High Field program in Europe

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Outline

- Ongoing HFM programs
  - Collaborative programs: FP6-CARE-NED
  - Core programs

- Starting HFM programs
  - CERN High Field Magnet program
  - FP7-EuCARD WP8 HFMs

FP6-CARE-NED

- The NED program was focused on Nb_3Sn conductor and insulation development. (after the initial “Next European Dipole” construction project funding was turned down)
- NED has four Work Packages and one Working Group

  1 Management & Communication (M&C),

  2 Thermal Studies and Quench Protection (TSQP),

  3 Conductor Development (CD),

  4 Insulation Development and Implementation (IDI),

  5 Magnet Design and Optimization (MDO) Working Group.
- It involves 7 institutes (8 laboratories)

•Total budget: ~2 M€; EU grant: 979 k€ (2005-2008).

•1, 2, 4 and 5 completed (see: http://care.lal.in2p3.fr/Deliverables/CARE_Deliverables.htm)

NED-CD: Conductor development

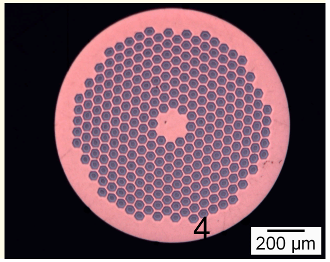
2 conductor development contracts for a 1.25 mm strand with filaments size down to 0.05 mm and a Jc up to 3000A/mm2 @ 12 T:

EAS/SMI Powder in tube technology

- Results of development phase: Jc up to 2600A/mm2 with 0.05 mm filaments and RRR~200
- Final strand manufacturing (12.7 km of strand) is currently underway, with 1 km delivered last month (the remaining is expected during summer 2008)
- Part of the final strand (~ 1 length) will be used to produce at CERN a 14-strand cable for Short Model Coil (SMC) program.

Alstom MSA Internal tin diffusion technology

- Development phase finishing end 2008, good prospect to attain a Jc of 2500A/mm2 (filament size 0.05 mm)
- Final strand production (20 km) in beginning of 2009

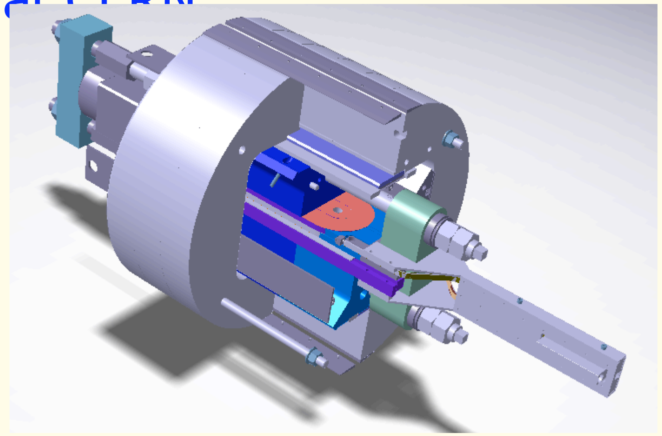


courtesy Thierry Boutboul and Luc Oberli

Extension of NED: Short Model Coil

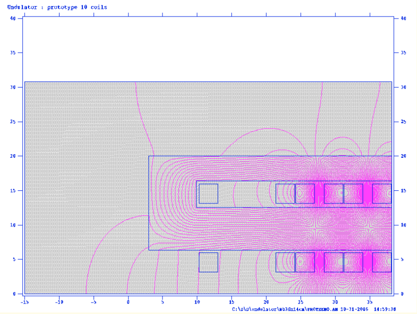
- Participant funding only (formally outside FP6-CARE-NED)
- STFC/RAL, CEA and CERN have agreed to manufacture and test a series of LBNL-type Short Model Coils wound from NED-sub-cables so as to investigate
  - cable and insulation performances in real coil environment
  - design limits for transverse and longitudinal loads
  - and to get experience with Nb_3Sn coil manufacturing
- Coil design and cold mass design being finalized, winding tests with dummy in progress by RAL-CERN team (interactions with LBNL).
- Nb_3Sn strand from NED will be available in July

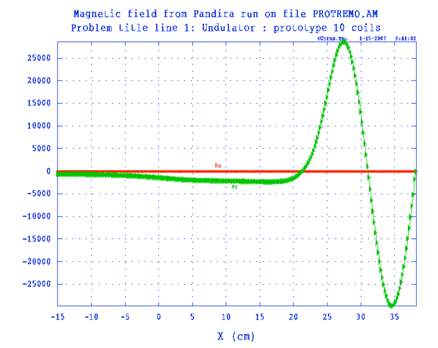
  First magnet foreseen to be tested in Sept-Oct at CERN
- SMC coil sets to be made and tested:
  - One with glass fibre-epoxy insulation by RAL
  - One with ceramic insulation by CEA
  - One with glass fibre-epoxy insulation by CERN

