Cross Section and Luminosity

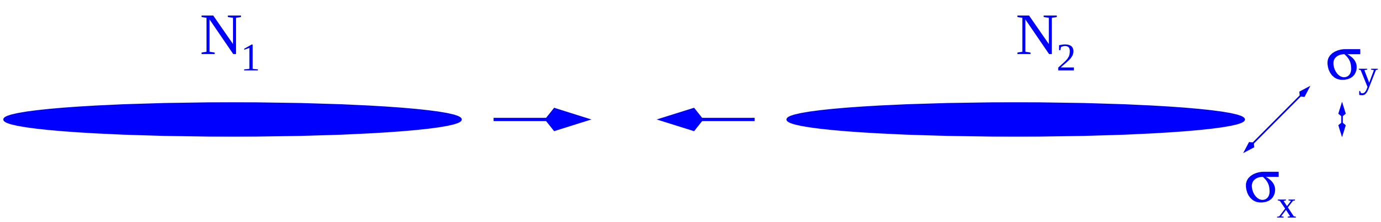
Instantaneous reaction rate:

$$R = \varepsilon \mathcal{L} \sigma$$

R	reaction rate	measured	[events/s]
ε	efficiency	experiment	[1]
$\mathcal{L}$	luminosity	accelerator	[$\mathrm{cm}^{-2}\mathrm{s}^{-1}$]
σ	cross section	physics	[cm^2, $\mathrm{pb}=10^{-36}\ \mathrm{cm}^2$]

Incoming rate, luminosity:

$$\mathcal{L} = \frac{N_1 N_2 \nu}{4\pi\sigma_x\sigma_y}$$



Time integrated reaction rate:

$$N = \varepsilon \int \mathcal{L} dt \ \sigma$$

$\int \mathcal{L} dt$ integrated luminosity [events/pb]

Emittance and β Function

Luminosity:

$$\mathcal{L} = \frac{n_b N_e^2 f}{4\pi\sigma_x\sigma_y} H_D$$

n_b	number of bunches/pulse
N_e	number of $e^\pm$ per bunch
f	pulse repetition frequency
$\sigma_{x,y,z}$	horiz., vertical, longitudinal beam size at IP
H_D	disruption enhancement factor (pinch effect) $\simeq 1.5$

Average beam power:

$$P_b = n_b N_e f \sqrt{s} = \eta P_{\mathrm{AC}}$$

η	power conversion efficiency $\simeq 16\%$ for SCLC
P_{AC}	AC power consumption

Collective energy loss by beamstrahlung:

$$\delta_E = \frac{\Delta E_b}{E_b} \sim \frac{r_e^3 N_e \gamma}{\sigma_z(\sigma_x+\sigma_y)^2} \sim \frac{r_e^3 N_e \gamma}{\sigma_z \sigma_x^2}$$

Flat beams allow to increase $\mathcal{L}$ without intolerable beamstrahlung $\rightarrow$ reduce vertical beam size σ_x

Emittance and β Function

Beam phase space at IP given by emittance and β function:

$$\sigma_x = \sqrt{\varepsilon_y \beta_y}$$
$$\beta_y \simeq \sigma_z$$

Luminosity in these terms:

$$\mathcal{L} \sim \frac{\eta P_{\mathrm{AC}}}{\sqrt{s}} \sqrt{\frac{\delta_E}{\varepsilon_y}} H_D$$

Advantages of superconducting LC:

- High power conversion efficiency, $\eta \simeq 16\%$
- Low emittance dilution by short range wake fields due to lattice misalignment r.m.s. δy^2

$$\frac{\Delta\varepsilon}{\varepsilon} \sim F \bar{\beta} \delta y^2$$

Dilution factor:

$$F \sim \frac{N_e^2 \sigma_z f_{\mathrm{RF}}^6}{\varepsilon_y}$$

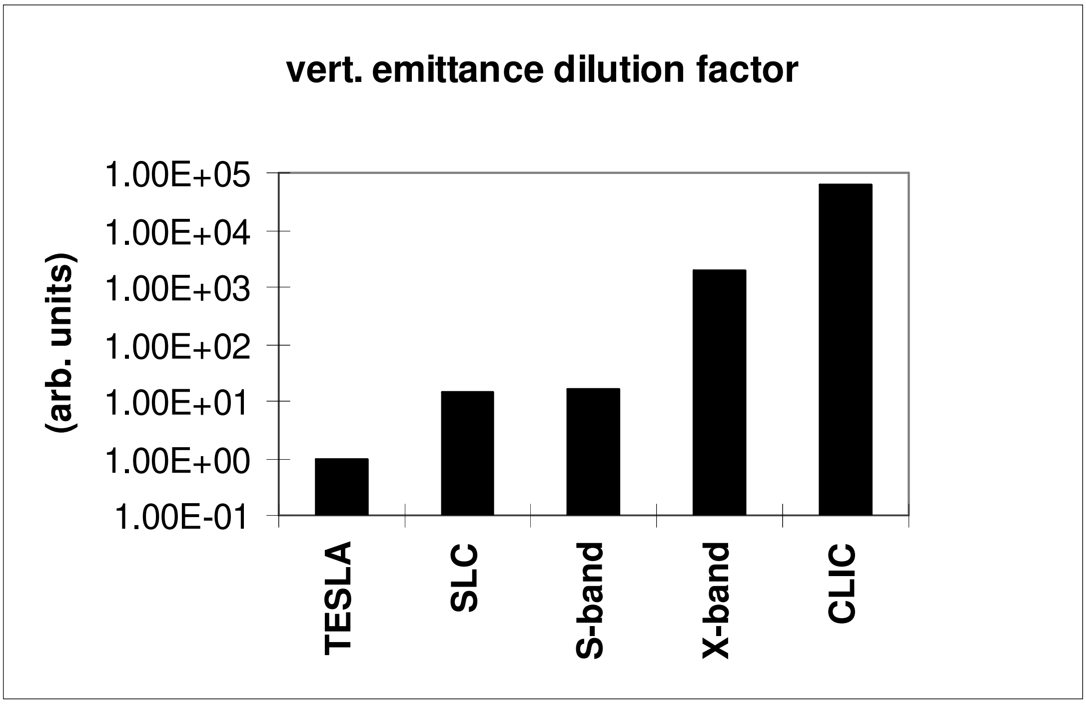
Low frequency f_{RF} $\leftrightarrow$ relaxed r.m.s. tolerances δy^2

