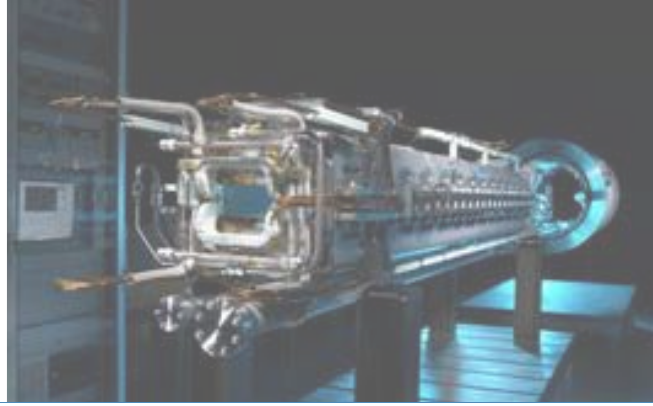




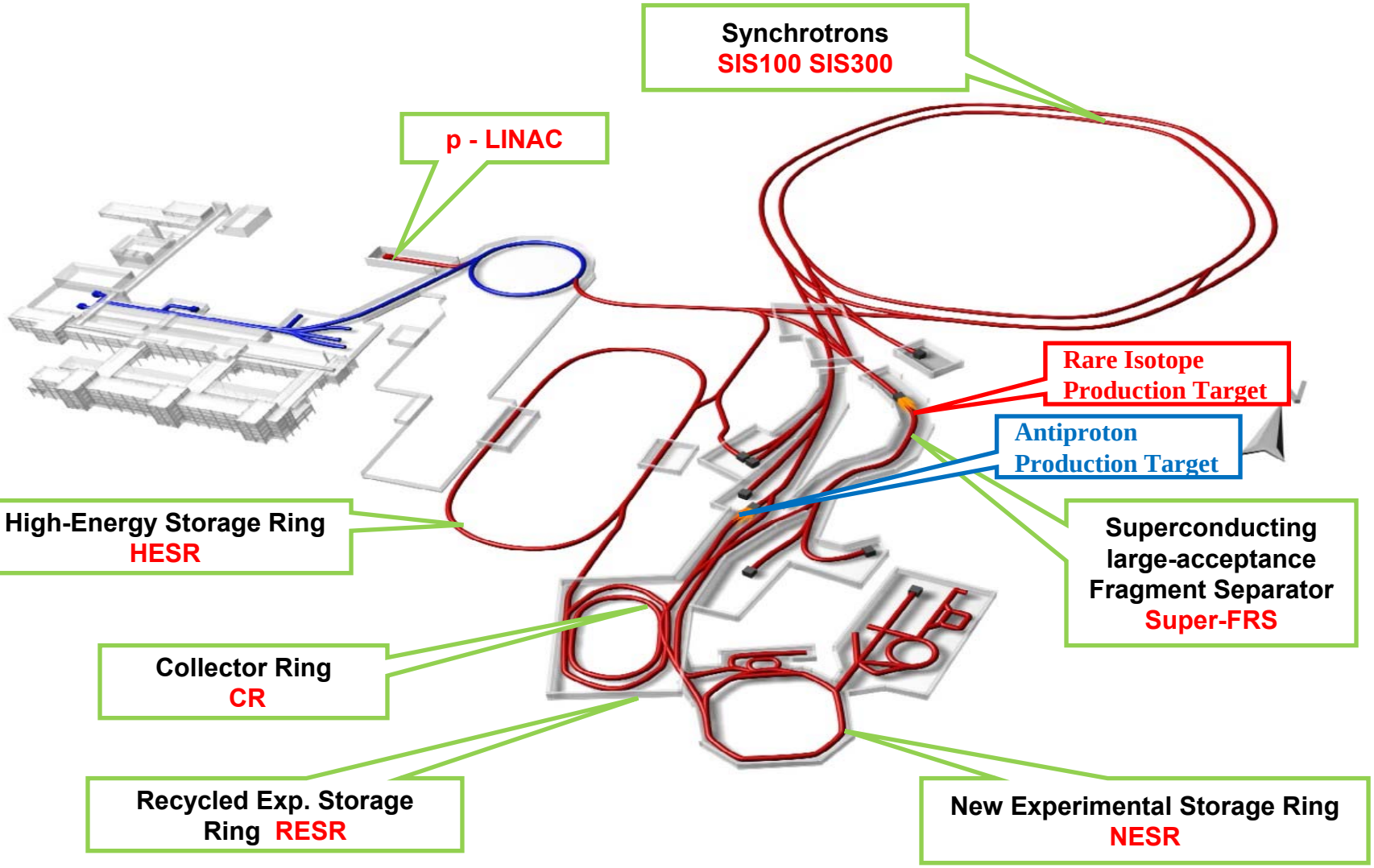
FAIR for Extreme State of Matter Physics

