Preliminary Design Report: Accelerator

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Outline

- Requirements
- Machine parameters and configuration
- FF design
- Radiation damping control
- Electron beam polarization
- Luminosity
- Nonlinear beam dynamics
- Injector
- Site construction
- Conclusions

Main requirements

- Beam energy from 1.0 to 2.5 GeV
- Peak luminosity is 10^{35} $cm^{-2}s^{-1}$ at 2 GeV
- Electrons are polarized longitudinally at IP
- Energy calibration by Compton backscattering ($\sim 5 \div 10 \cdot 10^{-5}$)

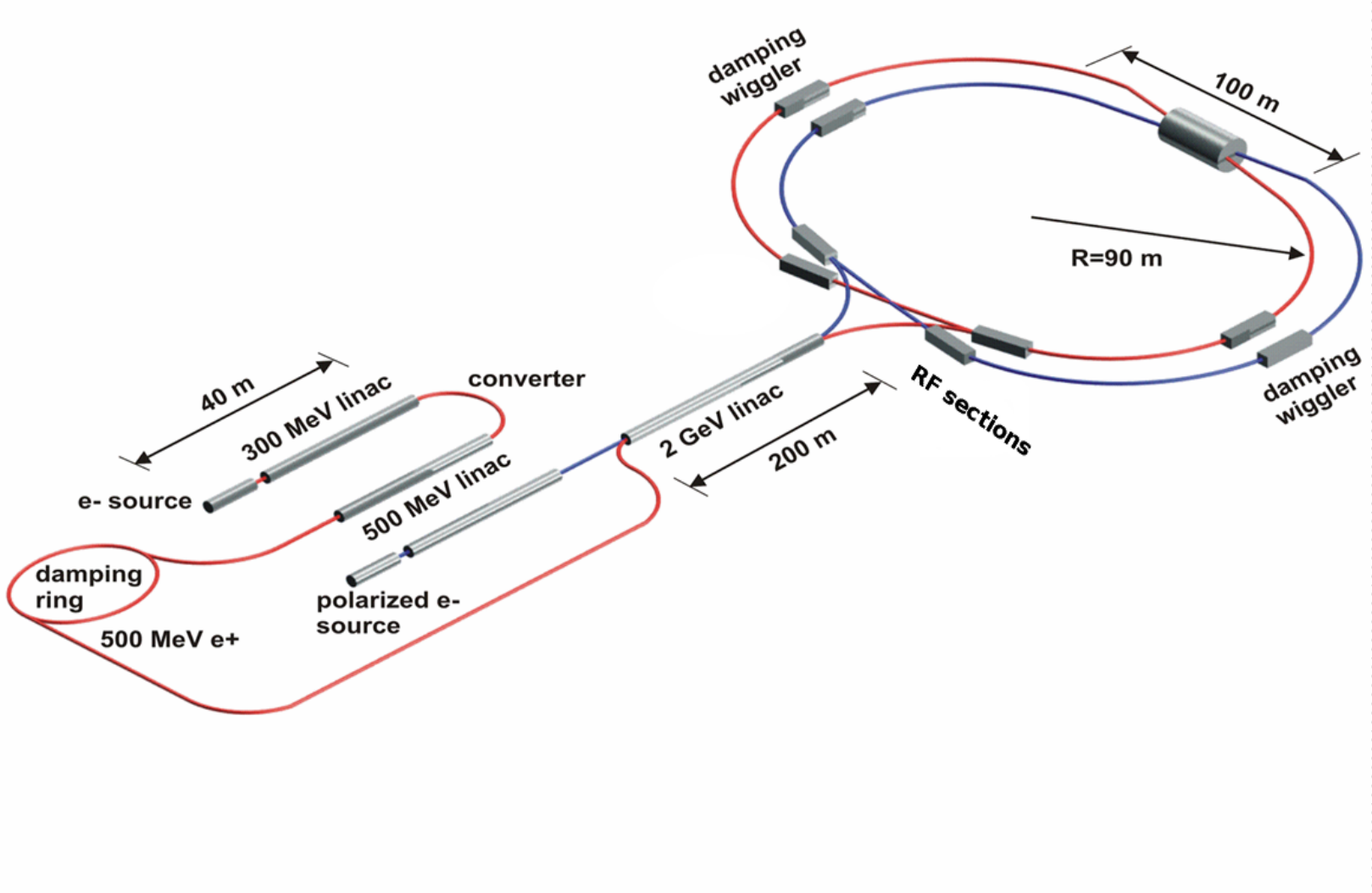
Main specs

- Two rings with Crab Waist collision scheme and single interaction point
- Sub-mm beta-y at IP
- Preserving of damping parameters (by 4 SC wigglers) through the whole energy range to optimize the luminosity
- 5 Siberian snakes to obtain the longitudinally polarized electrons for the whole energy range
- Highly effective positron source (50 Hz top-up injection)
- Polarized electron source
- 2.5 GeV full energy linac

