Status of the Superconducting Magnet System for the J-PARC Neutrino Beam Line

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On behalf of
SC Magnet System Construction Group for the J-PARC Neutrino Beam Line

Staff at CSC and IPNS, KEK

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+

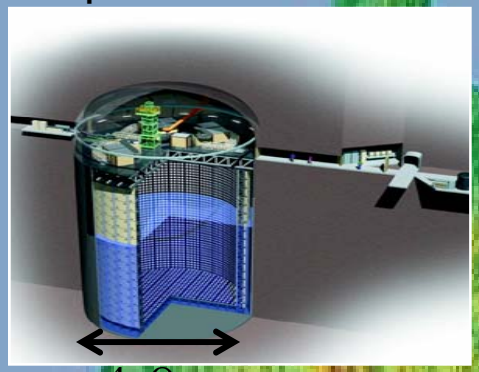
10 engineers and technicians

Outline

- **Introduction**
- **SC Magnet System**
  - **Magnet**
  - **Doublet Cryostat**
  - **Interconnect Cryostat**
  - **Refrigerator**
  - **Quench Protection**
- **Construction at J-PARC**
- **Fast Ramp Test**
- **Summary and Schedule**

Neutrino physics at J-PARC
Tokai-to-Kamioka (T2K) LBL ν experiment

Super-Kamiokande



T2K (2009~)

295 km

東海村

J-PARC
@JAERI

神岡

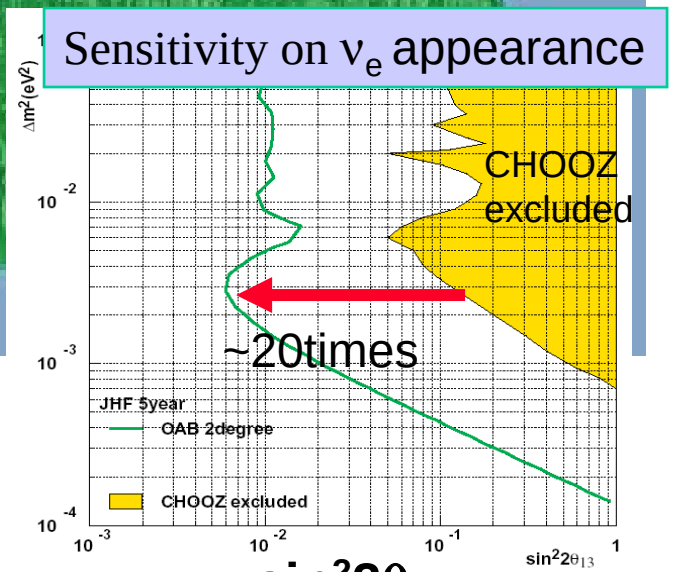
250km

K2K (1999~2005?)

KEK

- Off-axis sub-GeV ν_μ beam from J-PARC 50GeV-PS
- ~3000 ν_μ CC int./yr (w/o osc.)
  ν_e appearance discovery
  ν_μ disapp. presice meas.
- 5 year const. Start exp. in 2009.

Sensitivity on ν_e appearance

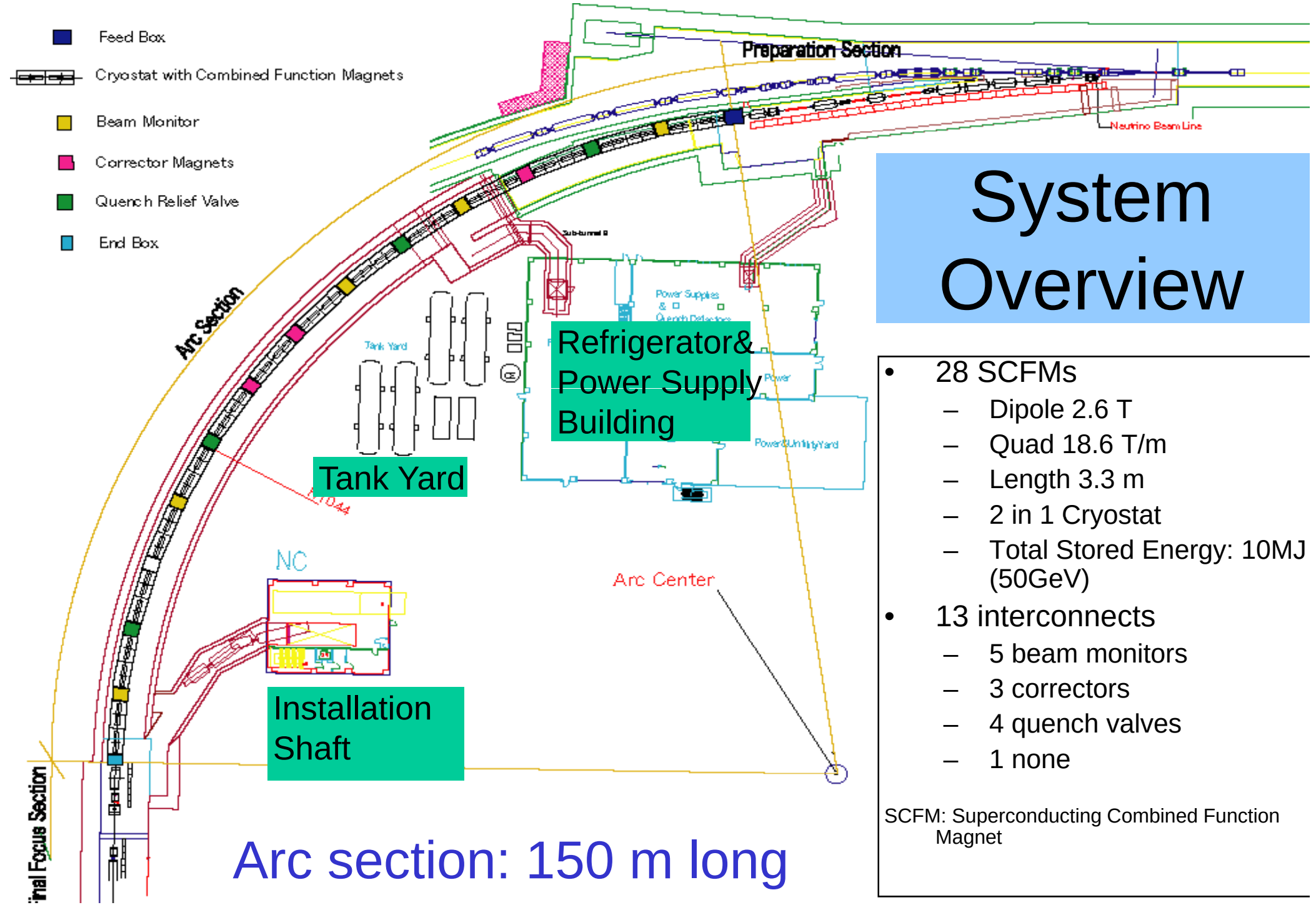


$\sin^2 2\theta_{13}$

J-PARC and Neutrino Beam Line for T2K exp.

- **Cost reduction was seriously requested:**
  >> 14 Cells of "Superconducting Combined Function Magnets" (SCFM)
  28 CFMs + 4 spares (+ 2 prototypes)
- **Operated at 30 GeV for the initial several years.**
  >> Then upgraded to 40 & 50 GeV

System Overview



- 28 SCFMs
  - Dipole 2.6 T
  - Quad 18.6 T/m
  - Length 3.3 m
  - 2 in 1 Cryostat
  - Total Stored Energy: 10MJ (50GeV)
- 13 interconnects
  - 5 beam monitors
  - 3 correctors
  - 4 quench valves
  - 1 none

SCFM: Superconducting Combined Function Magnet

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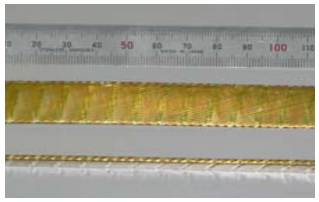
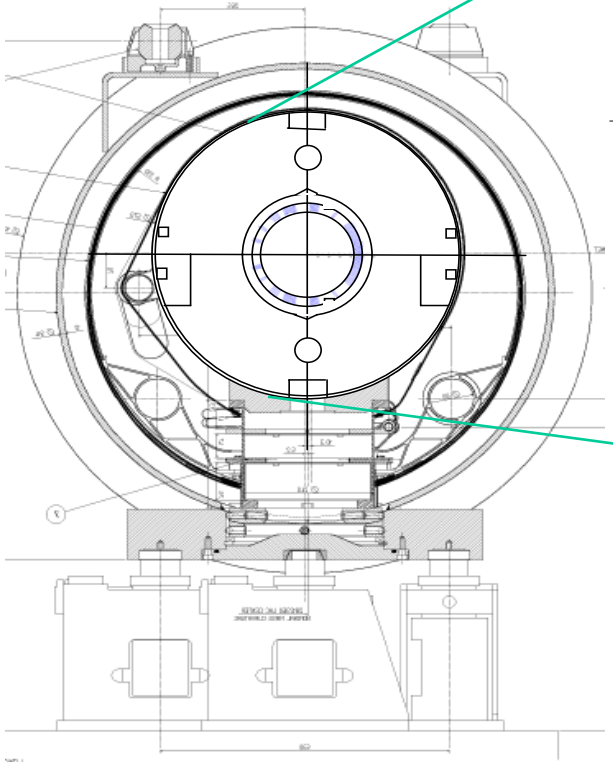
SC Combined Function Magnet

