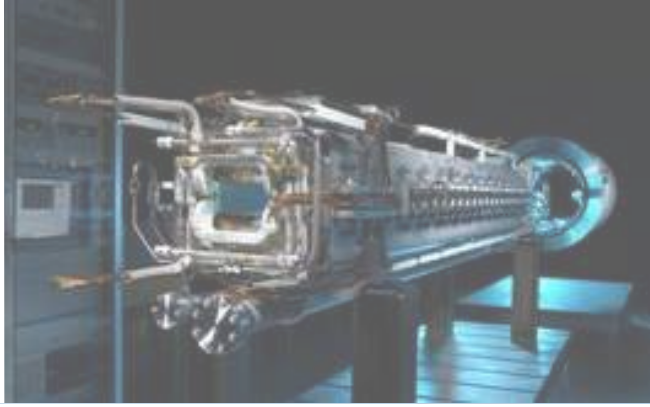




FAIR in Progress: Status and Plans

Boris Sharkov

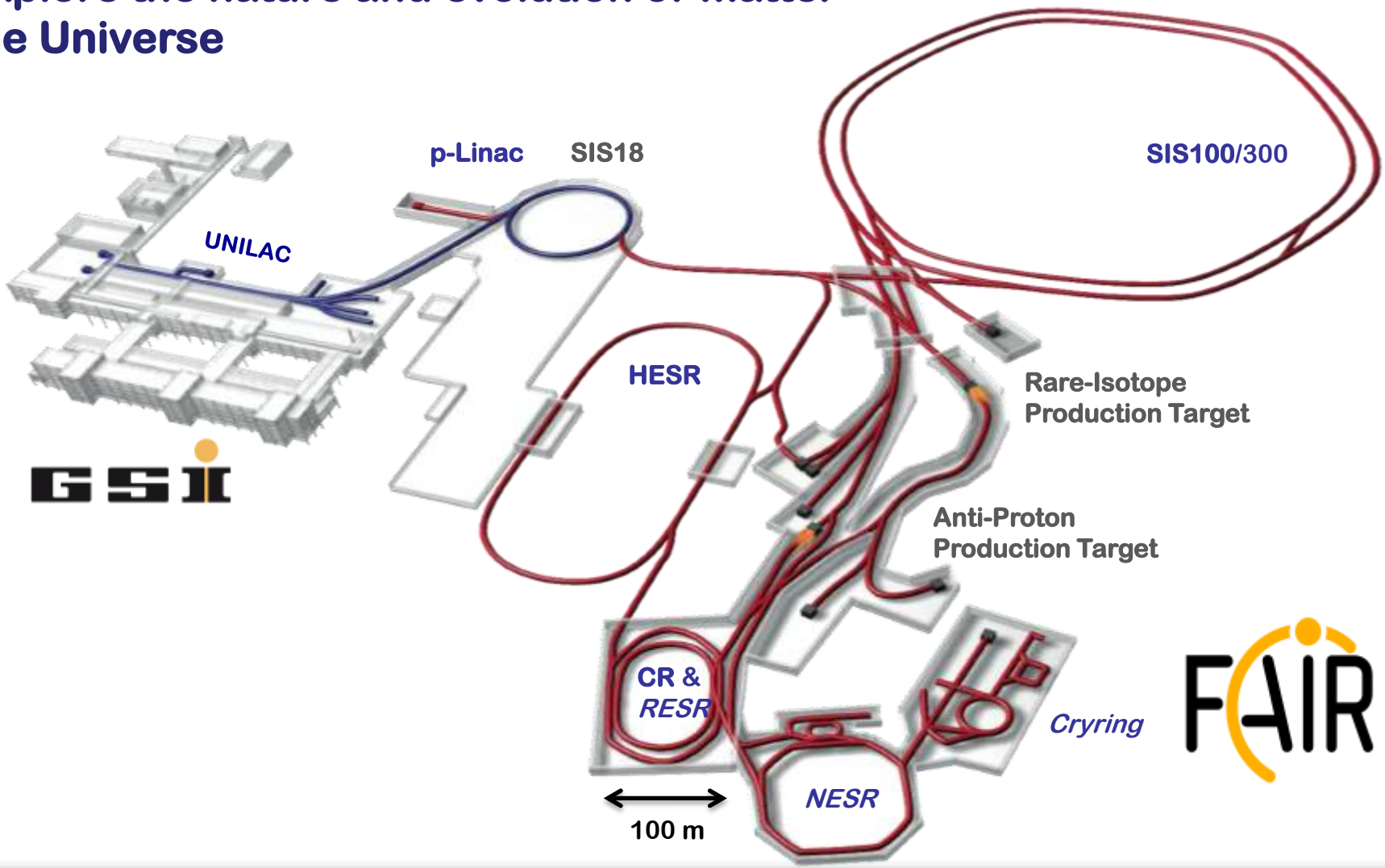
Worms 13.10.2014.

Finland France Germany India Poland Romania Russia Slovenia Spain Sweden UK

FAIR

Facility for Antiproton and Ion Research

– new international research laboratory under construction to explore the nature and evolution of matter in the Universe



The FAIR Project

Accelerator Facility

Primary Beams

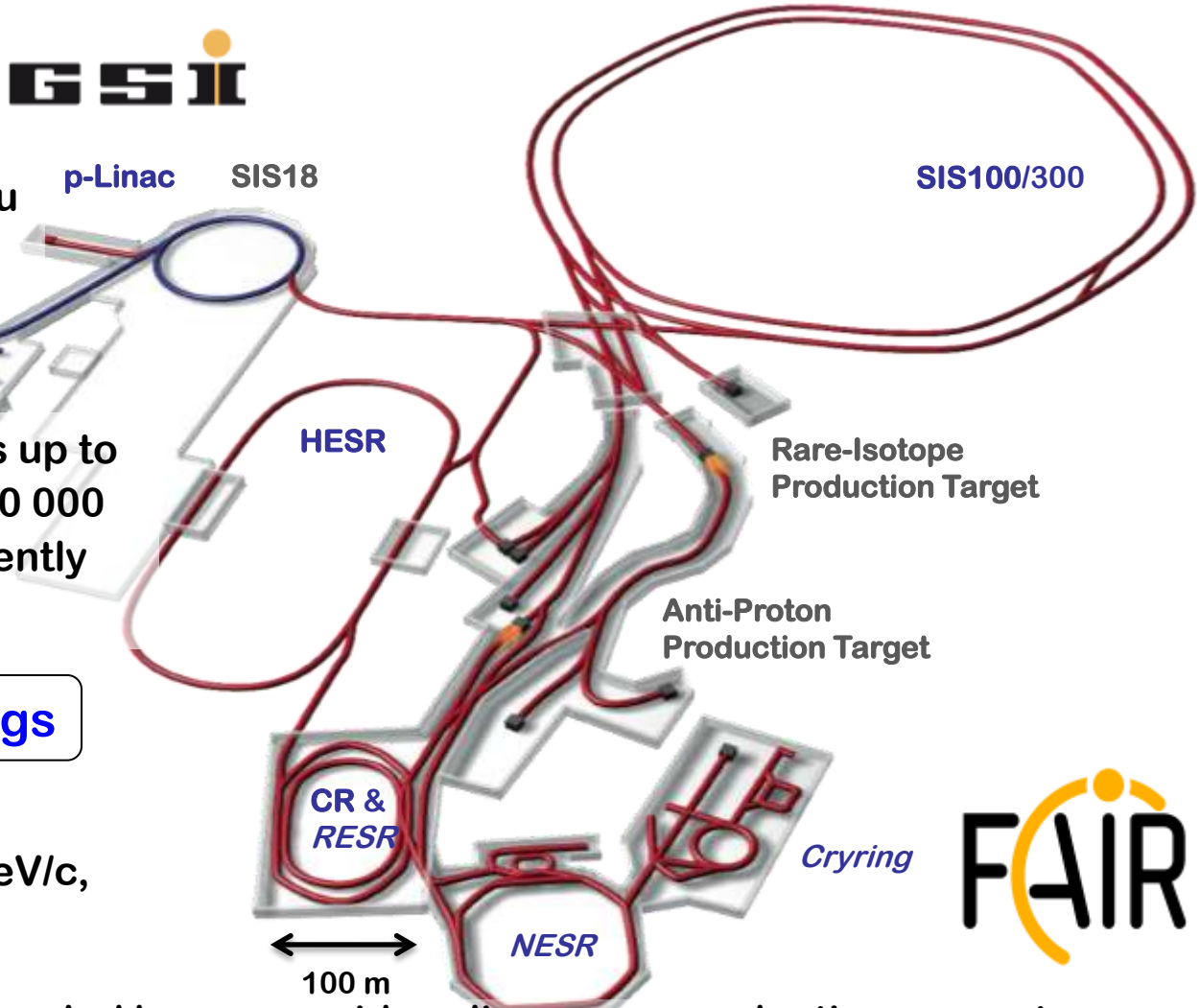
- 10^{12}/s; 1.5 GeV/u; $^{238}U^{28+}$
- 10^{10}/s $^{238}U^{73+}$ up to 35 GeV/u
- 3x10^{13}/s 30 GeV protons

Secondary Beams

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

Acc Performance for FAIR Experiments

- Beam Intensities:
  - intensities of primary beams: x 100 – x 1000
  - intensities of secondary beams: x 10.000
- Beam Energies:
  - energies: x 30
- Unprecedented Variety of Ions:
  - antiprotons
  - protons to Uranium, radioactive beams
- Beam Quality:
  - cooled antiprotons
  - intense cooled RIBs
- Pulse Structure:
  - extremely short pulses (70 ns) to slow extraction (quasi CW)
- Parallel Operation:
  - (Finally) operation of up to four experiments simultaneously

Physics at FAIR

Nuclear Structure & Astrophysics
(Rare-isotope beams)

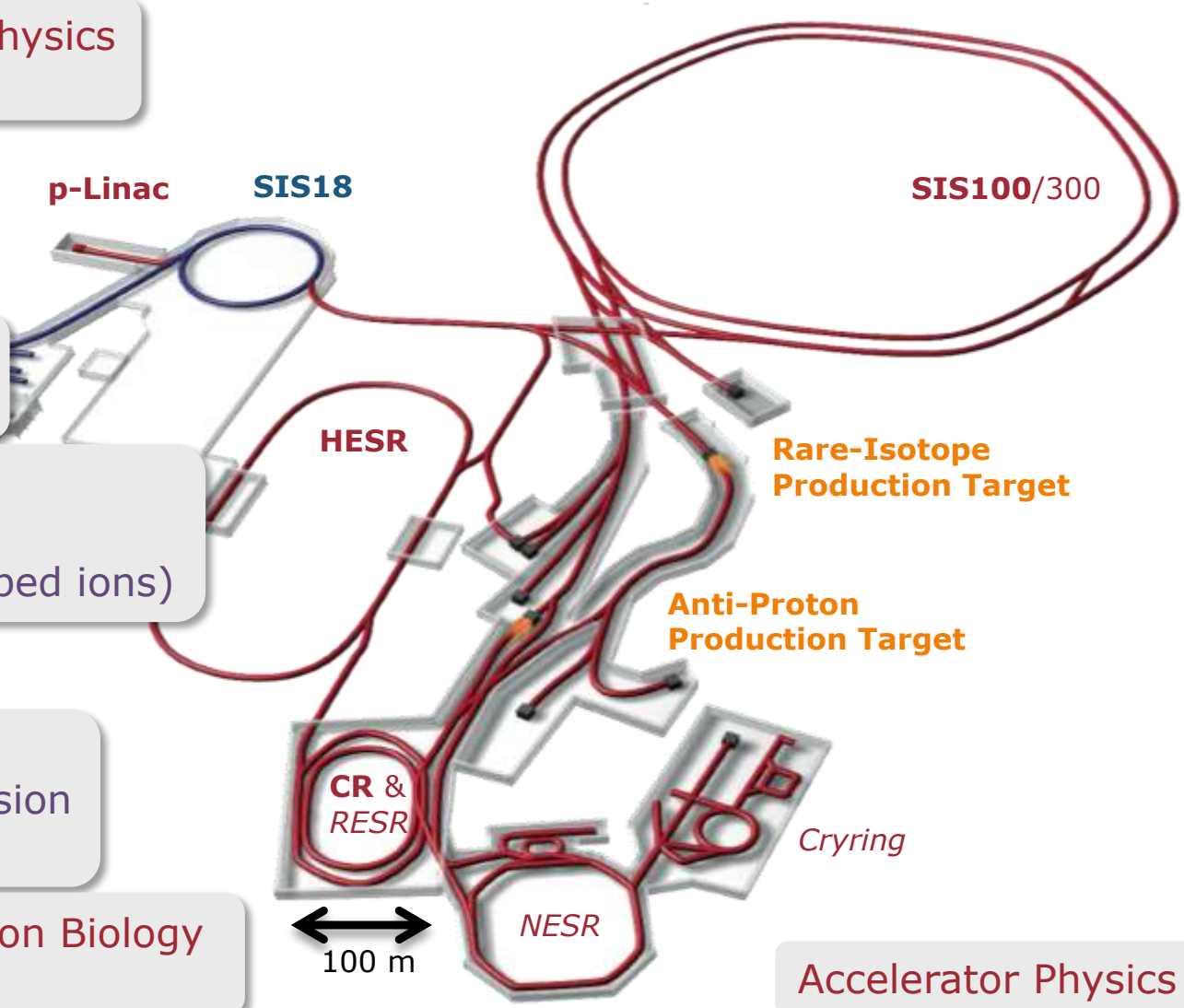
Hadron Physics
(Stored and cooled
14 GeV/c anti-protons)

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

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

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

Materials Science & Radiation Biology
(Ion & antiproton beams)



