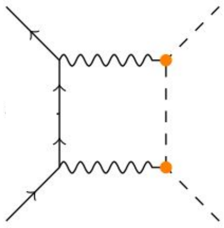
Radiative return meets GVMD

Pau Petit Rosàs

In collaboration with O. Shekhovtsova & W. J. Torres Bobadilla.
Based on **[2603.13171]**

1 Introduction



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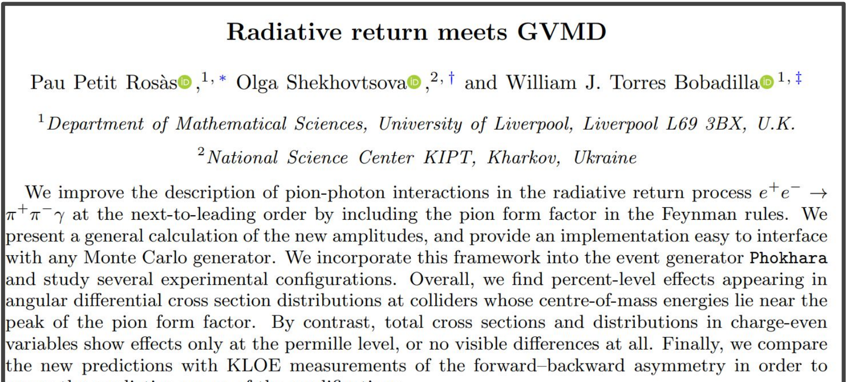

Radiative return meets GVMD

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[1] *Department of Mathematical Sciences, University of Liverpool, Liverpool L69 3BX, U.K.*

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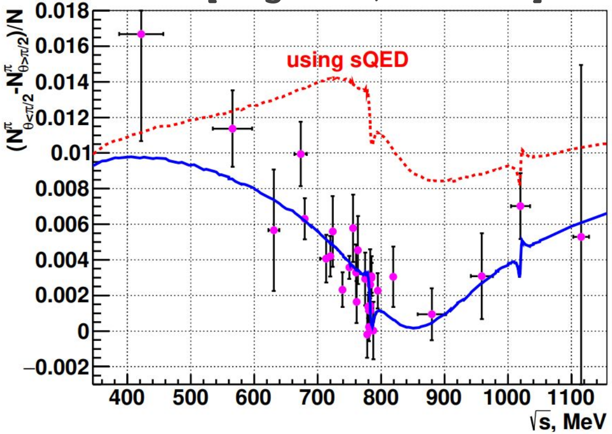
We improve the description of pion-photon interactions in the radiative return process $e^+e^- \to \pi^+\pi^-\gamma$ at the next-to-leading order by including the pion form factor in the Feynman rules. We present a general calculation of the new amplitudes, and provide an implementation easy to interface with any Monte Carlo generator. We incorporate this framework into the event generator Phokhara and study several experimental configurations. Overall, we find percent-level effects appearing in angular differential cross section distributions at colliders whose centre-of-mass energies lie near the peak of the pion form factor. By contrast, total cross sections and distributions in charge-even variables show effects only at the permille level, or no visible differences at all. Finally, we compare the new predictions with KLOE measurements of the forward–backward asymmetry in order to

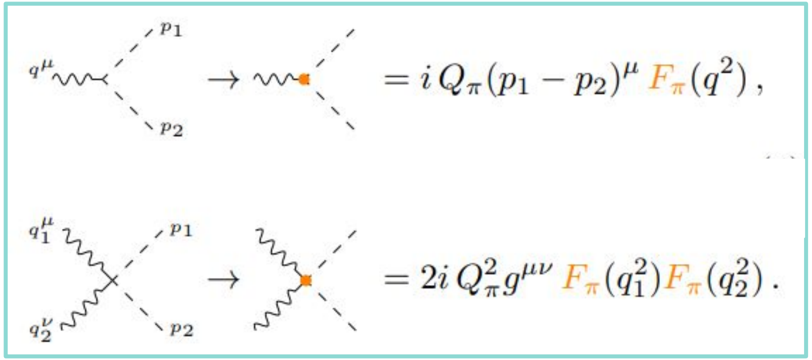
[F. Ignatov, R. N. Lee]



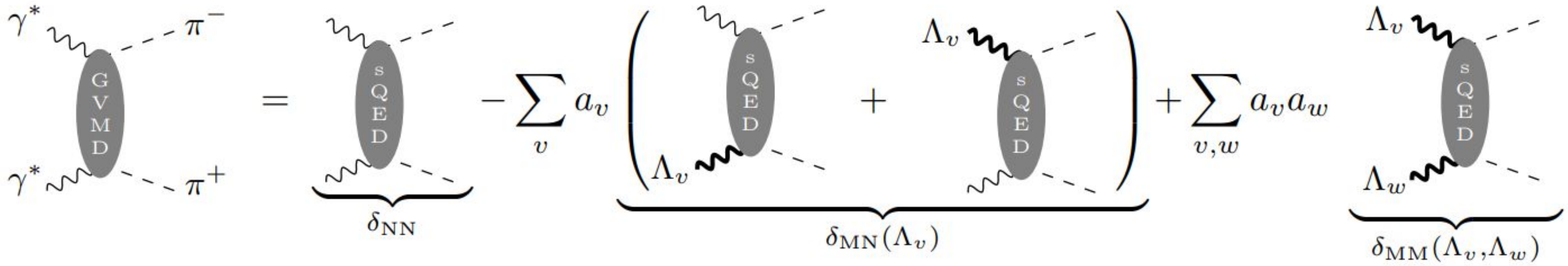
2 Quick recap on GVMD

1. Modify the Feynman rules to include the FF.
2. Fit the FF to a sum of Breit-Wigner functions.

$$F_\pi(q^2) = \sum_v a_v \left(1 + \frac{q^2}{\Lambda_v - q^2}\right)$$



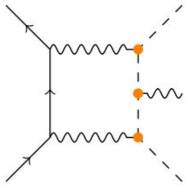
3. Calculate:

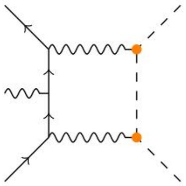


3 Prelude

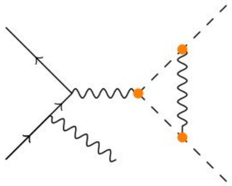
This work.

