Strong and Electromagnetic J/ψ and $\psi(2S)$ Decays into Pion and Kaon Pairs

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in collaboration with J. H. Kühn based on arXiv:0904.0515

- Motivation
- Description of narrow resonances
- Present experimental situation
- BESIII - what one can improve
- Summary

Experimental data: PDG09 + ...

	J/ψ	$\psi(2S)$
M [MeV]	3096.916±0.011	3686.09±0.04
Γ_{ee} [keV]	5.55±0.14±0.02	2.38±0.04
$\mathcal{B}(e^+e^-)[\%]$	5.94±0.06	0.752±0.017
$\mathcal{B}(K^+K^-)[10^{-5}]$	23.7±3.1	6.3±0.7
$\mathcal{B}(K_S^0 K_L^0)[10^{-5}]$	14.6±2.6	5.4±0.5
$\mathcal{B}(\pi^+\pi^-)[10^{-5}]$	14.7±2.3	0.9±0.5[w.a. by CLEO]
$\sigma(K^+K^-)$[pb]	-	5.7±0.8 [CLEO]
$\sigma(K_S^0 K_L^0)$[pb]	-	< 0.74 (90% C.L.) [CLEO]
$\sigma(\pi^+\pi^-)$[pb]	-	9.0±2.2 [CLEO]
$\Delta\alpha$	0.02117 [F.J.+...]	0.02219 [F.J.+...]

Previous analyses

- $F_\pi(J/\psi)$

J. Milana, S. Nussinov and M. G. Olsson Phys. Rev. Lett. **71**, 2533 (1993)

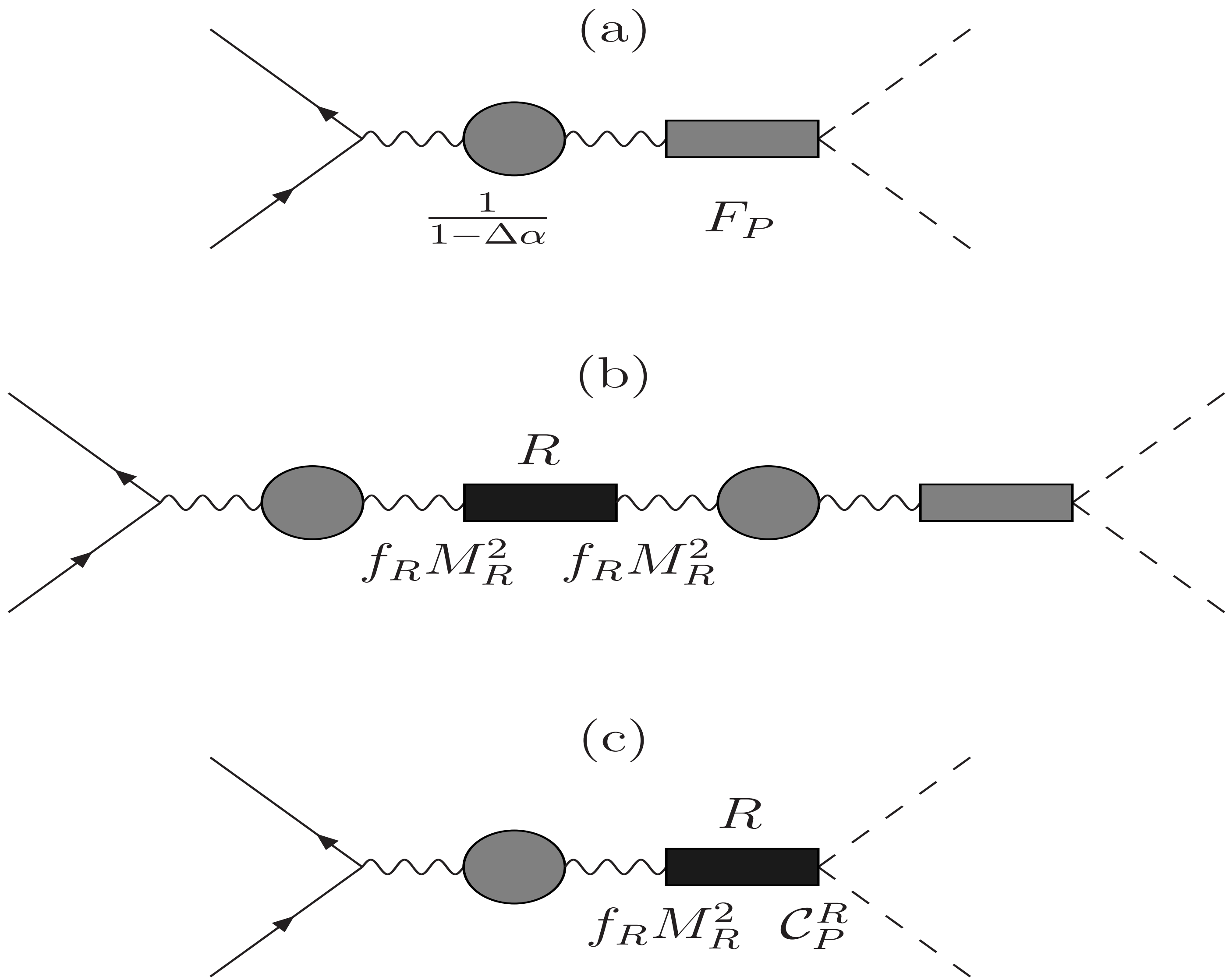
- $J/\psi \to \pi^+\pi^-, K^+K^-, K_S K_L$

J. L. Rosner, Phys. Rev. D **60** (1999) 074029

M. Suzuki, Phys. Rev. D **60**, 051501(R) (1999)

K. K. Seth, Phys. Rev. D **75** (2007) 017301

Contributions to $e^+e^- \to M\bar{M}$



Contributions to $e^+e^- \to P\bar{P}$

$$\sigma\left(e^+e^- \to P\bar{P}\right) = \frac{\pi\alpha^2}{3s}|F_P|^2\,\beta^3$$

$$\times\left|\frac{1}{1-\Delta\alpha} + \sum_R \frac{3\sqrt{s}}{\alpha}\frac{\Gamma_e^R(1+c_P^R)}{s-M_R^2+i\Gamma_R M_R}\right|^2$$

Contributions to $e^+e^- \to P\bar{P}$

$$\sigma\left(e^+e^- \to P\bar{P}\right) = \frac{\pi\alpha^2}{3s}|F_P|^2\,\beta^3$$

$$\times\left(\frac{1}{(1-\Delta\alpha)^2} + \sum_R\left\{\frac{9s}{\alpha^2}\frac{(\Gamma_e^R)^2}{(s-M_R^2)^2+\Gamma_R^2M_R^2}\right.\right.$$

$$\times\left[|1+c_P^R|^2 + \frac{2\alpha M_R}{3\sqrt{s}(1-\Delta\alpha)}\frac{\Gamma_R}{\Gamma_e^R}\mathrm{Im}(c_P^R)\right]$$

$$\left.\left.+\frac{6\sqrt{s}\Gamma_e^R}{\alpha(1-\Delta\alpha)}\frac{\left(1+\mathrm{Re}(c_P^R)\right)(s-M_R^2)}{(s-M_R^2)^2+\Gamma_R^2M_R^2}\right\}\right)$$

Decay width

One should not use

$$\Gamma(R \to P\bar{P}) = \Gamma^{QED} \times |1 + c_P^R|^2$$

but

$$\Gamma(R \to P\bar{P}) = \Gamma^{QED} \times \Big[|1 + c_P^R|^2 + \frac{2\alpha M_R}{3\sqrt{s}(1-\Delta\alpha)} \frac{\Gamma_R}{\Gamma_e^R} \mathrm{Im}(c_P^R) \Big]$$

Pion form factor

$$|F_\pi|^2 = \frac{4\mathcal{B}(R\to\pi^+\pi^-)}{\beta_\pi^3\mathcal{B}(R\to e^+e^-)}$$

	J/ψ	$\psi(2S)$
$\lvert F_\pi\rvert^2[10^{-3}]$ above Eq.	10.0±1.6	4.8±2.73
$\lvert F_\pi\rvert^2[10^{-3}]$ off peak	-	5.92±1.46

CLEO:Phys. Rev. Lett. **95**,(2005) 261803

$$|F_\pi|^2(\sqrt{s} = 3.671\text{GeV}) = (5.63 \pm 1.42)\cdot 10^{-3}$$

$\psi(2S) \to K^+K^-$

$$R_+ \equiv \frac{4\mathcal{B}(K^+K^-)}{\beta^3_{K^+}\mathcal{B}(e^+e^-)} = |F_{K^+}|^2 \left[|1+c_+|^2 + r\,\mathrm{Im}c_+\right]$$

$$r = \frac{2\alpha}{3(1-\Delta\alpha)\mathcal{B}(e^+e^-)} = 0.663 \pm 0.015$$

$$R_+ = (3.75 \pm 0.43) \cdot 10^{-2}$$

$\psi(2S) \to K^+K^-$

$$S_+ - R_+\frac{\gamma^2}{4} = |F_{K^+}|^2\left[1 + \gamma(1 + \mathrm{Re}c_+)\right]$$

$$S_+ = \sigma(e^+e^- \to K^+K^-)(1 - \Delta\alpha)^2 / \left(\frac{\pi\alpha^2}{3s}\beta^3_{K^+}\right)$$

