

Towards NNLO Phokhara

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Mainz Workshop - 06/06/2024

MITP
TOPICAL
WORKSHOP

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

June 3 – 7, 2024

<https://indico.mitp.and-mainz.de/event/352>

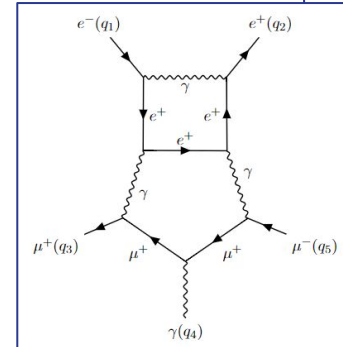
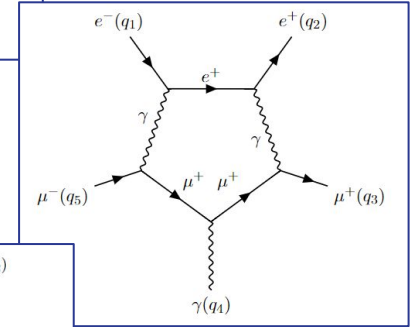
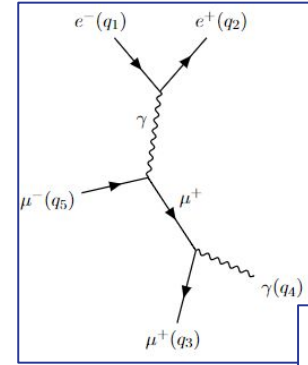
μ ONE

