

Status of MC generators for radiative return

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Motivation - what is the radiative return

What do we have on the market

Tests - comparisons, which were performed

My wish list

What do we like to measure and why:

WHAT : $\sigma(e^+e^- \rightarrow \text{hadrons})$

WHY:

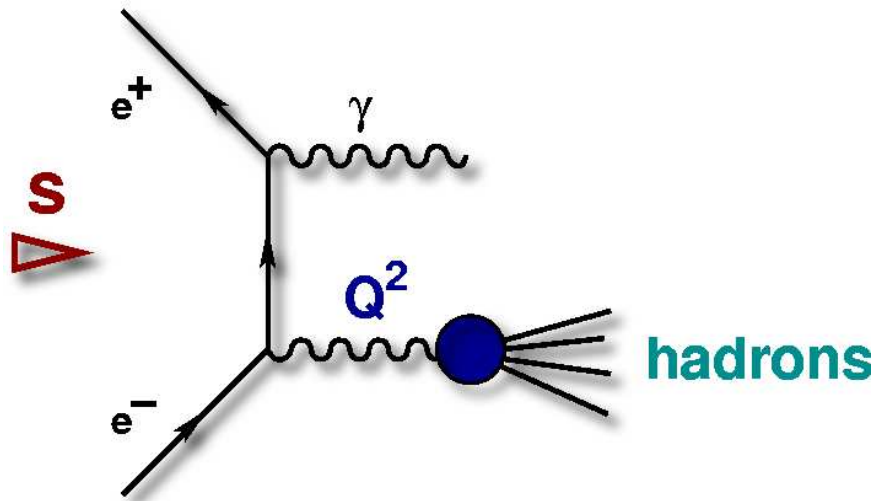
$$a_{\mu}^{\text{had,LO}} = \frac{\alpha^2}{3\pi^2} \int_{4m_{\pi}^2}^{\infty} \frac{ds}{s} K(s) R(s)$$

$$R(s) = \frac{\sigma(e^+e^- \rightarrow \text{hadrons})}{\sigma_{\text{point}}}$$

THE RADIATIVE RETURN METHOD

$$d\sigma(e^+e^- \rightarrow \text{hadrons} + \gamma(\text{ISR})) =$$

$$H(Q^2, \theta_\gamma) d\sigma(e^+e^- \rightarrow \text{hadrons})$$



- ▶ measurement of $R(s)$ over the full range of energies, from threshold up to \sqrt{s}
- ▶ large luminosities of factories compensate α/π from photon radiation
- ▶ radiative corrections essential (NLO,...)

High precision measurement of the hadronic cross-section
at meson-factories

From EVA to PHOKHARA and ...

EVA: $e^+e^- \rightarrow \pi^+\pi^-\gamma$

- tagged photon ($\theta_\gamma > \theta_{cut}$)
- ISR at LO + Structure Function
- FSR: point-like pions

[Binner et al.]

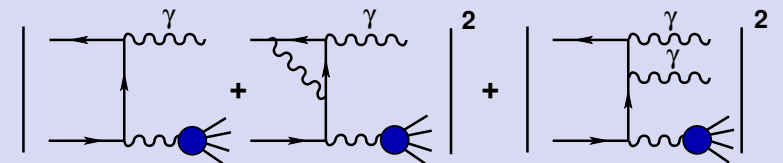
$e^+e^- \rightarrow 4\pi + \gamma$

- ISR at LO + Structure Function

[Czyż, Kühn]

PHOKHARA 5.1: $\pi^+\pi^-$,
 $\mu^+\mu^-$, 4π , $\bar{N}N$, 3π , KK

- **ISR at NLO:** virtual corrections to one photon events and two photon emission at tree level



- **FSR at NLO:** $\pi^+\pi^-$, $\mu^+\mu^-$, K^+K^-
- tagged or untagged photons
- Modular structure

<http://cern.ch/german.rodriego/phokhara>

From EVA to ...