Boris Sharkov

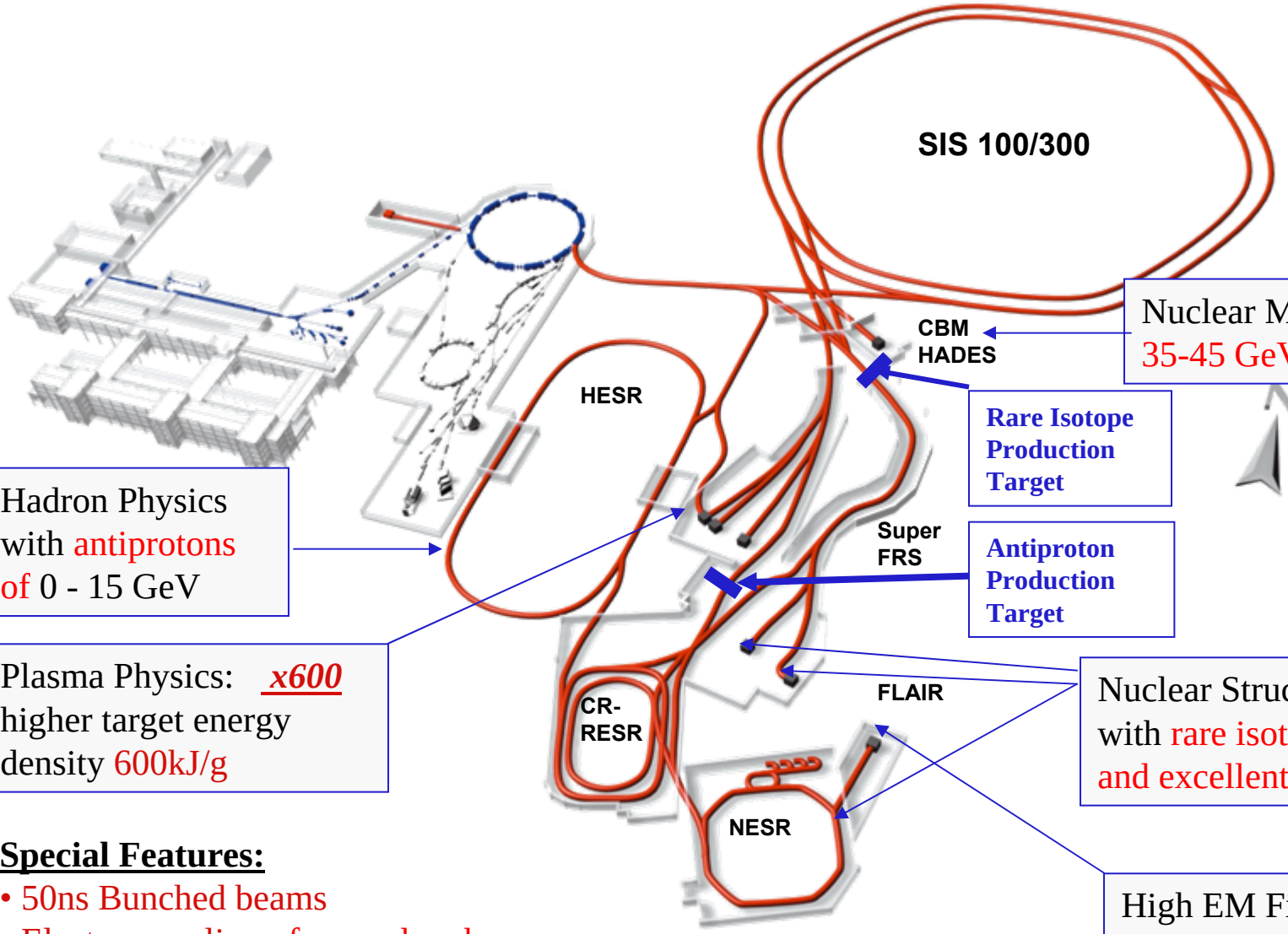
FAIR Scientific Director,
Chairman of the management board

