CASE STUDY 5:

The CERN Accelerator School

FEL driven by Plasma Injector

A <u>Group 9</u> Collaboration:

TECHNISCHE UNIVERSITÄT DARMSTADT

DESY

IPM

JG|U

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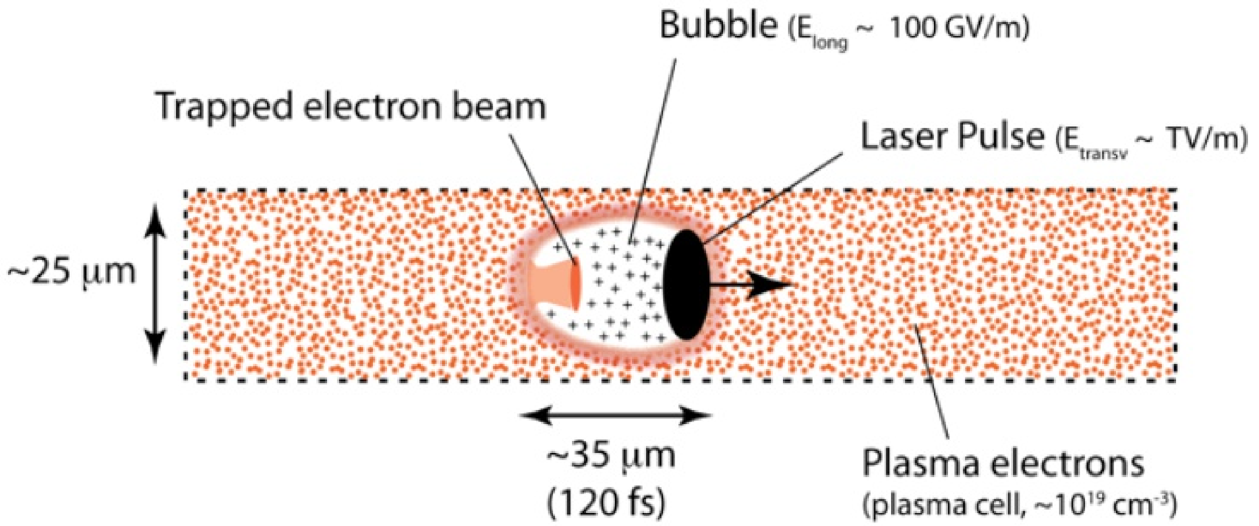
FEL driven by Plasma Injector

- Goal:

Use the output from a plasma injector to drive an FEL in the UV range.

- Background:
  - Laser driven plasma generates a relativistic electron beam with small emittance
  - Advantage: Injectors will be short
  - Challenge: Deal with high energy spread

