Magnetic measurements at Danfysik

IMMW 18

Christopher W. Ostenfeld
Application Physicist, Ph.D.

1964 - Danfysik A/S was founded by Ejnar Jespersen

Company history – headlines

DANFYSIK

- 1964 – Founding of Danfysik A/S

- 1964 – First power supplies
- 1967 – First ion accelerator system
- 1974 – First synchrotron magnet system
- 1995 – First insertion device

- 1997 – First turnkey synchrotron
- 2001 – First synchrotron X-ray beam line
- 2006 – First particle therapy synchrotron(Siemens agreement)

- 2007 – X-ray beam lines business sold off
- 2008 – Particle therapy business sold off to Siemens

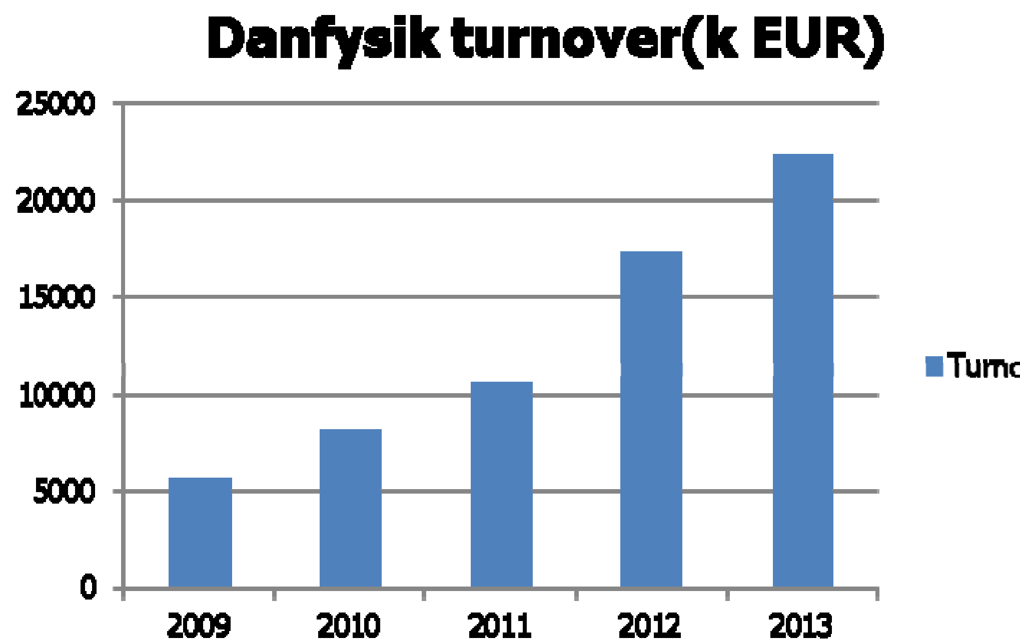
- 2009 – New owner – Danish Technological Institute

  27 people at Danfysik at this time...

