PRECISION LUMINOSITY MEASUREMENT AT ILC

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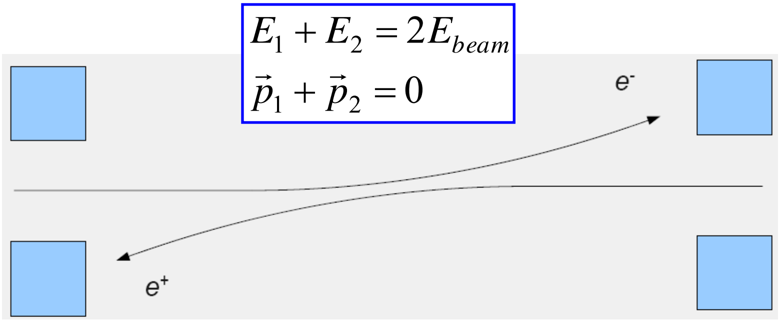
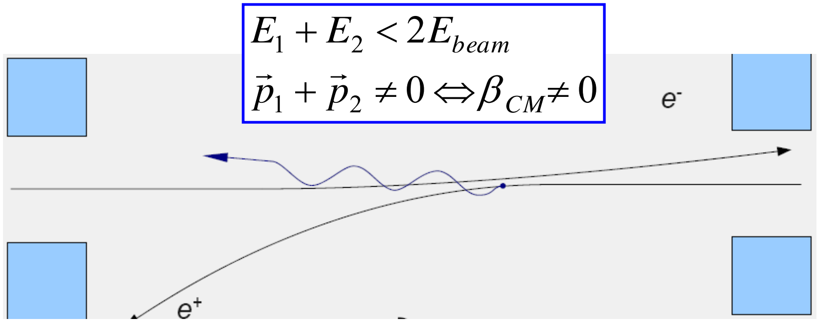
OVERVIEW

- Concept of luminosity measurement
- Forward calorimetry at ILC
- Beam-induced effects
- How to deal with the beam-induced uncertainties – novel approach
- 500 GeV and 1 TeV ILC
- Event selection for luminosity measurement
- Electromagnetic deflection
- 250 GeV ILC
- Conclusions

CONCEPT OF LUMINOSITY MEASUREMENT





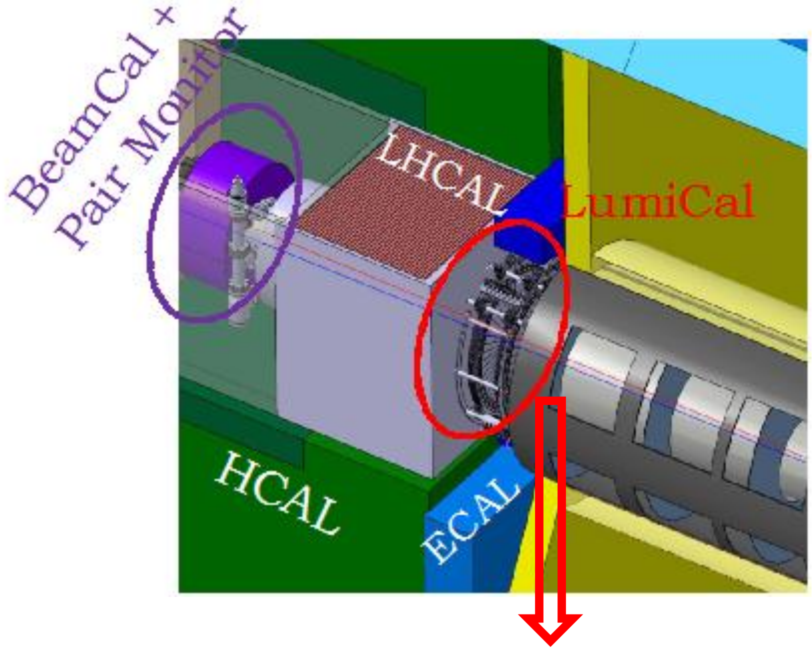
- Bhabha events scattered at small angles are detected in coincidence in the luminometer
- Luminosity is determined from the known theoretical cross-section for Bhabha scattering $L = N_S / \sigma_{th} \cdot \varepsilon$

- However, beam-beam effects (+ISR) induce deviation from the ideally symmetric kinematic of the Bhabha scattering
- Corresponding counting losses dominantly come from the asymmetric energy loss of the initial state (~10% effect at ILC).

