

NuPECC Long Range Plan

***Focused on nuclear structure and reactions, astrophysics
and applications***

&

Poland in European Nuclear Physics Facilities

***Marek Lewitowicz
GANIL & NuPECC***

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

Representing about 6000 scientists

Members: 31 representatives from
20 countries + JINR Dubna

2 associated members (iThemba &
Nishina Centre, RIKEN)

5 observers

Polish representative in NuPECC: Adam Maj

3 regular Committee meetings/y

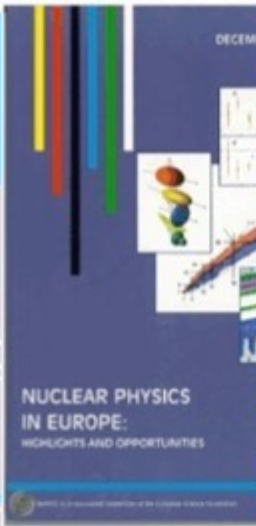
Next: March 1-2, 2019 in Warsaw



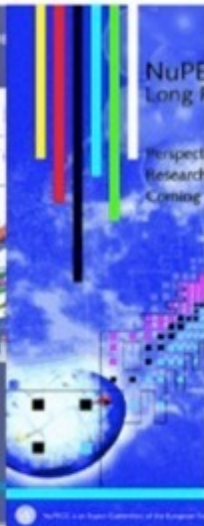
1991



1997



2004



2010



2017



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

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

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**Community working in the field :
200 experts in experiments and theory
7 working groups**

**Town meeting
in Darmstadt
January 2017**

**Report
June 2017**

**2016
beginning**

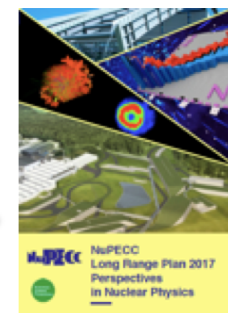
end 2017

LRP presentation – Brussels November 27, 2017

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

NuPECC LRP contributing Polish physicists:

- 5 from Krakow: Wojciech Florkowski, Kazimierz Bodek, Bogdan Fornal, Adam Maj, Piotr Salabura
- 3 from Warszawa & Swierk: Tomasz Matulewicz, Krzysztof Pachulski, Jacek Jagielski
- 2 working abroad: Maurycy Rejmund (GANIL), Marek Lewitowicz (GANIL)



**Report
June 2017**

**Town meeting
in Darmstadt
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**Community working in the field :
200 experts in experiments and theory
7 working groups**

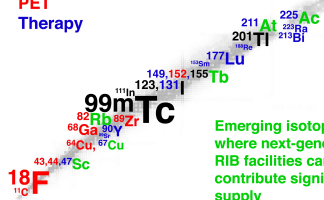
**2016
beginning**

end 2017

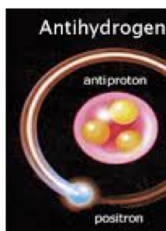
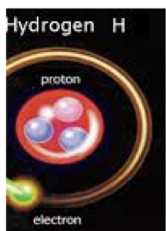
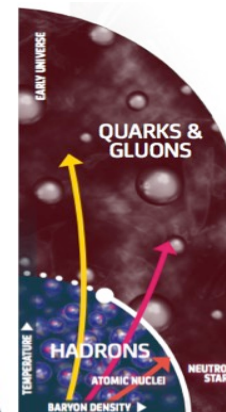
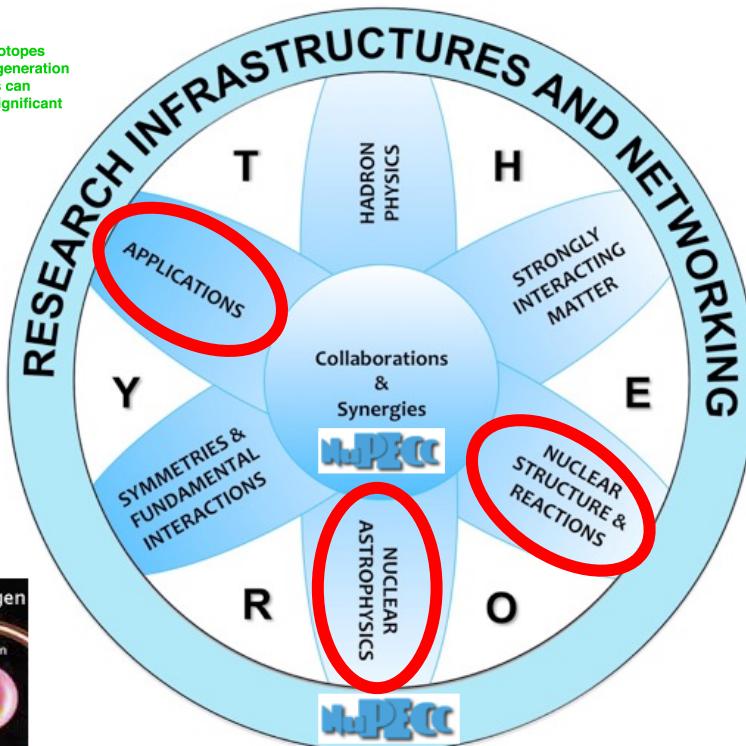
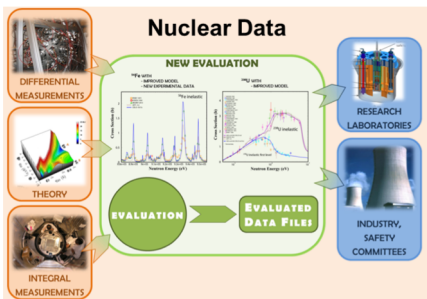
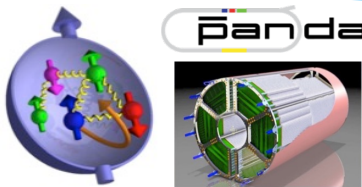
LRP presentation – Brussels November 27, 2017

