Developing SC magnet activity
Objectives, difficulties and benefits

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EUCAS 2017
• Sigmaphi presentation
  – General
  – Sigmaphi SC magnets
• Why making this development/Difficulties/Key factors
• Impact on Sigmaphi and its stakeholders
• Conclusion
Sigmaphi presentation
• Sigmaphi is focused on Particle Accelerator Technologies and Superconducting Magnets
• Founded in 1981, Sigmaphi group has sales of 32 M€ and employs 200 highly qualified people, of which 6 physicists, 70 engineers and managers, and many talented workers
• We have 4 companies: Sigmaphi Magnets in Brittany, Sigmaphi Electronics in Alsace, Sigmaphi China in Beijing, Sigmaphi Japan in Tokyo
Turnkey systems for particle accelerators

- Particle beamlines and components
  (from optics to installation and alignment)

**Magnets**
from small to very large
PM/resistive/SC/AC

**High stability power supplies**

**Vacuum**

**Diagnostics**

**Installation**

Acculina 70m heavy ion beamline
• Injection/extraction systems

FAIR/CRYRING Kicker magnet and pulser
3500A / 280ns

• RF sources solutions (solid state amplifiers, Klystron modulators)

FZD
10kW @1.3 GHz

Fermilab –
75 kW @ 162 MHz

Klystron modulator for IPN Orsay 115kV / 50A
Superconducting magnets quench detection/CC/power supplies

- NbTi

33 correction dipôles for LHC (CERN)

Dipôle for JLAB (4,2T, 4m)

Cyclotron magnet (He free)

- MgB2

MgB2 coil tested at 460 A

Power supply for SC magnets

- HTS: program starting for a SMES and a dipole
2 main sectors

- Physics research labs
  - CERN-LHC
  - ESRF
  - Jefferson Lab

- Hadrontherapy centers manufacturers
  - IBA
  - Varian Medical Systems
Some examples - research labs

- CERN-LHC-LHCb detector coils
- Soleil-124 sextupoles
- LOA – PM quad and PM 1.4T in vacuum dipole
- ALBA Barcelona Dipoles PS
- Dubna-70m heavy ion beamline
- Soleil under vacuum septum
- CERN-LHC 33 superconducting x-y dipoles
- RF SSPA at HZD
  10 kW CW / Pulse at 1.3GHz

- Europe: GSI, Bessy, Desy, Anka, LMUM, Stuttgart, CERN, PSI, INFN, Trieste, CEA, IN2P3, Ganil, Soleil, ESRF, Diamond, CCLRC, Alba, UCL…
- North America: BNL, ORNL, ANL, Fermilab, SLAC, MIT, JLAB, Triumf, CLS…
- Asia: KEK (Japan), Tohoku (Japan), CIAE (China), NSRL (China), CAEP (China), Barc (India), VECC (India)…
SC MAGNETS
MCBX Correctors for CERN LHC
Dipole V ID90 mm - 3.26 T – Dipole H ID120.8 mm – 3.35T - 550 A
NbTi Liquid helium 1.9 K
2001

1st SC activity
Cold mass only
Built to print
Large SC cyclotron coil
4.6 m diameter, 1000 A with 2 currents per coil (C 6+ and H2+),
2 openings in cryostat
2008

1st Sigmaphi design activity
project unfortunately stopped, might revive
SIGMAPHI SUPERCONDUCTING MAGNETS

SHMS Dipole for JLAB
24 tons, warm bore 600 mm, 4.25 T, NbTi Liquid helium 4.2K – 3500 A
Delivery 2016
Q2 Q3 quadrupoles for JLAB
15 tons, warm bore 600 mm, 16T/m, NbTi Liquid helium 4.2K – 4250 A
Delivery 2016
Magnets installed in Hall C at JLAB

Q2  Q3  DIPOLE
MgB2 double pancake and solenoid  R&D with CEA partnership
Double pancakes and Solenoid in MgB2  - 1T in 3T background field – 460 A conduction cooled 2015
WAVE Vector Magnet for CEA
1T/1T/1T Bore diameter 100 mm - NbTi Liquid Helium Zero boil off – 200 A
High field homogeneity 50 ppm within R5mm – Turn key sytem delivered with 4 Sigmaphi power supplies and quench protection system
2017
LOTUS Cyclotron magnet with CEA R&D partnership
Solenoid warm bore 514 mm – 2,36 T – NbTi Helium Free – 100 A – Persistent 2017
BOSSE Solenoid for energy storage in partnership with CNRS for DGA
YBaCuO solenoid – bore 180 mm – 13.1 T – 972A - 1.3MJ
2018
BOSSE Dipole for an electromagnetic launcher in partnership with CNRS for DGA
YBaCuO dipole – 20 kA – 1,2 T
2018
QUACO Quadrupole R&D for CERN Hilumi
Double aperture quadrupoles ID 90 mm – Gradient 120 T/m (peak field 6.1 T)
Length 4 meters – NbTi – 1.9K – 4596 A - 2020
Our means

- Design and test
- Building and equipment
- Team
SIGMAPHI SUPERCONDUCTING MAGNETS

MAGNETIC (Static, AC, Transient, Eddy currents, Inductances...)

DESIGN & ENGINEERING

TESTING EQUIPMENT

STRESS (magnetic, forces, pressure, thermal, multiphysics...)

