Beam Dynamics

Towards CompactLight completion and beyond

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for the CLIC team

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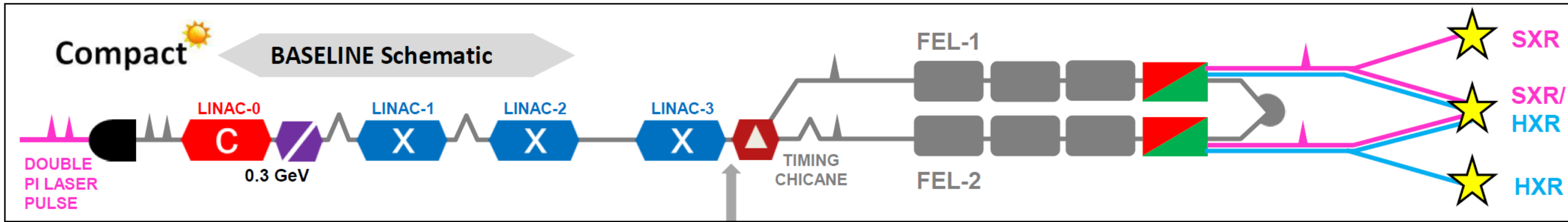
- CompactLight (XLS) overview
  - Short introduction for those who are not up to date
- Beam dynamics update
  - Status (highlight on CERN contributions)
- To-do list
  - Areas of collaboration

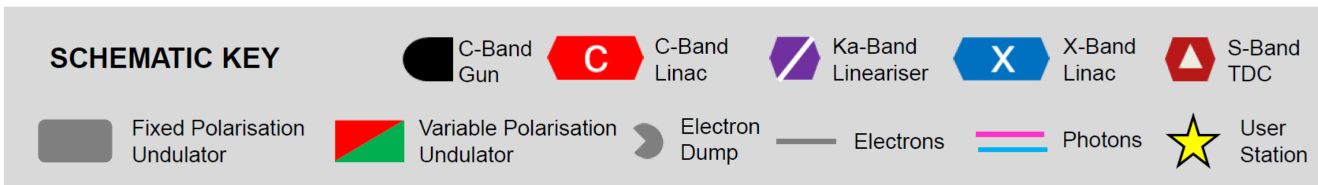
BASELINE

'Dual Mode Linac' – single linac, single klystron



C+K injector -> now C+X+K

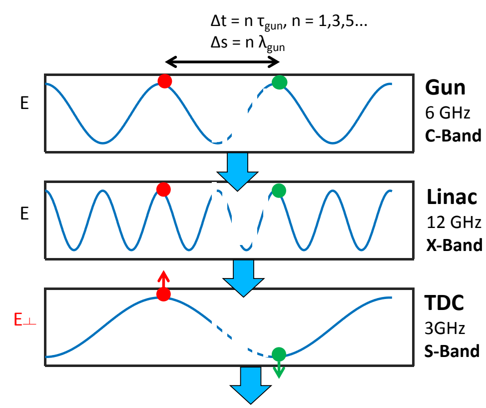
0.97 to 2.4 GeV @ 250 Hz (SXR/SXR)
2.75 to 5.5 GeV @ 100 Hz (HXR/HXR)



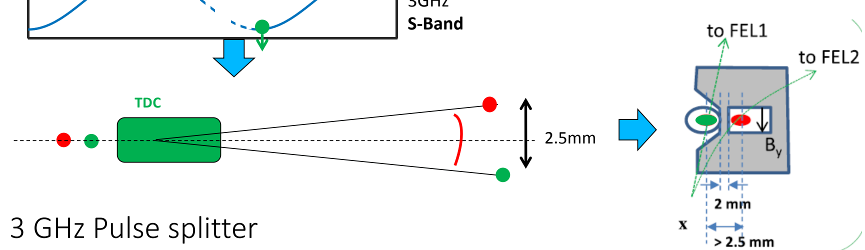
Two-bunch train

Table 3: Injector beam parameters.

Parameter	At gun exit	At L0 exit	Units
Repetition rate	0.1, 0.25, 1		kHz
Charge	75		pC
Proj. norm. emittance (RMS)	0.15 (x), 0.15 (y)		μm rad
Energy	6	280	MeV
Rel. energy spread (RMS)	0.7	0.5	%
Bunch duration (RMS)	1.2	0.4 (w/ VB)	ps
Peak current (core)	20	60 (w/ VB)	A



n	Δt	Δs
1	166 ps	50 mm
3	500 ps	150 mm
5	833 ps	250 mm
7	1.16 ns	350 mm
9	1.5 ns	450 mm



3 GHz Pulse splitter

[XLS Deliverable 2.2]

