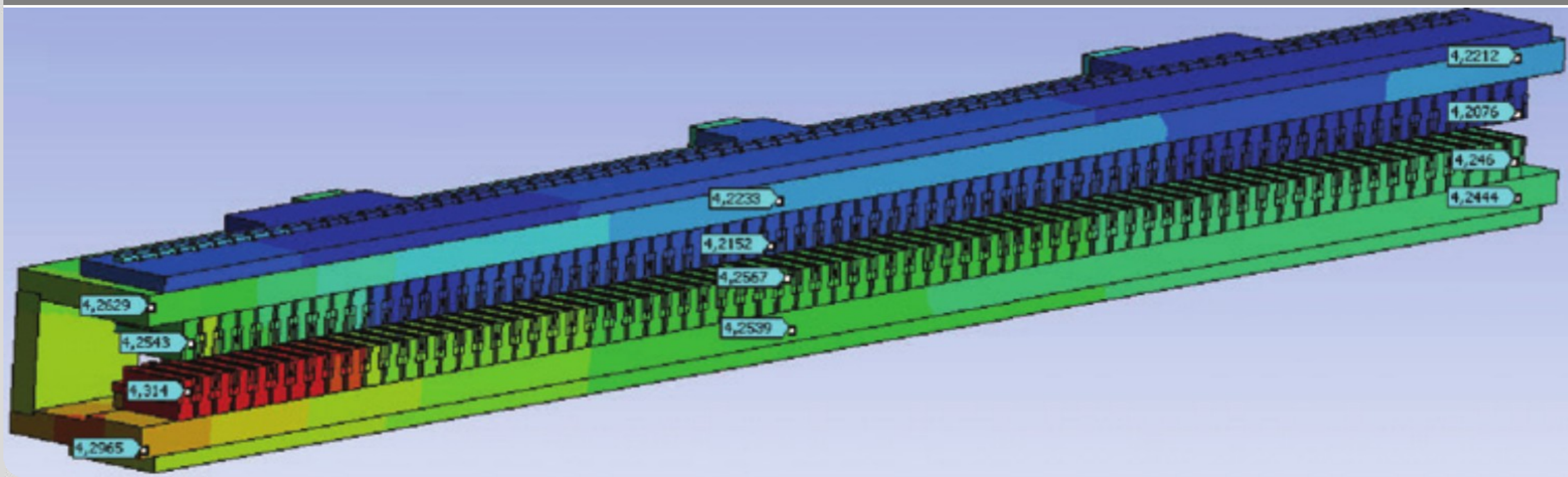
Nb-Ti Wiggler: design, progress, and experimental plan at ANKA

Steffen Hillenbrand,
For the KIT-CLIC collaboration



Acknowledgment

- BINP:

  Alexey Bragin, Nikolay Mezentsev, Vasily Syrovatin, Konstatin Zolotarev

- CERN:

  Marton Ady, Paolo Ferracin, Laura Garcia Fajardo,

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- KIT:

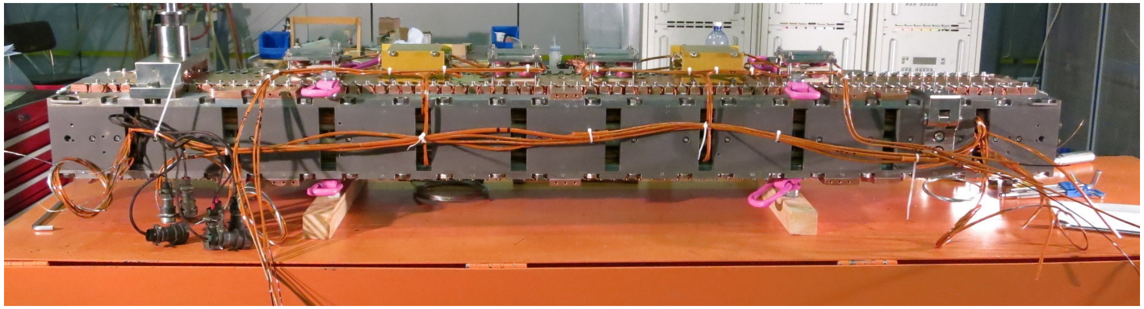
  Axel Bernhard, Erik Bründermann, Sergey Gasilov,

  Julian Gethmann, Andreas Grau, Edmund Hertel,

  Erhard Huttel, Anke-Susanne Müller, Robert Rossmanith

Outline

- Introduction:
  - CLIC Damping Rings (DR) and ANKA light source
  - The superconducting Nb-Ti Damping Wiggler (DW)



- Project Status
  - First Measurement results
- Planned Experiments
- Outlook and Summary

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Introduction – CLIC Damping Rings

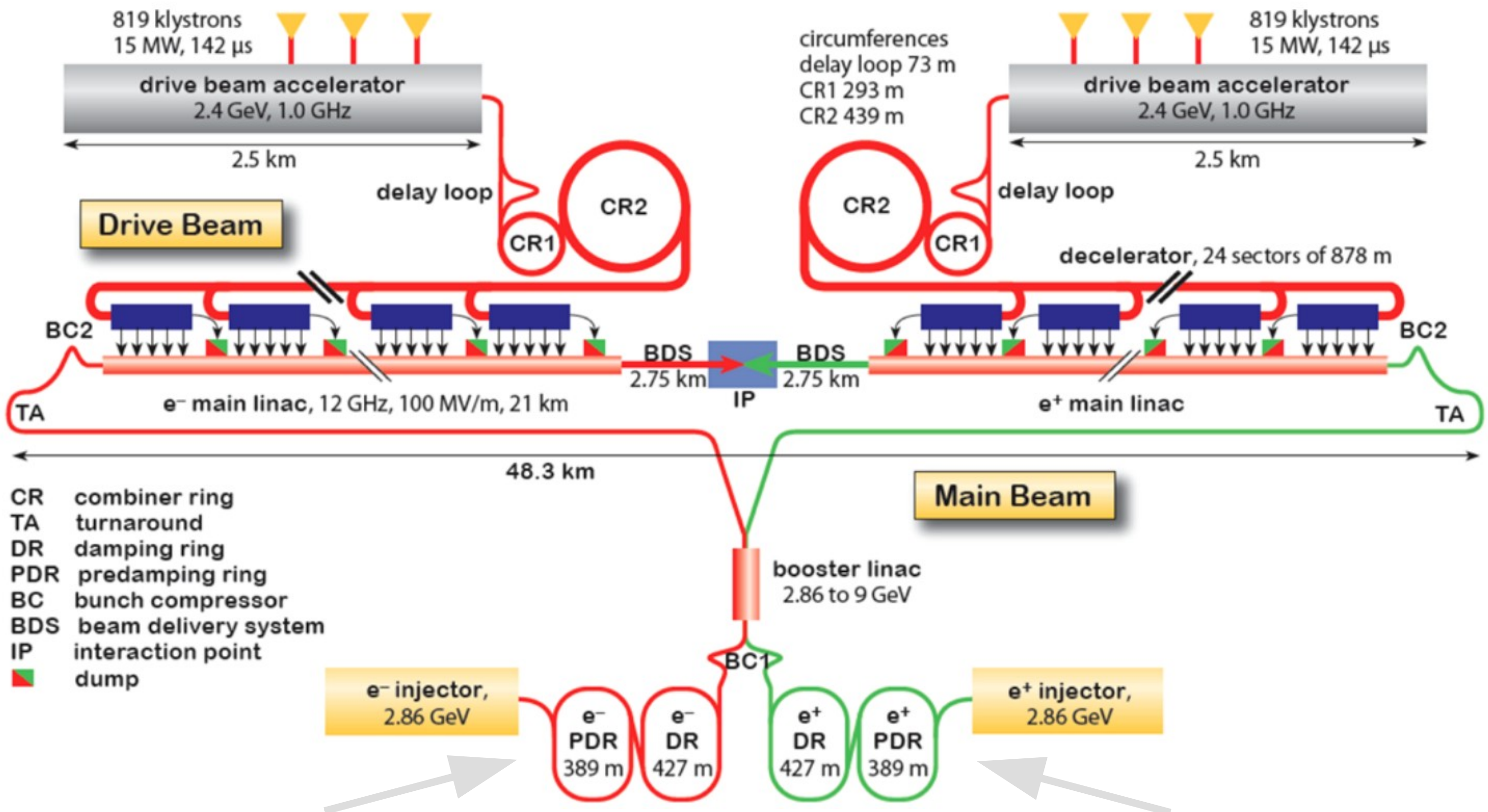
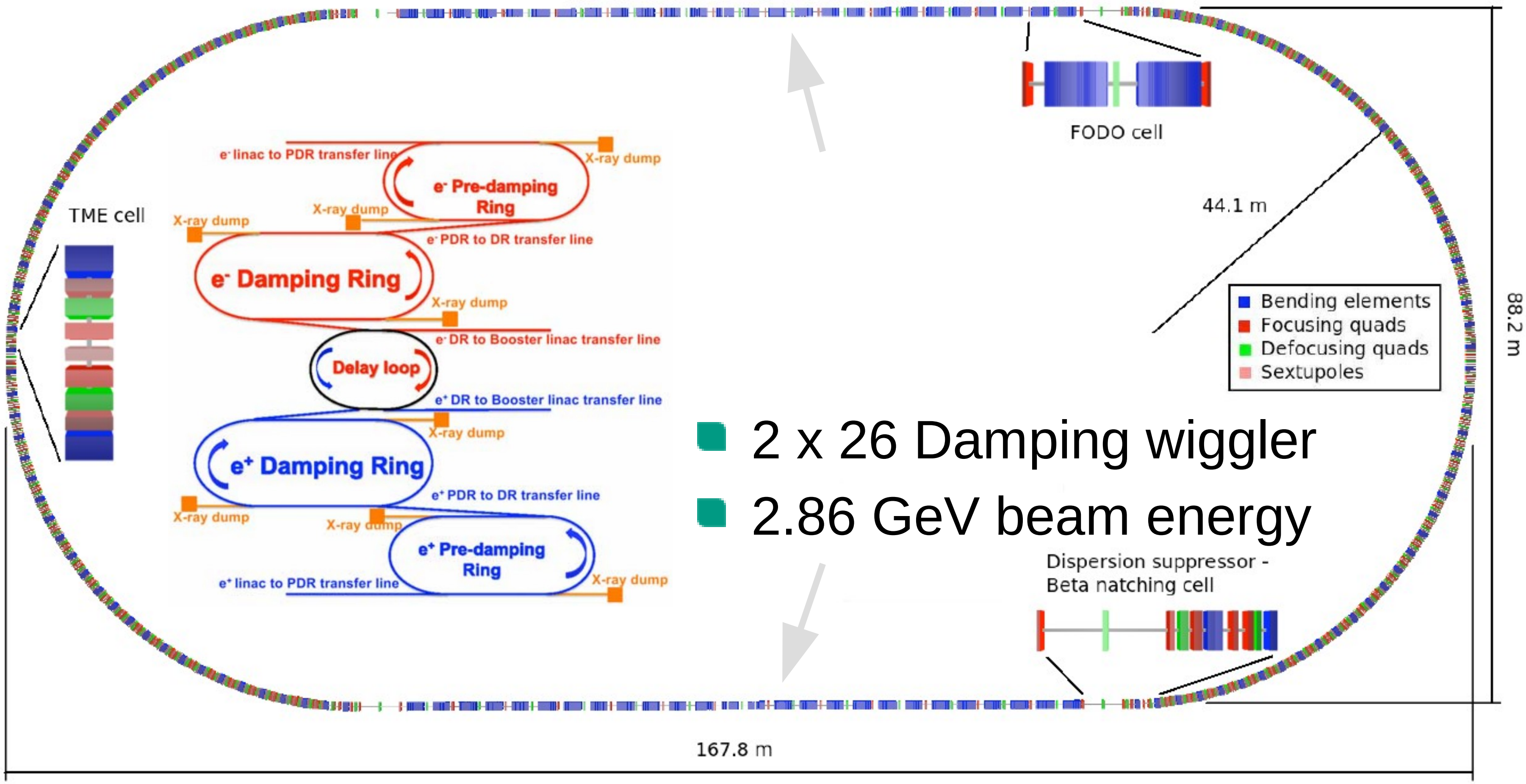


Figure: ICFA beam dynamics newsletter 62

- Very small beam size needed for high luminosity, thefore
- Damping rings (DR) needed to reach emittance requirement.

