Folding Model Analysis of Elastic Scattering between Polarized Proton and ^{6}He

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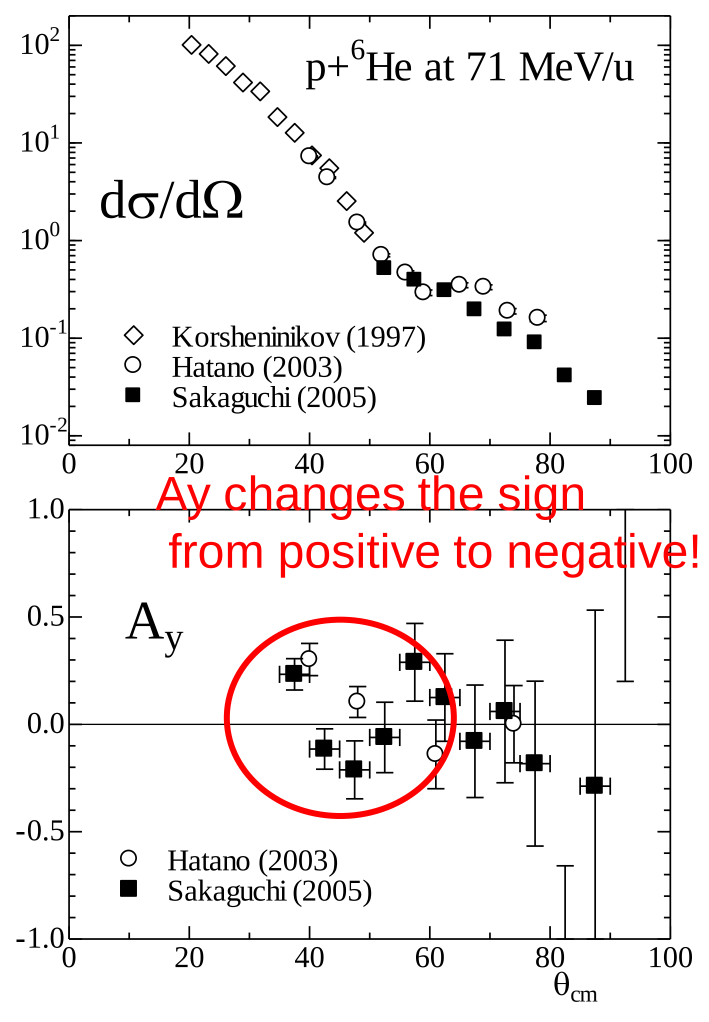
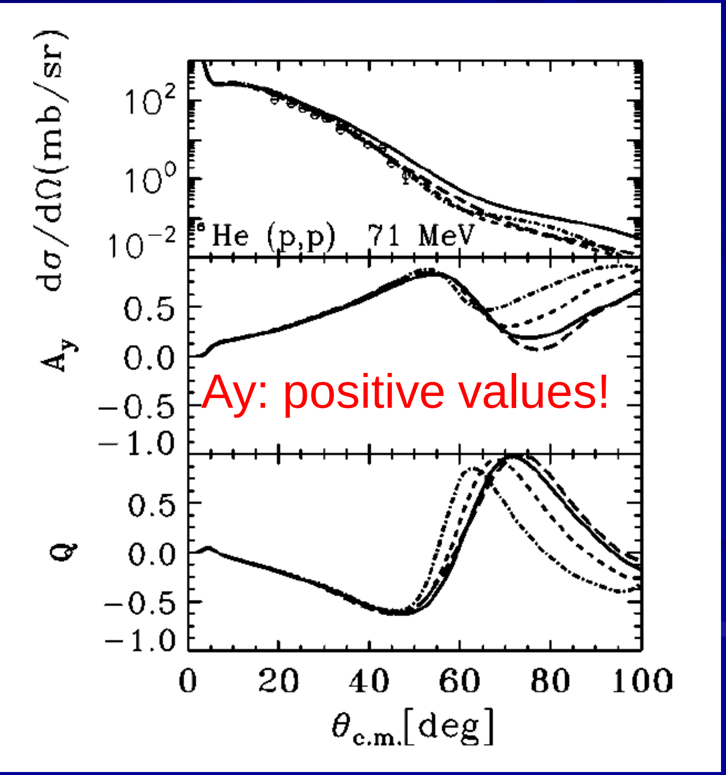
Polarized p+^{6}He elastic scattering

- Measurements of Ay at RIKEN
  - M.Hatano et al. (2003)
  - S.Sakaguchi et al. (2005)



Microscopic Calculation
S.P.Weppner, Ofir Garcia & Ch.Elster,
PRC61(2000)044601
"full-folding optical potential model"