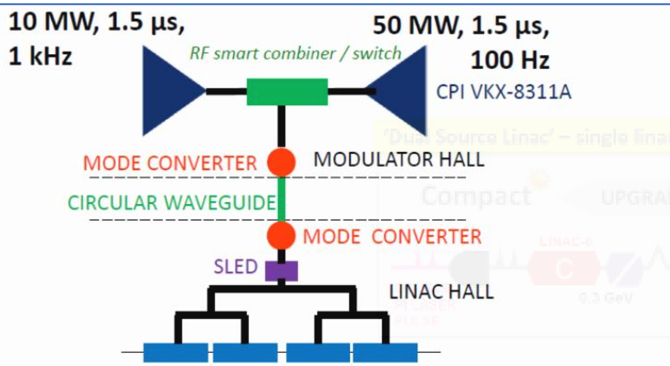
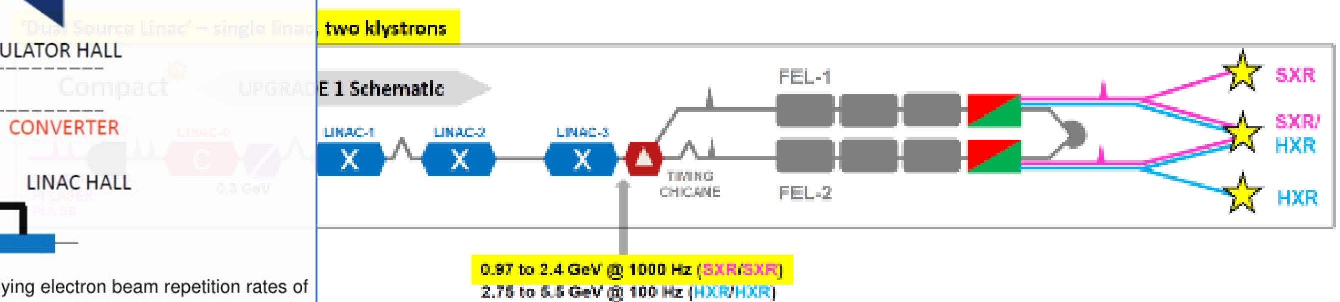
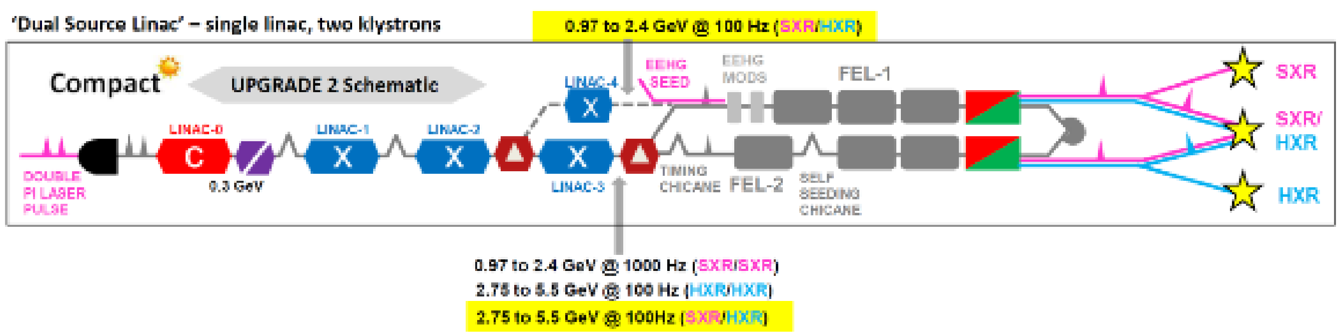


Figure 6: RF distribution system for the main linac supplying electron beam repetition rates of 0.1, 0.25 and 1 kHz.

