Mini Workshop on
"New aspects of few–nucleon systems and related topics"
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Study of Three–Nucleon Forces via p–^{3}He Elastic Scattering

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Contents

1. Introduction
2. The polarized ^{3}He target
3. p + ^{3}He scattering experiment
4. Summary and Comments

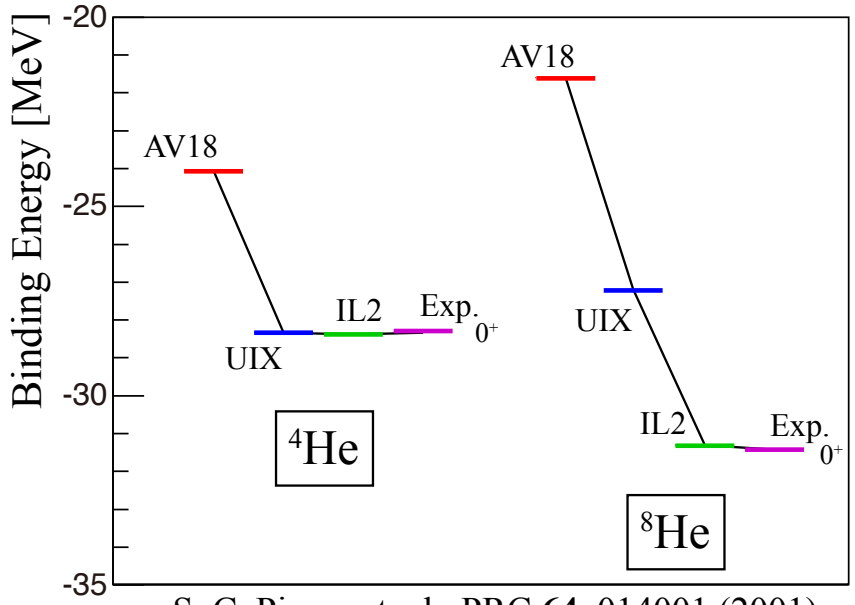
3NFs & few-nucleon scattering

Three-Nucleon Forces (3NFs)

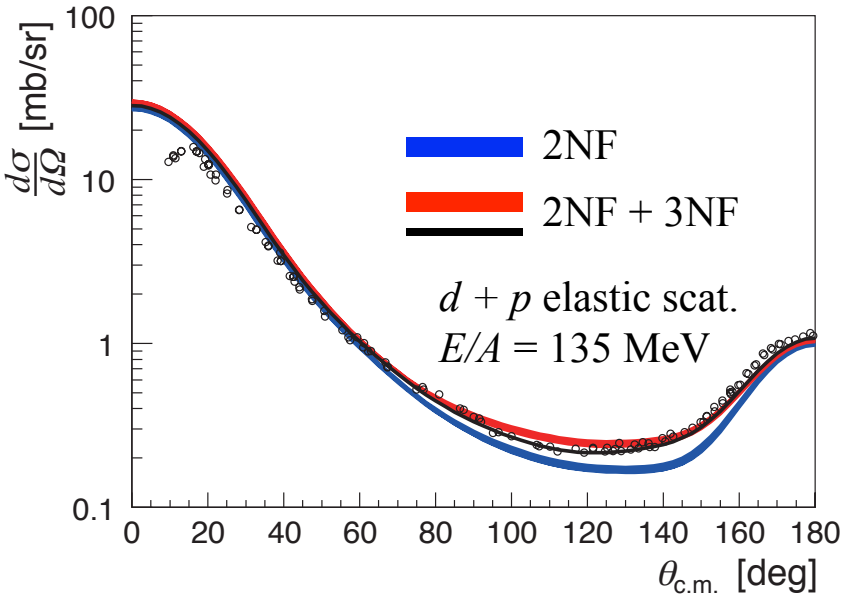
- Binding energies of light mass nuclei ($A \geq 3$)
- Scattering observables of few-nucleon scat.
- Properties of nuclear matter

  (e.g. saturation density, radius or mass of neutron star)

Reproduced by including **Three-Nucleon Forces (3NFs).**



S. C. Pieper et. al., PRC **64**, 014001 (2001).



K. Sekiguchi *et al.*, PRC **65**, 034003 (2002).

Study of 3NFs in p + ^{3}He scattering

The measurement of p + ^{3}He system ($E_p \geq 65$ MeV)

