Nuclear Physics Mid Term Plan in Italy

LNL – Session

Legnaro (Pd), April 11th-12th 2022

Nuclear Structure @ LNL
Summary & conclusions

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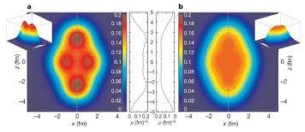
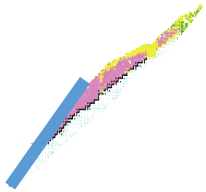
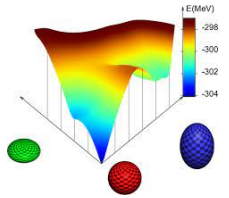
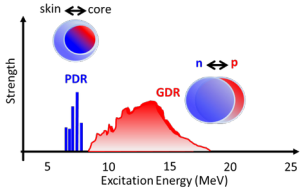
Nuclear Structure @LNL Nuclear Physics Mid Term Plan:

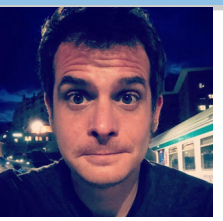
- Light and medium-mass exotic nuclei
- N~Z nuclei and isospin symmetry
- Shell evolution
- Deformation and collective modes



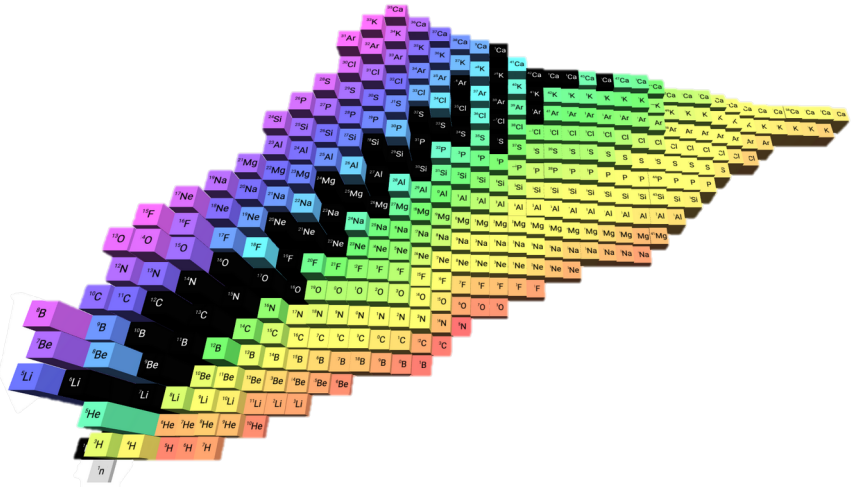






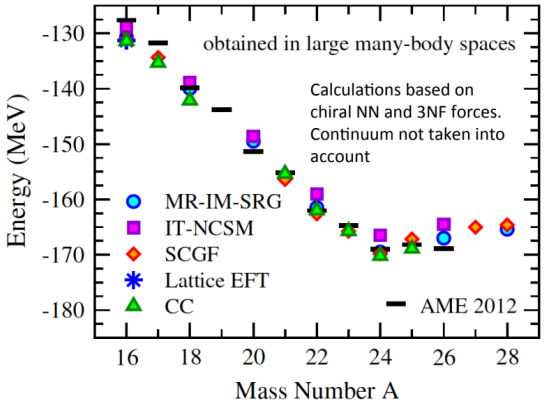


Light and medium-mass nuclei

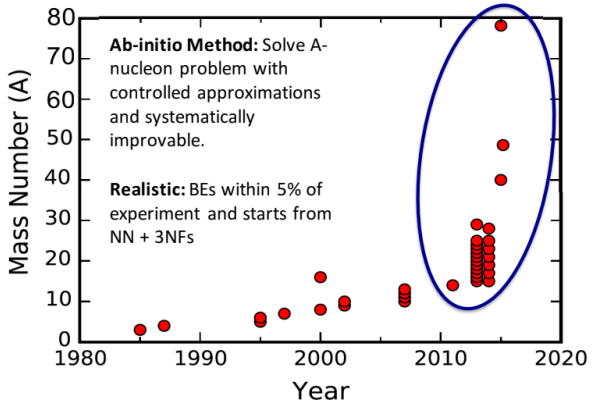


Enormous progress in theory

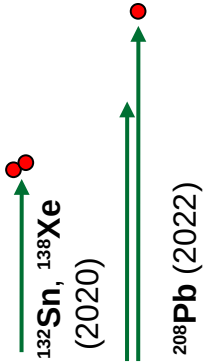
- Interaction
- models



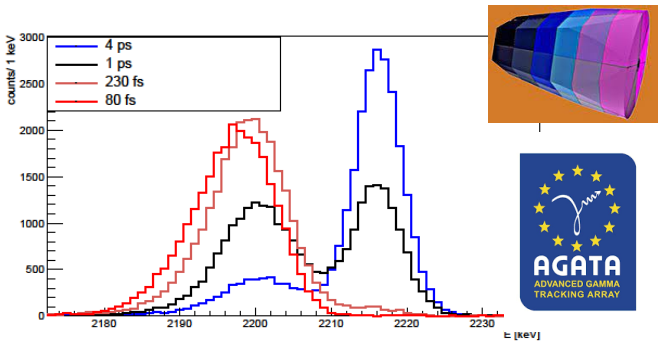
Annu. Rev. Nucl. Part. Sci. **65**, 457 (2015)



Nature Physics **12**, 186 (2016)

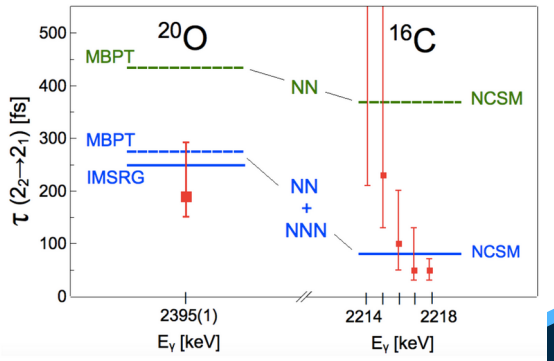


Deep-inelastic reactions with ^{18}O

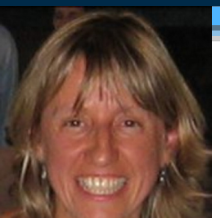


Enormous leap forward in exp techniques

- High-sensitivity to lifetime measurement thanks the tracking array tech
- Discrimination among different models

