Future interests on high gradients at FERMI@Elettra FEL

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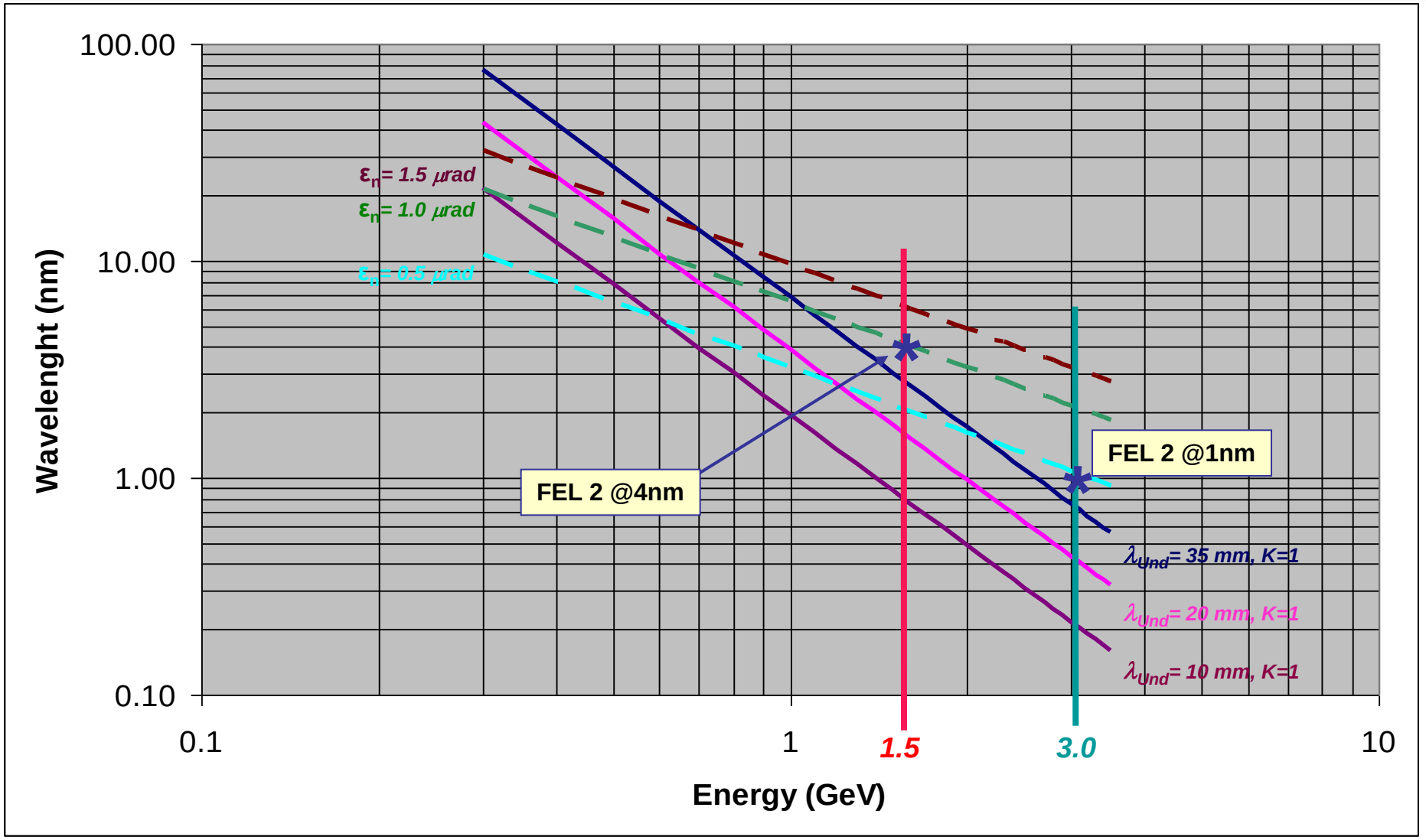
Preliminary considerations

- FERMI@Elettra is a seeded FEL Facility under commissioning at the Elettra – Sincrotrone Trieste Laboratory.
- It operates in the ultraviolet and soft x-ray range, providing fully coherent ultra short photon pulses (10-100 fs).
- The machine is based on a normal conducting linac operating up to 1.5 GeV.
- With the present layout FERMI is expected to reach a wavelength of 4 nm. An extension of its wavelength capabilities (down to 1 nm or lower), is very attractive for the Users Community.
- To reach the above mentioned wavelength region, it would be necessary to increase the electron beam energy up to 3 GeV or more. Considering the limited space available in the machine tunnel, the use of very high gradient structures is mandatory.

