Wakefield study at ATF2 beamline

Outline

1. Introduction & Motivation
2. Wakefield sources in the ATF beamline
3. Introduce the impact of each wakefield source on the IP beam size
4. Evaluation of the wakefield effects as a single wakefield source
5. Evaluation of the wakefield effects caused by the orbit fluctuation
6. Wakefield mitigation at ATF final focus beamline
7. Summary

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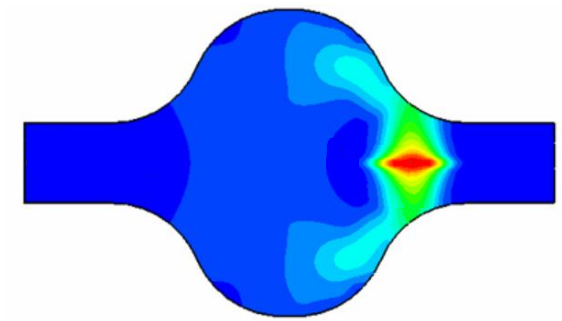
Introduction：Wakefield and its effect on the beam

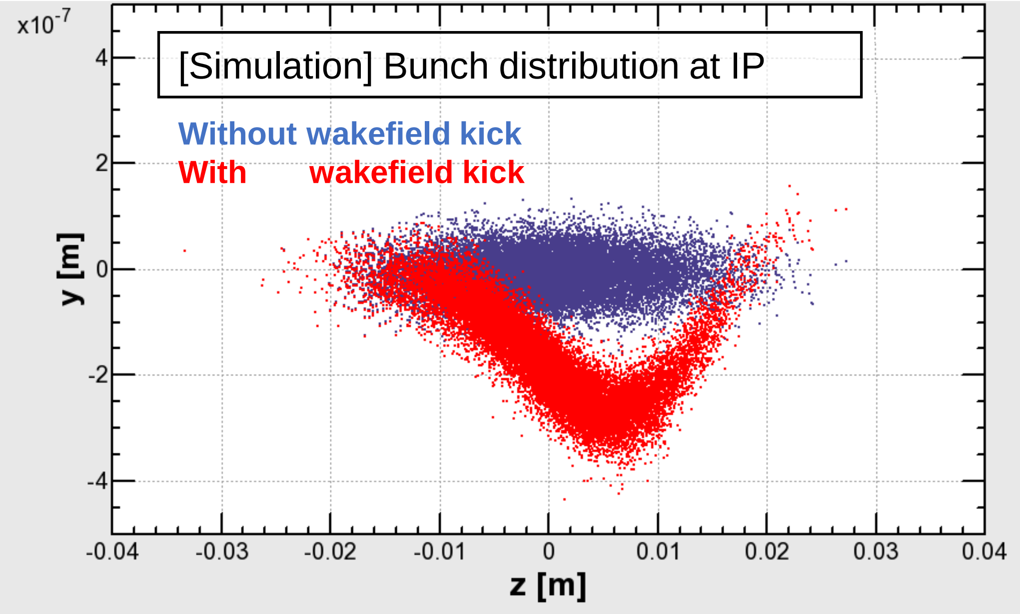
- Wakefield： **excited electromagnetic fields** when the beam passes through the section of structural change

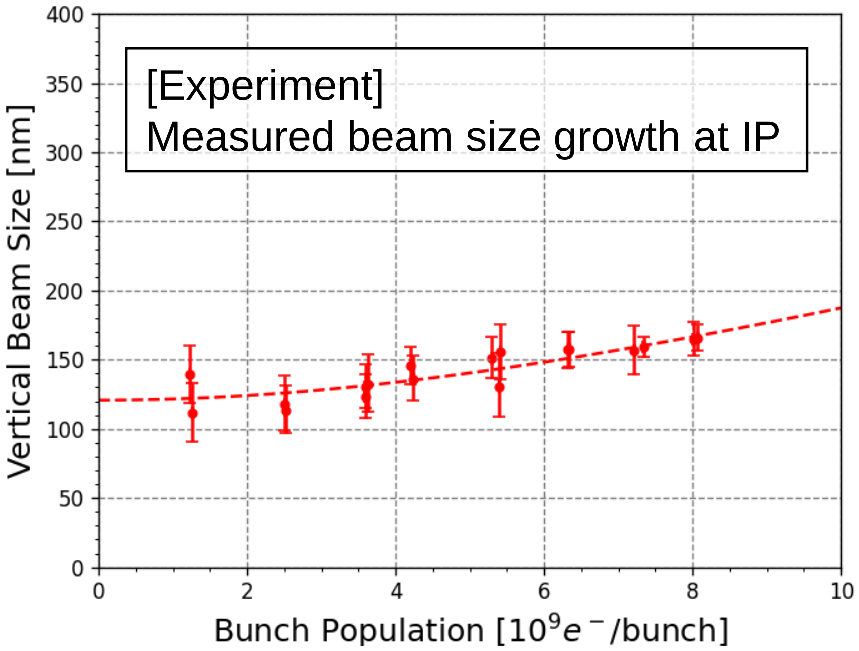
- **Not negligible：Wakefield effects on the nanometer small beam**
  - Wakefield kicks become stronger depending on **bunch intensity** and **offset** from the geometrical center of the wakefield source
  - Induce the **beam size growth** and **bunch position change**

Overview of the induced wakefield



CST Particle studio- wakefield solver overview





Evaluation of the wakefield effects on the nanometer small beam

- **This study is important for the next generation accelerators**
  - Nanometer small beam：the key technology for the Linear Collider
  - Wakefield effects on the nanometer small beam：**Not negligible small**
- **ATF is the best research environment for this study**
  - Generate the **low emittance** and **nanometer size beam**
  - Measure the bunch position and beam size in nm order with **high precision monitors**

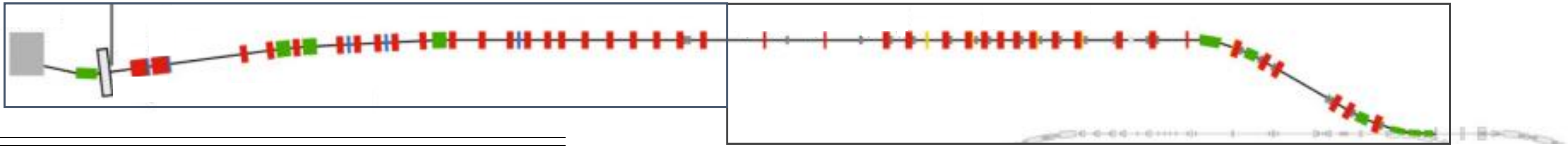
Research activity as my PhD study

1. **Evaluation of the wakefield effect as a single wakefield source**
   Experimentally confirmed the constructed wakefield models

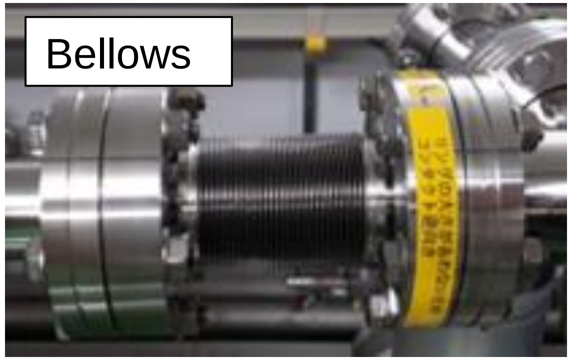
2. **Evaluation of wakefield effects caused by the orbit fluctuation**
   Estimated result showed the effect：Not negligible small
   So experimentally confirmed the effect

