

Pumping ion

Earlier this year, Linac 1 at CERN's Proton Synchrotron was moved back 12 metres to allow improved shielding. This way installation work for the new heavy ion injection system could proceed in parallel with normal PS working.

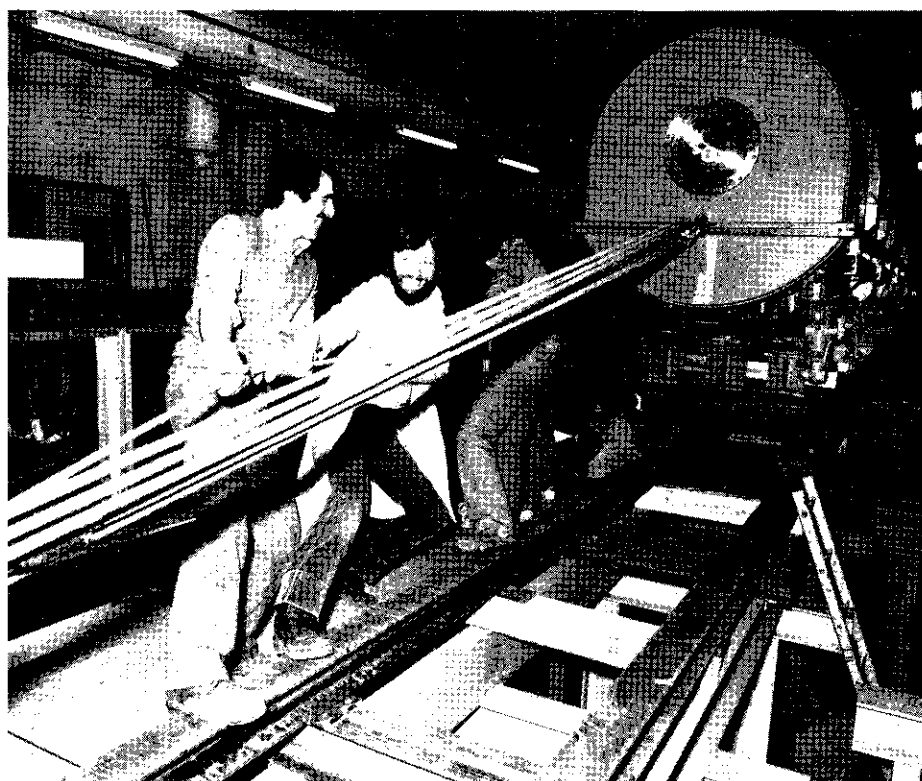
(Photo CERN 370.1.85)

In 1982 a Darmstadt (GSI)/Berkeley/Heidelberg/Warsaw team proposed that oxygen ions be accelerated in the CERN 'Proton' Synchrotron in order to be able to study collisions between nuclei at energies higher than were available at the heavy ion machines at Darmstadt (the UNILAC linear accelerator) or Berkeley (the Bevalac synchrotron). Since the proposing Laboratories were able to do much of the work and provide much of the financing for the injection system for oxygen ion acceleration, the proposal was accepted despite the crowded CERN programme and the necessary development work began in a Berkeley/CERN/Darmstadt collaboration.

Interest in using the ions, both from the PS and from the SPS, has escalated to give an ambitious experimental programme (described below). Major items of equipment are coming together at CERN, and first tests with the ion beams are scheduled when the CERN machines come back on the air at the beginning of 1986.

An important element in the decision to pursue ion beams was the existence of Linac 1 (the 'old' linac) still linked to the PS Booster. This linac had already been used in the acceleration of deuterons and alpha particles and there was thus already experience of coping with particles other than protons. The trick for the ions is to increase the accelerating (and focusing) fields so that the ions travel down the linac at exactly half the velocity of the usual protons. That way the ions stay in step with the accelerating fields in the drift tube gaps.

Knowledge of the sparking limits in the first tank of the linac dictates the permissible field levels



