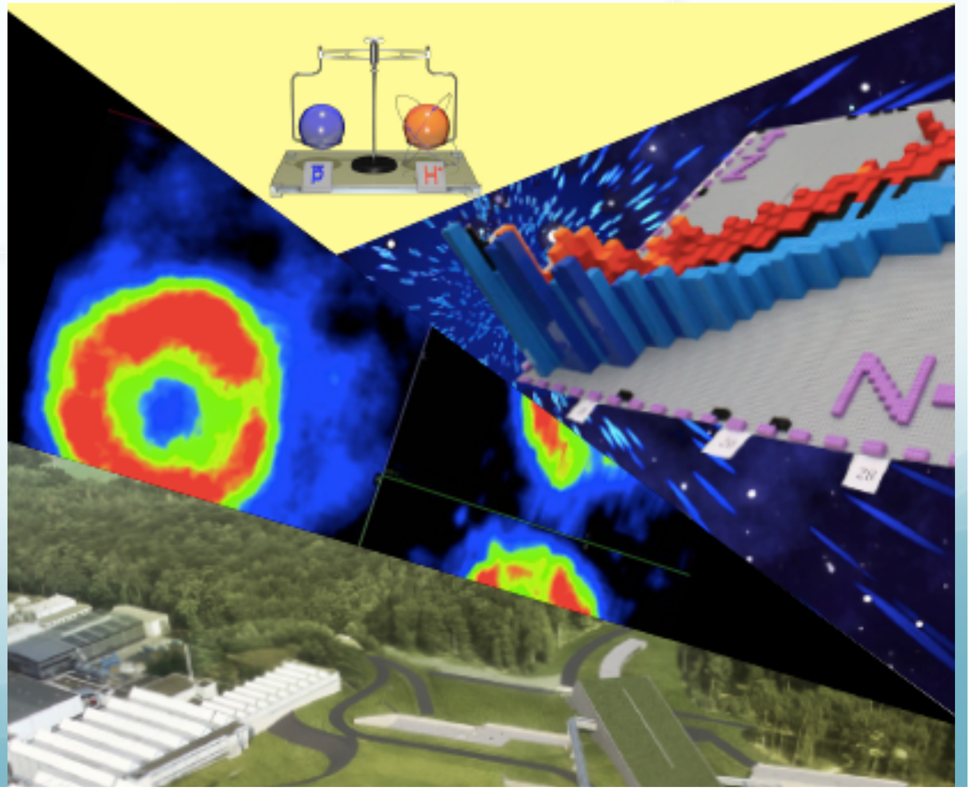
THE HENRYK NIEWODNICZAŃSKI
INSTITUTE OF NUCLEAR PHYSICS
POLISH ACADEMY OF SCIENCES

NUPECC Long Range Plan 2017

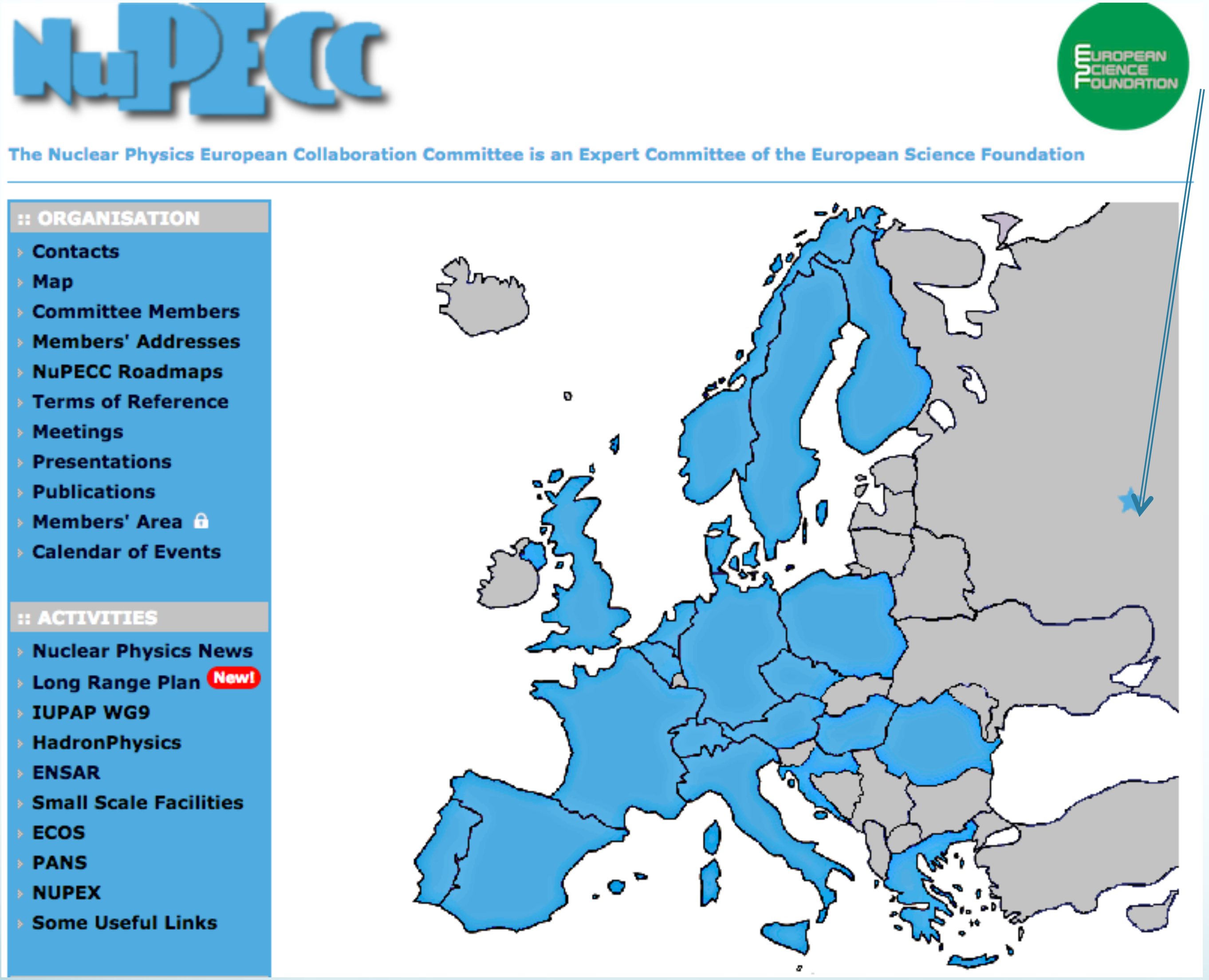
Perspektywy fizyki jądrowej w Europie

Adam Maj
IFJ PAN Kraków



Zakłąd Fizyki Jądrowej UW
Warszawa, 2 marca 2017

NUPECC - The Nuclear Physics European Collaboration Committee



Joint Institute for Nuclear Research Dubna- Recently joined

Request from Turkey and Israel

exchanges with

- AnPHA
- NSAC (mutual)
- Canada

+ ALAFNA

21 countries – 31 Members

List of Members

	Navin ALAHARI	Caen (FRANCE)
	Nicolas ALAMANOS	Gif-sur-Yvette (FRANCE)
	Eduardo ALVES	Lisboa (PORTUGAL)
CV	Maria BORGE	Madrid (SPAIN)
CV	Angela BRACCO	Milano (ITALY)
	Pierre DESCOUVEMENT	Brussels (BELGIUM)
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CV	Jens GAARDHØJE	Copenhagen (DENMARK)
	Paolo GIUBELLINO	Darmstadt (GERMANY)
	Andreas GÖRGEN	Oslo (NORWAY)
	Paul GREENLEES	Jyväskylä (FINLAND)
	Sotirios HARISSOPULOS	Athens (GREECE)
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	Mikhail ITKIS	Dubna (RUSSIA)
	Tord JOHANSSON	Uppsala (SWEDEN)
	Klaus JUNGMANN	Groningen (THE NETHERLANDS)
	Bernd KRUSCHE	Basel (SWITZERLAND)
	Karlheinz LANGANKE	Darmstadt (GERMANY)
	Marek LEWITOWICZ	Caen (FRANCE)
	Adam MAJ	Krakow (POLAND) *(Delegowany przez Prezesa PAN: 2011-2014, 2015-2018)*
CV	Ulf-G. MEISSNER	Bonn (GERMANY)
	Matko MILIN	Zagreb (CROATIA)
	Alexander MURPHY	Edinburgh (UNITED KINGDOM)
CV	Eugenio NAPPI	Bari (ITALY)
CV	Christelle ROY	Strasbourg (FRANCE)
	Raimond SNELLINGS	Utrecht (THE NETHERLANDS)
	Hans STRÖHER	Jülich (GERMANY)
	Ioan URSU	Bucharest (ROMANIA)
CV	Jochen WAMBACH	ECT* Trento (ITALY)
CV	Eberhard WIDMANN	Wien (AUSTRIA)
	György WOLF	Budapest (HUNGARY)

NuPECC Chair,

CV	Angela BRACCO	Milano (ITALY)

Scientific Secretary

	Gabriele-Elisabeth KÖRNER	NuPECC München (GERMANY)

Główne zadanie NUPECC to wzmocnienie europejskiej współpracy w dziedzinie fizyki jądrowej poprzez m.in. promowanie fizyki jądrowej, wykorzystanie jej w transdyscyplinarnych naukach oraz zastosowaniach, we ścisłym kontakcie z grupami badawczymi w Europie.

