Diagnostics overview and FB for the XFEL bunch compressors

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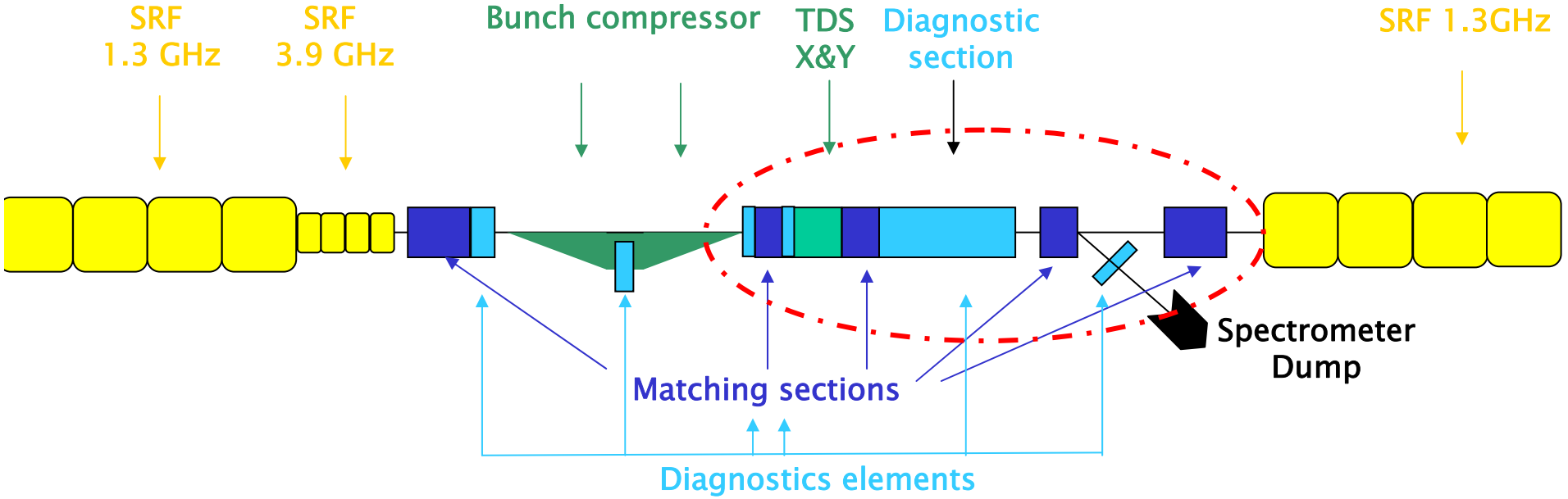
Diagnostics overview BC1

- proposed beam line design:



→ Will be discussed by Ch. Gerth in details

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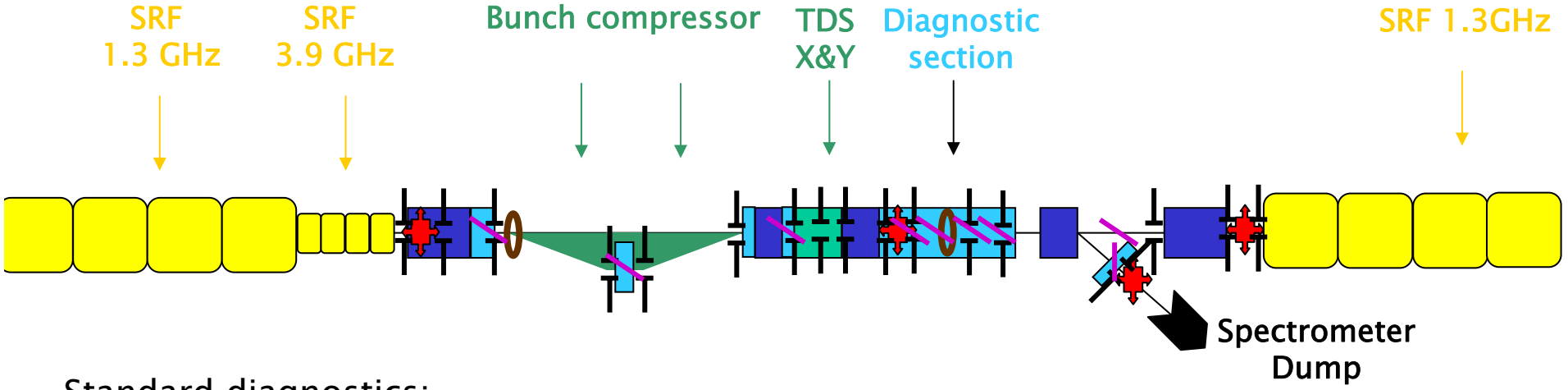
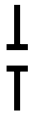


