The Insertable Beam Stop in the ESS SPK section WEPP07

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EUROPEAN SPALLATION SOURCE

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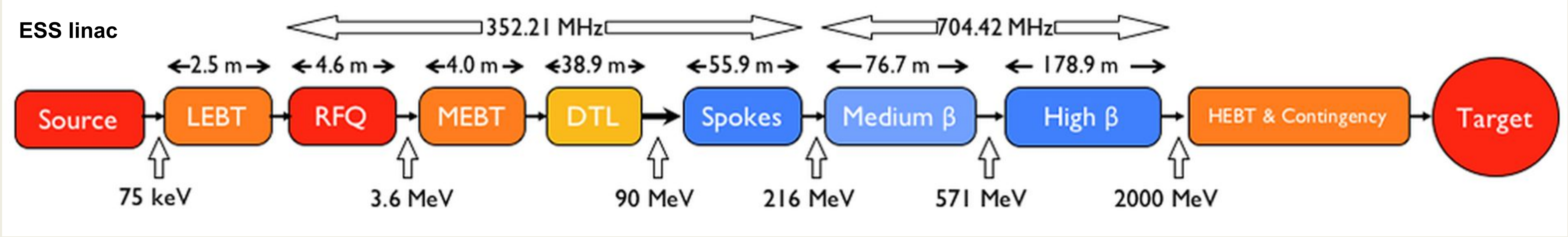
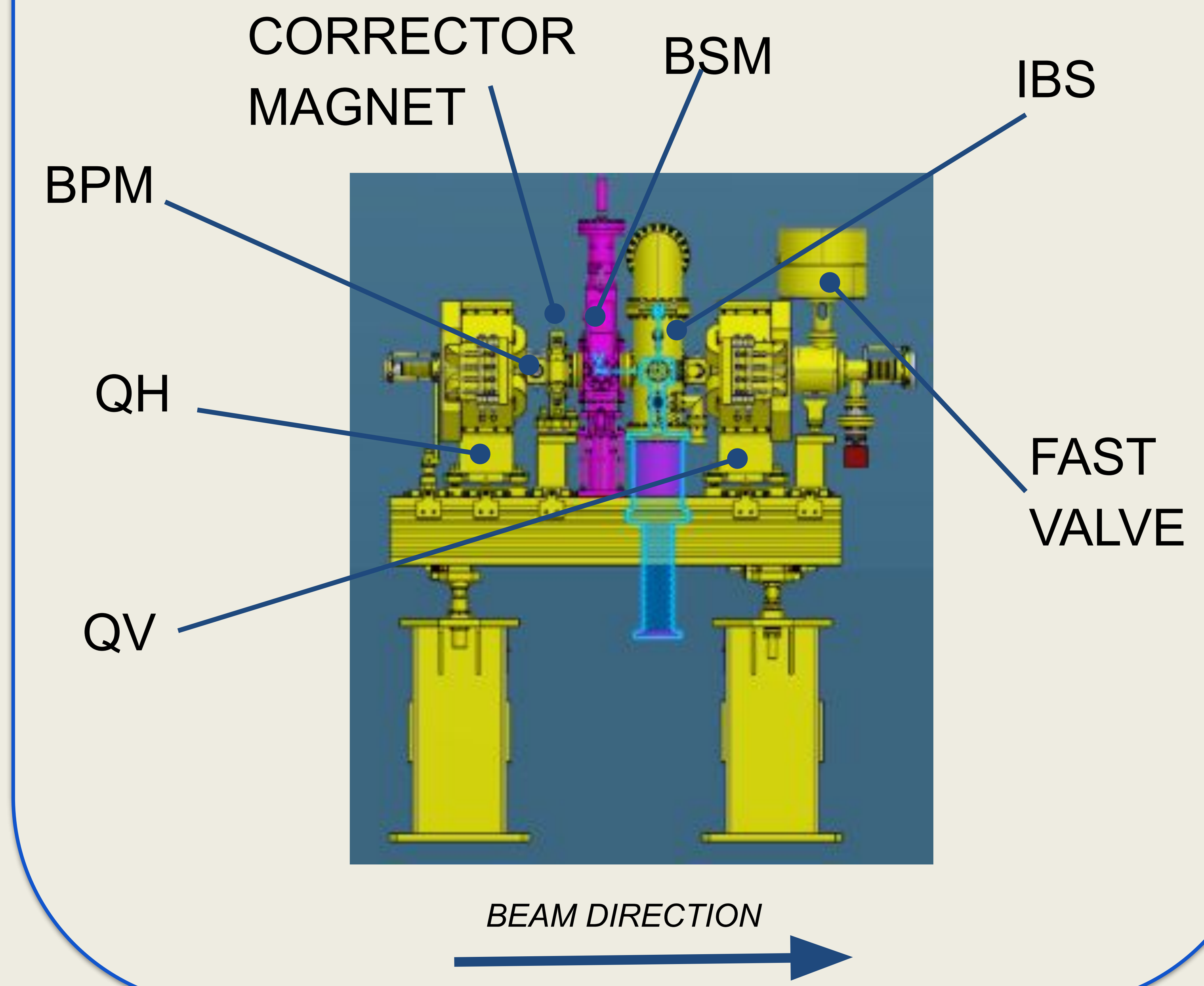
- The European Spallation Source **(ESS)** is one of the largest science and technology infrastructure projects being currently built. The ESS accelerator high-level requirements are to provide a **2.86 ms long proton pulse at 2 GeV at repetition rate of 14 Hz**. This represents **5 MW of average beam power** with a 4% duty cycle on the spallation target.
- A suite of beam instrumentation and diagnostics has started to support the commissioning and operation of the Normal Conducting Linac (NCL) section. **At the transition between the NCL and the SCL** sections, an **Insertable Beam Stop (IBS)** will be installed to avoid beam losses in the cold cavities during tuning up and commissioning of the ESS linac.



