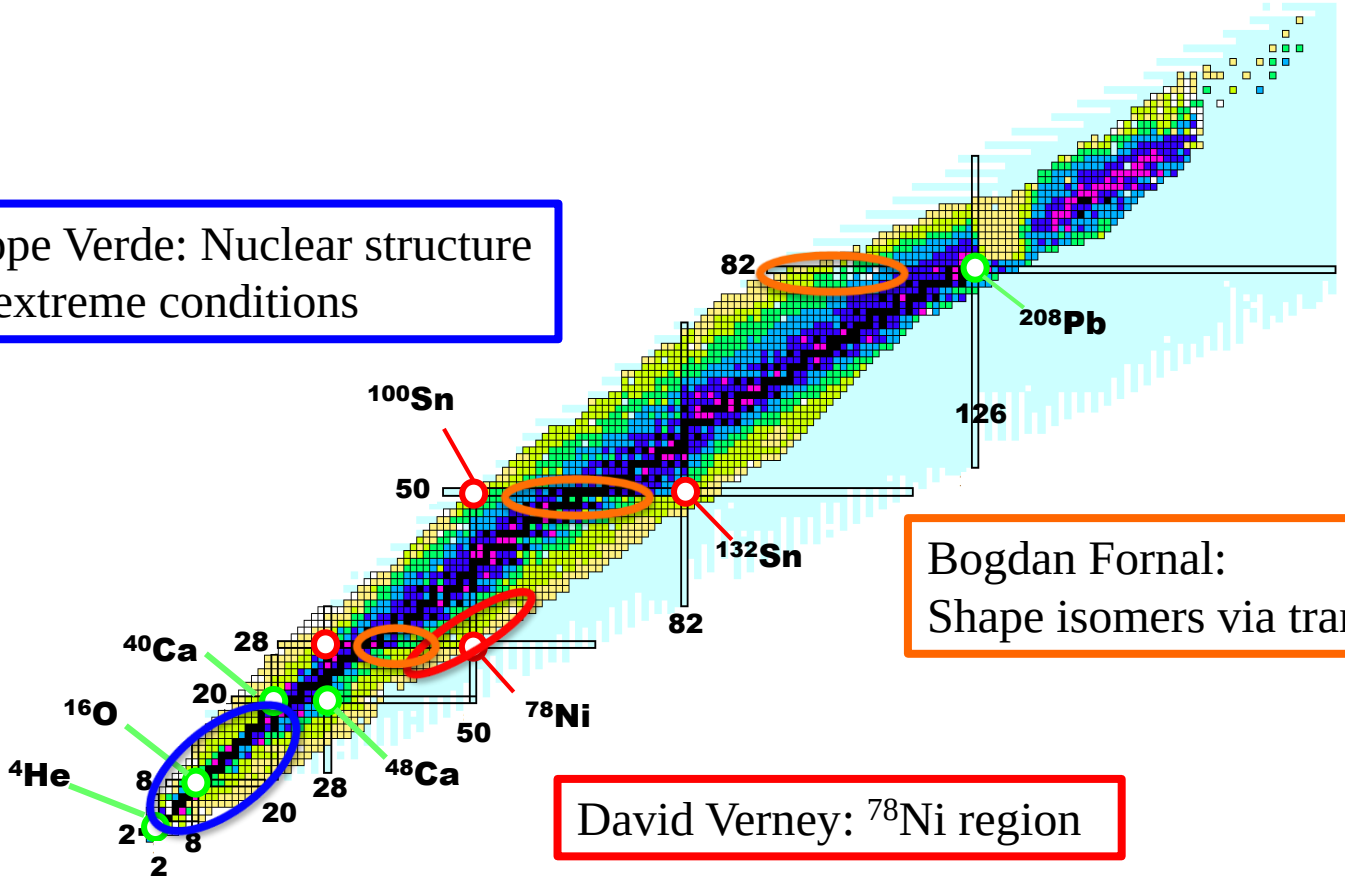
# Topic V:
# Going to the limits of mass, temperature, spin and isospin with heavy Radioactive Ion Beams