- Approaching to $T = 3/2$ component of 3NFs — S. C. Pieper *et. al.*, PRC **64**, 014001 (2001).
  - Large contributions to B.E. of neutron-rich nuclei (e.g. ^{8}He, etc.)
  - Great importance in the pure neutron matter — S. Gandolfi *et. al.*, EPJA **50**, 10 (2014).
- We have performed the following experiments:

Incident Energy	70 MeV	65 MeV	65 MeV	100 MeV
Beams	p	pol. p	pol. p	pol. p
Observables	$A_y^{3\mathrm{He}}$	$d\sigma/d\Omega$, A_y^p	A_y^p, $A_y^{3\mathrm{He}}$, $C_{y,y}$	A_y^p, $A_y^{3\mathrm{He}}$, $C_{y,y}$
Measured Angles ($\theta_{\mathrm{c.m.}}$)	46°–141°	27°–170°	46°–133°	47°–149°
Facilities	CYRIC, Tohoku Univ.	RCNP, Osaka Univ.	RCNP, Osaka Univ.	RCNP, Osaka Univ.
Exp. Course	41 course	WS course	ENN course	ENN course

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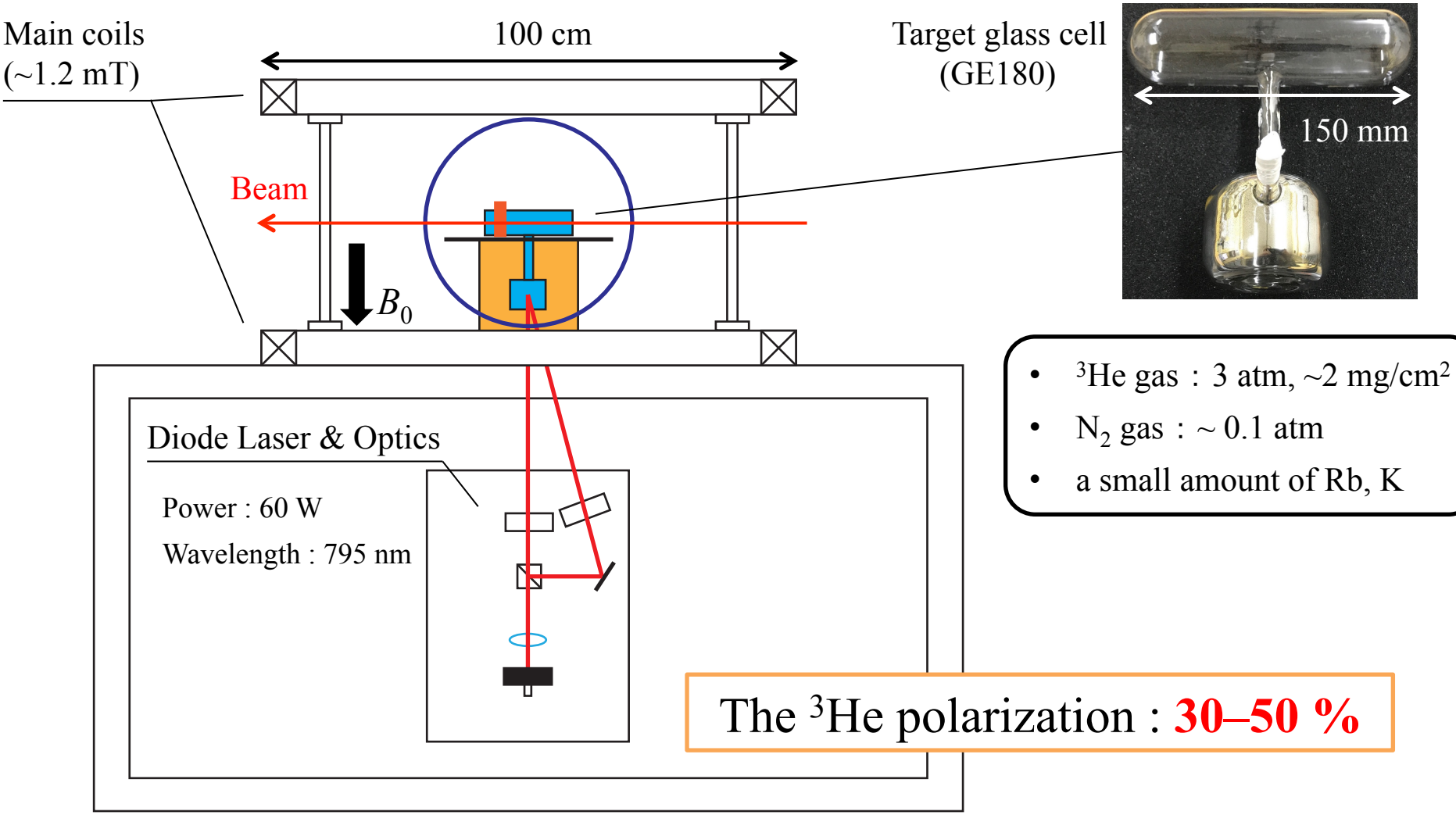
Polarized ^{3}He target system



