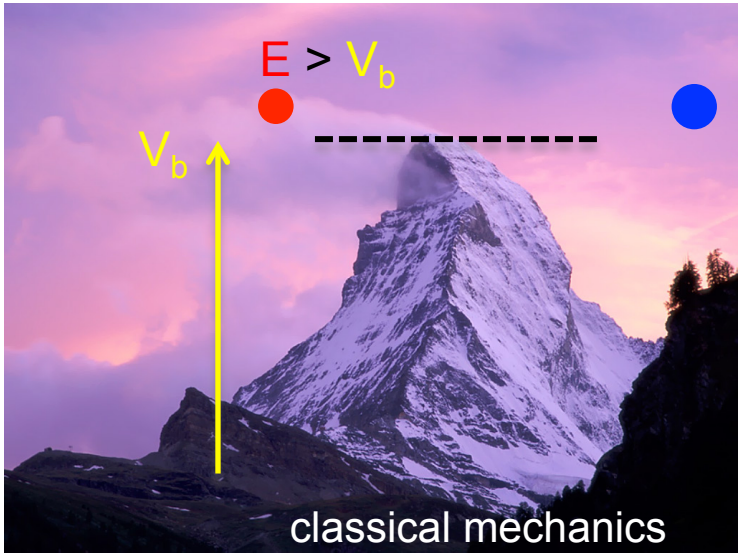
Heavy-ion fusion reactions involving Ni and Ca isotopes at sub-barrier energies

D. Bourgin, S. Courtin, and F. Haas

Motivations

- Fusion: dominant reaction mechanism in heavy-ion collisions at low bombarding energies



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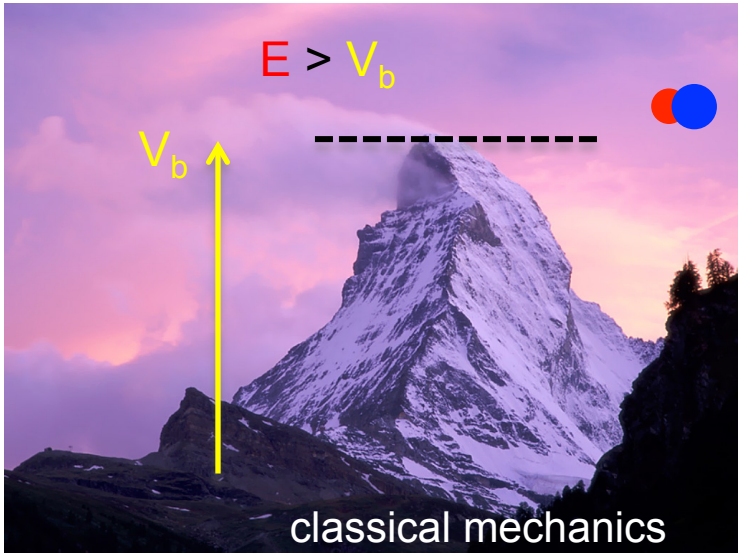

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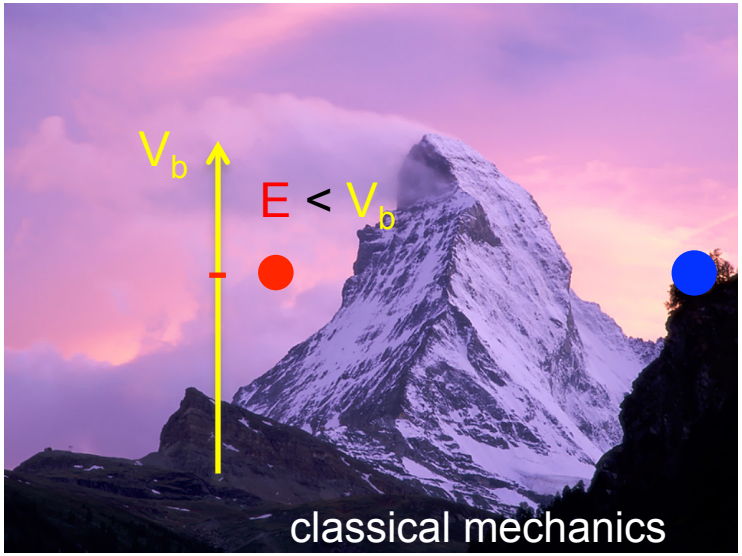

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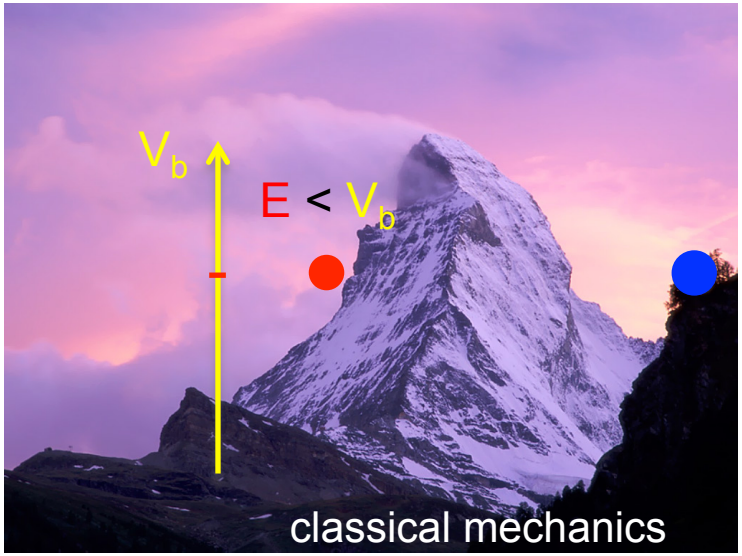

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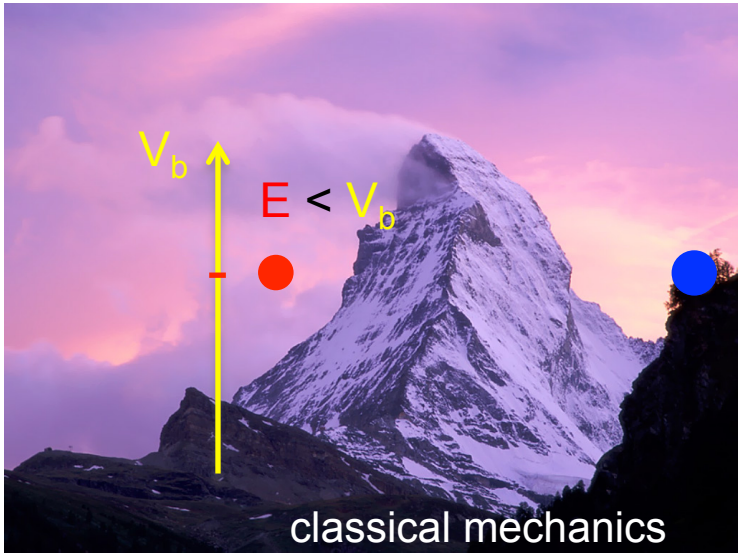

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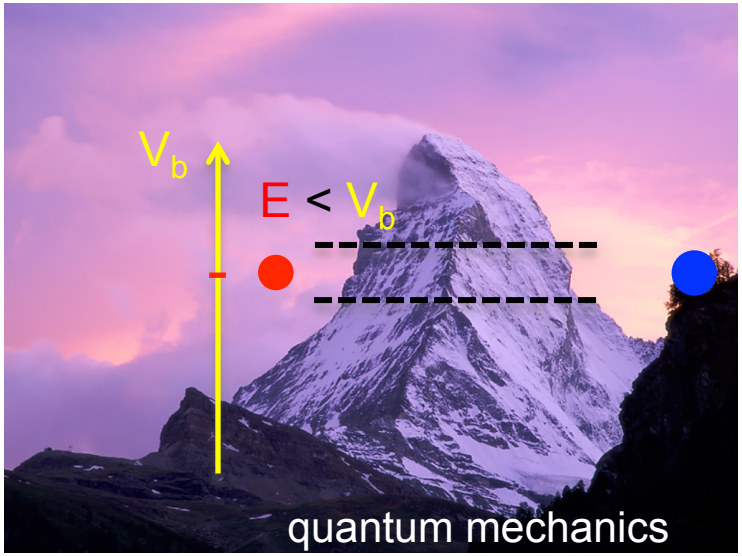
- Fusion: dominant reaction mechanism in heavy-ion collisions at low bombarding energies

