Status of Monte Carlo generators for luminosity measurement

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Working Group on Radiative Corrections and Generators for Low Energy Hadronic Cross Section and Luminosity
Laboratori Nazionali di Frascati, 16-17 October, 2006

Based on work in collaboration with
G. Balossini, C.M. Carloni Calame, O. Nicrosini, F. Piccinini
hep-ph/0607181, to appear in Nucl. Phys. B

Luminosity and generators

- Precision measurements of the hadronic cross section require a precise knowledge of the collider luminosity

$$\int \mathcal{L}\, dt \;=\; N_{\rm obs}/\sigma_{\rm th}$$

- Precise knowledge of the luminosity needs a reference process with high statistics, clean topology and high theoretical accuracy: large–angle Bhabha, $\gamma\gamma$, $\mu^+\mu^-$, $\mu^+\mu^-\gamma$. Presently @KLOE

$$\frac{\delta\mathcal{L}}{\mathcal{L}} \;=\; \frac{\delta\mathcal{L}_{\rm exp}}{\mathcal{L}_{\rm exp}} \oplus \frac{\delta\sigma_{\rm th}}{\sigma_{\rm th}} \;=\; 0.3\%\,({\rm exp}) \,\oplus\, 0.5\%\,({\rm th}) \;=\; 0.6\%$$

A. Aloisio *et al.*, Phys. Lett. **B606** (2005) 12

F. Ambrosino *et al.*, Eur. Phys. J. **C47** (2006) 589

- High theoretical accuracy and comparison with data require precision generators including radiative corrections

Status of luminosity generators

$\star$ For large–angle Bhabha $\star$

Generator	Processes	Theory	Accuracy	Ref.
Bagenf	e^+e^-	$\mathcal{O}(\alpha)$	0.5%	INFN-AE-97-48
BabaYaga	$e^+e^-, \gamma\gamma, \mu^+\mu^-$	Parton Shower	$0.5 \div 1\%$	hep-ph/0003268
BabaYaga@NLO	$e^+e^-, \gamma\gamma, \mu^+\mu^-$	$\mathcal{O}(\alpha)$ + PS	$\sim 0.1\%$	hep-ph/0607181
MCGPJ	$e^+e^-, \mu^+\mu^- \ldots$	$\mathcal{O}(\alpha)$ + SF	$< 0.2\%$	hep-ph/0504233
BHWIDE	e^+e^-	$\mathcal{O}(\alpha)$ YFS	$\sim 1\%$(LEP)	hep-ph/9608412

- Estimate of th. uncertainty: tuned comparisons, evaluation of available $\mathcal{O}(\alpha^2)$ corrections

  see talk by C.M. Carloni Calame

- No complete $\mathcal{O}(\alpha^2)$ corrections, infrared $\mathcal{O}(\alpha^2 L)$, $L = \ln Q^2/m^2$, terms through factorization $\mathcal{O}(\alpha L) \times \mathcal{O}(\alpha)_{\mathrm{non-log}}$

  G. Montagna *et al.*, Phys. Lett. **B385** (1996) 348

- For specific (non Bhabha) channels, other generators available: BKQED for $\gamma\gamma$, KKMC for $\mu\mu$, $\mu\mu\gamma$, PHOKHARA for $\mu\mu\gamma$...

Large–angle Bhabha: radiative corrections

G. Balossini *et al.*, `hep-ph/0607181`

Selection criteria – ϕ and B factories

a. $\sqrt{s} = 1.02\,\mathrm{GeV},\ E^{\pm}_{\mathrm{min}} = 0.408\,\mathrm{GeV},\ \vartheta_{\mp} = 20^{\circ} \div 160^{\circ},\ \xi_{\mathrm{max}} = 10^{\circ}$

b. $\sqrt{s} = 1.02\,\mathrm{GeV},\ E^{\pm}_{\mathrm{min}} = 0.408\,\mathrm{GeV},\ \vartheta_{\mp} = 55^{\circ} \div 125^{\circ},\ \xi_{\mathrm{max}} = 10^{\circ}$

c. $\sqrt{s} = 10\,\mathrm{GeV},\ E^{\pm}_{\mathrm{min}} = 4\,\mathrm{GeV},\ \vartheta_{\mp} = 20^{\circ} \div 160^{\circ},\ \xi_{\mathrm{max}} = 10^{\circ}$

d. $\sqrt{s} = 10\,\mathrm{GeV},\ E^{\pm}_{\mathrm{min}} = 4\,\mathrm{GeV},\ \vartheta_{\mp} = 55^{\circ} \div 125^{\circ},\ \xi_{\mathrm{max}} = 10^{\circ}$

