

# Beam characteristics measurements of neutral beam injector in Versatile Experiment Spherical Torus by using commercial smartphone camera

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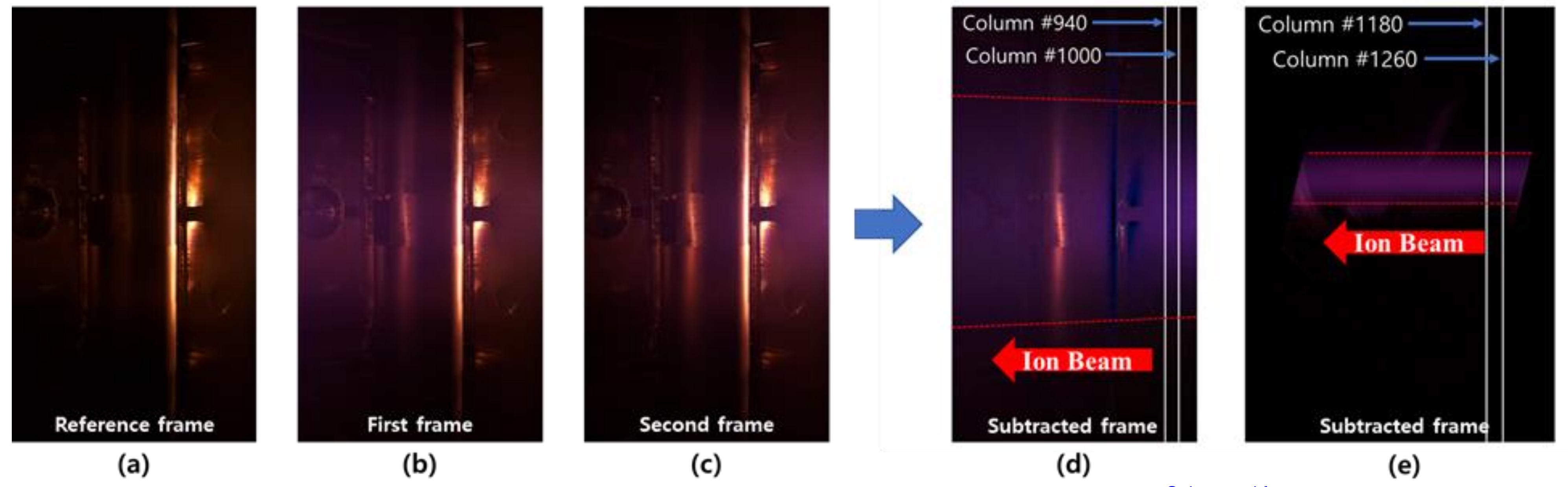
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**ABSTRACT** : This paper introduces a novel approach utilizing a commercial smartphone camera to measure the beam profile parameters such as size and divergence angle of the Neutral Beam Injector (NBI) in Versatile Experiment Spherical Torus (VEST). A simple and detailed image correction process is applied. The findings for the NBI operating at the beam energy of 8 keV and the beam current of 12 A include a beam height of 480 mm and a beam width of 114 mm at the beam dump, with vertical and horizontal divergence angles measured as 1.66° and 0.62°, respectively. These results agree reasonably well with the design values of the VEST-NBI system, which was designed and constructed by Korea Atomic Energy Research Institute (KAERI). This approach can be utilized as a simple beam monitoring diagnostics and extended as an advanced ion beam diagnostics for the design of new NBI systems by employing the high frame rate of smartphone cameras instead of an expensive, high-quality scientific camera.

## Introduction

- > **Motivation**
  - ✓ There is a need for direct measurements of the overall characteristics of the beam, such as cross-sectional distribution or divergence angles, to estimate its performance as heating and diagnostics role, which will be carried out after the power system upgrade of the VEST.
- > **Comparison with conventional method**
  - ✓ Typically, beam profile is measured using calorimeter. But, extraction time of VEST NBI (10ms) is relatively short to effectively heat up target calorimeter. This makes it difficult to use that conventional technique.
  - ✓ In addition, conventional divergence measurement requires expensive spectroscopic equipment. For more precise measurement it requires more than two measurement points.