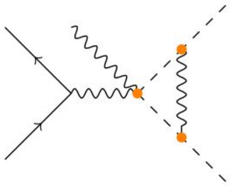
Focus on ISR, extend FSR with meson decays.





Not included. ISR diagram can be done fully dispersively. No model independent calculation of FSR. Small contribution expected.

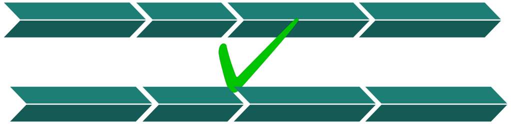




3 Prelude

Amplitude calculation:

qgraf + Form + Tapir + Collier



FeynArts + FeynCalc + AMFlow

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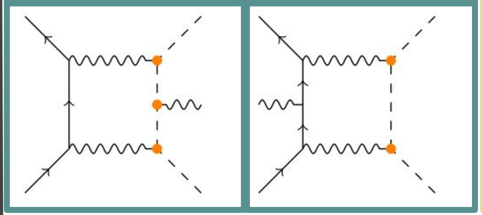

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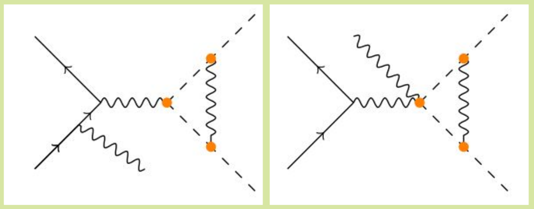

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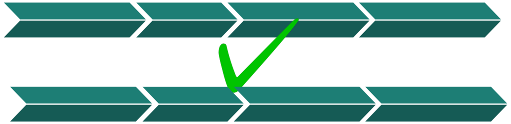

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Amplitude evaluation:

1. Kira + Canonical form + Collier
2. Tensor reduction + PV basis

IBPs greatly reduce # integrals.

Multivariate kinematics make 2 faster.

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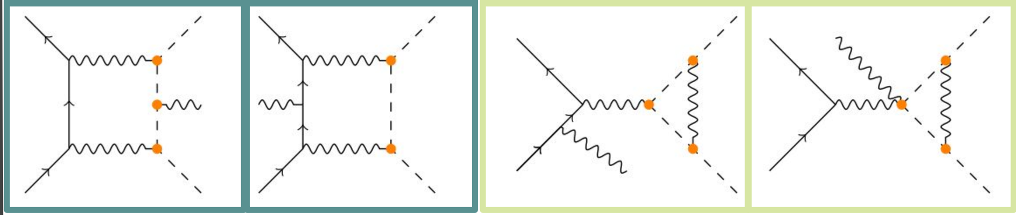

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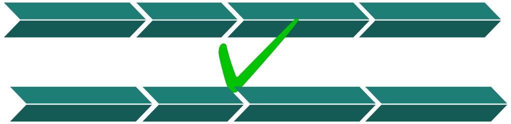

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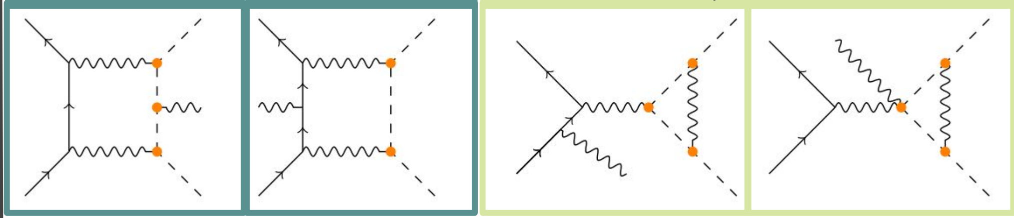
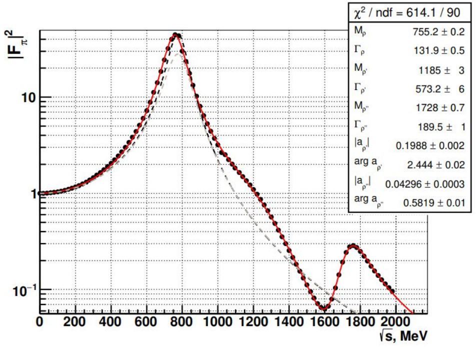
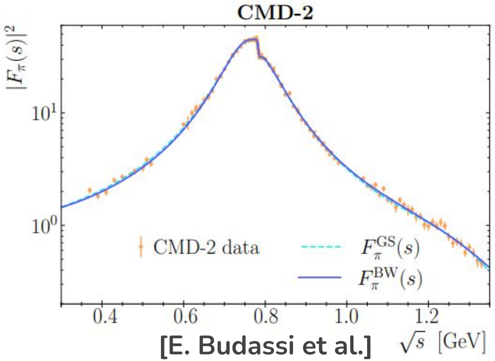


Different VFF parametrization used in the upcoming plots



[F. Ignatov, R. N. Lee]



[E. Budassi et al.]