Relative corrections (in %)

set up	a.	b.	c.	d.
δ_{VP}	1.73	2.43	4.59	6.03
δ_{α}	−13.06	−17.16	−19.10	−24.35
δ_{HO}	0.43	0.93	0.87	1.76
$\delta_{\alpha}^{\mathrm{non-log}}$	−0.39	−0.66	−0.41	−0.70
$\delta_{\alpha^2 L}$	0.04	0.09	0.06	0.11

- Both exact $\mathcal{O}(\alpha)$ and higher-order corrections necessary for 0.1% theoretical precision

Large–angle Bhabha: tuned comparisons

Without vacuum polarization, to compare consistenly

Till a few months ago...

A. Denig and F. Nguyen, KLOE Note n. 202

Generator	Cross Section (nb)	$\delta_{ij}(\%)$
BabaYaga	459.4 ± 0.1	$\delta_{BBH} = 0.7$
BHWIDE	456.2 ± 0.1	$\delta_{BHM} = 0.3$
MCGPJ	457.4 ± 0.1	$\delta_{MB} = 0.4$

- (Dis)agreement at $\sim$ 0.5% level

Present situation

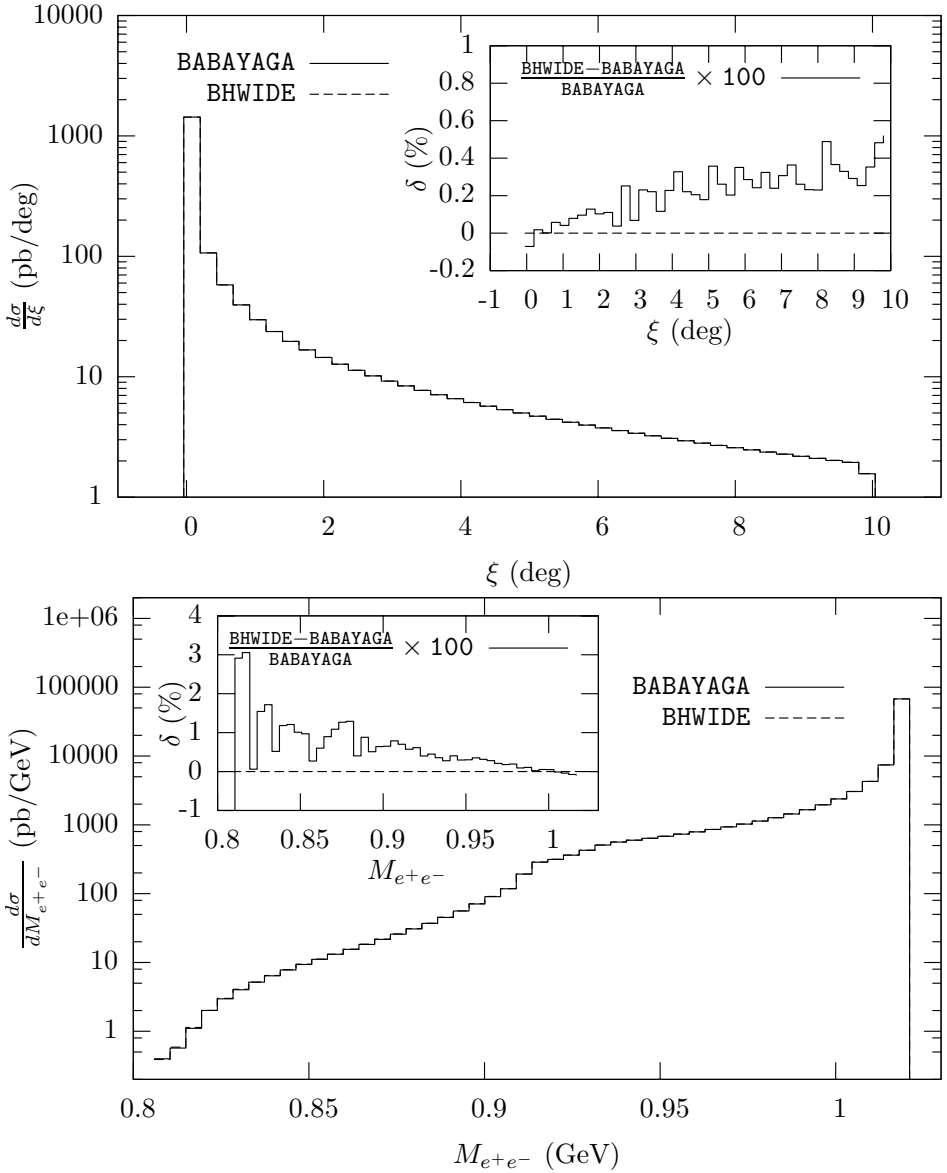
G. Balossini *et al.*, hep-ph/0607181

set up	BabaYaga@NLO	BHWIDE	LABSPV	$\delta_{BBH}(\%)$	$\delta_{BL}(\%)$
a.	$6086.6(1)$	$6086.3(2)$	$6088.5(3)$	0.005	0.030
b.	$455.85(1)$	$455.73(1)$	$456.19(1)$	0.030	0.080

$\star$ Agreement within 0.1%!