$$e^+e^- \rightarrow 4\pi + \gamma$$

- ISR at LO + Structure Function

[Czyż, Kühn]



$$e^+e^- \rightarrow \text{hadrons} + \gamma$$

- upgraded by BaBar - not public (?)
- PHOTOS [Barberio et al.] for FSR

$$\text{EVA: } e^+e^- \rightarrow \pi^+\pi^-\gamma$$

- tagged photon ($\theta_\gamma > \theta_{cut}$)
- ISR at LO + Structure Function
- FSR: point-like pions

[Binner et al.]



$$e^+e^- \rightarrow \pi^+\pi^- + \gamma$$

- FSR studies

[Pancheri, Shekhovtsova, Venanzoni]

KKMC

S. Jadach, B. F. L. Ward and Z. Was

- ▶ YFS exponentiation
- ▶ high accuracy only for muon pairs
- ▶ can we hope for: upgrades ???
broader collaboration ???

Summary

- We found very good agreement of KKMC and PHOKHARA to within 0.2% for μ -pair final states for pure ISR
- Discrepancy of order 1-2% between KKMC and PHOKHARA or even larger at low mass, was found for π -pair final state.
- This is due to use of the inferior EEX matrix element in KKMC instead of CEEX.
- NB. We know how to upgrade ISR in KKMC to CEEX level for any hadronic final state...

Dubna - Novosibirsk papers 2003

A. B. Arbuzov, E. Bartos (Bratislava),
V. V. Bytev, E. A. Kuraev, Z. K. Silagadze

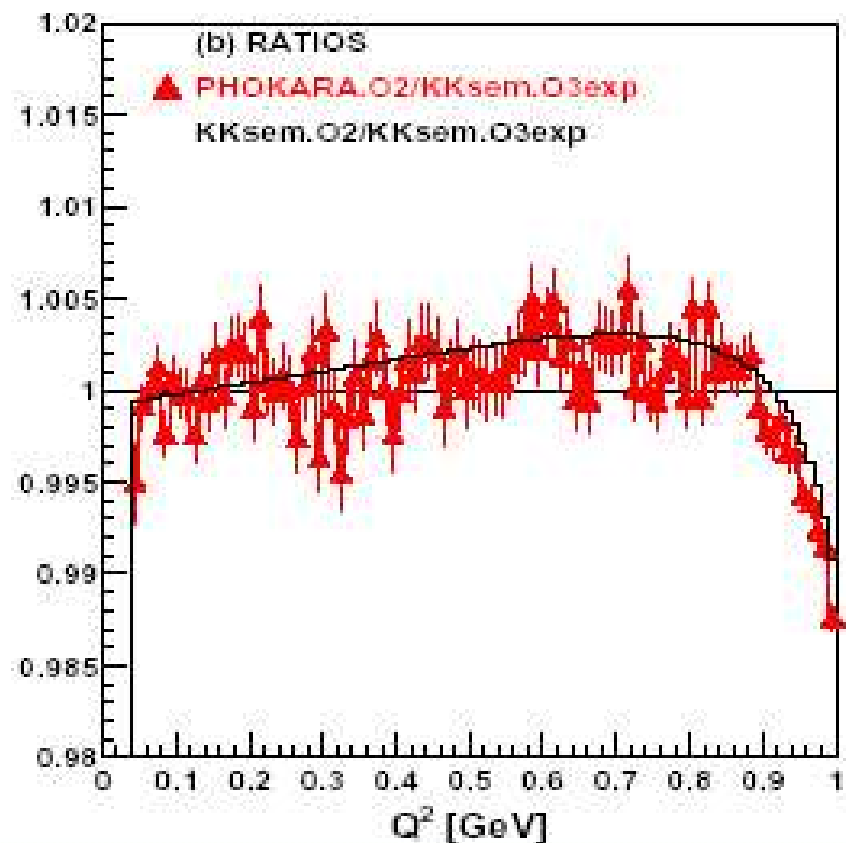
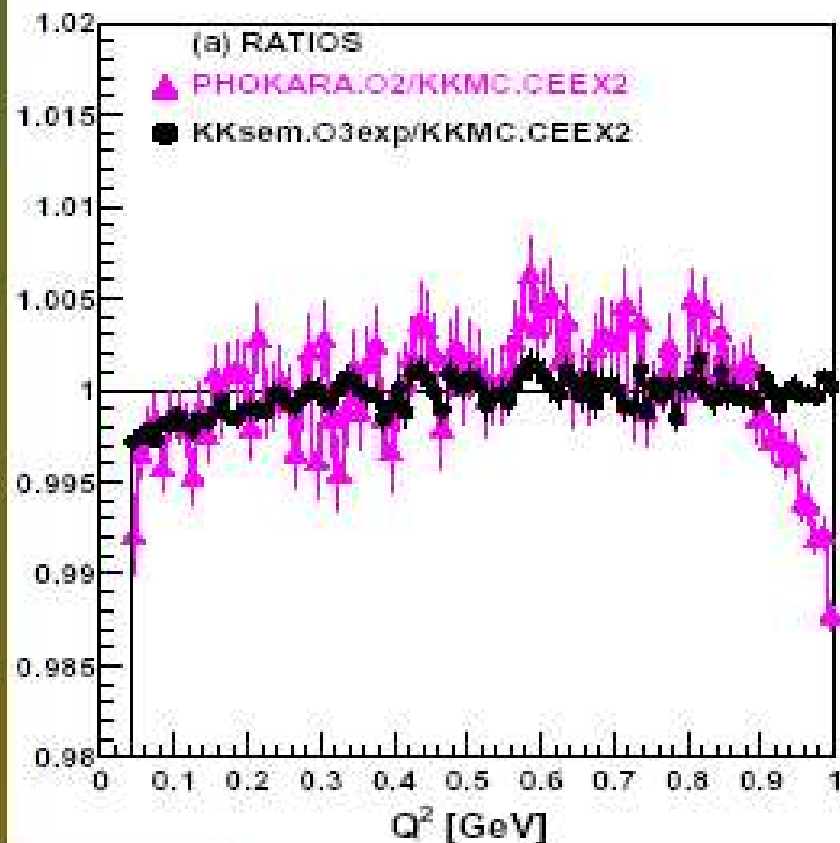
▶ muon and pion (??) pairs

