Beam Position Monitoring of Multi-Bunch Electron Beams at the FLASH Free Electron Laser

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DESY.

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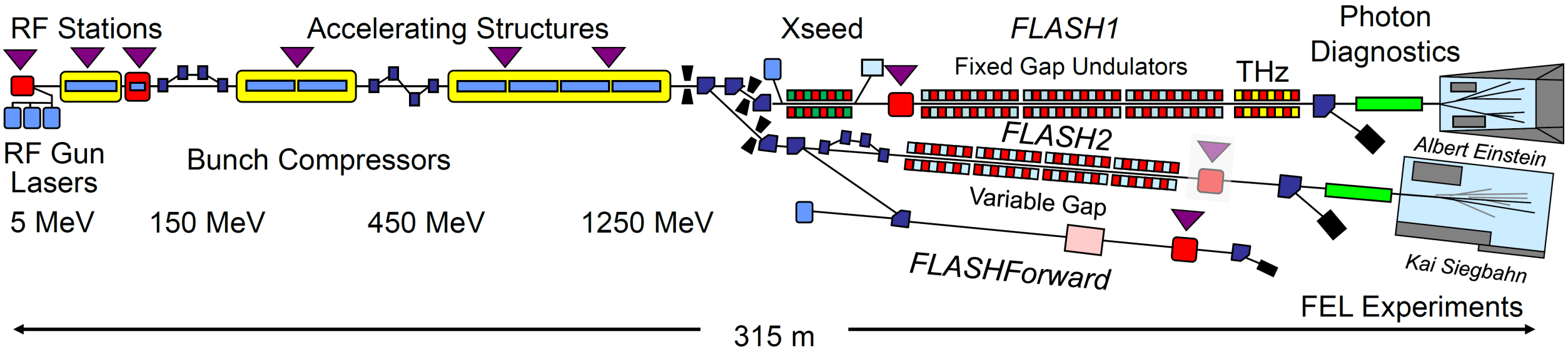
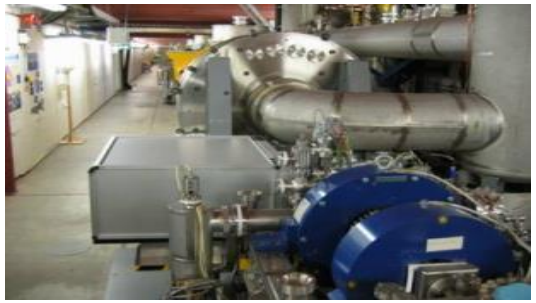
4 Summary

1 Introduction

The FLASH Facility at DESY, Hamburg

(**F**ree electron **LA**Ser in **H**amburg)





Normal conducting 1.3 GHz RF gun

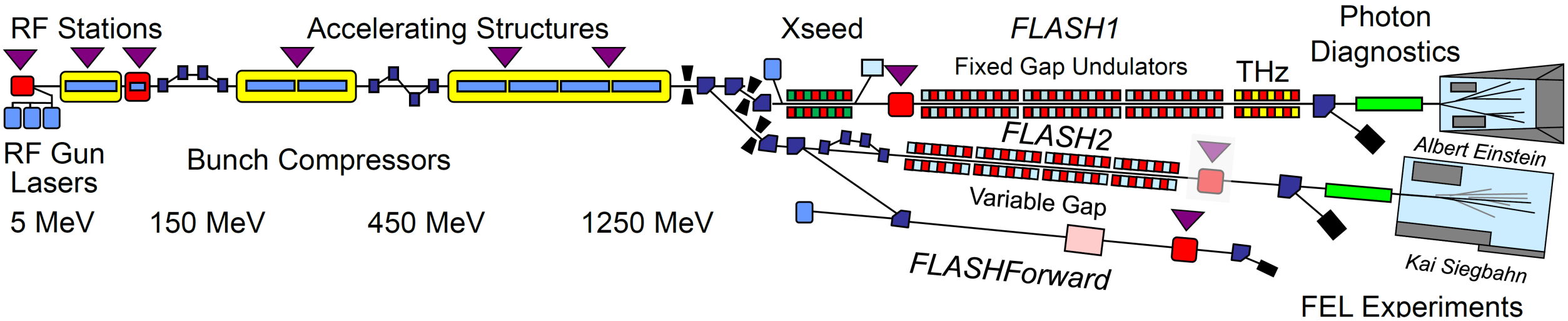
TESLA type superconducting accelerating modules 1.3 GHz

