Laser Heater Integration into XFEL Injector and Overview of the Space Margins

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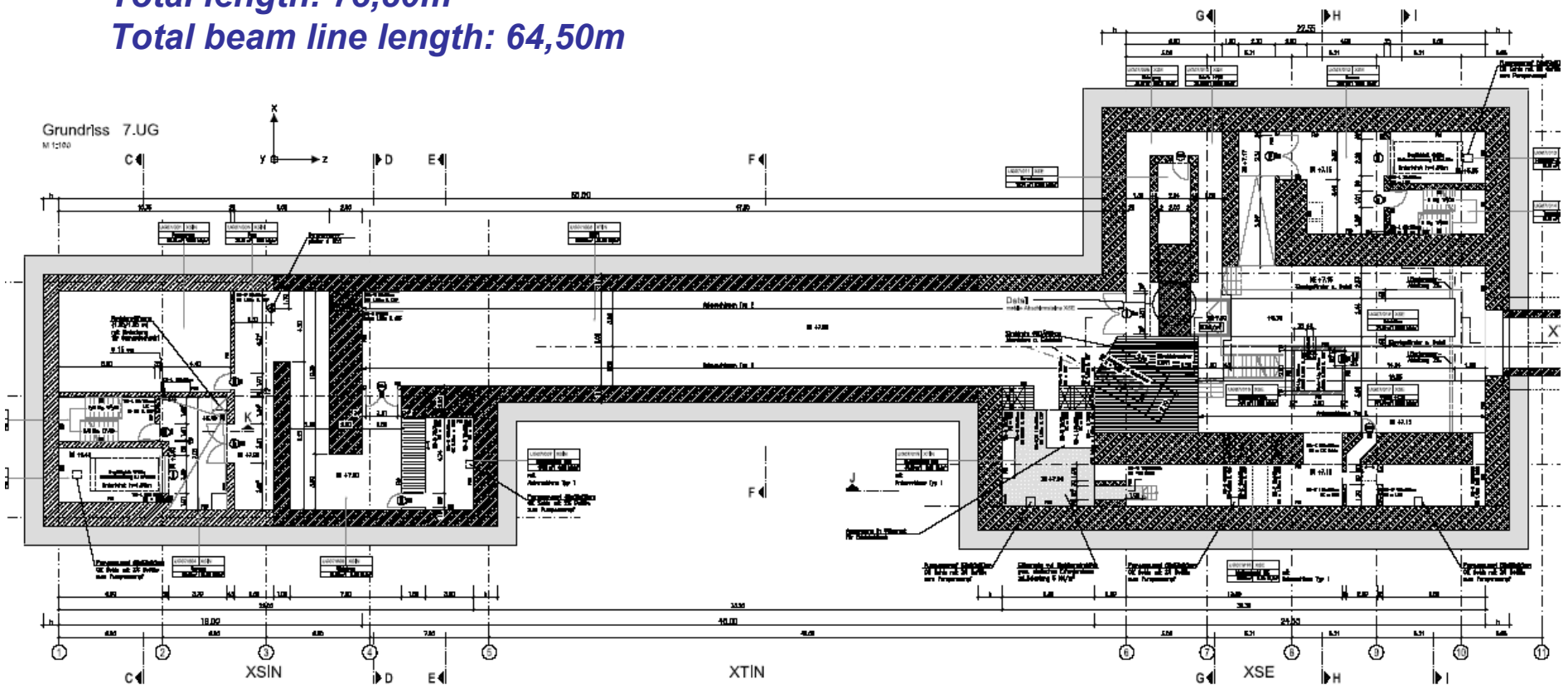
Contents

- Injector Building Plan and „boundary conditions“
- Laser Heater Integration in short version
- Laser Heater Integration in comfortable Version
- Discussion on Space Margins at the Injector.

