Phenomenology of μe scattering at NLO (in QED)

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The Evaluation of the Leading Hadronic Contribution to the Muon Anomalous Magnetic Moment

MITP topical workshop

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with M. Alacevich, M. Chiesa, G. Montagna, O. Nicrosini, F. Piccinini

Outline

→ Quantify the impact of QED NLO radiative corrections on observables

→ Play with cuts to select elastic events and explore their effects

→ Show differences between μ^- and μ^+ beams

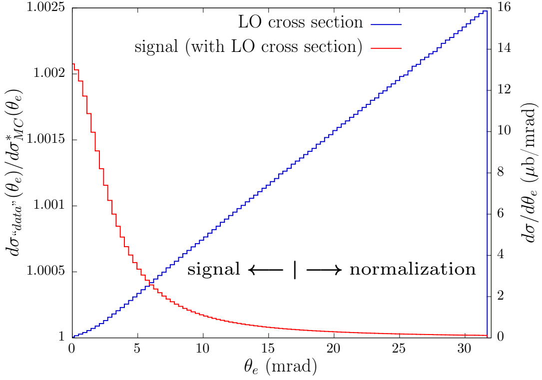
→ Show the impact of radiative corrections on the extraction of $\Delta\alpha_{had}(q^2)$ from μe scattering

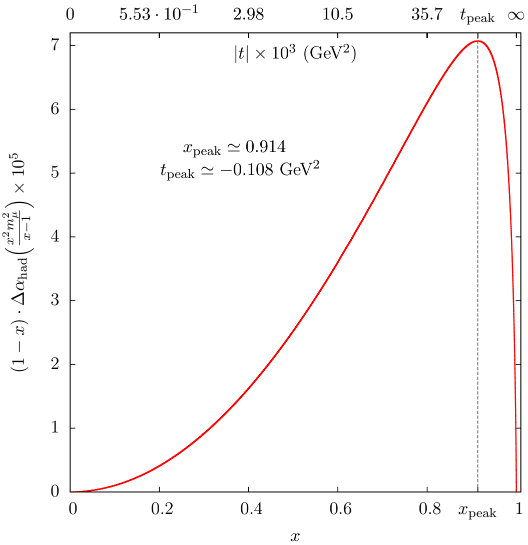
- Master formula

$$\text{Our signal} \equiv \frac{dN_{data}(O_i)}{dN_{MC}(O_i)|_{\Delta\alpha_{had}(t)=0}} \equiv \frac{dN_{data}(O_i)}{dN^*_{MC}(O_i)} =$$

$$= \frac{d\sigma_{data}(O_i)}{d\sigma^*_{MC}(O_i)} = \frac{dN_{data}(O_i)}{N^{norm}_{data}} \times \frac{\sigma^{norm}_{MC}}{d\sigma^*_{MC}(O_i)} \simeq$$

$$\simeq 1 + 2\left[\Delta\alpha_{lep}(t_i) + \Delta\alpha_{had}(t_i)\right]$$





$$t = -\frac{x^2 m_\mu^2}{1-x} \qquad t_{peak} \simeq -0.108\ \text{GeV}^2$$

Simulation setups

- Two setups have been considered for $E_\mu^{beam} = 150$ GeV ($\sqrt{s} \simeq 0.4055$ GeV)

Setup A:

- for elastic events $E_e > 1$ GeV implies $t_{min} < t_{24} = t_{13} < t_{max}$

$$t_{min} = -\lambda(s, m_\mu^2, m_e^2)/s \simeq -0.1429 \text{ GeV}^2 \qquad t_{max} \simeq -1.021 \cdot 10^{-3} \text{ GeV}^2$$

- any event generated requiring

$$t_{min} < t_{24} < t_{max} \qquad t_{min} < t_{13} < t_{max}$$

i.e. $E_e > 1$ GeV and an effective cut on $E_\mu \cdot (1 - \cos\theta_\mu)$

Setup B:

- acceptance: $E_e > 200$ MeV $\quad \theta_e, \theta_\mu < 100$ mrad

$\mapsto$ **no cuts**: only acceptance and, *to select elastic events*,

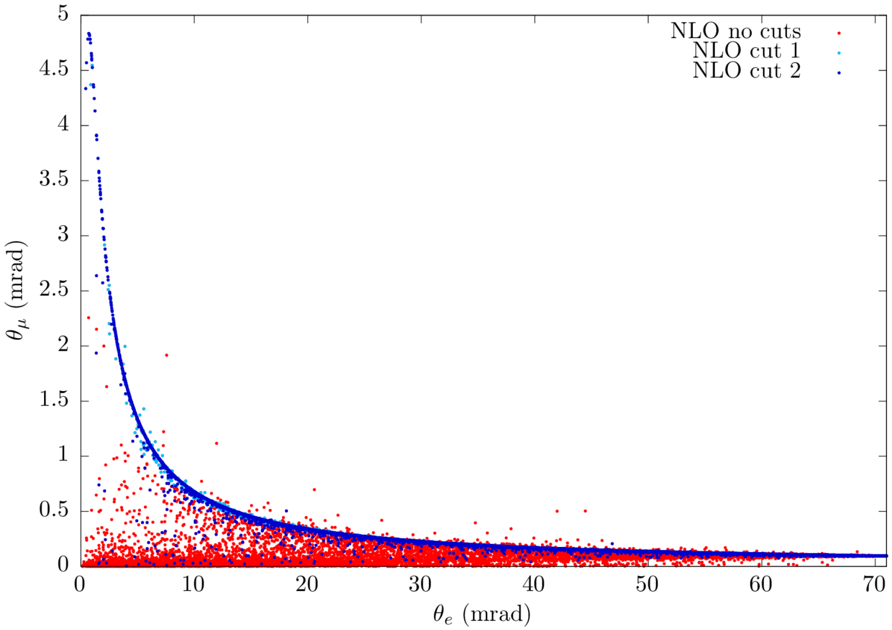
$\mapsto$ **cut 1**: $\Delta\theta_{\mathrm{NA7}} < 0.5$ mrad $\quad \Delta\theta_{\mathrm{NA7}} \simeq$ mimimum distance from the elastic curve in the θ_e-θ_μ plane

$\mapsto$ **cut 2**: acoplanarity $\equiv |\pi - (\phi_e - \phi_\mu)| < 3.5$ mrad

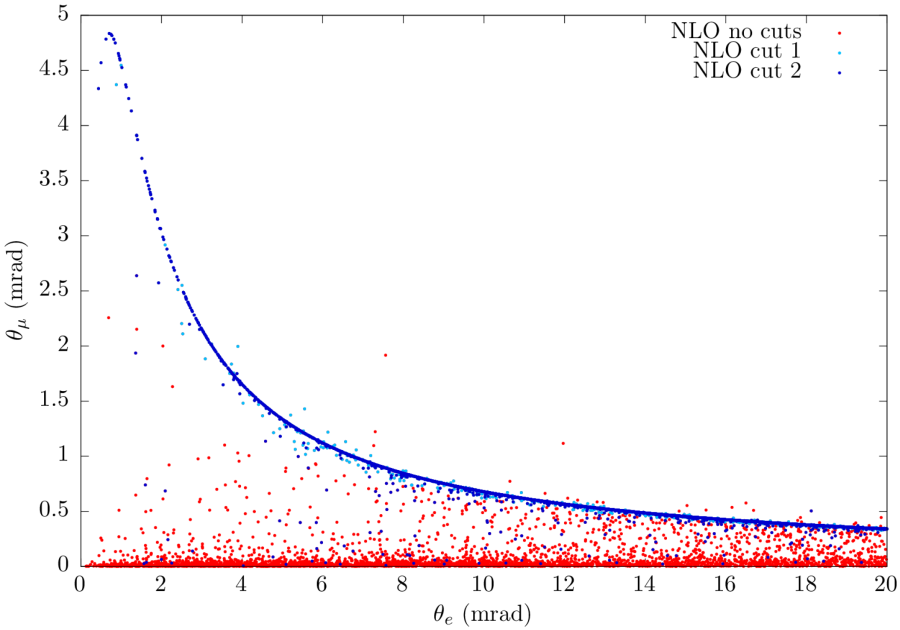
$\mapsto$ **Setup B [no cuts] > Setup A**

$\mapsto$ In **setup B** only angular cuts are applied, besides acceptance

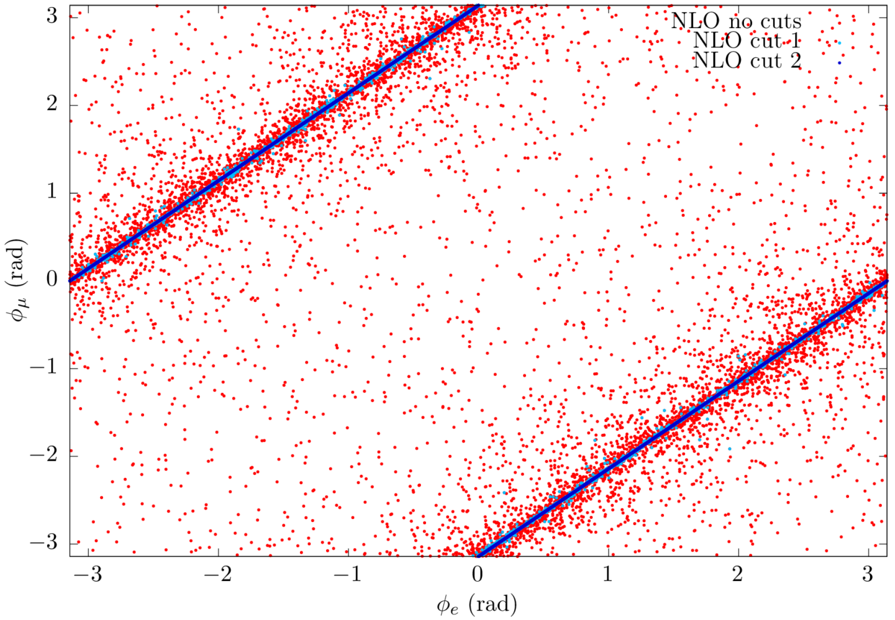
μ^--e^- angle correlation in the lab (setup B)