Standard diagnostics:

TOR		toroid system for transmission measurements (1,3&4 for interlock)
DC		dark current monitors (upstream BC1, downstream BC1)
BPM		beam position monitor ~ 20 (not yet determined … every quad?) purpose: orbit correction, transfer measurements, dispersion correction
OTR		optical transition screen (with wire scanners WS?)

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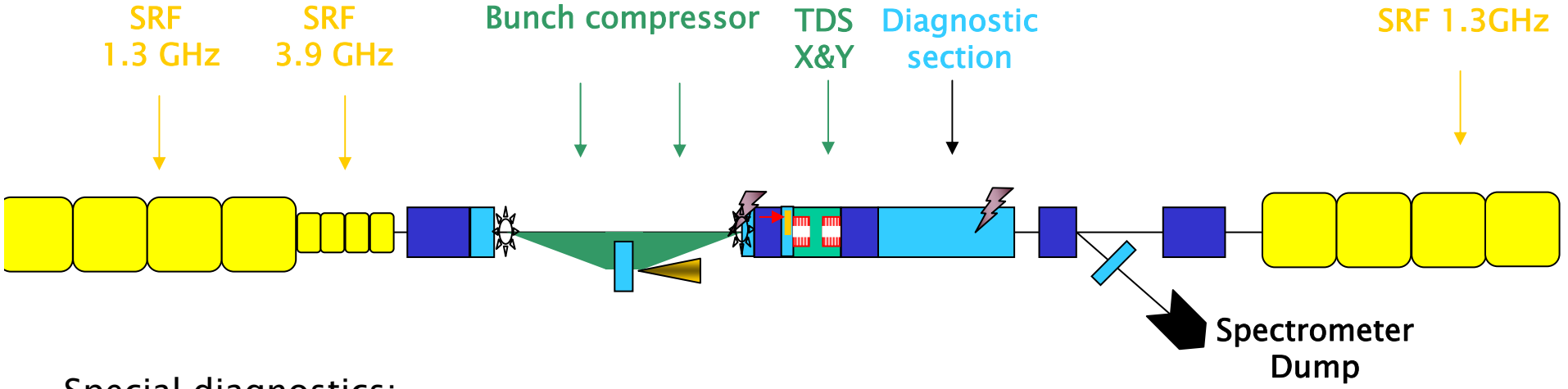

Special diagnostics:

TDS		transverse deflecting structure X & Y
EO		electro-optic longitudinal beam profile monitor
BCM		bunch compression monitors (CSR at D4 and CDR/CTR)
SR		synchrotron radiation monitor (energy and energy spread)
BAM		beam arrival time monitor

-> B Schmidt

Diagnostics overview BC1

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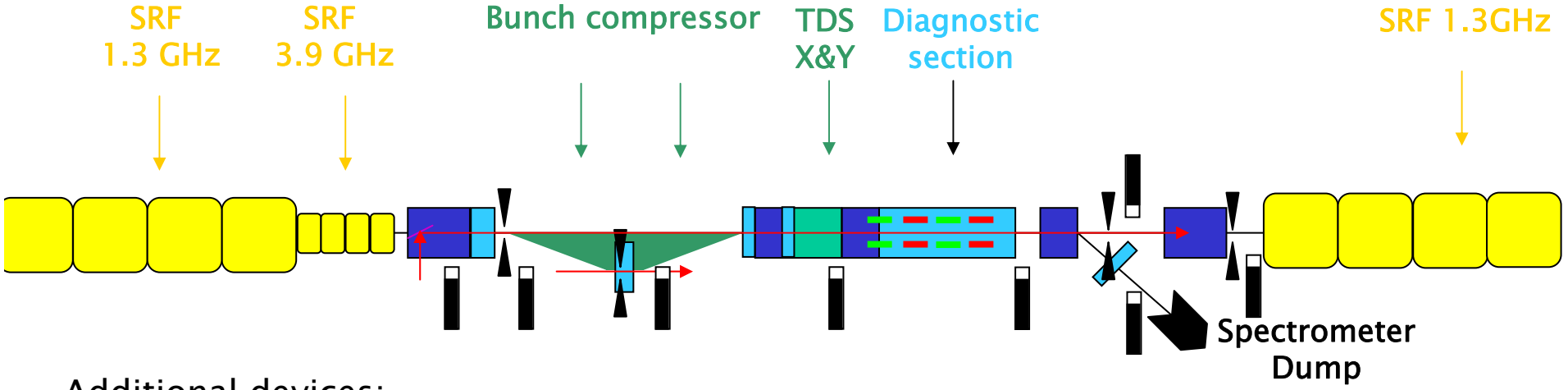


