Do we expect problems with theory error in the luminosity measurement using double-tag Bhabha at 25-100 mrads, 1-3 TeV?

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- Introduction
- LumTeV Monte Carlo
- Photonic versus beamstrahlung
- Is exponentiation important?
- Z contribution and EW corrections
- Hadronic vacuum correction
- Summary

Acknowledgements

We thank W. Płaczek and T. Riemann for discussion and help.

WARNING

All numerical results are PRELIMINARY

Most of them are x-checked but they may still change!

Appologies

We did not have time to use latest results

on the hadronic vacuum polarization

These transparences are here http://jadach.home.cern.ch/jadach/

Expected important sources of TH error of σ^{tot}_{Bhabha} at 1-3TeV, 25-100mrad:

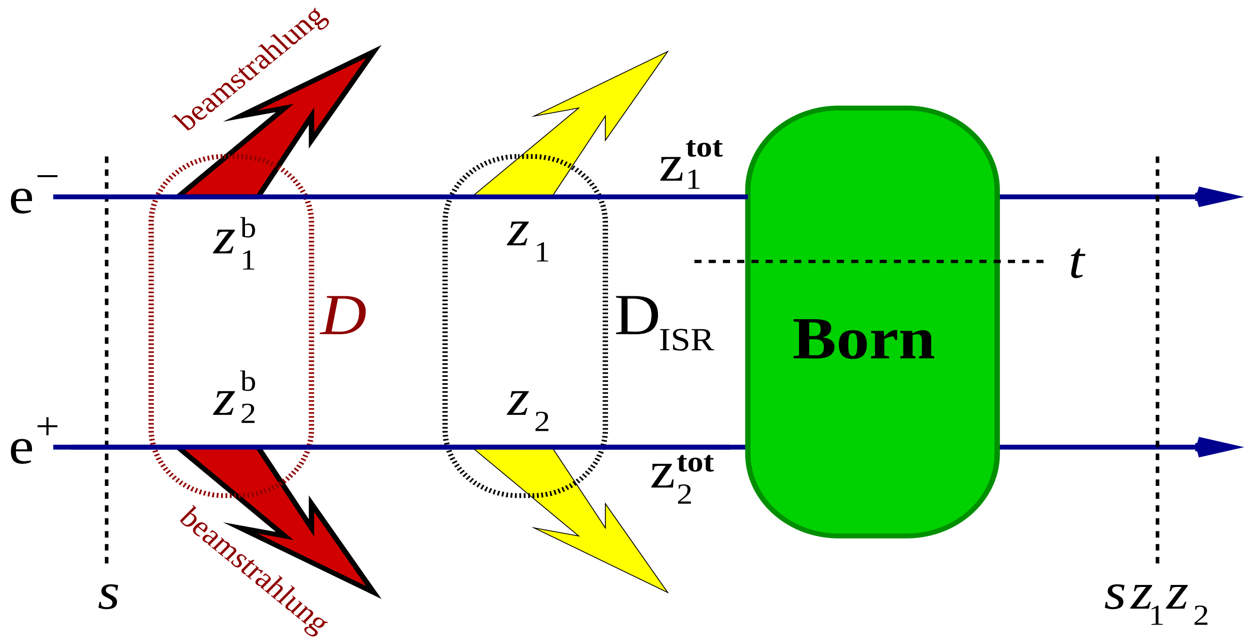
- QED photonic corrections
- EW corrections to Z_t
- Hadronic vacuum polarization

Basic difference with LEP1:

The average transfer $\sqrt{|t|} \sim 75$GeV instead of $\sqrt{|t|} \sim 2$GeV !
t-channel Z becomes important, hadronic vacuum polarization possibly bigger.
Photonic QED corrections scale with $\sim \alpha \ln(|t|/m_e^2) \ln(\vartheta_{max}/\vartheta_{\min})$ and might be bigger by a factor $\sim \ln(3TeV/M_Z)/\ln(M_Z/m_e) \sim +30\%$.

Due to beamstrahlung luminosity is a function $\mathcal{L}(z_1, z_2)$, not a number!

