Hera

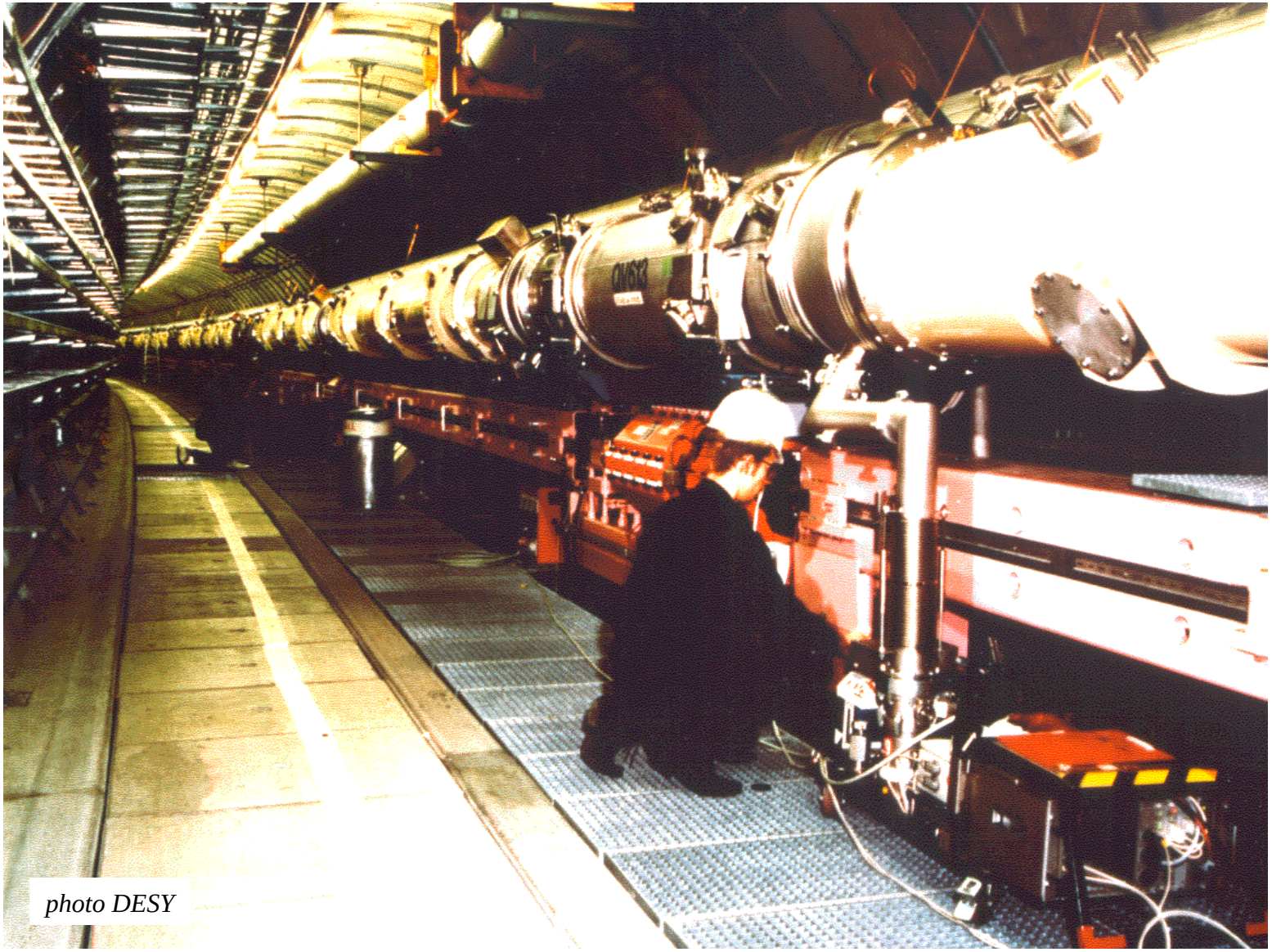