Additional devices:

COL collimators (1st & 2nd to remove dark current, 3nd & 4th for kicked e⁻)

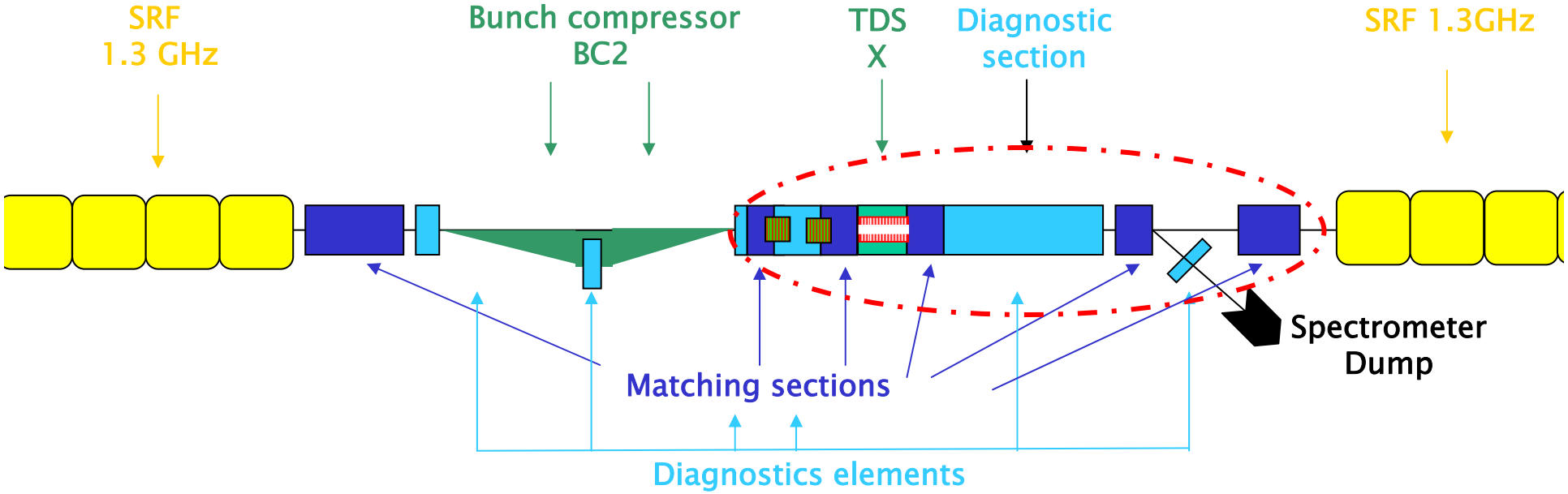
KIC fast kicker to off-axis screens (2 x and 2 y)

Align laser for optics alignment

BLM beam loss monitors (about 8-10 sufficient)

Diagnostics overview BC2

- proposed beam line design:



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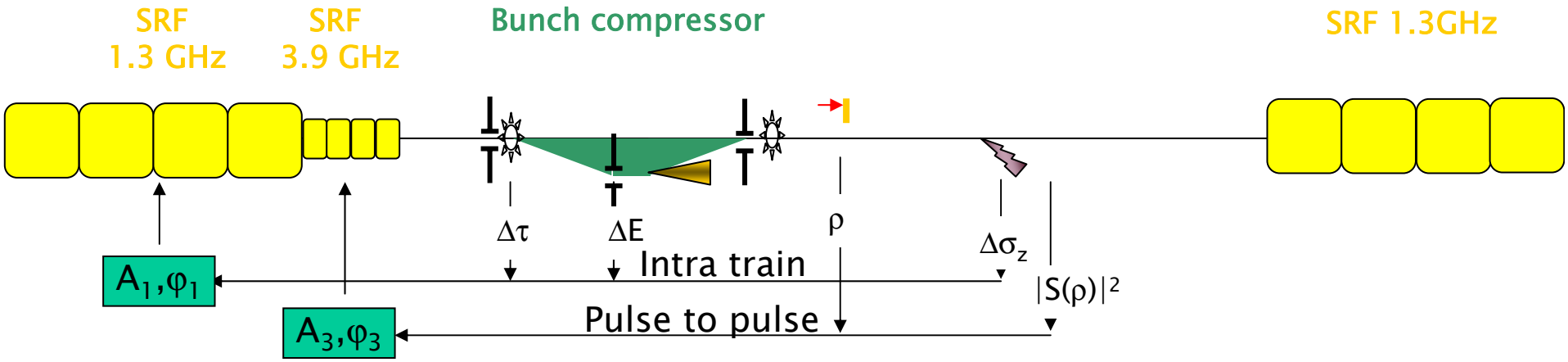
TDS transverse deflecting structure (only X <-dump line in Y)

ORS optical replica synthesizer

Remaining diagnostics/devices are basically the same as for BC1

Longitudinal Feedback

- most challenges for BC1



Problem: 4 regulation parameter $A_1, \varphi_1, A_3, \varphi_3$
+ τ arrival time of beam into acceleration module ($\varphi = -\omega_{rf}\tau$)

Direct measurement:

$\langle\tau\rangle$	beam arrival time τ	($<$30fs)
$\langle dE/E\rangle$	beam energy (after orbit correction)	($<10^{-5}$)
$\langle z^2\rangle$	bunch length (integral pyro signal)	($<$0.01°)

more difficult

$\lvert S(\rho)\rvert^2$	spectral content of compressed bunch	
ρ	profile (limit resolution!!!)	

Ideal operation point: where 2 of 4 parameter have relaxed tolerance (e.g. A_3, φ_3)

Longitudinal Feedback

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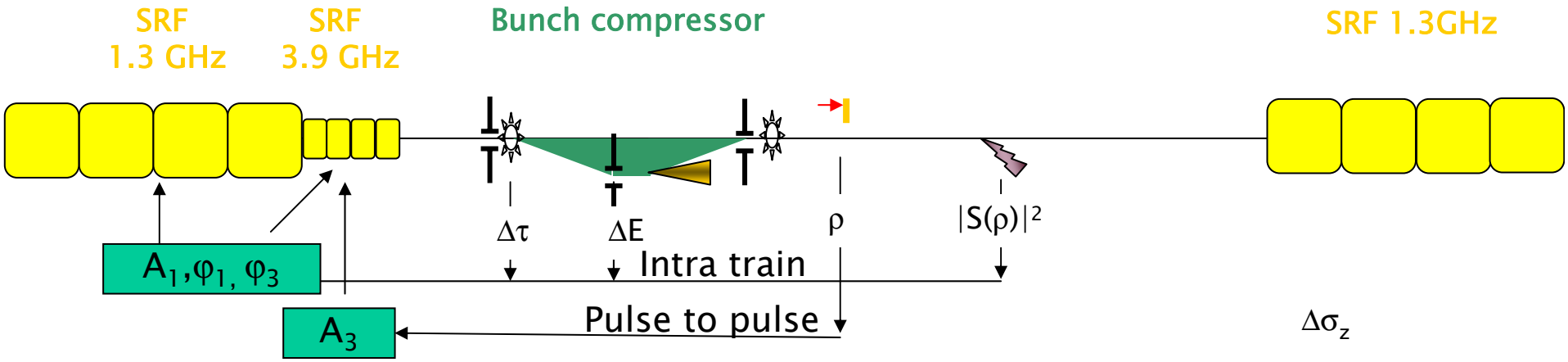