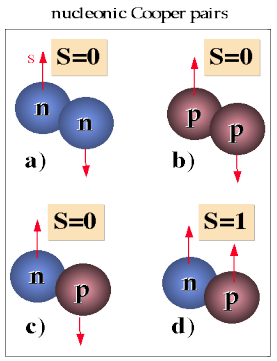


M. Ciemała , *et al.*,
Phys. Rev. C **101**, 021303(R) (2020)

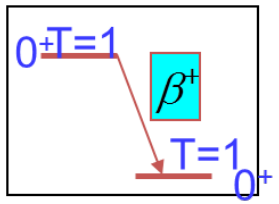


N~Z nuclei and isospin symmetry

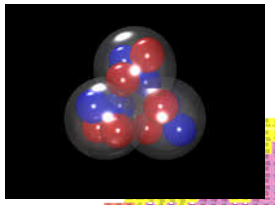
p-n pairing



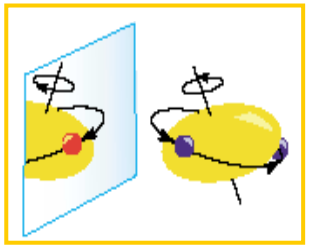
fundamental interactions



alpha clusterization

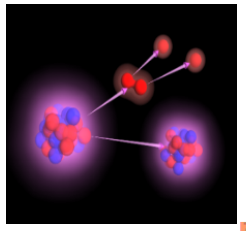


Isospin symmetry breaking

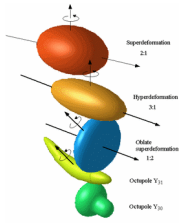


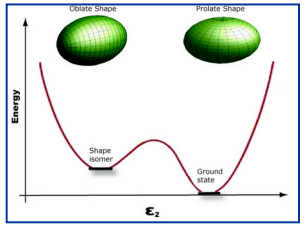
N=Z

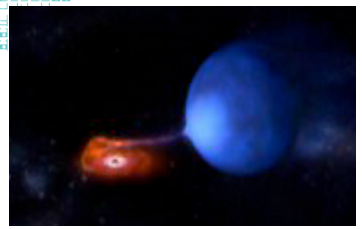
Coupling to the continuum



Nuclear shapes and coexistence







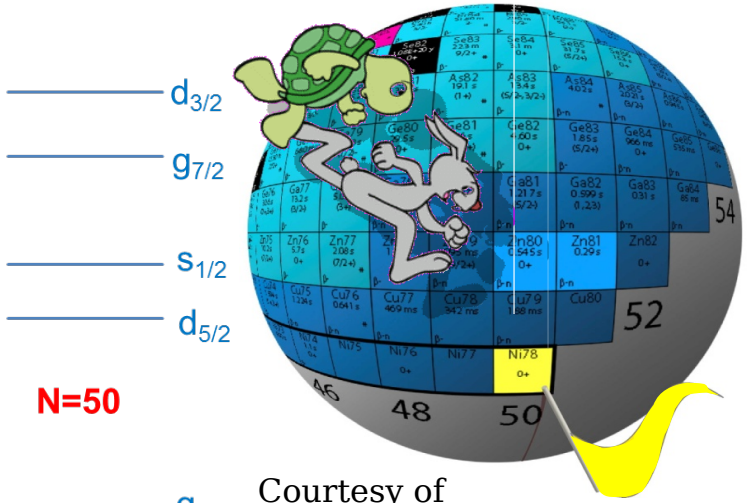
Nuclear Astrophysics

Richness of phenomena and perfect ground for *pn* interaction:

- Short term opportunities with stable beams (quadrupole collectivity); MED+TED
