

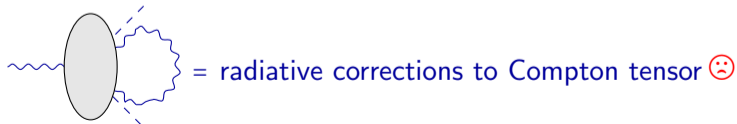
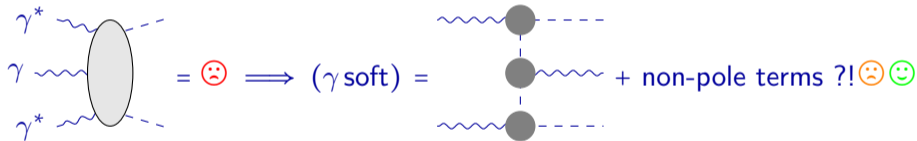
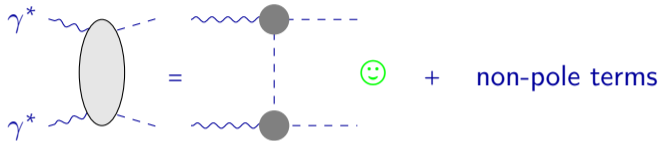
3rd RadioMonteCarLow2 Meeting
McMule update on $ee \rightarrow \pi\pi\gamma$

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Paul Scherrer Institute / University of Zurich



through a vector form factor F_π^V 😊 and Compton tensors $\pi\pi n\gamma^{(*)}$ ☹️



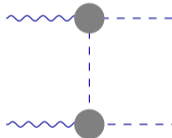
FsQED = include pole terms of the hadronic matrix elements

[RMCLW2 25]

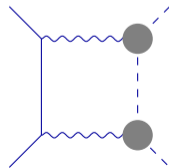
We extend this definition and also use FsQED as a technical definition



- we use $F \times sQED$ for the **Compton tensor**



- ...we put this into the **amplitude** and call it $FsQED$



future / to discuss

done $ee \rightarrow \pi\pi$

[YF, SK, Rocco, Signer, Ulrich, Zoller 25]

- established **disperon QED**
- combined with NNLO ISC

ongoing $ee \rightarrow \pi\pi\gamma$

- first, subset of mixed (at most $\pi\pi 2\gamma^{(*)}$)
- second, include *some* $\pi\pi 3\gamma^{(*)}$
- ... numerical problems 😞
- combine with NNLO ISC

[talk by Sara]

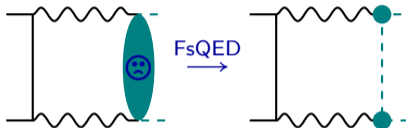
- improve with **rescatteron QED** ?

- further contributions ?



$ee \rightarrow \pi\pi$ @ NLO FsQED

[Colangelo et al 2207.03495]



dispersion relation

$$\mathcal{A}_{\text{FsQED}} \supset \frac{F_{\pi}^V(k^2)}{k^2} = \frac{1}{k^2} - \frac{1}{\pi} \int_{4m_{\pi}^2}^{\infty} dS \frac{\text{Im} F_{\pi}^V(S)}{S(k^2 - S)}$$

$$\Rightarrow \left[\text{tree-level} \right] - \int \frac{dS_1}{\pi S_1} \left[\text{loop} \right] \text{ (threshold singularity @ } S_1 \rightarrow s) + \int \frac{dS_1 dS_2}{\pi^2 S_1 S_2} \left[\text{loop} \right]$$

with threshold subtraction via counterterm (CT) for amplitude
 ... can be described by a massive **dispersive photon**, a **disperon**

- calculate loop integral with form factors inside
- dispersive integral containing disperon(s)
- threshold subtraction



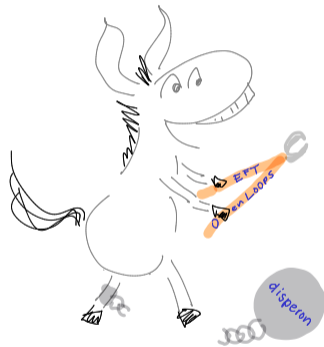
- calculate loop integral with form factors inside
 ⇒ dispersion relation ☺
 disperon + dispersive integral (McMULE)

