Update on the beam-beam effects in luminosity measurement at 3 TeV CLIC

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FCAL workshop, CERN, November 2012

Outline

- Luminosity measurement and the beam-beam effects
- Invariant counting
- Collision-frame method
- Deconvolution of the ISR energy loss for CLIC
- Correction of the counting bias due to the finite energy resolution of the LumiCal for CLIC
- Summary and conclusions

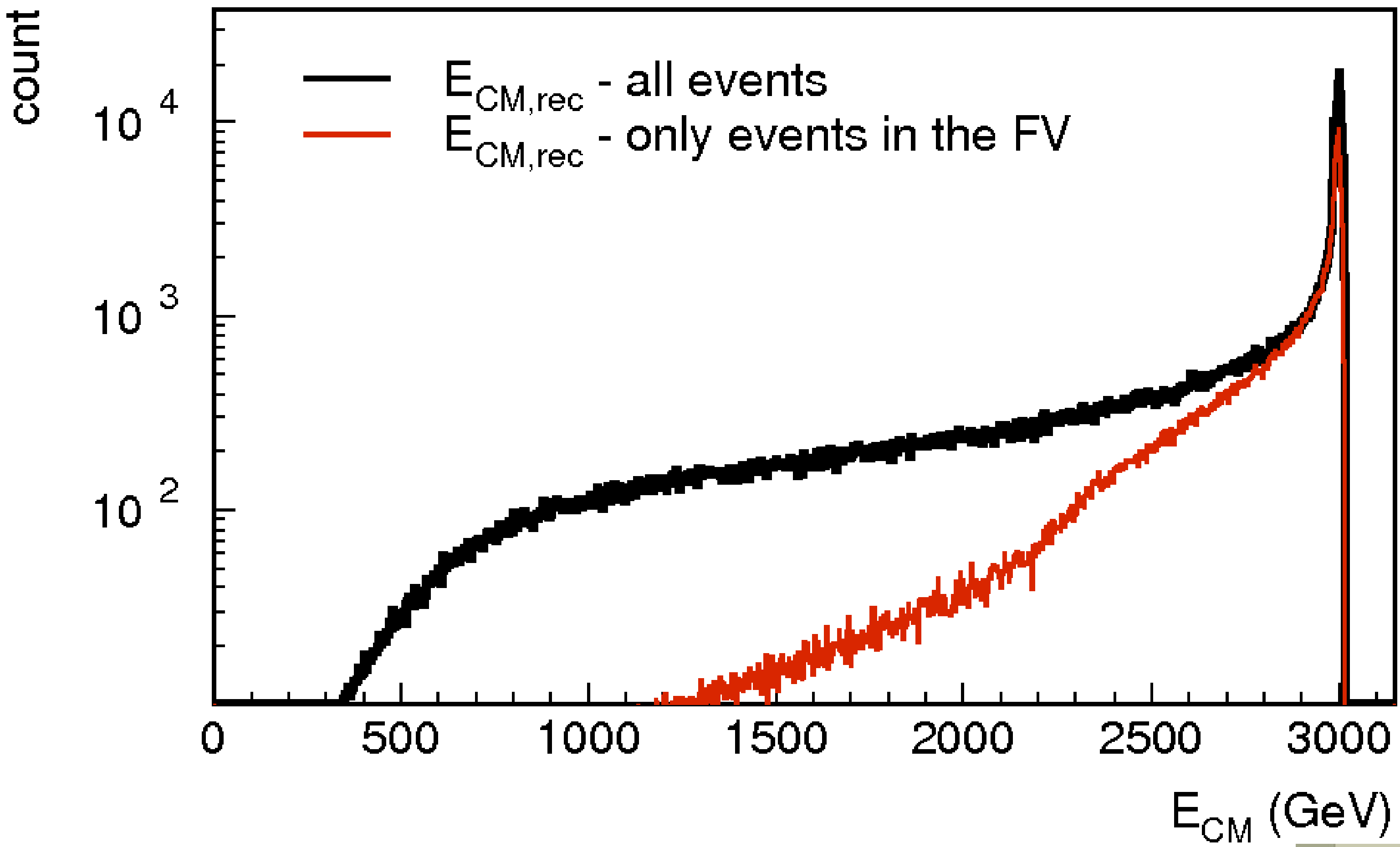
Luminosity measurement

$$L=\frac{N\left(\Xi\left(\Omega_{1,2}^{lab},E_{1,2}^{lab}\right)\right)}{\sigma\left(\Xi'\left(\Omega_{1,2}^{CM},E_{1,2}^{CM}\right)\right)}$$

