CLIC-DR lattice optimized for low emittance and high SR power evacuation

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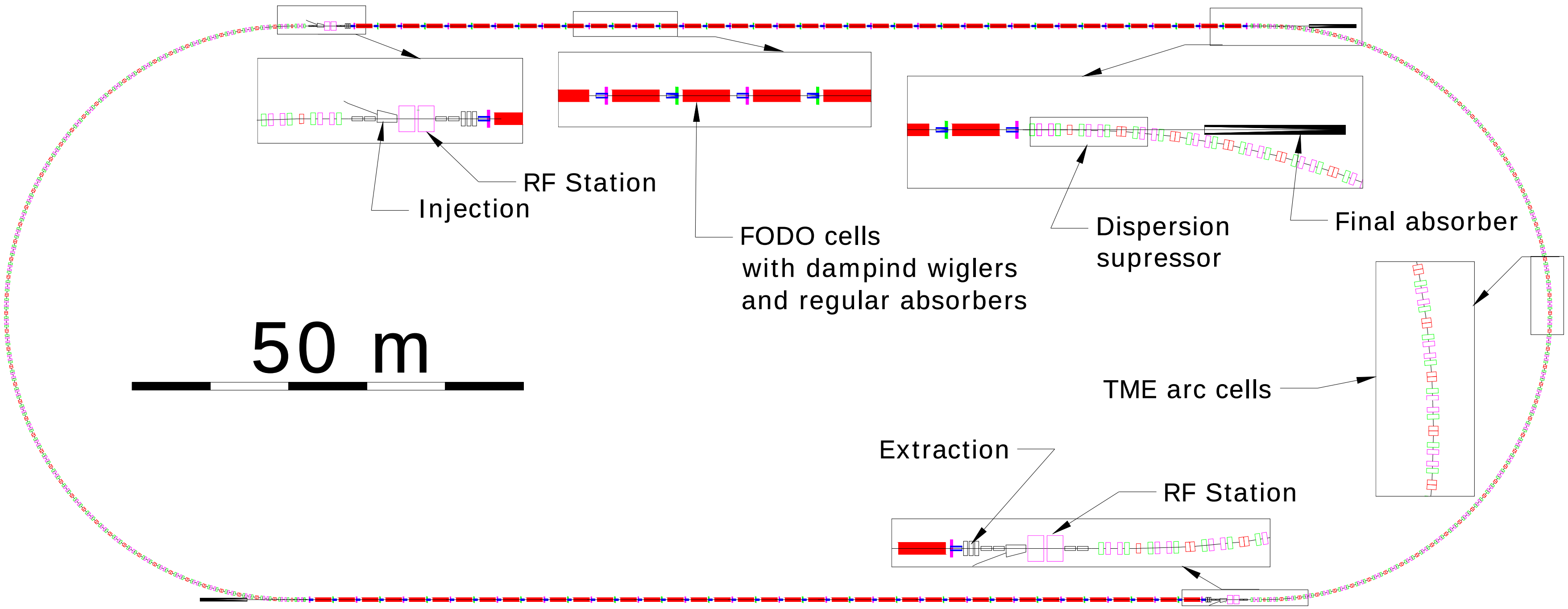
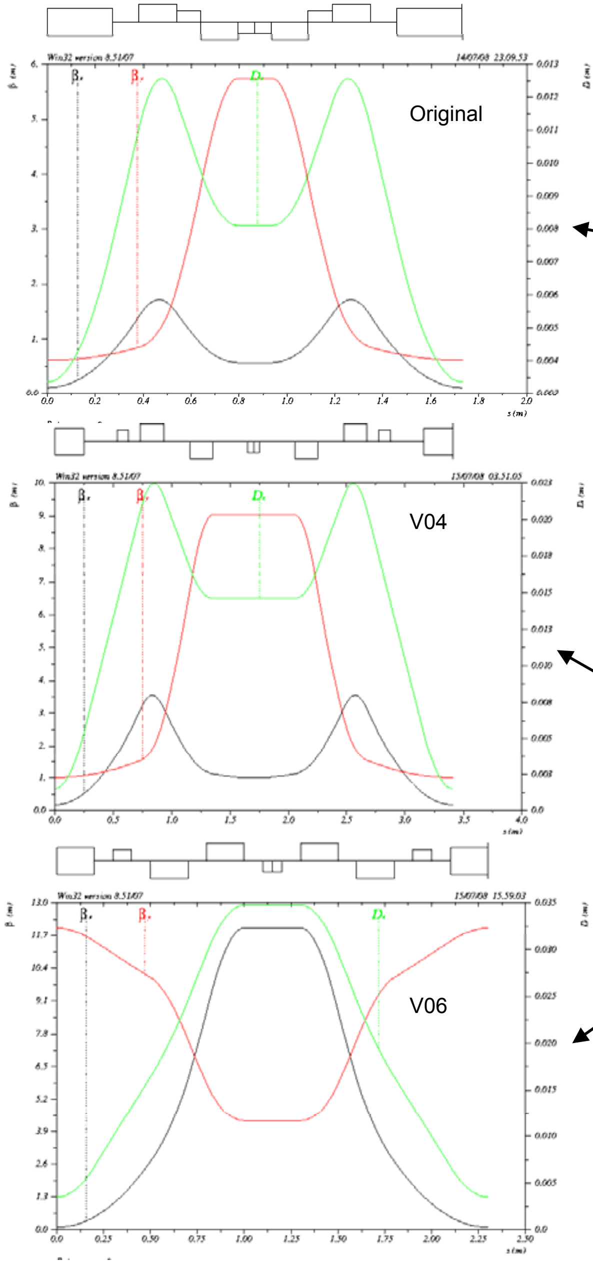
Aims of this work

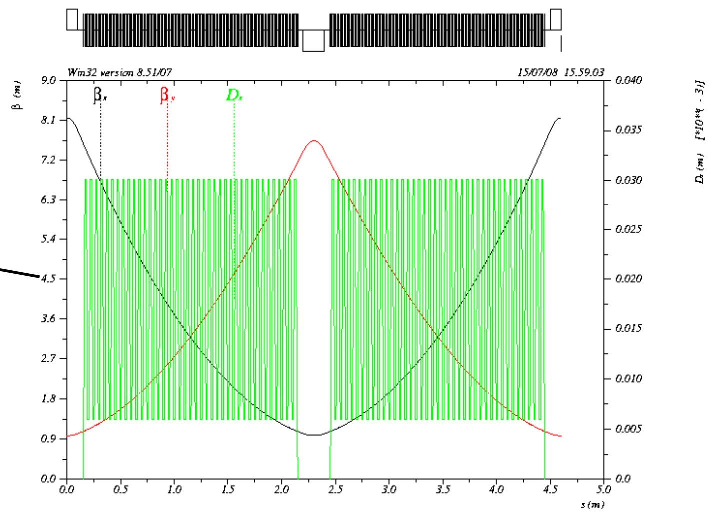
- Realistic design of a lattice for CLIC-DR
- Proposal for design of high gradient magnetic elements (hybrid quadrupoles and sextupoles)
- A Superconductive wigglers design and optimization
- Proposal for SR absorption scheme
- Optimizing SR absorption system for different types of superconductive wigglers

