CERN Accelerator School

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MAGNETS

Magnet types and performances
Part 1

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Magnet types and performances
Part 1

- A few things to remember about magnetism
- Think FLUX
- If I was an electron
- Basic concepts
- Example of the SOLEIL magnets
- Details on the SOLEIL Dipole magnet

Experience of J.C. Oersted (1820)

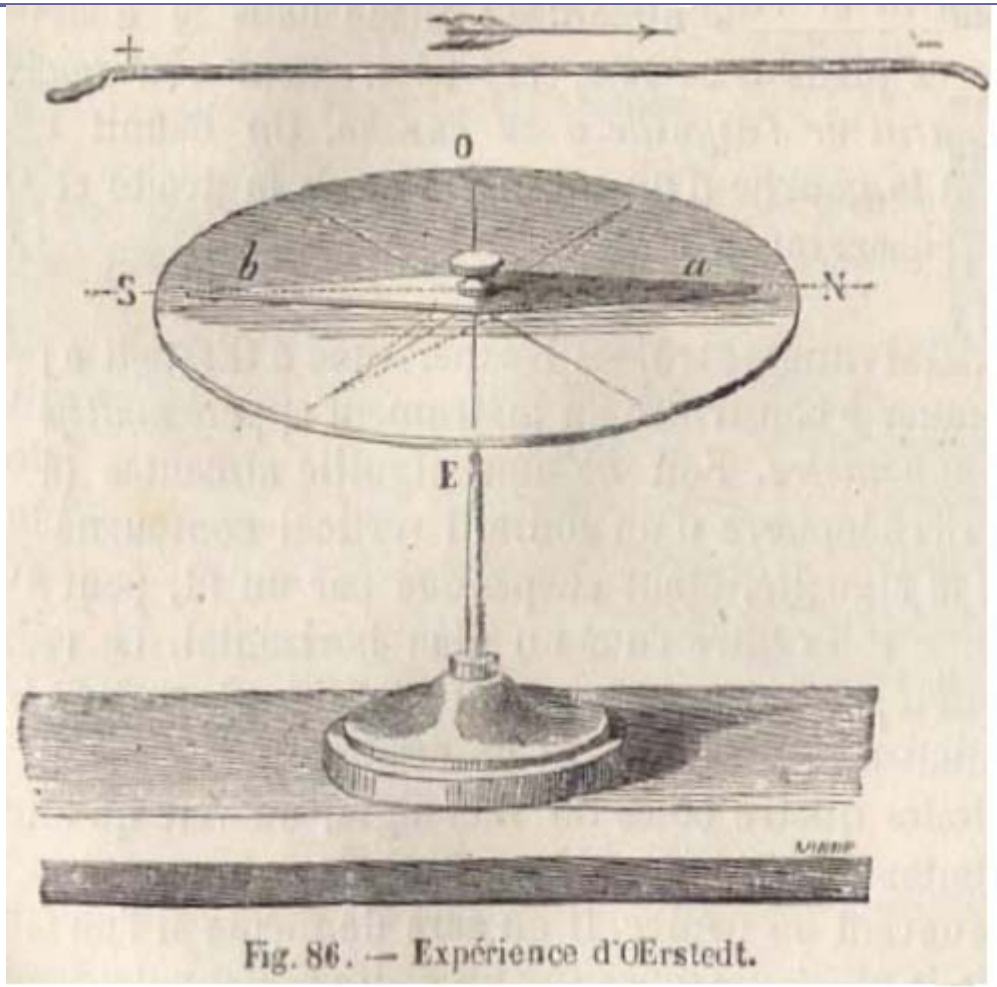
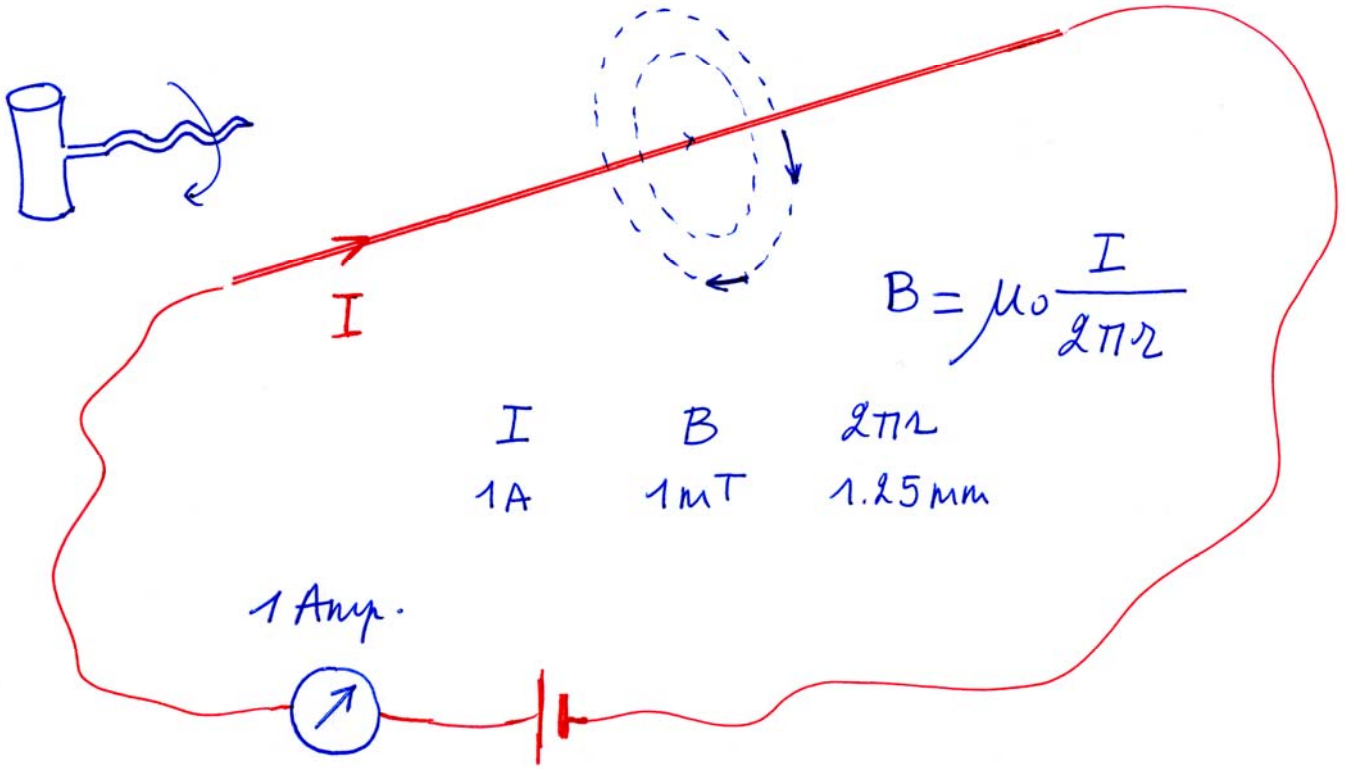
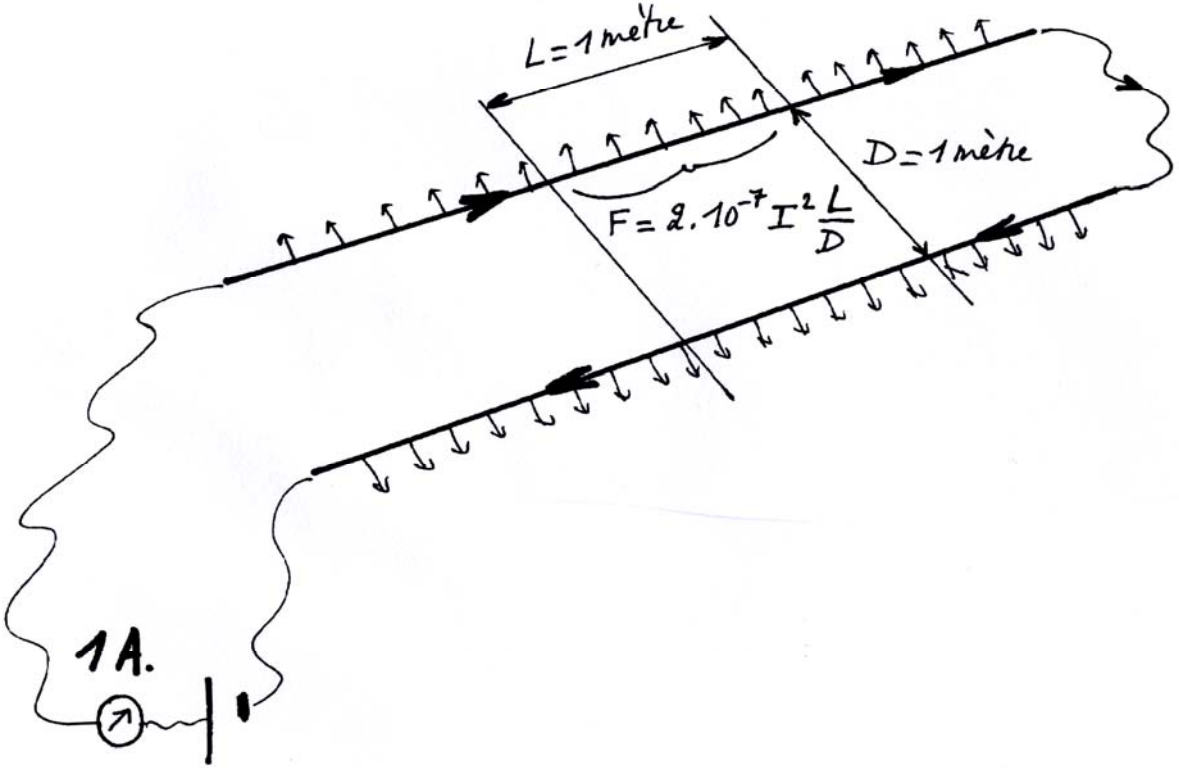