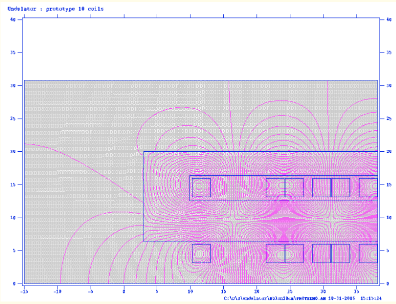


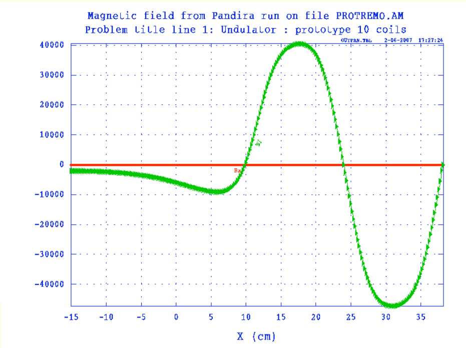
(Courtesy P. Ferracin, LBNL)

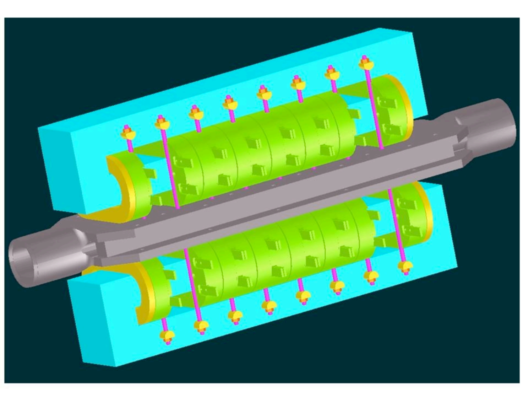
On going : undulators for lead ions in LHC









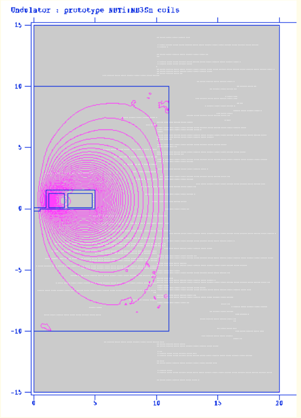


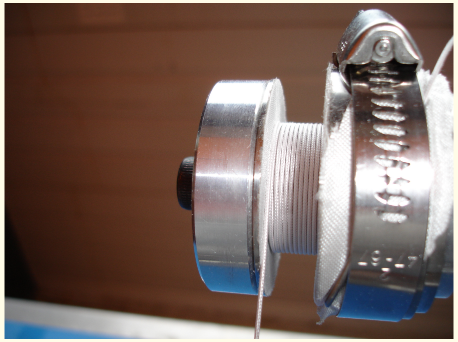
	PROTONS	LEAD IONS
Period length :	280 mm	140 mm
Number of periods:	2	2
Minimum Peak Field on the Beam axis :	5T	3 T
Gap Size:	60 mm	60 mm