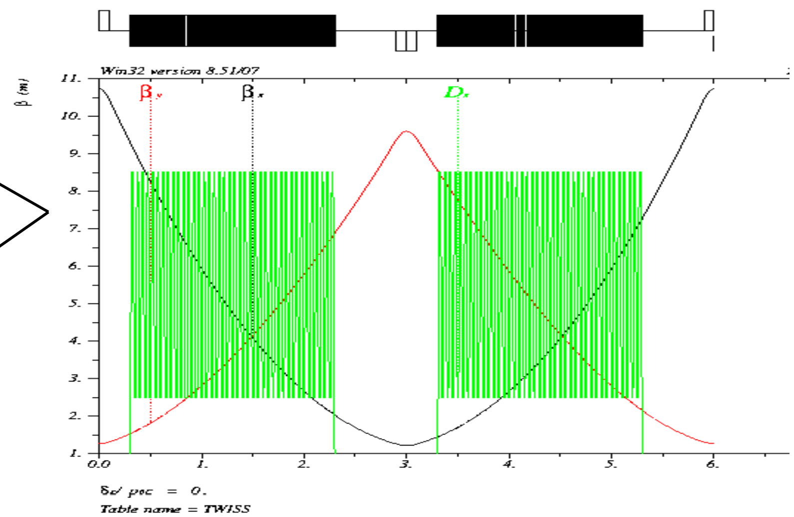
General view



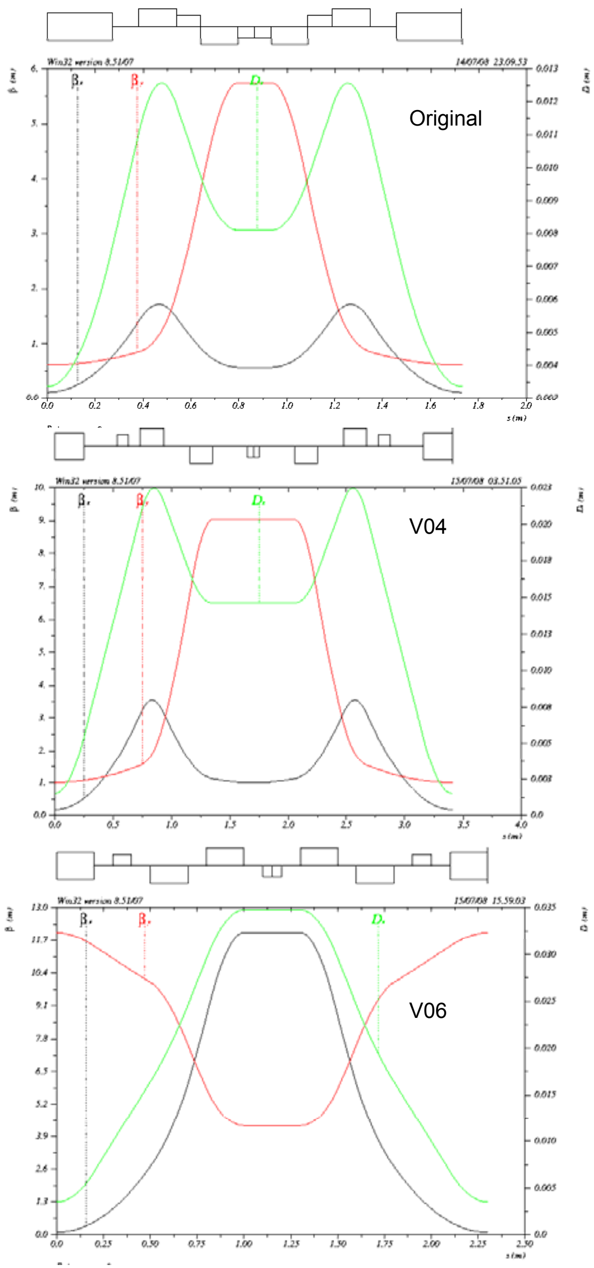
Arc and FODO cells structures





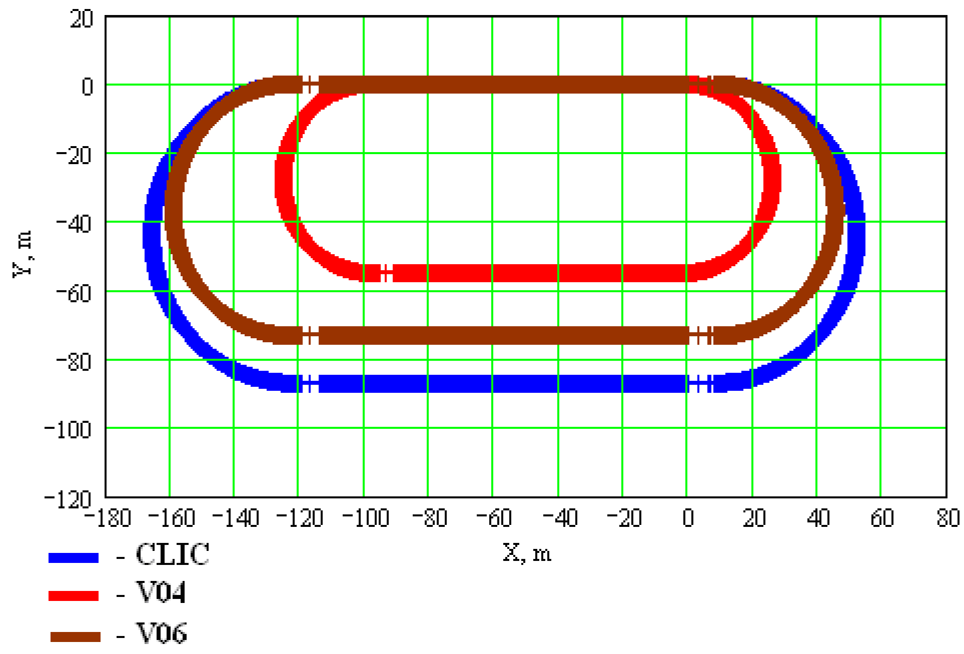


Arc cell structures

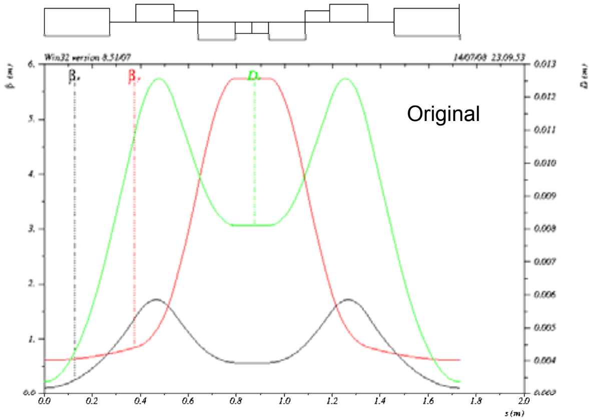


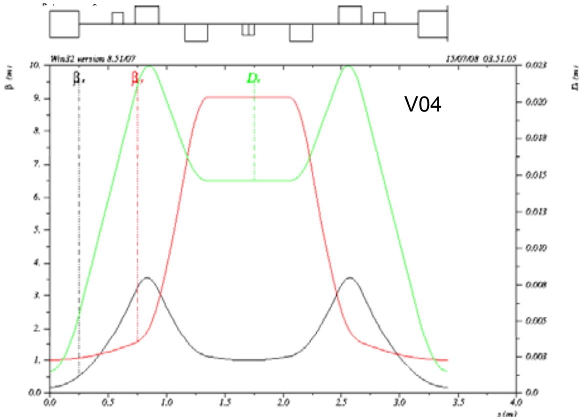
TME structures for CLIC-DR (Original and proposals)

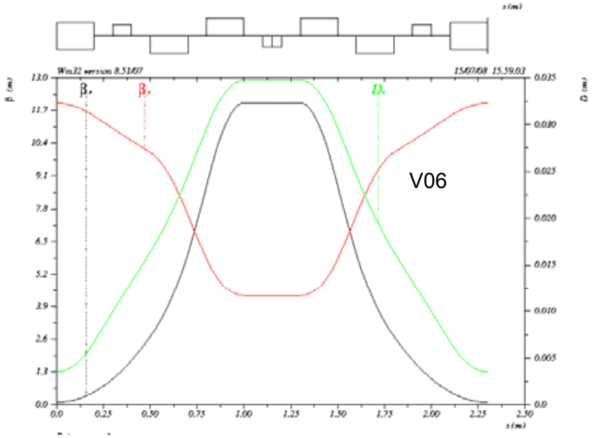
Structure version	Original	V04	V06
Energy E [GeV]	2.424		
Circumference P [m]	365.21	534	493.05
Emittance [nm*rad]	0.0182	0.0256	0.0312
Normalized Emittance [nm*rad]	86.3	121.44	148
Dynamic aperture a/σ_{inj} x / y	±3.5 / 6	±1.5 / 5	±12 / 50



Arc cell structures



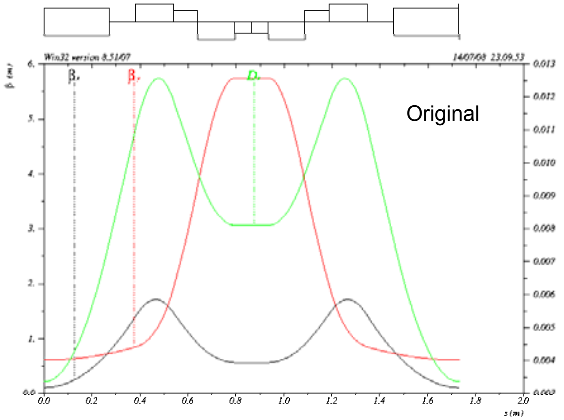


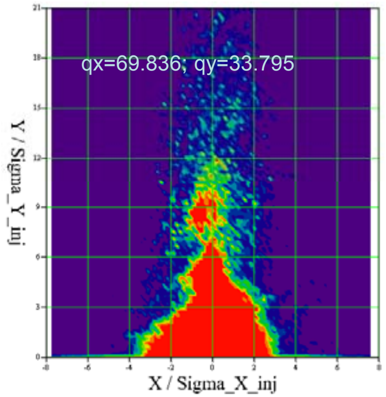


Arc cell parameters for CLIC-DR (Original and proposals)

Arc cell			
Structure version	Original	V04	V06
Bend field [T]	0.93	1.27	1.27
Bend gradient [1/m^2]	0	0	-1.10
Quad coefficient K1 [1/m^2]	27.21 / -16.17	13.33 / -8.24	7.47 / -4.27
Quad gradient [T/m]	220 / -131	107.7 / -66.6	60.3 / -34.5
Sextupole coefficient K2 [1/m^3]	7700 / -9839	2985 / -2058	780 / -815
Sextupole strength [T/m^2]*10^3	62 / -80	24.1 / -16.6	6.30 / -6.59
IBS			
Bunch current I, mA	0.539	0.3681	0.399
Bunch population, N*10^9	4.1	4.1	4.1
Emittance [nm*rad] / IBS gain factor	0.0946 / 5.1831	0.0926 / 3.62	0.090 / 2.89
Normalized Emittance [nm*rad] ***	449	439.26	428.4
Energy spread / IBS gain factor	1.571 / 1.402	1.620 / 1.45	1.551 / 1.38
Bunch length [mm]	1.402	1.450	1.380
Longitudinal beam emittance [eV m]	5339	5694	5188

