Research Matters SPRING 2003 Sc

# ORPHEUS – Cryogenic System for Dark Matter Search at the University of Bern

**The Laboratory for High Energy Physics, University of Bern, Switzerland has developed "Orpheus" an innovative detector system for dark matter research.**

The mystery of dark matter started in 1933 when Swiss astronomer Fritz Zwicky concluded that most matter in galactic clusters is invisible. Evidence suggests that much of the matter in the universe is nonluminous and nonbaryonic but its precise nature is unknown. One possibility is the family of heavier neutral particles known as WIMPs (Weakly Interacting Massive Particles). These may be detected by the nuclear recoil energy of a particle interaction with a nucleus of the detector material measured as a small rise in temperature, electric charge liberation or photon emission. To observe WIMPs the detector must register energies of one keV and below.

Cryogenic detectors are promising WIMP detectors. At temperatures near absolute zero the heat capacity is small, and tiny nuclear recoil energies can produce a measurable signal. The Orpheus system is based on the phase transition of a type I superconducting single granule from the metastable superheated state to the normal conducting state. Interaction of a particle within a granule can induce a phase transition that can be detected with a pickup coil. The signal is proportional to the granule volume and applied magnetic field. The detector threshold is given by the minimum deposited energy needed to raise the granule temperature from the operating to the phase transition temperature. A threshold of below 1 keV is possible.

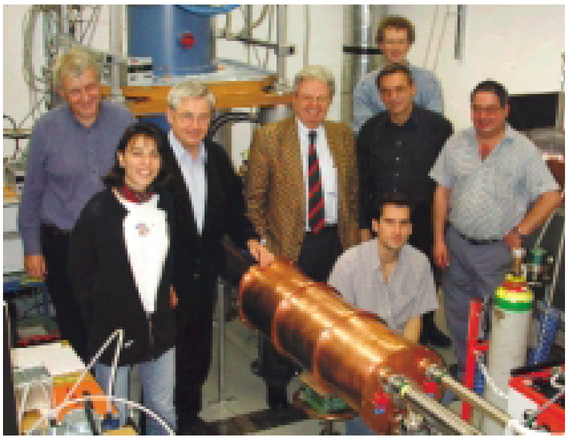

*Figure 1. The copper cold box connected to the Oxford Instruments dilution refrigerator Kelvinox-300.*

For dark matter research Orpheus must be shielded from background cosmic and local radiation, it is, therefore, sited underground (hence the name Orpheus) and the detector chamber installed in a cold box separate from the dilution cryostat. Active shielding is provided by 2 cm thick plastic scintilators. There is also a passive shield of 15 cm lead, 4 cm oxygen free copper, and 18 cm boron-doped (5%) polyethylene (Figure 1). The detector chamber and cold box copper thermal shields (2.6 K, 4 K, 80 K) have been constructed using low radioactivity materials. Inside the 54 x 12 cm detector chamber there are 56 signal coils each with 1500 windings of 60 μm diameter high purity copper wire, and filled with 8g of tin granules. The detector consists of around four billion small superconducting tin granules (448g of 28 and 46 μm diameter) embedded in teflon powder with a volume filling factor of 10 % (Figure 2).

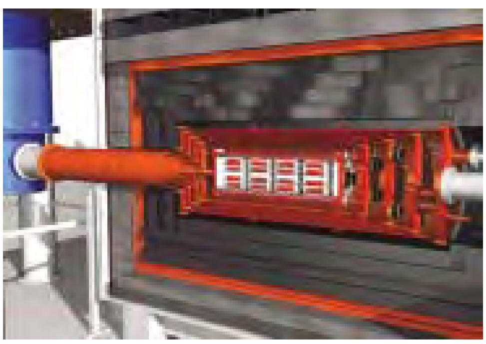

*Figure 2. Schematic illustration of the detector chamber with signal coils, thermal shields, side access and the passive radioactive shield.*

It is operated in the superheated superconducting state at 170 mK in an applied 28.5 mT magnetic field. Because of the limiting height of the underground laboratory (3.2 m) the thermal extension contacts from the dilution cryostat to the cold box are horizontal. Cooling of the dilution refrigerator (Oxford Instruments Kelvinox-300) had to be transferred through a 1.7 m copper rod with flexible connection to the mixing chamber. The thermal shields, connecting the dilution cryostat and side access, were also connected flexibly to compensate for thermal contractions. A 4 K connection must be vacuum tight to separate the outer and inner vacuum spaces. This was achieved using 28 membrane pairs of stainless steel bellow, which compensate for about 5 mm of vertical contraction.

Prototype cooling experiments showed that heat conduction via copper alone is insufficient. Additional liquid nitrogen and helium cooling systems were developed using a continuous flow cryostat mode and a liquid bath. These used vacuum isolated transfer lines with needle valves and a membrane GF3 gas flow pump (for liquid helium) with an Oxford Instruments gas flow controller to regulate flow through heat exchangers soldered directly to the thermal shields at 4 K and 80 K. Temperature stability was better than 10 mK. A Kelvinox IGH gas handling system and ITC[503] temperature controller were also used for monitoring the dilution refrigerator. Main operation parameters are displayed in real time on the Internet.

Orpheus operated continuously at 170 mK for two months. Results were presented at the 4th International Workshop on the Identification of Dark Matter, York, September 2002. The next run will start probably in Spring 2003.

*Contact: **Dr. Stefan Janos**, Laboratory for High Energy Physics, University of Bern, Switzerland, stefan.janos@lhep.unibe.ch*