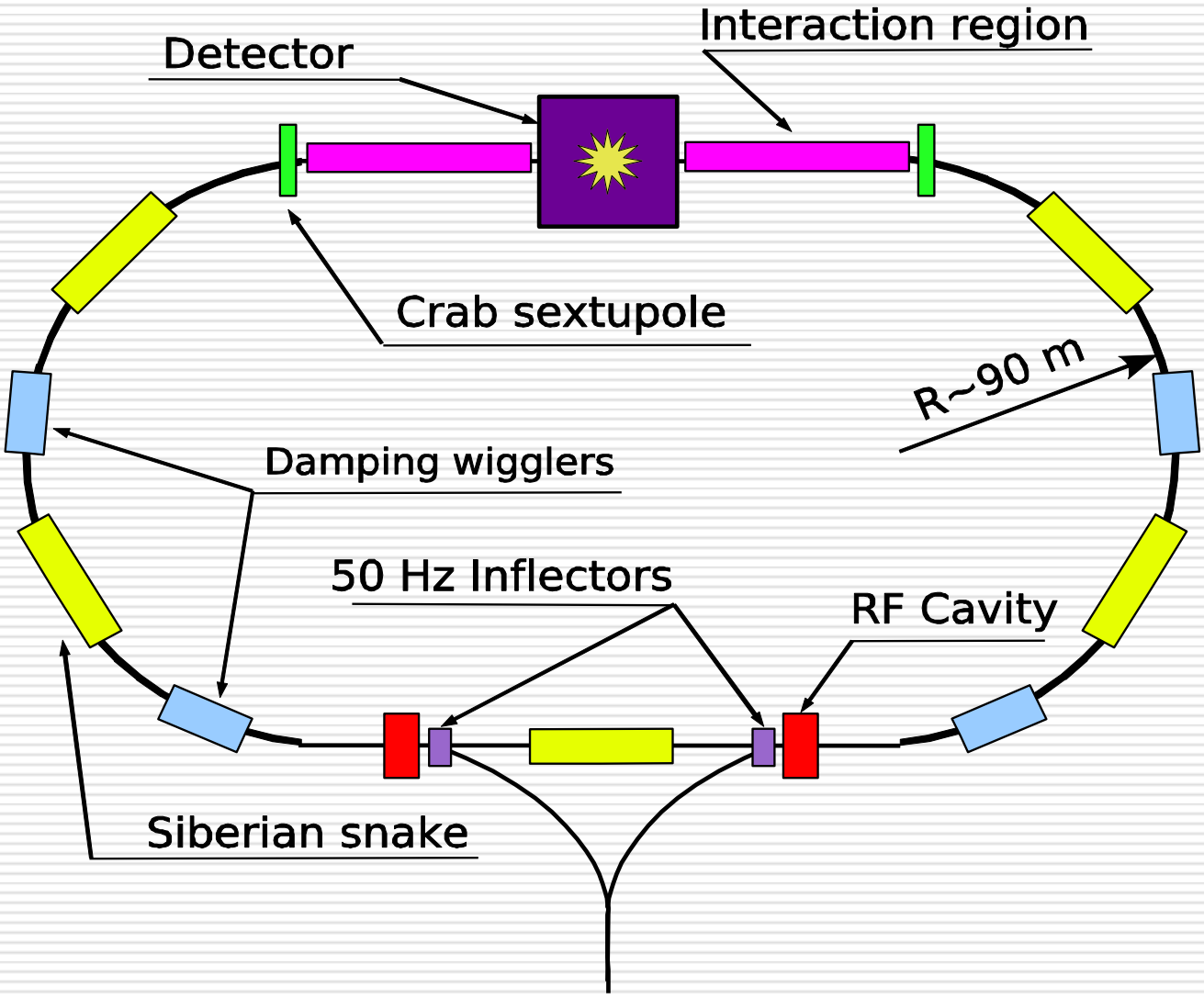
Accelerator challenges

- Beta-y at IP = 0.8 mm $\rightarrow$ extremely high chromaticity
- Large Betas in the FF quadrupoles $\rightarrow$ sensitivity to the field errors
- Low emittance $\rightarrow$ strong chromatic sextupoles in the arcs
- Luminosity optimization in the wide energy range $\rightarrow$ damping parameters control (damping wigglers)
- Longitudinally polarized electrons in the whole energy range $\rightarrow$ system of Siberian snakes
- Large enough current $\rightarrow$ impedance budget limitation
- Strong IBS due to the low emittance lattice $\rightarrow$ large energy acceptance is needed
- Background, injection, feed-backs, RF, …

Facility artist view



Main ring schematically

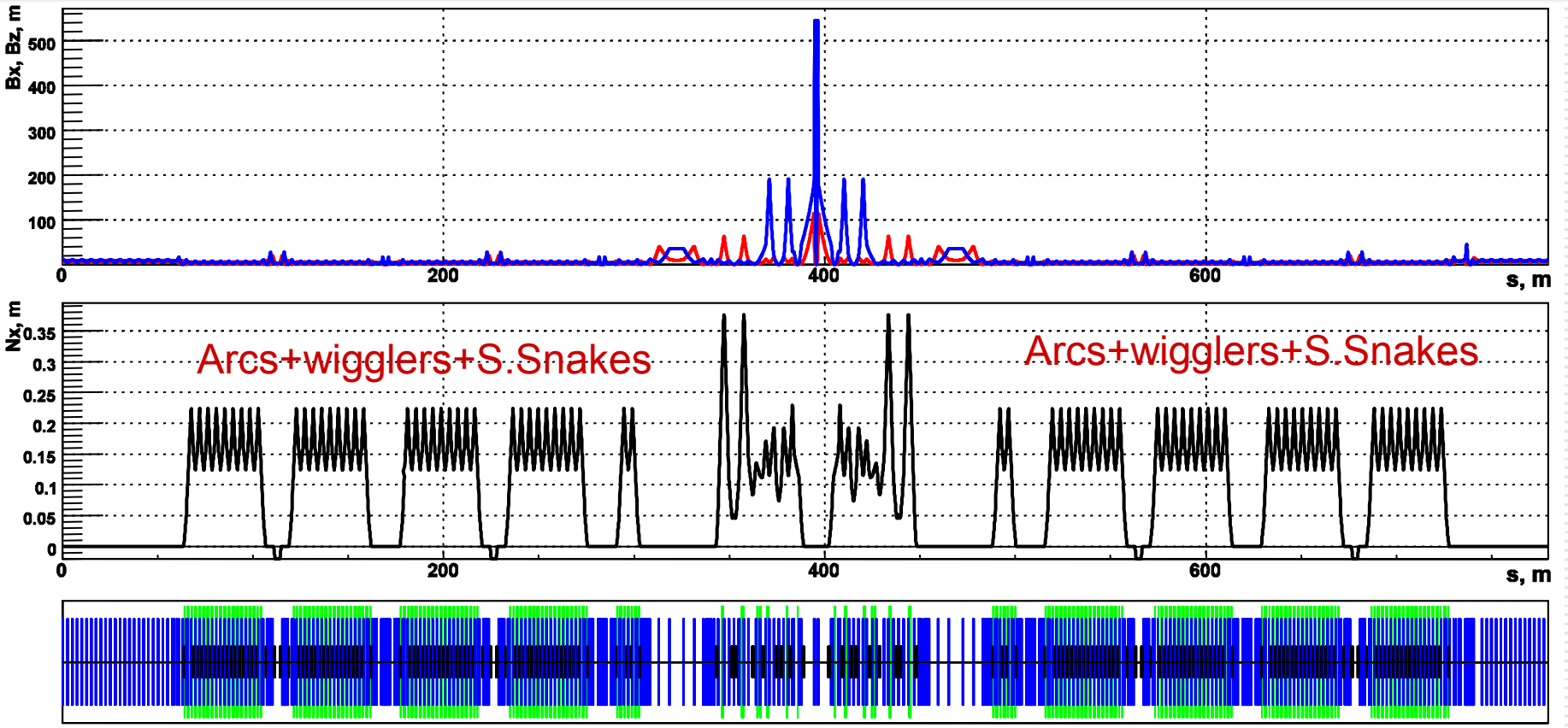


Parameters

Energy	1.0 GeV	1.5 GeV	2.0 GeV	2.5 GeV
Circumference	780 m			
Emittance hor/ver	8 nm/0.04 nm @ 0.5% coupling			
Damping time hor/ver/long	30/30/15 ms			
Bunch length	16 mm	11 mm	10 mm	10 mm
Energy spread	$10.1 \cdot 10^{-4}$	$9.96 \cdot 10^{-4}$	$8.44 \cdot 10^{-4}$	$7.38 \cdot 10^{-4}$
Momentum compaction	$1.00 \cdot 10^{-3}$	$1.06 \cdot 10^{-3}$	$1.06 \cdot 10^{-3}$	$1.06 \cdot 10^{-3}$
Synchrotron tune	0.007	0.010	0.009	0.008
RF frequency	508 MHz			
Harmonic number	1300			
Particles in bunch	$7 \cdot 10^{10}$			
Number of bunches	390 (10% gap)			
Bunch current	4.4 mA			
Total beam current	1.7 A			
Beam-beam parameter	0.15	0.15	0.12	0.095
Luminosity	$0.63 \cdot 10^{35}$	$0.95 \cdot 10^{35}$	$1.00 \cdot 10^{35}$	$1.00 \cdot 10^{35}$