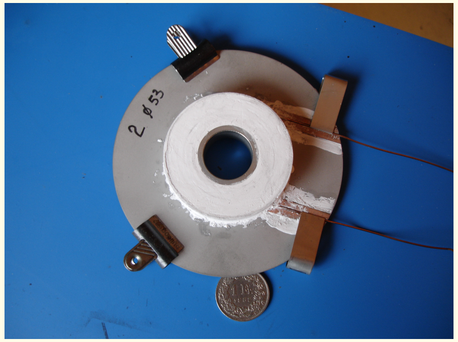
Courtesy Remo Maccaferri

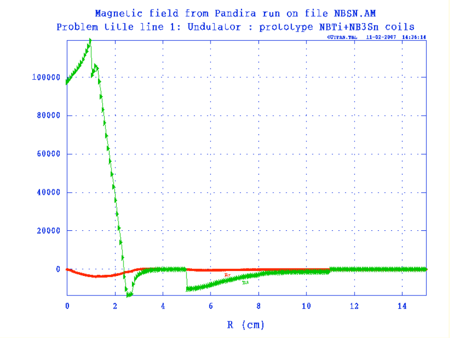
On going : mini dipole split coils

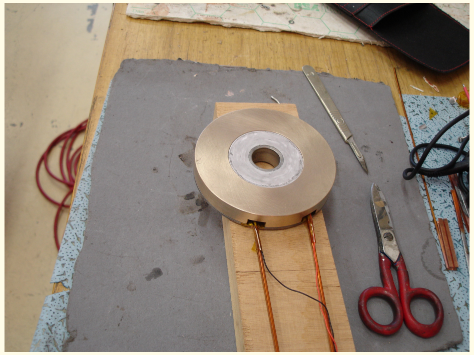
Ceramic wet winding

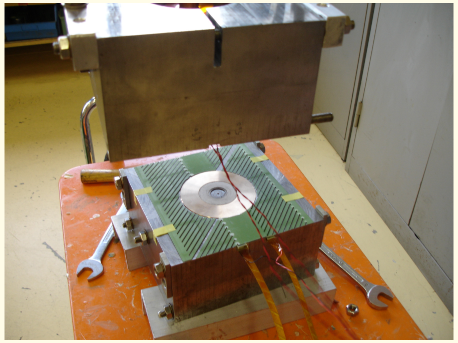












Reached 12 Tesla in the gap,10.5 Tesla on the coils

I_{max} 1250 A (short sample) at 4.2 K with **no** training quenches

Courtesy Remo Maccaferri

CEA Nb_3Sn quadrupole

Model 1 m quadrupole with Nb_3Sn coils with the identical cross section as the LHC main arc quadrupole

- aim learn Nb_3Sn coil technology
- Design gradient 211 T/m in a 56 mm diameter bore
- Test this summer

See presentation by J-M. Rifflet

CERN High field magnet program

- Need for HFM program
  - LHC luminosity upgrade: high field low beta quadrupole magnets