Kinematics of LumTeV



$\sigma(s) =$

$$\int_0^1 dz_1^b dz_2^b \mathcal{D}(z_1^b, z_2^b) \int_0^1 dz_1 dz_2 D^{\rm LL}_{\rm ISR}(z_1, z_2) \int dt \; \frac{d\sigma}{dt}(s z_1^{tot} z_2^{tot}, t) \Theta(\vartheta_1, \vartheta_2).$$

where

$\mathcal{D}(z_1^b, z_2^b)$ is bemstrahlung function normalized to one,

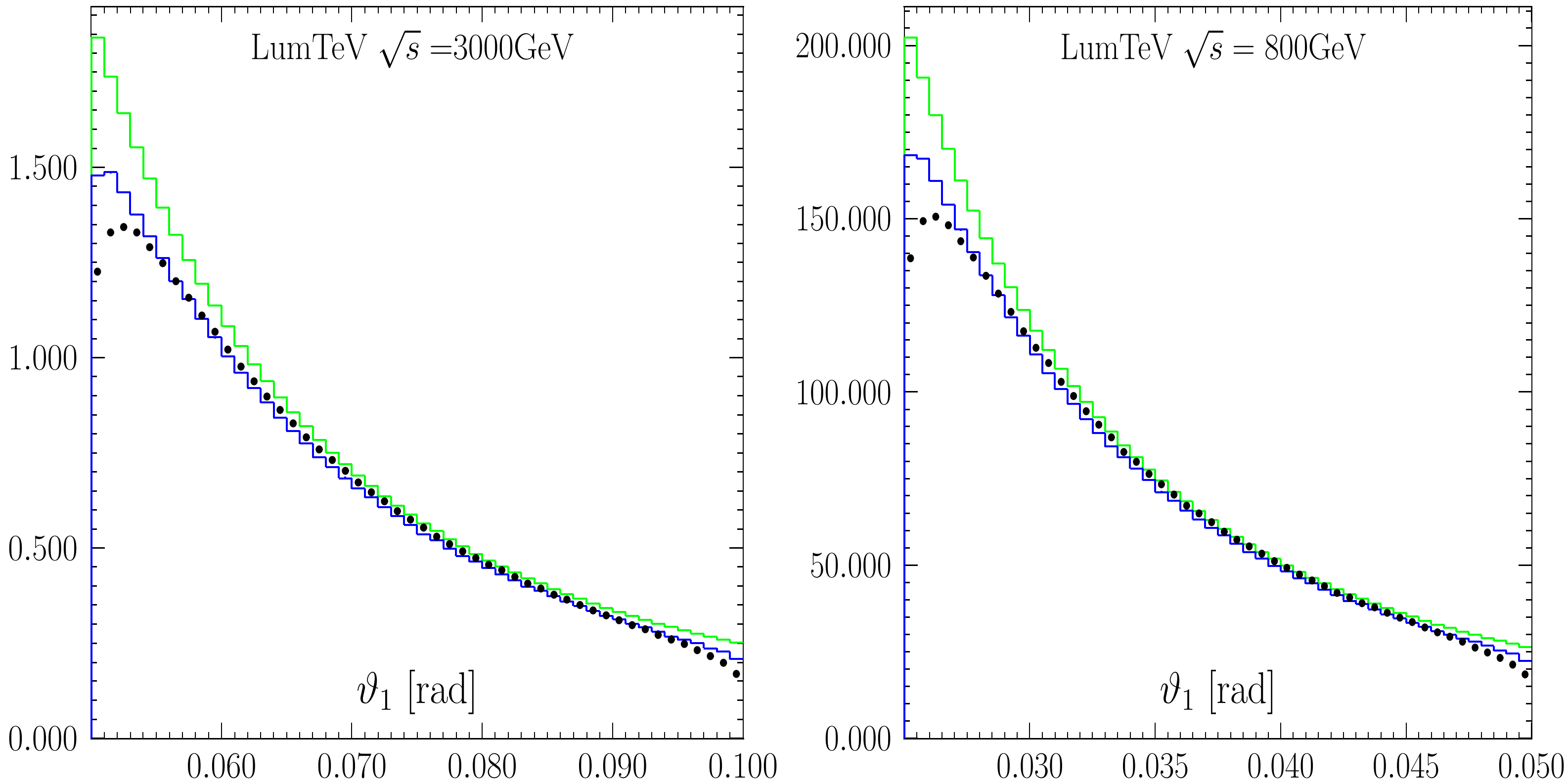
$D^{\rm LL}_{\rm ISR}(z_1, z_2)$ is the QED leading-Log (LL) ISR structure function (Jadach, Skrzypek, Ward).

