



EUCARD-WP7-HFM

Short Model Coil review

12 December 2011

SMC

Design overview of the construction and project issues

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on behalf of SMC collaboration team

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OUTLINE

- Introduction
- What's SMC?
- FEM models
- SMC coils and structure
- Manufacturing steps and magnet assembly
- SMC#1 coils fabrication and cold powering tests results
- SMC#2 coils fabrication
- SMC#3_a coils fabrication and cold powering tests results
- SMC#3_b coils fabrication
- Conclusion

INTRODUCTION

- The SMC project started in 2007 as a CERN-CEA-RAL-LBNL collaboration (NED 1.5)
- SMC is a way to test Nb₃Sn cables in a small racetrack magnet and reach 12 T on the cable
- SMC is a modified version of the subscale magnet of LBNL
- SMC has been used to cross-check results using different codes formulations (CAST3M, ANSYS, ROXIE, Vector fields OPERA)
- Several coil configurations have been produced in the different laboratories and cold tested in a common structure at CERN

WHAT's SMC?

SMC is a **tool** to **learn** and **test** :

- Technologies needed for a Nb₃Sn based high field magnet fabrication:
 - Cable insulation
 - Coil reaction
 - Coil impregnation
 - Trace fabrication
 - Bladder fabrication
- Techniques of coil fabrication and magnet assembly
 - Winding
 - Coil instrumentation and Protection
 - Structure instrumentation
 - Magnet assembly with bladders and keys
 - Nb₃Sn/Nb-Ti cable connection

SMC is a tool to **qualify**:

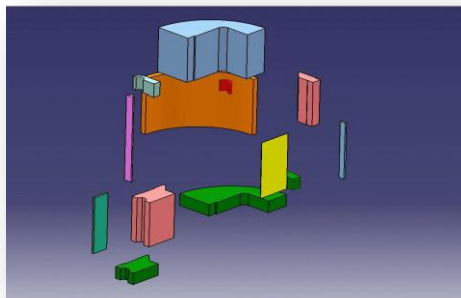
- Nb₃Sn cables in a real magnet configuration