- Fusion through the Coulomb barrier: quantum tunneling

- Studying the interplay between nuclear structure and reaction dynamics

- $^{58,64}Ni + {}^{58,64}Ni$ and $^{40,48}Ca + {}^{40,48}Ca$



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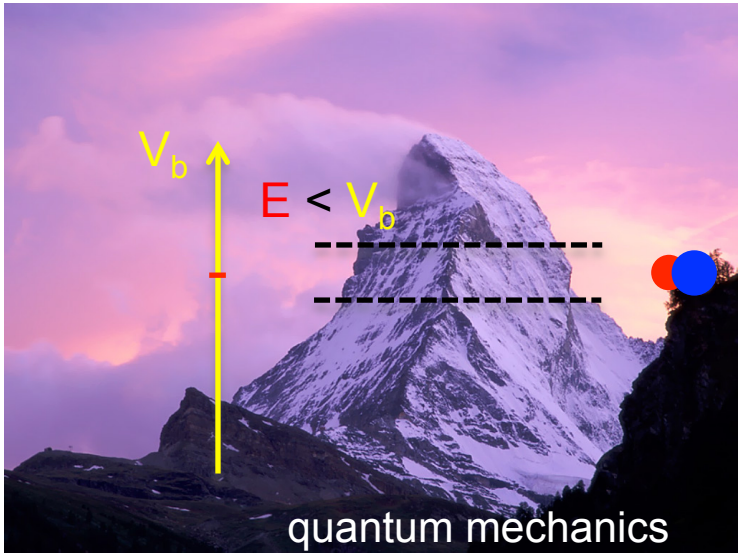
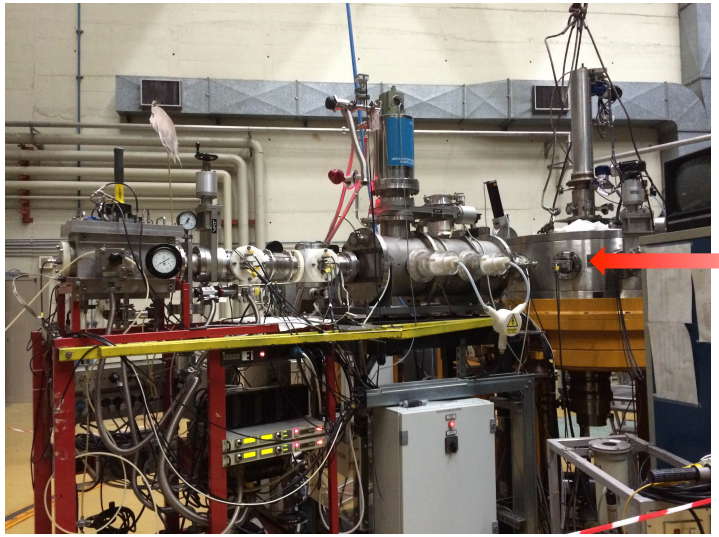


Fusion reactions: $^{40}Ca + ^{58,64}Ni$

Exp.: S. Courtin *et al.*

- Studying the influence of ^{40}Ca and $^{58,64}Ni$ nuclear structures on the fusion process
- Fusion cross section measurements



XTU Tandem accelerator

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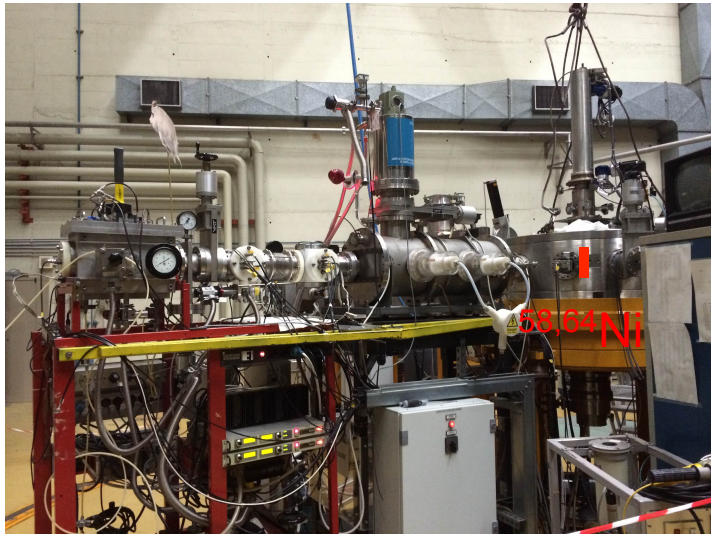

reaction chamber

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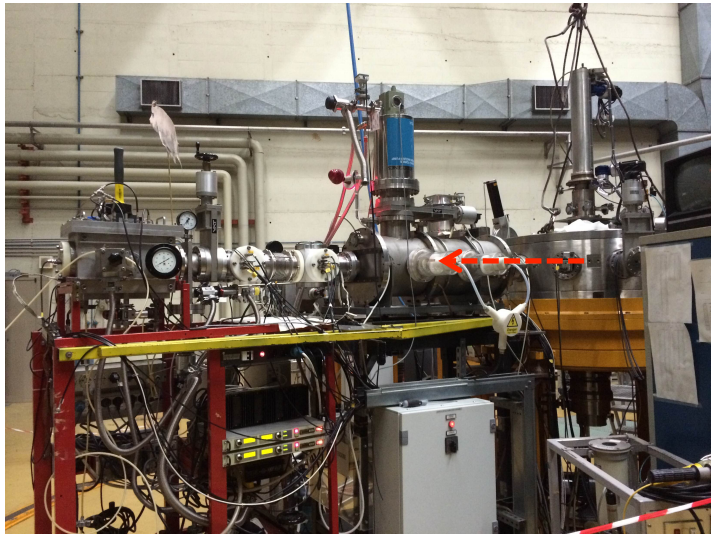

LNL electrostatic deflector

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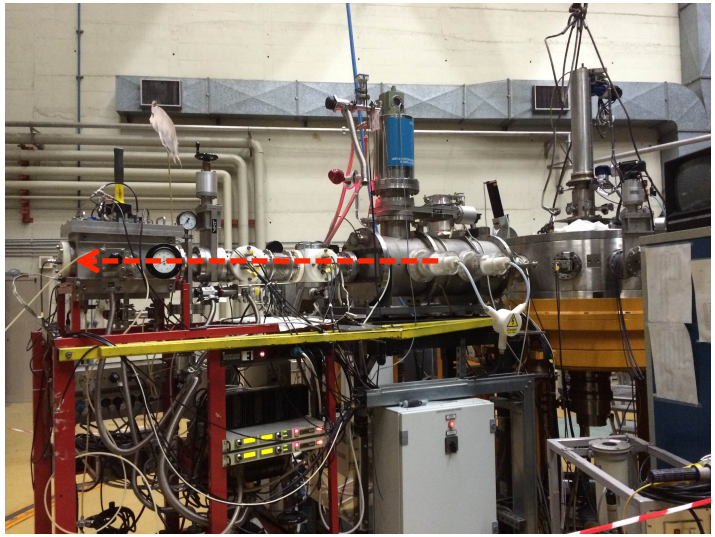
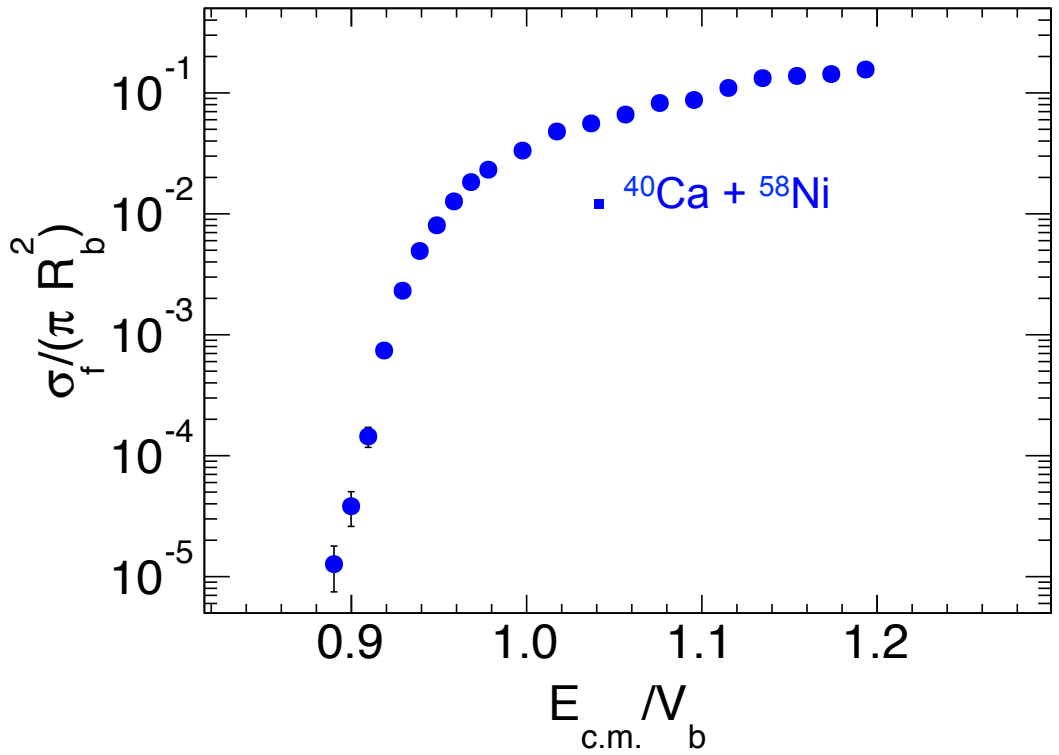