FORWARD CALORIMETRY AT ILC

Tecnology options:

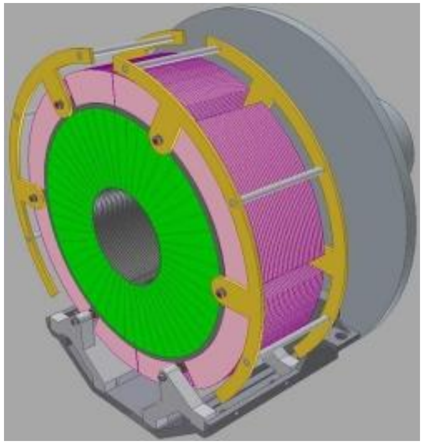
- LumiCal sampling SiW
- BeamCal W absorber +poly(mono)crystaline CVD diamond/GaAs/rad-hard Si
- Pair Monitor $2\cdot10^5$ Si pixel (0.4, 0.4) mm



Luminometer:

- small Moliere radius O(1cm) – good E resolution
- segmentation (azimuthal/radial): 48/64
- energy resolution: $0.21\mathrm{GeV}^{1/2}$
- resolution in polar angle: $(2.18\pm0.02)\cdot10^{-2}$mrad

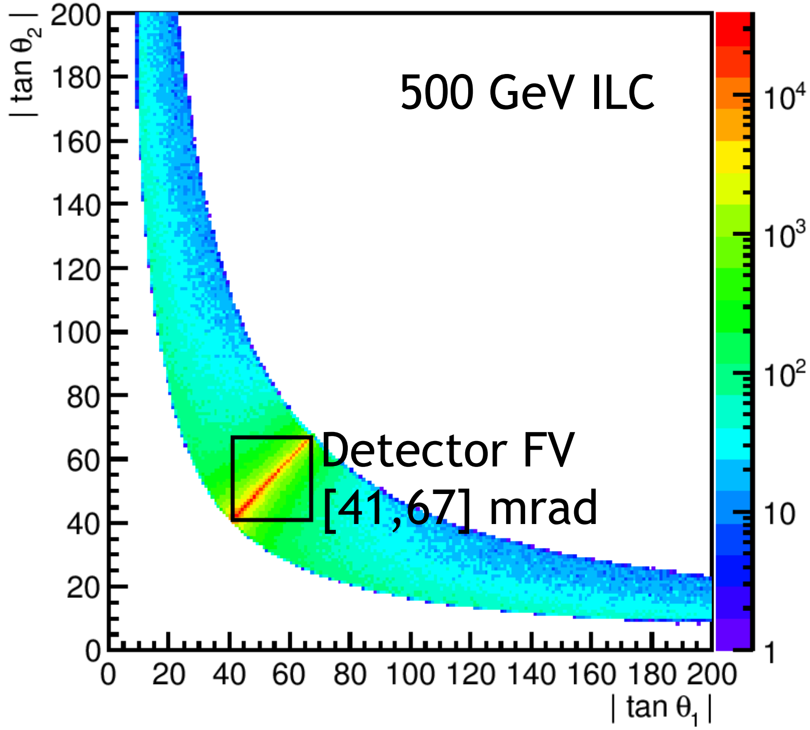
Very forward region of the ILD detector
LumiCal [31,77] mrad
BeamCal [5.8,43.5] mrad



See W. Lomann talk on status of FCAL instrumentation

BEAM-INDUCED EFFECTS

- Beamstrahlung emission is the main (though not the only) source of polar angle distortion of the final state electrons
- Bhabha coincidence is lost due to asymmetric boost of one of the final state electrons towards larger polar angles



