Measurement of spin correlation coefficient $C_{y,y}$ for proton-^{3}He elastic scattering

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- ***Vilnius University***
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- ***RIKEN Nishina Center***
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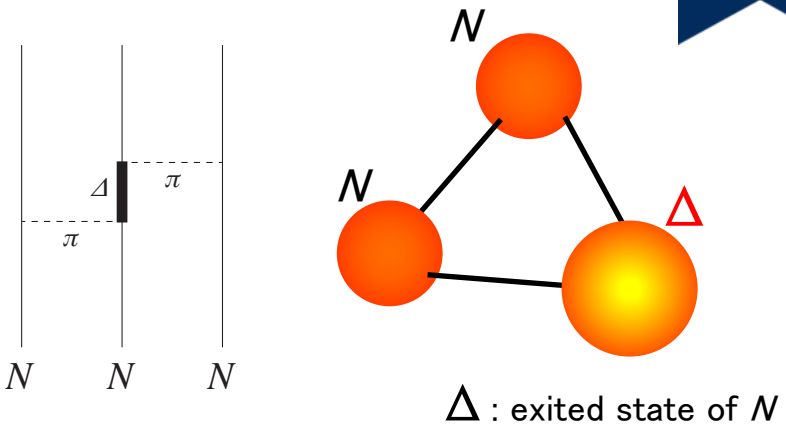
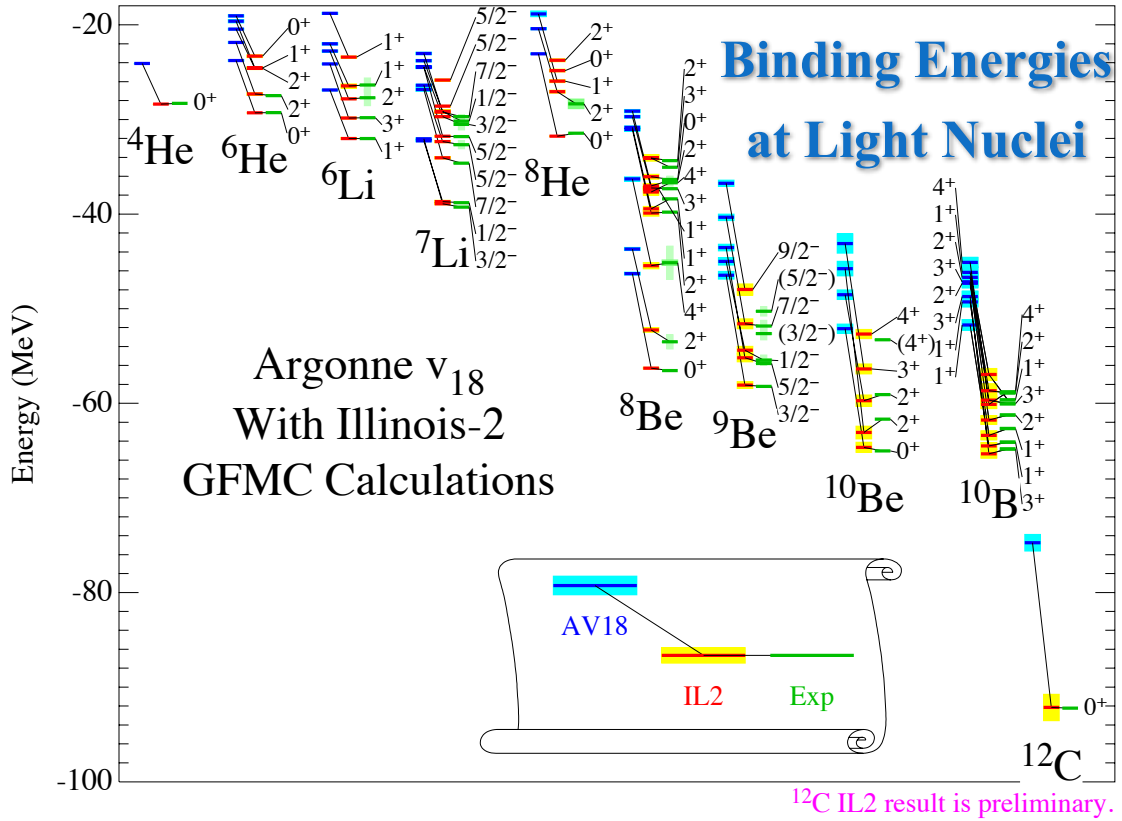
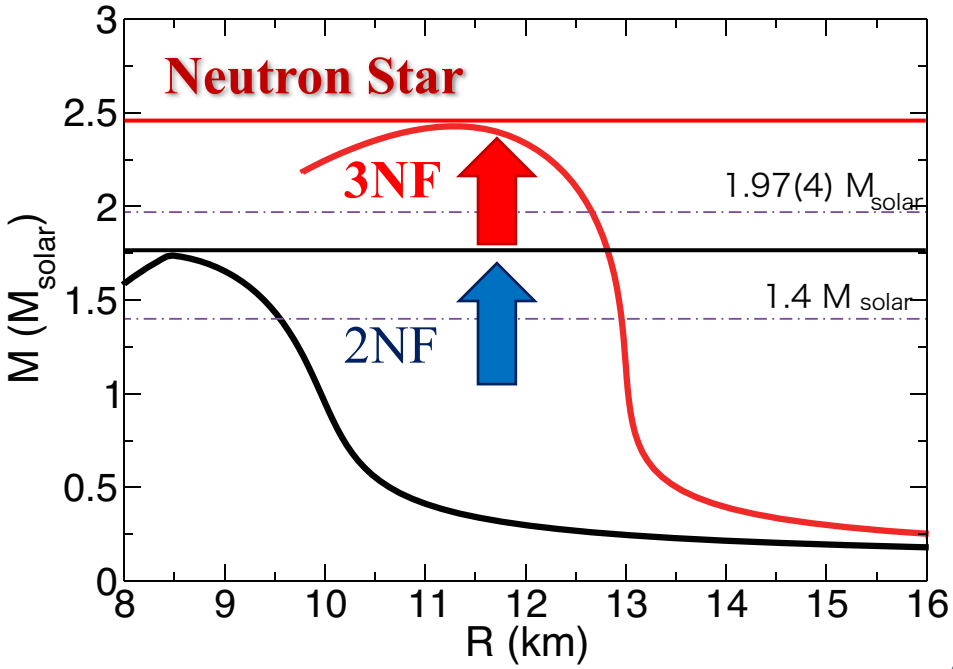
$T = 3/2$ channel of 3-Nucleon Forces

