Angular Distribution studies of Neutron-Rich Projectile-like Fragments from ^{86}Kr -induced peripheral collisions at 15 MeV/nucleon

O.Fasoula[1], G.A. Souliotis[1], Y.K. Kwon[2], K. Tshoo[2], A. Bonasera[3,4] , M. Veselsky[5]

[1]Laboratory of Physical Chemistry, Department of Chemistry, National and Kapodistrian University of Athens

[2]The Rare Isotope Science Project (RISP), Institute for Basic Science, Daejeon 305-811, Korea

[3]Cyclotron Institute, Texas A&M University, College Station, Texas 77843, USA

[4]Laboratori Nazionali del Sud, INFN, via Santa Sofia 62, I-95123 Catania, Italy

[5]Institute of Physics, Slovak Academy of Sciences, Bratislava, Slovakia

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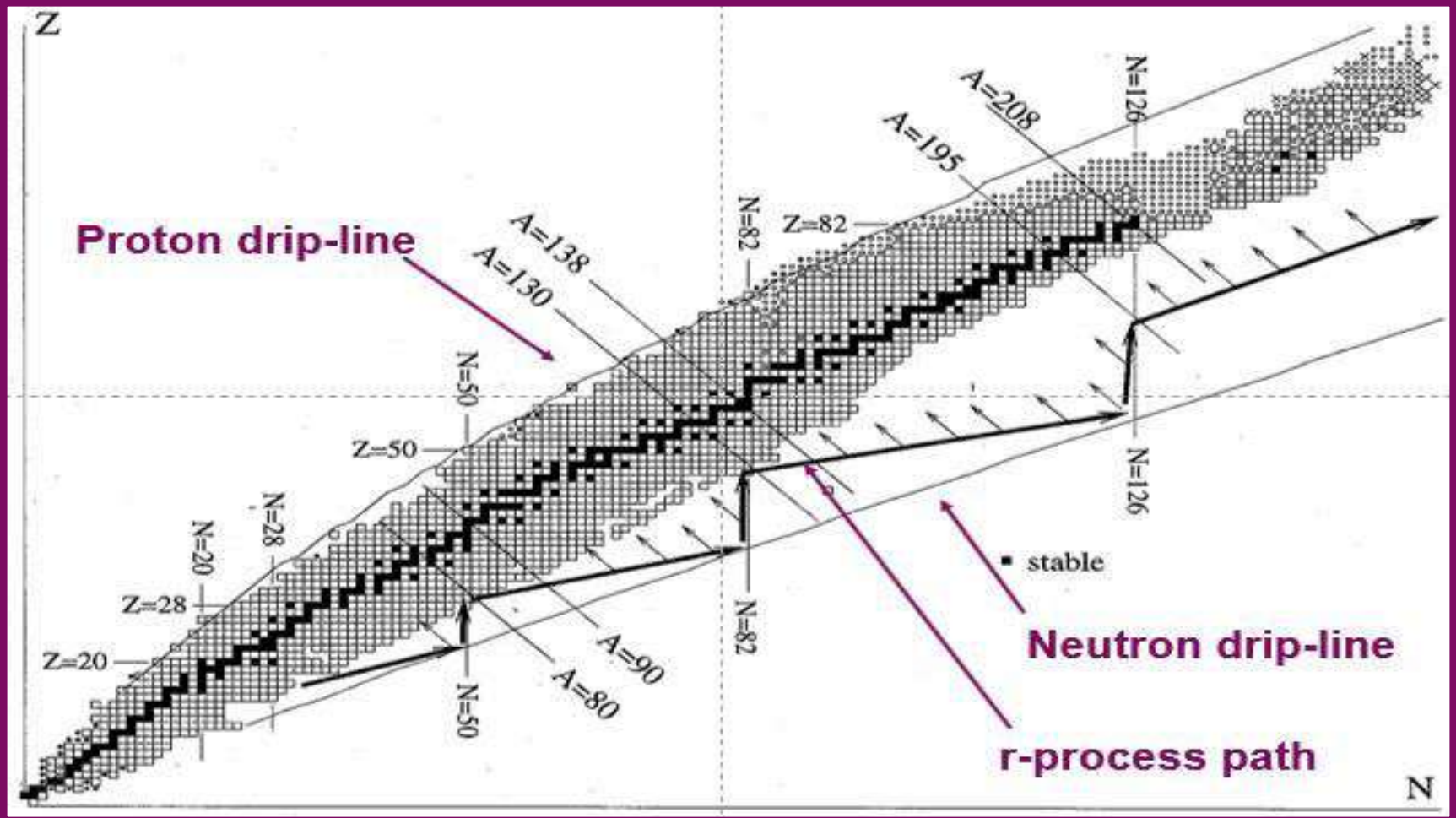
ΕΘΝΙΚΟ ΚΑΙ ΚΑΠΟΔΙΣΤΡΙΑΚΟ ΠΑΝΕΠΙΣΤΗΜΙΟ ΑΘΗΝΩΝ

Overview:

- Introduction
- Explanation of the models
- Comparison of our calculations with experimental results of our group
- Summary and conclusions

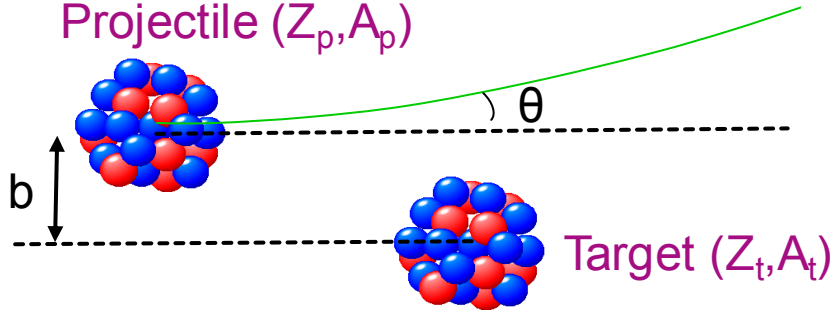
The Nuclear Landscape



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

Peripheral Collisions, Deep Inelastic Transfer (DIT)*

Approaching phase:

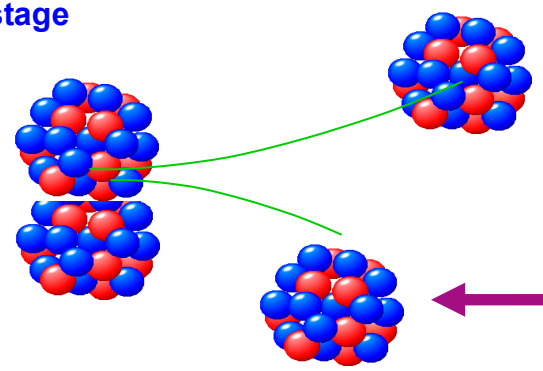


- Neutrons
- Protons

b: impact parameter
θ: scattering angle

Overlapping (interaction) stage

Exchange of nucleons:



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

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

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

*DIT: L. Tassan-Got, C. Stephan, Nucl. Phys. A 524, 121 (1991)

