NuPECC and Strategy for Nuclear Physics in Europe

Marek Lewitowicz
Chair of NuPECC

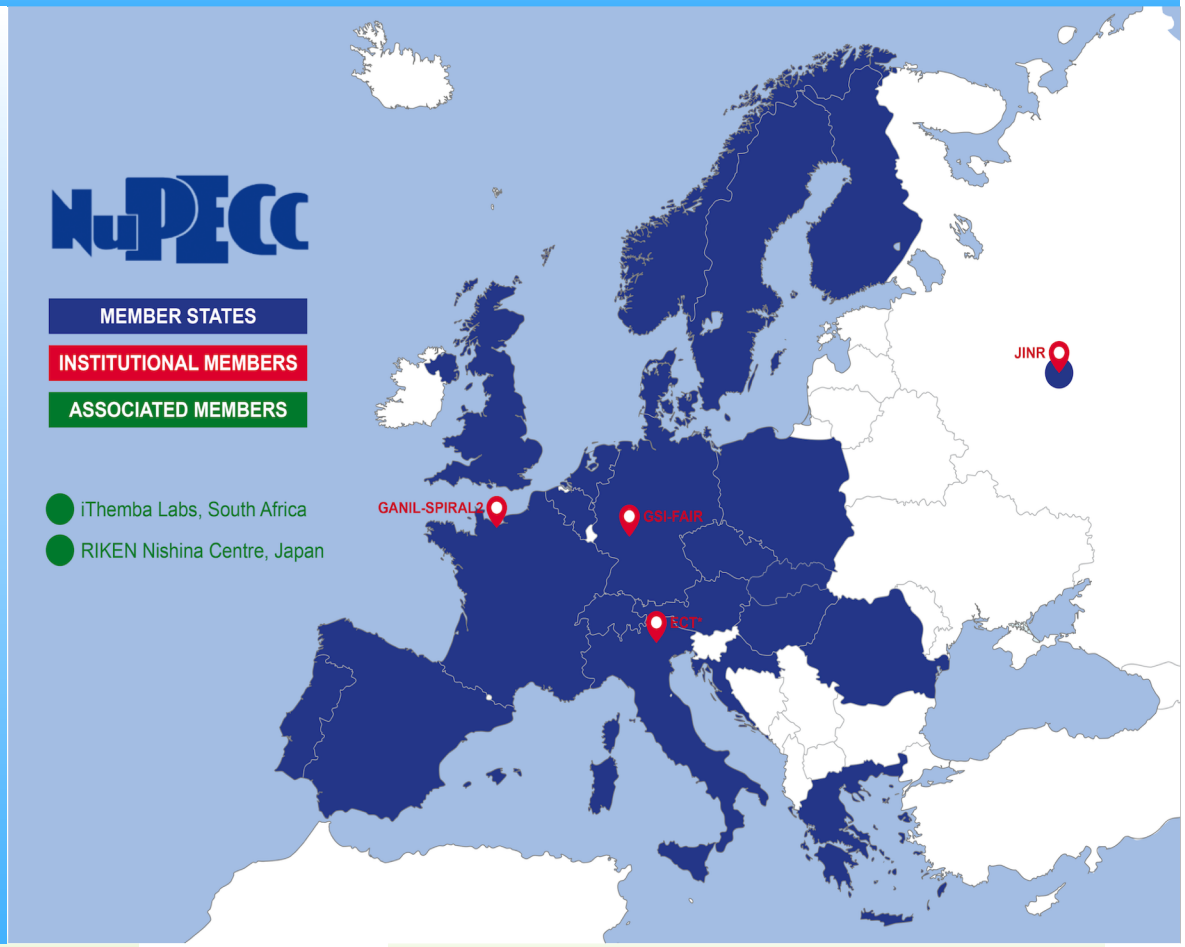
Disclaimer: ***Focus on Nuclear Physics Facilities***
Introduction to following talks

What is NuPECC ?

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

Representing
about 6000 scientists
Composition:

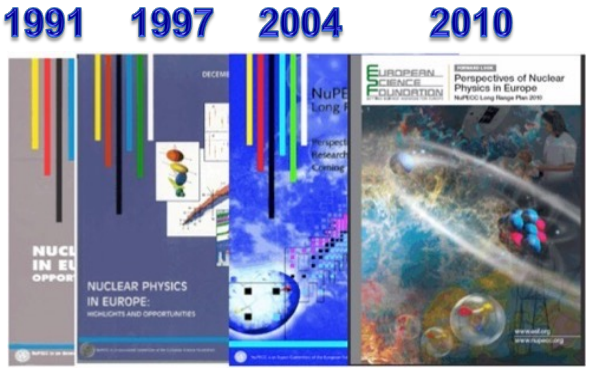
- 32 representatives from 21 countries, ESFRI NP Infrastructures & JINR Dubna
- 2 associated members (iThemba Labs and Nishina Center)
- 7 observers (NPD/EPS, ECFA, NSAC, ANPhA, APPEC, ALAFNA, CINP, IAEA)



3 regular Committee meetings/y

30 Years of NuPECC activities

Long Range Plan organization & schedule



- **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**

Community
200 experts
7 working groups

Town meeting in Darmstadt January 2017

Report June 2017

LRP presentation in Brussels Nov. 27, 2017

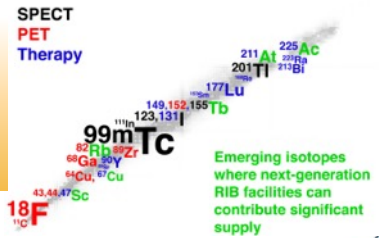
Beginning of 2016 → **End of 2017**

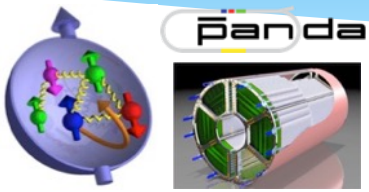
http://www.nupecc.org/lrp2016/Documents/lrp2017.pdf

