MICROSCOPIC DESCRIPTION OF NEUTRON-INDUCED FISSION WITH THE CONSTRAINED MOLECULAR DYNAMICS (CoMD) MODEL: RECENT PROGRESS

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ΑΘΗΝΩΝ

Outline

- Contemporary studies in nuclear fission
- Description of the theoretical model CoMD
- Theoretical results
- Summary and conclusions
- Future work plan

Contemporary studies in nuclear fission

Proton induced fission theoretical studies

- [1]N. Vonta, G.A. Souliotis et al, Phys. Rev. C92, 024616 (2015)
  - Study of the above reactions: p + ^{232}Th, ^{235}U, ^{238}U with Code CoMD and comparison with experimental data

- [2] **P. Demetriou et al Phys. Rev. C 82, 054606 (2010)**
  - experimental and theoretical study of the above reactions: p + ^{232}Th, ^{237}Np, ^{238}Pu and ^{239}Am
  - Comparison with Code Talys

CONTEMPORARY STUDIES IN NUCLEAR FISSION

- **Neutron induced fission and theoretical studies**
- [3] R. Yanez, W. Loveland et al, arXiv: 1605.09690v2 [nucl-ex] (2016)

➢ Total kinetic energy release in the fast neutron-induced fission of ^{235}U for En 2-100 MeV

- [4] **The n_TOF Collaboration (F. Belloni et al.): Eur. Phys. J. A (2011) 47:2**

  ➢ neutron induced fission cross-section of ^{235}U at the CERN n_Tof facility relative to ^{235}U between 0.5 and 20 MeV.

Description of the theoretical CoMD model

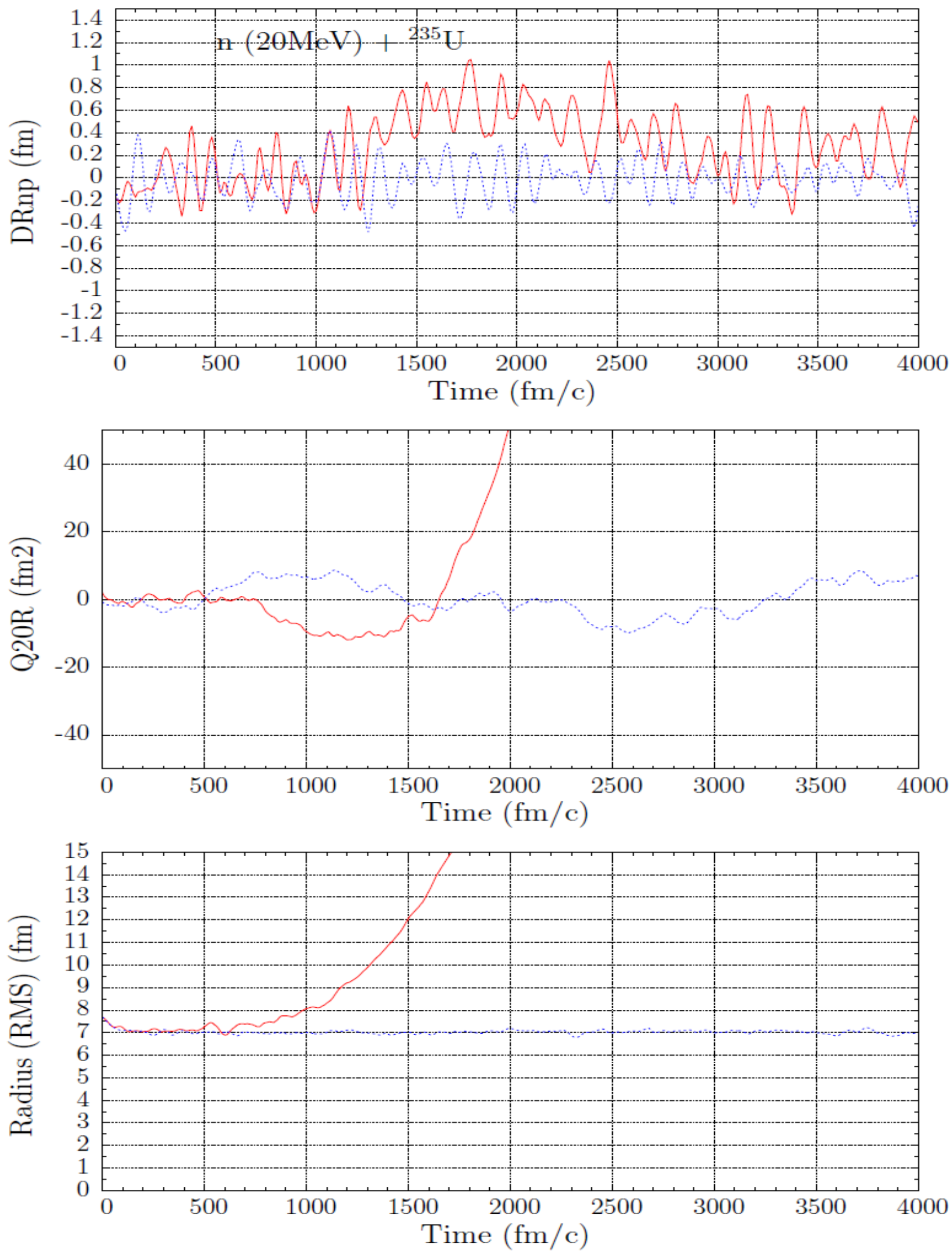
CoMD: Quantum Molecular Dynamics Model (Semiclassical)

