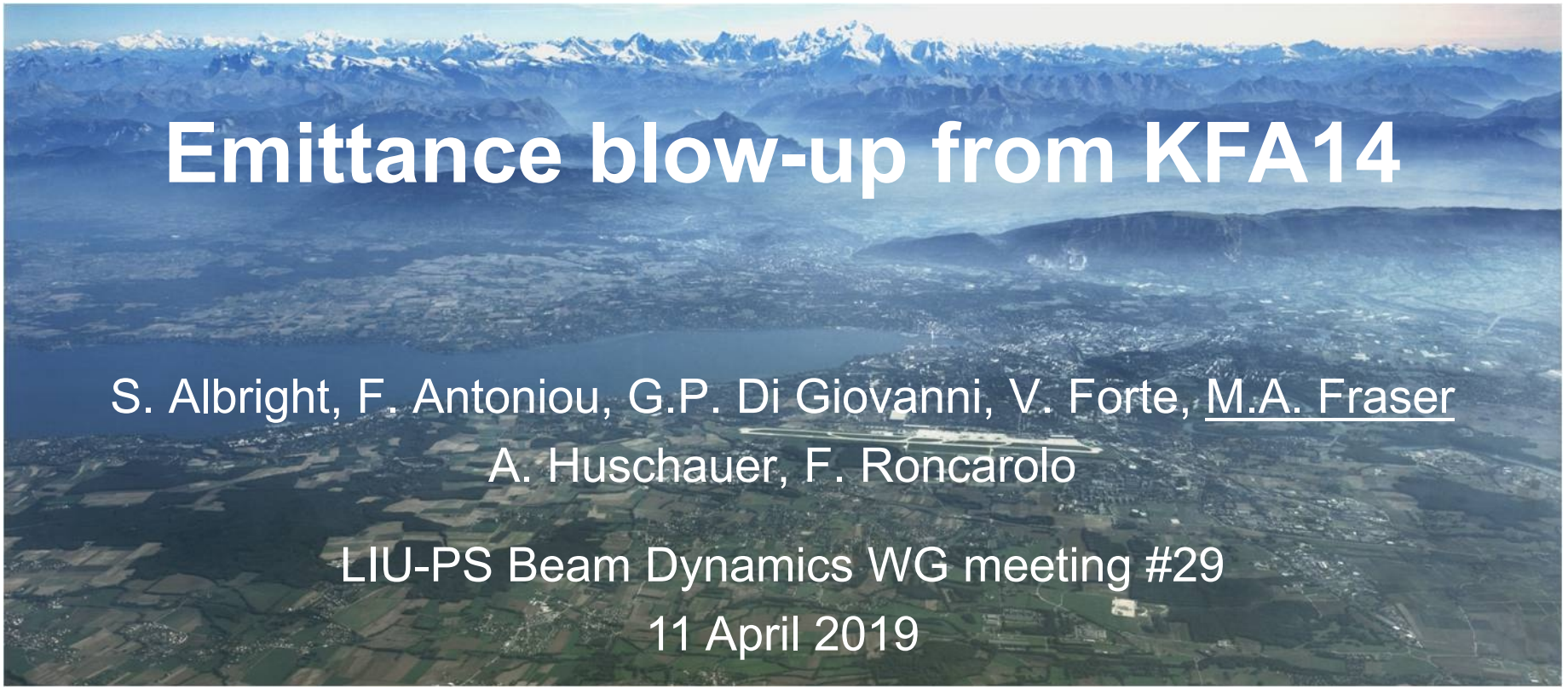
LHC Injectors Upgrade

CERN



LHC Injectors Upgrade

Emittance blow-up from KFA14

S. Albright, F. Antoniou, G.P. Di Giovanni, V. Forte, M.A. Fraser
A. Huschauer, F. Roncarolo

LIU-PS Beam Dynamics WG meeting #29
11 April 2019

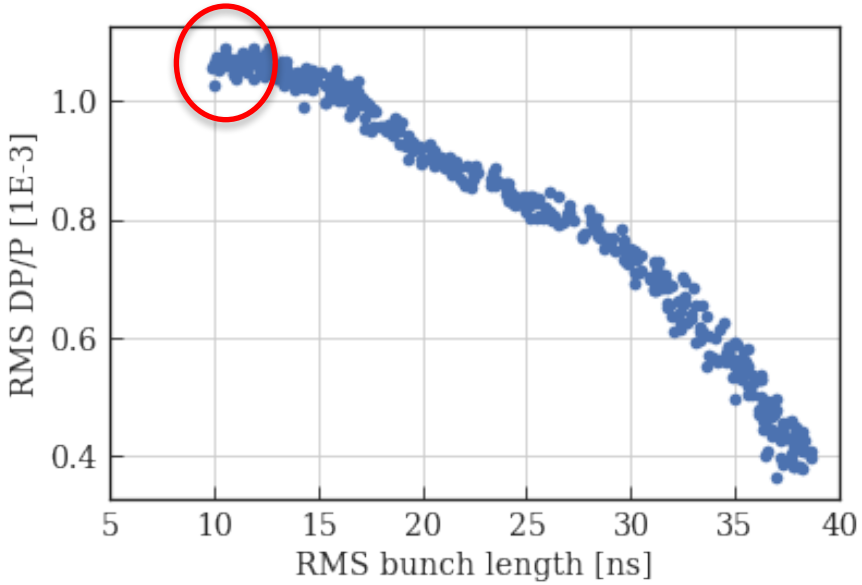
CERN

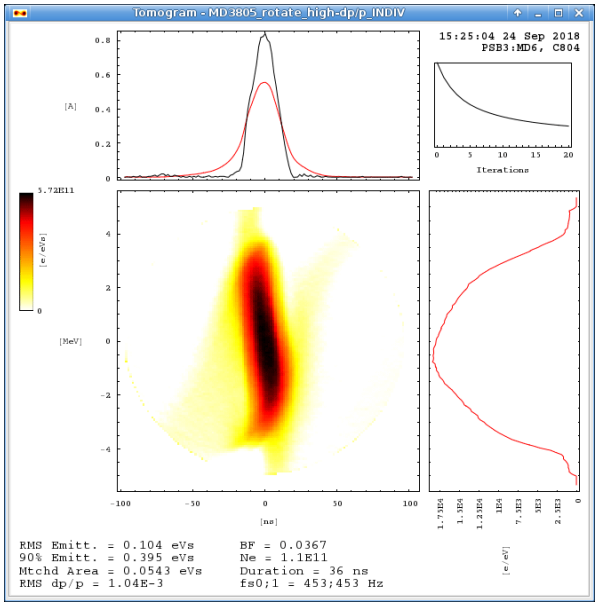
Contents

- **Motivation and technique**
  - For more details see presentation here on 27th September 2018
- **Expected emittance blow-up:**
  - BCMS Operational (0.9 eVs) and MD (1.5 eVs)
  - LIU BCMS and Standard
- **Measured impact on beam size at BTM.SGH2**
  - Short LHC INDIV (40 ns)
  - BCMS Operational (0.9 eVs) and MD (1.5 eVs)
- **Conclusion**

Motivation and technique

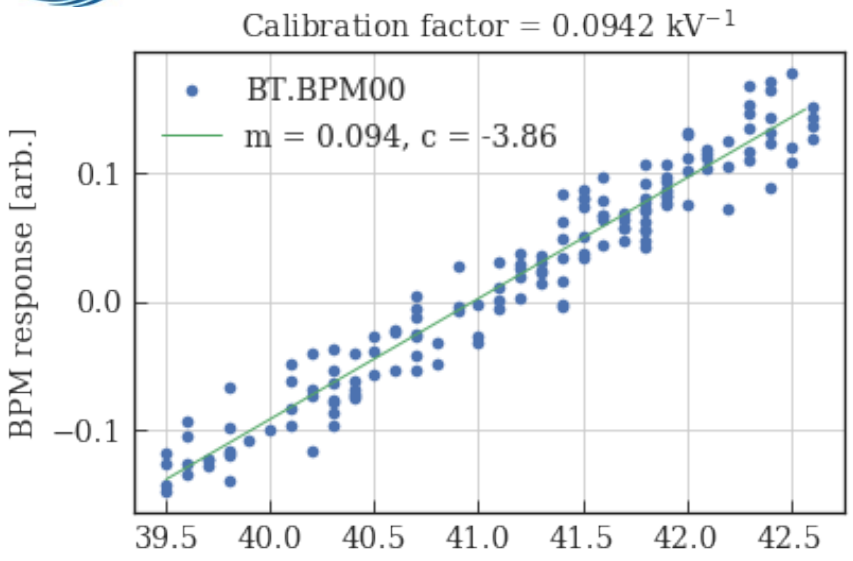
- **Another attempt to understand the source of H emittance blow-up on LHC beams at PS injection:**
  - Adjust KFA14 fine delay, measure beam movement downstream
- **Exploiting the short INDIV bunches: with bunch rotation before extraction (10 ns RMS bunch length) to probe the KFA14 waveform**

