Impact of beam screen vibrations on field quality and emittance growth

Riccardo de Maria, Tom Kroyer, Marco Calvi, Bernhard Auchmann
Vladimir Shiltsev*, Luca Bottura

CERN, *FNAL

FQWG, 2 May 2006

Introduction

Field fluctuations in the kHz range affect the emittance growth rate. Tolerances are very tight.

One possible source of field fluctuations are the beam screen vibrations driven by the helium flux in the cooling tubes.

Preliminary measurements have been done; the data does not allow to exclude the possibility of an observable and potentially dangerous effect for LHC operation.

A refined measurement set-up reproducing as well as possible LHC working conditions should give realistic data. This could help to improve the theoretical understanding of this effect and possibly lead to remedies for LHC operation.

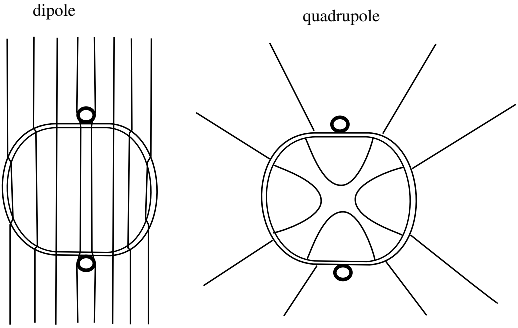
Emittance Growth Rate

In first approximation the transverse beam dynamics of the LHC is a linear oscillator whose frequency is
$f = f_{rev}Q \simeq 11kHz * 0.3 = 3.3kHz$
Field noise in this frequency and the relative harmonics transfer energy directly into the beam turn-by-turn yielding a constant emittance growth.
Using a simple model we can estimate[1,2] that a $\Delta B/B \approx 2.8 * 10^{-10}$ will double the emittance in 10 hours, the LHC machine time.

[1] Magnetic field fluctuations in SC dipole magnet. V. Shiltsev (Fermilab) , B. Baklakov, S. Singatulin (Novosibirsk, IYF) . FERMILAB-CONF-01-155, PAC-2001-RPPH102, Aug 2001. 3pp.
[2]V.A. Lebedev, V.V. Parkhomchuk, V.D. Shiltsev, G.V. Stupakov, "Emittance Growth due to Noise and its Suppression with the Feedback System in Large Hadron Colliders", Particle Accelerators , vol.44, No. 3- 4, pp. 147-164 (1994).

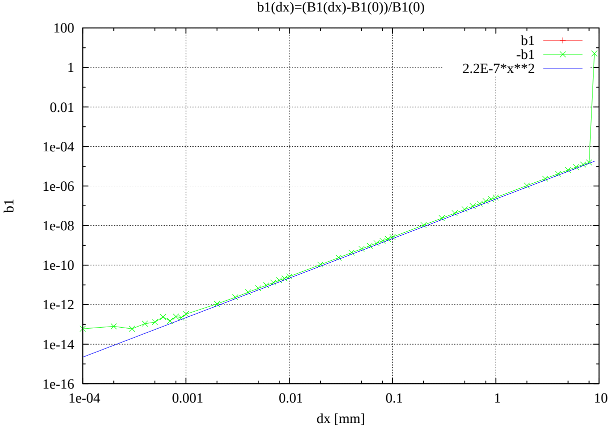
Beam screen

The beam screen change the main field by
its non vanishing magnetic permeability in a dipole field and by eddy currents a quadrupole fields resulting in a feed-down error.



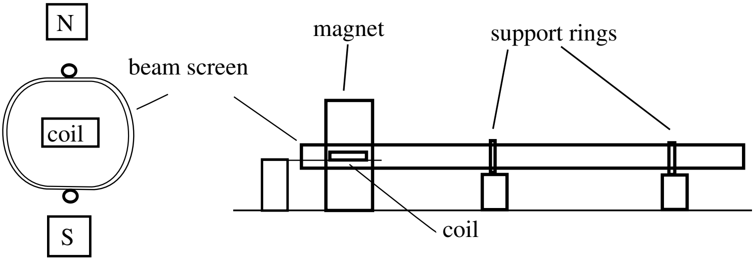
Effect of Beam screen displacement in a dipole

A calculation with ROXIE shows the magnetic fluctuation depending on the beam screen displacement taking into account only the peramability effect.



