

# Luminosity measurement calculations: status and open issues

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X RMCWG meeting

BINP, Novosibirsk, 23 September 2011



# BabaYaga@NLO: latest theoretical accuracy

After new JHEP paper presented yesterday  
by BabaYaga authors + Czyz, Gluza, Gunia, Riemann, Worek  
JHEP 1107 (2011) 126, arXiv:1106.3178[hep-ph]

Source of error (%)	$\phi$ -factories	$\tau$ -charm	BaBar/Belle
$ \delta_{\text{VP}}^{\text{err}} $ [Jegerlehner]	0.00	0.01	0.03
$ \delta_{\text{VP}}^{\text{err}} $ [HMNT]	0.02	0.01	0.02
$ \delta_{\text{SV},\alpha^2}^{\text{err}} $	0.02	0.02	0.02
$ \delta_{\text{HH},\alpha^2}^{\text{err}} $	0.00	0.00	0.00
$ \delta_{\text{SV,H},\alpha^2}^{\text{err}} $ [reducible?]	0.05	0.05	0.05
$ \delta_{\text{pairs}}^{\text{err}} $ [FIXED!]	0.03	0.02	0.03 – 0.07
$ \delta_{\text{total}}^{\text{err}} $	0.10÷0.12	0.10	0.12÷0.16

- $J/\psi$  and  $\psi(2S)$  narrow resonances excluded for  $\tau$ -charm factories because of large vacuum polarization uncertainty
- Room for more reliable assessment of  $|\delta_{\text{SV,H},\alpha^2}^{\text{err}}|$

# Pairs: exact NNLO vs. BabaYaga@NLO

With realistic luminosity reference event selections

	$\sqrt{s}$		$\sigma_{BY}$ (nb)	$S_{e^+e^-}$ [%]	$S_{lep}$ [%]	$S_{had}$ [%]	$S_{tot}$ [%]
KLOE	1.020	NNLO		-3.935(5)	-4.472(5)	1.02(4)	<b>-3.45(4)</b>
		BabaYaga	455.71	-3.445(2)	-4.001(2)	0.876(5)	<b>-3.126(5)</b>
BES	3.097	NNLO		-2.246(8)	-2.771(8)	—	—
		BabaYaga	158.23	-2.019(3)	-2.548(3)	—	—
BES	3.650	NNLO		-1.469(9)	-1.913(9)	-1.3(1)	<b>-3.2(1)</b>
		BabaYaga	116.41	-1.521(4)	-1.971(4)	-1.071(4)	<b>-3.042(5)</b>
BES	3.686	NNLO		-1.435(8)	-1.873(8)	—	—
		BabaYaga	114.27	-1.502(4)	-1.947(4)	—	—
BaBar	10.56	NNLO		-1.48(2)	-2.17(2)	-1.69(8)	<b>-3.86(8)</b>
		BabaYaga	5.195	-1.40(1)	-2.09(1)	-1.49(1)	<b>-3.58(2)</b>
Belle	10.58	NNLO		-4.93(2)	-6.84(2)	-4.1(1)	<b>-10.9(1)</b>
		BabaYaga	5.501	-4.42(1)	-6.38(1)	-3.86(1)	<b>-10.24(2)</b>

★ Good agreement! BabaYaga@NLO accuracy always below 1 % ! ★

- Maximum difference  $\sim 0.7\%$  at Belle,  $\sim 0.3\%$  at KLOE and BaBar,  
 $\sim 0.2\%$  at BES

# Non-perturbative nature of narrow resonances at BESIII

**Table:** *Soft+virtual NNLO contributions  $\sigma_{\text{rest,res}}^{\text{NNLO}}$  from narrow resonances (n.r.) for the Bhabha process with  $\omega/E_{\text{beam}} = 10^{-4}$  (in nb). The narrow resonance located closest to the center of mass energy of the given collider is included (first column, res) and excluded (second column, res').*

