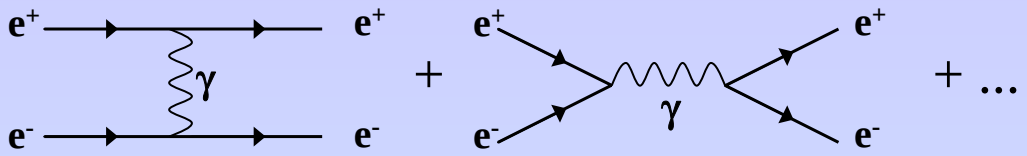
Limitation on precision luminosity measurement from beam-beam effects

European LC Workshop, January 8-9 2007, Daresbury Laboratory, UK

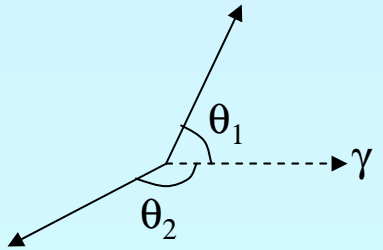
Cécile Rimbault, LAL Orsay

Luminosity measurement in the LumiCal using Bhabha scattering at small angles



- Bhabha particles are detected in coincidence in the LumiCal covering a range of 26.2 to 82 mrad.
- $\mathcal{L} = N_{Bh}/\sigma_{Bh}$ from counting rate ➔ integrated luminosity (10^{-3} - 10^{-4})
- Measurement of energy and scattering angle of the Bhabhas ➔ luminosity spectrum reconstruction using *ref. LC-PHSM-2000-60-TESLA from K. Mönig*

$$x_{th} = \frac{\sqrt{s'}}{\sqrt{s}} = \sqrt{1 - 2\frac{\sin(\theta_1 + \theta_2)}{\sin(\theta_1 + \theta_2) - \sin\theta_1 - \sin\theta_2}} = x_{\exp}$$



Beam-Beam effects on Bhabha scattering

- Bhabhas produced with BHLUMI, $\sqrt{s}$ = 500 GeV, 25<θ<90 mrad, **ISR included**

  Bhabha0

- Beam-Beam effect treatment with GUINEA-PIG

  - **Modification of initial state**: **Beamstrahlung ➔** $\sqrt{s'} \leq \sqrt{s}$, $\Delta\theta_{ini} \neq 0$, $E_{elec} \neq E_{posit}$