detection system

Fusion reactions: $^{40}Ca + ^{58,64}Ni$

- Fusion excitation functions

D. Bourgin *et al.*, Phys. Rev. C **90**, 044610 (2014)



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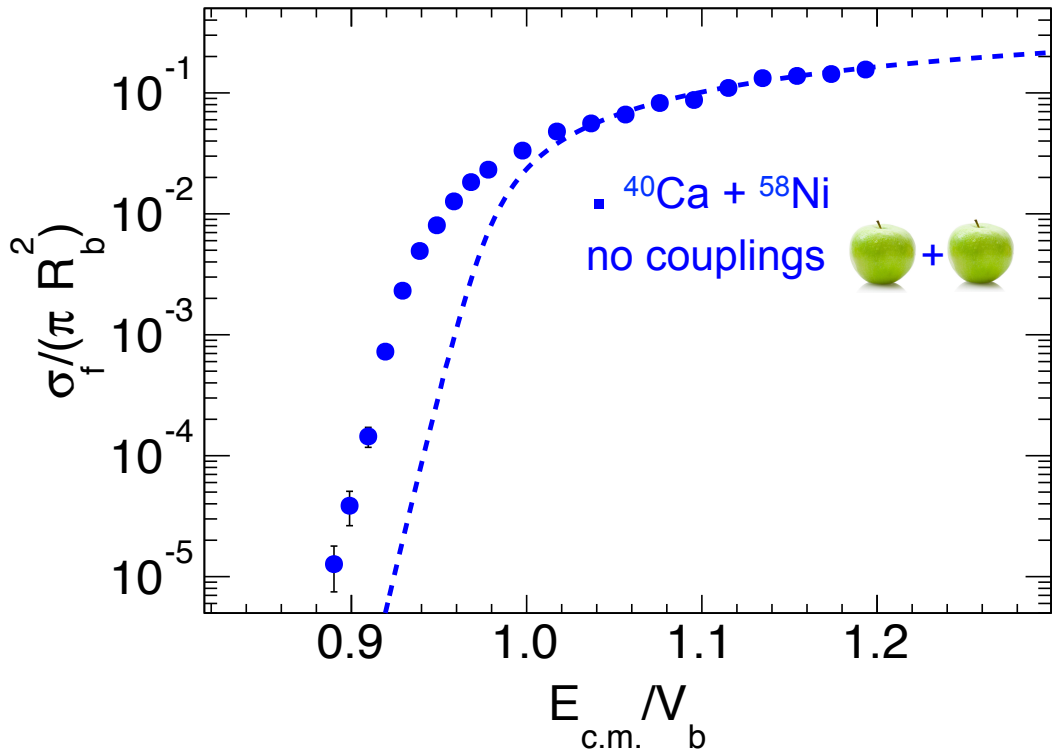

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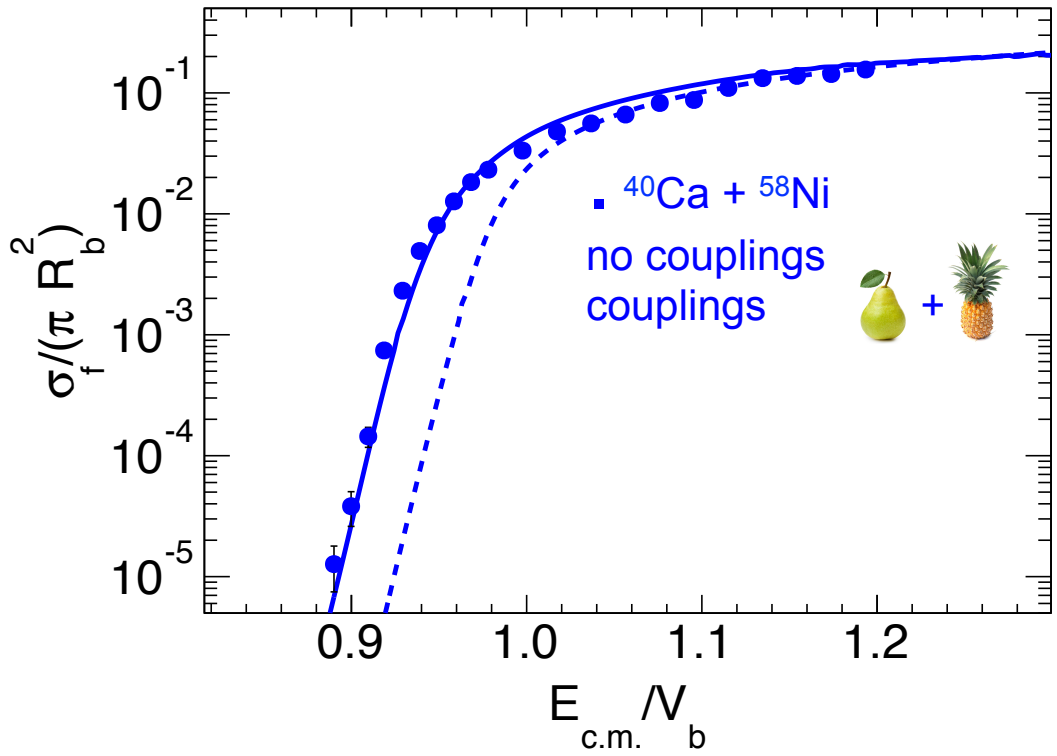

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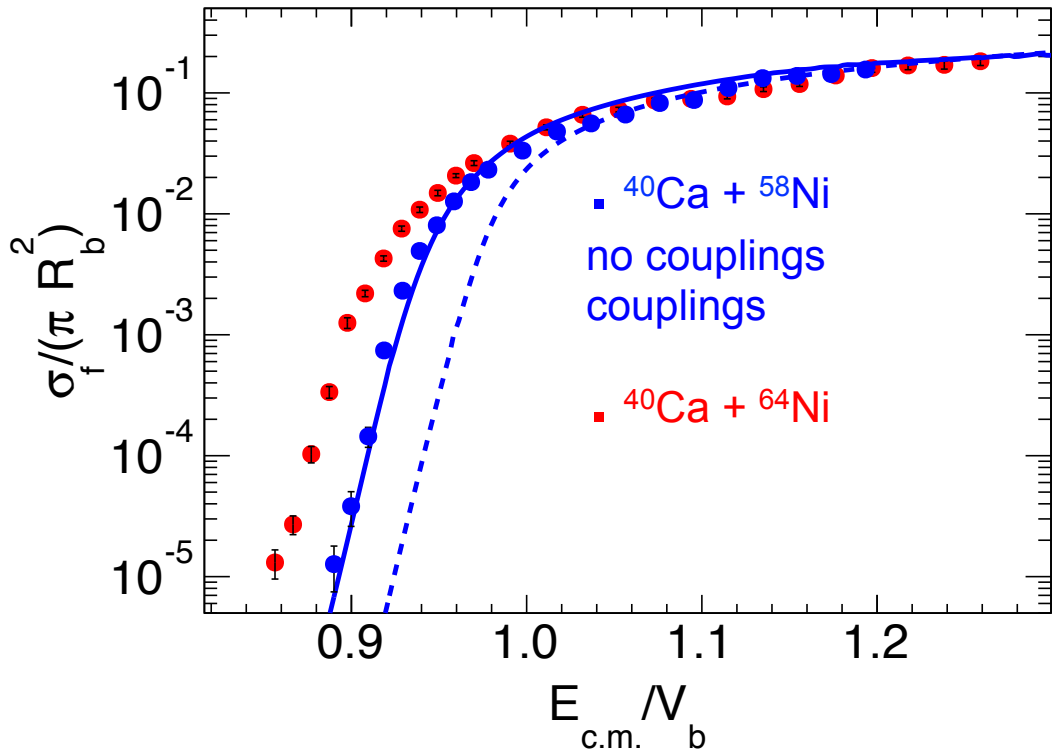

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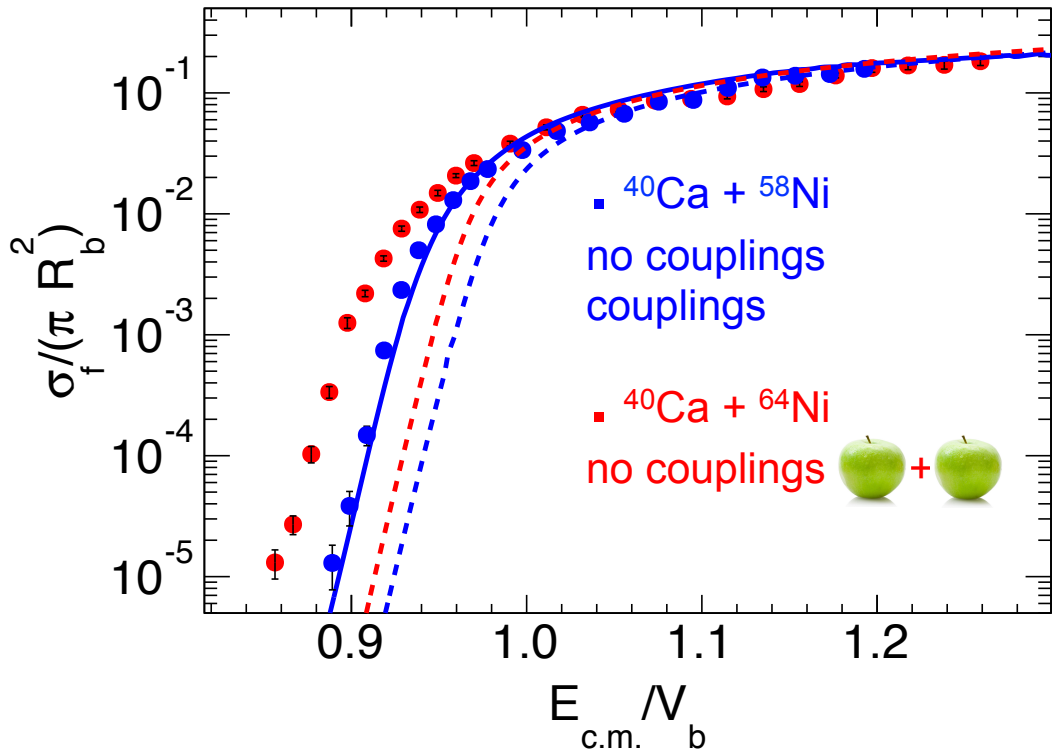

