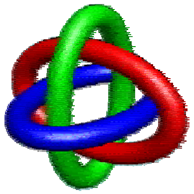


Study of the ground state wave function of ^{6}He via 2n transfer reaction $^{6}He(p,t)\alpha$

- ^{6}He benchmark nucleus for halo phenomenon and 3-body correlations

- previous work: Elastic scattering, Charge exchange reaction, σ_R

M.D. Cortina-Gil et al., Phys. Lett. B 371 (96) 14
M.D. Cortina-Gil et al., Nucl. Phys. A 641 (98) 263
A. de Vismes et al, Phys. Lett. B 505 (01) 15
A. de Vismes et al., Nucl. Phys. 703 (2002) 573

- Present work : Study of the ground state wave function of ^{6}He via $^{6}He(p,t)\alpha$ reaction at 25 MeV/nucleon. Contribution of α+2n and t+t configurations.

Collaboration

Ganil

C. Demonchy
L. Giot
W. Mittig
P. Roussel-Chomaz
H. Savajols

Uni. of Surrey

I. Thompson
N.Timofeyuk

Collège de France

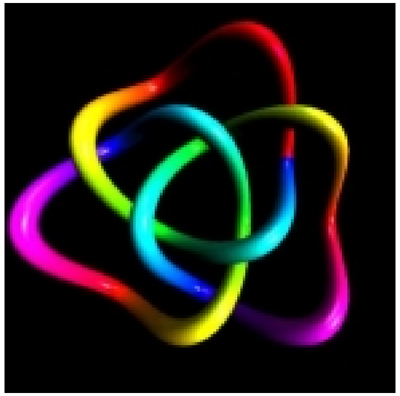
S. Pita

Cracow

R. Wolski

SPhN Cea/Saclay

N. Alamanos
F. Auger
C. Jouanne
V. Lapoux
L. Nalpas
E.C Pollaco
A. Gillibert
J-L Sida
F. Skaza



Dubna

S. Stepantsov
- Rodin
A. Fomichev
S. Sidortchuk
G. Ter Akopian

Warsaw

K. Rusek

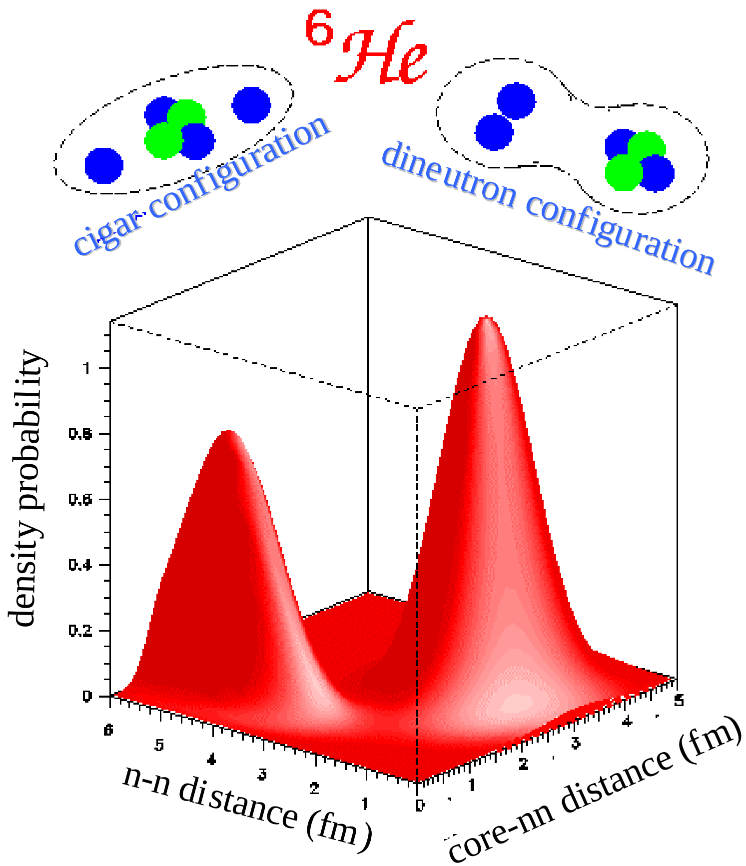
Uni. Santiago de Compostela

M-D. Cortina-Gil
J. Fernandez

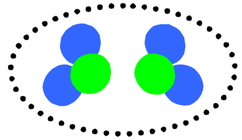
Uni. of Ioannina

A. Pakou

Ground state wave function of ^{6}He



M. Zhukov et al. Phys. Rep. 231 (1993) 151



- ^{6}He binding energy well reproduced with a t+t configuration

  A. Csoto, PRC 48 (1993) 165

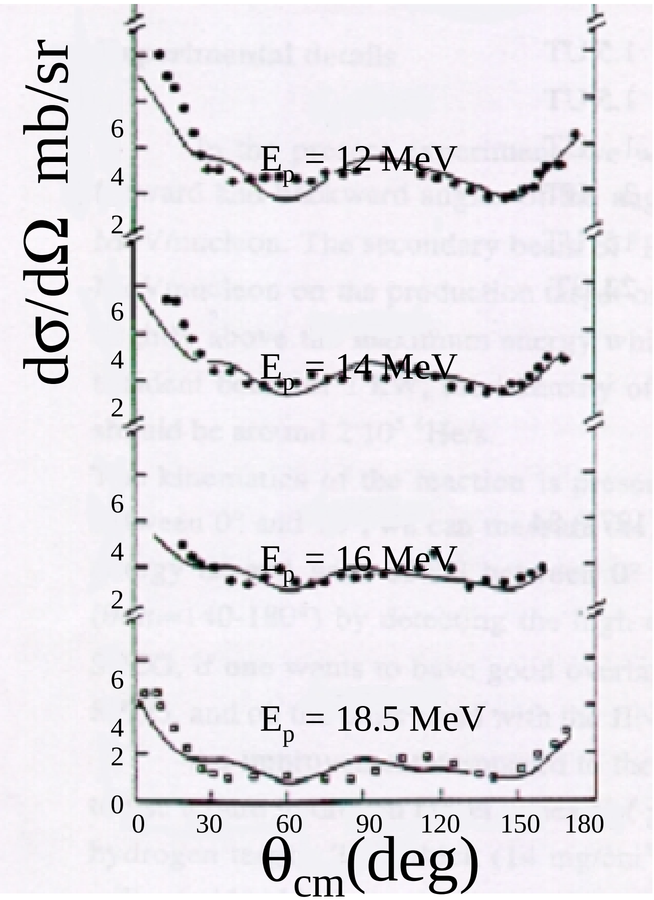
- Microscopic calculations

$\langle {}^6He \mid {}^4He + n + n \rangle$	1.10 - 1.56
$\langle {}^6He \mid t + t \rangle$	0.44 - 1.77

Yu. F. Smirnov, PRC 15 (1977) 84
K. Arai et al, PRC 59 (1999) 1432

Analogy between ^{6}Li and ^{6}He

^{6}Li(p,^{3}He)^{4}He



M.F Werby et al, PRC 8 (1973) 106

- ^{6}Li: ^{6}Li(p,^{3}He)α
  clusters: α+d, ^{3}He+t

^{6}Li + p → ^{3}He + α

(α + d) + p → ^{3}He + α

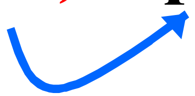
(^{3}He+ t) + p → α + ^{3}He

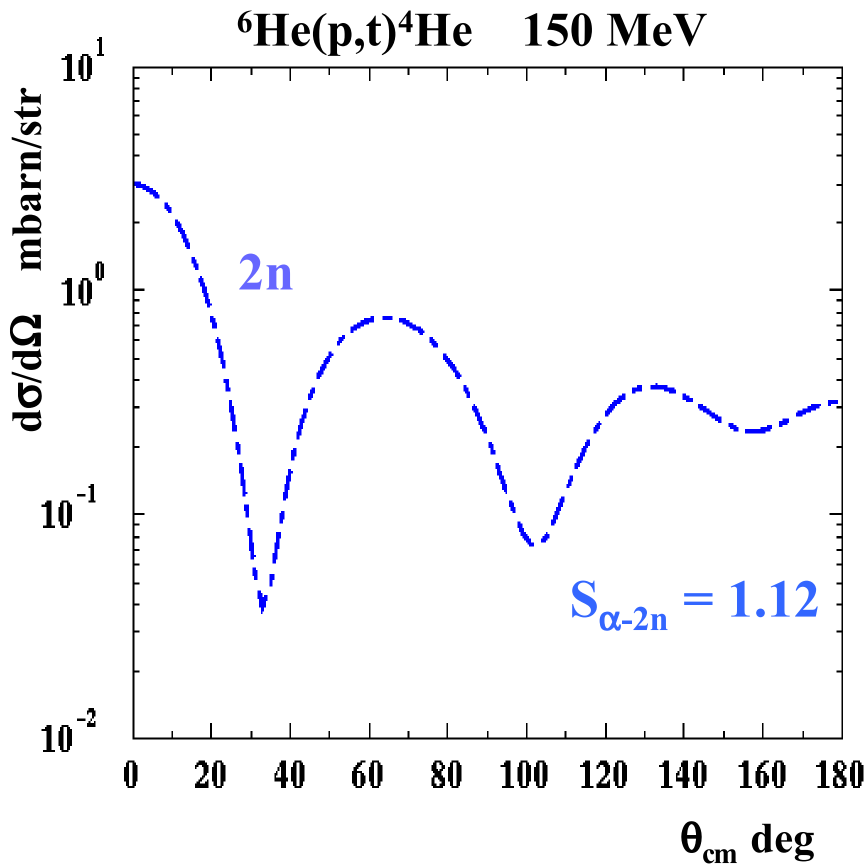
- ^{6}He: ^{6}He(p,t)α

clusters: α + 2n, t+t ??

$^{6}He(p,t)^{4}He$ transfer reaction

$(^{4}He + 2n) + p \rightarrow \alpha + t$

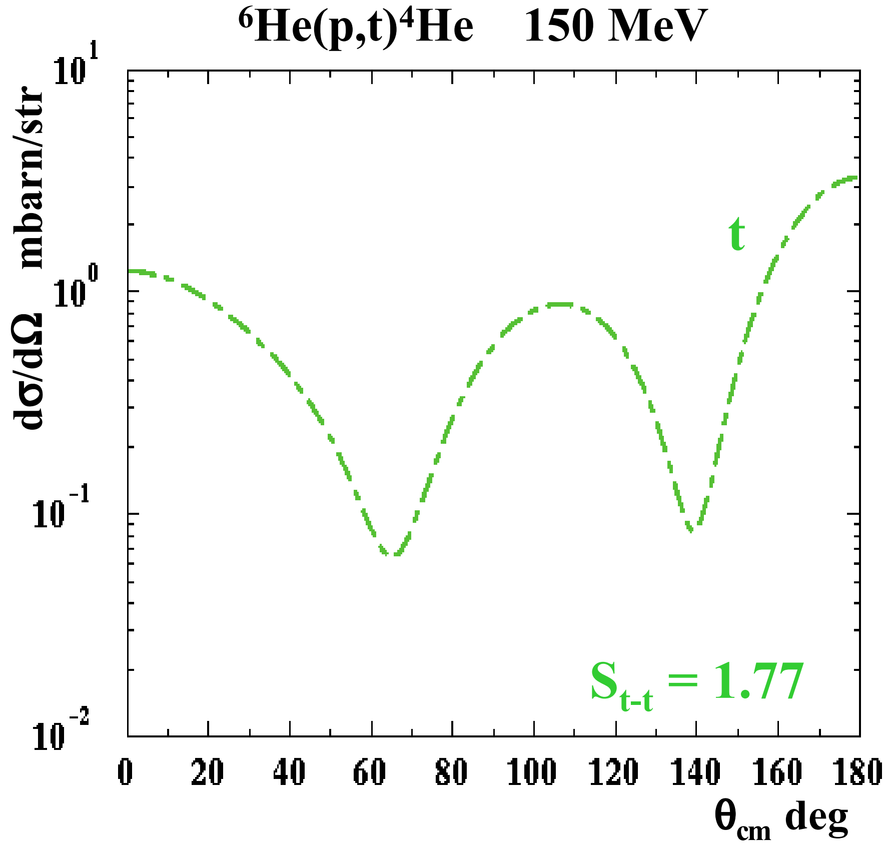




$^{6}He(p,t)^{4}He$ transfer reaction

$(^{4}He + 2n) + p \rightarrow \alpha + t$

$(t + t) + p \rightarrow t + \alpha$



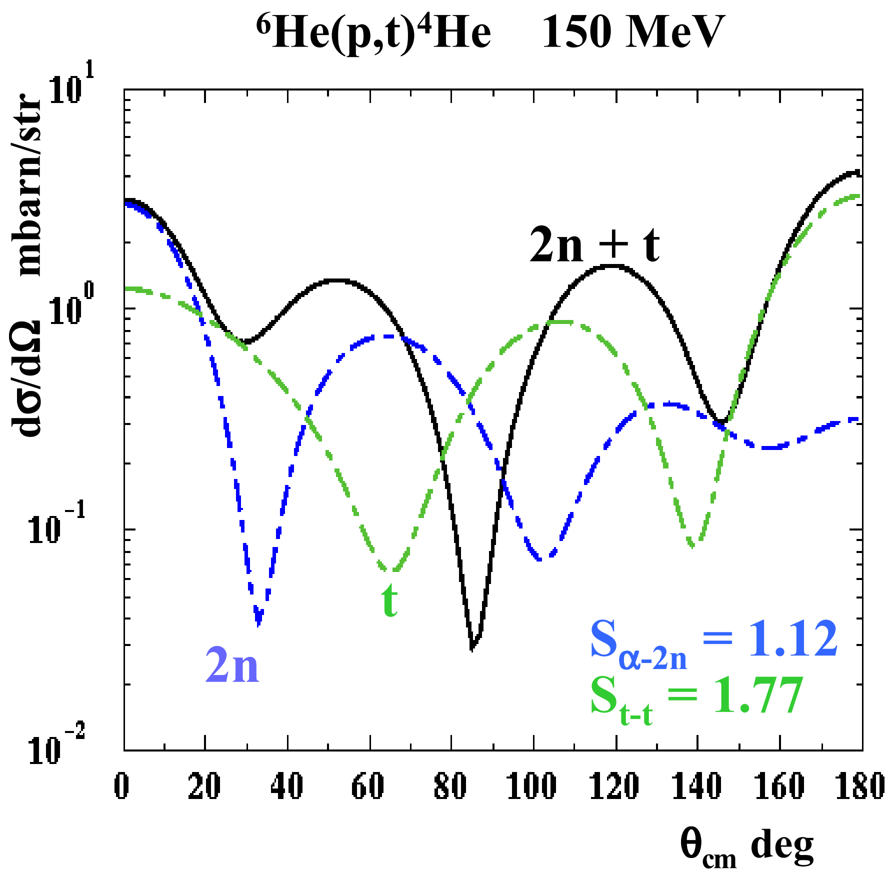
$^{6}He(p,t)^{4}He$ transfer reaction

$(^{4}He + 2n) + p \rightarrow \alpha + t$

$(t + t) + p \rightarrow t + \alpha$

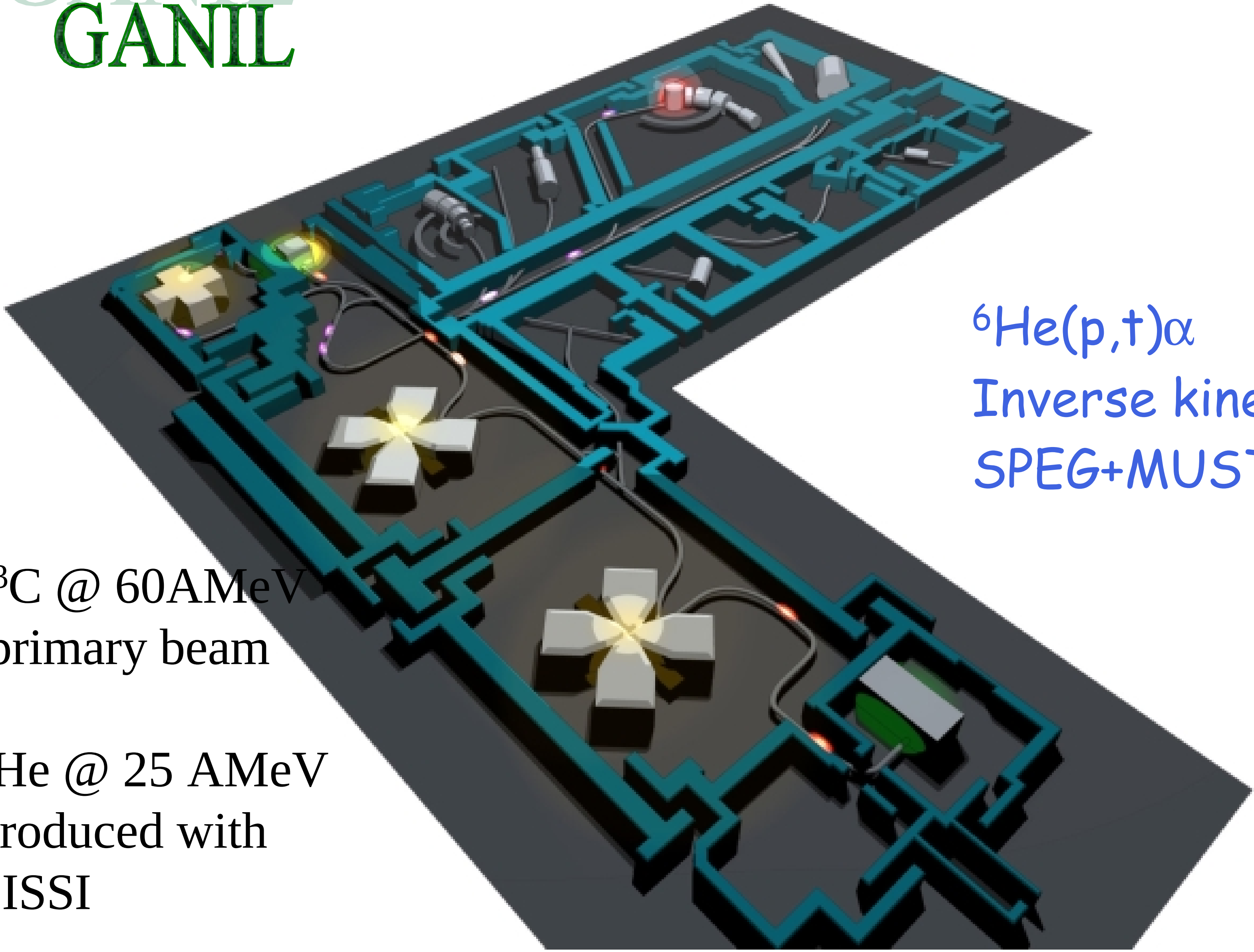
- First experiment at Dubna: intermediate angles
  R. Wolski et al., PLB 467 (1999)