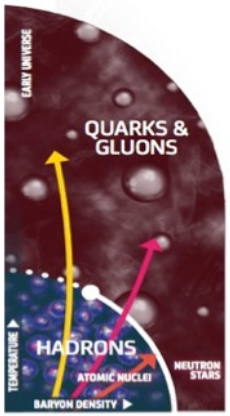
Nuclear Physics in Europe

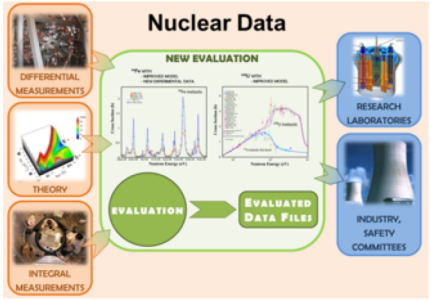
http://www.nupecc.org

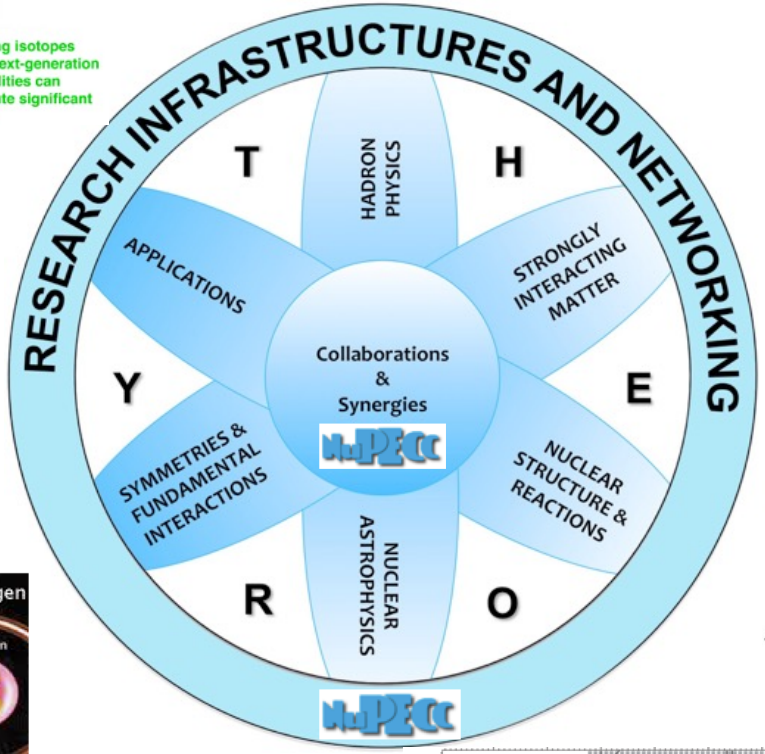
Talk of Marco Durante



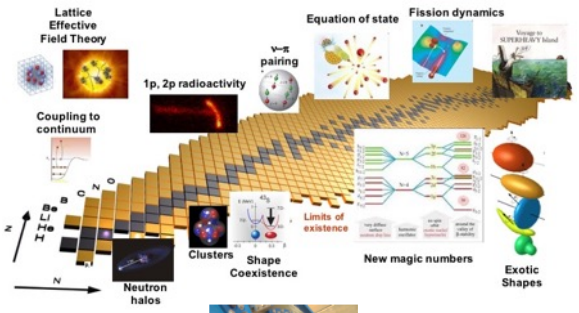


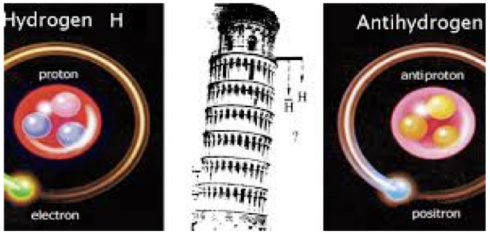




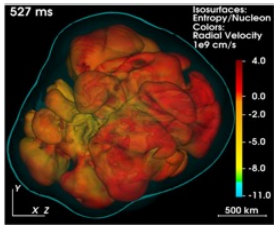


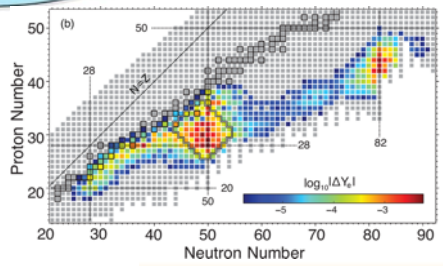
Talk of Piet Van Duppen

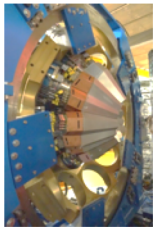




Talks of Piet Van Duppen, Nathal Severijns and Klaus Kirch



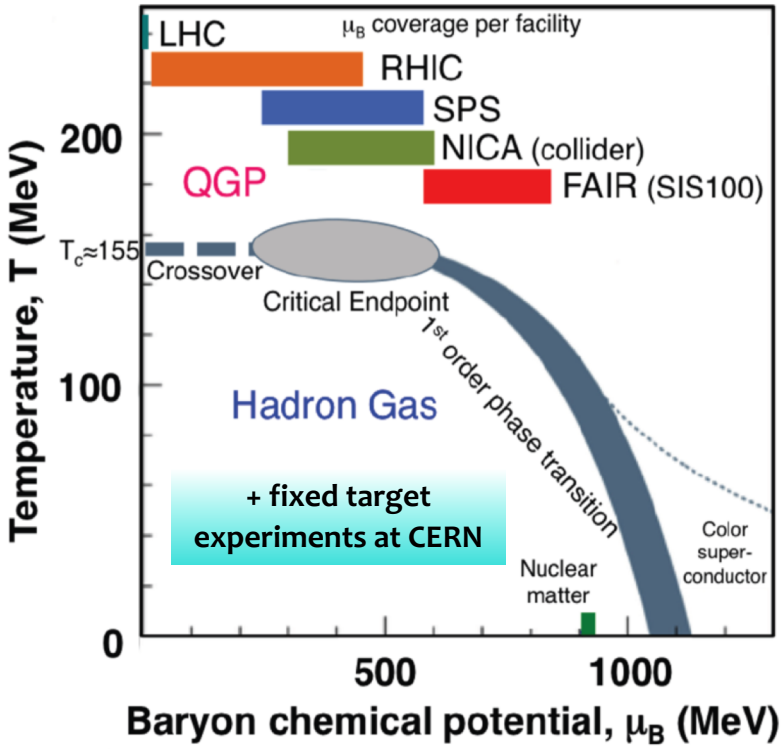


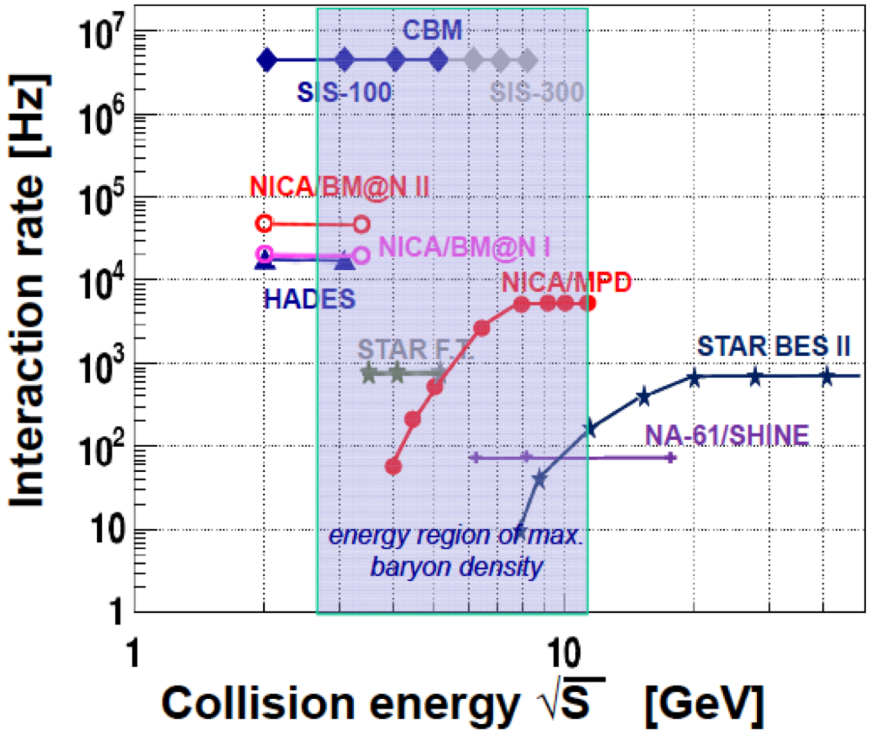


Talk of Gabriel Martinez Pinedo

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?**

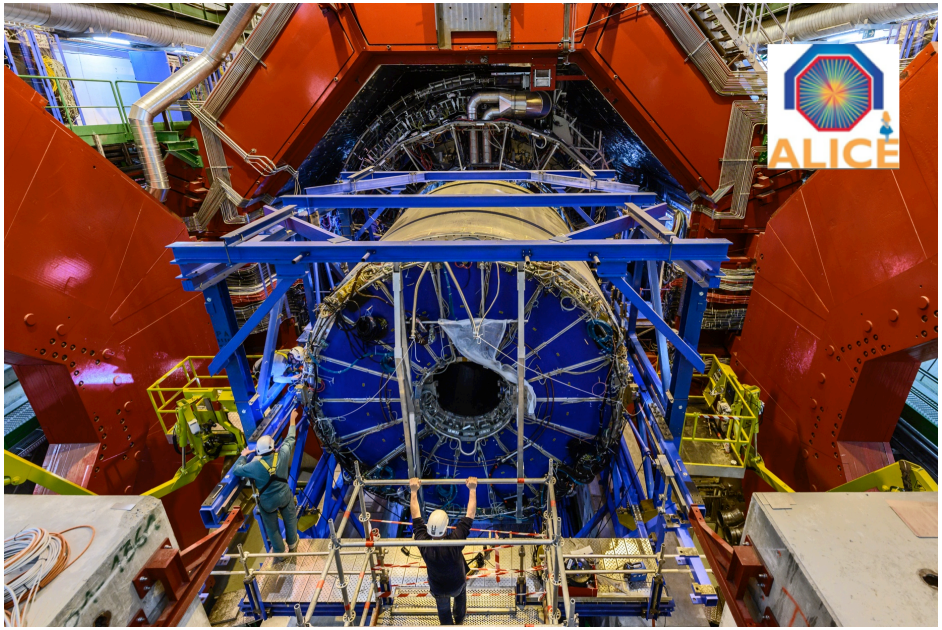




NuPECC LRP recommendation:
Fully develop synergies between ALICE, NICA, FAIR and fixed target experiments at CERN

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 (2019-2020)
  - 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



Future: A next-generation all-silicon LHC heavy-ion experiment after 2031

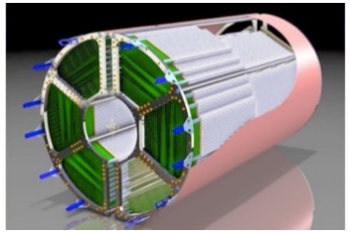
Main NuPECC LRP recommendation:
All aspects of the LHC heavy-ion programme, including manpower support and completion of the detector upgrades, are strongly supported.

The Physics of Hadrons

- How is mass generated in QCD and what are the static and dynamical properties of hadrons?
- How does the strong force emerge from the underlying quark-gluon structure of nucleons?

The proton

- discrepancies in measurements of the proton radius
- "proton spin puzzle"



High resolution experiments with antiprotons (PANDA) at FAIR to test QCD in detail

Main NuPECC LRP priority for this topic:

The antiproton programme at the FAIR/PANDA facility combined with programmes with polarised protons in Dubna (NICA) and those with lepton and hadron beams at existing facilities (MAMI, Bonn, INFN-Frascati, COMPASS).

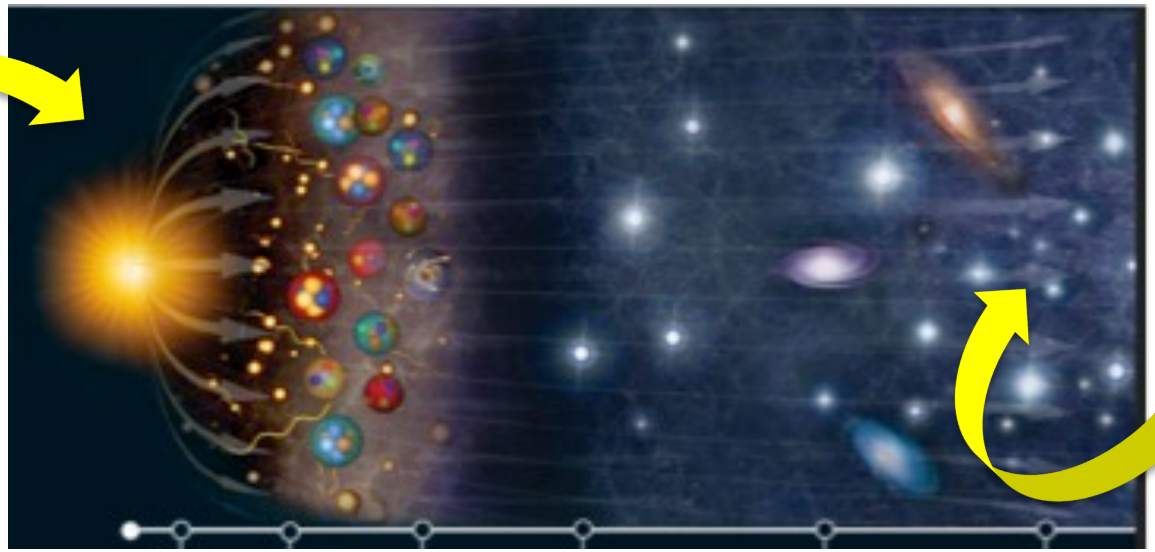
A New QCD Facility at the M2 beam line of the CERN SPS