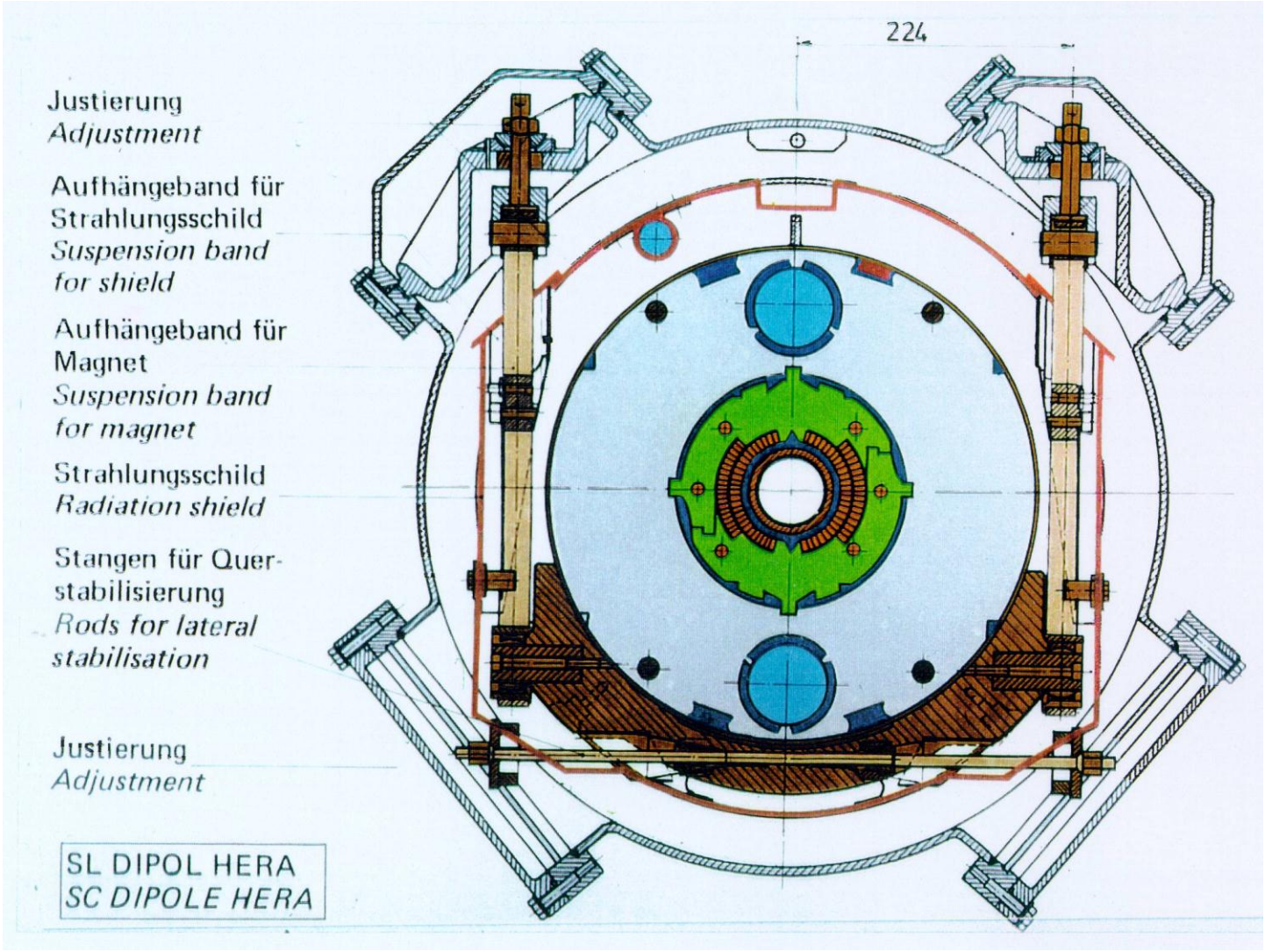
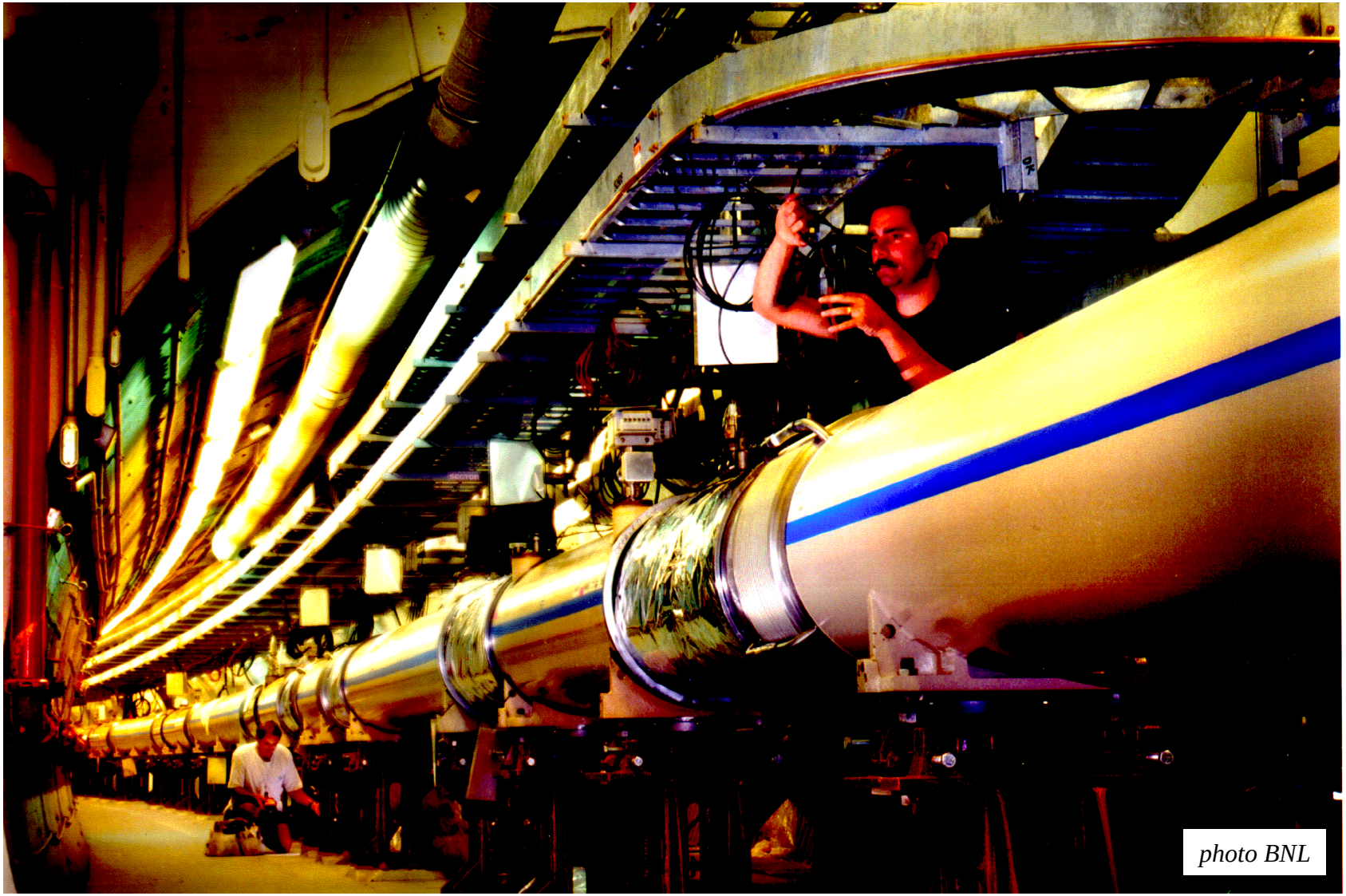


