The instrumented magnets for the OPERA experiment: construction and commissioning

- Construction (2003-2005)
- Characterization of the iron
- Electric and magnetic characterization
- Thermal behaviour
- First run: August 2006
- Conclusion

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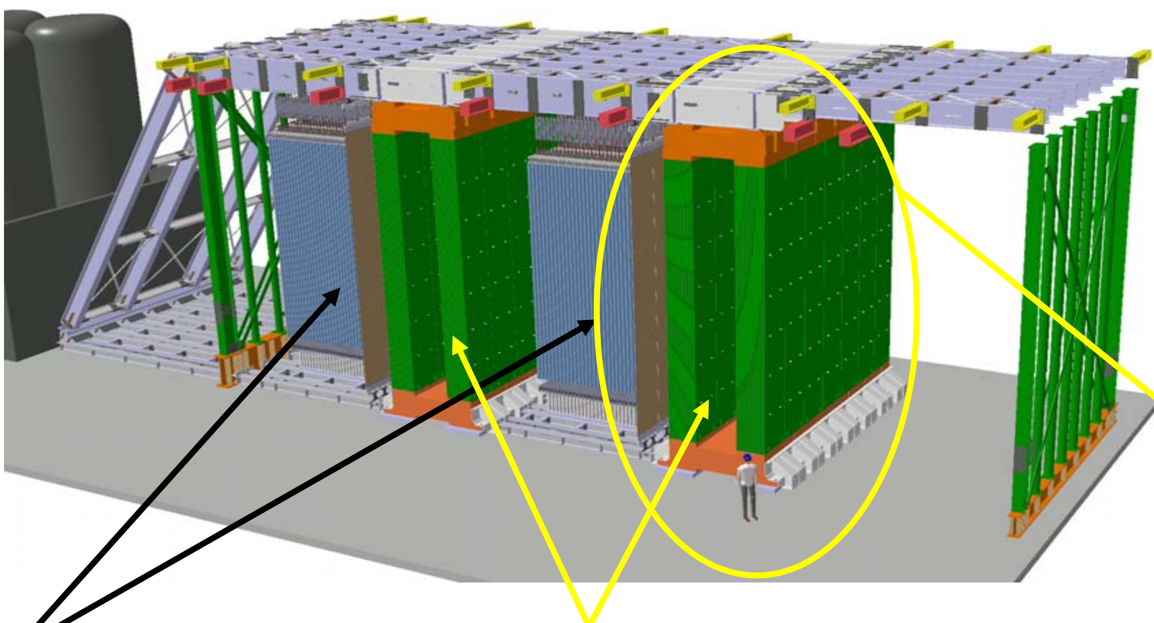
Magnetic spectrometer