Accelerator Physics

The 4 Scientific Pillars of FAIR

APPA: Atomic, Plasma Physics and Applications

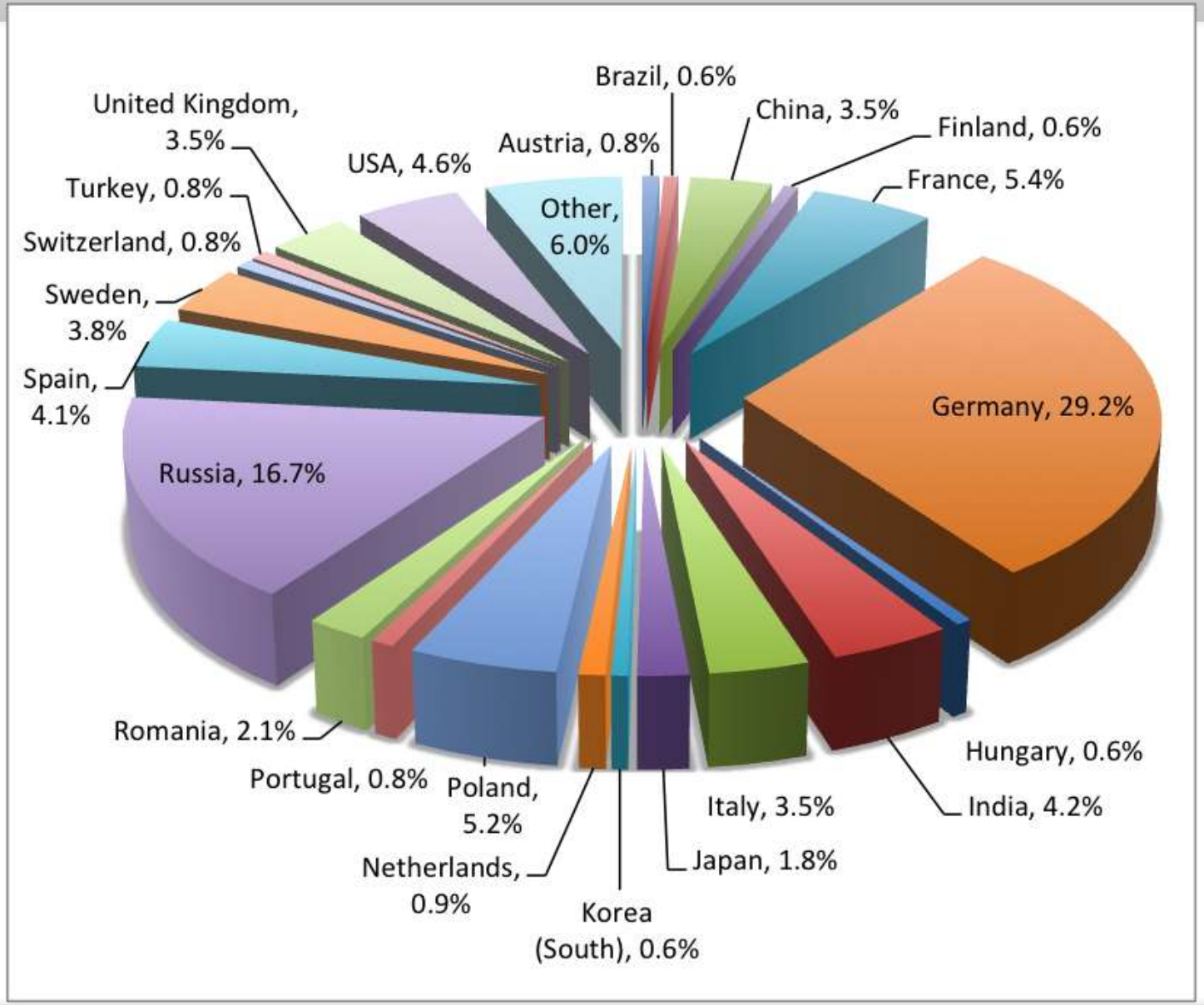
CBM: Compressed Baryonic Matter

NUSTAR: Nuclear Structure, Astrophysics and Reactions

PANDA: Antiproton Annihilations at Darmstadt

In total: 2500 – 3000 Users

Collaboration Members by Country



FAIR Members' Contributions

Contracting Party	Contribution (in 2005 M€)
Finland	5.00
France	27.00
Germany	705.00
India	36.00
Poland	23.74
Romania	11.87
Russia	178.05
Slovenia	12.00
Sweden	10.00
Total	**1.008,66**

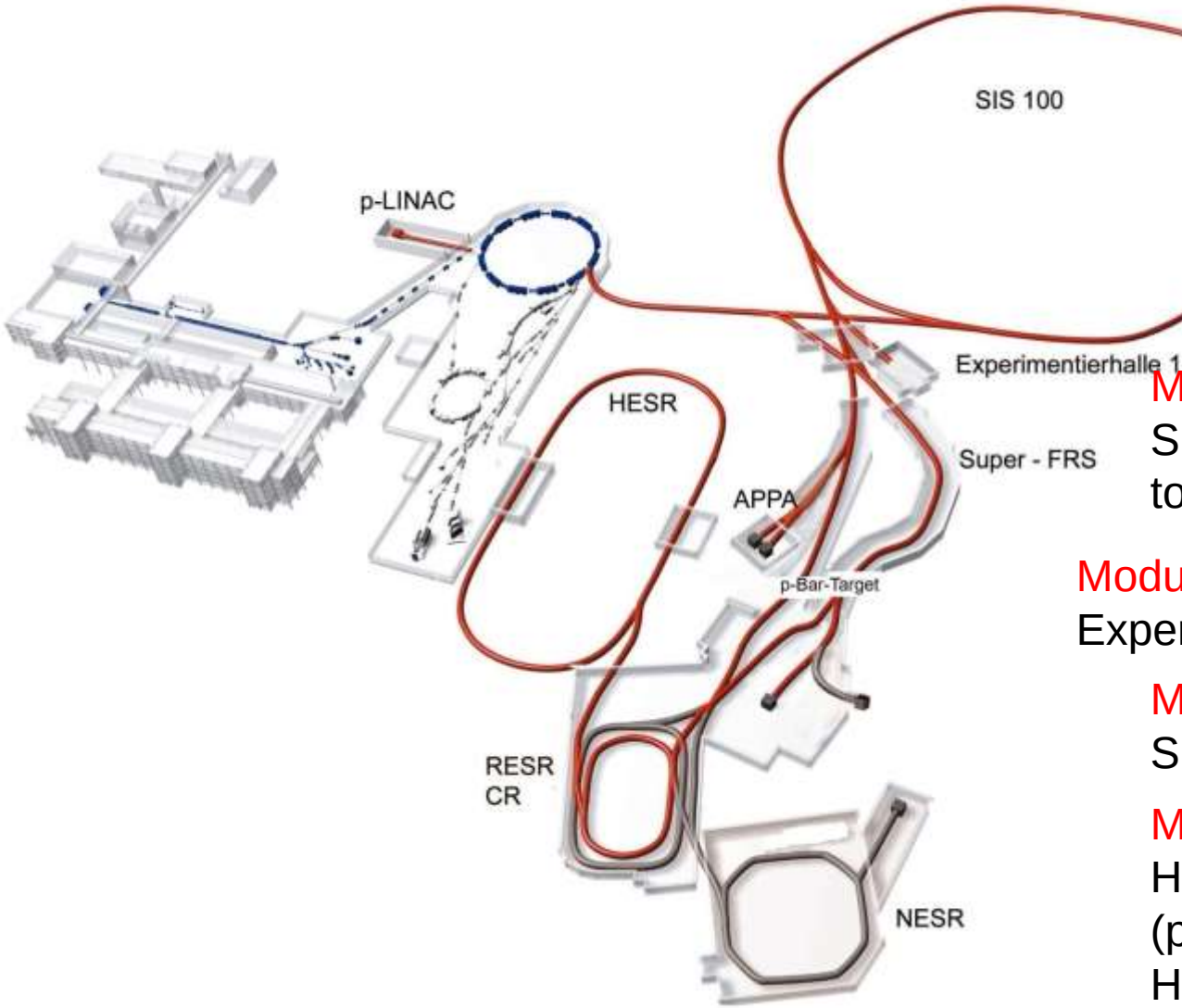
- **All numbers in 2005 €**
  escalation until 2018 ca. +50%
  i.e. about € 1.6 billion
- Most contributions in-kind
- Discussions with Spain and Italy on-going
- Interested parties
  - ESA, Saudi Arabia, Netherlands, China, Turkey, Brazil, Ukraine, S Korea, Japan, USA

Staging

Start Version Phase A (SIS100)						Phase B (SIS300)
Modularised Start Version						
Module **0**	Module **1**	Module **2**	Module **3**	Module **4**	Module **5**	
SIS100	**Exp. halls** *CBM & APPA*	**Super-FRS** *NuSTAR*	**Antiproton Facility** *PANDA & options NuSTAR*	**LEB, NESR, FLAIR** *NuSTAR & APPA*	**RESR** *PANDA, NuSTAR & APPA*	

"Based on recent cost estimates (2009) and the funding commitments of the FAIR Member States MSV of the Projects comprises modules 0 – 3."

Scope of The Modularized Start Version



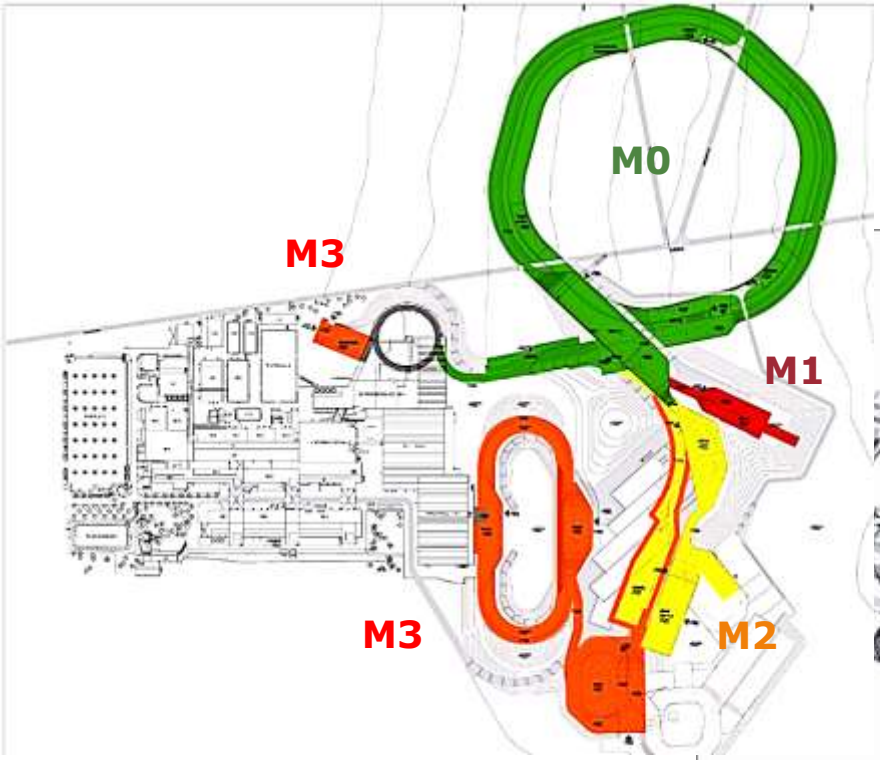
Module 0:
SIS100 and connection to existing GSI accelerators

Module 1:
Experimental areas CBM, APPA

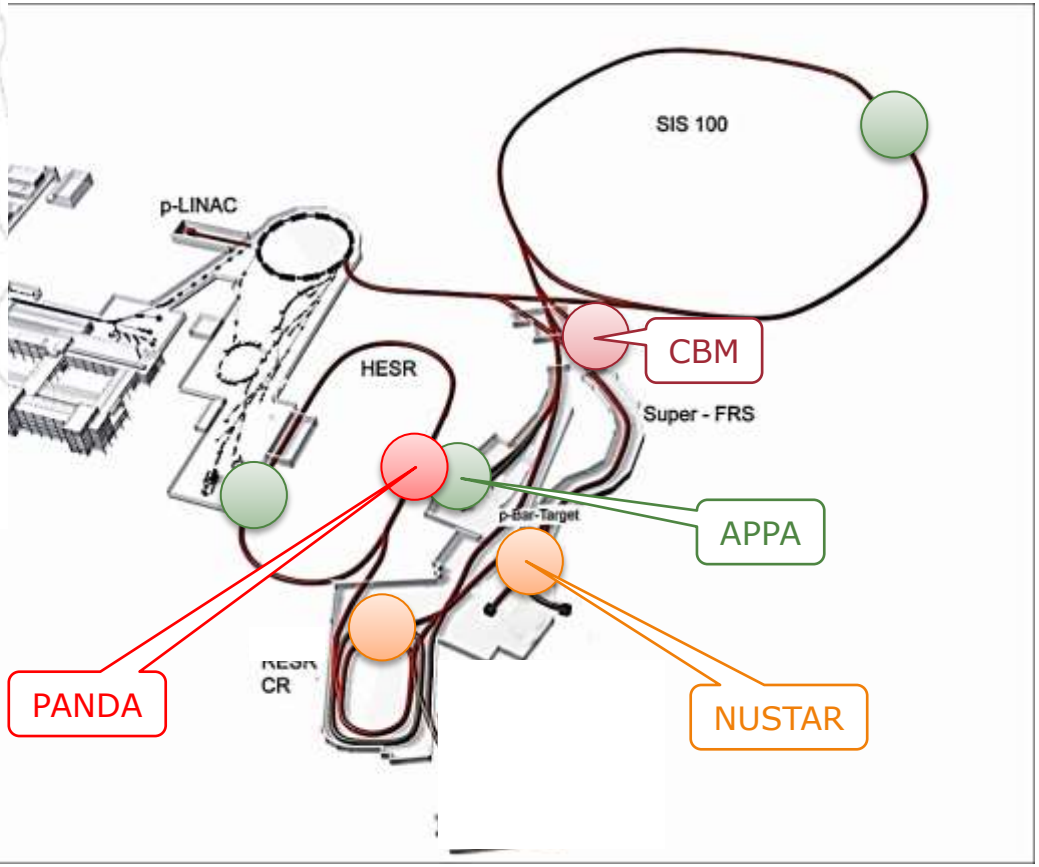
Module 2:
Super-FRS

Module 3:
High-energy antiprotons (p-linac, pbar-target, CR, HESR)

FAIR Modularised Start Version



Science with the MSV



Experiments

M0: SIS100
M1: CBM,APPA
M2: NUSTAR
M3: PANDA, APPA, NUSTAR

The MSV should enable realization of outstanding forefront research program to all 4 scientific pillars of FAIR

FAIR GmbH

- Steering company
- International Convention
- Partners

Wiesbaden, 2010

Finland France Germany India Poland Romania Russia Slovenia Sweden UK

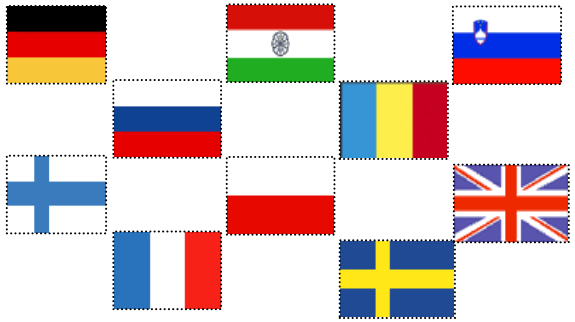
FAIR: an international endeavour

The FAIR Convention: contractual foundation of FAIR

- 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 costbook based

Partners

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



FAIR Partner Issues

- Shareholders
  - **FAIR Convention in force since March 2014**
- Associate members
  - Talks with **Netherlands, Norway, Turkey, Greece and Saudi Arabia** ongoing
- Partners
  - Internal discussions in **Spain** and **Italy** ongoing
- Interested parties
  - Talks with scientists/research councils/academies of sciences /state agencies/ministries of
    Brazil, China, Japan, South Korea, Ukraine, USA
  - Talks with **ESA**
- Operation Costs
- Merger of GSI and FAIR

FAIR: Facility for Antiproton and Ion Research

- Linked to the existing facility GSI (Darmstadt, Germany)
- Based upon an international convention
- New research possibilites with high intensity antiproton and ion beams
- Stepwise approach to the realisation (**M**odularized **S**tart **V**ersion – MSV- modules 0-3.) modules 4 to 6 are scientifically highly desirable
- MSV provides for outstanding and world-leading research programmes in all four scientific areas: Nuclear, Hadron (Particle), Atomic- and Plasma Physics, Biomedicine and Materials Science
- Various physics programs can be operated in parallel
- FAIR will offer outstanding research opportunities for about 3000 scientists from about 50 countries.