Giuseppe Verde: Nuclear structure under extreme conditions




Bogdan Fornal:
Shape isomers via transfer reactions

David Verney: $^{78}$Ni region

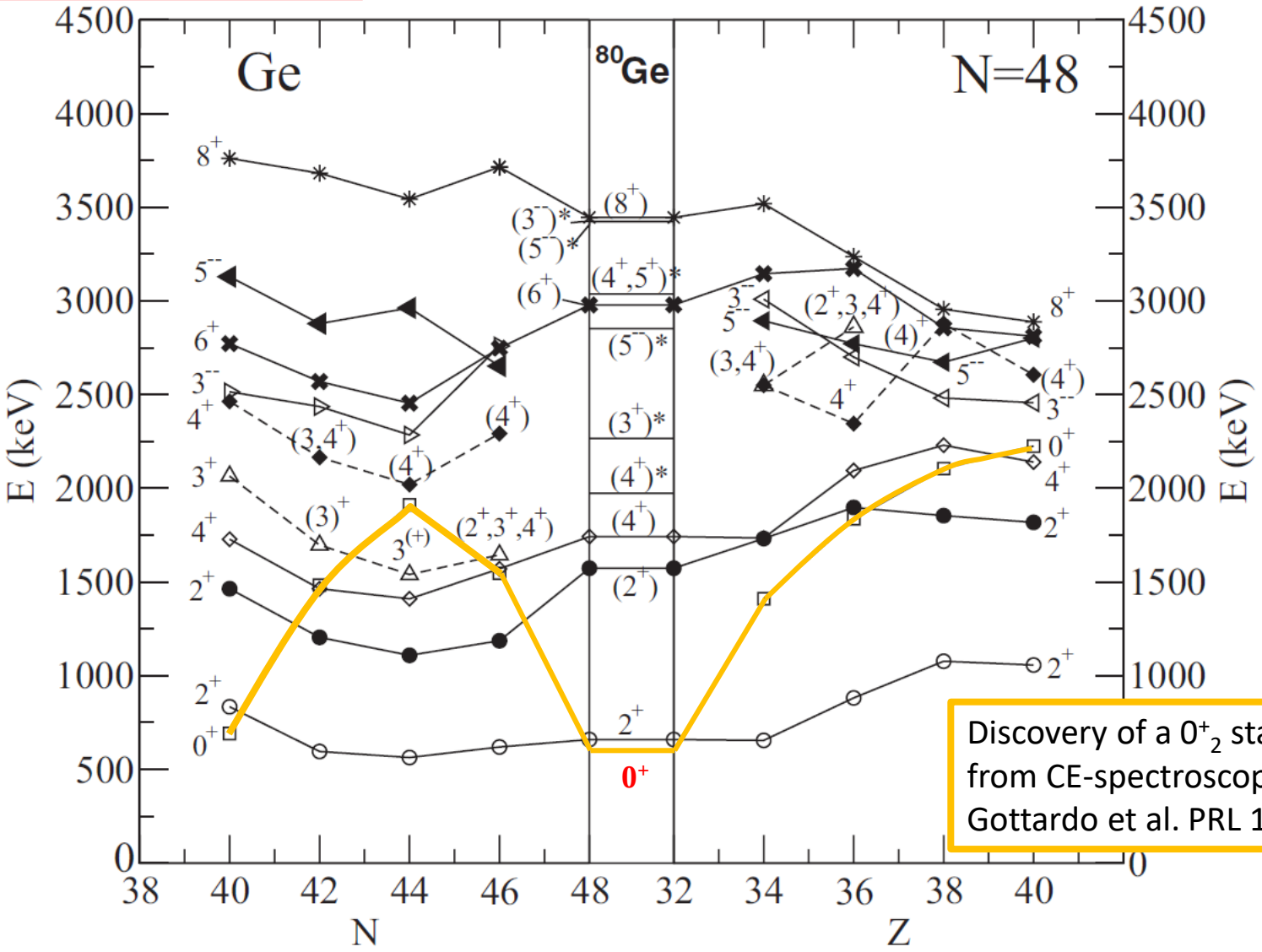
# What we have learned and what we still need to learn:

- gap size → Z=32 "singularity"
  - monopole effect ? (quadratic ??) ⟶ mass measurements
  - dynamical effect ? (triaxiality corridor ??) ⟶ (multiple) coulex
- shape coexistence
  - $0^+_2$ states ⟶ β-delayed e- spectroscopy
  - extruder states at N=51 ⟶ direct nucleon exchange (t,p)
- neutron valence space above $^{78}$Ni ⟶ direct nucleon exchange (d,p) and ($\alpha$,$^3$He)
- first-forbidden transitions in the $^{78}$Ni region ⟶ β-delayed neutron and high-energy $\gamma$ spectroscopy

