SCALING LAWS AND FIELD QUALITY

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Task definition

(1) Scaling laws depend on the wiggler type (permanent magnet, superconducting, electromagnet, etc.), design, etc.

(2) We restricted our self with the permanent magnet damping wiggler for the CLIC damping ring and study the following parameters of the device:

- Field amplitude
- Transverse field distribution
- Longitudinal field distribution

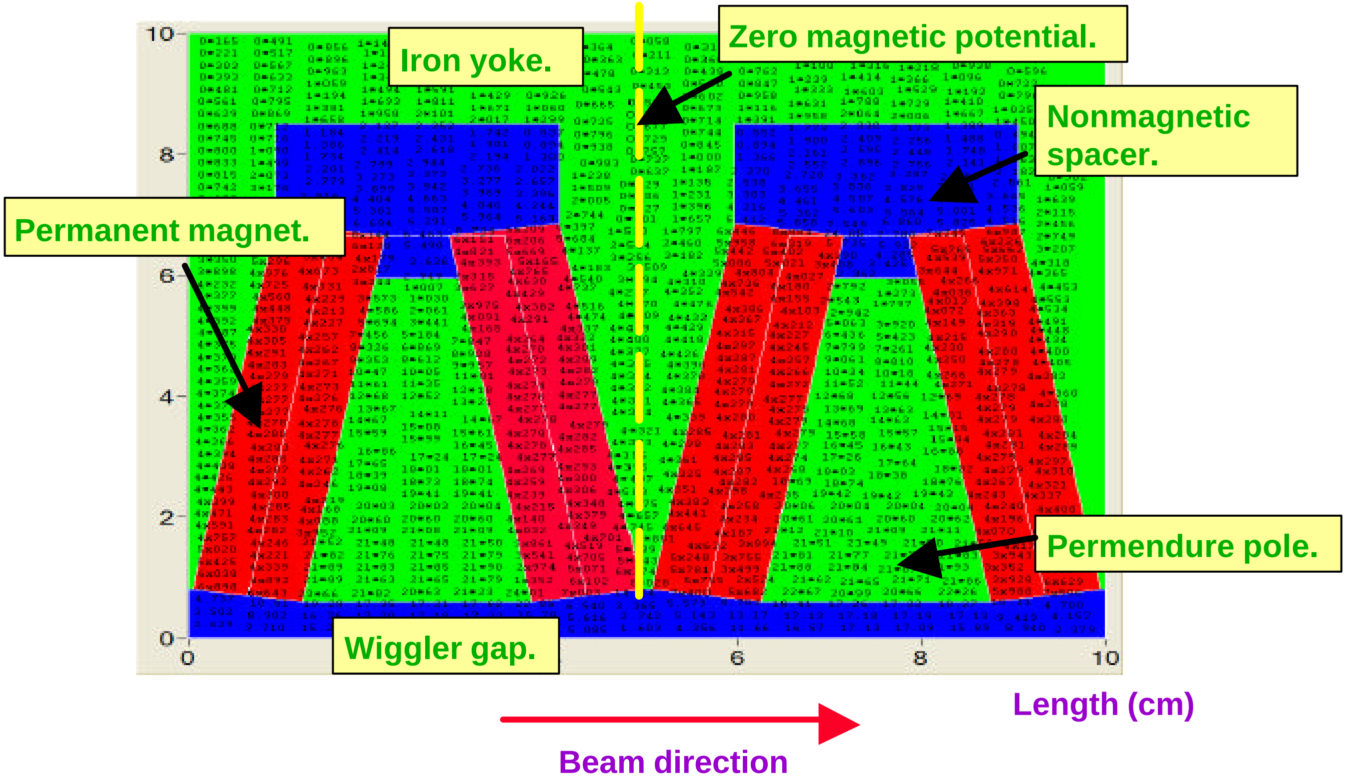
as a function of wiggler's

- Gap
- Period length
- Pole (magnet) width

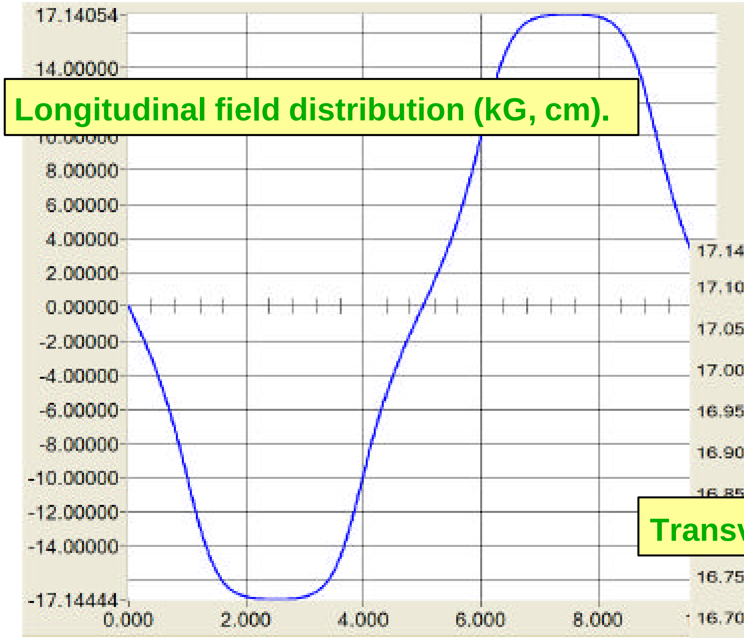
CLIC damping wiggler parameters

Period:	10 cm	12 cm	14 cm
Gap:	12 mm	14 mm	16 mm
Pole width:	50 mm	60 mm	60 mm
Length:	2 m		
Field amplitude:	1.7 T	1.8 T	1.69 T
Field quality @ ±1 cm:	10^{-3}		
Total length:	160 m		
Total radiation power:	1.7 MV at 1 A current		