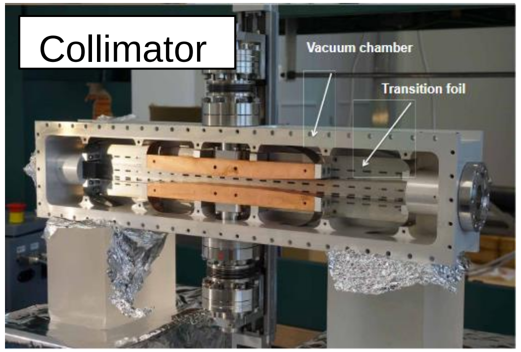
Wakefield sources in the ATF final focus beamline

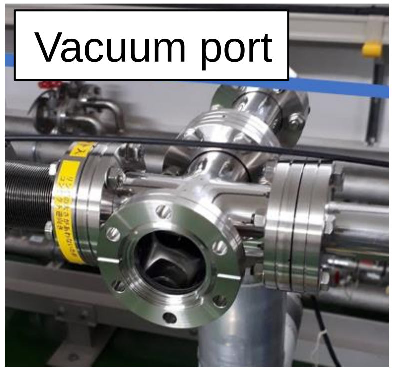
Final Focus beamline **Extraction beamline**

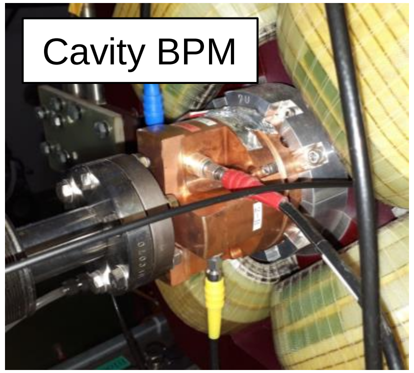


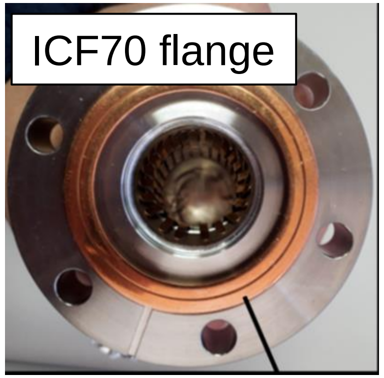
No.	Name	Location	Amount
1	Vacuum Port	EXT	15
2	Bellows	EXT	34
3	Optical Transition Radiation Monitor	EXT	4
4	Septum magnet chamber	EXT	3
5	Stripline BPM	EXT	12
6	Stripline kicker	EXT	2
7	Rectungular chambers	EXT	4
8	Vacuum Flange (ICF70)	EXT, FF	223
9	Reference Cavity	EXT, FF	2
10	Cavity BPM	EXT, FF	25
11	Gate valve	EXT, FF	3
12	Stripline BPM	FF	1
13	Shielded Vacuum Flange (ICF70)	FF	20
14	Shielded Bellows	FF	34
15	shielded Vacuum Port	FF	13
16	manual gate valve	FF	1
17	Collimator	FF	1
18	Wakefield corrector	FF	1
19	Wakefield Study chamber	FF	1
20	Vacuum Flange (ICF114)	FF	12
21	Vacuum Port (ICF114)	FF	2











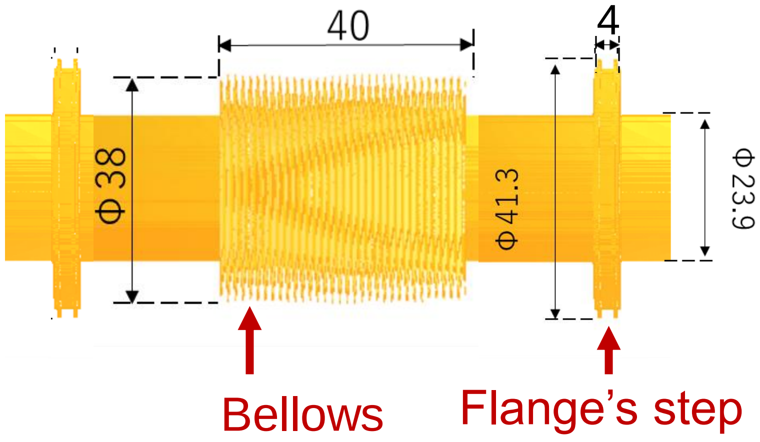
Constructed new wakefield model
Included all of the wakefield sources

Wakefield calculation by 3D electromagnetic field calculation (GdfidL)

- Created 3D models of the vacuum area
  - Reproduce internal geometry of wakefield sources (step and gap of components)

modeling

ex：bellows and ICF70 flange
(mesh size：0.1mm)

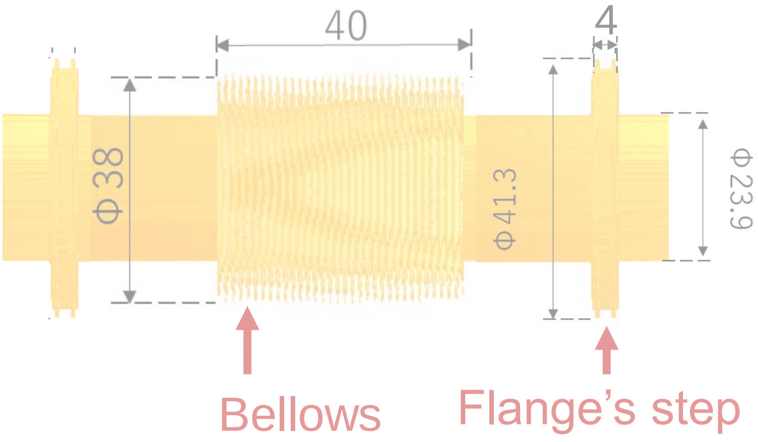


Estimated the impact of each wakefield source on the IP beam size

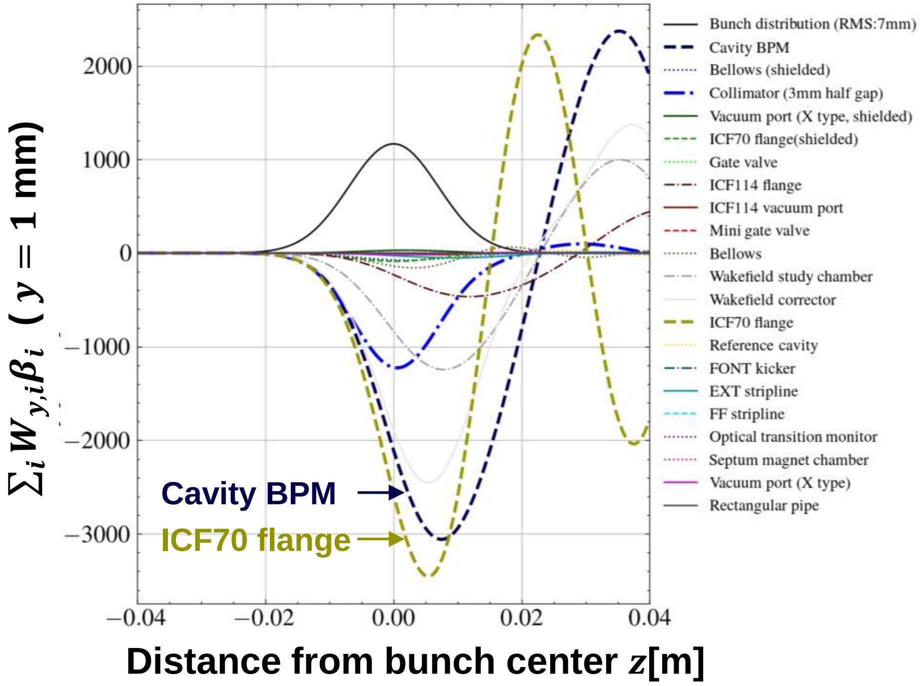
- Created 3D models of the vacuum area
  - Reproduce internal geometry of wakefield sources (step and gap of components)

modeling

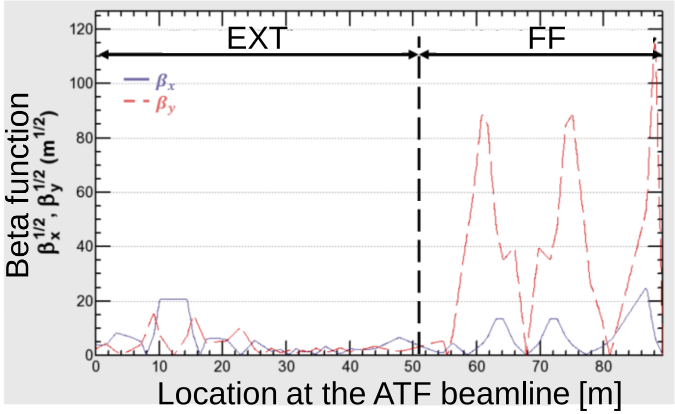
ex：bellows and ICF70 flange
(mesh size：0.1mm)



