PROGRESS ON ESS MEDIUM ENERGY BEAM TRANSPORT

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Abstract

The considered versatile ESS MEBT is being designed to achieve four main goals: First, to contain a fast chopper and its correspondent beam dump, that could serve in the commissioning as well as in the ramp up phases. Second, to serve as a halo scraping section by means of various adjustable blades. Third, to measure the beam phase and profile between the RFQ and the DTL, along with other beam monitors. And finally, to match the RFQ output beam characteristics to the DTL input both transversally and longitudinally. For this purpose a set of eleven quadrupoles is used to match the beam characteristics transversally, combined with three 352.2 MHz CCL type buncher cavities, which are used to adjust the beam in order to fulfil the required longitudinal parameters. A thorough study on the optimal input beam parameters will be discussed. Quadrupole design update will be presented along with new RF measurements over the buncher prototype. Finally, updated results will be presented on the chopper and beam-dump system.

LAYOUT

During last year the ESS linac cost was reevaluated, in order to cope with the cost objective, final energy of the linac was reduced and both gradients and beam current were increased [1]; as a consequence important modifications were introduced to the linac design that affected MEBT section. RFQ output beam energy increased from 3 MeV to 3.62 MeV, and beam current under nominal conditions was increased from 50 to 62.5mA. From the envisaged layout [2] most affected systems were: quadrupole, buncher and chopper and beam-dump.

Fig. 2 shows the updated layout, where a quadrupole triplet is still used to focus the beam out of the RFQ. After leaving the chopper and beam-dump, the beam expands. Another triplet is used to focus the beam before entering the space for diagnostic devices. The last set of four quadrupoles is used to obtain DTL periodic transverse solution; accompanied by three CCL type buncher cavities for the longitudinal plane. In both cases, a good compromise in the focusing is required to prevent beam excursions to non-linear field regions, while avoiding over-focused bunches that would enhance inner space-charge repulsive forces [3].

Required Inputs for MEBT

In order to improve MEBT performance, a systematic approach was conducted to seek best input beam. 2 different sets of potential RFQ outputs were used as input of the ESS warm linac. MEBT focusing elements were used to match the beam to the required DTL periodic solution, and different beam parameters were evaluated at the end of the warm linac section.

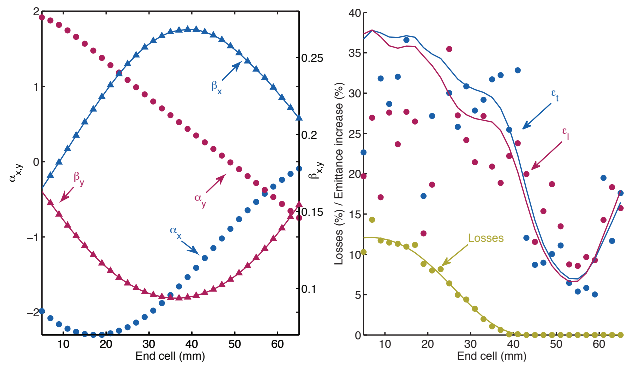

Figure 1: **Left:** Generated inputs from RFQ. **Right:** Output parameters at the end of ESS warm linac.

In order to produce the possible inputs, different end-cell and transition-cell lengths were adopted. Fig. 1 shows the particular case where end cell length adopts different values. This figure shows the combination of Courant-Snyder parameters ($\alpha_{x,y}, \beta_{x,y}$) employed at the input distribution (left frame), and the results obtained at the end of the warm linac in terms of transmission and transverse emittance increase respect to RFQ output distribution. Different simulations prove that lower values of α are desirable as input for this lattice. In the particular simulations presented in Fig. 1, this corresponds to end-cell values between 50 and 60mm. Therefore, it is recommended that RFQ includes a transition cell to obtain a symmetric output beam.

BUNCHER CAVITY

A prototype for the 352.2 MHz CCL type buncher cavity [2] was machined in stainless steel, characterised using a tridimensional metrology system (see Fig. 3) and thoroughly characterised by means of an RF bead pull system. Although, metrology report confirmed that machining in the lower ends of the cavity were substantially out of specs; in the critical nose-cone region, metrology report shows that surface flatness was within tolerances (92 μm), but distance between them was found to be 14% off its expected value. Such problem was solved using a pre-calibrated corrector ring. This ring was latter used in the RF bead pull measurement campaign. For this RF characterisation, three different dielectric beads were employed (Macor, Glass, Teflon). The form fac-

