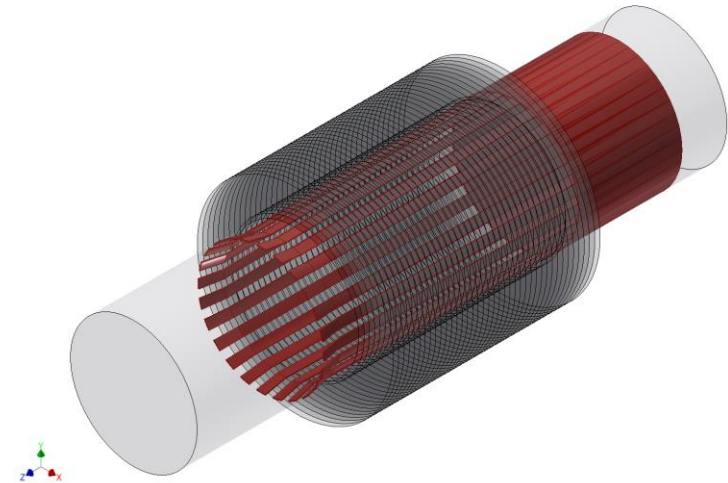




Wakefield calculations for the extraction/ATF2 beamline

Contents

1. Summary of this presentation
2. Wakefield sources in ATF beamline
3. Wakefield calculation
4. Tracking simulation (briefly)
5. Summary & Further works



Yuki Abe (SOKENDAI)

Nobuhiro Terunuma, Kiyoshi Kubo, Toshiyuki Okugi (KEK, SOKENDAI)

Summary

- ATF IP beam size has Intensity dependence by wakefield
 - Several wakefields calculated by A.Lyapin(RHUL) with GdfidL
 - **Unestimated wakefield sources exist??**
- **Recalculated** his work and **calculated other additional wakefield sources**
- Done **Tracking calculation** with newly calculated wakepotentials

Results : Wakefield calculation

- Recalculation got almost same wake potential results
- Septum chamber's wake : **Larger** than CBPM (x4)
- Rectangular chamber's wake : **Smaller** than CBPM ()
- Bellows : **RF shield reduces** wakefield less than **1/100**
- Vacuum port : **inner shield reduces** wakefield less than **1/10**

Results : Tracking simulation

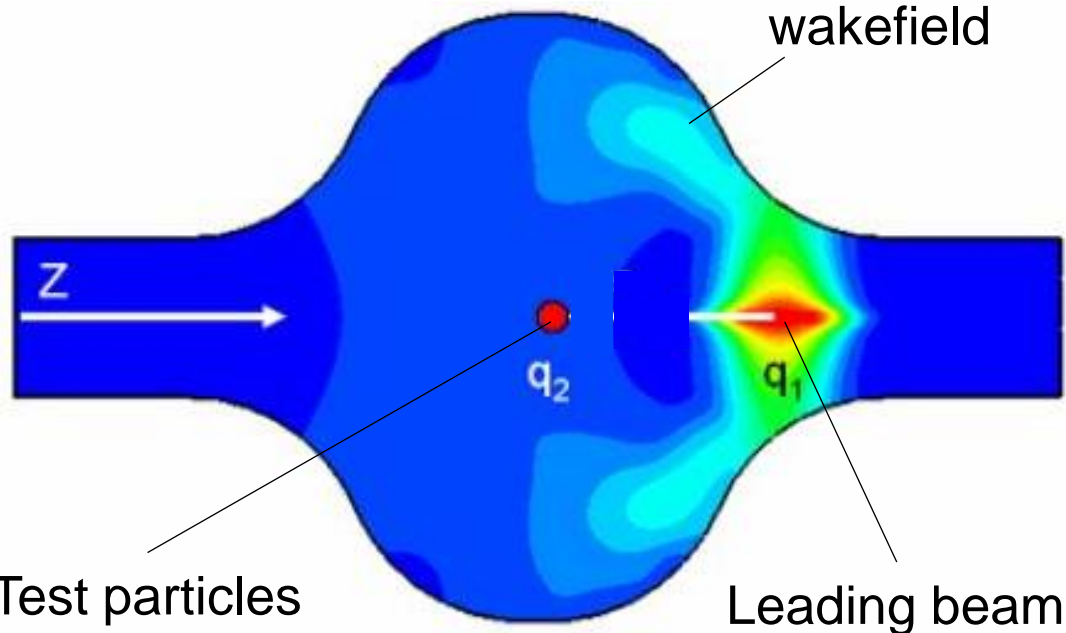
- wakefield in Extraction (include septum chamber) : **weak** effects
- Wakefield in Final Focus : **strong** effects
Especially, Vacuum Flange!

