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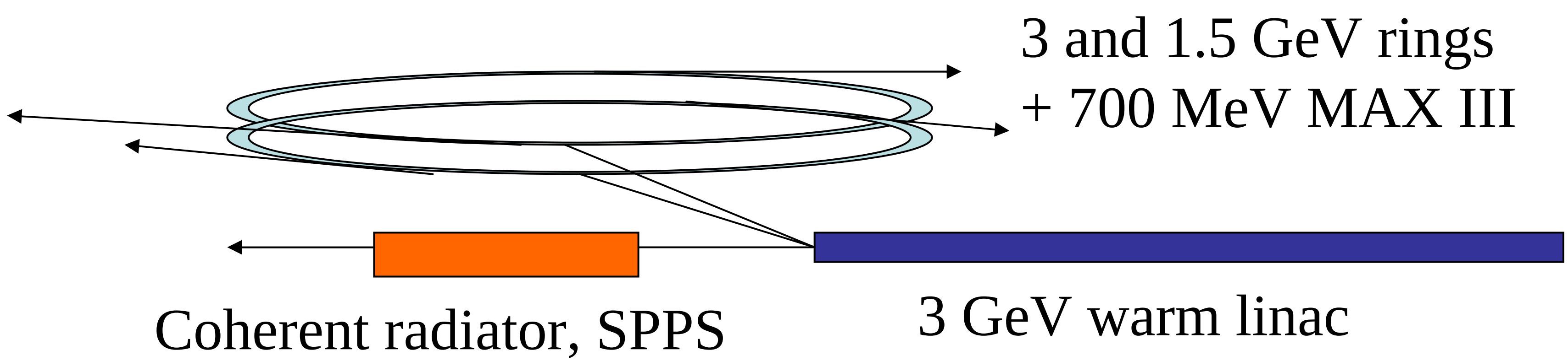
Hamed Tarawneh (SESAME, Amman)

MAX IV Design: Pushing the Envelope

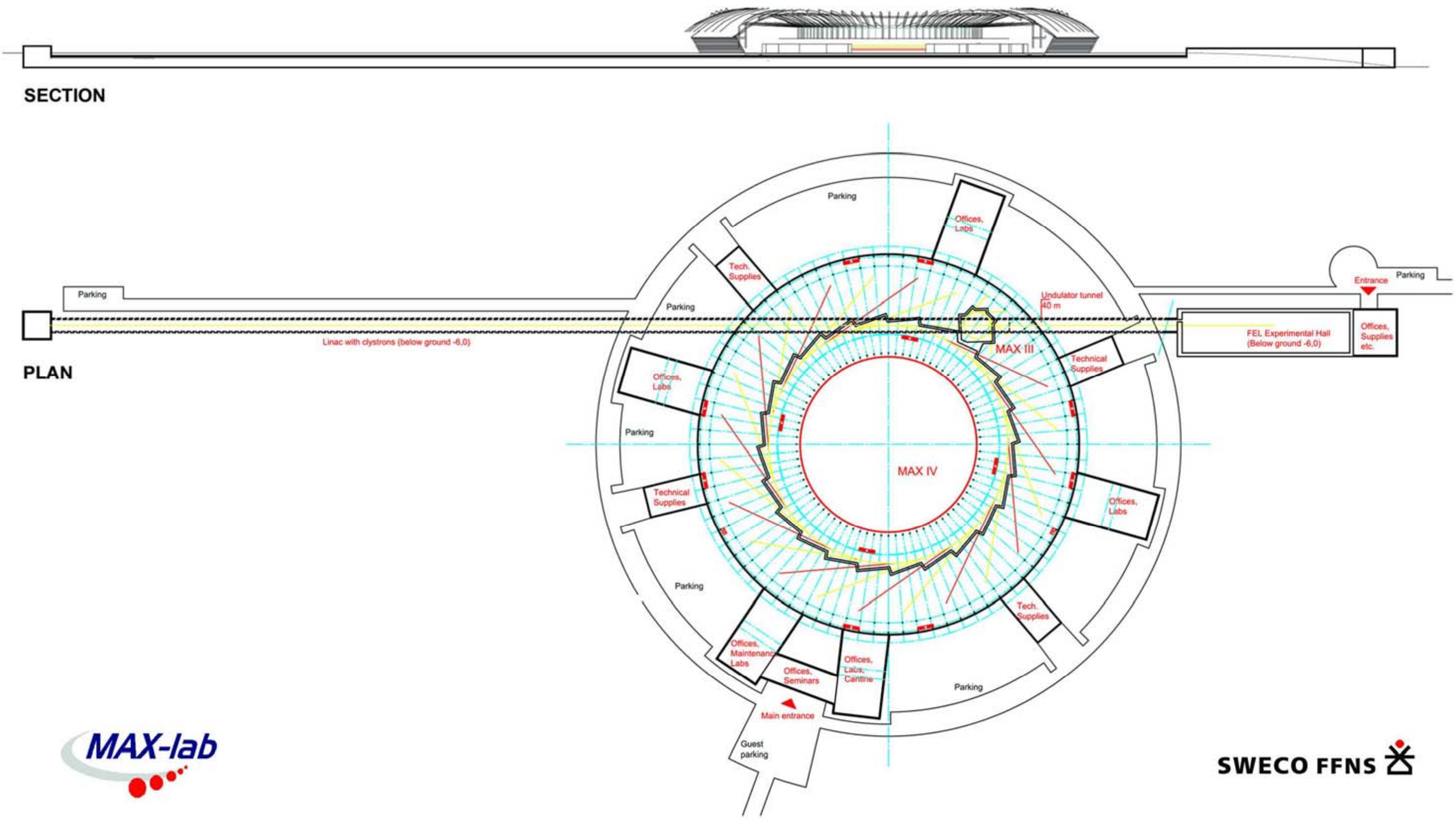
Our outlook

- 3rd gen sources will be the SR workhorses for the fore-seeable future
- Modern sources can be developed closer to the diffraction limit (New Ids, smaller emittance)
- Short-pulse (coherent as well as spontaneous) sources will complement rings and bring added value

Max IV strategy



- Linac for short pulses, rings for stability + mean brilliance
- 2 new rings + MAX III=>broad spectral range, low cost
- Compact magnet technology=>compact, exact lattice, small emittance and possibility to stack rings



MAX-lab

SWECO FFNS

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New Ring Characteristics

Many small ”damping-ring” magnets (integrated dipole/quadrupole/sextupole)=>small emittance, small apertures, good dynamic aperture

Apertures small, but so are β and offmomentum functions functions=>large admittance, energy acceptance

Apertures anyhow restricted by small gap IDs

Small apertures=>special vac chambers

Ring main parameters

Electron energy (GeV)	3	1.5	0.7 (MAX III)
Circumference (m)	287	287	36
No of straight sections	12	12	8
Straight sect length (m)	4.6	4.6	2.5
Circulating current (A)	0.5	0.5	0.4
Emittance (nmrad)	0.86*	0.34	13
RF (MHz)	100	100	100
Quadrupole bore radius (mm)	12	12	20
Dipole full gap (mm)	24	25	30
Photon energy (und)	5eV- 40 keV		

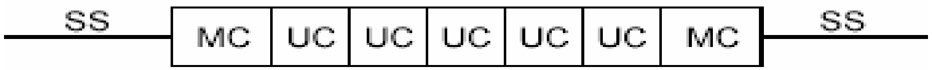
* Including 2 damping wigglers

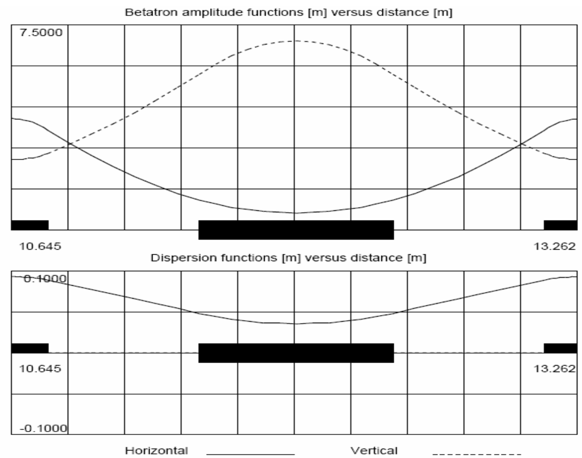
Linear Lattice

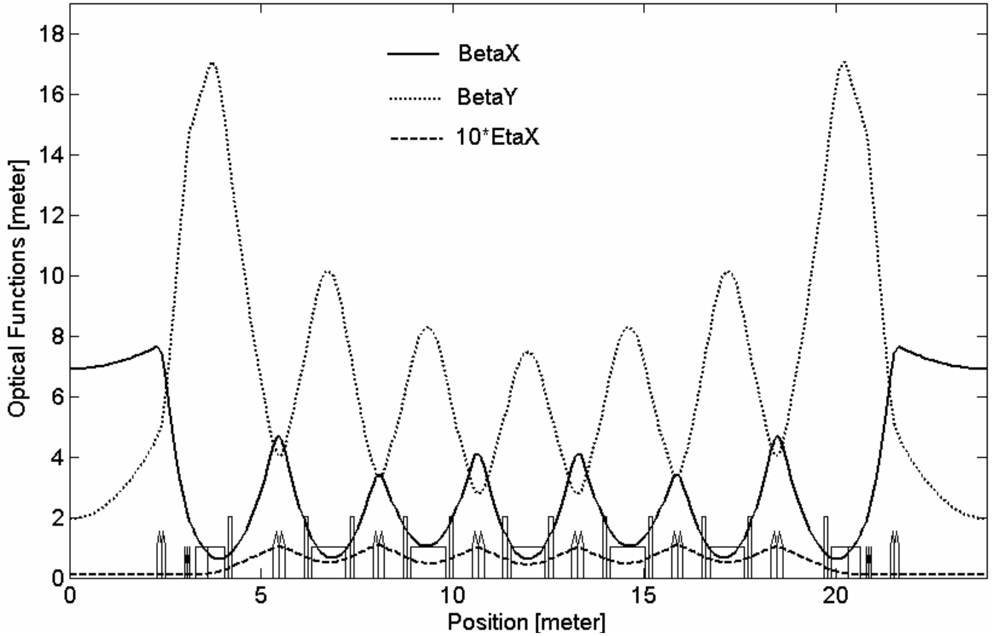
-Multiple Bend Achromat
-High gradient in the dipole magnet

