New Results on the Theoretical Precision of the LEP/SLC Luminosity*

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OUTLINE

- INTRODUCTION
- EXACT RESULTS ON $O(\alpha)$ CORRECTION TO 1γ BREMSSTRAHLUNG
- EXACT RESULTS ON 2γ BREMSSTRAHLUNG: TECHNICAL PRECISION CHECK
- EXACT 2-LOOP VIRTUAL CORRECTION
- NEW ERROR ANALYSIS FOR BHLUMI 4.04
- CONCLUSIONS

• INTRODUCTION

* MOTIVATION

PRECISION SM TESTS AT LEP

$$\Delta\vartheta/\vartheta = \left(\left(\frac{\partial\vartheta}{\partial\sigma_{\mathcal{L}}}\left(\frac{\Delta\sigma_{\mathcal{L}}}{\sigma_{\mathcal{L}}}\right)\frac{\sigma_{\mathcal{L}}}{\vartheta}\right)^2 + \cdots + \right)^{1/2}$$

$\Rightarrow$ $\frac{\Delta\sigma_{\mathcal{L}}}{\sigma_{\mathcal{L}}}$ NEEDED AS SMALL AS POSSIBLE

$\Rightarrow$ $\left.\frac{\Delta\sigma_{\mathcal{L}}}{\sigma_{\mathcal{L}}}\right|_{th}$ NEEDED AS SMALL AS POSSIBLE

* STATUS

$\left.\frac{\Delta\sigma_{\mathcal{L}}}{\sigma_{\mathcal{L}}}\right|_{TH}$ (A.P.P. B28, 925 (1997))

	LEP1		LEP2
Type of correction/error	Past	Present	Present
(a) Missing photonic $\mathcal{O}(\alpha^2 L)$	0.15%	0.10%	0.20%
(b) Missing photonic $\mathcal{O}(\alpha^3 L^3)$	0.008%	0.015%	0.03%
(c) Vacuum polarization	0.05%	0.04%	0.10%
(d) Light pairs	0.01%	0.03%	0.05%
(e) Z-exchange	0.03%	0.015%	0.0%
Total	0.16%	0.11%	0.25%

Table 1: Summary of the total (physical+technical) theoretical uncertainty for a typical calorimetric detector. For LEP1, the above estimate is valid for the angular range 1°–3°; for LEP2 it covers energies up to 176 GeV, and angular ranges of 1°–3° and 3°–6° (see the text for further comments).

$\left.\frac{\Delta\sigma_{\mathcal{L}}}{\sigma_{\mathcal{L}}}\right|_{EXPT} \lesssim .05\%$ $\Rightarrow$ NEED TO MOVE $\frac{\Delta\sigma_{\mathcal{L}}}{\sigma_{\mathcal{L}}}$ TO

.05%-REGIME, AT LEAST.

* DOMINANT CONTRIBUTION TO $\Delta\sigma_{\mathcal{L}}/\sigma_{\mathcal{L}}|_{TH}$

(a) MISSING PHOTONIC $O(\alpha^2 L)$ ⟷ .1%

- PHYSICAL PRECISION
  1. $O(\alpha)$ CORR. TO 1γ BREMSSTRAHLUNG: $\bar{\beta}_1$
  2. $O(\alpha^2)$ CORR. TO $\bar{\beta}_0$ (2-LOOP VIRTUAL CORR.)

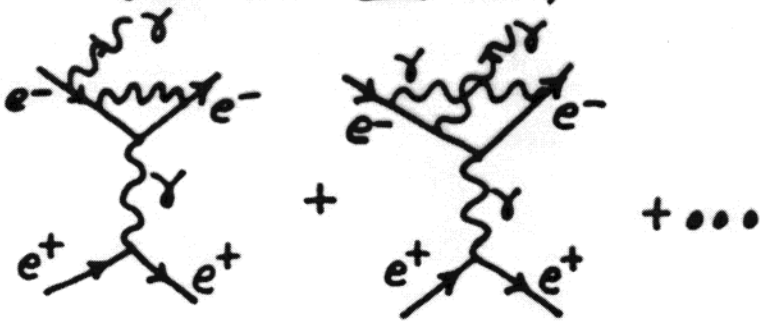
- TECHNICAL PRECISION
  1. $O(\alpha^2)$ 2γ BREMSSTRAHLUNG: $\bar{\beta}_2$

