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REMARKS ON THE POSSIBLE USE OF THE SPS FOR ^{16}O ION BEAMS

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1) In its meetings on 16 February and 20 April, 1982, the PSCC discussed the proposal P53 for the study of relativistic nucleus - nucleus reactions induced by ^{16}O beams of 9-13 GeV per nucleon from the PS. In this connection, it has been proposed also to consider the possible use of the SPS as an intermediate stage between the PS and the experiment so that the latter could be installed in the West Area rather than in the East Hall.

In the mean time the lower energy limit of interest has been decreased to 7 GeV per nucleon. This note therefore examines the feasibility of the use of the SPS for an ^{16}O ions beam with energies of 7 GeV per nucleon and higher.

2) Most beam parameters are not known at present, but the following assumptions are made for our considerations;

i) The slow extracted ^{16}O beam must have a spill structure acceptable for counter experiments

ii) The ^{16}O ions will be fully ionized, i.e they will have a charge to mass ratio of 0.5 compared to that of the proton.

iii) The beam intensity will be 2 10^8 ions per pulse at injection into the SPS, i.e. 1.6 10^9 charges per pulse

iv) The beam will be accelerated in the PS to a momentum equivalent to that of 14 GeV/c protons for magnetic and electrostatic deflections. This corresponds to an energy per nucleon of 7 GeV, i.e. $\gamma = 7.5$

v) The horizontal and vertical transverse beam emittances after extraction from the PS will be 1Π mm mrad. The momentum spread of the beam will be:

$$\Delta p/p = \pm 10^3.$$

3) The beam extracted from the PS in SS16 will be transfered via TT10, injected into the SPS in LSS1 and extracted from LSS6 for transfer via TT60 toward the West Hall. The extraction channel and the TT60 transfer line form the acceptance limitation which horizontally and vertically is about 1 Π mm mrad.

4) The existing hardware for extraction from SS16 in the PS and for injection in LSS1 from the SPS restrict the possible modes of beam transfer. At the side of the PS no hardware exists for slow extraction in SS16 and only fast extraction up to 26 GeV/c or multi-turn extraction up to 14 GeV/c are possible. The SPS inflector in LSS1 has a maximum pulse duration of 12 μ s and can inject a beam of up to 26 GeV/c. However the injection of a one turn fast extracted beam from the PS is not attractive, as it fills only 1/11 of the SPS circumference with a correspondingly bad duty cycle for a slow extracted beam from the SPS. This leaves as only possibility the injection of a beam extracted from the PS over 5 turns at an equivalent momentum of 14 Gev/c.

5) Once a 14 GeV/c beam is circulating in the SPS with the rf system kept off and with a momentum spread $\Delta p/p = \pm 10^{-3}$, it can be resonant extracted from the SPS at that momentum. The servo control of the beam spill for a total extracted intensity of 1.6 10^9 charges per pulse needs a special detector to measure the extraction rate of the ions.

6) The influence of the PS bunch structure on the duty cycle of the slow spill from the SPS will be negligible as a result of debunching. On the other hand, even a 5-turn extraction from the PS fills only 5/11 of the SPS circumference. The remaining hole in the circulating beam will not fill up due to debunching and this will reduce correspondingly the duty cycle of the spill. This high frequency structure determines an upper limit of the duty cycle of 45 %. A duty cycle of 30 % or less is however more realistic, since there will be a considerable low frequency structure for the following reason: The tolerances of the current ripple in the main SPS quadrupoles and in the extraction magnets, particularly the extraction sextupoles, have been defined for a minimum momentum of 100 GeV/c. At 14 GeV/c the larger relative ripple will therefore lead to an important spill modulation.

For dedicated ^{16}O operation of the PS and the SPS, which would be at least unavoidable for the latter, double batch injection will not improve the time average of the duty cycle. Double batch injection might further be hampered by control limitations due to the low intensity. For the same reason spill durations longer than about 2 seconds cannot be considered at the present stage.

7) The observations of the closed orbit and therefore also its correction for a "continuous" and low intensity beam in the SPS is a problem. The available hardware requires minimum intensities of 10^{11} charges/pulse for electrostatic pick-ups as well as a 200 MHz rf structure on the circulating beam.

The closed orbit observation and correction must therefore be made from time to time with a proton beam of the same momentum and the PS must be able to switch from an ^{16}O beam to a proton beam and vice-versa without much effort and time delay. These considerations are also valid for the beam steering in the TT10 and TT60 transfer lines as well as for the setting-up of extraction..

On the other hand, it should be possible with a beam current transformer to measure beam intensities down to 10^9 charges per pulse.

8) It has been verified that the transfer of an extracted ^{16}O beam at an equivalent momentum of 14 GeV/c along the external proton beam line and the secundary beam line H3 in TT60 is possible without important modifications to the existing hardware.

In the region of the target station T1 in TCC6 and its downstream TAX collimator, the ion beam must pass through some thin vacuum windows and about 15 m of air. The resulting multiple scattering, even at 14 GeV/c, is acceptable. The importance of the loss rate of the beam through nuclear interactions is still under study.

9) If an ion beam with an equivalent momentum of 14 GeV/c can be injected and made to circulate in the SPS, it should also be possible to capture such a beam by the SPS rf system and accelerate it to any energy of up to 200 or 225 GeV per nucleon.

The difference in speed at 14 GeV/c between ^{16}O ions and protons corresponds to an rf frequency difference $\Delta f/f = 0.6\%$ which is outside the bandwidth of the 200 MHz cavities of the PS. A bunch to bucket transfer to the SPS is therefore excluded and the beam must be trapped adiabatically by the SPS rf system.

The frequency swing required for the acceleration of the ^{16}O ions after their injection at 14 GeV/c is too large for the usual acceleration at variable frequency in the SPS. Instead, one should accelerate at fixed rf frequency and with a variable harmonic number. This is considered feasible, but will require machine development time.

10) The present radial loop which controls the rf frequency in order to keep the beam on a constant orbit uses a pick-up with a minimum sensivity of 10^{10} charges per pulse. It will therefore be necessary to reach a sensivity that is higher by an order of magnitude which may be possible. Alternatively, the beam could be accelerated according to a frequency program, but this may make it more difficult to pass transition.

11) When the ion beam is captured at 14 GeV/c by the SPS rf system, its momentum spread is expected to increase by at most a factor 2. This should not unduly hamper resonant extraction of the ions from the SPS. Although the beam can be accelerated to any energy up to 225 GeV per nucleon, there is however an energy region around transition (γ_t =23.2) where the momentum spread is too large for resonant extraction. The span of this energy region will depend on the longitudinal emittance of the beam and can only be accurately defined experimentally. Nevertheless, we are confident that resonant extraction will be possible between equivalent momenta of 14 to 26 GeV/c (7 to 13 GeV per nucleon) and above 100 GeV/c (50 GeV per nucleon).

12) The considerations given above tend to show the feasibility of the use of the SPS for ^{16}O ions as proposed in point 1. It should then also be possible to envisage its use for ion beams with equivalent momenta in the range of 100 to 450 GeV/c.

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