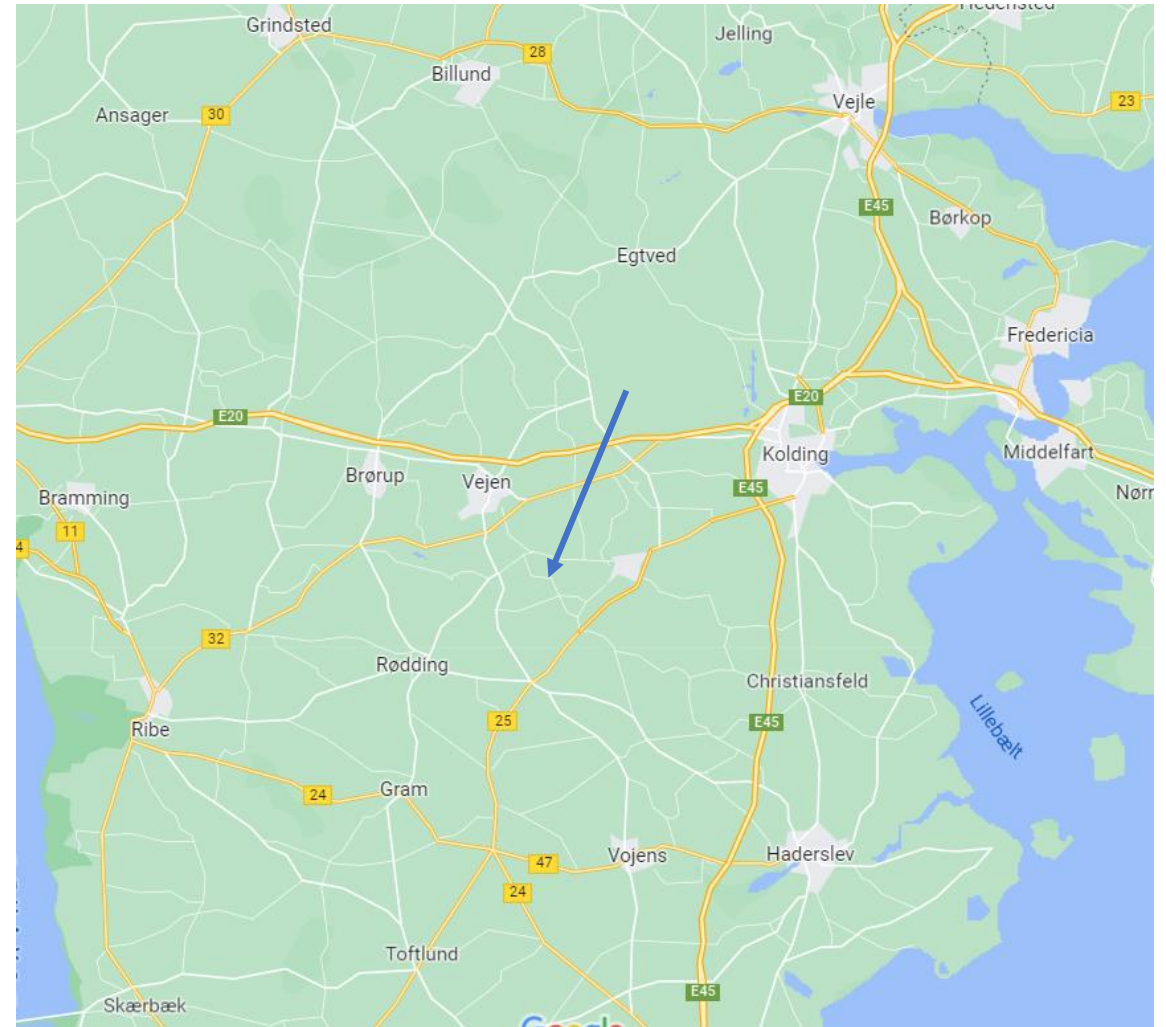




# Simon Straarup

Maskinmester på CERN

- Jeg er 31 år
- Kommer fra Vejen omegn
- Bor i Gex, Frankrig
- Arbejder ved CERN's Large Magnet Facility
  
- Mesterlære som Landbrugsmaskinmekaniker
- Adgangskursus på Maskinmesteruddannelsen
- Maskinmester



# Baggrund

Min rejse til CERN



Landbrugsmaskinmekaniker  
2010-2014

Entreprenør i  
fars biks  
2014-2017

Selvstændig  
Entreprenør  
2017-2022

Adgangskursus til  
Maskinmester-  
uddannelsen  
2019-2019

Maskinmester-  
studerende  
2019- 2022

Bachelorpraktik  
ved CERN  
2022-2022

Mechanical Technical  
Engineer ved CERN  
2022-nu



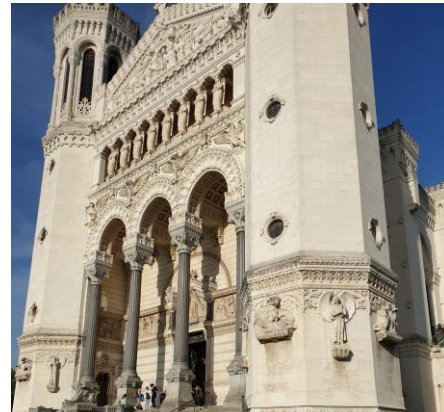
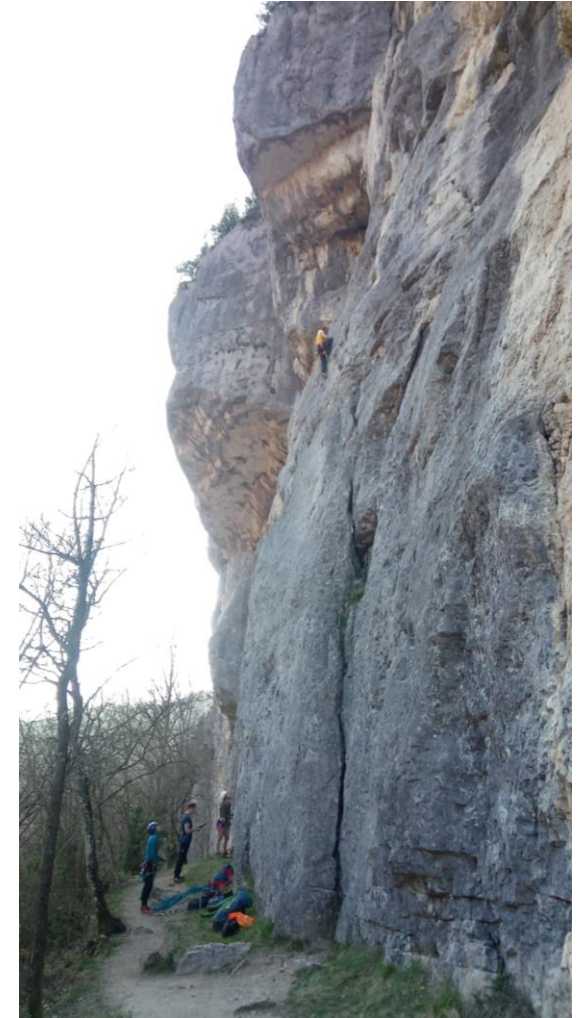
Folkeskole & 10. klasse



