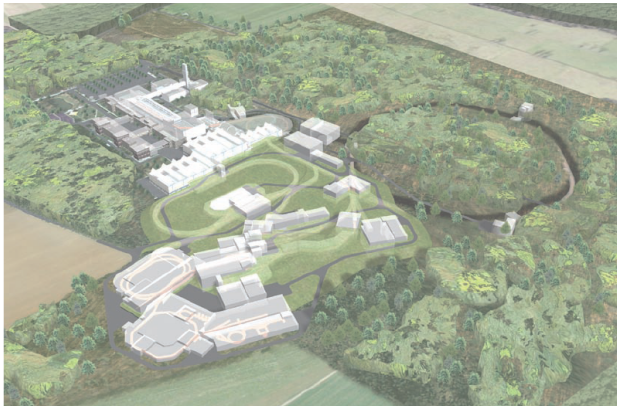
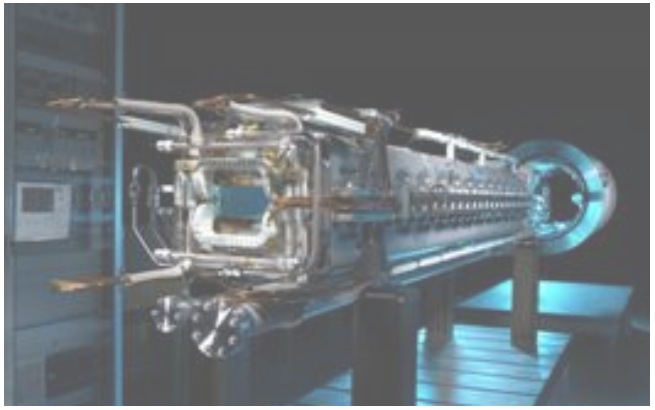




FAIR and its impact on Science and Technology

Nasser Kalantar-Nayestanaki

KVI-CART/University of Groningen

Spokesperson of the NUSTAR collaboration (2014-2018)

Building Bridges 2018

AE-Barcelona Knowledge Hub

28-29 NOVEMBER 2018

Finland France Germany India Poland Romania Russia Slovenia Sweden UK

FAIR

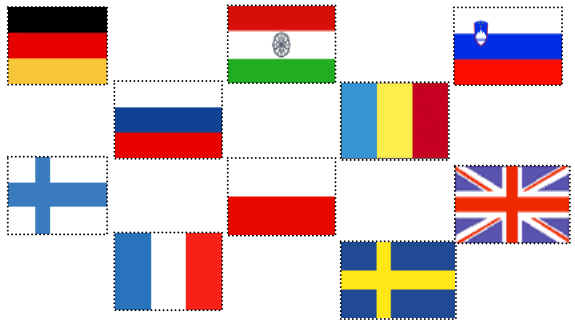
Historical Overview

- End of the 19**90s**: Ideas on the future of He
- **2001:** Conceptual Design Report to Germar
- **2003**: Decision on a step-wise realization of
  >25% contributions by international pa
- **2005**: MoU on FAIR,
  Establishment of ISC, STI, AFI, TAC,
  CORE-E
- **2006**: The FAIR Baseline Technical Report
- **2009**: FAIR Modularized Start Version (Scientific Evaluation, Green Paper)
- Oct. **2010**: Signing the FAIR Convention – START of *The Project*
  Establishing of the FAIR GmbH
- June **2016**: All parties agreed to provide the extra costs.

FAIR: an international endeavour

2010 - contractual foundation of FAIR : FAIR Convention signed

- International convention concerning the construction and operation
- The FAIR company and the GSI will collaborate in the construction, commissioning and operation on the basis of long-term agreements.
- International partners provide an interest about 30%.
- Contributions to the construction costs may be provided in-kind or in-cash.
- Shares are cost-book based.
- The latest cost cap is **1,357 M€** (1,262 M€ paid by the consortium and 95 M€ already paid by the German government). These prices are all fixed to the 2005 price level and should be inflated to the present day accordingly.



Partners

Germany, Russia, Finland,
France, India, Poland, Romania,
Sweden, Slovenia, United Kingdom

International Participation in FAIR

- FAIR governed by international convention
  - 9 shareholders + 1 assoc. partner (orange)
- Scientists from all over the world are engaged
  - More than 200 institutions from 53 countries are involved with their 2500-3000 scientists (orange + blue)

Facility for Antiproton and Ion Research

Primary Beams

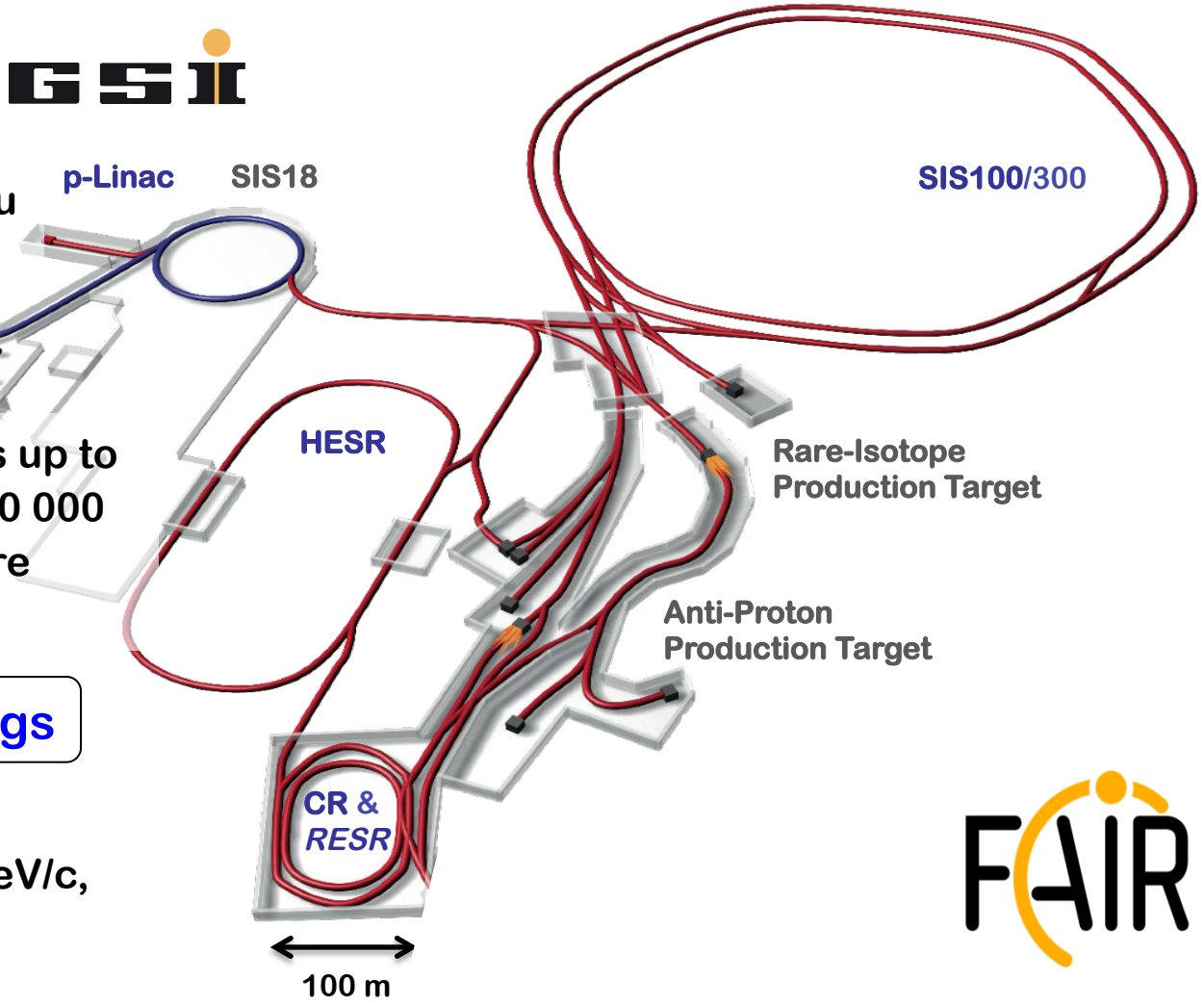
- 10^{12}/s; 1.5 GeV/u; $^{238}U^{28+}$
- 10^{10}/s $^{238}U^{73+}$ up to 35 GeV/u
- 3x10^{13}/s 30 GeV protons

Secondary Beams

- range of radioactive beams up to 1.5 - 2 GeV/u; up to factor 10 000 higher in intensity than before
- antiprotons 3 - 30 GeV

Storage and Cooler Rings

- radioactive beams
- 10^{11} antiprotons 1.5 - 15 GeV/c, stored and cooled

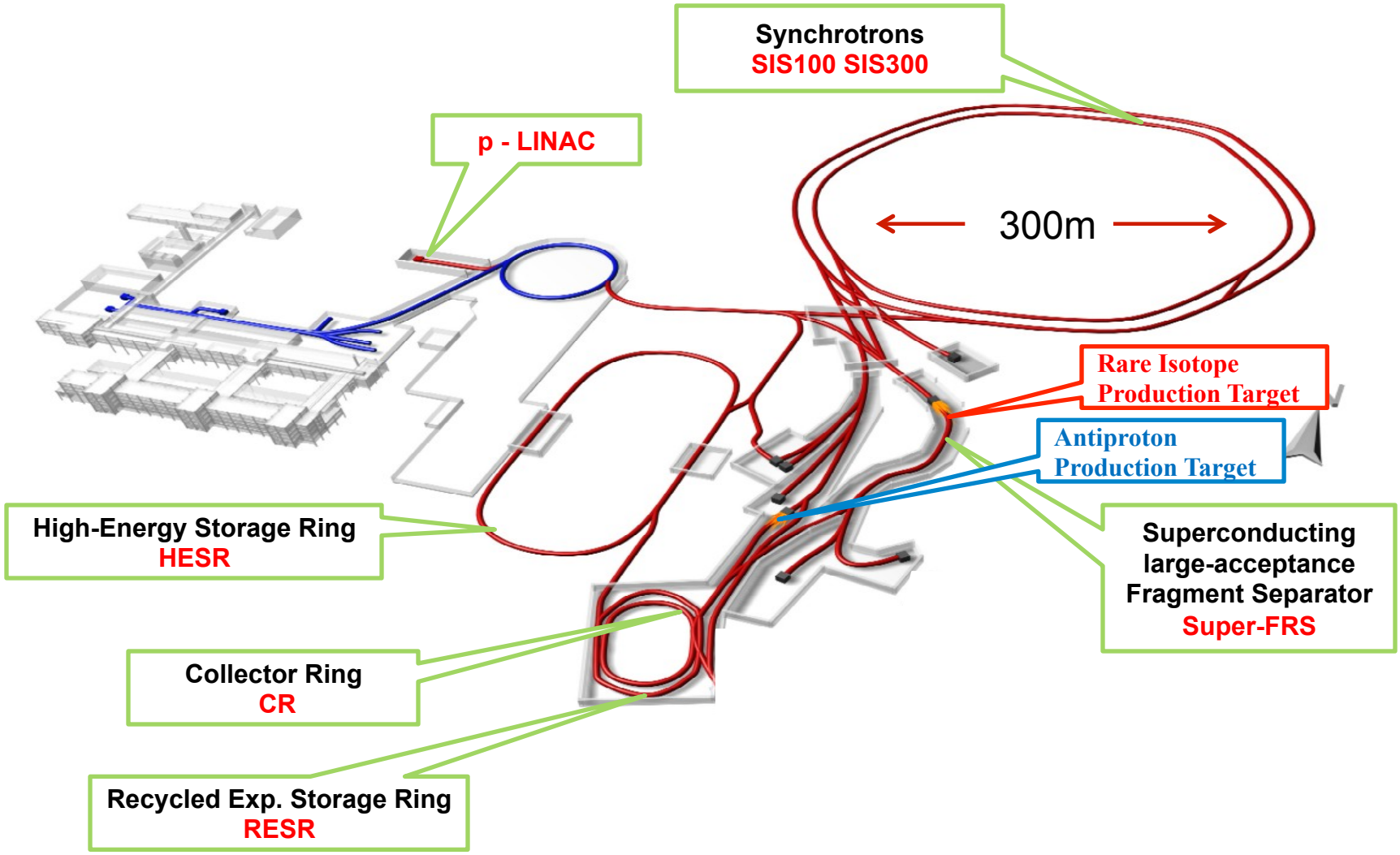


Technical Challenges

- cooled beams, rapid cycling superconducting magnets

Facility for Antiproton and Ions Research – the light tower of the ESFRI Roadmap

New accelerator systems entered the construction phase in Darmstadt



Physics at FAIR

Nuclear Structure & Astrophysics, NUSTAR
(Rare-isotope beams)

