CP-violating Phase ϕ_s measurement

$B_s^0 -> J/\psi\ \phi$ potential at CEPC

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Introduction

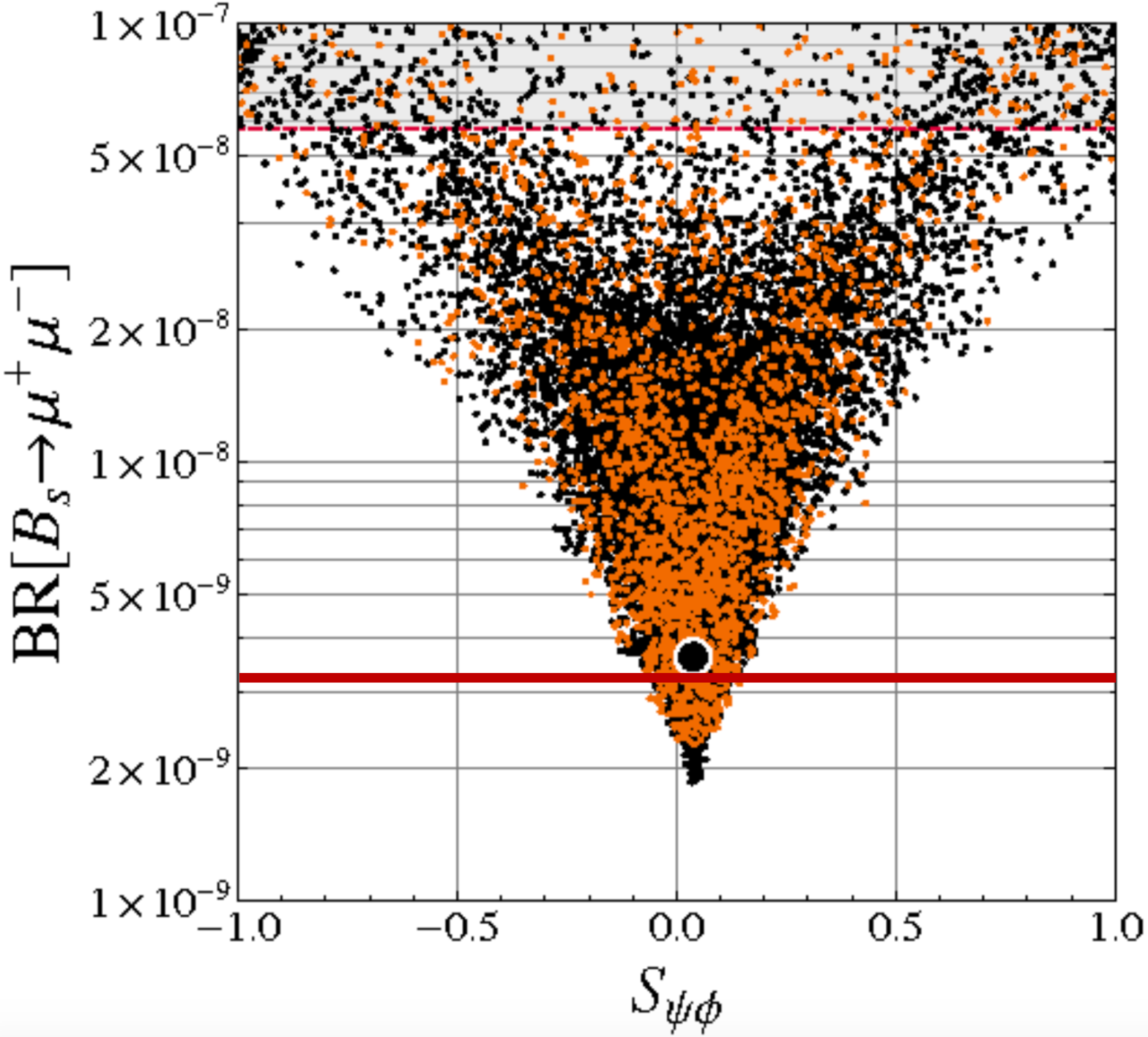
- CP violation arises through a single phase in the CKM quark mixing matrix.
- In neutral B meson decays to a final state the interference between the amplitude for the direct decay and the amplitude for decay after oscillation, leads to a time-dependent CP-violating asymmetry between the decay time distributions of B and anti-B mesons.
- $\Delta\Gamma_s \equiv \Gamma_L - \Gamma_H, \phi_s = -2\arg(-\mathrm{V}_{ts}\mathrm{V}_{tb}^*/\mathrm{V}_{cs}\mathrm{V}_{cb}^*)$
- SM: small CPV phase-ϕ_s
- Contributions from physics beyond the SM could lead to much larger values of ϕ_s.