Zebrania odbywają się przynajmniej 3 razy w roku, w różnych krajach członkowskich

http://www.nupecc.org

Publikacje NUPECC w ostatnich 6 latach

- **NUPECC Report „International Access to Nuclear Physics Facilities in Europe (6th Edition):**
  http://nupecc.org/pub/hb12/hb2013.pdf
- **NUPECC Report „Nuclear Physics for Medicine”:**
  http://nupecc.org/pub/npmed2014.pdf
- **NUPECC Brochure „Nuclear Physics for Medicine”:**
  http://nupecc.org/pub/npmed2014_brochure.pdf
- **NUPECC Brochure „Light to Reveal the Heart of Matter”:**
  http://nupecc.org/pub/np_light_2015.pdf
- **Nuclear Physics News (4/rok)**

Projekty europejskie: ENSAR2 i Hadron Physics Horizon

ENSAR2 (już jest finansowany): 1.3.2016 – 1.3.2020
(10 mln. Euro_

Polski udział: UW (IF+ŚLCJ) i IFJ PAN Kraków
(Ponad 300 tys. Euro)

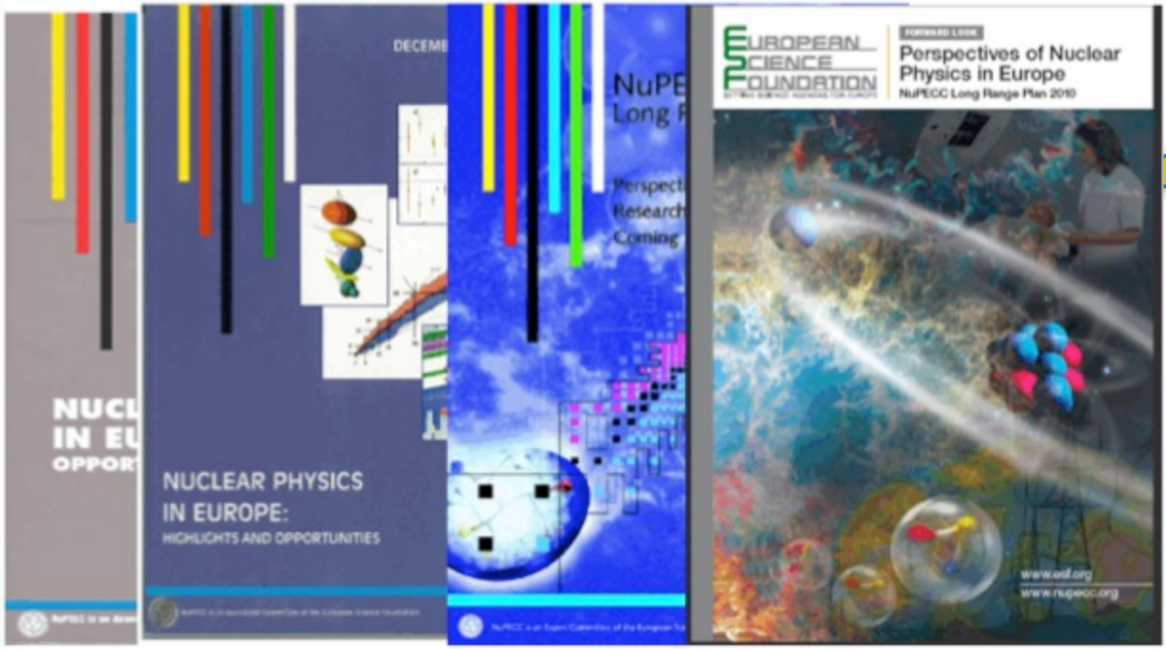
TNA:
GANIL-SPIRAL2 (France), LNL-LNS (INFN, Italy), ISOLDE (CERN, Switzerland)
JYFL (Finland), ALTO (CNRS, France), GSI (Germany), KVI-CART (The Netherlands)
NLC (HIL/IFJ PAN, Poland), IFIN-HH/ELI-NP (Romania), ECT* (Italy)
NA: FISCO2, NuSPRASEN, MIDAS, NUSPIN, MediNet, GDS, ENSAF, NuPIA
JRA: PASPAG, PSeGe, TheoS, RESIST. SATNuRSE, EURISOL, TecHIBA

Hadron Physics Horizon nie został na razie zakwalifikowany do finansowania

Long Range Plan 1991-2010

Perspectives of Nuclear Physics in Europe

1991 1997 2004 2010



- **Volume**
- **Brochure**
- **video**

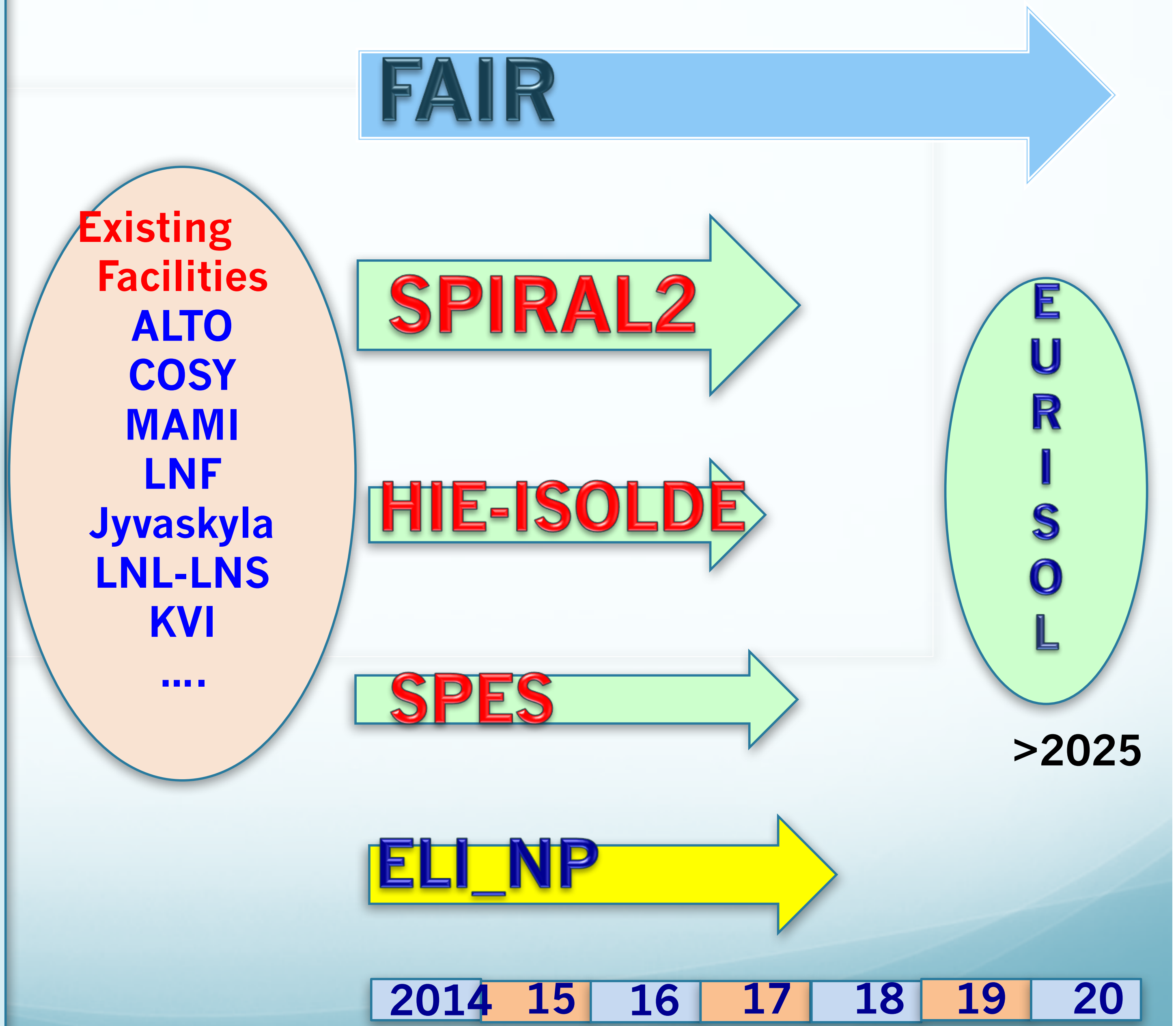
- The progress in Nuclear science in Europe has been guided by LRP providing a framework for coordinated advances

- The LRP put in evidence opportunities and priorities for the reaserch in this field

NuPECC LRP (2010)

- FAIR and SPIRAL2 (ESFRI)
- HIE-ISOLDE and SPES
- ALICE at CERN
- Existing Laboratories + Luna
- Instrumentation (AGATA)
- Theory
- Applications
- New ESFRI fac.

