Beam-spread determination for luminosity measurement @ CEPC

Ivanka Bozovic Jelisavcic, Ivan Smiljanic, Goran Kacarevic
VINCA Institute of Nuclear Sciences, Belgrade, SERBIA

CEPC WS 2019, 18-19 November 2019, Beijing

Overview

- Requirements on beam-spread from $\mathcal{L}$ precision
- Experimental method
- ***s'*** sensitivity to beam-spread
- What do we need to be sensitive to $10^{-1,-2,-3}$ variations of the beam-spread?
- Conclusion

Requirements on beam-spread from $\mathscr{L}$ precision

10^{-3} in $\mathscr{L}$, 240 GeV CEPC, 10^{-4} @ Z^0 pole

Asymmetric bias on beam energy

$|E_+ - E_-| = \Delta E \Rightarrow \beta_z = \Delta E / E_{CM}$

- Longitudinal boost of the CM frame of the colliding particles to the lab frame β_z

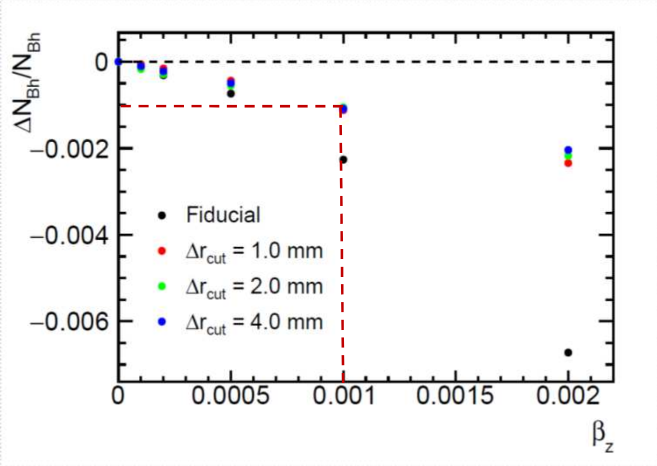
$\Rightarrow$ counting loss due to the loss of colinearity

- Asymmetry in beam energies should be smaller than $10^{-3}(10^{-4})$ at 240 GeV (Z^0 pole)

One needs to know asymmetry in beam energies as 12.5% of the beam- spread at Z^0 pole (150%@240 GeV)

Effective center of mass energy

- Bhabha cross-section changes as ~1/s $\Rightarrow$ relative uncertainty on (average net) CM energy $< 5 \cdot 10^{-4}$ for $\mathscr{L}$ uncertainty of 10^{-3}
- If there is no asymmetry, there is no impact on counting



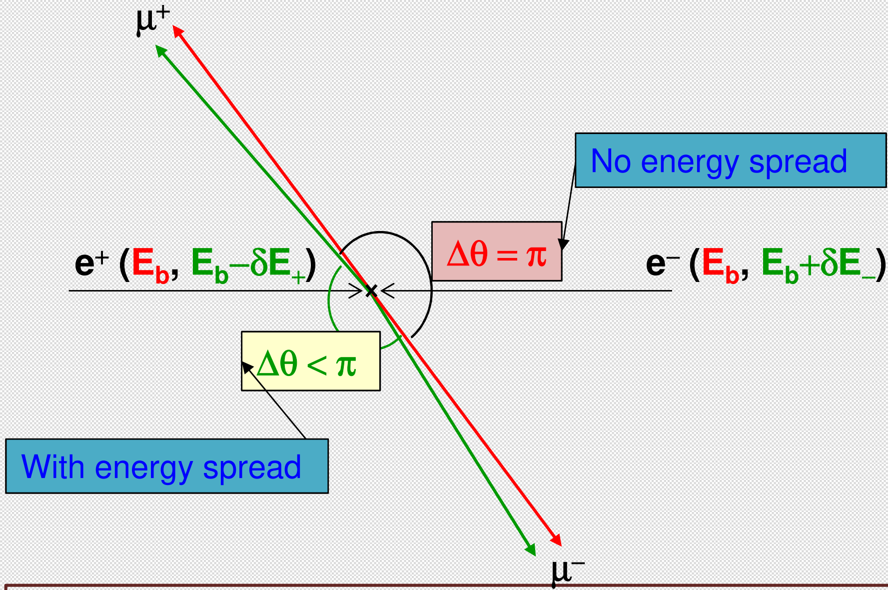
Experimental method

The method:

- ***s'*** can be determined from the reconstructed muons polar angles

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

- Method is proposed for FCCee [P. Janot, FCCee polarization WS, 2017]
- Muon polar angle resolution of ~0.1 mrad (100 μm of TPC resolution) is assumed over the tracking volume



Additional effects:

- ISR
- Beam-beam interactions
- Deterioration of the muon polar angle resolution
- Physics backgrounds

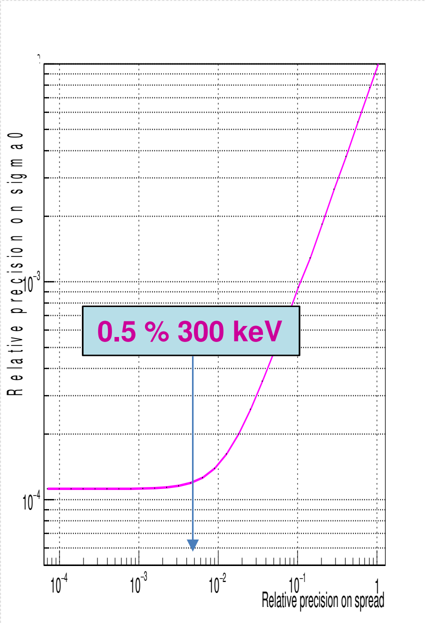
We'll try to answer:

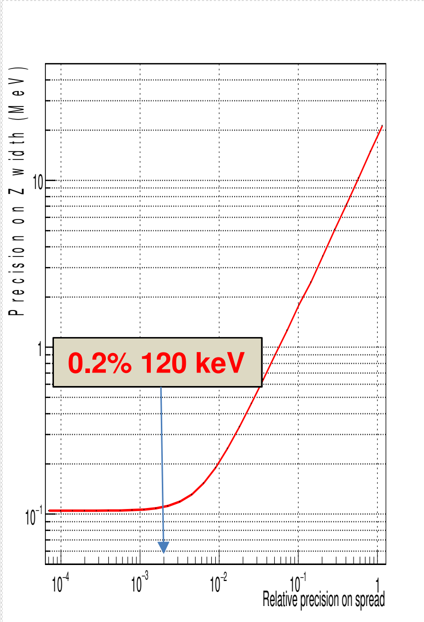
- What is the sensitivity (of ***s'***) to the beam-spread, ISR and detector resolution?
- How many muons (what time/integrated $\mathscr{L}$) one needs to achieve aimed sensitivity?

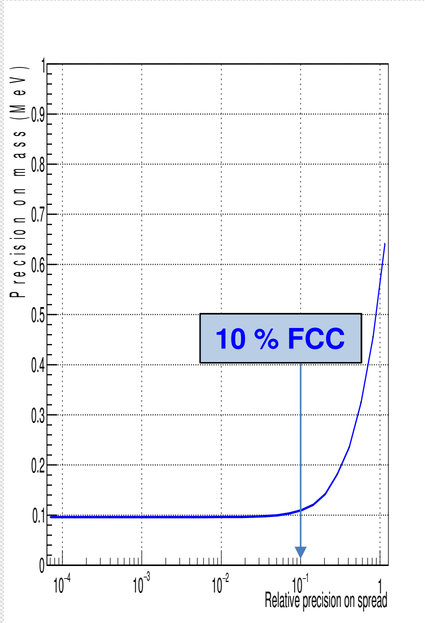
Further motivation

It is interesting to note that other observables critically depend on the knowledge of the beam-spread (@ Z^0 pole):

