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CONSIDERATIONS ON PROVIDING ^{16}O ION BEAMS TO THE SPS EXPERIMENTAL AREAS

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CONTENTS

Page :

1. INTRODUCTION

This report is written with the aim of providing updated information on the possibilities and limitations of the future operation of the SPS and its experimental areas with ^{16}O ions. It further discusses the different options for the installation of the proposed experiments in the experimental areas.

2. ACCELERATOR ASPECTS

2.1 Injection

Fully ionized ^{2}H, ^{4}He and ^{16}O ions have a ratio of $Z/A = 0.5$. This offers the possibility of using ^{2}H or ^{4}He beams for a major part of the development and for the setting-up of the accelerators, to avoid problems due to the limited intensity of the ^{16}O beam. Furthermore, for relativistic beams of any of these ions, the energy per nucleon is only one half of the energy of a proton with the same magnetic rigidity $B\rho$. Any of these ions can therefore be accelerated in the SPS to a maximum energy of 225 GeV per nucleon, i.e. equivalent to 450 GeV protons.

The ^{16}O ions delivered by the source will be successively accelerated by an RFQ linac, the Linac I, the Booster (PSB) and the PS. The intensity available at the source is a determining parameter for this mode of operation. The minimum intensity which is needed for reliable operation is determined by the SPS because of its 11 times larger circumference as compared to that of the PS.

The RF beam control of the SPS requires a minimum intensity at injection of 2×10^{8} ions per batch, i.e. 1.6×10^{9} charges per batch from the PS. The present radial loop, which controls the RF frequency to keep the beam on the central orbit, uses a pick-up with a sensitivity of 10^{10} charges per batch. It is, however, considered possible to develop electronics for a sensitivity down to 10^{9} charges per batch. This latter intensity should also be sufficient for closed orbit observation with the new electronics for the electrostatic pick-ups of the SPS which is being installed for $e^{\pm}$ operation.

In conjunction with the PS Division, it has been decided to transfer 2 batches of fast extracted ^{16}O ions from the PS to the SPS at an energy of 10 GeV per nucleon, i.e. equivalent to 20 GeV protons, for the following reasons:

i) 10 GeV per nucleon is the maximum energy which permits a 1.2 s duration for the PS cycle.

ii) It is the minimum energy compatible with the bandwidth of the travelling wave structure of the SPS cavities without change of harmonic number during the SPS cycle.

iii) It is also the minimum energy compatible with the bandwidth of the 200 MHz cavities in the PS, which have been installed to enable a proton beam to be prebunched at 200 MHz prior to the bunch-into-bucket transfer to the SPS. This latter mode of transfer is also desirable for the ^{16}O ions and a 200 MHz modulation of the beam is necessary for closed orbit observation in the SPS.

iv) A high transfer energy reduces the transverse emittances at injection into the SPS.

The lower velocity of the ions as compared to protons of the same equivalent momentum at extraction from the PSB and the maximum pulse duration of the fast pulsed kicker magnets for extraction from and recombination at the PSB as well as injection into the PS will distribute the beam in the latter over 15 bunches instead of the 20 bunches for protons. After acceleration and fast extraction, 2 batches of ^{16}O ions will be injected at opposite points of the circumference of the SPS. The beam will be redistributed around the circumference through debunching during 1.1 s, twice the time constant for this process, whereafter it will be recaptured by the RF system. It will then be possible to accelerate the ion beam to any energy up to 225 GeV per nucleon.

The alternative method of 2 batch transfer with 5-turn extraction from the PS which would fill 10/11 of the circumference of the SPS has been discarded because of the following drawbacks:

i) The existing hardware at the PS only permits 5-turn extraction up to 7 GeV per nucleon.

ii) The PS has no beam instrumentation for the surveillance of the 5-turn extraction at the low intensity of the ^{16}O beam.

iii) It is not possible to set up 5-turn extraction for ^{16}O with a ^{2}H or ^{4}He beam due to the sensitivity of this process with regard to the transverse beam emittances.

2.2 SPS Cycles

Although it is in principle possible to operate the SPS with short cycles for supplying low energy ^{16}O beam, the shortest cycle duration is in practice determined by the running time of the scheduled programs in the computer control system of the SPS. The cycle durations will therefore be in the range of 9.6 s to 14.4 s, as for fixed target operation with protons and depending on the required beam energy on the flat top. Typical flat top lengths may range from 4.9 s for 50 GeV per nucleon to 2.8 s for 225 GeV per nucleon. As from 1988, it will be possible to operate the SPS with ^{16}O cycles, or proton cycles, interleaved with $e^{\pm}$ cycles.

2.3 Extraction

For extraction of ^{16}O ions at high momentum, 225 GeV/c per nucleon, the properties of the extracted beam are expected to be very similar to those of the proton beam which is at present extracted for fixed target physics. The effective spill time should, in particular, be about 70 % of the flat top duration, provided that debunching and recapture at injection lead to a sufficiently uniform ion distribution along the SPS circumference and that a detector of adequate sensitivity for low intensities is built for the closed loop servo control of the extraction process. As an illustration a typical spill of 450 GeV/c protons is shown in Fig. 1.

If the momentum of the ^{16}O ions at extraction is decreased, the low-frequency structure of the spill will become more pronounced for two reasons. Firstly, there will be a tendency to increase the flat top duration and therefore to slow down the rate of change of the horizontal betatron tune, Q, which controls the spill-out of the particles. Ripple on the magnetic fields, particularly on the main quadrupoles, will then cause a more important modulation of the rate of change of Q. Secondly, this ripple which is about constant in absolute terms, becomes relatively stronger at lower currents in the magnets. During the SPS construction, ripple tolerances were specified for a lowest proton momentum at extraction of 100 GeV/c. With these tolerances the spill modulation at low frequencies will reach 100 % for a ^{16}O spill of some 5 sec duration at 50 GeV/c per nucleon.

At very low momentum, 10 GeV/c per nucleon, the ^{16}O extraction differs strongly from present proton extraction in several respects :

i) The circulating beam emittances are of the order of 4π mm.mrad and 2π mm.mrad in the horizontal and vertical planes respectively, compared to about 0.1π mm.mrad for proton extraction at 450 GeV/c.

ii) The fields and currents in the extraction elements, in particular the horizontal and vertical orbit dipoles, become very low, descending below 20 Gauss and 1 A in certain magnets.

iii) The aforementioned relative ripple on the magnetic fields becomes very important.