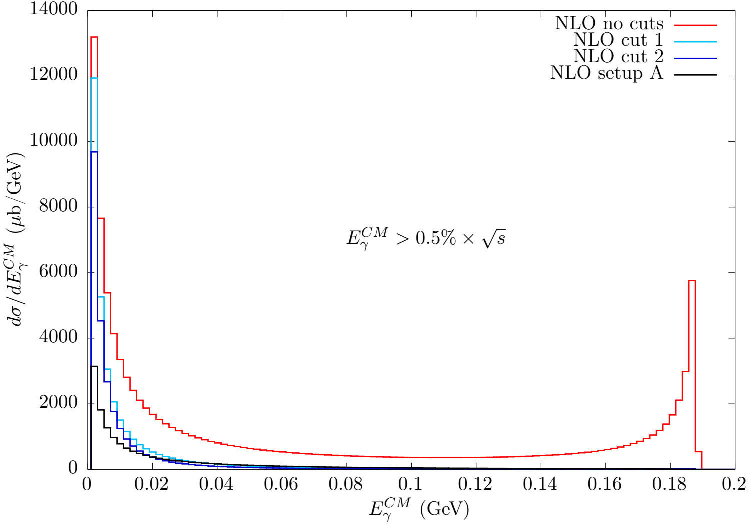
μ^--e^- angle correlation in the lab (setup B) - zoom



ϕ_{μ^-}-ϕ_{e^-} angle correlation (setup B)

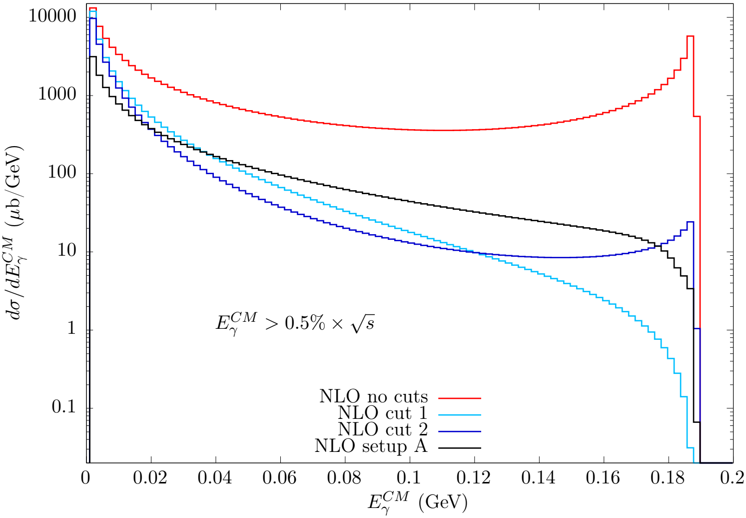


Photon energy **in the center of mass**, incoming μ^-

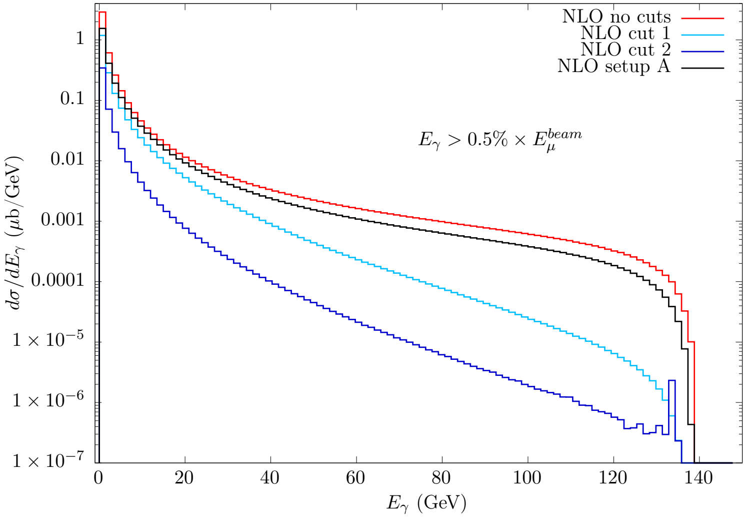


- a peak at large photon energy is present with no cuts
- it is cut off by applying cuts

Photon energy **in the center of mass**, incoming μ^-



Photon energy **in the lab**, incoming μ^-



Cross sections

- Any vacuum polarization effect is switched off, to quantify only NLO photonic RCs