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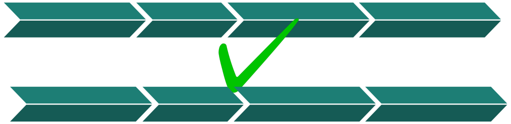

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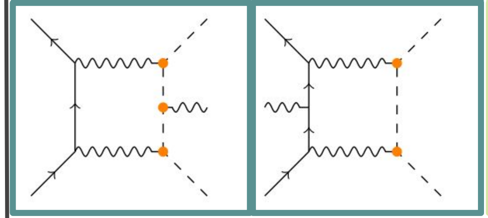

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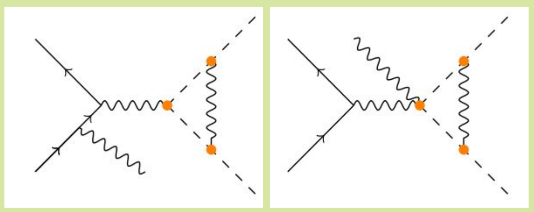

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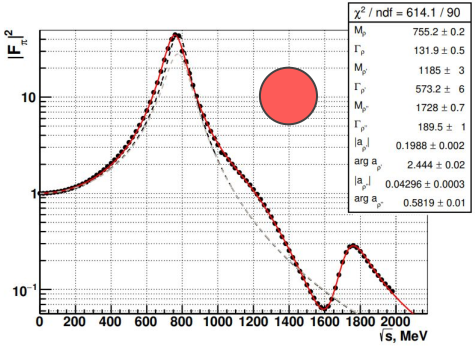

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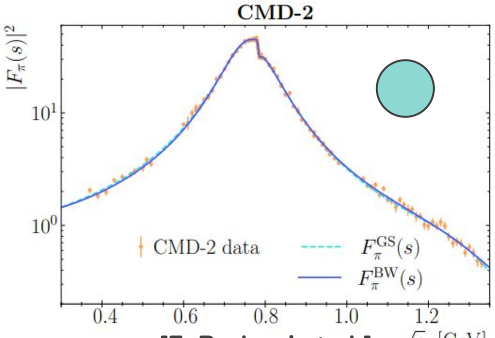

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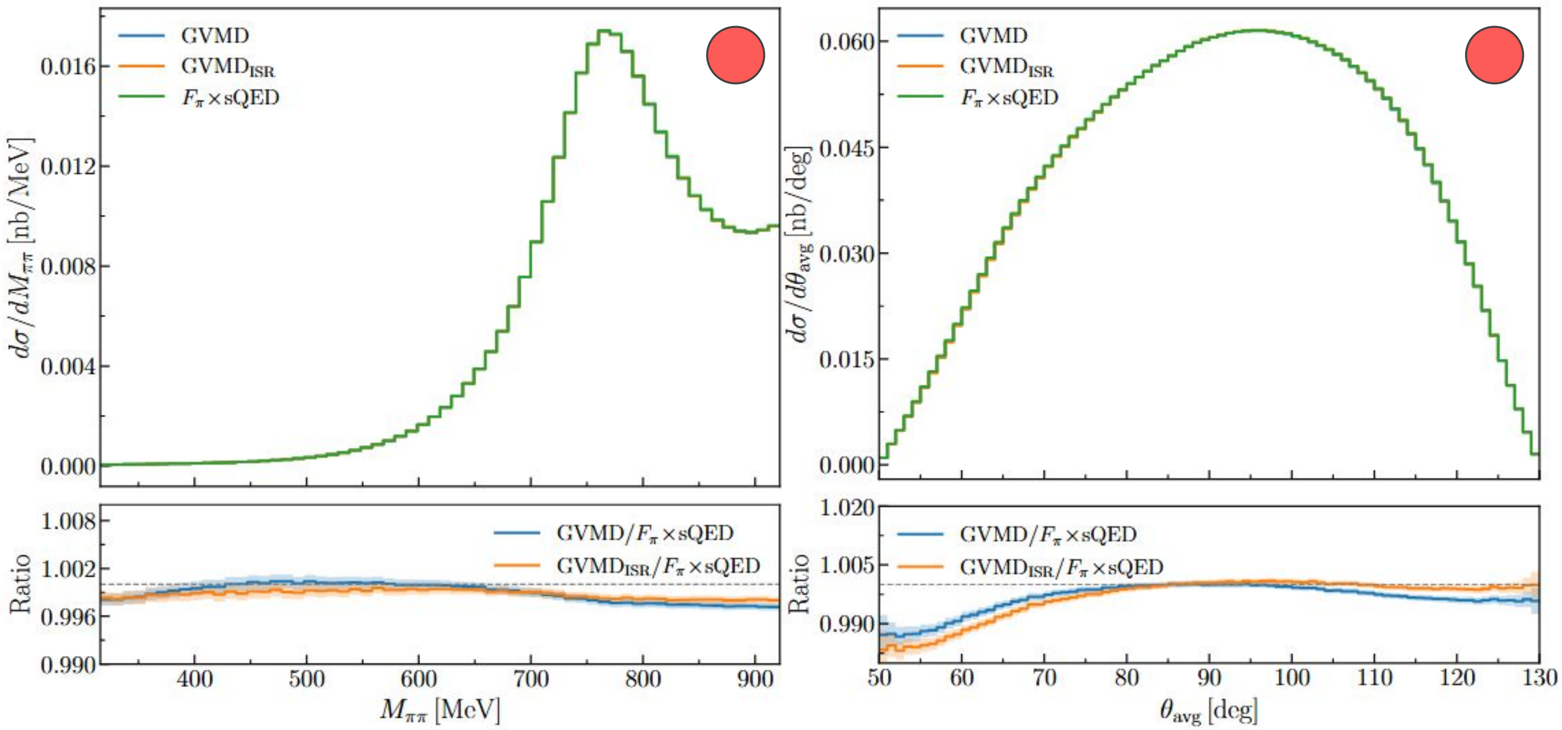
4 Results: Kloe LA



