Probing the ^{17}F+p optical potential at near barrier energies in a microscopic approach

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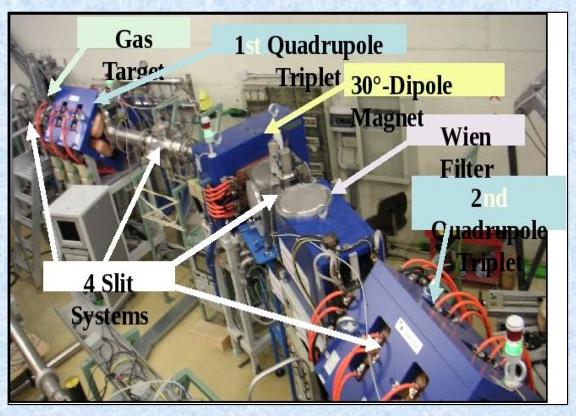
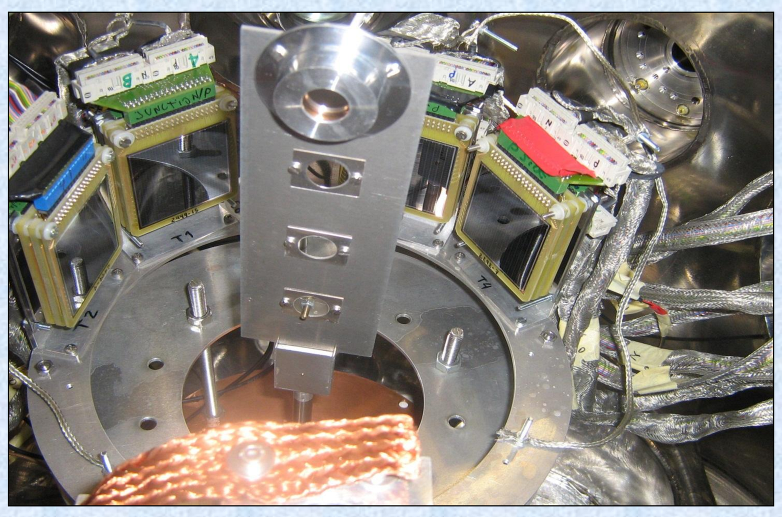
Abstract

Data of a recently measured proton elastic scattering angular distribution of ^{17}F+p, at 4.3 MeV/u, were analyzed in the JLM microscopic approach and the optical potential as well as the structure of this proton rich nucleus was probed. The data were collected over a wide angular range ($\Theta_{c.m.}=20^0$ -160^0) by means of the DINEX Si-detector array with an overall solid angle of ~0.8 sr. The ^{17}F radioactive beam was produced at the EXOTIC facility of LNL Italy by means of the in-flight technique and by using the reaction ^{1}H (^{17}O, ^{17}F) n. The solid angle and angular calibration of the DINEX-array were obtained via an additional run of ^{17}F+^{198}Au at the sub-coulomb energy. The normalization of the data was done according to the work of Harss et al. [PRC65,035803 (2002)].
The ^{17}F+p data have provided the plain ground to test the applicability of the JLM model to drip line nuclei with low mass (test the Local Density Approximation (LDA)) and at low energies. Further on the obtained total reaction cross sections have probed the proton skin structure of this nucleus.

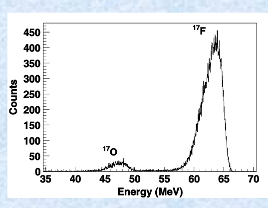
Experimental Details

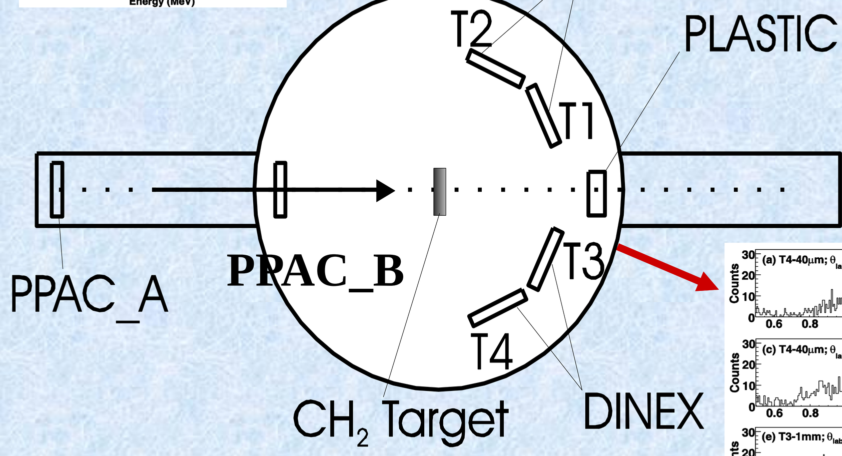
The ^{17}F beam was produced at the EXOTIC fasility at LNL-Italy by means of the in-flight technique and by using the reaction ^{1}H(^{17}O), ^{17}F)n. The primary beam was directed to a 5cm long gas-cell with pressure and temperature during the experiment such as to produce an effective thickness of 0.4mg/cm^2. The selection, separation and focusing of the secondary beam was achieved by a quadrupole triplet, a 30^0 bending magnet, a 1m-long Wien filter and a secondary quadrupole triplet.