Wakefield

● Wakefield

Excited electromagnetic field

after beam passed through structure change on the beamline



Ref : CST Particle Studio-Wakefield Solver Overview

● Wake potential

Effects of Lorentz force by Excited electromagnetic field

Transverse Wake potential

$$\frac{1}{q_1} \int_{-\infty}^{\infty} q_2 (E + c \vec{e}_z \times B) dz \equiv W_{\text{pot},x/y}$$

● Wakefield and motions of particles

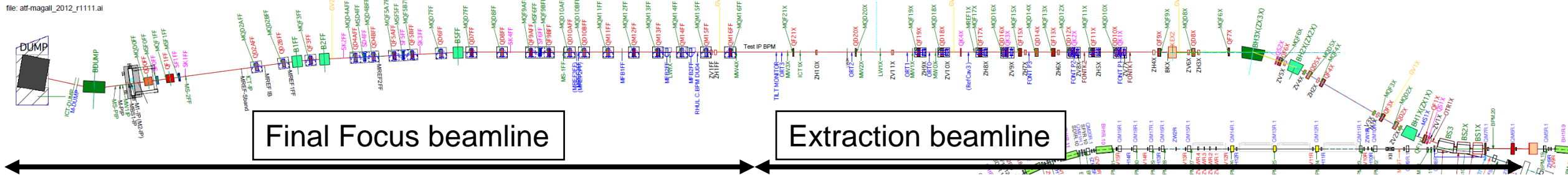
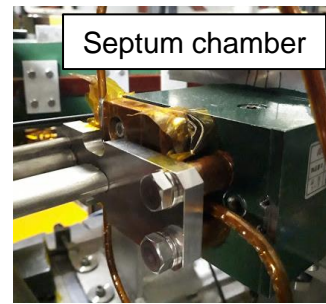
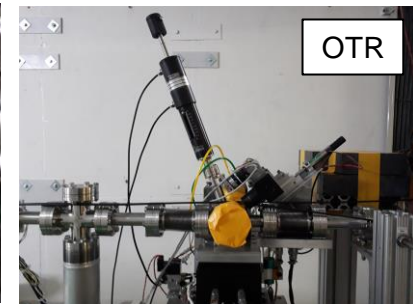
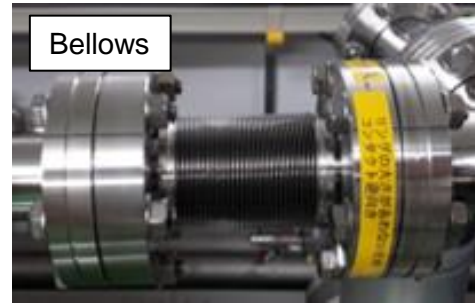
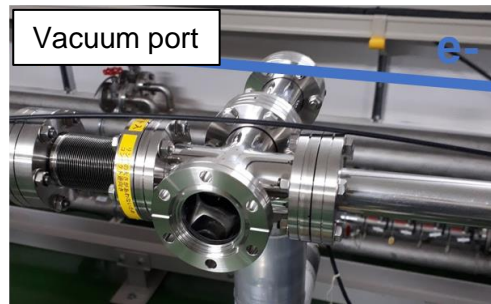
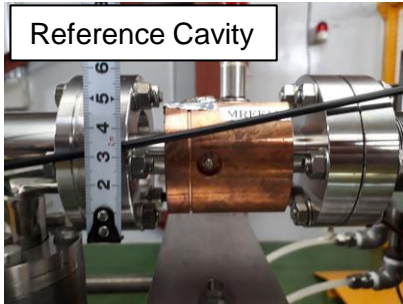
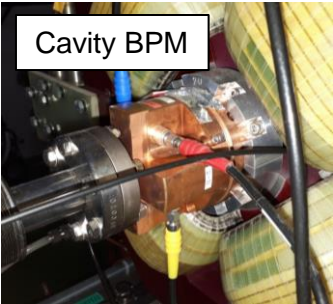
Position of particle : y , Angle of particle : y'
Angle change by wakefield kick : $\Delta y'_{\text{wake}}$

$$\Delta y'_{\text{wake}} = \frac{\Delta p_y}{p_0} = \frac{q_1}{E} W_{\text{pot},y}(s)$$

$W_{\text{pot}}(s)$: wake potential
 q_1 : bunch charge E : Beam energy

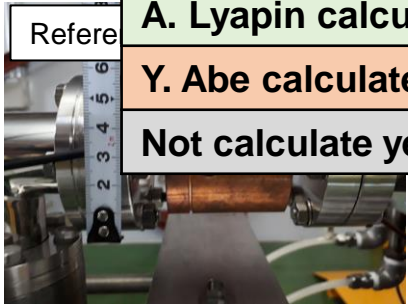
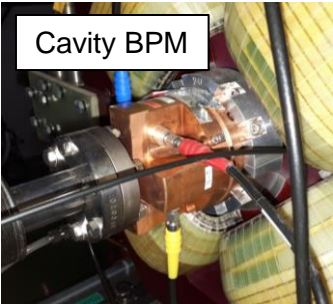
Wakefield source in ATF EXT/FF beamline