photo DESY

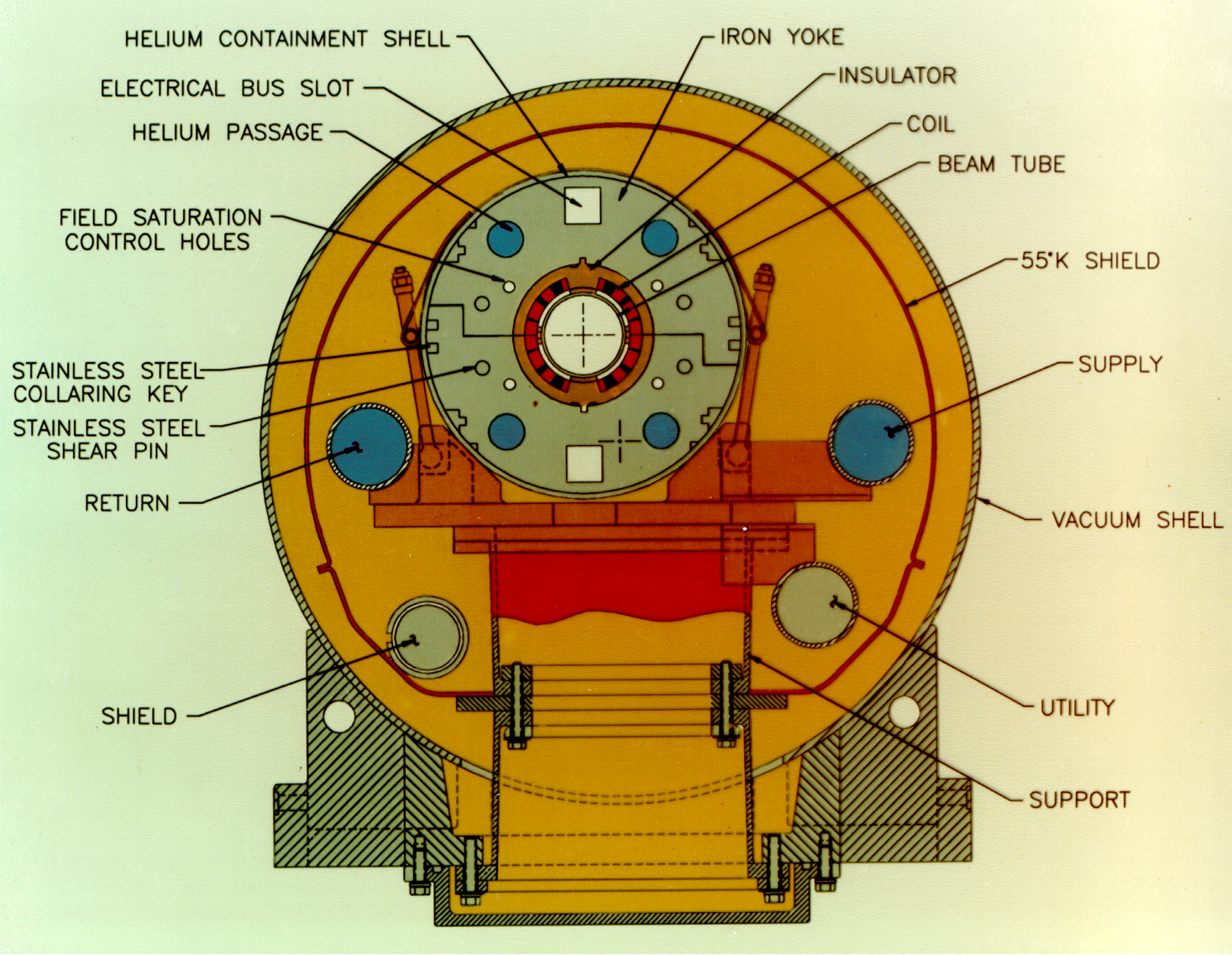
Hera dipole


224
Justierung
Adjustment
Aufhängeband für Strahlungsschild
Suspension band for shield
Aufhängeband für Magnet
Suspension band for magnet
Strahlungsschild
Radiation shield
Stangen für Quer-stabilisierung
Rods for lateral stabilisation
Justierung
Adjustment
SL DIPOL HERA
SC DIPOLE HERA