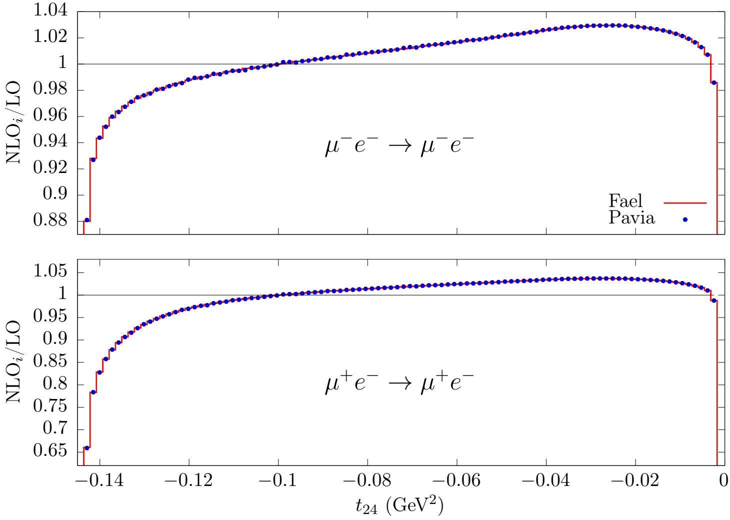
Setup A:

$\mapsto$ $\mu^\pm$ LO	$=$	$245.04\ \mu$b	
$\mapsto$ μ^- NLO	$=$	$241.49\ \mu$b	(-1.45%)
$\mapsto$ μ^+ NLO	$=$	$242.21\ \mu$b	(-1.15%)

Setup B:

$\mapsto$ $\mu^\pm$ LO	$=$	$1265.06\ \mu$b	
$\mapsto$ μ^- NLO no cuts	$=$	$1323.48\ \mu$b	$(+4.62\%)$
$\mapsto$ μ^- NLO cut 1	$=$	$1179.22\ \mu$b	(-6.79%)
$\mapsto$ μ^- NLO cut 2	$=$	$1161.89\ \mu$b	(-8.16%)
$\mapsto$ μ^+ NLO no cuts	$=$	$1325.23\ \mu$b	$(+4.76\%)$
$\mapsto$ μ^+ NLO cut 1	$=$	$1180.71\ \mu$b	(-6.67%)
$\mapsto$ μ^+ NLO cut 2	$=$	$1162.45\ \mu$b	(-8.11%)

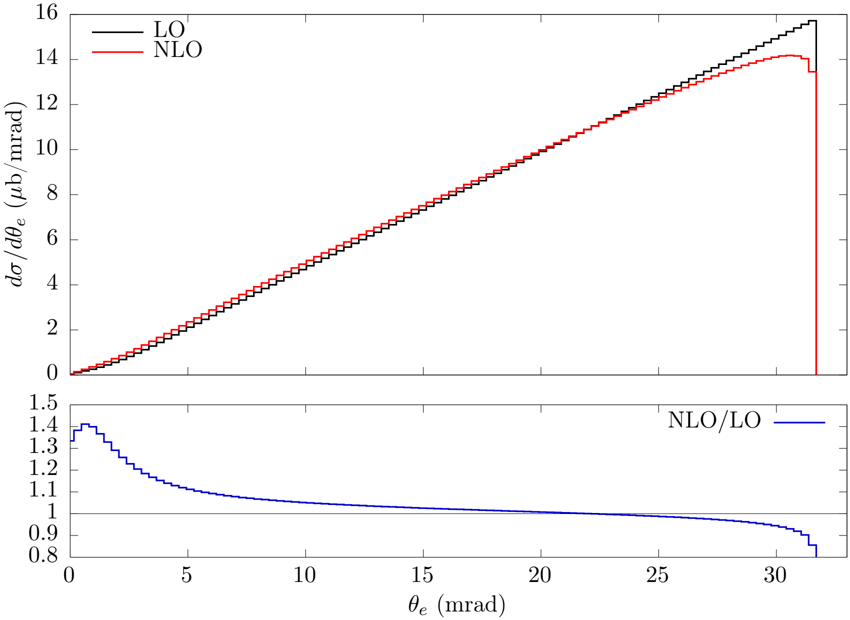
Tuned comparison with independent calculation (Fael) (setup A)