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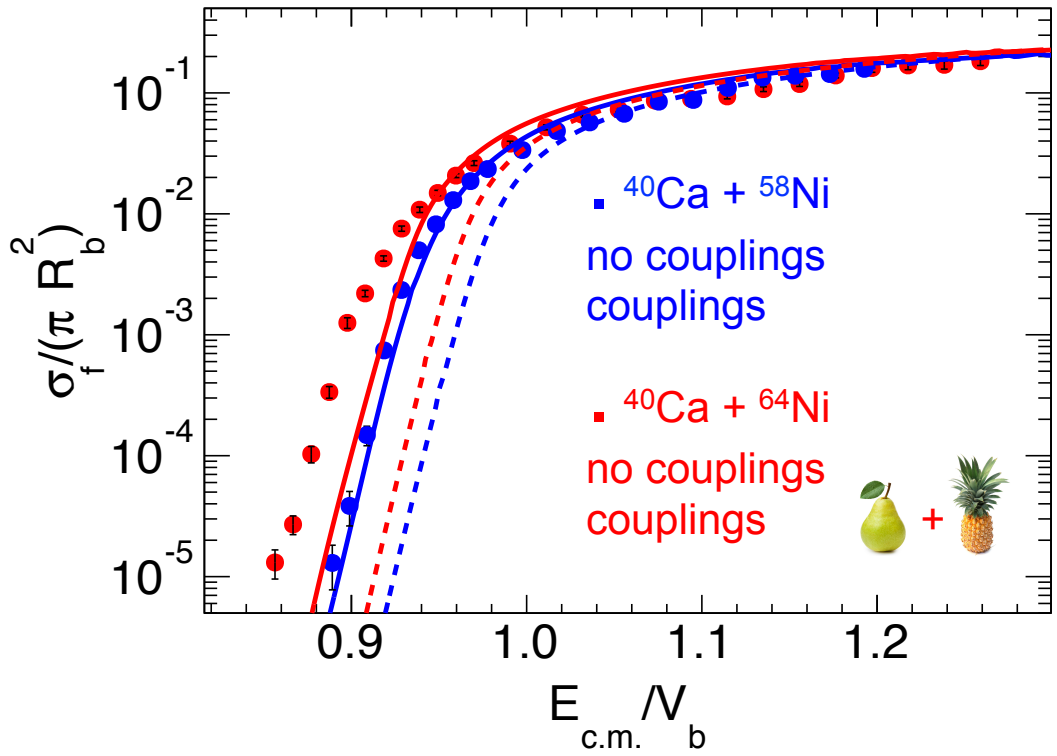

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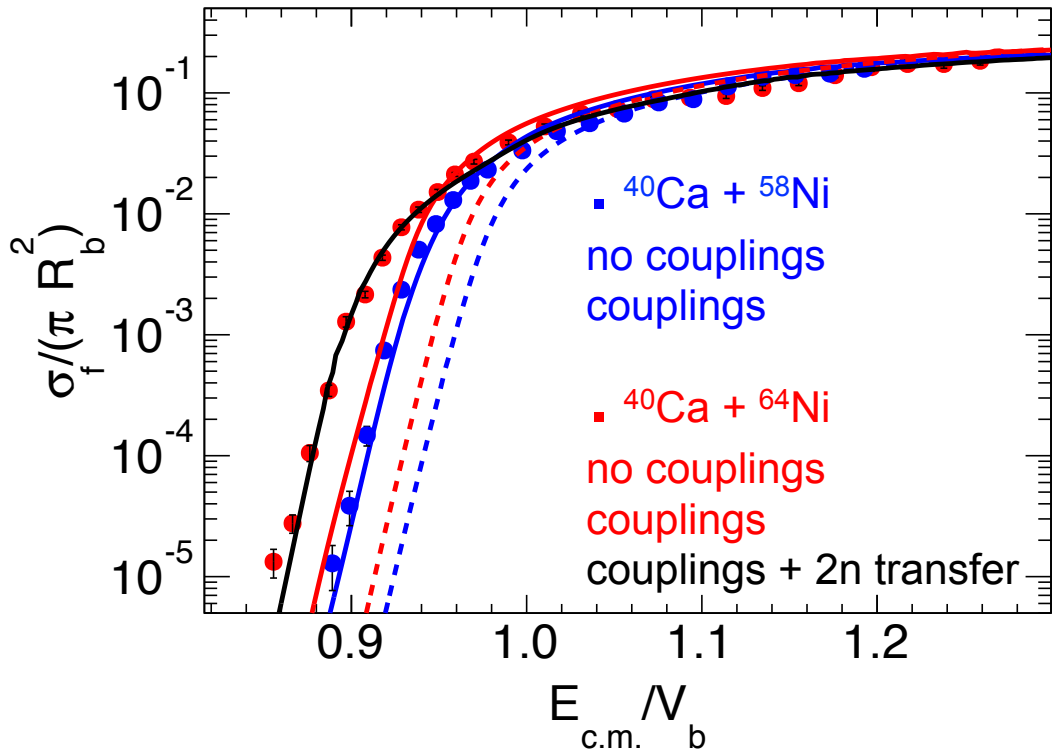


Fusion reactions: $^{40}Ca + ^{58,64}Ni$

- Nucleon transfer Q-values [MeV]

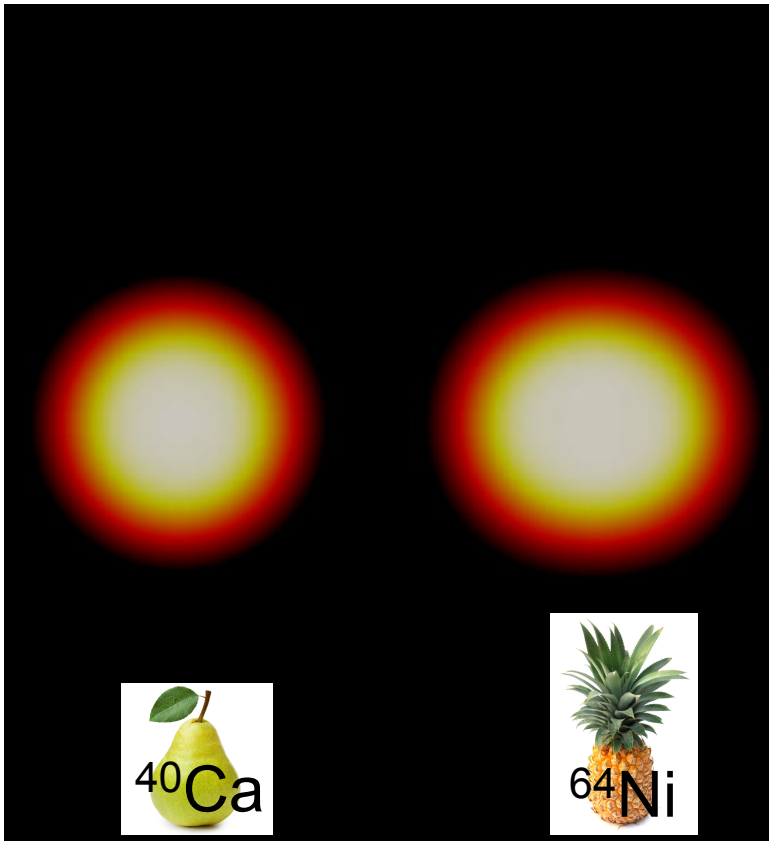
$^{58,64}Ni \xrightarrow{n} {}^{40}Ca$ $\quad$ $^{40}Ca \xrightarrow{p} {}^{58,64}Ni$

System	+1n	+2n	-1p	-2p
$^{40}Ca+^{58}Ni$	-3.8	-2.5	-3.8	-3.6
$^{40}Ca+^{64}Ni$	-1.2	+3.5	+0.3	+4.2