Superconducting Concept

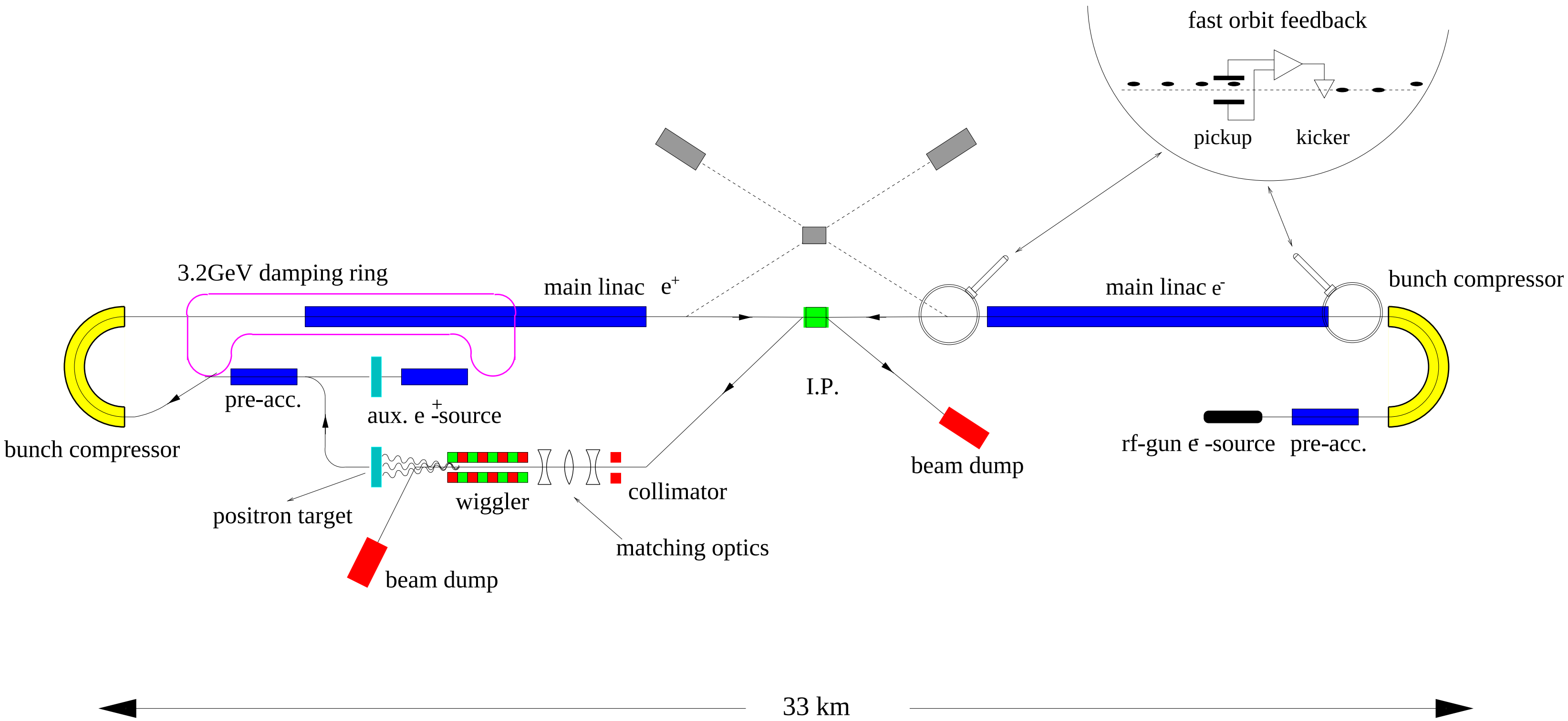
SCLC: good power efficiency → high beam power → relaxed beam spot size

	S-band	X-band	Two-beam	TESLA
Accelerating gradient [MV/m]	17	29...55	78	25
RF-frequency [GHz]	3	11.4	30	1.3
RF-peak power [MW/m]	12	50...100	144	0.2
Av. beam power [MW]	7.3	4	4	8.2
Beam pulse length [μs]	2	0.1	0.006	800
Bunch spacing [ns]	6	1.4	0.67	708
Vertical spot size at IP [nm]	15	5	7	19
Luminosity [10^{33}cm^{-2}s^{-1}]	5	6	5	6

