A few non-expert questions on the accuracy of the hadronic mass spectra provided by MC generators

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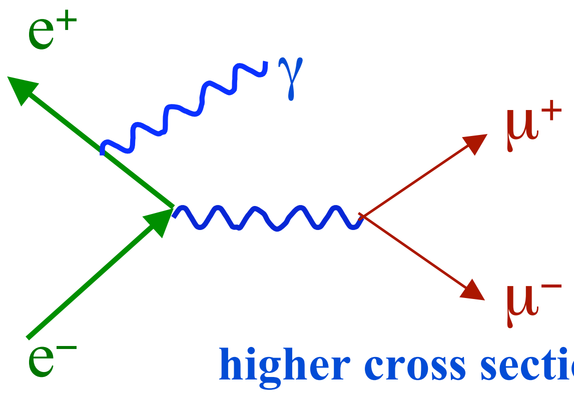
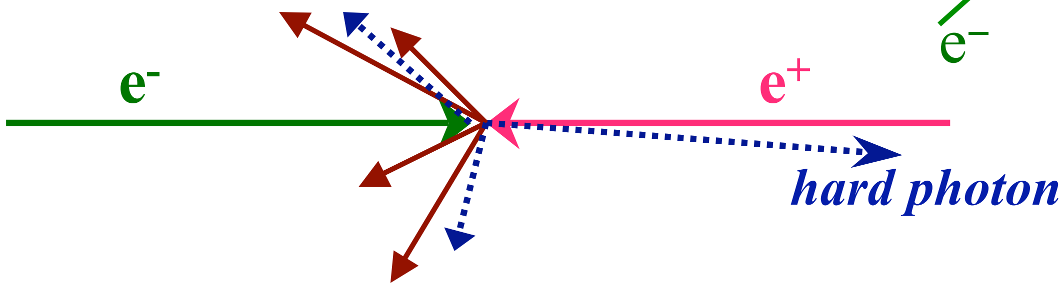
This is rather not a real talk but some questions to experts and an attempt to initiate a discussion on the accuracy of the MC generators for processes with initial state radiaton.

Recent successes in a study of the hadrons production in ee annihilation using ISR approach induced high interest in a clear understanding of the achievable accuracy in the determination of the cross sections from the experimental data as well as a need in the precise and well understood MC generators.

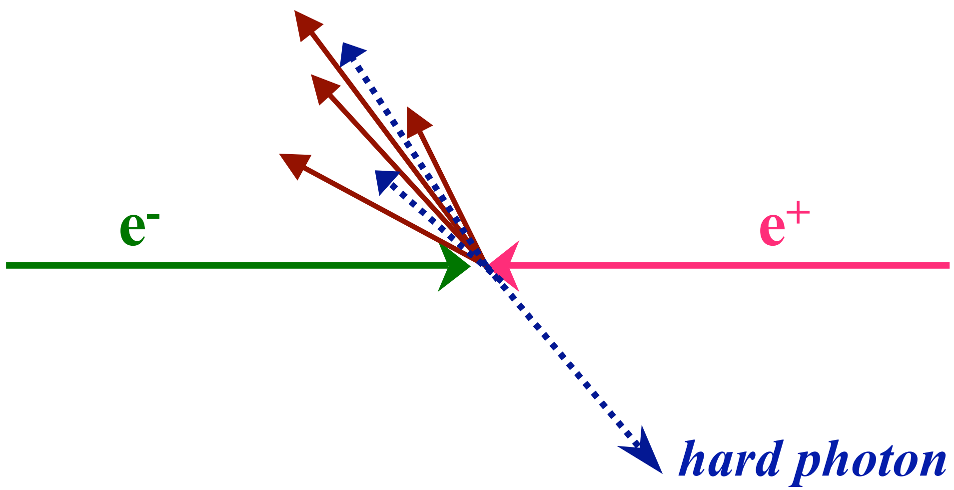
Another motivation to apply more efforts in this field is new projects for super B-factories with luminosity by 50 or more times higher than the present colliders KEKB and PEP-II.

