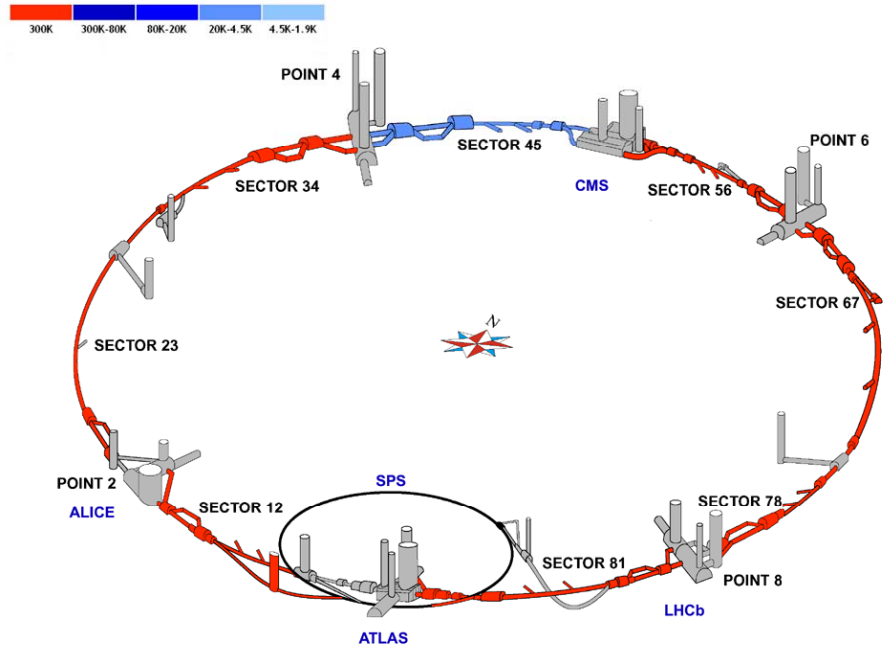
CERN plans on high field magnet development

Davide Tommasini

- **Present situation of the LHC**
- **Sc magnet activities beyond LHC start**
- **R&D topics**
- **On going**
- **Conclusions**

Present situation of the LHC

- Machine arc interconnections have being completed (last bolt tighten **today**)



- IR regions will be closed by March 2008
- **LHC open days 5-6 April 2008 (machine is planned to be cold)**
- **June 2008 beam injection in the LHC**
- **Summer 2008 first collisions**
- **21 OCT 2008 LHC Inauguration day**
- **Physics run: 2009**

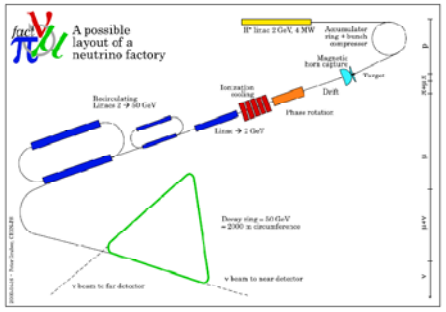
Sc magnet activities beyond LHC start

- Necessary - Funded
  - magnet R&D in "The White Paper" 2008-2011 (6 year-version under study):
    - 20.5 MCHF + 73 FTE-y in HFM (primarily Nb_3Sn but HTS considered)
    - 1.5 MCHF + 7 FTE-y for FCM
  - magnet R&D in the FP7
  - installation of a "long" magnets facilities in 2008-2009
- Desirable (necessary ?) - Not funded
  - Triplet upgrade with existing NbTi conductor (R.Ostojic session 2)
- Being considered
  - D0
  - Q0
  - Undulators for beam diagnostics with lead ions
  - Wigglers for CLIC damping ring
  - Cycled magnets for PS2

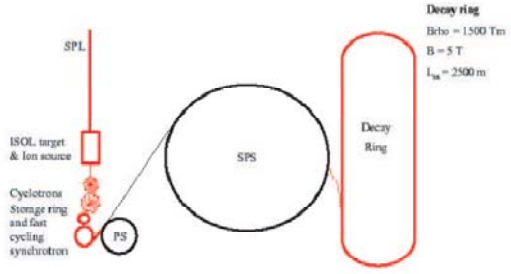
We will specifically consider high field magnet developments

