## General perspectives of physics with Radioactive Ion Beams from SPES

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Statement of the Scientific Advisory Committee (May 29, 2014)

- The SAC was impressed with the number of LOI's and the broad scientific spectrum proposed to be studied with the SPES Radioactive Ion Beams (RIB).
- ....the preparation of the experimental program, including the necessary instrumentation
- The involveme the plans to bri

### Outline

- Physics Questions
- Developments in nuclear-structure theory

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- Generalities of RIB research -> SPES
- Examples from ISOLDE
- Go and downlc
  General conclusion
- Focus on changes since 2014 and put some other emphasis

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nfeld Icléaire - Orsay
reactions and Multinucleon transfe ion

The concluding remains

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#### The Nuclear Landscape and Key Question in Nuclear Physics Research (see also NuPECC LRP (A. Bracco))

- How are complex nuclei built from their basic constituents and the fundamental interactions at work in nuclear matter?
- How to explain collective properties from individual nucleon behavior?
- How and where are the elements made?



"Challenges in nuclear structure theory" W. Nazarewicz, J. Phys. G 43 (2016) 044002

"...Three pillars of modern research with nuclei: experimentation, analytic theory, and computer simulations..."



LQCD

**Degrees of Freedom** 

constituent guarks

Resolutio



- (see e.g. Ekstrom,PRL 110, 192502 (2013))
- New many-body methods extending to heavier masses
- G. Hagen, "Structure of <sup>78</sup>Ni from first principles computations" PRL accepted

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#### Energy Density Functional calculations

McDonnell,- PRL 114, 122501 (2015) "Uncertainty Quantification for Nuclear Density Functional Theory and Information Content of New Measurements" Tarpanov,- PRL 113, 252501 (2014) "Spectroscopic Properties of Nuclear Skyrme Energy Density Functionals"

#### Large scale and Monte Carlo based shell model calculations

Tsunoda et al. PRC 89, 031301(R) (2014)



Togashi, - PRL accepted "Quantum phase transition in the shape of Zr isotopes"

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### **Radioactive Beam Research - experiments**





"Plumbing Neutron Stars to New Depths with the Binding Energy of the Exotic Nuclide  $^{82}Zn$  (N=52) (T<sub>1/2</sub> < 0.5 s)" (Wolf PRL 2013)





Goriely,- PRC (2010).

HFB-19

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#### 10 Van De Walle, PRL 2007, PRC 2009

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LASER ON

## <sup>66</sup>Ni(d,p)<sup>67</sup>Ni





- 100 μg/cm<sup>2</sup> CD<sub>2</sub> target
- <sup>66</sup>Ni beam: 3 10<sup>6</sup> pps 2.85 MeV/u
- > 99% pure beam (RILIS)
- Q = 3.583 MeV
- Wealth of proton-γ-γ coincidence data

J. Diriken, PLB 2014 - PRC 2016 R. Orlandi, PLB (2015) (<sup>78</sup>Zn(d,p)<sup>79</sup>Zn)



**Relative SFs** 



- Identified  $d_{5/2}$  (and  $s_{1/2}$ ) single-particle strength at 'low' excitation energy
- Comparison with shell model calculations (LNPS int. [1]) and with <sup>88</sup>Sr(<sup>3</sup>He,d)<sup>89</sup>Y (Z=39, N=50)
  - d<sub>5/2</sub> fragmented but shifted (around 1 MeV) at higher energy

#### 12 [1] S. Lenzi et al., PRC82 054301 (2010)

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50

40

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Experiment consistent with 0<sup>+</sup><sub>2</sub> in <sup>68</sup>Ni being a two-neutron excitation above N=40



13 Wimmer PRL(2010), Nowak PRC (2016), Elseviers to be published

#### Some general statement of Radioactive Ion Beam (RIB) Science

- RIB science started 50 years ago with low-energy beams and experiments followed 20 years later by energetic beams (in-flight and ISOL)
- These five decades were characterized by identification of many new isotopes and several discoveries that have advanced our understanding discovery frontier of RIB science
- The low-energy RIB program moved towards precision experiments
- The high energy RIB program is entering the era of higher statistics
  precision frontier of RIB science
- This is certainly one area where **SPES** can play a very important role.





## The ISOL roadmap in Europe – EURISOL Distributed Facilities (see talk Sara Pirrone)

#### Goals of the EURISOL-DF

- Prepare strong scientific case for RIB science and applications
- Support, upgrade, optimize and coordinate ISOL-based European facilities and projects as a necessary step towards EURISOL
- Foster R&D on RIB production and Instrumentation towards EURISOL
- Get EURISOL-DF on the ESFRI list as a candidate project by 2018
- EURISOL as a single site facility as a long term goal

## EPS Divisional Conference Towards EURISOL Distributed Facility EURISOL DF 2016, Leuven, October 18-21, 2016



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## Radioactive Ion Beams for Science and Society

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# **SPES Project**

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At the heart of SPES: the cyclotron and ISOL target

Production of radionuclides for applications The acceleration of neutron-rich unstable nuclei

Multidisciplinary neutron sources

- SPES offers an excellent opportunity for research in the "precision frontier" and can address important physics questions (beam intensity, purity and time)
- Fundamental RIB research (the alpha and beta part) and new instrumentation is essential to address these physics questions
- **AND** to develop the related to applications (the gamma part)

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