Two approaches



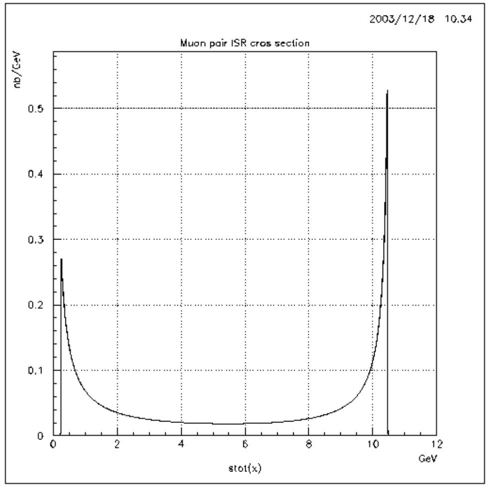


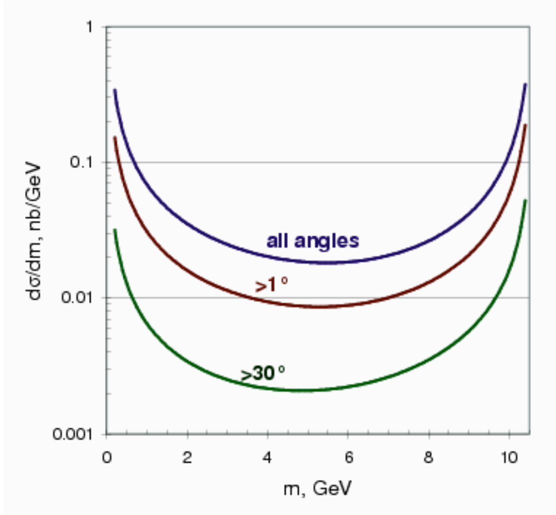
higher cross section,
but
partial reconstraction,
higher background



full reconstraction,
low background
but
lower cross section,

$e^+e^- \to \mu^+\mu^-\gamma, \pi^+\pi^-\gamma$





$R = \sigma_{study}/\sigma(e^+e^- \to \mu^+\mu^-)$

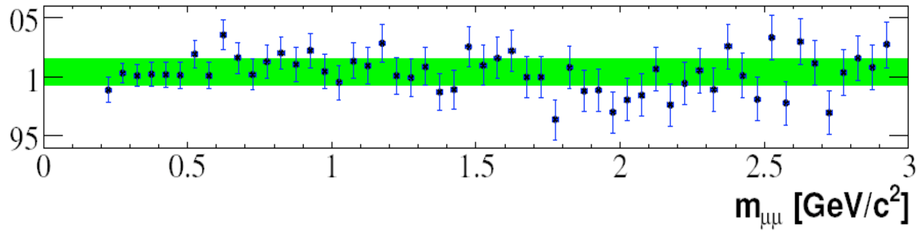
$$\frac{d\sigma}{dm} = \frac{0.4035[nb \cdot GeV^2]}{s[GeV^2]} \frac{R(m^2)}{m} \left[\frac{s^2+m^4}{s(s-m^2)} (\ln \frac{s}{m_e^2} - 1) \right]$$

$$\frac{d\sigma}{dm} = \frac{0.4035(nb)}{s(GeV^2)} \frac{R(m)}{m} \left[\frac{s^2+m^4}{s(s-m^2)} \ln \frac{1+z_{\min}}{1-z_{\min}} - \frac{s-m^2}{s} z_{\min} \right], \quad z_{\min} = \cos\theta_{\min}$$

$$\frac{n_{\pi\pi\gamma}(m)}{n_{\mu\mu\gamma}(m)} = \frac{\beta_\pi^3 |F_\pi^2|}{2\beta_\mu(3-\beta_\mu^2)} \quad \Rightarrow \quad \frac{\varepsilon_\pi}{\varepsilon_\mu} \cdot \frac{\delta_\pi^{NLO}(F_\pi)}{\delta_\mu^{NLO}}$$