REQUIREMENTS

1) **Stop [73, 92] MeV protons** (fast- and slow-tuning modes of the ESS linac),
2) Minimize the **heat transfer** to the cold linac section downstream,
3) Minimize the **residual radioactivity** of the IBS and surrounding components,
4) **ISO-5** qualified, i.e. particle free,
5) The **dose rate** at 30 cm from the IBS **shielding** should not exceed 100 uSv/h, after 120 hours of irradiation at the max average power and 4 cooling hours,
6) Fit within the allocated **space in the LWU**. The picture below show the ESS spoke (SPK) section, with the IBS highlighted in blue.

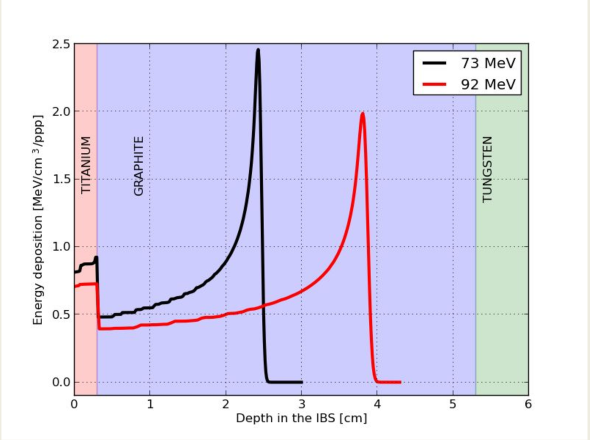
Therefore, the IBS has a graphite core in a tungsten shell, surrounded in turn by a 3 mm thick layer of titanium. Outer cylinder radius = 5.5 cm, length = 8 cm. The IBS is water cooled and the pipes of the water cooling systems are made of SSL.

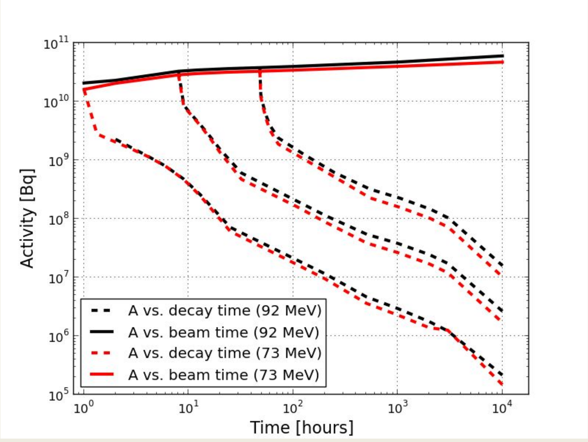


DESIGN

Studies performed:

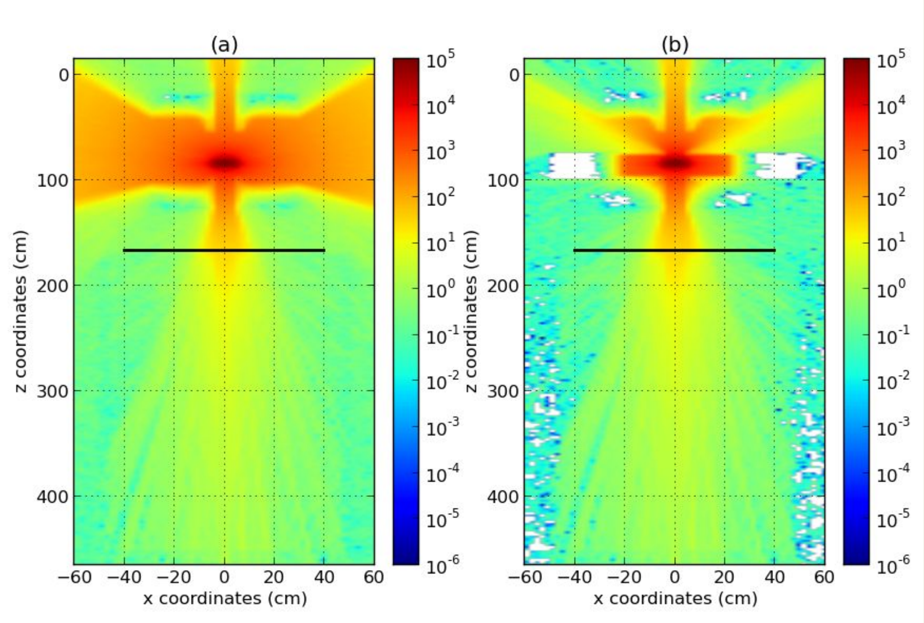
- **Thermo-mechanical studies in MCNPX/ANSYS.** Max energy deposition = 350 MeV/cm^3/ppp. Max graphite temperature = 450°C, maximum titanium temperature < 200°C (see Bragg peaks locations in the left plot).
- **Activation calculations in MCNPX/CINDER'90** after irradiation and cooling times of interest for the ESS linac commissioning (see right plot).





Studies to be completed:

- **Von-Mises stress and optimization of the water cooling system.**
- **Calculations of the expected signals in beam loss monitors closeby.**
- **Shielding design:** the pictures below show the residual-dose distribution (in uSv/h) after irradiation for 120 h with 93 MeV protons and cooling for four hours. The black line indicates the LWU end and the SPK cryomodule start. (a) no shielding (b) with a compact lead shielding around the IBS.



A BEAM PROFILE MONITOR?

To avoid melting any of the IBS components due to a too high power-density, embedding a beam-profile monitor is being investigated in three ways:

1) With an **imaging system** composed of two elements: the light source (**chromium-doped alumina**), flame coated on the titanium surface of the IBS. This coating material is the same for the imaging system of the ESS target. The material is luminescent and radiation tolerant. The luminescence is high, in excess of up to 10000 photons per MeV deposited in the material. Samples have been produced and are being tested for ISO-5 cleanness qualification. The image from the beam would be produced by a standard industrial camera and lens, designed to get a field of view of about 100 mm. The camera and lens would be positioned outside of vacuum, looking through a view-port on an upstream vessel that supports also the Bunch Shape Monitor (BSM). The optical path contains a single flat mirror, reflecting the light from the IBS to the lens. The system performance is expected to image a probe beam pulse in single shot, and with resolution in the 0.1 mm range,

2) With a **multi-wire grid** composed of a grid of tungsten wires, assembled on a ceramic frame, and connected on both sides to a triax connector, so that the shielded ground and signal can be read by an AMC pico4 current ADC. The wire diameter should be thick enough to enhance the signal, as well as thin enough to withstand beam-induced heat loads. Based on previous studies by the ESS Beam Diagnostics Section, a 40 um tungsten wire would satisfy the requirements. One may note that this system is not a full 2D diagnostics, but it may be sufficient for reporting beam sizes smaller than 1 mm. Assuming a wire spacing of 2 mm, the system would be composed of 100 wires, positioned both in the vertical and horizontal axes of the proton beam,

3) or with a **multi-strip silicon detector** on top of the entrance IBS face could serve as beam-position, profile- and also halo-monitor. Moreover, it could potentially monitor the beam intensity if absolutely calibrated e.g. with an upstream Faraday cup or Beam Current Monitor. On one hand this latter solution would be the most compact and radiation-hard one, but on the other hand it is expected to be the most expensive one.