CLIC Damping Wiggler

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Outline

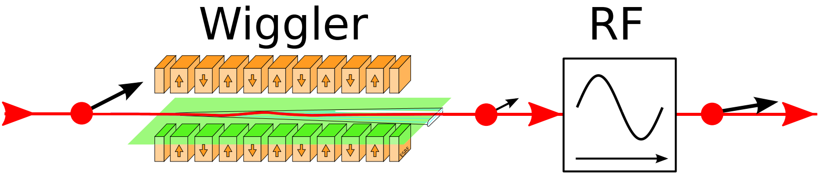
1. **Introduction**

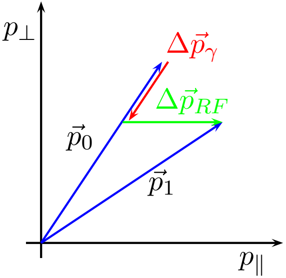
2. **Short Model – NbTi Racetrack Design**

3. **Nb_3Sn Wiggler**

4. **Future work**

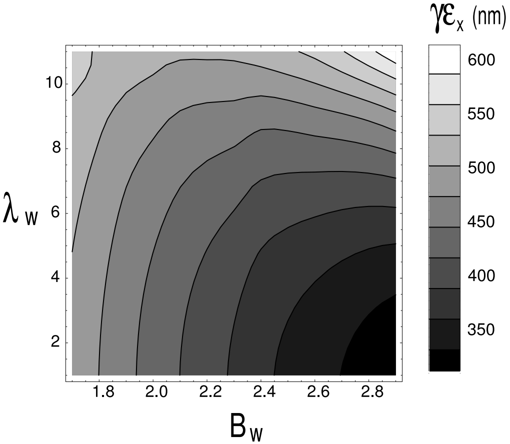
Introduction – Motivation





Aimed equilibrium emittances		
$\gamma\epsilon_x$	$\gamma\epsilon_y$	ϵ_t
$<450\,\mathrm{nm}$	$<3\,\mathrm{nm}$	$<5000\,\mathrm{eVm}$

CLIC Wiggler's optimum efficiency

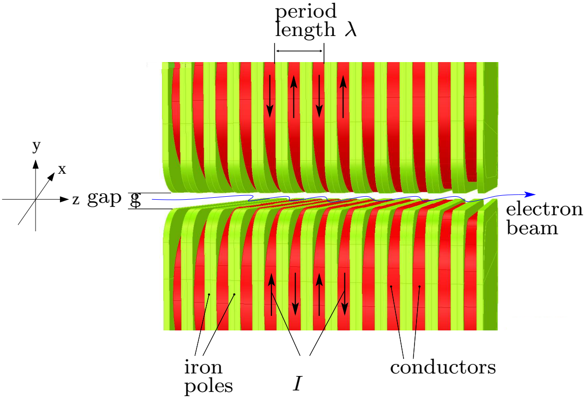


Transverse equilibrium emittance $\gamma\epsilon_x$ at fixed wiggler length

M. Korostelev: *Optics Design and Performance of an Ultar-Low Emittance Damping Ring for the Compact Linear Collider*

Possible wire technologies: NbTi or Nb_3Sn

Superconducting wiggler – Example NbTi

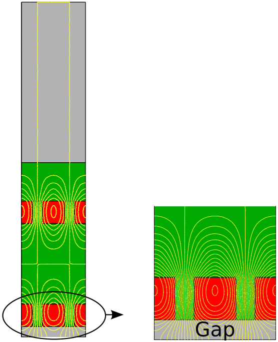


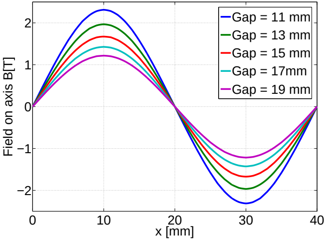
Courtesy of Daniel Wollmann

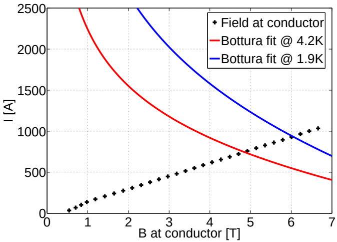
Main parameters:

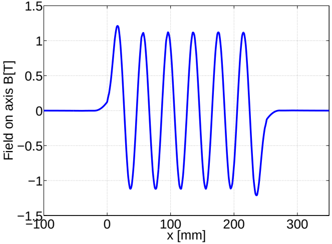
- Gap 13 mm.
- Field on axis: $B = 2.5\,\mathrm{T}$.
- Period length: $\lambda = 40 \ldots 50\,\mathrm{mm}$.