Arc cell structures

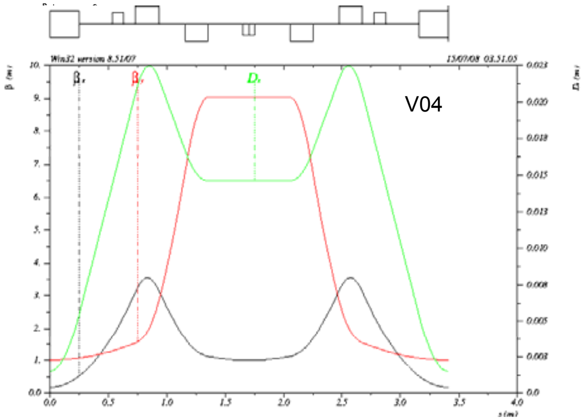


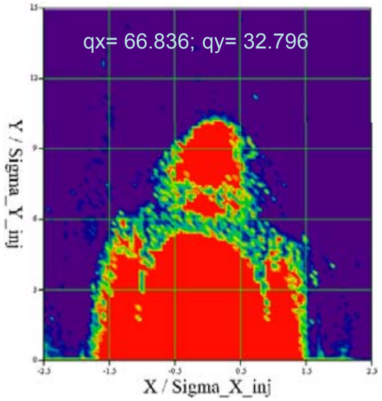


Summary

Compact and effective

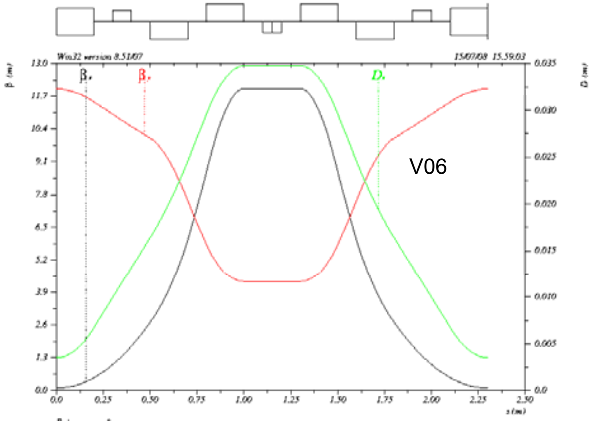
Extremely high lenses, non realistic design for conventional lens technology

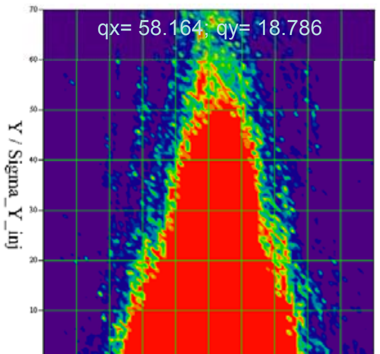




Realization

Big circumference

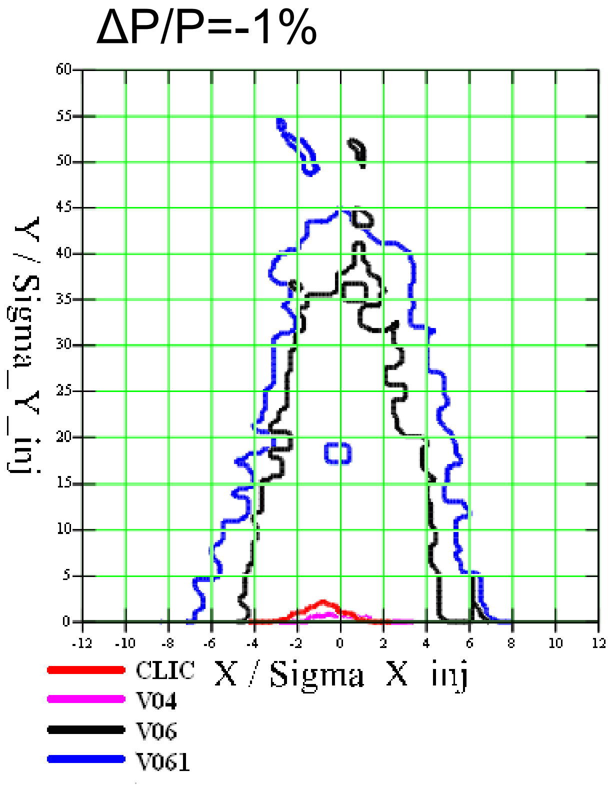


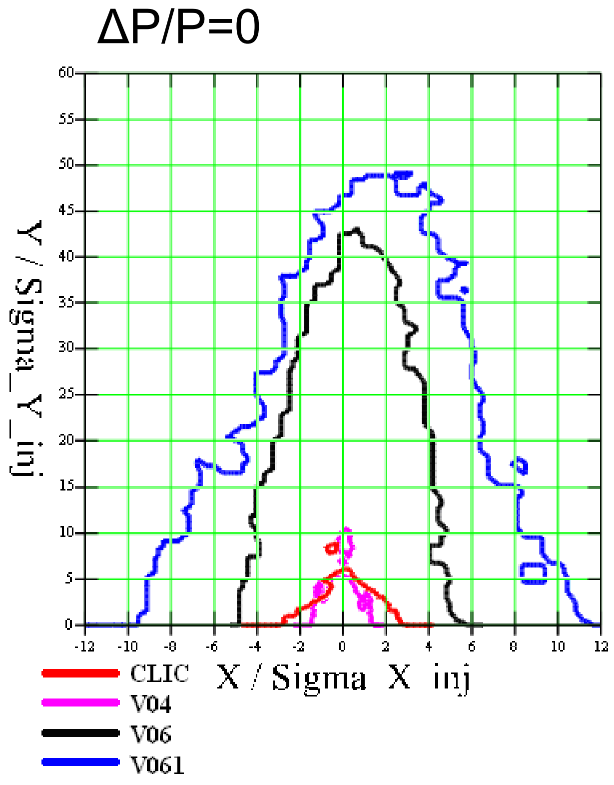


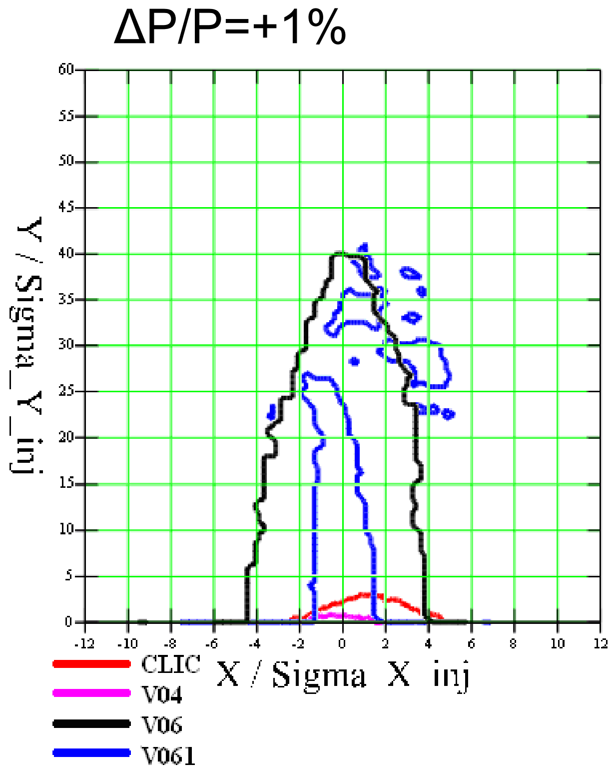
Small lenses gradient, big dynamic aperture