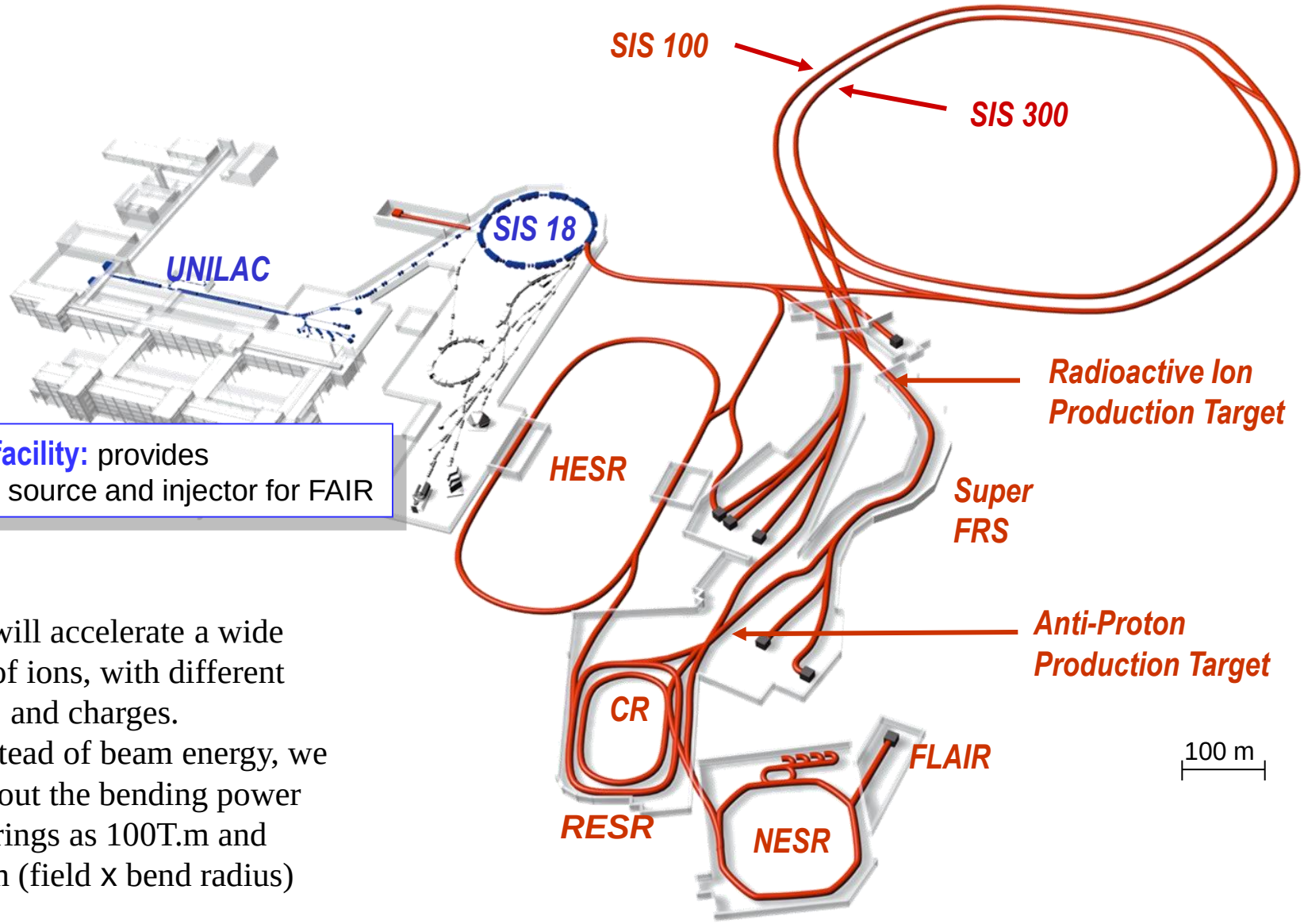
RHIC



RHIC Dipole


HELIUM CONTAINMENT SHELL
IRON YOKE
ELECTRICAL BUS SLOT
INSULATOR
HELIUM PASSAGE
COIL
BEAM TUBE
FIELD SATURATION CONTROL HOLES
55°K SHIELD
STAINLESS STEEL COLLARING KEY
SUPPLY
STAINLESS STEEL SHEAR PIN
RETURN
VACUUM SHELL
SHIELD
UTILITY
SUPPORT

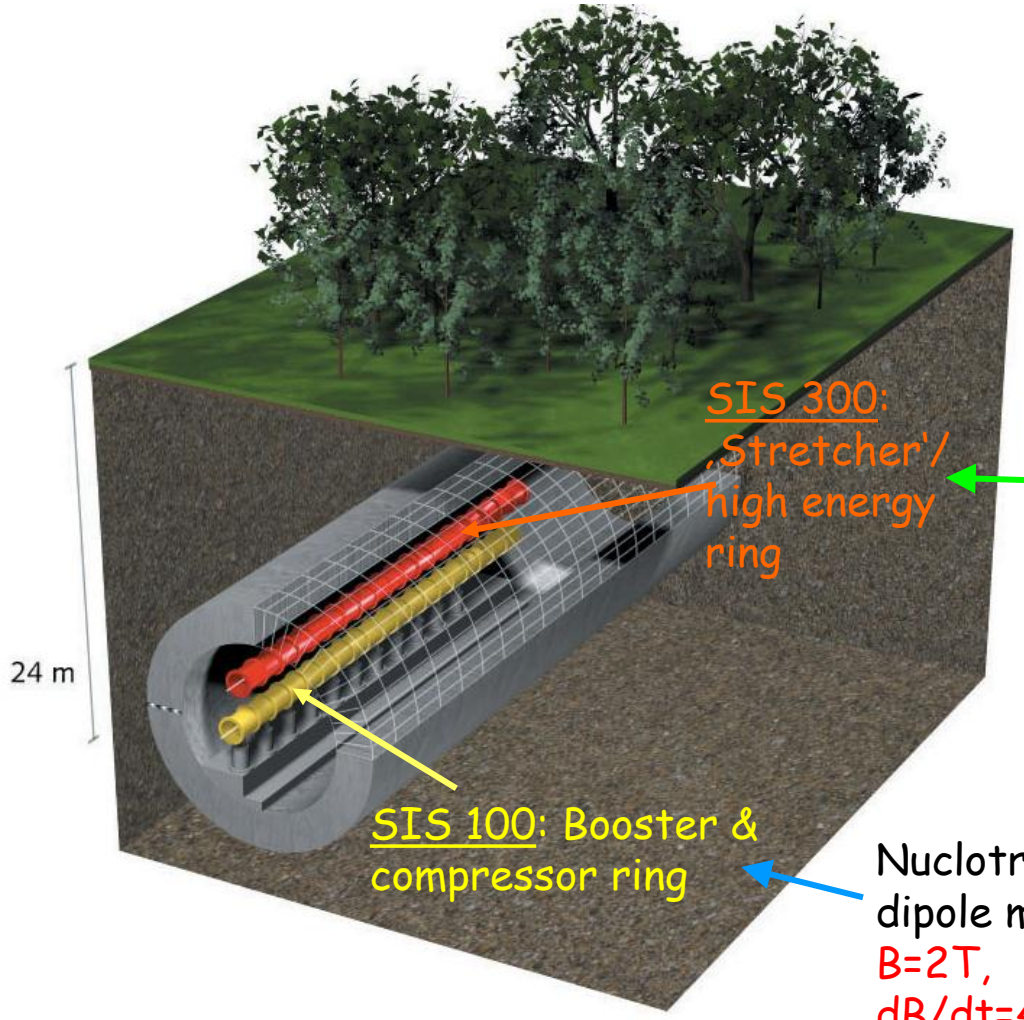
Facility for Antiproton and ion research FAIR