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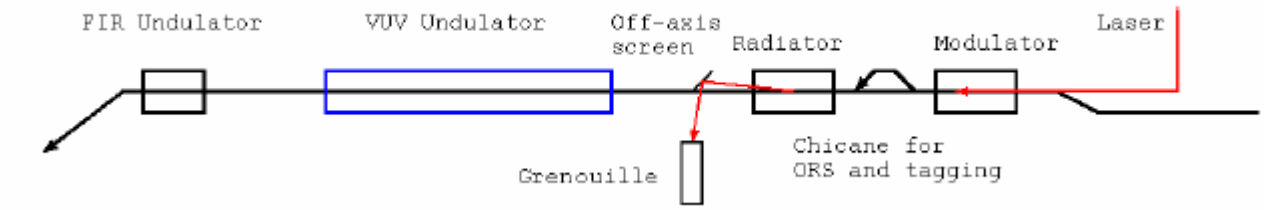
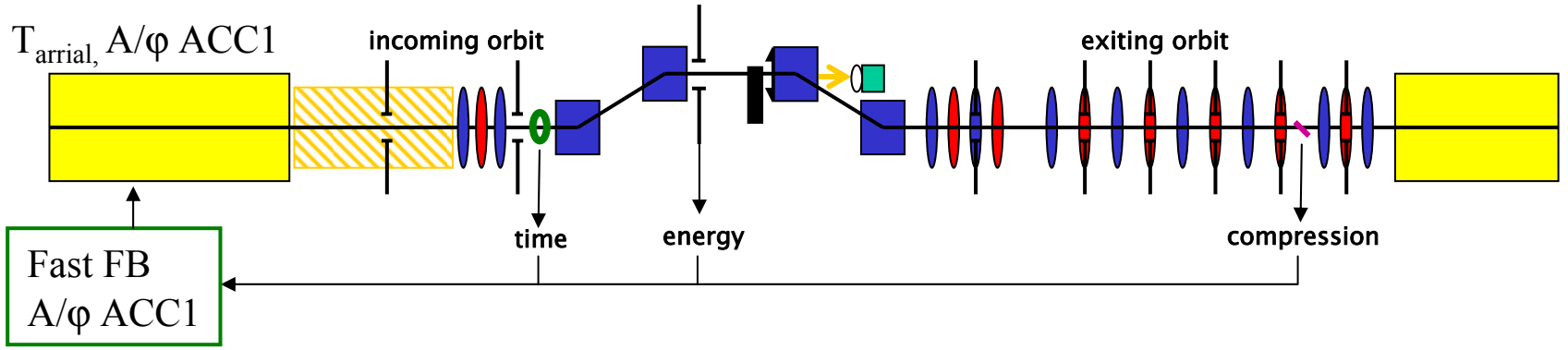
Ideal operation point: but typically only 1 can be made insensitive

Next steps at FLASH

- 2007 installation of optical replica synthesizer (< 5fs resolution) in cooperation with Uppsala & Uni. Stockholm



- preparation of longitudinal feedback system (mainly new monitor systems)



- allow for laser based beam manipulation and external seeding option:
  requires ~ 30-60 fs rms arrival time stability

Potential upgrades

- normal conducting acceleration cavities for large bandwidth longitudinal FB
  => upstream of BC1 — 2 * 1 m

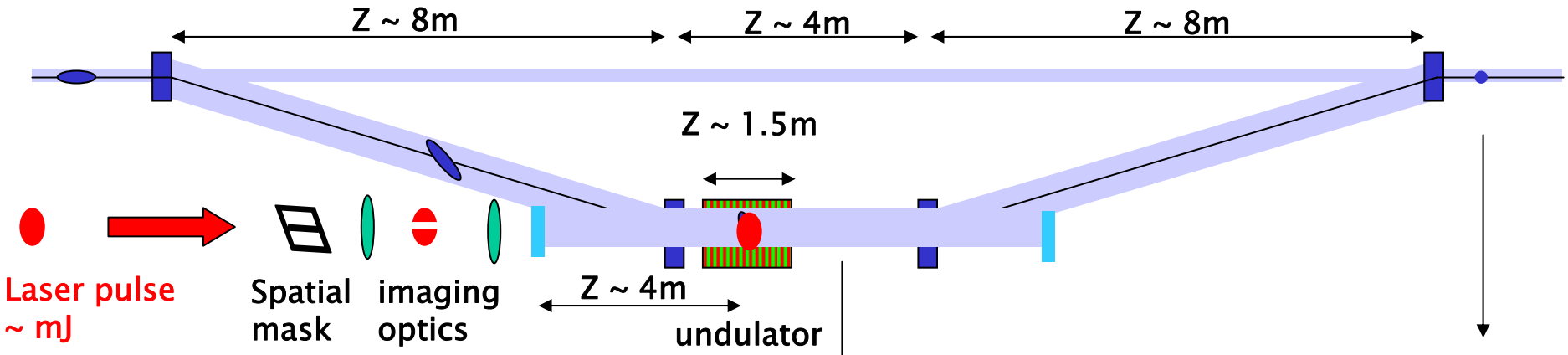
- fast kicker for orbit feedback at BC1 or at BC2
  => downstream chicanes — 4 * 1m

