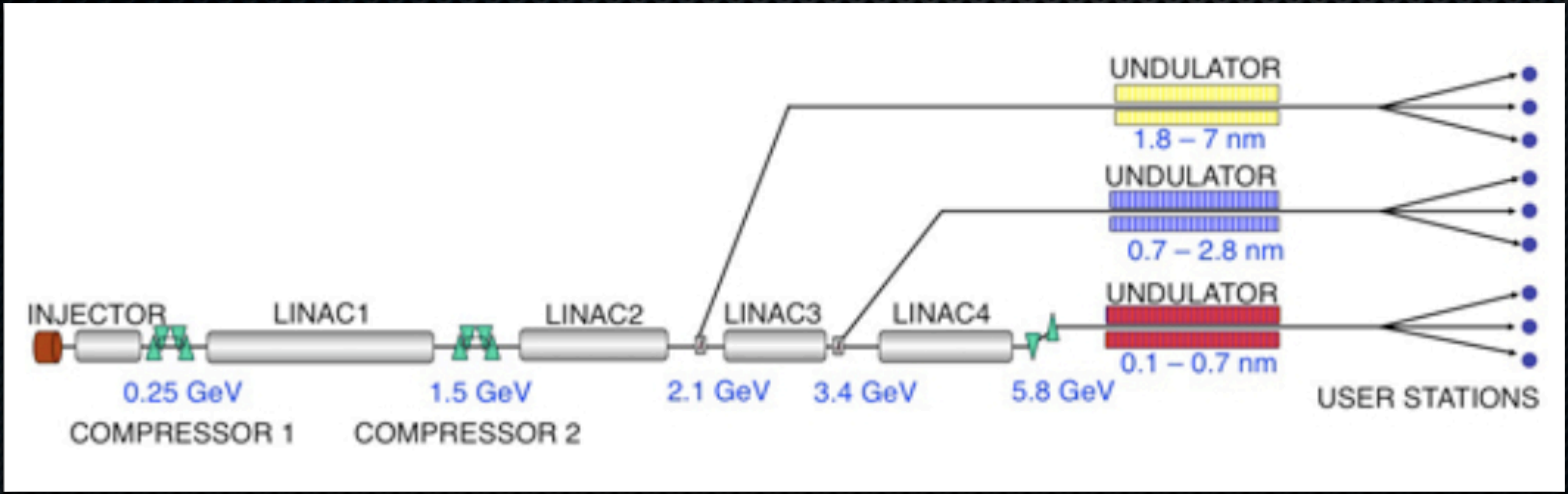

Design of the PSI-XFEL switchyard

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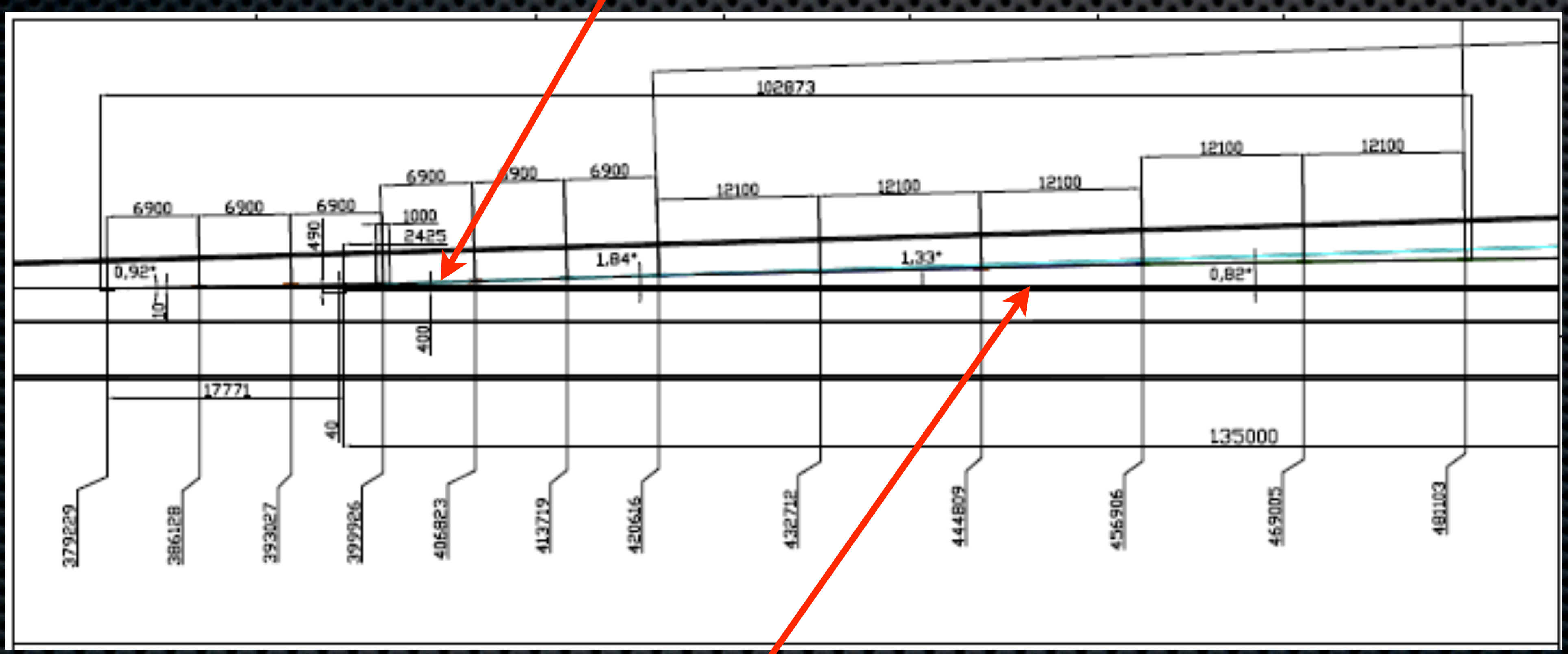
Outline

