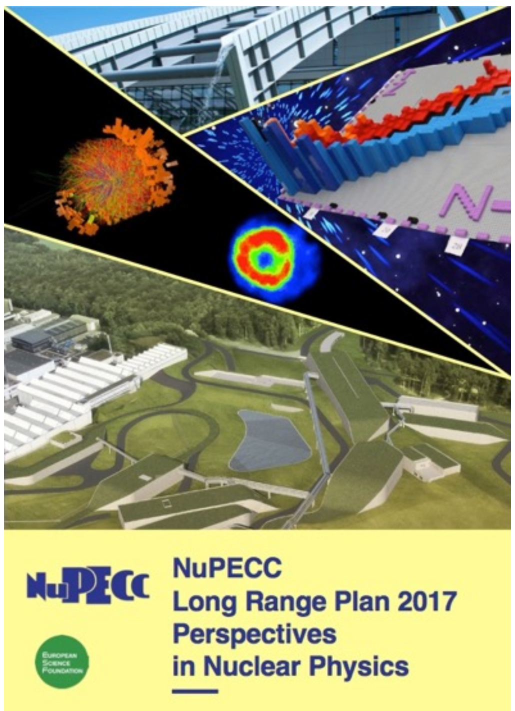
Challenges in Nuclear Physics from NuPECC Perspective



Marek Lewitowicz
Chair of NuPECC

Seminarium IFJ, Kraków , 11 luty 2021

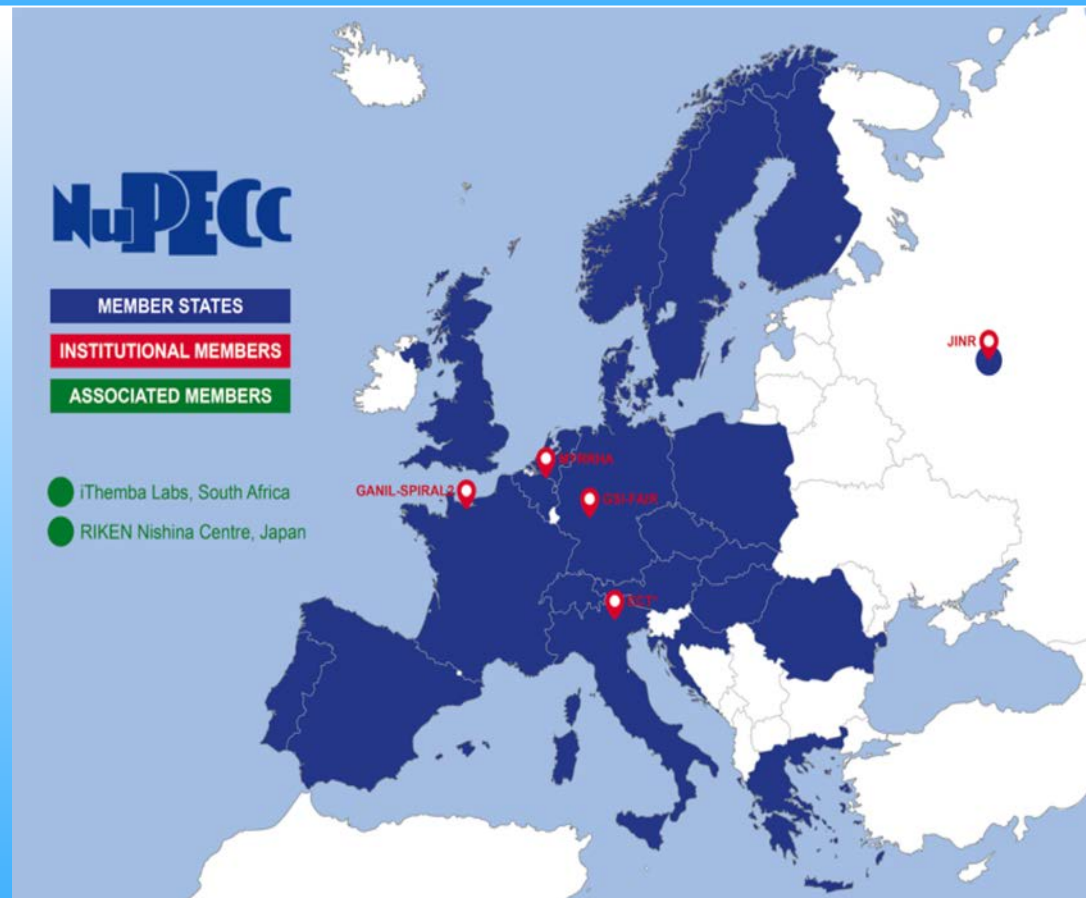
What is NuPECC ?

The European Expert Board for Nuclear Physics
hosted by European Science Foundation

Representing
about 6000 scientists

Composition:

- 34 representatives from 21 countries, 3 ESFRI NP Infrastructures & JINR Dubna
- 3 associated members (Israel, iThemba Labs and Nishina Center)
- 9 observers (ESF, NPD/EPS, ECFA, NSAC, ANPhA, ALAFNA, CINP, IAEA, APPEC)



3 regular Committee meetings/y

32 Years of NuPECC activities

Important contribution of Poland in all NuPECC activities

NuPECC Main Activities

- **NuPECC European Long Range Plans in Nuclear Physics**
- **NuPECC Task Force (country/organisation visits)**

  Meetings with representatives of international/national/local Funding Agencies in order to discuss and promote the implementation of the recommendations of the NuPECC Long Range Plan.

- **Monitoring of European NP Infrastructures and EU projects**
- **Joint ECFA-NuPECC-APPEC Activities (JENAA)**
  - **Mutual participation in strategic plans**
  - **Joint seminars**
  - **Expressions of Interest**
  - **Joint working groups**

http://www.nupecc.org

- **Nuclear Physics News International**
- **NuPECC Special Reports**
  - *Nuclear Physics for Medicine, Nuclear Physics in Everyday Life,…*

- **Support for nuclear physics conferences in Europe**
- **Public Awareness of Nuclear Science (PANS) activities**

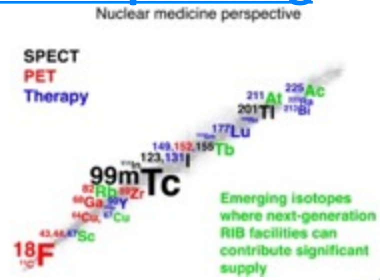
Long Range Plan of NuPECC

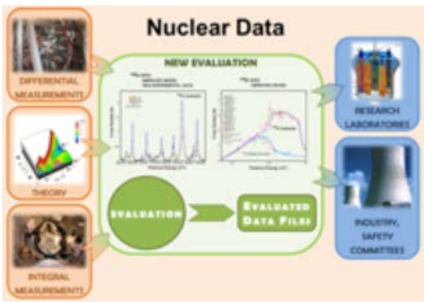
- **The LPR identifies opportunities and priorities for the nuclear science in Europe**
- **The LRP provides national funding agencies, ESFRI and European Commission with a framework for coordinated advances in nuclear science in Europe**

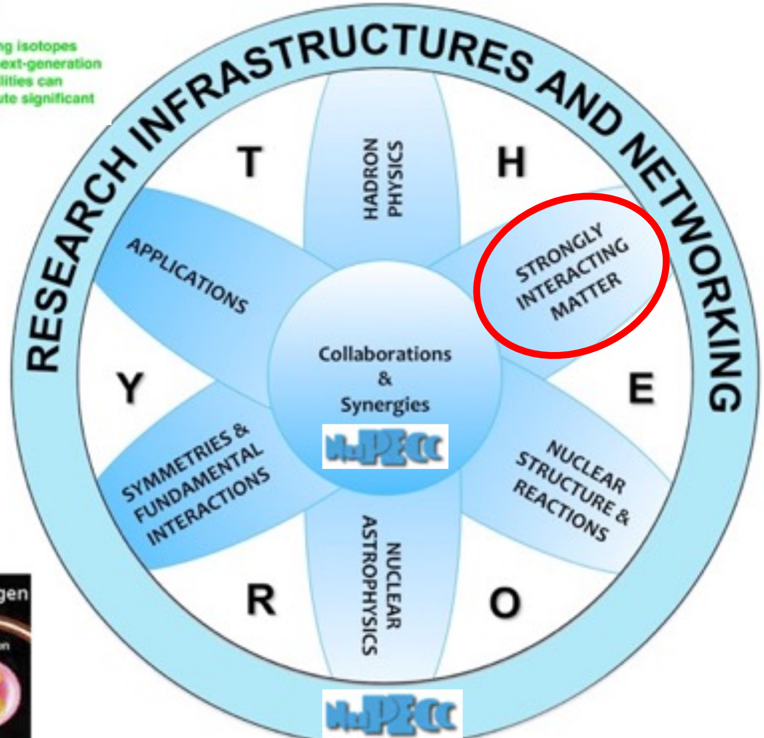
http://www.nupecc.org/lrp2016/Documents/lrp2017.pdf

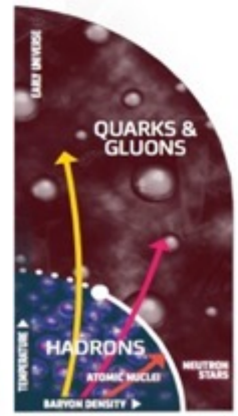
Nuclear Physics in Europe

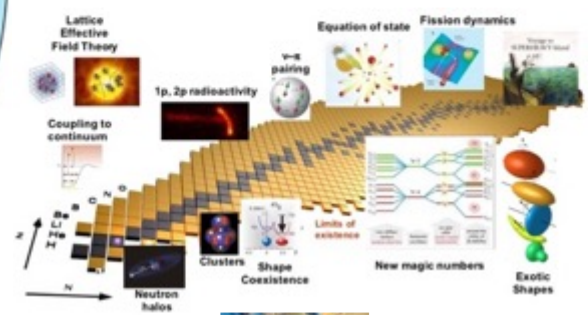
http://www.nupecc.org

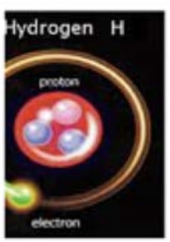


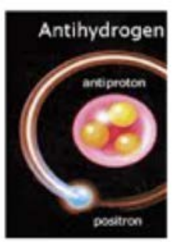


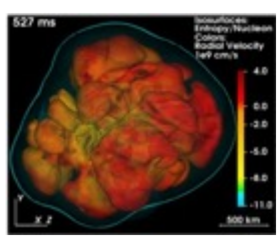


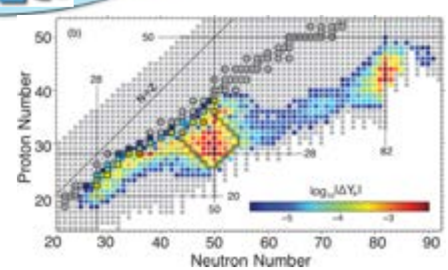










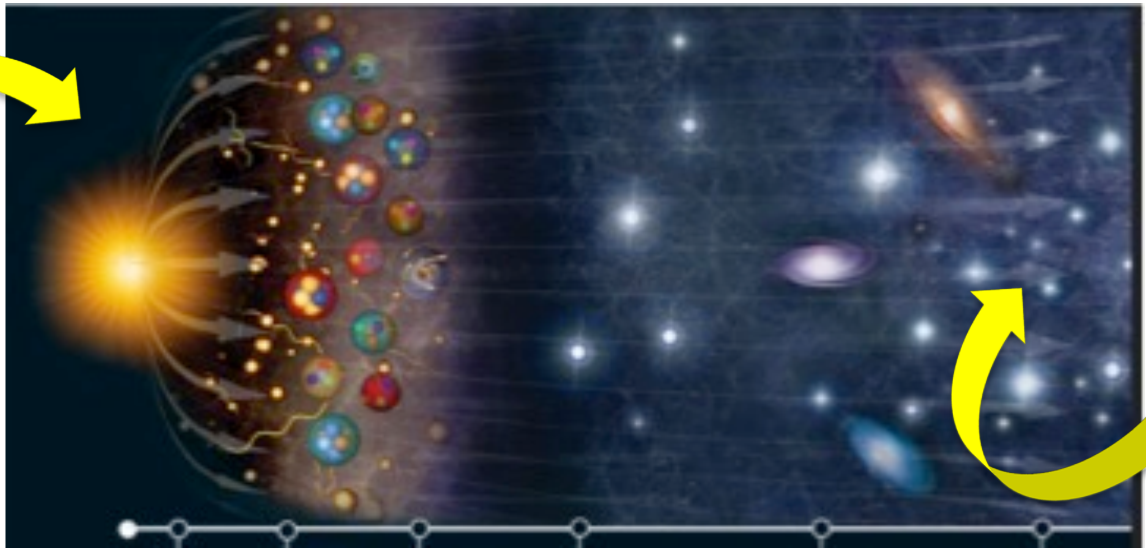


Nuclear physics and the evolution of the Universe

- **What are the properties of nuclei and strong-interaction matter as encountered shortly after the Big Bang, in catastrophic cosmic events, and in compact stellar objects?**
- **How and where in the universe are the chemical elements produced?**

QCD

QCD in hot compressed matter



10^{-32} sec | 10^{-6} sec | 100 sec | 100 Millions years | 500 Millions years | 4 Billions years

Nuclear structure
Nucleosynthesis

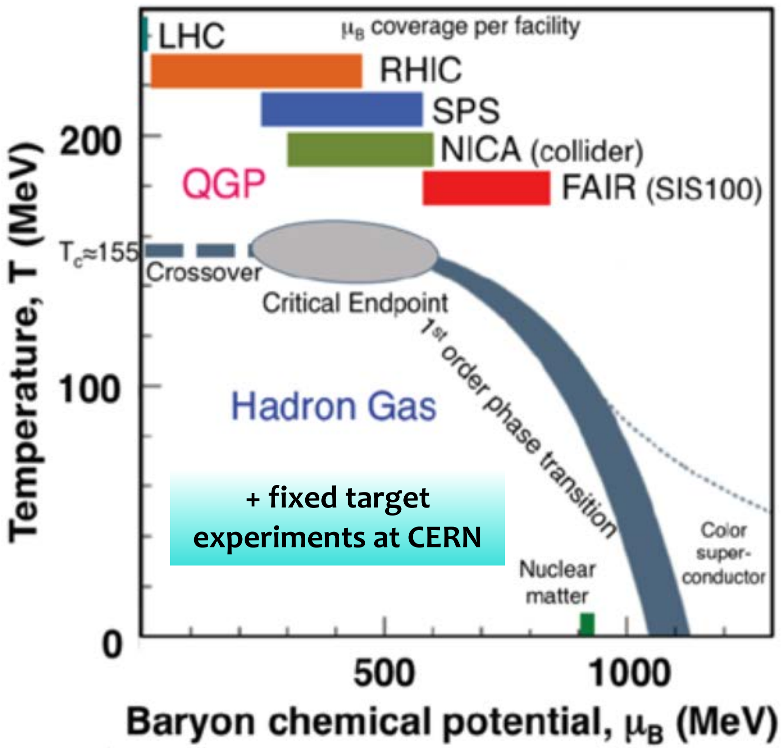
Reactions for astrophysics

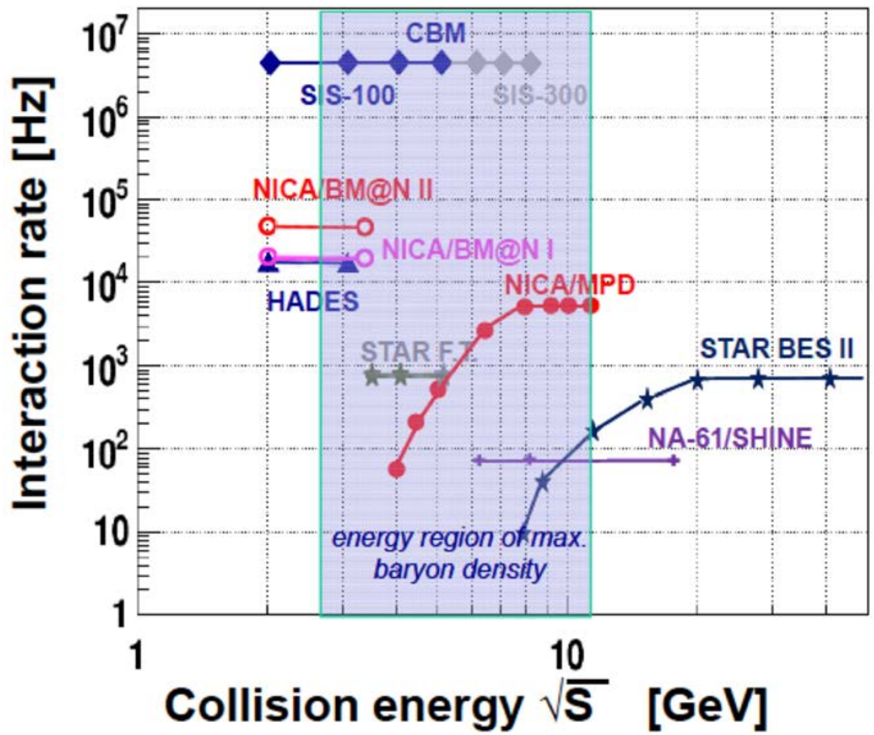
Compressed nuclear matter

To tackle the different related problems one needs a distributed approach and efforts : different facility types and energies

Hadronic Matter at the very extremes

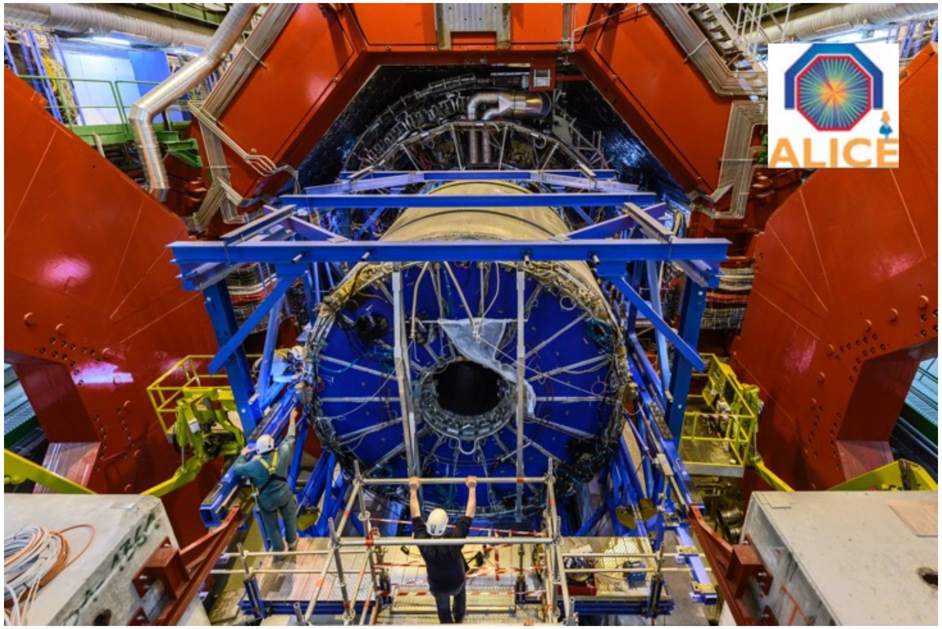
- **What are the properties of nuclei and strong-interaction matter as encountered shortly after the Big Bang, in catastrophic cosmic events, and in compact stellar objects?**





Ongoing: Heavy-ion program at the LHC

- LHC Run 2 completed (Dec 2018)
  Target integrated luminosity $1nb^{-1}$ reached!
  Large harvest of physics results
- LHC Long Shutdown 2 (2019-2021)
  - Improvements on LHC injection chain to reach 50 kHz Pb-Pb collision rates
  - Major detector upgrades for ALICE and LHCb →
- 2021-2029: Run 3 and 4
  - Goal: $13nb^{-1}$ integrated luminosity
  - Heavy-ion physics program arXiv:1812.06772

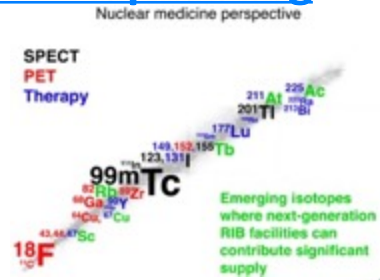


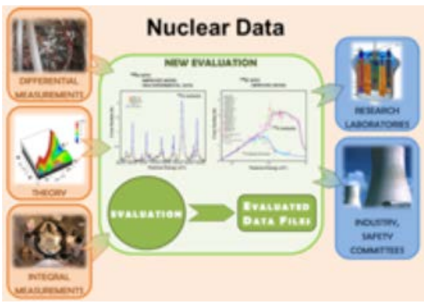
ALICE at HL-LHC up to 2038

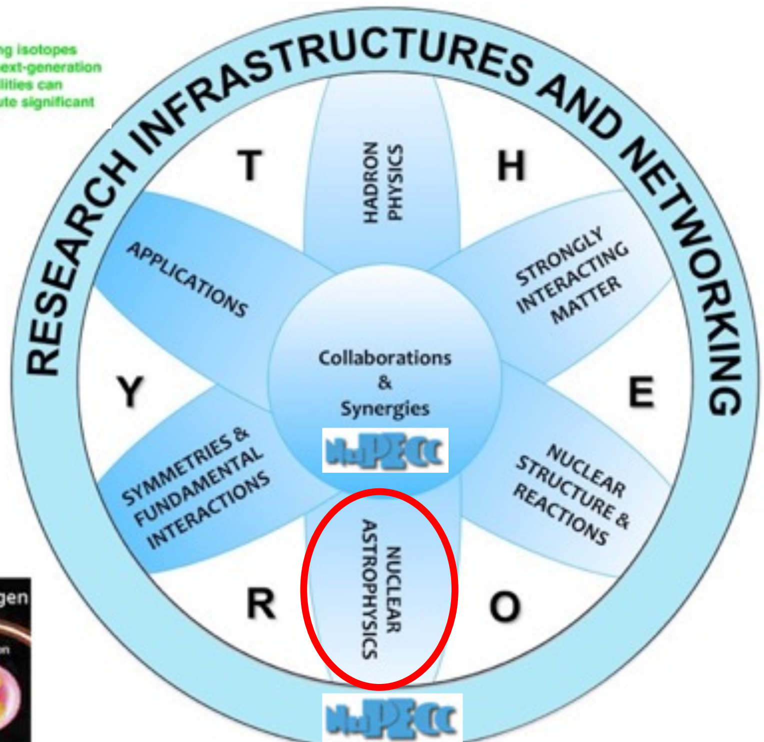
Main NuPECC LRP recommendation:
All aspects of the LHC heavy-ion programme, including manpower support and completion of the detector upgrades, are strongly supported.