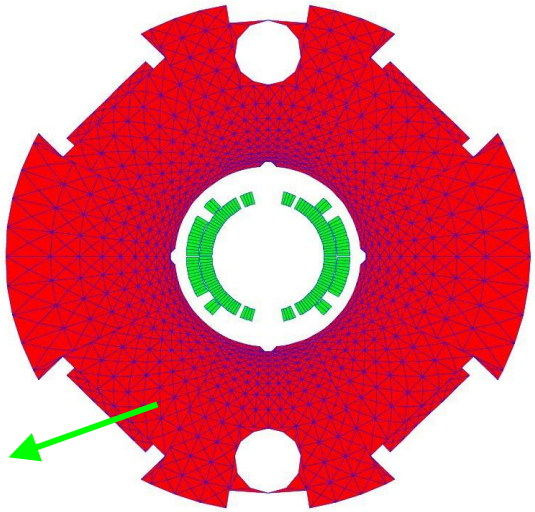


Existing facility: provides ion-beam source and injector for FAIR

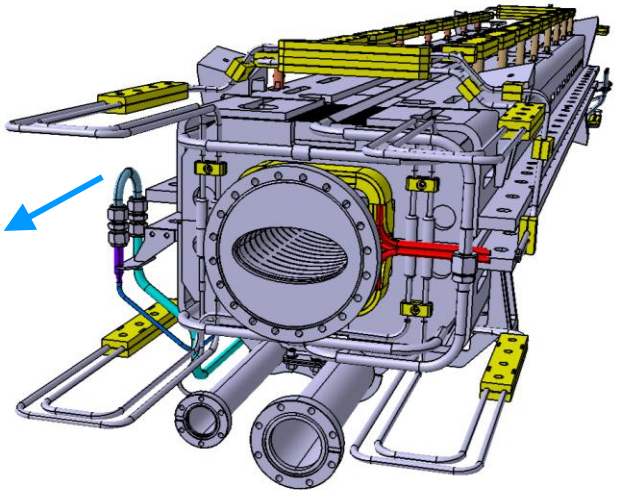
FAIR will accelerate a wide range of ions, with different masses and charges.
So, instead of beam energy, we talk about the bending power of the rings as 100T.m and 300T.m (field x bend radius)

FAIR: two rings in one tunnel





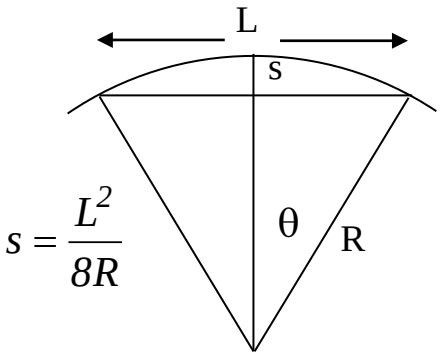
Modified UNK dipole 6T at 1T/s



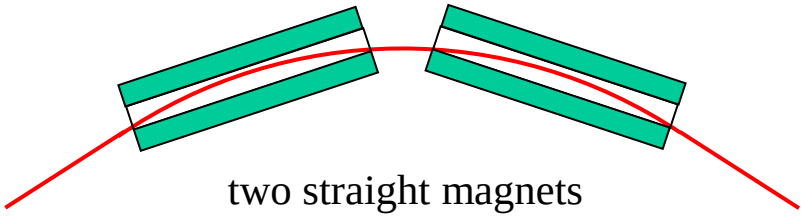
Nuclotron-type dipole magnet: B=2T, dB/dt=4T/s