FEL scaling laws

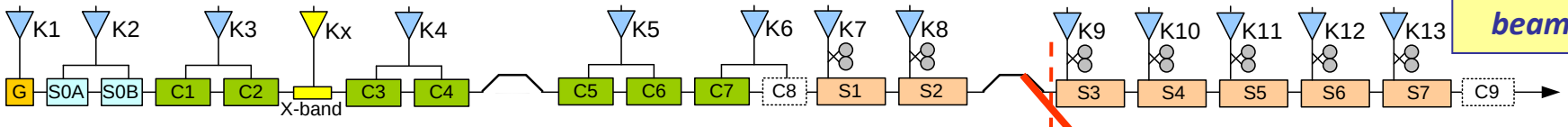


—— *Resonance condition* $\lambda_L = \frac{\lambda_{Und}}{2\gamma^2}\left(1+\frac{K^2}{2}\right)$ ------ *Emittance condition* $\varepsilon_n/\gamma \leq \lambda_L/4\pi$

Present layout and proposed energy upgrade

FERMI current layout and performance:

- E_{beam} up to 1.5 GeV
- FEL-1 at 80-10 nm and FEL-2 at 10-4 nm
- Seeded schemes
- Long e-beam pulse (up to 700 fs), with "fresh bunch technique" for FEL-2



FEL-1 & FEL-2 beamlines

Beam input energy
≥ 750 MeV

X-band linac extension

~50 m available

40 m (80%)
available for acceleration

X-band energy upgrade

• Space available for acceleration	40 m
• Accelerating gradient @12 GHz	60 MV/m
• X-band linac energy gain	2.4 GeV
• Injection energy	.75 GeV
• Linac output energy	3.15 GeV

e-beam for a new FEL beamline

$\lambda \leq 1$ nm

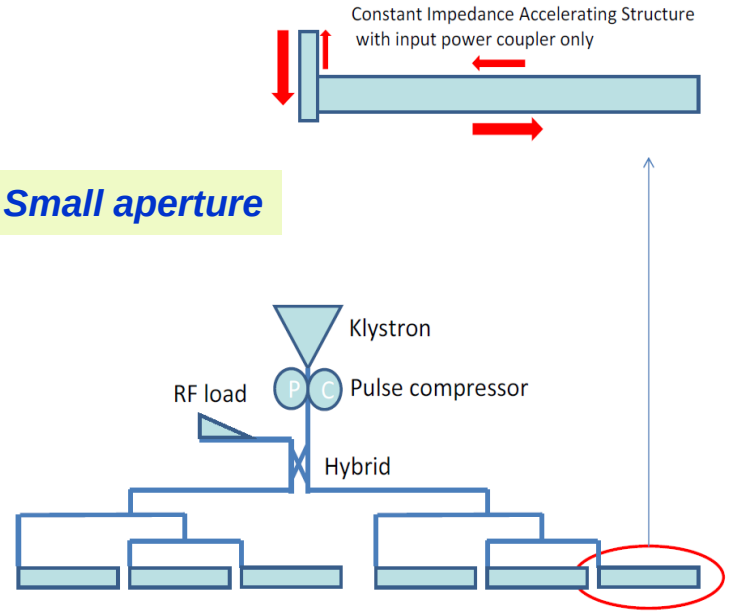
Operation:

- *short bunch (< 100 fs)*
- *low charge (< 100pC)*

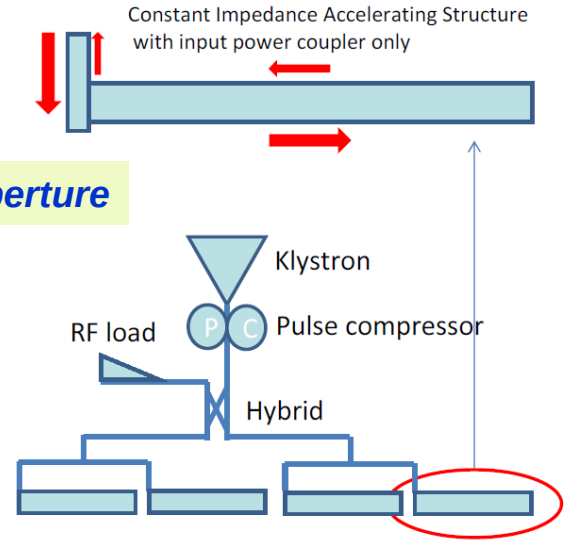
Preliminary evaluations

A. Grudiev

Small aperture



Middle aperture



Parameter	*Small Aperture*	*Middle aperture*
Energy gain (GeV)	**2.4**	
Active length (m)	**40**	
Aperture (mm)	**2.95**	**3.62**
Structure length (m)	**0.833**	**1.0**
Accelerating gradient (MV/m)	**60**	
No. of structures	**48**	**40**
RF power (MW)	**322**	**401**
No. of klystrons	**8**	**10**