- cross-section
- Z^0 total width
- Z^0 mass

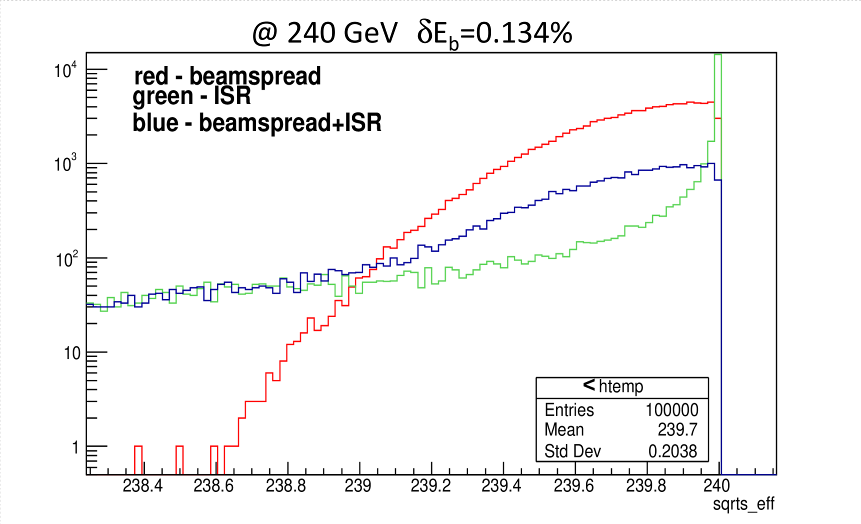


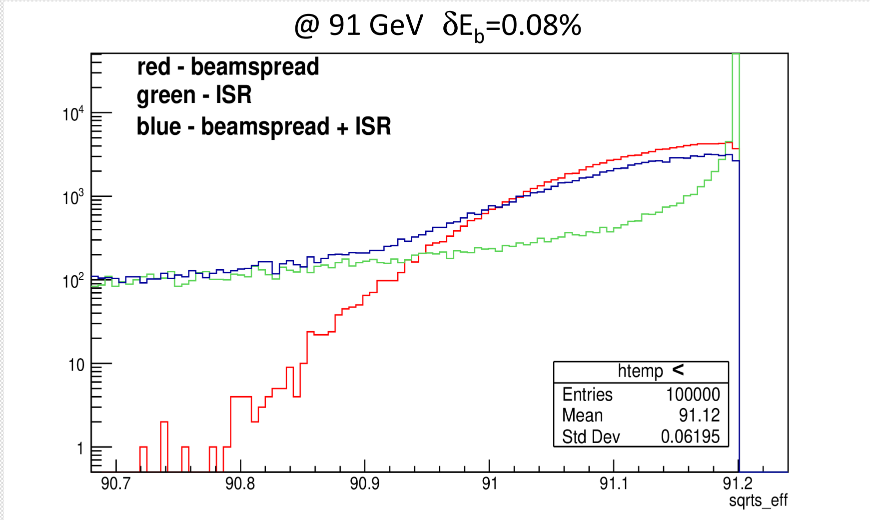




* [P. Janot, FCCee polarization WS, 2017]