- Important roles for Neutron-rich nuclei, Neutron matter, etc. ...
- Total isospin channel of 3NFs is <u>limited to $T = 1/2$ for d+p.</u>





S. C. Pieper *et al.*, NPA **751**, 516 (2005).



A. Akmal *et al.*, PRC **58**, 1804 ('98).

3NF Study via p-^{3}He Scattering

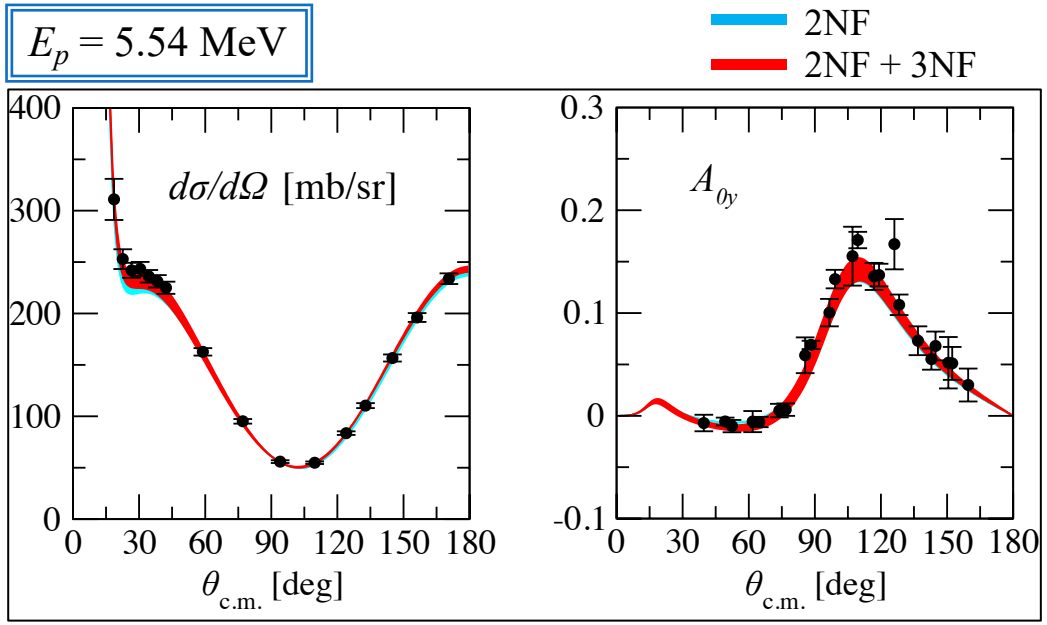
Measurement of p+^{3}He system ($E_p \geq 65$ MeV)

- Approach to iso-spin dependence of 3NFs ($T = 3/2$ 3NFs)
- First Step from few to many nucleon systems
- Theory in progress…

Observables

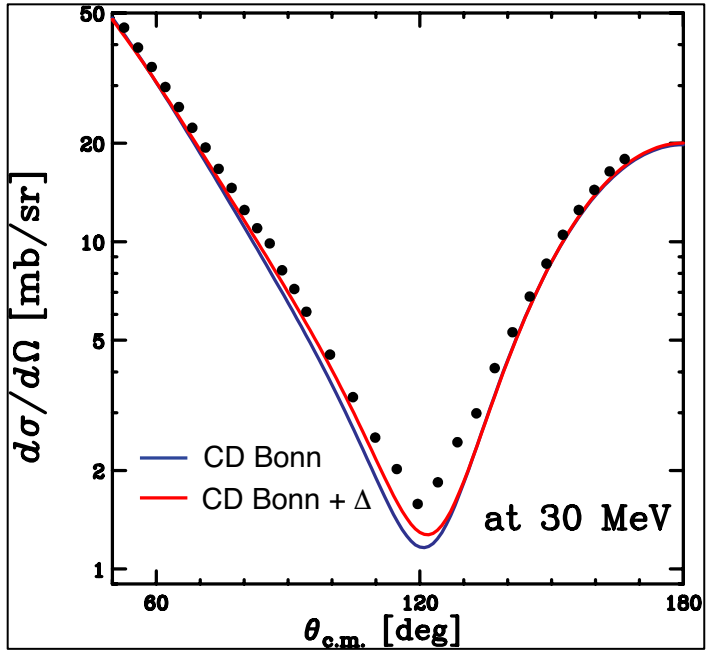
Cross section,
Analyzing powers,
Spin correlation coefficients.