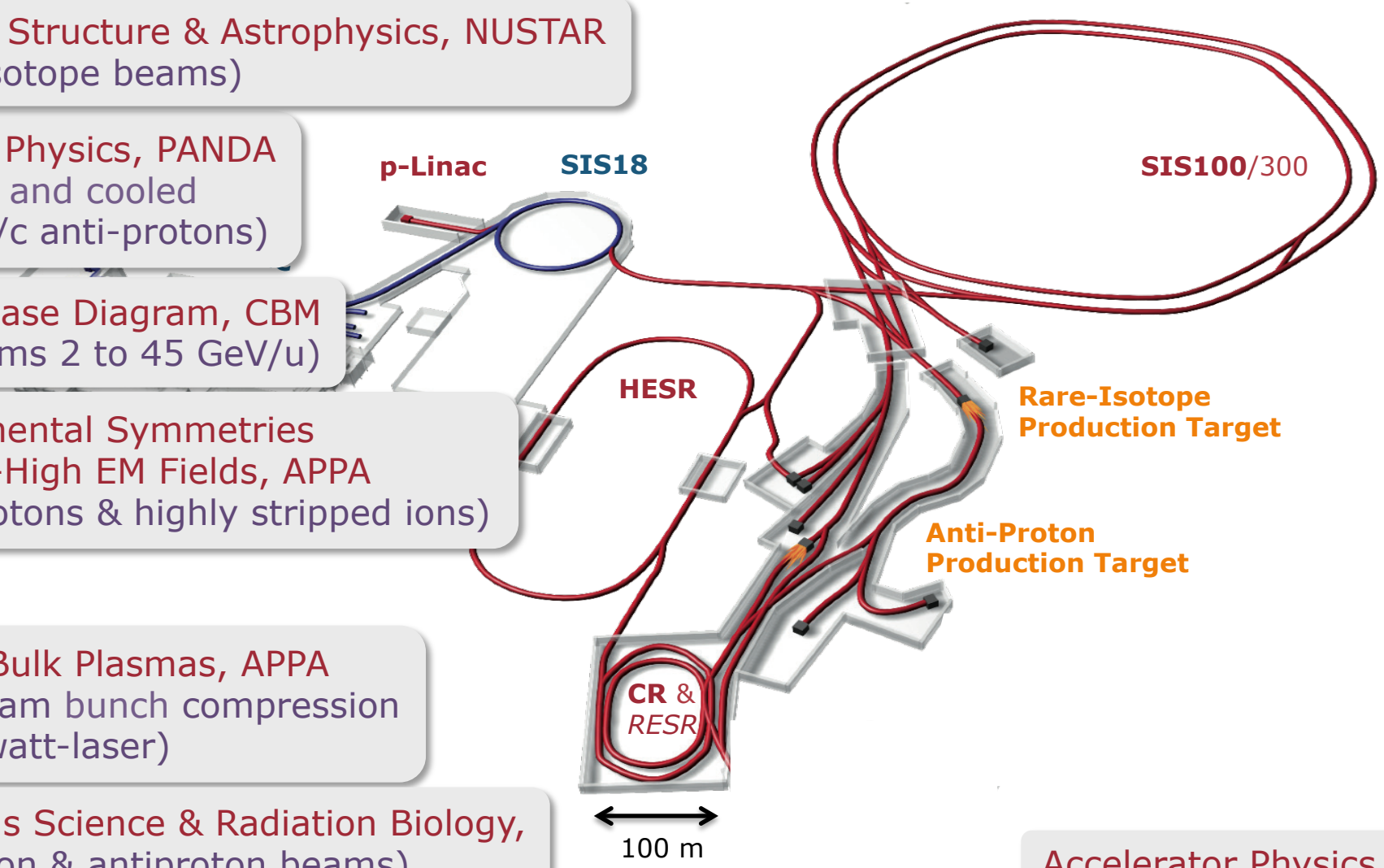
Hadron Physics, PANDA
(Stored and cooled
15 GeV/c anti-protons)

QCD-Phase Diagram, CBM
(HI beams 2 to 45 GeV/u)

Fundamental Symmetries
& Ultra-High EM Fields, APPA
(Antiprotons & highly stripped ions)

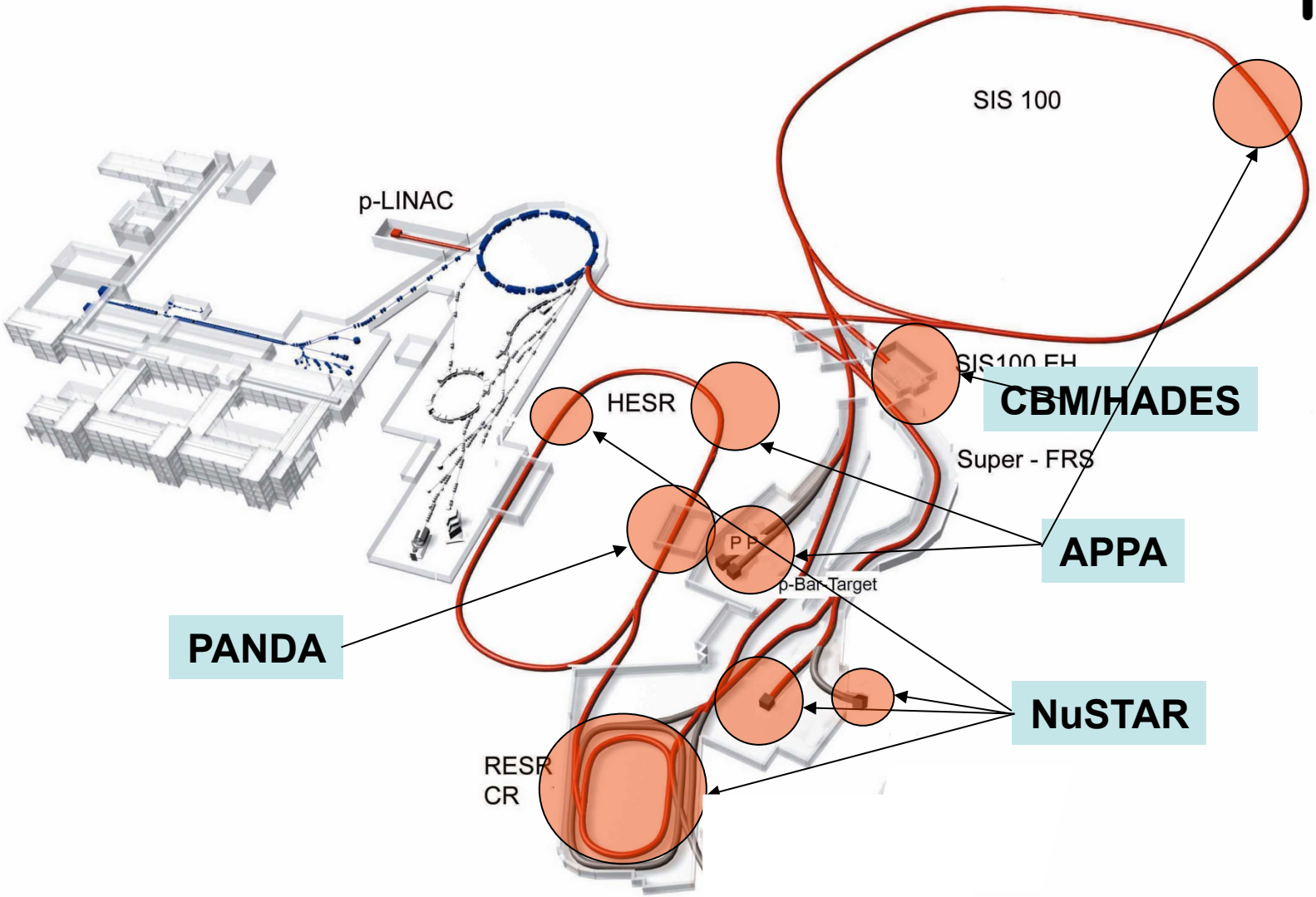
Dense Bulk Plasmas, APPA
(Ion-beam bunch compression
& petawatt-laser)

Materials Science & Radiation Biology,
APPA (Ion & antiproton beams)