@ EMMI 02.05.2011

New accelerator systems to be constructed



Research Communities at FAIR



Nuclear Matter Physics with 35-45 GeV/u HI beams, ***x1000***

Rare Isotope Production Target

Antiproton Production Target

Hadron Physics with antiprotons of 0 - 15 GeV

Plasma Physics: ***x600*** higher target energy density 600kJ/g

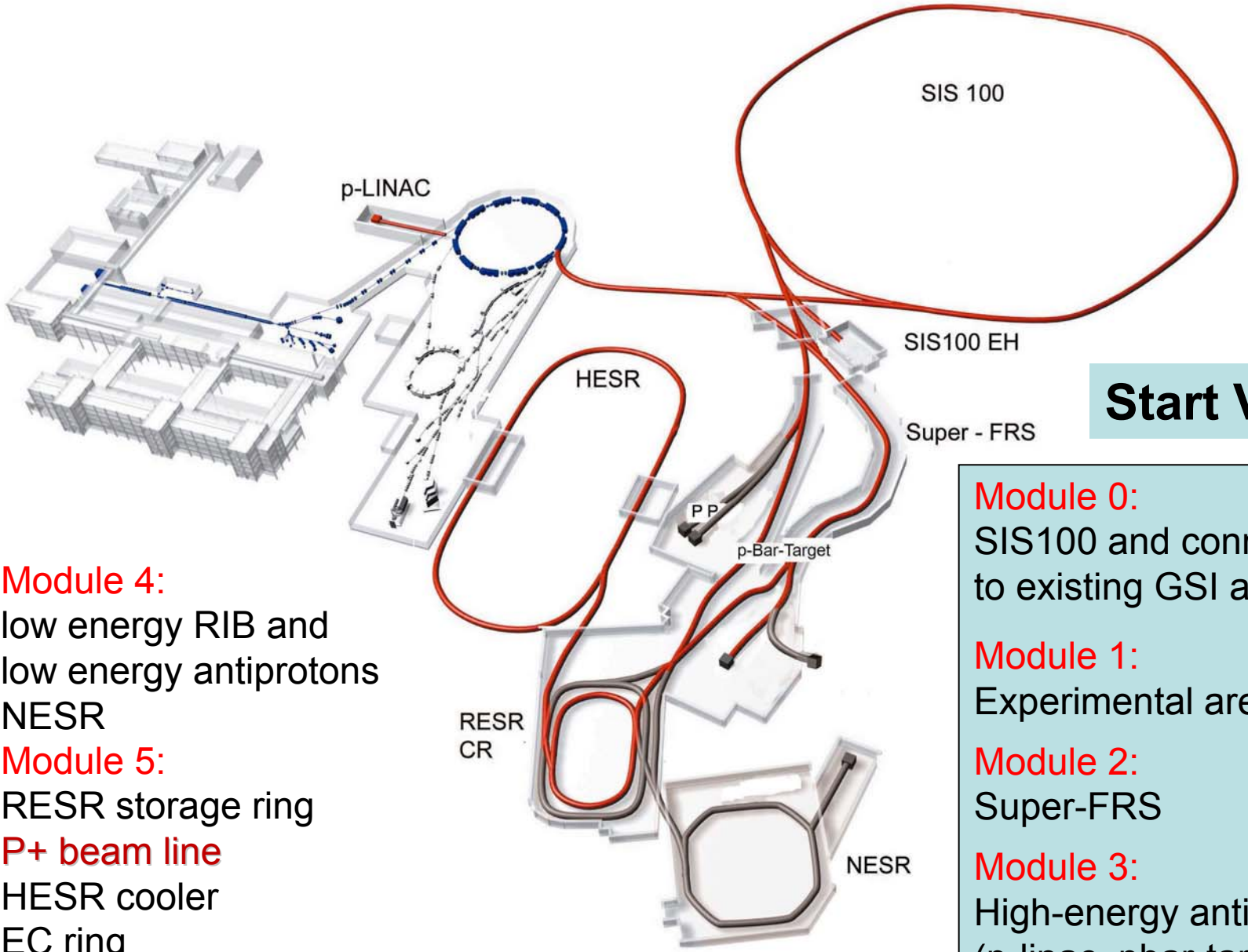
Nuclear Structure & Astrophysics with rare isotope beams, ***x10 000*** and excellent cooling

High EM Field (HI)
Fundamental Studies (HI & p)
Applications (HI)

Special Features:

- 50ns Bunched beams
- Electron cooling of secondary beams
- SC magnets fast ramping
- Parallel operation

B. Sharkov



Start Version

Module 0:
SIS100 and connection to existing GSI accel.