- E-SASE operation (laser launched after BC2)
  => ORS can be used (to be confirmed) — Laser?

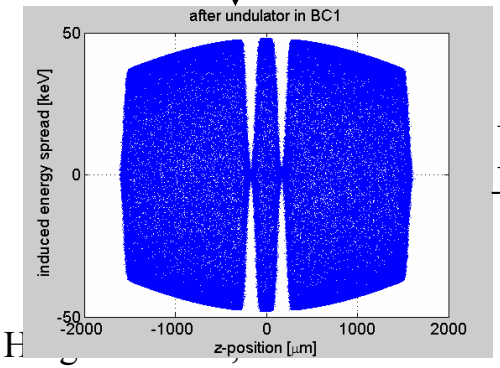
- Beam manipulation in BC1
  => requires addition space!

Laser manipulation BC1

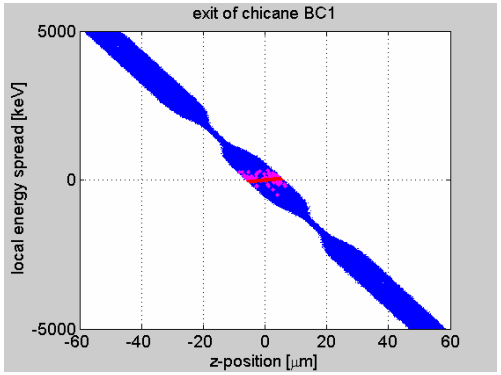
- Most suited in bunch compressor chicane due to large R16 ~ 600mm
- Longitudinal space is mapped to spatial components (Y)
- LCLS insertion of slotted foil to increase emittance for macropulse not possible
- But laser based energy manipulation provides similar option!



- inducing energy spread
- particle migration due to R_{54} (σ_y' smears out $\sigma_E(z)$)
- in BC2 the energy distribution induced 2.5 larger peak current
- requires 2m space ín BC1