Initial Situation



Courtesy of:
R.W. Aßmann

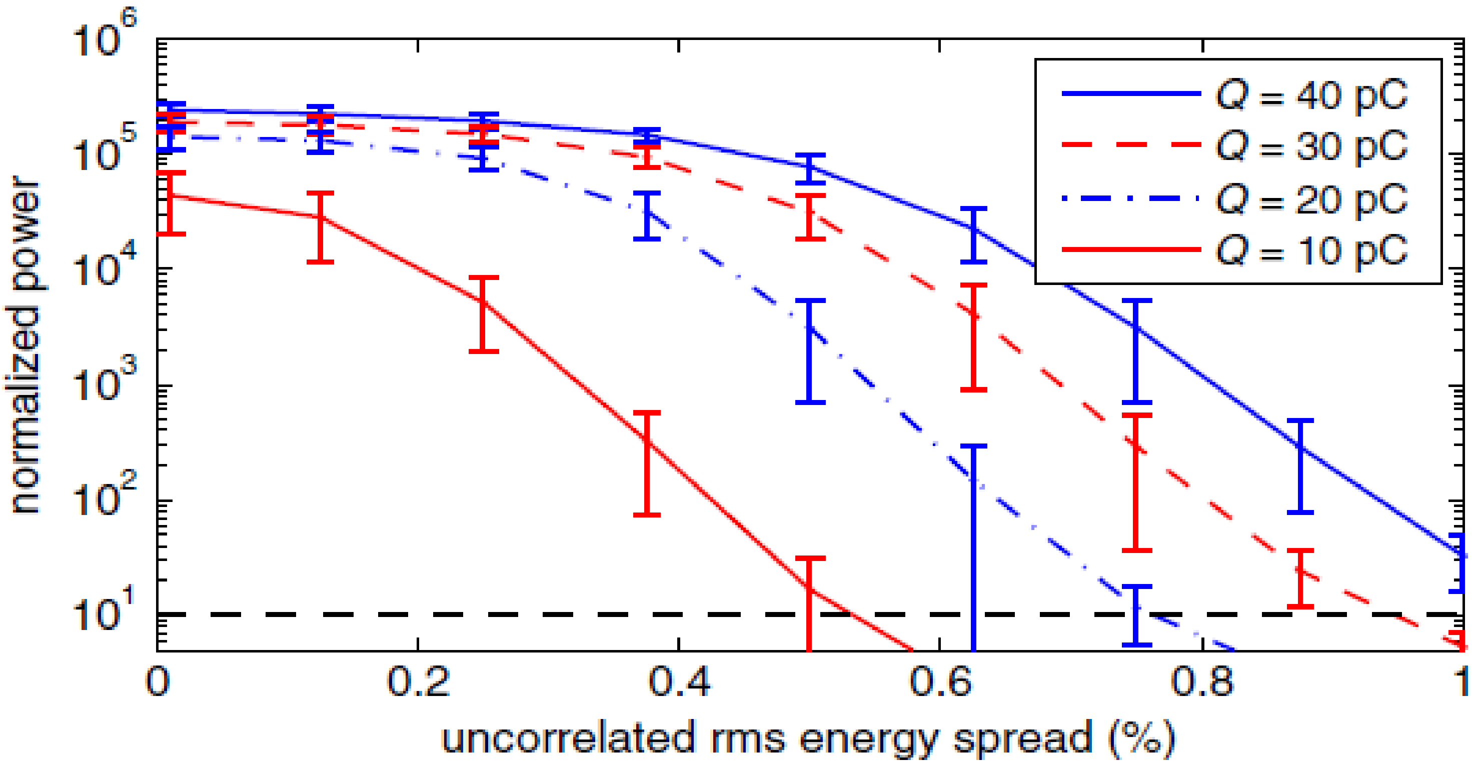
- Given by case study:
  - Normalized emittance ε = 200 nm
  - E=300 MeV; ΔE=1%
  - Wavelength λ=50 nm
- Estimated beam parameter:
  - Q= 40 pC
  - ß=2m

Optimize the beam current to overcome the impact of energy spread of 1%.

Why 40 pC bunch charge?

- Maier et al. has shown: [2]