- Experiment at GANIL complete angular distribution



GANIL

GANIL



^{6}He(p,t)α

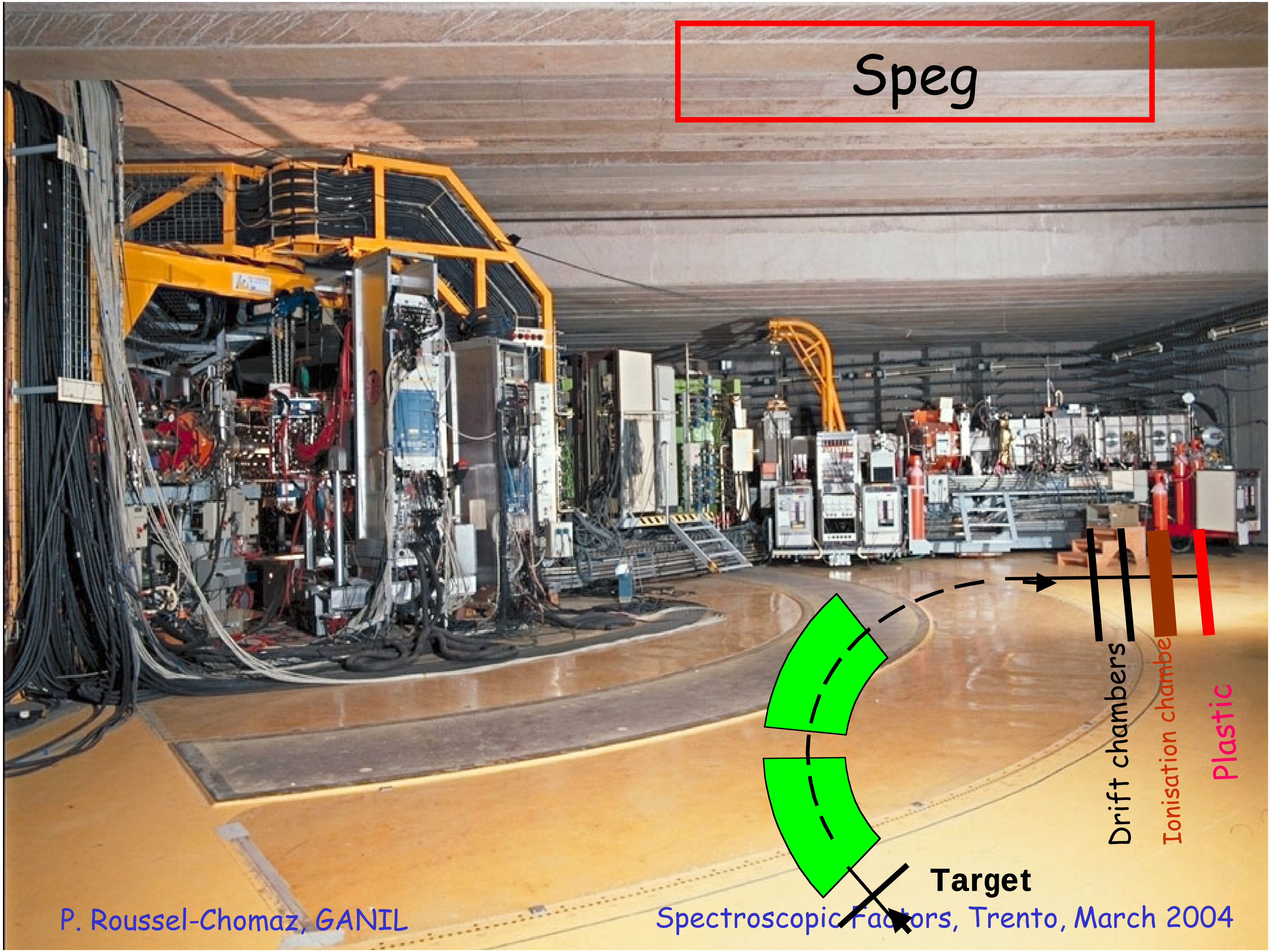
Inverse kinematics

SPEG+MUST

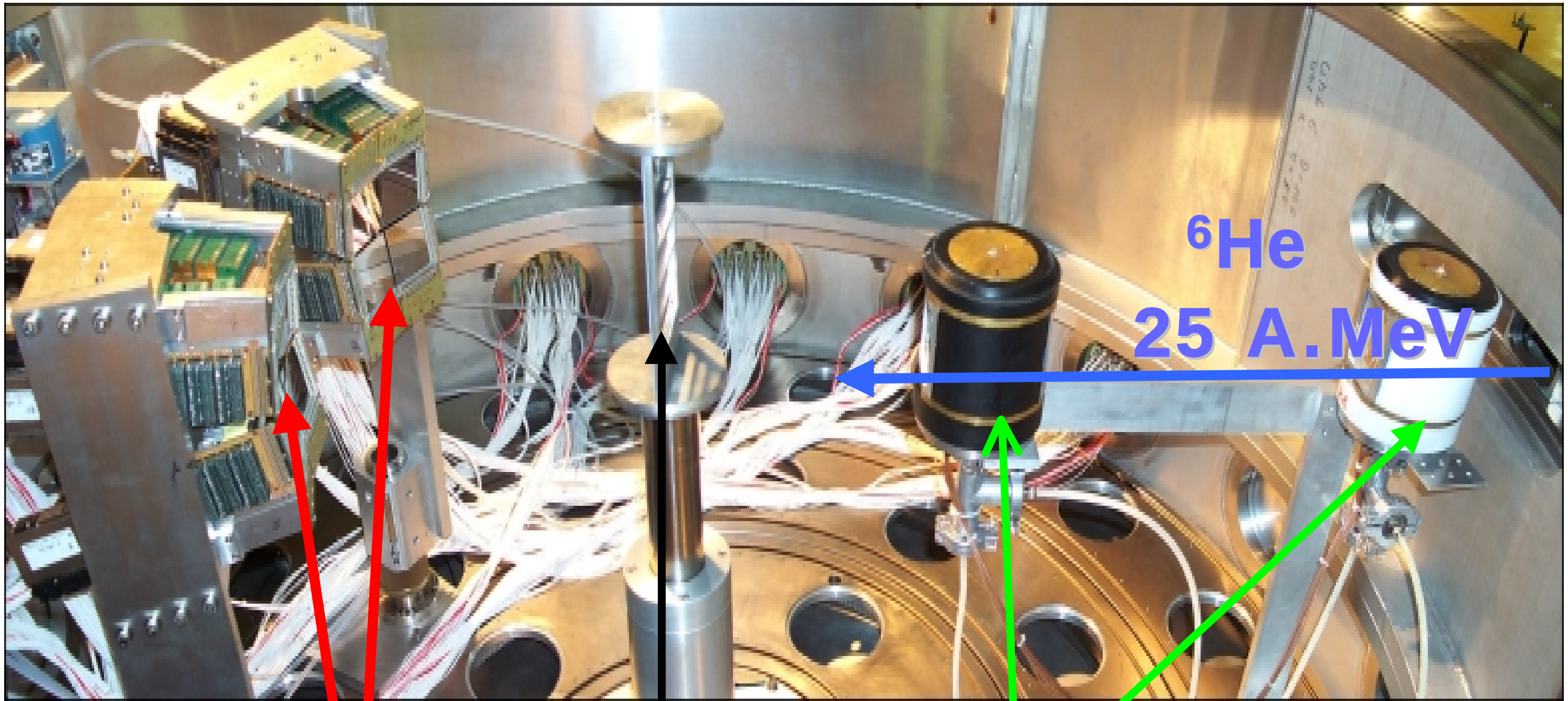
^{13}C @ 60AMeV
primary beam

^{6}He @ 25 AMeV
produced with
SISSI

Speg



$^{6}He(p,t)^{4}He$ experimental set-up: MUST



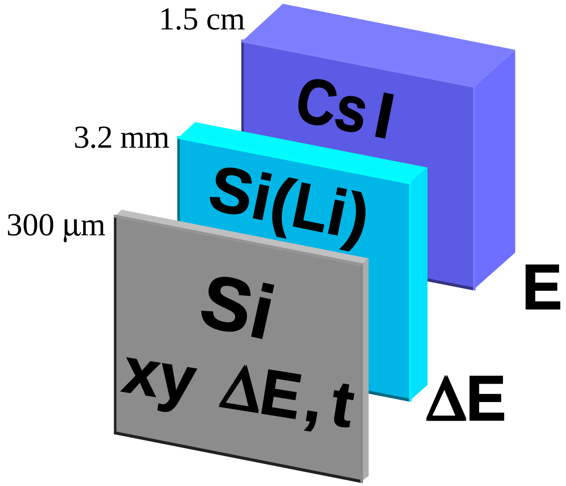
SPEG

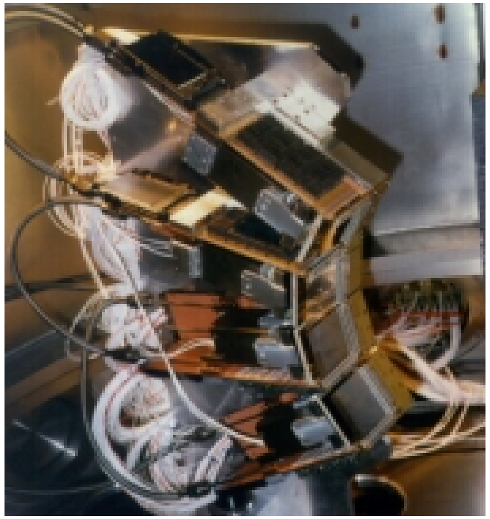
MUST

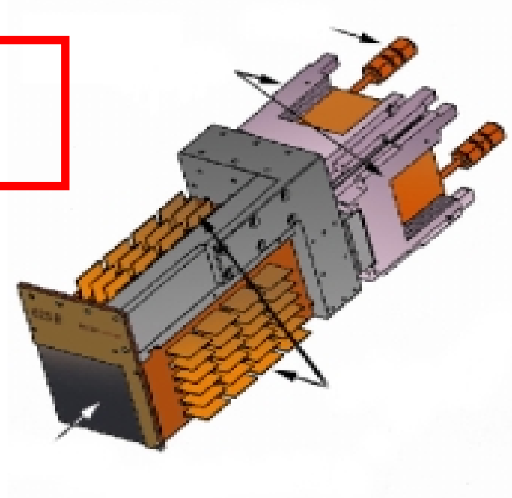
C_3H_6

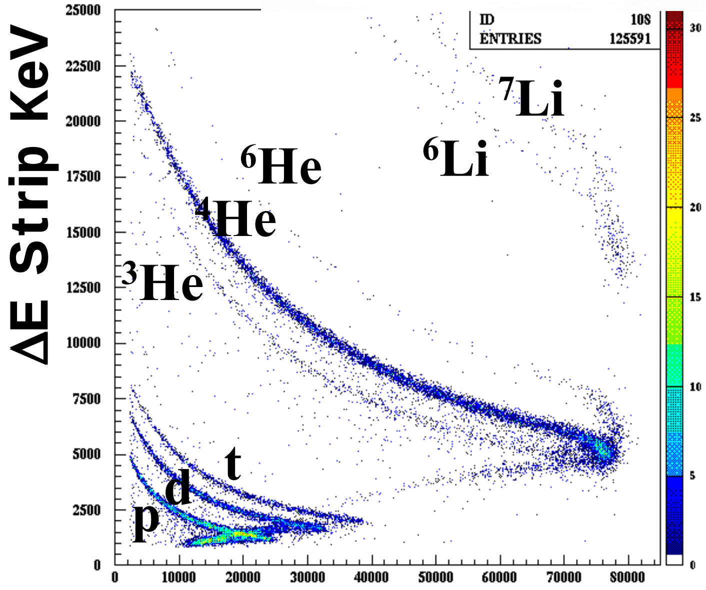
Drift Chambers

MUST: MUr à STrips









Si: 60 strips in x and y

Energy resolution 60 keV, p up to 6 MeV

Si(Li) : protons up to 25MeV

CsI : protons up to 70 MeV

8 telescopes 6x6 cm²

1000 channels of electronics

Y. Blumenfeld et al,