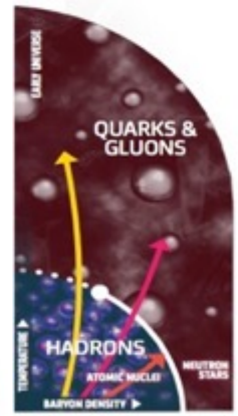
Nuclear Physics in Europe

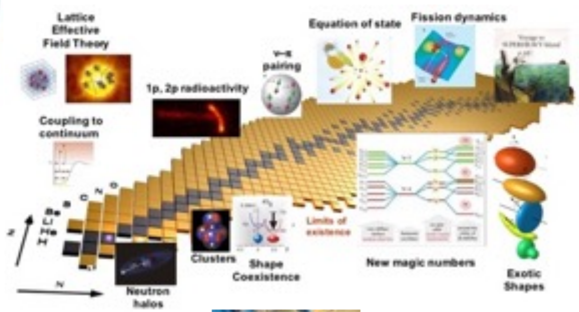
http://www.nupecc.org

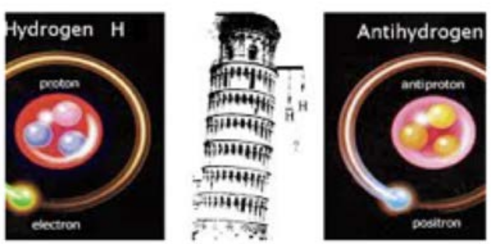


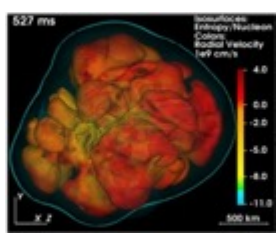


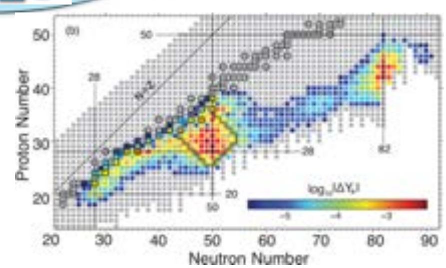












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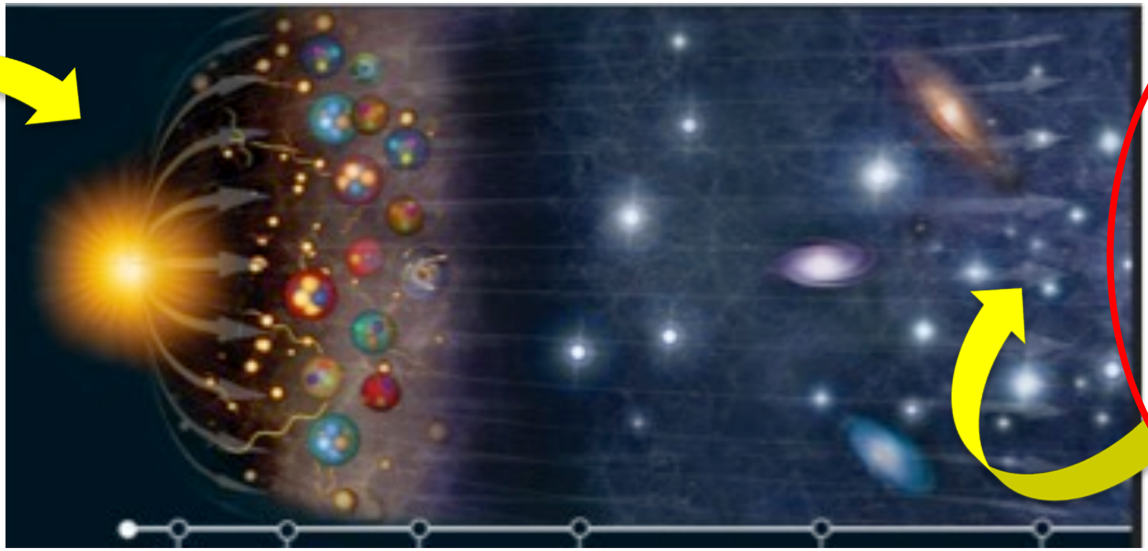


Nuclear structure
Nucleosynthesis

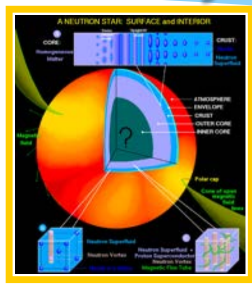
Reactions for astrophysics

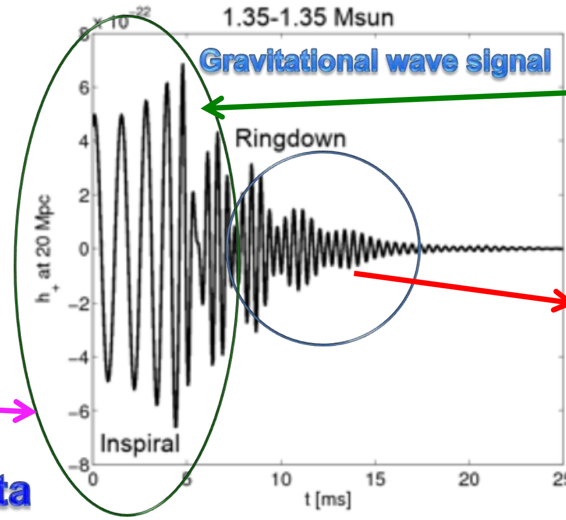
Compressed nuclear matter

10^{-32} sec	10^{-6} sec	100 sec	100 Millions years	500 Millions years	4 Billions years

To tackle the different related problems one needs a distributed approach and efforts : different facility types and energies

Neutron star mergers
Truly interdisciplinary research



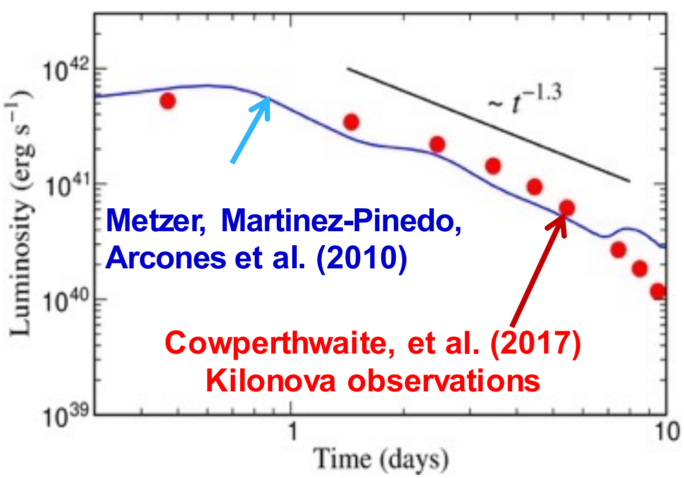


Neutron star mass

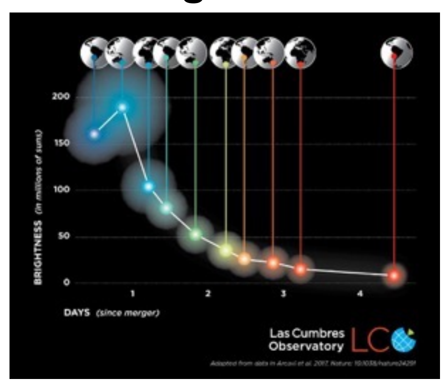
Ringdown depends on the Nuclear Equation of state

The messengers from neutron star mergers :

- **Gravitational waves**
- **Electromagnetic signals characterizing the nuclei in the ejecta**
- **neutrinos**



Gravitational wave emission seen together with electromagnetic signals



Time evolution determined by the radioactive decay of r-process nuclei (science drive of facilities with RIB)

Joint ECFA-NuPECC-APPEC EoI: Gravitational Waves for fundamental physics

http://www.nupecc.org/jenaa/?display=eois

Nucleosynthesis (nuclear structure and reactions information)

LRP Recommendations: Strong support for a large effort involving small scale accelerators …… & large infrastructures

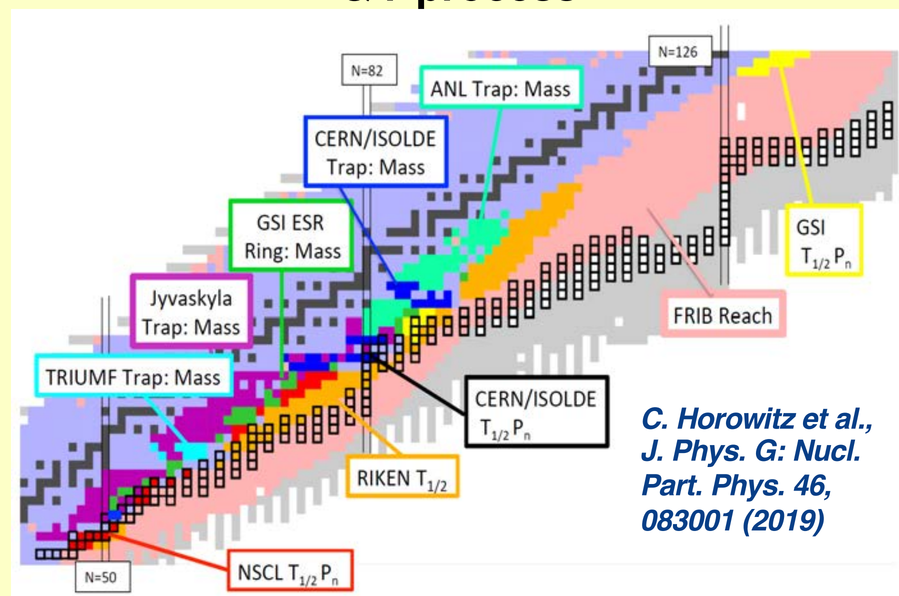
In particular at smaller scale accelerators :

- **BBN and fusion reaction in stars for light nuclei nucleosynthesis**
- **reactions for energy generation**

LUNA, LNS, ALTO, n-TOF,…

Nucleosynthesis of medium to heavy nuclei

Example: Mass measurements & r-process

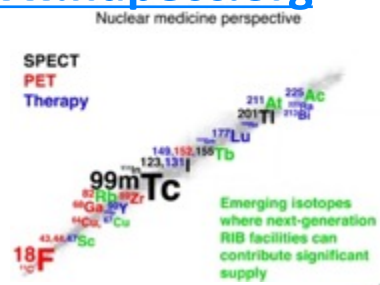


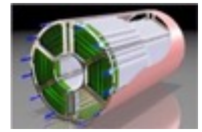
Scientific programs at :

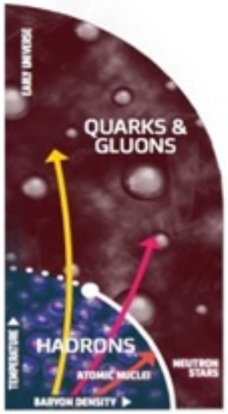
- **FAIR**
- **ISOLDE-SPES-JYFL**
- **GANIL**

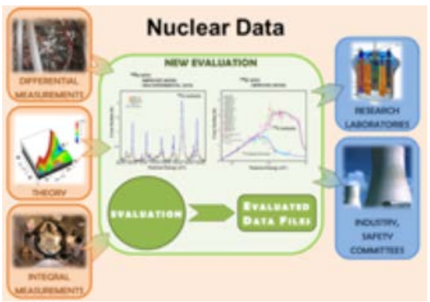
Nuclear Physics in Europe

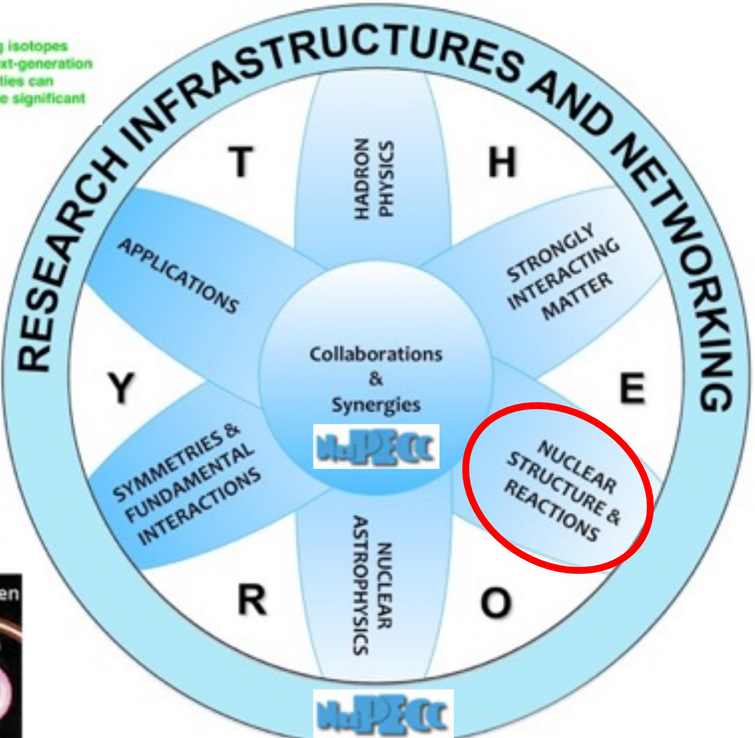
http://www.nupecc.org

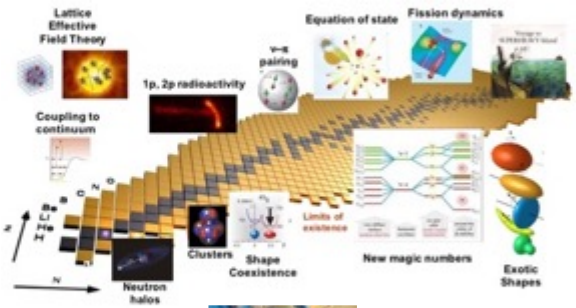


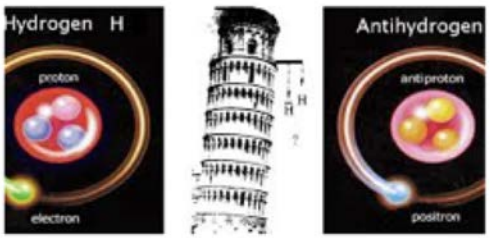


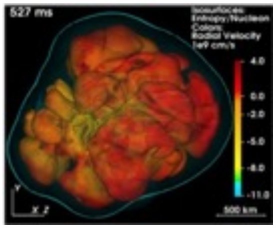


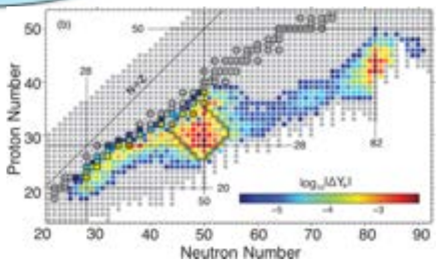


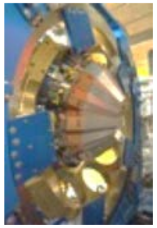






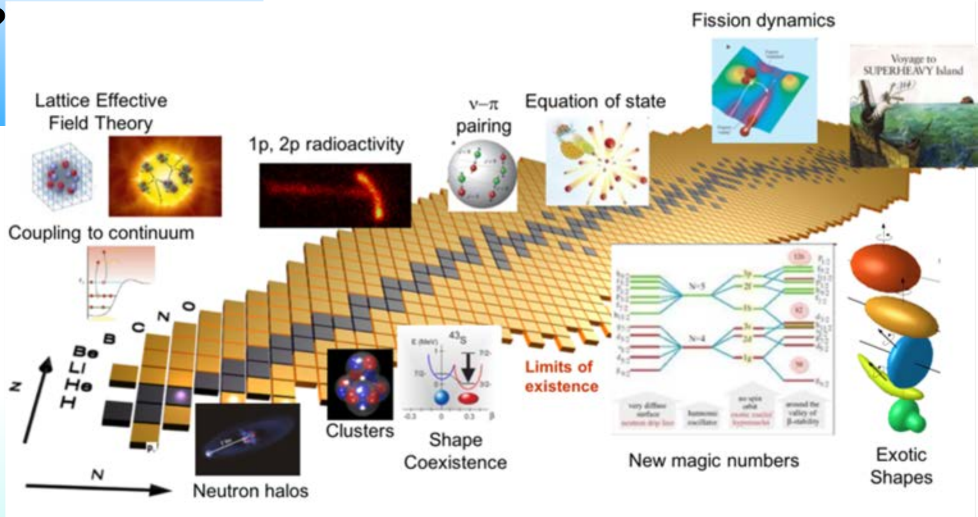






Structure of complex nuclei

- How does the complexity of nuclear structure arise from the interaction between nucleons?
- What are the limits of nuclear stability?



- **Quest for Limits**
- **Precision Measurements**
- **Beauty of Systematics**
- **New Era of Nuclear Theory**
- **Where is New Physics?**