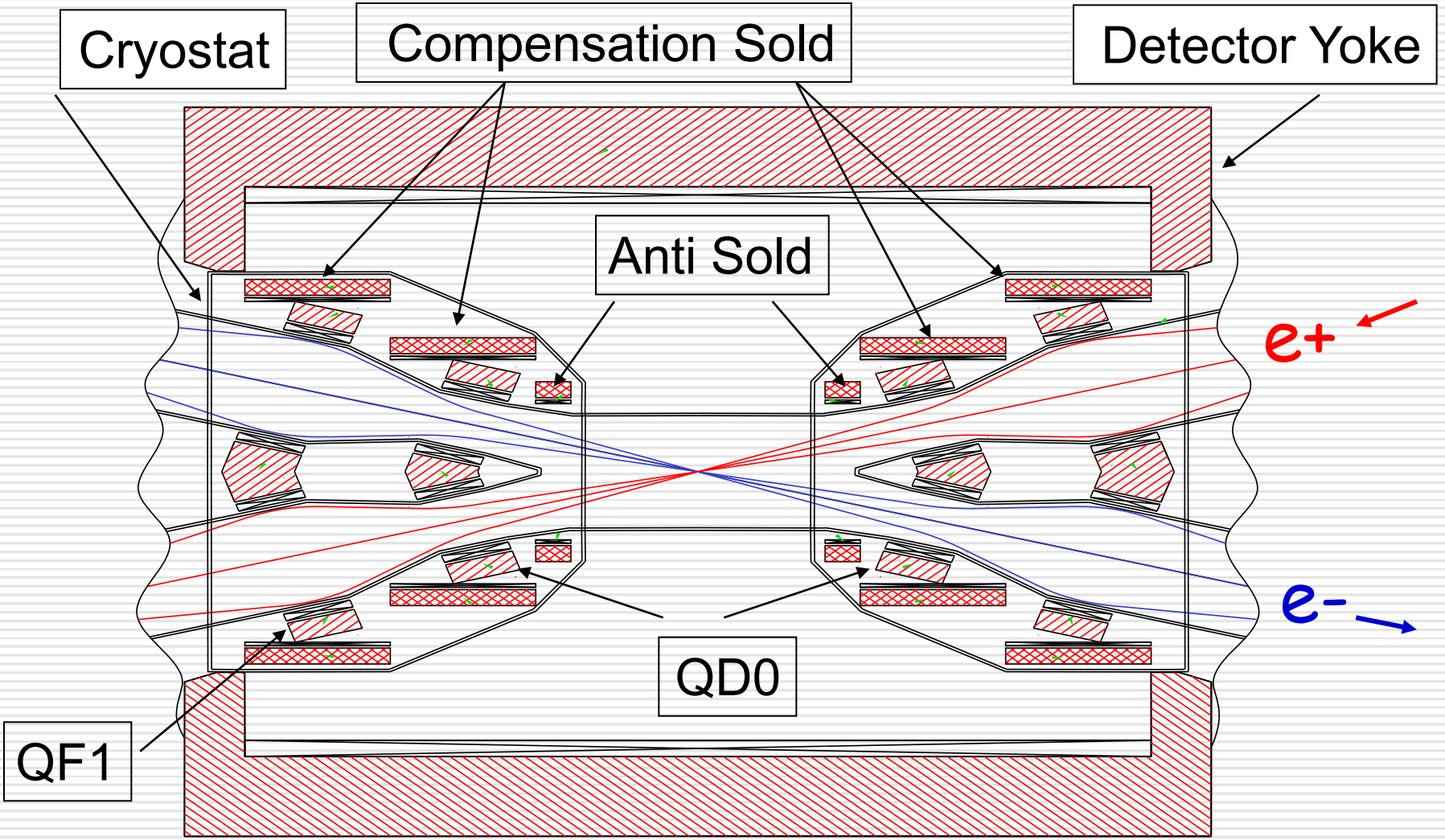
Optical functions

FF + Chr.Corr sections

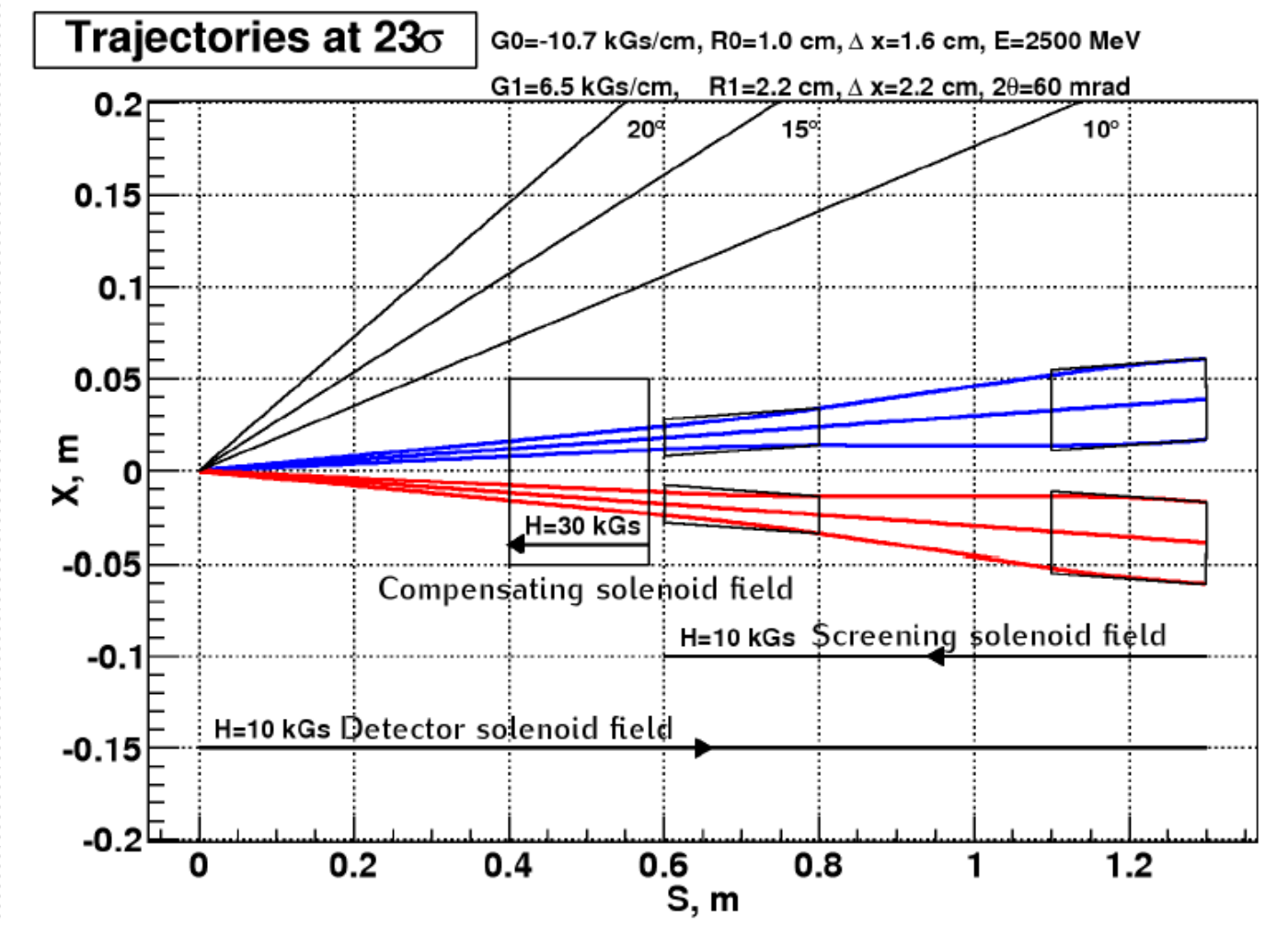


Beta_y at IP = 0.8 mm Beta_x at IP = 40 mm

Final Focus System



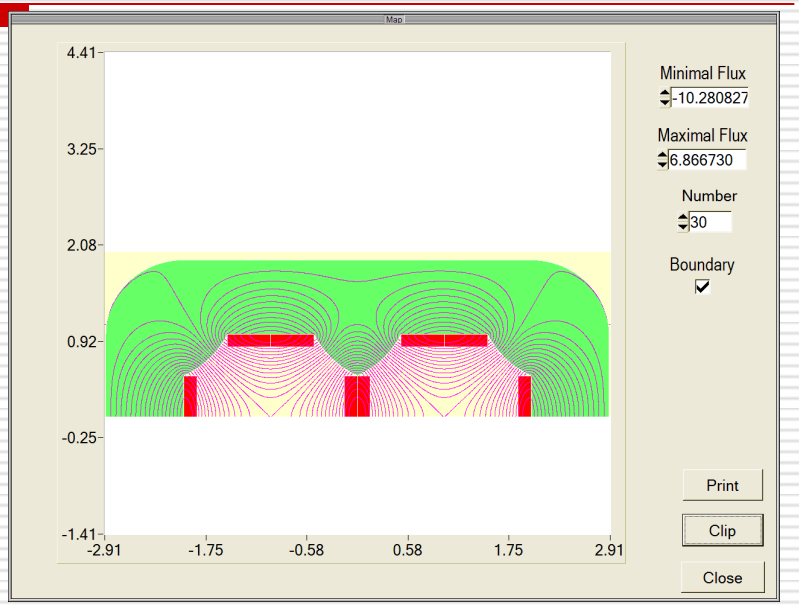
Final Focus Quad Doublet

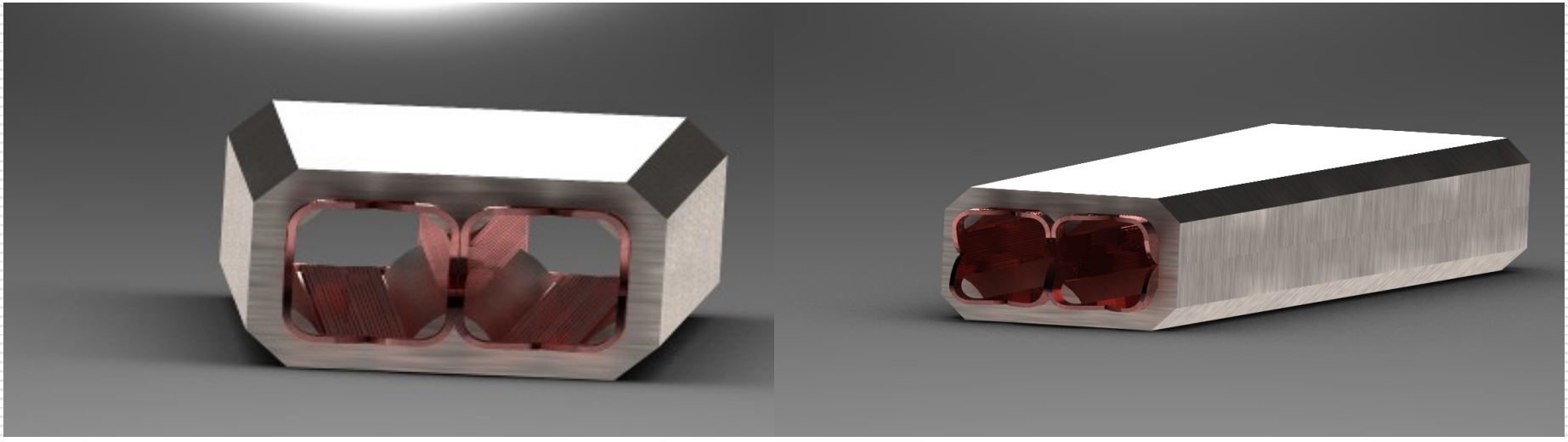


QD0 Lens

SC iron yoke twin aperture magnet
Excitation current 8.5 kA·turns
Single aperture 2 cm
Gradient 10.7 kGs/cm
Length 20 cm

Prototype production has started!





Radiation parameters

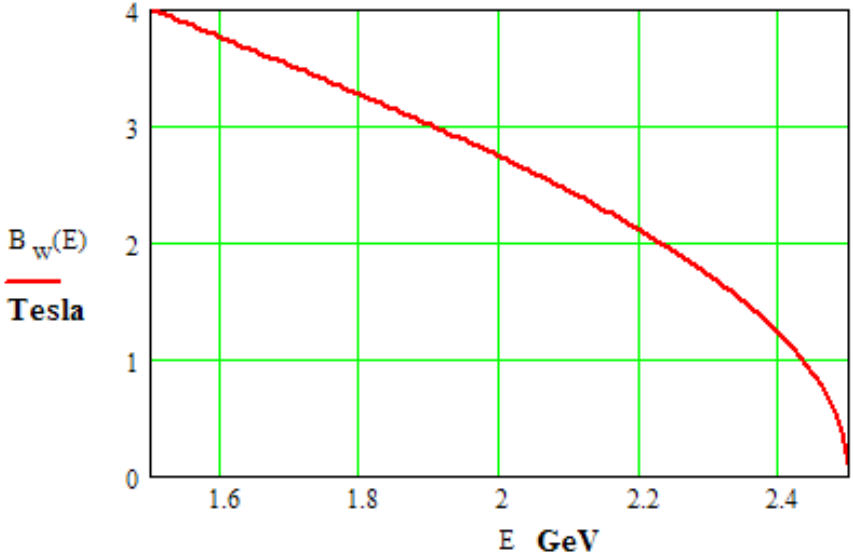
4x1.5m Wigglers @ 50 kGs λ=20cm