Gradient in bend dipoles, orbit correction dificulties

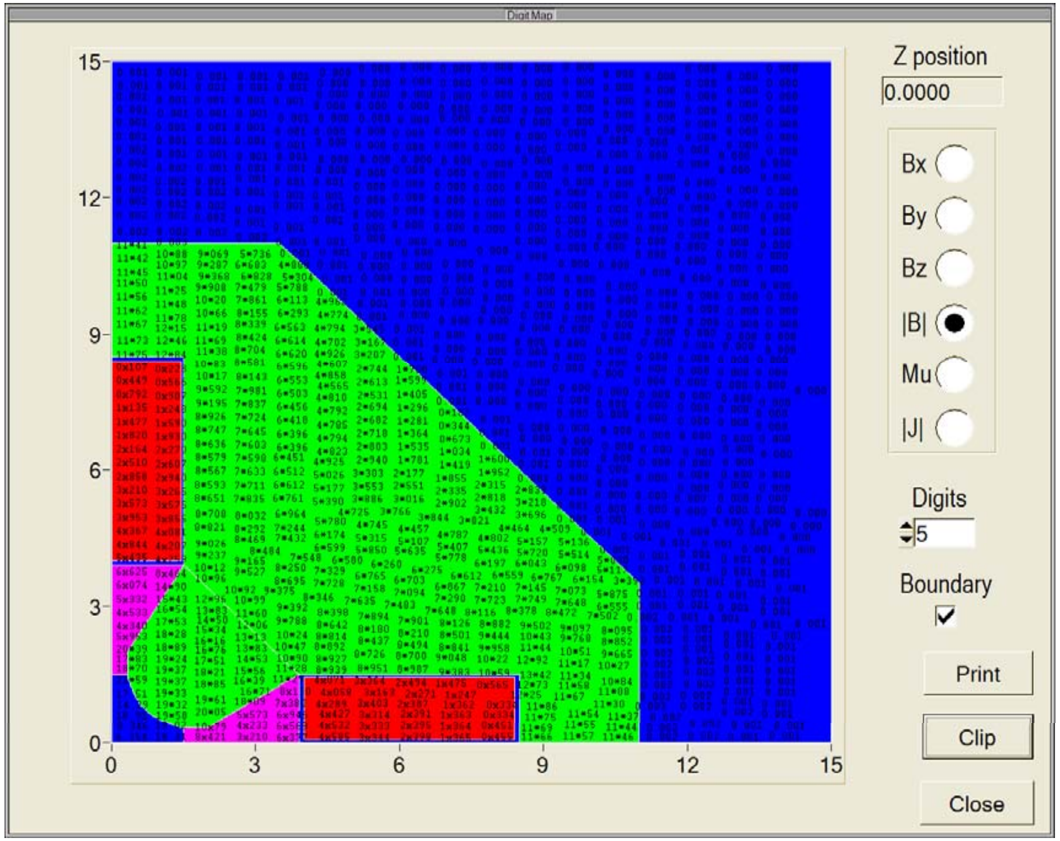
DA comparisson

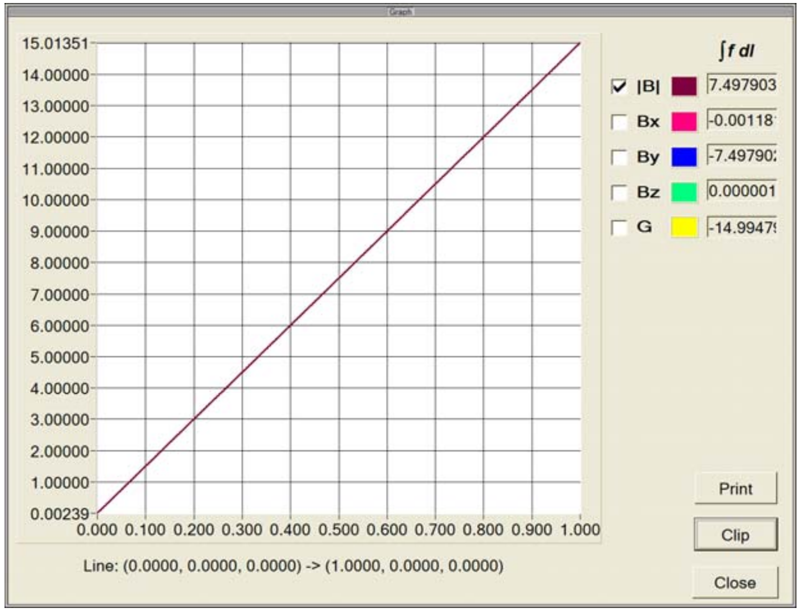


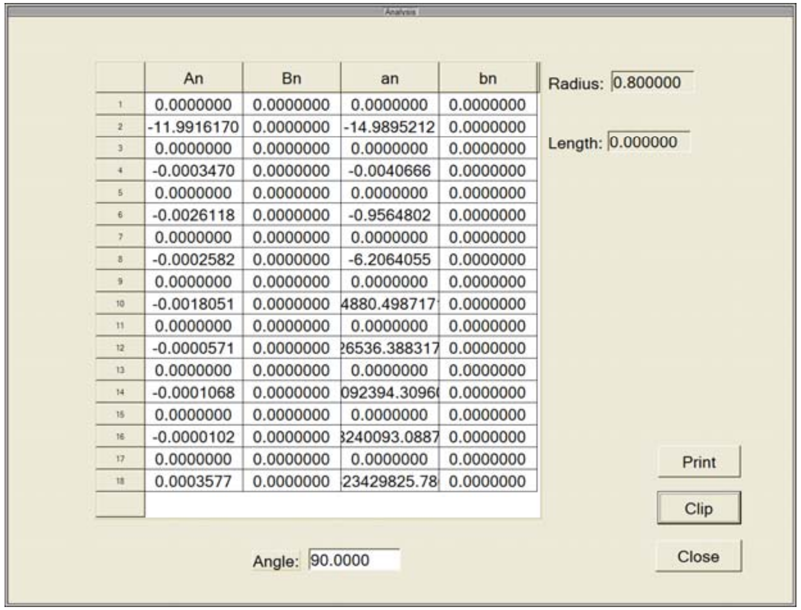




Hybrid quadrupole (g = 150T/m, r = 10 mm)





