# Integrated luminosity measurement at CEPC

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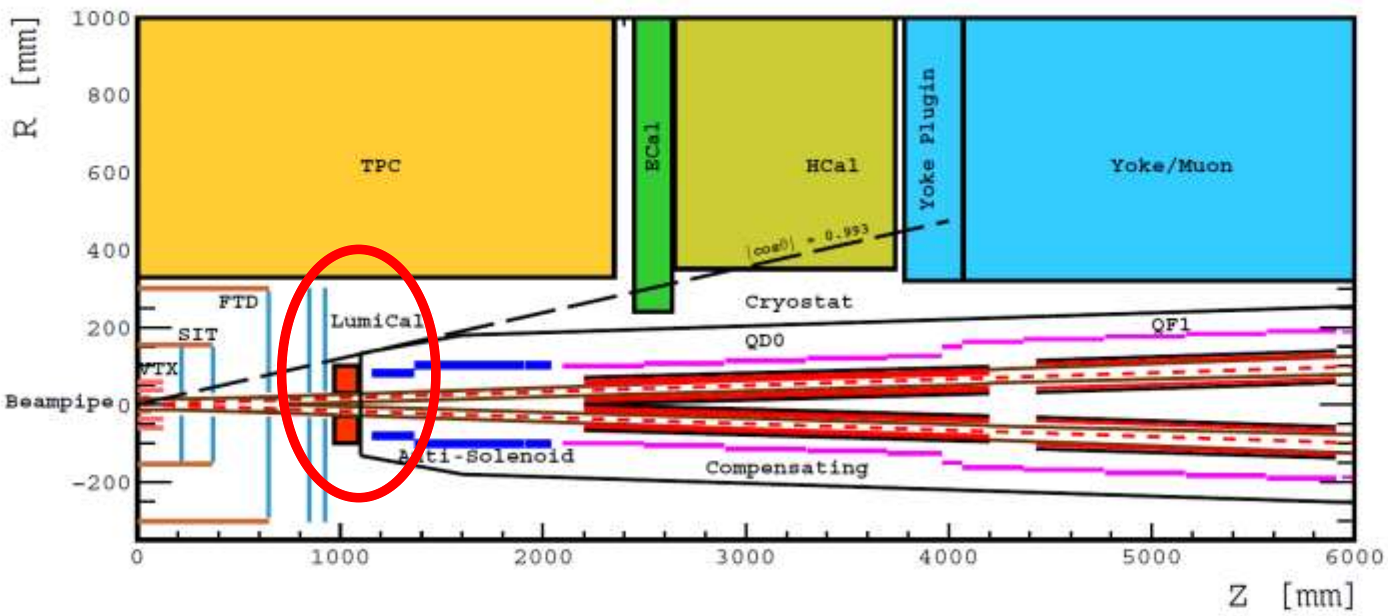
# Luminometer at CEPC




•Si-W sandwich type of calorimeter, over 20 $X_0$ (longitudinal, not larger than 10 cm)
•distance from IP: 100 cm
•polar angle coverage: 26 mrad – 105 mrad
•fiducial volume: 53 mrad – 79 mrad
•goals: relative uncertainty of the integrated luminosity measurement ~$10^{-4}$ at $Z^0$ pole and ~$10^{-3}$ at 240 GeV
•beam crossing angle: 33 mrad

Integrated luminosity measurement - a counting experiment based on Bhabha scattering, $L=N_{bh}/\sigma$ (in theory)
Major effects (uncertainties) influencing Bhabha count:
•mechanics (positioning and alignment)
•beam-energy asymmetry, beam synchronization, IP displacements
•effective center-of-mass energy
•physics background from 2-photon processes
•Beam-induced effects: EM deflection

**mechanics and MDI**

# Systematic uncertainties of integrated luminosity from mechanics and MDI

**The MDI related effects are:**
•uncertainty of the effective center-of-mass energy ($\Delta E_{CM}$) for the x-section calculation
•uncertainty of the asymmetry in energy of the $e^+$ and $e^-$ beams, ($|E_{e+}-E_{e-}|$)
•IP position displacements with respect to the luminometer, radial and axial ($\Delta x_{IP}$, $\Delta z_{IP}$), caused by the finite beam transverse sizes and beam synchronization, respectively
**Detector-related uncertainties arising from manufacturing, positioning and alignment:**
•uncertainty of the luminometer inner radius ($\Delta r_{in}$)
•spread of the measured radial shower position w.r.t. to the true impact position on the luminometer front plane ($R_r$)
•uncertainty of the longitudinal distance between left and right halves of the luminometer ($\Delta d$)
•mechanical fluctuations of the luminometer position with respect to the IP caused by vibrations and thermal stress, radial and axial ($\sigma_{x\_IP}$, $\sigma_{z\_IP}$)
•twist of the calorimeters corresponding to different rotations of the left and right detector axis with respect to the outgoing beam ($\Delta\phi$)

**Physics background : $10^{-4}$ contamination at all energies without specific selection**

| parameter | limit@240 GeV symmetric sel. | limit@240 GeV asymmetric sel. | limit@91 GeV asymmetric sel. |
|---|---|---|---|
| $\Delta E_{CM}$ (MeV) | 120 | 120 | 5 |
| ($\|E_{e+}-E_{e-}\|$) (MeV) | 120 | 240 | 11 |
| $\Delta x_{IP}$ (mm) | 0.1 | 1.0 | 0.5 |
| $\Delta z_{IP}$ (mm) | 1.4 | 10.0 | 2.0 |
| beam synch. (ps) | 1 | 15 | 3 |
| $\Delta r_{in}$ ($\mu$m) | 13 | 10 | 1 |
| $R_r$ (mm) | 0.15 | 1.00 | 0.20 |
| $\Delta d$ (mm) | 1.00 | 1.00 | 0.08 |
| $\sigma_{x\_IP}$ (mm) | 0.1 | 1.0 | 0.5 |
| $\sigma_{z\_IP}$ (mm) | 1 | 10 | 7 |
| $\Delta\phi$ (mrad) | 6.0 | 6.0 | 0.8 |

