Using long strings of s.c. HERA dipoles in search for Axion Like Particles (ALPs).

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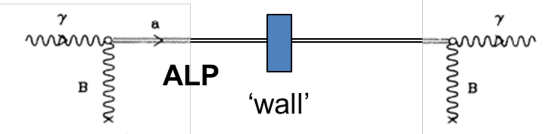
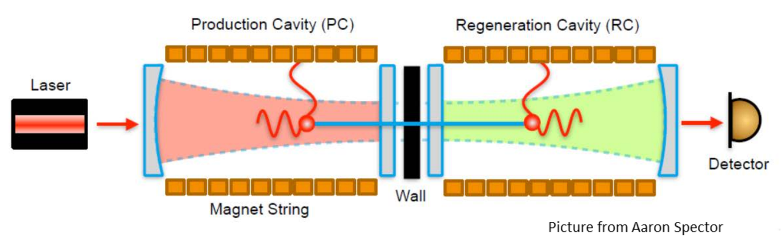
Experiment main concept



Laser photons interact with a magnetic field (B) and produce a ALPs.

ALPs pass through matter (the 'wall') practically unaffected; the photons are absorbed.

ALPs are re-converted into photons by interaction with a magnetic field. The photons are detected at the other side of the 'wall'.



The number of photons in the magnetic field is increased by an optical cavity (production cavity)

The conversion probability in the magnetic field is increased by an optical cavity (regeneration cavity)

Using superconducting (s.c.) HERA dipoles

The detection **sensitivity** for ALPs **scales with B*L** (B = magnetic field and L = length of the magnet)

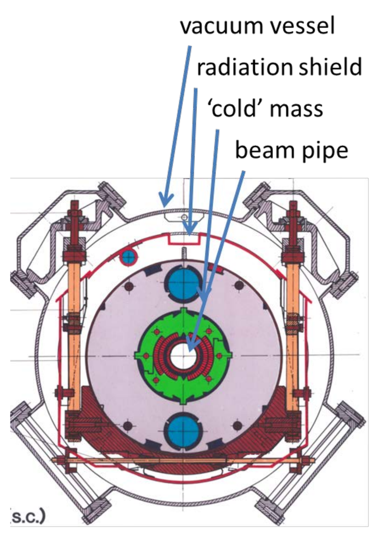
Use **long strings** of **strong magnets** ⟶ **HERA superconducting dipoles** available at DESY

HERA dipole parameters

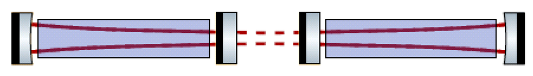
magnetic length	8829.6 mm
total length	9766 mm
magnetic field at 5700 A	5.3 T

HERA dipole main dimensions

vacuum vessel diameter	610 mm
cold mass diameter	400 mm
radiation shield diameter	510 mm



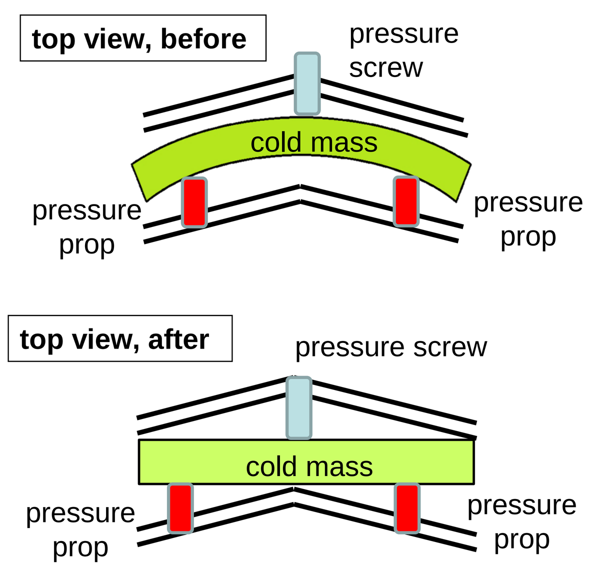
The power buildup of the laser is limited by the aperture of the magnet beam pipe; the pipe must not cut into the tails of the stored photon beams.



