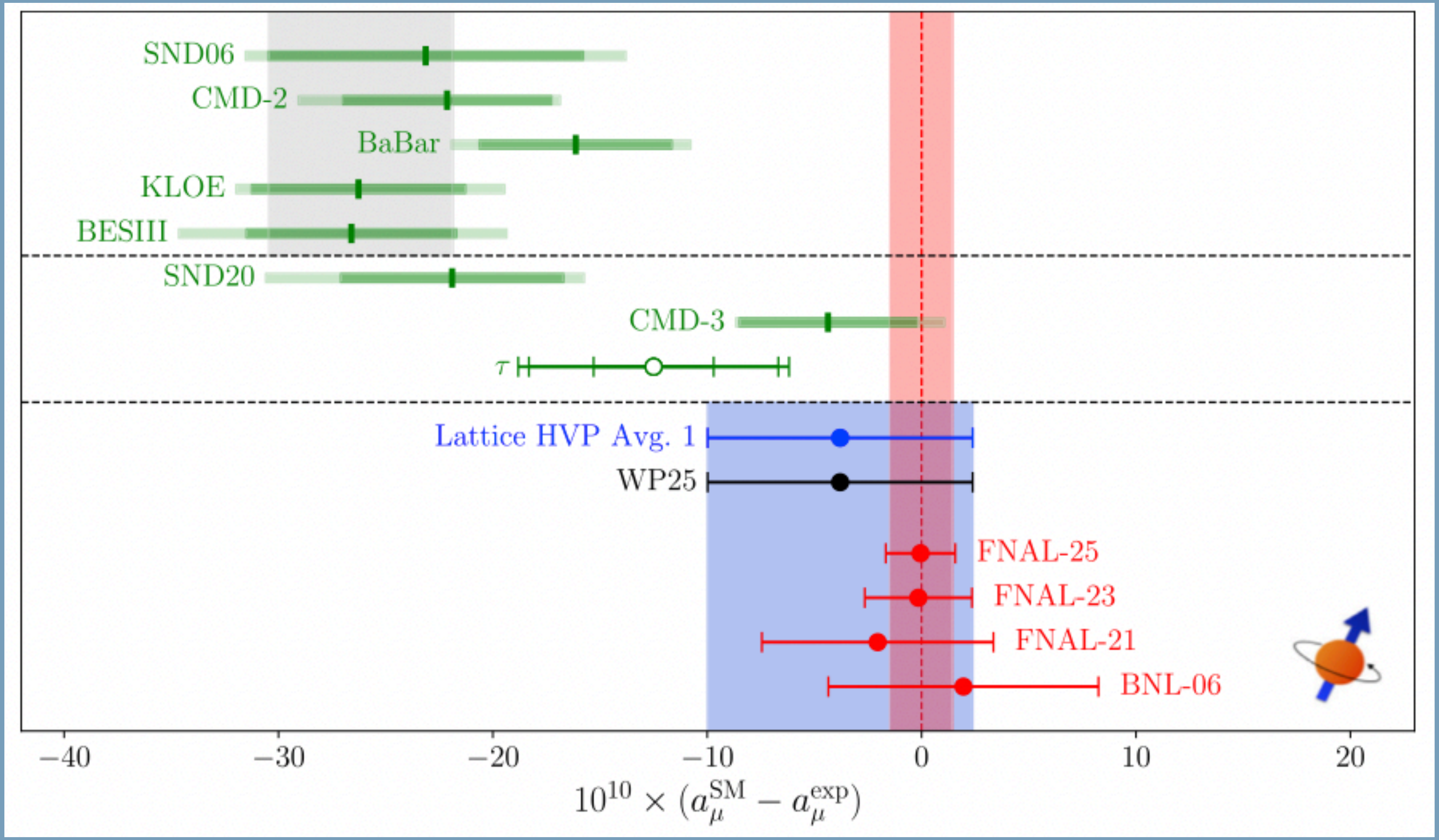
LEVERHULME
TRUST

Radiative Corrections in Monte Carlo Generators

Jérémy Paltrinieri