- ^{6}He structure .... several models
- NN interaction ..... Nijmegen I

Our approach

- simple folding model
  - ^{6}He excitation(breakup) is not included

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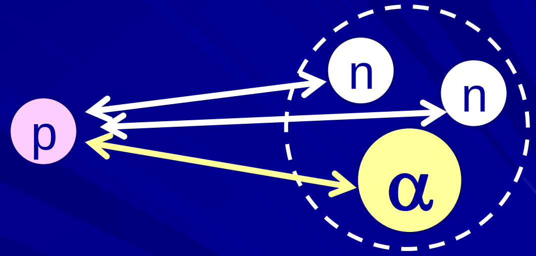
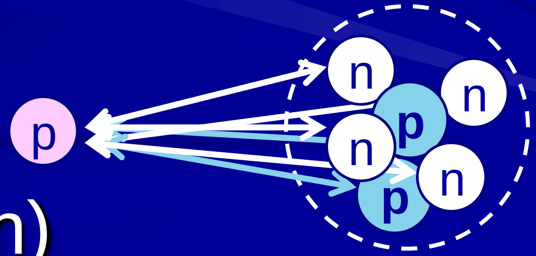
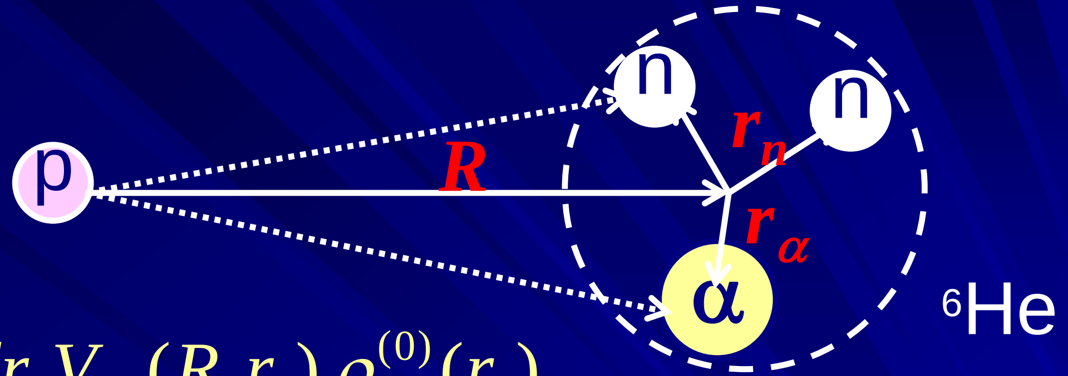
- Two kinds of the folding model
  - Cluster folding (CF) model
    - $^6\text{He} = {}^4\text{He} + n + n$
    - $V(p\text{-}^6\text{He}) \leftarrow V(p\text{-}^4\text{He}) + 2\,V(p\text{-}n)$



  - 6-body folding (6BF) model
    - $^6\text{He} = 6N\ (= 2p + 4n)$
    - $V(p\text{-}^6\text{He}) \leftarrow 2V(p\text{-}p) + 4\,V(p\text{-}n)$



Folding model

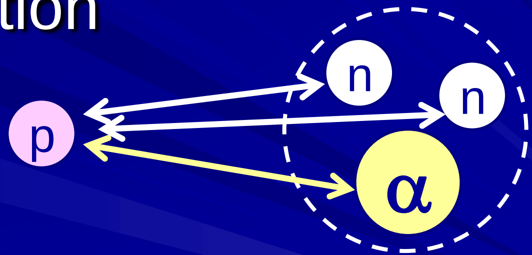


- Folding potential

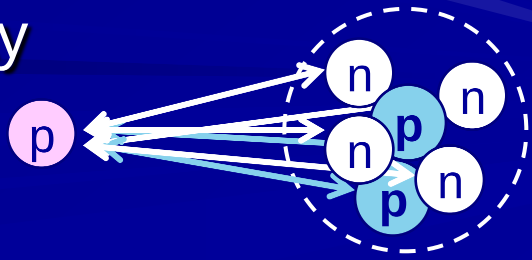
$$U^{\text{fold}}(R) = 4\pi \sum_{x=\alpha,n,n} \int r_x^{\,2} dr_x V_{px}(R, r_x)\, \rho_x^{(0)}(r_x)$$

- To calculate the folding potential, the ^{6}He density and the interactions concerned are required.