Fig. 86. — Expérience d'Œrstedt.

H.C. Oersted (July 1920)



André Marie AMPÈRE ~1820



Ampere's Theorem

- Please remember:

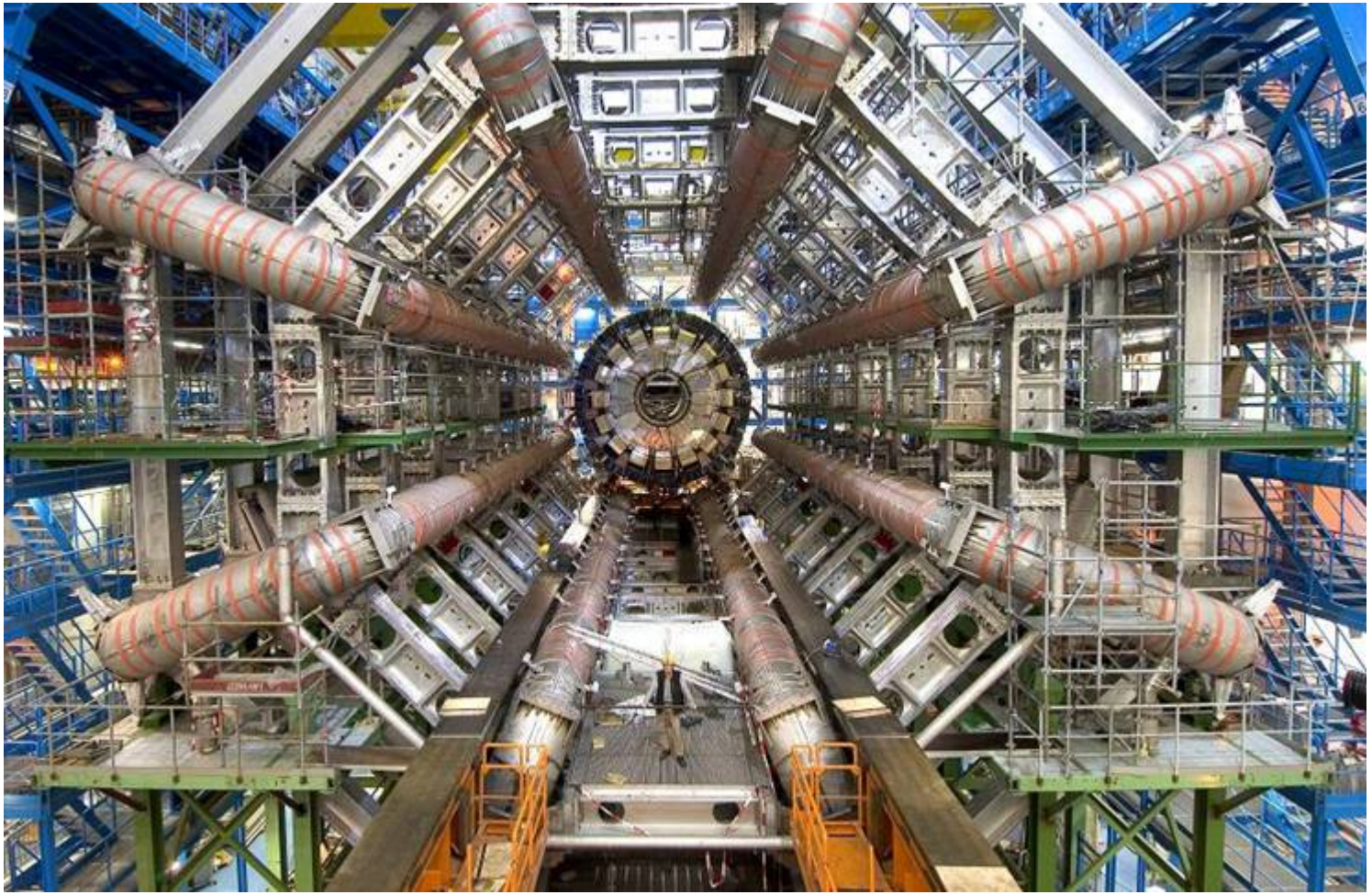
Current	Field	Length
1A	1mT	1.25 mm

YOU NEED: 46.4/2/1.25= 4.6*4= 19MAmps	0.5 Tesla	46.4 m

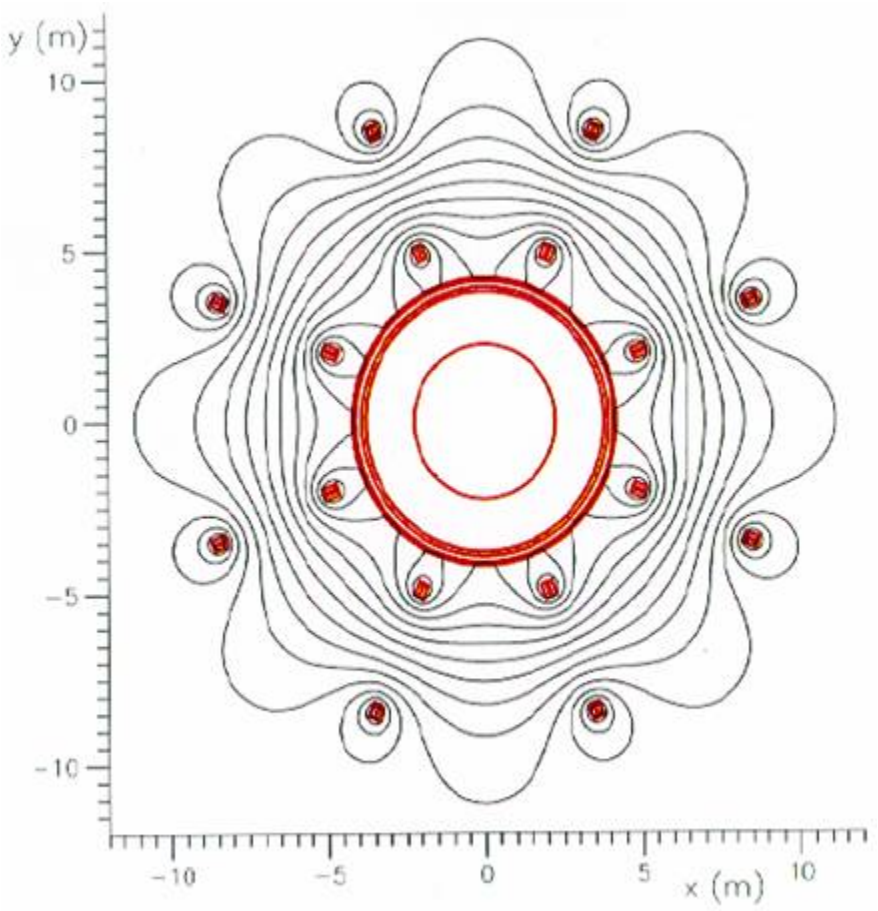
ATLAS barrel toroid parameters

- Internal diameter : 9,4 m
- External diameter : 20,1 m
- Average diameter: 14.75 m
- Length : 25,3 m
- Number of coils : 8
- Ampere-turns: 19,7 MAmps
- Nominal current: 20,5 kA (8 coils of 120 turns)
- Stored energy :1080 MJ

