Systematic limitations to luminosity determination in the LumiCal acceptance from beam-beam effects

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Systematic limitations to luminosity determination in the LumiCal acceptance from beam-beam effects

1. **Motivation**
2. **Method**
3. **Study of beam-beam effects on Bhabha scattering**
4. **Conclusions and next steps**

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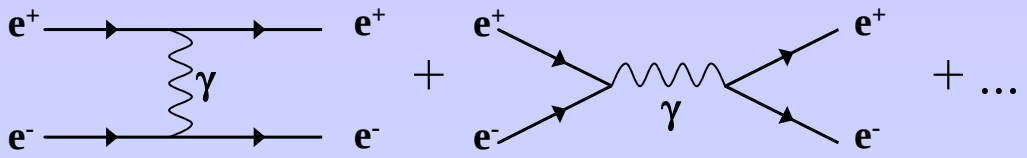
Bhabha scattering for the luminosity measurement



- Bhabhas are used to measure the luminosity: $\mathcal{L}_{int} = N_{Bhabha}/\sigma_{Bhabha}$

  $\mathcal{L}_{int}$: luminosity accumulated during the data taking period
  N_{Bhabha}: Nb of Bhabha event identified within a certain acceptance region
  σ_{Bhabha}: corresponding cross section calculated from theory

- Bhabha cross section at small angles:

$$\frac{d\sigma_{Bhabha}}{d\vartheta} = \frac{2\pi\alpha^2}{s}\frac{\sin\vartheta}{\sin^4\vartheta/2} \approx \frac{32\pi\alpha^2}{s}\frac{1}{\vartheta^3} \qquad with\ s = E_{CM}^2$$

- Beam-Beam effect ➔ **Energy radiation + EM deflections**
  - ➔ **modification of the angular distribution and E_{CM}**
  - ➔ **modification of the theoretical cross section ?**
  - ➔ **Would it be possible to estimate $\mathcal{L}$ with $\Delta\mathcal{L}/\mathcal{L} < 10^{-4}$?**

Method to study beam-beam effect on Bhabha scattering

•***Bhabha events are produced with BHLUMI:***

Phase space region: $\sqrt{s}$=500 GeV, 25≤θ≤90 mrad

➔input Bhabha file for beam-beam interaction code GUINEA-PIG

•***Inside GUINEA-PIG:*** **Lorentz transformation to boost Bhabhas in the laboratory frame and energy rescaling, because of beamstrahlung emission (e^+e^- is no more a head-on collision at 500 GeV)**

•***GUINEA-PIG electromagnetic deflection treatment*** *:*

the one existing for the e^+e^- pairs

•***Cut for the analysis*** *:* Two Bhabhas in the LumiCal acceptance: 26≤θ≤82 mrad

Cut on energy: $E_{Bhabha} \geq 0.8\ E_{beam}$

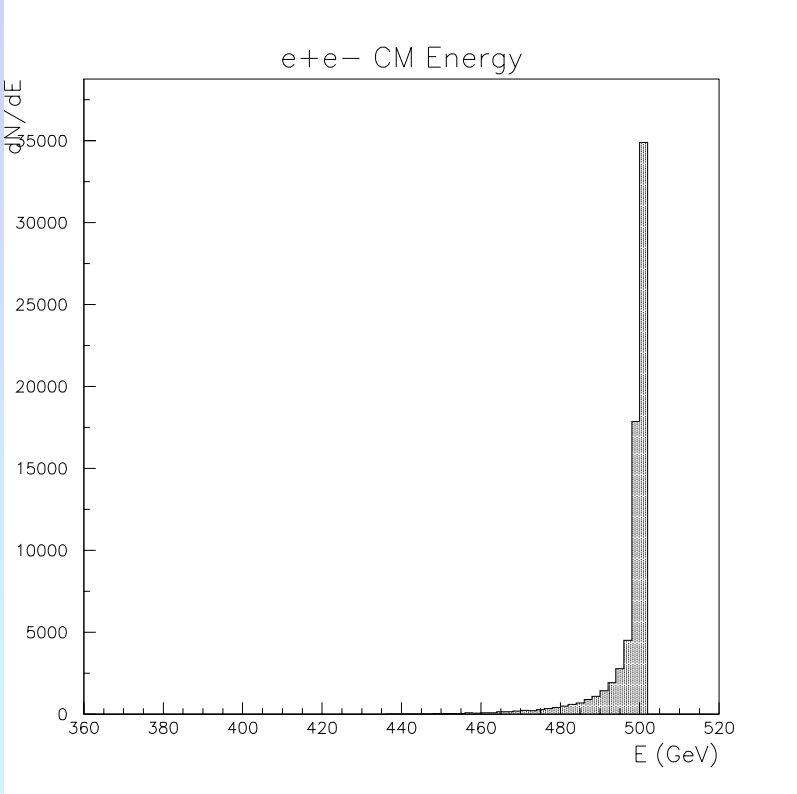
Nominal Beam parameter set

•For each Bhabha comparison of the 4momentum at the production point and the 4momentum after the deflection by the opposite beam.