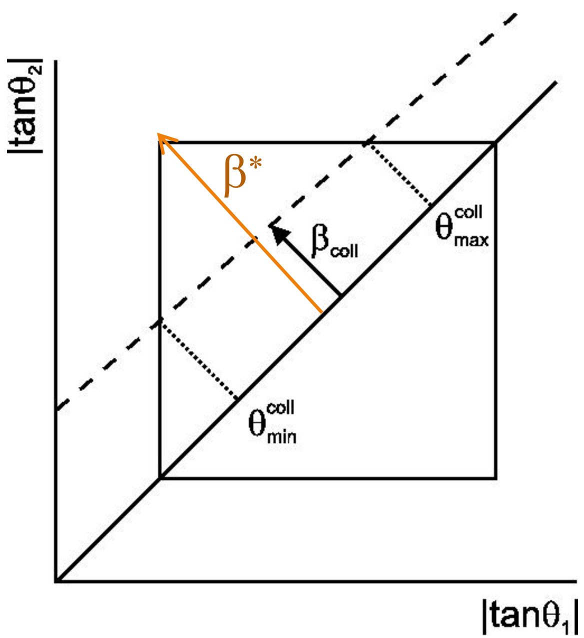
Simulation with Guinea Pig 1.4.4

The effect is severe: 8.4% (250 GeV), 12.8% (500 GeV) and 14.0% (1 TeV) in the top 20% of the luminosity spectrum

BEAM-INDUCED EFFECTS – HOW TO HANDLE?

Beamstrahlung + ISR $\Rightarrow \vec{p}_1 + \vec{p}_2 \neq 0 \Leftrightarrow \beta_{CM} \neq 0$

- e^+e^- CM system after BS+ISR and before FSR (collision frame) is moving with β_{CM} w.r.t. the lab frame
- Bhabha scattering is described with the unique deflection angle θ_{coll}
- $\beta_{coll} = \dfrac{\sin(\theta_1^{lab} + \theta_2^{lab})}{\sin\theta_1^{lab} + \sin\theta_2^{lab}}$ approx. to be collinear with z axis
- Events with $\beta > \beta^*$ ($\beta^* \sim 0.24$) are irreducibly lost from the detector FV

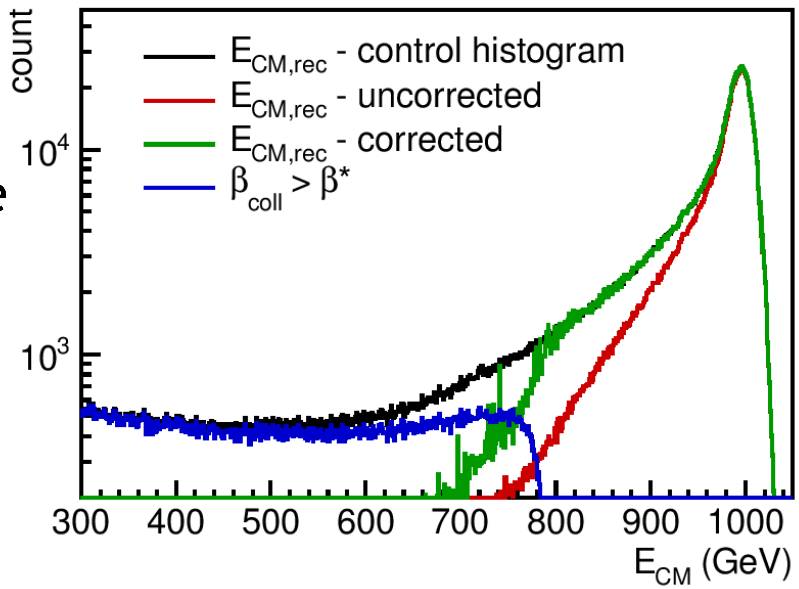


- β_{coll} can be used to calculate weighting factor $w(\beta_{coll})$ to correct for the angular loss on the event-by-event basis
- The fraction of lost events : $\geq$ 14.5%, 15.6%, 17% at 250 GeV, 500 GeV and 1 TeV

$$w(\beta_{coll}) = \frac{\int_{\theta_{\min}}^{\theta_{\max}} \frac{d\sigma}{d\theta} d\theta}{\int_{\theta_{\min}^{coll}}^{\theta_{\max}^{coll}} \frac{d\sigma}{d\theta} d\theta}$$