g ~ 10 T/m

$\varepsilon \sim \gamma^2/N^3$







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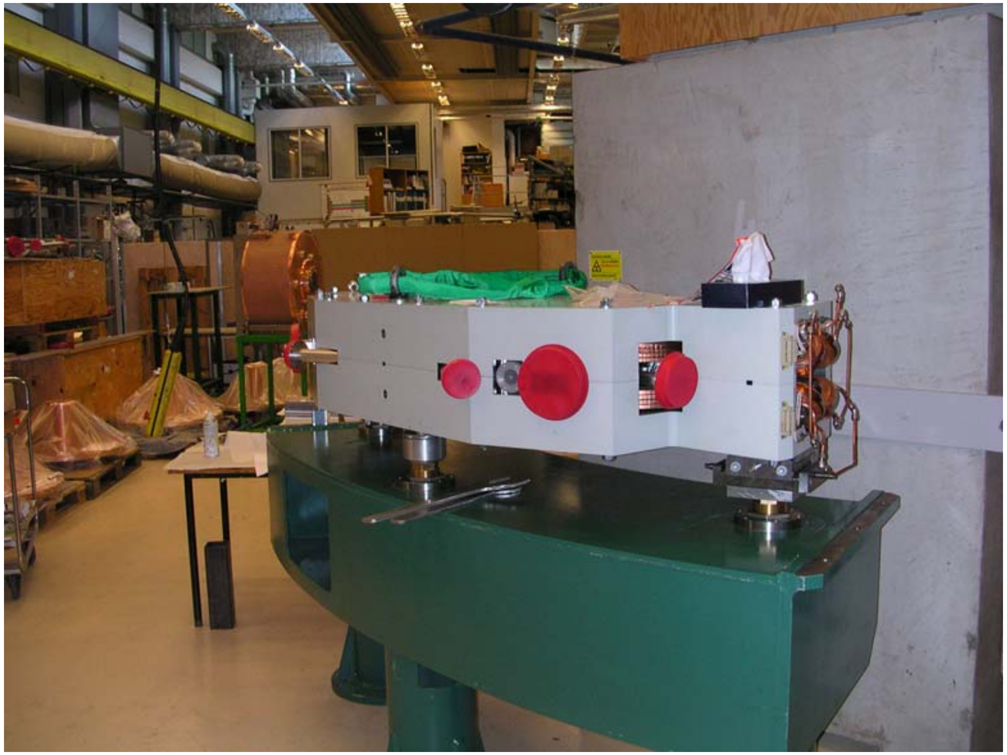
Magnet technology (MAX III)

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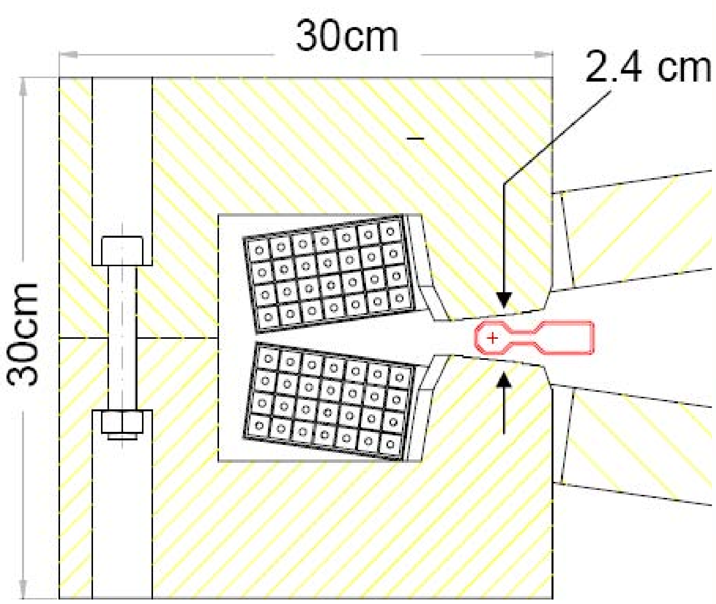
Magnet Technology, New Rings



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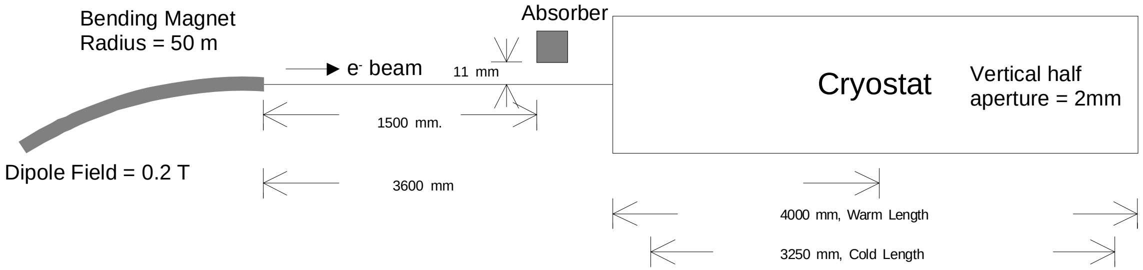
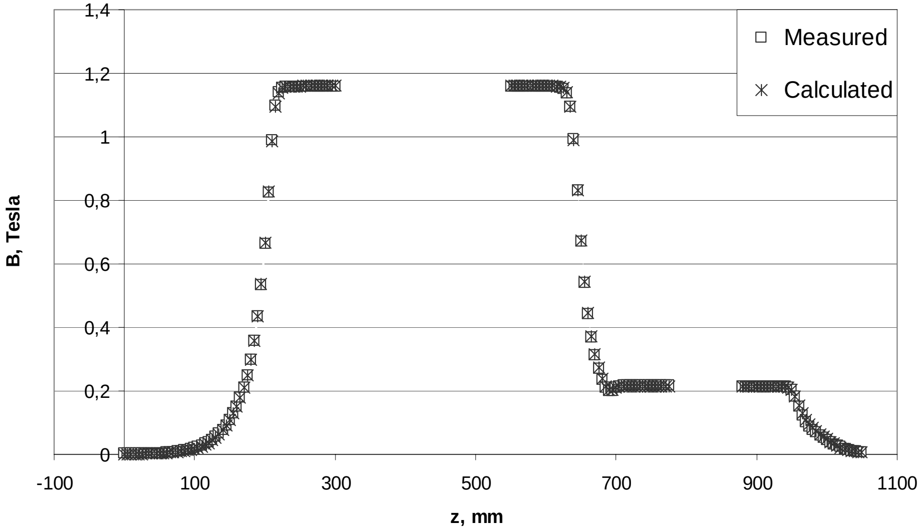
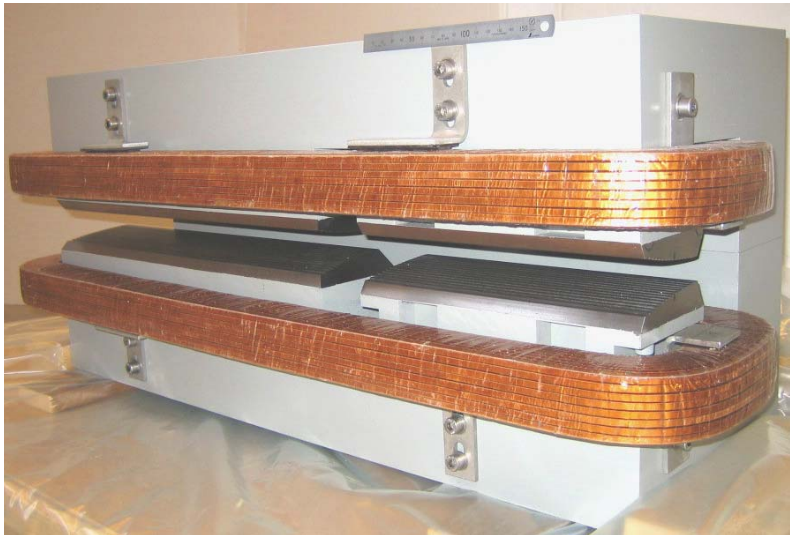
Matching Cell Dipole with Soft End

The synchrotron radiation power hitting the cold bores is restricted by the introduction of soft end magnet preceding the SC ID.

