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SITE LAYOUT OF THE PROPOSED NEW HADRONS' INJECTOR CHAIN AT CERN

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Abstract

The replacement of almost all the LHC injector complex on the Meyrin-site of CERN (Linac2, PSB and PS) is planned within the next 10 years. The layout foreseen for the new accelerators is described in this paper, together with its compatibility with the existing experimental physics facilities. These machines can, after upgrade, supply with high beam power future physics facilities for radioactive ions and/or neutrinos. Their possible layout is also sketched in this document.
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1. Renovation of the LHC injection chain

New accelerators are proposed to be constructed in stages to upgrade the injector complex and reliably provide the beam needed for the LHC luminosity upgrade [1, 2]:

- Linac4, a 160 MeV - 80 m long H^- linear accelerator using normal conducting accelerating structures [3].
- LPSPL (Low Power Superconducting Proton Linac), an extension of Linac4 up to 4 GeV beam energy, having a length of about 400 m and using superconducting accelerating structures [4, 5].
- PS2, a new 50 GeV proton synchrotron which will replace the present PS as SPS injector [2, 6].

Linac4 will be built first, starting in 2008. It will replace Linac2 and inject beam directly in the present PS Booster (PSB) [7]. It will become the source of all protons at CERN in 2013.

The construction of the LPSPL and PS2 is planned to take place in 2012-2016 without interfering with the operation for physics of Linac4 and all the other existing accelerators. For beam commissioning, the LPSPL and PS2 will exploit unused beam pulses from Linac4. Once the new complex is commissioned (~2017), the SPS will be upgraded and connected to the PS2 during a long shutdown. Afterwards the old complex will be decommissioned.

Different locations for the new accelerators have been analyzed and compared. For Linac4, the preferred site is on the South-West of the PS (see Figure 1), under a small artificial hill made with excavation materials dating from the PS construction. This location allows for a short and simple connection to the present Linac2 to PSB transfer line and for an extension to a long underground tunnel housing the LPSPL followed by a straight transfer line to the PS2 machine, nearly tangential to the SPS. The precise position of Linac4 is dictated by the needs to have a stable foundation of the equipment building on the surface (the site presents an important slope towards the PS area) and to keep sufficient distance between this building and the Swiss-French border, where constructions are forbidden by international laws. Other sites considered for Linac4 were (i) the existing PS South Hall, economic but impossible to extend to SPL and with a difficult connection to the PSB through the PS [3], (ii) the present Linac2 location, impossible to extend to SPL and forcing to a long interruption for switching between the two machines [3], and finally (iii) the SPS West Hall, which offers a limited option for an extension but requires a long and expensive transfer line to the PSB.

Apart from the easy connection to the PSB and LPSPL, the selected location is one of the few areas on the Meyrin site which is free from constructions. The Linac4 tunnel can be built with a “cut-and-cover” technique, less expensive than tunneling, at nearly the same level as the PSB and PS machines. The remaining layer of earth between the accelerator tunnel and the surface provides an effective radiation shielding that allows a minimum thickness of the accelerator walls, when compared to solutions above ground or within existing halls.

The LPSPL is located in an underground extension of the Linac4 tunnel having a length of 460 m and a slope of ~1.7 %. The klystrons and power supplies will be housed in a gallery parallel to the accelerator tunnel at 9 meters distance.

PS2 will have a *"race-track"* shape. It will be built close to the SPS and at the same level, for better shielding and to ease beam transfer. The line between the LPSPL and PS2 will therefore have a slope of ~ 8%. The radius of curvature in all bending magnets of the transfer line has to be higher than 400m, to minimize beam loss due to H- stripping. Services and access pits will be located in surface buildings located on land plots already allocated for CERN use.