Module 1:
Experimental areas CBM,APPA

Module 2:
Super-FRS

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

Module 4:
low energy RIB and
low energy antiprotons
NESR

Module 5:
RESR storage ring

P+ beam line
HESR cooler
EC ring

Financial Constrains

Cost of Modularized Start Version = 1027 M

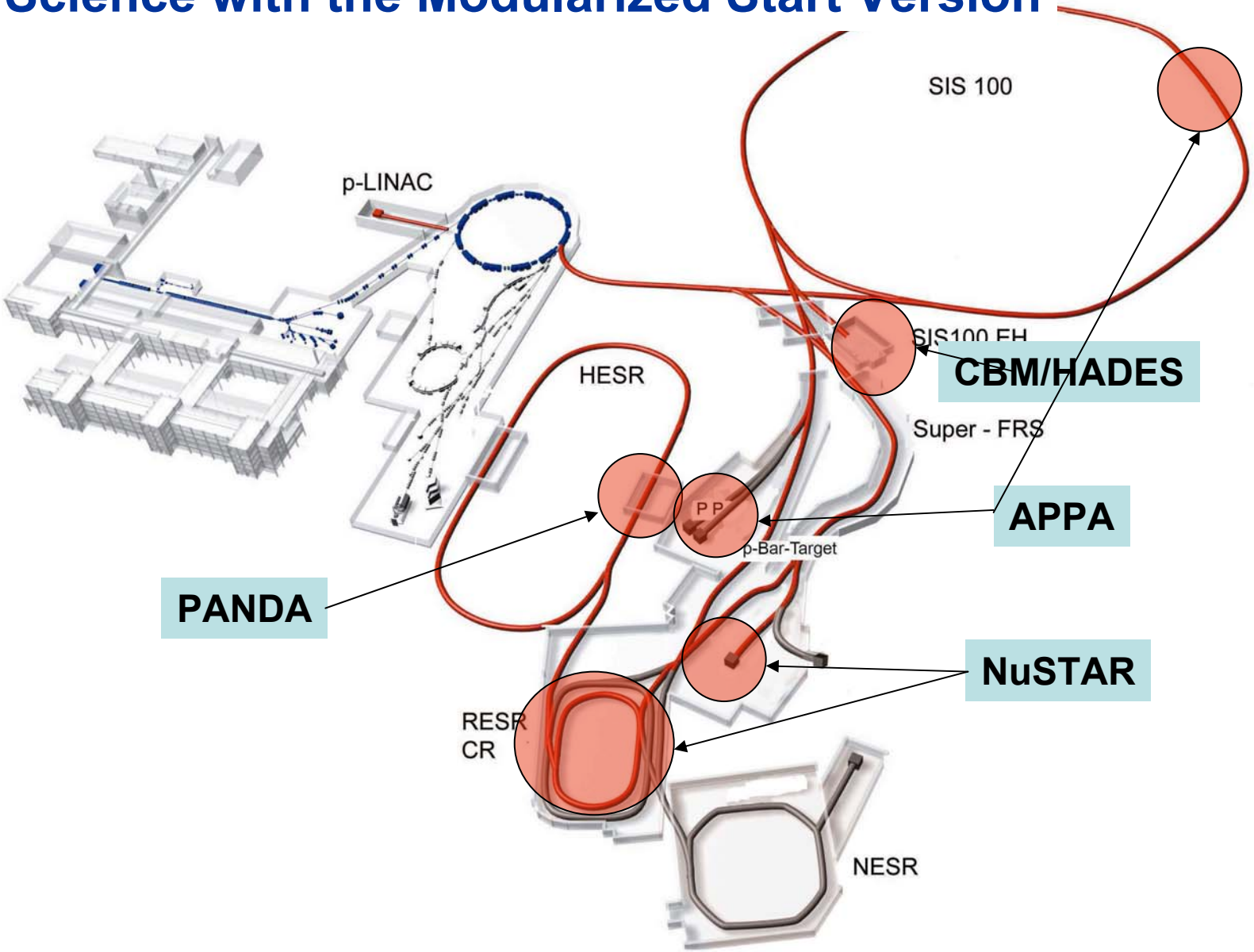
Firm funding commitments of FAIR Partners