SMC is the “STEP 0” to build a Nb₃Sn accelerator magnet at CERN

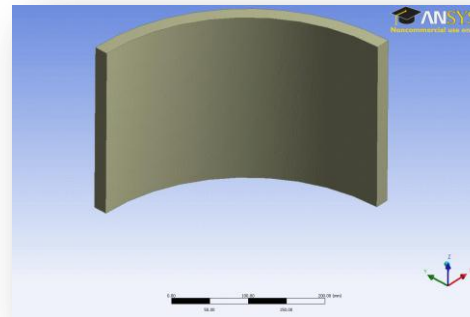
FEM Models



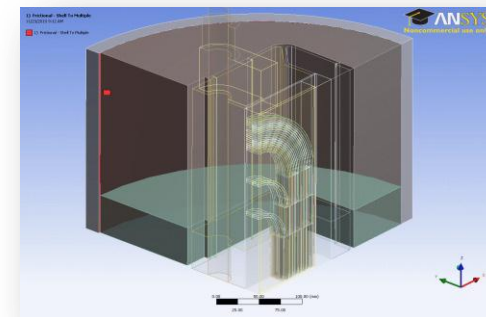
Assembly Design



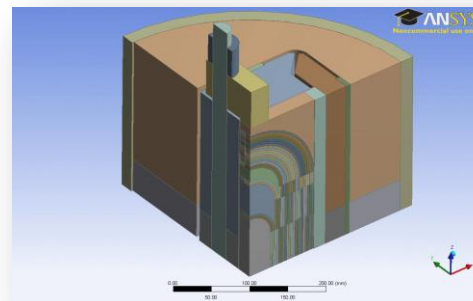
Geometry Design



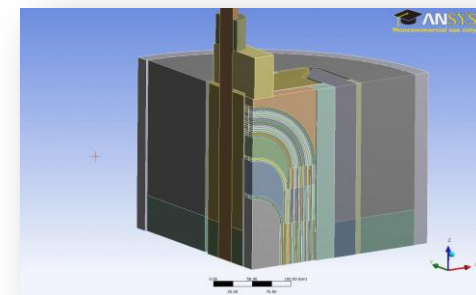
Contact Regions



Parametric Coil Block



Meshing Process

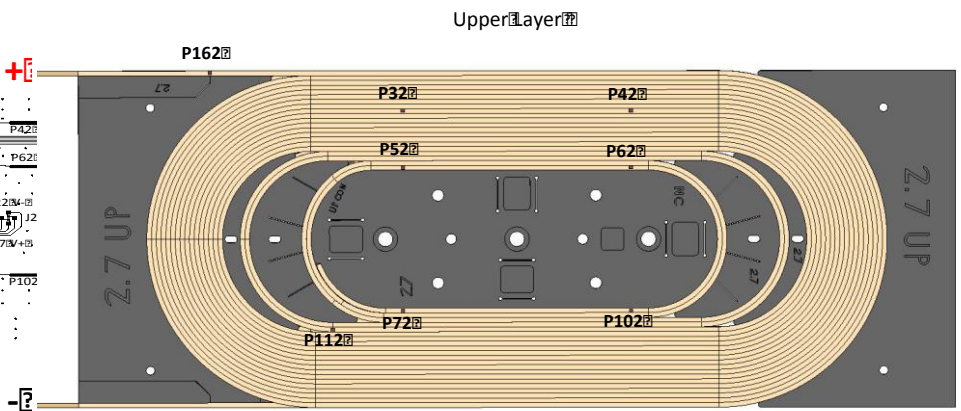
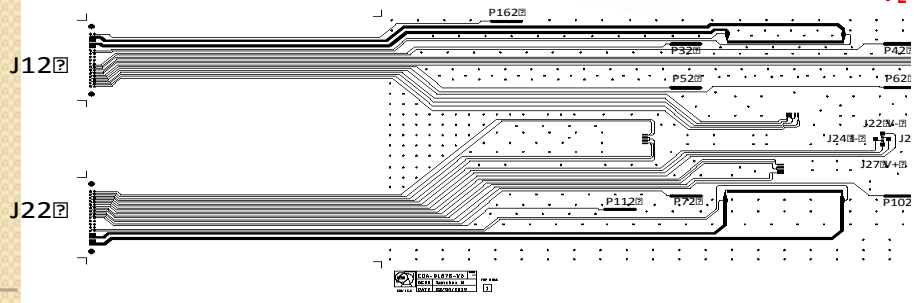
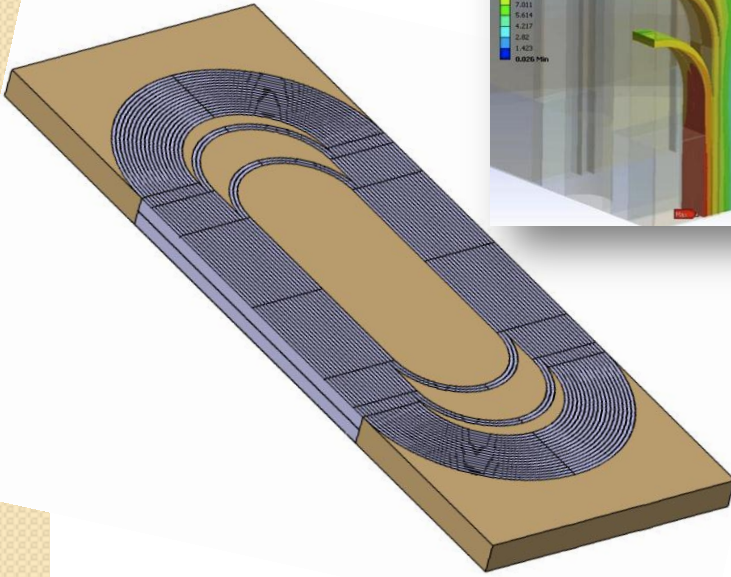
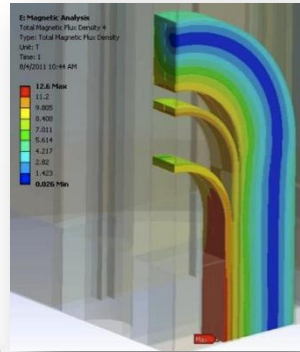


