

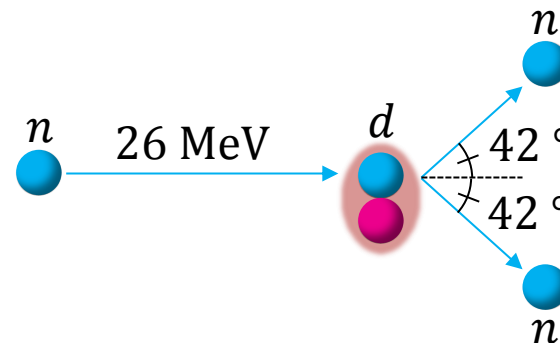
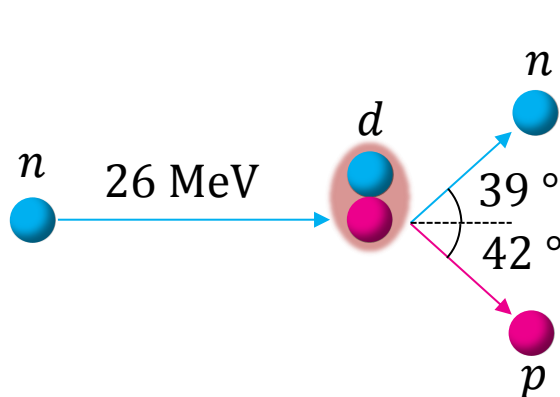
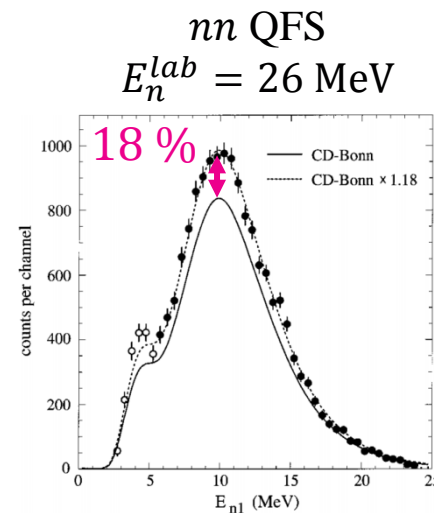
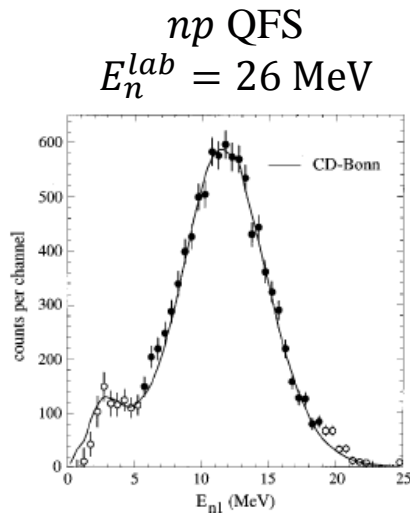
Feasibility study of  $nn$ -resonance state search  
using  ${}^2\text{H}(n, p)nn$  reaction at  $E_n = 12 \text{ MeV}$

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## neutron-neutron resonance state ?

- Underestimation of the  $nn$  QFS (Quasi-Free Scattering) cross section  
A. Siepe *et al.* (Phys. Rev. C **65**, 034010 (2002))



- $nn$  QFS peak is formed by  $V_{nn}(^1S_0)$
- $1.08 \times V_{nn}(^1S_0)$  ( $\lambda = 1.08$ )  
can reproduce the  $nn$  QFS peak
- “ It is seen that taking  $\lambda = 1.08$   
leads to a nearly bound state of two neutrons.  
H. Witała and W. Glöckle  
( Phys. Rev. C **83**, 034004 (2011))

