COMMISSIONING PLANS FOR THE ESS DTL

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Abstract

The Drift Tube Linac (DTL) of the European Spallation Source (ESS) is designed to operate at 352.2 MHz with a duty cycle of 4% (a beam pulse of 2.86 ms, 14 Hz repetition rate) and will accelerate a proton beam of 62.5 mA pulse peak current from 3.62 to 90 MeV. This article describes the commissioning strategy plans for the DTL part of the linac, techniques for finding the RF set point of the 5 Tanks and steering approach. Typical beam parameters, as proposed for commissioning purposes, are discussed as well and how the commissioning sequence of the Tanks fits together with ongoing installation works in the tunnel.

INTRODUCTION

In the ESS accelerator the initial warm linac section is composed by Ion Source, Low Energy Beam Transport line (LEBT), Radio Frequency Quadrupole (RFQ), Medium Energy Beam Transport line (MEBT) and DTL [1].

Table 1. DTL Main Parameters

Tank	1	2	3	4	5
Cells	61	34	29	26	23
E0 [MV/m]	3.00	3.16	3.07	3.04	3.13
L [m]	7.62	7.09	7.58	7.85	7.69
R Bore [mm]	10	11	11	12	12
LPMQ [mm]	50	80	80	80	80
BPM	6	3	2	2	2
EMD	12	6	4	4	4
PMQ	30	16	14	13	11
Ptot [kW]	2191	2191	2196	2189	2195

INFN-LNL is in charge of the design and production of the DTL [2]. The DTL is a 38.8-m long system, divided in five Tanks. Each Tank is a standalone structure, composed of four 2-m-long modules made of AISI 304L stainless steel with internal electro-copper deposition.

The Drift Tubes are positioned in the girder, a precisely machined aluminum alloy structure, which is housed in the upper part of each module. Drift Tubes (DT) are equipped with various components: Beam Position Monitor (BPM), Electro Magnetic Dipole (EMD), and Permanent Magnet Quadrupole (PMQ). The PMQs are placed in the F0D0 layout. The BPM and EMD are placed in the empty tubes. An ACCT as Beam Current Monitor (BCM) is present in each inter-tank section, installed in the end plates where PMQ are not present as shown in Fig. 1.

The main DTL parameters and final distribution of elements Tank by Tank are reported in Table 1.

In the next paragraphs, the authors describe a scientific proposal for the ESS DTL commissioning, developed in order to verify the required performances of the machine. At present time, this plan of measurements is not the reference-commissioning plan of ESS.

ESS DTL INSTALLATION AND COMMISSIONING SEQUENCE

The installation and commissioning of the ESS linac will start in 2017 and the first proton beam at 570 MeV is scheduled to be delivered to the target by the second quarter of 2019. Further details of the overall commissioning plan can be seen in [3]. Commissioning of a large-scale machine, such as the ESS linac, within a relatively short time imposes challenges on many areas including planning and preparations for the beam commissioning.

Each DTL Tank will be assembled and tuned in the ESS RATS facility. Vacuum and cooling systems will be tested in the RATS as well. DTL Tank will be then transported to the tunnel and aligned in its final position, where the high power RF conditioning will take place. The sequence of Tank installation in the tunnel will be Tank4, Tank1, Tank3, Tank2, and Tank5.

The ESS DTL will be commissioned with beam in 3 phases:

1. First phase, Tank1 will be commissioned, using the diagnostic plate already used for 3.62 MeV commissioning. For this reason, Tank2 cannot be installed and conditioned before this phase, while RF conditioning of Tank3 and Tank4 can in principle proceed during Tank1 beam commissioning.
2. During the second phase, Tank2 to Tank4 will be commissioned.
3. Third phase is the full commissioning out of Tank5.

EMD AND BPM DISTRIBUTION

EMDs and BPMs have been recently redistributed inside the 5 Tanks, in order to have more BPMs and EMDs and ease the beam steering in Tank 1, where the phase advance per cell is much larger than the other tanks and a small number of BPMs and EMDs could cause an overshooting issue. The first BPM is located before the first EMD in order to set up the last MEBT elements (Figure 1).

The constrains of this analysis were to keep 15 BPMs and 15 EMDs pairs in the DTL section and to have at least 2 BPMs per Tank for time-of-flight measurement.