Location	Wakefield source	Amount	Location	Wakefield source	Amount
FF	Vacuum port with inner shield	14	EXT	Optical Transition Monitor (OTR)	4
EXT	Vacuum port	15	EXT	Septum chamber	3
FF	Bellows with RF shield	37	EXT	Rectangular chamber	4
EXT	Bellows	51	EXT	Stripline BPM / kicker	15
FF / EXT	Vacuum Flange (ICF70)	237	FF	Vacuum Flange (ICF114)	12
FF / EXT	Reference Cavity	2	FF	Vacuum port (ICF114)	2
FF / EXT	Cavity BPM	24	FF	Collimator	1

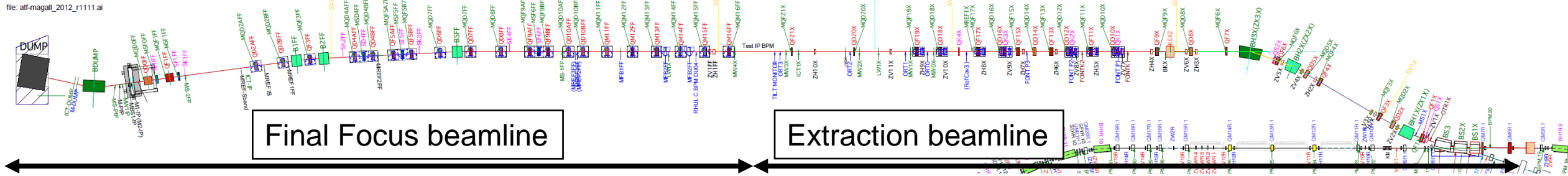
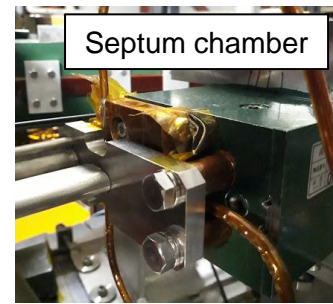
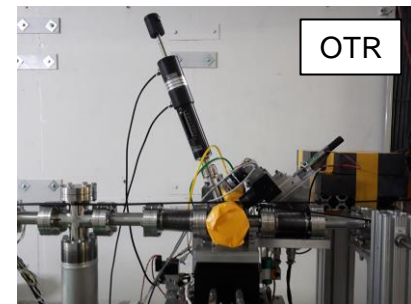
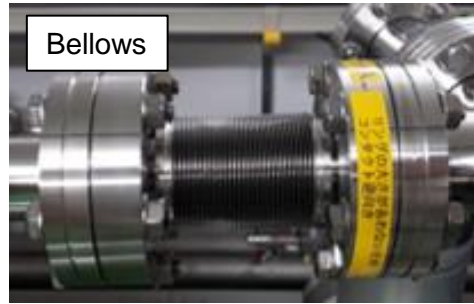
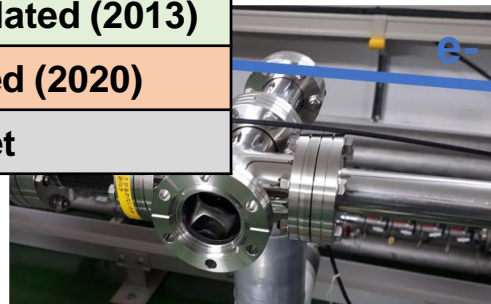


Wakefield source in ATF EXT/FF beamline

Location	Wakefield source	Amount	Location	Wakefield source	Amount
FF	Vacuum port with inner shield	14	EXT	Optical Transition Monitor (OTR)	4
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FF / EXT	Reference Cavity	2	FF	Vacuum port (ICF114)	2
FF / EXT	Cavity BPM	24	FF	Collimator	1