**Detector and MDI-related uncertainties at Z0 pole and 240GeV, contribution to the CEPC CDR**

Main systematic effects are coming from the uncertainty of the luminometer inner radius and uncertainty of the effective center-of-mass energy

# Systematic uncertainties of integrated luminosity from uncertainty of the effective center-of-mass energy

**Effective center-of-mass energy can be determined within the beam-spread from experimentally measurable quantities**

- From the acolinearity of muons from $e^+e^- \rightarrow \mu^+\mu^-$ measured in the central tracker, as proposed for FCC-ee*

$$\frac{s'}{s} = \frac{\sin\theta^+ + \sin\theta^- - |\sin(\theta^+ + \theta^-)|}{\sin\theta^+ + \sin\theta^- + |\sin(\theta^+ + \theta^-)|}$$

-We've shown that with the nominal polar angle resolution of the central tracker @ CEPC (0.1 mrad), effective center-of-mass energy can be determined with 2.5% of the beam-spread (<1 MeV) relative accuracy, at $Z^0$ pole, after 4 minutes of data taking

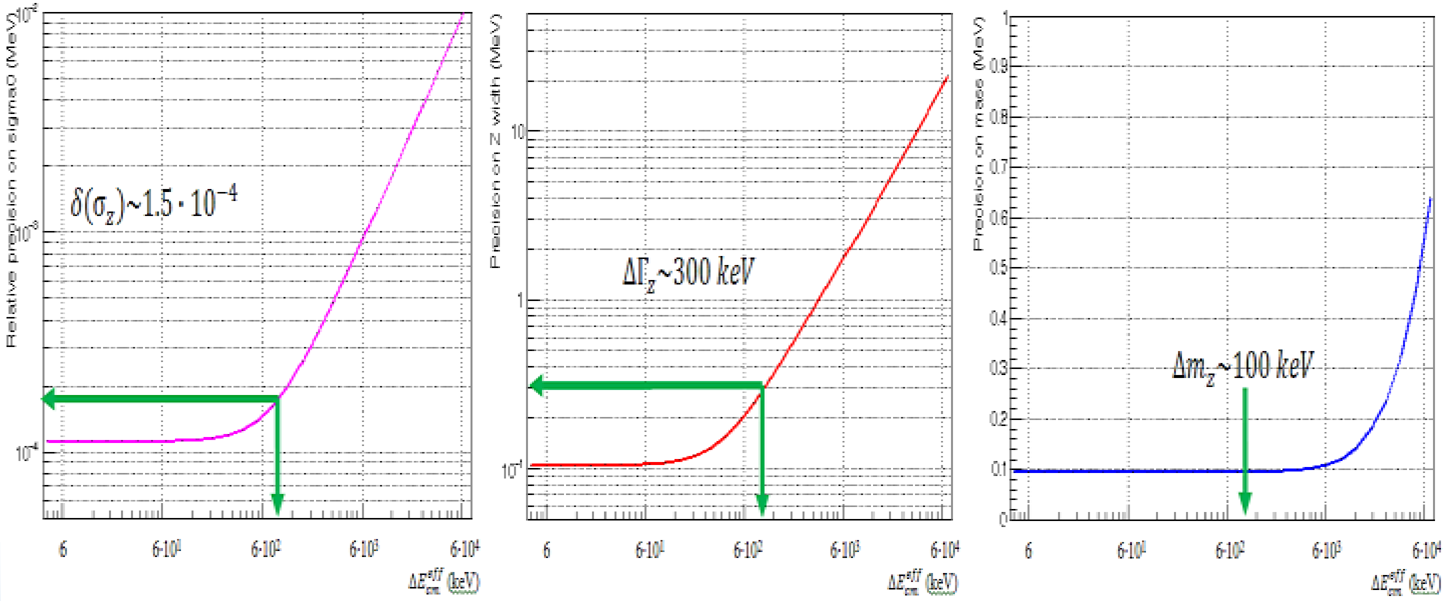
-The above meets precision requirements of $1.5 \cdot 10^{-4}$, 300 keV and 100 keV for the relative precision on $Z^0$ cross-section, total width and mass, respectively

-Only 2 minutes of running at the $Z^0$ pole are required to meet the relative precision of integrated luminosity of $10^{-4}$

-At 240 GeV, effective center-of-mass energy uncertainty within the existing beam-spread is satisfactory for $10^{-3}$ relative precision of integrated luminosity

| CEPC | Luminosity @ IP ($cm^{-2}\ s^{-1}$) | Nominal beam-spread (%) | Number of events | Cross-section $e^+e^- \rightarrow \mu^+\mu^-$ | Collecting time | Beam-spread variation ($\delta E_b$) |
|---|---|---|---|---|---|---|
| $Z^0$ pole | $3.2 \cdot 10^{35}$ | 0.080 | 250 KEvt. | 1.5 nb | ~ 4 min (2 min for $10^{-4}$ of ) | ~(2.5%)·$\delta E_b$ (900 keV) |
| Higgs factory | $3.0 \cdot 10^{34}$ | 0.134 | 100 KEvt. | 4.1 pb | ~ 10 days | ~ (15%)·$\delta E_b$ (~24 MeV) |

2.5% CEPC (900 keV)




*P. Janot, Beam Energy Spread Measurement @ FCC-ee, talk given at the FCC-ee Polarization Workshop, CERN, 2017