17 September 2025

The g-2 Landscape



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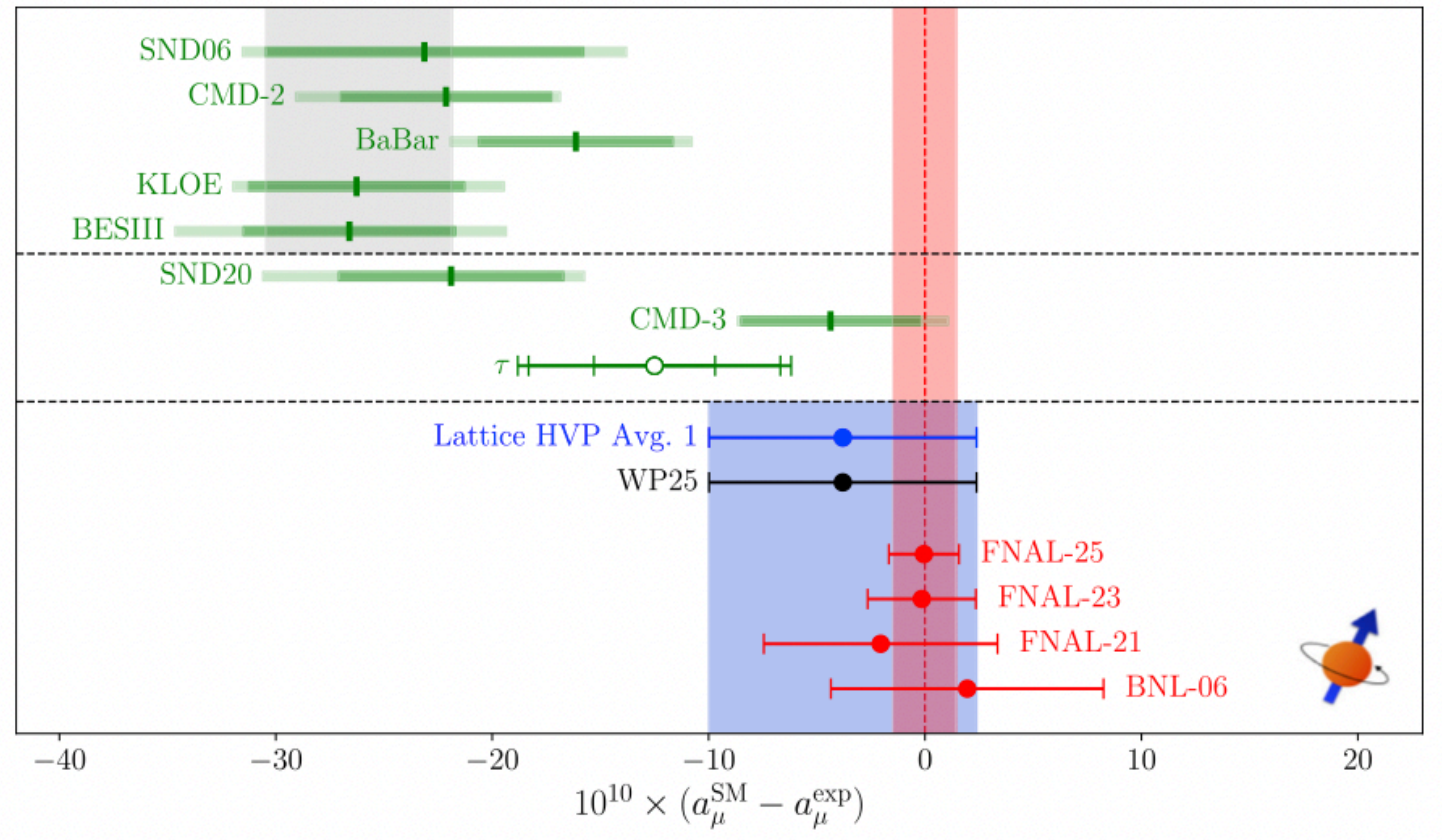