# Fritid

Maskinmesterpraktikant på CERN

- Vandring
- Klatring
- Ski
- Genève
- Lyón
- CERN-venner



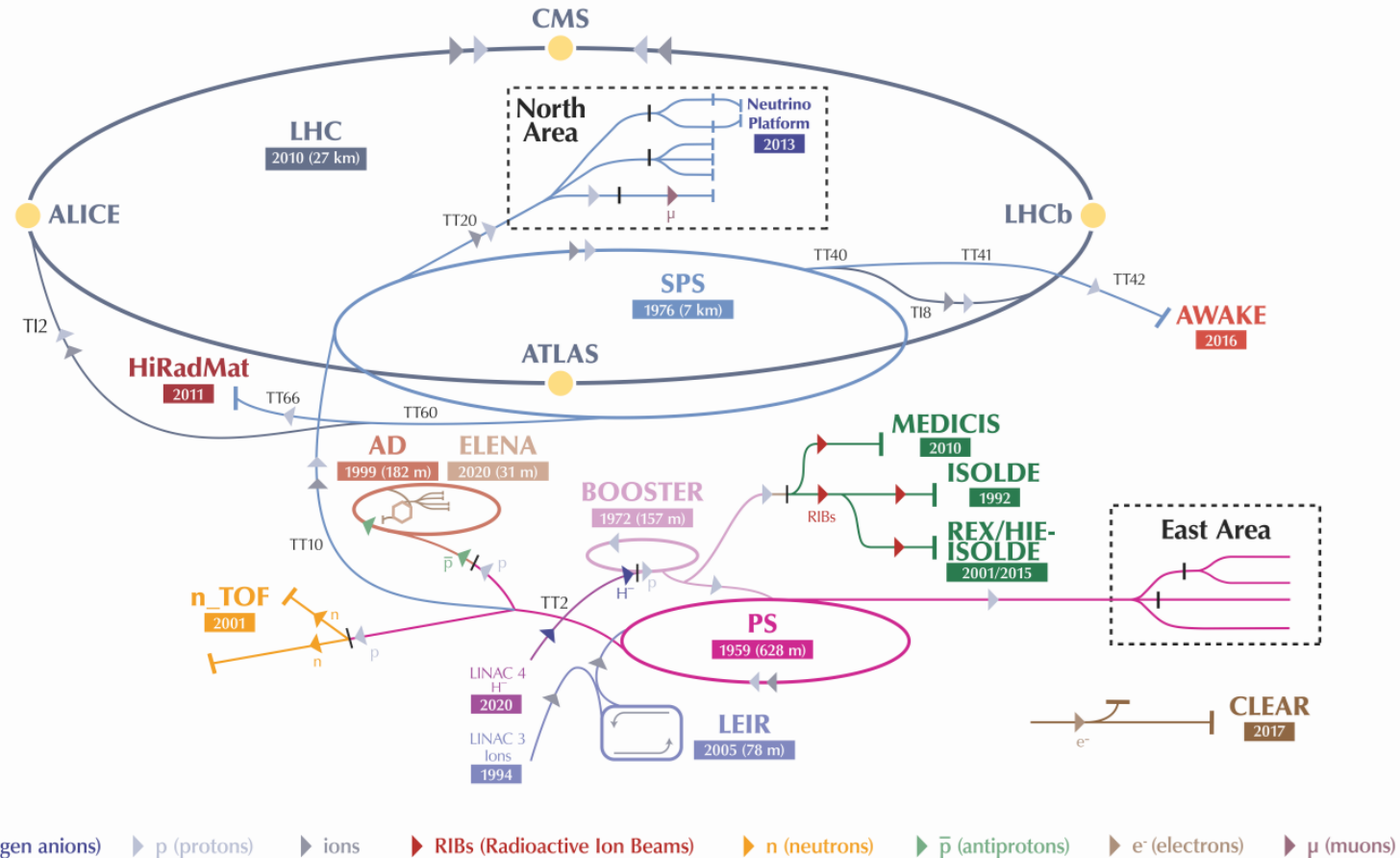
# Coming up

- Acceleratorer ved CERN
- LHC'en
- Magnet – hvorfor bruger vi dem
- Superledende vs. Normalledende magneter
- Magnet design
- Hilumi
- Large Magnet Facility – Bygning 180



