Electromagnetic deflection (and other systematics) in luminosity measurement at the Z-pole at CEPC

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Overview

- Introduction
- Does position matters (s-axis vs. z-axis)?
  - EMD of the initial state at the Z-pole (cont. of ongoing study)
  - Other systematics (from mechanics and MDI)
- Summary

Introduction

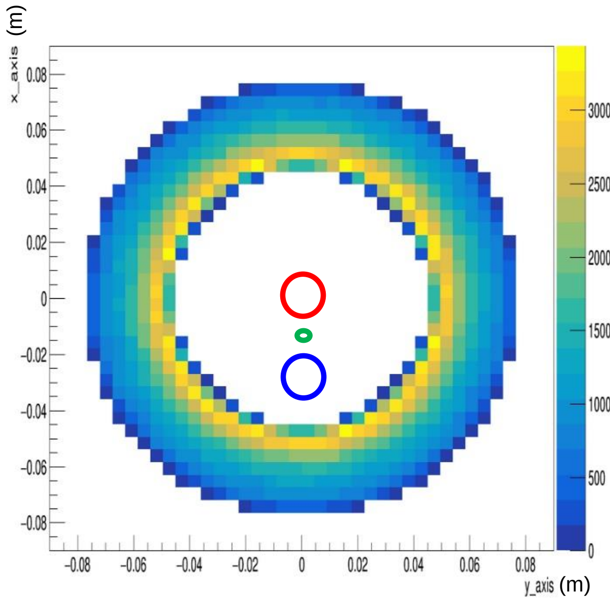
- **Challenging control of luminosity systematics at 10^{-4} at 91.2 GeV**

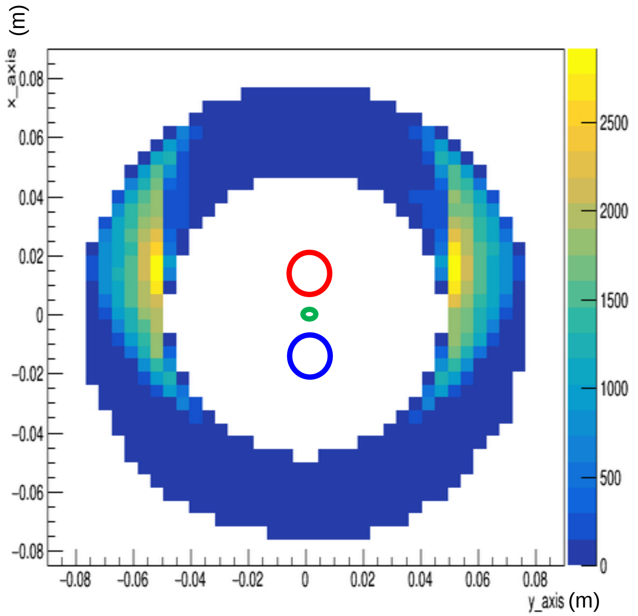
- **Most sources from mechanics and MDI have been studied** and documented in CEPC CDR and *JINST 17 P09014, 2022,* including experimental determination of the beam energy spread and its impact on integrated luminosity and precision EW observables

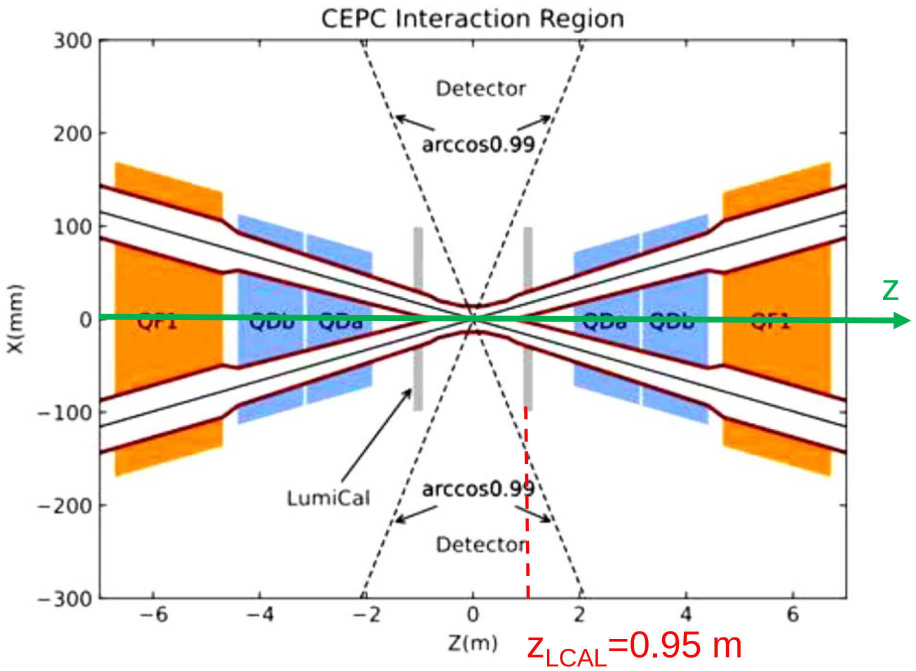
- We started to look into **beam-beam effects**, presenting p_x-kick induced by EMD of the initial state at the WS in Edinburgh *[https://indico.ph.ed.ac.uk/event/259/contributions/2470/attachments/1372/2066/CEPC_WS2023_EMD1_Bozovic.pdf]*.