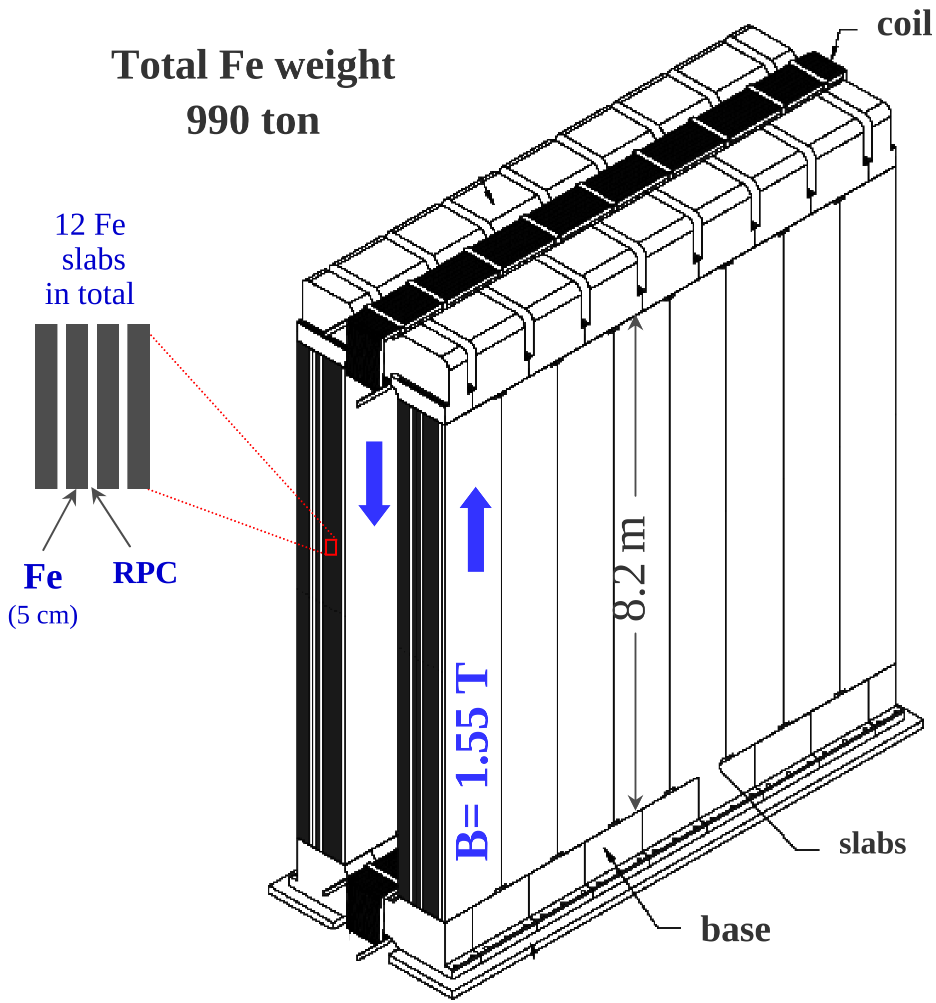


Targets
(31TT+31Walls/SM)

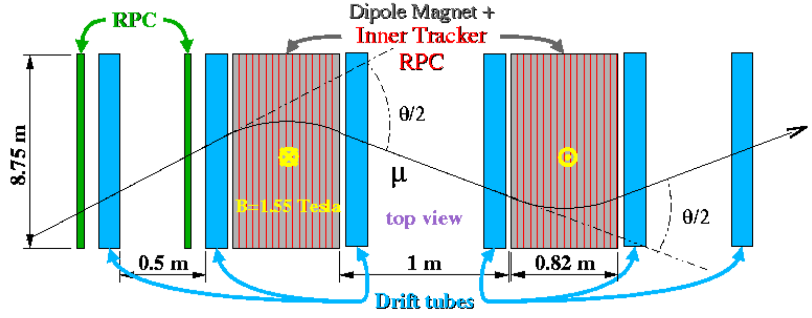
Magnetic Spectrometers
(Magnet + RPC + Drift Tubes)

Its role in OPERA: muon charge identification to suppress charm background; muon momentum measurement and hadron calorimetry (complete the kinematic reconstruction of tau candidates); beam spectrum reconstruction, physics of cosmic rays etc.

Why a gapless dipolar magnet?



- Uniform field along the slabs
- 1dim high precision trackers
- A very robust structure to hold the neutrino target (bricks and scintillators)
- Dead zones (return yokes) with strongly varying field
- Relatively high fringe field in the surrounding area (PMT's!!)