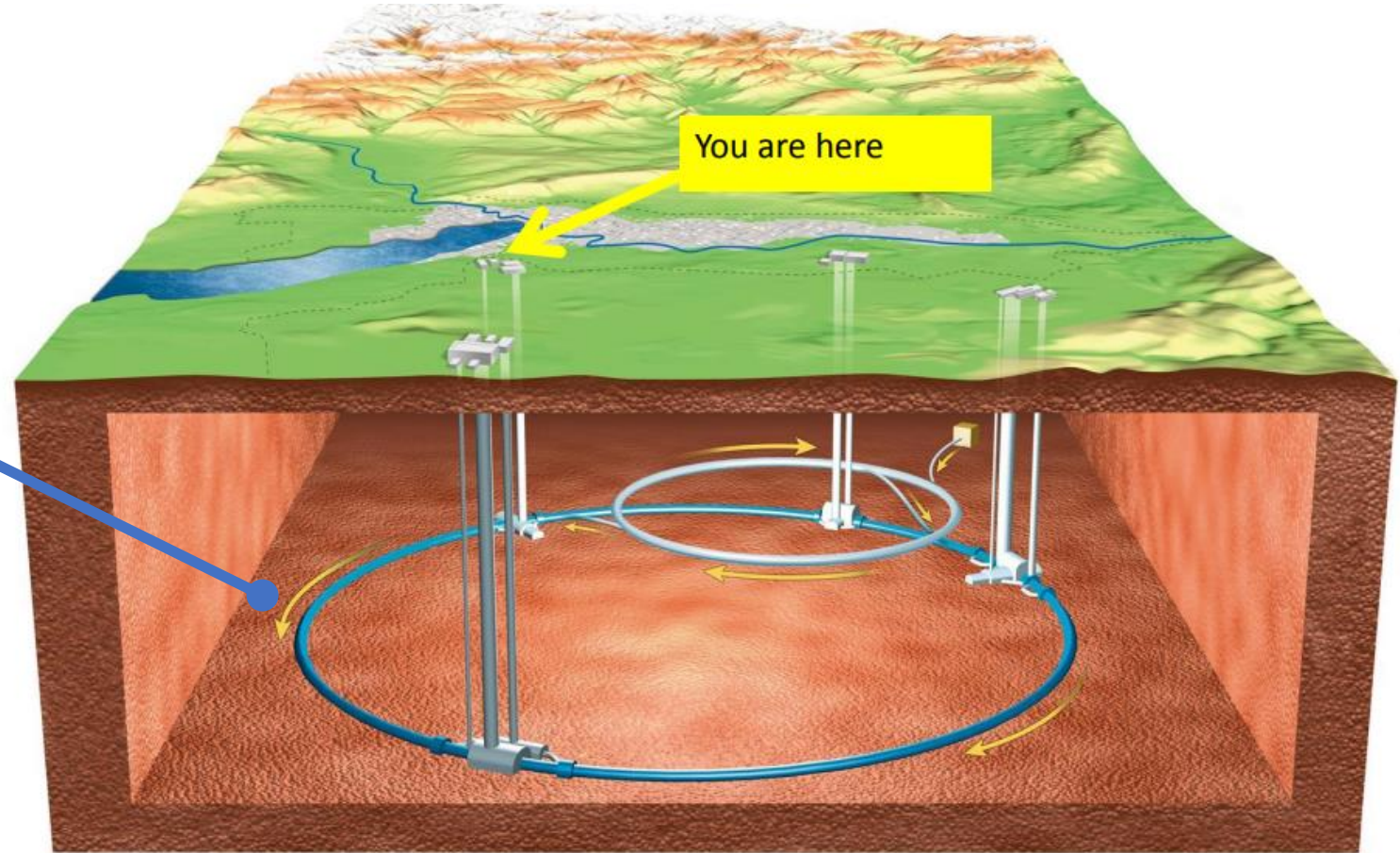
# Acceleratorer Anlæg

The CERN accelerator complex  
*Complexe des accélérateurs du CERN*



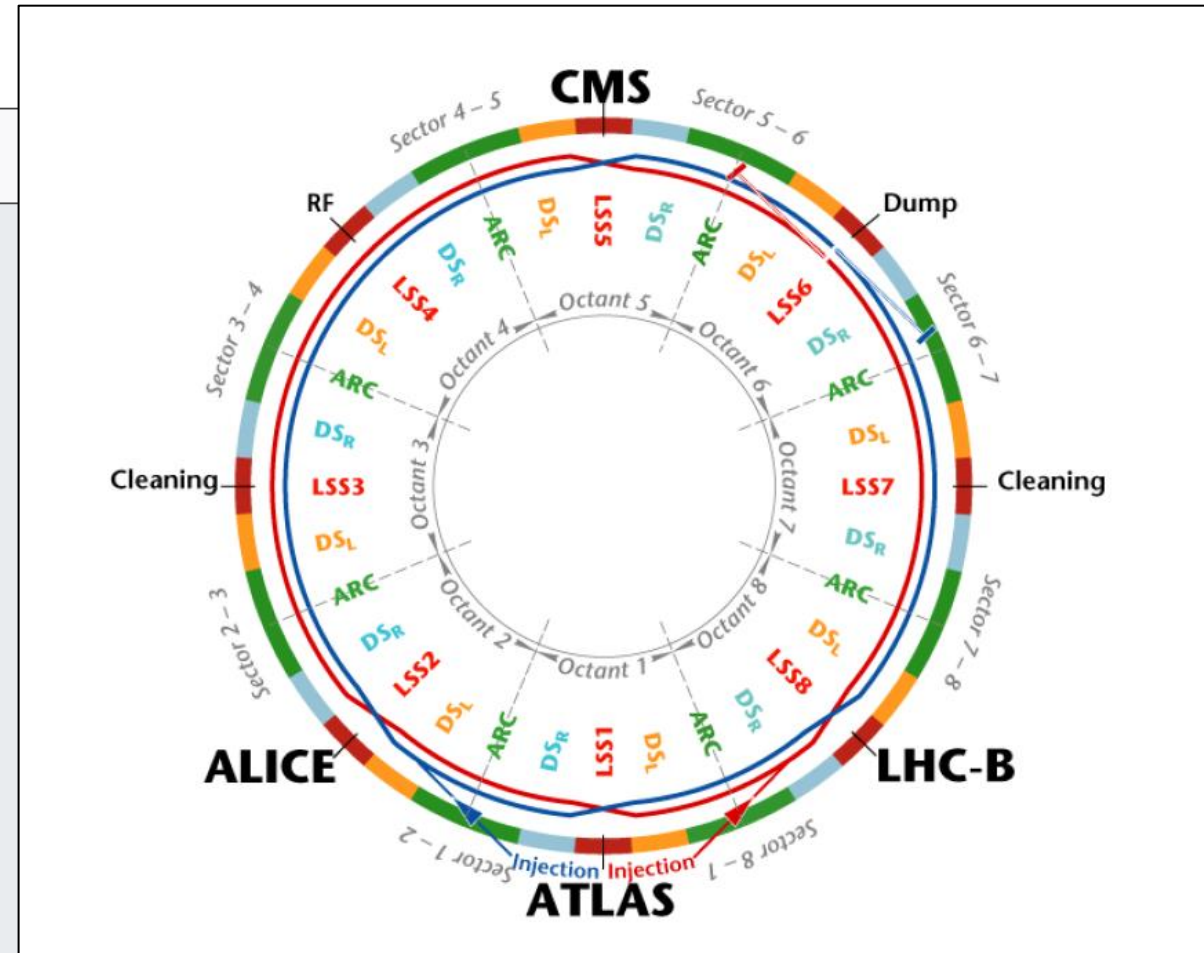
LHC - Large Hadron Collider // SPS - Super Proton Synchrotron // PS - Proton Synchrotron // AD - Antiproton Decelerator // CLEAR - CERN Linear Electron Accelerator for Research // AWAKE - Advanced WAKEfield Experiment // ISOLDE - Isotope Separator OnLine // REX/HIE-ISOLDE - Radioactive EXperiment/High Intensity and Energy ISOLDE // MEDICIS // LEIR - Low Energy Ion Ring // LINAC - LINear ACcelerator // n\_TOF - Neutrons Time Of Flight // HiRadMat - High-Radiation to Materials // Neutrino Platform

# LHC facts



# LHC facts

Quantity	Number
Circumference	26 659 m
Dipole operating temperature	1.9 K (-271.3°C)
Number of magnets	9593
Number of main dipoles	1232
Number of main quadrupoles	392
Number of RF cavities	8 per beam
Nominal energy, protons	6.5 TeV
Nominal energy, ions	2.56 TeV/u (energy per nucleon)
Nominal energy, protons collisions	13 TeV
No. of bunches per proton beam	2808
No. of protons per bunch (at start)	$1.2 \times 10^{11}$
Number of turns per second	11245
Number of collisions per second	1 billion





# Magnetviden

Brug højre hånd

Electro-magnetic field accelerates particles

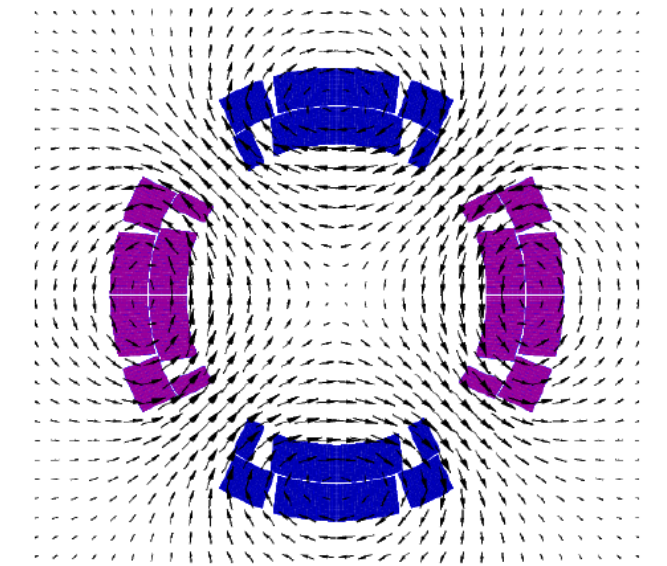
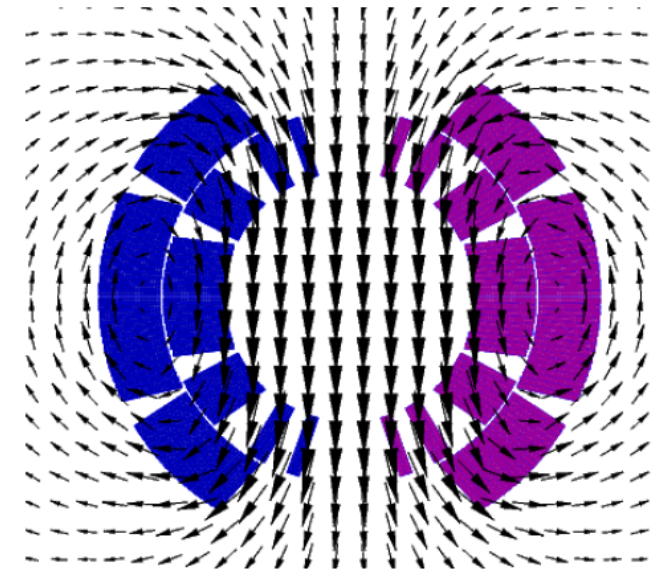
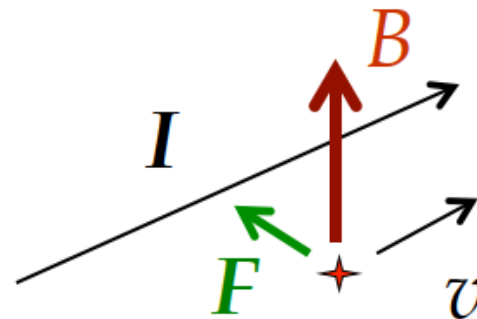
$$\vec{F} = e\vec{E}$$