NbTi Vertical Racetrack Design – Overview

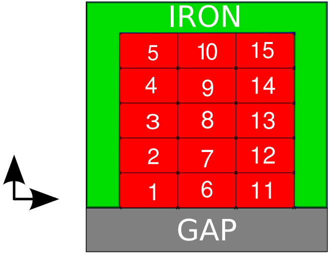




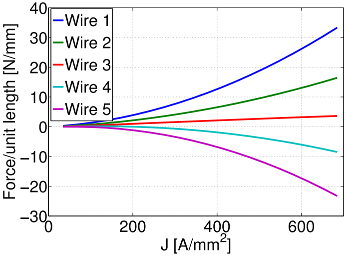




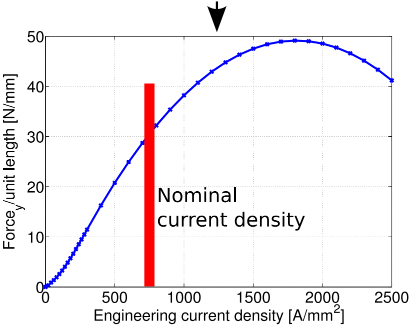
NbTi Vertical Racetrack Design – Forces



Forces on wire 1 to 5



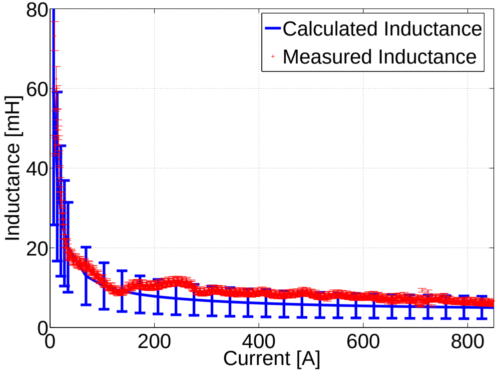
Forces on wire bundle



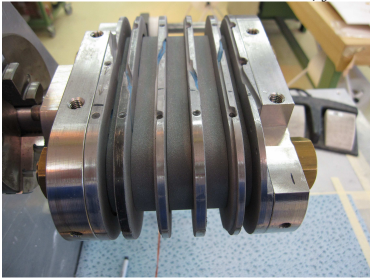
NbTi Vertical Racetrack Design – Inductance

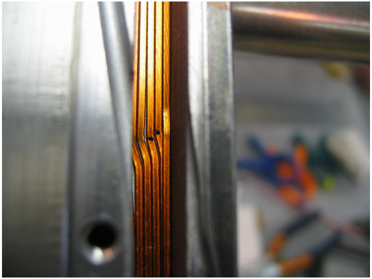
$$L_{\text{Wiggler}} = 2p\frac{E_{\text{period}}}{\left(\frac{I}{n}\right)^2}$$

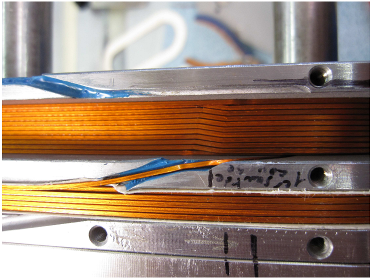
p	# periods	E_{period}	stored energy/period
I	current in groove	n	# wires in groove