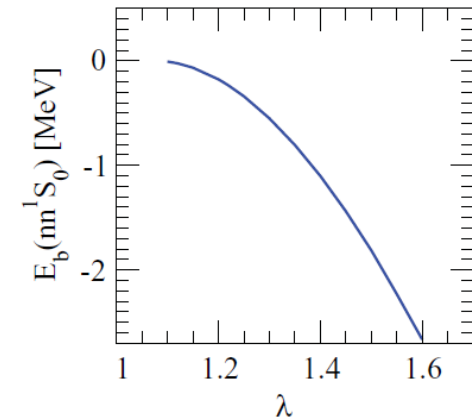
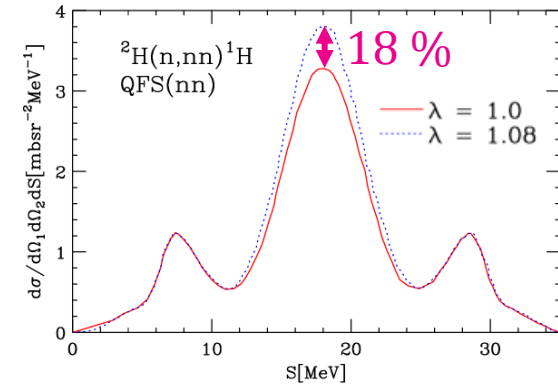
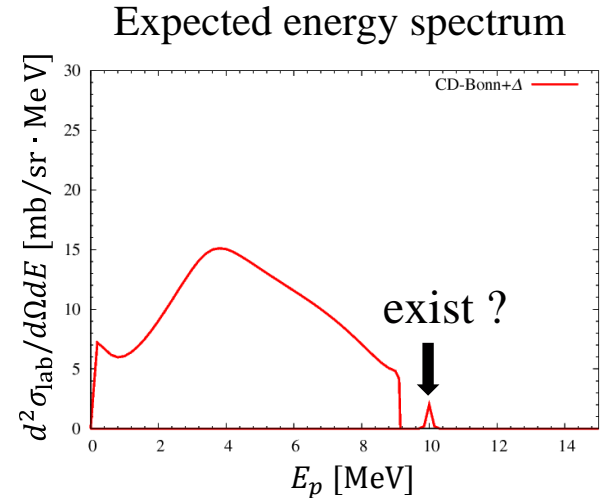
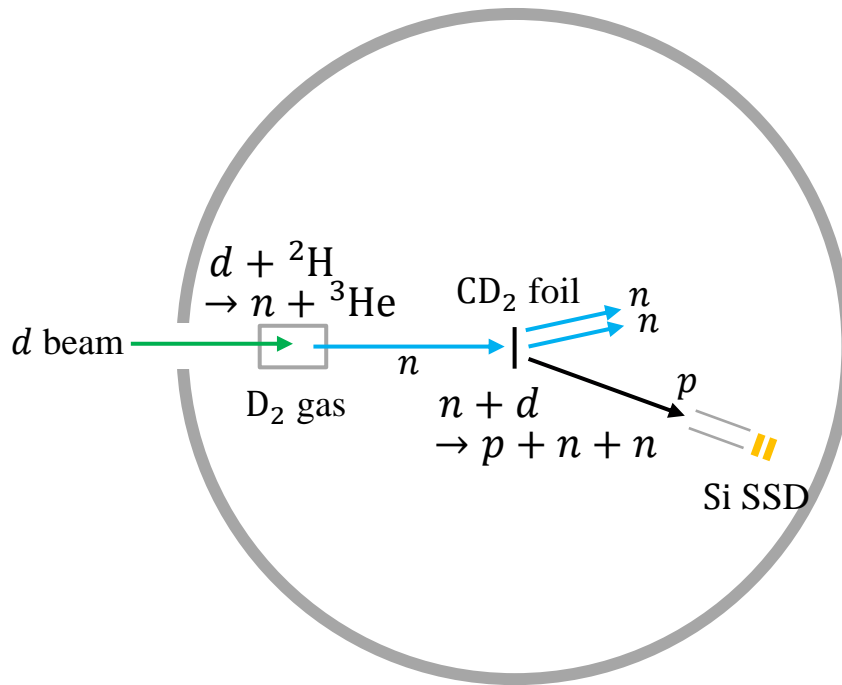


FIG. 5. (Color online) The range of  $\lambda$  values by which the  $^1S_0$   $nn$  matrix element of the CD Bonn potential is multiplied [ $V_{nn}(^1S_0) = \lambda V_{\text{CDBonn}}(^1S_0)$ ], for which the two neutrons form a bound state with the binding energy  $E_b$ .

## Our experiment

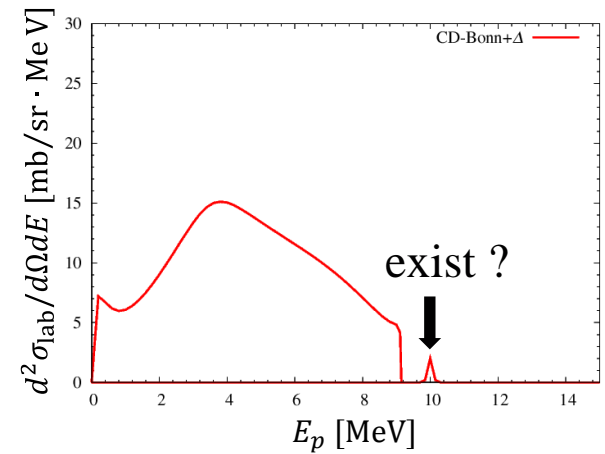
- $nd$  breakup reaction at  $E_n = 12$  MeV  
 $n + d \rightarrow p + n + n$
- Detect only protons
- If  $nn$ -resonance state exists, a single peak may be observed.