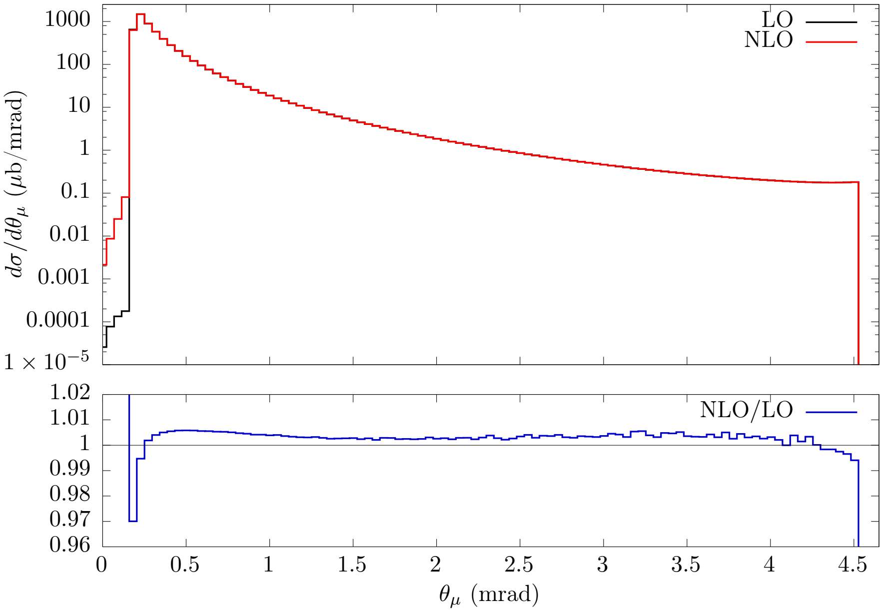
↦ Fael's calculation uses FKS subtraction for IR and collinear singularities