Quest for Limits
Neutron drip-line

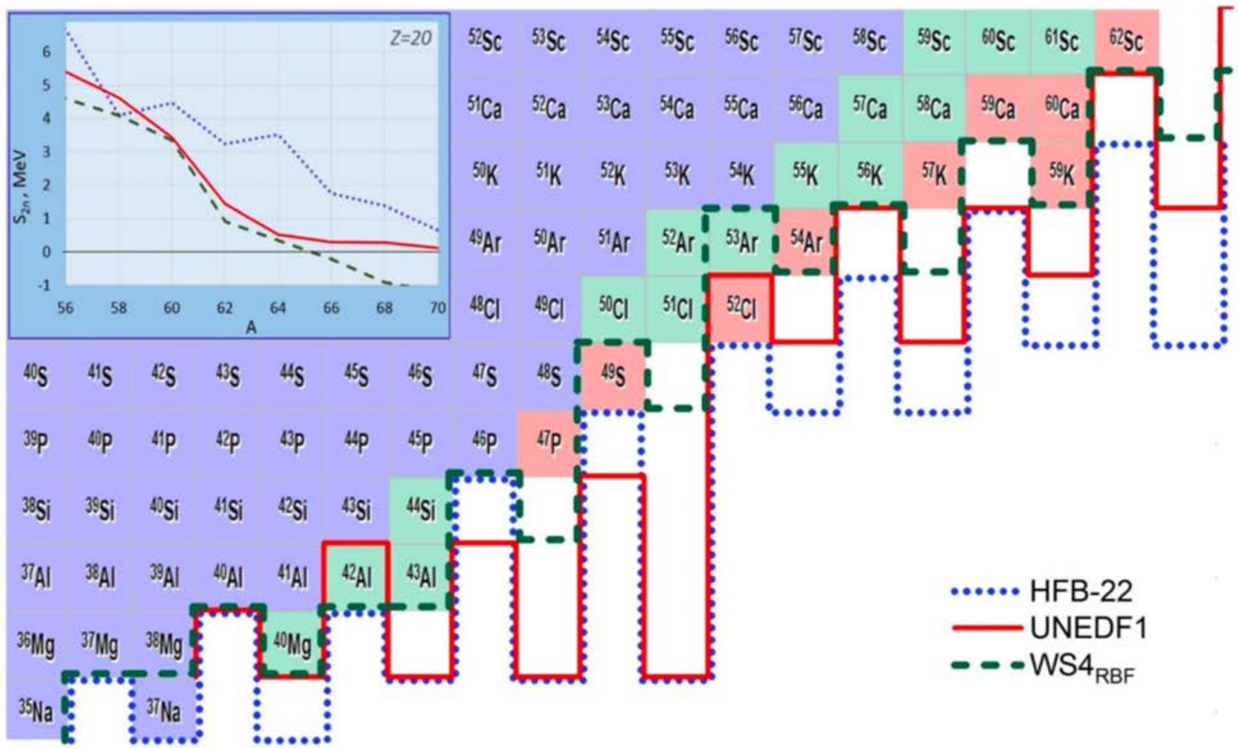
Editors' Suggestion

Discovery of ^{60}Ca and Implications For the Stability of ^{70}Ca

O. B. Tarasov *et al.*

Phys. Rev. Lett. **121**, 022501 (2018) – Published 11 July 2018

RIBF

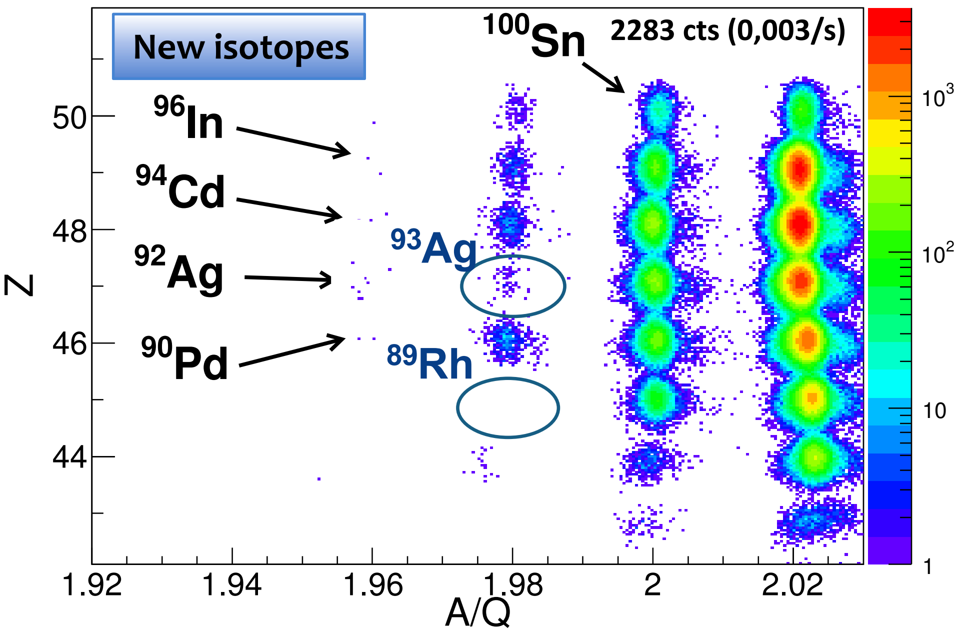


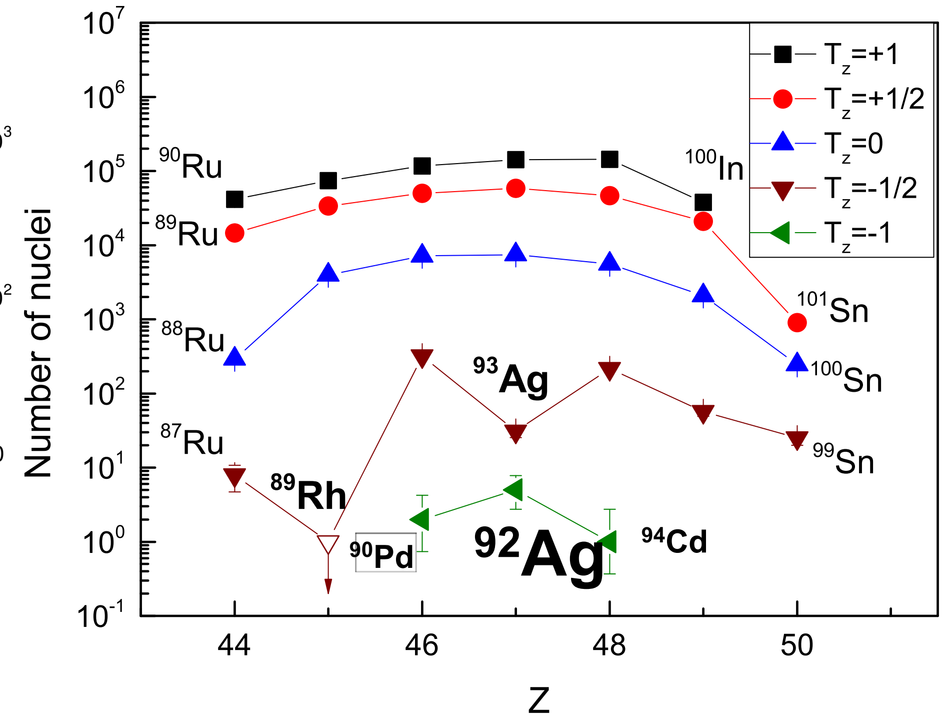
Main players: RIBF, FRIB, FAIR, RAON

Courtesy of O. Tarasov

New isotopes & proton emitters

Identification plot irradiation with 30 pnA ^{124}Xe beam during 203 h





- significant drop in number of detected ^{93}Ag and ^{89}Rh nuclei

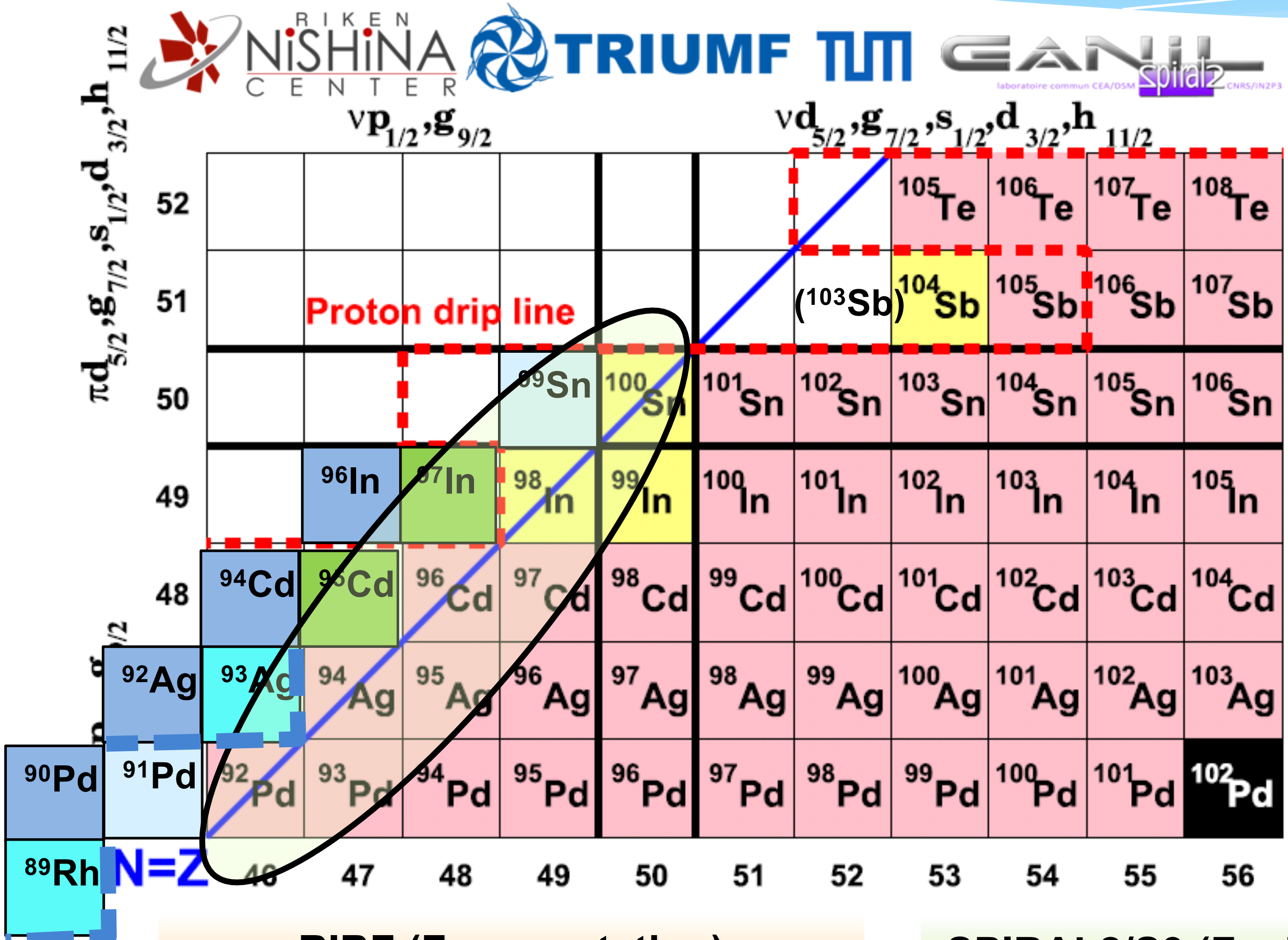
-> ^{93}Ag and ^{89}Rh: new proton emitters

NB: all identified nuclei are stable against 2p and α emission

Celikovic, I.; Lewitowicz M. et al., Phys. Rev. Lett. 116, 161102 (2016)

Quest for Limits
Proton drip-line

RIKEN NISHINA CENTER · TRIUMF · TUM · GANIL spiral2



One RIBF experiment

- 8 new isotopes
- 2 new proton emitters
- 2 new half-lives & Q_β
- 2 new precise half-lives & Q_β
- spectroscopy

+ New Isotopes ^{85,86}Ru and ^{81,82}Mo
Part. instability of ^{103}Sb

RIBF (Fragmentation)
100 pnA 345 AMeV 124Xe beam
➔ ^{100}Sn 0.01 pps

(FRIB max. 4 pps)

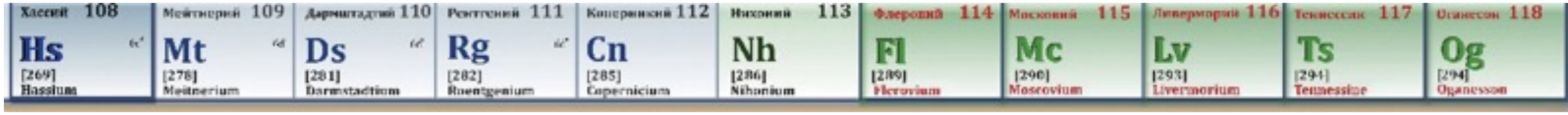
SPIRAL2/S3 (Fusion-Evaporation)
^{58}Ni(10pμA)+^{46}Ti σ_{th}=5nb
➔ ^{100}Sn 30 pps

High and low beam energy facilities competitive

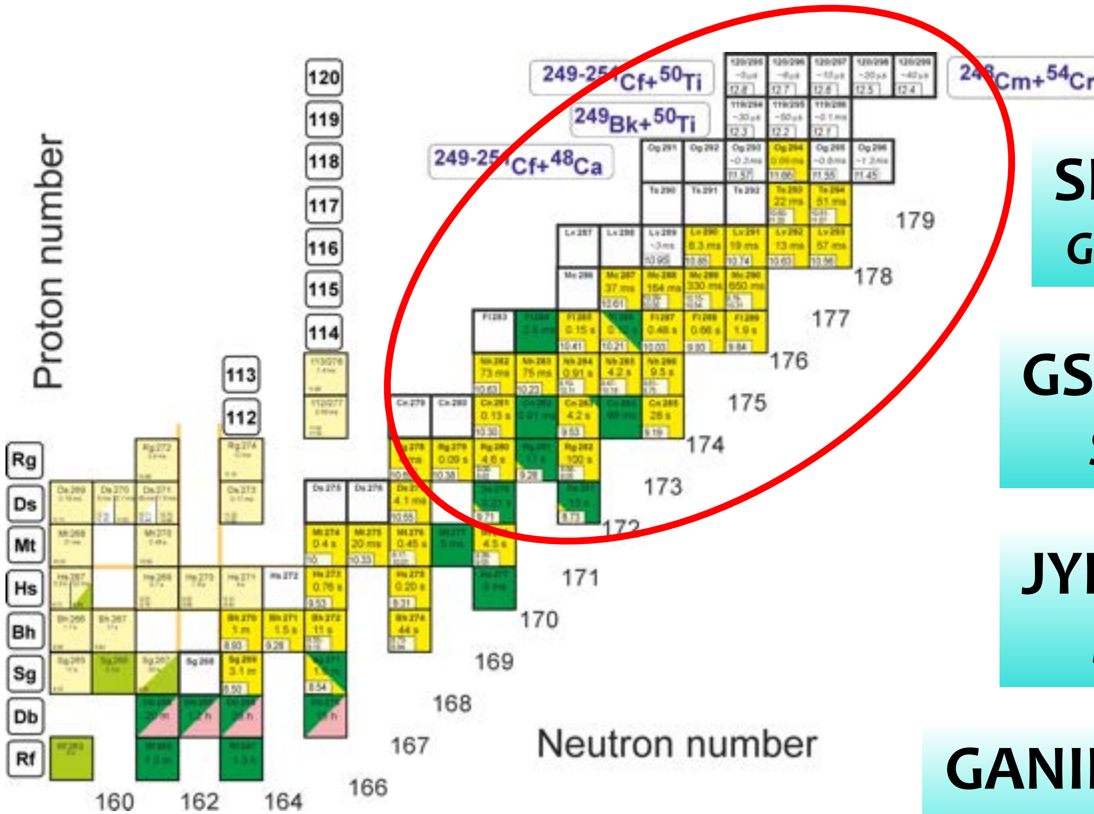
NuPECC

Quest for Limits
Study of Heavy and SH nuclei

SCIENCE CONNECT — YOUR PARTNER IN SCIENCE



10 out of 11 elements discovered at GSI and JINR



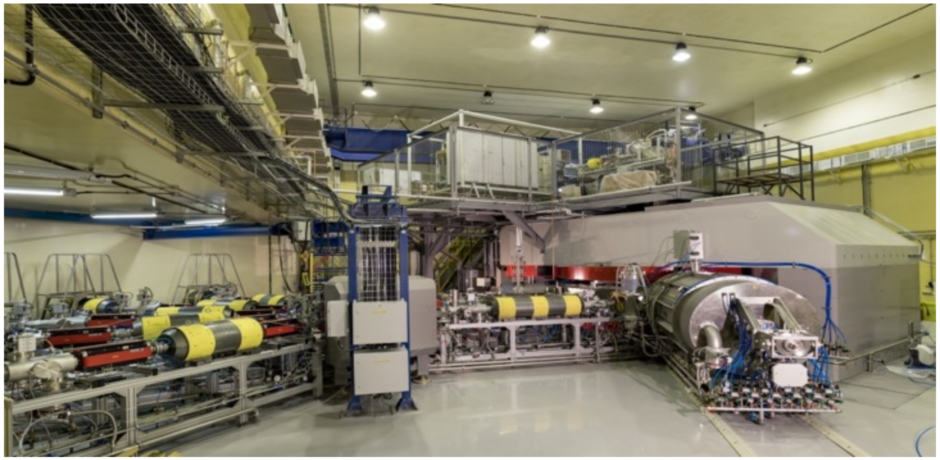
Scientific programs at:

SHEF – Dubna	*GFS II & III, SHELS*	*Commissioning*
GSI – Darmstadt	*SHIP & TASCA*	*Taking data*
JYFL – Jyväskylä	*RITU & MARA*	*Taking data*
GANIL/SPIRAL2 – Caen	*S3 & VAMOS GFS*	*Commissioning of LINAC*

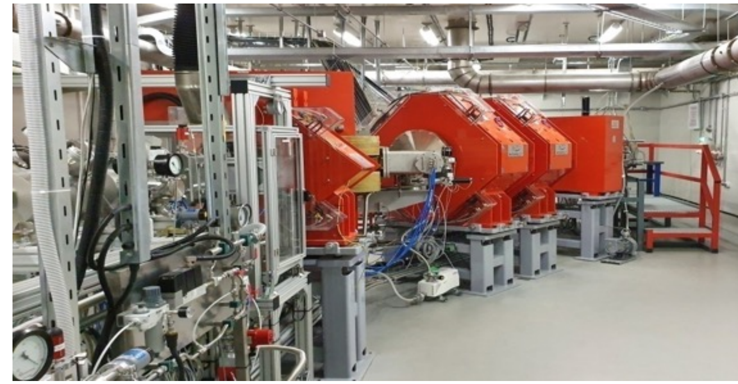
Search for new elements Z=119 and 120

Super Heavy Element Factory at JINR Dubna

New DC-280 Cyclotron



New DGFRS-2 separator

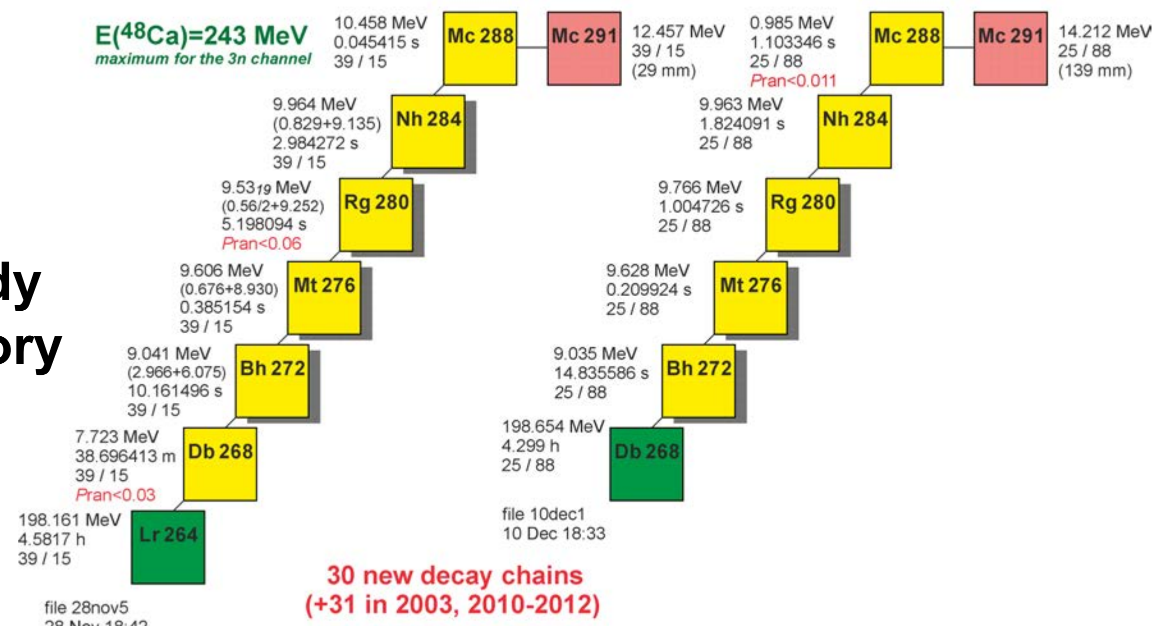


Reached today:

- ^{40}Ar beam intensity 10 pμA;
- ^{48}Ca beam Intensity 5 pμA;

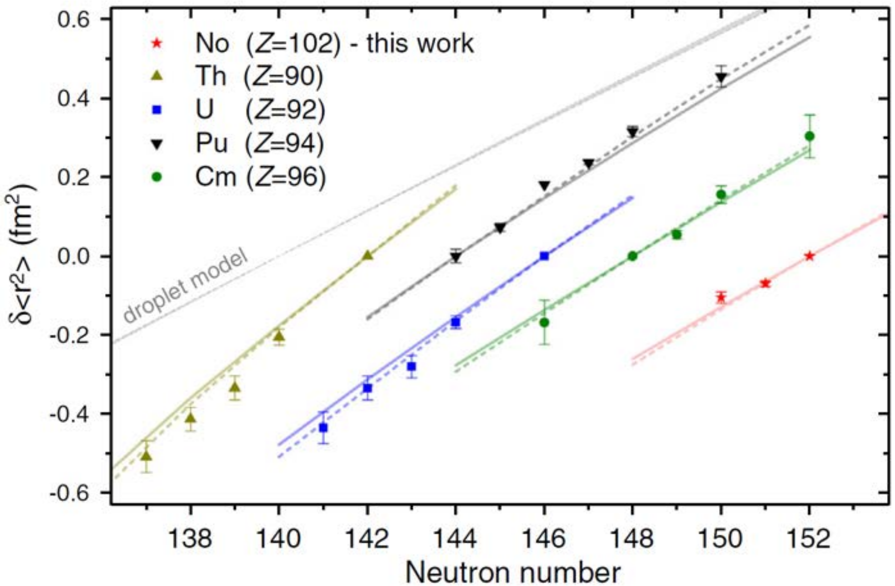
First results on study of SHE at SHE Factory

^{243}Am + ^{48}Ca

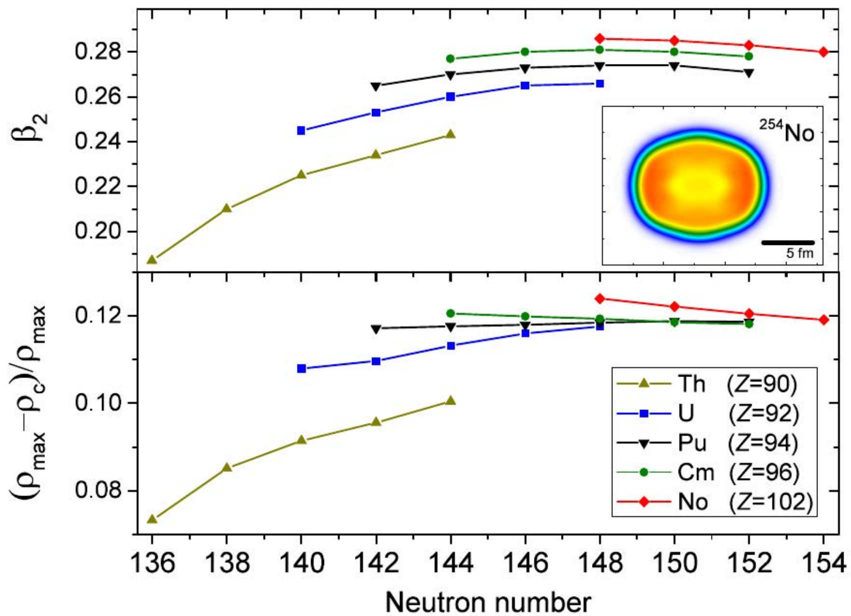


Laser ionization spectroscopy of ^{252,253,254}No

- Isotope shift for $^{252-254}$No measured
- Change in charge radii: Input from atomic theory



Deformation from DFT calculations: Coulomb frustration



- Nuclear moments of ^{253}No

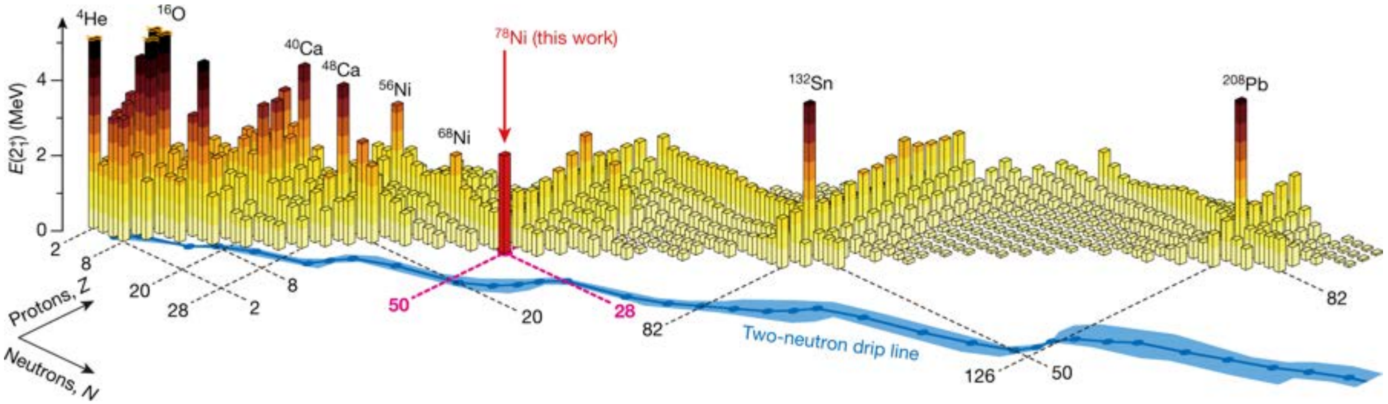
	μ (μ_N)	Q_s (eb)
Laser spec. (this work)	-0.527(33)[75]	5.8(14)[8]

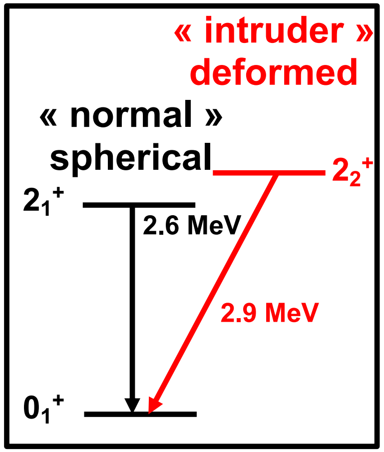
statistics atomic theory

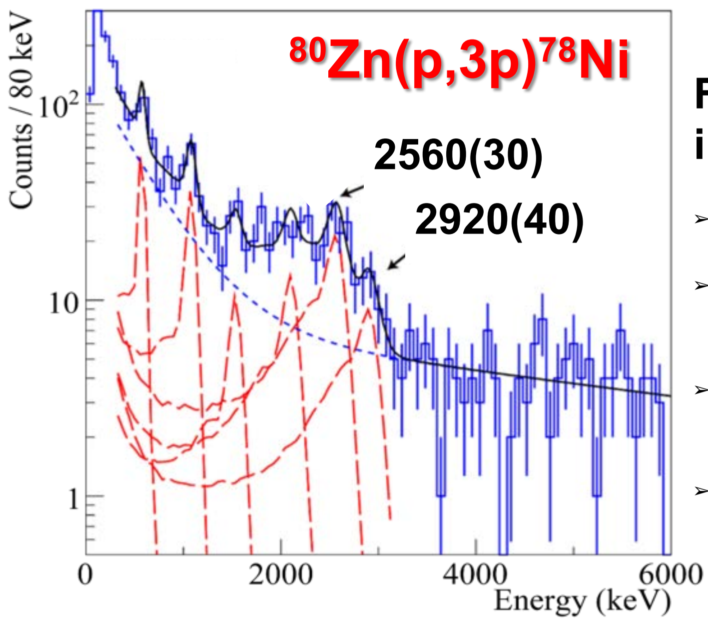
GSI

Laatiaoui et al., Nature 538 (2016), Raeder et al. PRL120 (2018), Chhetri et al. PRL120 (2018)