HF magnets

- Large aperture, high peak field low-beta insertion quadrupoles Q1-Q2-Q3
- Large aperture, high peak field correctors for low-beta insertions
- High field (< 15 T) , any cost, dipole for Fresca upgrade
- High field, compact, any cost, D0 dipole (with 2 beam-beam LR at 5 σ, > 7 m)
- Very high field (15-25 T), low cost, dipole (LHC energy upgrade)
- Use of temperature margin for large heat deposition (D1, Q0, D0)
- High peak field undulators for LHC lead ions beam diagnostics
- High peak field wigglers for CLIC damping rings
- Open midplane dipoles for neutrino factories



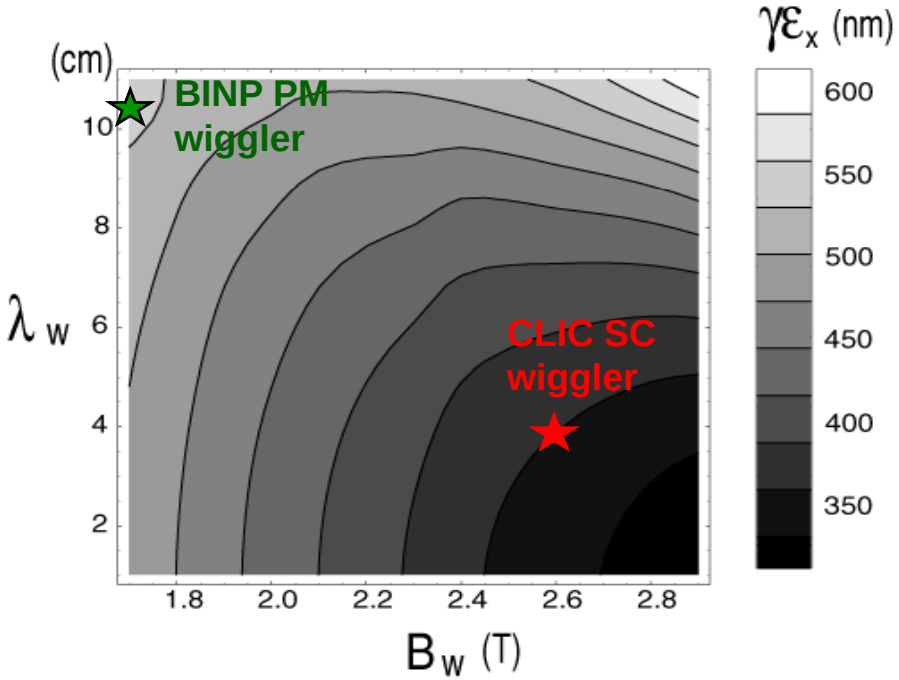