$E_p = 5.54$ MeV



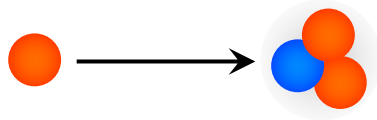
M. Viviani *et al.*, PRL **111**, 172302 (2013).

up to 30 MeV



A. Deltuva and A. C. Fonseca, PRC **87**, 054002 (2013).

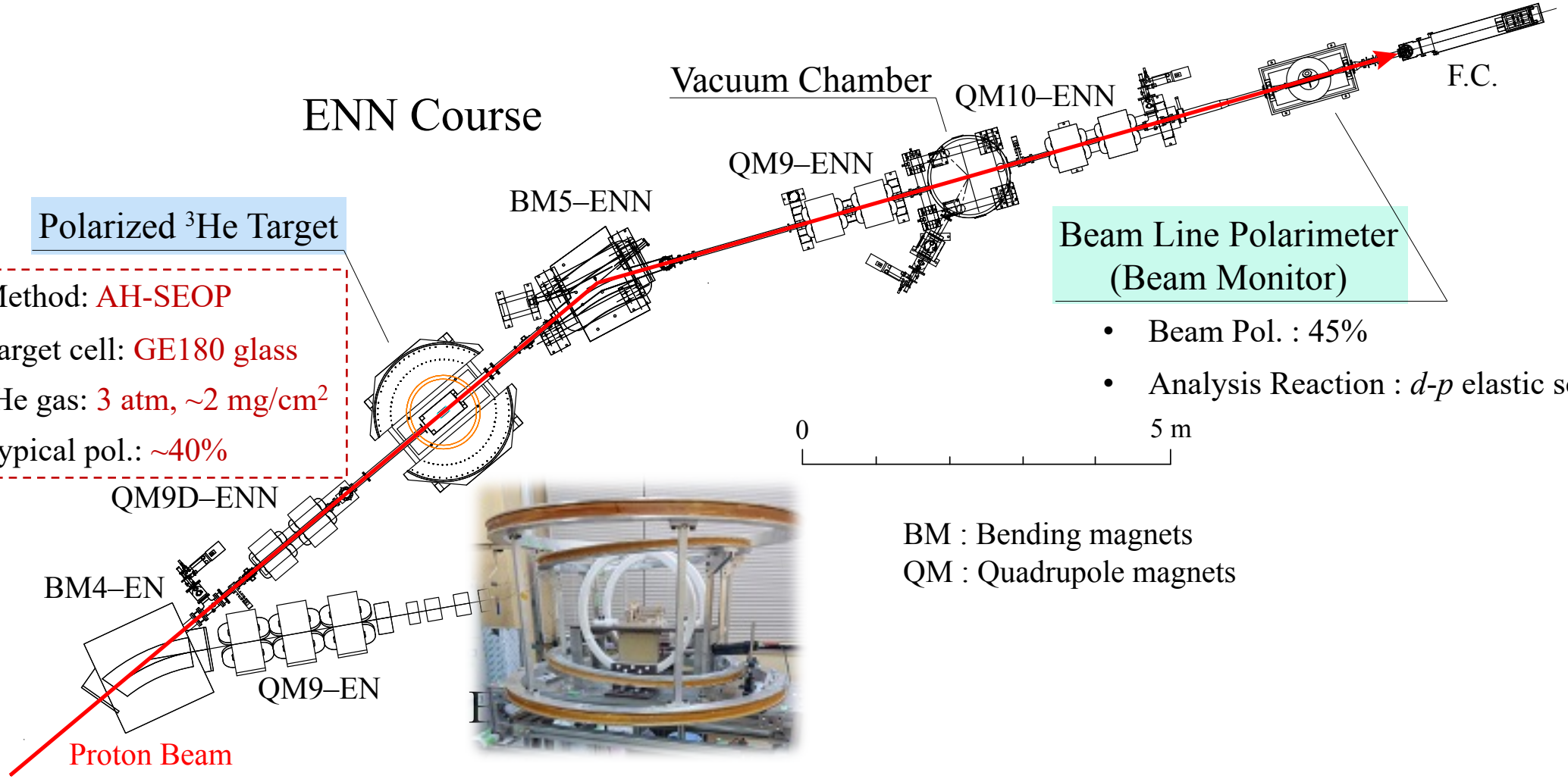
Measurements of proton-^{3}He Scattering