- The nucleons considered as gaussian wavepackets
- Phenomenological interaction N-N (effective interaction): V_{eff}

$$V_{eff} = V_{vol} + V_{surf} + V_{Coul} + V_{sym}$$

- Symmetry potential N-N depending on the nuclear density
- $V_{sym} \propto \rho$ ("standard")
- $V_{sym} \propto \sqrt{\rho}$ ("soft")
- Application of Pauli Principle through appropriate restriction in the phase space
- Recognition of fragment formation ($R_{N-N} < 3.0$ fm)
- Simulation of successive events **(Monte Carlo approach)**
- Maximum time t=15000 fm/c
- Special choice of the surface term
- Correct configuration of the ground state (Cs=-2) → NO FISSION
- In order to get fission we set Cs=0

DEPENDENCES



Blue line: Cs= -2

Red line: Cs=0

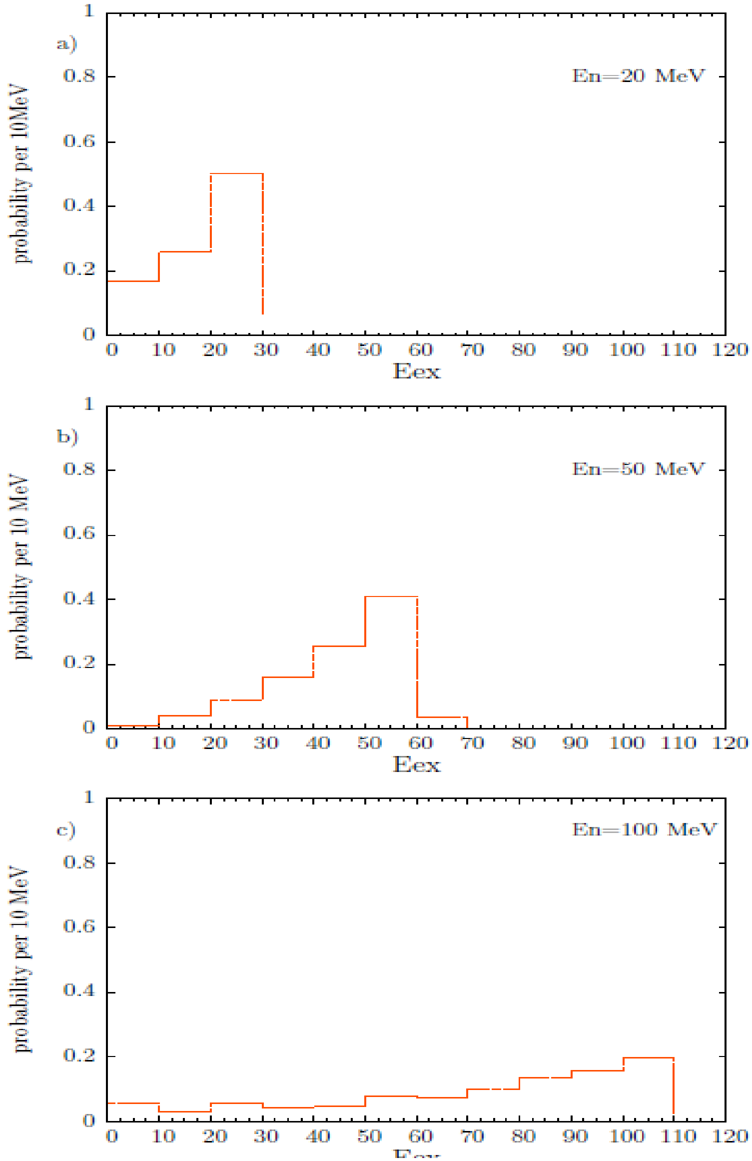
(a) $\Delta z \rightarrow$ GDR

(b) $Q_{20} \rightarrow$ GQR

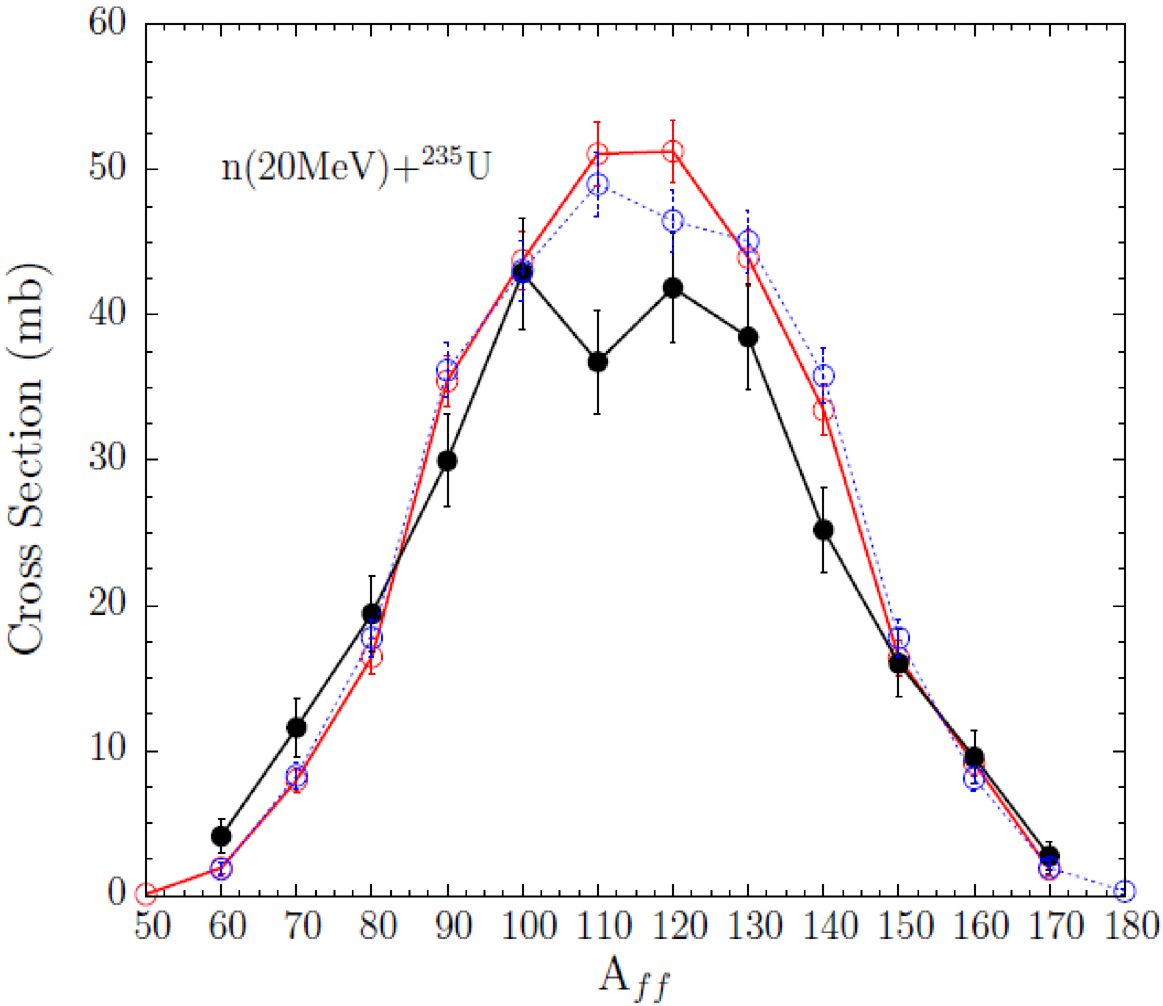
$$Q_{20} = 3z^2 - x^2 - y^2$$

(c) R $\rightarrow$ GMR

PRIMARY STAGE: EXCITATION ENERGY OF $^{236}U^*$



YIELD CURVE: N(20MEV) +^{235}U



*Method similar to N. Vonta, G.A. Souliotis et al, Phys. Rev. C92, 024616 (2015)