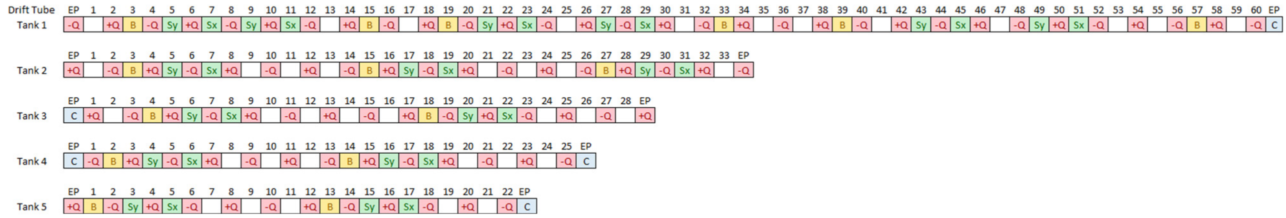

Figure 1: PMQ (-/+Q = defocusing/focusing effect for proton beam in the Horizontal plane), BCM (C), BPM (B) and Steerers (Sx/Sy = Horizontal/Vertical deflection of proton beam) distribution in the 5 Tanks. EP identifies the End Plates of Tanks.

The statistical analysis shows a relevant impact of steering the beam on the emittance growth, while the effect in the beam transmission trough the DTL can be neglected if compare to the emittance [4].

BEAM COMMISSIONING PLAN

After 3.62 MeV section commissioning, the MEBT beam will be characterized, and matching conditions for the injection into DTL section will be determined using the diagnostic plate.

The main goals of the Tank1 commissioning are to determine the operational values of the cavity phase and the RF amplitude, as well as to confirm the correct beam dynamics through the DTL Tank1 permanent magnet focusing system.

A guess value of the nominal RF amplitude is obtained by the pick-up measurements performed during RF conditioning phase, where calorimetric power measurements are used as benchmark of RF measurements.

Figure 2 shows the transmission as function of the phase scan for the Tank 1. This graph shows that it is possible to define in a rough way the phase by looking at the DTL transmission. This technique can be useful to counter check the correct phase setting and to paint the longitudinal phase space of the beam in order to verify the DTL phase acceptance [5]. Nevertheless, the curves for different field level do not allow an accurate determination of the nominal field amplitude.

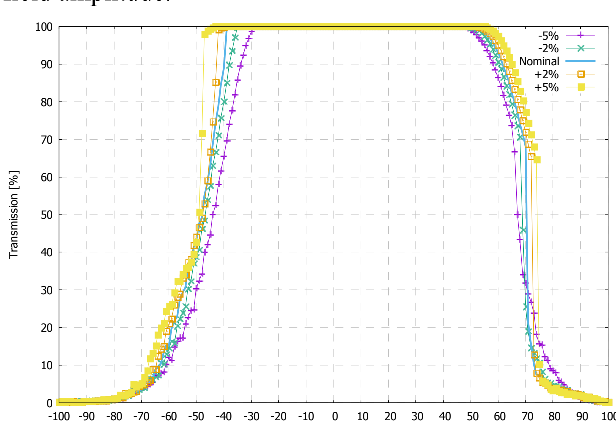

Figure 2: Transmission of Tank1 at different field level as function of the phase scan.

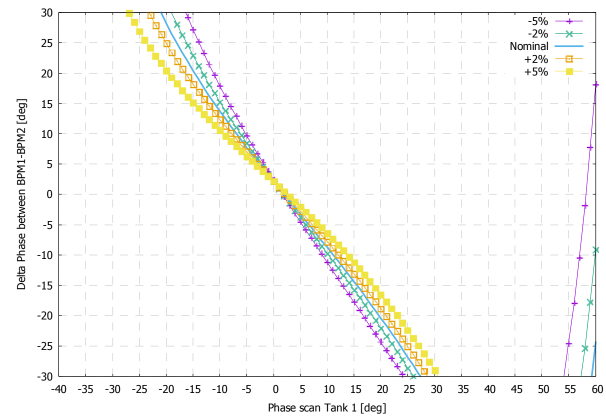

Figure 3: phase scan of Tank1 looking to BPM1 and BPM2 inside Tank1 (reference phase is 0 deg).

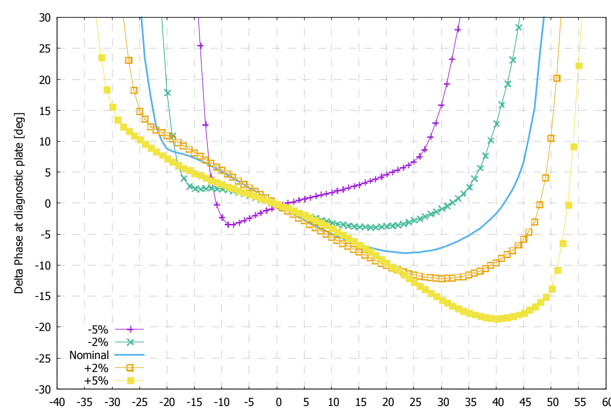

Figure 4: phase scan of Tank1 looking the induced phase shift between two external BPMs, located 1.06 m apart each other (around 6 βλ).

The precise RF set point is determined by phase scan method [6]: one observes the beam induced phase difference between BPMs, as a function of RF phase and repeats this scan for different RF amplitudes.