- For cluster folding (CF) model
  - ^{6}He density ➔ 3-body cluster distribution
  - p-n interaction
  - p-α interaction

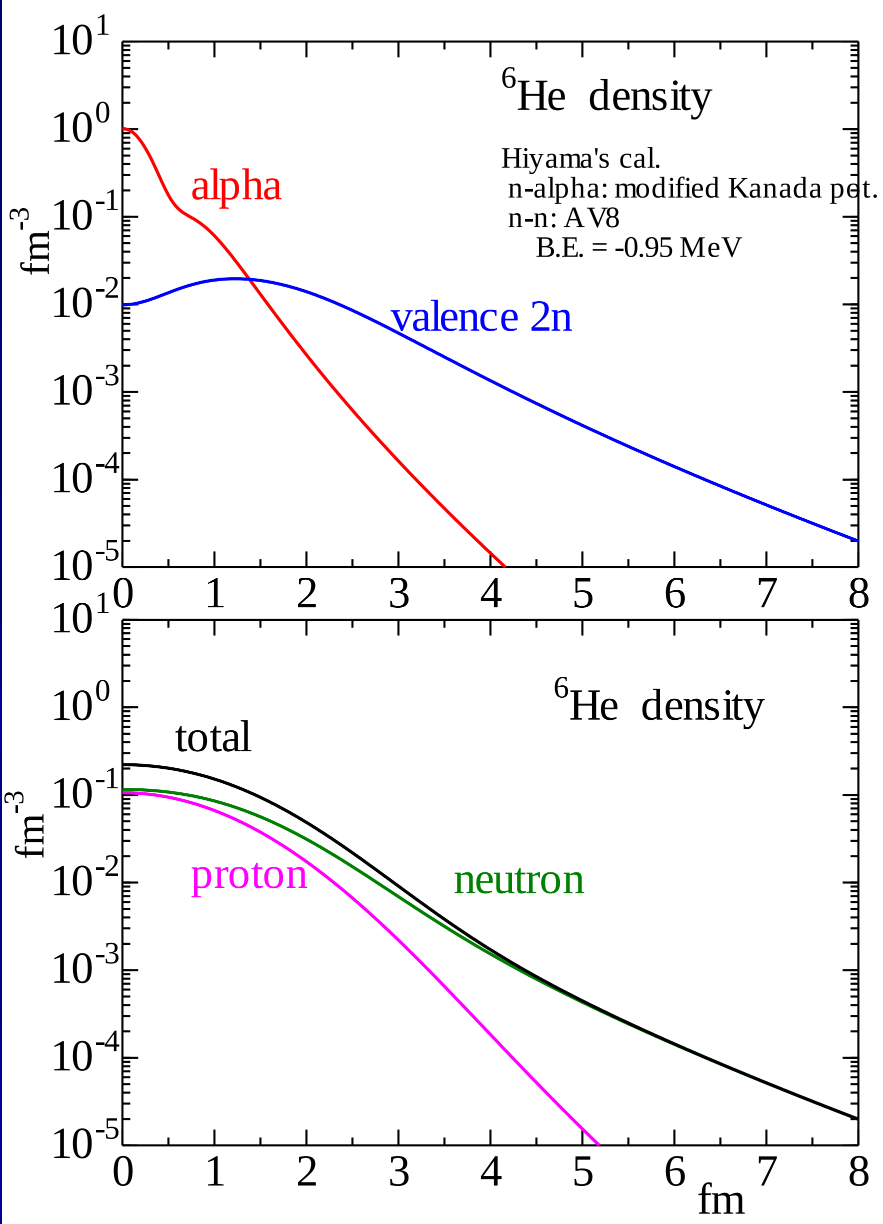


- For 6-body folding (6BF) model
  - ^{6}He density ➔ 6-body nucleon density
  - p-N interaction



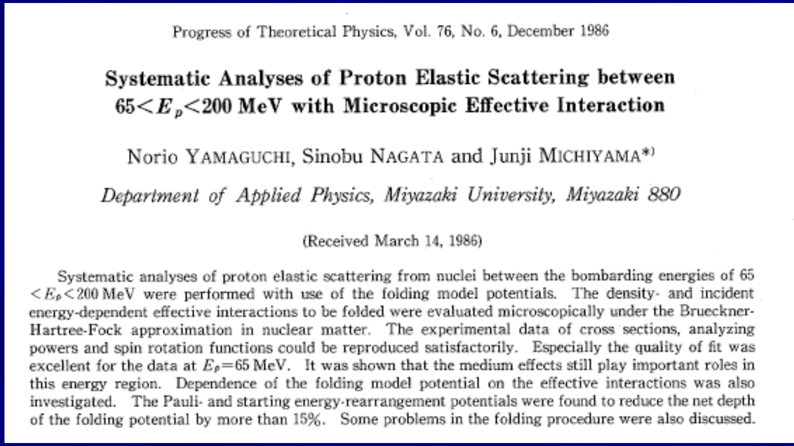
^{6}He density

- 3-body density
  - Gaussian expansion method (GEM): Hiyama et al. PRC 53(1996)2075
    - 3 body model: ^{6}He = α+n+n
    - variational calculation with rearrangement channels
  - interaction
    - N-N : AV8
    - N-α: Kanada potential slightly modified to reproduce B.E. of ^{6}He
  - Pauli principle between N-α
    - OCM
- 6-body density
  - decompositon of α → 4N
  - one-range Gauss wave function r_0 = 1.4 fm