SR Power ~ 1/ρ







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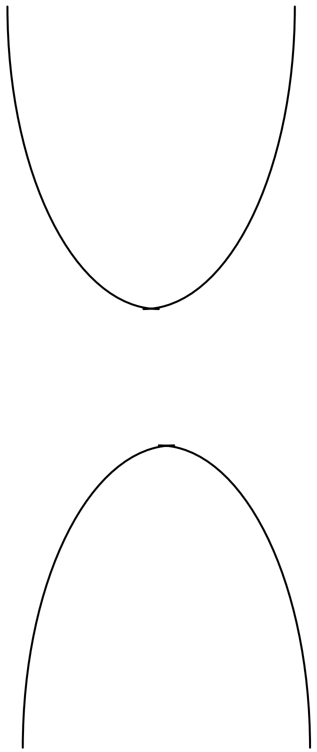
Magnet parameters, New Rings

	Dipole	Quad	Sext
Length (m)	0.9	0.3	0
Dipole field (T)	0.9	0	0
Gradient (T/m)	-9.3	41	0
Sextupol (T/m^2)	0	744	2000
Octupole (T/m^3)	0	5004	0

Work in progress:

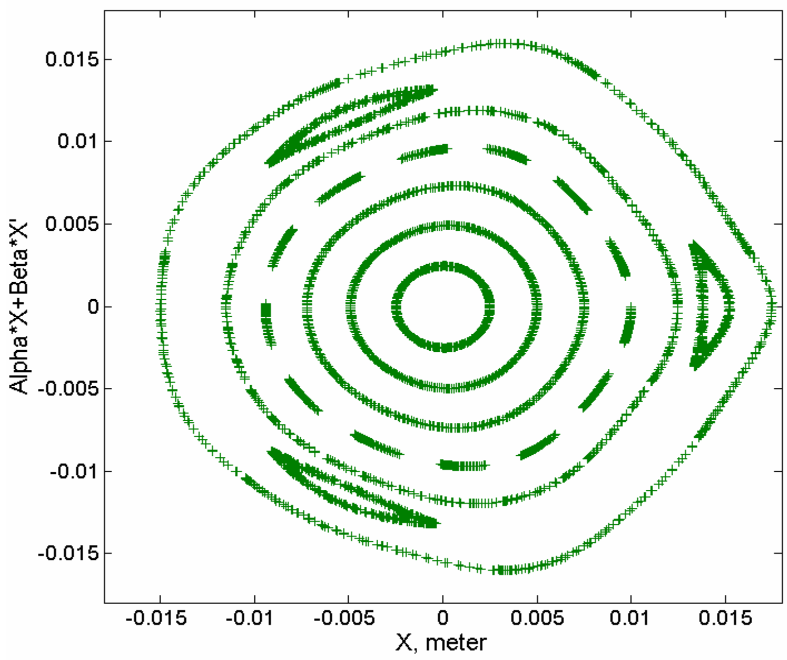
Dipole ends with strong roll-off =>



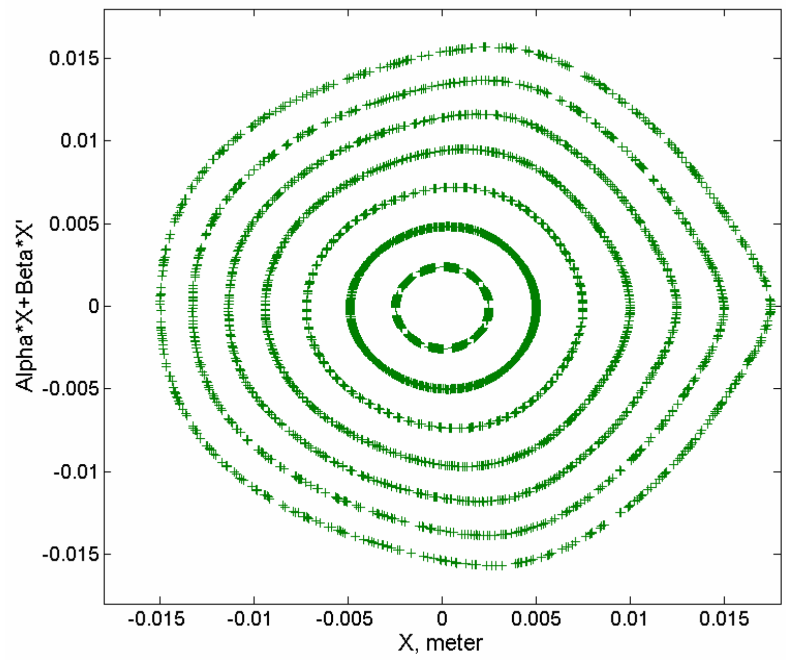
- No discrete sextupoles needed
- Lower dipol end fields, emittance reduction to 0.6 nm rad

Impact of Octupole field

Sext: ON & Oct: OFF



Sext: ON & Oct: ON



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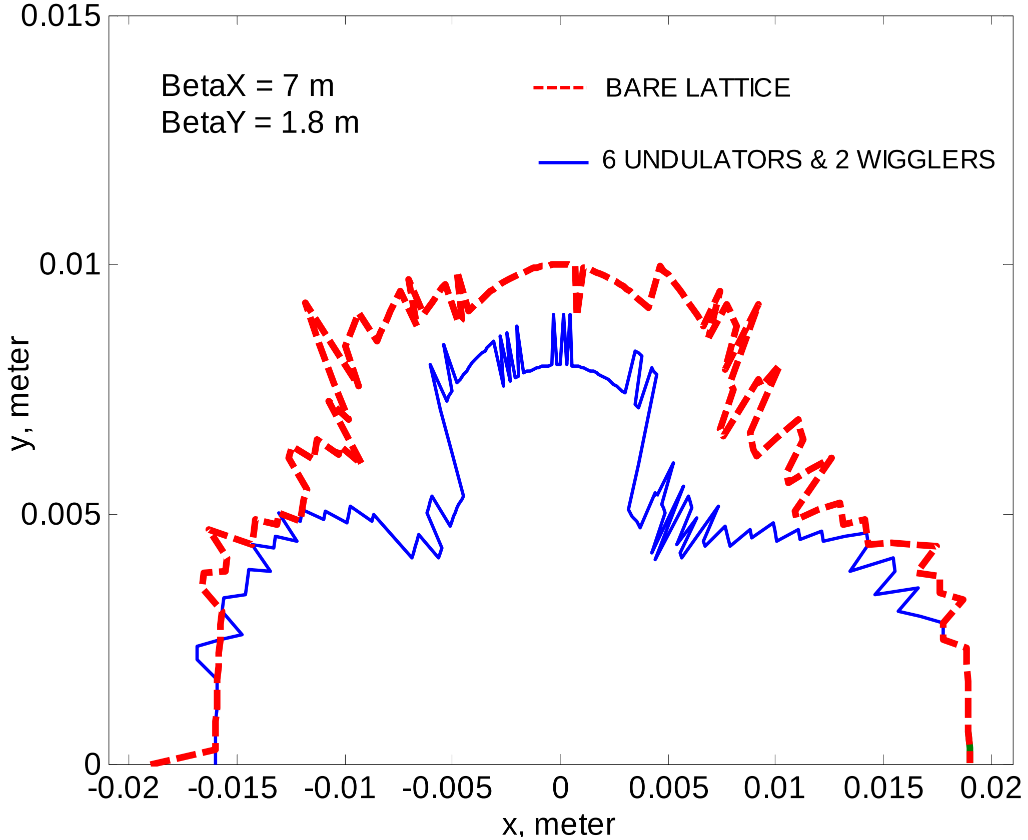
Effect of ID's

	K-value	λ (mm)	No. of Period
SC Undulator	2.2	14	200
SC Wiggler	20	60	35



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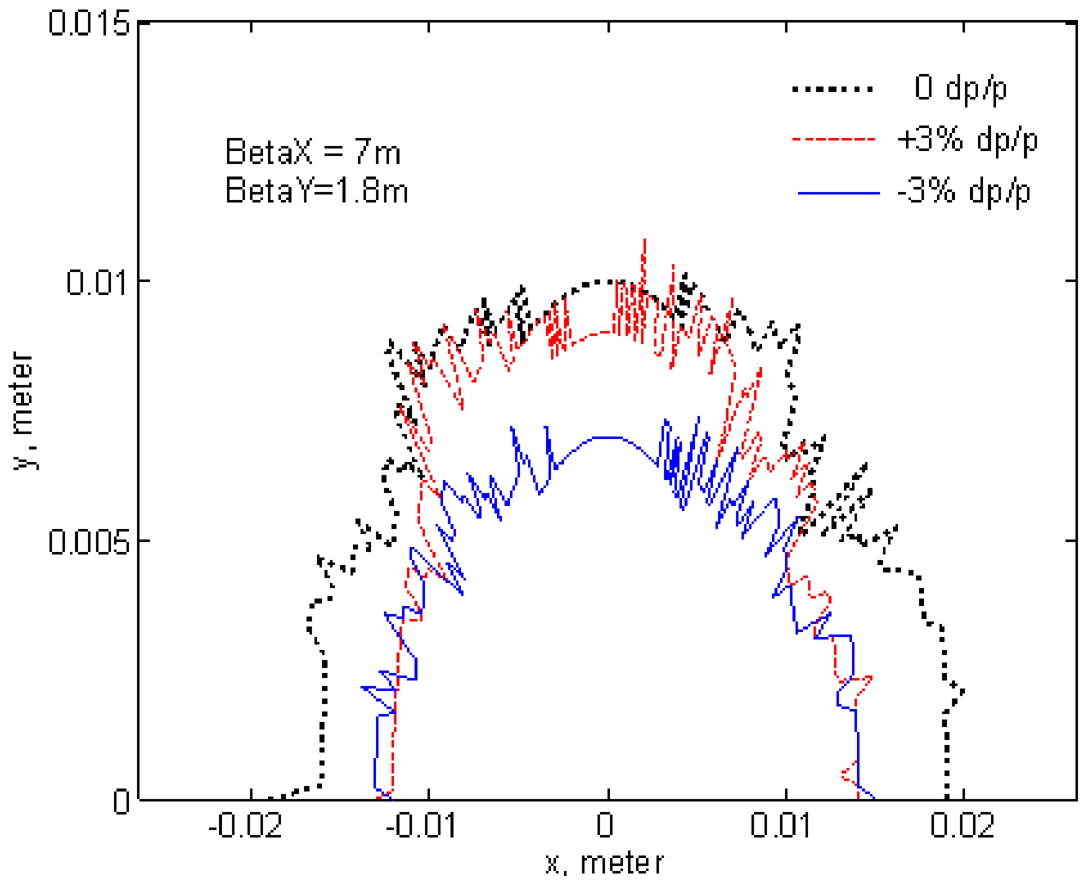
Dynamic Aperture for off-momentum particles