UPGRADE 1

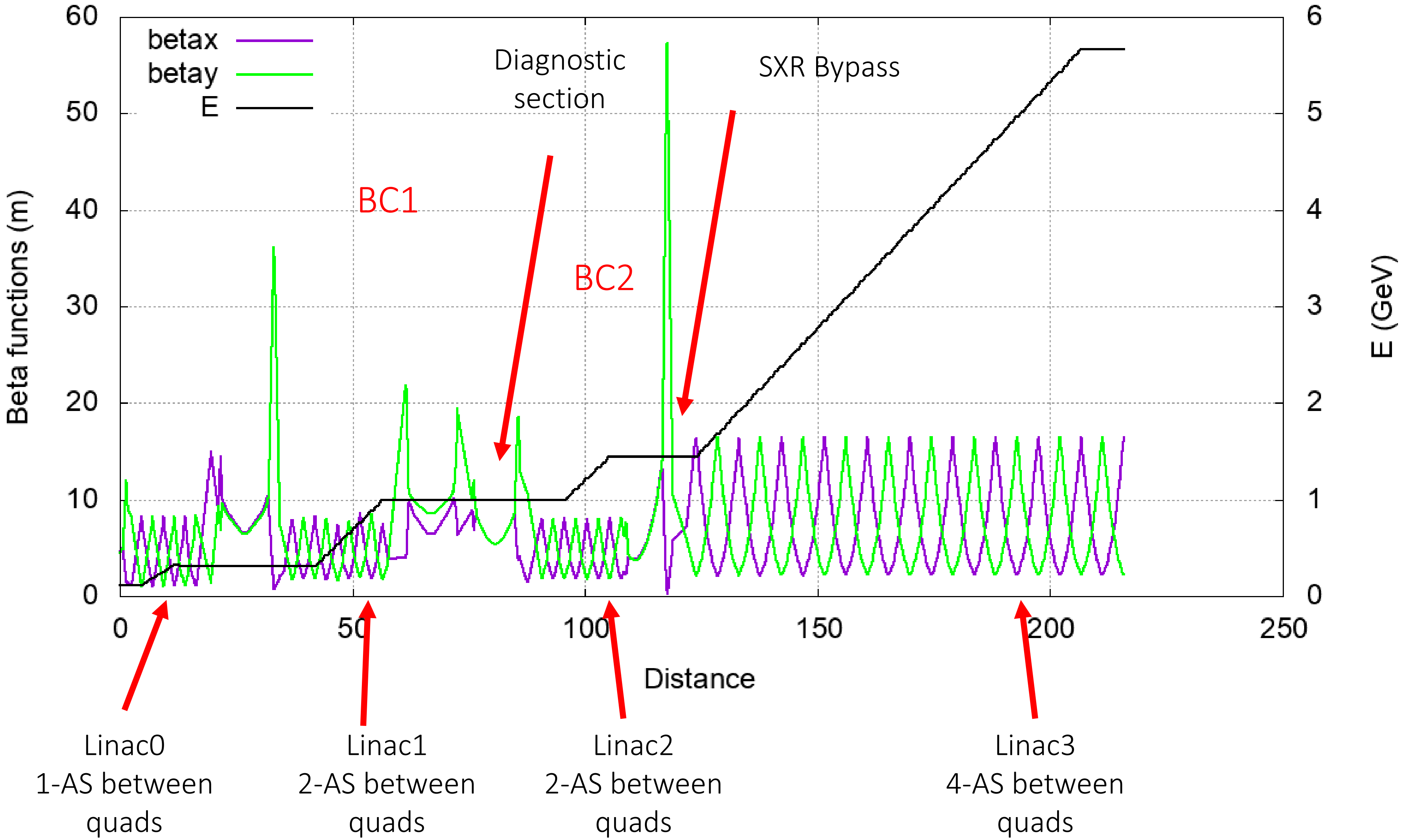


UPGRADE 2



[XLS Deliverable 2.2]

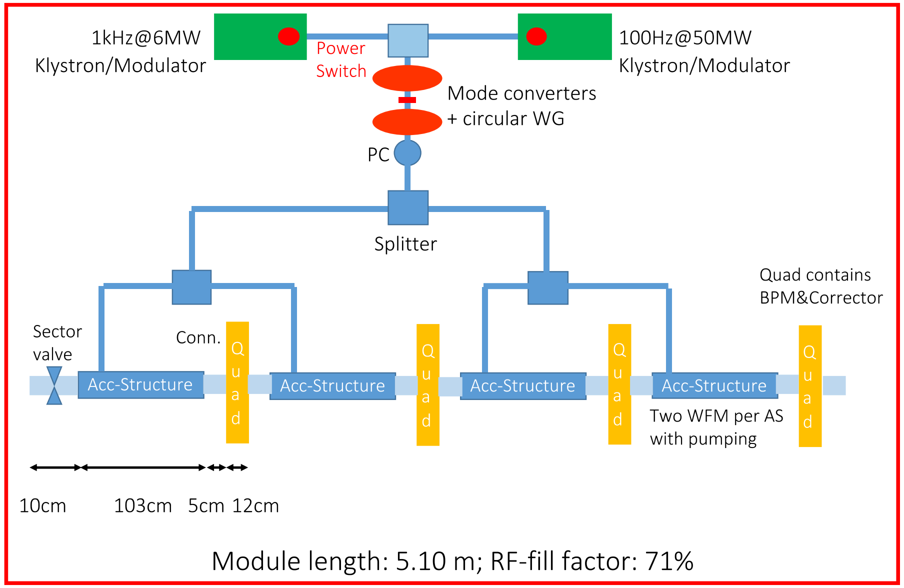
XLS lattice



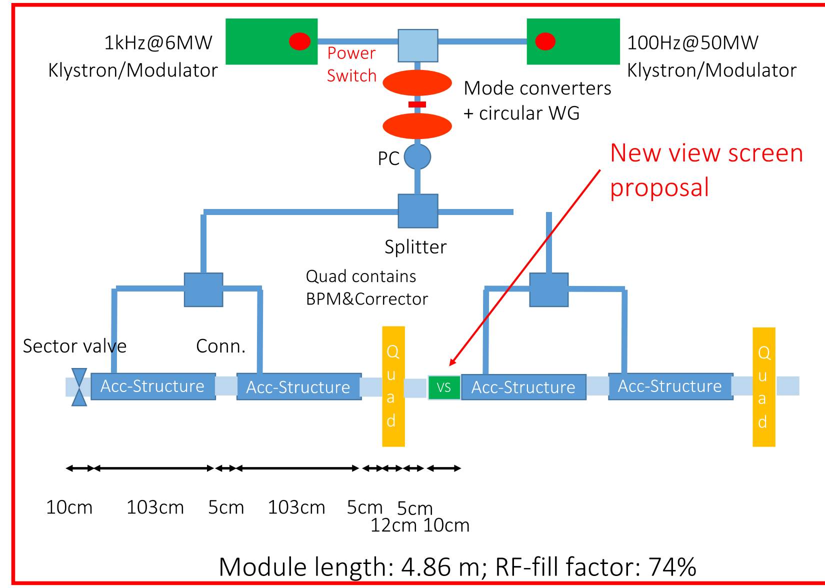
betax
betay
E
Diagnostic section
SXR Bypass
BC1
BC2
Beta functions (m)
E (GeV)
Distance
0
10
20
30
40
50
60
0
1
2
3
4
5
6
0
50
100
150
200
250
Linac0
1-AS between quads
Linac1
2-AS between quads
Linac2
2-AS between quads
Linac3
4-AS between quads