The inner diameter of the HERA dipole beam pipe is 55.3 mm. 'Unfortunately' the pipe is curved, leaving for the optical cavities (laser straight) a usable diameter of ~35 mm only, which - for a power buildup of 40000 - would limit the number of HERA dipoles to 2*4.

Therefore we increased the aperture of the beam pipe by **straightening the cold mass** of the magnet in the lateral direction, allowing a setup with **2*10 dipoles**.

Straightening a magnet



Straightening procedure of a HERA dipole

- The HERA dipole cold mass is attached to the external vacuum vessel at 3 different longitudinal positions, two at the extremities and one in the middle.
  For each of the lateral positions (1 and 3 in figure 1), the suspensions of the cold mass are removed and the titanium pressure props are mounted one at a time, to fix the position of the cold mass with respect to the vacuum vessel at the end of the magnet. The transportation fixtures opposite the position of the props prevent the cold mass from moving during the insertion.
- Since the original suspensions (figure 3a) of the cold mass don't allow the installation of the pressure props, they are replaced, one at a time to avoid deformation of the cold mass, with new and modified (figure 3b) suspensions.
- Before any further action, the position of the beam pipe axis is measured by the survey group with an optical tracker and a 'mouse' with a reflector (figure 4).
- A 'pressure screw' (figure 5) is installed at the middle support (pos. 5 in figure 1) and used to deform the cold mass. A few turns of the screw allow a deformation of more than 10 mm.
- The deformation is again measured with the 'mouse' and compared with the original values (figure 7); once the required deformation is reached the pressure screw is replaced with a third pressure prop (figure 6), holding the cold mass in the deformed position, also during cold operation of the dipole.
- Once the straightening is done, the magnet is prepared for cold testing: all openings are closed and the magnet is connected to the test stand, supplying the cryogenic fluids and the current to power the magnet.