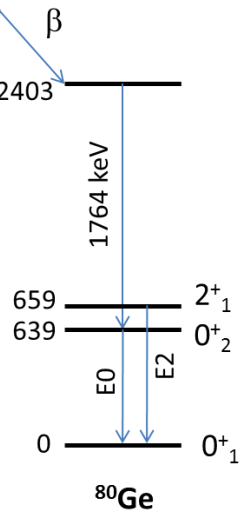
David Verney: $^{78}$Ni region

Z=32 : definitely a "special" proton number

David Verney: $^{78}$Ni region

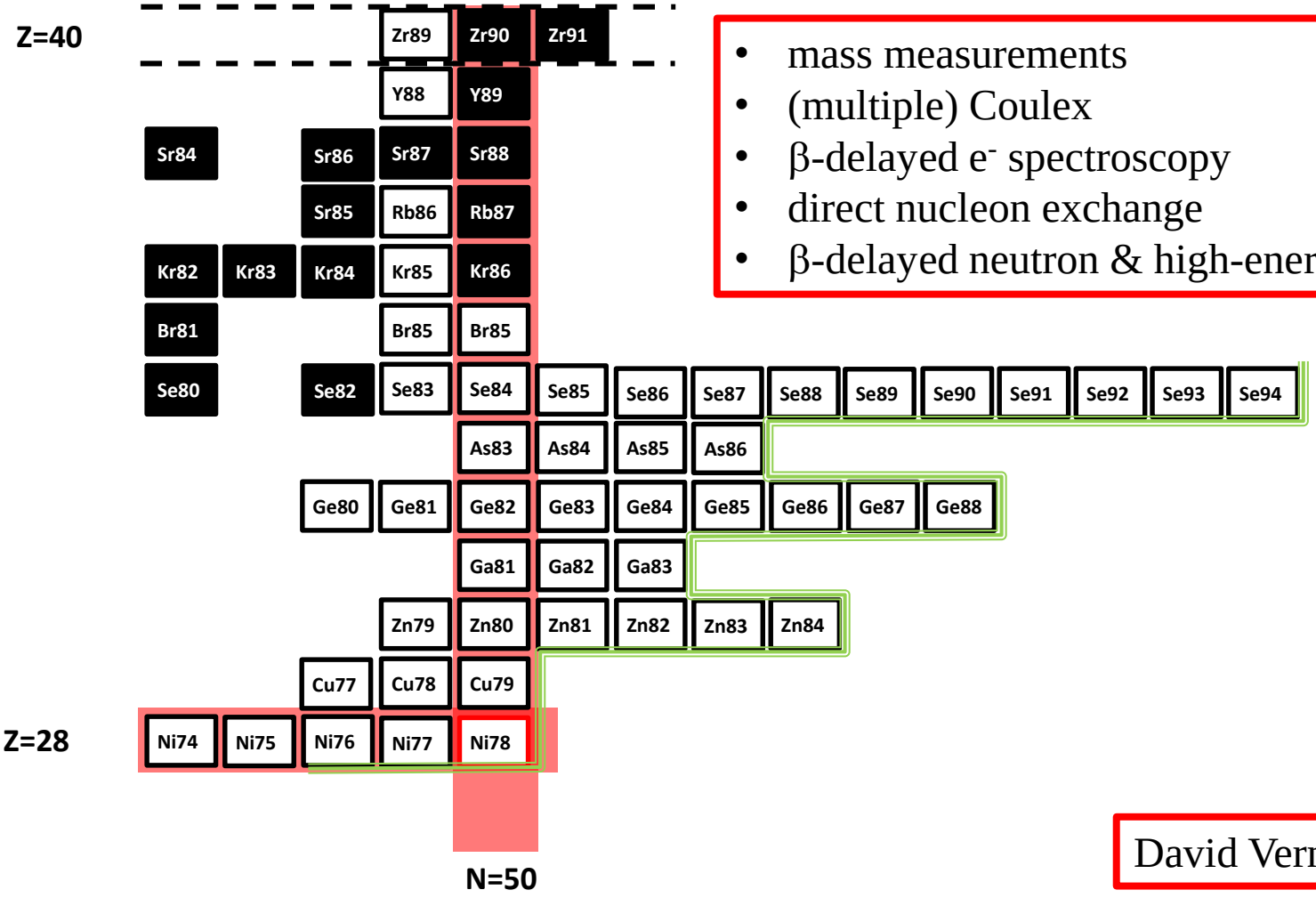



3⁻ isomer in $^{80}$Ga
[$T_{1/2}(3^-)$=1.3±0,2 s;
PRC 87 (2013)]




Discovery of a $0^+_2$ state in $^{80}$Ge from CE-spectroscopy at ALTO
Gottardo et al. PRL 116 (2016)

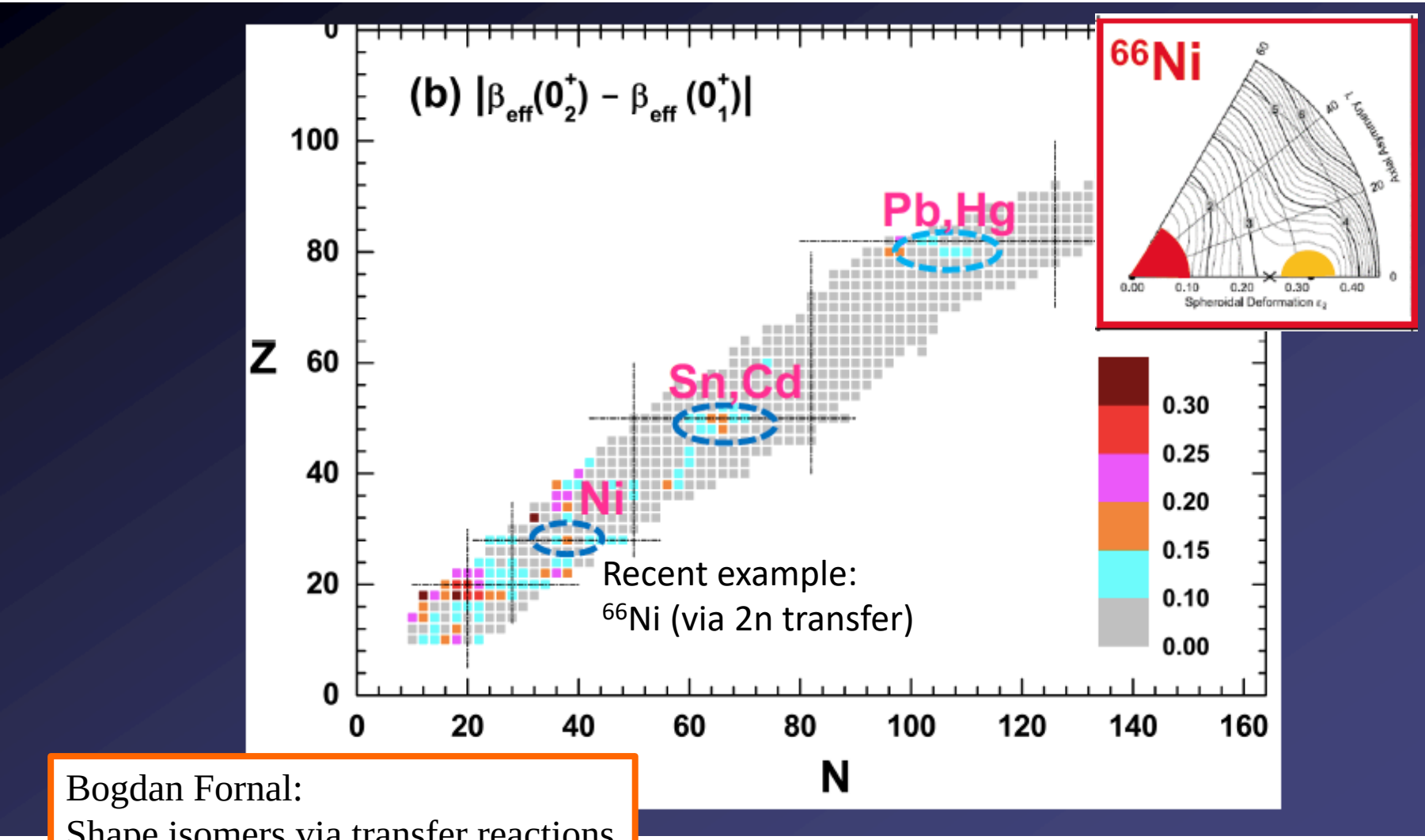
# Coordinated program using a variety of techniques and involving several laboratories (HIE-ISOLDE, SPES, ALTO)




