Benchmark of wake calculation for a small-gap collimator

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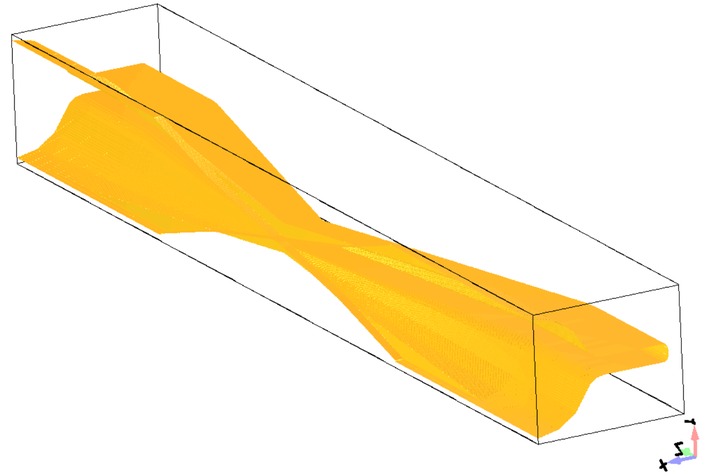
Acknowledgements

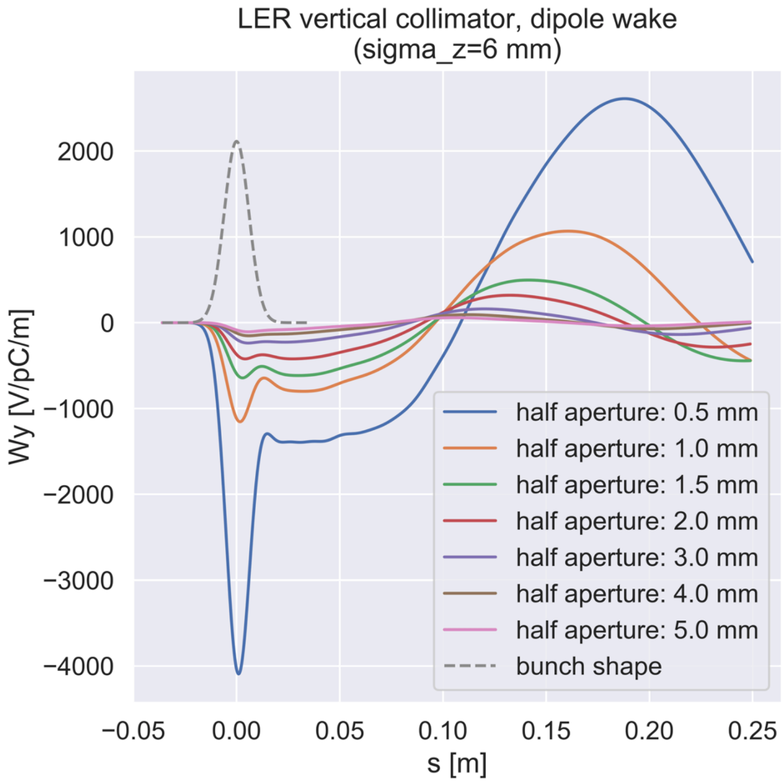
A. Blednykh, W. Bruns, I. Zagorodnov, M. Migliorati, Y.-C Chae, G. Wang, M. Blaskiewicz

SuperKEKB TMCI workgroup meeting, Nov. 09, 2021, KEK

SuperKEKB-type collimator

- Benchmark case
  - SuperKEKB-type collimator
  - Half gap 1 mm.
- Wake calculation using GdfidL at KEK
  - Driving bunch σ_z=0.5/6 mm.
  - Mesh sizes: dx=dy=0.2 mm, dz=0.1 mm (limited by available computing resources).
  - Use standard “-fdtd” method.