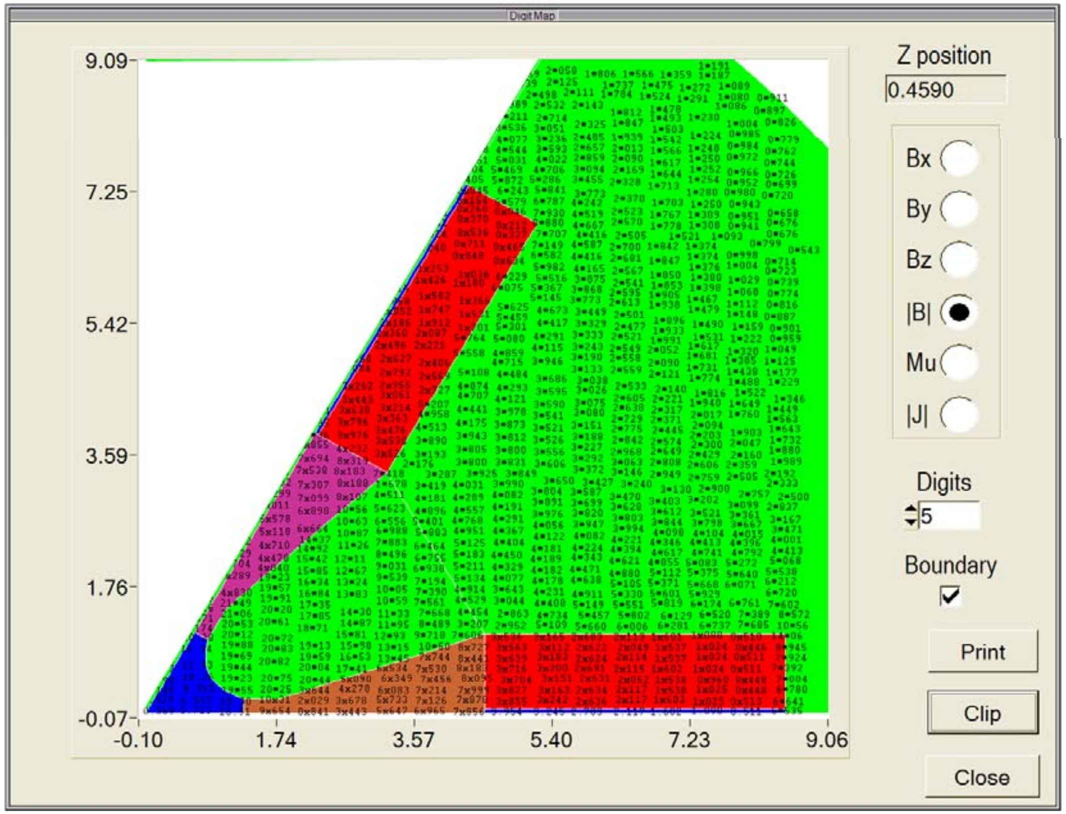


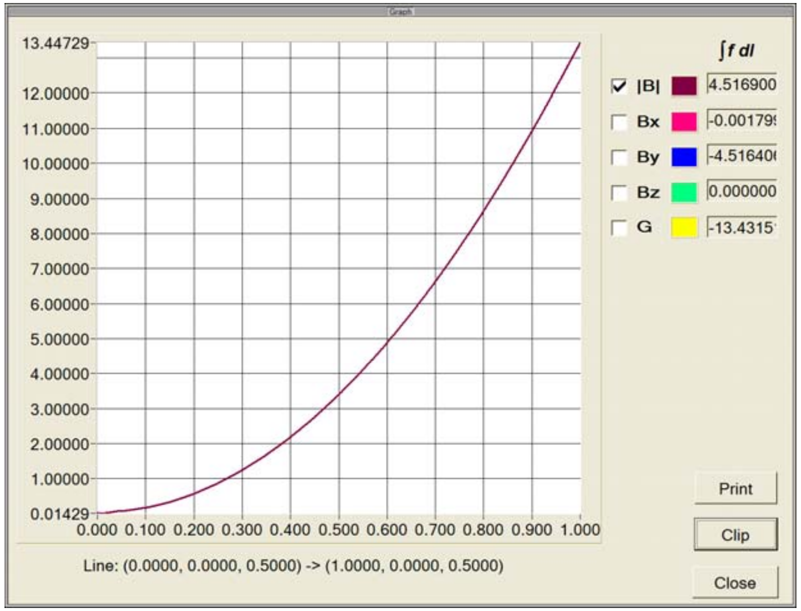
	An	Bn	an	bn
1	0.0000000	0.0000000	0.0000000	0.0000000
2	-11.9916170	0.0000000	-14.9895212	0.0000000
3	0.0000000	0.0000000	0.0000000	0.0000000
4	-0.0003470	0.0000000	-0.0040666	0.0000000
5	0.0000000	0.0000000	0.0000000	0.0000000
6	-0.0026118	0.0000000	-0.9564802	0.0000000
7	0.0000000	0.0000000	0.0000000	0.0000000
8	-0.0002582	0.0000000	-6.2064055	0.0000000
9	0.0000000	0.0000000	0.0000000	0.0000000
10	-0.0018051	0.0000000	4880.498717	0.0000000
11	0.0000000	0.0000000	0.0000000	0.0000000
12	-0.0000571	0.0000000	26536.388317	0.0000000
13	0.0000000	0.0000000	0.0000000	0.0000000
14	-0.0001068	0.0000000	092394.30960	0.0000000
15	0.0000000	0.0000000	0.0000000	0.0000000
16	-0.0000102	0.0000000	3240093.0887	0.0000000
17	0.0000000	0.0000000	0.0000000	0.0000000
18	0.0003577	0.0000000	23429825.78	0.0000000

BINP Mermaid
Magnetic code

Units at the plots – kG and cm

Hybrid sextupole (s = 26·10³ T/m², r = 10 mm)





Analysis

	An	Bn	an	bn
1	0.0000000	0.0000000	0.0000000	0.0000000
2	0.0000000	0.0000000	0.0000000	0.0000000
3	-8.6129885	0.0000000	-26.9155891	0.0000000
4	0.0000000	0.0000000	0.0000000	0.0000000
5	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000
7	0.0000000	0.0000000	0.0000000	0.0000000
8	0.0000000	0.0000000	0.0000000	0.0000000
9	-0.0017251	0.0000000	-414.5816660	0.0000000
10	0.0000000	0.0000000	0.0000000	0.0000000
11	0.0000000	0.0000000	0.0000000	0.0000000
12	0.0000000	0.0000000	0.0000000	0.0000000
13	0.0000000	0.0000000	0.0000000	0.0000000
14	0.0000000	0.0000000	0.0000000	0.0000000
15	0.0010614	0.0000000	3927683.3422	0.0000000
16	0.0000000	0.0000000	0.0000000	0.0000000
17	0.0000000	0.0000000	0.0000000	0.0000000
18	0.0000000	0.0000000	0.0000000	0.0000000

Radius: 0.800000

Length: 0.000000

Angle: 30.0000

Print

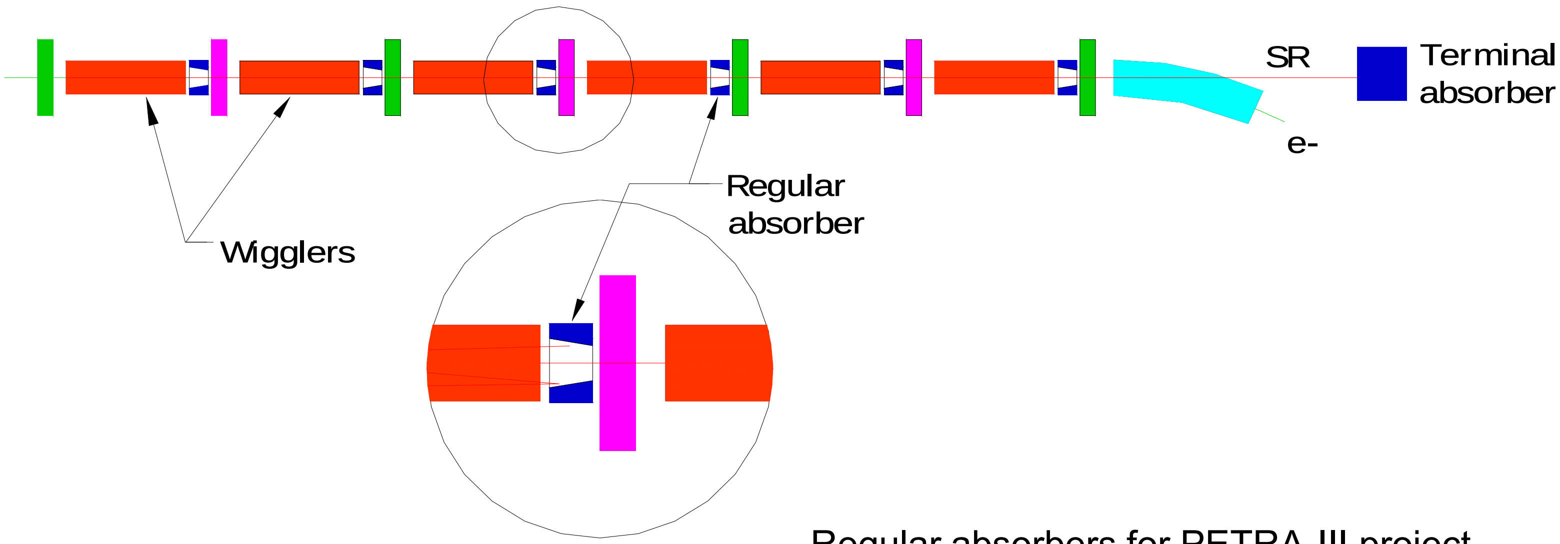
Clip

Close

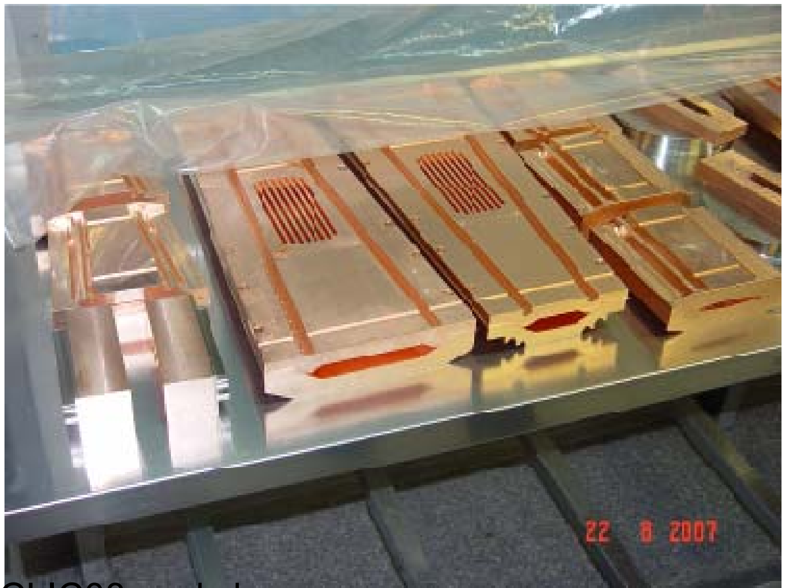
BINP Mermaid
Magnetic code

Units at the plots – kG and cm

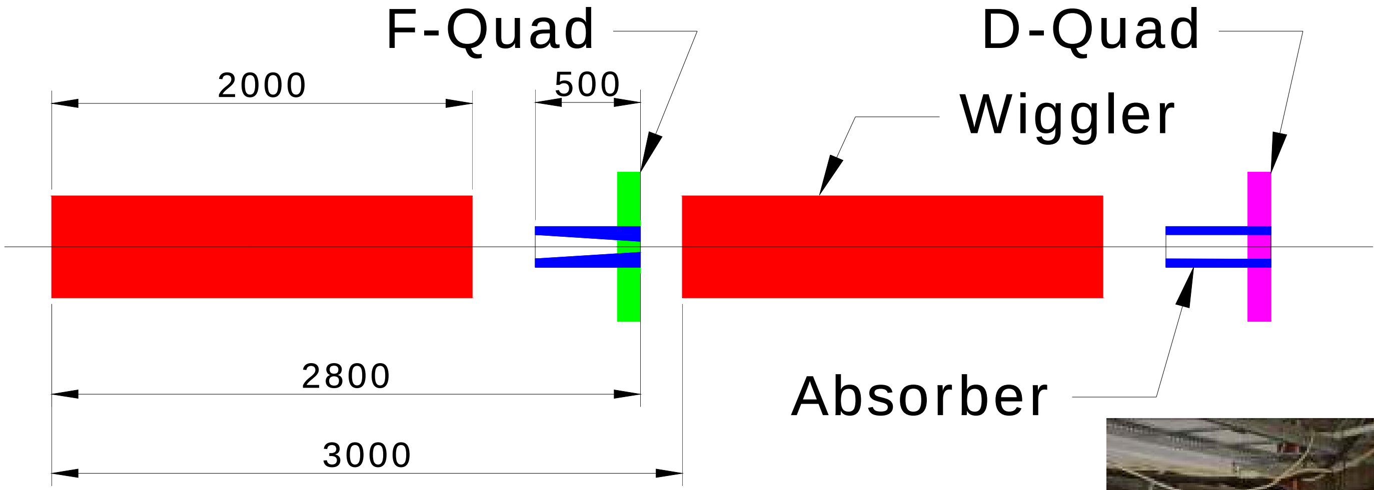
SR power evacuation strategy



Regular absorbers for PETRA-III project



Wiggler sections structure



Regular absorber (26 kW)