Acceptance $\Theta(\vartheta_1, \vartheta_2) = 1$ only if $\vartheta_{\rm min} < \vartheta_i < \vartheta_{\rm max}$ for both ϑ_i in CMS.

LumTeV main points

- LumTeV is not a replacement for finite p_T photons MC like BHLUMI/BHWIDE! LumTeV is for testing and prototyping future MC based on (modified) BHLUMI.
- Basic MC algorithm of LumTeV is that of LUMLOG (implementing $\Theta(\vartheta_1, \vartheta_2)$).
- 5-dimensional integral done using `Foam`, 25M events/hour. Very efficient, 95% acceptance rate (`Vegas` could do $\sim 1\%$ accept. only).
- Beamstrahlung SF $\mathcal{D}(z_1^b, z_2^b)$ is an **arbitrary** "user provided function", presently SF's of `Circe` of T. Ohl is used (with $\delta(1-z)$ singularities!).
- QED ISR structure function $D_{\rm ISR}^{\rm LL}(z_1, z_2)$ (Jadach, Skrzypek, Ward) is implemented: in exponentiated form at $\mathcal{O}(\alpha^i)_{exp}$ $i = 0, 1, 2, 3$ and also without exponentiation at $\mathcal{O}(\alpha^i)$ $i = 0, 1, 2$ (as in LUMLOG).
- 4-momenta in CMS are provided – ISR photons have all $p_T = 0$.
- Programmed in g77 (pseudoclass).

Angular distribution



Photonic QED corrections and beamstrahlung are of similar size.