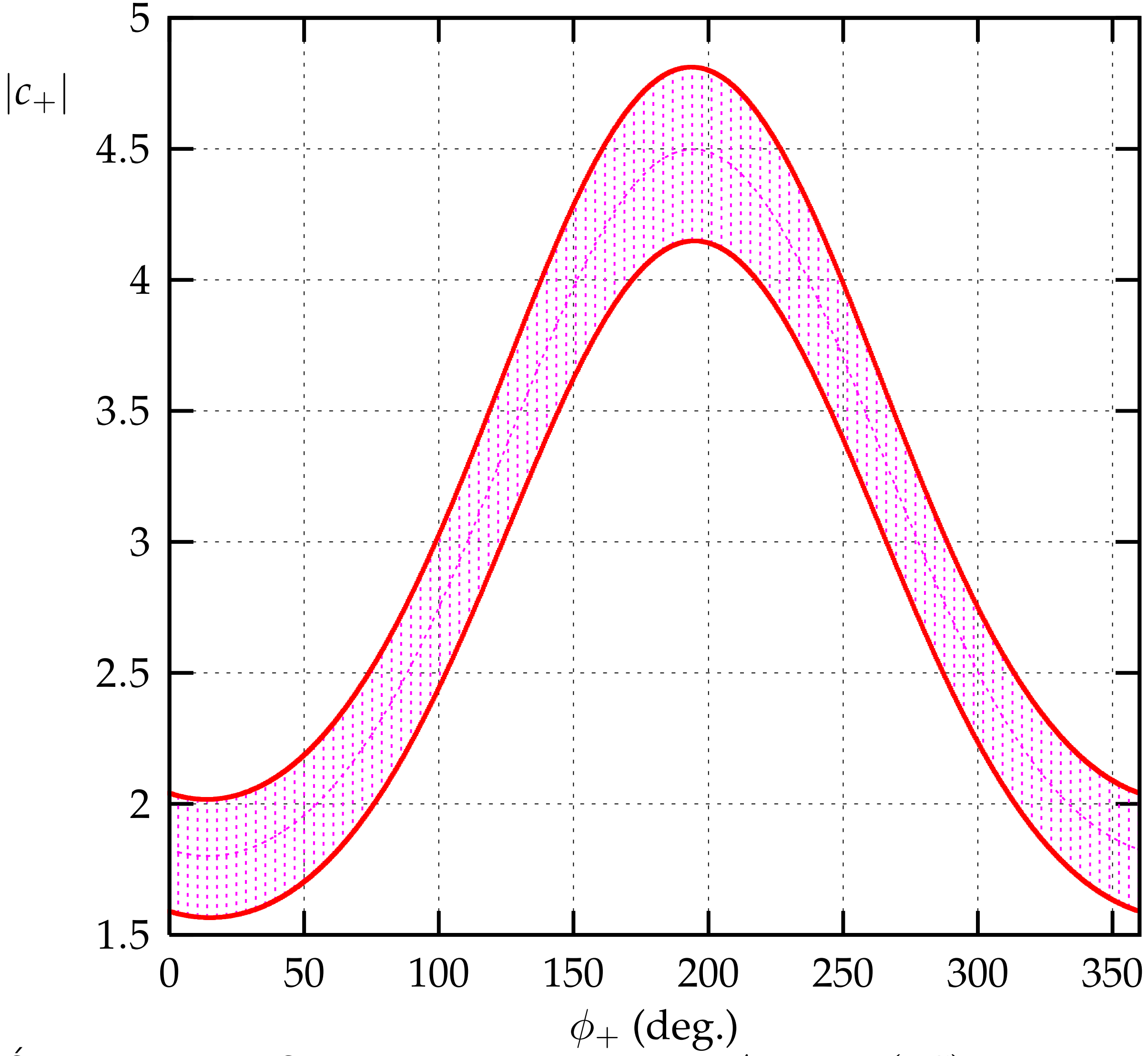
$$\gamma = \frac{\Gamma_e}{E - M_R}\frac{3(1-\Delta\alpha)}{\alpha}$$

CLEO: $\gamma = -0.063 \pm 0.001$

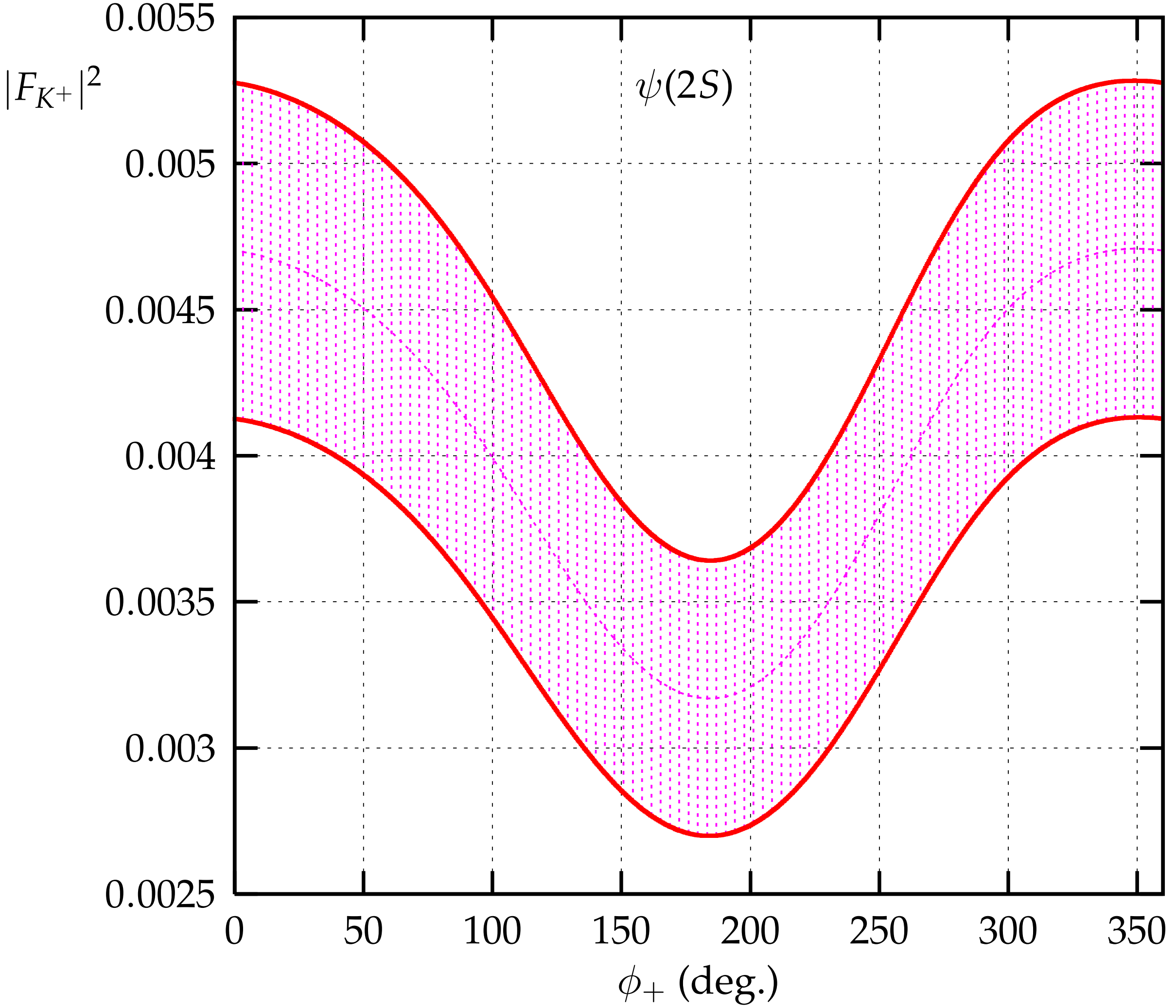
$\psi(2S) \to K^+K^-$

$$\frac{R_+}{S_+ - R_+\frac{\gamma^2}{4}} = \frac{1+2|c_+|\cos(\phi_+)+|c_+|^2+r|c_+|\sin(\phi_+)}{1+\gamma(1+|c_+|\cos(\phi_+))}$$

$\psi(2S) \to K^+K^-$



$\psi(2S) \to K^+K^-$



0.0055
0.005
0.0045
0.004
0.0035
0.003
0.0025
$|F_{K^+}|^2$
$\psi(2S)$
0
50
100
150
200
250
300
350
ϕ_+ (deg.)