- mass measurements
- (multiple) Coulex
- β-delayed $e^-$ spectroscopy
- direct nucleon exchange
- β-delayed neutron & high-energy γ spectroscopy

David Verney: $^{78}$Ni region

# Regions of the nuclear chart in which coexisting nuclear shapes are predicted ➡ Search for shape isomers !

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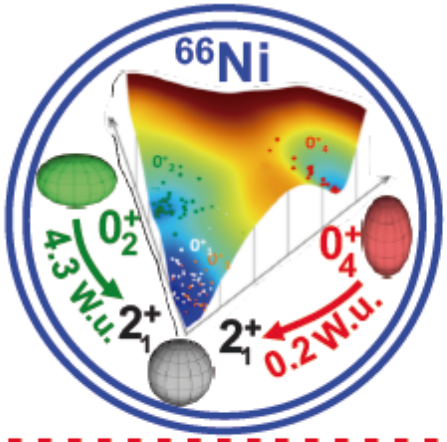
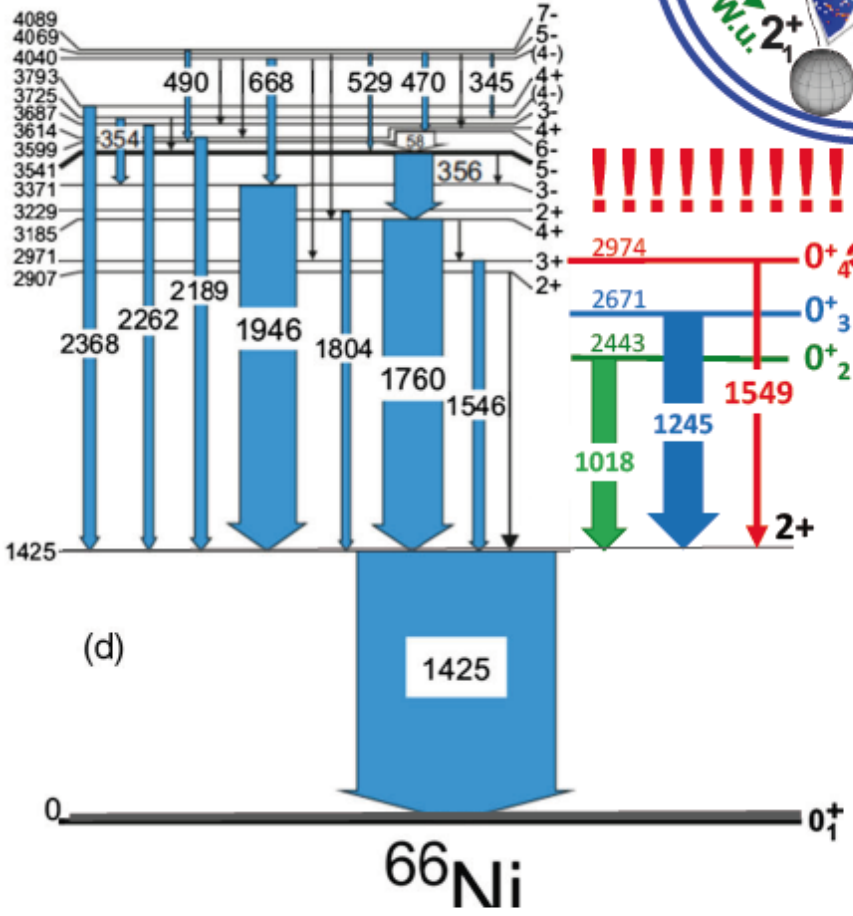
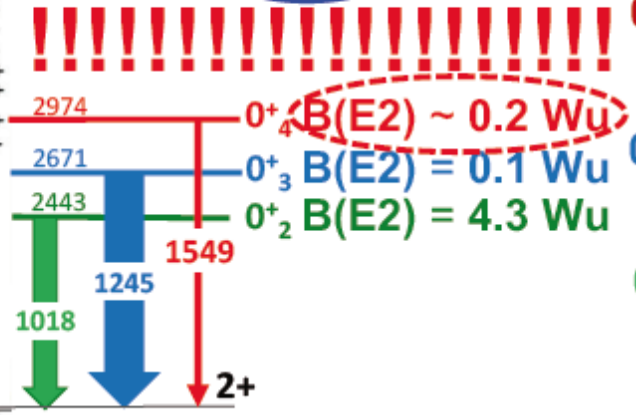
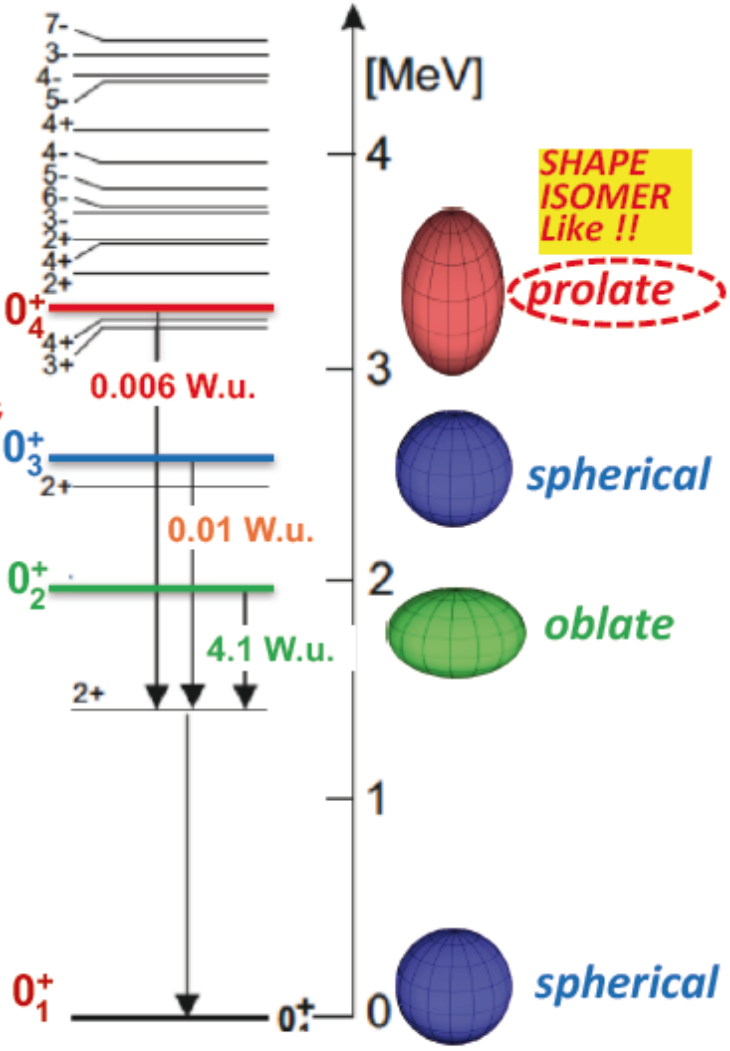