- Measurement in the lab frame
- Cross-section integration in the (pre-ISR) CM frame
- Different reference frames lab/CM due to the Beamstrahlung
  - Ξ and Ξ' cover different parts of the phase space
- Additional small bias due to EMD

Angular loss by E_{CM} at CLIC

- Angular loss affects the low-*E* tail more, but there is a loss of several % in the peak as well



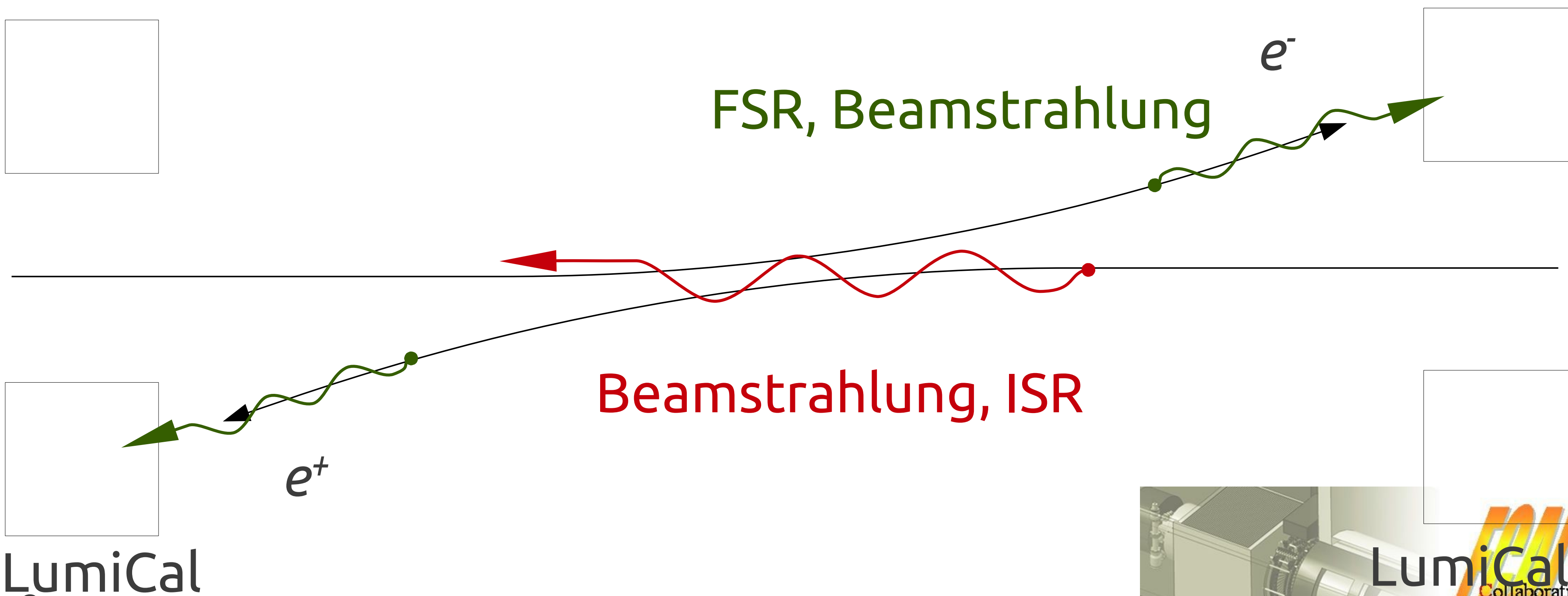
Invariant counting

$$\Xi = \prod_i \xi_i$$

- Is it possible to define Ξ and Ξ' such that they cover the same part of the phase space?
  - Cuts on Lorentz-invariant parameters
    (in practice only the invariance wrt the axial boost required)
  - Cuts in the same reference frame
    - Reconstruction of the parameters in the common frame
    - Reconstruction of the number of events in the c.f.