Red line: standard

V_{sym} ~ ρ, Cs=0 *

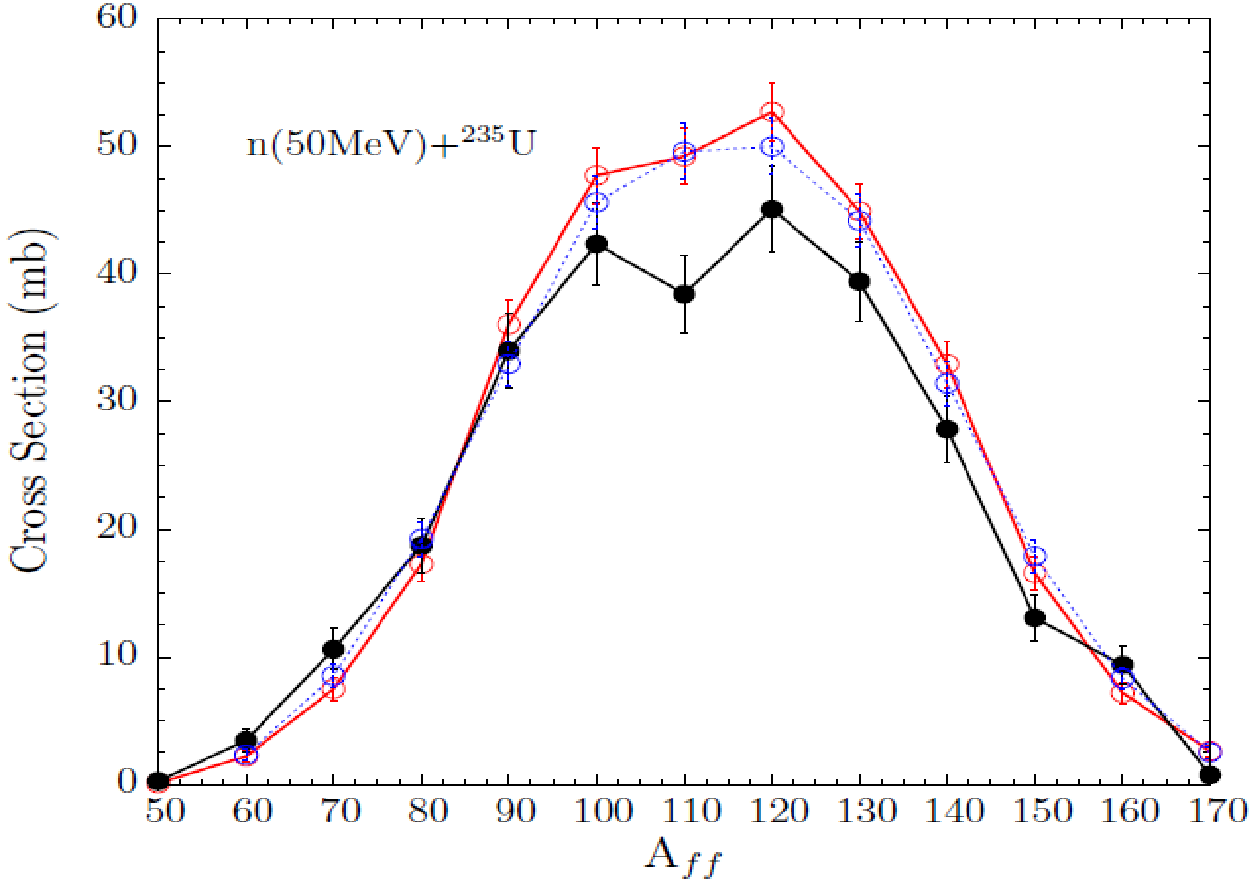
Blue line: soft V_{sym} ~ $\rho^{1/2}$, Cs=0*

NEW APPROACH

Black line: standard

Vsym ~ρ, Cs=f(t)