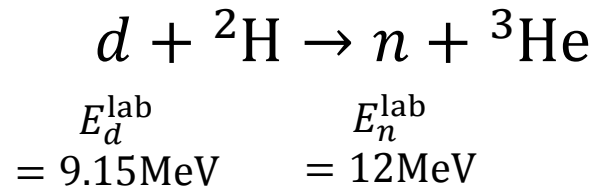


Scattering chamber

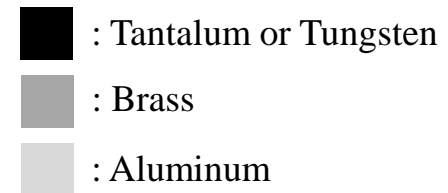
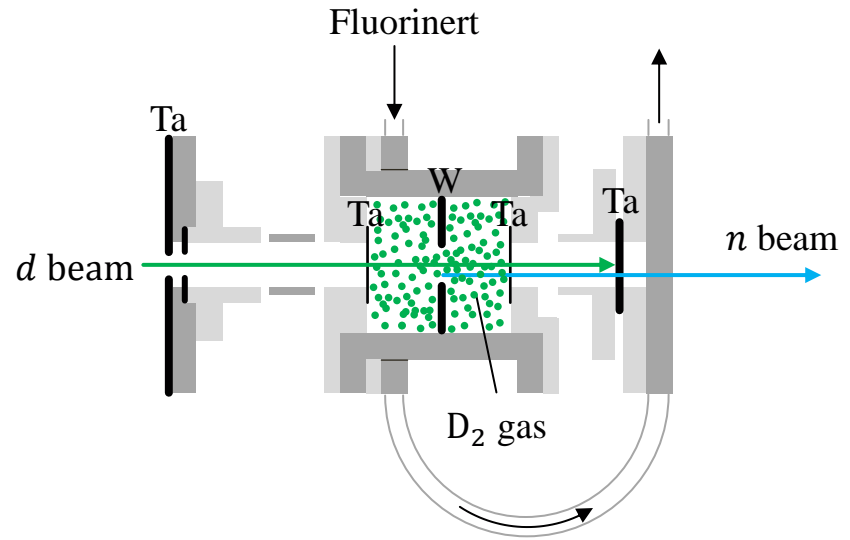
Expected energy spectrum

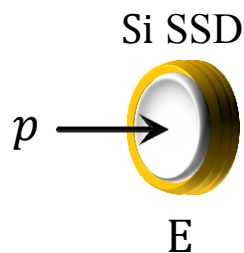
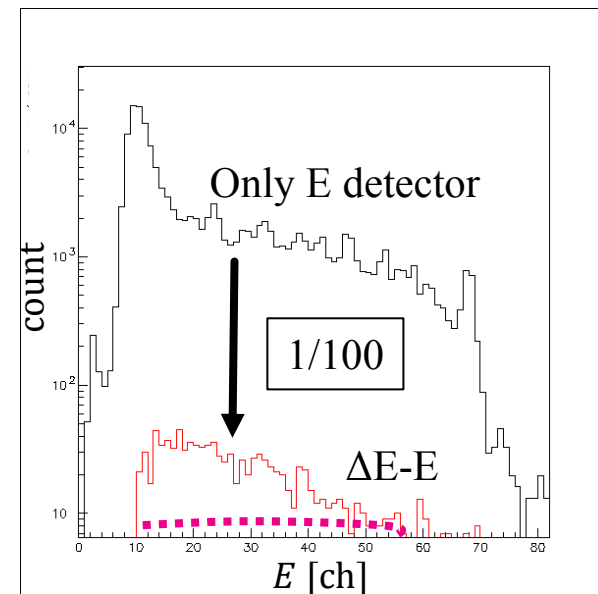
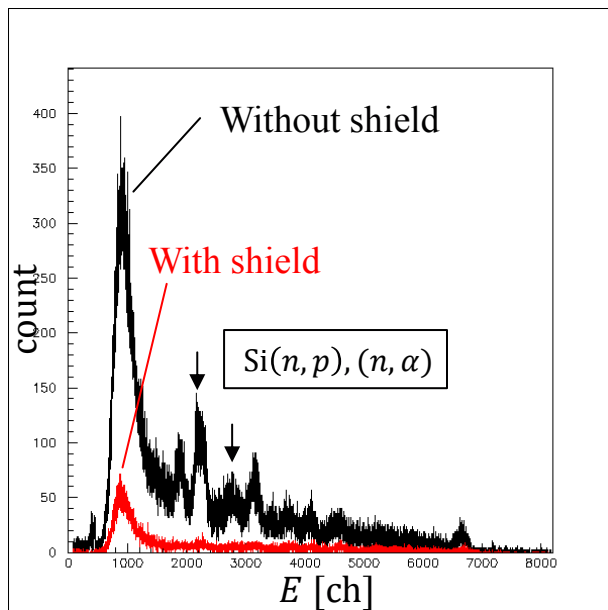
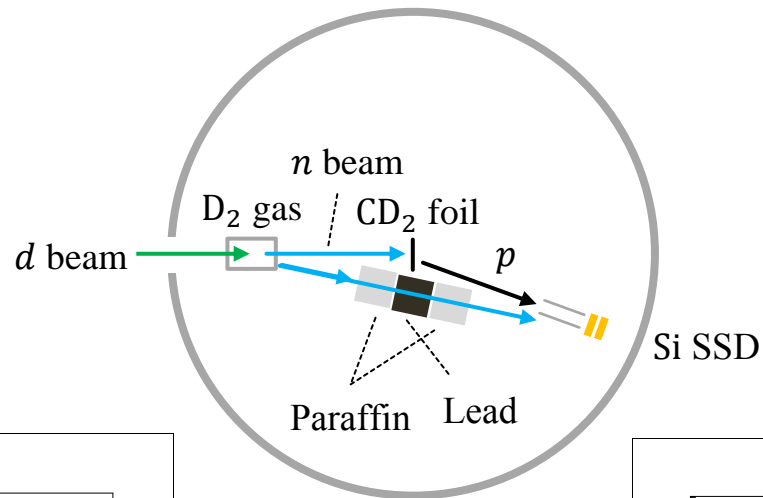