Nuclear medicine perspective

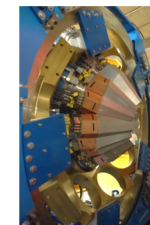
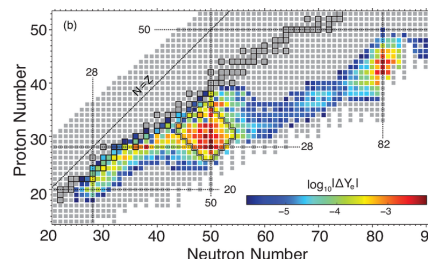
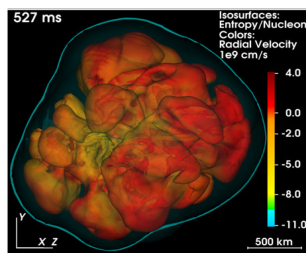
SPECT
PET
Therapy



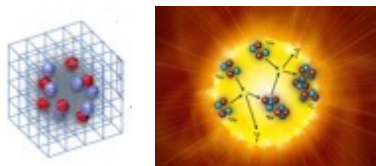
Emerging isotopes where next-generation RIB facilities can contribute significant supply



Topics: Lattice Effective Field Theory, Coupling to continuum, Neutron halos, Clusters, Shape Coexistence, New magic numbers, Exotic Shapes, Limits of existence, ν - π pairing, Equation of state, Fission dynamics, 1p, 2p radioactivity.



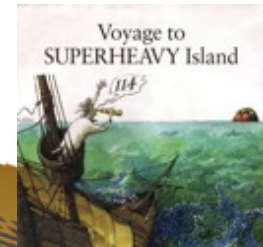
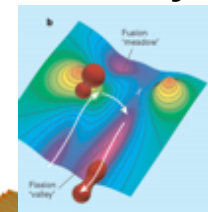
Lattice Effective Field Theory



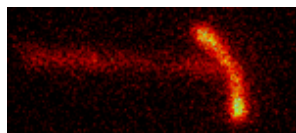
Equation of state



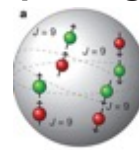
Fission dynamics



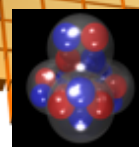
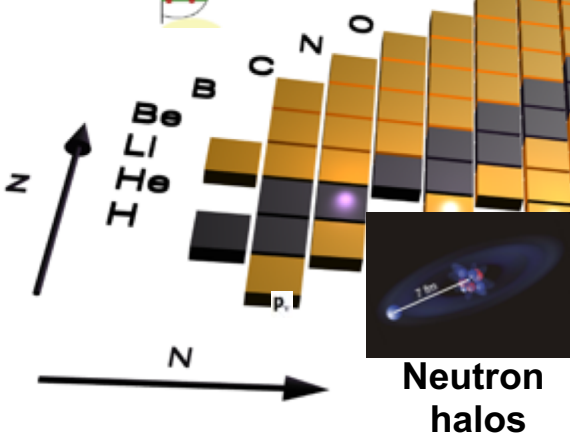
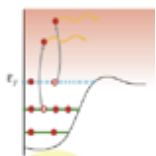
1p, 2p radioactivity



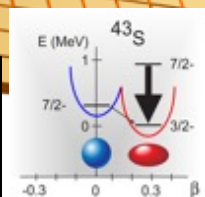
$\nu-\pi$ pairing



Coupling to continuum

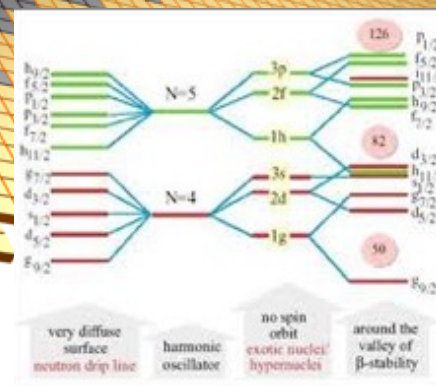


Clusters

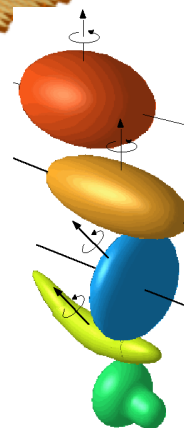


Shape Coexistence

Limits of existence



New magic numbers



Exotic Shapes

Main NuPECC recommendations:

- Timely construction of FAIR/NUSTAR, ISOL Facilities, ELI-NP and full AGATA array

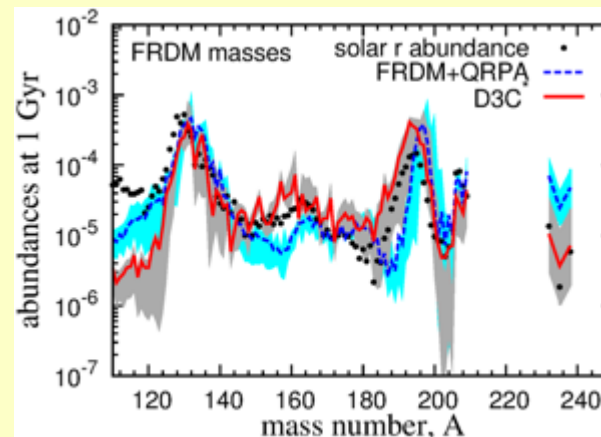
Strong support for a large effort involving small scale accelerators & very large infrastructures



In particular at small scale accelerators :

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

**Medium to heavy nuclei
Nucleosynthesis - neutron rich**

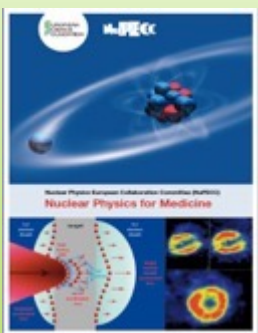


Scientific programs at :

- **FAIR**
- **SPIRAL2- ISOLDE-SPES**
- **ELI-NP**
- **SHE factory (Dubna)**
- **.....**

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: specific radio-isotopes and more efficient imaging techniques.
- With the availability of high-intensity accelerators and new installations (GANIL, ESS, FAIR, ISOLDE) new studies in materials science, atomic and plasma physics will be possible, exploring matter in extreme conditions.