NIM A421 471 (1999)

DSM - DAPNIA Service de Physique Nucléaire

DAM DIRECTION DES APPLICATIONS MILITAIRES

IPN Orsay

$^6He(p,t)^4He$ kinematics

High energy ^4He in SPEG

SPEG at 3° - 6°

Forward c.m. angles : 8°-27°

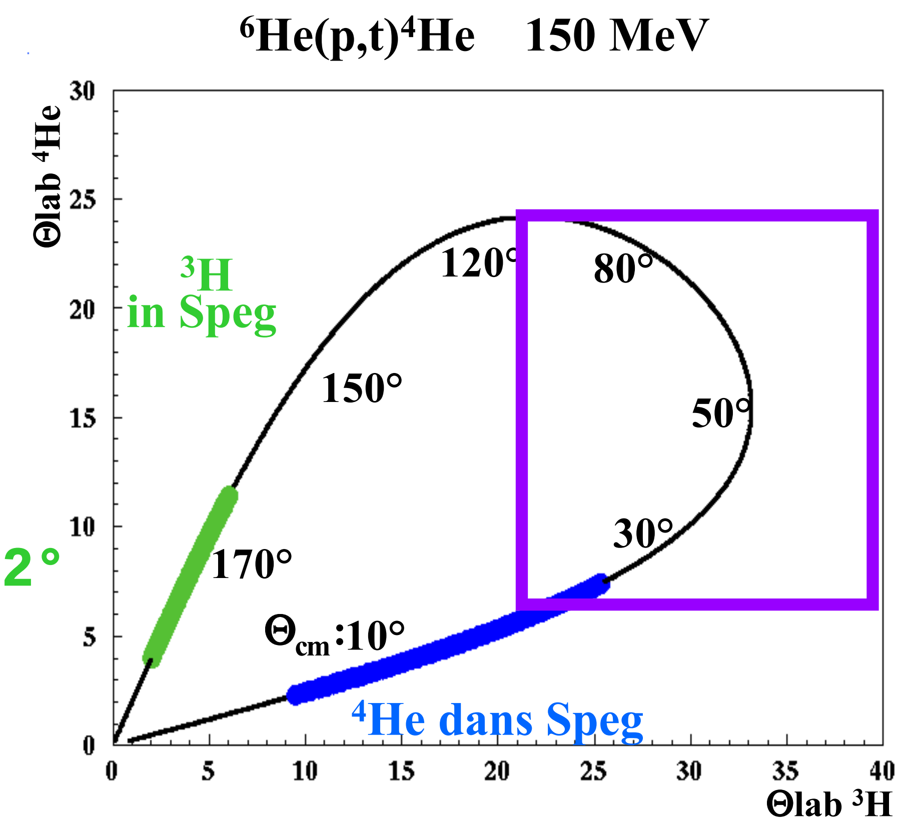
High energy ^3H in SPEG

SPEG at 1, 3° and 6°

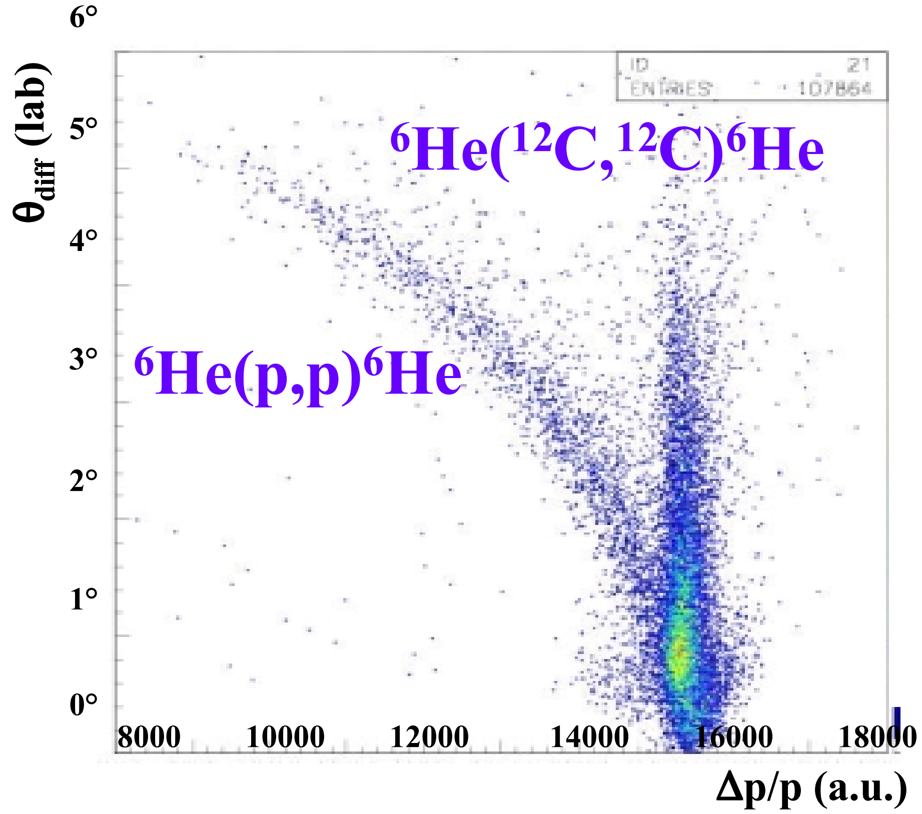
Backward c.m. angles : 155°-172°

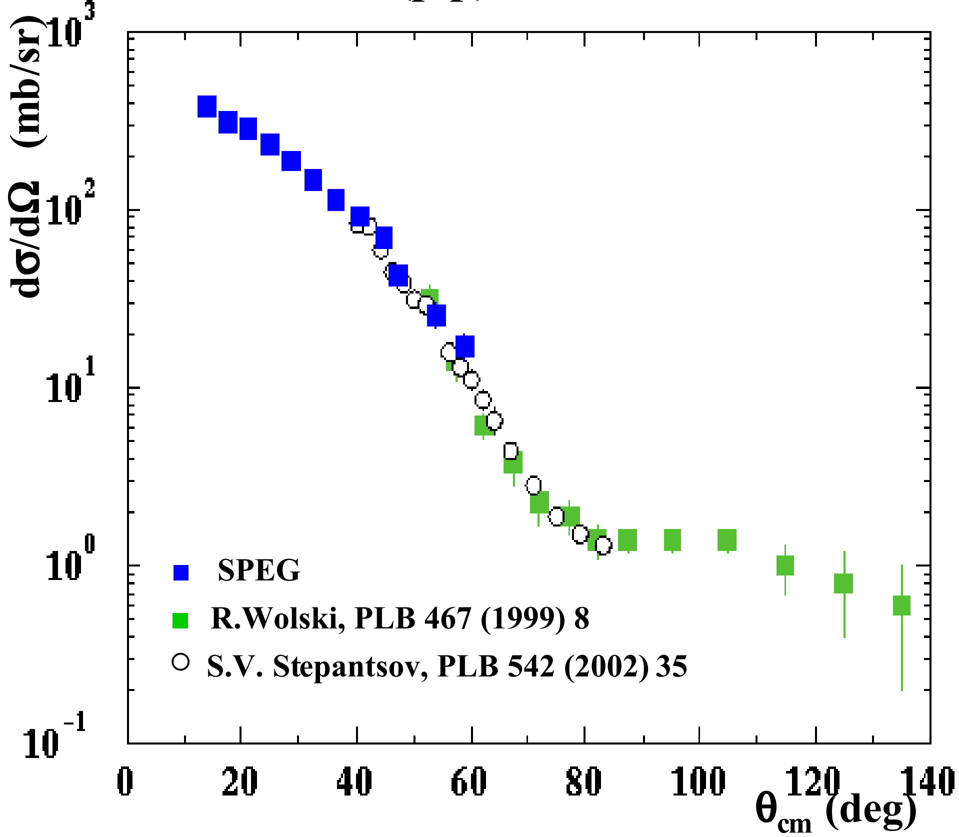
^3H and ^4He in coincidence in MUST

Intermediate angles : 19° - 112° (cm)

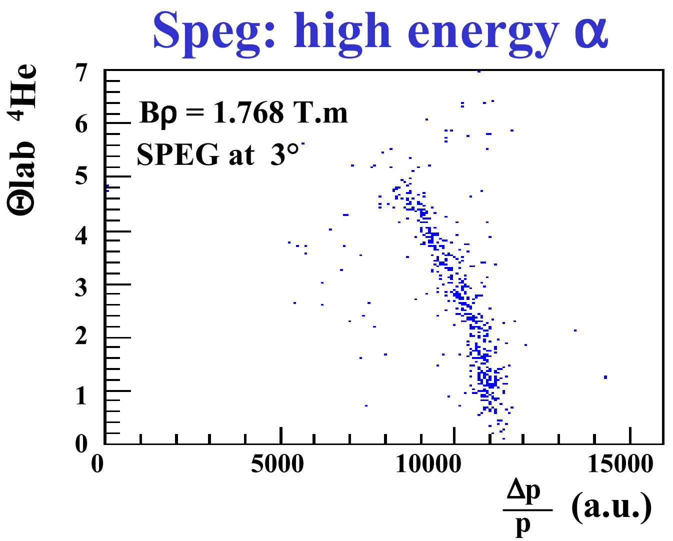


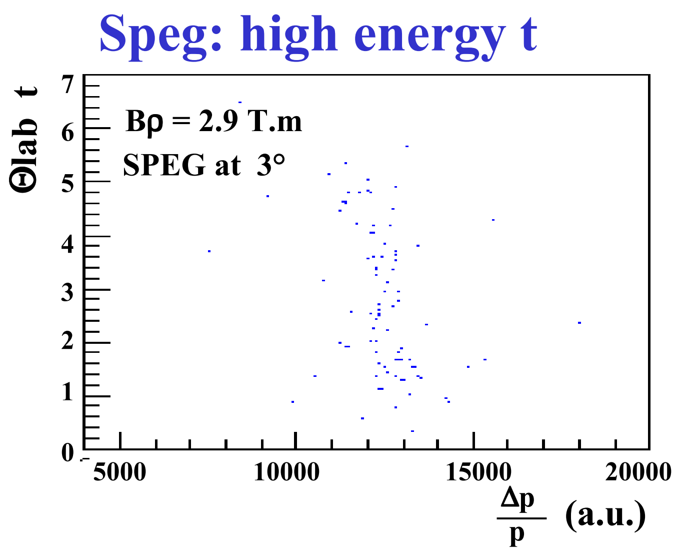
Elastic scattering $^{6}He+CH_2$

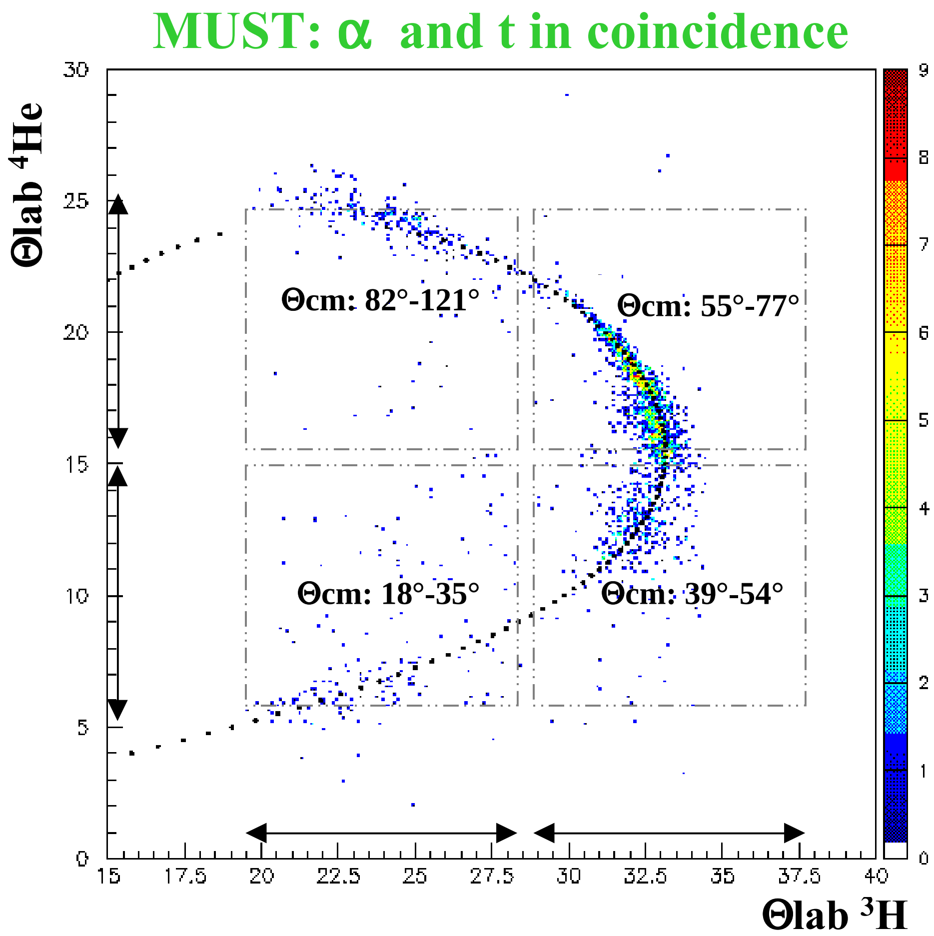




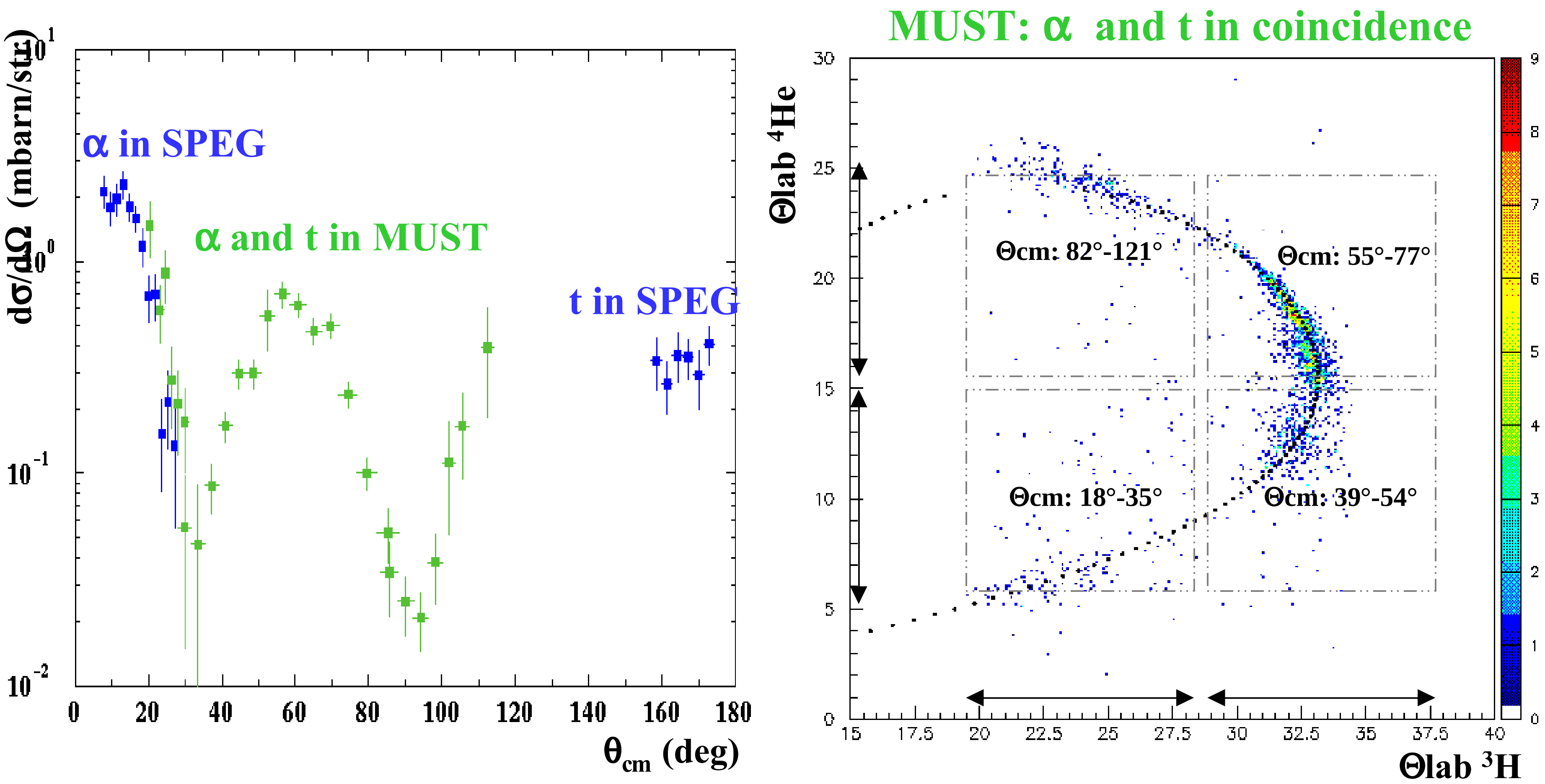
$^6He(p,t)^4He$ transfer reaction at 25 MeV/u