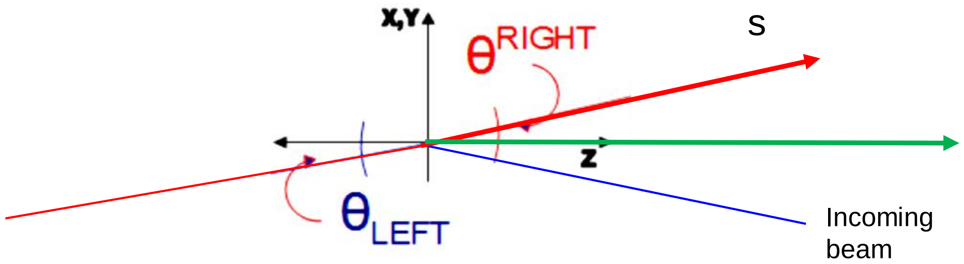
- However, everything has been done for the luminometer at the s-axis.

The geometry of the CEPC interaction region





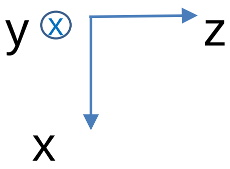


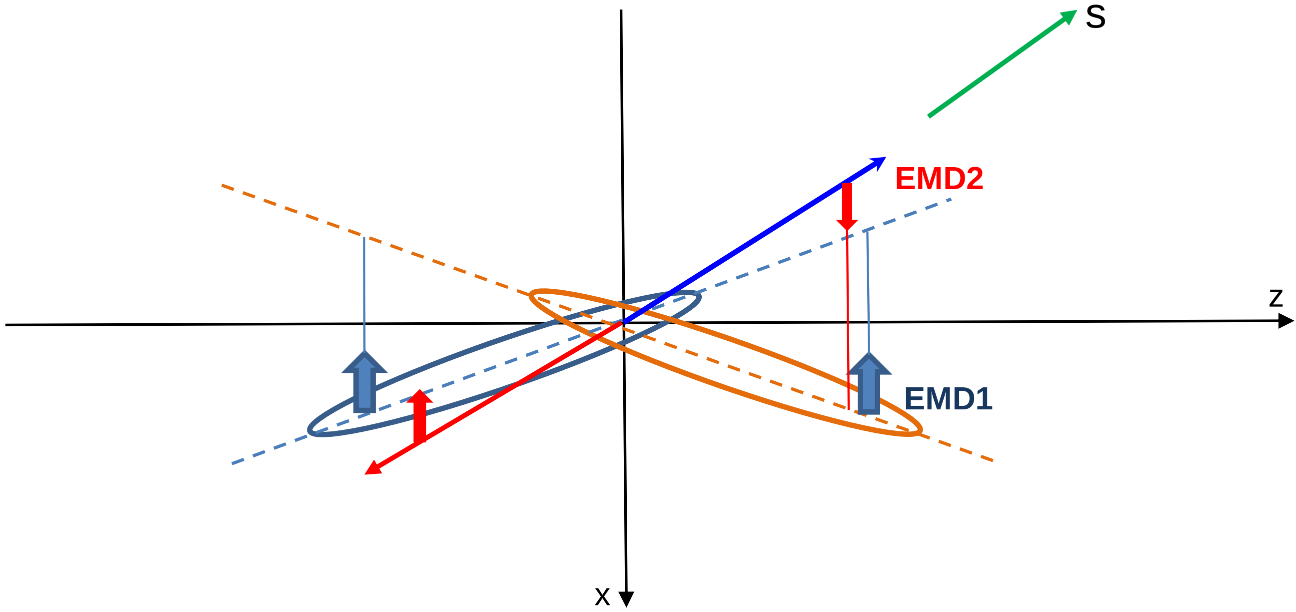


Does position matters?

EMD1 – p_x-kick of the initial state (s-axis)

- GuineaPig C++ V.1.2.2
- E_{beam}= 45.5 GeV
- Post-CDR CEPC beam:
    - N_e= 1.5 ·10^{11}
    - σ_x= 6 μm
    - σ_y= 35 nm
    - σ_z= 11.8 mm