Magnetic field steers the

$$\vec{F} = e\vec{v} \times \vec{B}$$

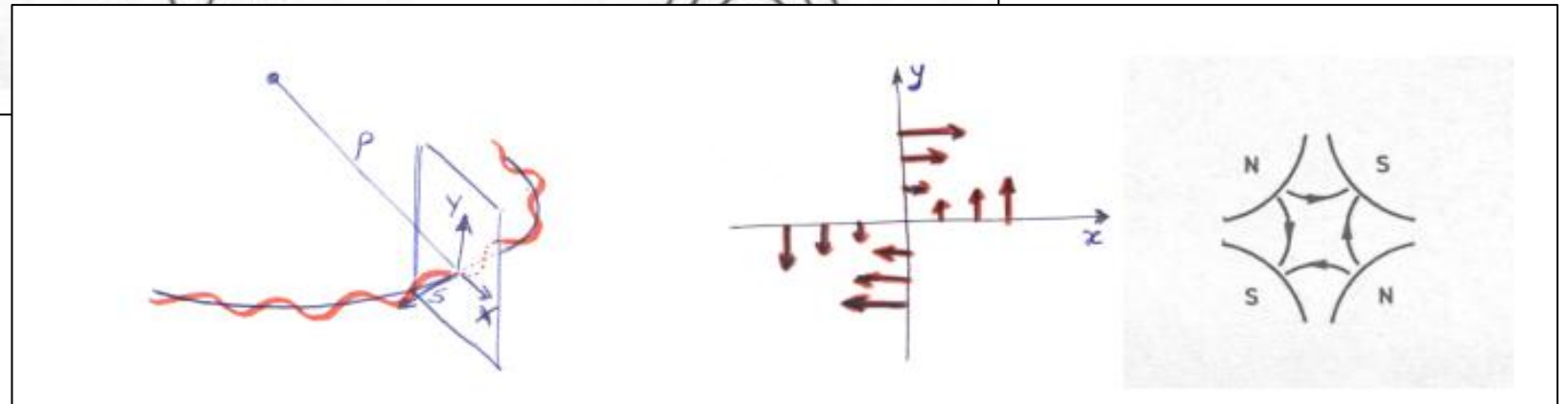
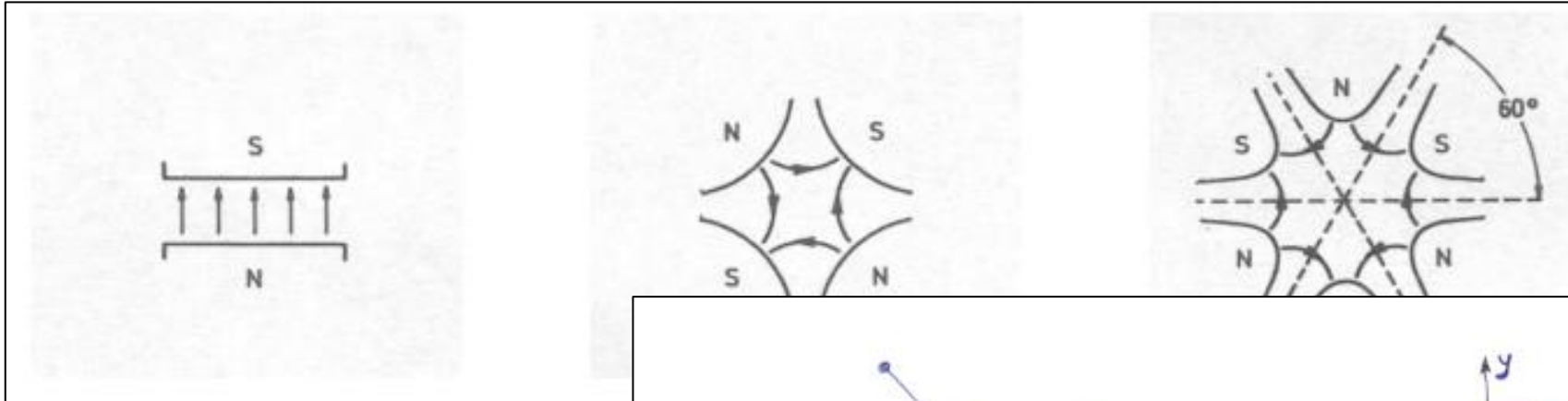
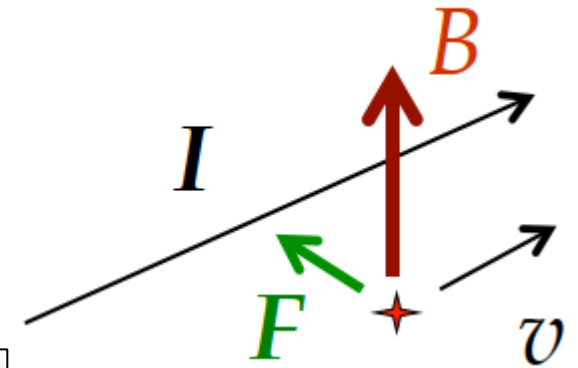
How do we keep the particles in a cycle? **MAGNETS!**

- **Dipole magnets** provide a constant field, to be increased with time to follow the particle acceleration, steering (bends) the particles in  $\approx$  circular orbit
- **Quadrupole magnets** keep the particles in the orbit, providing a linear force that keep them focused acting as a spring. They provide a field
  - Equal to zero in the center
  - Increasing linearly with the radius