A. Lyapin calculated (2013)
 Y. Abe calculated (2020)
 Not calculate yet



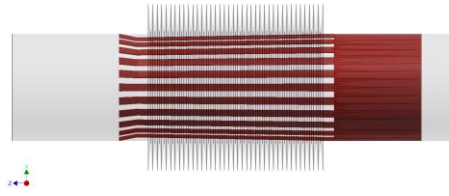
Wakefield calculation

How to calculate wakefield by GdfidL

Wakefield calculation flow by GdfidL

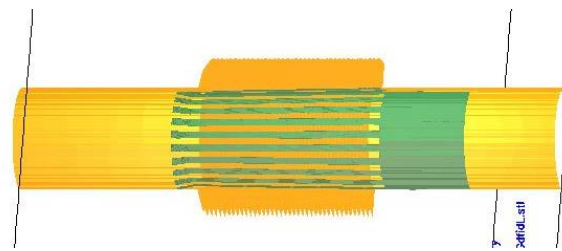
CAD soft : Inventor

Create 3Dmodel by CAD



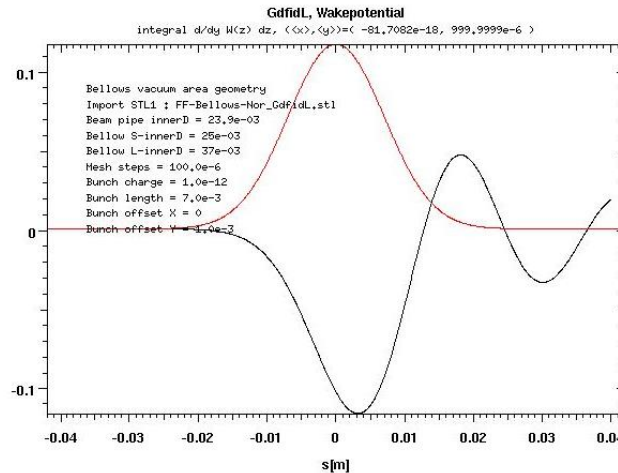
GdfidL

Import 3Dmodel to GdfidL



Electrical magnetic Field calculation (time domain)

Wake potential calculation

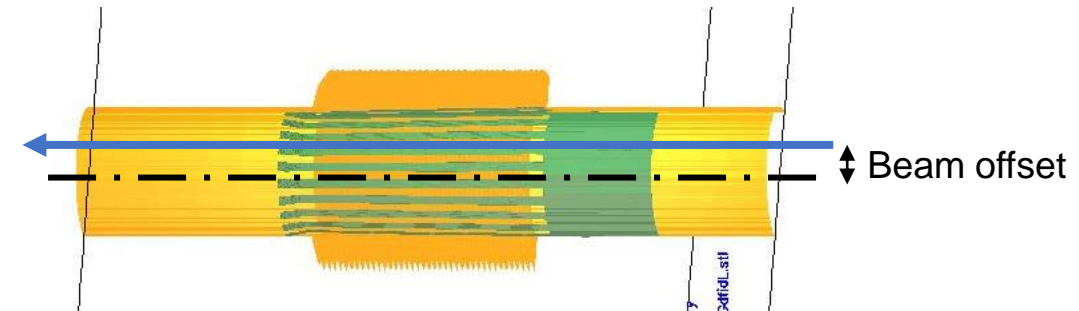


GdfidL

- Electromagnetic fields calculator in 3D
- Finite difference method

Calculation parameter

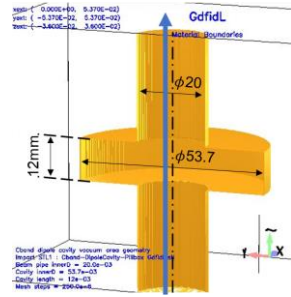
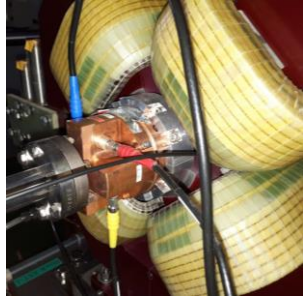
- Line charge with Gauss distribution
 - Bunch length : **7.0 mm**
 - Beam offset (position) : 0 ~ 5.0 mm
 - Bunch charge : 1.0 pC



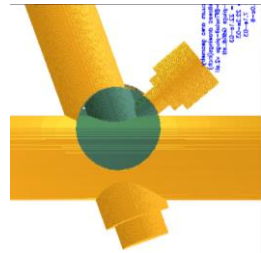
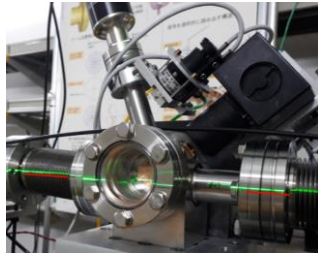
Wakefield calculation model (examples)

Recalculation

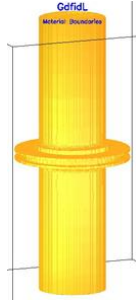
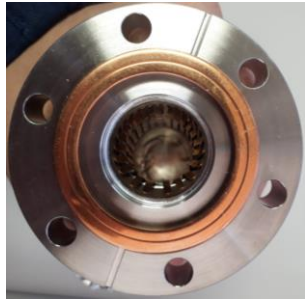
Cavity BPM



OTR

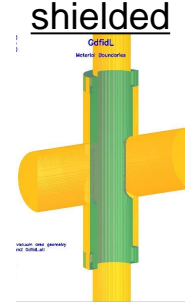
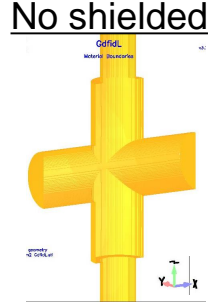


Vacuum lange



New calculation

Vacuum Port



Septum chamber



Bellows



No shielded



shielded



Rectangular chamber



- I report about new calculations.
- I will upload results of recalculation to atf.wiki. Please follow later about recalculation detail.