Linac modules integration

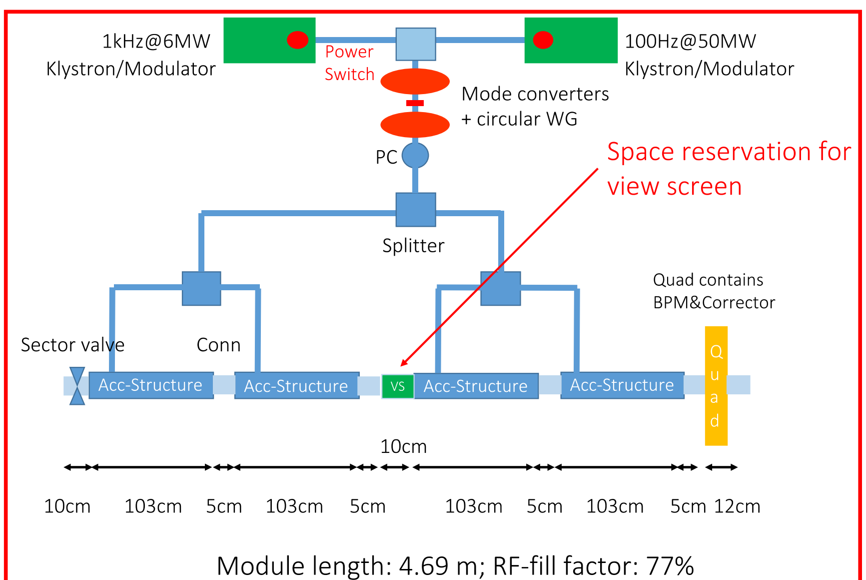
Linac 0 (up to 300 MeV)

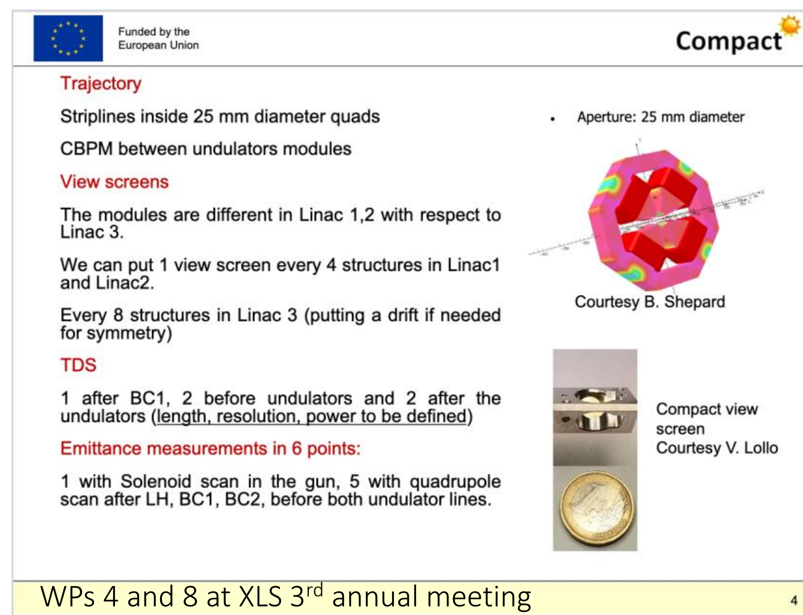


Linacs 1-2-4 (up to 1.7 GeV)



Linac 3 (up to 5.5 GeV)





1D start-to-end optimisation

Requirements :

- Arrival time: same as bunch length = sigma_z
- Peak current (compression factor) = 5%
- Average beam energy = 0.05%

1D optimization results :