muon decay ring

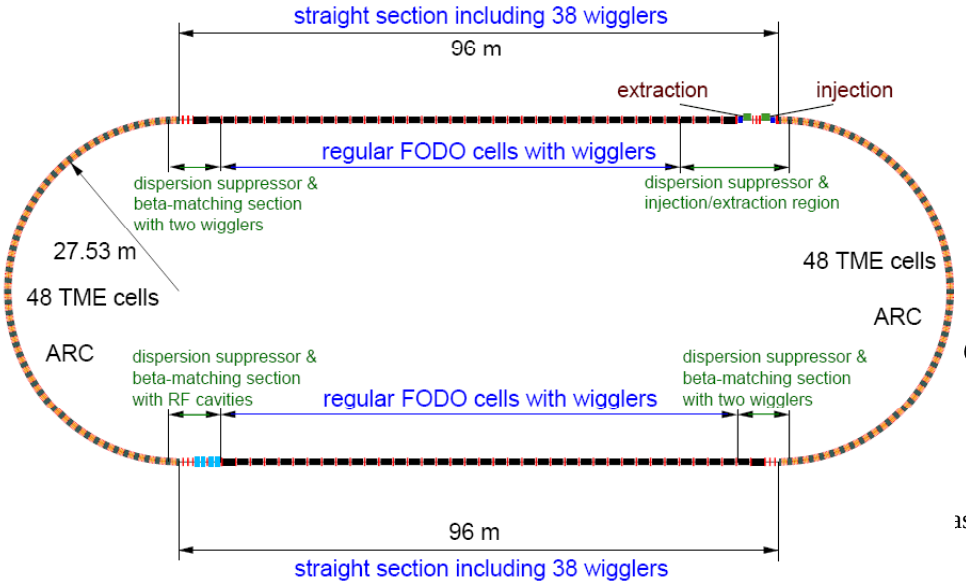


beta beam decay ring

The reasons for some of these magnets are covered by other talks

Wigglers for CLIC DR

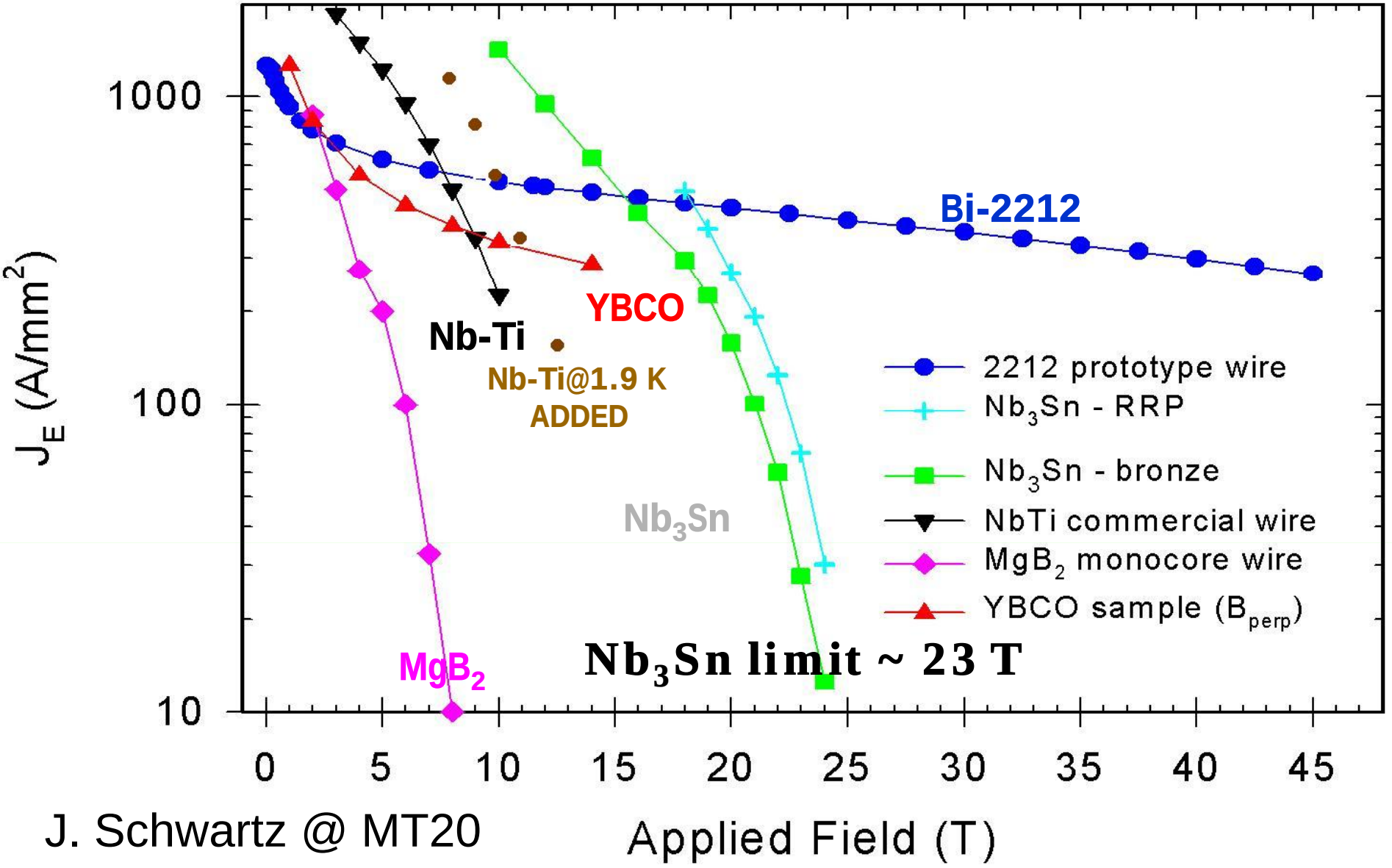




- In presence of intra-beam scattering, the target horizontal normalised emittance of **450nm** is reached only with damping wigglers
- **Smaller** transverse emittance attained for **higher** wiggler fields and **lower** periods
- **Super-conducting** wiggler prototype in Nb_3Sn reaching **2.6T**, **4cm** period, with aperture of 8-10mm, to be designed, built and tested with beam at ANKA synchrotron light source