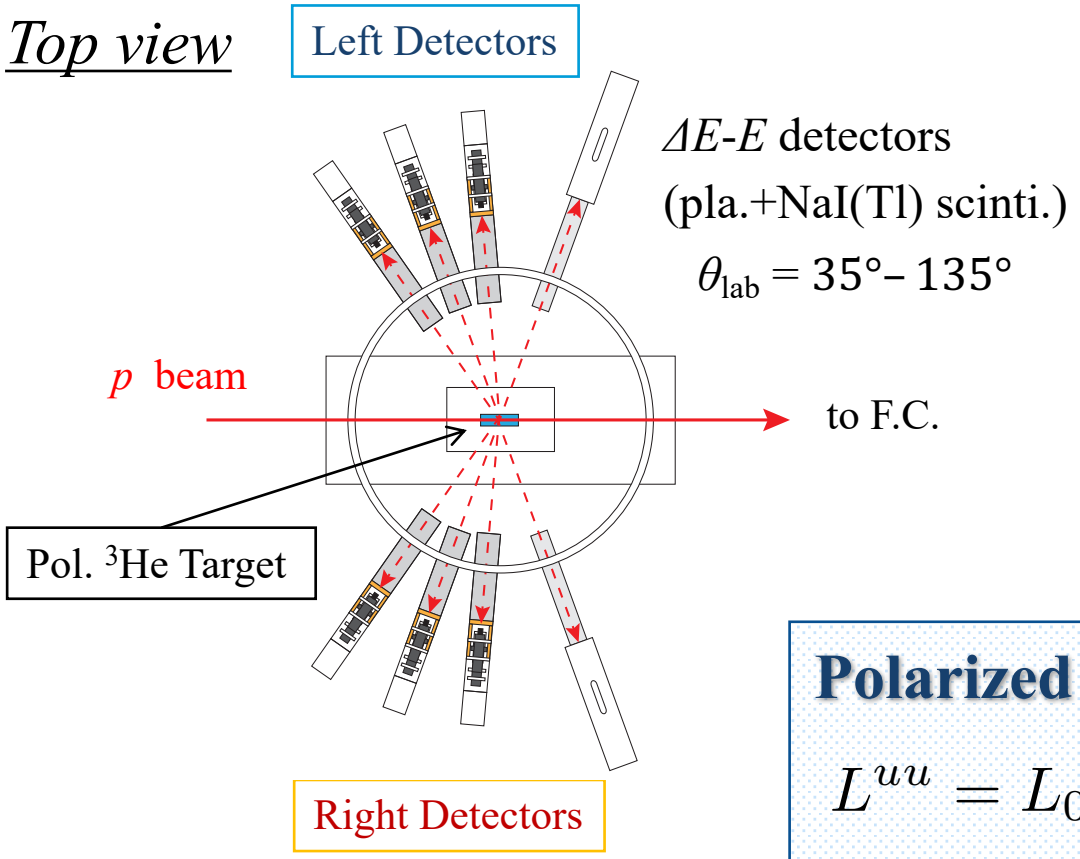
E_p = 65, 70, 100 MeV

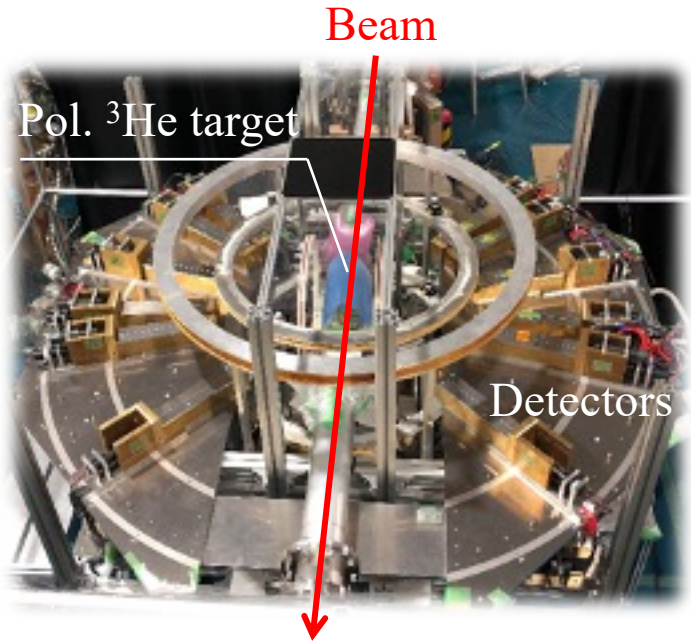
Reported in "AW *et al.*, Phys. Rev. C **103**, 044001 (2021)" for 65, 70 MeV,
"AW *et al.*, Phys. Rev. C **106**, 054002 (2022)" for 100 MeV.

Experimental Setup @RCNP, ENN course



Experimental Setup Around the Target





p_y : Beam pol. p_{0y} : Target pol.

A_y, A_{0y} : Analyzing power

$C_{y,y}$: Spin-correlation coefficient

Polarized Cross Sections

$$L^{uu} = L_0 \left(1 + p_y A_y + p_{0y} A_{0y} + p_y p_{0y} C_{y,y}\right)$$

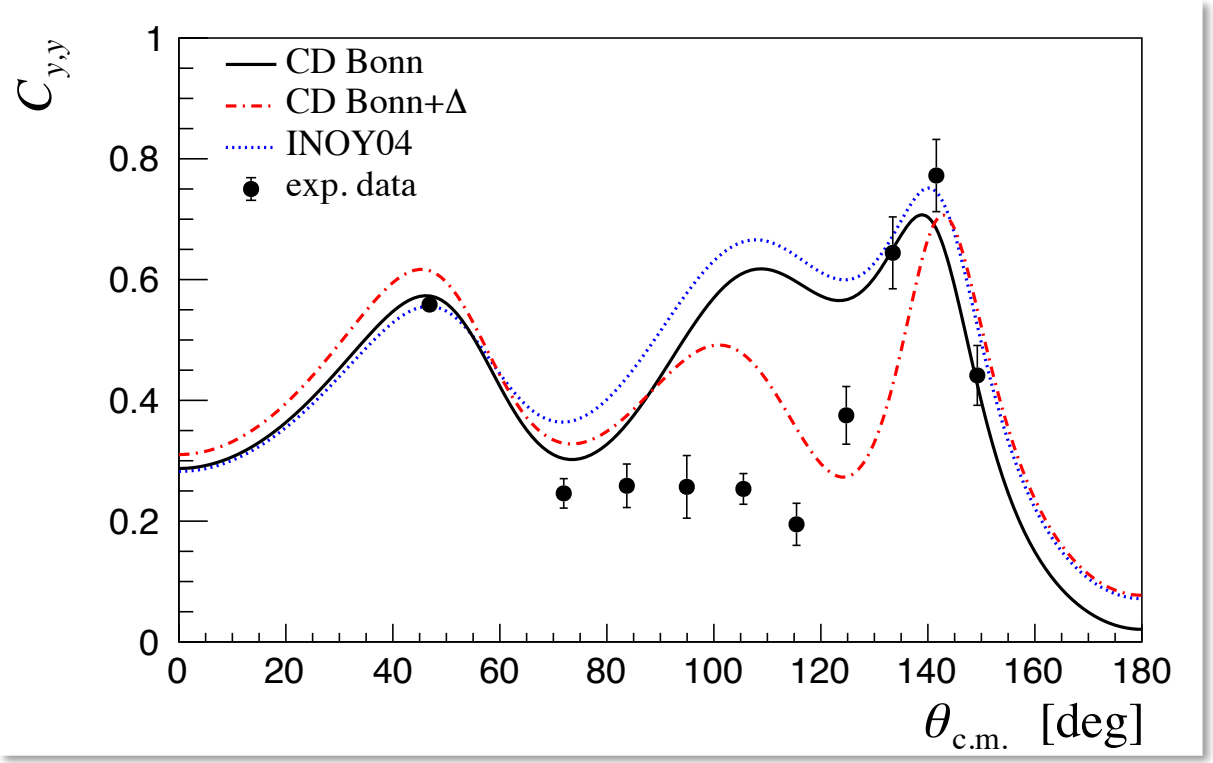
$$R^{uu} = R_0 \left(1 - p_y A_y - p_{0y} A_{0y} + p_y p_{0y} C_{y,y}\right)$$

Spin observables are extracted from ***scattering asymmetry***.