Introduction – CLIC Damping Rings



- 2 x 26 Damping wiggler
- 2.86 GeV beam energy

Cf. ICFA beam dynamics newsletter 62

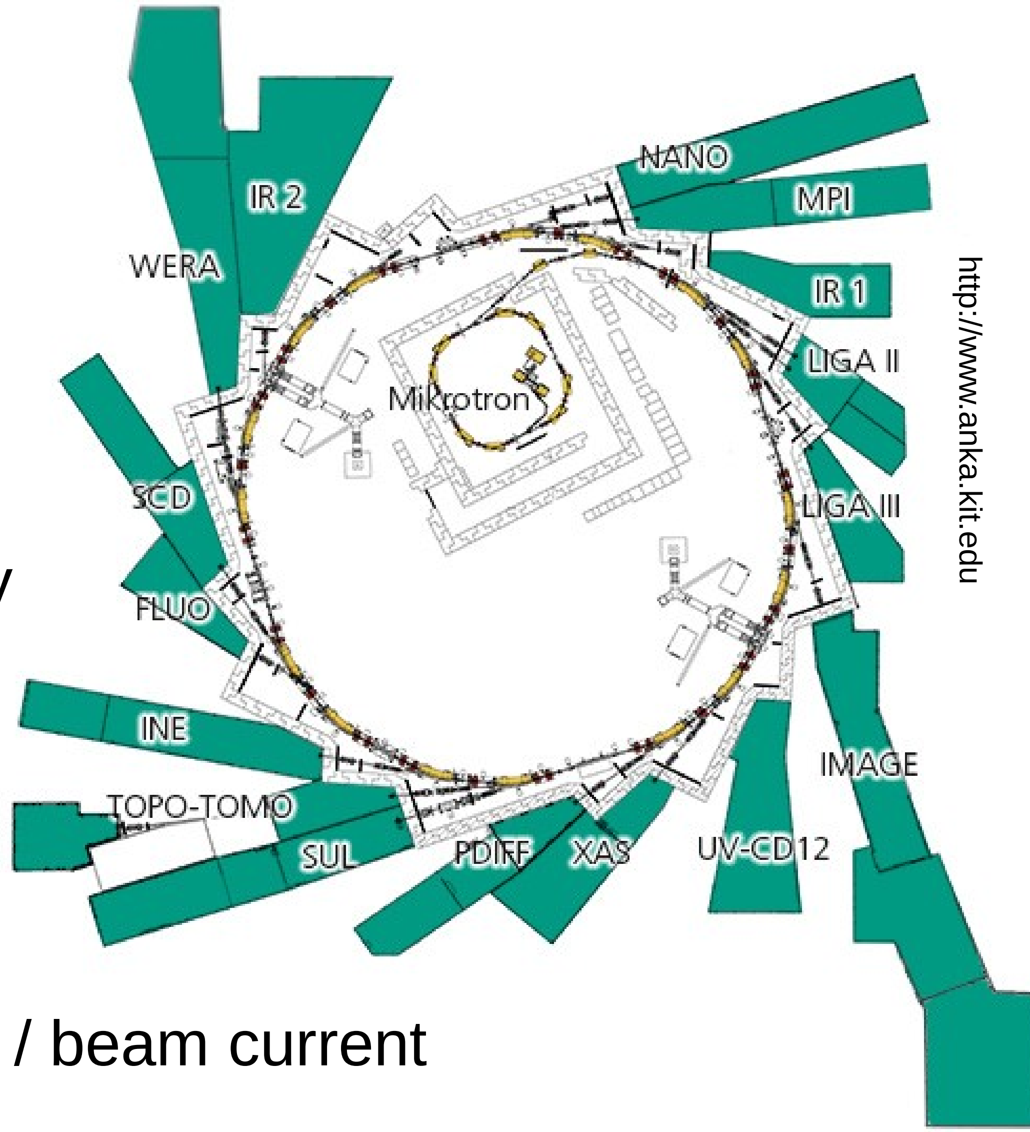
Introduction – ANKA Synchrotron

- **ÅN**gström source
  KArlsruhe at KIT

- User facility.

- Normal user operation:
  - 2.5 GeV beam energy
  - 200 mA

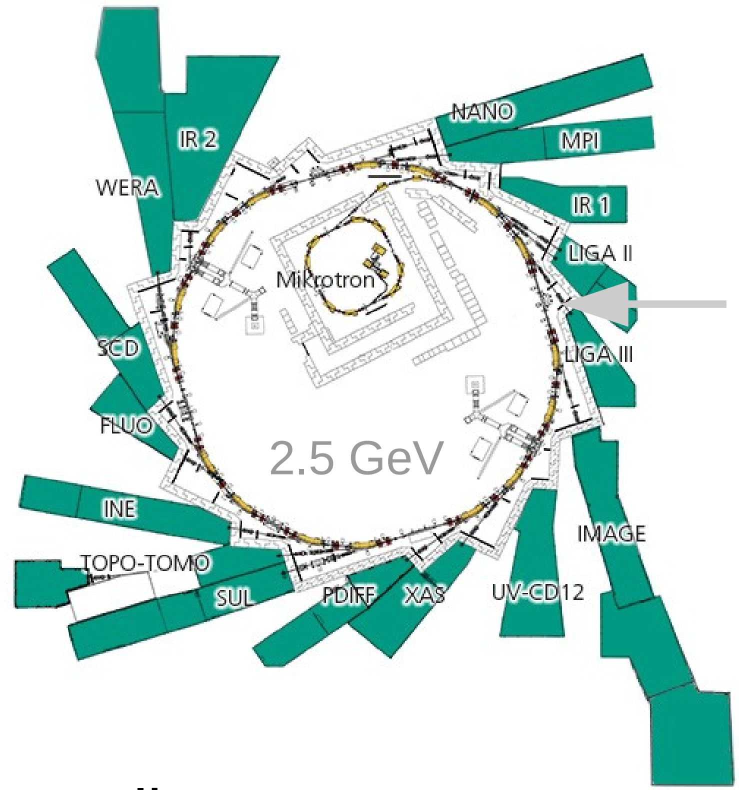
- Special user:
  - 1.3 / 1.6 GeV low-α_c
  - Variable filling pattern / beam current



S. Hillenbrand, for the KIT-CERN collaboration
CLIC workshop, February 29th 2015

Collaboration ANKA - CLIC

- Wiggler parameters interesting for both CLIC DW and as light source found.
- Wiggler developed and produced by BINP (Budker Institute of Nuclear Physics).



- Will provide hard x-rays for IMAGE beamline:
  - Light source for ANKA,
  - Long-term reliability test for CLIC DW.

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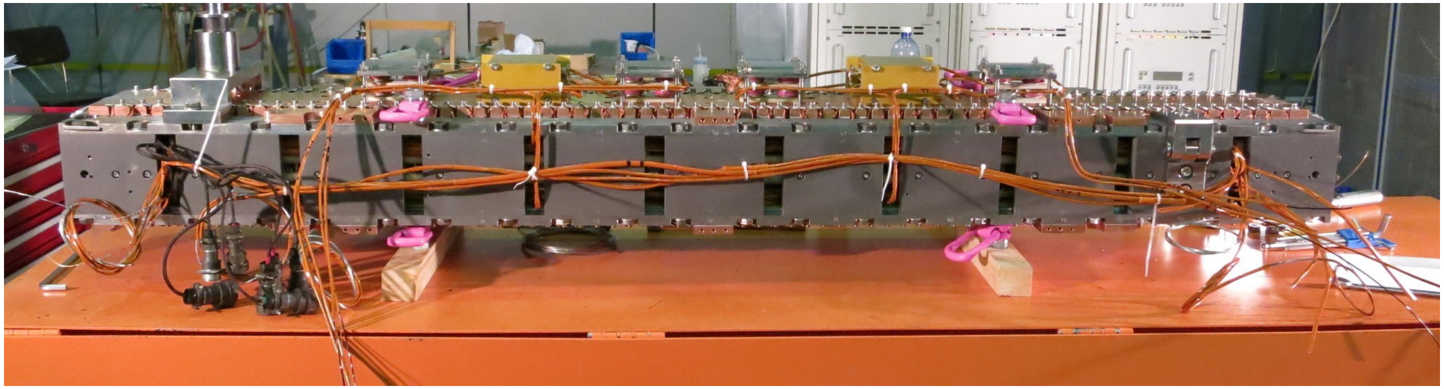
Wiggler Design Parameter