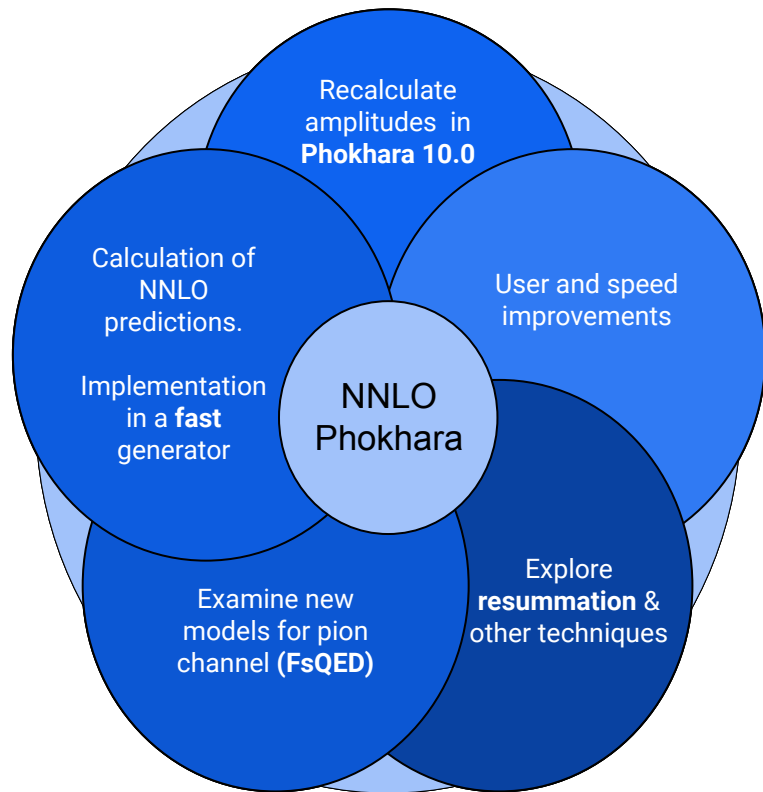
PART III

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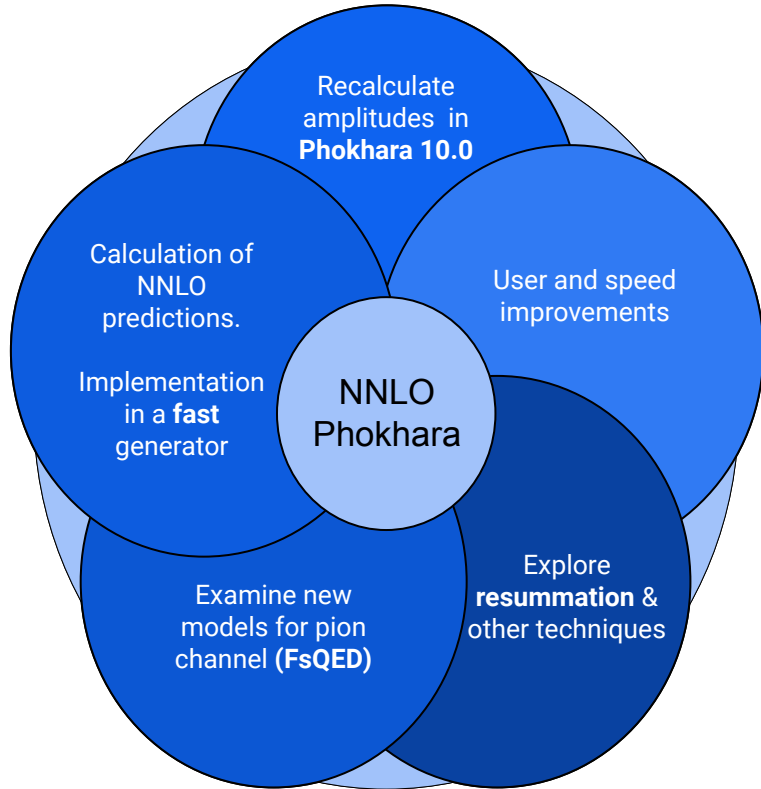
Phokhara 10.0

- Final version released in 2019
- Support of $e^+e^- \rightarrow \mu^+\mu^- / \pi^+\pi^- + \gamma$ at NLO
- Other processes like $e^+e^- \rightarrow \pi^+\pi^-\pi^0 / K^+K^- / \eta\pi^+\pi^-$
- Rely on PJFry tensor reduction package and QCDLoop/FF or OneLoop to evaluate integrals