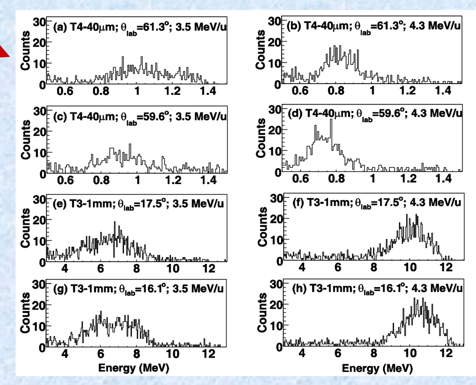


Beam spectrum





Proton spectra



Particle detection

DINEX:
4 triple DSSSD -PAD-DSSSD silicon telescopes at 10cm distance from the target

Angular coverage: Θ_{lab}= 10^0 -90^0 corresponding to $\Theta_{c.m.}$=20^0-160^0

BEAM monitoring
PPAC A and PPAC B and end channel Plastic detetector

Running conditions
Intensity of secondary beam 10^4-10^5 pps purity> 95%/ beamspot <10mm

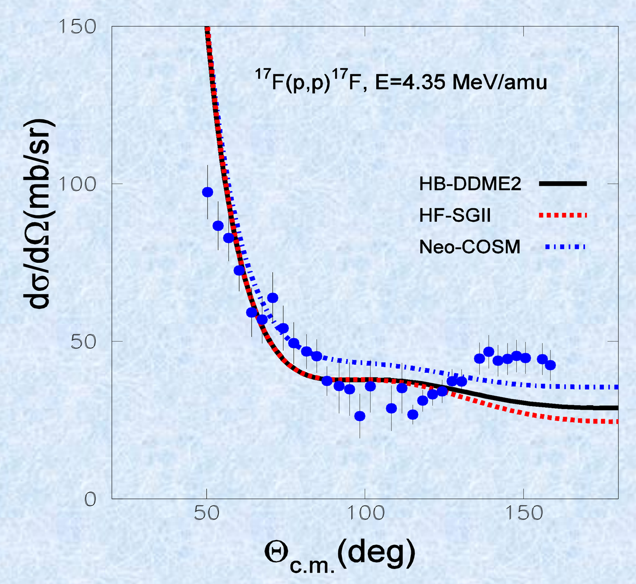
THEORETICAL MICROSCOPIC ANALYSIS – JLM POTENTIAL

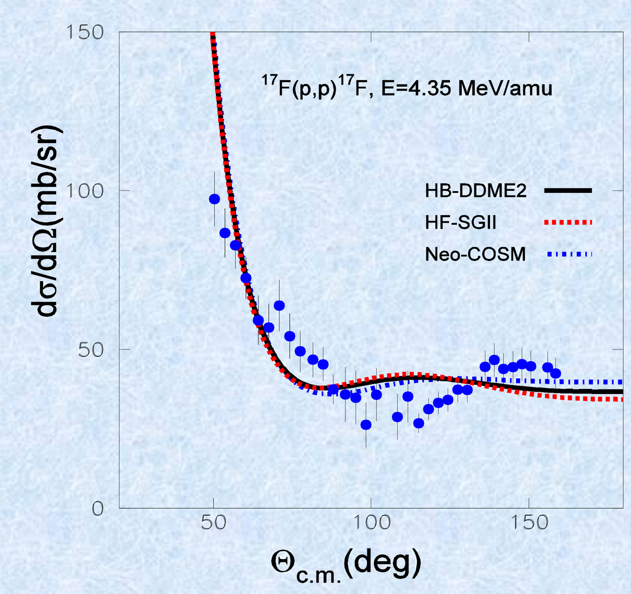
For the microscopic approach we adopted the JLM model in a DWBA approach, according to the code developed by F. S. Dietrich. The model was derived by Jeukenne, Lejeune and Mahaux and was extensively studied for stable nuclei describing elastic proton and neutron scattering from medium and heavy mass stable nuclei with slight adjustments mainly on the imaginary part of the central potential . The application of these calculations on light nuclei by F. S. Dietrich and within this work with ^{17}F, constitutes a severe test on the applicability of the local density approximation that is used to obtain optical potentials for finite nuclei from calculations performed to "infinite nuclear matter". Within this work the extension of the model to drip line nuclei is also justified.
Initially JLM elastic scattering calculations were performed in a standard normalization (λ_V=1.0 and λ_W =0.8). Proton and neutron density distributions were calculated according to three models. All these models indicate a proton skin for ^{17}F.