- dispersive integral containing disperon(s)
 ⇒ Disperon EFT + OpenLoops ☺

- threshold subtraction

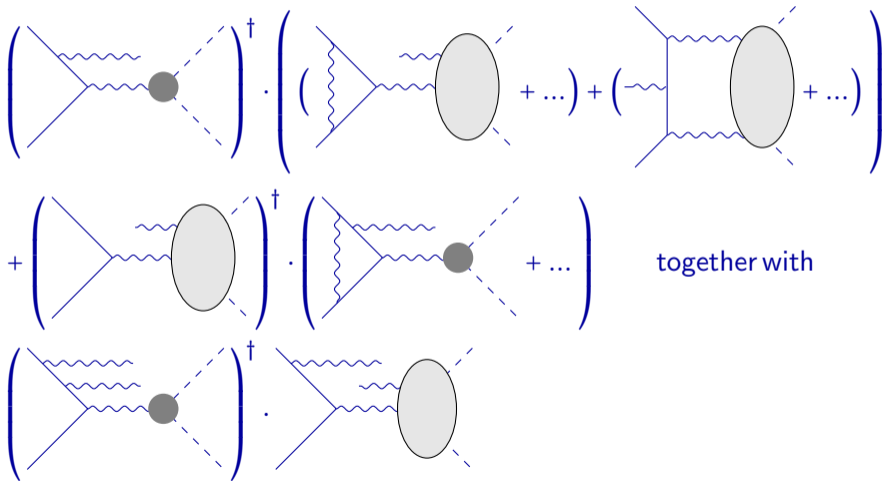
$$\Rightarrow \int \frac{dS_1}{\pi S_1} \left(\text{Diagram} - \text{CT} \right) + \int \frac{dS_1}{\pi S_1} \text{CT}$$

$$\text{CT} = \text{Diagram} + \mathcal{O}(S_1 - s)^0 \quad \text{☺}$$

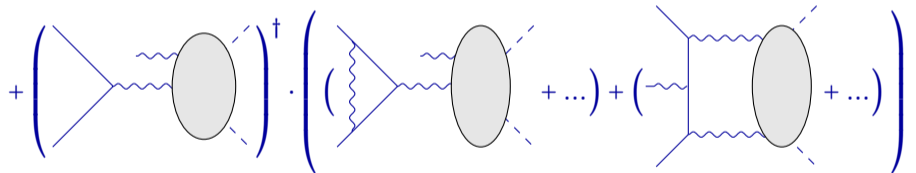
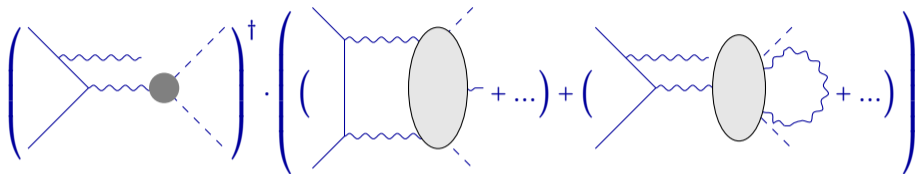