  (INDEPENDENT REALIZATION OF 2γ PHASE SPACE IN 'TEST' MC)

WE NOW TURN TO THESE IN TURN

• EXACT RESULTS ON $O(\alpha)$ CORRECTION TO 1γ BREMSSTRAHLUNG

* S. JADACH ET AL., P.L. B377, 168 (1996)



⇒ $O(\alpha)$ CORR. TO $\bar{\beta}_1$, EXACT

* FOR COMPARISON, WE ALSO IMPLEMENT TO RESULT OF ARBUZOV ET AL. (NPB485, 457 (1997)) WHICH IS SUPPOSED TO INCLUDE $O(\alpha^2 L)$, NLLB

* WE ALSO IMPLEMENT A SIMPLIFIED FORM OF OUR EXACT RESULT BASED ON A SOFT γ ANSATZ , ANSATZ (SOFT)

⇒ RESULTS IN FIGS. 1 AND 2

LEP1

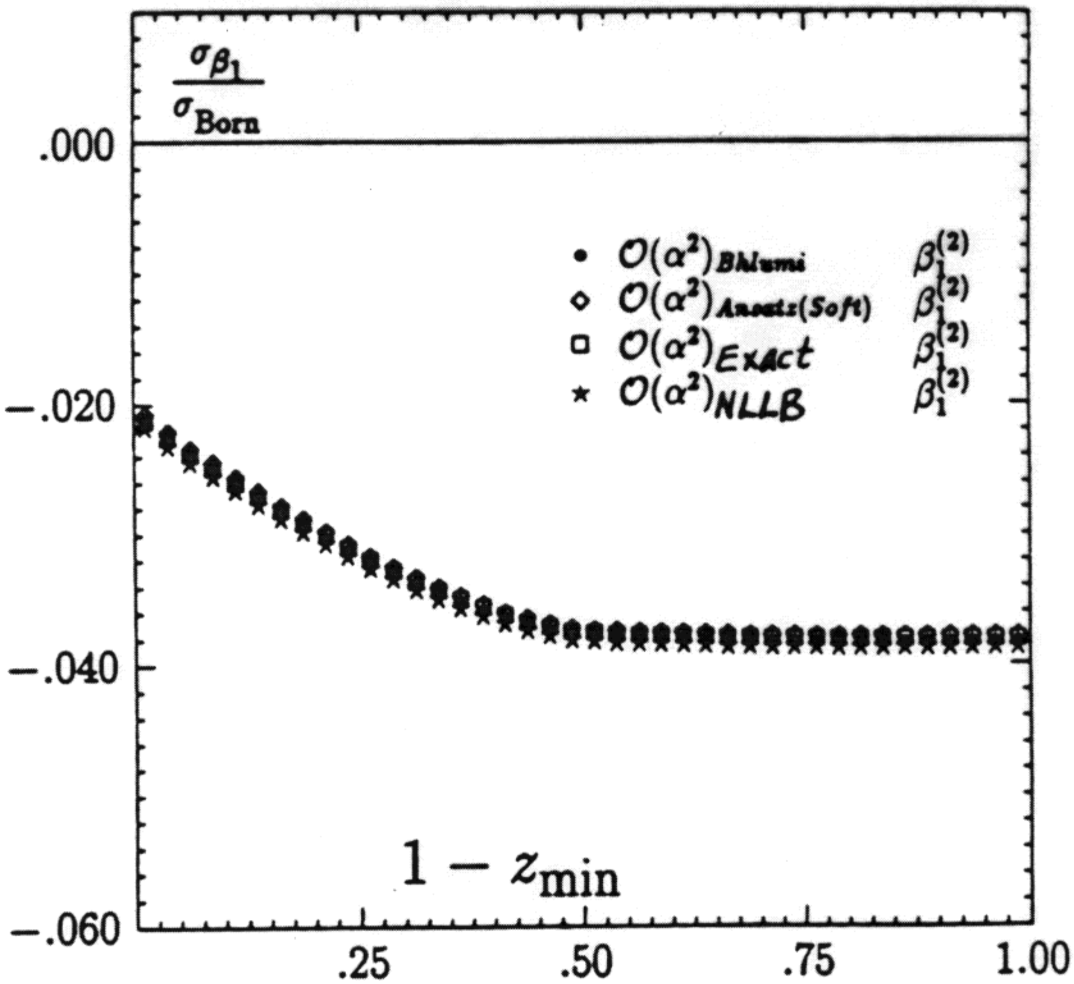


Figure 1

LEP I

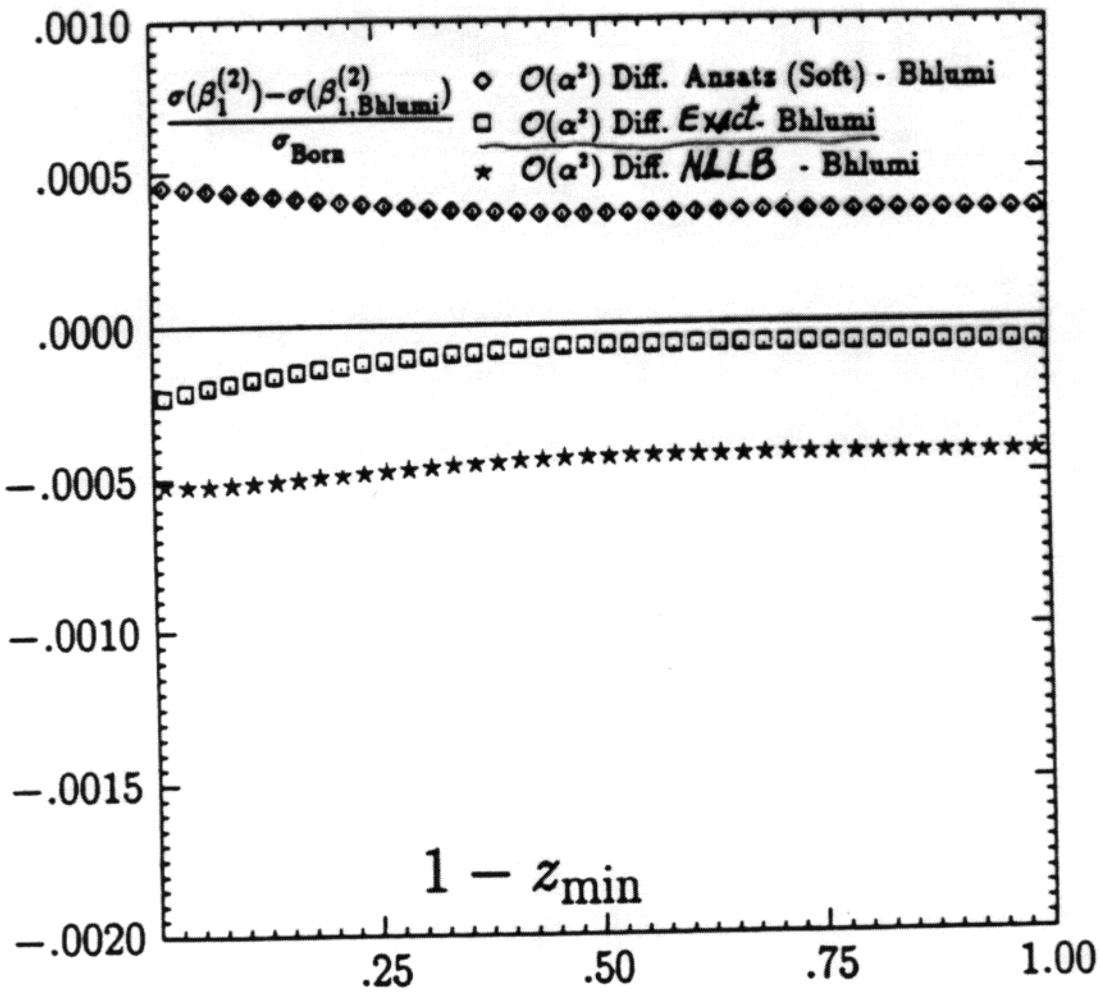


Figure 2

⇒ FOR $.2 \lesssim 1-z_{min} \leq 1$, $\left.\frac{\Delta\sigma_{\mathcal{L}}}{\sigma_{\mathcal{L}}}\right|_{O(\alpha^2 L \bar{\beta}_1)} \leq .02\%$