Wiggler

PETRA-III (regular absorber)

Code for calculation of SR power loads for SR absorbers

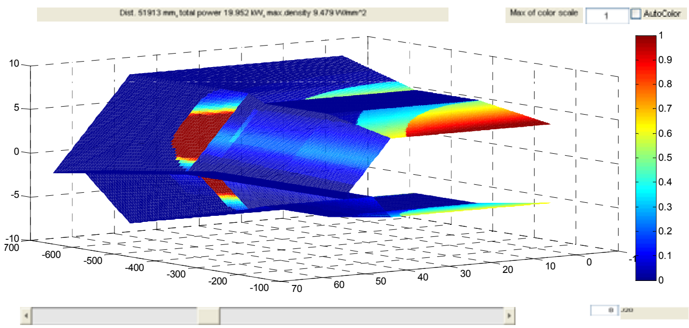
$$\frac{dP}{d\Omega} = \frac{d^2P}{d\theta\, d\psi} = P_T \frac{21\gamma^2}{16\pi K} G(K)\, f_K(\gamma\theta, \gamma\psi)$$

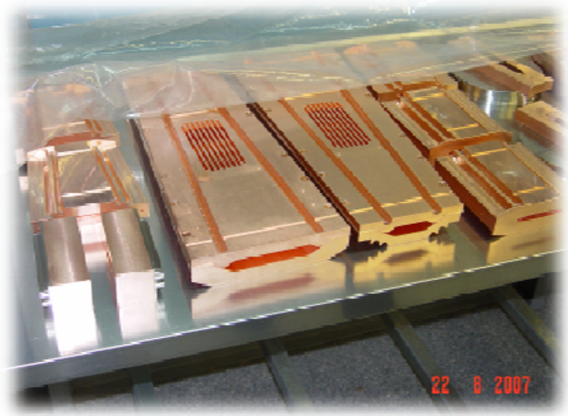
$$P_T[\mathrm{kW}] = 0.633 \cdot E_e^2[\mathrm{GeV}] \cdot B^2[\mathrm{T}] \cdot L[\mathrm{m}] \cdot I[\mathrm{A}]$$

$$f_K(\gamma\theta, \gamma\psi) = \sqrt{1 - \left(\gamma\theta / K\right)^2} \left\{ \frac{1}{\left(1 + (\gamma\psi)^2\right)^{5/2}} + \frac{5(\gamma\psi)^2}{7\left(1 + (\gamma\psi)^2\right)^{7/2}} \right\}$$

$$G(K) = K \frac{K^6 + \frac{24}{7}K^4 + 4K^2 + \frac{16}{7}}{\left(1 + K^2\right)^{7/2}}$$

K.-J. Kim, Nucl. Instr. And Meth A246(1986)





For design and optimization of Petra-III damping section a special codes were developed for SR power load simulations. The codes performs a following actions:

- Ray tracing technique for accounting of absorber shadows
- Parametric optimization of absorber shape
- COD accounting
- 3D modeling of complicated absorber shape

Superconductive wiggler design

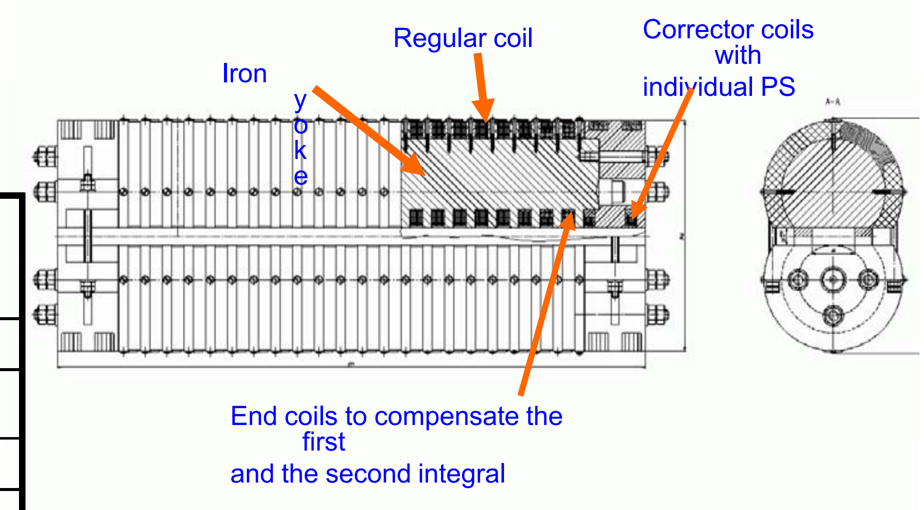
CLIC-DR beam parameters

Parameter	Symbol	CLIC-DR
Electron energy	E_e	2.424 GeV
Current of beam (maximal)	I	170 mA

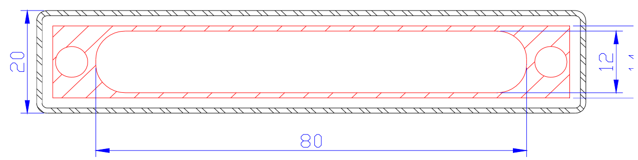
CLIC-DR wiggler parameters

Parameter	Symbol	BINP wiggler (Pavel Vobly)	CERN wiggler (Remo Maccaferry)
Coils material		NbTi	Nb_3Sn
Maximal magnetic field, T	B	2.5	2.8
Period of wiggler, cm	λ_u	5	4
Magnetic gap of wiggler, mm	G_m	20*	24*
Number of periods	N	40	50
SR critical energy, keV	ε_c	9.62	10.8
Deflection parameter	K	11.7	10.5
SR power, kW	P_T	7.90	9.91
VC temperature, K		60 (LN)	4.2 (LHe)
Critical longitudinal power density over VC, W/m		10	1
VC vertical aperture, mm	G_{VC}	12	16
Length of wiggler, m	L	2	2

General view for BINP wiggler prototype



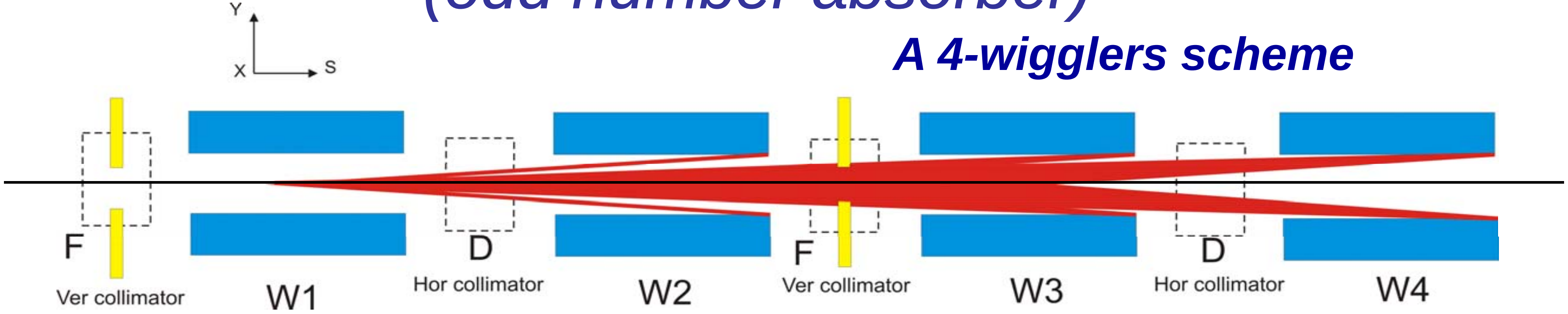
Internal Cu liner with LN temperature protects LHe elements from SR