Injection aperture needed

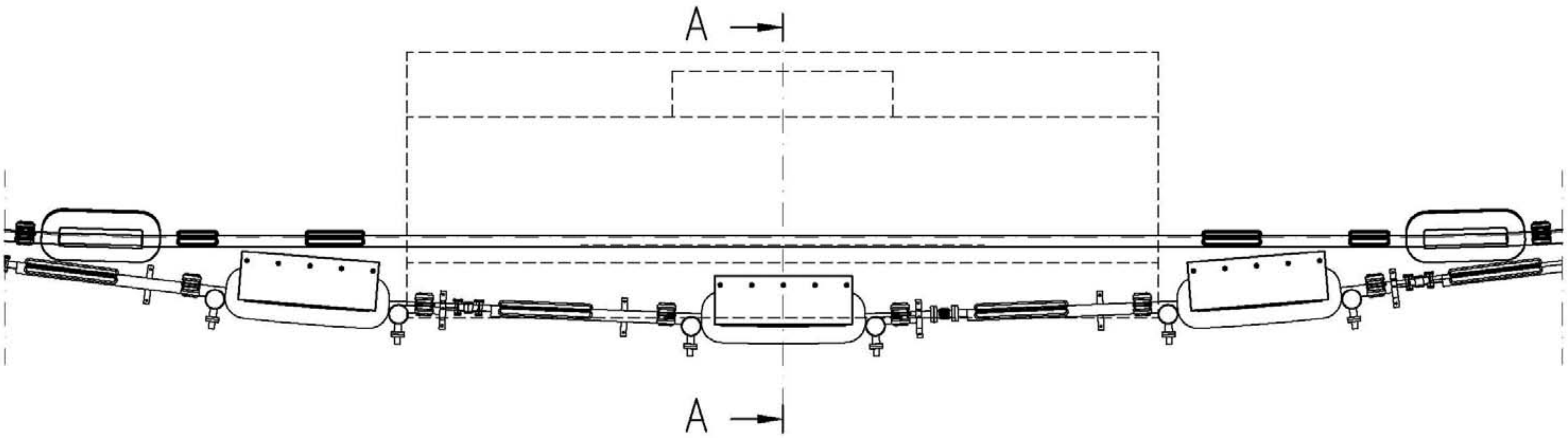
- 2 mm Lambertson septum (effective thickness)
- σ_{inj}<0.1 mm
- σ_{stored}<0.1 mm

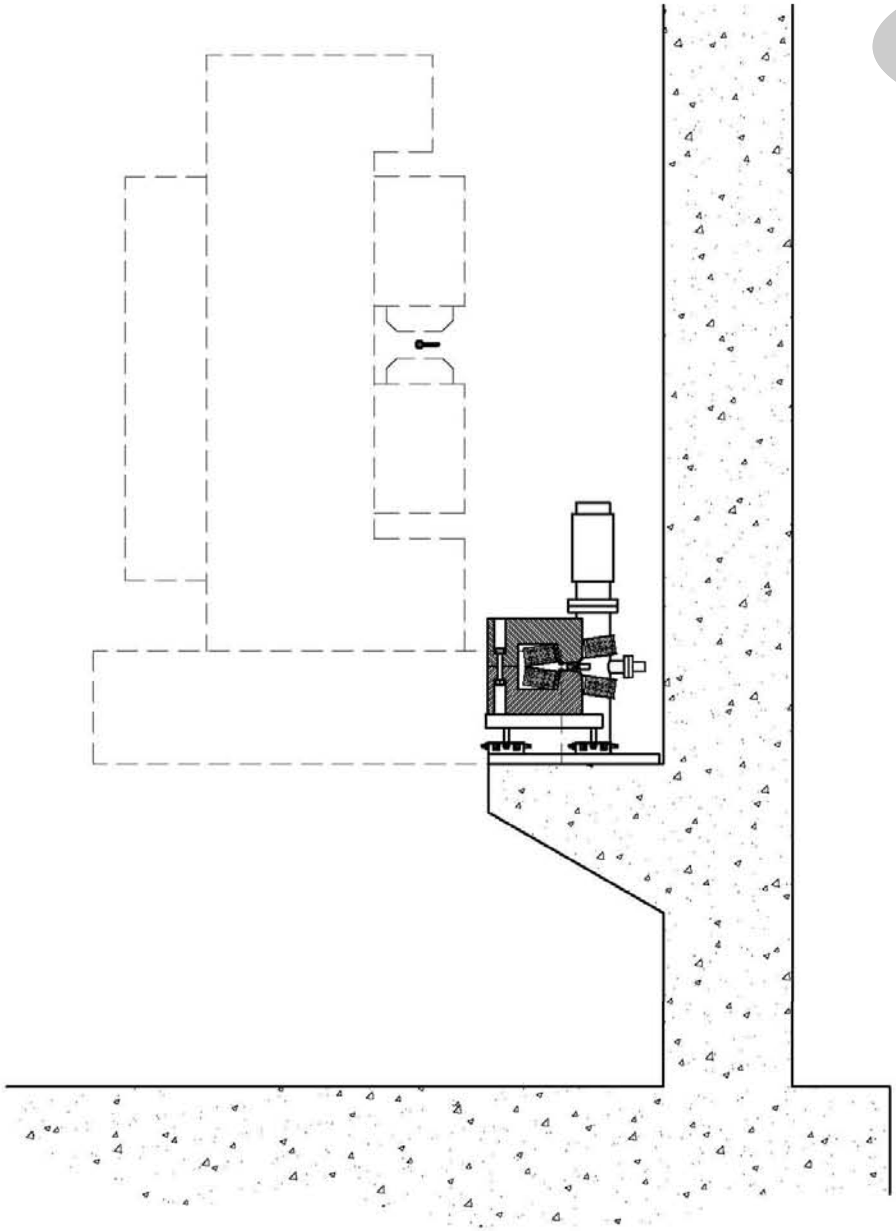
Injection aperture<3 mm

Admittance

The minimum admittance needed is defined by elastic scattering and injection.

At the middle of SS.		Stable	Needed
3 GeV	Horizontal	57.14×10^{-6}	14.28×10^{-6}
	Vertical	55.55×10^{-6}	2.22×10^{-6}
1.5 GeV	Horizontal	57.14×10^{-6}	14.28×10^{-6}
	Vertical	55.55×10^{-6}	5.00×10^{-6}


A
A



SECTION A–A

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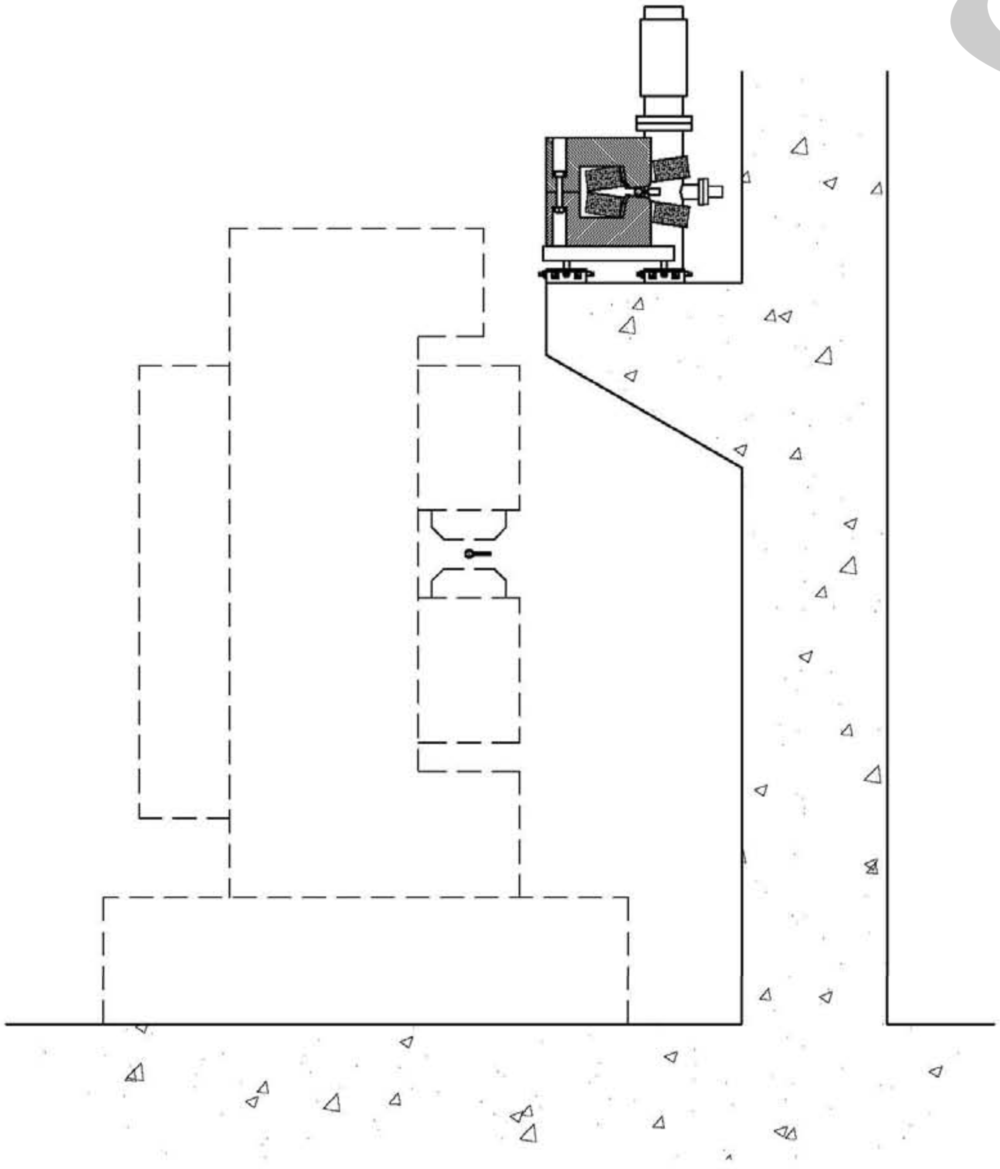