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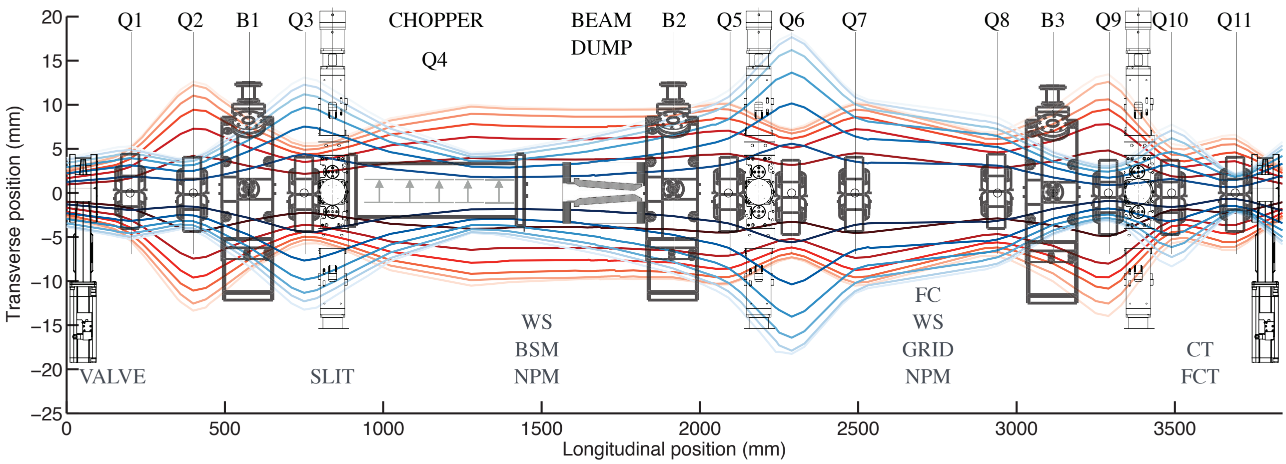

Figure 2: 2014 Layout proposed for the ESS MEBT; comprised of 11 quadrupoles 3 bunchers and 3 collimators [4]. Power density contours for x (*red*) and y (*blue*) are represented from dark (10^3 W) to light (10^{-2} W) beam power contour lines extracted from TRACEWIN. Both axis are expressed in mm.

tor of each bead was deducted using a well known pill-box cavity. Overall, measured figures of merit of the buncher cavity showed a good agreement with those provided by full-wave electromagnetic simulations [5]. In parallel, a new electromagnetic design is in progress to fulfil new specifications. Increasing transported beam energy and current affect primarily to transit time factor and required effective voltage, which increases up-to 146 kV for the last buncher under nominal conditions. In order to reach required performance in the available space, optic design has been adapted to allow a lower aperture for the bunchers (Ø29 mm).

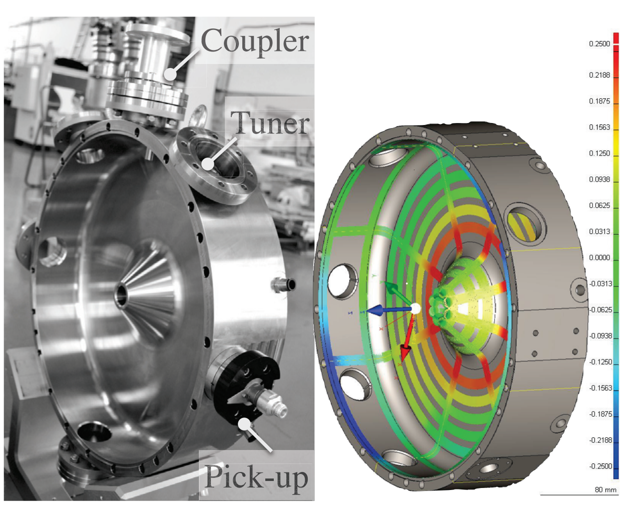

Figure 3: **Left:** Picture of the *AISI 304* buncher prototype after machining. **Right:** 3D metrology corresponding to *Body* part of the prototype. Colorbar scale represents measured deviation respect to drawings values, in mm.

QUADRUPOLE

Changes adopted in the ESS linac impacted directly on MEBT layout, leading thus to a new set of requirements for the quadrupoles, summarised as follows: Ø41 mm aperture, $\int B = 2.5$ T with 100 mm maximum physical size (length) and ~15 G.m deflection for the steerers. With these new values, two alternatives were studied. Fig. 4 shows both: Steerer Coils In (SCI) and Steerer Coils Out (SCO) approaches. Although each configuration covers a different physical space, within the beam aperture they both provide virtually identical magnetic results. The foreseen strip-line BPM can fit in both designs as well as the required four fiducial points at the top of the yoke.