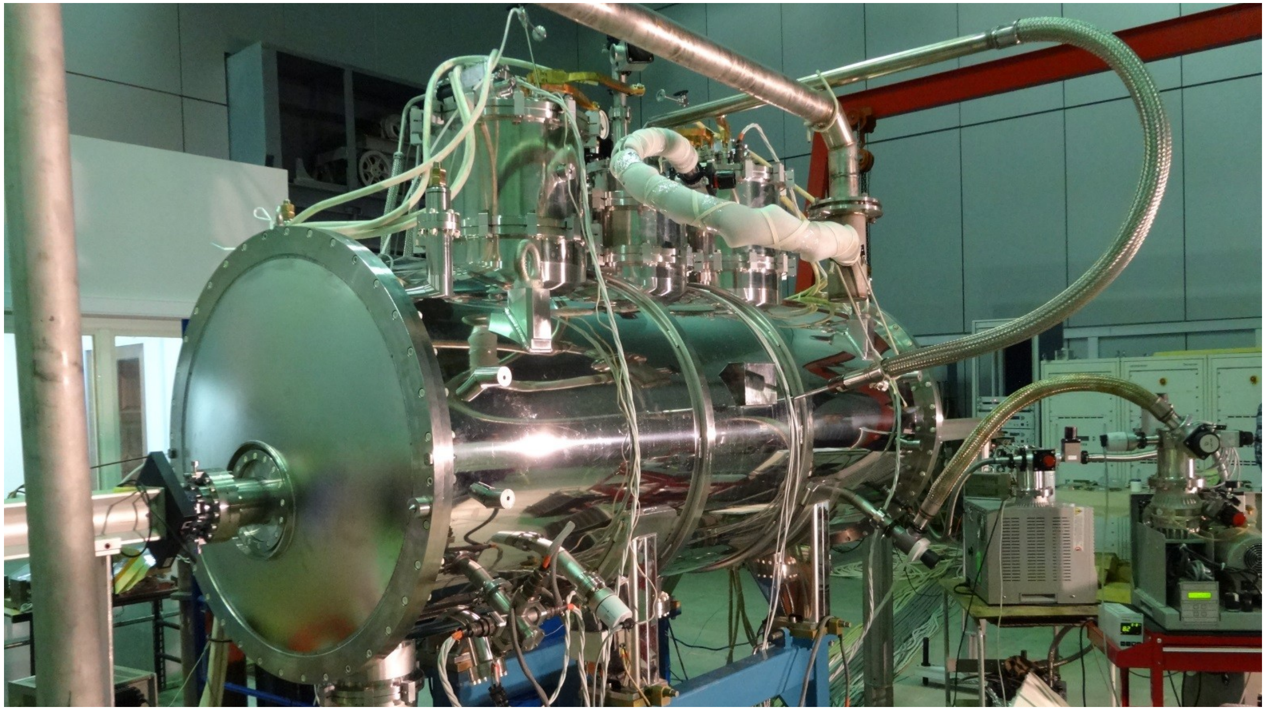
Basic parameters	
Wiggler period λ_w	$51mm$
Magnetic gap	$18mm$
Flux density amplitude on axis $\widetilde{B_y}$	$3T$
I/I_c on load line @ $T = 4.2K$	86%
$T_{quench}@\widetilde{B_y} = 3T$	$4.8K$
Number of main poles	68
Winding scheme	
1/4 coil, $N_1 I_1$	$62 \times 487A$
3/4 coil, $N_2 I_2$	$124 \times 487A$
Main, inner, $N_1 I_1$	$62 \times 487A$
Main, outer, $N_1(I_1 + I_2)$	$62 \times 974A$
Wire parameters	
Diameter (bare)	$0.85mm$
Nb-Ti:Cu ratio	1.1:1
Filaments	312

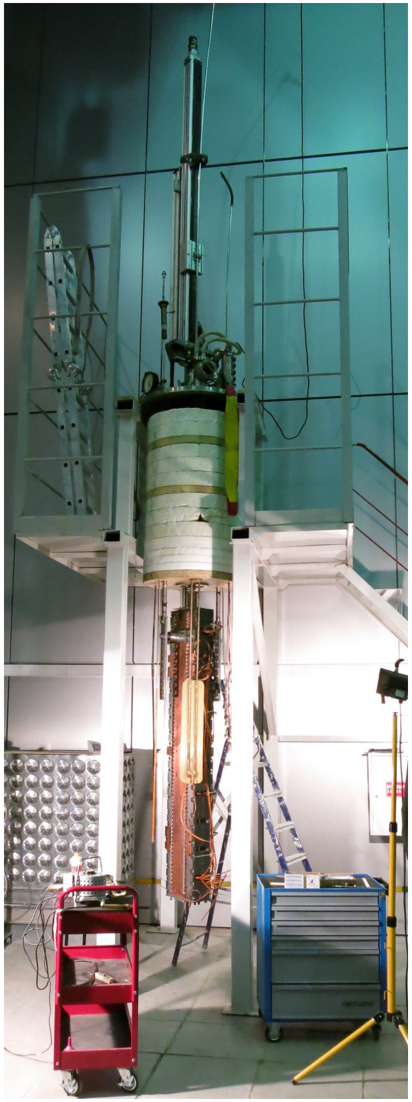
A. Bernhard, P. Ferracin, K. Zolotarev, in *ICFA beam dynamics newsletter 62*

- K = 14, compromise between high field and ANKA acceptance.
- Results in 13 kW radiated power at 200 mA beam current.
- $\varepsilon_{crit} \approx 12$ keV for 2.5 GeV beam energy.

The Wiggler at BINP







Conduction Cooling I / III

- Bath cooling:
  - established technology
- Conduction cooling:
  - Minimized coil gap
  - No pressure increase during quench
  - Easier to extract heat from beam pipe
  - Facilitates modular design

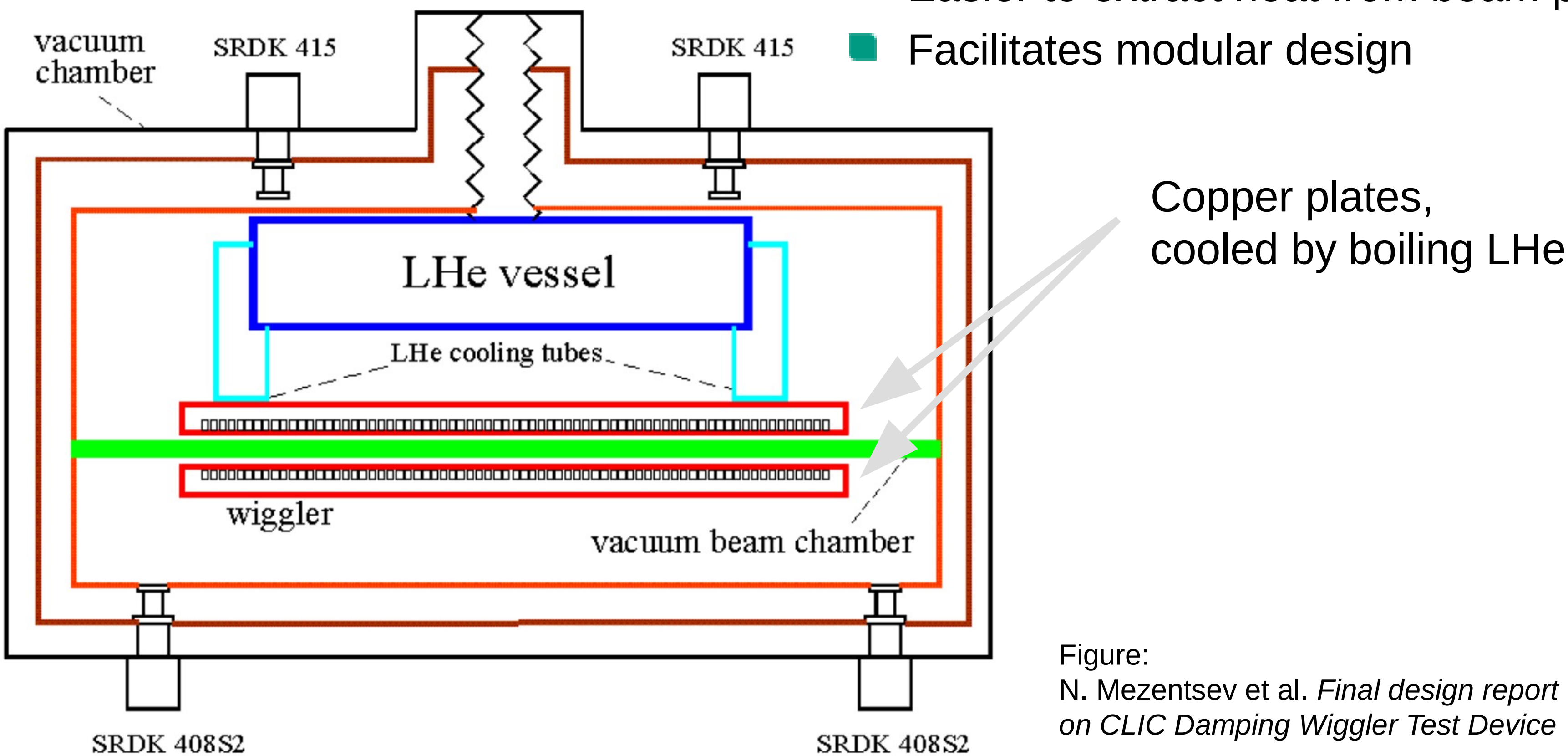
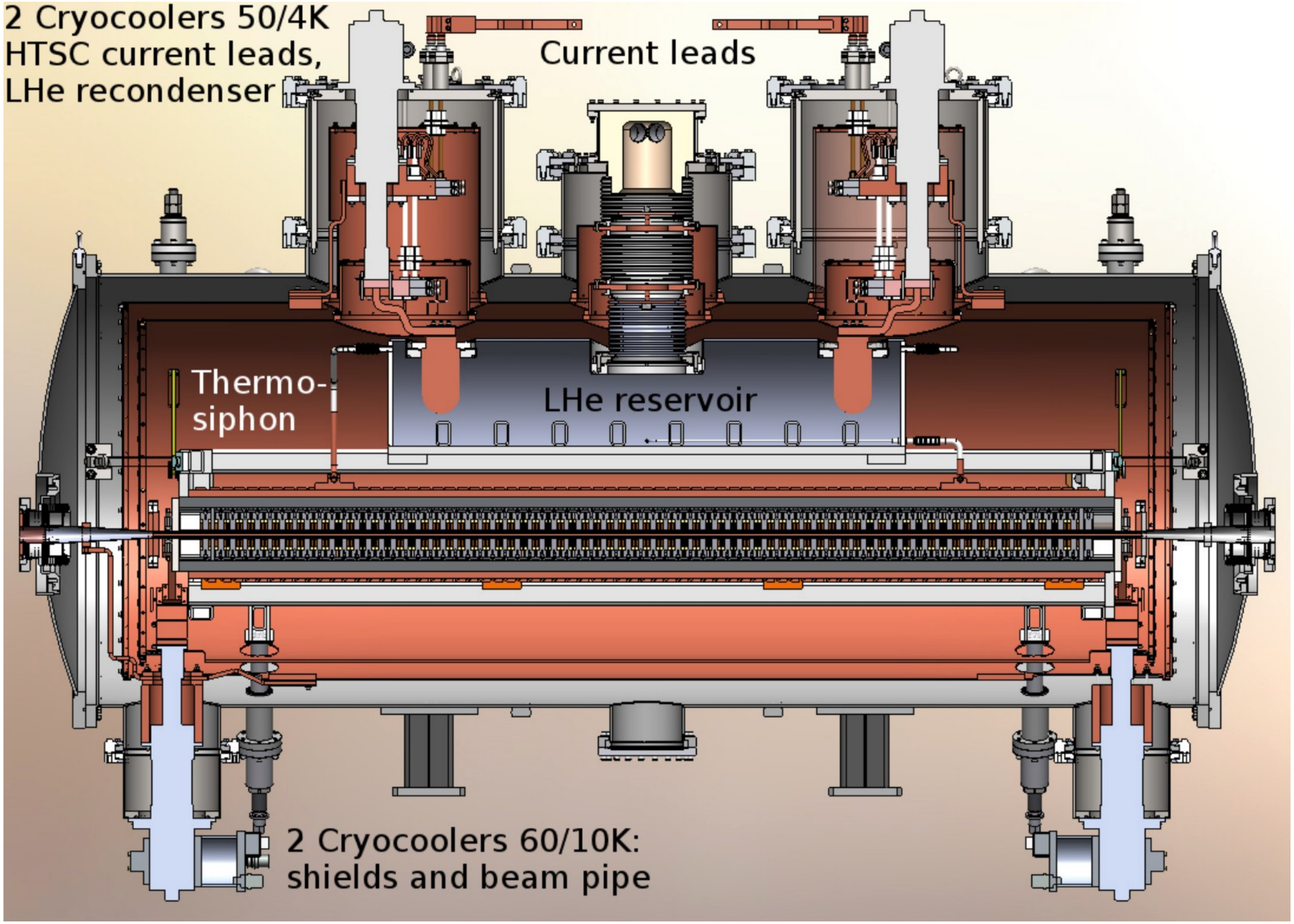