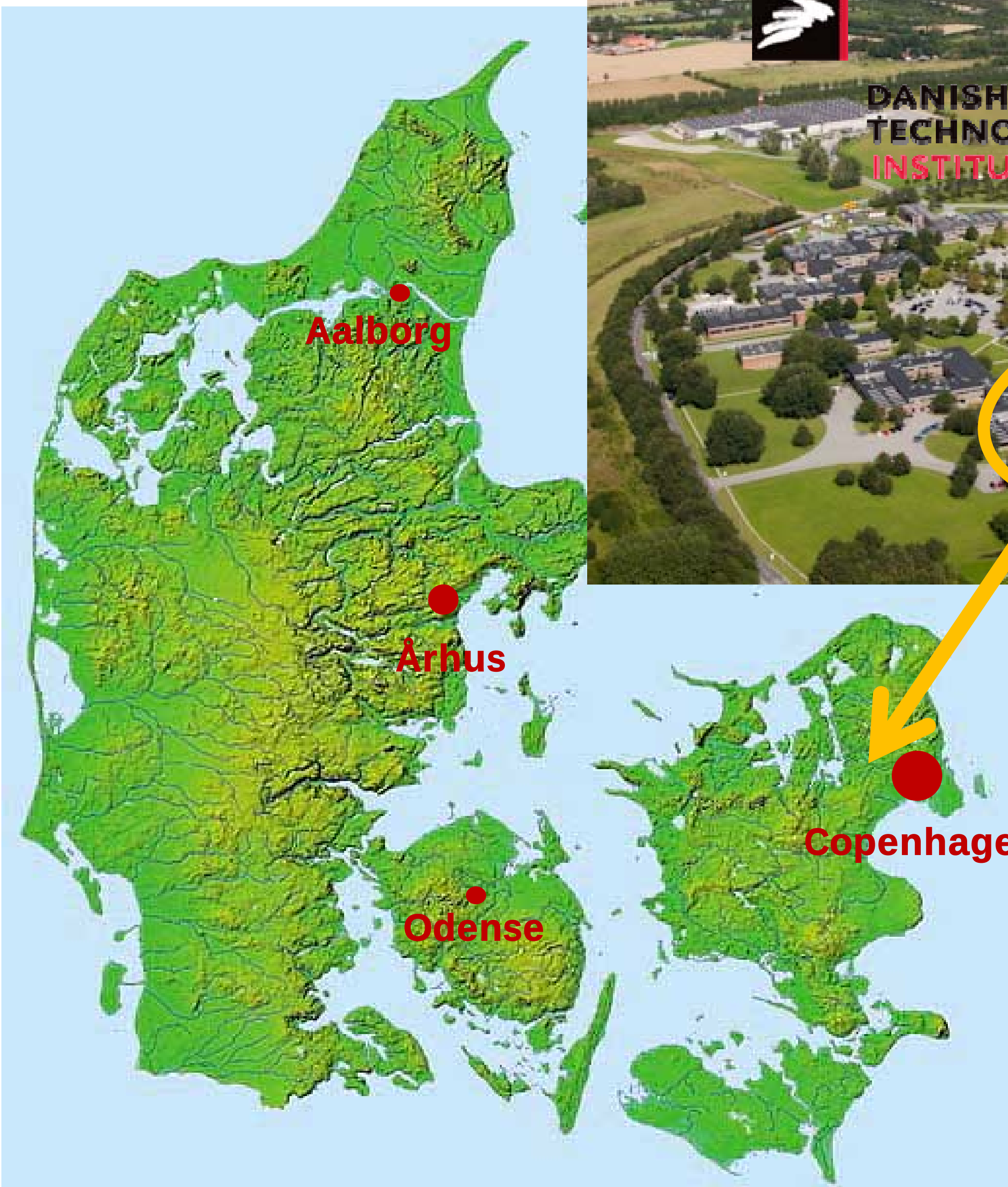
Since 2009

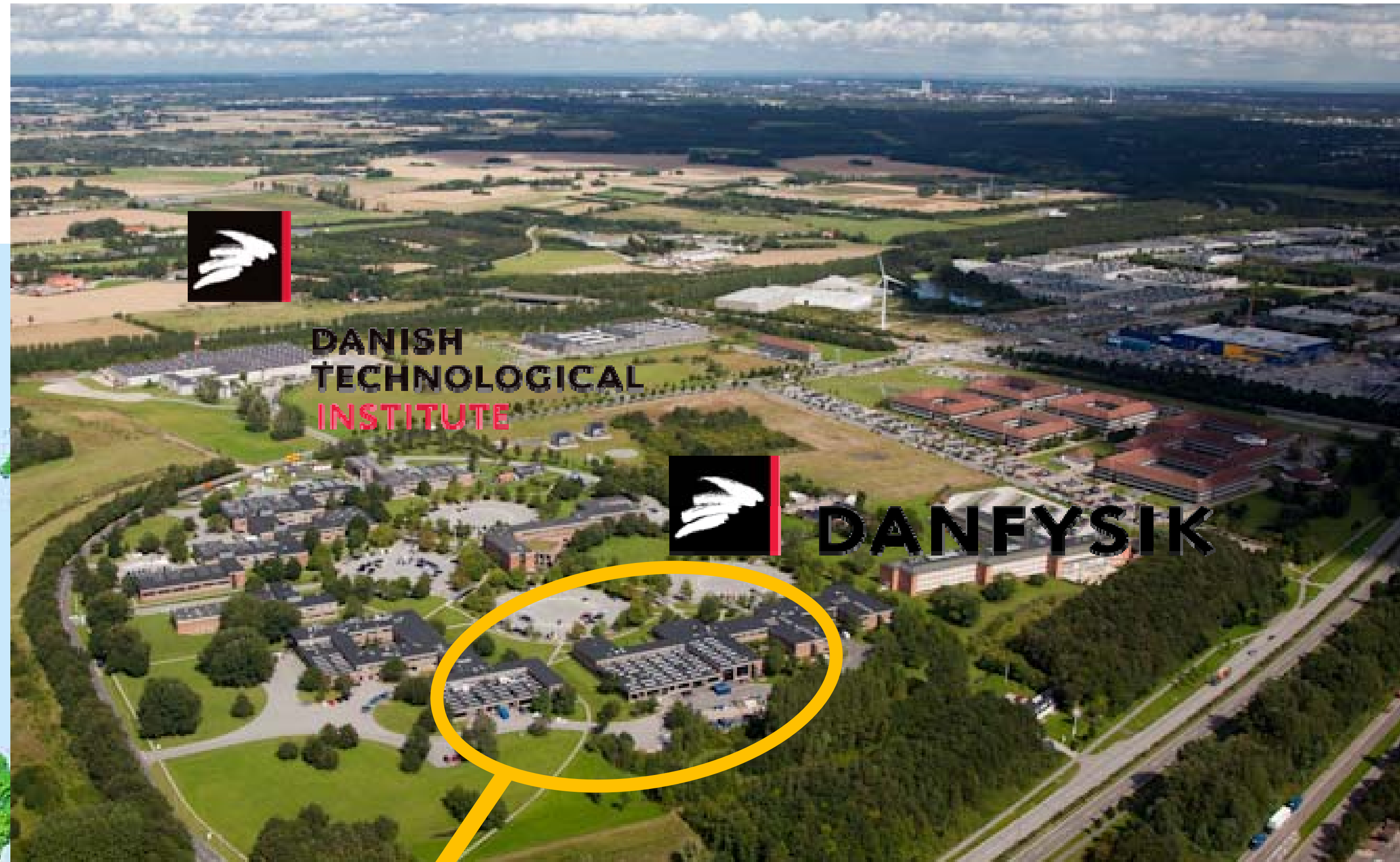
DANFYSIK

- Key (large) projects
  - NSLS-II Standard Sextupoles
  - ASTRID-II complete girder sections
  - NSLS-II Damping Wigglers
  - Maxlab 3 GeV girders
  - Maxlab 1.5 GeV girders
  - Solaris 1.5 GeV girders
  - Service agreement with Siemens towards Shanghai accelerator installation and service
- Currently 104 people are employed
  - Engineers, physicists, administration, production staff



Location





- Taastrup,
  ~ 20 km west from downtown CPH
- Approx. 30 min from CPH airport

Danfysik today

Staff : 104

Design & Projects:	30
Production and Logisitics:	40
Admin., Sales & Service:	20
Particle Therapy:	14

Annual turn-over:

approx. 15 M€

Ownership:

100% subsidiary of Danish Technological Institute

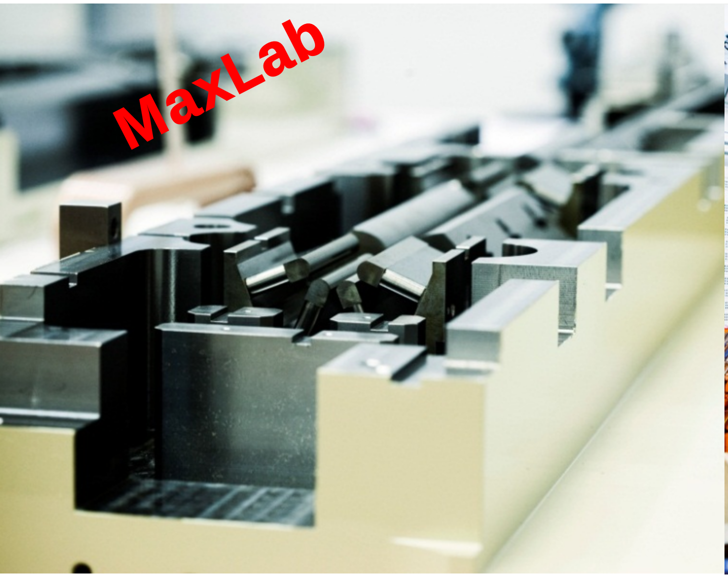
Danfysik turn-key accelerator systems

- Ion implanters and isotope separators (many systems)
- Booster synchrotrons and microtrons
  - ANKA (Karlsruhe, Germany)
  - CLS (Saskatoon, Canada) 2.9 GeV, Ø 35 m
  - Australian Synchrotron (Melbourne, Australia), 3 GeV, Ø 42 m
- Particle therapy systems
  - RKA/Siemens Healthcare in Marburg, GER, 450 MeV/n, Ø 21 m
  - Siemens Healthcare in Shanghai, China, 450 MeV/n, Ø 21 m