Courtesy Yannis Papaphilippou

Technologies beyond NbTi



J. Schwartz @ MT20

Next steps

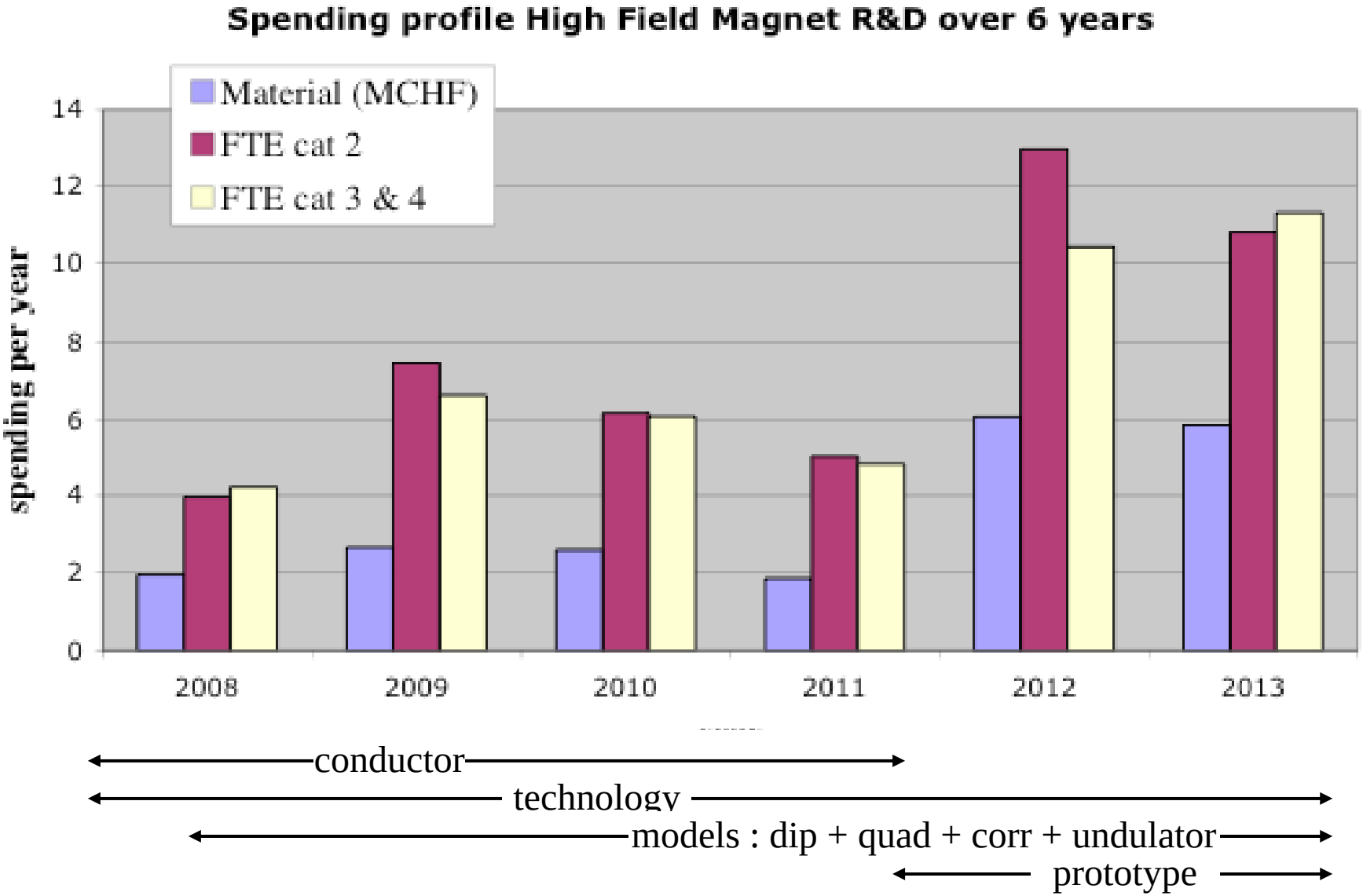
coordinated by Gijs de Rijk

- White paper HFM program
  - Formulate definitive HFM program
  - Selection of WP leaders
  - Form collaborations with other institutes (eg CEA, CIEMAT, INFN, STFC-RAL, UNIGE, Twente, Wroclaw, etc…)
  - Define collaboration with LARP
  - Start work on 1/1/2008
- FP7-IA-HFM
  - Preparative negotiations until end of year (ESGARD, DG, DL, GLs, activity leaders, potential partners) to get a program proposal
  - Write WPs for the FP7-IA submission (Febr. 08)
  - Wait for EU approval (mid 2008)
  - FP7-IA negotiation phase
  - FP7-IA contract signature (2nd part 2008)
  - Start work in 2009

R&D Topics

- Conductor
  - **Develop stable, high Jc conductors**
  - **Magnetization ?**
- Enabling technologies & support studies
  - **Electromagnetic layouts**
  - **Mechanical structures**
  - **High thermal transfer insulation**
  - **Radiation resistant insulation**
  - **Model coils (solenoid-racetrack) to study insulation & thermal treatment**
  - **Prospect HTS possibilities (design and build a 20 T insert)**
- Model magnets
  - **Design build and tests short models (dipole, quad and corrector)**
- Prototype magnet
  - **Design build and test 4 m prototype (dipole or quad)**

Budget