As far as the circulating beam emittances are concerned it has been computed that a horizontal emittance of 4π mm.mrad can still be safely extracted. The extraction process reduces the horizontal emittance to about 1 - 1.5π mm.mrad since the particles of a given momentum are peeled off successively according to the amplitudes of their betatron oscillation. Vertically, the emittance which can be extracted is limited to about 1π mm.mrad by the aperture of the SPS extractor magnet, the last element of the extraction channel. Vertical scraping of the beam prior to extraction, either in the CPS or in the SPS, is therefore required.

In order to study the problems connected with the low fields and currents in the orbit dipoles and with the magnetic field ripple, a machine development session was devoted to proton extraction at 20 GeV/c which corresponds to 10 GeV/c per nucleon in the case of ^{16}O ions. The results of this machine experiment can be summarized as follows :

i) In spite of the low field and current levels the precision and stability of the orbit dipoles remain perfectly adequate.

ii) The ripple on the magnetic fields, in particular on the main quadrupoles, leads to a very ragged spill-out as shown in the upper photograph of Fig. 2.

The only possibility to improve this spill structure with present SPS hardware consists in an excitation of the beam with stochastic RF noise. This leads to a diffusion of the particles towards and across the stability limit rather than purely transporting them into resonance by a conventional variation of their tune.

The lower photograph of Fig. 2. shows how the low frequency structure of the spill was reduced by applying RF noise during the machine experiment with 20 GeV/c protons. This spill structure would at present have to be expected for an ^{16}O extraction of 5 sec duration at 10 GeV/c per nucleon. More theoretical and experimental studies are needed in order to investigate whether any further improvement of the spill-out is possible.

The beam emittances of the extracted ^{16}O beam at lowest momentum will be of the order of $1 - 1.5\pi$ mm.mrad in both planes.

With the described limitations of the spill quality ^{16}O ions can be extracted in the whole range from 10 to 225 GeV/c per nucleon except for a small interval around transition stretching from about 20 to 25 GeV/c per nucleon. Simultaneous shared extraction for the West and North Area is possible at any of these momenta, except for the restriction that the large 25 kA power supply for the extractor magnet in LSS2 would have to be modified for operation at lower than 40 GeV/c per nucleon.

3. TRANSPORT VIA THE PRIMARY BEAM LINES TO THE WEST AND NORTH AREAS

3.1 Power supplies

For the transfer of ^{16}O beams via the primary beam lines to the West and the North Area, there are no significant problems due to the power supplies at beam momenta $\geq$ 40 GeV/c per nucleon.

The transfer of ions with less than 40 GeV per nucleon to the North Area would require considerable modifications to the power supplies of the TT20 primary beam line and to those of the secondary beam lines. Upgrading of 53 power supplies for TT20 would take 3 man-years of work by SPS staff and would cost about 1000 kFr.. The changes to be made on power supplies of the secondary beam lines would take 1 man-year of effort, but involves no significant investment.

The situation is entirely different for low energy ion transfer to the West Area, via TT60, as most of its power supplies have already been modified for antiproton transfer at 26 GeV/c from the PS to the SPS. Also the power supplies of the secondary beams in the West Area are already adapted for low energies.

3.2. Beam observation

Instrumentation along the beam transfer lines is needed for beam steering, emittance measurements and for the control of the servo-spill. Most of the detectors currently used for the primary proton beam transfer lines of the SPS are based on the phenomena of secondary emission. They use aluminium or titanium foils with a thickness of 25 µm. The ratio :

$$\tau = \frac{\text{number of secondary electrons}}{\text{number of incident particles}}$$

is of the order of 5 % for protons with an energy of more than one GeV.

The following three types of secondary emission monitors (S.E.M.) are regularly used :

i) BSI.

These are used for intensity measurements and also as a reference for the control of the servo-spill. These foils cover the whole useful aperture of the beam line.

ii) BSP.

These are used for beam steering and consist of pairs of half-moon-shaped foils.

iii) BSG.

These are used for profile and therefore emittance measurements and consist of a comb of 16 equally-spaced strips.

The signal at the outputs of the BSP and BSG are integrated over periods which are multiples of 20 msec (1/50 Hz), digitized and treated by a computer or a microprocessor. Their present electronics is located in auxiliary buildings which are, on average, 400 m from the monitors. The environment-induced noise signals on the cables, when integrated over 20 msec, are equivalent to 3-4 10^8 charges passing through the foil.

In order to keep the minimum ratio signal/noise to about 3, with the present electronics, the least significant bit (LSB) corresponds to 10^9 charges.

It is now possible to derive the minimum intensity, for different types of measurements, of a beam with a transverse Gaussian distribution :

$$N(x) = N_0 \frac{1}{\sigma\sqrt{2\Pi}} \exp\left(-\frac{x^2}{2\sigma^2}\right)$$

where N_0 is the total number of particles.

i) When using a BSP, for beam steering, N_0 must be at least 25 × 1 LSB = 2.5 10^{10} charges per 20 ms to detect a displacement by 0.1 σ of the centre of the charge distribution.

ii) When using a BSG, for profile measurements, N_0 must be at least 100 × 1 LSB = 10^{11} charges per 20 ms to measure 1 bit at the 2 σ foil.

According to the present literature, for high energy particles the secondary emission coefficient should be proportionnal to Z^2. Therefore it can be stated that for SEM : 10^8 oxygen $^{16}O^{8+}$ ions correspond to $8^2.10^8 = 6.4.10^9$ protons. This shows that the present SEM electronics does not permit a useable detection of the ^{16}O beam.

Dedicated electronics must therefore be designed, constructed and tested. It will be located near the detectors in the tunnel, to avoid the noise of the cables. It will consist of an integrating amplifier and will therefore cope with beams of duration less than 20 msec. The digitisation will also be done in the tunnel. It is expected to improve the sensitivity by a factor of 50 such that 1 LSB = 2.10^7 protons. As a consequence :

i) This electronics can be used for the beam to be injected into the SPS.

ii) An exceptional slow extraction, lasting only 20 ms, has been successfully tried at the SPS. This could be used to set up the extracted beams and transfer lines using the SEM monitors with the new electronics and to check the steering and emittance if required. However, during the normal slow extraction of several seconds, it would not be possible to monitor the beam between the extraction point and the normal target areas.

iii) This electronics must be mounted and dismounted before and after ^{16}O runs, to avoid radiation damage by high intensity protons.

The corresponding new software must also be implemented. A gain control will be provided in the case of beams, such as deuterons, with 10^{11} to 10^{12} particles.

