

CERN Courier Archive: 1971

A LOOK BACK TO CERN COURIER VOL. 11, DECEMBER 1971, COMPILED BY PEGGIE RIMMER

CERN NEWS

Getting colder

[Earlier this year] we reported the bringing into operation of a 45 cm³ polarized proton target working at 0.55 K. It now looks as if the development can be carried further with the testing of a new refrigerator using a 10 cm³ sample, which can be maintained at a temperature of less than 0.05 K. This is a step not only towards higher rates of polarization but also towards “frozen spin” targets, which could allow particles emerging from collisions to be detected over almost 4 π solid angle.

The refrigerator, built by T O Niinikoski

of the Technical University of Helsinki in collaboration with the CERN Polarized Targets Group, is based on the principle of He³/He⁴ dilution. The use of high-speed pumps (250 m³/h) give a cooling power that is the greatest ever reached for such low temperatures, making it possible to maintain the sample at 0.03 K under normal operating conditions and to sustain temperatures as low as 0.022 K.

The final aim is to perfect 15 cm long targets for the large aperture magnet in the East Hall or the Omega spectrometer. To derive the maximum amount of information from these spectrometers it is desirable to analyse particles leaving the target at any angle. With targets built so far,

very homogeneous and intense magnetic fields were necessary, with poles close to the target, reducing the solid angle for observations.

The lower the temperature, the longer the relaxation time for the polarized protons to revert to a completely disorientated state. At very low temperatures, the inertia of spins is such that prolonged polarization can be maintained even if the magnetic field ceases to have the homogeneity and intensity necessary for creating the effect. This is a “frozen spin” target. It is hoped that, in Omega’s 1.5 T field, the target will be able to maintain its polarization for several days at a temperature of 0.06 K.

● Compiled from texts on p353.

BATAVIA

15-foot chamber

The major bubble-chamber facility at the National Accelerator Laboratory, a 15-foot chamber, is at an advanced stage of construction in the Neutrino Laboratory at the 200/500 GeV accelerator.

Initially it had been hoped to build a 25-foot chamber but, with no sign of money to construct a chamber of this size, the scale was trimmed down to a 15-foot version. An important factor has been the readiness of the NAL Group under W Fowler to bring in extensive help. Thus the chamber design incorporates ideas from Argonne on the magnet, Stanford on the expansion system, Brookhaven on the vessels, and CERN on the optics, piston and seal.

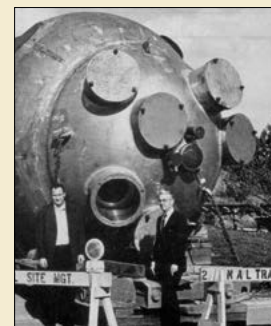
The volume of liquid is 30,000 litres, contained in an almost spherical vessel with a length along the beam direction of 15 foot. It is designed to operate with hydrogen, deuterium, neon or mixtures. The superconducting magnet will provide a field of 3 T at the centre of the chamber.

The expansion system will operate about once per second, giving the possibility of four expansions per accelerator cycle. The profligate use of six cameras, located at the top of the chamber in two triangular arrays, enables hadron pictures to be taken while neutrino experiments are running. Thus the neutrino beam to the chamber might absorb 70% of the beam early in the flat top, leaving the opportunity for a burst of charged particles at the end.

The project began in summer 1970. Since early this year, the globe of the 7 m diameter vacuum vessel has been a prominent feature



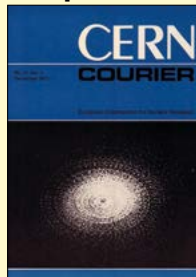
of the NAL site. On 25 October the chamber body arrived at the laboratory, and was installed in its final position in the vacuum tank on 30 November. It is hoped that the first cool-down will take place in July 1972, and that the chamber will be ready for experiments by the beginning of 1973.



Left: Aerial view of the neutrino laboratory at NAL. On the right is the globe shape of the bubble-chamber vacuum vessel. Right: Arrival of the chamber body, looking at the top where the six camera ports are located.

● Compiled from texts on pp358–359.

Compiler's Note



Absolute zero, 0 K, thought of as the lowest temperature possible, is taken as –273.15°C. The LHC cryogenic system, the largest in the world, gets to within 1.9 K, making it one of the coldest places on Earth, colder than outer space at 2.7 K. Recently, a cubic metre of copper weighing 400 kg was cooled to 0.006 K (6 mK) for the CUORE experiment in Gran Sasso (see p5 this issue). The lowest temperature ever recorded, 0.000000001 K (100 pK) was reached at the Helsinki University of Technology Low Temperature Lab by nuclear magnetic ordering – bbbrrrrrr!

