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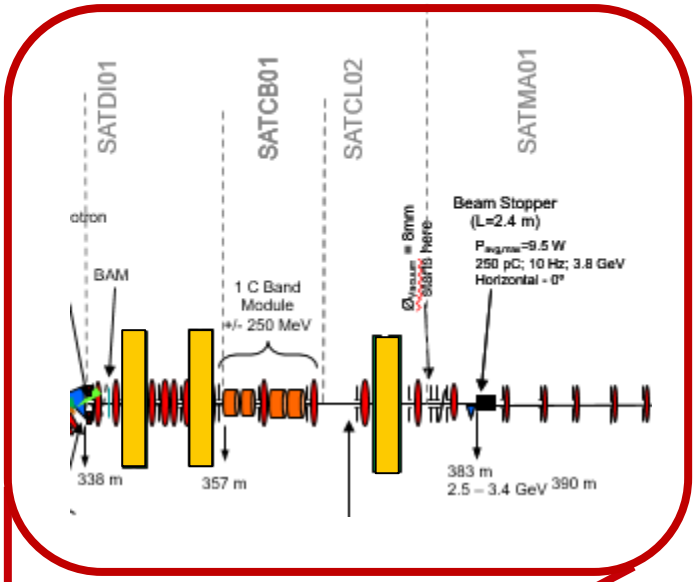
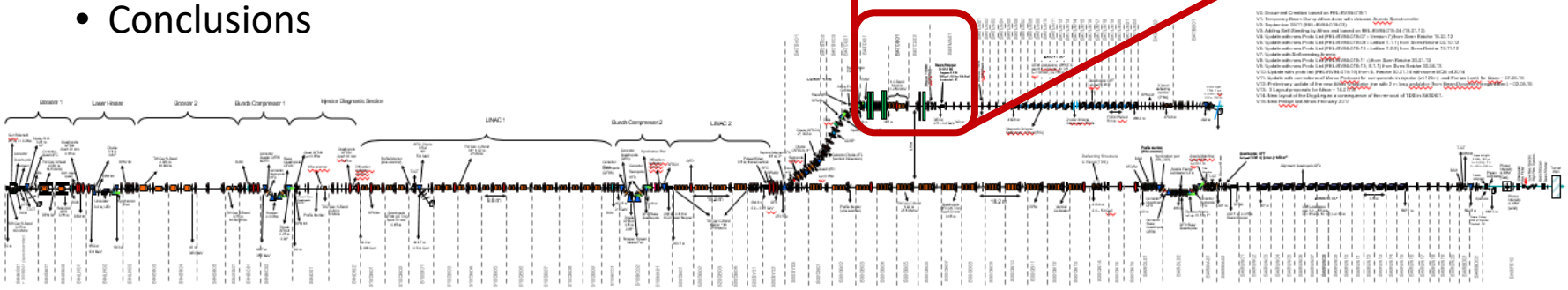
Transfer line commissioning

ATHOS WORKSHOP

Outline

- Transfer line composition and main commissioning blocks:
  - BBA of the quadrupoles
  - C-band commissioning
  - Dechirper
- Why do we need a Dechirper
- Dechirper at SwissFEL:
  - Design and expectations
  - Possible features
- Measurements campaign:
  - Transverse
  - Longitudinal
- Conclusions





Main commissioning blocks

1. **BBA of quadrupoles**
   - Hardware: BPMs
   - Software: BBA tool
   - Number of shifts: 0.5