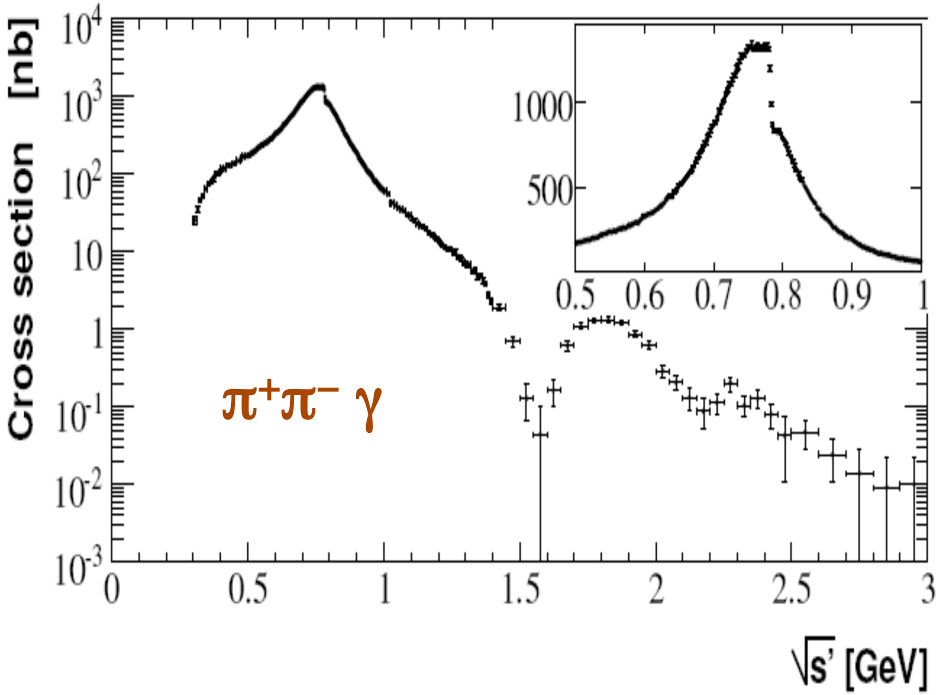
$\mu^+\mu^-\gamma$,$\pi^+\pi^- \gamma$ from BaBar

$\mu^+\mu^-\gamma$ - exp/QED



$$\frac{\sigma^{data}_{\mu\mu\gamma}}{\sigma^{NLO\,QED}_{\mu\mu\gamma}} = 1 + (4.0 \pm 2.0 \pm 5.5 \pm 9.4) \times 10^{-3}$$

Stat. Syst. Lumi.



The systematic accuracy includes the precision of the simulation. Thus the accuracy of MC generator should be much better than 1%.

The accuracy of better than 1% is stated for all modern MC generators (Phokhara, BHwide, KKMC, Baba-yaga etc. The estimation of this accuracy is based on the estimations of the values of the terms of higher orders.

What is the accuracy of the MC simulation? Authors of MC generators give a precision of 0.1 – 0.5%, that is, however, concerns rather total cross sections than the differential ones. How we can prove the accuracy?