- In the peak (>80% of the nominal CM energy), the fraction of unrecoverable events (due to off-axis ISR) is small, $\leq$1.5 permille and can be reduced further by the event selection
- This bias is insensitive to beam parameter variations (up to 1/10 of a permille)

1 TeV ILC



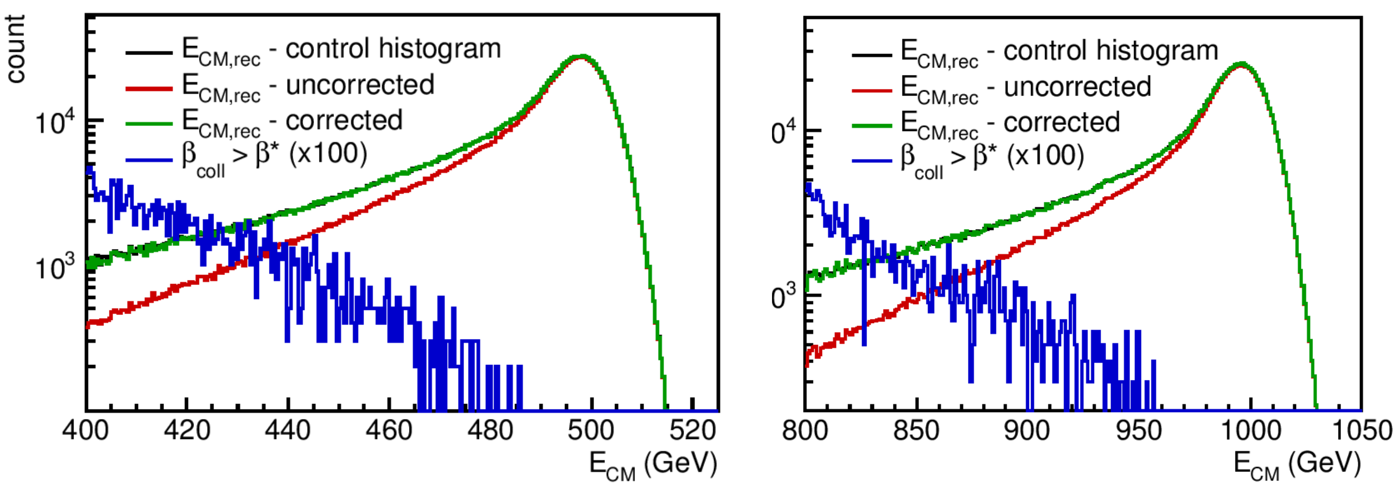
500 GEV AND 1 TEV COUNTING LOSSES DUE TO BS+ISR

- After correction from simulation for the bias due to the off-axis radiation (+ minor systematic effects), residual counting uncertainty is:

(0.4 ±0.1) permille at 500 GeV and (0.7 ±0.1) permille at 1 TeV

- Equivalent effect can be achieved with the acoplanarity based event selection

Counting losses at 500 GeV and1 TeV ILC



EVENT SELECTION

- Energy of the reconstructed Bhabha pair >80% E_{CM}
- Acoplanarity of the reconstructed particles <5 deg.
- Signal selection efficiency >90%

$$\Downarrow$$

- Suppression of physics background
- Restriction on acoplanarity reduces fraction of lost events in FV (suppresses events with off-axis radiation) from ~1.5 permille to ~0.4 permille at ILC energies