Injector Building Plan

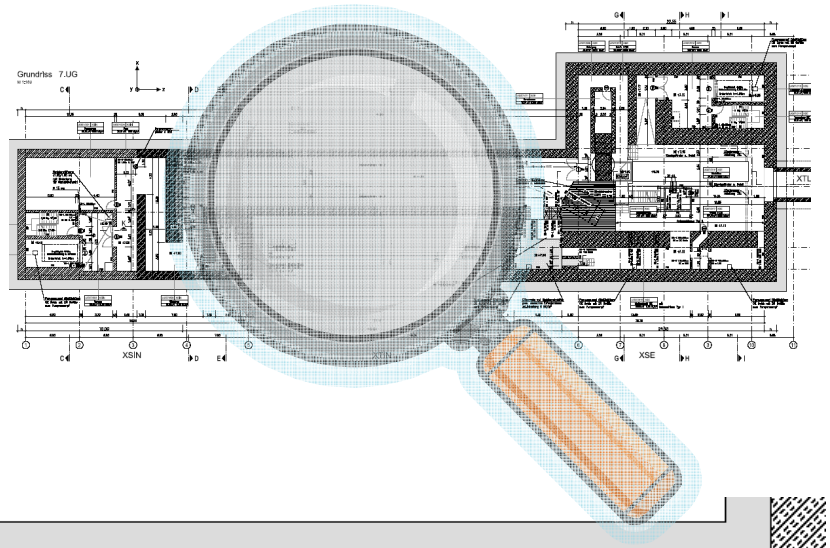
Injector is divided by reinforced concrete wall (Shielding) in two unequal parts:
- left one is used for injection tuning
- in the right one the beam is matched by means of Dogleg into the Linac