New Facilities and Major upgrades



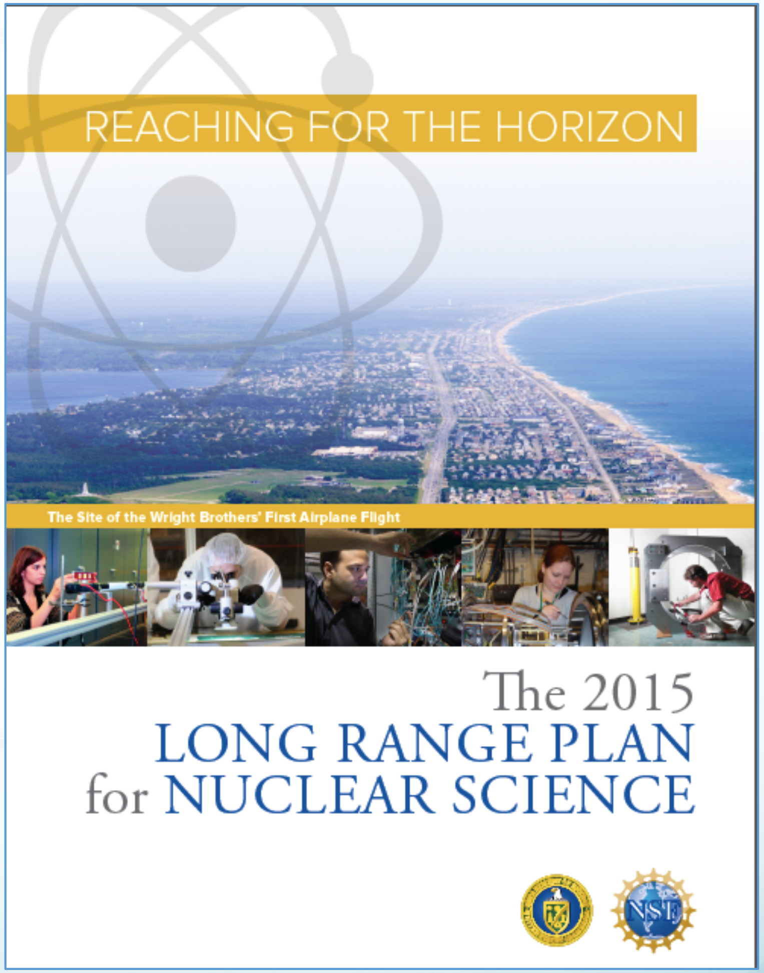
Shifts in time as compared with 2009

After 6 years a new Long range plan is needed

- The plans made in 2009 (published in 2010) are not yet fully realized

- Changes and delays in the original plans for major facilities are ongoing.

The 2015 NSAC Long Range Plan
Reaching to the Horizons



NuPECC was invited to present the European status-

SUBJECTS FOR LRP 2017

- What are the main objectives ?
- What are the main topics defining the field of Nuclear Physics ?
- What are the main key questions to be addressed?
- Wide field….what are the common issues and the coherent actions that are needed?

Motto:

the physics of nuclei is fundamendal in our undestanding of the universe and is interwined in many different aspects of our lives

LRP - Objectives

- **Review** status of the field

- Issue **recommendations** to advance
  The science
  Its applications in Europe

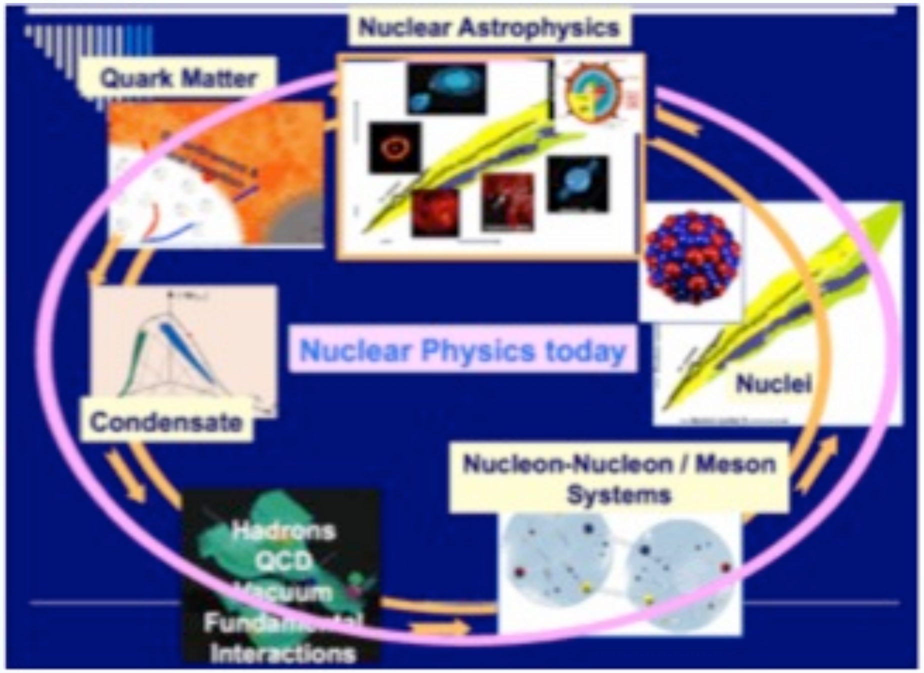
- Develop **action plan (roadmap) for:**
  Building new large-scale Research Infrastructures
  Upgrading existing Nuclear Physics facilities
  Collaborate closely with smaller scale facilities

- support **EU** projects (IAs, ERA-net ……)

- Put European Nuclear Physics into **global context**

For that contacts with : NSAC (DoE & NSF) in USA, ANPhA in Asia, ALAFNA in Latin America IUPAP and OECD Global Science Forum -

LRP 2016 - structure



1) Hadron Physics
2) Phases of Strongly Interacting Matter
3) Nuclear Structure & Dynamics
4) Nuclear Astrophysics
5) Fundamental Interactions
6) Nuclear Physics Tools & Applications

- **Facilities status**
- **Summary and recommendations**

6 chapters on the achievements and specific plans concerning these different themes

Przygotowywanie wydania NuPECC Long Range Plan 2016

LRP2016/2017 Working Groups

Working Group	Conveners	NuPECC Liaison Members	Członkowie z Polski
Hadron Physics	Diego Bettoni Hartmut Wittig	Bernd Krusche Tord Johansson Eberhard Widmann	T. Matulewicz P. Salabura
Properties of strong-interaction matter	Silvia Masciocchi François Gélis	Eugenio Nappi Christelle Roy Raimond Snellings	W. Florkowski
Nuclear Structure and Reaction Dynamics	John Simpson Elias Khan	Adam Maj Faiçal Azaiez Ari Jokinen	B. Fornal
Nuclear Astrophysics	Gabriel Martinez Pinedo Alison Laird	Alex Murphy Maria José Garcia Borge Pierre Descouvement	Ch. Mazzochi
Symmetries and Fundamental interaction	Klaus Kirch Klaus Blaum	Joakim Nystrand Hans Ströher	K. Bodek K. Pachucki
Applications and societal benefits	Marco Durante Alain Letourneau	Jan Dobeš Nicolas Alamanos Ioan Ursu	J. Jagielski

NuPECC Long Range Plan 2017, Town Meeting

http://indico.gsi.de/conferenceDisplay.py?confId=5177

11-13 January 2017

Wednesday, January 11, 2017	**Thursday**, January 12, 2017	**Friday**, January 13, 2017
8:00-8:45 **Registration**		
8:45-9:00 Welcome	**9:00-9:45** WG3: Nuclear Structure & Reaction Dynamics	**9:00-10:45** NSAC ANPhA CERN
9:00-9:30 Outline LRP2017 *Angela Bracco*	**9:45-10:30** Discussion WG3	
10:45-11:15 Coffee Break	10:30-11:00 Coffee Break	10:45-11:15 Coffee Break
11:15-13:00 Future Large-Scale Facilities *FAIR:* *EURISOL-DF* - *Spiral2:* - *HIE-ISOLDE:* - *SPES:* *ELI-NP:*	**11:00-11:45** WG4: Nuclear Astrophysics	**11:15-11:30** Introduction to Panel Discussion *Angela Bracco*
		11:30-12:30 Panel discussion of overall recommendations, priorities & roadmap *LRP2017 Steering Committee*
	11:45-12:30 Discussion WG4	**12:30-12:45** Farewell
13:00-14:30 Lunch	12:30-14:00 Lunch	
14:30-15:15 WG1: Hadron Physics	**14:00-14:45** WG5: Symmetries & Fundamental Interaction	
15:15-16:00 Discussion WG1	**14:45-15:30** Discussion WG5	
16:00-16:30 Coffee Break	15:30-16:00 Coffee Break	
16:30-17:15 WG2: Properties of Strong-Interaction Matter	**16:00-16:45** WG6: Applications & Societal Benefits	
17:15-18:00 Discussion WG2	**16:45-17:30** Discussion WG6	
18:00-20:00 **Welcome Reception**		

darmstadtium
Room 3.0234 europium3
Schlossgraben 1
64283 Darmstadt
Germany

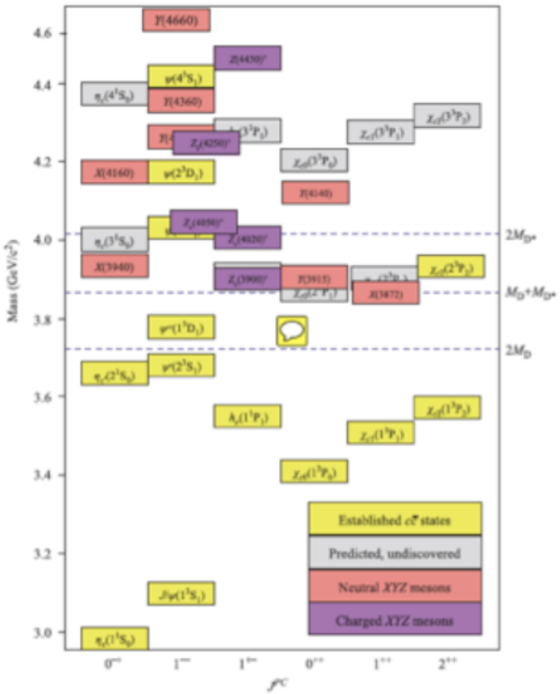
WG1. HADRON PHYSICS

1. **Introduction** (1.5 pages*)
2. **Theoretical framework** (2 pages)
3. **Experimental Methods** (1 page)
4. **Hadron Spectroscopy** (5.5 pages)
5. **Hadron Structure** (9.5 pages)
6. **Hadronic Interactions** (4 pages)
7. **Lattice QCD** (2 pages)
8. **Physics Perspectives** (3 pages)
9. **Recommendations** (1.5 pages)