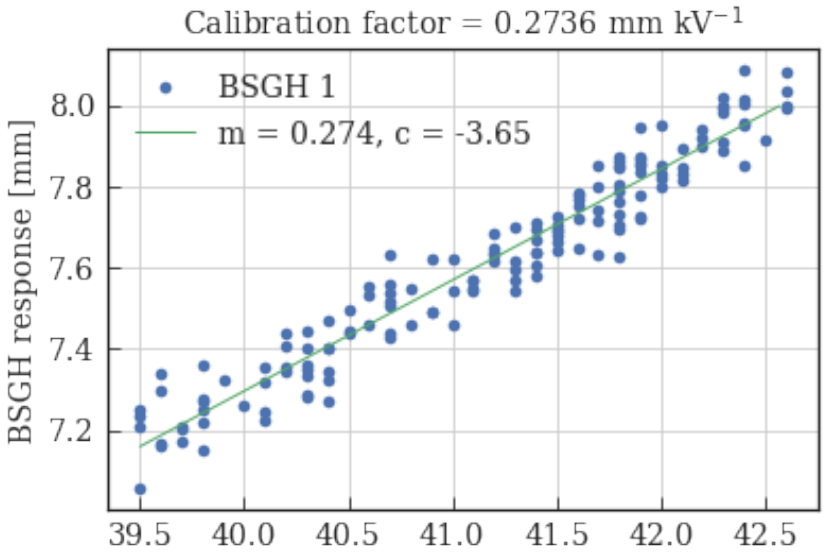


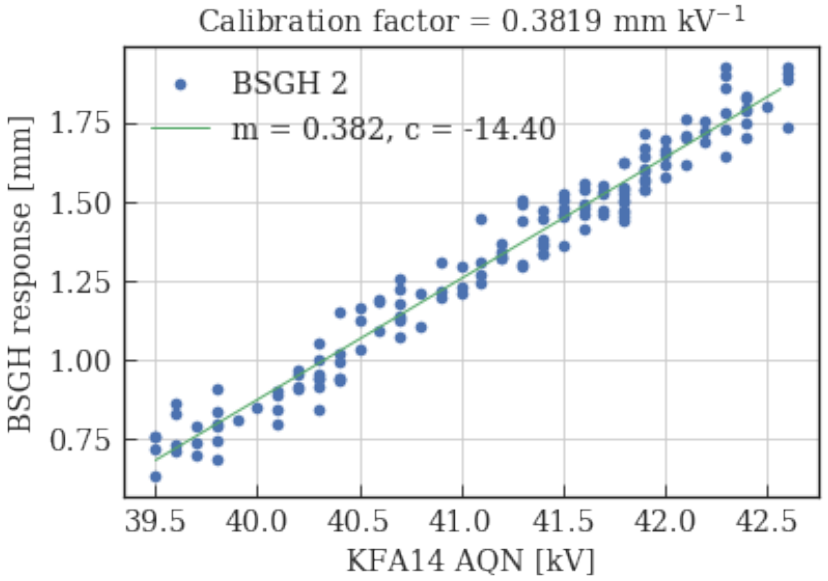


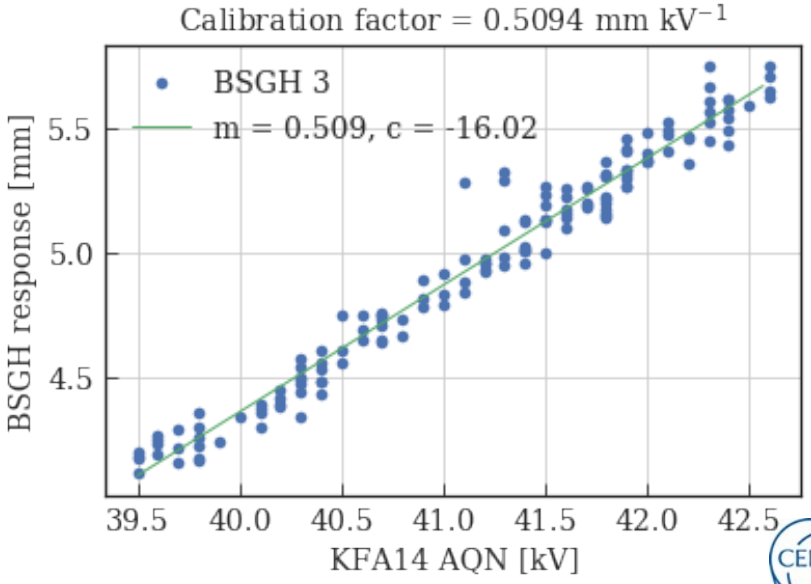
E.g. BT.3.KFA14L1 calibration

Reference values:
V_{AQN} = 41.2 kV
V_{CCV} = 41.0 kV



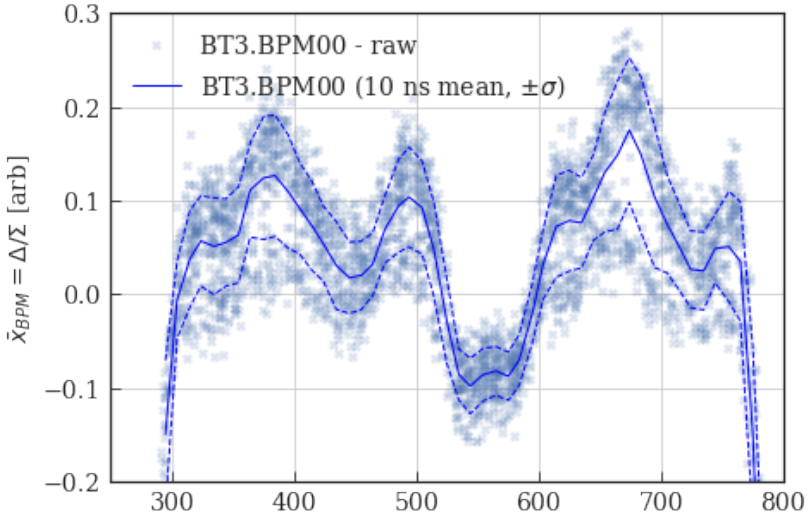


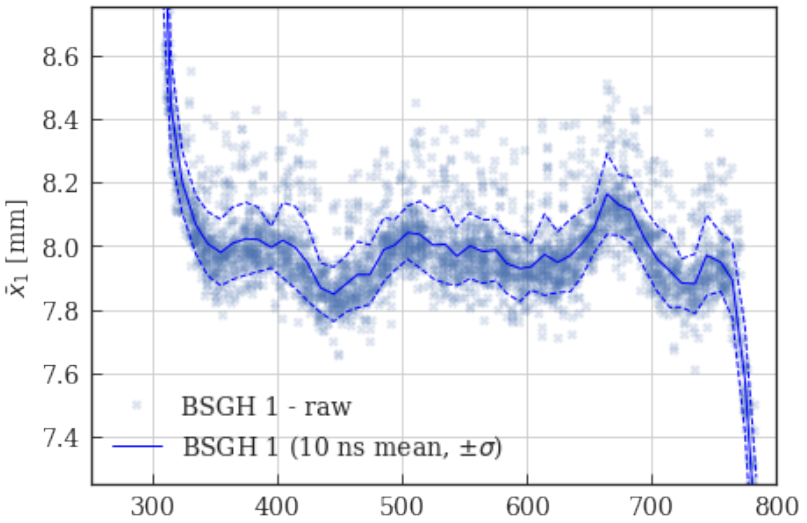


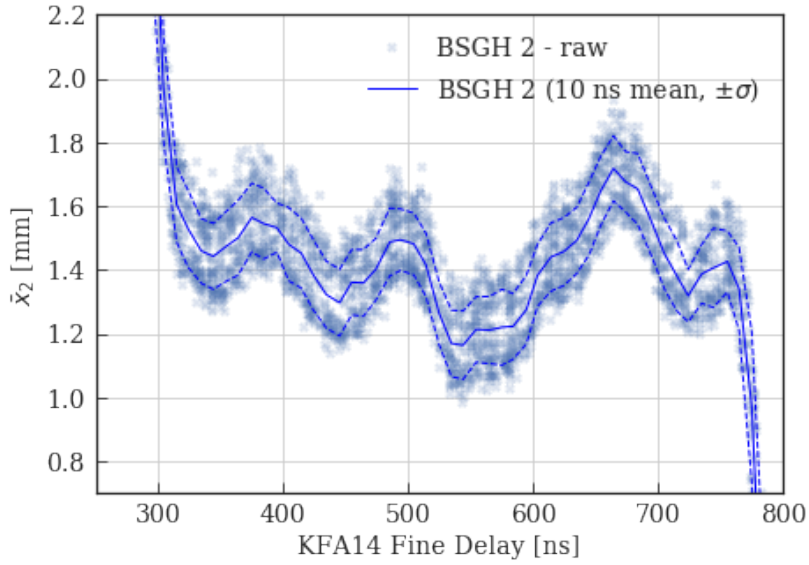


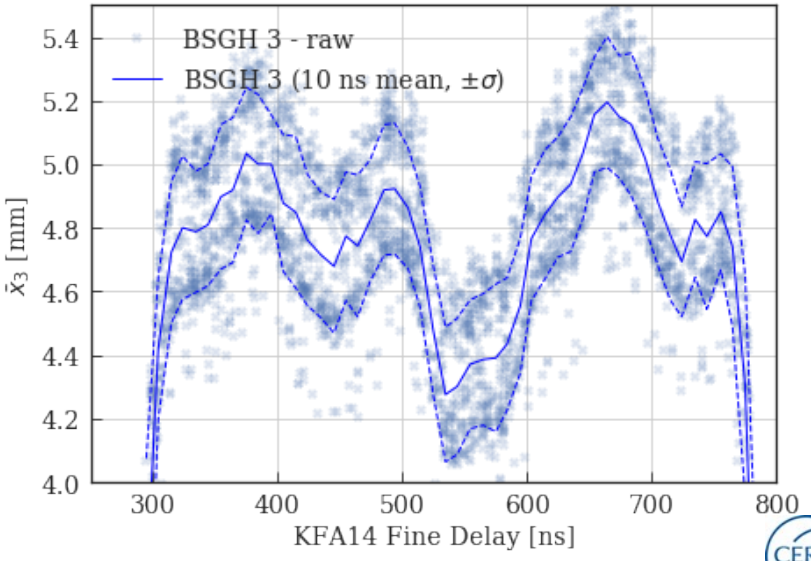