Those venerable bubble chambers surely had charisma, resembling iconic submersibles such as the Bathysphere of William Beebe and Otis Barton, who descended to a record-breaking 920 m in 1934, and the Deepsea Challenger of film director James Cameron, who, in 2012, hit the bottom of the Mariana Trench, the oceans’ deepest point, where the temperature is a comfortable 1 to 4°C but the pressure is 1000 times the value at sea level, 11 km above.

New heights in magnetic field measurement

Today's "gold standard" for magnetometers, based on Nuclear Magnetic Resonance (NMR), was conceived at the CERN in the late 1970's. Now an all-new NMR magnetometer promises a breakthrough in high precision magnetic field measurement.

A 35-year old design goes into retirement

CERN's 1970's-era design for an NMR magnetometer turned out to be a huge hit in the (admittedly minuscule) world of high precision magnetic field measurement. Originally conceived for one of the muon g-2 experiments, and perfected by the Geneva-based company Metrolab, it has established itself as the unrivaled magnetic-field reference for standards and research laboratories. It has also become an essential production tool for, for example, MRI system manufacturers. A derivative of the original design is still being sold today, as the Metrolab Precision Teslometer PT2025.

But now its designated successor, the PT2026, is in the starting blocks. This flexible and modern laboratory instrument promises to improve all key performance specifications of NMR magnetometers, by roughly an order of magnitude.

Pushing back the limitations of NMR magnetometers

The foremost improvement concerns the measurement range. NMR magnetometers actually measure the NMR resonant frequency of a sample, directly proportional to the surrounding magnetic flux density. The PT2026 measures up to 1 GHz; for hydrogen nuclei, this corresponds to over 23 T, whereas the PT2025's limit was 2.1 T. The primary beneficiaries are manufacturers of ultra high-field superconducting magnets. The PT2026 also improves the measurement resolution. Today's systems use the Continuous-Wave (CW) technique to detect the NMR resonance: sweep the RF frequency (or equivalently, modulate the field) and detect the absorption peak. The PT2026 also supports the Pulsed-Wave (PW) technique: excite the sample with a broadband pulse and detect the re-emitted frequency. The PW technique is more direct, and, combined with low noise and advanced signal processing, results in < 1 Hz resolution in stable, homogeneous fields – nearly one part per billion for strong fields! This allows, for example, magnet manufacturers to measure the field decay rate of new superconducting magnets more quickly, providing a clear productivity gain.



If appropriate, this resolution can be traded off against speed, by reducing the measurement integration time. Measurement rates of up to 20 Hz, instead of 1 Hz, now allow capturing short-lived transients.

Another key limitation of NMR magnetometers is sensitivity to inhomogeneous fields, which cause a spread of resonant frequencies and make the resonance harder to measure. Side-by-side comparisons show that the PT2026 is 2.5x more tolerant than the PT2025, thus making NMR magnetometers suitable for many new real-world applications.

The NMR sample size – on the order of millimeters – limits their use in very small gaps. CW probes also contain modulation coils and electronics close to the sample, which aggravates the situation. PW probes feature a much simpler, smaller probe head that can be several meters removed from the electronics. This is also useful in hostile environments, such as high radiation or low temperatures, which would cause the electronics to fail.

Ease of use through systems improvements

In addition to pushing back physical limits, a modernized and improved system design improves the ease of use. A frustrating aspect of using an NMR magnetometer is that before starting to measure, the instrument has to painstakingly sweep through its entire frequency range to seek out the NMR resonant frequency. This process typically takes ten seconds – and may never terminate if something is wrong. The PT2026 dramatically reduces the time

required, using a built-in 3-axis Hall sensor that reduces the search range by two orders of magnitude.

A feature of the original CERN design is the close coupling of the RF generator with the probes. Feedback loops keep the RF generator tuned to the NMR resonance detected by the probe, and each step of a frequency divider corresponds to a probe with a different range. In the PT2026, the RF generator is freely programmable and decoupled from the probes, thus allowing customized probe ranges.

Other examples of the many systems-level improvements include modern interface standards, full software support, input and output triggers, and the possibility of eliminating the need for calibration by using an external reference clock.

Wanted: challenging applications

The PT2026 is a breakthrough in precision magnetic field measurement. Metrolab is especially excited to present this instrument to the high energy physics community, where it has its roots and where it will certainly find some of its most challenging and innovative uses.

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