CLIC damping wiggler configuration

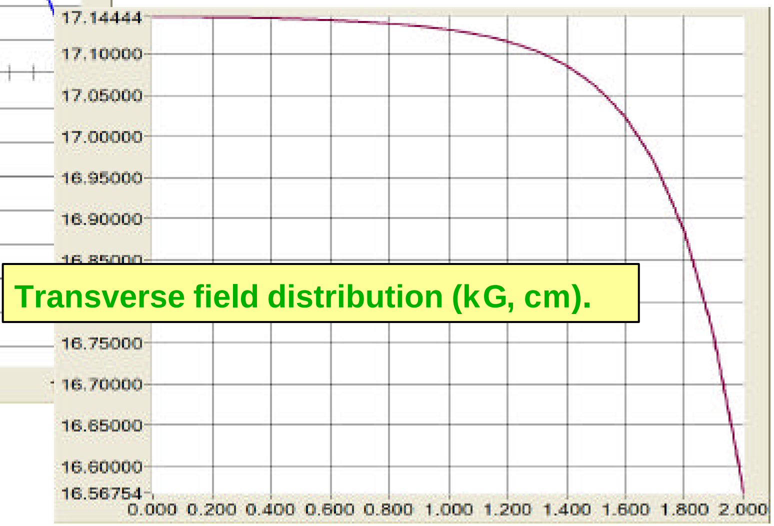


CLIC damping wiggler field distribution

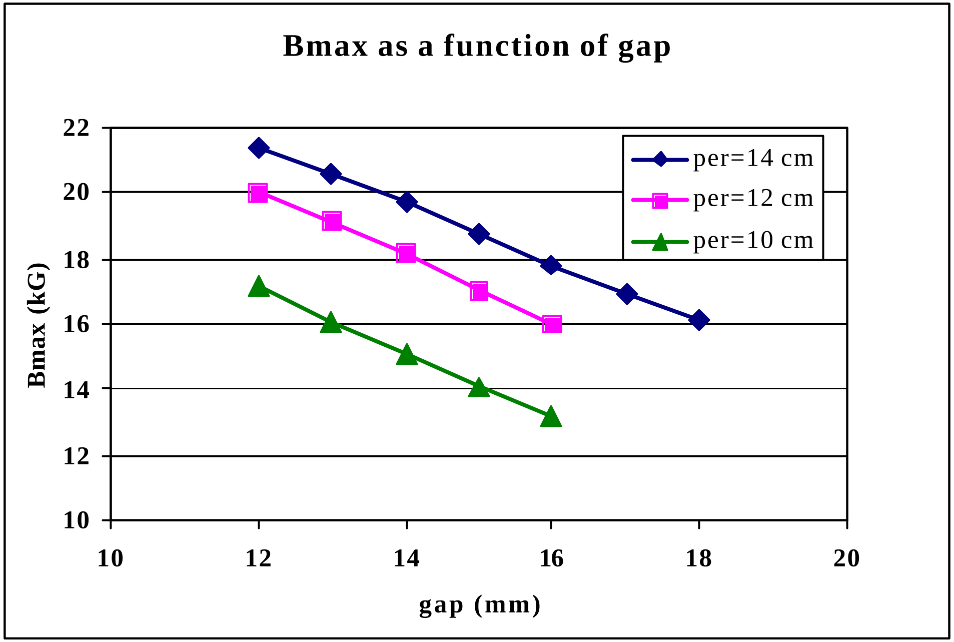


Bmax = 17.1 kG

$\Delta B/B < 5\times10^{-3}$ at 1 cm.



Peak field amplitude vs. pole gap

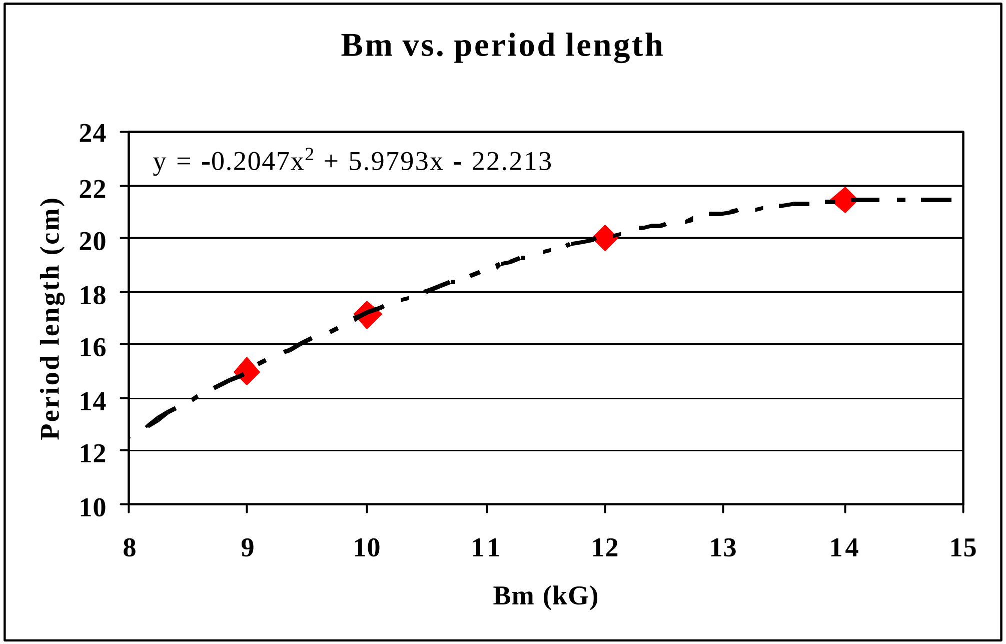


$$B_{max} \propto \exp\left(-\frac{p \cdot g}{l_w}\right)$$

- for barely permanent magnet devices (M.N.Smolyakov, PRST Vol.4, 040701 (2001))