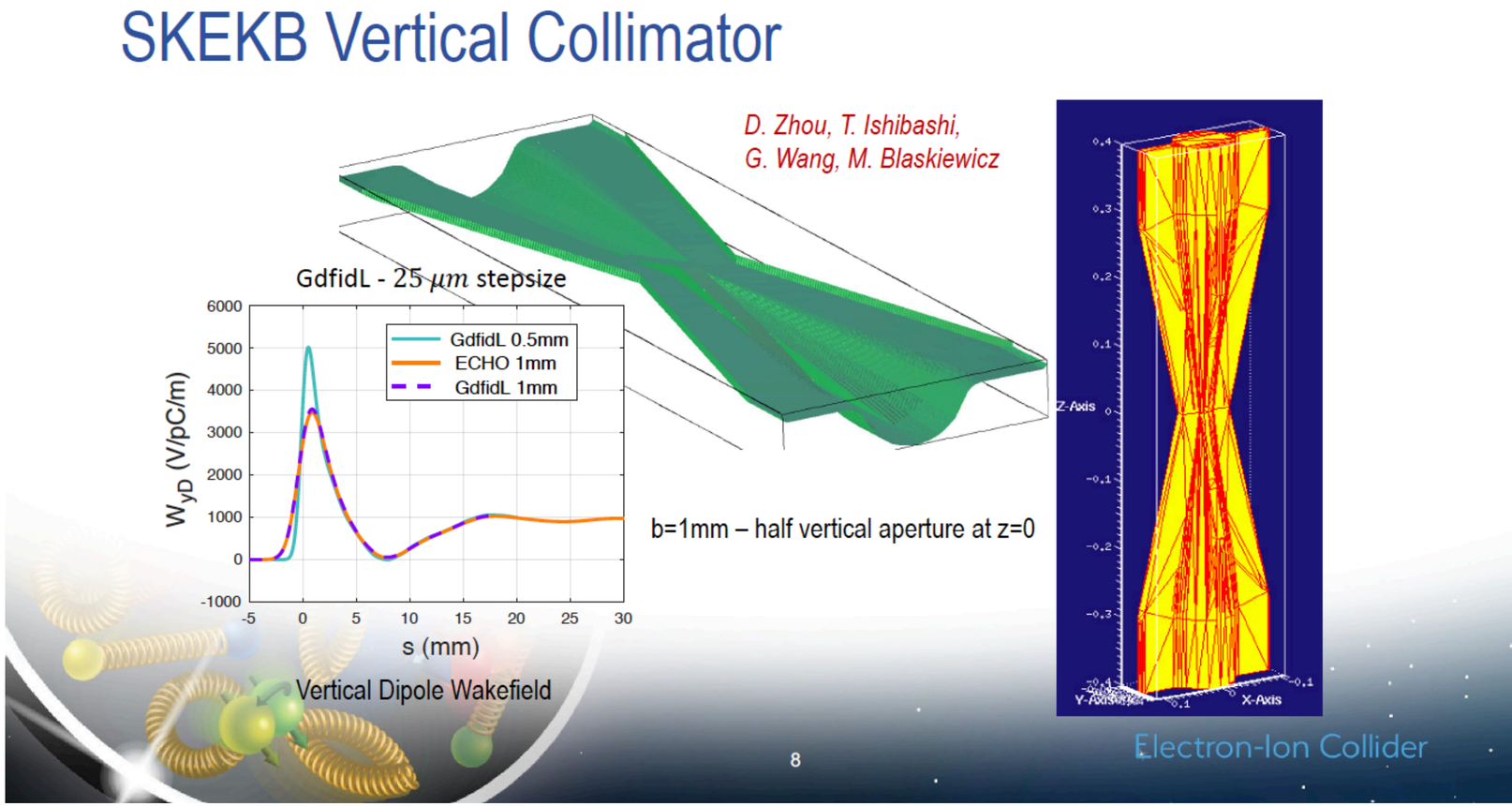




Courtesy of T. Ishibashi

SuperKEKB-type collimator

- Wake calculation using GdfidL and ECHO3D at BNL
  - Thanks to A. Blednykh, G. Wang, M. Blaskiewicz.
  - Driving bunch σ_z=0.5/1 mm.
  - Mesh sizes: dx=dy=dz=0.025 mm.
  - Use“-windowwake” method.