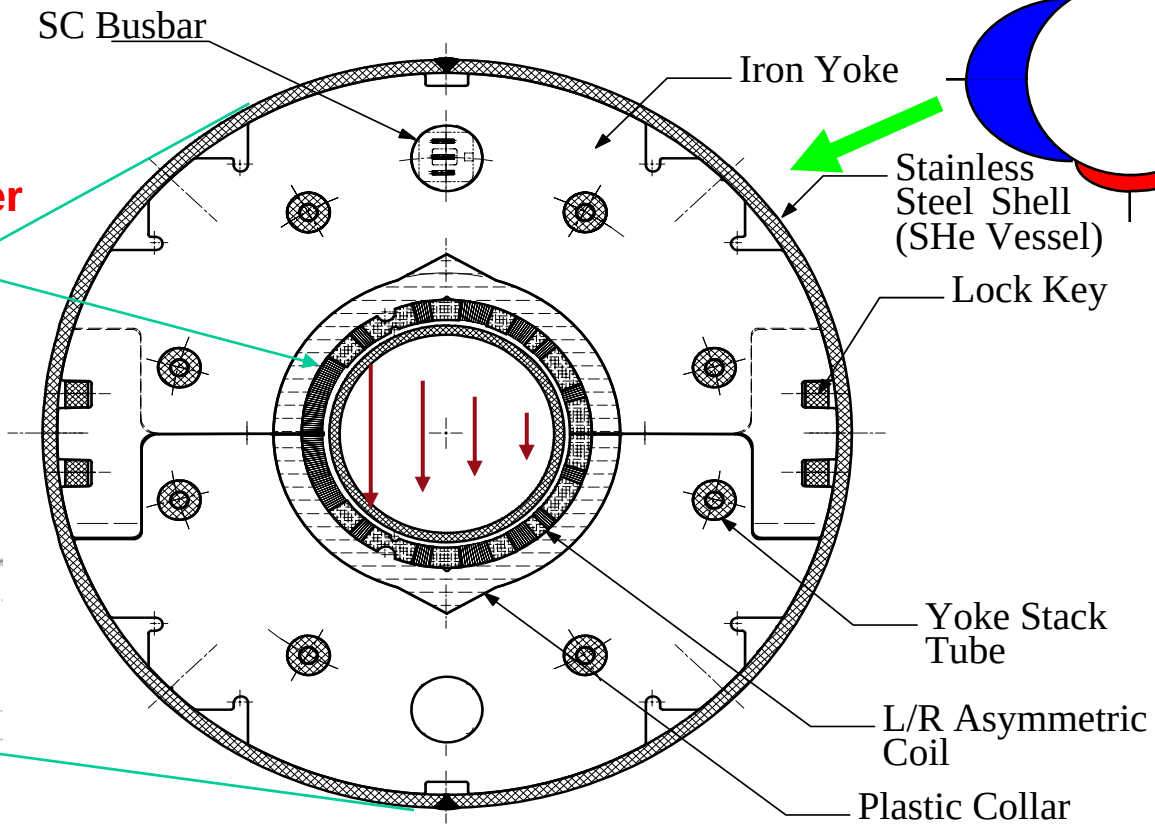
Mag. Design: Single Layer Coil

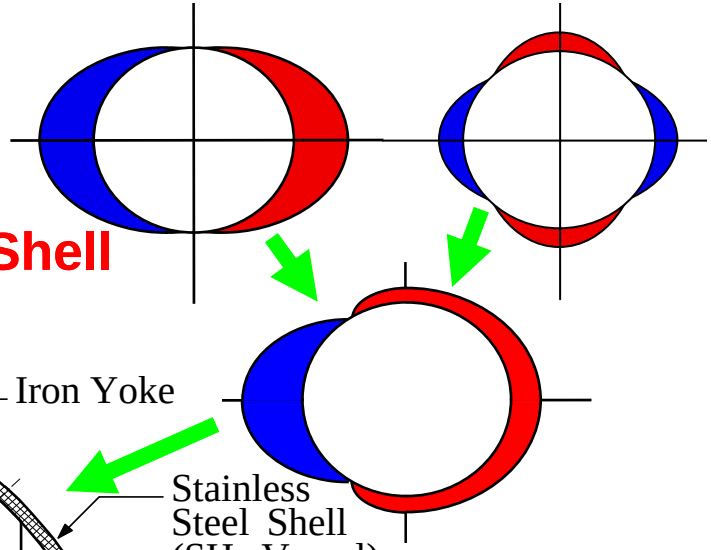
Mech. Design: Plastic Spacer, Keyed Yoke, SUS304L Shell