Target glass cell
(GE180)

- ^{3}He gas : 3 atm, ~2 mg/cm^2
- N_2 gas : ~ 0.1 atm
- a small amount of Rb, K

The ^{3}He polarization : **30–50 %**

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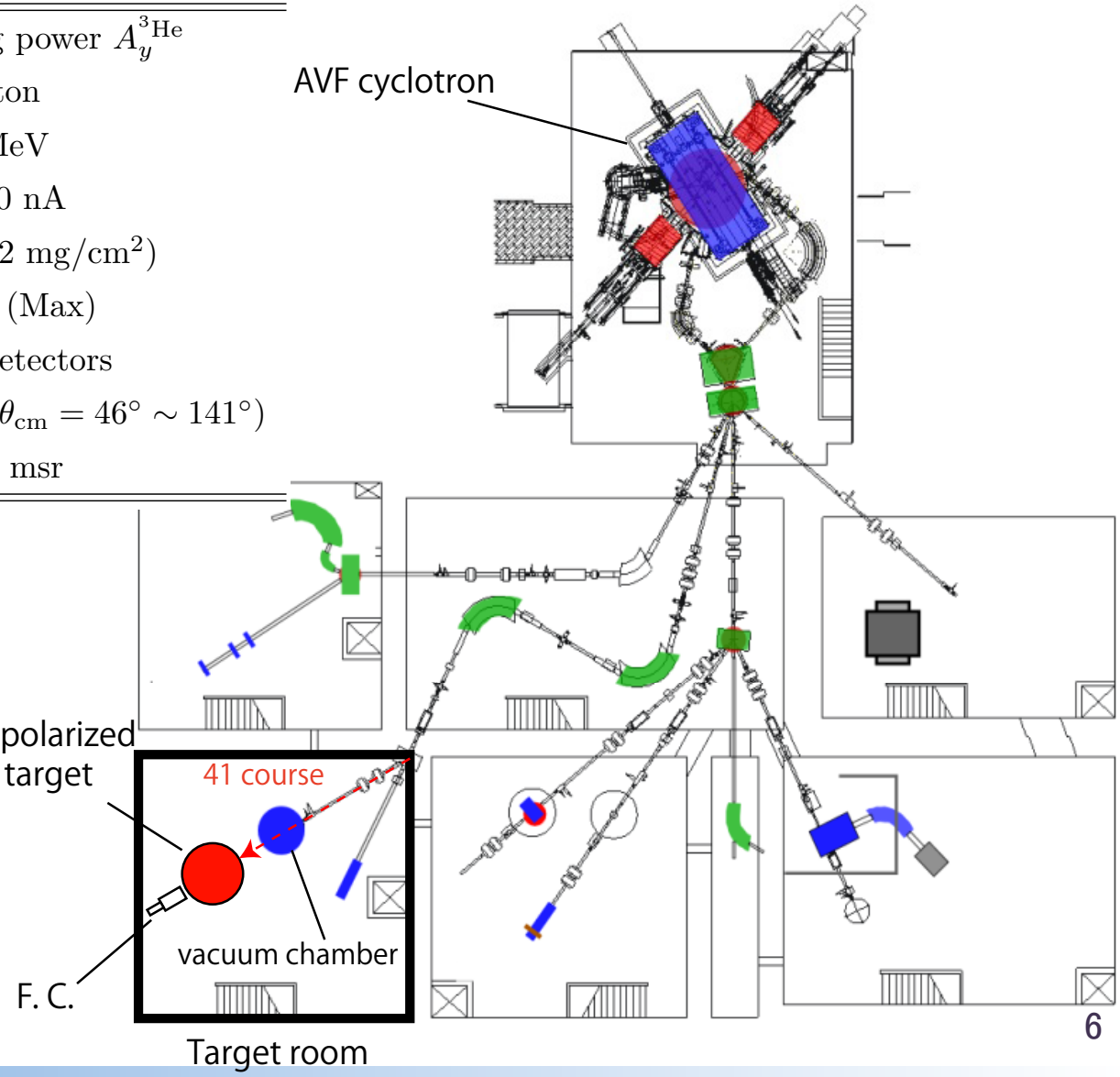
Observables	^{3}He analyzing power $A_y^{^3\mathrm{He}}$
Beam	proton
Beam energy	70 MeV
Beam intensity	$5 \sim 10$ nA
Target	^{3}He gas (~ 2 mg/cm^2)
Target polarization	~ 50 % (Max)
Detectors	ΔE–E detectors
Measured angles	$\theta_{\mathrm{lab}} = 35^\circ \sim 125^\circ$ ($\theta_{\mathrm{cm}} = 46^\circ \sim 141^\circ$)
Solid angles	~ 0.4 msr