Estimated impact on the IP beam size



Optics in ATF-FF/EXT



$\Delta y_{\mathrm{IP}}(z) = \sum \Delta y'_i(z)\sqrt{\beta_{y,\mathrm{IP}}\beta_{y,i}}\sin\Delta\Phi_i$

Δy_{IP} ： position of the particle at IP

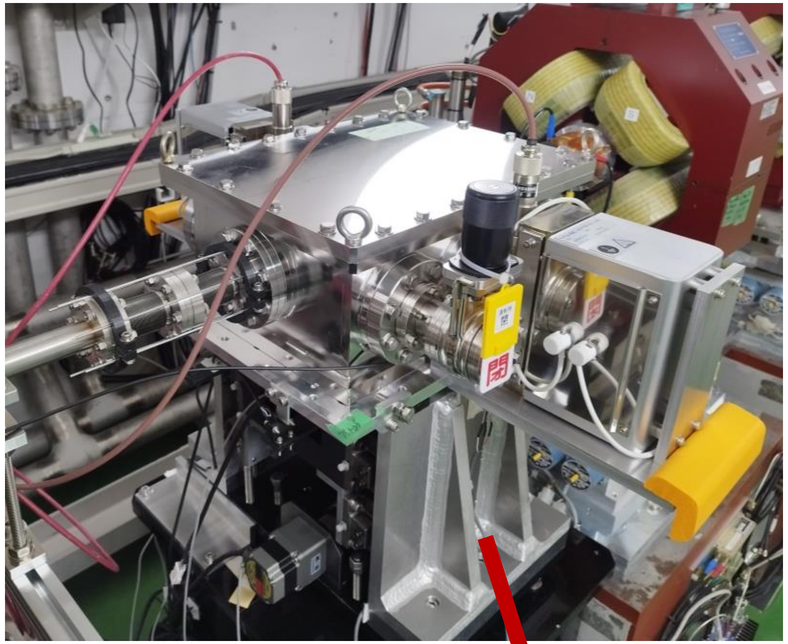
$\Delta y'_i$ ：wakefield kick

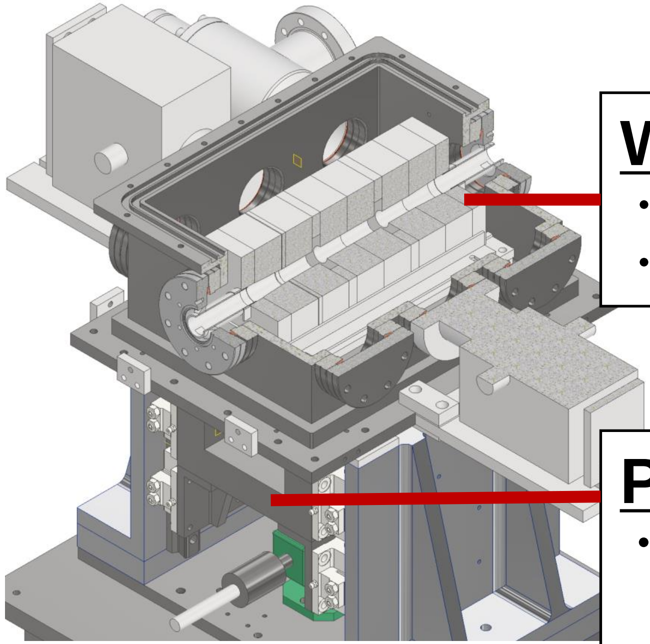
- Wakefield sources located in FF (**Cavity BPM, vacuum flange** etc)
  Strong impact on the IP beam size
- **Beta function in FF greater than EXT**

Evaluation of the wakefield effects as a single wakefield source

Installed a movable wakefield source to generate targeted wakefield kick

- **Evaluate the acted wakefield kick at the single wakefield source**
  - Measure the beam orbit change downstream from the wakefield source after the wakefield source is moved

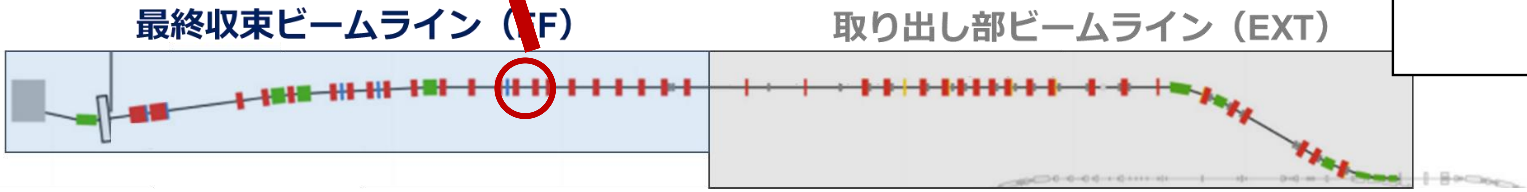




<u>Wakefield study chamber</u>
・**Produce the target wakefield source**
・Set on the block with arbitrary inside structure

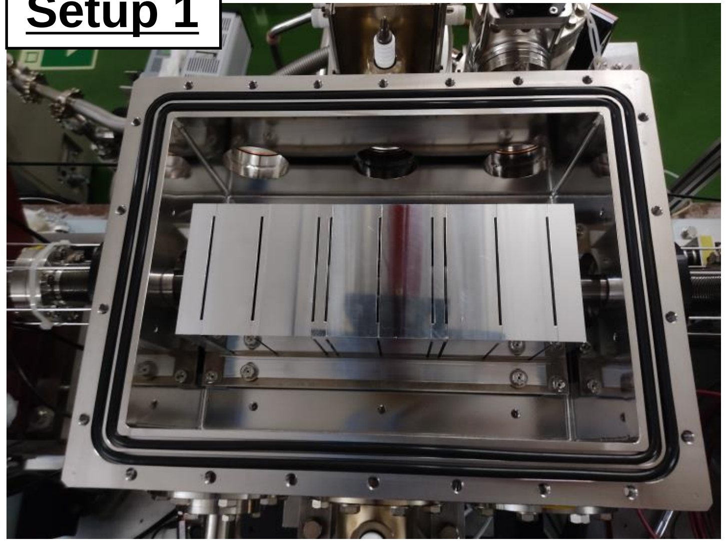
Easy to compare with simulation results

<u>Position adjustment mover</u>
・**Control the wakefield kick strength** by adjusting the position of the wakefield source
・movable range：Ver. ±10 mm (1um step)
Hor. ±6 mm (10um step)