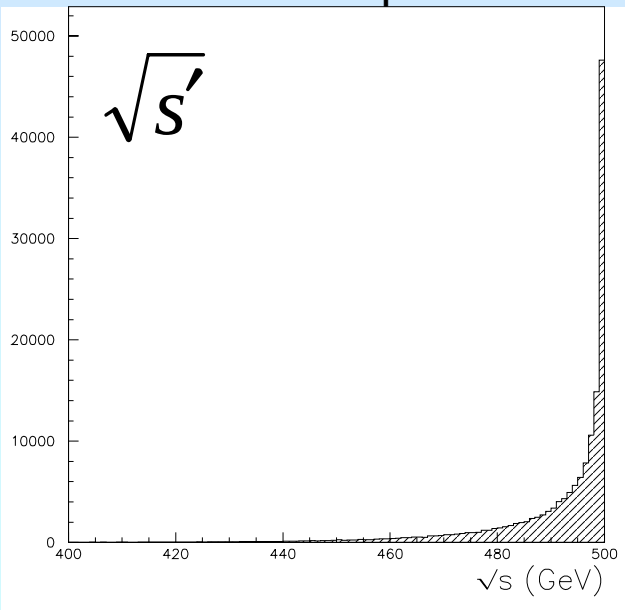
    Bhabha1

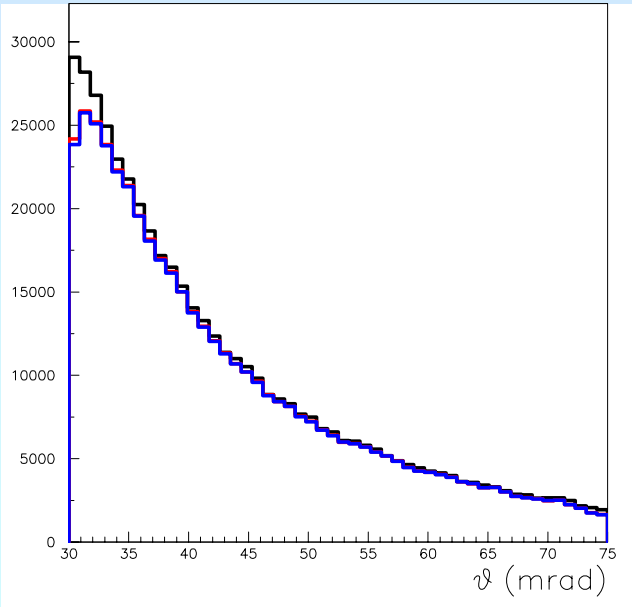
  - **Modification of final state**: **Electromagnetic deflections ➔** bhabha angle reduction + small energy losses

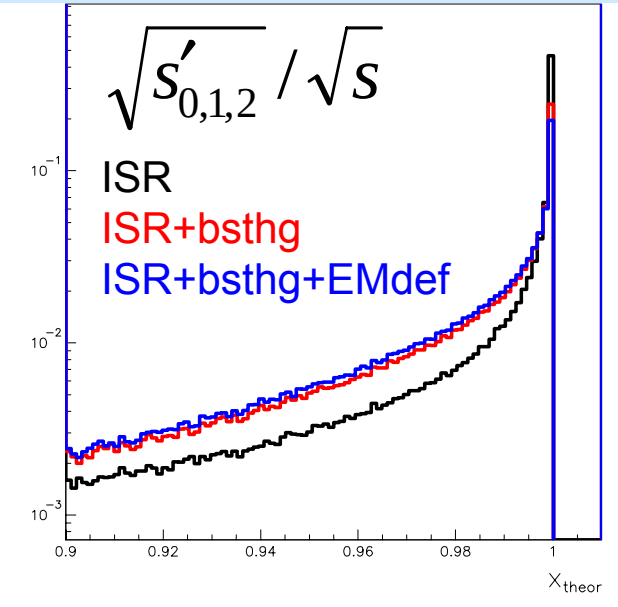
    Bhabha2

- selection cuts: $30<\theta_{bhabha}<75$ mrad, $E_{bhabha} > 0.8\ E_{beam}$.

- Nominal beam parameter set used







Beam-Beam effects on integrated luminosity measurement:

Bhabha counting suppression

Suppression of Bhabha particles inside the selection cuts $30<\theta_{bhabha}<75$ mrad and $E_{bhabha} > 0.8\ E_{beam}$:

Due to modification of initial state = beamstrahlung: (-3.78 ± 0.04)%

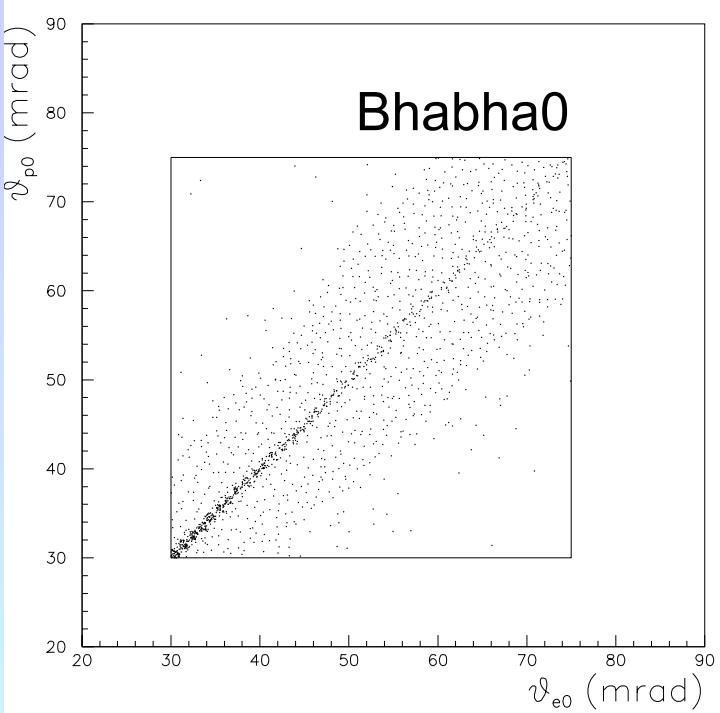
Due to modification of final state = EM deflections: (-0.65 ± 0.02)%