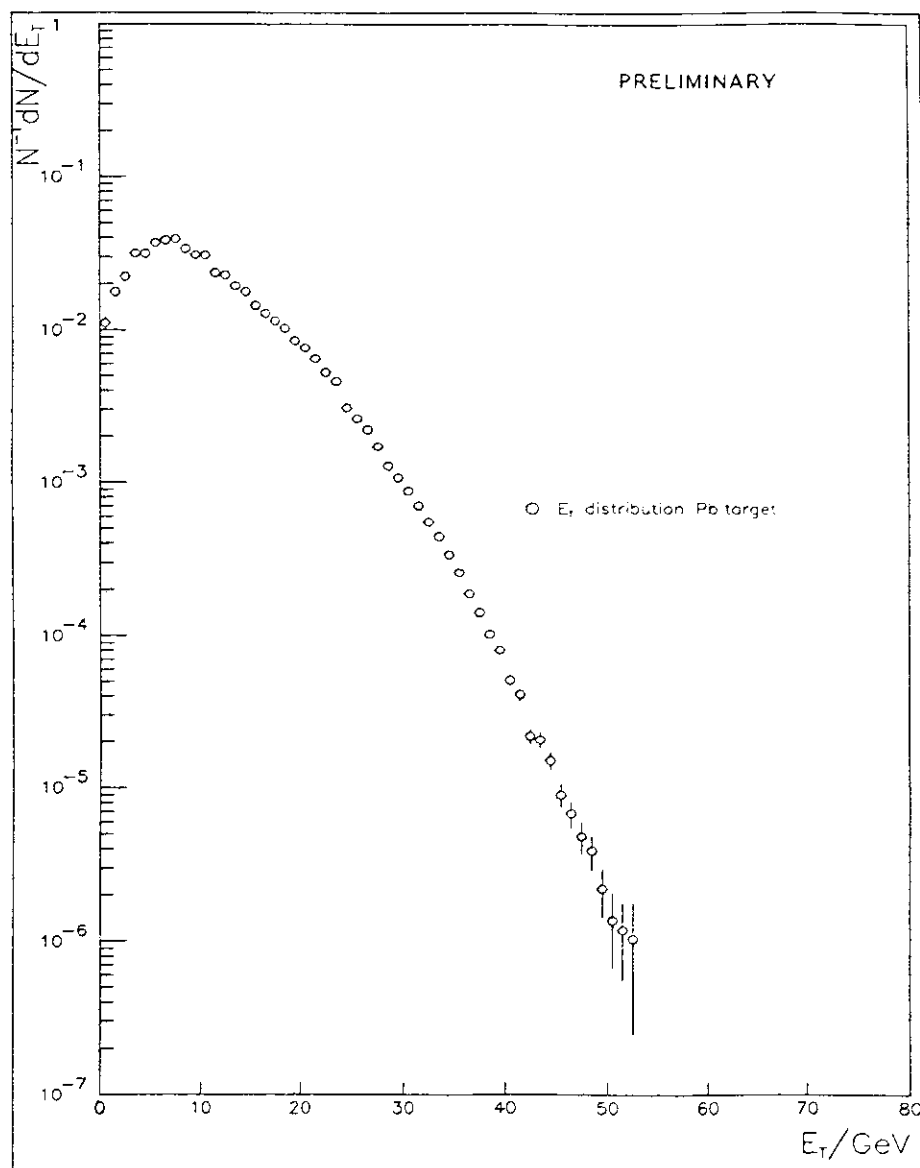
which in turn imply a charge to mass ratio for the ion species of at least 0.38. A further limitation is that the beam diagnostics throughout the PS complex need a minimum beam current of about 10 microamps from the linac in order to pick up adequate signals.

These two constraints led naturally to the selection of oxygen $6+$ ions (oxygen atoms stripped of six electrons). They have a charge to mass ratio at the limit of what is acceptable and adequate ion current can be drawn from an ECR (Electron Cyclotron Resonance) source. An additional requirement is that the ions be injected into the first tank at about 140 keV per nucleon; this can be provided by a radiofrequency quadrupole. These conditions defined the major features of the injection system to accelerate oxygen $6+$ ions to an energy of 12.5 MeV per nucleon.

The ECR source has been developed at CEN Grenoble and over a year ago achieved an over 80 microamp ion beam of the required quality. It was taken to GSI in May of this year where it was joined by a radiofrequency quadrupole (RFQ) from Berkeley. The RFQ, which is designed to take the oxygen $6+$ ions from 5.6 keV to 140 keV per nucleon, follows the design of the heavy ion RFQ installed and successfully operating on the Bevalac. Preceding the decision to use this was the successful experience with the RFQ built at CERN which demonstrated that the necessary matching of the particle beam bunches to the accelerating field 'buckets' in the first tank of the linac could be successfully accomplished.

The ECR source, a low energy beam transport system and the Berkeley RFQ achieved 140 keV

Transverse energy distribution observed in 200 GeV proton collisions in a lead target at CERN, extending far beyond the proton-nucleon kinematical limit near 20 GeV. This intriguing result for wide angle scattering promises well for studies with heavy ion beams.



per nucleon ions with a current of up to 80 microamps in recent tests at Darmstadt. All these units are now being transferred to CERN for installation at Linac 1. This machine will then have two pre-injectors, each with an RFQ. The linac has already been moved back from its initial position for improved shielding. Without this the necessary work on the ion sys-

tems could not go on while the PS was being run for protons and antiprotons.

Although the losses of ions, due to charge stripping in encounters with molecules of residual gas, are tolerable in the single passage of the beam down the linac, it is necessary to convert to fully stripped oxygen 16 before injection into the PS Booster where the ions need to

live for many turns. Also the Booster r.f. system needs to perform some gymnastics to cope with ions having only half the velocity of the usual protons. A 'harmonic jump', where the beam is debunched and then reformed at half the initial r.f. frequency, is applied. (This is done in the Booster so as not to add yet another manoeuvre to the already complex programme of the r.f. system in the PS ring.)