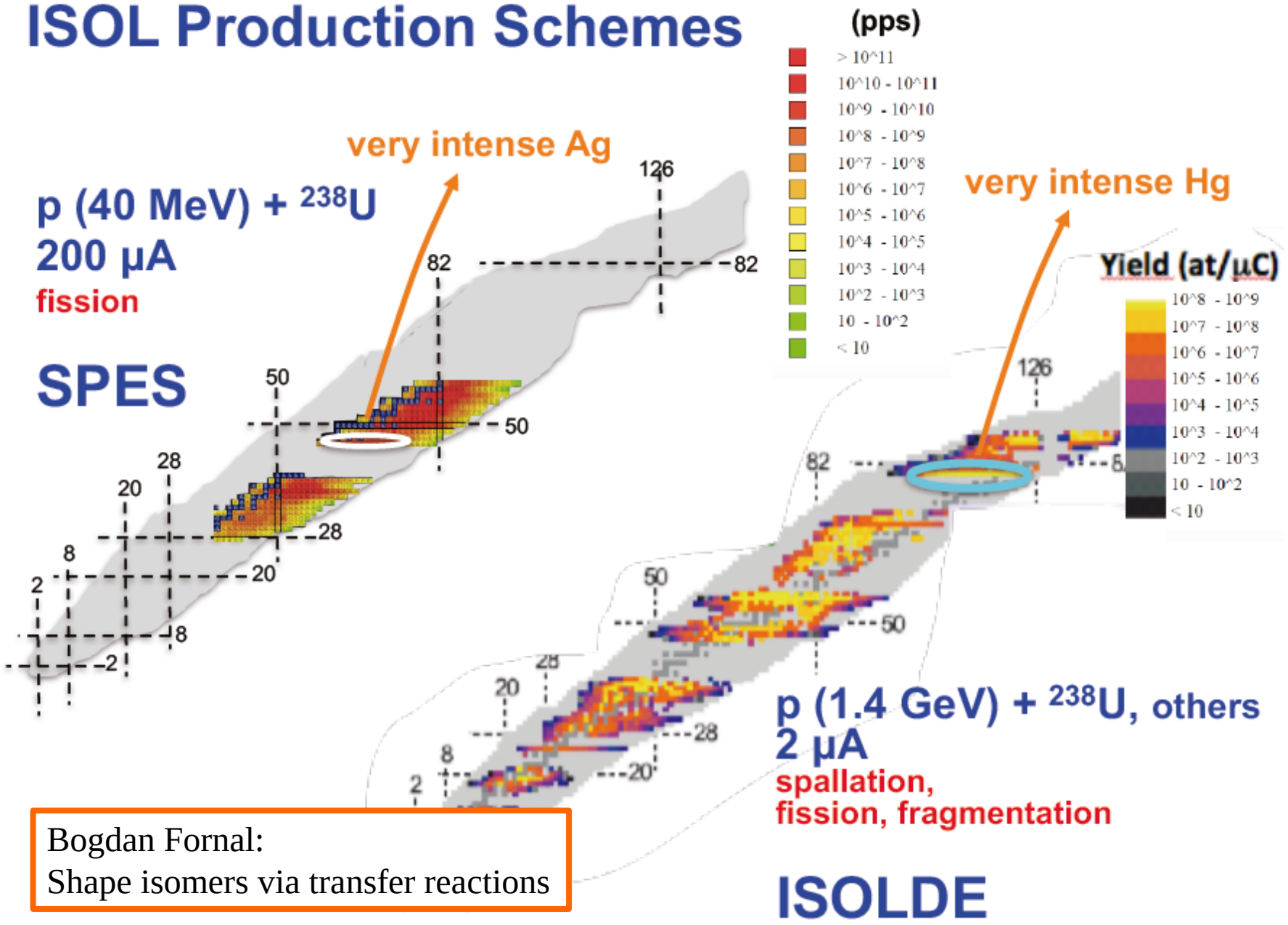




HINDRANCE due to **shape change** through high potential barrier !!!!

# ISOL Production Schemes

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