NP prediction

- AC model (0910.1032)

- Red line: measurement
- Black dot: SM

- Deviation ~ 0.1



Analysis strategy for real analysis

$$B_s^0 \to J/\psi\,\phi \to \mu^+\mu^- K^+ K^- \quad (e^+e^-)$$

Disentangle the CP -even and CP -odd components.

$$\frac{\mathrm{d}^4\Gamma(B_s^0 \to J/\psi\,\phi)}{\mathrm{d}t\;\mathrm{d}\Omega} \propto \sum_{k=1}^{10} h_k(t)\, f_k(\Omega)\,.$$

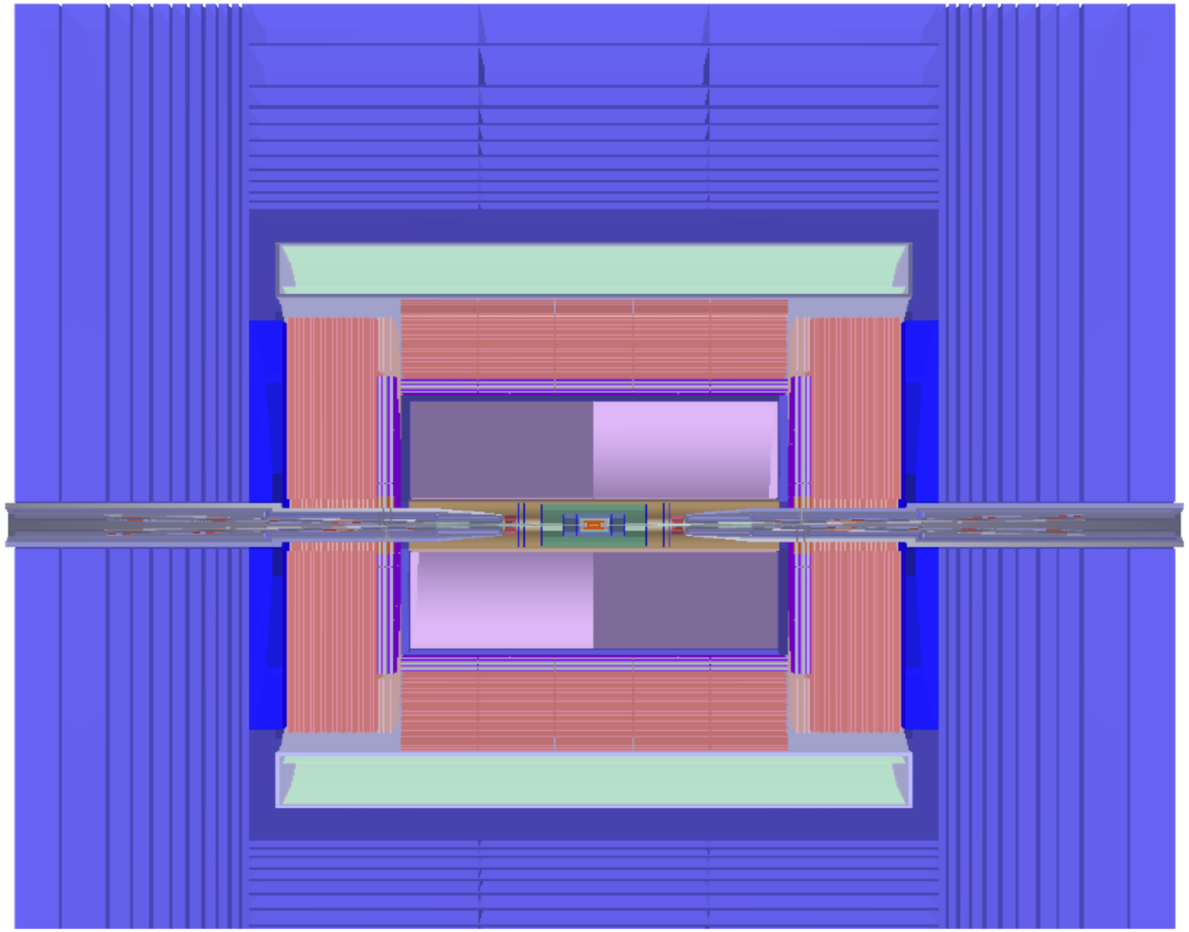
$$\begin{aligned} h_k(t) \;=\; & N_k e^{-\Gamma_s t}\, \left[c_k \cos(\Delta m_s t) + d_k \sin(\Delta m_s t)\right. \\ & \left. + a_k \cosh\left(\tfrac{1}{2}\Delta\Gamma_s t\right) + b_k \sinh\left(\tfrac{1}{2}\Delta\Gamma_s t\right)\right]\,. \end{aligned}$$

- Distinguish B, anti-B: Flavour tagging(tagging power)
- Time resolution

CEPC benchmark detector

- Excellent vertex reconstruction.
- Good PID!
- Clean environment.