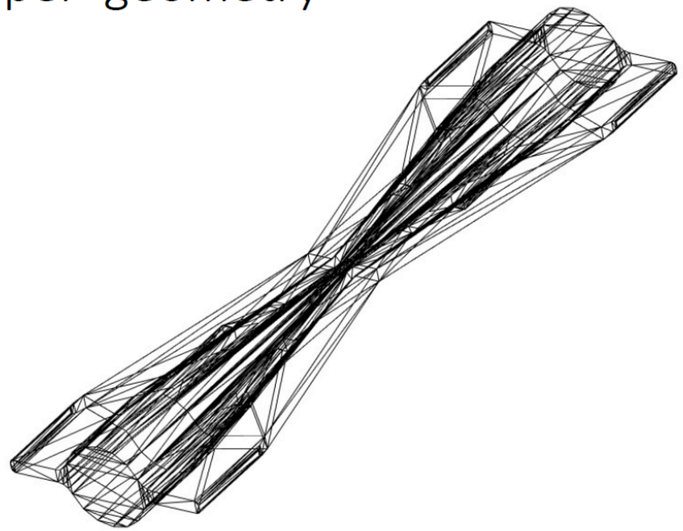


Courtesy of A. Blednykh

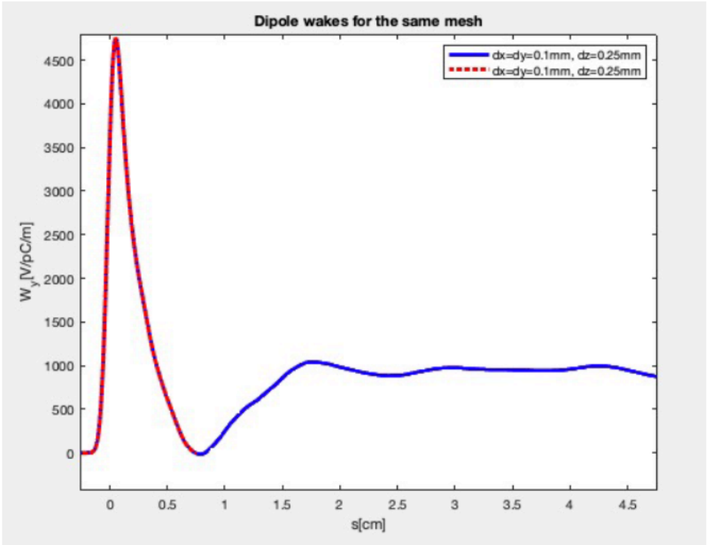
SuperKEKB-type collimator

- Wake calculation using ECHO3D at DESY
  - Thanks to I. Zagorodnov.
  - Driving bunch σ_z=0.5 mm.
  - Mesh sizes: dx=dy=0.1 mm, dz=0.25 mm.

Taper geometry



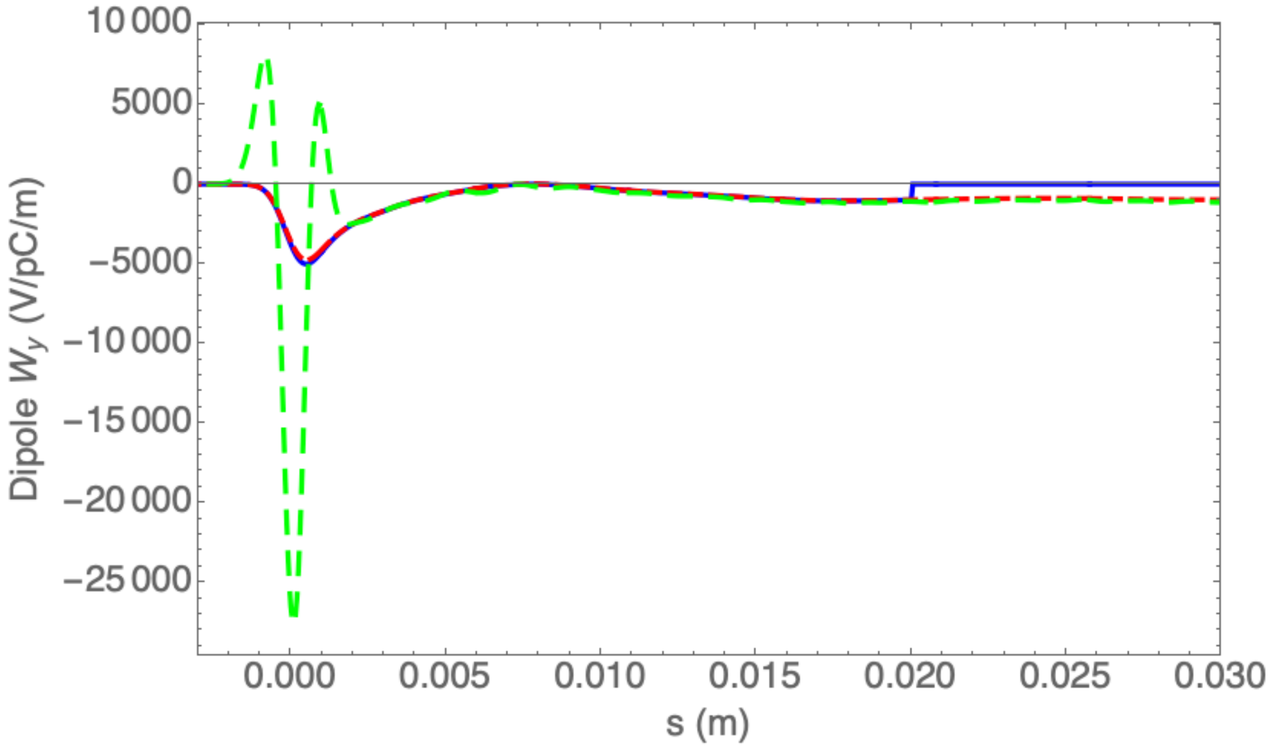
KEK taper. Gaussian bunch with RMS length 0.5 mm. Dipole transverse wake.



