ISOLDE: A NEW CLIENT FOR THE CERN PS BOOSTER

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Abstract

The on-line isotope separator facility ISOLDE at the CERN 600 MeV Synchro-Cyclotron (SC) is a unique tool for studying problems in nuclear, atomic and solid state physics.It has been proposed [1,2,3] and decided to move ISOLDE from the SC to the Proton-Synchrotron Booster (PSB).

The main reasons for this move are the following:

- The PSB can produce at present more protons than required by the CERN High Energy Physics programme; the unused cycles will provide the ISOLDE targets with protons at the same intensity as at the SC.
- The energy at the PSB is 1 GeV, instead of 600 MeV at the SC; the ISOLDE physics programme will benefit from higher production cross-sections.
- CERN will close the 33 year old SC; permanent and important savings of money and man-power will result.

In this paper, we briefly present the performances of the PSB and the implications due to the new client.We describe the layouts of the future transfer line, target zone and experimental area. Some possible options are also mentioned.

Performance of the PS-Booster

Protons

A vigorous improvement programme [4] has pushed the four-ring intensity of the PSB up to 3.2 10^{13} protons/pulse (see fig. 1 for the best ring). Moreover, the ejection energy was raised from 0.8 to 1 GeV. Since the available intensity is not fully used by the CPS and its customers, in a typical CPS supercycle (see fig. 2), about one PSB pulse in two would be available for ISOLDE, that is, about 2 microamps.

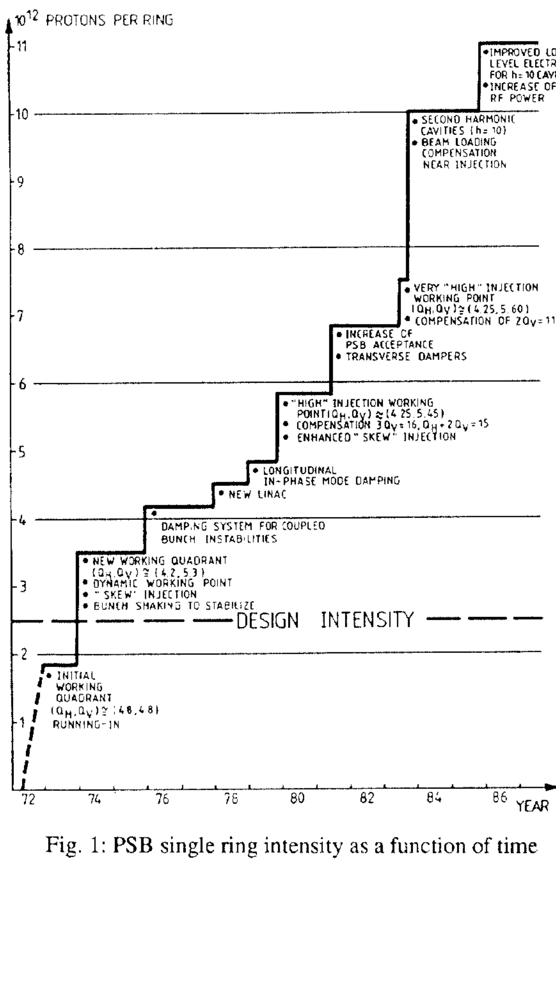

Fig. 1: PSB single ring intensity as a function of time

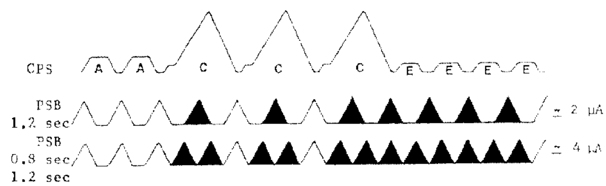

Fig. 2: Typical CPS and PSB supercycles (Isolde cycles shaded)

PSB and SC beam characteristics are compared in table 1; note that the machines differ considerably in time structure, as the PSB provides very short high intensity pulses at low repetition rate.

Parameter		PSB	SC
Beam energy	GeV	1	0.6
Max. intensity on target	p/pulse	3.2 10^{13}	1 10^{11}
Pulse length	microsec	2.4	40
Repetition time (typ.)	sec	2.4	0.005
Current (max.)	microamps	2.1	2.8
Transv. emittances (H,V)	pi.mm.mrad	35,25	6,10
Beam availability	hours/year	6000	4000

Table 1: PSB and SC beam parameters (protons)

Ions

The ion beam performance is somewhat difficult to predict as this will be strongly dependant on the future of the ion beam programme at CERN. Although Linac 2, normally dedicated to protons, could be used to produce reasonable intensities of deuterons, alpha and 3He2+, this would require exclusive operation of the preinjector with ions, thus precluding simultaneous proton operation.