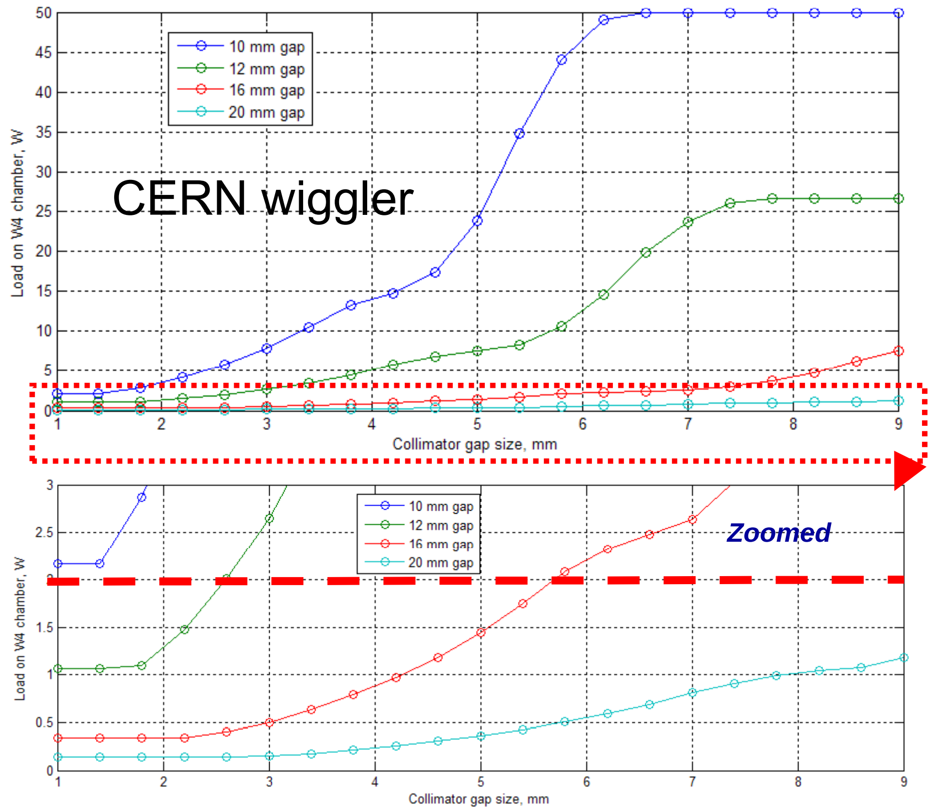


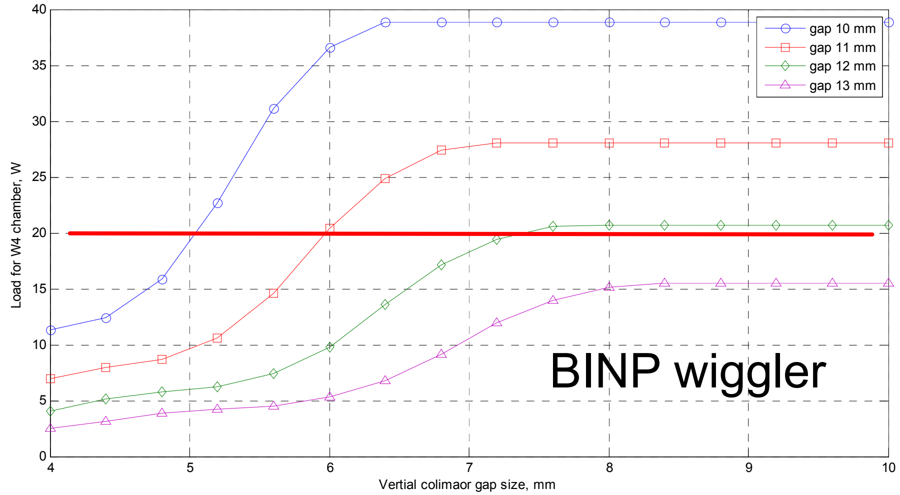
A cryogenic cooler SUMITOMO SRDK 408S2 permits evacuate up to 50 W power from 60 K liner.

Choice for wiggler gap and vertical collimator size (odd number absorber)

A 4-wigglers scheme

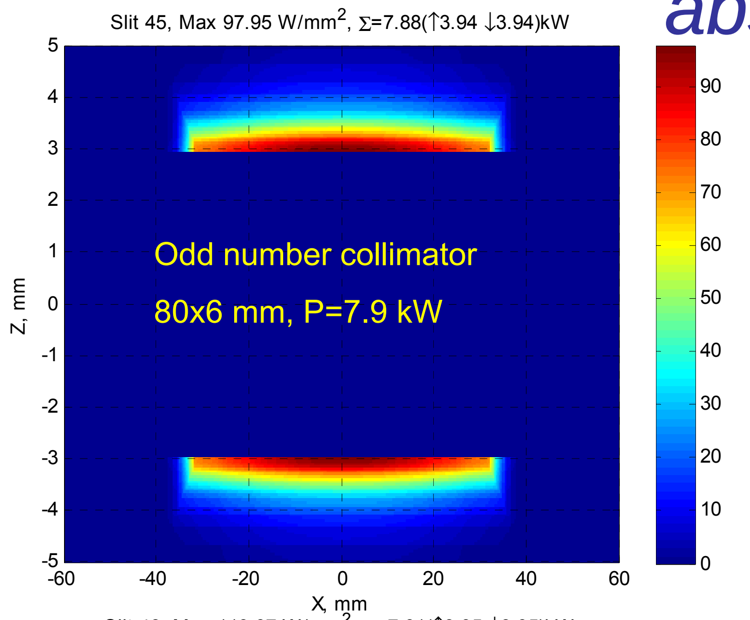


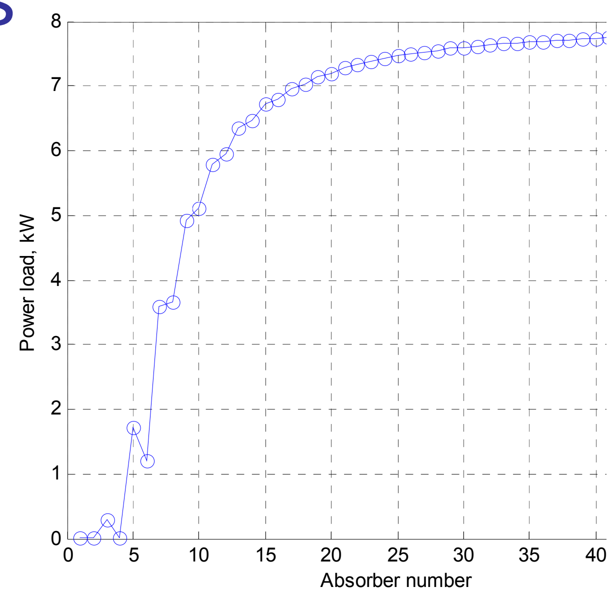


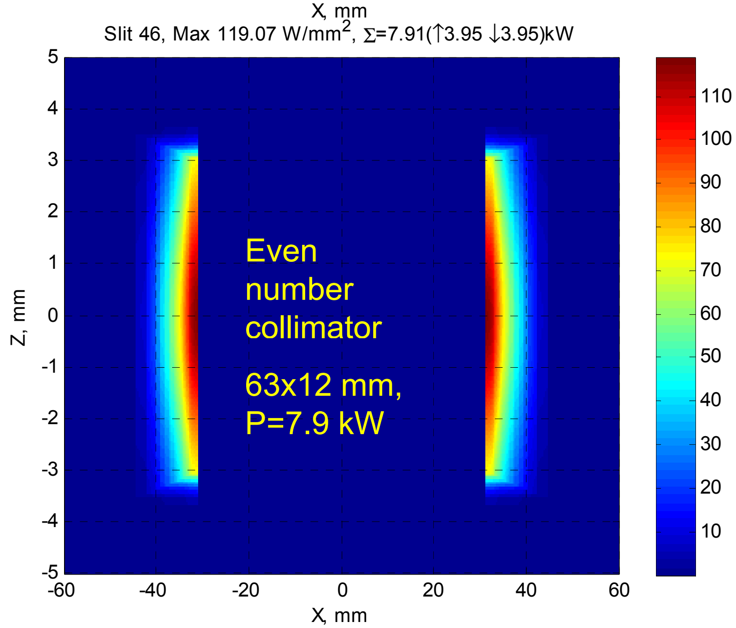


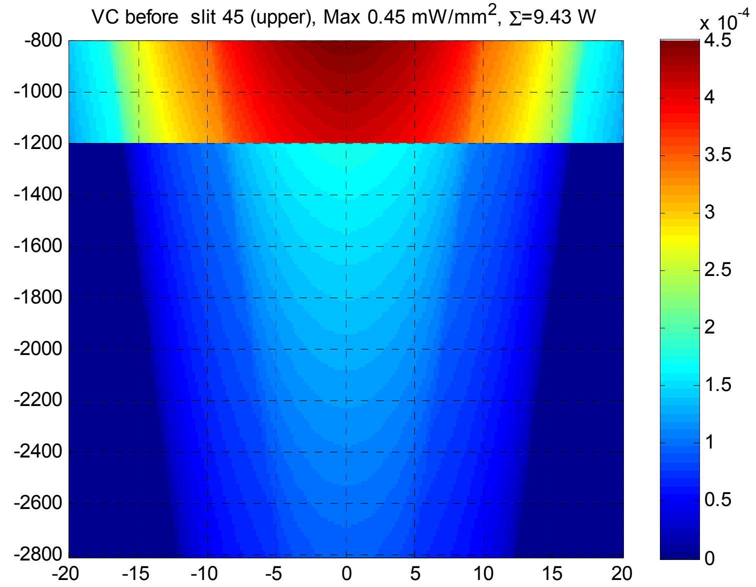
Choice for horizontal aperture for even number absorbers

