RADIATIVE RETURN AND THE PHOKHARA MONTE CARLO EVENT GENERATOR

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S.Binner, J.H.Kuehn and K.Melnikov, PLB459(1999)279
H.C., J.H.Kuehn, EPJ C18 (2001)497
G.Rodrigo, A.Gehrmann, M.Guilleaume and J.H.Kuehn, EPJ C22(2001)81
G.Rodrigo, H.C., J.H.Kuehn and M.Szopa, EPJ. C24(2002)71
G.Rodrigo, J.H.Kuehn, hep-ph/0204283
H.C., J.H.Kuehn, G.Rodrigo, in preparation

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EURIDICE START-OFF MEETING
FRASCATI, OCTOBER 2002

RADIATIVE RETURN

ALLOWS MEASUREMENT OF $R(Q^2)$

FROM THRESHOLD TO $Q^2 = S$

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

LARGE LUMINOSITIES OF FACTORIES

(DAΦNE, CLEO-C, B- FACTORIES)

ALLOWS FOR PRECISE MEASUREMENTS

ADVANTAGE OVER ENERGY SCAN:

-NORMALIZATION NEEDED ONLY ONCE

-NO DEDICATED EXPERIMENT NEEDED

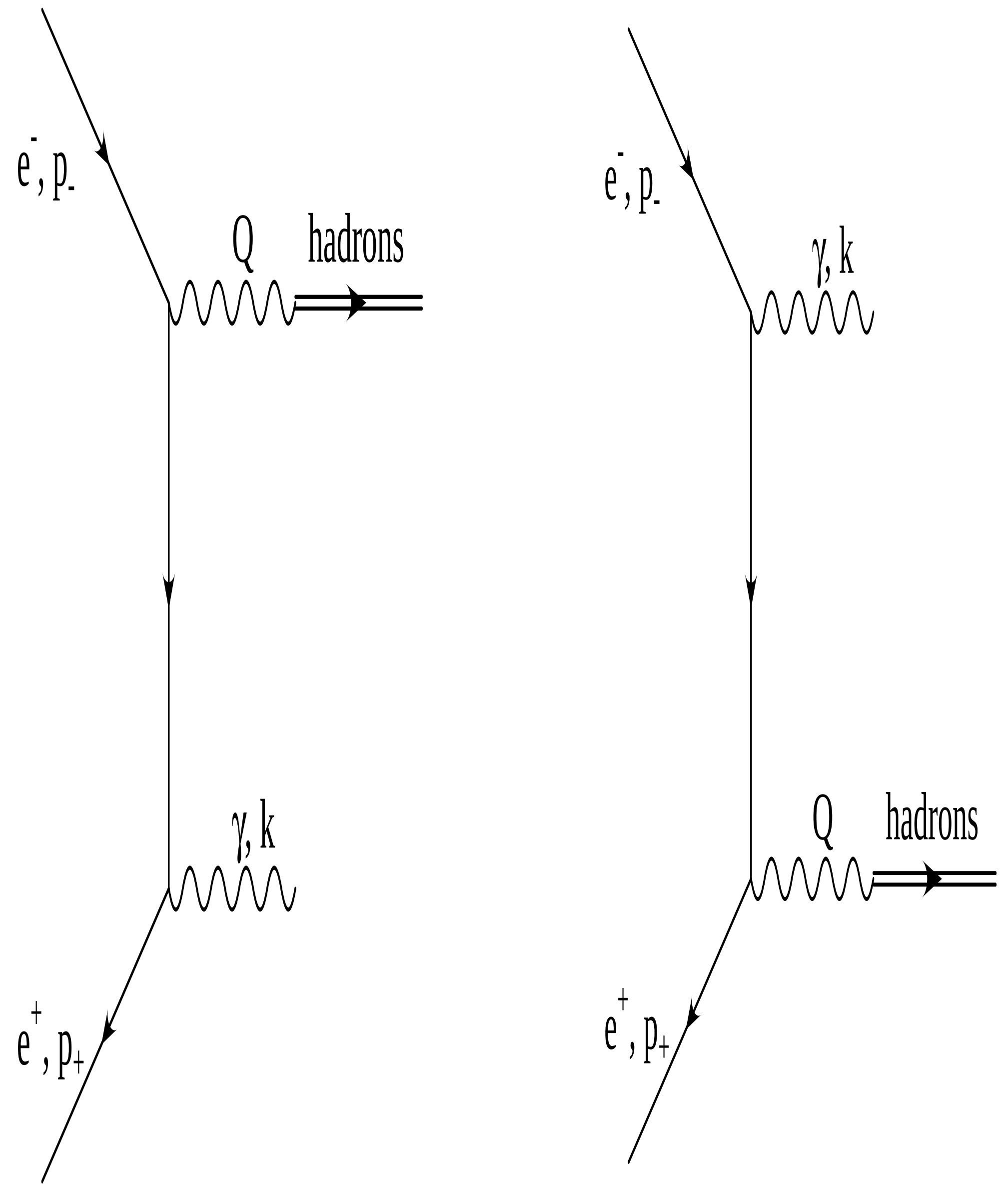
PHOKHARA :
MC EVENT GENERATOR

1.0 :