Figure:
N. Mezentsev et al. *Final design report on CLIC Damping Wiggler Test Device*

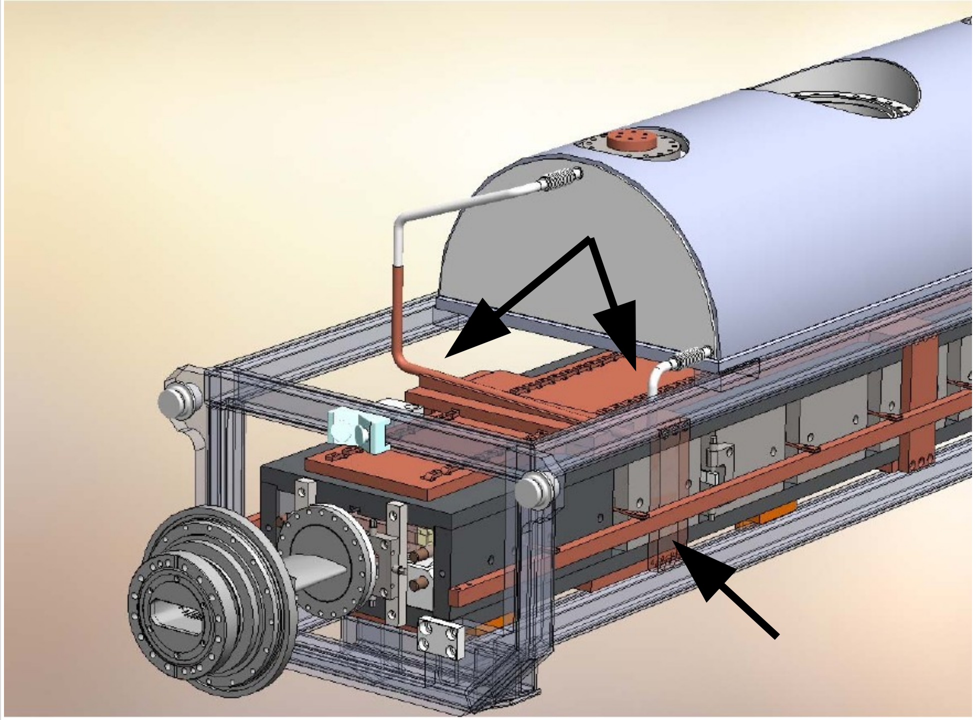
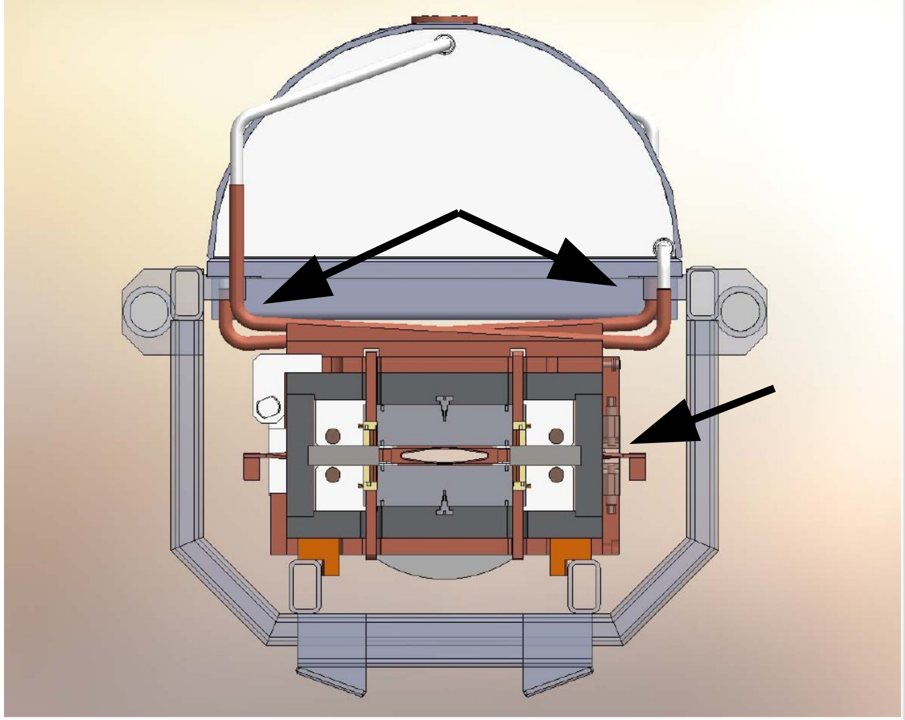
Conduction Cooling II / III



Figures:N. Mezentsev et al. *Final design report on CLIC Damping Wiggler Test Device*

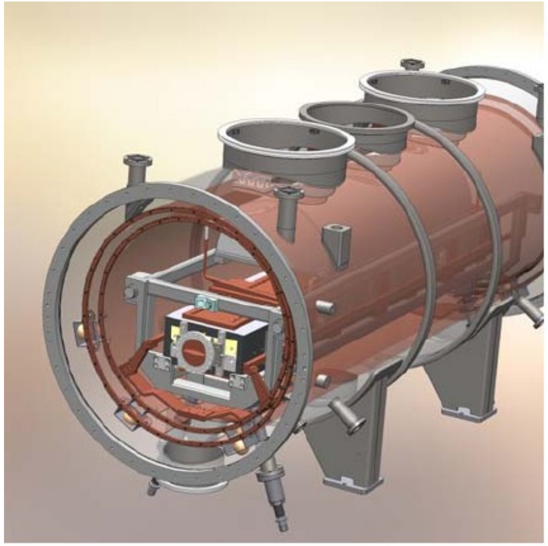
Conduction Cooling III / III

- Top coils cooled via thermo-siphons at the ends.
- Bottom coils connected to top via copper links.

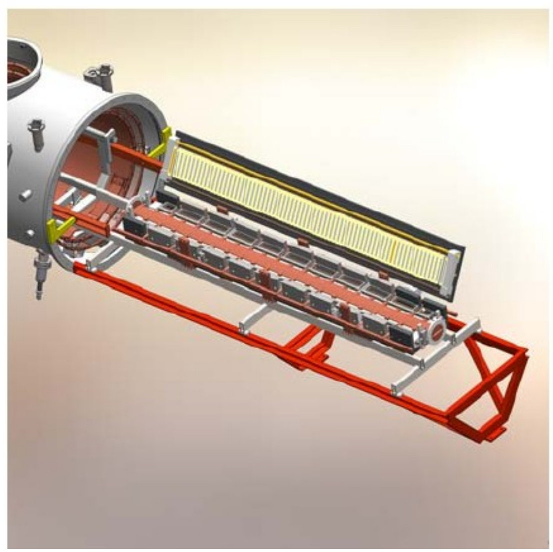
Figures: N. Mezentsev et al. *Final design report on CLIC Damping Wiggler Test Device*

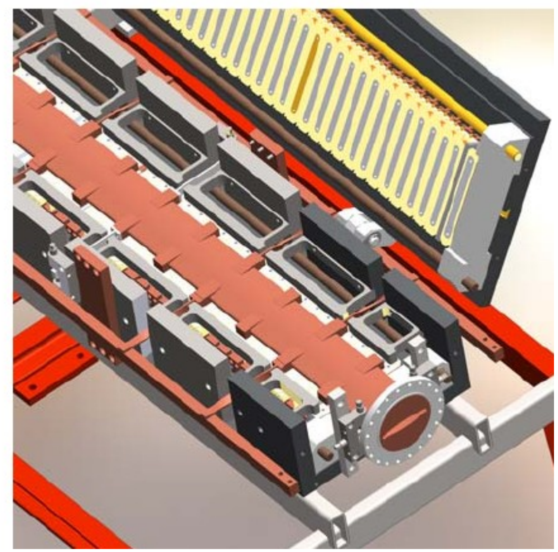
Modular Design – Easy Access



Figures:N. Mezentsev et al.
Final design report on CLIC Damping Wiggler Test Device

- ANKA:
  test of different coils and beam pipes
- CLIC-DR:
  repair / maintenance