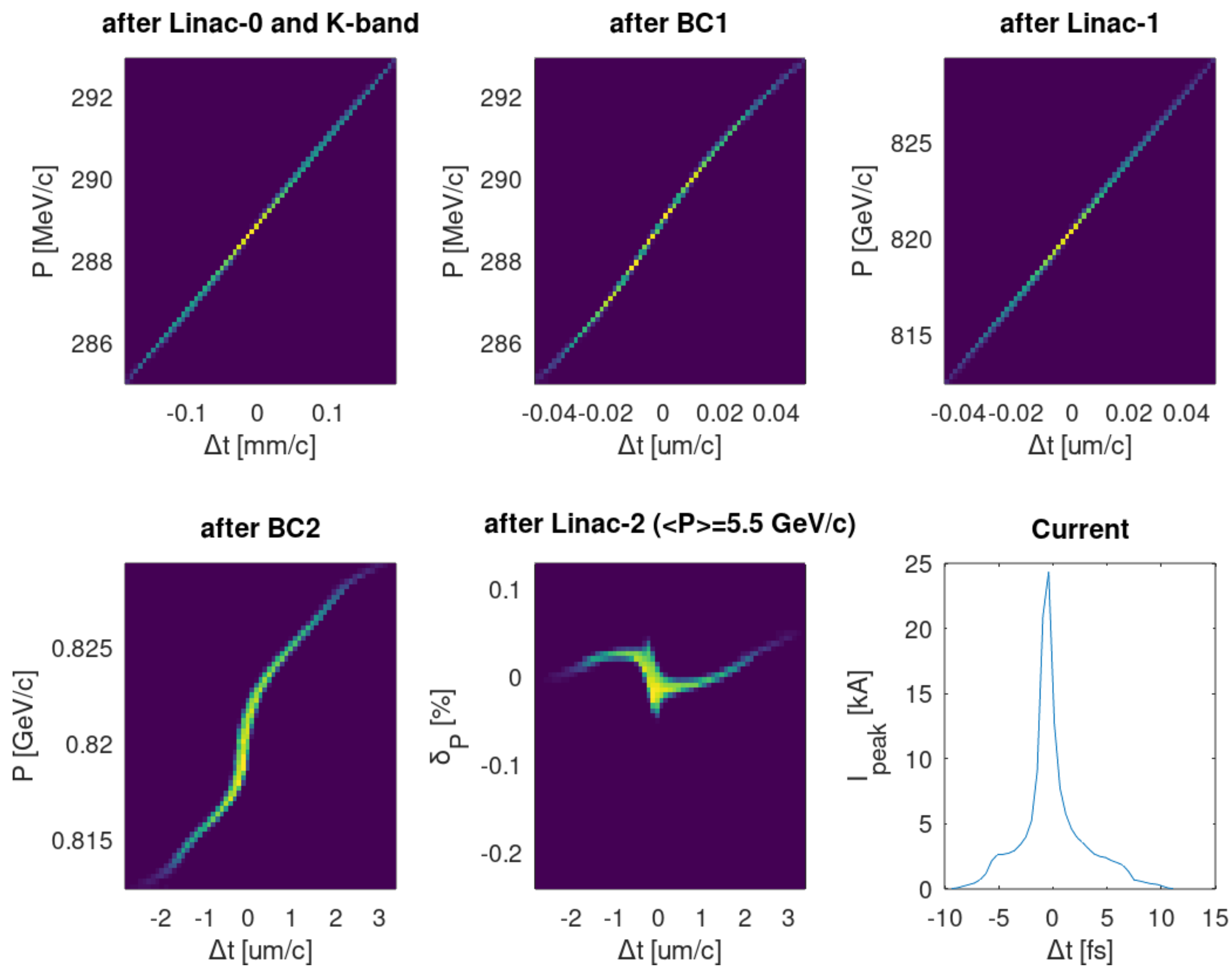
- a >= 2 mm iris aperture radius
- β function at Ka-band <= 5 m
- The required integrated voltage ≤ 20 MV

"Track1D" optimisation

L0_PhiD = 20.761 deg
L0_Voltage = 203 MV
Ka_PhiD = 180 deg
Ka_Voltage = 11 MV
BC1_R56 = -0.0091825 m
L1_PhiD = 40 deg
L1_Voltage = 0.7 GV
BC2_R56 = -0.00425 m
L2_PhiD = 16.175 deg
L2_Voltage = 0.45 GV
L3_PhiD = 2.6 GV
L3_Voltage = 4.2 GV