## Neutron beam production

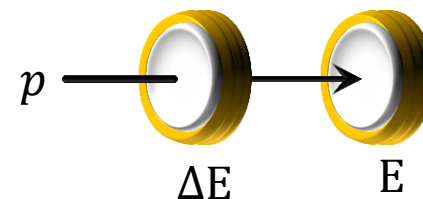


- Aperture : Ta plate ( $3\phi$ , w:  $500\mu\text{m}$ )
- Closed with Ta foil (w:  $3\mu\text{m}$ )
- W aperture at the middle of the cylinder ( $6\phi$ )
- Beam stop : Ta plate (w:  $400\mu\text{m}$ )
- Cooled by fluorinert ( $15^\circ\text{C}$ )

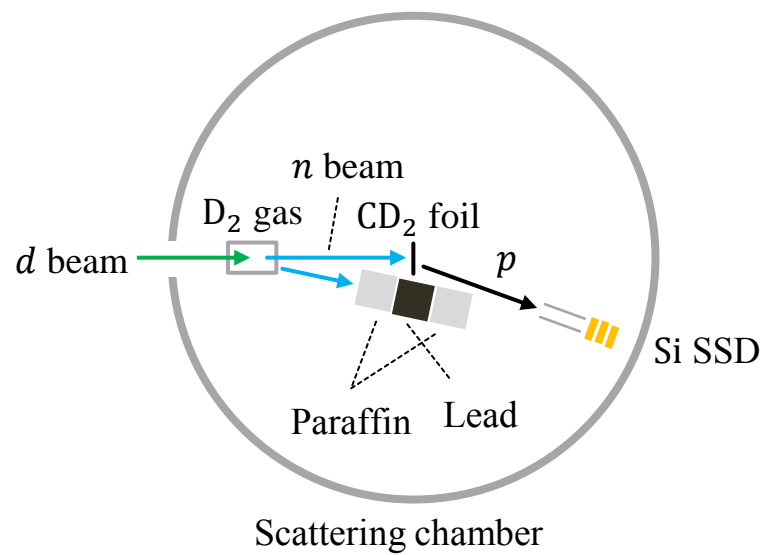
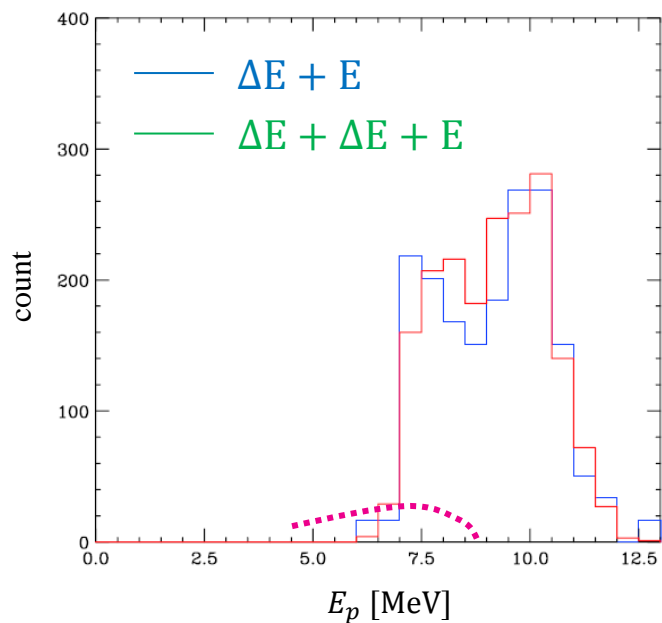
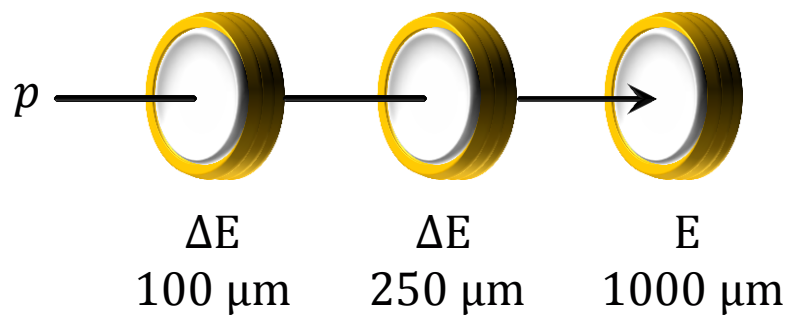