▶ analytic formulae based on RG - SF

▶ Question:

is a MC or at least a numerical code
available for comparisons ?

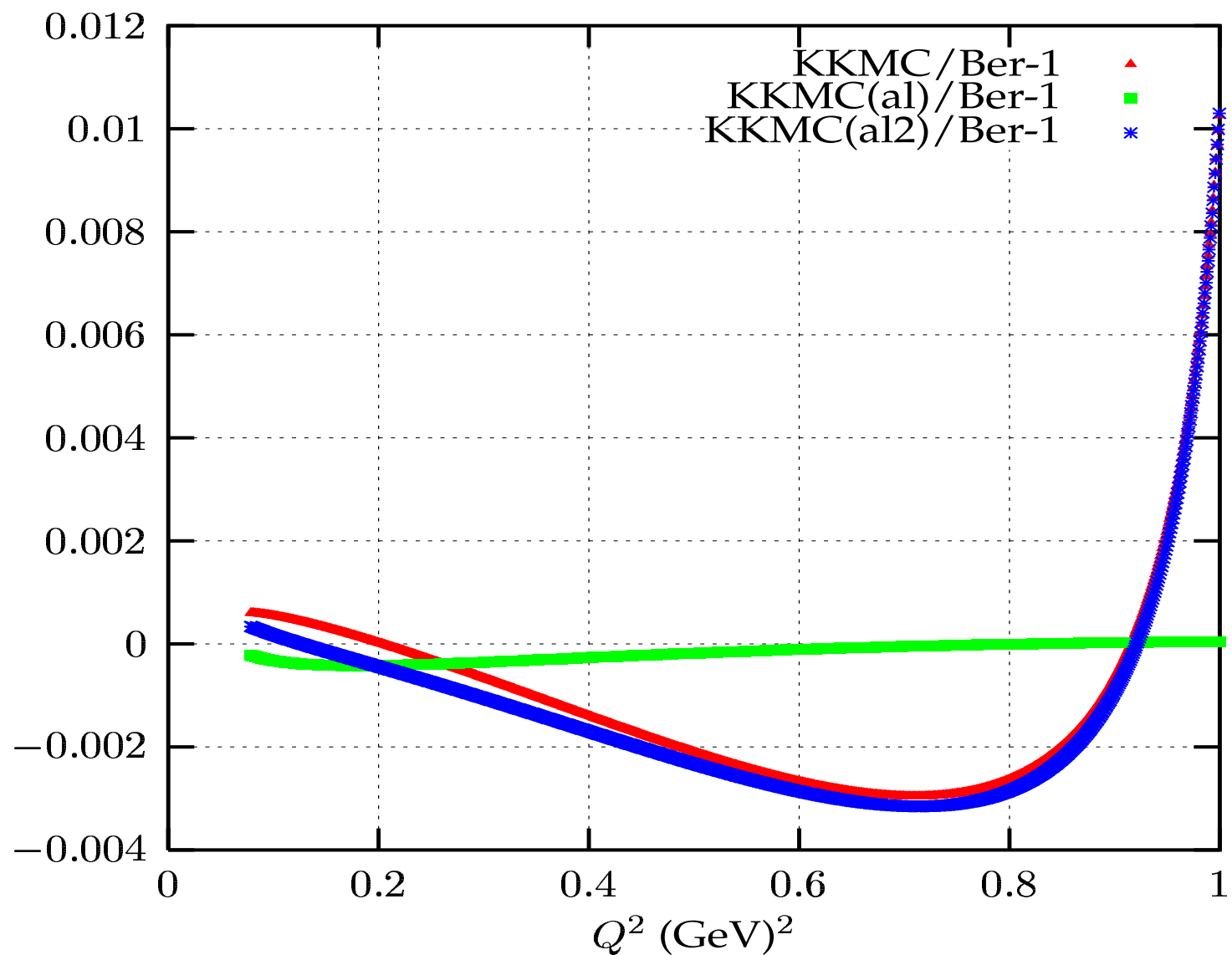
PHOKHARA included in the game, μ -pairs again



PHOKHARA agrees to within 0.3% with KKMC and KKsem.