Independently of the new electronics and of the 20 msec extraction, beam intensity measurement for the control of the servo-spill must be made. We will consider the case of 2.10^8 oxygen ions extracted over 5 secs. The average current at the BSI output is then :

$$I = \frac{2.10^8 Z^2 \tau e}{5} = 2.10^{-11}\ A.$$

An efficient servo-spill needs an input voltage of about 1 volt. Therefore the current-to-voltage converter would have to use an operational amplifier with a feed-back resistance of $5.10^{10}\Omega$. Apart from the resistor noise and the amplifier offset, the output signal would have a bandwidth of a few Hertz which makes this type of detector of no use. Therefore studies are underway directed towards the use of scintillation counters downstream of the BSI. Also in this case the scintillator, light guides and photomultipliers will have to be dismounted during high intensity proton runs. Depending on the type of detector chosen the present servo-spill will have to be modified.

As a conclusion, a new SEM electronics and a new intensity monitor must be developed. Tests have to be made during 1985 with low intensity ($\simeq 10^9$) proton beams and if possible with ions.

4. INTERACTIONS OF ^{16}O IONS WITH MATTER

4.1. General comments

A nucleus-nucleus collision can, to some extent, be considered as the sum of several nucleon-nucleon collisions, at the same momentum per nucleon. In the case of ^{16}O, the total inelastic cross-section is about three times larger than for protons, and the average multiplicity of secondaries is ~ 5-10 times larger. This could require, for some experiments, additional transverse shielding in beam lines.

In section 4.2., we discuss the phenomenology of nuclear fragments, and in section 4.3. the related implications for beam lines.

In section 4.4., we give some numbers related to the effect of a Beryllium (Be) filter to attenuate alpha (α) and deuteron (d) beams when these are required by experiments.

4.2. Phenomenology of nuclear fragmentation

In nuclear collisions, it is very unusual that all nucleons of the incident nucleus (or the target nucleus) take part in an interaction. Non-interacting nucleons, or spectators, are usually bound together (nuclear fragments) and keep the velocity of the parent beam or target nucleus. Target fragments do not contaminate beams, as they are emitted nearly at rest in the LAB frame.

Beam fragments, however, if emitted at rest in the beam rest frame, are Lorentz boosted in the LAB frame to have a momentum

$$q_{/\!/} = \gamma m_F$$

m_F being the fragment mass, or

$$p_{/\!/} = \gamma m_{proton}$$

which, when expressed in momentum/nucleon, is numerically equal to the beam momentum/nucleon

Nucleons have a Fermi-motion in the parent nucleus which can be characterised by a Gaussian distribution with rms. value of $\sigma = 100\text{–}200$ MeV/c$^{1)}$. The nuclear fragments will therefore have some global Fermi-motion in the nucleus rest frame and this will give a momentum spread when Lorentz-boosted into the LAB frame (for beam fragments) of the value :

$$\frac{\sigma(p)}{P_o} = \frac{\sigma(q^*_{/\!/})}{m_F}$$

and which, for an ^{16}O beam, varies from 6 % for a deuteron (d) to 1 % for a ^{14}N fragment.

The Fermi-motion perpendicular to the ^{16}O beam will also cause an angular spreading of beam fragments of $\sim 10^{-4}$ rad at 225 GeV per nucleon.

4.3. Cross-sections and contamination

The integrated cross-sections for the fragments production are given in Table 1$^{2)}$. The phenomenology of fragment production and the measurements done in the GeV range indicate that production cross-sections are essentially energy independent. In the table, for simplicity, the dominant fragments, d and α, are grouped together as one entry and the other entry is the sum of all other fragments with $Z/A = 1/2$. The cross-sections are summed over the fragments combined together in a considered group.

The amount of unavoidable material in the beam lines is $\sim 2\ g/cm^2$ of ^{12}C equivalent (i.e. about 7 % of an interaction length) located mainly in the upstream part of the secondary beam lines. The resulting contamination can be calculated from the cross-sections given.

The splitters are another source of background due to the interactions of the beam with the splitter septum magnets. Estimations for contamination from this source are also given in Table 1.

This splitter component was estimated using nearly 0° fragment production ($\sigma(\theta) \simeq 2.10^{-4}$ rad around 0°). Parent ^{16}O hitting the iron far from the beam should never scatter back into the vacuum. Successive collisions with additive angles of production for daughter fragments can be approximated by a fast converging geometrical series and the process can be seen as coming from a skin effect, the skin depth being $S \simeq \lambda.\sigma(\theta) = 2.10^{-2}$ mm, where λ is the interaction length of ^{16}O (or d or α) in iron.

If the beam and the splitters are vertically not perfectly aligned, forming an angle δ, then S is replaced by $\Delta = \delta.\ell$, ℓ being the splitter length.

Fragments produced before a momentum redefining collimator can be strongly attenuated because of the very small momentum dispersion of the ^{16}O beam (a few 10^{-3}), compared to that of the fragments.

The angular dispersion of the fragments is too small to be efficiently used to reduce the contamination at high energy, but it will provide additional factors at the lowest energies.

A special case mentioned in Table 1. is the H3 beam in the West area which has a 3-way splitter installed downstream of the main bending sections. X5 and X7 have subsequent bending magnets, but H3 has only a small bending angle downstream of the splitter.

Thus, in the case of a 3-way split between H3, X5 and X7, the contamination in the H3 line cannot be reduced by the momentum selection outlined above. If there is no splitting to X5 and X7, the H3 contamination should be as for H1, because the beam can then be steered to clear the splitter septa.

The most crucial region for contamination is the last straight section of the beam lines as all fragments will reach the experiments.

Numerically, 1 metre of air produces 0.8 % of fragments, and 1 metre of helium 0.4 %. So, the vacuum should be carried as close as possible to the target of experiments. If a particle identifier is to be installed, it should be installed inside the vacuum chamber.

4.4. Beam attenuation

Sources of α or d ions could provide $\simeq 10^{11}$ ions/pulse. This intensity must be reduced to $\lesssim 10^{8}$ for radiation safety reasons.

This reduction could be achieved with a Beryllium (Be) filter, which attenuates by a factor ~ 100 for 4.6 λ(α-Be), i.e. 4.6 x 42.3 g/cm^2 or 105 cm of Be, the remaining factor being reached by collimation in the secondary beam lines.

In α-Be collisions, deuterons are produced as beam fragments. As the cross-section σ(d-Be) is smaller than σ(α-Be) in the ratio 0.74, the α beam will be "enriched" in deuterons after the filter. We can estimate the yield of forward d production per α-Be collision to be 0.2. Then computing the differential attenuation of α and d, we get, after the filter a ratio $n_d/n_\alpha = 1.8$, roughly twice as many deuterons as alphas. The r.m.s. value of Fermi-motion of d in α is σ(q) = 181 MeV/c[3]. Thus the LAB momentum dispersion of deuterons will be $\sigma(p)/p_0 = 10.4$ %. The momentum slit can be used to reduce the deuteron contamination by about a factor of 65 and hence the final beam will contain ~ 3 % of deuterons.