Counter telescope of two Si SSDs

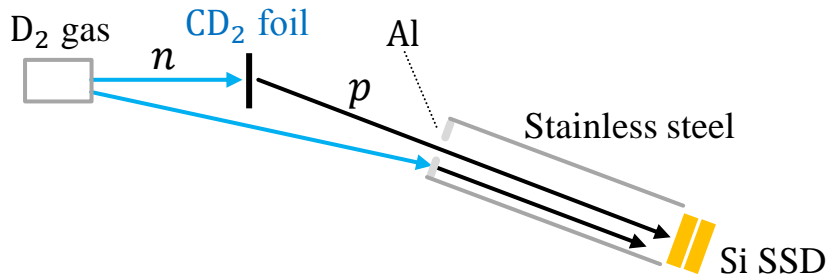


Counter telescope of three Si SSDs

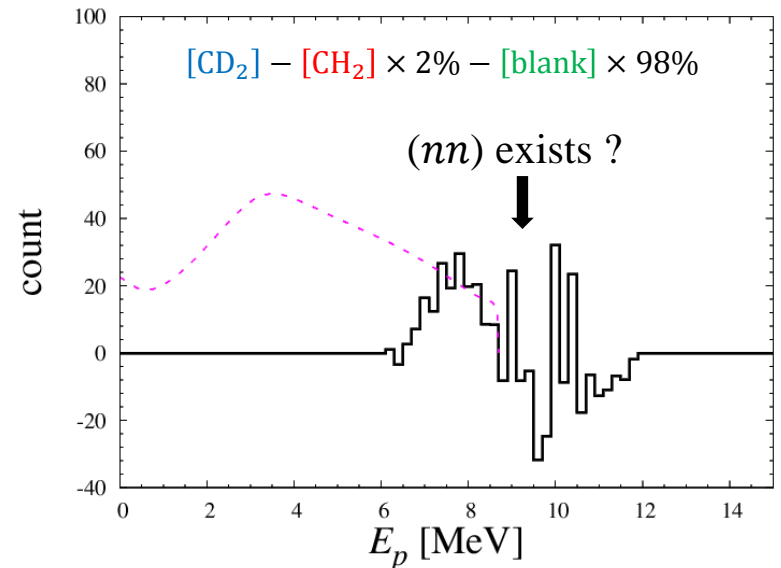
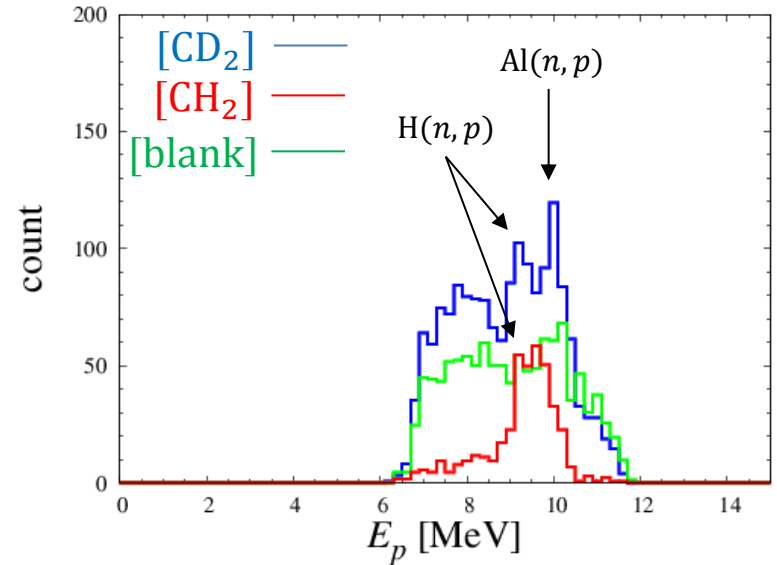