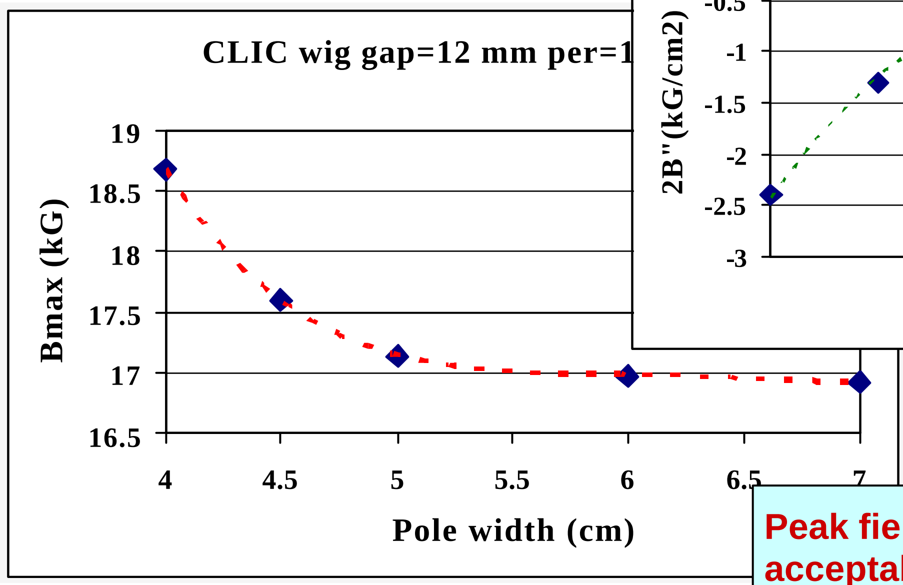
Peak field is linear for reasonably small change of pole gap.

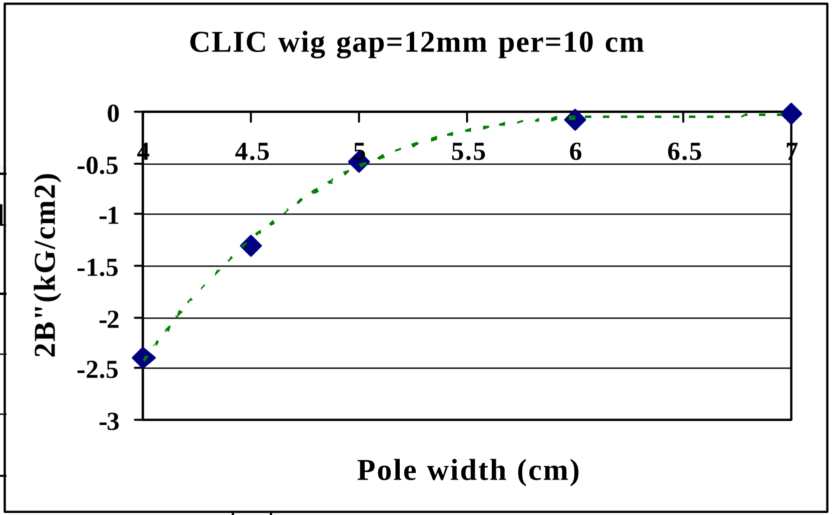
Peak field amplitude vs. period length



Peak field tends to be saturated with increasing of the period length.

