Funded by the
European Union

Compact

Schemes for the Simultaneous Operation of SX and HX FEL beamline

Simone Di Mitri, *Elettra Sincrotrone Trieste*

on behalf of N. Thompson, S. Spampinati, and WP2 collaborators.

FEL Specifications

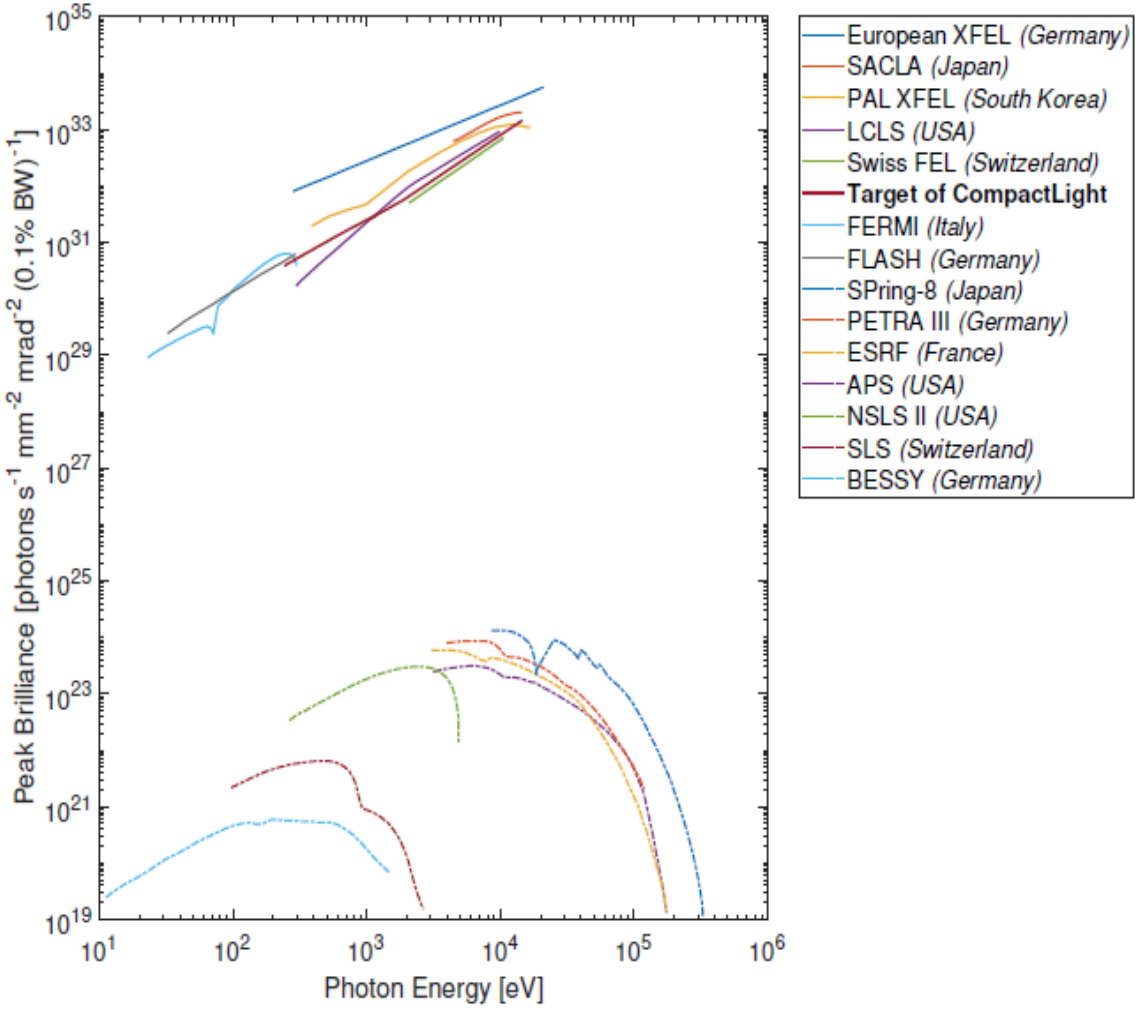
Table 1: Main parameters of the CompactLight FEL.