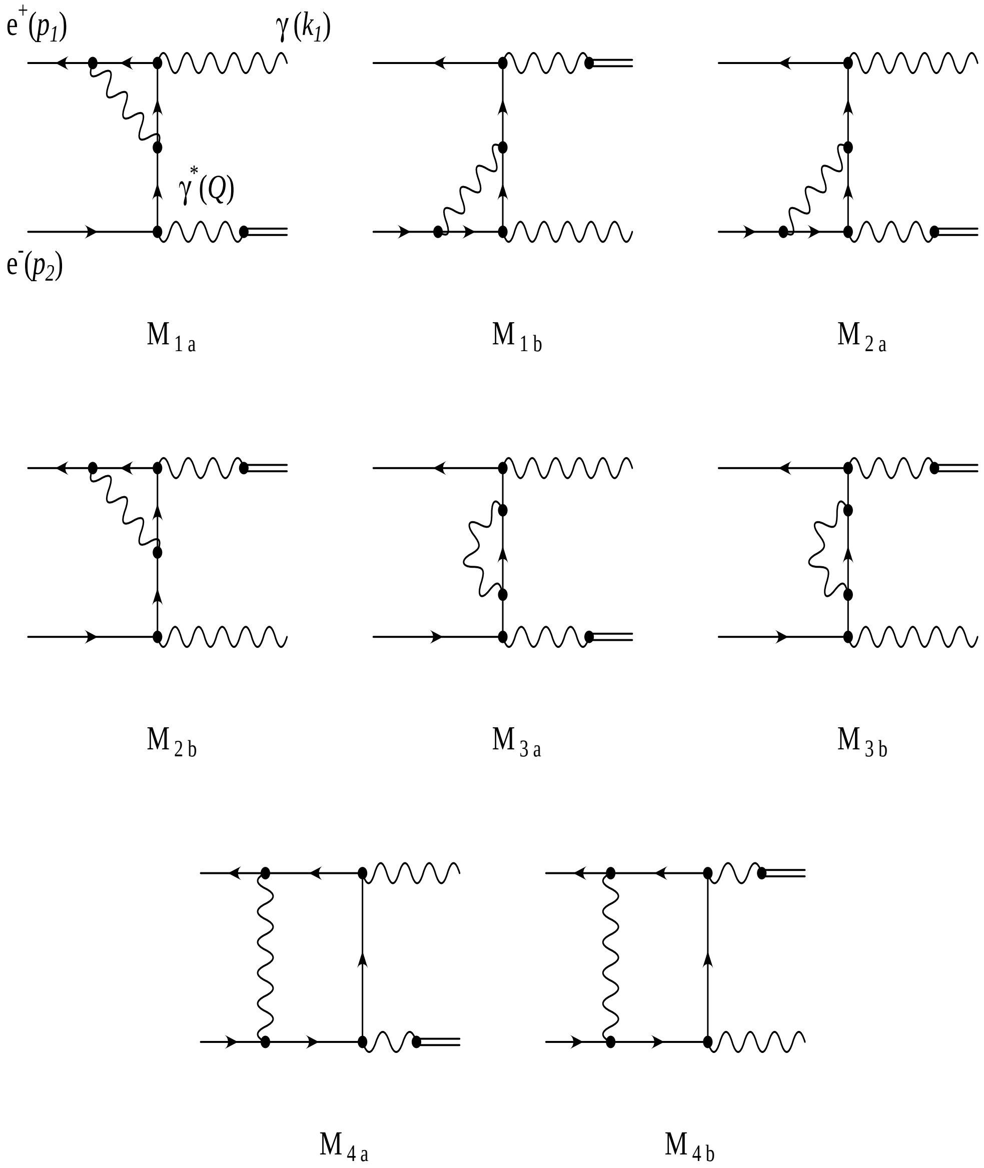
- **RELEASED DEC. 2001**
- $\pi^+\pi^-$ **and** $\mu^+\mu^-$
- **VIRTUAL + SOFT + HARD CORRECTIONS TO ISR**

NEW FEATURES:

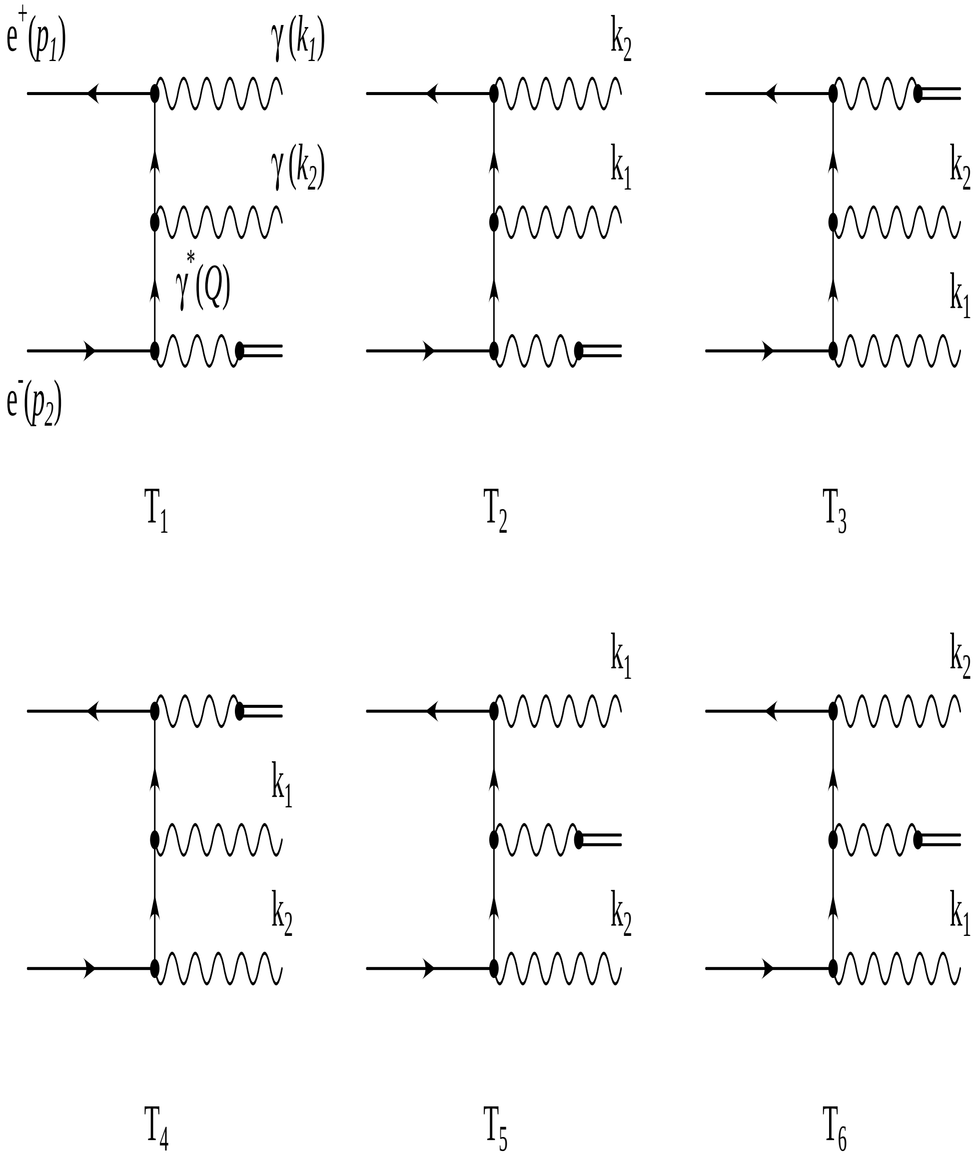
- **SMALL PHOTON ANGLES TESTED**
- **FSR FOR 2 PIONS AND MUONS INLCUDED**
- **4 π FINAL STATES ADDED**



