KKMC and YFS Resummation

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The Evaluation of the Leading Hadronic Contribution to the Muon g-2: Consolidation of the MUonE Experiment and Recent Developments in Low Energy e^+e^- Data.

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Overview - the KKMC code

- Deals with $e^+e^- \to \mu^+\mu^-, \tau^+\tau-, \nu^+\nu^-, q\bar{q}$ processes [2204.11949][1].
- Includes Coherent Exclusive Exponentiation (CEEX) [0006359][2], twist on YFS resummation [YFS][3].
- Event Generator and Integrator which produces differential cross-sections.
- First written in `F77` [9912214][2], now rewritten in `C++`.

[1] S. Jadach, B.F.L. Ward, Z. Wąs, S.A. Yost, A. Siodmok
[2] S. Jadach, B.F.L. Ward, Z. Wąs
[3] D.R Yennie, S.C Frautschi, H Suura

Resummation of soft photons

- Fixed order computations are notoriously hard.
- Resummation: probing higher-order effects by approximating the amplitude at all-orders.
- Key idea behind KKMC: formalism developped in [YFS][1].

The Infrared Divergence Phenomena and High-Energy Processes*

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Resummation of soft photons

- Soft real and virtual photons produce divergences in the matrix element, beyond Born level.
- They can be turned into a multiplicative factor at all orders in perturbation theory.
- Infrared safe remnants are obtained through recurrence relations.

Resummation of soft photons

$$\sigma = \sum_{n_\gamma=0}^{\infty} \int (dPS)_Q \exp\left(2\alpha B + 2\alpha \tilde{B}\right) \left[\prod_{j=1}^{n_\gamma} (dPS)_j \tilde{S}(k_j)\theta(\Omega, k_j)\right] \tilde{\beta} \quad (1)$$

In this setup:

- the infrared divergences is contained in the YFS form factor $Y = \exp\left(2\alpha B + 2\alpha \tilde{B}\right)$.
- the presence of the $\theta(\Omega, k_j)$ factor excludes the soft phase space of the real photon j.
- $\tilde{\beta}$ corresponds to the IR finite matrix elements which are built upon Feynman diagrams.

KKMC for Strong 2020

- For each scenario, can produce $e^+e^- \to \mu^+\mu^-$ predictions.
- Analysis of the output is made in `Python` after event generation.
- Added cuts for each scenario to boost event generation: requisite for stats needed.
- Also simplified output file to minimise the storage needed.

Scenario	B	BES3	CMD	KLOE-I	KLOE-II
$\frac{\#\text{ev passing cuts}}{\#\text{ev generated}}$	3.1%	32%	54%	1.1%	5.5%

Figure: Efficiency of cut implementation by scenario

- For each scenario and setup: ran 20 million of events.
- Few hours for generation per scenario, $\leq$ 1h for analysis.

One example of scenarios - CMD

Process: $e^+e^- \to \mu^+\mu^-$ at $\sqrt{s} = 0.7$ GeV.
Cuts are defined as:

- $1 \text{ rad} \leq \theta_{\text{av}} = (\theta^- - \theta^+ + \pi)/2 \leq \pi - 1 \text{ rad}$
- $p_\pm > 0.45\sqrt{s}/2$
- $\delta\phi = ||\phi^+ - \phi^-| - \pi| < 0.15 \text{ rad}$
- $\xi = |\theta^+ + \theta^- - \pi| < 0.25 \text{ rad}$

CMD Scenario

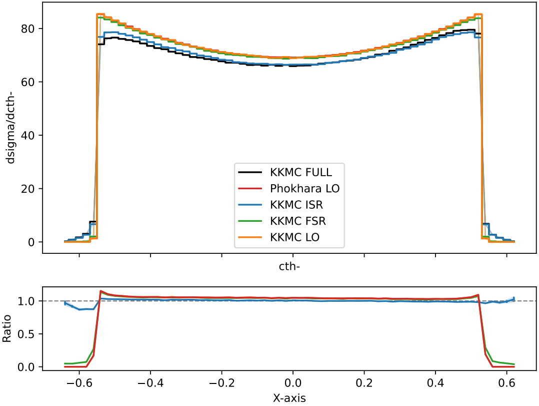

Figure: Differential cross-section $d\sigma/d\cos\theta^-$

CMD Scenario

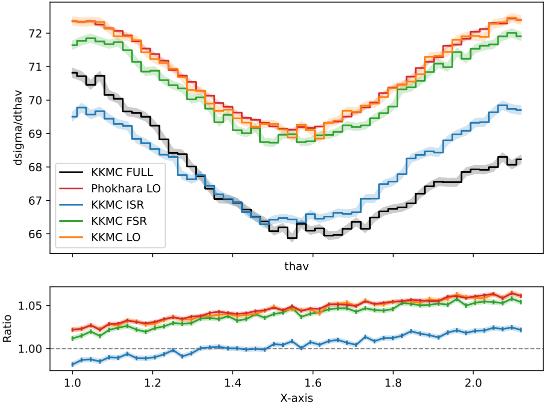

Figure: Differential cross-section $d\sigma/d\theta_{\text{av}}$

Summary and outlook

- Main modifications of KKMC: cuts at generation level and less storage needed.
- Finish runs with high statistics for LO, ISR, FSR and both for all scenarios.
- Write up of the KKMC section in the Strong 2020 report.