Spending profile High Field Magnet R&D over 6 years
Material (MCHF)
FTE cat 2
FTE cat 3 & 4
spending per year
0
2
4
6
8
10
12
14
2008
2009
2010
2011
2012
2013
conductor
technology
models : dip + quad + corr + undulator
prototype

Dipole model

1.5 m long, 13T bore field, 100 mm aperture model magnet for Fresca

Undulator

140 mm period, 60 mm gap for LHC with lead ions

mm period, 10 mm gap, for CLIC damping ring

Quadrupole model

Start coils not before mid-2012 to fully benefit from LARP experience

1.5 m long, 130 mm aperture or larger

Corrector model

Sextupole or octupole, wound from a single wire conductor around a 130 mm aperture

20 T HTS insert

HTS insert in the 1.5 m model to provide 6 T additional field

Bi-2212 round wire (Rutherford cable) or YBCO 2nd generation tape

Prototype

13 T, 100 mm aperture dipole or 180 T/m, 130 mm aperture quadrupole, 4 meters

Type and parameters to be refined depending on LHC relevance

Collaborations

Partners which have been contacted

- CEA-Saclay
- STFC-RAL
- CIEMAT
- CNRS Grenoble
- INFN Milano
- Univ. Genève
- FZ Karlsruhe
- Tampere Univ. of Techn.
- Twente Univ. of Techn.
- Wroclaw Univ. of Techn.

LARP

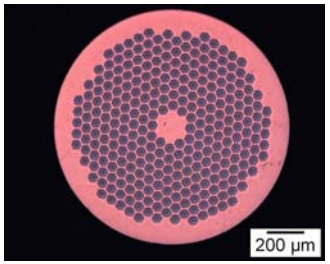
On going : European wire

Target : Jc = 3000 A/mm2 @ 12 T , industrial process suitable for large-scale applications
2 technologies in Europe have the potential to reach the target :