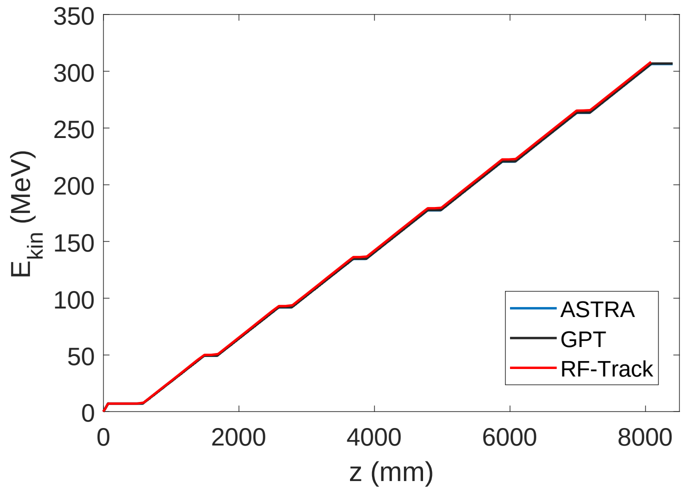
Final rms bunch length = 0.9 um = 3 fs

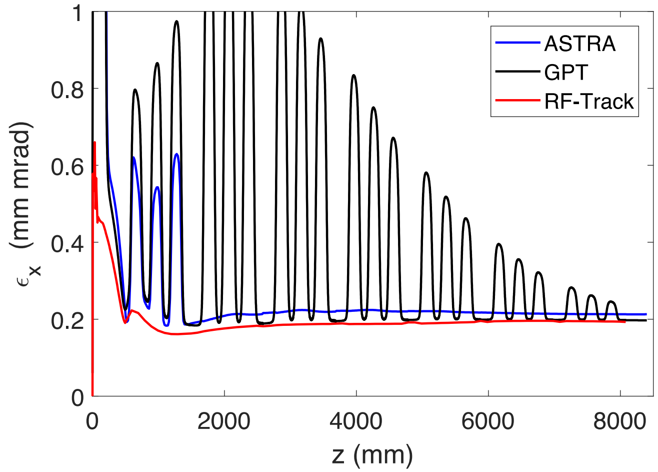
Using a 30 cm long Ka band lineariser

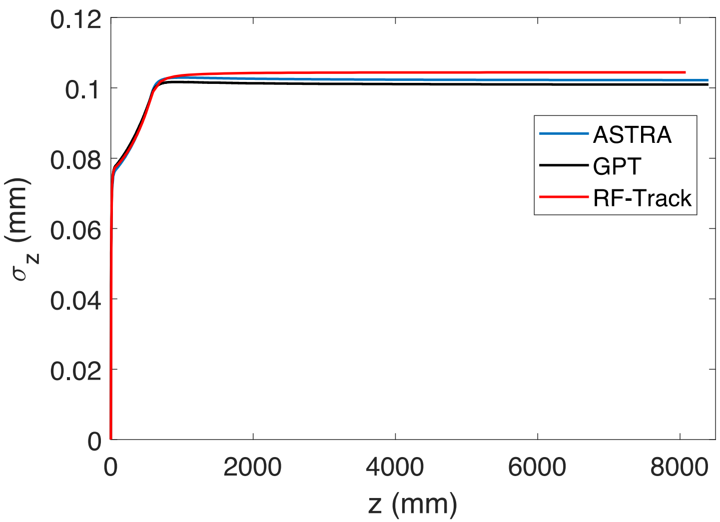


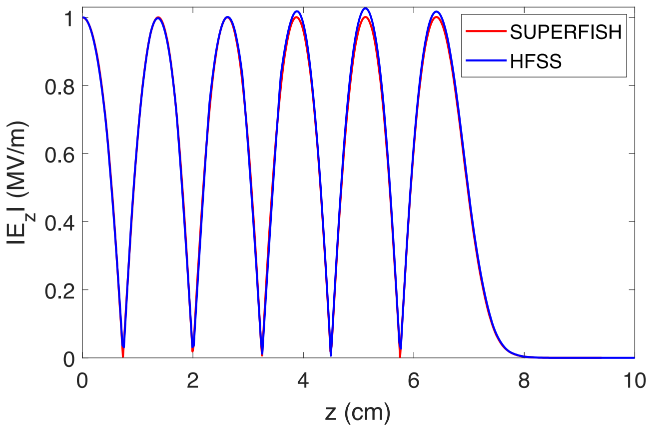
Injector simulation

- “RF-Track” simulation code, we use it also for medical applications and will use for Inverse-Compton Scattering simulations
- Example: XLS X-band based 5.6-cell gun





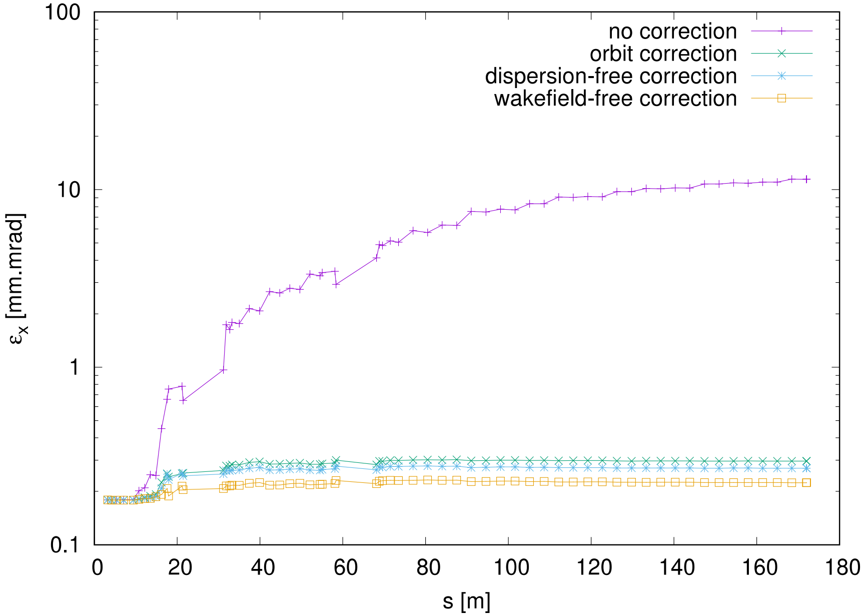


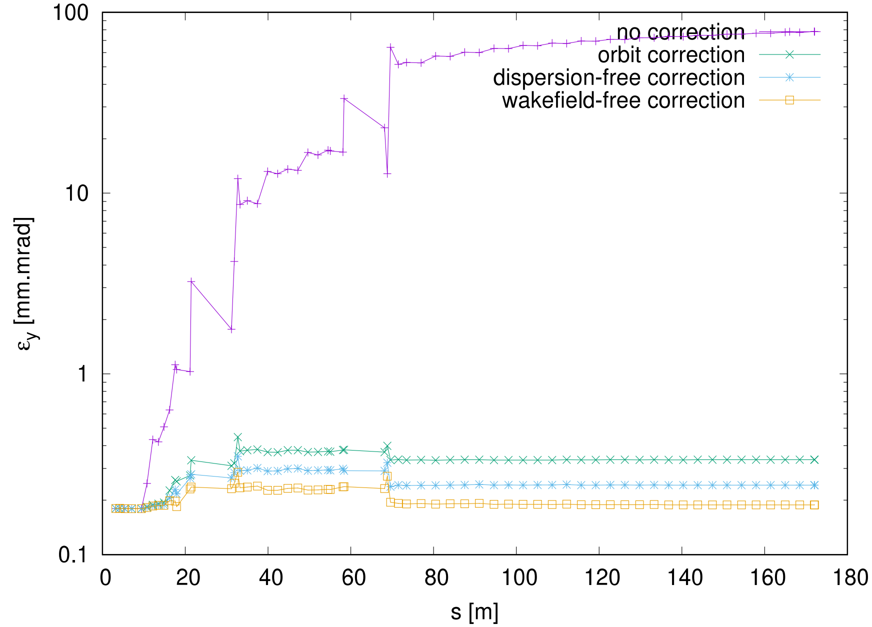


Lattice performance (static imperfections)