⇒ focus on mixed corrections

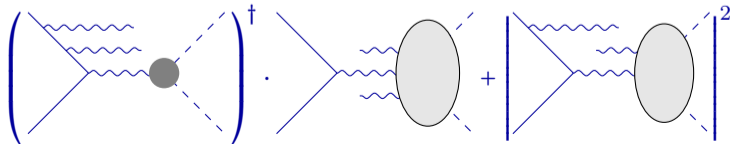
first subset: $q_e^5 q_\pi^3$



the next subset: $q_e^4 q_\pi^4$



together with



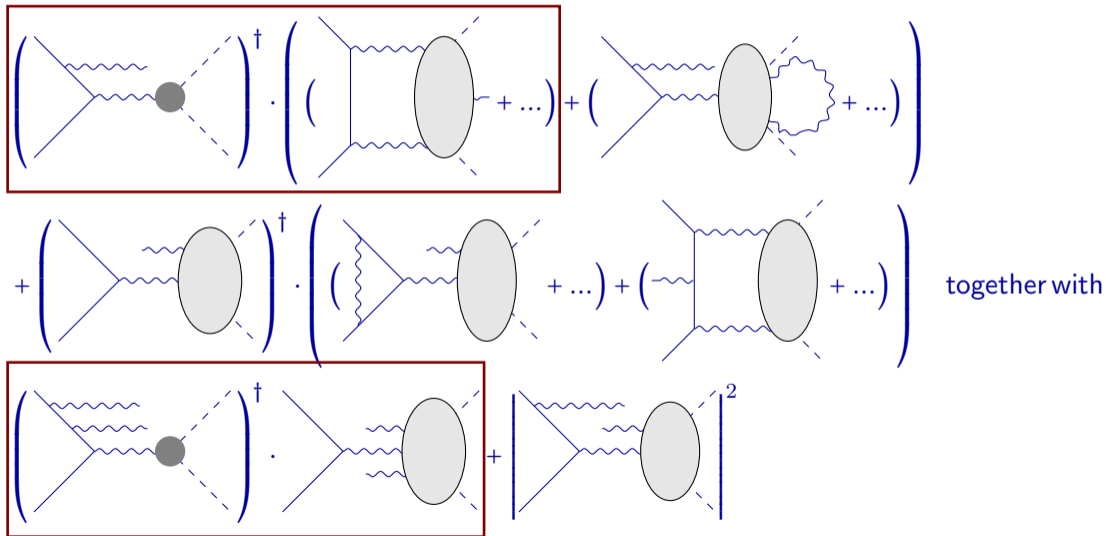
problem

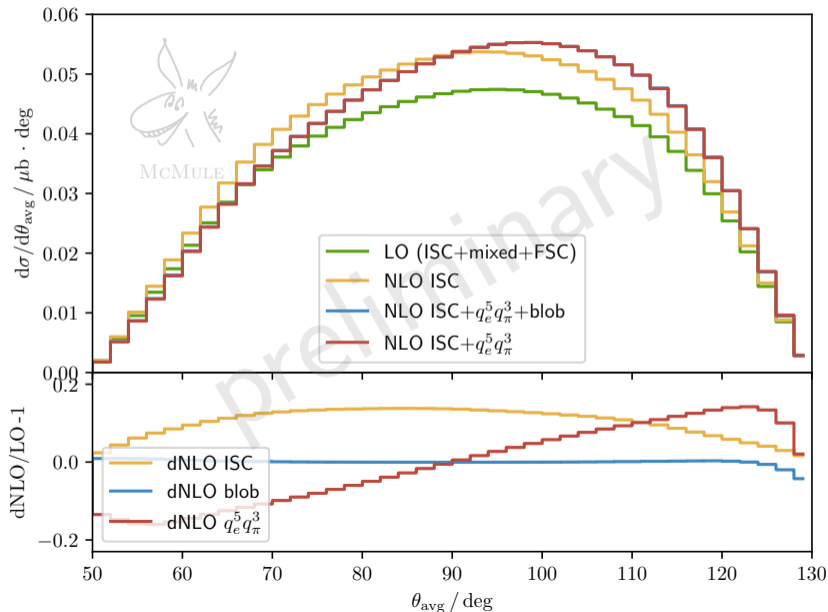
- we do not include radiative corrections to Compton tensors
 - all virtual correction pieces “talk” to each other in IR cancellation
- ⇒ complete calculation of $q_e^4 q_\pi^4$ is problematic

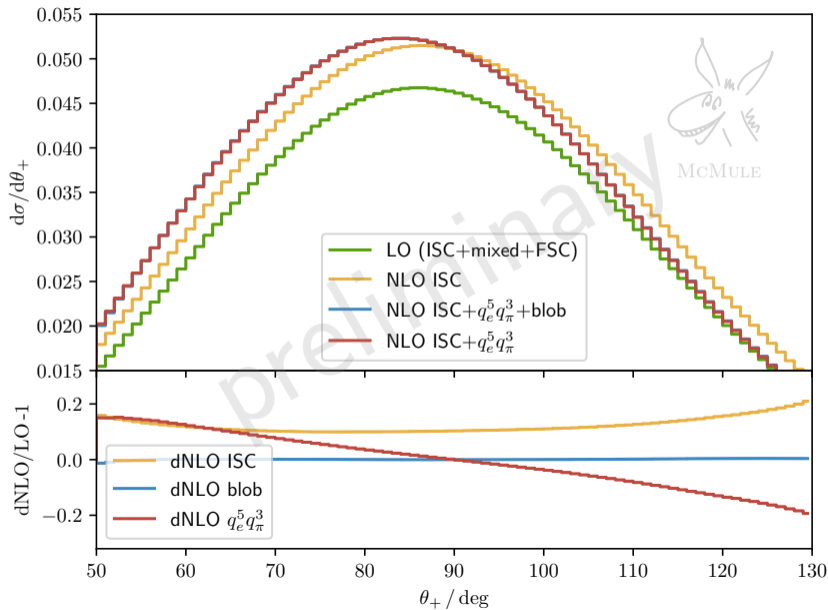
solution :: we use a ‘blob theory’ as error estimate