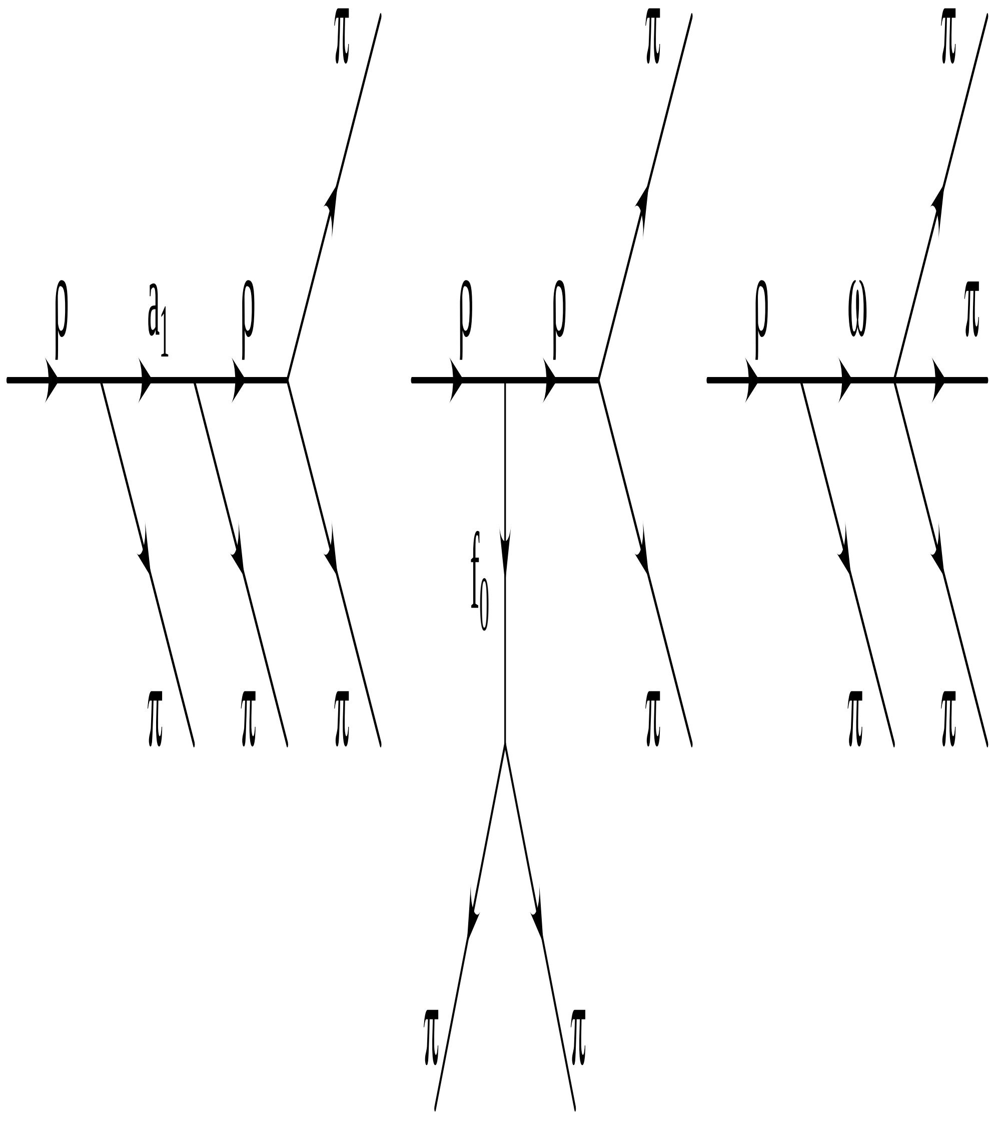
e-, p-
Q
hadrons
γ, k
e+, p+
e-, p-
γ, k
Q
hadrons
e+, p+



$e^+(p_1)$
$\gamma(k_1)$
$\gamma^*(Q)$
$e^-(p_2)$
M_{1a}
M_{1b}
M_{2a}
M_{2b}
M_{3a}
M_{3b}
M_{4a}
M_{4b}