The Linac, Booster and PS beam diagnostics have been upgraded to cope with the low beam intensities and so has the SPS. A variety of considerations (avoiding transition energy, intensity problems, beamline parameters) mean that the lowest beam energy from the SPS will be 40 GeV per nucleon but rising from there to an energy of 225 GeV per nucleon, so that the emerging ions can have energies up to 3600 GeV (3.6 TeV)!

Experiments

Experiments with ion beams and with particle beams hitting nuclear targets are already hinting strongly at new physics. As well as the realization that under certain conditions nuclei can be viewed as assemblies of quarks and gluons (see page 423), heavy ion experiments have also revealed other new aspects of the behaviour of nuclear matter, providing new ideas for astrophysics (see July/August 1984 issue, page 243).

There is also a strong conviction that once ion beams exceed some threshold energy, crashing them into laboratory targets could finally produce the long-awaited quark-gluon plasma – a new type of matter with properties very dif-

ferent to ordinary nuclear material.

When the first plans to use heavy ion beams in the CERN high energy machines were put forward (see July/August 1983 issue, page 223), the idea was that the collisions would be monitored in the West Experimental Area of the SPS using a streamer chamber and the 'Plastic Ball/Plastic Wall' detector used in lower energy heavy ion beams at the Berkeley Bevalac.

Since then interest has grown considerably. Even with the big North Experimental Area of the SPS housing most of the experiments, there were more potential customers than CERN's restricted facilities could handle.

The Plastic Ball study, still for the West Area, now involves a Berkeley/Darmstadt (GSI)/Lund/Marburg/Munster/Oak Ridge/Warsaw group. The 820-module Plastic Ball scintillator identifies reaction products by energy loss. Downstream calorimetry and a multiplicity detector complete the apparatus.

The streamer chamber experiment proposed with the Plastic Ball has migrated to the North Area and involves a collaboration of Athens/Bari/CERN/Cracow/Darmstadt/Frankfurt/Freiburg/Heidelberg/Berkeley/Marburg/Texas A and M/Warsaw/Zagreb. The equipment, including the streamer chamber, comes from a previous North Area experiment which finished taking data in 1980.

Finding evidence for quark-gluon plasma is the goal of Athens/Bergen/Berkeley/Birmingham/Brookhaven/Carnegie Mellon/CERN/Chandigarh/City College, New York/Cracow/Madrid/Santiago/Strasbourg/Vienna group which will look explicitly for the

production of (anti)baryons carrying the strangeness quantum number. Formation of quark-gluon plasma is expected to result in an increase of secondary strange particles. A powerful superconducting magnet will disperse the intense sprays of secondaries, while a Time Projection Chamber will look for heavy particle decays. The calorimeter from the old European Hybrid Spectrometer completes the setup.

The other North Area heavy ion studies are offshoots from large experiments originally built for use with particle beams. A Brookhaven/CERN/Heidelberg/Los Alamos/Lund/McGill/Montreal/Moscow/Novosibirsk/Pittsburgh/Saclay/Stockholm/Tel Aviv group has modified a big experiment originally proposed to study lepton production by particle beams (see September 1984 issue, page 281).

For ion beams, the apparatus will include additional large angle spectrometry and soft photon detection. Multiple target arrays with suitable spacing will be used to minimize secondary interactions and optimize triggering rates. Already initial tests with proton beams have shown intriguing effects producing very high (50 GeV) transverse energies far beyond the allowed kinematics of proton-proton interactions. This promises well for the heavy ion beams.

Another modification of an existing experiment is by a Bergen/CERN/Clermont Ferrand/Lisbon/Lyon/Neuchâtel/Orsay/Palaiseau/Strasbourg/Valencia collaboration using apparatus built to investigate the production of muon pairs by particle beams (see April issue, page 104). For heavy ion work, the apparatus will be supplemented by beam counters, calorimetry,

and special targets.

In addition to the large electronic detectors, several studies using emulsions are planned, with participating institutions from Europe, North America, India and Egypt.

First heavy-ion beams are scheduled for next September, with a sizeable run just before the 1986 end-of-year shutdown. These experiments promise relatively rapid results, and already some two hundred physicists are involved.

Inevitably the physicists are already thinking of ions beyond oxygen since heavier nuclear masses could give additional information. A beam of sulphur ions of much lower intensity is possible from the source and could be squeezed through the linac and Booster together with the oxygen beam without too much difficulty, although passing through the transition energy will be problematic in both the PS and SPS. Exotic ideas are therefore being generated about accelerating oxygen and sulphur, tuning the machines on the oxygen, and calculating from that to the appropriate settings for the sulphur. But all that is some way into the future, there is already plenty to keep the ion enthusiasts busy.