$\psi(2S) \to K^+K^-$

$$0.052 < |F_{K^+}| < 0.073$$

to be compared with CLEO

$$0.059 < |F_{K^+}| < 0.067$$

Can we improve ?

$$\sigma(e^+e^- \to K^+K^-, E = M_{\psi(2S)} - 20\mathrm{MeV})$$

$$= (5.55 \pm 0.28) pb$$

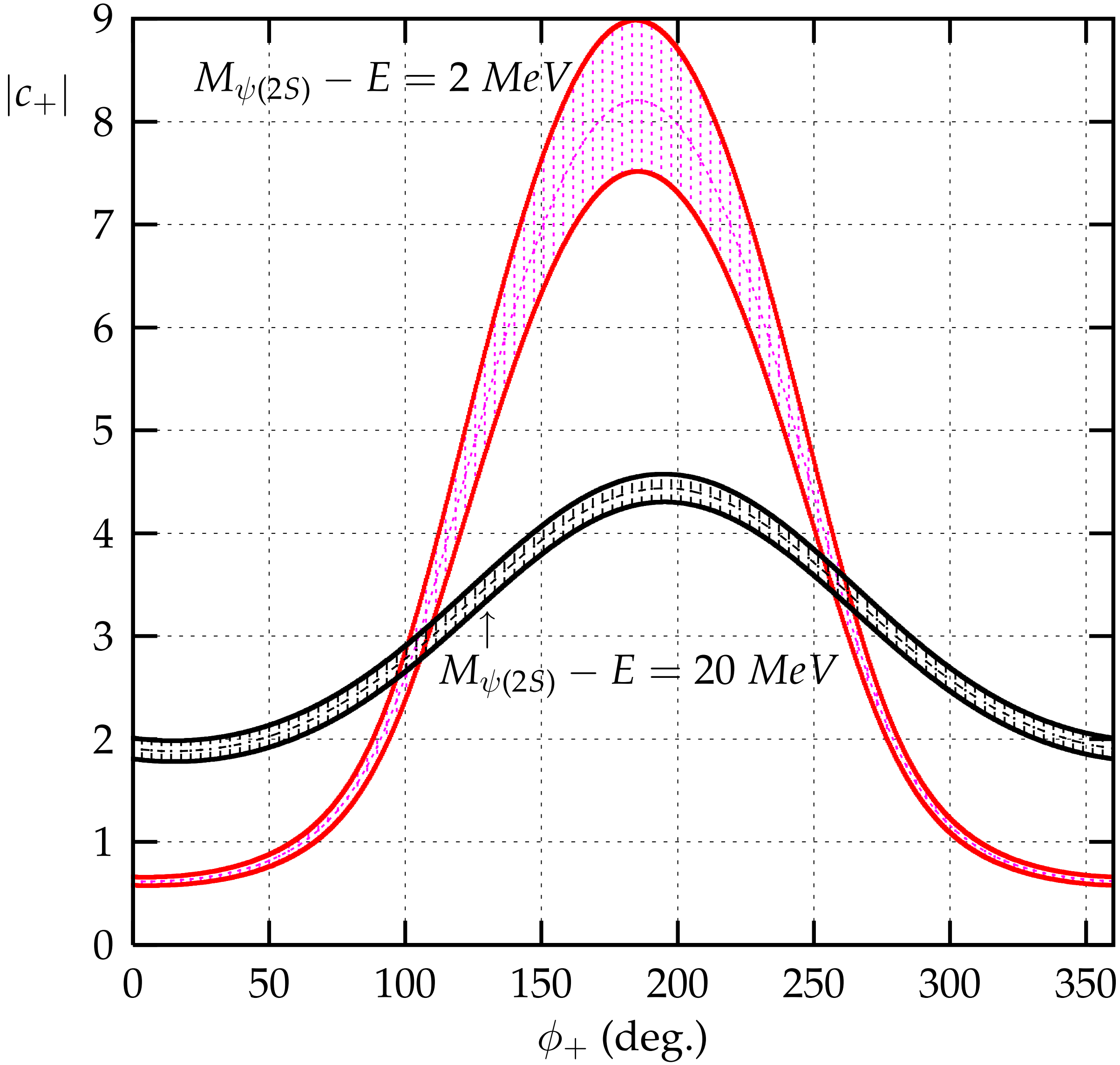
$$\sigma(e^+e^- \to K^+K^-, E = M_{\psi(2S)} - 2\mathrm{MeV})$$

$$= (7.68 \pm 0.38) pb$$

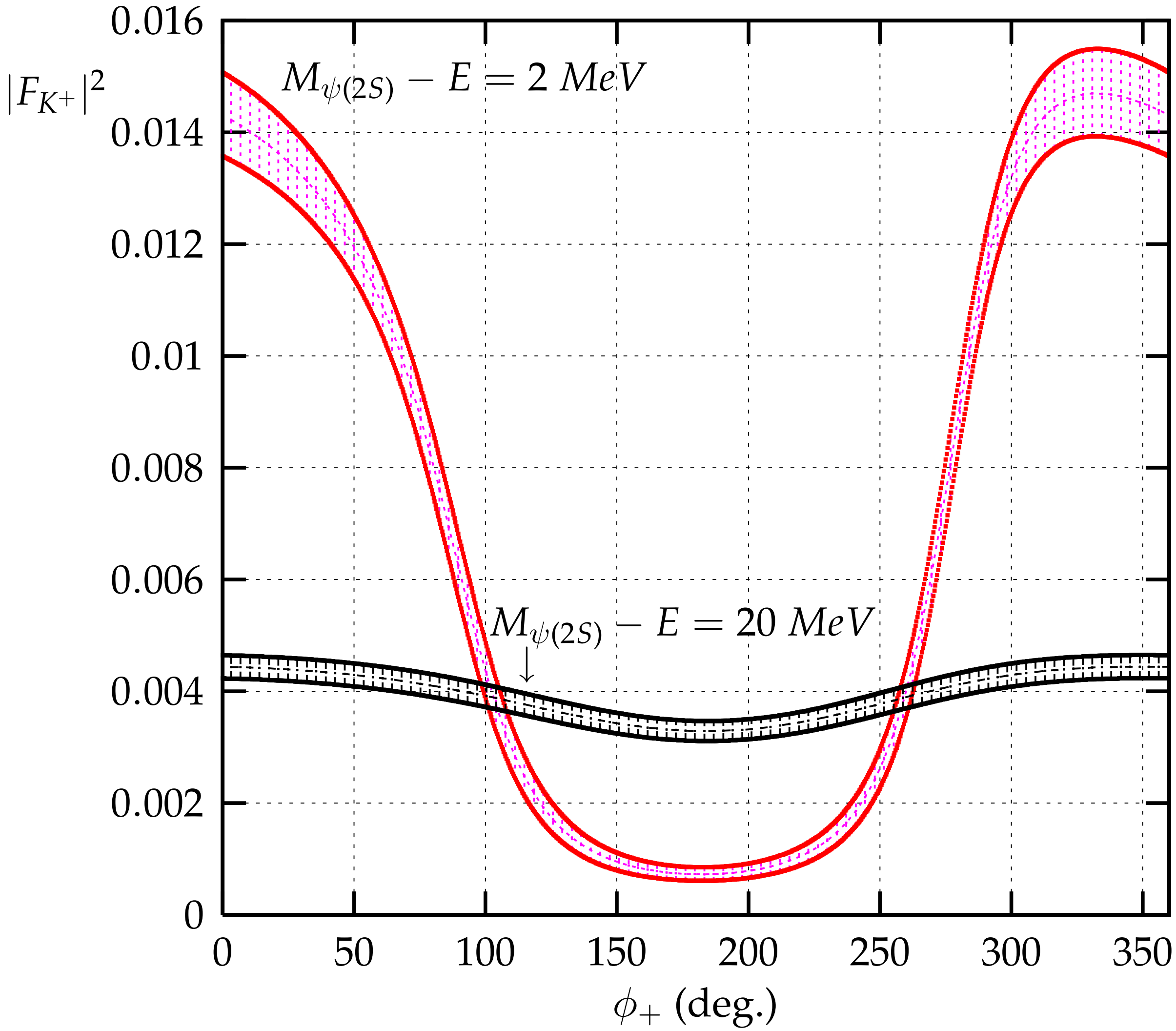
$$\mathcal{B}(\psi(2S) \to K^+K^-) = (6.3 \pm 0.35) \cdot 10^{-5}$$

With a luminosity of BES III of $2.6 \cdot 10^3 \mathrm{pb}^{-1}/\mathrm{month}$ one expects about 1000 K^+K^- events in 2 days of running