Experimental situation

- Electrons and the collinear radiation detected
- Radiation along the beam axis lost
- Kinematic properties of the event in the *collision frame* can be reconstructed experimentally



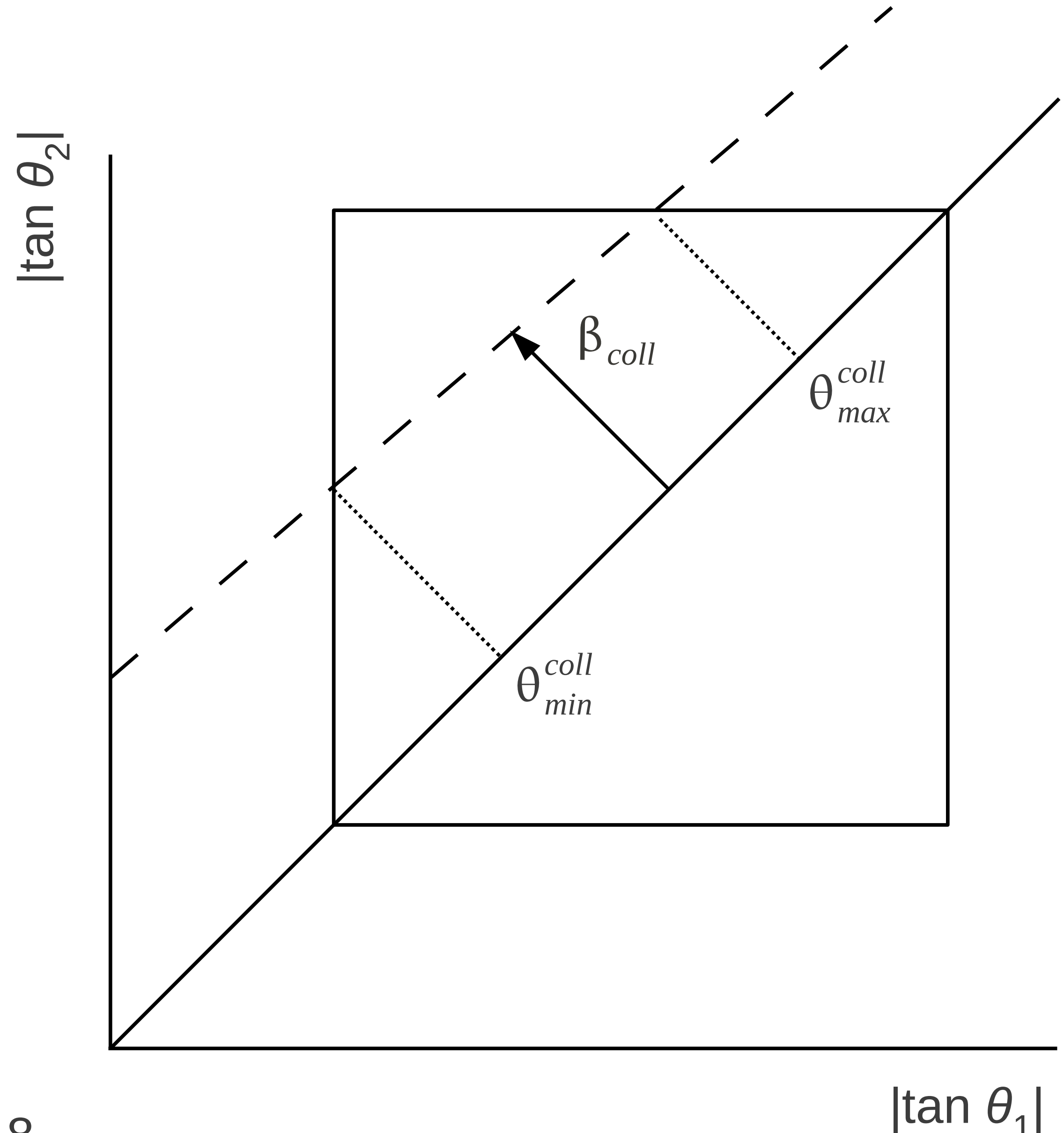
Collision frame

- Velocity wrt the lab frame

$$\beta_{coll}=\frac{\sin\left(\theta_1^{lab}+\theta_2^{lab}\right)}{\sin\left(\theta_1^{lab}\right)+\sin\left(\theta_2^{lab}\right)}$$