Courtesy of C. Kokkinos

See more details in the presentation made by C. Kokkinos

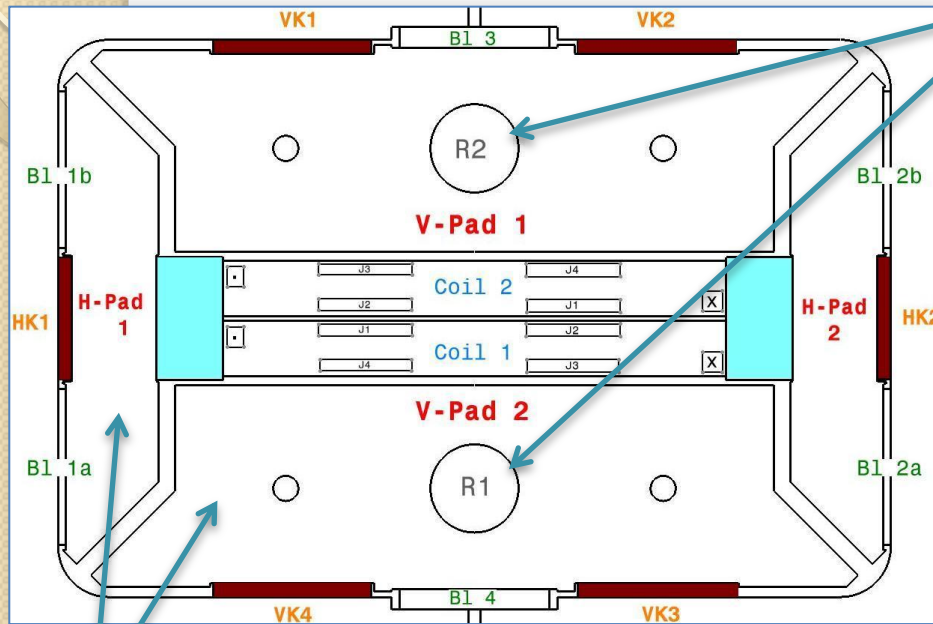
SMC Coils

- Double pancake race-track coil configuration
- High field zone located in the straight part of the central island thanks to the presence of end-spacers
- Titanium spacers & end-saddles
- Nb₃Sn/NbTi splice integrated in the end-saddle connection side
- Instrumented with Vtaps and stain gauges using dedicated printed circuits (“Traces”)