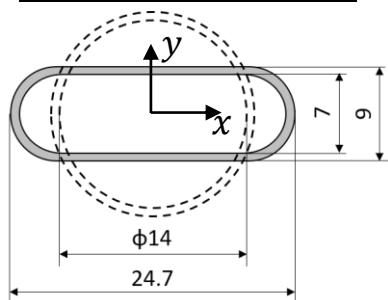
Chambers

- Septum(A/B/C) chamber

- Racetrack and Cylindrical shape
- Aperture : Small than FF beam chamber
- Chamber curved with each bending radius
 - Create model as straight chamber
 - No problem to evaluate wakefield (ver.)



Chamber cross area



Septum chamber model (A)

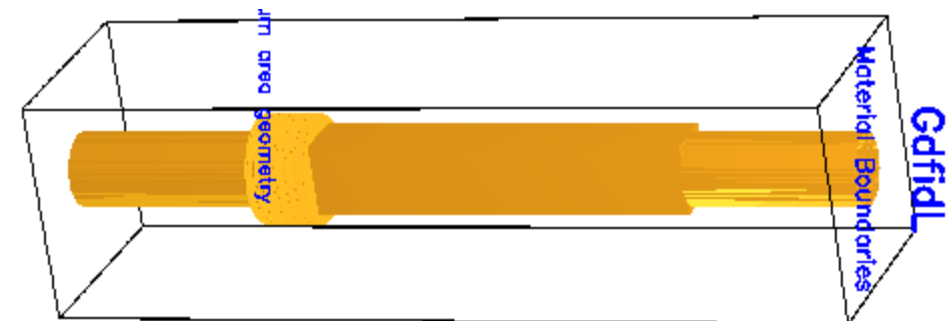
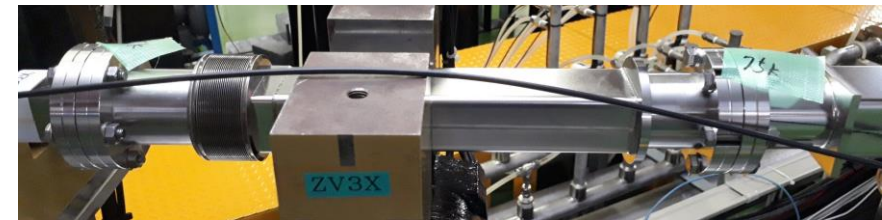


Septum chamber model (B/C)



- Rectangular chamber

- After septum magnet section
- Some rectangular chambers exist (4)
- Rectangular and Cylindrical shape



Vacuum Parts

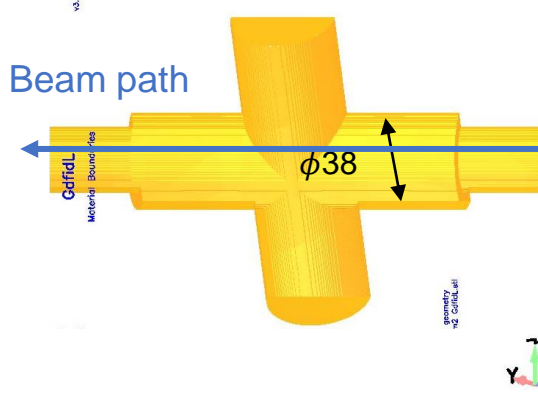
- Vacuum Port (shielded / no shielded)

- 2016 : inner shielded inserted
- Same radius to beam chamber
- 2 slits for vacuum exhaust

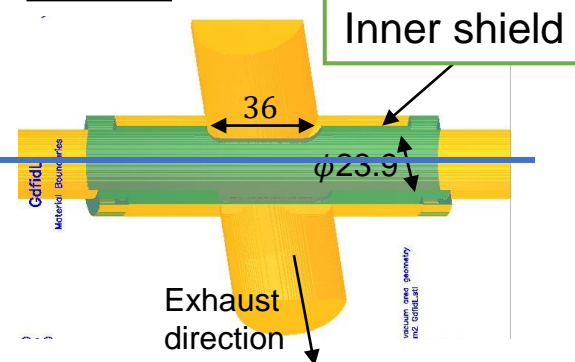
Vacuum port with shield



No shielded



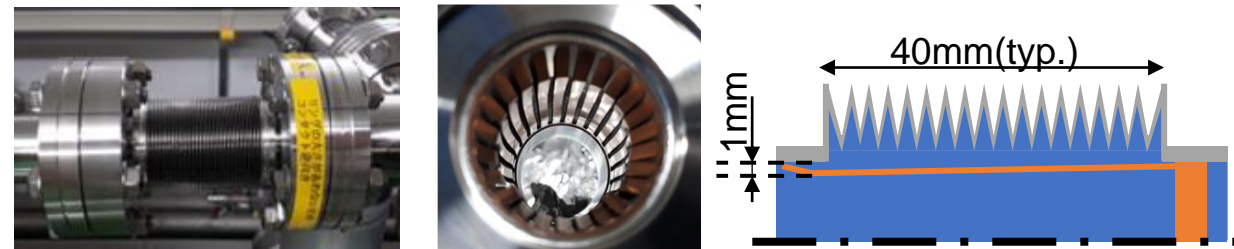
Shielded



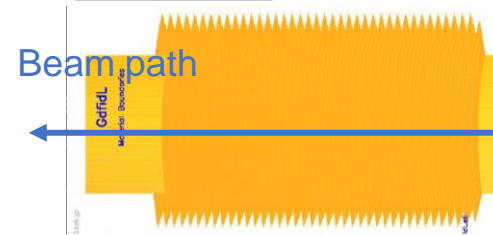
- Bellows

- 2016 : RF shield inserted at FF
- RF shield touching from bellows inside
- 1mm gap exist