Courtesy of I. Zagorodnov

SuperKEKB-type collimator

- Compare results from A.B., I.Z., T.I.
  - Driving bunch σ_z=0.5 mm.
  - Only compare dipole Wy.
  - GdfidL wake data from A.B.: shigh=0.02 m.
  - ECHO3D wake data from I.Z.: shigh=0.0475 m.
  - GdfidL wake data from T.I.: shigh=0.25 m.
- Findings
  - Good agreement between ECHO3D and GdfidL (fine mesh + windowwake)
  - Large dispersion error seen in the data of GdfidL (crude mesh + fdtd): high-frequency noise in the short-range wake

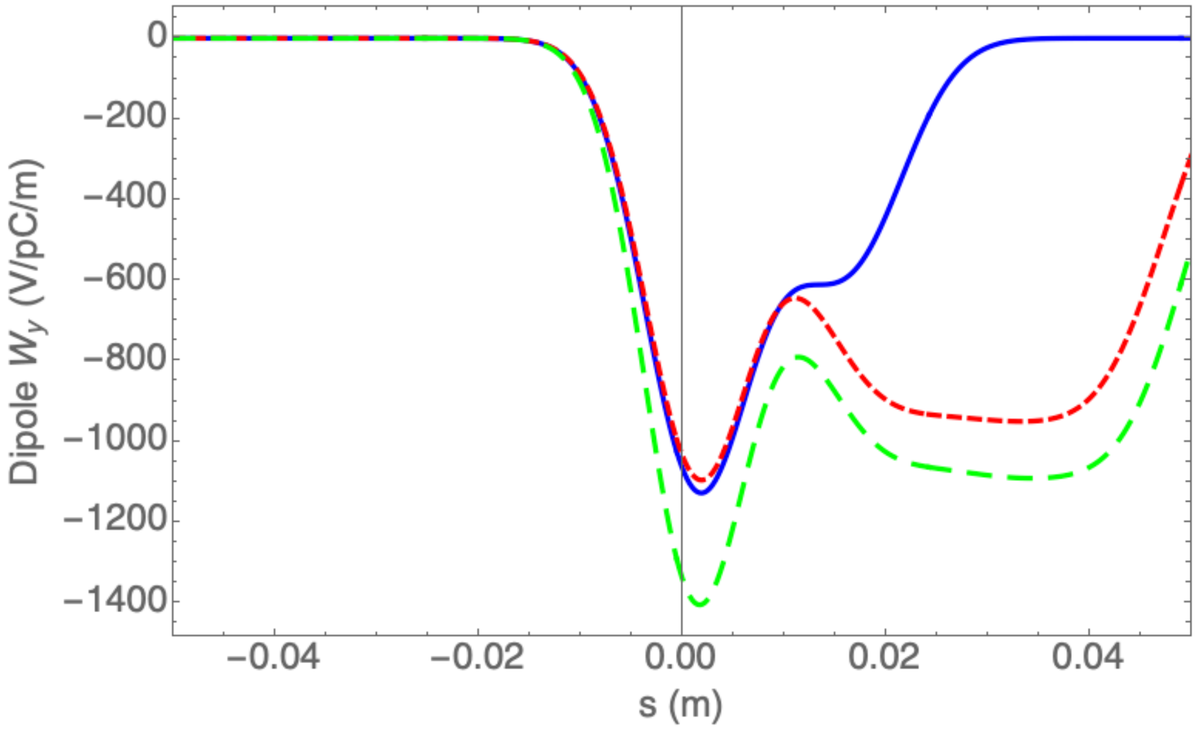


Blue solid line: A.B.'s data
Red dashed line: I.Z.'s data
Green dashed line: T.I.'s data