S.C. Cable for LHC-Dipole-Outer w/ MQXA Insulation



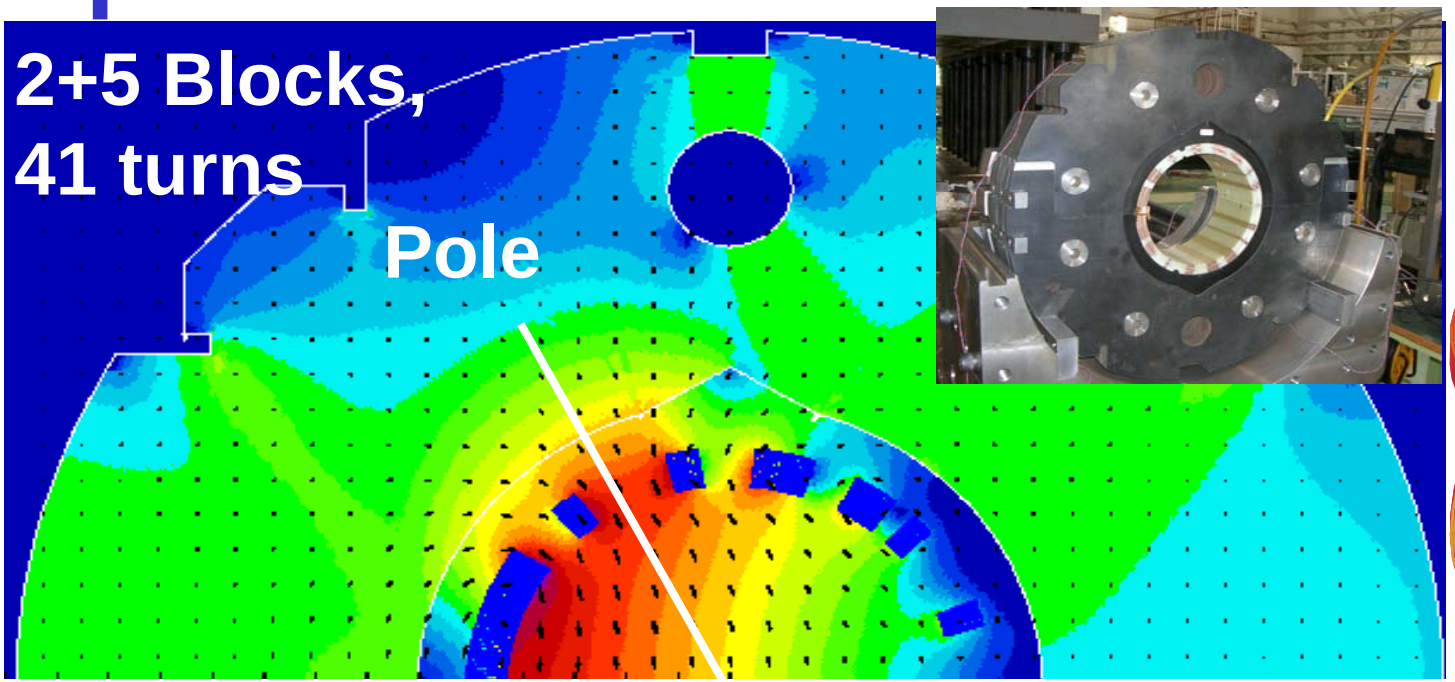


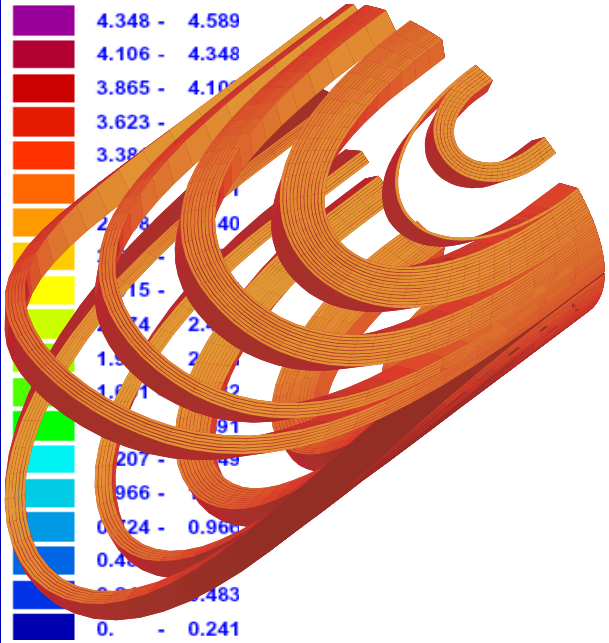


Dipole/Quadrupole Combined Bending + Focusing

Specificatio

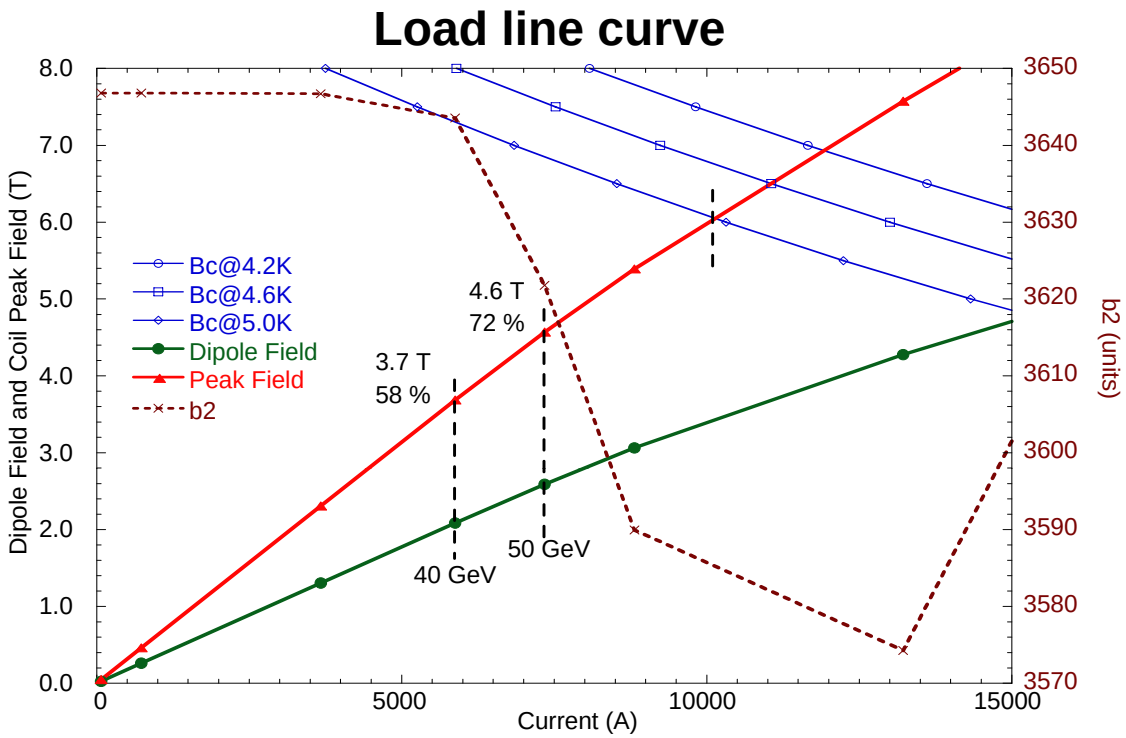
2D & 3D Model by ROXIE





Coil ID.:	**173.4mm**	**Op. Current:**	**7345 A**
Mag. Length:	**3300 mm**	**Op. Margin:**	**72%**
Mech. Length:	**3630 mm @RT**	**Inductance:**	**14.3 mH**
Tmax:	**< 5.0K**	**Stored Energy:**	**386 kJ**
	(Supercritical Helium)	**# of Magnet:**	**28**
Dipole Field:	**2.59 T**	**SC Cable:**	**NbTi/Cu for LHC**
Quad. Field:	**18.6 T/m**		**Dipole Outer-L**
Field Error:	**< 10^-3**		

Load line & Field Quality



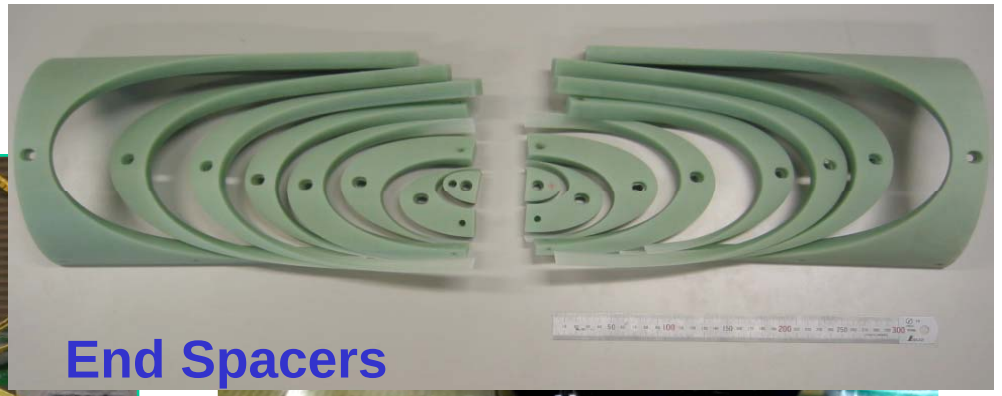
3D Field Quality (Rref=50 mm)

	3D-SS	3D-LE	3D-RE	3D-Integral
Lmag(m)	1.94	0.78	0.58	3.3
B1 (T)	2.591	2.602	2.603	2.601
b2(unit)	3628	3567	3517	3581
b3(unit)	-0.93	-581	-1015	-337
b4(unit)	5.01	-111	-235	-2.3
b5(unit)	2.07	-8.9	-160	-3.5
b6(unit)	-6.36	-7.9	-9.8	-7.2
b7(unit)	-1.16	-3.5	-5.3	-2.4
b8(unit)	-3.95	-2.9	-3.6	-3.7
b9(unit)	-8.86	-7.7	-7.9	-8.4
b10(unit)	-0.25	0.3	0.3	-0.0
b11(unit)	-3.10	-2.7	-2.6	-2.9
b12(unit)	2.07	1.7	1.6	1.9

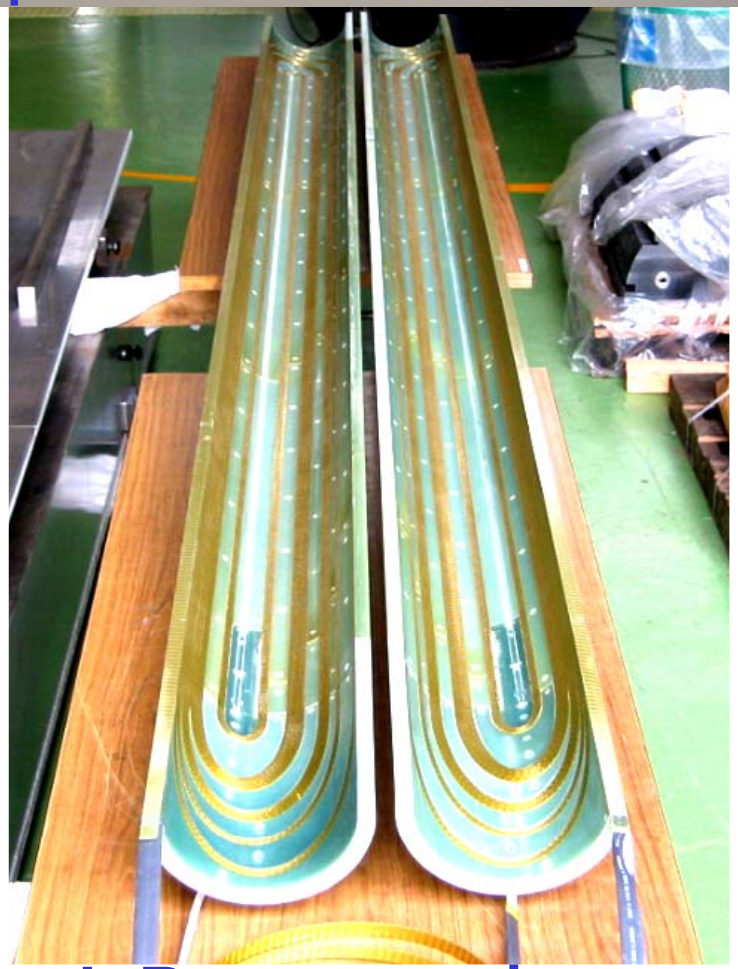
Good at SS | **Not so good at ends** | **Good enough**

