Study of sub-barrier fusion systematics

Adam Broniš

Supervisor: Dr. Roman Wolski

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JINR, Flerov laboratory of nuclear reactions

adam.bronis@gmail.com

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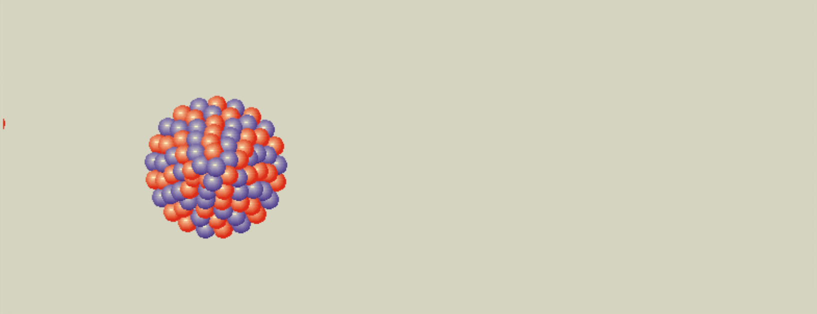
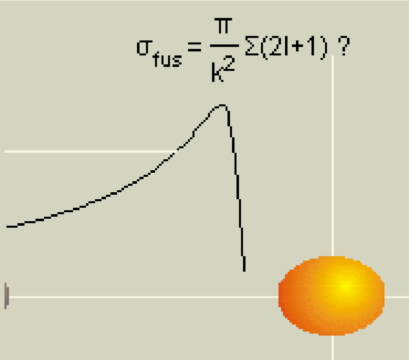
Bohr's two stages model:

- Formation of compound nucleus (*CN*) from colliding nuclei. Nucleon-nucleon interactions lead to thermal equilibrium.
- Evaporation of α particles or nucleons from the excited compound nucleus followed by γ ray emission.



However, CN may not survive - fission!

- Fusion cross section (σ_{fus}) depends on the energy E and angular momentum l.
- Partial wave model: approach and contact of nuclei $\frac{\pi}{k^2}\sum(2l+1)$, probability of tunneling partial l wave through the Coulomb barier $T_l(\mathrm{E})$.
- However for sub-barrier fusion it is necessary to overcome Coulomb barrier $\rightarrow$ quantum tunneling.



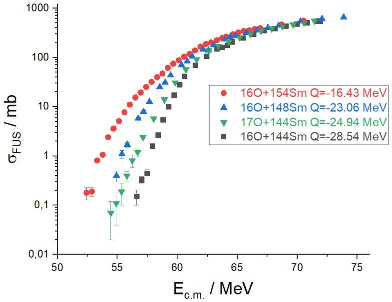
Empirical model based on the partial wave summation [1].

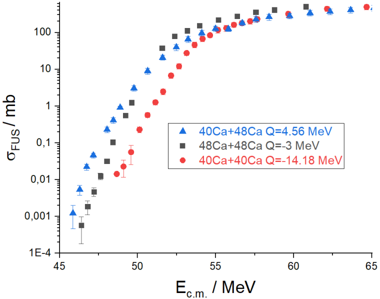
[1] http://nrv.jinr.ru/nrv/webnrv/fusion

- At low energy the cross sections will be higher for systems with higher Q-value, "CN aspect" $\rightarrow$ Q-value rule

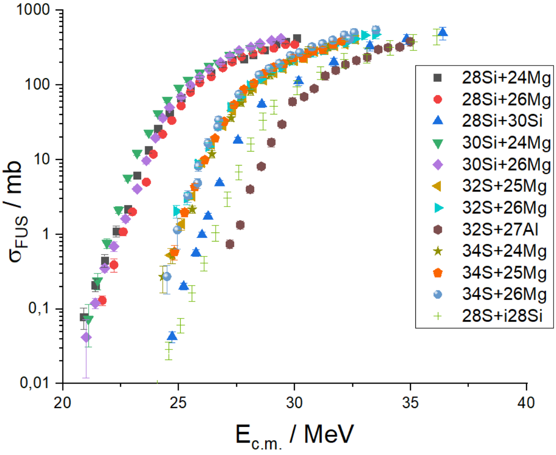
- Excitation functions for different fusion systems $\Longrightarrow$ which obey Q-value rule. $E_{c.m.}$ is energy in center of mass frame.

- Excitation functions $\rightarrow 0$ if $Q \rightarrow Q_{(Threshold)}$.