p-N interaction

- CEG (complex effective interaction with Gaussian form)
  - effective potential ← N-N G-matrix
    - complex central force
    - complex LS force
  - references
    - Yamaguchi et al., PTP 70(1983)459
    - Nagata et al., PTP 73(1985)512
    - Yamaguchi et al., PTP 76(1986)1289



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Systematic Analyses of Proton Elastic Scattering between $65<E_p<200$ MeV with Microscopic Effective Interaction

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(Received March 14, 1986)

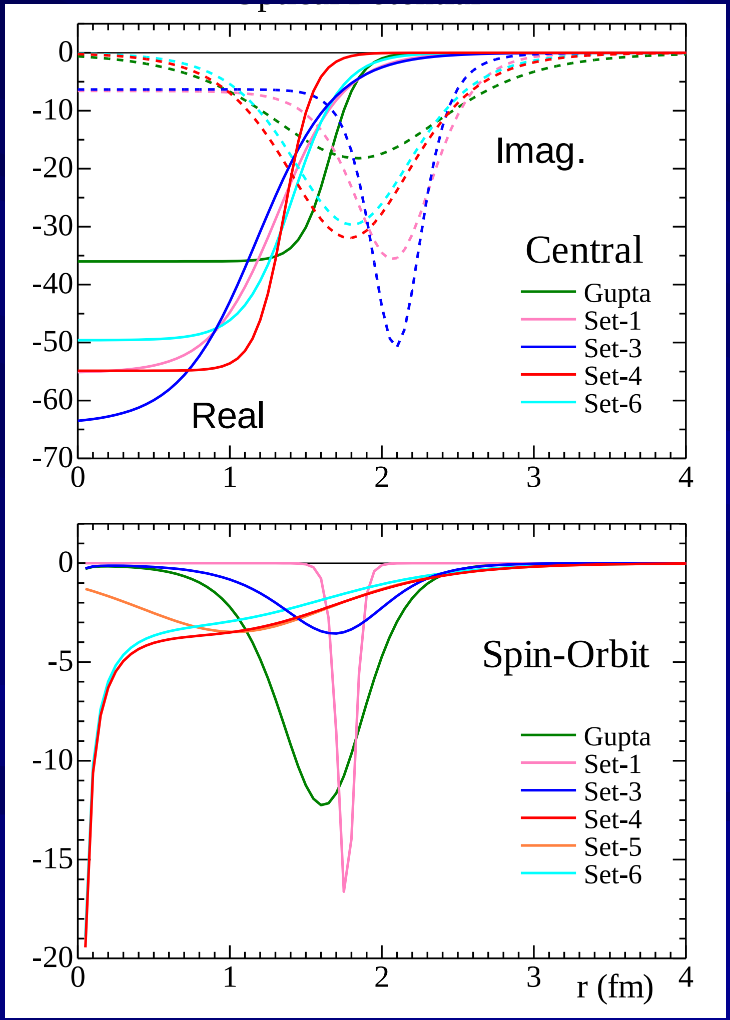
Systematic analyses of proton elastic scattering from nuclei between the bombarding energies of $65<E_p<200$ MeV were performed with use of the folding model potentials. The density- and incident energy-dependent effective interactions to be folded were evaluated microscopically under the Brueckner-Hartree-Fock approximation in nuclear matter. The experimental data of cross sections, analyzing powers and spin rotation functions could be reproduced satisfactorily. Especially the quality of fit was excellent for the data at $E_p=65$ MeV. It was shown that the medium effects still play important roles in this energy region. Dependence of the folding model potential on the effective interactions was also investigated. The Pauli- and starting energy-rearrangement potentials were found to reduce the net depth of the folding potential by more than 15%. Some problems in the folding procedure were also discussed.

