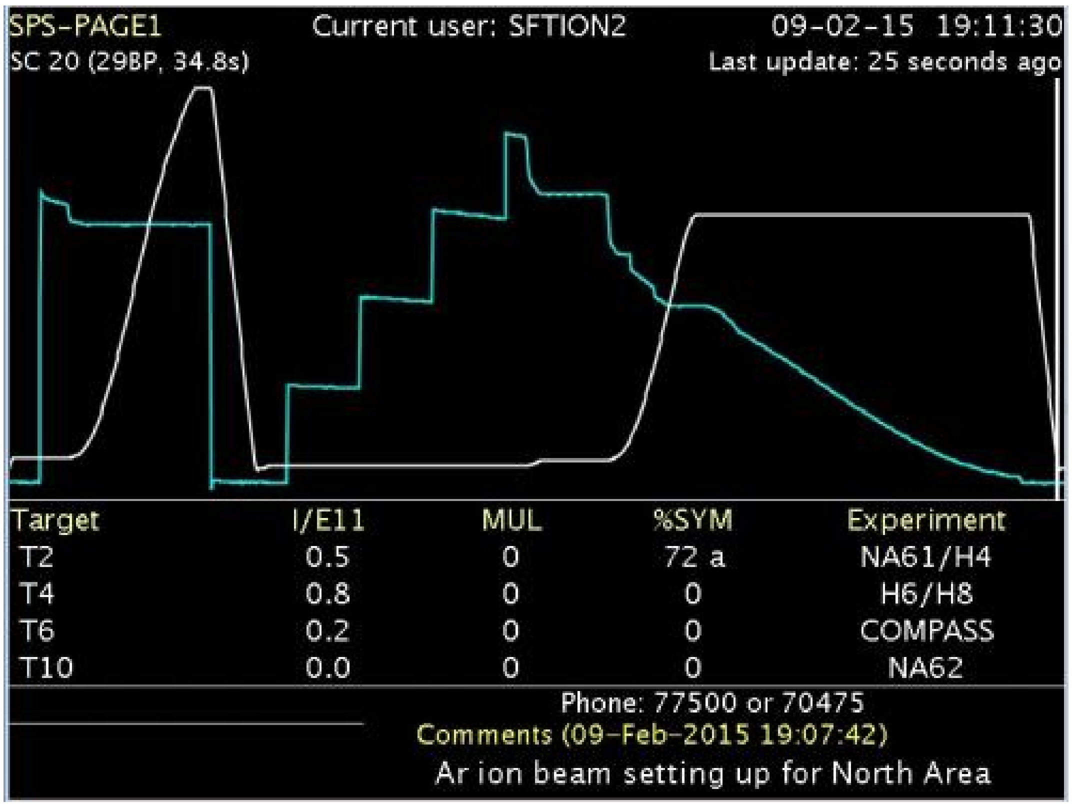
Accelerating argon

February 16 2015



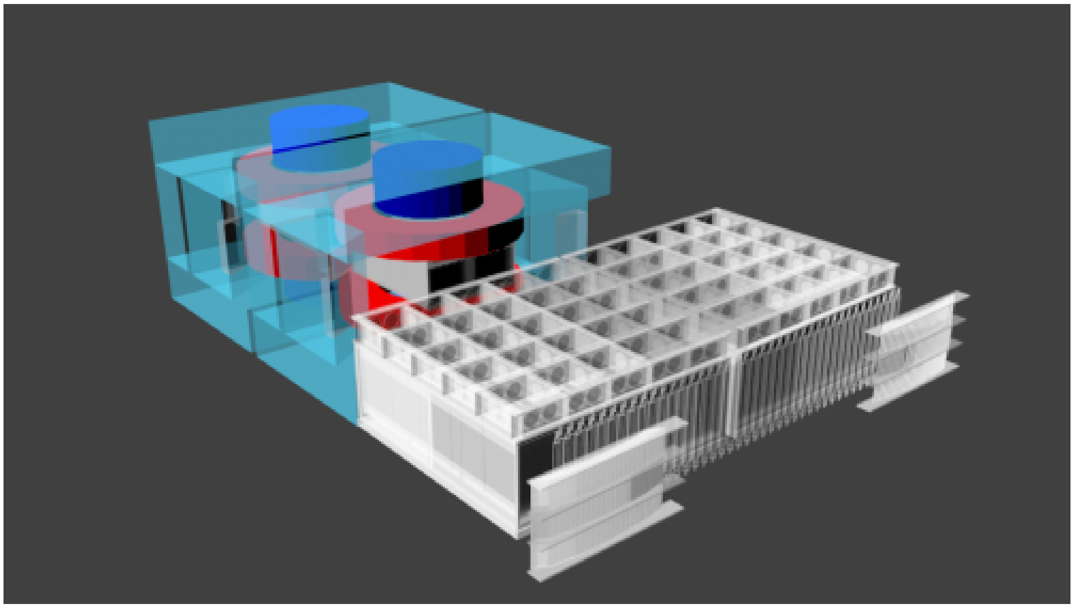
Picture 1: a "super-cycle" of the SPS, featuring a proton cycle for the LHC, followed by an argon ion cycle for the North Area.