↦ same level of agreement on t_{13} distribution

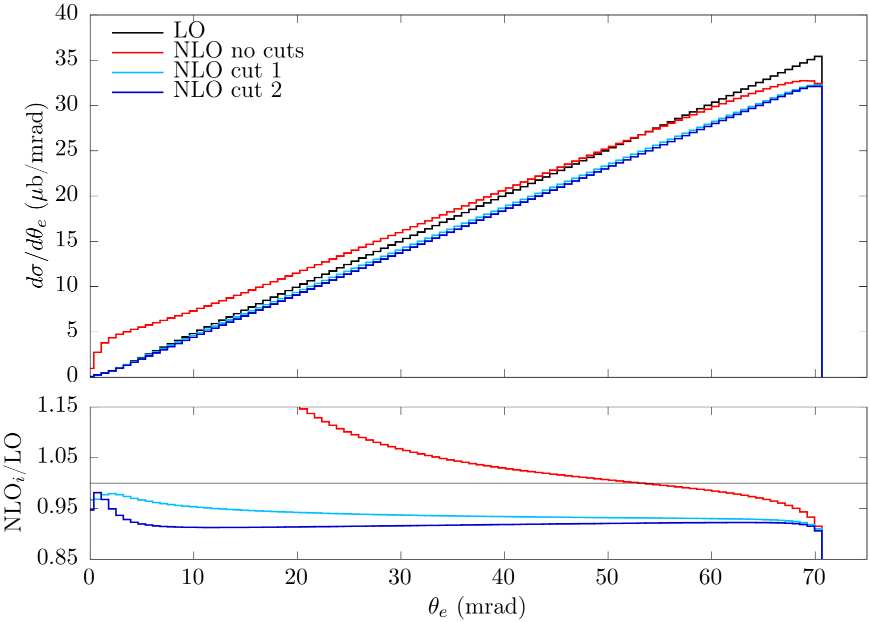
θ_e distribution, incoming μ^-, setup A



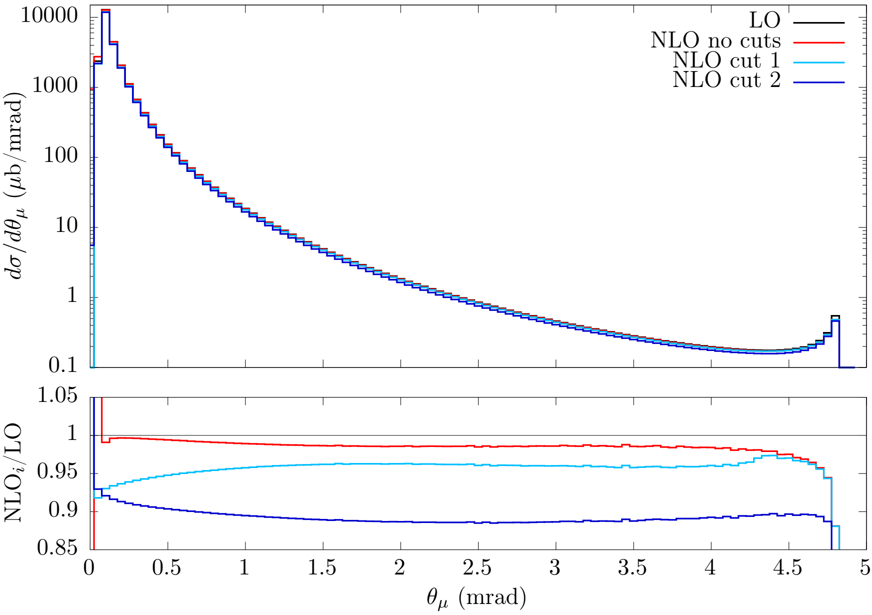
θ_μ distribution, incoming μ^-, setup A



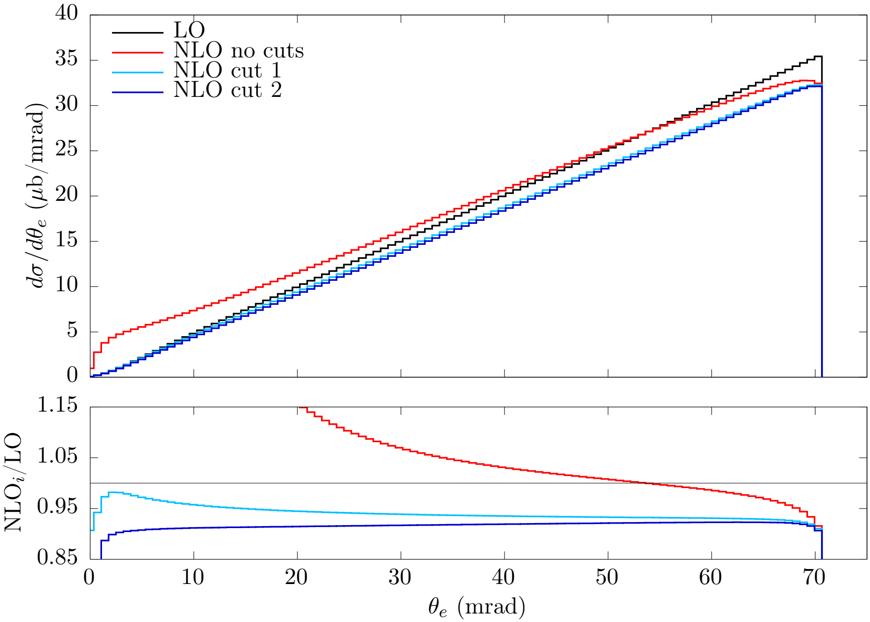
θ_e distribution, incoming μ^-, setup B