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



Nuclear structure
Nucleosynthesis

Reactions for astrophysics

Compressed nuclear matter

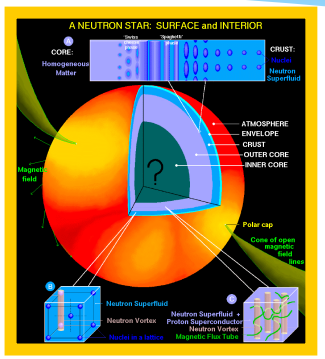
10^{-32} sec	10^{-6} sec	100 sec	100 Millions years	500 Millions years	4 Billions years

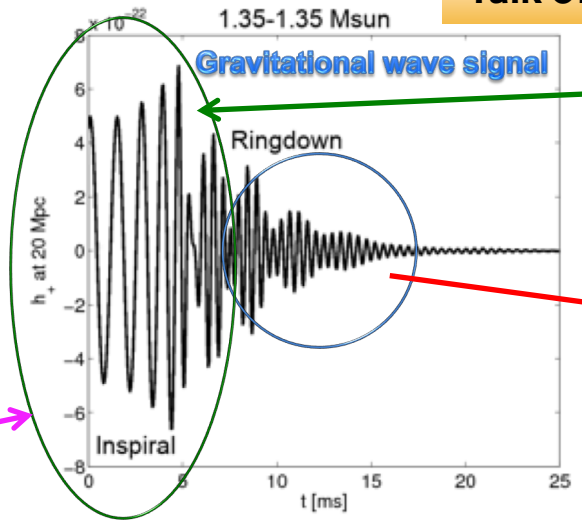
Talk of Gabriel Martinez Pinedo

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

Neutron star mergers: GW and production of heavy elements

Talk of Gabriel Martinez Pinedo





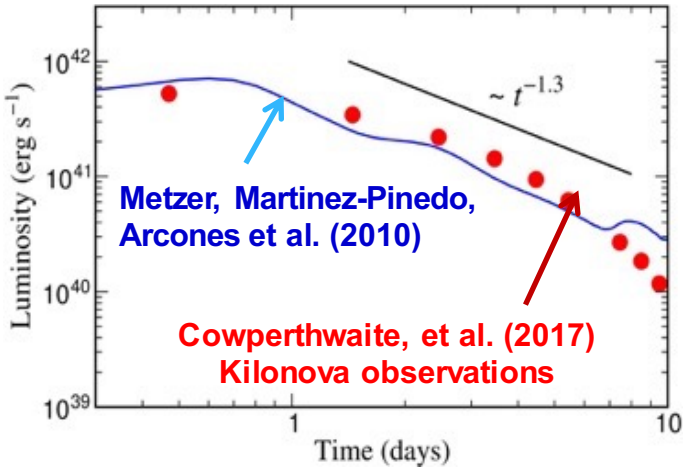
Neutron star mass

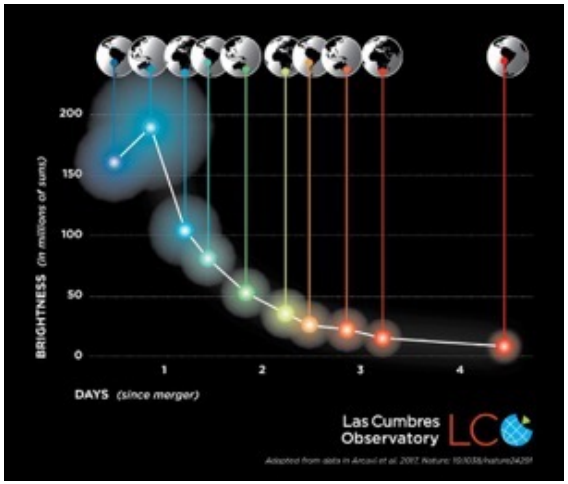
Ringdown depends on the Nuclear Equation of state

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



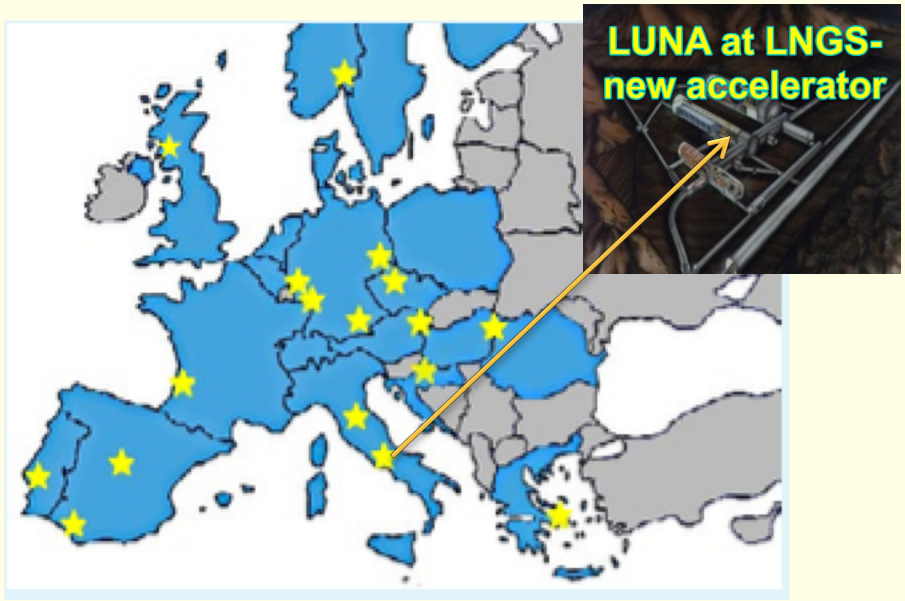


Time evolution determined by the radioactive decay of r-process nuclei (science drive of facilities with RIB)

Nucleosynthesis (nuclear structure and reactions information)

Strong support for a large effort

involving small scale accelerators …… & large infrastructures



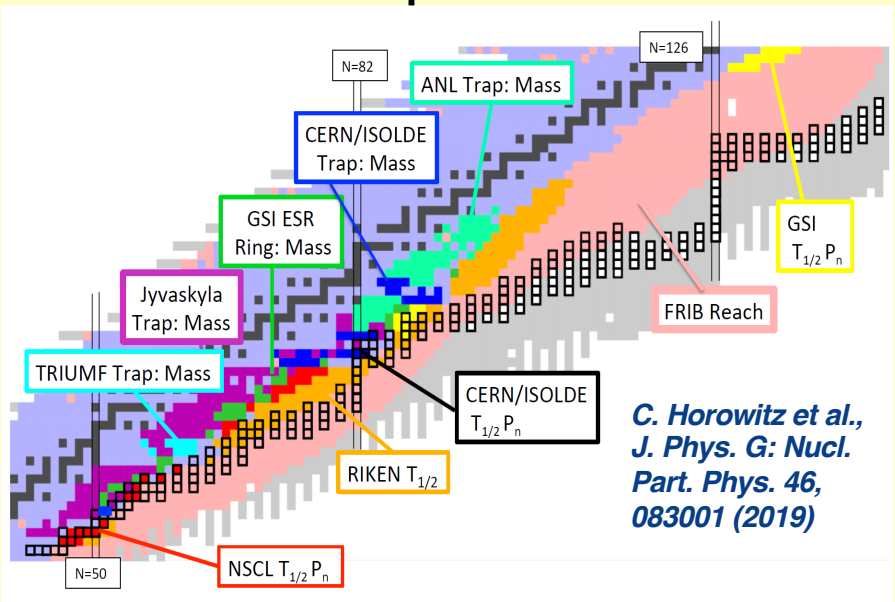
In particular at smaller scale accelerators :

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

LUNA, LNS, ALTO,…

Nucleosynthesis of medium to heavy nuclei

Example: Mass measurements & r-process



C. Horowitz et al., J. Phys. G: Nucl. Part. Phys. 46, 083001 (2019)

Scientific programs at :

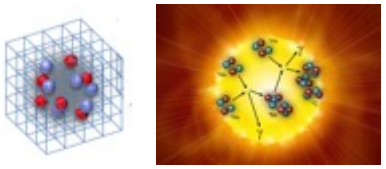
- **FAIR**
- **ISOLDE-SPES-JYFL**
- **GANIL**