    - Increase luminosity by a factor 1.4 due to the high fields alone
    - Larger apertures possible (high B_{max}) ==> needed for high beam currents
  - Special magnets in LHC at high radiation zones (cleaning insertions, dispersion suppressors, etc.). Presently posing limits
  - (far) Future new machines: neutrino factories, LHC doubler
- The conductor: Nb_3Sn (and some HTS)
  - Critical parameters Nb_3Sn vs Nb-Ti

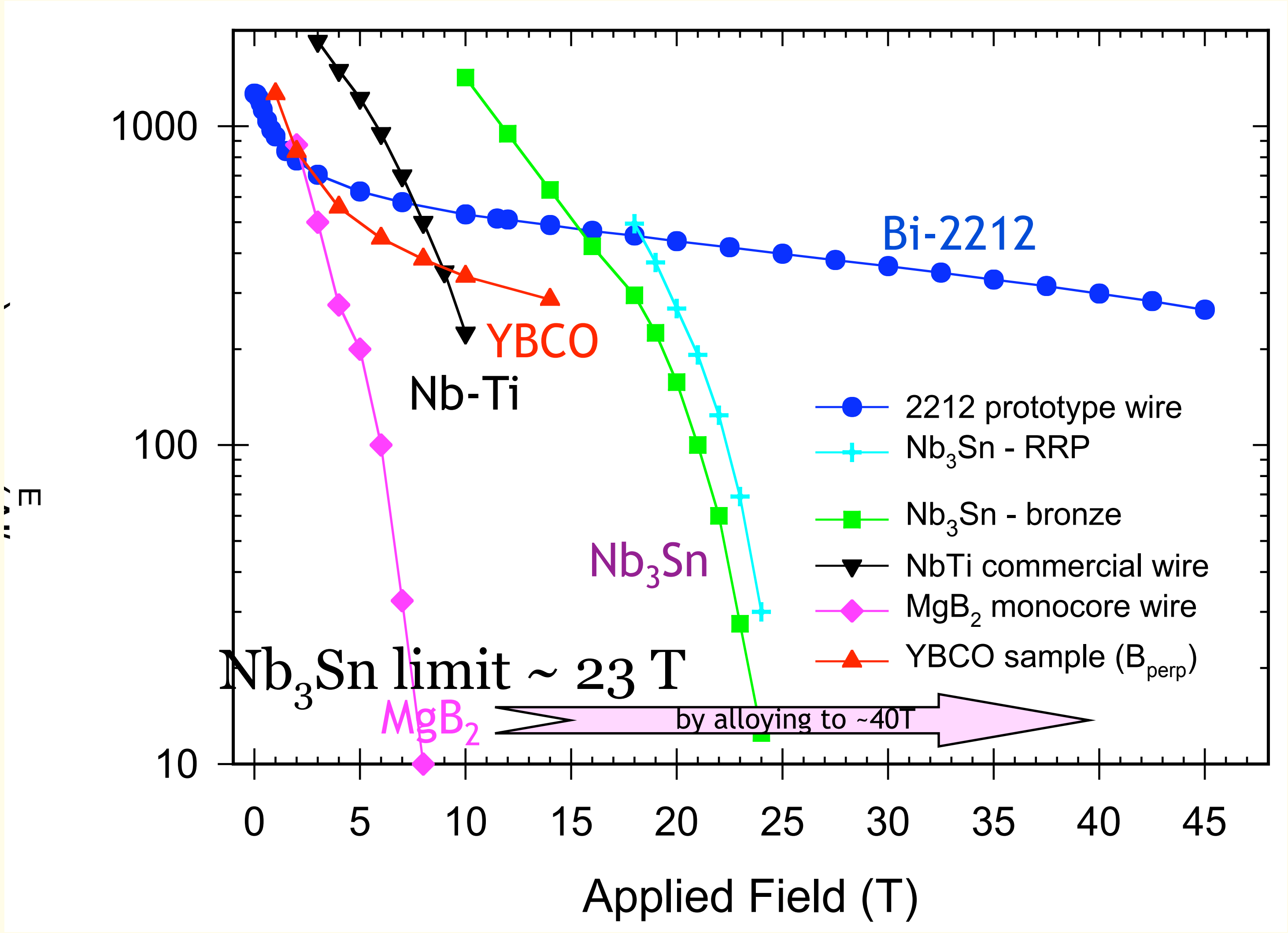
    field: 27 T vs 13 T temp: 18 K vs 9 K
  - But : not easy due to brittleness and stress sensitivity
- Vigorous R&D program needed if we want this technology to be applied for the LHC phase II upgrade in 2017
- CERN High Field Magnet program starting in 2008 with several funding sources: “white paper” program, FP7-IA-EuCARD, CERN core program