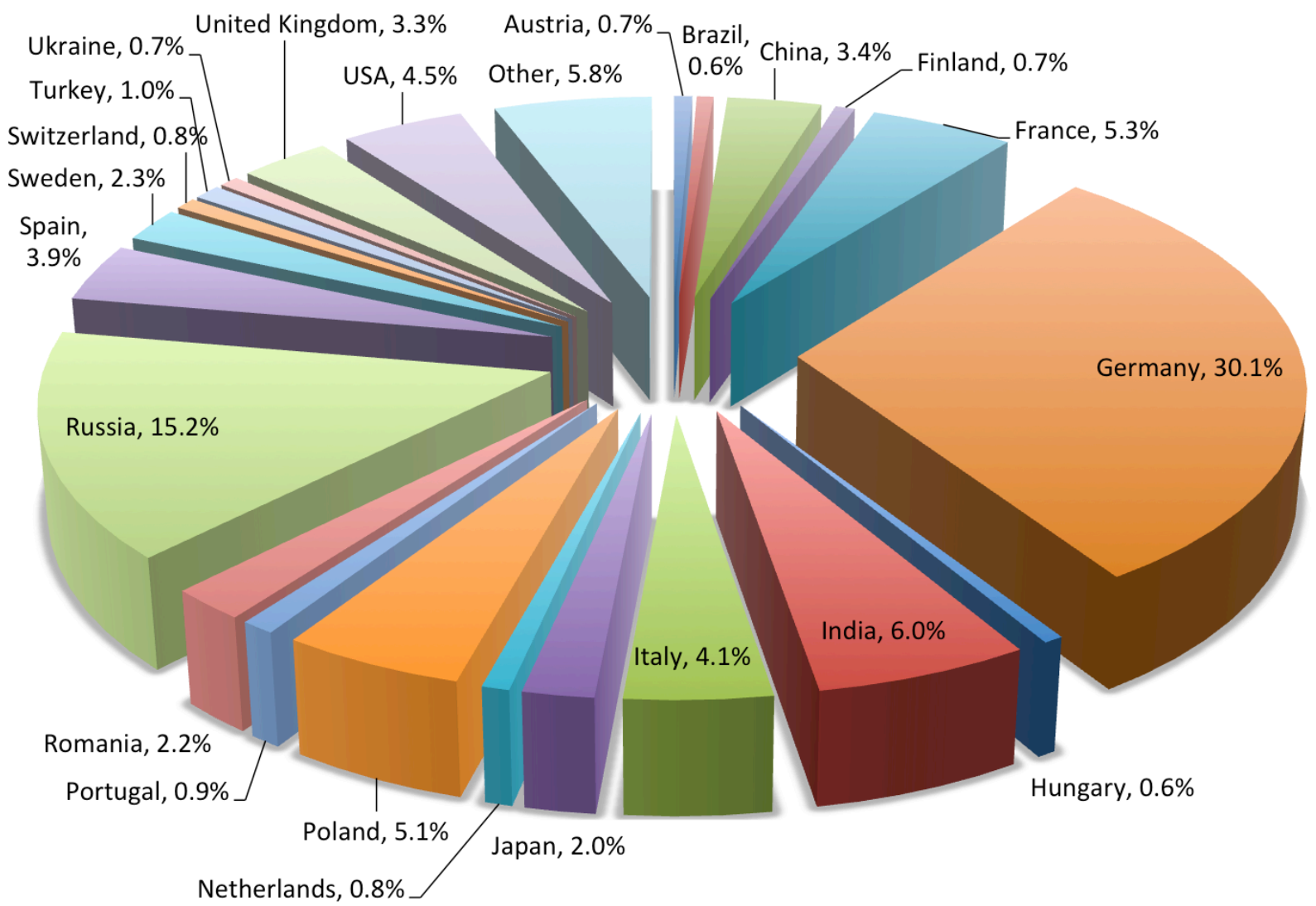


Accelerator Physics

Science with the Modularized Start Version

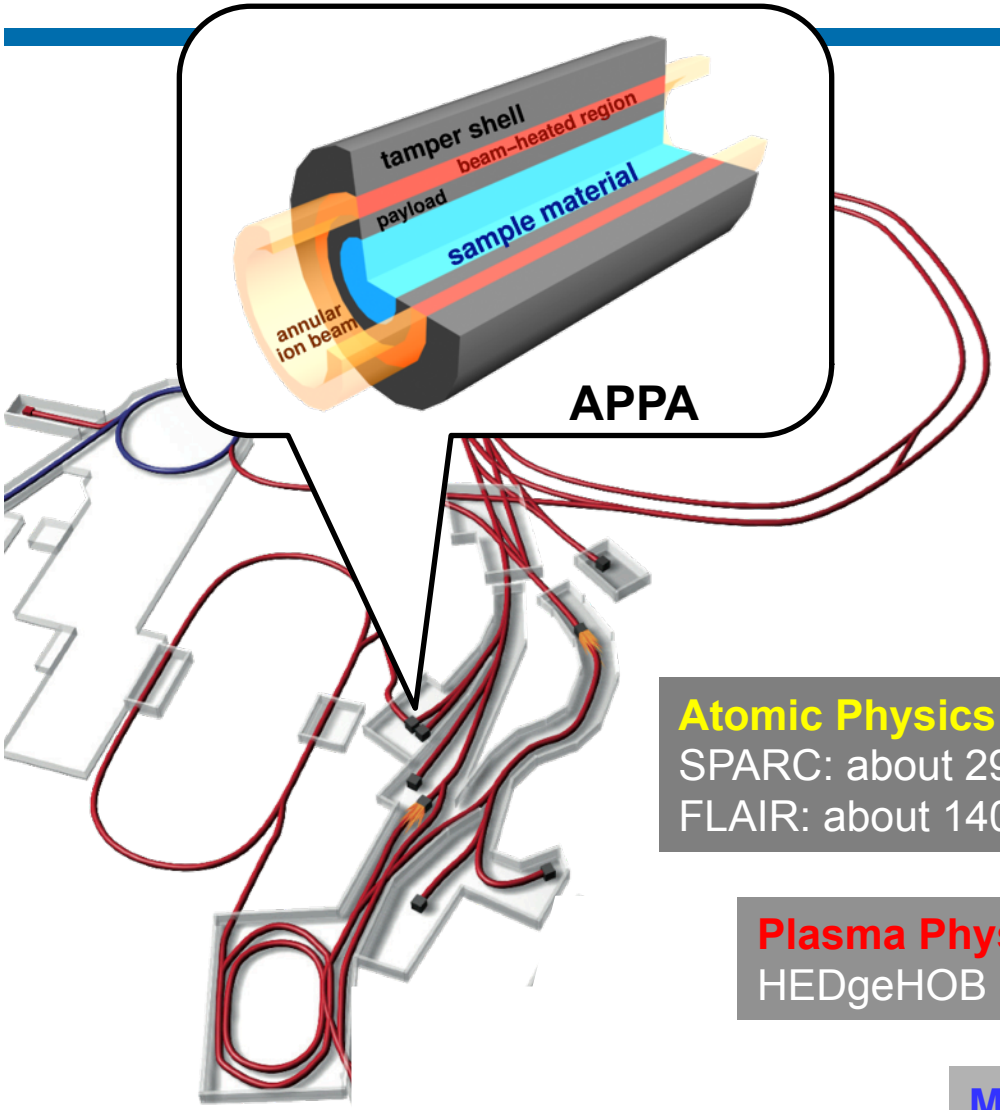


Collaboration Members by Country



In total 2500-3000 scientists

APPA



Atomic, Plasma Physics and Applications

- About 700 members

  Spokesperson R. Schuch

- Wide field of science

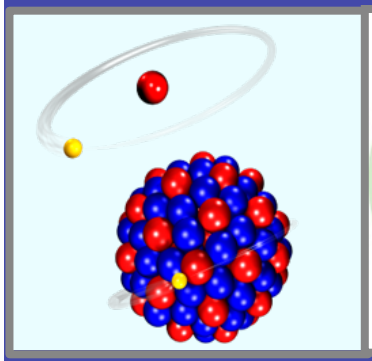
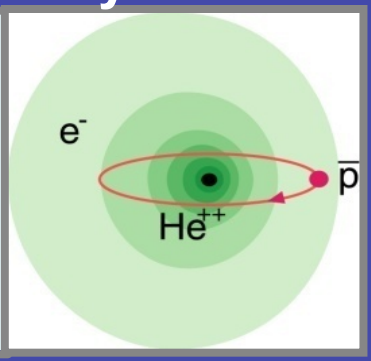
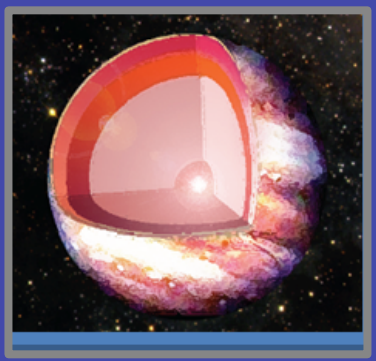
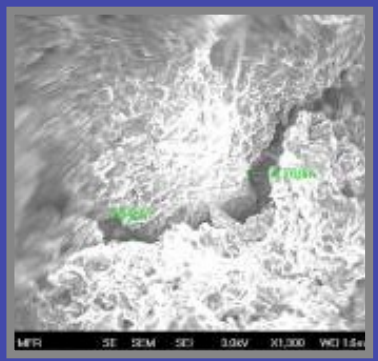
  basic research to material, biological and medical applications

Atomic Physics
SPARC: about 290 members from 26 countries
FLAIR: about 140 members from 15 countries

Plasma Physics
HEDgeHOB & WDM: about 180 members from 16 countries

Materials Research and Biophysics
BIOMAT: about 110 members from 12 countries

APPA Science Case

Atomic Physics		Plasma	Materials	Bio
				
SPARC	**FLAIR**	**HEDgeHOB/WDM**	**MAT/BIOMAT**	**BIO/BIOMAT**
strong field research ... probing of fundamental laws of physics	**anti-matter** ... matter / anti-matter asymmetry	**planetary interiors** ... states of matter common in astrophysical objects	**extreme conditions** ... radiation hardness modification of matt. Cancer treatment	**aerospace engineering** ... radiation shielding of cosmic radiation

Highest Charge States	***Extreme Static Fields***
Relativistic Energies	***Extreme Dynamical Fields and Ultrashort Pulses***
High Intensities	***Very High Energy Densities and Pressures***
High Charge at Low Velocity	***Large Energy Deposition***
Low-Energy Anti-Protons	***Antimatter Research***

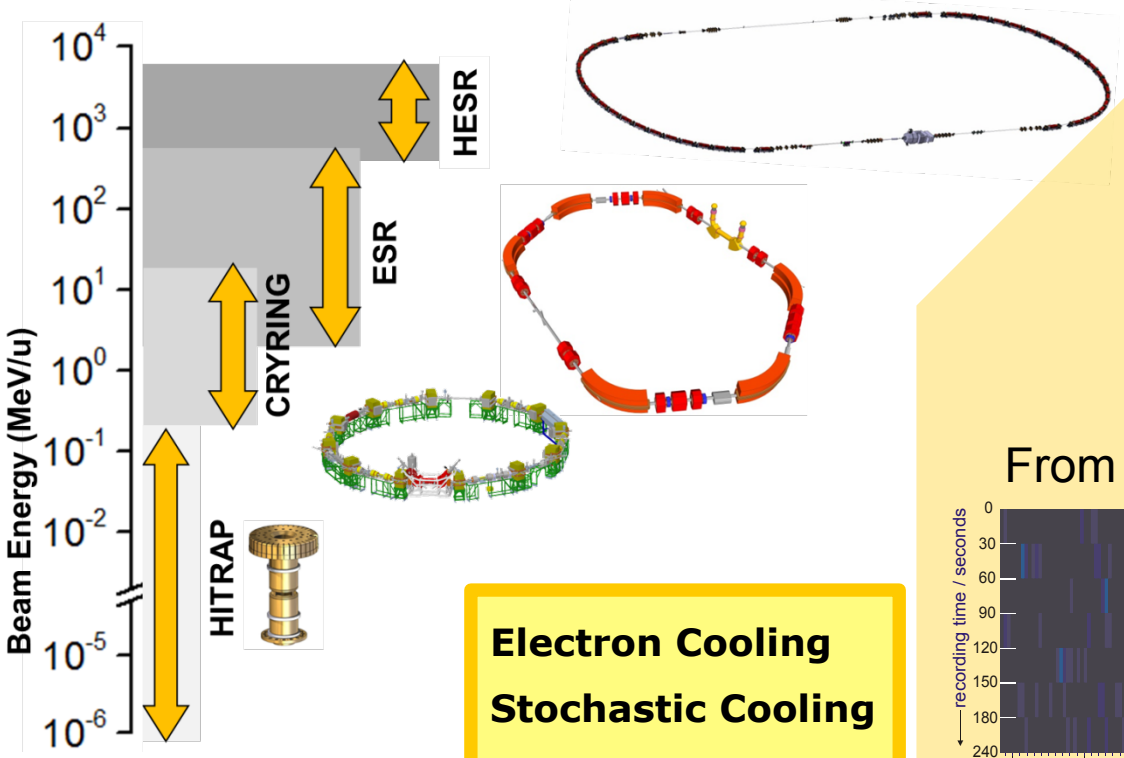
APPA Integration: SPARC with Stored and Cooled Ions

Stored and cooled highly charged ions and RIBs

Protons to Uranium in various charge states (U^{28+} to U^{92+})

