Microscopic Dynamic Description of Multinucleon Transfer in Peripheral Collisions of ^{40}Ar with ^{64}Ni, ^{58}Ni at 15 MeV/nucleon

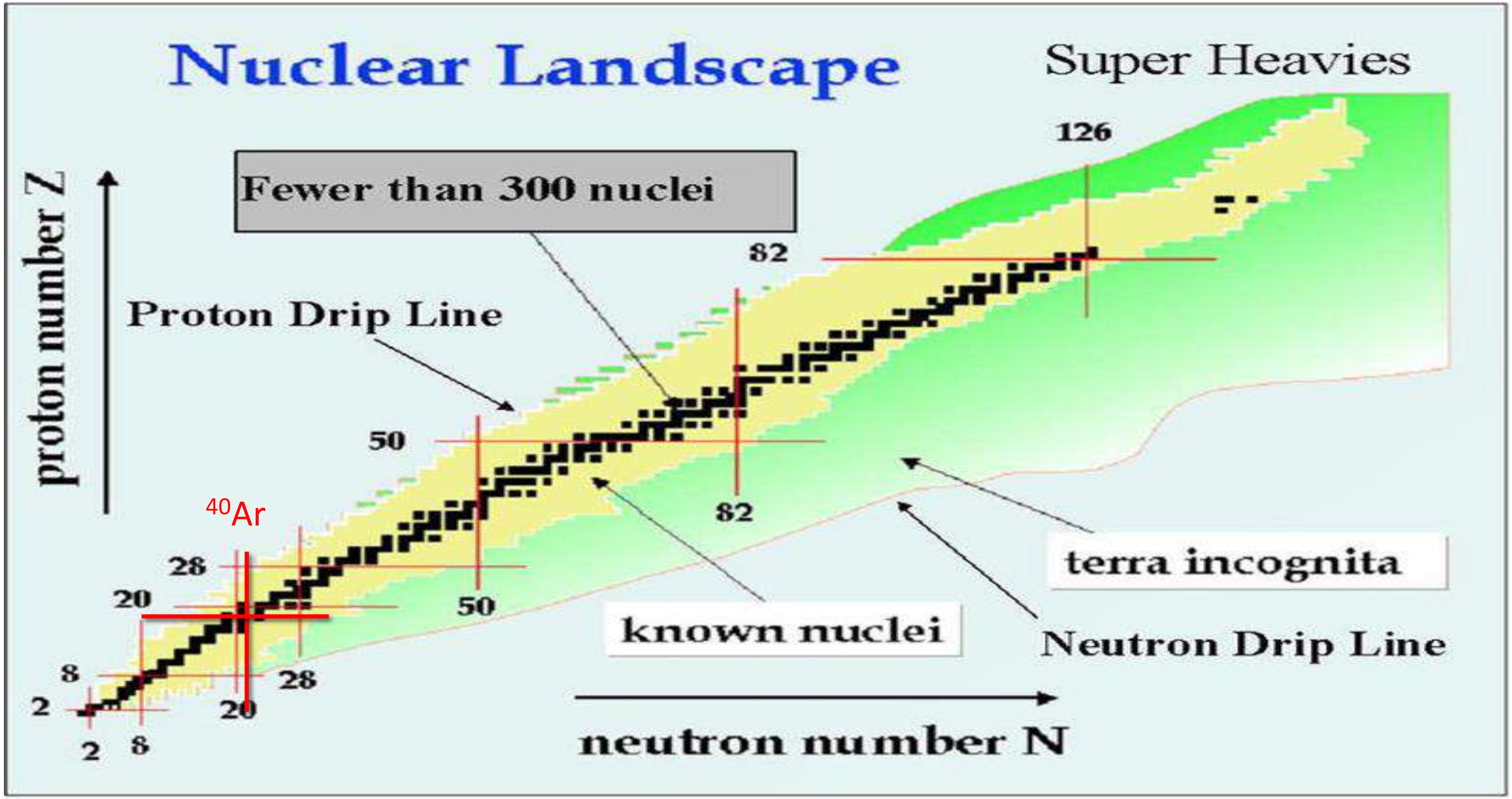
K. Palli [a] , G.A. Souliotis [a] , I. Dimitropoulos[a], T. Depastas [a] , O. Fasoula [a]
S. Koulouris [a] , M. Veselsky [b] , A. Bonasera [c,d]

a. Laboratory of Physical Chemistry, Department of Chemistry, National and Kapodistrian University of Athens, Athens, Greece
b. Institute of Physics, Slovak Academy of Sciences, Bratislava, Slovakia
c. Cyclotron Institute, Texas A&M University, College Station, Texas, USA
d. Laboratori Nazionali del Sud, INFN, Catania, Italy

Overview

- Chart of Nuclei
- Deep Inelastic Transfer Model
- Constraint Molecular Dynamics Model
- De-excitation Process
- Experimental Data
- Calculations and Comparisons
- Summary and Conclusions

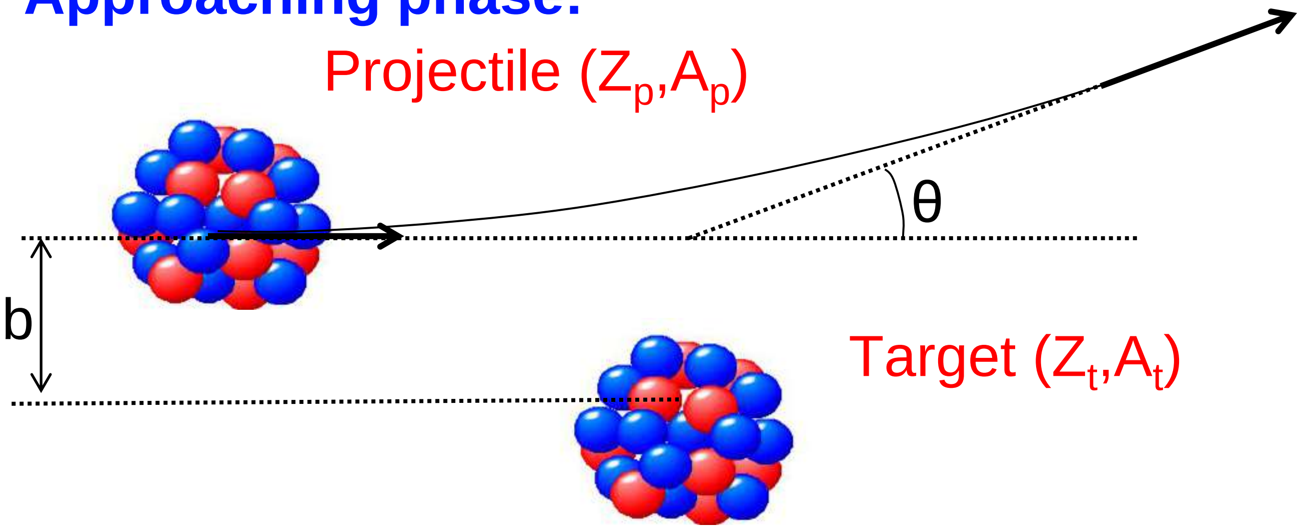
Chart of Nuclei



- 288 stable
- ~ 3300 short-lived (radioactive) nuclei synthesized to date
- large region of neutron-rich nuclei is still unexplored (~4000 nuclei)