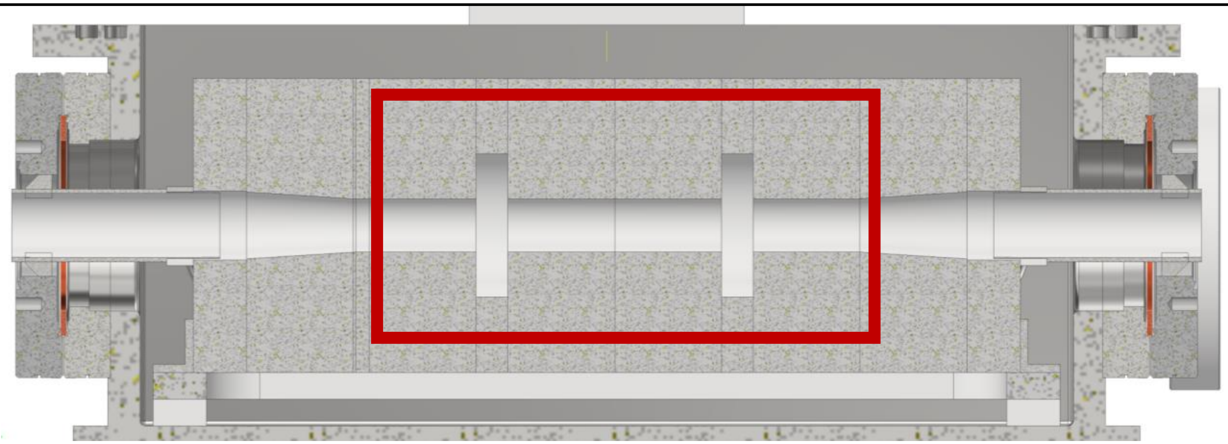


The internal setup of the wakefield study chamber

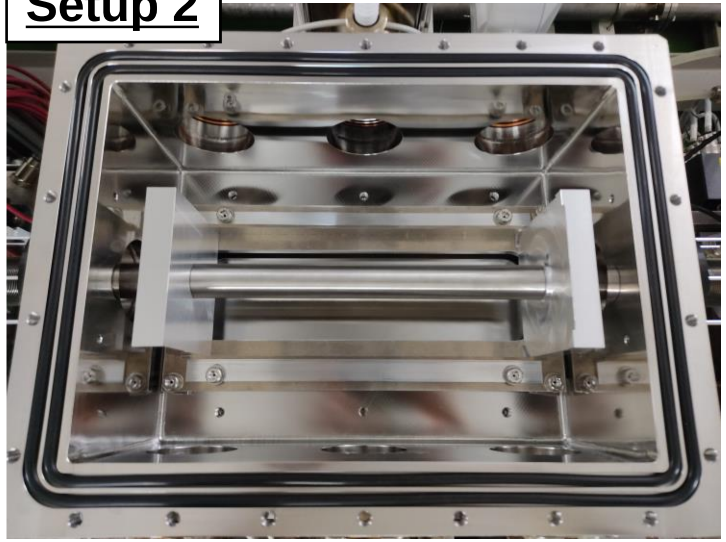
Setup 1



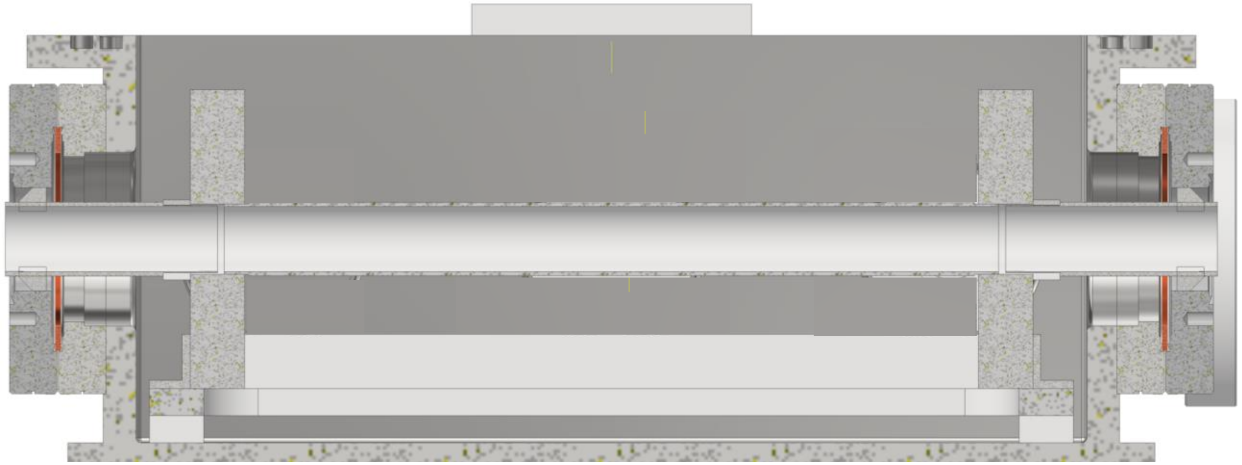
To evaluate the effect of Cavity BPM (major wakefield source)
Produced Cavity BPM(pill box) structure