BabaYaga@NLO vs BHWIDE

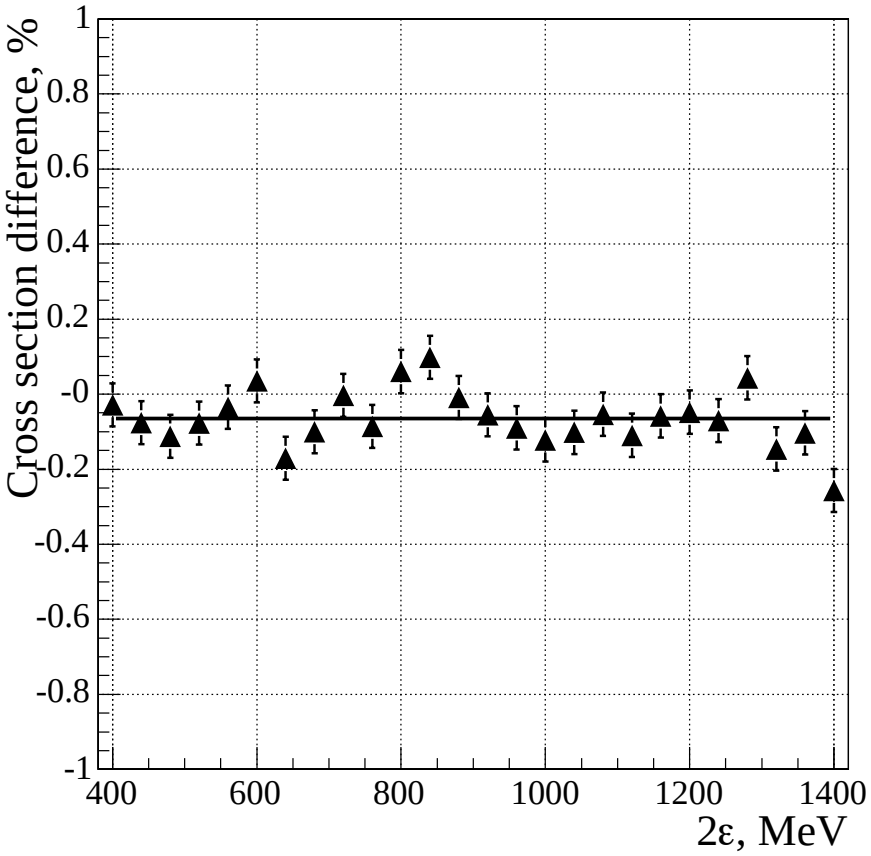
G. Balossini *et al.*, hep-ph/0607181

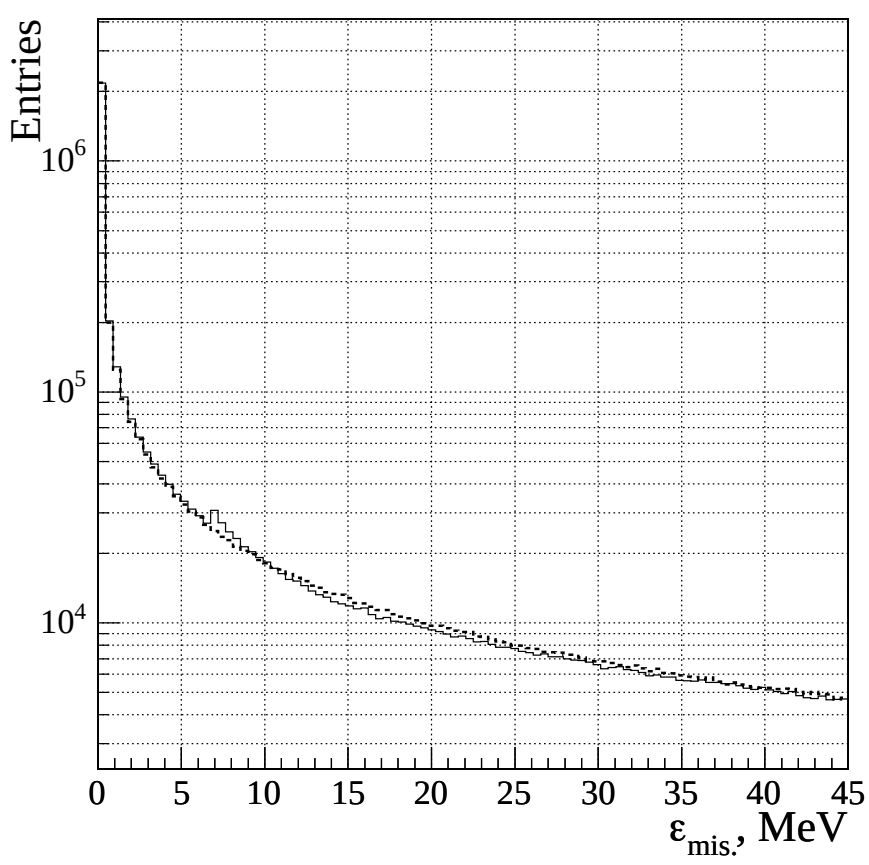


- Agreement within a few 0.1%, a few % only in the hard tails

MCGPJ vs BHWIDE

A.B. Arbuzov *et al.*, hep-ph/0504233





- Agreement within $0.1 \div 0.2\%$ for integrated cross section.
  Agreement within $\sim 1\%$ for distributions

Conclusions...and input for the discussion

- Recent progress in reducing the theoretical error to luminosity measurement at low-energy e^+e^- colliders down to $\sim$ 0.1%
- Exact $\mathcal{O}(\alpha)$ and multiple photon corrections are necessary ingredients for 0.1% theoretical accuracy
- At least three generators for large–angle Bhabha scattering (`BabaYaga@NLO`, `BHWIDE`, `MCGPJ`) agree within $\sim 0.1\%$ for integrated cross section and $\sim 1\%$ for distributions
- Precision generators also available for $\gamma\gamma$ production (`BabaYaga@NLO`, `BKQED`) and $\mu\mu, \mu\mu\gamma$ final states (`KKMC`, `MCGPJ`, `PHOKHARA`)

$\star$ Are full $\mathcal{O}(\alpha^2)$ corrections really needed for 0.1% Bhabha?