2x120 superconducting dipole magnets
132+162 SC quadrupole magnets

Problem of the sagitta in SIS300



$$s = \frac{L^2}{8R}$$

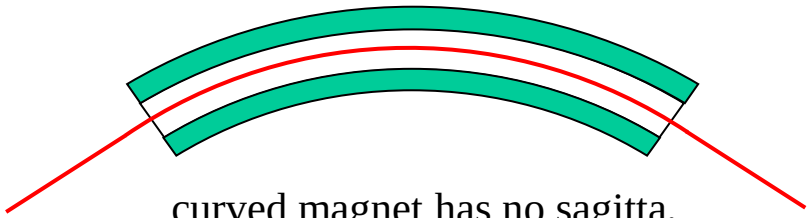


two straight magnets

must be short because of sagitta

$\Rightarrow$ B = 6T

must use double layer coil



curved magnet has no sagitta,

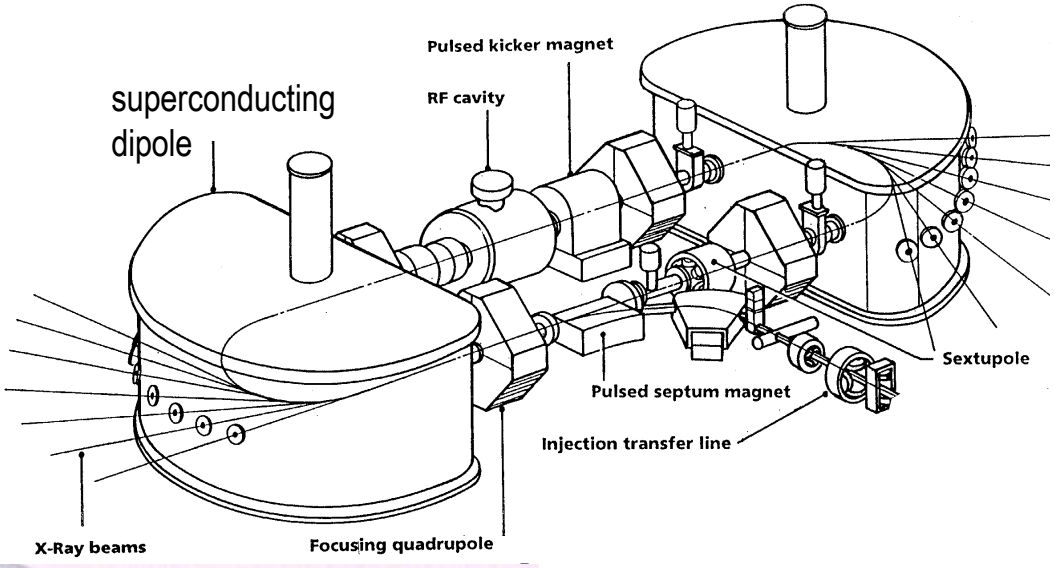
can be long, save space of end turns

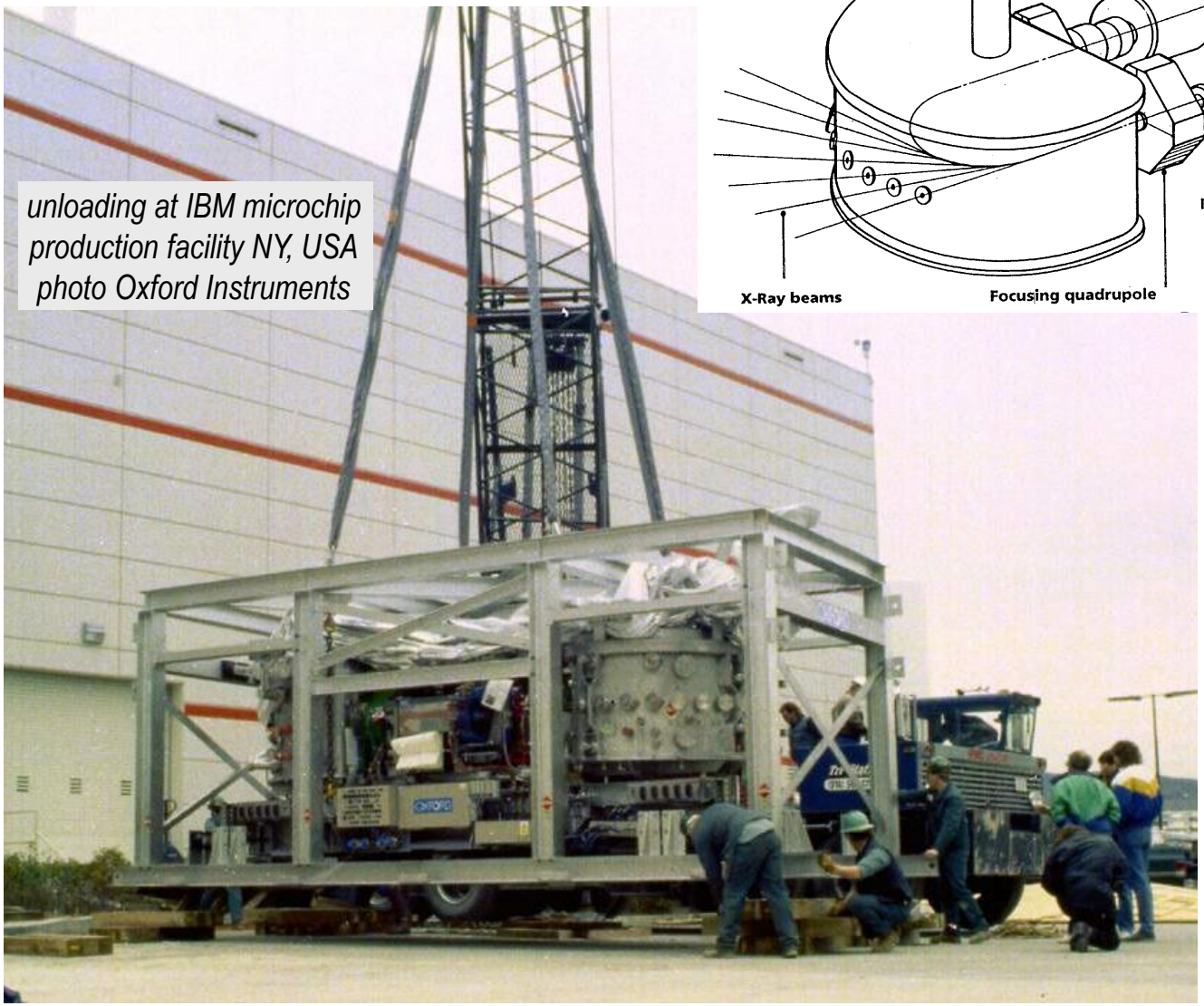
$\Rightarrow$ B = 4.5T

can use single layer coil