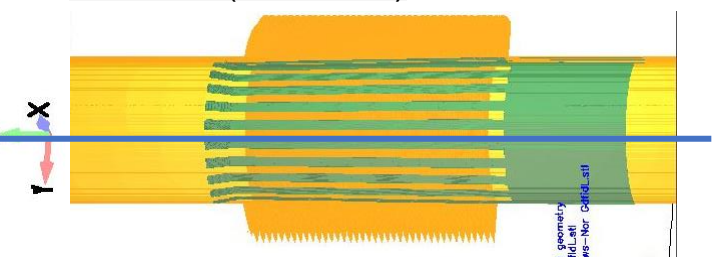
Bellows and RF shield



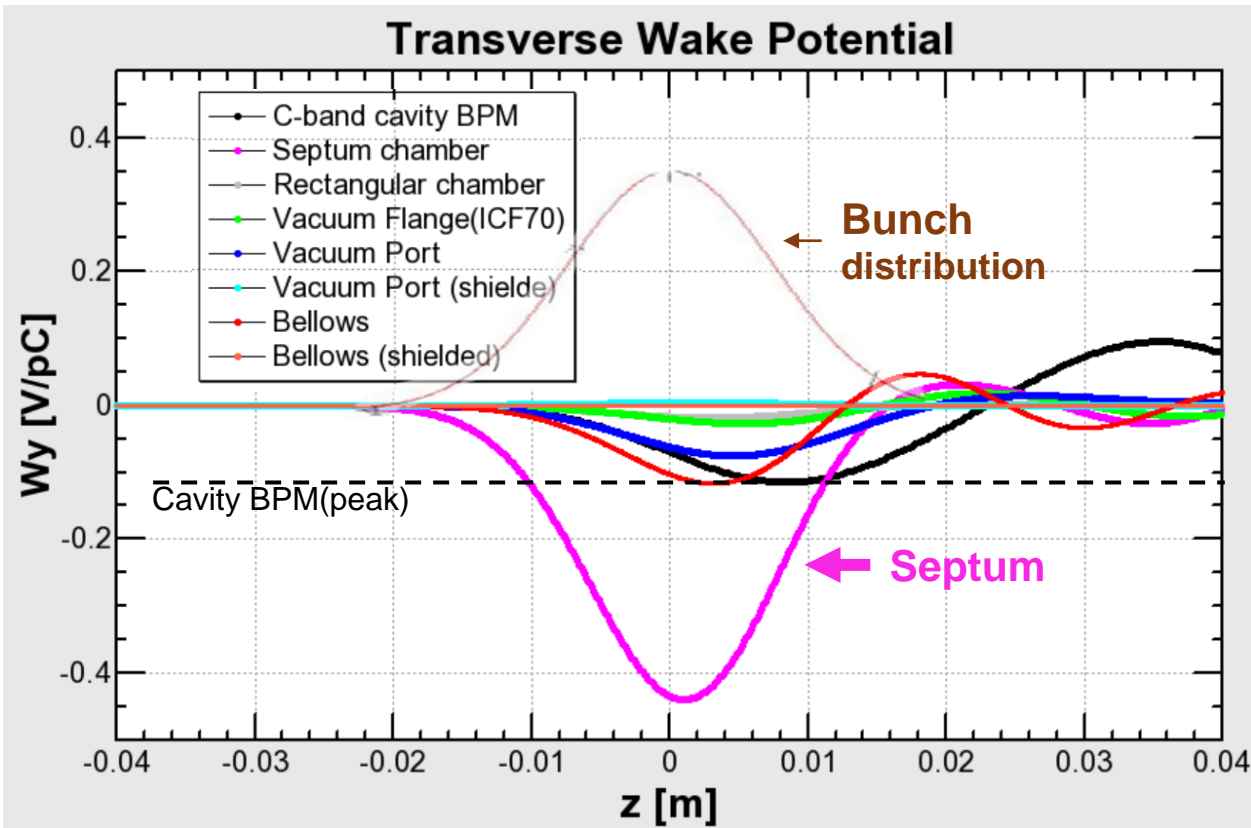
No shielded



Shielded (RF shield)



Wakefield calculation results (beam offset: $y=1$)