Energy	1.0	1.5	2.0	2.5	GeV
Horizontal Emittance	8				nm·rad
Damping time	30				msec
Energy spread	1.01	0.99	0.85	0.74	$\cdot 10^{-3}$
Wiggler field	45	33	22	0	kGs
Energy loss	170	256	343	434	keV
SR Power @ Bends	19	96	304	743	kW
SR Power @ Wiggs	272	342	282	0	kW
Total SR Power	291	438	586	743	kW

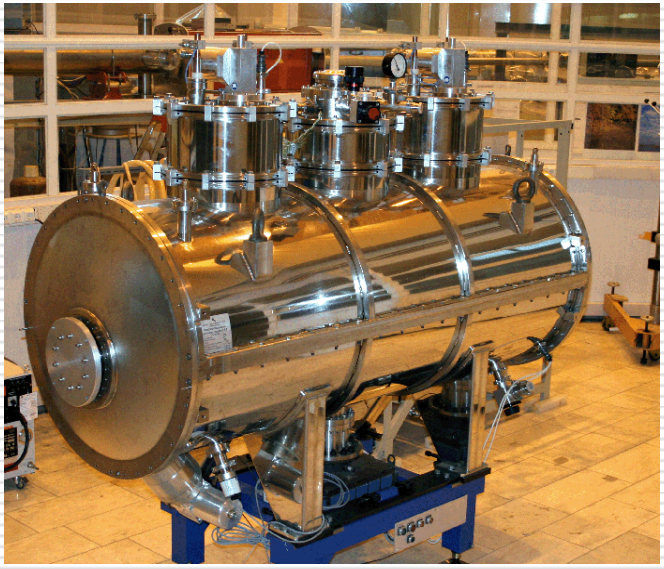
Ibeam = 1.7 A @ 390 bunches

Damping wiggler

Field amplitude at 1.5 GeV	**5 T**
Period length	**0.2 m**
Total length	**5.5 m**
Damping integral i_2 at 1.5 GeV	**2.76 m^{-1}**
Excitation integral i_5 at 1.5 GeV	**0.01 m^{-1}**