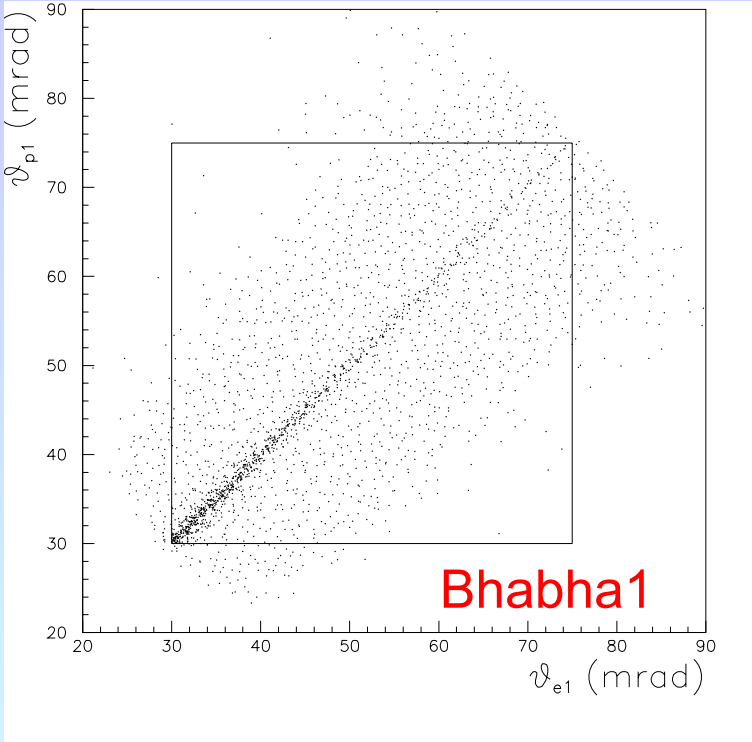
Total BHabha Suppression Effect : (-4.41 ± 0.05)%

Why is there such an important BHSE ?

Beam-Beam effects on integrated luminosity measurement:

Bhabha counting suppression





Beamstrahlung ➔ enhancement of acolinearity.