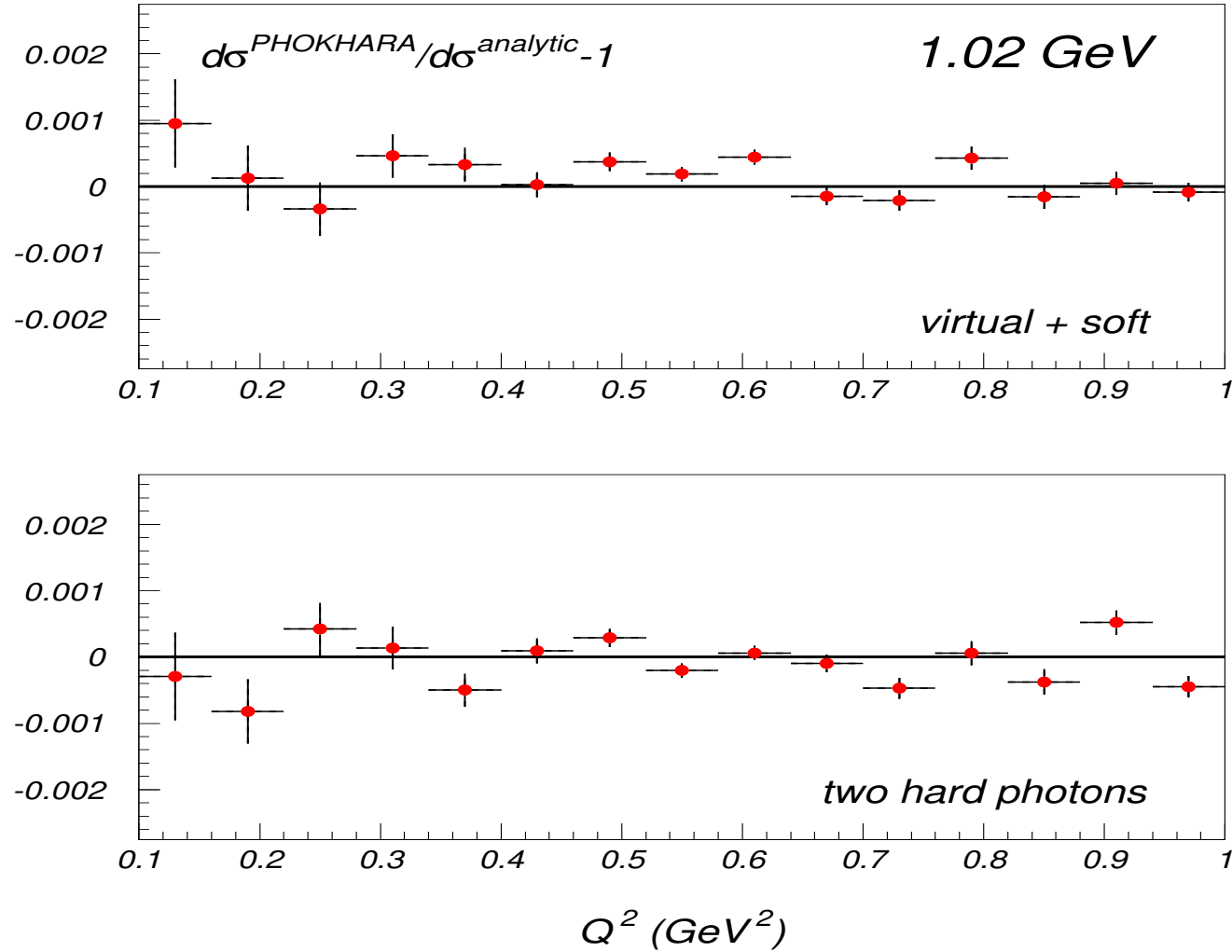
Discrepancy at high Q^2 reflects lack of exponentiation in PHOKHARA

PHOKHARA vs. KKMC cnd.



