The Status of the Damping Wiggler Project for the CLIC Damping Rings

Peter Peiffer

for the CLIC/CTF3 collaboration

Outline

CLIC / CTF3 overview

Damping Rings and Wigglers

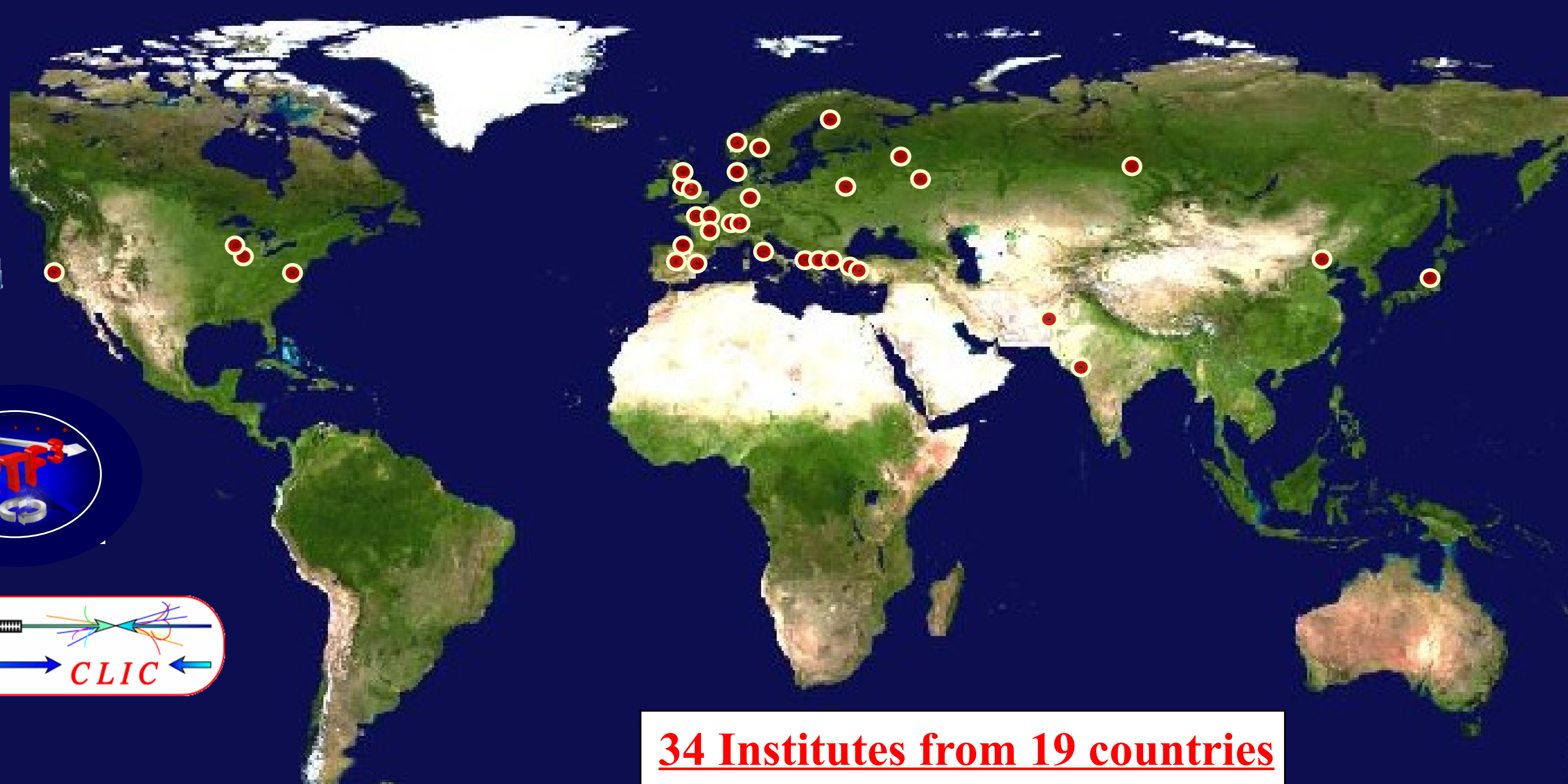
NbTi vs. Nb_3Sn

Winding Body options

Nb_3Sn coil test

Current Status and Conclusions

World-wide CLIC&CTF3 Collaboration



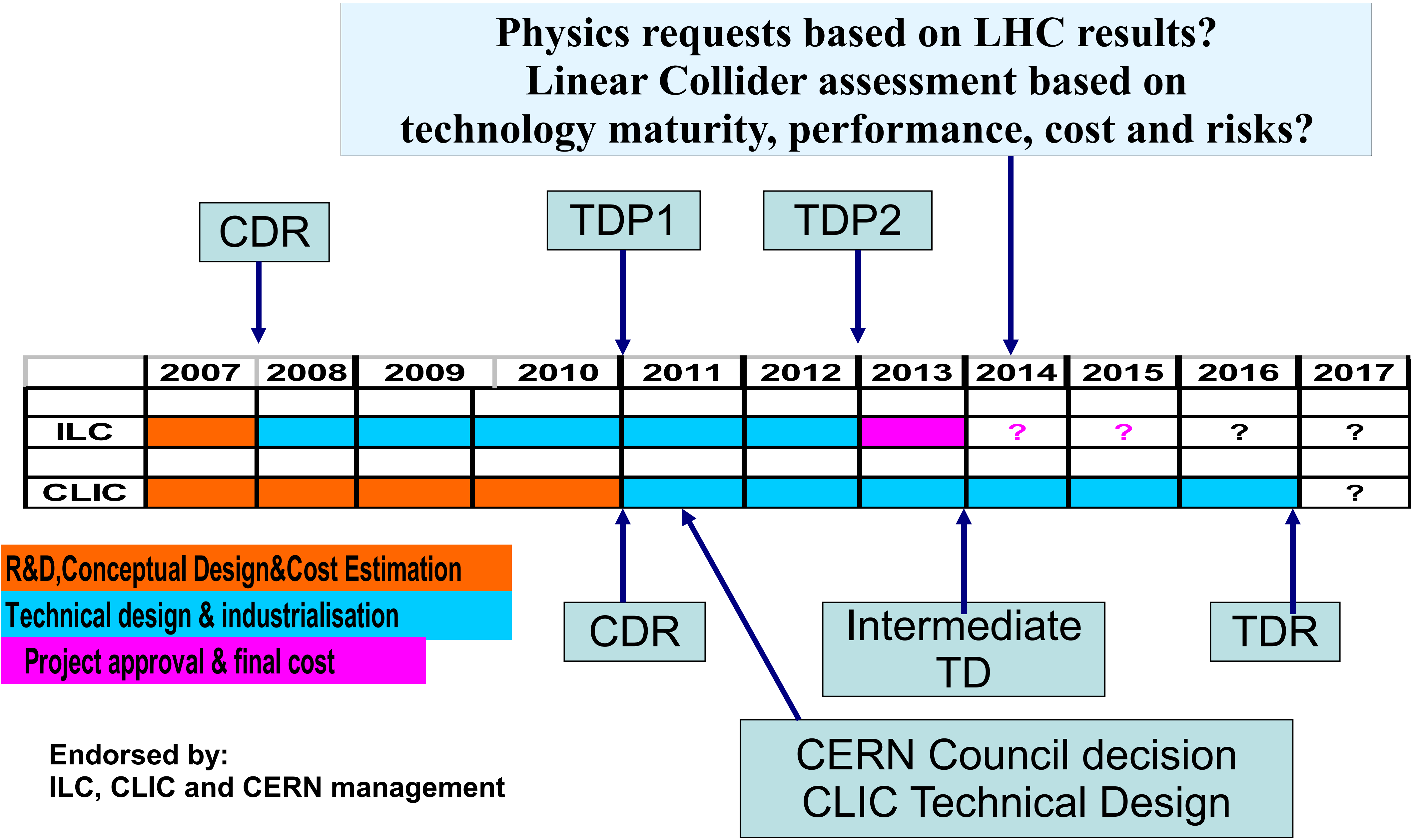
Aarhus University (Denmark)
Ankara University (Turkey)
Argonne National Laboratory (USA)
Athens University (Greece)
BINP (Russia)
CERN
CIEMAT (Spain)
Cockcroft Institute (UK)
Gazi Universities (Turkey)