Funds are Rolling In

Grants

by BMBF/Germany/:

- **526** M euro for civil construction
- **65** M euro for the construction of the HESR
- **53** M euro for the operation of the FAIR GmbH

> **40** M euro EU funding

~ **100** M euro cash from international partners

Permits:

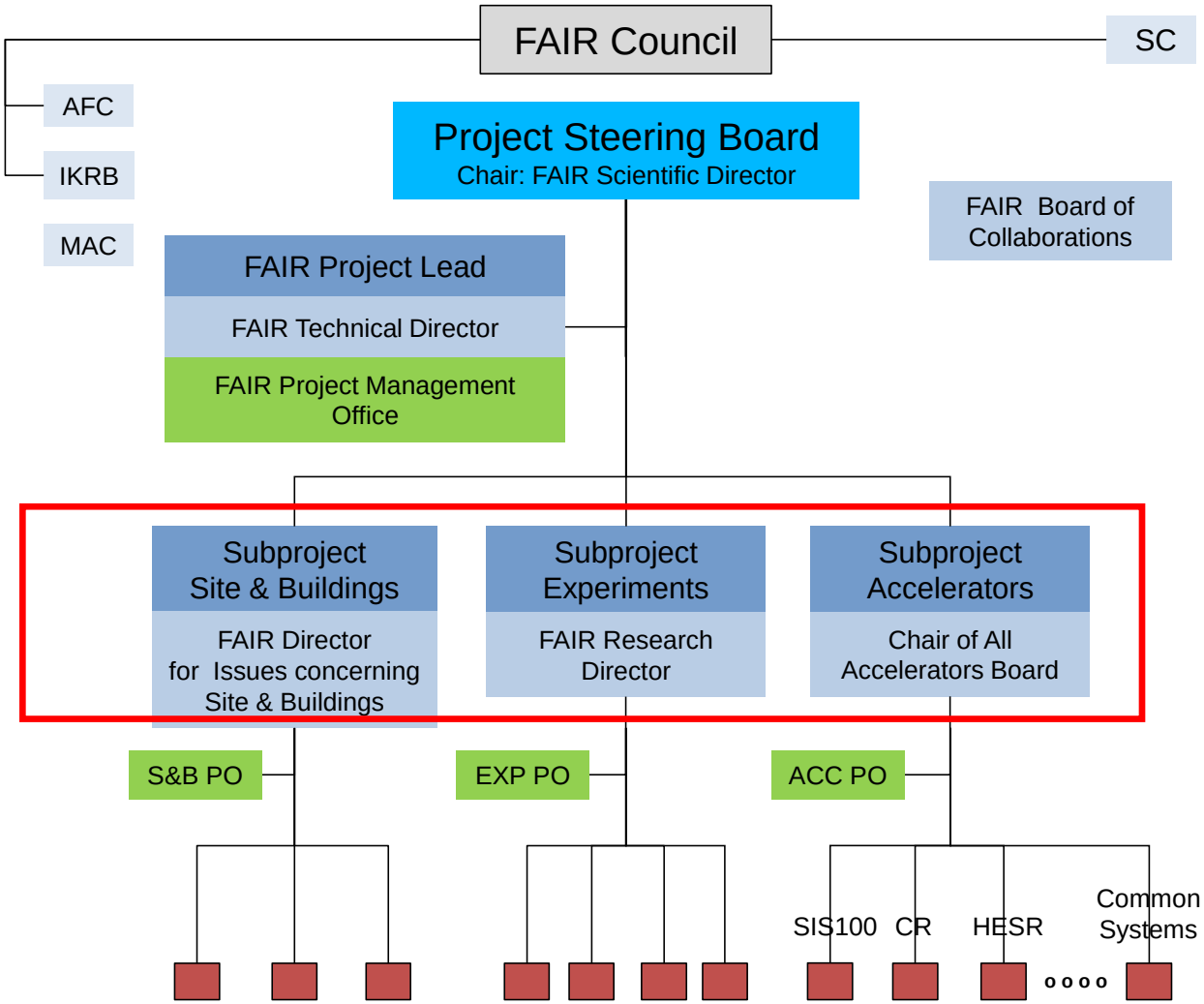
- General construction permit for **all** buildings by city of Darmstadt

- 13 radioprotection licenses received.

2 July 2012

FAIR and GSI Project Governing Structure

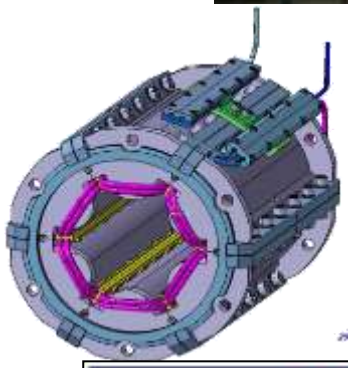
Strategic FAIR Project issues (i.p. in relation to GSI) are dealt with by PSB

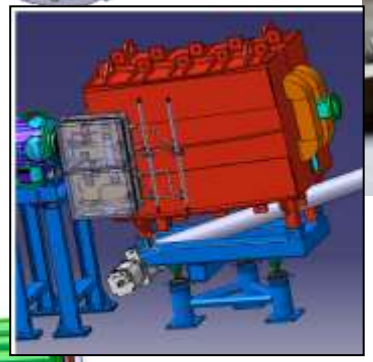


Accelerator's Status

- Progressing well

- SIS 100 dipoles
  - First series del.+tested
- SIS 100 sextopoles
  - Dubna prototype
- HEBT magnets
  - Efremov, St Petersburg
- SIS 100 quadrupoles
  - JINR, Dubna