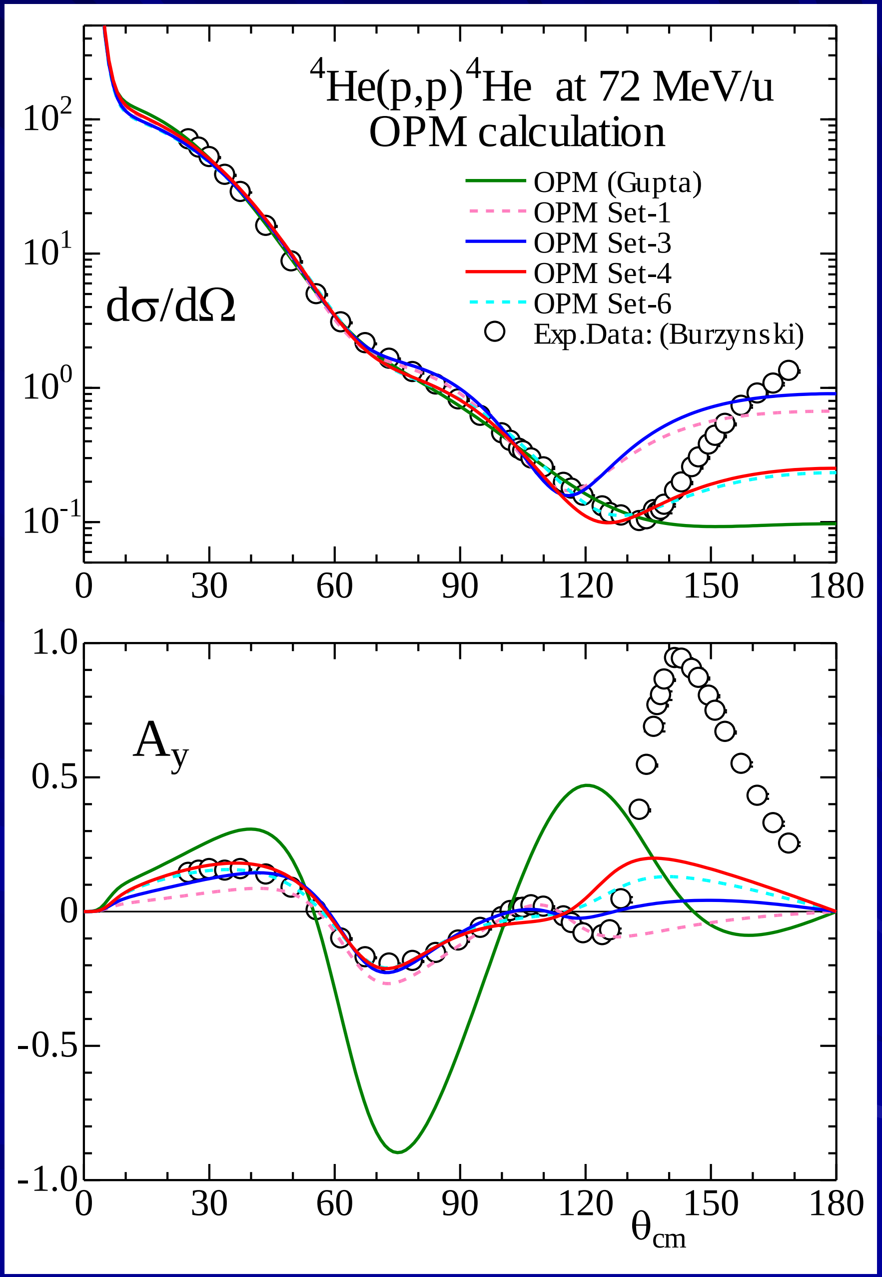
  - succeed in describing the various p-A elastic scatterings
- in actual calculation
  - exchange term ➔ localize with usual technique
    local density approx., local momentum approx.(selfconsistent cal.)
  - imag. pot.
    effective k-mass factor = 0.7 (const.)
  - LS interaction
    finite range correction

    Rikus and von Geramb, NP A426(1984)496

p-α interaction

- p-^{4}He optical potential
  - automatic search to reproduce the p+^{4}He data at 72 MeV/u.