Total length: 73,80m
Total beam line length: 64,50m

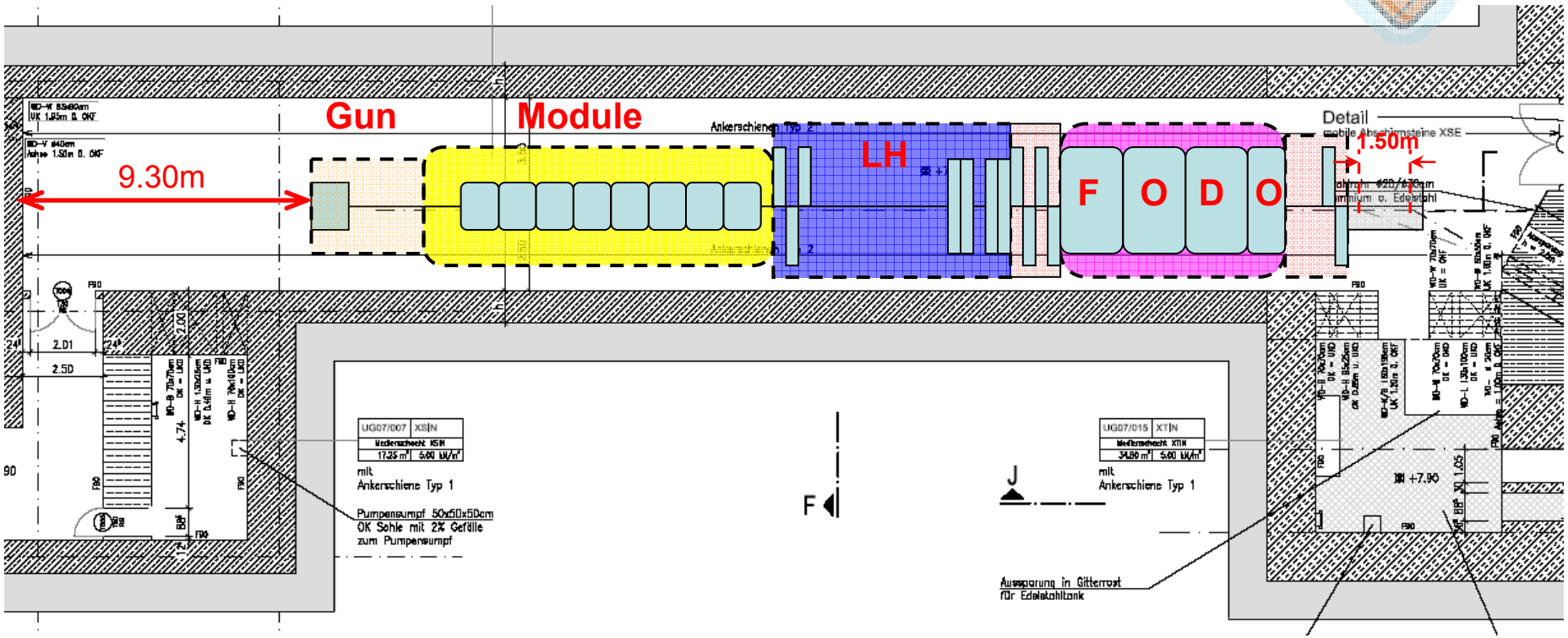


Point of Interest: from Gun to Dump

Boundary conditions:
The wall on the left ←→Dump dipole on the right.
All diagnostics have to be be placed there.



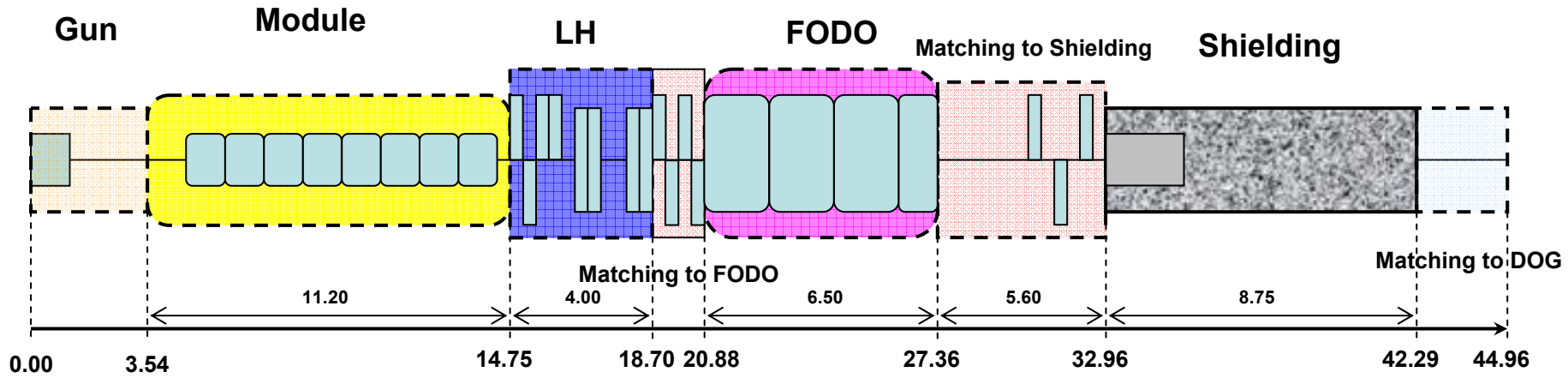
Beamline length from Gun to Dump: 32,40m