- Short and mid term (T=0 and quartetting)
- Longer term SiC+TiC beam development (FI)

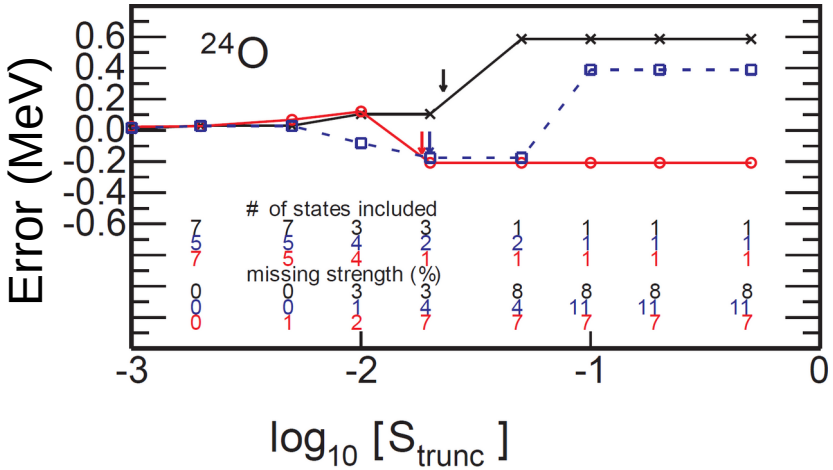
Shell evolution

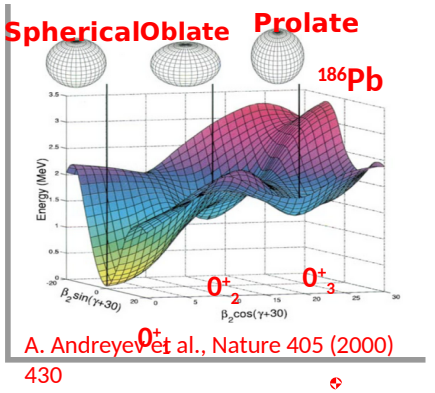
- Shell evolution around 78Ni
- Deformation and shape coexistence
- Shell evolution around 132Sn



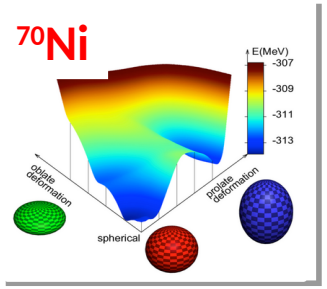
Stable beams (fission): core-coupled states and intruders
1+ SPES beams
q+ SPES beams : lifetime (plunger or DSAM) after transfer (d,p) , (d,t), coulex on intruder states

Limit of observability

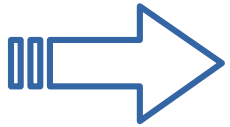




A. Andreyev et al., Nature 405 (2000) 430



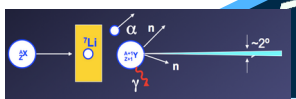
T. Tsunoda et al., Phys. Rev. C 89 (2014) 031301(R)

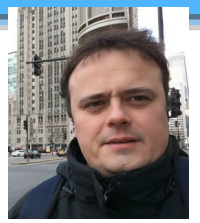


Need for <u>precision</u> measurements ..