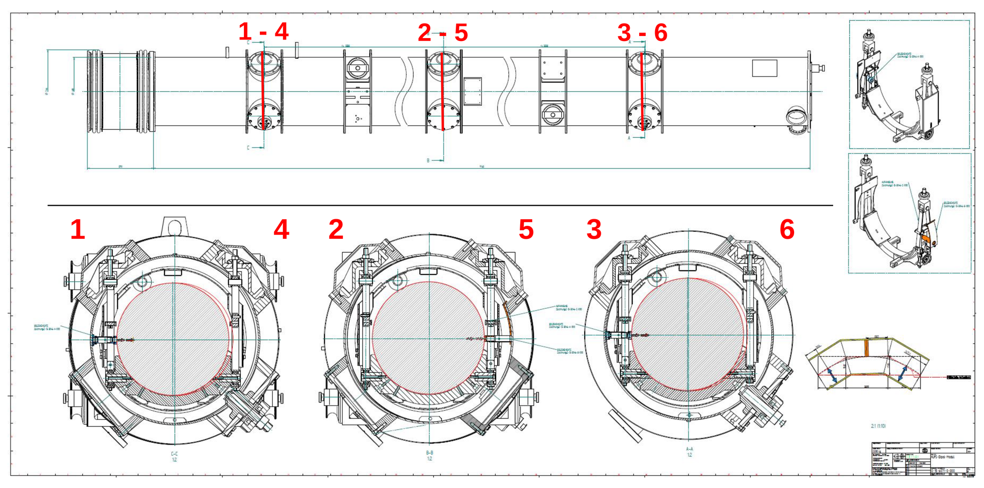


Figure 1: schematic view of a modified HERA dipole

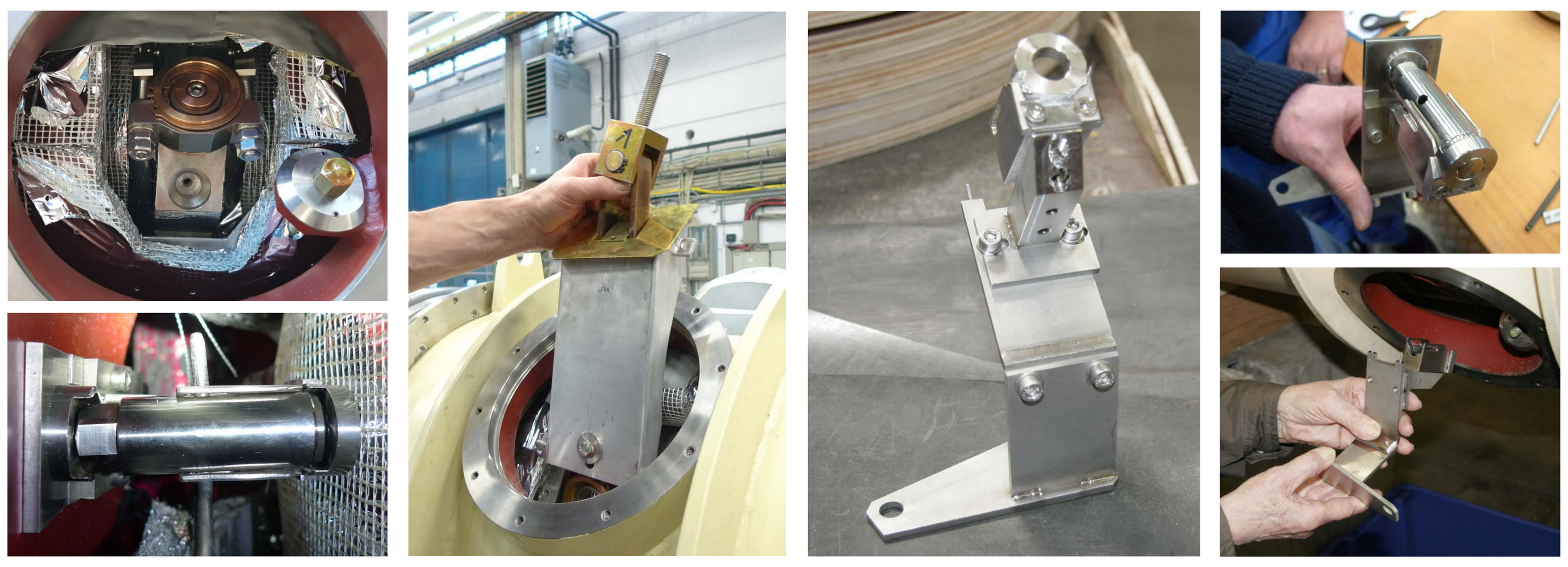


Figure 2: different phases of the pressure prop installation at pos. 1 and 3

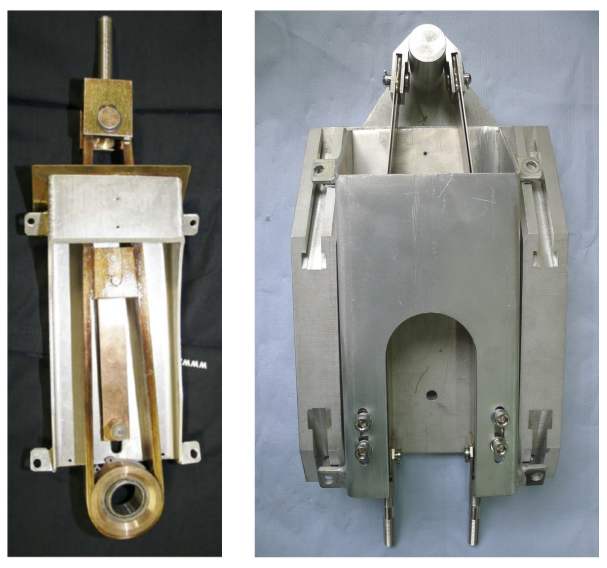