- Huge B production in Z pole run



Estimation of $\Delta\phi_s$ at CEPC

- $\sigma(\phi_s) \propto 1/\sqrt{N_{\mathrm{Eff}}}$

- $N_{\mathrm{Eff}} \propto N_{b\bar{b}}$
- $N_{\mathrm{Eff}} \propto$ Efficiency
- $N_{\mathrm{Eff}} \propto$ Tagging power

- $\sigma(\phi_s) \propto 1/e^{-\frac{1}{2}\Delta m_s^2 \sigma_t^2}$ (Time resolution)

Scaling from LHCb measurement

$b\bar{b}$ statics at LHCb and CEPC

- **LHCb**
- Luminosity at HL-LHC: $300\ \mathrm{fb}^{-1}$ [1]
- $b\bar{b}$ cross-section at LHCb at 13 TeV: $144\mathrm{\mu b}$[2]
- Total statics: 43.2×10^{12}

- **CEPC**
- Z production at Z pole: 10^{12} Z[3]
- $b\bar{b}$ branching fraction: 15.2%[4]
- Total statics: 0.152×10^{12}

$b\bar{b}$ statics at LHCb(run 1) for cross check

- **LHCb**
- Luminosity at LHC: $0.37\ \mathrm{fb}^{-1}$
- $b\bar{b}$ cross-section at LHCb at 7 TeV: 72 μb
- Total statics: 26.64×10^{9}

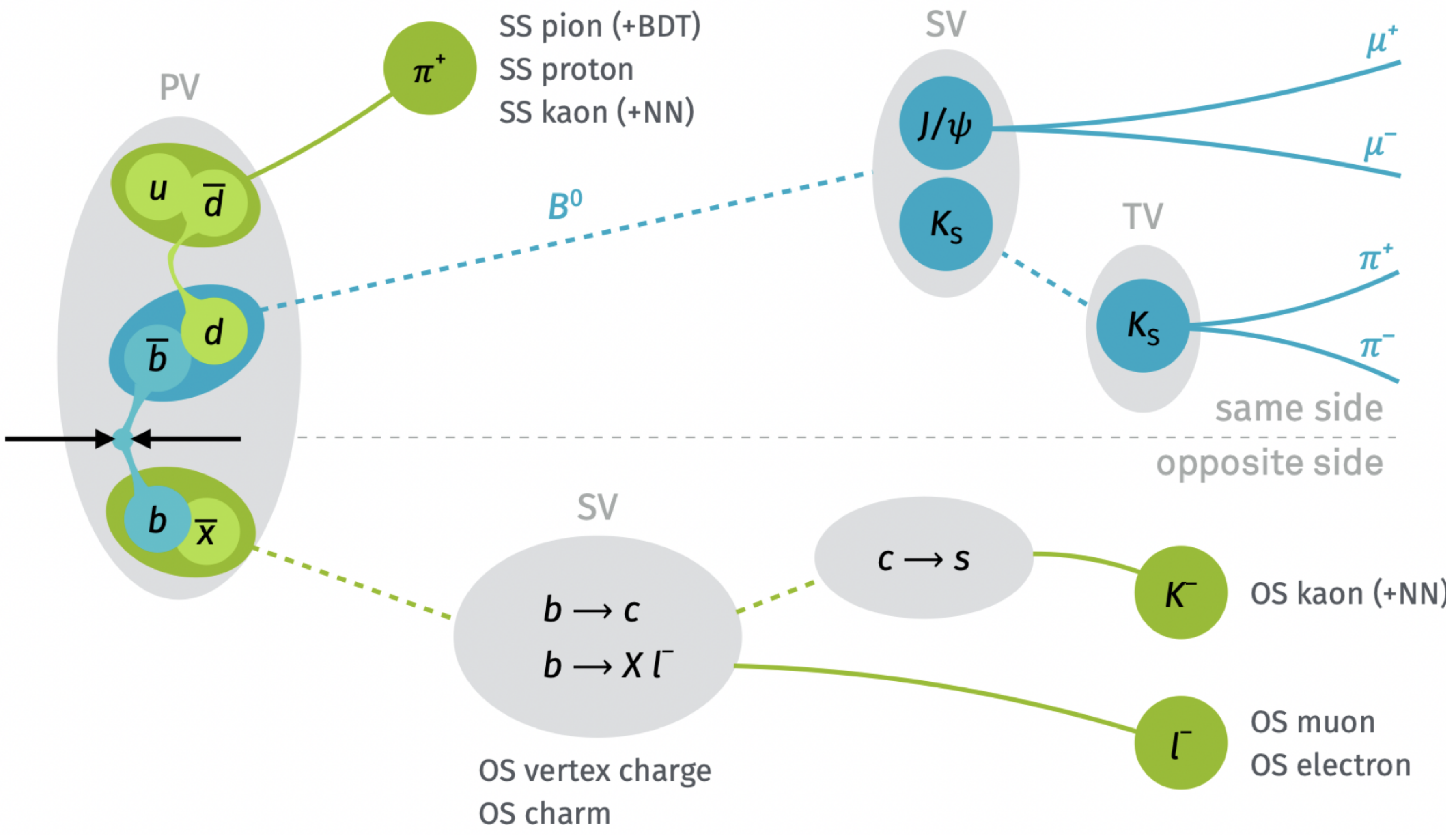
- **CEPC**
- Z production at Z pole: 10^{12} Z[3]
- $b\bar{b}$ branching fraction: 15.2%[4]
- Total statics: 0.152×10^{12}

Reconstruction efficiency

- Acceptance * Reconstruction * Trigger
- LHCb: 20% (Comments after the talk: the efficiency is the trigger and reconstruction in LHCb acceptance because we the bb\bar cross-section is the one in LHCb acceptance)
- CEPC: 100%
- Full-simulation is needed for more detailed study.