ΔE-E detectors

- ΔE det. (plastic, 0.2, 0.5, 1 mm^t) + E det. (plastic or NaI(Tl))
- Double slit systems
  - Determine the effective target thickness & solid angels
  - Reduce B.G.



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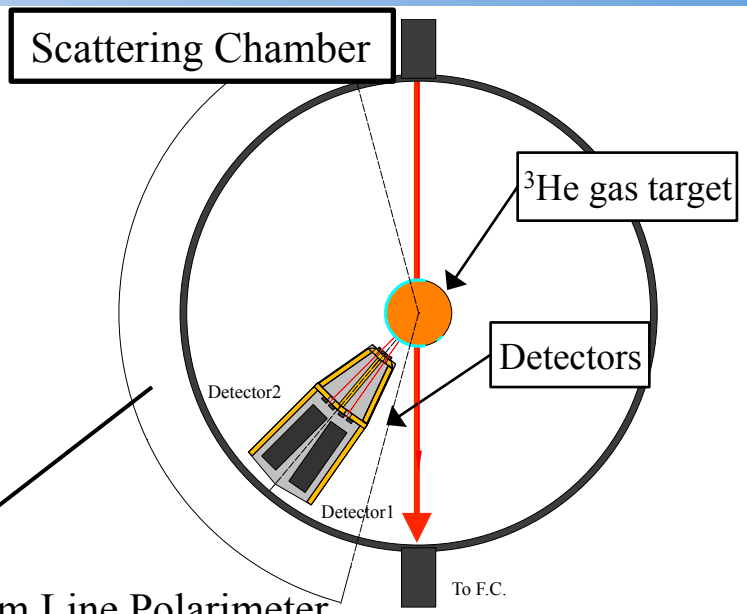
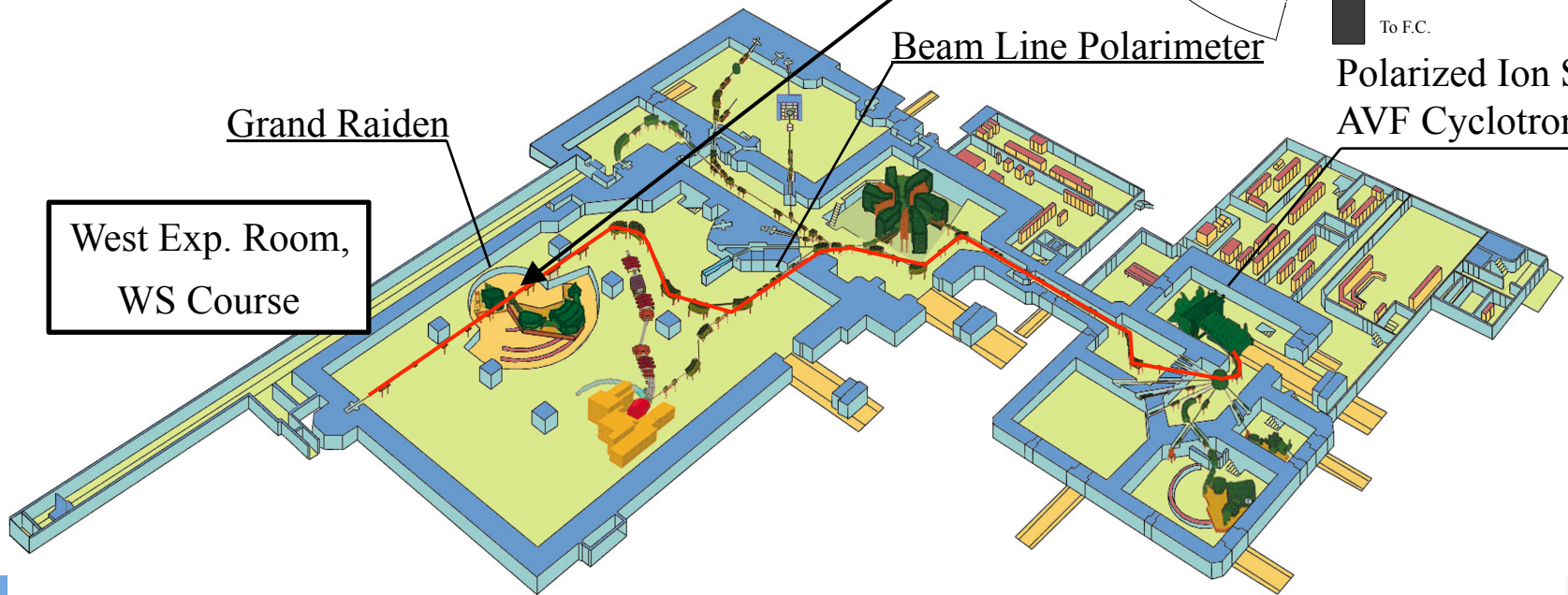
Observables	$d\sigma/d\Omega, A_y^p$
Beam	Polarized proton (Pol. $\sim$ 50 %)
Beam energy	65 MeV
Beam intensity	20 $\sim$ 100 nA
Target	^{3}He gas (1 atm)
Detectors	ΔE–E detectors
Solid angles	$\sim$ 0.3 msr