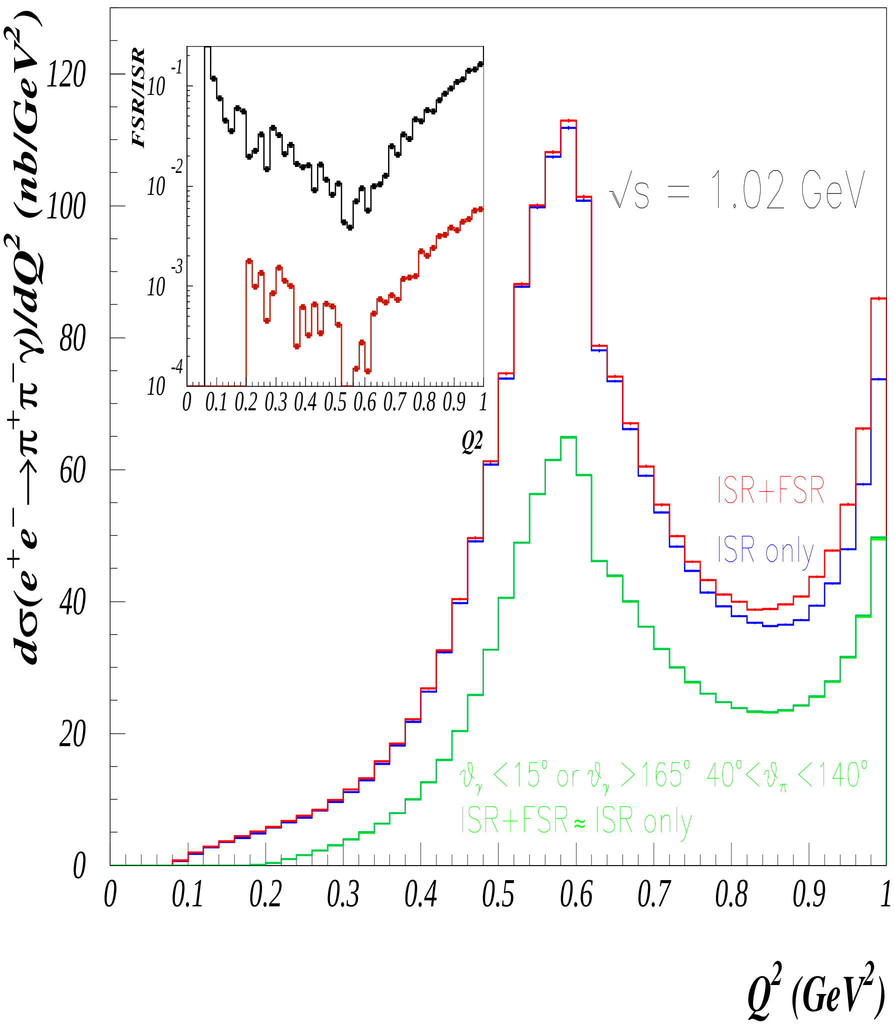


$e^+(p_1)$
$\gamma(k_1)$
$\gamma(k_2)$
$\gamma^*(Q)$
$e^-(p_2)$
k_2
k_1
k_2
k_1
T_1
T_2
T_3
k_1
k_2
k_1
k_2
k_2
k_1
T_4
T_5
T_6