Low RF frequency → good emittance preservation → relaxed alignment tolerances



TESLA Machine Layout



Université de Genève

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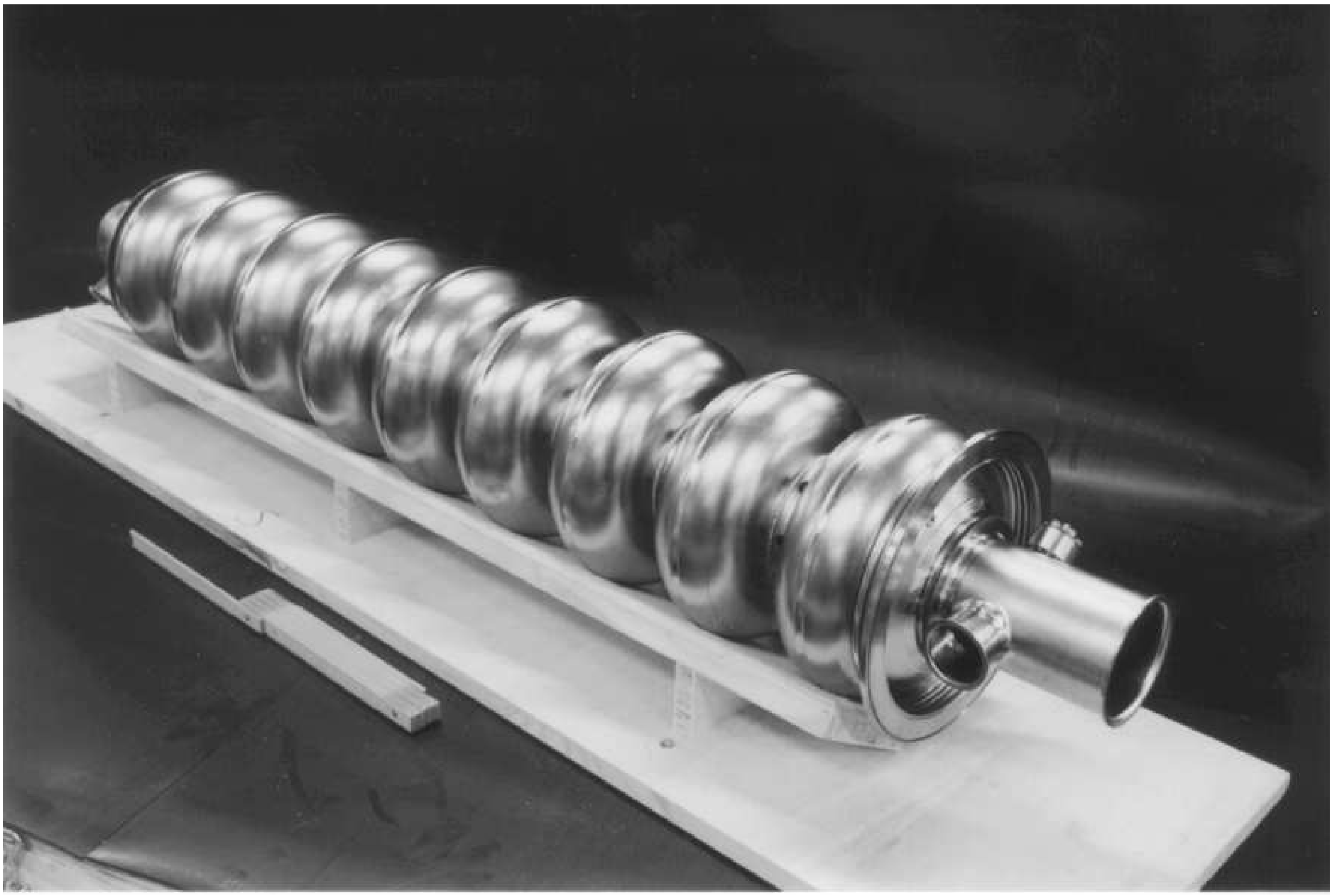
TESLA Machine Parameters

	LEP II	TESLA	
type	storage ring	linear collider	
maximum energy	200 GeV	500 GeV	2000 GeV
total length	26.7 km	33km	
accelerating gradient	6 MV/m	25 MV/m	40 MV/m
maximum bunches	8	1410	4028
beam size at IP [μm]	150×10	0.85×0.02	0.34×0.02
luminosity [$cm^{-2}s^{-1}$]	10^{32}	1×10^{34}	5×10^{34}

Proviso: This is my (free) interpretation of numbers from various sources, includes some wishful thinking