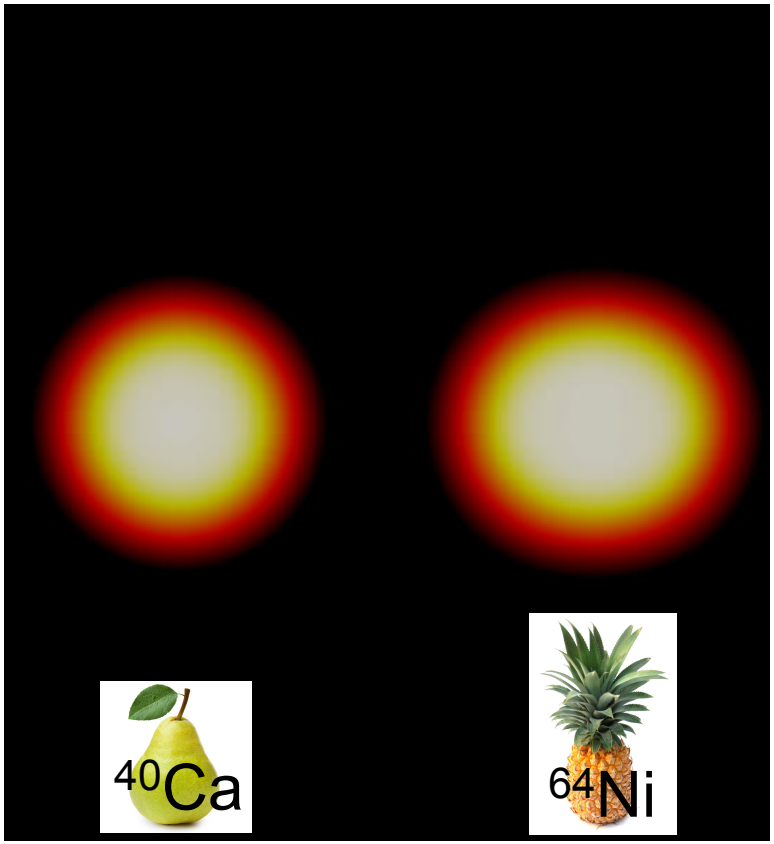
Fusion reactions: $^{40}Ca + ^{58,64}Ni$

- Time-Dependent Hartree-Fock calculations:

scattering process



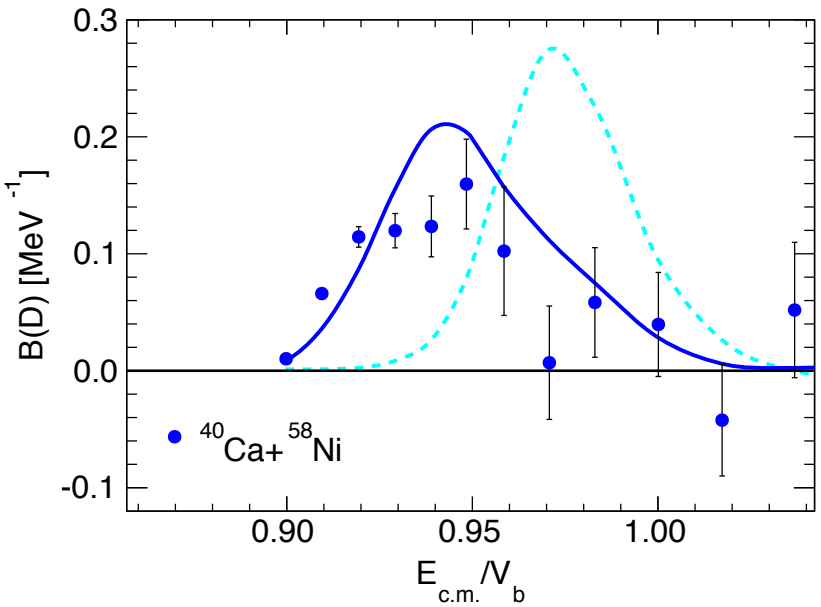
fusion process

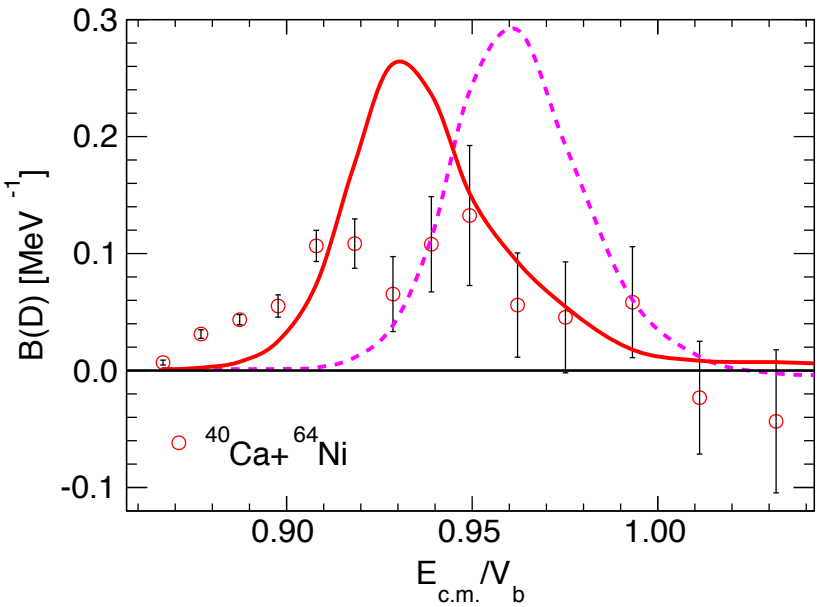


In collaboration with C. Simenel, Department of Nuclear Physics, RSPE, Australian National University, Australia

Fusion reactions: $^{40}Ca + ^{58,64}Ni$

- Barrier distributions





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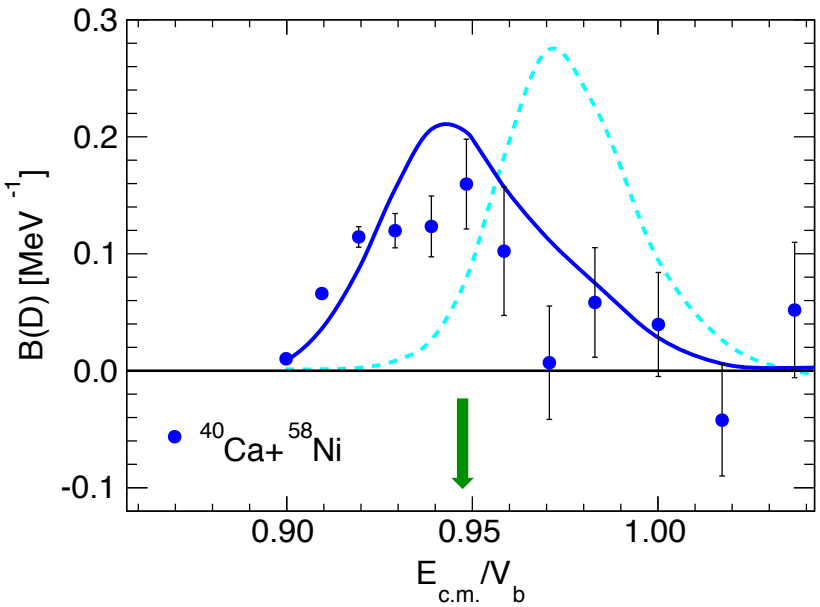

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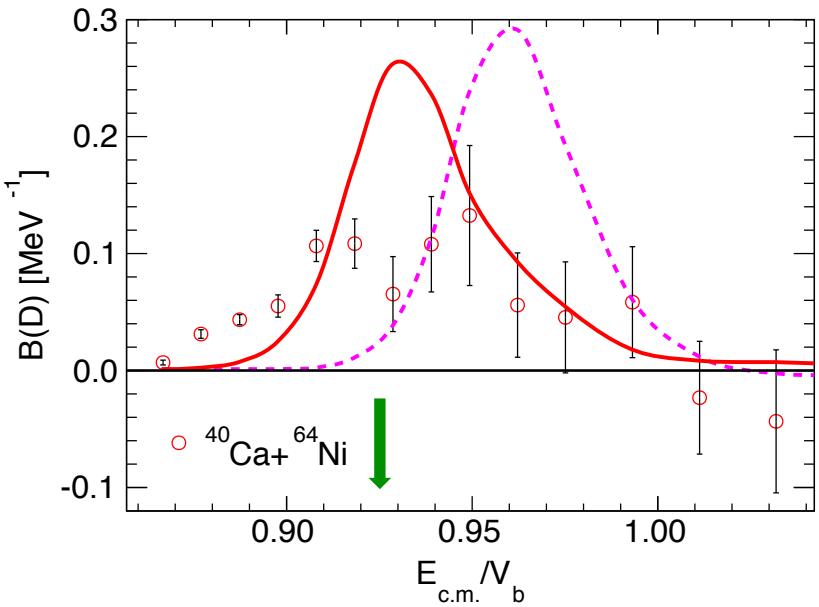

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- Influence of the nuclear structure of the colliding nuclei on the fusion process for $^{40}Ca + ^{58,64}Ni$

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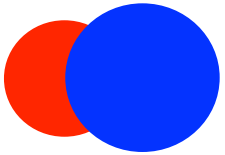

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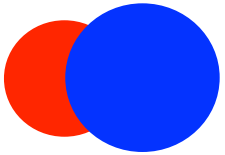

- Effect of the neutron transfer channels on the fusion process in $^{40}Ca + ^{64}Ni$

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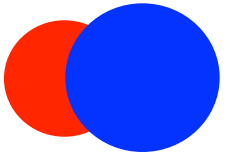

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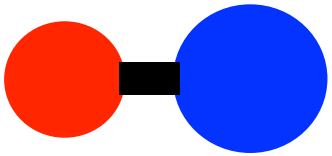

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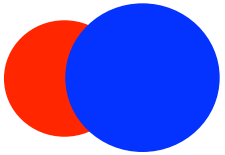