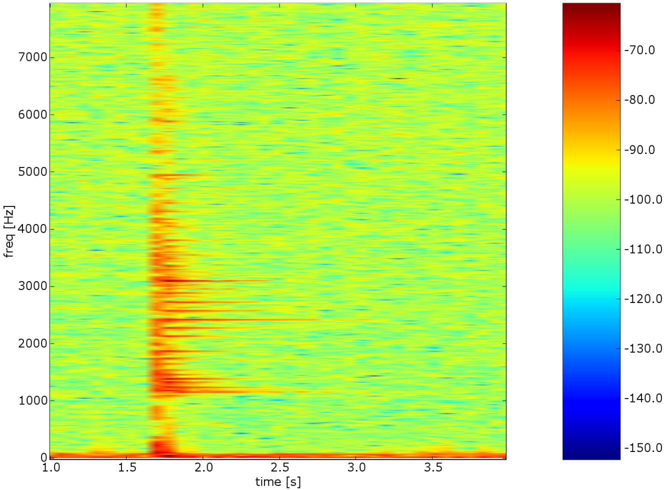
Measurements

We measured the beam screen field fluctuations due to 2m long sample beam screen vibrations in a dipole field. We used a permanet magnet and a resistive reference dipole as main field and a coil as probe.



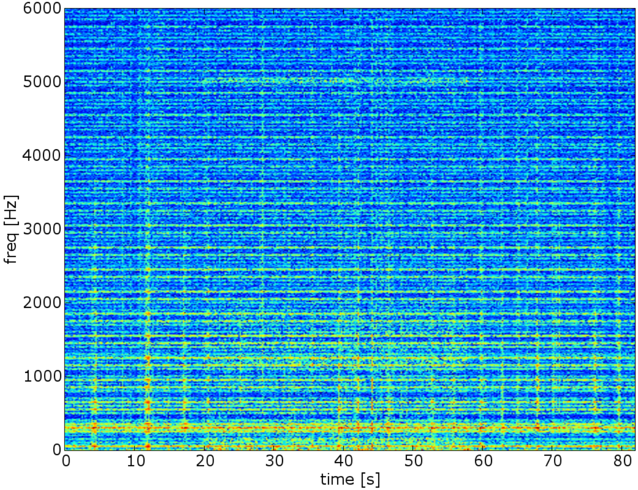
Impulse response

0.080T permanent dipole main field. 0.1m^2 equivalent surface coil. $\Delta B/B \approx 10^{-5}$. Color scale is dBV.



Compressed air response

1T resistive dipole main field, 8 bar compressed air.
0.4m^2 equivalent surface coil.
$\Delta B/B \approx 10^{-8}$



Conclusions

The beam screen shows resonant frequencies at $1, 2, 3, 5$ kHz. The measure set up can detect a $\Delta \mathrm{B}/\mathrm{B} \approx 10^{-8}$ and already shows that the beam screen can be excited by turbulent flow in the cooling tubes.

Nevertheless the mechanical properties of the b.s. can be different inside the beam pipe. The helium (supercritical, 4bar) effect on the b.s. is difficult to predict.

In case this effect is recognized by this committee as a potential problem, we could propose a new measurement set-up on a LHC dipole at 8T with the beam screen and helium flow installed in order to reproduce as much as possible the operating conditions.

Similar measurements have been performed in Tevatron[1] for explaining a 10% of emittance blowup and the results shows a pessimistic estimation of the effect.

[1] Magnetic field fluctuations in SC dipole magnet. V. Shiltsev (Fermilab) et al. .

Plan

We propose a measurement to be performed in one day in SM18 on a LHC dipole at nominal current.
The preparation of the coils and their mechanical supports will need a technician for one week.
The instrumentation and the acquisition system is already available at CERN.
Resources from Fermilab and LARP may be available.

Acknowledgement

I would like to thank Oliver Bruening, Massimo Giovannozzi, Bernard Jeanneret, Simone Gilardoni, Sandro Bonacini, Stefano REdaelli, Guy Deferne, the magnet test lab for the support, useful discussion and assistance during the realization of the measurements.