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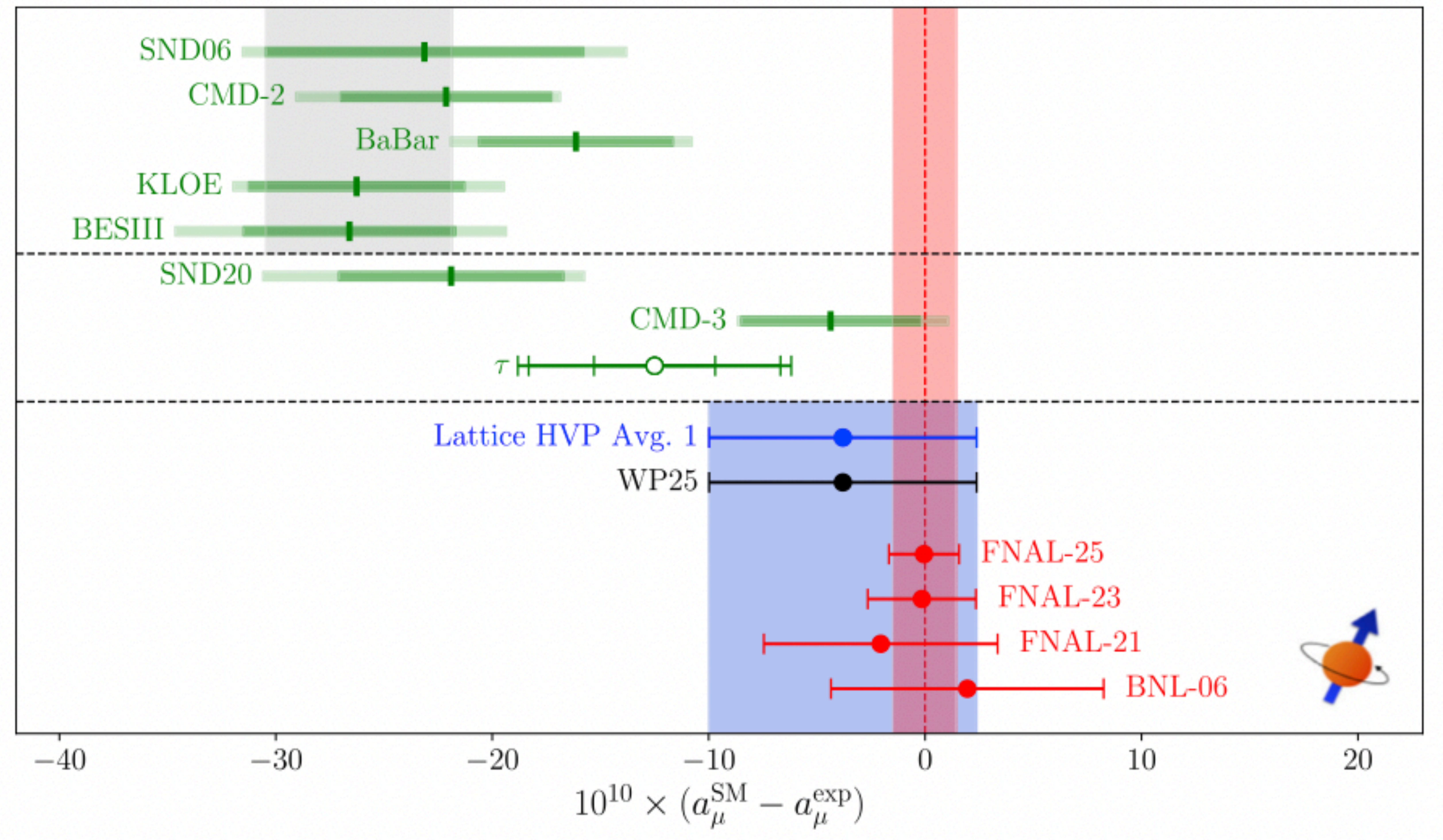

Jeremy is puzzled by the situation

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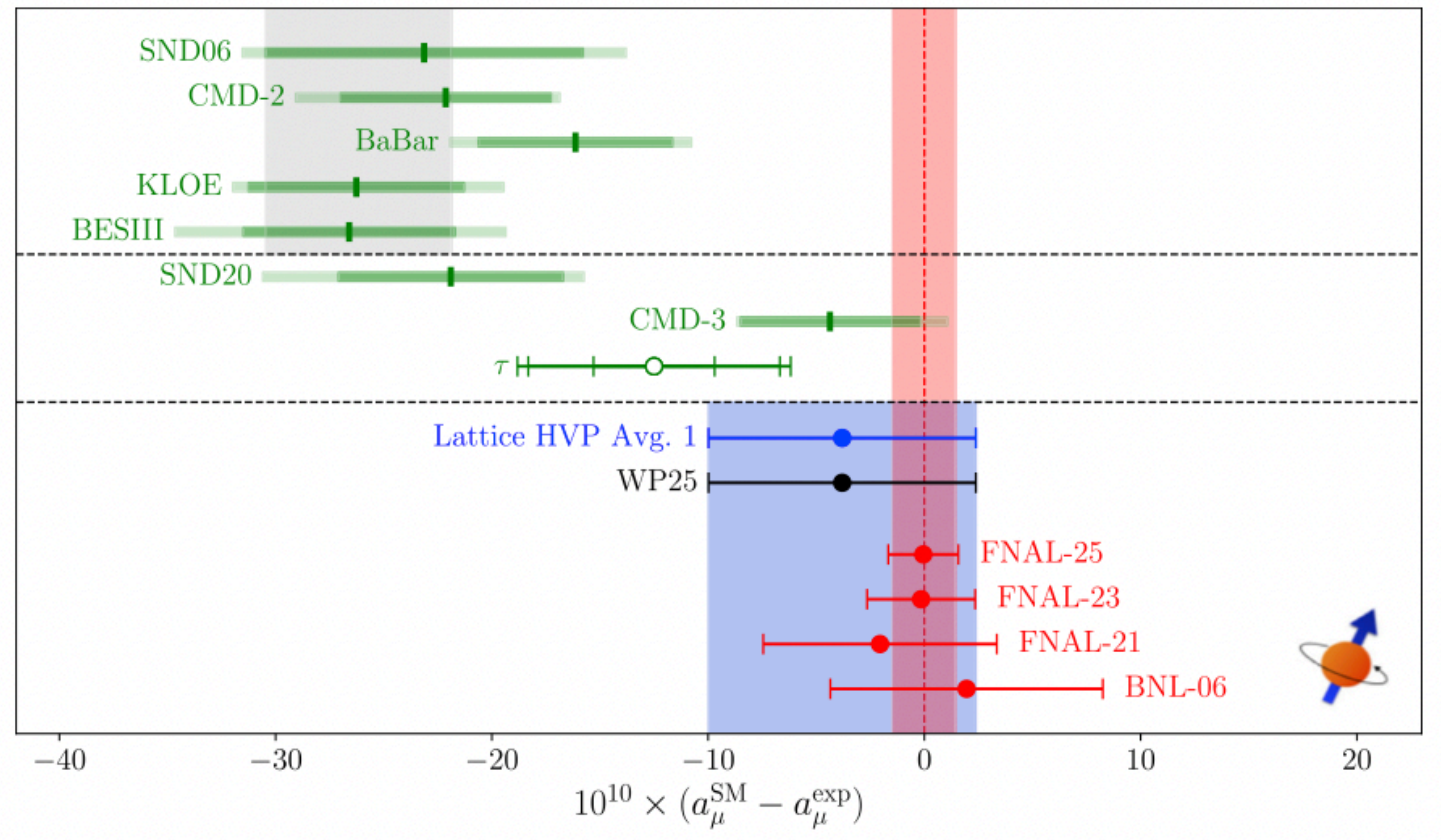