	$\sqrt{s}$	$\sigma_{\text{rest,res}}^{\text{NNLO}}$	$\sigma_{\text{rest,res'}}^{\text{NNLO}}$	$\sigma_B$
KLOE	1.020	[all n.r.] -0.04538	[n.r. without $J/\psi(1S)$ ] -0.0096	529.5
BES	3.097	[all n.r.] 228.08	[n.r. without $J/\psi(1S)$ ] -0.0258	14.75
BES	3.650	[all n.r.] -0.1907	[n.r. without $\psi(2S)$ ] -0.023668	123.94
BES	3.686	[all n.r.] -62.537	[n.r. without $\psi(2S)$ ] -0.0254	121.53
BaBar	10.56	[all n.r.] -0.0163	[n.r. without $\Upsilon(4S)$ ] -0.01438	6.744
Belle	10.58	[all n.r.] 0.04393	[n.r. without $\Upsilon(4S)$ ] -0.0137	6.331

At BESIII with c.m. energies  $3.097 \text{ GeV} = J/\psi(1S)$  and  $3.686 \text{ GeV} = \psi(2S)$  the narrow resonances can not be treated like mere perturbative corrections to  $\sigma_B \rightarrow$   
need of including beam spread effects

# Vacuum polarisation: HADR5N09 vs. HMNT for $e^+e^- \rightarrow e^+e^-$

For a discussion see the Vacuum polarisation Section of the WG Report

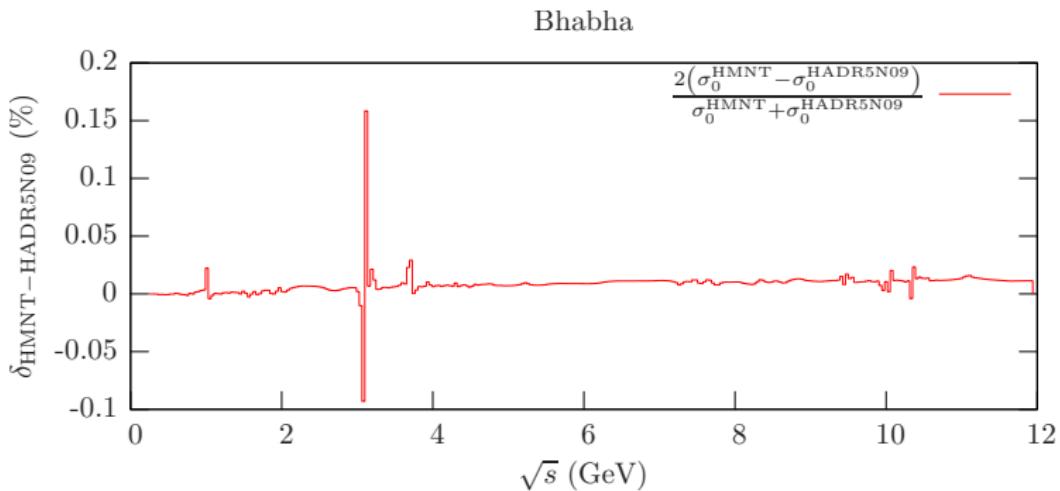
HADR5N09, F. Jegerlehner, <http://www-com.physik.hu-berlin.de/~fjeger/hadr5n09.f>

Nucl. Phys. Proc. Suppl. 135 (2008) 181

HMNT: K. Hagiwara, A.D. Martin, D. Nomura and T. Teubner, Phys. Lett. B649 (2007) 173

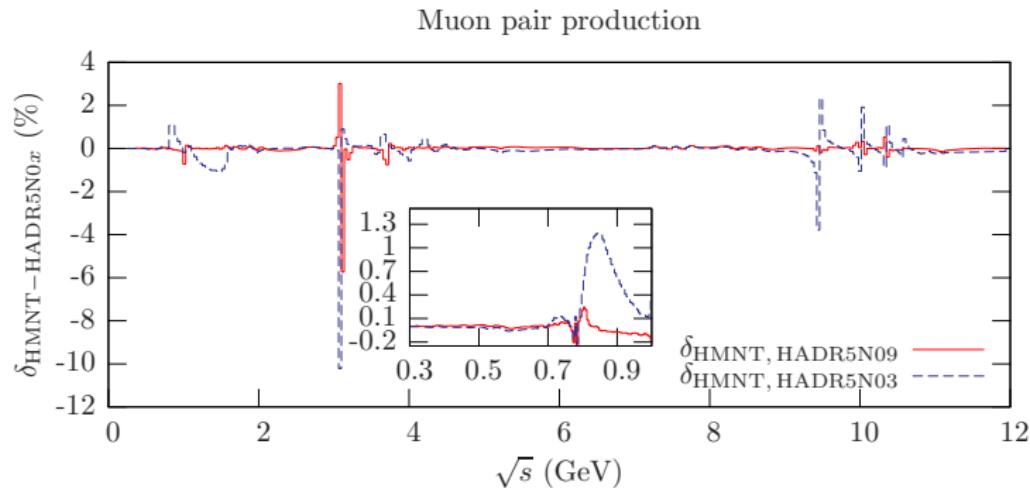
T. Teubner, K. Hagiwara, R. Liao, A.D. Martin and D. Nomura