OPM(Gupta):
D.Gupta, C.Samanta & R.Kanungo, NP A674(2000) 77

p-α optical potential parameters

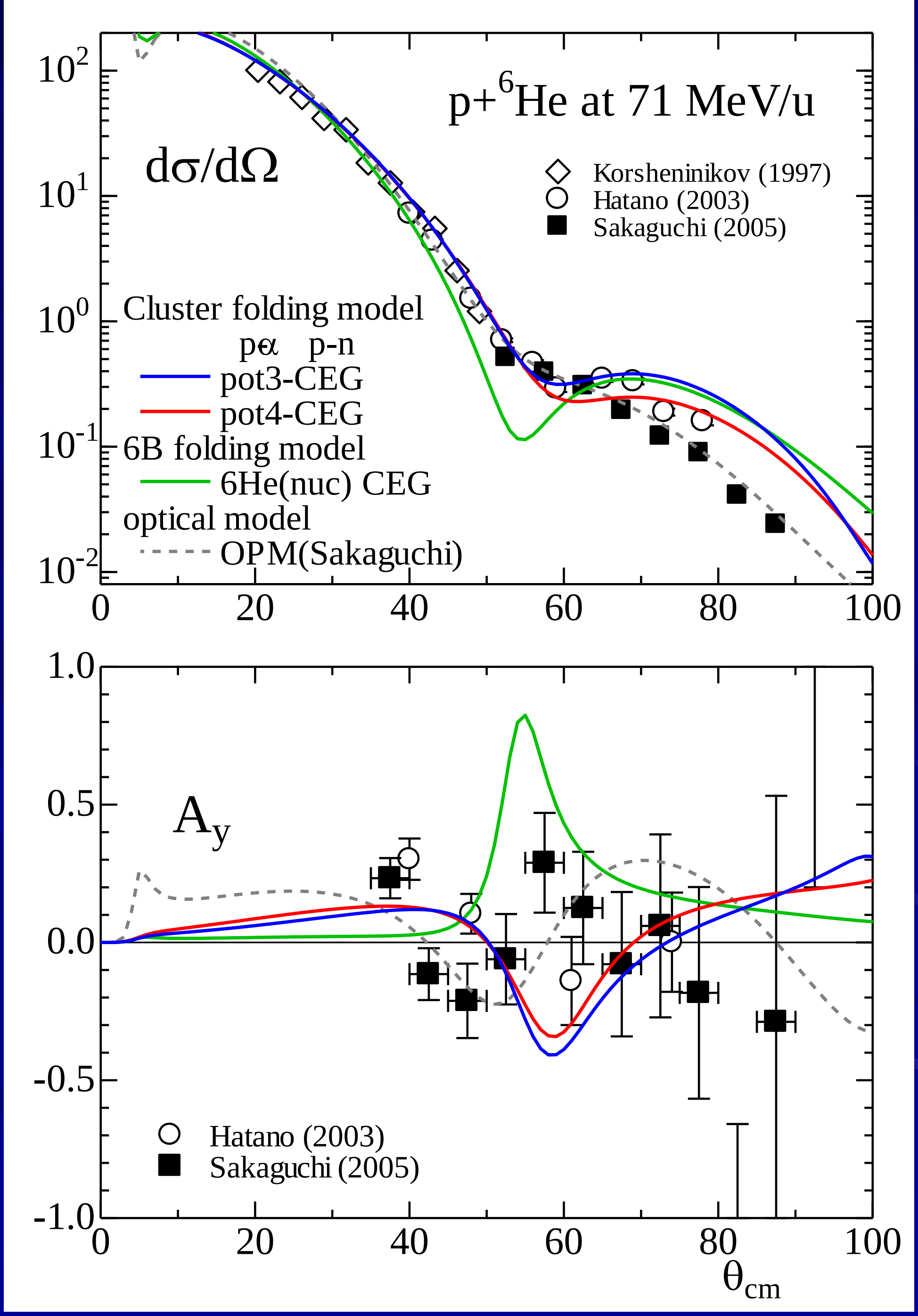
p+^{4}He at 72 MeV/u

	Gupta	Set-1	Set-2	Set-3	Set-4	Set-5	Set-6
V_0	36.00	55.229	64.1345	64.1345	54.8672	55.0140	49.5960
r_{0R}	1.044	0.8305	0.7440	0.7440	0.8566	0.8565	0.8921
a_R	0.096	0.2182	0.2562	0.2562	0.0960	0.0960	0.1604
W_0	0.0	6.5892	6.3380	6.3380	0.0	0.0	0.0
r_{0I}	--	1.3143	1.3325	1.4497	--	--	--
a_I	--	0.1750	0.1148	0.2089	--	--	--
W_D	18.20	32.309	46.2287	46.229	31.9247	31.9284	29.6771
r_{0ID}	1.158	1.3143	1.3325	1.3196	1.1248	1.1235	1.1361
a_{ID}	0.387	0.1750	0.1148	0.1100	0.2811	0.2814	0.2683
r_{0C}	1.40	1.40	1.40	1.40	1.40	1.40	1.40
V_{SO}	7.46	2.2364	2.7261	2.7520	3.9247	(*) 3.2524	3.3281
r_{0RS}	1.044	1.1131	1.1003	1.1003	0.8563	0.6475	0.8271
a_{RS}	0.186	0.0364	0.2252	0.2252	0.4914	0.4549	0.5159
J_R/A	177.3	168.4	162.1	162.1	151.6	151.9	166.2
rmsr	1.332	1.304	1.320	1.320	1.112	1.112	1.248
J_I/A	342.5	383.4	365.9	370.3	389.4	388.5	349.1
rmsr	2.407	2.130	2.090	2.097	2.115	2.114	2.103

(*) In Set-5, Spin-orbit potential has a Woods-Saxon derivative form.
In other sets, the Thomas form is used.