Modularized Start Version secures a swi
current funding commitme

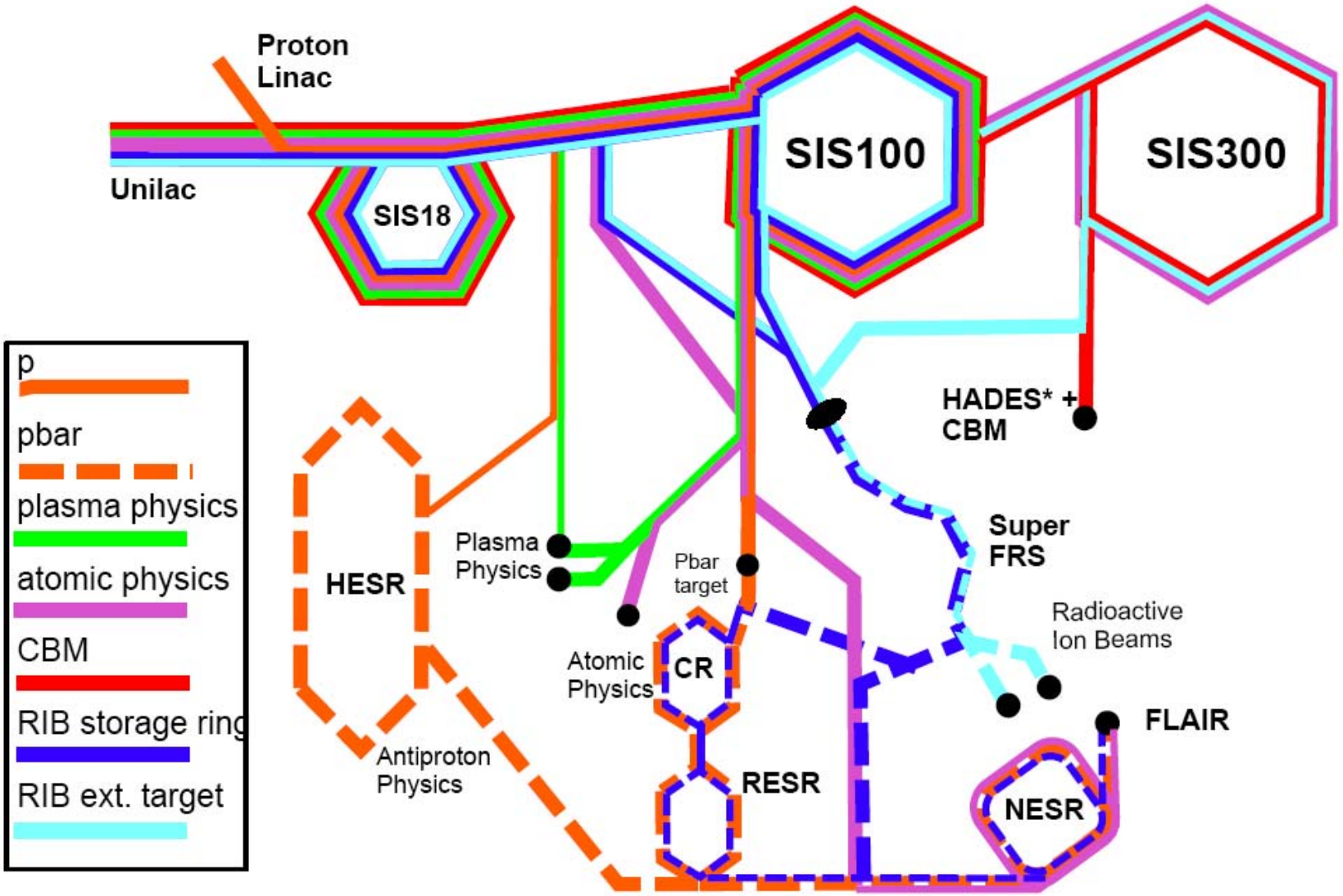
Basic criteria of new FAIR construction scenario:

The Modularized Start Version should enable realization of outstanding forefront research program to all four scientific communities of FAIR

Science with the Modularized Start Version



Up to 6 fold Parallel Operation at FAIR !