Nb_3Sn magnets

- To date:
  - Accelerator quality Nb_3Sn magnet start to exist but are not yet 'installable'
  - All dipole or quadrupoles are either short or have an insufficient field quality or a too small aperture
  - One 4 m racetrack magnet exists now since this summer (LARP)
  - The LARP program (FNAL, LBNL, BNL) is working on Nb_3Sn quadrupoles since a few years (+ FNAL, LBNL, BNL core programs) and getting to working magnets. They need support and competition/ collaboration (hardware).
- Nb-Ti technology is limited to a maximum field of 9 T at operational currents and with limited temperature margin
- Nb_3Sn solenoids exist commercially up to ~20 T
- If we need higher fields (Max B > 9T) in accelerators then we have to get Nb_3Sn technology under control also for dipole and quadrupole coil geometries

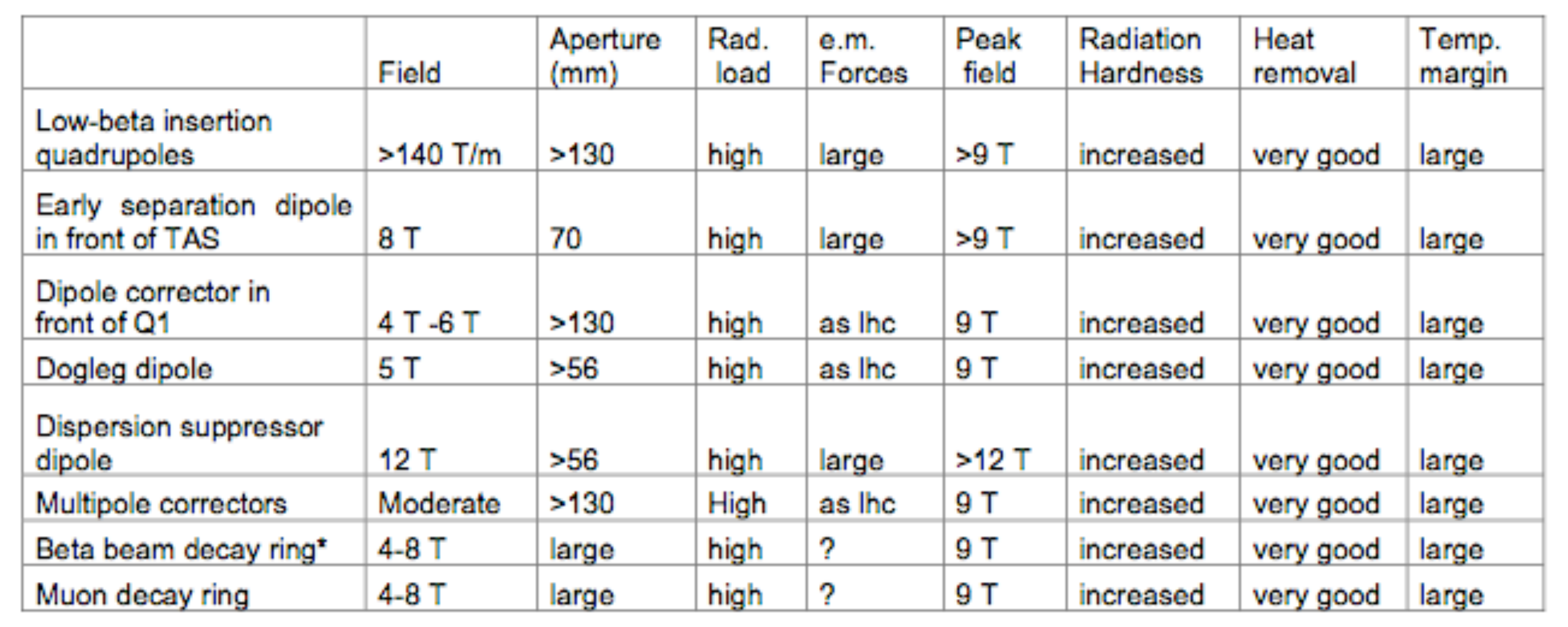
High field superconductors

everything starts with $J_e(B)$



From compilation by Peter Lee

Summary: requirements



	Field	Aperture (mm)	Rad. load	e.m. Forces	Peak field	Radiation Hardness	Heat removal	Temp. margin
Low-beta insertion quadrupoles	>140 T/m	>130	high	large	>9 T	increased	very good	large
Early separation dipole in front of TAS	8 T	70	high	large	>9 T	increased	very good	large
Dipole corrector in front of Q1	4 T -6 T	>130	high	as lhc	9 T	increased	very good	large
Dogleg dipole	5 T	>56	high	as lhc	9 T	increased	very good	large
Dispersion suppressor dipole	12 T	>56	high	large	>12 T	increased	very good	large
Multipole correctors	Moderate	>130	High	as lhc	9 T	increased	very good	large
Beta beam decay ring*	4-8 T	large	high	?	9 T	increased	very good	large
Muon decay ring	4-8 T	large	high	?	9 T	increased	very good	large

Common points:

All magnets need radiation hardness, good heat removal and a large temperature margin

and

The Low-beta quad, dispersion suppressor dipole and early separation dipole need the Nb_3Sn high Jc @ 12 T