undulators

flash.desy.de
K. Honkavaara et al., FEL2022, MOP37

1 Introduction

FLASH main parameters



Parameter	FLASH1	FLASH2	Units
Electron beam:			
Beam energy	0.38 - 1.25		GeV
Normalised emittance (rms)	0.5 - 1.0		mm.mrad
Bunch charge	0.1 - 1.2	0.02 - 1	nC
Bunches per second	≤ 5000		
Photon beam:			
Wavelength	51 - 4.2	90 - 4	nm
Pulse duration (FWHM)	<30 - 200		fs
Pulse energy	1 - 500	1 - 1000	mJ

flash.desy.de
M. Vogt et al., IPAC'22, TUPOPT005

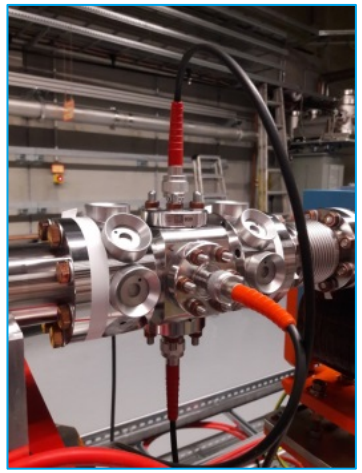
Currently major upgrade of facility

L. Schaper et al., FEL2022, TUP51

1 Introduction

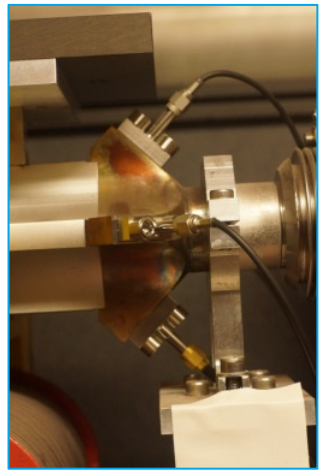
Beam Position Monitors in FLASH

- Various types of BPMs:
  button, stripline and cavity BPMs
  - Each type in several designs
- Here are only a few examples:



Button BPM

Pickup: D. Lipka et al., DIPAC2011, p. 83
Readout: B. Lorbeer et al., IPAC18, p. 072011

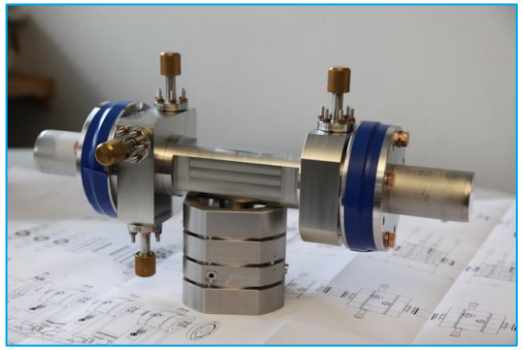


Stripline BPM

Pickup: D. Noelle et al., BIW 2004, p. 166
Readout: B. Lorbeer et al., IPAC18, p. 072011

System	Electronics Type	# (2022)	Location
Button BPMs	FLASH	ca. 40	All
Stripline BPMs	FLASH	ca. 35	All
Cavity BPMs	E-XFEL	ca. 20	FL2, FLFwd
Cold Cavity BPMs	TTF2	4	Linac
Magnetic BPMs	FLASH	2	FL1, FL2

Cavity BPMs



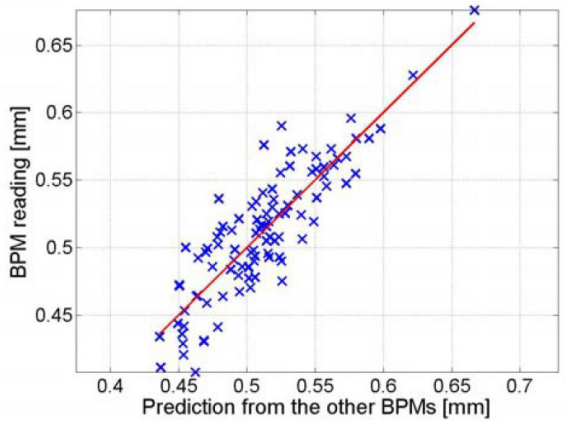
Pickup and readout:
D. Lipka et al., IBIC 2014, p. 315