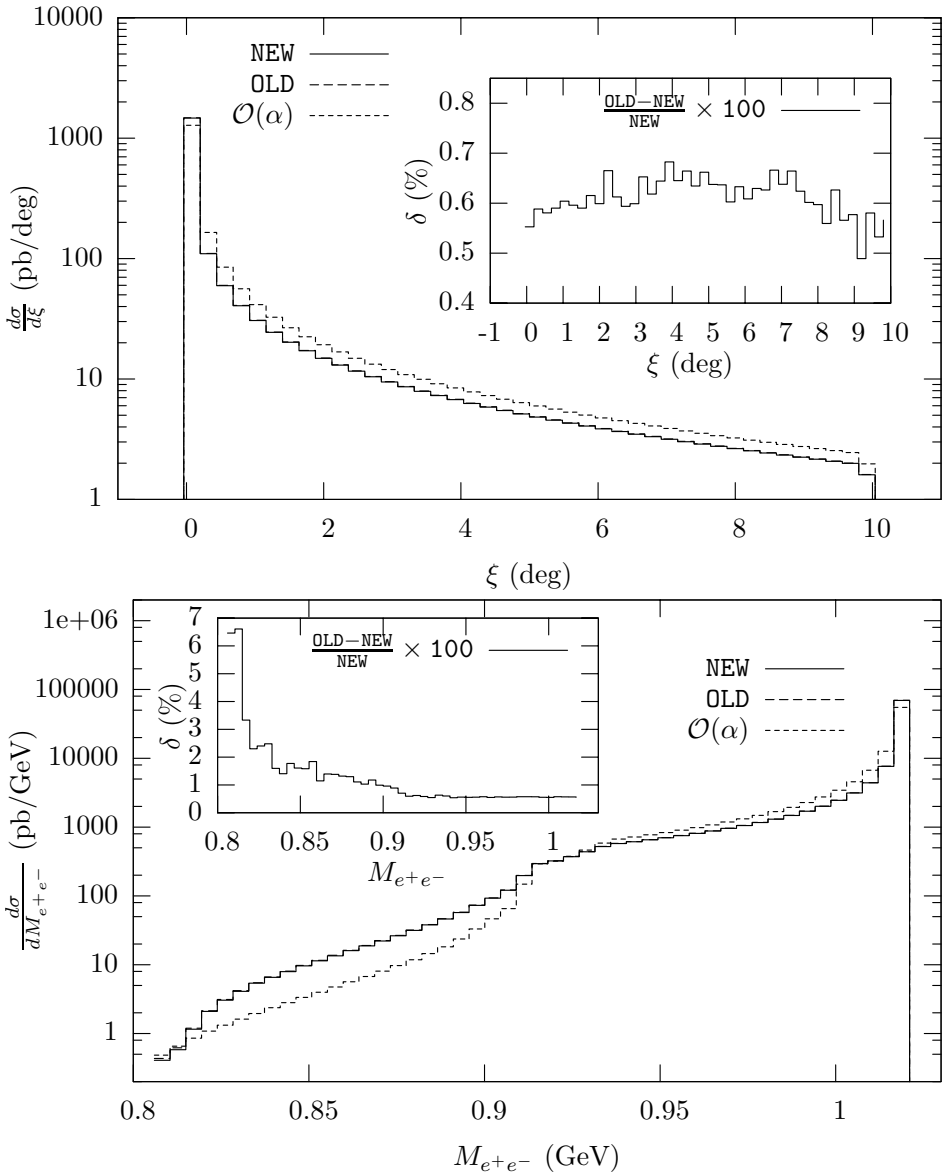
see talk by C.M. Carloni Calame

$\star$ Are new tuned Bhabha comparisons really necessary? Maybe, more important for $\gamma\gamma$, $\mu\mu$, $\mu\mu\gamma$...