Discorap curved dipole INFN Frascati / Ansaldo

Helios
synchrotron X-ray source





unloading at IBM microchip production facility NY, USA photo Oxford Instruments

superconducting dipoles

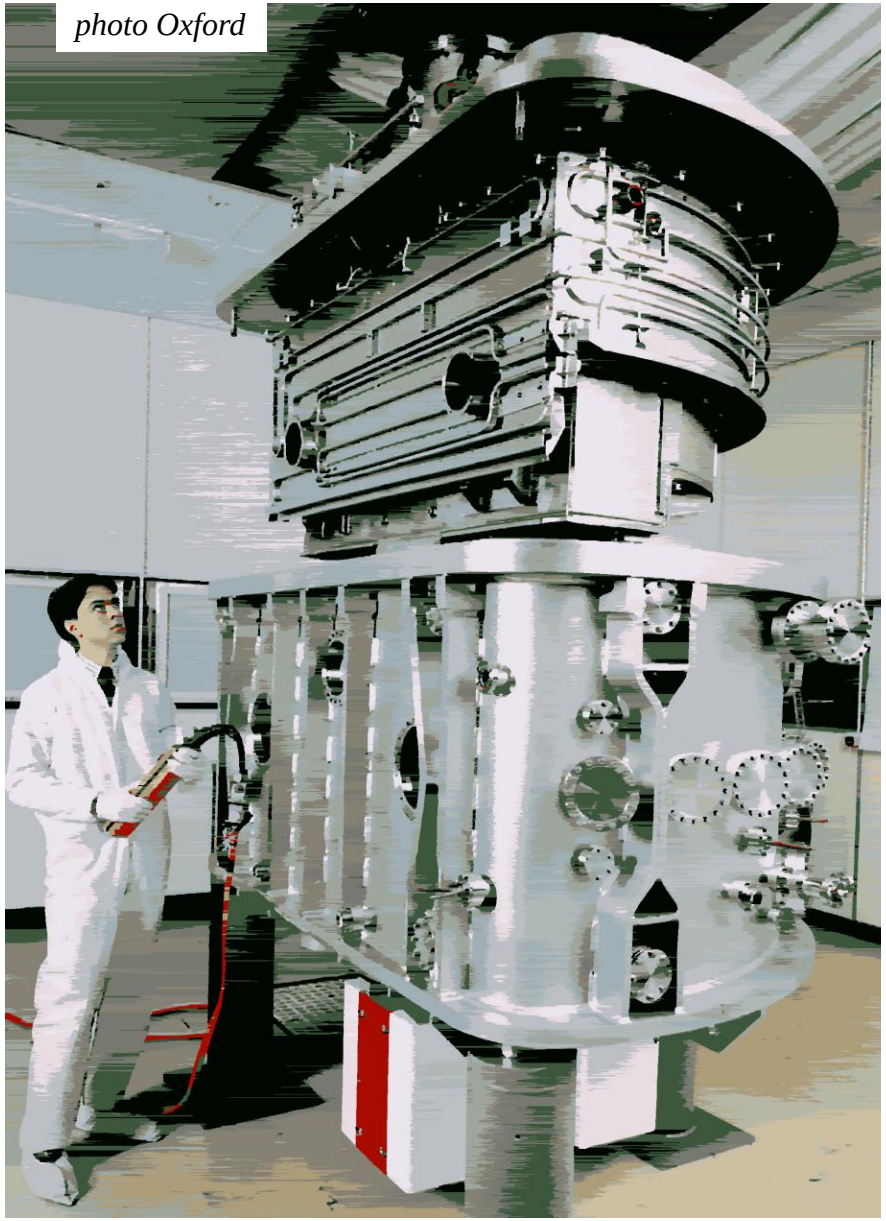
⇒ high field

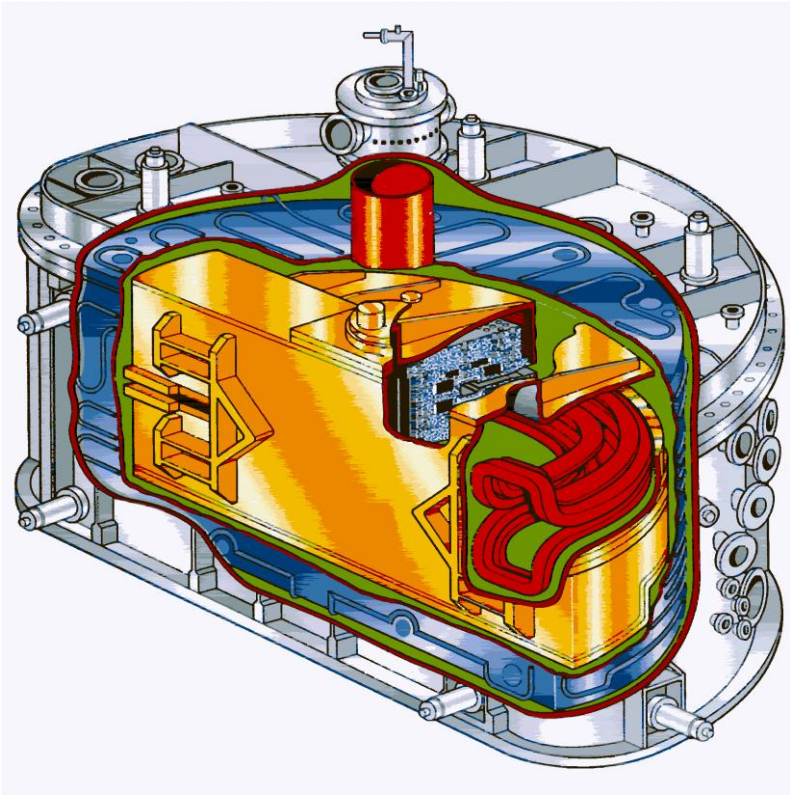
⇒ tight bending radius

⇒ compact size

⇒ transportability

Helios dipole





- bent around180°
- rectangular block coil section
- totally clear gap on outer mid plane for emerging X-rays (12 kW)