Flavour tagging power

- LHCb: 3~4%
- CEPC: 15%
- B factory: ~30%

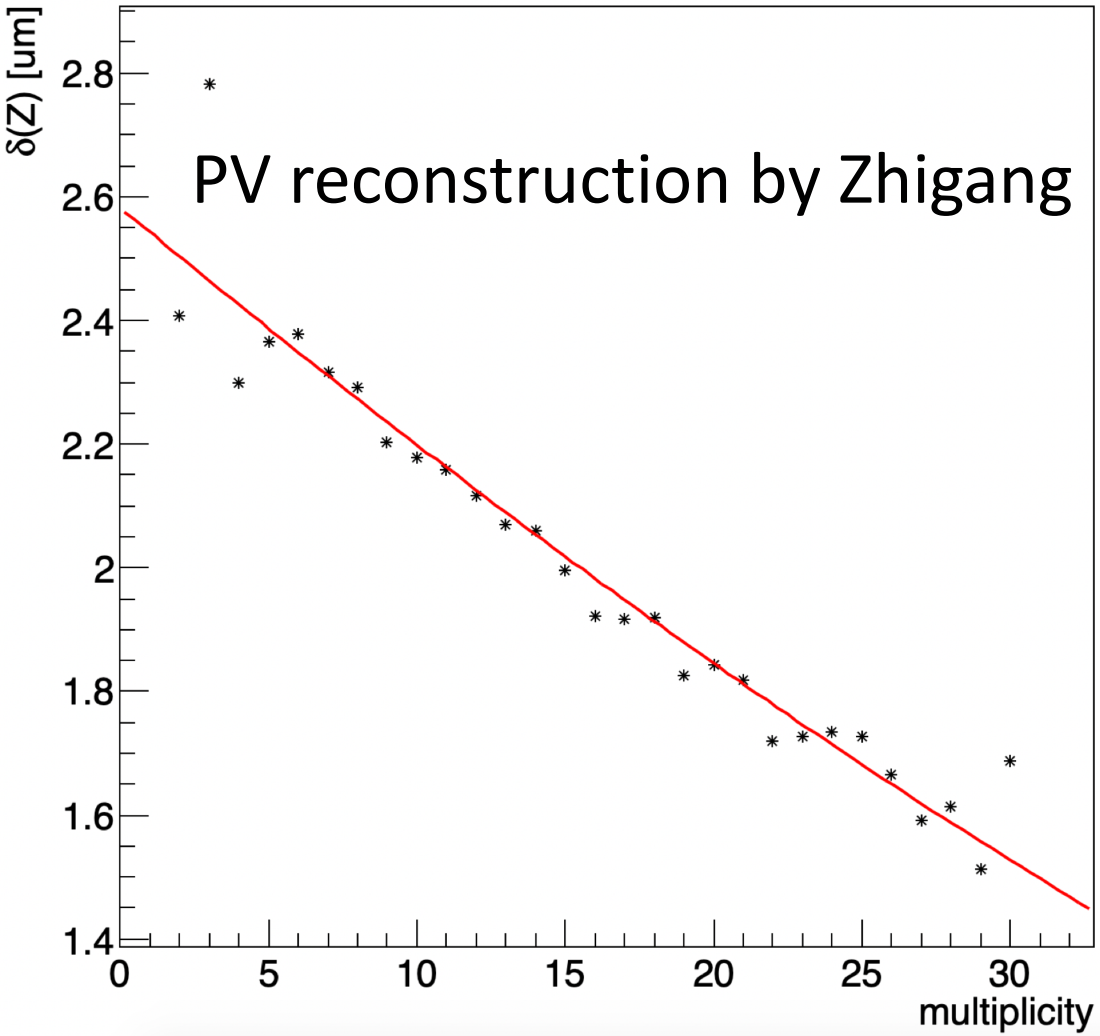


Time resolution effect

$$\sigma(\phi_s) \propto 1/e^{-\frac{1}{2}\Delta m_s^2 \sigma_t^2}$$ (see backup)

- $\Delta m_s = 17.757 \times 10^{12}\ \hbar s^{-1}$
- LHCb: $\sigma_t = 50$ fs -> 0.67
- CEPC: $\sigma_t = 10$ fs -> 1

- Conservative assumption that the SV reconstruction is 10 times worth than PV reconstruction.