CRYOGENIC & QUENCH

SOFTWARE:
Mechanical: Solidworks
FEA: Ansys, Tosca, Elektra, Quench, Tempo
Dedicated workshop and equipment
A skilled and committed team, working with a high team spirit
(2 PhD, 5 high level engineer, 8 workers)
Why making SC magnets development
Decision is a combination of feeling, strategy and opportunity

- 15 years ago, strategy was more “educated feelings”, we had a sense of where to go
  - increase the technical content of our produits
  - Look for the fonction beyond the produit; in the case of a magnet, be able to propose any technical solution deviating particles

- But we had no action plan, no opportunity for SC magnet, we also feared that it was too difficult and did nothing for years
Opportunity showed up in 2008 with IBA RFQ for SC cyclotron coil

- We had 0 knowledge, 0 equipment, 0 process
- But it was in our mind to do something in SC magnets
- IBA proposed to reimburse proposal cost if technical proposal was fine
- Our key people were willing to go for it
We jumped on this, decided to find top level experts to help us making this proposal

And built a “dream team” mixing

- top experts
  - Martin Wilson
  - Charles Monroe

- dedicated Sigmaphi ressources keen to learn:
  - William Beeckman
    - physicist
  - Frederick Forest
    - technical director
They started to work on this proposal

A major difficulty was to make a cost evaluation, with a high risk of losing a significant amount of money (our total annual sales were 6 M€ !)
- Risk assessment
  - Need first to have a good technical work, just enough “belt and braces”

- Risk mitigation
  - Securing potential additional funding from French Innovation agencies

- Decision process
  - In a small family owned company
    - Fast decision process, easier to make long term decisions (ex China)
    - but you are alone at the end
- It moves from the brain to the heart

  Do you **believe** that you must do it; do you love this, is it good for your business?

- SC magnets “shine” technically
- It can only develop for future accelerators
- Competition exists, but no major player controlling the market (unlike MRI)
- It is a noble activity, saving energy, good for the planet
- A lot of potential medical applications

- Entrepreneurship requires a high risk acceptance! Loosing money is acceptable for good reasons, with the limitation of not endangering the company
After all, we made a very comprehensive and convincing proposal

We had a letter of intent from IBA

This was the real start of our SC magnet activity
• we soon realized that we would spend a lot more money in design, and could find additional financing for innovation

• IBA unfortunately stopped the project 1 year later (but it might revive !)
• The JLAB enquiry came 1 year later,
• We were still under the dynamics of the IBA teamwork, and had already learnt a lot
• same recipe, same conclusion
• But this time, we had to design, and manufacture...

• And we kept moving ahead
Challenges
• Every project brought its challenges,
  – From JLAB, we had to learn every process, with many unknown/unforeseen technical challenges
  – New people to train
  – Exceeded budgets
• The 2 most difficult and most important challenges were
  – To change culture from manufacturing products which can be repaired to products which cannot
  – To have a good assessment of the risk level and of mitigation possibilities
Our answers

• People
  – Set up dedicated workshop and management
  – Allocate/recruit rare people
  – get them trained and trained again, capitalize know how
  – get them commited, make them grow (learn from mistakes)
  – Trust them
• No choice, once started, success is the only possible conclusion
• Be transparent with our customers when there is a difficulty, and try to solve it together; both learn
• Be flexible with budgets when in development phase, but find additional financing
A good example of difficulty and collaboration to resolve it

Conductor consolidation

Conductor mechanical strength improved from 50 Mpa (20°C) to 100 Mpa (at 20°C) by mechanical hardening
Special pressing machine designed and built to process 22 km of conductor
On line thickness control, cleaning and photography
Mechanical testing at room temperature, 77K and 4K to validate the process
Benefits
• For Sigmaphi
  – Working on highly demanding products drives all Sigmaphi Magnet activity and organization
  – It is a growth factor in our markets, and offers opportunities in other markets
  – It is another occasion to develop synergies between Sigmaphi Magnets and Sigmaphi Electronics
  – It enabled to develop a strong link with CEA Saclay team
• For our stakeholders
  – It has been a very nice opportunity to enlarge employees skills, responsabilities, and personal dimension (according to Sigmaphi Identity: create economical and human wealth)

  • David moved to SC workshop manager, and is now Manufatureign Deputy Manager

  • Leopold was winding technician, is now SC workshop magnet manager

  • Raphael started as a PhD student shared between Saclay and Sigmaphi, and is now Project Manager at Sigmaphi

And many others, thanks to them
• For our suppliers
  – We helped several suppliers to develop their skills (example: spacers machining, or vacuum vessel manufacturing)
• For the world of education
  – We regularly make visits for schools, and this helps (we hope) to attract more interest for careers in technical and scientific field
  – We developed relationship with local university to make conductor characterization

• More generally, communicating locally about our SC Magnet activity helps giving a better image of industry
• More generally, we are proud of contributing to
  – Minimizing energy consumption
  – Through our Lotus project (cyclotron small thanks to SC coils) to the capacity to bring isotope production possible in remote areas

• This proudness is important for our employees
Conclusions
– We spent time, effort, € in developing SC magnets since 2008
– We developed a reasonably knowledgeable team, with equipments and processes
– We are more (better ?) organized and have a strategic plan Group-SC strategy-Eucas 2017
Group strategic approach

Upper right corner: dilemma, invest or leave

We evaluated our strengths and weaknesses and our capacity to change category, and decided to take necessary steps to increase our market share
Thank you for your attention