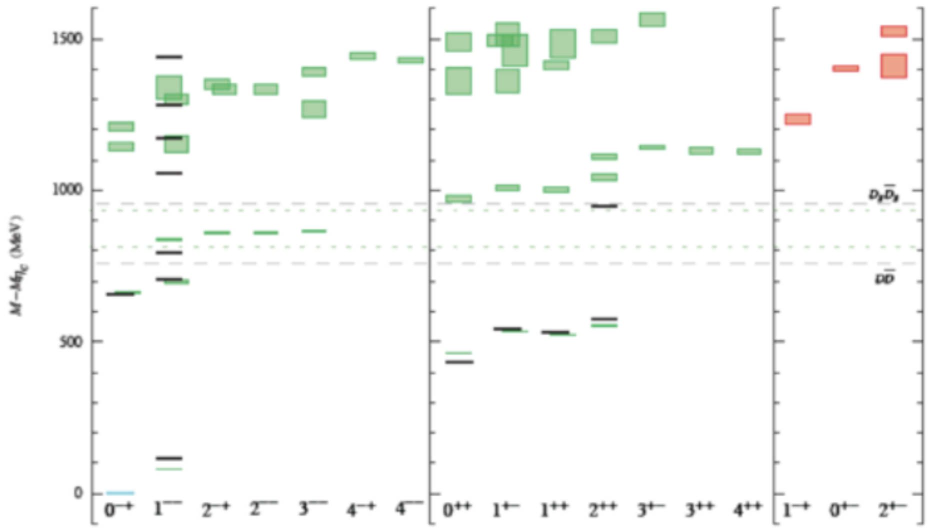
Subsection: Hadron Spectroscopy

* General introduction
* Heavy quarks: X, Y, Z states in the charmonium sector

Spectrum of X, Y, Z states



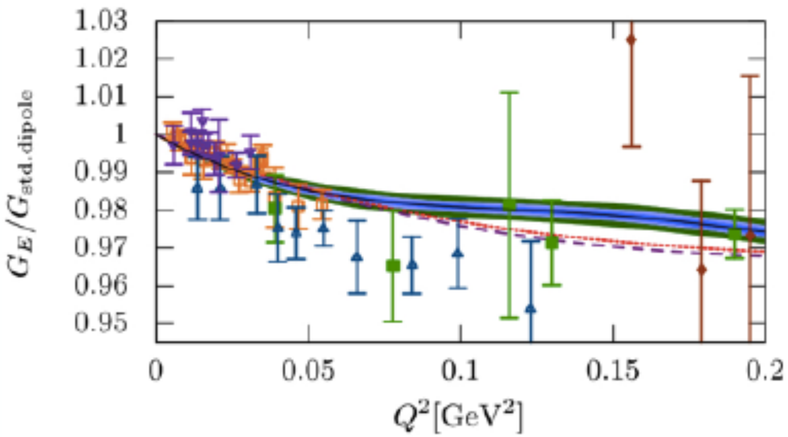
Charmonium spectrum from lattice QCD



Subsection: Hadron Structure

- Nucleon form factors:
  - Proton radius puzzle —> WG 5
  - G_E/G_M: Rosenbluth separation versus recoil polarisation
  - time-like versus space-like momentum transfers
  - strangeness and weak form factors; parity-violating asymmetries

Proton electric form factor

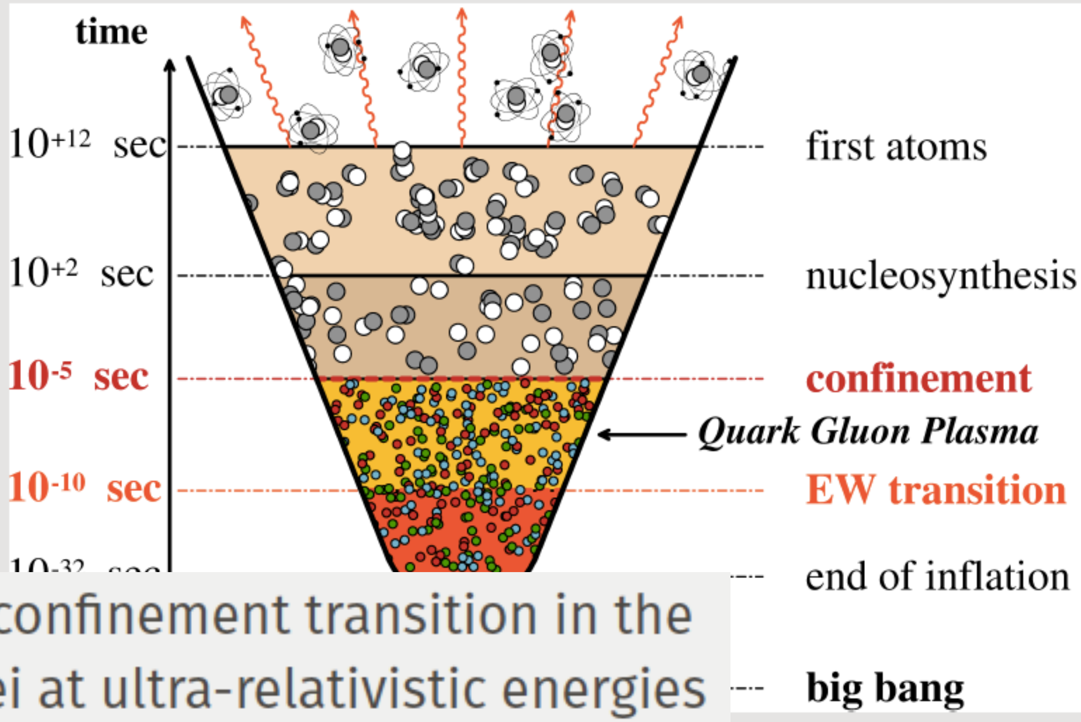


PRELIMINARY Recommendations of WG1:

- Completion of PANDA@FAIR
- Support for a research programme in precision physics at existing facilities
- Support for theory and computing

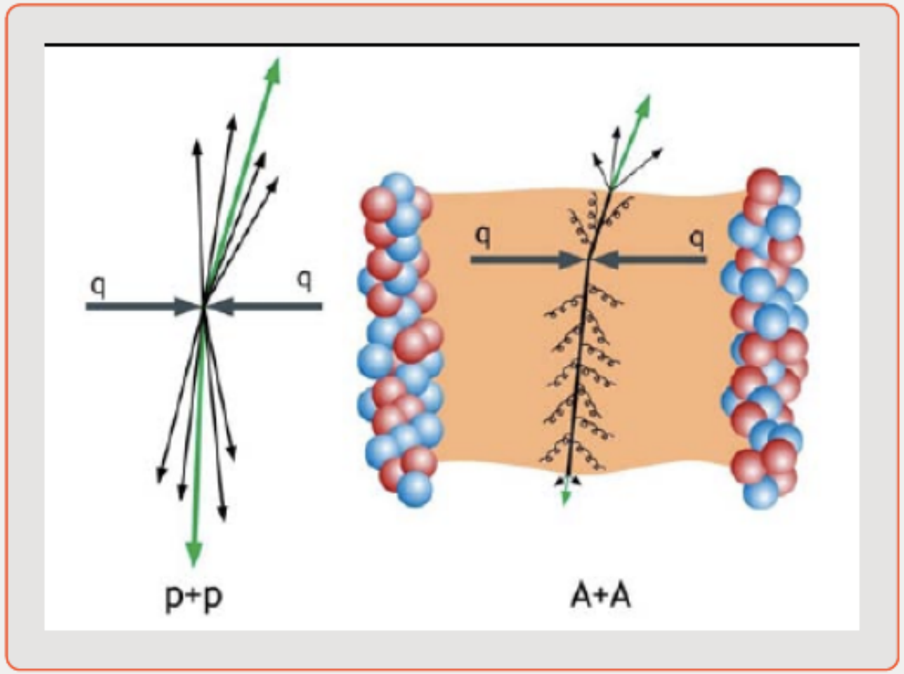
WG2. PROPERTIES OF STRONGLY-INTERACTION MATTER

1. Introduction
2. High-Temperature matter
3. High-Density matter
4. Computing, facilities and instrumentation
5. Recommendations



Recreate the conditions of the deconfinement transition in the laboratory by colliding large nuclei at ultra-relativistic energies

ENERGY LOSS, JET QUENCHING



- The QGP enhances the radiative energy losses of hard partons
  $\Longrightarrow$ use these observables as a "tomographic" tool

PRELIMINARY Recommendations of WG2:

- **Completion of FAIR (SIS-100, CBM, SIS-300)**
- **Construction of NICA**
- **Continuous support of theory**
- **....**