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. Combining theory initiatives in a concerted effort is essential for optimal use of the available resources, in particular by providing platforms for scientific exchange and the training of the next generation. At the same time it is important to increase the work force and to strengthen collaborations and accessibility in the area of high-performance computing.

NuPECC is monitoring evolution of:

- **Nuclear Physics infrastructures on the European Strategy Forum on Research Infrastructures roadmap**
 - **ESFRI 2016(18) roadmap**
 - Landmark infrastructures: FAIR and SPIRAL2
 - On the roadmap: ELI-NP and MYRRHA
 - Intern. projects complementary to ESFRI projects: NICA in Dubna
 - Newcomer: IFMIF-DONES
 - *New project for the 2020 update: EURISOL-DF,...*
- **EU funded Integrating Projects**
 - Today ongoing ENSAR2 and near future new proposal
 - *Hadron Physics STRONG-2020 proposal*

NuPECC Long Range Plan

*Focused on nuclear structure and reactions, astrophysics
and applications*

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Poland in European Nuclear Physics Facilities

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Recommendations for European 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.



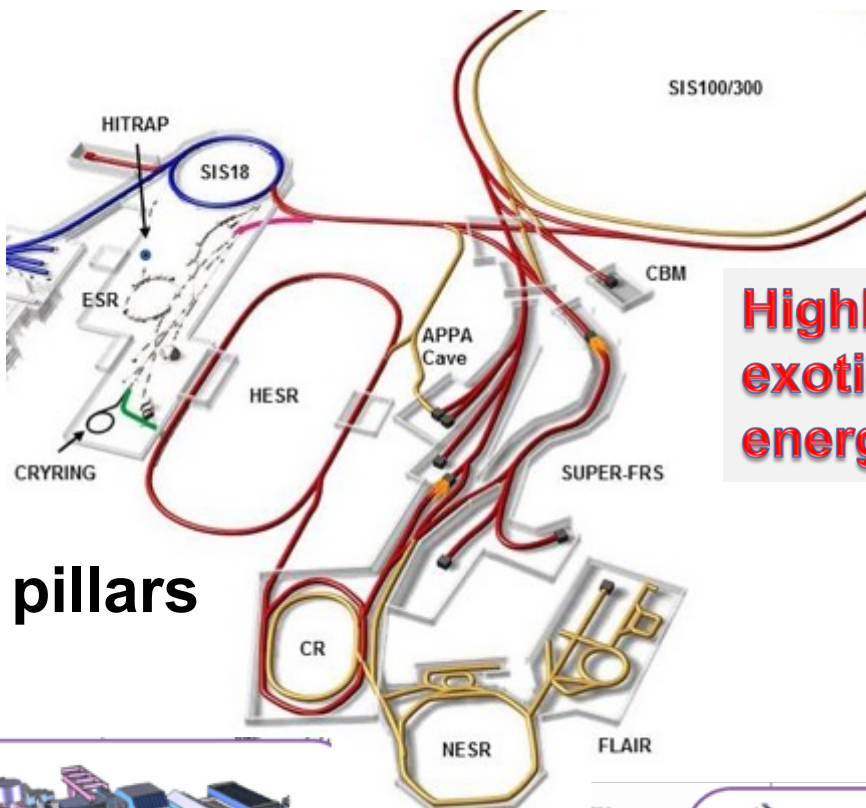
Support for the full exploitation of existing and emerging facilities

**ELI-NP
NICA, SHEF**

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



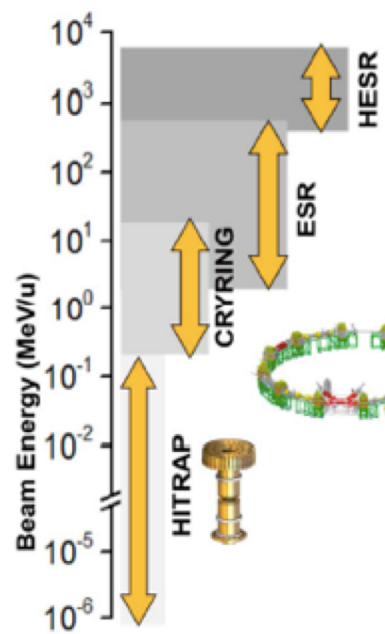
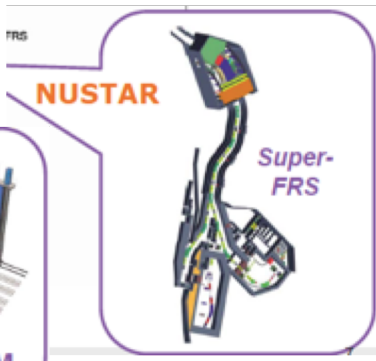
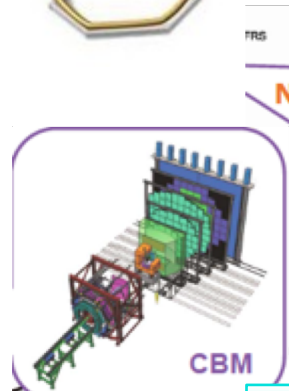
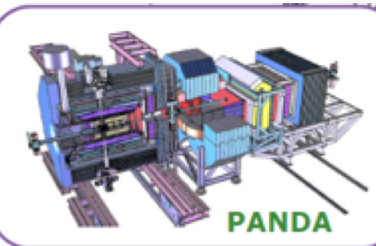
Support to the completion of AGATA in full geometry.