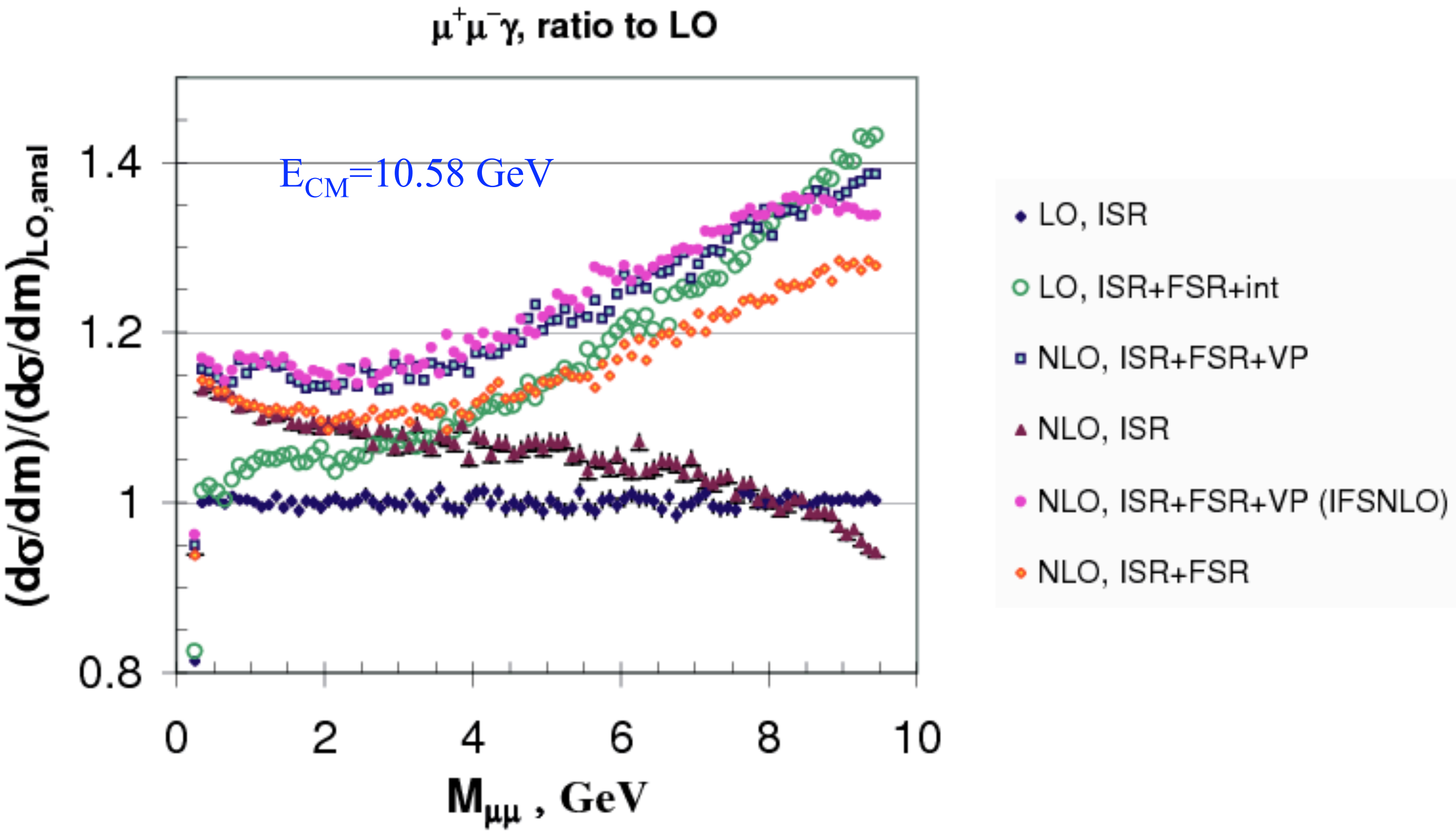
A primitive idea – just to look, first of all, to the difference between calculations in LO and NLO:

$$\delta = \frac{\left(\frac{d\sigma}{dm}\right)_{LO} - \left(\frac{d\sigma}{dm}\right)_{NLO}}{\left(\frac{d\sigma}{dm}\right)_{LO}}$$

Possible yeilds:

1. **δ is small (O(1%)) - we are satisfied since NNLO contribution should be (much) less than NLO from a common sense.**
2. **δ is large (O(100%)) – we are thoughtful**
3. **δ is in between (O(10%)) – additional prove of the NNLO contributions are needed.**

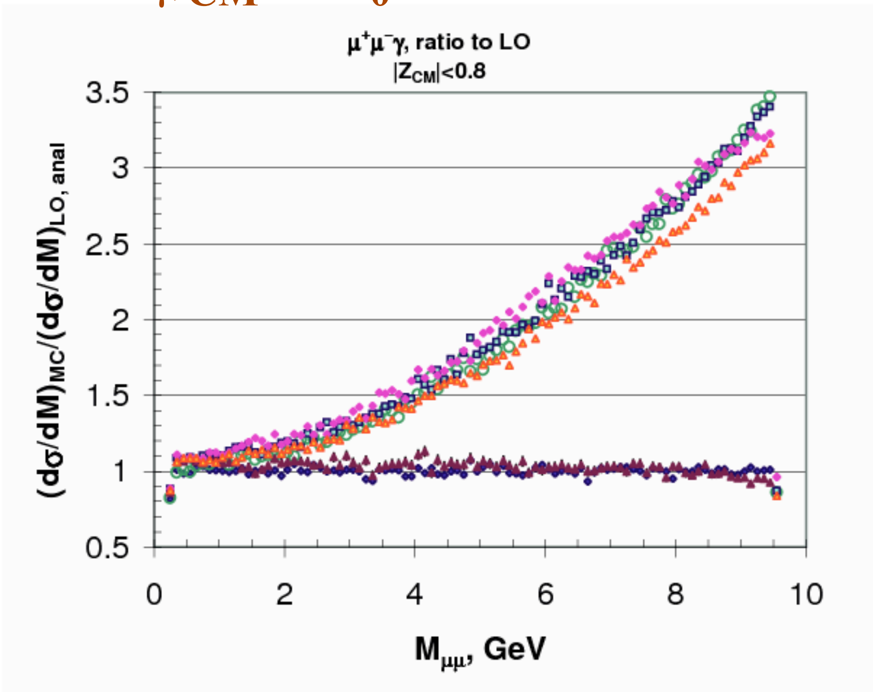
The Phokhara generator is quite covenient for that study.