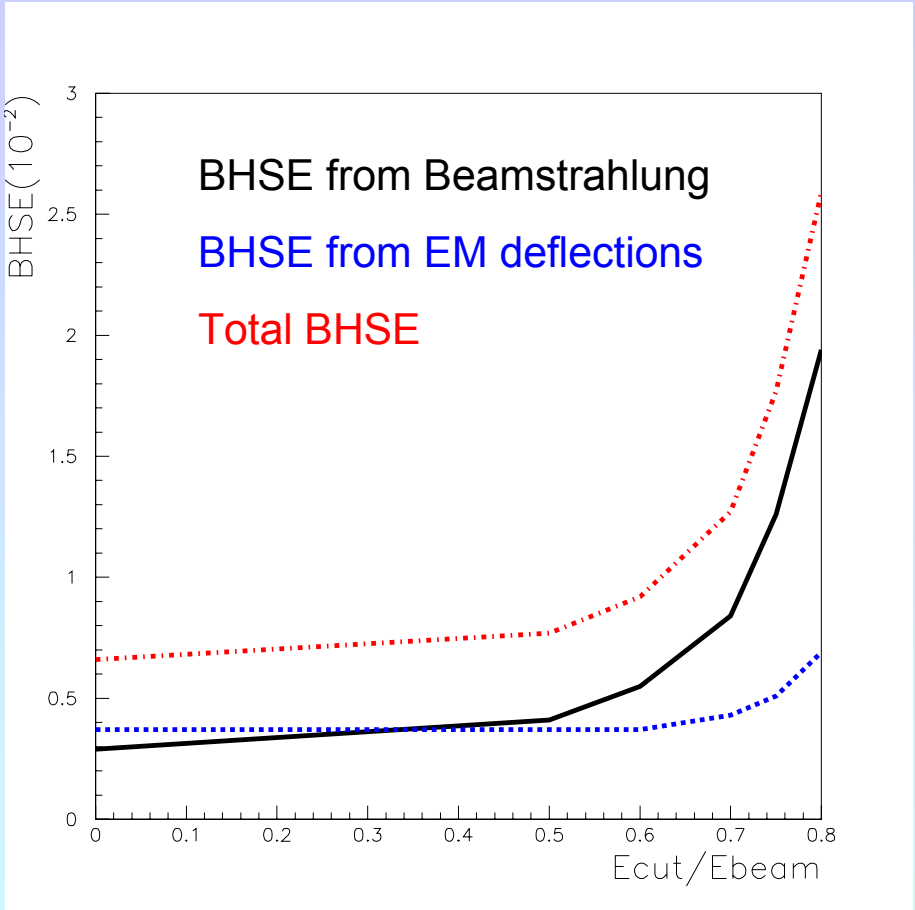
The angular cut should not be symmetric: new **asymmetrical** cuts

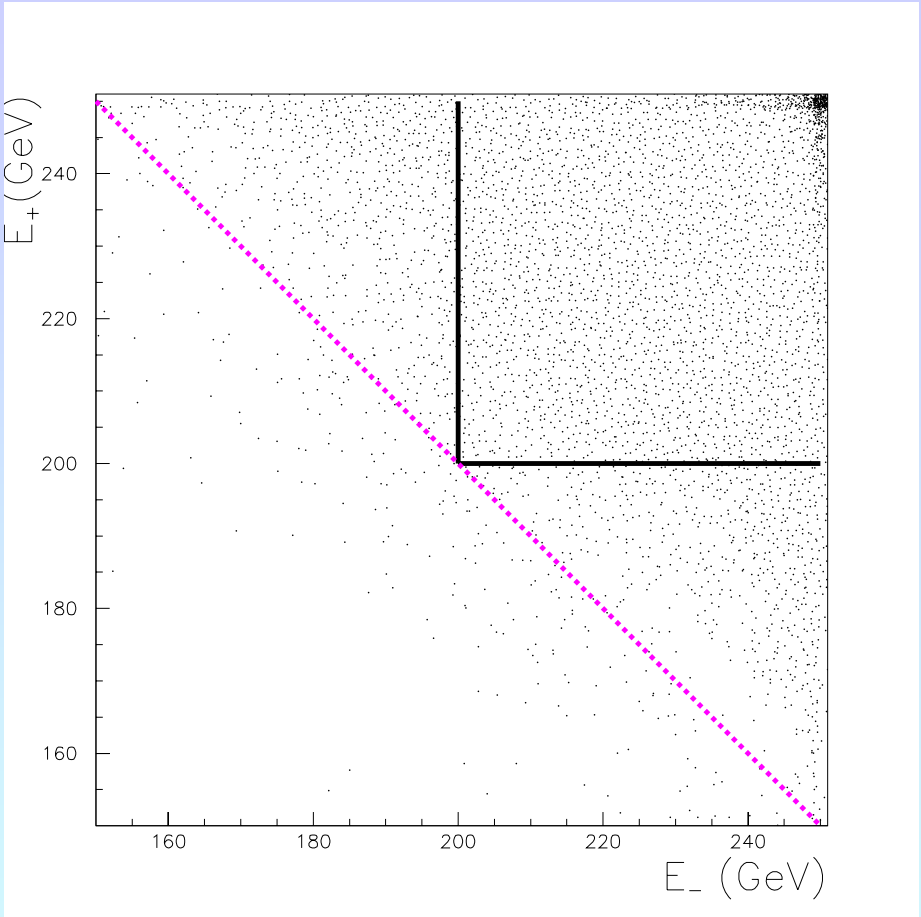
30 mrad<$\theta_{1,2}$<75 mrad & 26.2 mrad<$\theta_{2,1}$<82 mrad

ref. A. Stahl LC-DET-2005-004

Beam-Beam effects on integrated luminosity measurement:

Bhabha counting suppression





Beamstrahlung & EM deflections: Bhabha energy reduction + energy asymmetry enhancement ➔ use $E_+ + E_- > 0.8\sqrt{s}$

Beam-Beam effects on integrated luminosity measurement:

Bhabha counting suppression

Suppression of Bhabha particles inside the selection cuts $30<\theta_{bhabha}<75$ mrad and $E_{bhabha} > 0.8\ E_{beam}$:

Due to modification of initial state = beamstrahlung: (-3.78 ± 0.04)%

Due to modification of final state = EM deflections: (-0.65 ± 0.02)%

Total BHabha Suppression Effect : (-4.41 ± 0.05)%

Suppression of Bhabha particles inside the selection cuts 30 mrad$<\theta_{1,2}<75$ mrad & 26.2 mrad$<\theta_{2,1}<82$ mrad and $E_+ + E_- > 0.8\sqrt{s}$:

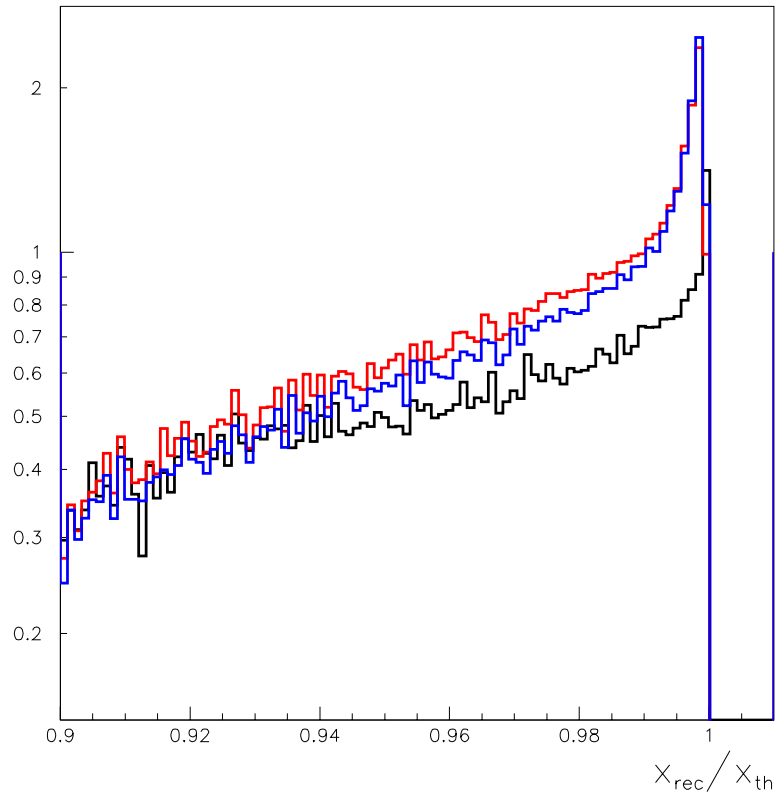
Due to modification of initial state = beamstrahlung: (-1.03 ± 0.04)%