Single to 10^9 stored ions

From rest to relativistic (γ=6) energies

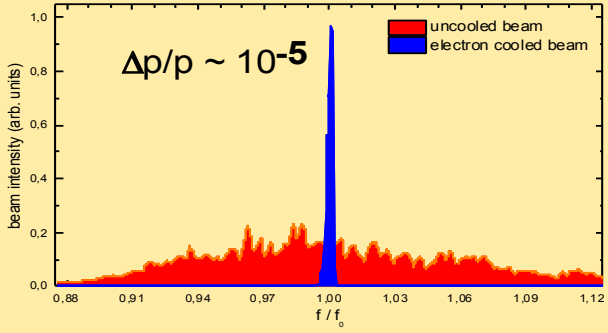


Electron Cooling

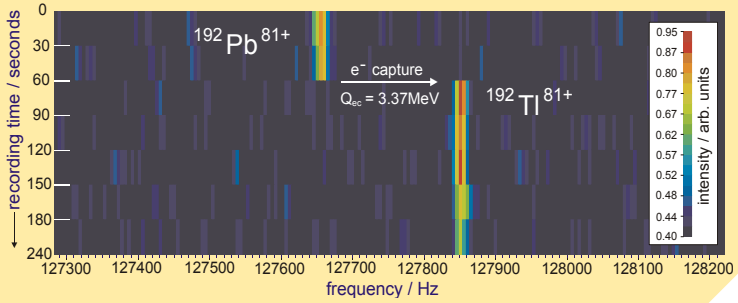
Stochastic Cooling

Laser Cooling

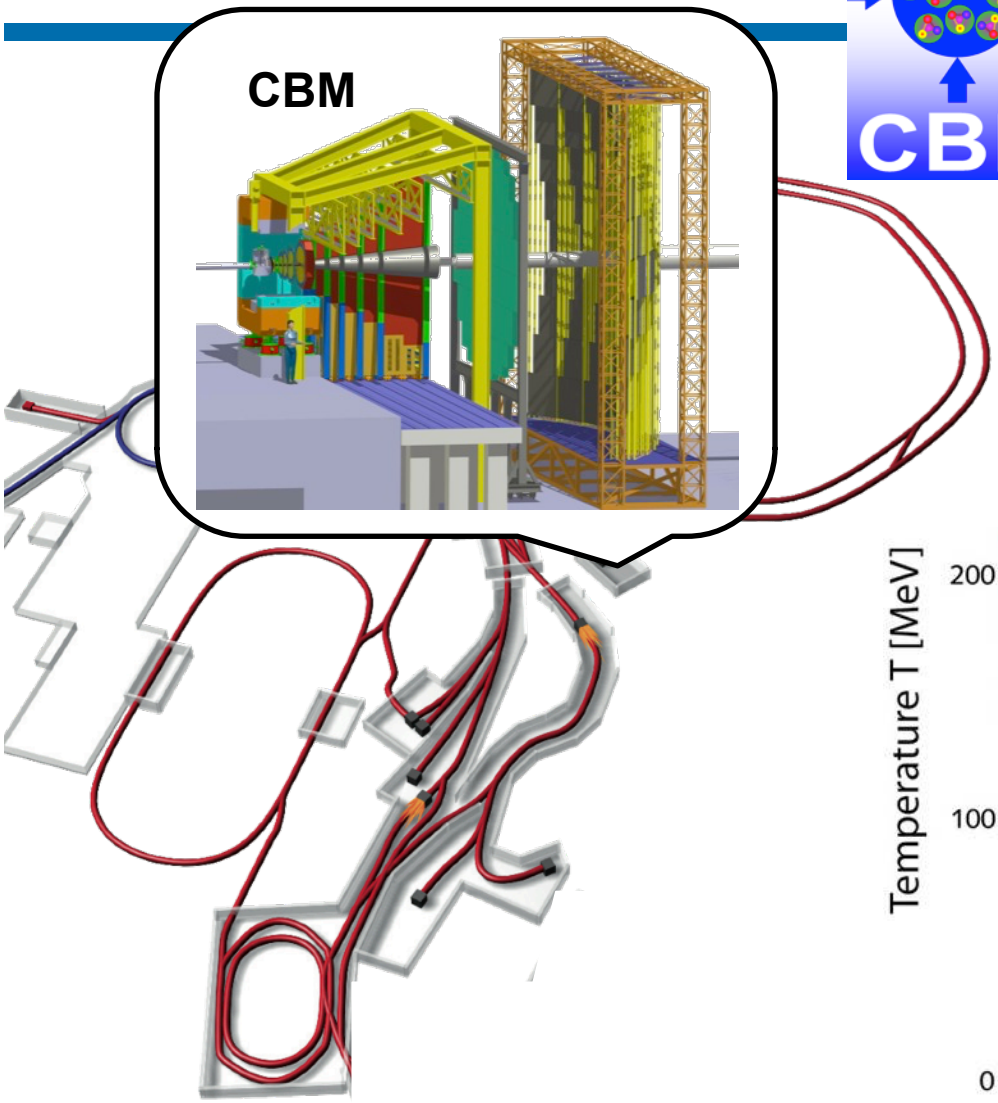
Cooling: The Key for Precision



From Single Ions to Highest Intensities



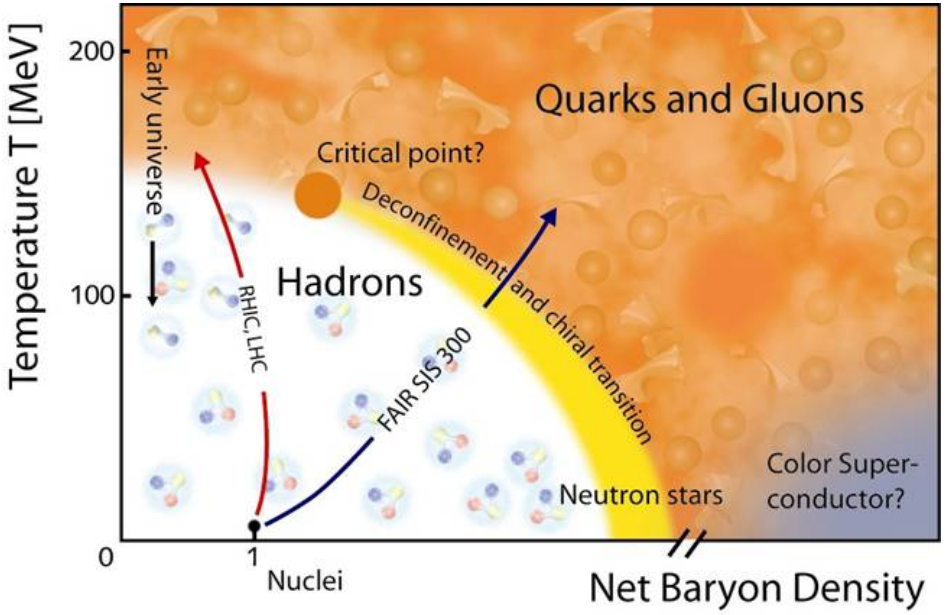
CBM



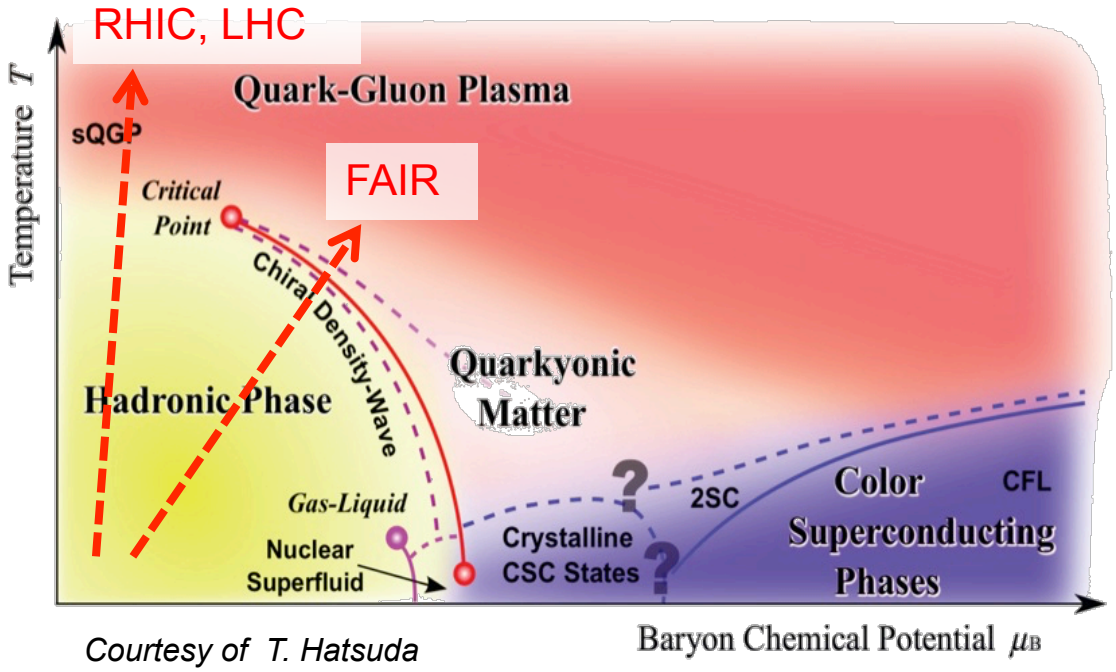
Compressed Baryonic Matter

- About 400 members

  Spokesperson N. Herrmann



CBM Physics Case



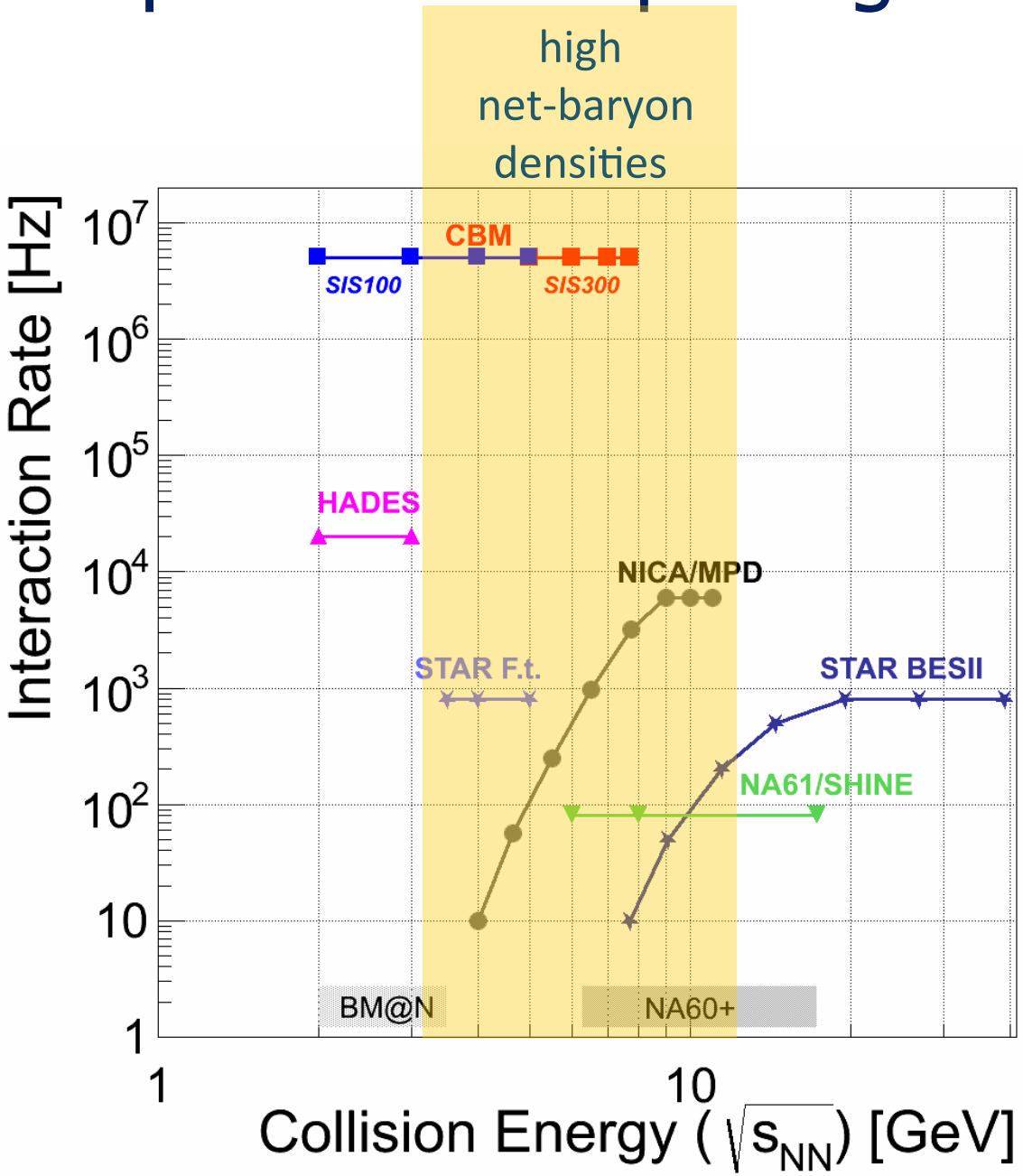
Courtesy of T. Hatsuda

- The equation-of-state at high baryonic density
- New phases of strongly-interacting matter
- Deconfinement phase transition at high baryonic density
- QCD critical endpoint
- Onset of chiral symmetry restoration at high baryonic density
- Strange matter

CBM observables:

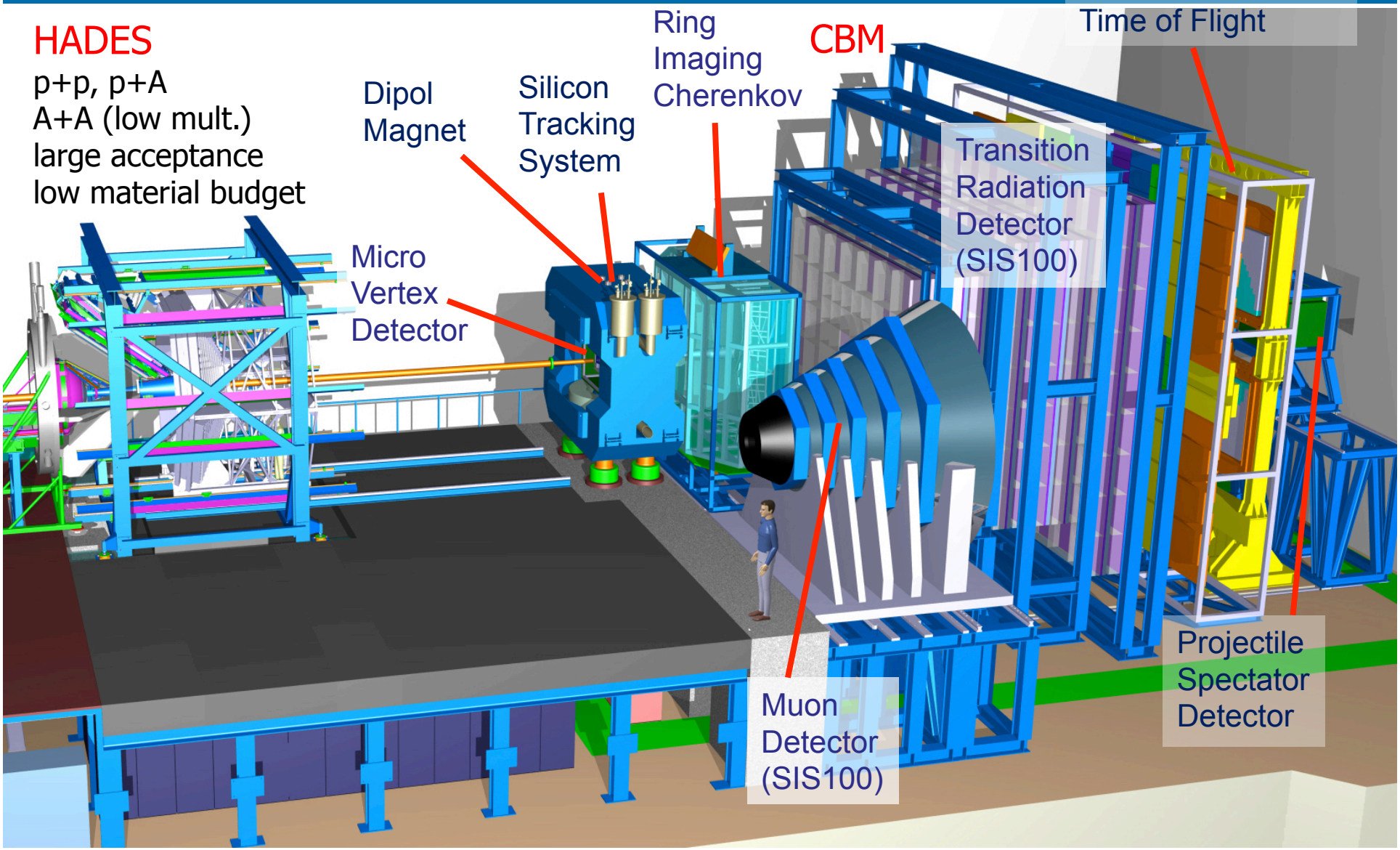
- dileptons and fluctuations
- charmonium production
- and ....