Figure 3: a (left) original suspension, b (right) modified suspension

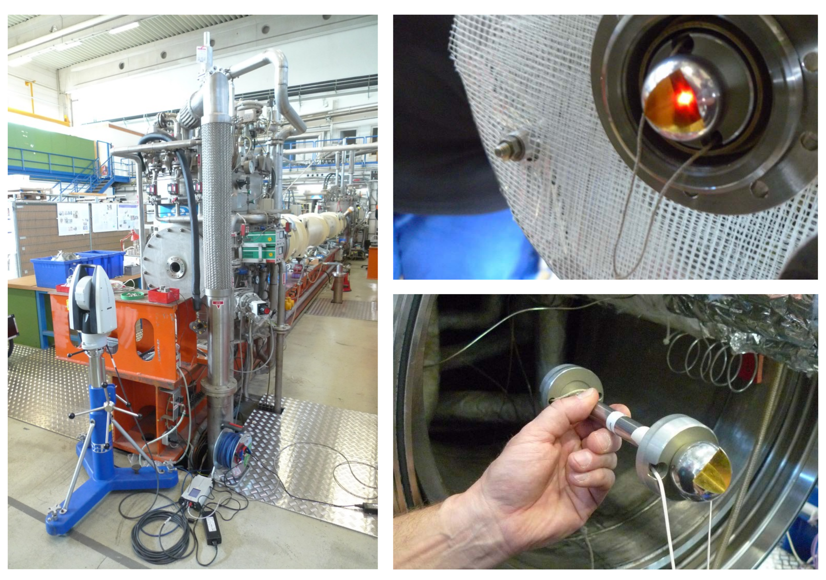


Figure 4: survey of the cold mass position before straightening (left, laser tracker - right, the "mouse")