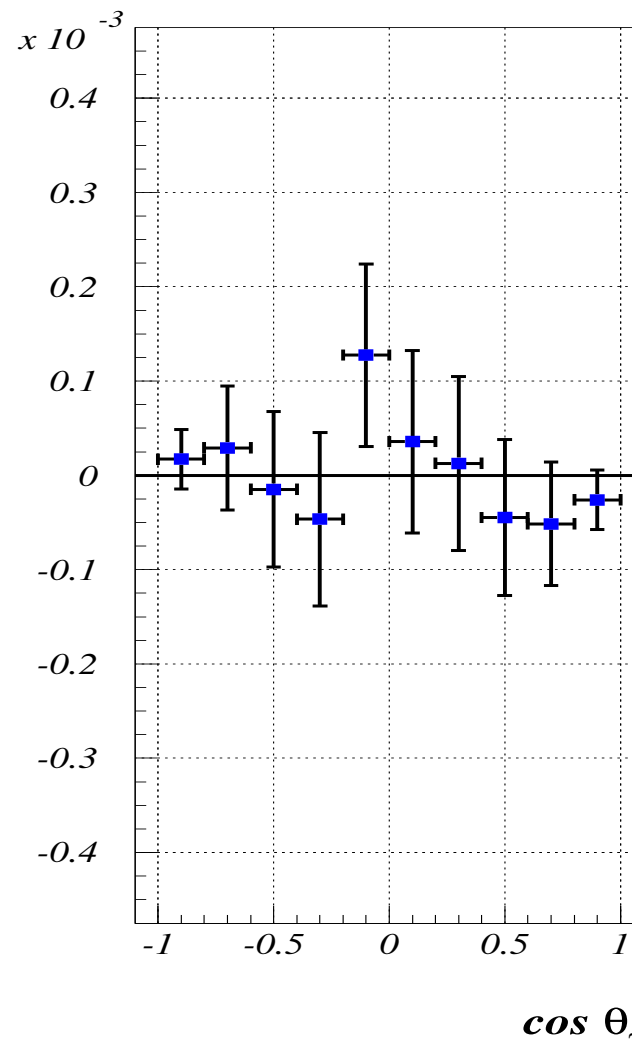
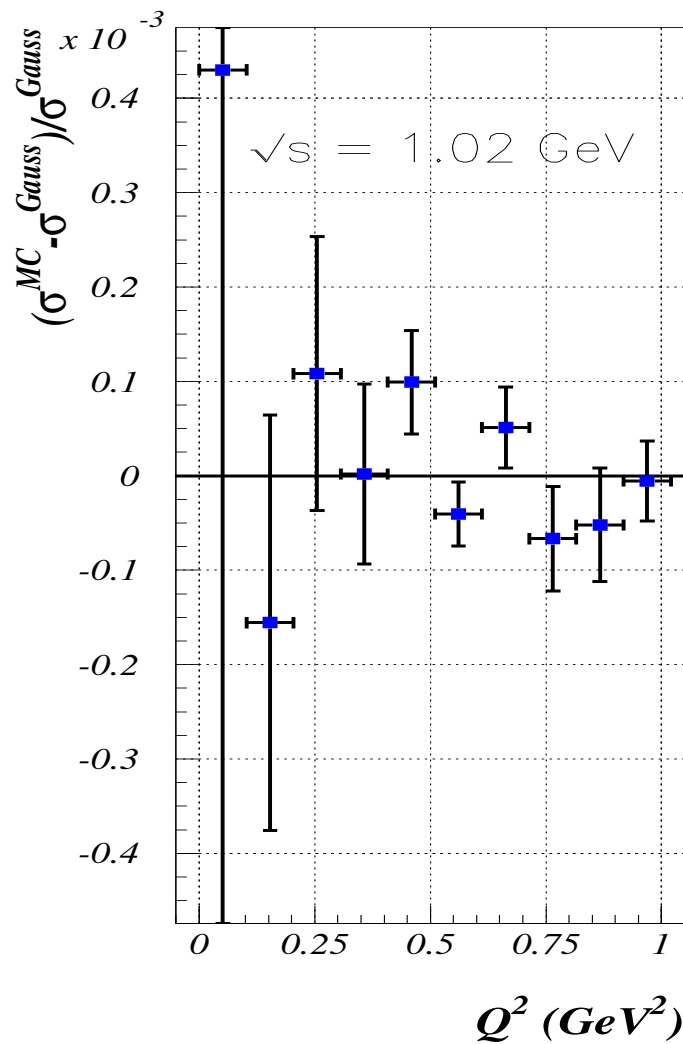
PHOKHARA generation tests

H. Czyż, A. Grzeźlińska, J.H. Kühn and G. Rodrigo EPJ C27 (2003)563



PHOKHARA generation tests

G. Rodrigo, H. Czyż, J.H. Kühn and M. Szopa, Eur.Phys.J.C24 (2002)71



KKMC vs. PHOKHARA - ISR virt. corr.

C. Glosser, S. Jadach, B. F. L. Ward and S. A. Yost
Phys. Lett. B **605** (2005) 123;
Phys. Rev. D **73** (2006) 073001

▶ a precision $1.5 \cdot 10^{-5}$

▶ not direct tests

My wish list

- ▶ benchmark for ISR NLO
separately (?) for virtual and real corrections
- ▶ benchmark for ISR NNLO ???
What accuracy do we need ?
- ▶ beyond ISR for muon and pion pairs:
testing the codes and FSR models
- ▶ collect the results of separate code tests
and comparisons