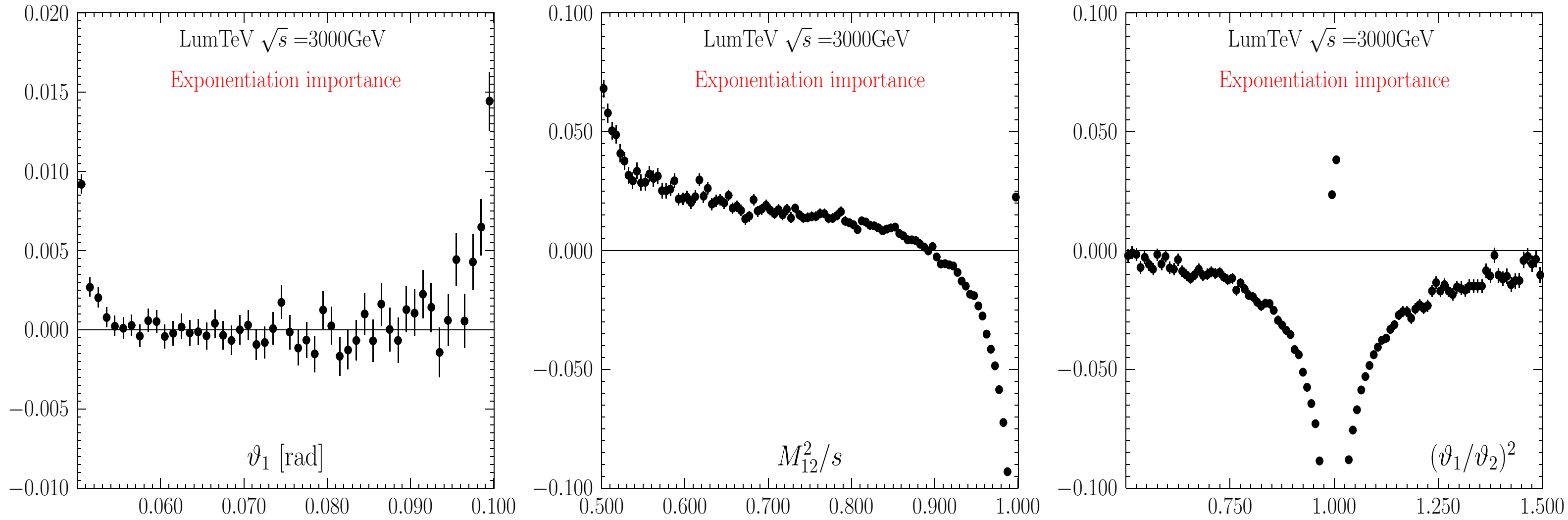
Green continuous line: Born

Blue dotted line: photonic QED (LL)

Black dotted line: photonic QED (LL) + beamstrahlung, (Circe TESLA)

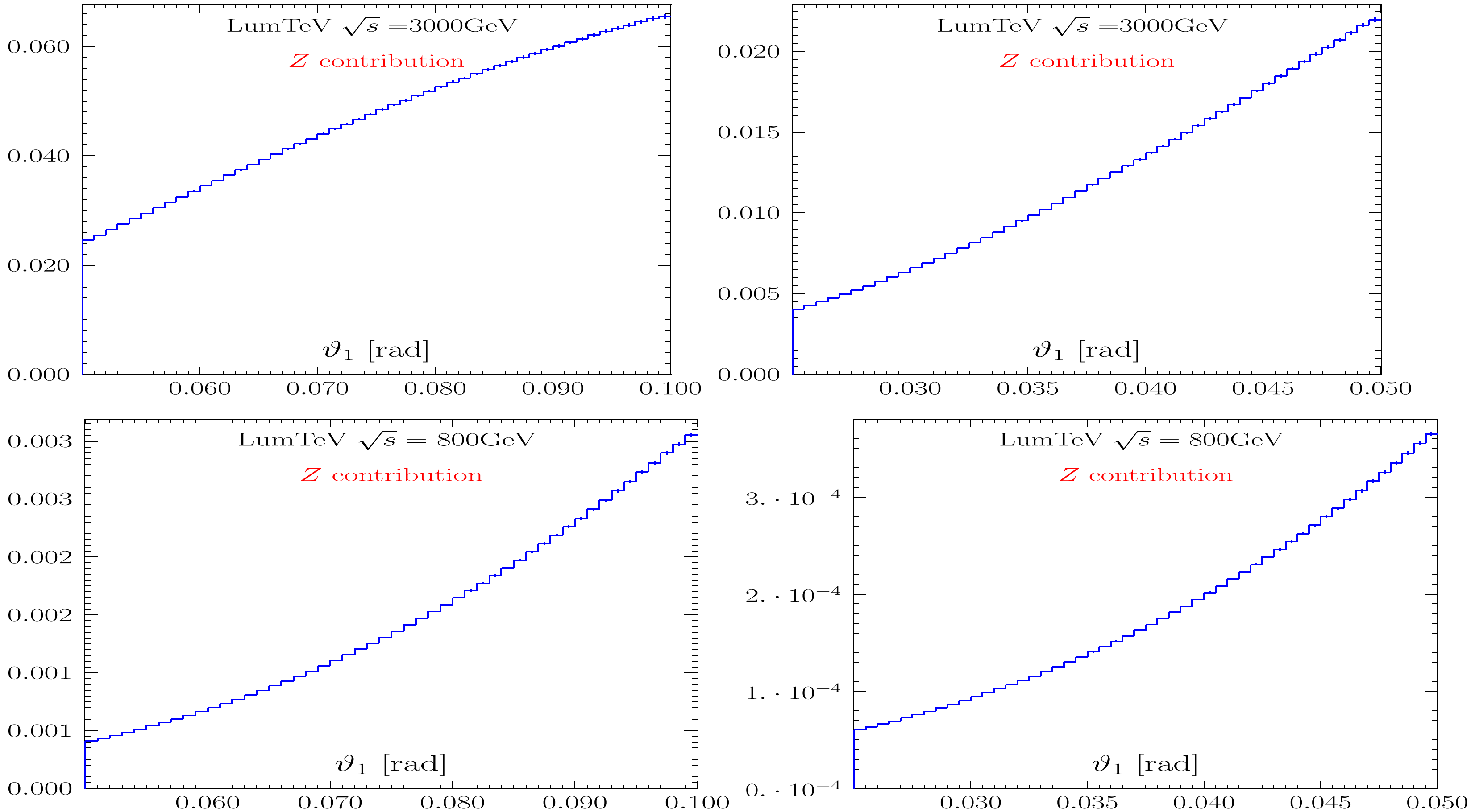
Is exponentiation important?