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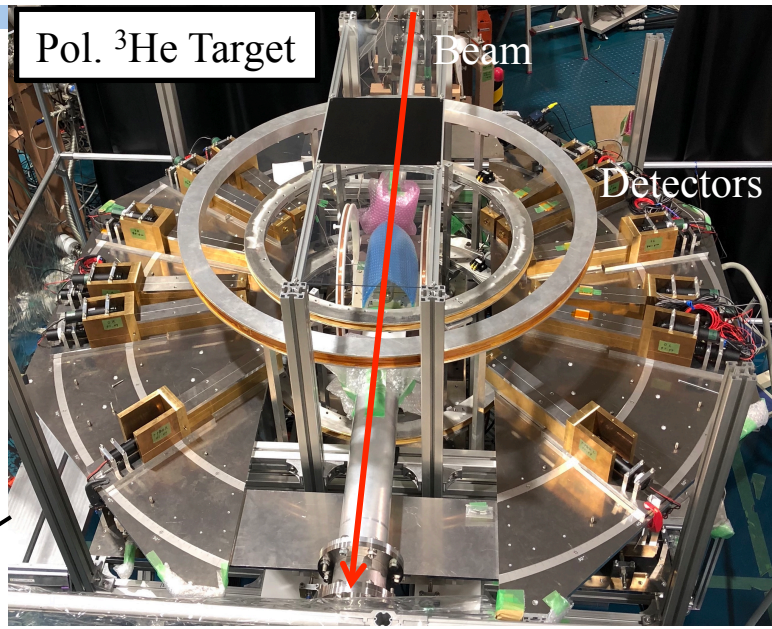
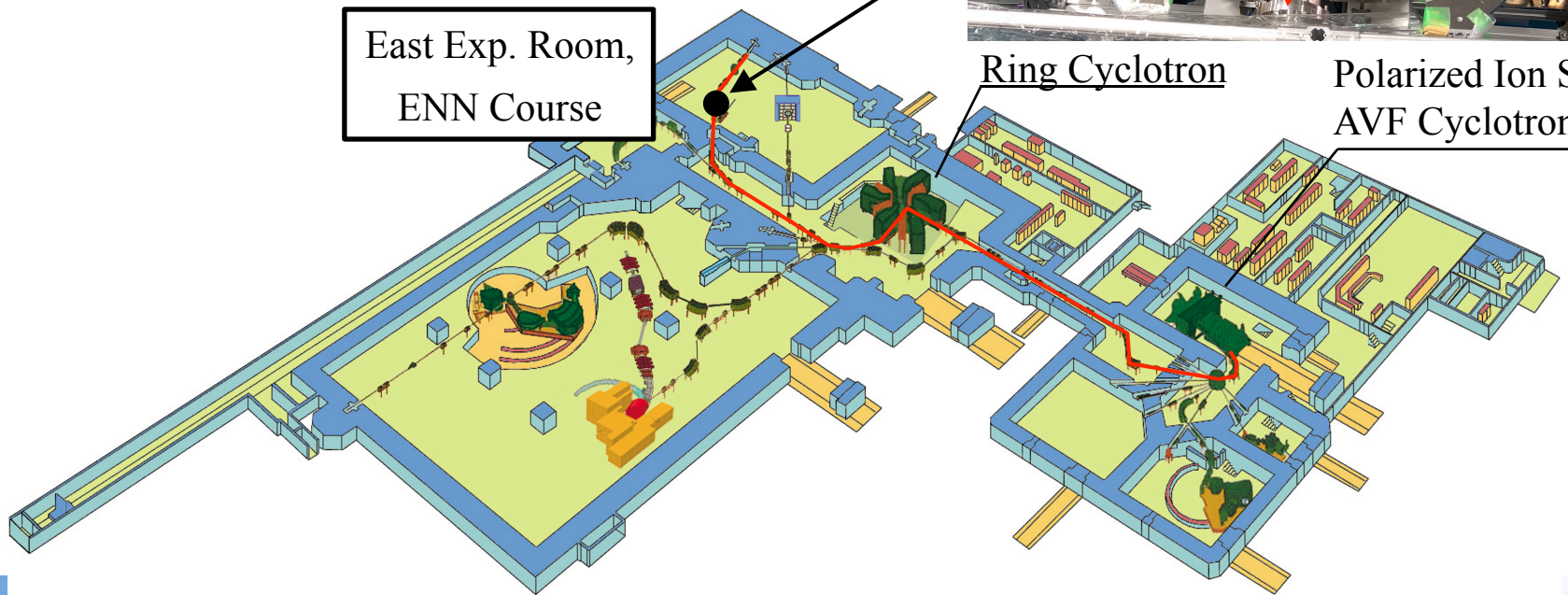
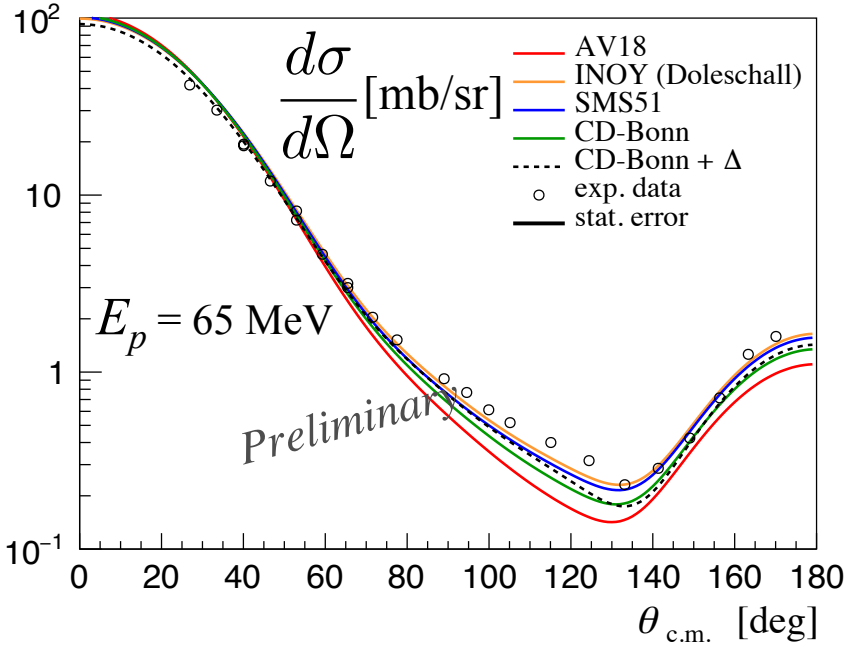
Observables	$A_y^p, A_y^{^3\mathrm{He}}, C_{y,y}$
Beam	Polarized proton (Pol. ~ 40 %)
Beam energy	65, 100 MeV
Beam intensity	~ 30 nA
Target	^{3}He gas (~ 2 mg/cm^2)
Target polarization	~ 50 % (Max)
Detectors	ΔE–E detectors
Solid angles	~ 0.4 msr