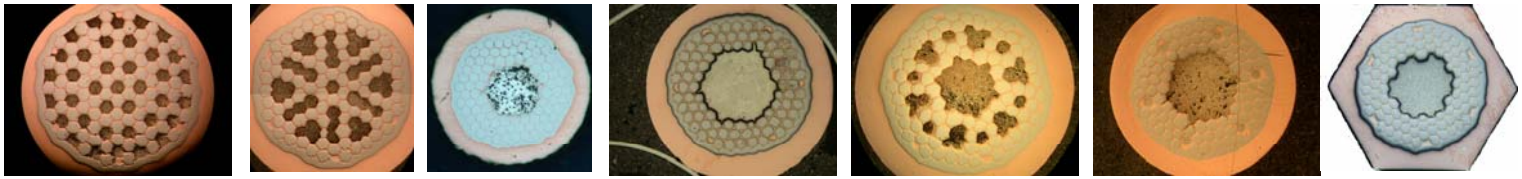
1. Powder In Tube (contract awarded to SMI)
2. Internal Tin Diffusion (contract awarded to Alstom)

- Step 1 : Qualification of initial strand design - Fabrication and test of 10 kg of strand
- Step 2 : Qualification of final strand design - Fabrication and test of 10 kg of strand and cabling tests
- Step 3 : Strand and cable production

STATUS



- **SMI STEP2 COMPLETED**
  - 288 filaments of 50 m in diameter with a 3 kg billet
  - 10 kg billet (B215) drawn to 1.25 mm in diameter without breakage (~ 900 m)
  - Jc = 2500 A/mm2 @ 12 T and 4.2 K, Ic ~1440 A @ 12 T, Ic ~760 A @ 15 T
  - Cable tests : degradation 4-8% HT 120 hours @ 650 °C, RRR ~ 90 virgin & extracted strands
- **ALSTOM STEP 2 IN PROGRESS (LAST BILLET EXPECTED JAN 2008)**
  - 4 billetS with different filament layout. 2 completed : reached Jc = 2100 A/mm^2; 2 under completion



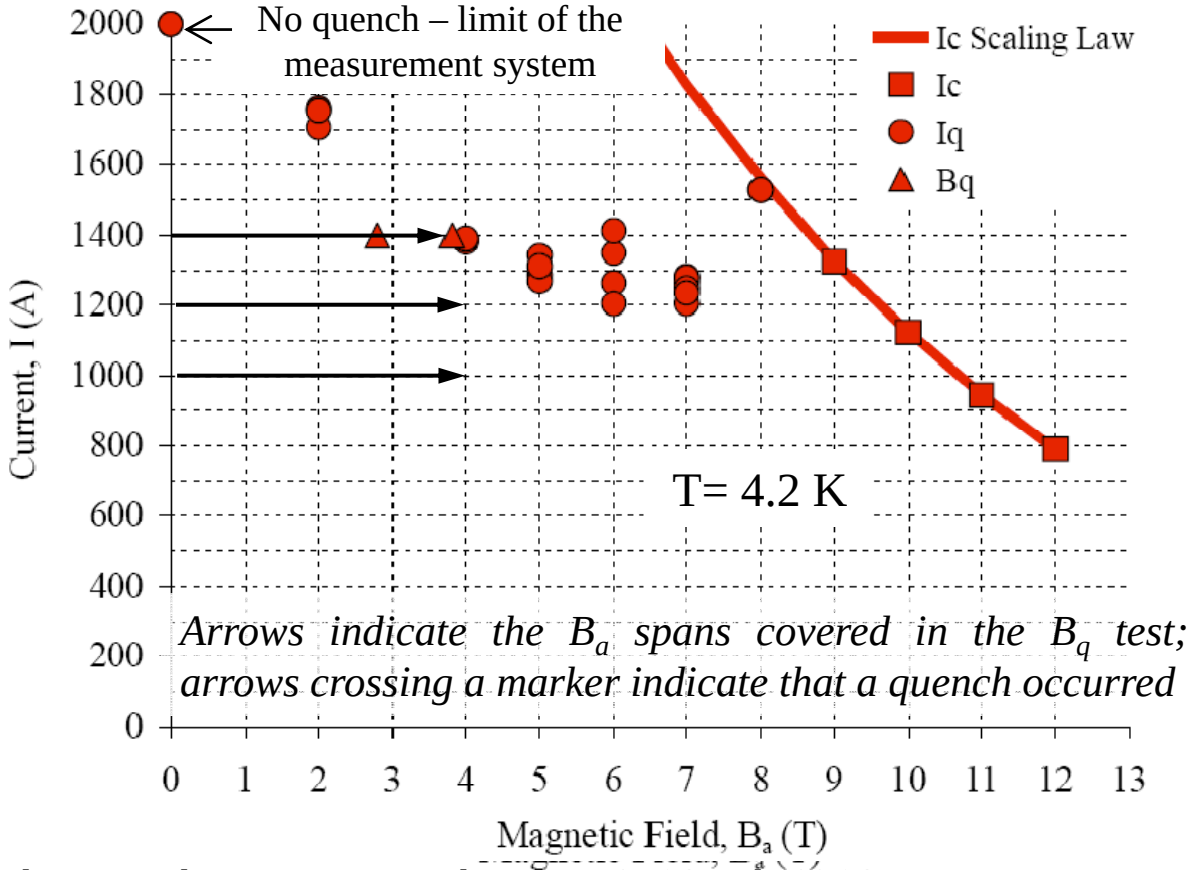
Some filament layouts studied by Alstom during STEP 1