Common to other sections

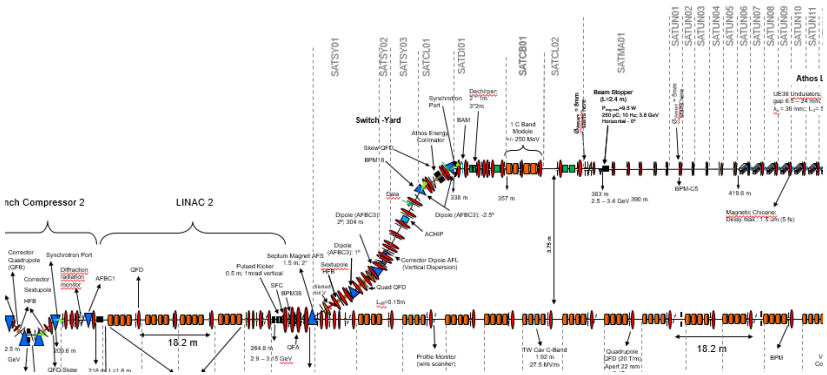
2. **C-band commissioning**
   - Hardware: bend and screen at Athos dump
   - Software:-
   - Milestone: energy gain 250 MeV
   - Number of shifts: 0.5

Common to other sections

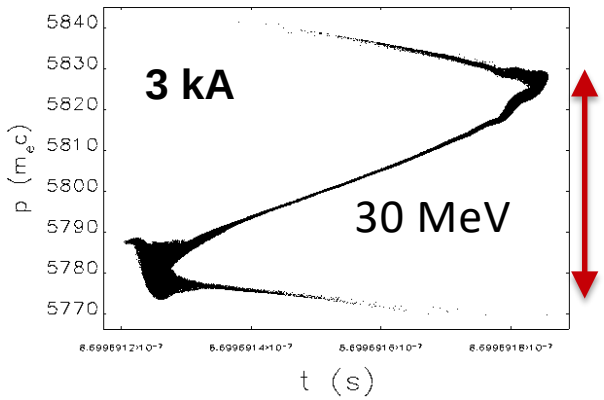
3. **Dechirper**
   - Hardware: BPMs, TDC
   - Software: emittance measurement tool, alignment tools, energy loss
   - Subtasks: alignment of structures, characterize the structures and jitter
   - Milestone: as flat as possible longitudinal profile while preserving emittance and mismatch with acceptable jitter
   - Number of shifts: 5+?

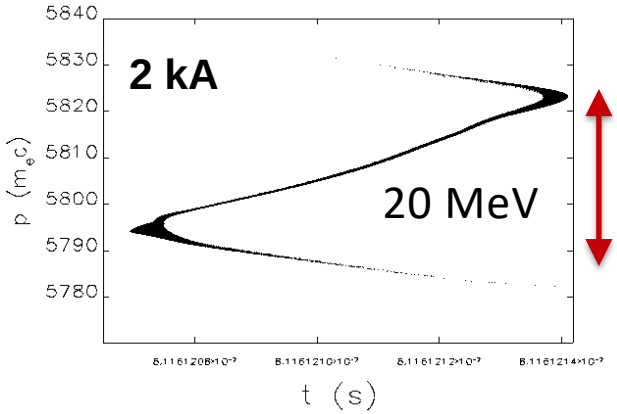
Unique in this section

Why do we need a Dechirper?



- Energy-time correlation (chirp) is introduced going off-crest in the RF cavities
- In a magnetic chicane the particles with different energy have different trajectory (they arrive before or after)
- Bunch length is changed
- Some residual chirp may remain after the compressors
- This is detrimental for some modes (see Eduard's talk)