- **Peak field at conductor in straight section is 4.6 T at 50 GeV.**
- **Load line ratios at 5 K for 40 & 50 GeV are 58 % & 72 %, respectively.**
- **Field quality within a tolerance of 10^{-3} is acceptable.**

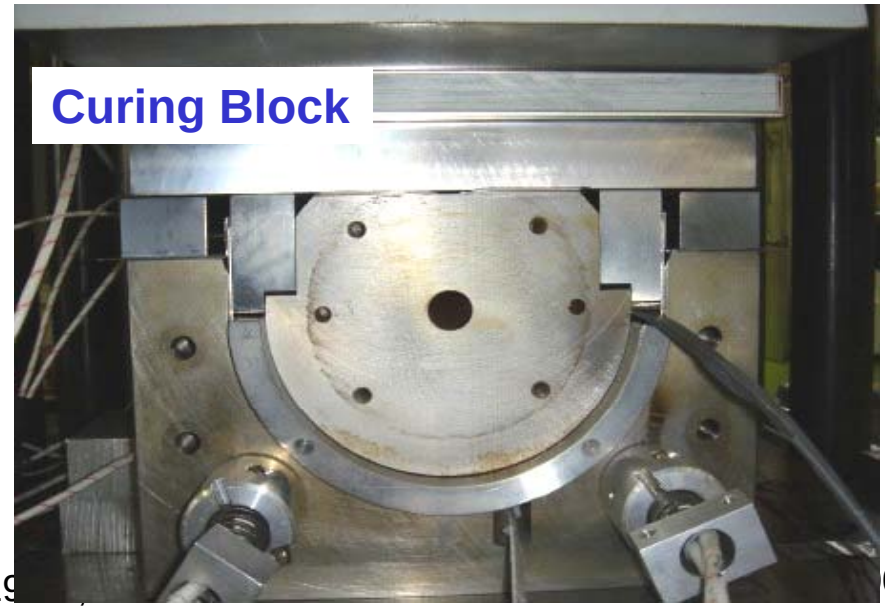
Coil Winding



End Spacers

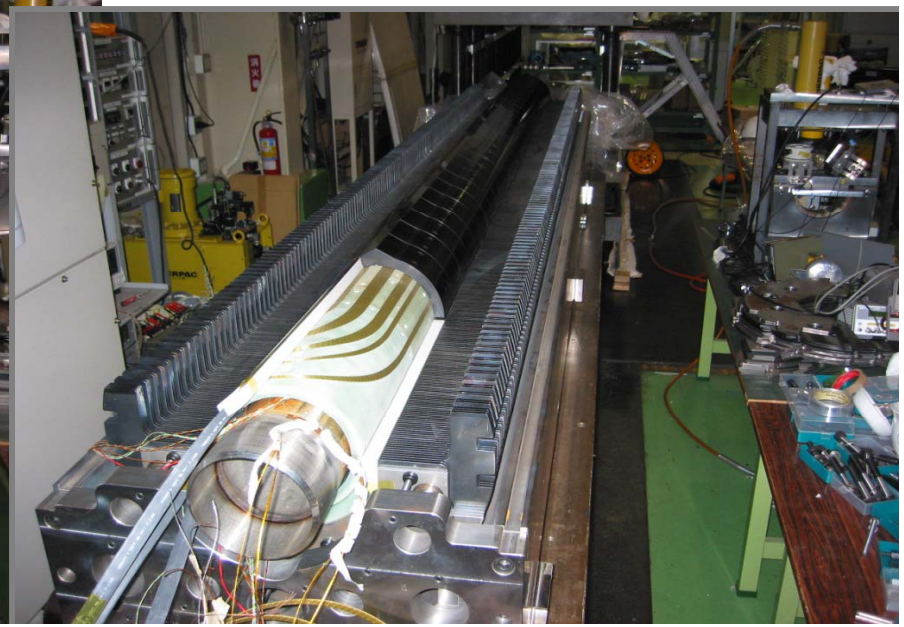


L-R asymmetric



Curing Block

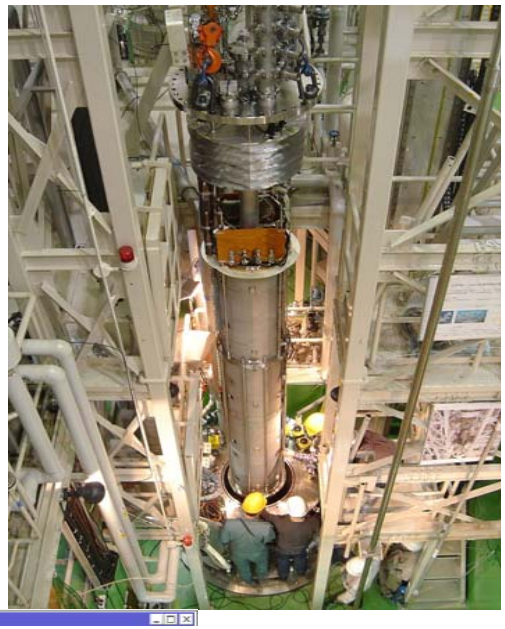
Magnet Assembly

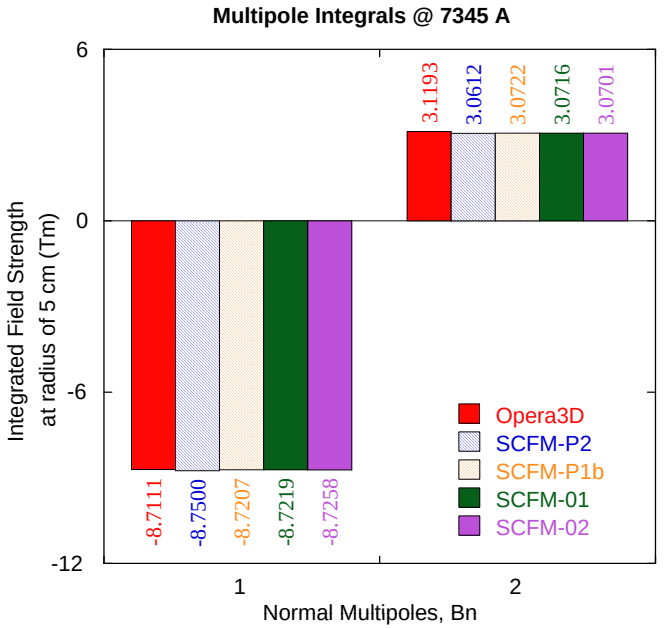


Magnet Assembly

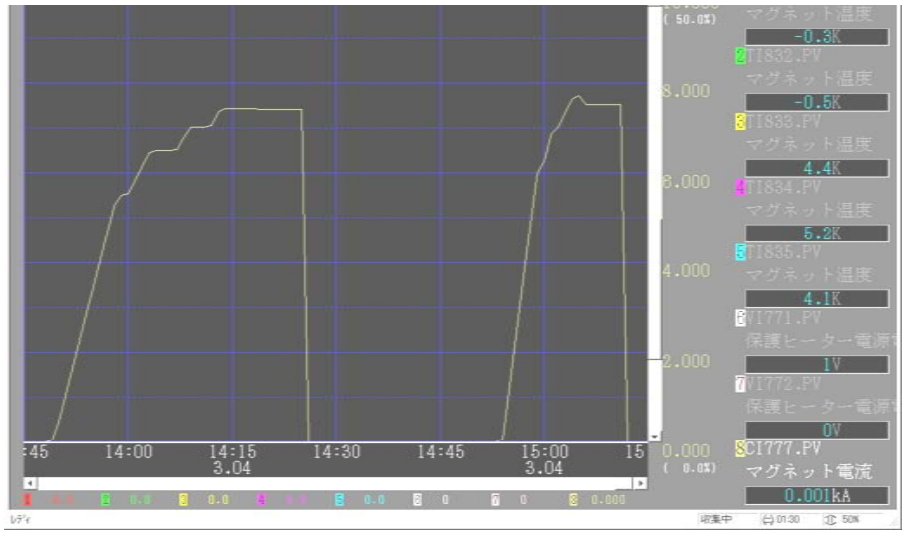
Magnet Test in Vert. Cryo.