Backup Slides

BabaYaga vs BabaYaga@NLO

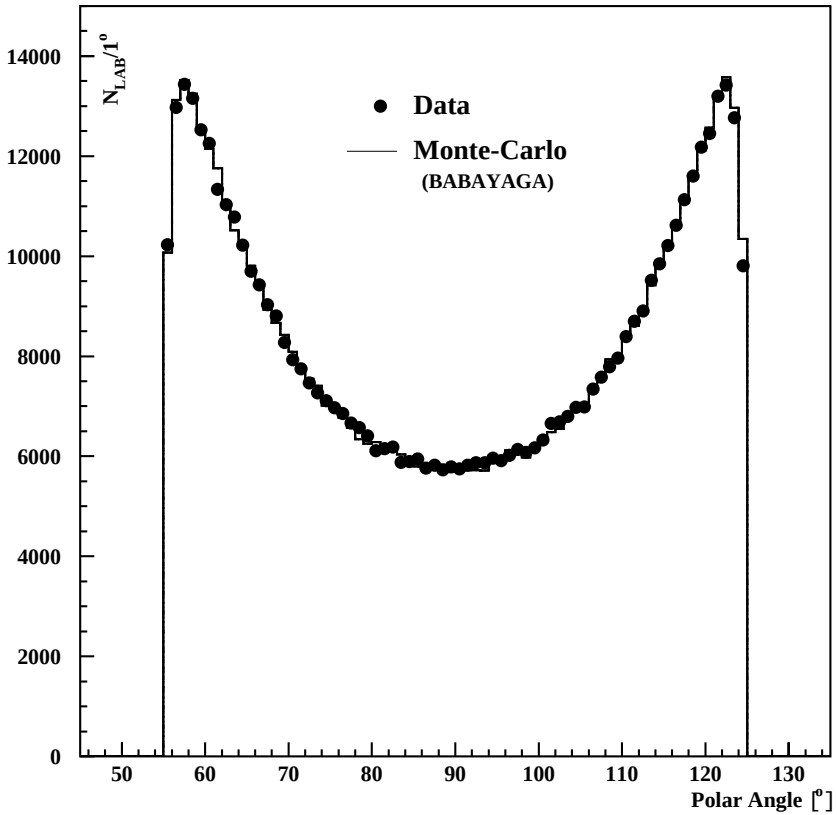
G. Balossini *et al.*, hep-ph/0607181

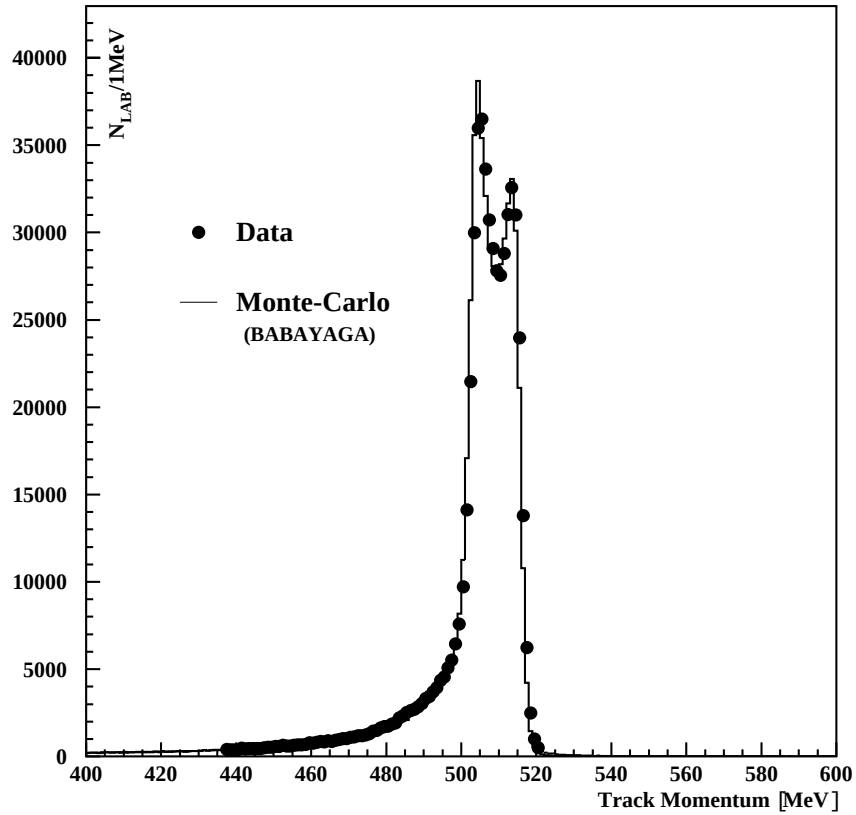


- BabaYaga@NLO differs from BabaYaga at 0.5% level

BabaYaga vs KLOE data

F. Aloisio *et al.*, Phys. Lett. **B606** (2005) 12





MCGPJ vs CMD-2 data

A.B. Arbuzov *et al.*, hep-ph/0504233