Figure 3 shows the induced phase difference observed between internal BPMs in Tank1, where the reference phase is 0 deg. Figure 4 shows the phase difference observed between two external BPMs, located downstream Tank1, 1.06 m apart each other. The different RF amplitudes result in curves that are much more distinguishable in Fig. 4 than in Fig. 3.

This effect is due to the phase stability principle itself: for small difference of RF amplitude, inside the DTL cavity

ISBN 978-3-95450-169-4

turned on, particle motion is maintained stable on energy inside the separatrix. If the BPMs are external, the small difference in energy due to RF amplitude and phase are amplified by the distance between BPMs.

Constraints on the emittance growth along the ESS linac are very demanding [4] and, on the DTL section, beam simulations show that the largest emittance growth happens inside Tank1 [7]. The experience of other important projects (CERN Linac3, SNS DTL, CERN Linac4) recognized beam commissioning of DTL tank1 as the most critical of all DTL tanks. Then for DTL tank1, an adequate characterization of the beam is recommended.

Simulations can be compared with emittance measurements performed with an emittance meter placed on the diagnostic plate after Tank1, in order to confirm the MEBT quadrupole setting and the beam dynamics design through Tank1. Moreover, the longitudinal matching given by the correct MEBT buncher setting can be verified after Tank1 with the acceptance scan method done at different buncher configuration [4].

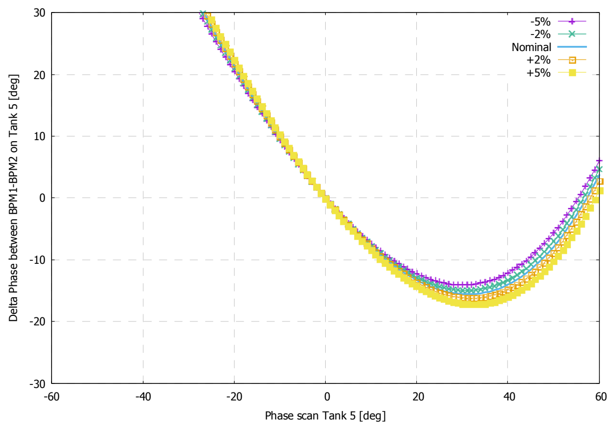

Figure 5: Phase scan of Tank5 looking to internal BPMs.

Table 2. DTL Commissioning Plan

Tank	Phase	Field	Emittance	Transmission
T1	D-plate	D-plate	D-plate	BCM T1, D-Plate
T2	BPM T3	BPM T3	-	BCM T3
T3	BPM T4	BPM T4	-	BCM T4in
T4	D-plate	D-plate	-	BCM T4out, D-Plate
T5	D-plate	D-plate		BCM T5, D-Plate

Once Tank1 has been commissioned and the D-plate has been replaced by Tank2, DTL commissioning will proceed, using in-line diagnostics up to the end of Tank4. The RF set point in amplitude and phase will be determined by phase scan method for Tank2 and Tank3, looking to the BPM located in the next tank turned off.

Simulations show that transmission out of Tank3 is better than 99.9% for the entire phase and amplitude scan of Tank2, which makes acceptance scan technique difficult to implement for second and third DTL beam commissioning phases.

As explained in the previous paragraphs, RF set point of Tank4 and Tank5 requires external BPMs (Fig. 5).

In order to have a counter calibration of the BCMs after each Tank, the diagnostic plate should be equipped with a Faraday Cup with proper power range for 90 MeV beam commissioning.

CONCLUSIONS

This paper proposes a commissioning plan for the ESS DTL, which takes into account the installation and commissioning sequence harmonized with the rest of the linac. The measurement steps described along the paper and summarized in Table 2, constitute the minimum set in order to verify the DTL performances as ESS project requires.

REFERENCES

[1] M. Eshraqi *et al*, "ESS linac beam physics design update", MOPOY045, in *Proc. IPAC16*, Busan, Korea, paper MOPOY045, p. 947.

[2] F. Grespan *et al*, "ESS DTL design and drift tube prototypes", in *Proc. LINAC14*, Geneva, Switzerland, THPP086, p. 1047.

[3] R. Miyamoto *et al*, "ESS LINAC plans for commissioning and initial operations", in *Proc. HB2016*, Malmö, Sweden, TUPM5Y01, p. 342.

[4] F. Grespan *et al*, "ESS DTL status: critical design review and start of production phase", LNL Annual Report 2015.

[5] V.A.Dimov *et al.*, "Beam commissioning of LINAC4 up to 12 MeV", in *Proc. IPAC2015*, Richmond, VI, USA, THPF085, p. 3886.

[6] Dong-o Jeon, "Comparison of phase scan VS acceptance scan for the SNS DTL", in *Proc. LINAC06*, Knoxville, TN, USA, TUP070, p. 415.

[7] M.Comunian *et al*, "ESS DTL Beam Dynamics Comparison between S-Code and T-Code", paper TUPRC002, this conference.