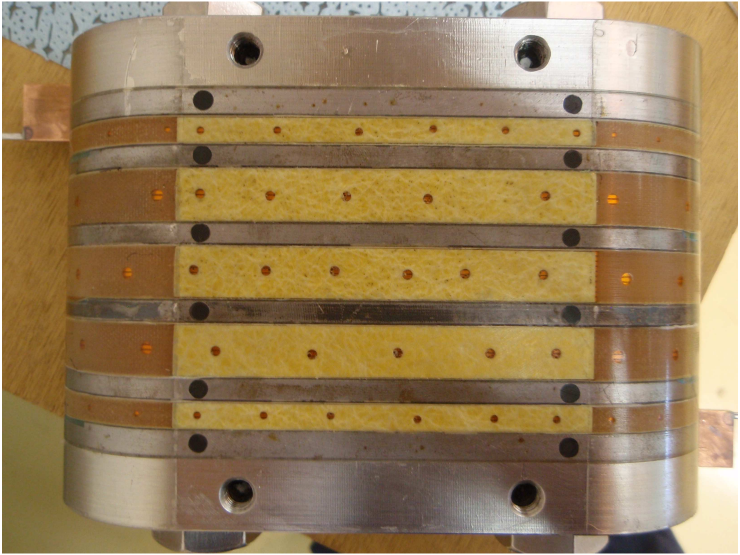
NbTi Racetrack design – Manufacturing



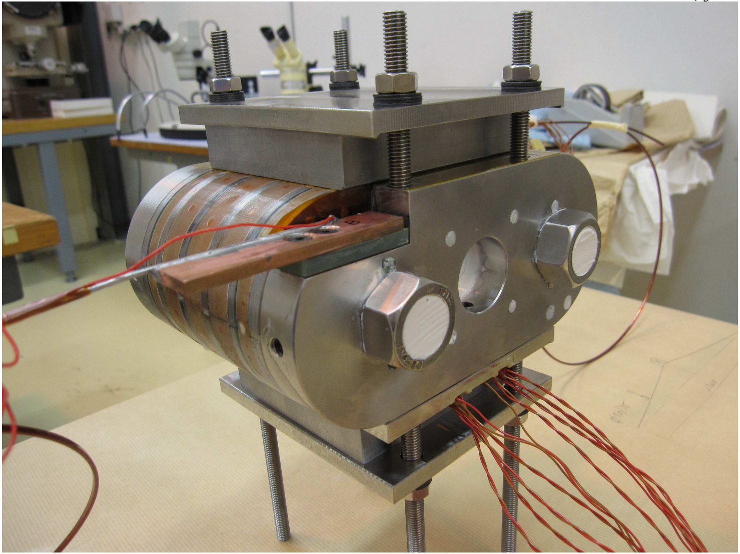




NbTi Racetrack design – Short model

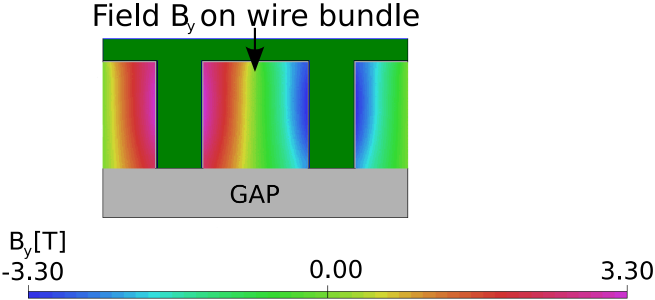


Racetrack design – Set-up for measurement



Details and result: Talk by Remo Maccaferri

Limitations of NbTi

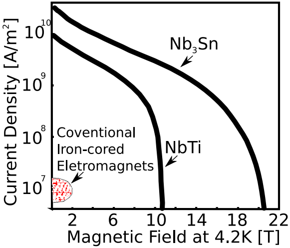


- High gradients in the wire bundle of $\approx 470\,\mathrm{T/m}$
- For a given configuration:

$$B_{max}\,[\mathrm{T}] \propto J\,[\mathrm{A/mm^2}]$$

H. Moser and R. Rossmanith: Magnetic field of superconductive in-vacuo undulators in comparison with permanent magnet undulators

Comparison – NbTi and Nb_3Sn



M. Wilson: *Superconducting Magnets*

NbTi	Nb_3Sn
Robust and ready to use	Brittle, needs thermal treatment
Magnetical stable	Unstable under certain circumstances
Standard EU and US Production	Limited availability
Limited Field	Higher field limits
1W/m heat deposition[1]	10W/m heat deposition[1]

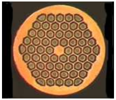
[1] L. China, D. Tommasini (2008): *Comp. study of heat transfer from NbTi and Nb_3Sn coils to He*

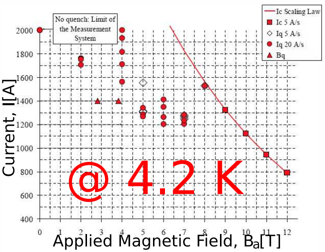
Nb_3Sn Strand

Oxford Instruments, Nb_3Sn/RRP®

- **Properties**

Bare diameter	0.8 mm
Cross section	$0.5\,mm^2$
Stabilizer	Cu
Non-Cu Volume	53% ± 3%
Twist Pitch $\varnothing < 1$ mm	12 ± 4 mm
Twist Pitch $\varnothing \geq 1$ mm	40 ± 10 mm
Bare size tolerance	±5 μm
Insulation	S-Glass braid
Insulation build	130 μm (nominal)
Ins. size tolerance	±15 μm





B.Bordini, R.Maccaferri, L.Rossi, D.Tommasini, *Test Report of the Ceramic-Insulated Nb_3Sn Small Split Solenoid*, EDMS:907758

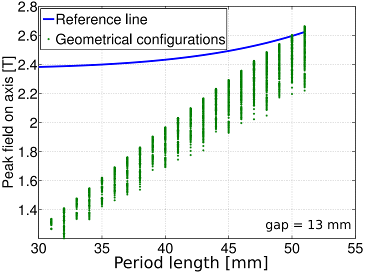
- **Heat Treatment**

Cycle with improved RRR and magneto-stability, B.Bordini
#1 Increase T to 205°C (25°C/h), hold for 72 h
#2 Increase T to 400°C (50°C/h), hold for 48 h
#3 Increase T to 695°C (50°C/h), hold for 17 h