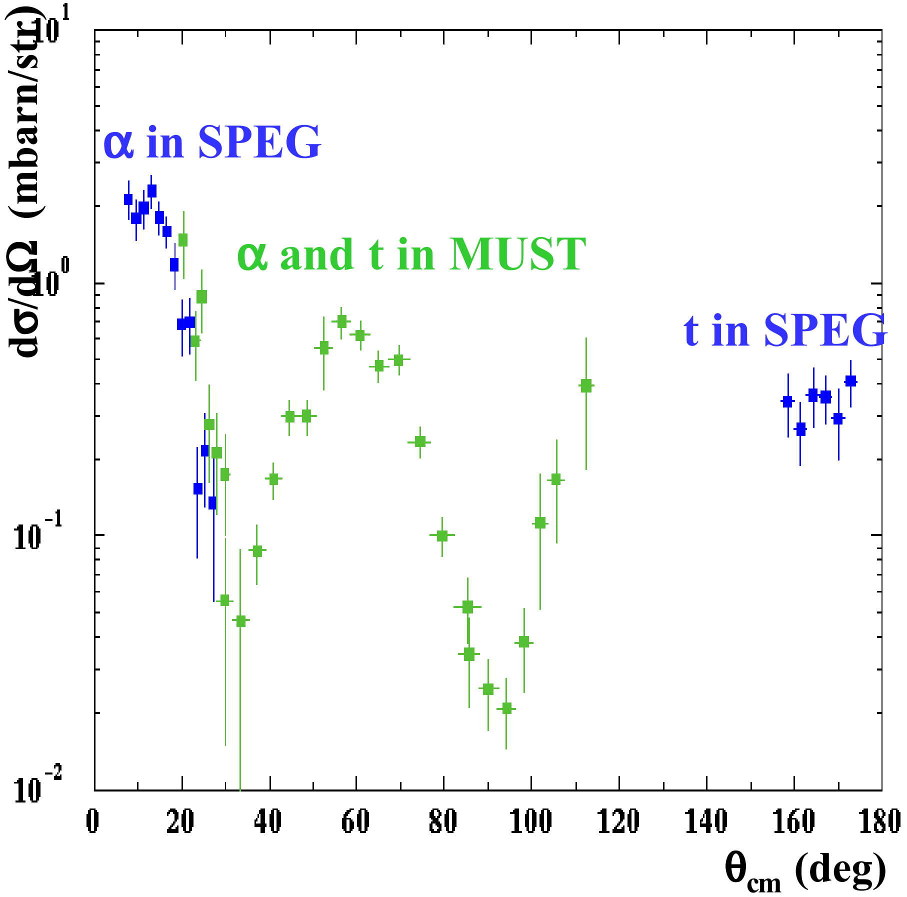


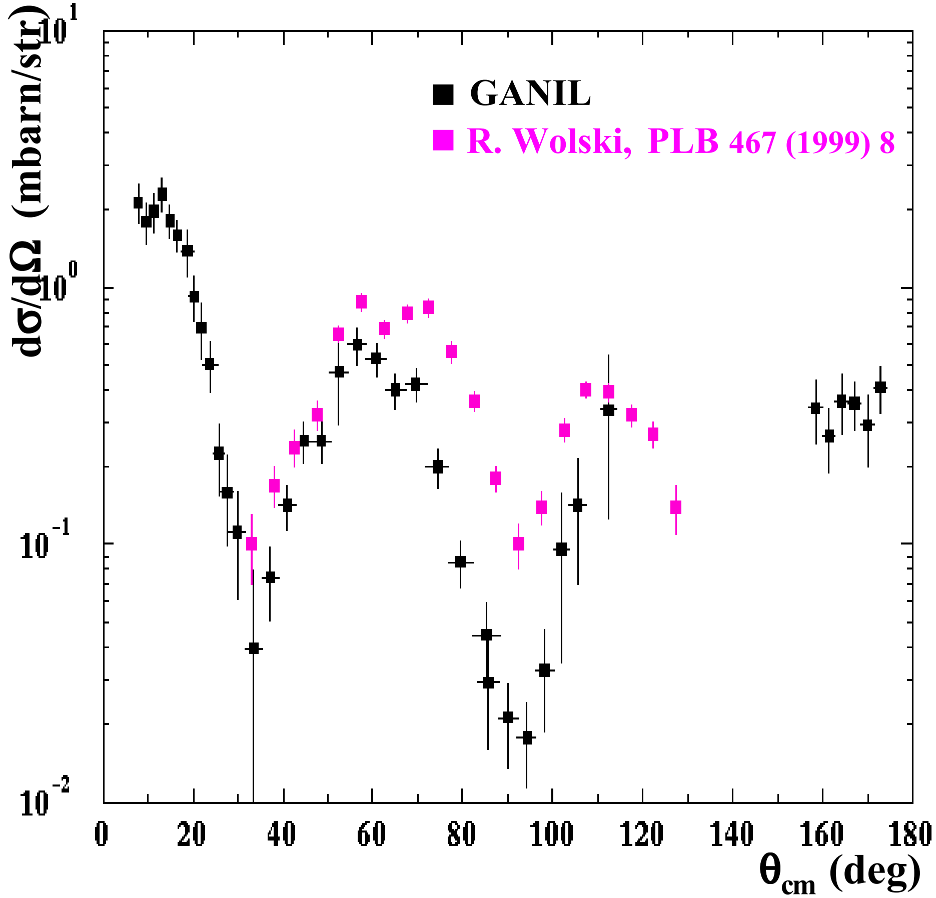


$^{6}He(p,t)^{4}He$ transfer reaction at 25 MeV/u



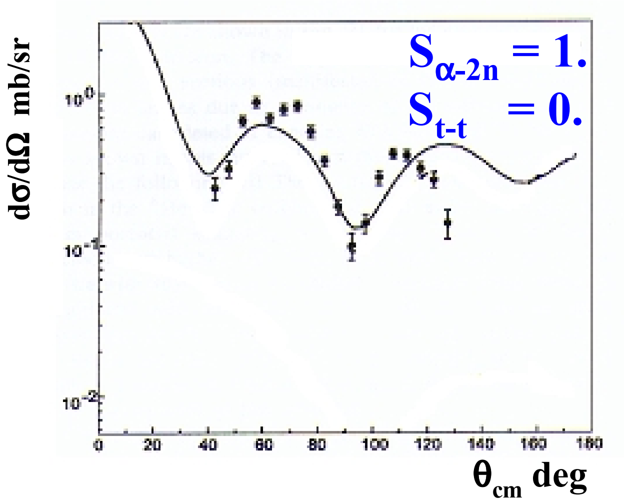
$^6He(p,t)^4He$ transfer reaction at 25 MeV/u



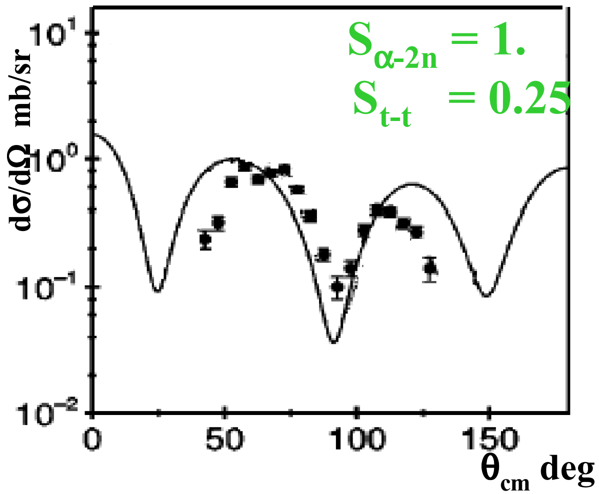


$^6He(p,t)^4He$ transfer reaction at 25 MeV/u

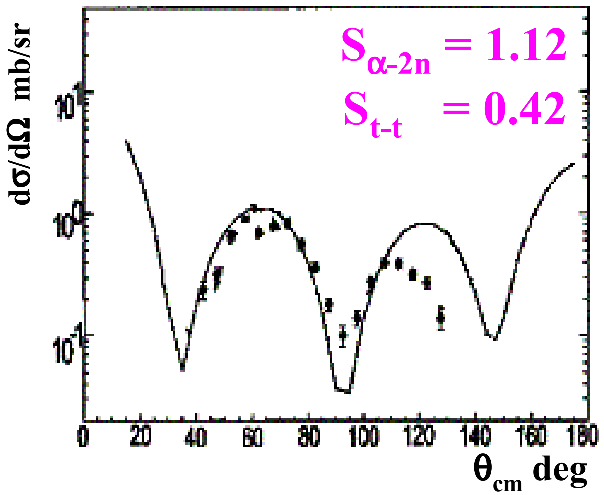
Previous results



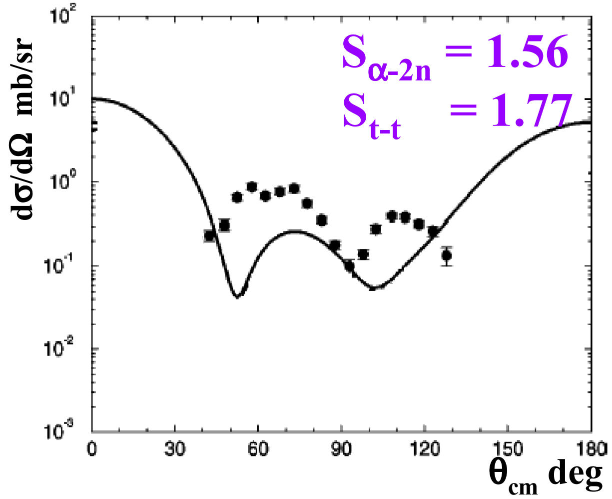
Yu. Oganessian et al, PRC 60 (1999) 044605



K. Rusek et al, PRC 64 (2001) 044602

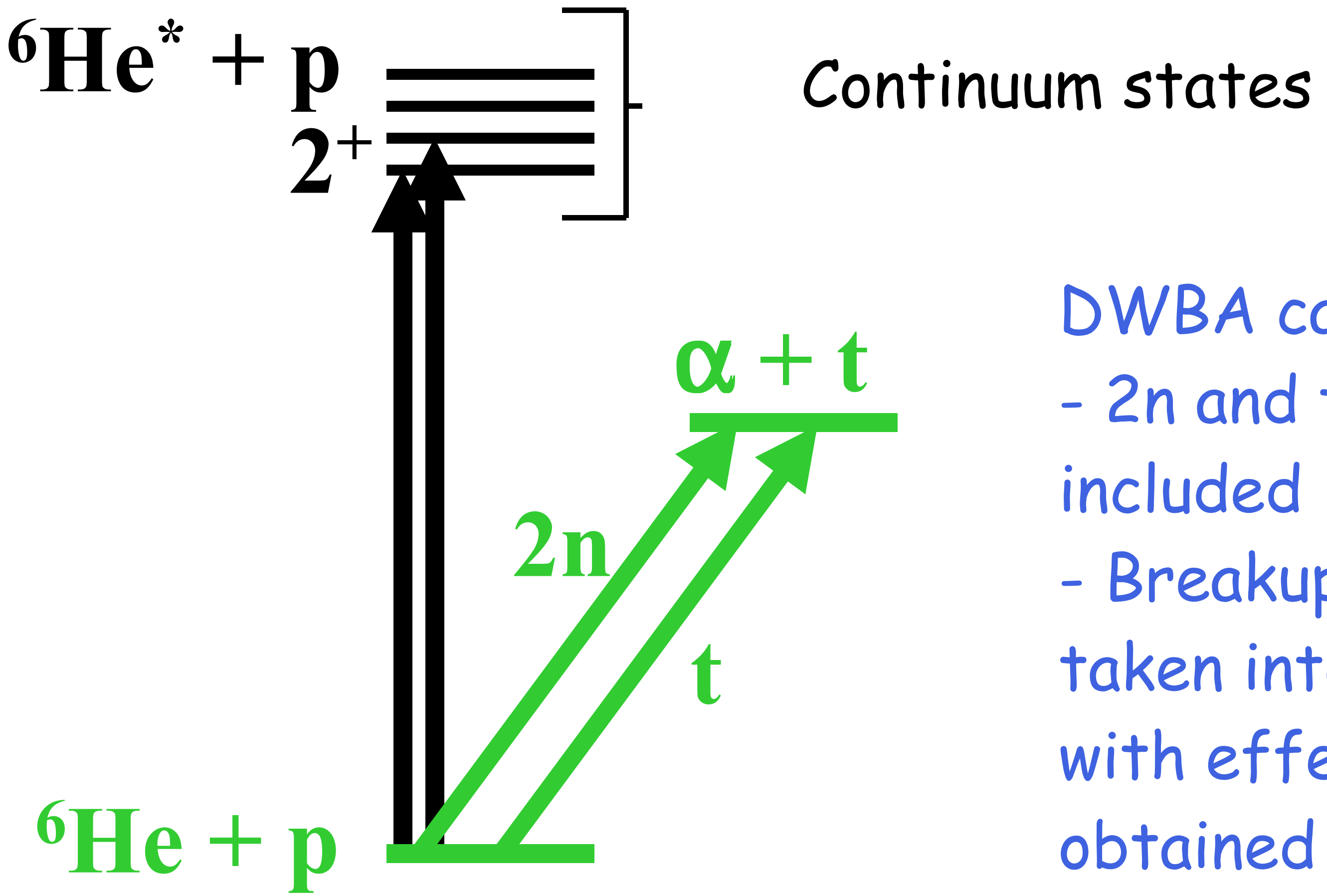


R. Wolski et al, PLB 467 (1999) 8



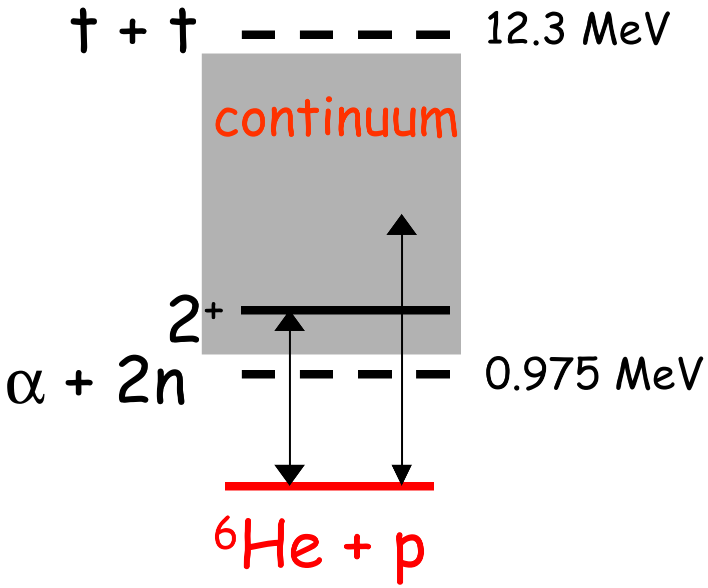
N. Timofeyuk et al, PRC 63 (2001) 054609

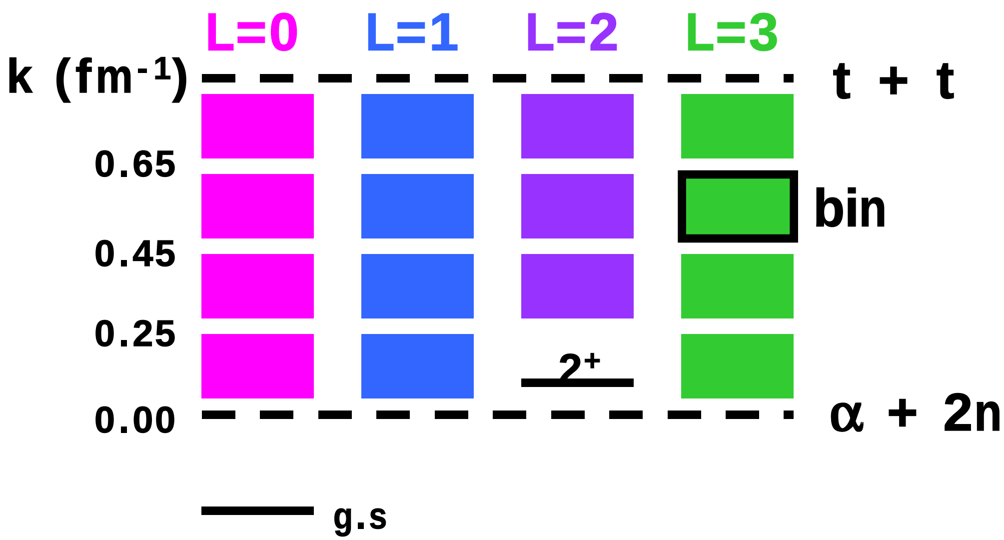
^{6}He(p,t)^{4}He transfer reaction at 25 MeV/u



DWBA calculation
- 2n and t transfer included
- Breakup up effects taken into account with effective potential obtained from inversion procedure (R. Mackintosh et al., PRC 67 (2003)034607)

Breakup of ^{6}He: CDCC calculations





- ^{6}He(^{4}He,^{4}He)^{6}He
- fusion ^{6}He + ^{208}Pb
- ^{6}He(p,t)^{4}He

$$\Psi(r)=\frac{1}{\sqrt{N\Delta_k}}\int_{\Delta k}\phi(r,k)\,dk$$

Y. Sakuragi et al., Prog. Theor. Phy. Suppl. 89, 136 (1986)

K. Rusek et al., PRC 61, 034608 (2000)

K. Rusek et al., PRC 67, 041604 (2003)

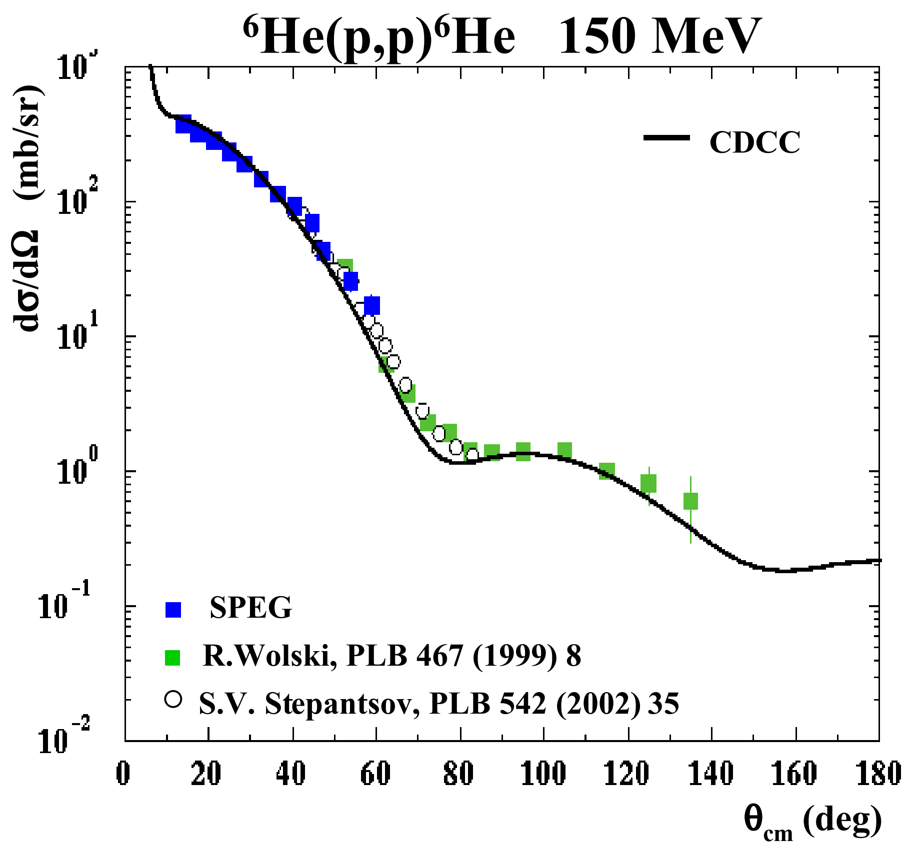
K. Rusek et al., PRC 64, 044602 (2001)