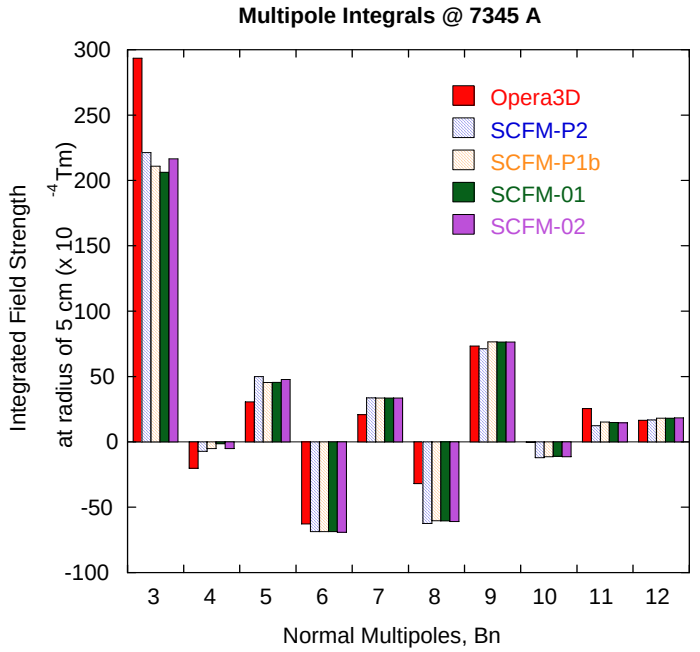
- For all 32 magnets
- Up to 105 % nominal current
- QPH Tests
  - Check to fire
  - Full energy dump
- MFM
  - Z-scan
  - @ 30, 40, 50 GeV





I_{op} = 7345 A @ 50 GeV (and I_{max} = 7,700 A)





No training quench for all tested magnets so far

- **Good reproducibility**
- **General agreement with computations**

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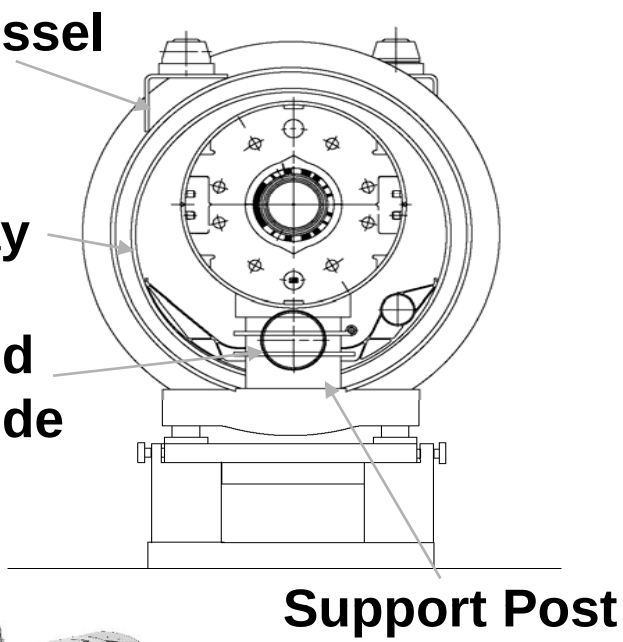
Doublet (2-in-1) Cryostat

Cryostat Design

Modification of LHC-Main Dipole Cryostat

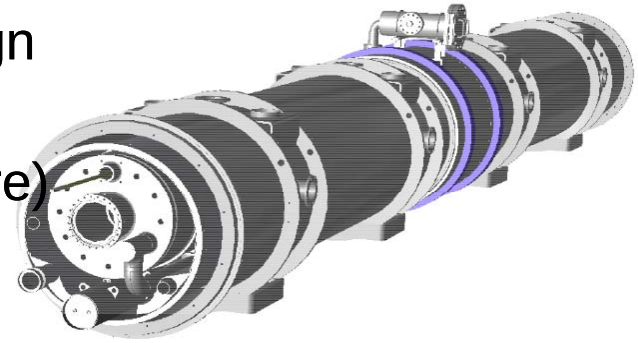
>> Drastic reduction of design risk and cost

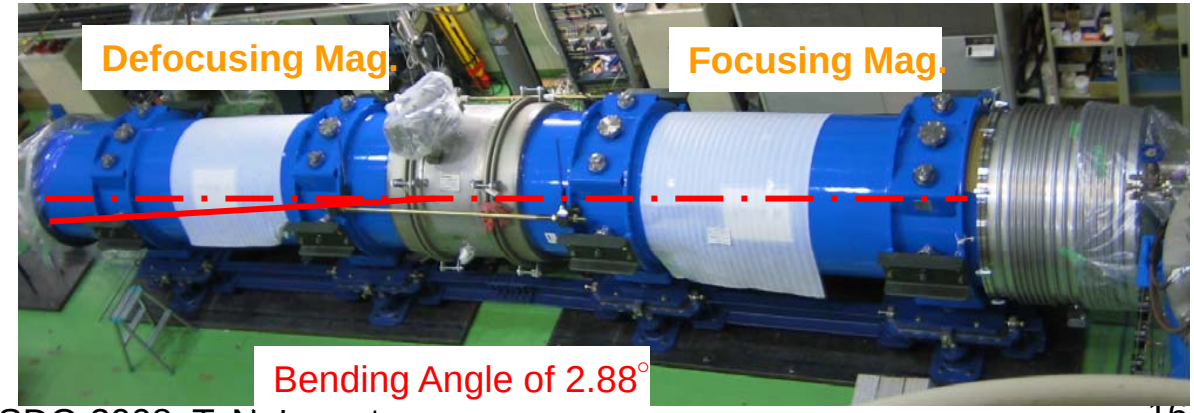
2 vessels mechanically connected



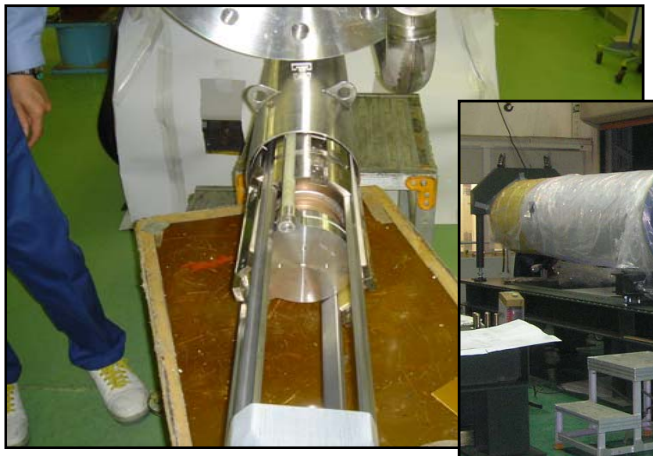
Collaboration with CERN

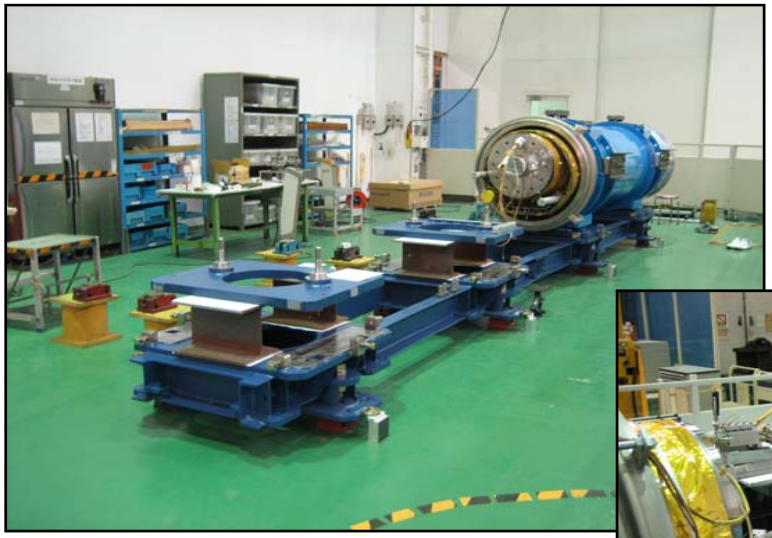
- Technology Transfer on Cryostat Design
- Procurement, Inspection, Testing
  - –Vacuum Vessel (Spain, This picture)
  - –Cold Diode (CERN)
  - –Support Post (CERN)
  - –Shield Tray (Netherlands)
  - –Connecting Bellows (UK)