# Experiment

- Three kinds of runs
  1.  $n + [\text{CD}_2] \times 98\%$
  2.  $n + [\text{CH}_2] \times 2\%$
  3.  $n + [\text{blank}]$} 100 %



- Background sources
  1.  $(n, p)$  reactions in Al-aperture and stainless-steel shield
  2. H component in CD2 target
  3. Others

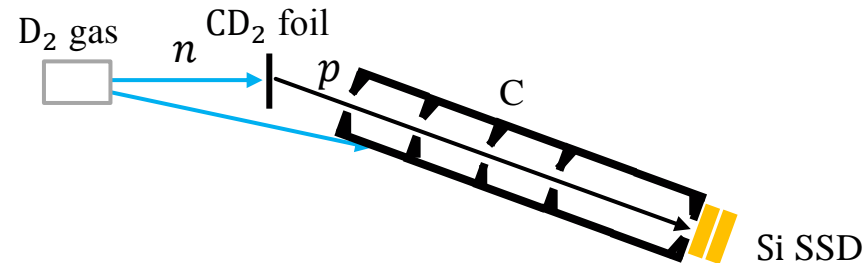
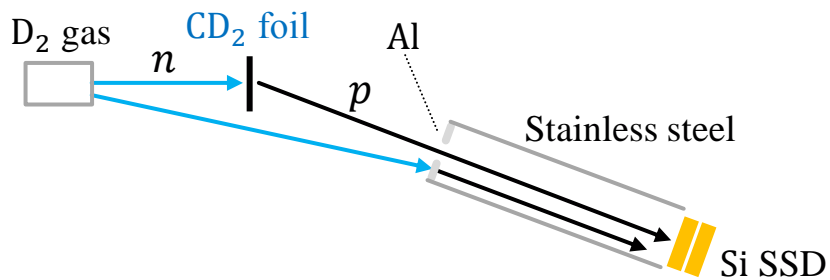
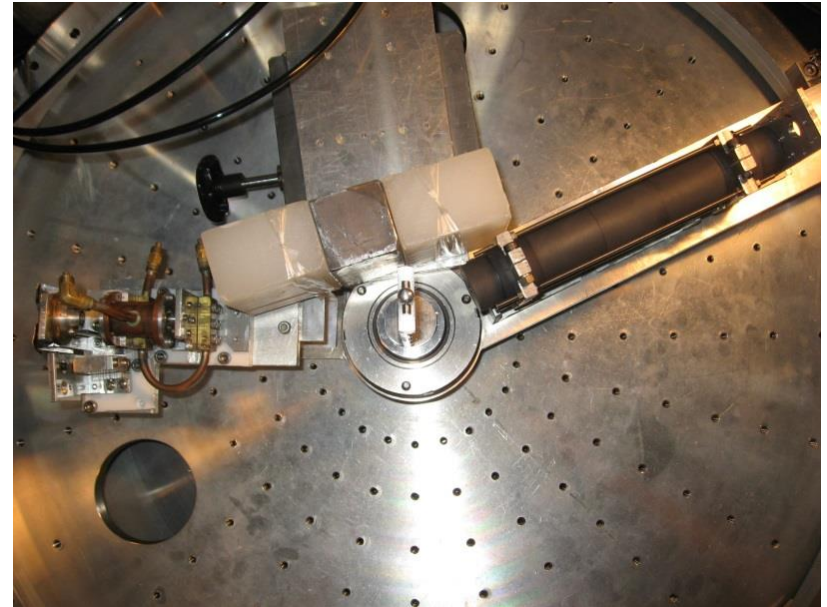