Deep Inelastic Transfer, Peripheral Collisions

Approaching phase:



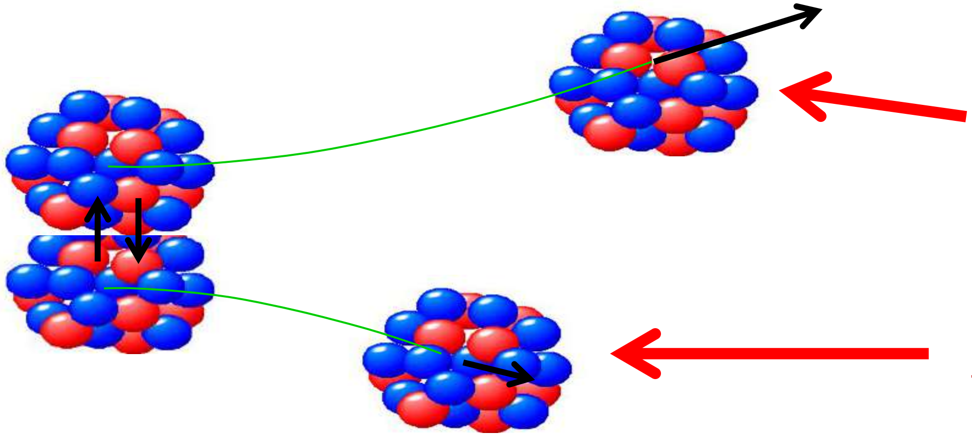
Neutrons
Protons

b: impact parameter
θ: scattering angle

Overlapping (interaction) stage

Exchange of nucleons:

Deep Inelastic Transfer (DIT) Model
L. Tassan-Got and C. Stephan, Nucl. Phys. A 524, 121 (1991)



excited projectile-like fragment (PLF) or quasi-projectile

excited target-like fragment (TLF) or quasi-target

Deep Inelastic Transfer Model (DIT)

DIT : Phenomenological model (Monte Carlo implementation)

- Formation of a di-nuclear configuration
- Exchange of nucleons through a “window” formed by the superimposition of the nuclear potentials in the neck region
- Dissipation of Kinetic energy into internal degrees of freedom

DIT : L. Tassan-Got, C. Stephan, Nucl. Phys. A 524, 121 (1991)
DIT(modified): M. Veselsky, G.A. Souliotis, Nucl. Phys. A 765, 252 (2006)

Constrained Molecular Dynamics Model (CoMD)

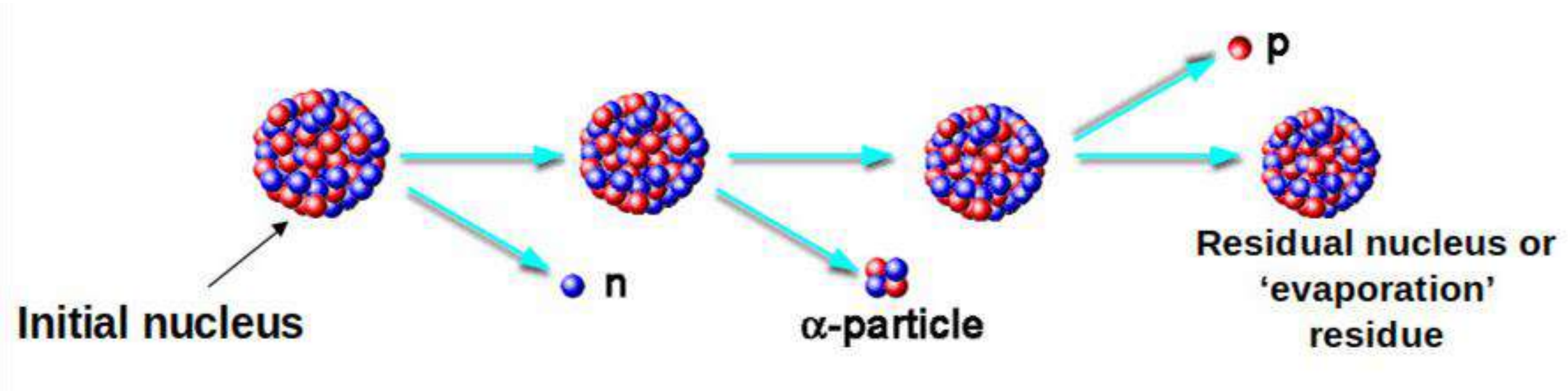
CoMD: Quantum Molecular Dynamics model (Semiclassical)

- Nucleons are considered as Gaussian wavepackets
- **N-N effective interaction** (Skyrme-type with K=200 MeV/fm^3)
- Several forms of **N-N symmetry potential V_{sym} (ρ)**
- **Pauli principle** imposed via a phase-space constraint
- **Fragment recognition algorithm** (R_{min} = 3.0 fm)
- **Monte Carlo** implementation. Description of the dynamical stage t = 0-600 fm/c

*M. Papa, A. Bonasera et al., Phys. Rev. C 64, 024612 (2001)

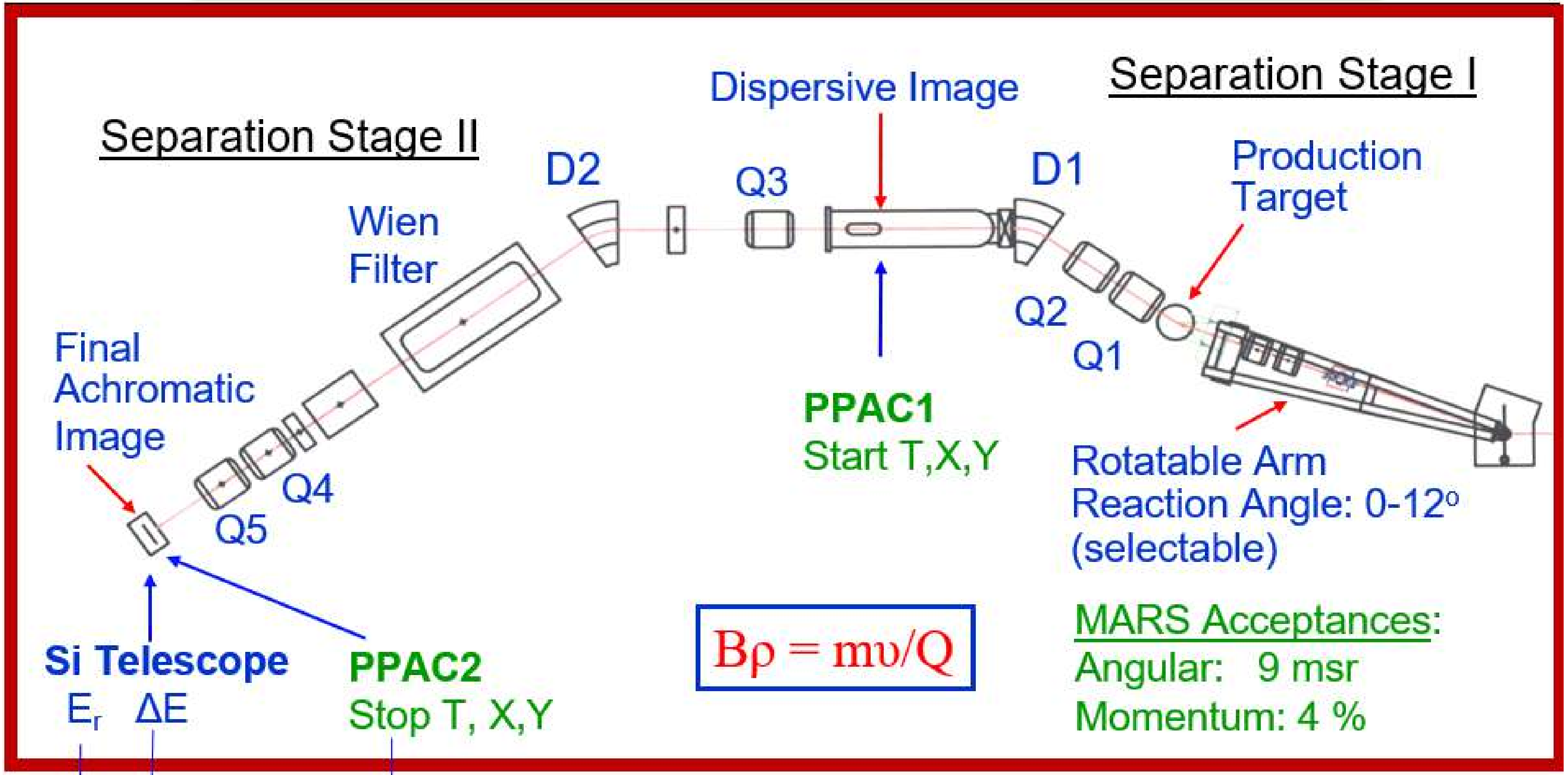
De-excitation Mechanism : Sequential Evaporation