Need for better Monte-Carlo generators?

AfkQED, Babayaga, KKMC,MCGPJ, Phokhara, Sherpa

What should we use? Why?

[Theory White Paper 2025]

What I’ve worked on

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Status of Monte-Carlo

- Within KLOE, studied MC effects

  (see [Theory White Paper 2025])

- Within Radio-Monte-Carlow2

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Soft-photon resummation

- Based on YFS formalism: resummation of soft photons effects
- Goal: achieve better precision and control of higher-order terms in Phokhara

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Jeremy is smiling despite making slides

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Jeremy in Pisa at the 2025 RMCL2 workshop

What do Monte-Carlo tools do

$$\sigma_{LO} = \int d(\mathrm{PS})_2 \, |\mathscr{M}_{LO}|^2$$

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Phase-space algorithm

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Numerical integration

Phase-space algorithm

Beyond LO, need to cancel IR singularities with a scheme, but principle is the same

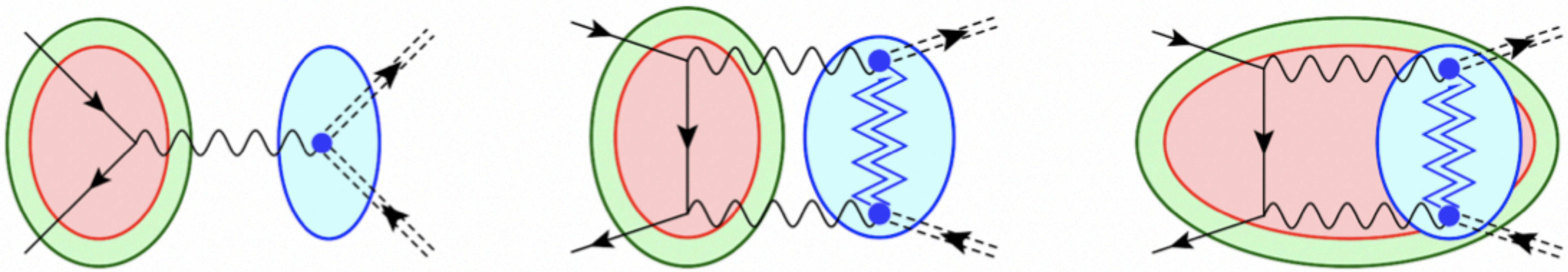
NLO is automated for most processes (sometimes NNLO)

What about effects that are important but arise at NN…NLO?

Fixed-Order / All orders

The calculations

- Red blob: fixed-order QED.
- Blue blob: Techniques beyond fixed-order to incorporate pions in a standard perturbative framework (they are models, however complicated they are).
- Green blob: approximations which capture leading contributions at all orders in the QED coupling.