Yield curve: n(50MeV) +^{235}U

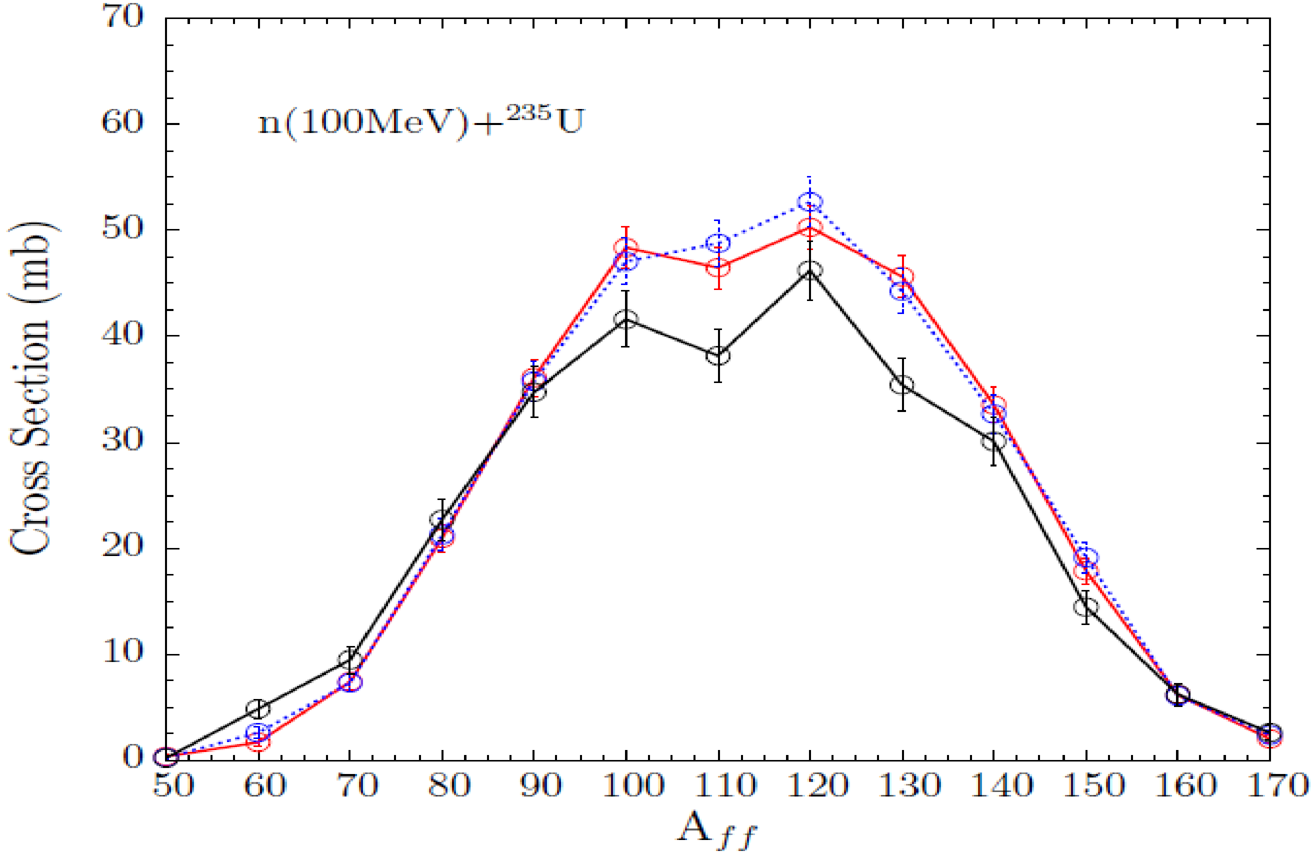


Red line: standard V_{sym} ~ ρ, Cs=0

Blue line: soft V_{sym} ~ $\rho^{1/2}$, Cs=0

Black line: standard Vsym ~ρ, Cs=f(t)