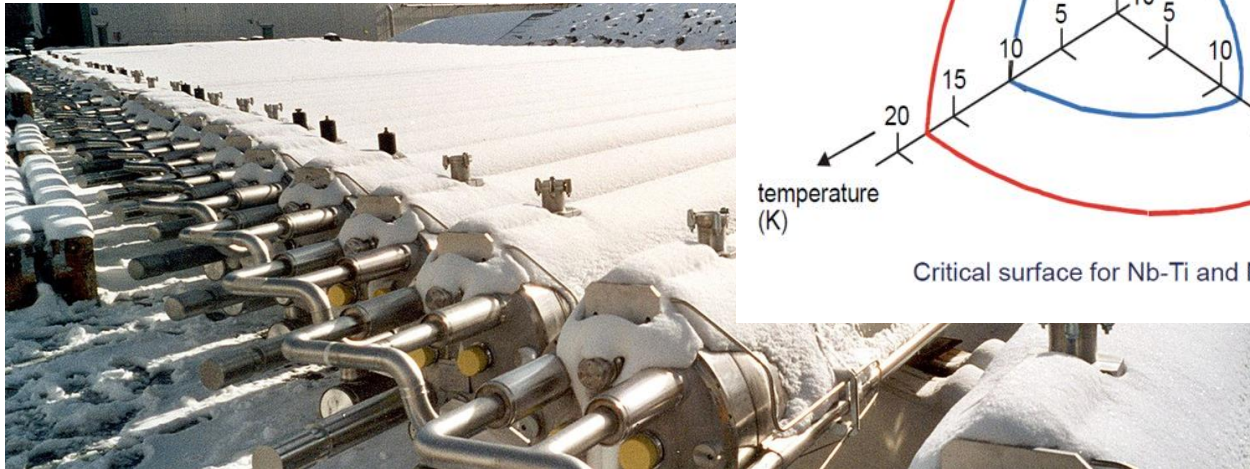
# Magnetviden

Brug højre hånd

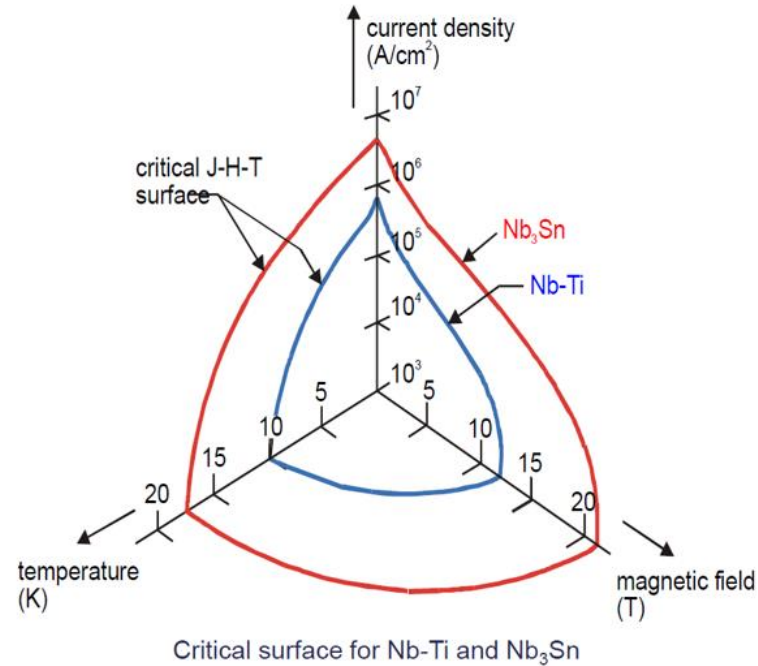


# Magneter

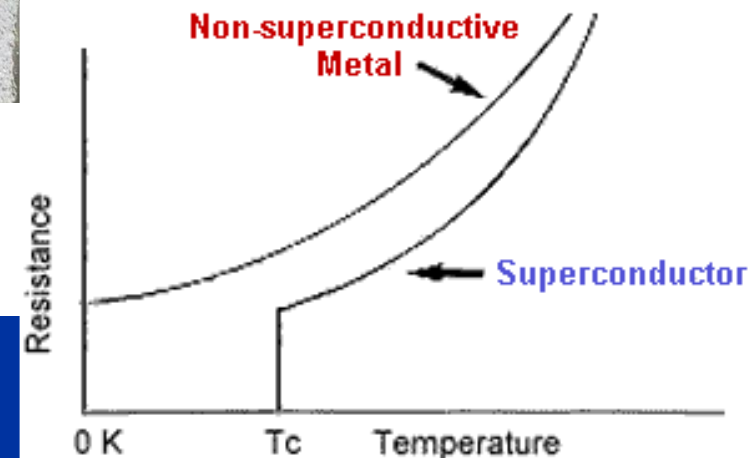
- Superledende magneter
- Normalledende magneter
- Permanente magneter



LHC main bending.  
8.3 T, 12 kA, 1.9 K



SPS main bending.  
2.0 T, 5.8 kA



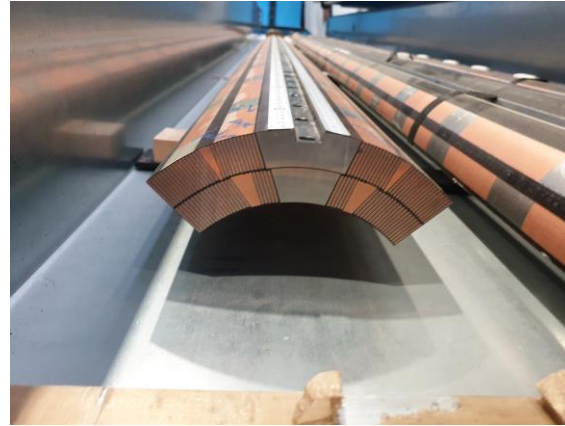
# Magnetviden

- Der er 1232 Dipoles magneter i LHC
- Der er 476 Quadropoles magneter i LHC
- Dipolerne er  $\sim 15$  m.
- Dipolerne har et Sagitta på 9,143 mm.
- Magneterne køles ned til  $1,9\text{K} \approx -271,3^\circ\text{C}$



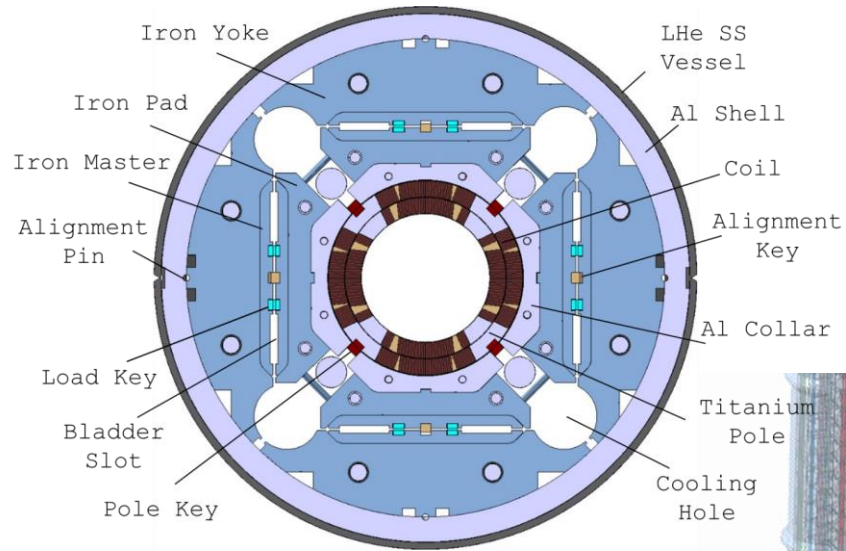
# Large Magnet Facility

Hvad laver LMF?