ATLAS Barrel Toroid



Please remember : Think FLUX



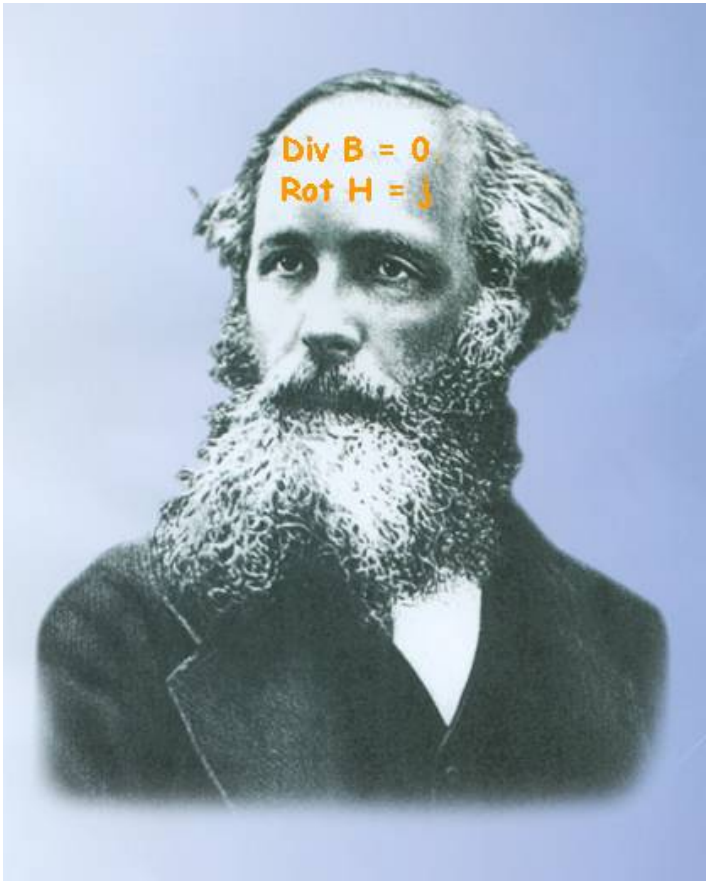
- Flux is kept inside tubes
- These tubes must close on themselves
- The shape of these tubes is obeying to very constraining laws : the Maxwell equations are the mathematical translation of these laws
- B is the flux density : when the tubes enlarge B is decreasing , when the tubes are narrowing field is increasing

Maxwell equations : think Flux

James Clerk MAXWELL

- All the day we obey to Maxwell equations to create magnetic field.
- The representation of flux tubes is a very powerful method.
- Flux is going from North to south

Maxwell’s equations for magneto-statics



- The phenomenon's are perfectly known.
- Maxwell’s equations have been solved by different methods.
- The precision request is in the range of 10-4
- Ferromagnetic material properties are non linear and are not easy to simulate.

Historical overview of magnetic circuit

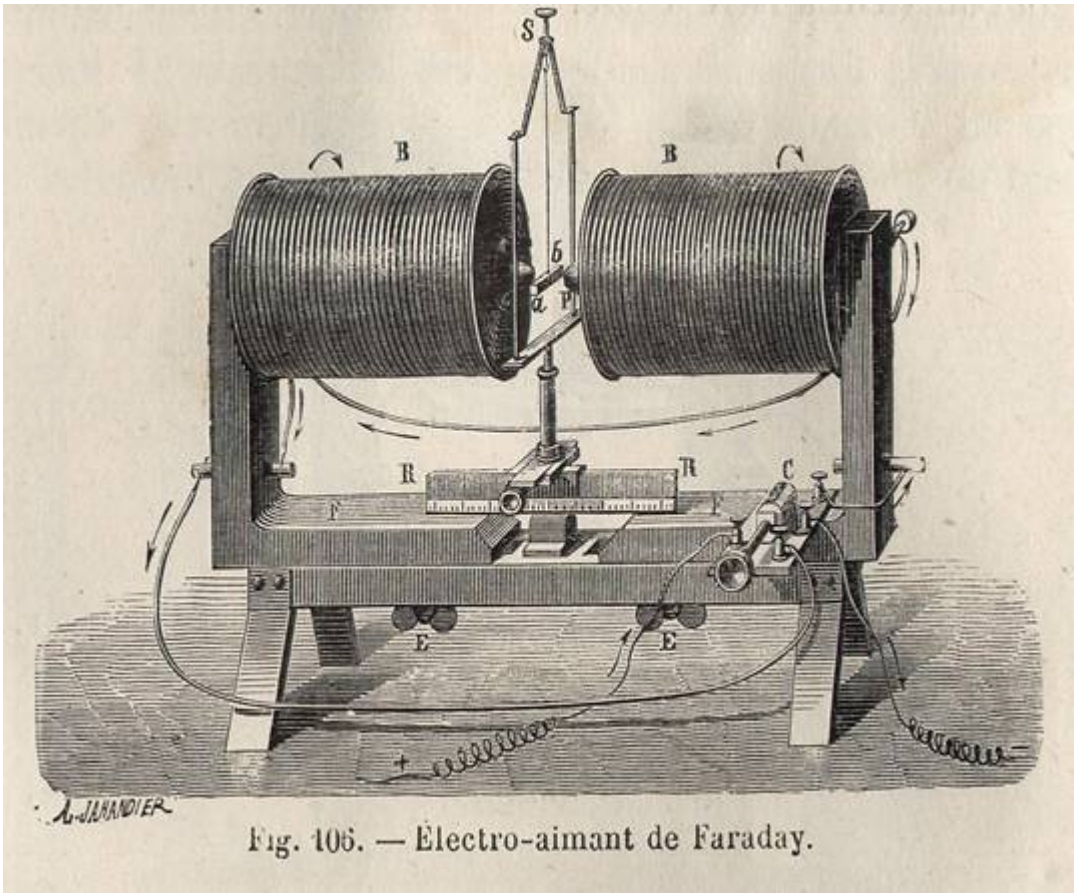


Fig. 106. — Électro-aimant de Faraday.

- This electromagnet was used by Faraday to measure diamagnetic elements
- The role of pole tips, coils and yoke was perfectly known in the 19th century
- Some improvement was possible in the sizing of the yoke
- These improvements appeared with the series of laboratory magnets in the beginning of 20th century

If I was an electron

Please remember:

- When Field is up , electrons go left
- Field integral through a magnet is

$$\int_{-S_o}^{+S_o} B_z ds$$

In common language we say $\int Bdl$

$\int Bdl$ divided by the magnetic rigidity is giving the angular deflection in radians.

For 2.75 GeV electrons, magnetic rigidity is 9.2 Tm.