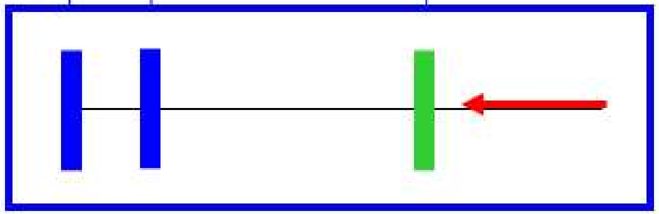
- GEMINI: Code used for deexcitation process.
- E*/A < 2 MeV
- T < 4 MeV



R. Charity et al., Nucl. Phys. A 483, 371 (1988)

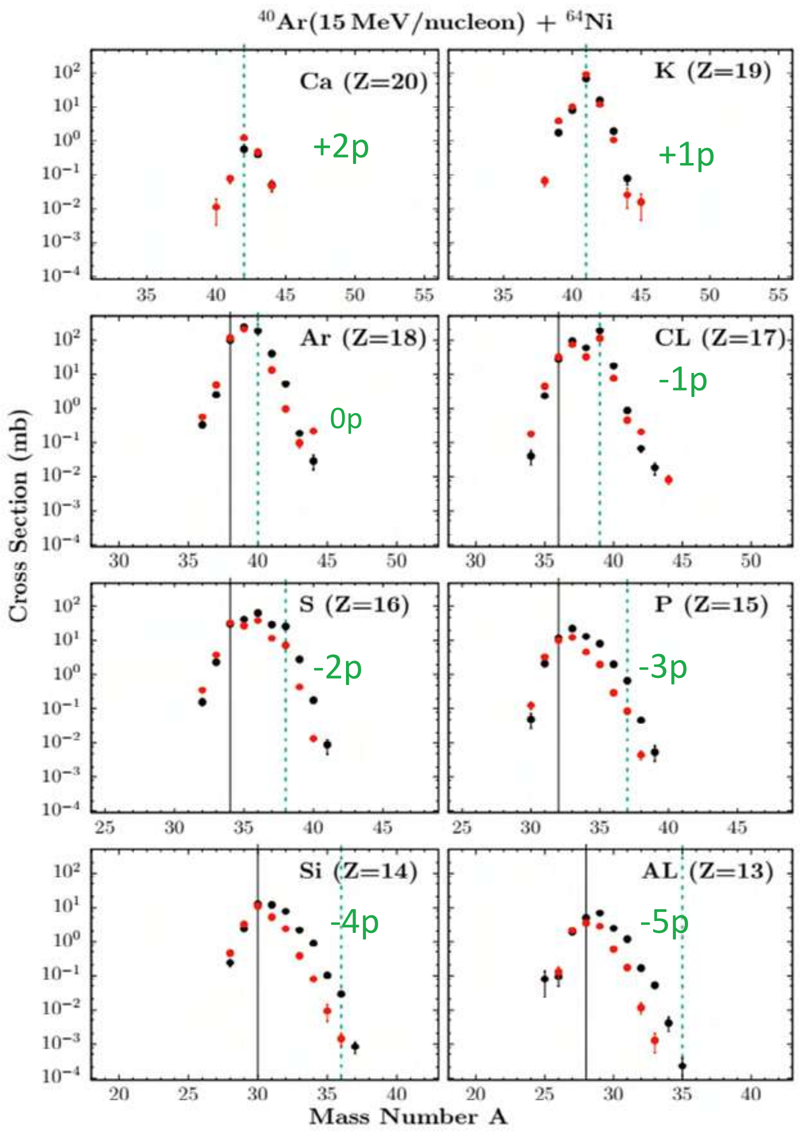
MARS Spectrometer





*G. A. Souliotis et al.,
Nucl. Instr. Methods B, 266, 4692 (2008)
and references therein