YIELD CURVE: N(100MEV) +^{235}U

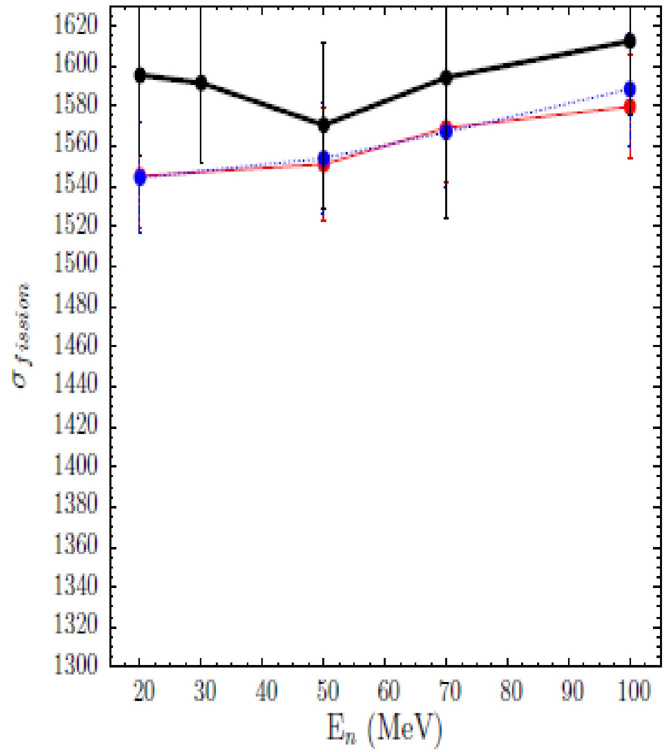


Red line: standard V_{sym} ~ ρ, Cs=0

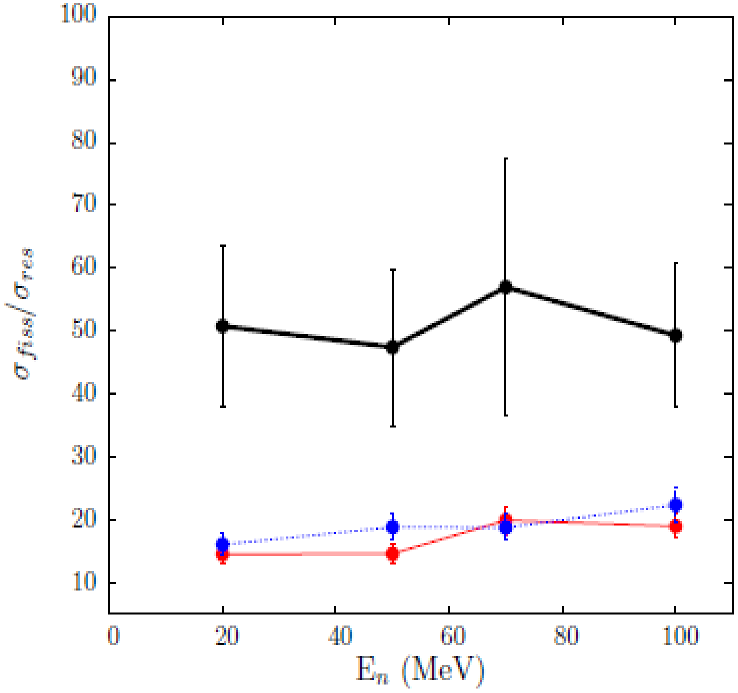
Blue line: soft V_{sym} ~ $\rho^{1/2}$, Cs=0

Black line: standard Vsym ~ρ, Cs=f(t)

Total fission cross section



Fission cross section/residue cross section

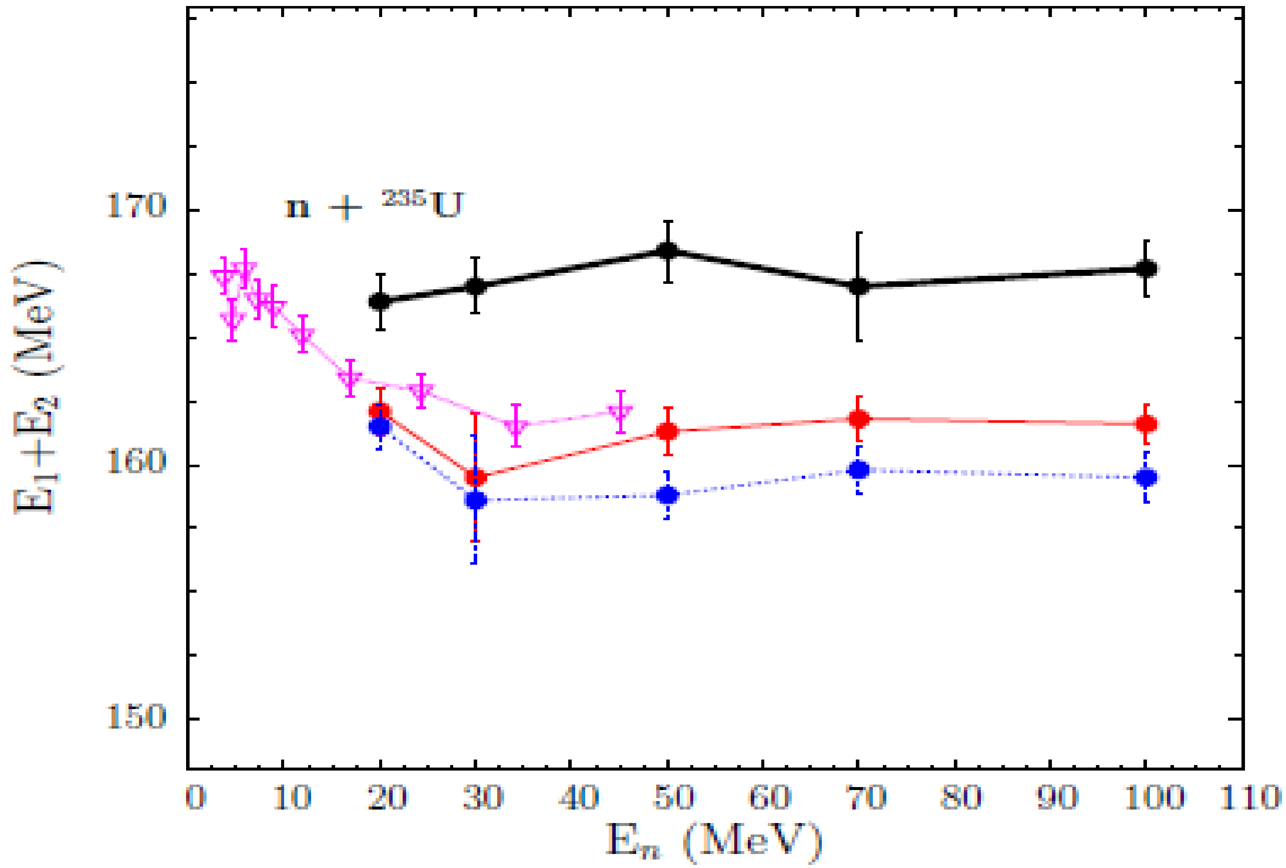


Red line: standard $V_{sym} \sim \rho$, Cs=0

Blue line: soft $V_{sym} \sim \rho^{1/2}$, Cs=0

Black line: standard Vsym ~ρ, Cs=f(t)