Wiggler field amplitude vs energy



Wiggler prototype is ready

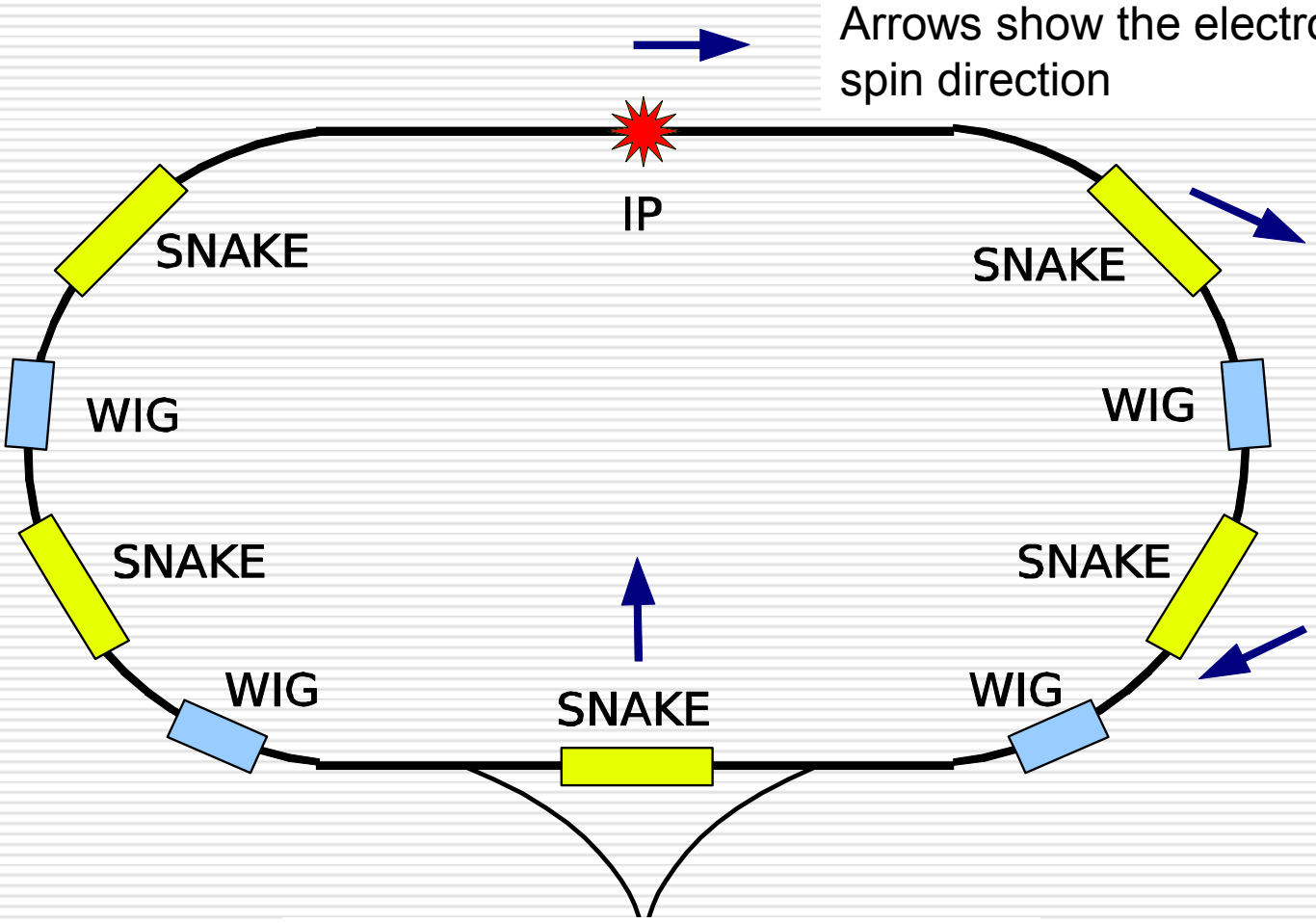
Polarized electron source

• Beam polarization	90 %
• Polarization lifetime	3000 – 4500 s
• Cathode voltage (pulsed mode)	100 kV
• Photocathode type	Strained InGaAsP
• Laser type	Ti – Sapphire
• Light wavelength	700 – 850 nm
• Laser energy in a pulse	10 mkJ
• Pulse duration	2 ns
• Repetition rate	50 Hz
• Number of electrons/pulse	2*10^10
• Photocathode quantum efficiency	1%
• Photocathode recesiation time (depends on laser power)	190 – 560 hours

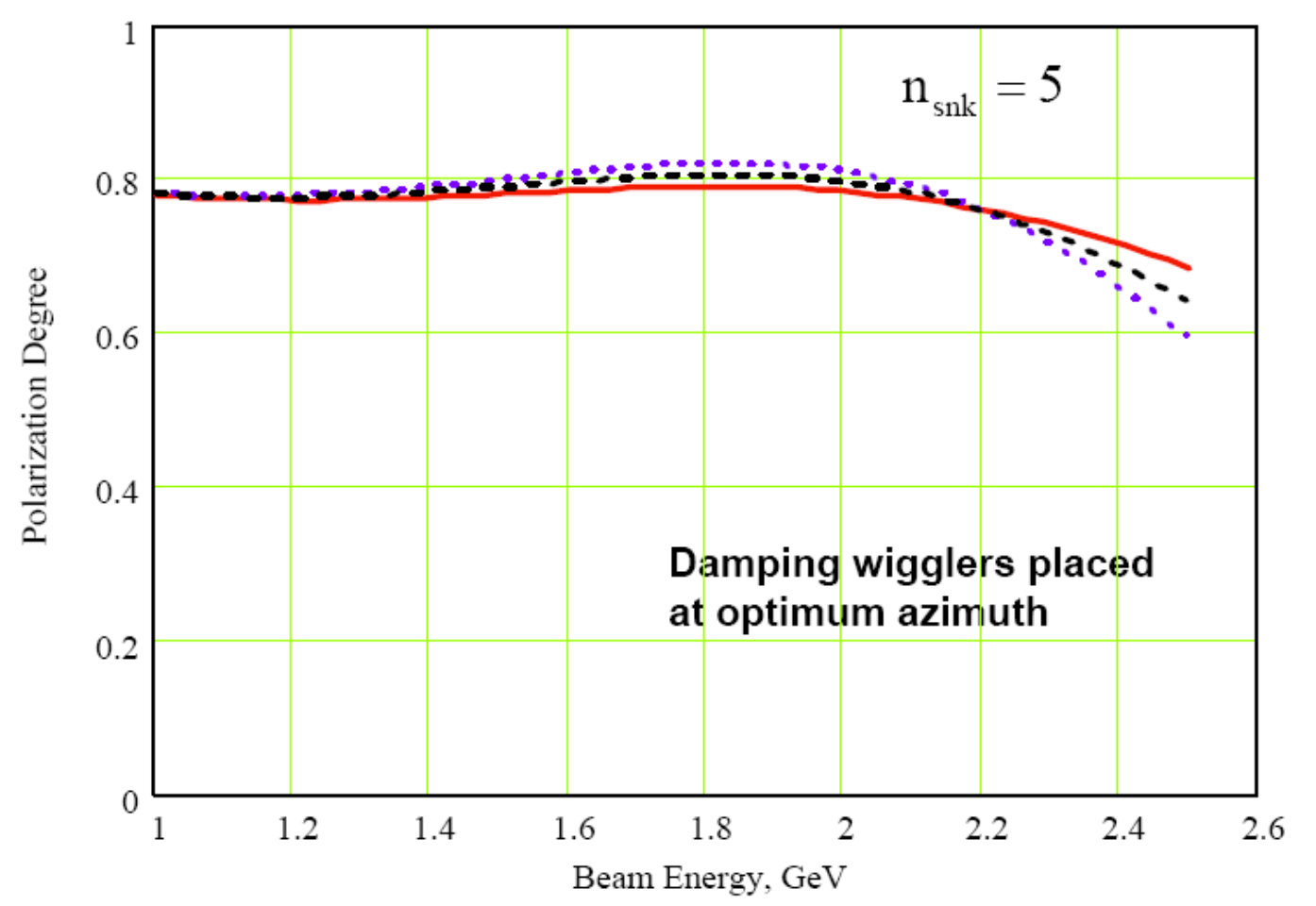
In 1995 this kind of PES was developed by BINP for NIKHEF (Amsterdam)

Well-known technology!