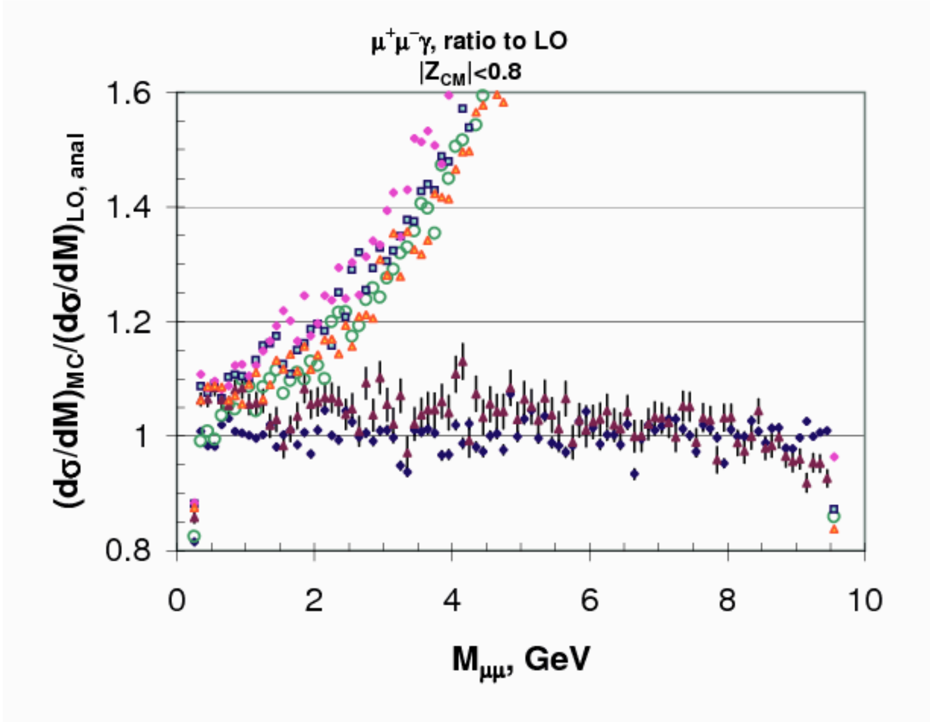


As seen, the NLO contribution is from 15% near threshold to about 40% at M=10 GeV.

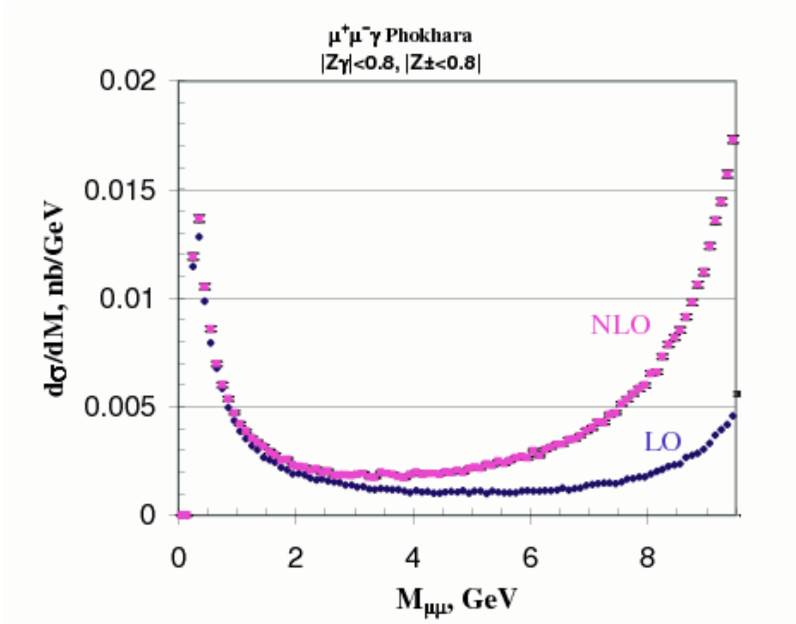
What is the values of the higher terms which are neglected?