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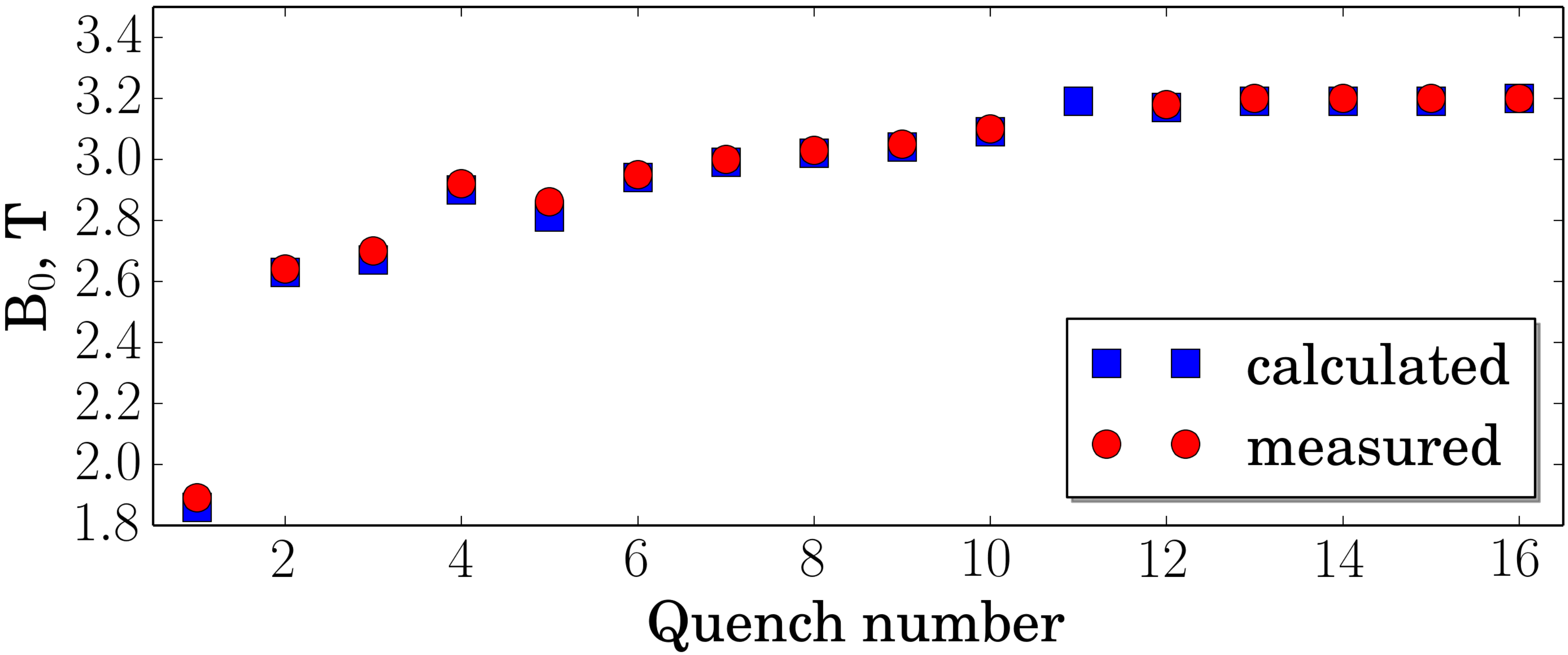
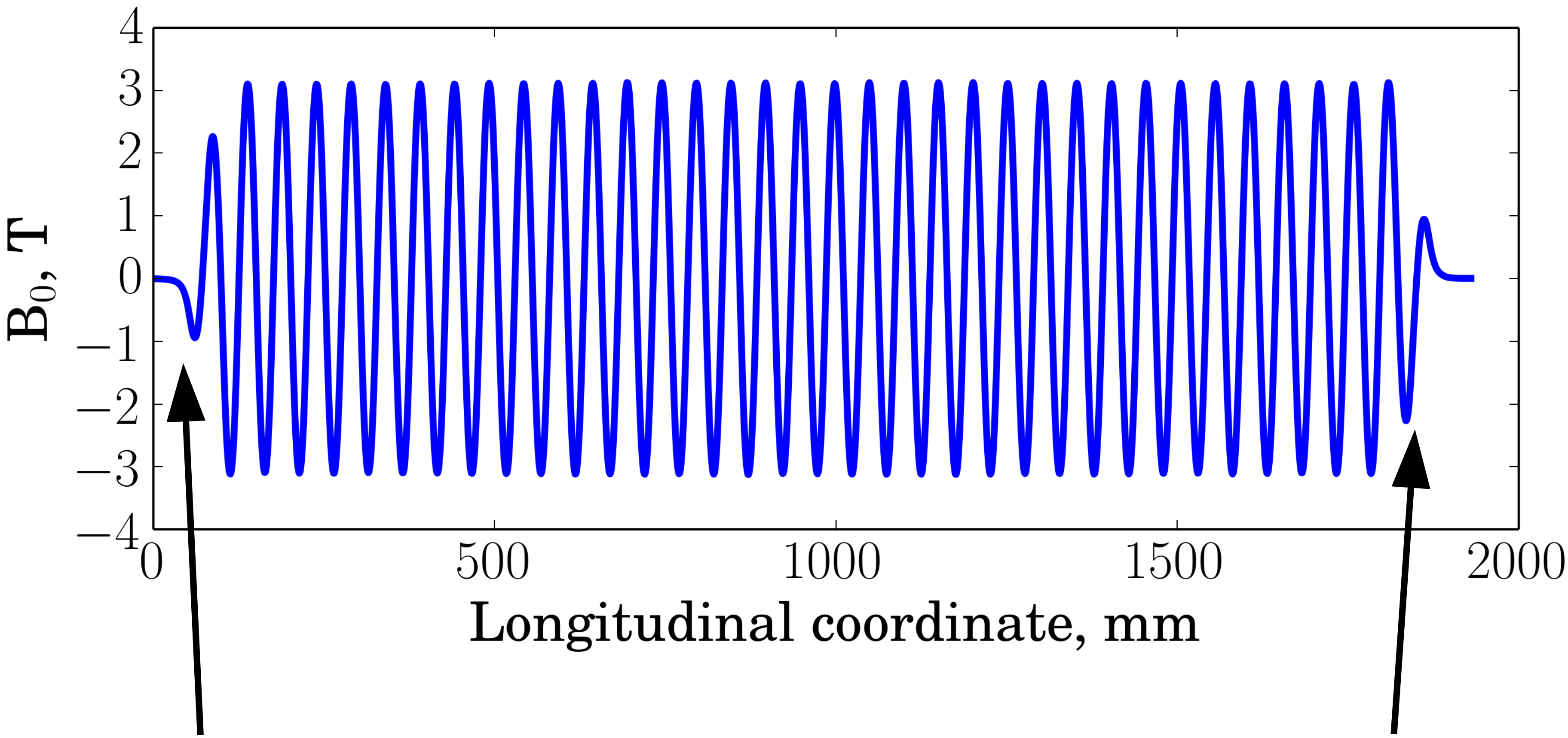
Bath test at BINP I / II

- Field of 3.2 T reached after 13 quenches at T≈4.3 K
- Lower temperature expected for final cryostat, leaving enough margin for operation at 3 T.



Bath test at BINP II / II

- Field maps have been taken for different B_0.



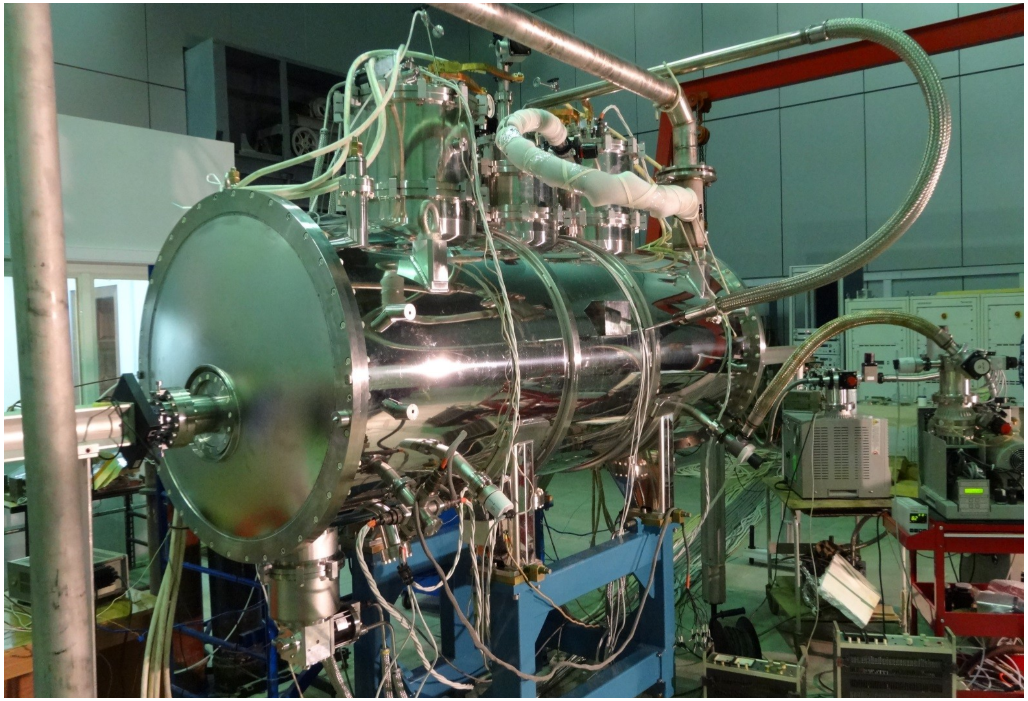
Vary I_1 / I_2 to minimize field integrals

Test in own cryostat

- Wiggler reached $T \leqslant 3.1$ K in its cryostat.

- Holding quenches happened for $B > 2.8$ T.
- $B > 3$ T reached with fast ramping of magnets.

- Tests and modifications currently ongoing.



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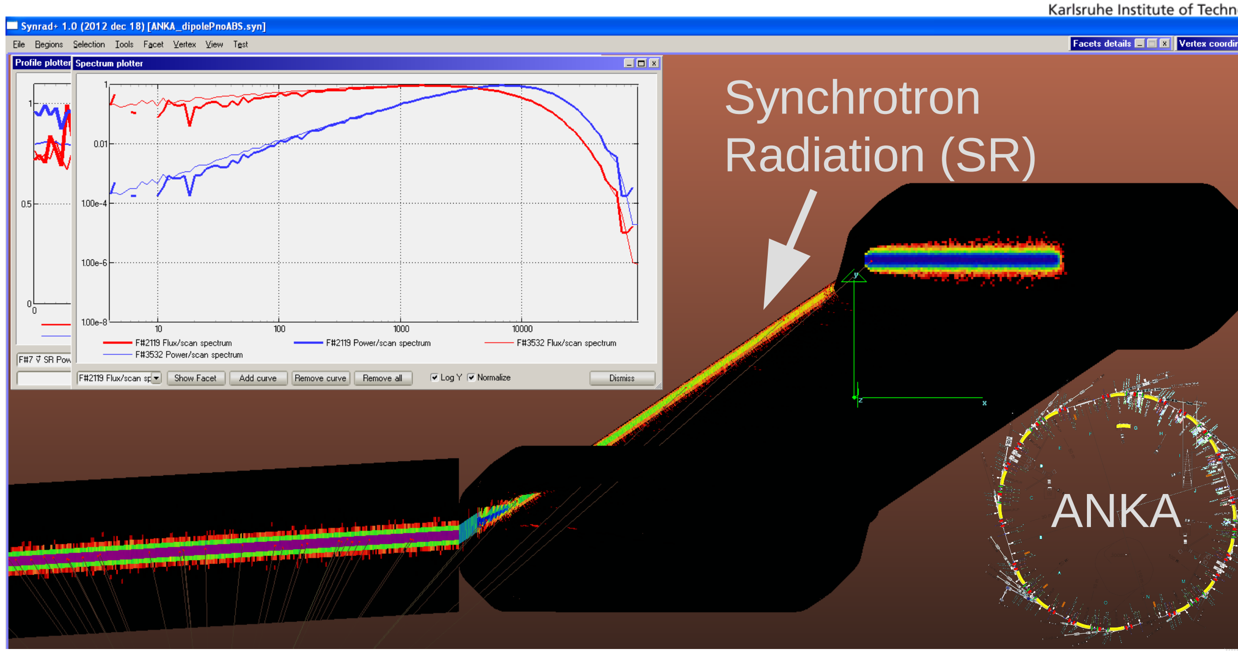
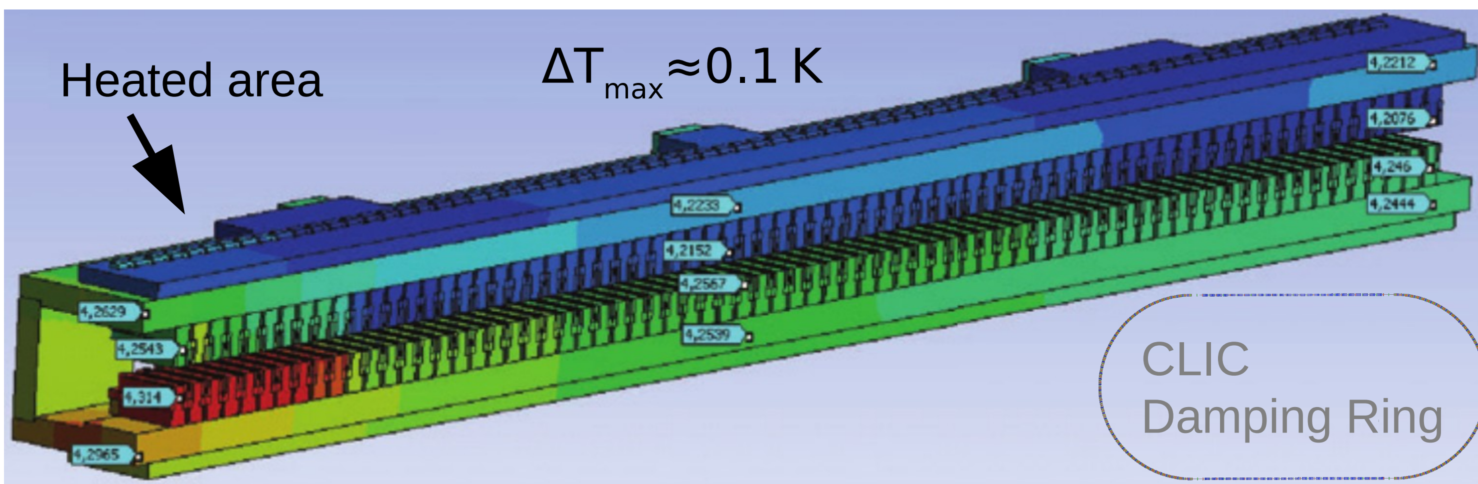
Early Experiments - Cooling