E.g. R3 measurement results

Constant scale on plots at 1.5 mm

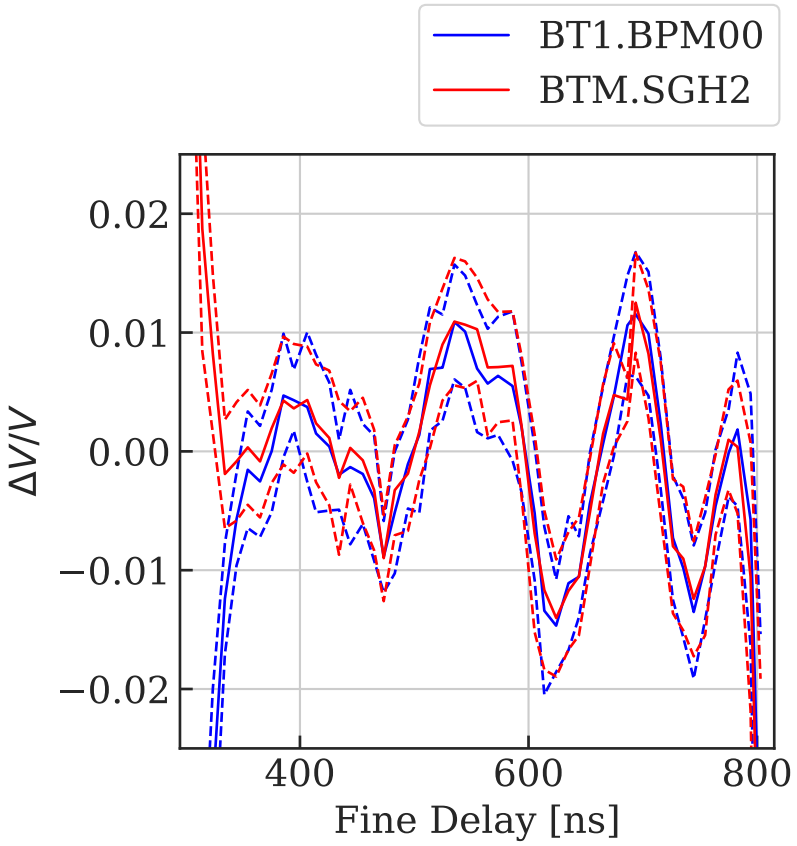


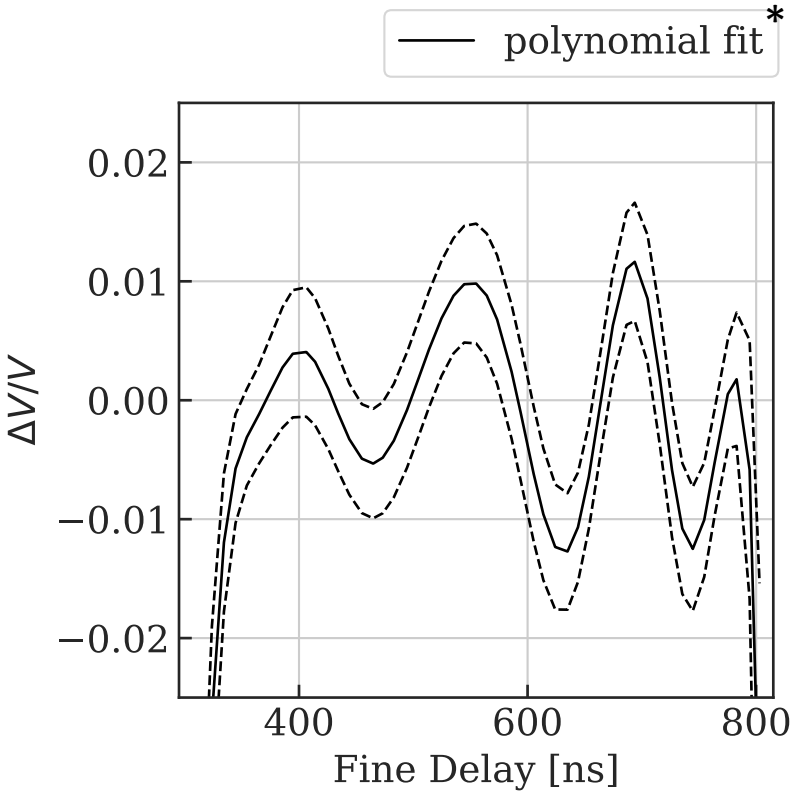






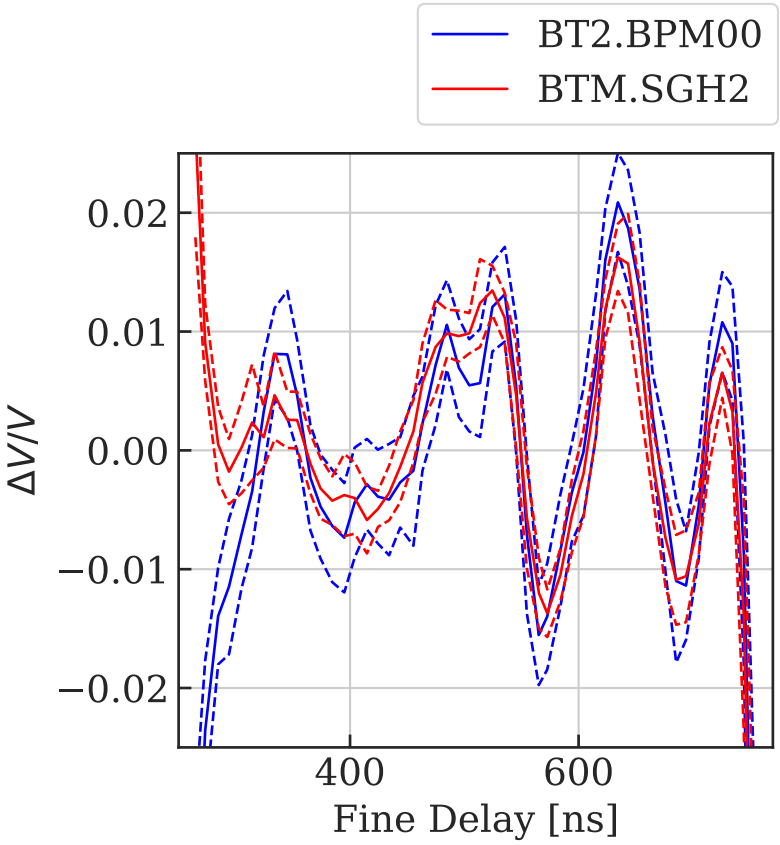
R1 waveform measurement results

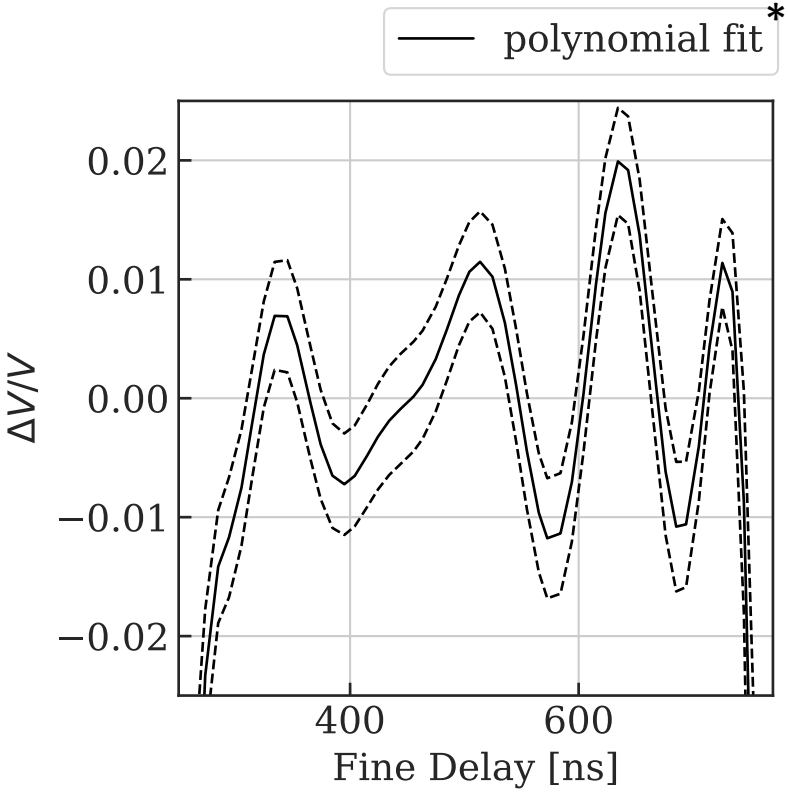




*Polynomial fit at 20th order used to simulate and predicted the expected emittance blow-up using a particle distribution