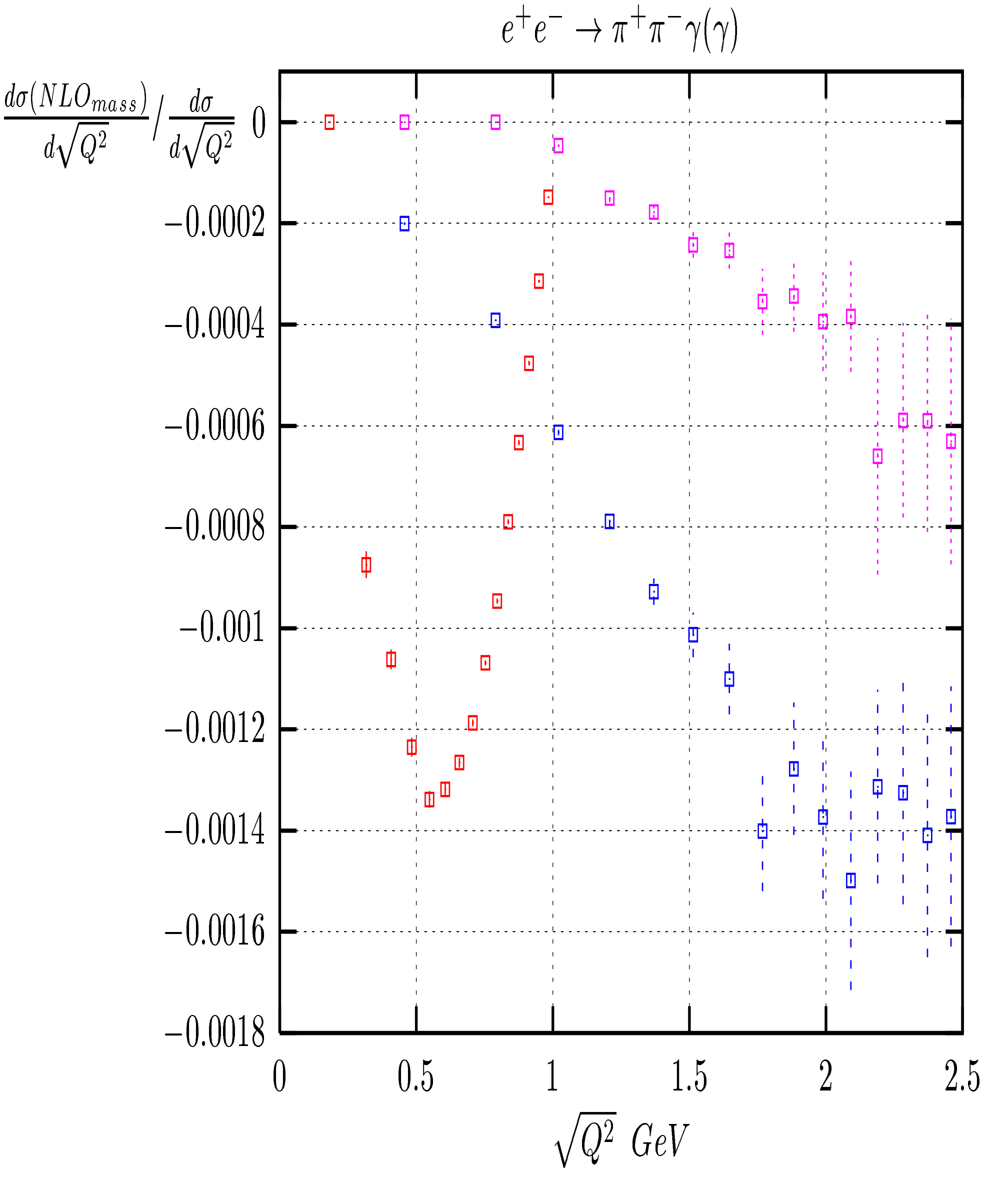


ρ
a1
ρ
π
π
π
π
ρ
ρ
f0
π
π
π
π
ρ
ω
π
π
π
π

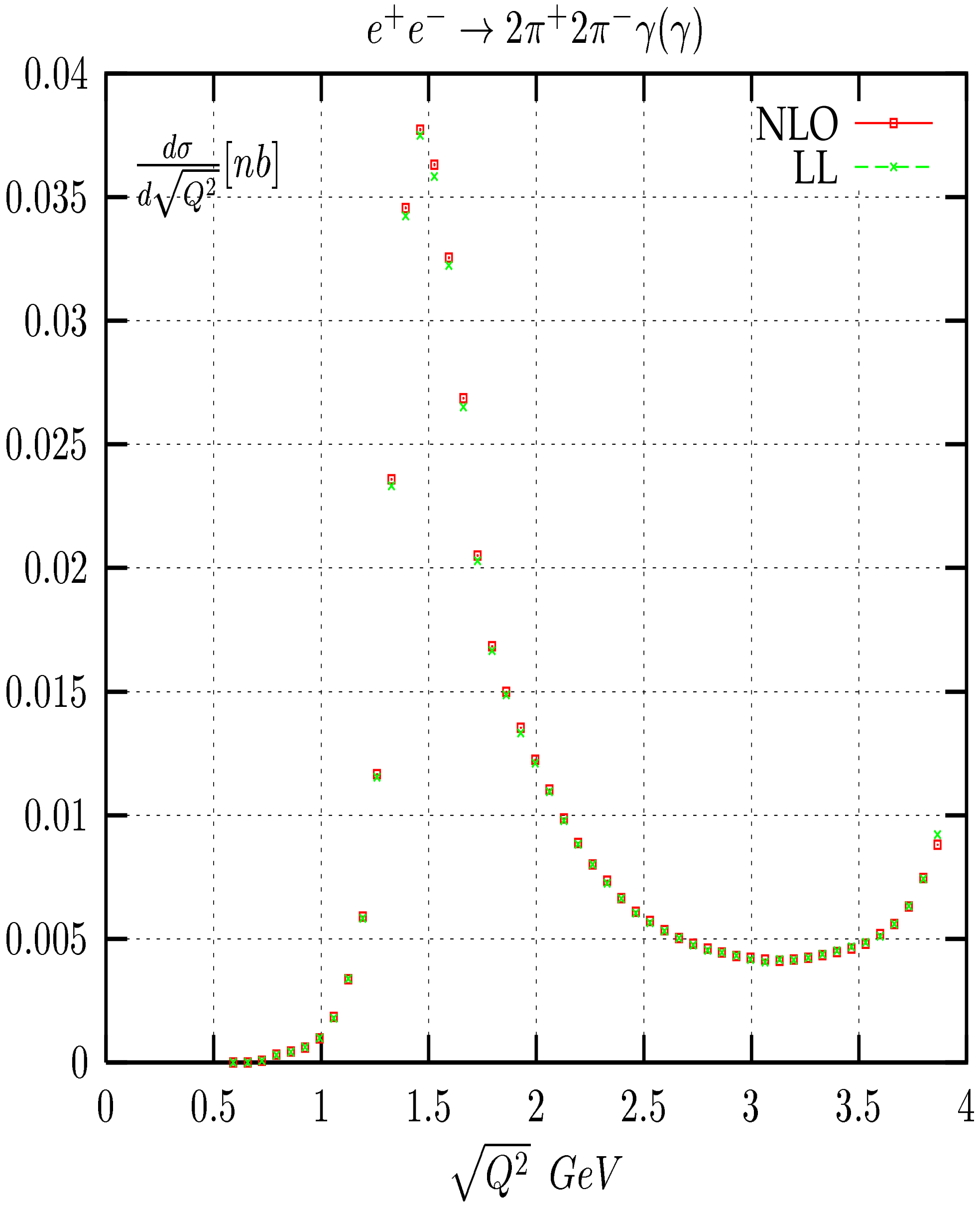
FSR/ISR : $e^+e^- \to \pi^+\pi^-\gamma(\gamma)$