- Top:
  SR on side of chamber
- Bottom:
  Heaters to simulate DR load



M. Ady, R. Kersevan, priv. com.



A. Bernhard et al., TUPME005, IPAC13

Early Experiments – Beam Dynamics

- Influence on beam:
  - Tune shift, orbit changes;
  - Change in vacuum pressure / Beam lifetime;
  - Map higher order multipole-field via orbit variation.

- Strong collaboration with CERN.

- Methods tested using recently installed 2.5 T wiggler (CATACT).

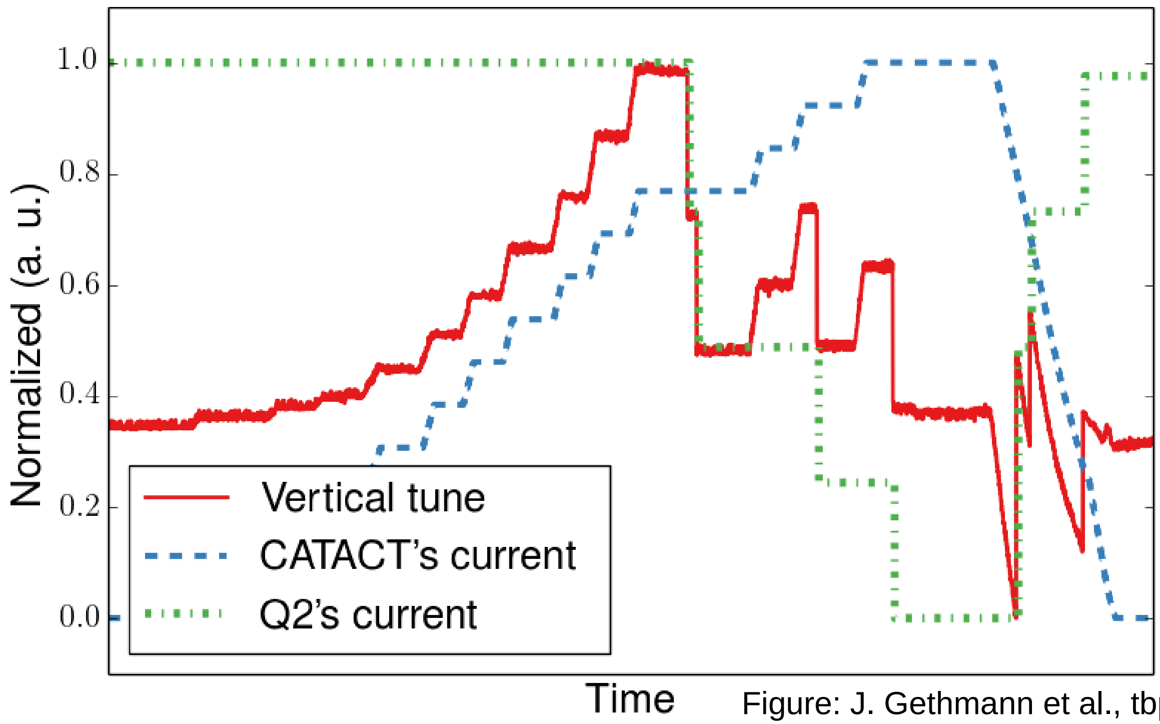
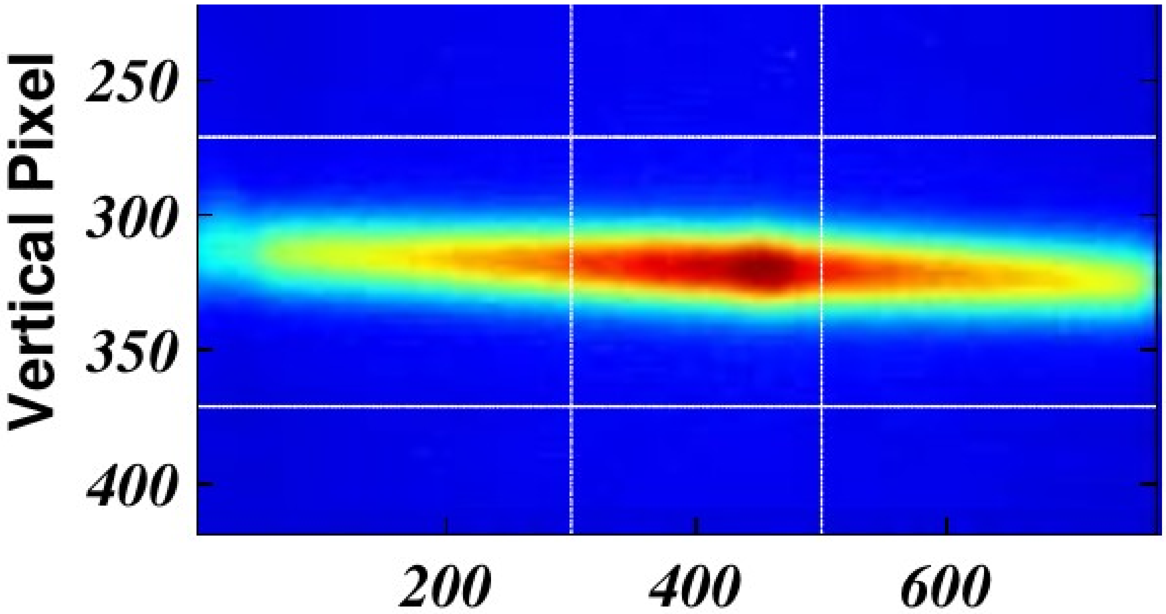


Figure: J. Gethmann et al., tbp.

Advanced Experiments I / II

- Grow-Damp measurements to measure damping time change.

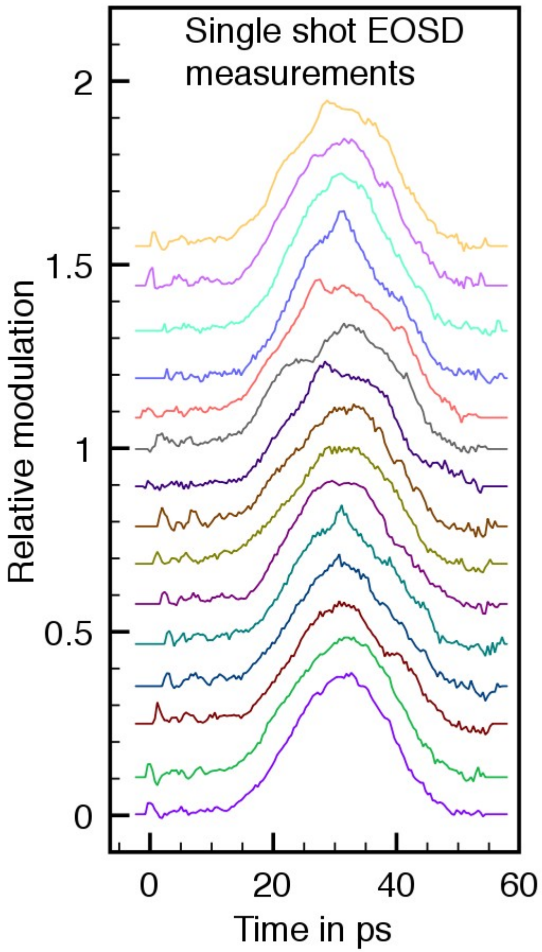


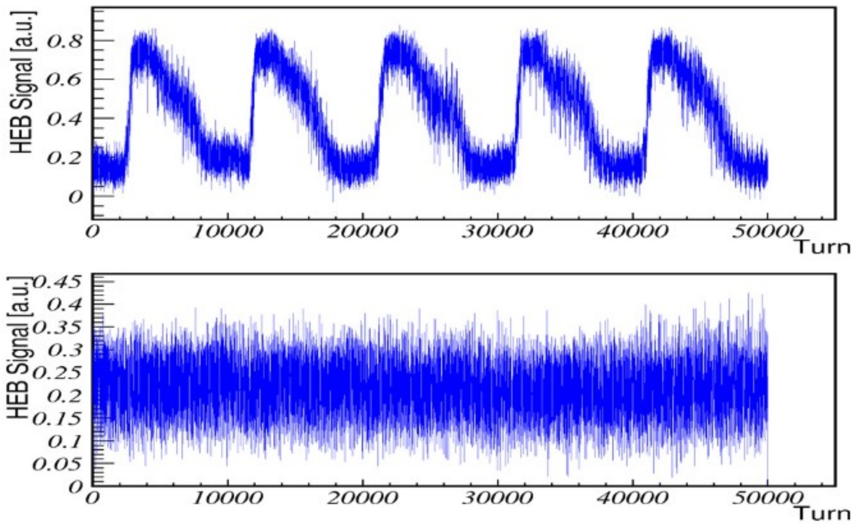
A.-S.- Müller et al., EPAC06

- Emittance measurement via synchrotron radiation based beam size measurement under investigation

Advanced Experiments II / II

- Emittance coupling horizontal / vertical
- Low-α_c at 1.3 GeV– short bunch lengths:
  - Bunch structure, CSR bursting patterns
  - Multibunch effects





Figures:
V. Judin et al., Observation of Bursting Behavior Using Multiturn Measurements at ANKA, IPAC10
N. Hiller et al., Electro-Optical Bunch Length Measurements at the ANKA Storage Ring, IPAC13

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Vision: Nb_3Sn Wiggler

- Nb-Ti as more mature technology chosen for first full-scale prototype.
- Nb_3Sn technology offers larger parameter range than Nb-Ti, but is technically more challenging.