Results

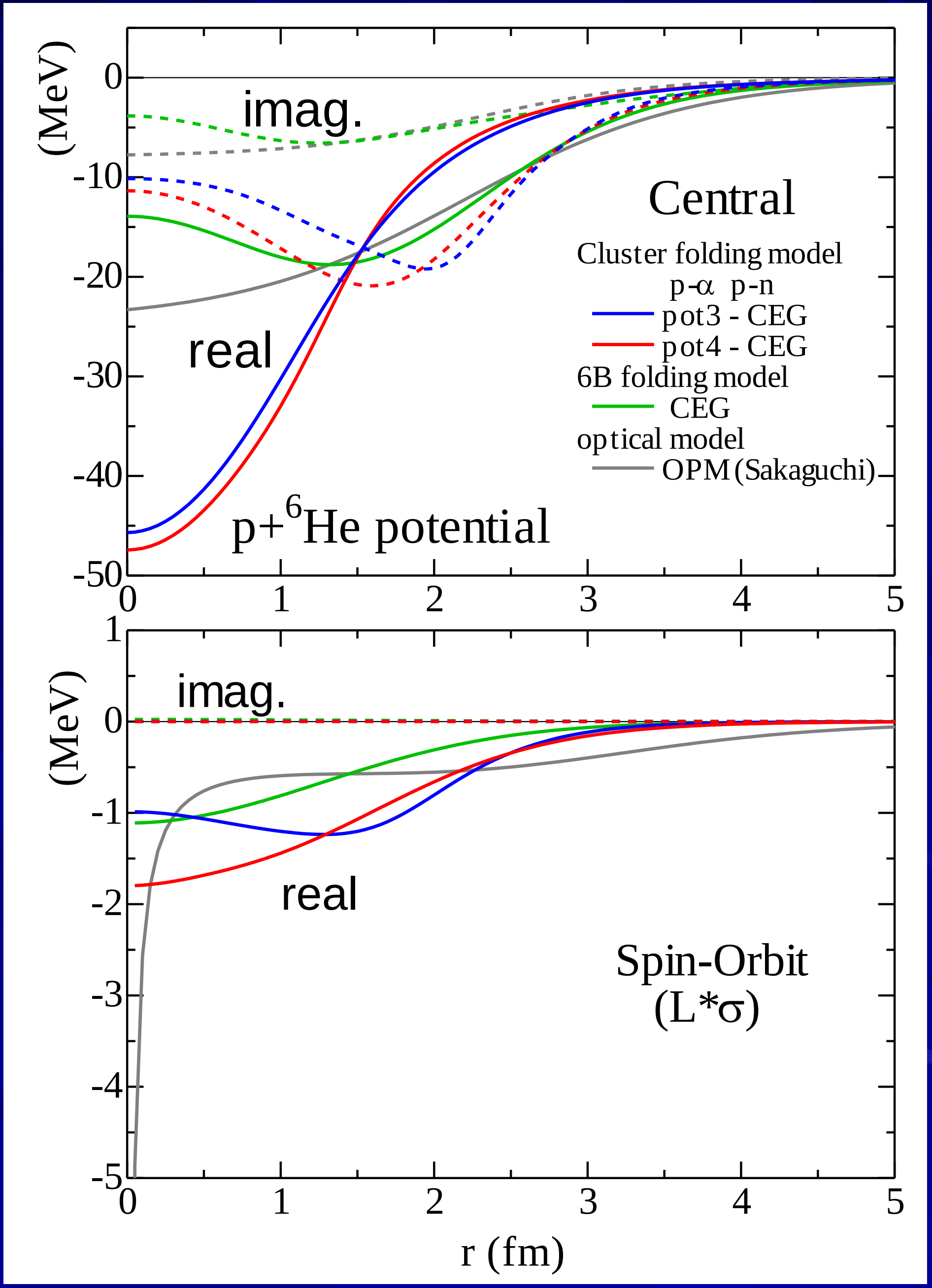
- Cross section
  - Cluster folding (CF) model gives a good description
  - 6-body folding (6BF) model shows a discrepancy at middle angles (θ=40°-60°)
- Vector analyzing power: Ay
  - CF calculation reproduces the characteristic of the exp. data.
    - change of the sign
    - negative minimum at a middle angular region
    - but, position of minimum slightly shifts backward
  - 6BF calclulation does not reproduce the exp. data
    - positive values in the entire region



Comparison of potentials

- Folding potential has a long tail
  ← halo neutron

- The phenomenological optical potential
  which can reproduce
  the experimental data
  has a longer and larger tail
  → especially for LS pot.



Possibility of improvement

- Due to the existence of the valence 2n, α in ^{6}He is not the α in free space.