- Assumptions
  - $\vec{\beta}_{coll}$ is collinear with the beam axis
  - ISR and FSR are cleanly separated

Boost of the polar angles of Bhabha pairs



- Among events with a given β_{coll} (dashed line), the angular counting loss can be analytically calculated

- Correct by the appropriate weighting factor

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

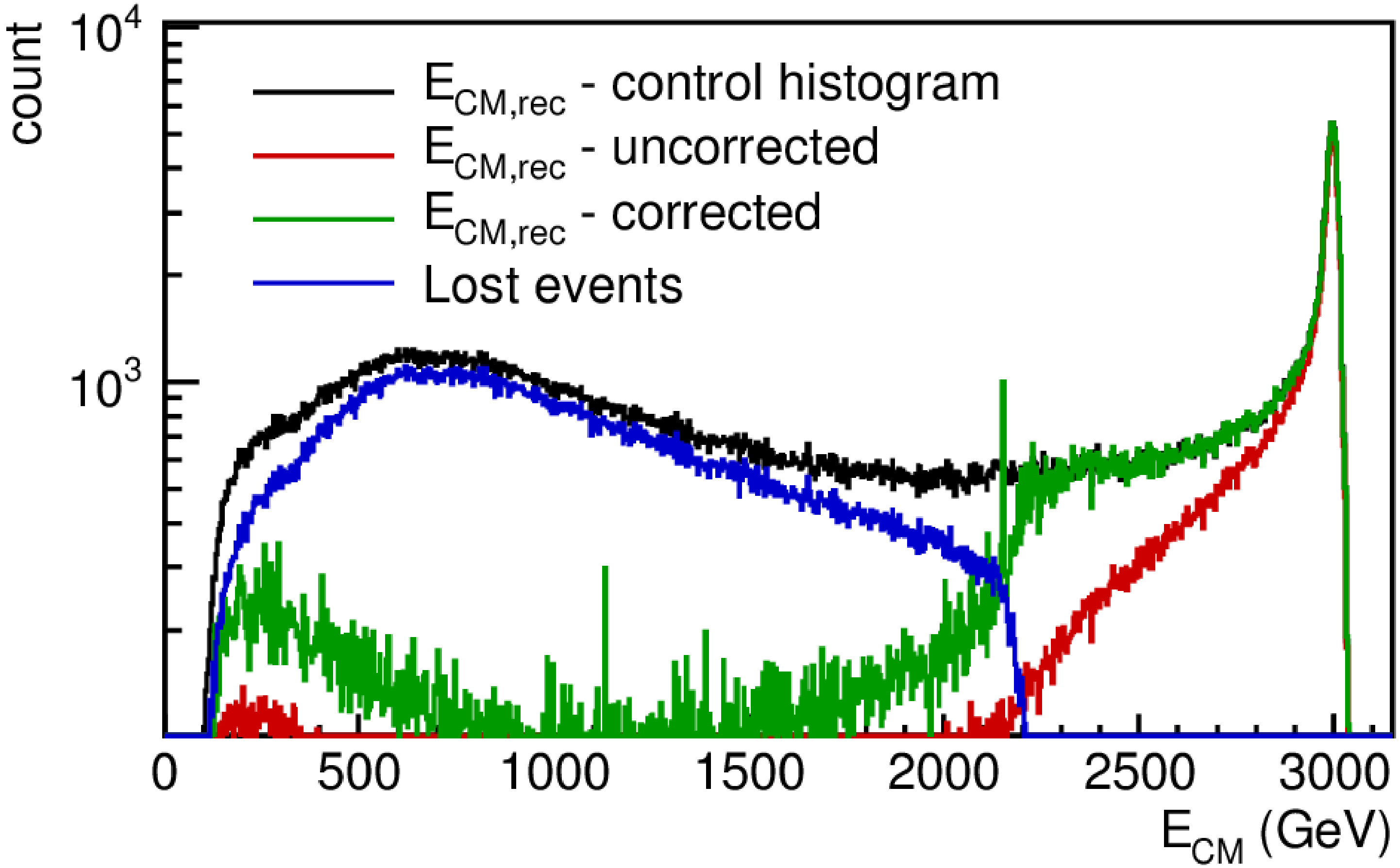
Simulation test

- Guinea-PIG + BHWIDE (similar to Ref. [1])
- Approximation of the interaction with the detector
  - Energy and polar angle smearing according to the respective instrumental resolutions in LumiCal
  - Clustering of the indistinguishable showers
- Update wrt May: *Clustering of the final showers around the most energetic shower and not around the electron*

[1] C. Rimbault et al., JINST 2, P09001 (2007)

Results of the angular-loss correction

- Reconstructed CM energies (after emission of ISR,
  - without correction of the *s*-dependence of the Bhabha xs,



- LumiCal energy response included,
- collinear outgoing photons added)

Results of the angular-loss correction