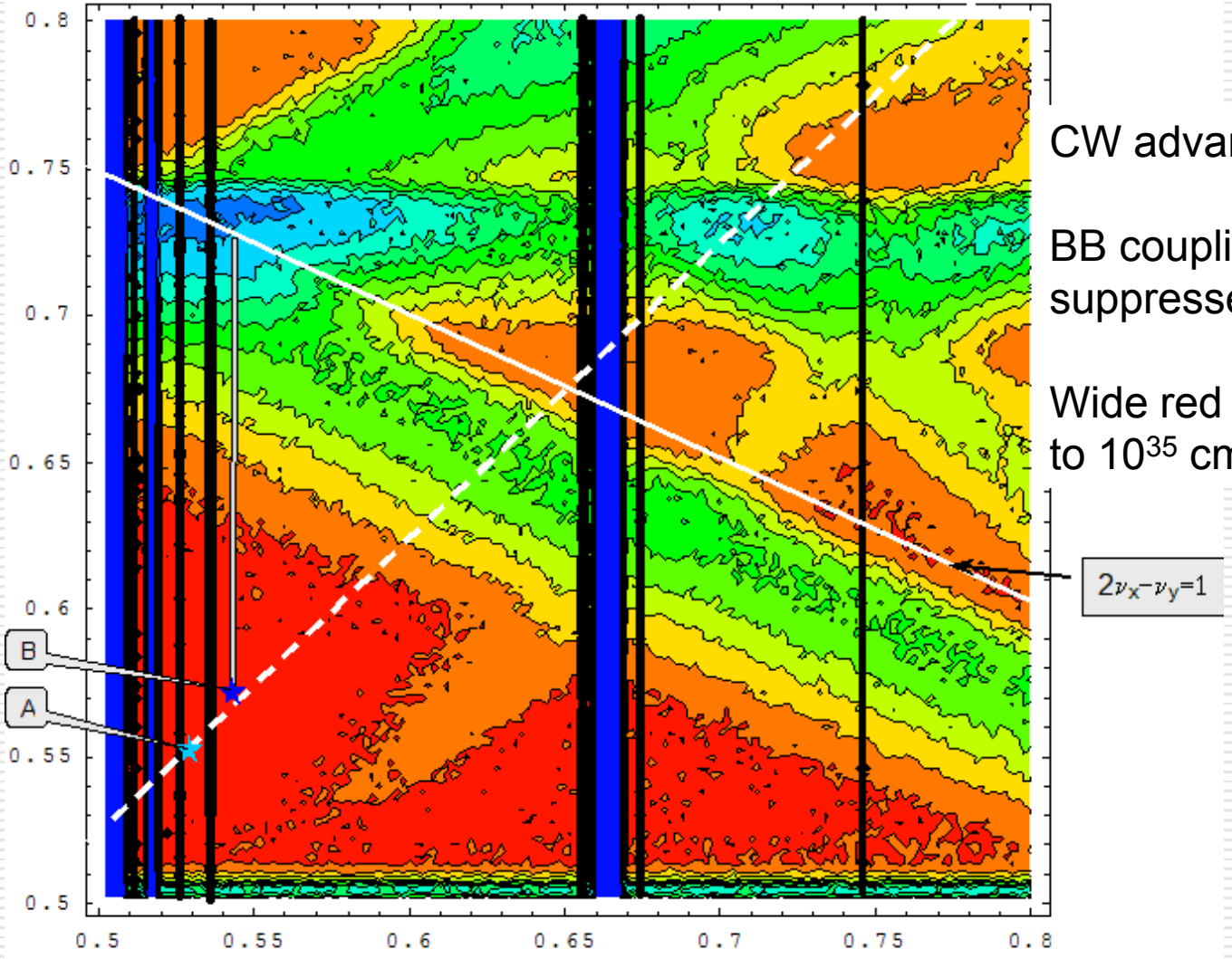
Polarization scheme



Polarization degree vs energy



Luminosity tune scan

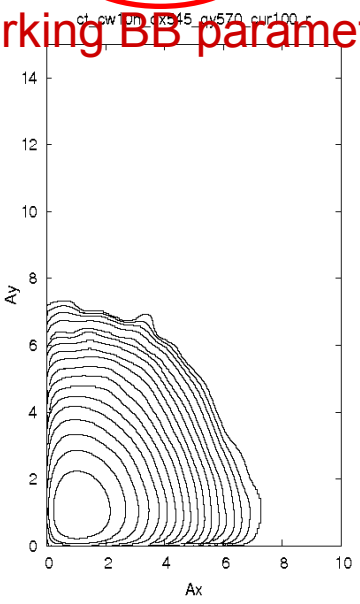
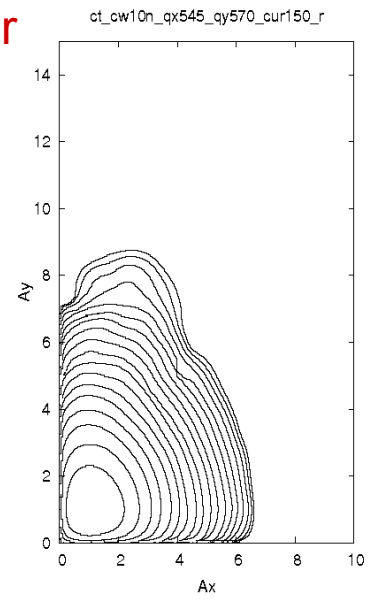
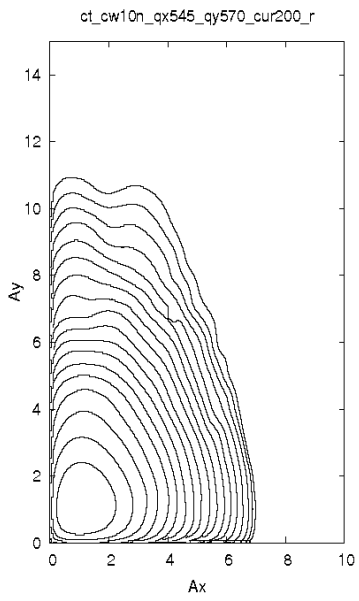
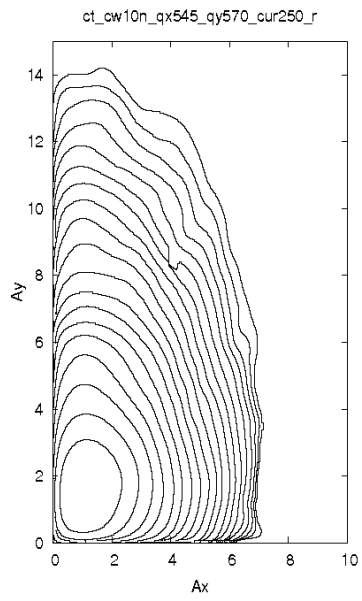


CW advantage:

BB coupling resonances are suppressed

Wide red area corresponds to 10^{35} $cm^{-2}s^{-1}$

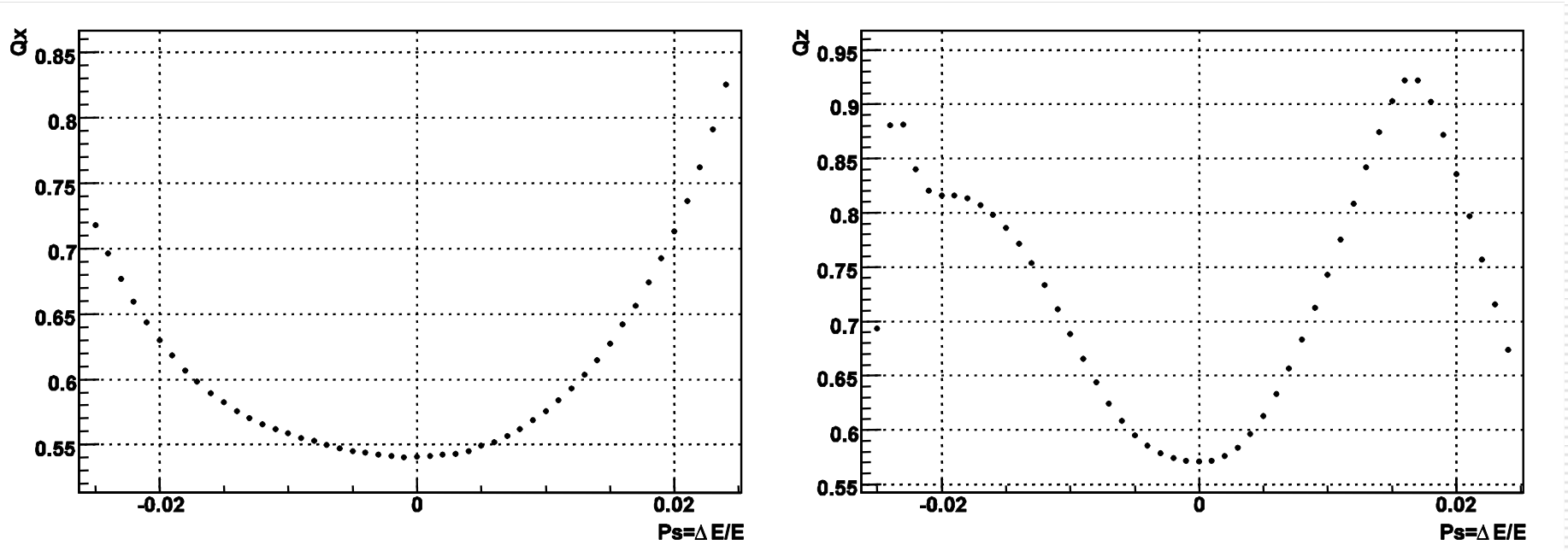
Beam-Beam Simulation

ξ_y	0.12	0.18	0.24	0.30
Density				
ϵ_y/ϵ_{yo}	1.12	1.16	1.30	2.23
L_c/L_{co}	1.00	0.99	0.96	0.85