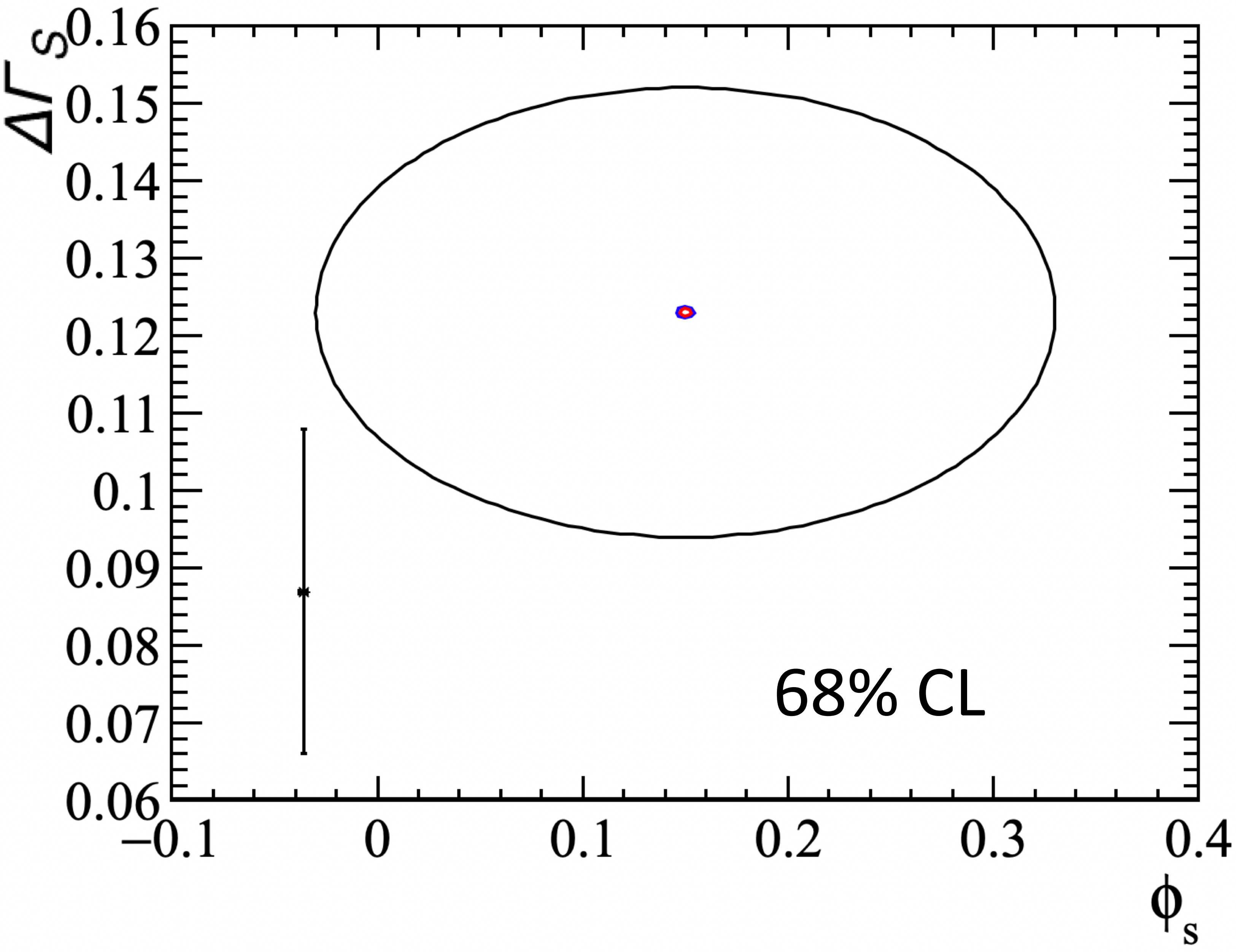


Summary on effecitive stat

	LHCb	CEPC	LHCb(Run 1)
$b\bar{b}$ statics	43.2 * 10^12	0.152 * 10^12	26.64 * 10^9
Acceptance * trigger * Reconstruction	5%	100%	5%
Br($b\bar{b}$ -> Bs)	10% * 2(b and anti-b)	10% * 2	10% * 2
Br(Bs->Jpsi Phi) *Br(Jpsi->ll) *Br(Phi->KK)	0.001 * 0.06 * 0.5	0.001 * 0.12 (ee channel) * 0.5	0.001 * 0.06 * 0.5
Bs->Jpsi(->ll)Phi(->KK) stat			8000 consist with paper
Flavour tagging	4%	15%	4%
Time resolution	0.67	1	0.67
Total effective statics	0.23 * 10^6	0.27 * 10^6	144