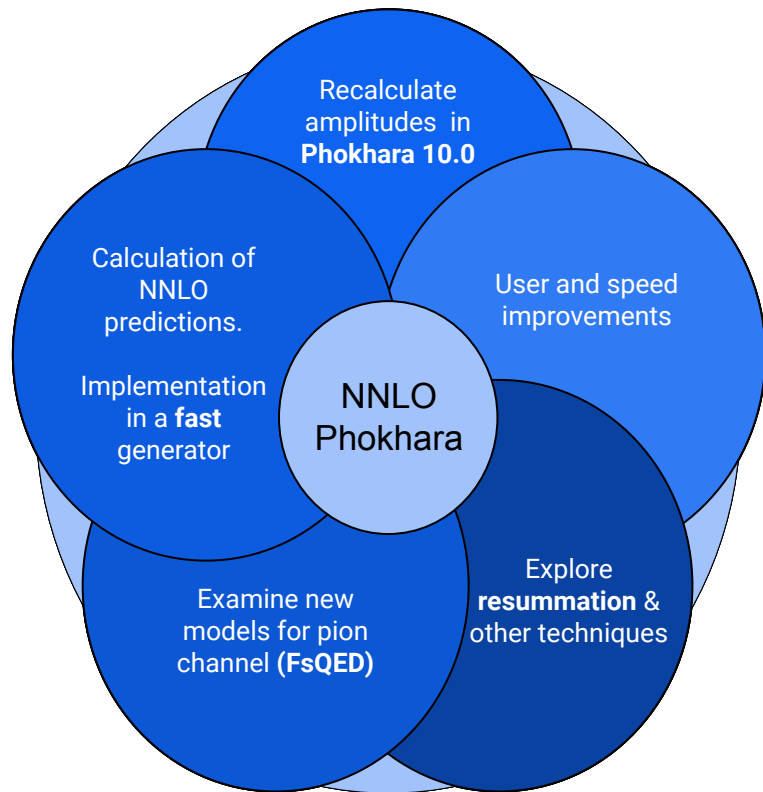
Components of NNLO Phokhara



NNLO Theoretical Predictions

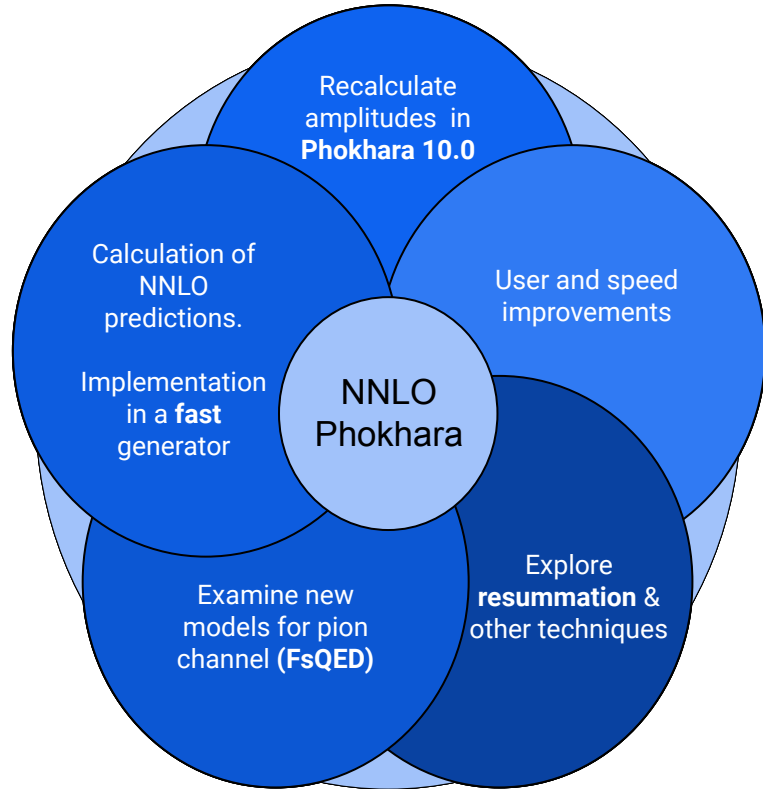
- $|\text{Tree } 3\gamma|^* |\text{Tree } 3\gamma|$
- $|\text{1Loop } \gamma|^* |\text{1Loop } \gamma|$
- $|\text{Tree } \gamma|^* |\text{2Loop } \gamma|$
- $|\text{Tree } 2\gamma|^* |\text{1Loop } 2\gamma|$