Thanks to Luc Oberli

On going : treatment of OST wire

- HTs for optimum magneto-thermal stability & J_c
  - Long HT 100 hrs @ 695°C
    J_c~ 2600 A/mm^2,
    RRR ~8, I_s ~ 500 A
  - Standard HT 25 hrs @ 695°C
    J_c~ 2800±100 A/mm^2,
    RRR ~80, I_s ~750 A
  - Short HT 17 hrs @ 695°C
    J_c~ 3000 A/mm^2,
    RRR>150, I_s ~ 1200 A

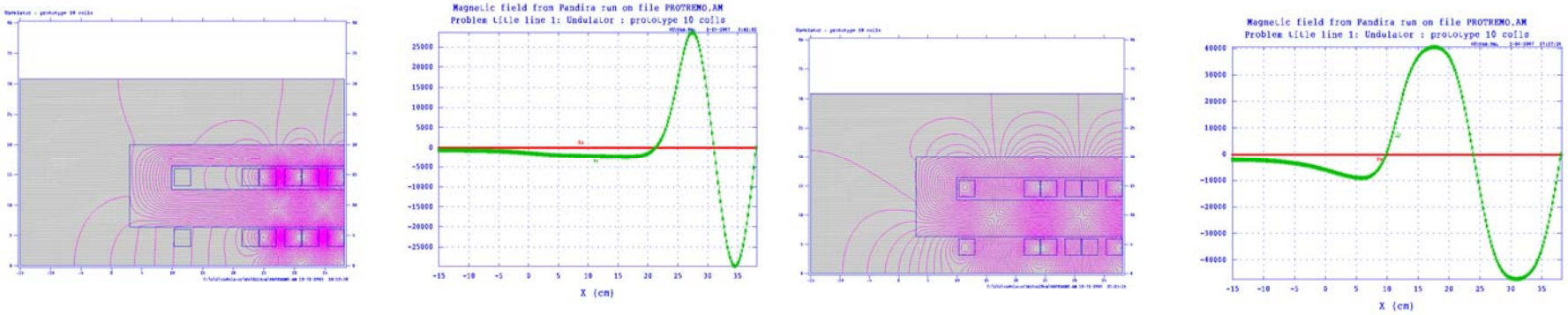
Strand diam. [mm]	*Strand type*	*J_c @ 4.2 K-12 T [A/mm^2]*	*B_{c2} @ 4.2 K [T]*	*D_{eff} [µm]*	*RRR*
0.8	RRP 54/61	3030	24.9	80	>150