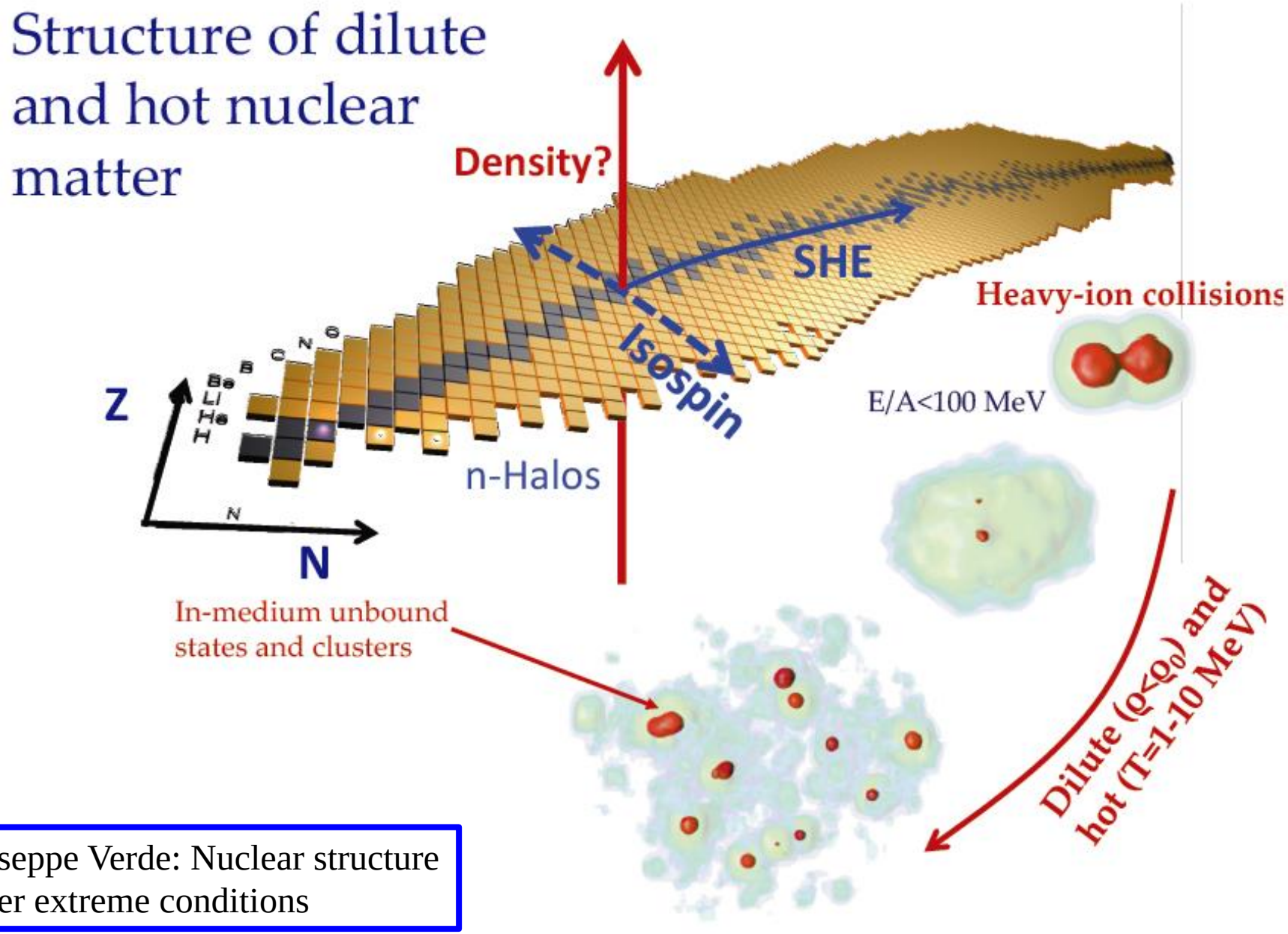
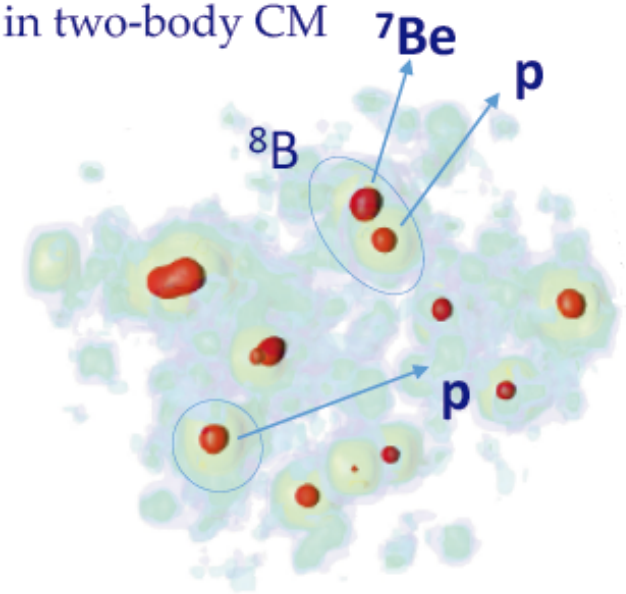
# Structure and dynamics of systems under extreme conditions



