



Cryogenic Neutron Detector by InSb Semiconductor Detector with High-Density Helium-3 Gas Converter

T. Nakamura,^{a,*} M. Katagiri,^a Y. Aratono,^a
I. Kanno,^b S. Hishiki,^b
O. Sugiura,^c Y. Murase^c

a: Japan Atomic Energy Research

b: Kyoto University

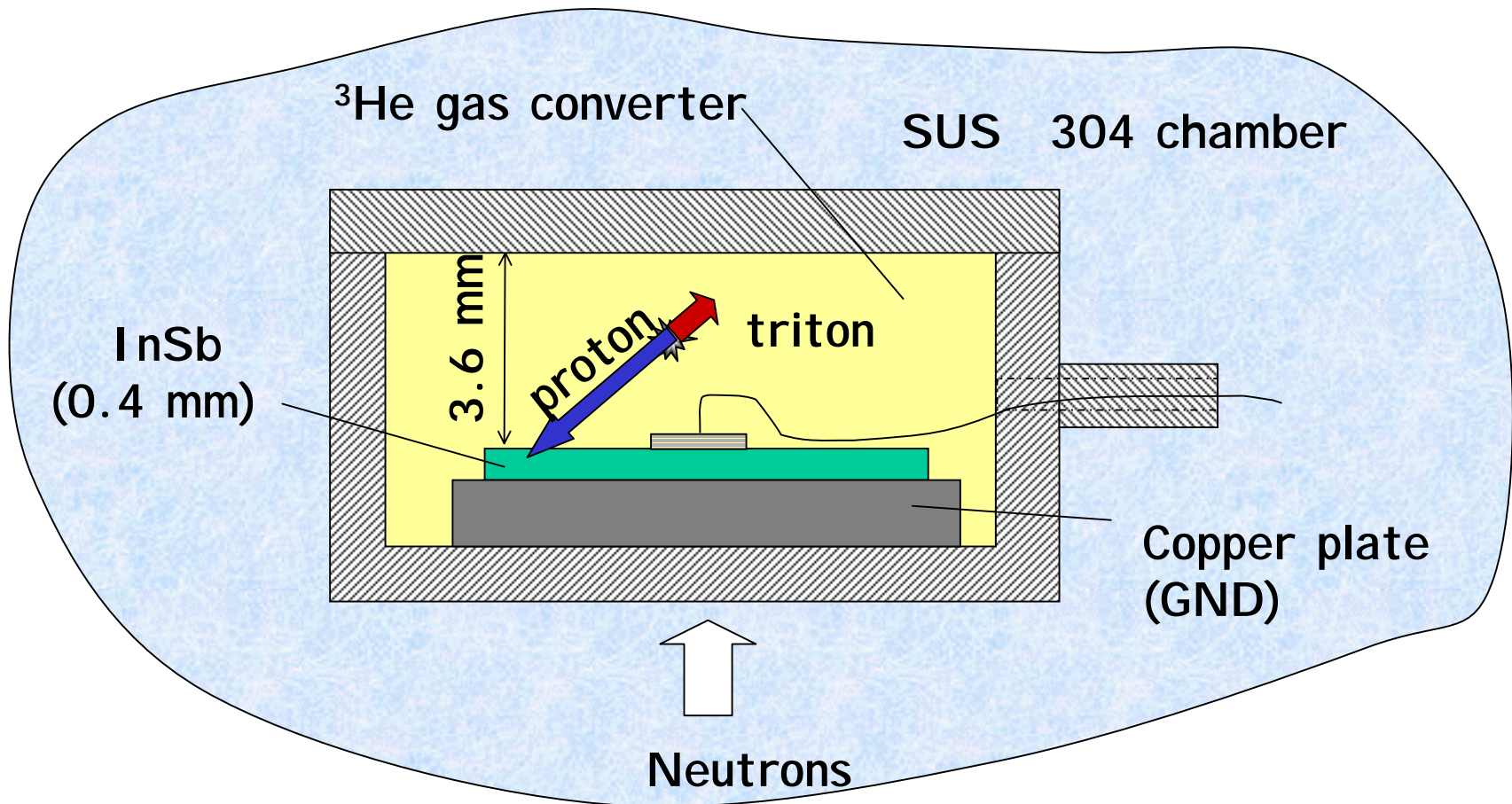
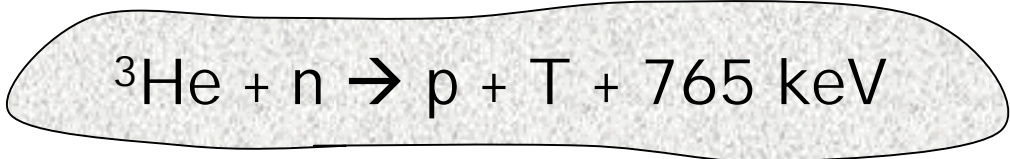
c: Tokyo Institute of Technology