12/12/2011

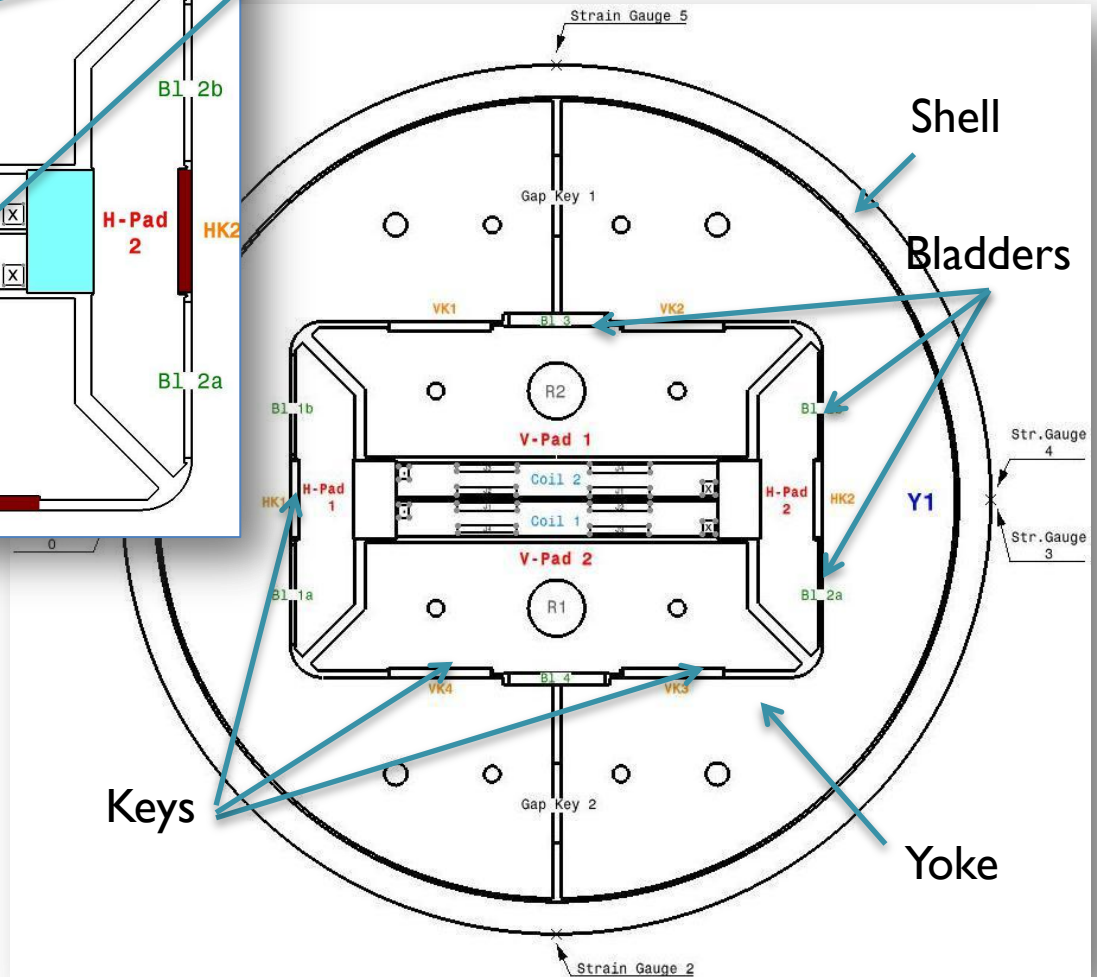
SMC Structure



Coil pads

Coil pack

Rods



Shell

Bladders

Keys

Yoke

SMC configuration

Longitudinal
compressing system
for the rods

Vertical key

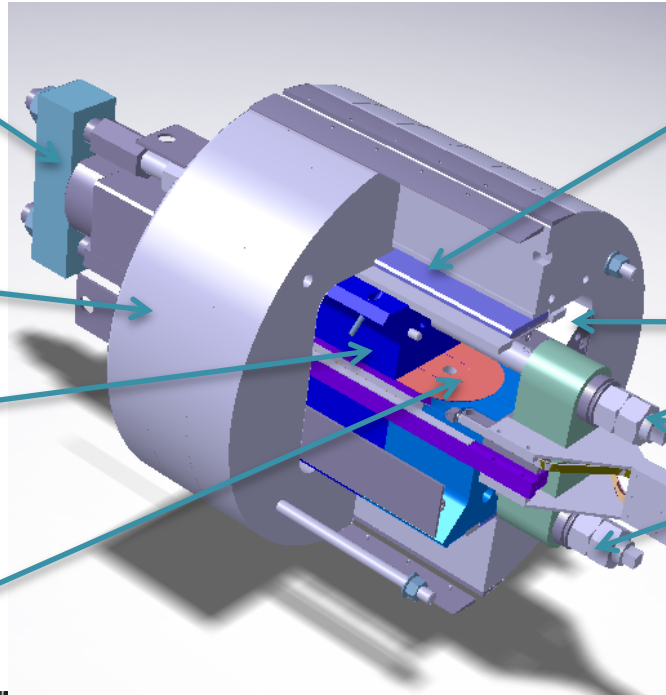
Iron yoke

Lateral pad

Vertical pad

Longitudinal rods

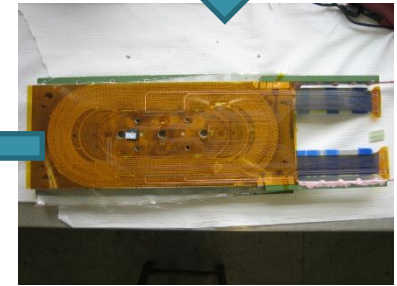
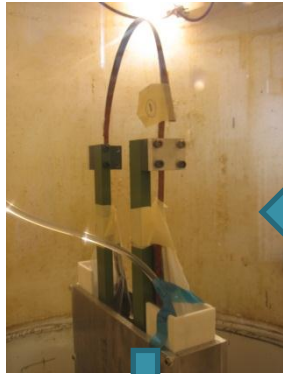
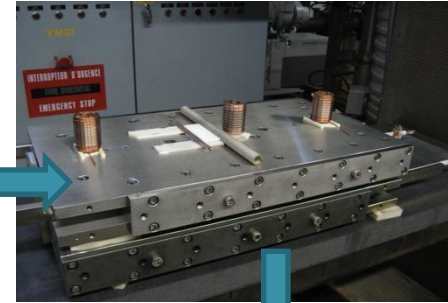
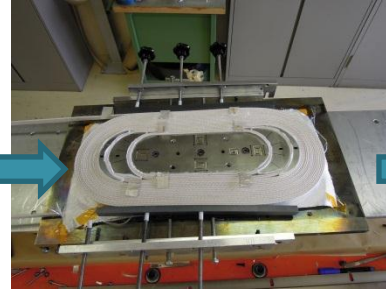
Racetrack coil