SuperKEKB-type collimator

- Compare long-bunch wakes
  - Gaussian bunch σ_z=5 mm.
  - Select wake data of shigh<0.05 m
- Findings
  - The discrepancy between blue and red lines is mainly due to lack of data for s>0.02 m in A.B.'s short-bunch wake.
  - The discrepancy between red and green lines is due to the dispersion error

$$W(s,\sigma_z) = \int ds' w(s-s',\sigma_{z0}) \frac{e^{-\frac{s'^2}{2\sigma_z^2}}}{\sqrt{2\pi}\sigma_z}$$



Blue solid line: Using A.B.'s data
Red dashed line: Using I.Z.'s data
Green dashed line: Using T.I.'s data

SuperKEKB-type collimator

- Compare long-bunch wakes
  - Gaussian bunch σ_z=6 mm.
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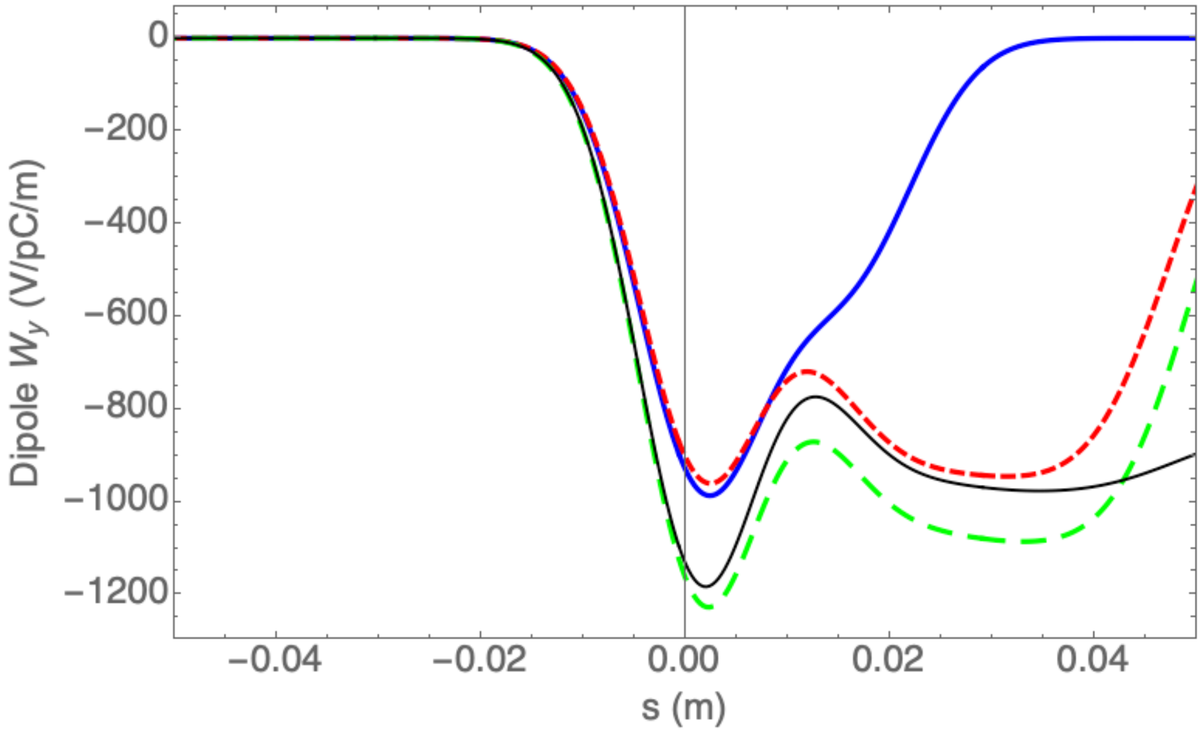
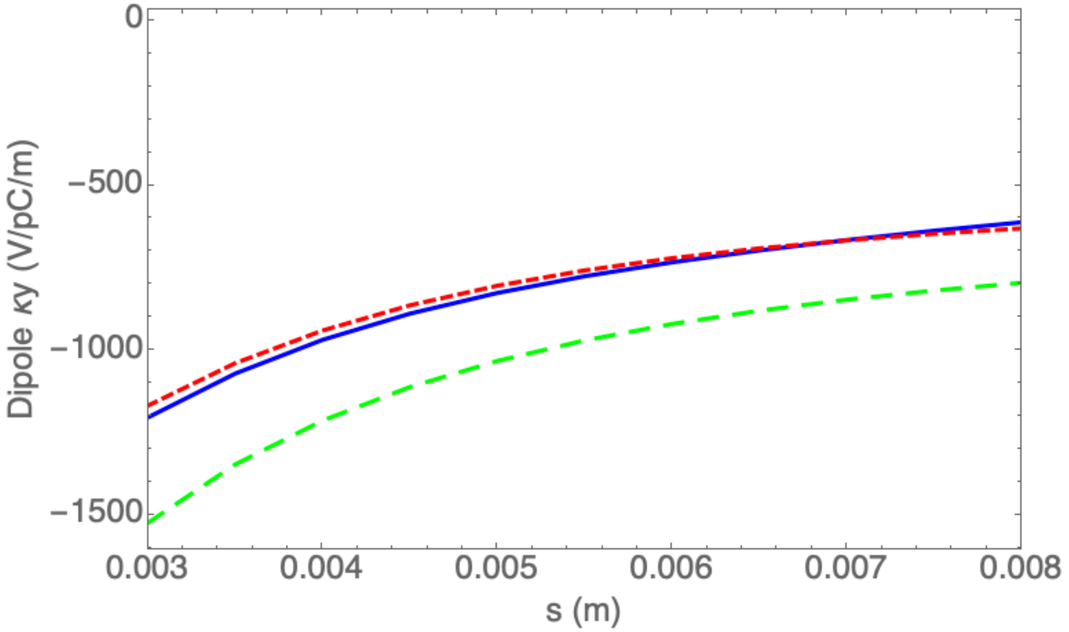
$$W(s,\sigma_z)=\int ds' w(s-s',\sigma_{z0})\frac{e^{-\frac{s'^2}{2\sigma_z^2}}}{\sqrt{2\pi}\sigma_z}$$