Parameter	Unit	Soft-x-ray FEL	Hard-x-ray FEL
Photon energy	keV	0.25 – 2.0	2.0 – 16.0
Wavelength	nm	5.0 – 0.6	0.6 – 0.08
Repetition rate	Hz	1000	100
Pulse duration	fs	0.1 – 50	1 – 50
Polarization		Variable, selectable	Variable, selectable
Two-pulse delay	fs	±100	±100
Two-colour separation	%	20	10
Synchronization	fs	<10	<10

SX and HX run simultaneously 2nd level priority

Though, a **simultaneous operation** puts strong **constraints to the e-beam dynamics**, and thereby to the linac design (final energy, magnetic compressors, injector parameters,…)

→ Wiser to consider it from the very beginning….

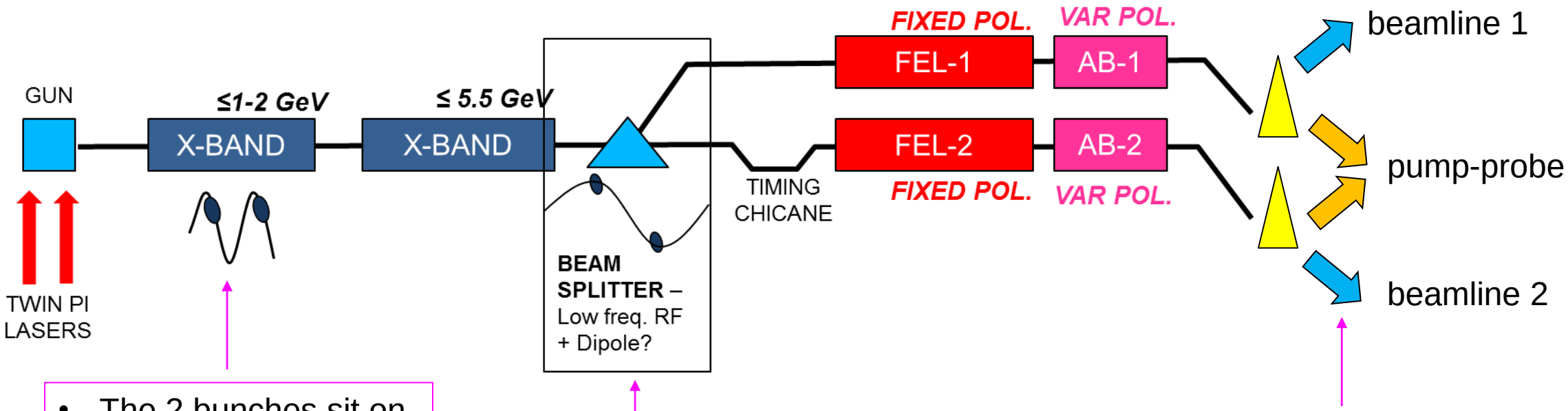


Relevant Numbers

- Original specifications:
  - < 50 fs fwhm FEL pulse duration (in SASE, this is the duration of the lasing electrons)
  - Independent and simultaneous operation of SX and HX at 100 Hz
  - 2-pulse operation with time separation ± 100 fs
  - 2-color operation with energy separation by 20% in SX and 10% in HX

- Our present understanding:
  - A factor 2 wavelength tuning in both SX and HX, together with <20% color separation implies same undulator parameters for SX and HX.
    - e-Beam energy for SX < 3 GeV, for HX < 6 GeV. The beam is extracted at an intermediate location for SX.
  - High peak power in 2-pulse, 2-color mode suggests a "parallel" FEL operation, rather than in "series"
    - Ideally, one undulator line per pulse/color.