s' sensitivity to beam-spread

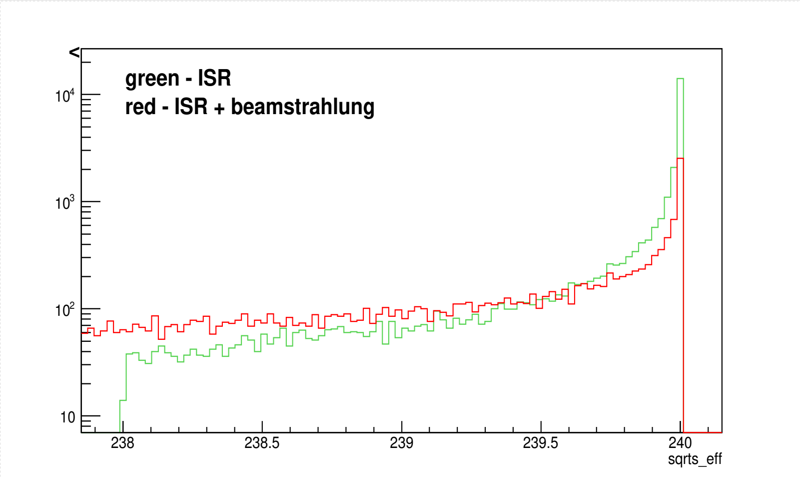


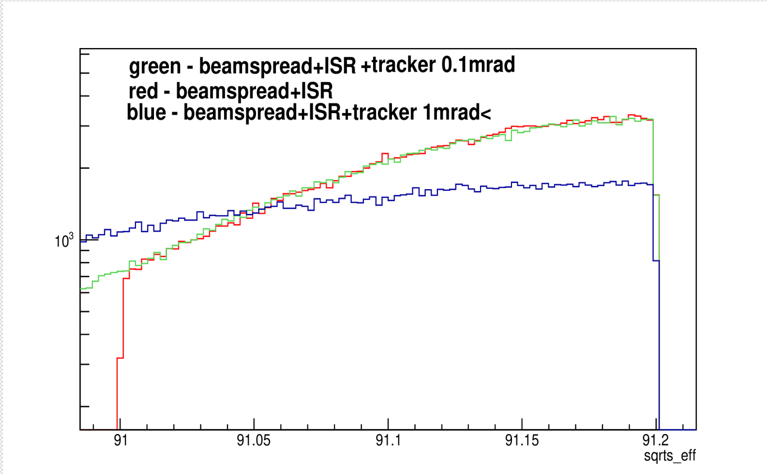


We need:

- Excellent theoretical description of ISR
- Full detector simulation – impact of the muon tracking resolution
- Presence of backgrounds

s' sensitivity to beam-spread + BS+detector resolution





s' remains sensitive to beam-spread in the presence of ISR and Beamstrahlung

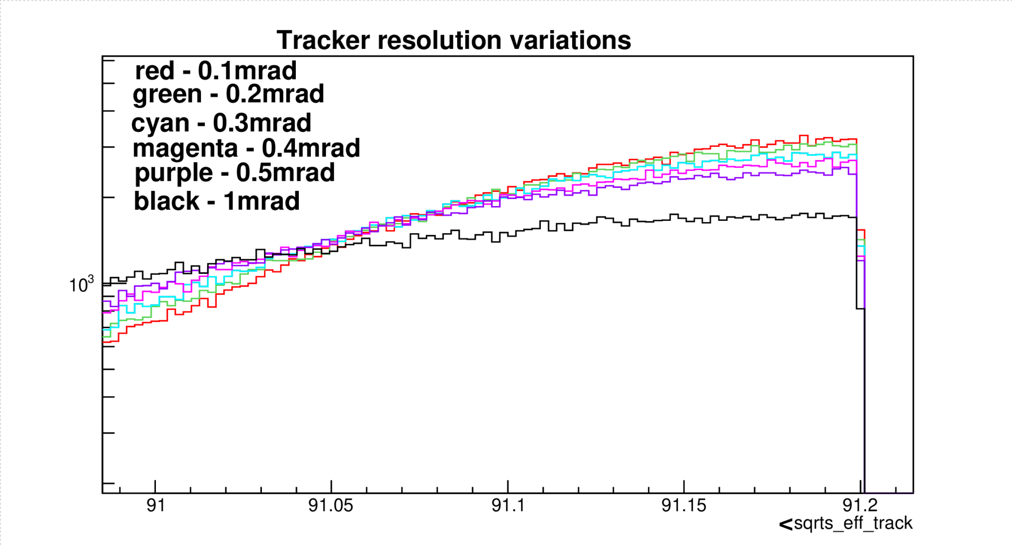
(this is WHIZARD default parameterization for TESLA beam, should be smaller at CEPC (ongoing study))