Experimental Results
&
Discussion

Spin Correlation Coefficients $C_{y,y}$ @100 MeV

*Calculations : A. Deltuva, private communications



CD-Bonn : Realistic *NN* potential

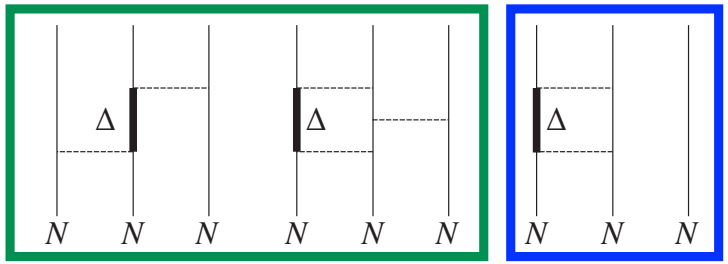
CD-Bonn+Δ : Coupled channel potential with Δ-isobar
→ **Effective 3NFs**

INOY04 : reproduce 3*N* binding energies

- ✓ Date are compared with the calculations based *NN* potentials.
  (total angular momentum : $j < 4$)
- ✓ **Large Δ-isobar effects** are predicted.
- ✓ The Δ-isobar effect improves the agreement with the data.

Δ-Isobar Effects for Differential Cross Sections

- The effects of the 2N dispersion and those of 3, 4NF effect are singled out separately.
  - 2N Dispersion : 2N interaction including Δ-isobar
  - 3, 4NFs : Effective 3, 4NFs by taking into account Δ-isobar



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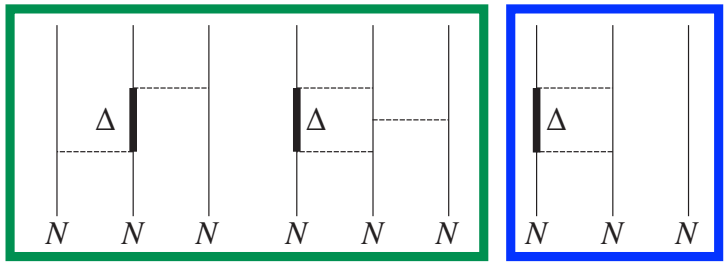
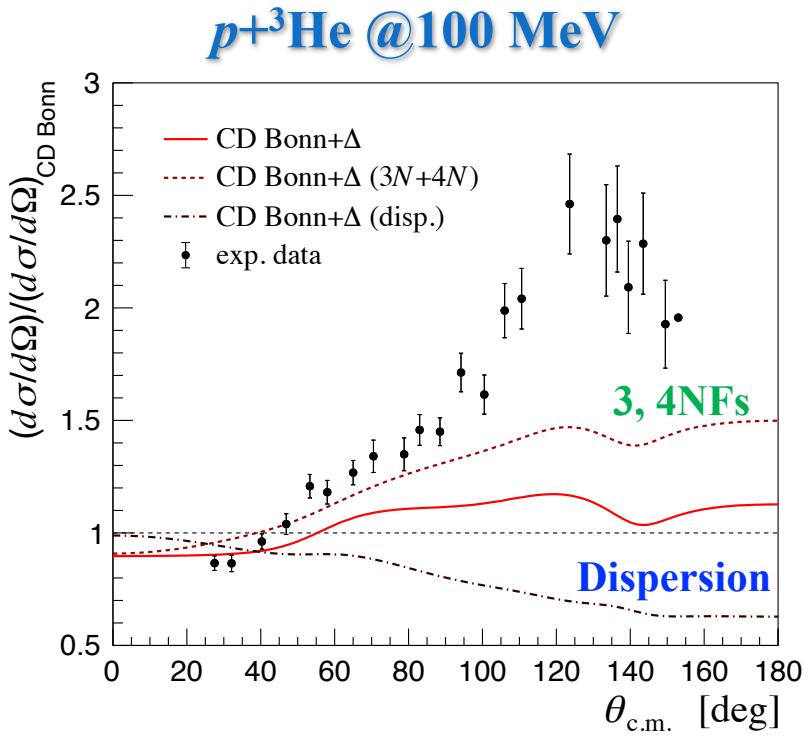
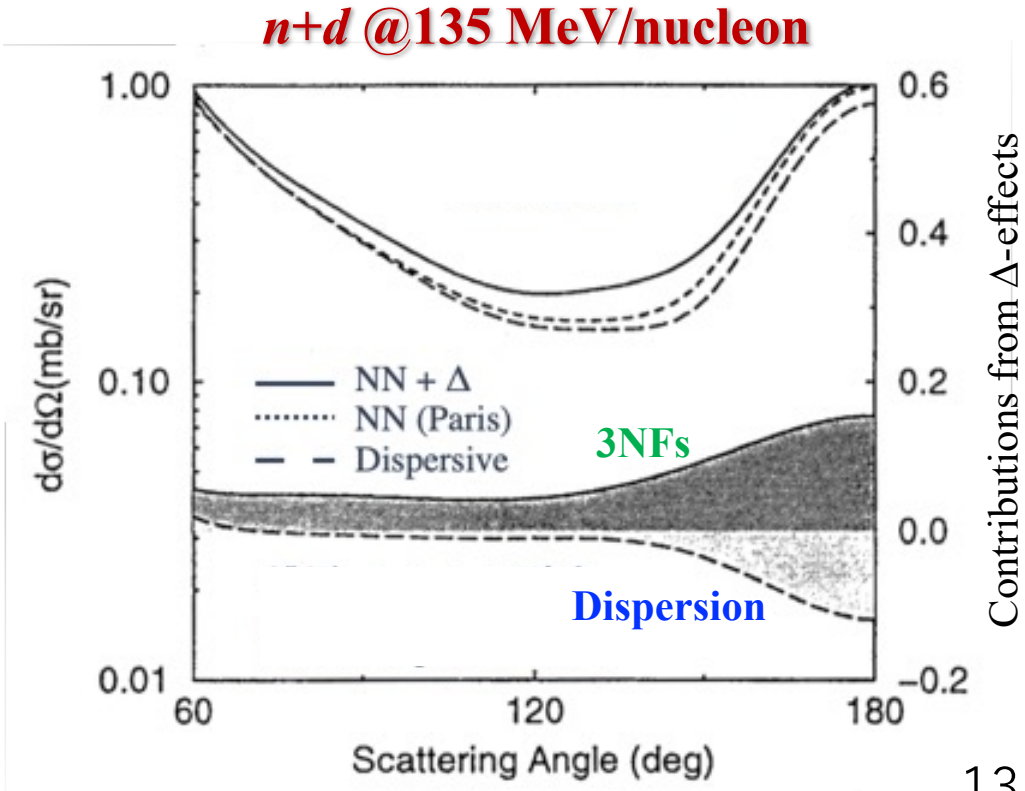