Coil pack and Iron yoke mounted
in the instrumented Al2219 T851
shell

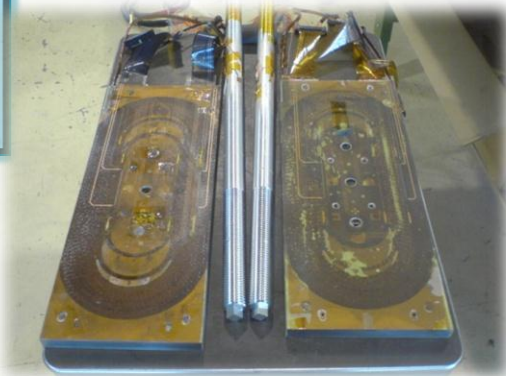


Manufacturing steps



SMC assembly

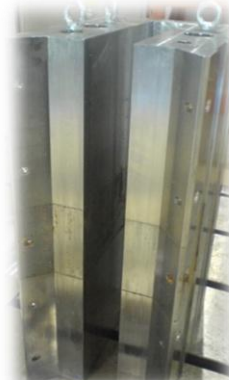
Assembly Parts



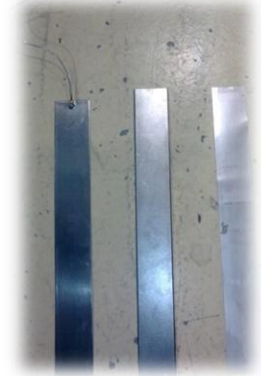
Coils & Rods



Shell & Yoke

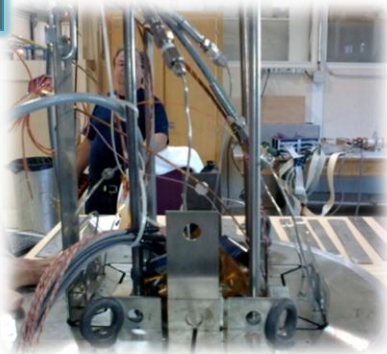


Pads



**Bladders
Keys
Shims**

Assembly Overview



Keys insertion



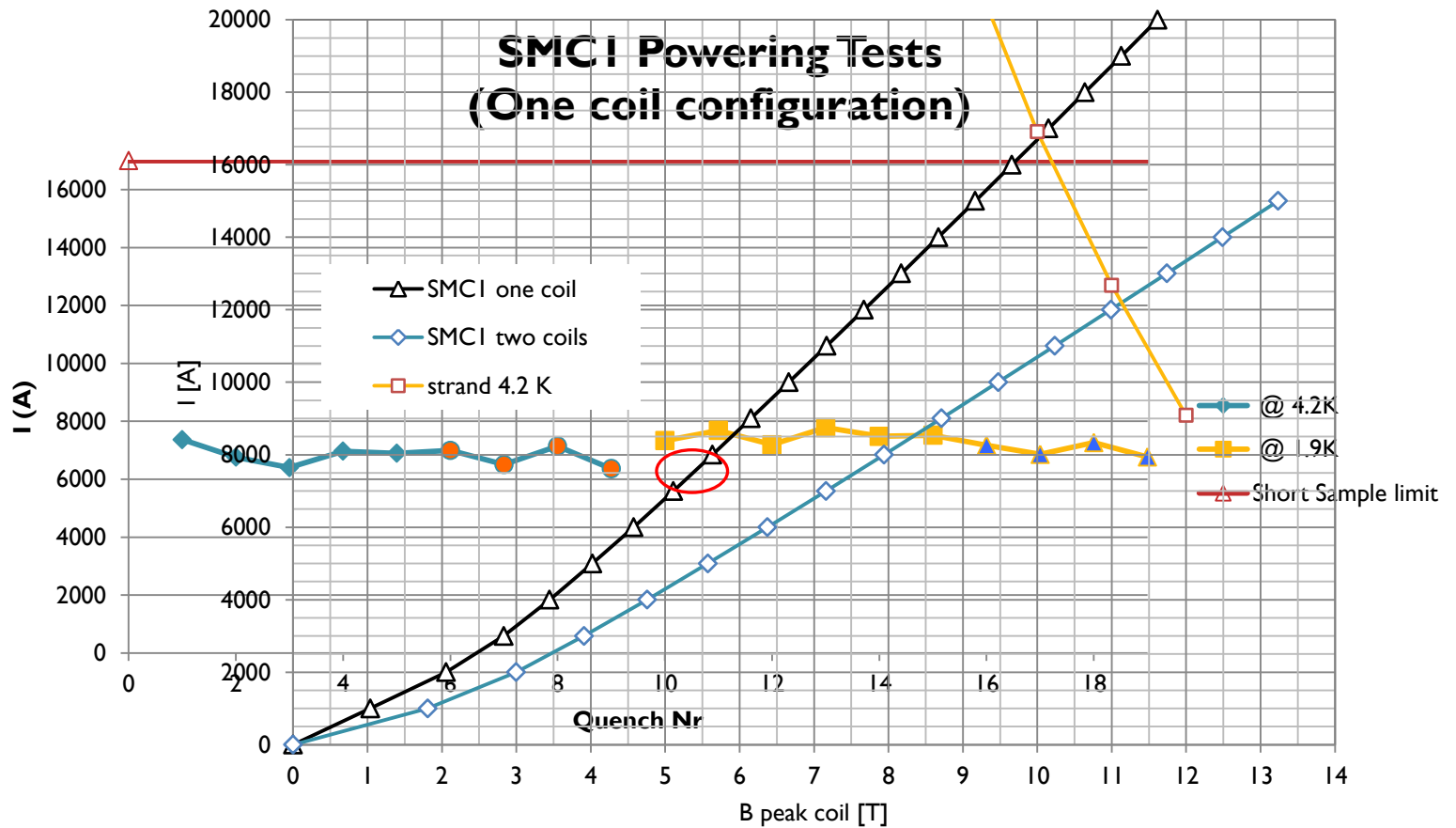
Electrical connections



SMC#1 coil fabrication

- 2 double pancakes wound @ CERN in collaboration with RAL using “Low performance” cable (14 x Ø1.25 mm Alstom IT with low Jc from NED)
- Cables insulated with S2-Glass tape wrapped with 50% overlap
- Coils reacted @ RAL in TWO different furnaces and reaction tooling
- Coils instrumented and potted @ RAL in collaboration with CERN using TWO different moulds
- Coils fabrication dates:
 - Coil #1 made in November 2009.
 - Coil #2 made in March 2010
- Cold test 1:
 - Magnet limited to 3915 A.
 - Quench detected in one Nb₃Sn/NbTi splice of coil# 2 : 40 nOhms contact resistance measured
- Cold test 2: Single coil powering configuration using coil #1.
 - Only one quench detected in layer 1
 - All other quenches detected in layer 2 and never in the splice area

SMC#I: Cold Powering Tests



Courtesy of A. Milanese

SMC#2 coil fabrication @ CEA

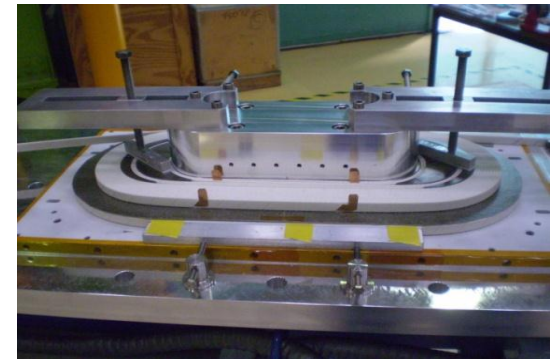
- One coils wound with PIT EAS 14 x Ø1.25 mm strand
- Cable insulation made of 2 layers of Hiltex S2-Glass tape + ceramic precursor (CEA formulation)
- Cable wrapped at CERN in June 2010
- First coil wound at CEA in July 2010



Impregnation Setup



Insulated cable



Winding operation

Coils not assembled in the structure, not cold tested.