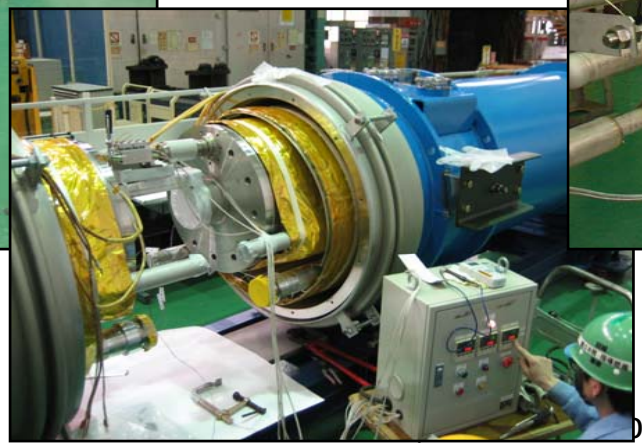




“2-in-1” Cryostat Assembly

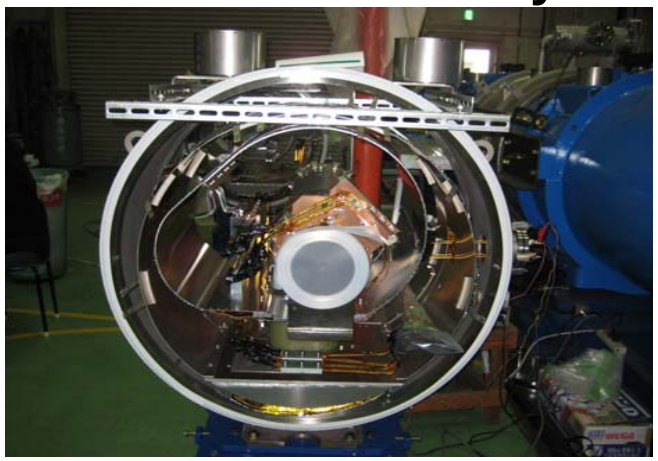




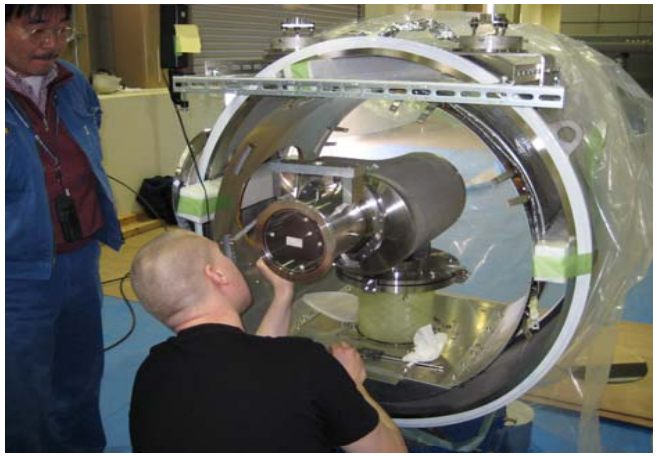


Interconnect Cryostats

- between Doublet Cryostats >> 13 locations
- 3 Types (functions)
  - 3 Corrector Magnets (conduction cooled)
  - 4 Quench Relief Valves
  - 5 Beam Position Monitors
  - 1 blank cryostat



Corrector Magnets
(Normal & Skew Dipoles)

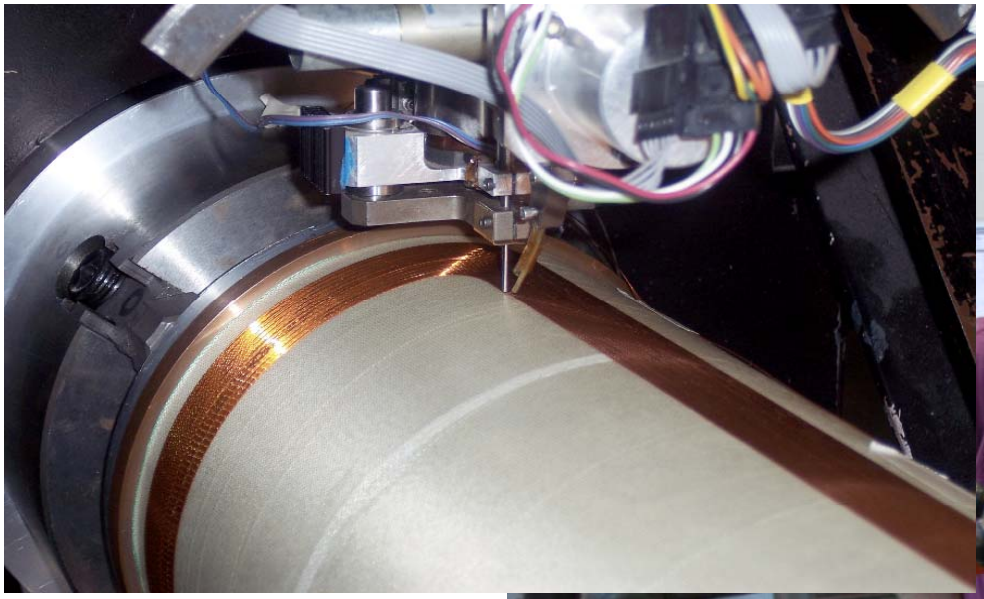


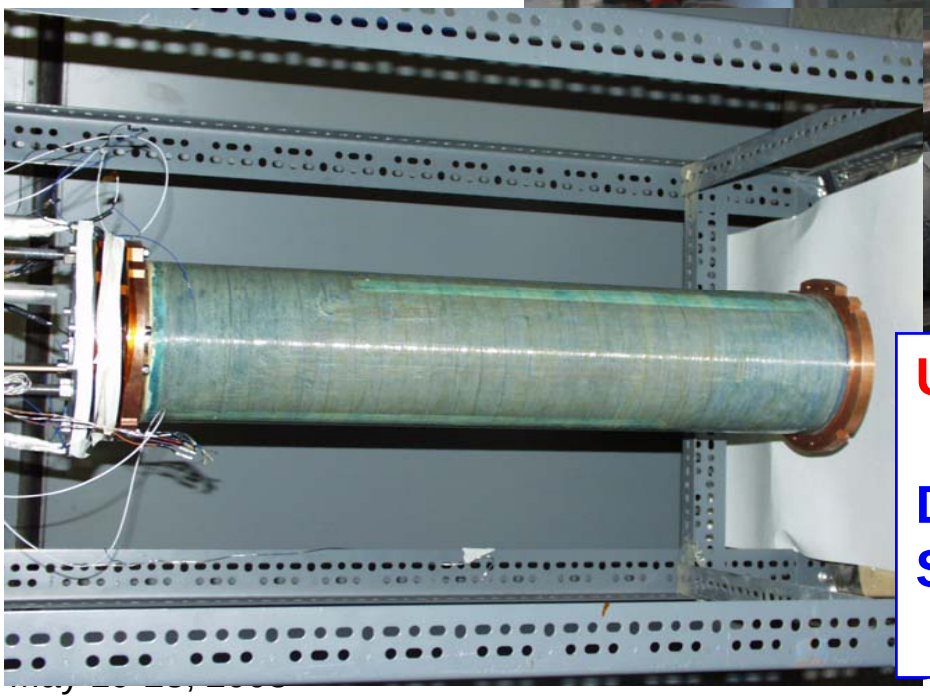
SEM & BPM

Relief Valve

Standardization of Doublet Cryostats

International Collaboration: BNL





US Contribution to T2K ν Experiment

Development and Production of Normal and Skew Dipole Corrector Magnets

(1 prototype, 3 production, 1 spare)