The difference $\mathcal{O}(\alpha^3)_{exp} - \mathcal{O}(\alpha^2)$ in LL approximation (ISR only) gives us hint how wrong the calculation in $\mathcal{O}(\alpha^2)$ without exponentiation actually is:



Conclusion: Exponentiation of photonic QED is absolute necessity!

Note that $M_{12}/s = z_1 z_2$ and $\vartheta_1/\vartheta_2 \simeq z_1/z_2$ are basic variables for determination of the luminosity distribution. Effects close to ϑ-edges are due to soft ISR photons.



t-channel Z contribution is sizeable, up to 6%.

This result was x-checked with 2 Born programs of BHWIDE and DIZET.

NB. s-channel $Z + \gamma$ is negligible $< 10^{-4}$.

How big is uncertainty of Z-contribution due to EW corrections?

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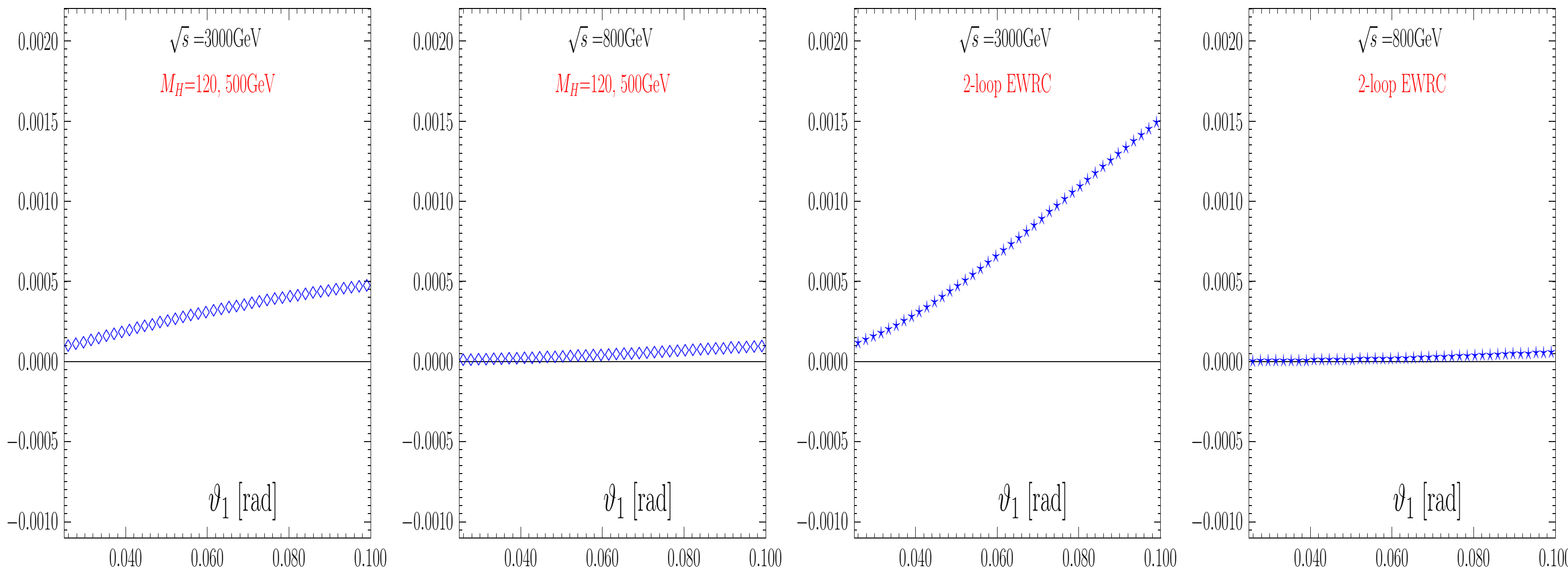

Answer from DIZET 6.35: Below 0.1%. Negligible at lower $\sqrt{s}$ and/or angles

Above we varied M_H =120⟶500GeV. Changing M_t =165⟶185GeV has similar effect.