Twin bunches – *Alternated* SX/HX operation

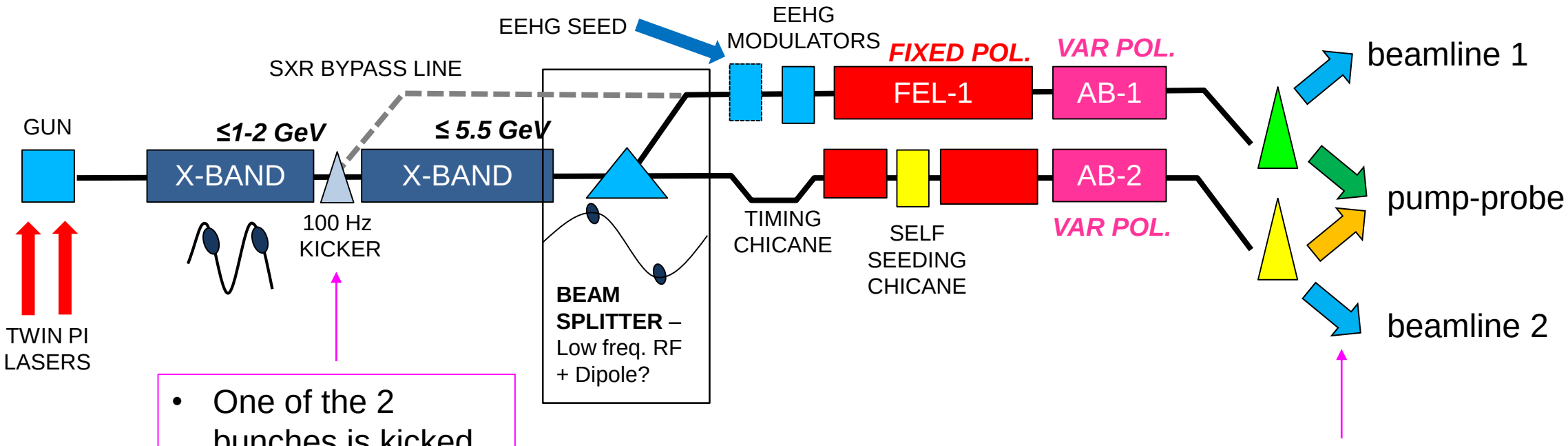


- The 2 bunches sit on consecutive RF cycles (of the injector).
- Ideally, they do identical gymnastic.

- A sub-harmonic RF cavity of X-band splits them in energy.
- A magnetic splitter (septum) separates them transversally.

- **Both FEL** pulses in **HX@100 Hz**, **or** in **SX@1 kHz.**
- Suitable for FEL pump-FEL probe, or 2 distinct beamlines.

Twin bunches – *Simultaneous* SX/HX operation

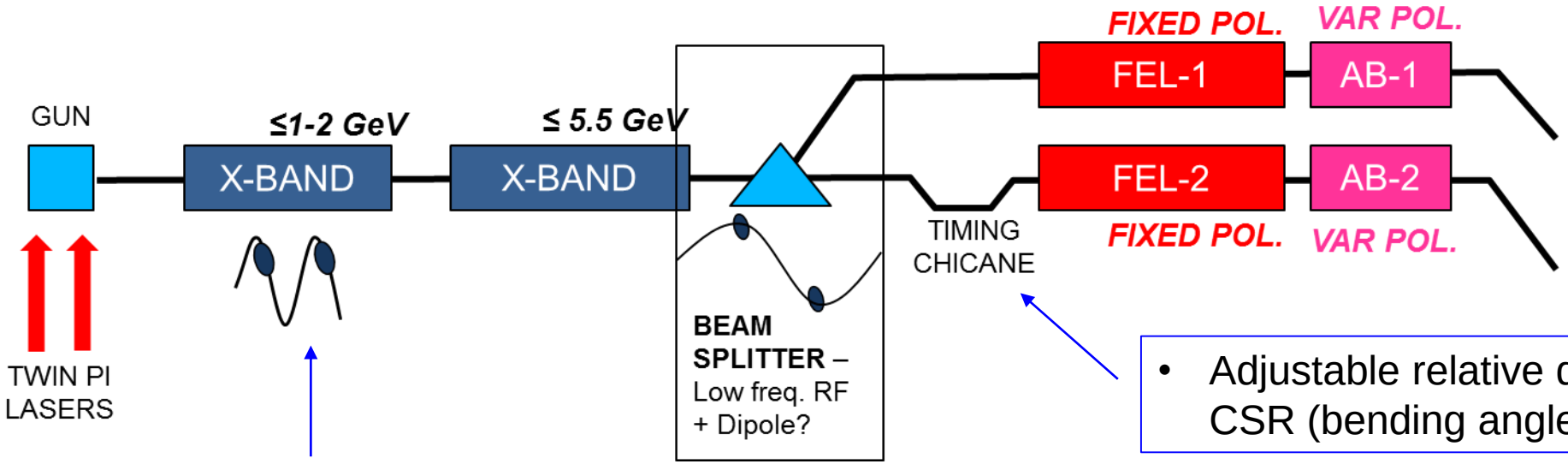


- One of the 2 bunches is kicked out at lower energy.