First spectroscopy of the doubly-magic nuclei ^{78}Ni







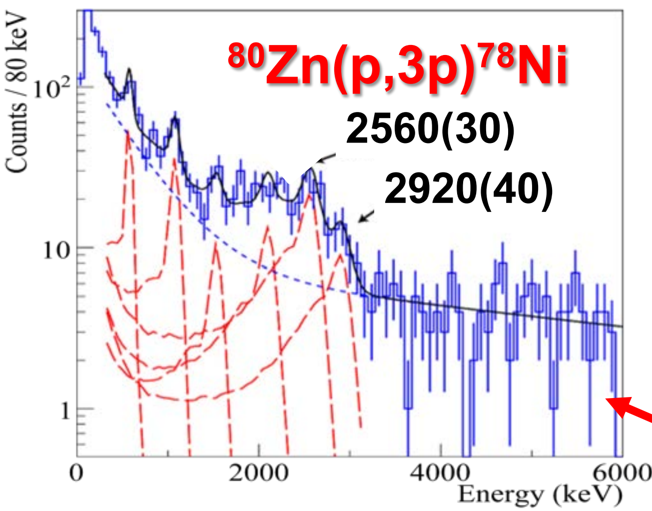
First 2^+ of ^{78}Ni at 2.6 MeV, second 2^+ at 2.9 MeV from in-beam gamma spectroscopy at RIKEN

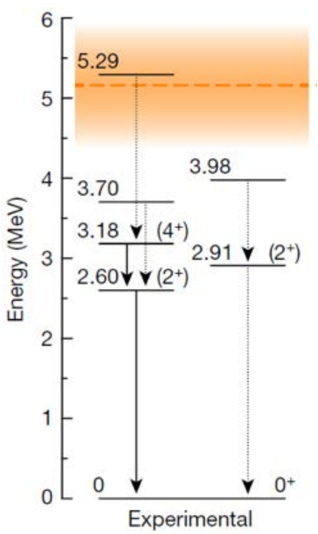
- **^{78}Ni doubly magic**
- **possible disappearance of the N=50 shell closure beyond ^{78}Ni**
- **comparison with ab initio and phenomenological shell model**
- **link to nuclear astrophysics (r-process nucleosynthesis)**

Courtesy: A. Obertelli **Taniuchi,- Nature 569 (2019)**

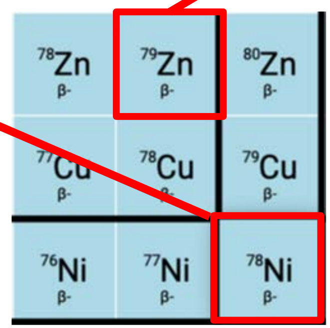
Structure of complex nuclei
Precision measurements

RIBF - Fragmentation
DALI2 (NaI) – ^{80}Zn 290pps

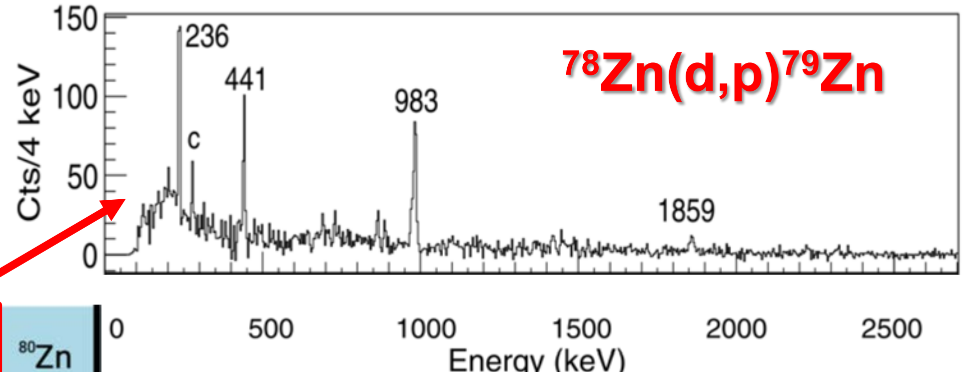


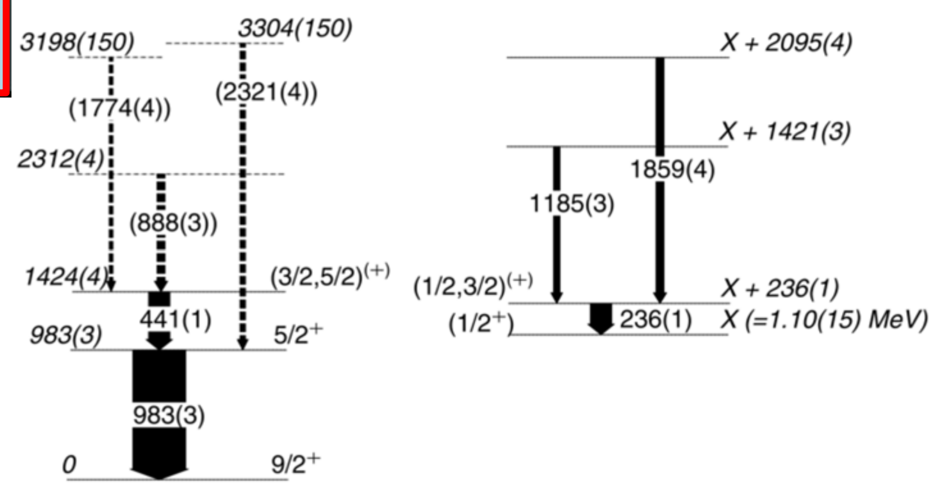


R. Taniuchi et al. Nature 569 (2019)



REX-ISOLDE – ISOL
Miniball (Ge) - ^{78}Zn 7.8(7)x10^{5}pps





R. Orlandi et al. Phys. Lett. B740 (2015)

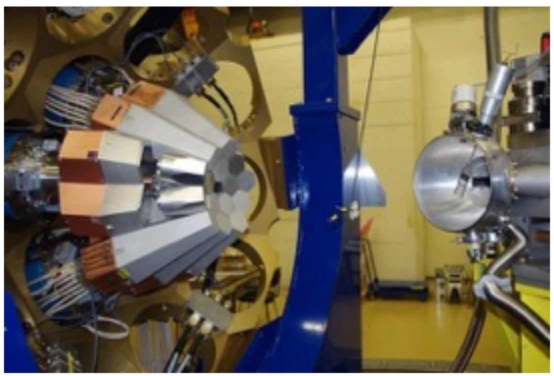
High-sensitivity for nuclear structure of exotic nuclei – used in several EU laboratories

2010 → 2011 LNL, Italy
5TC (15 detectors)

2012 → GSI, Germany
6TC+3 DC (22 detectors)

2014 → GANIL, France
15TC (45 detectors)

2021 -> LNL

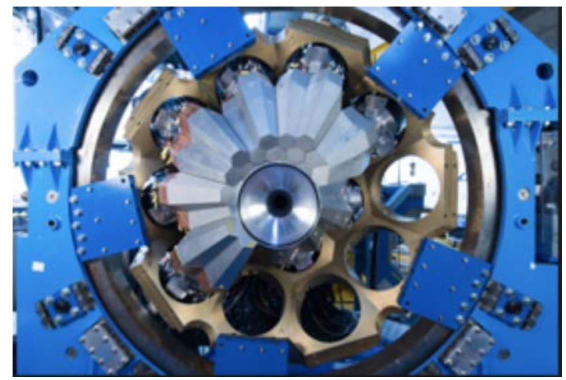


AGATA Demo. + PRISMA

Total Eff $_{\text{Nominal}}$. ~2.6%

AGATA @ FRS

Total Eff. (β=0.5) ~ 10%



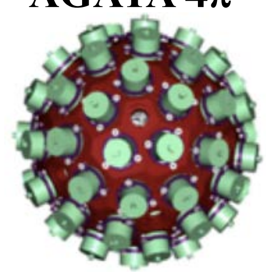
AGATA @G1

Total Eff ~ 8% to 14%

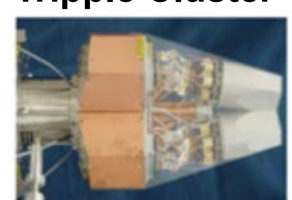
→ 60 detectors by 2020

AGATA array: A powerful traveling instrument - its construction has to proceed in the next years up to 4π coverage (60 triple clusters = 160 detectors) !

AGATA 4π



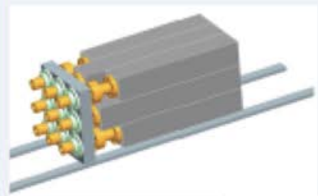
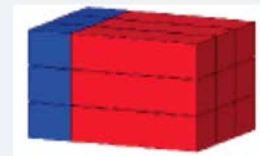
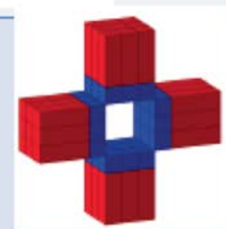
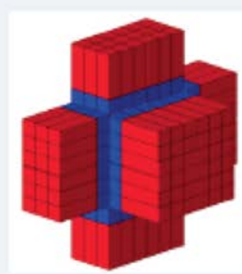
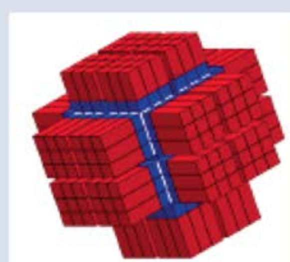
Tripple Cluster



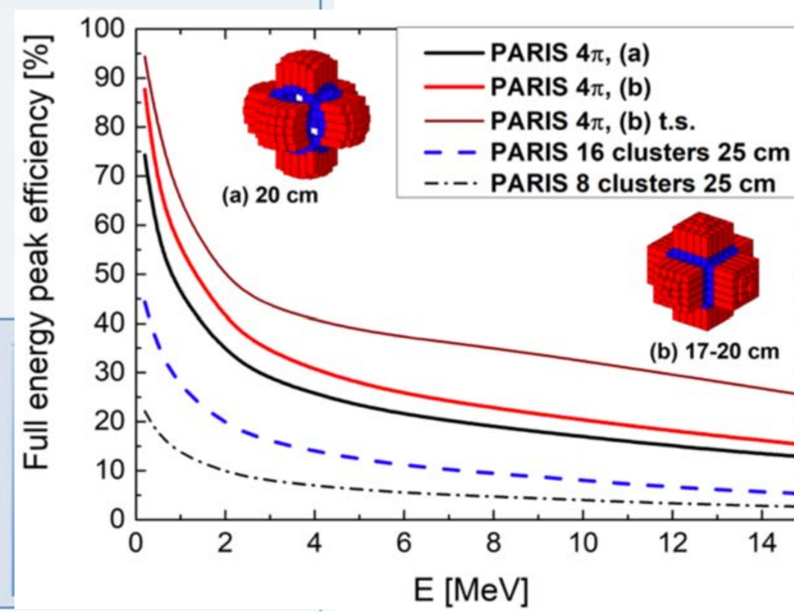
Marek Lewitowicz

Advance instrumentation
PARIS phoswich array

PARIS phases and cost estimates

Phase 1 **2011/2012** PARIS Prototype — PARIS cluster	1 cluster: 9 phoswiches	 
Phase 2 **2021** PARIS Demonstrator	**8 clusters 72 phoswiches**	
Phase 3 **2025?** PARIS 2π	12 clusters: 108 phoswiches	
Phase 4 **After 2025** PARIS 4π	≥24 clusters: ≥216 phoswiches	

Collaboration:
IN2P3 (France),
COPIN (Poland)
GANIL/SPIRAL2 (France)
TIFR/BARC/VECC (India)
IFIN HH (Romania)
INFN (Italy)
UK,
Turkey,
JINR Dubna
GSI (Germany)



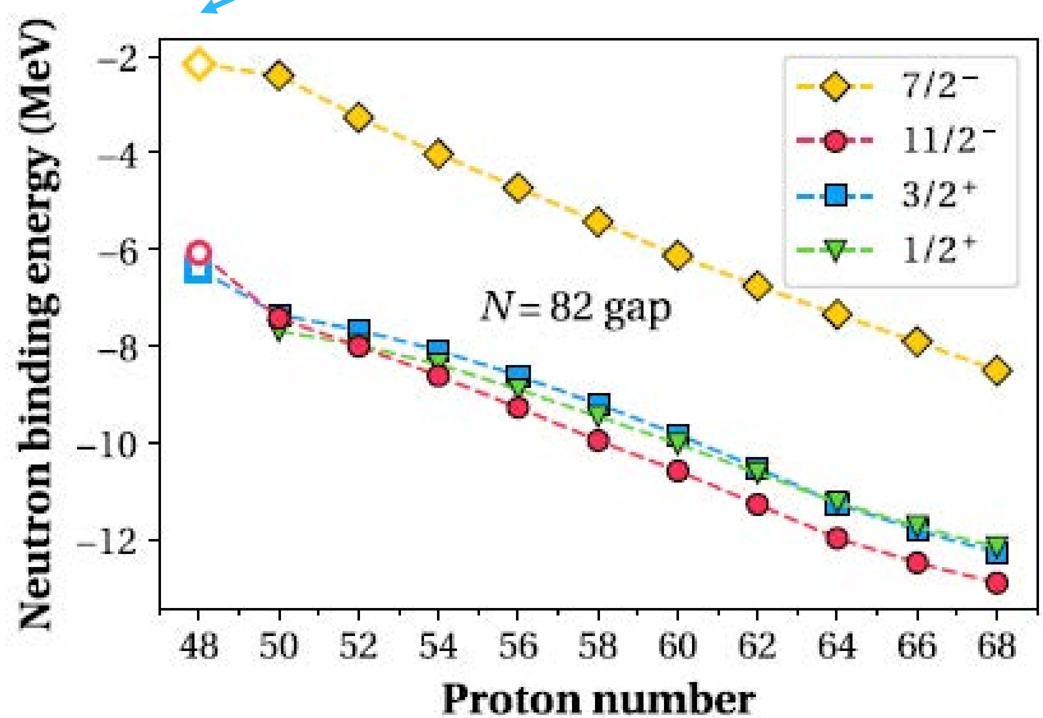
Courtesy of A. Maj & M. Ciemała

Probing the N=82 gap below ^{132}Sn

ISOL TRAP

^{132}Sb	^{133}Sb	^{134}Sb	^{135}Sb	^{136}Sb
^{131}Sn	^{132}Sn	^{133}Sn	^{134}Sn	^{135}Sn
^{130}In	^{131}In	^{132}In	^{133}In	^{134}In
^{129}Cd	^{130}Cd	^{131}Cd	^{132}Cd	^{133}Cd

The neutron binding energy is extracted for the first time below Z=50:
➔ the N=82 shell gap is reduced for Z=48



V. Manea, J. Karthein et al., Phys. Rev. Lett.124, 092502 (2020)

Courtesy of Gerda Neyens

ISOLDE, CERN

Probing shell gaps and deformation

- **Gamma-ray spectroscopy**

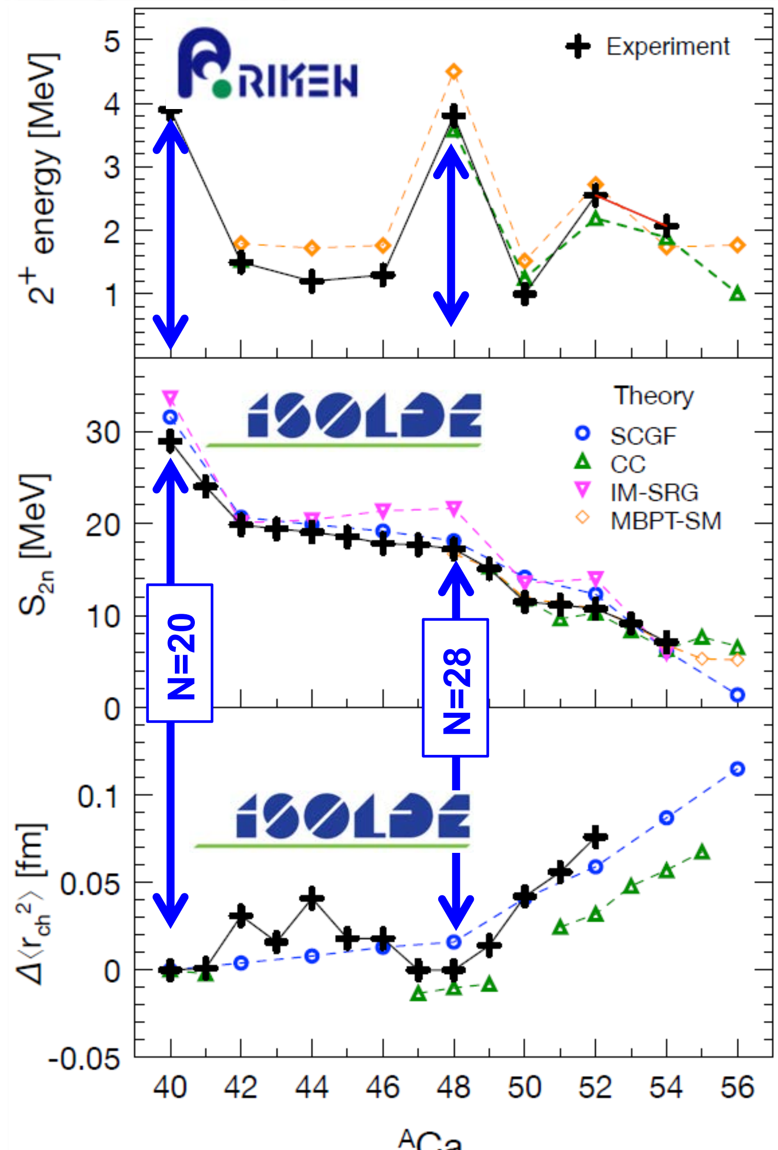
Steppenbeck,- Nature 502 (2013)

- **Mass measurements**

Wienholtz ,- Nature 498 (2013)

- **Laser spectroscopy**

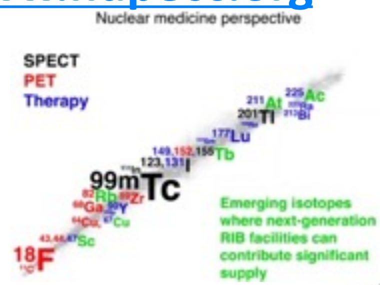
Garcia Ruiz,- Nature Physics 12 (2016)

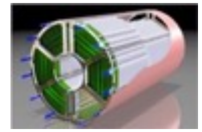


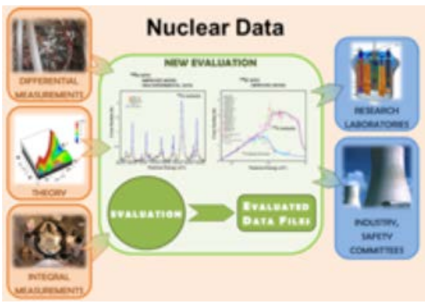
See also: A.J. Miller,- Nature Physics 15 (2019)