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- α in ^{6}He may be enlarged from free-α size.

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- Test :
  change the p-α pot. in CF model
  - increase radius parameters (r_0) by 10%
  - increase diffuseness parameters (a) by 0.1 fm
  - change depth parameters so as to keep volume integrals

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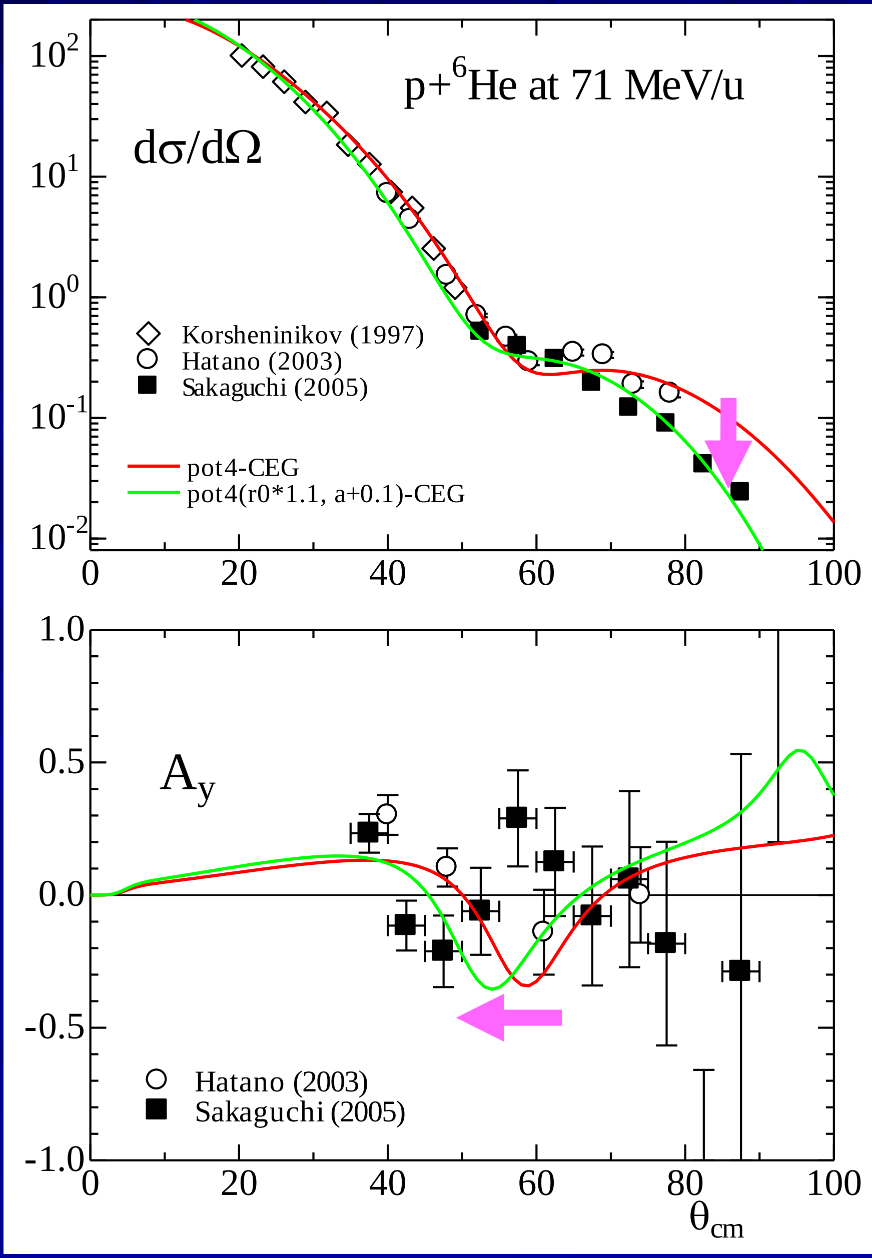
- Improvement of the fit is obtained



Summary : p-^{6}He elastic scattering at 71 MeV/u

- Folding model calculation
  - Cluster folding (CF) model
    - ^{6}He=α+n+n ← GEM (Gaussian expansion method)
    - p-α int. ← optical pot.
    - p-n int. ← N-N effective int. (CEG)
  - 6-body folding (6BF) model
    - ^{6}He= 6N
    - p-N int. ← N-N effective int. (CEG)
- Comparison of calculated results and exp. data
  - CF model
    - cross section → sufficiently well reproduced
    - Ay → succeeded in reproducing a gross feature
    - folding potential → p-α component is important
  - 6BF model
    - fails to reproduce the experimental data (especially Ay)
- A key to the good description of the p+^{6}He scattering is to improve the description of the p+^{4}He scattering in ^{6}He