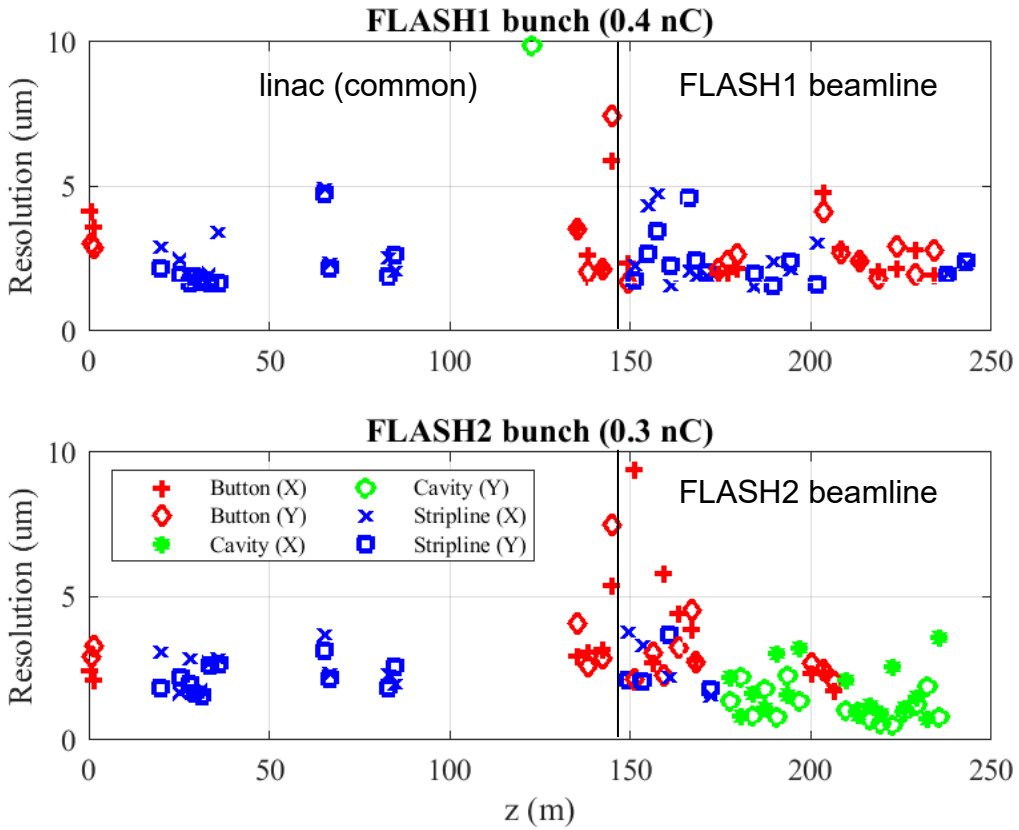
1 Introduction

RMS BPM resolution

- Linear correlation among all the BPMs → prediction
  - $Resolution = \sqrt{\frac{1}{n}\sum\left(x_i - x_{pred,i}\right)^2}\ rms$