Total kinetic energy of the fission fragments



Red line: standard V_{sym} ~ ρ, Cs=0

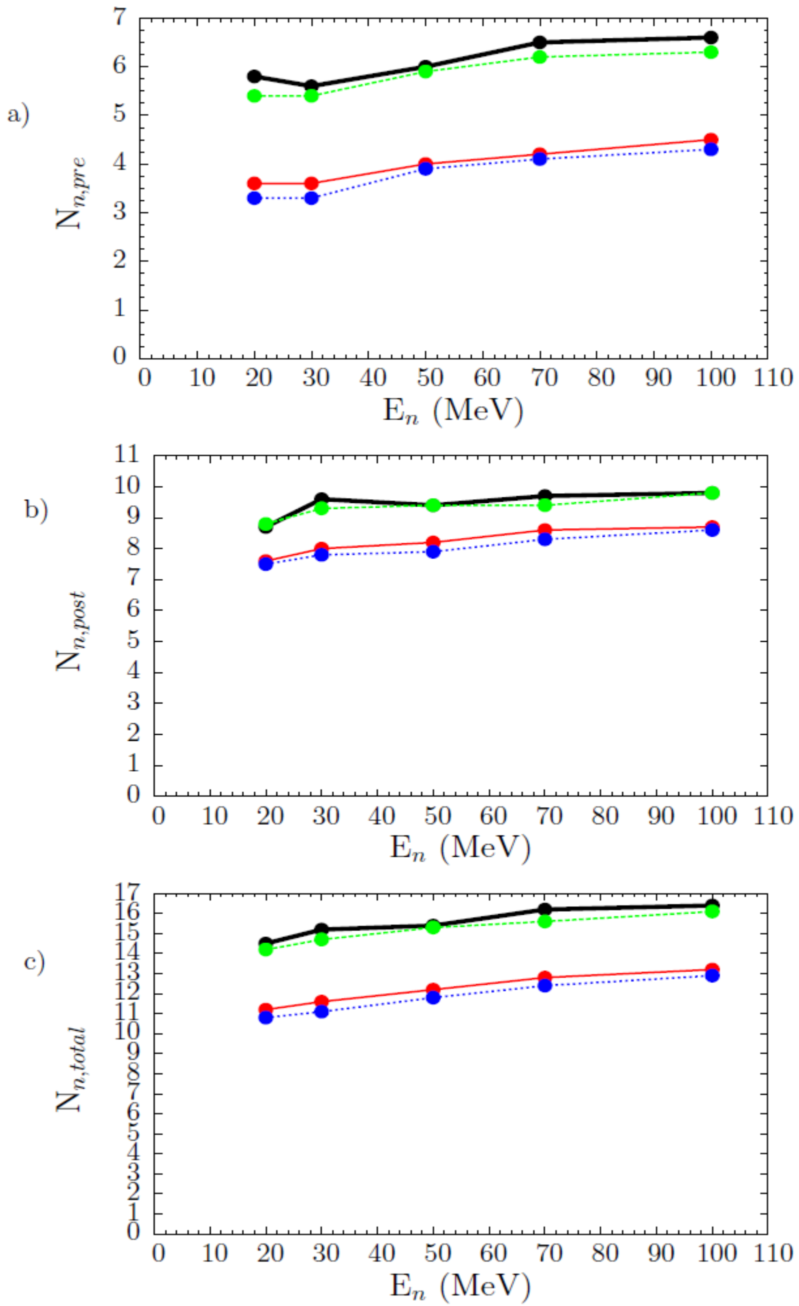
Blue line: soft V_{sym} ~ $\rho^{1/2}$, Cs=0

Black line: standard Vsym ~ρ, Cs=f(t)

Pink line: exprimental data

[3]R. Yanez, W. Loveland et al, arXiv: 1605.09690v2 [nucl-ex] (2016)