Coils fabrication stopped in June 2011 at the CSP (Comite Suivi Protocol) of the Exceptional French Contribution.

See detailed presentation by F. Rondeaux

SMC#3_a coils fabrication @ CERN

- 2 coils for SMC3 with PIT 14 x Ø1.25 mm strand with Ti- islands and spacers wound in November 2010
- Cable insulated with S2-Glass sleeve (FNAL type)
- Electrical insulation of the central island on the layer jump area with ceramic 989F
- Heat treatment in a vacuum furnace @ CERN
- Coils potted using Epoxy NY 750 & Jeffamine D-400
- **Electrical problems, no longitudinal pre-load**
- Magnet assembled in May 2011
- 1st assembly: 2 runs of cold powering tests performed in the new vertical test station (SM18) in June and September 2011
- 2nd : reloading to increase pre-stress on coils and magnet retested in December 2011

SMC#3_a Assembly Configuration

	Shell-Azim.strain [$\mu\text{m}/\text{m}$]			Coil-Normal stress σ_x (MidPlane) [Mpa]			Coil-VM stress (MidPlane) [Mpa]			
	Initial strain value @ 0,3_Theta	@300K	@4.2K	@Iss	@300K	@4.2K	@Iss	@300K	@4.2K	@Iss
SMC3 1 st test run June 2011	500	500	1320	1275	-47	-133	-126	37	125	153
SMC3 2 nd test run 2011	340	340	1196	1228	-34	-123	-116	24	114	140
SMC3 Reload and 3 rd test run November 2011	673	673	1598	1608	-69	-147	-147	47	137	164