Location	Wake source	Wake pot. (peak) [V/pC]
FF	Cavity BPM	0.115
EXT	Bellows	0.117
FF	Bellows (shielded)	0.001
EXT	Vacuum port	0.027
FF	Vacuum port (shielded)	0.004
FF / EXT	Vacuum Flange	0.028
EXT	Septum chamber	0.440
EXT	Rectangular chamber	0.018

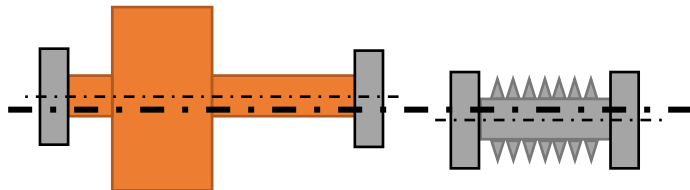
- Septum chamber's wake : **Larger** than CBPM (x4)
- Rectangular chamber's wake : **Smaller** than CBPM (1/10)
- Bellows : **RF shield reduced** wakefield less than **1/100**
- Vacuum port : **inner shield reduced** wakefield less than **1/8**

※FF: Final Focus, EXT: Extraction

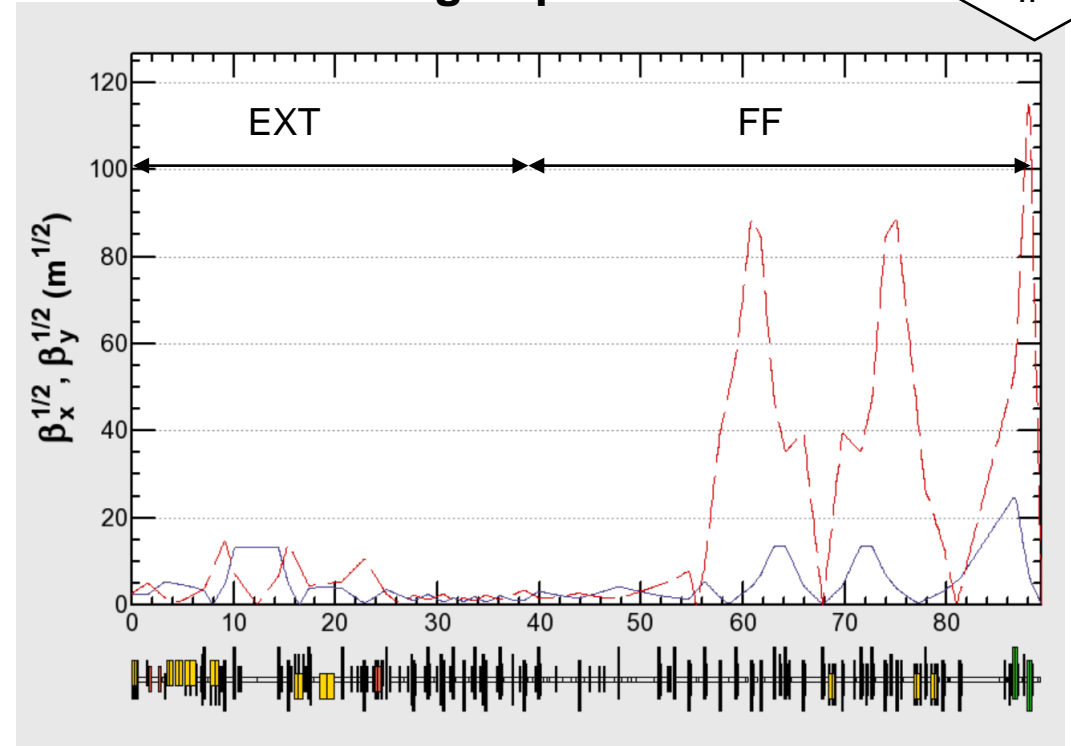
Tracking simulation

Tracking simulation by SAD

- Check effects of **short range wakefield (vertical)**
- Tracking simulation performed using SAD
 - Include kicks by wakefield proportional to beam position (**Linear approx.**)
 - Use ATF design optics
- Using newly calculated wakepotentials
 - Bellows (shielded / no shield ✕not deforming),
 - Vacuum port (shielded / no shield), Vacuum Flange
 - OTR, Septum chamber, Rectangular chamber, CBPM
- **Misalignment definition** (based on measurement)
 - Cavity BPM : 0.3 ± 0.3 mm (random)
 - Bellows, Vacuum port etc : ± 1.0 mm (random)
 - Vacuum Flange : Same with connected components



ATF2 EXT/FF design optics



Calculation Parameter

β_{IP} : 40 mm (Hor.) / 0.1mm (Ver.)

ε : 12 pm · rad (Hor.) / 2 nm · rad (Ver.)