Experimental Data : Mass Distributions

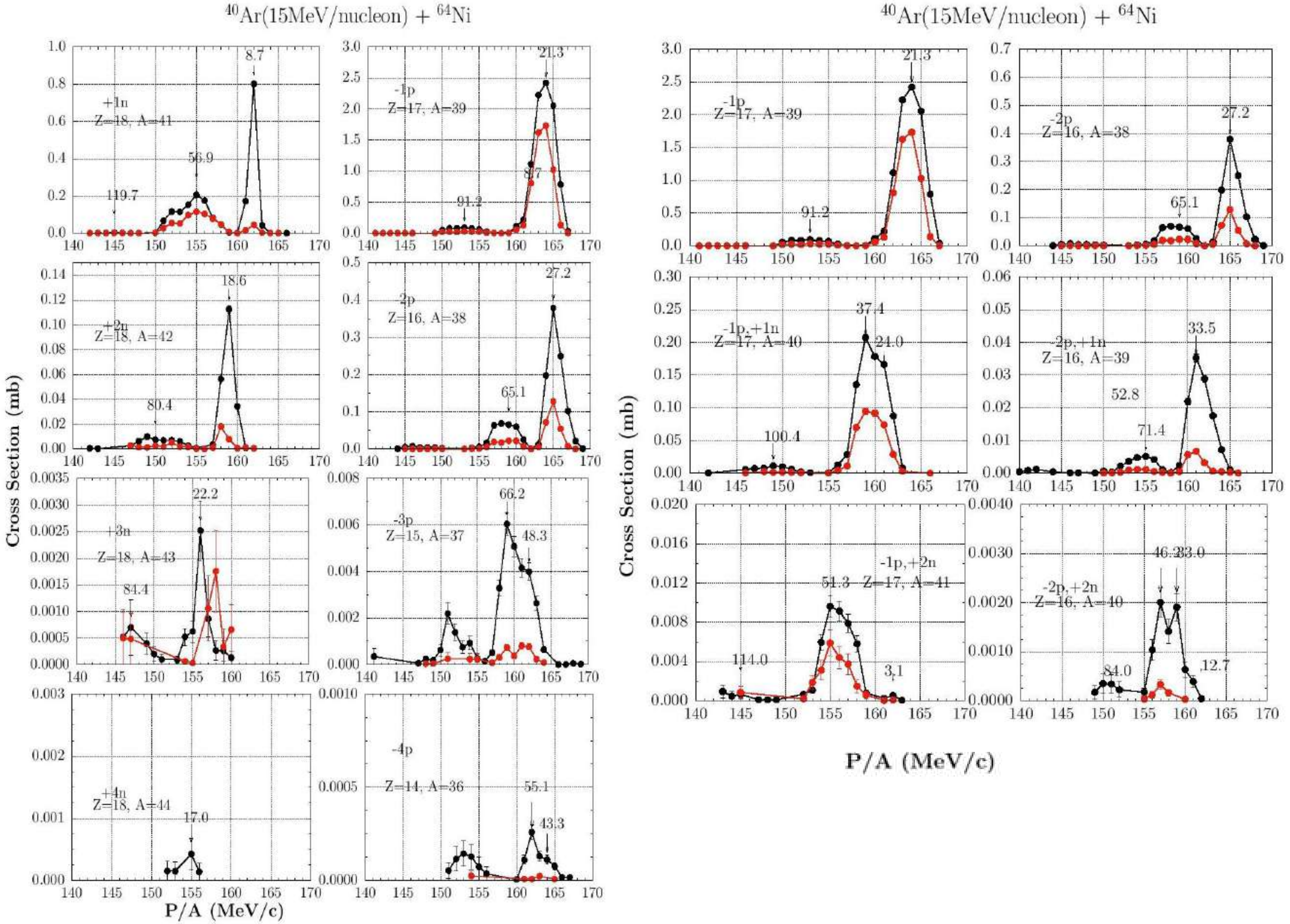


- ^{40}Ar + ^{64}Ni
- ^{40}Ar + ^{58}Ni

- The experimental data were obtained by the MARS Spectrometer at the Cyclotron Institute of Texas A&M University

*A. Papageorgiou, G. Souliotis et al., J. Phys. G: Nucl. Part. Phys. 45 095105 (2018)

Experimental Data : Momentum Distributions

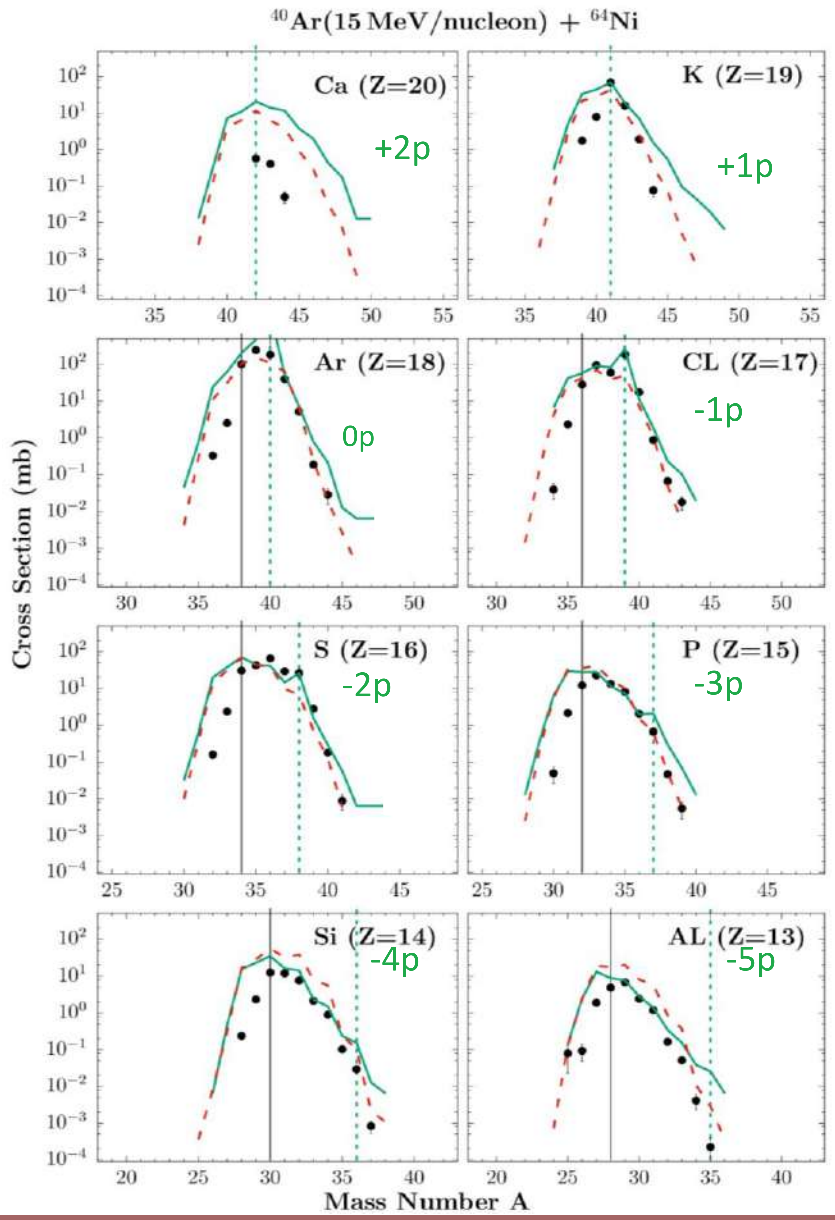


● ^{40}Ar + ^{64}Ni

● ^{40}Ar + ^{58}Ni

- The experimental data were obtained by the MARS Spectrometer at the Cyclotron Institute of Texas A&M University
- Resolution: 0.3%