- Nb_3Sn R&D performed in parallel at CERN.
(See talk by Laura GARCIA FAJARDO)

Figure: L. Garcia Fajardo, *Nb3Sn damping wiggler development at CERN,* Low Emittance Ring workshop 2013

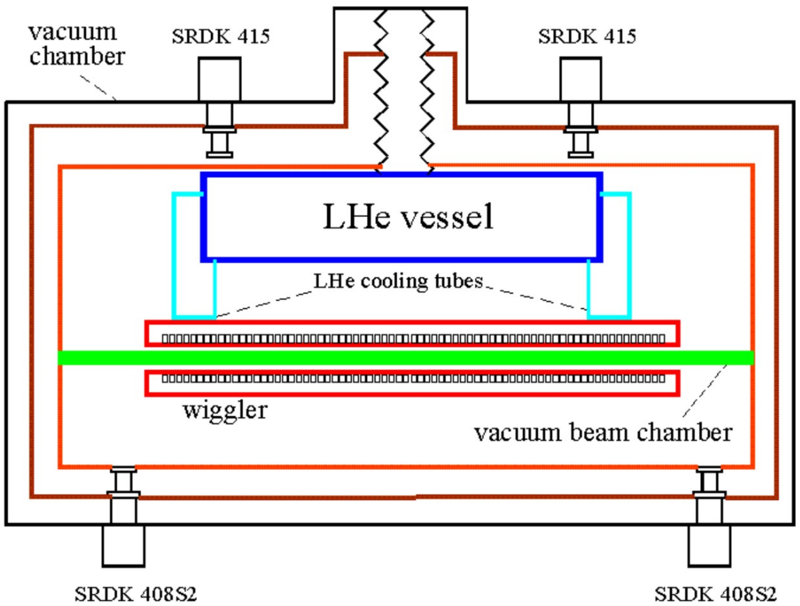
Vision: Benchmark Experiments Simulation Transient Effects

- Transient effects (quenches) difficult to simulate
  - Electromagnetic + thermal + mechanical effects
  - Strong, non-linear coupling
- Benchmark experiments necessary for code evaluation
  - Test coils, short models
  - CLIC wiggler
- Collaboration between CERN + KIT + TU Darmstadt applied for funding

Summary

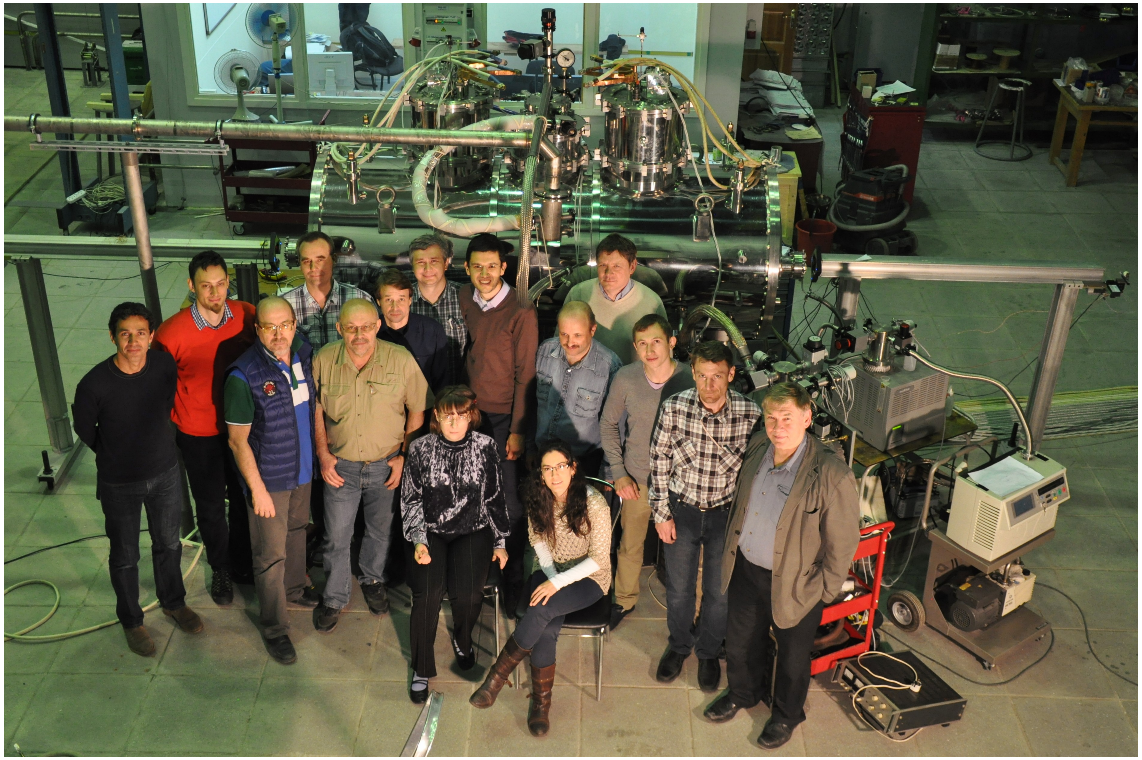
- Production of a superconducting Nb-Ti wiggler with
  - conduction cooling,
  - modular design

  at BINP is almost finished.

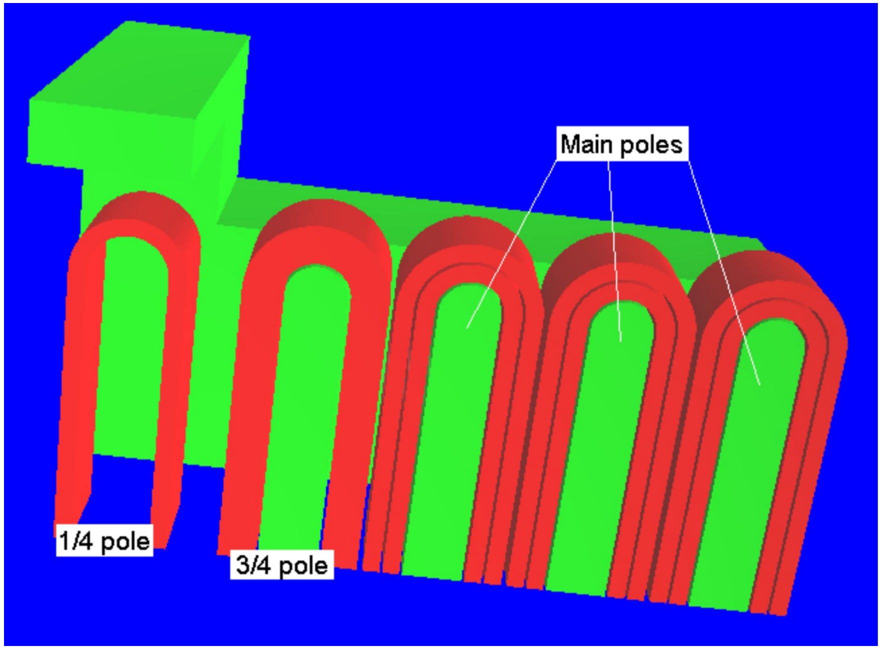


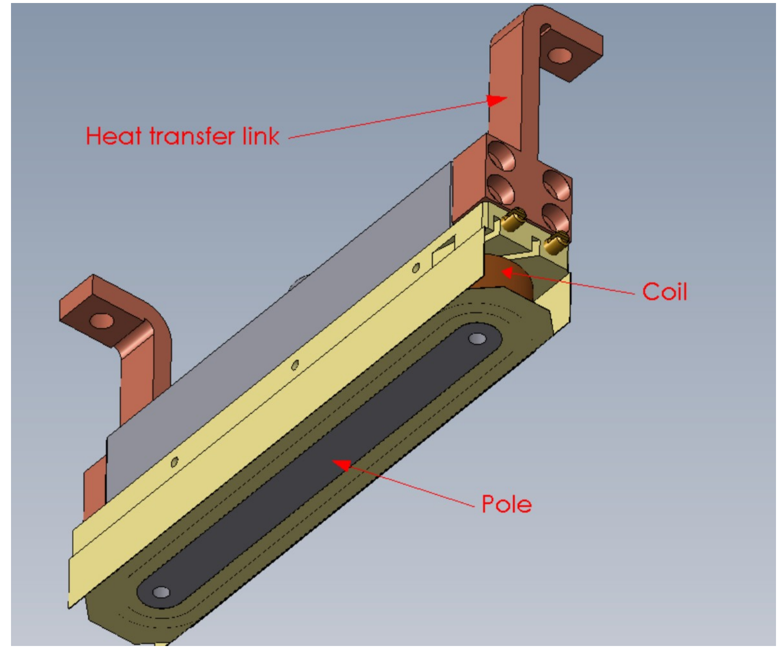
- It will serve both as
  - light source at ANKA,
  - long-term test of damping wiggler prototype.

Thank you for your attention!