Helium state diagram

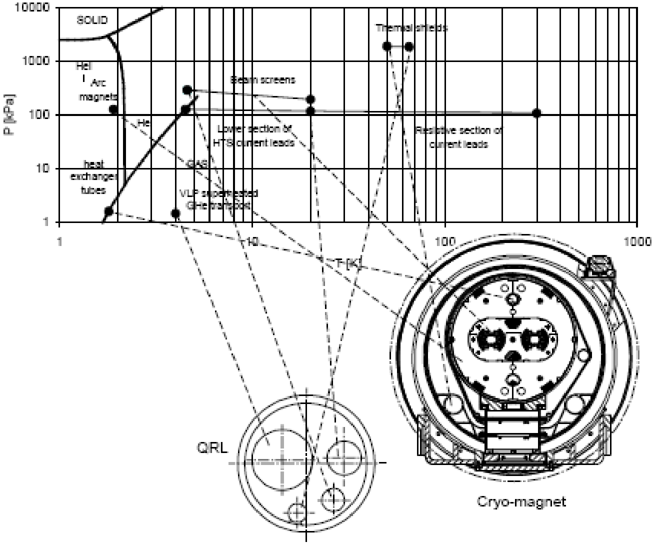
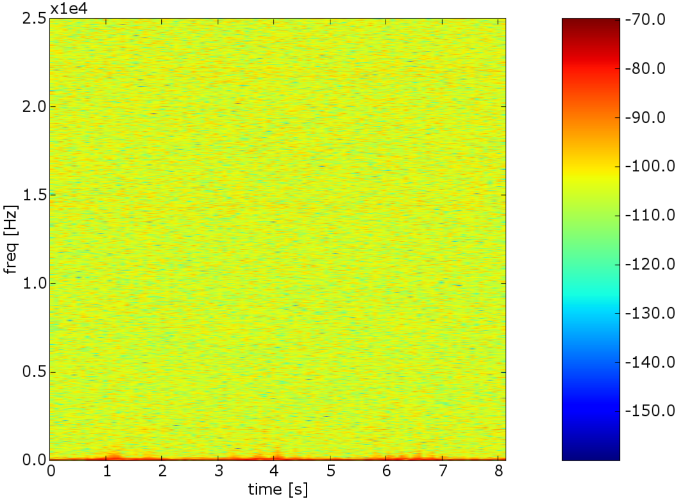
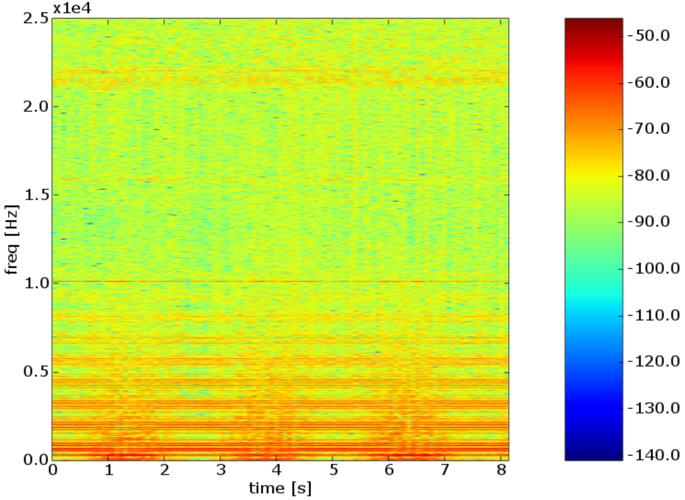


Figure 11.4 Thermodynamic states of helium in the LHC cryogenic system

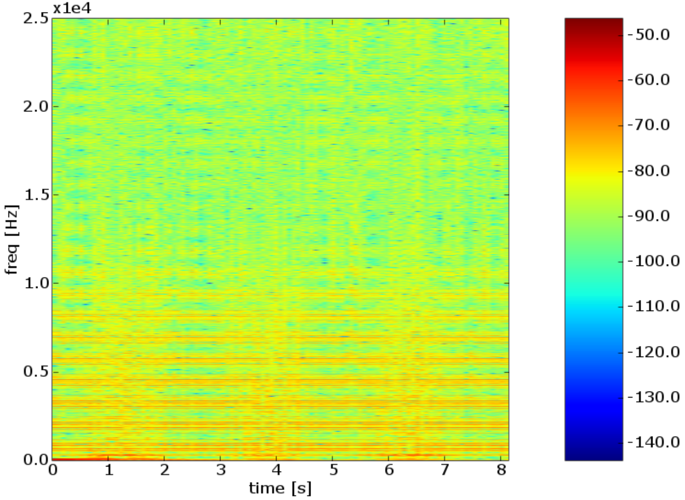
Permanent magnet noise



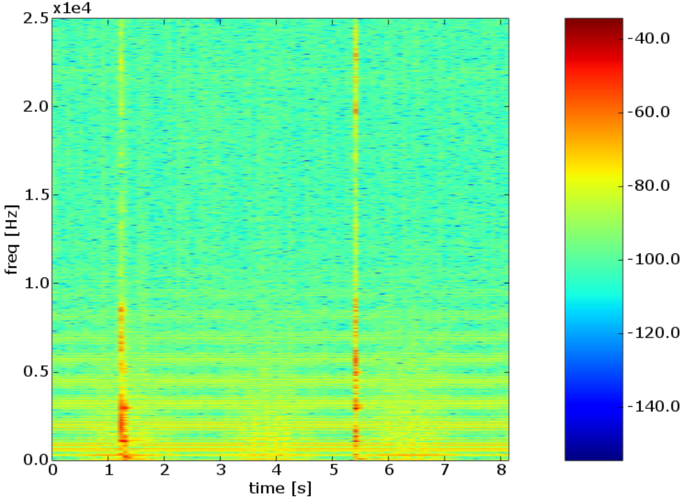
1 Tesla noise, big coil



1 Tesla noise, small coil



1 Tesla ping



x1e4
2.5
2.0
1.5
1.0
0.5
0.0
freq [Hz]
0
1
2
3
4
5
6
7
8
time [s]
-40.0
-60.0
-80.0
-100.0
-120.0
-140.0

Measure scheme