CERN High field magnet program: 4 “chapters” of R&D

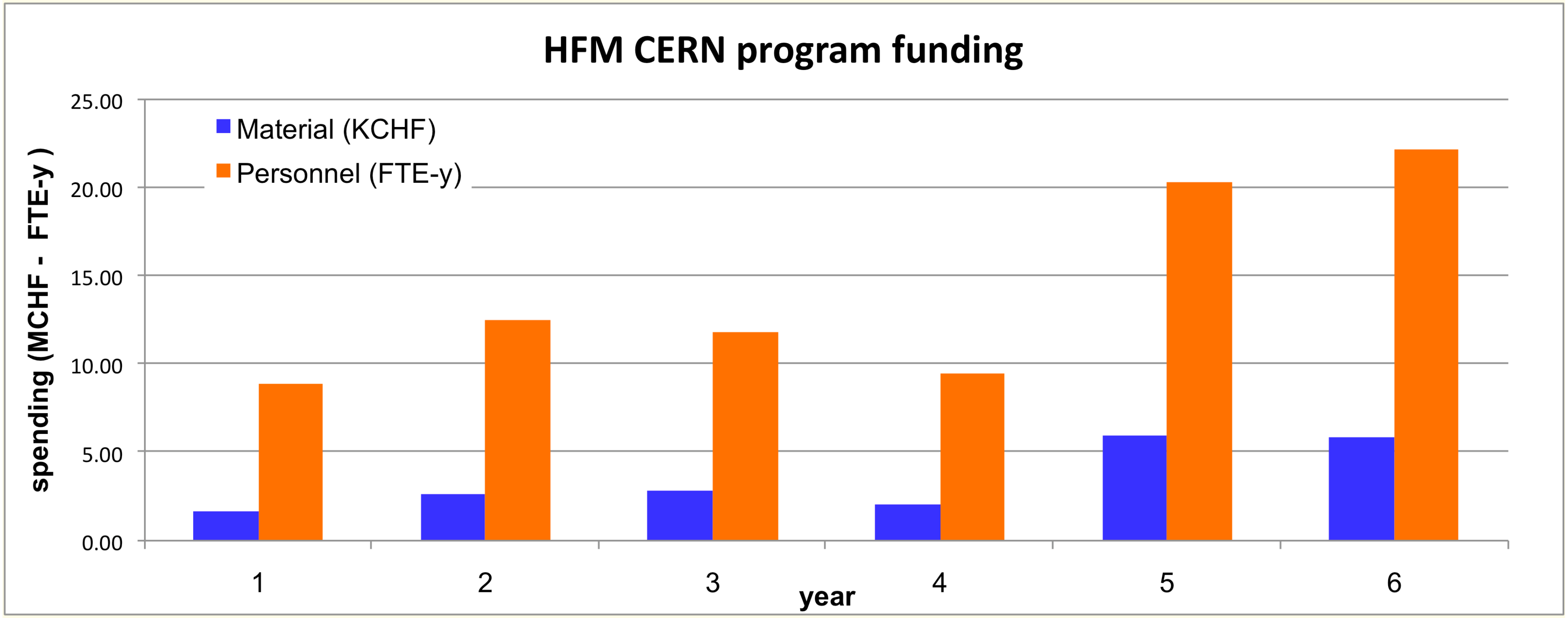
- Conductor
  - 6 yr continuous development program (aim: Jc=3000 A/mm^2, filaments <0.05 mm, low and understood stress sensitivity)
- Enabling technologies
  - design choices(cos(theta) vs block coil, collars vs shell)
  - Insulation, thermal effects, radiation hardness, mechanical tests
  - Subscale models (racetrack coil tests)
  - High temp superconductor: prospect insert coils to go up to 20 T
- Models
  - Dipole model (1.5 m long, 100 mm aperture, 13 T) ==> FP7-IA-EuCARD 2010-2011
  - Quadrupole model (1 m, 130 mm aperture, >150 T/m) 2012
  - Corrector models 2012
- Prototype magnet
  - 4 m long prototype 2012-2013

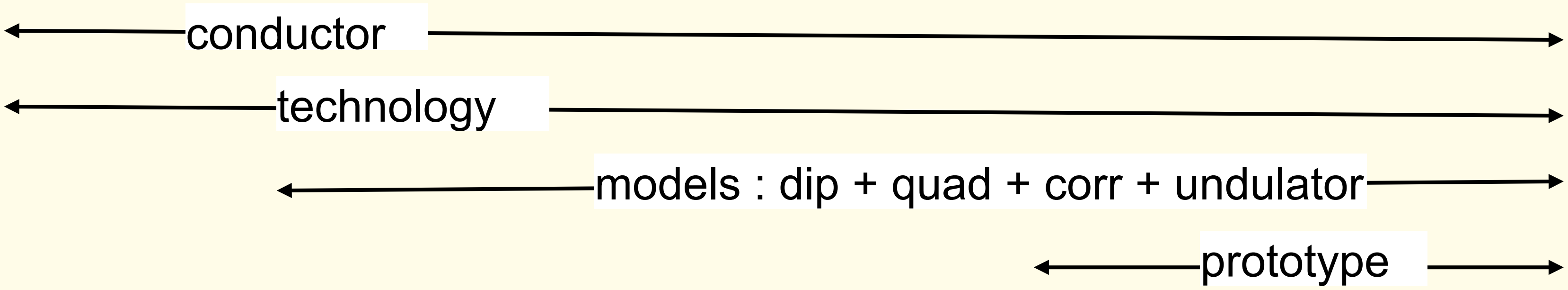
Very important: In collaboration with other institutes:
(e.g. BNL, CEA, CIEMAT, CNRS, FNAL, FZK, INFN, KEK, LBNL, RAL, TUT, UNIGE, UT, PWR, etc)

HFM “building program”

- Dipole model
  - 1.5 m long, 13T bore field, 100 mm aperture model magnet for Fresca
- Undulator/wiggler
  - 140 mm period, 60 mm gap for LHC with lead ions
  - 40 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, G ~180T/m
- Corrector models
  - quadrupole / sextupole / octupole, wound from single wire conductor around a 130 mm aperture (start 2012)
- 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
- 4 m Prototype
  - 13 T, 100 mm aperture dipole or 180 T/m, 130 mm aperture quad, Type and parameters to be defined depending on LHC relevance