Neutron multiplicity



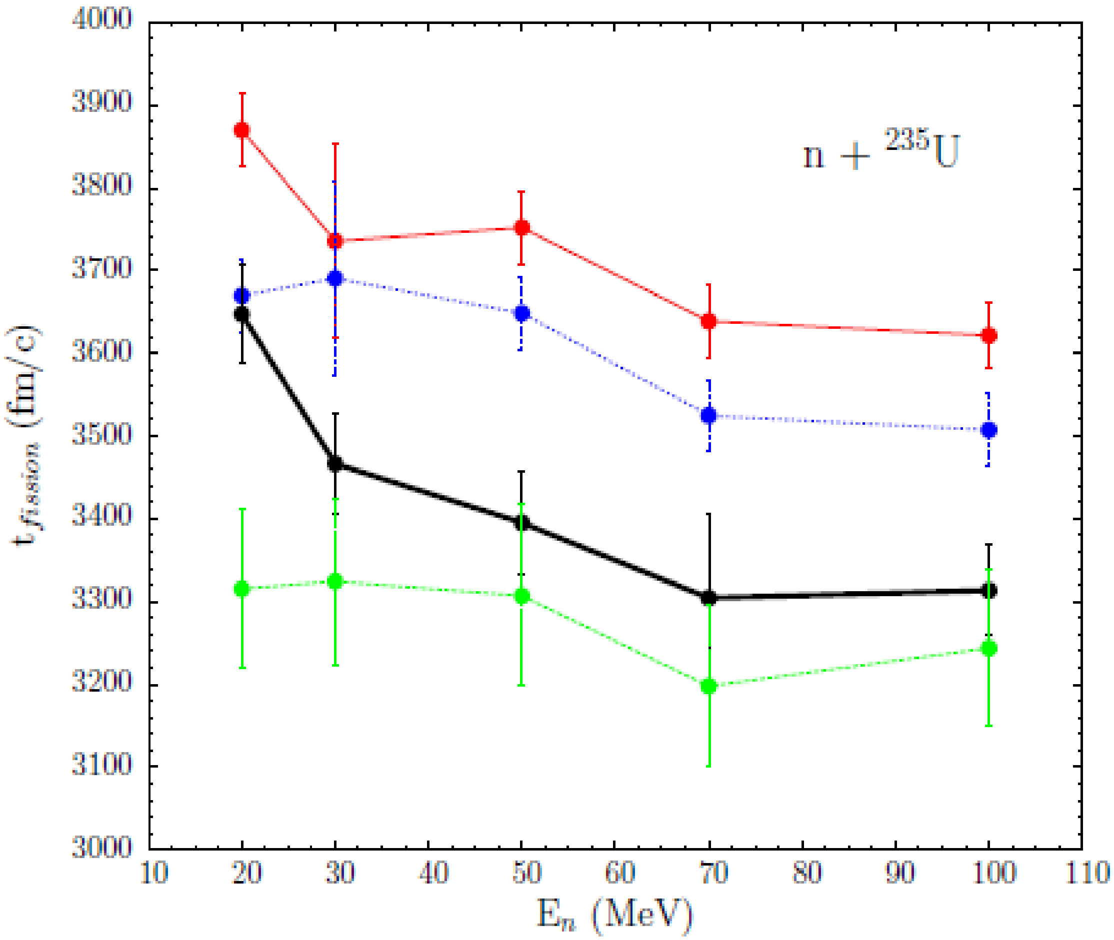
Red line: standard $V_{sym} \sim \rho$ (Cs=0)

Blue line: soft $V_{sym} \sim \rho^{1/2}$ (Cs=0)

Black line: standard $V_{sym} \sim \rho$ (Cs=f(t))

Green line: $V_{sym} \sim \rho^{1/2}$ (Cs=f(t))

Time of fission process



← Old approach

← New approach

Red line: standard V_{sym} ~ ρ, Cs=0
Blue line: soft V_{sym} ~ $ρ^{1/2}$, Cs=0
Black line: standard Vsym ~ρ, Cs=f(t)
Green line: V_{sym} ~ $ρ^{1/2,}$ Cs=f(t)

Summary and conclusions

- **Microscopic dynamical calculations of low energy fission induced by neutrons**
- **Careful treatment of the surface term and energy correction**
- **Our recent calculations point to asymmetric fission as known from experiment**
- **Collective dynamics of the fission process is described “adequately”**
- **Meaningful fission –time information**

FUTURE WORK PLAN

- **Systematic study of fission observables**
  - ✓ **mass yield curves**
  - ✓ **Energy distributions**
  - ✓ **Fission time scale**
  - ✓ **Pre-fission and post fission neutron emission**
- **Inclusion of the shell effects in the model** **(spin-orbit term in the potential)**
- **Possible experimental work in Catania with MAGNEX using ^{238}U on light targets (inverse kinematics)**

THANK YOU!