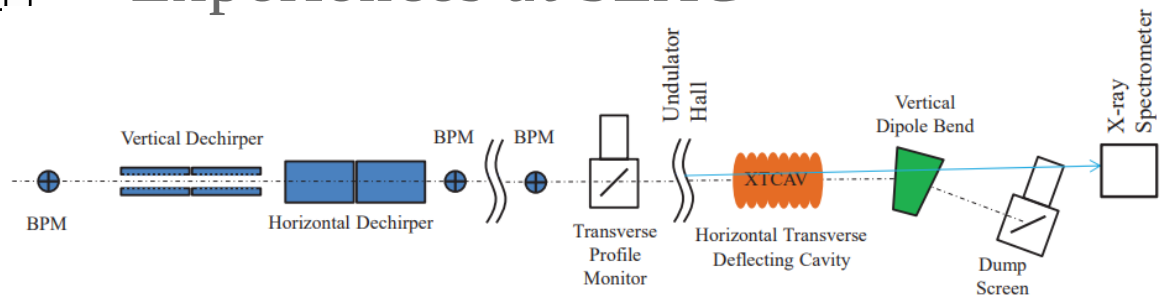




- We expect residual energy chirp from the compression
- For the Aramis beam the wakefield in Linac 3 compensate the chirp
- For the Athos beam we lack in wakefield from the C-band
- We need to add wakefield sources: dechirper

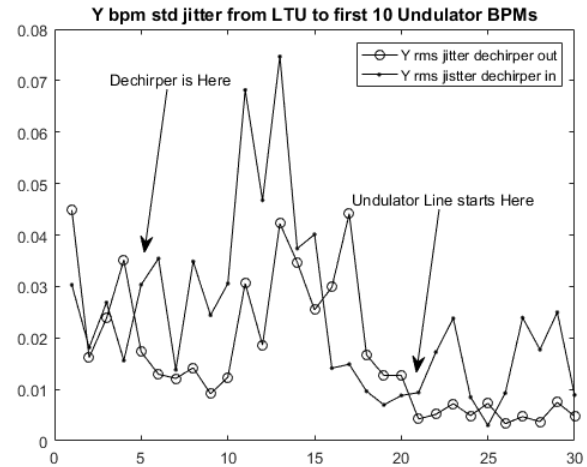
Distributions optimized by B. Beutner and A. Saa Hernandez

Experiences at SLAC



Fin period	0.5 mm
Fin depth	0.5 mm
Nominal gap	1.4 mm
Min. gap	0.7 mm
Peak-to-peak flatness	50 um
Motion Repeatability	25 um

- Key points:
  - Enough "dechirping"
  - Emittance and mismatch control
  - Jitter tolerance (minimum gap)



Jitter amplification for conditions similar to Athos

3.8 GeV 1.53 mm gap*

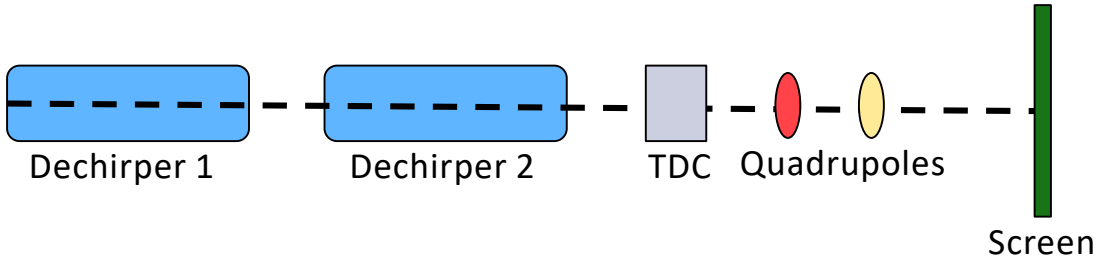
(1 mm gap without any issue, 0.7 mm possible but not used*)

More info in: http://accelconf.web.cern.ch/AccelConf/napac2016/talks/wea1io01_talk.pdf

* A. Lutman and M. Guetg private communication

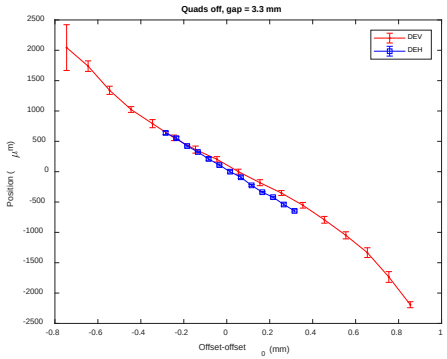
Measurements campaign: transverse

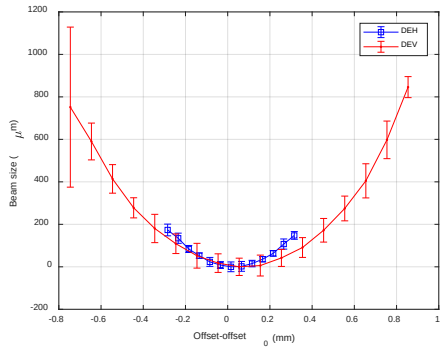
Measurement of the longitudinal phase space with the dechirpers closed