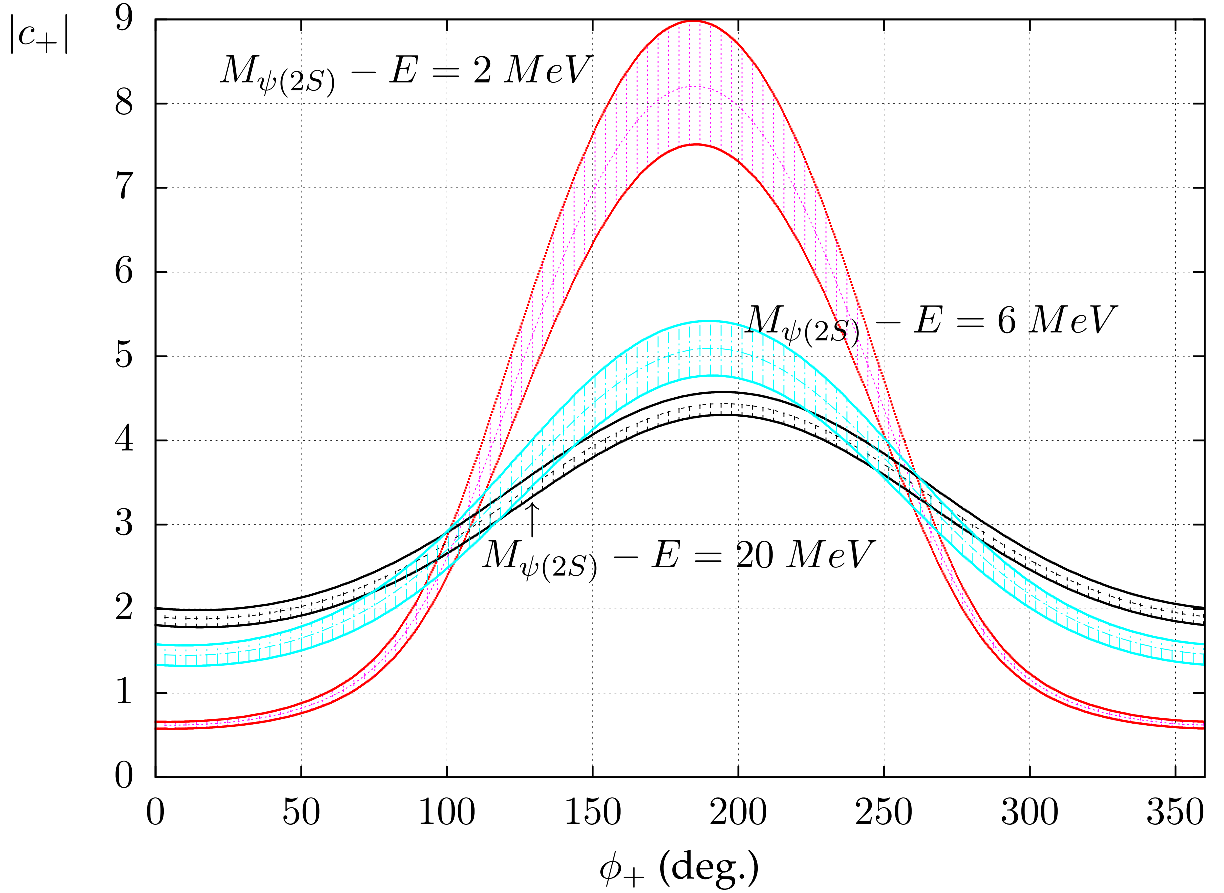
The expected improvement



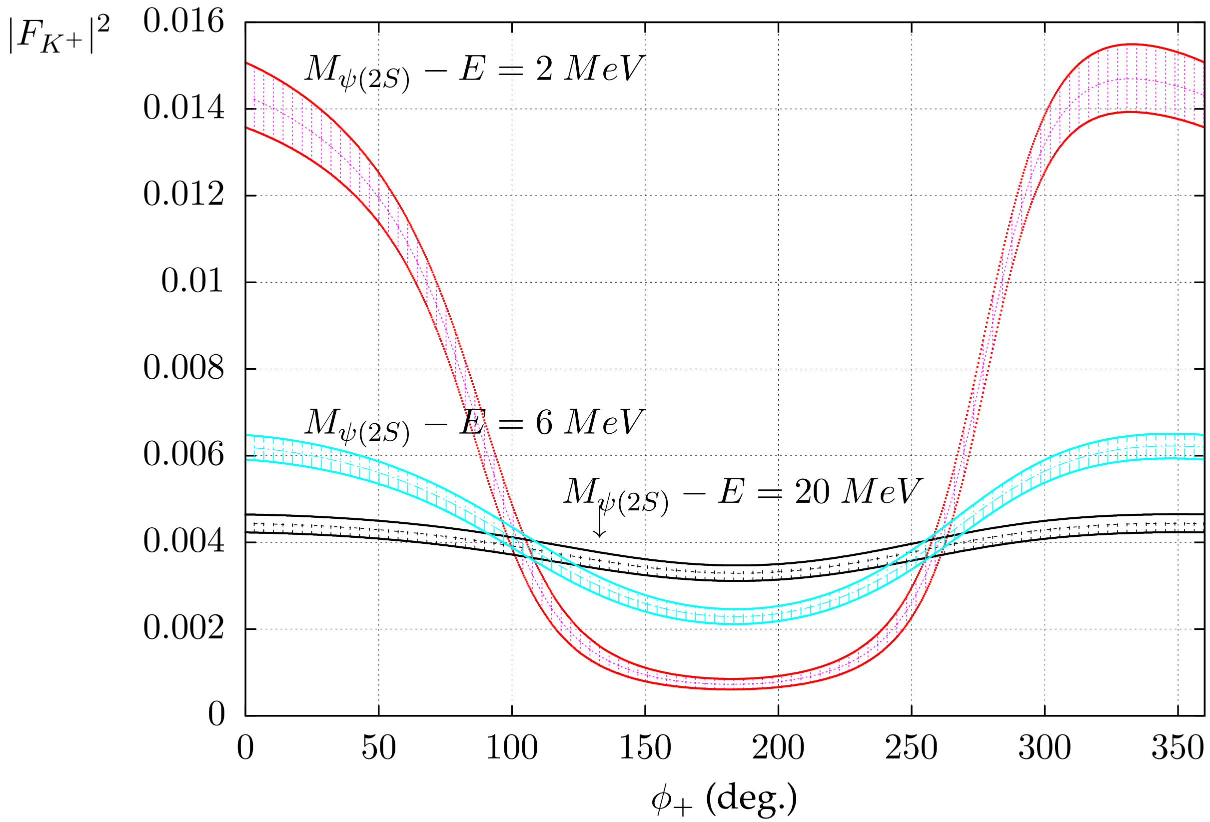
The expected improvement



The expected improvement



The expected improvement



$\psi(2S) \to K^0 \bar{K}^0$

$$\sigma(e^+e^- \to K^0_S K^0_L) < 0.74\mathrm{pb}$$

at 90% C.L., obtained by CLEO 15 MeV below the resonance.

isospin symmetry:

$$A^R_{QCD}(K^+K^-) = A^R_{QCD}(K^0\bar{K}^0)$$

$$c_+ F_{K^+} = c_0 F_{K^0}$$

$\psi(2S) \rightarrow K^0 \bar{K}^0$

$$\left| \frac{1}{c_0} \right| = \left| \frac{A^R_{QED}}{A^R_{QCD}} \right| < 0.187 \pm 0.008$$