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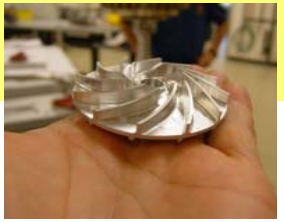
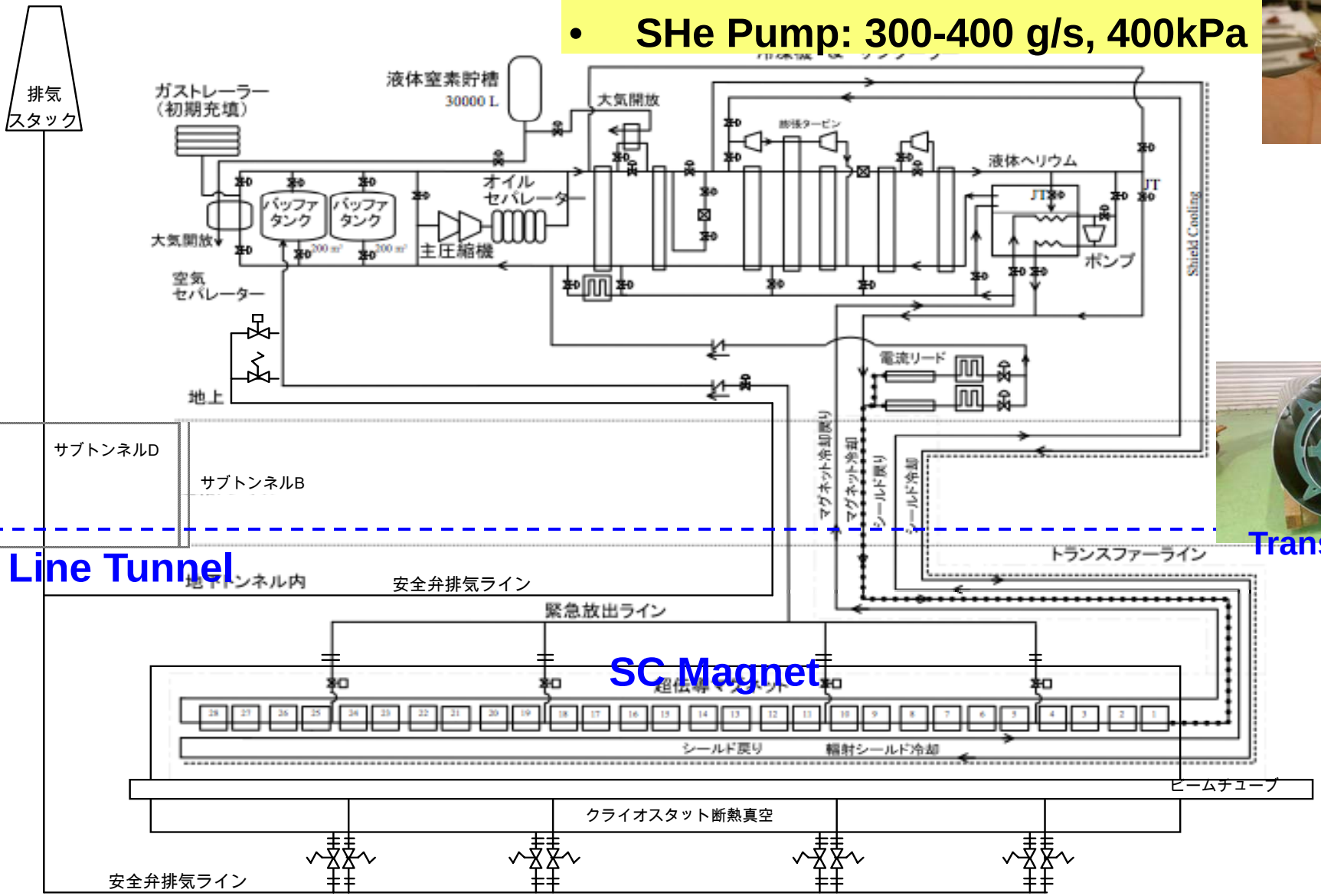
Cooling Flow

- Refrigerator: Contract given to Taiyo Nippon Sanso (Linde)
- Cooling Power: 1.2kW@4.5K, 2.5kW@80K
- Electric Power Needed: 600kW
- SHe Pump: 300-400 g/s, 400kPa