5. TRANSPORT VIA THE SECONDARY BEAM LINES

5.1. Beam intensities and interlocks

The use of primary beams of different particles implies the need to interlock the sources in order to prevent dangerous intensities in experimental areas.

When ^{16}O are in use, the intensity is source-limited to about 10^8 ions/pulse. Collimators can subsequently be used to reduce the intensity in individual beam lines to $\lesssim 10^6$ ions/pulse, which is the intensity limit in OPEN experimental areas.

However when d or α are accelerated, the sources can provide much higher intensities (> 10^{11} ions/pulse) which we propose to limit by passing the α or d beams through beryllium attenuators. The results of section 4.4. show that the d background in an α beam would be about 3 % for an attenuation factor of 100. An alternative would be to limit the accelerated intensity to less than 10^9/pulse, but this contradicts the aim of setting-up the accelerator with reasonable intensity and it would be difficult to operate with the required degree of reliability. Unless the Be attenuators are in position, the d and α sources would be interlocked "OFF".

5.2. Material in the beam lines

The main source of material in the beam lines is situated in the region of the target stations and proton beam dumps. Although these are not required for ion operation they must nonetheless be left in place for use in the normal fixed-target programme. The amount of material is ~ 2 gm/cm^2 of carbon equivalent and consists of titanium, aluminium and stainless steel vacuum windows, aluminium detector foils and several metres of air. Following the results of section 4.3. this represents about 7 % of an absorbtion length for ^{16}O.

A large fraction of the background particles due to ^{16}O interactions upstream of the last momentum-defining bend can be removed by collimation. This is because the momentum spread of the background daughter particles is larger than that of the parent beam. A typical beam momentum resolution is ± 0.1 % and as this corresponds to the momentum spread of the extracted ^{16}O beam, it allows removal of those background particles outside this range. In addition, the angular spread of the background particles will be larger than that of the ^{16}O beam and acceptance and image-defining collimators can help reduce the background (see Table 1 for numerical results).

Background due to interactions in material downstream of the last momentum-defining bend cannot be removed by collimation. CEDAR and threshold Cerenkov counters will therefore be removed and replaced by vacuum pipes, and retractable monitors will be used wherever possible.

Splitters in the West Area H3 beam complex are treated in sections 4.3. and 5.5..

5.3. Monitoring Equipment

It would clearly be desirable to have a means of monitoring the beam composition ; to this end an existing detector (FISC counter) will be further developed. Since it consists of a very narrow strip of scintillator, it could be placed where the beam is large and could be used during runs without significantly affecting the background conditions. Note that this is not a tagging counter but gives a measurement of the percentage background on average over the spill.

If FISC's were to be placed near the final focus onto the experiment, they could in addition measure the spot size with high precision at this location.

5.4. Change-over time

A detailed study of the work needed to change over from normal fixed target operation to ion beam transport has not been made. However, if sufficient advance notice is given, about 2 weeks should be adequate.

5.5. Beams to the West Area

A schematic layout of beams, experimental areas and their present occupation is shown in Fig. 3.

Note that the ion beam could be split among the 3 beams of the H3 complex (i.e. H3, X5 & X7), but the X5 and X7 beams have energy limitations indicated on the figure.

Also, in this case the contamination in H3 due to the splitters has been estimated to be about ~ 25 % (Table 1), whereas the X5 and X7 branches would have less contamination since momentum re-definition is provided after the splitters.

As there is no splitter before target T1, one CANNOT have ions SIMULTANEOUSLY in H1 and H3.

5.6. Beams to the North Area

Basically, the North Area is served simultaneously by three primary beam branches following two 2-way splits upstream of target stations T2, T4 and T6.

A schematic layout of the beams, experimental areas and their present occupation is shown in Fig. 4.

For operation with ion beams, two experiments located downstream of T2 in beam H2 (EHN1) would have to run alternately to each other.

Similarly, two experiments located downstream of T4 in beams H8 and P0-H10 would at present have to run alternately. It is, however, planned to install a link connecting the front end of the M2 muon beam following T6 with the P0 beam line, as shown in Fig. 5. This facility is needed to provide the possibility of simultaneous primary beam running in beams H8 (EHN1) and P0-H10/E12 (ECN3) and forms part of the project approved for experiment NA34.

ECN3 is the only area which is completely shielded and should therefore be reserved for experiments capable of receiving the majority of the ^{16}O flux available after splitting (say, $\geq 5 \times 10^7$ ions/pulse). Also, the P0 beam leading to this area is only equipped with secondary emission monitors for high intensities and new detectors would need to be built and installed if "low" intensities were used.

6. POSSIBLE SCENARIOS TO ACCOMMODATE EXPERIMENTS

6.1. Proposed experiments

The Proposals and Letters of Intent which have so far been submitted to the SPSC for experiments with ^{16}O ion beams are listed in Table 2. The Table furthermore indicates the principal detection method proposed, the use of any existing apparatus, need for analysing magnet(s), and the energies and intensities of the beam required (as indicated in the proposals or intents).

6.2. Possible beam assignments

In view of the requirements listed in Table 2. we attempt in Table 3. to assign possible locations in experimental areas and beams to each experiment. We note that more than one experiment may be in competition for a particular location. Comments on specific consequences of a particular assignment are included in the Table, and more general considerations are discussed in this section :

i) Intensities
Intensities in OPEN experimental areas must be limited to $\simeq 10^6$ oxygen ions/pulse. Higher intensities are however possible in ECN3, up to the full machine intensity.

ii) Energies
Following the conclusions of section 3.1. and supposing that the main SPS long-term ion programme to be at higher energies, we propose to use only the West Area for energies < 40 GeV per nucleon. The West and North Areas could both be used for energies $\geq$ 40 GeV per nucleon.

iii) Number of simultaneous beams

Only ONE beam per target station can run at a given time, in constrast to normal fixed target operation where 2 beams are generally derived from the same target.

An exception is the West Area H3 beam, which can be split in 3 branches but, as noted in section 5.5., X5 and X7 are limited in energy and the background in H3 is very high. Also these beams are heavily used as LEP test beams and will continue to be so, particularly if the use of the M2 beam in EHN2 as a new test area does not materialise.