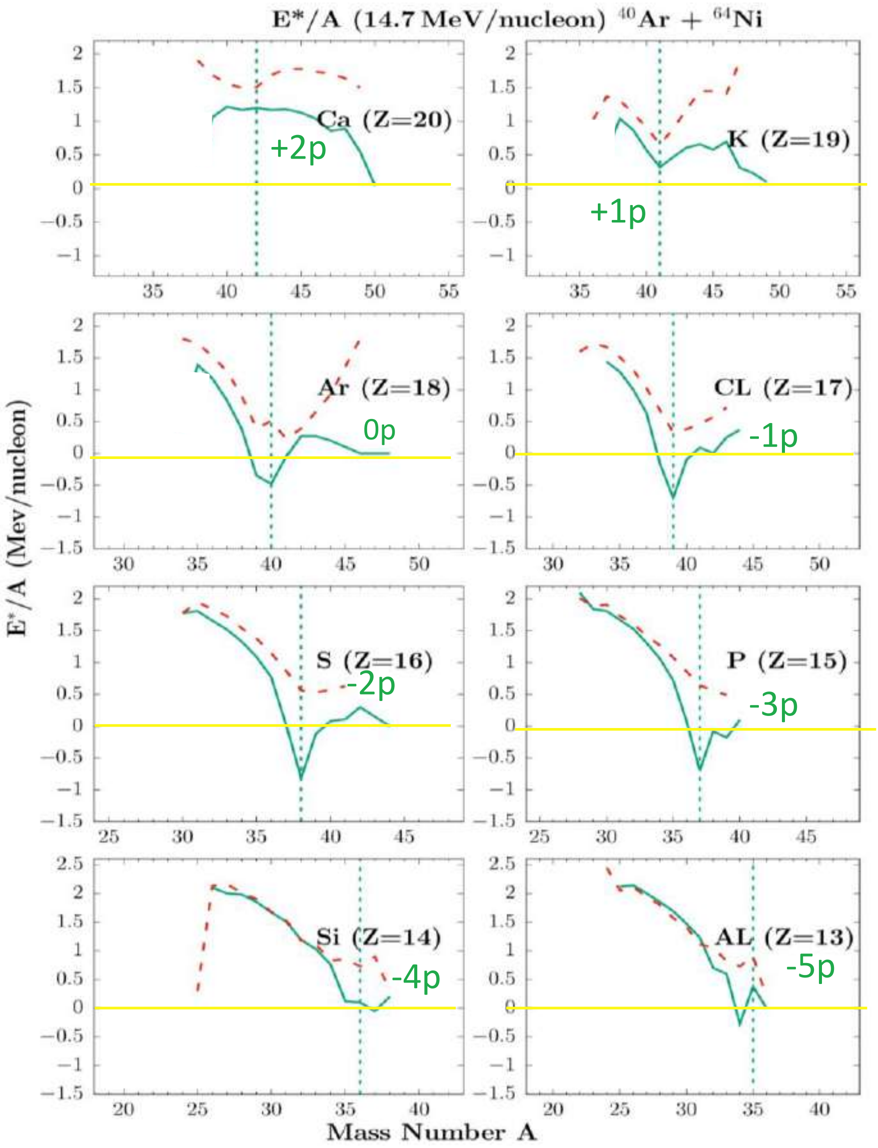
Comparison of best calculations DIT vs CoMD
Mass Distributions



● Experimental Data

- Red dashed line: DIT (0.75E*)
- Green full line: CoMD paulm=87

Comparison of best calculations DIT vs CoMD Excitation Energy Distributions



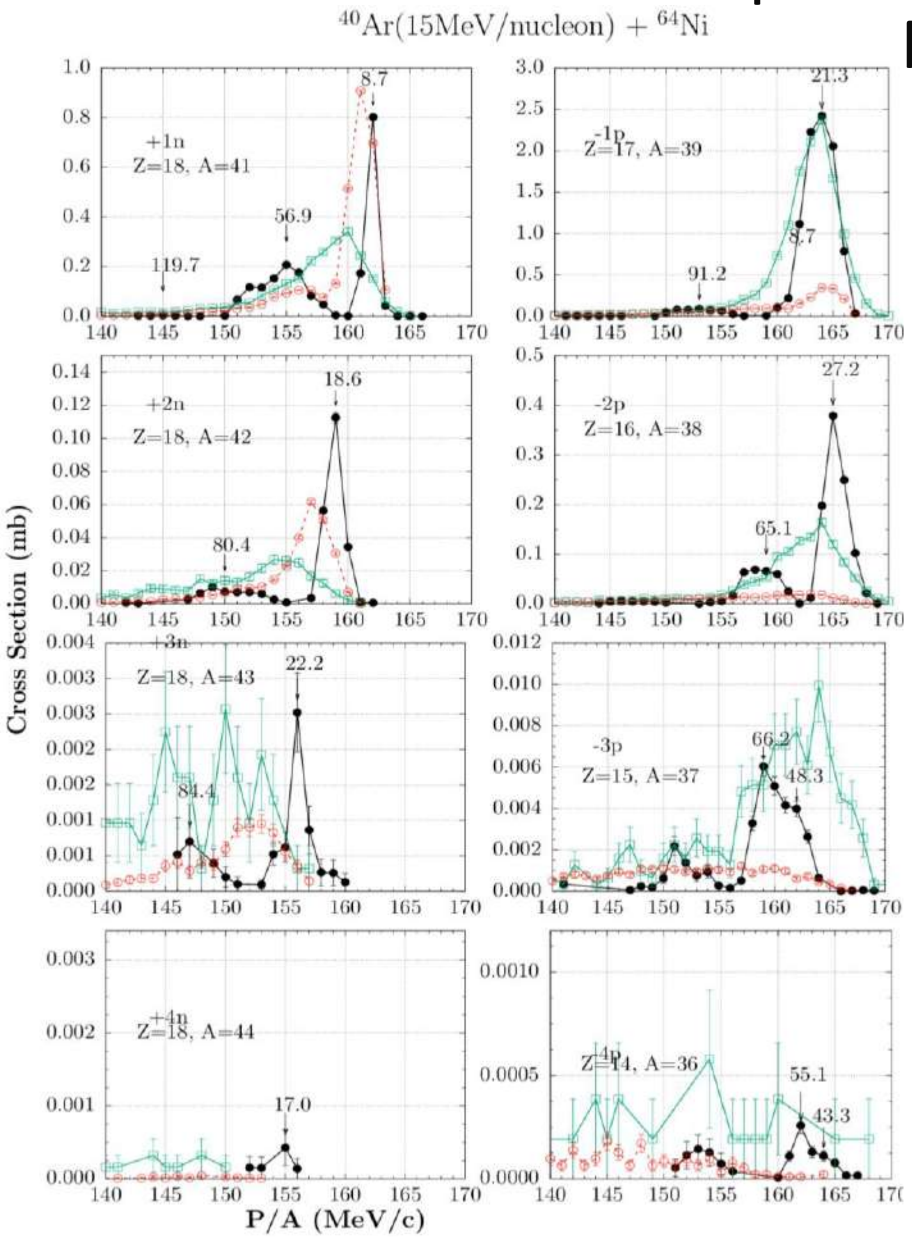
Comparison of DIT vs CoMD calculations.