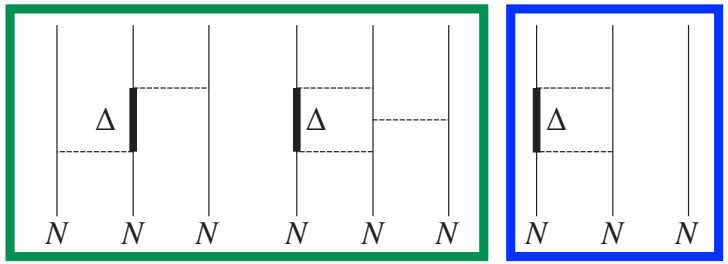
※Data from N. P. Goldstein *et al.*, Can. J. Phys. **48**, 2629 (1970).

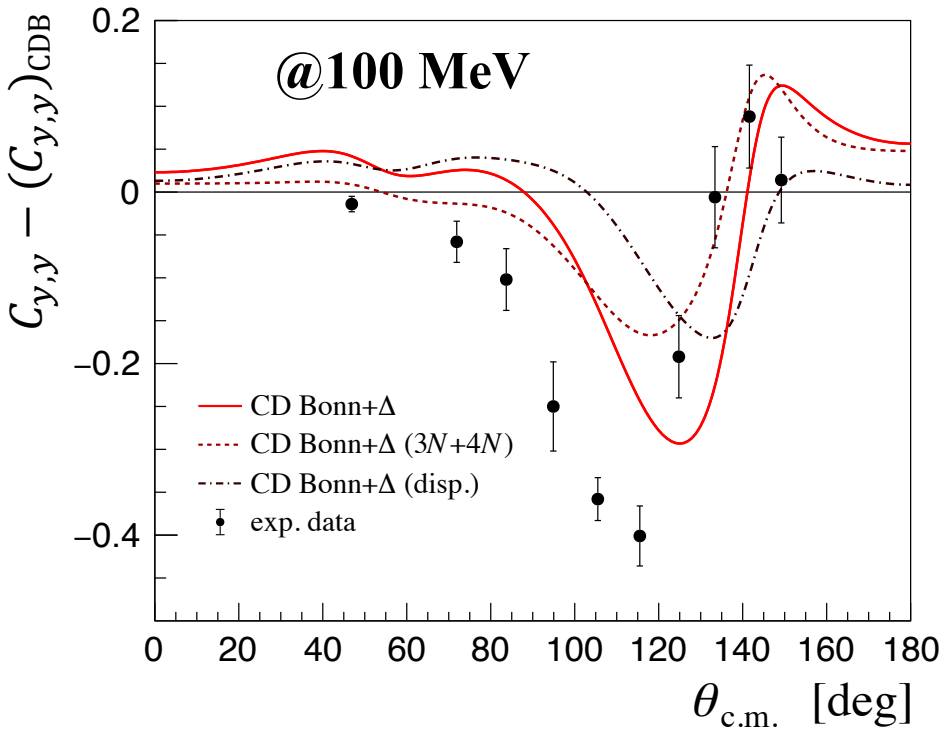


Ref. S. Nemoto, Ph. D thesis (1999).

Δ-Isobar Effects for Scattering Observables

- The effects of the 2N dispersion and those of 3, 4NF effect are singled out separately.
  - 2N Dispersion : 2N interaction including Δ-isobar
  - 3, 4NFs : Effective 3, 4NFs by taking into account Δ-isobar





- ✓ Contributions of dispersive effect and effective 3, 4NFs are comparable.
- ✓ Effects of 3, 4NFs are enhanced at 100 MeV. (At 65 MeV, the Δ-isobar effects are mostly from the 2N dispersion.)

$C_{y,y}$ expands the knowledge of nuclear interactions with the Δ-isobar.