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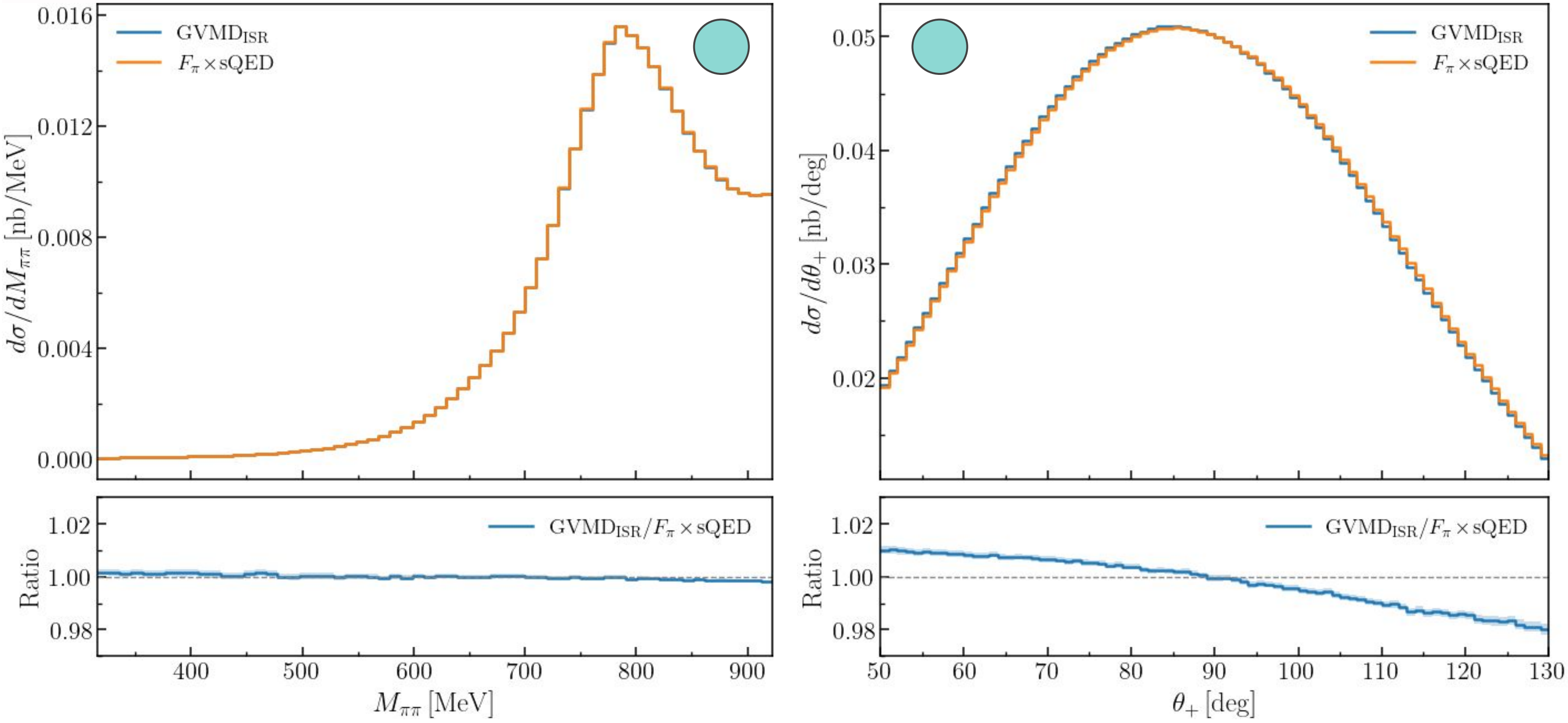

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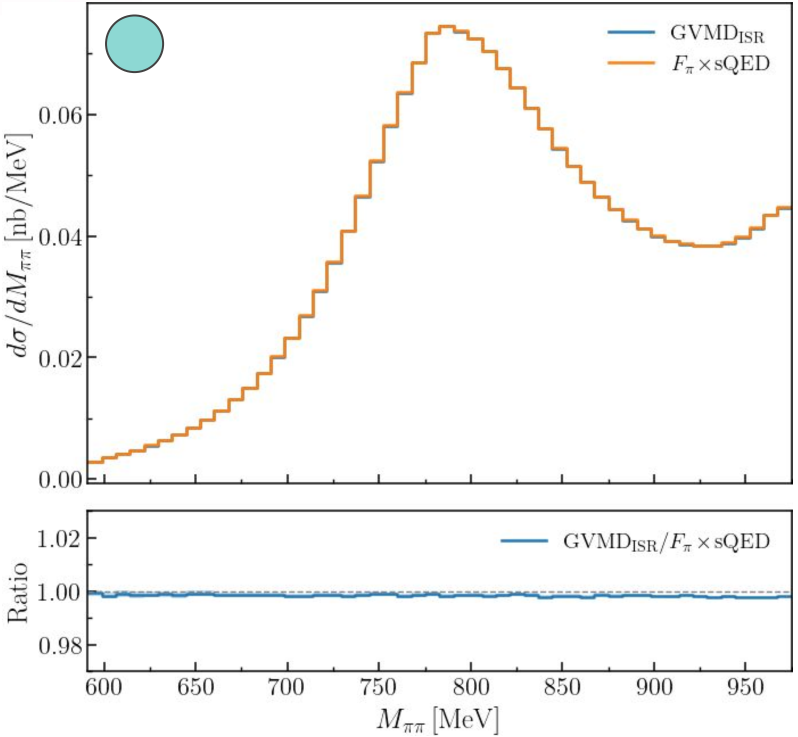