Effective ^{6}He+p potential

R. Mackintosh et al., PRC 67 (2003) 034607

DWBA calculations : entrance and exit channels

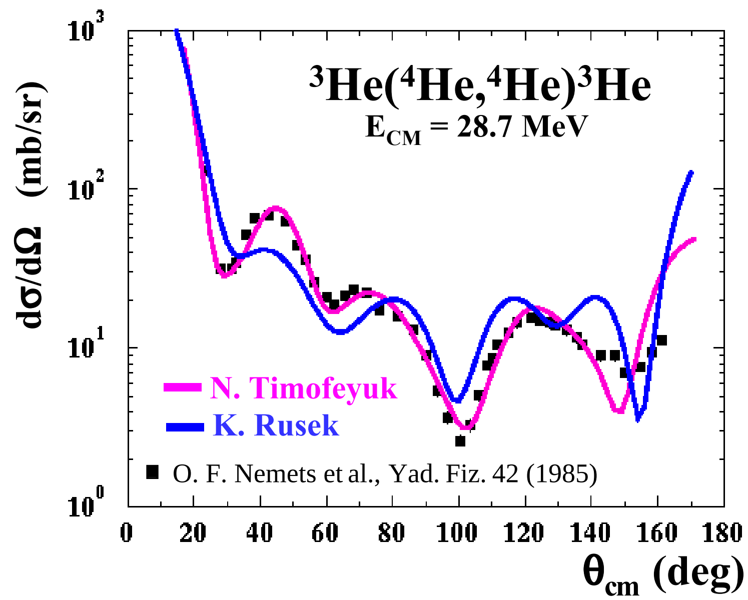
1) Entrance channel



2) Exit channel

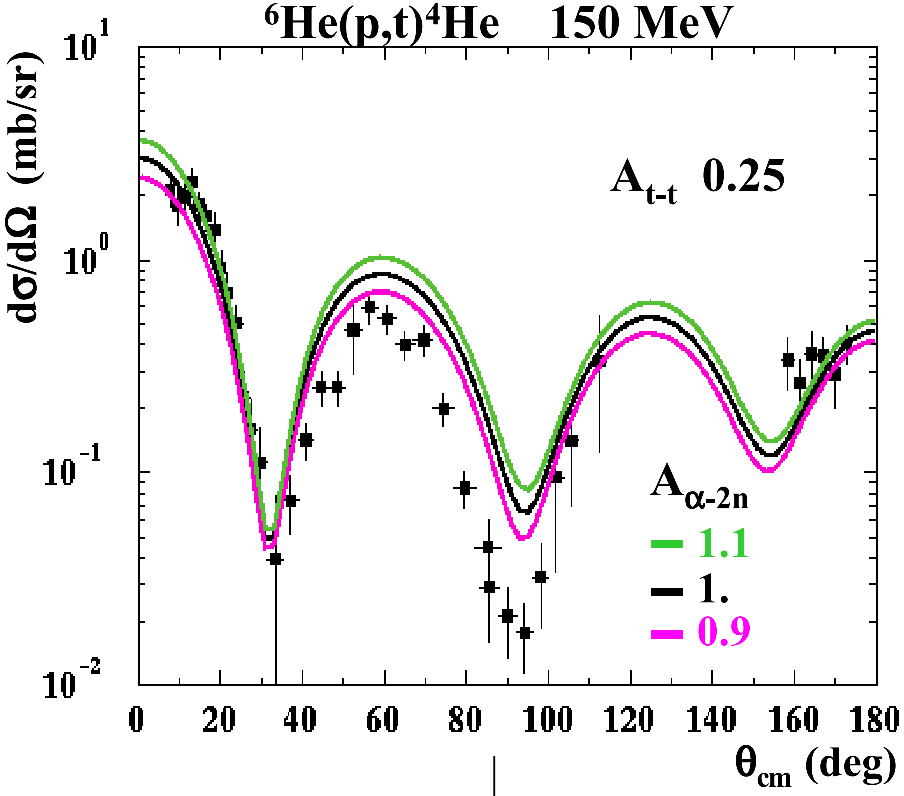
No data for α+t system

Use ^{3}He+^{4}He potential instead



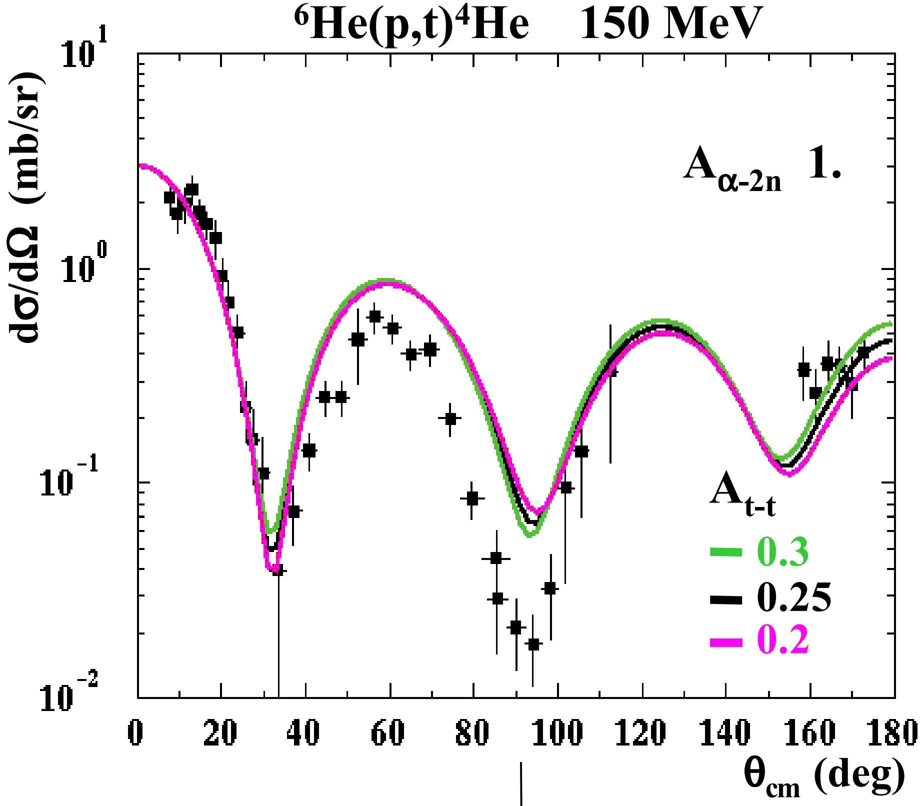
DWBA calculations : spectroscopic amplitudes

$A_{\alpha\text{-}2n}$



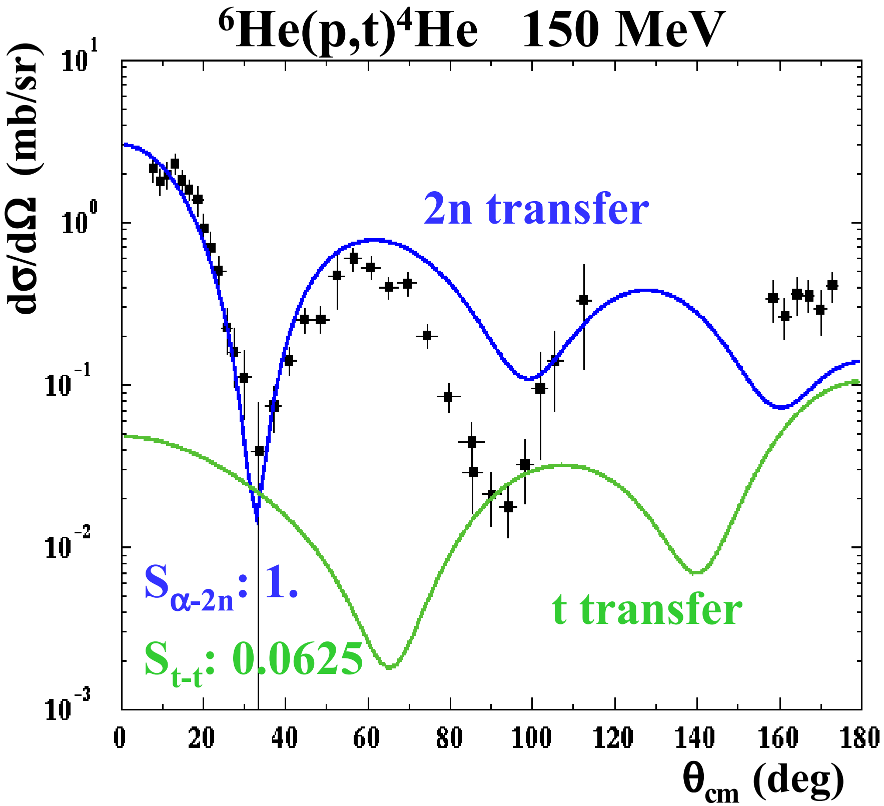
$S_{\alpha\text{-}2n} \simeq 1.$

$A_{t\text{-}t}$



$0.04 < S_{t\text{-}t} < 0.09$

DWBA calculations : spectroscopic amplitudes



Experiment

$S_{\alpha\text{-}2n} \simeq 1.$

$0.04 < S_{t\text{-}t} < 0.09$

Theory

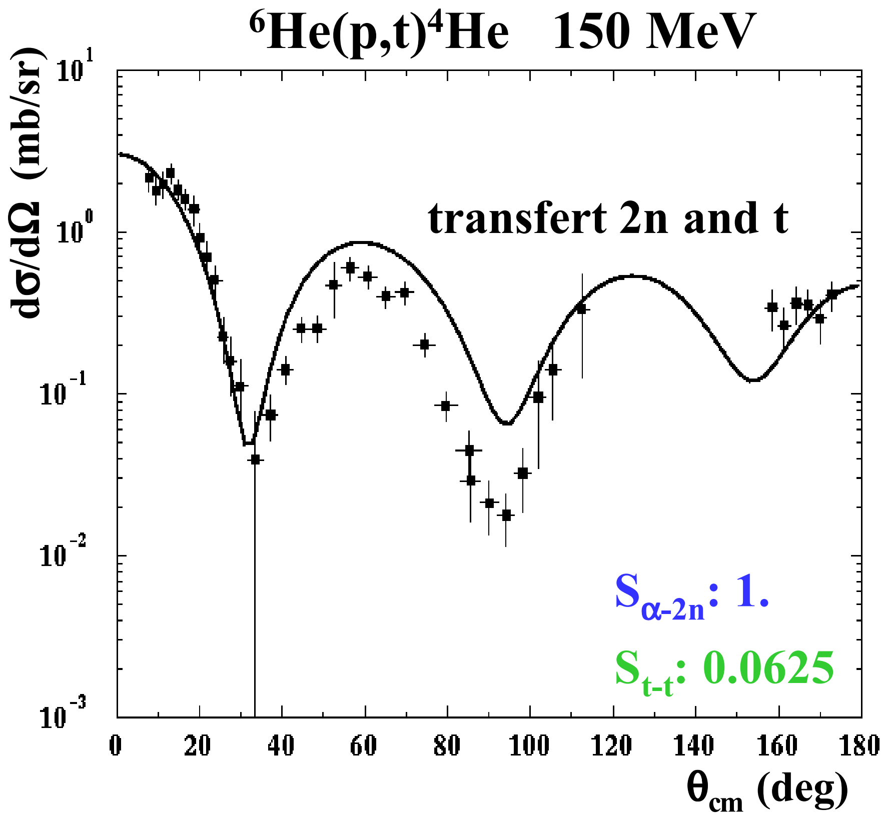
- **TISM** $S_{\alpha\text{-}2n} = 1.12$
  $S_{t\text{-}t} = 1.77$

  Yu. F. Smirnov, PRC 15 (1977) 84

- **RGM** $S_{t\text{-}t} = 0.49$

  K. Arai et al., PRC 59 (1999) 1432

DWBA calculations : spectroscopic amplitudes



Experiment

$S_{\alpha\text{-}2n} \simeq 1.$

$0.04 < S_{t\text{-}t} < 0.09$

Theory

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  Yu. F. Smirnov, PRC 15 (1977) 84

- **RGM** $S_{t\text{-}t} = 0.49$

  K. Arai et al., PRC 59 (1999) 1432

Which exit channel potential?

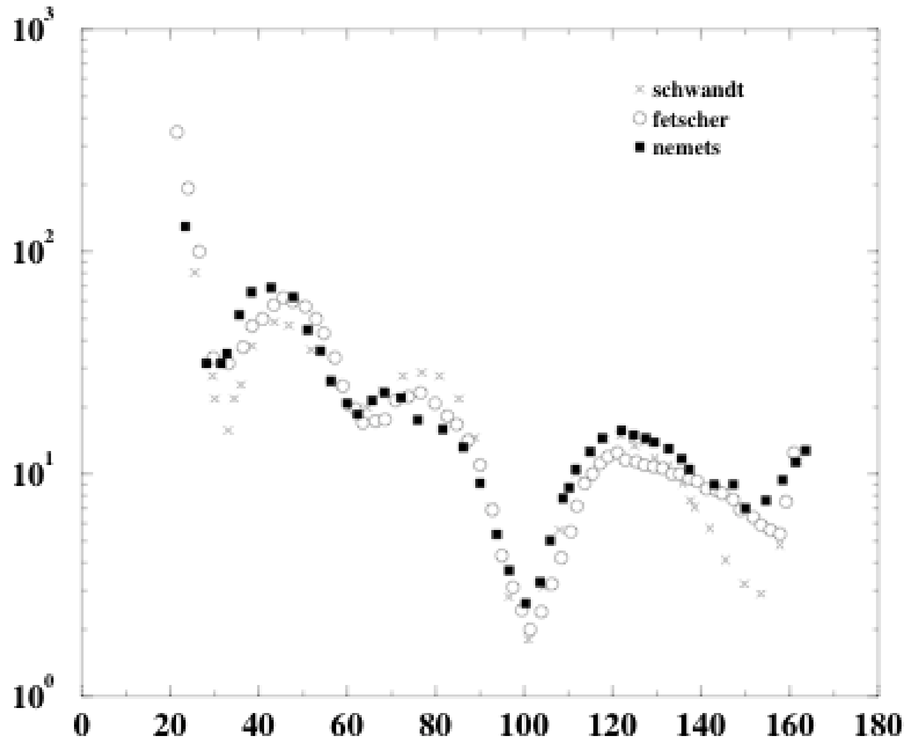
-No data for α-t system in the energy range considered

-^3He+^4He data

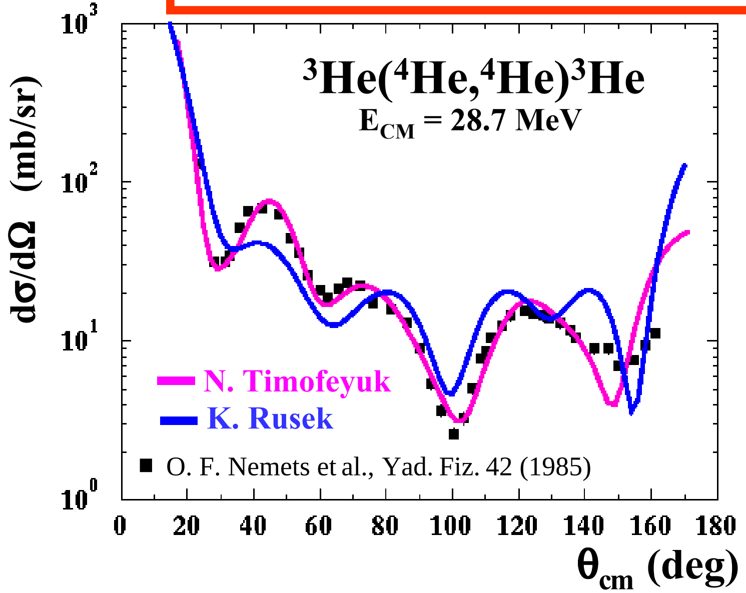
Ecm=28 MeV, W. Fetscher et al., Phys. Lett. B35 (1971) 32

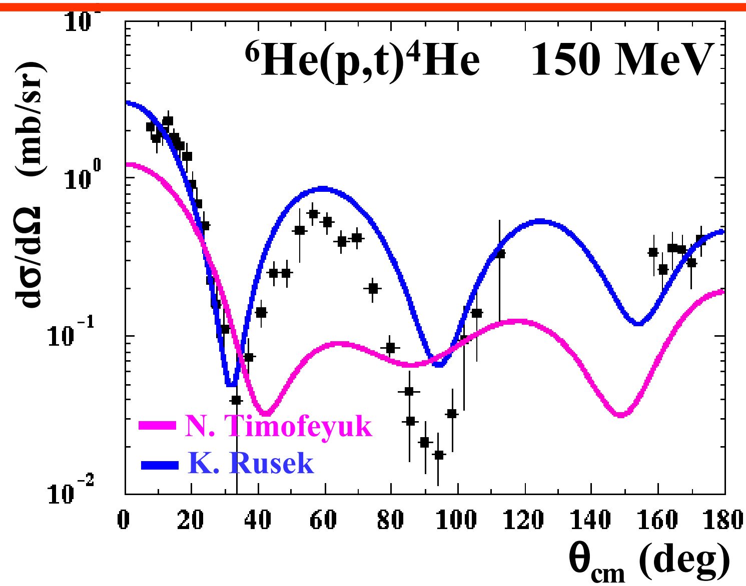
Ecm=24.5 Mev, O.F. Nemets et al., Yad. Fiz. 42 (1985) 809

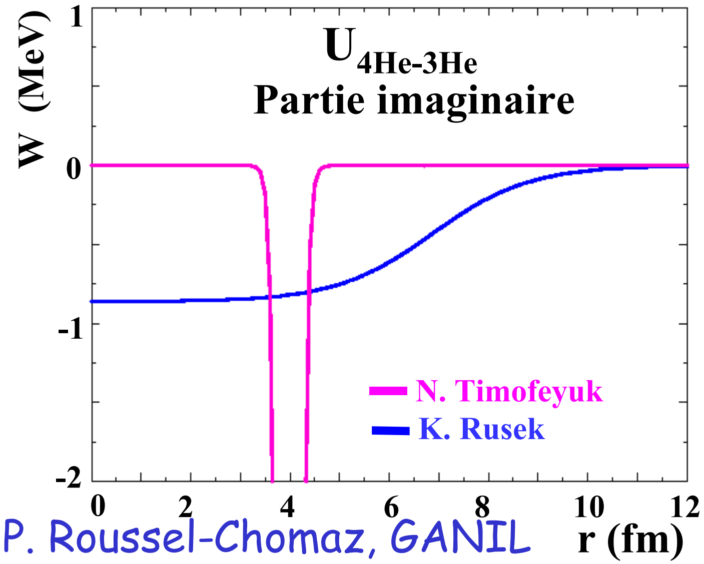
Ecm=28.7 MeV, P. Schwandt et al., Phys. Lett. B30 (1969)1



Which exit channel potential?