- **SX + HX, @ 100 Hz**

- State-of-the-art stripline kickers have ~ns rise/fall time.
- Twin bunches relatively far each other.
- OK for independent SX and HX operation.

Twin bunches – *Implementation Aspects*

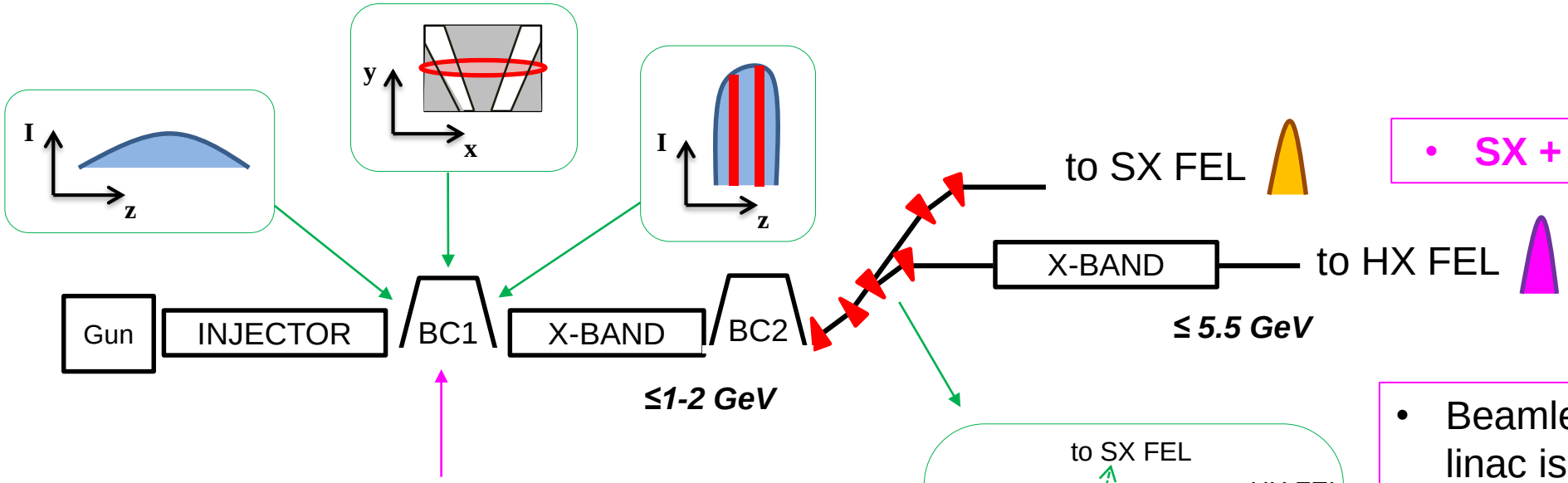


- Adjustable relative delay limited by CSR (bending angles).

- Time separation is ~330 ps @ 3 GHz, ~165 ps @ 6 GHz, ~83 ps @ 12 GHz.
- The shorter the separation, the smaller the RF fluctuations sampled within the RF pulse.
- The shorter the separation, the stronger the linac wakefields effect on the trailing bunch

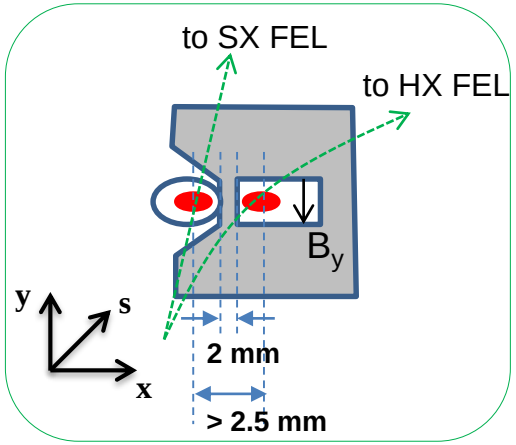
- Careful optics design of the splitter line to preserve beam quality (CSR)

