The B0 in a nutshell:

Why, when ?

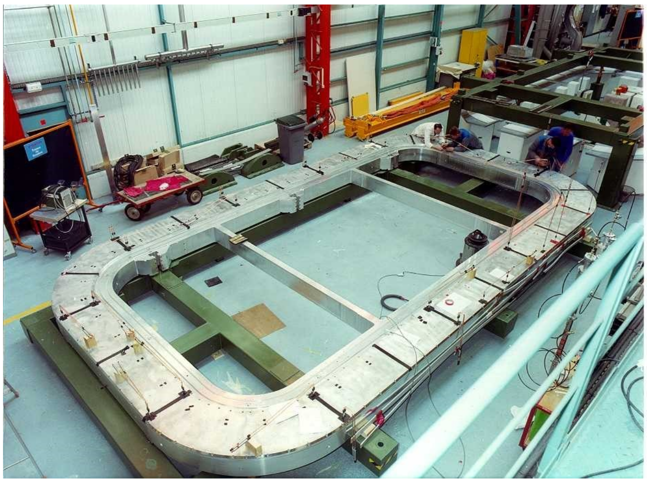
It was around 1995, 1996. The ATLAS technical proposal was published in December 1994 but the Toroid project was not approved yet [the 4 ATLAS magnet system TDR were published in 1997]. The coil conductor properties had been successfully tested: cooling down to 4 K, current ramping up, induced magnetic field. Everything was fine… but on a 1m long setup, which would fit on a table. Would the construction technique proposed be proper for a 25m x 5m magnet ? The magnet team felt that they had to get started, and that the experience gained would speed up ATLAS construction. A special project was created and financially sponsored by CEA, INFN and CERN together, called "the B0". Shorter in length, but fully representative in terms of cross section, it was a "learning on the job" demonstrator, setup to shorten the construction time of the full ATLAS magnet.

For those who saw it arriving at CERN, the B0 was at the same time impressive – by its size and the magnetic filed it created – and very exciting: even if it was "only" a prototype, they were seeing "something concrete of ATLAS". Some of the postdocs involved had only worked on data analysis, and discovered in the testing hall a very peculiar phase of experimental physics: when ideas become prototypes, lessons are learned the hard way, problems are fixed thanks to team spirit and dedicated technical expertise. It made then feel like being students again.

Even if it is now "naked" and the test setup that one can see on the 2001 photos is missing, the B0 remains for the ATLAS community a precious witness of the long, difficult and creative years of the experiment preparation and construction. Having it transported to P1 while the collaboration celebrates its 25th anniversary… and is at the same time busy with the TDR of the detector upgrade… is particularly nice.

Validation of the design, operational margins, and production techniques

A prototype helps to verify magnetic fields calculations, but above all validates the construction process and how the real object behaves.



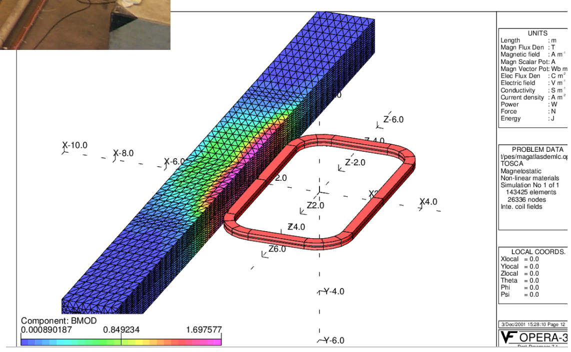
To understand the technical challenge of the time, one needs to know that at ambient temperature the conductor is soft, at least on such a length. Once the 20 kA current circulates, the magnet has a tendency to become a circular shape, movements might create quenches and deformations modify the field map. One of the first objectives of the B0 was thus to test the stability of its “coil box” and “glass blinders” structure, and determine the operational margins. Indeed, the B0 worked without problems with a current of 24 kA, to be compared to the 20.5 kA currently used in ATLAS.

To mimic ATLAS environment: the magnetic mirror

In principle the ATLAS toroid is an air coil, one can predict very precisely the field map. In reality, ATLAS contains stainless steel structures and some iron, which distort the field heavily. A second feature to be studied is the effect of forces induced on each coil by others and detector elements, the tile calorimeter in particular. The resulting force is radial and about 1400 tonnes.

Both effects were accounted for through a metallic wall – called magnetic mirror – build next to the inner side of the B0. 3 “bielettes” in titanium were holding mechanically the (cold) connector and the (warm) mirror, supporting each up to 250 tonnes.