TESLA Accelerating Cavities

Nine-cell niobium superconducting cavity

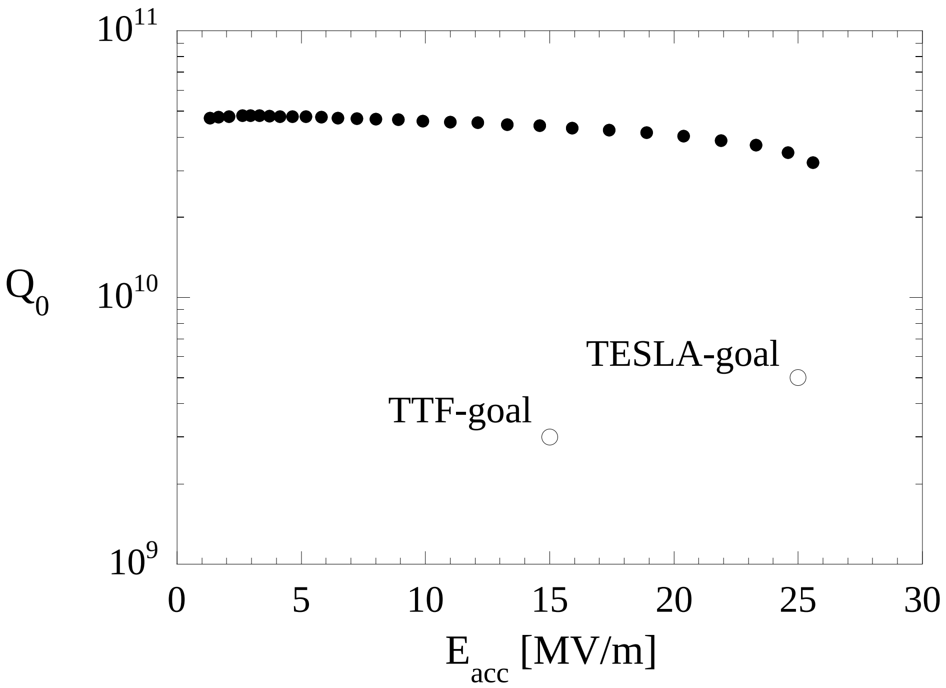


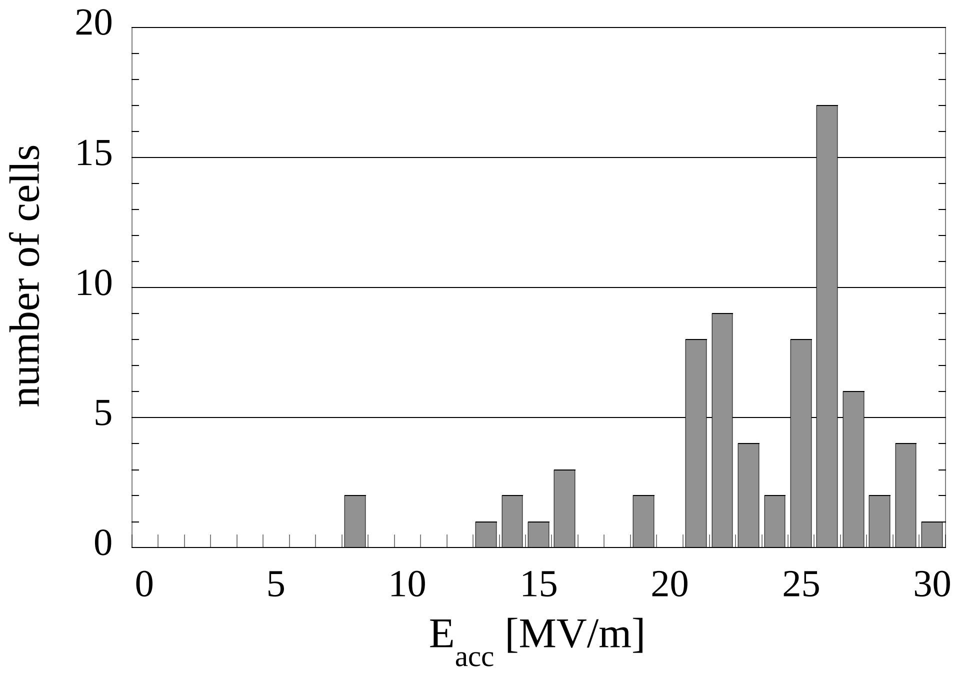
TESLA will need 20000 such structures.