Microscopic Calculations: Constrained Molecular Dynamics (CoMD)*

- CoMD: Quantum Molecular Dynamics model (Semiclassical)
- Nucleons are considered as Gaussian wavepackets
- Pauli principle imposed via a phase-space constraint
- N-N effective interaction (Skyrme-type with K=200 MeV/fm^3)
- Several forms of N-N symmetry potential Vsym (ρ)
- Fragment recognition algorithm (Rmin = 3.0 fm)
- Monte Carlo implementation. Description of the dynamical stage for t = 0-800 fm/c

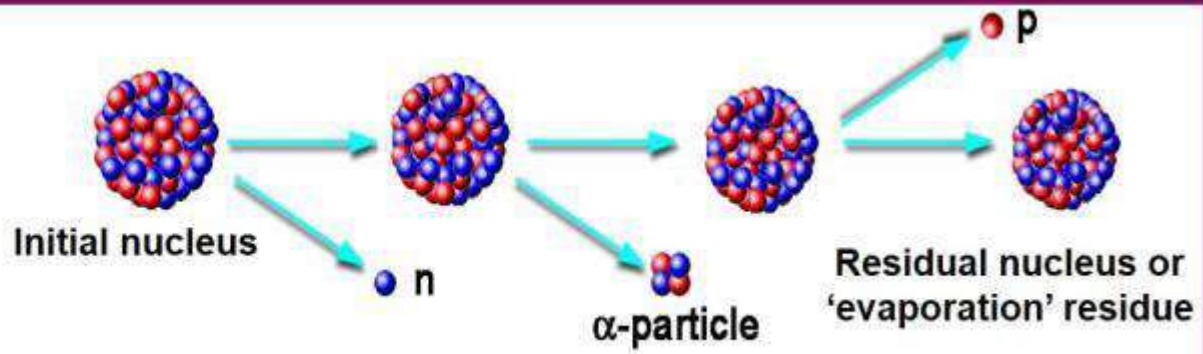
*M. Papa, A. Bonasera et al., Phys. Rev. C 64, 024612 (2001)

Nuclear De-excitation Mechanisms

I. Sequential Evaporation

E*/A < 2 MeV

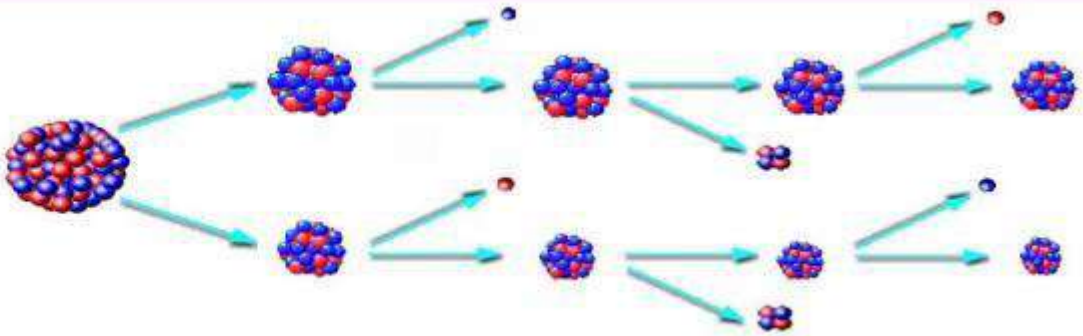
T < 4MeV



II. Sequential Binary Decay

E*/A ~ 2-3 MeV

T ~ 4-5 MeV



III. Multifragmentation

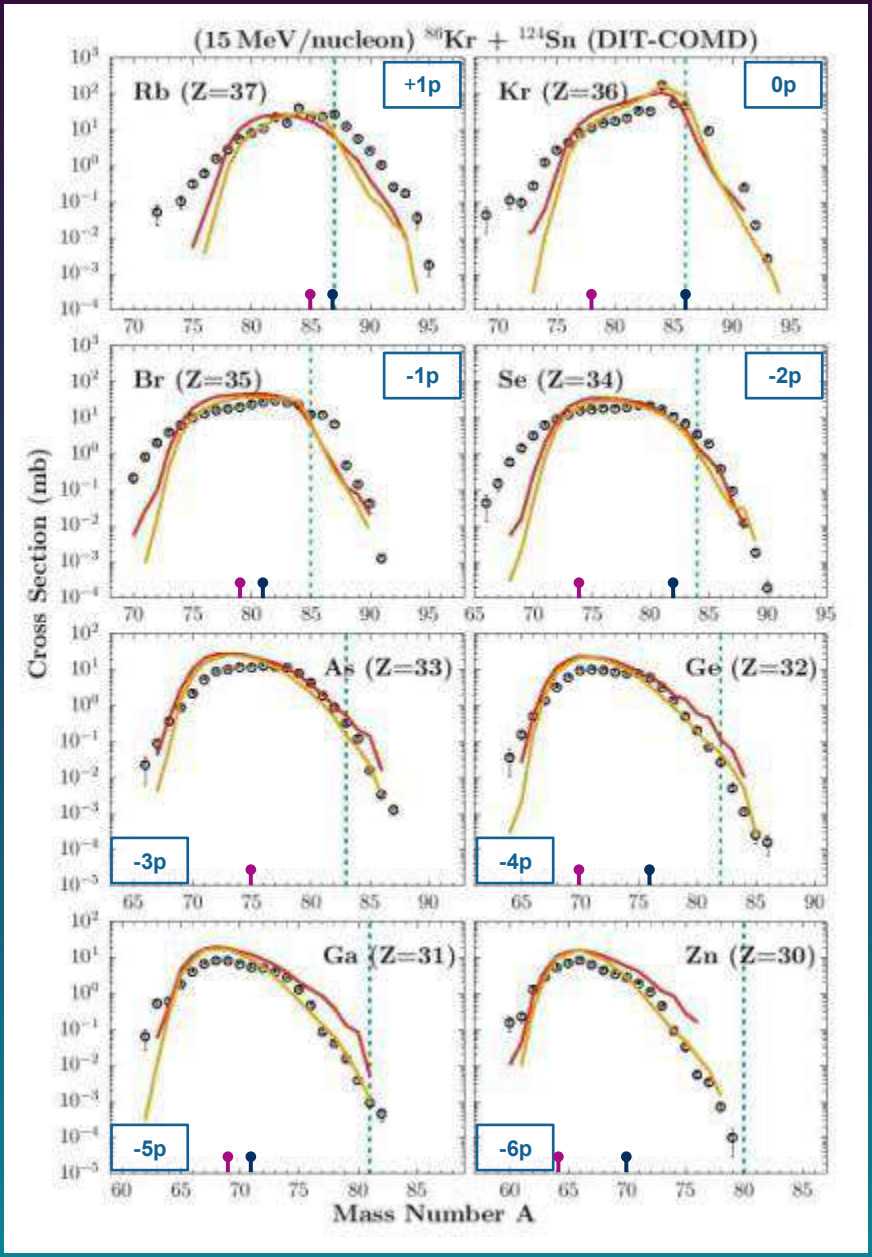
E*/A > 4 MeV

T > 6 MeV

Simultaneous emission of
several fragments, dt = 50 fm/c (10^{-22} s)

SMM Code: A. Botvina et al., Phys. Rev. C 65, 044610 (2002)

Comparison: ^{86}Kr (15 MeV/nucleon) + ^{124}Sn, ^{124}Sn



^{124}Sn: N/Z=1.48

Dots: Exp. Data ^{86}Kr+^{124}Sn
: DIT
: CoMD (standard)
: N-def stable isotope
: N-rich stable isotope