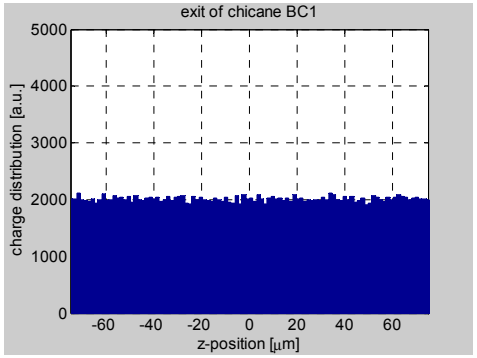


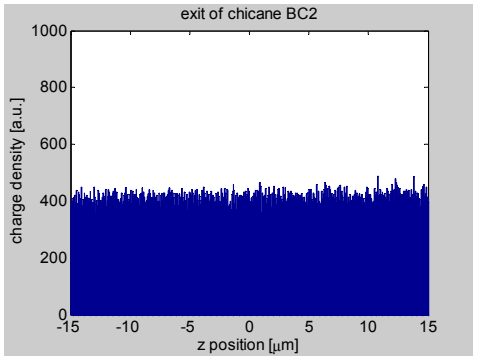
R_{54}

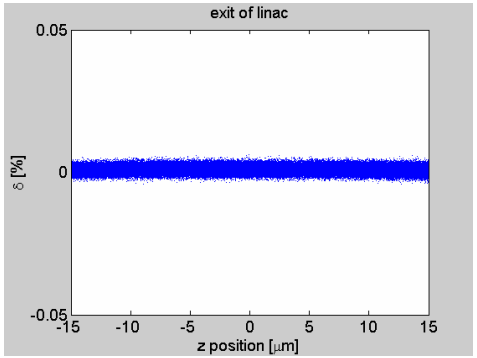


Beam manipulation BC1
- simple simulation -

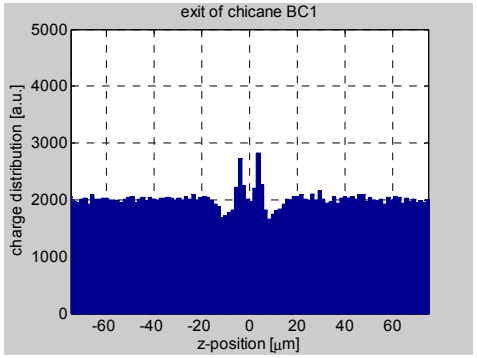
Laser off



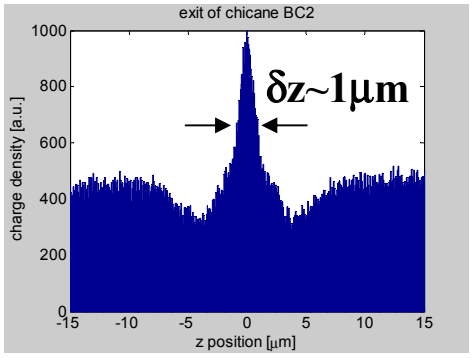


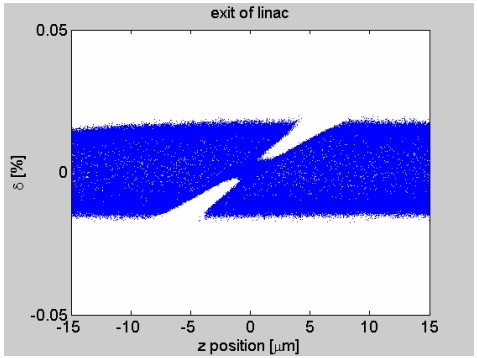


Single gap

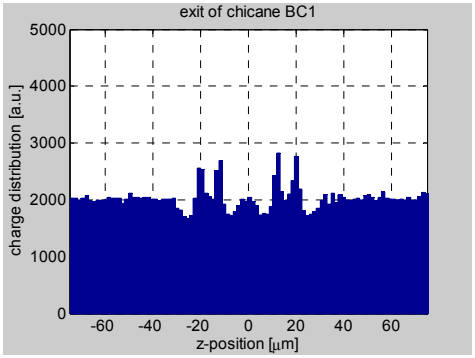


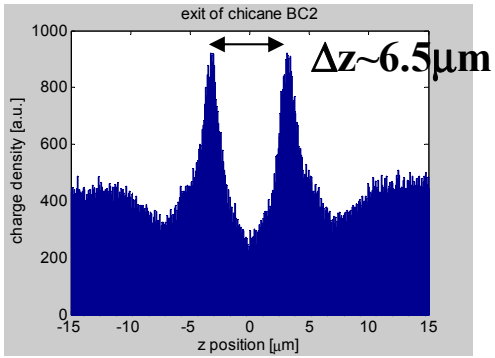
2.5 * I_{peak}

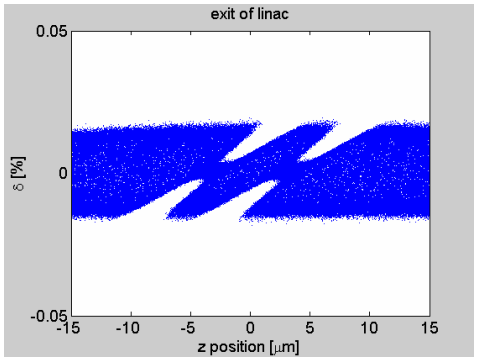




Two gaps Δx=4mm







Beam manipulation BC1

- spike width and peak current increase tunable via initial energy spread (laser heater)
- allows more complex longitudinal pattern using different masks
- requires more detailed simulation concerning
  - laser launch condition and laser parameters
  - collective effects BC1 & particular at BC2 (micro bunch inst.)
  - FEL simulation

  to verify possibilities and limitation
- currently not baseline of XFEL design
  but: space should be reserved for future upgrade
- Space requirements (approximately):

  1.5 m for undulator
  2 m total including screens
  optical table for laser launching
  laser beam line injector building to BC1 ?!
- BC2 ?: not so interesting since lower compression (2.5) and much high laser power required