Helsinki Institute of Physics (Finland)
IAP (Russia)
IAP NASU (Ukraine)
INFN / LNF (Italy)
Instituto de Fisica Corpuscular (Spain)
IRFU / Saclay (France)
Jefferson Lab (USA)
John Adams Institute (UK)

JINR (Russia)
Karlsruhe University (Germany)
KEK (Japan)
LAL / Orsay (France)
LAPP / ESIA (France)
NCP (Pakistan)
North-West. Univ. Illinois (USA)
Patras University (Greece)
Polytech. University of Catalonia (Spain)

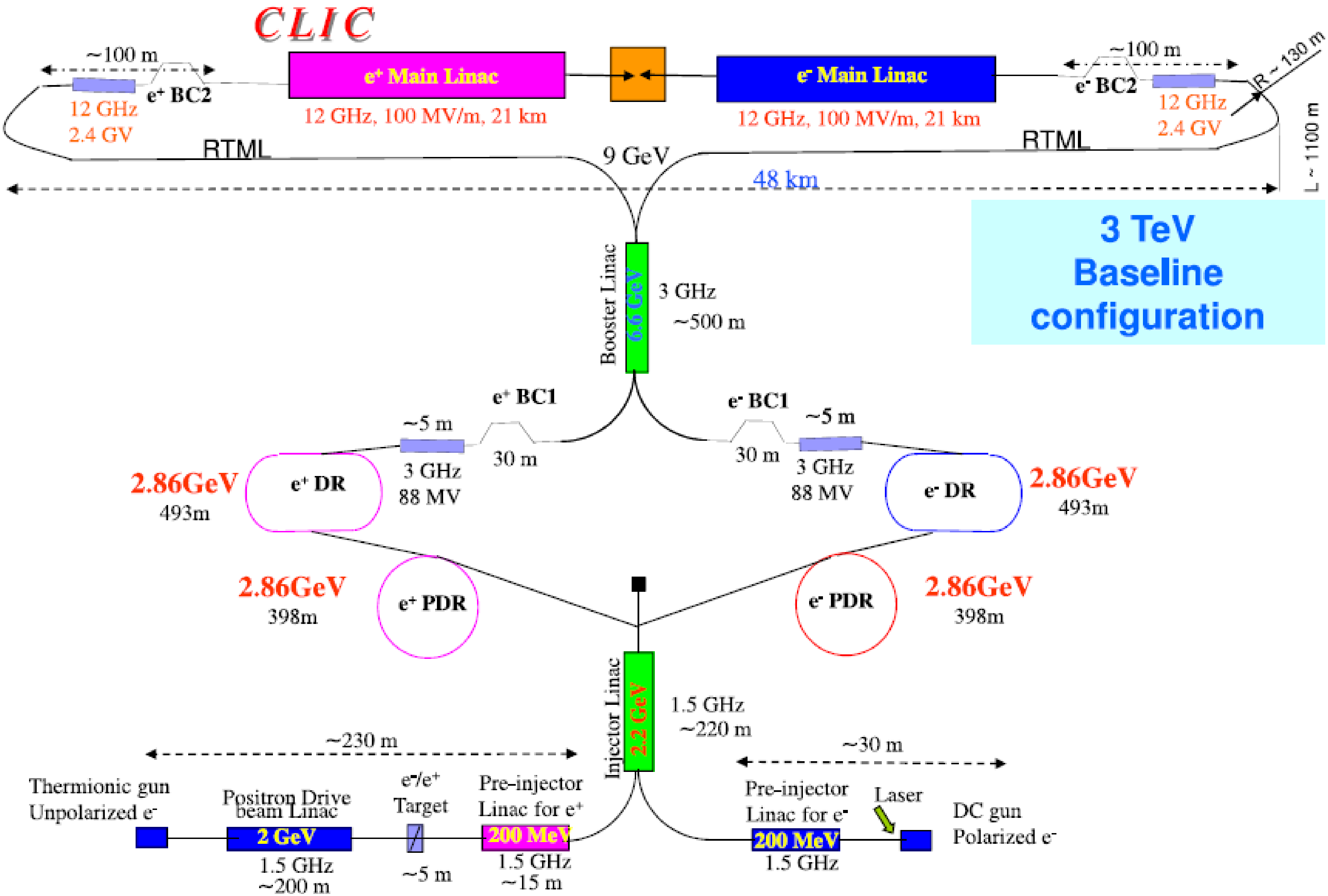
PSI (Switzerland)
RAL (UK)
RRCAT / Indore (India)
SLAC (USA)
Thrace University (Greece)
Tsinghua University (China)
University of Oslo (Norway)
Uppsala University (Sweden)