Experiments exploring dense QCD matter

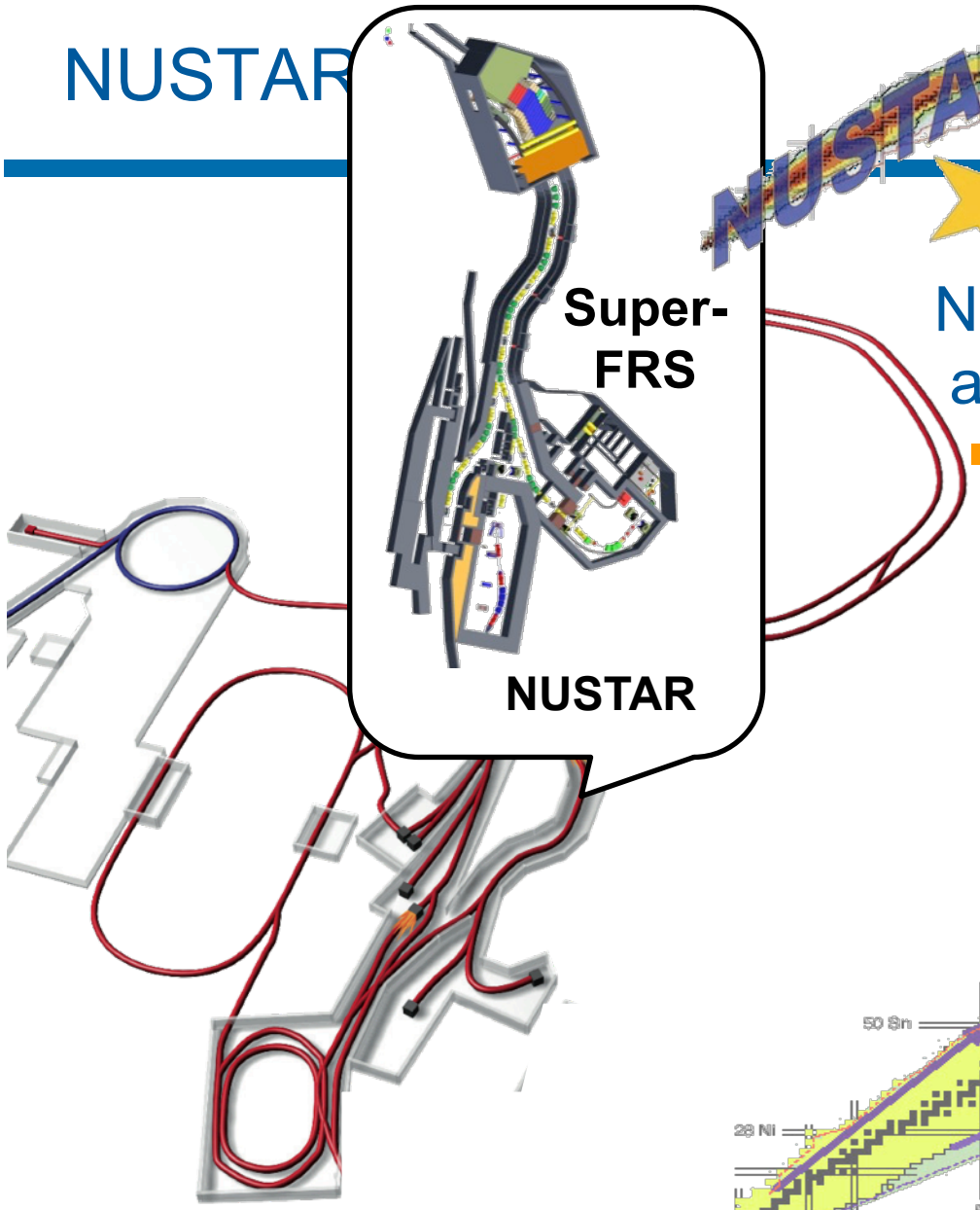


Key experimental requirement:
operation at unprecedented high rates

CBM / HADES Detector



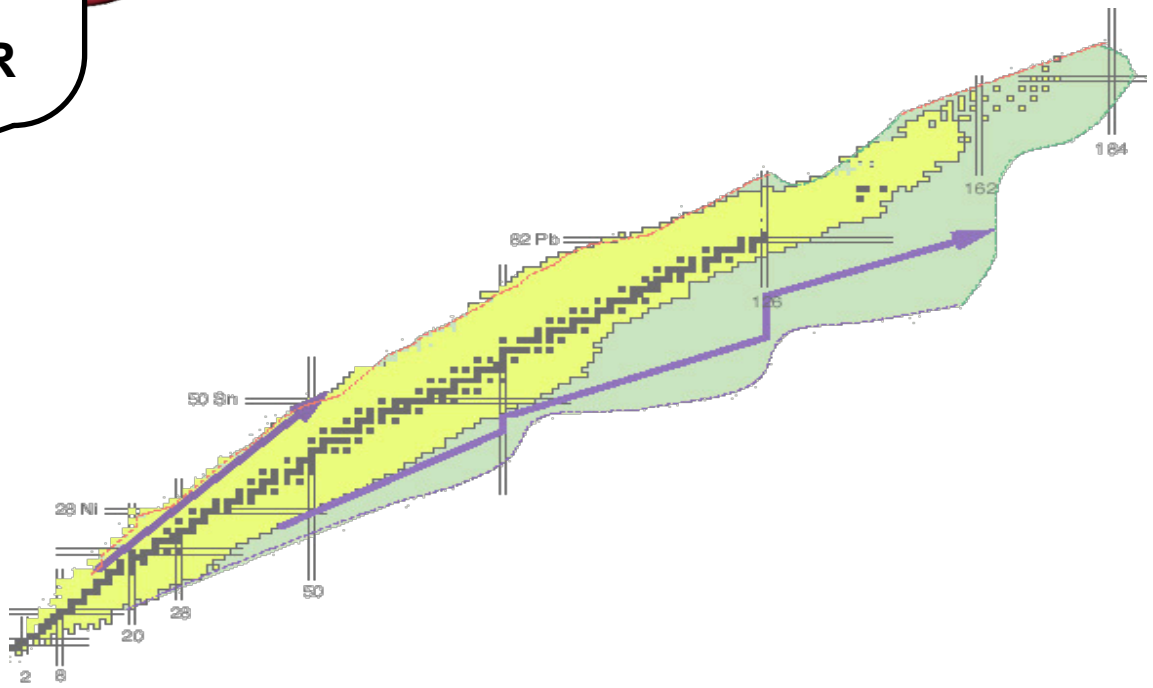
NUSTAR



Nuclear Structure, Astrophysics and Reactions

- About 800 members

  Spokesperson W. Korten



NUclear STructure Astrophysics and Reactions

How are complex nuclei built from their basic constituents?

– What is the effective nucleon-nucleon interaction and how does QCD constrain its parameters?

– How does the three-nucleon force modify the picture?

How does the effective nuclear force depend on varying proton-to-neutron ratios?

– What is the isospin dependence of the spin-orbit force?

– How does shell structure change far from stability?

– How does the role of N-N correlations in nuclei and nuclear matter change with isospin?

How to explain collective phenomena from individual motion?

– What are the phases, relevant degrees of freedom, and symmetries of the nuclear many-body system?

What are the limits of existence of nuclei?

– Where are the proton and neutron drip lines situated?

– What are the heaviest elements?

How does the equation of state of nuclear matter change with neutron-to-proton asymmetry?

– How large is the symmetry energy and its density dependence?

– What are the properties of neutron-rich matter?

Which nuclei are relevant for astrophysical processes, what are their properties and what is their impact on nucleosynthesis modeling?

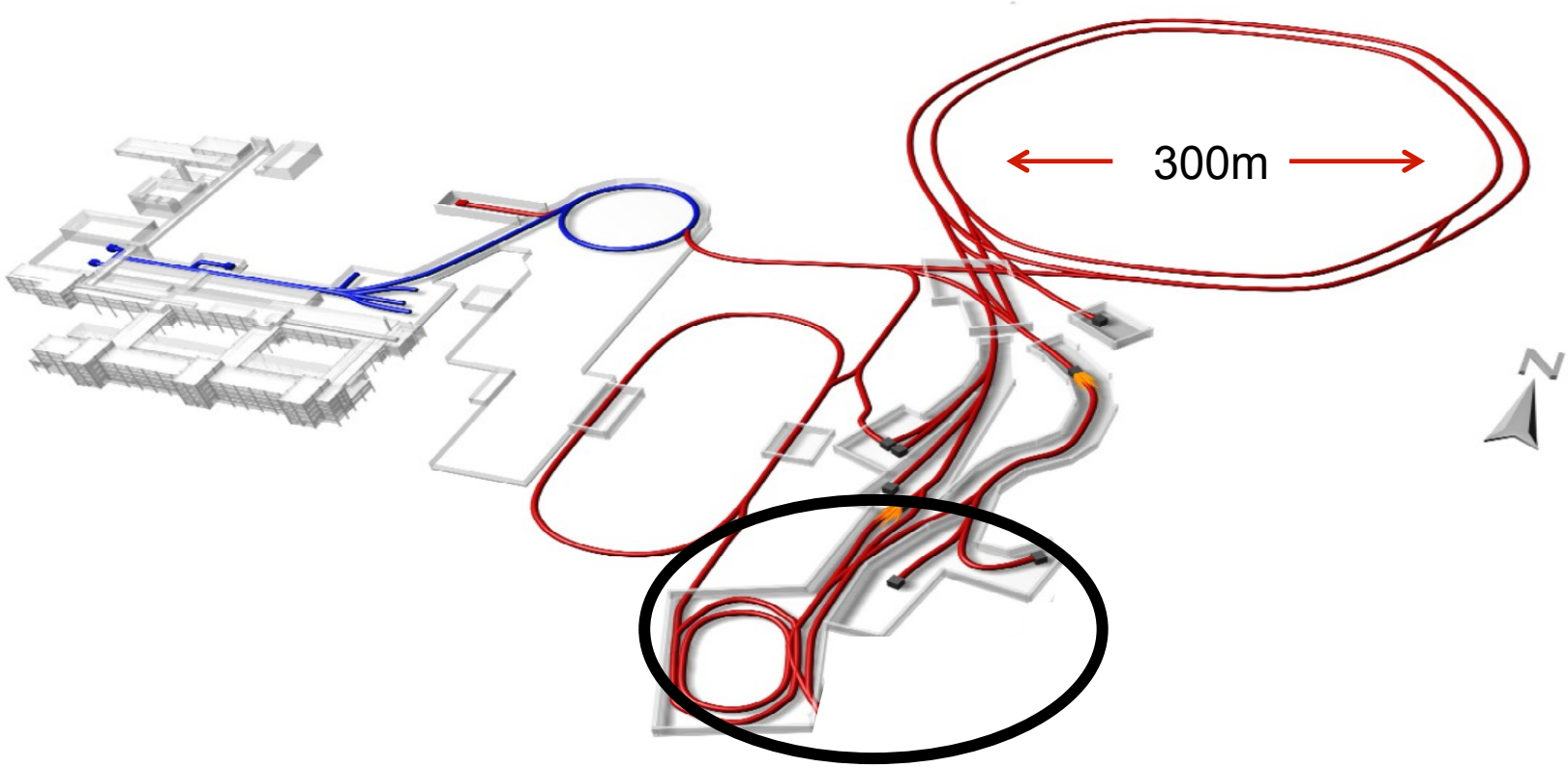
Nuclear Astrophysics at FAIR

FAIR will provide unique access to many nuclei relevant in explosive nucleosynthesis

rp-, p-process:
- masses at & beyond the proton drip-line
- (p,g), (g,p) rates

r-process:
- masses, half-lives
- b-delayed neutron emission
- (g,n), (n,g) rates
- shell structure