Motive



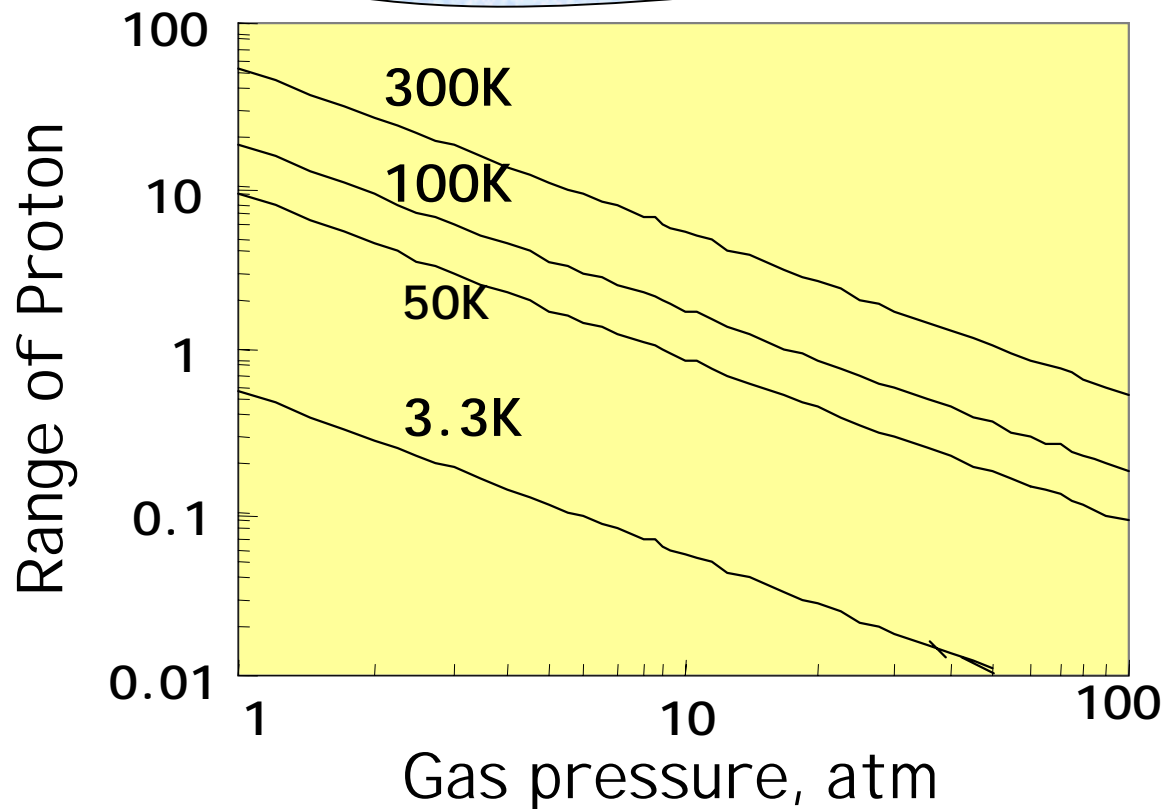
We proposed **a cryogenic neutron detector that is comprised of an InSb semiconductor detector and a helium-3 gas converter**. In this detector, neutrons are absorbed at helium-3 by the nuclear reaction, ${}^3\text{He} + n \rightarrow p + T + 765 \text{ keV}$ (${}^3\text{He} (n,p) T$), and either a proton or a triton is detected at the InSb semiconductor detector. The important key of this detector is **usage of cryogenic environment**. This enables easy access to **high-density of helium-3 nucleus**. Under such condition, a range of a proton becomes very short, hence, **high position resolution** of a few tenth μm will be obtained. High density helium-3 increases capture rate of neutrons and, moreover, a gas converter ensures very uniform detection efficiency at each incident position. It would be greatly advantageous when the arrayed detectors are used to obtain neutron images. **The use of InSb semiconductor is advantageous at low temperature operation** because its carrier, electrons and holes, mobility is about 40 and 20 times larger than that of silicon semiconductor, respectively.