Talk of Gabriel Martinez Pinedo

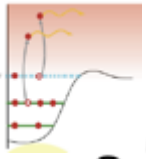
Structure of complex nuclei

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

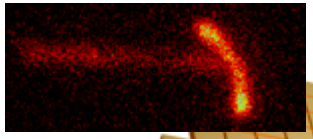
Lattice Effective Field Theory



Coupling to continuum



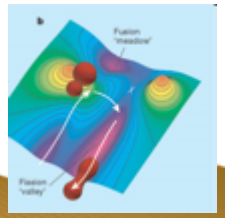
1p, 2p radioactivity

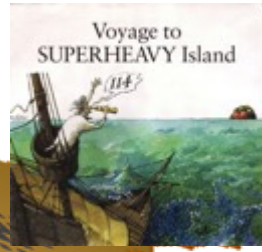


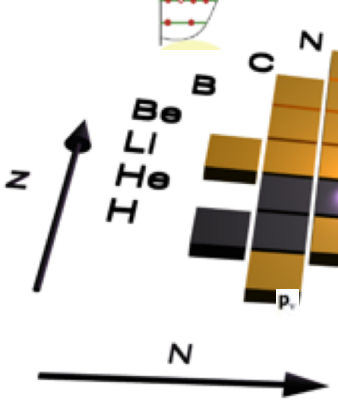
ν–π pairing

Equation of state

Fission dynamics

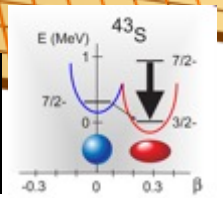






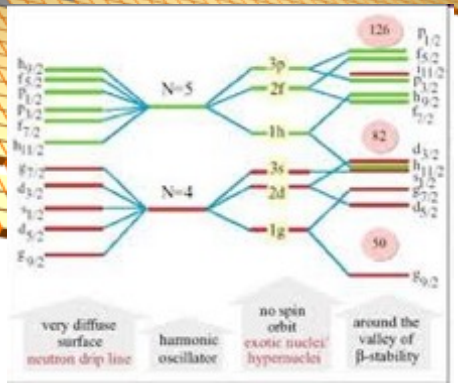
Neutron halos

Clusters

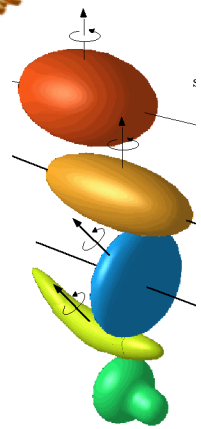


Shape Coexistence

Limits of existence



New magic numbers

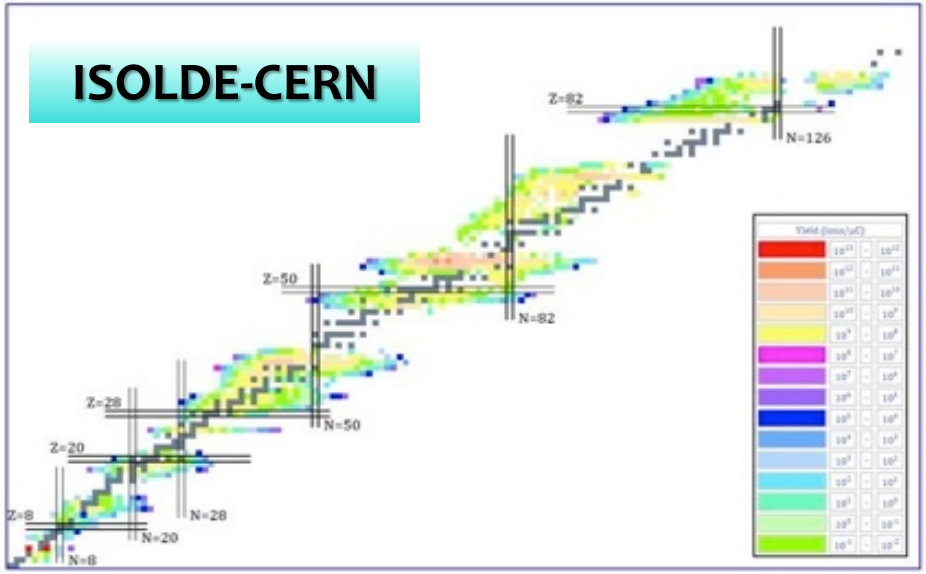


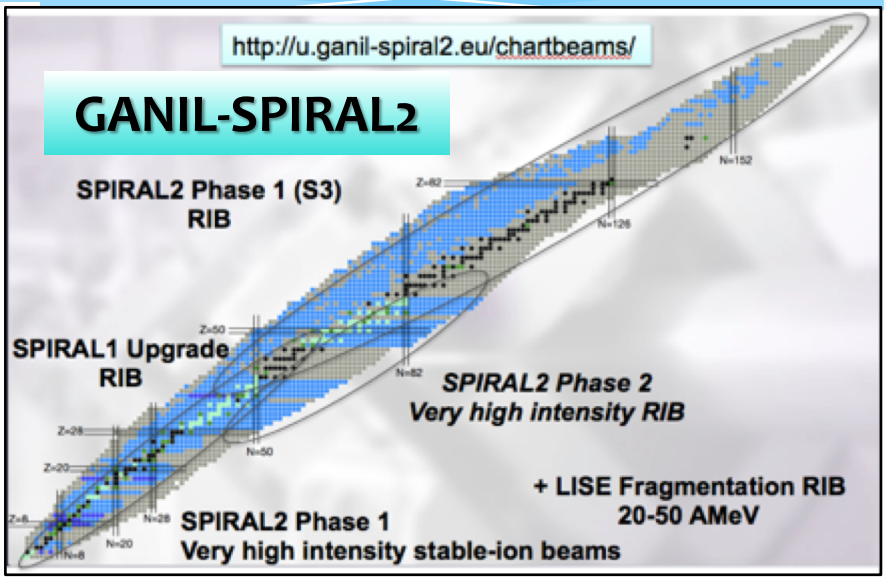
Exotic Shapes

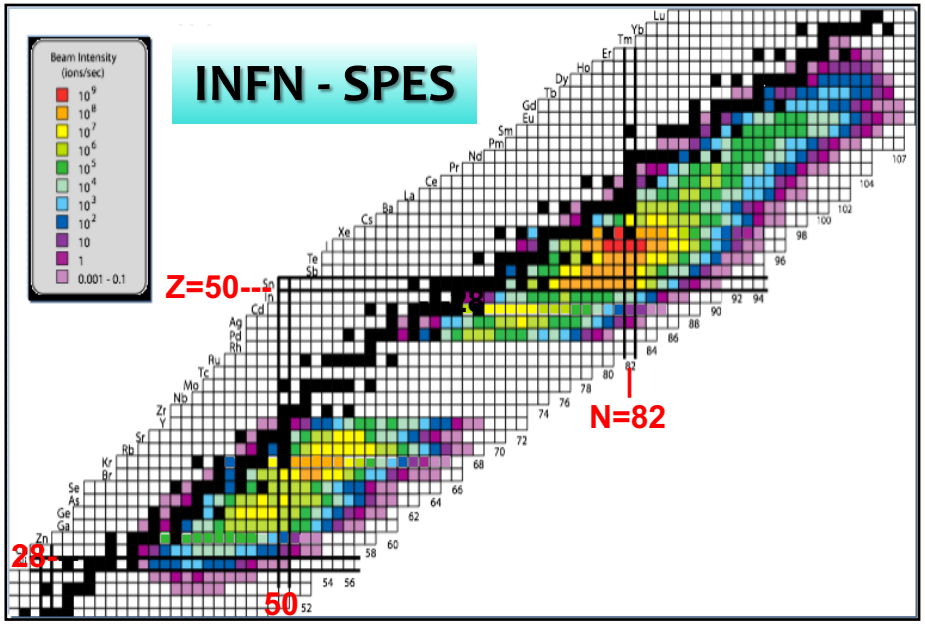
Talk of Piet Van Duppen

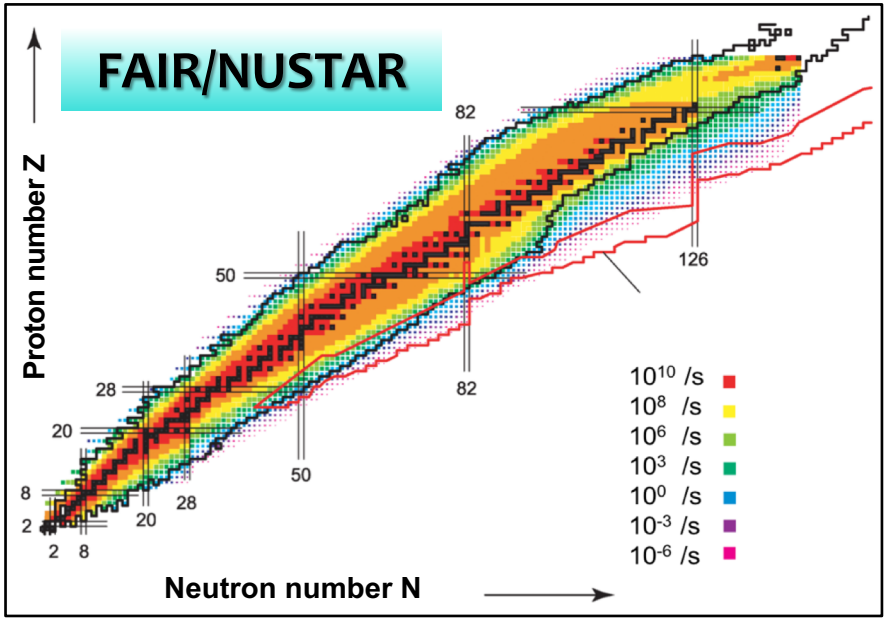
Main NuPECC LRP recommendation:
Construction of FAIR/NUSTAR, ISOL Facilities, ELI-NP and full AGATA array