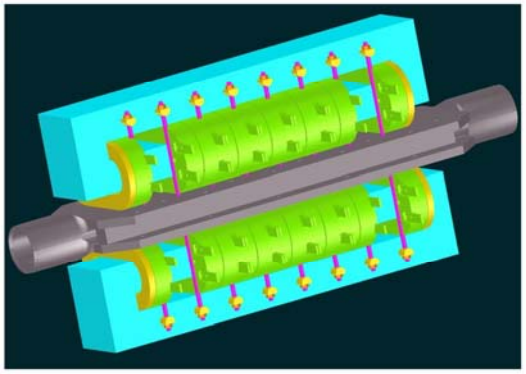


The HTs also include intermediate temperature plateau at 205 °C and 400 °C

Courtesy Bernardo Bordini

On going : undulators for lead ions



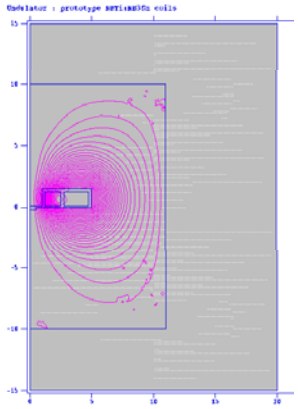


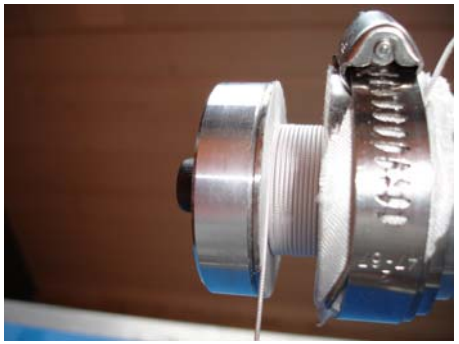
		PROTONS	LEAD IONS
Period length	:	280 mm	140 mm
Number of periods	:	2	2
Minimum Peak Field on the Beam axis	:	5T	3 T
Gap Size	:	60 mm	60 mm

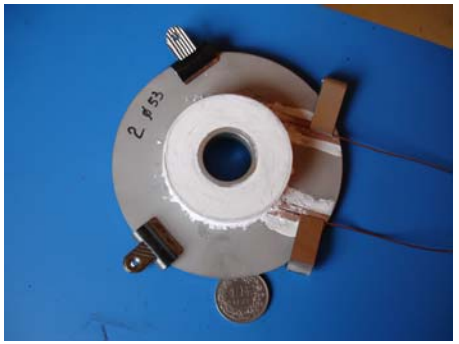
Courtesy Remo Maccaferri

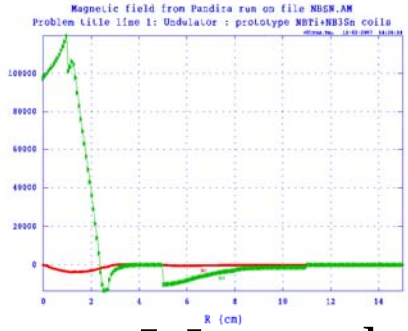
On going : mini dipole split coils

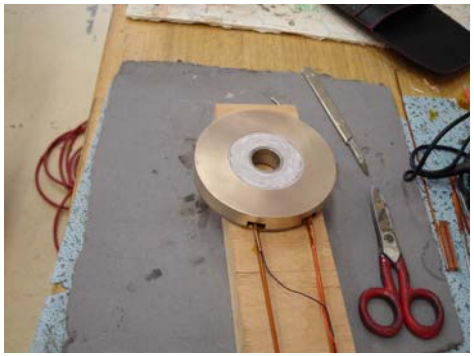
Ceramic wet winding

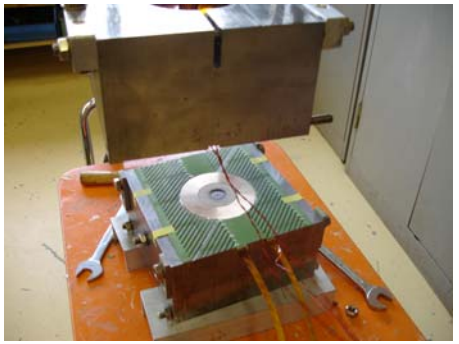












We reached 12 Tesla in the gap,10.5 Tesla on the coils

I max 1250 A (short sample) at 4.2 K with **no** training quenches

Courtesy Remo Maccaferri

Conclusions

CERN is starting a vigorous High Field accelerator magnets program

2008-2009 will be mostly dedicated to enabling technologies

CERN program shall be trimmed for maximum synergy with EU and US