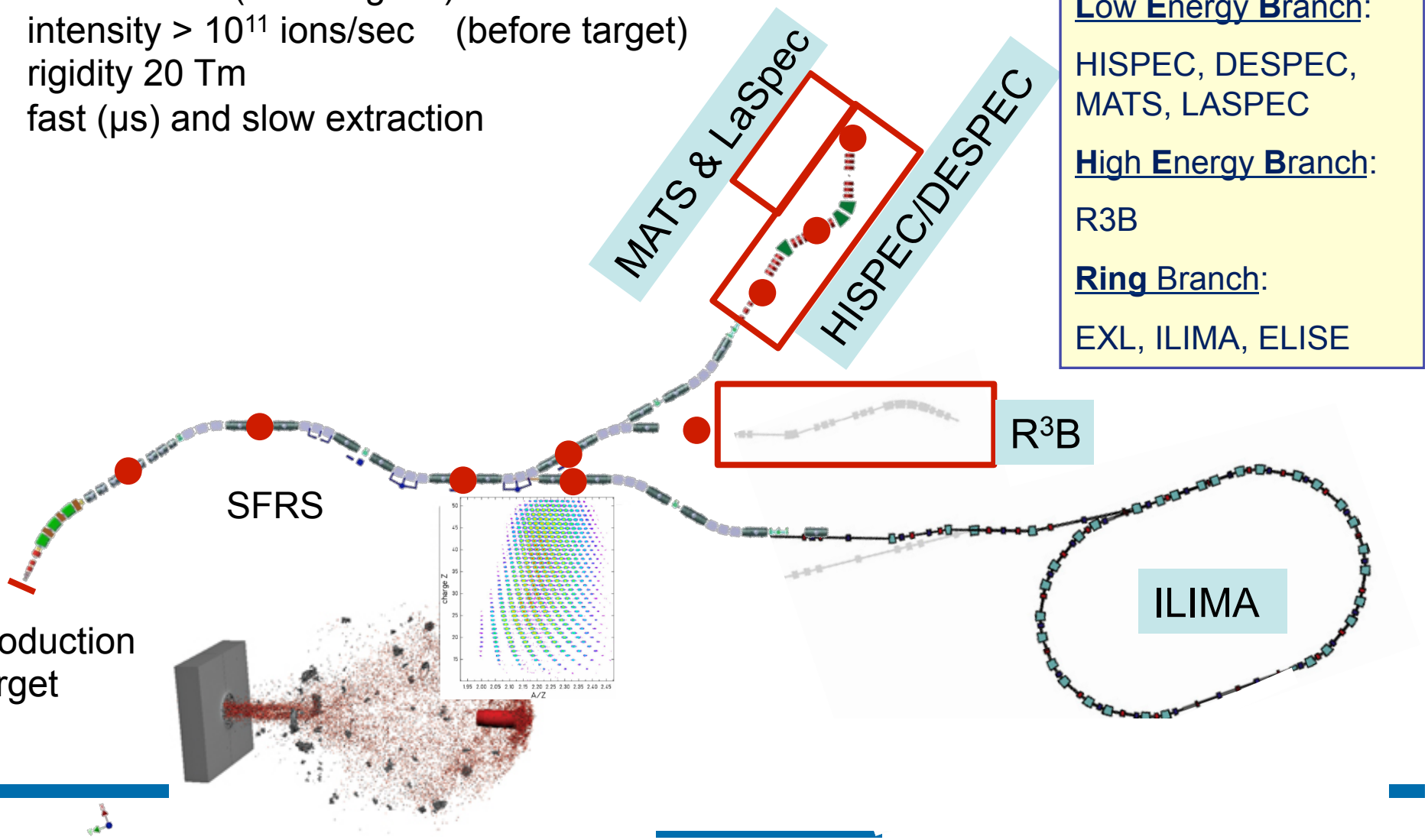
➔ Combine accurate **nuclear physics** with precision **astronomy** to **constrain astrophysical scenarios**


300m
N

NUSTAR - FAIR asset – rings and instrumentation

Parameters:

- all elements (H through U)
- intensity > 10^{11} ions/sec (before target)
- rigidity 20 Tm
- fast (μs) and slow extraction



Low Energy Branch:

HISPEC, DESPEC, MATS, LASPEC

High Energy Branch:

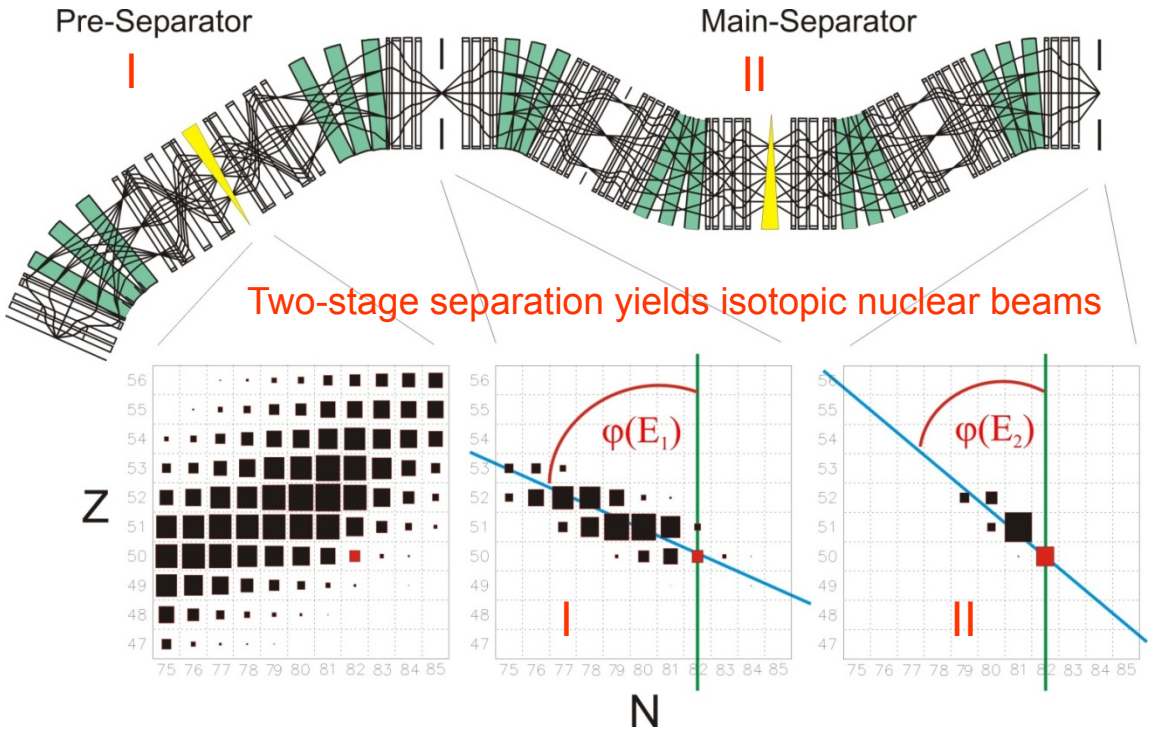
R3B

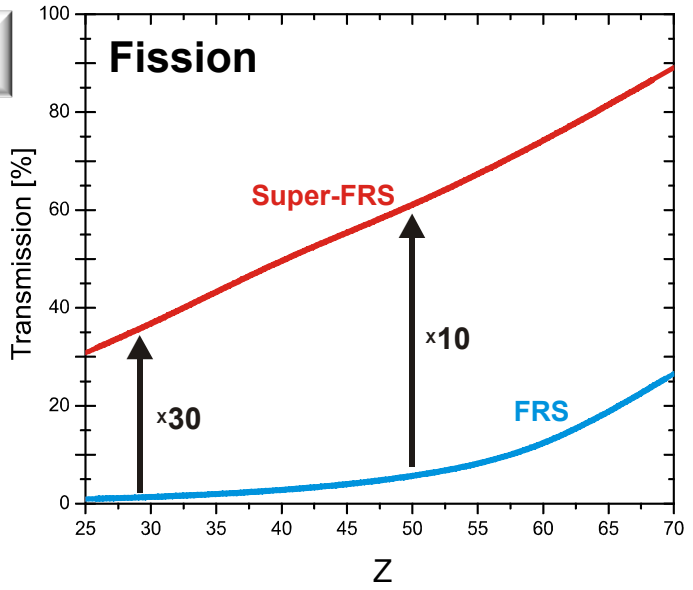
Ring Branch:

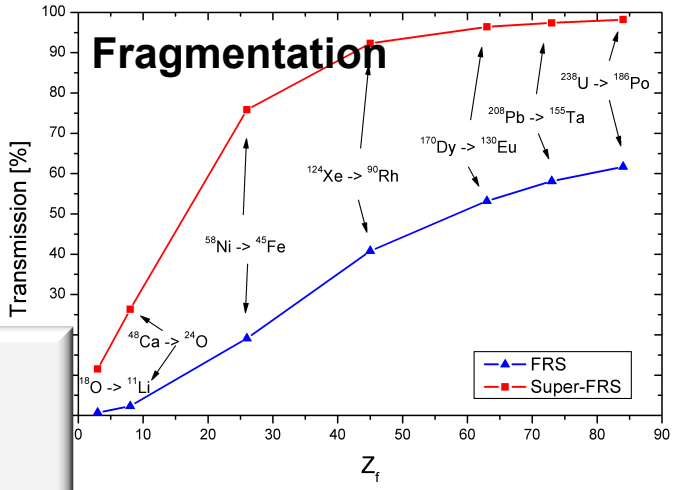
EXL, ILIMA, ELISE

The Super-FRS

Central instrument for the NuSTAR program!!