Coil Geometry





A. Bernhard et al., in *ICFA BDN 62*,
N. Mezentsev et al. *Final design report on CLIC Damping Wiggler Test Device*

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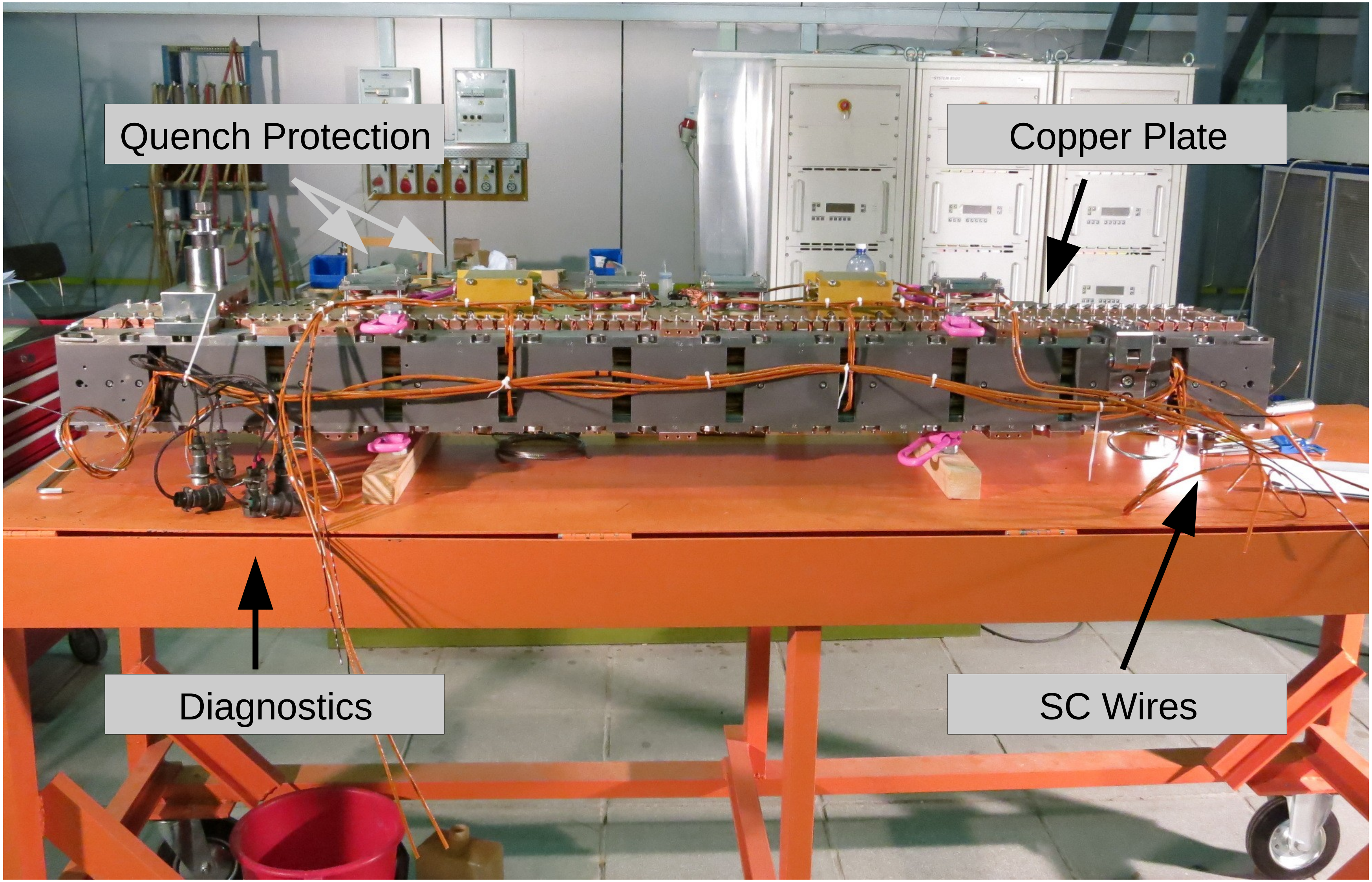
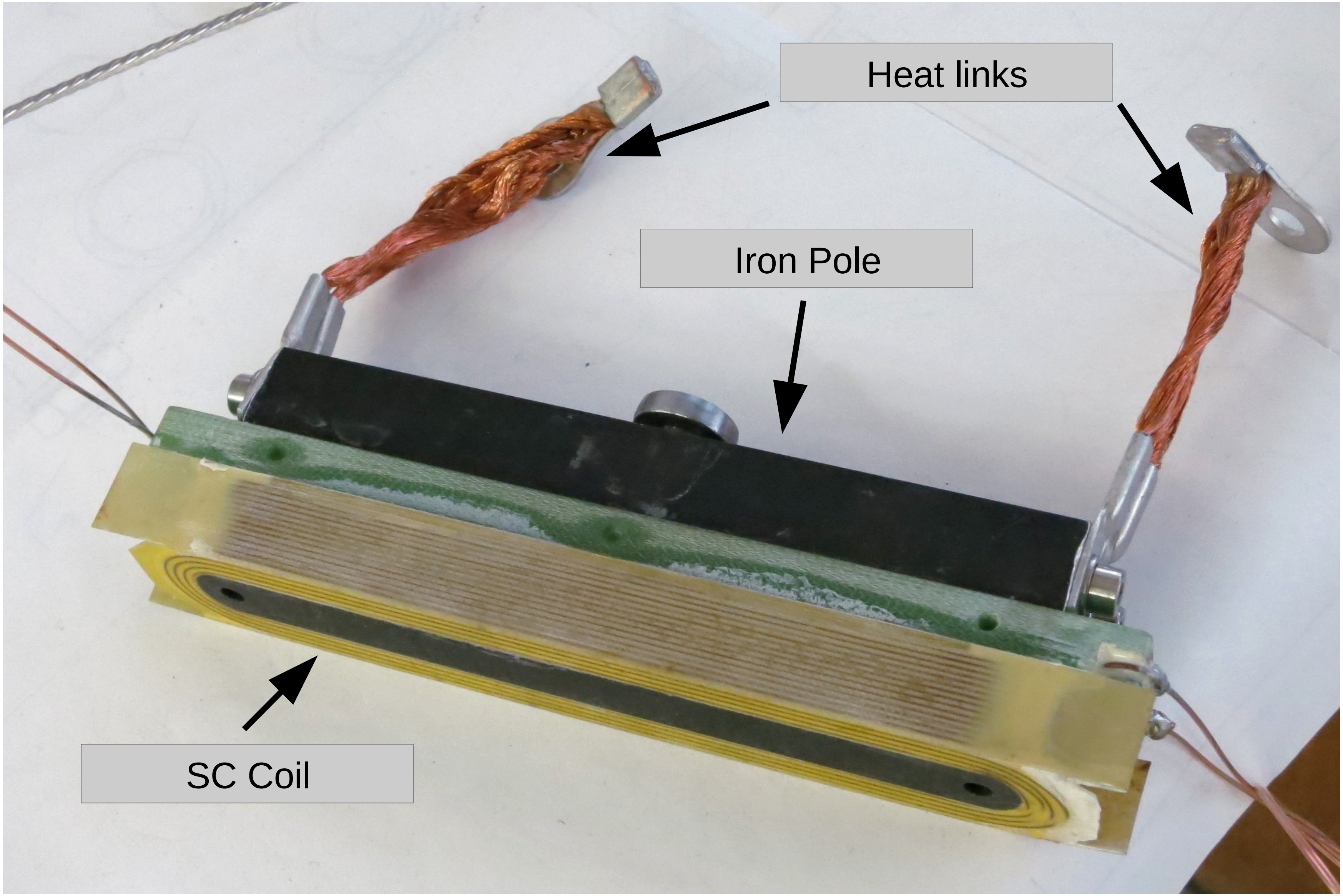
3/4 coil, $N_2 I_2$	$124 \times 487A$
Main, inner, $N_1 I_1$	$62 \times 487A$
Main, outer, $N_1(I_1 + I_2)$	$62 \times 974A$

- Powering outer poles separately allows to compensate field integrals, i.e. influence on beam.
- Main poles powered by I_1+I_2.

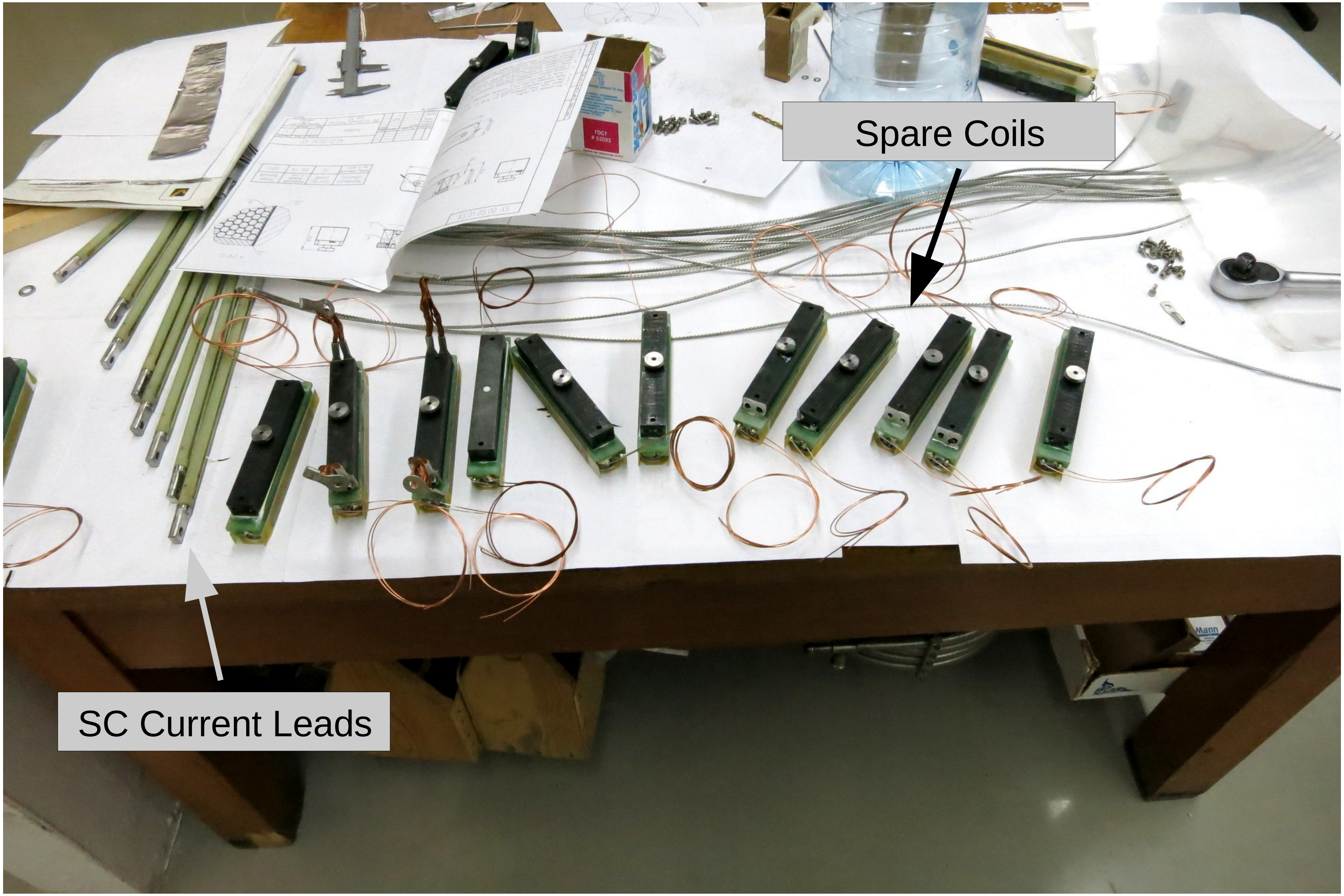
CLIC Damping Wiggler



Superconductive Coil



Superconductive Coils II



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