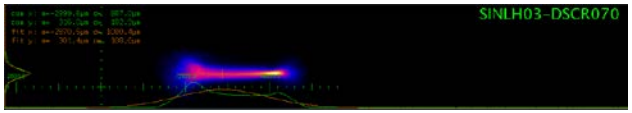


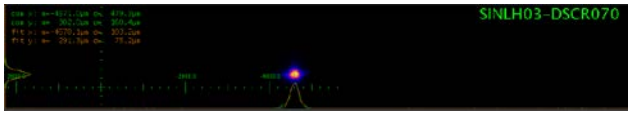
	Hardware	When	Software	Milestones	Number of shifts	Risk
Slice emittance and mismatch	TDC, quadrupoles and screen	TDC installed mid 2020	Common to other sections	Preservation of slice emittance and mismatch	2	
Kick factor and beam size vs gap	BPM and screen	From Nov 2019 (first 6 m structures)	Ready (channel names to be updated)	Align the structures	3+?	We cannot fully move the plates. We rely on the alignment group. Possible that we need several machine accesses.

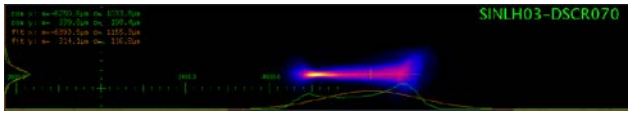
Same measurements done at the injector





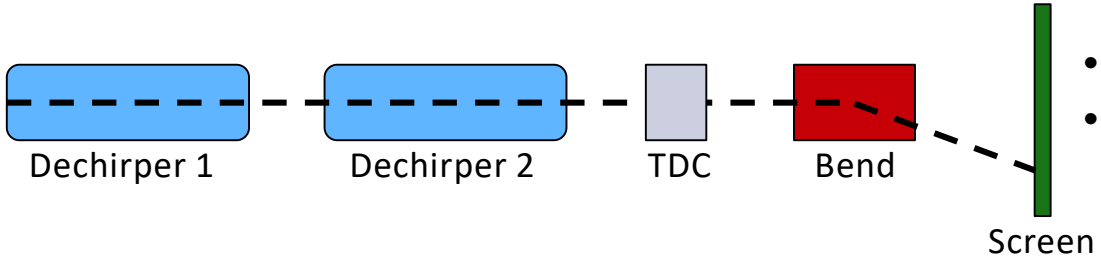






Measurements campaign: longitudinal

Measurement of the longitudinal phase space with the dechirpers closed



- TDC gives the time information
- Bend gives the energy information

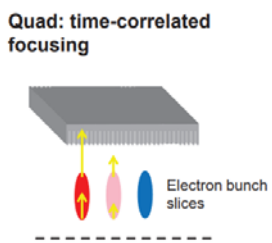
	Hardware	When	Software	Milestones	Number of shifts
Longitudinal phase space	Bend and screen or BPM and TDC	TDC installed mid 2020	Common to other sections	Longitudinal phase space as expected from model	0.5
Projected energy loss	Bend and screen or BPM	Bend installed end 2019	Ready (channel names to be updated)	Energy spread reduced by 2/3 of the final (only 6 m)	0.25
First checks on moving system transmission and jitter	Dechirper	Partial from Nov 2019 (and not guaranteed)	Rely on Controls software	Characterize the jitter of the beam as a function of the gap	0.25