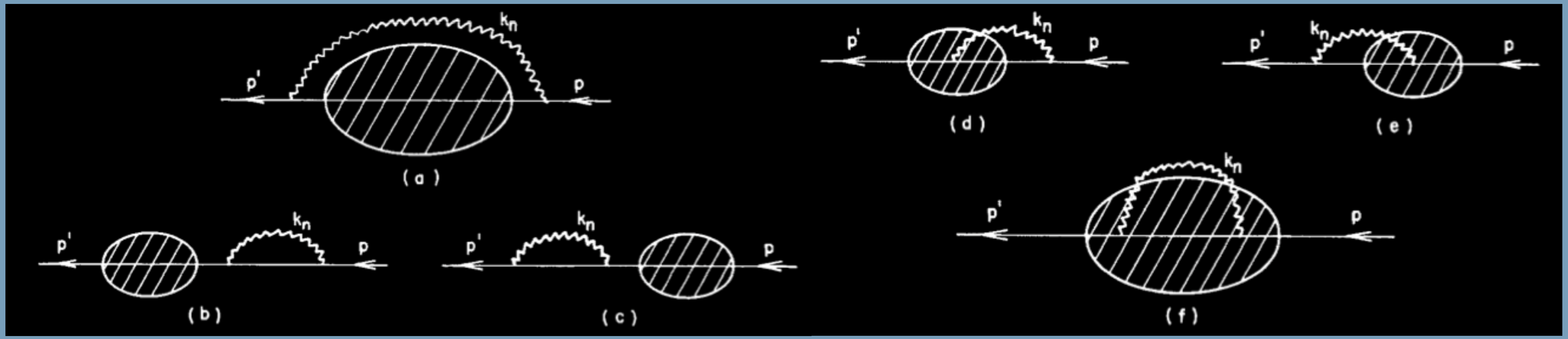
Many effects captured by different codes

The codes

Code \ Process	$\mu^+\mu^-$	$\mu^+\mu^-\gamma$	$\pi^+\pi^-$	$\pi^+\pi^-\gamma$
AfkQed	–	LO+CS	–	LO+CS no FSC
BabaYaga@NLO	NLO+PS	LO+PS	NLO+PS F×sQED	LO+PS F×sQED
KKMC	CEEX	CEEX	–	–
MCGPJ	NLO+CS	LO+CS	LO+CS GVMD	LO+CS GVMD
McMule	NNLO	NLO	NNLO ISC	NLO ISC
Phokhara	–	NLO	–	NLO F×sQED
Sherpa	NLO+YFS	NLO	YFS sQED	YFS sQED