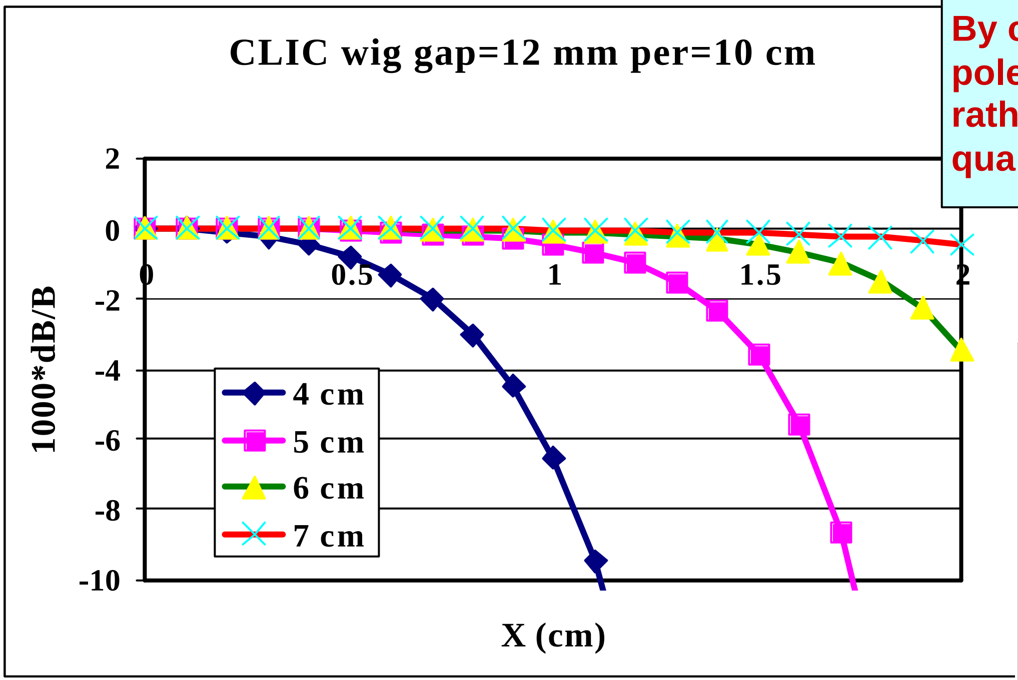
Peak field amplitude vs. pole width





Peak field has to be compromised with acceptable transverse field quality.

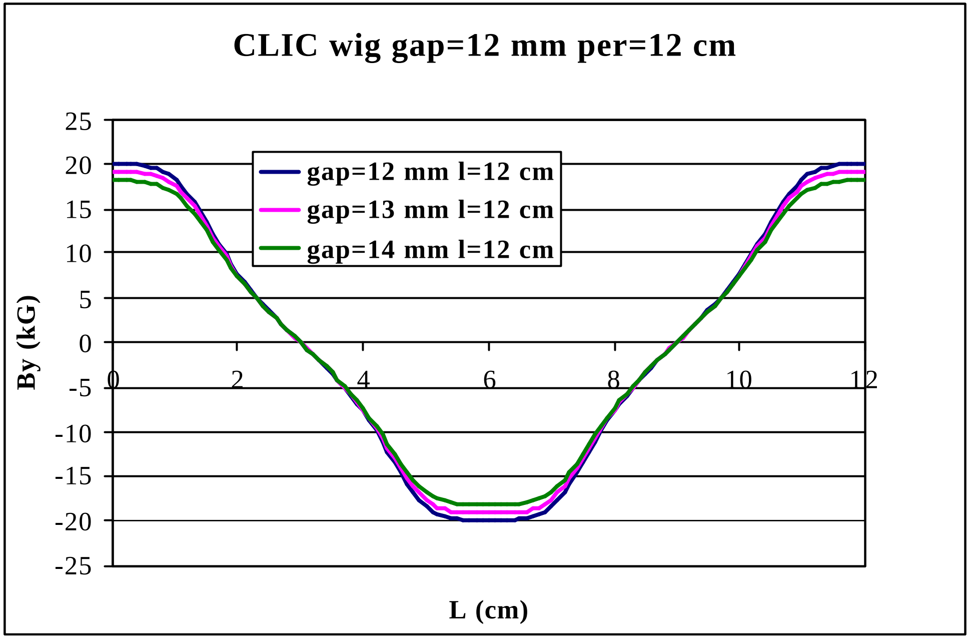
Field quality vs. pole width



By choosing of the proper pole size and shimming rather good transverse field quality can be achieved.