Similar approaches for the the regions around 132Sn (~2 order of magn. more intense than currently available at ISOL facilities) key nucleus for physics and astrophysics purposes

Also with higher-l transfer → alpha transfer



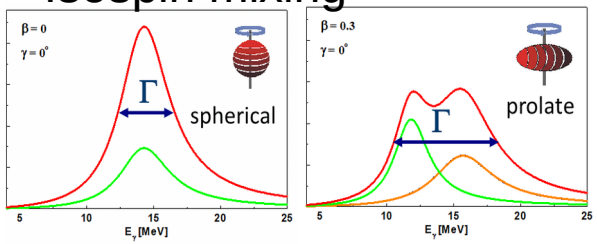


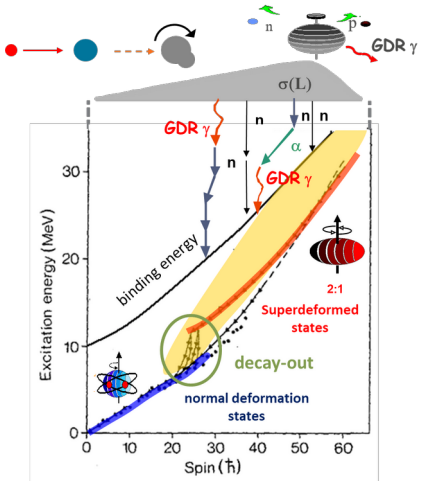
Deformation and Collective states

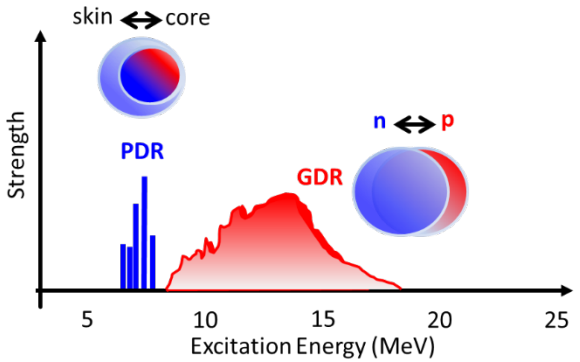
<u>Simplicity from complexity and relevant implications on nuclear matter and astrophysics.</u>

Isovector Electric Giant Dipole Resonance that can be understood as a density oscillation of neutrons against protons. *This is also a perfect example of how a complex quantum system like the atomic nucleus can exhibit very simple collective configurations.*

GDR/GQR
Jacobi shape
Isospin mixing

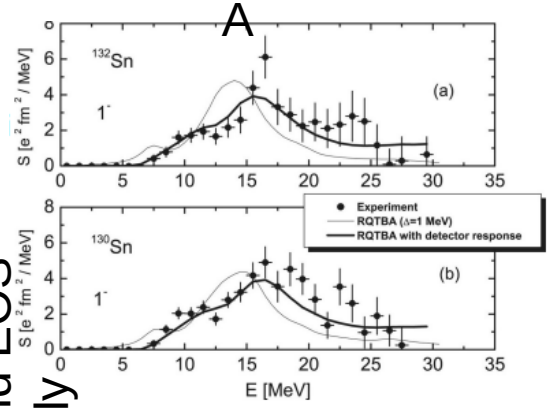






PDR,PQR, with stable, SPES 1+ and q+
(α,α'), (p,p')
(d,p), (d,t)