BINP wiggler version

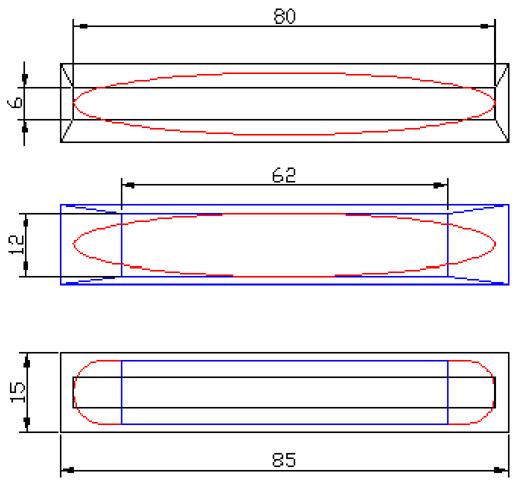


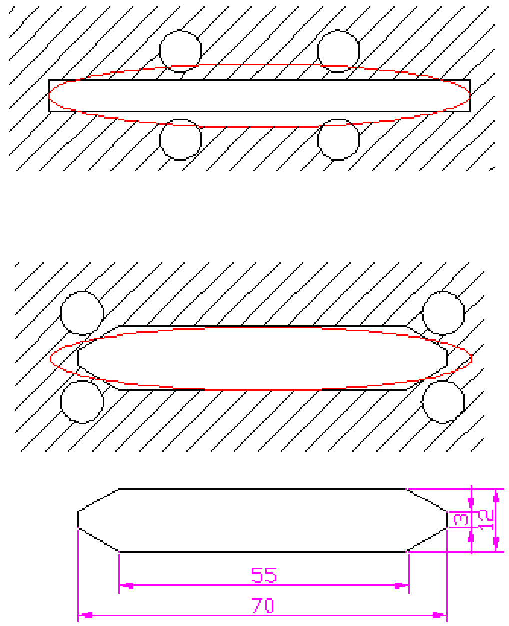




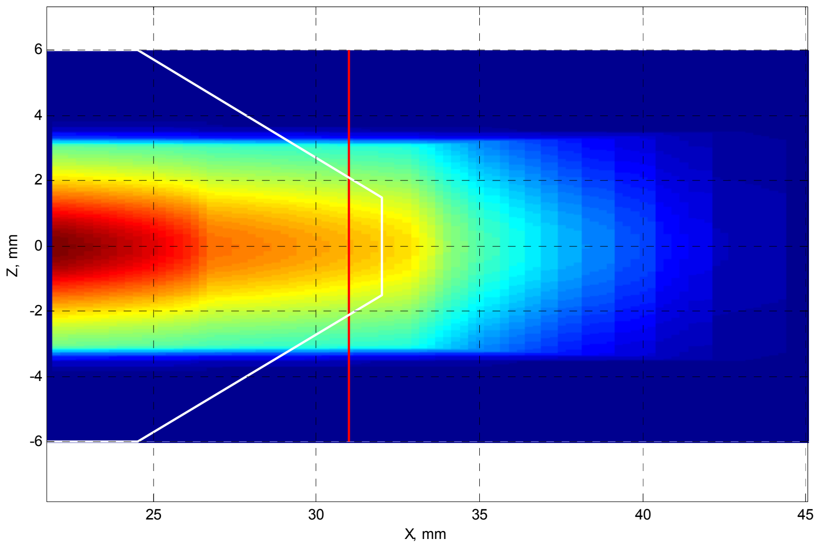


Even number wiggler VC load distribution, P=9.4 W

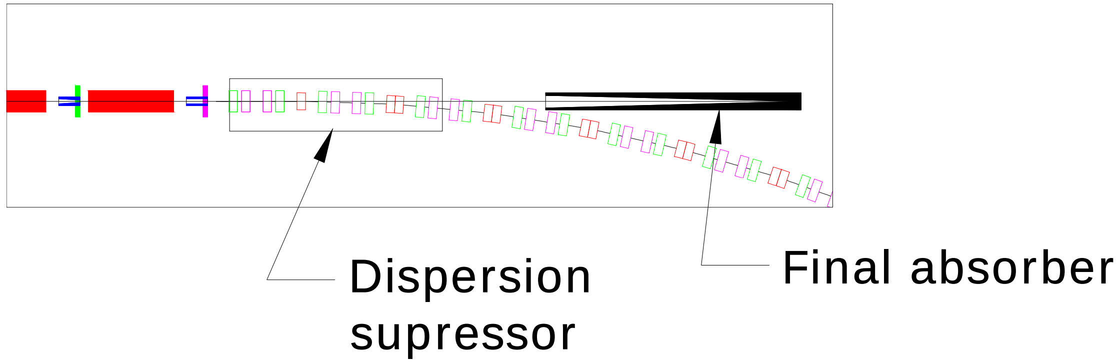


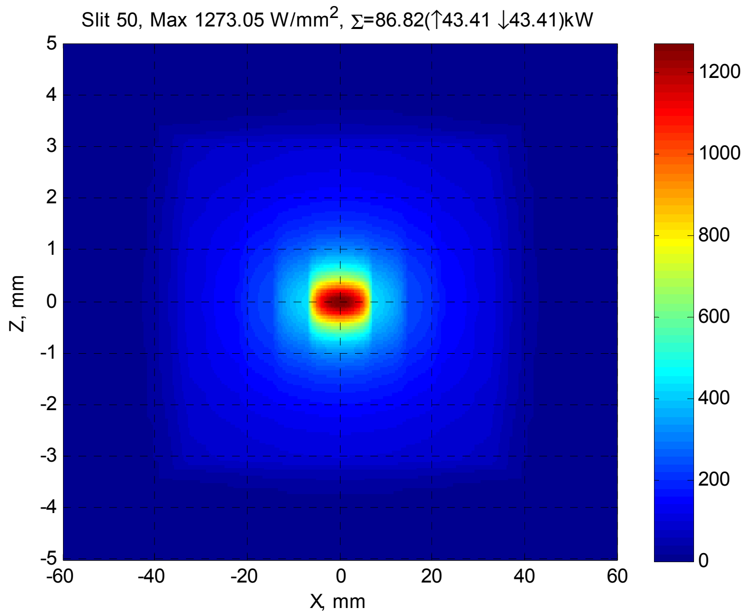


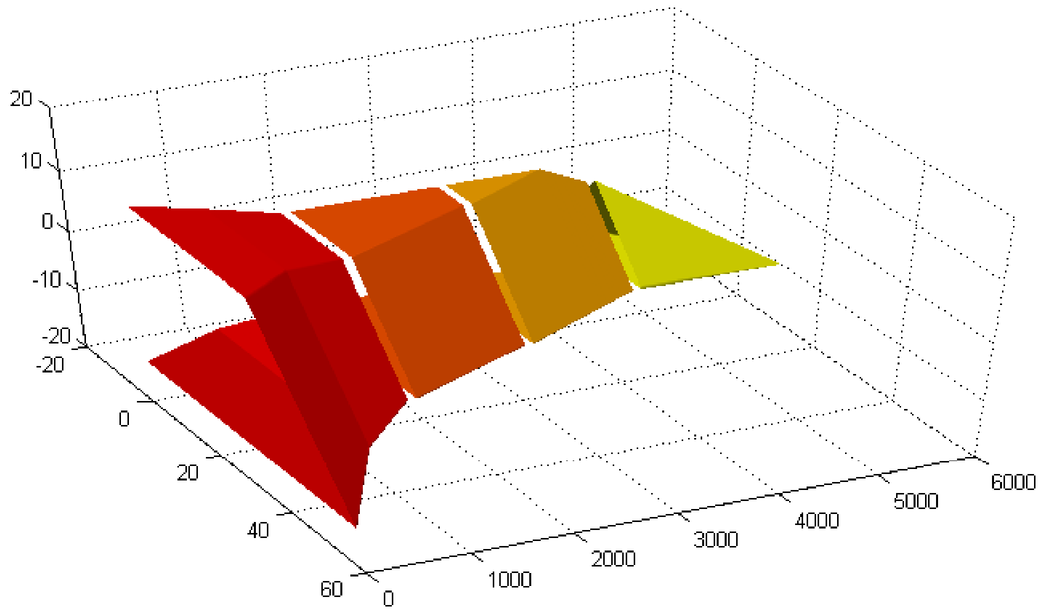
Slit 36, Max 166.47 W/mm^2, Σ=20.59(↑10.30 ↓10.30)kW



Final absorber







6 m length final absorber can absorb up to 170 kW of SR power

Conclusions

- Two ways for modification of basic CLIC Damping Ring lattice structure were proposed
- The V06 lattice version in spite of gradient dipole disadvantage has many positive moments including large dynamic aperture and low gradients in quadrupole and sextupole lenses
- In frame of this work the ideas for high gradient hybrid quadrupole and sextupole lenses were proposed, first calculations promise a good field quality
- The scheme for SR power absorption and evacuation was proposed for FODO damping section, quantitative estimations for SR absorbers were performed for few versions of wiggler designs (BINP, CERN, ANKA)
- Proposed absorbers scheme should be carefully analyzed for estimation contribution of straight section in total DR impedance budget and for e-cloud production issue (in collaboration with Maxim Korostylev and Warner Bruns)

Thank you for attention