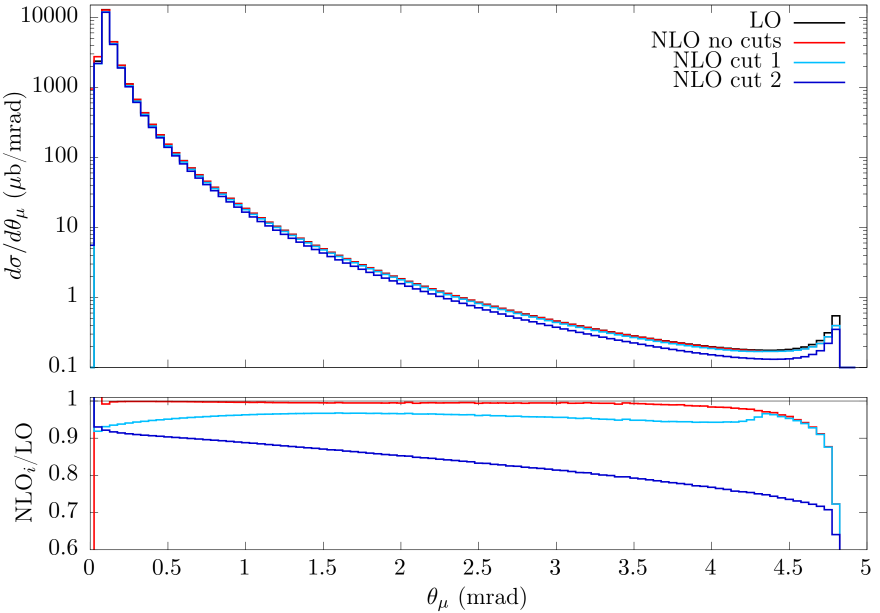
θ_μ distribution, incoming μ^-, setup B



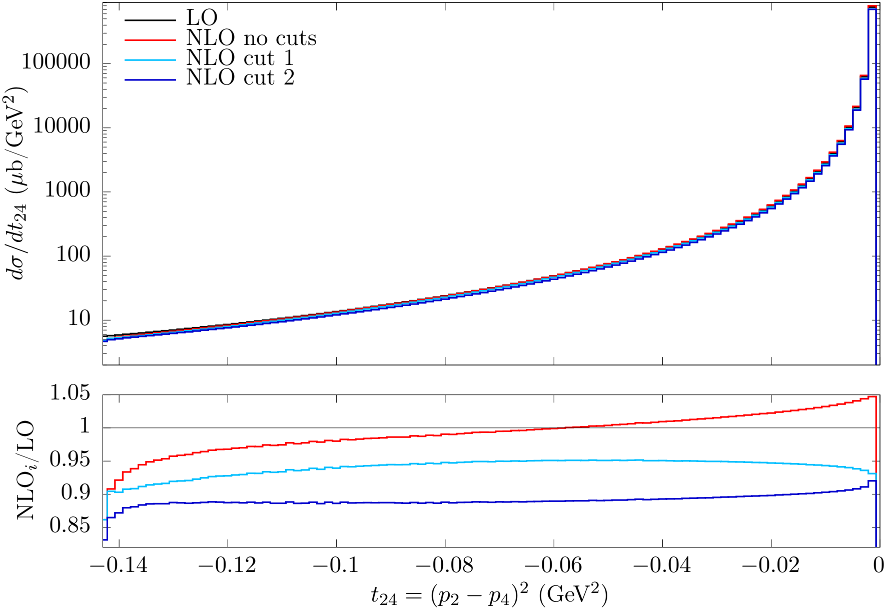
θ_e distribution, incoming μ^+, setup B



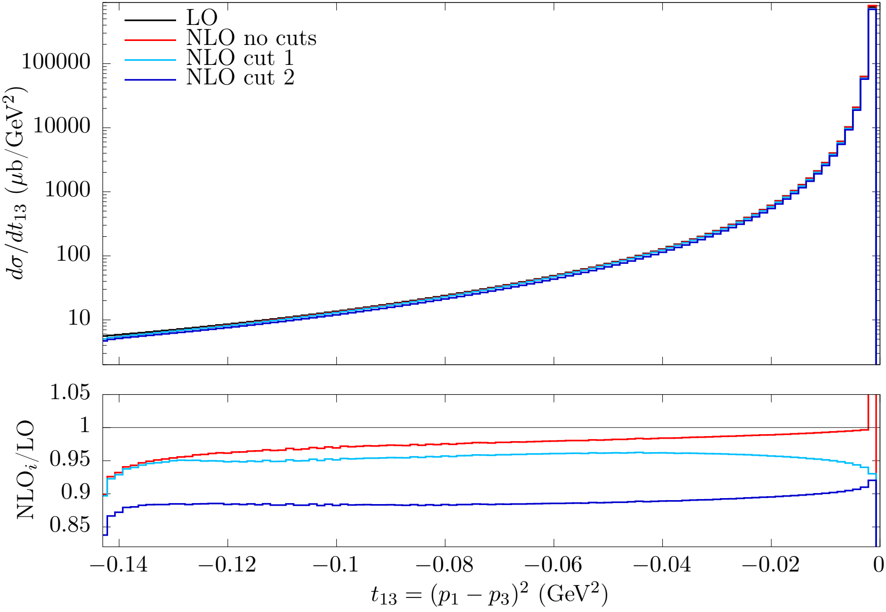
θ_μ distribution, incoming μ^+, setup B



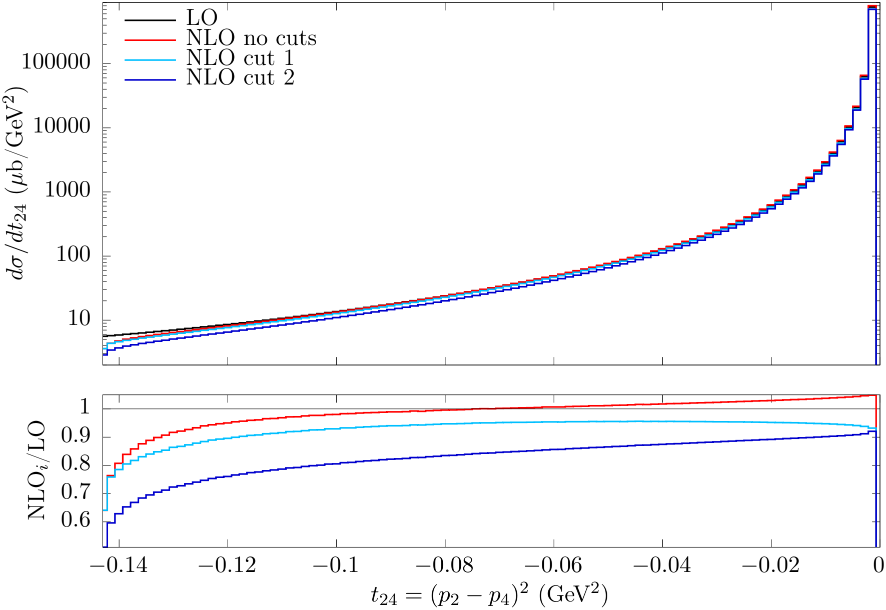
t_{24} distribution, incoming μ^-, setup B