Setup 2

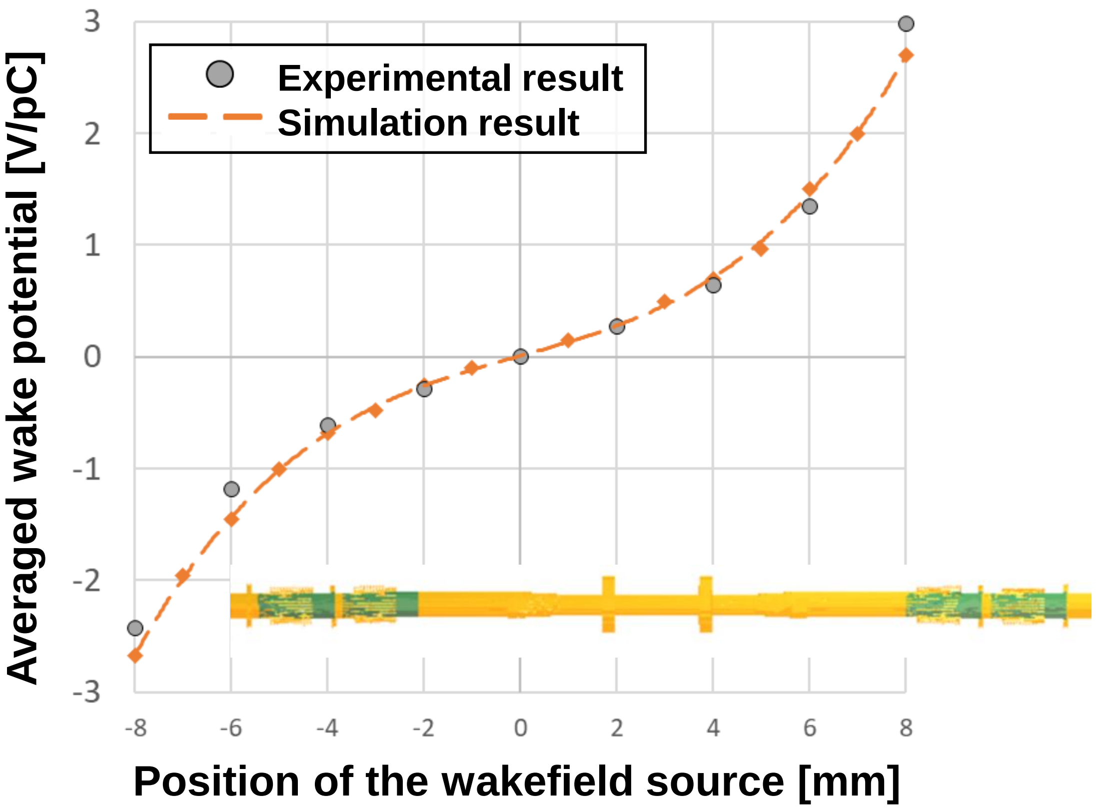


Straight pipe for the reference

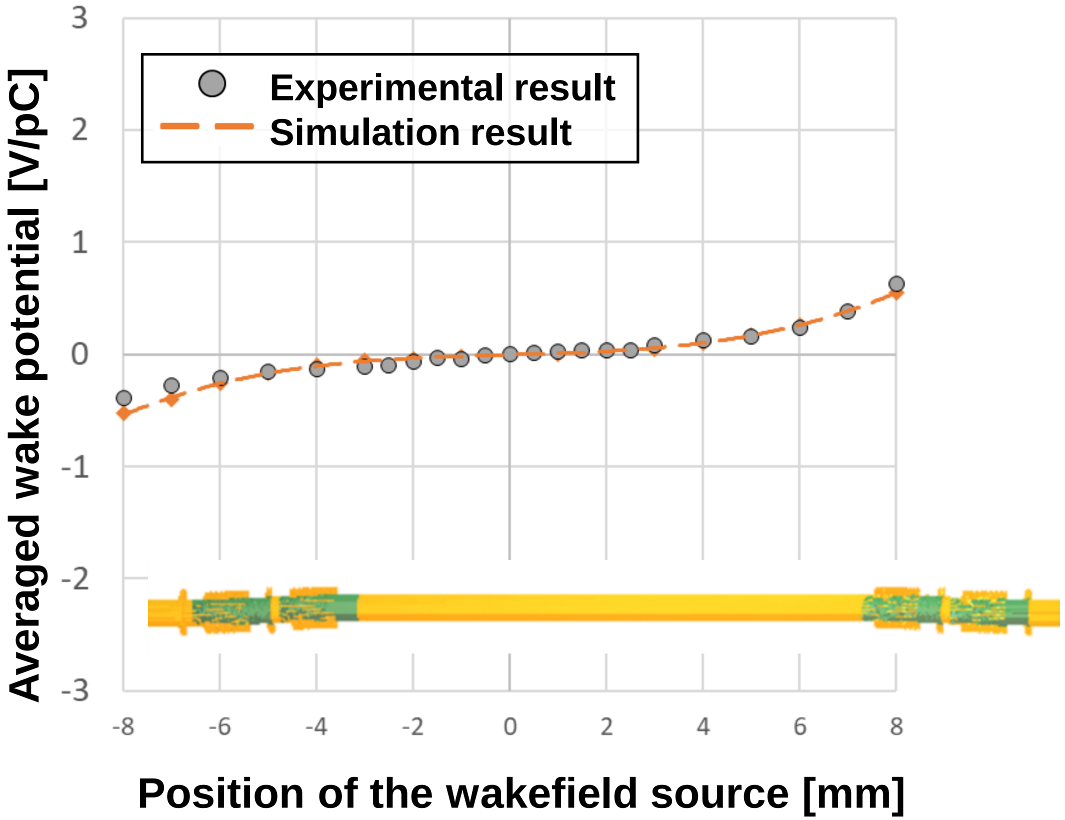


Evaluation results of the wakefield effects as a single wakefield source

Setup 1 : Cavity BPM



Setup 2 : Straight pipe



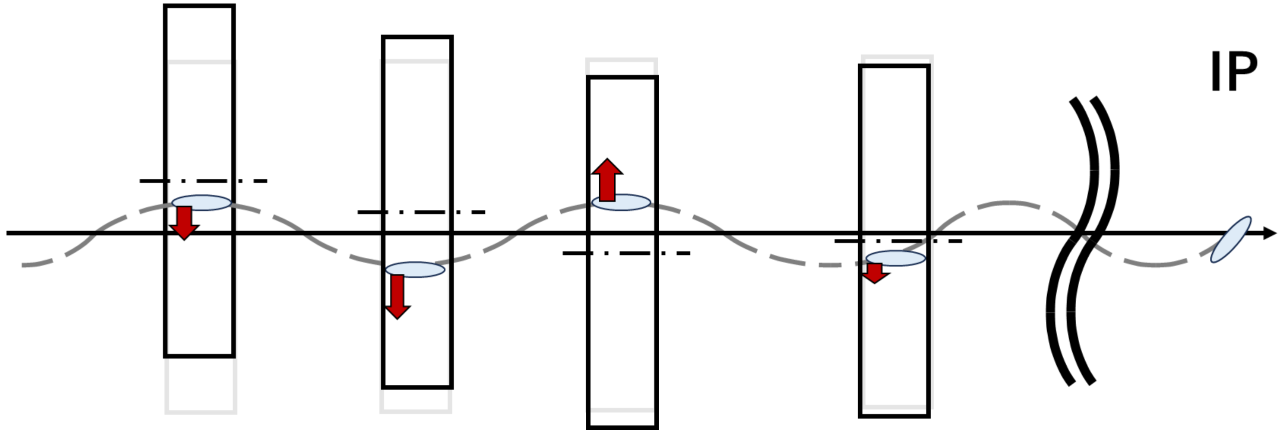
- Experimental, and Simulation result based on the constructed model
- **Confirmed that the constructed wakefield model well reproduced the experimental results**

Evaluation of the wakefield effects caused by the orbit fluctuation

Wakefield effects caused by static and dynamic orbit change

- **Static effect**

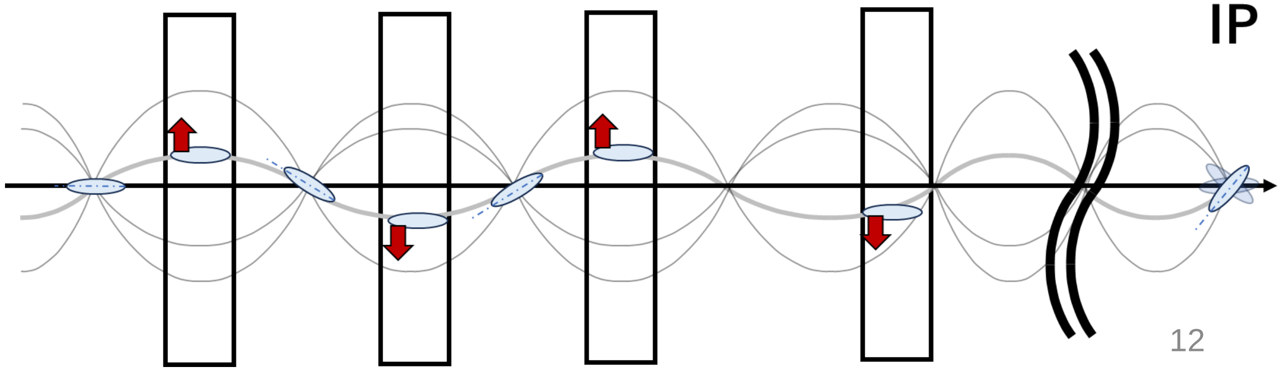
  Excited due to misalignment of wakefield source or beam orbit distortion



- **Dynamic effect**

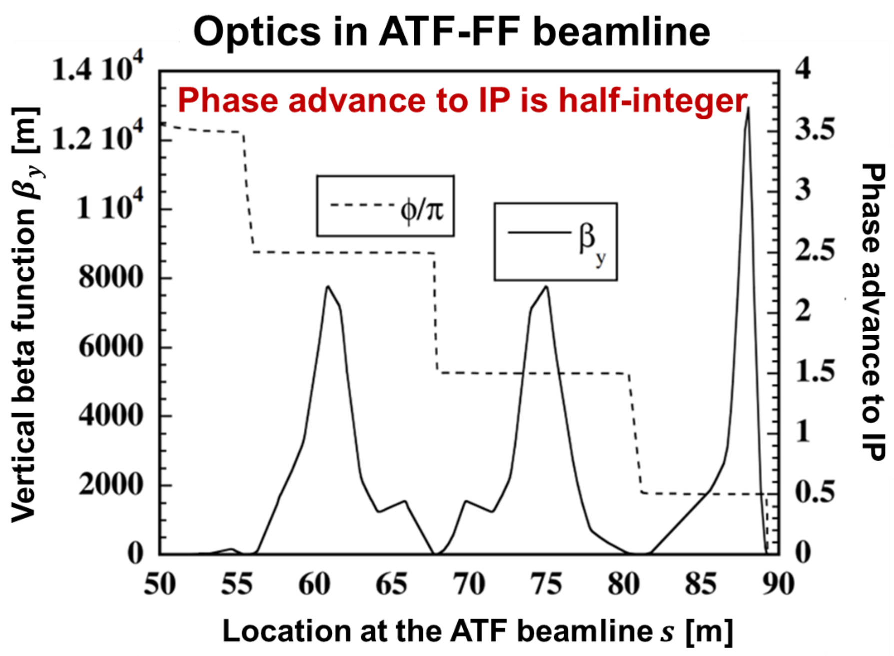
  Excited due to the shot-by-shot orbit fluctuation by injection