Pole Width (cm)	1000´DB/B	
	@ 1 cm	@ 2 cm
4	-6.53	-
5	-0.45	-32
6	-0.09	-3.5
7	-0.05	-0.5

Longitudinal distribution of magnetic field



Relative harmonics content

A_1	100%
A_3	7%
A_5	5%
A_7	2%
A_9	0.4%

Damping integral is proportional to the quadratic sum of longitudinal field harmonics

$$i_2 \propto \sum_k B_k^2$$

Wiggler field quality

Pole width and shims can provide rather good quality of the transverse magnetic field in the permanent magnet systems (~5×10^{-4}).

In real life the field quality is defined by

? Magnetic material characteristics.

? Pole material characteristics and pole saturation.

? Quality of manufacture and assembling (especially gap manufacture tolerance).

Wiggler nonlinearity

The main effect is due to the wiggler magnets edge field producing strong vertical cubic nonlinearity.

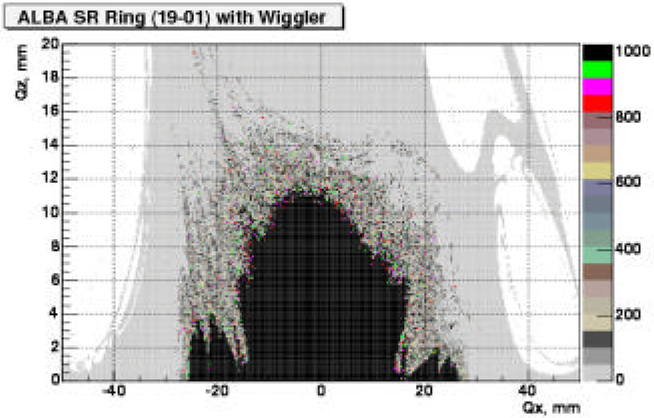
$$\Delta H = \frac{1}{24} n(s) y^3 \qquad \text{?} \qquad (n \cdot l) = \frac{B''' \cdot l_w}{Br} = \frac{8p^2}{l_w r_w^2}$$

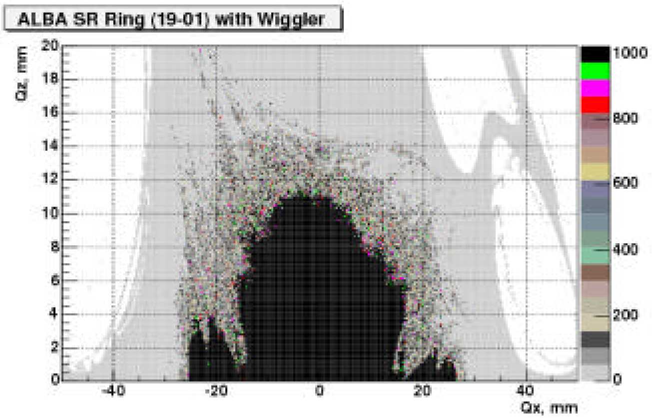
and relevant amplitude-dependent tune shift is given by

$$\Delta n_y (J_y) = \left(\frac{p \cdot L_w \overline{b}_y^2}{l_w^2 r_w^2} \right) \cdot J_y$$

Example of wiggler reduction of dynamic aperture

Wiggler DA simulation: 3 GeV light source, single 2.4-m 3.5 T wiggler with period length 6.4 cm.





Wiggler model with vertical 1D octupole.

Wiggler model with vertical 1D octupole and sextupoles.

Conclusions

- Scaling laws are useful to select wigglers parameters. In real life the wiggler field behaviour depends on wiggler type, material features, saturation, etc. so it seems for every particular case scaling laws can be found by simulation only.

- In principle rather high quality of the wiggler transverse field can be achieved. However to take into account influence of production tolerance, material characteristics, etc. small (2-3 periods) prototype development and measurement is desirable.

- The main nonlinear component of the wiggler field is the vertical 1D octupole but its effect might be minimized by regular octupole magnets placed at azimuth with high beta-y and low beta-x value.