		500 GeV	1 TeV
Signal	E_s	94 %	94 %
Leptonic background	R_{bck}	60%	56%
$e^+e^- \to e^+e^-e^+e^-$	B/S	$1.6 \cdot 10^{-3}$	$0.7 \cdot 10^{-3}$
Hadronic background	R_{bck}	70 %	91 %
$e^+e^- \to e^+e^-q\bar{q}$	B/S	$0.6 \cdot 10^{-3}$	$0.1 \cdot 10^{-3}$
$\Delta L/L$		$2.2 \cdot 10^{-3}$	$0.8 \cdot 10^{-3}$

EMD

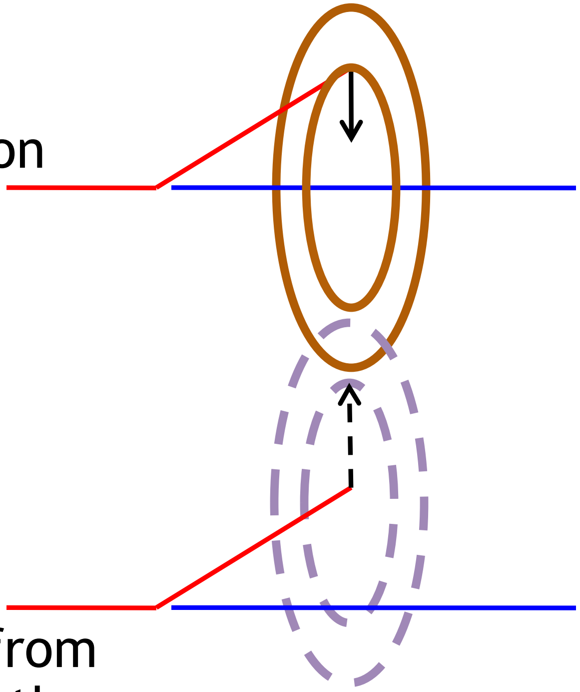
- Effective decrease of the Bhabha x-section
- Equivalent to an effective shift $\Delta\theta$ of the detector FV ($\theta_{min}+\Delta\theta, \theta_{max}+\Delta\theta$)
- $\Delta\theta$ can be determined from simulation:

$$\frac{\Delta L_{EMD}}{L} = x_{EMD}\Delta\theta$$

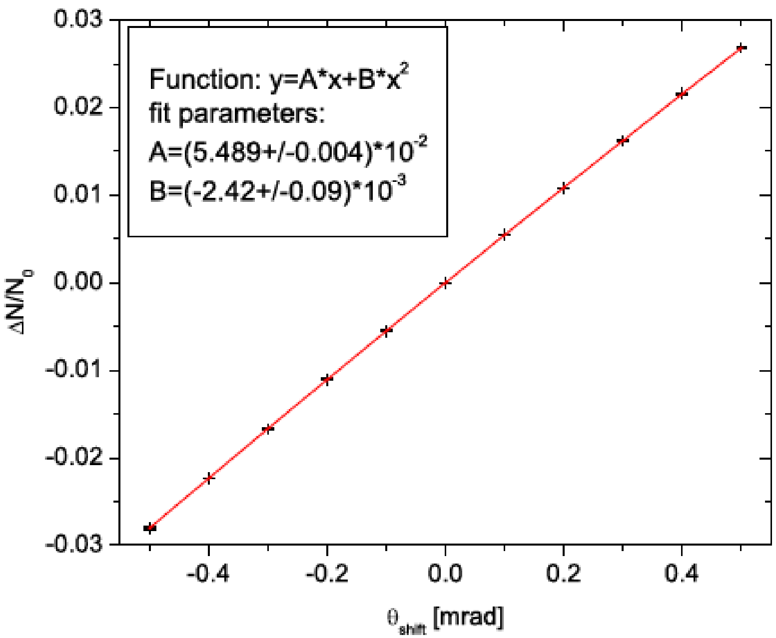
where

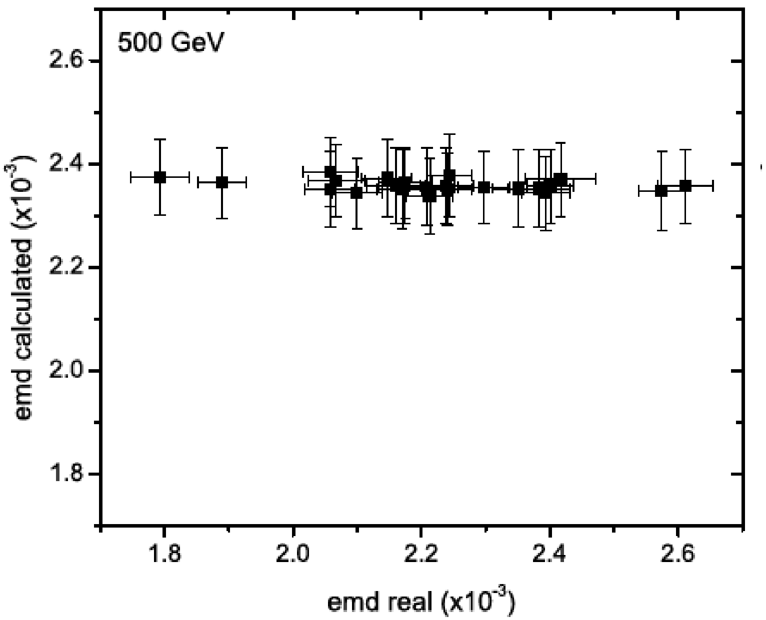
$$x_{EMD} = \frac{1}{N}\frac{dN}{d\theta}$$

- In experiment, x_{EMD} can be determined from data as fractional difference in counts in the shifted volume w.r.t FV, and, consequently, ΔL can be obtained knowing $\Delta\theta$
- $\Delta\theta$ equals 0.020 mrad at 1 TeV, 0.043 mrad at 500 GeV and 0.067 mrad at 250 GeV, obtained by simulation



- $\Delta L/L \leq 5$ permille at all ILC energies and can be taken as correction
- Systematic uncertainty of the correction due to beam parameter variations is 0.2 permille at 1 TeV, 0.5 permille at 500 GeV and 250 GeV
- The method is insensitive w.r.t beam parameter variations (i.e up to 20% variation of bunch charges and sizes)





250 GEV ILC

- Beamstrahlung effects (initial state radiation) are less than at higher CM energies: 8.4% (250 GeV), 12.8% (500 GeV) and 14.0% (1 TeV) in the top 20% of the luminosity spectrum
- Electromagnetic deflection is more pronounced than at higher energies 4.3‰ (250 GeV), 2.3 ‰ (500 GeV) and 1.7 ‰ (1 TeV) and it's not corrected in a completely simulation independent manner

250 GeV	
BS+ISR uncorrected	8.4%
BS+ISR corrected/top 20% of *L* spectrum*	1.2‰
BS+ISR corrected/full event selection*	0.4‰
EMD uncorrected	4.3‰
EMD corrected	0.5‰