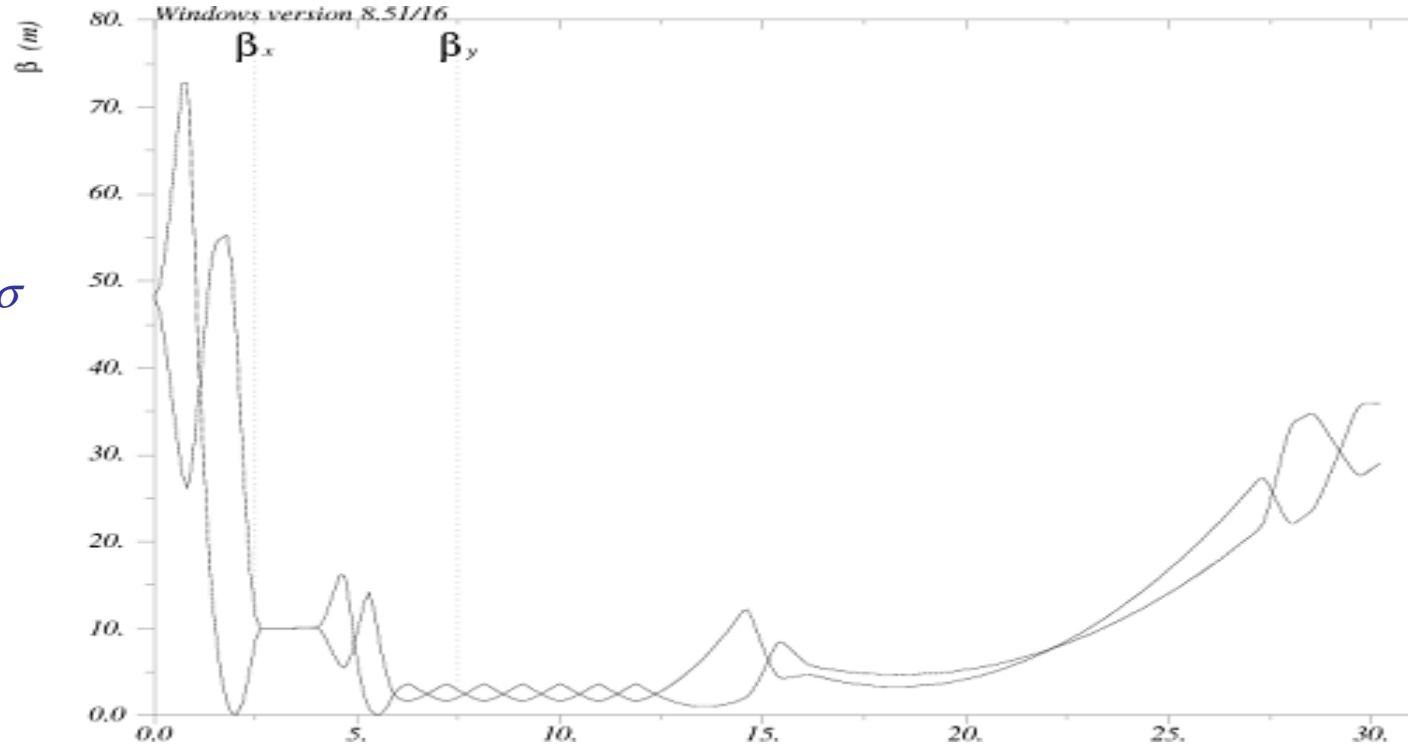
Laser Heater Integration: Optics Considerations

Point of view	Assumptions	Requirements on Optics
Aperture margins	ϕ =7mm (pipe diameter) ε=1.4 mm mrad E=125MeV	β_x < 85m β_y < 85m for 10σ β_x < 60m β_y < 60m for 12σ
Laser Heater	Same as at LCLS: Magnetic chicane of 1.20m length. Interaction length with laser: 0.5m	< β_x > = < β_y > = 10m. Beta functions as constant as possible.
Diagnostics		FODO with 45° phase advance
Beam dynamics		Beam as round as possible
Sensiblity to errors		Preferably smaller k values of the quadrupoles

Laser Heater Integration: Short Version



- LH requires 4.0m
- max β = 72.25m
  corresponds to 10.9σ
- max (σ_x/σ_y) = 19.2
- max k_1 = 8.464
- constant beta function along the heater