$$|F_{K^0}| < 0.0282 \pm 0.0003$$

to be compared with the limit obtained by CLEO: interference neglected

$$|F_{K^0}| < 0.023$$

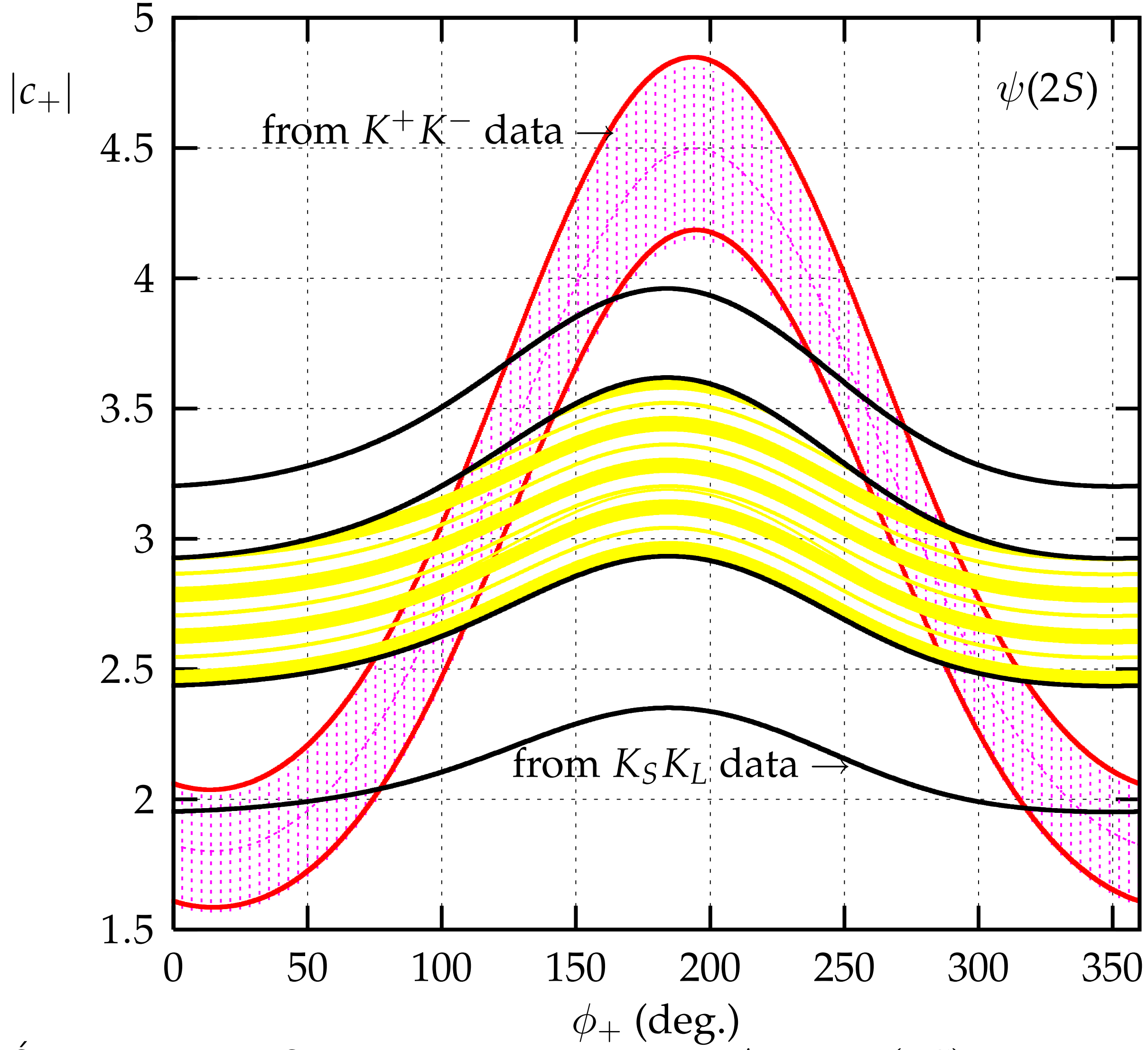
$\psi(2S) \to K^0 \bar{K}^0$

$$|F_{K^0} \cdot c_0| < 0.174 \pm 0.009 \pm 0.024$$

first error is due to the error on R_0 and the second originates from the unknown strength of the interference between A^R_{QED} and A^R_{QCD}

$$|F_{K^0} \cdot c_0| = |F_{K^+} \cdot c_+|$$

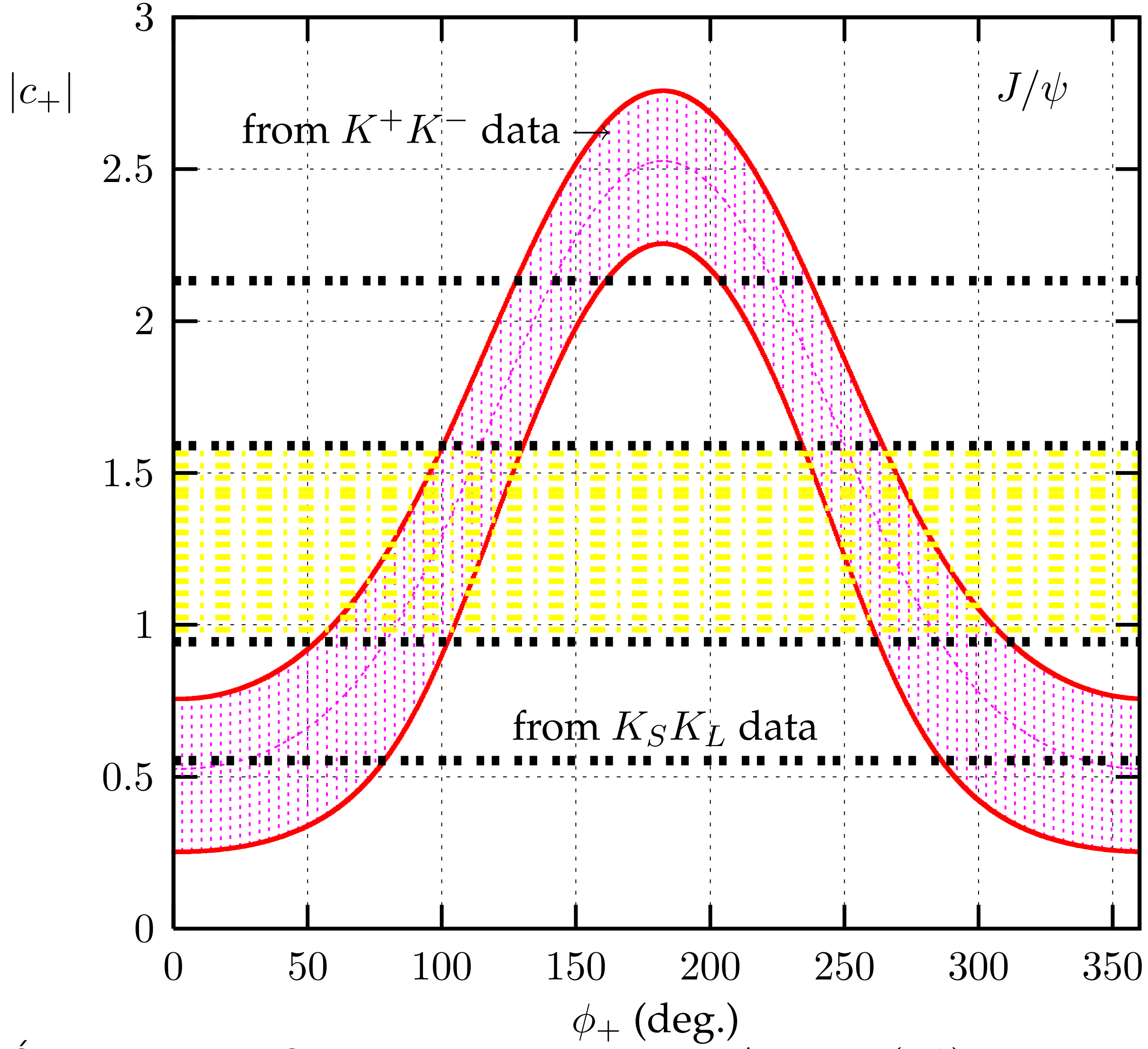
$\psi(2S) \to K^+K^-, \psi(2S) \to K_SK_L$



$J/\psi \to K^+K^-, J/\psi \to K_S K_L$

- NO off resonance measurement available
- analysis depends critically on the assumptions on the kaon form factors
- $A_{QED}^{J/\psi}(K_S^0 K_L^0) = 0$ vs. $\neq 0$
- interference important