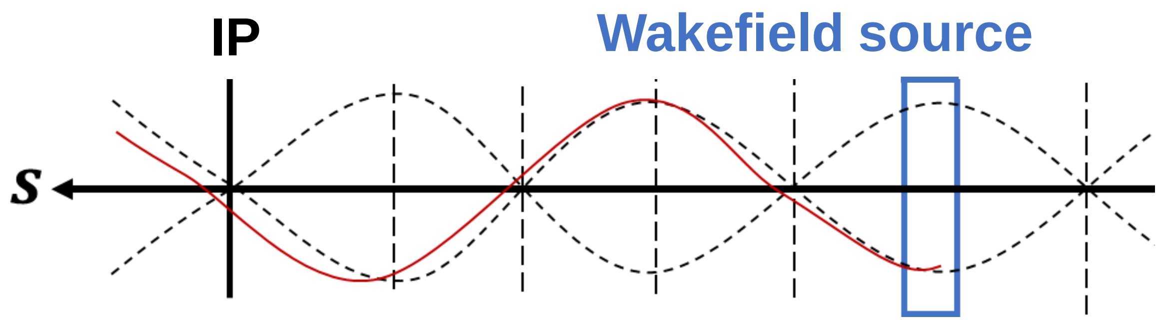
  The orbit fluctuation caused by the injection beam fluctuation



Impacts of the pulse-by-pulse orbit fluctuation in ATF-FF beamline

- Phase advance to IP in final focus optics is half-integer
  - Almost wakefield sources located at FD phase (phase advance to IP: half-integer)

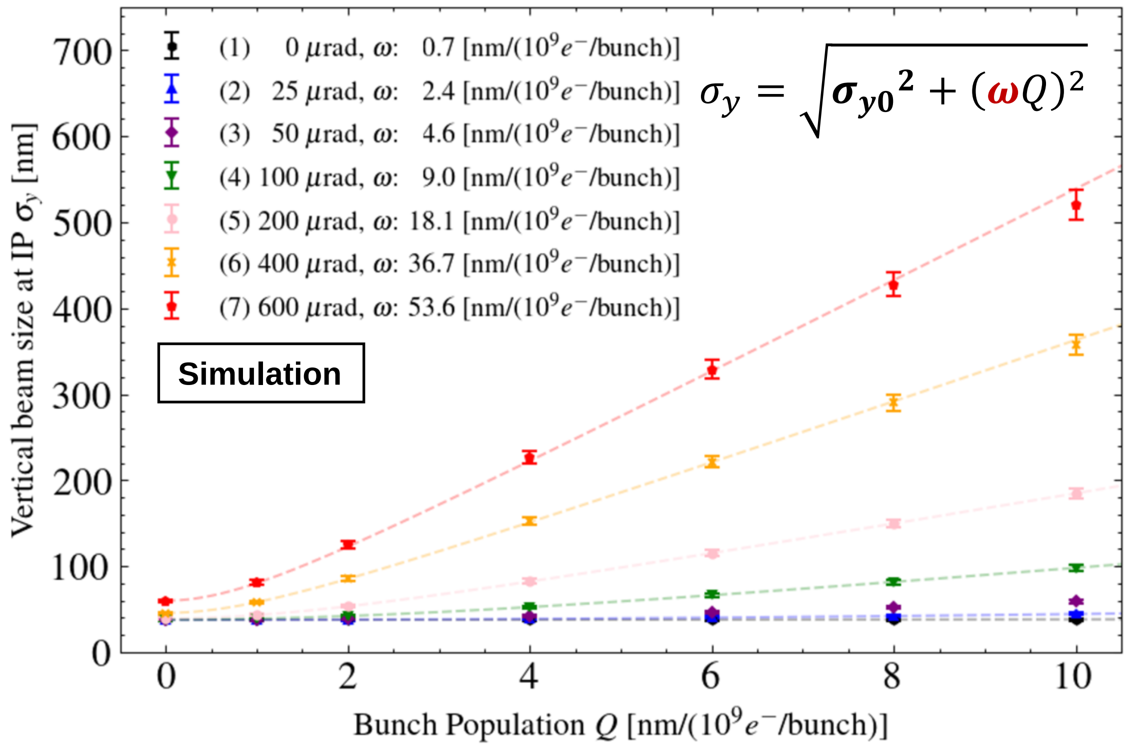




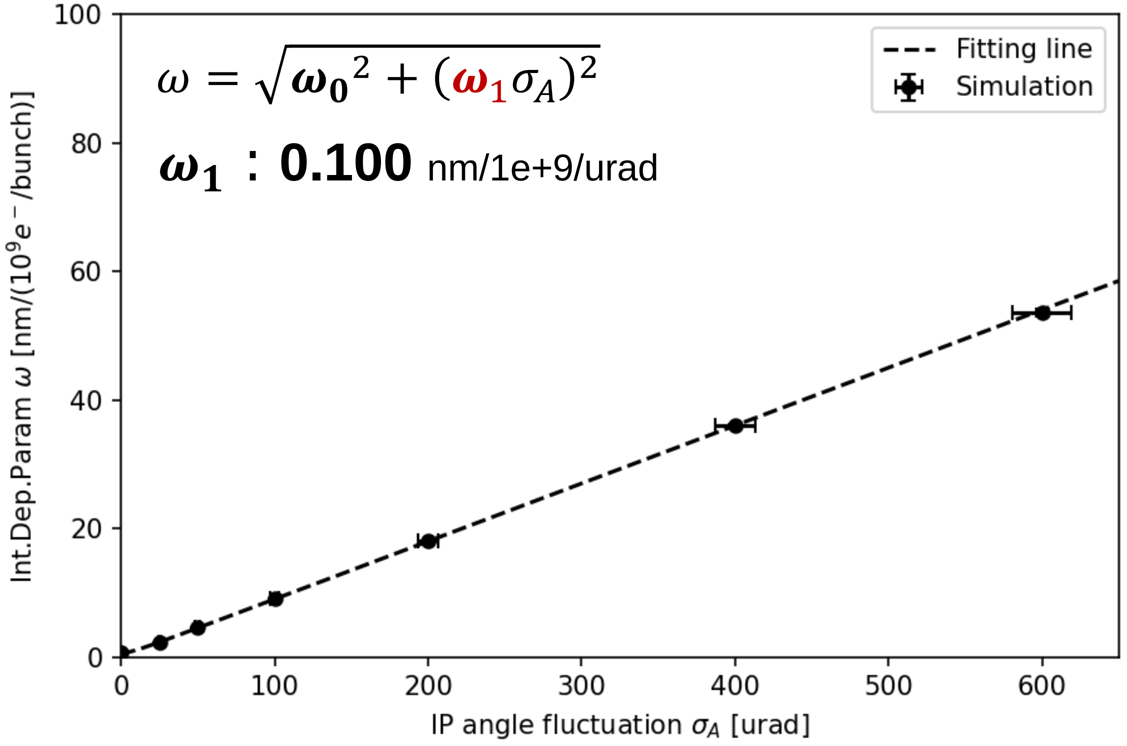
- Bunch angle at IP is fluctuated when orbit fluctuated at FD phase
  - **To quantitatively evaluate the wakefield effects** due to orbit fluctuations
  - Confirm relationship between **bunch angle fluctuations** and **beam size at IP**