Same measurements done at the injector

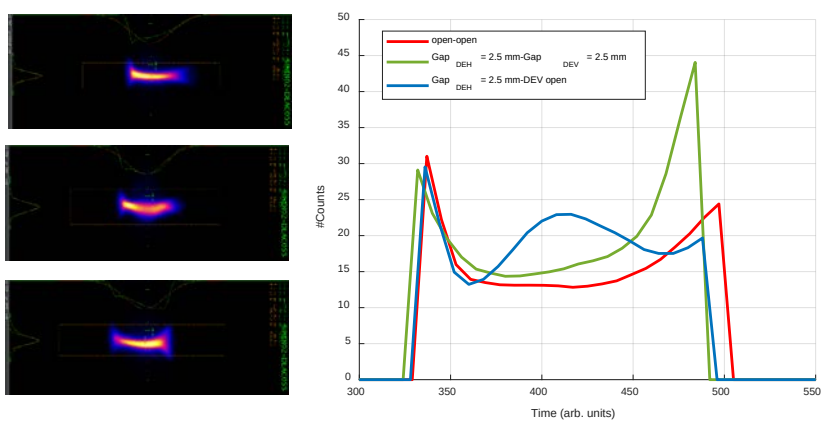
Possible “features”

A Dechirper was conceived as a device to remove the residual chirp, but it is used for several purposes now:

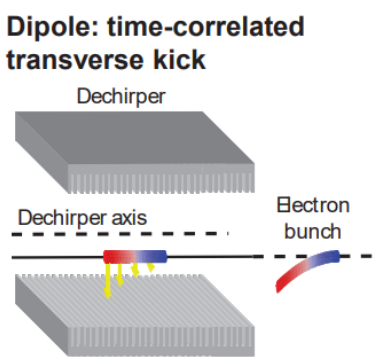
- Two color using the mismatch variation along the bunch (1 shift)
- Tilted beam and orbit in the undulators (2 shifts)
- Increase the bandwidth: starting from overcompression increase the dechirp (1 shift)
- Passive streaking (parasitic with transverse wakefield measurements)



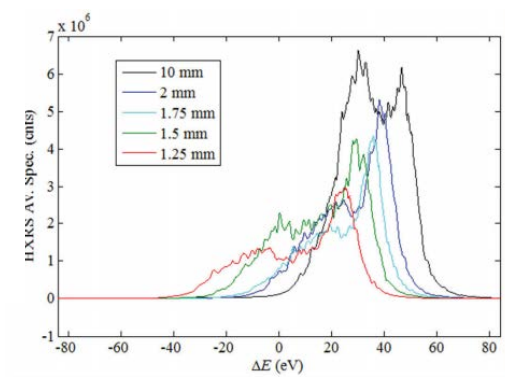
SLAC



PSI



SLAC (exp), PSI (sim)



SLAC

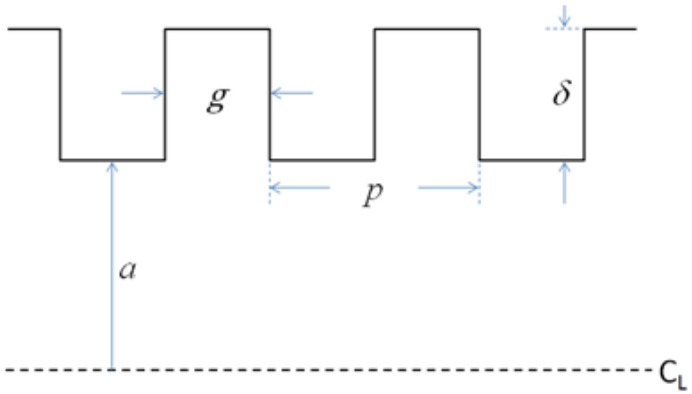
The main part of the TL commissioning will be the dechirper