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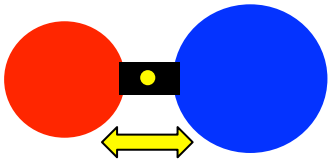

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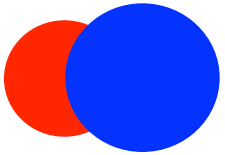

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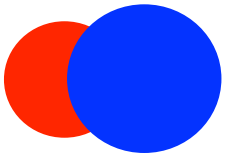

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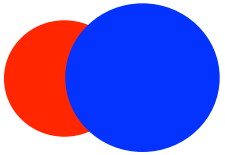

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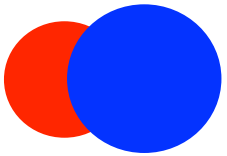
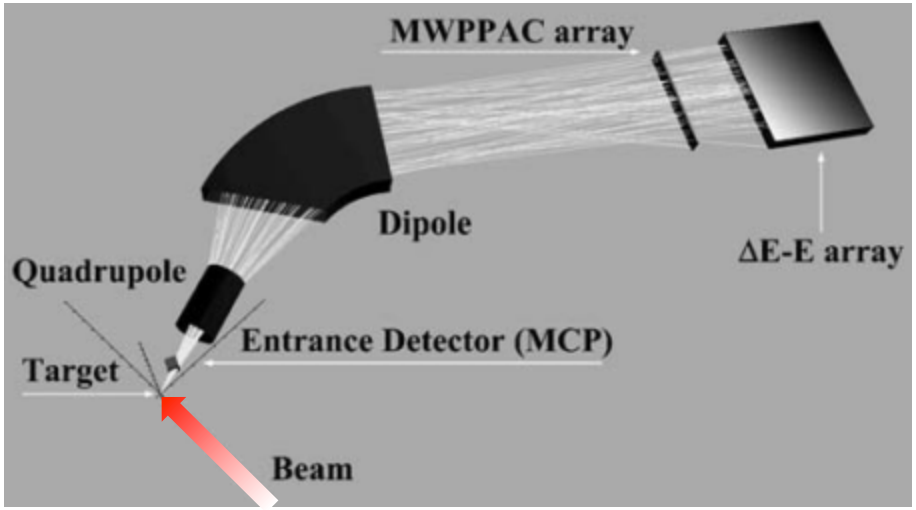


- Nucleon transfer cross section measurements for $^{40}Ca + ^{58,64}Ni$

Transfer reactions: $^{40}Ca + ^{58,64}Ni$

Exp.: D. Bourgin *et al.*

- Nucleon transfer cross section measurements



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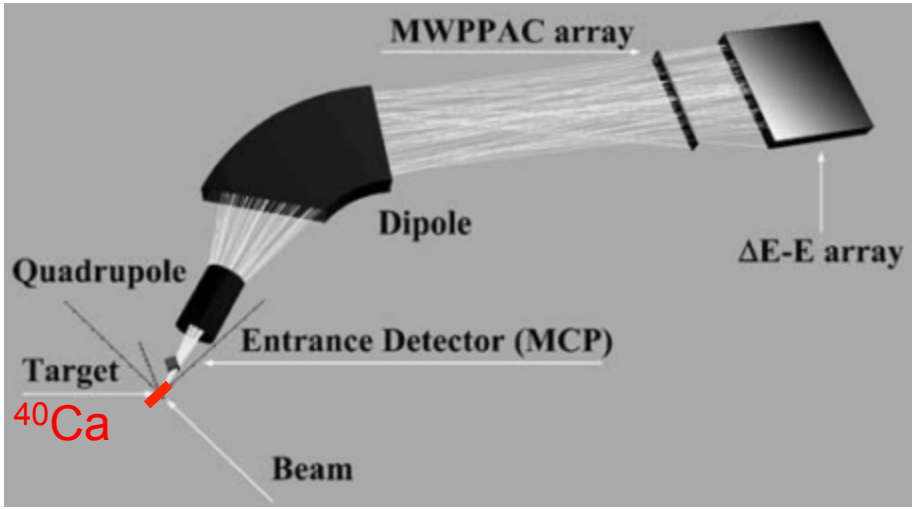

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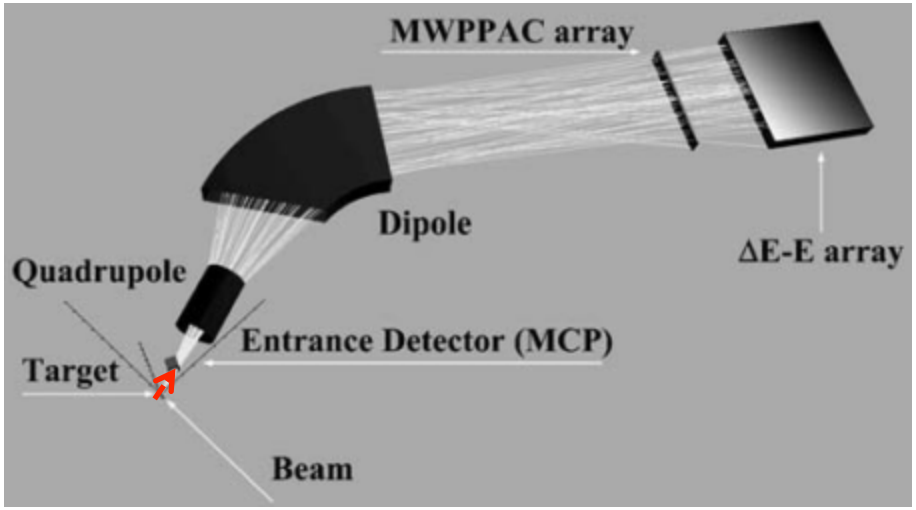

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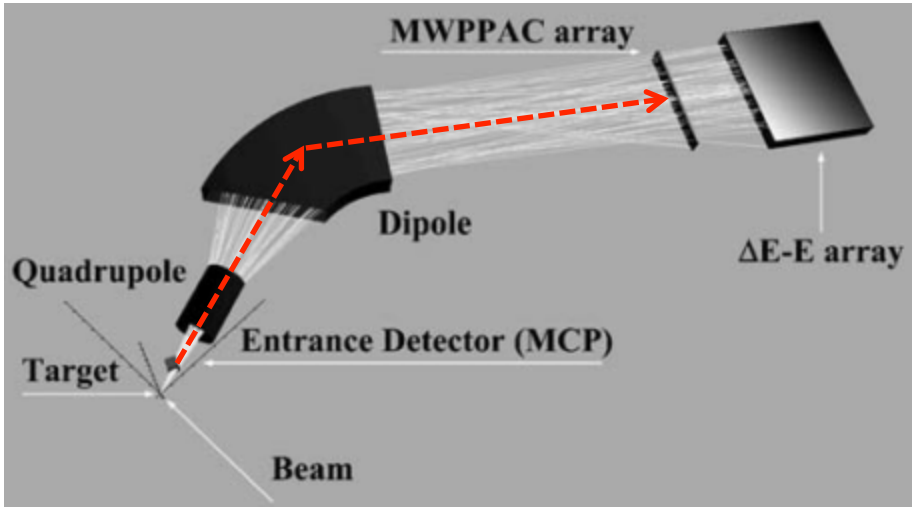

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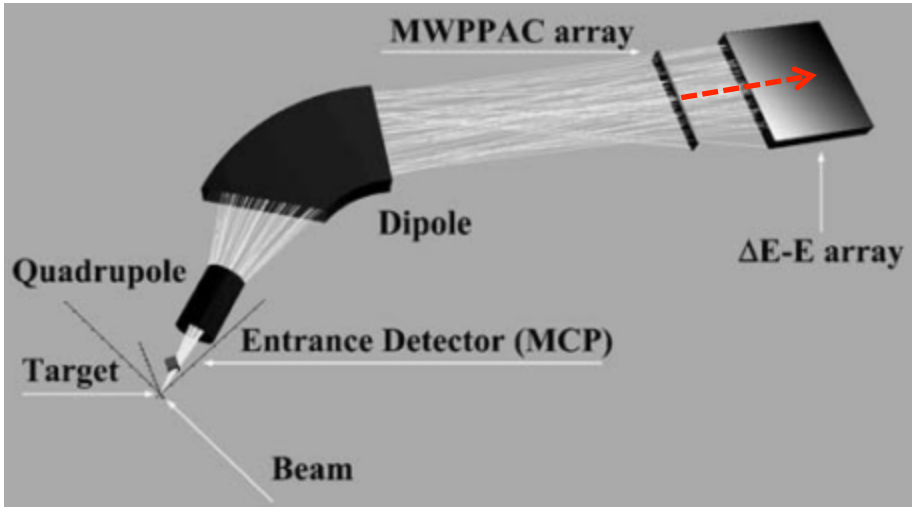

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Thank you for your attention !