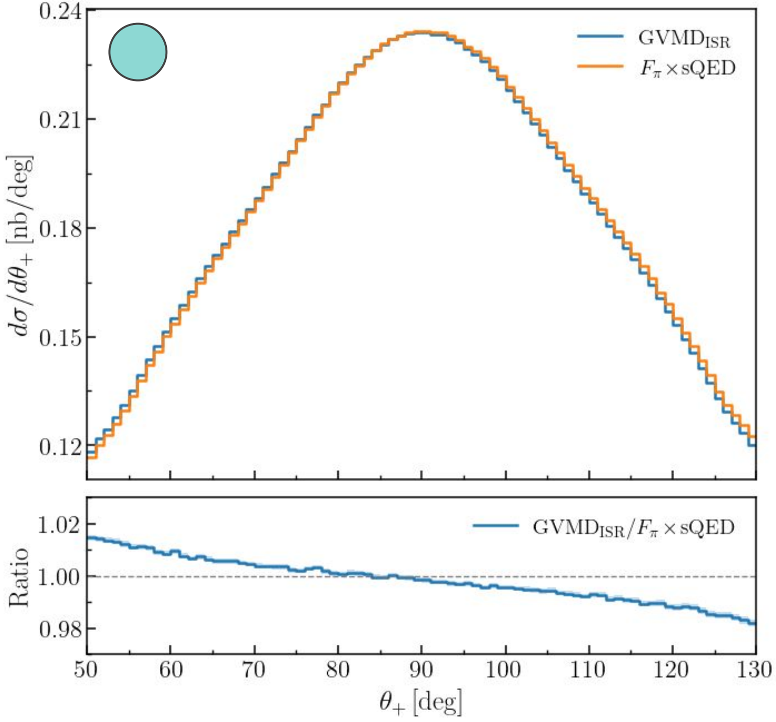

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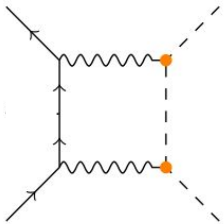

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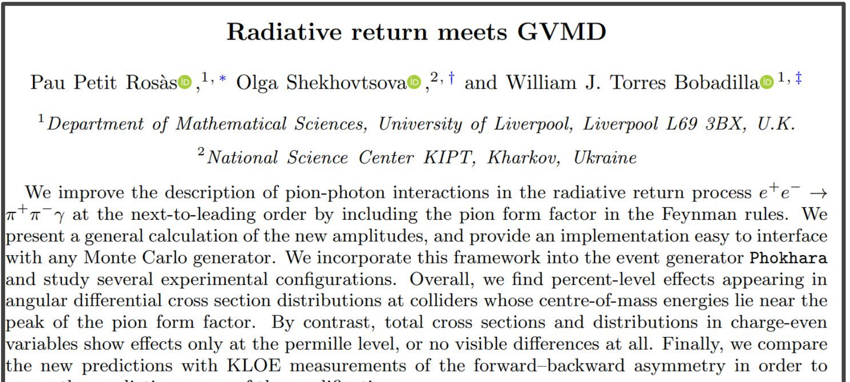

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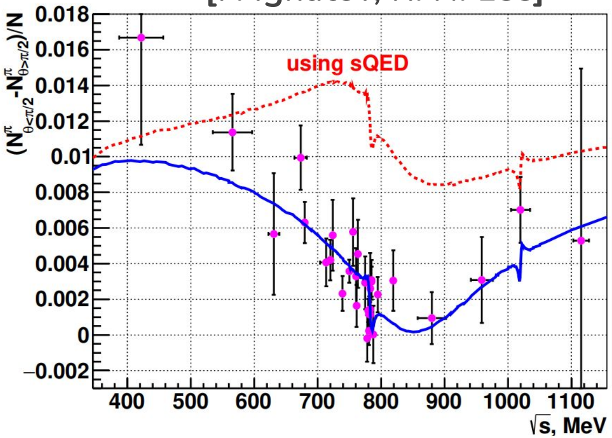
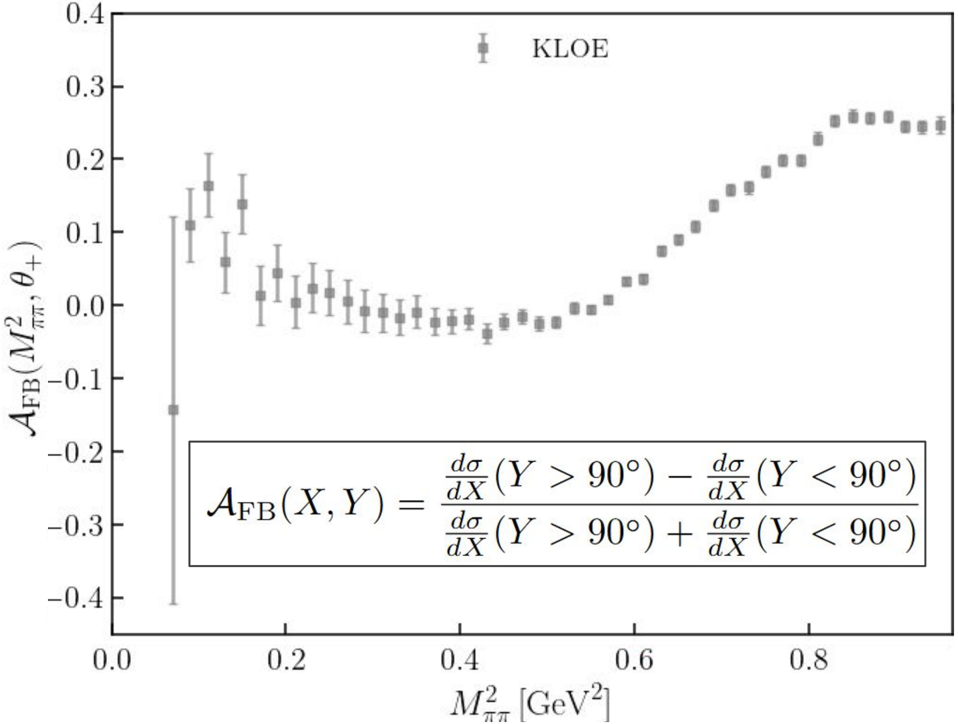