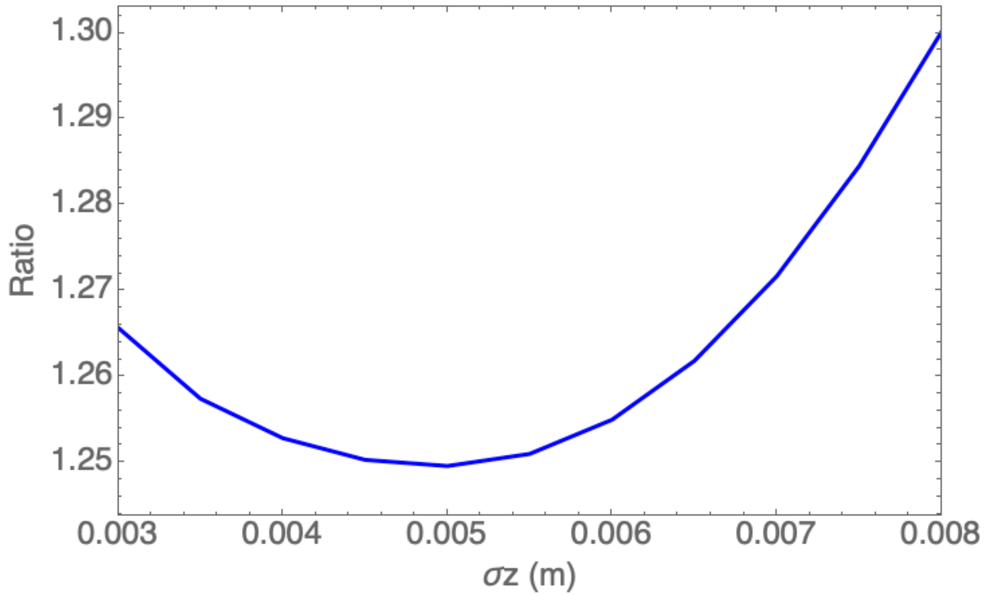
Blue solid line: Using A.B.'s data
Red dashed line: Using I.Z.'s data
Green dashed line: Using T.I.'s data
Black solid line: direct GdfidL calculation using 6 mm driving bunch

SuperKEKB-type collimator

- Compare kick factor
  - Gaussian bunch σ_z=3-8 mm.
  - Select wake data of shigh<0.05 m
- Findings
  - There is remarkable difference between blue and green lines. Green line overestimates kick factor by ~25% at σ_z=5 mm.