SECTION A–A

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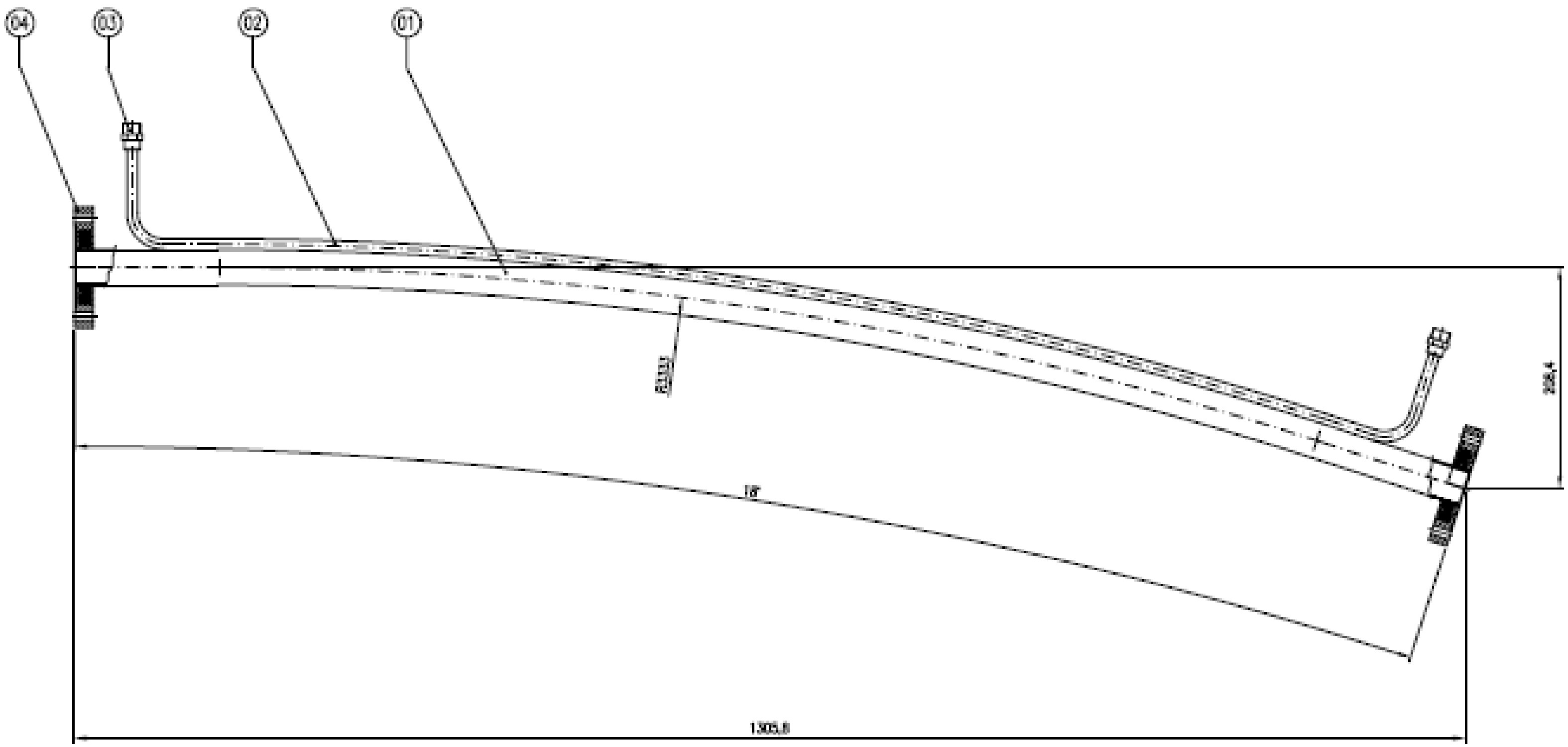
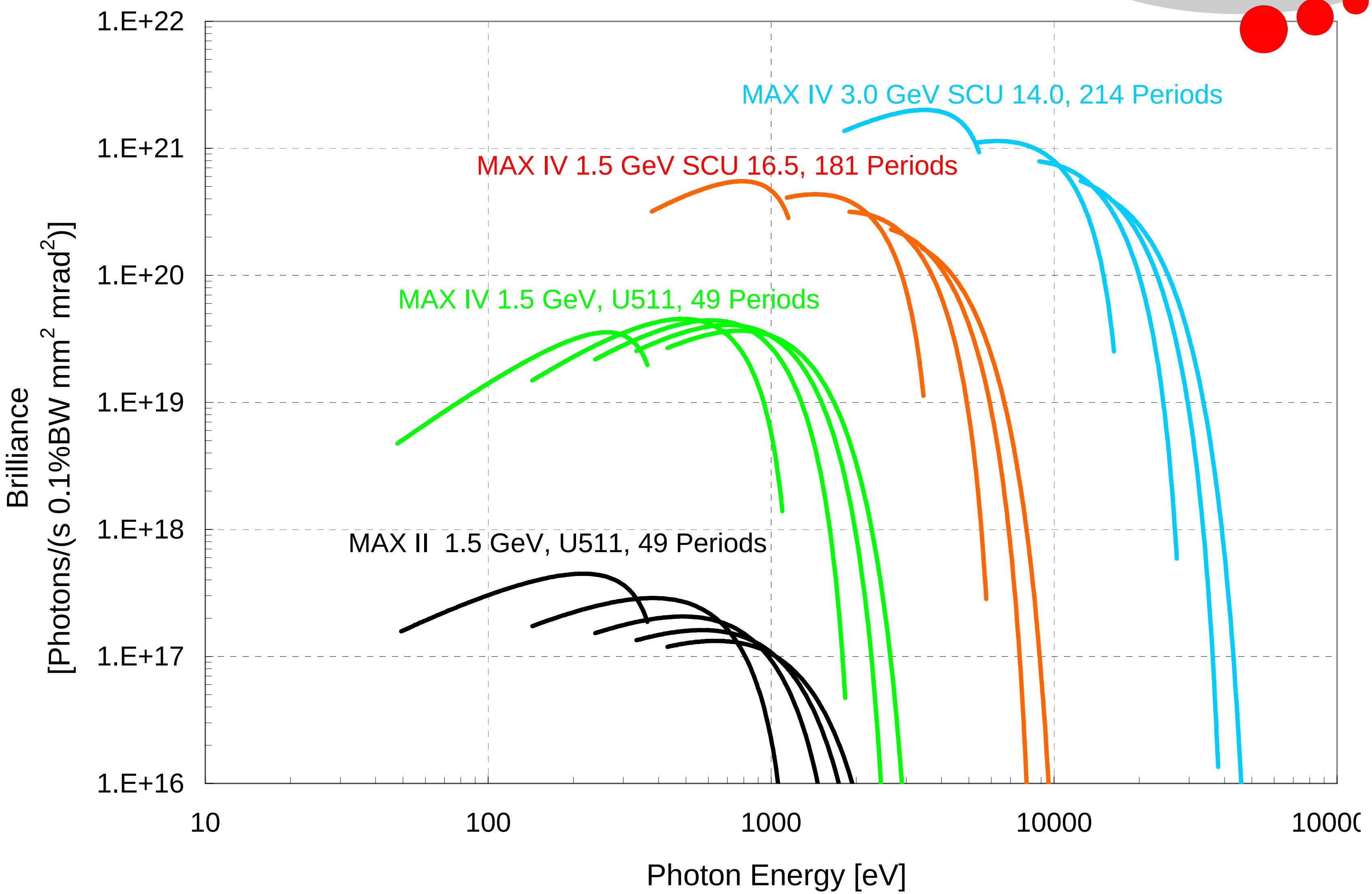
NEG-coated test dipole vac chamber (in MAX II)