- Red dashed line: DIT (0.75E*)
- Green full line: CoMD paulm=87

$$E^*_{tot} = Q_{gg} - Q_r$$

$$E^*_{qp} = \frac{E^*_{tot}}{2}$$

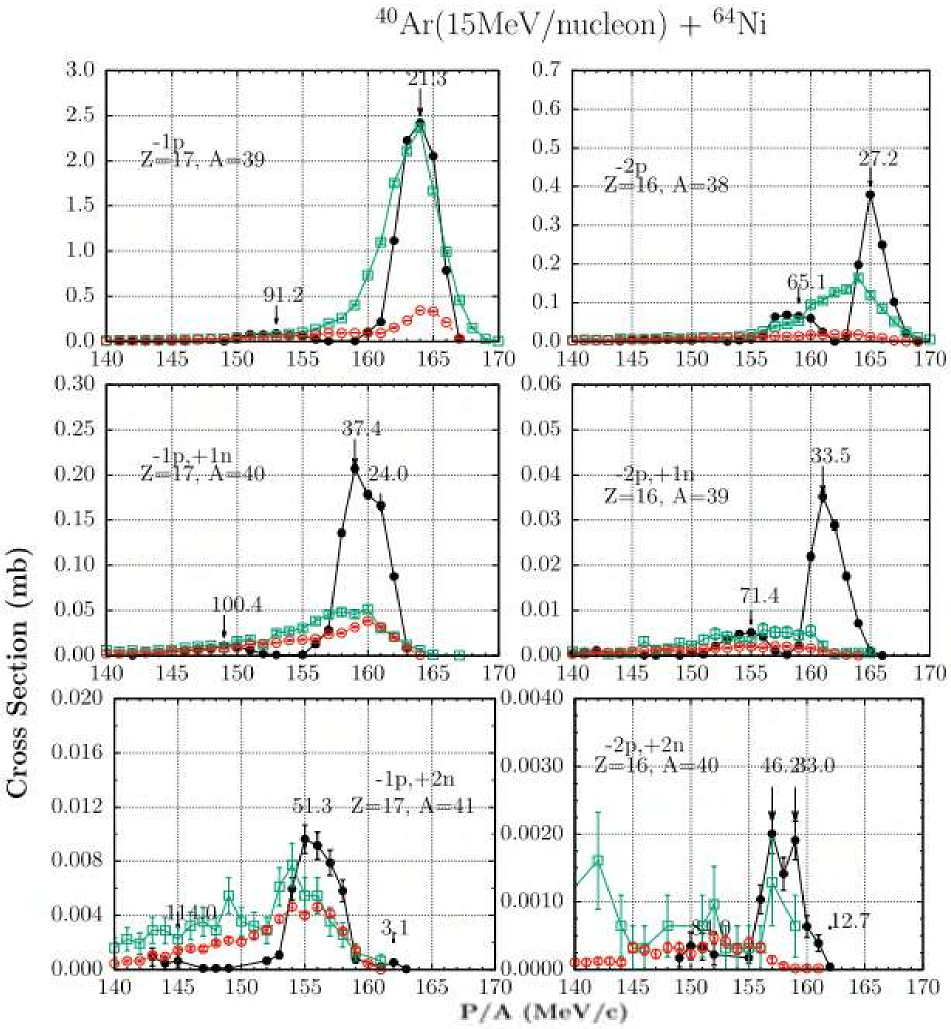
Comparison of best calculations DIT vs CoMD Momentum Distributions



● Experimental Data

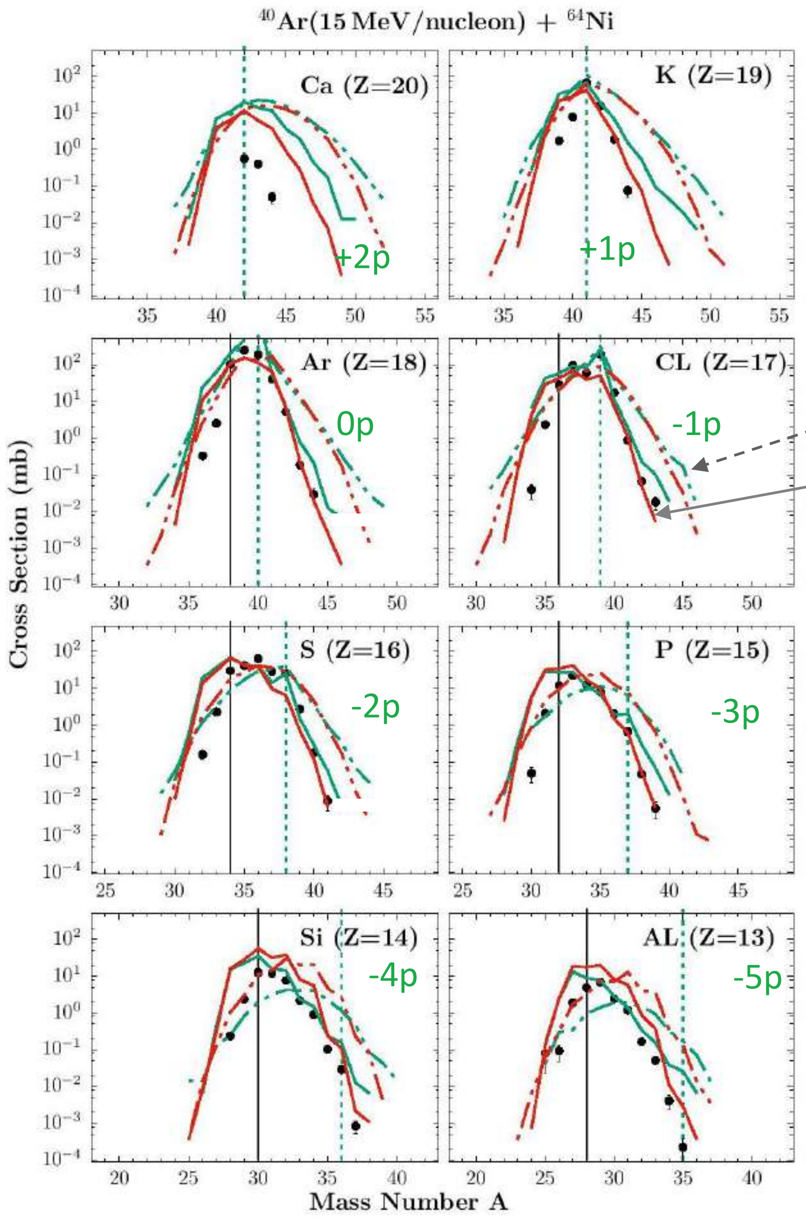
- Red dashed line: DIT (0.75E*)
- Green full line: CoMD paulm=87

Comparison of best calculations DIT vs CoMD Momentum Distributions



- ● Experimental Data
- Red dashed line: DIT (0.75E*)
- Green full line: CoMD paulm=87