Linear Colliders tentative schedule in collaborative/competitive environment



Endorsed by:
ILC, CLIC and CERN management

CLIC – general layout



3 TeV
Baseline
configuration

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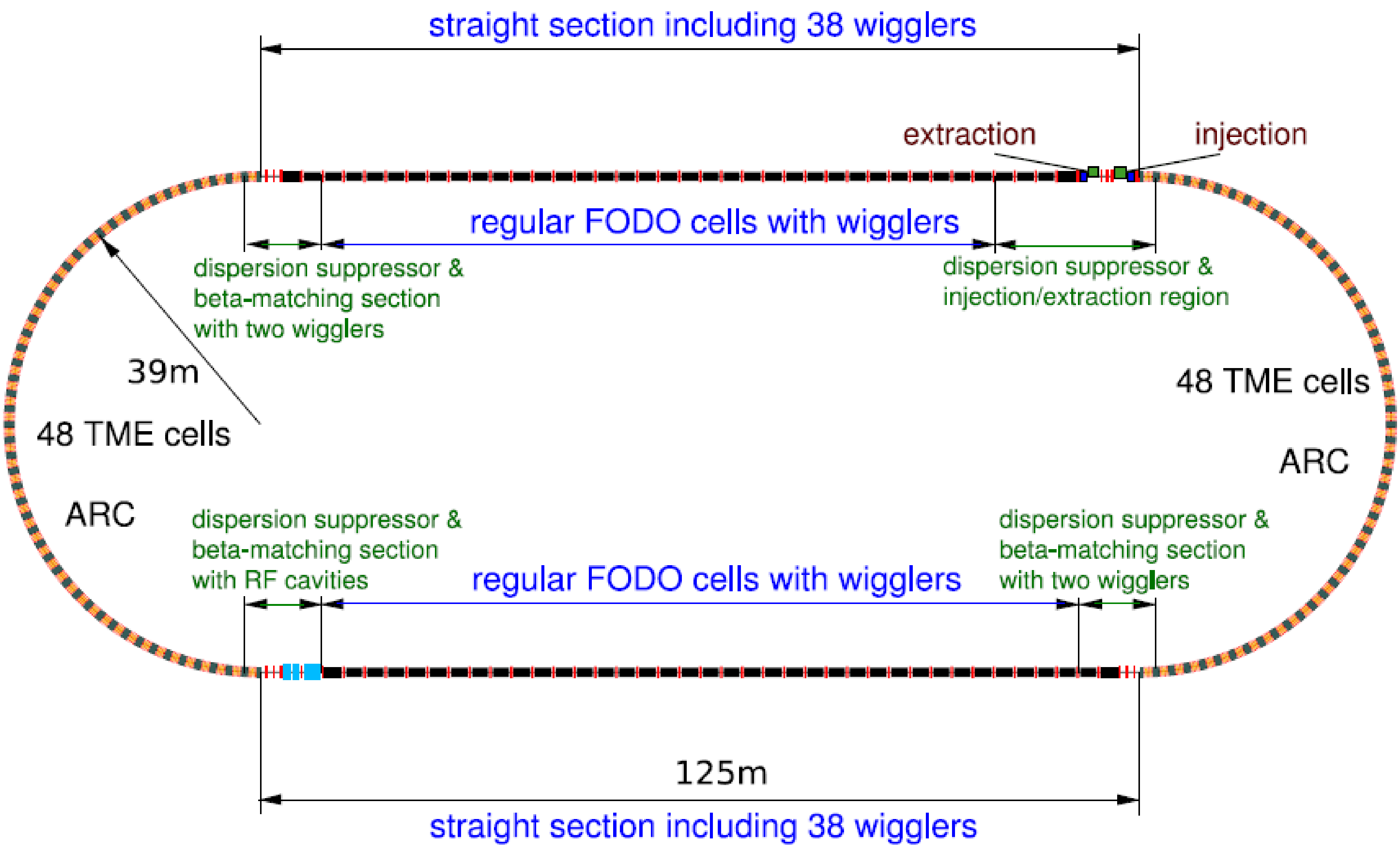
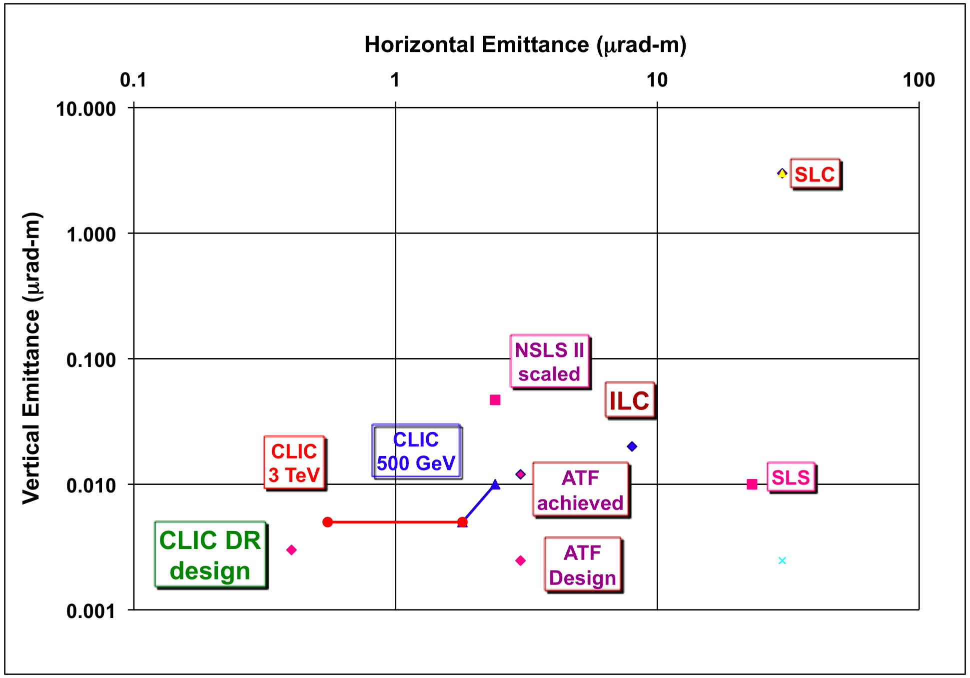
Damping rings