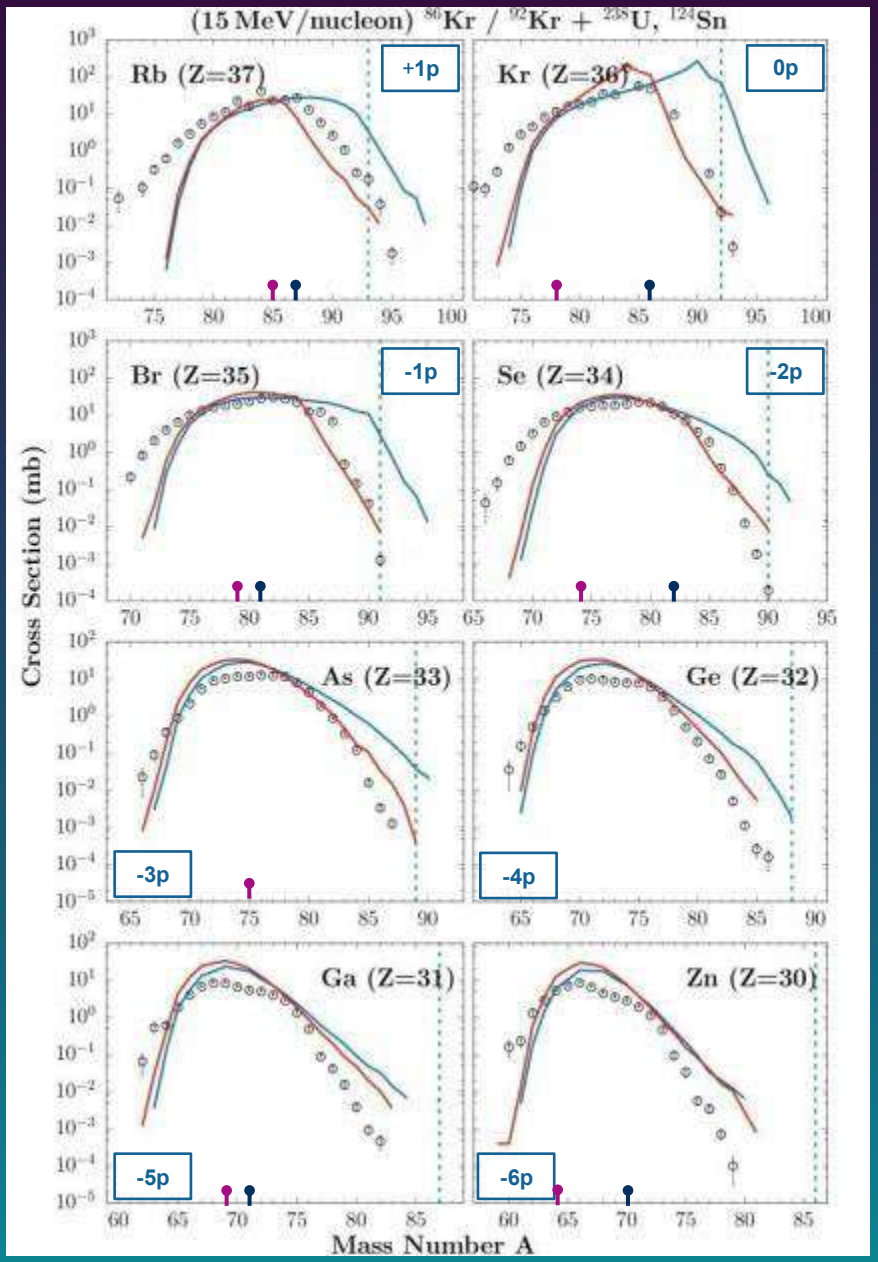
Experimental data: G.A. Souliotis et al., Texas A&M, Phys. Rev. C, 84, 064607,(2011)

DIT: Deep inelastic transfers: L. Tassan-Got, C. Stefan, Nucl. Phys. A, 524, 121, (1991)

CoMD: Constrained Molecular Dynamics, M. Papa et al., Phys. Rev. C, 64, 024612, (2001)

SMM: Statistical Multifragmentation Model: A. Botvina et al., Phys. Rev. C, 65, 044610, (2002); Nucl. Phys. A 507, 649, (1990)

Comparison: ^{86}Kr /^{92}Kr (15 MeV/nucleon) + ^{238}U, ^{124}Sn



^{238}U: N/Z=1.59

Dots: Exp. Data ^{86}Kr+^{124}Sn

: ^{86}Kr (DIT)

: ^{92}Kr (DIT)

: N-def stable isotope

: N-rich stable isotope

Experimental data: G.A. Souliotis et al., Texas A&M, Phys. Rev. C, 84, 064607,(2011)

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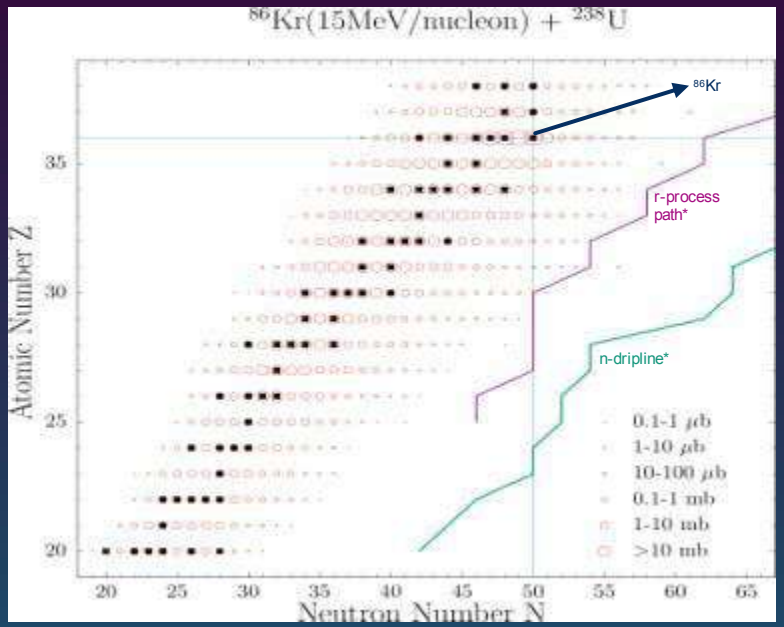
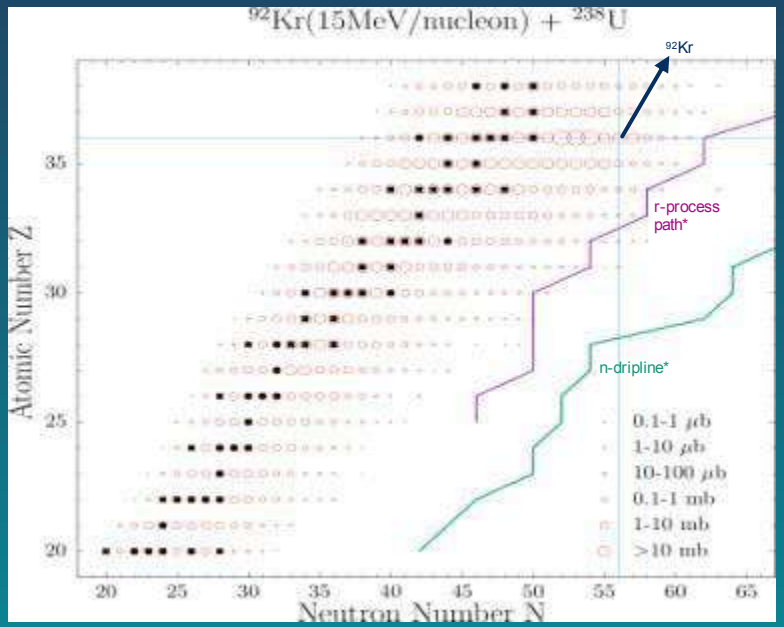
Comparison: ^{86}Kr /^{92}Kr (15 MeV/nucleon) + ^{238}U