In-Kind Status (June 2014) ACC

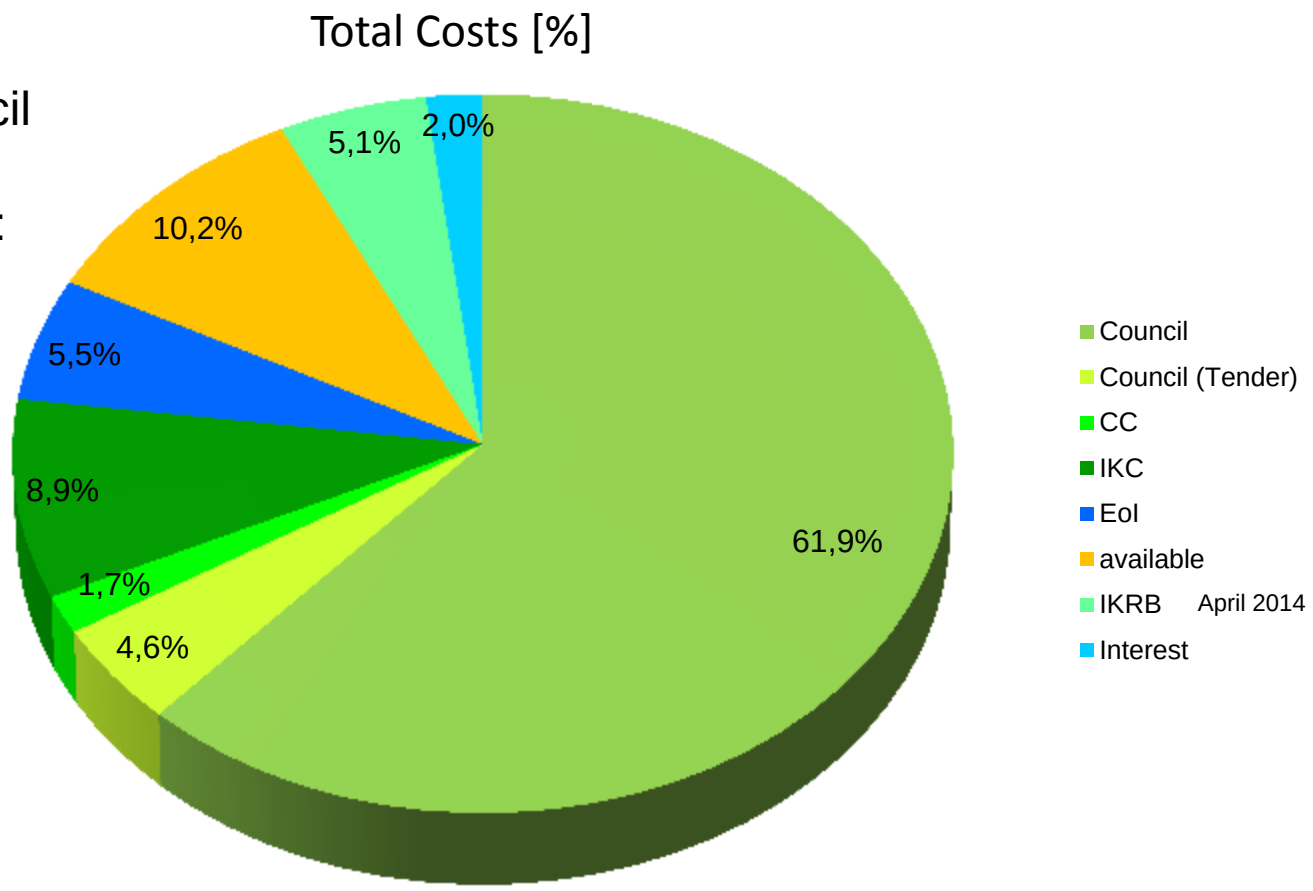
77% assigned by Council

Collaboration Contracts:
34.4 M€

In-Kind Contracts:
6.6 M€

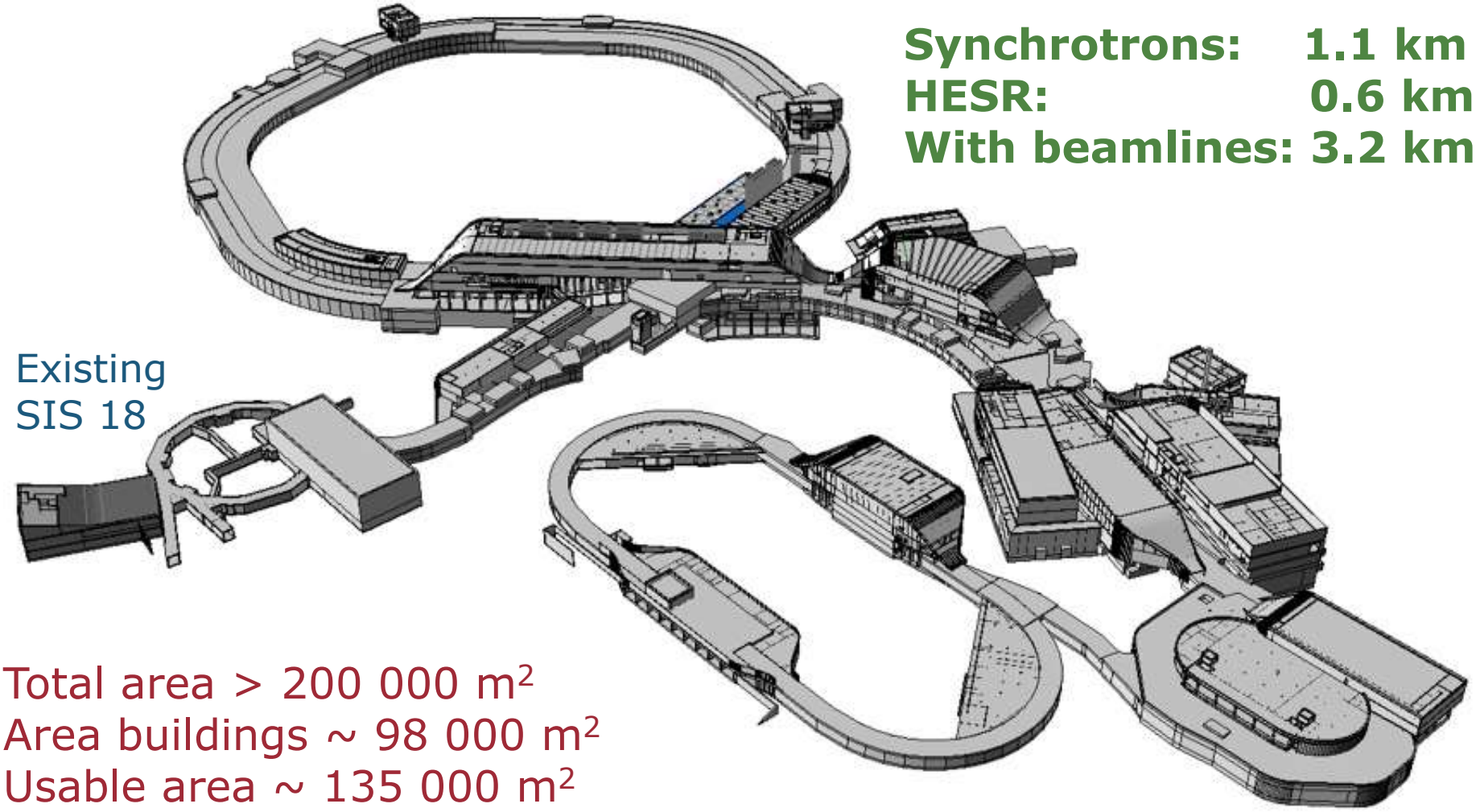
Tender:
12.8M€

Available:
39.5 M€



Status June 2014

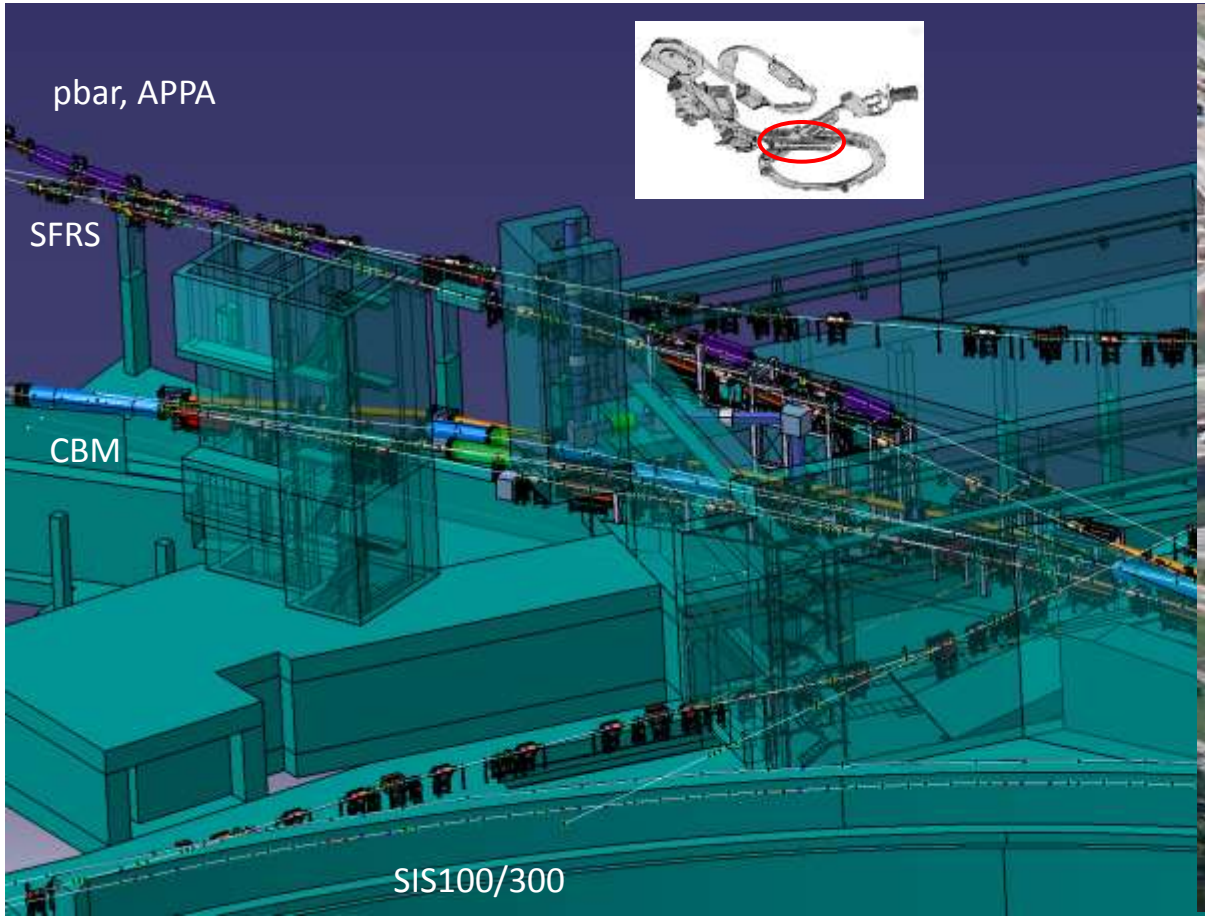
Civil Construction



Synchrotrons: 1.1 km
HESR: 0.6 km
With beamlines: 3.2 km

Total area > 200 000 m²
Area buildings ~ 98 000 m²
Usable area ~ 135 000 m²
Volume of buildings ~ 1 049 000 m³
Substructure:~ 1500 pillars, up to 65 m deep

HEBT (High Energy Beam Transfer)



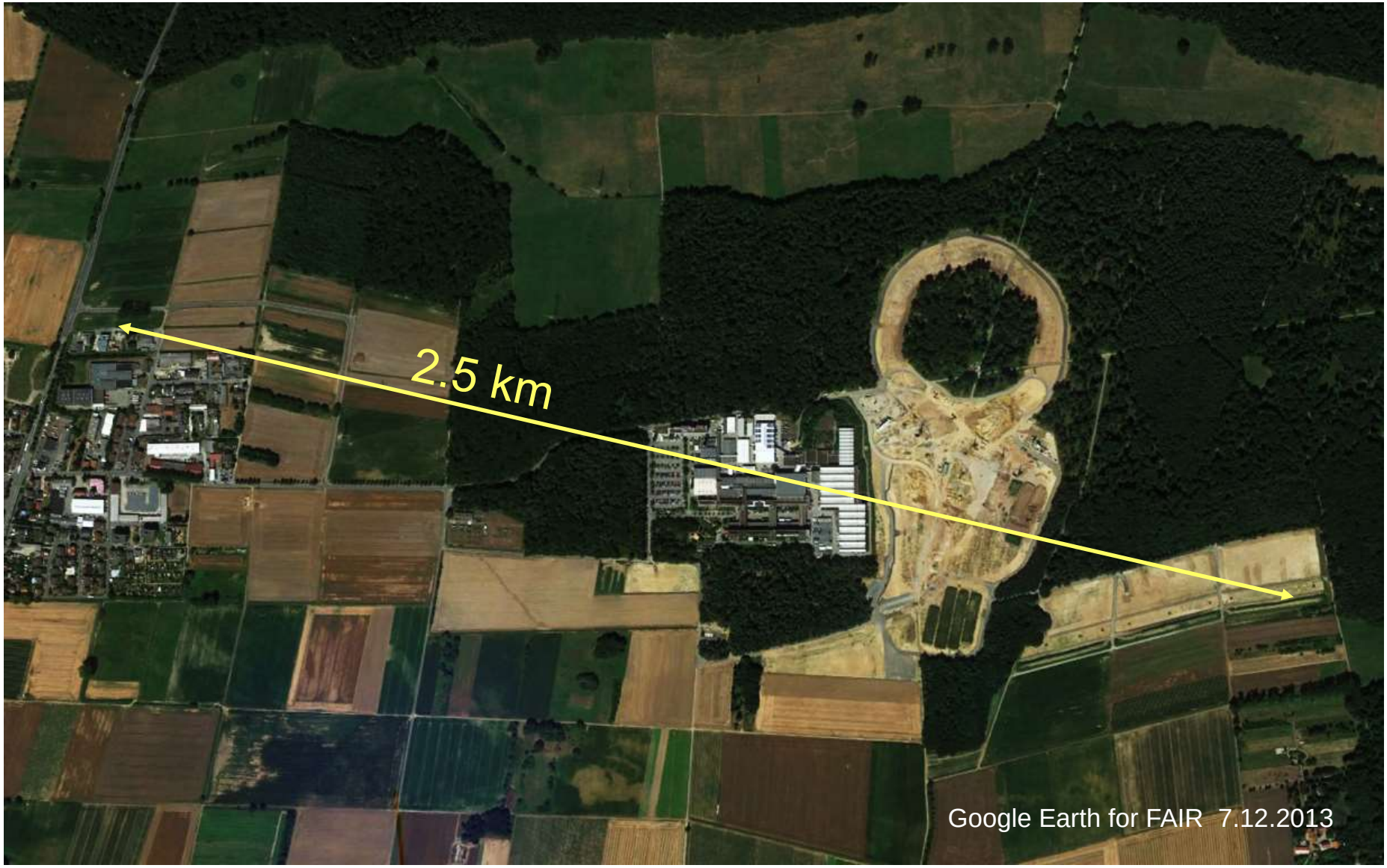
Batch 1 -> 51 dipoles, vacuum chambers

Batch 2 -> 17 dipoles, 102 quadrupoles, 80 steering magnets, vacuum chambers

Batch 3 -> 5 dipoles, 71 quadrupoles, 12 steering magnets, vacuum chambers

Suppliers -> BINP (magnets) and Efremov Institute (vacuum chambers)