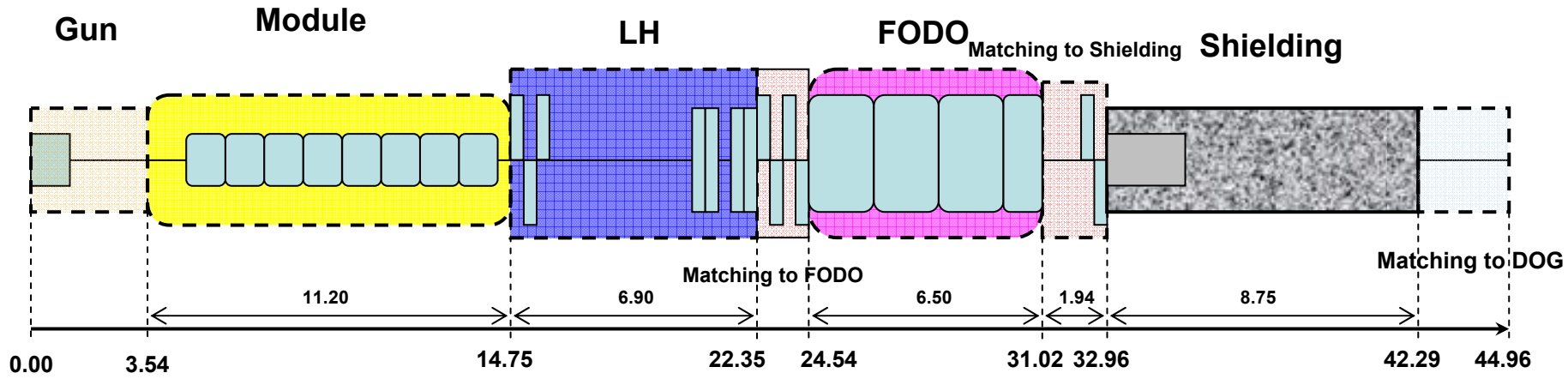


Laser Heater Integration. Short Version - II

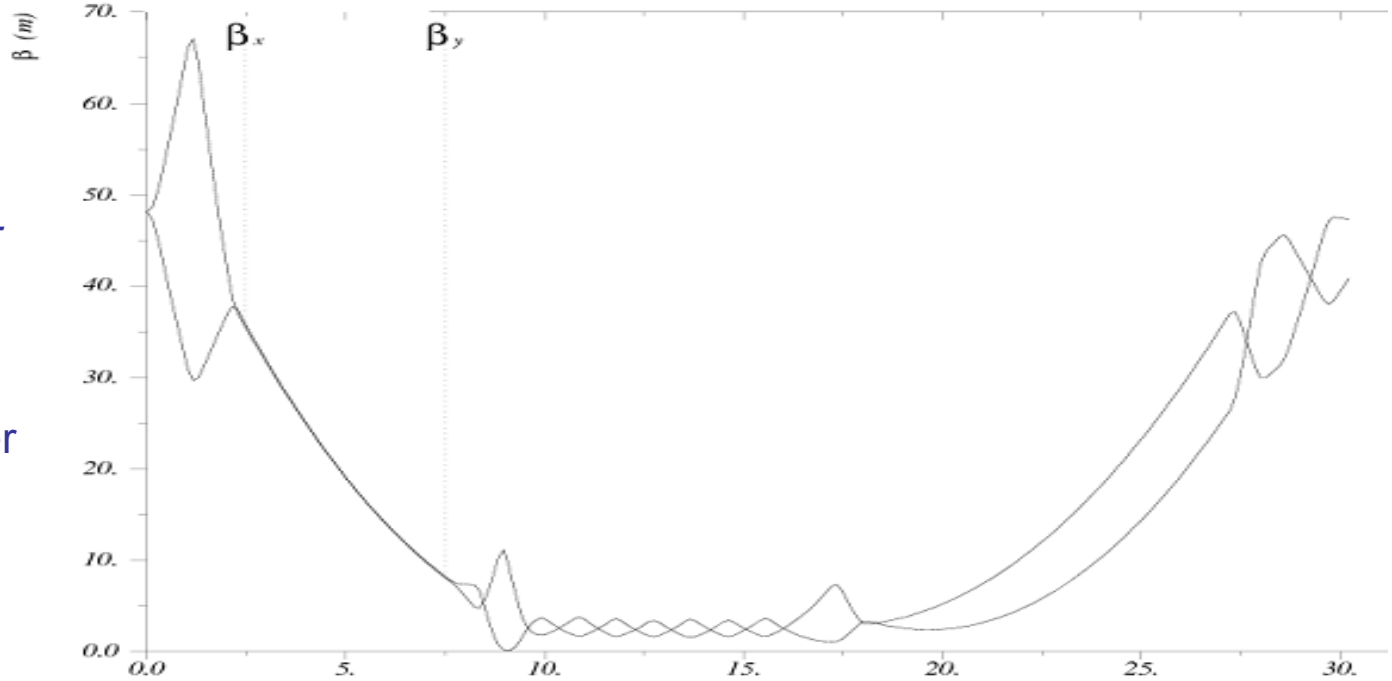
Quad	β_x/β_y	k_1	comments
Q.0	0.770	1.446	Cold quadrupole
QI.21	0.482	**-5.569**	LH
QI.22	6.380	2.225	
QI.23	**369.83**	4.202	
QI.3	0.753	2.191	Matching to FODO
QI.4	0.526	**-7.703**	
QI.5	**77.644**	**7.818**	
QI.25	0.607	**-8.464**	
QI.1	0.537	-3.602	FODO
QI.2	2.037	3.603	
QI.7	3.784	3.481	Matching to Shielding
QI.8	0.498	-4.059	
QI.31	0.798	0.966	
QI.9	1.211	1.115	Matching to Dogleg
QI.10	0.687	-1.071	
QI.11	0.748	-0.560	
QI.12	1.252	0.700	