Beam scraping – *Simultaneous* SX/HX operation



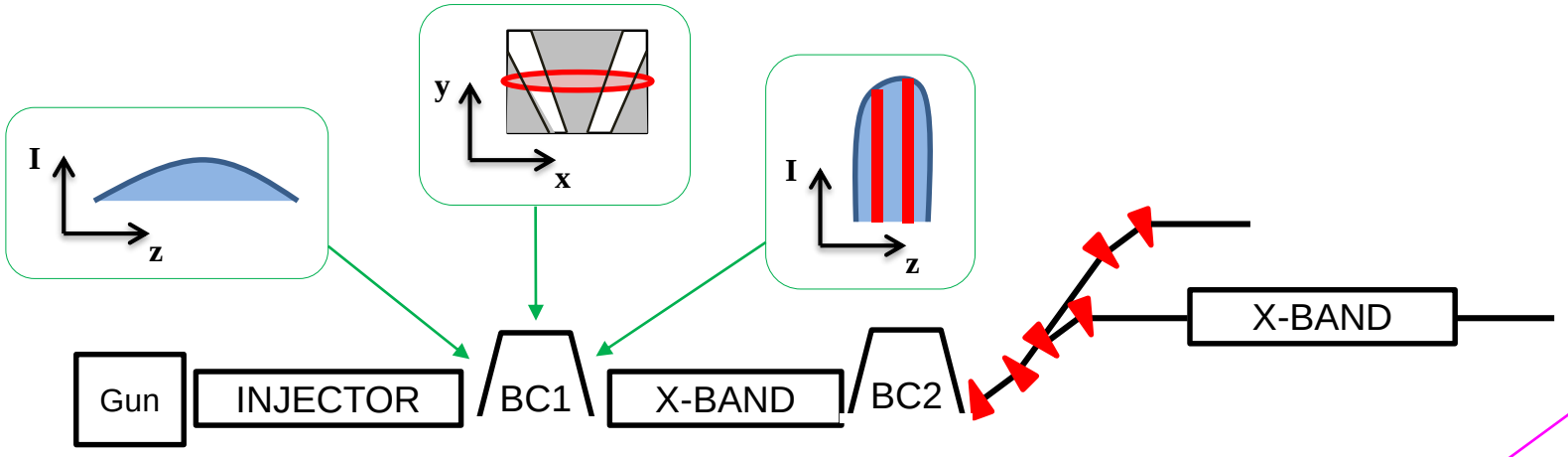
- SX + HX, @ 100 Hz

- Beamlets are physically selected within each bunch.
- Time separation is < few ps.
- Beamlets duration is tuneable, > 10 fs or so.



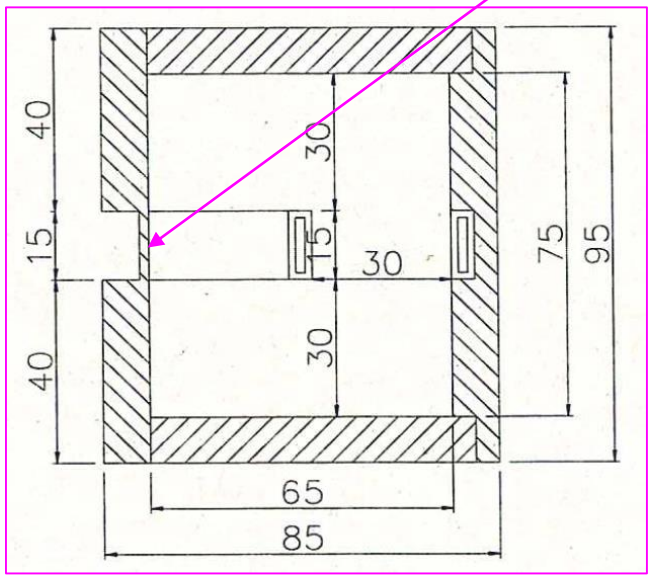
- Beamlets dynamics in the linac is coupled – optimum phasing for large E-difference, small E-chirp.
- Beamlets reach the septum at few-% energy difference, where they are transversally separated.