One clever trick: resummation

Virtual corrections



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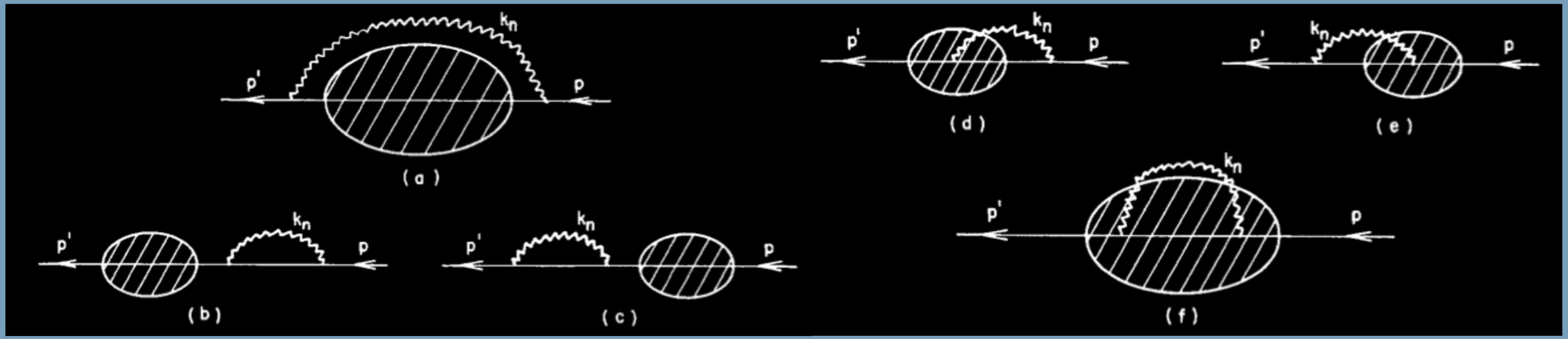
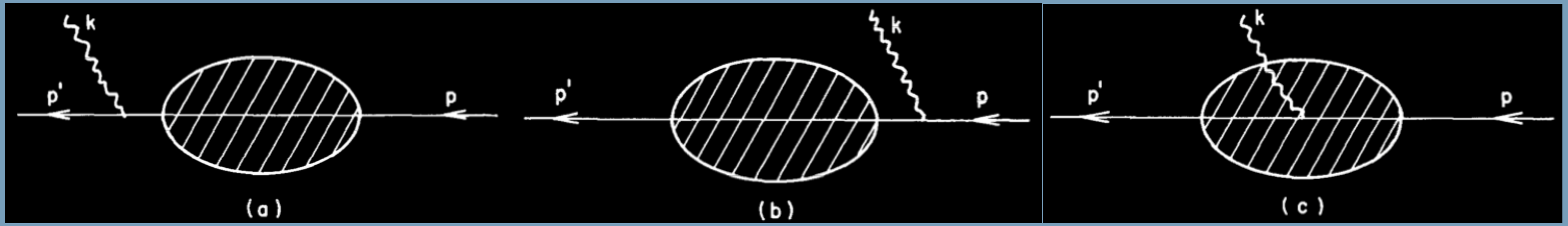
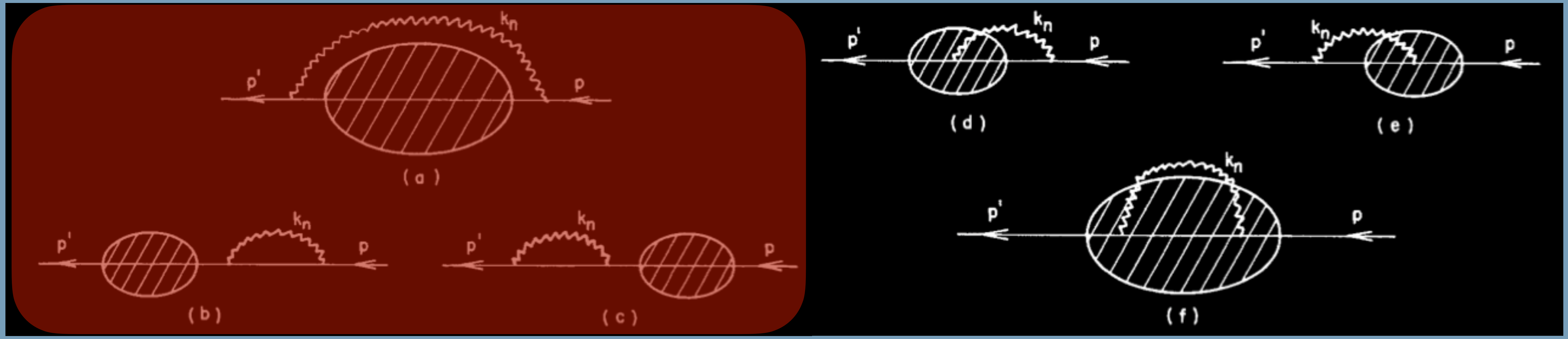