N. Baboi et al., BIW2006, p. 227





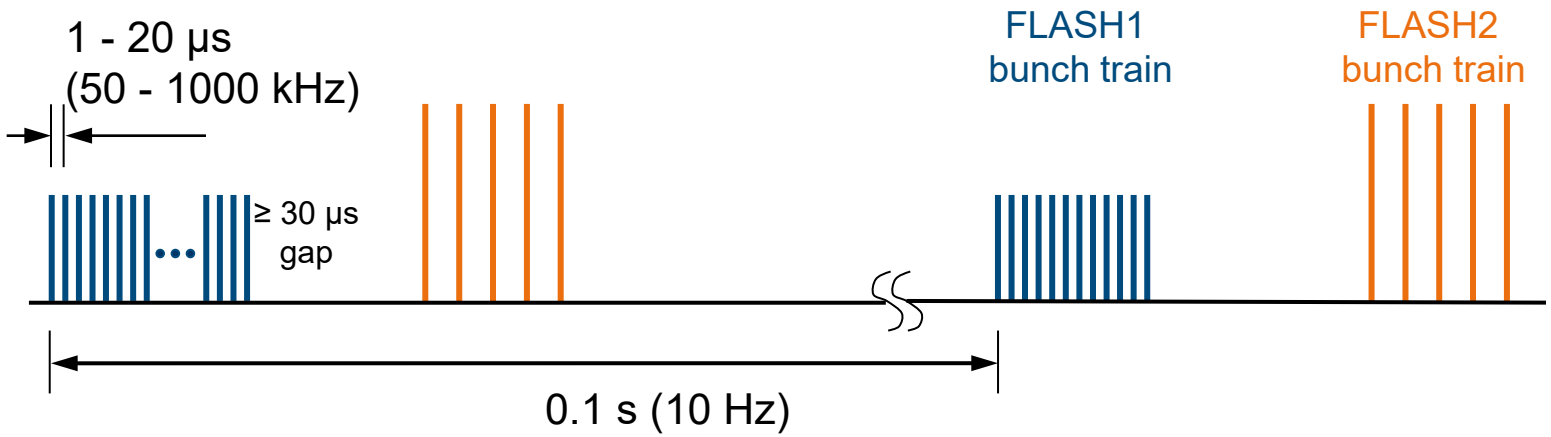
Typical BPM parameters

BPM-type	Charge [nC]	Offset [% diam.]	Single-bunch resolution [µm rms]
Button	0.02-1	ca. 30%	3-100
Stripline	0.01-1	ca. 30%	2-15
Cavity	0.01-1	ca. 10%	1-3
Cold cavity	0.4-1.5	ca. 20%	20-100

1 Introduction

Scope of this paper

- Only the first bunch has been analyzed before
- Bunch trains are accelerated
  - 10 Hz train repetition freq.
  - 50 – 1000 kHz bunch freq. within the train



- The BPMs have to measure each bunch
  - Here we analyze each bunch in long bunch trains
  - Same method applied as for single bunch pulses

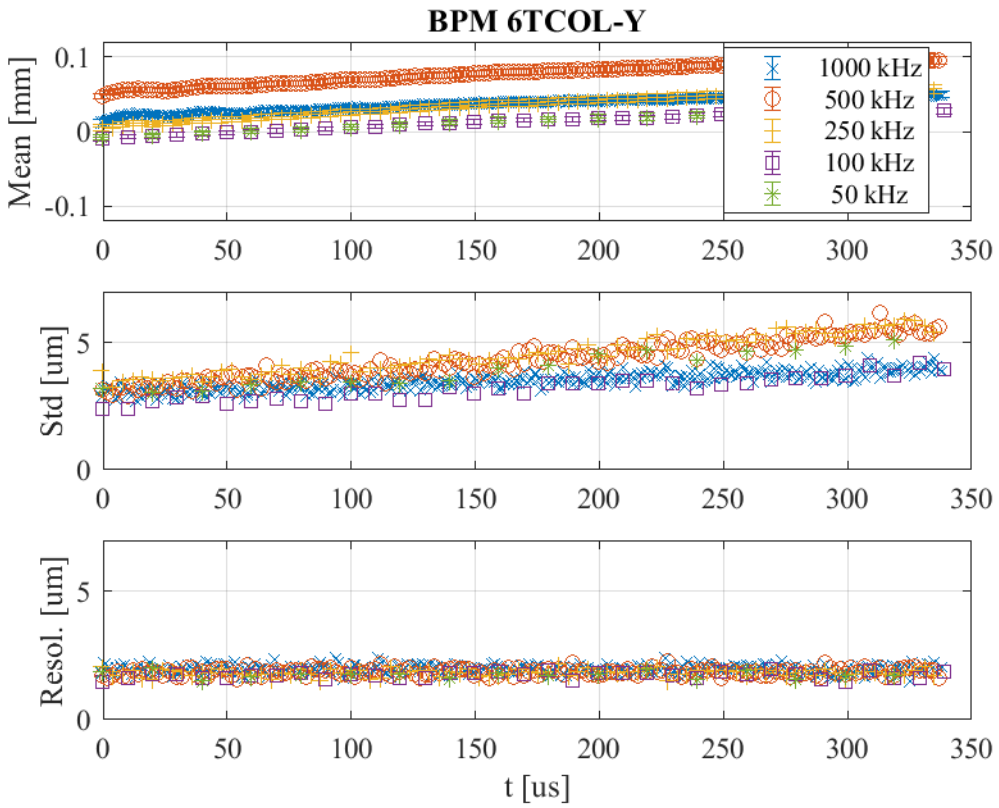
- Will show results for measurements of the FLASH1 bunch train, for **button and stripline BPMs**