8 Intermezzo: F-B asymmetry



$$\mathcal{A}_{\rm FB}(X,Y) = \frac{\frac{d\sigma}{dX}(Y > 90^\circ) - \frac{d\sigma}{dX}(Y < 90^\circ)}{\frac{d\sigma}{dX}(Y > 90^\circ) + \frac{d\sigma}{dX}(Y < 90^\circ)}$$

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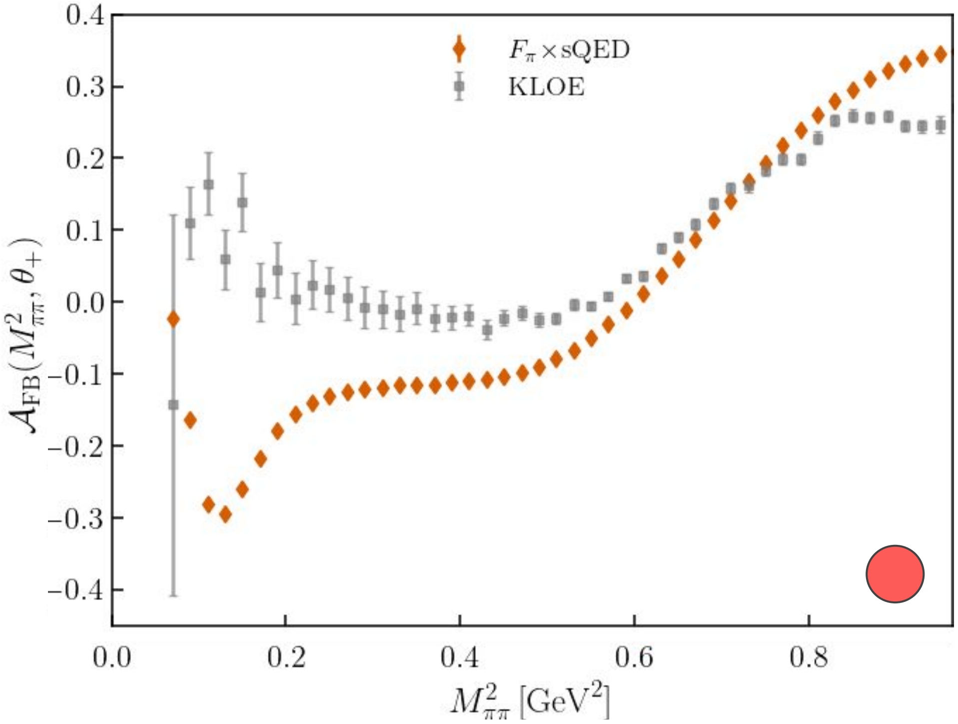
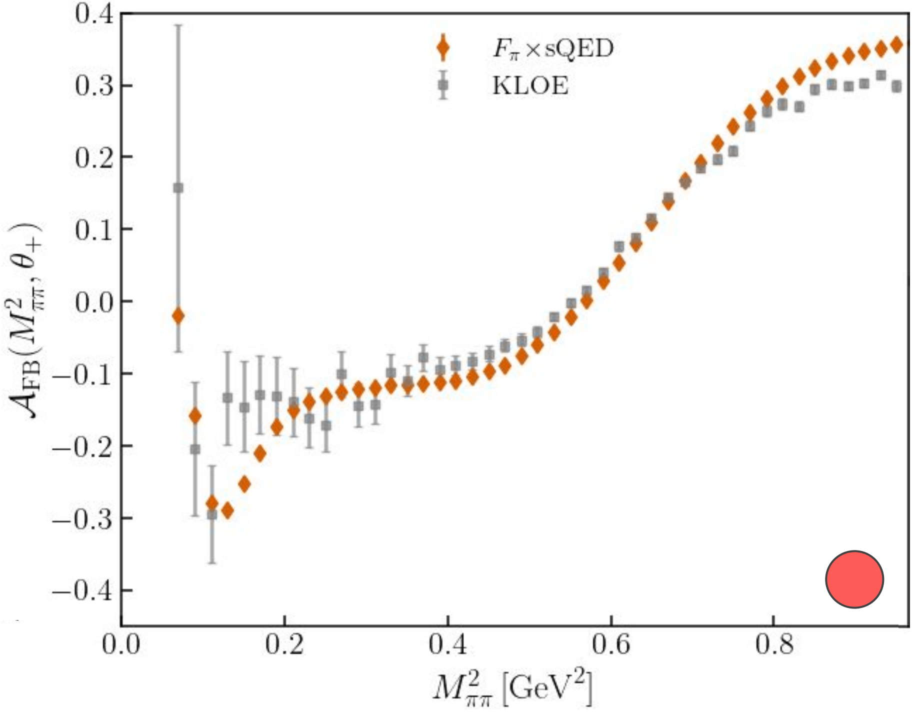