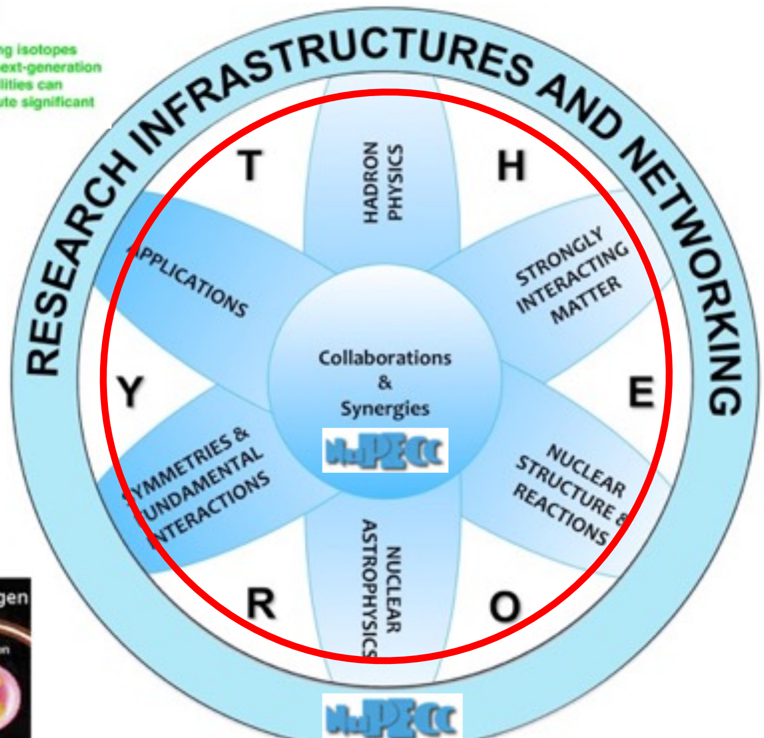
Nuclear Physics in Europe

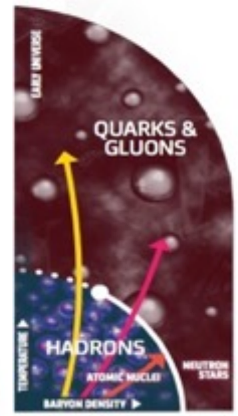
http://www.nupecc.org

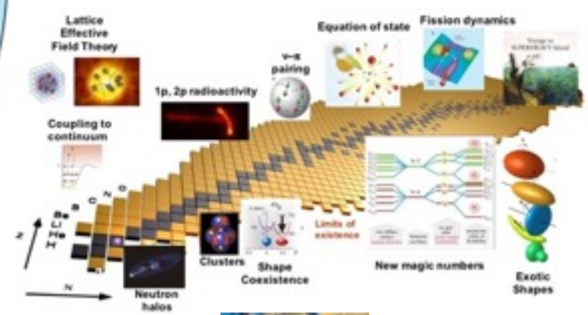


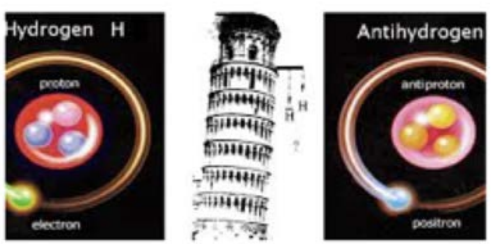


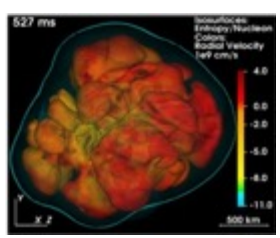


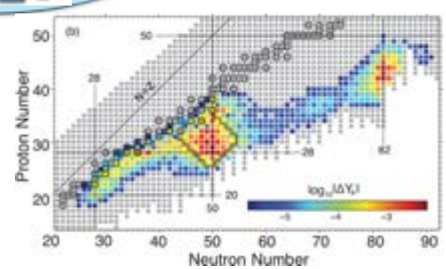






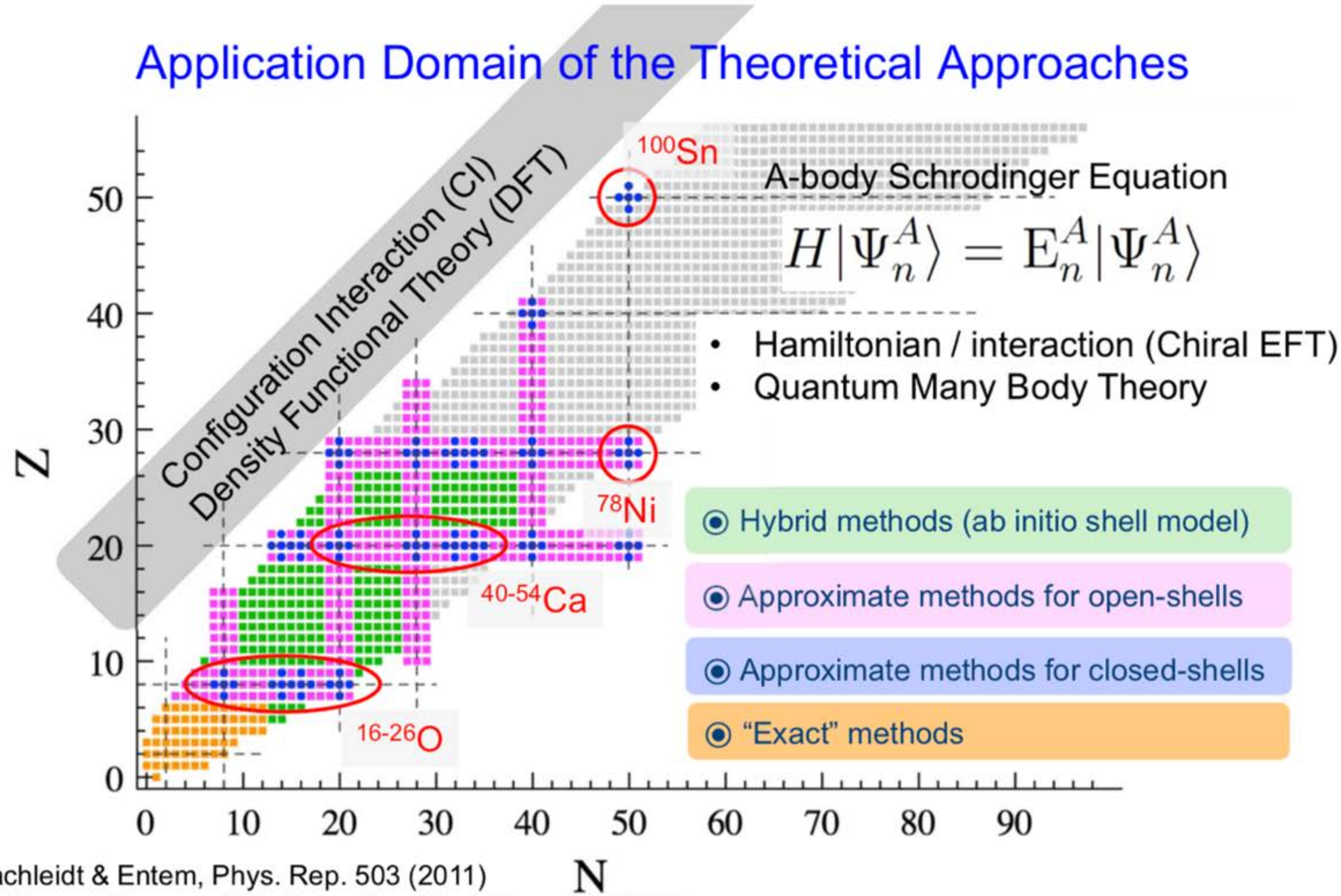






Structure of complex nuclei

New Era of Nuclear Theory

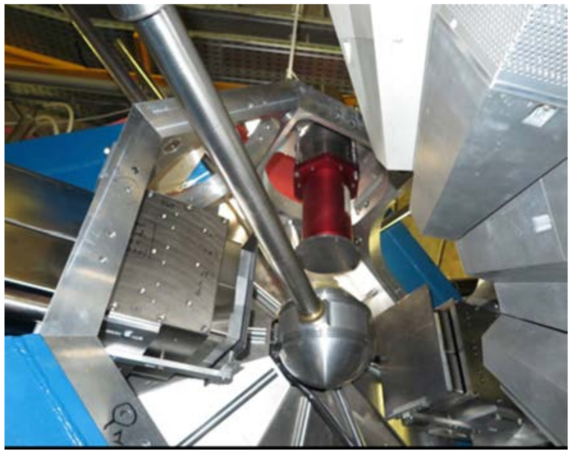


Machleidt & Entem, Phys. Rep. 503 (2011)
Epelbaum, Hammer & Meißner, Rev. Mod. Phys. 81 (2009)
Hagen,- Rept. Prog. Phys. 77 (2014)
Hergert,- Phys. Rep. 621 (2016)

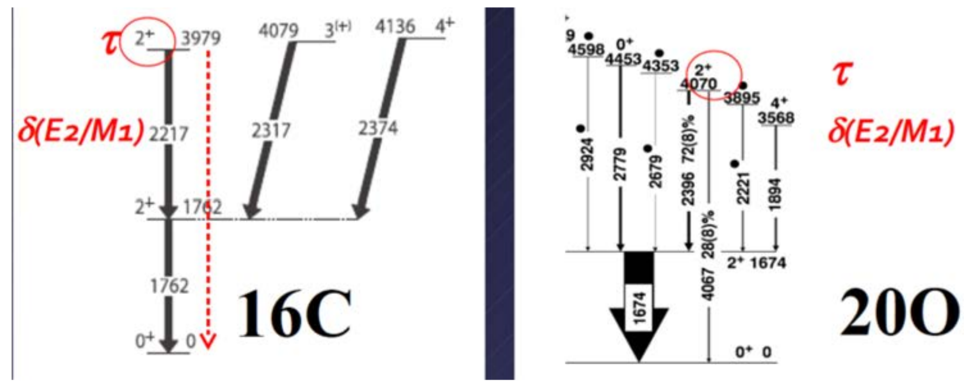
Courtesy T. Duguet

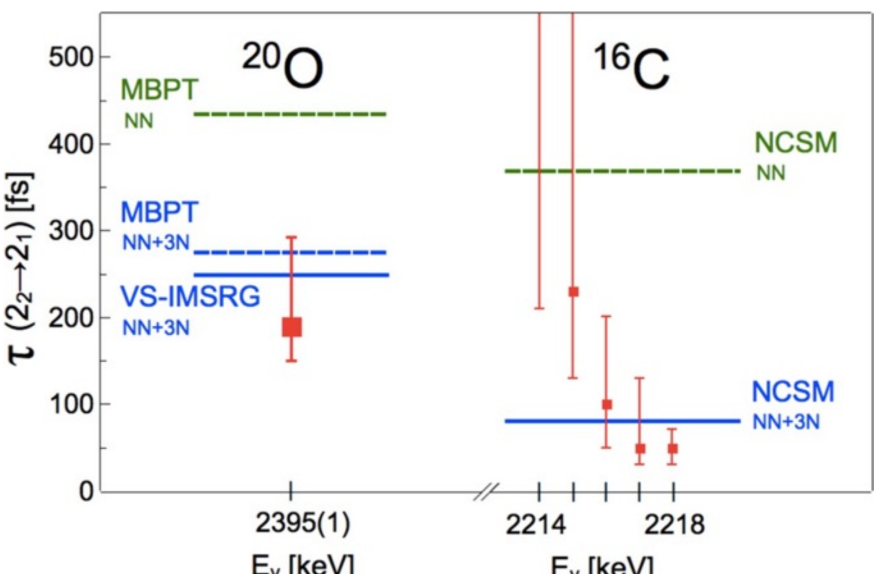
Testing 3-body interactions

Polish-Italian-French collaboration



AGATA, PARIS, VAMOS, Plunger setup at GANIL





The achieved results on transition probabilities agree well with predictions from MBPT and ab initio VS-IMSRG for ^{20}O and NCSM calculations for ^{16}C, showing that 3N interactions are needed to accurately describe electromagnetic observables in neutron-rich nuclei.

M. Ciemała et al. Phys. Rev. C101, 021303(R) (2020)

Support for Nuclear Theory

ECT*
European Centre for Nuclear Theory and related areas in Trento (Italy)

The IBM Blue Gene/Q system JUQUEEN with 5.9 Pflops peak performance at the computing center of the Forschungszentrum Jülich

Computing infrastructures

With continued major conceptual and computational advances, nuclear theory plays a crucial role in shaping existing experimental programmes.

- **Provide platforms for scientific exchange and training of theorists**
- **Increase the work force and strengthen collaborations and accessibility in the area of high-performance computing.**

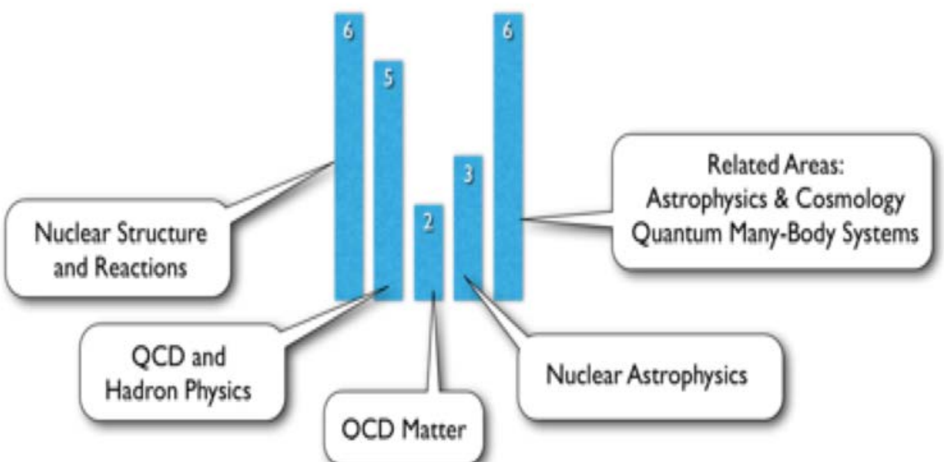
New: Quantum computing initiatives, European Open Science Cloud (EOSC)

LRP Recommendations: Support for Nuclear Theory

Scientific activities at ECT* *Trento, Italy*

- International **workshops** and **collaboration meetings** (typically around 20-25 events per year)
- **Doctoral training** programs and **Talent schools** (4 weeks of lectures for advanced PhD students)

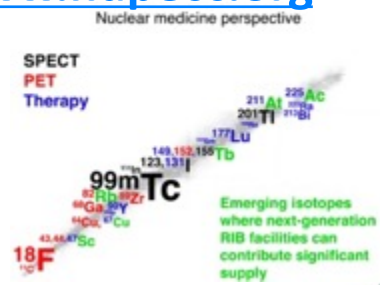
Broad spectrum of topics

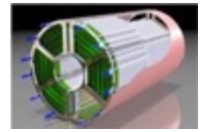


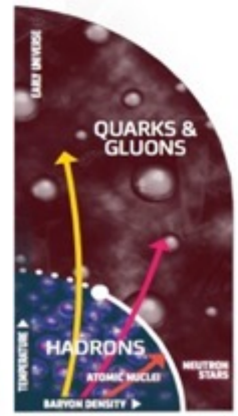
Important contribution of Poland to ECT* activities

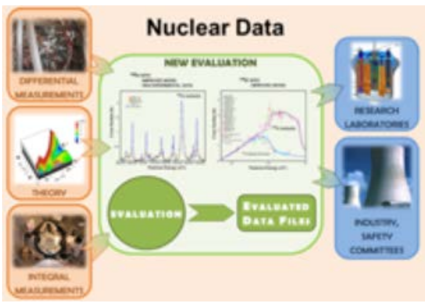
Nuclear Physics in Europe

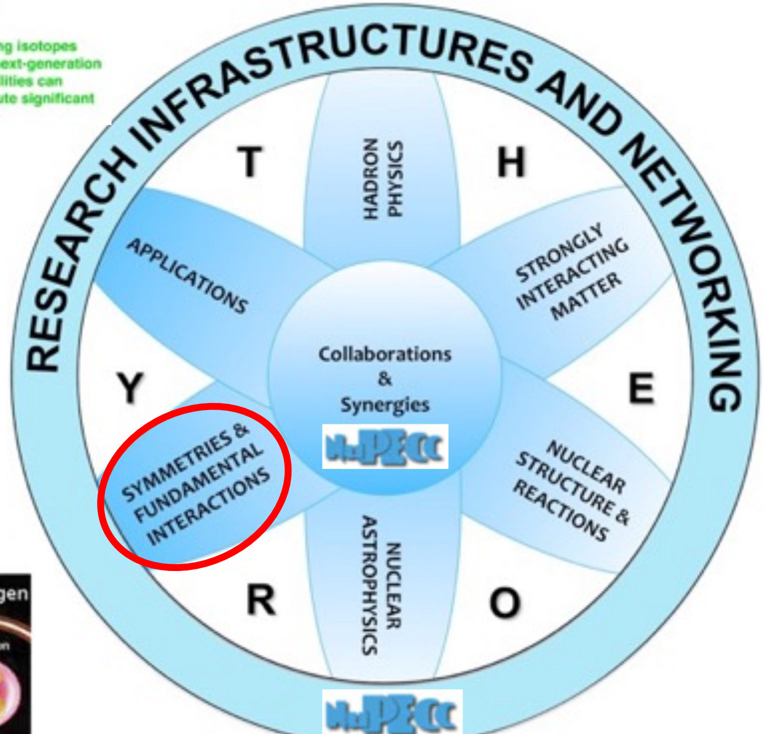
http://www.nupecc.org

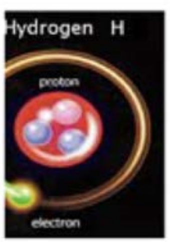


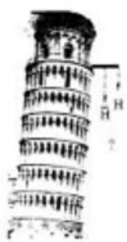


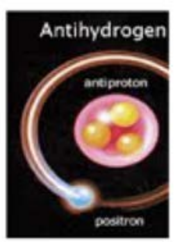


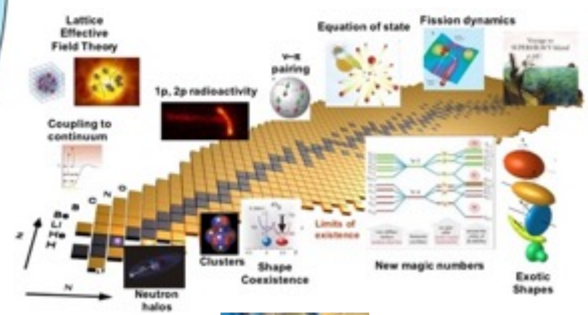


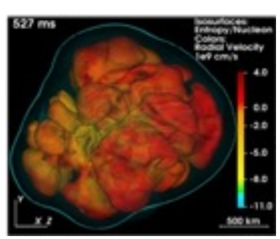


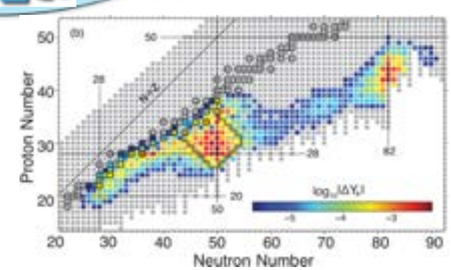










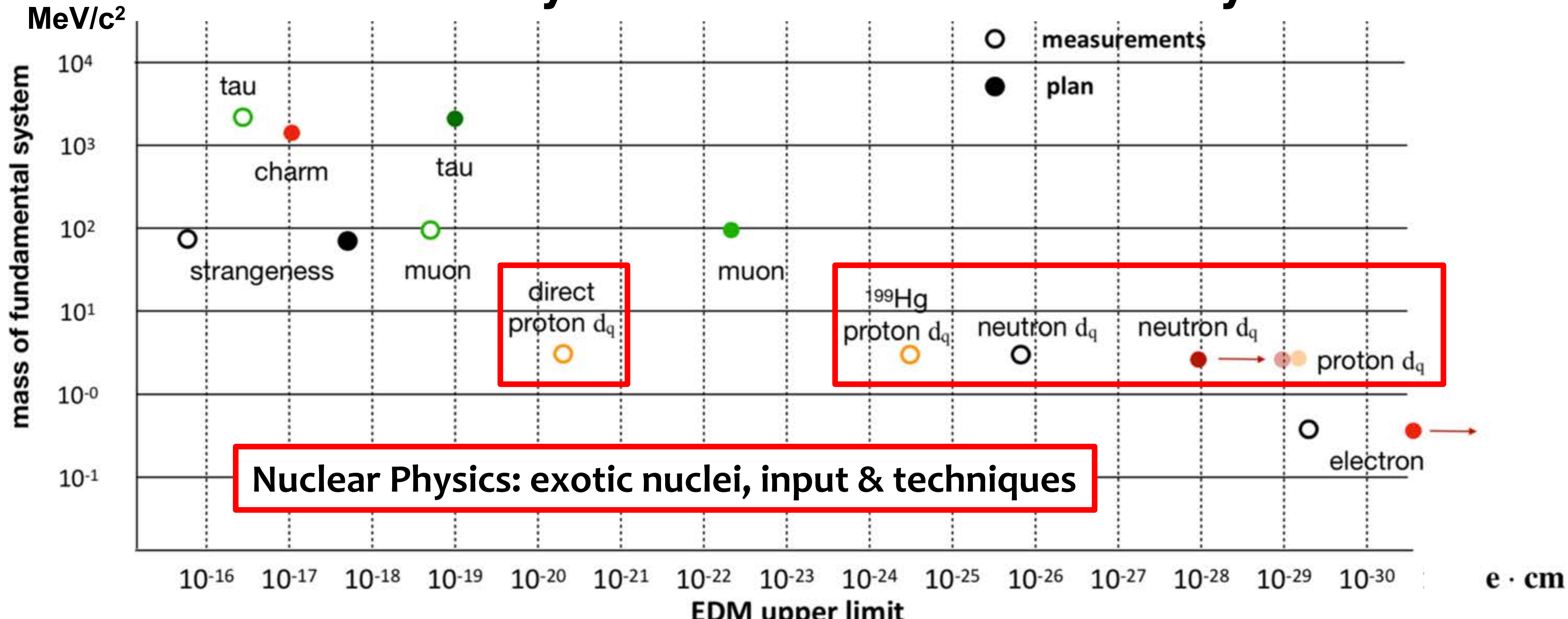


Where is New Physics?

- **Electric Dipole Moment (EDM)**
- **Electron and neutrino correlations for the weak interaction**

- **High precision measurements at low energies**
- **Complementary to experiments at the highest energies and offering sensitivities to new effects beyond the Standard Model**

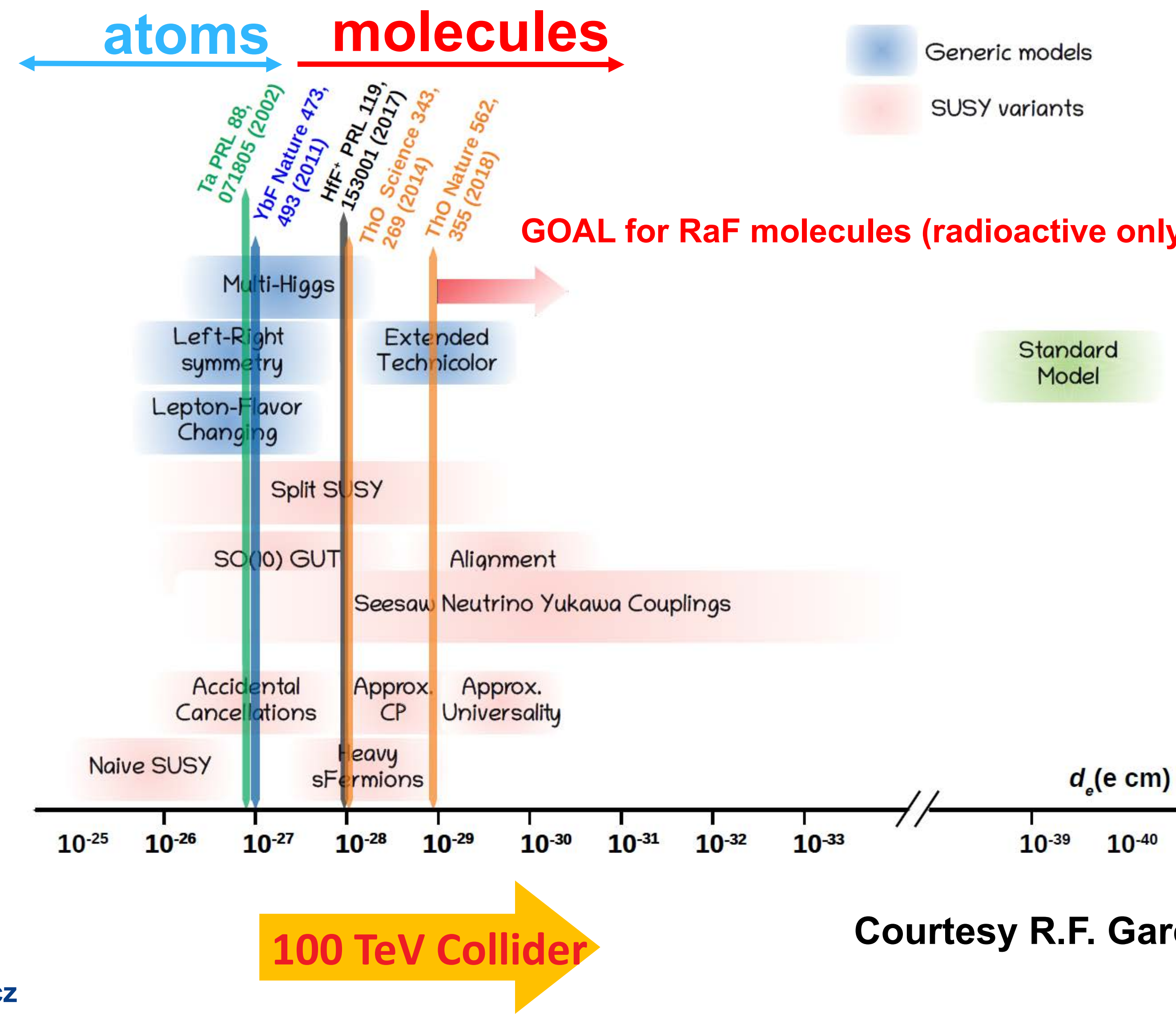
EDMs Summary - Different Fundamental Systems



Courtesy of Stephan Paul

Where is New Physics?