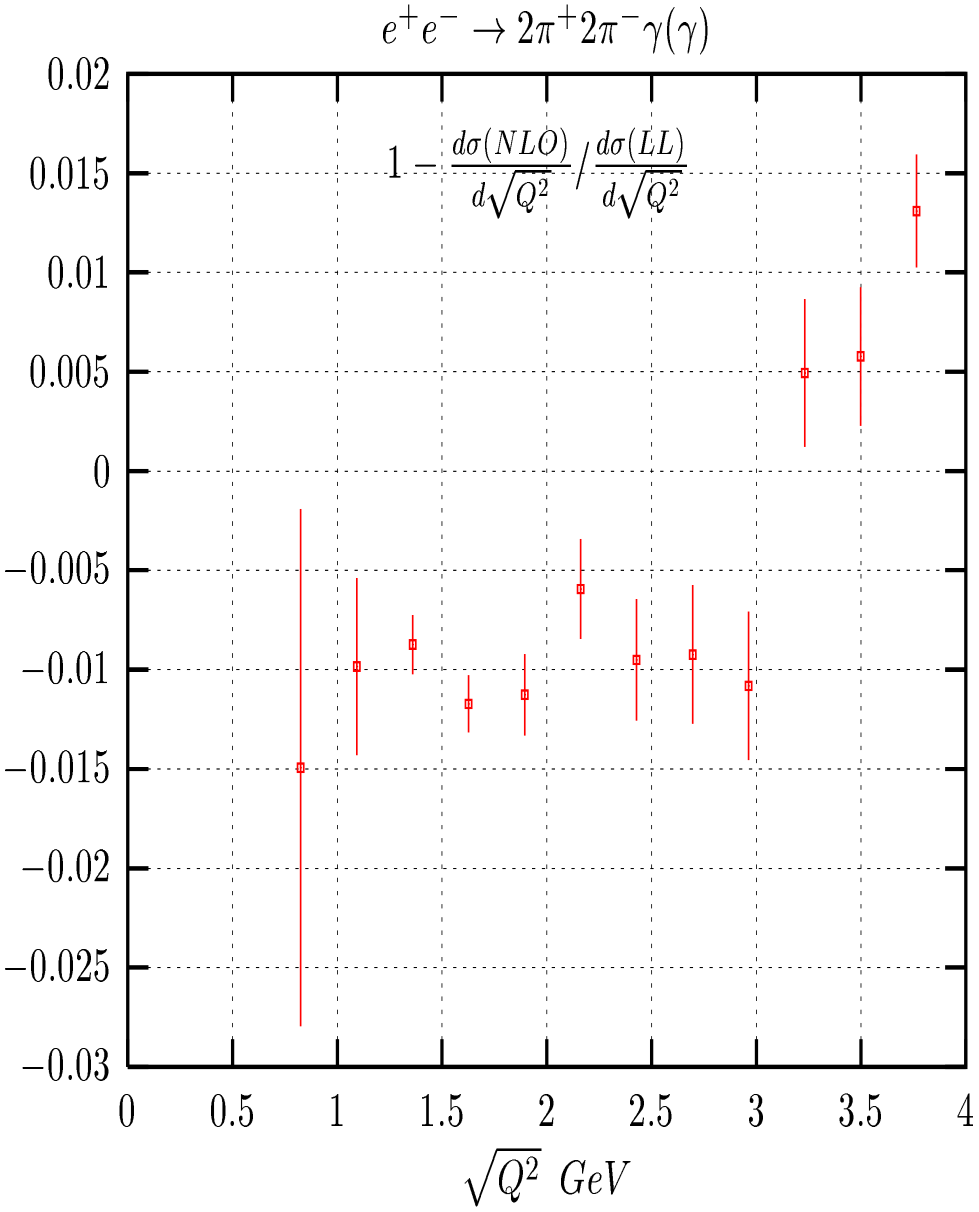
NON-LEADING MASS CORRECTIONS



$\sqrt{S} = 1$ **GeV , 4 GeV and 10 GeV**



$$\sqrt{s} = 4 \ \ GeV, \quad Q^2_{\pi^+\pi^-\gamma} > 12 \ \ GeV^2$$
$$10^\circ < \theta_\gamma < 170^\circ, \quad 20^\circ < \theta_\pi < 160^\circ$$
$$E_\gamma^{min} = 100 \ \ MeV$$



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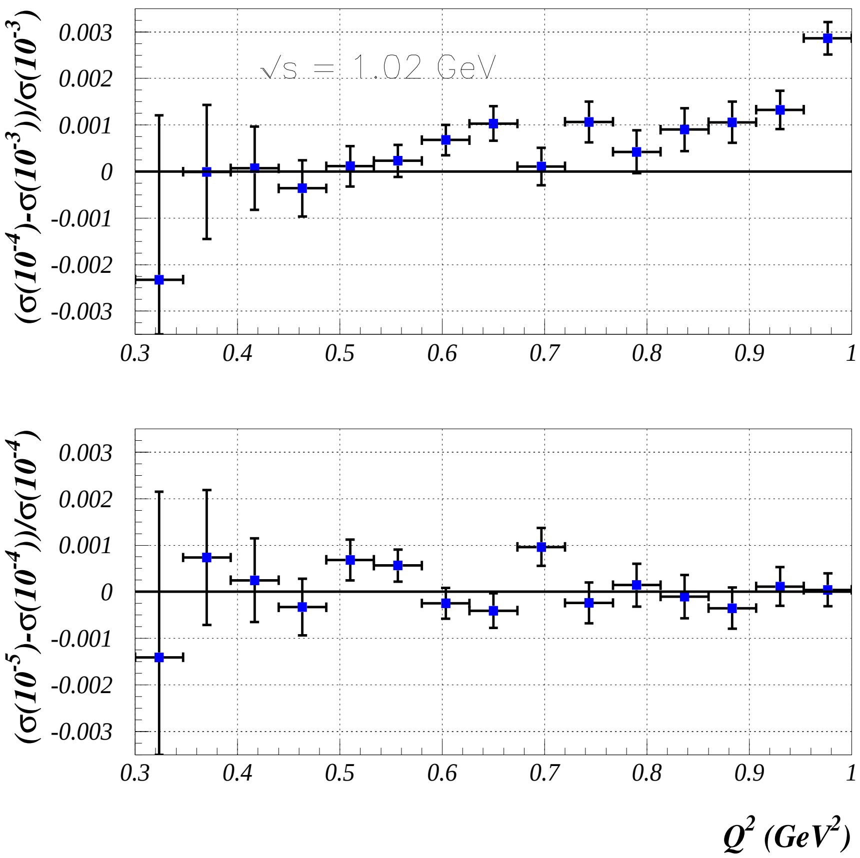
$$10^\circ < \theta_\gamma < 170^\circ, \quad 20^\circ < \theta_\pi < 160^\circ$$
$$E_\gamma^{min} = 100 \;\; MeV$$