Working BB parameter

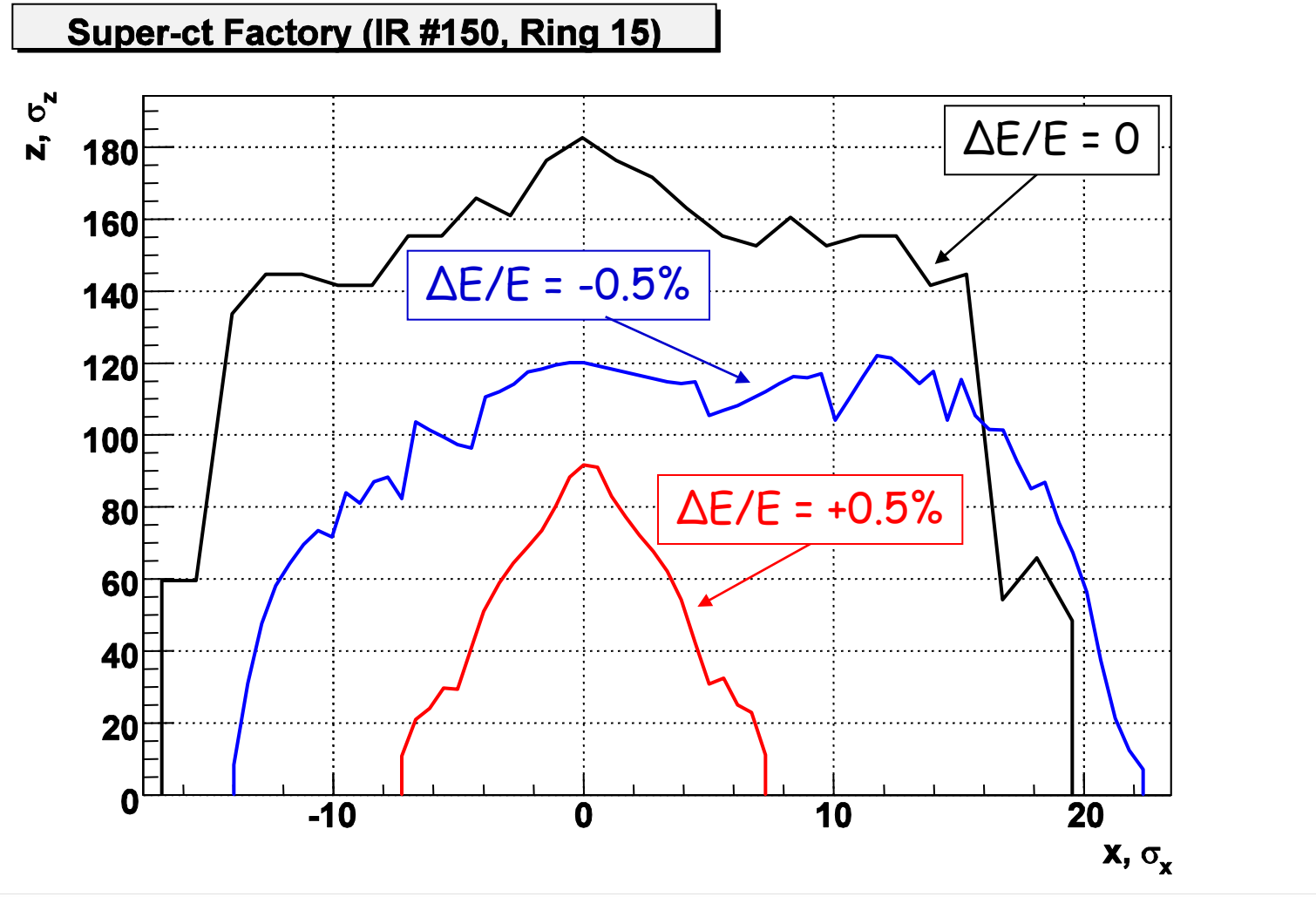
CW advantage: even for xi = 0.2 there is no large beam blow-up and luminosity degradation. Safety margin for BB effects!

Nonlinear dynamics: energy acceptance

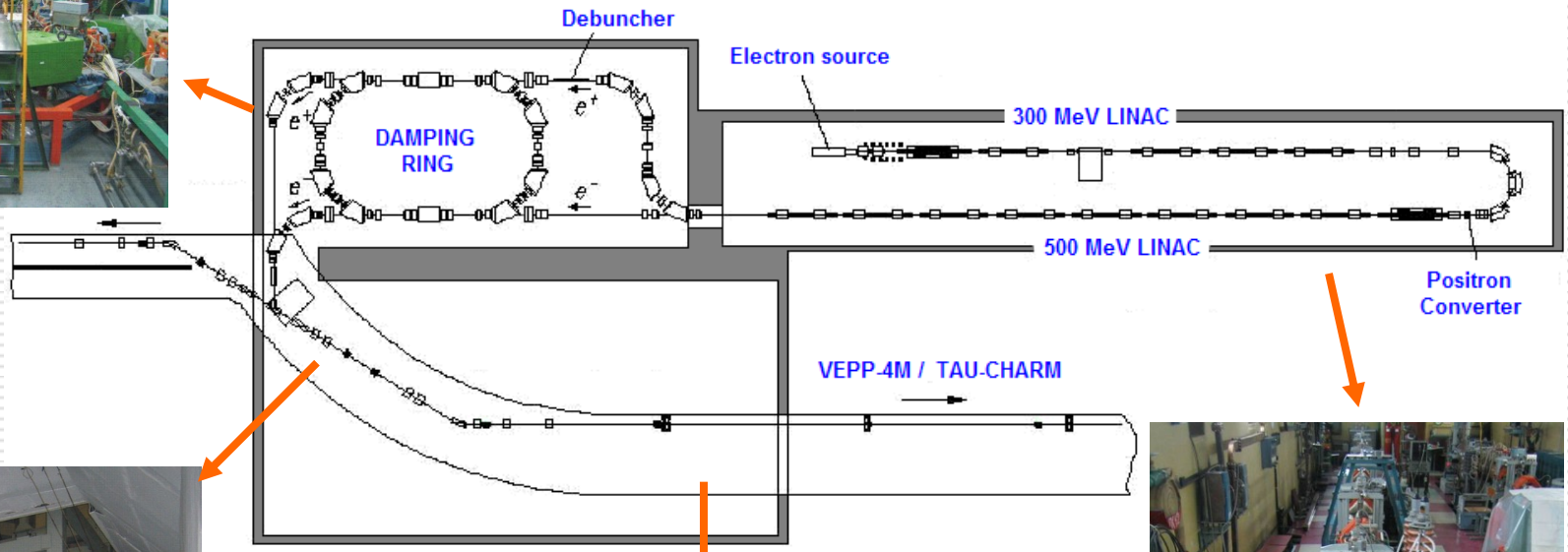


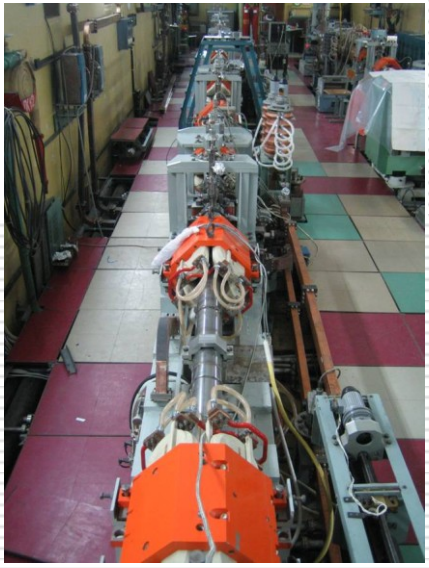
Energy bandwidth ±2% with chromaticity corrected and all main nonlinearities (including the crab sextupoles) is obtained.