EXAMPLE: best limit on the electron EDM comes from molecules

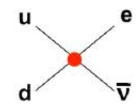


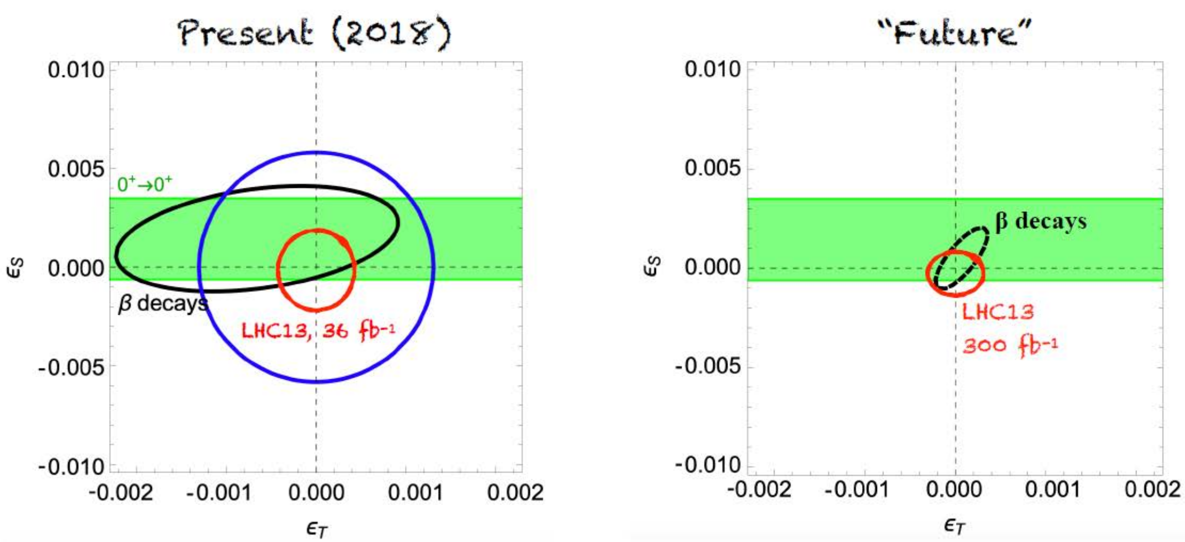
Courtesy R.F. Garcia Ruiz

Where is New Physics?

- **Electron and neutrino correlations for the weak interaction**

Scalar & tensor interactions





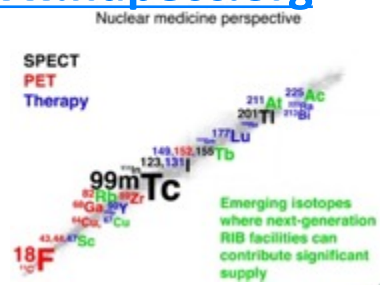
WISArD (^{32}Ar)
+ TRIUMF
+ TA&M

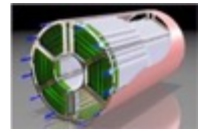
Courtesy of
M. Gonzalez-Alonso,
N. Severijns, B. Blank

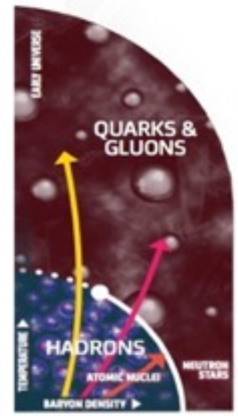
[M. Gonzalez-Alonso, O. Naviliat Cuncic, N. Severijns, Prog. Part. Nucl. Phys. 104 (2019) 165;
Gupta et al. Phys.Rev. D98 (2018) 034503]

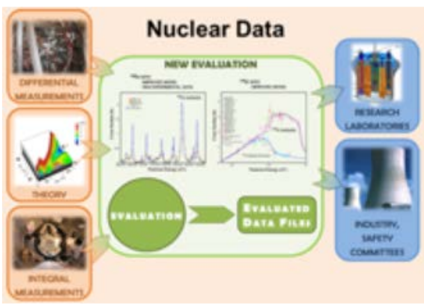
Nuclear Physics in Europe

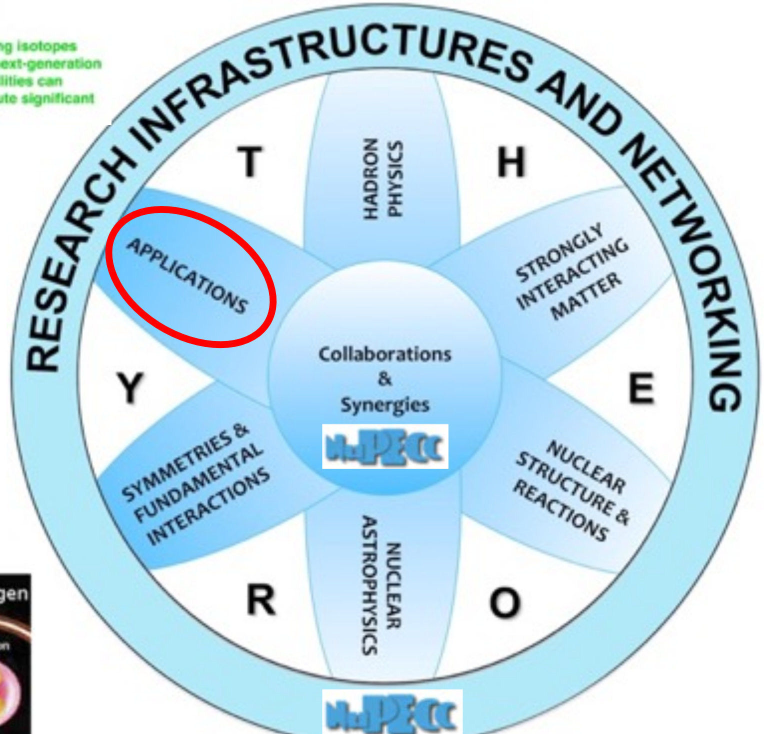
http://www.nupecc.org

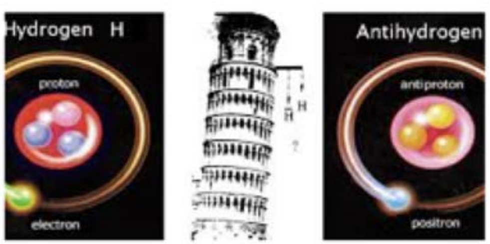


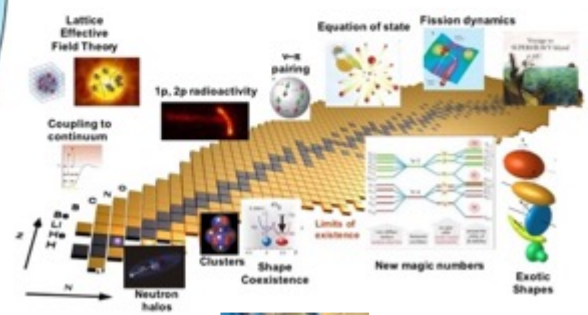


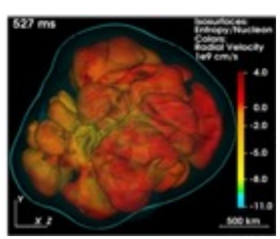


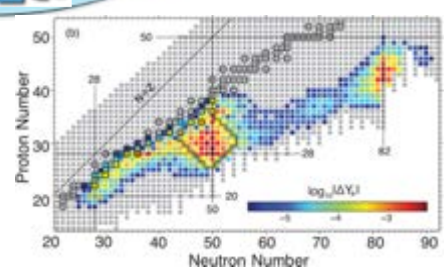








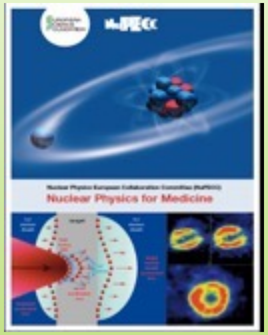




Applications of nuclear science

Vigorous programmes in nuclear applications

- **For nuclear energy systems the development of predictive and reliable models and simulation tools is mandatory.**



- **Development of adapted techniques for cancer treatment: hadrontherapy, specific radio-isotopes and more efficient imaging techniques.**

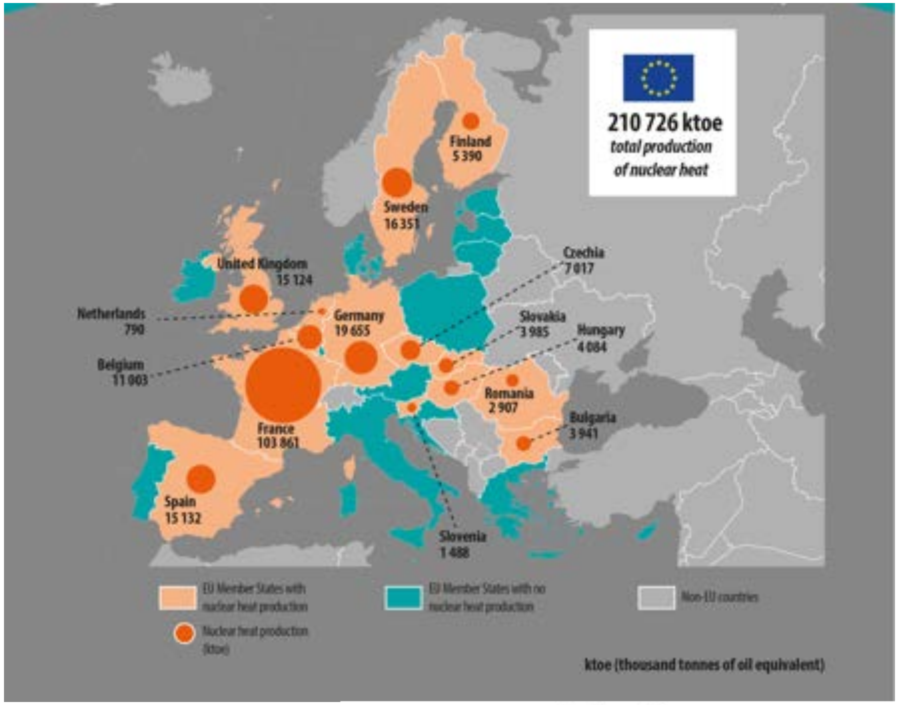
NuPECC Report "Nuclear Physics for Medicine"

http://nupecc.org/pub/npmed2014.pdf

- **With the availability of high-intensity accelerators and new installations (GANIL, ESS, FAIR, ELI-NP, HIE-ISOLDE) new studies in materials science, atomic and plasma physics will be possible, exploring matter in extreme conditions.**

Energy applications

Nuclear Energy in EU



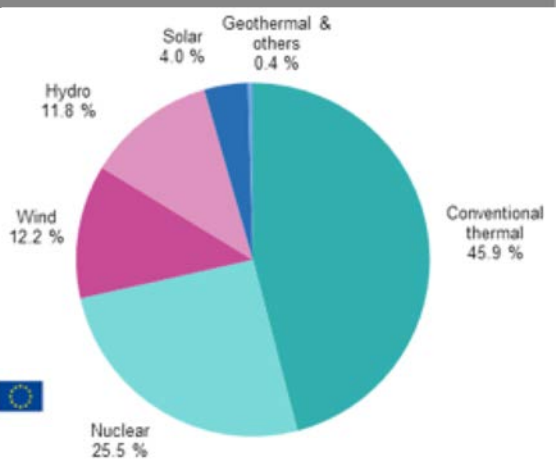
In 2018, nuclear plants generated 25,5 % of the electricity produced in the European Union, with nuclear reactors operating in 14 Member States

128 nuclear power reactors (119 GWe)

Under construction: 4 reactors in EU + 10 in Russia and Belorussia

Electricity production by source, EU-28, 2018 (%)

eurostat

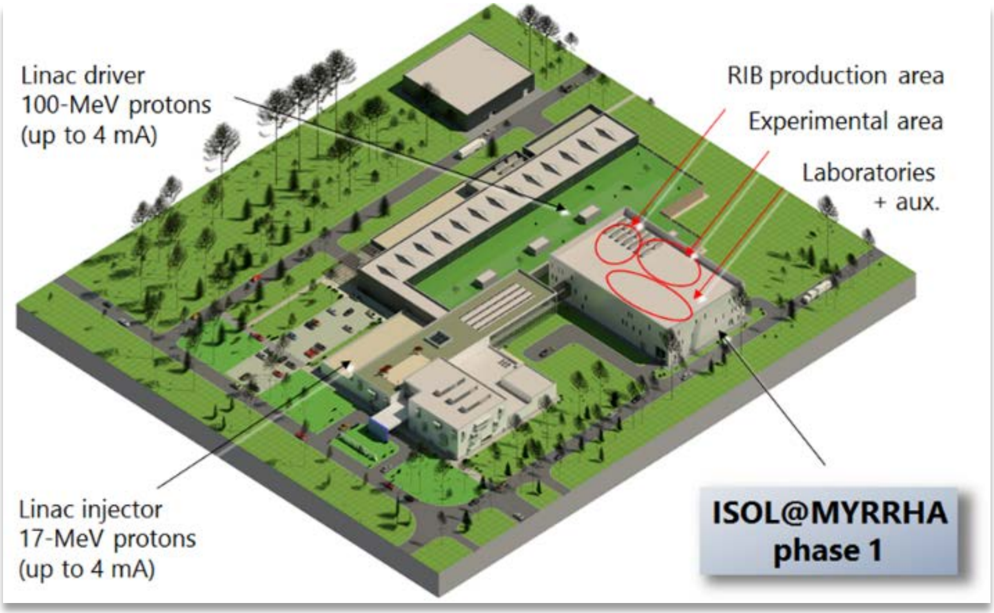


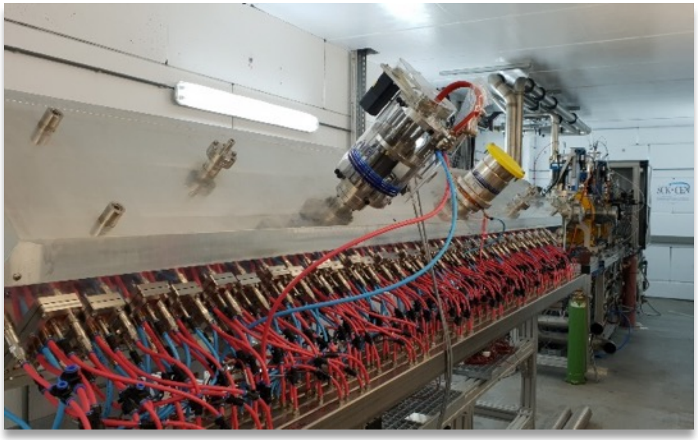
ESFRI

First phase of MYRRHA ADS facility under construction in Belgium

IFMIF-DONES - test facility for fusion materials under design proposed in Granada, Spain

MYRRHA ADS project phase 1/MINERVA at SCK Belgium



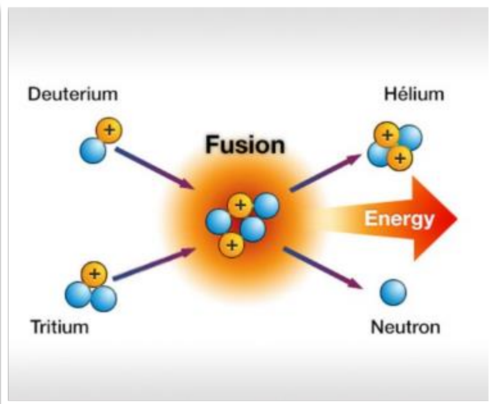


- Accelerator in Phase 1 = a subset of the MYRRHA accelerator
- Beam sharing allows for parallel activities :
  - feeding the PTF hosting **the ISOL** system (ISOL@MYRRHA phase 1)
  - commissioning the linac for **reliability evaluation**
  - irradiation capabilities for the **fusion** community
- Layout is compatible with Linac extension to 600 MeV
- Conceptual Design of the PTF – to be finalized in 2019
- **First Radioactive Ion Beams expected by 2027**

Courtesy of Lucia Popescu

Energy applications

ITER – Bringing the power of the sun to earth



Fusion on earth needs temperatures of 100-150 million ° C

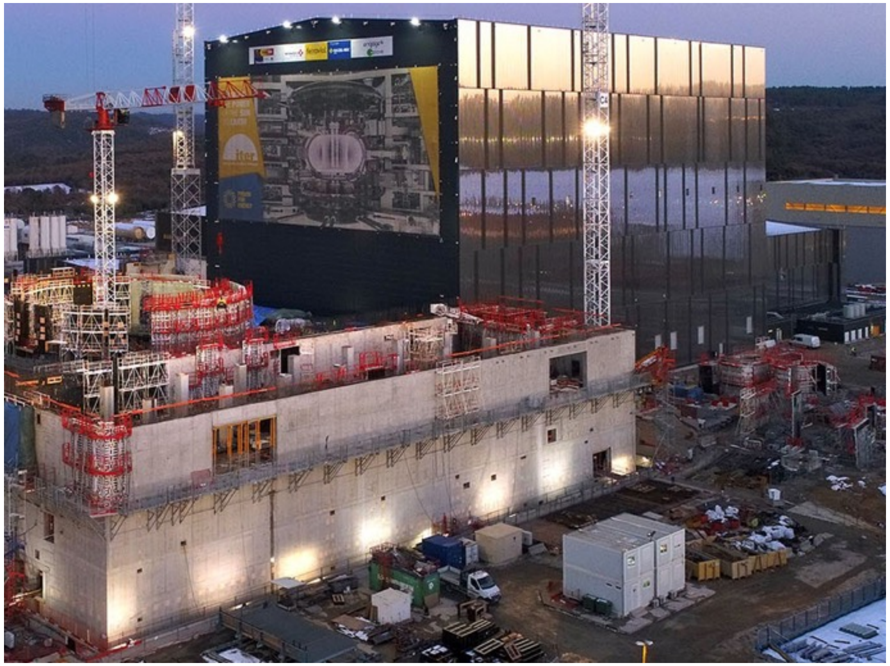
Many experiments in Europe and the rest of the world

Tore Supra	JET	ITER	DEMO
25 m^3	80 m^3	800 m^3	~ 1000 - 3500 m^3
~ 0 MW_{th}	~16 MW_{th}	~ 500 MW_{th}	~ 2000 - 4000 MW_{th}