Estimated wakefield effects caused by shot-by-shot orbit fluctuation

Beam size growth as a function of bunch intensity



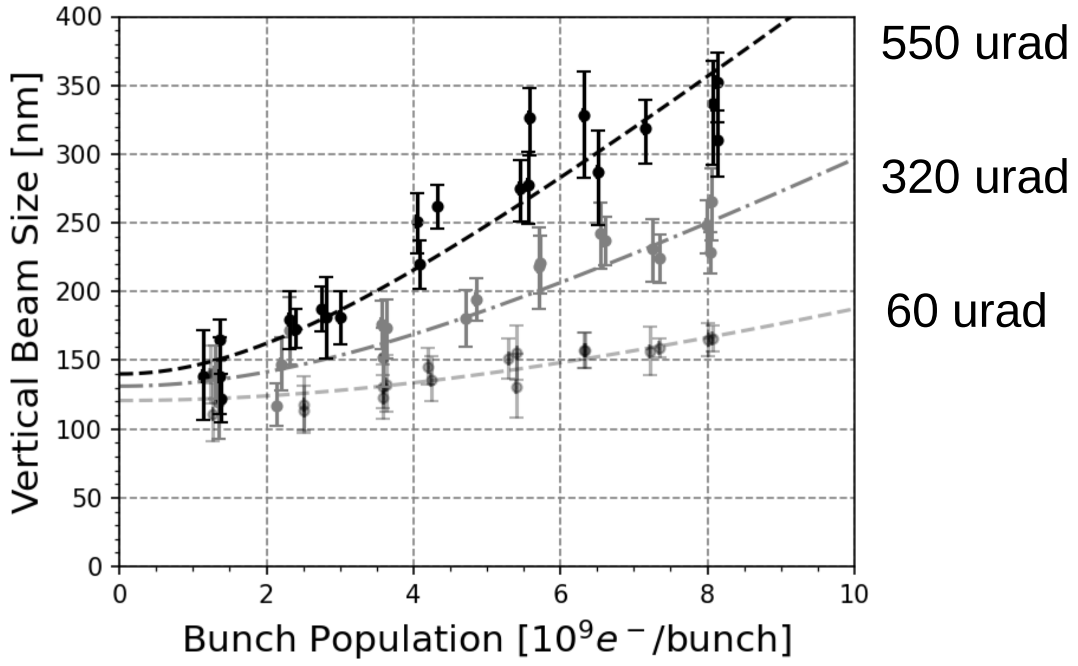
Strength of beam size growth and IP angular fluctuation



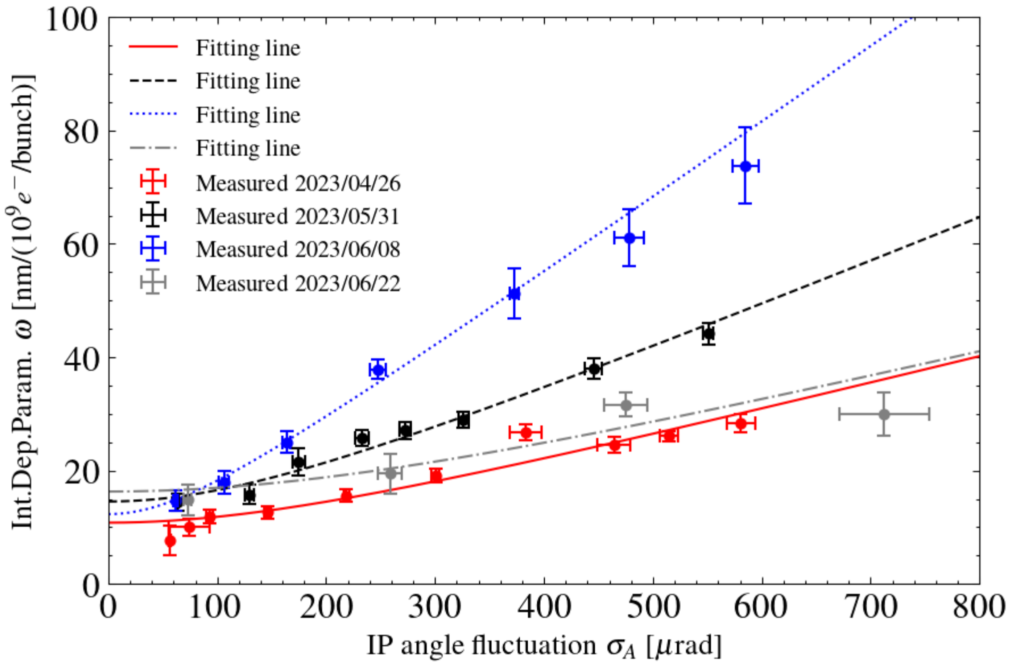
- Beam size at IP increases depending on the bunch intensity
- **Beam size growth** becomes **stronger** due to the **bunch angle fluctuation at IP**
  →orbit fluctuation at FD phase becomes bigger

Experimental evaluation of wakefield effects caused by orbit fluctuation

Beam size growth under different IP angle fluctuation



Strength of beam size growth and IP angular fluctuation

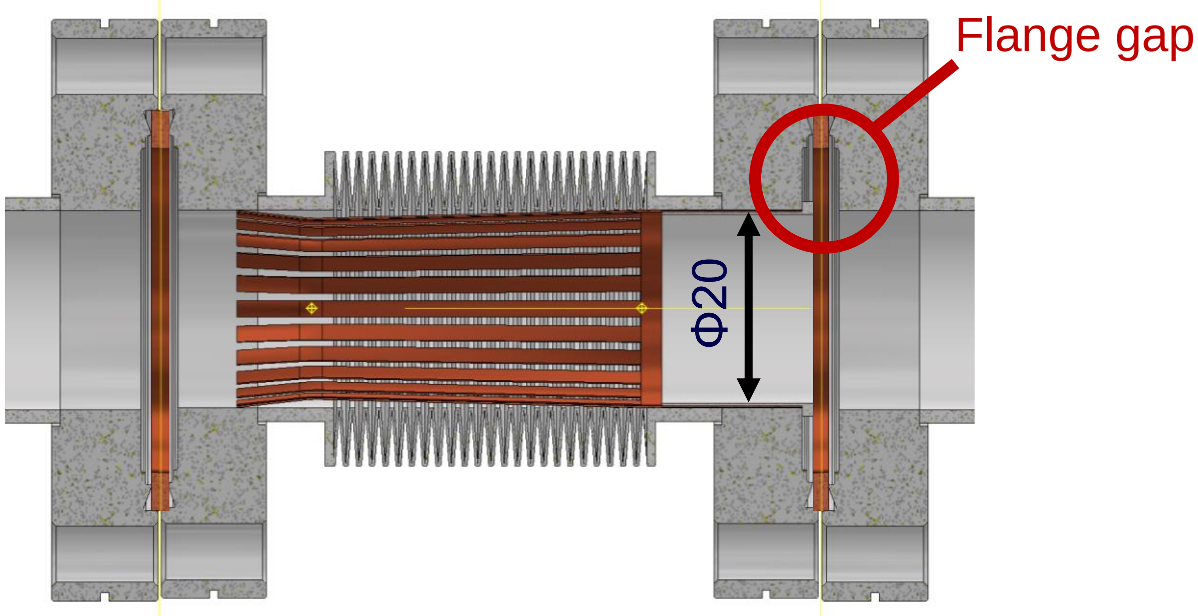


- Generated artificial orbit fluctuations by pairs of steering magnet
  - Only change the FD phase orbit (bunch angle at IP) by artificial orbit fluctuations
- **Experimentally demonstrated the effects caused by the orbit fluctuation is significant large**
  - Experimental result (average) : 0.077±0.024 nm/10^9/bunch/urad
  - Simulation result : 0.100 nm/10^9/bunch/urad