FINAL CONDITION @ 293 K – SMC3 June 2011

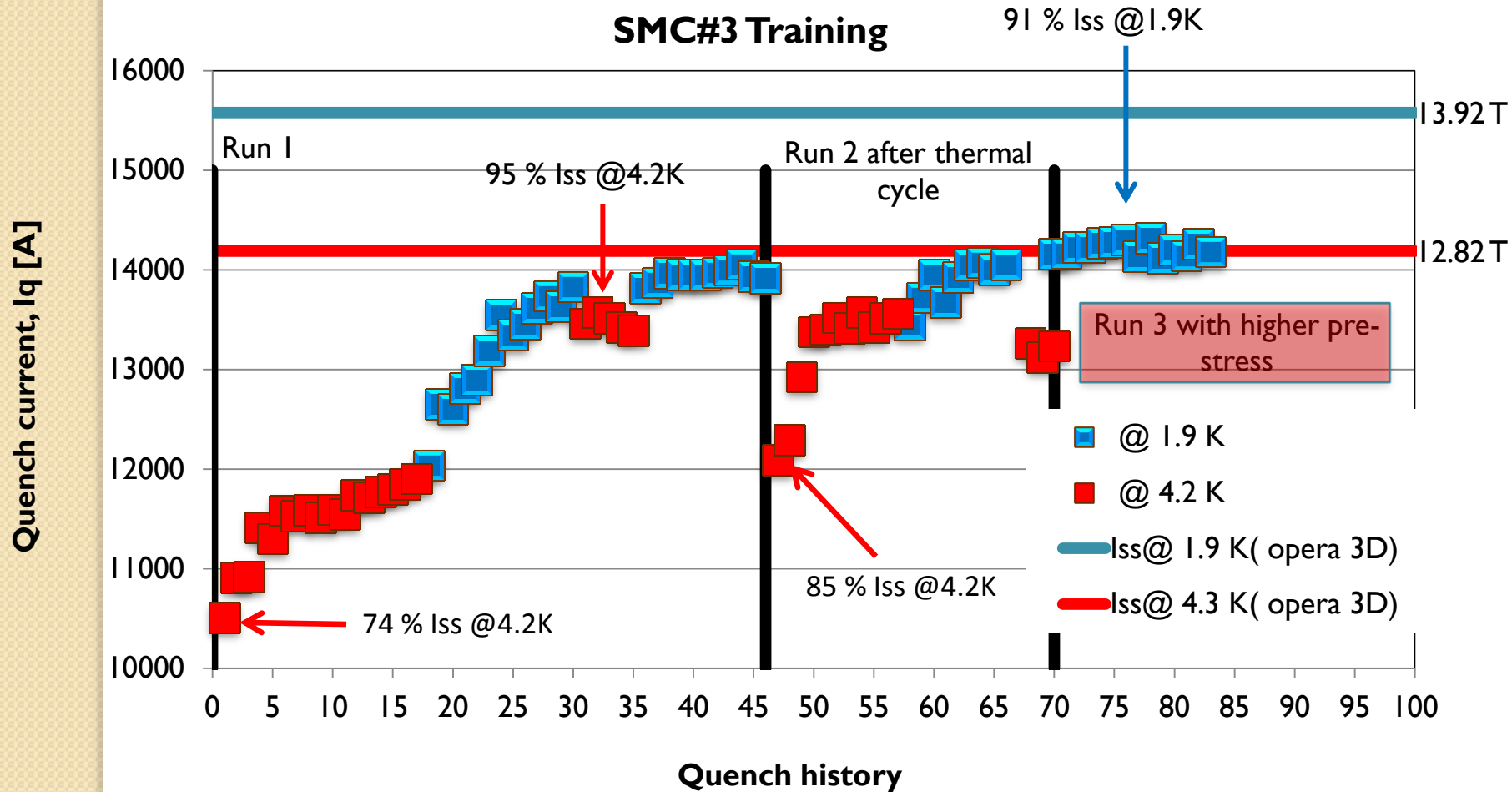
VK 1 (mm)	VK 2 (mm)	VK 3 (mm)	VK 4 (mm)	HK 1 (mm)	HK 2 (mm)	Rod 1 ($\mu\text{m}/\text{m}$)	Rod 2 ($\mu\text{m}/\text{m}$)	Shell_0_T ($\mu\text{m}/\text{m}$)	Shell_3_T ($\mu\text{m}/\text{m}$)
6.65	6.9	6.5	6.8	10.5	10.5	82	44	541	477

FINAL CONDITION @ 293 K – SMC3 November 2011

VK 1 (mm)	VK 2 (mm)	VK 3 (mm)	VK 4 (mm)	HK 1 (mm)	HK 2 (mm)	Rod 1 ($\mu\text{m}/\text{m}$)	Rod 2 ($\mu\text{m}/\text{m}$)	Shell_0_T ($\mu\text{m}/\text{m}$)	Shell_3_T ($\mu\text{m}/\text{m}$)
6.65	6.8	6.5	6.8	11	10.7	55	32	706	648

See detailed presentation by Ch. Kokkinos

SMC#3_a cold tests results



See detailed presentation by M. Bajko

SMC#3_b coils fabrication status and program

- Status
 - 2 coils for SMC3_b using PIT 14 x Ø1.25 mm strand with Ti-islands and spacers wound in September 2011
 - Electrical insulation of the central island and spacers with Al₂O₃ plasma spray coating
 - Cable insulated with S2-Glass sleeve (FNAL type)
- Plan
 - Heat treatment on Argon atmosphere furnace @ CERN
 - Coils to be potted using Epoxy NY 750 & Jeffamine D-400
 - Magnet assembly scheduled Q1-2012

Conclusions

- 7 SMC coils have been produced until today
- 2 SMCs : SMC#1 and SMC# 3 have been completely assembled and cold tested
- 2 types of Nb₃Sn cables (IT and PIT) have been used
- 2 types of insulation techniques, tape and sleeve, have been tried
- Bladder design and production have been qualified
- The impregnation method, using an open mold, shows good results for this type of coils
- Lessons learned during SMC#1 fabrication and applied for SMC#3 improved significantly the magnet performance
- The excellent results obtained with SMC#3_a assembly must be confirmed on SMC#3_b where we seek to repeat performance and eliminate electrical problems between coils and spacers
- The SMC project is a perfect example of efficient collaboration between different teams and laboratories

Thanks for your attention !!

3D view of SMC model