Impact of estimated 0.1 mrad and 1 mrad detector resolution @ 91 GeV

Apparently, 0.1 mrad (100 µm TPC) doesn't compromise sensitivity to the beam-spread

s' sensitivity to detector resolution

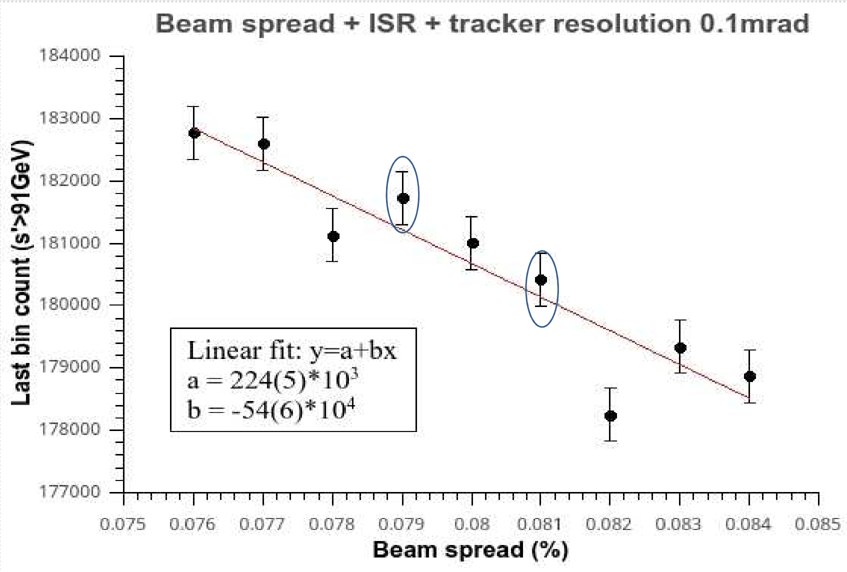
Can the method survive weaker tracking performance?
What is the uncertainty of the tracker resolution?

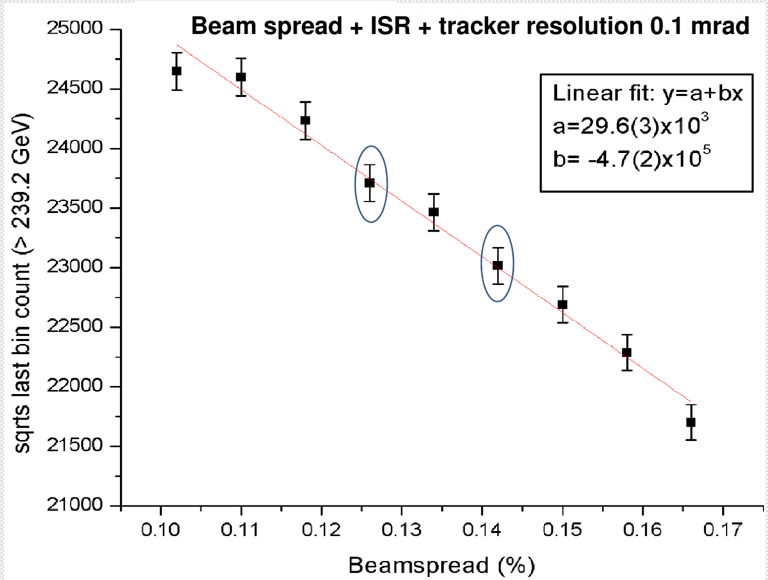


One should stick to the foreseen 0.1 mrad muon angular resolution (100 μm track resolution for TPC) to be known with 0.1 mrad margin

Beam-spread determination from *s'*

s' sensitivity to beam-spread @ 91 GeV (left) and 240 GeV (right)





250 kEvt. at Z^0 pole and 100 kEvt. at 240 GeV are sensitive to the beam-spread variations at 2.5 % (15 %) level, respectively

What do we need to be sensitive to $10^{-1,-2,-3}$ variations of the beam-spread?