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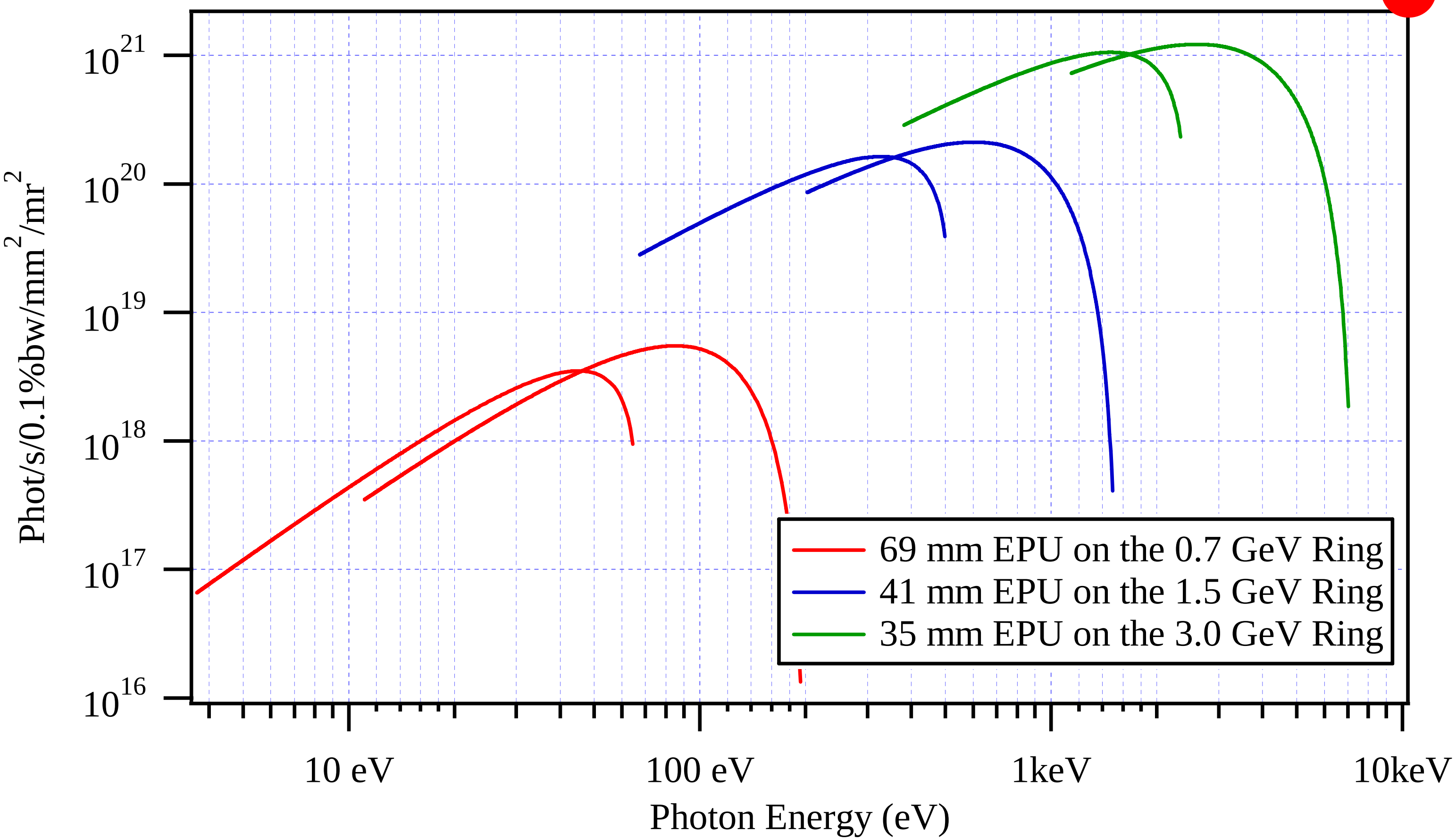
Brilliance for EPUs on MAX IV



- 1.98 m long 69.1 mm period EPU with 57 poles on the 0.7 GeV ring
- 4 m long EPU with 41 mm period and 193 poles on the 1.5 GeV ring
- 4 m long EPU with 35 mm period and 226 poles on the 3 GeV ring.

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Beam Lifetimes

Beam 1/e lifetime (h) @ 0.5 A

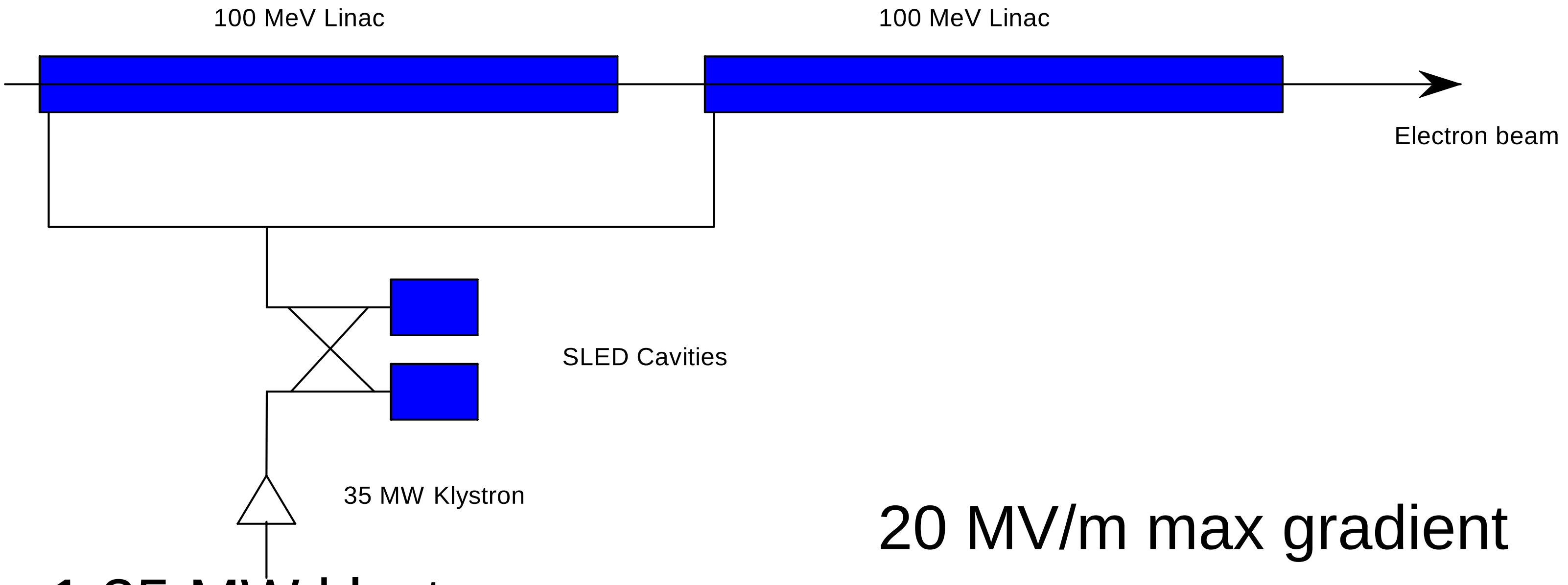
& 100 MHz +5th harmonic Landau Cavity

	3 GeV	1.5 GeV
Touschek	10.5	89
El scattering	71.5	132
Bremsstrahlung	64.6	60.8
Total	8.4	24.5

Linac Injector

- 17 stations, 200 MeV each (Redundancy)
- Duty-factor=0.001 + Variable pulse length=> 220 Hz ≤ Rep rate ≤ 1 kHz
- Solid state modulators: Variable pulse length, high stability, low EM noise
- Electron source: according to SCSS
- SPPS in phase 1
- FEL driver in phase 2

Linac Module (17 of them)



1 35 MW klystron

1 Pair of SLED cavities

2 pcs 5 m linac structures

20 MV/m max gradient

Max dutyfactor 0.001

Solid state modulators
=>variable pulse length

Rep rates

RF pulse length (μs)	Rape rate (Hz)	Max energy (GeV)
4.5 (SLED)	220	3.4
3.0 (SLED)	330	3.0
1.0 (no SLED)	1000	1.9 (FEL)