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

DR – Design Parameters and Challenges



Design Parameters	CLIC
Energy [GeV]	2.86
Circumference [m]	420.56
Energy loss/turn [MeV]	4.2
RF voltage [MV]	4.9
Compaction factor	$8x10^{-5}$
Damping time x / s [ms]	1.88/0.96
No bends / wigglers	100/52
Dipole/ wiggler field [T]	1.4/2.5

High-bunch density

Emittance dominated by **Intrabeam Scattering**, driving energy, lattice, wiggler technology choice and alignment tolerances

Electron cloud in e^+ ring imposes chamber coatings and efficient photon absorption

Fast Ion Instability in the e^- ring necessitates low vacuum pressure

Space charge sets energy, circumference limits

Repetition rate and bunch structure

Fast damping achieved with wigglers

RF frequency reduction due to many challenges @ 2GHz (power source, high peak and average current)

Output emittance stability

Tight jitter tolerance driving kicker technology

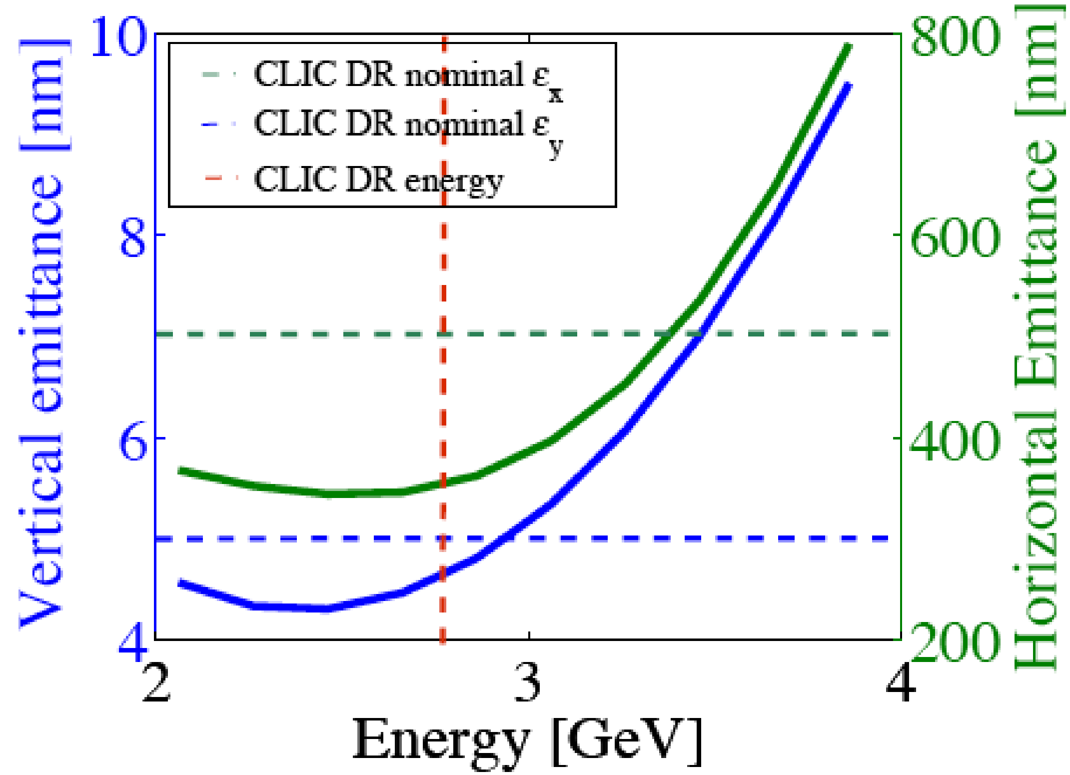
Positron beam dimensions from source

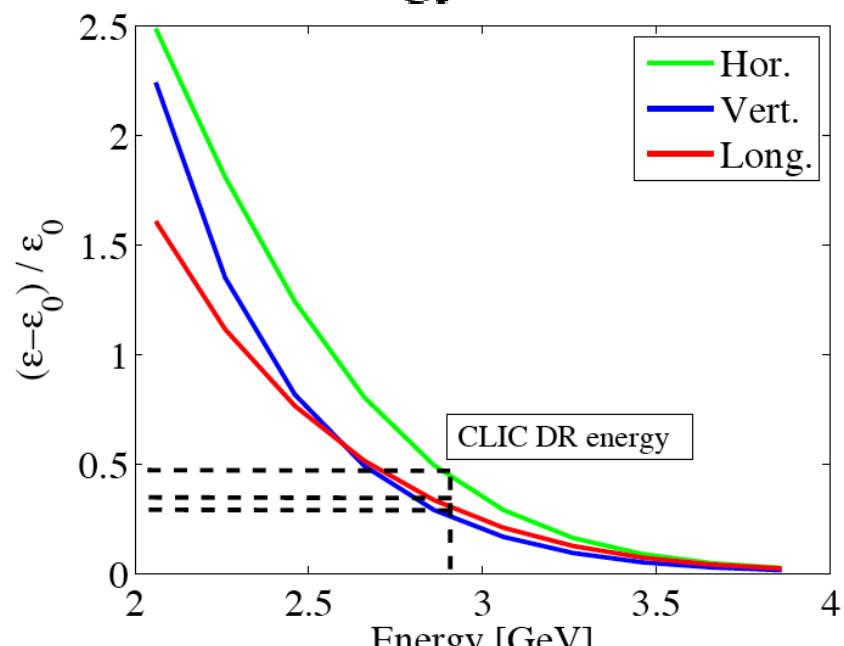
Pre-damping ring challenges (energy acceptance, dynamic aperture) solved with lattice design