RIBs at Major EU Facilities





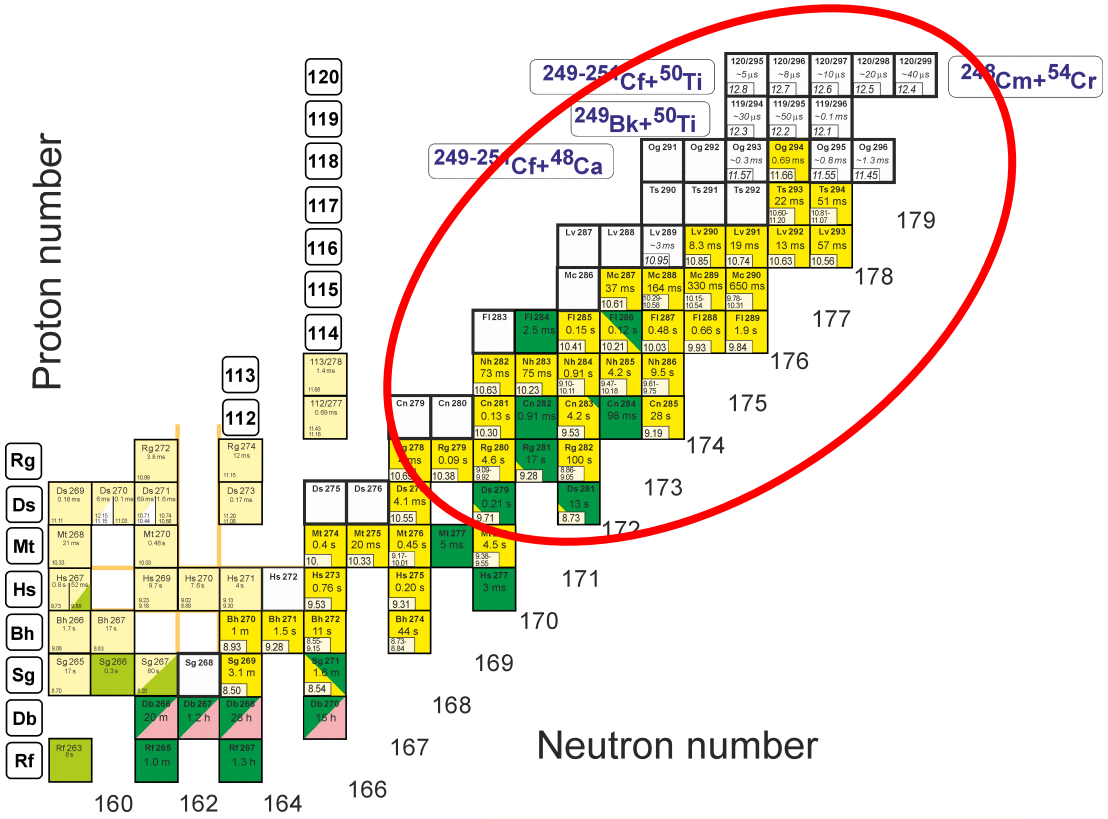




Study of Heavy and SH nuclei

Хассий 108	Мейтнерий 109	Дармштадтий 110	Рентгений 111	Коперникий 112	Нихоний 113	Флеровий 114	Московий 115	Ливерморий 116	Теннессин 117	Оганесон 118
Hs [269] Hassium	Mt [278] Meitnerium	Ds [281] Darmstadtium	Rg [282] Roentgenium	Cn [285] Copernicium	Nh [286] Nihonium	Fl [289] Flerovium	Mc [290] Moscovium	Lv [293] Livermorium	Ts [294] Tennessine	Og [294] Oganesson

10 out of 11 elements discovered at GSI and JINR



Talk of Piet Van Duppen

Scientific programs at:

SHEF – Dubna
GFS II & III, SHELS

GSI – Darmstadt
SHIP & TASCA

JYFL – Jyväskylä
RITU & MARA

GANIL/SPIRAL2 – Caen
S3 & VAMOS GFS

AGATA Tracking array for gamma spectroscopy

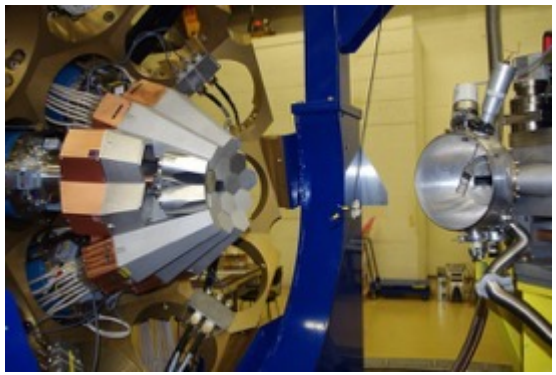
High-sensitivity for nuclear structure of exotic nuclei – used in several EU laboratories

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

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

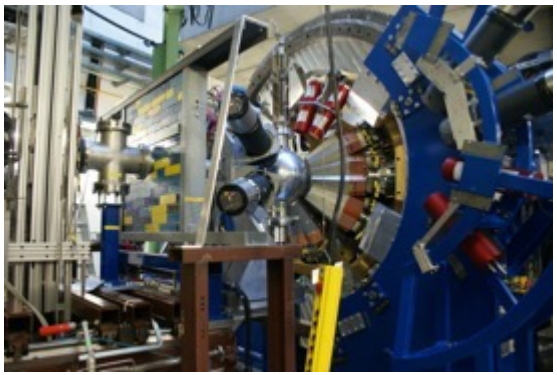
→ 2014 → GANIL, France
15TC (45 detectors)

→ 2021 -> LNL



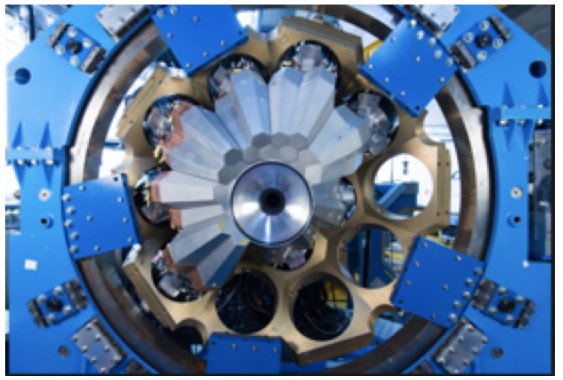
AGATA Demo. + PRISMA

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



AGATA @ FRS

Total Eff. (β=0.5) ~ 10%



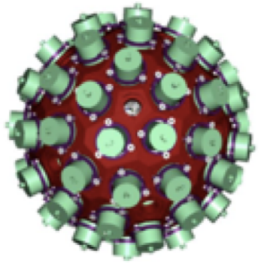
AGATA @G1

Total Eff ~ 8% to 14%

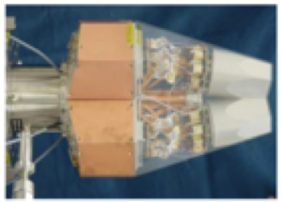
→ 60 detectors by 2020

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



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.

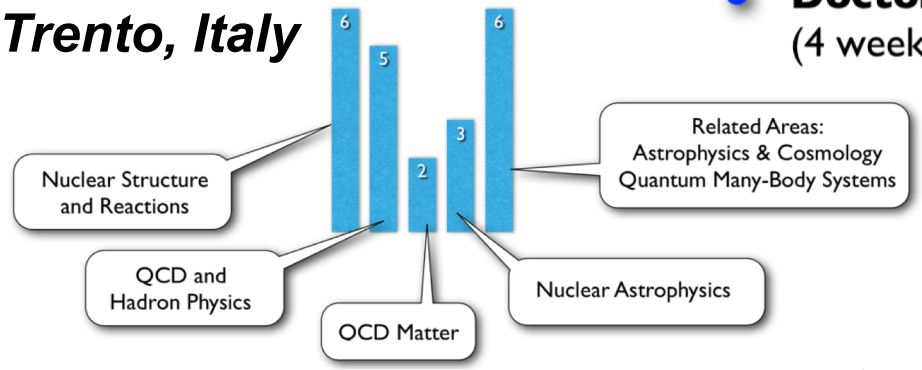
- **Provide platforms for scientific exchange and training of theorists**
- **Increase the work force and strengthen collaborations and accessibility in the area of high-performance computing.**