Presently, Linac 1 is only capable of producing a limited range of low intensity ion beams (up to sulphur). In the event of a dedicated ion linac being built, a whole new range of particles becomes available. Table 2 gives some indications (at least to an order of magnitude) of what could be produced. For certain light ions, a dedicated source and optimized RFQ injector would improve the performance of an ion linac.

Table 2: Possible ion beams for ISOLDE

Ion	Linac	Ions per cycle	PSB total energy (GeV)	Comments
alpha	Linac 1	8 10^9	1.306	Estimated ECR 14 GHz
	Ion Lin	1.2 10^{12}		Using heavy ion injector
	Ion Lin	3 10^{12}		Special light ion injector
$3He^{2+}$	Linac 1	8 10^9	1.593	Estimated ECR 14 GHz
	Ion Lin	1 10^{11}		Heavy ion injector
	Ion Lin	3 10^{12}		Light ion injector
16O8+	Linac 1	1.5 10^9	5.22	Achieved ECR 10GHz
	Linac 1	4 10^9		Estimate ECR 14GHz
	Ion Lin	1.6 10^{10}		Estimate ECR 14GHz
32S16+	Linac 1	1 10^8	10.44	Achieved ECR 14GHz
	Ion Lin	4 10^8		Estimate
208Pb53+	Ion Lin	1 10^7	19.7	Projection

Implications for the PSB [5]

Although 3.2 10^{13} p/pulse as quoted in Table 1 have already been achieved during machine studies, routine operation at this intensity would be problematic right now due to losses of about 10^{12} protons/ring between capture and extraction. The bulk of these losses occurs below 100 MeV and consists of particles either diffusing out of the tight (due to limited RF voltage) bucket or being driven vertically to the walls by stopbands. Above 600 MeV spurious longitudinal instabilities account for one or two per cent loss and finally the halo of the beam is scraped off at the extraction septum while the auxiliary orbit bump is approaching it. The loss management proposed to cope with this situation consists of the following counter measures:

- Increase of the RF cavity voltage by 10-15 per cent.
- Improvement of the stability margin of both electronic (longitudinal coupled-bunch and horizontal wide-band) dampers.
- Suppression of the driving coupling impedances (damping of resonating vacuum tanks of septa, etc.).
- Protection of the extraction septum by remotly controlled tungsten collimators (one per ring) with adjacent scatter foil.

For the future option of higher PSB repetition rate, a complementary collector to concentrate longitudinal losses is being studied.

The transfer line

About 100 meters of new line is needed to transfer the beam from the PSB switch-yard to the ISOLDE target zone. It will be a continuation of the existing measurement line but at a different level (3.34 meters higher) to avoid crossing problems with other existing tunnels.

The optics (shown in fig. 3) can be described as four functional sections. The first consists of the four quadrupoles and two bending magnets of the actual measurement line with a new quadrupole inserted between the two magnets to reduce their dispersion. The second is a vertical nondispersive translating system composed of two rectangular magnets with three quadrupoles between them. Then come three quadrupole triplets spaced about 25 meters apart to bring the beam to the target switching magnet. Finally, the two ISOLDE target stations need a strong focussing doublet in front of them to obtain small beam spots. One line is straight, but the other has a 400 mrad non-dispersive bend and needs one more quadrupole doublet.

The elements required for implementing this line are:

- 4 laminated bending magnets having a nominal bending power of 1.14 Tm.
- 18 laminated quadrupoles of 130 mm aperture having a gradient of 8 T/m and a length of .5 m.
- 4 solid core quadrupoles of 200 mm aperture having a gradient of 8 T/m with a length of 1 m.
- 7 horizontal +/- 5 mrad steering dipoles
- 7 vertical +/- 5 mrad steering dipoles

Most of these elements must be laminated in order to enable pulse to pulse switching between:

- PS and ISOLDE,
- Measurement line and ISOLDE,
- Target 1 and target 2.

Some of them are already available at CERN and may be used after a few modifications, but the 18 quadrupoles of 130 mm aperture have still to be designed. A total of 9 scintillator screens and 2 beam current transformers are sufficient for monitoring the beam. The use of loss monitors is foreseen for loss warning.