Over the past few days, the SPS has been accelerating argon ions, which have started to be sent to the NA61/SHINE experiment. This operating mode, using a new type of ion, required a number of modifications to the accelerator.

Today, the accelerators are once again juggling particles and even performing completely new tricks. The SPS is supplying beams of argon ions for the first time, at energies never before achieved for this type of beam. They are destined for the NA61/SHINE experiment (see box) located in the North Area, which began receiving the beams on 11 February.

Argon ions have a relatively large mass, as they consist of 40 nucleons, so they can be used in a similar way to lead ions. The main difficulty in accelerating them lies in the SPS, where the variation in acceleration frequency is limited. "The SPS was designed for accelerating protons," explains Django Manglunki, who is responsible for the project, "but argon ions are injected at a relatively slow speed compared to protons, and their revolution frequency during acceleration varies considerably. It's beyond the usual operating range of the machine." The radiofrequency specialists must therefore use the acceleration method known as "fixed frequency", which resynchronises the phasing during acceleration, as in the case of lead ions.

Another difficulty arises from the range of energies required by the experiment: beams of six different momenta, between 13 and 150 GeV/c per nucleon, will be produced over the course of eight weeks in 2015. So as not to monopolise the SPS during argon operation, the argon beams will alternate with beams of protons being sent to the LHC. A "super-cycle" of the SPS will therefore include both proton and argon cycles (see picture 1). This double operation required the installation of a safety system to ensure that proton beams cannot accidentally be sent to the North Area.