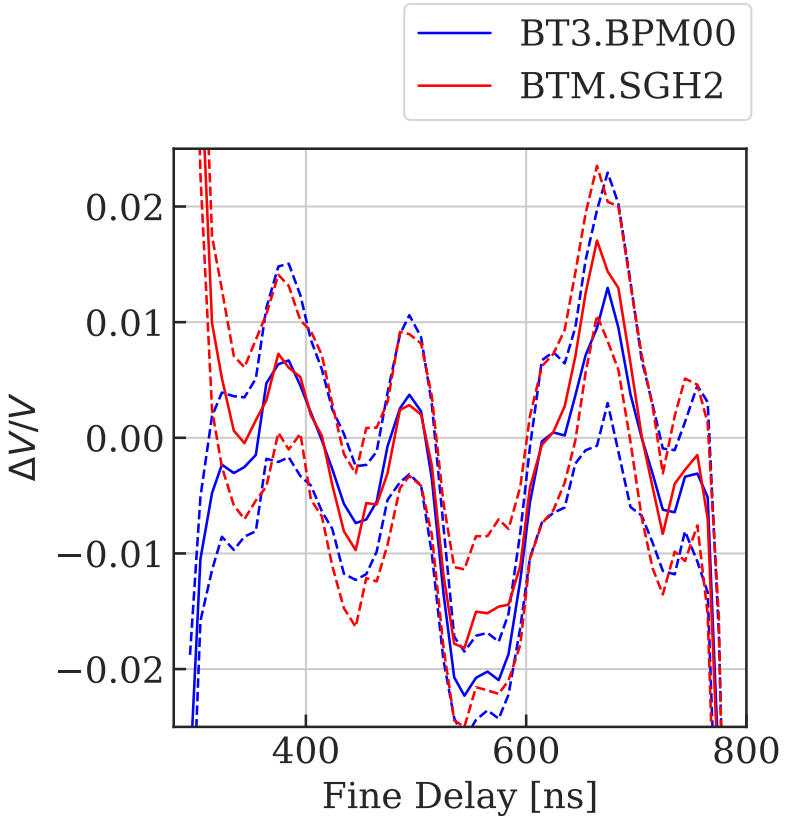
R2 waveform measurement results

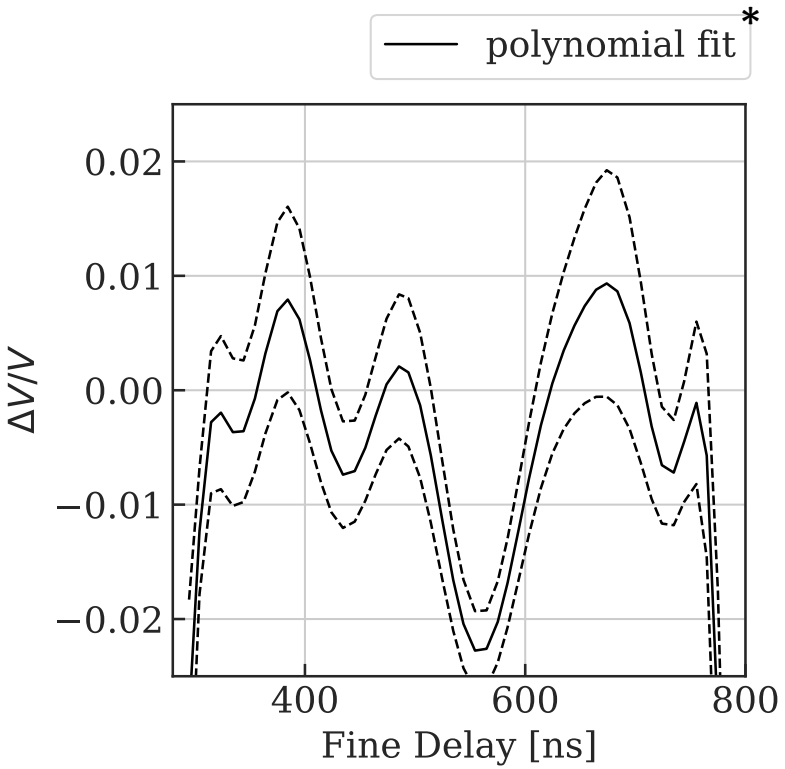




*Polynomial fit at 20th order used to simulate and predicted the expected emittance blow-up using a particle distribution

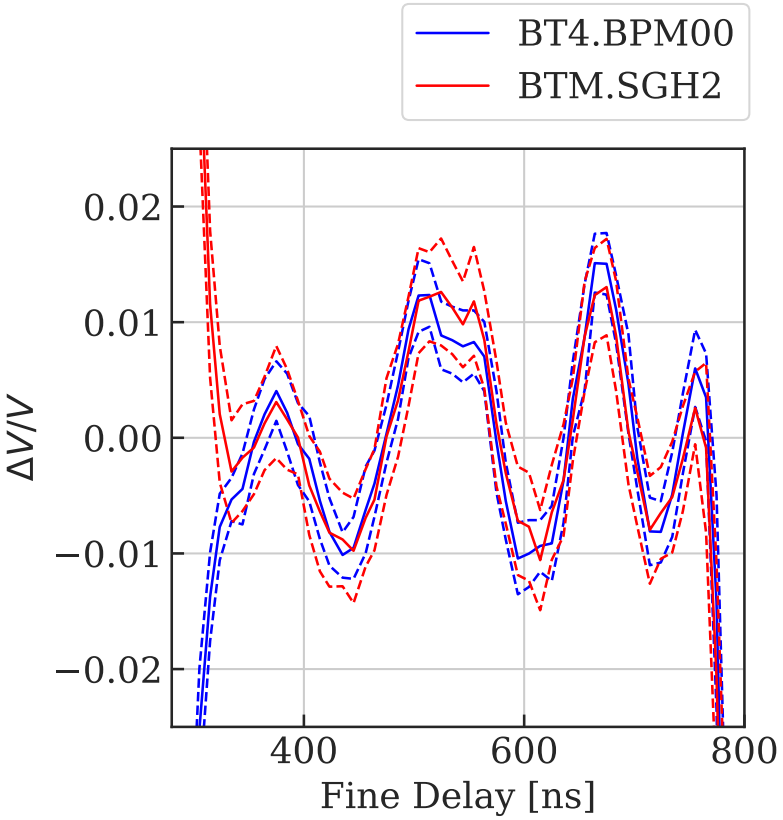
R3 waveform measurement results

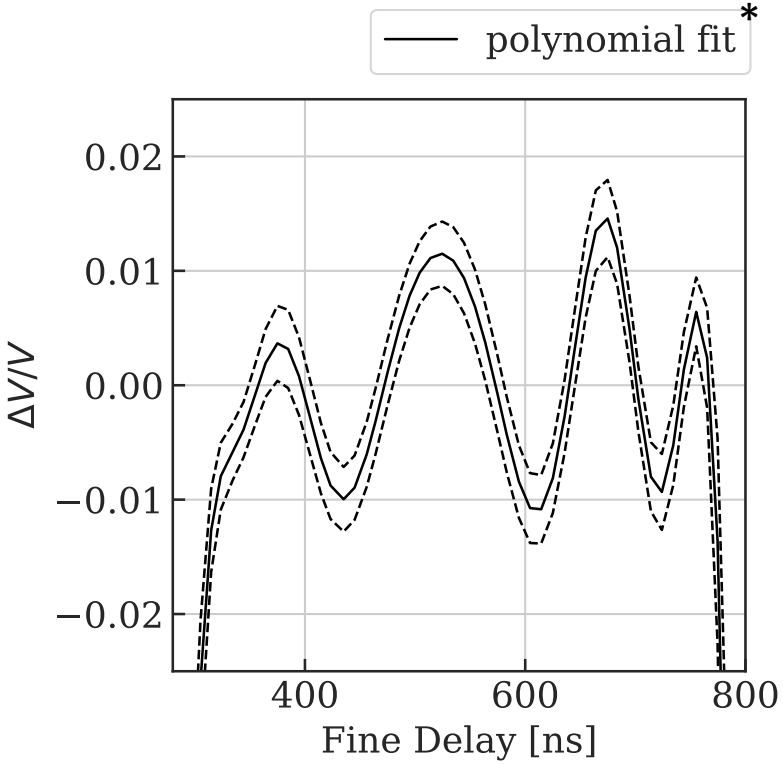




*Polynomial fit at 20th order used to simulate and predicted the expected emittance blow-up using a particle distribution

R4 waveform measurement results





*Polynomial fit at 20th order used to simulate and predicted the expected emittance blow-up using a particle distribution

LHC and LIU beam parameters considered

	LHC beam type	E [GeV]	I [10^{11} ppb]	$\varepsilon_{x,n}$ [mm mrad]	ε_z [eV s]	$4\sigma_t$* [ns]
Achieved	Operational BCMS	1.4	7.50	1.0	0.9	145
	MD BCMS	1.4	7.50	1.1	1.5	155
Targeted	LIU BCMS	2.0	16.25	1.4	1.5	135
	LIU Standard	2.0	32.50	1.8	3.0	205