Comparison of best calculations DIT vs CoMD
Mass Distributions



● Experimental Data

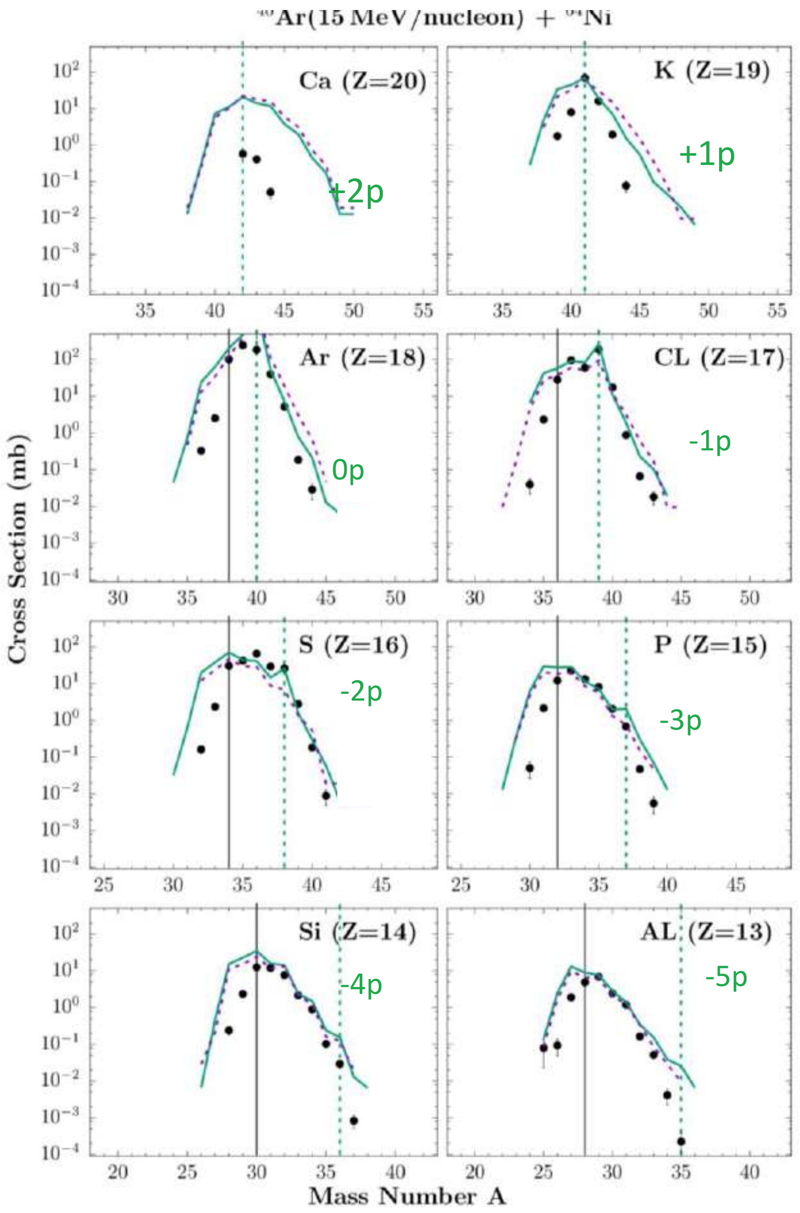
Dashed lines: primary products

Full lines: secondary products

Red: DIT (0.75E*)

Green: CoMD paulm=87

Pauli Constraint Effect on CoMD Calculations
Mass Distributions



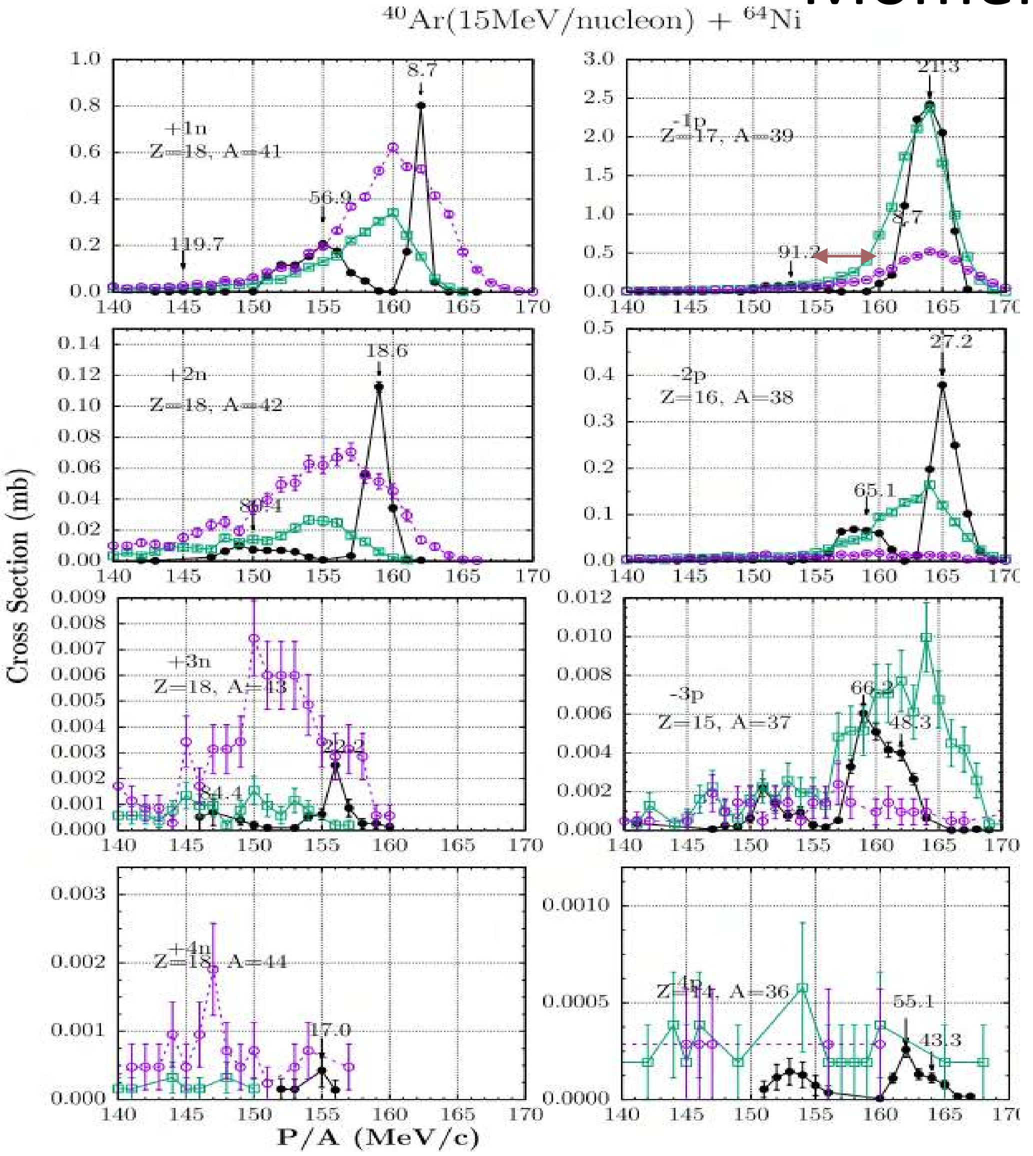
- Experimental Data

Adjusting the Pauli constraint

- Purple dashed line: paulm=96
- Green full line: paulm=87

By lowering the value of the parameter paulm, we enforce the Pauli constraint.