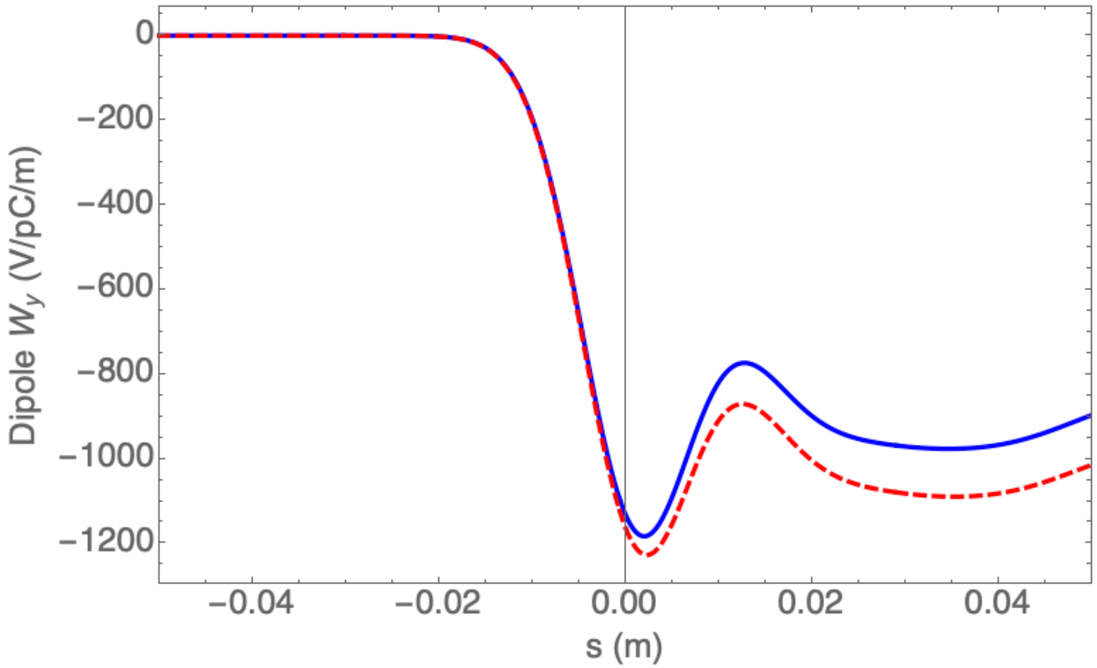


Blue solid line: Using A.B.'s data
Red dashed line: Using I.Z.'s data
Green dashed line: Using T.I.'s data



SuperKEKB-type collimator

- Use short-bunch wake to calculate the long-bunch wake
  - Gaussian bunch σ_z=6 mm.
  - Using the short-bunch (0.5 mm) wake with shigh=0.25 m.
- Findings
  - Short-bunch wake roughly reproduces the long-bunch wake. The difference might be due to dispersion error.
  - The calculated kick factor for 6 mm bunch:
  - The kick factors are 884 (blue line) and 921 (red line) V/pC/m, about 4% difference.



Summary

- Benchmark between ECHO3D and GdfidL
  - Good agreement was seen between ECHO3D and GdfidL (fine mesh + “-windowwake” method).
  - Large dispersion error was seen in GdfidL results with crude mesh + “-fdtd” method.
- GdfidL calculation at KEK
  - Version 200723 was used. This version has serious bug (informed by W. Bruns) in “-windowwake” option and cannot produce physical wake for small-gap collimators (tested by T. Ishibashi).
  - Standard “-fdtd” method was used.
  - Mesh sizes dx=dy=0.2 mm, dz=0.1 mm.
- Future plan
  - To use the latest version of GdfidL (need support from W. Bruns in installation to KEK’s GdfidL cluster (its OS is old)) with “-windowwake” method.
  - To use smaller mesh sizes. dx=dy=dz=0.1 mm seems to be the limit with the available CPUs and RAMs of KEK’s GdfidL cluster.
  - To use ECHO3D on linux workstations (Thanks to I. Zagorodnov).