- **Measurements** RRR > 300, B.Bordini

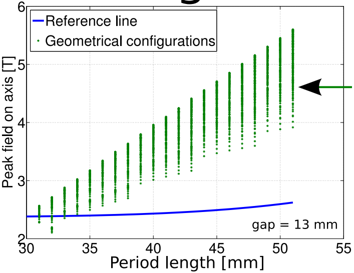
Optimal geometry– NbTi and Nb_3Sn

NbTi



LHC NbTi corrector wire #3, 1.25 x 0.73 mm^2 including insulation, 1.13 x 0.61 mm^2, Cu:Sc 1.71; 70% of maximal current density

Nb_3Sn



Differences due to different wiggler geometries

0.8 mm RRP Nb_3Sn Strand; 70% of maximal current density

Future work – Heat load from the beam

Important for:

- Cryostat design.
- Magnetic design, i.e., gap size.

Sources of beam heat load:

- Synchrotron radiation.
- Image currents on the cold surface (resistive wall heating).
- Resonant RF-heating.
- Ions and electrons accelerated to the walls by the transverse field of the ultrarelativistic beam.

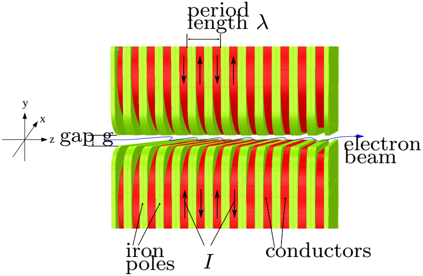
S. Casalbuoni et al.: Beam heat load and pressure rise in a cold vacuum chamber; *K. Zolotarev et al.*, 2008

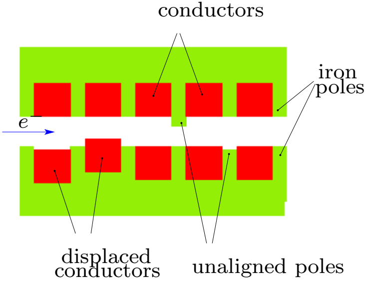
Future work – Field error corrections

Field errors can influence the trajectory in the wiggler and therefore the minimum emittance:

- Quality of pole material
- Persistent currents
- Mechanical tolerances

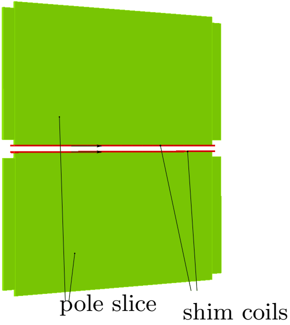
⇒ Tolerances to be defined!

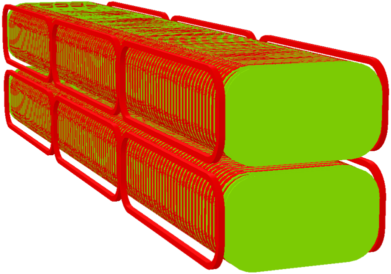




Courtesy of Daniel Wollmann

Future work – Field error corrections





Courtesy of Axel Bernhard/Daniel Wollmann

- Mechanical shimming
- Trajectory correction with integral correctors
- Active shimming with local correction coils
- Induction shimming

Summary and conclusion

- Short model shows technical feasibility of wiggler.
- NbTi wiggler is able to fulfill magnetic requirements at $\lambda = 50\,\mathrm{mm}$ (present CERN/Karlsruhe design: $\lambda = 40\,\mathrm{mm}$).
- Magnetic forces can be handled, stored magnetic energy is very small compared to conventional dipole magnet.
- Nb_3Sn wiggler is less sensitive for beam heat load and can generate higher magnetic fields.
- At 13 mm gap the period length for NbTi at 4.3 K is 50 mm, for Nb_3Sn 34 mm.
- Field quality requirements have to be defined ⇒ Mechanical tolerances.
- Heat load has to be estimated and considered in the design.
- Different NbTi and Nb_3Sn wiggler designs will be tested at CERN/Karlsruhe.

Future work – Milestones

- **End 2009** Electromagnetic and mechanical design and realisation of a NbTi model.
- **Mid 2010** Electromagnetic and mechanical design and realisation of a Nb_3Sn model.
- **Mid 2011** Design of a full scale prototype.
- **Mid 2012** Manufacturing & test of a full scale prototype.

Thanks!