From MT5 in Roma to MT19 in Genoa

- In 1975 an invited paper « Developments in magnet technology » was presented by Roy Billinge from CERN at the MT5.
- The « state of the art » of magnet technology could be demonstrated by the requirements , design , construction and measurements of the SPS magnet system (800 bending magnets each 6.25m long and 200 quadrupoles each 3m long
- In 1976 The SPS started successfully and operated for 30 years

The SPS was representing the ultimate in magnet engineering and technology: all the basic concepts and techniques had been fixed from 1950 to 1975

Peak field : 1.8T

Peak Current : 4900A

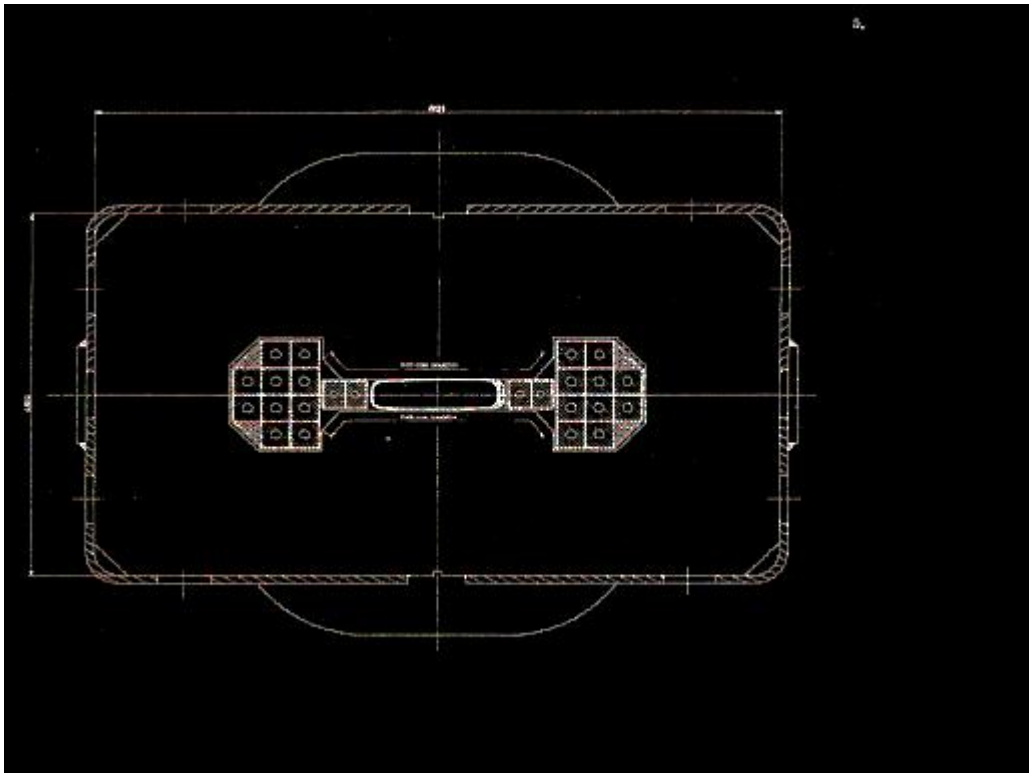
Power : 31 kW

Stored Energy : 88 kJ

Tolerances :

Maximum systematic variation : +-3.10-4

Maximum random variation : 5.10-4



MT19 at Genoa 2005…where are we ?

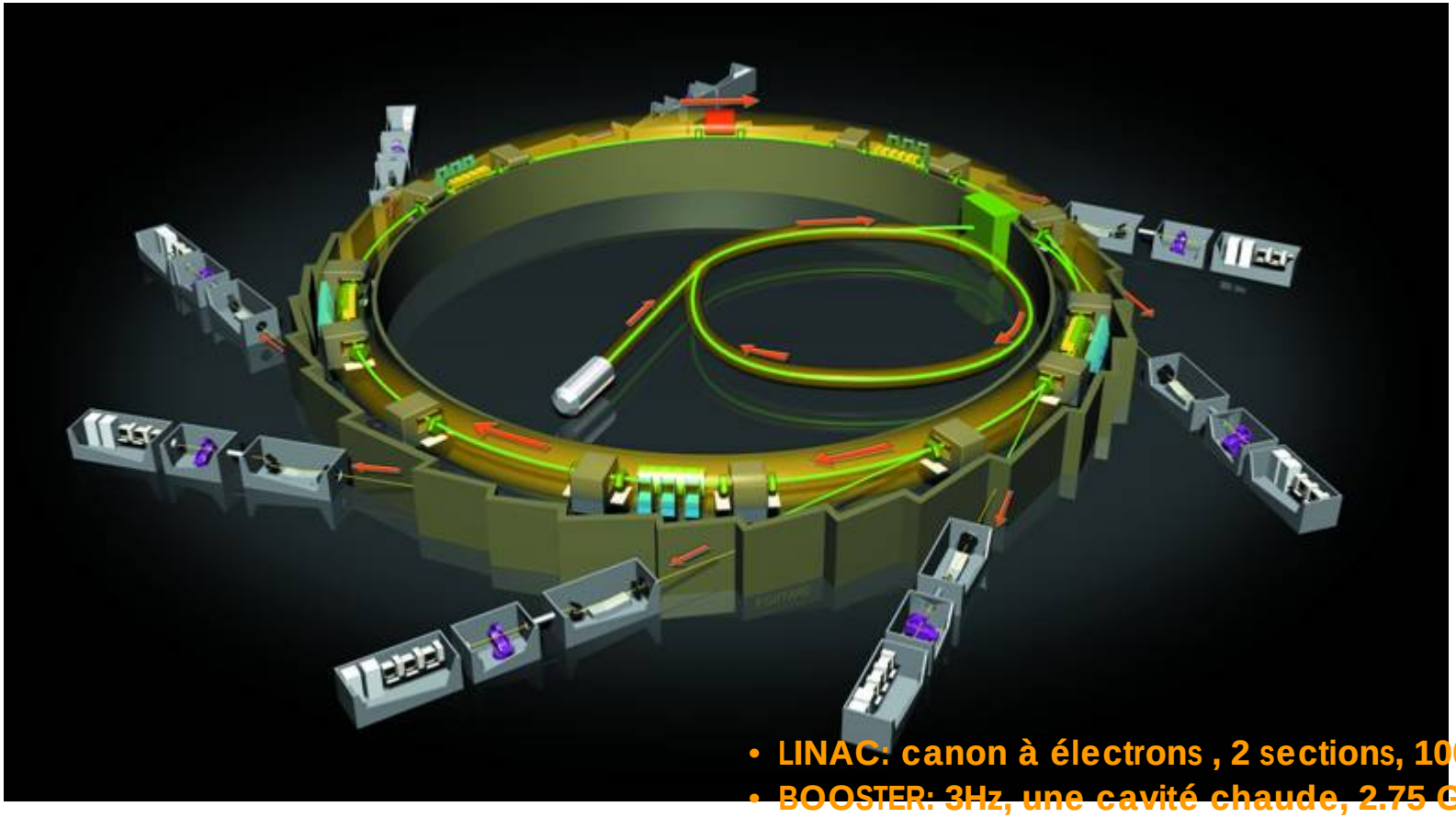
- The present « state of the art » of Accelerator magnet technology can be illustrated by the magnet system of the 3rd generation synchrotron light sources