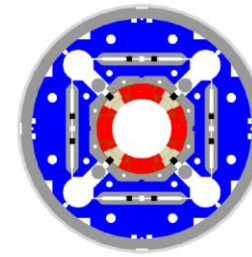


# Hvad laver vi nu - HiLumi

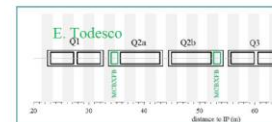
Udskifter triplet magneter



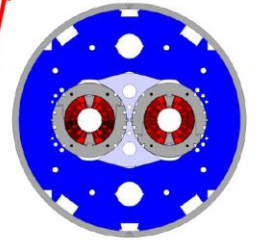
**MQXF**



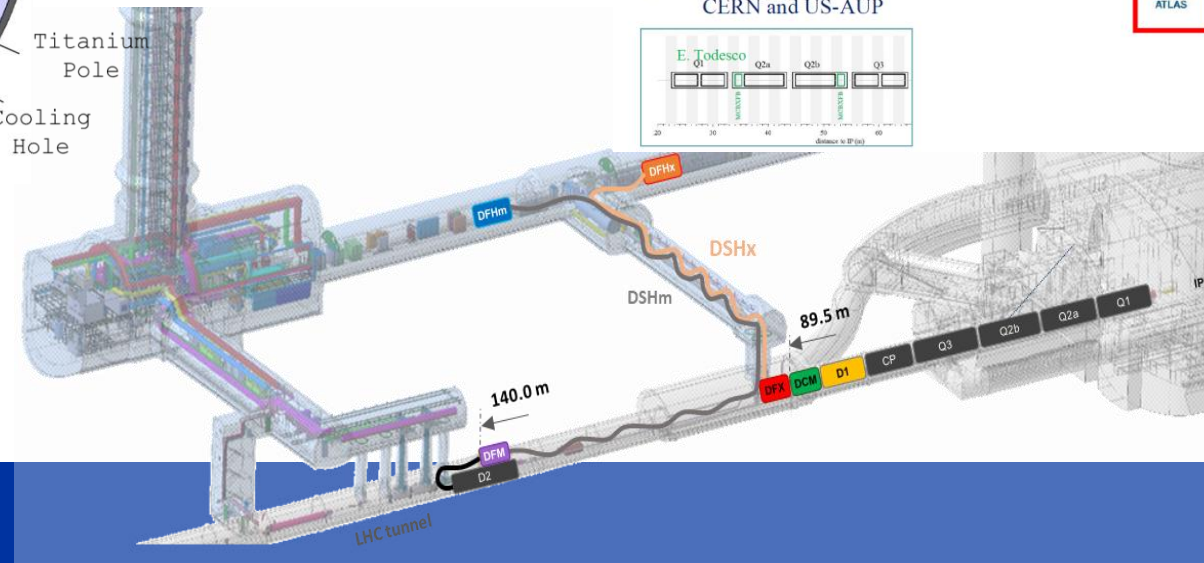
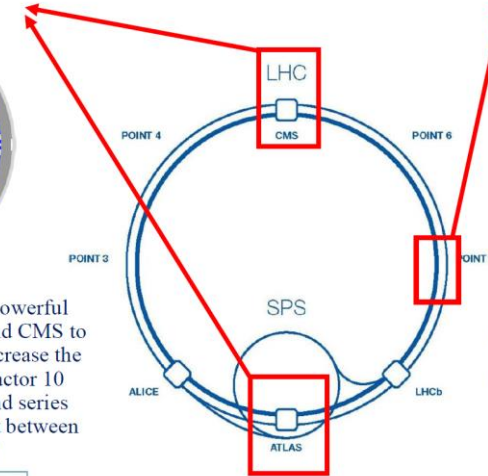
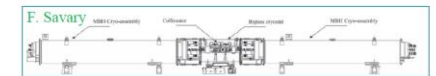
30 large aperture and more powerful quadrupoles around ATLAS and CMS to decrease the beam size and increase the integrated luminosity by a factor 10  
Construction of pre-series and series magnets on-going, joint effort between CERN and US-AUP



**HL-LHC MBH 11 T**

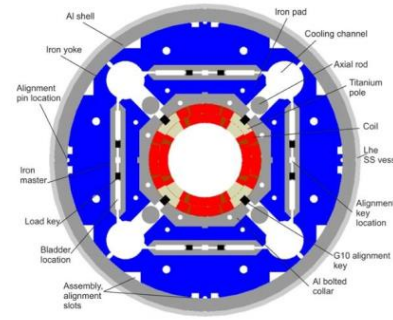


4 pairs of shorter and more powerful dipole bending magnets to free up space for the new collimators (2x5.5 m length 11 T dipoles to replace 14.3-m-long LHC MB dipole)  
Initially planned for 2020, now delayed



# HiLumi

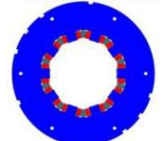
Det er et globalt samarbejde



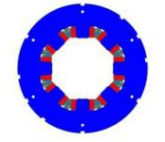
Triplet [G. Ambrosio, P. Ferracin et al.]



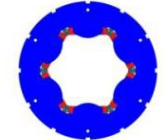
Dodecapole



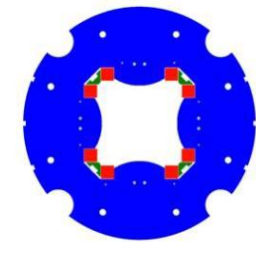
Decapole



Octupole

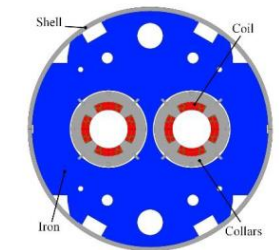


Sextupole

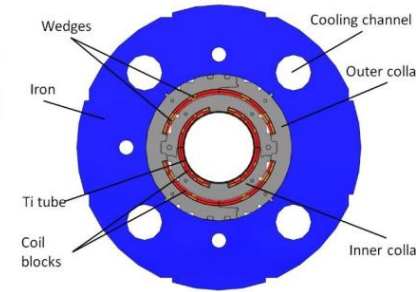


Skew quad

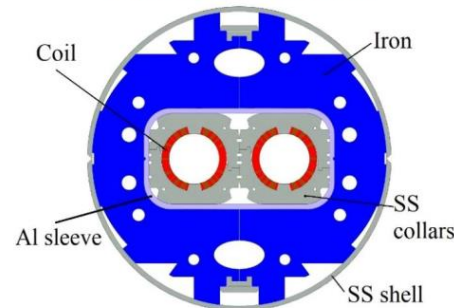
[M. Sorbi, M. Statera, et al.]



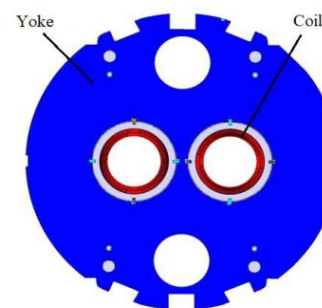
MQYY [H. Felice, et al.]



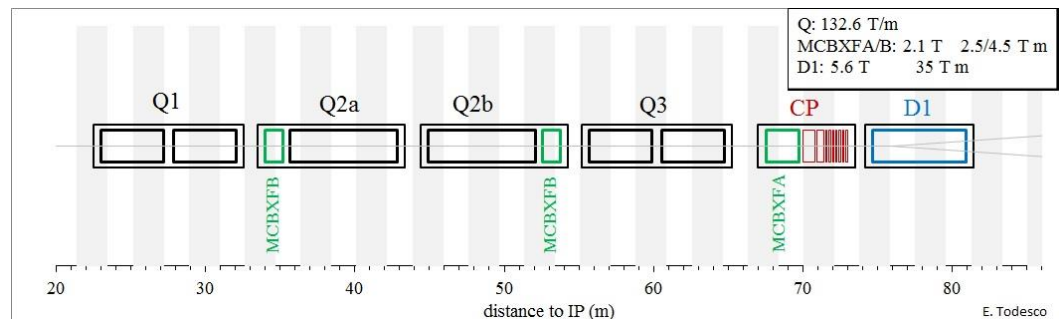
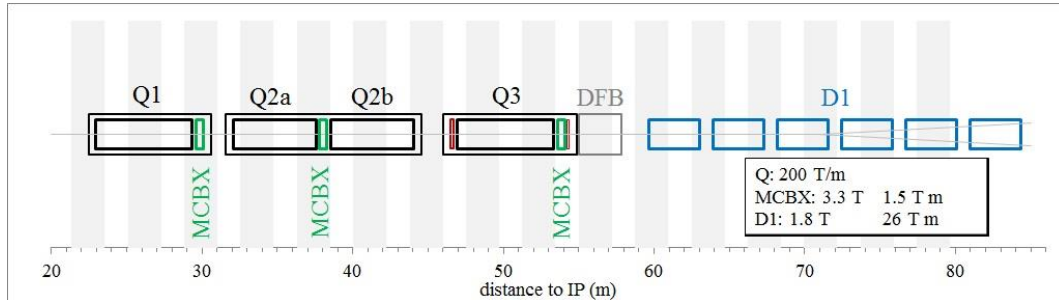
MCBXF [F. Toral, et al.]



D2 [P. Fabricatore, S. Farinon, et al.]