DANFYSIK products

Magnet technology

- Normal and superconducting magnets
- State-of-the-art magnetic field calculations 2D, 3D
- Manufacturing design
- Coil winding and yoke lamination
- Assembly (clean room)
- Magnetic testing (2D, 3D and harmonic content)
- Magnet measurement systems



Accelerator products, services & systems

DANFYSIK

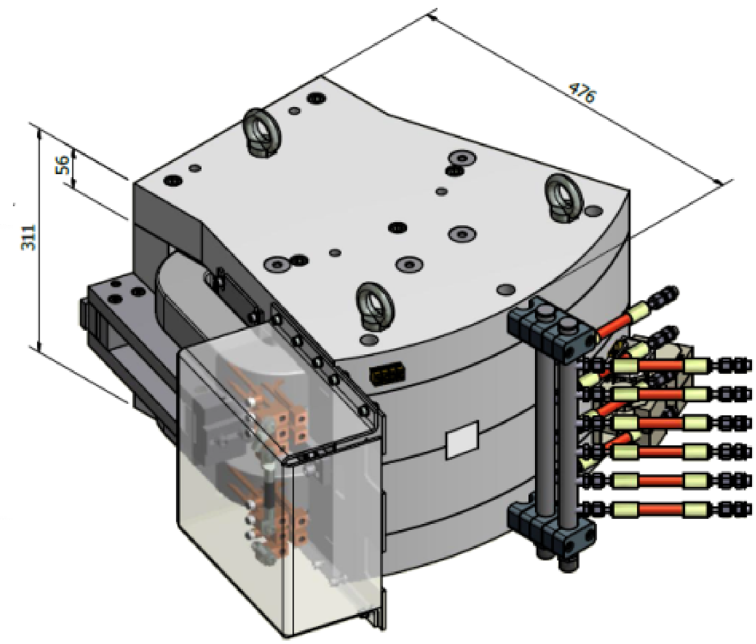
- Magnets (fast & slow), electrostatics + related equipment
- Ultrastable power supplies + converter technology
- Insertion devices, undulators and wigglers
- Ion sources and beam diagnostics
- Ion accelerators, ion implanters and isotope separators
- Turn-key systems, electron & ion synchrotrons, microtrons
- Installation, commissioning and after-sales service

GREEN MAGNETS®

DANFYSIK

Green Magnets project

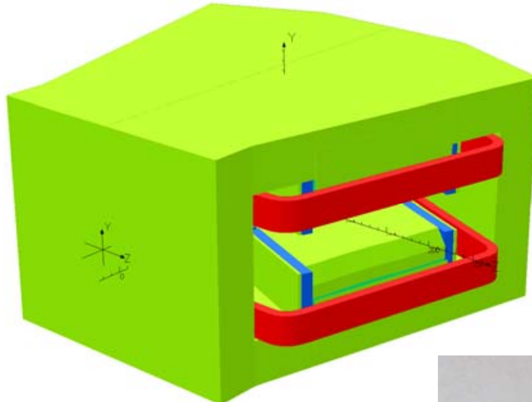
- Sustainable accelerator systems
- Reduction of total cost of ownership of magnet solutions
- New generation of highly efficient and reliable power supplies



GREEN MAGNETS®

DANFYSIK

- Permanent magnets generate a fixed field
- Trim coils for magnetic field adjustment
- Negligible power consumption
- No cooling water infrastructure
- Easy installation
- Compact design
- Lower total lifetime cost



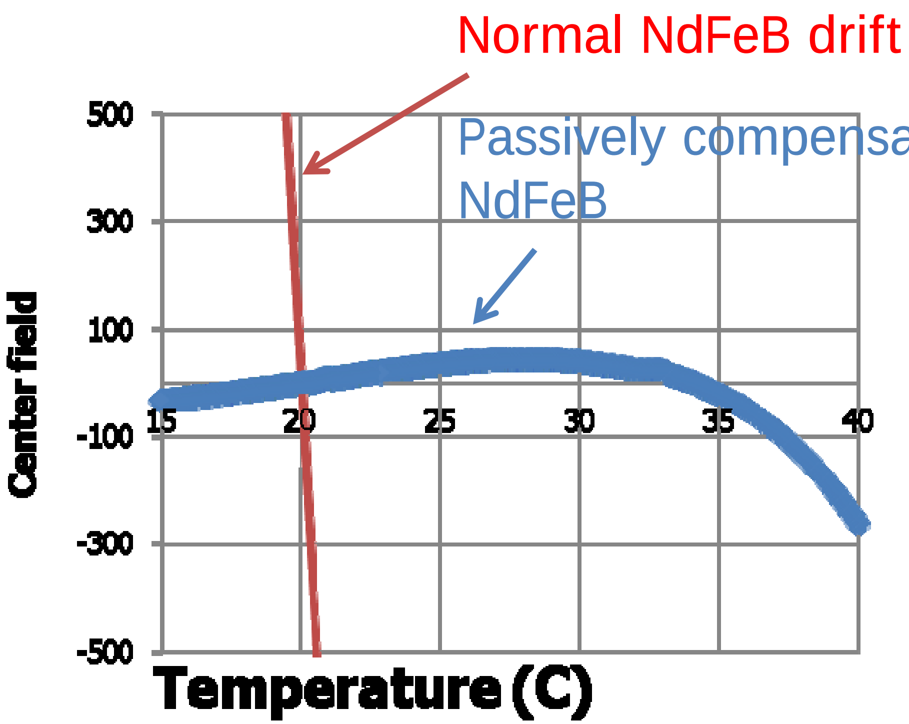
- Green Magnet was installed in an AMS facility at ETH
- Installation was found to be easy
- “We could not observe any difference to the normal operation condition using conventional electromagnets”

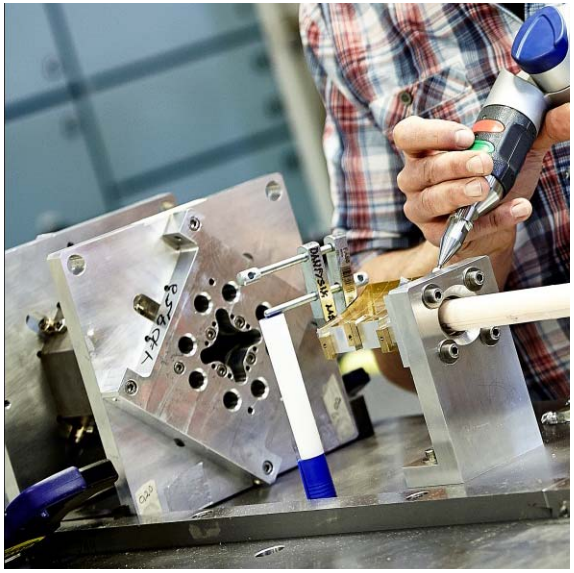
TEMPERATURE STABILITY

- Thermal drift of permanent NdFeB magnets is about 1000 ppm/°C
- Reduced to 10-50 ppm/°C
- Temperature drift can be negligible in about a 10°C range around optimum.
- Test result is shown

