EMITTANCE MEASUREMENT WITH DOUBLE-SLIT METHOD IN CADS INJECTOR-I*

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Abstract

The CADS accelerator is a CW (Continuous-Wave) proton linac with 1.5 GeV in beam energy, 10 mA in beam current, and 15 MW in beam power. CADS Injector-I accelerator is a 10-mA 10-MeV CW proton linac, which uses a 3.2-MeV normal conducting 4-Vane RFQ and superconducting single-spoke cavities for accelerating. The 5MeV test stand of CADS accelerator Injector I is composed of an ion source, a LEBT, a 325MHz RFQ, a MEBT, a cryogenic module (CM1) of seven SC spoke cavities (β=0.12) , seven SC solenoids, seven cold BPMs and a beam dump line. Emittance measurement is very important for the understanding of beam behaviour and matching to the next accelerating section. Detailed emittance measurement with double-slit method after CM1 are presented in this paper.

INTRODUCTION

The ADS project in China (CADS) is a strategic plan to solve the nuclear waste problem and the resource problem for nuclear power plants in China. For the C-ADS accelerator that is a CW proton linac with the proton beam of energy 1.5 GeV and current 10 mA [1]. The C-ADS accelerator uses superconducting acceleration structures, except for the RFQs and is composed of two major accelerating parts: the injector and the main linac. For the first phase, the project goal is to build a CW proton linac of 25 MeV. The first phase itself will be executed progressively in several steps, with the first step to build two 5-MeV test stands of different front-end designs. After the beam commissioning of RFQ accelerator and Test Cryogenic Module (TCM) for injector-I in IHEP, we have finished the beam commissioning of CM1 (Cryogenic Module 1) test stand shown in Fig 1, which is composed of an ion source, a LEBT, a 325MHz RFQ, a MEBT1, a cryogenic module (CM1) of seven SC spoke cavities (β=0.12), seven SC solenoids, seven cold BPMs and a beam dump line [2].

Emittance measurement is very important for the understanding of beam behaviour and matching to the next accelerating section. In CM1 test stand, we measured the transverse emittances at MEBT1 with quadrupole scan method by wire scanners and measured the transverse emittance after CM1 with the emittance monitor which is a conventional double-slit type. Detailed emittance measurements with double-slit method after CM1 are presented in this paper.

DOUBEL-SLIT METHOD

The emittance monitor was a conventional double-slit type to measure the transverse emittances after CM1. In this method, two issues are important: One is the measurement grid and another is the noisy of measured signal. The noisy of measured signal will affect emittance measurement greatly in double-slit method, so we should analysis the influence of noisy to get reasonable measurement results.

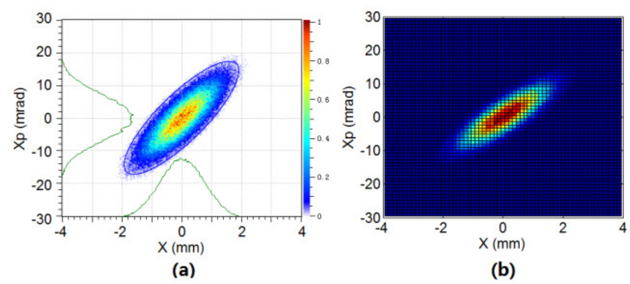

Figure 2: (a) The 3 standard deviations Gaussian distribution; (b) Gridding distribution into 64×64.

To determine the measurement grid and the threshold of signal, we use one 3 standard deviations Gaussian distribution as the research case, which is shown in Fig 2 (a). We have calculated the emittance and twiss parameters at different gridding cases shown in Table 1, where the gridding range are [-4 4] mm and [-30 30] mrad and Fig 2 (b) shows the gridding distribution into 64×64. According to the results, consider the measuring accuracy and measuring time, we have adopted 64×64 gridding case.

To analysis the threshold of signal, we add a random noisy distribution to the 64×64 gridding case, where the noisy distribution is uniform and maximum noisy signal is

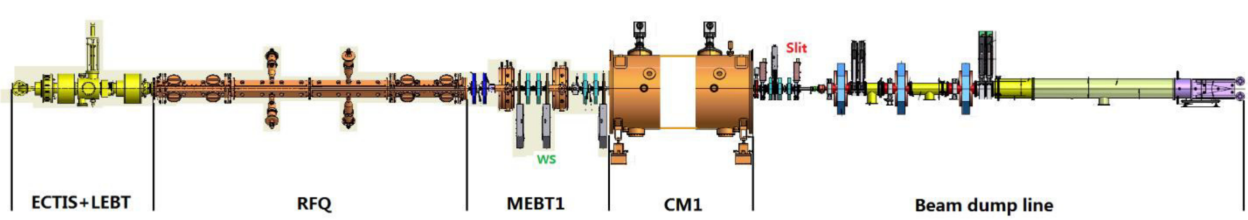

Figure 1: Layout of the CM1 test stand.