Damping ring energy

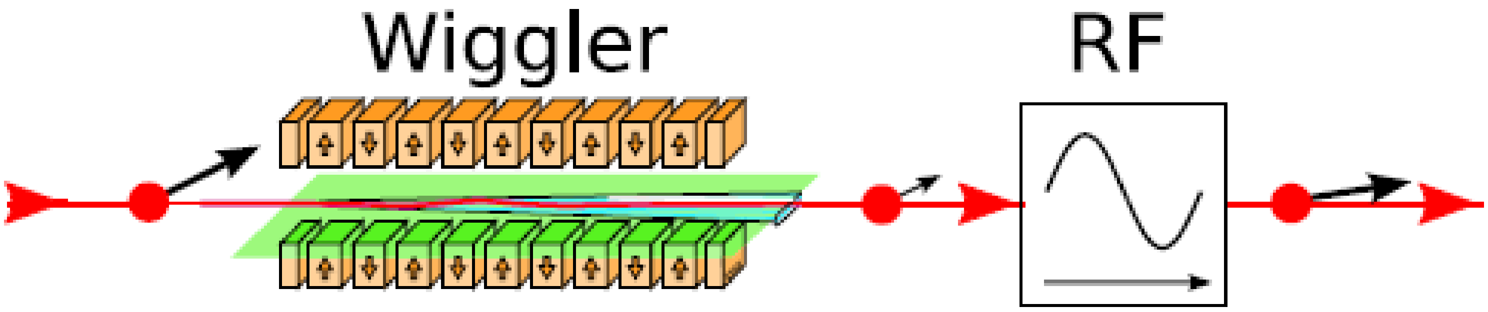
- Scaling of emittances with energy obtained with analytical arguments and including IBS effect (constant longitudinal emittance)
- Broad minimum for horizontal emittance ~2-3GeV

- Higher energy reduces ratio between zero current and IBS dominated emittance
- Similar results obtained for other machines (e.g. CESRTA)
- Choice of 2.86GeV in order to relax collective effects while achieving target emittances





Damping Wiggler - principle



Equilibrium Emittance	$\epsilon = C_q \gamma^2 \frac{I_5}{J_x I_2}$
Damping via photon emission	$I_2 = \oint \frac{1}{\rho^2}$
Excitation via dispersion	$I_5 = \oint \frac{\mathcal{H}}{\lvert\rho^3\rvert} \mathrm{d}z$
$J_x = 1 - \frac{I_4}{I_5} \approx 1$	$\mathcal{H} = \gamma(z)\eta^2 + 2\alpha(z)\eta\dot{\eta} + \beta(z)\dot{\eta}^2$

→ strong magnetic fields at not too large period length

Damping wiggler - parameters

Emittances: $\gamma\varepsilon_y < 5$nm, $\gamma\varepsilon_x < 500$ nm, $\varepsilon_t < 4000$ eVm

Period length: 40 – 50 mm

Field on axis: 2.5 – 2.8 T

Gap: 16 – 19 mm

Beam stay clear: 13 mm

Two competing options:

- NbTi – CERN funded BINP project
- Nb_3Sn – joint CERN/KIT project

Synchrotron radiation

- Synchrotron radiation power from bending magnets and wigglers

$$P_{bend} = \frac{2c^2 r_e}{3m_0^3} E^2 l_b B^2 I$$

$$P_w = \frac{2c^2 r_e}{3m_0^3} E^2 l_w B_w^2 I$$

- Critical energy for dipoles and wigglers

$$E_c = \frac{3\text{h}c}{2m_0^3} \frac{E^3}{r} \quad E_{cw} = \frac{3\text{h}c^2}{2m_0^3} B_w E^2$$

- Radiation opening angle

$$\theta_y = \frac{0.608}{g}$$

DR radiation parameters	PDR	DR
Power per dipole [kW]	3.3	1.2
Power per wiggler [kW]	15.2	16.1
Total power [MW]	0.7	1.3
Critical energy for dipole [keV]	16.0	19.0
Critical energy for wiggler [keV]	9.3	13.6
Radiation opening angle [mrad]	0.11	

- 90% of radiation power coming from the 76 SC wigglers
- Design of an absorption system is critical to protect machine components and wigglers against quench
- Radiation absorption also important for PDR (but less critical, i.e. similar to light sources)

Outline

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Damping Rings and Wigglers

NbTi vs. Nb_3Sn and winding body options

Nb_3Sn coil test

Current Status and Conclusions

Nb_3Sn advantages and challenges

Less sensitive to heat load

Higher field on axis

Brittle

Has to be wound first and then reacted

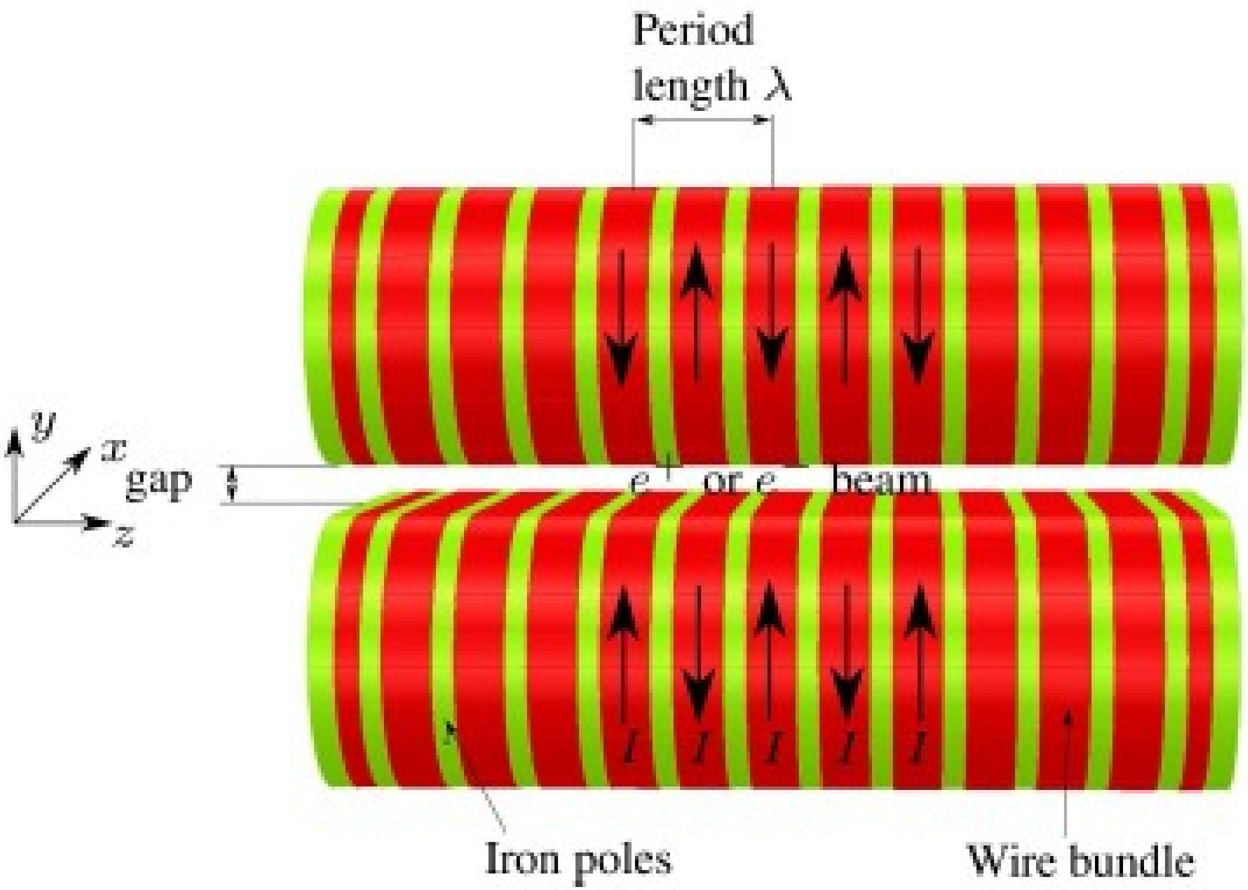
Non-linear thermal expansion coefficient