Due to modification of final state = EM deflections: (-0.48 ± 0.02)%

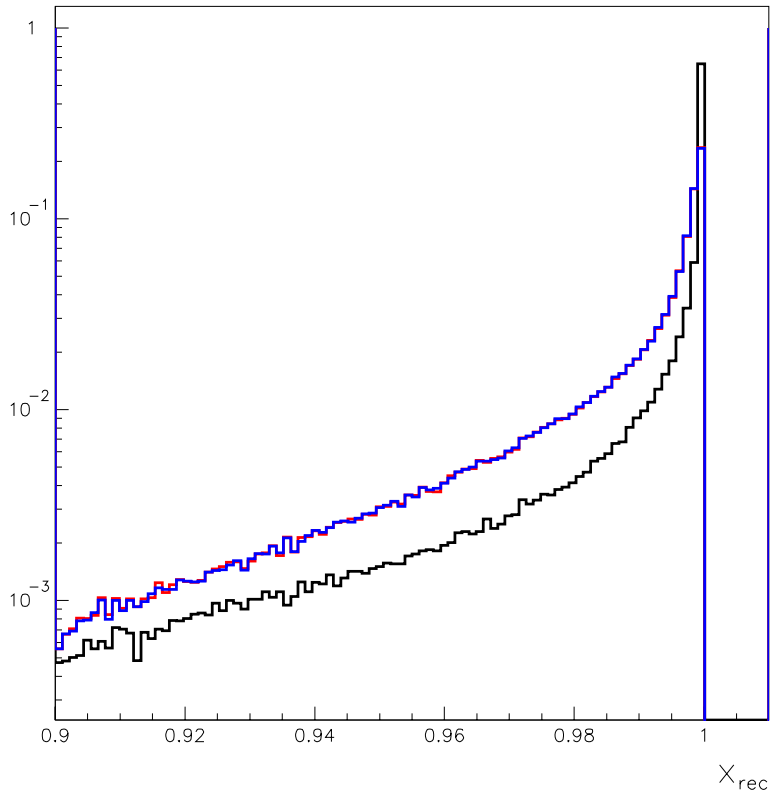
Total BHabha Suppression Effect : (-1.51 ± 0.05)%

Reconstruction of luminosity spectrum from lumical - 1

$$x_{th} = \frac{\sqrt{s'}}{\sqrt{s}} \approx \sqrt{1 - 2\frac{\sin(\theta_1 + \theta_2)}{\sin(\theta_1 + \theta_2) - \sin\theta_1 - \sin\theta_2}} = x_{\exp}$$

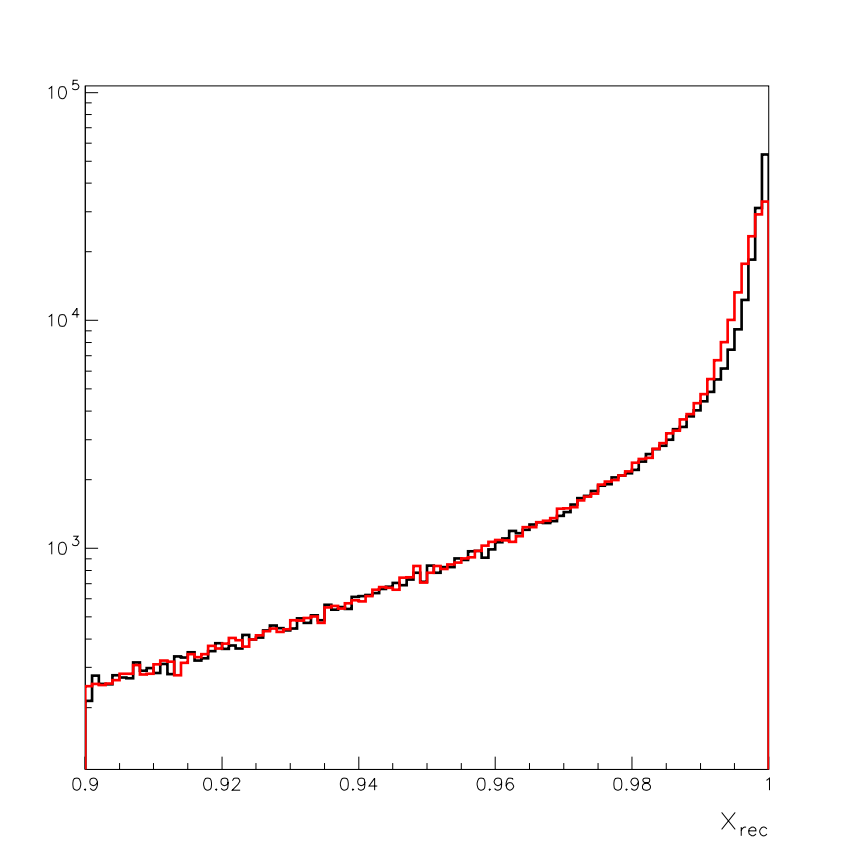


bhabha0
bhabha1
bhabha2



Experimentaly EM deflections have no impact on the reconstructed lumi spectrum, using K. Mönig method.