Principle of Cryogenic Neutron Detector



Dependence of proton range on temperature and gas pressure

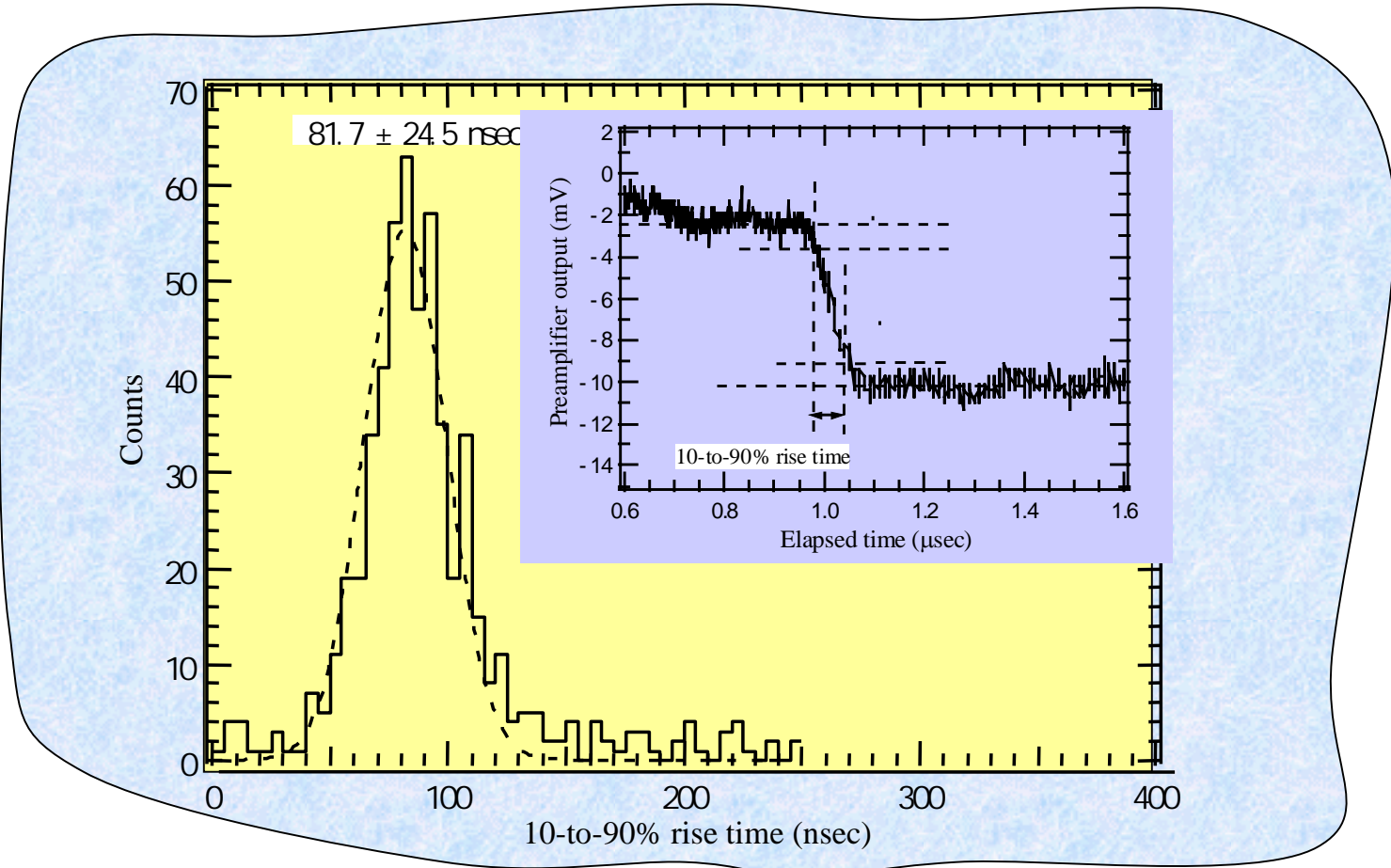
Final purpose : High resolution neutron imaging
→ Short range of proton < 500mm