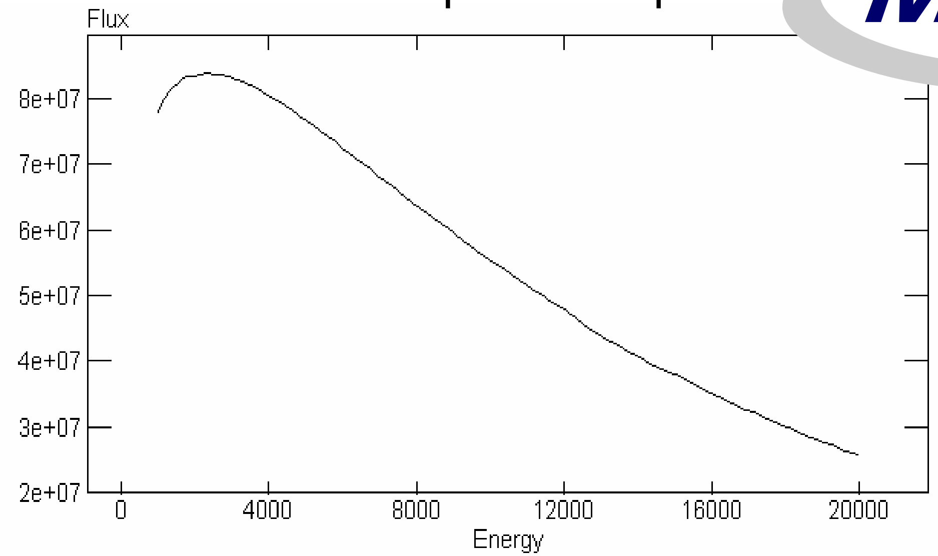
3.4 MW from the wall

MAX IV Linac

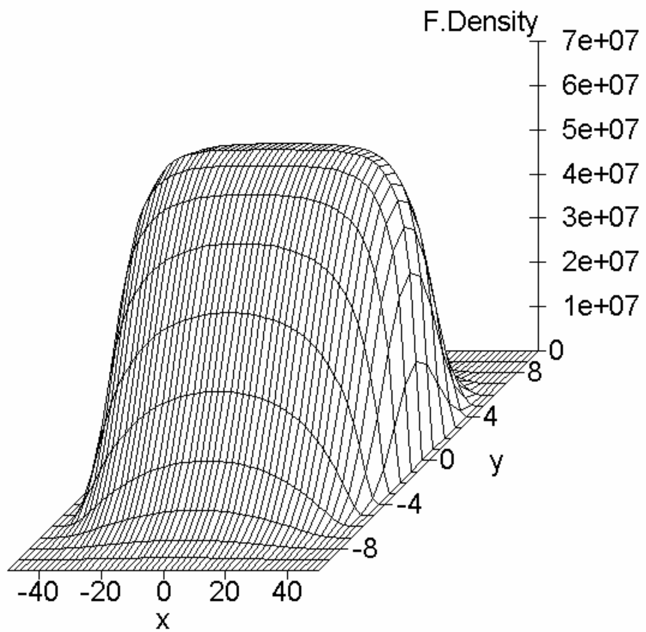
3 GeV
1 nC Charge
100 fs bunch length
0.1 % ΔE/E

Wiggler
Length 10 m
PL = 5 cm
Field = 2 T

Total flux of photons / pulse



Flux density / pulse for 10 keV photons 30 m from source



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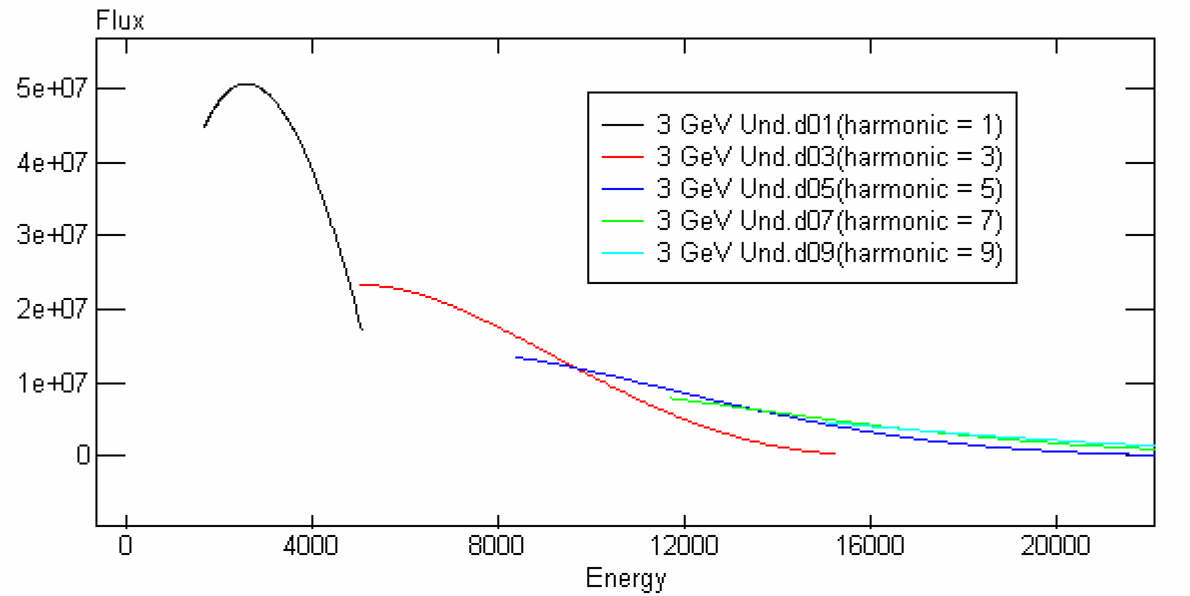
MAX IV Linac

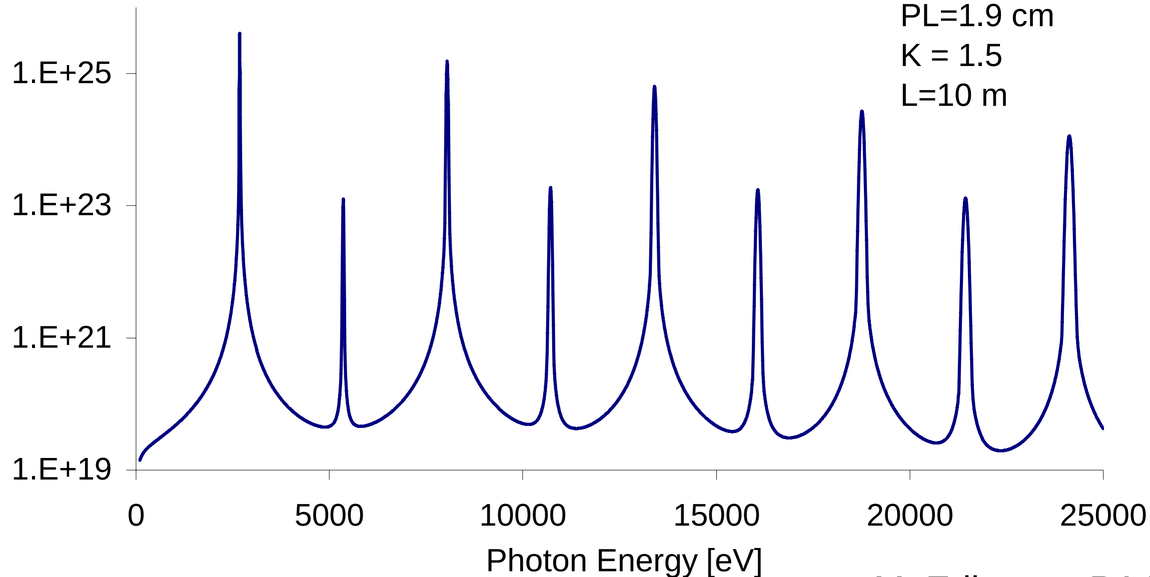
3 GeV
1 nC Charge
100 fs bunch length
0.1 % $\Delta E/E$
3×10^{-10} Emittance

Total flux of photons / pulse through slits 1×1 mm^2 30 m from source



Undulator
Length 10 m
PL = 1.9 cm
K = 0.5 -2.2

Peak Brill. = 1.1×10^{26}



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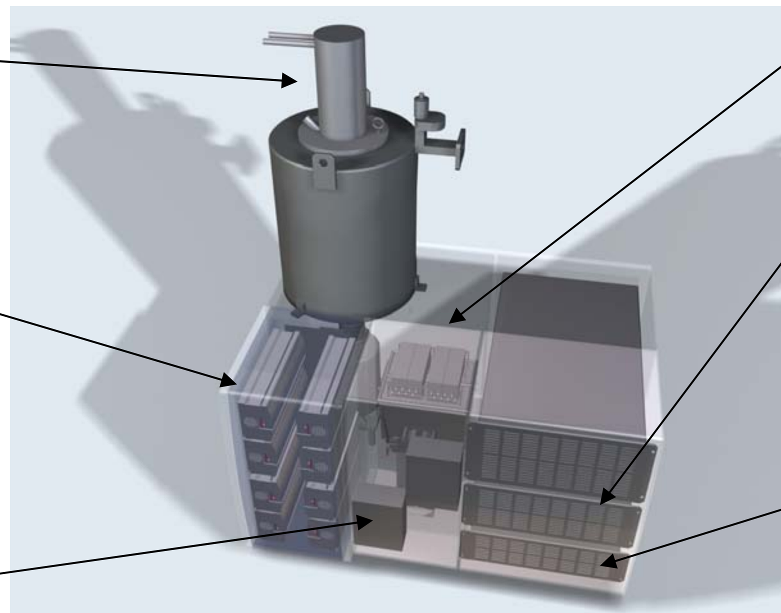
Solid state modulator

Klystron

Solid state switch modules

Controls,

diagnostics



Pulse transformer

Kly mag PS

LLRF, amplifier

Thanks for your attention!

Injection rates

- 5 h life-time, 1 % ´beam current variation=>3 minutes between injections
- Stored charge=0.5 μC=>5 nC at each injection
- Fill 5 consequtive bunches with 1 nC in each

Legend

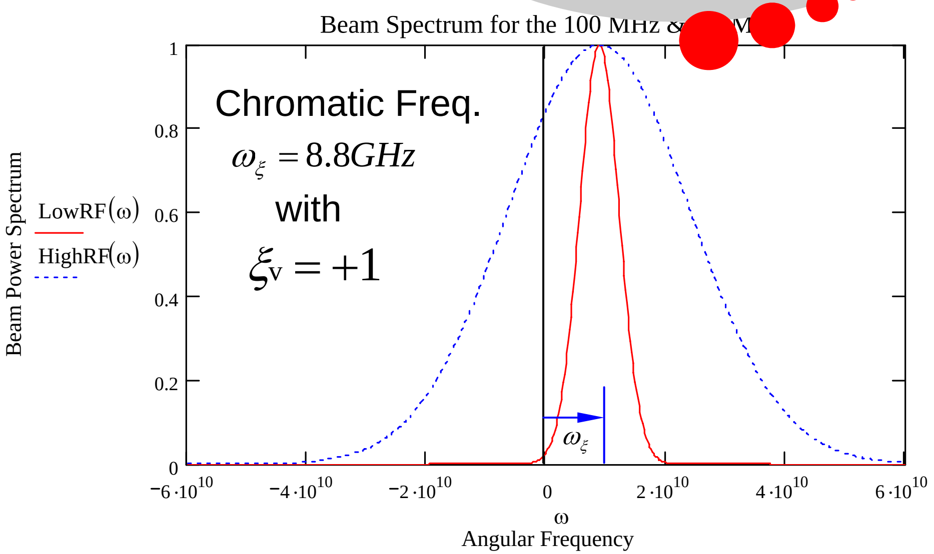
- 2002: Starting looking at ”damping ring” lattices.
- 2004: CDR application awarded (Wallenberg Fundation).
- Nov 2005: Machine evaluated by the Swedish Research Council (VR).
- Dec 2006: Scientific Case evaluated by VR. (Phase 1).
- 2007: VR funds Detailed Design Study.
- June 2007: Letter from VR to Dep of Education: VR recommends the MAX IV project warmly and recommends the Department to find ways to finance MAX IV. (Phase 1).