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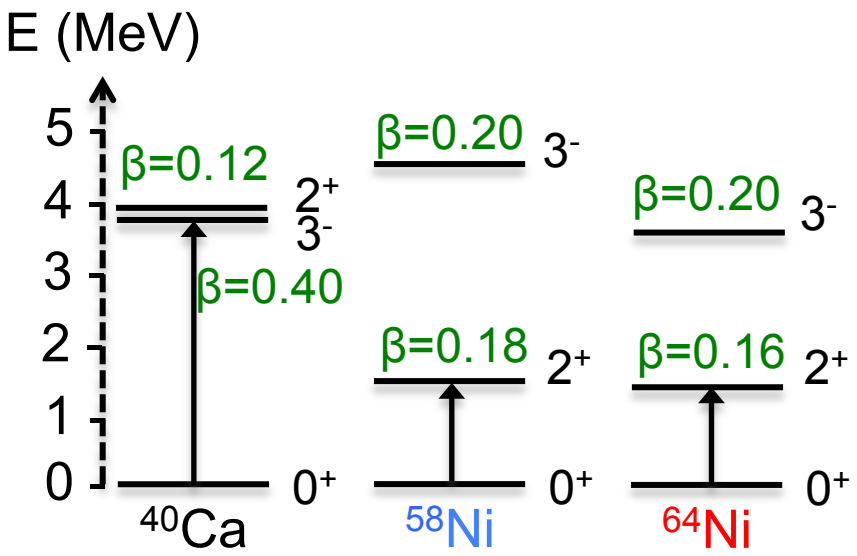
Fusion reactions: $^{40}Ca + ^{58,64}Ni$

- Fusion excitation functions



Fusion reactions: $^{40}Ca + ^{58,64}Ni$

- Barrier width
  - Fit of the two fusion excitation functions with the Wong formula
  - Wong formula:

$$\sigma_f(E_{c.m.}) = \frac{R_0^2}{2E_{c.m.}} \hbar\omega_0 \ln\left(1 + e^{\frac{2\pi}{\hbar\omega_0}(E_{c.m.} - V_0)}\right)$$

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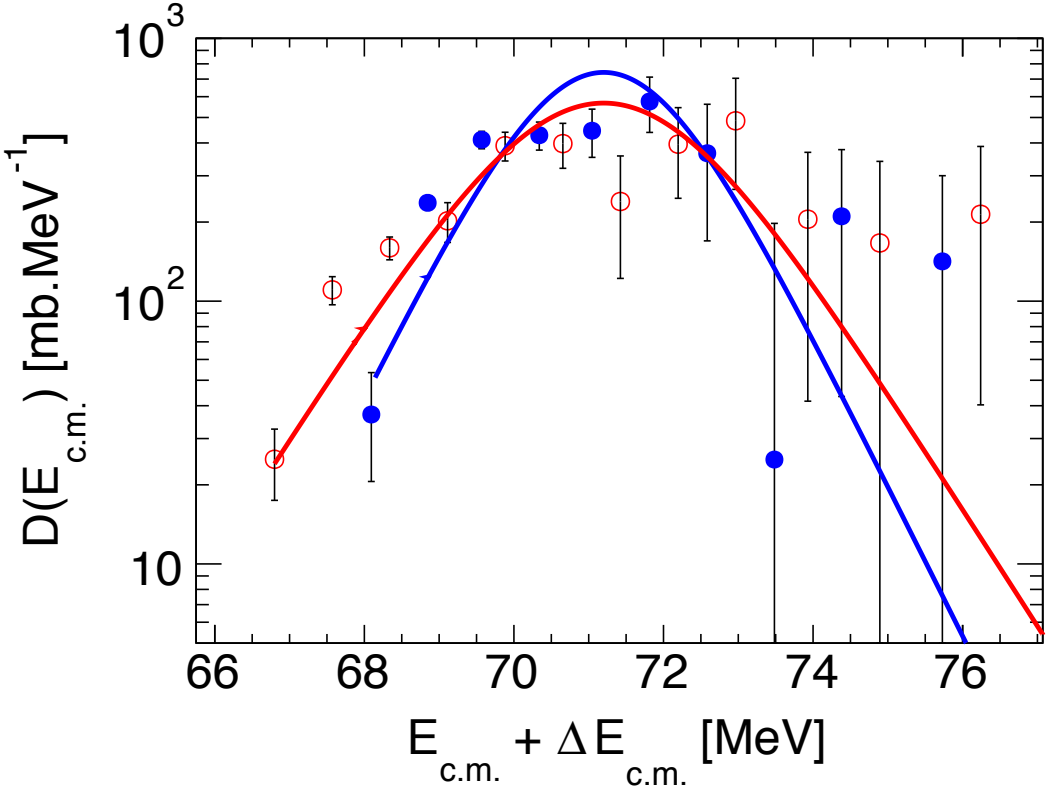
System	$\hbar\omega_0$ [MeV]	V_0 [MeV]	R_0 [fm]
$^{40}Ca+^{58}Ni$	4.8 ± 0.2	71.2 ± 0.1	8.5 ± 0.1
$^{40}Ca+^{64}Ni$	6.1 ± 0.2	69.1± 0.1	8.4 ± 0.1

Fusion reactions: $^{40}Ca + ^{58,64}Ni$

- Barrier width



$$D(E_{c.m.}) = \frac{d^2(E_{c.m.}\sigma_f)}{dE^2_{c.m.}}$$

- $^{40}Ca + ^{58}Ni$, $\Delta E_{c.m.} = 0$ MeV

Wong formula fit

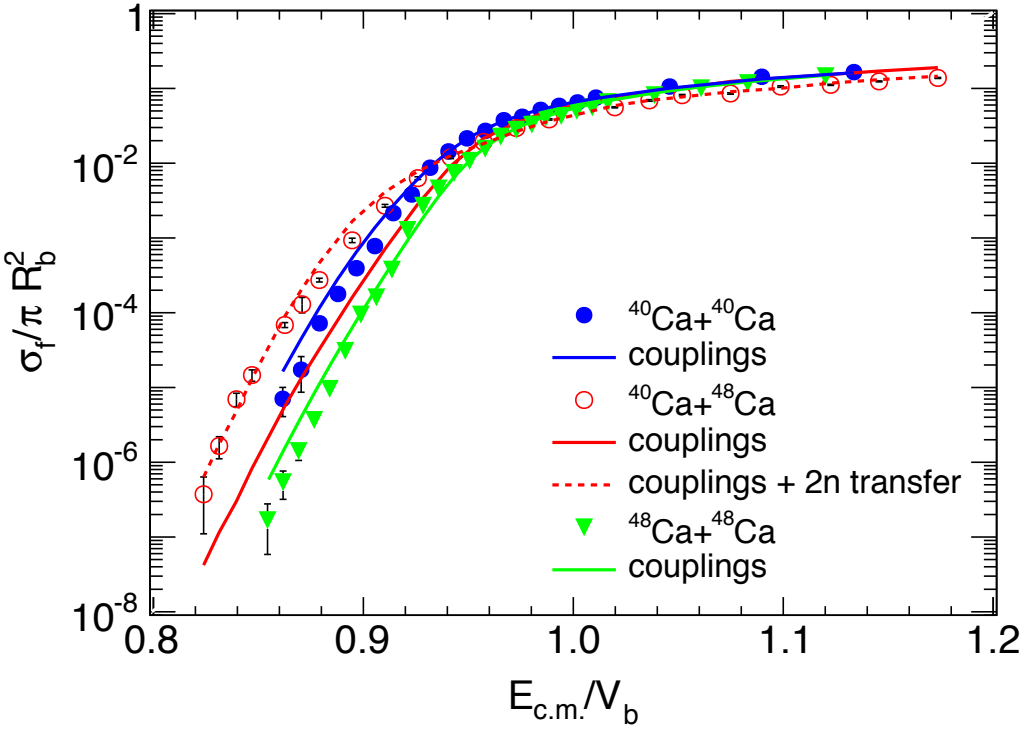
- $^{40}Ca + ^{64}Ni$, $\Delta E_{c.m.} = 2.09$ MeV

Wong formula fit

Fusion reactions: $^{40,48}Ca + ^{40,48}Ca$

- Fusion excitation functions for $^{40,48}Ca + ^{40,48}Ca$

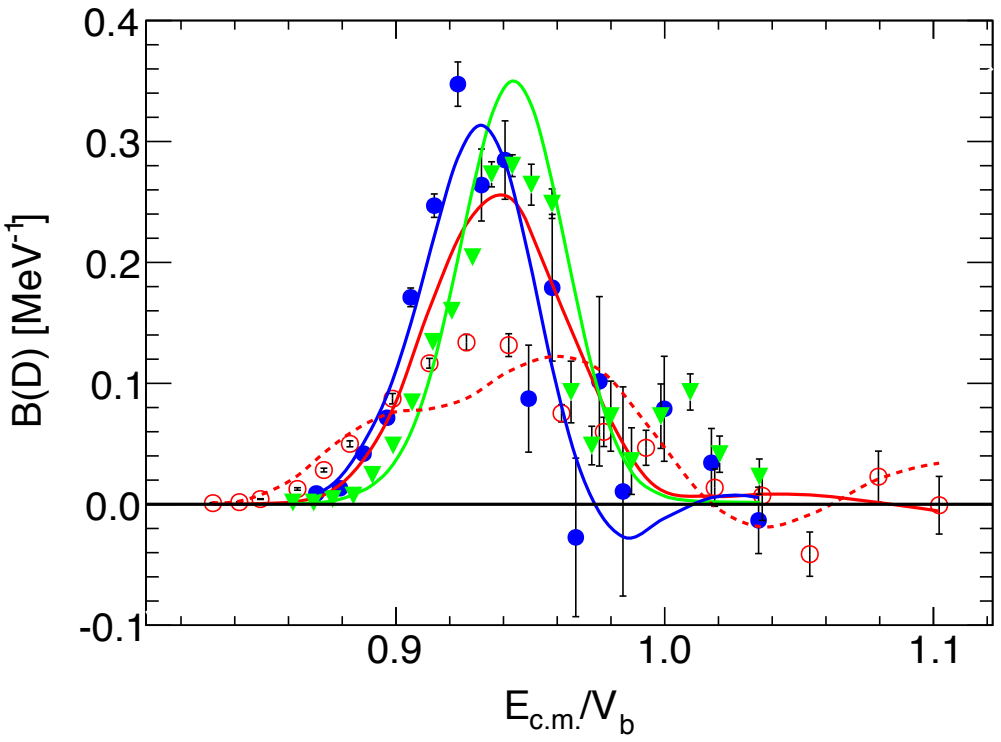
G. Montagnoli *et al.*, Phys. Rev. C **85**, 024607 (2012)
A. M. Stefanini *et al.*, Phys. Lett. B. **679**, 95 (2009)