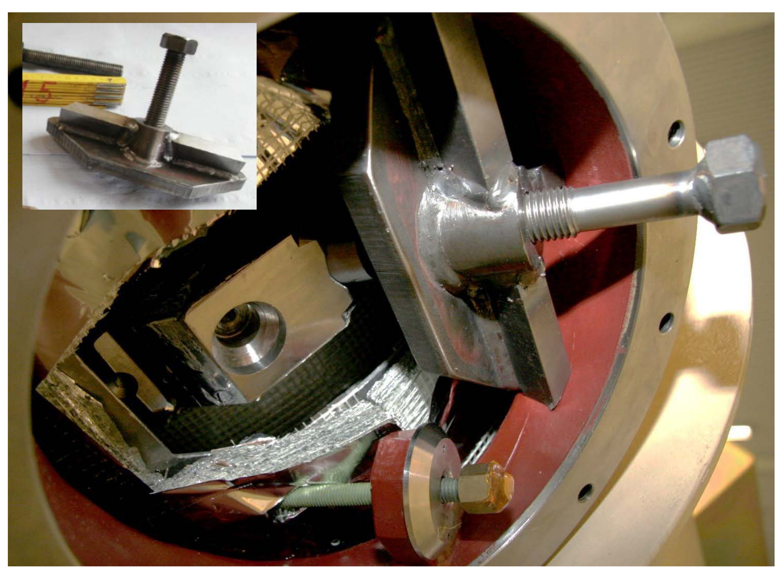


Figure 5: the 'pressure screw' installed at position 5

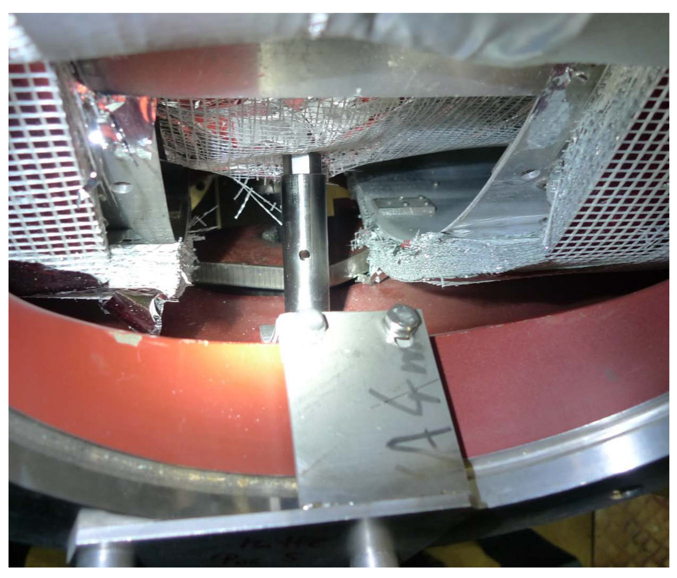


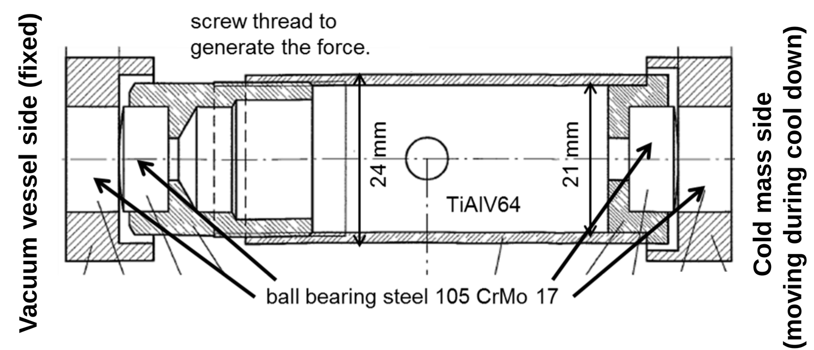
Figure 6: the pressure prop installed at position 5, after straightening

The pressure props

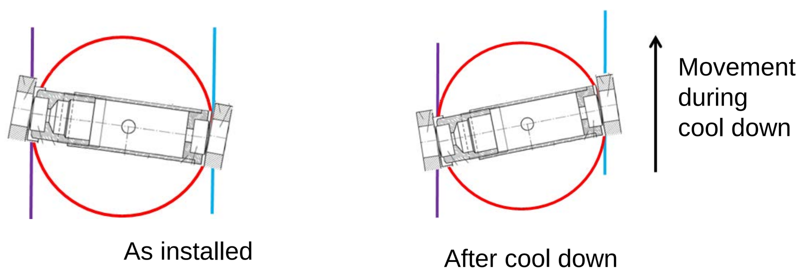
The pressure props are installed during the straightening of the dipole and, since the deformation is elastic, they have to remain in position during the whole experiment, i.e. in cold condition (4K operation of the superconducting magnets).

Therefore the design of the pressure prop has to:

- guarantee **low heat flow to the 4K helium vessel**
- **allow for the length change** of the 'cold' mass during cool down and warm-up



The distance between the warm and cold "wall" (diameter of the red circle below) does not change during cool down (except for a thermal shrinkage of the pressure prop itself):