- But how to compare various fusion systems?
- In these cases simple energy scaling is introduced.
- $E_R = \frac{E_{c.m.}+Q}{V_C+Q}$



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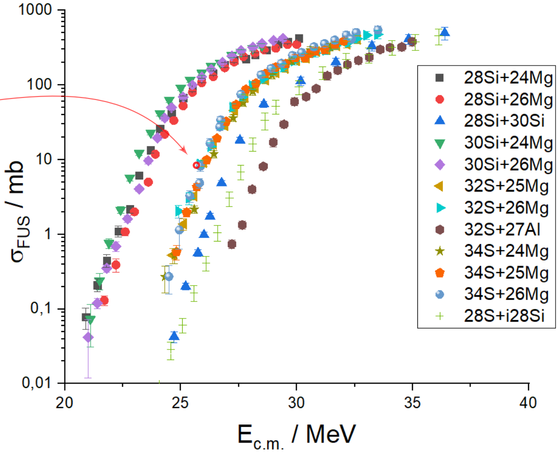

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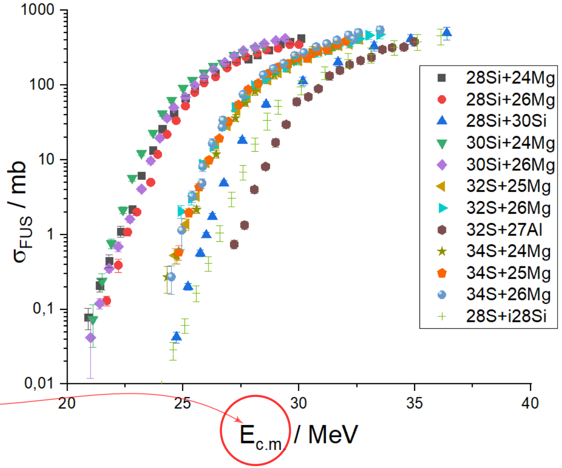
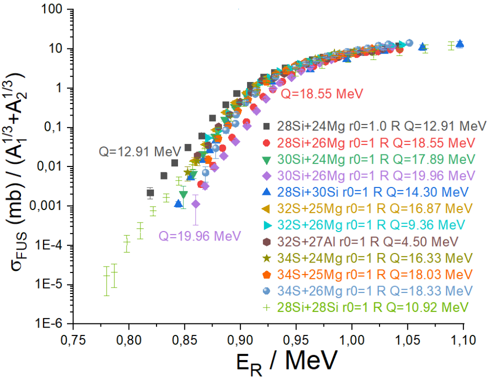


$E_R = \frac{E_{c.m.}+Q}{V_C+Q}$ - reduced energy, $\frac{\sigma_{FUS}}{(A_p^{1/3}+A_t^{1/3})}$ - reduced cross section

- $E_{c.m.}$ - energy in center of mass frame.
- Q - fusion Q value
- $V_C = \frac{Z_p Z_t e^2}{4\pi\epsilon_0 R}$ - Coulomb barrier where
  - $R = r_0(A_p^{1/3} + A_t^{1/3})$
- However, some data follows trend opposite to the Q-value rule!



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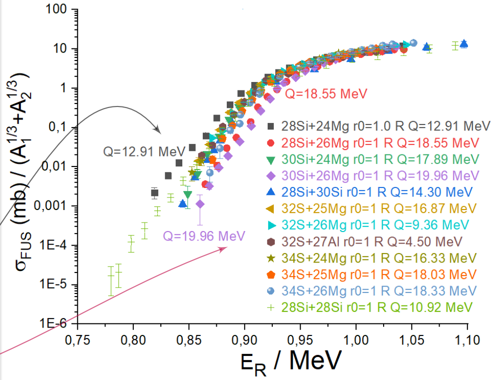
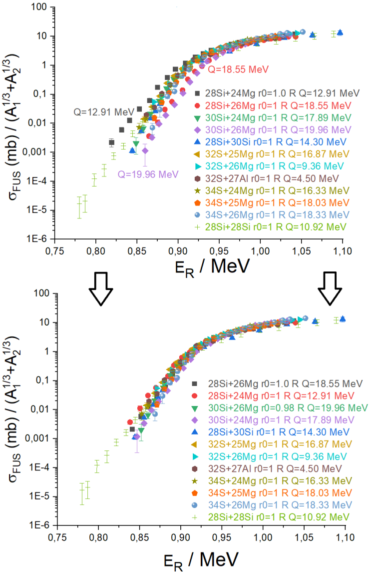


- Possible mismatch in data sets $^{28,30}\mathrm{Si}+^{24,26}\mathrm{Mg}$?
- Changing the data sets $^{24}\mathrm{Mg} \longleftrightarrow {}^{26}\mathrm{Mg}$ makes them much more consistent with similar systems
- Another experiments focused on these datasets needed to confirm our assumption.