Construction

Start of the works in Hall C: summer 2003

END OF MAGNET INSTALLATION: June 2005

END OF INFRASTRUCTURE INSTALLATION: February 2006

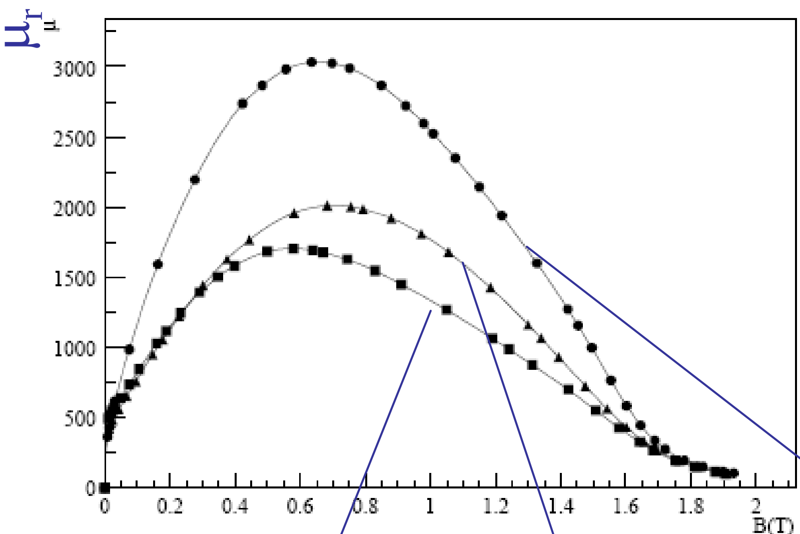
FIRST SWITCHING ON: MARCH 2006

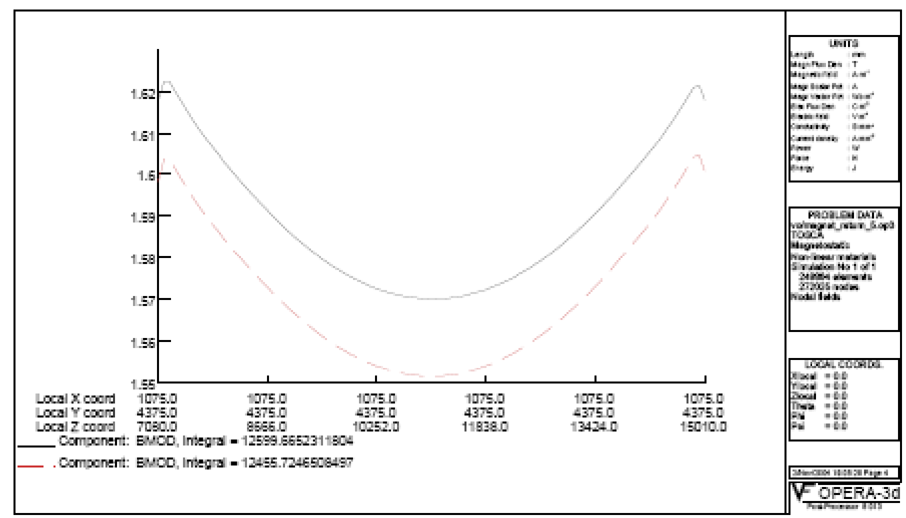
END OF COOLING SYSTEM INSTALLATION: MAY 2006

Steel properties

Element	Spec.	Slab steel	Yoke steel
C	<0.080	0.08 ± 0.01	0.004 ± 0.002
P	<0.025	0.011 ± 0.003	0.003 ± 0.001
S	<0.010	0.005 ± 0.003	0.005 ± 0.002
Mn		1.24 ± 0.13	0.24 ± 0.02
Si		0.20 ± 0.03	0.84 ± 0.03
B	<0.0005	< 0.0001	0.00016 ± 0.00005

Mechanical specs played a crucial role to determine the magnetic response of the steel