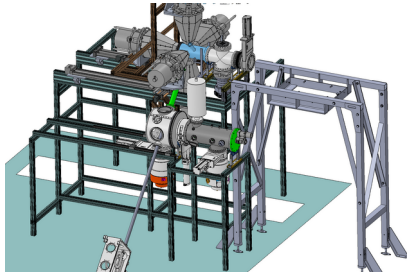
QRPA



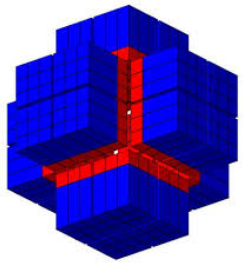
Shapes and EOS consistently

X.Roca-Maza, N.Paar Rep Part and Nuc Phys. 101 (2018) 96

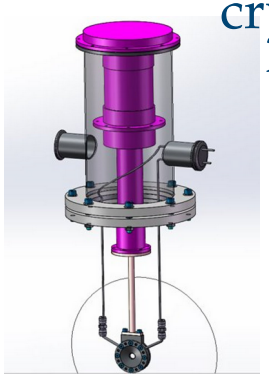
β-decay
station



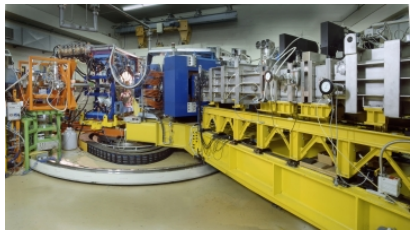
PARIS
γ-rays



CTADIR
cryogenic
target

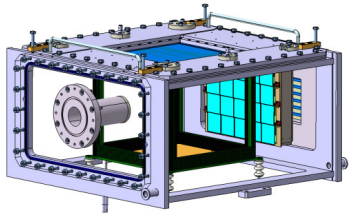


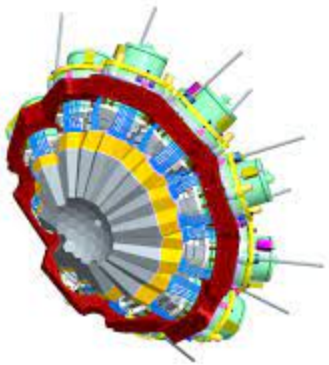
PRISMA
heavy ions



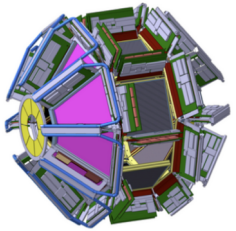
Forefront contemporary nuclear structure needs ground-breaking integrated systems