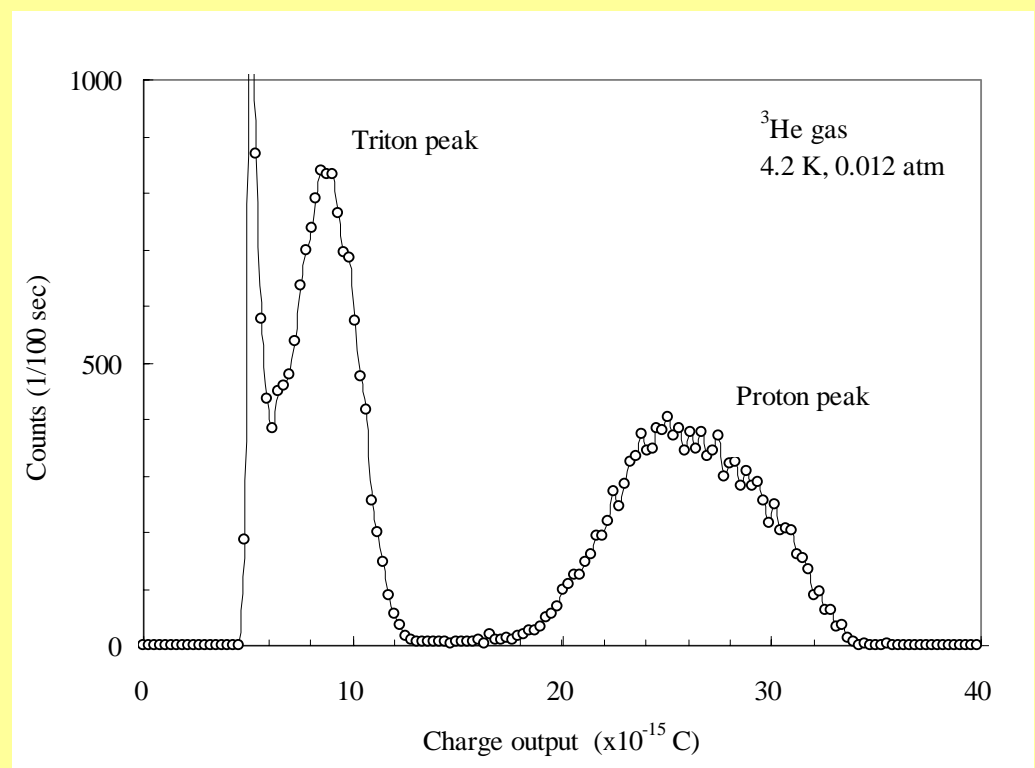
Gas pressure (3.3K, 10 atm) = Gas pressure (300K, ~900 atm)

Pulse shape and rise time of preamplifier output signal

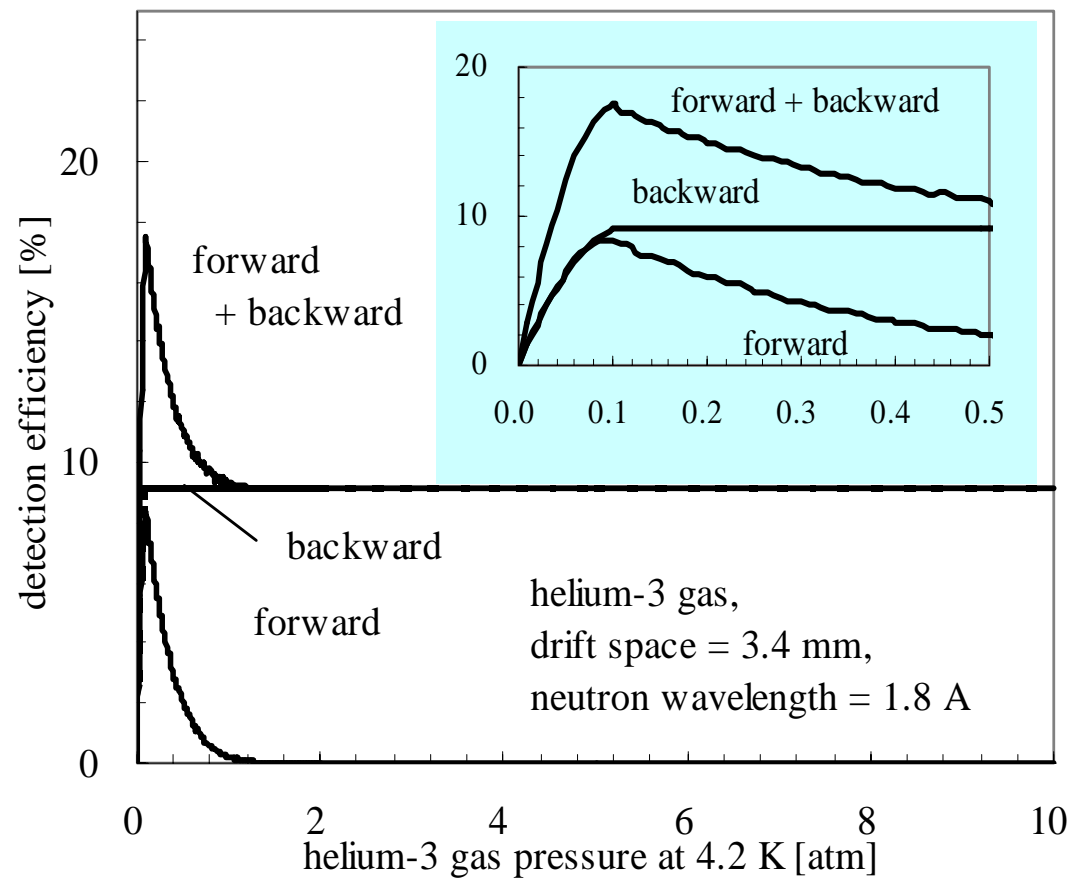
Rise time : 82ns ← Electron mobility : $78000\text{cm}^2\text{V}^{-1}\text{s}^{-1}$
Hole mobility : $750\text{cm}^2\text{V}^{-1}\text{s}^{-1}$