$\phi_s \sim \Delta\Gamma_s$

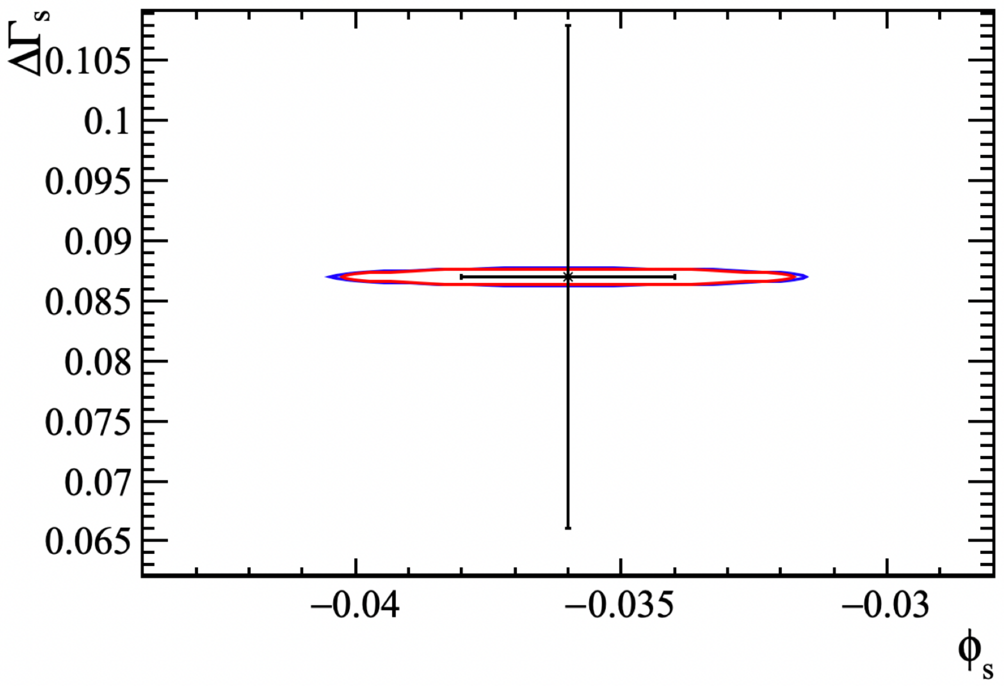
- Dot: SM prediction
- Black: LHCb(Run 1)
- Blue: LHCb(HL-LHC)
- Red: CEPC