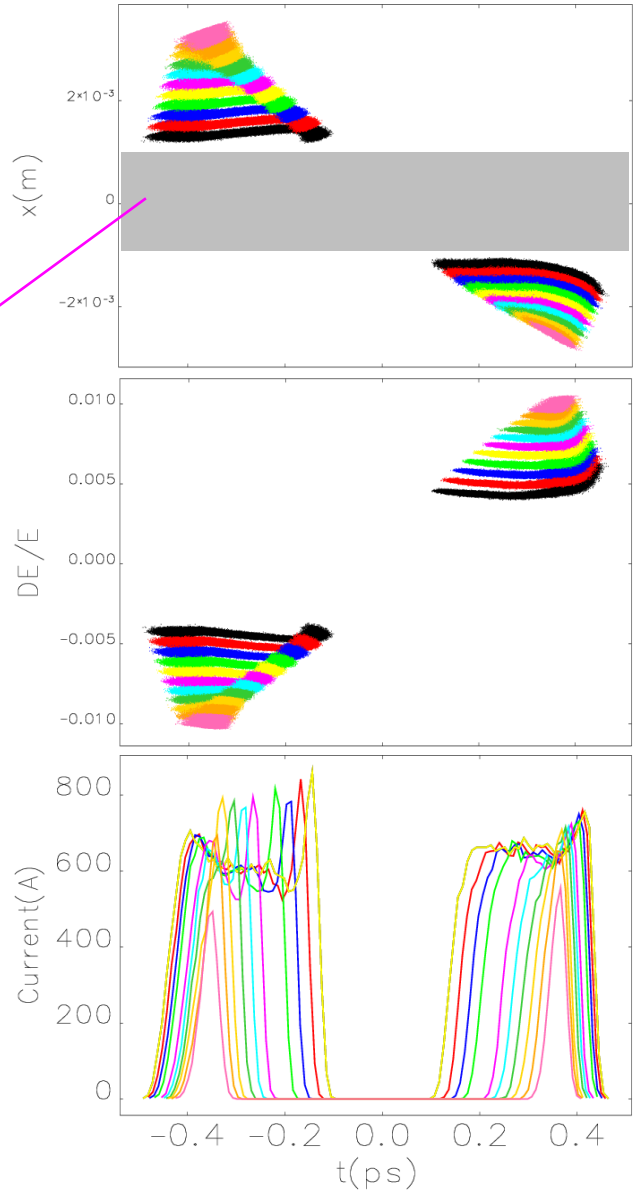
Beam scraping – *Septum and Tuneability*



- Small spatial separation of the beamlets,
→ thin septum magnet,
→ eddy-current device (pulsed, in-vacuum)
→ low rep rate (dissipated power in vacuum)