Bunch electrons : 8.0×10^9

Bunch length : **7.0 mm**

$\Delta E/E$: 0.008

Tracking simulation results

Wakefield source		Amount	Misalignment	Wake pot. (peak)	Mean beam size ± Standard deviation
			mm	V/pC	nm
No wake			-		<u>37.9</u>
EXT	Septum chamber	3	±1.0	0.440	37.9 ± 0.1
	Rectangular chamber	4	±1.0	0.018	37.9 ± 0.0 ₀₄
	Vacuum Port	15	±1.0	0.027	37.9 ± 0.2
	Bellows	51	±1.0	0.117	38.4 ± 0.8
	Vacuum Flange	96	-	0.028	37.9 ± 0.2
	All wake sources			-	
FF	Cavity BPM	24	0.3 ± 0.3	0.115	40.8 ± 3.2 (↑ 7.6%)
	Vacuum port (shielded)	14	±1.0	0.004	37.9 ± 0.0 ₀₇
	Bellows (shielded)	37	±1.0	0.001	40.9 ± 2.9 (↑ 7.9%)
	Vacuum Flange	141	-	0.028	43.8 ± 5.6 (↑15.6%)
	All wake sources			-	
EXT + FF : All wake sources			-		<u>54.0 ± 16.6 (↑43.5%)</u>

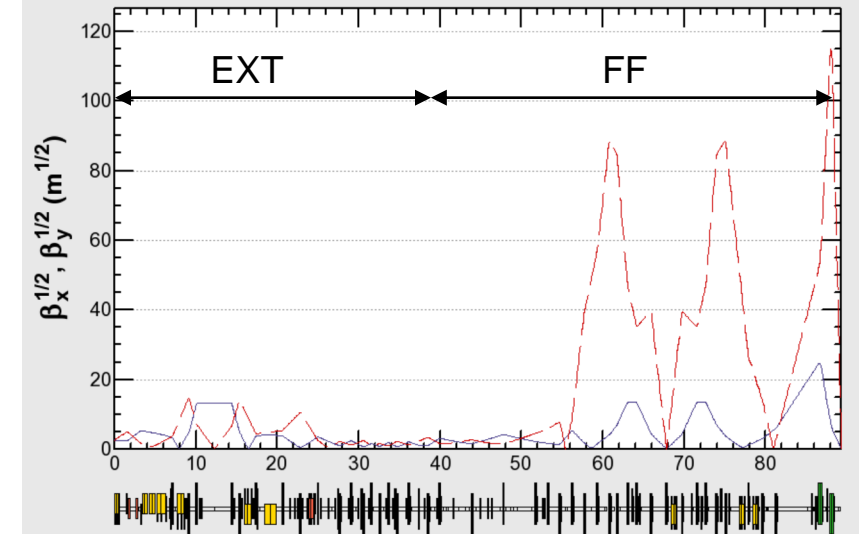
Not Effective

Effective

Tracking simulation results

Wakefield source		Amount	Wake pot. (peak)	Mean beam size ± Standard deviation
			V/pC	nm
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	Vacuum Port	15	0.027	37.9 ± 0.2
	Bellows	51	0.117	38.4 ± 0.8
	Vacuum Flange	96	0.028	37.9 ± 0.2
	All wake sources		-	38.4 ± 0.7 (↑ 4.7%)
FF	Cavity BPM	24	0.115	40.8 ± 3.2 (↑ 7.6%)
	Vacuum port (shielded)	14	0.004	37.9 ± 0.0 ₀₇
	Bellows (shielded)	37	0.001	40.9 ± 2.9 (↑ 7.9%)
	Vacuum Flange	141	0.028	43.8 ± 5.6 (↑15.6%)
	All wake sources		-	52.4 ± 11.9 (↑38.3%)
EXT + FF : All wake sources			-	<u>54.0 ± 16.6 (↑43.5%)</u>

ATF2 EXT/FF design optics



$$\begin{pmatrix} \Delta y_{IP} \\ \Delta y'_{IP} \end{pmatrix} = \begin{pmatrix} R_{11} & R_{12} \\ R_{21} & R_{22} \end{pmatrix} \begin{pmatrix} 0 \\ \Delta y'_{WAKE} \end{pmatrix}$$

$$\Delta y_{IP} = \Delta y'_{WAKE} \sqrt{\beta} \beta_{IP} \sin \Delta \phi$$

β : β function at wake source
 β_{IP} : β function at IP
 $\Delta \phi$: Phase advance to IP

β function in EXT < β function in FF

Summary & Further works

Summary

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- Vacuum port : **inner shield reduces** wakefield less than **1/8**

Results : Tracking simulation

- wakefield in Extraction (include septum chamber) : **Not effective**
- Wakefield in Final Focus : **Effective** (Especially, Vacuum Flange!)

Further Works

- Check **other sources & deforming condition** (chamber gap, stripline BPM, ICF114 parts etc)
 - **Please give me drawings of ATF components (FONT stripline, collimator etc)**
- Upgrade tracking calculation setup (Non-linear term of wakefield, x-y coupling, jitter ...)
- I will upload results to **atf.wiki** page