# Multi-particle correlation spectroscopy in low density medium

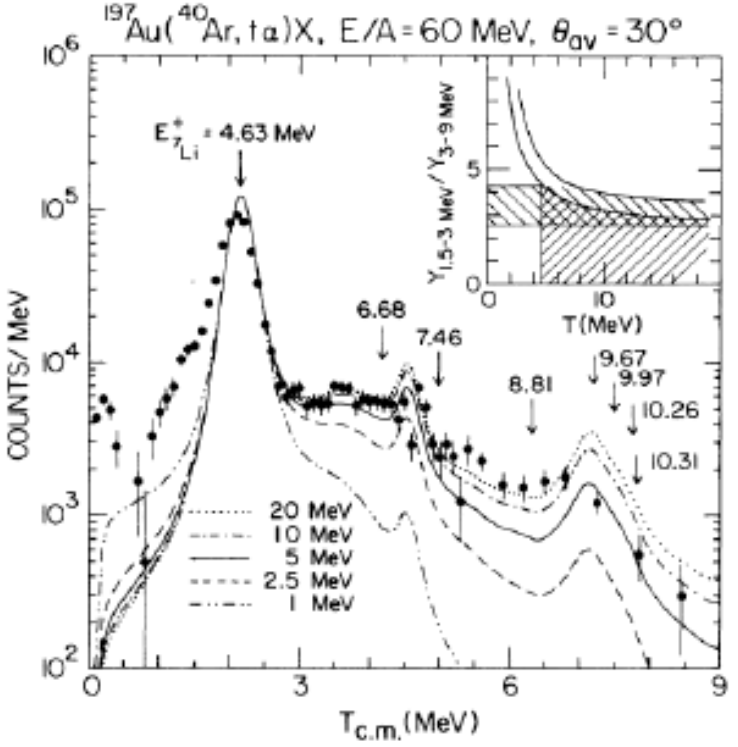
## Intermediate energies

$\vec{v}_p, \vec{v}_{7Be}$ velocity vectors in two-body CM




Particle emitting sources extended in phase-space

$^{7}$Li->t-α




Fragmentation and fusion-evaporation

- Different energy regimes → temperature
- RIBs needed to fully explore isospin dependence

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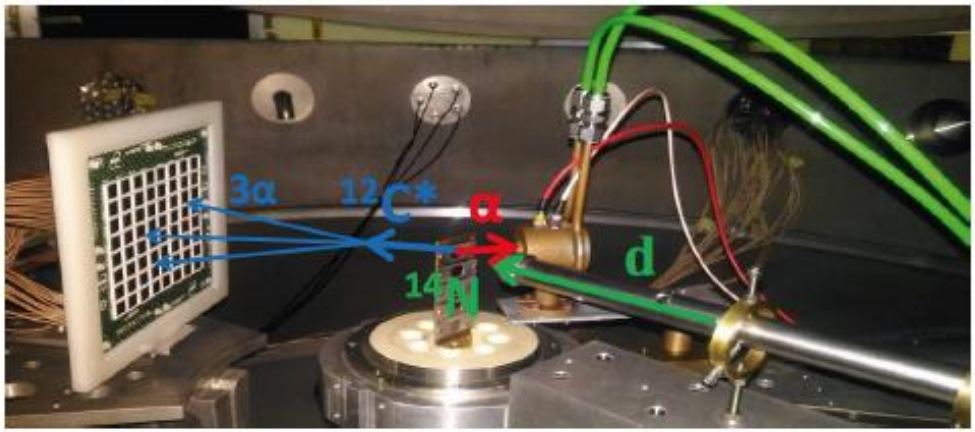
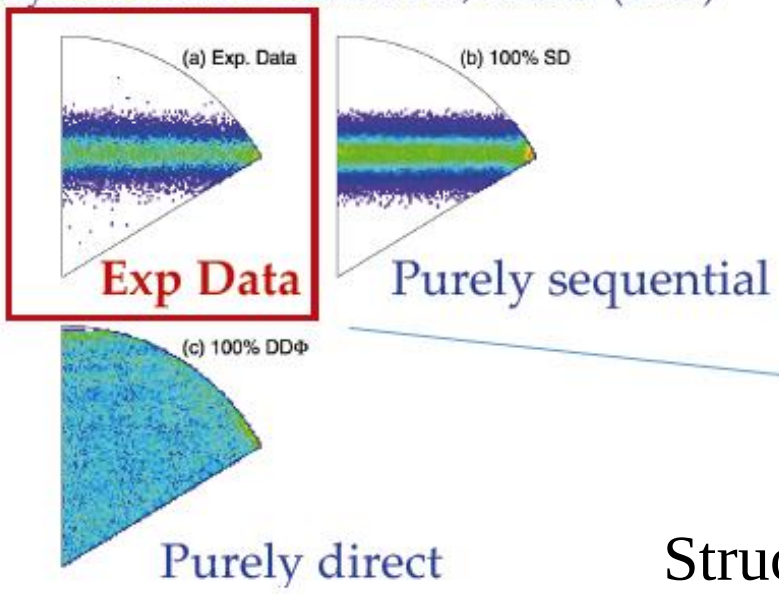
# Direct reaction measurements