Chinese Phys. C34 (2010) 728, arXiv:1001.5401



- Bhabha largely dominated by *t*-channel (space-like) scattering
- The two parameterisations agree within  $0.5 \times 10^{-3}$  for all c.m. energies, at  $\sim 0.1 - 0.2 \%$  around the  $J/\psi$

# Vacuum polarisation: HADR5N09[03] vs. HMNT for $e^+e^- \rightarrow \mu^+\mu^-$



- Muon pair production mediated by *s*-channel (time-like) virtualities
- The different parameterisations can induce cross section differences at the per cent level around the very narrow resonances

# The $e^+e^- \rightarrow \gamma\gamma$ process: alternative normalization?

G. Balossini *et al.*, Phys. Lett. **B663** (2008) 209

S. Eidelman *et al.*, Eur. Phys. J. **C71** (2011) 1597

## Selection criteria – $\phi$ , $\tau$ –charm and $B$ factories

a)  $\sqrt{s} = 1, 3, 10$  GeV,  $E_{min} = 0.3\sqrt{s}$ ,  $\vartheta_\gamma^{min,max} = 45^\circ \div 135^\circ$ ,  $\xi_{max} = 10^\circ$

### Cross sections (nb) & relative corrections (%)

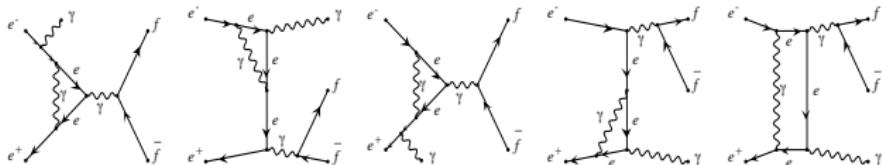
$\sqrt{s}$ (GeV)	1	3	10
$\sigma_{Born}$	137.53	15.281	1.3753
$\sigma_\alpha^{PS}$	128.55	14.111	1.2529
$\sigma_{NLO}$	129.45	14.211	1.2620
$\sigma_{exp}^{PS}$	128.92	14.169	1.2597
$\sigma_{matched}$	129.77	14.263	1.2685
$\delta_\alpha$	-5.87	-7.00	-8.24
$\delta_\infty$	-5.65	-6.66	-7.77
$\delta_\alpha^{non-log}$	0.70	0.71	0.73
$\delta_{HO}$	0.24	0.37	0.51

- Like for Bhabha, both exact  $\mathcal{O}(\alpha)$  and higher-order corrections necessary for 0.1% theoretical precision in  $\gamma\gamma$  production
- ★ Theoretical accuracy:  $\sim 0.1\%$ , also thanks to no contribution (and related  $\Delta\alpha_{had}^{(5)}$  uncertainty) due to vacuum polarisation correction