C. L. Jiang *et al.*, Phys. Rev. C **82**, 041601(R) (2010)

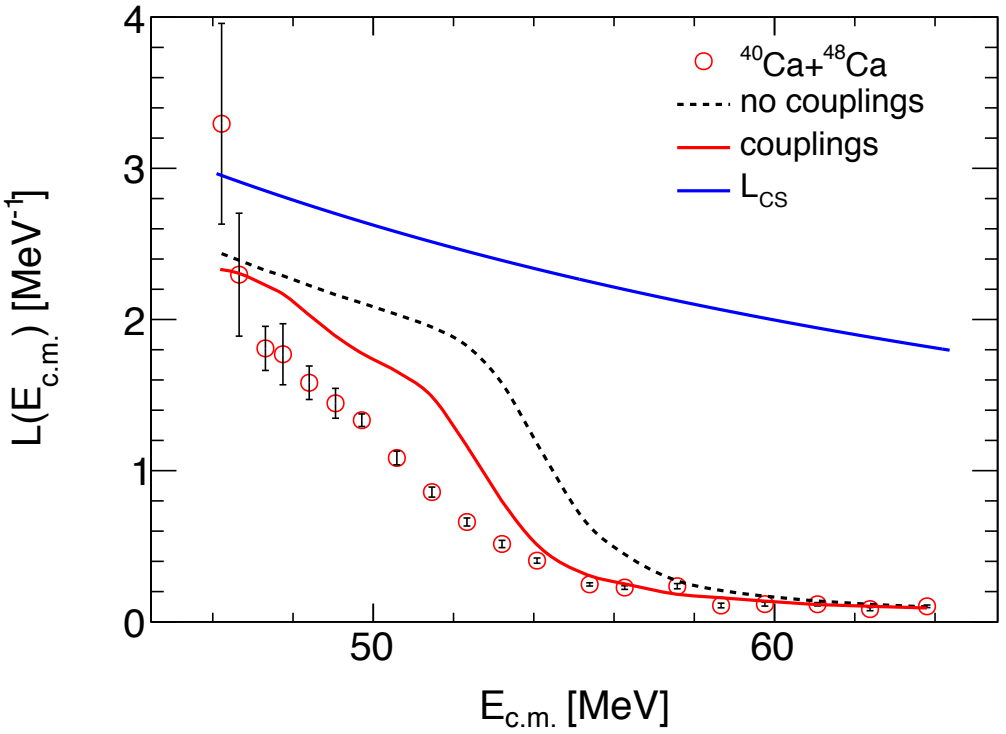
Fusion reactions: $^{40,48}Ca + ^{40,48}Ca$

- Barrier distributions for $^{40,48}Ca + ^{40,48}Ca$



Fusion reactions: $^{40,48}Ca + ^{40,48}Ca$

- Logarithmic derivative for $^{40}Ca + ^{48}Ca$



Fusion reactions: $^{40,48}Ca + ^{40,48}Ca$

- Fusion excitation functions for $^{58,64}Ni + ^{58,64}Ni$

M. Beckerman *et al.*, Phys. Rev. C **23**, 1581 (1981)
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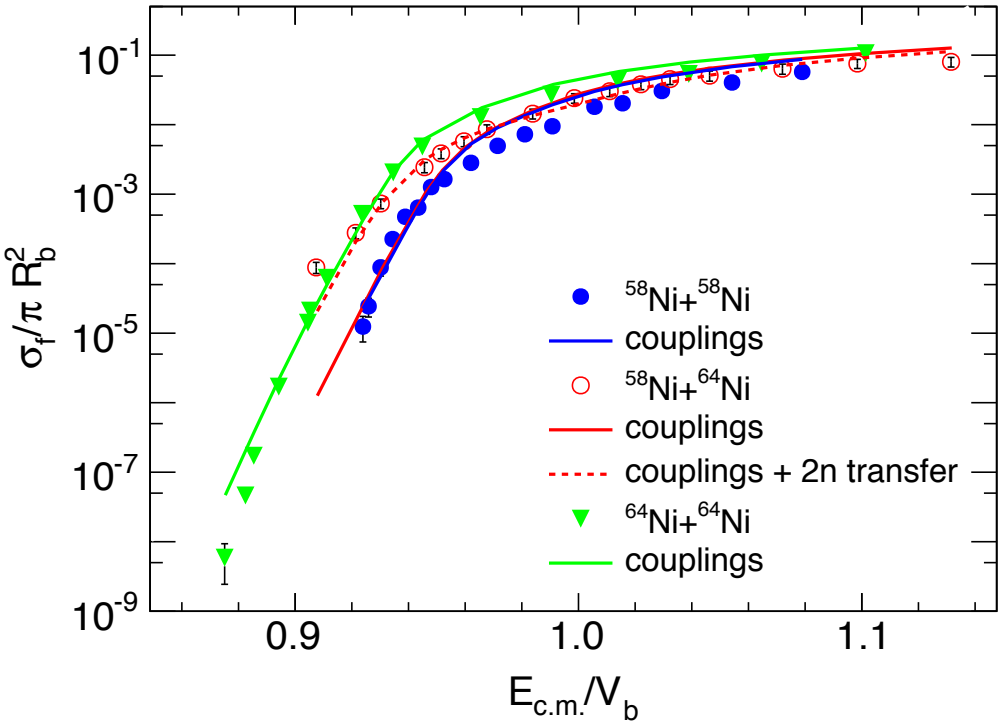
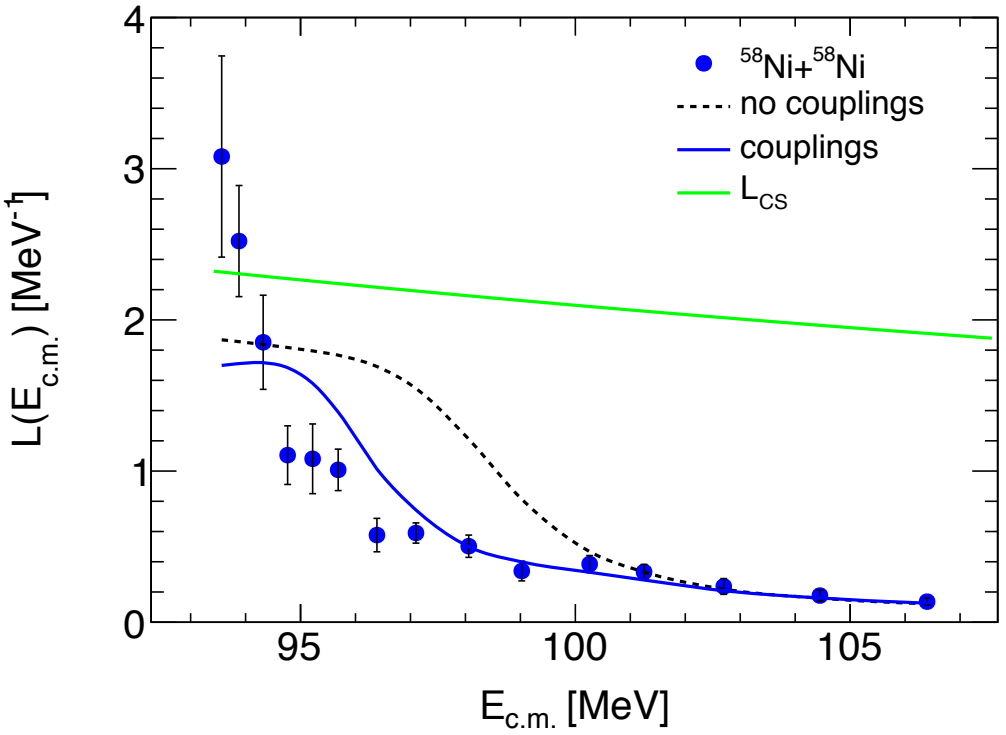


D. Ackermann *et al.*, Nucl. Phys. A **609**, 91 (1996)

Fusion reactions: $^{40,48}Ca + ^{40,48}Ca$

- Logarithmic derivative for $^{58}Ni + ^{58}Ni$



Fusion reactions: $^{40,48}Ca + ^{40,48}Ca$

- Logarithmic derivative for $^{64}Ni + ^{64}Ni$