Black Dots : Stable Nuclei
Red Circles : DIT
Green Line : n-drip line*
Purple line : r-process path*

Experimental data: G.A. Souliotis et al., Texas A&M, Phys. Rev. C, 84, 064607,(2011)

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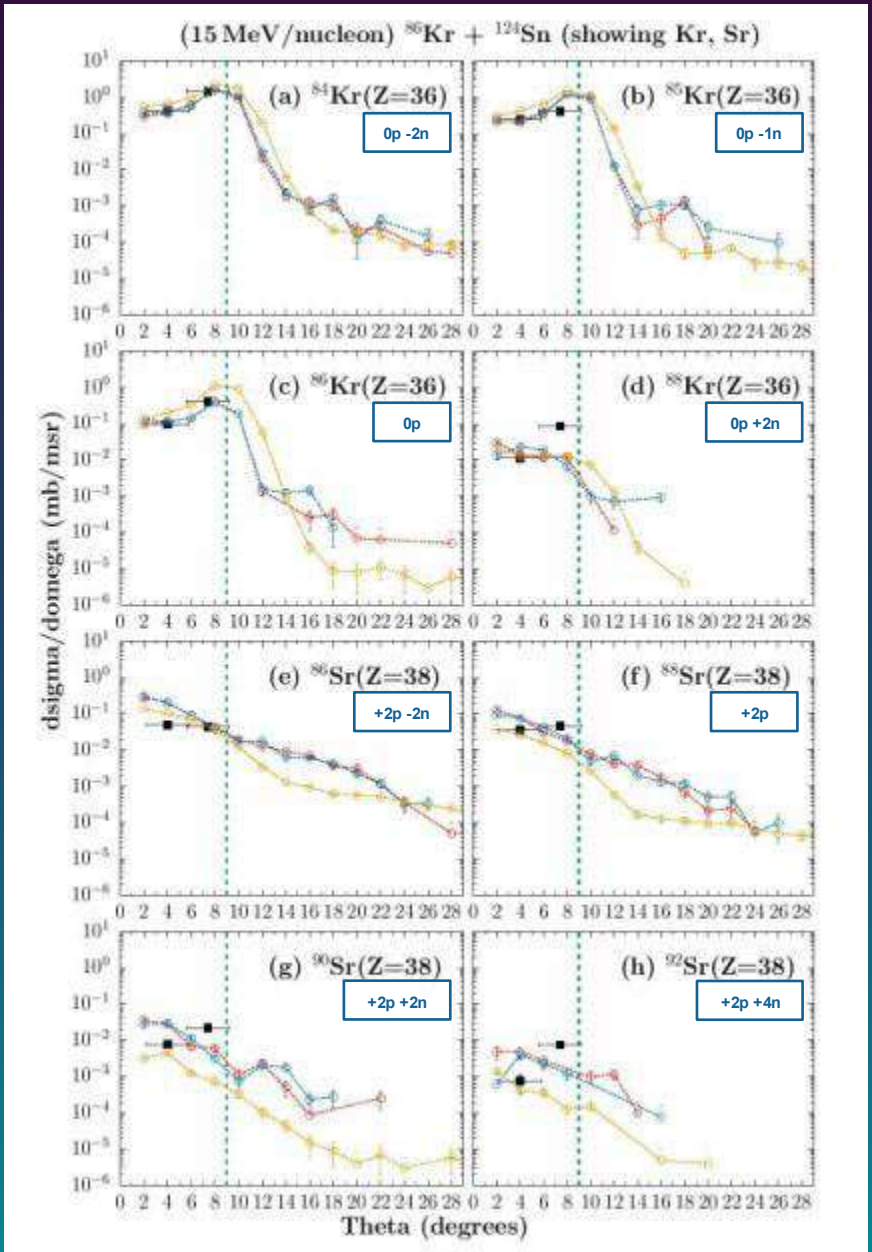
*P. Moller, J. R. Nix, K. L. Kratz, At. Data Nucl. Data Tables **66**, 131 (1997).

Angular Distribution: ^{86}Kr (15 MeV/nucleon) + ^{124}Sn, (Z:36,38)



Squares: Exp. Data ^{86}Kr+^{124}Sn

: DIT

: CoMD (standard)

: CoMD (pairing term)

Experimental data: G.A. Souliotis et al., Texas A&M, Phys. Rev. C, 84, 064607,(2011)

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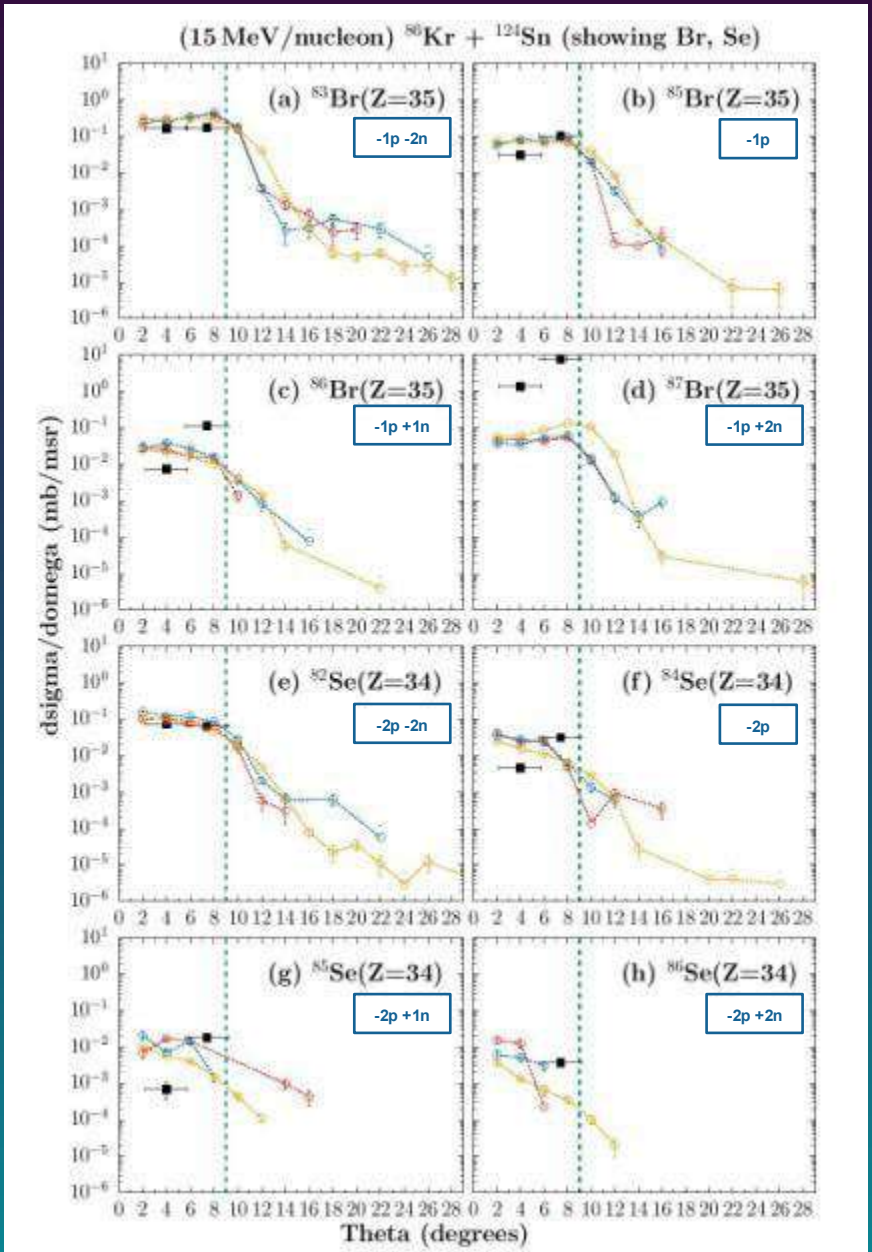
Angular Distribution: ^{86}Kr (15 MeV/nucleon) + ^{124}Sn, (Z:35,34)