- Carbon cylinder

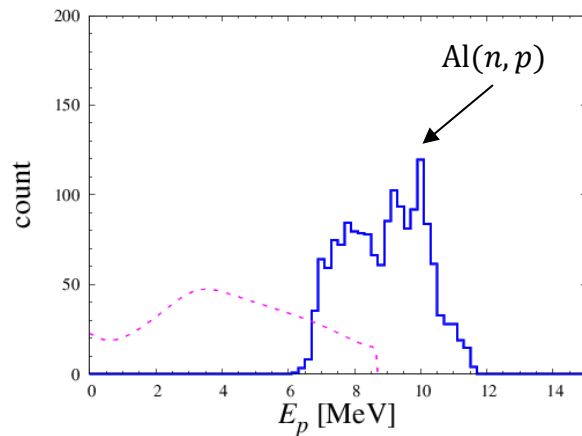
$Q$  values of  $(n, p)$  reactions

Atom	$Q$ value [MeV]
$^{27}\text{Al}$	-1.8
$^{60}\text{Ni}$	-2.0
$^{56}\text{Fe}$	-2.9
$^{52}\text{Cr}$	-3.2
$^{12}\text{C}$	-12.6
$^{13}\text{C}$	-12.7

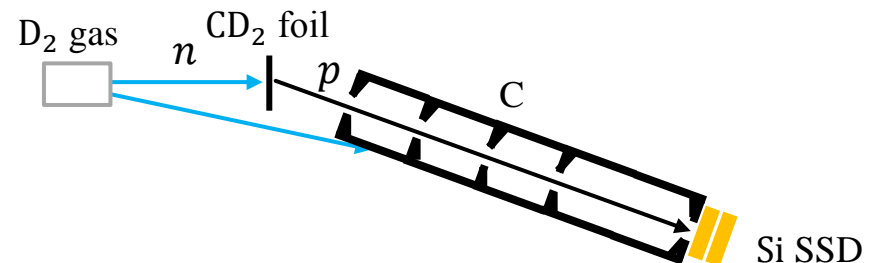
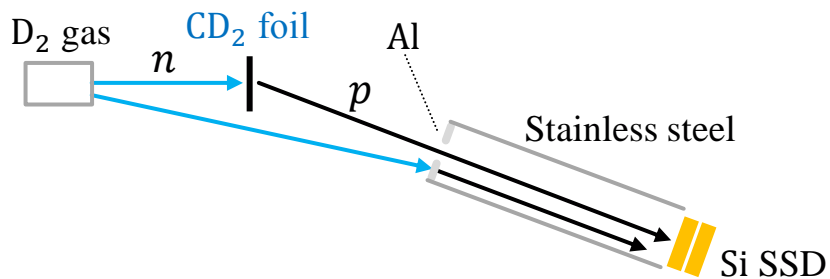
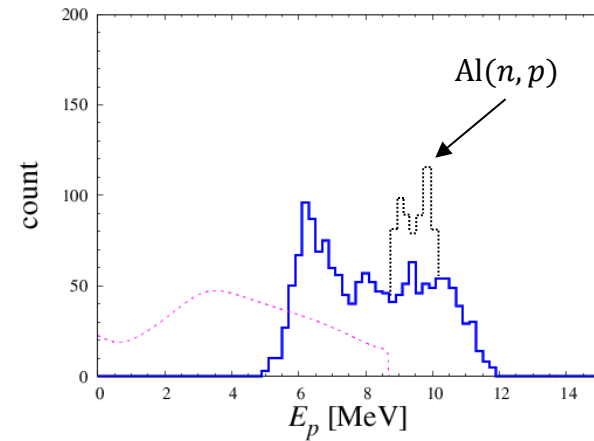
$\leftrightarrow E_n = 12 \text{ MeV}$



Aluminum aperture  
and  
stainless steel cylinder

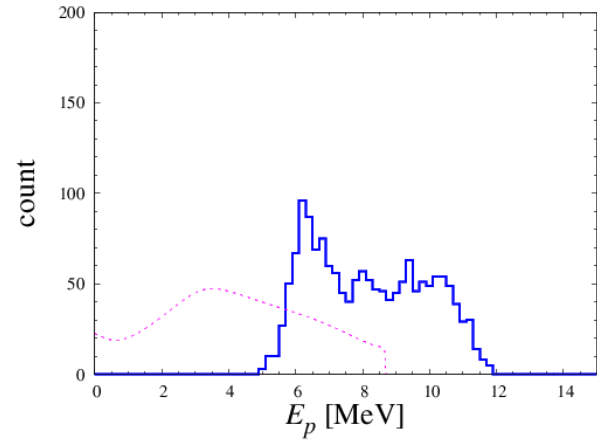


Carbon Cylinder



- Background reduction so far

	Background reduction
Paraffin and lead shield	$\sim 1/10$
Counter telescope of 2 SSDs	$\sim 1/100$
Counter telescope of 3 SSDs	$\sim 9/10$
Carbon cylinder	No $Al(n,p)$