Large facility covering all nuclear physics domains !

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

4 pillars

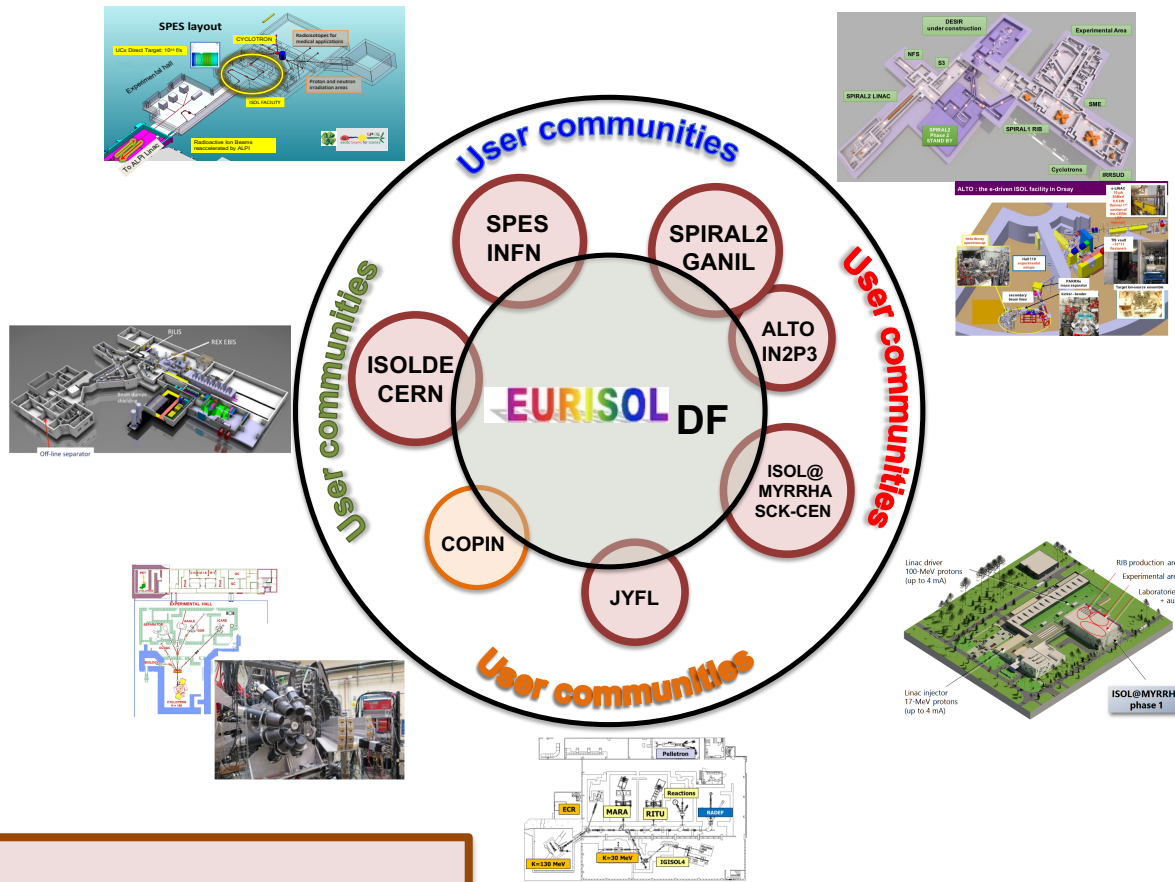


Worldwide Unique

Poland is one of the members of FAIR

EURISOL – Distributed Facility (DF) Initiative

Candidate for the 2021 ESFRI roadmap update



Members:

HIE-ISOLDE/CERN
SPES-INFN
SPIRAL2-GANIL with ALTO
JYFL
ISOL@MYRRHA-SCK*CEN

Associated Member:

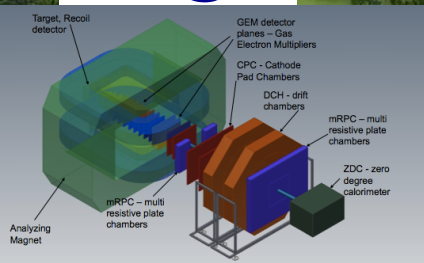
COPIN Consortium, Poland

+ Poland is a member of ISOLDE collaboration and a candidate to become a scientific partner of GANIL

Poland is one of the members of JINR



BM@N



BM@N (Detector)
Extracted beam

Collider ring (c=503 m)

MPD

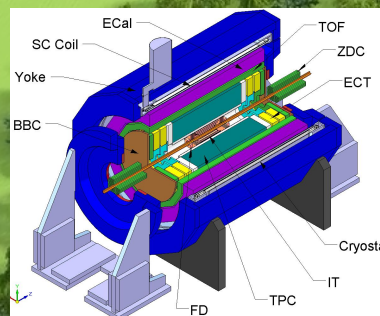
Poland member of the collaboration

Injection Complex

Nuclotron

Booster

Nuclotron ring (c=251,5 m)