This implies the need of higher orders of ϵ in the integrals



FsQED and resummation

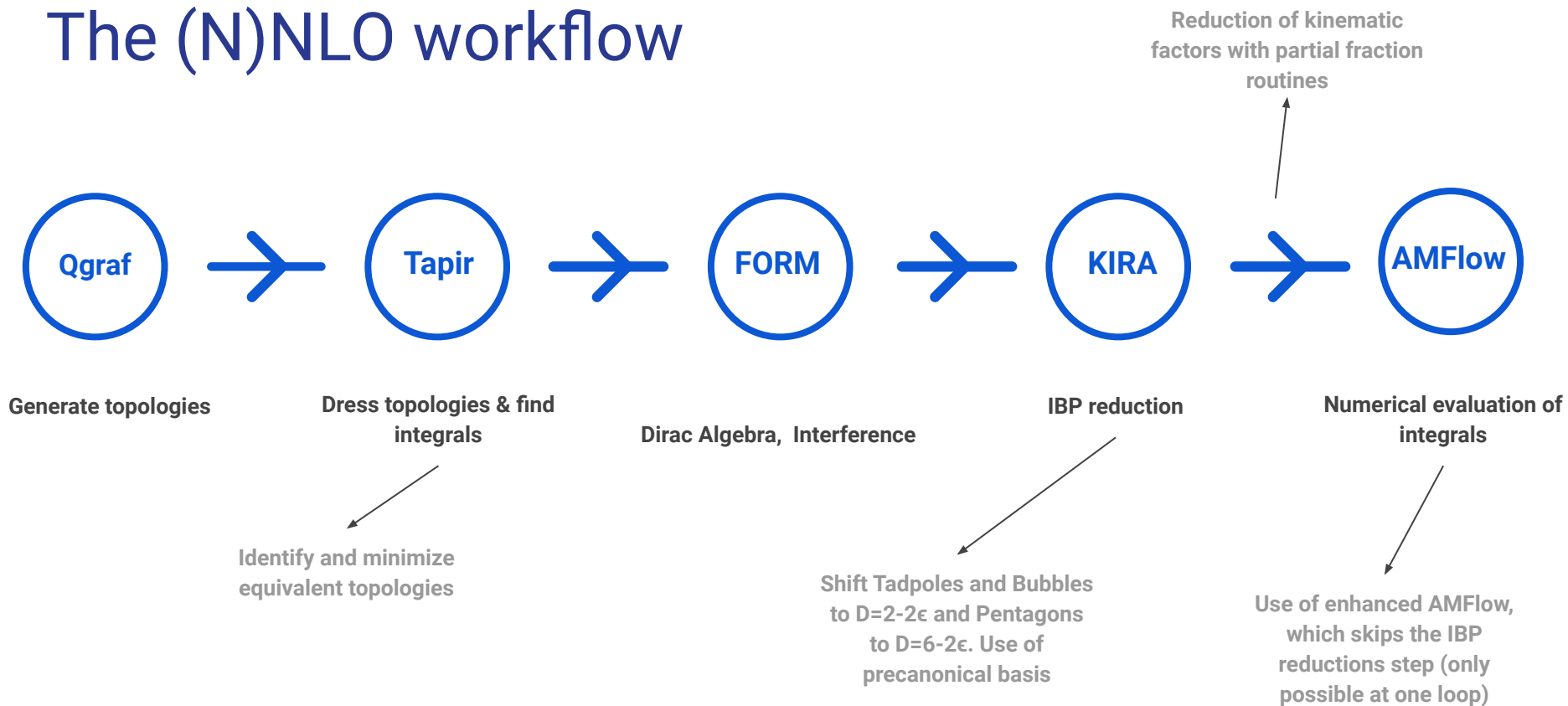
- Possible combination of fixed order and YFS resummation
- Explore FsQED with the extra photon required for $\pi^+\pi^- + \gamma$

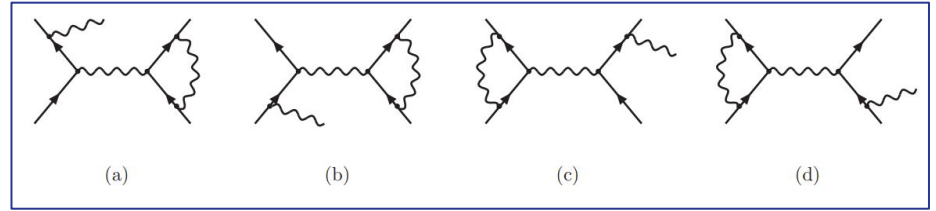
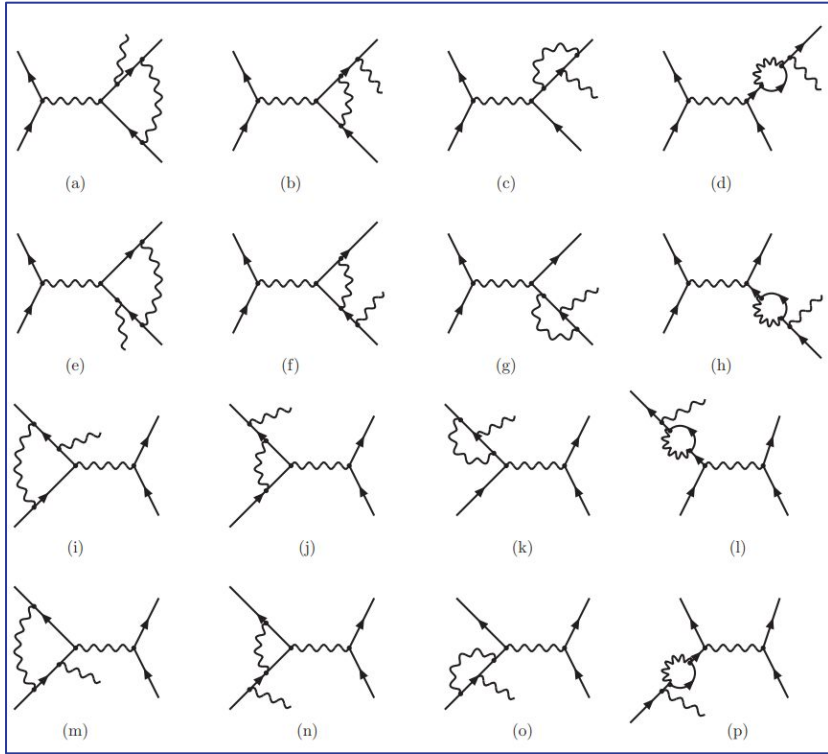