- Further reduction is necessary

- Remaining background sources
  1.  $\text{Si}(n, p)$  in Si detector by continuous neutron flux
  2.  $\text{H}(n, p)$  by H in  $\text{CD}_2$  foil ( $E_p \approx 9 \text{ MeV}$ )

- In the near future,

----- Background reduction -----

1. Decrease in neutrons with complete shield
2. Use of high purity  $\text{D}_2$  target (98%  $\rightarrow$  99.8%)
3. Use of additional detectors (e.g. gas counter)

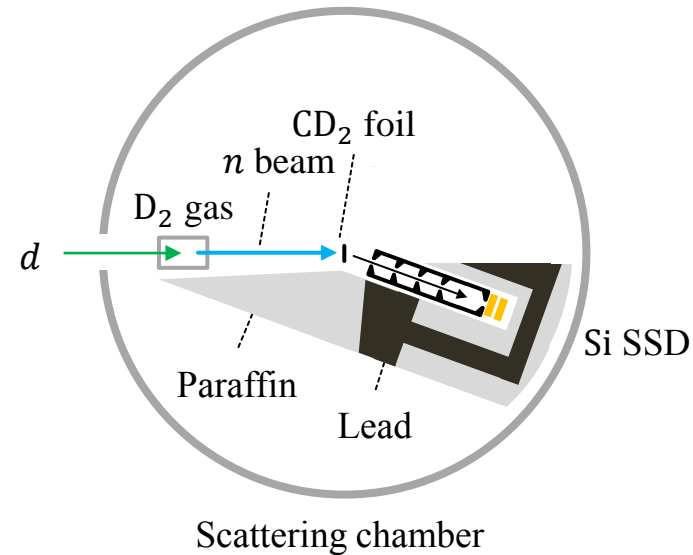
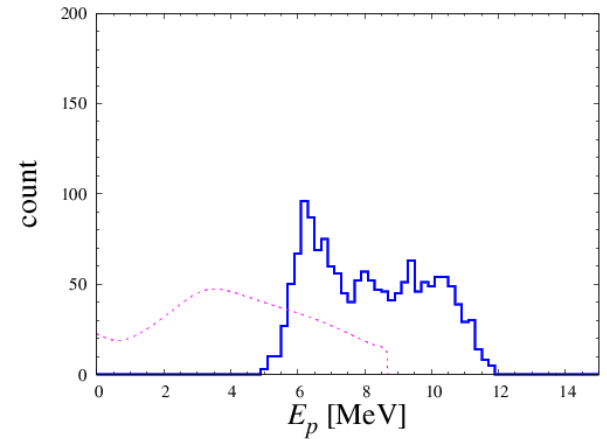
- After then,

----- Energy resolution -----

4. Improvement of the energy resolution

----- Statistics -----

5. Increase in proton counts



- Two neutrons can nearly bound if  $V_{nn}(^1S_0)$  is stronger
- $n + d \rightarrow p + n + n$ ,  $E_n^{\text{lab}} = 12\text{MeV}$
- Detect only protons at  $\theta_p^{\text{lab}} = 25$  degree
- Background reduction is necessary

	Background reduction
Paraffin and lead shield	$\sim 1/10$
Counter telescope of 2 SSDs	$\sim 1/100$
Counter telescope of 3 SSDs	$\sim 9/10$
Carbon cylinder	No $\text{Al}(n,p)$

- In the near future,

----- Background reduction -----

1. Decrease in neutrons with complete shield
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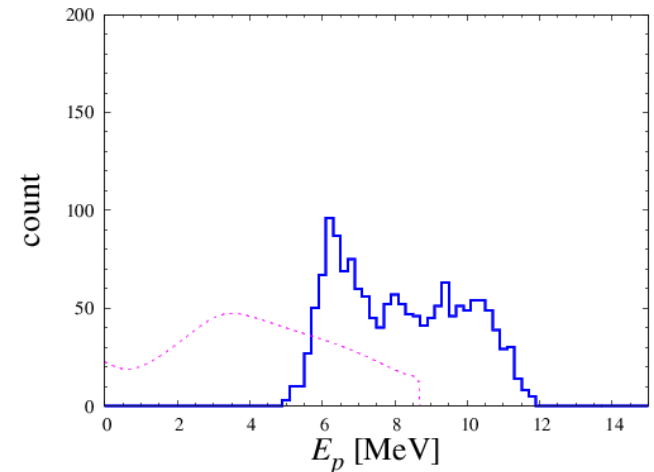
- After then,

----- Energy resolution -----

4. Improvement of the energy resolution

----- Statistics -----

5. Increase in proton counts



*Thank you !!*