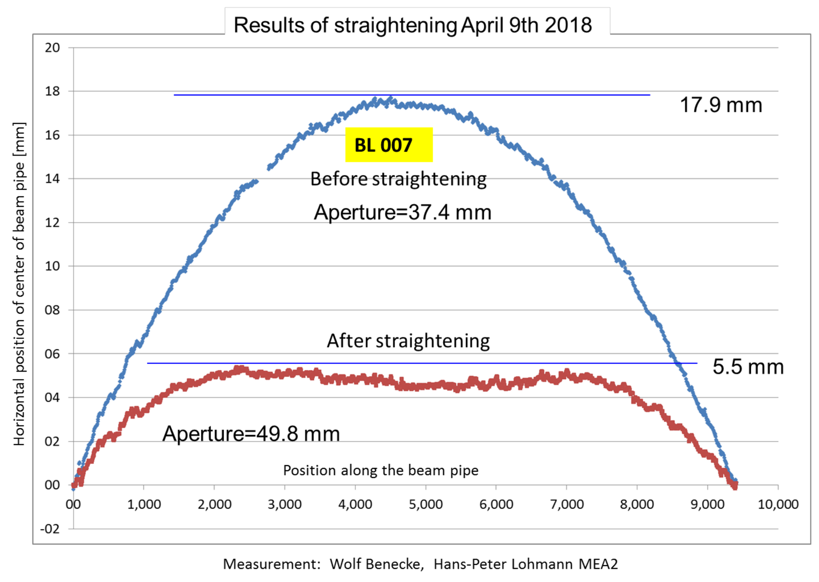
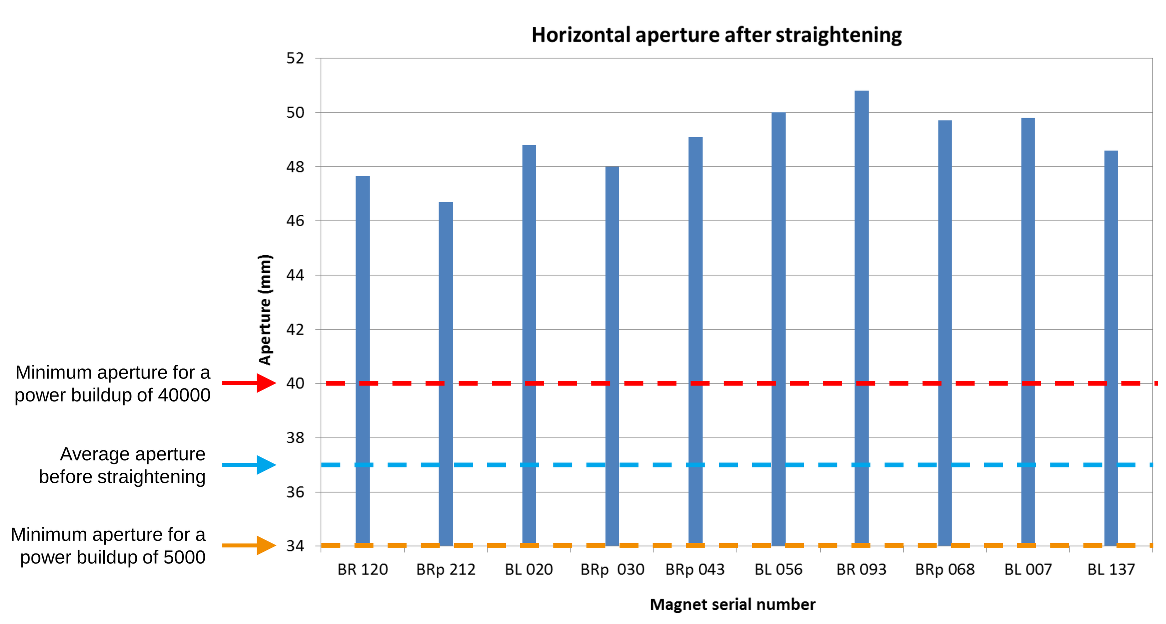


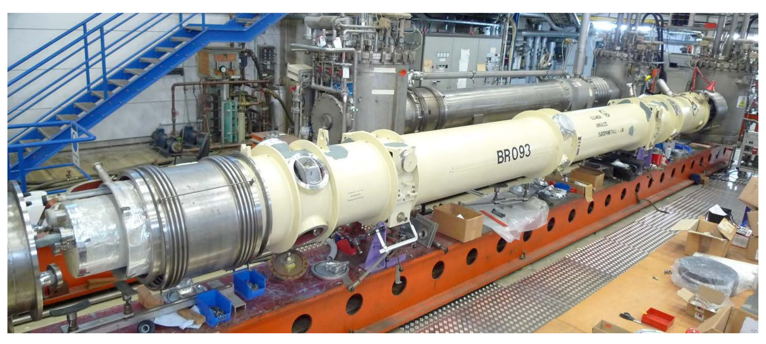
Figure 7: comparison of the beam axis position before and after straightening

Aperture after straightening

Ten magnets (out of twenty) have been straightened and tested until May 2018.



