Response letter

We appreciate the referee for pointing out many inappropriate descriptions and typos, which benefit improving this paper. According to the referee's report, we have made some modifications. More details are shown in the point-to-point response below.

The authors have made adequate revisions in reply to my original comments.
I have only few minor comments:

1. Session 2

"The pulse is constant for all shots shown in this paper. A 105 GHz/500 kW/1s ECH system was ~~developd~~ developed in 2019."

Please add a reference, if any.

Reply: We have revised this typo and added a latest accepted paper as reference: Xia, Donghui, et al., Plasma Science and Technology 24(12), 124010 (2022).

2. End of session 3.1

" The estimated connection length is 1590 m, which ~~is possible~~ allows to achieve a successful breakdown in a large prefill pressure range"

Reply: Accepted.

3. Session 3.2

"It will lead to an extremely high breakdown (loop) voltage of about 34 V (E=5.2 V/m) ~~(#1068920 in figure 4)~~."

The authors have just finished the description of fig.2. And caption of fig 4 is clear. Maybe it is better to eliminate the reference of fig 4 here, before discussion on fig 3.

Reply: Accepted.

4. Session 3.2

"~~The following observations are found~~, when ECH power is applied, the electron density and hydrogen-alpha increase, 15 ms after the application of ECH power (but before the loop voltage). The ionization caused by ECH power can be explained by non-linear wave-particle interaction [10] Pre-plasma density ~~reveals the principle of low loop voltage startup. It~~ (which principle?) makes breakdown easier by generating more seed particles before the application of loop voltage. Less volt-seconds will be consumed for a lower breakdown voltage."

Reply: The recommended expression is much succinct and scientific. We have accepted it.

5. Session 3.3

It can be easily observed that high ECH power leads to quick ~~ionization~~ and high-intensity ionization during preionization phase, as shown in electron density and hydrogen-alpha radiation signals.

Reply: Accepted

6. Session 3.3

"For an electron cyclotron beam with Gaussian-like profile, ~~there will be a relationship of~~ it results: E∝

√P, where P and E are the incident electron cyclotron power and the wave electric field amplitude, respectively. It indicates that high ECH power leads to a high electric field. When ~~particles~~ electrons travel through the wave electric field area, they will be accelerated in a ~~more short~~ shorter time to gain enough energy to achieve ionization or to higher energy, which will promote ionization in turn.

A more accurate expression, proposed by Farina, shows the ~~relationship of~~ maximum energy gain of an electron ~~can~~ at second harmonic ~~obtain is~~ as Wmax,n=2 ∝ √ P in non-linear interaction[10]. We can deduce the minimum required ECH power to achieve ionization. However, besides the ionization, if this energy is sufficiently large, in the trapping region, the energy transfer exceeds the energy needed to ionize the neutral ~~paricles~~ particles(?) in the pre-fill ~~pas~~ gas(?)"

This section 3.3 describe the effect of EC power on ionization phase first, and then on burn-through. The model in reference [10] provides a description for pre-ionization by ECH. When the electron energy gain is in the range of 60 eV, i.e. where the H ionization cross-section is maximum, one can have an estimation of the minimum power needed for ionization to occur, knowing the EC beam injection condition. Did you try to calculate?

From " ECH power is also important after the application of loop voltage…." This part is not clear.

At the beginning of sec 3.3 the "critical ECRH power" is defined as the power for both ionization and initial burnthrough: " It aims to search for the critical ECH power not just to achieve pre-ionization but for this ionization to be sufficient to effectively support the entire plasma initiation process."

But then, authors say: " It is easy to observe in Figure 5 that shot #1073819 fails while shot #1073820 succeeds, illustrating that the critical ECH power is approximately 200 kW" where it seems that critical ECH power is only for successful pre-ionization. Is that correct?

Specifically, which claim the authors want to support? the power of 200kW found experimentally is to sustain which phase? Given the results of Fig 5 (at low power level, 200kW, in blue, the pre-ionization is effective, but the subsequent plasma phase fails), the authors seem to support the fact that the critical ECH power to obtain ionization could not be sufficient to form high quality pre-plasma, that is not consistent with initial statement. Please consider to rephrase.

Reply: We have accepted all the recommended revision.

The minimum power can be estimated by equation (1). For J-TEXT, n= 2, f= 105 GHz, w= 38.4 mm. Given W_{max}= 60 eV, $N_{//}$=0, the minimum ECH power for ionization is about 13 kW. We have added this ECH power into the revised manuscript: We can deduce the minimum required ECH power of about 13 kW to achieve ionization on J-TEXT.

$$W_{\max,n=2} \cong 2.1\frac{P^{1/2}}{fw\left(1-N_{\parallel}^{2}\right)^{1/2}} \qquad (1)$$

The ECH assisted start-up considers the entire start-up process. The 200kW is an estimated critical power for a successful ECH assisted start-up. We can estimate it from some physical characterizations. It can be observed from figure 5 that for shots #1073819 and #1073820, some parameters, such as plasma current, line-integrated density at the core and the loop voltage, are nearly the same before t=7 ms. Plasma current of shot #1073820 ramps up smoothly toward the pre-set value of 180kA. However, the plasma current of shot #1073819 drops down as it nearly reaches about 10 kA. These two shots indicate the critical power for assisted start-up is between 200 kW and 250 kW. As the plasma current of shot #1073819 ramps up to about 10 kA, it is possible to achieve a successful start-up if the

injected ECH power is larger, which can form a better pre-plasma at higher density and temperature and a wider area, and provide more power for tokamak plasma. Hence, the critical power for the ECH assisted start-up is 200 kW. Strictly, more shots with different ECH power can provide a more accurate value. Limited by shots, we estimate this value from physical characterizations.
We use the above expressions to rephrase these sentences.

7. Session 3.3

“Here is a preliminary quantitative analysis.” why quantitative?
Reply: We have replaced it with “qualitative”.

8. Session 3.4

“For shot #1068928, ECH power is the highest, and the ECH pulse lasts for 36 ms. Its density and hydrogen-alpha appeared first. However, the intensity, especially hydrogen-alpha, is not the highest.”
Have you also considered that in shot #1068928 the ECH stops before the application of loop voltage (at 8 ms, while all the others last up to 10 ms)?
Reply: For shot #1068928, the loop voltage is applied at t=~1 ms, while ECH stops at t=8 ms. Hence, ECH stops after the application of loop voltage.
We also analyze the effect of switching off the ECH power at the last paragraph of section 3.4. The earlier shutoff of ECH power causes a failed start-up because of lack of input power.

“Proper ECH timing is important. High ECH power and long ECH pulse-width lead to failed discharge, while low ECH power and short ECH pulse width (shot #1068924) succeed. These results are similar to recent DIII-D studies on ECH pre-ionization.[12] “
In [12], the EC pulse duration is always 30 ms and the end of the pulse corresponds to the application of loop voltage. Can you clarify?
Reply: This sentence should be moved to the end of sentence “Lower ECH power (below critical power) will fail during burn-through because of a lack of input power.” We have done it.