- **One neutron exchange**

  $(^3He+n) + {}^3He \rightarrow {}^3He + {}^4He$

- **One-proton exchange**

  $(^3H+p) + {}^3H \rightarrow {}^3H + {}^4He$

Which exit channel potential?

-Very strong neutron exchange

-DWBA calculations for $^{3}He+^{4}He$ elastic scattering with « bare » optical potential and explicit treatment of neutron exchange

-Gaussian potentials ($\alpha-\alpha$, α-^{3}He, α-t)

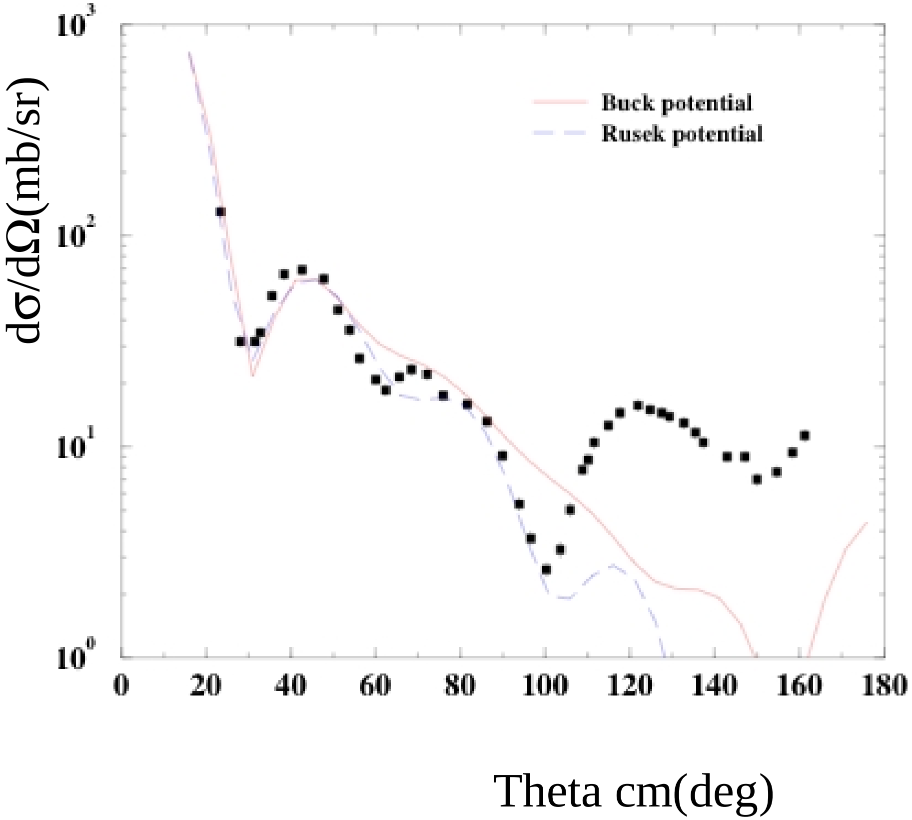
Buck et al., Journ. Phys. G 14 (1988) L211

-Woods-Saxon potentials

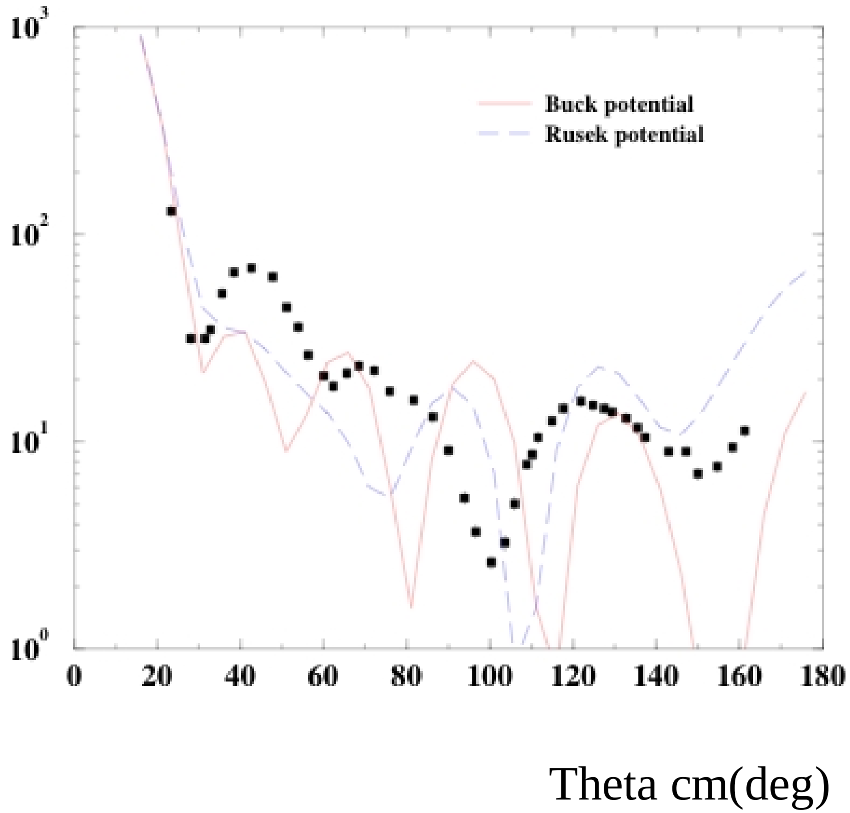
(« Rusek » potentials)

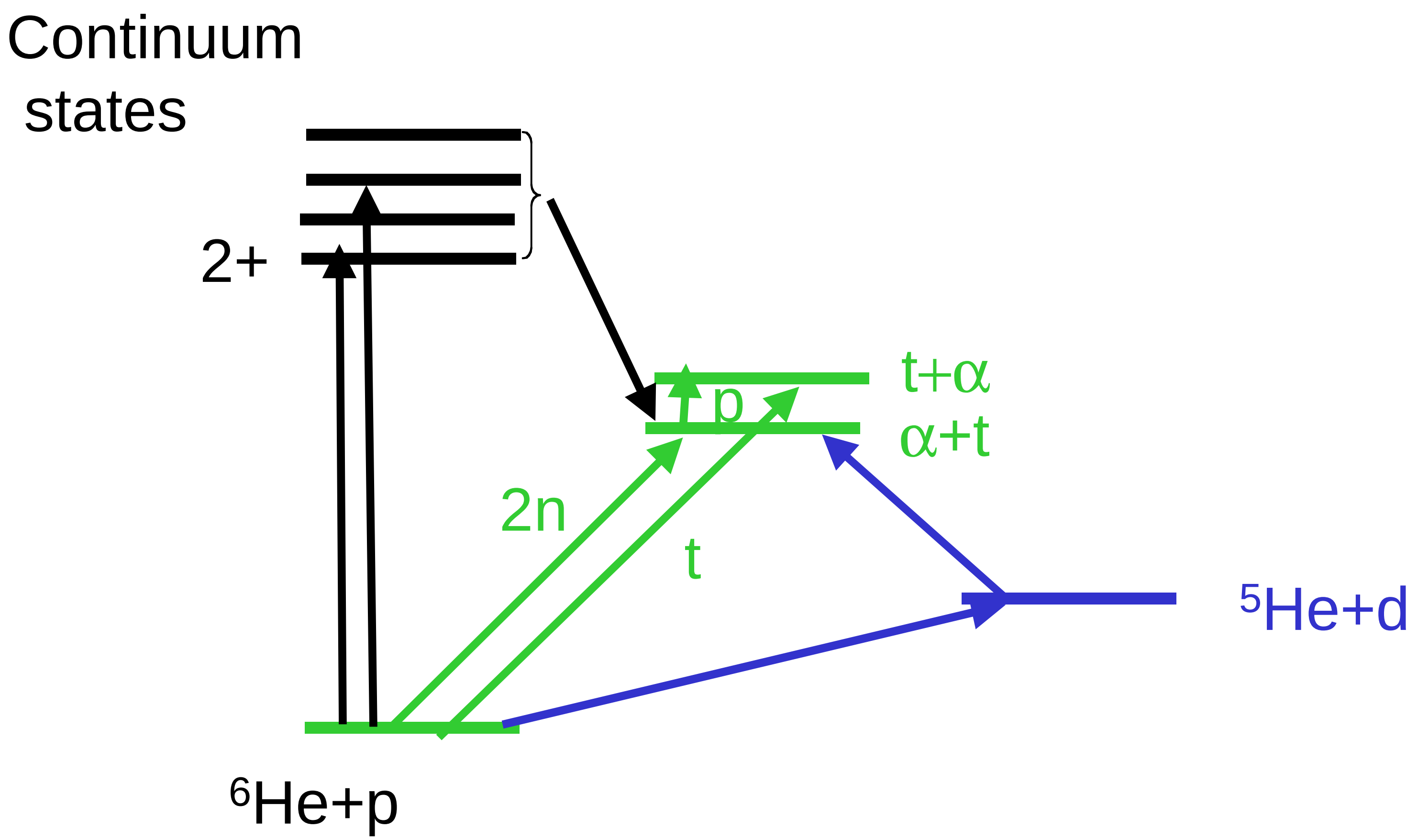
Test on $^3He+^4He$ elastic scattering

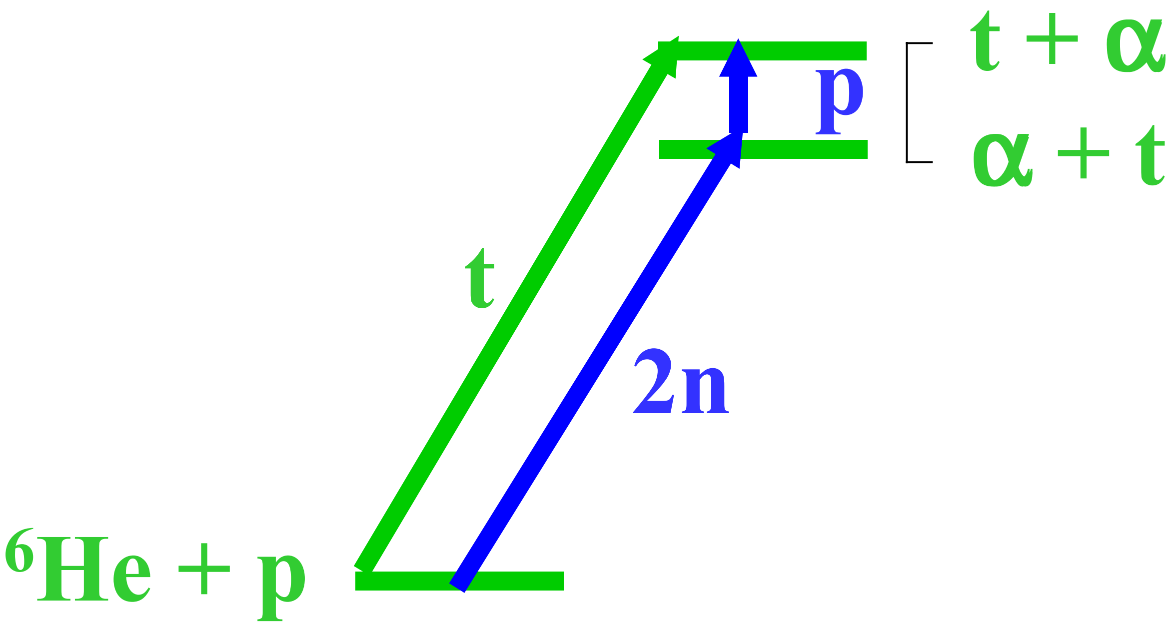
Pure elastic scattering calc.