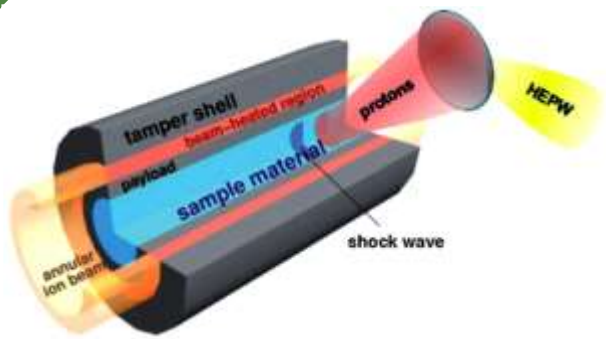
Satellite's View



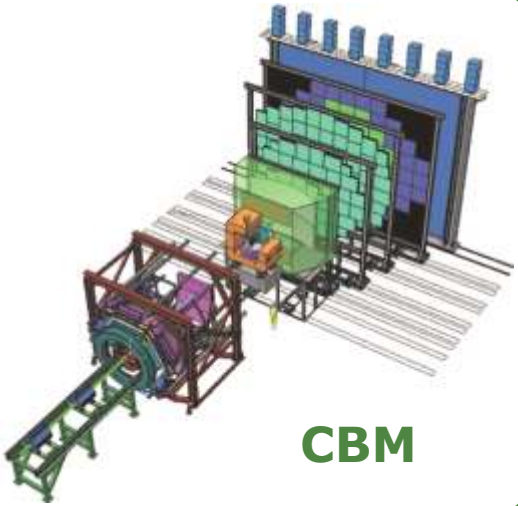
Bird's View

FAIR Construction Site

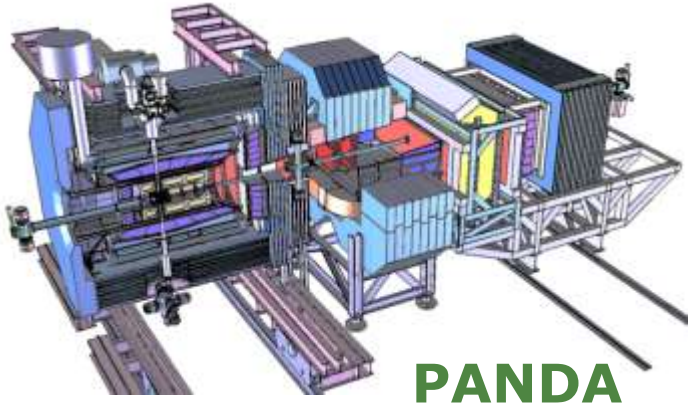
Experiments



APPA



CBM

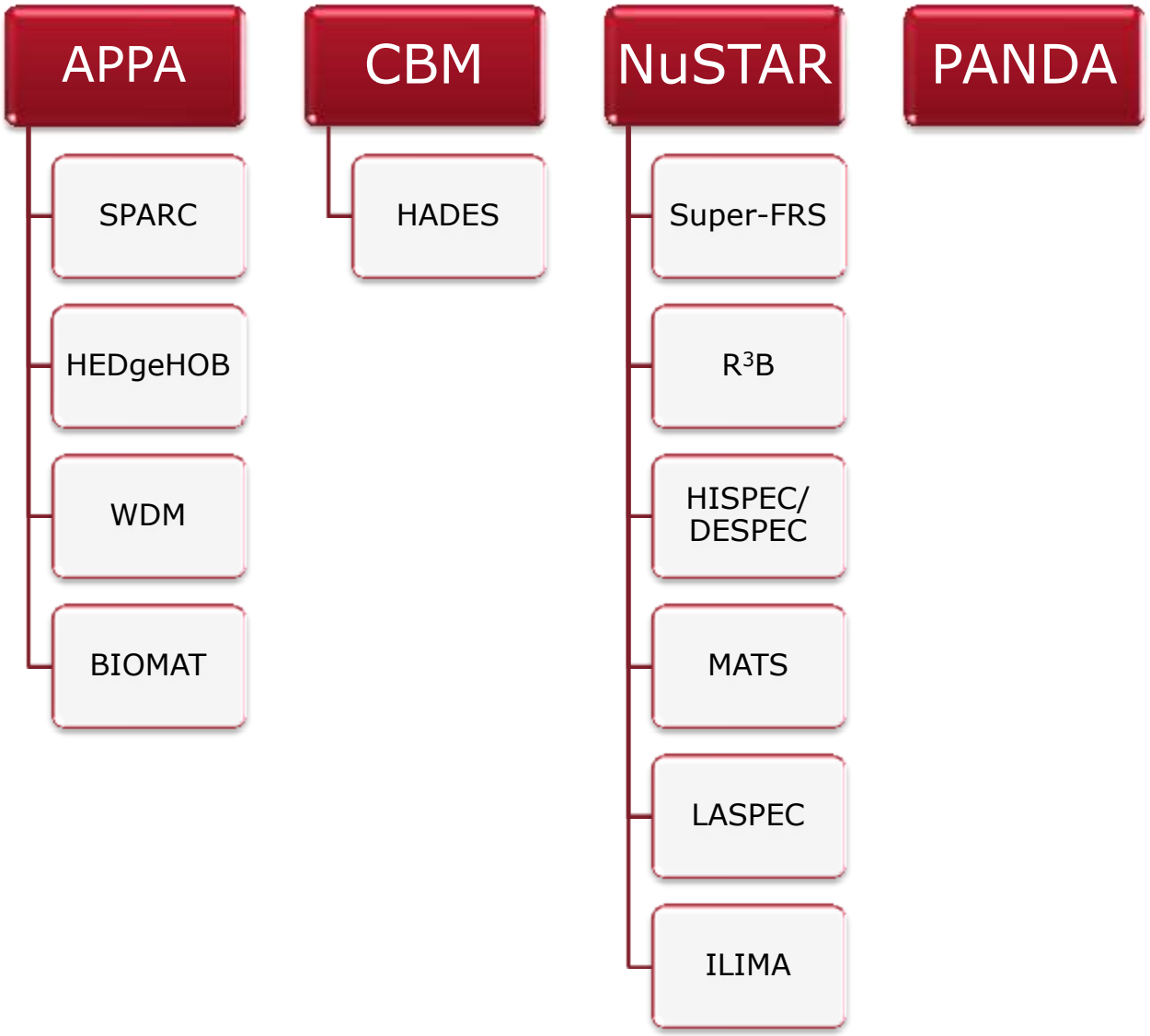


PANDA

Super-FRS

NuSTAR

FAIR Collaborations



Research Division

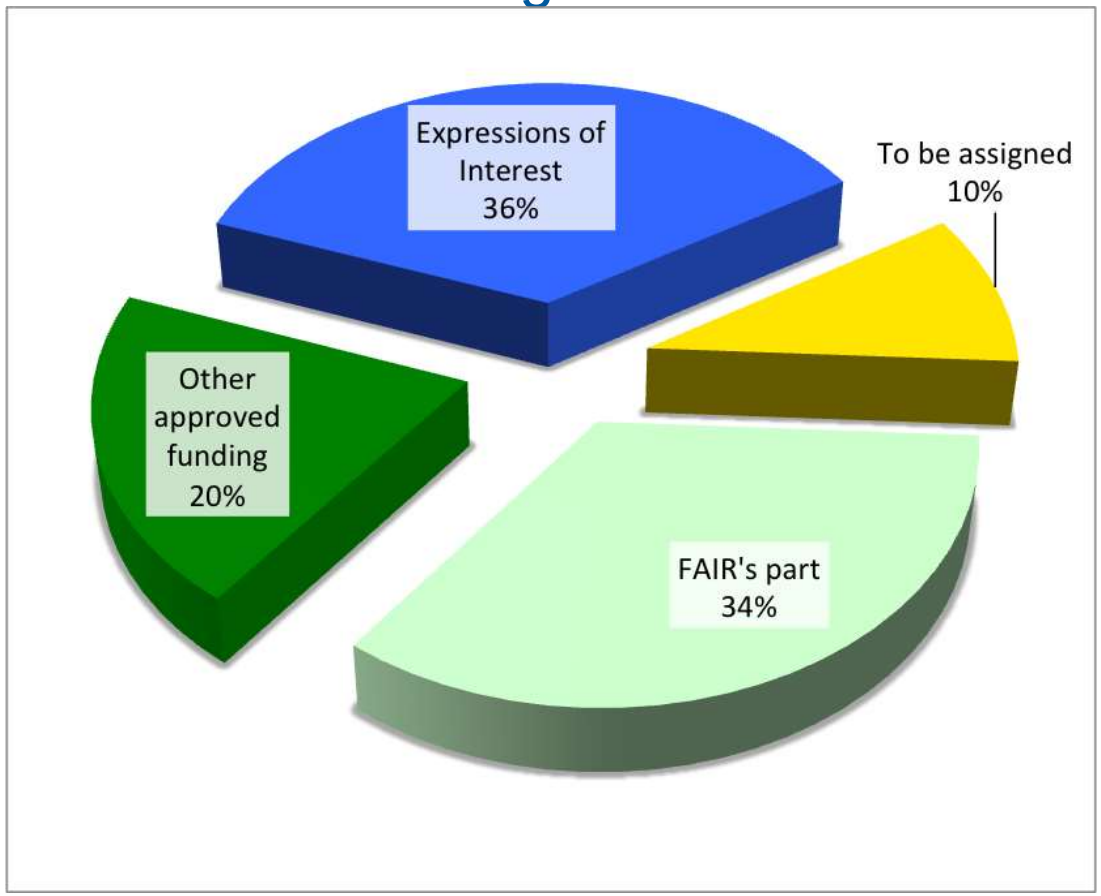
- Optimization of integrated timelines in progress
  - Coordination with Accelerators and Civil Construction
  - Early installation of experiments
  - Day 1 experiments (SC + WR)
- Fully included into Risk Management
- **Construction MoUs to be agreed upon in RRBs**

Technical Design Reports and their current status

Collaboration	Approved	Submitted	Still outstanding	Announced for 2014	Total expected
APPA	4	4	16	7	24
CBM	3	4	4	3	11
NUSTAR	10	3	28	12	41
PANDA	6	0	13	5	19
Total	23	11	61	27	95

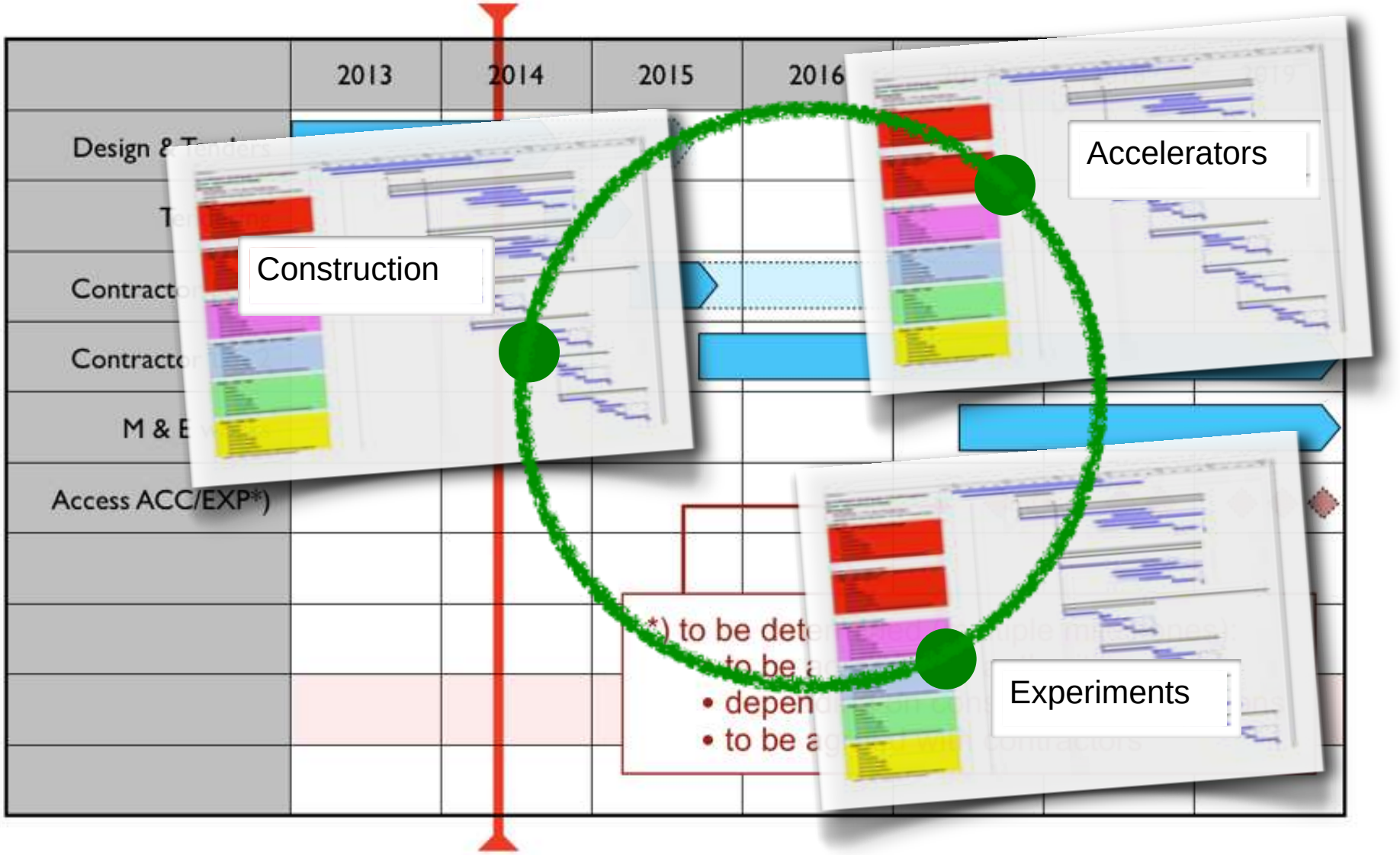
Experiment Funding

- Meeting of the Resource Review Boards (RRB) in February and June 2014.
- about 55% of the funding can be considered secured



Status June 2014
as of 3rd RRB

Route to a consolidated schedule



Summary and Outlook

FAIR is progressing well, FAIR + GSI is now in the position to execute and steer efficiently the project in all three subprojects - CC, ACC, Exp.

Consolidated, synchronized timeline with CC start ASAP

- **Civil construction is presently the lead process**.
- **FAIR accelerator complex** pushed as much as possible, big steps forward achieved in 2013/2014,
- **UNILAC, p-LINAC, and SIS 18 must be prepared to deliver nominal FAIR ion and proton beams.**
- **Exp + Collaborations and ACC shall be prepared for first-beam scenarios and FAIR day-one experiments (-> Sept. 2014, WB + SC).**

Strong and experienced research community, more scientists will join in near future.

Final Remark

- Don’t want only Civil Construction…

  with Beton, Tunnels, Buildings, Shielding Blocks, Cables, Infrastructure etc.

- Don’t want only Accelerators…

  with Magnets, RF, Beam Diagnostics, Vacuum, Cryogenics, Beam Dumps, Radiation Protection etc.

- Don’t want only Experiments…

  with Sophisticated Detectors, Electronics, DAQ’s etc.

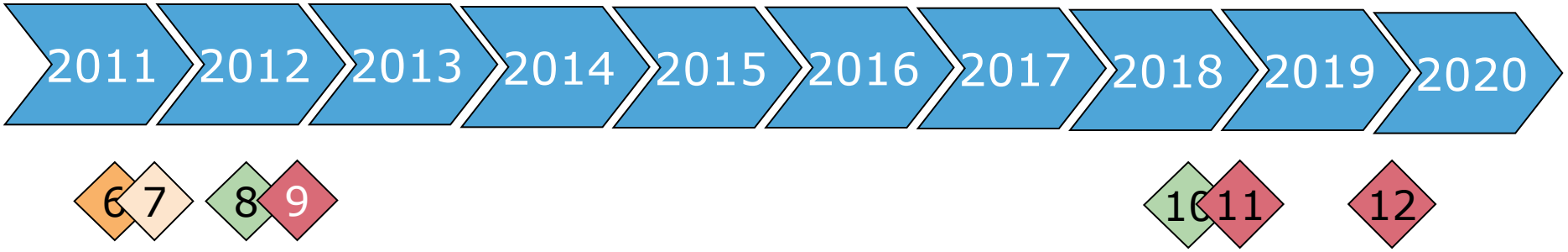
BUT, we want EVERYTHING TOGETHER, until the END of this DECADE!

we motivate everybody and push - together with all our colleagues - for this goal

From today we still have ~ 2000 days (5 years + 3 month) until 31.12.2019

The FAIR Project

Timeline FAIR MSV



6 Submission of construction application

7 Start Site preparation

8 First civil construction contracts

9 Building of accelerator & detector components

10 Civil construction work partly finished

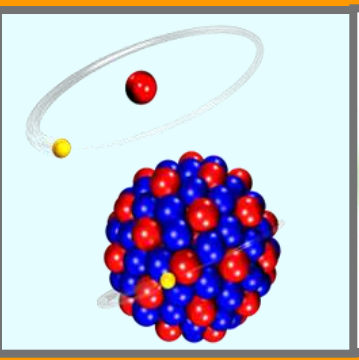
11 Start installing & commissioning accelerator and detector components

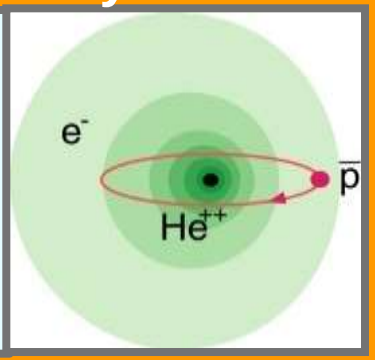
12 Start commissioning part of the facility with beam

Atomic Physics, Plasma Physics, and Applied Sciences APPA@FAIR

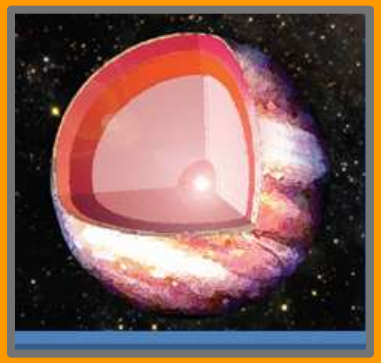
Highest Charge States	***Extreme Static Fields***
Relativistic Energies	***Extreme Dynamical Fields and Ultrashort Pulses***
High Intensities	***Very High Energy Densities and Pressures***
High Charge at Low Velocity	***Large Energy Deposition***
Low-Energy Anti-Protons	***Antimatter Research***

Atomic Physics

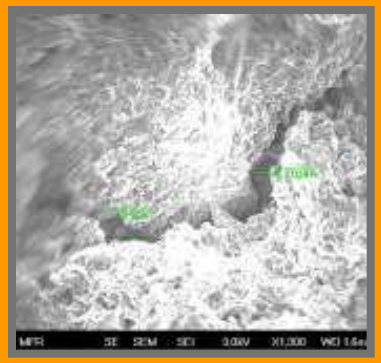




Plasma



Materials



Bio

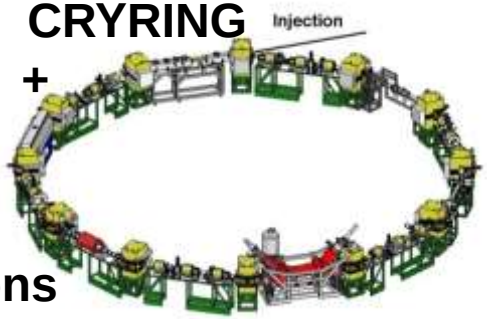
SPARC	FLAIR	HEDgeHOB/WDM	MAT/BIOMAT	BIO/BIOMAT
strong field research	**anti-matter**	**planetary interiors**	**extreme conditions**	**aerospace engineering**
... probing of fundamental laws of physics	**... matter / anti-matter asymmetry**	**... states of matter common in astrophysical objects**	**... radiation hardness and modification of materials**	**... radiation shielding of cosmic radiation**