# Uncertainty due to $e^+e^- \rightarrow e^+e^-\gamma$ at one loop

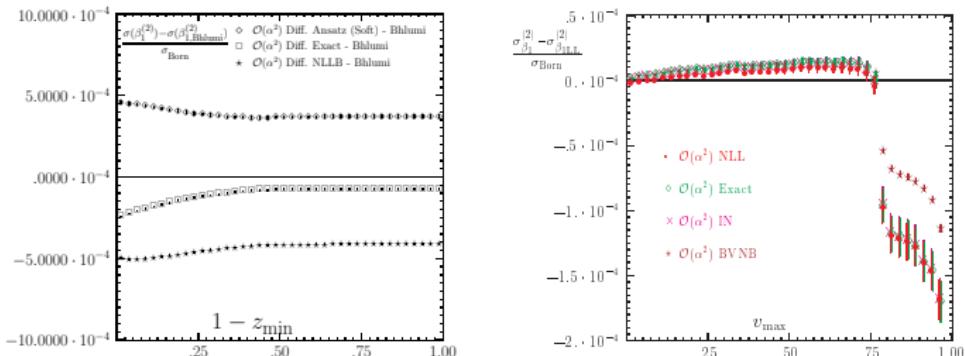
★ New! The exact perturbative calculation of  $\sigma_{SV,H}^{\alpha^2}$  for full  $s+t$  Bhabha scattering in QED appeared about one year ago ★

S. Actis, P. Mastrolia and G. Ossola, Phys. Lett. B682 (2010) 419, arXiv:0909.1750



- Using the results available for  $t$ -channel Bhabha scattering (left plot) and  $s$ -channel annihilation processes (right plot)

S. Jadach, M. Melles, B.F.L. Ward and S. Yost, PL B377 (1996) 168 & PL B450 (1999) 262  
C. Gossler, S. Jadach, B.F.L. Ward and S. Yost, Phys. Lett. B605 (2005) 123

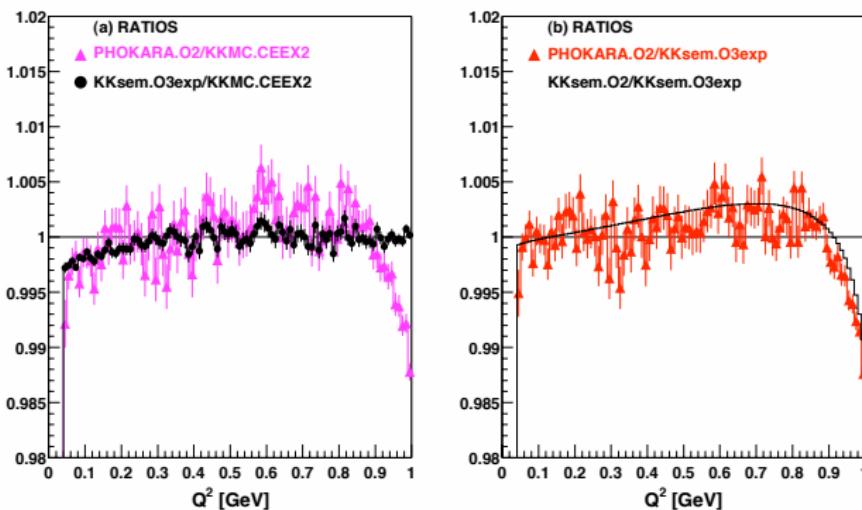


the uncertainty can be estimated  $\sim 0.05\%$

# Tuned comparisons for non-Bhabha luminosity processes

S. Jadach, Acta Phys. Pol. B36 (2005) 2387

KKMC vs PHOKHARA for  $e^+e^- \rightarrow \mu^+\mu^-\gamma(\gamma)$ : including initial-state radiation only,  
both in the signal and radiative corrections