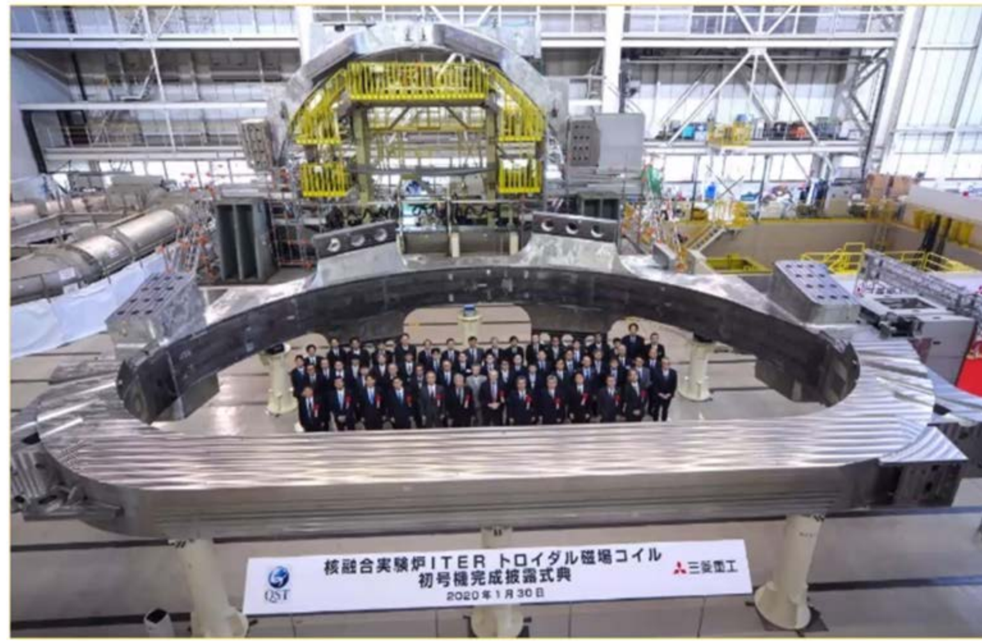
Energy applications

ITER – Bringing the power of the sun to earth

Construction site at Cadarache, France



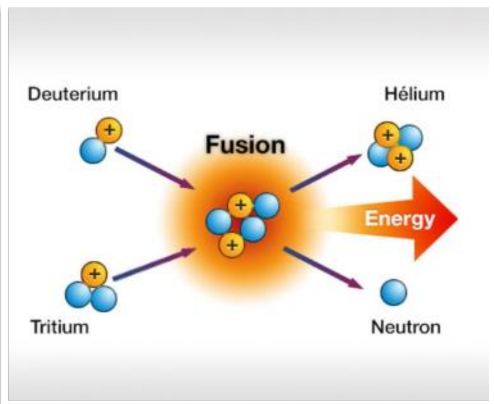
Completed Superconducting TF Coil



First plasma by the end of 2025
Full power by 2035

Energy applications

ITER – Bringing the power of the sun to earth



Fusion on earth needs temperatures of 100-150 million ° C

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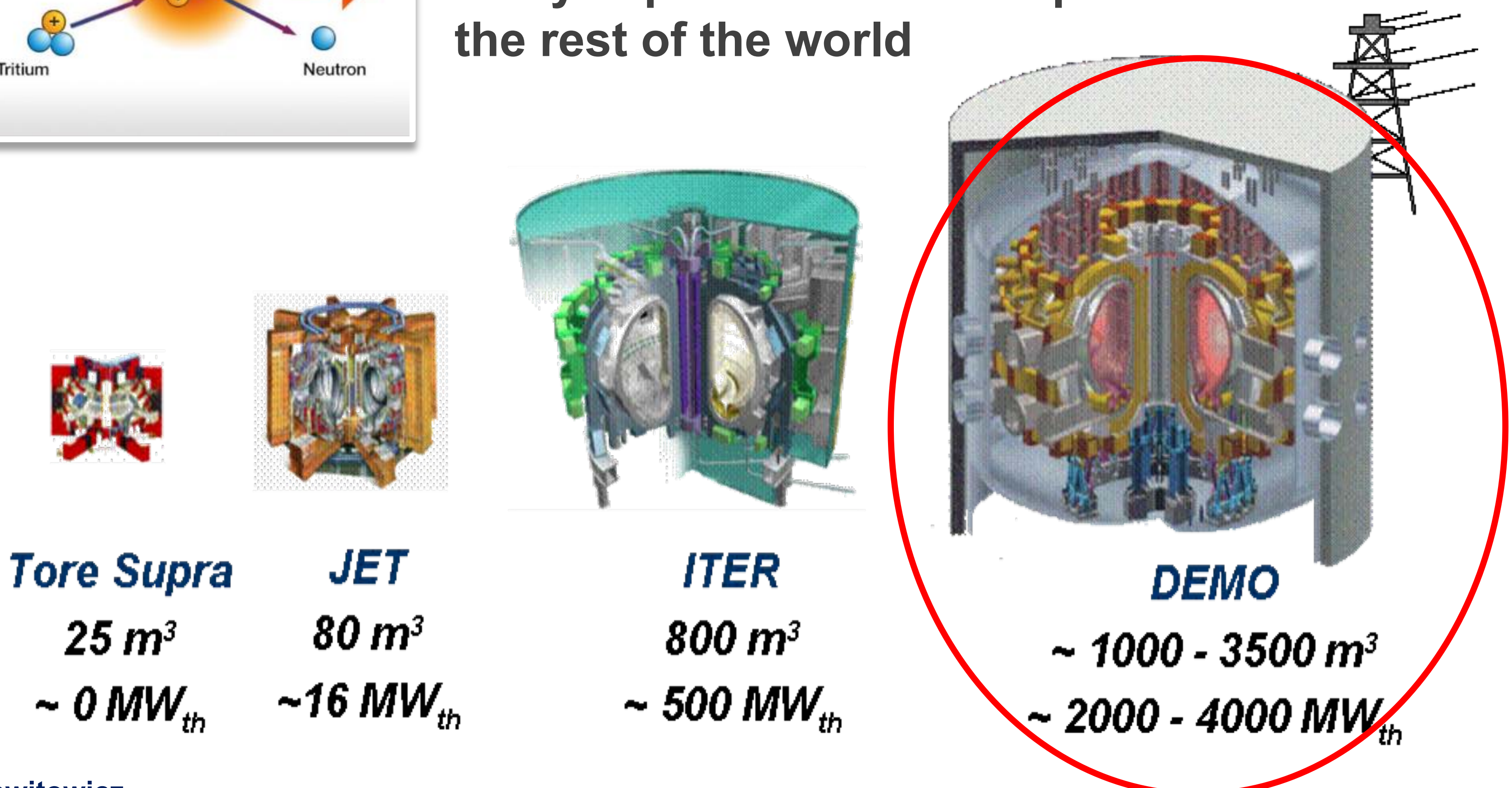
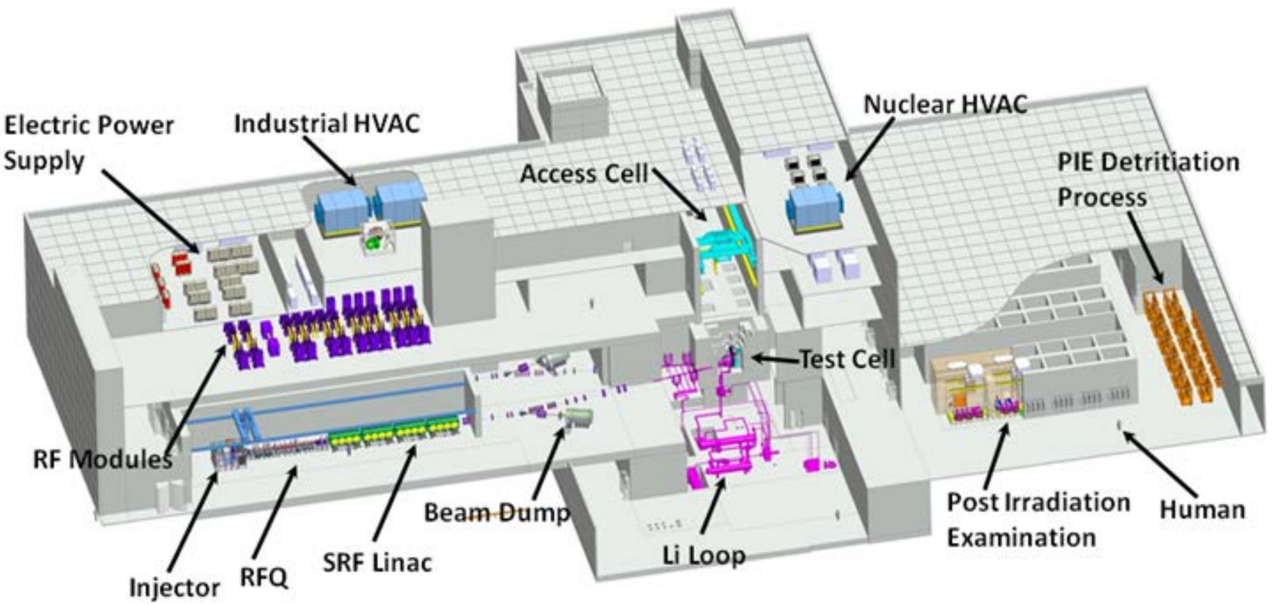


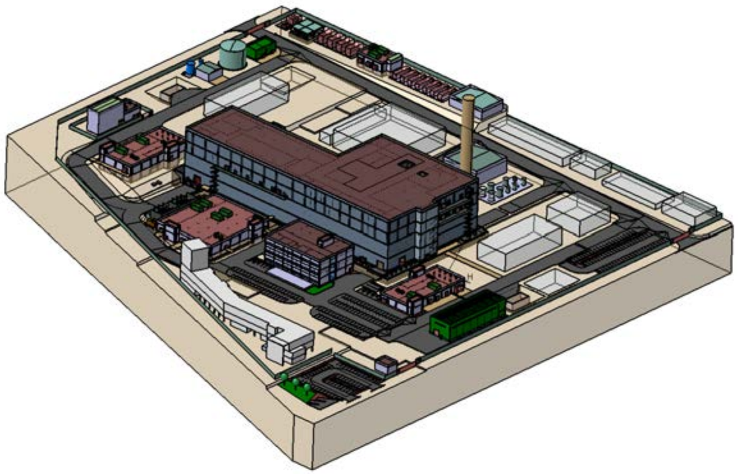
IFMIF- DONES project in Granada, Spain

IFMIF, International Fusion Materials Irradiation Facility



A fusion relevant neutron source is necessary step for the successful development of fusion energy.

The International Fusion Materials Irradiation Facility – Demo Oriented NEutron Source (IFMIF-DONES) is a single-sited novel research infrastructure for testing, validation and qualification of the materials to be used in future fusion power plants like DEMO (a demonstration fusion reactor prototype)

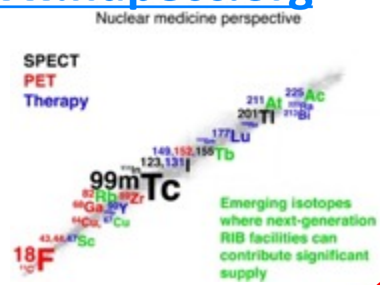


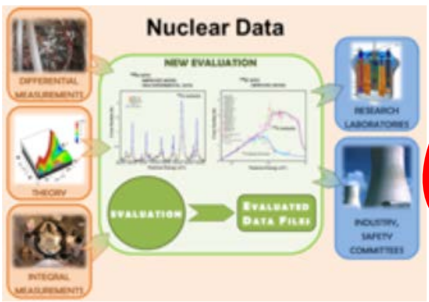
Includes research in nuclear physics

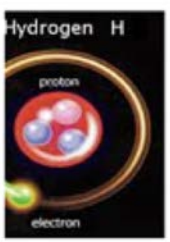
https://ifmifdones.org

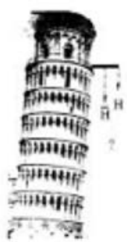
Nuclear Physics in Europe

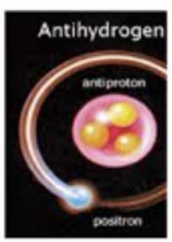
http://www.nupecc.org

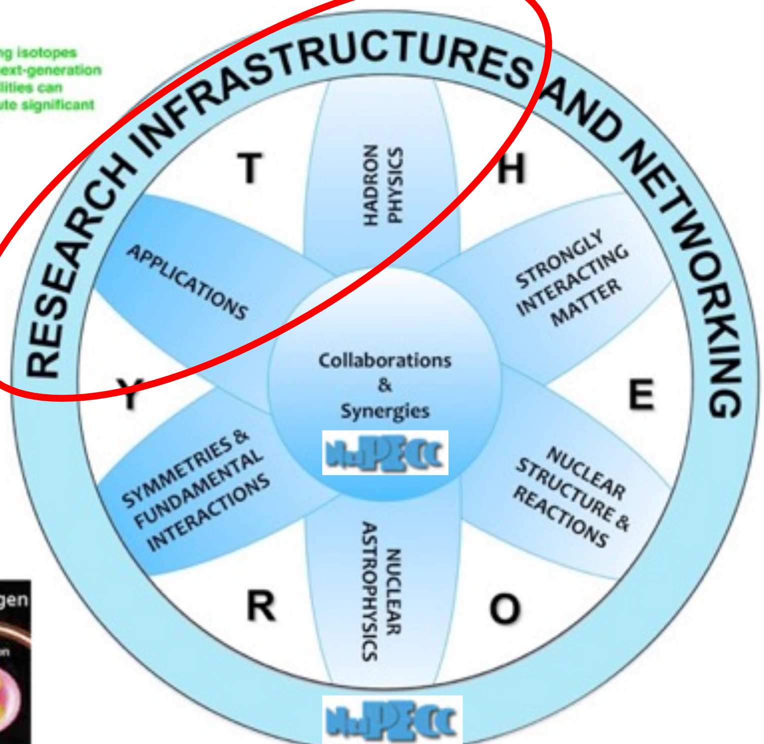


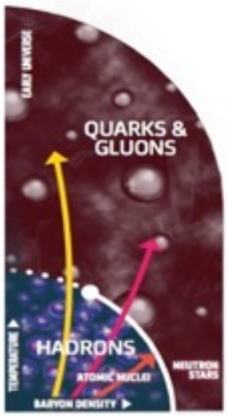


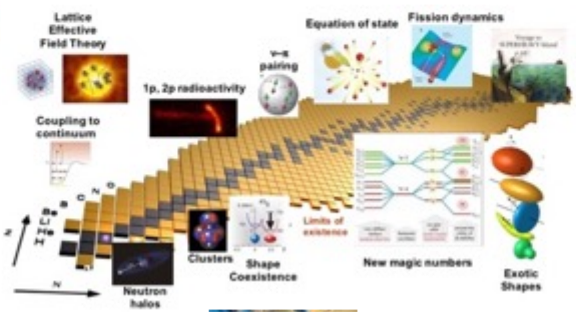


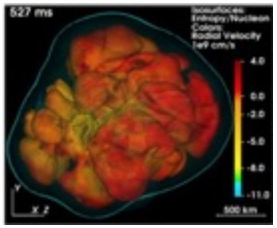


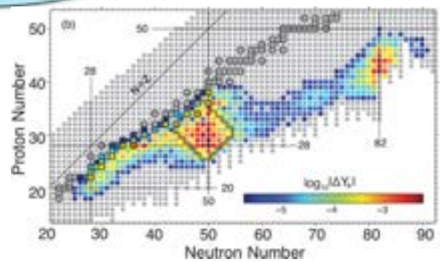


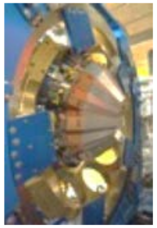






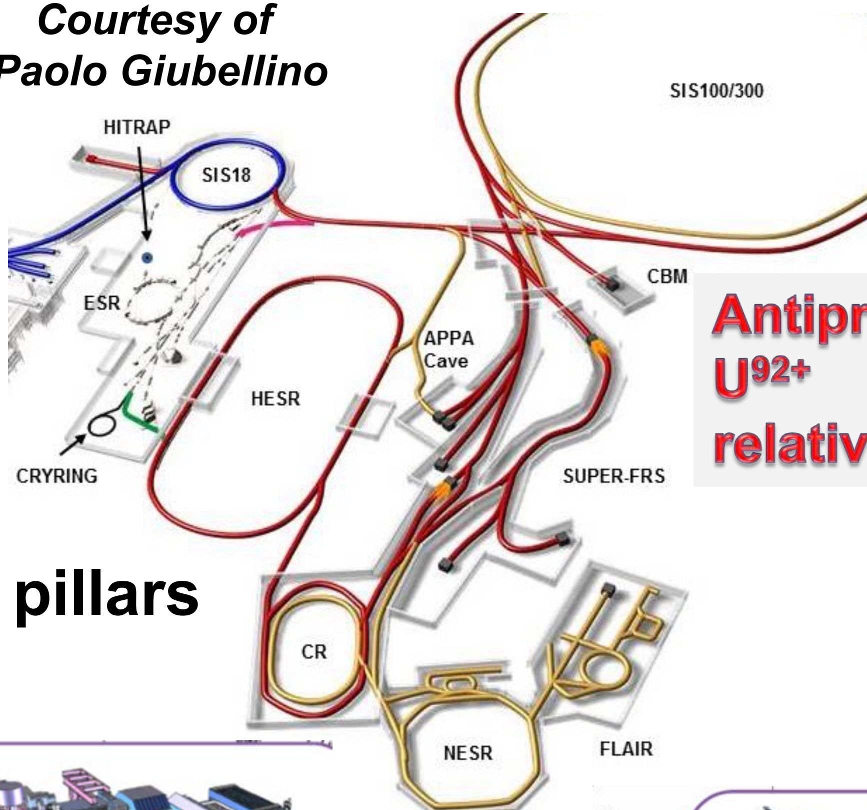






Darmstadt, Germany

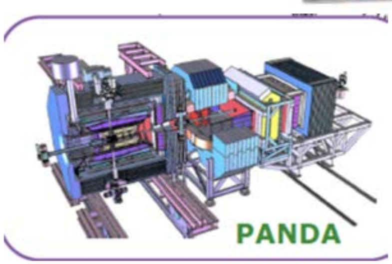
Courtesy of Paolo Giubellino

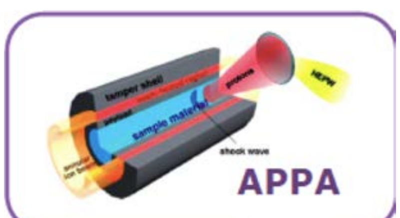


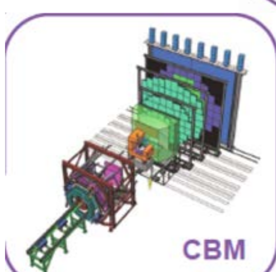
Large facility covering all nuclear physics domains !

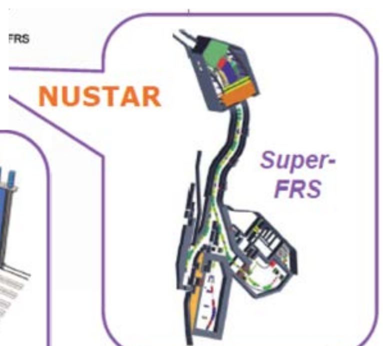
Antiprotons, highly charged ions (e.g. U^{92+}) and exotic Nuclei) from rest to relativistic energies 4.9 GeV/A

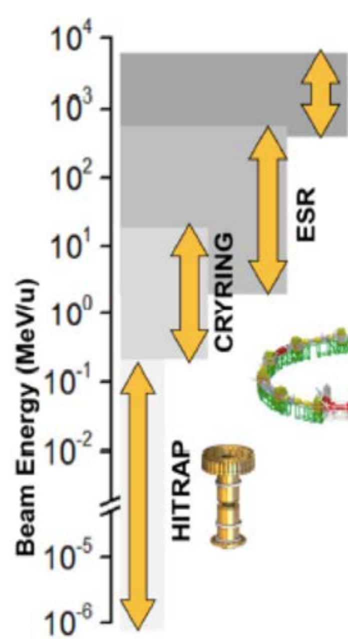
4 pillars

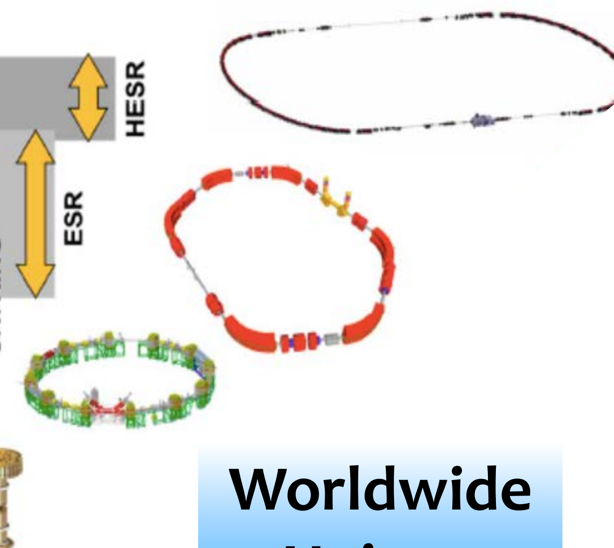












Worldwide Unique

Ongoing experiments FAIR Phase-0 (since 2019)

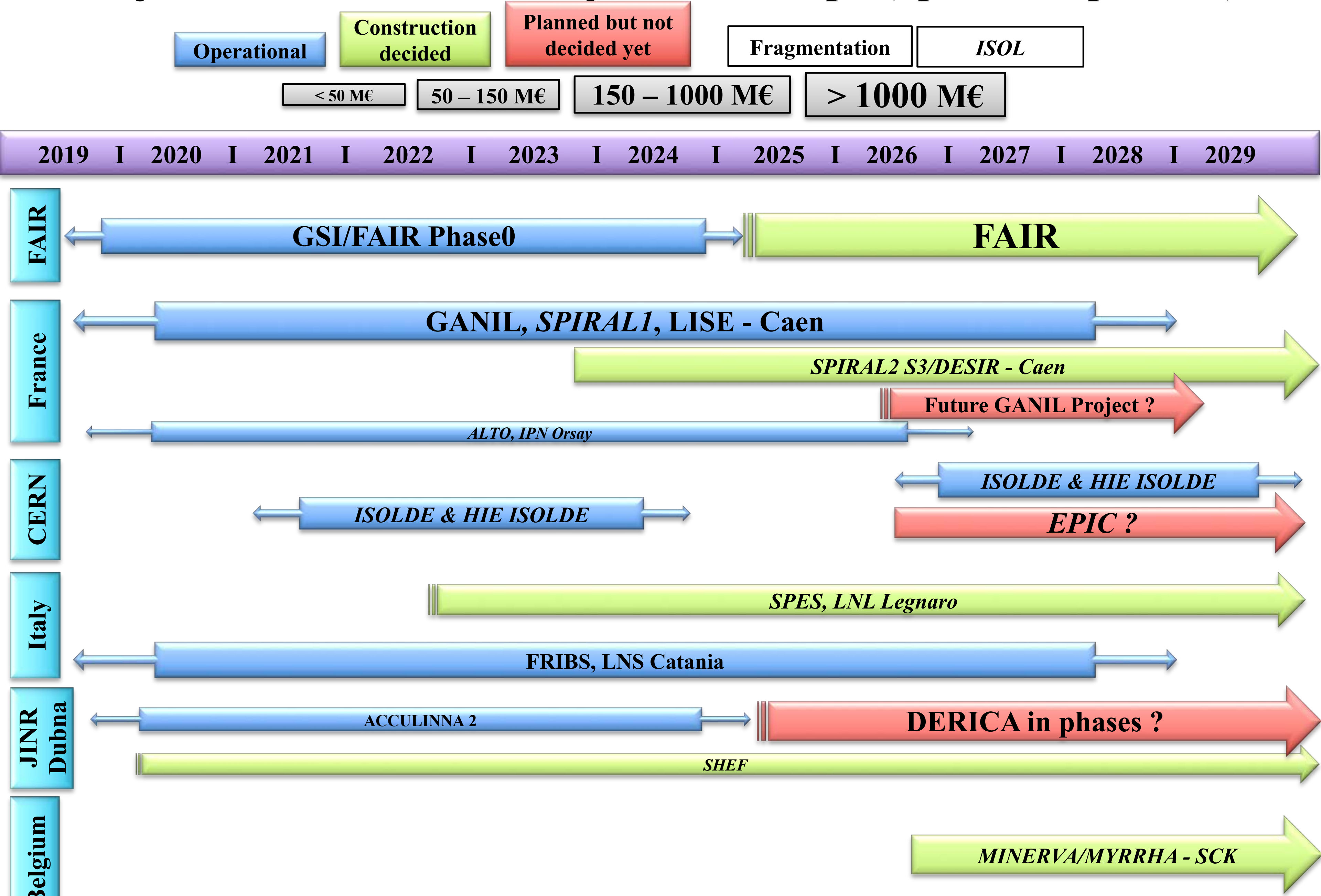
Status of FAIR Project: Civil Construction

FAIR GSI

See movie at http://www.nupecc.org

Curtesy of Paolo Giubellino

Major RIB Facilities & Projects in Europe (operation periods)



(status before COVID-19 pandemic)

Integrating community with EU projects

SCIENCE CONNECT — European Science Foundation — YOUR PARTNER IN SCIENCE

Support for users and facilities

ENSAR2

Nuclear structure reactions and applications

Contract 2016-2021 (10M€)

Coord. Muhsin Harakeh
GANIL

- **GANIL (France)**
- **LNL-LNS (Italy)**
- **ISOLDE (CERN)**
- **JYFL (Finland)**
- **ALTO (CNRS, France)**
- **GSI (Germany)**
- **KVI (The Netherlands)**
- **NLC (HIL/IFJ PAN, Poland)**
- **IFIN-HH/ELI-NP (Romania)**
- **ECT* (Italy)**

HadronPhysics

Hadron physics STRONG-2020

Contract 2019 -2023 (10M€)

Coord. Barbara Erazmus
IN2P3/CNRS

- **CERN LHC & fixed target exp.**
- **GSI/FAIR (Germany)**
- **LNF, Frascati (Italy)**
- **MAMI, Mainz (Germany)**
- **ECT*, Trento (Italy)**
- **ELSA, Bonn (Germany)**
- **COSY, Jülich (Germany)**

Conclusion

- **The 2017 NuPECC Long Range Plan defined an ambitious strategy for European Nuclear Physics**
- **Joint efforts of the European nuclear physics community, funding agencies and NuPECC to transform the LR Plan into reality**

Nuclear Structure and Reactions

- Quest for Limits
- Precision Measurements
- Beauty of Systematics
- New Era of Nuclear Theory
- Where in New Physics?