Reconstruction of luminosity spectrum from lumical - 2

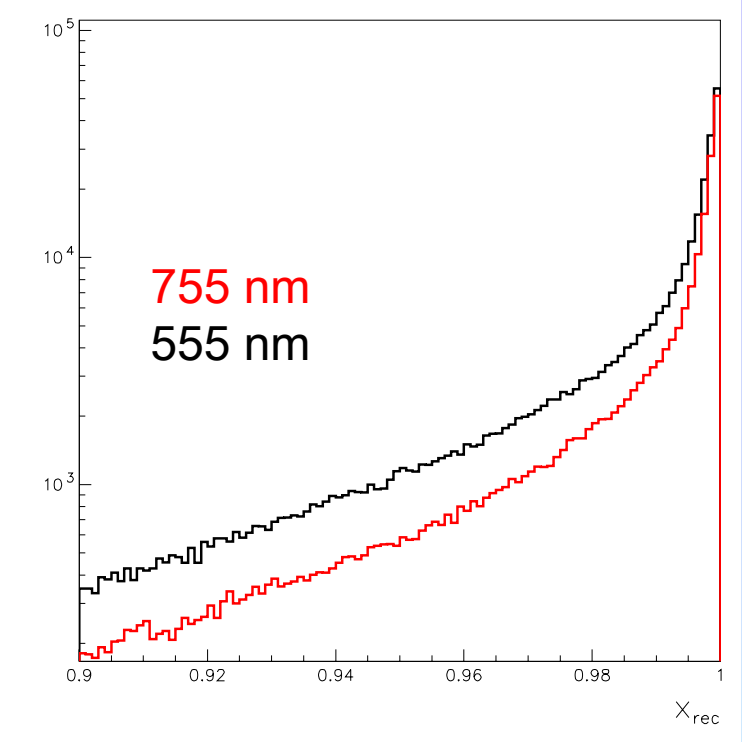


bhabha2 lumi spectrum

bhabha2 lumi spectrum with error on angular reconstruction: σ_θ=0.13 mrad

Experimental angle resolution ➔ $\Delta\langle x_{rec}\rangle/\langle x_{rec}\rangle$ 5 10^{-4}

Evolution of the luminosity spectrum with beamstrahlung



modification of beamstrahlung with horizontal size, σ_x, of the spot beam

Should be possible to fit

σ_x [nm]	$\mathcal{L}$ [μb^{-1}]	$<x_{theor}>$	$<x_{rec}>$	BHSE [%]
555	1.8	0.9569	0.9762	-2.22
755	1.2	0.9628	0.9801	-1.14
Δ		$6\ 10^{-3}$	$4\ 10^{-3}$	$1\ 10^{-2}$

Summary

- Beam-beam effects on Bhabha scattering create acolinearity and energy asymmetry on the Bhabha particles. This leads to a **bias on the integrated luminosity measurement of few 10^{-2}**
- BHSE mainly arises from beamstrahlung.
- The reconstructed luminosity spectrum in the LumiCal is almost not modified by EM deflections
- Angular resolution induces a relative error of 5 10^{-4} in the Luminosity spectrum reconstruction
- To reduce the bias on luminosity measurement to 10^{-3}, we would need to reconstruct luminosity spectrum with a precision of 4 10^{-4}
- To reduce the bias to 10^{-4}, we would need to devise a method based on fitting reconstructed lumi spectrum; but since 10^{-4} is needed for the Giga-Z option, beam-beam effects may no longer be a problem...

Modified version of GUINEA-PIG available at:
see G. Le Meur talk tomorrow morning.