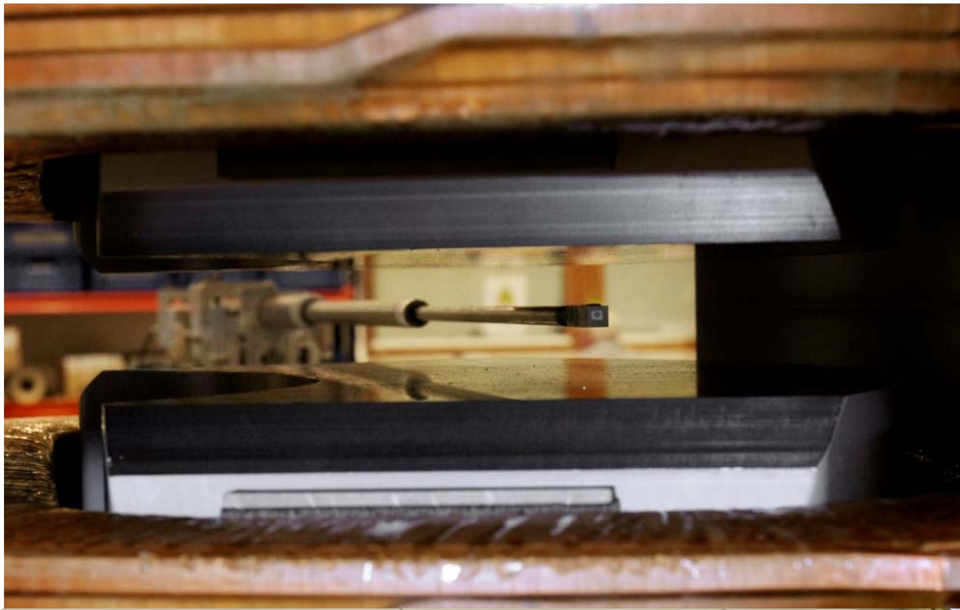
- Similarly for calibration quadrupole(PMQ)

- Very good for calibration purposes





3D field mapping with Hall



Hall probe field mapping

- Step-by-step or on-the-fly
- Mainly dipole mapping
    - Center field homogeneity
    - Shim angles

- Positioning accuracy < 0.1 mm
- Large rectangular grids can be programmed, as requested
    - MedAustron solenoid grids

Group3 Hall probes:

- Digital: ± (0.01% of reading
  + 0.006% of full scale) up to 3 Hz

- Analog: ± 0.01%
  (of reading +0.02% of full scale) up
  to 10 kHz

Rotating coil measurements

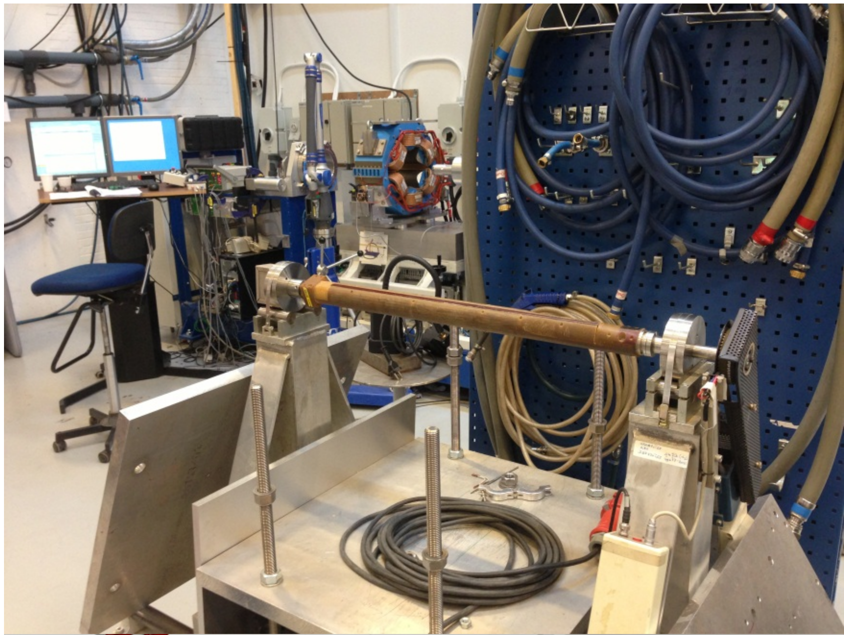
DANFYSIK

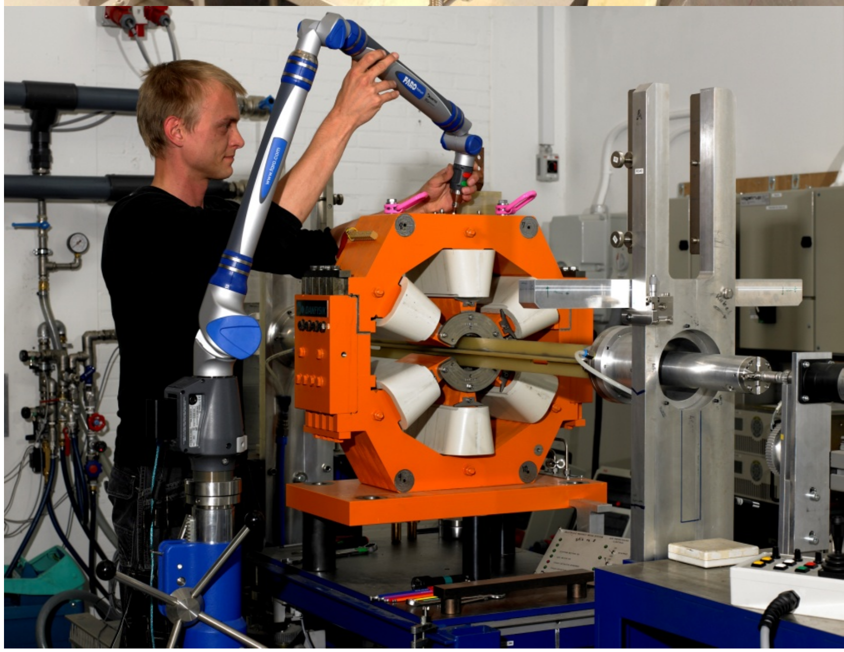
Fast rotating multipole test system 690:

- Coil length range: 500 – 1100 mm
- Existing measuring rod radii:
  - 7.6 ... 44.5 mm(compensated and non-compensated)
- Measuring in the magnet center
- Amplitude measurement
- Sold units to Bessy, RRCAT
- **Analyzes voltage**

Slow rotation multipole test system 692:

- Coil length range: Custom-built for specific magnet application.
- Tangential and radial coils
- Existing measuring radius:
  - 17, 24.5, 30, 47 , 80.5 mm
    - Quadrupole and sextupole compensated
- Magnet alignment within: ±0.03 mm, ±0.2 mrad
- Sold units to INFN, SSCL, Argonne, Bessy, RRCAT, and others
- **Analyzes integrated voltage**





Measuring bench 692

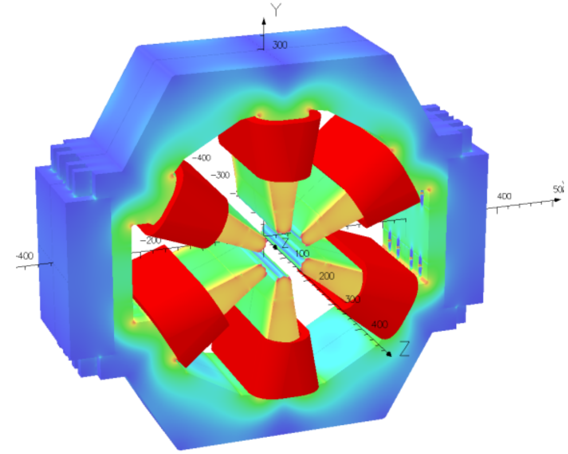
DANFYSIK

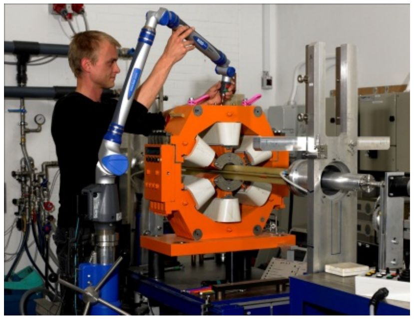
- Based on design from CERN, technology transfer
- Latest order(RRCAT) was scaled up to handle large magnets
- Coil radius up to 138 mm
- Coil length around 2000 mm
- Voltage integration using **Metrolab** new **FDI 2056** with 2 channels and encoder module
- ”Seamless” integration of FDI into our old software

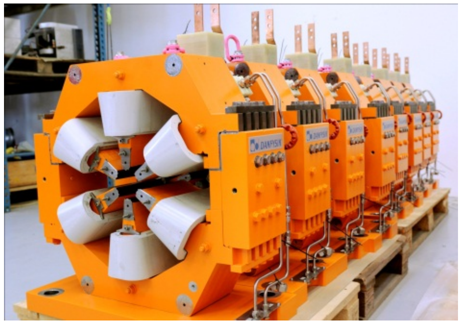
Recent measurement campaigns

DANFYSIK

- 169 Standard sextupole magnets for NSLS-II
- Tight specifications for harmonic content, and magnetic mid-plane.
- Asymmetric design
- Removable central pole(for inserting coil)
- Optimized in Vectorfields OPERA
- *Coil and raw yoke production by Scanditronix*



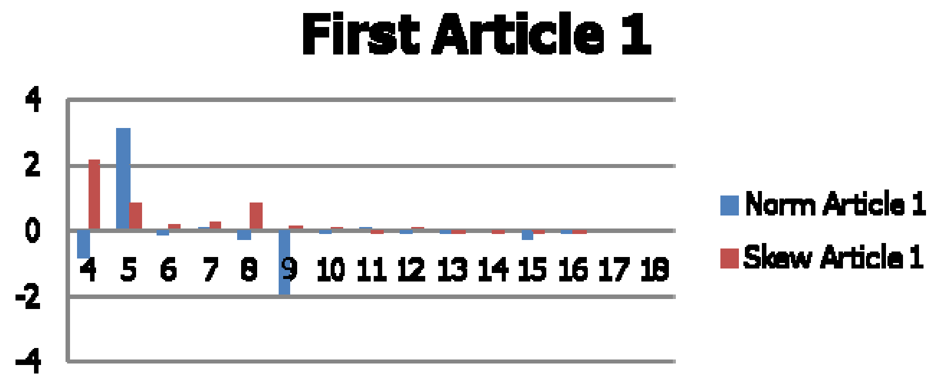


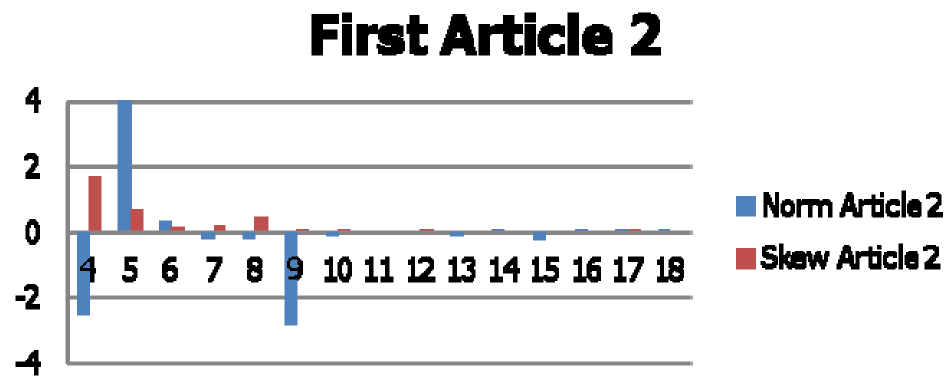


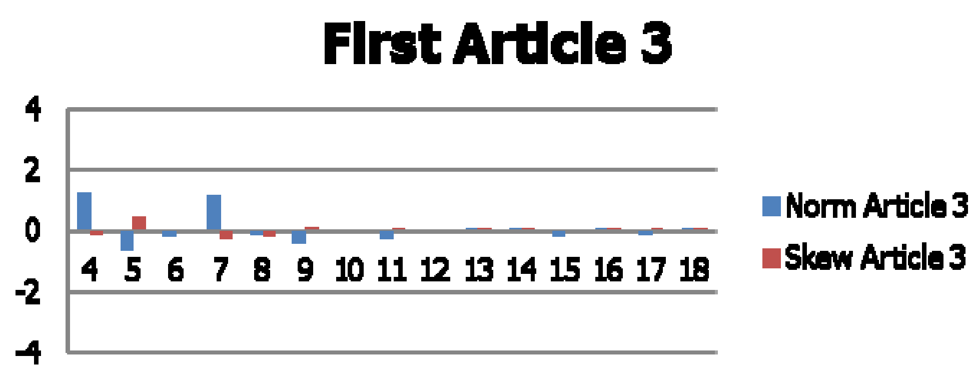
Measurement results

DANFYSIK

- Initially produced 3 ”First Article” magnets
- Pending approval of these, the rest could be produced
- First Article **1** and **2** were shimmed to within specifications.
- First Article **3** was flawless.
- Machining process was refined for Article 3 and remaining magnets