fixation issues

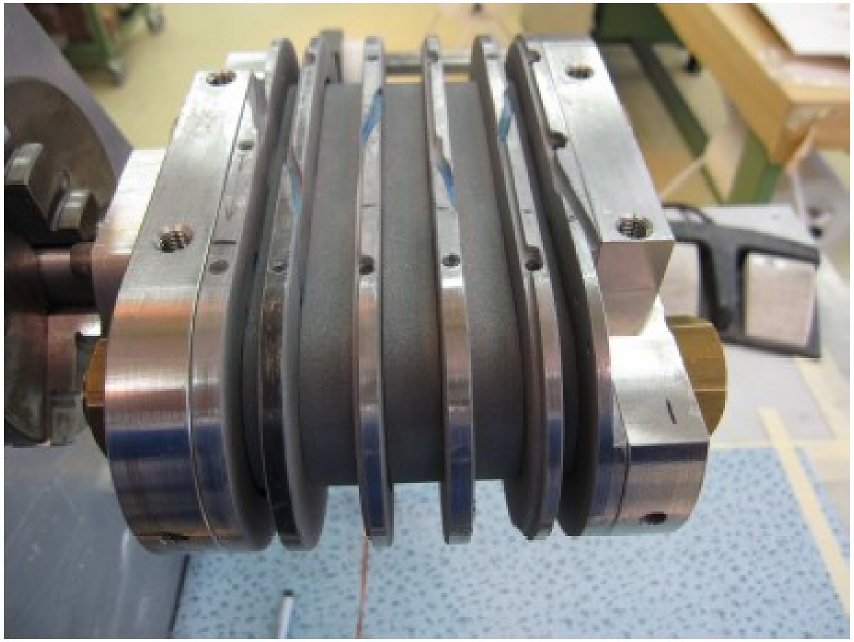
- solved !

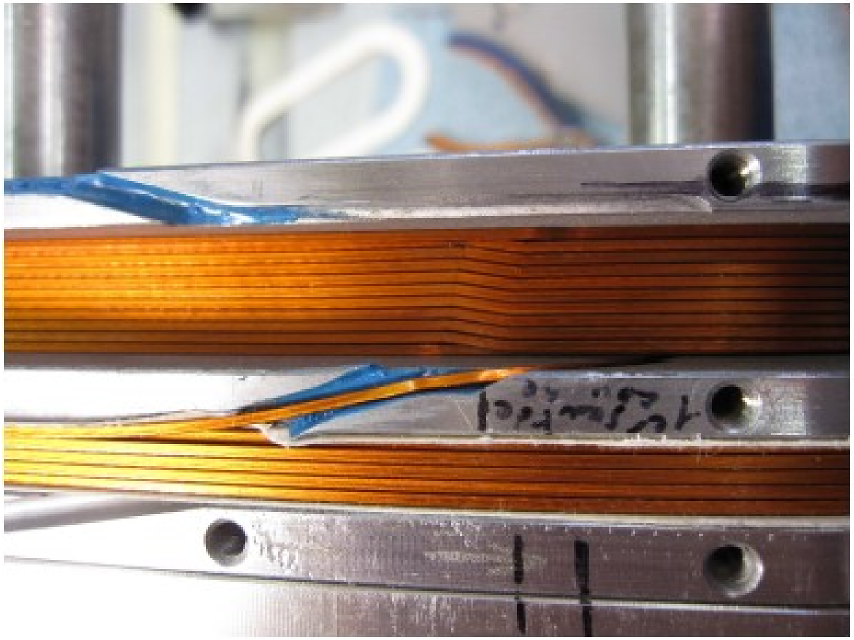
Low field instabilities – difficult downscaling

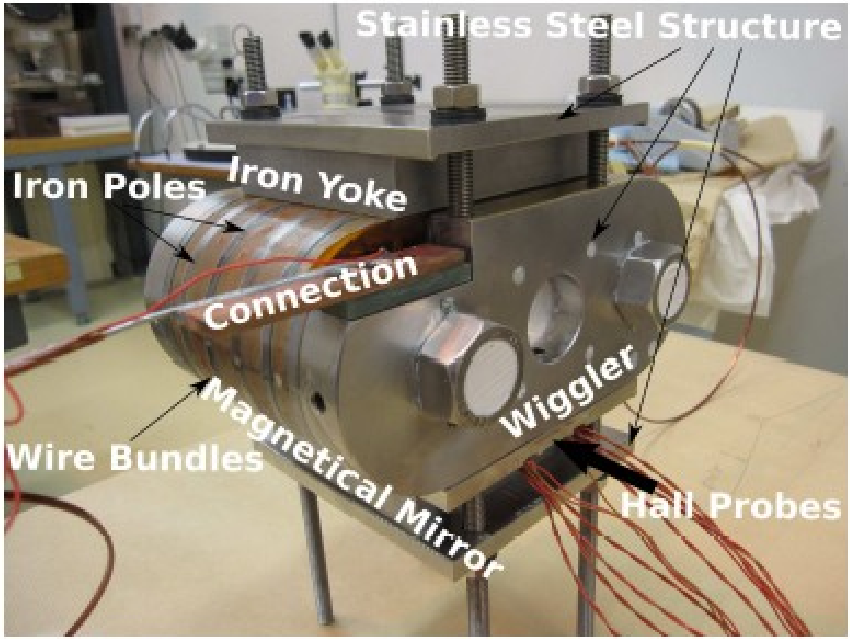
Winding body options - Vertical Racetrack