Layout

The geography of the new facility is shown in fig. 4. The PSB beam is delivered to the target zone via a new transfer line through a new 70-metre tunnel from the PSB "measuring line". Fig. 5 shows the two ISOLDE target stations, the radioactive handling area, and the experimental hall. Beam sharing operation will be possible in order to permit development work on one target with a few pulses while a production run takes place on the second. Great attention has been paid to the shielding since the target zone will receive a very intense beam; the topography of the site allows for construction by excavation, but the target zone will then be buried under about 8m of earth.

A special ventilation system will take care of any accidental radioactive contamination due, for example, to a leaking target container. Handling of the highly radioactive target units will be done with industrial robots, and the plans include a small laboratory area where some work of repair and diagnosis can be carried out on radioactive units, after some cooling time has elapsed. The targets will be of a standard ISOLDE design [6] in which the chosen target material is housed in a tantalum container at very high temperature, and the gaseous reaction products diffuse into an ion source situated a few cm away inside the same vacuum can; this whole assembly is held at 60 kV and the 1+ ions of interest are injected into the front end of the separator system by means of an extraction electrode at earth potential. The ions are then mass-separated in one of the two separators, one of which has medium resolving power (around 500), the other one being capable eventually of 30,000.

However, it is possible that some modifications to the target design might be necessary due to the high instantaneous proton beam intensity at the PSB compared to what is available at the SC machine.

The two separators feed ions of the chosen radioactive species to the experiments in the 700m2 experimental hall. The experimental programme includes nuclear and atomic physics, solid state, astrophysics, and some medical applications, and the beam will serve a community of some 250 physicists.

Possible future options

Staggering

The ISOLDE targets may suffer from the very short, high intensity bursts sent from the PSB. This stress could be eased by separating the beam into four bursts about 1 ms apart, obtained by staggered ejection from the rings on the ISOLDE pulses. This option would require new pulsed ejection bumper magnet supplies.