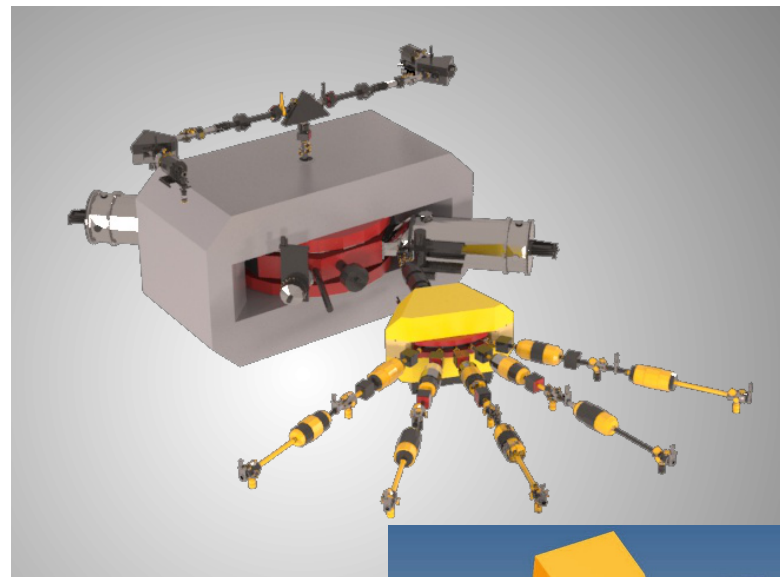


Fully develop synergies between NICA, FAIR and ALICE

Poland is one of the members of JINR



SHE Factory Building

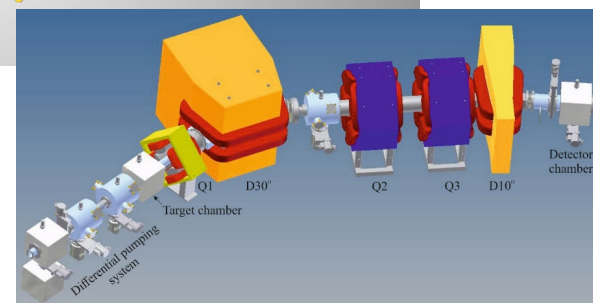


High-current cyclotron DC-280

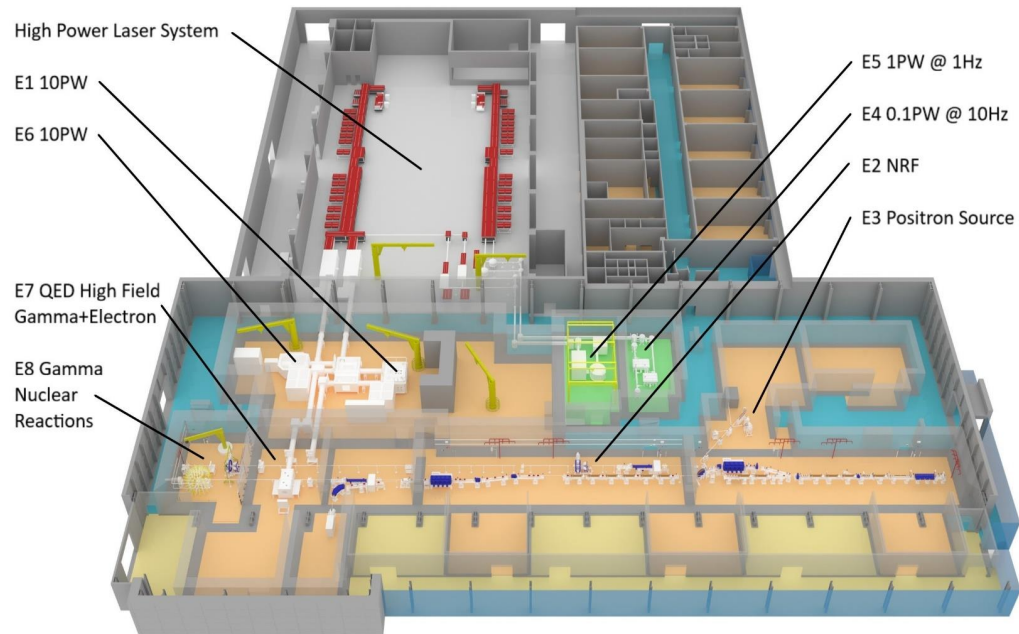
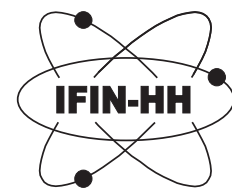
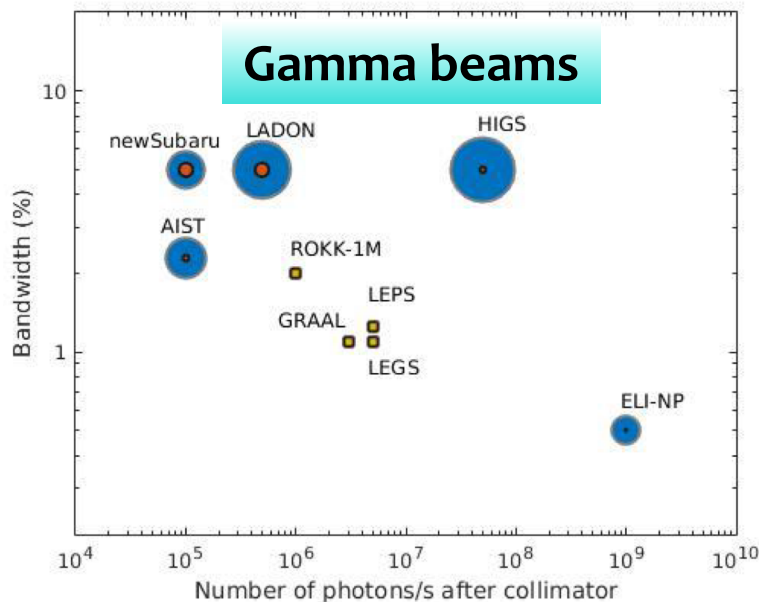
New facilities:

- New gas-filled separator
- Pre-separator for chemistry experiments
- SHELS
- Etc.