- Recent examples are SLS (PSI) , Diamond (UK) and SOLEIL (France)

SOLEIL Site

MINISTERE DE LA RECHERCHE
Région Ile de France
LE CONSEIL GENERAL
© Atelier d'architecture Chaix & Morel et associés

Chaîne des accélérateurs



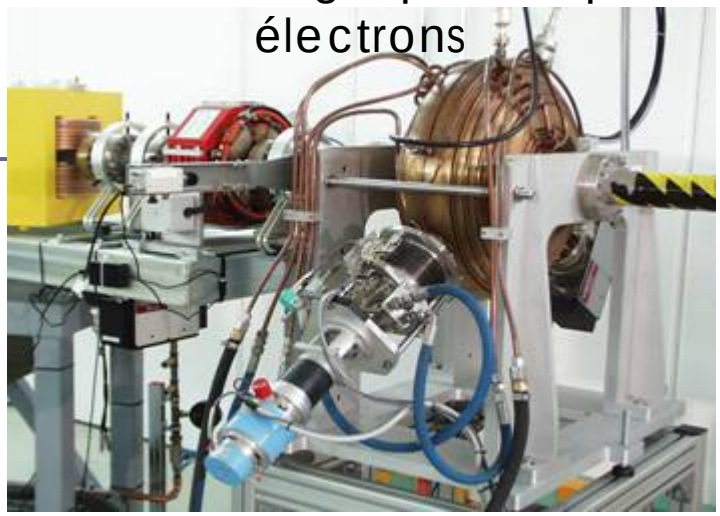
- LINAC: canon à électrons , 2 sections, 100 MeV
- BOOSTER: 3Hz, une cavité chaude, 2.75 GeV
- Anneau de stockage: 2.75 GeV électrons ultrarelativistes

- Les quadrupôles exercent sur les électrons une force de rappel proportionnelle à leur déviation par rapport à la trajectoire de référence.
- L'association de quadrupôles défocalisants et focalisants permet d'obtenir un système de focalisation dans les 2 plans : horizontal et vertical.

QUADRUPOLES

Cavité accélératrice

restituer l'énergie perdue par les électrons



SEXTUPOLE

pour corriger certaines aberrations

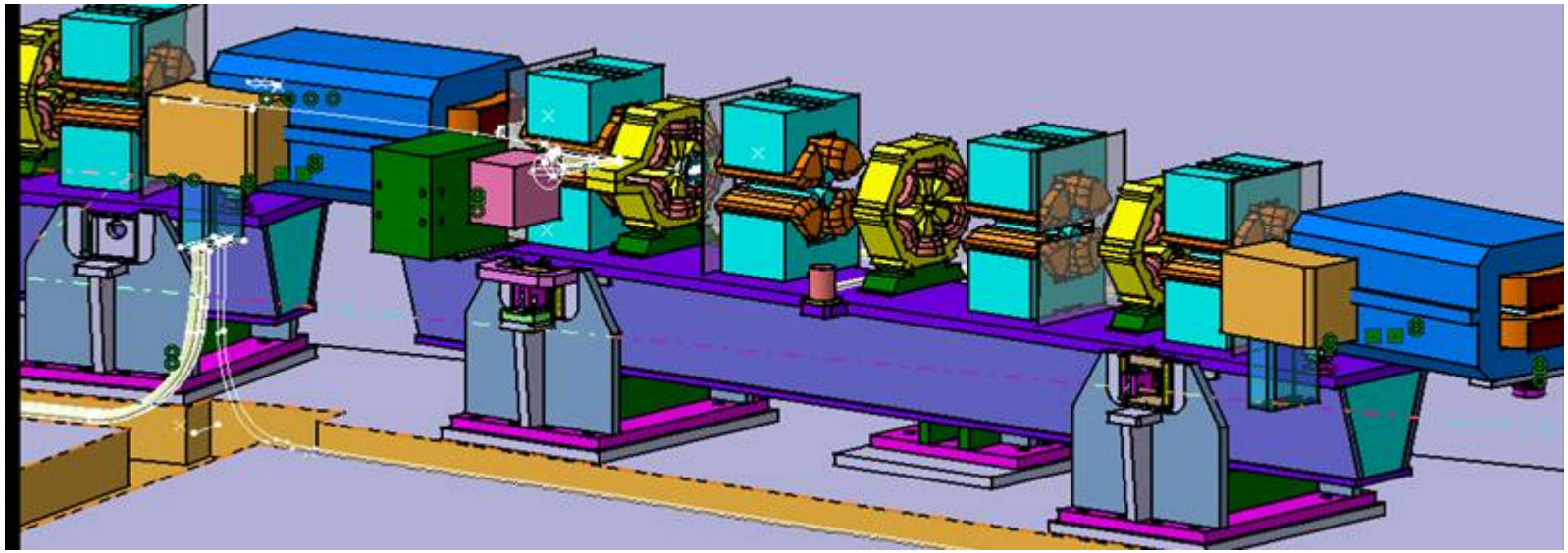
Industrial production of synchrotron sources