Pulse height spectrum of ${}^3\text{He} + n \rightarrow p + T + 765 \text{ keV}$

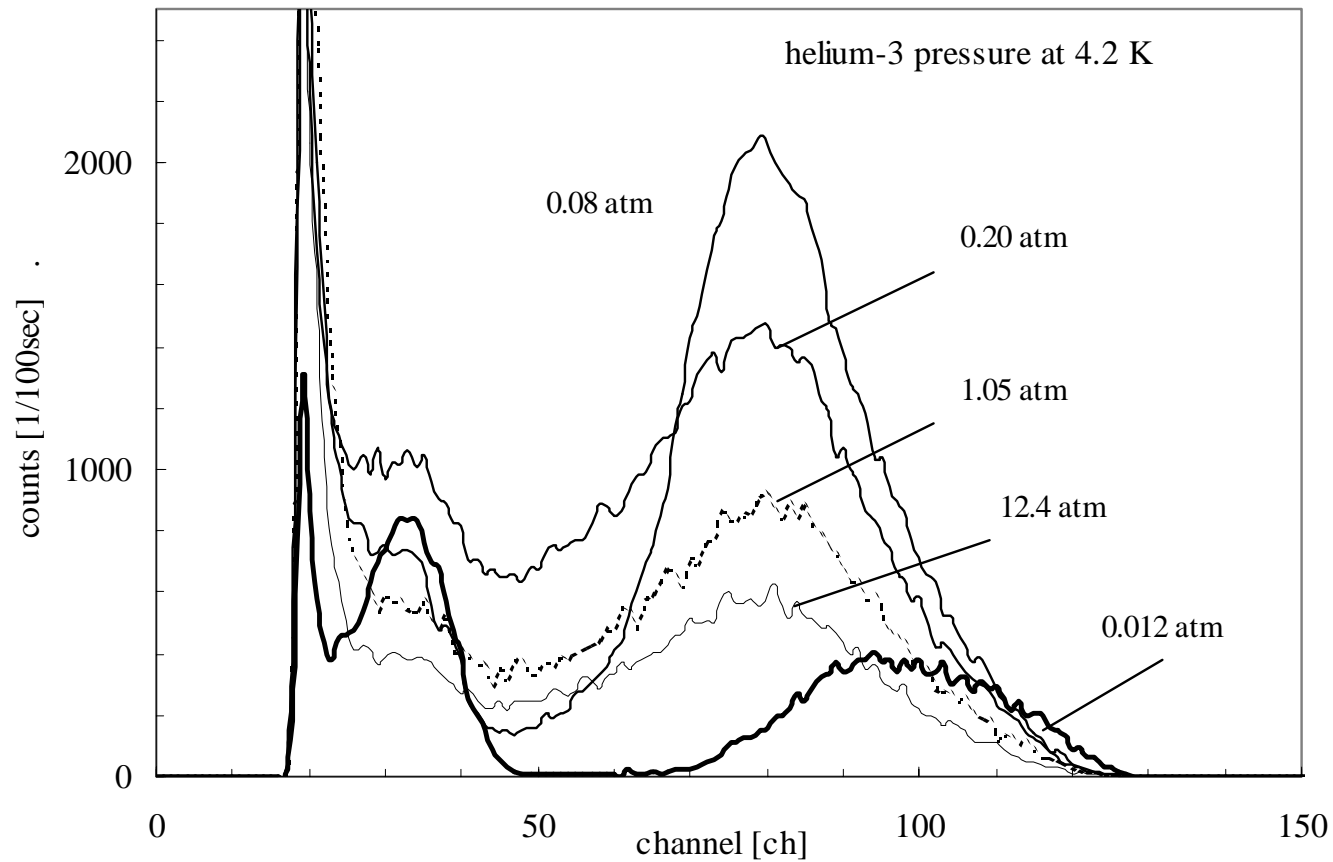


Simulated detection efficiency for the cryogenic neutron detector

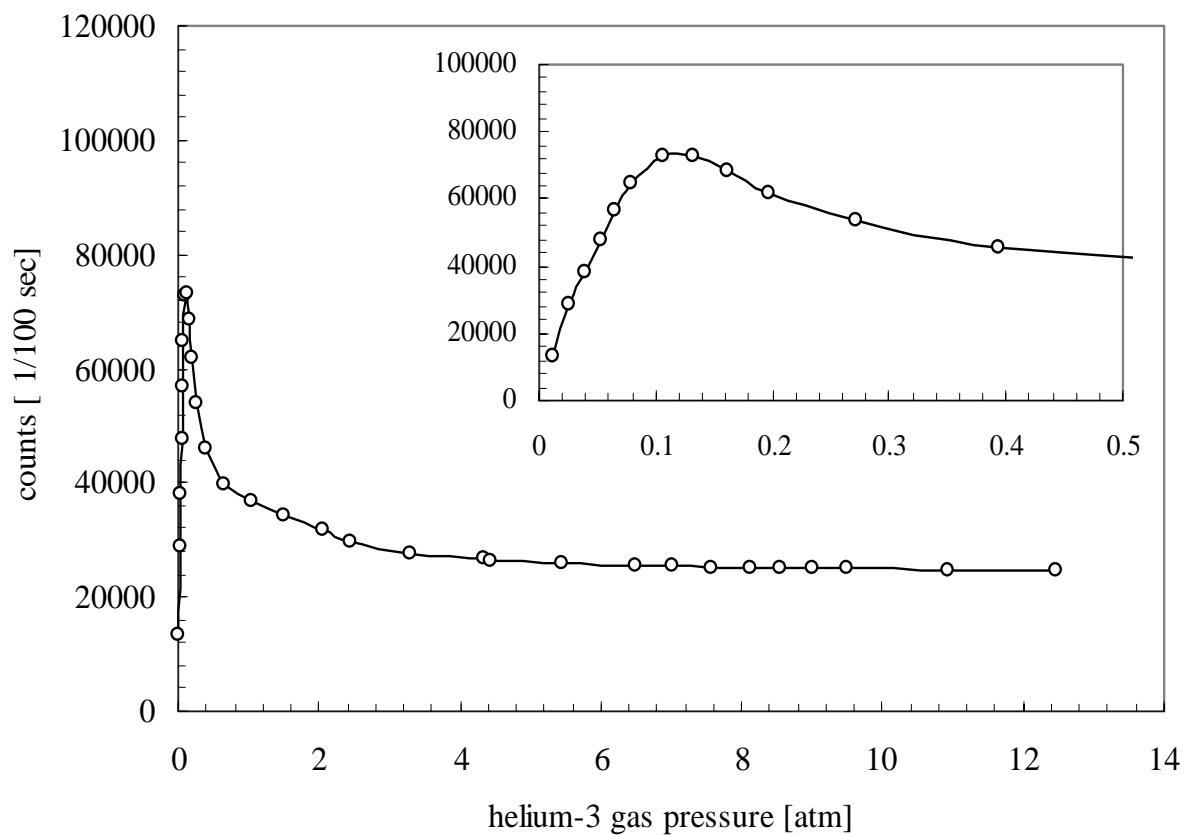




Pulse height distribution of at the gas pressure
from 0.1 to 12.5 atm at 4.2K



Neutron counts as a function of Helium-3 gas pressure at 4.2K



Conclusion

In conclusion, we confirmed that neutrons could be detected by a single InSb semiconductor detector at a gas pressure of 12.5 atm, where a spatial resolution of several tenth microns is expected.

We intend to develop an arrayed InSb semiconductor detector system in order to obtain neutron images.