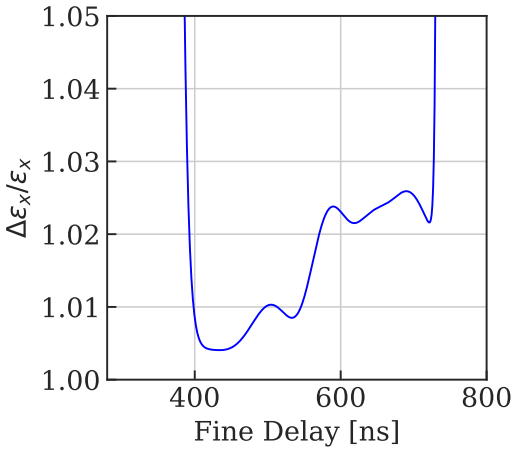
*Parabolic longitudinal distribution ($\propto 1 - t^2$) was simulated and the RMS matched to the values in the table

Location	α	β [m]	$\Delta\mu$ [2π]	D_x [m]
BT*r*.KFA14L1	-0.21	5.94	0	-1.45
BTM.SGH2 (Ring 3)	0.00	1.44	1.22	0.02

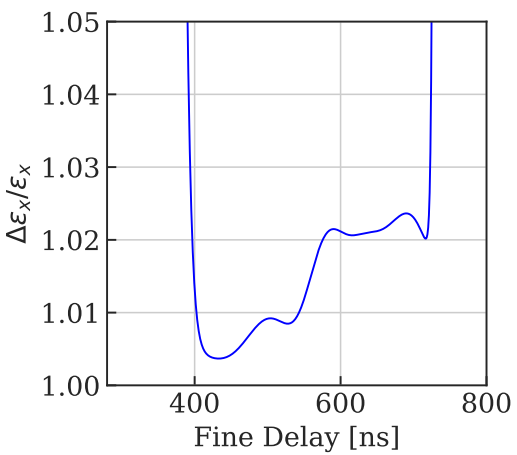
*Dispersion neglected in emittance growth estimates

BT1.KFA14L1 blow-up estimates

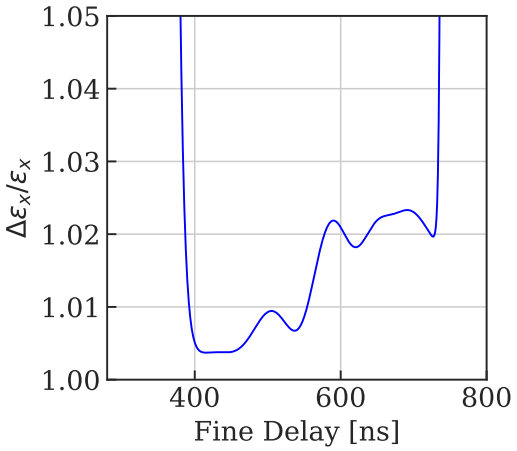
Operational BCMS (0.9 eVs)



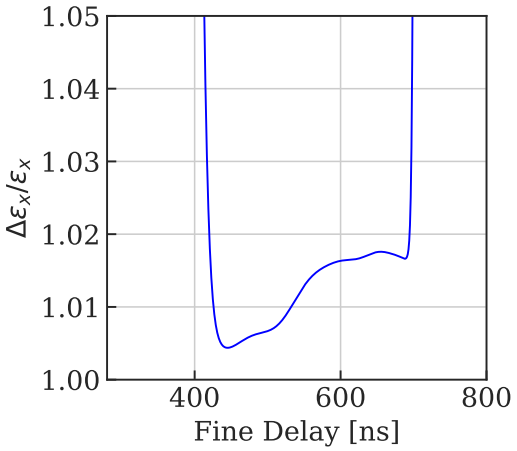
MD BCMS (1.5 eVs)



LIU – BCMS (1.5 eVs)

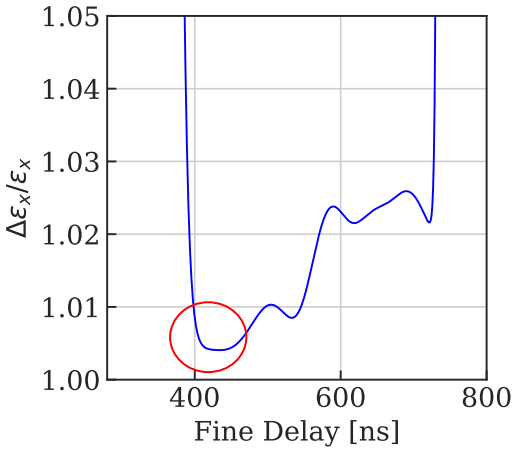


LIU - Standard (3.0 eVs)

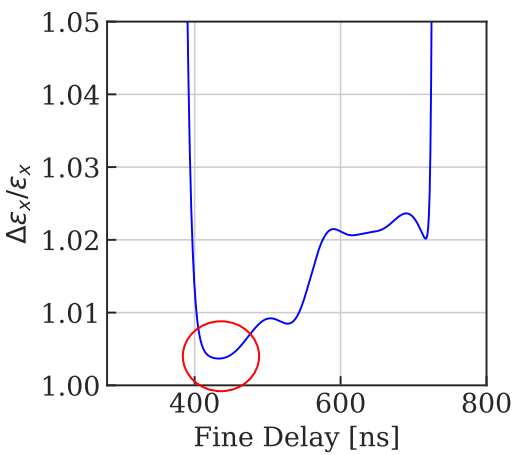


BT1.KFA14L1 blow-up estimates

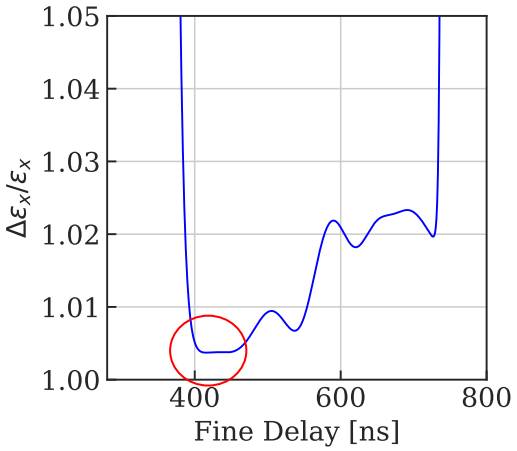
Operational BCMS (0.9 eVs)



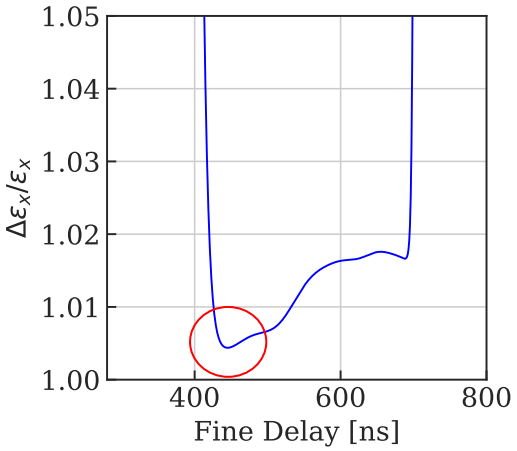
MD BCMS (1.5 eVs)



LIU – BCMS (1.5 eVs)

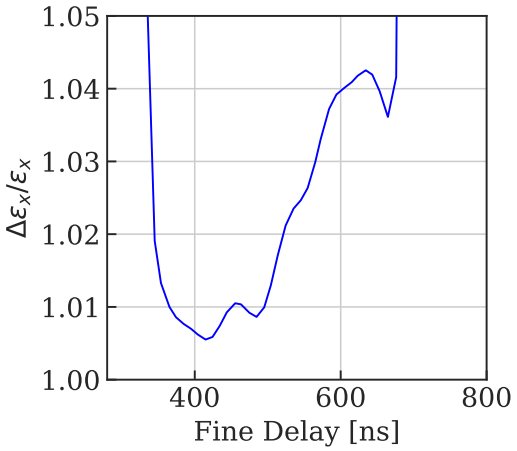


LIU - Standard (3.0 eVs)

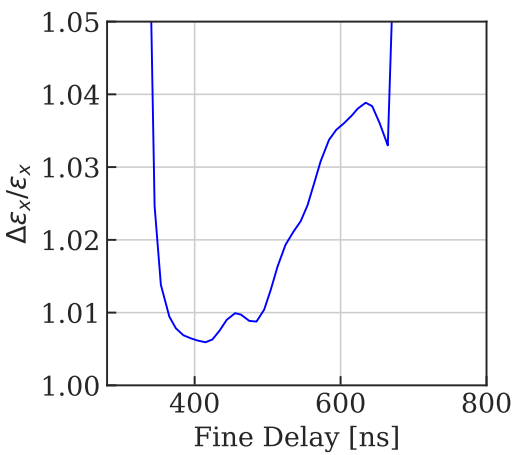


BT2.KFA14L1 blow-up estimates

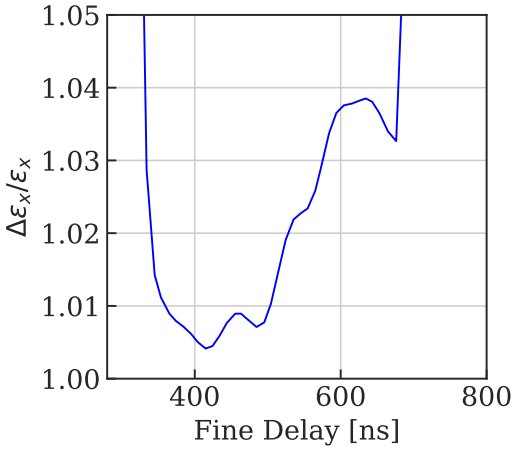
Operational BCMS (0.9 eVs)