E in nm	E in MeV	ΔE	I in kA
200	~300	<1%	~2-10

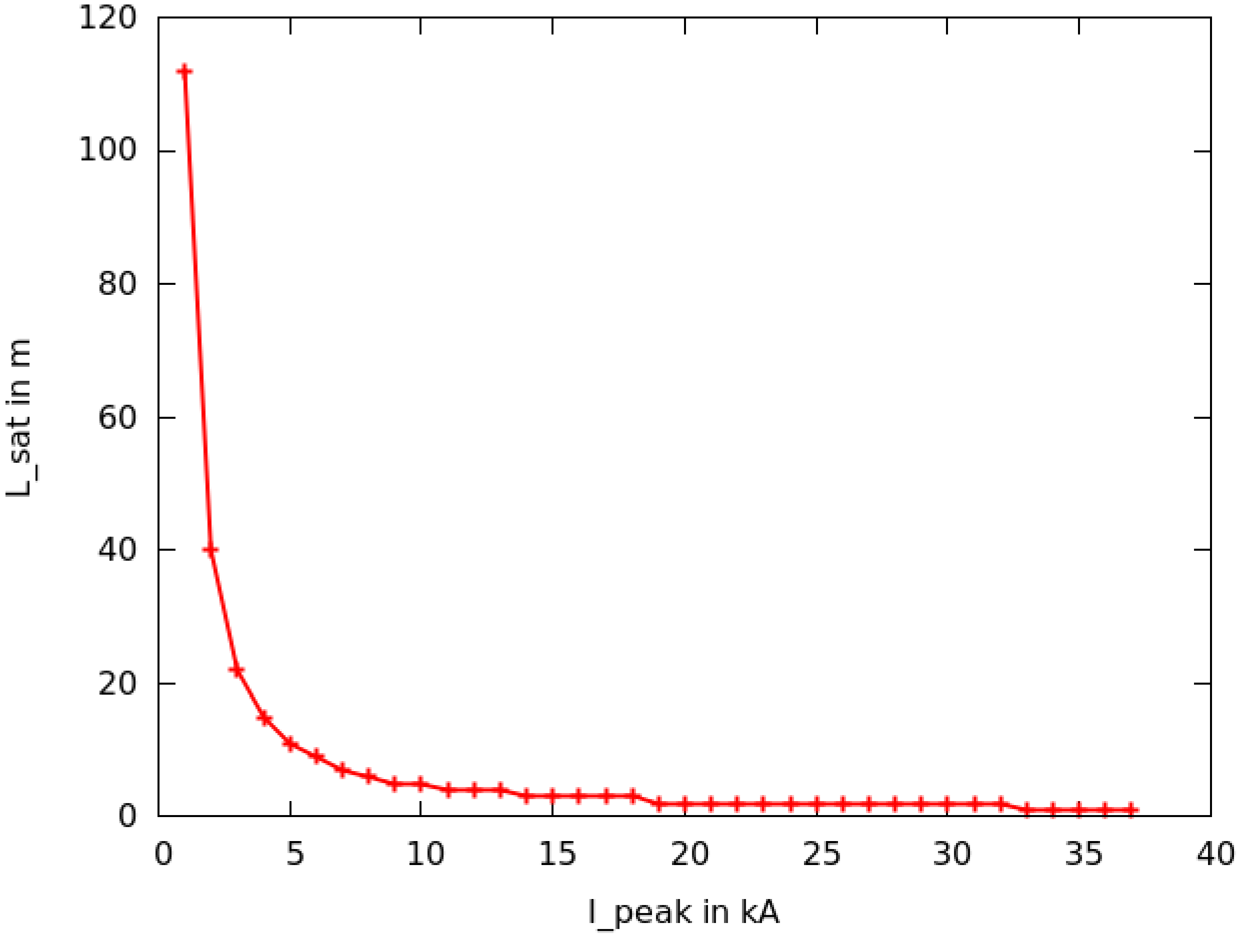


Peak Current Optimization

- Based on Ming Xie model: [3]

Our choice of I_Peak is at 10 kA. This limits the length of the undulator to a buildable value.

Space Charge has to be concidered at I>10 kA.



Undulator Parameters

- Based on Ming Xie model [3]:

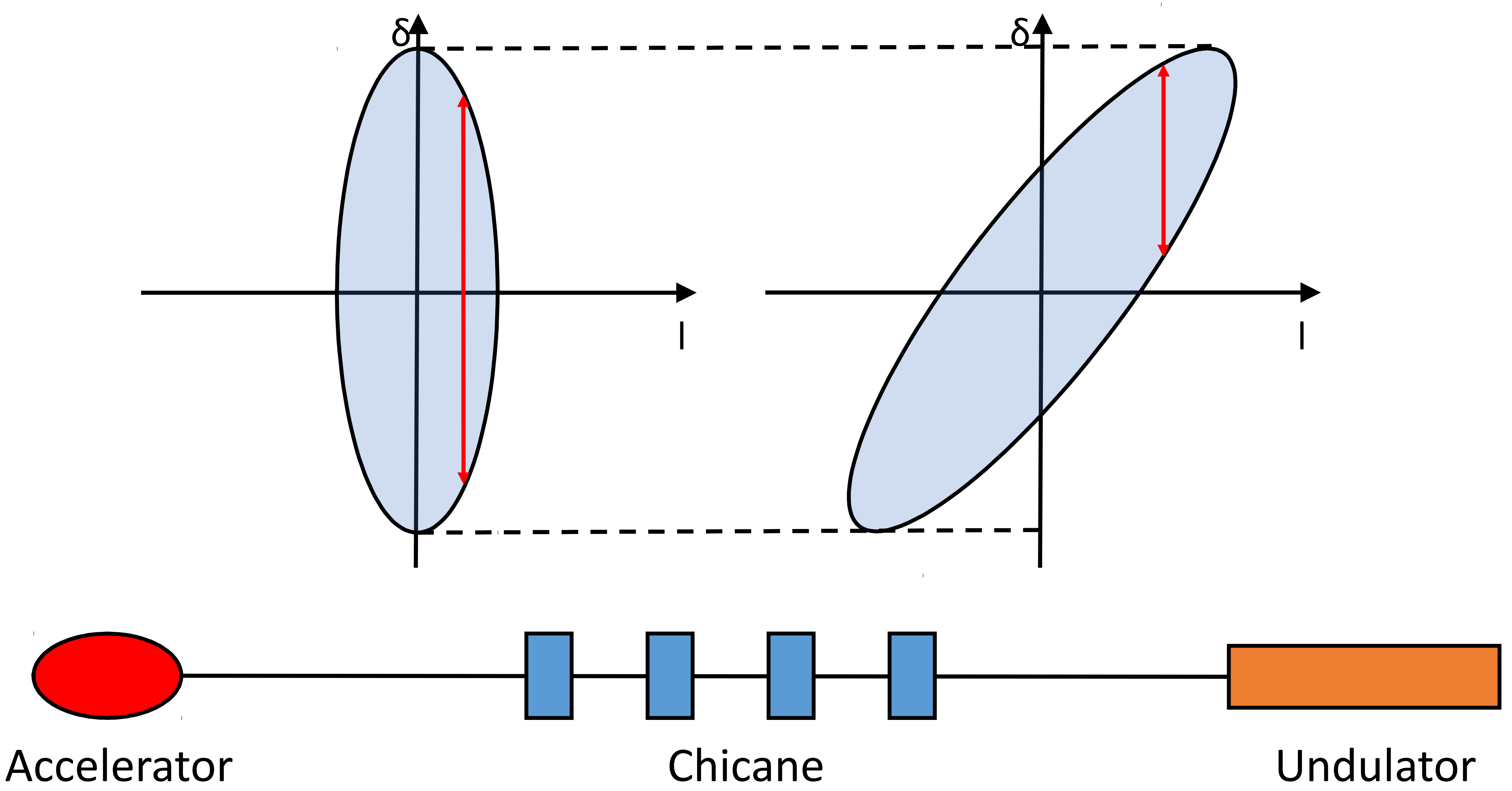
- Wavelength fixed at ~50 nm
- Saturation length at I=10kA