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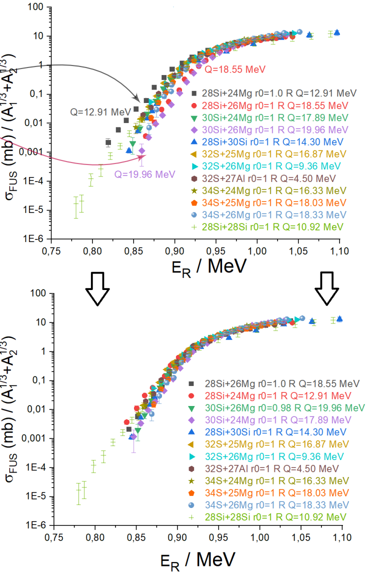

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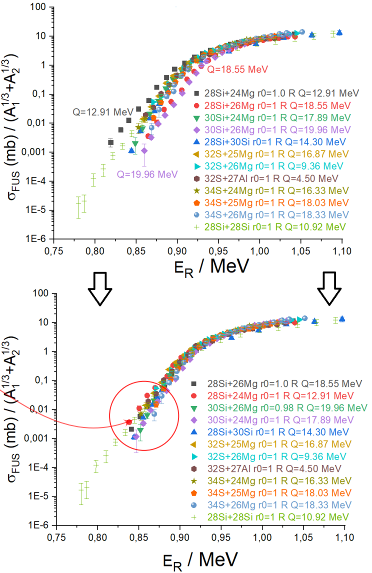
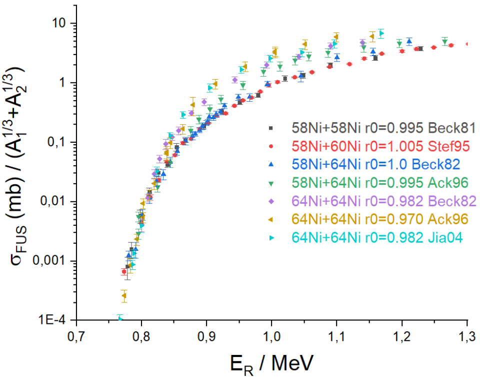


- Another inconsistency found in $^{64}\mathrm{Ni} + {}^{64}\mathrm{Ni}$ systems
- Free parameter r_0 differs for $^{64}\mathrm{Ni} + {}^{64}\mathrm{Ni}$ measurements
- Even if the difference is not large, it cannot be explained by the uncertainties.



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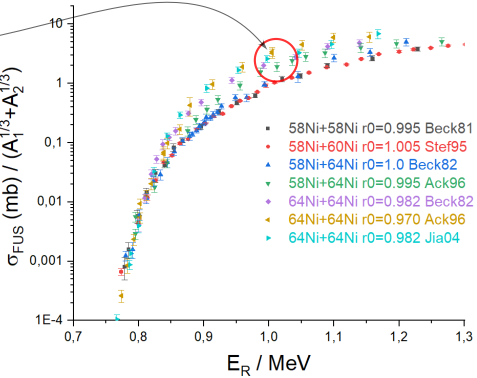

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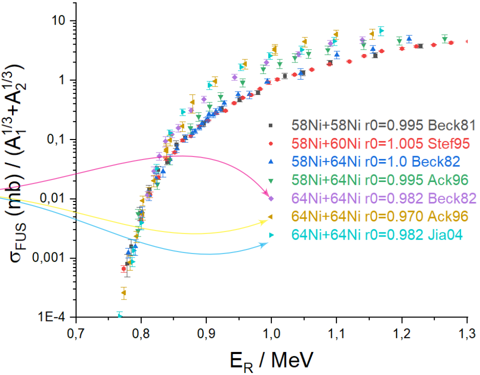
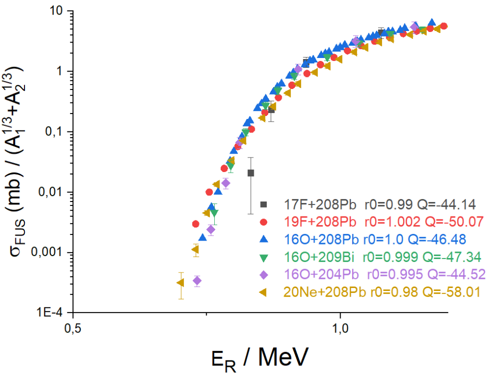


- Similar trend also for asymetrical systems.
- However, one data point correspondig to the $^{17}\mathrm{F} + {}^{208}\mathrm{Pb}$ clearly out of systematics
- Nevertheless, the variations of the r_0 seems to be small.



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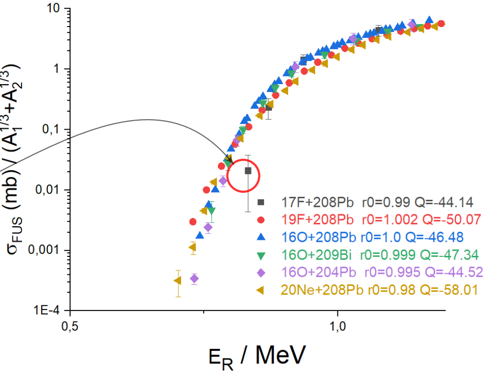

- Reduced energy scaling can be used for comparison of different fusion systems.
- Furthermore, data inconsistencies can be identified by use of this energy reduced scaling.
- "Quality" of data can be evaluated even with this relatively simple approach.