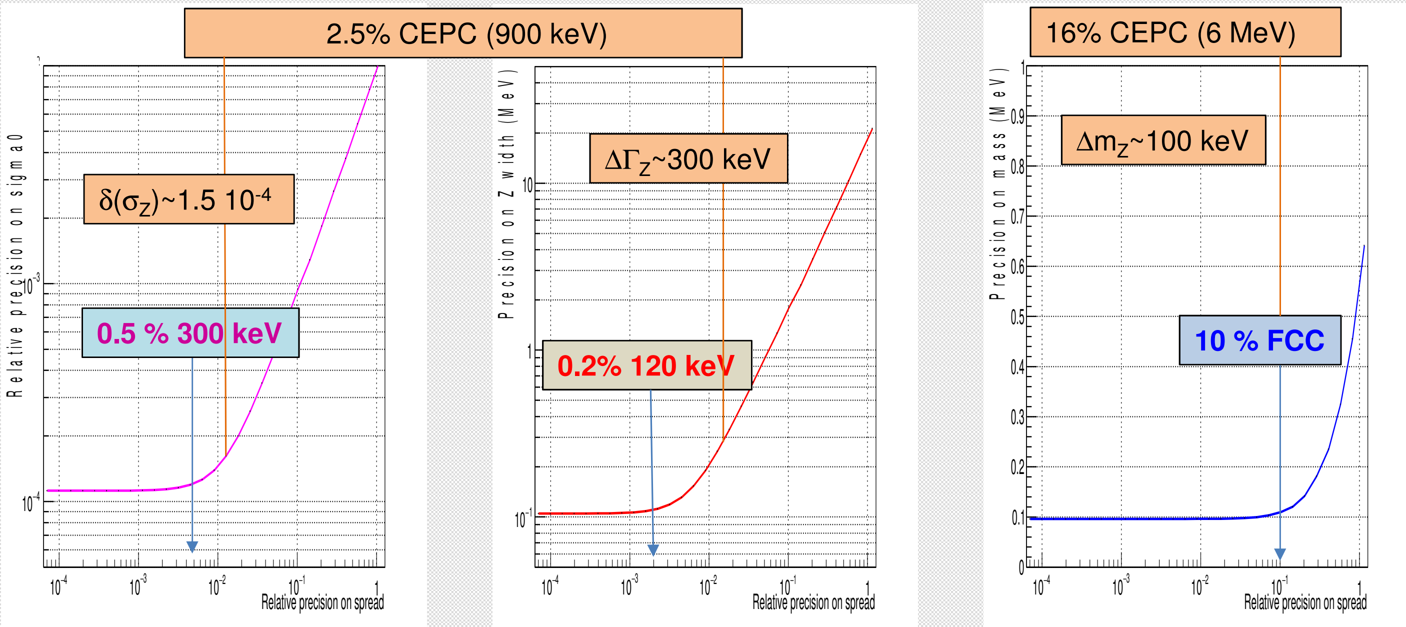
Table of assumptions w.r.t. time/statistics

	Luminosity @ IP ($cm^{-2} s^{-1}$)	Energy spread (%)	Number of events	Cross-section $e^+e^- \to \mu^+\mu^-$	Collecting time	Beam-spread variation
Z pole (91.2 GeV)	$32 \cdot 10^{34}$	0.080	250K	1.5 nb	~ 10 min (2 min for 10^{-4} of $\mathcal{L}$)	$\sim 2.5 \cdot 10^{-2} \cdot \delta E_b$ (900 keV)
Higgs factory** (240 GeV)	$3 \cdot 10^{34}$	0.134	100K	4.1 pb	~ 10 days	$\sim 0.15 \cdot \delta E_b$ (~24 MeV)
FCCee Z pole*	$2.3 \cdot 10^{36}$	0.132	540 K	1.5 nb	~ 3 min	$\sim 2 \cdot 10^{-3} \cdot \delta E_b$ (~120 keV)

* [P. Janot, FCCee polarization WS, 2017]

** For $\mathscr{L}$ uncertainty of 10^{-3} we don't need control better than the beam-spread of 0.134% (so the second row is for illustrative purposes)

Other observables @CEPC?



Conclusions

- Method (proposed for FCCee) of beam-spread determination based on muon polar angle reconstruction **nicely works at low energies** (Z^0 pole), due to high $e^+e^- \rightarrow \mu^+\mu^-$ cross-section and high instantaneous luminosity
- **@ Z^0 pole CEPC, ~2.5% accuracy of the beam spread is feasible (i.e. < 1 MeV)**
- **Integrated luminosity control of 10^{-4} at the Z^0 pole, requires only 2 min of data collection**
- @ 240 GeV, beam-energy asymmetry within the existing beam-spread is satisfactory for luminosity measurement
- Method requires further study: effect of ISR (theoretical) uncertainty, full detector simulation, impact of similar final states backgrounds