- EXACT RESULTS ON 2γ BREMSSTRAHLUNG: TECHNICAL PRECISION CHECK

  * WE USE EXACT RESULTS ON 2γ BREMSS. FOR $\bar{\beta}_2$ (S. JADACH <u>ET AL</u>., P.R.D<u>47</u>, 2682(1993); <u>ibid.</u> <u>D42</u>, 2977(1990))

  * WE REALIZE 2γ PHASE SPACE VIA AN INDEPENDENT 'TEST' MC FOR TECHNICAL PRECISION CHECK OF $\bar{\beta}_2$

  ⇒ BY PRODUCT: CROSS CHECK PHYSICAL PRECISION OF $\bar{\beta}_2$ AS WELL

  ⇒ RESULTS IN FIG. 3

LEPI

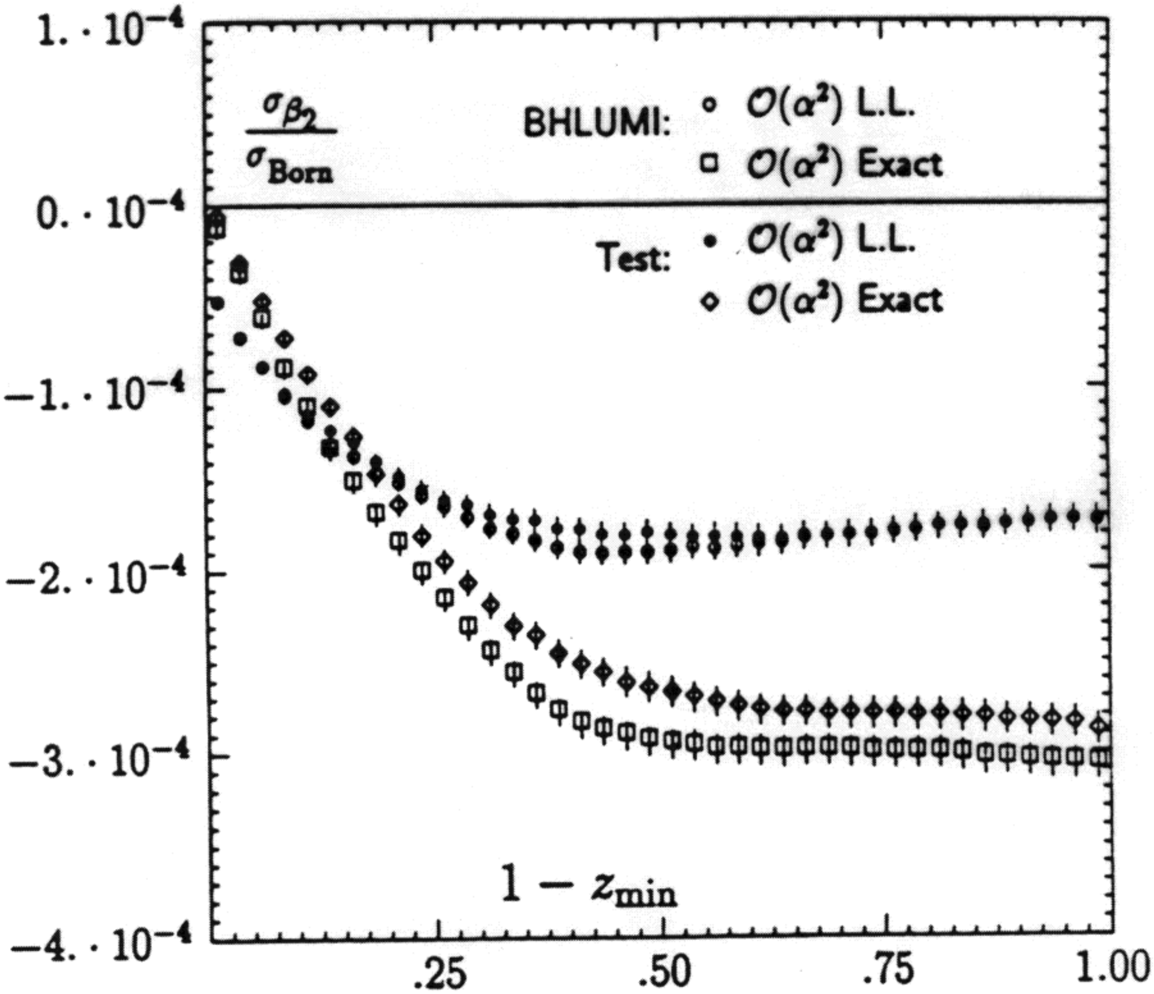


Figure 3

$$\Rightarrow \quad \frac{\Delta\sigma_{\mathcal{L}}}{\sigma_{\mathcal{L}}}\Bigg|_{(O(\alpha^2\ \bar{\beta}_2;\ \text{TECH. PREC.})} \leq .003\%$$

$$\frac{\Delta\sigma_{\mathcal{L}}}{\sigma_{\mathcal{L}}}\Bigg|_{(O(\alpha^2\ \bar{\beta}_2;\ \text{PHYS. PREC.})} \leq .012\%$$

• EXACT 2-LOOP VIRTUAL CORRECTION

* WE ANALYTICALLY CONTINUE THE WORK OF BERENDS ET AL. (NP. B297, 429(1988)) TO t-CHANNEL

$$\Rightarrow \Delta\bar{\beta}_0 / \bar{\beta}_0\Big|_{\text{Born}} = \left(\frac{\alpha}{\pi}\right)^2 L \left(6 + 6\zeta(3) - \frac{45}{8} - \frac{\pi^2}{2}\right) + \left(\frac{\alpha}{\pi}\right)^2 \left(6 - 9\zeta(3) + \left(\frac{17}{8} - 2\ln 2\right)\pi^2 - \frac{8}{45}\pi^4\right) \qquad (1)$$