2 Beam position resolution along the bunch train

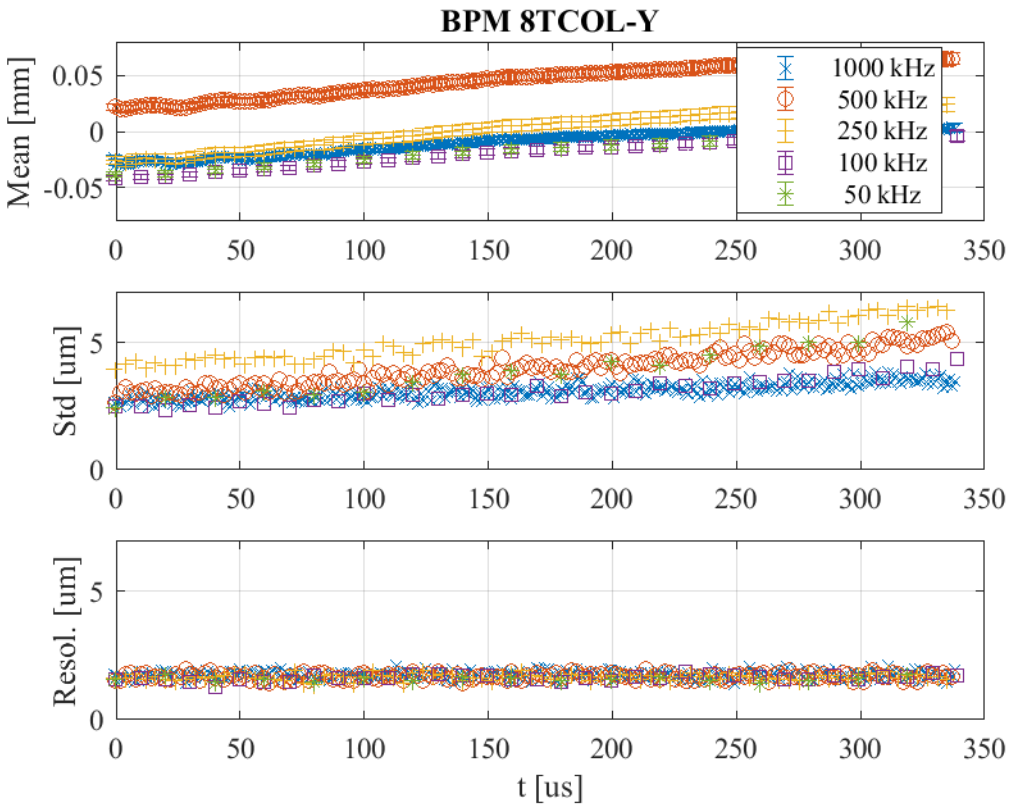
Mean, standard deviation and resolution for button and stripline BPMs