Slabs

Prototype

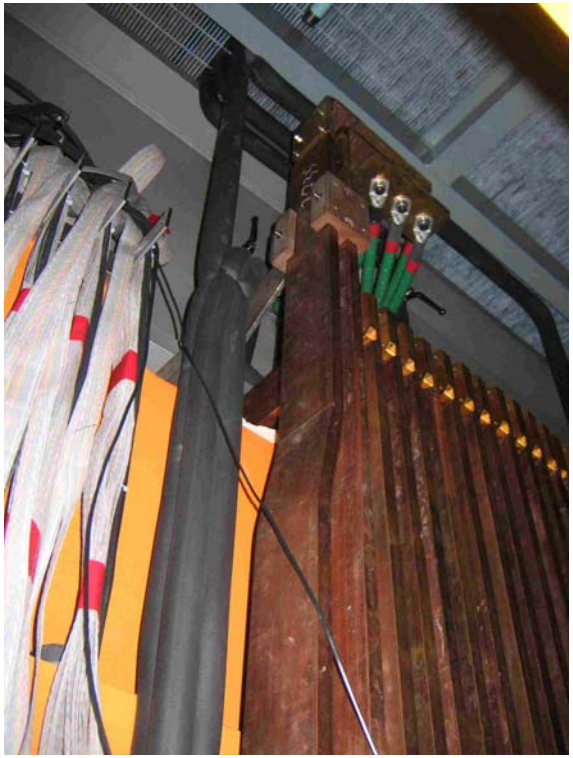
Return yokes

Driving coils and power supplies

Current: 1600A

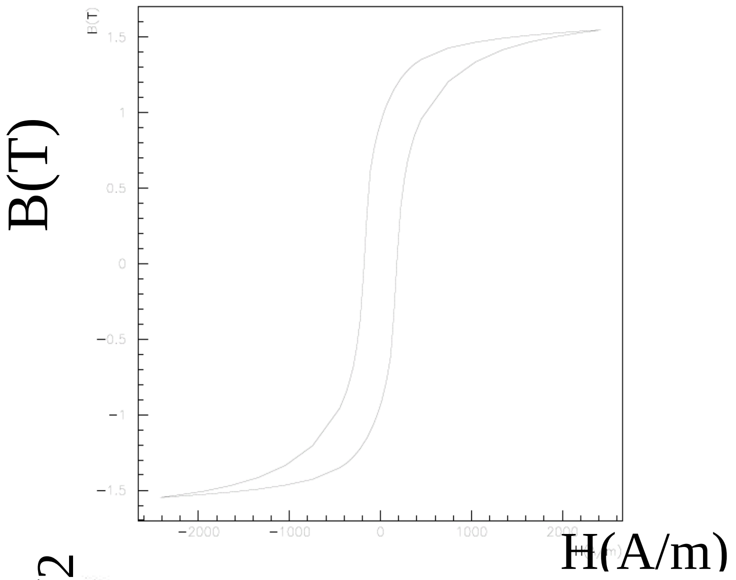
Coil: copper bar 100x20 mm^2 [careful machining, golden deposition to assure proper electric connections, R=8 mΩ at T=55 deg], 20x2 turns, 800m

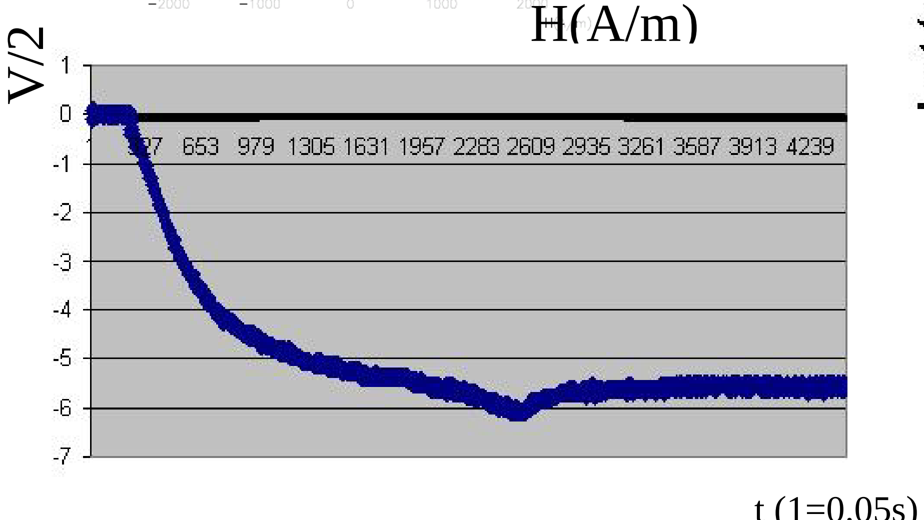
Power supplies: 2 quadrant AC $\rightarrow$DC, current stable below 0.1%, max 1700A 20V, designed and built by EEI Vicenza