8 **Intermezzo: F-B asymmetry**



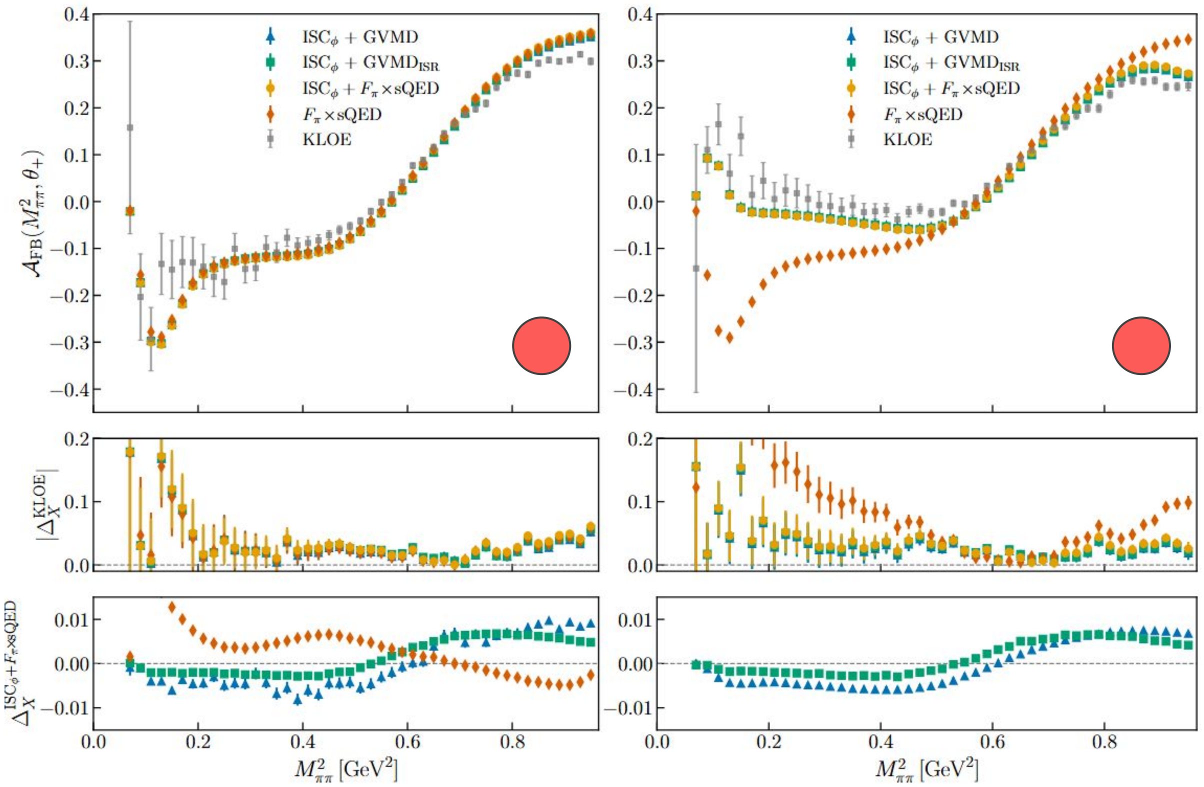
8 Intermezzo

- At the phi resonance, **additional meson decays** contribute to the xsection.

$$e^+e^- \to \gamma^* \to V \to S\gamma \to \pi^+\pi^-\gamma$$
$$e^+e^- \to V_1 \to (V_2\pi)\gamma \to \pi^+\pi^-\gamma$$

- Scalar mesons $\{f_0, \sigma\}$ and the vector meson nonet $\{\rho,\omega,\phi\}$ need to be considered.
- The processes can be expressed in terms of three independent tensor structures, using gauge invariance, transversality and on-shellness. This is **model independent**.
- However, this decomposition does not fix three Lorentz invariant functions (hadronic structure functions). These are **model dependent**.