The depth of Linac4 and LPSPL is defined by radiation protection requirements [8], taking into account that these machines could later be upgraded to the high beam power required by potential future physics facilities (see section 3). For the needs of hands-on maintenance, activation must be minimized and tightly controlled. The new accelerator complex will therefore be designed for and will have to be operated with a maximum of 1 W/m of uncontrolled beam loss [9]. The combination concrete-earth shielding of the Linac4 tunnel and the depth of the SPL have been defined in order to keep the estimated dose in public access areas (surface buildings and infrastructure, service tunnels, etc.) below the limits defined by Radiation Protection. The result is that the Linac4 beam axis must be 2.5 m below the present PSB-PS level. Figure 2 shows the side view of the accelerator complex, and reference 8 reports the interferences between the SPL and transfer line tunnels and the closest existing infrastructures.

2. Preservation/improvement of the present experimental physics facilities

Apart from the improvements for LHC, the impact of the replacement of the PS complex on the other present experimental physics programmes will be the following:

- *Heavy ions for LHC* [10]. The LEIR complex will send its ion beam directly to PS2 using the TT2-TT10 transfer tunnels. Connections shall be established between the LEIR ejection and the TT2 transfer line, and between the TT2 transfer line to the PS2 injection. The LEIR ejection energy has to be increased up to the maximum allowed by its magnets (momentum equivalent to ~ 2.1 GeV/c for protons) and the PS2 magnetic field at injection of ions has to be set at a level which is significantly smaller than for protons from the LPSPL (factor ~1/2.4).

- *Neutrino superbeam from the SPS* [11]. Compared to the PS that needs two cycles to fill the SPS at 14 GeV for fixed target physics, the PS2 will be able to fill the SPS in a single pulse at 50 GeV and with twice the intensity. A much higher proton flux is therefore expected at 450 GeV. The degree of improvement will largely depend upon additional upgrades of the SPS (e.g.: new higher power RF system) [11].

- *Fixed target experiments*. The present East Hall cannot be easily connected to PS2 and it is not able to use its high intensity beam. New experimental hall(s) in underground cavern(s) are therefore proposed to be built in the vicinity of PS2. For low intensity experiments a new hall at the surface could be built (Figure 1).

- *n-TOF facility*. This facility cannot continue after the PS is stopped. It can however remain active during most of the construction of the new accelerators, except for a period of one year while digging and equipping part of the SPL tunnel. At a later stage, the experiment could be rebuilt in a new PS2 experimental area.

- *ISOLDE*. The LPSPL can be equipped with a deflection system at 1.4 GeV to send beam through a transfer line onto the ISOLDE target. Most of the line would reuse the existing TT6 transfer tunnel (Figure 3).

- *AD and antiprotons*. According to the planning of the FAIR project, the antiproton facility in GSI should have succeeded to the AD after the year 2017. The continuation of antiproton experiments at CERN after the PS complex is decommissioned is therefore unlikely. In spite of this, if an antiproton facility is still needed on the CERN site, the following scenarios can be envisaged:
    - For a limited period of time (1-2 years) the old PS complex could be kept active and dedicated to the production of antiprotons.
    - For continuation in the medium term, the AD target could receive a proton beam from PS2 via a 1.3 km transfer line, using a new 650 m long tunnel and passing through 3/4 of the PS ring (figure 4, new transfer line in black color).
    - For continuation in the long term, a new and modern antiproton facility with its target area should be built in a cavern close to PS2.

3. Next generation of physics facilities

Future facilities requiring multi-MW of beam power at a few GeV are the subject of intensive studies:

- A radioactive ion beam facility based on the ISOL technique ("EURISOL") [12]. The SPL can be equipped with a deflection system at ~2.5 GeV to send beam through a new transfer line to a new hall located close to the building 193. The area available in this part of the Meyrin site is adequate to host the EURISOL facility (Figure 3). A second underground location between the SM18 buildings and the PS2, for which the TT2/TT10 transfer lines would be used to transport the beam, is also being considered.

- A neutrino factory. The possibility to install a Neutrino Factory at CERN has been considered a few years ago [13, 14]. A recent study has confirmed the capability of the SPL, when combined with an accumulator and a compressor ring, to meet the specifications of the proton driver of such a facility [15]. The foreseen layout is also compatible with the position of the new accelerators (Figure 5).