Transfer Line

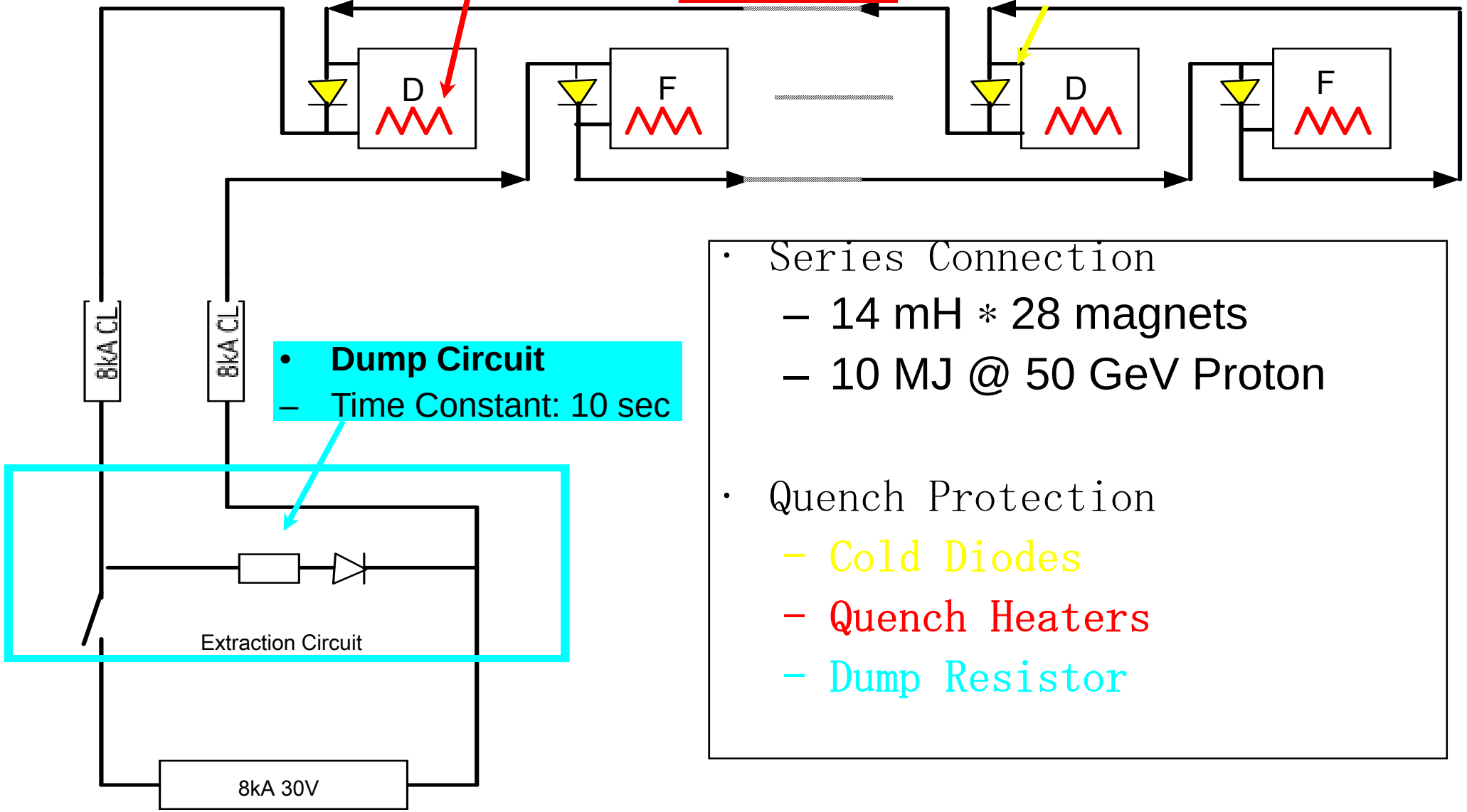


Beam Line Tunnel

Excitation Circuit

- **Quench Protection Heater**
  - Powered by Capacitor Bank

- **Cold Diode**
  - Turn On Voltage: 6V
  - Forward Voltage: 1V



- **Dump Circuit**
  - Time Constant: 10 sec

- Series Connection
  - 14 mH * 28 magnets
  - 10 MJ @ 50 GeV Proton

- Quench Protection
  - Cold Diodes
  - Quench Heaters
  - Dump Resistor

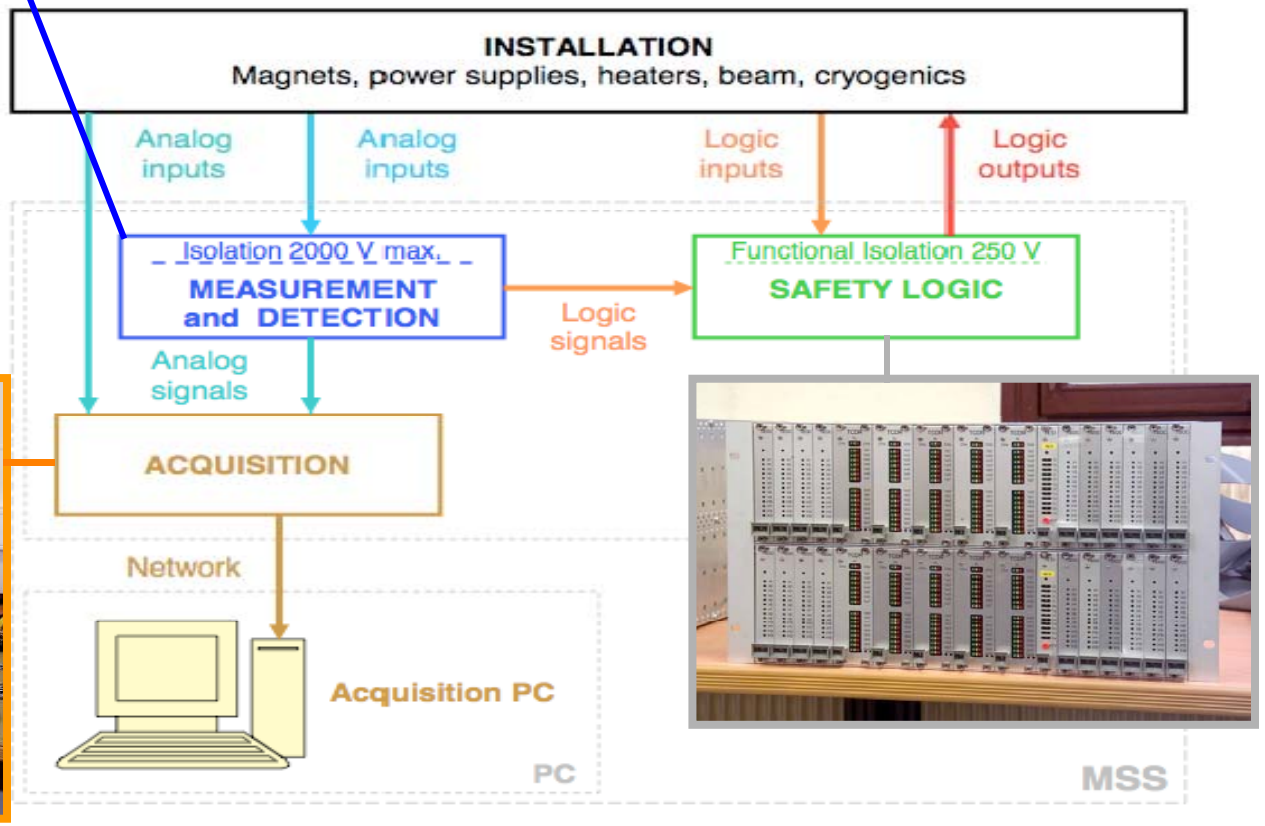
International Collaboration: CEA Sacley

French Contribution to T2K ν Experiment

Development and Production of Quench Detection and Monitoring System

dapnia
cea
saclay

T2K MSS : Synoptic overview of the MSS



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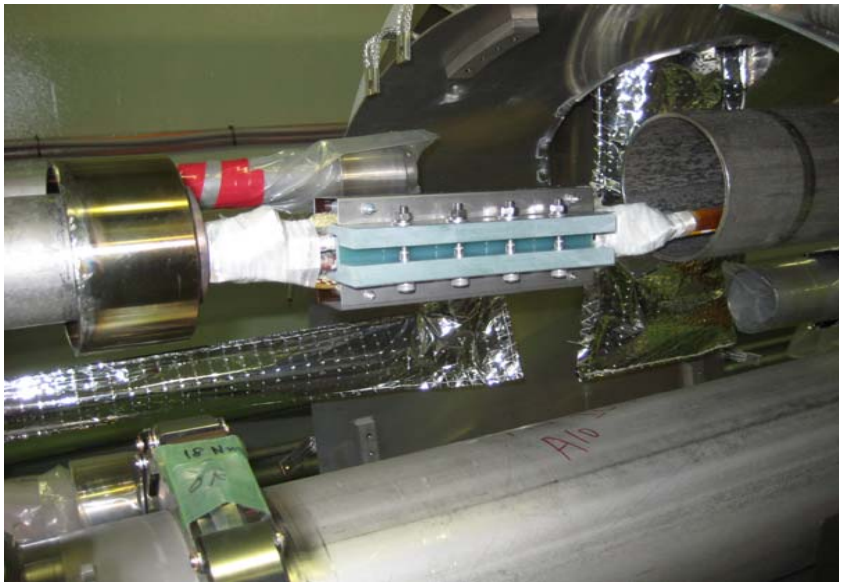
Transport

Installation

Interconnect Work



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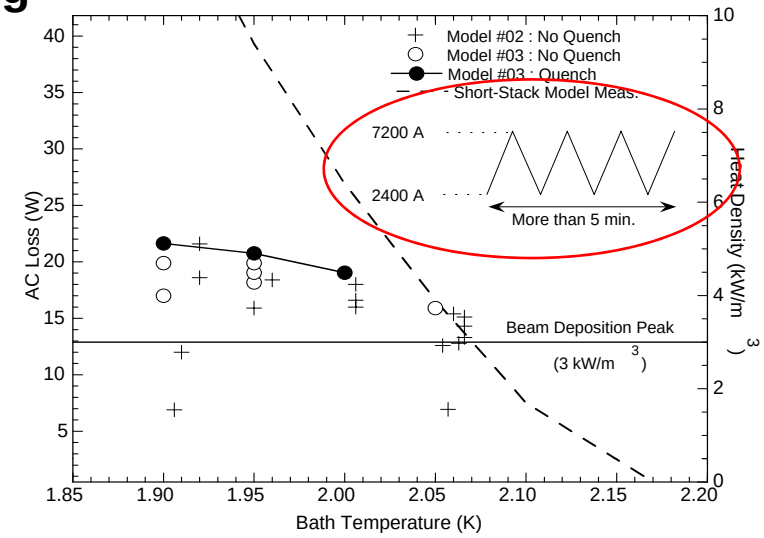
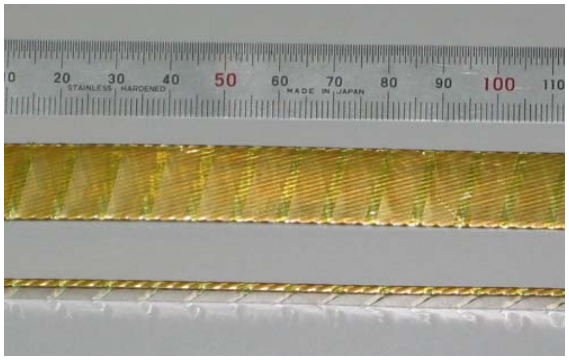
Demonstration of High Ramp Rate Excitation

- **Apart from J-PARC, this test could be interesting for the fast cycling SC magnet R&D.**
- **Ramp Rate: ~ 0.5 T/s**
- **Ordinary SC wire and cable**
  >> NbTi, LHC-Dipole-Outer
- **Ordinary Insulation System**
  >> Polyimide + B stage Epoxy
- **No quench observed for 2 prototypes up to the nominal current.**

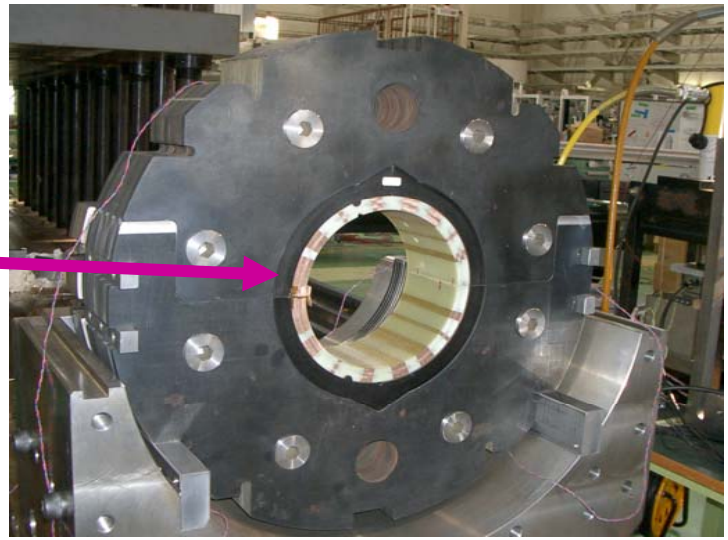


Ex.) AC loss measurement for MQXA model magnet. (ASC2000)

Calorimetric AC loss Meas. in LHe with zigzag ramp.



S.C. Cable for LHC-Dipole-Outer w/ MQXA Insulation



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Summary & Schedule

- R&D program to build 2 full-scale prototype magnets and 1 prototype “2-in-1” cryostat were successfully completed.
- Since 2005, 30 (of 32) production magnets and 12 (of 16) production cryostats have been fabricated by Mitsubishi Electric.
- All magnets showed good excitation performance and good field qualities fulfilled the specification.
- Magnet installation was started at Feb. 2008.
- Beam commissioning at MR is in progress.
- Installation of the refrigerator will be started June 2008.
- The magnet system in the tunnel will be completed by the end of 2008.
- **Cool-down and excitation test will be carried out in the first 3 months of 2009.**

Latest news: First beam circulation in MR was succeeded at May 20, 2008.