

References

- [1] A. N. Andreyev, *Nature*, 405(2000)186.
 [2] R. Julin, *J. Phys. G, Nucl. Part. Phys.*, 43, 2(2016)024004 .
 [3] W. Q. Zhang, *Phys. Lett. B*, 829(2022)137129.
 [4] H. Huang, *Phys. Lett. B*, 833(2022)137845.
 [5] W. Q. Zhang, *Phys. Rev. C*, 106(2022)024317.

* Foundation item: Strategic Priority Research Program of Chinese Academy of Sciences (XDB34000000), National Key R&D Program of China (2018YFA0404402), National Natural Science Foundation of China (12135004, 11635003, 11961141004, 11735017 and U2032138). Chinese Academy of Sciences Presidents International Fellowship Initiative (2020VMA0017), U.S. Department of Energy, Office of Nuclear Physics (DE-AC02-06CH11357, DE-FG02-94ER41041 (UNC) and DE-FG02-97ER41033 (TUNL))

3 - 12 A Gas-filled Recoil Separator, SHANS2, at the China Accelerator Facility for Superheavy Elements*

Xu Suyang^{1,2}, Zhang Zhiyuan^{1,2}, Gan Zaiguo^{1,2,3}, Huang Minghui^{1,2}, Ma Long¹, Wang Jianguo¹, Zhang Mingming¹, Yang Huabin¹, Yang Chunli¹, Zhao Zhen^{1,2}, Huang Xinyuan^{1,2}, Chen Lixin^{1,4}, Wen Xiaojiang^{1,4}, Zhou Hao^{1,2} Jia Huan¹, Sheng Lina¹, Wu Jianqiang¹, Peng Xiaolong¹, Hu Qiang¹, Yang Jing¹, Yao Qinggao¹, Qin Yuanshuai¹, Yan Huaihai¹, Chai Zhen¹, Zhang Jianchuan¹, Zhang Yong¹, Du Ze¹, Xie Hongming¹, Zhao Bo¹, Sun Guozhen¹, Wang Fengfeng¹, Yuan Chenzhang¹, Wu Xiaolei¹, Chen Ruofu¹, Zhang Hongbin¹, Lu Ziwei¹, Yang Herun¹, Xu Xinxing¹, Chen Youxin¹, Feng Anhui¹, Sun Peng¹, Xu Junkui¹, He Yuan^{1,2,3}, Sun Liangting^{1,2}, Zhou Xiaohong^{1,2}, Xu Hushan^{1,2,3}, V. K. Utyonkov⁵, A. A. Voinov⁵, Yu. S. Tsyganov⁵, A. N. Polyakov⁵ and D. I. Solov'yev⁵

¹Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou 730000, China;

²School of Nuclear Science and Technology, University of Chinese Academy of Sciences, Beijing 100049, China;

³Advanced Energy Science and Technology Guangdong Laboratory, Huizhou 516029, Guangdong, China;

⁴Guangxi Key Laboratory of Nuclear Physics and Technology, Guangxi Normal University, Guilin 541004, Guangxi, China;

⁵Joint Institute for Nuclear Research, Dubna 141980, Russian Federation)

Over the past years, experimentalists have launched an expedition to explore the predicted, centered near the double-magic $Z = 114$, $N = 184$ nucleus. With their remarkable efforts, elements from hydrogen up to element 118 at present. The discovery of the superheavy elements offers the possibilities to study properties of nuclei under extremely strong Coulomb fields and to explore the limits of existence of nuclei. The fusion evaporation reactions induced by low-energy heavy ions are employed for synthesis and study of superheavy isotopes, and the gas-filled recoil separator technique is always used to effectively separate the produced evaporation residues from projectile-like and target-like products.

Due to the extremely low production cross-section of superheavy nuclei with current above mentioned methods, it is urgent to build an accelerator for high-intensity heavy ions and to develop corresponding efficient separation and collection techniques. In 2019, a research project named CAFE2 (China Accelerator Facility for Superheavy Elements) was launched at IMP-CAS (Institute of Modern Physics, Chinese Academy of Sciences), with the purpose of constructing a dedicated experimental facility for the synthesis and study of superheavy nuclei. A gas-filled recoil separator, SHANS2 (Spectrometer for Heavy Atoms and Nuclear Structure-2), with five magnets arranged in a Q_v -D- Q_h - Q_v -D configuration was constructed at the end of beam line. Its structure shown in the left panel of Fig. 1 can be roughly divided into five parts: a differential pumping system, a rotating target system, a magnet system, a detection system, and a data acquisition system. The total optical length (from the target point to the focal plane) is 5.97 m and the detailed design is available in the published paper^[1].