Pauli Constraint Effect on CoMD Calculations Momentum Distributions



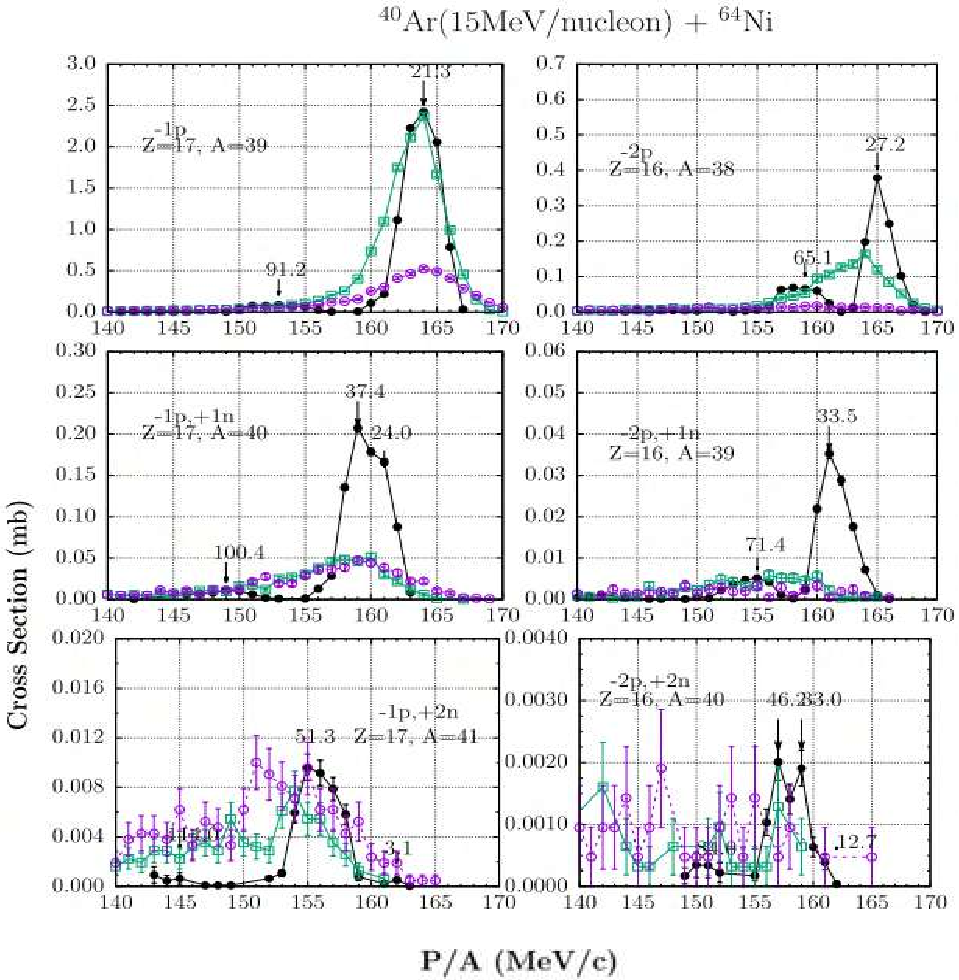
- Experimental Data

Adjusting the Pauli constraint

- Purple dashed line: paulm=96
- Green full line: paulm=87

- By lowering the value of the parameter paulm, we enforce the Pauli constraint.
- Δ(P/A)=5 MeV/c → 3% of the momentum

Pauli Constraint Effect on CoMD Calculations
Momentum Distributions



- Experimental Data

Adjusting the Pauli constraint

- Purple dashed line: paulm=96
- Green full line: paulm=87

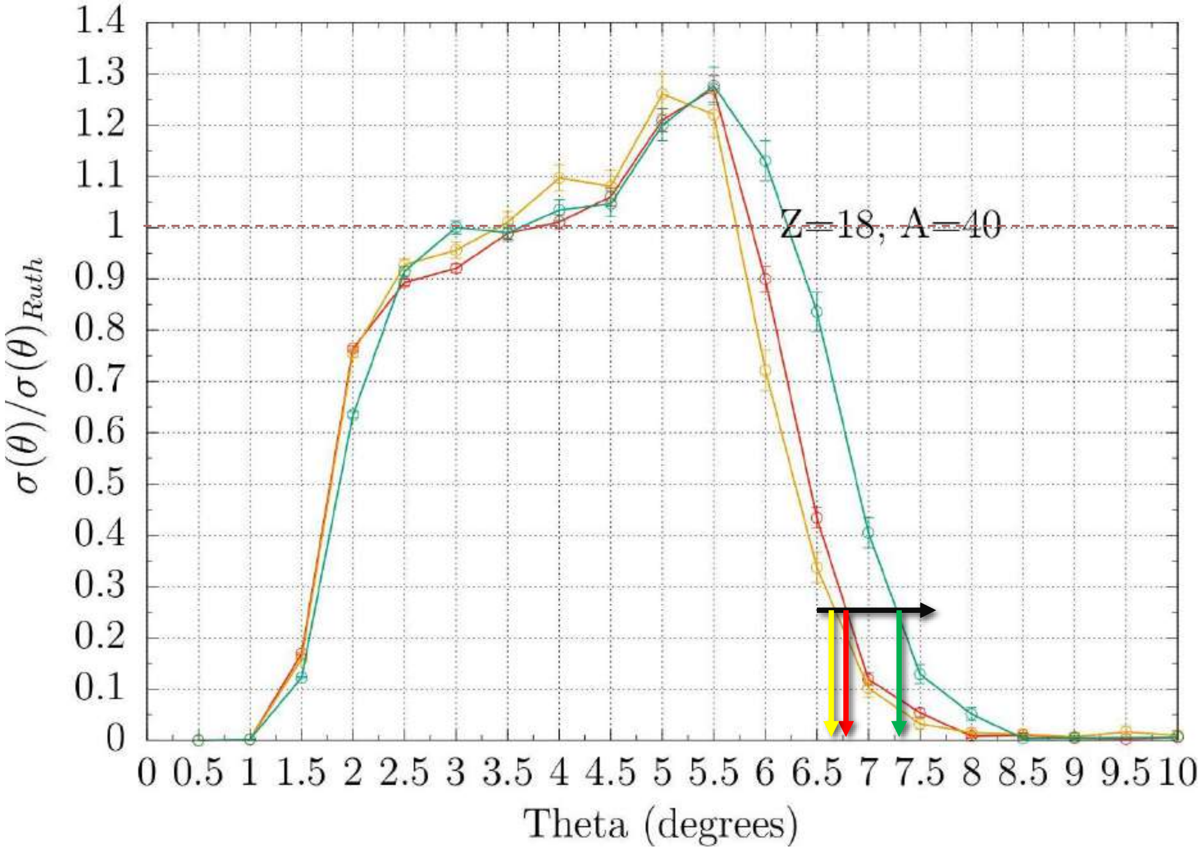
By lowering the value of the parameter paulm, we enforce the Pauli constraint.

CoMD Calculations: Angular Distributions

Angular Distribution Ratio: $(d\sigma/d\Omega) / (d\sigma/d\Omega)_{Ruth}$ scaled at 1.

Effect of the compressibility on the calculation.

All calculations are performed with paulm=87



Elastic Channel: Z=18, A=40

Yellow: K=200 / $\theta_{1/4} \approx 6.6^o$
Red: K=254 $\theta_{1/4} \approx 6.8^o$
Green: K=308 $\theta_{1/4} \approx 7.3^o$

- Bigger value for compressibility→ larger $\theta_{1/4}$
- b range: 0-40 fm.
- Empirical value of $\theta_{1/4} \approx 7.2^o$

W. W. Wilcke et. al., At. Data Nucl. Data Table, 25, 5-6, (1980).

Summary and Conclusions

- Investigation of the production mechanism for the peripheral reaction 40Ar + 64Ni at 15 MeV/nucleon: production of neutron-rich nuclides.
- We studied the experimental mass distributions and the recently extracted momentum distributions with the theoretical models: phenomenological model DIT, microscopical model CoMD.
- Detailed investigations of the parameters of the effective interaction in comd. Special attention to the Pauli constraint.

<u>Future Goals:</u>

- Under investigation, within the CoMD framework: compressibility K, symmetry energy, in-medium nucleon-nucleon scattering cross sections.
- Perform DWBA-type calculations with the FRESCO code in order to accurately describe the momentum distributions of the quasi-elastic products of one and two nucleon transfer processes.
- Aiming at the developing a theoretical framework for dependable predictions of the production of neutron-rich nuclei. Possibility to describe the production of extreme neutron rich isotopes (e.g. pick-up of 8-10 neutrons).
- Systematic study of optimum reactions in the Fermi energy region (10-30 MeV/nucleon) to move toward the neutron drip line.

Thank You !!!