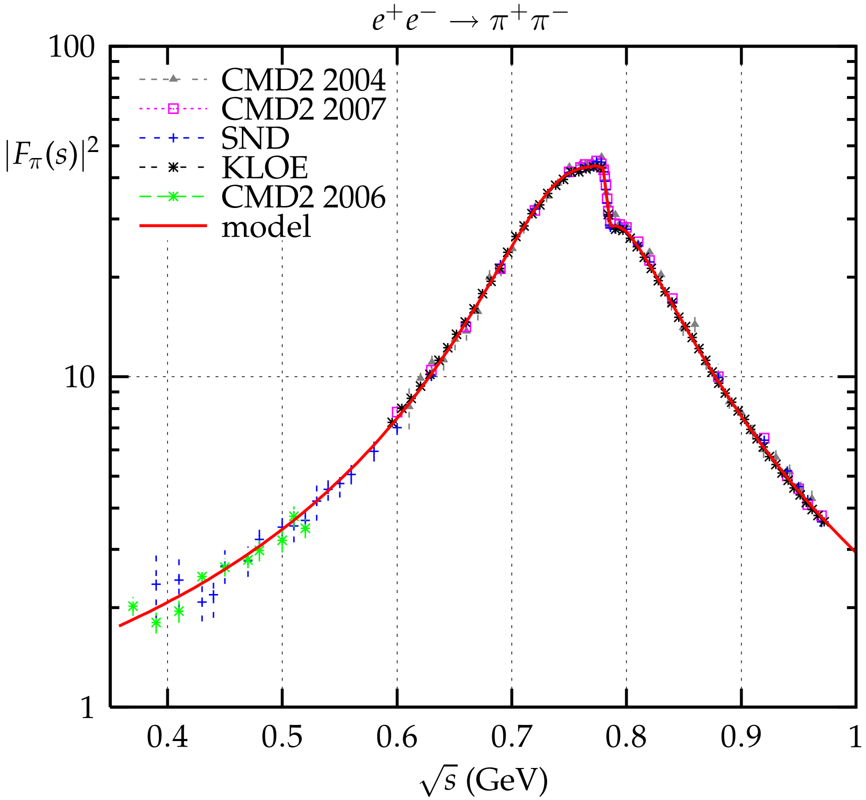
$J/\psi \to K^+K^-, J/\psi \to K_S K_L$

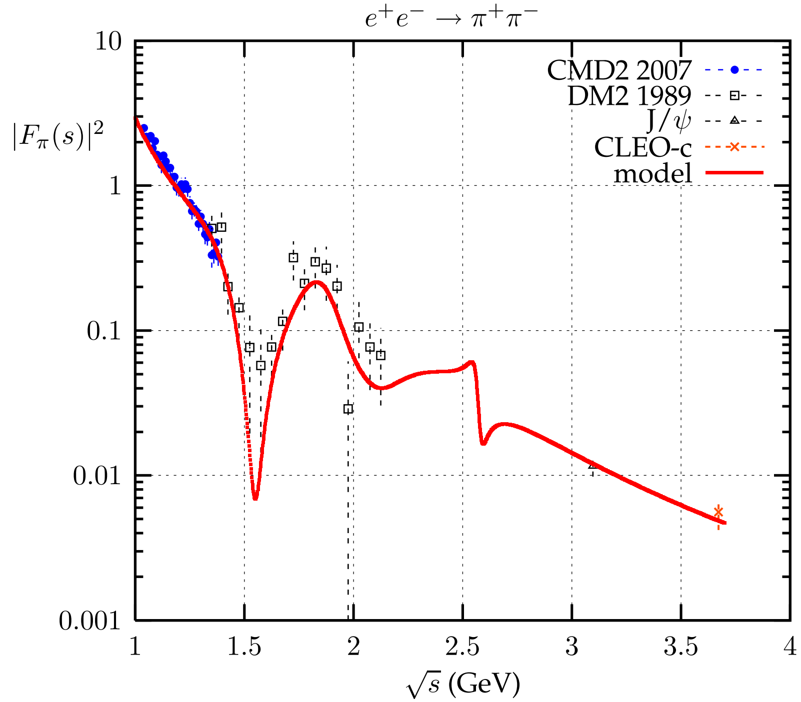


Conclusions

- J/ψ and $\psi(2S)$ decays into pairs of ps. mesons reanalysed
- previously neglected interference terms important
- assumptions on the neutral kaon form factor relevant
- the combination of two cross section measurements close to the resonance with the corresponding branching ratio leads to a model independent determination (up to a twofold ambiguity) of strong amplitude, form factors and their relative phase.