Elastic scattering + 1 neutron transfer, DWBA calc

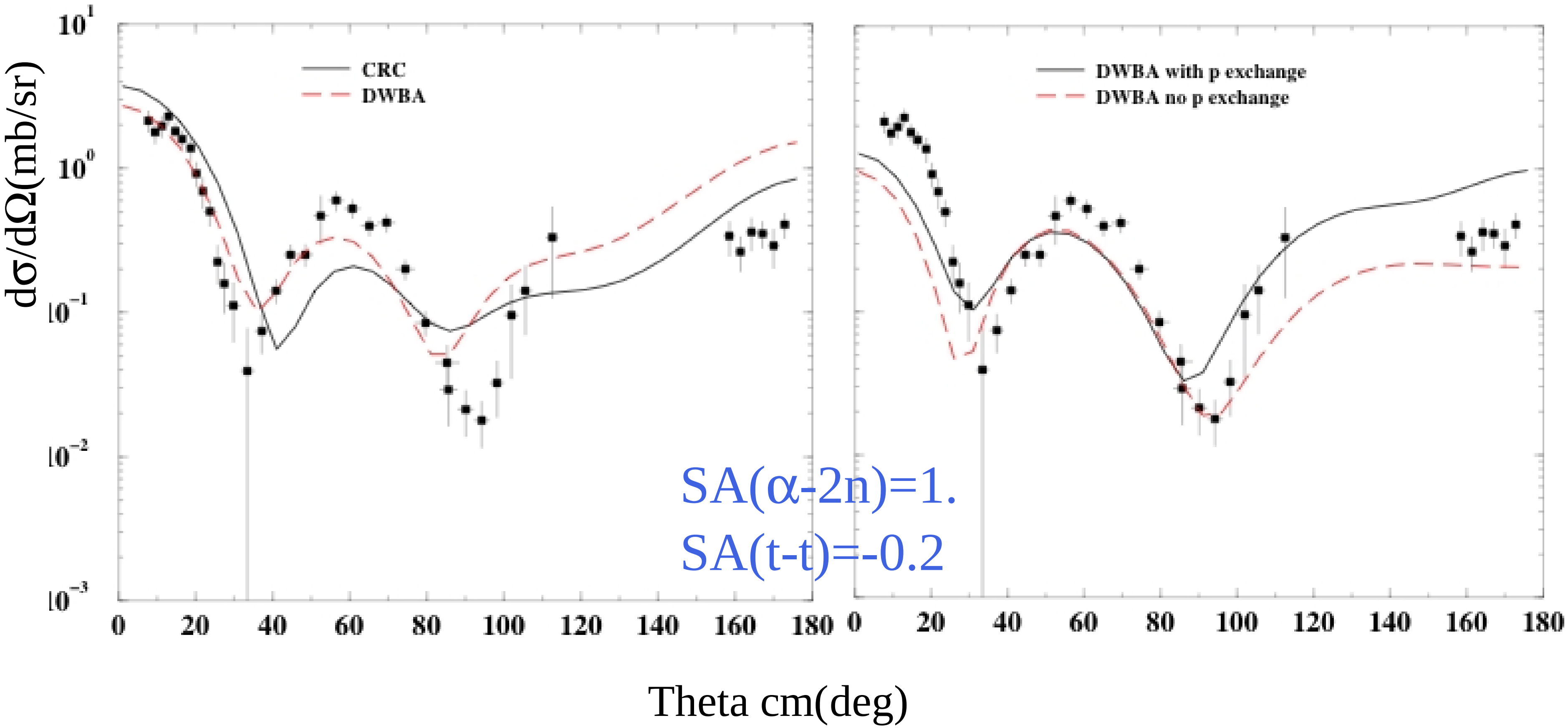


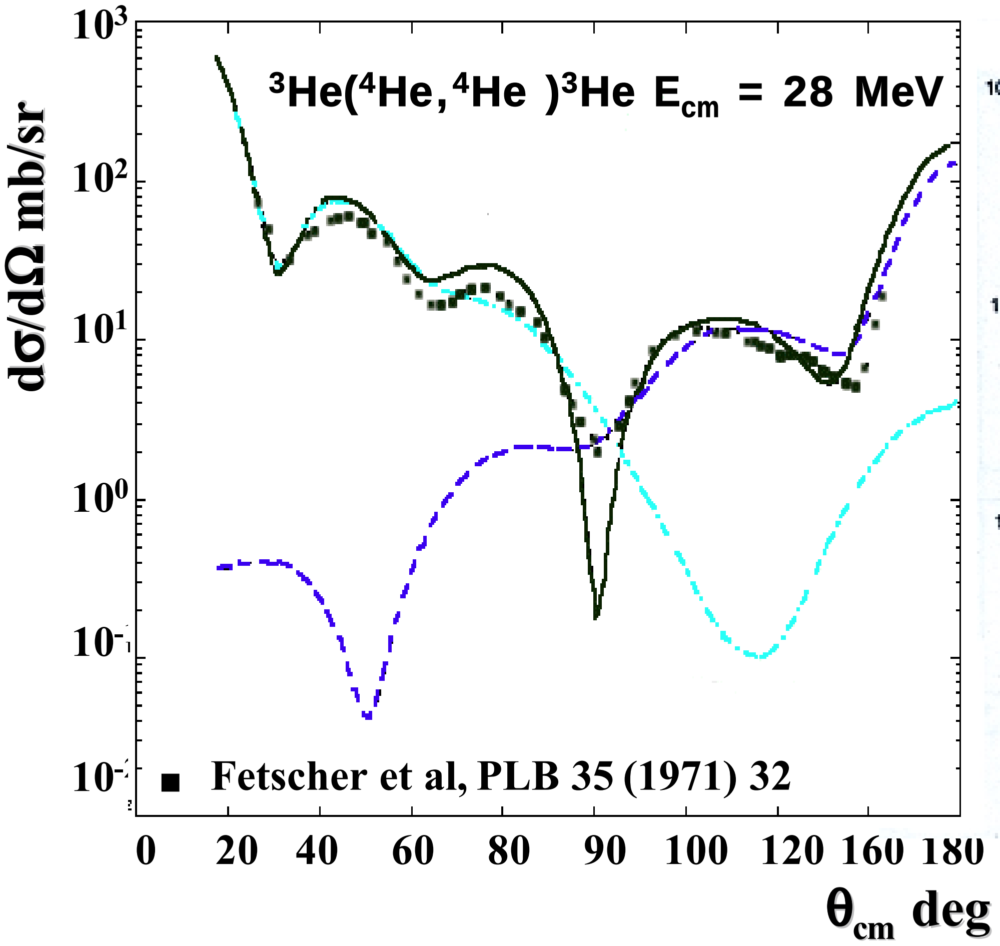

Continuum
states
2+
t+α
p
α+t
2n
t
^{5}He+d
^{6}He+p

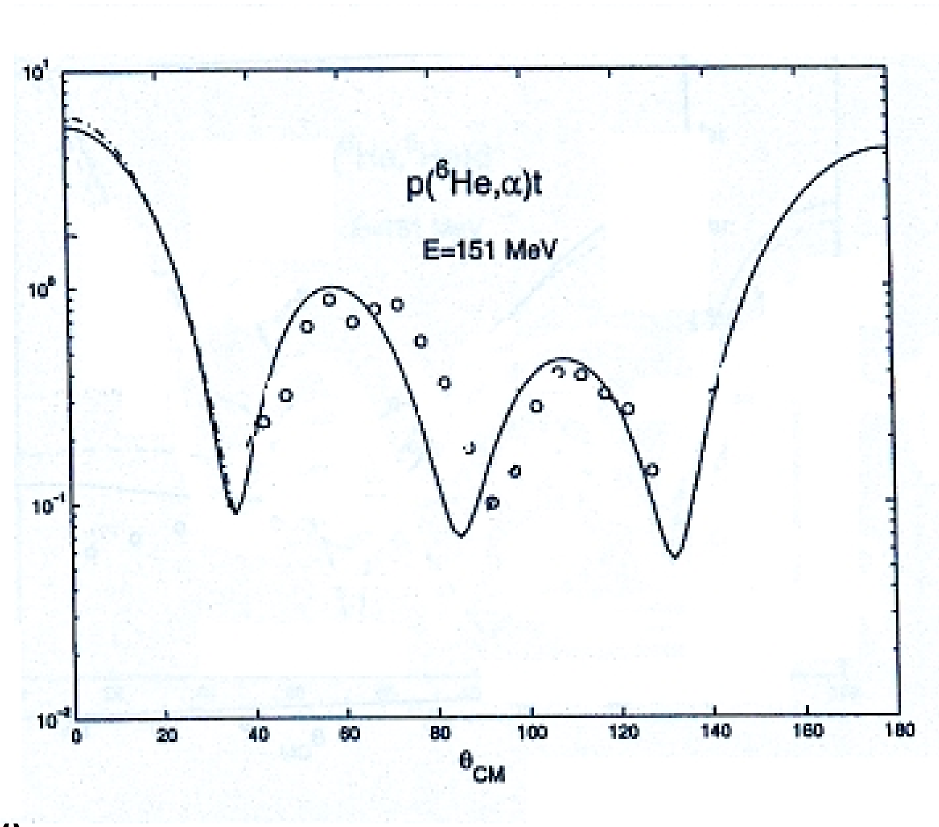

t + α
p
α + t
t
2n
^{6}He + p

Buck potential.

Rusek potential.







Heiberg Andersen, thesis, Bergen

Conclusions

$^{6}He(p,t)\alpha$ reaction at 25 MeV/nucleon

- Forward and backward angles measured for the first time
  necessary to determine $S_{t\text{-}t}$

-DWBA analysis

Many results already published

Special care for entrance and exit channel potentials

Entrance channel: breakup of ^{6}He (CDCC)

Exit channel $^{4}He+t$

strong neutron exchange effects

no good reproduction of $^{3}He+^{4}He$ elastic scattering with « bare » potential, including explicitely exchange channel

Spectroscopic factors

$S_{\alpha\text{-}2n} \approx 1$

$0.04 < S_{t\text{-}t} < 0.09$

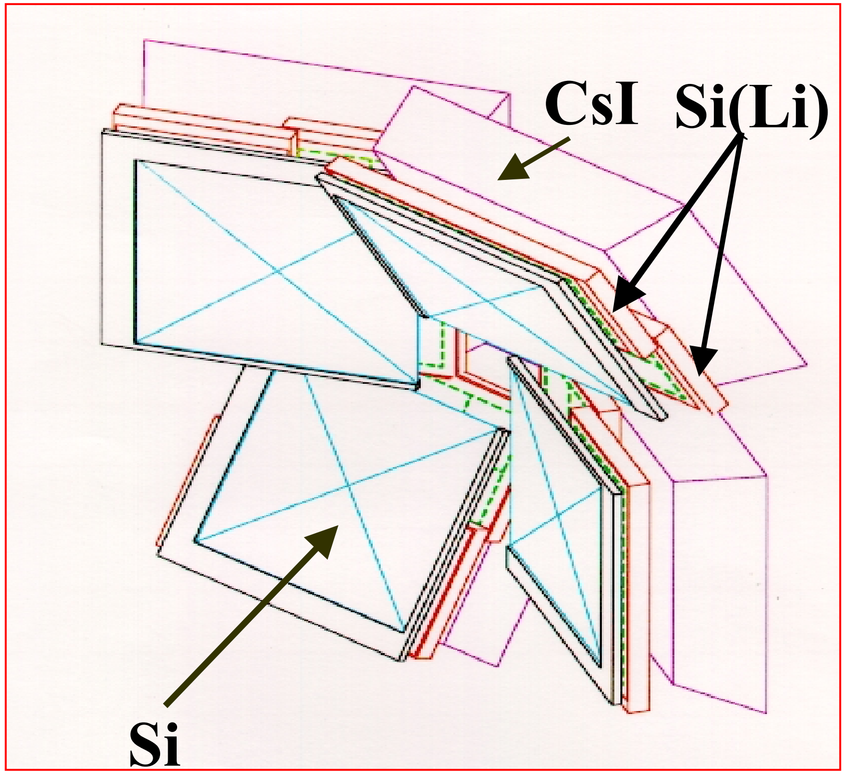
small value but necessary to reproduce $^{6}He(p,t)\alpha$ data

Perspective

Radioactive beams +transfer reactions

MUST II

1st Test:March 2004



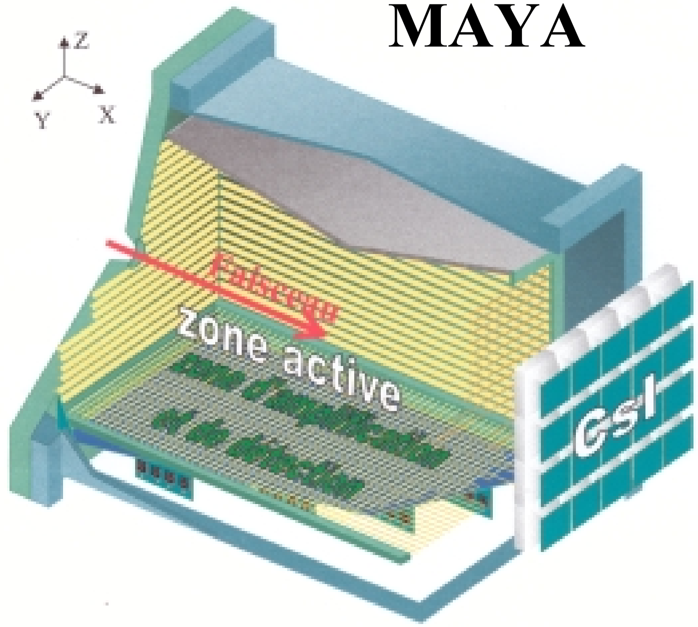
MUST	→ MUST II
. 122	544 Parameters
. 6	1 Volume
. 1	x3 active zone
. 6 (VXI-D)	1 (VXI-C) 3000 ch

. **Compact electronics: ASIC**

. **with EXOGAM and TIARA**

Perspectives

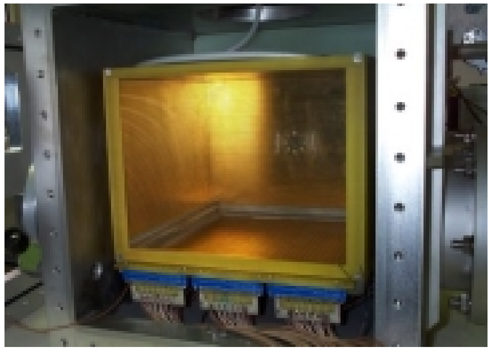
MAYA



Active target

- detection gas used as target

- ✓ **High efficiency**
- ✓ **Low detection threshold**
- ✓ **Used as thick target**
- ✓ **Large angular coverage**
- ✓ **Wide range in energy**



W. Mittig, C.E. Demonchy et al., GANIL

April 1-2, 2004
GANIL Maison d'hotes
www.ganil.fr/spiral2ws/

Perspectives

$S_{t\text{-}t}$

- **Influence od sequential transfer: $^{6}He(p,d)^{5}He$**
- **Experiment: $^{6}He(t,t)^{6}He$**

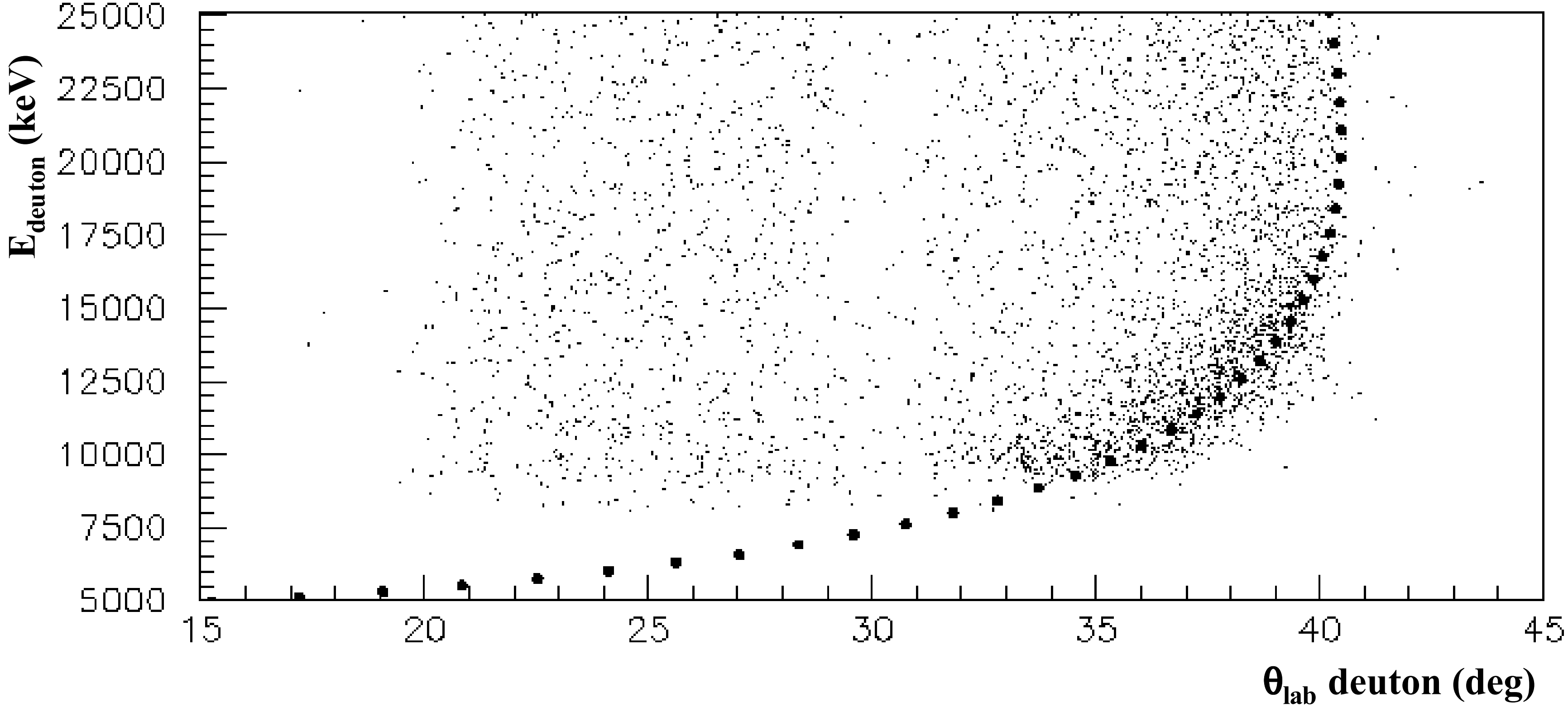
Radioactive beams + transfer reactions

- ^{5}**H**: $^{8}He(p,\alpha)^{5}H$, $^{3}H(t,p)^{5}H$
- ^{7}**H**: $^{8}He(d,^{3}He)^{7}H$, $^{8}He(t,\alpha)^{7}H$
- ^{10}**He**: $^{8}He(t,p)^{10}He$

MUST II

- **collaboration Ganil, Orsay, Saclay**

^{6}He (p,d) ^{5}He

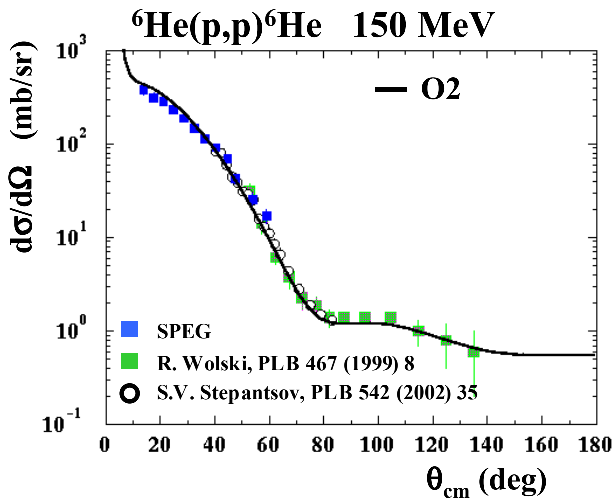


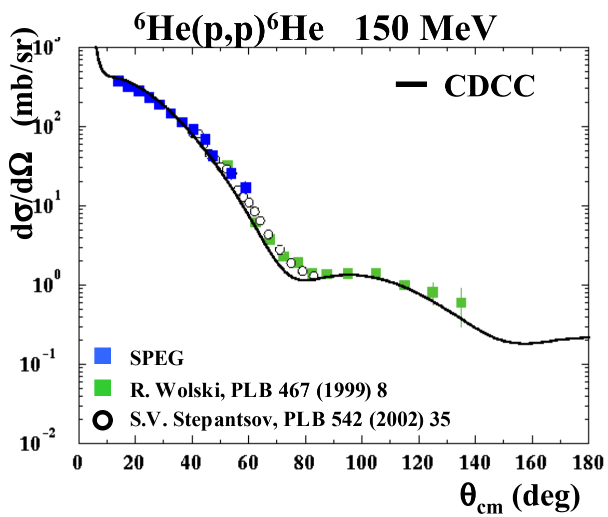
25000
22500
20000
17500
15000
12500
10000
7500
5000
15
20
25
30
35
40
45
E deuton (keV)
θlab deuton (deg)