ACTIVE TARGETS

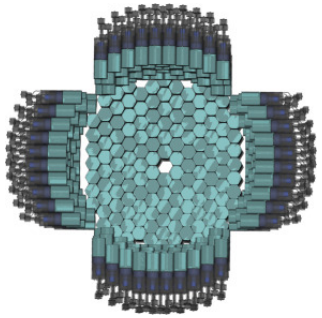




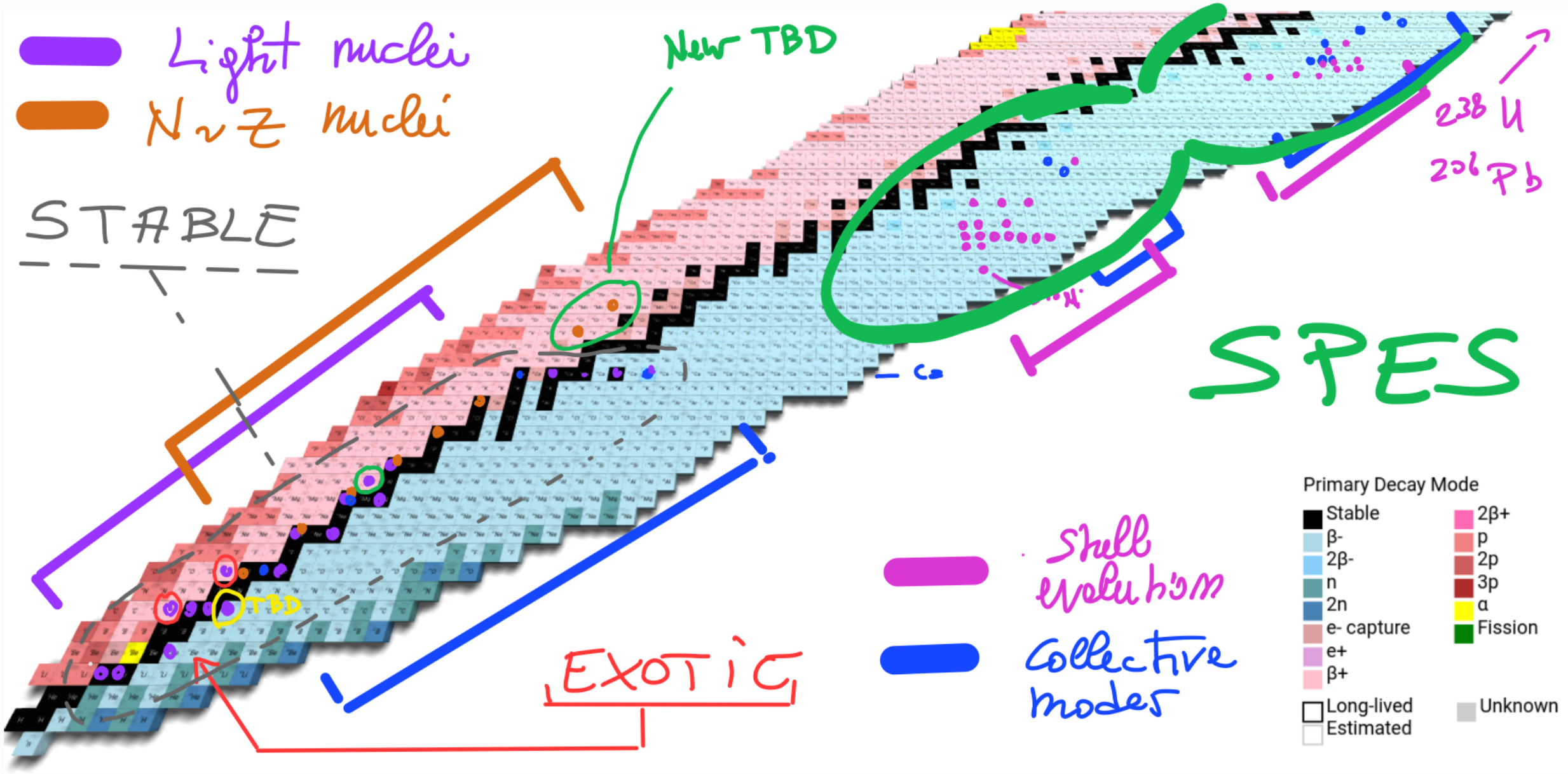
AGATA
γ-rays



GRIT
charged particles



NEDA
neutrons

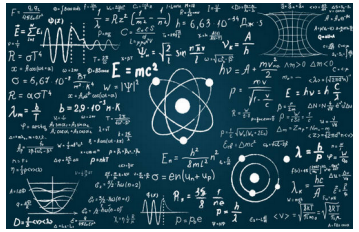

Light nuclei
N~Z nuclei
STABLE
New TBD
238 U
208 Pb
SPES
TBD
EXOTIC
Shell evolution
Collective modes
Primary Decay Mode
Stable
β-
2β-
n
2n
e- capture
e+
β+
2β+
p
2p
3p
α
Fission
Long-lived
Estimated
Unknown

time ... 

	A	B	C
Light and medium mass exotic nuclei	γ decay from near-threshold states	Particle decays from cluster states	γ decay from near-threshold states Nucleon correlations and molecular orbitals Isoscalar Giant Monopole Resonance in light deformed nuclei Proton excitations and 0+ states in Ar isotopes
N~Z nuclei	Isospin symmetry breaking, shape coexistence – lifetime measurements	Fundamental interactions (precision measurement of mirror beta decay branching ratios) T=0 vs T=1 p-n pairing	
Shell Evolution	New theory developments for shell structure Shell-evolution around N=50: shape coexistence and gap reduction towards 78Ni	Shape coexistence and type II shell evolution around N=60 in Zr, Sr	Lifetimes after transfer reactions for interplay of deformation and single particle Shell-evolution at N=82 around 132Sn
Deformation and Collective modes	GDR/GQR gamma+particle decay, Jacobi shape	PDR (alpha scattering inv. kin. with different stable nuclei and SPES beams) and PDR Beta Decay	

- The **International community** extensively participated to the mid-term plan for the nuclear structure at LNL, addressing a rich panorama of physics opportunities, encompassing shell evolution and collective phenomena, properties of light and medium-mass exotic nuclei and N~Z nuclei.

- Complementary **experimental techniques** and cross approaches to the workings groups, assisted by **theoretical guidance,** led to define challenging physics goals to **boost our understanding of exotic nuclei**



- The presence and support of **cutting-edge instruments** (AGATA, GRIT, NEDA, PARIS, CTADIR, PRISMA, ACTAR, ..) are key to achieve the physics objectives that have emerged

- The development of **new beams**, the availability of **exotic targets** as well as the operation of new accelerator complex **SPES** would guarantee a leading position to the laboratory within the panorama of nuclear structure community