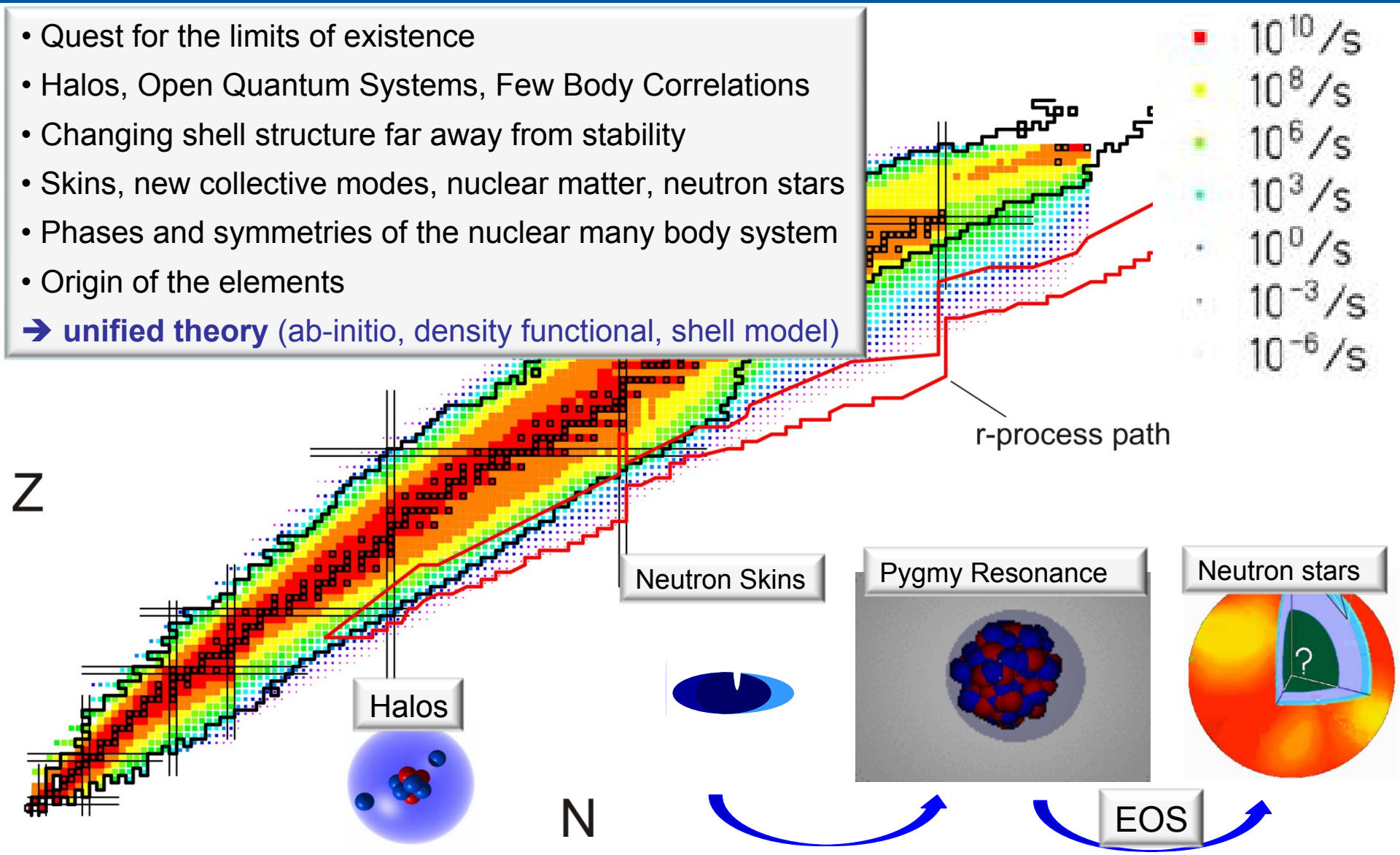
Nuclear STructure, Astrophysics and Reactions

> 800 members from 37 countries and 146 institutions

Central Topics for NuSTAR at FAIR ***How are nuclei made?***

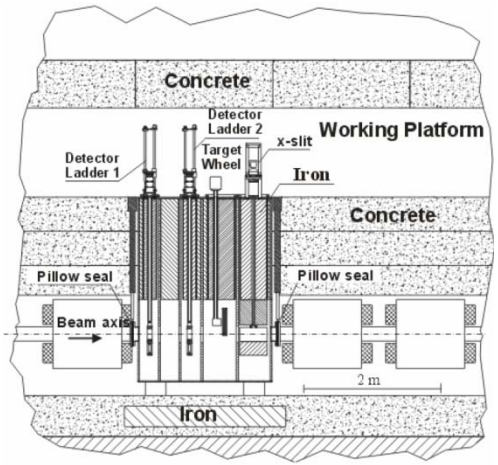
- Quest for the limits of existence
- Halos, Open Quantum Systems, Few Body Correlations
- Changing shell structure far away from stability
- Skins, new collective modes, nuclear matter, neutron stars
- Phases and symmetries of the nuclear many body system
- Origin of the elements