In one approach we considered a cluster model, the Neo-COSM model as developed by Masui, Kato and Ikeda (PRC73,034318(2004)), where resonant and bound states are considered in the same framework. The core dynamics are introduced via a core-size parameter. In a second approach, the Relativistic Hartree Bogoliubov model is considered. This model provides an excellent description of ground state and excited states in nuclei at and far away from stability in a unified description of mean field and pairing correlations. The Lagrangian parameter set DD-ME2 is used. This set has an explicit density dependence on both isoscalar and isovector channels and the finite range pairing force D1S of Gogny. In a third approach we have used the simpler non-relativistic Hartree-Fock model, using the parametrization SGII for the Skyrme interaction, within the filling approximation (we assume that the last proton fills by one sixth the $d_{5/2}$ shell).
Folding these densities with the JLM interaction (PRC16, 80(1977)) differential cross sections were calculated, remarkably close to the experimental values, while best fitted parameters did not deviate appreciably from the systematics.

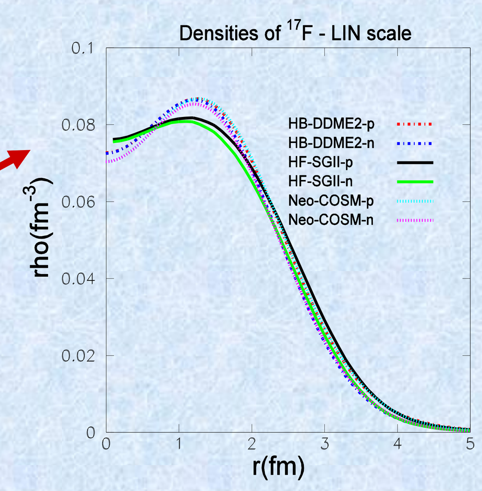
JLM-Standard λ_V=1.0 , λ_W =0.8

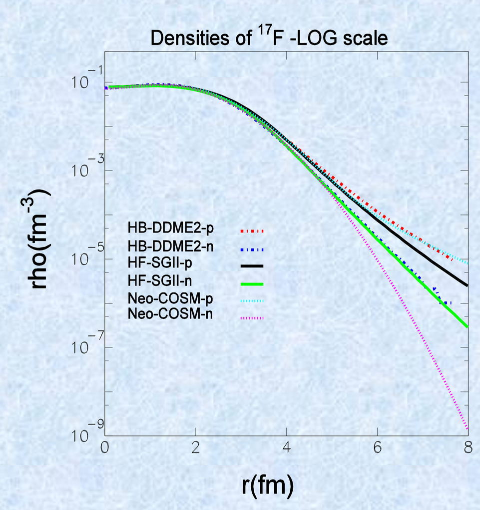
JLM-best
λ_V=0.99±0.02 , λ_w= 0.65±0.06 HB-ME2
λ_V=0.90±0.02 , λ_w= 0.66±0.06 HB-SGII
λ_V=0.93±0.08 , λ_W =0.86±0.08 Neo-COSM





Three density distributions displayed in linear and logarithmic scale.
No large differences are observed in the tail of the proton distribution

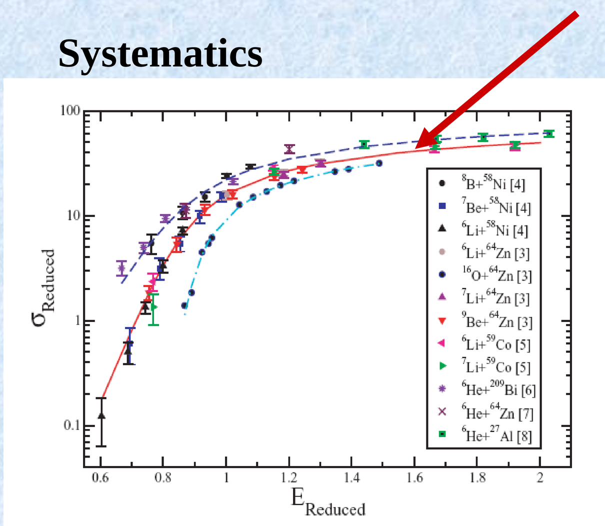




TOTAL REACTION CROSS SECTION

Systematics

present



KOLATA-ANGUILERA
PRC79,027603(2009)

σ_{WONG}=405mb

E=4.35 MeV/amu, σ=540±13 mb
measured

$E_{reduced}$ =1.6 MeV/amu , $\sigma_{reduced}$=42.3±1.0 mb

Concluding remarks

- The optical potential of light drip line nuclei at low energies (as low as 4MeV/amu) can well be described by the JLM microscopic approach as long as we are off resonances.
- Densities calculated in three different models, describing 17F as posessing a proton skin, when folded with the interaction of the JLM potential describe the experimental results very well. This is a good indication for the proton skin nature of the nucleus.
- Total reaction cross sections are larger than ones predicted for stable well bound nuclei but not as large as the ones for halo nuclei.