CERN Funding



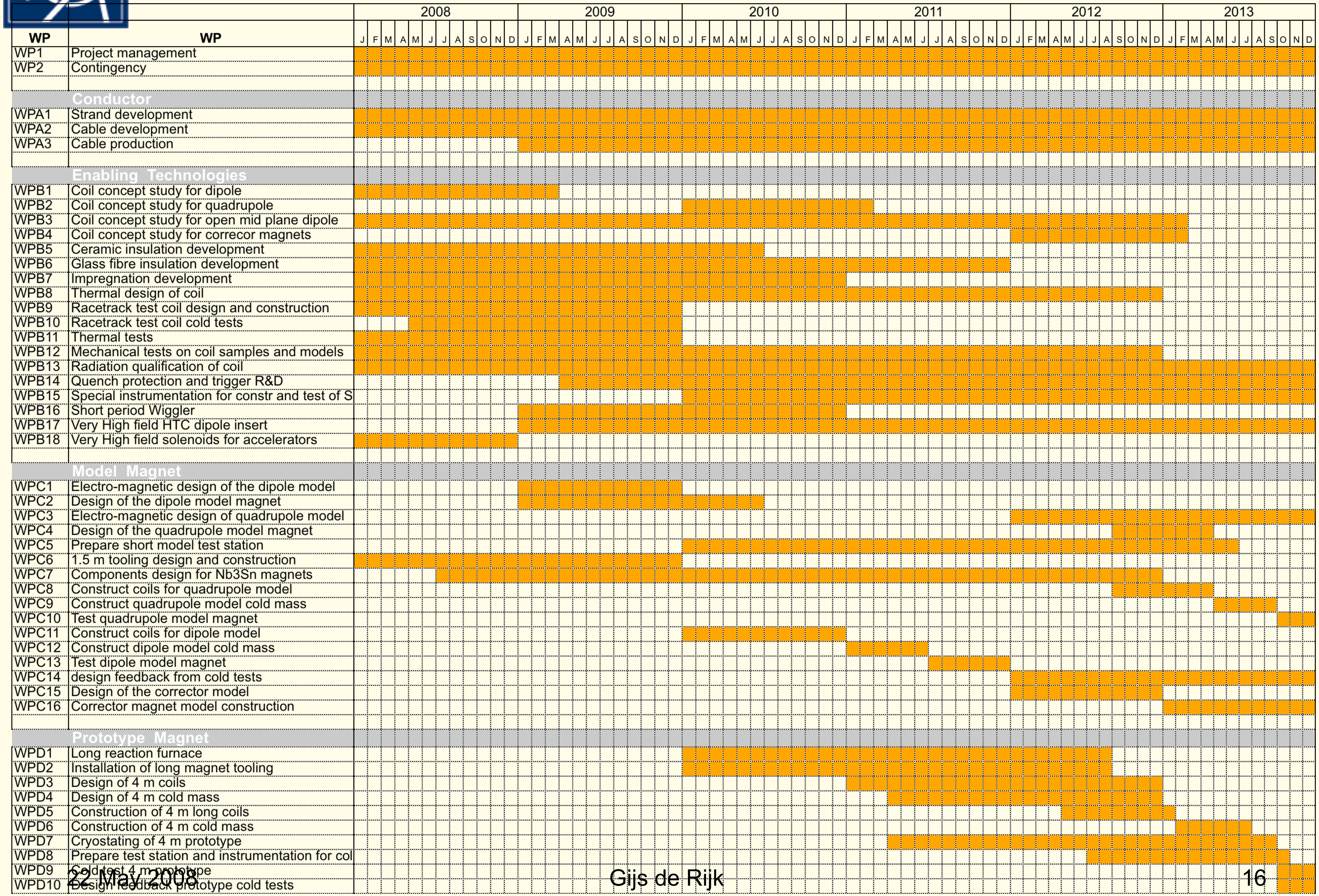

conductor

technology

models : dip + quad + corr + undulator

prototype

planning



WP	WP
WP1	Project management
WP2	Contingency
	Conductor
WPA1	Strand development
WPA2	Cable development
WPA3	Cable production
	Enabling Technologies
WPB1	Coil concept study for dipole
WPB2	Coil concept study for quadrupole
WPB3	Coil concept study for open mid plane dipole
WPB4	Coil concept study for correcor magnets
WPB5	Ceramic insulation development
WPB6	Glass fibre insulation development
WPB7	Impregnation development
WPB8	Thermal design of coil
WPB9	Racetrack test coil design and construction
WPB10	Racetrack test coil cold tests
WPB11	Thermal tests
WPB12	Mechanical tests on coil samples and models
WPB13	Radiation qualification of coil
WPB14	Quench protection and trigger R&D
WPB15	Special instrumentation for constr and test of S
WPB16	Short period Wiggler
WPB17	Very High field HTC dipole insert
WPB18	Very High field solenoids for accelerators
	Model Magnet
WPC1	Electro-magnetic design of the dipole model
WPC2	Design of the dipole model magnet
WPC3	Electro-magnetic design of quadrupole model
WPC4	Design of the quadrupole model magnet
WPC5	Prepare short model test station
WPC6	1.5 m tooling design and construction
WPC7	Components design for Nb3Sn magnets
WPC8	Construct coils for quadrupole model
WPC9	Construct quadrupole model cold mass
WPC10	Test quadrupole model magnet
WPC11	Construct coils for dipole model
WPC12	Construct dipole model cold mass
WPC13	Test dipole model magnet
WPC14	design feedback from cold tests
WPC15	Design of the corrector model
WPC16	Corrector magnet model construction
	Prototype Magnet
WPD1	Long reaction furnace
WPD2	Installation of long magnet tooling
WPD3	Design of 4 m coils
WPD4	Design of 4 m cold mass
WPD5	Construction of 4 m long coils
WPD6	Construction of 4 m cold mass
WPD7	Cryostating of 4 m prototype