- 200 bunch trains measured; 0.2 - 0.4 nC/bunch
- Various bunch frequencies

Button BPM, 34mm diameter



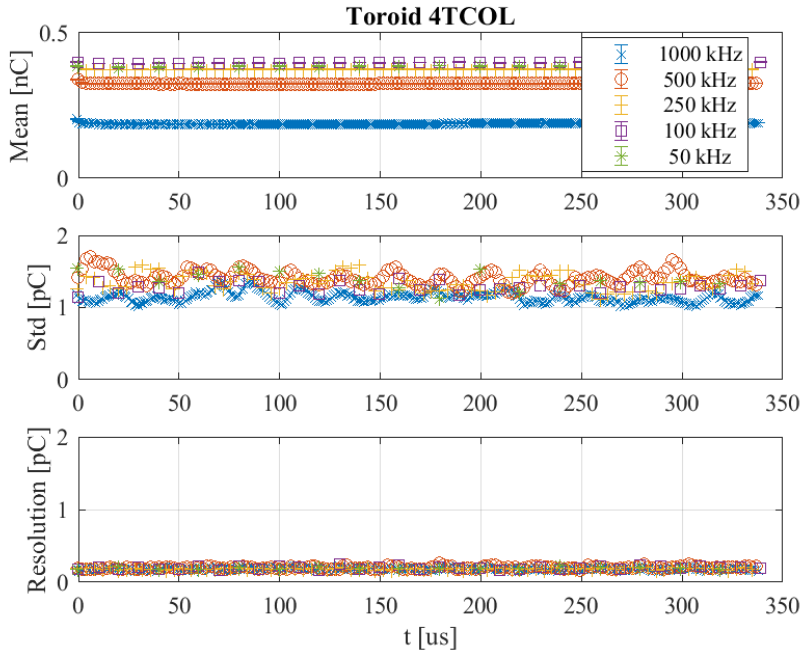
Stripline BPM, 34mm diameter



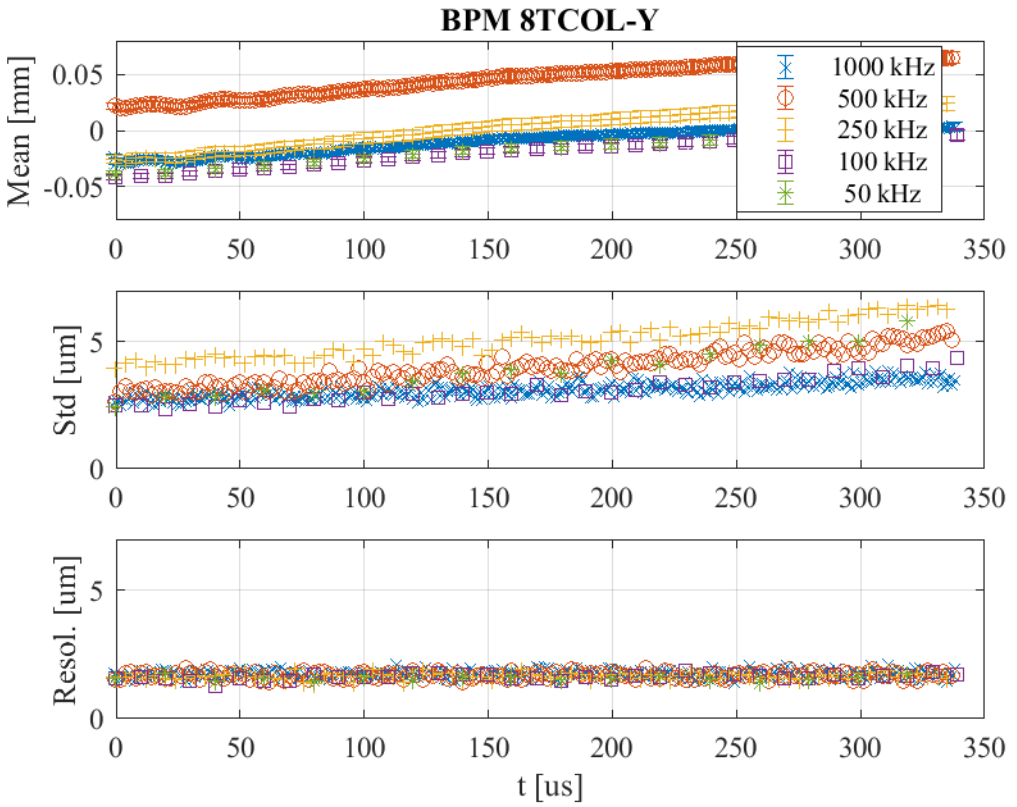
2 Beam position resolution along the bunch train

Button and stripline BPM: Remarks

- Different beam offsets for various bunch frequencies
- Variation of mean BPM reading along the train, as well as for its standard deviation
- Different bunch charge for different bunch frequencies



Stripline BPM, 34mm diameter



- **Constant position resolution for all bunches in the train, for all frequencies**

(Plots from previous slide)