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Table 1: Emittance and Twiss Parameters at Different Gridding Cases

	ε	α	β
Unit	π mm.mrad		m
Original	0.2000	-1.50	0.200
16×16	0.2224	-1.35	0.188
32×32	0.2057	-1.46	0.197
64×64	0.2015	-1.49	0.199
128×128	0.2003	-1.50	0.200

3% of maximum "measured" signal. Figure 3 shows emittances as function of threshold of signal. Here we proposed a new method to decide the threshold: one get the second derivative of emittance or α or β as functions of threshold, then get a threshold to make this value smaller or changes smoothly, which one is the threshold we wanted and we can get the emittance and twiss parameters. According to the analysis shown in Fig. 4, we got the threshold is 3 % same as the set value. From the results, we can get the emittance is 0.1783 π mm.mrad, beta is 0.198 m and alpha is -1.48 for one case. Although the emittance and twiss parameters are slightly different for different noisy distribution, one can get that twiss parameters are close to original value and the emittance is smaller. The smaller emittance by the processing method is obvious, because that we minus one constant noisy value. When the distribution have halo particles, the emittance measured by this method is close to core emittance.

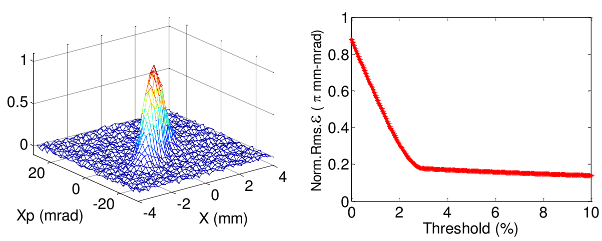

Figure 3: "Measured" distribution with noisy (left) and emittances as function of threshold of signal (right).

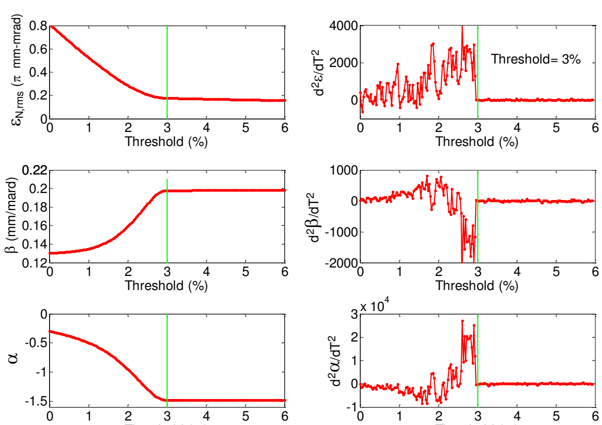

Figure 4: Emittance, beta function, alpha (left) and the second derivatives (right) as functions of threshold of signal.

EMITTANCE MEASUREMENT

The emittance monitor was installed at the exit of CM1 and there are three quadrupole magnets between the two slits. For convenience and simple we closed the three quadrupoles when we measured emittance. To prevent melting of the edge of the slits, the emittances of the 10-mA beam were measured with a width of 30 μs and a repetition rate of 2 Hz. The beam energy was measured as 5.98 MeV with the time of flight method by two FCTs.

After the cavity phase scan, we measured the emittance at CM1exit. Using the above mentioned method, one can get the emittance and twiss parameters. Figure 5 shows the analysis of the measured emittance and twiss parameters in vertical plane, and one can get the threshold of noisy is 3.2%. Figure 6 shows the distribution in phase space for the simulations and measurements. For the measurement the cavities' and magnets' settings were based on the twiss parameters by RFQ simulation, which was different from the actual case [3]. So the measured emittances were under large mismatch and one cannot simulated very well.

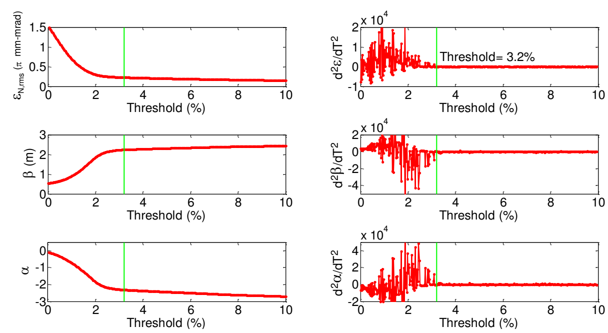

Figure 5: Emittance, beta function, alpha (left) and the second derivatives (right) as functions of threshold of signal.