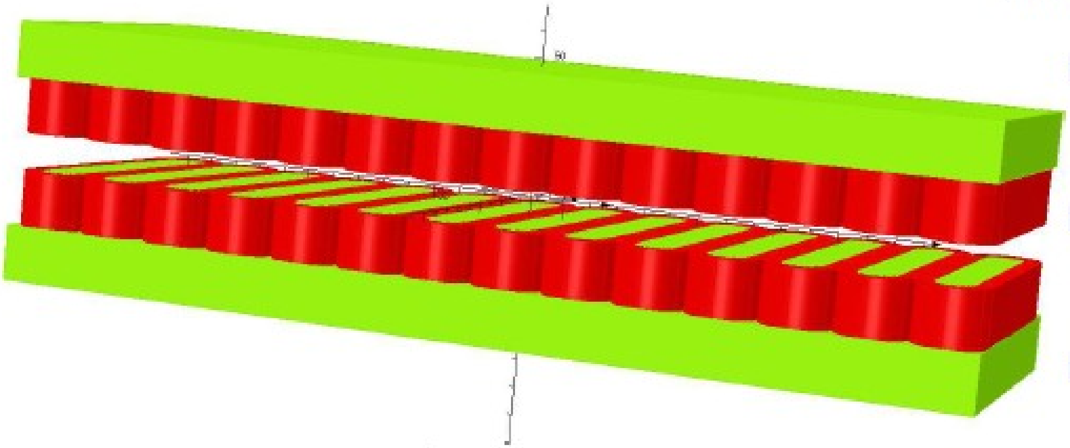
Winding body options - Vertical Racetrack

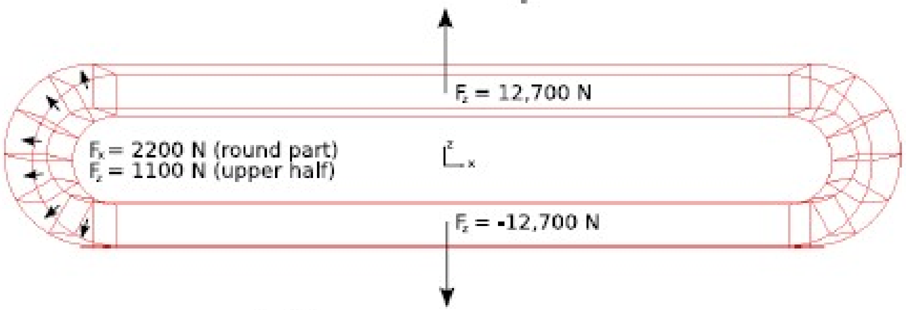


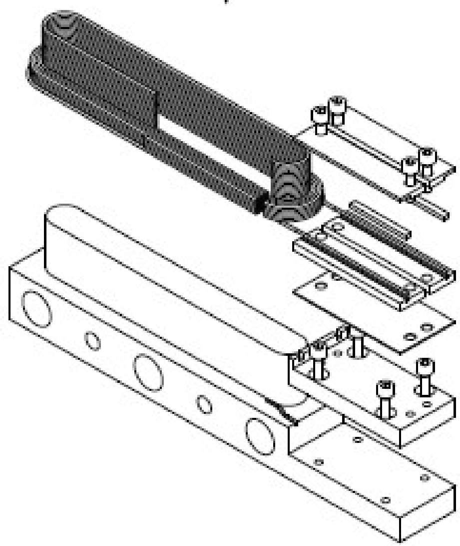




Winding body options - horizontal racetrack







Advantages:

- Feasible design for period length $\geq 50\,\mathrm{mm}$
- Up to 4 times less wire consumption
- Less cold mass and stored energy
- Easy mass production

Challenges:

- 80 Splices/Wiggler's meter: First results show a resistance of $< 10\,\mathrm{n}\Omega \Rightarrow P < 0.3\,\mathrm{W/m}$
- Forces can be handled by applying pre-tension in z-direction
- Bending radius of wire very small

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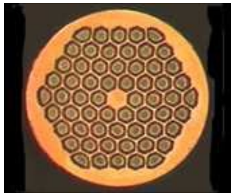
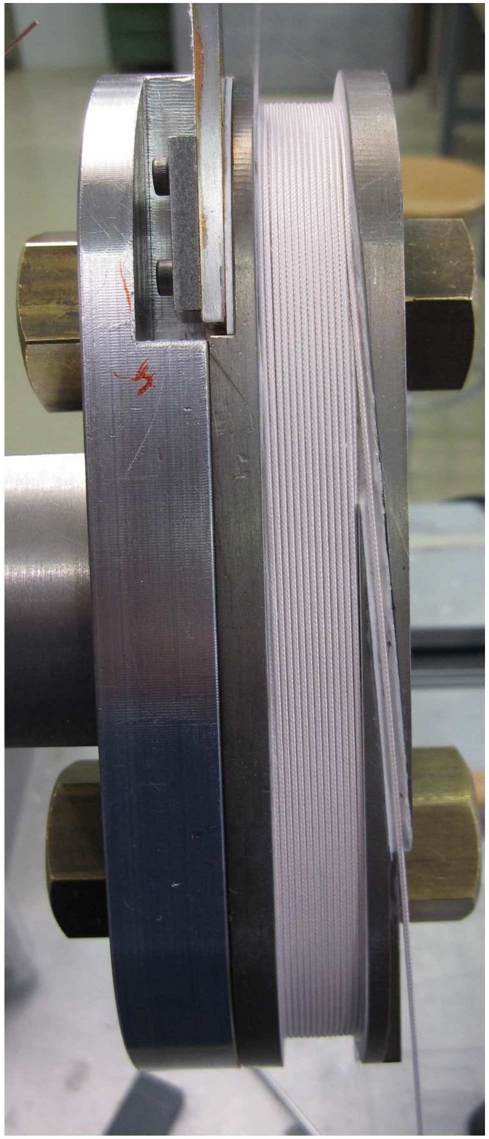
- Current Status and Conclusions