Squares: Exp. Data ^{86}Kr+^{124}Sn

: DIT

: CoMD (standard)

: CoMD (pairing term)

Experimental data: G.A. Souliotis et al., Texas A&M, Phys. Rev. C, 84, 064607,(2011)

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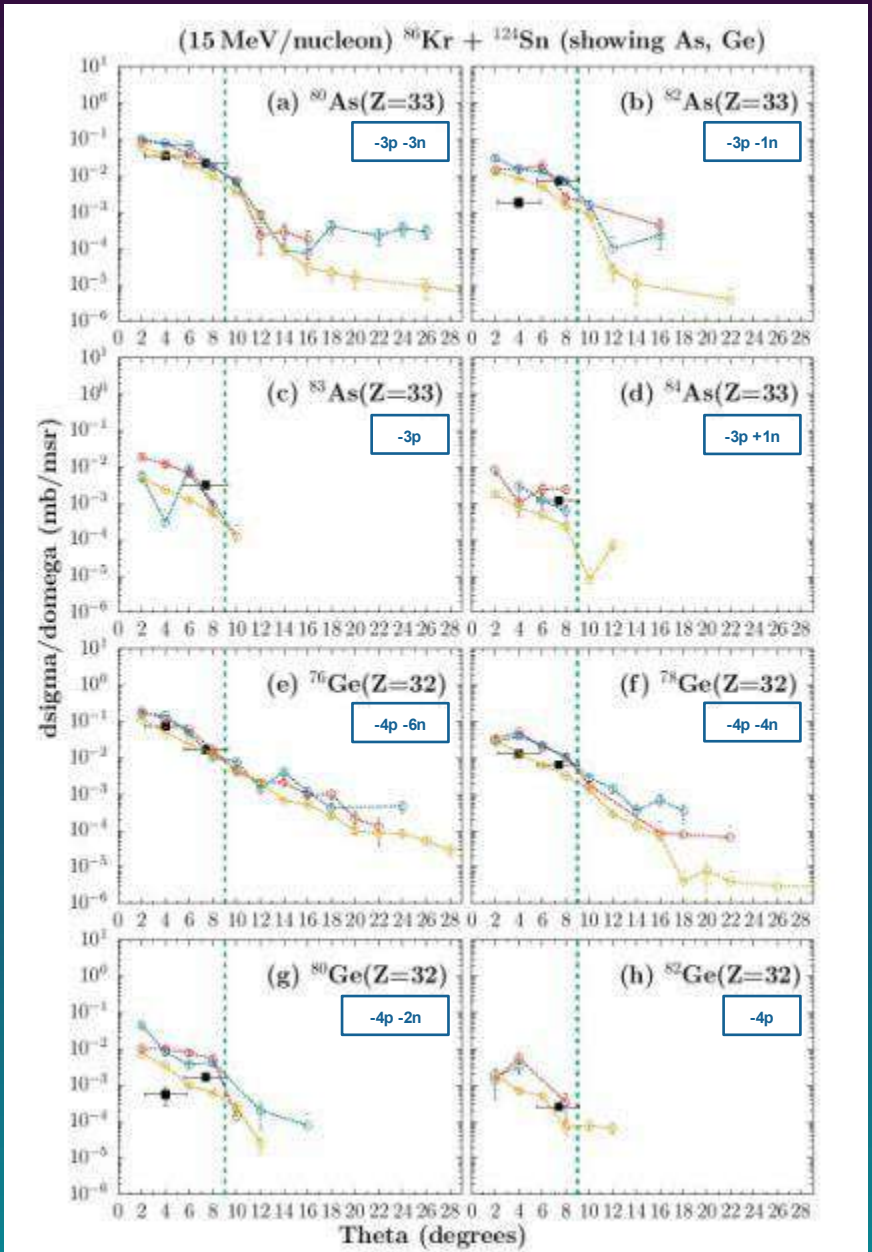
Angular Distribution: ^{86}Kr (15 MeV/nucleon) + ^{124}Sn, (Z:33,32)



Squares: Exp. Data ^{86}Kr+^{124}Sn

: DIT

: CoMD (standard)

: CoMD (pairing term)

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Summary and Conclusions

- Systematic study of production cross-sections of neutron-rich rare isotopes in peripheral reactions below the Fermi energy in mass range A ~40-60
- Systematic study of angular distributions
- Explore possible sensitivity of calculations to the effective N-N potential and the equation of state
- Satisfactory agreement with experimental results of our group
- Predictions of extremely neutron rich isotopes toward r-process path

Plans for future work:

- Further theoretical investigation with CoMD, DIT, SMM and improvement of our models
- Experimental work with ^{70}Zn stable beam of 15 MeV/nucleon at LNS Catania with the MAGNEX spectrometer

Acknowledgements

Special thanks to:

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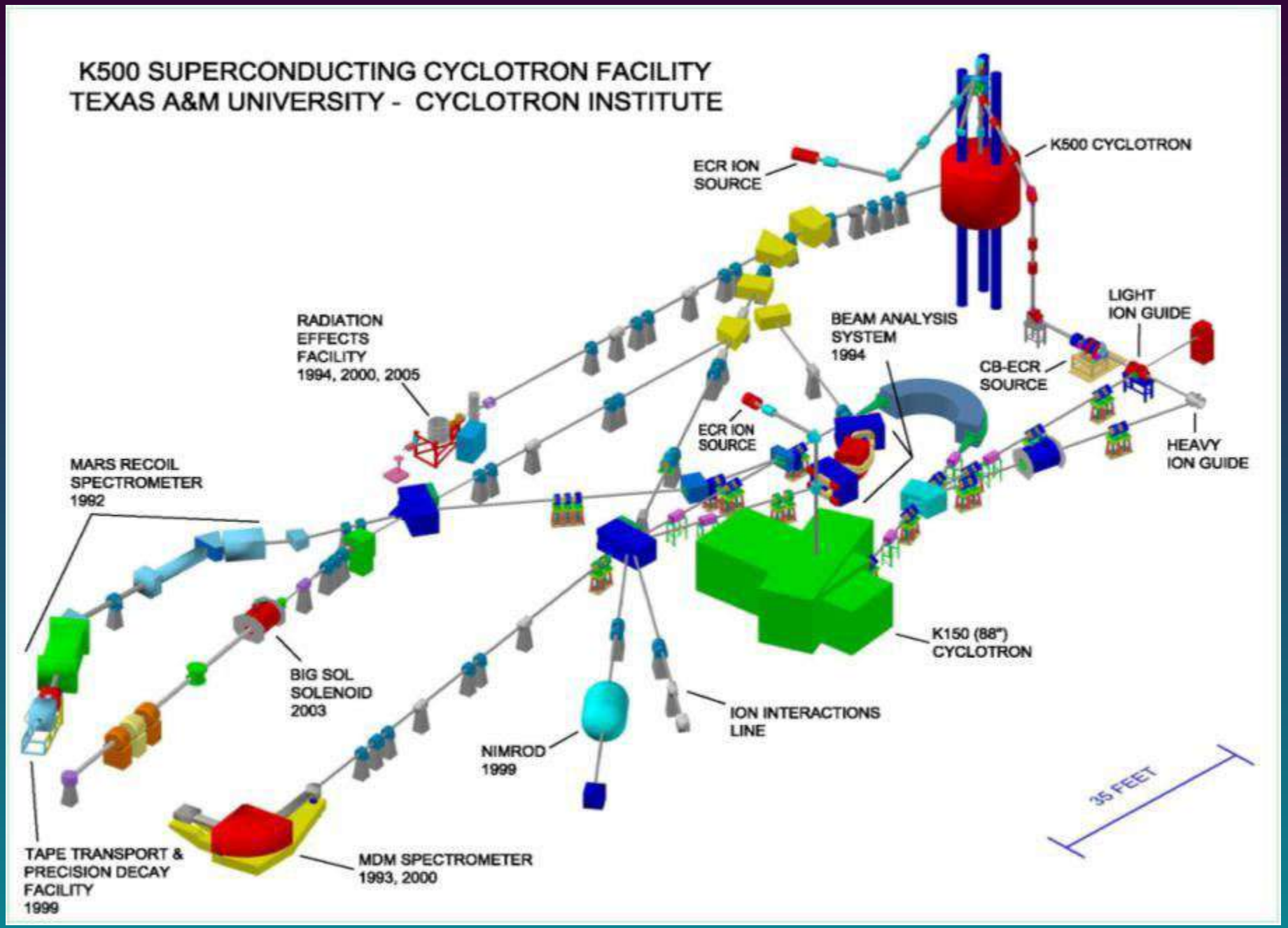
A. Botvina, FIAS, Frankfurt, Germany

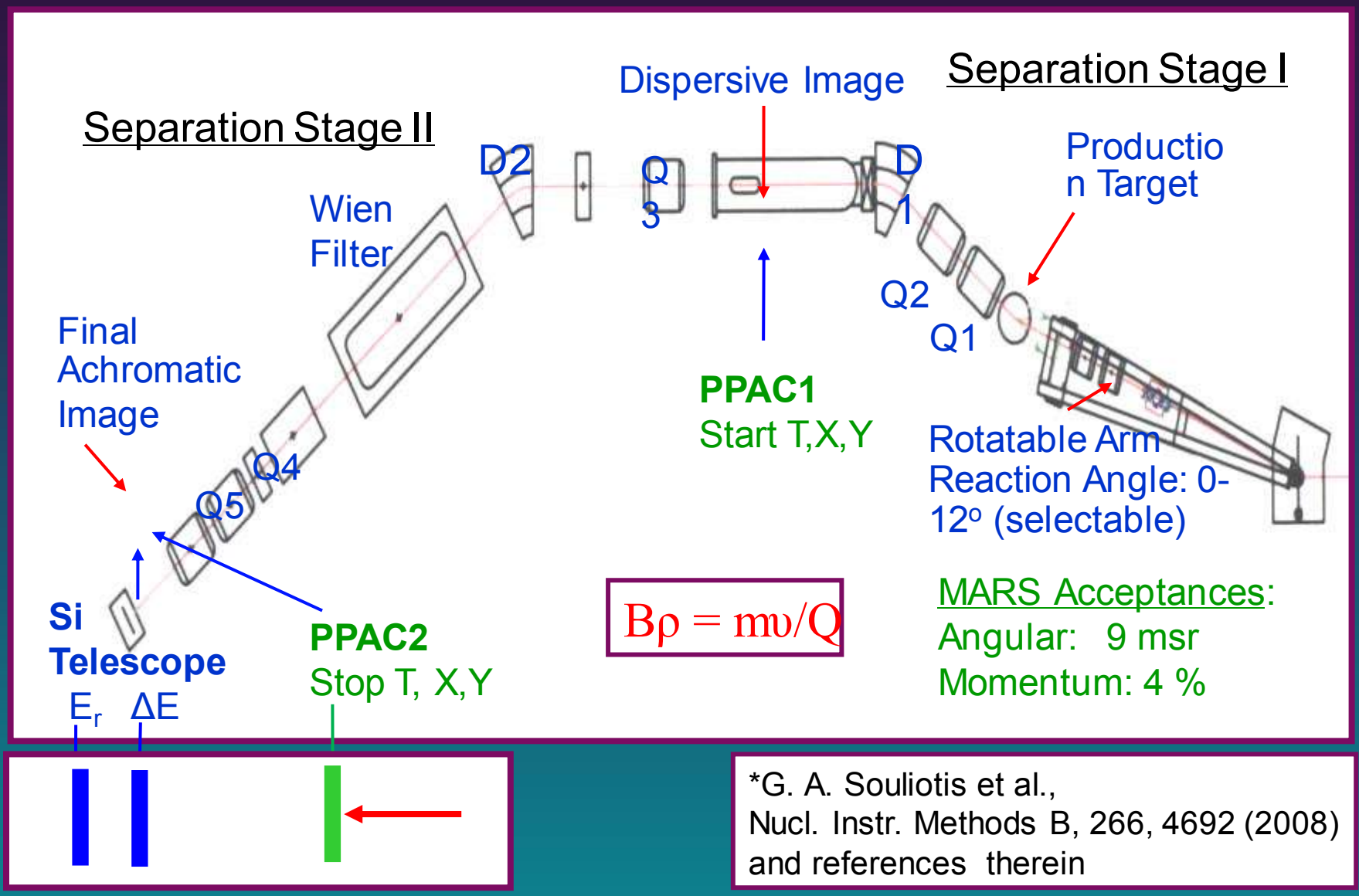
N. Nikolis, University of Ioannina, Greece

THANK YOU !