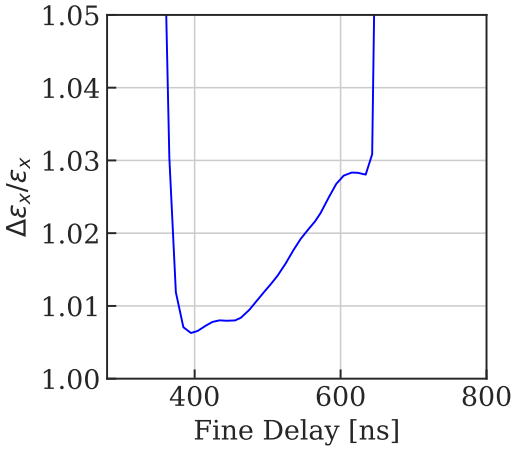
MD BCMS (1.5 eVs)



LIU – BCMS (1.5 eVs)

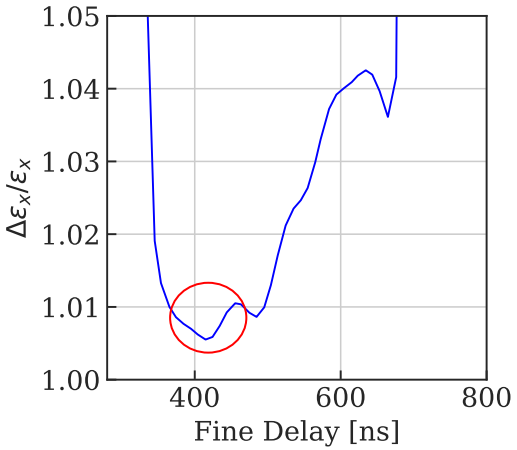


LIU - Standard (3.0 eVs)

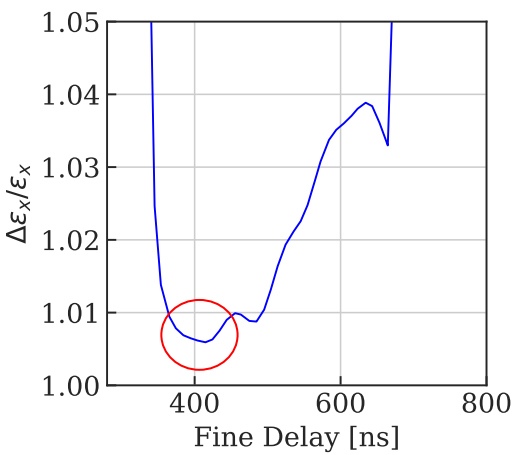


BT2.KFA14L1 blow-up estimates

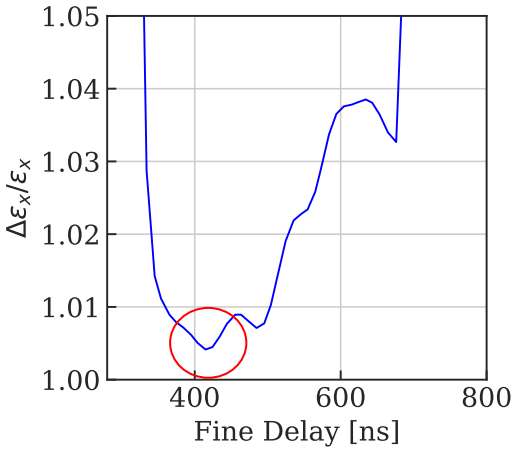
Operational BCMS (0.9 eVs)



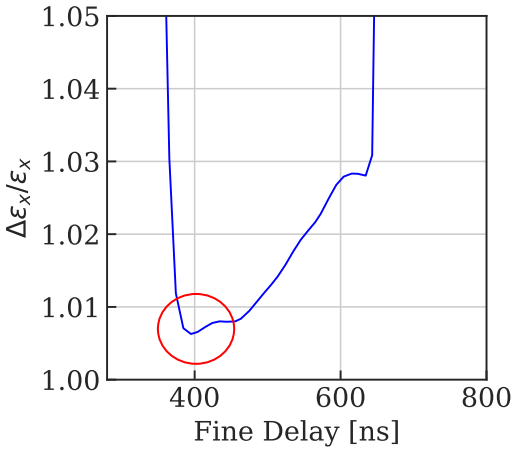
MD BCMS (1.5 eVs)



LIU – BCMS (1.5 eVs)

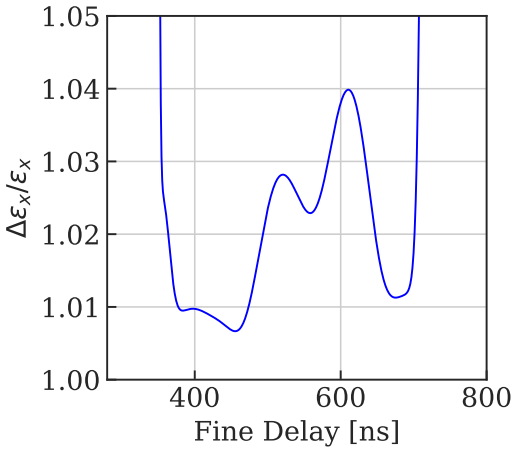


LIU - Standard (3.0 eVs)

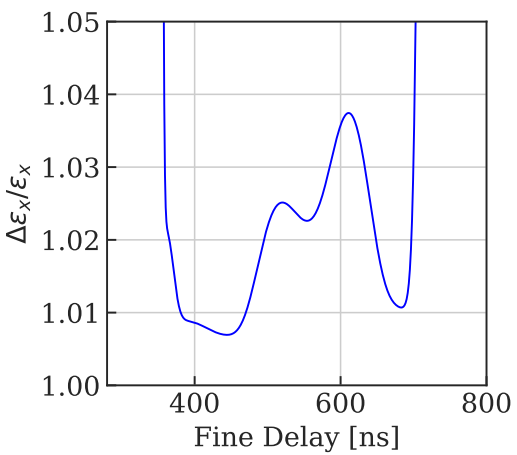


BT3.KFA14L1 blow-up estimates

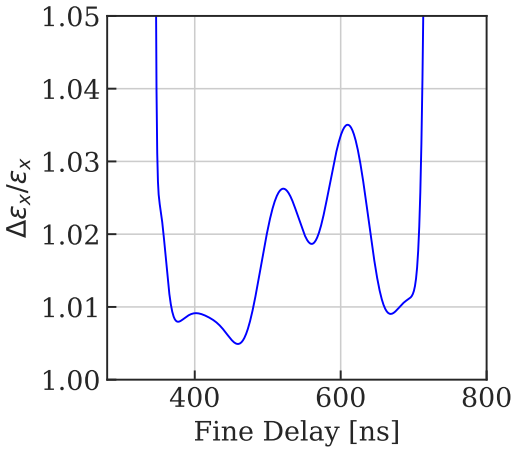
Operational BCMS (0.9 eVs)



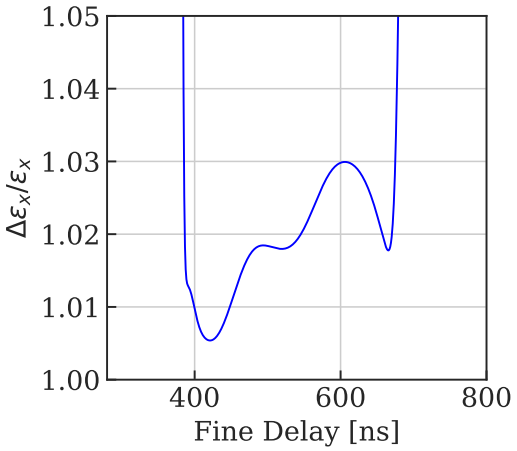
MD BCMS (1.5 eVs)



LIU – BCMS (1.5 eVs)

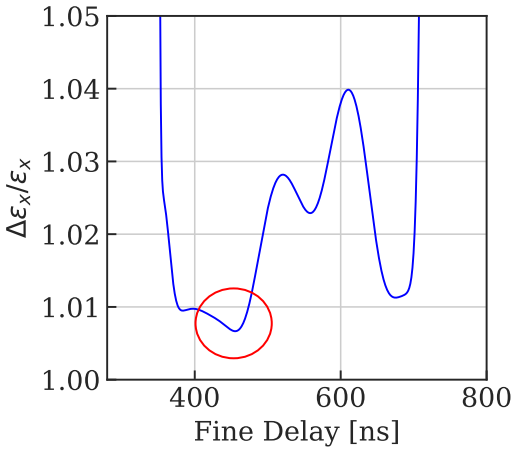


LIU - Standard (3.0 eVs)