The APPA Experimental Facilities

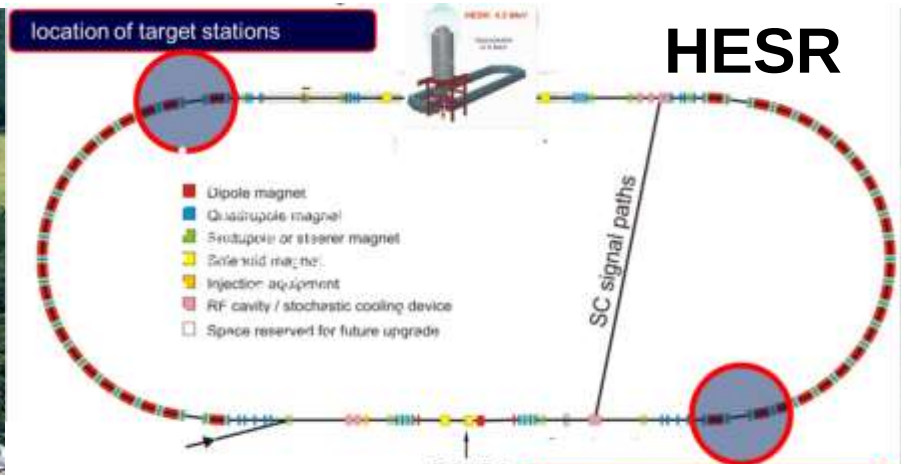
ESR

Cold High- to Low-Energy Heavy Ions

CRYRING +

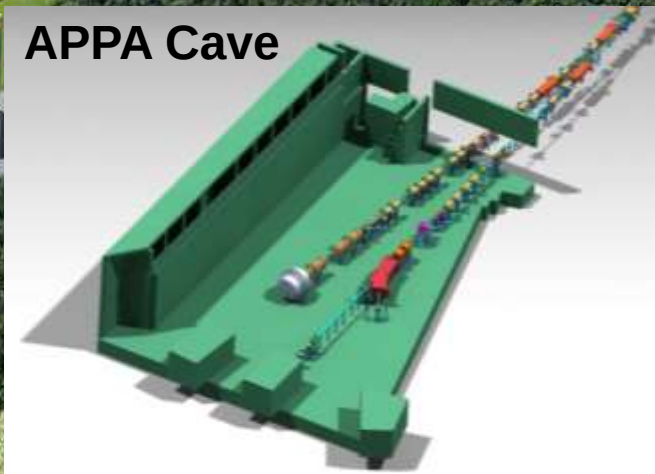


Later Anti-Protons

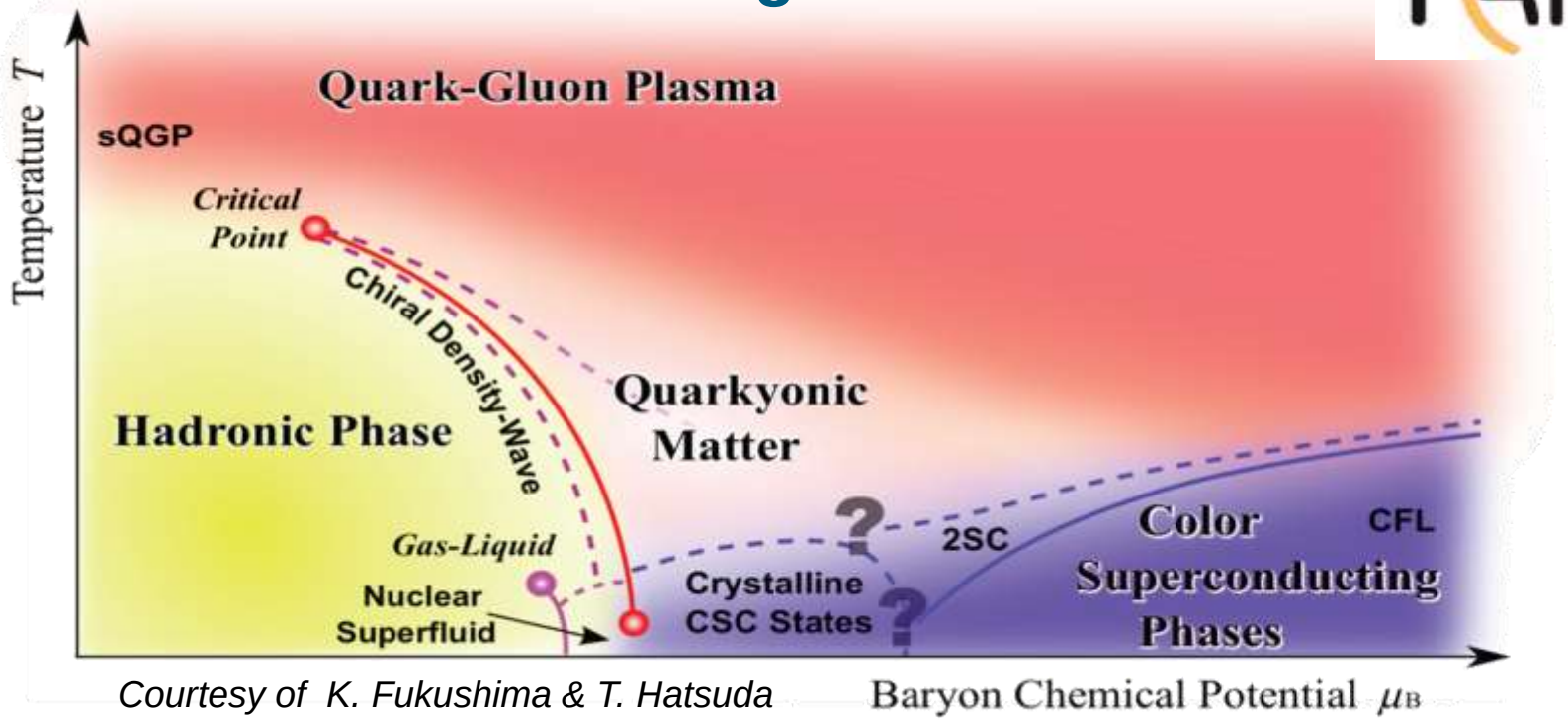


HESR

Cold Relativistic Heavy Ions



The CBM Research Program at FAIR



Courtesy of K. Fukushima & T. Hatsuda

Exploration of the QCD phase diagram at large baryon chemical potentials will provide information on:

- The equation-of-state of nuclear matter at neutron star core densities
- Phase transitions from hadronic matter to quarkyonic or partonic matter
- the existence and the location of the QCD critical point
- In-medium properties of hadrons and chiral symmetry restoration

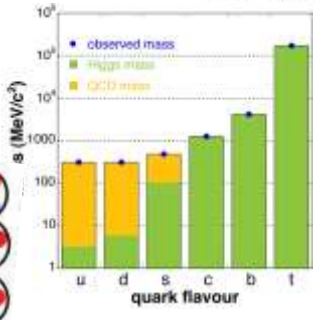
CBM Physics Case and Observables

The equation-of-state at neutron star core densities (SIS100/300)

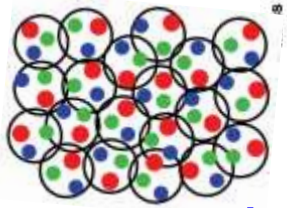
- collective flow of hadrons
- particle production at threshold energies (multi-strange hyperons)

Onset of chiral symmetry restoration at high ρ_B (SIS100/300)

- in-medium modifications of hadrons ($\rho,\omega,\phi \rightarrow e^+e^-(\mu^+\mu^-)$)



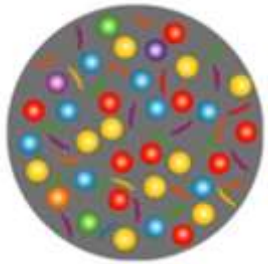
New phases of strongly-interacting matter (SIS100)



- excitation function and flow of lepton pairs
- excitation function and flow of strangeness (K, Λ, Σ, Ξ, Ω)

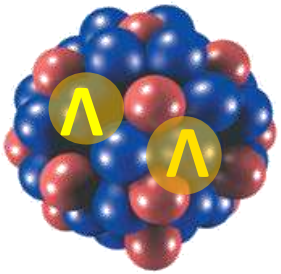
Deconfinement phase transition at high ρ_B (SIS300)

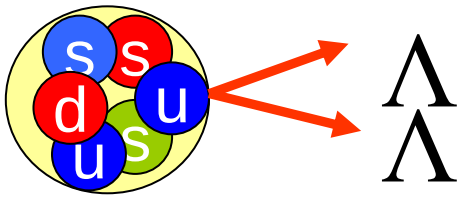
- excitation function and flow of charm (J/ψ, ψ', D^0, $D^{\pm}$, Λ_c)
- anomalouus charmonium suppression



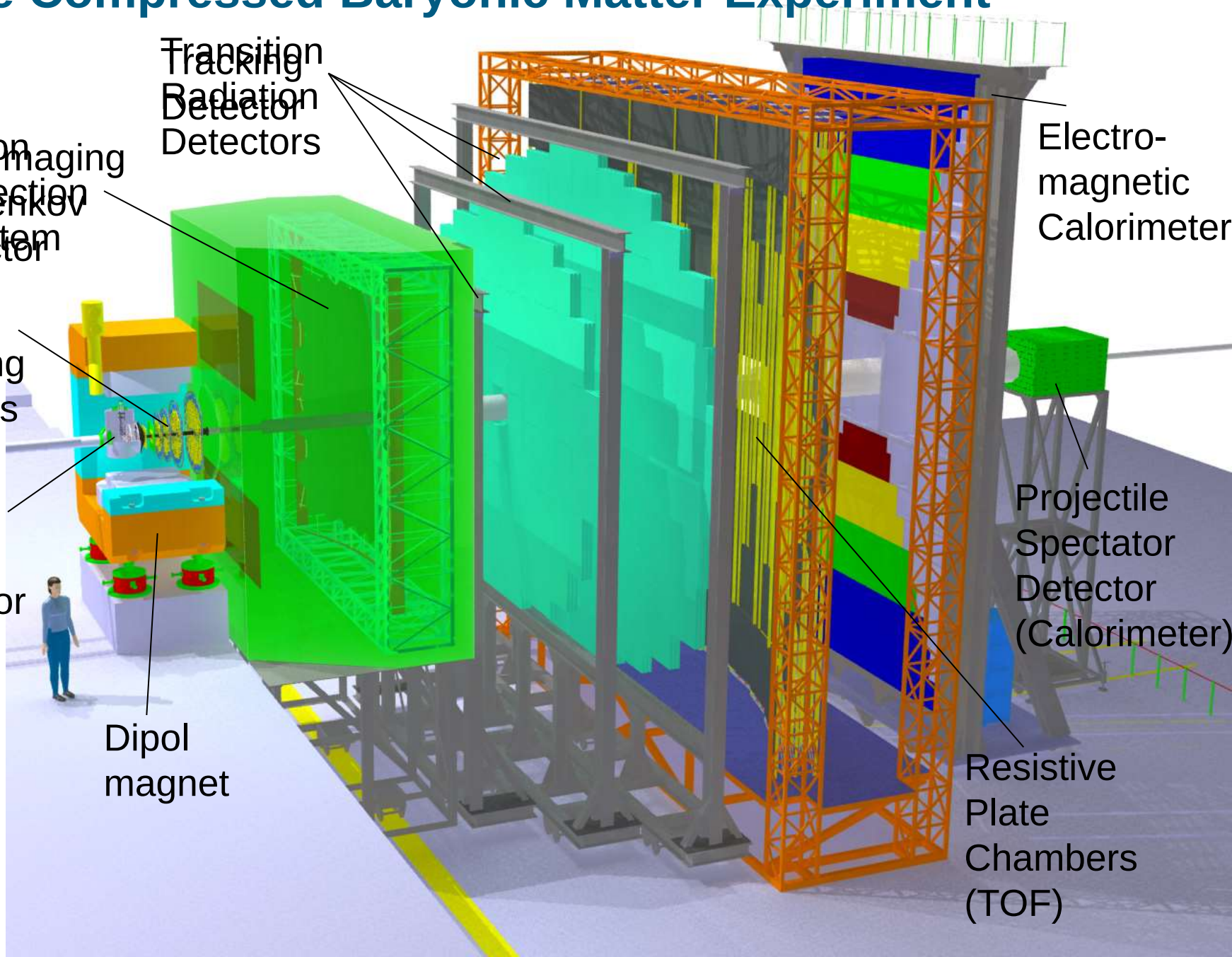
Strange matter (SIS100/300)

- (double-) lambda hypernuclei
- strange meta-stable objects (e.g. strange dibaryons)





The Compressed Baryonic Matter Experiment



The PANDA Physics Program

Hadron Spectroscopy

Experimental Goals: mass, width & quantum numbers of resonances

Charm Hadrons: charmonia, D-mesons, charm baryons

➔ Understand new XYZ states, $D_s(2317)$ and others

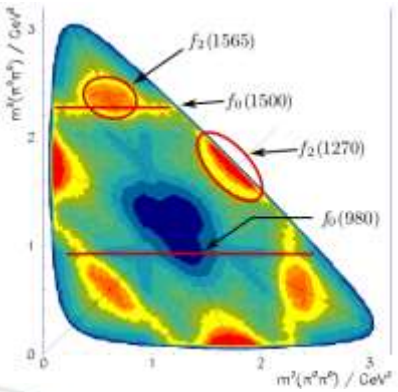
Exotic QCD States: glueballs, hybrids, multi-quarks

Spectroscopy with Antiprotons:

Production of states of all quantum numbers

Resonance scanning with high resolution

Baryon Spectroscopy: excited ss, sss, c baryons



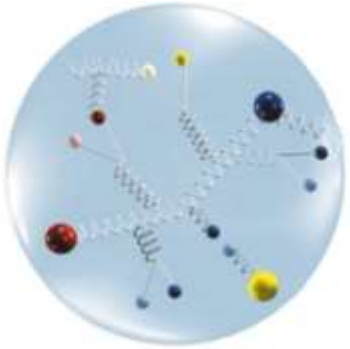
Hadron Structure

Generalized Parton Distributions

➔ Formfactors and structure functions, Lq

Timelike Nucleon Formfactors

Drell-Yan Process



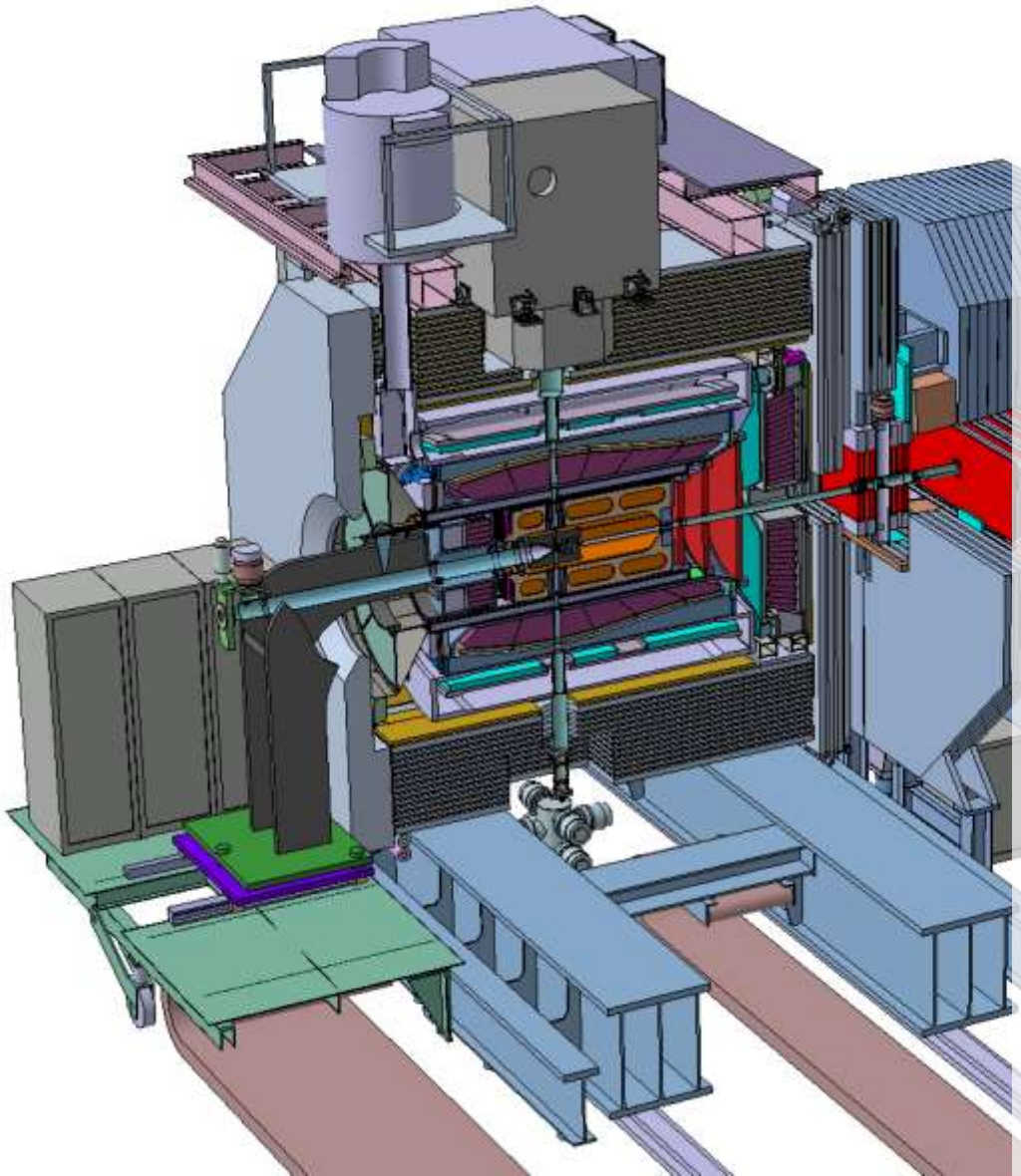
Nuclear Physics

Hypernuclei: Production of double Λ-hypernuclei

➔ γ-spectroscopy of hypernuclei, YY interaction

Hadrons in Nuclear Medium

The PANDA Spectrometer at FAIR



Detector requirements:

4π acceptance

High rate capability:
2×10^7 s^{-1} interactions

Efficient event selection
➔ *Continuous acquisition*

Momentum resolution ~1%
Vertex info for D, K^0_s, Y
($c\tau$ = 317 μm for $D^{\pm}$)
➔ *Good tracking*

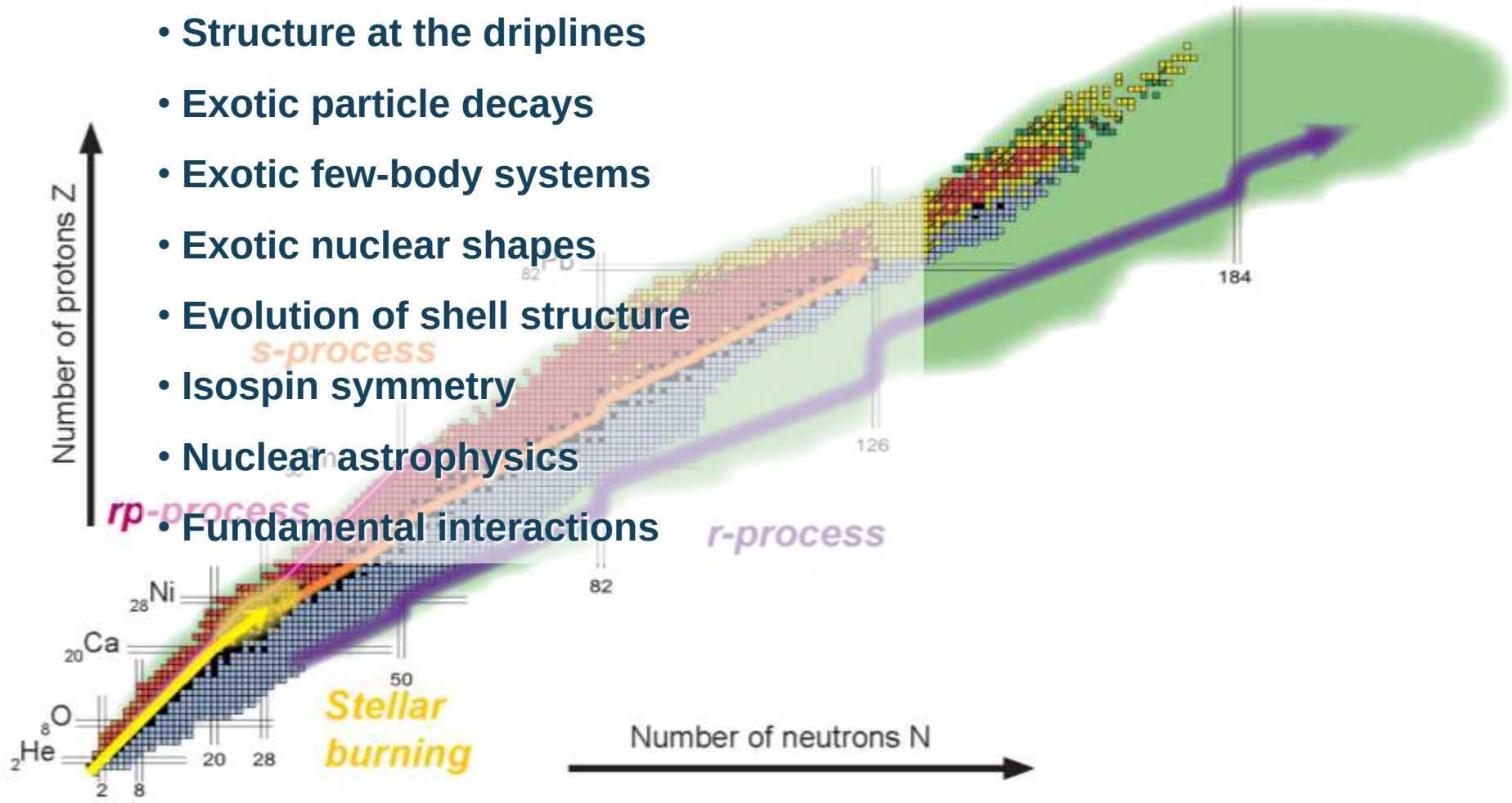
Good PID (γ, e, μ, π, K, p)
➔ *Cherenkov, ToF, dE/dx*

γ-detection 1 MeV – 10 GeV
➔ *Crystal Calorimeter*

NuSTAR: Nuclear Structure, Astrophysics, Reactions

Physics topics:

- **Structure at the driplines**
- **Exotic particle decays**
- **Exotic few-body systems**
- **Exotic nuclear shapes**
- **Evolution of shell structure**
- **Isospin symmetry**
- **Nuclear astrophysics**
- **Fundamental interactions**



The NUSTAR Experimental Facility at FAIR

Important beam parameters:

- all elements from H through U
- intensity up to ~ 10^{12} ions/sec.
- beam energies up to 1.5 GeV/u
- slow (DC-type) and fast extraction

Super-FRS characteristics:

$\varepsilon_x = \varepsilon_y = 40\ \pi$ mm mrad

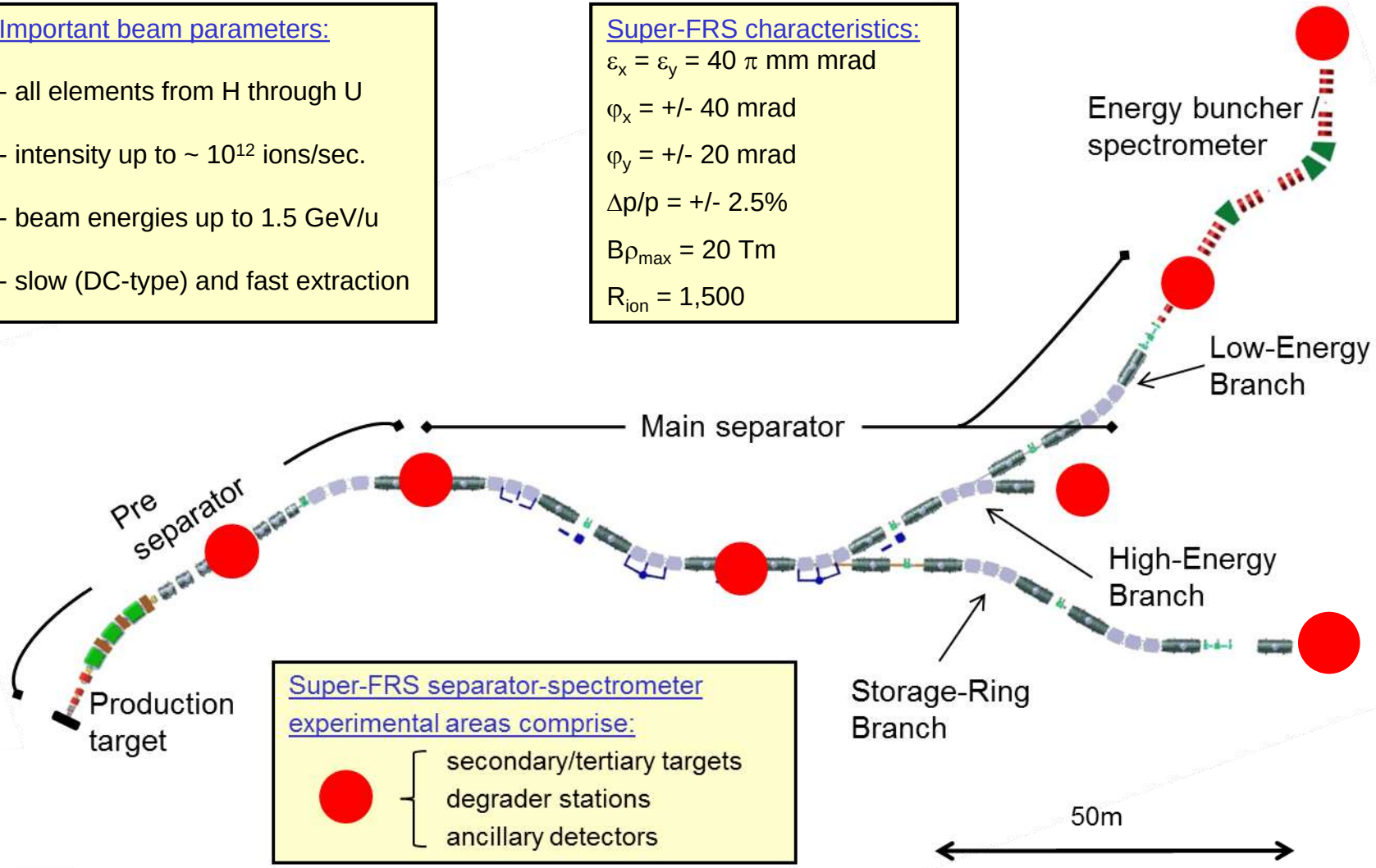
φ_x = +/- 40 mrad

φ_y = +/- 20 mrad

$\Delta p/p$ = +/- 2.5%

$B\rho_{max}$ = 20 Tm

R_{ion} = 1,500

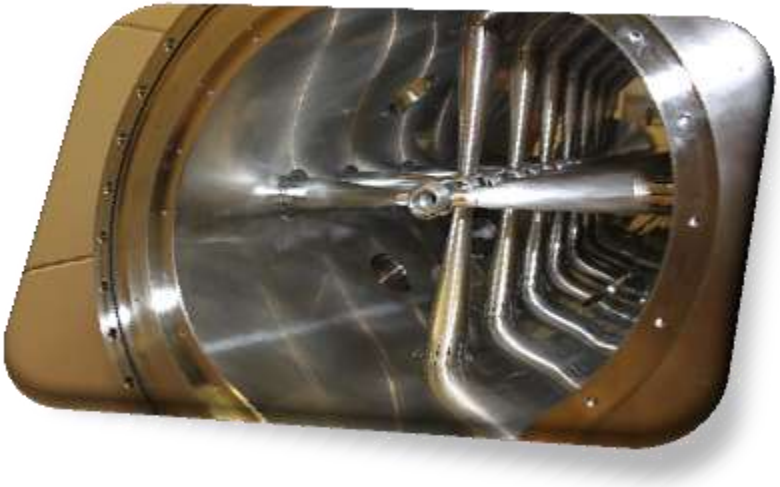


Accelerators Highlights I

- **SIS100** first of series (FOS) dipole module warm tests done, preparation of cold tests
  - First cool down 12/2013
- Design of first quadrupole doublet module family completed
  - Design of remaining module families ordered
- Test facilities
  - for SC-magnets GSI: Power converter cabinets and HTS-current leads commissioned @ GSI
  - CERN: Progress in test stand planning
  - Dubna: Preparation of test stands for NICA
- **SIS18** – Replacement of unipolar power converter for horizontal corrections coils by bipolar power converter completed
  - Closed orbit correction
- First h=2 system in SIS18 installed
  - Tests with beam in 2014