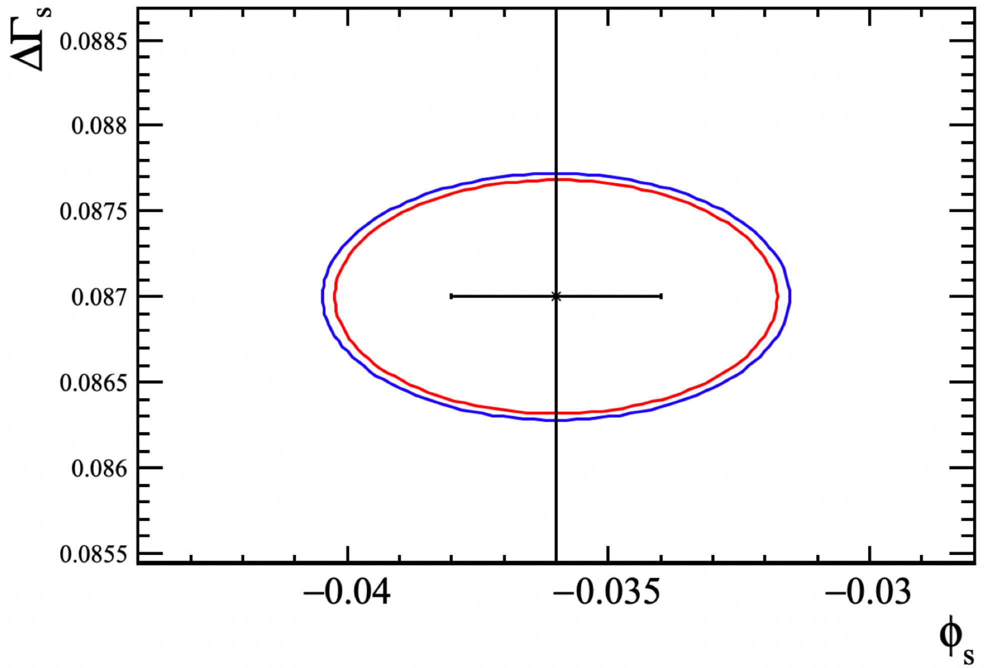


$\phi_s \sim \Delta\Gamma_s$

- Dot: SM prediction
- Black: LHCb(Run 1)
- Blue: LHCb(HL-LHC)
- Red: CEPC

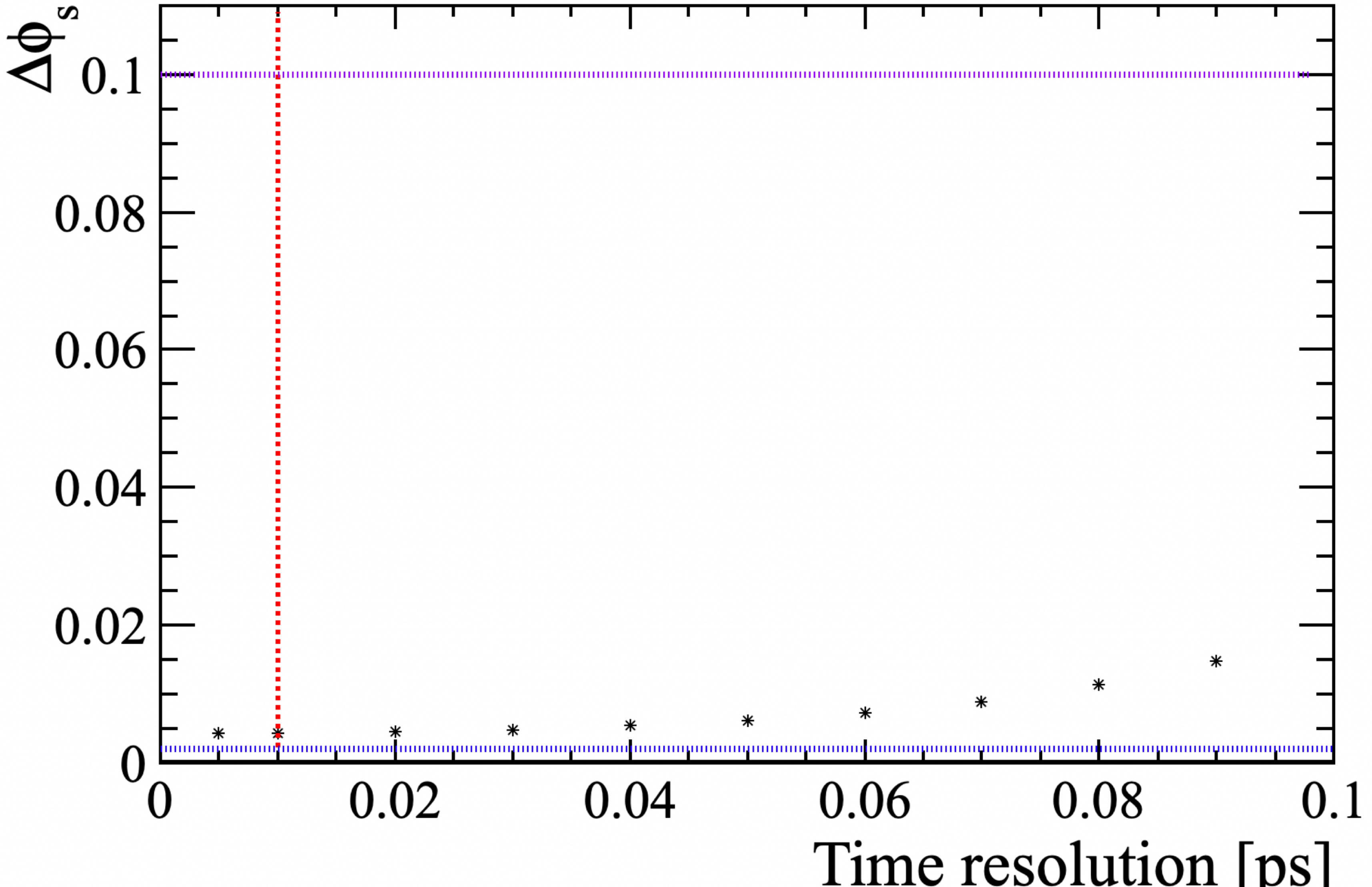
- Zoomed and move the central value to SM prediction