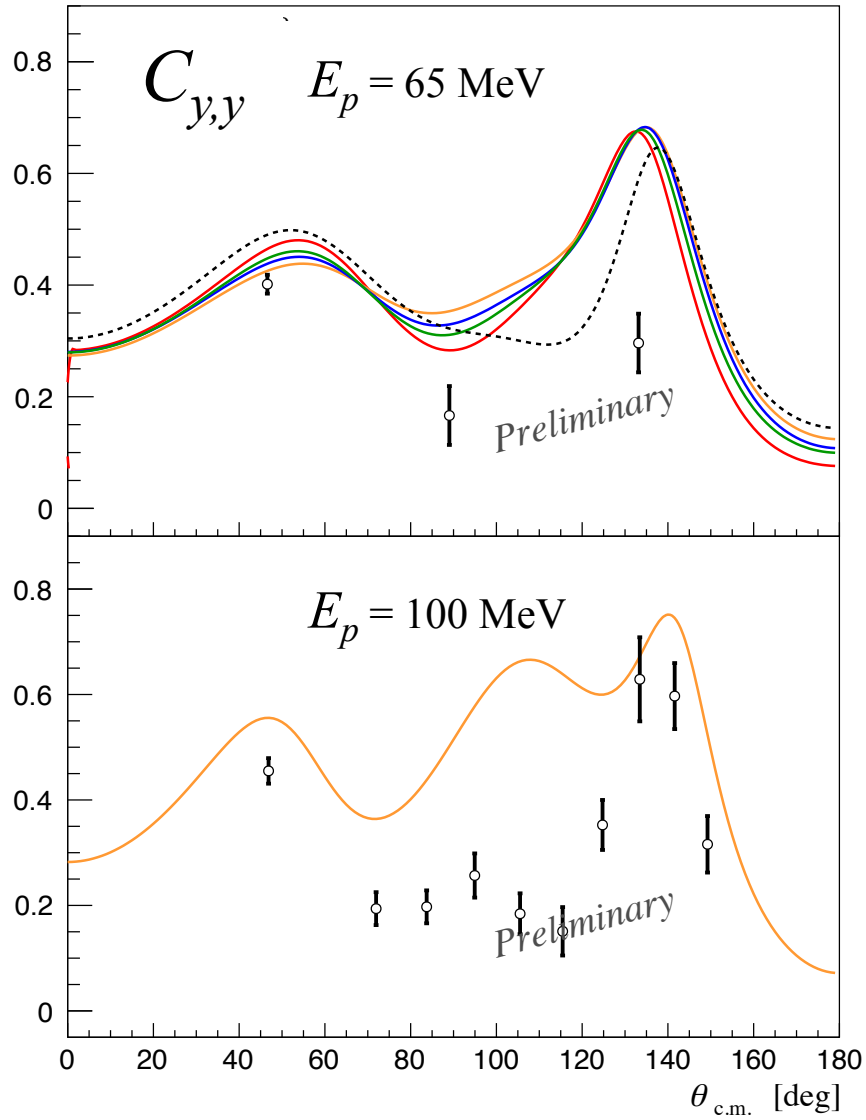


Results of $d\sigma/d\Omega$, $C_{y,y}$

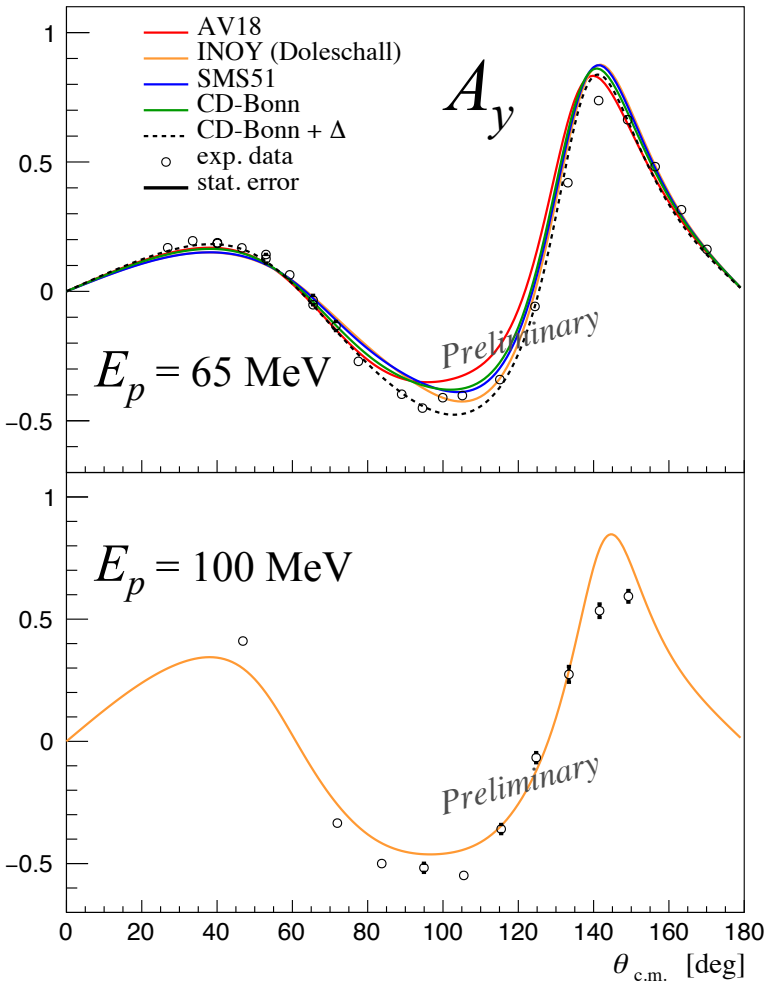


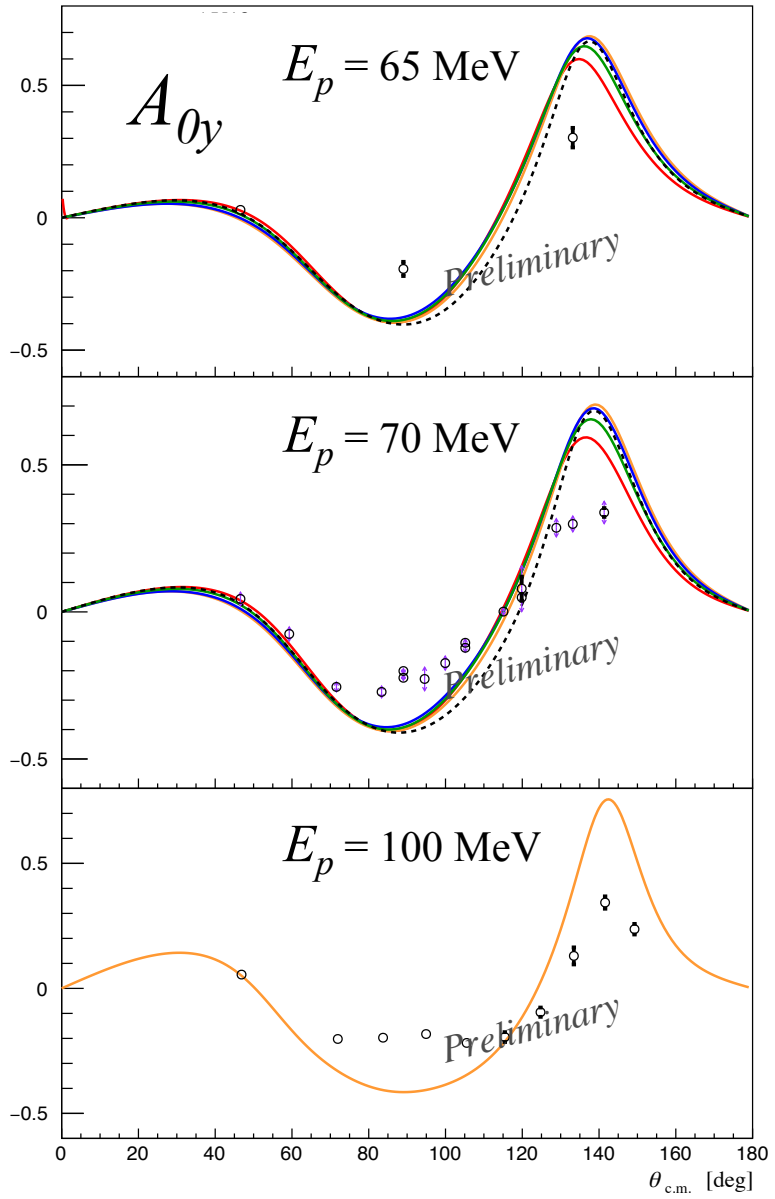
*Calculations by A. Deltuva, private communication

Analysis is in progress now.



Results of analyzing powers





*Calculations by A. Deltuva, private communication

Analysis is in progress now.

Summary and Comments

- Study of 3NFs via p + ^{3}He scattering system at intermediate energies. ($E/A \geq 65$ MeV)

- We developed the polarized ^{3}He target for the p + ^{3}He measurement (@CYRIC, RCNP).
  - Recently, we achieved the typical **^{3}He polarization of 30−50 %.**

- We obtained the angular distribution of $d\sigma/d\Omega$, A_y, A_{0y}, $C_{y,y}$ and compared to the theoretical calculations.
  - The data of $d\sigma/d\Omega$, A_y is almost reproduce by the calculations.
  - Large discrepancies are found at A_{0y}, $C_{y,y}$ → the 3NF effects are relatively large?
  - However, we need to precise measurements of the ^{3}He polarization to fix the data.

- To do next...
  - The measurement of ^{3}He polarization using neutron transmission (@RANS, RIKEN)

Thank you for your attention.