250 MeV Cyclotron for proton therapy

- superferric magnet
- sector focussed cyclotron

Some useful references

Superconducting Magnets

- Superconducting Accelerator Magnets: KH Mess, P Schmuser, S Wolf., pub World Scientific, (1996) ISBN 981-02-2790-6
- Case Studies in Superconducting Magnets, Second edition: Y Iwasa, pub Springer (2009), ISBN 978-0-387-09799-2.
- High Field Superconducting Magnets: FM Asner, pub Oxford University Press (1999) ISBN 0 19 851764 5
- Field Computation for Accelerator Magnets: S Russenschuk pub Wiley VCH ISBN 978-3-527-40769-9
- Superconducting Magnets: MN Wilson, pub Oxford University Press (1983) ISBN 0-019-854805-2
- Proc Applied Superconductivity Conference: pub as IEEE Trans Applied Superconductivity, Mar 93 to 99, and as IEEE Trans Magnetics Mar 75 to 91
- Handbook of Applied Superconductivity ed B Seeber, pub UK Institute Physics 1998

Cryogenics

- Experimental Techniques for Low-temperature Measurements: J. W. Ekin Pub. Oxford University Press, ISBN 978-0-19-857054-7
- Helium Cryogenics Van Sciver SW, pub Plenum 86 ISBN 0-0306-42335-9
- Cryogenic Engineering, Hands BA, pub Academic Press 86 ISBN 0-012-322991-X
- Cryogenics: published monthly by Butterworths
- Cryogenie: Ses Applications en Supraconductivite, pub IIR 177 Boulevard Malesherbes F5017 Paris France

Materials Mechanical

- Materials at Low Temperature: Ed RP Reed & AF Clark, pub Am. Soc. Metals 1983. ISBN 0-87170-146-4
- Handbook on Materials for Superconducting Machinery pub Batelle Columbus Laboratories 1977.
- Nonmetallic materials and composites at low temperatures: Ed AF Clark, RP Reed, G Hartwig pub Plenum
- Nonmetallic materials and composites at low temperatures 2, Ed G Hartwig, D Evans, pub Plenum 1982
- Austenitic Steels at low temperatures Editors R.P.Reed and T.Horiuchi, pub Plenum1983

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- Superconductor Science and Technology, published monthly by Institute of Physics (UK).
- Superconductivity of metals and Cuprates, JR Waldram, Institute of Physics Publishing (1996) ISBN 0 85274 337 8
- High Temperature Superconductors: Processing and Science, A Bourdillon and NX Tan Bourdillon, Academic Press, ISBN 0 12 117680 0
- Superconductivity: A Very Short Introduction by Stephen J. Blundell: Oxford University Press (2009) ISBN978-0-19-954090-7

on the Web

- **Lectures on Superconductivity** http://www.msm.cam.ac.uk/ascg/lectures.
  lectures produced for SCENET by Cambridge University

- **Superconducting Accelerator Magnets** http://www.mjb-plus.com.
  A course developed from SSC experience, available from website for $20

- www.superconductors.org website run by an enthusiast; gives some basic info and links

- **Superconductivity Course** at the (UK) Open University.
  http://openlearn.open.ac.uk/course/view.php?id=2397 Good coverage of basics.

- **Wikipedia** on Superconductivity http://en.wikipedia.org/wiki/Superconductivity
  Good on basics with lots of references and links.

- **European Society for Applied Superconductivity** http://www.esas.org/
  ESAS news forum http://www.ewh.ieee.org/tc/csc/europe/newsforum/

- **CONECTUS** Consortium of European Companies determined to use Superconductivity
  http://www.conectus.org/

- **IEEE Council on Superconductivity** http://www.ewh.ieee.org/tc/csc/
  News, events and people in the area of applied superconductivity (US based)

- **Data Tables** from Experimental Techniques for Low-temperature Measurements: J. W. Ekin
  http://researchmeasurements.com/figures/ExpTechLTMeas_Apdx_Chinese.pdf

Materials data on the Web

- Cryogenic properties (1-300 K) of many solids, including thermal conductivity, specific heat, and thermal expansion, have been empirically fitted and the equation parameters are available free on the web at **www.cryogenics.nist.gov**.
- Plots and automated data-look-up using the NIST equations are available on the web for a fee from **www.cpia.jhu.edu**.
- Other fee web sites that use their own fitting equations for a number of cryogenic material properties include: **www.cryodata.com** (cryogenic properties of about 100 materials),

  and **www.jahm.com** (temperature dependent properties of about 1000 materials, many at cryogenic temperatures).
- Commercially supplied room-temperature data are available free online for about 10 to 20 properties of about 24,000 materials at **www.matweb.com.**

thanks to Jack Ekin of NIST for this information

Cryodata Software Products

GASPAK

properties of pure fluids from the triple point to high temperatures.

HEPAK

properties of helium including superfluid above 0.8 K, up to 1500 K.

STEAMPAK

properties of water from the triple point to 2000 K and 200 MPa.

METALPAK, CPPACK, EXPAK

reference properties of metals and other solids, 1 - 300 K.

CRYOCOMP

properties and thermal design calculations for solid materials, 1 - 300 K.

SUPERMAGNET

four unique engineering design codes for superconducting magnet systems.

KRYOM

numerical modelling calculations on radiation-shielded cryogenic enclosures.

Practical Matters: concluding remarks

- LHC quench problems come from series connection of many magnets and high current density
  - diodes across each coil, dump resistor and quench heaters

- current leads should be gas cooled and the optimum shape for minimum heat leak,
  - shape depends on the material used
  - impure material is less likely to burn out
  - use HTS to reduce heat leak at the bottom end

- making accelerator magnets is now a well established industrial process
  - winding ⇒ compact to exact size ⇒ heat to cure adhesive
  - fit collars ⇒ compress to required stress ⇒ lock in place
  - fit iron ⇒ add outer shell ⇒ compress to size ⇒ weld
  - assemble in cryostat ⇒ install in tunnel ⇒ make interconnects

- in recent years all the largest accelerators (and some small ones) have been superconducting

what comes next may be up to you

customer helpline
martin.n.wilson@btinternet.com