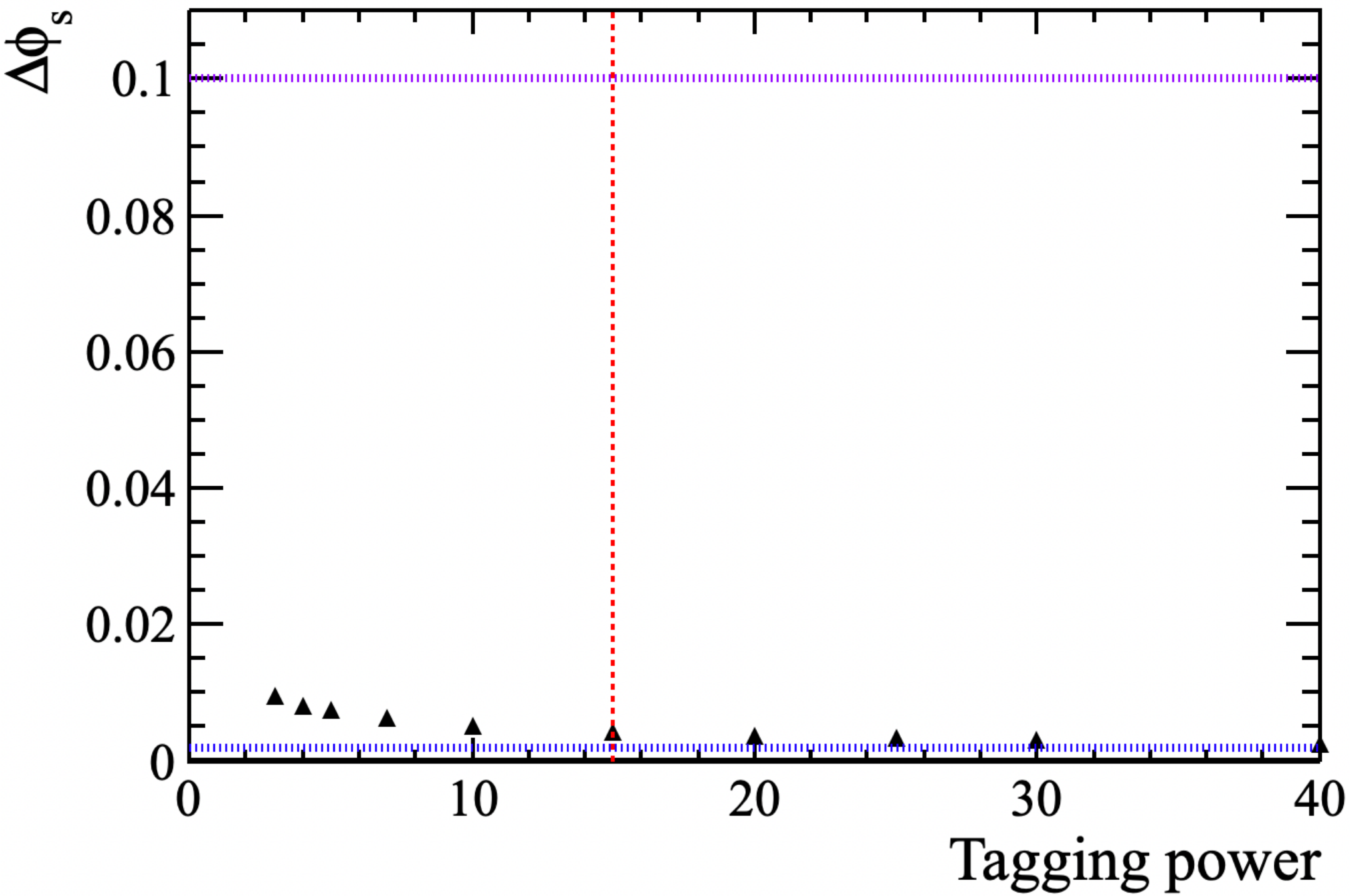
Time resolution effect

- Red: 10fs(CEPC)
- Blue: SM resolution
- Purple: NP deviation



Flavour tagging effect

- Red: 15(CEPC)
- Blue: SM resolution
- Purple: NP deviation



Conclusion

- Study of CPV-phase is promising at CEPC.
- Competitive with LHCb(HL-LHC).
- Powerful to test new physics model.
- Promising to reach SM accuracy.

- More detailed full-simulation analysis will be carried.

- Thank you

Comments from audiences (Added after the talk)

- Tagging power should be larger ~ 30% or higher could be reached according to the LEP study.
- The efficiency at LHCb is not quite correct. (I will correct it later).
- LHCb run1 has new result with full Run1 data. (Could be updated).

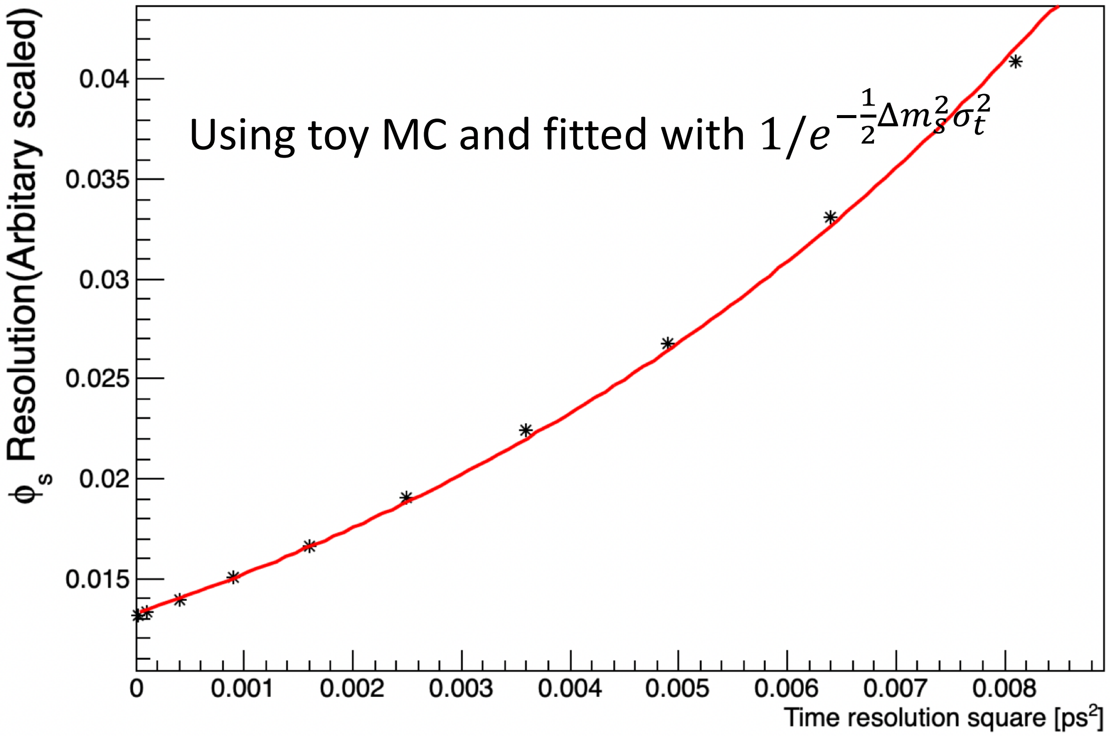
- The conclusion will be remaining after adding these comments.

Reference

- [1]https://cds.cern.ch/record/2630496/files/Parkes_ICHEP_U2_070718_vFinal.pdf
- [2] https://arxiv.org/pdf/1612.05140.pdf
- [3] CEPC CDR
- [4] PDG

Backups

- Validation of $\sigma(\phi_s) \propto 1/e^{-\frac{1}{2}\Delta m_s^2 \sigma_t^2}$



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