- Deviation in the integral count in the top 5% of energy with respect to the control histogram:
  - Before correction: $(\Delta N/N)_{top5\%} = -8.2\ \%$
  - After correction: $(\Delta N/N)_{top5\%} = (-1.8 \pm 0.6) \times 10^{-3}$
  - Lost fraction: $(n_{lost}/N)_{top5\%} = (0.008 \pm 0.008) \times 10^{-3}$ (negligible)
- In the region of 80-90% of CM energy:
  - Before correction: $(\Delta N/N)_{80\text{-}90\%} = -43\ \%$
  - After correction: $(\Delta N/N)_{80\text{-}90\%} = (-4.7 \pm 3.1) \times 10^{-3}$
  - Lost fraction: $(n_{lost}/N)_{80\text{-}90\%} = (1.7 \pm 0.2) \times 10^{-3}$

Energy range

$$L = \frac{N\left(\Xi\left(\Omega_{1,2}^{lab}, E_{1,2}^{lab}\right)\right)}{\sigma\left(\Xi'\left(\Omega_{1,2}^{CM}, E_{1,2}^{CM}, E_{CM}\right)\right)}$$

- Non-trivial pre-ISR E_{CM} spectrum
- Realistic absolute E_{CM} spectrum required for the determination of L

➔ Deconvolution of ISR from the experimental spectrum

ISR energy loss

$$h(E_{CM,rec}) = \int_0^{\infty} f(E_{CM})\, g\left(\frac{E_{CM,rec}}{E_{CM}}\right) \frac{1}{E_{CM}}\, dE_{CM}$$