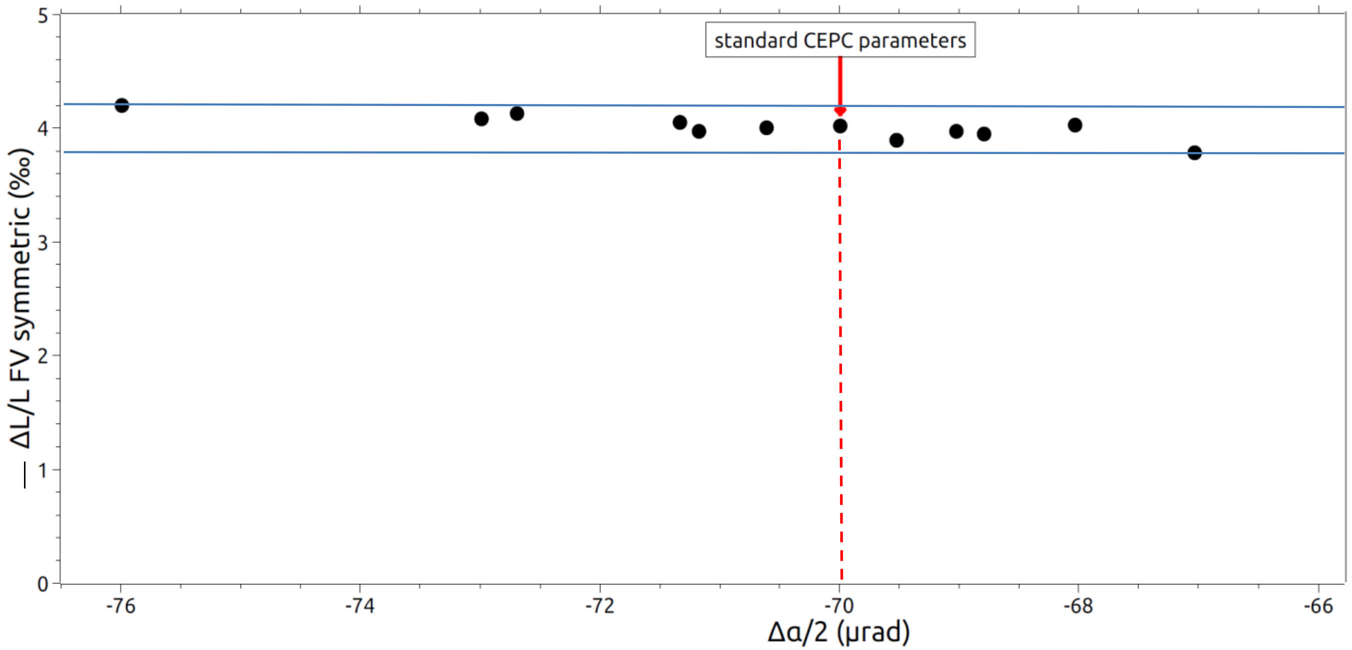


- e^+e^- system receives kick of ~5.8 MeV in –x direction, or ~2.9 MeV per particle in average
- No shift along y-axis
- x-angle effectively reduced for 140 μrad ($\delta\alpha$), 70 μrad per beam
- At distance of 0.95 m from IP p_x-kick is equivalent to a luminometer shift of ~60 μm along the x-axis
- Knowing that δE depends on both x-angle and $\delta\alpha$, δE is found to be ~52 keV

Does position matters?

EMD1 – p_x-kick of the initial state (s-axis)

- Change of four-vectors of initial state modifies final state's angles
- **Bhabha count in the FV changes for ~ 4 ·10^{-3} in the presence of EMD1 with nominal beams**
- **Variation of beam parameters (bunch charges and σ_x) in the ±10% range w.r.t. the nominal beam size produce deviation of $\Delta\mathcal{L}/\mathcal{L} \leq 2 \cdot 10^{-4}$**



Does position matters?

The way of counting matters at s-axis

EMD1 – p_x-kick of the initial state (s-axis)

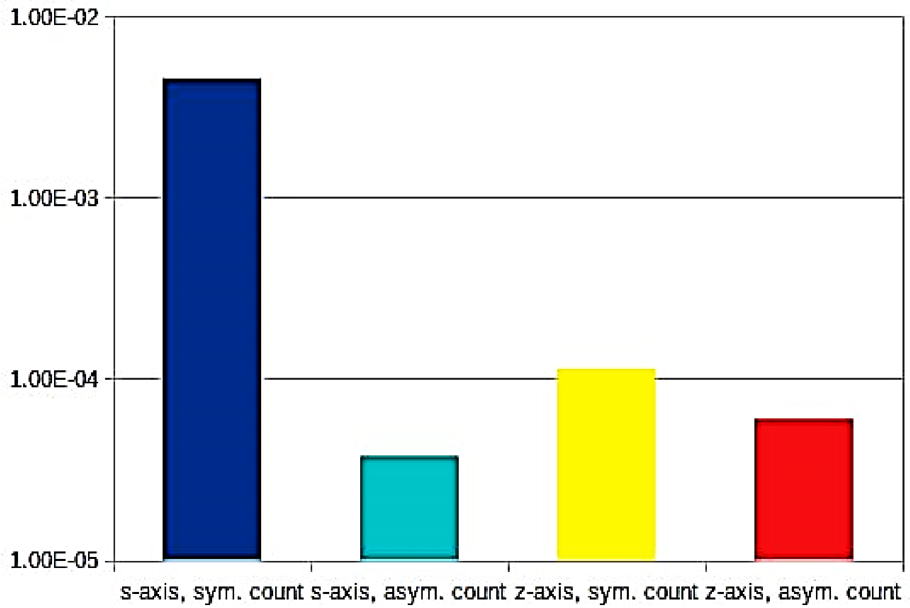
- BHLUMI V4.04
- Luminometer at 16.5 mrad
- 3.2 ab^{-1}