EXTRA STUFF


K500 SUPERCONDUCTING CYCLOTRON FACILITY
TEXAS A&M UNIVERSITY - CYCLOTRON INSTITUTE
K500 CYCLOTRON
ECR ION SOURCE
LIGHT ION GUIDE
BEAM ANALYSIS SYSTEM 1994
RADIATION EFFECTS FACILITY 1994, 2000, 2005
CB-ECR SOURCE
ECR ION SOURCE
HEAVY ION GUIDE
MARS RECOIL SPECTROMETER 1992
K150 (88") CYCLOTRON
BIG SOL SOLENOID 2003
ION INTERACTIONS LINE
NIMROD 1999
35 FEET
TAPE TRANSPORT & PRECISION DECAY FACILITY 1999
MDM SPECTROMETER 1993, 2000

MARS Recoil Separator and Setup for Heavy Rare Isotope Studies*



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

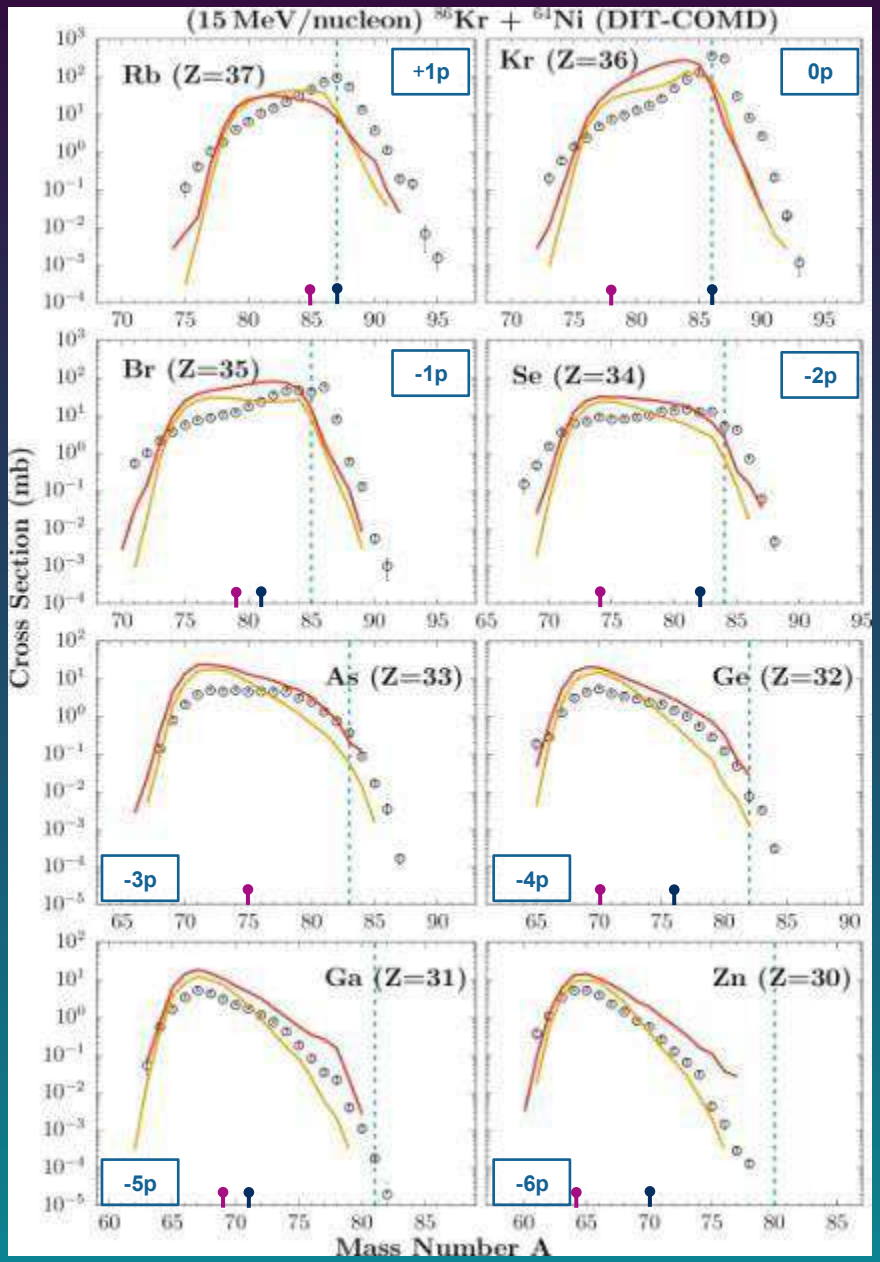
Rare isotope production study: Why?

Investigation of very neutron rich nuclei offers:

- Understanding of the nuclear structure with increasing N/Z
- Insight in nucleosynthesis processes (i.e. rapid neutron capture process, r-process)
- Reactions induced by n-rich nuclei provide information on:
  - isospin dependence N-N interaction
  - equation of state of asymmetric nuclear matter.

Production of very neutron-rich nuclides is a central issue in current and future rare isotope beam facilities.
(GSI, Ganil, NSCL/FRIB, TRIUMF, RISP/Korea etc.)

Comparison: ^{86}Kr (15 MeV/nucleon) + ^{64}Ni, ^{64}Ni



^{64}Ni: N/Z=1.29

Dots: Exp. Data ^{86}Kr+^{64}Ni
: DIT
: CoMD (standard)
: N-def stable isotope
: N-rich stable isotope

Experimental data: G.A. Souliotis et al., Texas A&M, Phys. Rev. C, 84, 064607,(2011)