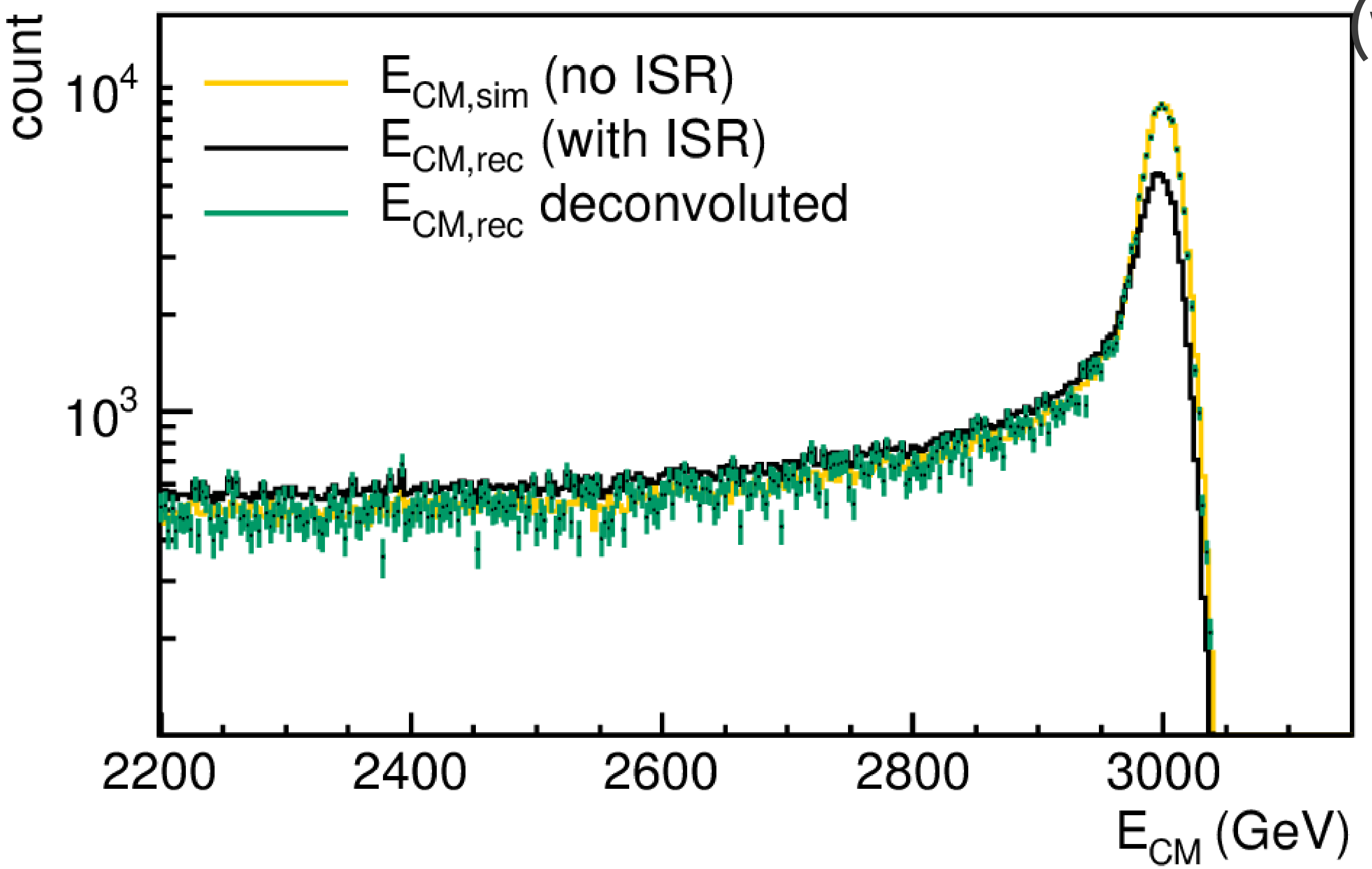
- Known distribution *g*(*x*) of ISR energy loss
  - Parametrize *g*(*x*) and fit to the generator results (BHLUMI, BHWIDE)
  - Discretize the equation for $h(E_{CM})$ and solve for *f*
- Update wrt. May/note: *Corrected an error in the discretization*

$$g_{i,j} = \int_{\cancel{\frac{j-1/2}{i-1}}\ \frac{j-1}{i-1/2}}^{\cancel{\frac{j-1/2}{i}}\ \frac{j}{i-1/2}} g(x)\, dx$$