$$\Rightarrow \boxed{\frac{\Delta\sigma_{\mathcal{L}}}{\sigma_{\mathcal{L}}}\Big|_{(\mathcal{O}(\alpha^2)\,\bar{\beta}_0)} \leq .014\%}$$

• NEW ERROR ANALYSIS FOR BHLUMI 4.04

* USING THE RESULTS JUST DERIVED WE GET

$$\left.\frac{\Delta\sigma_{\mathcal{L}}}{\sigma_{\mathcal{L}}}\right|_{O(\alpha^2)\text{-PHOTONIC}} = .027\%$$

⇒

|< JULY, 1998 >|

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Total	0.16%	0.061%	0.122%

Table 1: Summary of the total (physical+technical) theoretical uncertainty for a typical calorimetric detector. For LEP1, the above estimate is valid for the angular range 1°–3°; for LEP2 it covers energies up to 176 GeV, and angular range ≅ [1°, 3°] (see the text for further comments).

NOTE: EXTENSION TO 200 GeV AND 3°–6° IN PROGRESS

• CONCLUSIONS

⊗ NEW ANALYSIS OF ERRORS FOR BHLUMI 4.04 COMPLETED

$O(\alpha^2 L)$ PHOTONIC ERROR REDUCED TO .027% AT LEP1

$$\Rightarrow \left.\frac{\Delta\sigma_{\mathcal{L}}}{\sigma_{\mathcal{L}}}\right|_{TH} = .061\% \quad \text{LEP1}$$

⊗ FOR LEP2, UP TO 176 GeV,

$$\left.\frac{\Delta\sigma_{\mathcal{L}}}{\sigma_{\mathcal{L}}}\right|_{TH} = .122\%$$

⊗ EXTENSION TO 200GeV IN PROGRESS (AS WELL AS EXTENSION TO 3°–6°)

⊗ PREDICTIONS OF BHLUMI 4.04 UNCHANGED