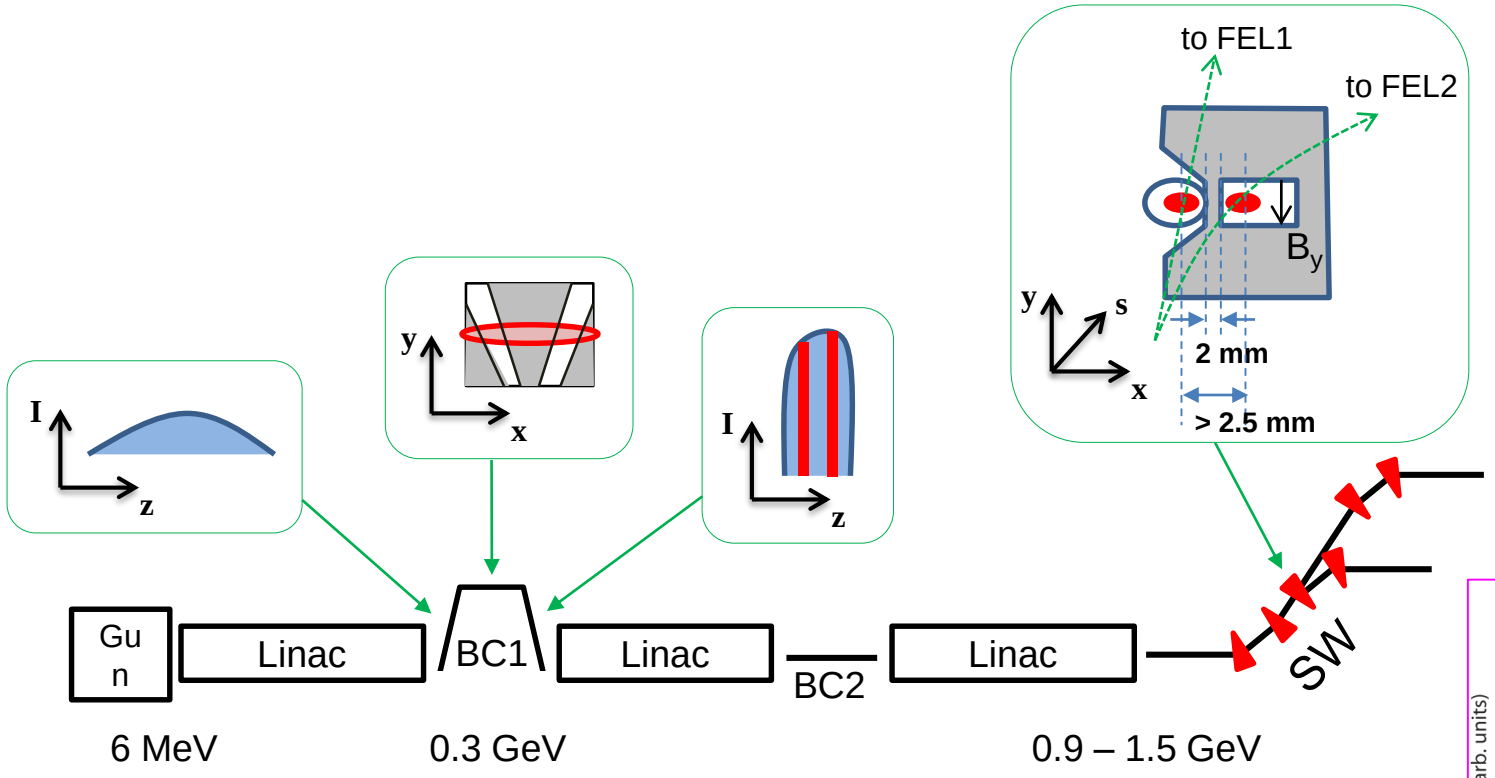
- Large spatial separation requires off-crest linac phasing, large dispersion function.

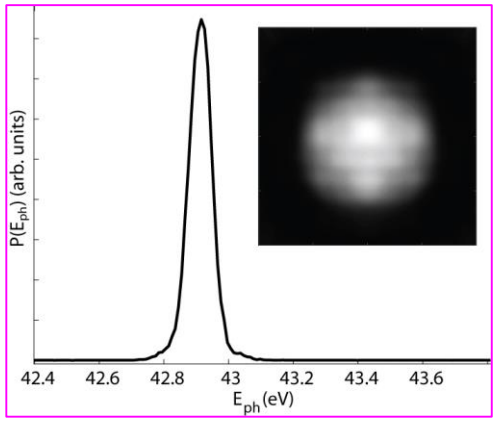




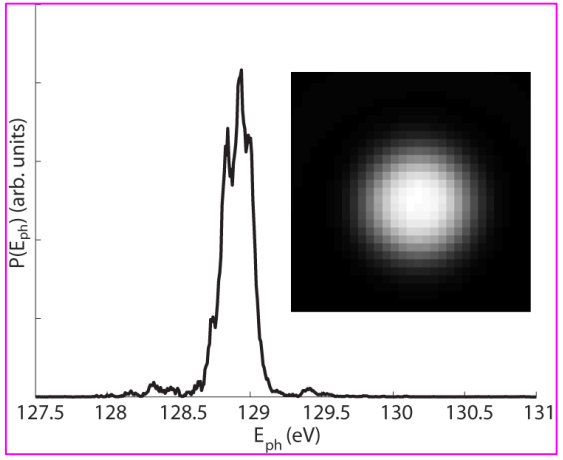
Septum study, courtesy of R. Fabris (Elettra)

Beam scraping – *FEL*





FEL1, HGHG



FEL2, HGHG-FB

- Both schemes can be applied to CompactLight
- Detailed feasibility study once the “macroscopic” beam and FEL parameters will be frozen.
- Main focus will be on the BC2 energy, the extraction lines optics design, the fast kicker and septum performance.

Thank you for your attention