166 more sextupoles to go

BROOKHAVEN
NATIONAL LABORATORY

This is to commend *December October 2012*

Danfysik A/S

Upon completion of girder manufacturing under BSA Contract #143327 for the Storage Ring Magnets for the Storage Ring of the National Synchrotron Light Source II at Brookhaven National Laboratory, Upton, New York

Built under contract with the U.S. Department of Energy, NSLS-II promises to be the most advanced and highest brightness synchrotron light source facility in the world. This facility will enable the study of physical and biological materials at 1 nanometer spatial and 0.1 millielectron volt energy resolutions.

Using superb ingenuity, precision equipment and meticulous fabrication, you have met the stringent requirements of this large-scale production of high-quality accelerator magnets.

We congratulate you for your contributions to this exciting NSLS-II Project.

Steve Dierker

Sam Aronson
Laboratory Director

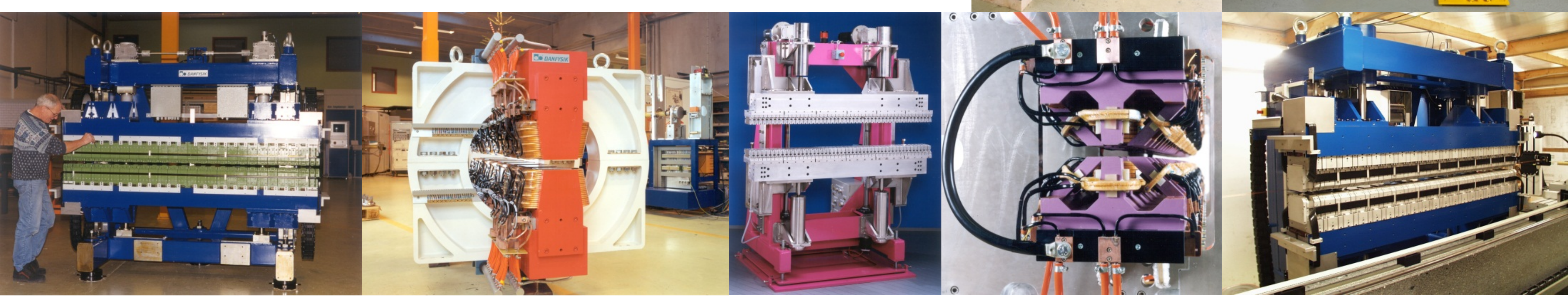
Steve Dierker
Associate Laboratory Director
For Photon Sciences

Ferdinand Willeke
Division Director of
Accelerator Systems

Satoshi Ozaki
Magnet Production Manager

Insertion devices

- Insertion device group within Danfysik
  - Project manager, design engineers, physicists, shim technician
- All kinds of insertion devices have been produced
  - Undulators: PPM and hybrid
  - Hybrid wigglers
  - Electromagnet wigglers
  - In-vacuum devices
  - Cryogenic hybrid device for Diamond
  - Apple-II type
- 2 wigglers results to present today



Electromagnetic wiggler for Helmholz Zentrum Dresden-Rossendorff

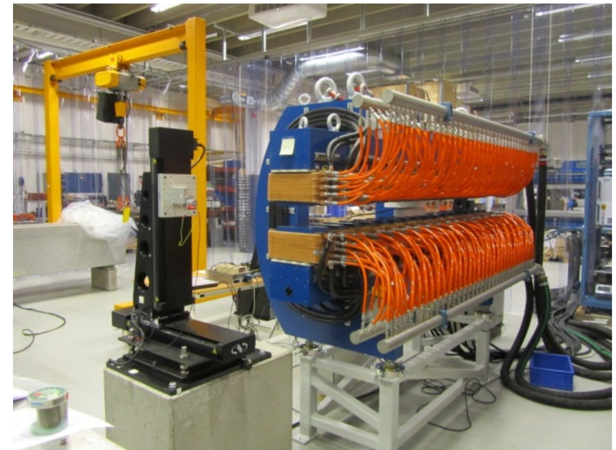
DANFYSIK

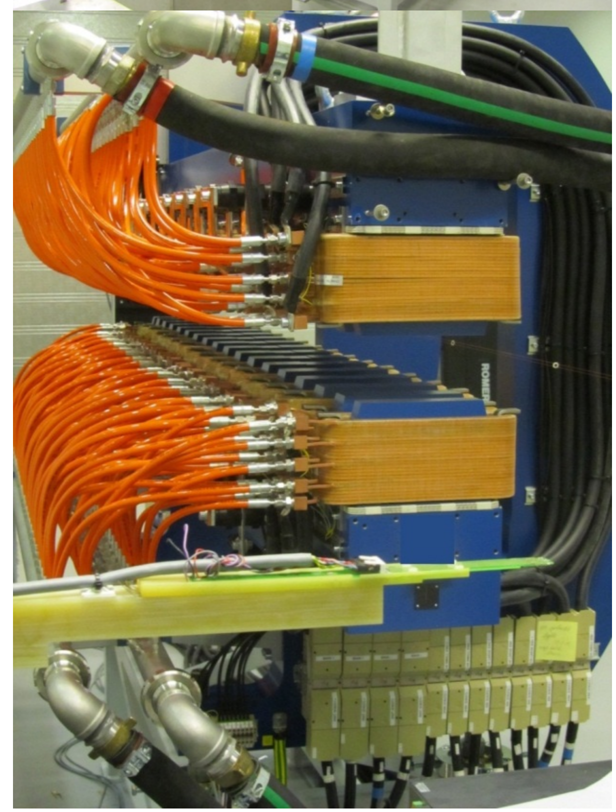
Wiggler specifications

Period length	300 mm
Number of full-size periods	8
# poles, including end poles	16+2
K_{RMS}	7.76
Peak field	0.38 T
Minimum clear gap	102 mm
Field flatness (x<20 mm)	+0.2 %

