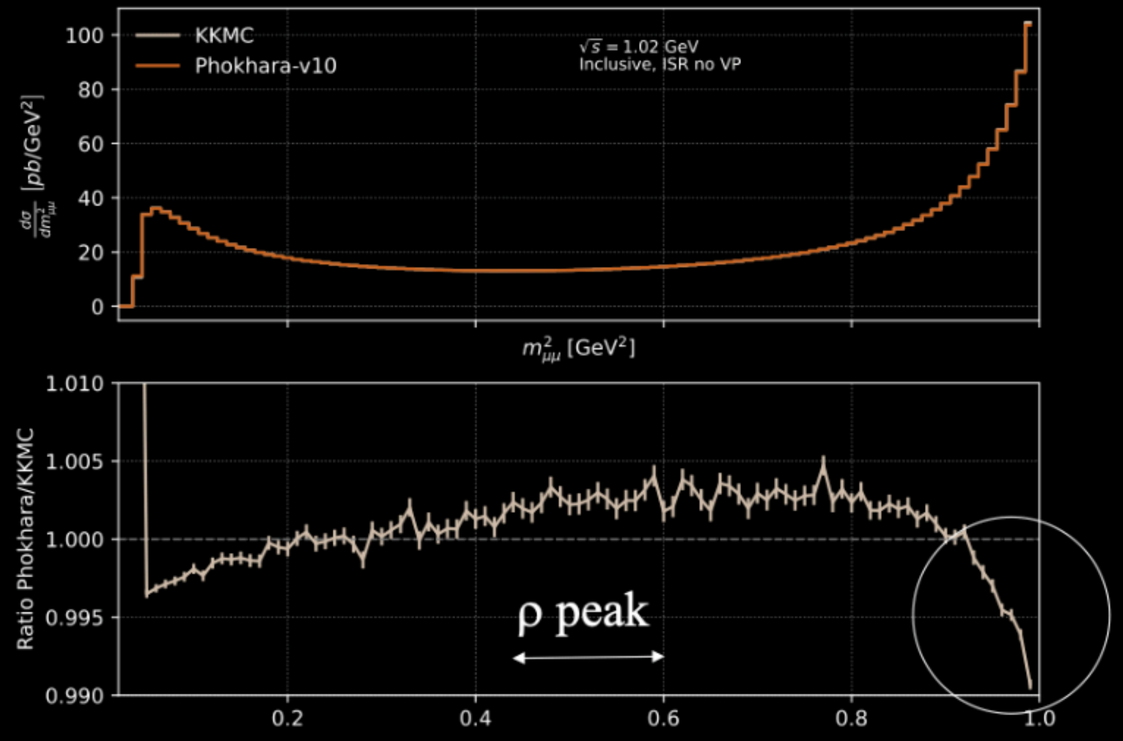
Liverpool, 31/01/2025

Motivation

- Studied the importance of higher-order effects (see Graziano's talk at TI)
- In order to gain further accuracy in Phokhara, need to add NNLO ingredients and beyond (in our case resummation of soft photon effects)
- Given the difficulty of high multiplicity loop calculations, approximations are the only way to get insight on higher-order effects (beyond accessible loop orders)



invariant muon mass spectrum at KLOE com energy

Generators status

Soft photon resummation:

- Sherpa (installed on the physics server)
- KKMC

Other type of resummation:

- BabaYaga (PS)

code		$ee \to \mu\mu$
AfkQed	$+\gamma$	LO+CS
BabaYaga@NLO	$+\gamma$	NLO+PS LO+PS
KKMC	$+\gamma$	CEEX CEEX
MCGPJ	$+\gamma$	NLO+CS LO+CS
McMule	$+\gamma$	NNLO NLO
Phokhara	$+\gamma$	NLO
Sherpa	$+\gamma$	NLO+YFS NLO

Soft photon resummation

- KKMC and Sherpa will act as benchmarks for the validation of the resummation implementation in Fortran
- Theoretical challenges:
    - Revisiting of resummation procedure (photon mass —> dim reg)
    - Calculation of loops that are neglected in CEEX
    - Matching procedure: cross section O(NNLO+CEEX)
- Technical challenges:
    - Implementation in Fortran (p-s, amplitudes, convergence)

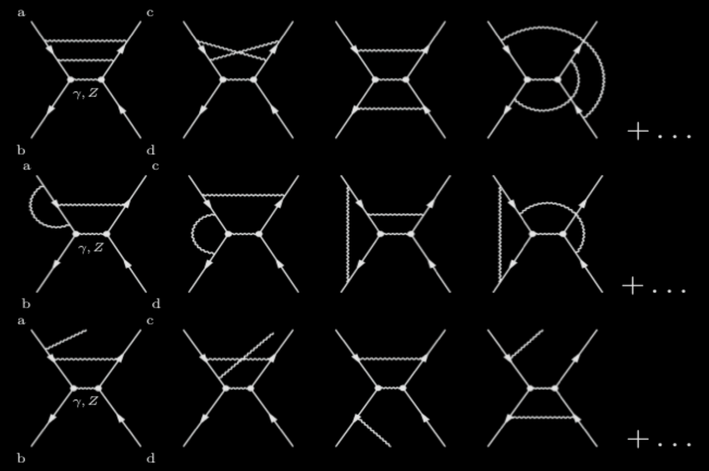


Figure 5: Missing second order diagrams.

YFS exponentiation

[Yennie, Frauschi, Suura Annals Phys. 13 (1961) 379-452]

- Insight on the structure of IR divergences in QED at all-order

  Separation of divergences at the cross-section level in an exponential factor

- No collinear singularities

  Dependence on all fermion/hadron masses must be taken into account

- All divergences are associated with emission off external legs

YFS exponentiation

Master Formula

$$d\sigma = \sum_{n_\gamma=0}^{\infty} \frac{e^{2\alpha(B+\tilde{B}(\Omega))}}{n_\gamma!} d\Phi_Q \left[\prod_{i=1}^{n_\gamma} d\Phi_i^\gamma \tilde{S}(k_i)\Theta(k_i,\Omega) \right] \left(\tilde{\beta}_0 + \sum_{j=1}^{n_\gamma} \frac{\beta_1(k_j)}{\tilde{S}(k_j)} + \cdots \right)$$

Implemented in Sherpa [2203.10948] and KKMC [0006359]

YFS Resummation for Future Lepton-Lepton Colliders in SHERPA

F. Krauss[a], A. Price[b], and M. Schönherr[a]

Coherent Exclusive Exponentiation For Precision Monte Carlo Calculations†

S. Jadach[a,b], B.F.L. Ward[a,c] *and* Z. Wąs[b,d]

YFS exponentiation: ongoing work

Progress

Core Fortran implementation of Born Matrix element plus Phase-Space integration

Analysis of the event generation through differential cross-sections

YFS form factors (theory + implementation)

Beta factors: regulated amplitudes

Soft multi-photon phase-space

Tests against KKMC