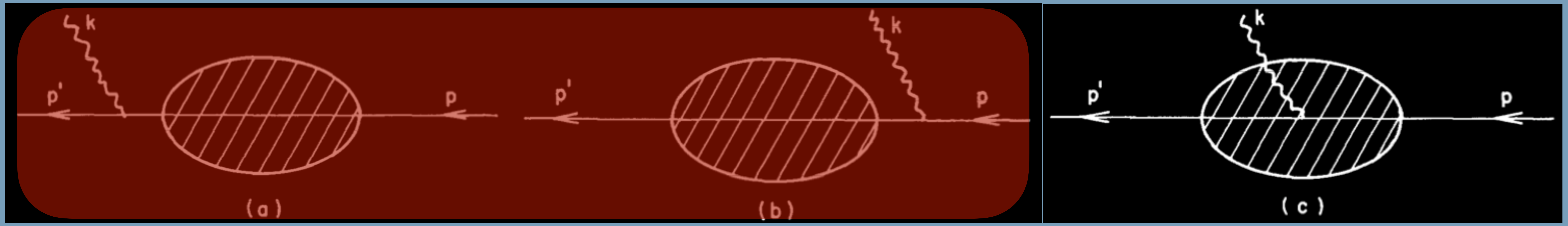
Real corrections



One clever trick: resummation

Divergent pieces isolated and put into a YFS form factor





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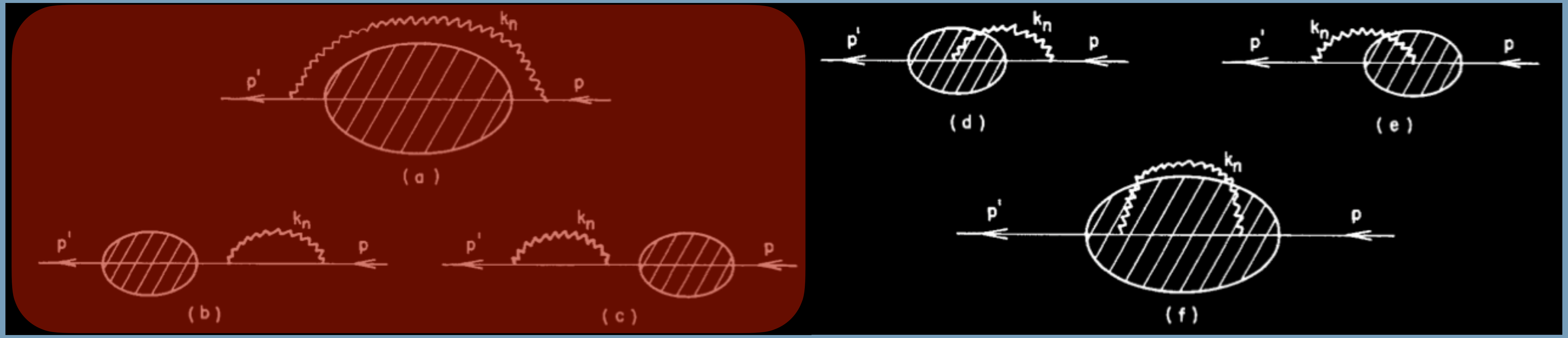
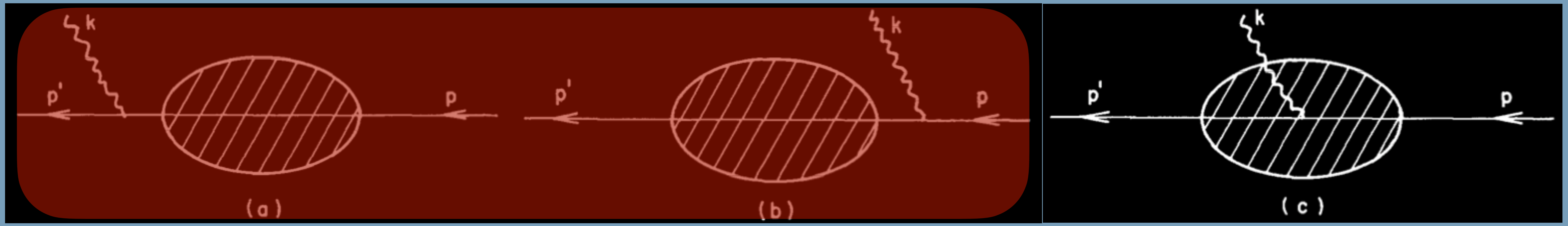


Cross-section rewritten as:



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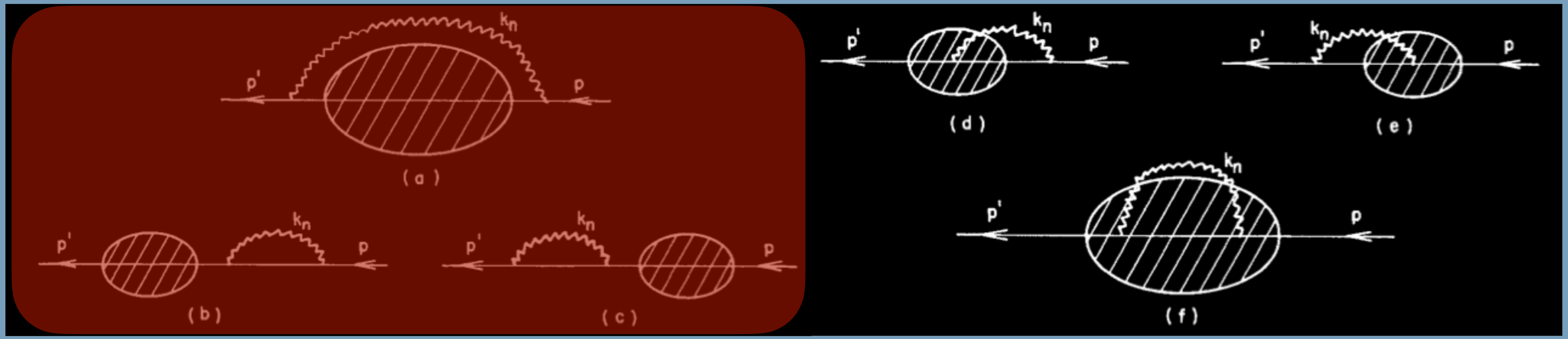