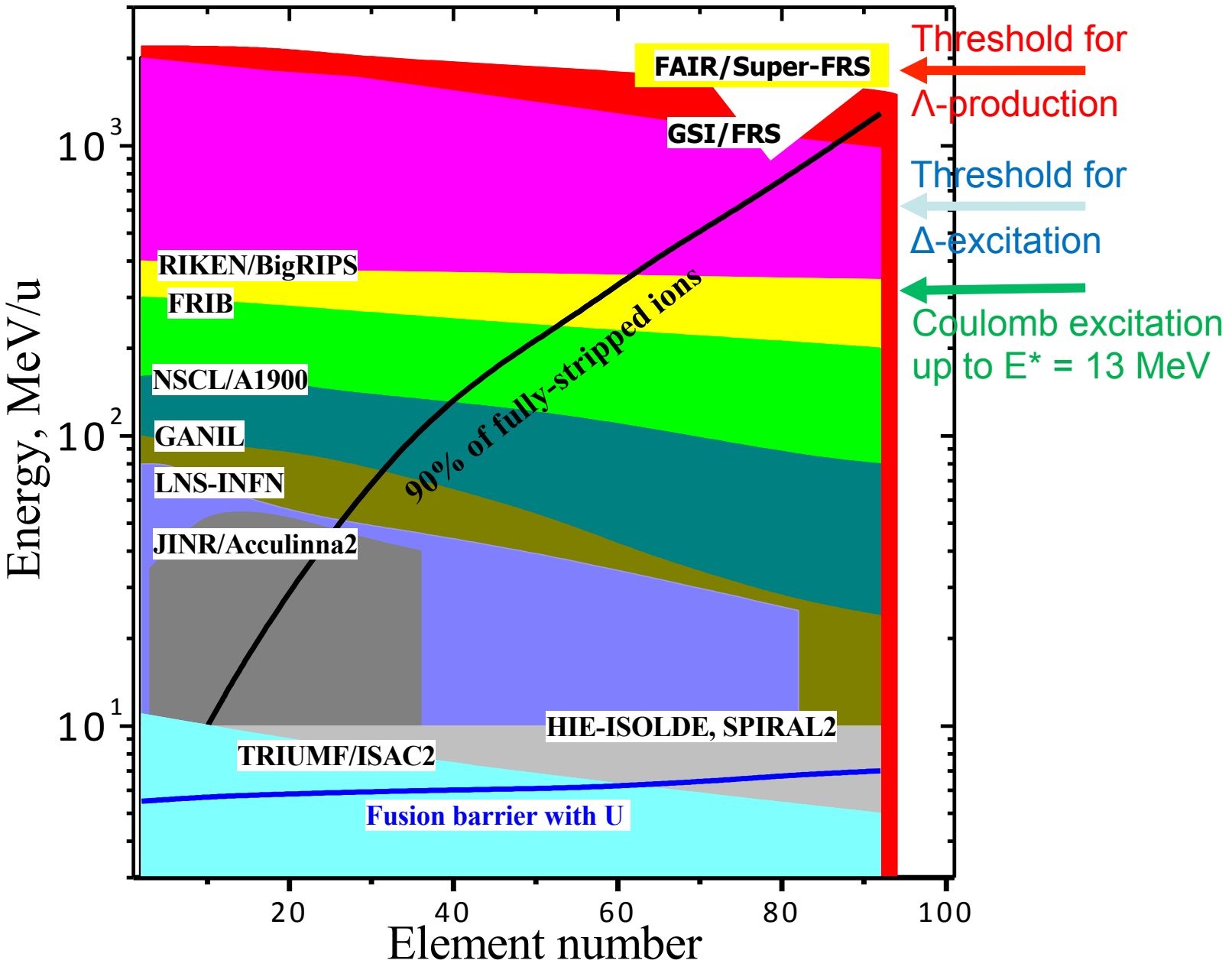




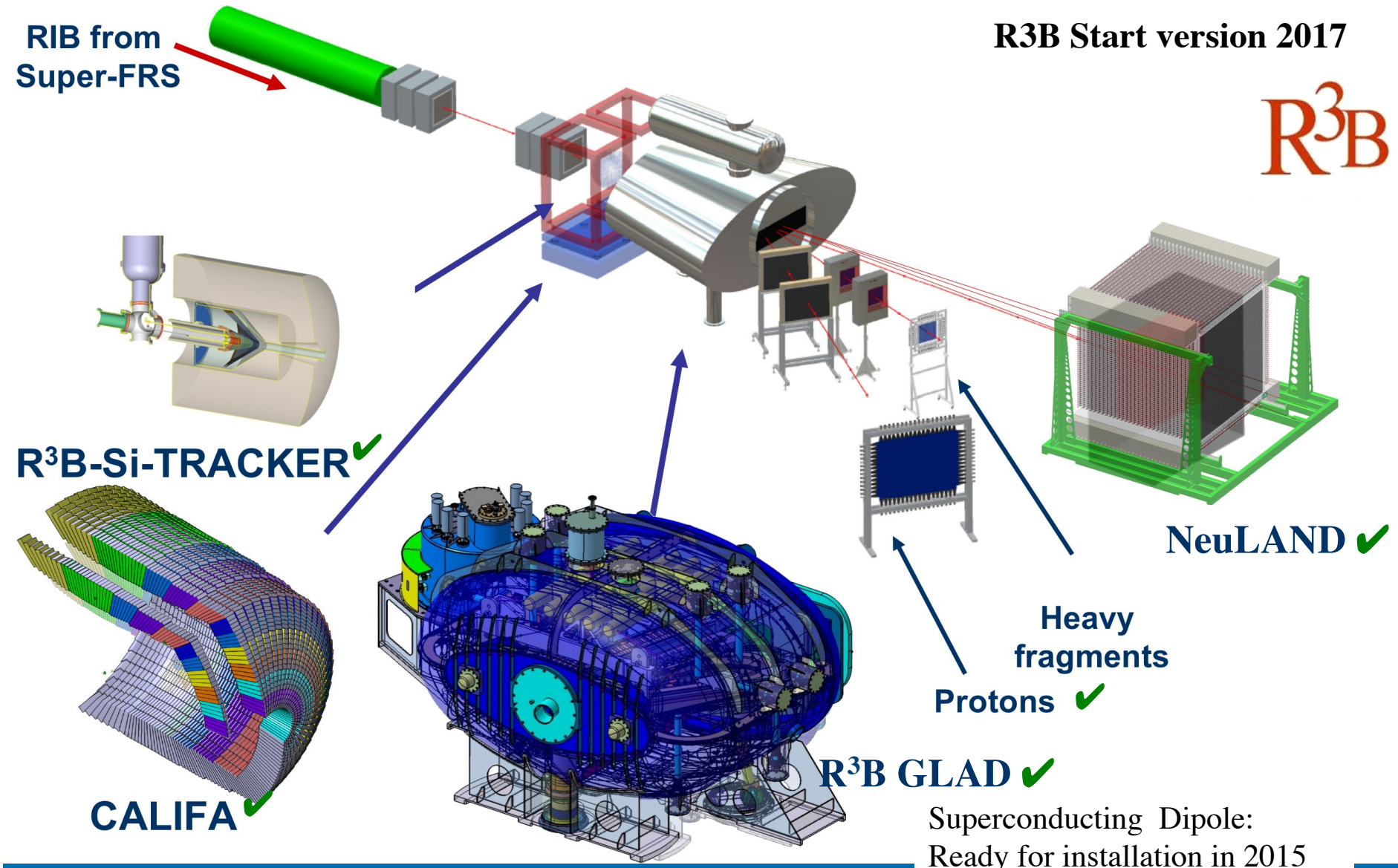


- High acceptance for projectile fragments and fission products
- Two-stage separation absolutely needed for clean beams
- **More than one order of magnitude transmission gain relative to FRS**

RARE-ISOTOPE BEAM FACILITIES

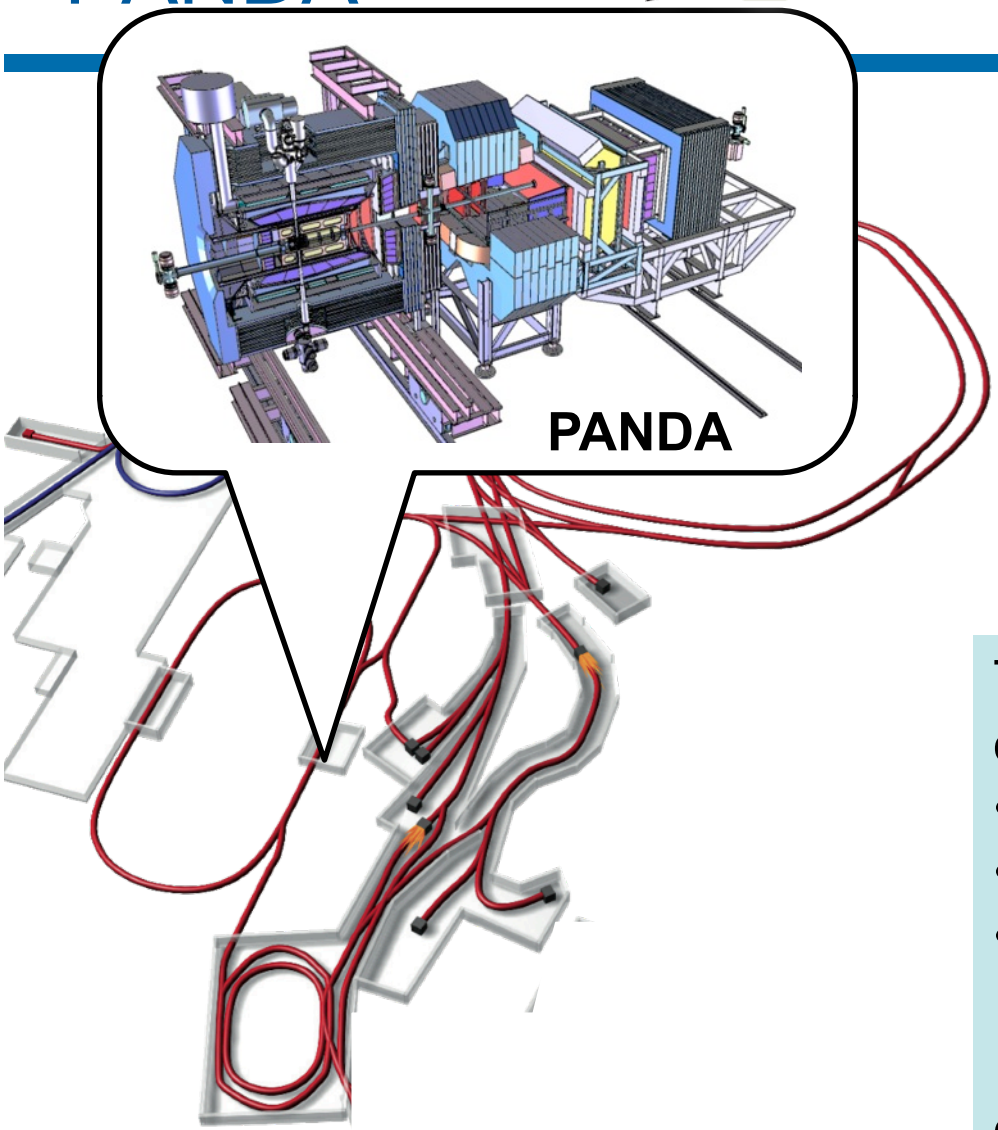


Reactions with Relativistic Radioactive Beams R^{3}B



GLAD magent

PANDA



Antiproton Annihilations at Darmstadt

- About 500 members

  Spokesperson K. Peters

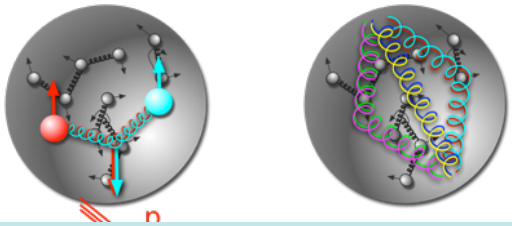
The scientific scope of PANDA is ordered into several pillars:

- hadron spectroscopy,
- properties of hadrons in matter,
- nucleon structure and hypernuclei.

Each of these addresses specific open issues of QCD.

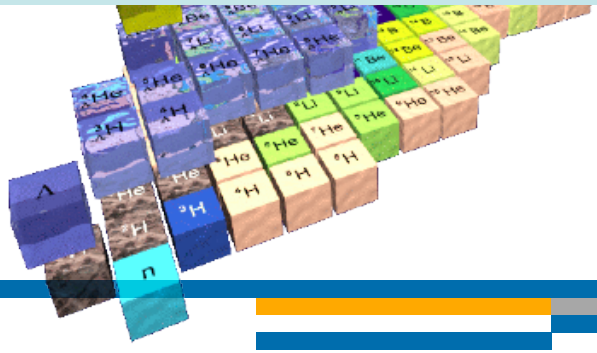
PANDA Physics Case

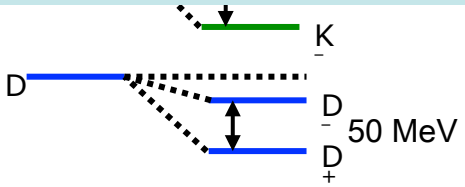
Gluonic excitations



PANDA will measure annihilation reactions of antiprotons with nucleons and nuclei in order to provide uniquely decisive information on a wide range of QCD aspects.

- Double hypernuclei

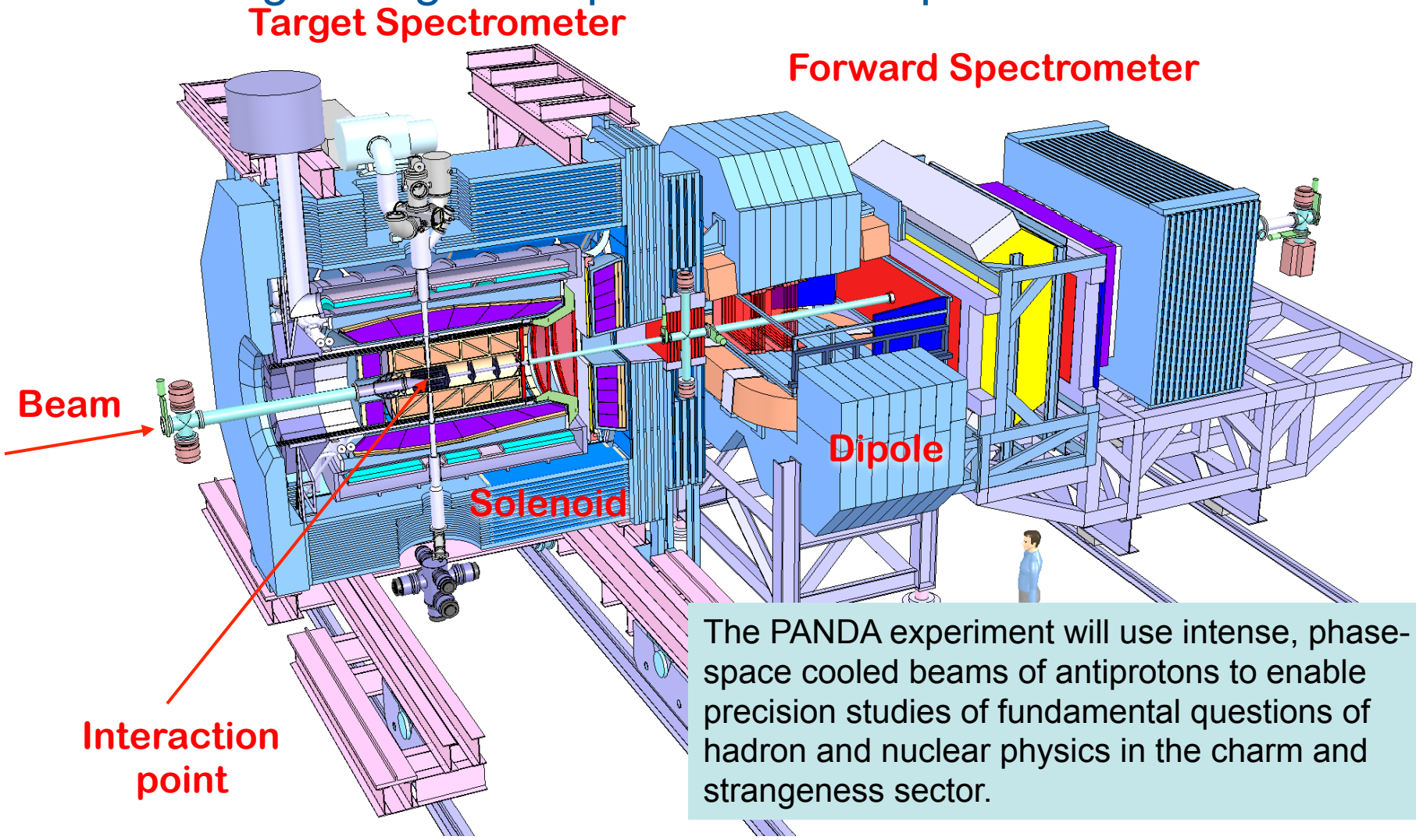




And much more...