A maximum of 4 experiments could therefore be run simultaneously if one excludes the test beams X5 and X7.

More than one experiment could be installed per beam line in the North, thereby sharing the available time for ion operation, although this raises the problem of making the upstream experiment transparent. At present we consider this possibility only on the H2 line. In the West similar time-sharing could be obtained by using H1 and H3 alternately.

iv) Experiments in the H3 complex

It is assumed that WA78 will have finished their experimental programme by the end of 1985 and that this position (and magnet) will become available for an ion experiment. It is assumed that ion experiments cannot be run in X5 or X7 due to competition for space and time with existing experiments, unless something is done to alleviate the critical situation on these beams. A possibility that has been discussed is to turn EHN2 into a test area, if the muon programme comes to an end in 1985, and to move DELPHI-test there. In this case the X7A area would become free for installing an ion experiment ; however the X7 momentum is limited to 110 GeV per nucleon and this increases considerably the background content of the H3 beam.

v) North Area M2 - PO link

At present H8 and PO (to H10 and E12 in ECN3) cannot receive primary beams simultaneously. A link between the muon beam (M2) and PO will be provided so that H8 and PO could run with ions at the same time.

vi) Experiments in the North Area

We assume that NA24 and NA10 will have completed their experimental programmes to allow the installation of ion experiments in H2 and H10.

vii) Assigning experiments to beams

All but three of the proposed experiments have natural beam assignments because they are proposed for existing equipment already in place or they are small and require so little beam time that they can easily be accommodated.

The remaining three for which positions have to be found are :

PS 190.A
PS 190.B
P 196

PS 190.A uses the vertex magnet, now in H3, and the calorimeter of NA24 now in H2. A natural assignment for this experiment would therefore be H3 (in direct conflict with I155) or H2 in series with P201 (requiring however the move of the vertex magnet with associated risk and cost).

If the vertex magnet stays in the West, then PS190.B or P196 could go in the H2 beam in the North or area X7A in the West if this becomes free and acceptable (see point iv above). If the vertex magnet is moved to the North, then H3 replaces H2 as possible beam location for PS 190.B or P 196.

6.3. Conclusions

Even if we do not include the West Area test beams (X5 and X7), we consider up to SIX possible experimental locations for ion experiments. FOUR of these can receive beams of ions simultaneously and no location is placed in competition with more than one other to receive beam. The locations and beams considered are indicated in Figs. 3 and 4.

In allocating experiments to particular locations, we argue that the following restrictions should be respected :

i) Experiments requiring beams of energies below 40 GeV per nucleon, if at all required, should be confined to the West Area (beams H1 and H3).

ii) For the five locations in open areas (those in the West Area and EHN1), the maximum ^{16}O intensity required per beam should not exceed ~ 10^6 ions per pulse.

iii) One location (ECN3) should be reserved for experiments capable of accepting the highest available ^{16}O intensity ($\geq 5 \times 10^7$ ions per pulse).

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TABLE 1.

CONTAMINATION FROM MATERIAL AND SPLITTERS

EXPRESSED AS FRACTIONS OF THE BEAM INTENSITY

Frag-ments	$\frac{\sigma(p)}{p_o}$	cross-section on ^{12}C [mb]	Contamin. from 2g/cm² of ^{12}C
d + α	~ 5 %	880	7.6%
Others Z/A = ½	~ 2 %	~ 200	1.8 %

Contamin. from splitters	Total produced	Residual after mom. recomb. $\Delta p/p = 4.10^{-3}$	Sum of fragments at end of beam	Area : Beam line
12.8 %	20.4 %	0.65 %	1.1 %	NA : H2, H8 receiving 10 % of intensity each
3 %	4.8 %	0.4 %		
–	7.6 %	0.25 %	0.4 %	WA : H1 WA : H3 without splitter NA : PO-H10 receiving 80 % of intensity
–	1.8 %	0.15 %		
20 %	27.6 %	20 % + 0.25 %	25.4 %	WA for H3 * with split to X7
5 %	6.8 %	5 % + 0.15 %		

* Splitter located downstream of momentum slit, so no reduction for splitter component.

TABLE 2.

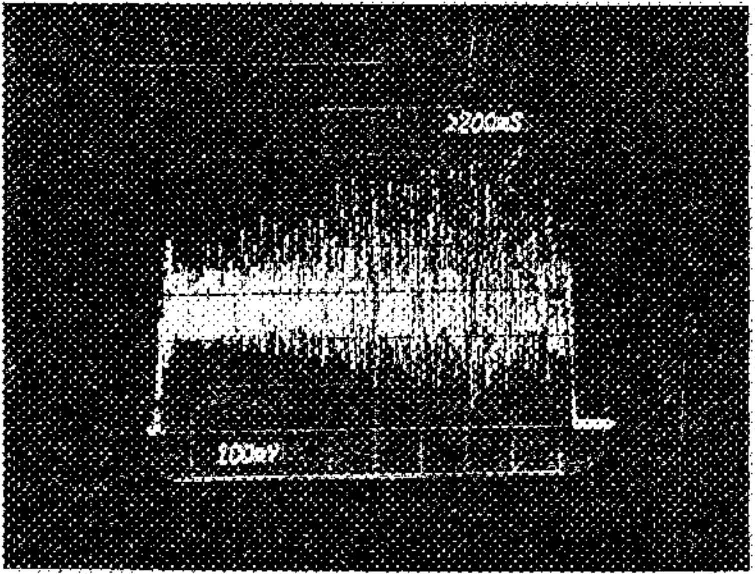
LIST OF PROPOSED AND INTENDED EXPERIMENTS WITH ^{16}O ION BEAMS AT THE SPS

Proposal or Letter of Intent	Spokesman Contactman	Detector	Existing apparatus	Analysing magnet(s)	Energies GeV per nucleon	Intensity ^{16}O/pulse
PS 190.A	STOCK	STREAMER CH.	VERTEX MAG +NA24 CALORIM	MVTX(S.C.)	50,200(15)	10^4–10^5
PS 190.B	GUTBROD	PLASTIC BALL	–	–	50,200(15)	10^5–$\geq 10^6$
P 196	GRUHN	μTPC	–	FILTER(S.C.) + DIPOLE	70,40, 200(13)	10^6
P 198	OTTERLUND	EMULSION	–	–	$\leq$15,50,200	$\sum=10^5$
P 201	FRATI FAESSLER	EHS	M1 + EHS	SWEEP (S.C.) + M1 (S.C.)	200	$10^4/10^6$
P 202	PRICE	LEAD+PLASTIC	–	–	225	$\sum=10^5$
P 203	SPECHT FABJAN	ACTIVE TGT + SPECTROM. + CALORIM.	NA34	MSP (S.C.) + EXT. SPECT.	200	10^6
I 154	ZITOUN QUERCIGH	MWA + RICH	Ω'	Ω(S.C.)	~ 200	10^6
I 155	MUSSET	EMULSION	WA75/78	MVTX(S.C.)	13,~70,225	~ 10^3
I 157	KLUBERG SALMERON	Di-μ SPECTRO.	NA10	ACM	$\geq$ 200	~ 10^8