Cold test of the straightened dipoles

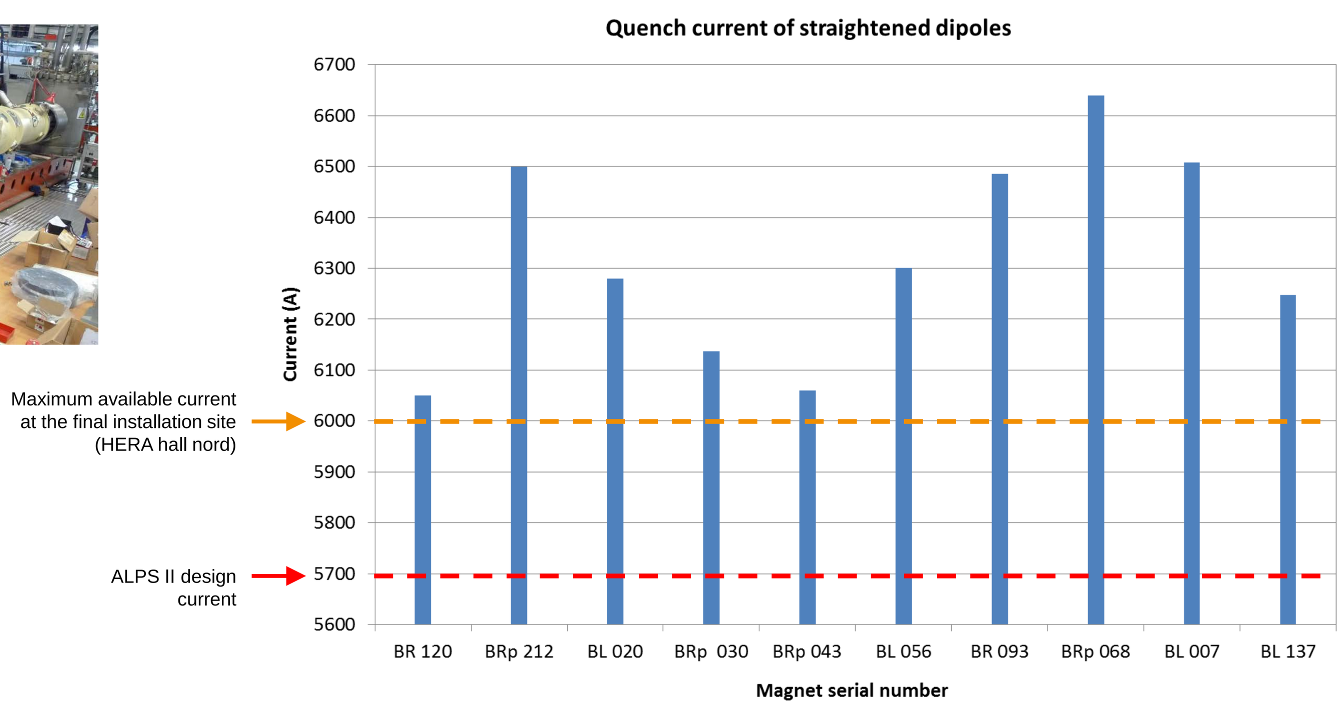


HERA dipole on the magnet test bench

After straightening, **all dipoles are cold tested** to prove that they can reach the ALPS II design current (5700 A).

The test has 2 phases:

- power the dipole up to the quench current
- continuously operate the dipole at 5700 A for at least 8 hours



Electrical connections: J. Eschke, O. Sawlanski, M. Stolper   Test performed by: O. Sawlanski, M. Stolper