- SYMMETRIC
- FV: 53-79 mrad

- ASSYMMETRIC
- Narrow FV: 55-77mrad
- Wide: 53-79 mrad

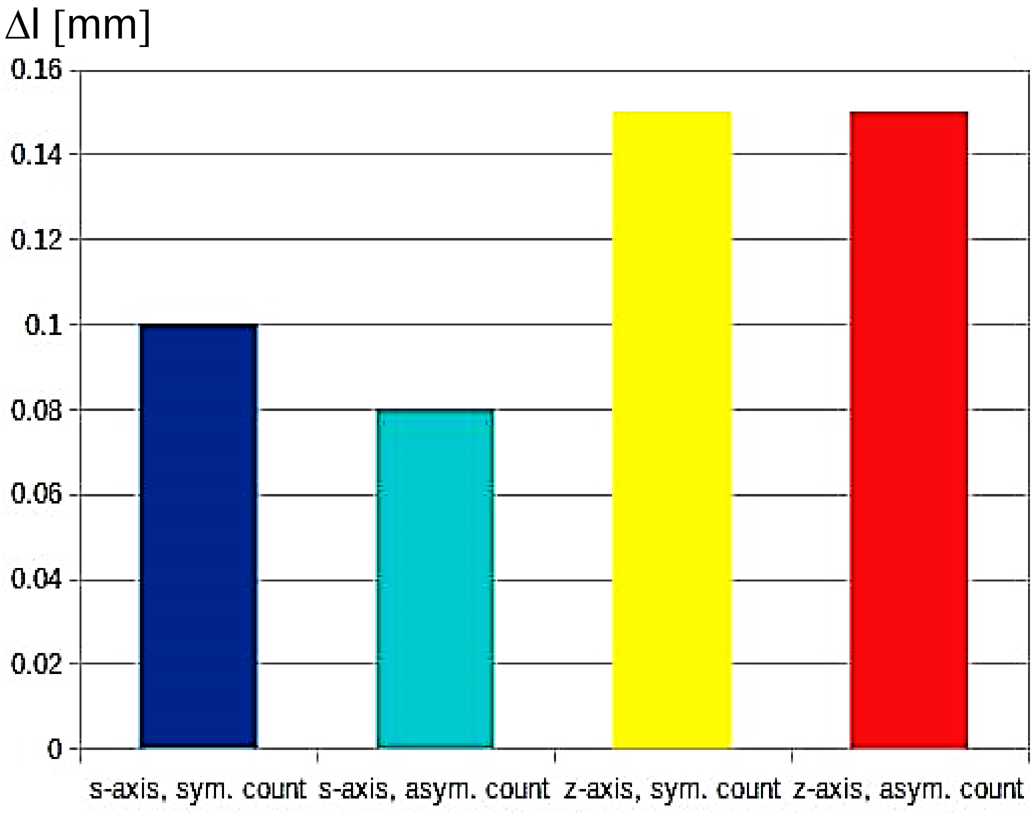
- As shown for other colliders (i.e. ILC and FCCee), the EMD1 effect on $\Delta\mathcal{L}/\mathcal{L}$ is reduced with asymmetric counting at s-axis;
  - **s-axis:** $\Delta\mathcal{L}/\mathcal{L} \approx 6 \cdot 10^{-5}$ with asymmetric counting, with symmetric app. 2 orders of magnitude worse**;**
  - **z-axis:** $\leq 10^{-4}$