The μ+μ–γ cross section in the limited acceptance $\cos\theta_{CM} = Z_{\gamma,CM} < Z_0$

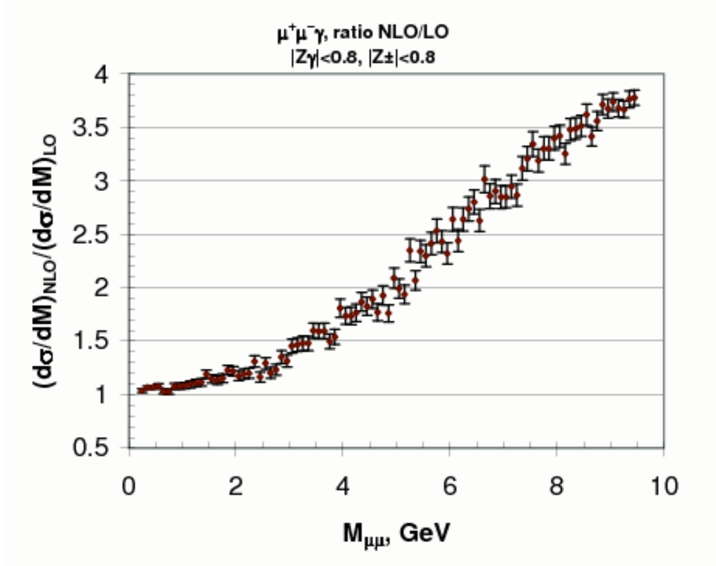




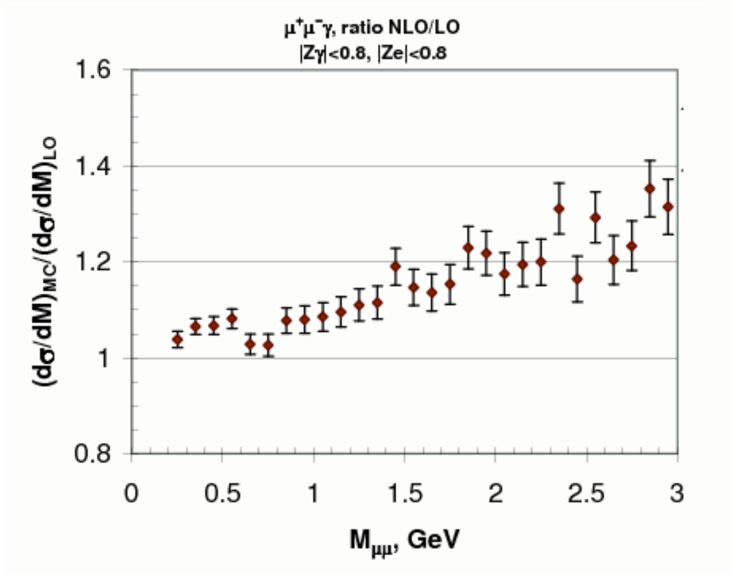
- ♦ LO, ISR
- ○ LO, ISR+FSR+int
- ▲NLO, ISR
- ▲NLO, ISR+FSR
- □ NLO, ISR+FSR+VP
- ● NLO, ISR+FSR+VP(IFSNLO)



$\mu^+\mu^-\gamma$ Phokhara
|Zγ|<0.8, |Z±<0.8|
dσ/dM, nb/GeV
NLO
LO
$M_{\mu\mu}$, GeV



$\mu^+\mu^-\gamma$, ratio NLO/LO
|Zγ|<0.8, |Z±|<0.8
$(d\sigma/dM)_{NLO}/(d\sigma/dM)_{LO}$
$M_{\mu\mu}$, GeV



$\mu^+\mu^-\gamma$, ratio NLO/LO
|Zγ|<0.8, |Ze|<0.8
$(d\sigma/dM)_{MC}/(d\sigma/dM)_{LO}$
$M_{\mu\mu}$, GeV

The value of δ is 10-20% in the range $m_{\mu\mu} < 3$ GeV. What is the value of the neglected terms of the high orders?

At high masses the FSR is clearly dominated. What is the accuracy of the calculations?