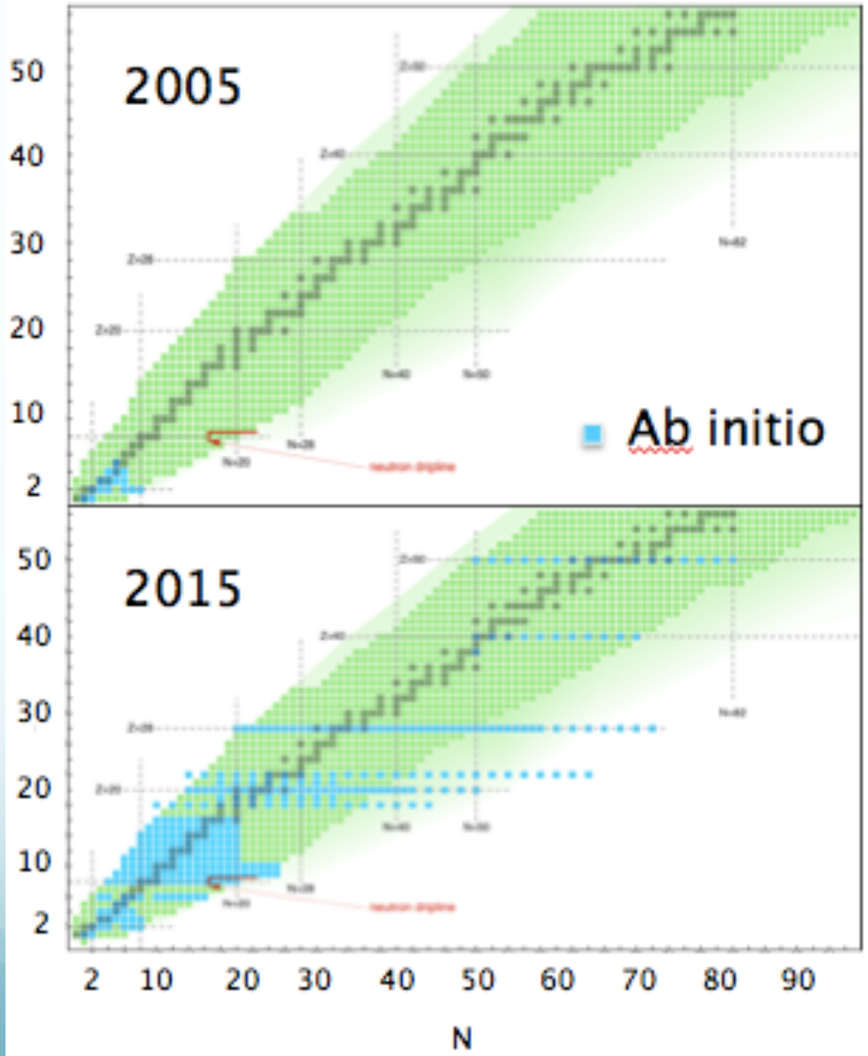
WG3. NUCLEAR STRUCTURE AND REACTION DYNAMICS

Key Questions

- *How does the nuclear chart emerge from fundamental interactions?*
- *How does nuclear structure evolve across the nuclear landscape and what shapes can nuclei adopt?*
- *How does the structure change with temperature and angular momentum?*
- *How to unify nuclear structure and reaction approaches?*
- *How complex are nuclear excitations?*
- *How do correlations appear in dilute neutron matter, both in structure and reactions?*
- *What is the density and isospin dependence of the nuclear equation of state?*

Achieving a unified description of all nuclei

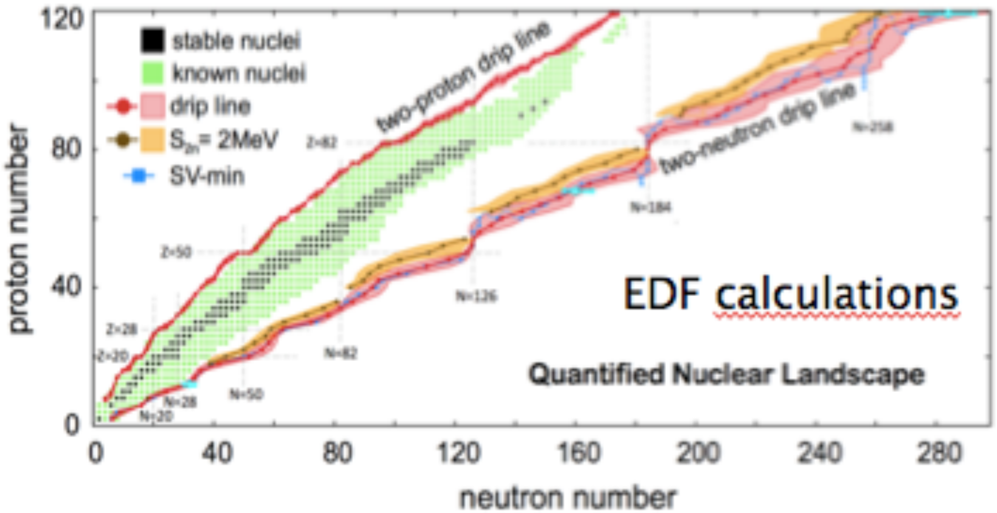
Increased reach of ab initio methods



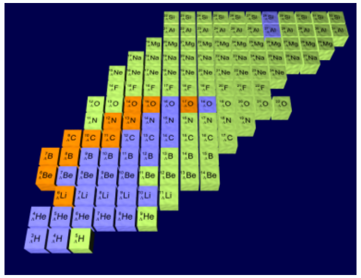
How does the nuclear chart emerge from the underlying interactions?

Nuclear structure theory has evolved into a field with

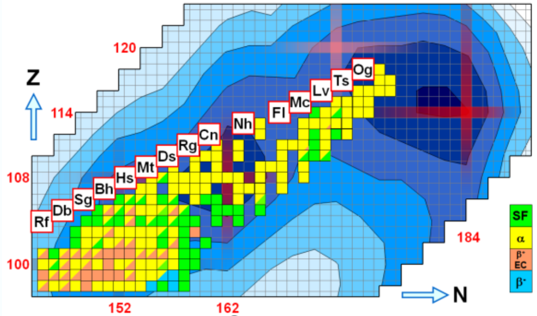
- a systematic theoretical foundation
- new and advanced few- and many-body methods with controlled uncertainties



Topics (selected)



Hypernuclei



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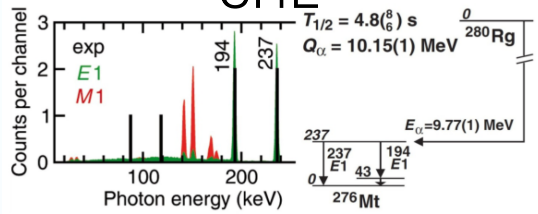
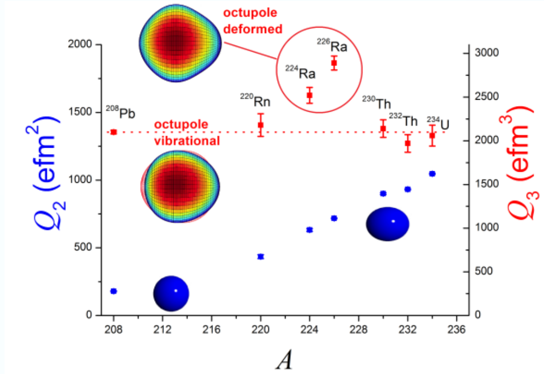
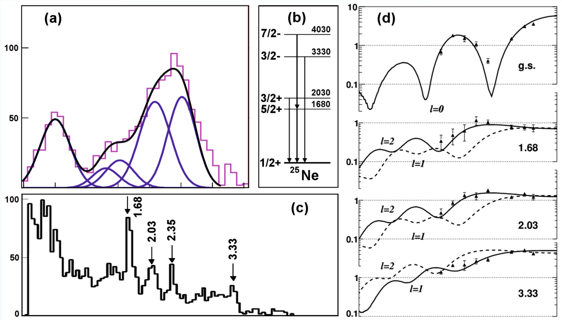
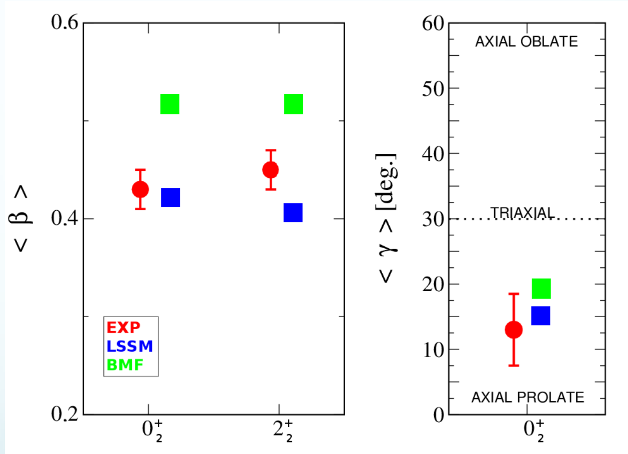




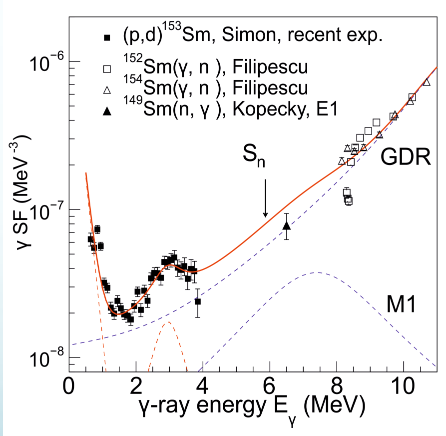
Shapes Rn



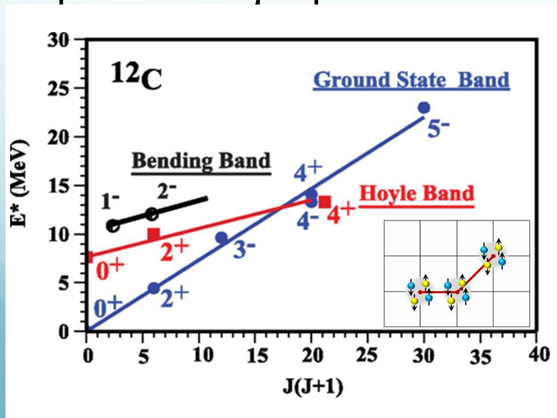
Transfer reactions, particle-γ spec ^{25}Ne