Support for Nuclear Theory

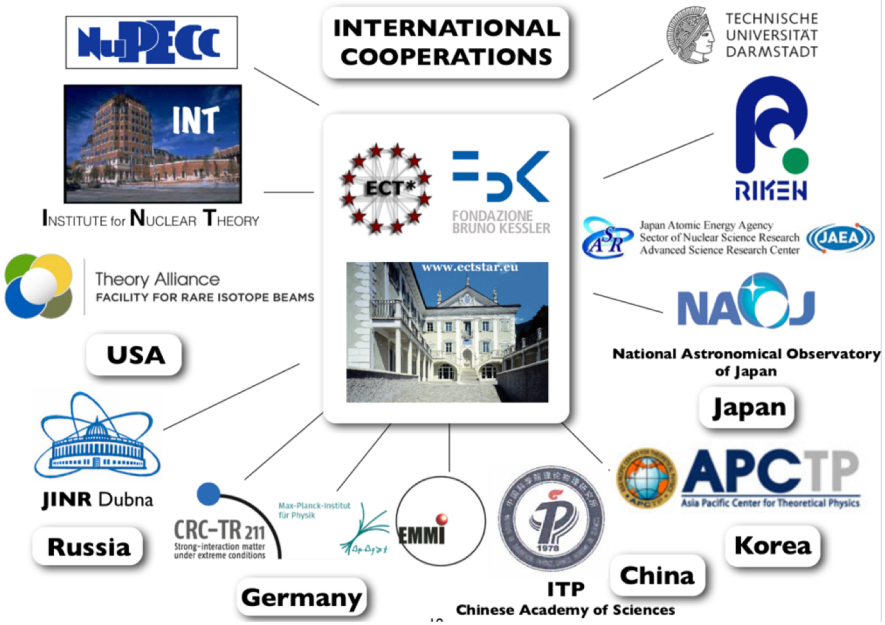
Talk of Barbara Erazmus

Scientific activities at ECT*

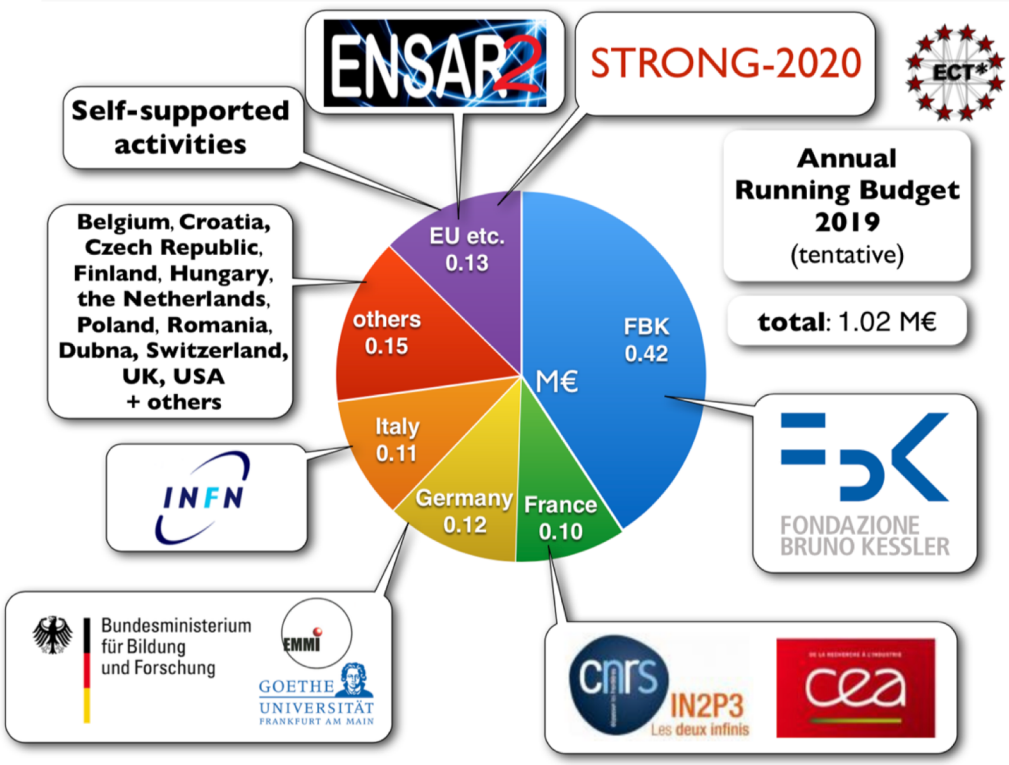
Trento, Italy



- 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)



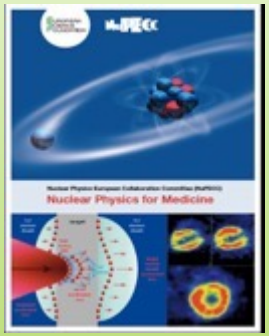
ECT* budget



Applications of nuclear science

Perform vigorous programmes in nuclear applications

- **For nuclear energy systems the development of predictive and reliable models and simulation tools is mandatory. The DEMO-Oriented Neutron Source (IFMIF/DONES) and the ADS demonstration project MYRRHA at SCK·CEN will be important in this domain.**



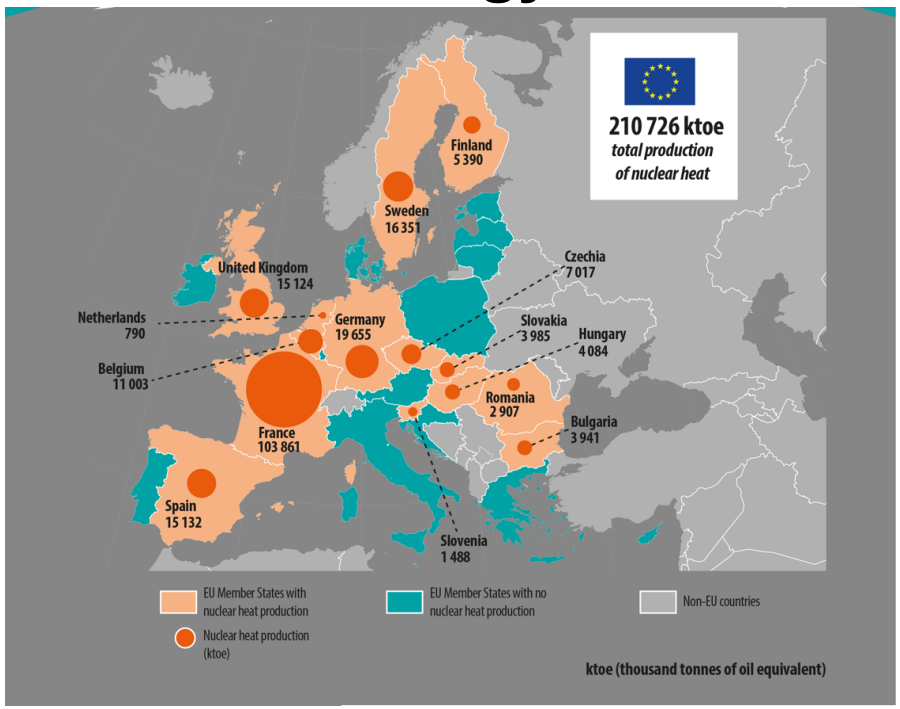
  - **Development of adapted techniques for cancer treatment: hadrontherapy, specific radio-isotopes and more efficient imaging techniques.**

Talk of Marco Durante

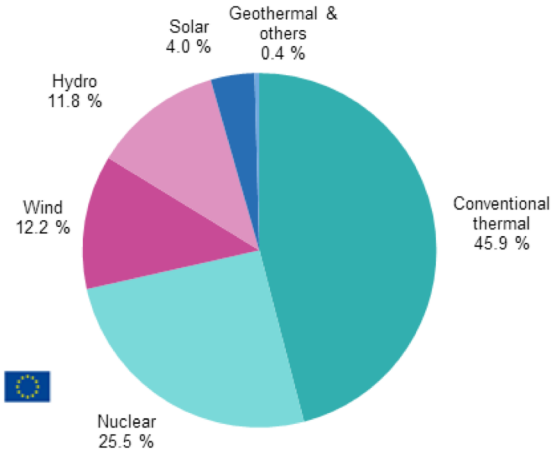
- **With the availability of high-intensity accelerators and new installations (GANIL, ESS, FAIR, ELI-NP, HIE-ISOLDE) new studies in materials science, atomic and plasma physics will be possible, exploring matter in extreme conditions.**

Energy applications

Nuclear Energy in EU



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



eurostat

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

First phase of MYRRHA ADS facility under construction

ESFRI

IFMIF-DONES - test facility for fusion materials under design

Recommendations for European Nuclear Physics facilities

Complete urgently the construction of the ESFRI flagship **FAIR** and develop and bring into operation the experimental programme of its four scientific pillars APPA, CBM, NUSTAR and PANDA.

Support for construction, augmentation and exploitation of world leading ISOL facilities in Europe towards **EURISOL**.

GANIL/SPIRAL2
ISOLDE, SPES,
JYFL

Support for the full exploitation of existing and emerging facilities

ELI-NP
NICA, SHEF
MYRRHA
IFMIF-DONES

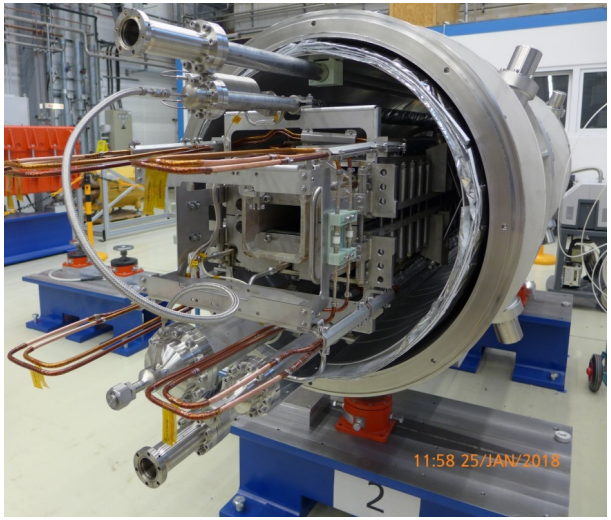
Support for ALICE and the heavy-ion programme at the LHC with the planned experimental upgrades.

Support to the completion of AGATA in full geometry.