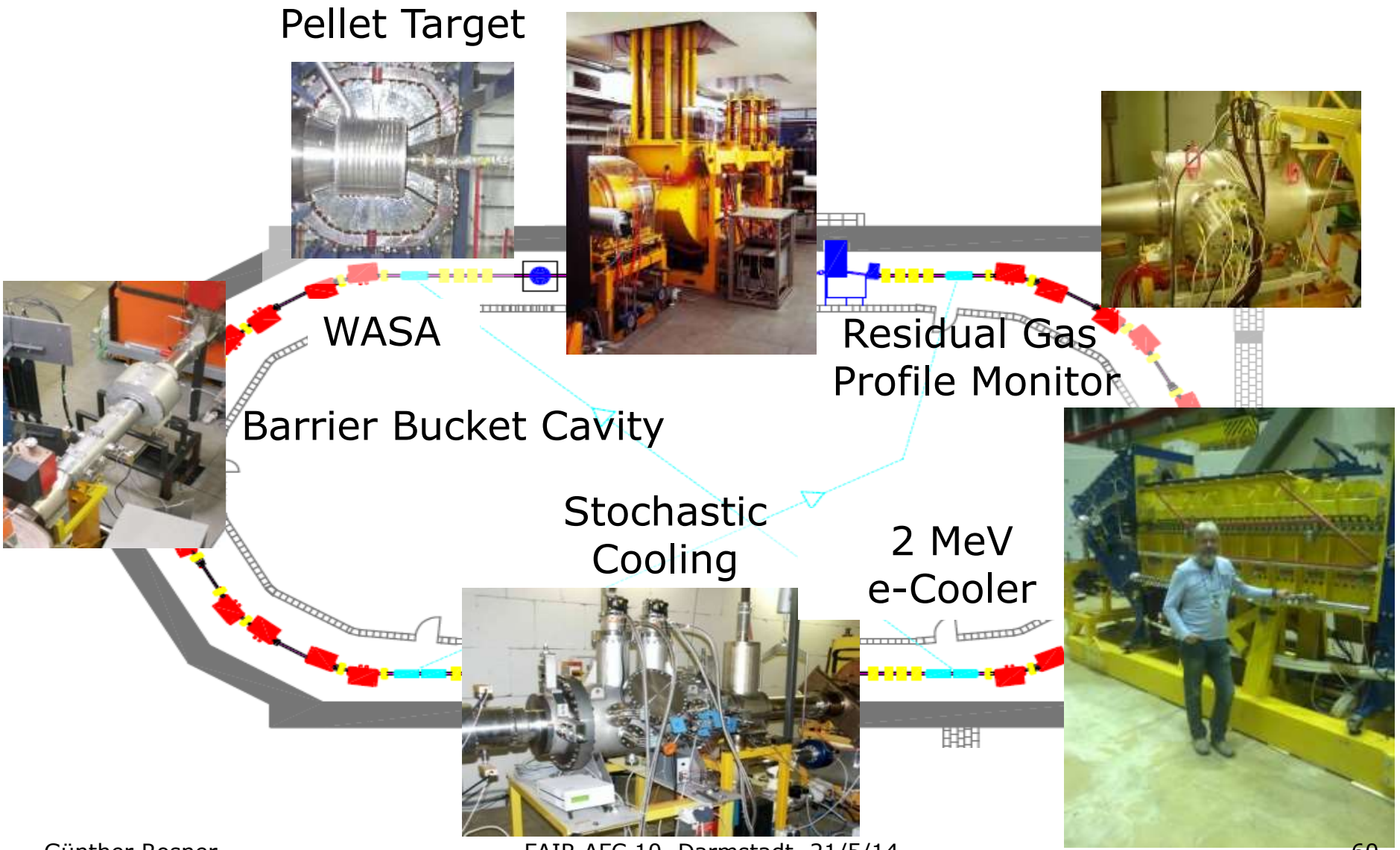
ACC Highlights II

- **p-LINAC** power supplies from GSI for the source
  - First test of Mini control system CH-cavity at GSI for copper plating
- **CR**-stochastic cooling
  - Tendering for RF components of stochastic cooling equipment (GSI In-Kind contribution) on the way; prototype tank in production



- **SIS100** – dipole vacuum chamber:
  - Manufacturer did first brazing tests (7/2013)
  - Material for series production delivered

HESR Prototyping @ COSY



FAIR Collector Ring
Transfer of CR Project Responsibility to Budker

- BINP, FAIR, and GSI are considering the entire CR machine, except the stochastic cooling and RF systems, as Russian contribution.
- MoU signed during a first visit in Novosibirsk (October).
- Technical Addendum of MoU discussed and signed during a Workshop in Darmstadt (November).

Memorandum of Understanding (MoU)

between

Budker Institute of Nuclear Physics (BINP, Novosibirsk)

and

Gesellschaft für Schwerionenforschung mbH (GSI, Darmstadt)

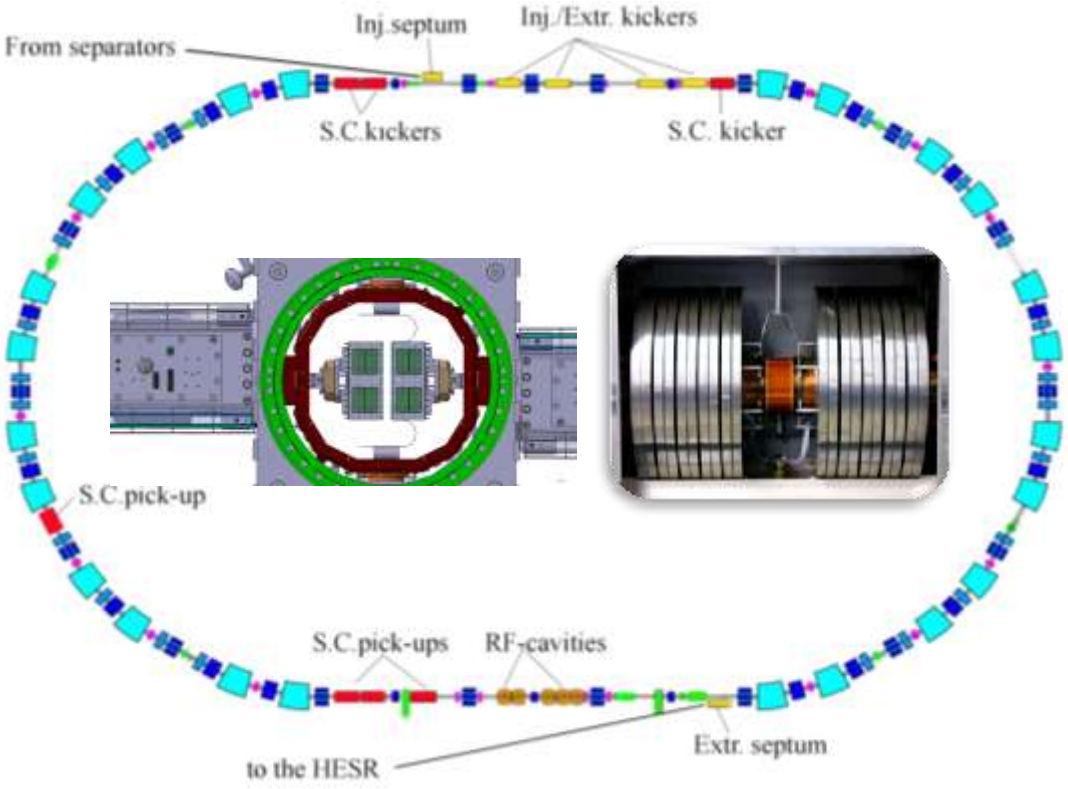
and

Facility of Antiproton and Ion Research in Europe GmbH (FAIR, Darmstadt)

on the

Realization of the FAIR Collector Ring (CR)

Prof. Dr. A. Skrinsky for BINP	Prof. Dr. Y. Shatunov for BINP
Prof. Dr. O. Kester for GSI	Dr. O. Dolinskyy for GSI
Prof. Dr. B. Sharkov for FAIR	Dr. E. Mahner for FAIR

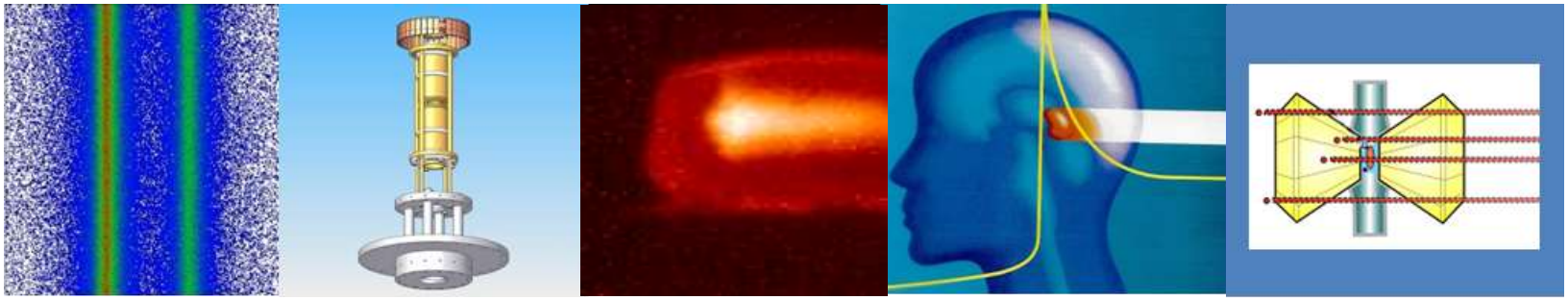


FAIR Members' Contributions

Contracting Party	Contribution (in 2005 M€)
Finland	5.00
France	27.00
Germany	705.00
India	36.00
Poland	23.74
Romania	11.87
Russia	178.05
Slovenia	12.00
Sweden	10.00
Total	**1.008,66**

- **All numbers in 2005 €** (escalation until 2018 ca. **+50%**)
- Full membership:
  - Spain expected to join soon
  - Talks with The Netherlands
  - Talks with Italy
- Associate Membership:
  - UK (STFC) since 3/5/13
  - Talks with China….
- Additional contributions to experiments by many countries

Atomic Physics, Plasma Physics, and Applied Sciences
APPA@FAIR



Jim Ritman

PANDA

Jim Ritman

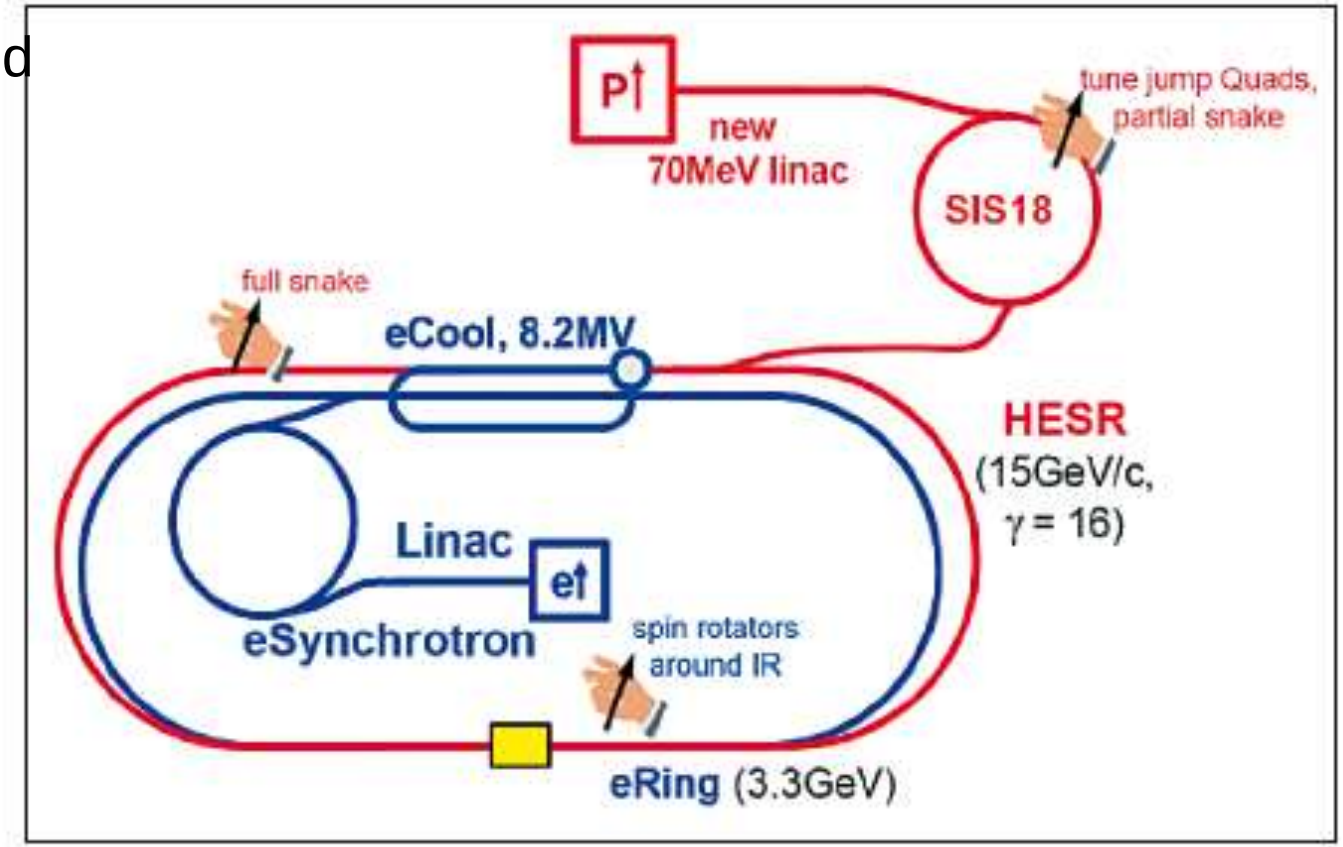
ENC at FAIR, Darmstadt

e-, P and D, polarized

up to 80% ↑

CM E = 14GeV

L = 10E32 cm-2 s-1



Layout of ENC@FAIR.