Dynamic aperture



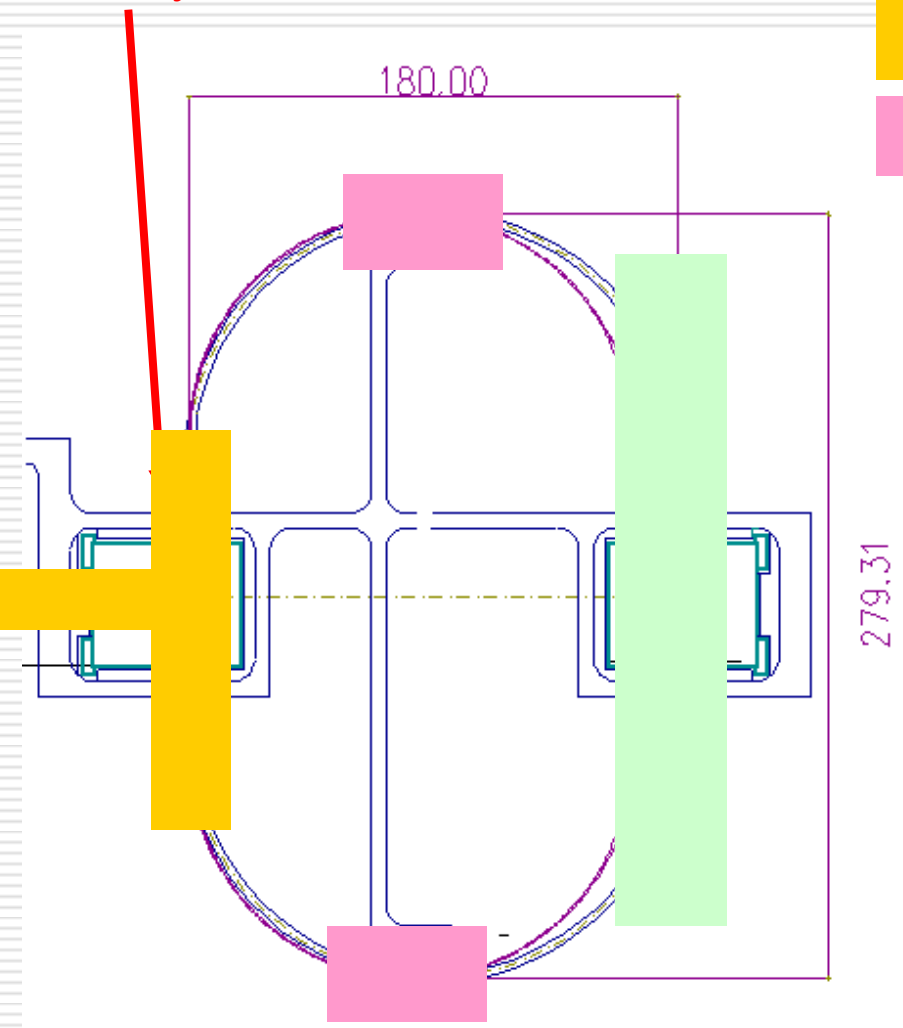
Injection facility





Site construction

Ready-built tunnel

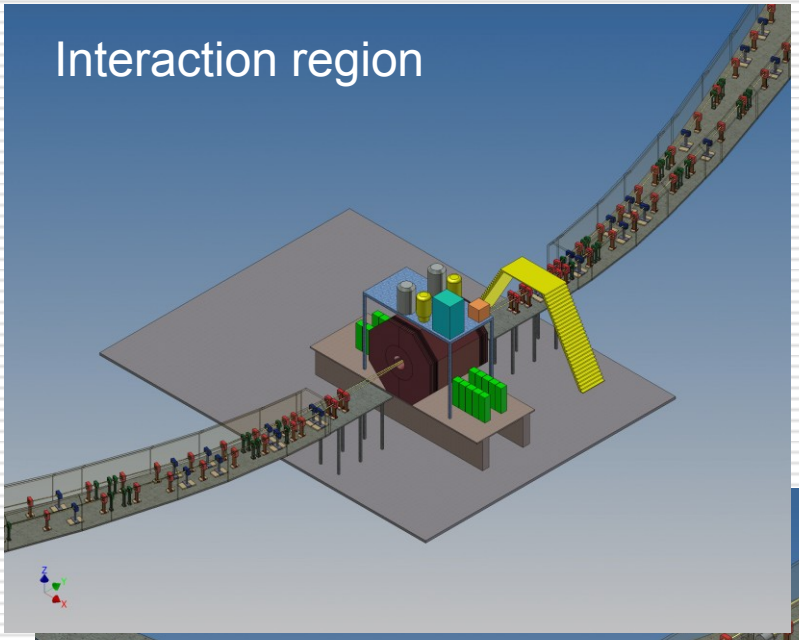


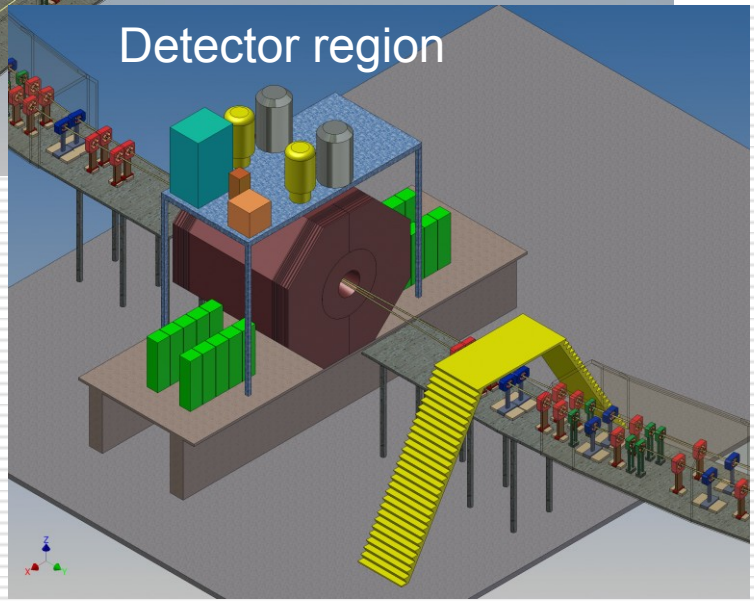
FF region

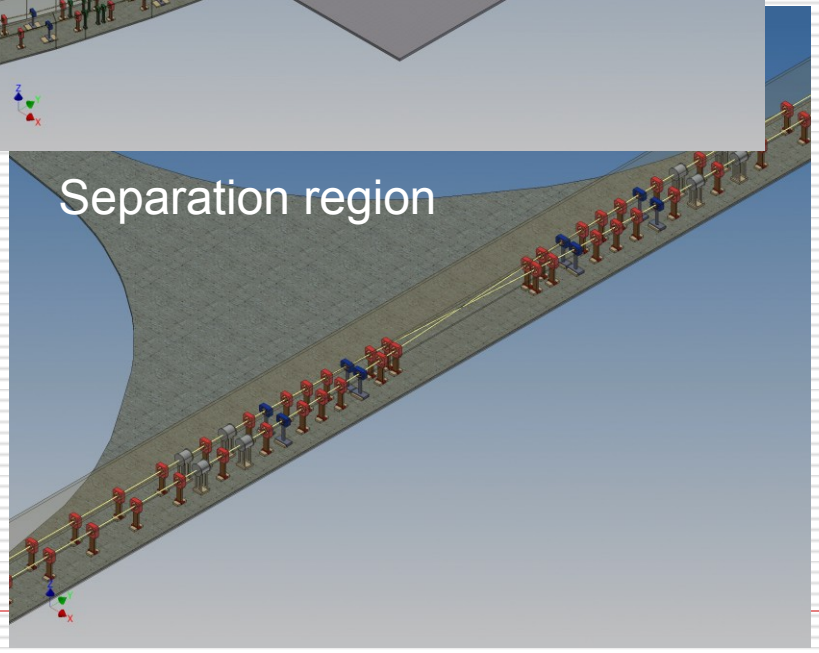
Technical reg. (RF and injection)

Damping wiggler sections

Machine 3D pictures







Conclusion

- The lattice, which meeting all main requirements (800 um beta-y, chromatic correction and DA, momentum bandwidth, longitudinal polarization, luminosity optimization for wide energy range, etc. is ready)
- FF key element, twin-aperture SC quadrupole is under manufacturing
- Prototype of the damping wiggler is ready
- Civil construction is under way
- Detailed machine design and beam dynamics simulation is in progress