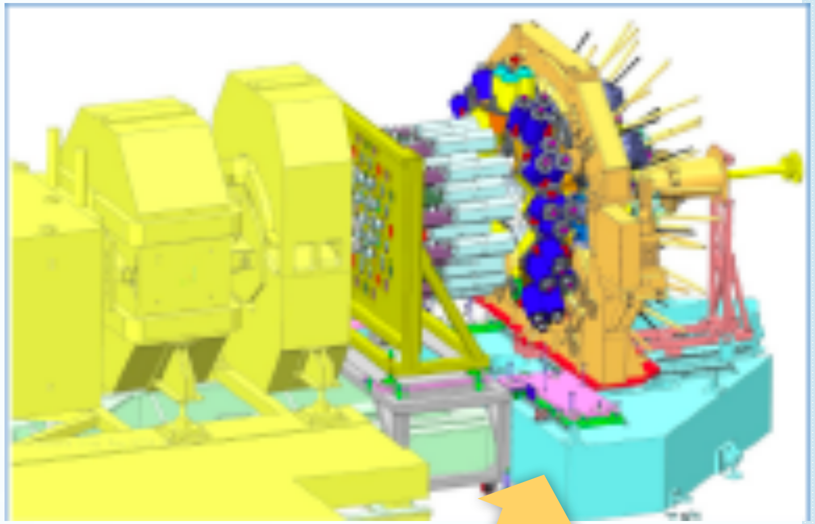
Shapes ^{42}Ca, triaxial-SD



γ strength function



Hoyle band



Permanent instrumentation

Traveling instrumentation

Accelerator facilities

RIB Facilities, Stable-beam, Gamma-beam

Instrumentation:

Separators, spectrometers and associated detection for the identification

Detectors for structure and dynamic studies

Gamma detectors (AGATA, PARIS,..)

Particle detectors (FAZIA,….)

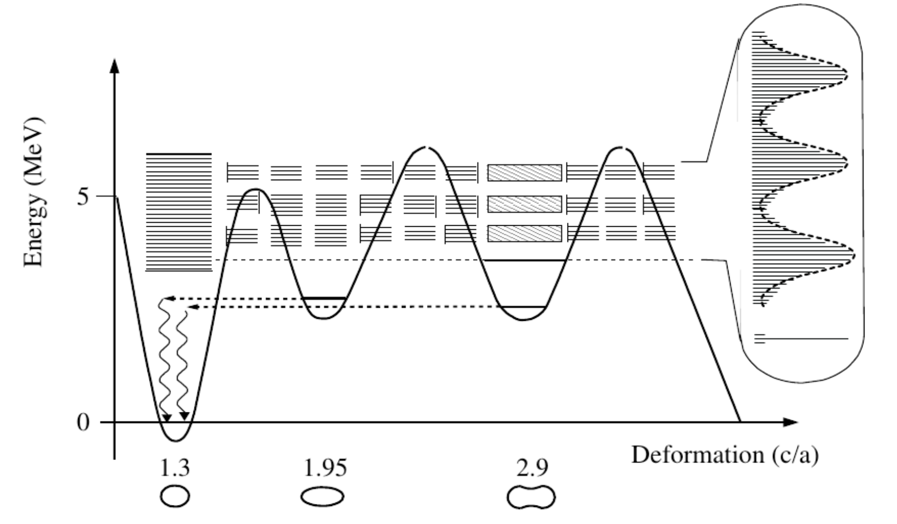
Neutron detectors (NEDA,…._

Active targets (ACTAR TPC)

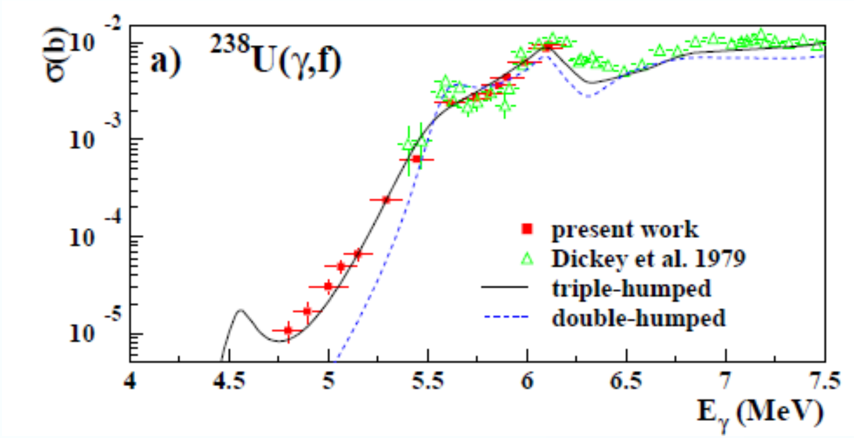
Trap and laser

Storage Rings

Accessing extreme deformation and rare fission modes



- ✓ Studies of the 2nd and 3rd minimum of the fission barrier
- ✓ Photofission cross section measurements, rare fission modes, ternary fission



PRELIMINARY Recommendations of WG3:

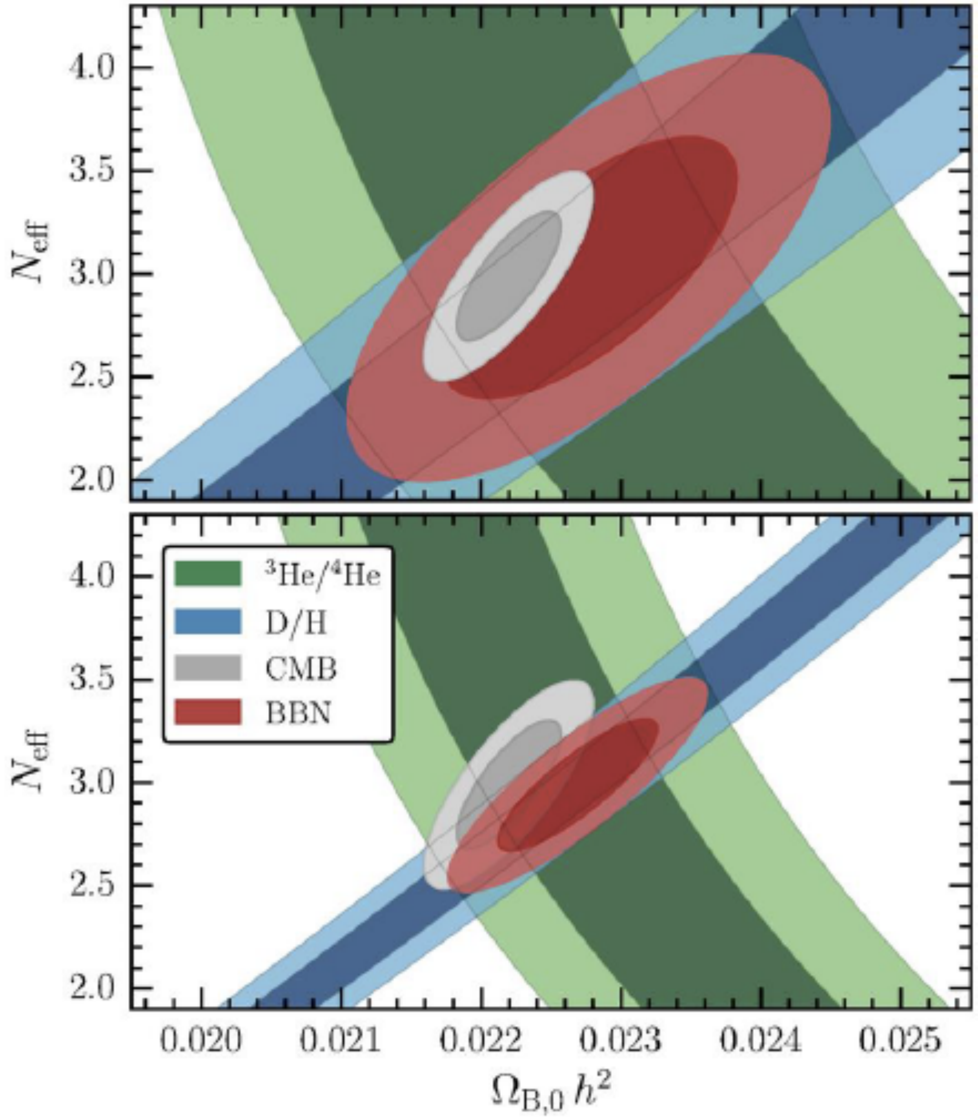
- Completion of radioactive beam facilities (FAIR, SPIRAL2, SPES, HIE-ISOLDE)
- Support for EURISOL-DF initiative
- Photon (ELI-NP) and stable beam facilities (a.o. NLC: Warsaw-Krakow,)
- Novel Instrumentaion: AGATA, FAZIA, PARIS, NEDA,...
- Strong support for Theory development

WG4. NUCLEAR ASTROPHYSICS

- What are the nuclear processes that drive the evolution of the stars, galaxies and the Universe?
- Where are the building blocks of life created?
- What are the different nucleosynthesis processes and how do they evolve with time?
- What is the nature of matter at extreme conditions and densities? Can multi-messenger observations provide access to conditions not reached at present laboratories?