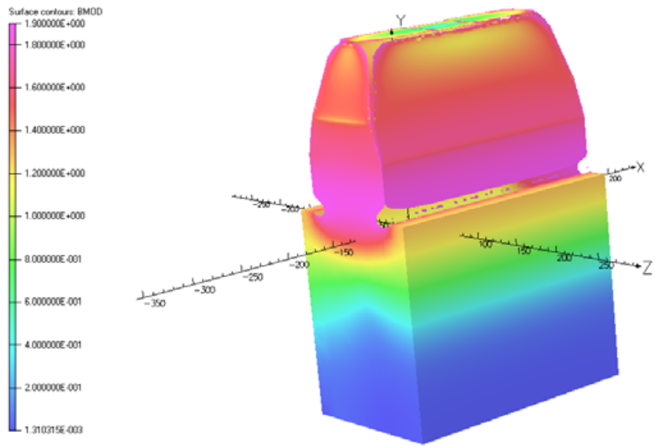
Independent powering of end poles

	MPS type	Quantity	Stability	Max. Current
Central poles	**854**	**1**	**10 ppm**	**625 A**
Large end poles	**854**	**2**	**10 ppm**	**235 A**
Small end poles	**9100**	**2**	**10 ppm**	**200 A**

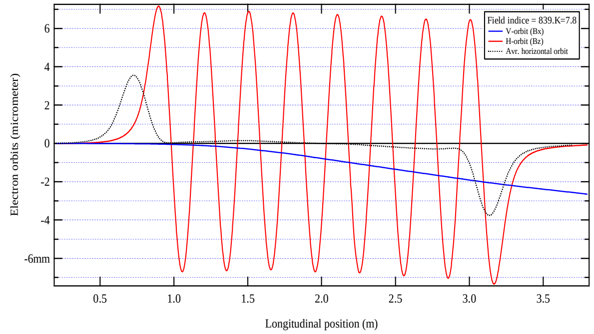




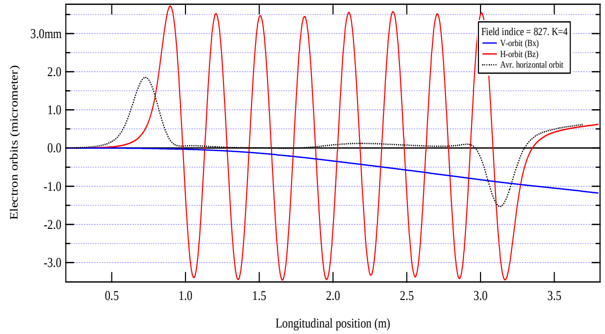
Modelling and results



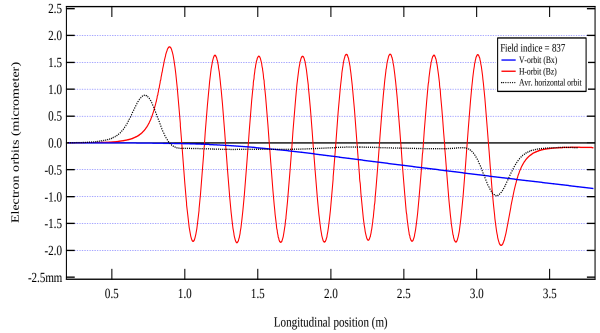
K=7.76



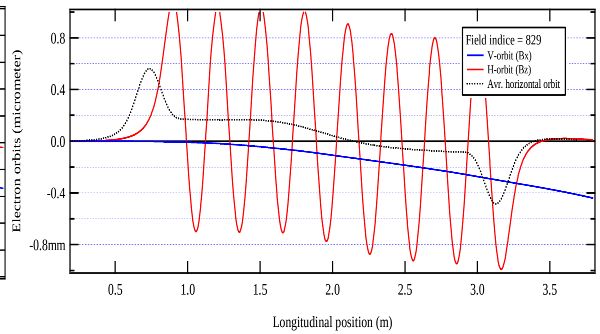
K=3.99



K=2.0



K=1.0

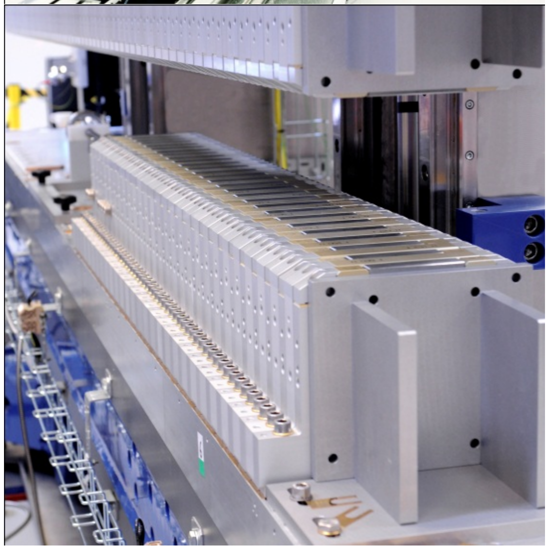


- Wiggler was shimmed by adjusting end polevcurrent, long coils
- High saturation of thin end poles at high power
- Low phase error: 1.2°

Movable gap damping wigglers for NSLS-II

Wiggler specifications

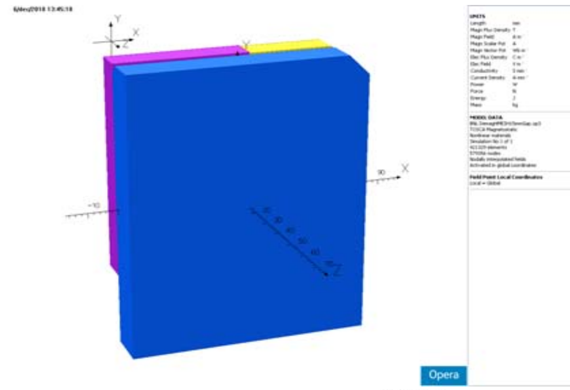
Period length	100 mm
Number of full-size periods	34
# poles, including end poles	74+2
Peak field	1.8 T
Minimum clear gap	15 mm
Minimum pole width	90 mm
First integral(x<15 mm)	20 Gcm(Horizontal) 50 Gcm(Vertical)
Second integral(x<15 mm)	2000 Gcm^2(Horizontal) 5000 Gcm^2(Vertical)