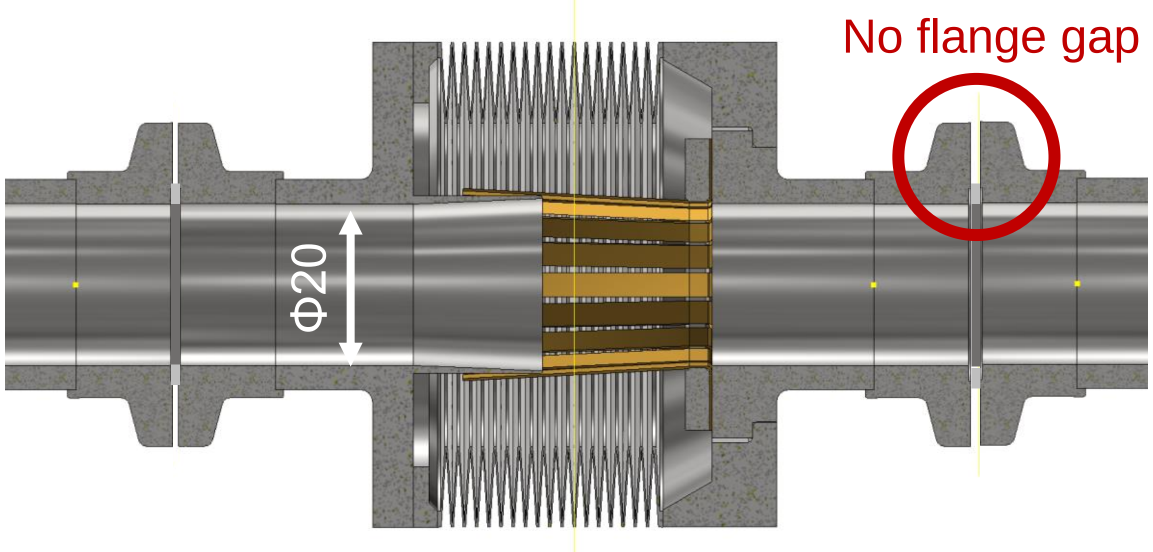
Wakefield mitigation at ATF final focus (FF) beamline

- Wakefield sources located in FF (**Cavity BPM, vacuum flange** etc)
  Strong impact on the nanometer small beam
- Optimizing chamber layout at the large beta section in ATF-FF
  - Replace ICF type vacuum (flange, bellows) components to **clamp chain type**
  - Change base beam pipe inner diameter：Φ23.9→ Φ20
  - Insert RF shield to not replaceable vacuum components (CBPM)

Present ICF flange and Bellows



New clamp chain type flange and Bellows



Summary

- This study is important for the next generation accelerators
- Evaluated the wakefield effects on the nanometer small beam
  using the best research environment as ATF
  1. **Evaluation of the wakefield effect as a single wakefield source**
     Confirmed that the constructed wakefield model well reproduced the experimental results
  2. **Evaluation of wakefield effects caused by the orbit fluctuation**
     Demonstrated by experiment and simulation, the effect is significant large

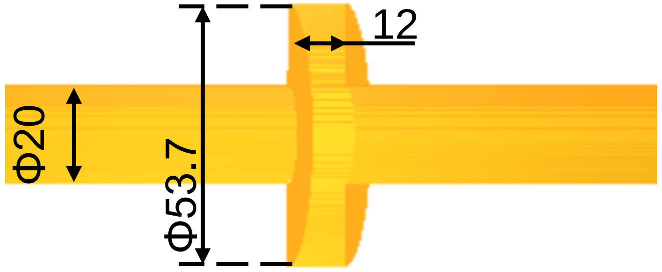
Further works

- Just in progress, beamline upgrade to reduce the excited wakefield
  - Ordered new vacuum component (bellows, beam pipe)
- Further investigation of the wakefield effects on the nanometer small beam

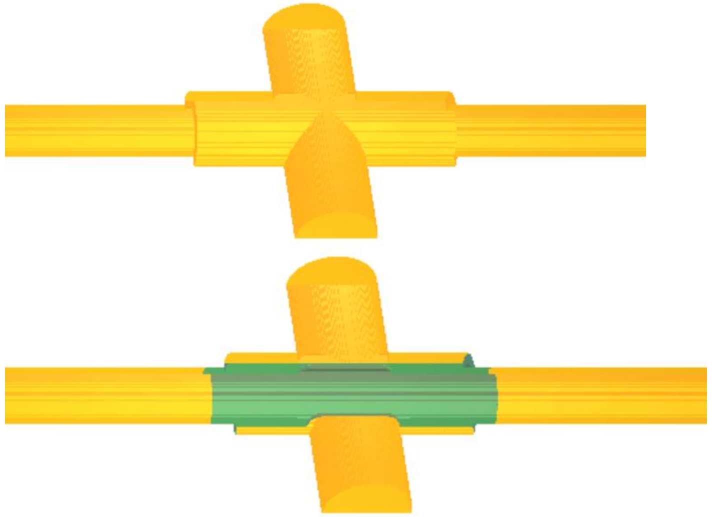
Backup

Inner structure model for wakefield calculation by GdfidL

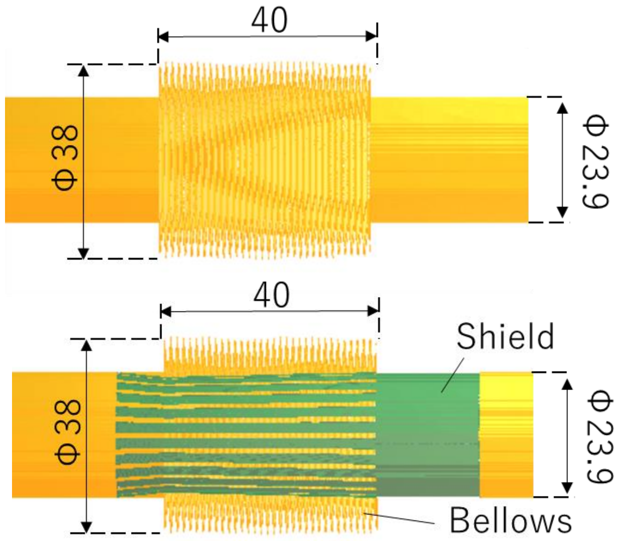
Cavity BPM (pillbox cavity)



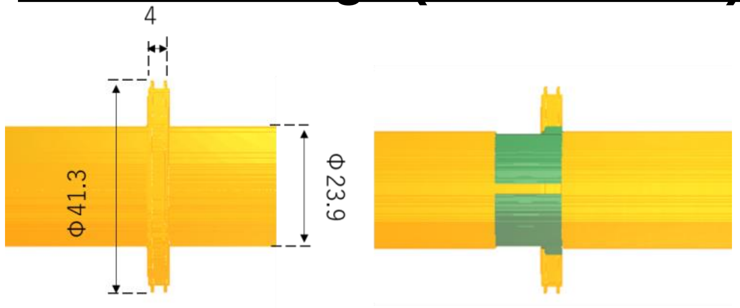
Vacuum port (w/wo shield)



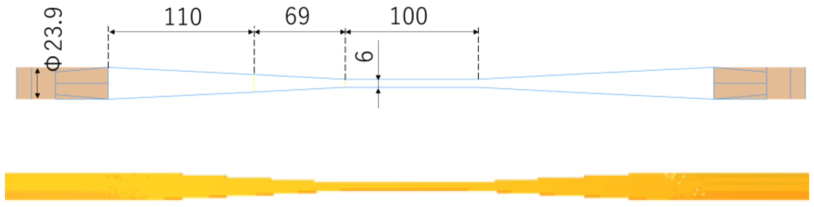
Bellows (w/wo RF shield)



Vacuum flange (w/wo shield)



Collimator (half gap 3mm)



Septum magnet chamber

Optical Transition Radiation Monitor (with plug)