Roadmap NP facilities

Courtesy of Paolo Giubellino

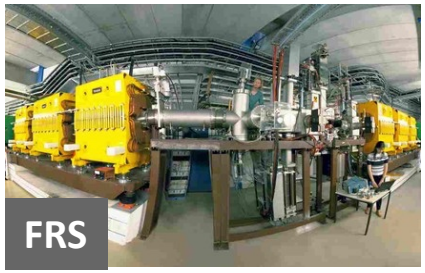
24 SIS100 (of 120) dipole magnets delivered and cold-tested



All HESR Dipoles are produced, in Jülich and 65% are delivered to FAIR

Accelerator and Experimental Facilities available for FAIR phase-0

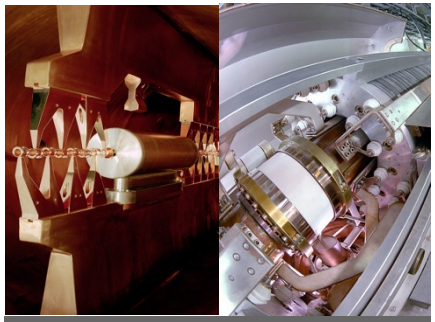
FAIR Phase 0 – experiments started in 2019

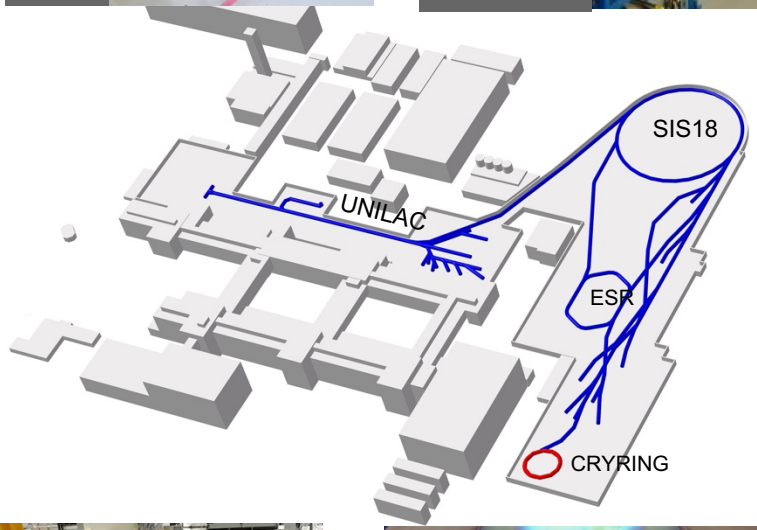

FRS

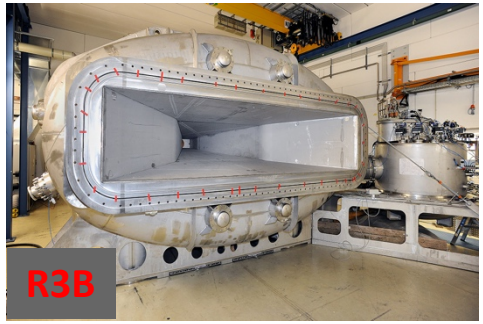

ESR

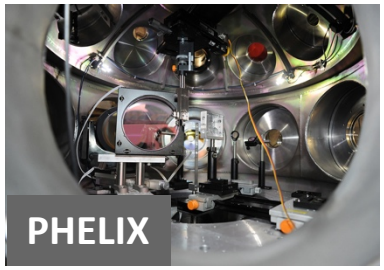

HITRAP

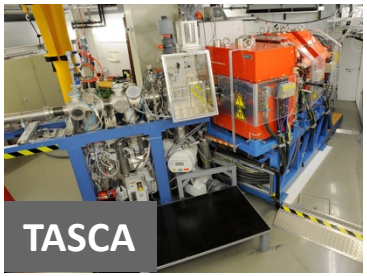

Cryring

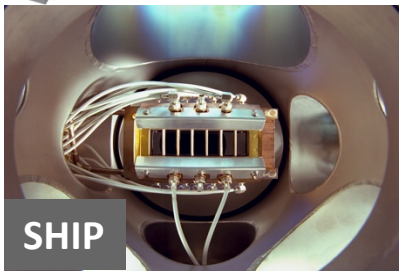

UNILAC / SIS18




R3B

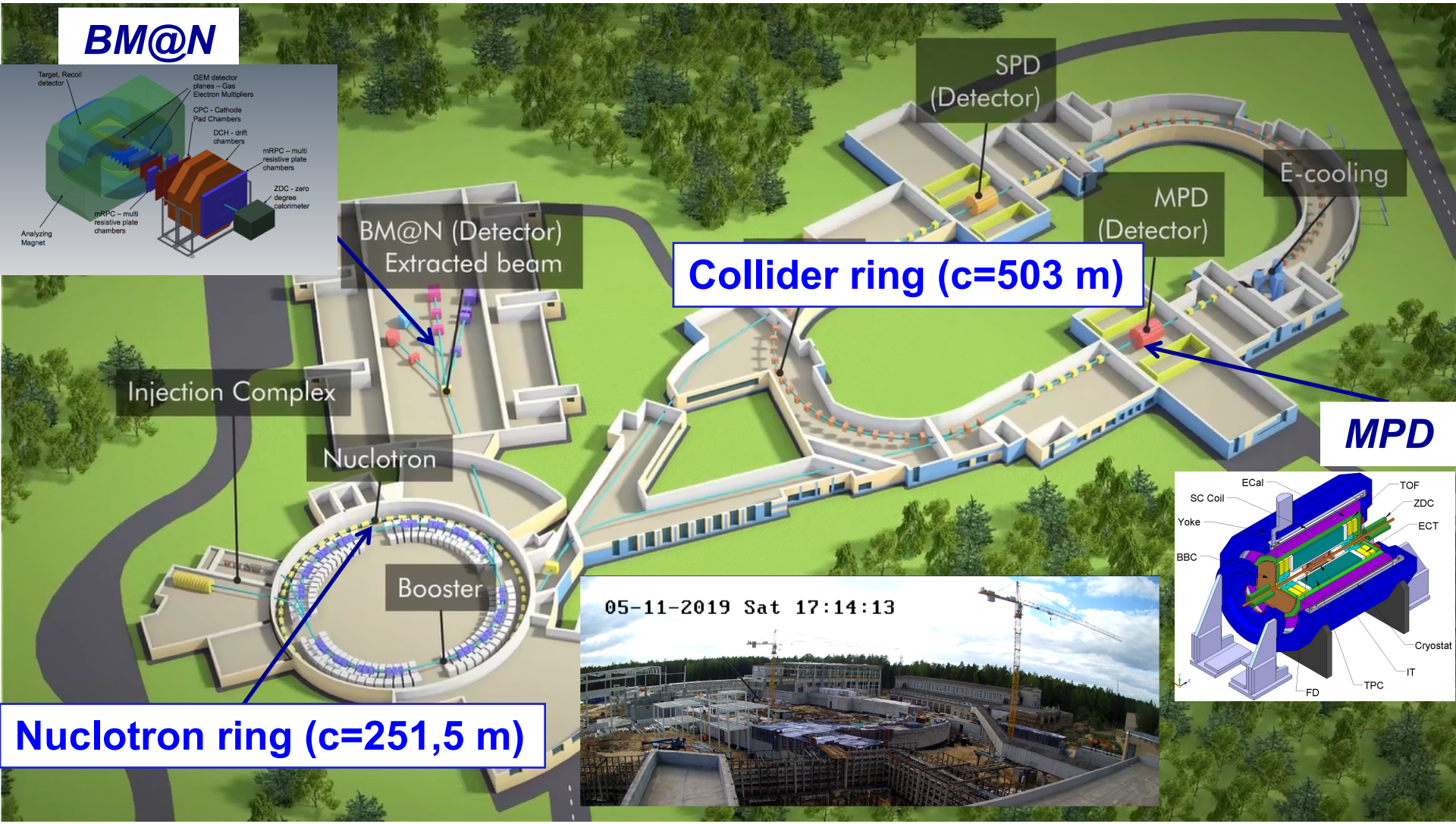

PHELIX


TASCA


SHIP

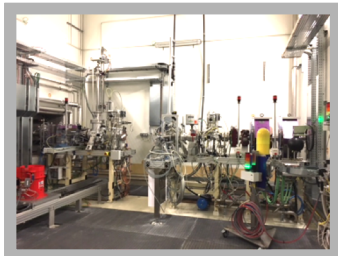

HADES

Roadmap NP facilities at JINR



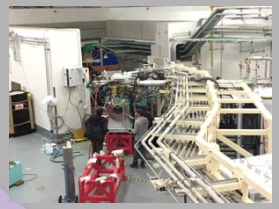
Courtesy of Boris Sharkov

Roadmap NP facilities



NFS

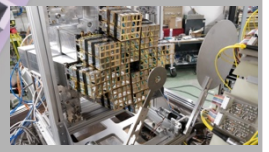
S3

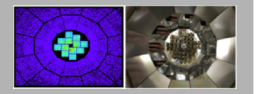


DESIR

AGATA
VAMOS

FAZIA
INDRA





HI SC LINAC

SPIRAL2 Phase 1

SPIRAL2 Phase 2
under discussion

SPIRAL1

0 10 20 30 40 50 m

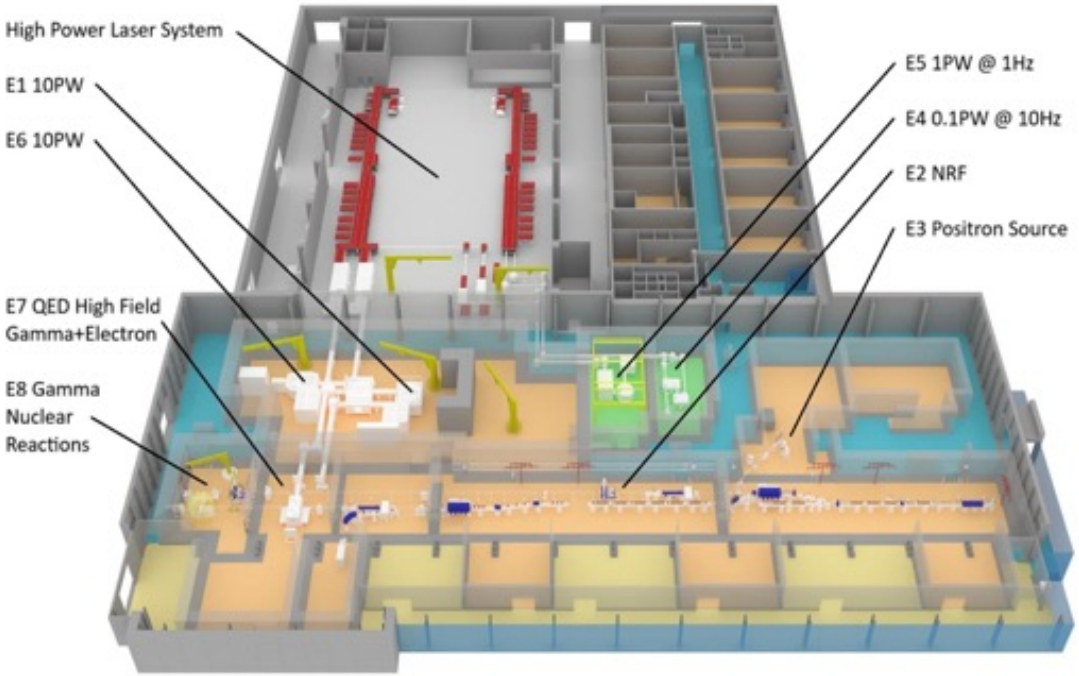
5mA 14-20 MeV/n light and heavy ions

First SPIRAL2 experiments in 2020

Courtesy of Navin Alahari

Future development of the facility under discussion – IN2P3 Long Range Plan

Roadmap NP facilities



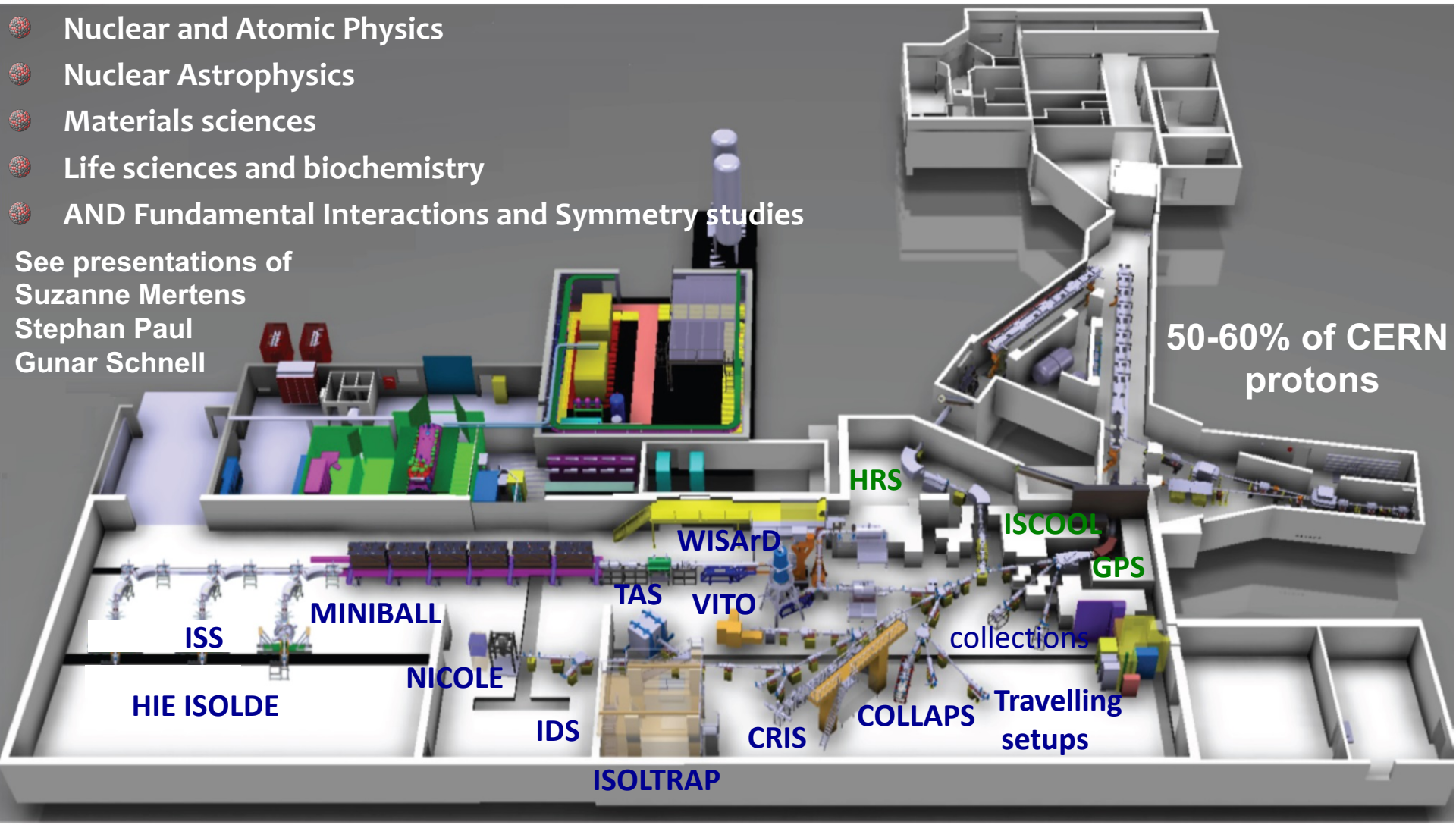
The nominal power of 10 PW laser system was achieved in March 2019, making HPLS from ELI-NP the most powerful laser in Europe

Courtesy of Dan Gabriel Ghiță & Ionel Andrei

CERN / ISOLDE
World-leading ISOL facility

- Nuclear and Atomic Physics
- Nuclear Astrophysics
- Materials sciences
- Life sciences and biochemistry
- AND Fundamental Interactions and Symmetry studies

See presentations of
Suzanne Mertens
Stephan Paul
Gunar Schnell



Future: Exploiting the Potential of ISOLDE at CERN - EPIC

Integrating community with EU projects

Support for users and facilities





ENSAR2

Nuclear structure reactions and applications