User and speed improvements

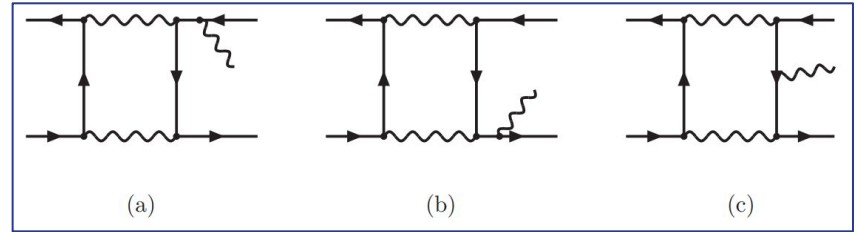
- Custom cuts at the generation level
- Histogram generation with user-defined variables
- New Pion FF and small but numerous speed updates

The (N)NLO workflow

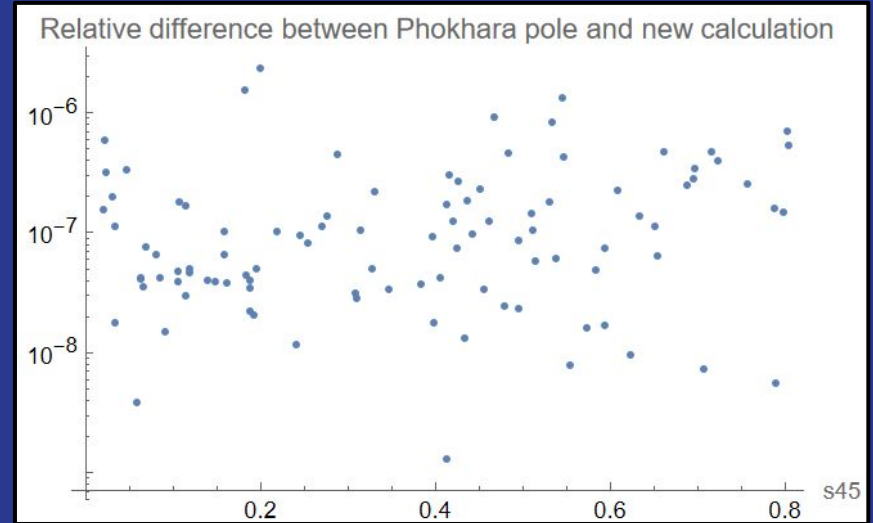




Gauge Invariant Groups



Currently...



Analytical solution

$$d\vec{J} = \epsilon \sum_{i=1}^n A_i d\log(\alpha_i) \vec{J}$$

- 21 Master Integrals
- 9 letters with square roots
- Can we find a good basis?
- Can we do the same for the whole NLO amplitude?

Summary

- First minor improvements in the Phokhara generator, many more under development
- First successful calculations of NLO amplitudes for radiative processes
- Updated workflow based on contributions from the high energy community
- Much more coming!