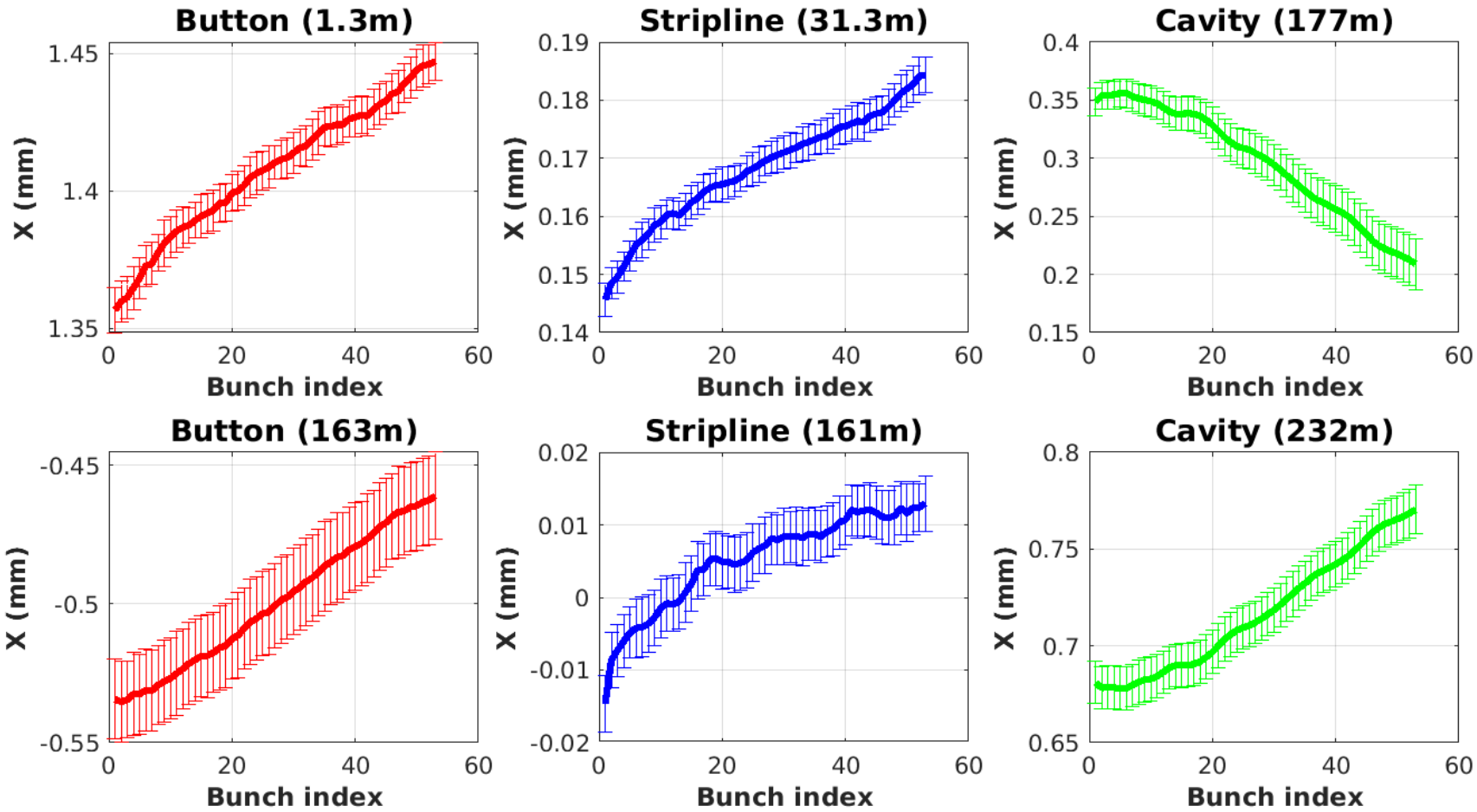
2 Beam position resolution along the bunch train