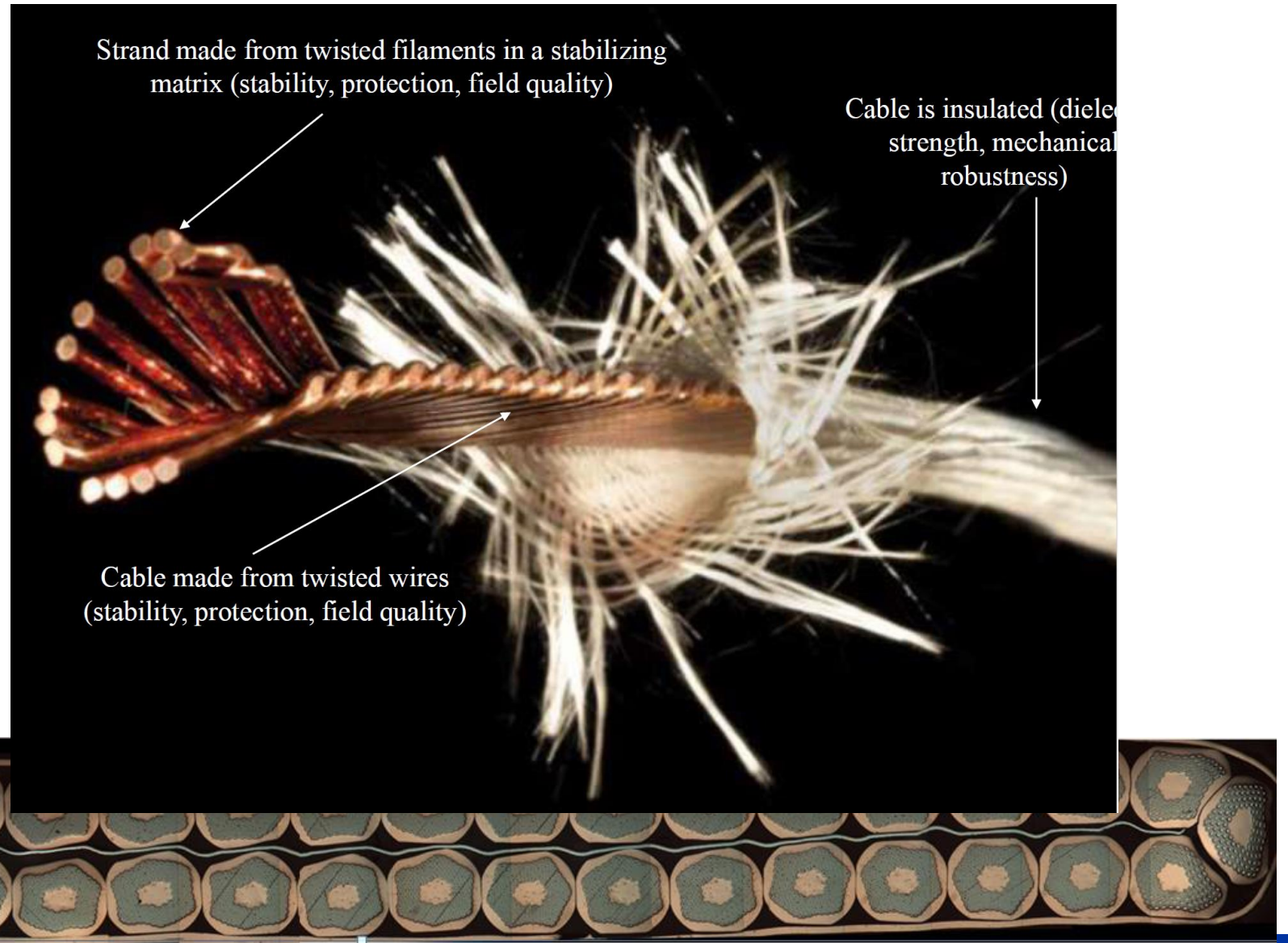
D2 correctors [G. Kirby, O. Xu, et al.]



# HiLumi

Nye materialer giver nye udfordringer

- Nb-Ti
- **Nb<sub>3</sub>Sn**

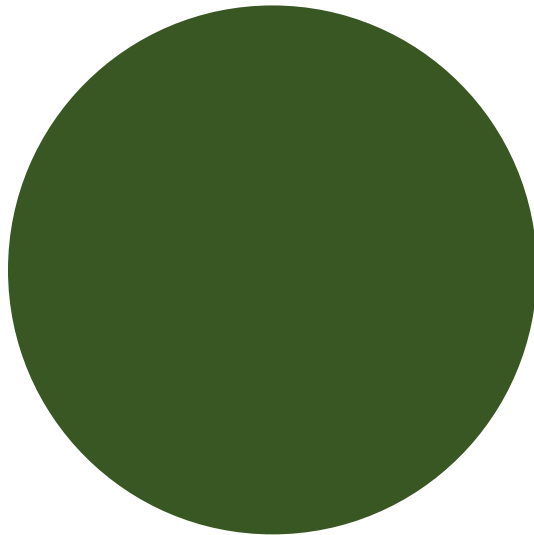




# HiLumi

Typical operational conditions (0.85 mm diameter strand)

Cu

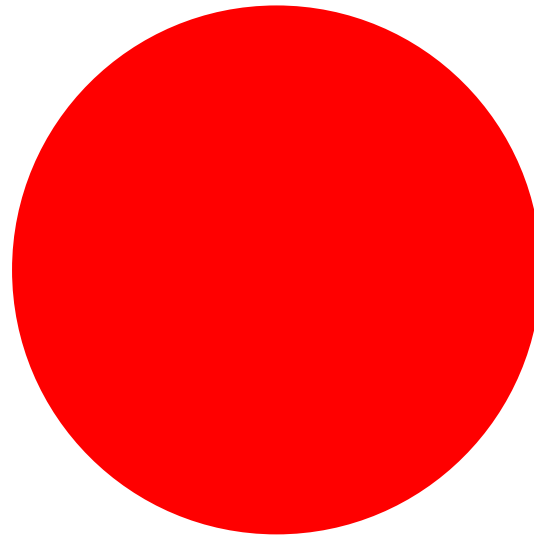


$$J_e \sim 5 \text{ A/mm}^2$$

$$I \sim 3 \text{ A}$$

$$B = 2 \text{ T}$$

Nb-Ti

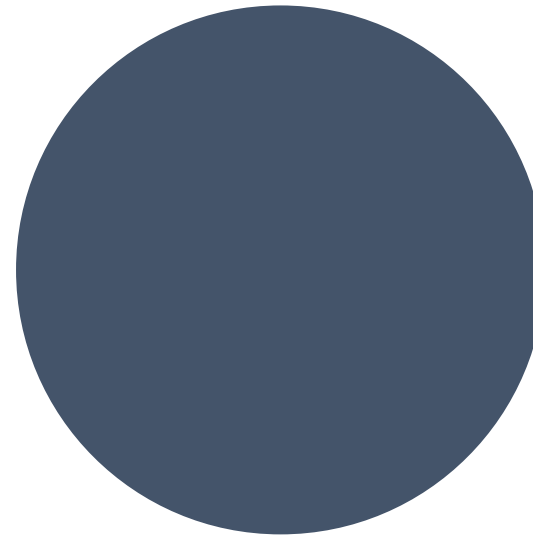


$$J_e \sim 600\text{-}700 \text{ A/mm}^2$$

$$I \sim 300\text{-}400 \text{ A}$$

$$B = 8\text{-}9 \text{ T}$$

Nb<sub>3</sub>Sn



$$J_e \sim 600\text{-}700 \text{ A/mm}^2$$

$$I \sim 300\text{-}400 \text{ A}$$

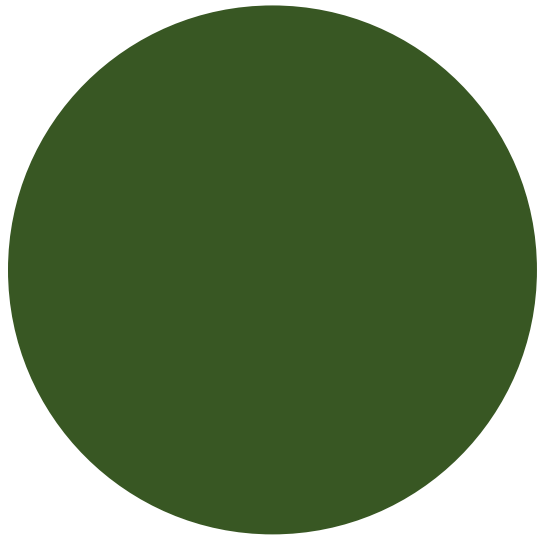
$$B = 12\text{-}13 \text{ T}$$

by P. Ferracin

# HiLumi

Typical operational conditions (0.85 mm diameter strand)