Nb_3Sn Test coil



Nb_3Sn/Cu wire

0.8 mm diameter

Nb_3Sn/Cu ratio: 1.13

Filiament diameter: 80 µm

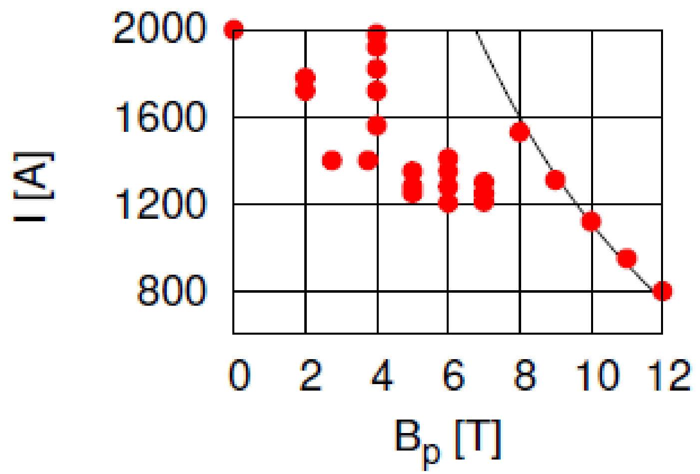
No. of Filiaments: 60

Glass S-braid isolation

Ceramic ground isolation of winding body

Tight mechanical fixation of straight sections during heat treatment, but some 'air' at the bends

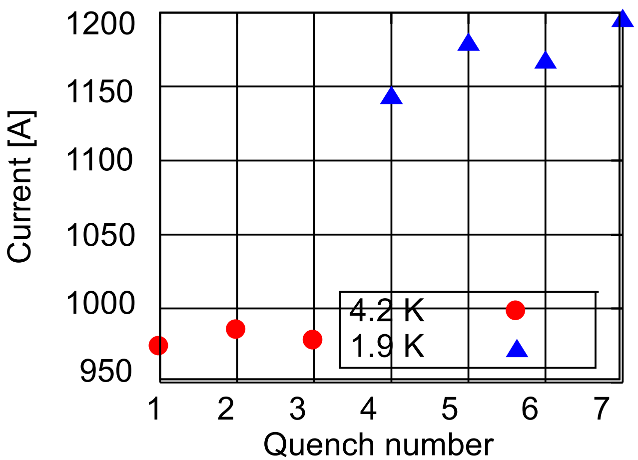
Vacuum impregnation to fix wires.



B.Bordini, R.Maccaferri, L.Rossi, D.Tommasini, *Test Report of the Ceramic-Insulated Nb3Sn Small Split Solenoid*, EDMS:907758

Test coil successfully trained and quench-tested. Stable over three thermal cycles

Nb_3Sn coil test

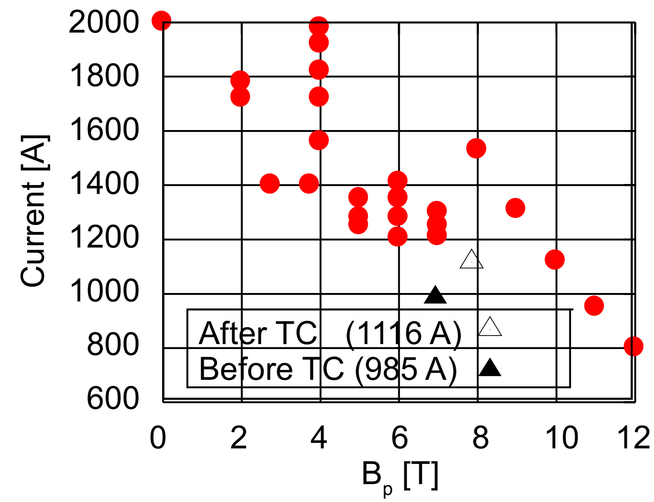


First quench training

Current reached:
1116 A @ 4.2 K
1194 A @ 1.9 K

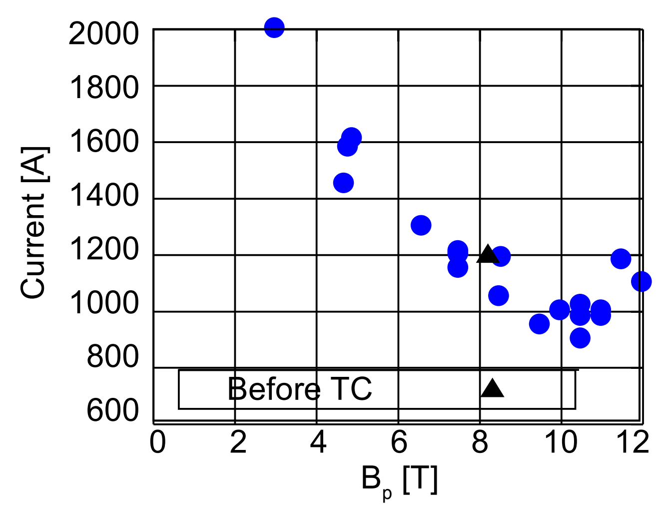
Filling factor ~1

→ Winding and tempering under control but still room for improvement.



Current achieved in coil (black triangles) compared to current achieved in short samples (colored dots)

Top: at 4.2 K, bottom: at 1.9 K



Testing the wiggler with beam

After production of prototype:

- Need to test the wiggler on real beam conditions
  - Validate cryogenic performance, reliability and heat load evacuation (absorber)
  - Test quench performance under presence of beam and synchrotron radiation
  - Validate measured field quality (wiggler should be transparent to beam)
  - Can be combined with vacuum chamber tests (photo-emission yield, desorption)
- Necessary experimental set-up
  - Storage ring with available straight section of ~3m for installing wiggler and absorber downstream of a dipole or other insertion device
  - Ability to install the cryogenic system
  - Average current of ~200mA for testing absorber in similar radiation conditions
  - For using wiggler as an X-ray user insertion device, *K*-parameter can be adjusted by reducing wiggler field (need to have good field quality at lower currents)

Status and outlook

NbTi can fulfill requirements at $\lambda = 50$ mm

Nb_3Sn advantages: higher field, heat load

Nb_3Sn Test coil tested and satisfactory

Fixation issue fixed

Experiments for rectangular wire profile ongoing

Milestones:

Mid 2011: Design of a full scale prototype

Mid 2012: Manufacturing & test of prototype

Thank you for your attention

And thanks to D. Schoerling, Y. Papaphilippou and H. Schmickler
for providing slides for this talk.