Beam position reading from various BPM types

- Data set for FLASH2 bunch
- 53 bunches for FLASH2
- 100 kHz, 0.1 nC

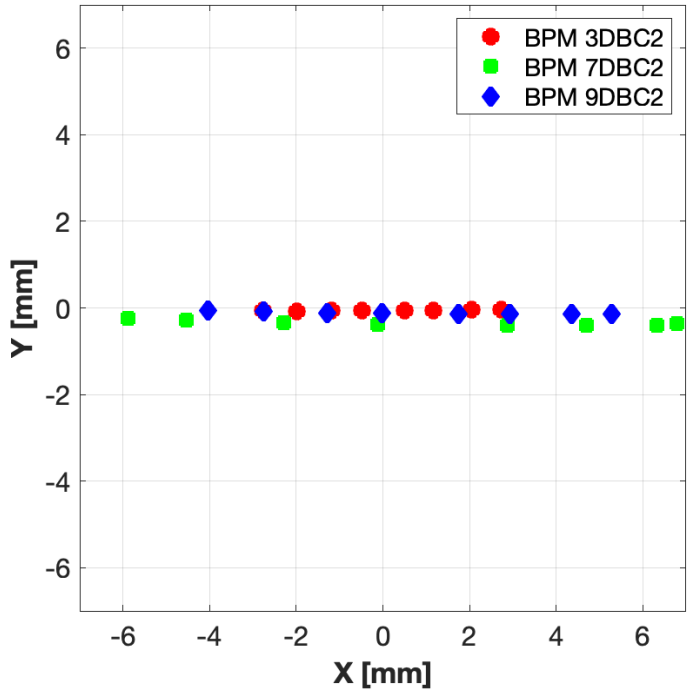
- Button and stripline BPMs
  → FLASH readout

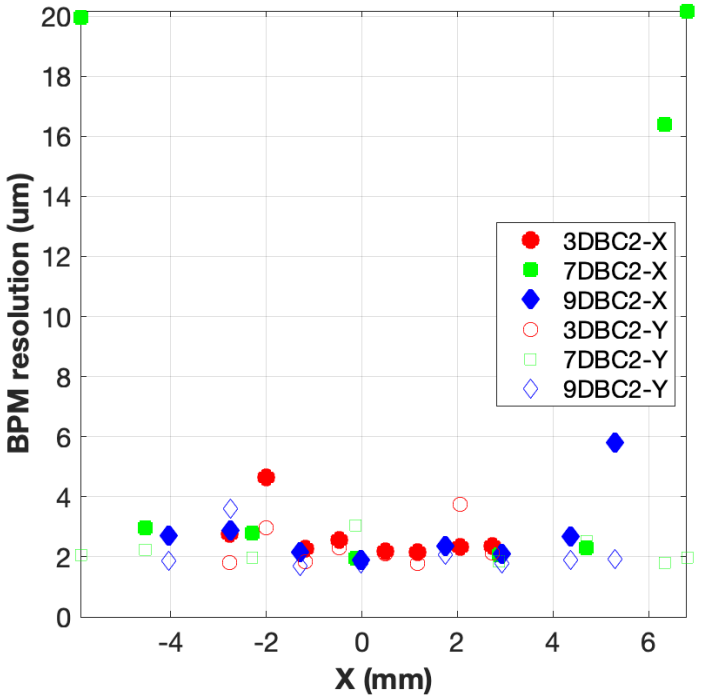
- Cavity BPMs
  → XFEL-type electronics



3 Beam position resolution versus bunch offset

Stripline BPMs





- Charge: ca. 0.4 nC
- The resolution stays below 4 µm rms for beam offsets < ±4 mm (beam pipe: ø34 mm)

Dependency on charge is shown in *B. Lorbeer et al., IPAC2018, WEPAF049*

4 Summary

- Many types of BPMs in FLASH: we give results for button and stripline BPMs
  - Single bunch resolution
    - Stripline BPMs: typically 2-15 µm for charges of 0.01-1 nC
    - Button BPMs: typically 3-100 µm for charges of 0.02-1 nC

- Long bunch trains:
  - The bunch offset changes along the train, also the standard deviation
    - The reason still needs to be understood
  - The single bunch resolution remains constant for all the bunches along the pulse

- The single bunch resolution for stripline BPMs is below 4 µm for beam offsets within ±4 mm

Acknowledgment

Many colleagues from the diagnostics and other groups have contributed directly or indirectly to this talk, by their work or through fruitful discussions.

We appreciate the support of the FLASH operators for making these measurements.

Thank you