Cu

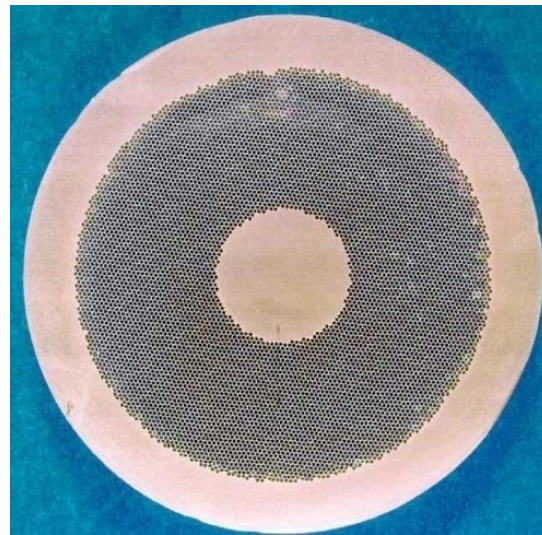


$$J_e \sim 5 \text{ A/mm}^2$$

$$I \sim 3 \text{ A}$$

$$B = 2 \text{ T}$$

Nb-Ti

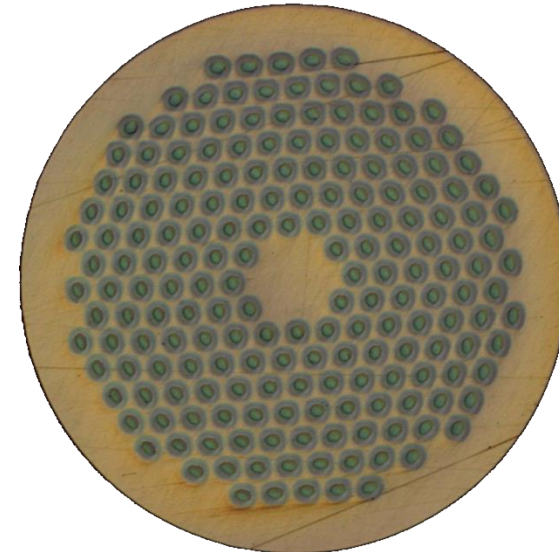


$$J_e \sim 600\text{-}700 \text{ A/mm}^2$$

$$I \sim 300\text{-}400 \text{ A}$$

$$B = 8\text{-}9 \text{ T}$$

Nb<sub>3</sub>Sn



$$J_e \sim 600\text{-}700 \text{ A/mm}^2$$

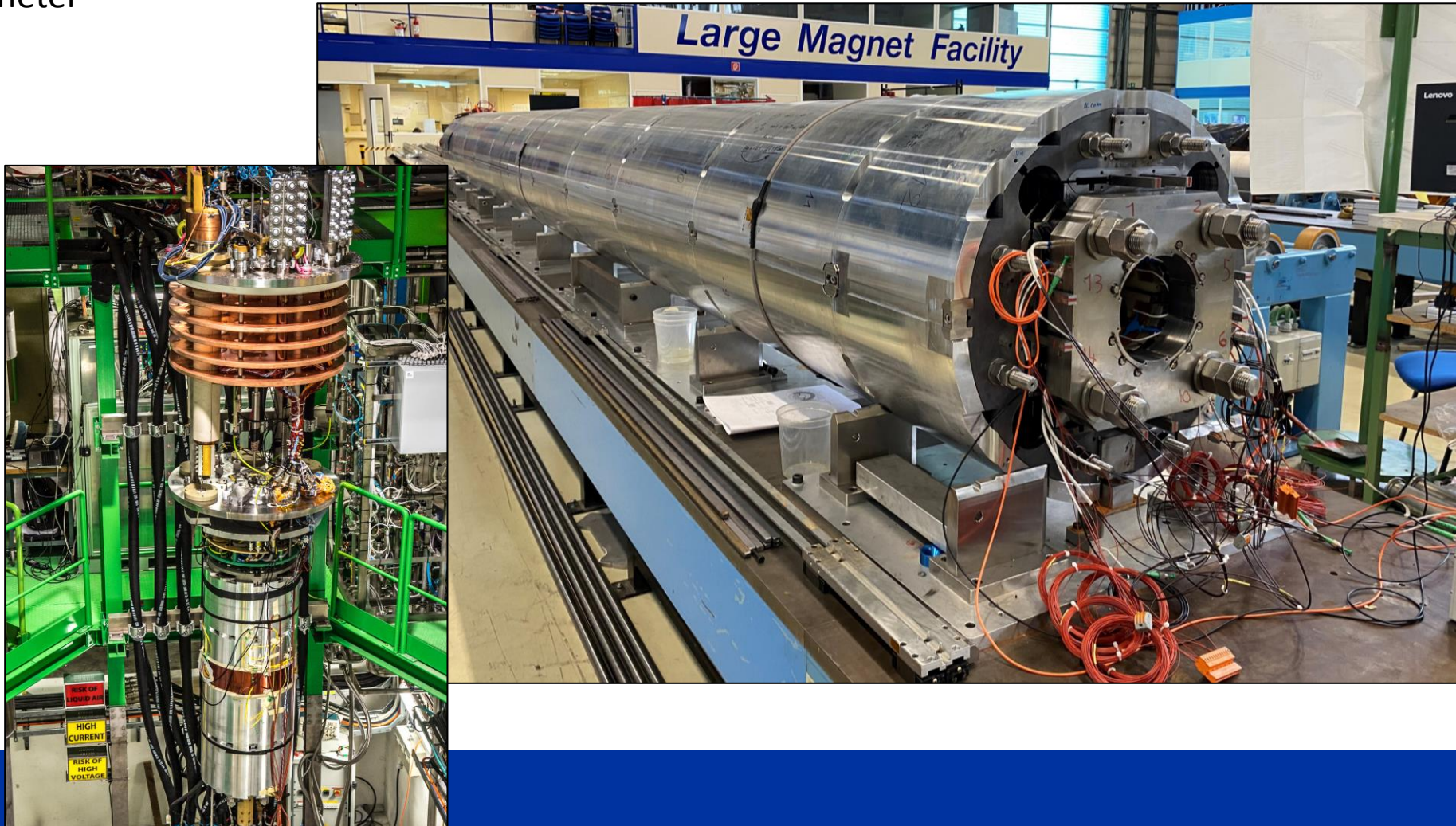
$$I \sim 300\text{-}400 \text{ A}$$

$$B = 12\text{-}13 \text{ T}$$

by P. Ferracin

# HiLumi

MQXFB/S magnet



# HiLumi

Vi ses i bygning 180

Aka :  
The Large Magnet Facility



LMF,  
29/03/2022

MQXFBP2:  
Temporary cold mass → Final cold mass

MQXFBP3:  
Magnet → Temporary cold mass

MQXFB02:  
Coils → Magnet

by S. Izquierdo Bermudez