- **Advantages:**
- Less space required. About 3 m free space available.
- Beta functions at laser heater are constant, allowing perfect adjustment (overlap with) to the laser beam.
- **Disadvantages:**
- Extreme flat beam at some quadrupoles. Beam dynamics affected?
- k-values at some quadrupoles are too high → higher sensibility to the errors.

Laser Heater Integration: Comfortable Version



- LH requires 6.9m
- max β = 65.61m
  corresponds to 11.4σ
- max (σ_x/σ_y) = 9.42
- max k_1 = 6.997
- Beta function is not constant along the heater



Laser Heater Integration. Comfortable Version - II

Quad	β_x/β_y	k_1	comments
Q.0	0.881	0.700	Cold quadrupole
QI.21	0.464	-1.723	LH
QI.22	1.010	0.964	
QI.3	0.884	0.728	Matching to
QI.4	1.160	**-6.088**	
QI.5	**88.673**	**6.997**	FODO
QI.25	0.648	**-6.140**	
QI.1	0.537	-3.602	FODO
QI.2	2.037	3.603	
QI.7	4.825	3.934	Matching to
QI.31	0.893	-3.912	Shielding
QI.9	1.211	1.115	Matching to
QI.10	0.687	-1.071	
QI.11	0.748	-0.560	Dogleg
QI.12	1.252	0.700	

- **Advantages:**

- Better conditions for the beam dynamics. „Round beam“ almost everywhere
- k-Values of the quadrupoles are lower as in the short version→ less sensibility to the errors

- **Disadvantages:**

- No more free space in the injector available.

Laser Heater Integration. Parameters of both Versions

	short version	comfort version	allowed/ desired
Quadrupoles required	18	16	?
Max β_x/β_y	370	89	1-?
Max k_1	8.46	7.0	<10.0
spare space	3.0 m	0	?
LH $<\beta_x>$	9.844	9.725	10.0
LH $<\beta_y>$	9.953	9.877	10.0
LH $\Delta\beta_x$	0.06%	18.0%	0
LH $\Delta\beta_y$	0.06%	17.6%	0

Components to install/discuss and space margins

- Space margins:
  - Move the gun to the left: about 3m more possible
  - Dump line: 30° instead of 20°: about 1.5m available
  - Short version of the laser heater instead of comfortable one: about 3m available.

→ In the most strained version of the injector there are 7.5 meter place margin to achieve

- Components which are still not taken into account:
  - Transverse deflecting cavity: less than 1m netto required.
  - Optical replica synthesizer: the one at FLASH requires 7m netto and about 15m brutto.

→ There is no possibility to install the same kind of ORS as at FLASH.

Conclusion

- Both extreme versions for the Integration of the Laser Heater designed. Any state in between is also possible.