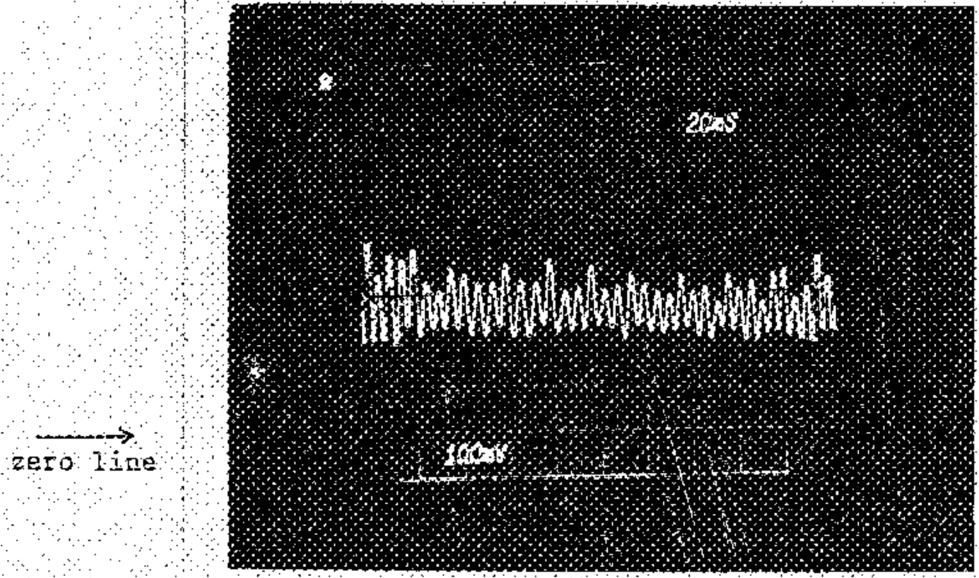
TABLE 3.

POSSIBLE BEAM ASSIGNMENTS FOR ^{16}O EXPERIMENTS

Proposal or Letter of Intent	Spokesman Contactman	Possible location		Comments
		Area	Beam	
PS 190.A	STOCK	WA	H3	TRANSPORT NA24 CAL. TO WEST
		NA	H2	TRANSPORT MVTX(S.C.) TO EHN1. COST ? TIME ? CRYOSTAT LEAK.
PS 190.B	GUTBROT	NA	H2	NA24 FINISHED.
		WA	H3	WA78 FINISHED ; MVTX TO EHN1
		WA	X7	DELPHI → EHN2. ≤ 110 GeV per nucleon
P 196	GRUHN	WA	X7	DELPHI → EHN2. ≤ 110 GeV per nucleon
		WA	H3	WA78 FINISHED ; MVTX TO EHN1
		NA	H2	NA24 FINISHED OR TOGETHER WITH EHS.
		NA	H10	NEEDS M2 → PO LINK. HIGH INTENSITY.
P 198	OTTERLUND	WA	H1 or H3	SIMPLE EXPOSURE.
P 201	FRATI FAESSLER	NA	H2	REMOVE NA24. OTHER EXPTS IN H2
P 202	PRICE	WA or NA	H3, H1 or H2	SIMPLE EXPOSURE.
P 203	SPECHT FABJAN	NA	H8	0.1 mm x 1.0 mm SPOT.
I 154	ZITOUN QUERCIGH	WA	H1	ALTERNATE RUNNING TO H3.
I 155	MUSSET	WA	H3	TOTAL INCOMPATIBILITY WITH PS190.A.
I 157	KLUBERG SALMERON	NA	H10	REQUIRES M2 → PO LINK FOR SIMULTANEOUS RUNNING WITH H8.

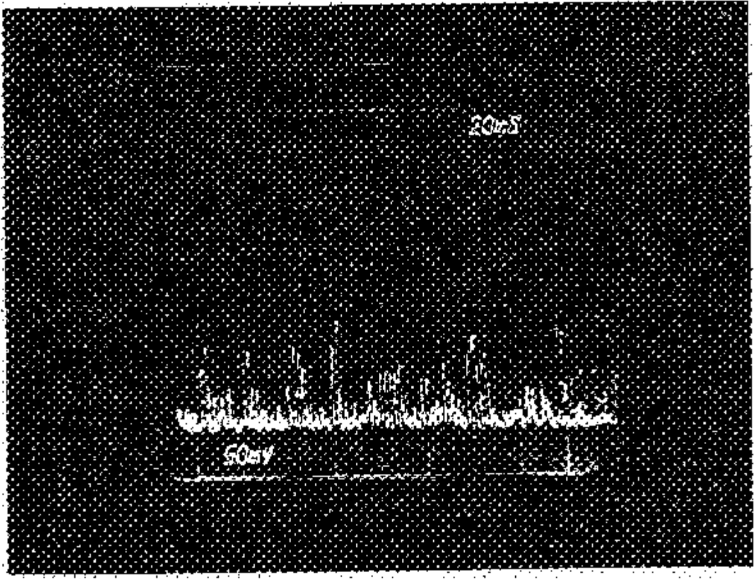


Typical proton spill at 450 GeV/c.

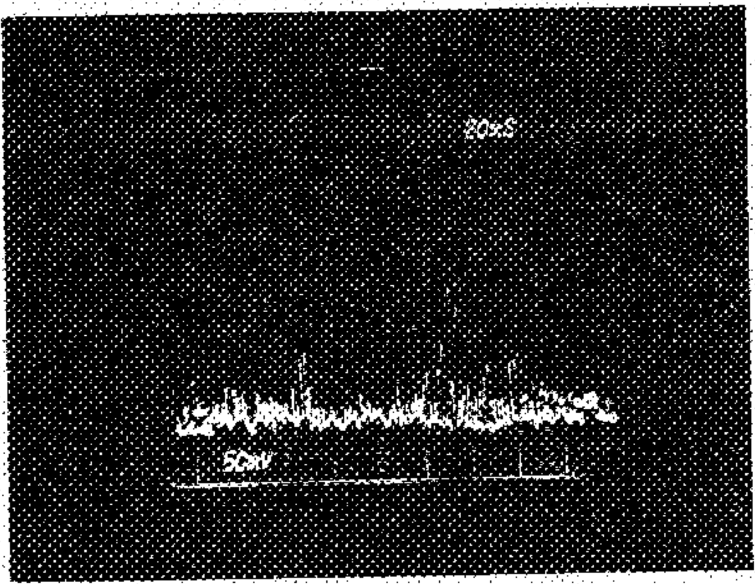


Part of the above spill near its onset.