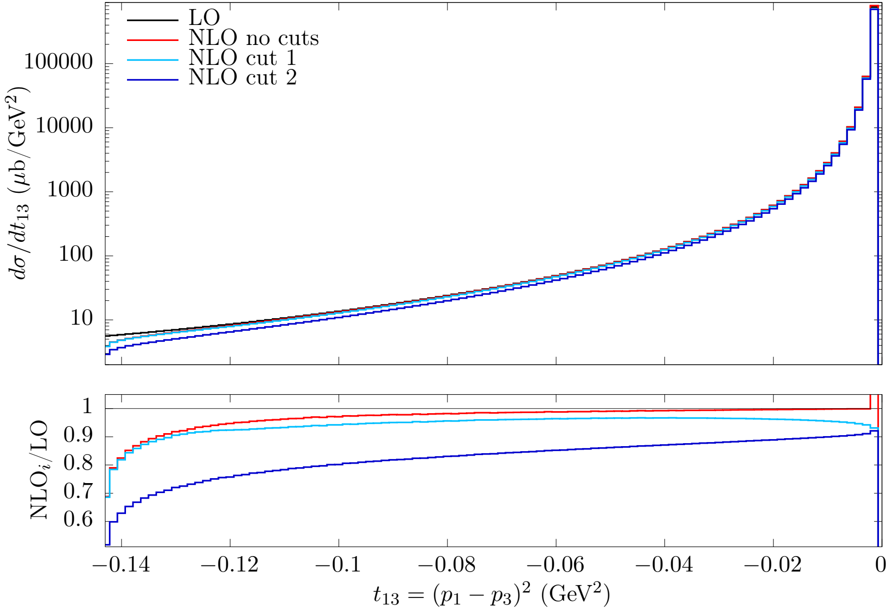
t_{13} distribution, incoming μ^-, setup B



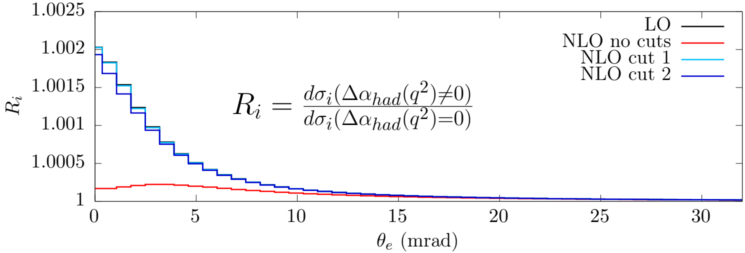
t_{24} distribution, incoming μ^+, setup B

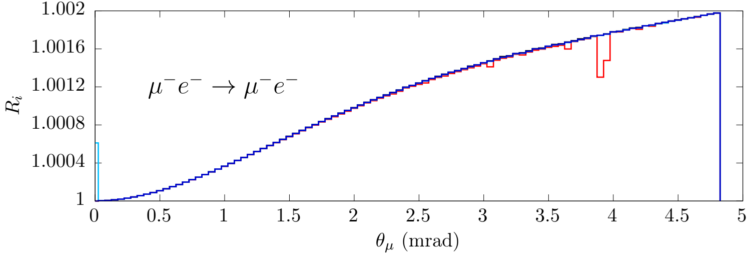


t_{13} distribution, incoming μ^+, setup B



Signal on θ_e and θ_μ distributions, incoming μ^-, setup B

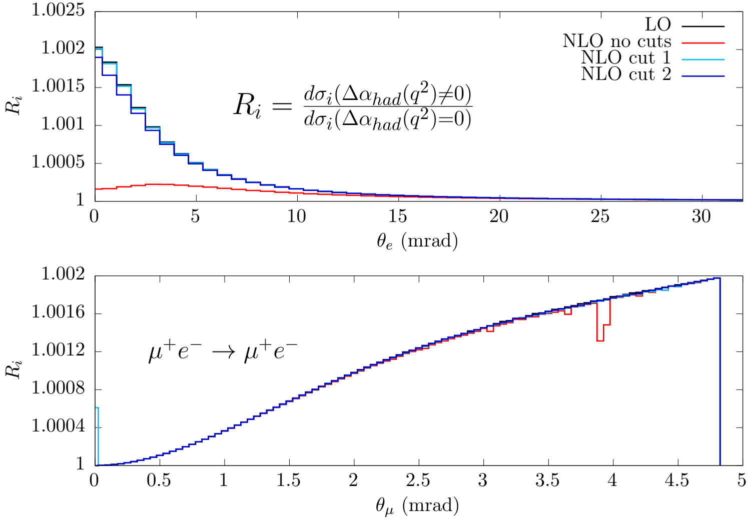




↦ without cuts, NLO RCs destroy the sensitivity to $\Delta\alpha_{had}(q^2)$ on θ_e distribution

↦ θ_μ distribution is much more robust under RCs and applied cuts

Signal on θ_e and θ_μ distributions, incoming μ^+, setup B



- $\mapsto$ without cuts, NLO RCs destroy the sensitivity to $\Delta\alpha_{had}(q^2)$ on θ_e distribution
- $\mapsto$ θ_μ distribution is much more robust under RCs and applied cuts

Conclusions

⋆ The outgoing muon angle seems to be the best observable where to measure $\Delta\alpha_{had}(q^2)$ in μe scattering

↦ a NLO MC generator has been developed

- ⋆ it allows to study the impact and size of RCs
- ⋆ it allows to optimize cuts when extra radiation is emitted
- ⋆ it allows to study sensitivity of the observables to $\Delta\alpha_{had}(q^2)$ and stability under inclusion of RCs and/or cuts

↦ it's a first step towards the inclusion of higher-order RCs and increasing theoretical accuracy