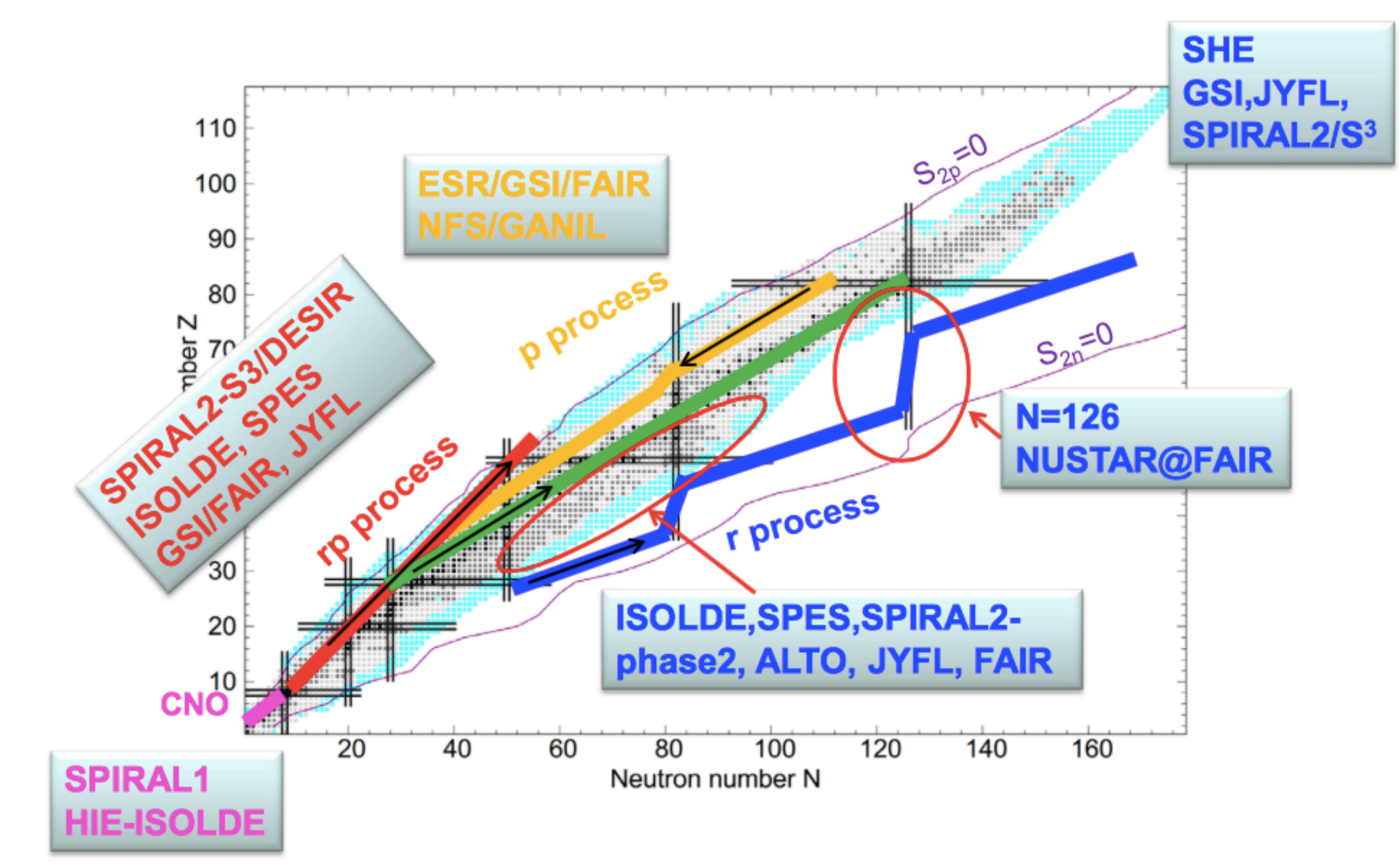
Opportunities: precision frontier

- Both Big Bang Nucleosynthesis and Solar Models have achieved such precision that nuclear reactions at 1% precision level are required.
- Achievable by a combination of experiment and theory:
  - Higher intensities at the LUNA underground facility
  - Ab-initio calculations based on chiral effective field theory
- BBN will probe New Physics in the early Universe at a level competitive to CMB observations
- Solar models will address the "Solar abundance problem" by providing accurate predictions of CNO neutrino fluxes (Borexino, SNO+)



R. J. Cooke, Astrophys. J. 812, L12 (2015)

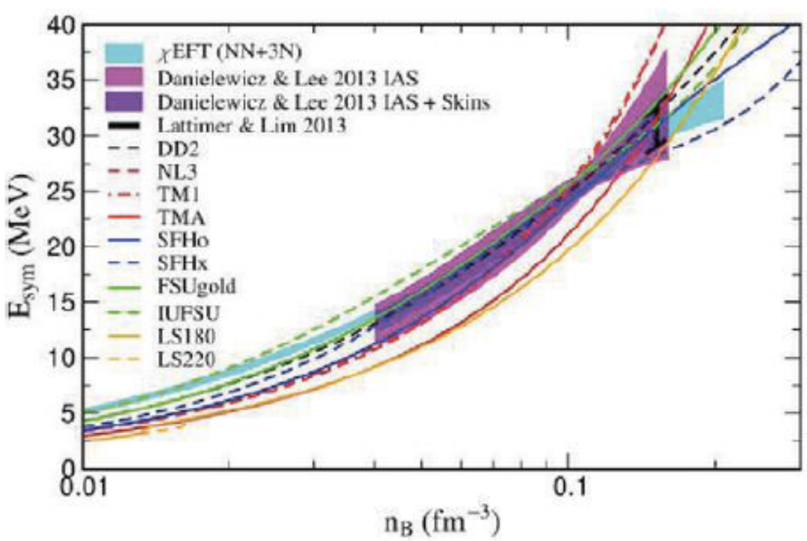
Nuclear Astrophysics: opportunities with RIB

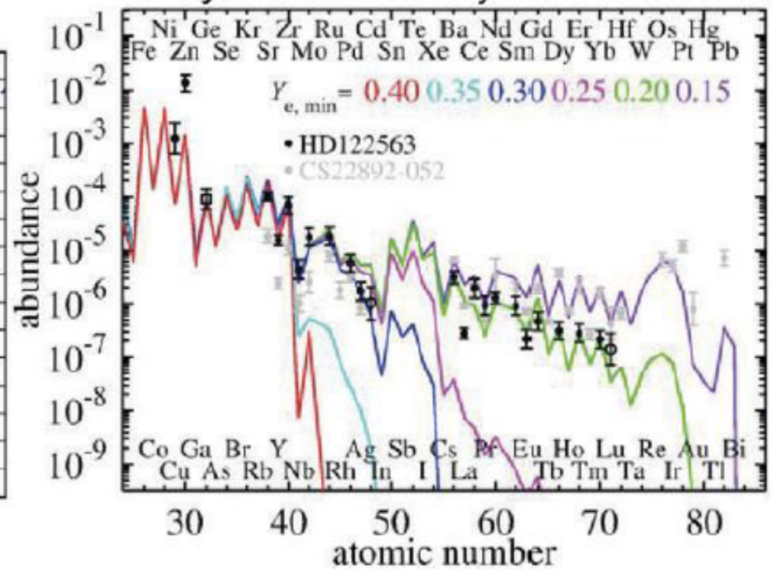


- **Studies relevant to all explosive scenarios**
- High quality (energy, time, etc.) radioactive beams for studying reaction cross sections (direct and spectroscopic measurements) at stellar energies
- **Measurements away from stability crucial for testing models**

Box 4: Heavy element nucleosynthesis in CCSNe

The determination of the heavy elements produced in core-collapse supernova requires accurate predictions for the spectral differences between electron neutrinos and antineutrinos. These differences are related to the nuclear symmetry energy at sub saturation densities. A combination of nuclear experiments and theory and astronomical observations have greatly contributed to constrain the density dependence of the symmetry energy. This puts strong constrains on equations of state used in core-collapse supernova simulations and furthers contributes to determine the neutron richness, Y_e, of the ejected material. This is the main parameter affecting the nucleosynthesis in the ejected material.





PRELIMINARY Recommendations of WG4:

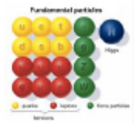
- **Completion of FAIR, ISOL-facilities, LUNA, ELI**
- **Continue the research programs at small labs**
- **Support for astronomical nuclear observation**

WG5. SYMMETRIES AND FUNDAMENTAL INTERACTIONS

1. Introduction
2. SM parameters
3. Searches beyond the SM
4. Future directions
5. Recommendations

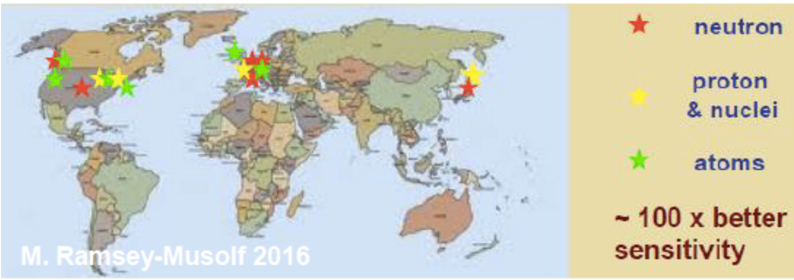
Some of the open issues in ν physics

- Absolute masses (and hierarchy)
  - Direct mass measurements (covered) vs. indirect cosmological determination (not covered)
- Nature of neutrinos
  - Dirac – Majorana; Lepton number violation?
- CP violation in neutrino mixing
  - Long baseline oscillation and high energy neutrino program (not covered) but:
  - need considerable work, in particular theoretical, on neutrino – nuclear cross sections especially in the range from few 100 MeV to several GeV (community input, should be included in LRP, → WG-3, WG-5 linking to WG-3)