WPD8	Prepare test station and instrumentation for col
WPD9	Cold test 4 m prototype
WPD10	Design feedback prototype cold tests

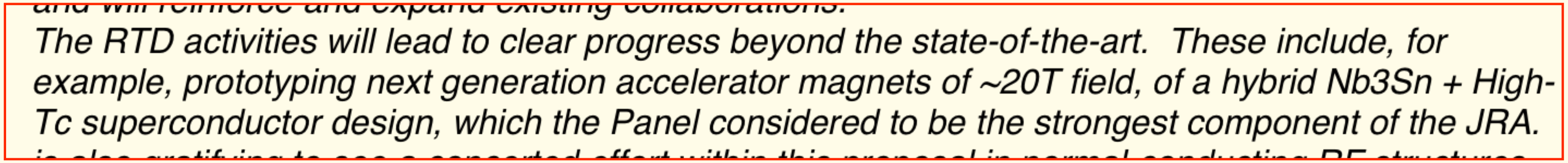
FP7-EuCard-WP8

- WP8 HFM: Superconducting High Field Magnets for higher luminosities and energies
  - Task1: Coordination and Communication.
  - Task 2: Support studies
  - Task 3 High field model
  - Task 4 Very high field dipole insert
  - Task 5 High Tc superconducting link
  - Task 6 Superconducting wiggler for ANKA
  - Task 7 Short period helical superconducting undulator
- WP8 is a CERN, CEA, CNRS, COLUMBUS, DESY, EHTS, FZK, INFN, PWR, SOTON, STFC, TUT, UNIGE collaboration
- Status: proposal submitted
- Project time span: 2009-2012
- “cog-wheels” with the programs in the participating labs (at CERN it is part of the HFM program)

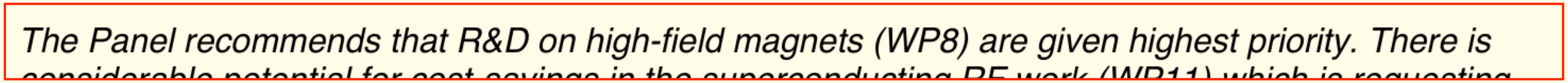
FP7-EuCard-WP8

- EuCARD evaluation result received this Tuesday: 14.5 points out of 15

2 citations from the evaluation report:



The RTD activities will lead to clear progress beyond the state-of-the-art. These include, for example, prototyping next generation accelerator magnets of ~20T field, of a hybrid Nb3Sn + High-Tc superconductor design, which the Panel considered to be the strongest component of the JRA.



The Panel recommends that R&D on high-field magnets (WP8) are given highest priority. There is

In the coming weeks the partners will be contacted for the “negotiation phase” of the EuCARD proposal

Outlook

- After the LHC completion we enter again in a new round of HFM R&D
- The difference with the last round in the 1990-ies : x1.5 in field for SLHC and x2.5 for DLHC
- The last round took 22 years between first ideas and machine commissioning (1986-2008)
- We have to hurry up if we want 12 T grade magnets in 2017-2018 for SLHC
- The 20 T frontier has to be attacked now in order to have something ready for a DLHC in 20 years