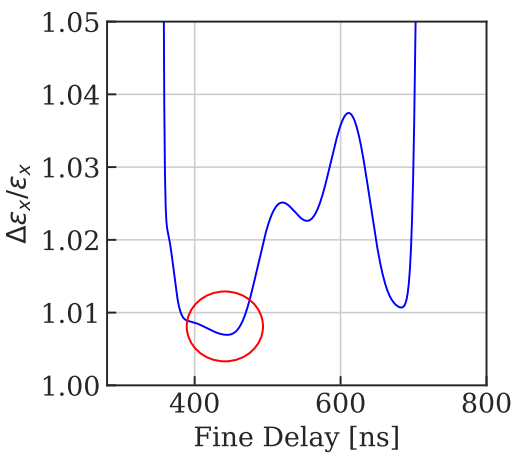


BT3.KFA14L1 blow-up estimates

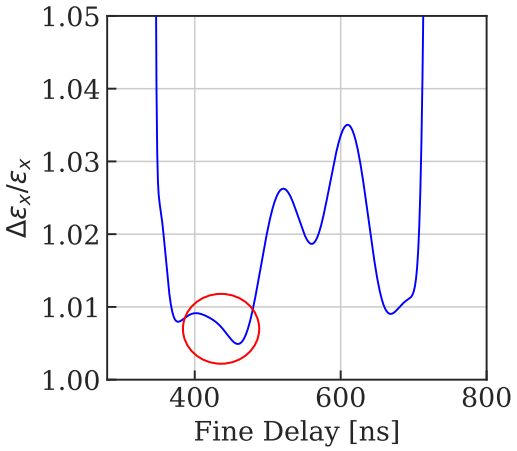
Operational BCMS (0.9 eVs)



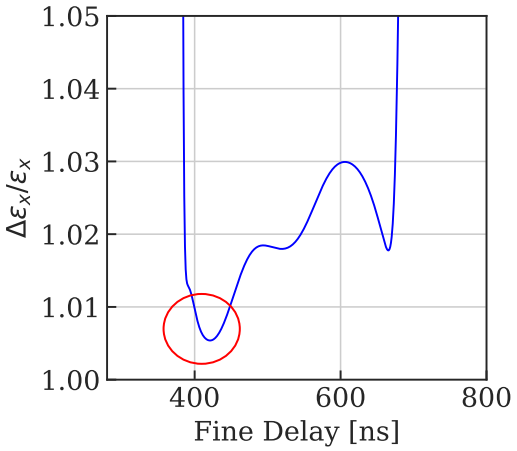
MD BCMS (1.5 eVs)



LIU – BCMS (1.5 eVs)

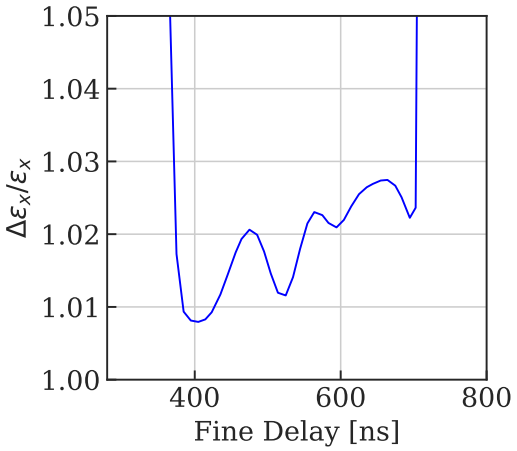


LIU - Standard (3.0 eVs)

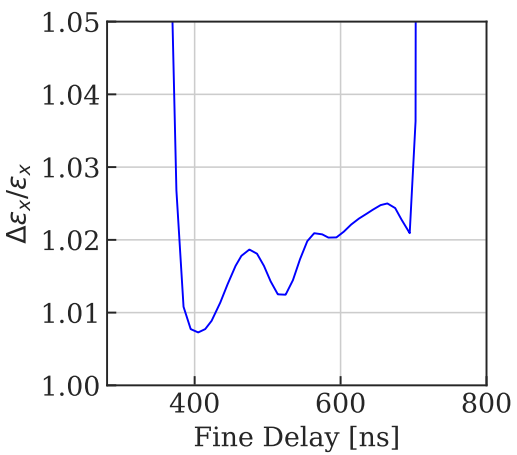


BT4.KFA14L1 blow-up estimates

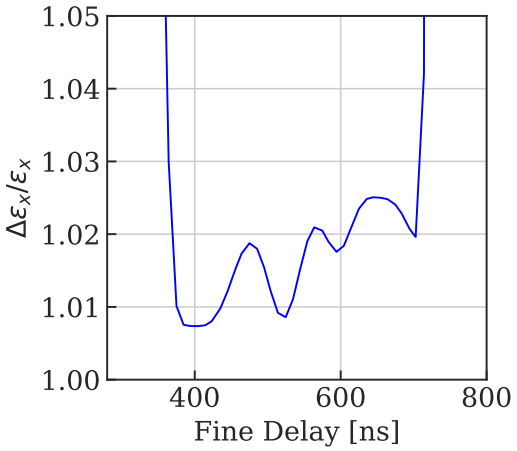
Operational BCMS (0.9 eVs)



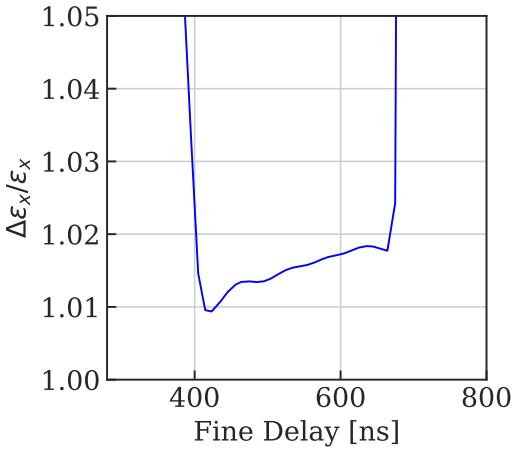
MD BCMS (1.5 eVs)



LIU – BCMS (1.5 eVs)

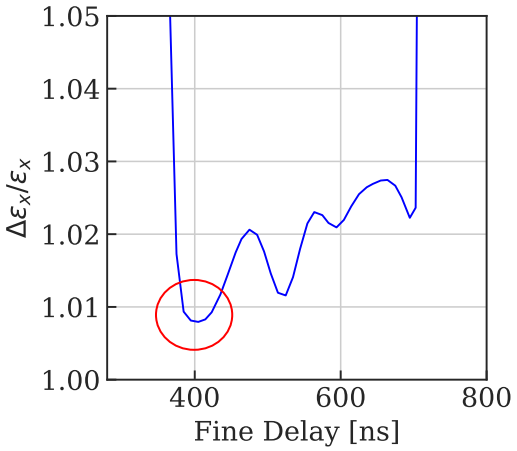


LIU - Standard (3.0 eVs)

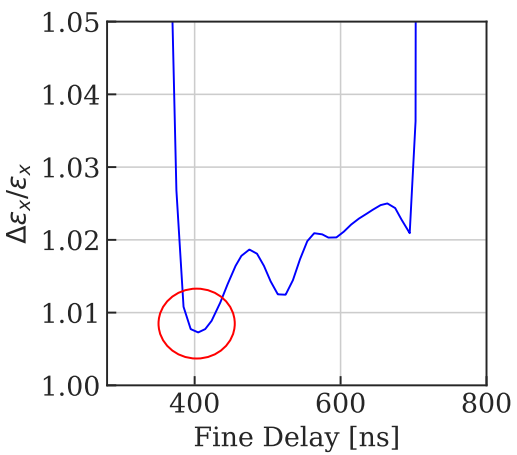


BT4.KFA14L1 blow-up estimates

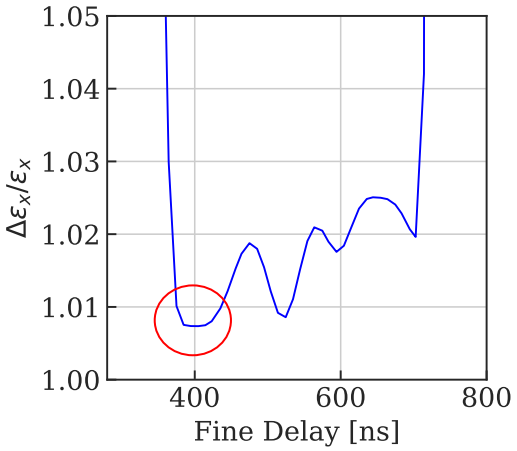
Operational BCMS (0.9 eVs)



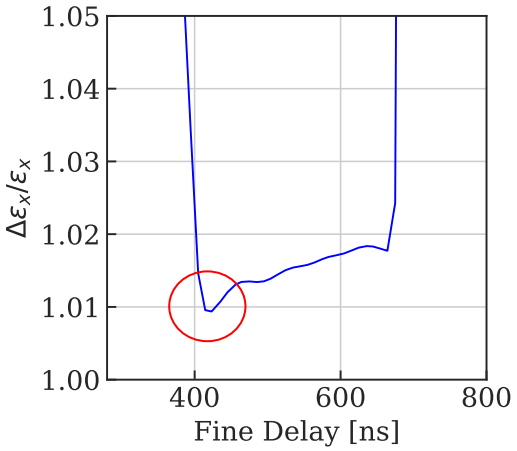
MD BCMS (1.5 eVs)



LIU – BCMS (1.5 eVs)