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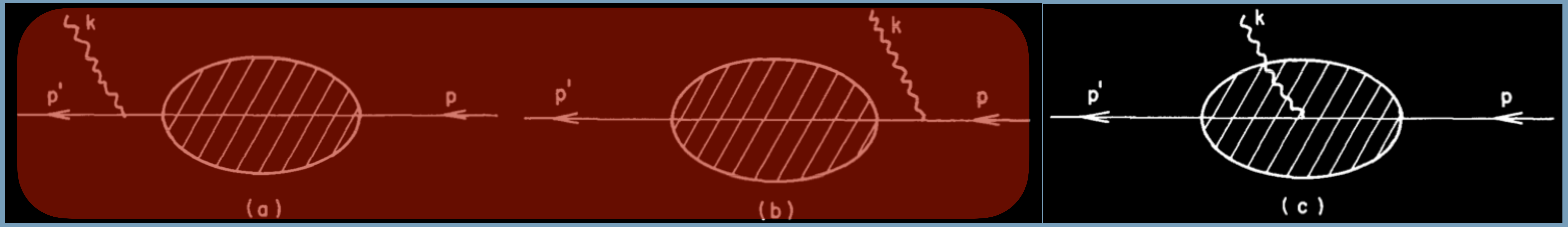

Jeremy likes magic

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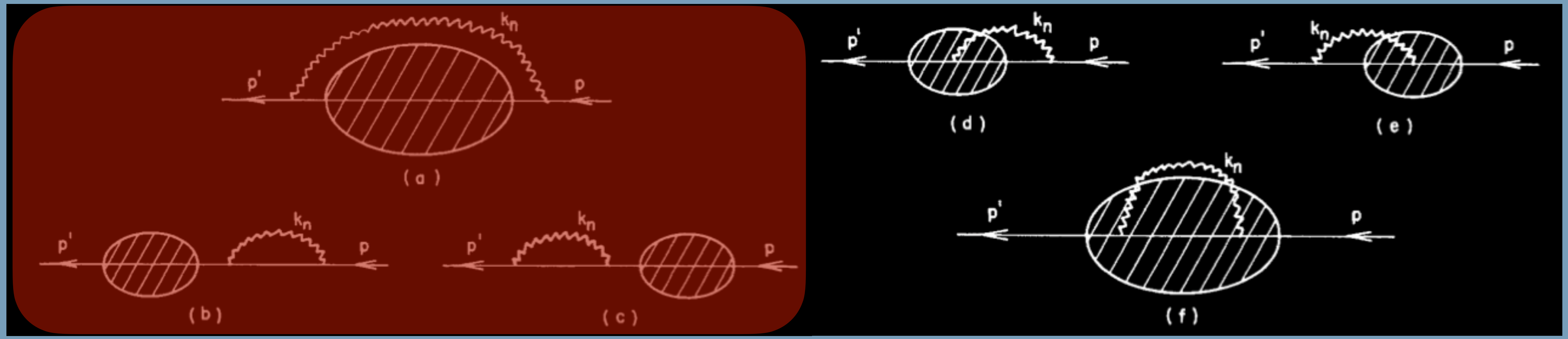

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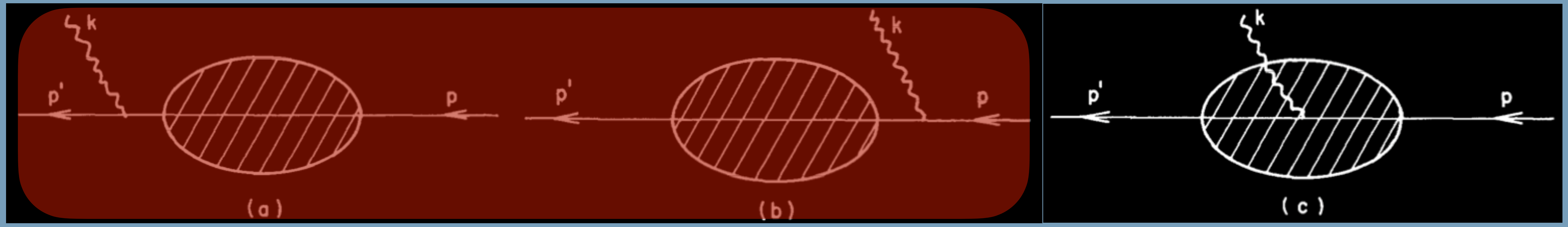

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$$d\sigma = \sum_{n_\gamma=0}^{\infty} \frac{e^{2\alpha(B+\tilde{B}(\Omega))}}{n_\gamma!} d\Phi_Q \left[\prod_{i=1}^{n_\gamma} d\Phi_i^\gamma \tilde{S}(k_i)\Theta(k_i,\Omega)\right]\left(\tilde{\beta}_0 + \sum_{j=1}^{n_\gamma} \frac{\beta_1(k_j)}{\tilde{S}(k_j)}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

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Phase-Space Integration

IR safe amplitude

Status of the Implementation

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- Implemented resummation at LO for scan mode
- Is implementing resummation at NLO for scan mode through automation of matrix element calculations
- Is working towards resummation at NLO for radiative mode

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Jeremy is implementing this in fortran

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Jeremy has finished his presentation

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