SOLEIL	Ring Dipoles	Ring Quadrupoles	Ring Sextupoles	Booster Dipoles	Booster Quadrupoles
Number	32	160	120	36	44
Force	1.71T	23T/m	320T/m2	.74T	11T/m
Length(mm)	1052	320 or 460	160	2160	400
COMPANY	TESLA	DANFYSIK	SIGMAPHI	SIGMAPHI	BUDKER BINP

DIAMOND	Ring Dipoles	Ring Quadrupoles	Ring Sextupoles	Booster Dipoles	Booster Quadrupoles
COMPANY	SIGMAPHI	TESLA	BUDKER BINP	DANFYSIK	DANFYSIK

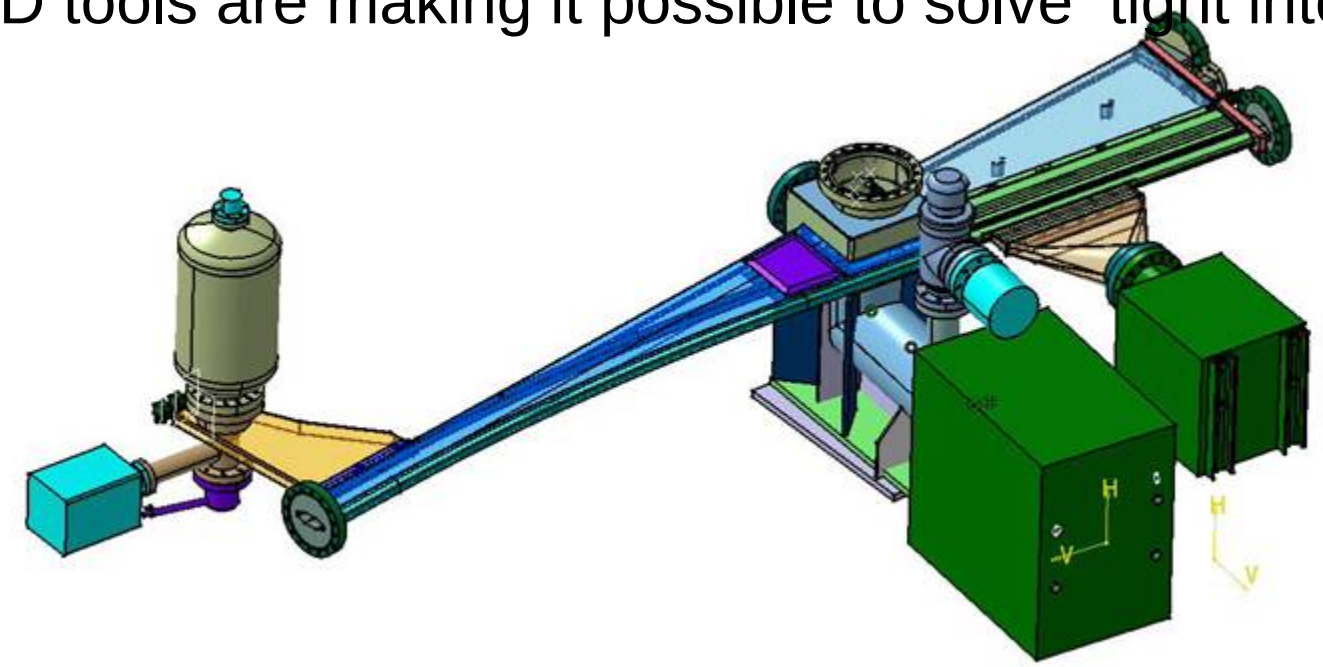
Magnet table SOLEIL

	RING			BOOSTER		
	Dipoles	Quadrupoles	Sextupoles	Dipoles	Quadrupoles	Sextupoles
Number	32	160	120	36	44	28
Force	1.71 T	19et 23 T/m	320 T/m²	0.74 T	11 T/m	16 T/m²
Length(mm)	1052	320 ou 460	160	2160	400	150