Fig. 1 - Normal high-energy spill over 2 to 3 secs.



Part of a conventional proton spill of 4.5 sec duration at 20 GeV/c.



Above spill improved by an excitation of the beam with stochastic RF noise.

Fig. 2 - Machine test of spill at the equivalent of 10 GeV per nucleon.

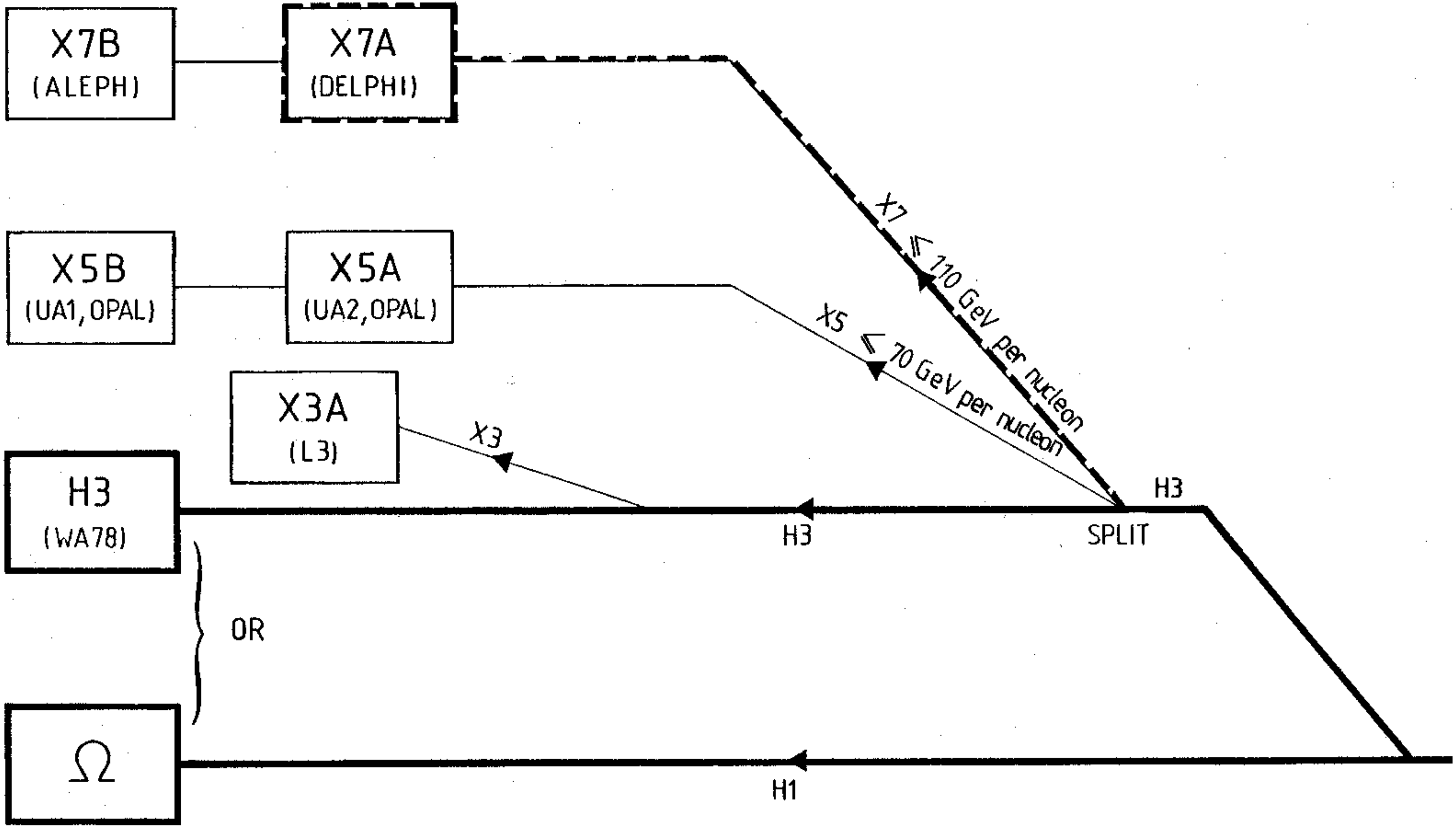


Fig. 3 -THE WEST AREA BEAMS AND PRESENT EXPERIMENTAL AREAS

(POSSIBLE ION BEAMS AND EXPERIMENTAL LOCATIONS ARE SHOWN BY HEAVY LINES)