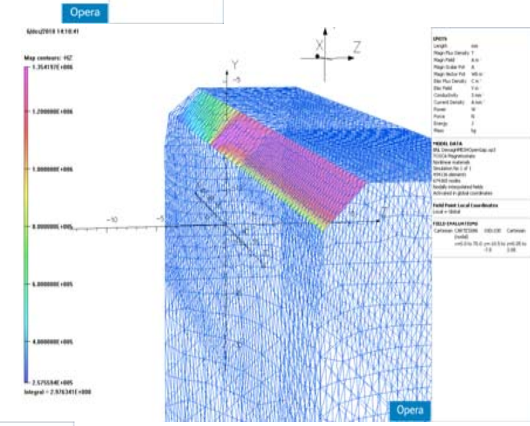


Modelling

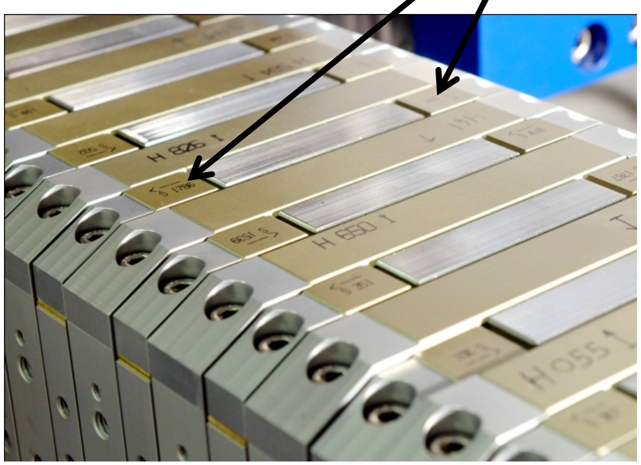
DANFYSIK

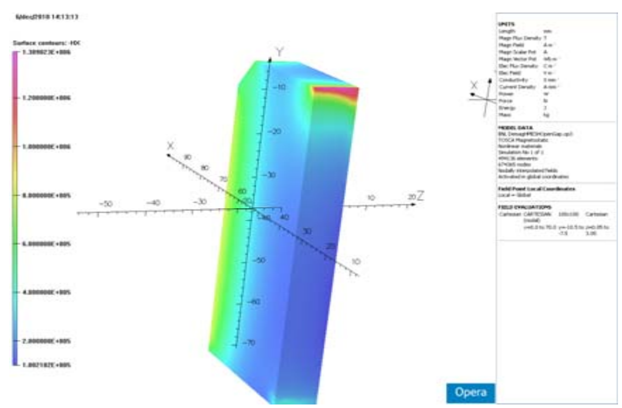
- Central section and demagnetization(open, closed gap) modelled using Vectorfield OPERA
- End termination modelled using RADIA





Adjustable side magnets



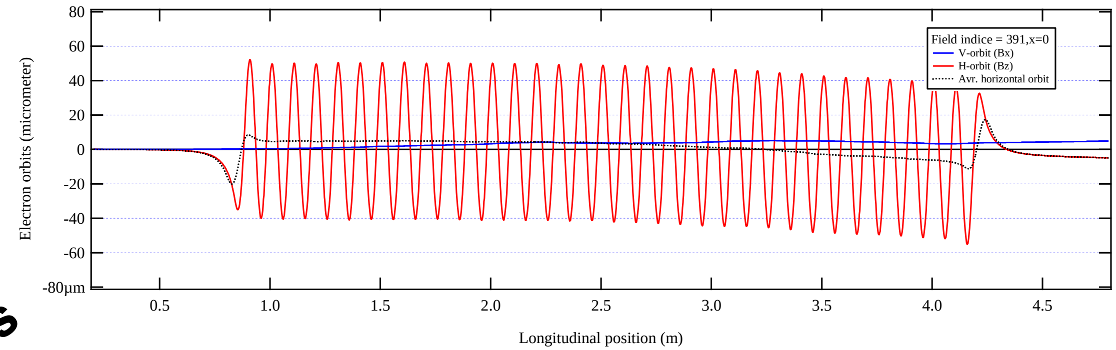


Results

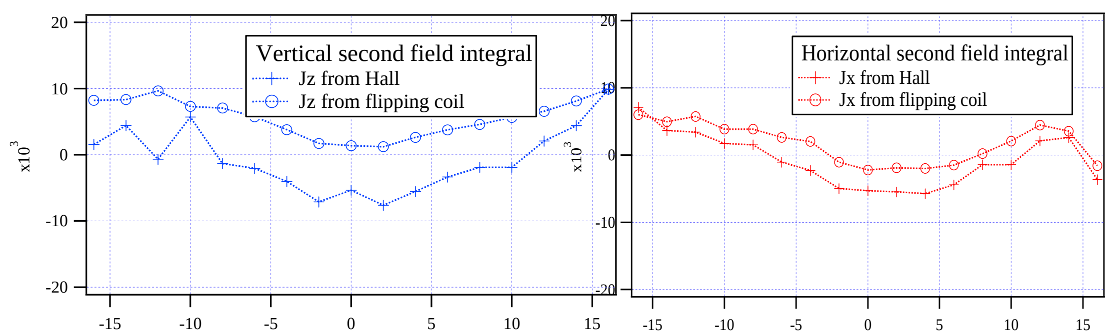
DANFYSIK

- Average peak field: 1.819 T
- Mounting and shimming time is improving
- 4th wiggler has completed magnet assembly, and is ready for shimming

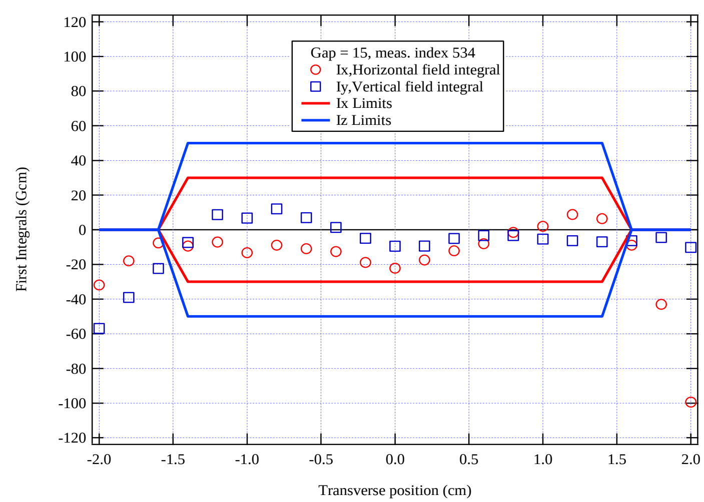
Trajectory



2nd integrals



1st integrals



Conclusion

DANFYSIK

- Many different projects since last IMMW
- Upcoming challenges
  - Completion of damping wigglers for NSLS-II
  - In-vacuum undulator for NSLS-II
  - Completion of compact girder systems for MaxLab
  - Measurement of 1.5 GeV complete girder systems for MaxLab/ Solaris projects
- Continued efforts to improve automatization of measuring processes, in ID and general magnetic measurements