9 Results: AFB in Kloe



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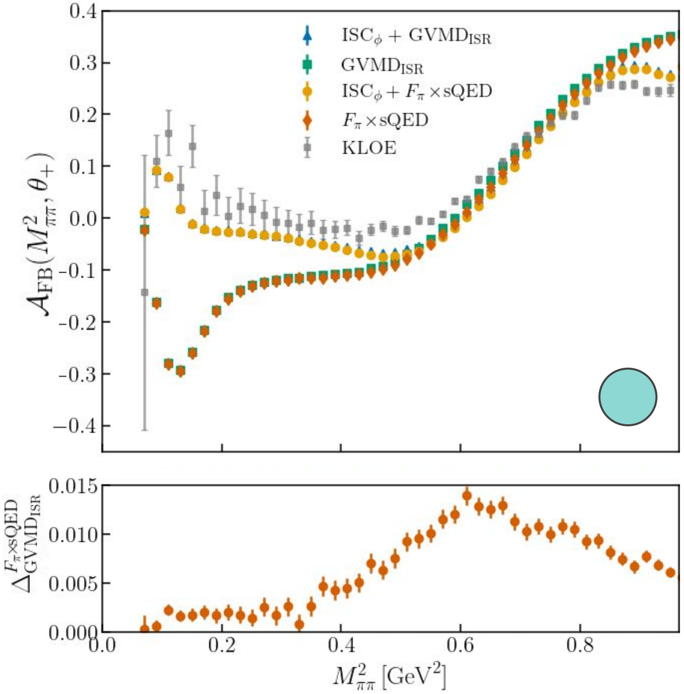
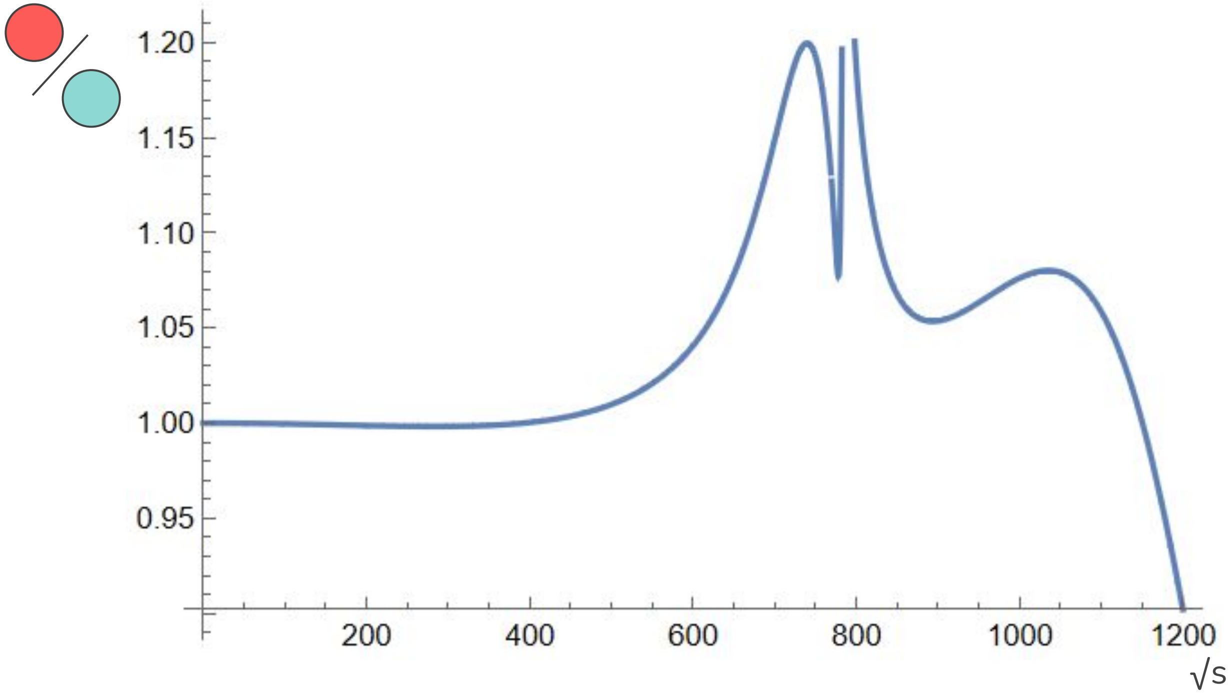


10 Conclusions

- Calculated the GVMD corrections to radiative return, provided an IR safe routine easy to implement in any MC, and interfaced it with Phokhara.
- GVMD captures percent level effects on angular differential xsections in radiative return.
- Smaller effects (at the level of ‰) in other differential distributions and integrated xsection.
- Additional meson decays are key to reproduce experimental data at c.o.m. near the ϕ peak.
- Comparison with other MC generators (and FsQED) to be made.
- Is FxsQED at NNLO an option?

Thanks!

Backup: FF ratios



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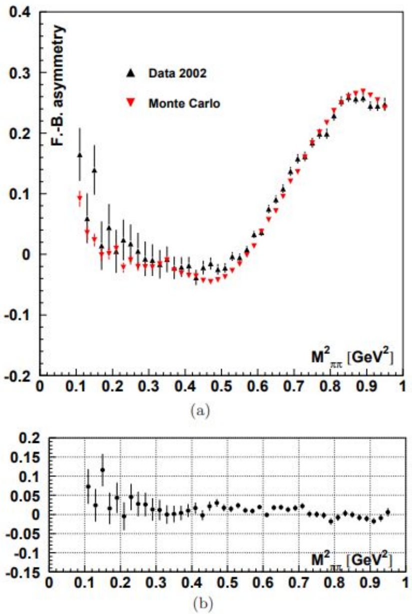

Fig. 53. (a) Preliminary Forward–Backward asymmetry for data taken at $\sqrt{s} = M_\phi$ in 2002, and the corresponding Monte Carlo prediction using the PHOKHARA v6.1 generator. (b) Absolute difference between the asymmetries from data and Monte Carlo prediction. Used with permission of the KLOE collaboration.

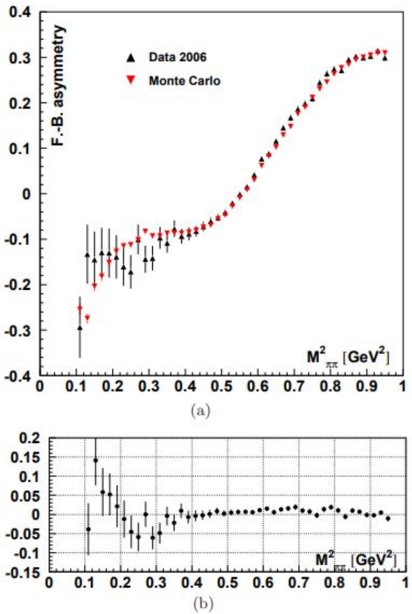

Fig. 54. (a) Preliminary Forward–Backward asymmetry for data taken at $\sqrt{s} \simeq 1000$ MeV in 2006, and the corresponding Monte Carlo prediction using the PHOKHARA v6.1 generator. (b) Absolute difference between the asymmetries from data and Monte Carlo prediction. Used with permission of the KLOE collaboration.

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