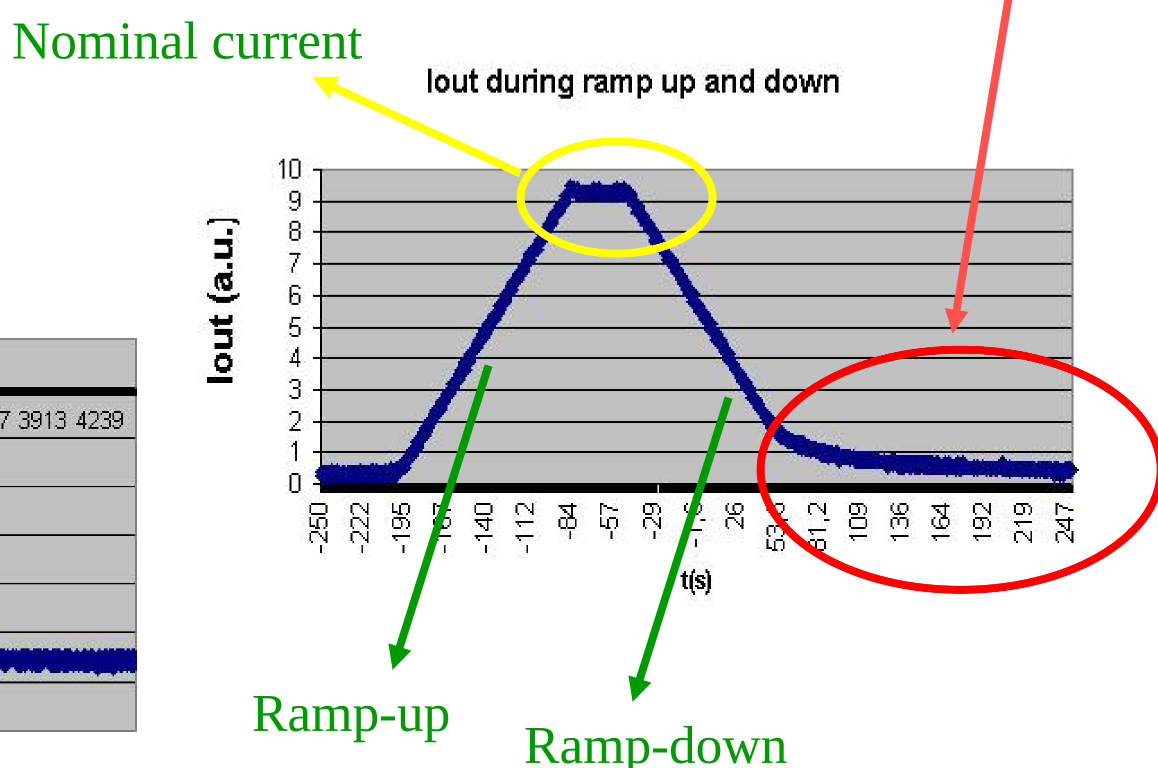
Inductive response

During ramp-up the inductance (L÷dB/dH) changes by order of magnitudes





The power supplies cannot change continuously the sign of the voltage, hence during rampdown (di/dt<0) they miss di/dt=const at time T when Ri+Ldi/dt becomes negative. For t>T the circuit discharged at its natural speed (L/R)



Measurement of magnetic field

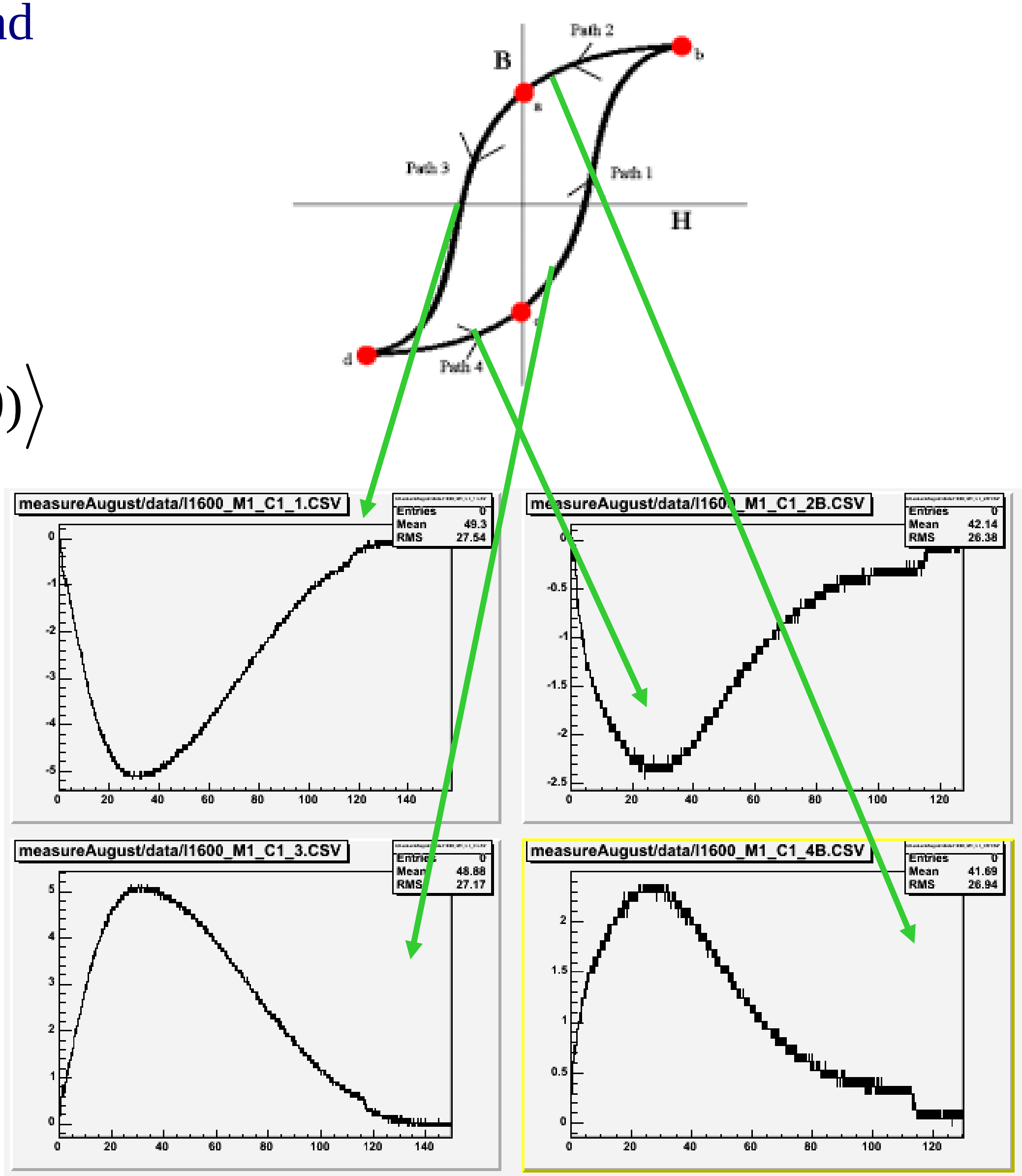
Techniques:

- ✓ Pick up coils along the height and the slabs ⇒ absolute calibration

$$V = -\frac{d\Phi(t)}{dt} = -SN\,\frac{d}{dt}\langle B\rangle$$

$$\frac{-1}{SN}\int_0^t dt'V(t') = \langle B(t)\rangle - \langle B(0)\rangle$$

- ✓ Hall probes in air to monitor relative variations and validate the simulation



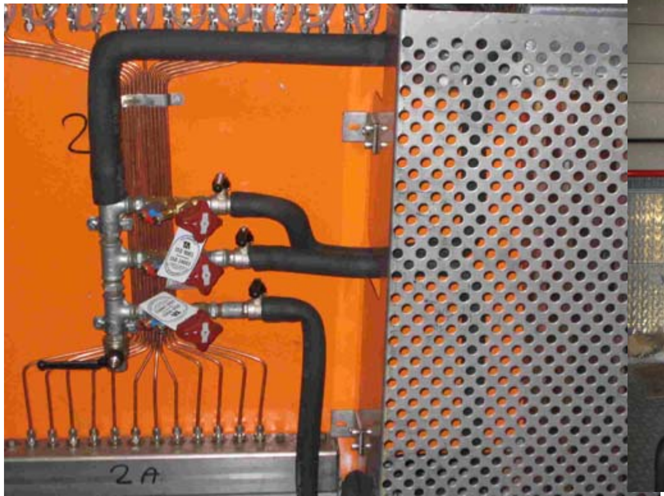
Results:

- ✓ Field uniformity within specs
- ✓ Flux deficit of about 4% (machining and air gaps)
- ✓ Two magnets identical within 1%

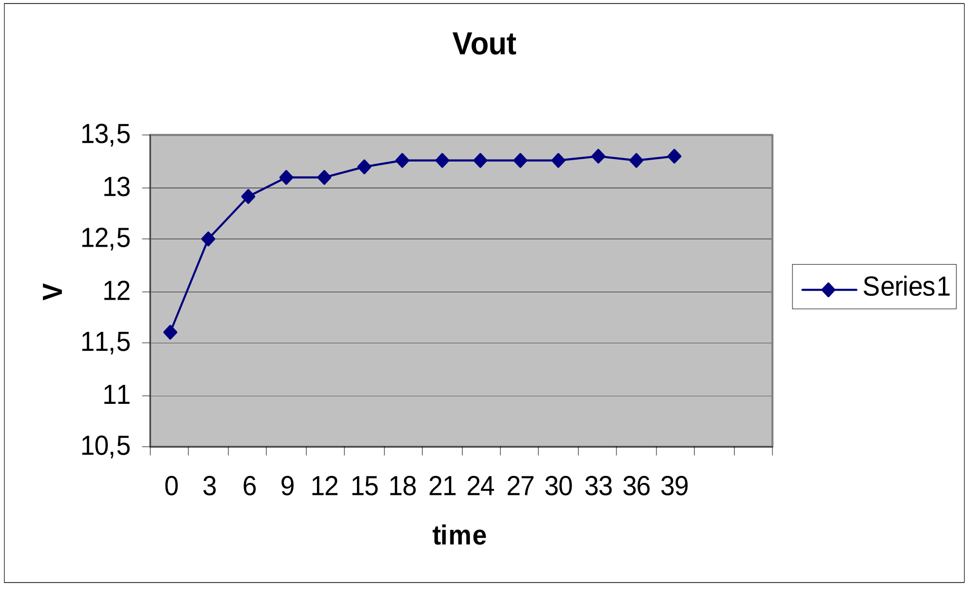
Water cooling system

Standalone system with:

- A primary circuit connected to an external chiller (outside the experimental hall): 80 kW cooling power
- Secondary circuit to water cool the coils (20 kW per magnet)
- Secondary circuit with DEMI water (<10 μS/cm) to cool PS
- Water cooling of electronics racks

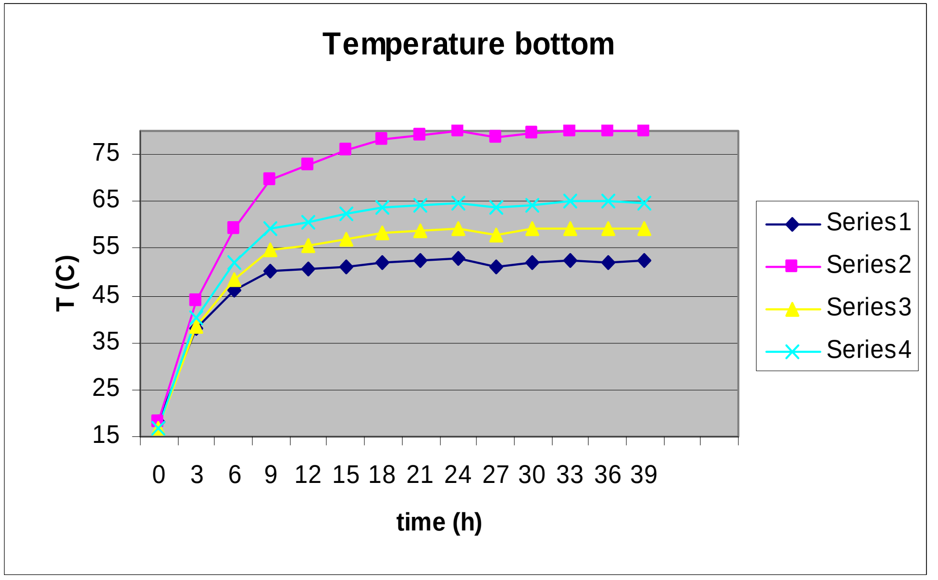


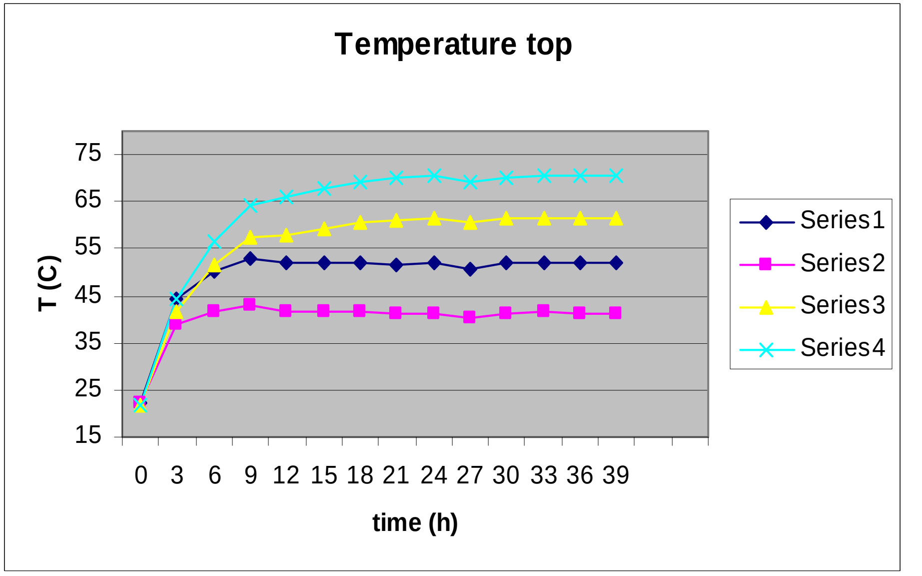
Temperature measurement



Temperature of the coil: 40-80 degree

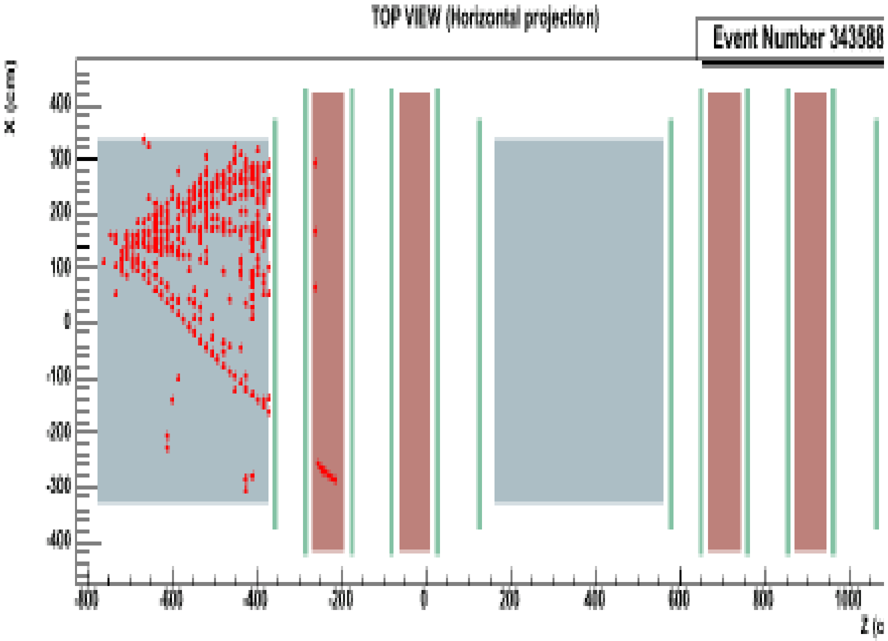
Temperature of the RPC: 20-23 degree (2 weeks of data taking)

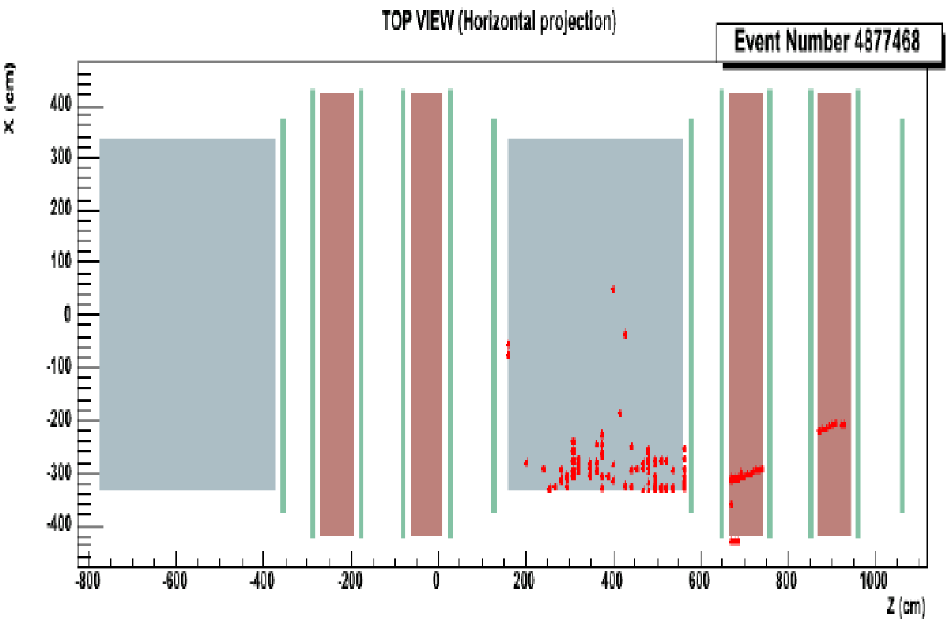




August run with CNGS

- Livetime of magnets: 100% (magnet1), 95% (magnet 2)
- Coil temperature stable after 40 hours, RPC after 7 days
- Reconstructed events: mainly μ- (obviously…). Reconstructed CNGS spectrum still not released by the Collaboration…





Conclusions

- The two ~1 kton magnets for OPERA are fully operative since July 2006
- No anomalies observed in the load (resistence and inductive response during ramp-up): we can run at nominal current and measure the field using pickup coils.
- Minimum field (center of the slab) is 1.49±0.01 T (Average 1.52 T)
  Expected for ideal mechanical contacts: 1.55 T (Average 1.575 T)
  The two magnets are equal within 1%
- August run:
  (a) Livetime: 100% (magnet1), 95% (magnet 2)

  (b) Coil temperature stable in 40 h. Cooling seems appropriate to keep RPC temperature below 25 degree.

  (c) First look at momentum reconstruction seems OK (in progress)

All in all, a pretty good success