Beam-beam effect on the Bhabha scattering
modification of initial state

Beamstrahlung ➔

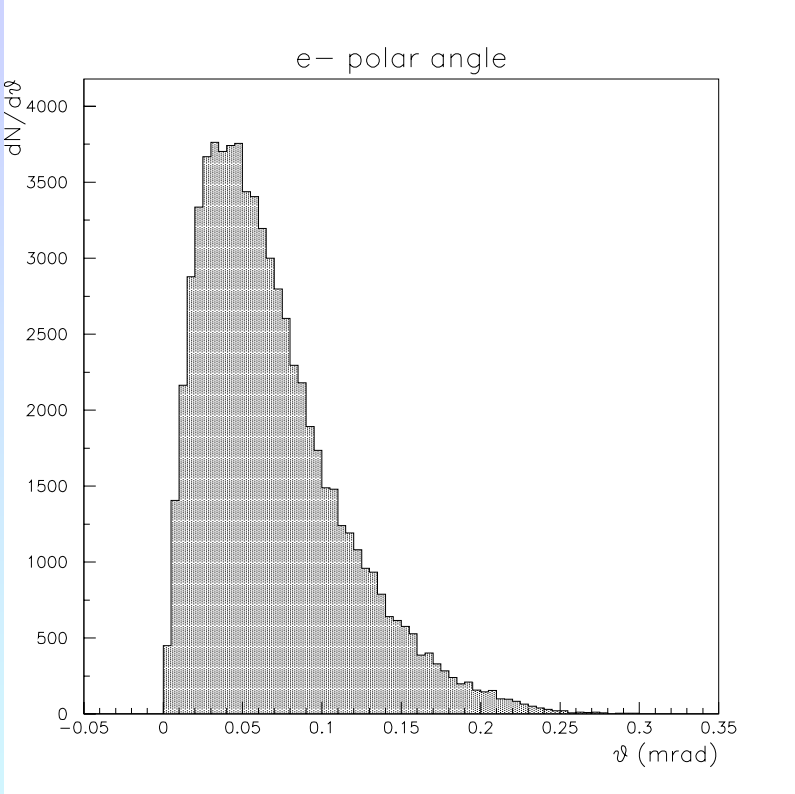
Modification of $e^+ e^-$ center of mass energy



➔ small Bhabha cross section increase

$$\frac{d\sigma_{Bhabha}}{d\vartheta} \approx \frac{32\pi\alpha^2}{s}\frac{1}{\vartheta^3}$$