- Switchyard concept:
  - Constrains - 2 or 3 bends?
  - Input and Output parameters (matching);
- Other Labs switchyards:
  - European XFEL and
  - LCLS;
- Tools available;
- Final Remarks.

Constrains: Geometry and available space

Begin of the first switchyard (3.4 GeV)



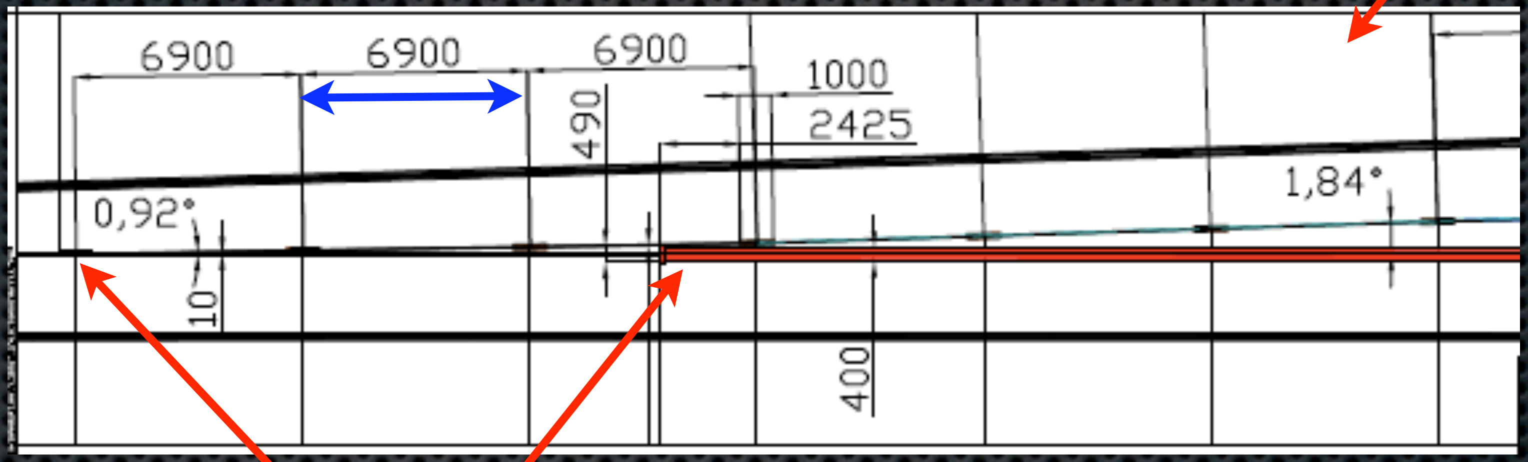
Main line (6GeV)

Separation of the beamlines ↕ at the experimental stations must be around 6-7 m

Constrains: Geometry and available space

distance between elements
6.9 m

total deflection



Minimum deflection angle

this is due to the accelerating structure for the main line which comes after the switchyard

2 or 3 bends?

- 2 Bends:
  - Simplicity;
  - Achromat but not Isochronous;
  - Use of the smallest possible angles -> reduces the damaging effects cause by ISR and CSR.
- 3 Bends:
  - More prone to have problems due to radiation since the angles are bigger and we have more bends;
  - Achromat and Isochronous and
  - Flexibility to adjust R_{56}.

Input and Output parameters:

- INPUT:
  - Energy: 3.4 GeV
  - sigma x/y (μm): 37.9/18.8
  - normalized emittance (μm rad): 0.463/0.346
  - bunch length (μm): 9.196
  - energy spread:

- OUTPUT (tolerances):
  - Average beta functions: 9 m
  - How much bunch lengthening?
  - Emittance growth?
  - etc...