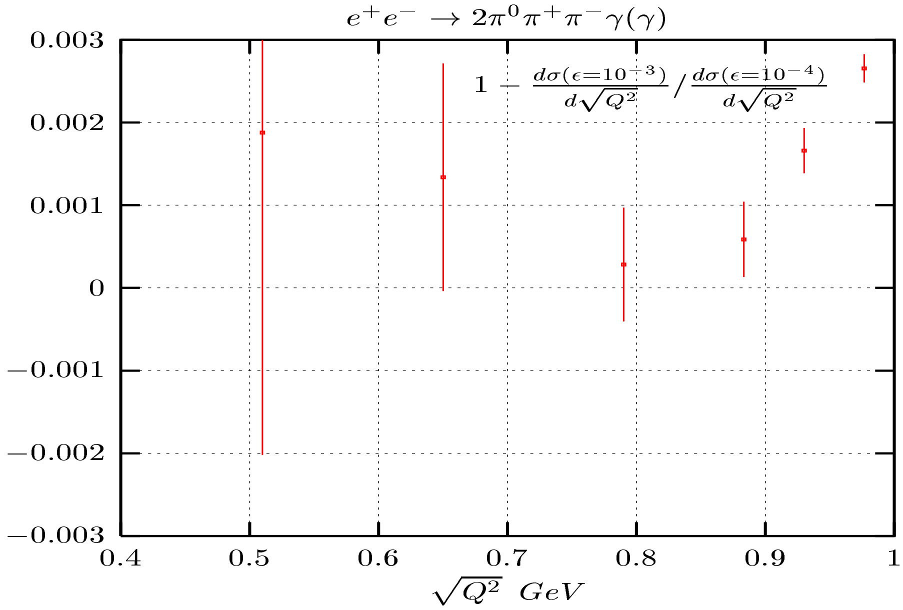
ϵ	$\sqrt{s}$ =1.02 GeV	4 GeV	10.6 GeV
10^{-3}	2.0324 (4)	0.12524 (5)	0.010564 (4)
10^{-4}	2.0332 (5)	0.12526 (5)	0.010565 (4)
10^{-5}	2.0333 (5)	0.12527 (5)	0.010565 (5)

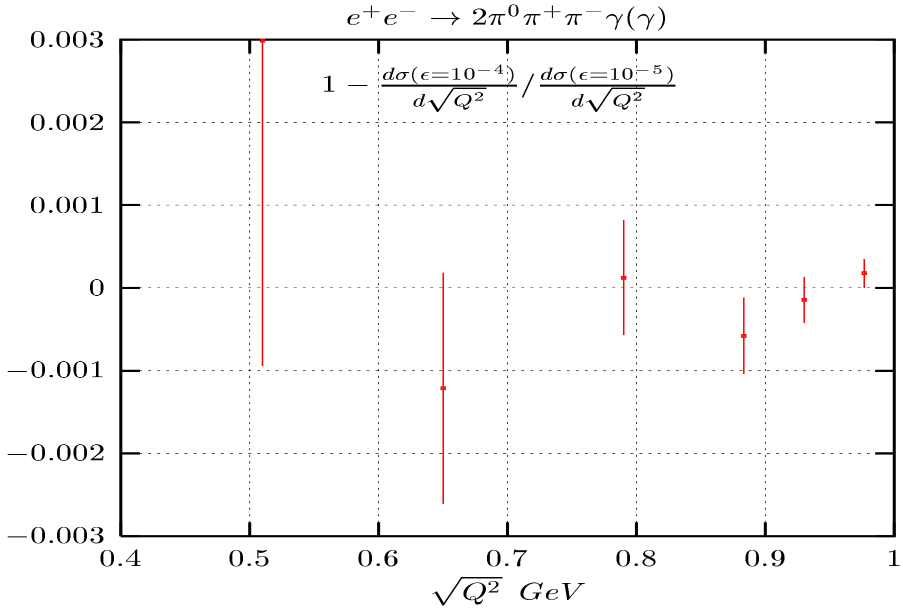
Total cross section (nb) for the process $e^+e^- \to \pi^+\pi^-\gamma$ at NLO for different values of the soft photon cutoff.



$$\sqrt{s} = 1.02 \quad GeV, \quad E_\gamma^{min} = 10 \quad MeV$$

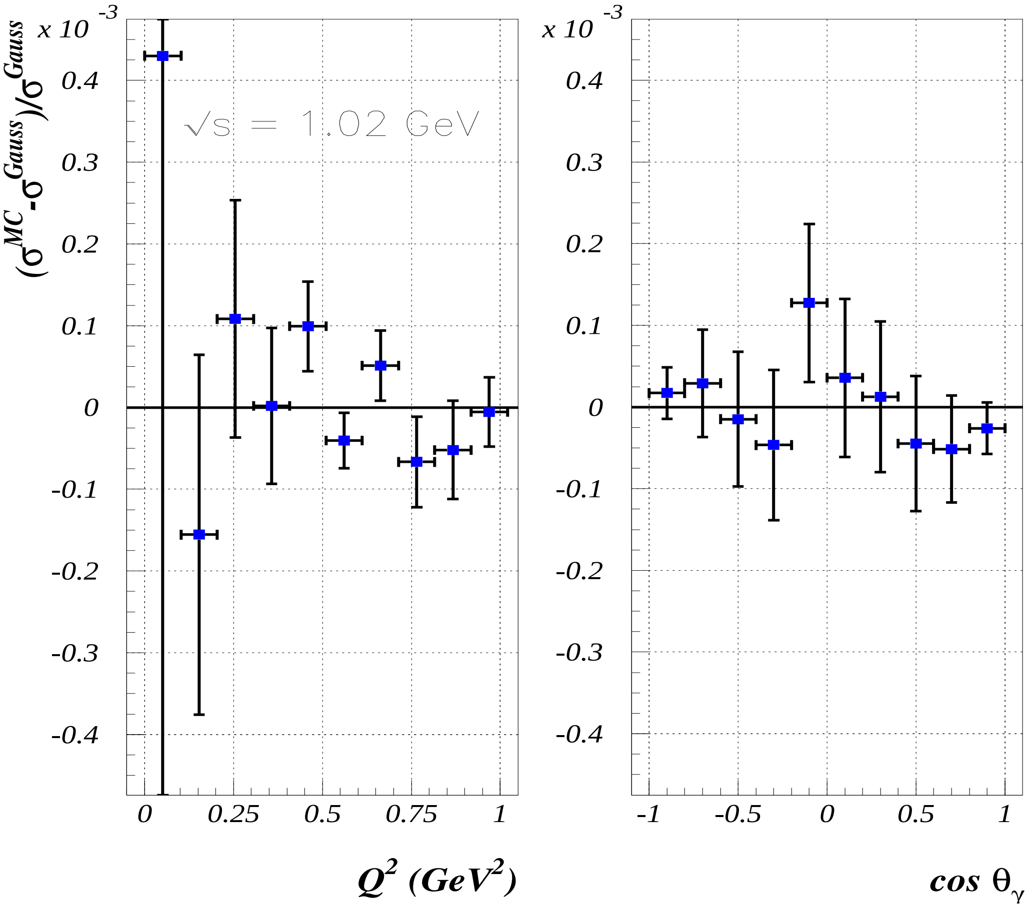
ϵ =	10^{-3}	10^{-4}	10^{-5}
$\sigma(nb)$ =	0.55725(5)	0.55844(5)	0.55845(5)