small "decolinearisation" of electrons

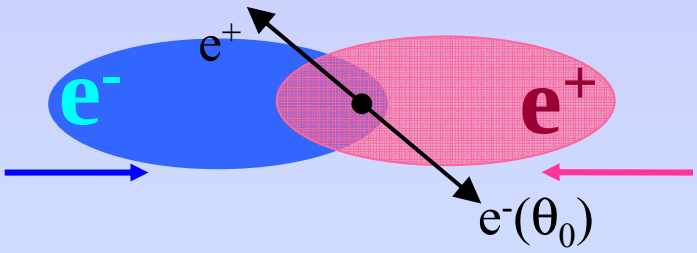


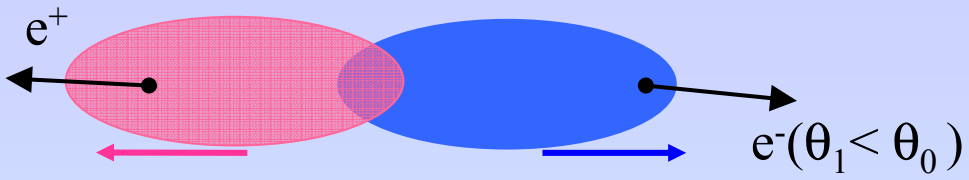
➔ "Defocusing" effect of ~10^{-2} mrad

Bhabha scattering & electromagnetic deflections

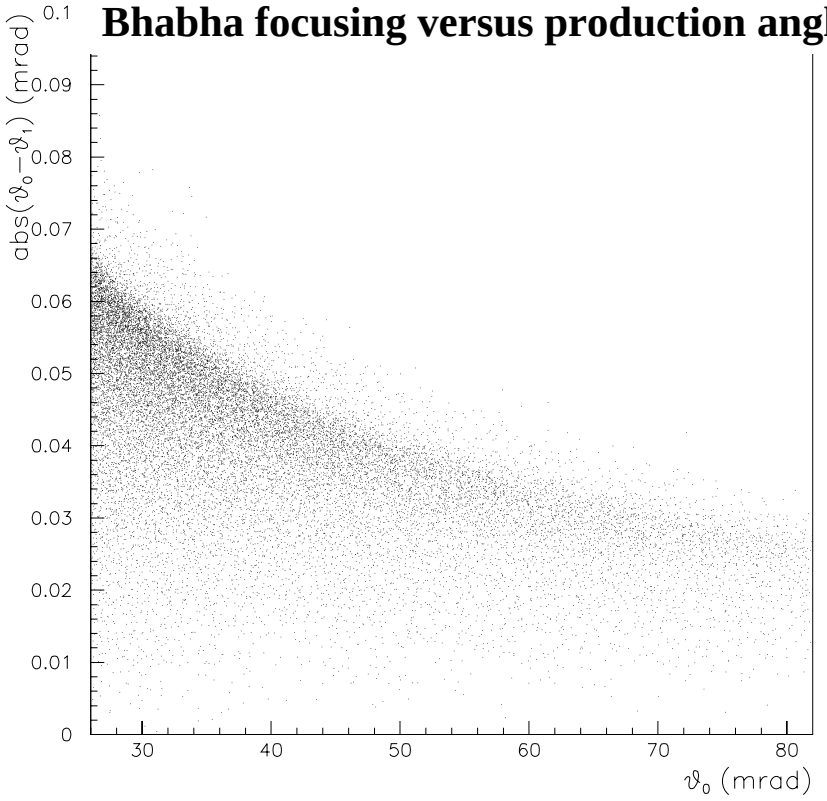
Modification of final state

Deflection of Bhabhas due to the field of the opposite beam

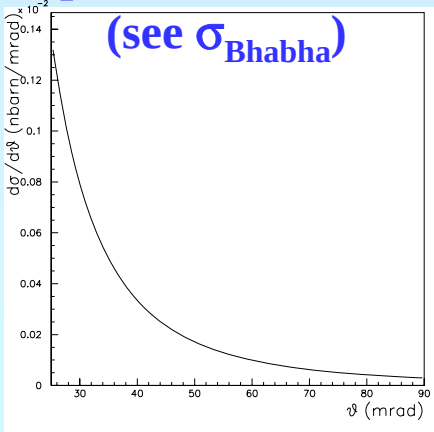




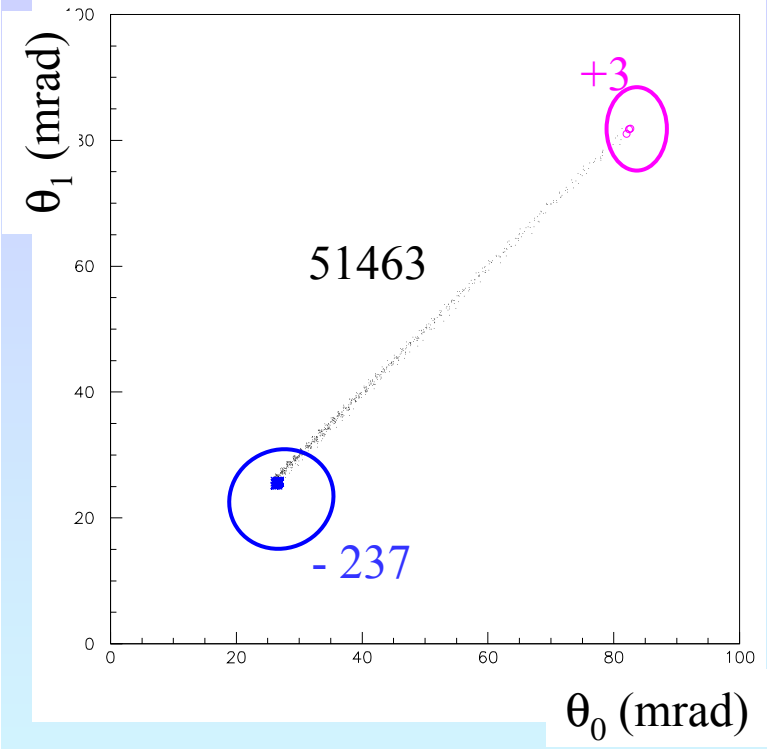
Bhabha focusing versus production angle θ_0 (mrad)



- **Bhabha angular deflections are about few 10^{-2} mrad**
- **The more θ_0 is small, the more the deflection is important.**
- **More Bhabhas are produced at low angles**



Impact of beam-beam effect on Bhabha detection in the LumiCal (26 mrad – 82 mrad)



- **In the considered acceptance, few Bhabhas are added at "large" angle, more are substracted at small angle ➔**

BHabha Suppression Effect of (0.45 ± 0.03)%

= 50 × the wished precision for ℒ

- **Reducing the acceptance to 30 mrad – 75 mrad: one reduces the BHSE to (0.36 ± 0.03)%**

- **BHSE depends on the beam parameters: e.g. for the Low Power option BHSE = (0.77 ± 0.04)%**

Conclusions and next steps

- **Impact of EM Deflection effect on Bhabha scattering :**

  Bhabha focusing partially compensated by defocusing effect from beamstrahlung

  ➔ BHabha Suppression Effect >> 10×10^{-4}

- **Can be reduced playing with LumiCal angular acceptance**

- **Will depend on the beam parameters**

- **Increase the statistic and study this effect during a realistic train simulation** (a preliminary study seems to indicate that BHSE does not depend on beam offset !?)

- **To evaluate the precision reachable for the luminosity ➔need to find a correction method for the induced bias, based on a simple variable allowing to follow the effect over time**

- **A new version of GUINEA-PIG for Bhabhas will be provided in few weeks.**

Thank You.