In this work^[1], several test experiments were conducted to evaluate the performance of SHANS2. The momentum dispersion, which influences background suppression and resolving power, was determined to be $21.1(5) \text{ mm}/\% (B \cdot \rho)$, which is in good agreement with the designed one ($21.7 \text{ mm per } 1\% \text{ of } (B \cdot \rho)$)^[2]. Through the data analysis of the $^{169}\text{Tm}(^{40}\text{Ar}, 4n)^{205}\text{Fr}$ reaction, the optimal pressure of the operating gas filled in the device was about 100 Pa

(Fig. 1). Meanwhile, the transmissions of SHANS2 for the $^{175}\text{Lu}(^{40}\text{Ar}, 4-5n)^{210,211}\text{Fr}$ and $^{169}\text{Tm}(^{40}\text{Ar}, 5n)^{204,204\text{m}}\text{Fr}$ reaction channels were 47(25)% and 58(32)%, respectively.

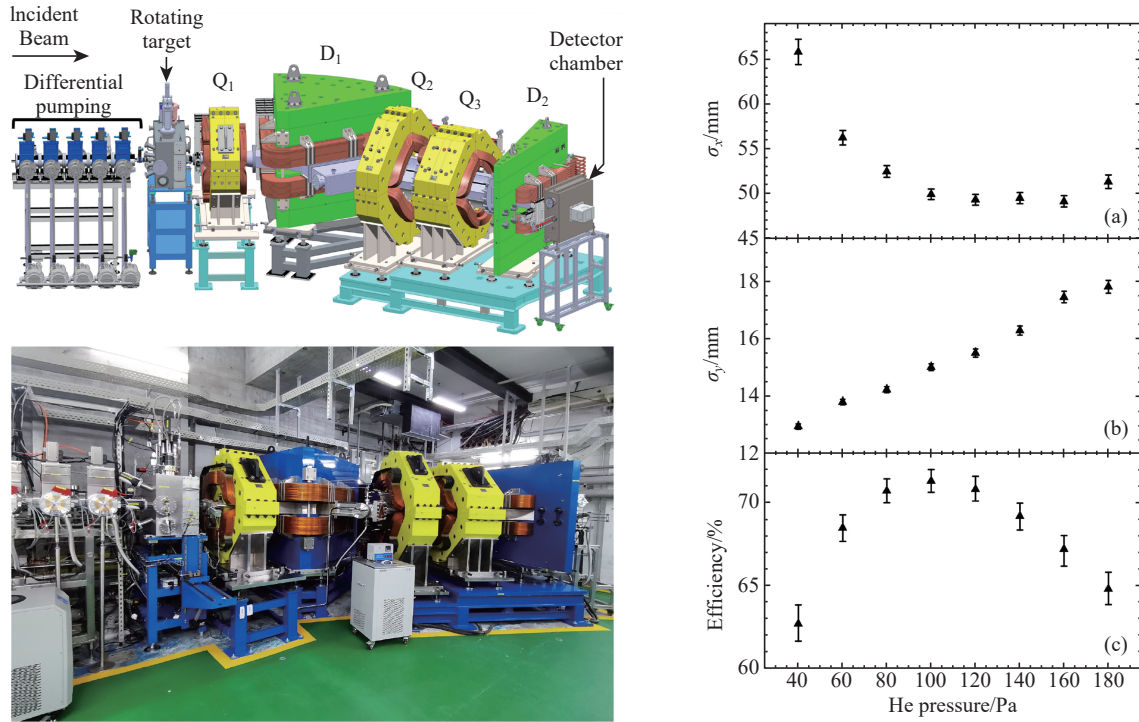


Fig. 1 (color online) The left panel is the schematic view and the photo of SHANS2. The right panel shows the widths of horizontal (a) and vertical (b) distributions of ^{205}Fr produced in the $^{40}\text{Ar} + ^{169}\text{Tm}$ reaction with incident energy 178.5 MeV in the focal plane of SHANS2 and relative collection efficiency (c) as a function of the helium pressure in the separator.

References

- [1] S. Y. Xu, Z. Y. Zhang, Z. G. Gan, et al., Nucl. Instrum. Meth. A, 1050(2023)168113.
- [2] L. N. Sheng, Q. Hu, H. Jia, et al., Nucl. Instrum. Meth. A, 1004(2021) 165348.

* Foundation item: Strategic Priority Research Program of Chinese Academy of Sciences (XDB34010000), Guangdong Major Project of Basic and Applied Basic Research (2021B0301030006), National Key R&D Program of China (2018YFA0404402) and Frontier Science Key Project of Chinese Academy of Sciences (ZDBS-LY-SLH017)