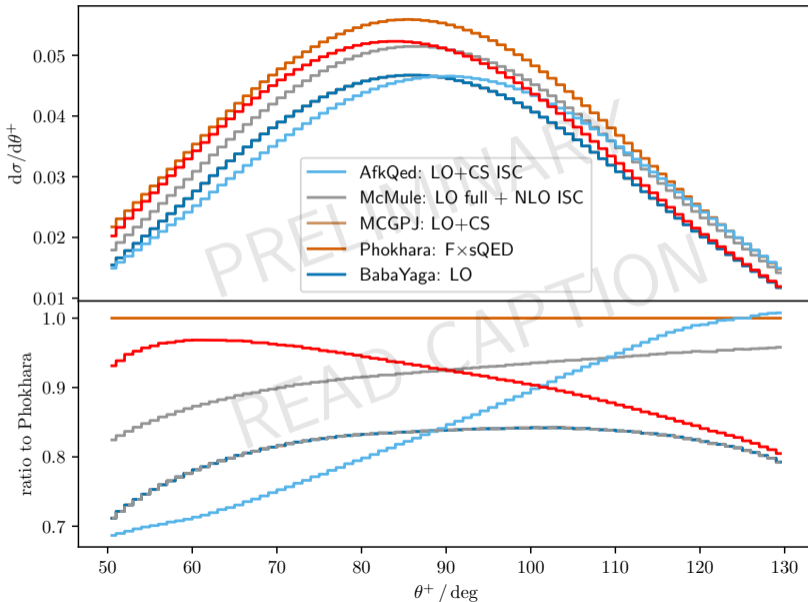
- blob = Compton tensor
 - ∃! one blob per squared amplitude
- ⇒ calculate gauge-invariant pieces whose IR cancellation is closed, in FsQED
- ⇒ estimate of $q_e^4 q_\pi^4$'s impact compared to $q_e^5 q_\pi^3$

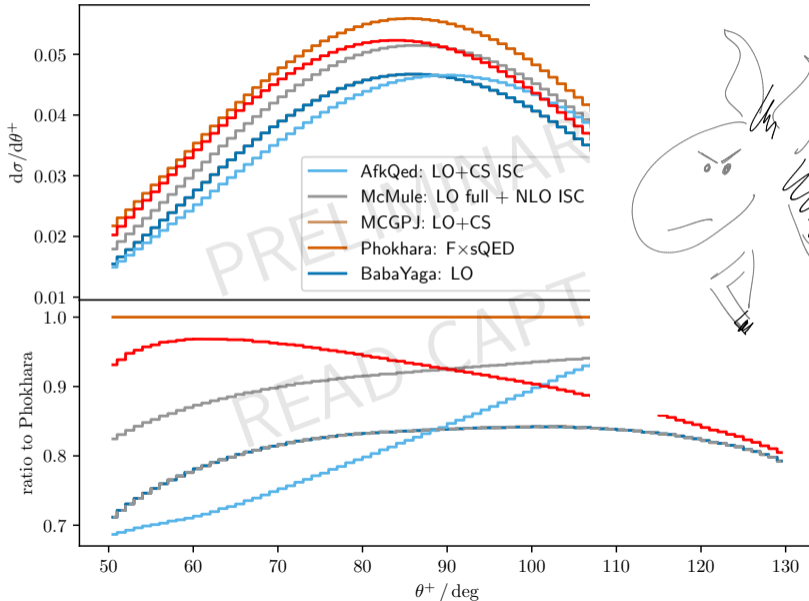
the next subset: $q_e^4 q_\pi^4$











next RMCLW2 meeting ...

- finalise $ee \rightarrow \pi\pi\gamma$ results
- compare against **up-to-date** BabaYaga / Phokhara
 \implies get error estimate on pion models & final state effects

while we are waiting for progress from Martin/Eirini/Emilis ...

we *could* use FsQED for beyond-‘blob’ contributions in $ee \rightarrow \pi\pi\gamma$

- would this be meaningful ?
- would this be a useful technical validation ?