Nevertheless, the SCO approach seems more adequate than the SCI. In the latter assembly, the yoke has to be transversely larger (about ~13%), to include the additional steerer coils that enclose the poles. These additional coils are also longer than in the SCO case, demanding higher electric power. Finally, the SCO configuration would allow a 2 sec-

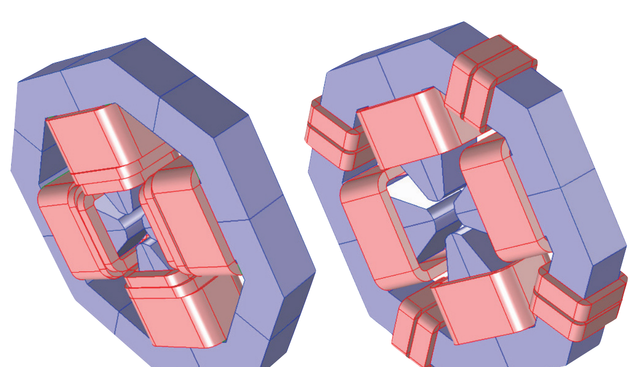

Figure 4: 3D models of proposed Steerer Coils In (**Left**) and Steerer Coils Out (**Right**). Coils are represented in red.

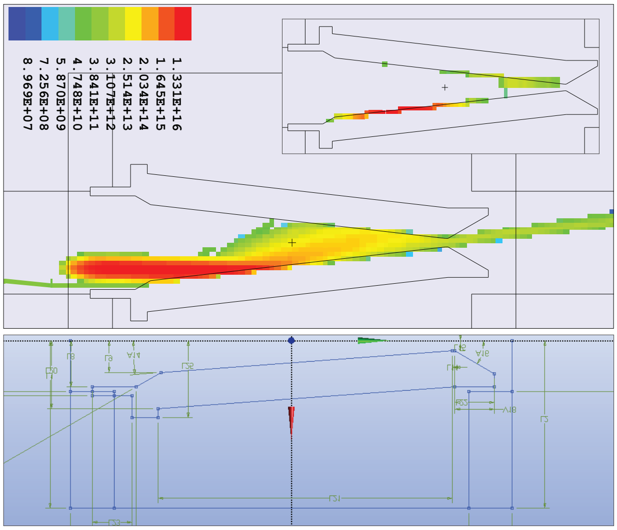

Figure 5: **Top Frame:** Side view of 62.5 mA 3.62 MeV proton flux density impacting on the beam dump. Onset figure indicates resulting heat map. **Bottom Frame:** Parametric representation of the beam dump.

tor mechanical assembly, whereas the SCI constricts to a 4 sector mounting.

CHOPPER AND BEAM DUMP

The foreseen *kicker* is required to deflect a 20μs fraction of the beam for a 14 Hz repetition rate for a 10 ns rise time. In a worst case scenario, machine protection system also expects a 1 ms train of bunches to be deflected against the beam dump. In order to prevent excessive heat deposition on the beam dump, Ion source magnetron should be used as an actuator [6]. Several solutions have been studied including the fast chopper solution at SNS, Linac-4, J-PARC, ISIS-FETS and Project-X. With the given requirements we focused on two: ISIS fast switching electrostatic approach and Linac-4 meander-line kicker structure as baselines. The TM RF cavity deflector, from J-PARC, was discarded from the study, due to the large space required for installation [7]. Once required rise time was relaxed significantly (10 ns) [8], an approach based on fast high voltage switches seemed to be the most reliable approach; due to its resistance to beam spills and much simpler fabrication. Partial deflected beams that exceeds 10 ns rise time requirement can be avoided by dividing the deflecting plates into sectors that would be activated with beam velocity. Length of each sector is determined by distance between bunches. $l \leqslant \beta c/f$. In our case, $l \leqslant 74.31$ mm. In order to avoid unwanted effects on pulse shape, special attention must be put in the slow pulse generators layout.

In order to optimise beam dump shape, main characteristics have been parameterized: inner cone angle, input and output beam aperture and wall thickness. Although different materials are under study, GLIDCOP AL60-LOX [9] poses as best candidate due to its high conductivity, resistance to radiation, thermal embrittlement and high temperature strength. A code has been developed *in-house* to combine TRACEWIN format as input beam distribution with an ANSYS geometry, to be meshed and simulated within MCNPX environment. Preliminary results indicated that beam deposition was very shallow. As Fig. 5 shows, depending on the beam impact conditions, a small fraction (0.13 %) of beam might be scattered downstream, which should be avoided.

SUMMARY

Presented results are part of the significant work that is being developed to adapt focusing and interceptive components to new requirements. Current layout allows the matching of the incoming beam; supplying room for both chopping system and beam instrumentation. Mechanical constrains have been taking into consideration, allowing a mountable vacuum tight system that can be aligned. An SCO type quadrupole prototype will be launched soon to confirm estimated quality field and performance. Buncher cavity will be copper-plated to ensure field quality and RF power specifications are fulfilled.

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