Additional investments in infrastructures (electrical power, cryo-cooling capacity, replacement of klystron power supplies…) can transform the 4 GeV, 200 kW LPSPL into the 5 GeV, 4 MW SPL. The Linac4 tunnel and equipment building are dimensioned for high beam power operation, as well as the Linac4 accelerating structures and klystrons. Power converters and infrastructure (water, electricity) are dimensioned only for low beam power operation and need to be replaced when going to high beam power. However, adequate space has been foreseen in the equipment building for the larger high-duty power converters and in the machine tunnel for larger cooling pipes, which could be easily installed during machine shut-downs. The additional external electrical and cooling installations required for the high-power operation can be integrated to those needed for the SPL and housed in the remaining space outside of Linac4 or in the old buildings of the PS complex, which will be free after the decommissioning of the PS.

In the same way, the conversion of the LPSPL to high-beam power operation will require the replacement of the power converters and the installation of additional klystrons in the space that has been foreseen in the klystron tunnel. The LPSPL tunnels will be made long enough to host the additional accelerating structures and klystrons necessary for increasing the beam energy up to 5 GeV.

Beyond the upgrade of the existing proton accelerators, the implementation of any of these facilities will also necessitate numerous other important investments:
- in both cases, the target(s) and the target(s) area will require in-depth studies to meet the demanding safety requirements resulting from the high beam power.
- for radio-active ions, an "EURISOL-like" facility requires target stations, its own radioactive ion linear accelerators and beam lines switchyard in addition to the experiments themselves.
- for a neutrino factory, the proton beam from the SPL must be transformed into a few (1 to 6) short bunches (~ 2 ns rms). An accumulator and a compressor ring of ~ 300 m circumference are required for that purpose [15]. They can be built in an underground area close to the transfer line SPL-PS2. After the target, an accelerator complex dedicated to the collection, cooling and acceleration of muons has to be built (Figure 5).