For ev questions

Damping RW Instability

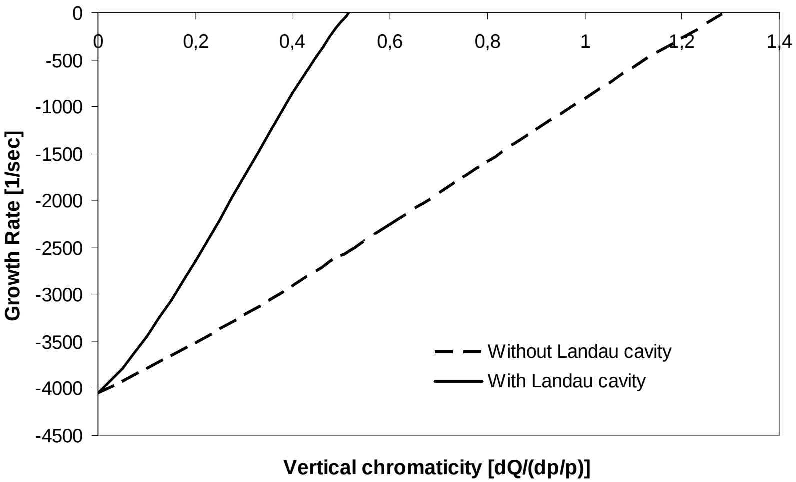
- Small gap IDs introduce high deflecting RW impedance($1/b^3$).

- Slightly positive chromaticity shifts the beam spectrum toward positive frequencies which acts damping.

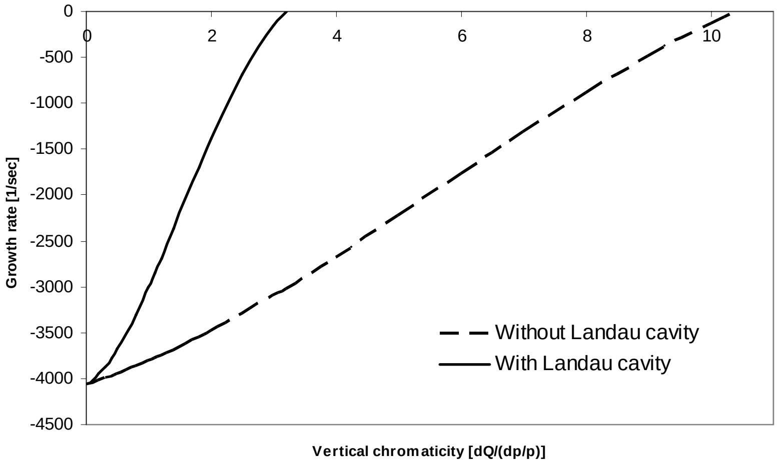


Vertical damping time =4.515 msec

100 MHz vs 100 MHz+5th harmonic cav.



500 MHz vs 500 MHz+3rd harmonic cav.



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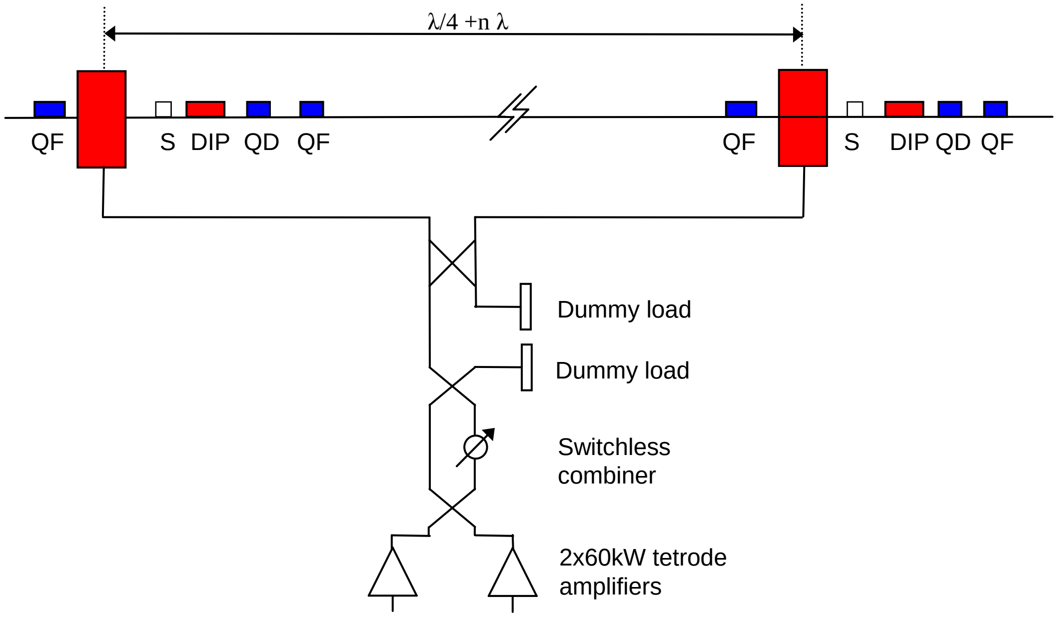
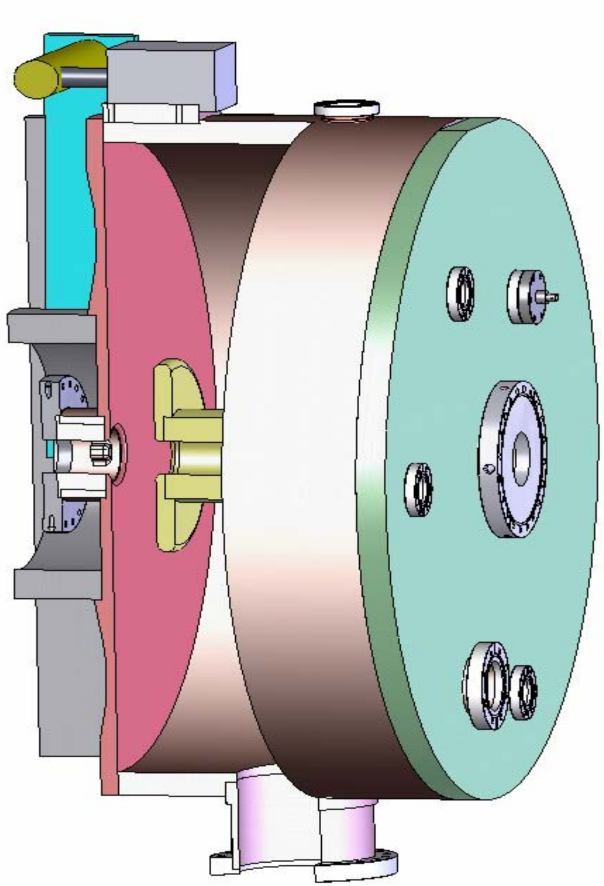
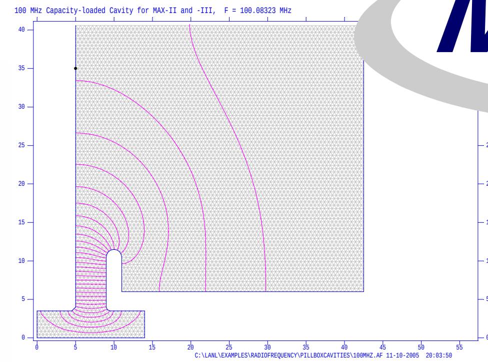
100 MHz RF system

- Five RF generator stations
- Each station consists of two cavities and two 60 kW tetrode amplifiers
- The RF power from the two amplifiers are combined in a switch-less hybrid combiner
- A 3db hybrid divides the power to the cavities

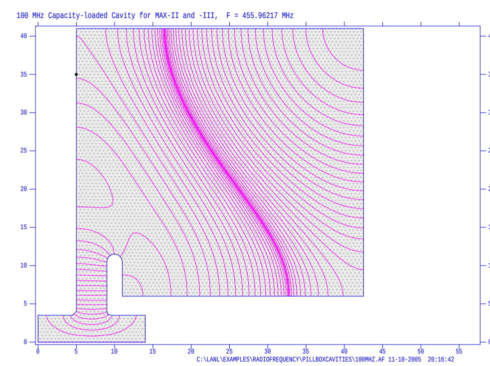


100 MHz cavity





100 MHz cavity profile with fundamental mode E-field lines



E-field lines of the high order mode at 456 MHz