… we are making some experience at the injector (tools, some possible issues,…) also if there 2 color, and linearizer tested until now

… the main unpredictable aspect to quantify the necessary number of shifts is the alignment, where we have less flexibility than in LCLS

Task	When	Shifts	Hardware
Longitudinal (DE loss)	Nov 2019	0.5	Bend+screen/BPM
Longitudinal (full)	Mid 2020	0.5	TDC
Alignment	Nov 2019	5+?	Screen/BPM
Other modes		4	

Design procedure at SwissFEL



Wakefield of corrugated plates $w(s) \approx \frac{Z_0 c}{\pi a^2} H(s) \cos(2\pi s/\lambda)$

The length and the a to have the full compensation are L_{ok} and a_{ok}

$$L(a) = F \frac{L_{ok}}{{a_{ok}}^2} a^2$$

Known from simulations

Geometry scaling factor

Effect proportional to L/a^2

F = 1: round

F = 0.86 square

F = 0.61: flat

- Let L_{ok_j} be the length at fixed a to fully compensate the chirp with the geometry j, and L_j the length of the geometry j, the fraction of the compensated chirp is:

$$\frac{L_j}{L_{ok\_j}}$$

- The fraction of the compensated chirp with a combination of geometries is:

$$\sum_{j=\,geometries} \frac{L_j}{L_{ok\_j}}$$

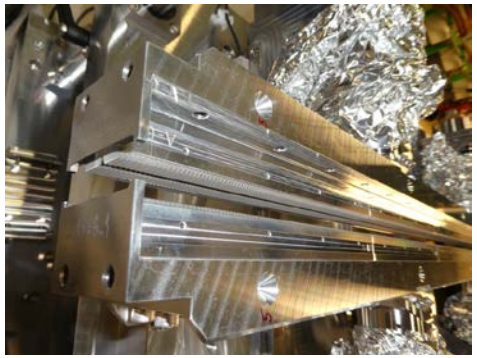
- The sum of the configurations must give 1 to fully compensate the chirp

Expectations at SwissFEL

- After experience in the injector, design for the corrugation/material to be finalized
- At the present status the residual energy spread in % is:
  - Design 1: corrugated plate (1 m + 1 m) and square structures (3*2 m):

Present design

	Gap = 3 mm	Gap = 2.5 mm	Gap = 2 mm
3 kA	0.39	0.13	-0.34
2 kA	0.07	-0.20	-0.66



  - Design 2: changed for more flexibility (8*1 m):

	Gap = 3 mm	Gap = 2.5 mm	Gap = 2 mm
3 kA	0.53	0.33	-0.02
2 kA	0.20	0.01	-0.35

  - Expected gap between 2 and 2.5 mm (with some safety margin compared to LCLS)

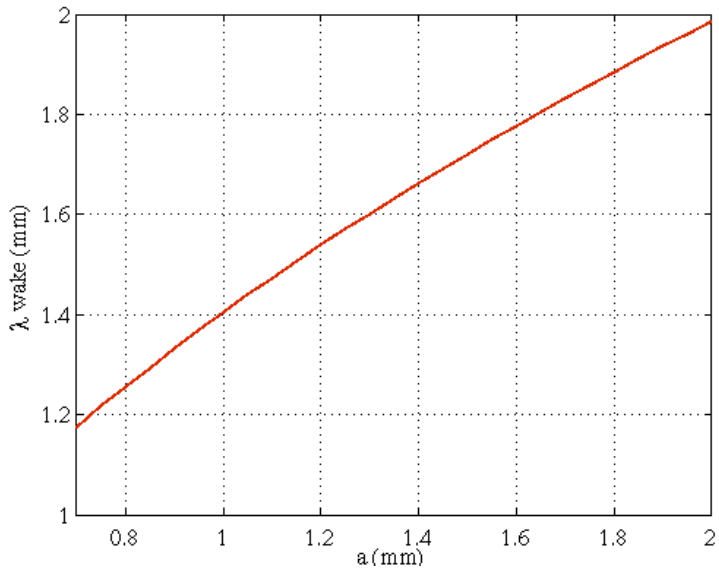
- Under consideration design 3 (8*1 m):