European XFEL switchyard

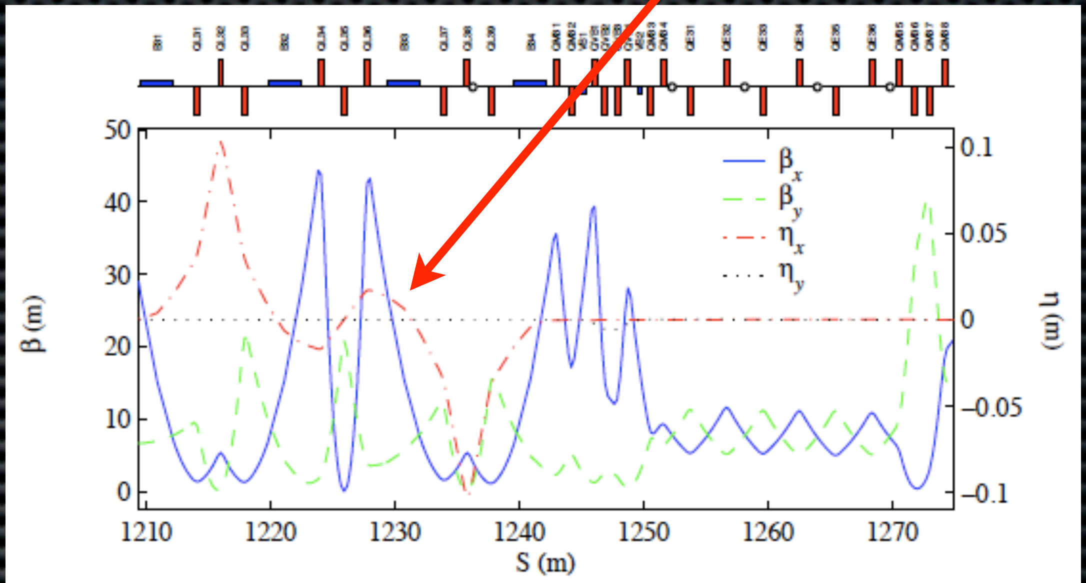
Energy = 17.5 GeV

- Switchyard: Double bend + magnetic chicane (necessary to compensate for negative R_{56});
- They need sextupoles to correct for chromatic effects;
- Main problems/concerns:
  - Allow for a high energy acceptance (2%);
  - Microbunch instability in the bends;
- Work in progress:
  - section is not isochronous (R_{56} is not zero) and chromatic properties need more study.

LCLS switchyard

two Chasman-Green cells
R_{56}=0 and T_{566}≈73 mm

- REQUIREMENTS:
- Not alter the bunch length;
- precise energy measurement capability and
- precise transverse emittance and matching diagnostics.



Parameter	Symbol	Unit	Value
Nominal high-end beam energy	E	GeV	14.35
Total horizontal beamline inflection	Δx	m	0.45
Total vertical beamline angle change (sets a level undulator)	$\Delta\theta_y$	deg	0.30
Nominal rms bunch length throughout dog-leg	σ_z	μm	22
RMS core relative energy spread (14.35 GeV)	σ_δ	%	<0.02
RMS uncorrelated energy spread (14.35 GeV, with wiggler)	σ_{δ_u}	10^{-4}	8
Net momentum compaction	R_{56}	mm	0
Net second order momentum compaction	T_{566}	mm	5
Length of each of four horizontal dipole magnets	L_H	m	2.62
Length of each of two vertical dipole magnets	L_V	m	0.4
Bend angle of each of 4 horizontal dipoles	$\|\theta_H\|$	deg	0.65
Bend angle of each of 2 vertical dipoles	$\|\theta_V\|$	deg	0.15
Magnetic field of each horizontal dipole (at 14.35 GeV)	$\|B_H\|$	kG	2.07
Magnetic field of each vertical dipole (at 14.35 GeV)	$\|B_V\|$	kG	3.13
Maximum horizontal dispersion	$\|\eta_{max}\|$	m	0.103
Emittance dilution due to ISR (at $\gamma\varepsilon_0 = 1$ μm)	$\Delta\varepsilon_{ISR}/\varepsilon_0$	%	0.8
Projected emittance dilution due to CSR (at $\gamma\varepsilon_0 = 1$ μm)	$\Delta\varepsilon_{CSR}/\varepsilon_0$	%	8
RMS ISR relative energy spread (at 14.35 GeV)	$\sigma_{\delta ISR}$	10^{-4}	0.05
RMS CSR relative energy spread (at 14.35 GeV)	$\sigma_{\delta CSR}$	10^{-4}	4.7

Tools available

- For the lattice evaluation:
  - TRACY and MAD-X - both have the PTC algorithms built in so the tracking is always symplectic;
  - I decided for MAD-X since it is more widely used and the there is some documentation available.
- For evaluation of CSR effects:
  - Need help with the simulations using Elegant/ TraFiC4.

Final Remarks

- How to attack the problem:
  - Simple lattice using only dipoles+quads;
  - Evaluate non-linear effects and radiation (ISR and CSR);
  - Modify lattice to include more realistic elements (field errors, alignments errors, septum, etc...);
  - Re-evaluate non-linear and radiation effects in this more realistic model and optimize it (introduce sextupoles, etc...).
- Suggestions, critics and advices are welcome.