$\Delta\mathcal{L}/\mathcal{L}$



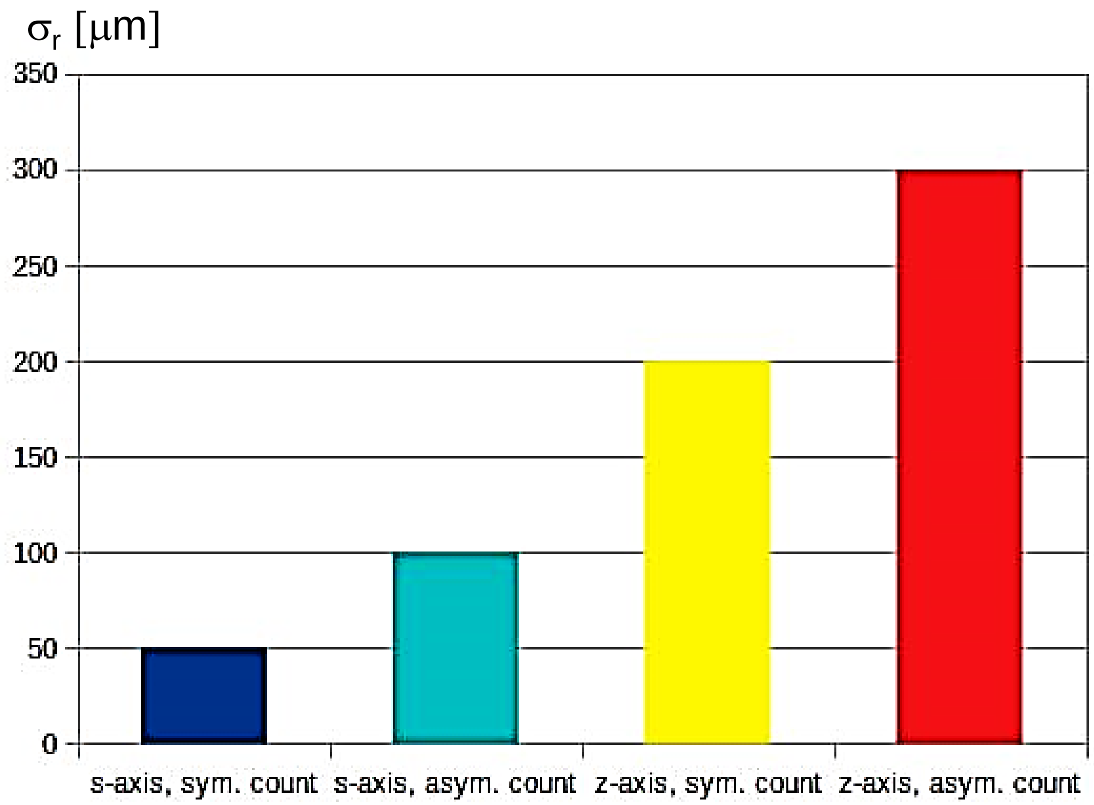
Does position matters?