Changing NPAR(2)=3⟶NPAR(2)=4 manipulates non-leading 2-loop EW corrections $\mathcal{O}(G_F^2 M_t^2 M_Z^2)$, Degrassi et.al., leading 2-loop EW corrections $\mathcal{O}(G_F^2 M_t^4)$ are kept.

Summarizing we fi nd 0.09% as a conservative estimation of Theor. Uncert. due to known subleading 2-loop EWRC at 3TeV, 50-100mrad.

How big is uncertainty due to hadronic vacuum polarization?

Type of Vac.Pol. (Authors)	Cross section [nb]	Relative change
$\sqrt{s} = 3000\text{GeV}, \quad \vartheta \in (0.50, 0.100)$ [rad], $\quad \sqrt{\vert t\vert} \in (75, 150)$ [GeV]		
No vacuum polarization	$\sigma_0 = 0.036141$	
Burkhardt 1981,1989	$\sigma_1 = 0.040978$	$\frac{\sigma_1-\sigma_0}{\sigma_0} = 0.133839$
Eidelman&Jegerlehner 1995	$\sigma_2 = 0.040921$	$\frac{\sigma_2-\sigma_1}{\sigma_1} = -0.001405$
Burkhardt&Pietrzyk 1995	$\sigma_3 = 0.040918$	$\frac{\sigma_3-\sigma_1}{\sigma_1} = -0.001476$
Eidelman&Jegerlehner(95)+ERROR	$\sigma_4 = 0.040865$	$\frac{\sigma_4-\sigma_1}{\sigma_1} = -0.001354$
$\sqrt{s} = 92\text{GeV}, \quad \vartheta \in (0.25, 0.050)$ [rad], $\quad \sqrt{\vert t\vert} \in (1.15, 2.3)$ [GeV]		
No vacuum polarization	$\sigma_0 = 147.418$	
Burkhardt 1981,1989	$\sigma_1 = 153.329$	$\frac{\sigma_1-\sigma_0}{\sigma_0} = 0.040092$
Eidelman&Jegerlehner 1995	$\sigma_2 = 153.289$	$\frac{\sigma_2-\sigma_1}{\sigma_1} = -0.000258$
Burkhardt&Pietrzyk 1995	$\sigma_3 = 153.288$	$\frac{\sigma_3-\sigma_1}{\sigma_1} = -0.000266$
Eidelman&Jegerlehner(95)+ERROR	$\sigma_4 = 153.240$	$\frac{\sigma_4-\sigma_1}{\sigma_1} = -0.000321$

This table is obtained using LumTeV with Born&VacPol taken from BHWIDE.

We did not include latest improvements (to be done).

The above result was also x-checked with DIZET 6.35 (using Eidelman& Jegerlehner 1995).

Error due to Hadronic vac.pol. $\times 4$ bigger than at LEP1, possibly dominant!

Summary

Conclusions from numerical results:

- Pure QED photonic probably only 30% bigger than at LEP1 (due to dominance of the t-channel exchange)
- EW corrections can be important; at 3TeV EW uncertainty $< 0.1\%$
- Error due to hadronic vacuum polarization $\sim 0.1\%$ seems to dominate
- Exponentiation unavoidable

QUESTION: Do we expect problems with theory error at the level of 0.1%

in the luminosity measurement using double-tagged Bhabha
within 25-100mrads, at 1-3 TeV?

ANSWER: Total error $< 0.1\%$ looks feasible

LumTeV Monte Carlo is our 1-st step towards combined analysis of QED and beamstrahlung – needed more input on the detector resolution, lumin. spectra, etc.