## Analysis Technique

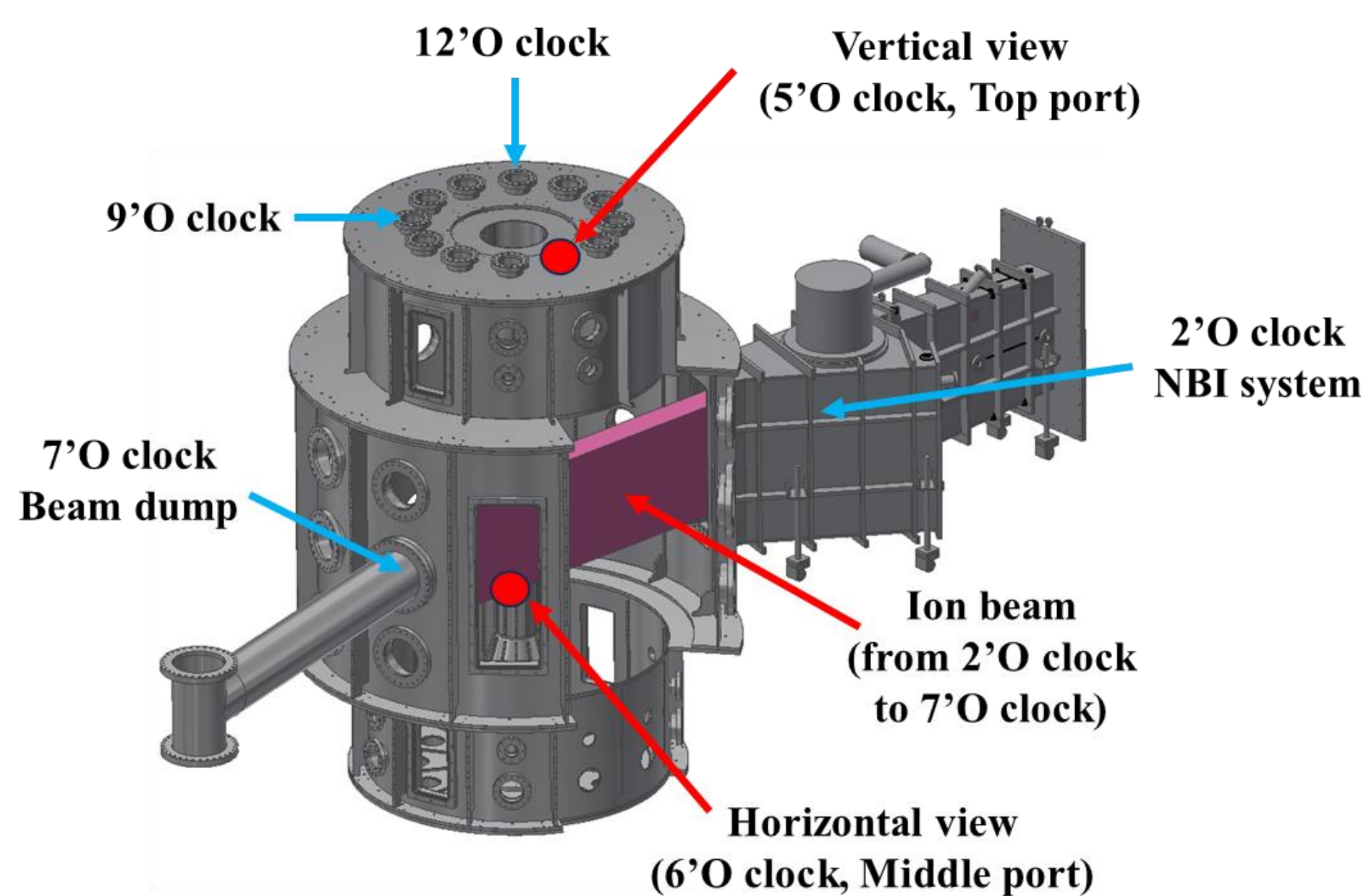


<Frames took from a single measurement>

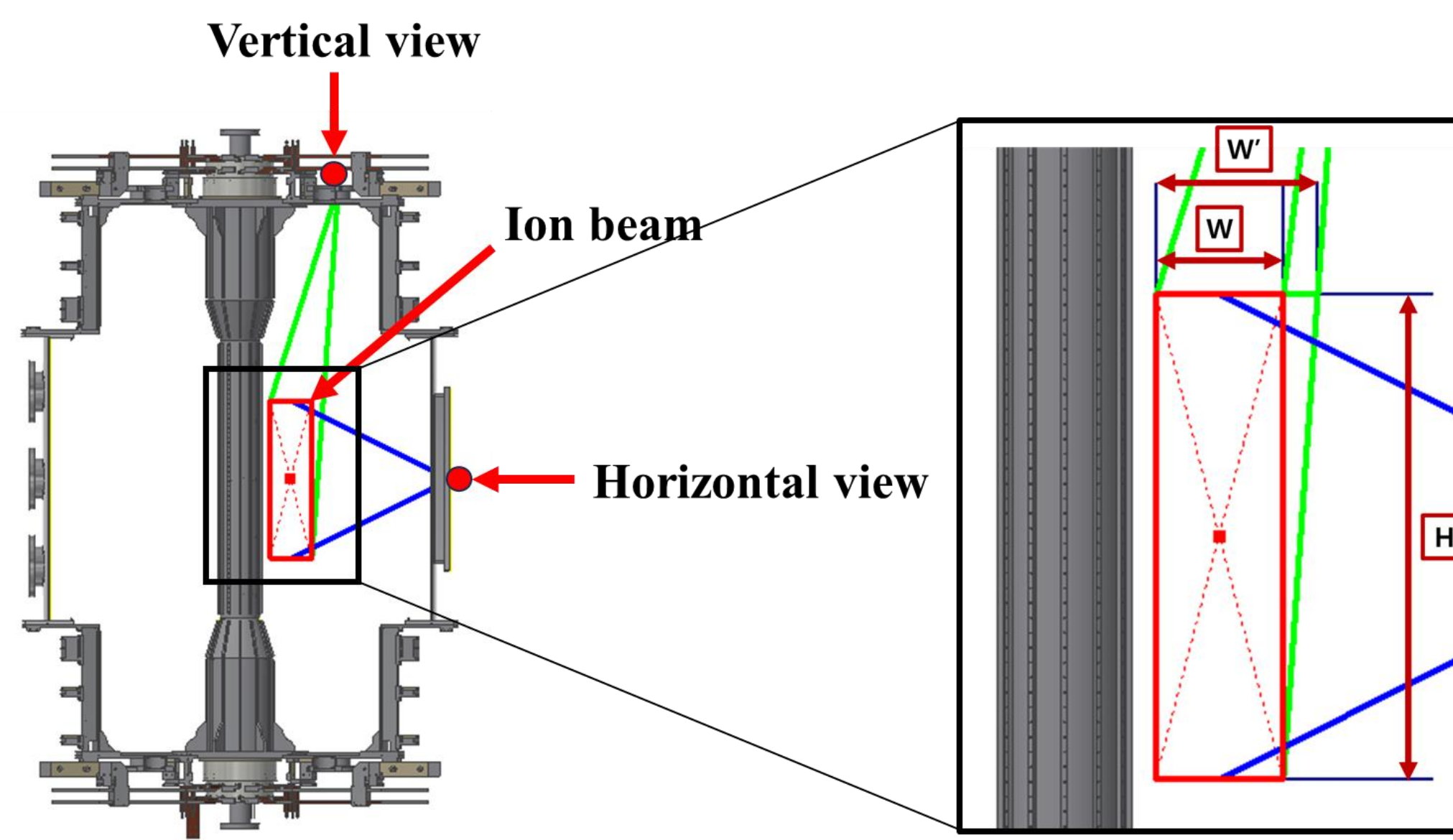
Each frame receive light for 16.67ms. So, light from the beam is captured in one or two frames. In above example case, light from the beam is captured in two frames.

(d) Subtracted frame is a frame which have get rid of effect of light from ion source. In this example case, it is calculated as follows: (b)-(a) + (c)-(a). (e) Example of subtracted frame of vertical measurement.