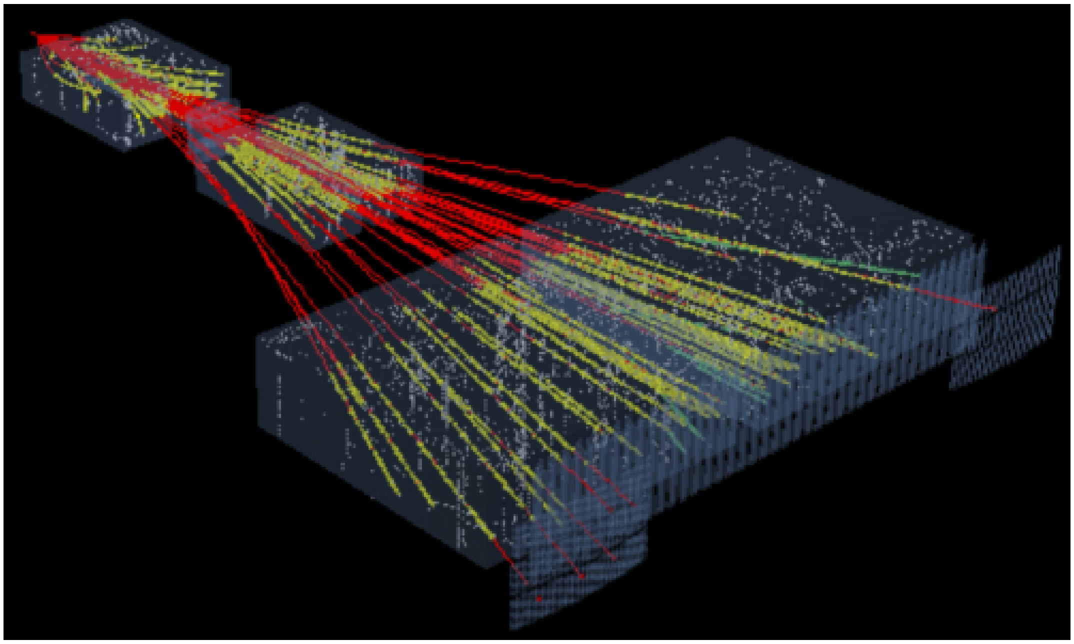


Picture 2: mock-up of the NA61/SHINE detector.

Operation with argon ions was originally proposed six years ago, and the accelerator teams have been planning for it for the past two years. In 2013, the source, the radio-frequency quadrupole and Linac 3 were commissioned using argon. Over the past year, as the LS1 work on them was completed, LEIR, the PS and the SPS received their first ions. "We restarted LEIR with a new power supply control system and a new type of ion all at once," explains Django.

The start-up of the SPS with argon ions at the end of January was a new challenge as the machine's components are more difficult to adjust with low intensity beams of this kind. Nevertheless, after just two weeks of warming up, the accelerator had already extracted ions at three different energies.

CERN's accelerators occasionally juggle particles other than protons. Aside from lead ions, the complex has also accelerated electrons, positrons, antiprotons, deuterons and α particles, as well as oxygen, sulphur and indium ions. The teams are already preparing for operation with other types of ions, lead and xenon, which will also be used by NA61/SHINE and other experiments in the North Area.



On Thursday, 12 February, the NA61/SHINE team recorded the first collisions of argon ions with a momentum of 150 GeV/c per nucleon with scandium nuclei. This picture shows one of these events as reconstructed by the NA61/SHINE team.

Exploring the phase transitions of hadronic matter

NA61/SHINE is part of a series of experiments using heavy ions that began in the late 1980s at the SPS, continuing at the RHIC collider at Brookhaven and then at the LHC. By studying heavy ion collisions, these experiments are exploring the phenomenon of "deconfinement", whereby quarks, bound by strong interaction, are subjected to very high energies and are set free for a fleeting period of time. They have gathered evidence of the existence of quark-gluon plasma, a state that is thought to have existed at the very beginning of the Universe and in which quarks moved around freely, unconfined by the strong force in protons and neutrons. NA61/SHINE is the direct successor of one of these experiments, NA49.

NA61/SHINE is concerned with the phase transition to quark-gluon plasma. We know that the properties of the transition between liquid water and water vapour vary with temperature and pressure. In the same way, the properties of the transition between the confined state of hadrons (where quarks are bound in hadrons) and quark-gluon plasma should change with temperature and the density of the baryons. Physicists can play with these two parameters by varying the type of nuclei and the energy of the collision.

More specifically, NA61/SHINE is interested in the "deconfinement" point, a collision energy threshold above which the creation of quark-gluon plasma would be possible. The experiment is also searching for a hypothetical critical point, beyond which the two phases would transform between each other seamlessly. "The theory of strong interactions, quantum chromodynamics, does not predict the values for phase changes and the critical point precisely," explains Marek Gazdzicki, spokesperson for NA61/SHINE. "Their discovery by an experiment would therefore be of huge importance."

NA61/SHINE is thus systematically testing many collision energies using ions of different masses. This research complements work at the LHC, where collisions at much higher energies are being studied. Between 2009 and 2013, NA61/SHINE studied proton-proton, then beryllium-beryllium interactions. "We're pinning a lot of hope on the collision of argon ions, as they are much lighter than lead ions and should allow us to find the infamous critical point. That would be a huge leap forward in our knowledge of the properties of matter subjected to the strong interaction," explains Marek, who can hardly wait for the first data.

Last update! On Thursday, 12 February, the NA61/SHINE team recorded the first collisions of argon ions with a momentum of 150 GeV/c per nucleon with scandium nuclei. This picture shows one of these events as reconstructed by the NA61/SHINE team.

Provided by CERN