First beam accelerated on
December 26, 2018!



- Reinforce synergies between SHE Factory, GSI, SPIRAL2 and JYFL
- Open FLNR accelerators for a large European nuclear physics community



The intermediate requirement for power higher than 3 PW was confirmed recently, making HPLS from ELI-NP the most powerful laser in Europe at the moment.

Poland in scientific collaboration at ELI-NP

Facility financed (300M€) using EU Structural Funds

Recommendations for European 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.



*** Exploit the facilities ALTO, GANIL-SPIRAL2, GSI- FAIR, IFIN-HH/ELI-NP, ISOLDE, JYFL, KVI-CART, LNL-LNS, NLC Warsaw-Krakow, mainly devoted to nuclear structure, nuclear astrophysics, reactions and applications.**

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



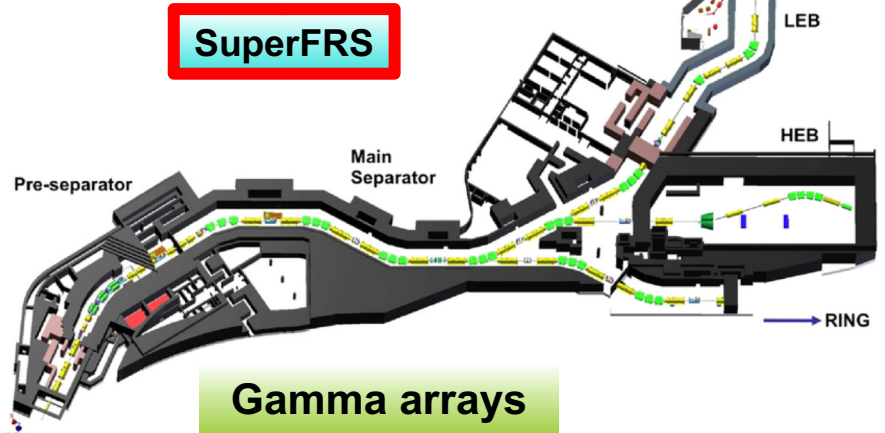
Support to the completion of AGATA in full geometry.

Innovative detectors, arrays and spectrometers – Examples

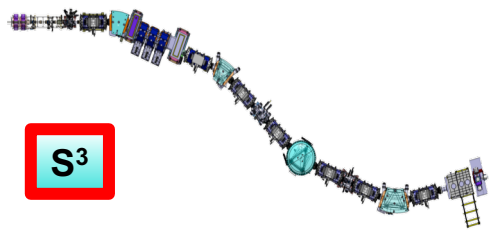
Polish contributions

Separators-spectrometers

Neutron arrays



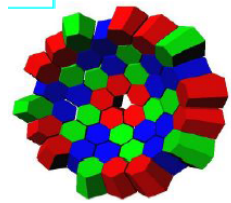
SuperFRS



S³

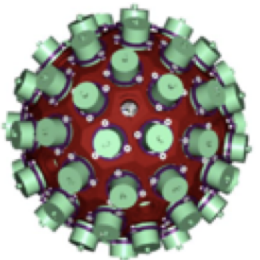
Charged-particle arrays & TPC

NEDA

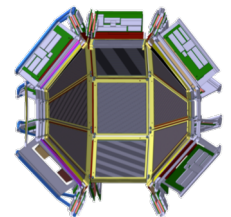


Gamma arrays

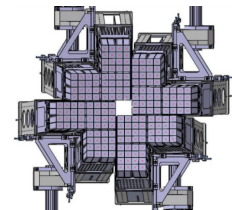
AGATA 4pi



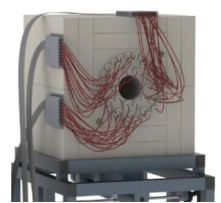
MUGAST/GRIT



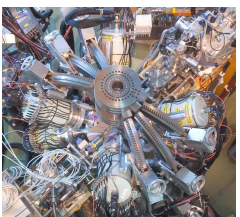
FAZIA



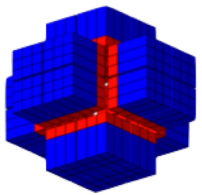
BELEN



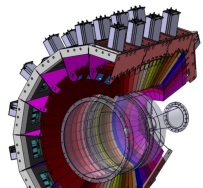
MINIBALL



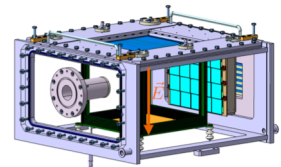
PARIS



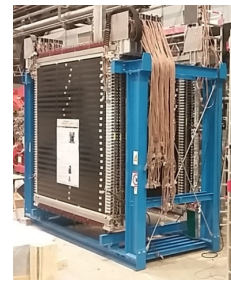
CALIFA



ACTAR-TPC



NeuLAND



Integrating community with EU projects



**Nuclear structure
reactions
and applications
Contract 2016-2020**

*Next proposal under
preparation (Coordinator
Angela Bracco – INFN) by
March 2019*

- 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)

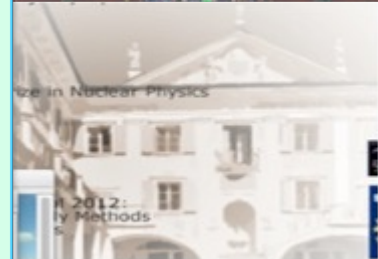


**Hadron physics
STRONG-2020**

*August 2018: First on the
reserve list after
evaluation
Good chance to be
funded*

- CERN
(LHC, COMPASS
fixed target)
- GSI/FAIR (Germany)
- LNF, Frascati (Italy)
- MAMI, Mainz
(Germany)
- ECT*, Trento (Italy)
- ELSA, Bonn (Germany)
- COSY, Julich
(Germany)