Wakefield dominated linac

PLACET simulation of normalized projected emittances along the accelerator (average of 100 random seeds)





90% of the machines achieve:

$\varepsilon_{x,\,90\%} < 0.244$ mm.mrad

$\varepsilon_{y,\,90\%} < 0.217$ mm.mrad

(if bpm resolution = 1 μm

$\varepsilon_{x,\,90\%} < 0.215$ mm.mrad

$\varepsilon_{y,\,90\%} < 0.182$ mm.mrad)

Element misalignment considered:

- 100 μm rms all elements
- 5 μm bpm resolution

Still to be considered:

- Pitch angle errors
- Roll errors

Diagnostics

Funded by the European Union

Compact

Diagnostics definitions

The basic elements for every kind of measurement are defined.

Striplines inside the quads are our choice of trajectory monitor.

Cavity BPM will be used between undulators modules

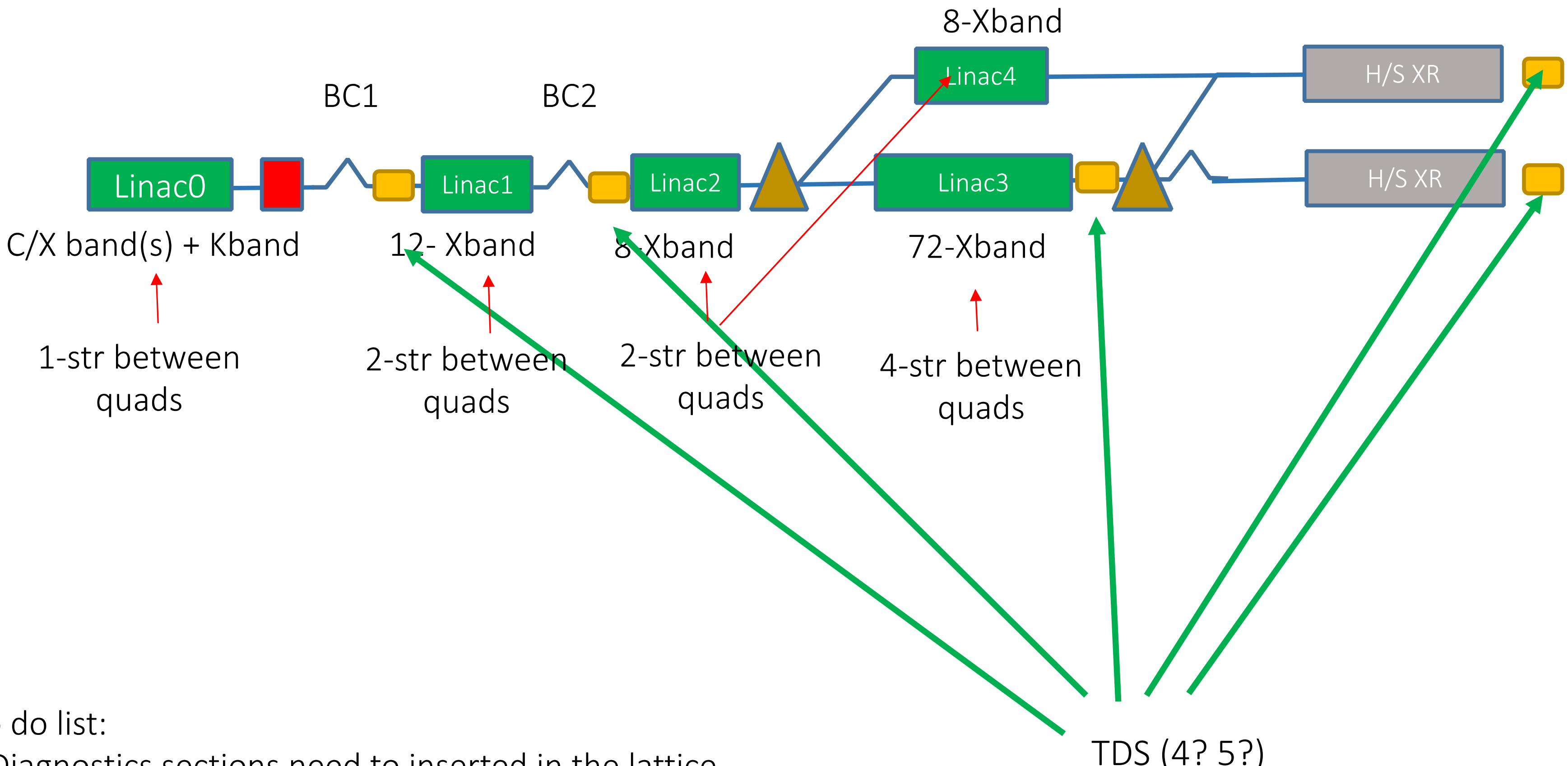
Wakefield monitor will be presented only as a possible and future option.