ISR energy loss deconvoluted

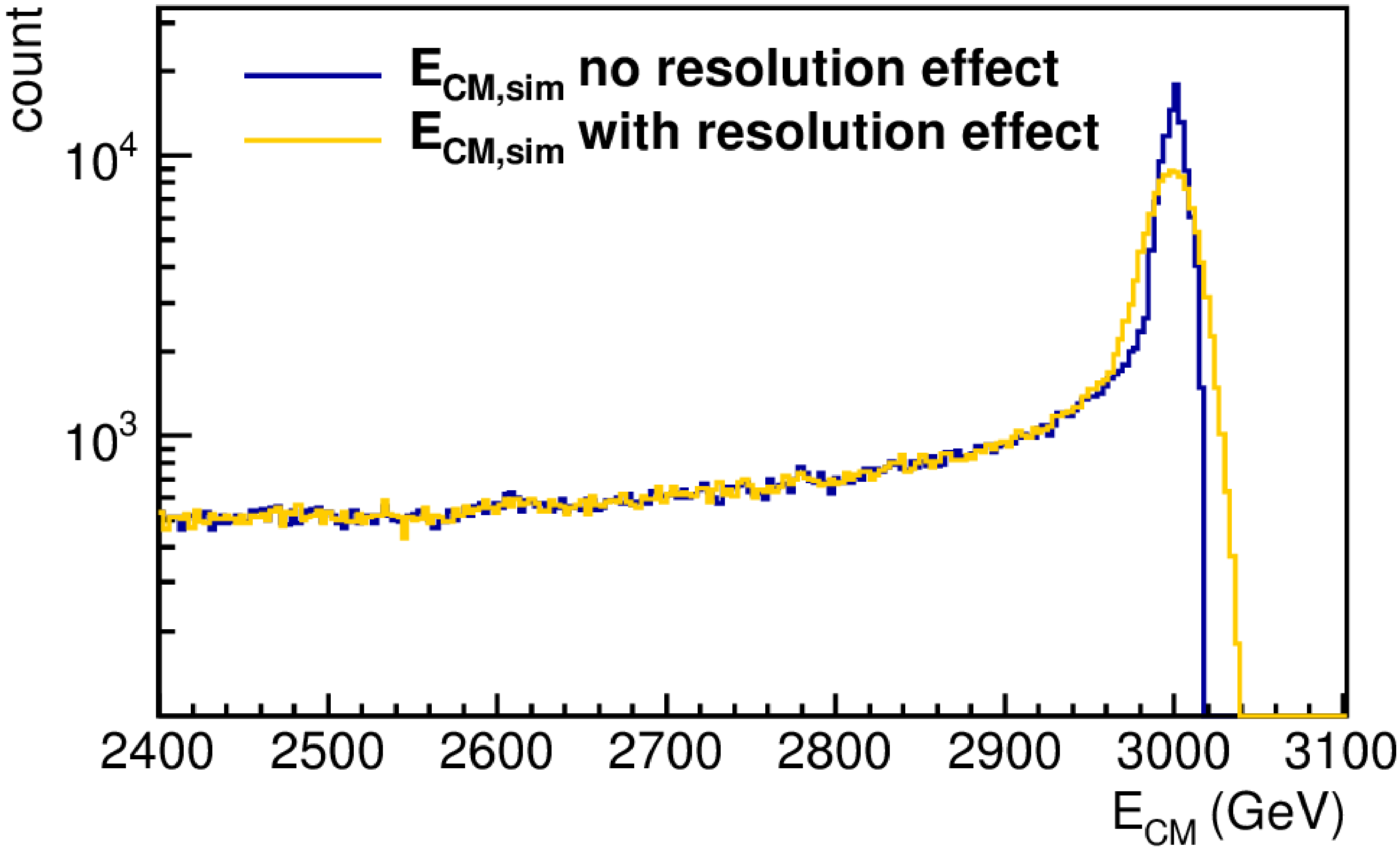
- Residual deviation in the top 5%: (-8.9 ± 3.1) x 10^{-3}
- Residual deviation in 80-90%: (7.8 ± 5.9) x 10^{-3}

(wrt 4% in May)