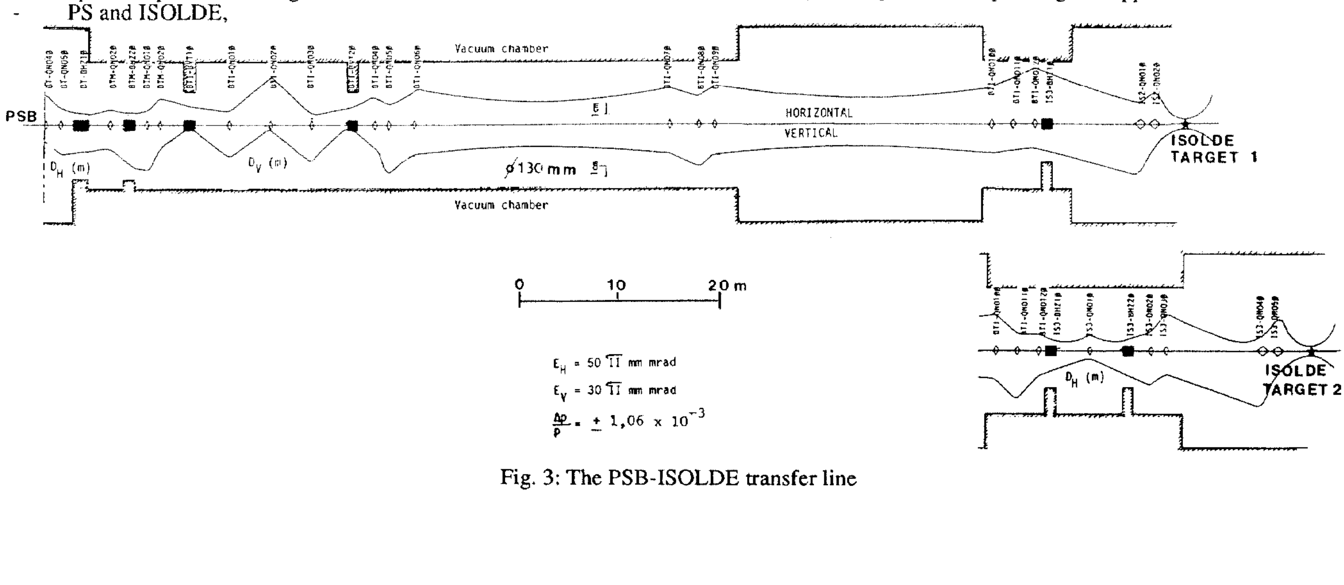

Fig. 3: The PSB-ISOLDE transfer line

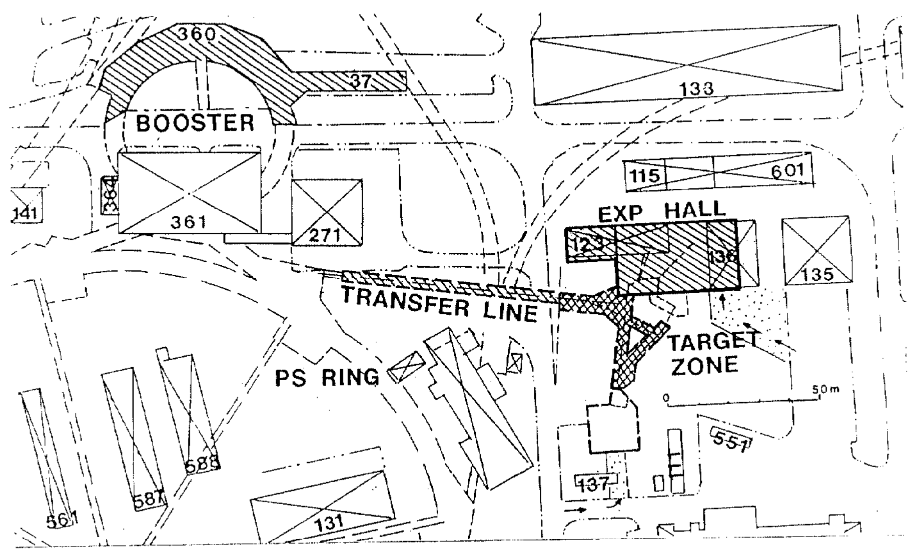

Fig. 4: Geographical situation

Higher PSB repetition rate

Whenever there is a CPS cycle of 2.4 sec duration, the PSB may deliver two pulses to ISOLDE with a repetition rate of 0.8sec, instead of one pulse with 1.2 sec. Obviously the detailed accounting depends on the particular CPS supercycle, but the essential message is that 0.8 sec PSB repetition rate would double the intensity available for ISOLDE (see the last line of fig. 2). This option is feasible, but not for free: the overall timing system with the intricate "Program Line Sequencer" would have to cope with irregular pulsing of Linac 2 and PSB (1.2/0.8 sec), and the shorter cycles seriously restrict the time slots available for computer control tasks.

Other uses

The target zone and experimental hall have been designed with the possibility in mind that one might wish to use the areas one day for other purposes. Thus it would be possible to re-arrange the zone such that a beam from the PSB could be transported directly into the new experimental hall. Clearly, the shielding would have to be carefully considered, and only much lower intensities would be allowed, but possibilities might be medical applications, or test beams.

Conclusion

The idea of feeding interesting beams to a new client on what would otherwise be unused PSB cycles, thus allowing the closure of the ageing SC machine, clearly makes good sense, and the implications for the PSB are acceptable. The project has been accepted by CERN and the ISOLDE community, and will be realised in the near future; the preliminary planning provides for first experiments at the new facility soon after the annual CPS shut-down of Jan/Feb 1992.

Acknowledgements

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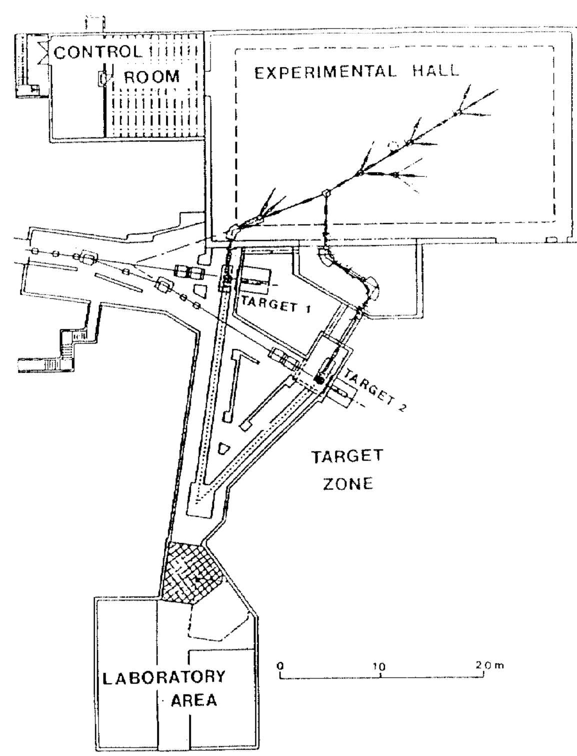

Fig. 5: Layout of the new facility