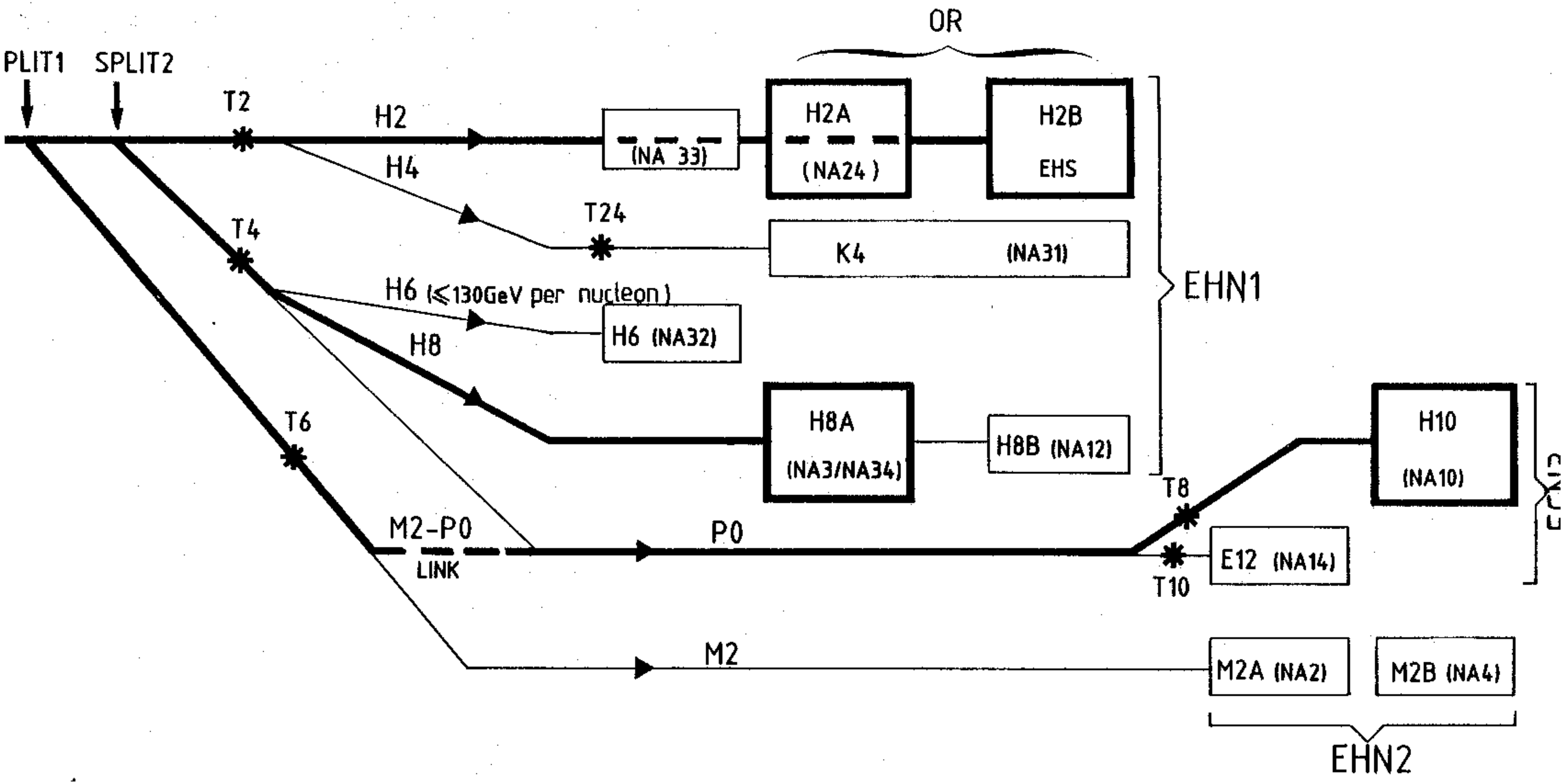


Fig. 4 THE NORTH AREA BEAMS AND PRESENT EXPERIMENTAL AREAS

(POSSIBLE ION BEAMS AND EXPERIMENTAL LOCATIONS ARE SHOWN BY HEAVY LINES)

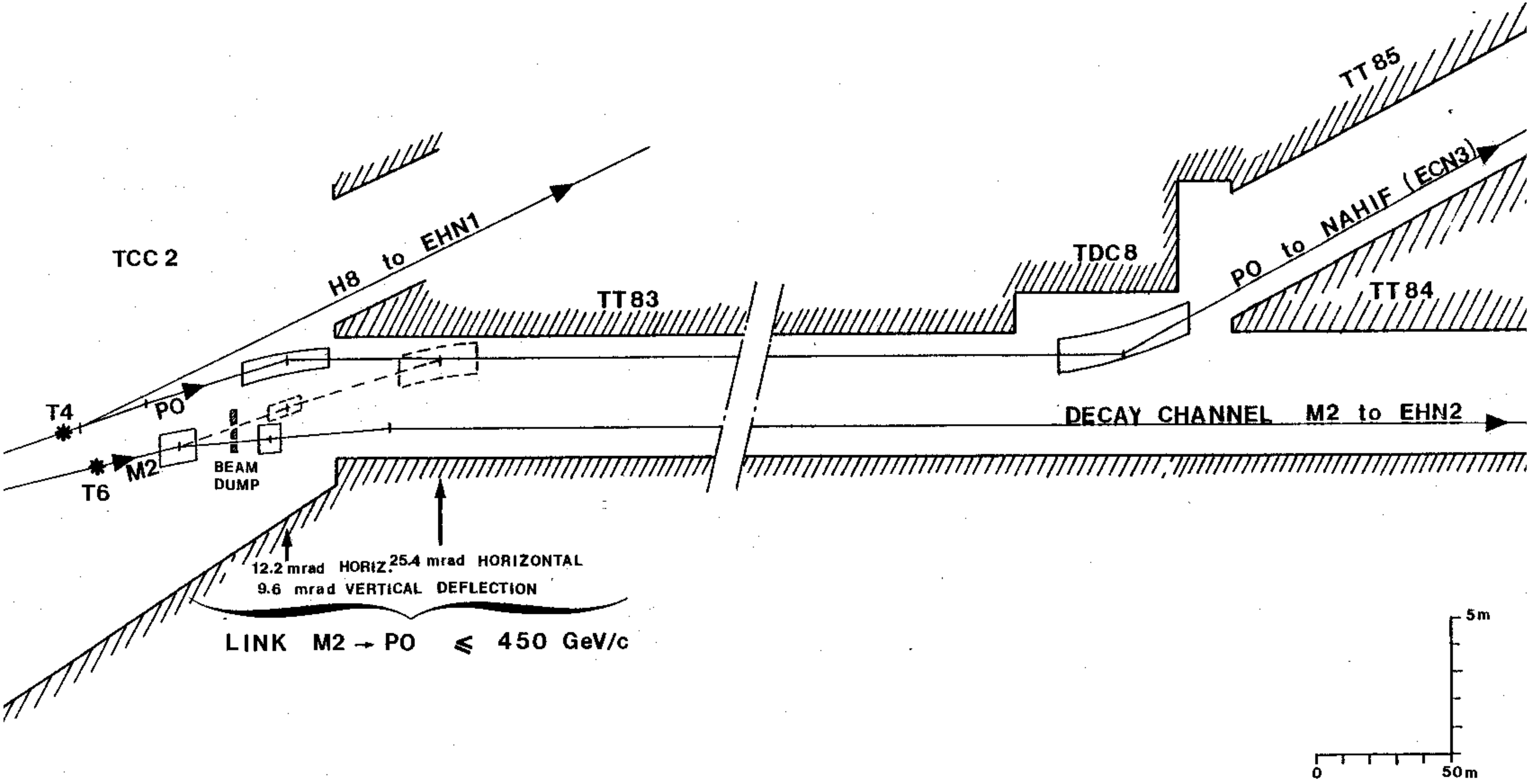


Fig.5 SCHEMATIC LAYOUT OF POSSIBLE BEAM LINK M2 ► PO