ICT toroids will be used for accurate charge measurement.

TDS (Polarix) will be used for longitudinal phase space characterization.

Compact view screens will be used for envelope and emittance measurement.

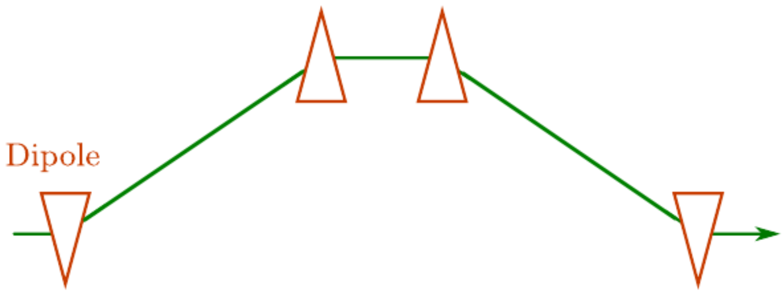
Diagnostics layout

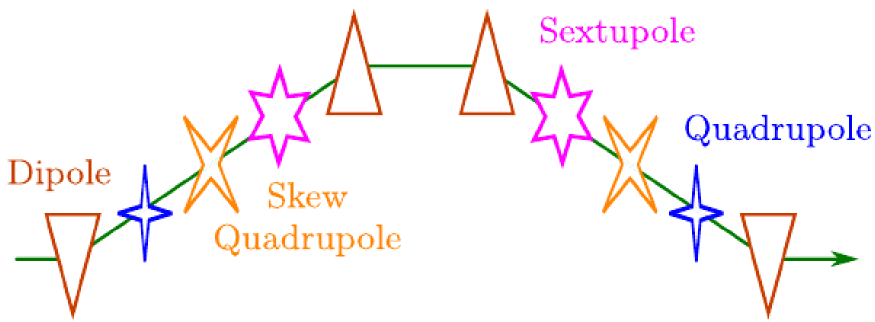


To do list:
- Diagnostics sections need to inserted in the lattice
- Diagnostic optimisation (reduce the number of required components)

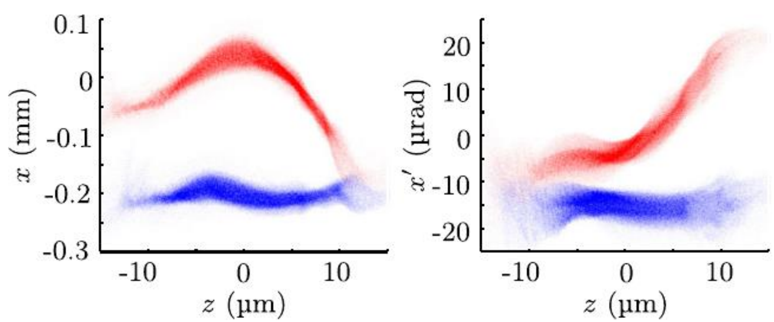
Bunch compressors design

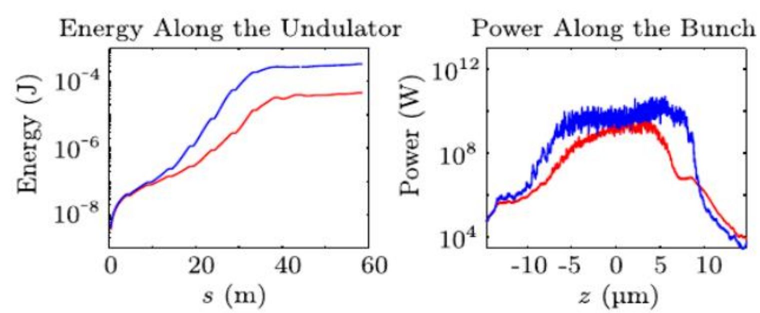
- We use standard chicane for BC1 and BC2 for bunch compressors
- We would need dispersion-based beam-tilt correction in order to increase FEL perormance





PRST- 18, 030701 (2015)





XLS beam dynamics to-do list

Overall parameters optimisation:

- 1D start-to-end optimization with distribution from new injector (with WP3 – INFN LNF)

Design work:

- Re-arrangement of beamlines (i.e. linac modules) to include the longer quadrupoles
- Insertion of the diagnostic sections
  - Diagnostics optimisation to reduce cost / power consumption
- BC's design including CSR and high-order corrections
- Design of missing beam lines
  - Transfer to the undulators including kickers (Ankara)
  - Linac 4

Performance studies:

- Static and dynamic imperfection studies, using the updated design
  - Static:: detailed tolerance study, including transport to the undulators
  - Dynamic: energy, arrival time, current variation due to beam / RF jitter, 2-bunches simulations (long-range wakes)
- Second-order studies (e.g. dark currents, bunch sliced profile w/ new bba techniques, …)

Summary

- CompactLight is nearly at 1 year from its end
    - Still a considerable amount of work to be done
    - We have expertise, but limited resources
- Not all of this work is needed for the CDR
    - We will probably need to sacrifice some studies
    - If XLS goes ahead then all studies would need to be performed
- Areas of collaboration:
    - Simulation codes: development, benchmark, and use
    - Beam dynamics studies
    - Beam performance optimisation