Contract 2016-2020 (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)





NuPECC LRP

- **The 2017 NuPECC Long Range Plan defined an ambitious strategy for European Nuclear Physics**
- **NuPECC efforts to transform the LR Plan into reality -> Task Force meetings**
- **Development of a global international approach to nuclear science in collaboration with IUPAP, NPD/EPS, ECFA, ApPEC, NSAC (US), ANPhA (Asia), ALAFNA (S.America), CINP (Canada)**

Joint activities of ECFA, ApPEC & NuPECC

- **Joint "JENAS" seminar**
- **European Strategy for Particle Physics**
- **Diversity Charter**
- **Recognition of young scientists**

Warm thanks to all contributing colleagues

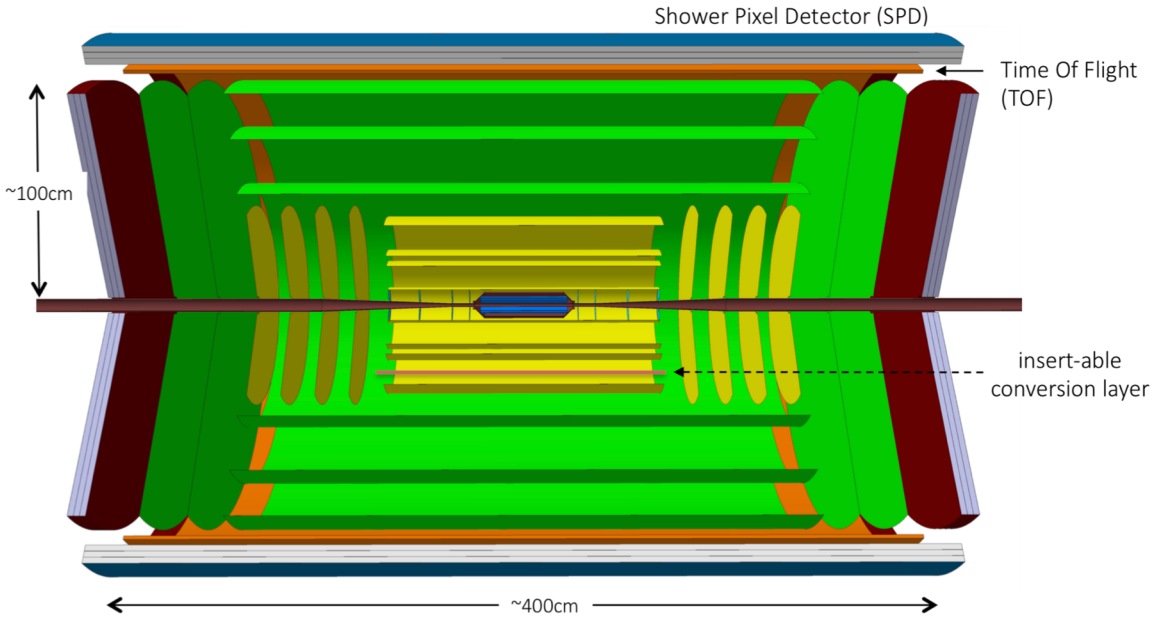
Warm thanks to Jorgen and Teresa for quickly developing collaboration

Thank you for your attention

Future: A next-generation LHC heavy-ion experiment

Ideas for a new heavy-ion experiment for Run 5 (from 2031), after LS4

capable to handle extremely high rates for rare probes (heavy flavors, heavy quarkonia, light (anti-)(hyper-)nuclei), and measure ultra low momentum particles



arXiv:1902.01211

Ultra-light all-silicon apparatus:

Tracker: ~10 tracking barrel layers based on CMOS sensors (blue, yellow, green)
Spatial resolution: 1-5 µm

Hadron ID: TOF with outer silicon layers (orange)
Time resolution: ~30 ps

Electron ID: pre-shower (outer blue)

Central questions in Nuclear Physics

- How is mass generated in QCD and what are the static and dynamical properties of hadrons?
- How does the strong force between nucleons emerge from the underlying quark-gluon structure?
- 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?
- How does the complexity of nuclear structure arise from the interaction between nucleons?
- What are the limits of nuclear stability?

RIB Facilities & Projects in Europe (operation periods)

Operational | Under Construction | Planned but not decided yet | Fragmentation | *ISOL*

< 50 M€ | 50 – 150 M€ | 150 – 1000 M€ | > 1000 M€