Estimated costs 16/17.5 M€

Short term perspectives

Prepare a preliminary design of the machine starting from:

- **the new FEL parameters, layout, wavelength range and expected performance (choices and assessments that are Users driven).**

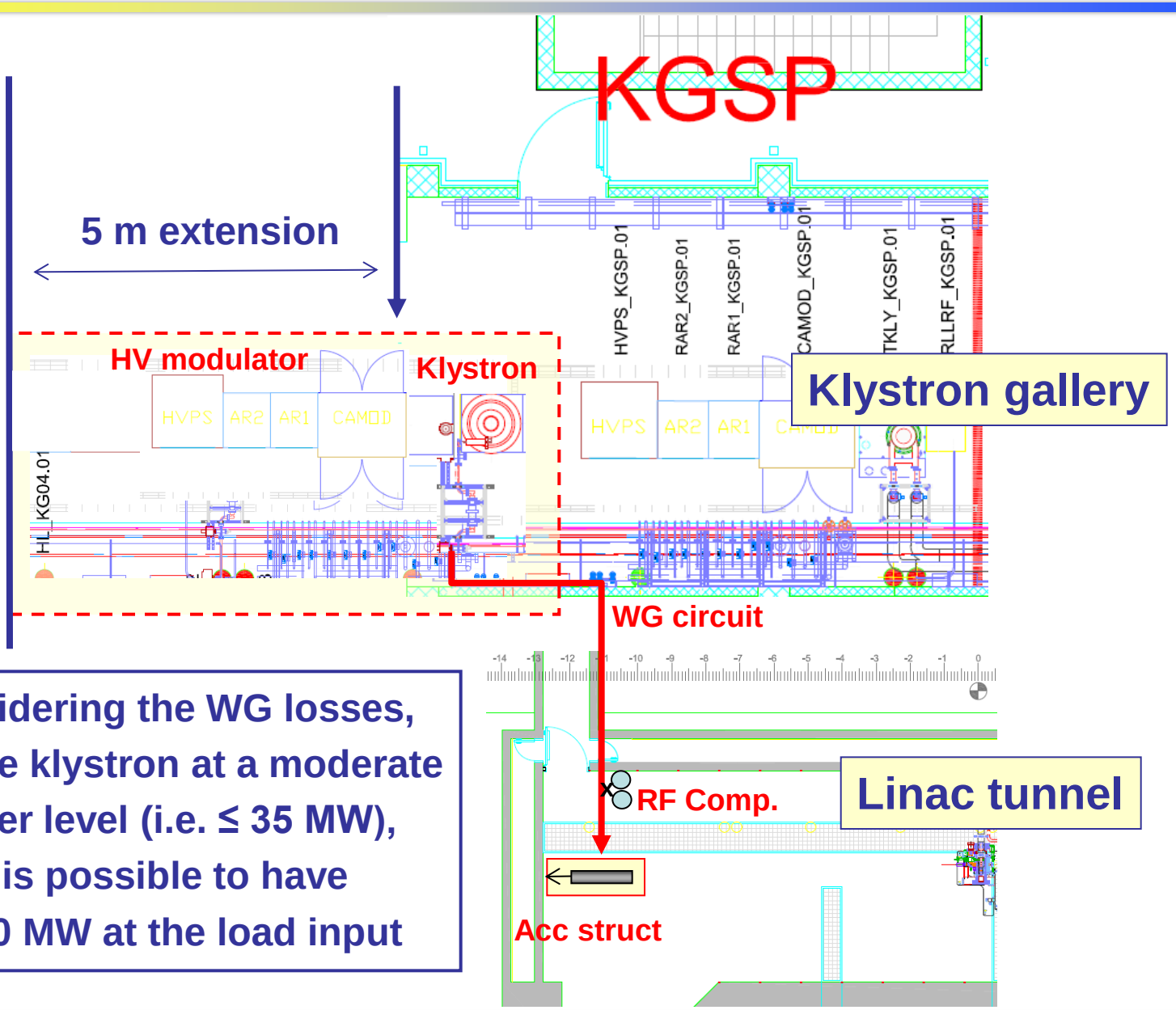
Then:

- **define the linac working point, maximizing the beam brightness keeping the collective effects under control;**
- **design an accelerating structure unit that minimizes the project costs, in terms of number of RF plants, for reaching the target energy;**
- **confirm the structure design parameters with high power RF tests performed with an X-band test station on prototypes.**