  L=5.3 m
- Output Power P=6 GW

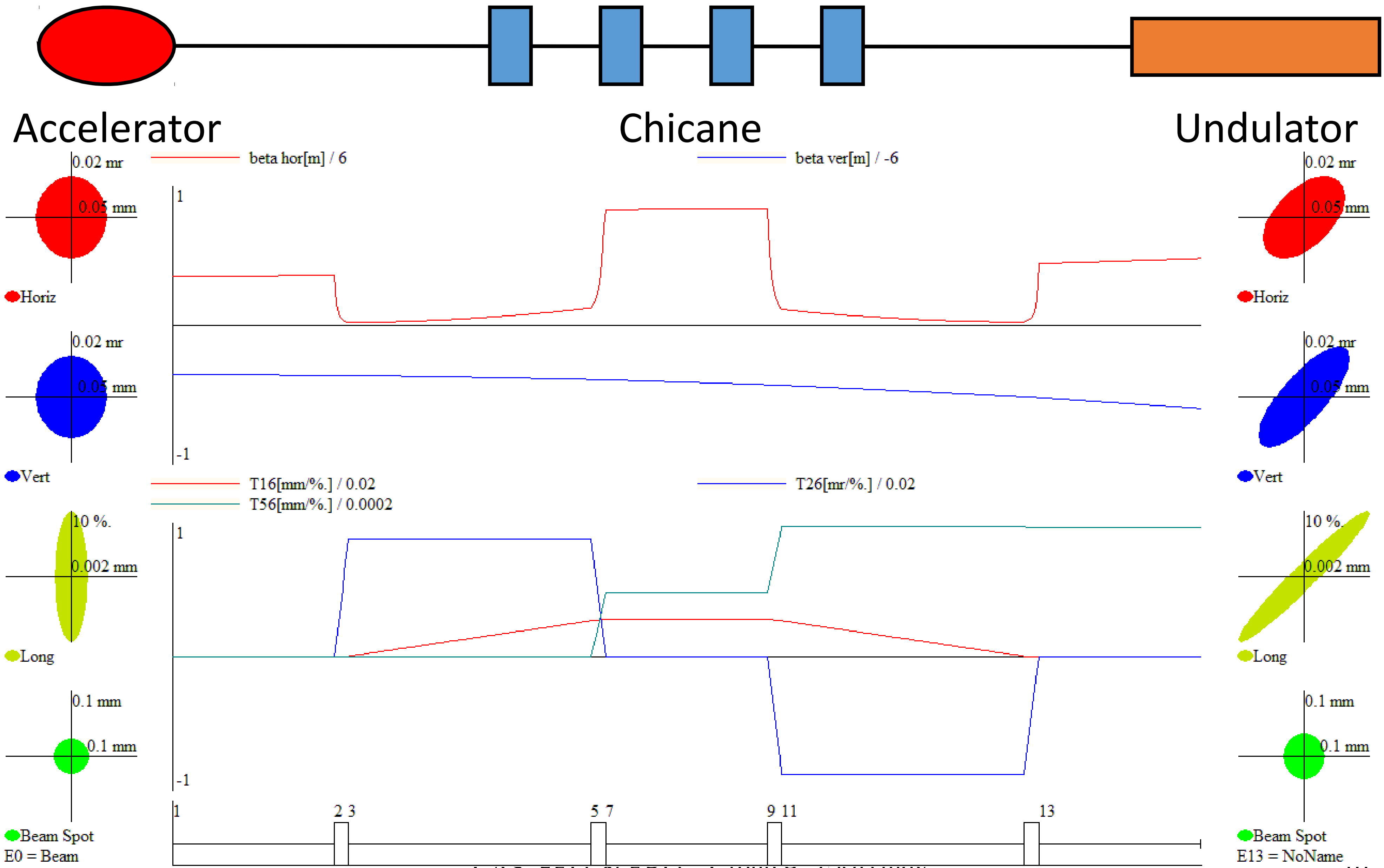
Version: 2009-04-15	
Electron Beam	
Energy (GeV)	0,300
Peak Current (kA)	1,000
Charge (nC)	0,040
Normalized emittance (mm mrad)	0,200
Energy Spread (MeV)	3,000
Undulator	
PPM planar Vertical Field	a
Period (mm)	22,000
Gap (mm)	9,500
K_rms	
FODO Period (m)	1,000
Quadrupole Length (m)	0,1500
beta (thin lens, m)	2,000
minimum gap (mm)	2,000
Undulator length (m)	30,000