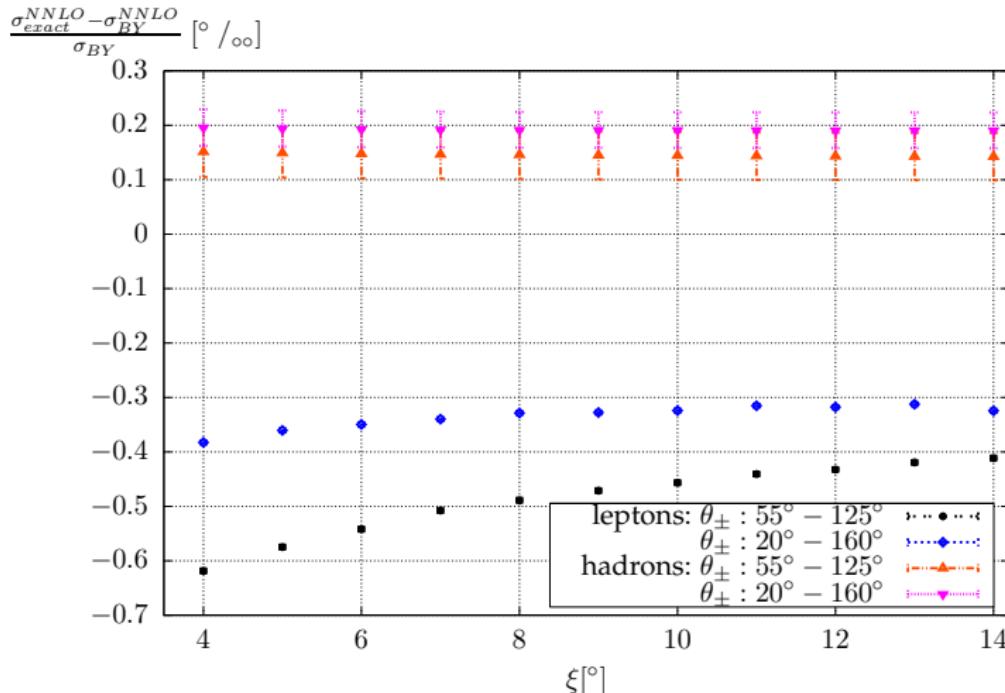


- Predictions of KKMC and PHOKHARA for the muon pair spectrum  $d\sigma/dQ^2$  in  $e^+e^- \rightarrow \mu^+\mu^-\gamma(\gamma)$  at  $\sqrt{s} = 1.02$  GeV agree within 0.2% in the central region and differ at high  $Q^2$  by  $\sim 1\%$
- New comparisons involving BabaYaga@NLO and new exact calculations?

# Numerical comparisons: cut dependence at KLOE

To what extent the agreement depends on the event selection cuts?

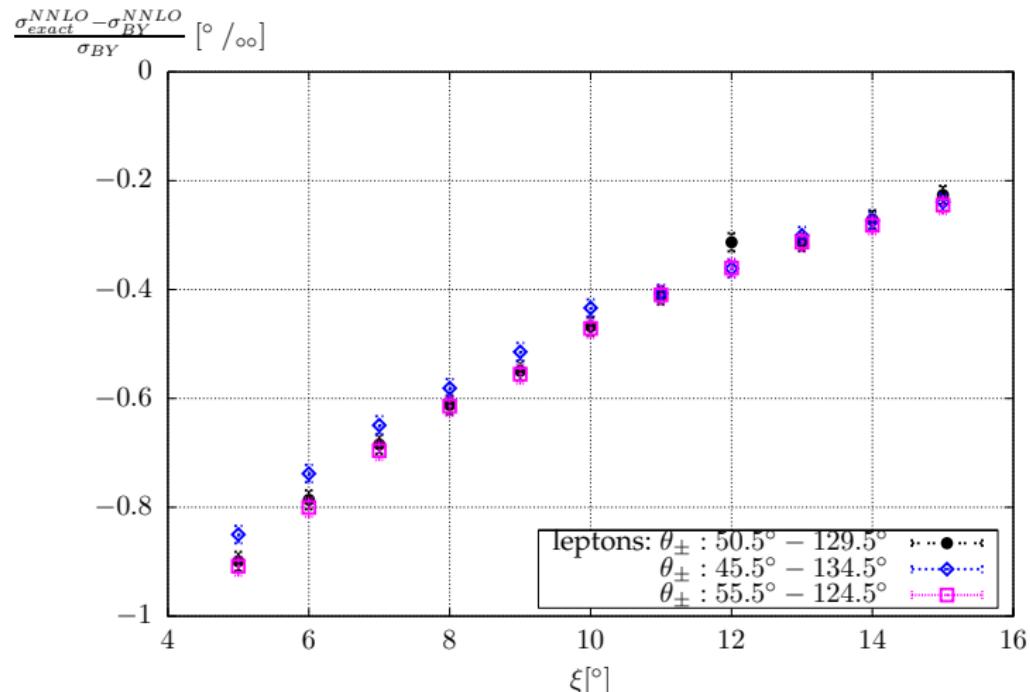
Example: acceptance/acollinearity variation for KLOE



For leptonic corrections, the difference can slightly increase for tight acollinearity cuts

# Numerical comparisons: cut dependence at Belle

Further example: acceptance/acollinearity variation for Belle



The maximum observed difference still remains below 1 %