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Figure 1: Baseline Scheme

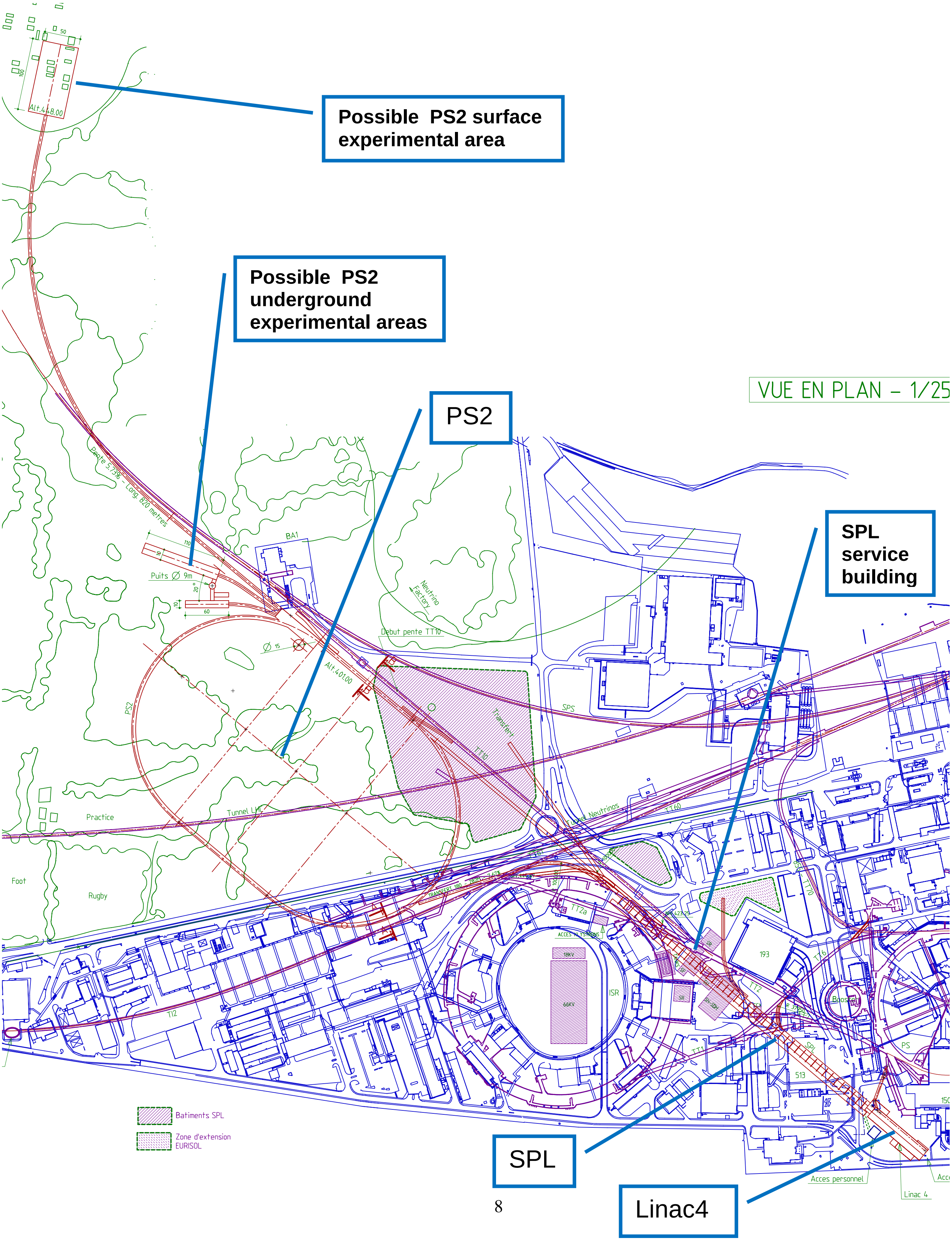

Figure 2: Side View of the Baseline Scheme

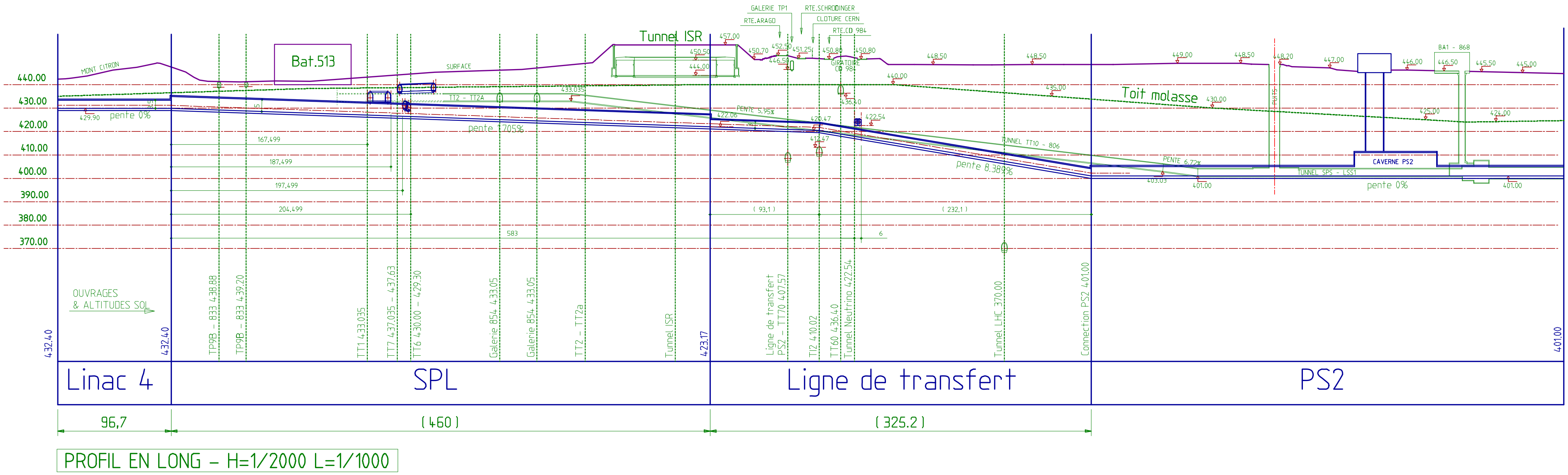

Figure 3: Connection with radio-active ion beam facilities (ISOLDE and EURISOL)