**Poland (NCBJ & UJ) is
a member of the consortium**





- **Strong participation of Poland in all major (ESFRI list and others) nuclear physics infrastructures & projects in Europe**
- **Lack of beamtime in Europe for fundamental research and applications**
- **There is a room for specialized and ambitious new infrastructures, complementary to the ESFRI ones**

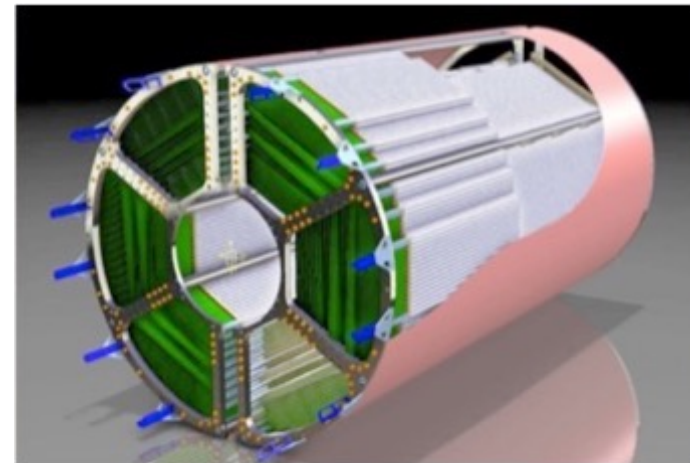
Thank you for your attention!



The proton

Studies have uncovered discrepancies in measurements of the proton radius made with different techniques.

New experiment planned to tackle this issue (one at Mainz-MESA) : new physics?

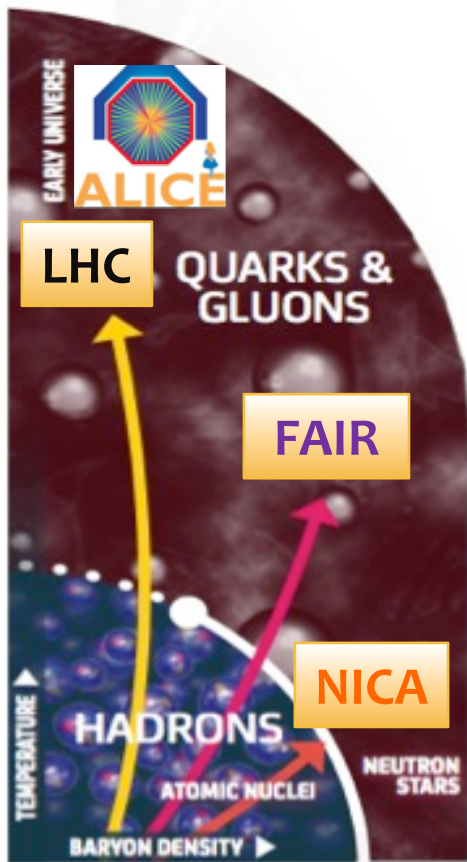


High resolution experiments with antiprotons (PANDA) at FAIR will address many issues to test in detail theory of Quantum Chromo Dynamics (QCD)

Main recommendations:

- Completion of the PANDA experiment at FAIR without further delays
- Support for a research programme in precision physics at existing facilities such as CERN (LHC, COMPASS), GSI (HADES), JLab, IHEP and NICA, but also at smaller scale facilities, such as DAΦNE, ELSA, MAMI and, in the near future, MESA at Mainz

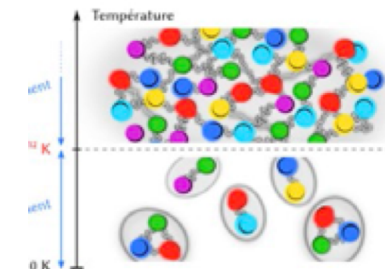
Hadronic Matter at the very extremes



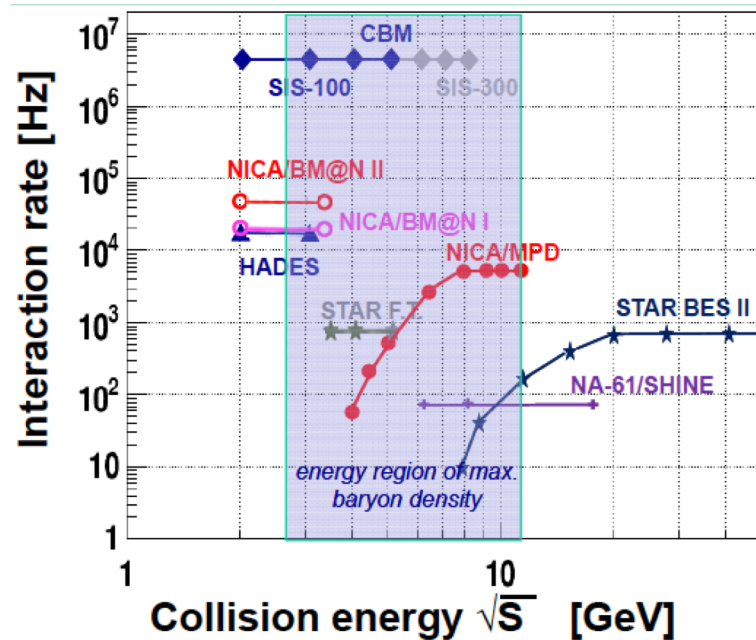
Matter at very high temperature and density Quark Gluon Plasma (QGP) reveals the high energy processes that drove the evolution of the universe after its birth.