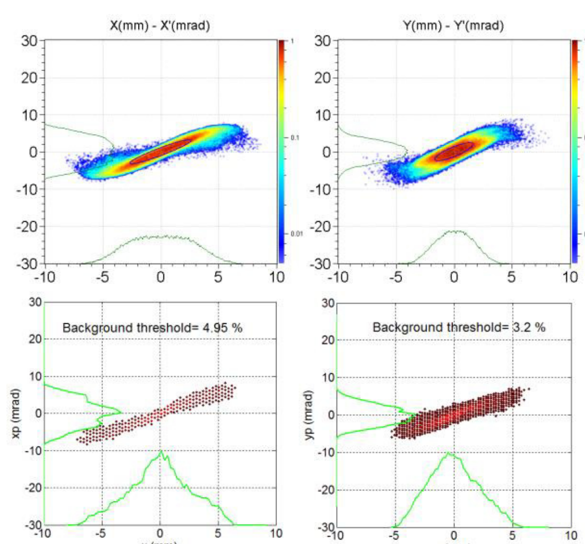

Figure 6: Distribution in phase space for simulation (up) and measurement (down).

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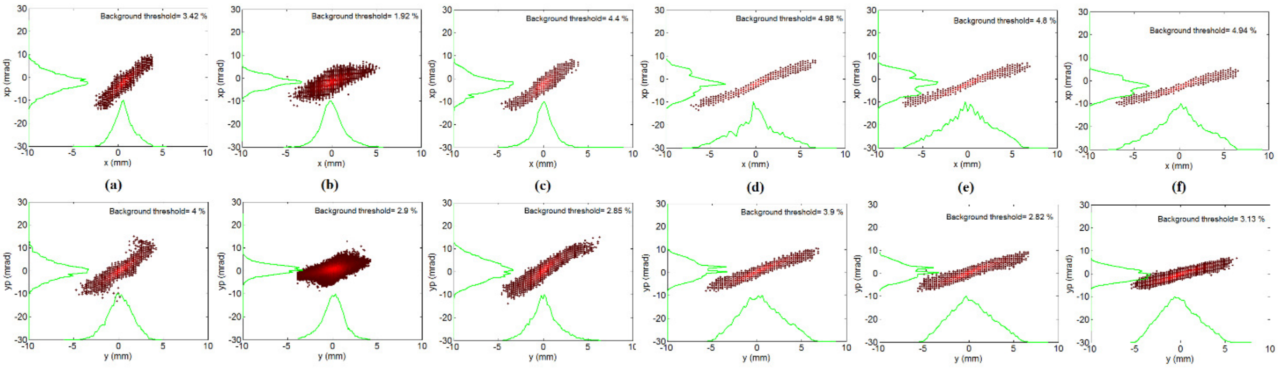

Figure 7: Distribution in phase space with different transverse focusing settings. (a) Solenoid current equal to 133 A; (b) Solenoid current equal to 143 A; (c) Solenoid current equal to 153 A; (d) Solenoid current equal to 164 A; (e) Solenoid current equal to 168 A; (f) Solenoid current equal to 170 A.

We have measured the distribution is phase space with different transverse focusing settings, shown in Fig 7, left to right shows solenoid current 133 A, 143 A, 153 A, 164 A, 168 A and 170 A. Fig 8 shows the measured emittance with different solenoid settings. The distributions in one dimensional real space were irregular distribution and the measured emittance varied largely, so we can infer that there were very large mismatch. In all the settings the measured twiss parameter α with same sign also exceeded expectations, especially for the solenoid current equal to 133 A case. According to the analysis, we need more measurements and simulations to explain the experiment results.

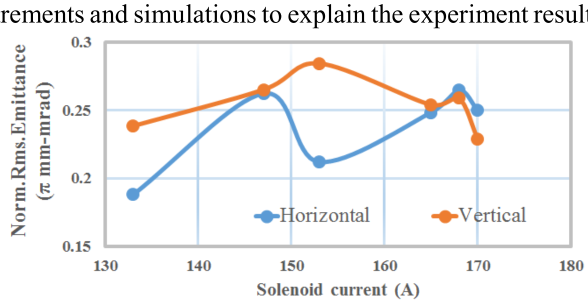

Figure 8: Emittance with different solenoid settings.

CONCLUSION

The 5-MeV CM1 test stand composed of an ECR ion source, LEBT, RFQ, MEBT, CM1 and beam dump have been installed and the first stage of beam commissioning have been finished at IHEP. The energy after CM1 was measured as 5.98 MeV by TOF method with FCTs. The transverse emittance at CM1 exit have been measured by double-slits emittance monitor. In this paper, the method and data processing have been discussed detailed and the measurement results was presented. We need more measurements and simulations to explain the experiment results.

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