* simulation independent

CONCLUSION

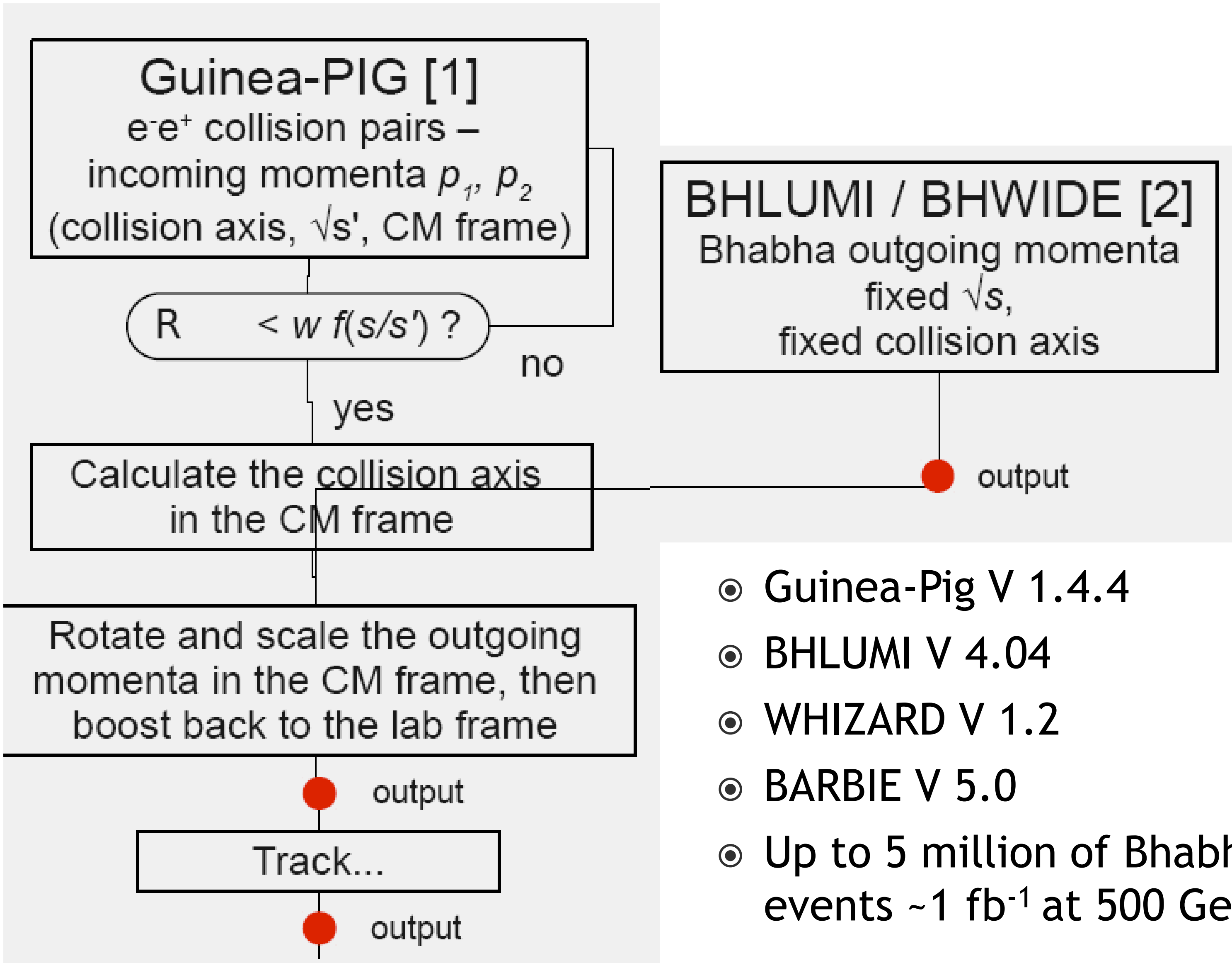
- Beam induced effects at ILC are severe (~10%) if one wants to determine integral luminosity with a permille precision
- The dominant effect is beamstrahlung and it can be reduced in a simulation independent manner with a residual uncertainty below permille
- Electromagnetic deflection increases at lower CM energies up to ~4.3 permille. From simulation, it can be corrected for below permille
- Background from physics processes dominantly contributes to the overall luminosity uncertainty up to a few permille

I. Bozovic Jelisavcic et al. Luminosity Measurement at ILC, JINST 8 P08012, August 2013, arXiv:1304.4082

S. Lukic et al. Correction of beam-beam effects in luminosity measurement in the forward region at CLIC, JINST 8 P05008, May 2013

BACKUP

SIMULATION



- Guinea-Pig V 1.4.4
- BHLUMI V 4.04
- WHIZARD V 1.2
- BARBIE V 5.0
- Up to 5 million of Bhabha events ~1 fb^{-1} at 500 GeV