Its very exotic nature is found in massively compressed stellar corpses : neutron stars

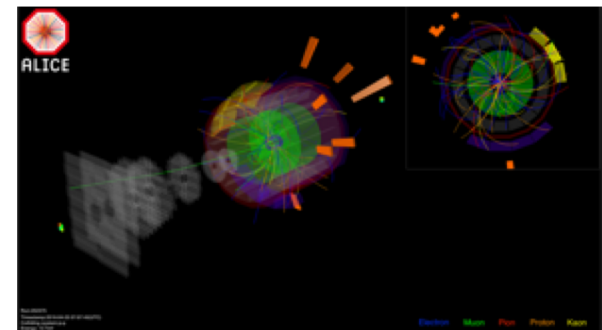
QGP turned into hadron few μ s after Big Bang. It is not seen in astronomical observations and thus is recreated in the Heavy Ion labs within volumes of nuclear size



signals from de-confinement and chiral symmetry restoration



Hadronic Matter at the very extremes



Main recommendations:

- **Vigorous efforts should be devoted to the continuation of the heavy-ion programme at the LHC with Runs 3 and 4, including manpower support and completing the planned detector upgrades**
- **Continuation of the on-going programmes: HADES at SIS-18, NA61 at SPS**
- **Timely construction of SIS-100 at FAIR and the realization of the CBM experiment**
- **Completion of the BM@N experiment at JINR, the construction of the NICA facility and the realization of the associated MPD experiment.**

and symmetries

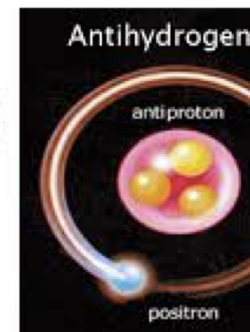
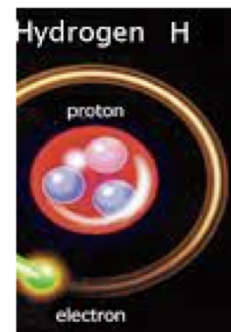
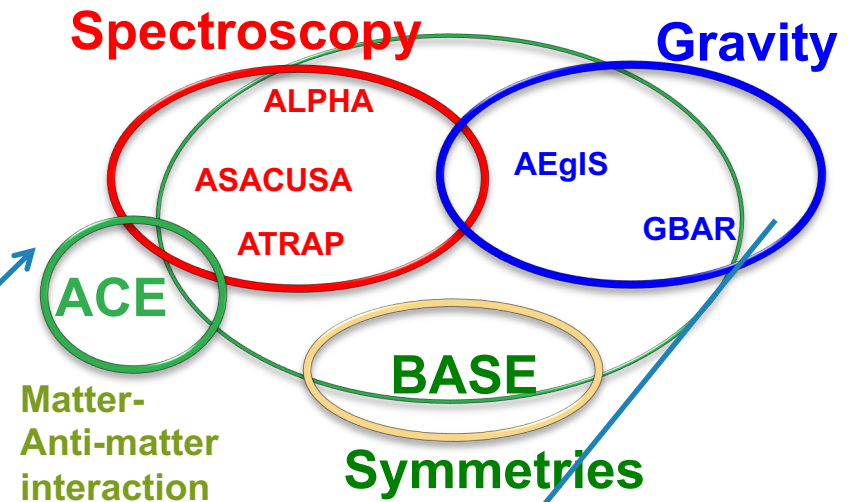
- High precision studies at low energies to test **interactions** and symmetries
- Complementary to experiments at the highest energies (LHC) and offer sensitivities to new effects beyond the Standard Model

Among them :

- Electric Dipole Moment of the Neutron (nEDM)
- Symmetries in antimatter (antihydrogen)
- Electron and neutrino correlations for the weak interaction

More and colder antiproton in ELENA from 2017

Experiments at AD
(antiproton and antihydrogen)



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



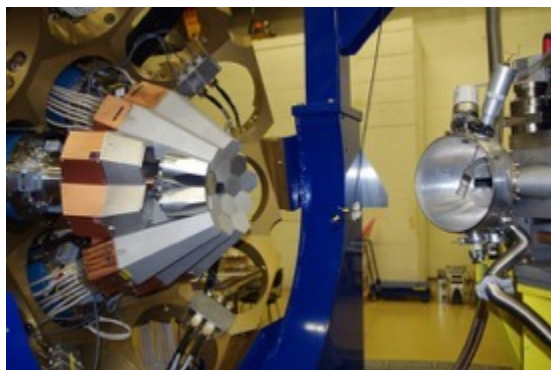
2010 → 2011 LNL, Italy
5TC (15 detectors)



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



2014 → GANIL, France
15TC (45 detectors)



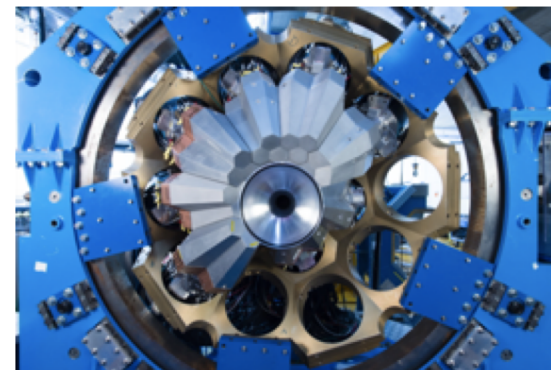
AGATA Demo. + PRISMA

Total Eff_{Nominal} ~2.6%



AGATA @ FRS

Total Eff. ($\beta=0.5$) ~ 10%



AGATA @G1

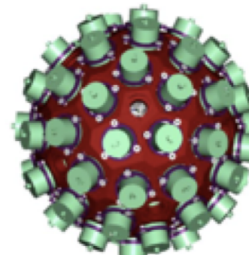
Total Eff ~ 8% to 14%

→ 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) !

Strong Polish contribution to AGATA

AGATA 4π



Tripple Cluster