Relative distance between left and right arms of the luminometer Δl



~100 μm at all axis

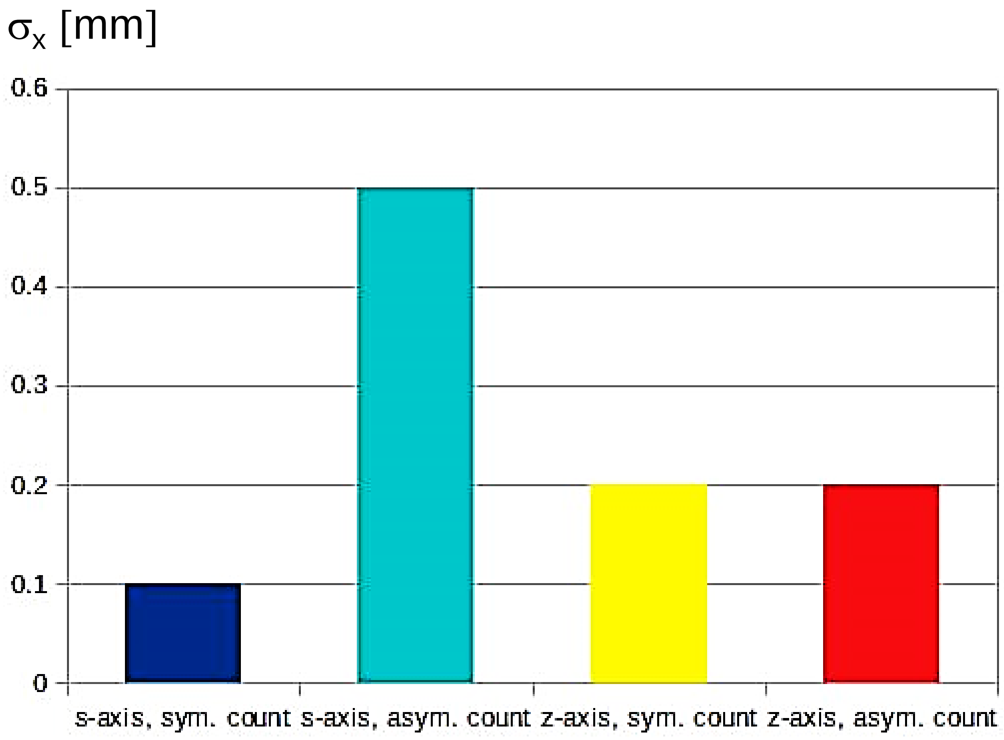
Radial shower position resolution σ_r



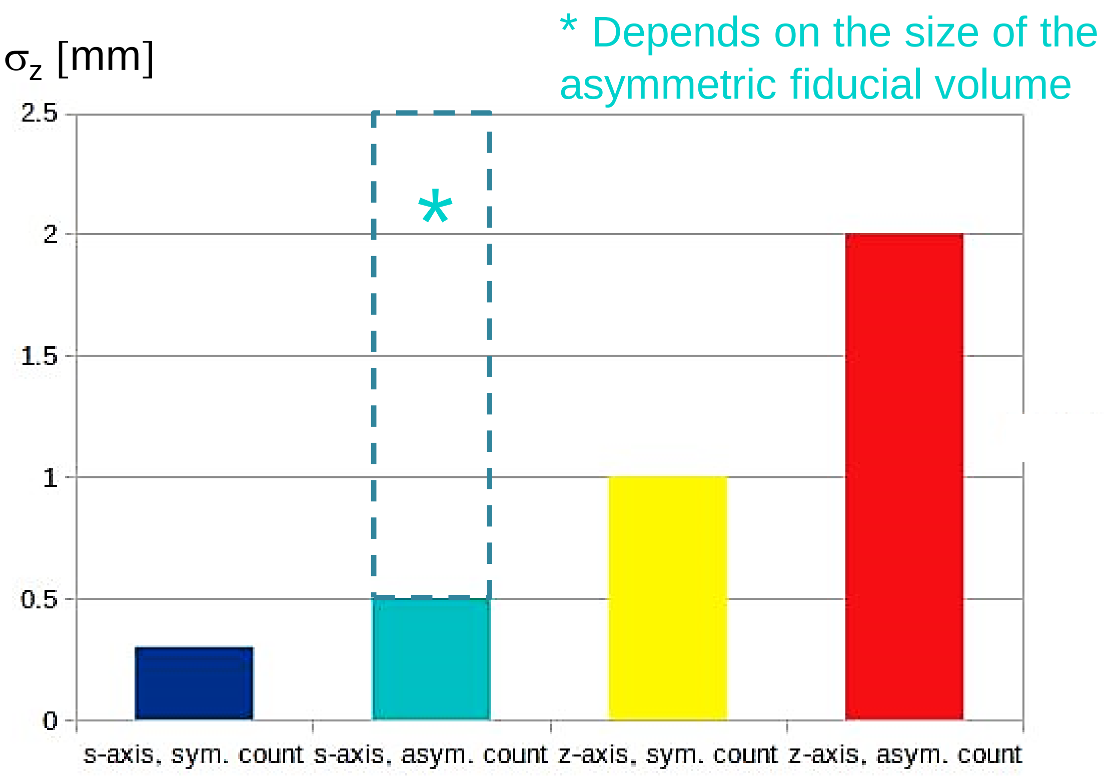
~100s of μm at all axis

Radial position fluctuations of the luminometer σ_x w.r.t. the IP