Progress with EDM searches

- Electron EDM: Next improvements from polar molecules (e.g. YbF, ThO) expected; some searches with paramagnetic atoms (Cs, Fr)
- Nuclear EDM: Hg-199 $d_{Hg} \leq 7.4 \times 10^{-30}$ e·cm (Graner et. al, PRL116(2016)161601), other efforts use different diamagnetic atoms (Xe-129, Ra-225)
- Neutron EDM: Various international collaborations
- Muon EDM: new g-2 experiments
- Other charged particle EDM: Proton, Deuteron, …
  R&D by storage ring collaboration, JEDI with precursor at COSY



Need multiple systems, to discover finite EDM and to eventually disentangle BSM physics

Some unique opportunities in Europe

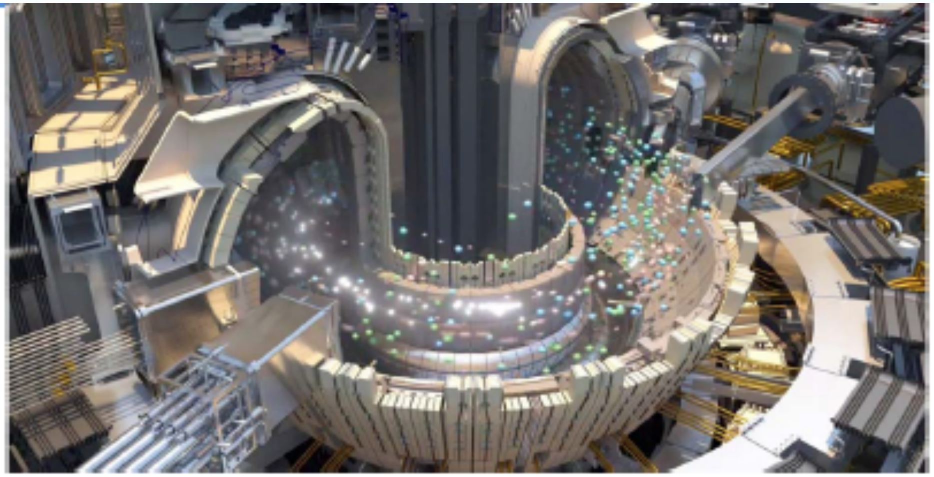
PRELIMINARY Recommendations of WG5:
- Support of small-sized laboratories and univeristy groups
- Theory support
- Facilities

WG5. APPLICATIONS AND SOCIETAL BENEFITS

ENERGY APPLICATIONS

1.3 Fusion reactors

- ITER (Cadarache, France) is the greatest challenge for fusion technology
- The very high fluxes of high-energy neutrons are a major problem for the structural reactor material
- IFMIF can play a key role as a test facility with 14 MeV n

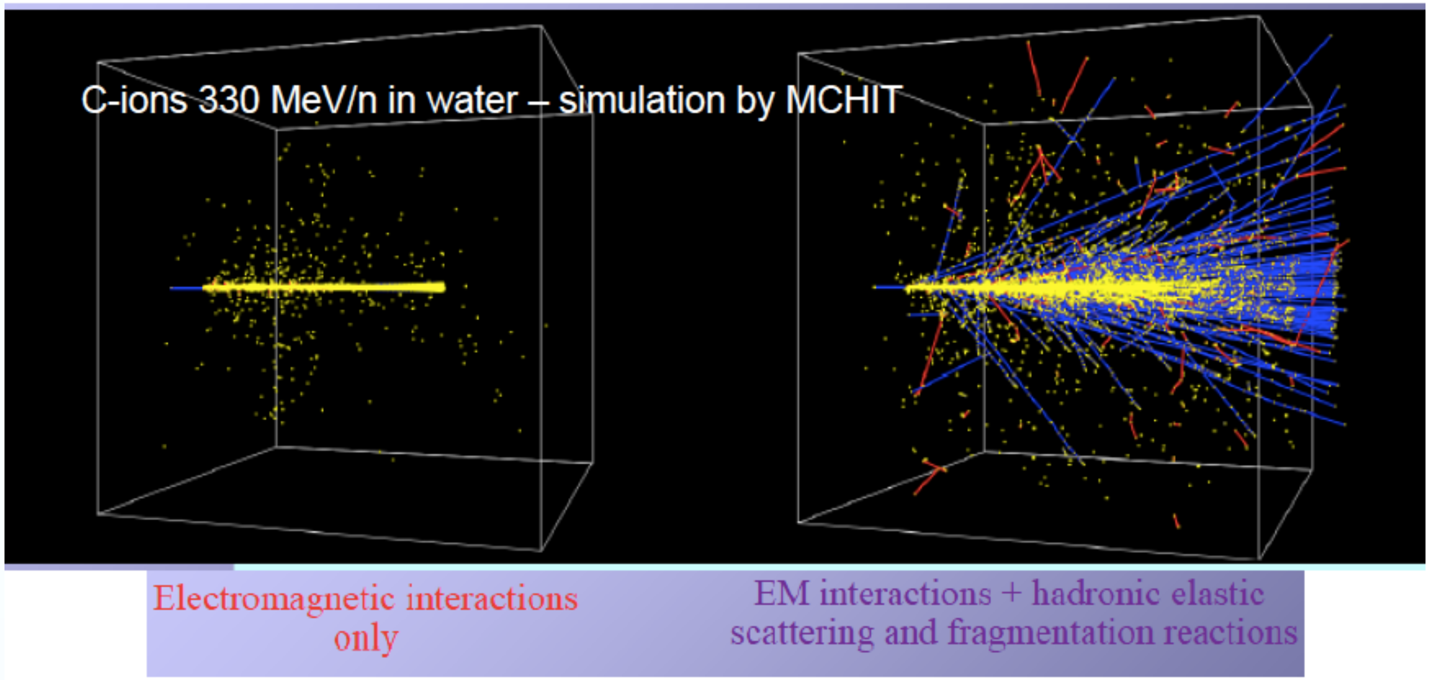


Recommendations

- *Support efforts in nuclear data measurements, evaluation and modeling.*
- *Continue developments for high power and high stability particle accelerators.*
- *Exploit synergies with other fields (detectors, accelerators,...).*
- *Support specific projects as MYRRHA and IFMIF/ELAMAT in Europe.*

HEALTH APPLICATIONS

2.1 Particle therapy

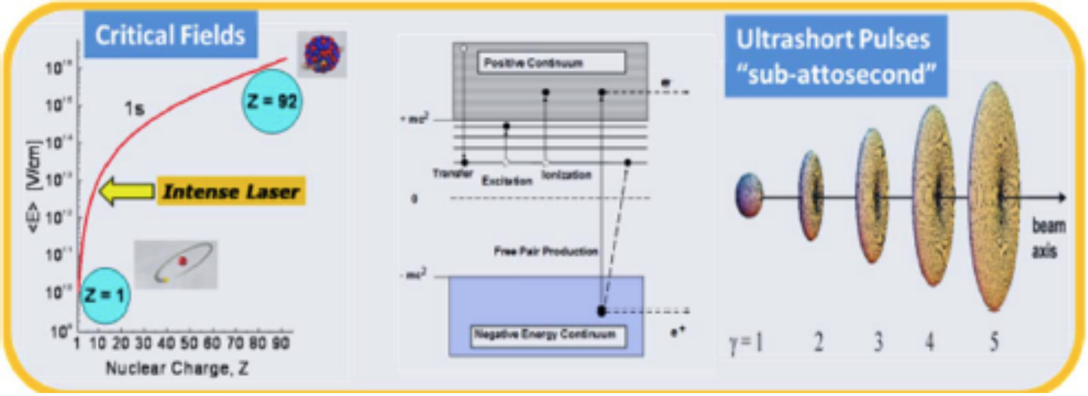


Recommendations

- *Develop Monte-Carlo approaches which combine and validate contemporary imaging, dosimetry and diagnostic processes.*
- *Development of new tools and techniques to improve the quality and computational speeds leading to more accurate and faster dosimetric calculations in real time, thereby optimising patient treatment planning and throughput.*
- *Promote the development of accelerators and targetry towards intense beams and consider in the design or upgrades of existing facilities the production of innovative radiopharmaceuticals. Develop related mass separation techniques to obtain high purity radio-isotopes.*
- *Promote the study of radionuclide production using suitable and focussed types of nuclear reactions in order to enlarge the choice of available radionuclides*
- *Take advantage of alternative radionuclide properties to develop new "theranostic" concepts in imaging and therapy*

CROSS-DISCIPLINARY IMPACT

5.2 Atomic and Plasma physics



- Study of atomic matter subject to extreme electromagnetic fields

→ QED tests in non-perturbative bound-states

- With the availability of new installations (ESS, FAIR, SPIRAL2, CILEX) providing intense cold neutrons, ion beams and laser pulses, outstanding and worldwilde unique experiments will be possible to explore the structure of materials and atomic properties in extreme conditions

Recommendations

It is our vital interest to find schemes that link operators of applied nuclear facilities to potential user groups in materials sciences and related areas.

Cały dokument będzie się rozpoczynał od **Executive Summary,** w którym m.in. będą zawarte Główne Rekomendacje (w przygotowaniu)


INTRODUCTION

SUMMARY AND RECOMMENDATIONS

Podsumowanie

- **NUPECC odgrywa ważną rolę w koordynacji wspólnych europejskich badań naukowych**
- **Wydawane przez NUPECC Długofalowe Programy Badawcze spełniały w dużej mierze swoją rolę, również w staraniach się o finansowanie badań**
- **Nowe opracowanie NUPECC Long Range Plan 2017, które pojawi się w połowie 2017 roku, gromadzi uzgodniony przez wiele europejskich grup spójny program badawczy fizyki jądrowej**
- **Polska fizyka jądrowa korzysta z przynależności do NUPECC**

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