PANDA Experimental Setup

Fixed target magnetic spectrometer experiment

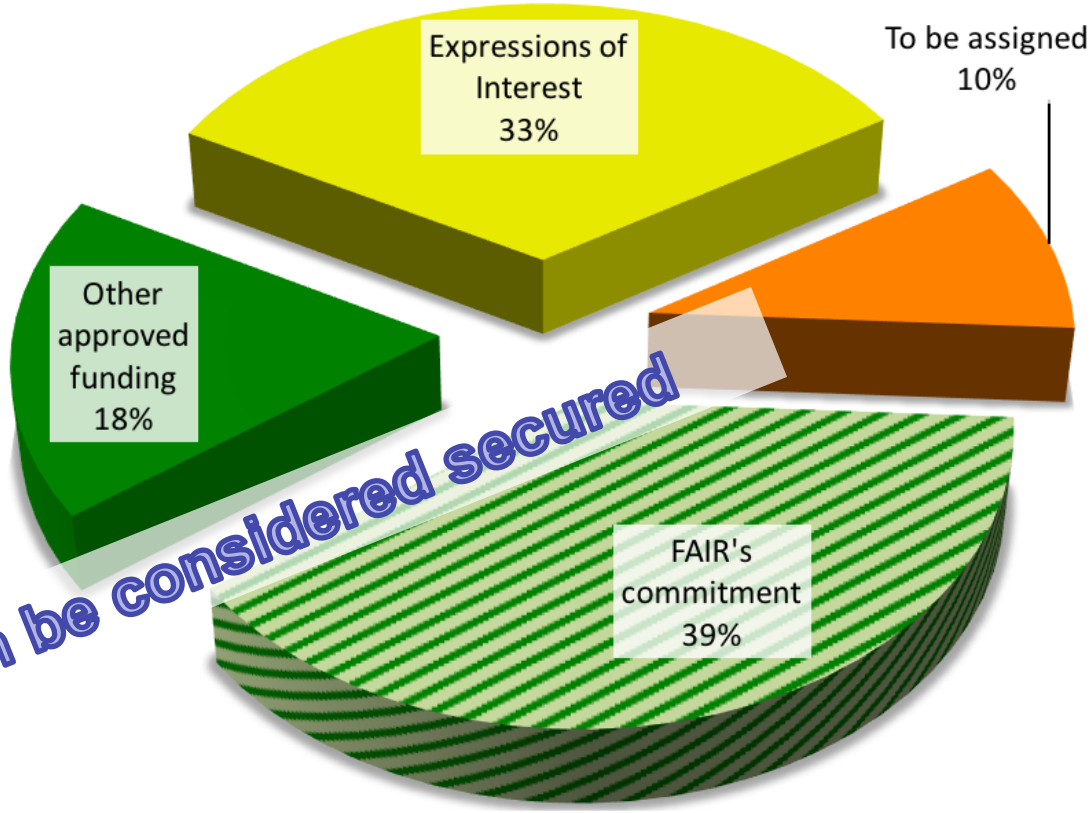


The PANDA experiment will use intense, phase-space cooled beams of antiprotons to enable precision studies of fundamental questions of hadron and nuclear physics in the charm and strangeness sector.

Experiments' Costs (5th RRBs, Feb 2016)

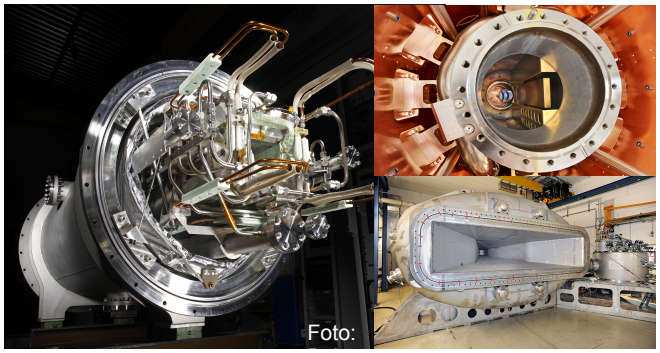
- Collaborations' input to
  Resources Review Boards (full MSV setups)
  - **About 200 M€** (2005 prices) = 249 M€ (2016 prices)

- Breakdown (2005 prices)
  - FAIR's commitment:
    77 M€ identified of 78 M€
  - Other approved funding:
    36 M€
  - Expressions of Interest:
    67 M€
  - To be assigned:
    19 M€



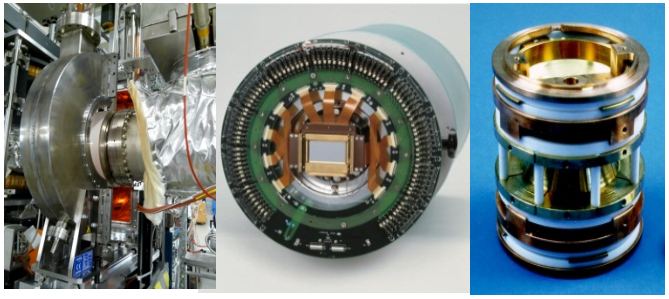
Currently, classifications of individual contributions outside FAIR's commitment are re-assessed.

Pushing the limits and driving new technologies

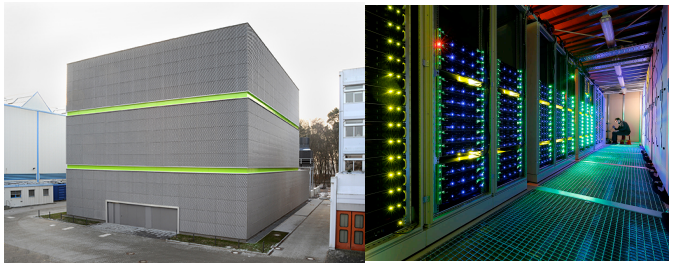


Fast cycling (4 Tesla /s) super conducting (s.c.) magnets incl. cryo-technology

Innovative, energy-efficient proton and ion beam LINACS

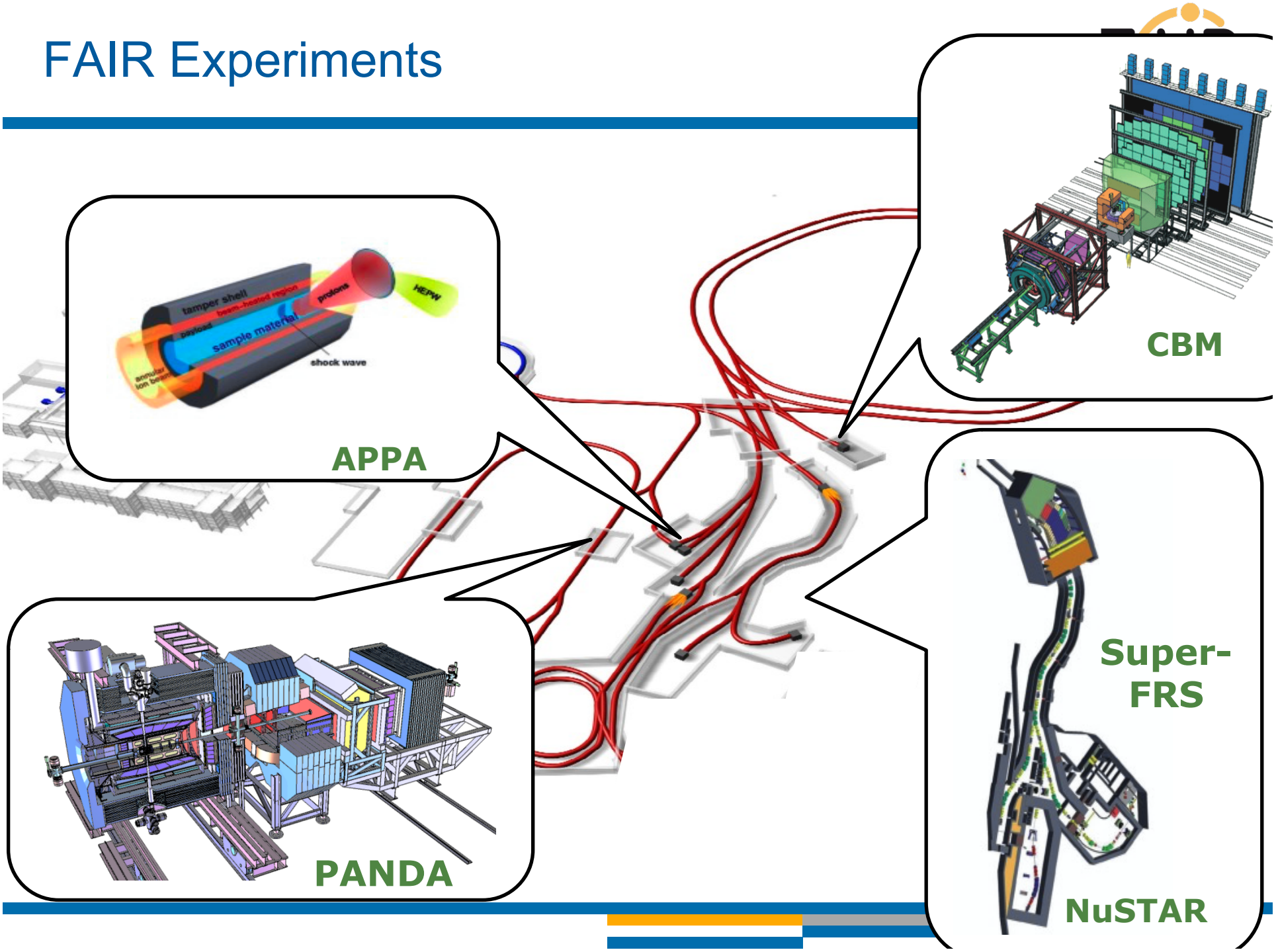


New target, detector and sensor technologies; novel data acquisition systems

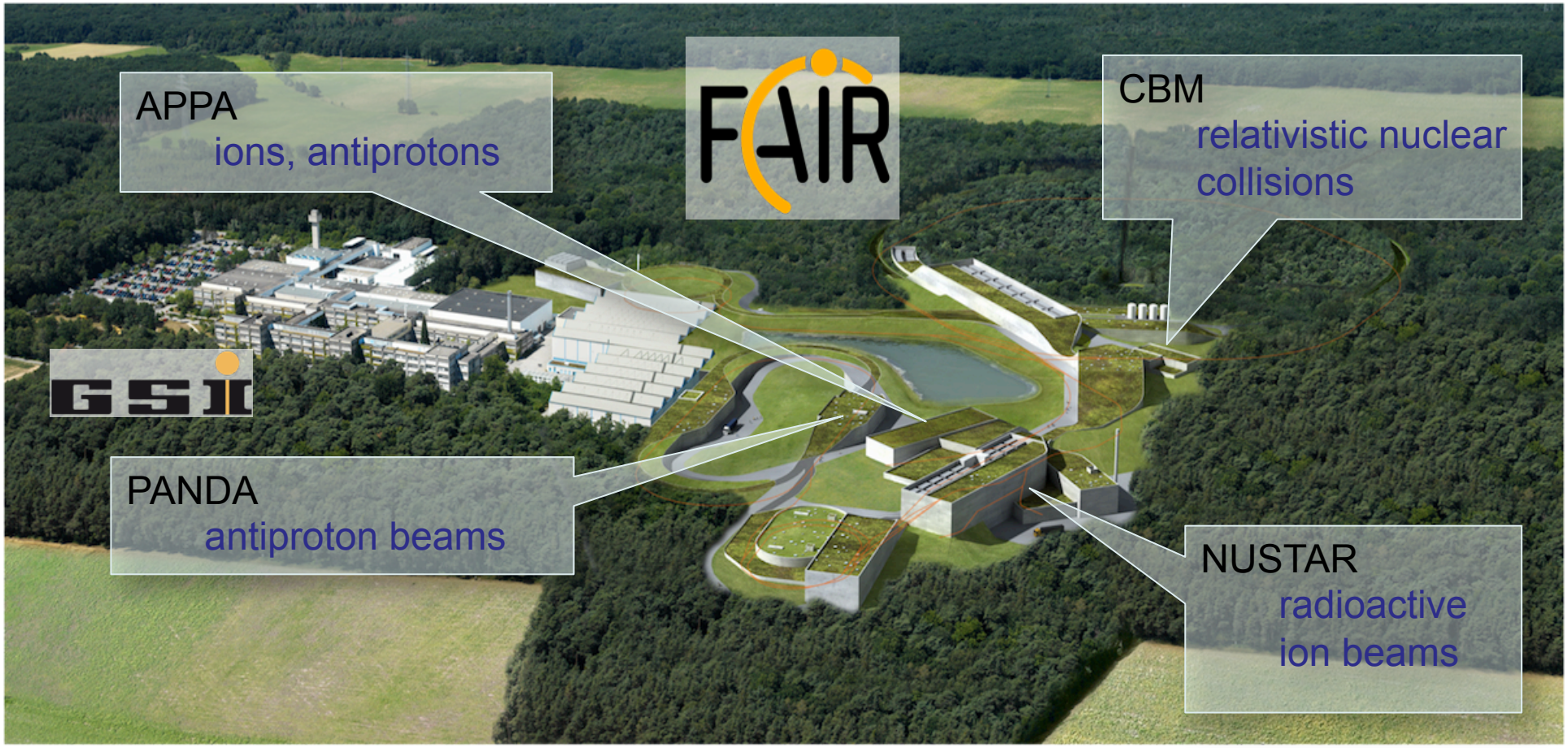


“Green” high performance computing systems and novel big data concepts

FAIR Experiments



The FAIR Project



The FAIR Project

Thank you!