GAUSS INTEGRATION VS MC

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

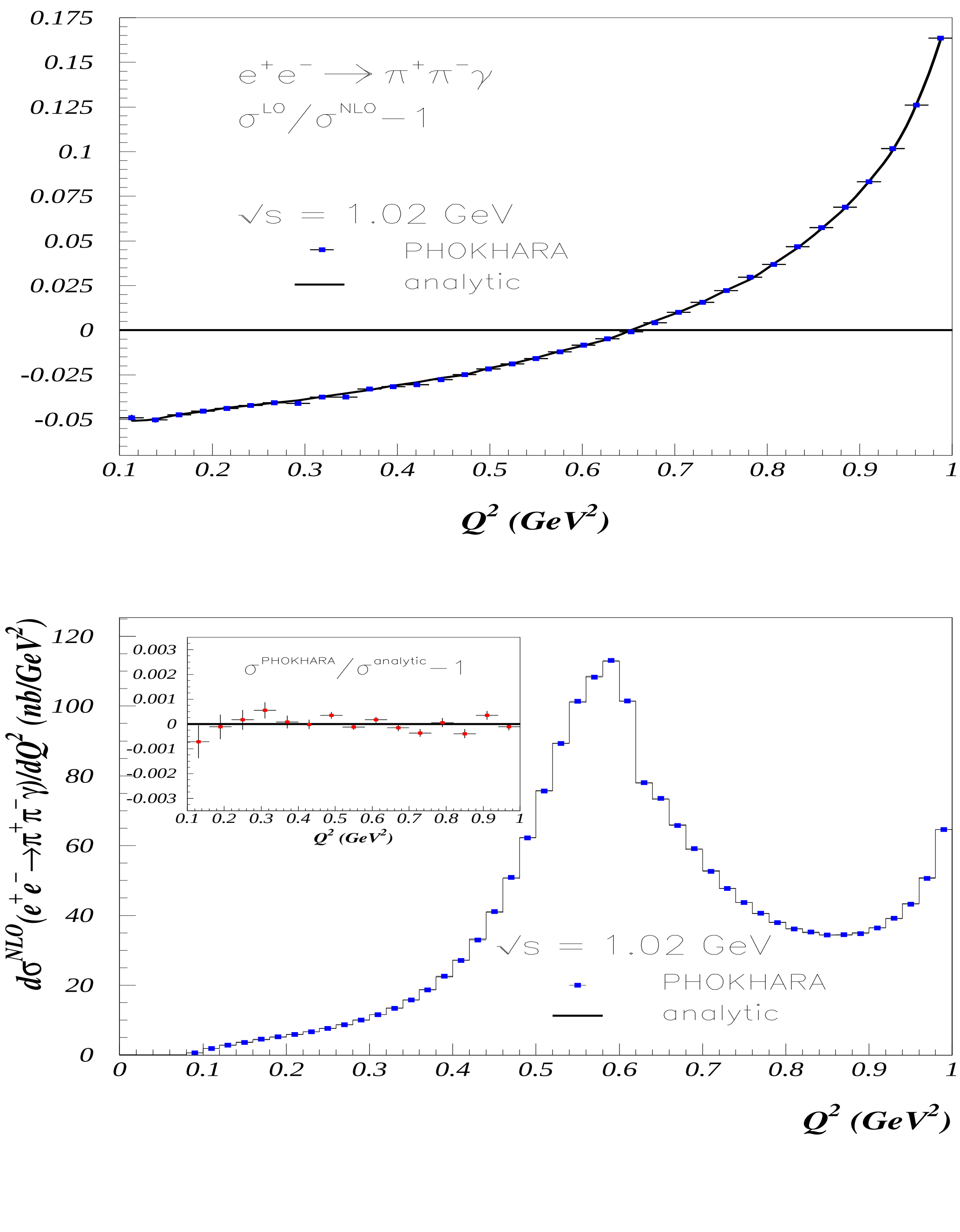


$$E_{cm} = 1.02\ GeV$$

$$10^\circ < \theta_\gamma < 170^\circ, \quad E_\gamma^{min} = 10\ MeV$$

$$4m_\pi^2 \ < \ Q^2 \ < \ 2E_{cm}(E_{cm}/2 - E_\gamma^{min})$$

Comparison with Berends *et al.* ($e^+e^- \to Z\,\gamma$)
Nucl.Phys.B297(1988)429,Phys.Lett.B177(1986)191.



PHOKHARA

SOUND

AND

CONTINUOUSLY IMPROVING
TOOL

HELPING

IN $R(S)$ MEASUREMENTS