X-Band test station

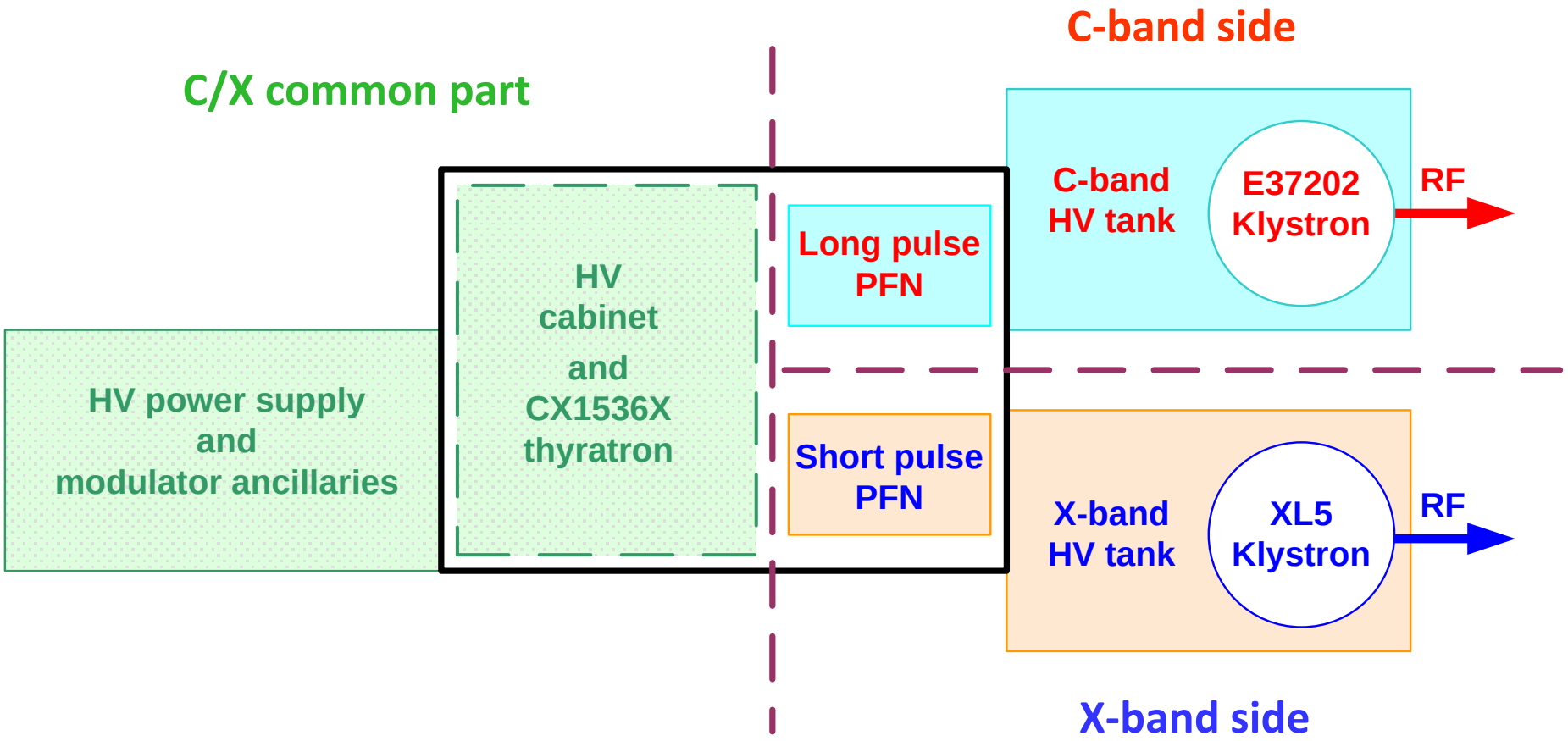
- The test station can use the XL5 spare klystron already at Elettra since August 2012. Note that a periodical check and operation of the tube is also suggested by SLAC.
- Equipped with a proper RF compressor, with ≤ 35 MW from the klystron, the station would deliver more than 80-90 MW at the load input.
- At these power levels, it would be possible to extensively test X-band structures and modules, obtaining the optimal choice for the FERMI energy upgrade.
- The station could also be used for the CLIC high gradient structures test program, giving the opportunity to continue to acquire experience and know-how at 12 GHz.

X-band test station layout



Considering the WG losses, with the klystron at a moderate power level (i.e. ≤ 35 MW), it is possible to have 80-90 MW at the load input

HV modulator layout



Conclusions

- An important development for the FERMI@Elettra FEL facility would be the estension of its capabilities in terms of shorter wavelengths.
- This requires an extension of the linac energy up to 3.0 GeV.
- Considering the limited space available in the present machine tunnel, the use of very high gradient structures is mandatory.
- To further explore this possibility, validating the machine layout and the component design, the assembly of a X band testing station is under evaluation.