Topics for JAS projects **Version 1.4, 01/11/2014**

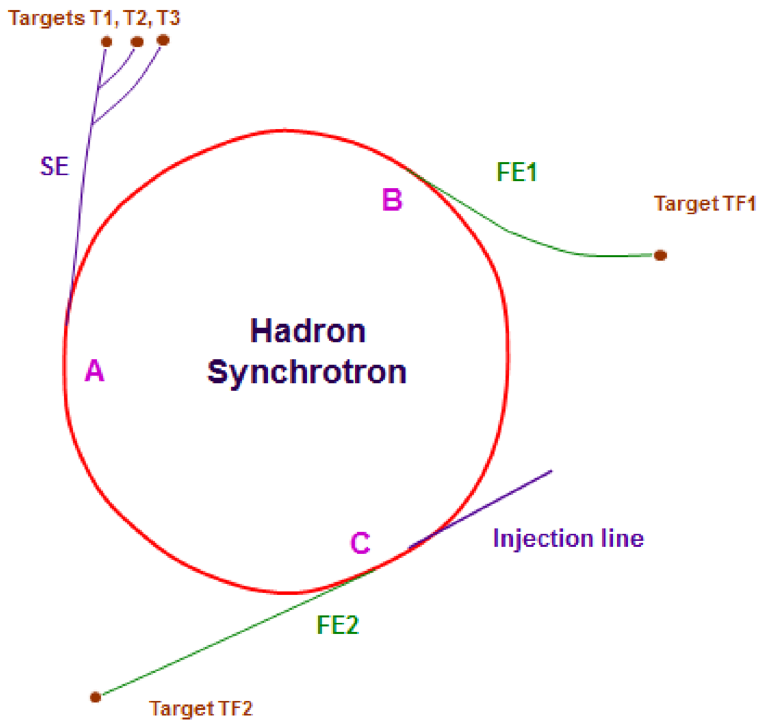
- **(1) FCC-hh proton transfer line**
  - The 100 km FCC-hh collider will be operated with bunches having a population of 1E11 protons. Two beams will circulate is separate beam vacuum chambers (as for the LHC). The bunch spacing will be 25 ns. The FCC top energy is 50 TeV per beam. The injection energy should not be more than a factor 20 lower than the top energy.
  - FCC-hh will be filled with groups of proton bunches that are pre-accelerated by the 26 km long LHC which will be recycled to become a fast cycling injector for FCC-hh. The injection energy into the LHC is 450 GeV, the maximum number of proton bunches in the LHC is 2800.
  - One would like to transfer the largest possible beam intensity in one shot to minimize the filling time of FCC-hh. What is the intensity that can be transferred safely? Try to find ways in the design of the ejection, transfer and extraction systems to obtain the highest possible transfer intensity. Make a conceptual design of optics, instrumentation and machine protection systems for the transfer. What about the transfer energy?

- **(2) FCC-hh dump for 50 TeV proton beam**
  - The 100 km FCC-hh collider will store 10600 bunches with a population of 1E11 protons in each bunch. The bunch spacing is 25 ns, the beam energy is 50 TeV.
  - Evaluate the stored energy and design a beam dumping system for the FCC-hh.
  - What are the challenges for such a system? Is one beam dumping system sufficient for each beam?
  - What is the impact of and on beam optics and on the overall machine layout (space, straight sections etc)?

- **(3) Beam halo**
  - For very high intensity and high energy accelerators, the number of particles in the halo can be a serious issue. There can be enough particles in the halo to quench or to damage accelerator components, for example the collimators that are supposed to absorb and clean the halo.
  - Discuss the energy stored in such beam halo, and the parameters that defined the halo.
  - Design one or more instruments to monitor the beam halo.
  - How could one clean the halo?

- **(4) Multi-purpose pulsed high intensity accelerator**
  - A high intensity accelerator is designed to deliver beams to a number of different “users”, e.g. targets, experiments or subsequent accelerators. For each user the accelerator has a dedicated extraction system and transfer line as shown in the figure. The beams are delivered at different energies. Some of the user beams are based on slow extraction (beam spill over 10 seconds), others on a fact extraction (beam extracted over one machine turn).

    - SE: slow extraction over 10 seconds. The extracted intensity is 5×10^{13} protons per spill at 300 GeV/c. The extracted beam is distributed to 3 targets T1, T2 an T3.
    - FE1: fast extraction over one machine turn to target TF1 (full beam extracted). The extracted intensity is 3×10^{13} protons per cycle at 500 GeV/c.
    - FE2: fast extraction to target TF2. The beam stored in the synchrotron is extracted in 4 shots of equal intensity (4 consecutive fast extractions). The time interval between 2 consecutive extractions is 10 ms. The total extracted intensity is 7×10^{13} protons per machine cycle at 250 GeV/c.
  - Design a MPS to protect the extractions of this accelerator (active and passive protection). Consider also the commissioning phase. Make sure that the beams cannot be mixed, i.e. send to the wrong destination. What are the requirements for this system?



- **(5) Beam incident in the TT40 transfer line at the SPS**
  - During extraction tests at the SPS, a beam of 3.2×10^{13} protons at 450 GeV/c was deflected into a vacuum chamber, resulting in damage to the vacuum chamber and to a magnet.
  - Start from the facts describing the incident (see supporting document): intensity, energy, damage (vacuum chamber, magnet), failure.
  - What are the parameters for beam induced damage of equipment? Deduce damage limits for this event; define experiment to test the limits.
  - Define protection measures.
  - Describe the commissioning of the extraction with the new measures.

- **(6) High intensity neutrino target**
  - Design a target for a high intensity neutrino beam, 1E14 protons/pulse at 200 GeV.
  - The target should obviously survive the impact of the beam. What about repetition rate? Design a protection system for the target. What interlocks would be required, what should be monitored?
  - How can you be sure at any time that the target is still intact? How do you diagnose this?
  - What about a target for neutron spallation (e.g. protons of 2 GeV, power of 5 MW)?

Topic suggested for all groups

- **Dependability for particle accelerators**
  - Modern accelerators require an availability for providing beam for the users exceeding 90% or even 95%. An accelerator is highly complex and comprises many systems.
  - Clarify terms such as reliability, availability, MTBF, MTTR, …
  - What systems are required to operate an accelerators?
  - Do all accelerators require a protection system?
  - What are sources of unavailability for the different systems?
  - Propose a partitioning for MTBF and MTTF for the different systems, with the objective to achieve an overall availability of more than 95%.
  - On the last evening, it is suggested to distribute an EXCEL sheet with different accelerator systems, to be filled by the groups for their ideas of partitioning.