Produced by several European companies, tested in TTF at DESY, specifications reached.

Cavity Properties

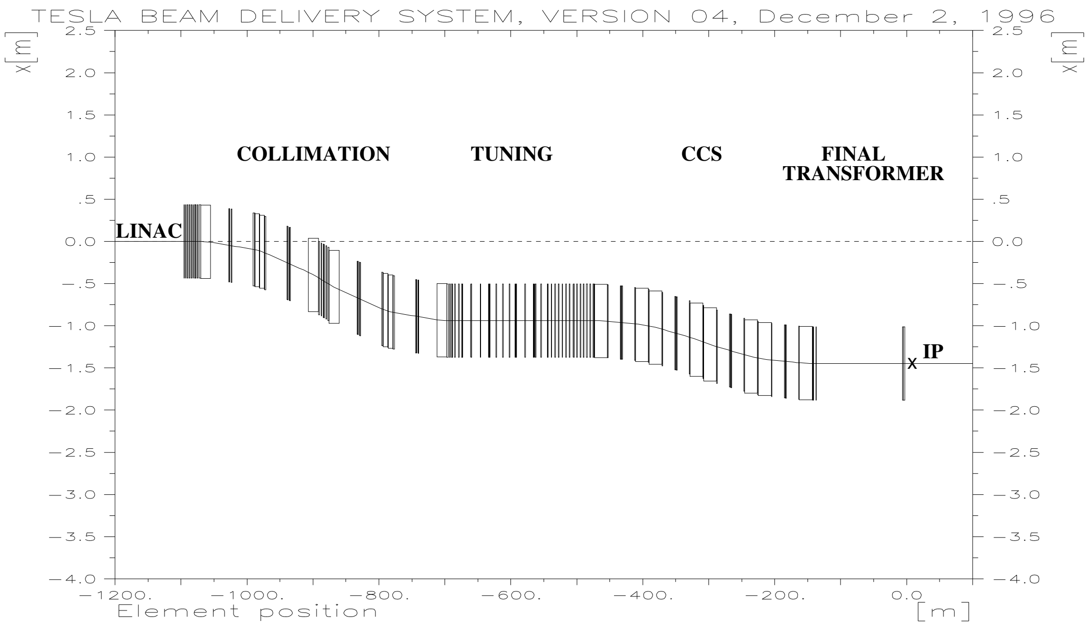
Tunnel length & design energy → accelerating gradient



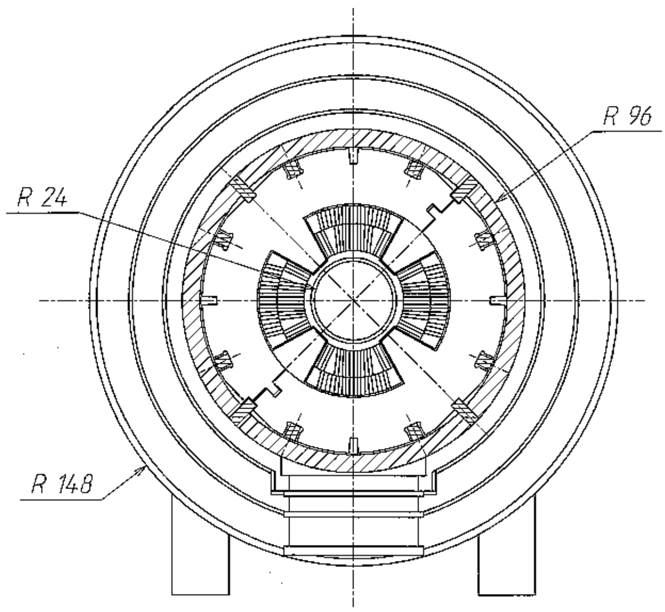


TESLA Beam Delivery System

Horizontal layout:

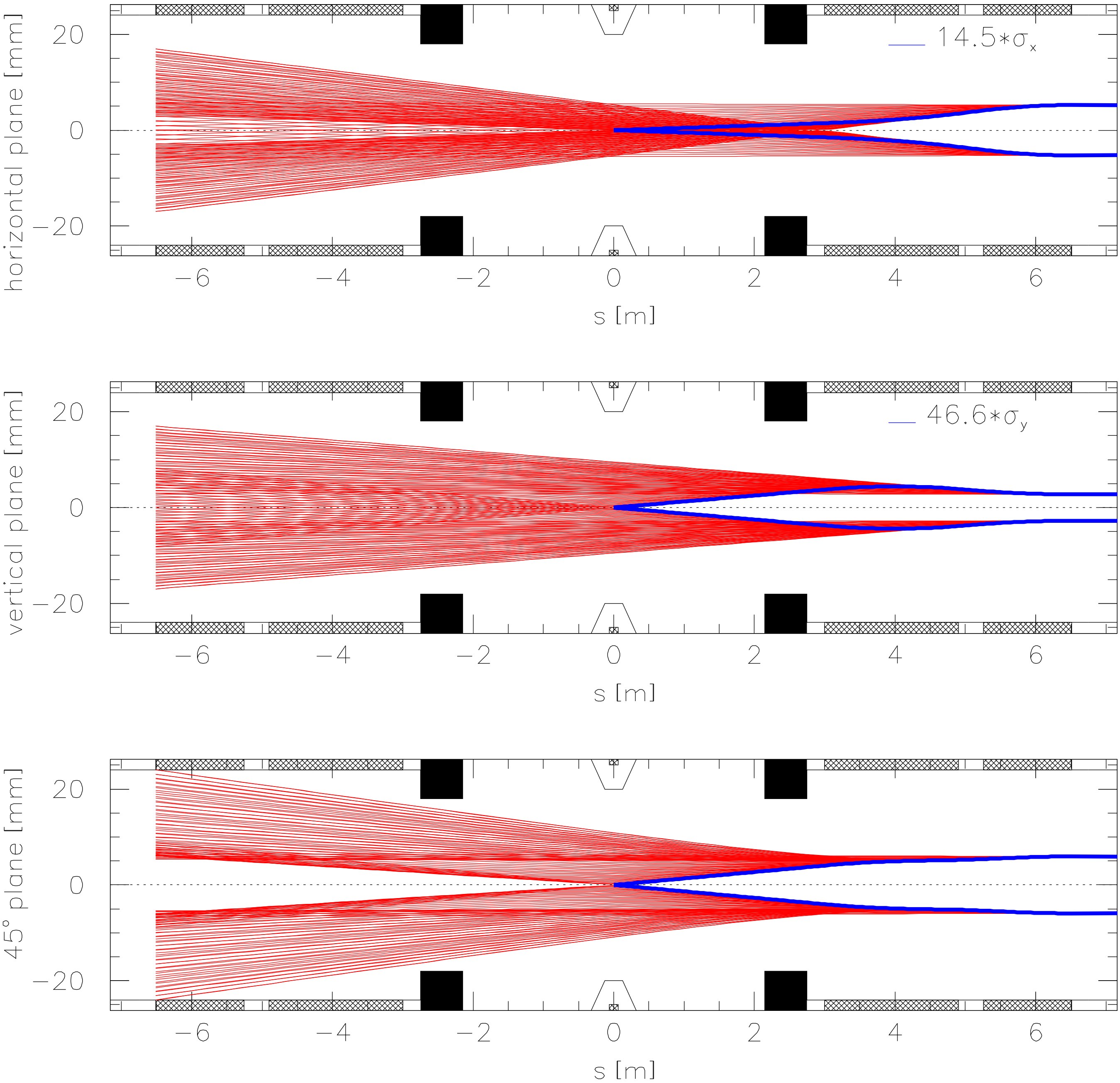


Final transformer: demagnification by factor 15×50



Under test in FFTB at DESY.