Dealing with 1% Energy Spread by Longitudinal Decompression

Longitudinal Decompression



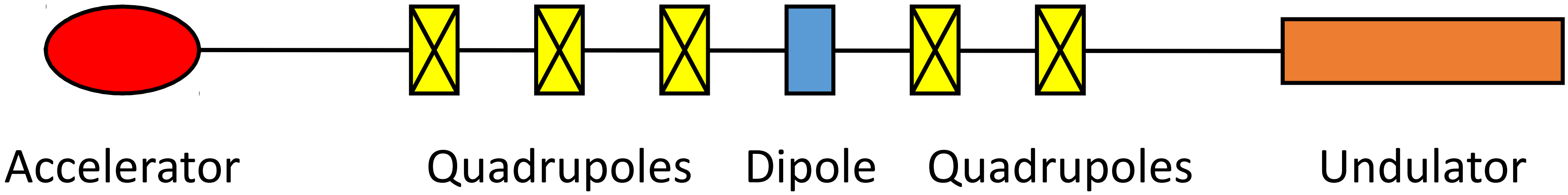
Longitudinal Decompression



Dealing with 1% Energy Spread by Transversal Decompression

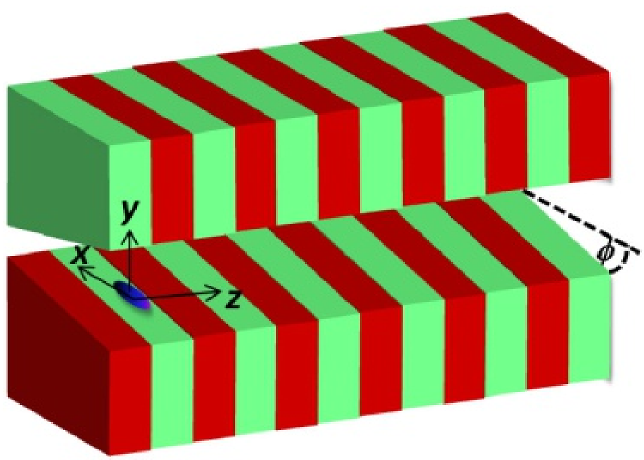
Transversal Decompression

- Beam line:

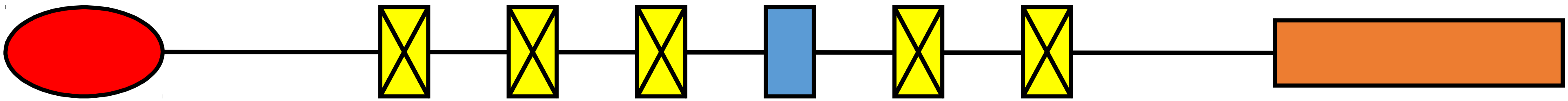


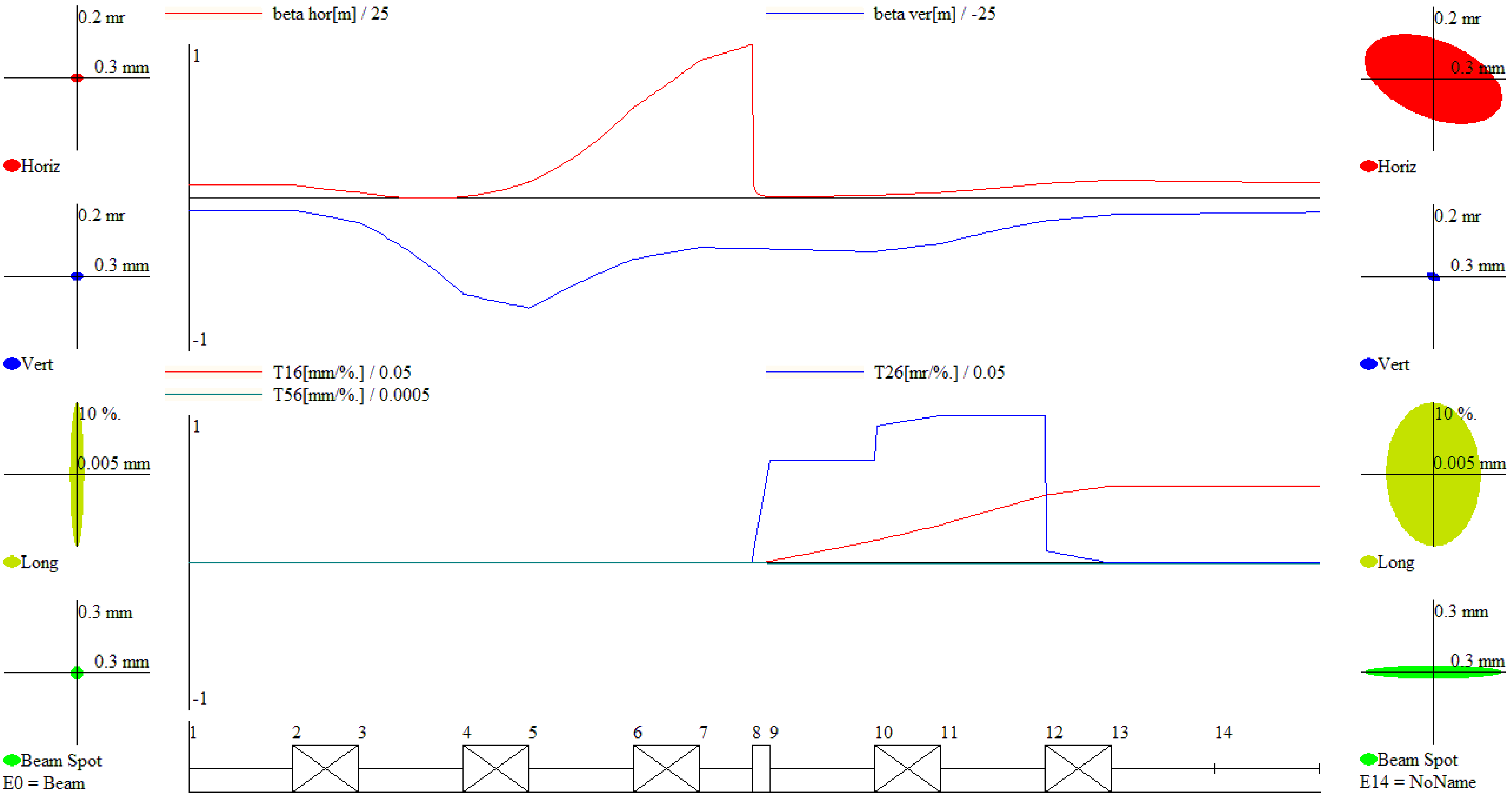
- Undulator [1]:

„Transverse gradient undulator (TGA) by cantingthe magnetic poles. Each pole is canted by an angle with respect to the xz plane. The higher energy electrons are dispersed to the higher field region (positive x) to match the FEL resonant condition.“



Transversal Decompression





Bibliography

[1] Compact X-ray Free-Electron Laser from a Laser-Plasma Accelerator Using a Transverse-Gradient Undulator, Huang et al.

[2] Demonstration Scheme for a Laser-Plasma-Driven Free-Electron Laser, R. Maier at al.

[3] Bart Faatz, DESY, http://adweb.desy.de/home/faatz/www/parms/parms.html

[4] BeamOptik Simulation: D. Simon, Johannes Gutenber-University Mainz, Germany,

Further Information:

[5] T. Seggebrock et al.,"Bunch decompression for laser-plasma driven free-electron laser demonstration schemes"

[6] F. J. Gruner et al, "Space-charge effects in ultrahigh current electron bunches generated by laser-plasma accelerators"

Thank you for your attention

BACK UP