Axial position fluctuations of the luminometer σ_z w.r.t. the IP



~few 100s μm at all axis

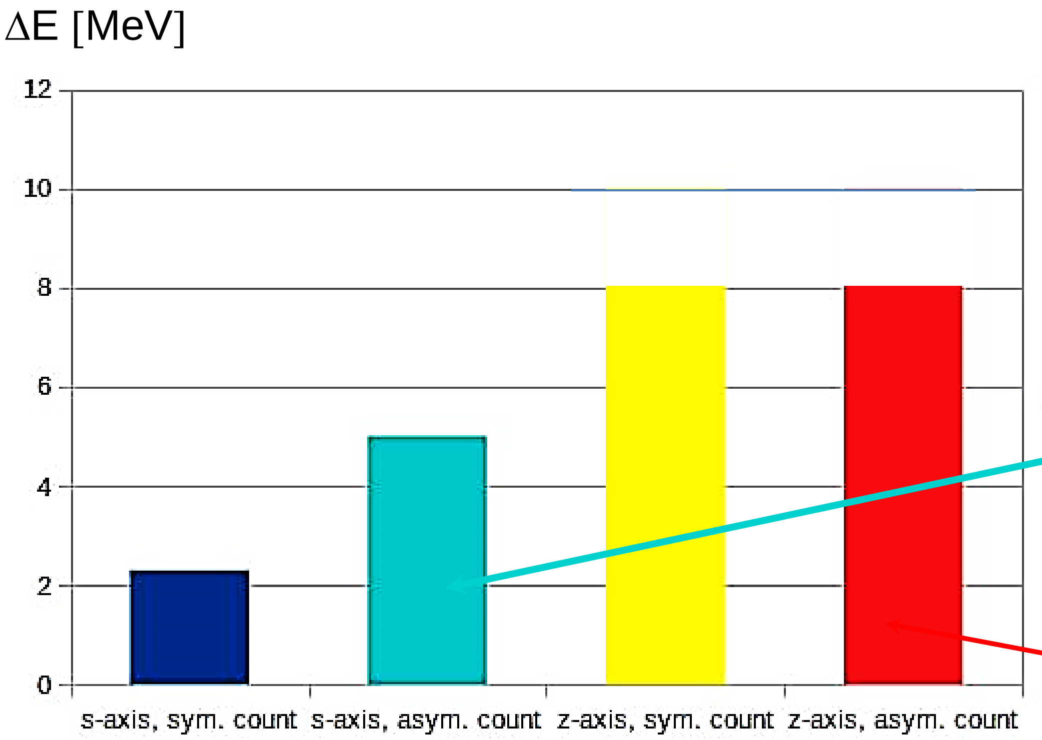


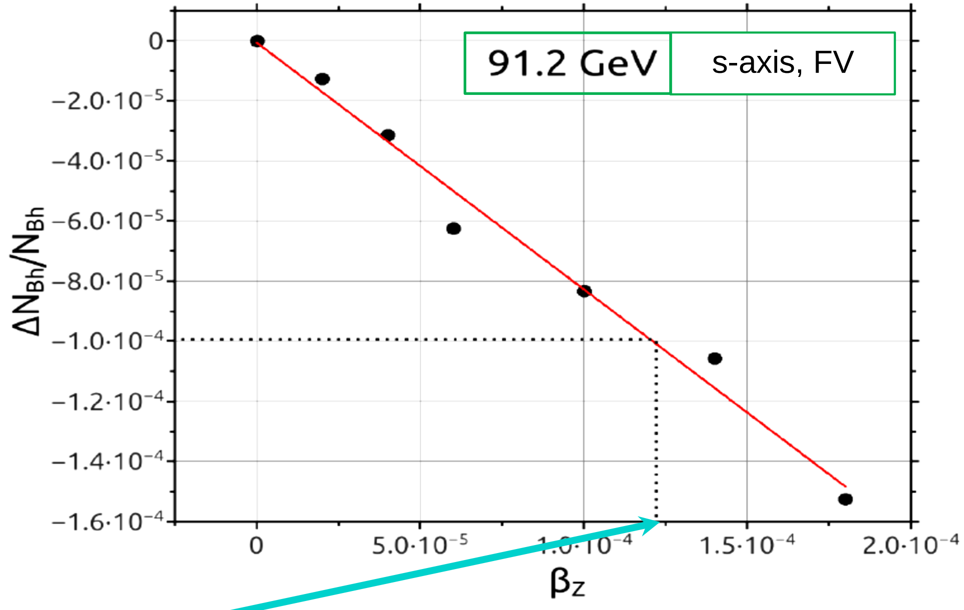
~few 100s μm up to a few mm

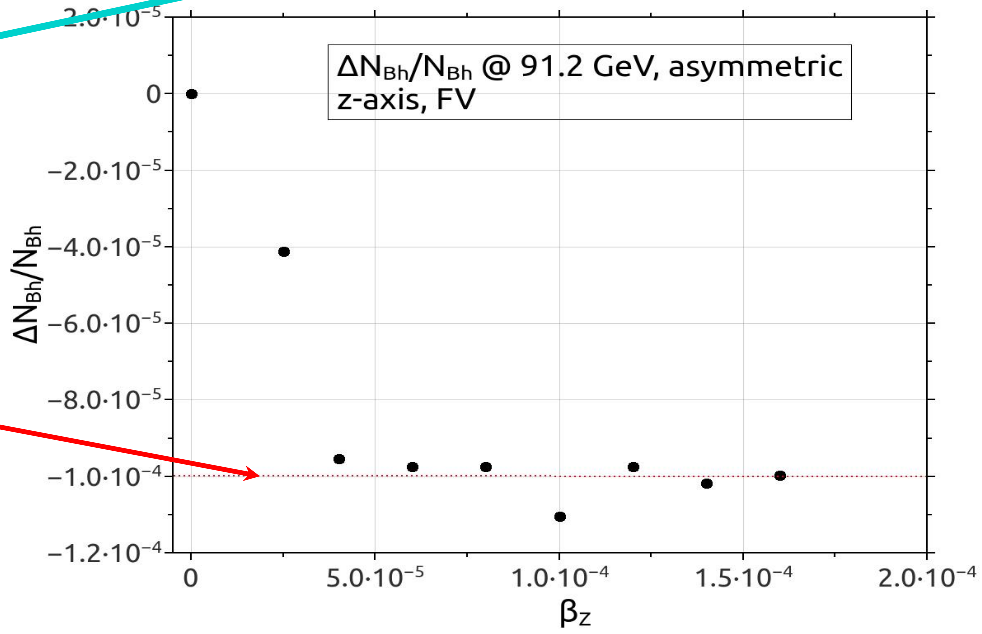
Does position matters?

[JINST 17 P09014, 2022]

Beam energy asymmetry ΔE (longitudinal boost)