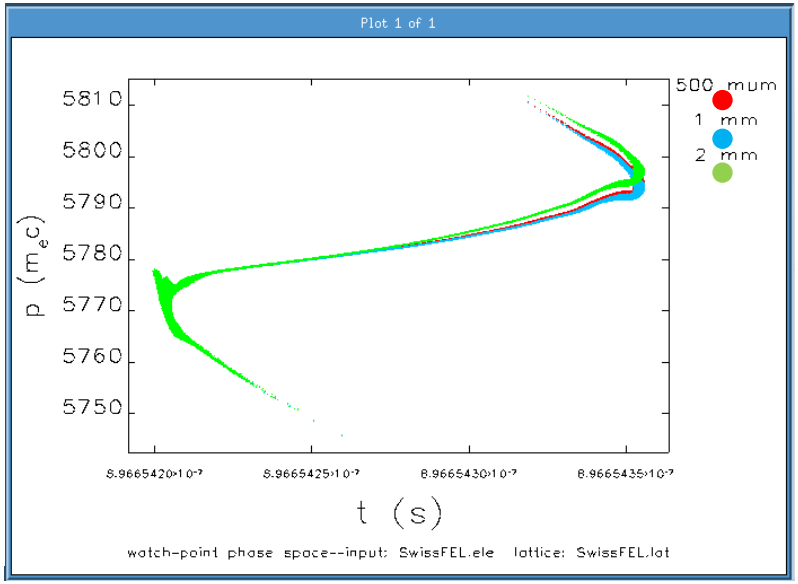
	Gap = 1.4 mm	Gap = 0.9 mm	Gap = 2.4 mm	Gap = 4 mm	Gap = 6 mm	Gap = 8 mm
3 kA	-2.90	-0.97	-0.24	-0.04	0.26	0.40
2 kA	-3.23	-1.29	-0.56	-0.36	-0.07	0.08