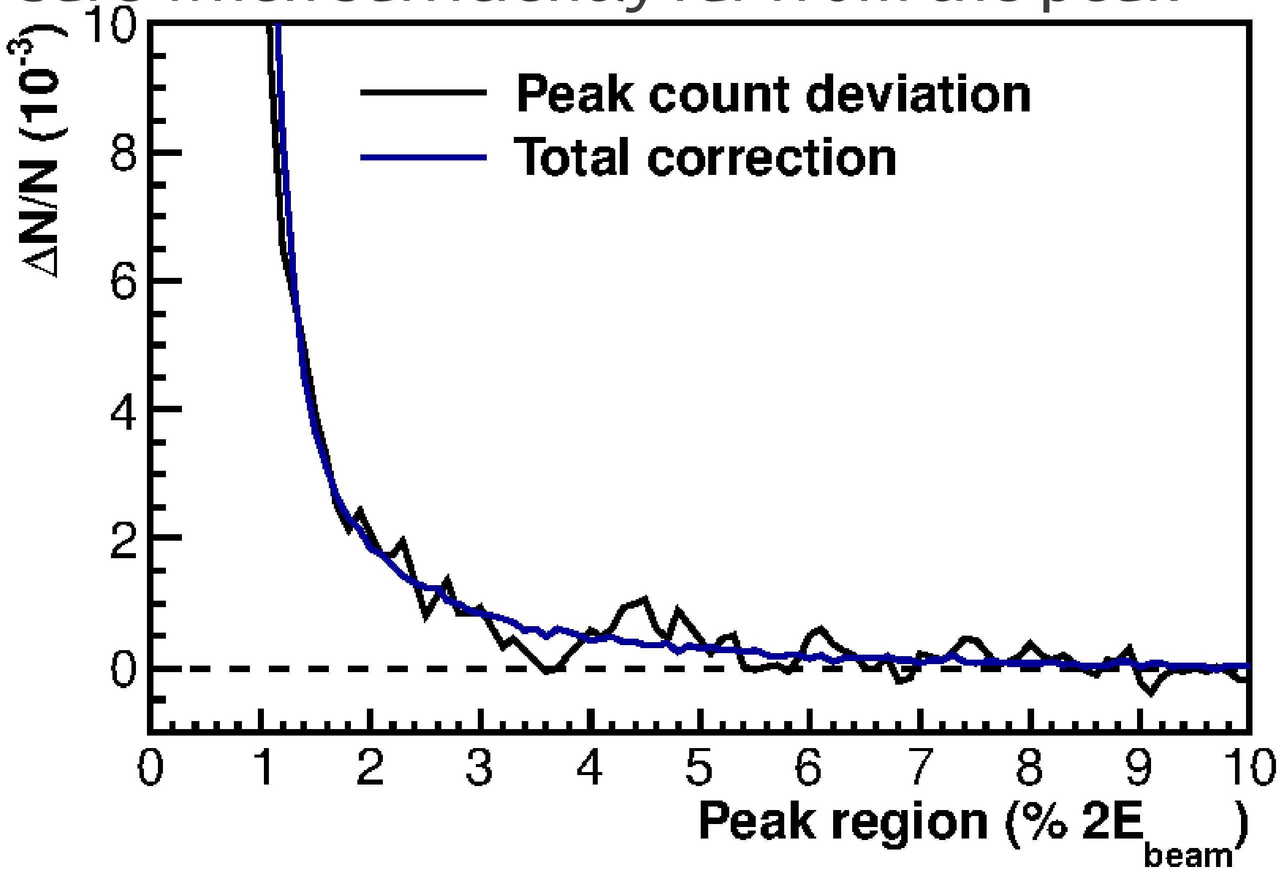
Finite energy resolution

- The count in the peak is affected by the smearing due to the finite energy resolution



Finite energy resolution

- The count in the peak affected by the energy resolution
- Relative bias estimate by fitting the deconvoluted spectrum and numerical inegration
- Safe when sufficiently far from the peak



CLIC - Uncertainties

Step	Residual relative deviation $\Delta N/N$ (10^{-3}) in the top 5%
BS+ISR correction	-1.8 ± 0.6
Deconvolution	-8.9 ± 3.1
Energy resolution	0.00 ± 0.03
EMD (uncorrected)	0.54 ± 0.08
Events with high β_{coll}	0.008 ± 0.008

Conclusions

- The collision-frame method achieves Lorentz-invariant counting of the Bhabha events.
  - Correction of the beamstrahlung effect independent of the knowledge of beam parameters
  - EMD small at 3 TeV CLIC
- Above 2200 GeV, the luminosity spectrum can be measured with precision better than 1%,
- Updates since May:
  - Instrumental uncertainty of the polar angle included in the sim.
  - Energy resolution from CLIC-CDR
  - LCD-Note-2012-008 (current version 4)
  - Clustering around the Most Energetic Shower
  - Corrected deconvolution (discretization)

Thank you!