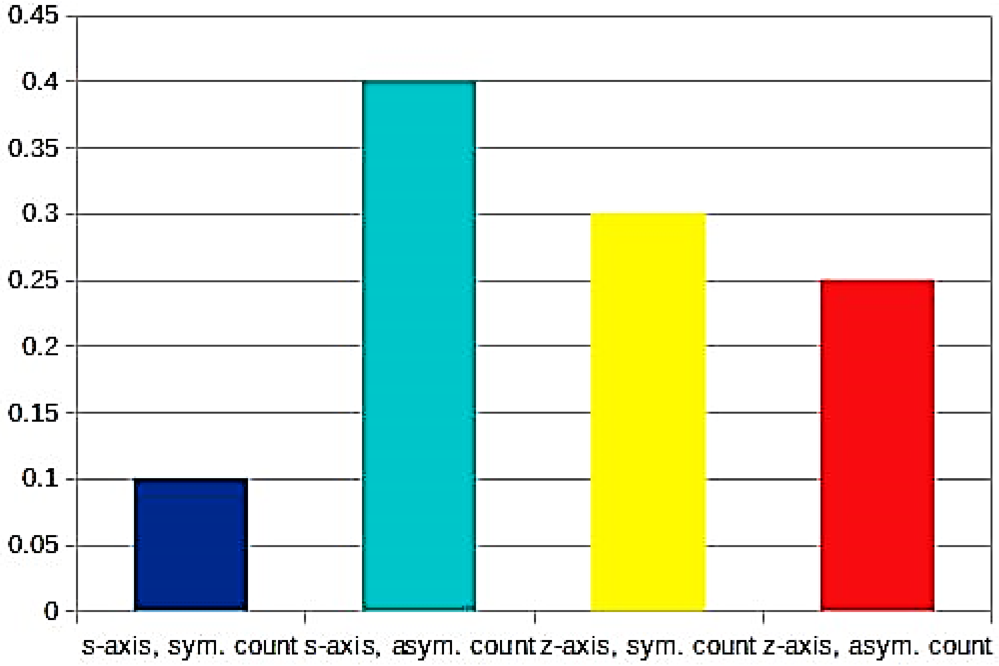


Somewhat less sensitivity at z-axis, BUT
trends are not obvious like at s-axis

Does position matters?

Radial IP displacements Δx_{IP}

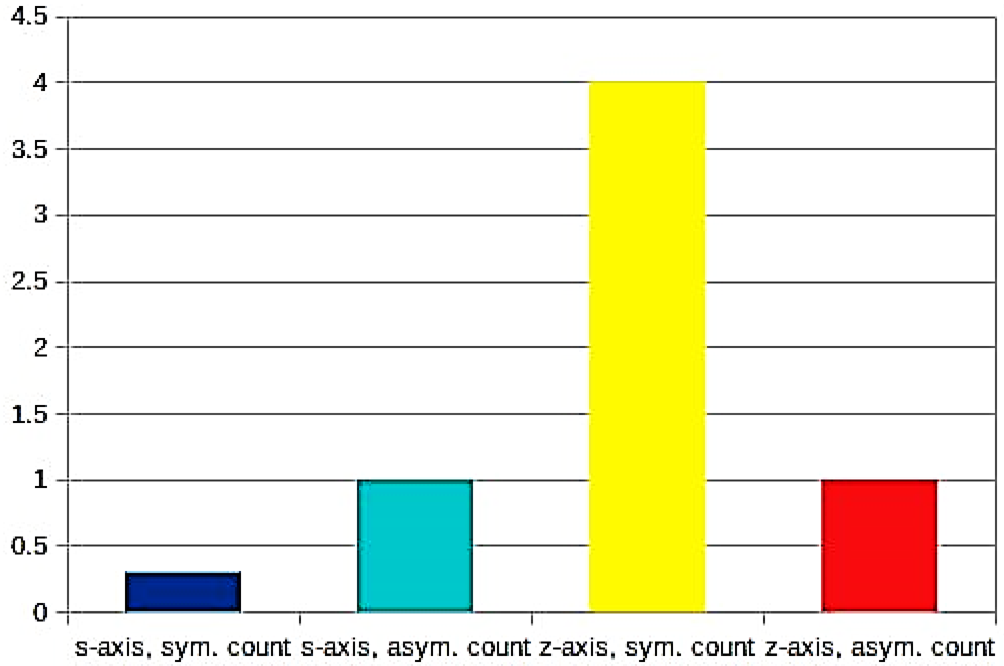
Δx_{IP} [mm]



~few 100s μm at all axis

Axial IP displacements Δz_{IP}

Δz_{IP} [mm]



few mm at all axis $\Leftrightarrow$ few ps in beam synchronization

Summary

- We've started to look into EMD effects at CEPC in the context of integrated luminosity precision at the Z-pole; **Sensitivity on the way of counting** draws us to investigate EMD1 and other **systematic effects w.r.t. the luminometer positioning** (s-axis vs. z-axis) as well;

- With the post-CDR beams **p_x-kick** of 5.8 MeV is found at the Z-pole. It translates into x-angle decrease of 70 μrad and beam energy increase of 52 keV. **It gets less than 10^{-4} with asymmetric counting on s-axis and with arbitrary counting on z-axis;**

- **Systematic effects from mechanics and MDI (metrology) are rather sensitive to the way of counting than to the luminometer position; However, asymmetric counting is not effective at the z-axis;**

- **No effect seems to be critical at z-axis (more than at s-axis);**

- **But, (mostly linear) dependences of counting loss present in symmetrical geometry (s-axis) get lost at the z-axis. In addition, asymmetric counting can be relaxed by tuning the size of the shrunken FV.**

Backup

Does position matters?

Correction for EMD1

- $\delta\alpha$ (like beam energy spread) can be precisely measured using the same central process (di-muon production)
- This implies that p_x-kick can be taken as correction to luminosity determination with the same uncertainty (standard error gives 0.26 mrad/$\sqrt{N_{\mu\mu}}$, 10^6 events takes 12min.)