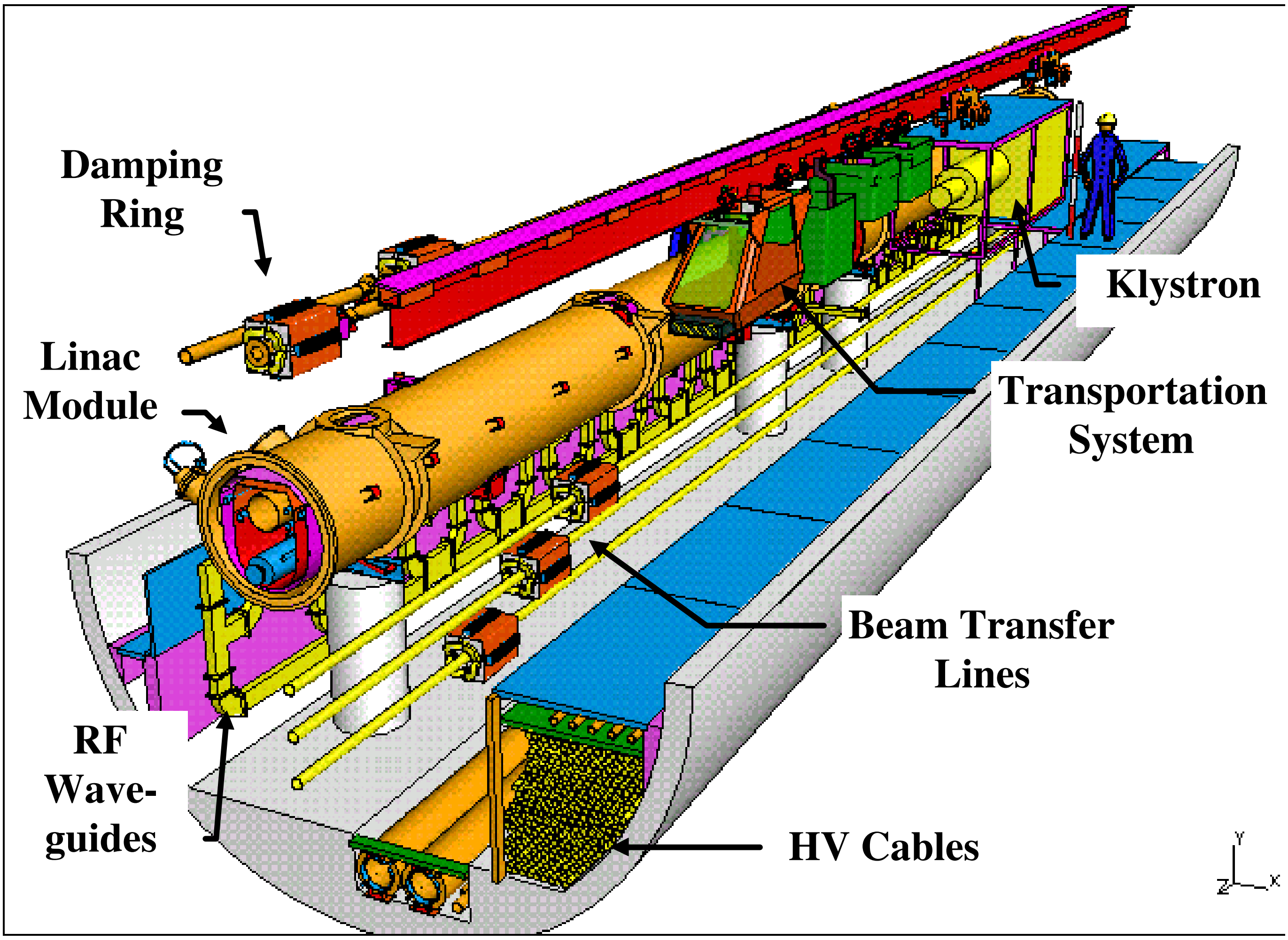
Sophisticated masking required



Forward-backward hole

The TESLA Linac Tunnel

Single 5m diameter tunnel for all accelerator elements



Fully under ground, minimum environmental impact