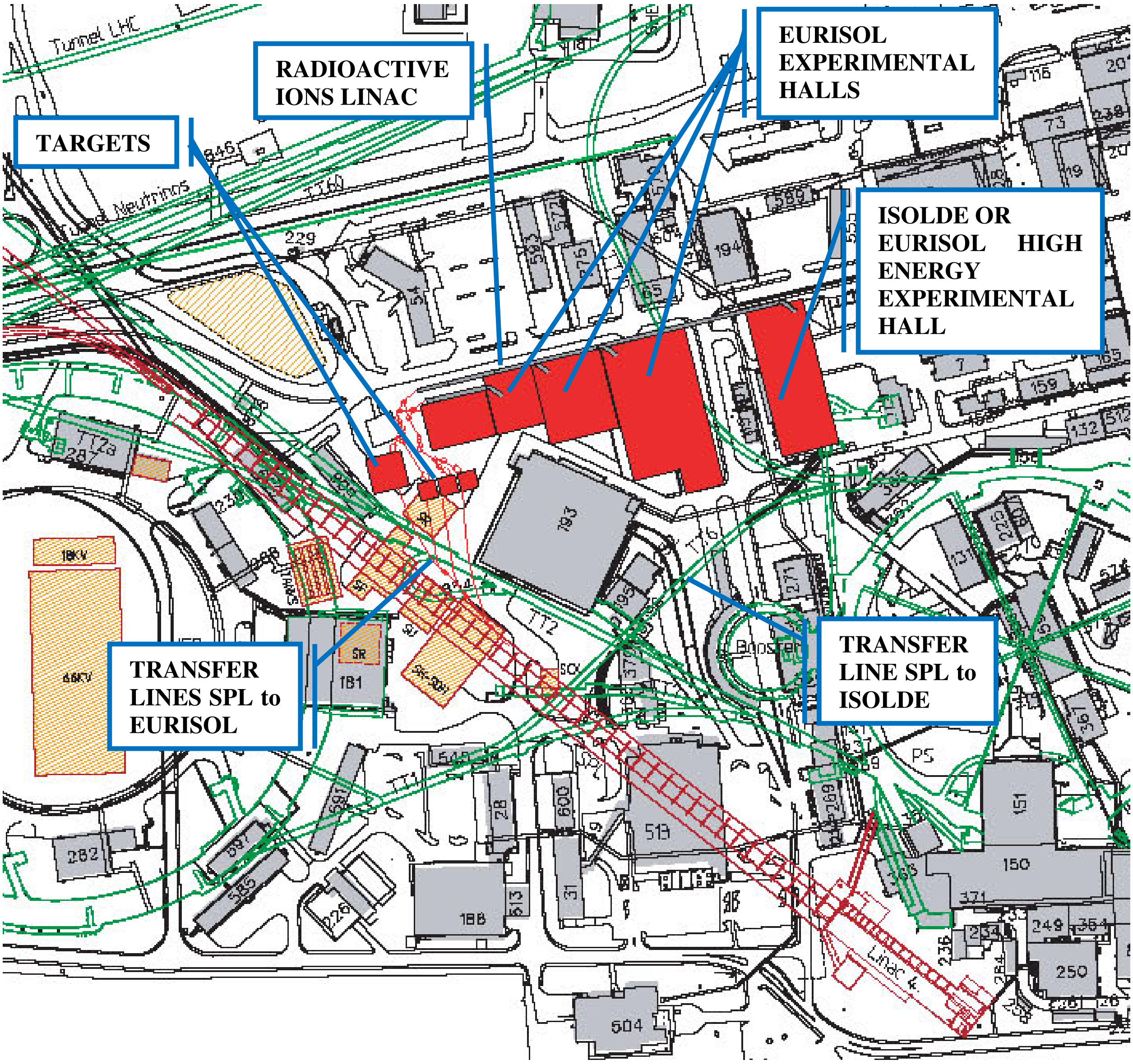

Figure 4: Connection with the AD for continuation of anti-proton physics