Pion form factor

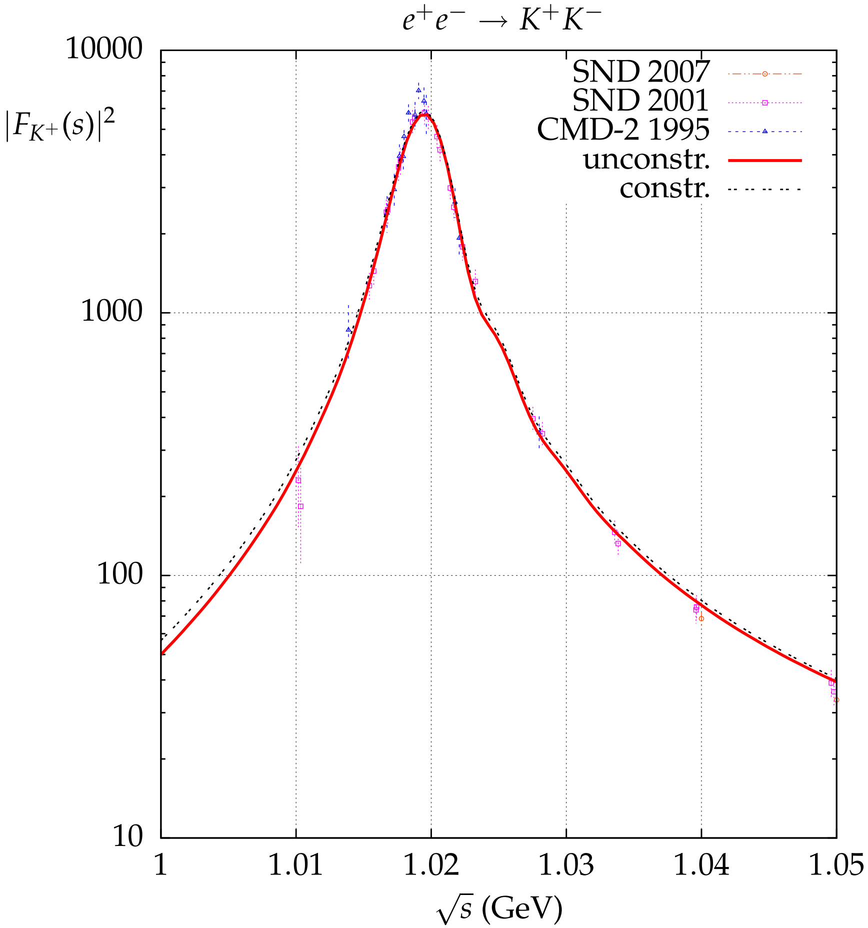


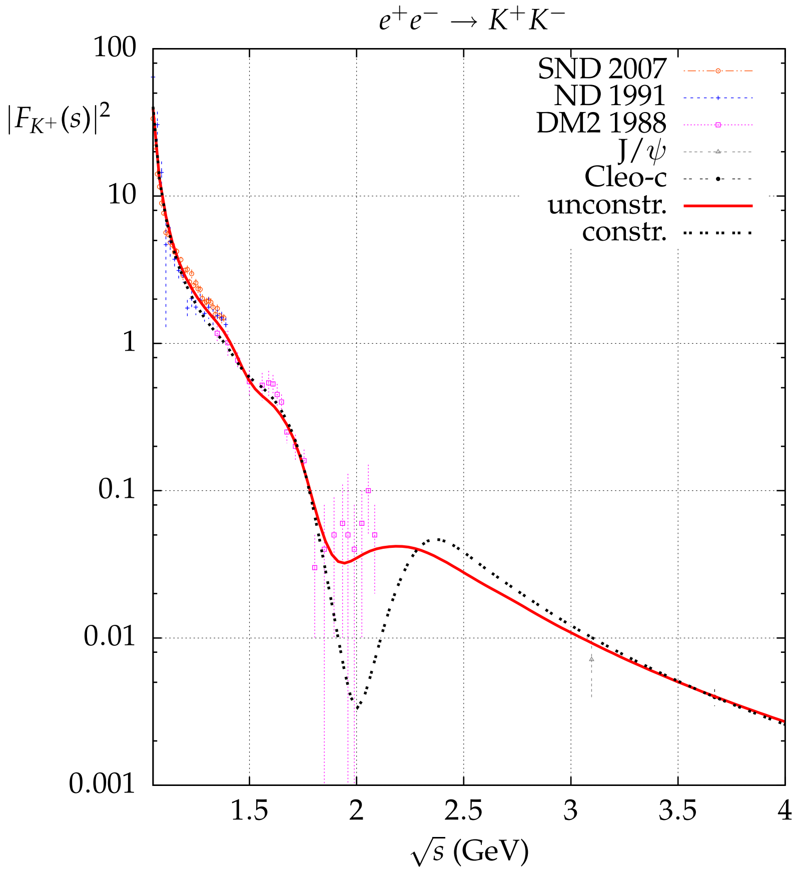


C. Bruch, A. Khodjamirian and J.H. Kühn, Eur. Phys. J. C39(2005)41

H. C., A. Grzelińska and J.H. Kühn, in preparation

Kaon form factor





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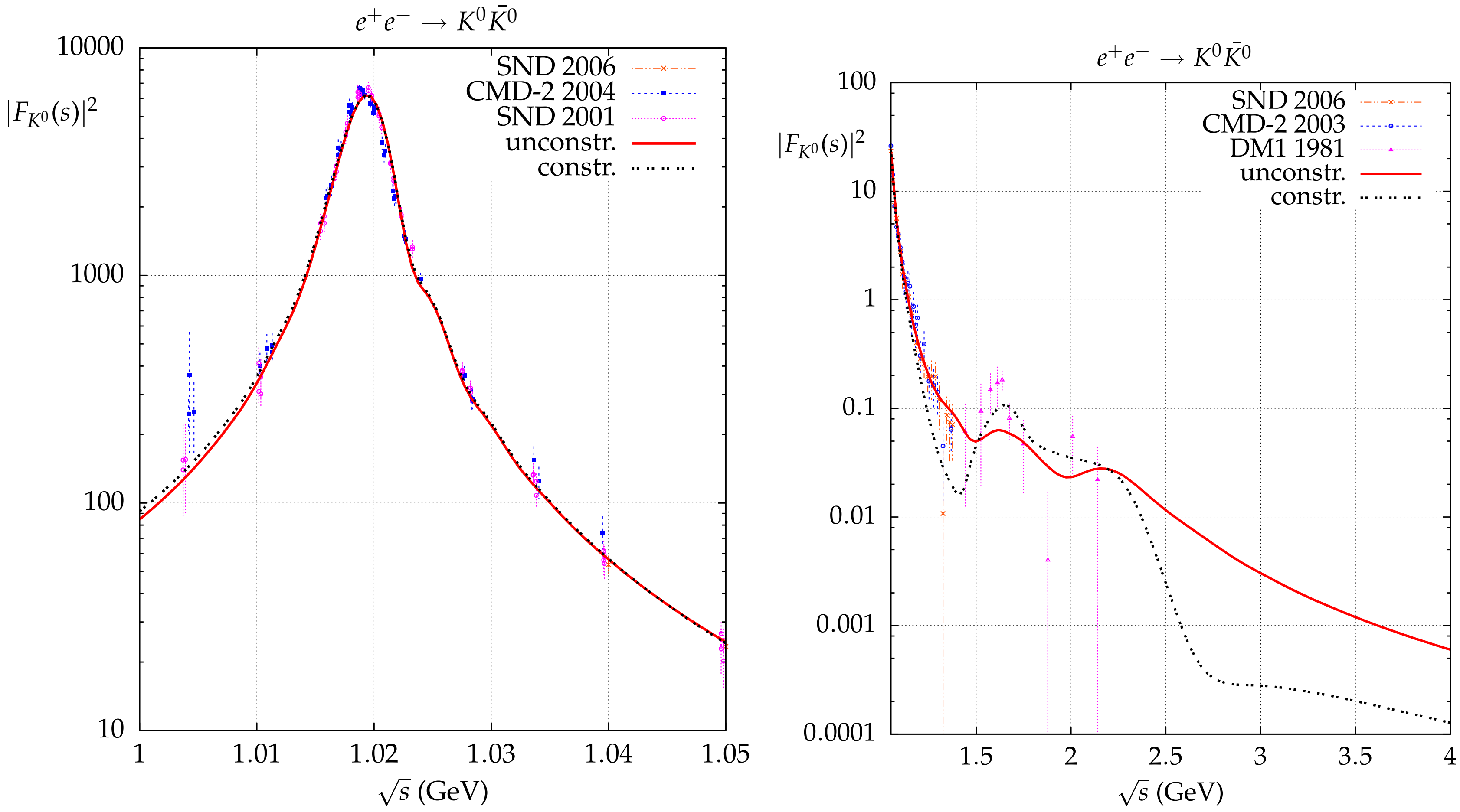

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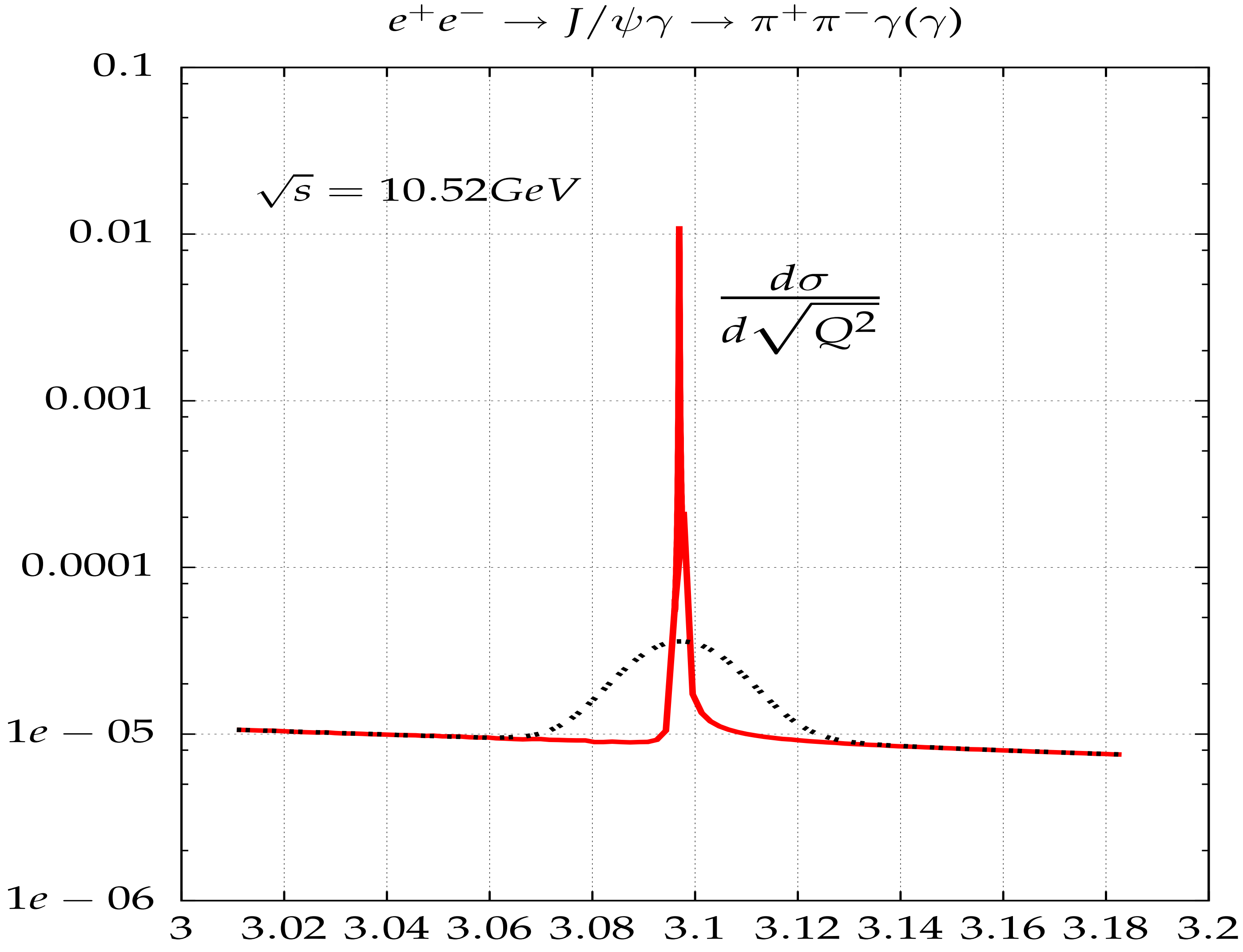
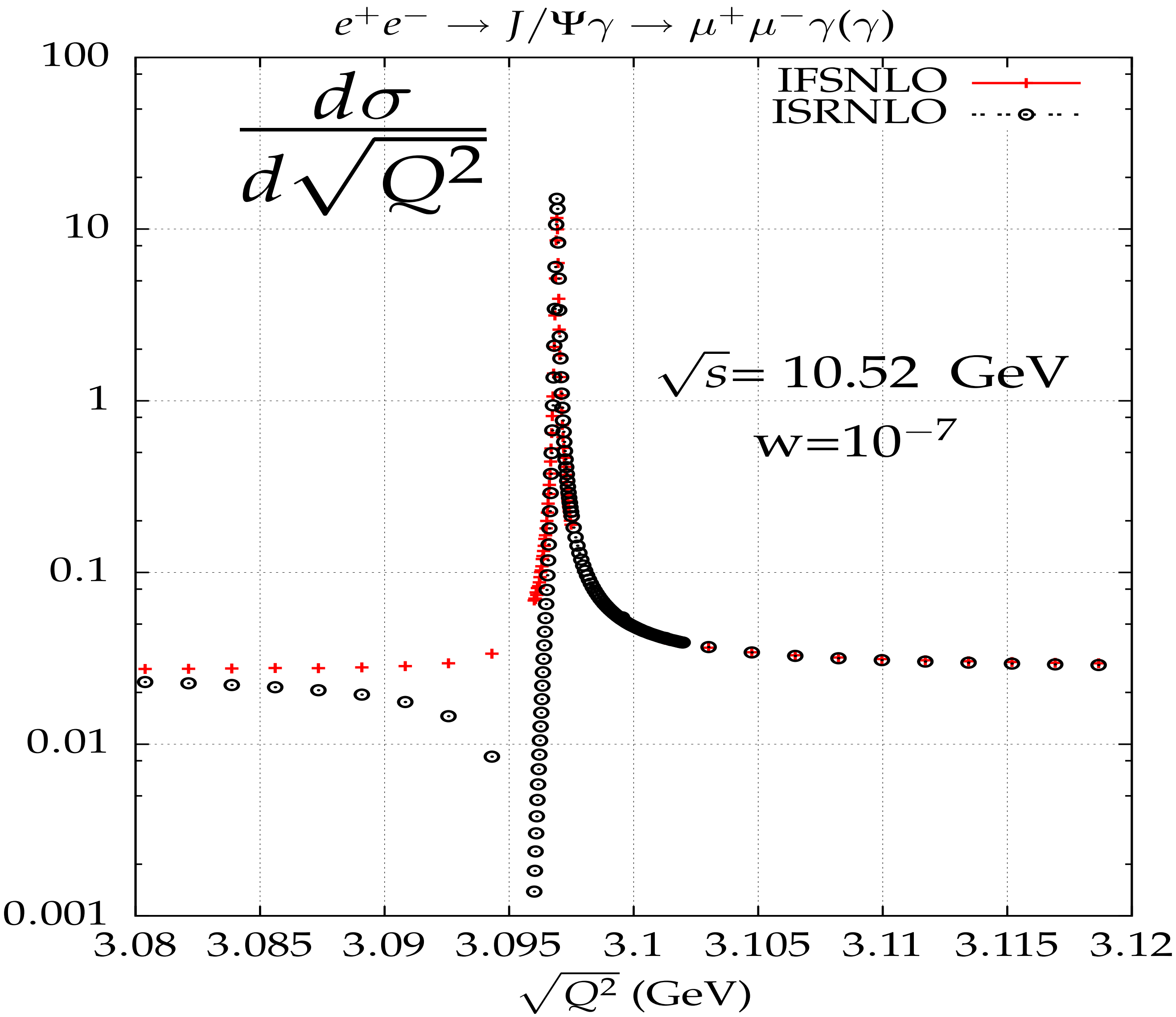
Energy resolution