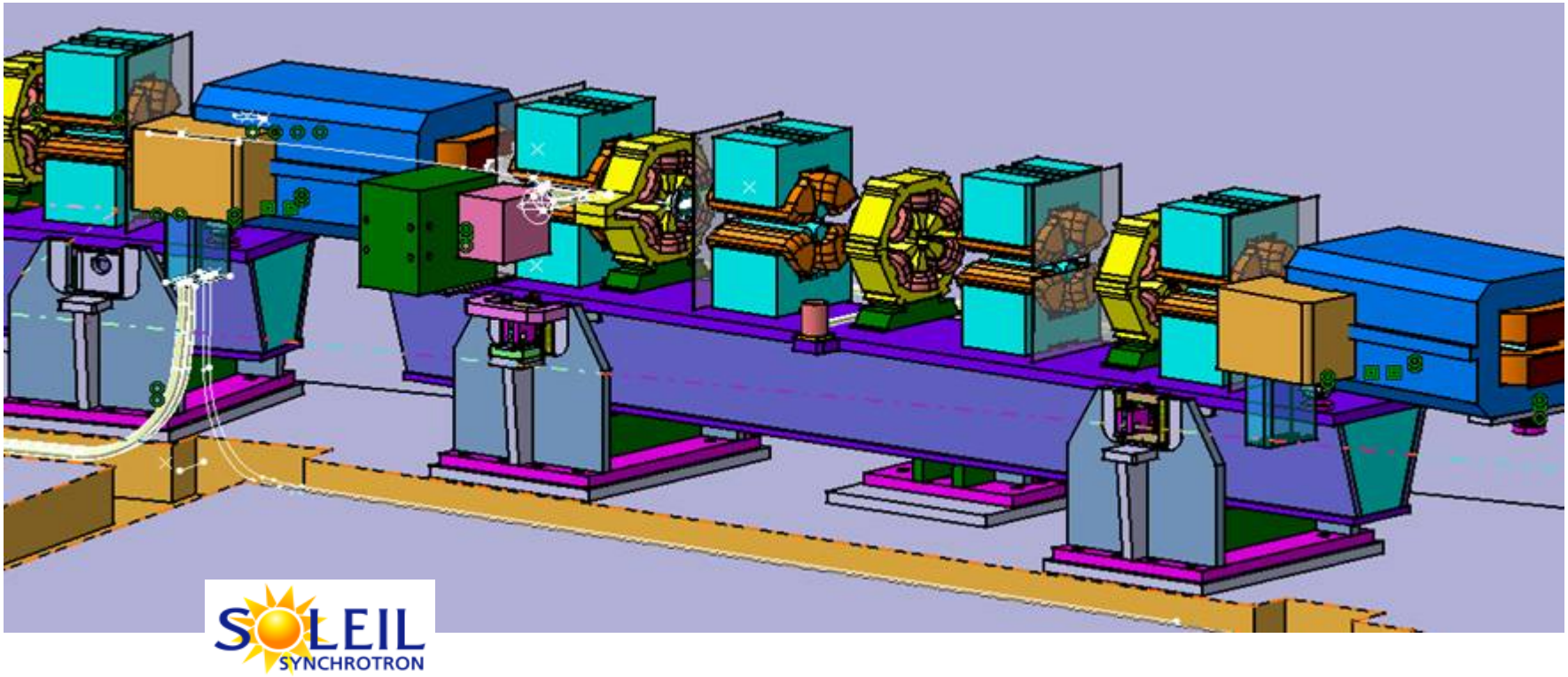


Around this vacuum chamber we have to put one dipole, one quadrupole & one sextupole

- Magnet design is strongly depending of vacuum chamber technology and pumping elements.
- Accelerators are more and more compact.
- CAD tools are making it possible to solve tight interfaces



One more step is the integration of magnets on girders

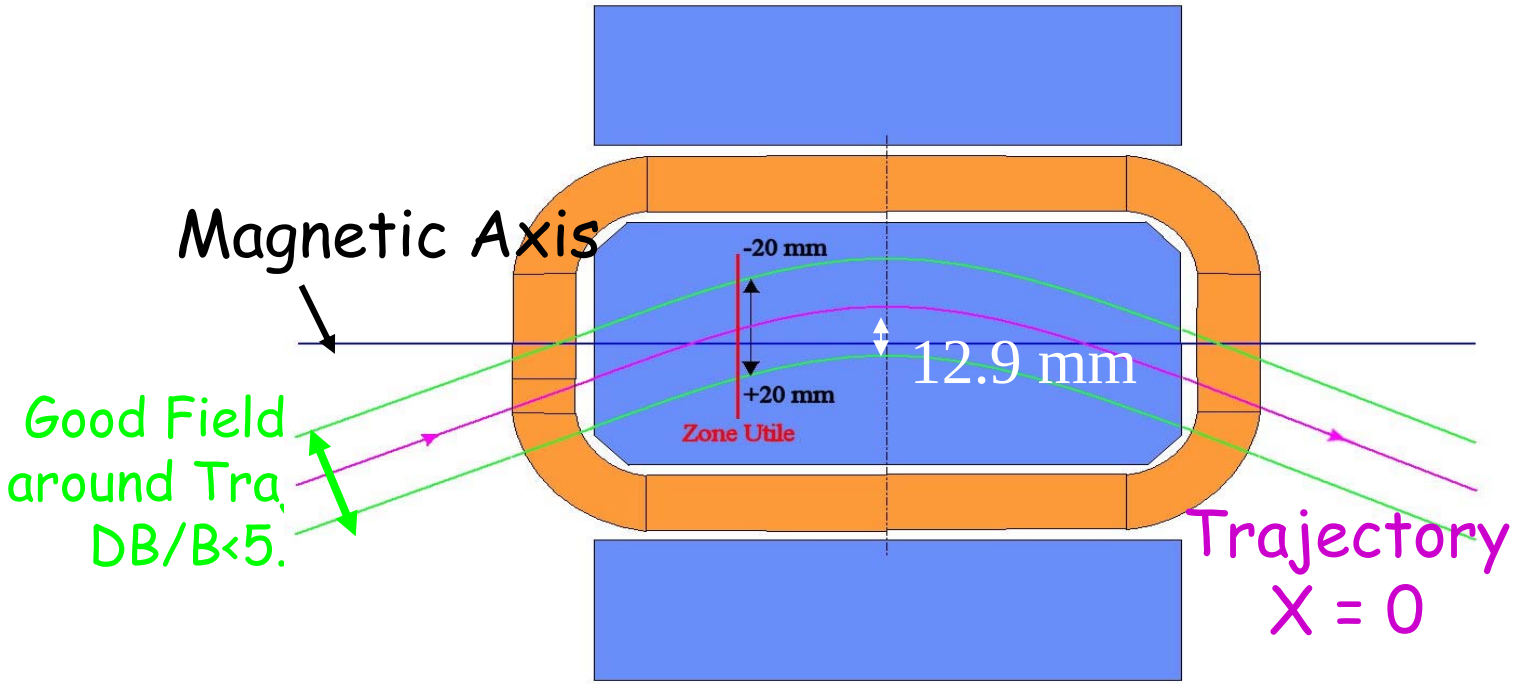


The design incorporates coherent motion rather individual magnet motions.It has consequences on survey techniques and vibration studies

Example of a dipole magnet

- Design criteria
- Flux lines
- Technological aspect
- Comparison between calculation and measurement.

Parameters for accelerator Physicists



Nominal induction :	1.71 Tesla	
Gap:	37.00	mm
Radius of curvature :	5360.00	mm
Bending angle :	11.25	deg