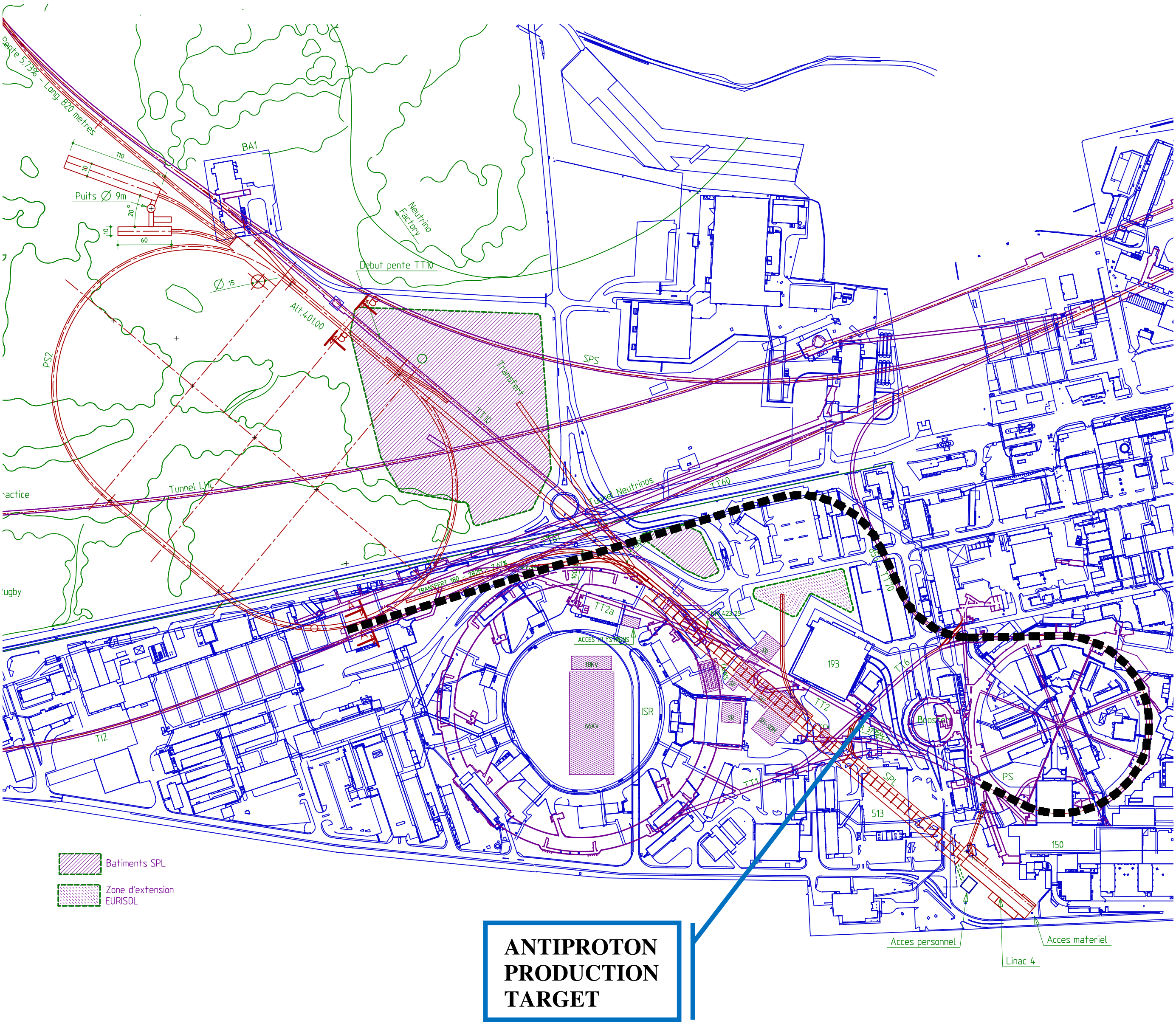

Figure 5: Connection with a neutrino factory