Ongoing

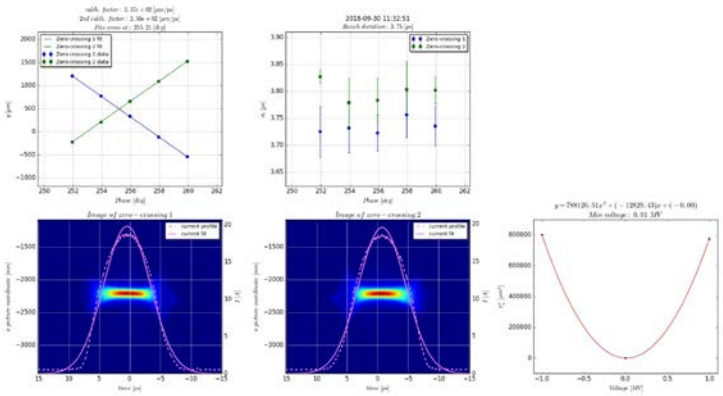
Dependencies on the gap

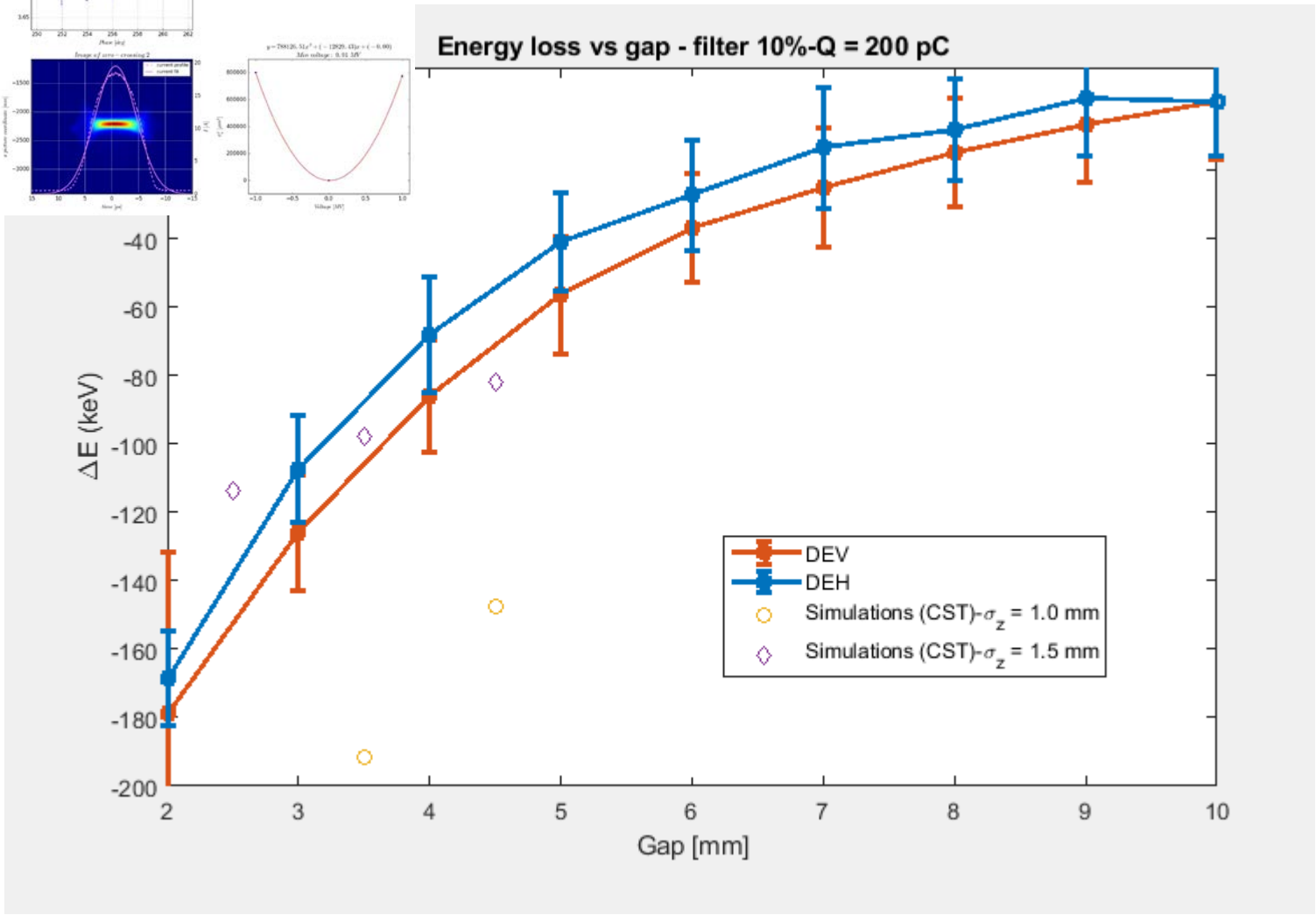
- We can quite freely scan the gap without modifying the electron bunch





Injector measurements vs simulations





Risks analysis

Task	Risk	Consequences
BBA of the quadrupoles	No issues foreseen	
C-band commissioning	No issues foreseen (RF)	
Dechirper	Alignment of the structures	We rely on the alignment group- only partial movement of the structures
	Emittance and mismatch preserved	Lasing intensity reduction
	Only partial compensation of the chirp	More critical for CHIC and HB mode
	Orbit jitter	Larger gap. Partial chirp compensation

The main unknown is the Dechirper:

- We cannot move in all the dimensions the plates (like in LCLS). There is the risk accesses will be needed with the alignment group
- Determine the minimum gap, given the orbit jitter in the machine. At the moment some safety margin taken.