$\Delta q = 14.5$ MeV

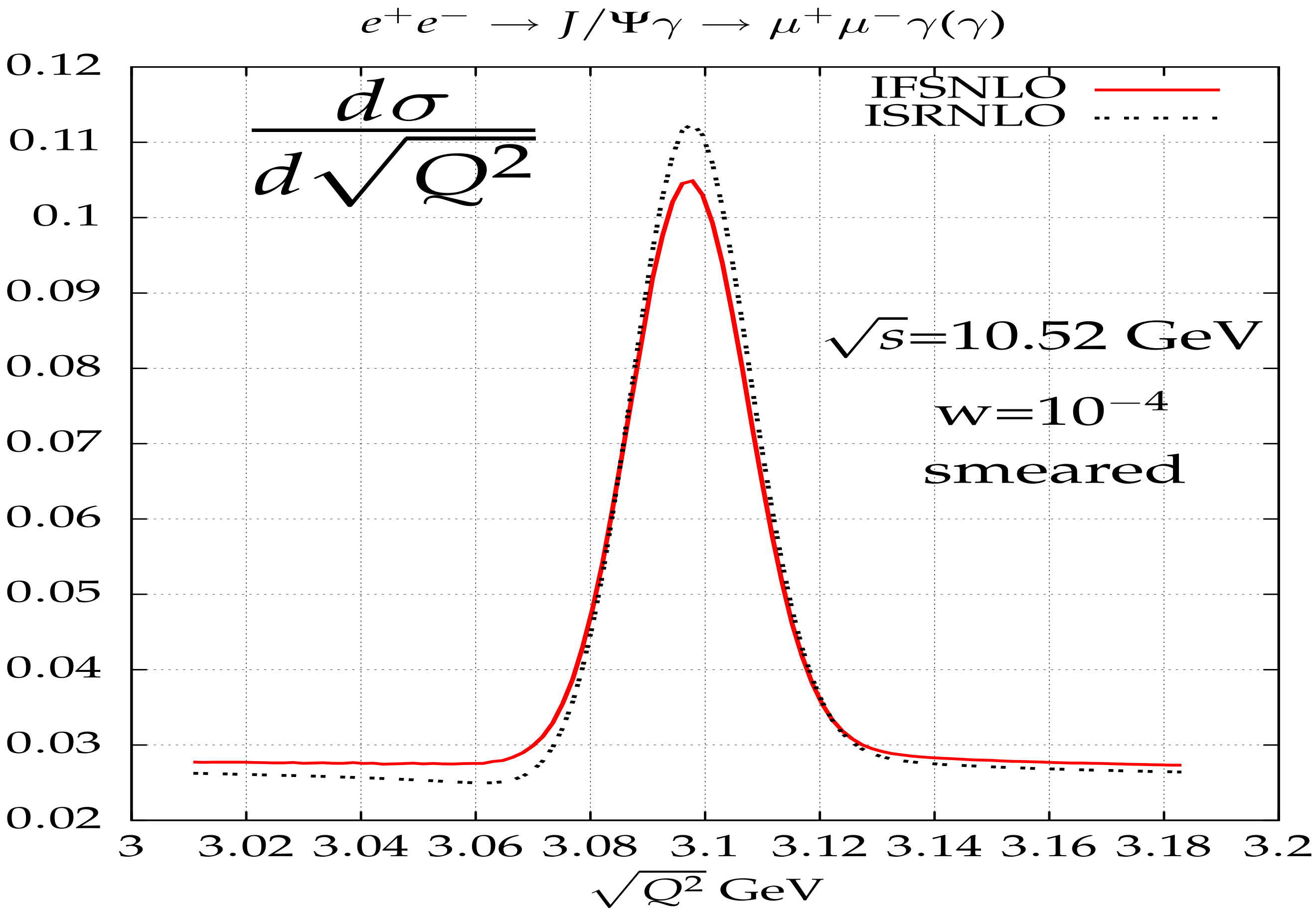


FSR - muons



$e^+e^- \to J/\Psi\gamma \to \mu^+\mu^-\gamma(\gamma)$
$\frac{d\sigma}{d\sqrt{Q^2}}$
IFSNLO
ISRNLO
$\sqrt{s}$= 10.52 GeV
w=10^{-7}
100
10
1
0.1
0.01
0.001
3.08
3.085
3.09
3.095
3.1
3.105
3.11
3.115
3.12
$\sqrt{Q^2}$ (GeV)

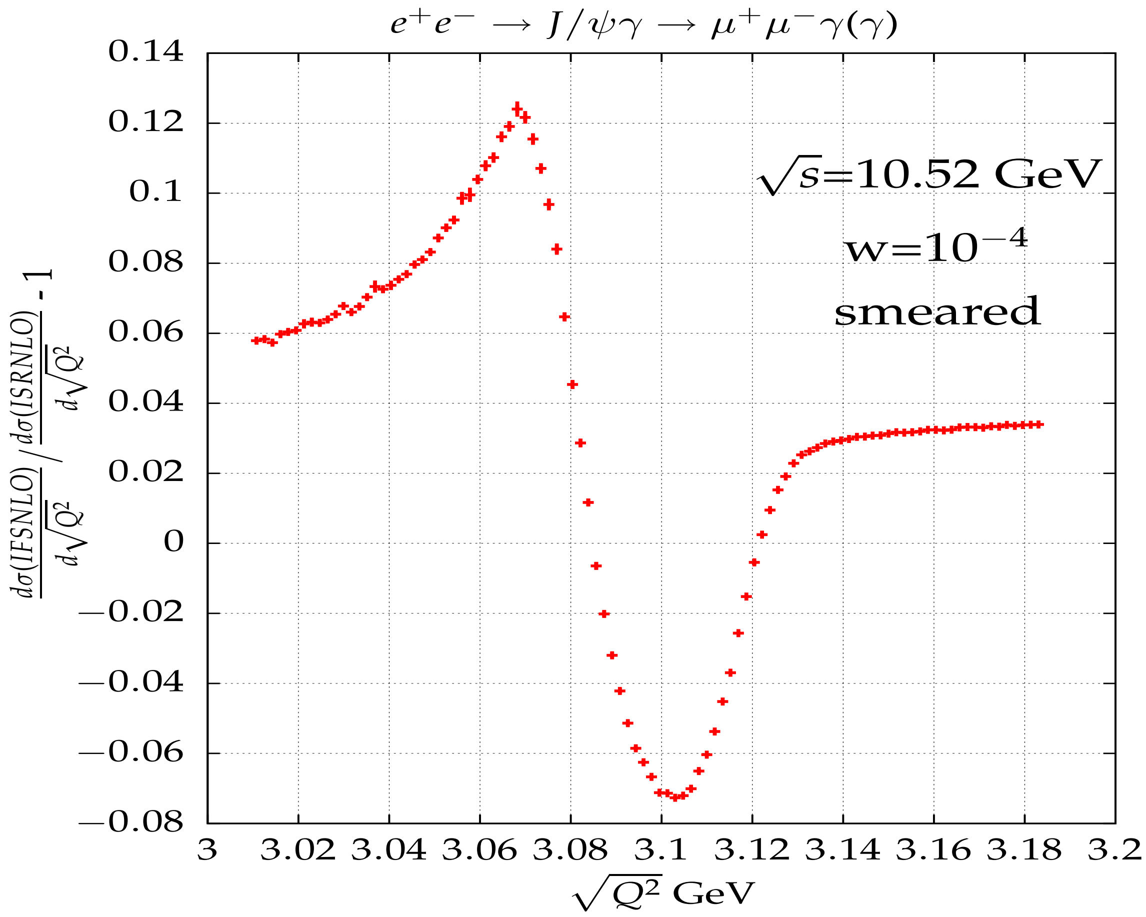
FSR - muons



$\sigma(IFSNLO) = ($ 6.8527 $\pm$ 0.0006 $)$ pb

$\sigma(ISRNLO) = ($ 6.79862 $\pm$ 0.00008 $)$ pb

FSR - muons



$\sigma(IFSNLO)$ = (6.8527 ± 0.0006) pb

$\sigma(ISRNLO)$ = (6.79862 ± 0.00008) pb

Conclusions II

- FSRNLO important for RR