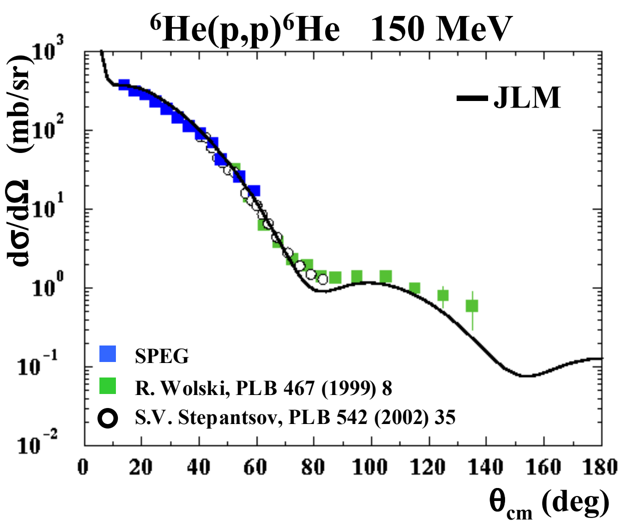
σ_R

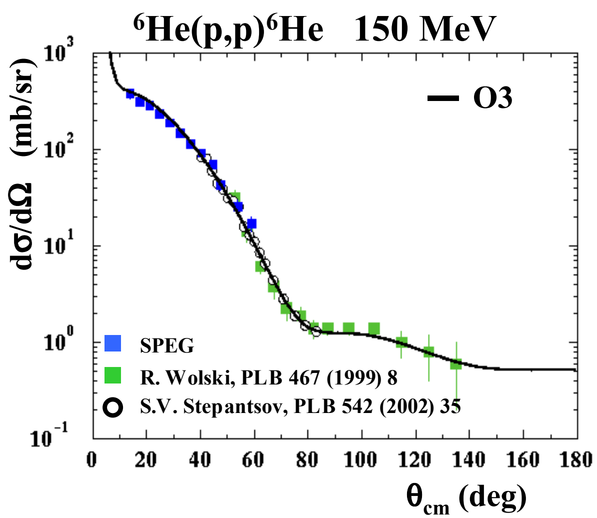
σ_R

- . O2 546 mb
- . O3 516 mb
- . JLM 394 mb
- . Potentiel effectif (CDCC) 501 mb









Voies couplées

- $\Psi_{CRC} = \sum_i \Phi_i^t \, \Phi_i^p \, \chi_i^{t-p}$ (cible: Φ_i^t ; projectile: Φ_i^p)

  i=a,b,c…

  partitions de masse

  Exemple: 6He + p, 5He + d, 4He + t

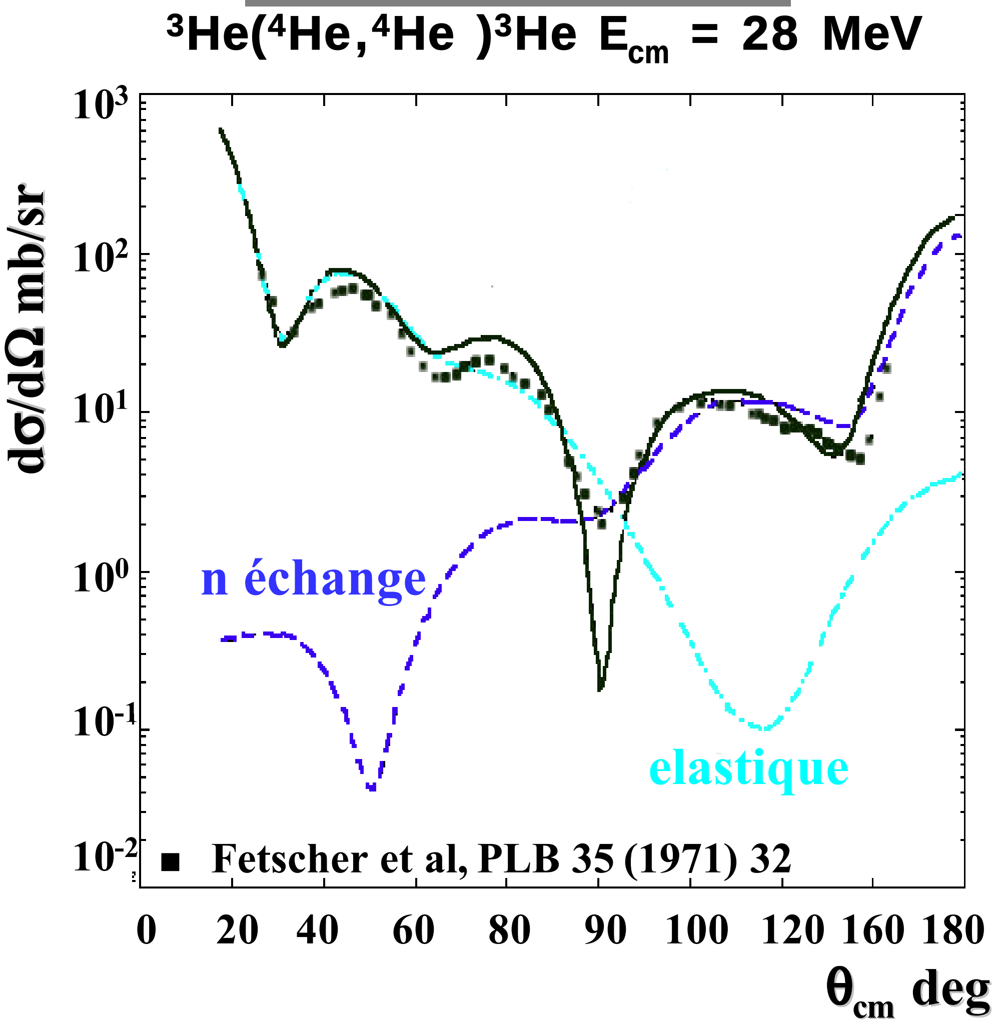
- $(H-E)\Psi_{CRC} = 0$

- Projection
  sur les différents états d'une partition de masse
  ↳ Système d'équations intégro-différentielles couplées
  reliant les χ_i^{t-p} inconnues

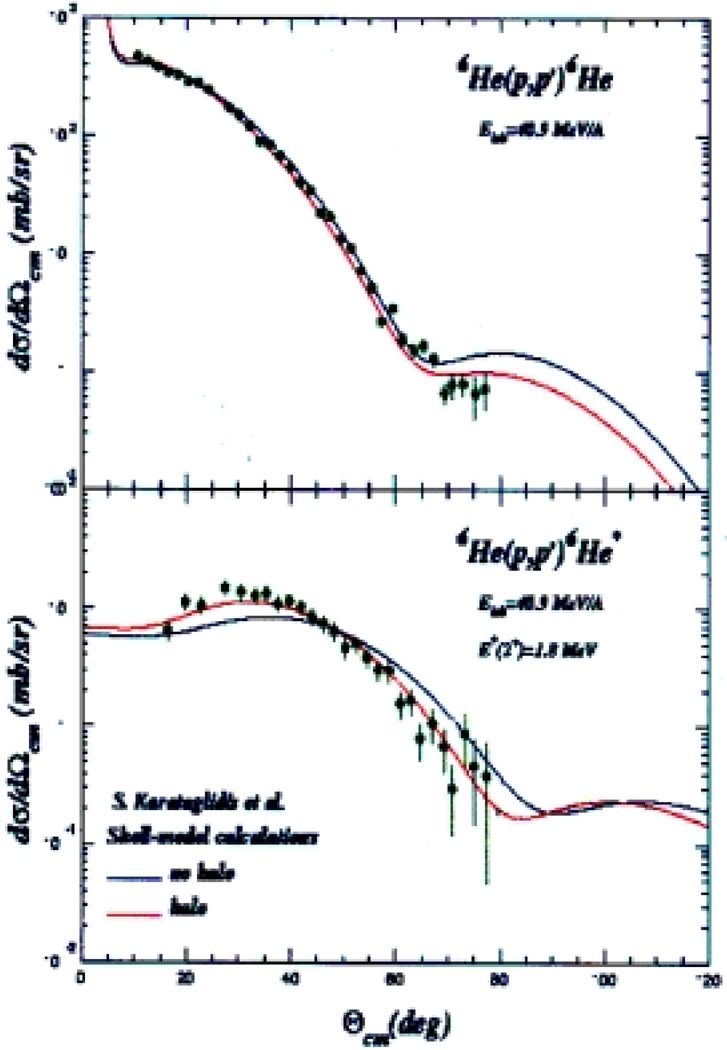
- Résolution système + conditions asymptotiques
  ↳ Amplitudes de diffusion f_{ab} , f_{bc}
  ↳ Section efficace différentielle de la réaction

voies couplées entre 2 partitions de masse:
on retrouve les résultats de DWBA !!!

Potentiel α+t

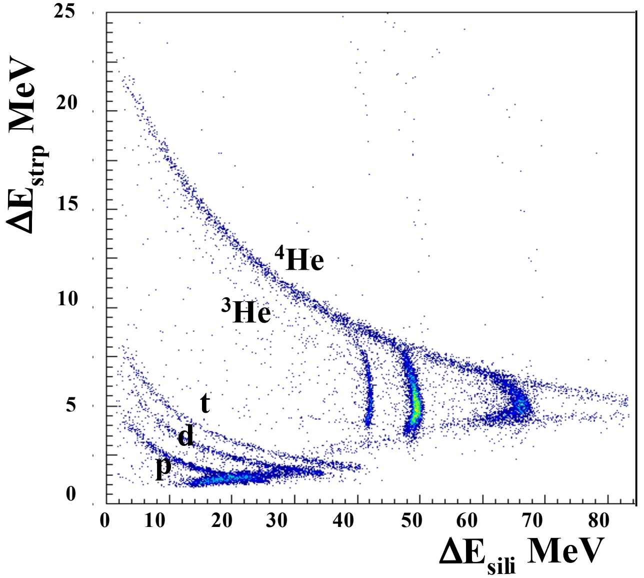


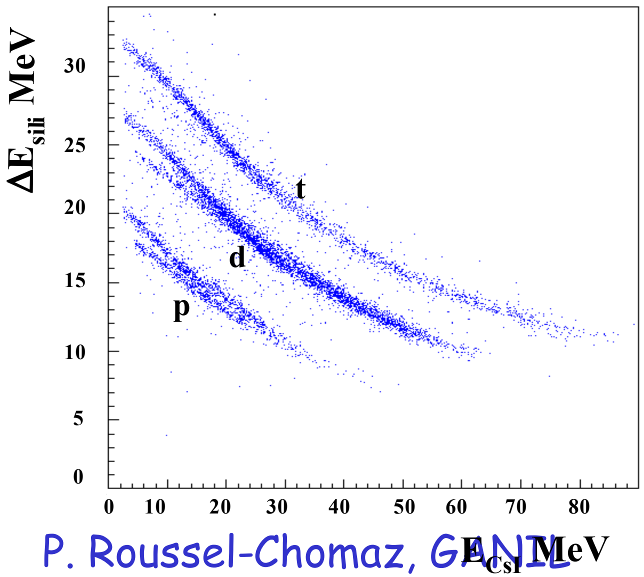
Heiberg Andersen, thèse, Bergen



A. Lagoyannis et al PLB 518 (2001) 27

Analyse de MUST





- 1[ère] expérience avec particules de haute E

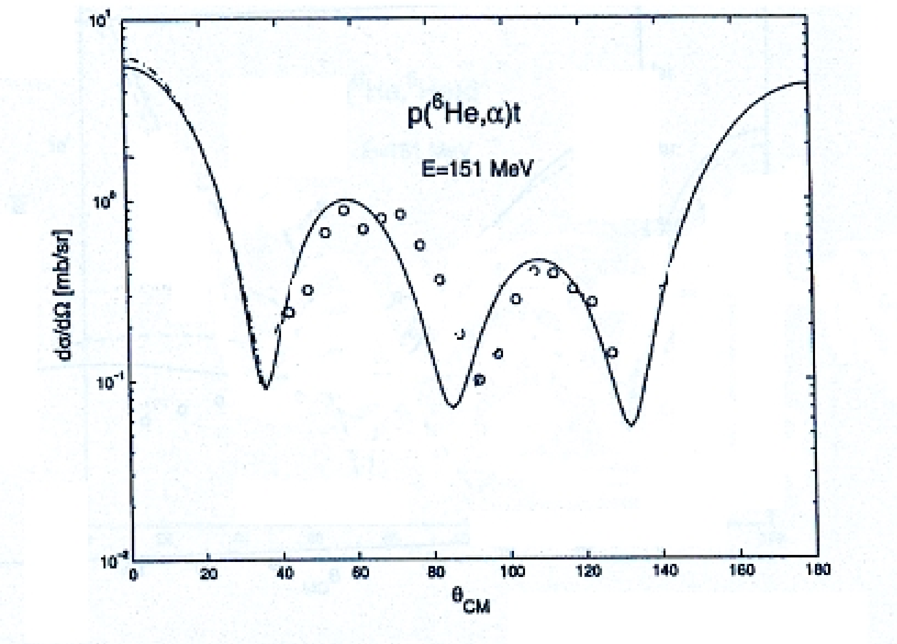
  Saturation ^{4}He dans préamplificateurs

- Calibration des CsI

  - dépend de la particule
  - repose uniquement sur une calibration avec source α des pistes

- Repérage dans l'espace des modules

  solution: bras télescopique



Heiberg Andersen, thèse, Bergen

III)

DWBA

- $A + a \longrightarrow B + b$ — x: nucléon(s) transféré(s)

  $\{B+x\} + a \longrightarrow B + \{a+x\}$ — ici: t, 2n

- $\frac{d\sigma}{d\Omega}$ dépend de T_{AB} : élément de matrice de la réaction

- $T_{AB} = \langle \chi^{-}_{bB} \Phi_b \Phi_B \mid W_{bB} \mid \Psi^{+}_{aA} \rangle$ post

  $\Psi^{+}_{aA} \leftarrow \chi^{+}_{aA} \Phi_a \Phi_A$ DWBA

  $\chi^{+}_{aA} \rightarrow$ Potentiel effectif $^{6}He+p$ Effets de breakup inclus

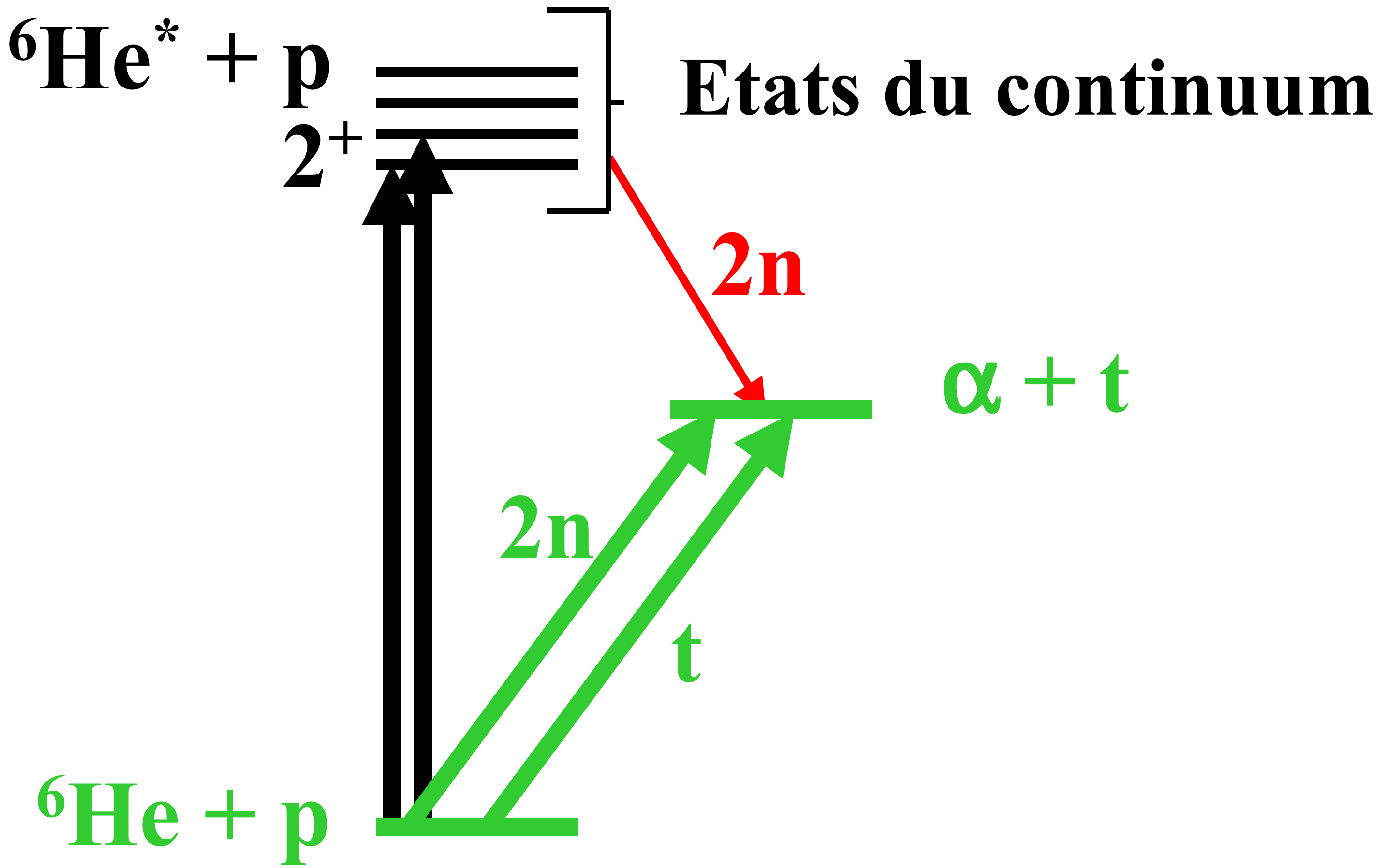
- $W_{bB} = V_{bB} - U_{bB}$

  $V_{bB} = V_{aB} + V_{xB}$

  U_{bB} : décrit la diffusion élastique de b+B

IV)

Transfert des 2 neutrons à partir



IV)

Transfert des 2 neutrons à partir