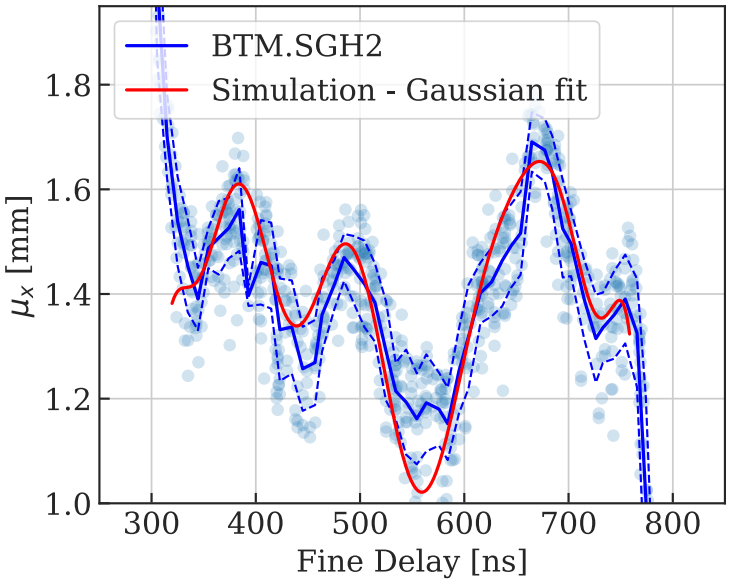


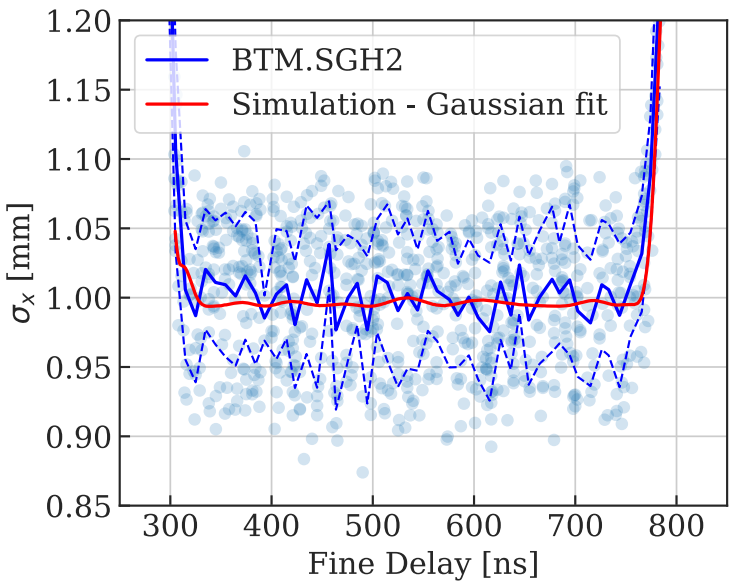
LIU - Standard (3.0 eVs)



Impact on measured beam size (1)

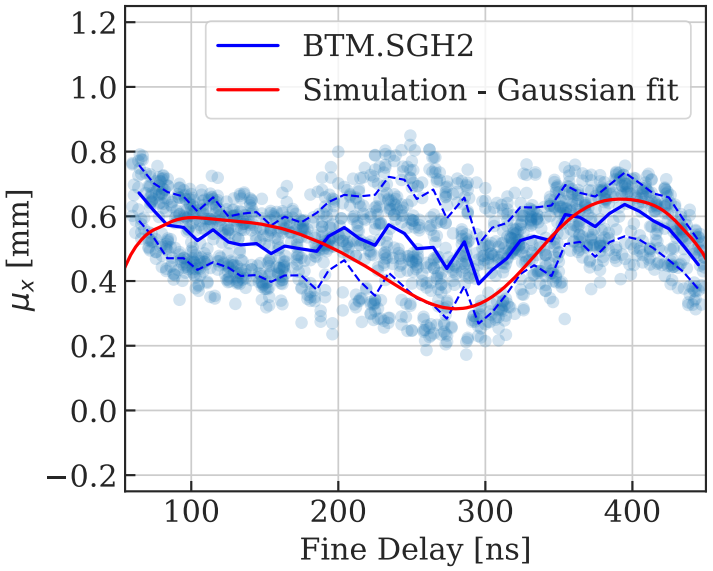
- **Short LHC INDIV (4σ ~ 40 ns) – Ring 3**
  - Measured BT3.KFA14L1 waveform and nominal beam/optics parameters applied: good agreement at BTM.SGH2
  - Self-consistency check: waveform measured at BT3.BPM00 tracked to BTM.SGH2 and compared to measurement data

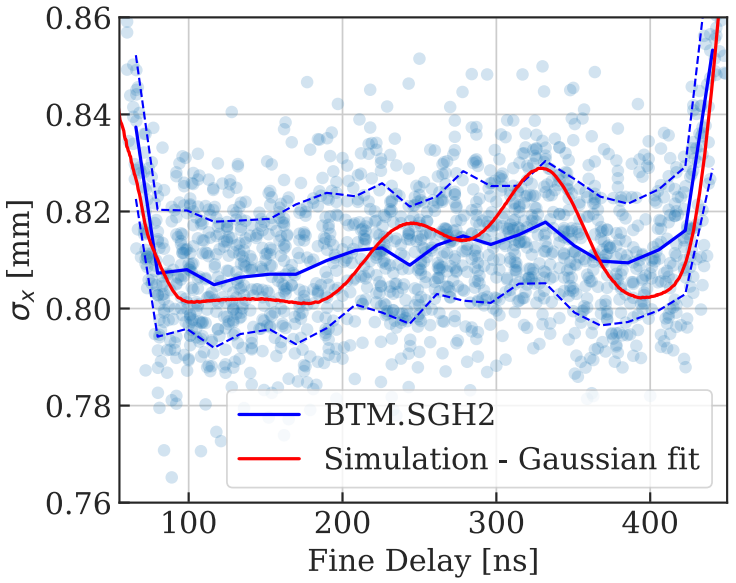




Impact on measured beam size (2)

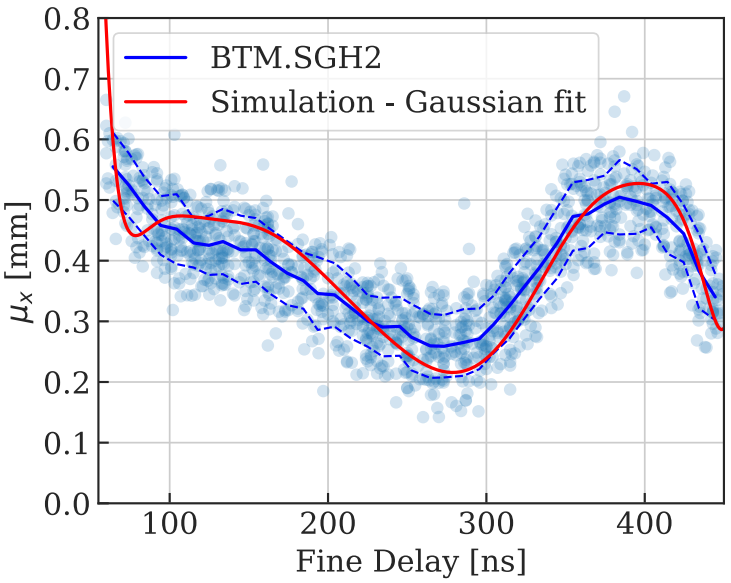
- **LHC BCMS 0.9 eVs (4σ ~ 145 ns) – Ring 3**
  - Measured BT3.KFA14L1 waveform and nominal beam/optics parameters applied: good agreement at BTM.SGH2
  - Perturbed particle distribution tracked from BT3.KFA14L1 to BTM.SGH2 (no dispersion) and compared to measurement

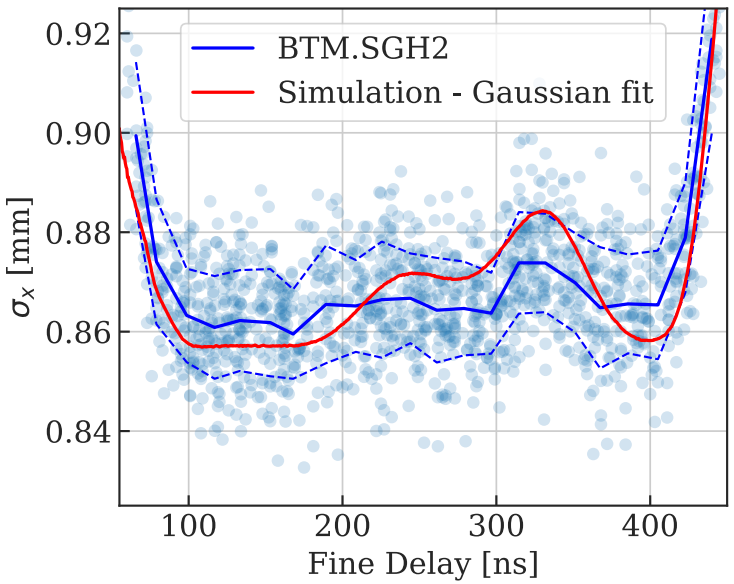




Impact on measured beam size (3)

- **LHC BCMS 1.5 eVs (4σ ~ 155 ns) – Ring 3**
  - Measured BT3.KFA14L1 waveform and nominal beam/optics parameters applied: good agreement at BTM.SGH2
  - Perturbed particle distribution tracked from BT3.KFA14L1 to BTM.SGH2 (no dispersion) and compared to measurement





Conclusions

- **KFA14 flat-top ripple measurements with beam carried out:**
  - Ripple on first 200 ns close to values quoted for the system in CERN-PS-CA-Note-2000-004 (± 0.8%)
- **Emittance growth computed with reference optics and beam parameters on all rings at the level of ~1%**
  - Including today's operational and MD beams, and future LIU beams
  - Synchronisation needs to be considered to minimise blow-up
- **Blow-up measured on BTM.SGH2 consistent with expectation:**
  - Large scatter in data but trend of increasing beam size is observed as the kicker fine delay is scanned
- **Details to be published at IPAC'19 and ATS note**
  - Drafts to be circulated soon