Necessity for coherent European & International efforts towards accomplishment of scientific goals, new facilities and upgrades of existing ones

Thank you for your attention

Roadmap NP facilities

5mA 14-20 MeV/n light and heavy ions

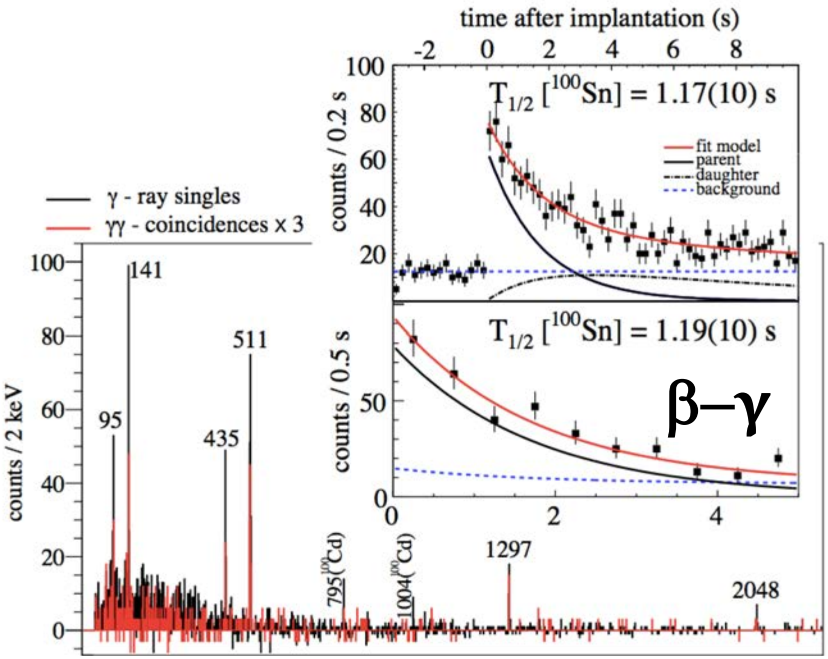
First SPIRAL2 experiments in 2021

Courtesy of Navin Alahari

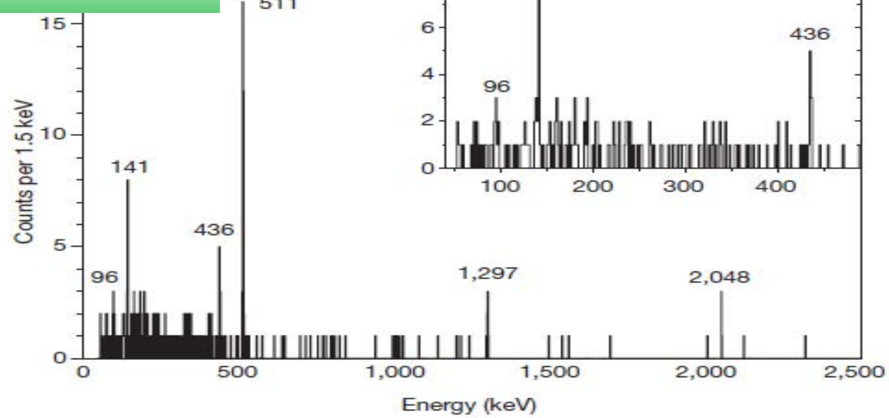
Future development of the facility under discussion

Analysis of ^{100}Sn data

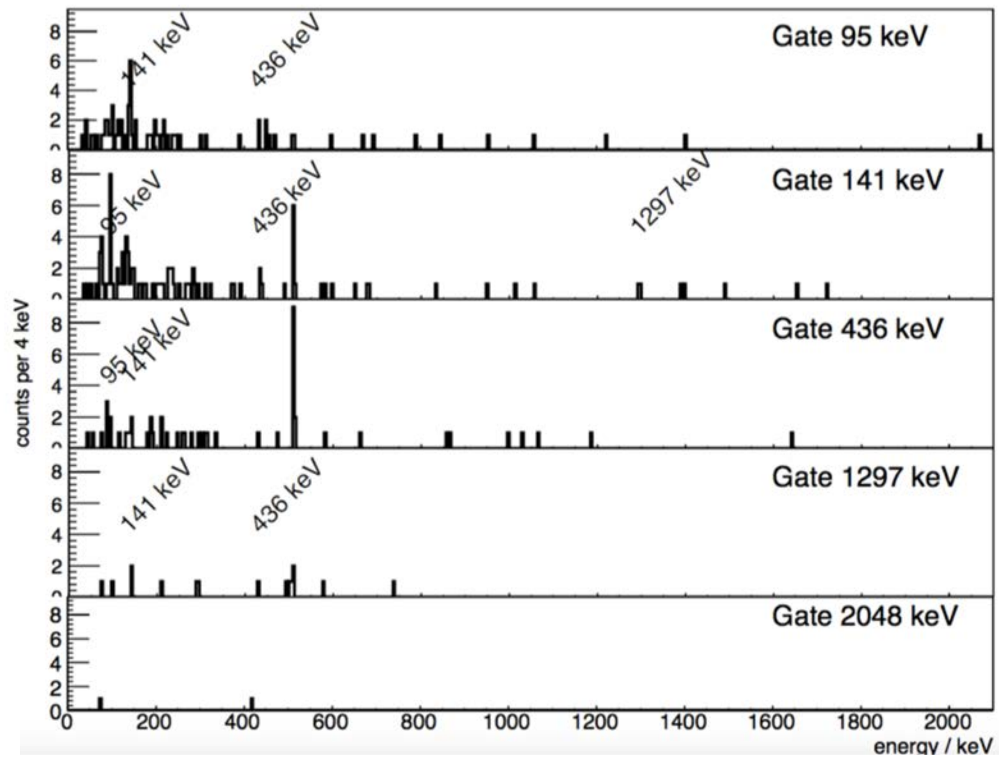
β–γ Spectroscopy



Hinke et al.



β–γ γ coincidences



8 times higher statistics than in the previous experiment at GSI but no new transitions found

D. Lubos et al.

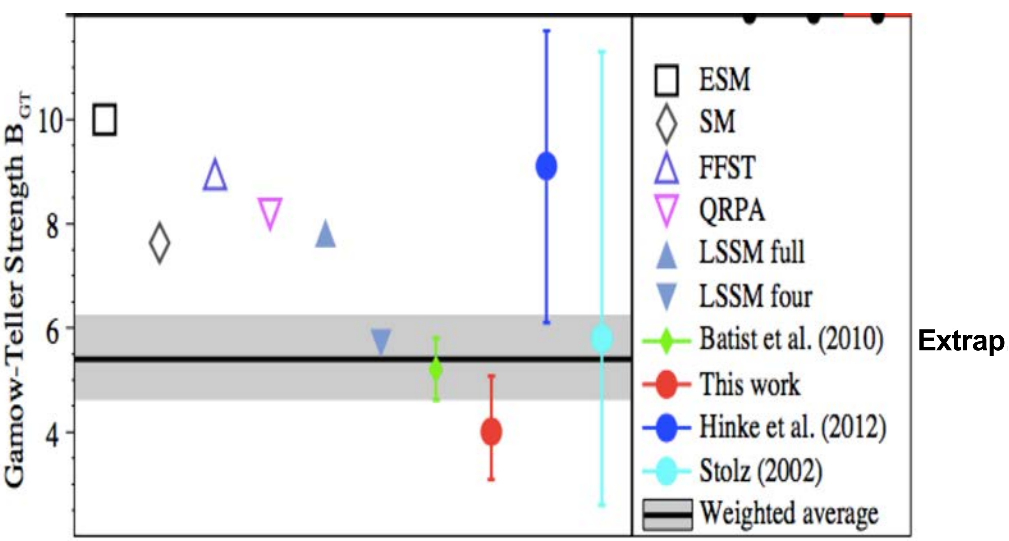
B(GT) strength of ^{100}Sn

Discrepancy between experimental and theoretical β-decay rates resolved from first principles

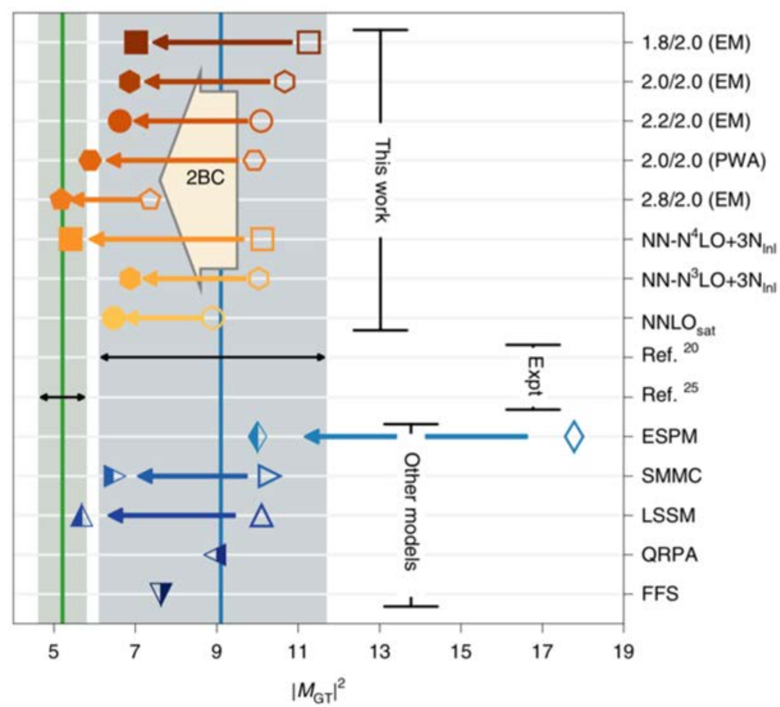
D. Lubos et al. PRL 2019
$T_{1/2}$ = 1.18 ± 0.10 s
Q_{β} = 4.0 ± 0.2 MeV
log(ft) = 2.98 ± 0.11
B_{GT} = 3.99+0.94/-0.90

C. B. Hinke et al.
1.16 s ± 0.20 s
3.29 ± 0.20 MeV
$2.62^{+0.13}_{-0.11}$

^{100}Sn one of the smallest known log(ft) values of any nuclear β-decay



D. Lubos et al. PRL 2019



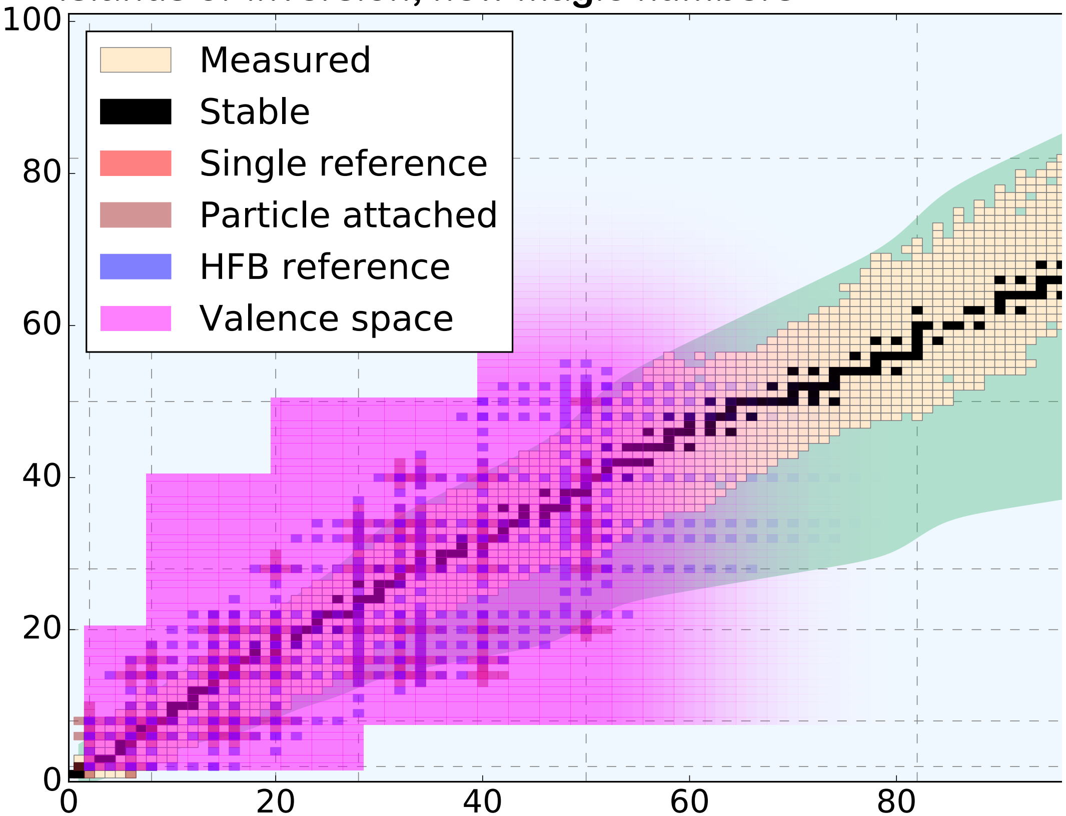
P. Gysbers et al. Nature Physics 2019

Theory for Next-Generation RIB Facilities

Ab initio valence-shell Hamiltonians

Ab initio prediction of nuclear driplines/r-process

Islands of inversion, new magic numbers



Fundamental physics

- Effective electroweak operators: M1, GT,...
- Effective $0\nu\beta\beta$ decay operator
- WIMP-Nucleus scattering
- Superallowed transitions

Outstanding issues

- Controlled many-body approximation
- E2 operators problematic
- Continuum essential beyond stability
- Quantify uncertainties

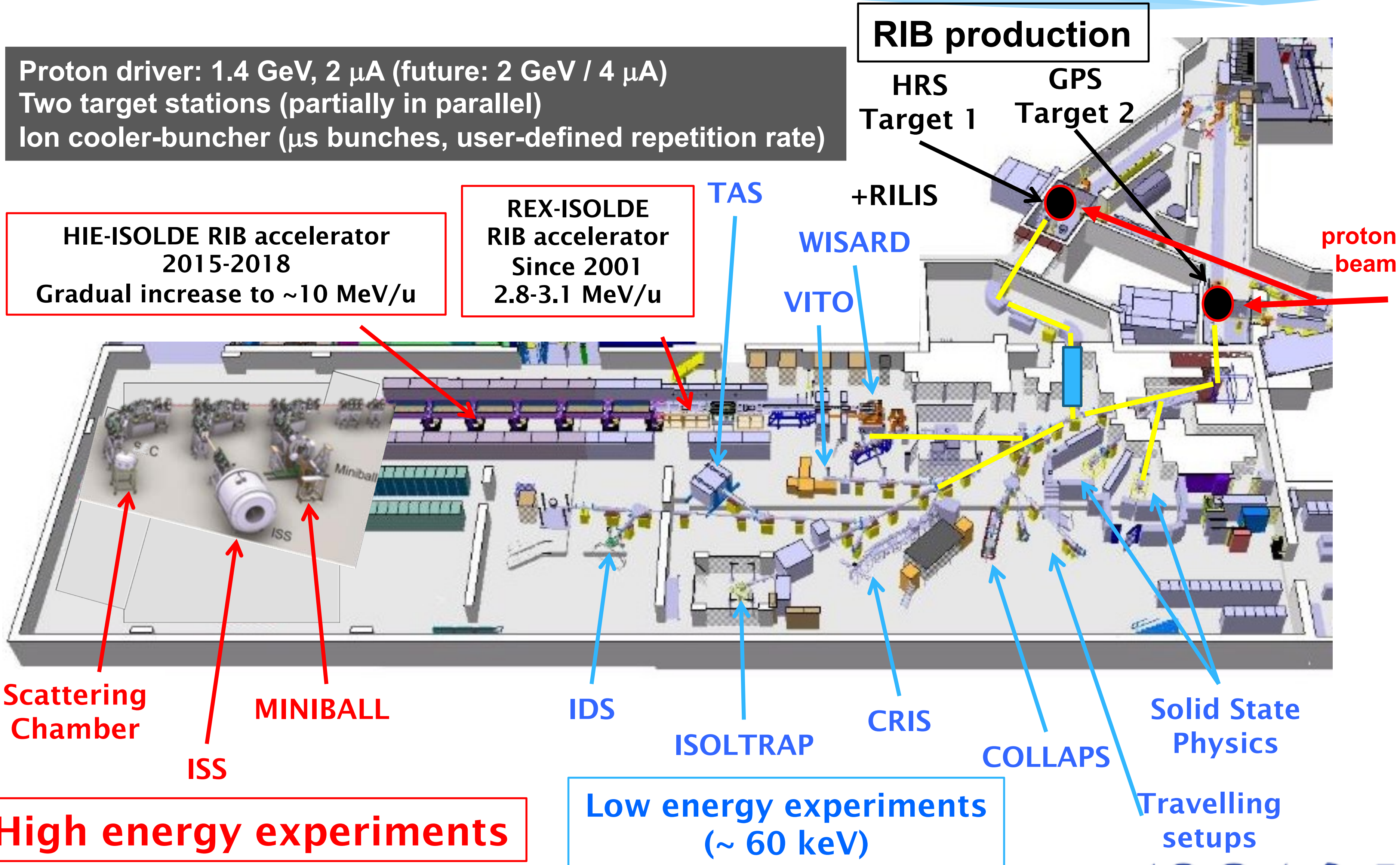
Experimental overlap

- Best data for constraining nuclear forces
- New measurements of driplines
- Data on magic numbers in exotic nuclei
- Precision data on GT transitions

Courtesy of Jason D. Holt

CERN/ISOLDE facility

Proton driver: 1.4 GeV, 2 μA (future: 2 GeV / 4 μA)
Two target stations (partially in parallel)
Ion cooler-buncher (μs bunches, user-defined repetition rate)

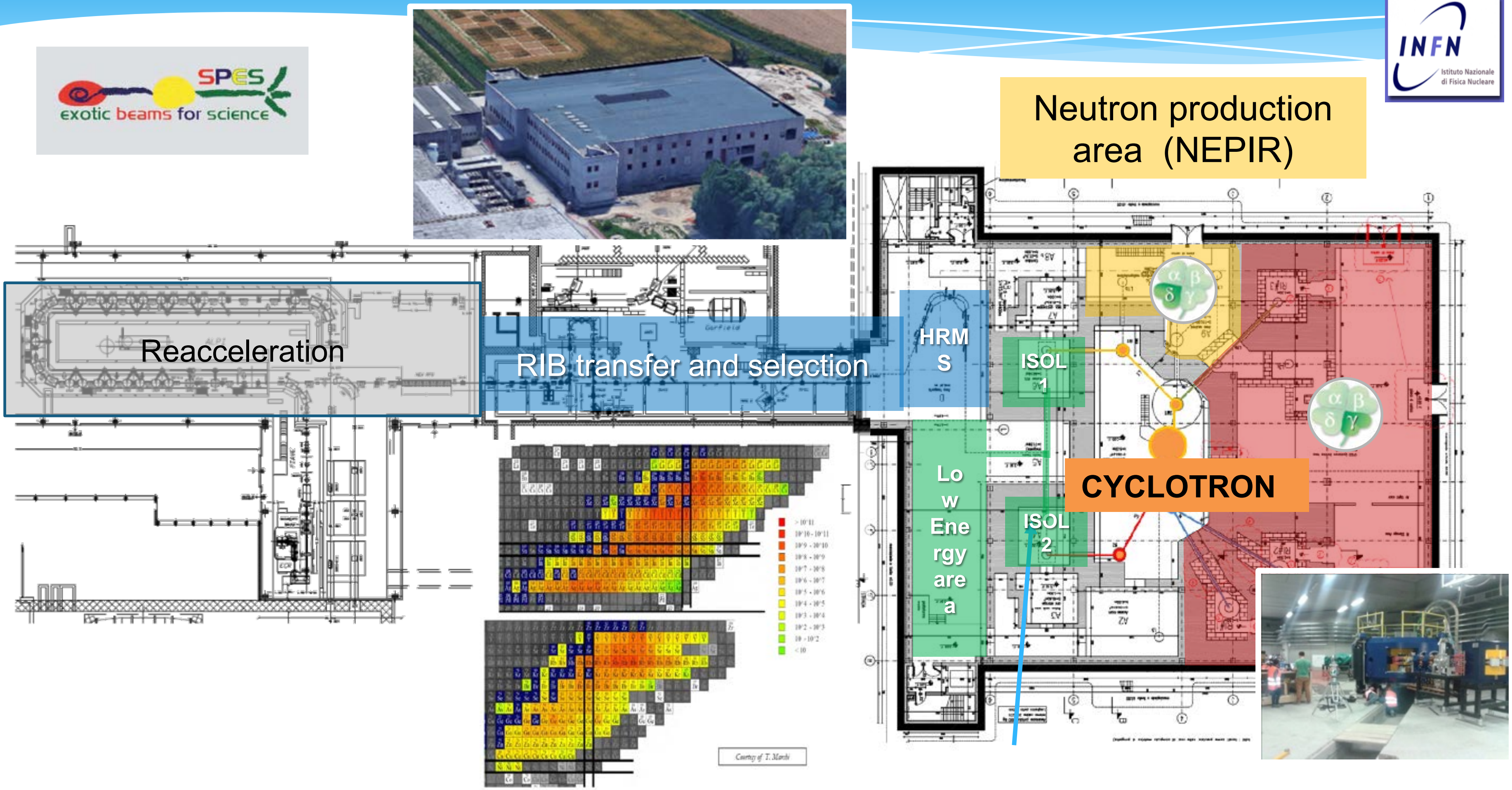


ISOLDE: A Laboratory Report, JPG44 (2017)

Courtesy of G. Neyens

SPES Facility at LNL, Italy

SPES exotic beams for science



RIB reacceleration:

- new RFQ
- ALPI

≥ 2023

1/20.000 Mass separator
(Beam Cooler + HRMS)
Elettrostatic beam transport
Charge Breeder (n+)
1/1000 mass separator

by 2023

ISOL bunkers
1/200 mass separator
low energy experimental area
by 2022

Radioisotopes production area (LARAMED)

Cyclotron: 70 MeV – 500 μA proton beam tested

Energy applications

ITER – Bringing the power of the sun to earth