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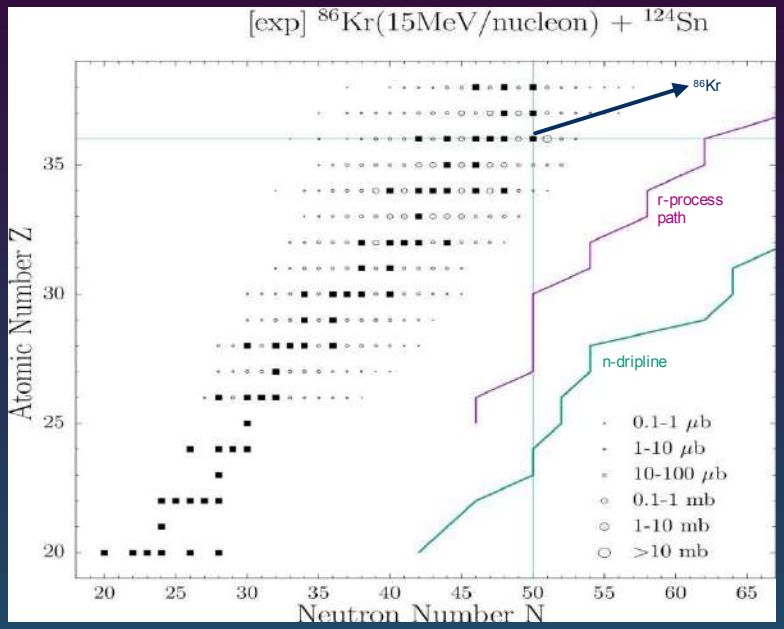
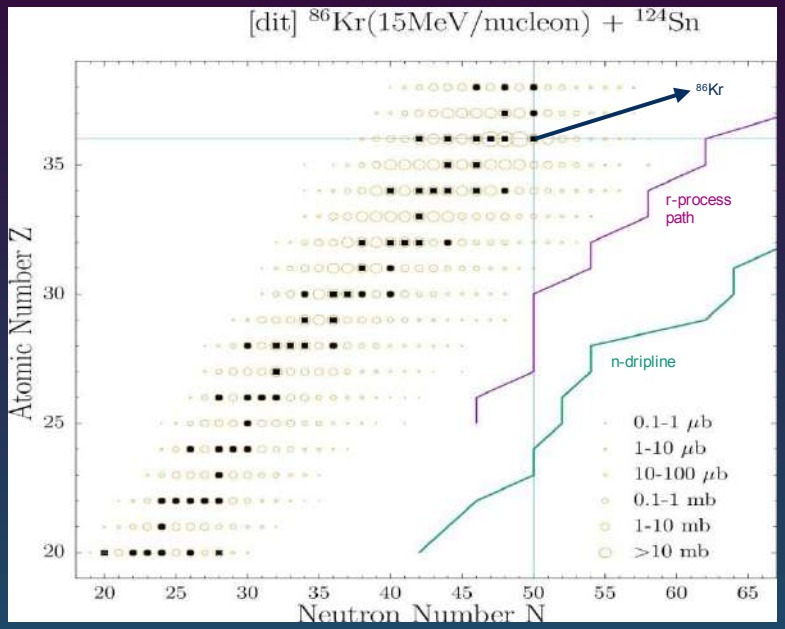
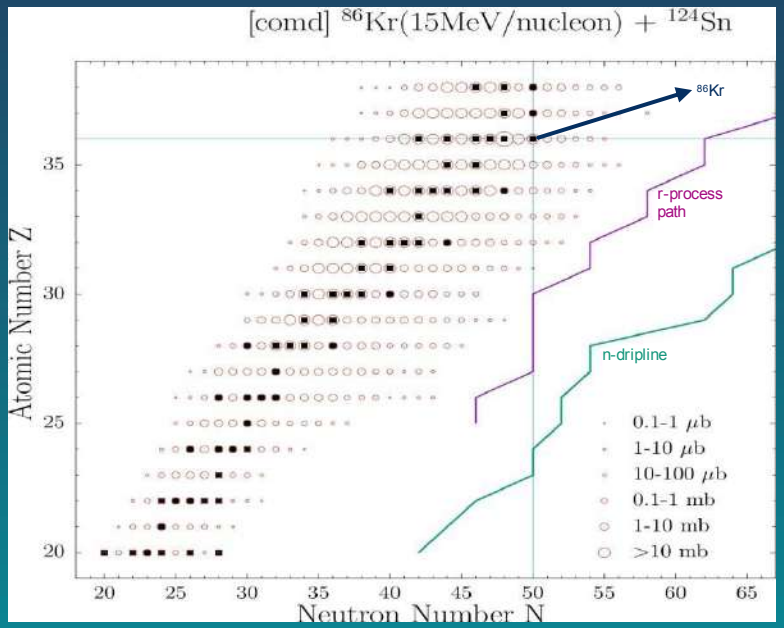
SMM: Statistical Multifragmentation Model: A. Botvina et al., Phys. Rev. C, 65, 044610, (2002); Nucl. Phys. A 507, 649, (1990)

Calculations (prod. rates) : ^{86}Kr (15 MeV/nucleon) + ^{124}Sn, ^{124}Sn







Dots	: Stable Nuclei
Black	: Experimental data
Yellow	: DIT
Red	: CoMD (standard)

Experimental data: G.A. Souliotis et al., Texas A&M, Phys. Rev. C, 84, 064607,(2011)

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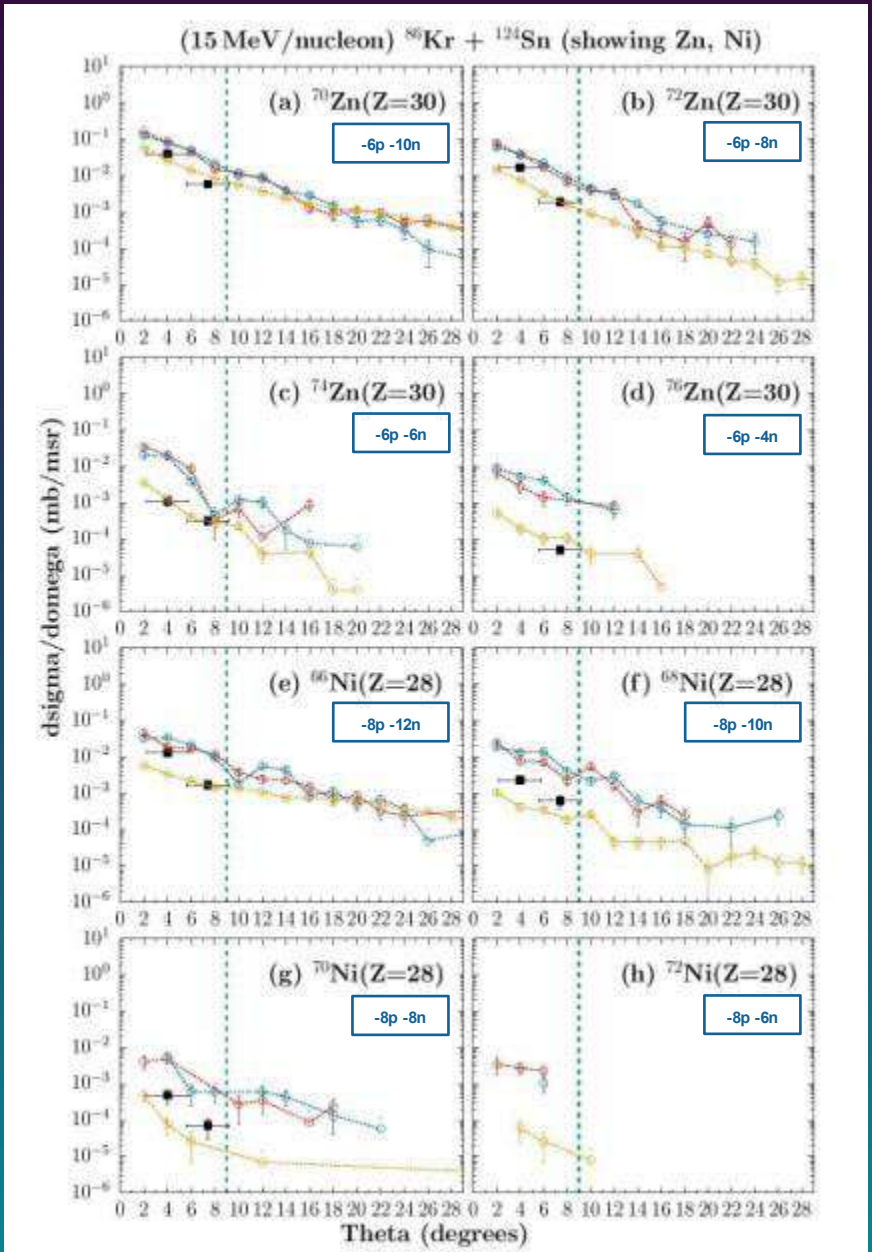
Angular Distribution: ^{86}Kr (15 MeV/nucleon) + ^{124}Sn, (Z:30,28)



Squares: Exp. Data ^{86}Kr+^{124}Sn

: DIT

: CoMD (standard)

: CoMD (pairing term)

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