Summary

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

- First step from few-nucleons to many body
- Approach to total iso-spin $T = 3/2$ channel of 3NFs

Measurement of $\boldsymbol{C_{y,y}}$ for p-^{3}He elastic scattering at 100 MeV

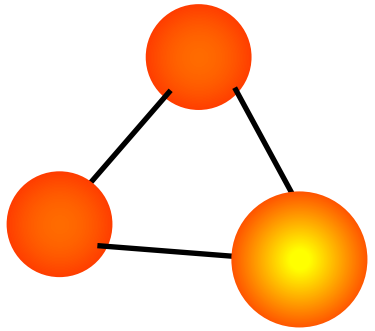
- Precise data of $C_{y,y}$ with wide angular range.
- Comparison the data with the predictions based on NN potential
  - ✓ Calculation (with Δ-d.o.f.) **improved the agreement with the data**
  - ✓ **Different properties from *d-p* scattering system**
    - → The possibility of exploring the 3NFs in p+^{3}He, which are not accessible in d+p.

Excellent tool for 3NF study

Future Plan

***d-p* scattering** : Complete set of spin correlation coefficients

→ **Determination of 3NFs based on χEFT from *d-p* scattering data**



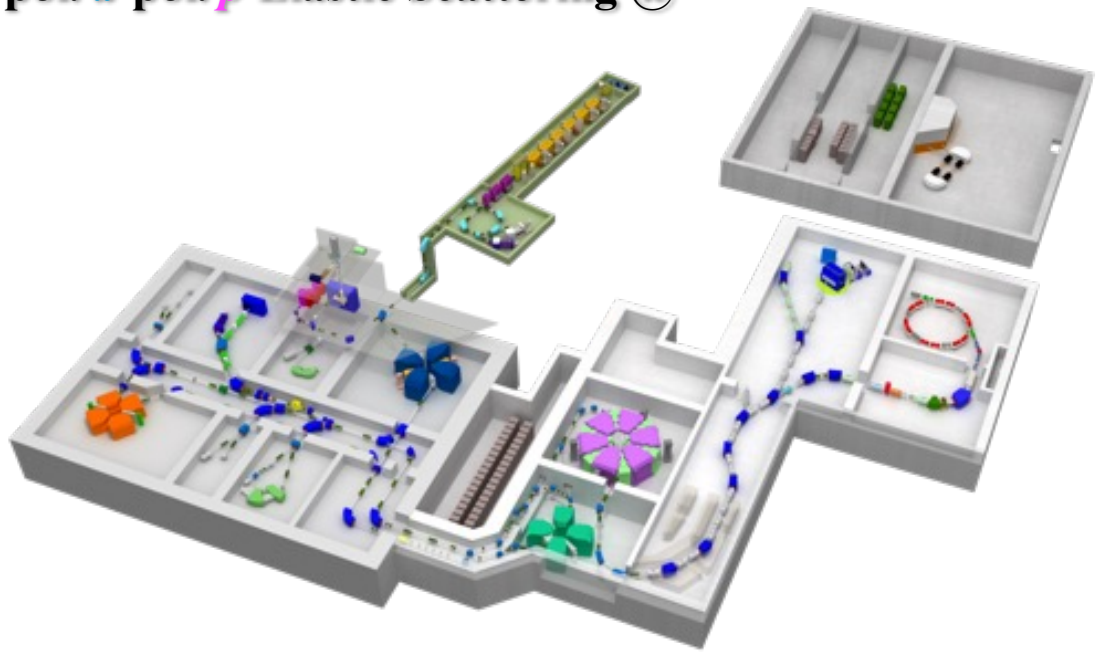
TOMOE *Project*

Determination of χEFT 3NFs from *d-p* elastic scattering

Experiment:

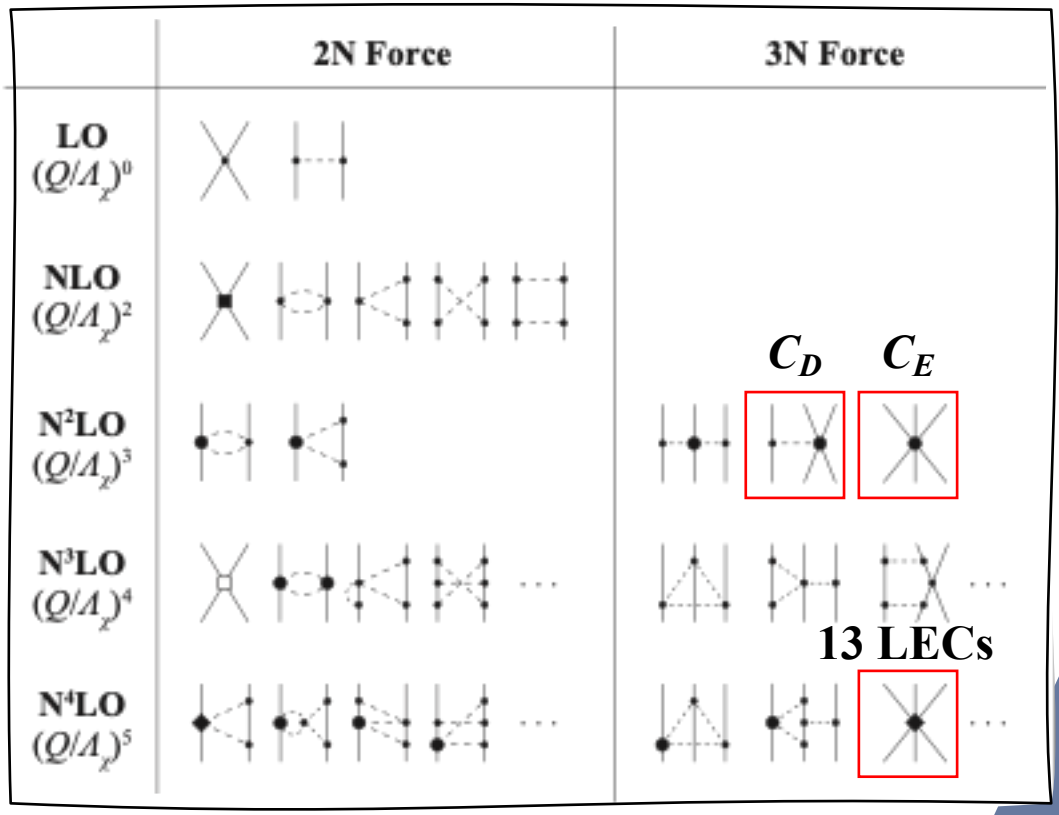
Measurement of spin correlation coefficients for *d*+*p*

pol. *d*-pol. *p* Elastic Scattering @*RIBF*



Theory:

Chiral Effective Field Theory (EFT)



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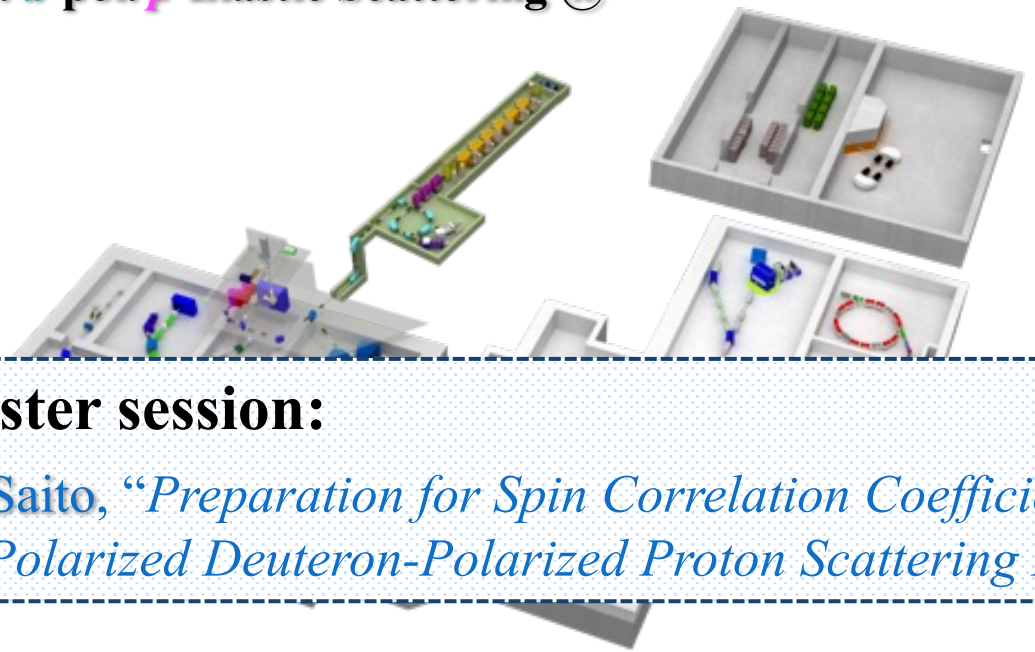

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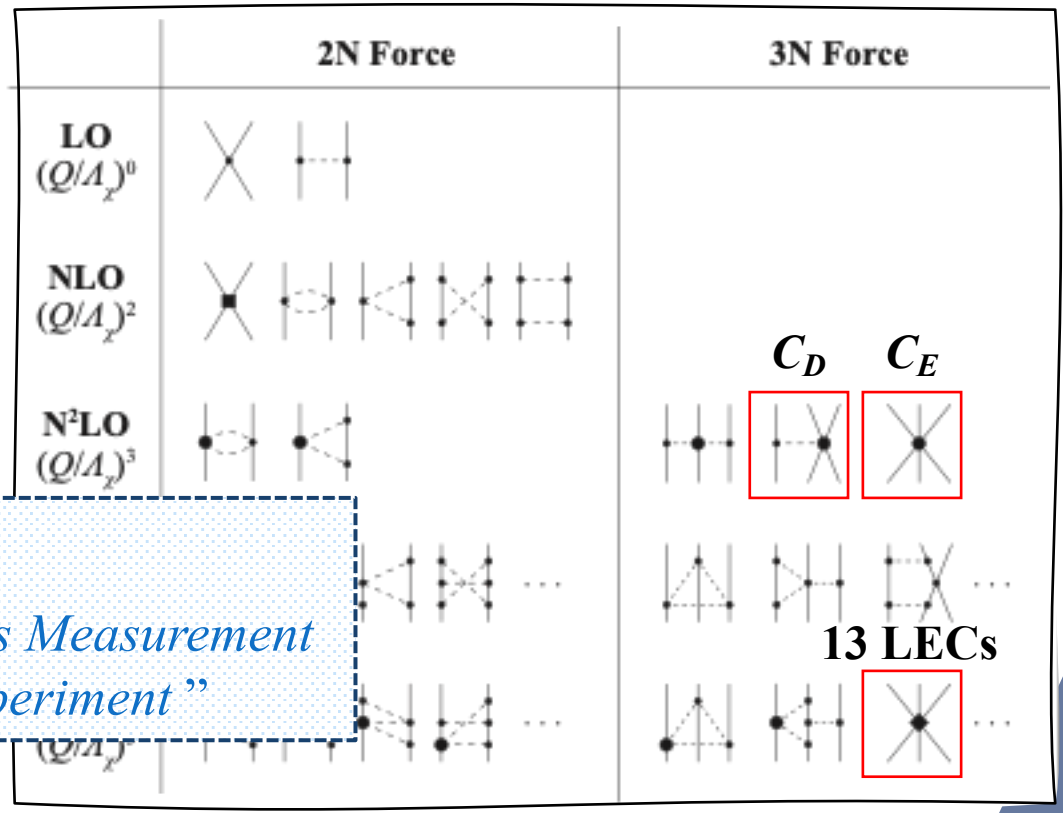

Poster session:

Y. Saito, "*Preparation for Spin Correlation Coefficients Measurement in Polarized Deuteron-Polarized Proton Scattering Experiment*"