## Geometric Specifications & Experimental Setup

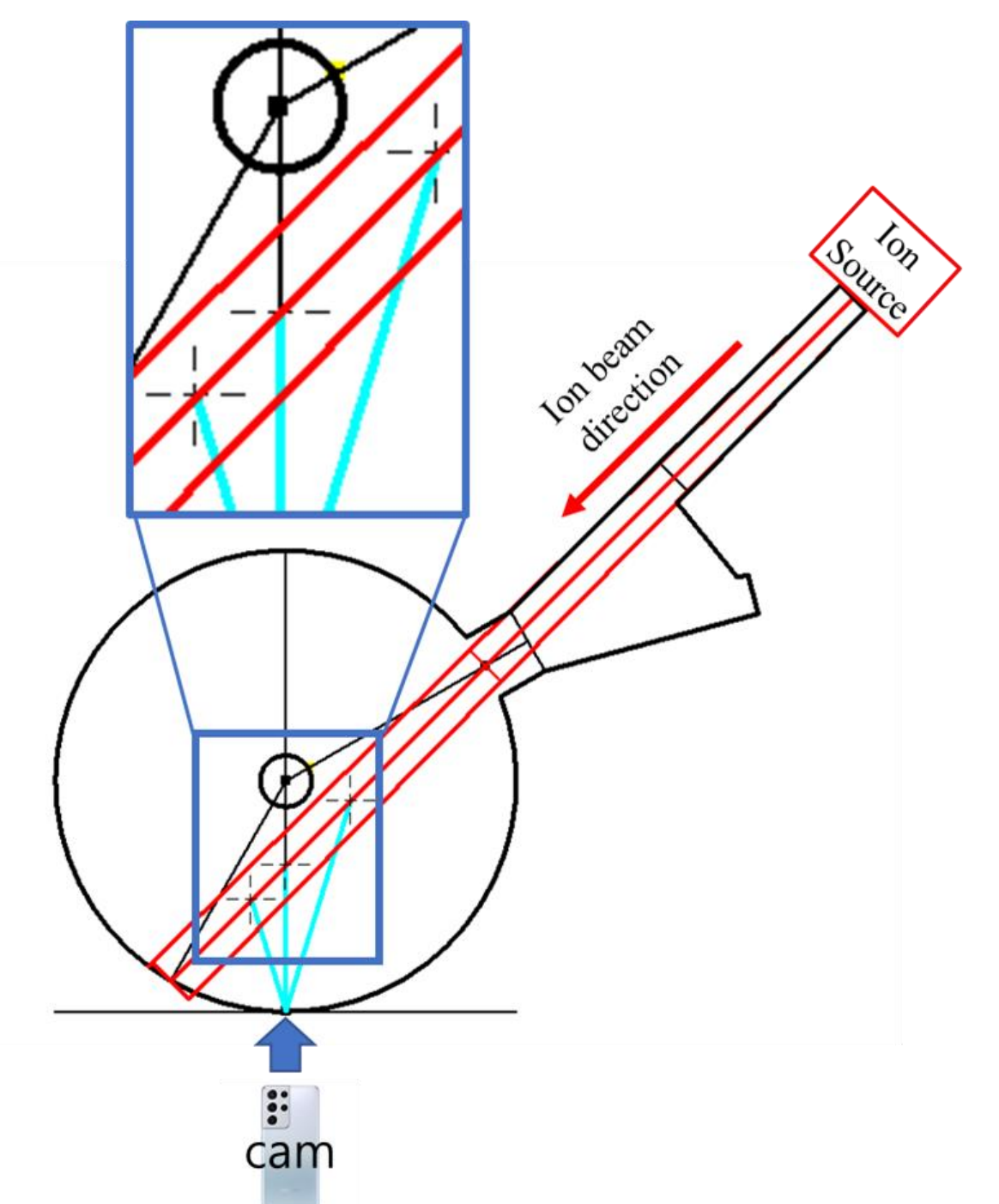


<Cross sectional view of VEST with NBI system>



<Vertical cross-sectional view of VEST and magnified view>

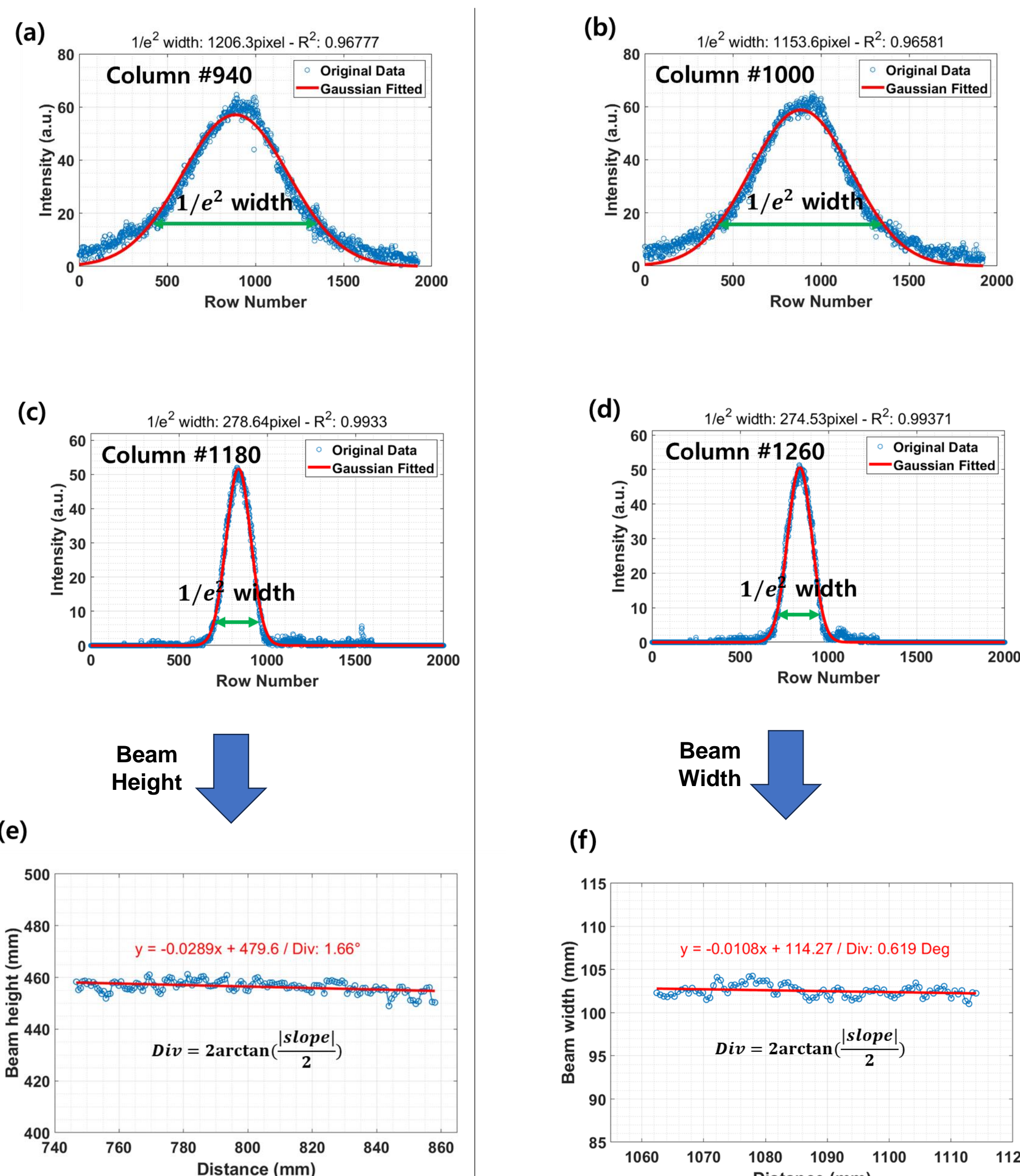
W is corrected beam width, W' is beam width calculated from raw subtracted frame, H is corrected beam height and H' is beam height calculated from raw subtracted frame



<Schematic top view of VEST chamber and magnified view>

The red lines denote ion beam. The cyan lines indicate the horizontal view of angle and distance from the center of the beam to camera, which should be considered when calculating the beam height.

## Results and Discussion



## Conclusion

- > Beam size and divergence angles of an 8keV, 12A ion beam from the VEST NBI was successfully measured using camera in smartphone and the results were somewhat in consistent with the simulation results from KAERI in the past.
- > It is noteworthy that even though there are cases of measuring beam size and divergence angles using optical cameras before, there is no precedent for using a commercial smartphone for the measurements. Since diagnostics using commercial smartphones requires less cost and effort than using another traditional optical diagnostics, future advances in visible plasma diagnostics in accordance with the improvement of smartphone camera are expected.

1/e <sup>2</sup> sized beam parameter	Measurement by Smartphone Camera	Simulation By KAERI [3]
Height at beam dump	480mm	570mm
Width at beam dump	114mm	179mm
Vertical divergence	1.66°	2.0°
Horizontal divergence	0.62°	1.0°

- References
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