Other unexpected features, like for example the presence of iron in the reinforced concrete of the building floor, had to be understood and accounted for when measuring the field produced by the B0.



Fitting the magnet shape and position

A precise magnetic field map, rapidly and repeatedly accessible by the reconstruction programs, is needed to measure the momentum of muons in ATLAS. Establishing this map requires a precise knowledge of the coils position and deformation… within the cryostats. This is determined by using 1840 sensors, equipped with 3 Hall probes measuring the 3 components of the field. Placed on the MDT chambers or the cryostats, these sensors provide the measurement needed to fit the position of each coil element, and then calculate the magnetic field everywhere in the Muon System, with a precision of 1 mT.

The setup currently used in ATLAS was designed, exercised and validated around the B0. Just like in any prototype development tests proved to be very helpful, as they lead to a dramatic improvement compared to the first version:

- The readout system was redesigned to support the rise of the magnetic field [which was not the case at the very beginning, leading to very… unpleasant days ☹]
- The material used to assemble the probes was completely revisited: the initial glue, for example, was sensitive to humidity and could not guarantee a stable geometry.
- A new calibration setup of the sensors was developed, in order to be able to determine the direction of the magnetic field, when only it absolute value was originally precisely obtained

All together, the field probes and measurement system developed by CERN, Saclay and Nikhef finally worked very well. In 2005 a new and "validation" campaign of the improved setup was proposed, this time on one of the current ATLAS toroid "BT8".

On the B0 the magnet bending due to its weight and length was too small to be measured, but on the final ATLAS coil elements it is measurable – small but measurable – and taken into account. All 8 coils eventually went through the same test.

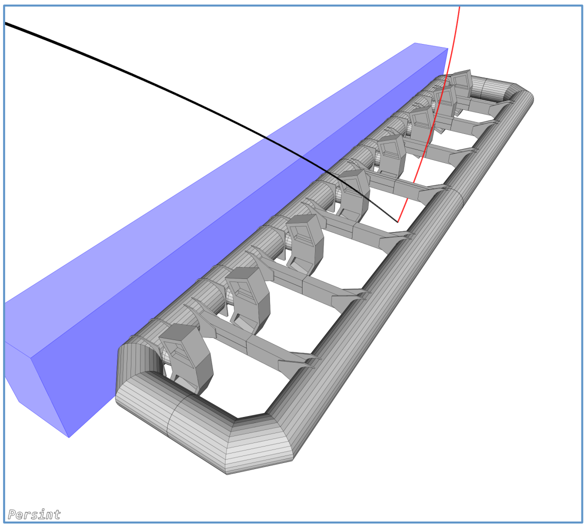
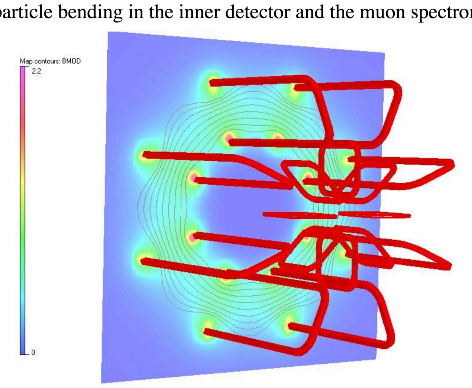


Image caption: trajectory of two muons of opposite charge, and momentum of 3 GeV. The magnetic mirror is drawn in blue.

The magnet system provides an optimised magnetic field configuration for particle bending in the inner detector and the muon spectrometer.



Mapping ATLAS

A complete ATLAS field measurement campaign took place few years later. These in situ measurements were made with a reduced current [8 kA] because working in a magnetic field is not so easy: movements need to be slow – if not they the current induced in the brain makes one feel sick. Safety shoes, which contain metal, make walking difficult. Tools or keys "float", and some mechanical work such as screwing simply cannot be done.

Currently all B-field sensors are operational and a complete cycle of measurements takes place every 30 minutes. They are positioned accurately [< 1mm, 2 mrad] in the locations where the field gradient is maximal, to get the best sensitivity. Readings are compared with field calculations, and used to fit the position and shape of the toroid conductors with respect to the muon chambers.

The field map is refitted about once a year, after each opening of the detector. The position and deformations of the ATLAS coils are known to ~ 1mm. The map also got more and more precise with years, as the knowledge of material in the detector improved.