OSCAR data @ LNS




D. Dell'Aquila, I. Lombardo, G. Verde et al.,
Physical Review Letters 119, 132501 (2017)




No direct decay
DD < 0.043% (95% C.L.)

$^{14}N(d,\alpha)^{12}C^*$


Structure of light nuclei ! (Topic II)

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Partially hidden in topics I (r-process) and III (N=Z)

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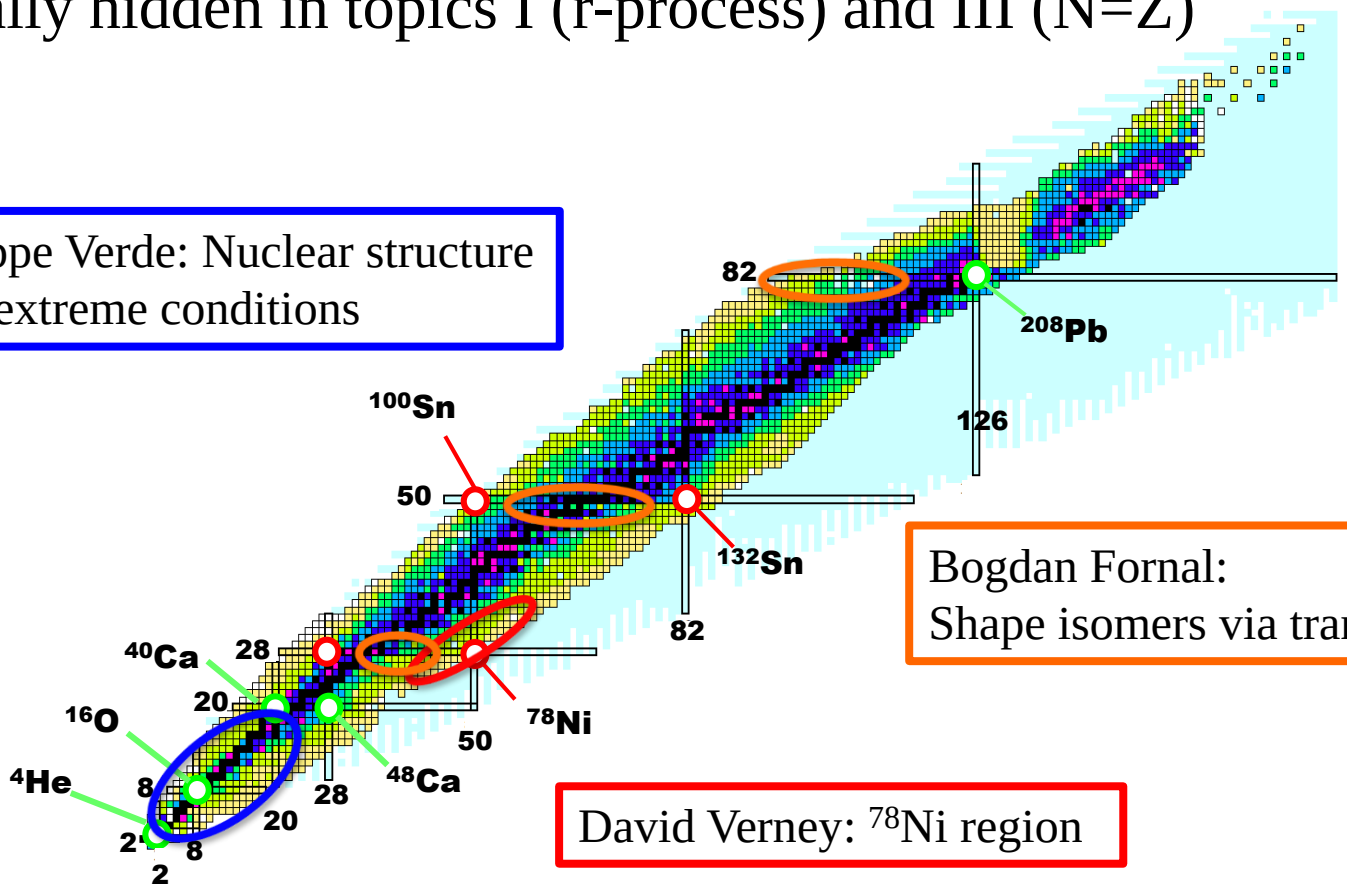


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What about the limits of mass and spin ???