➔ **unified theory** (ab-initio, density functional, shell model)

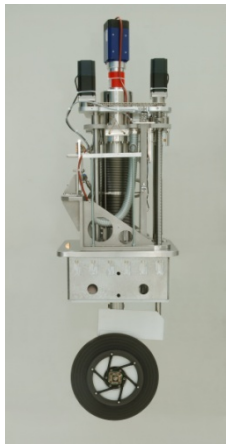


Technical Challenges

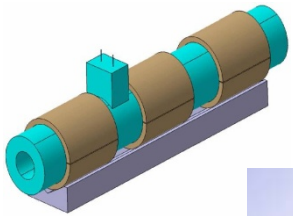
Remote Handling

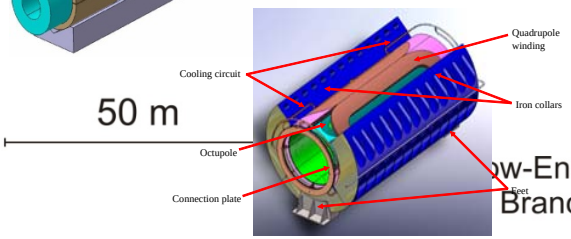


Target & Beam Catcher

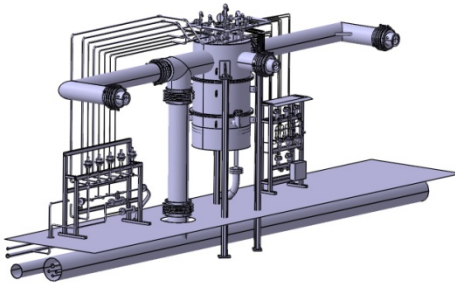


SC Multiplets

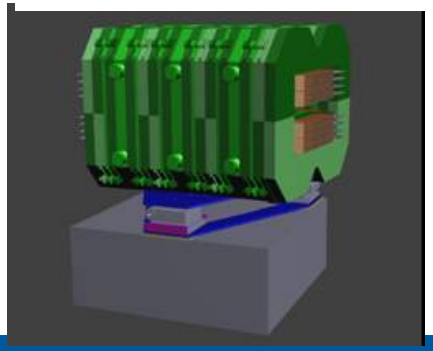


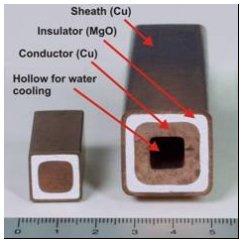


Cryogenics



Radiation Reistant Magnets





SC Dipoles

The CBM Collaboration: 55 institutions, 450 members

Croatia:
RBI, Zagreb
Split Univ.

China:
CCNU Wuhan
Tsinghua Univ.
USTC Hefei

Czech Republic:
CAS, Rez
Techn. Univ.Prague

France:
IPHC Strasbourg

Hungaria:
KFKI Budapest
Budapest Univ.

Norway:
Univ. Bergen

India:
Aligarh Muslim Univ.
Panjab Univ.
Rajasthan Univ.
Univ. of Jammu
Univ. of Kashmir
Univ. of Calcutta
B.H. Univ. Varanasi
VECC Kolkata
SAHA Kolkata
IOP Bhubaneswar
IIT Kharagpur
Gauhati Univ.

Korea:
Korea Univ. Seoul
Pusan Nat. Univ.

Germany:
Univ. Heidelberg, P.I.
Univ. Heidelberg, KIP
Univ. Heidelberg, ZITI
Univ. Frankfurt IKF
Univ. Frankfurt, FIAS
Univ. Münster
FZ Dresden
GSI Darmstadt
Univ. Wuppertal

Poland:
Jag. Univ. Krakow
Warsaw Univ.
Silesia Univ. Katowice
AGH Krakow

Portugal:
LIP Coimbra

Romania:
NIPNE Bucharest
Univ. Bucharest

Russia:
IHEP Protvino
INR Troitzk
ITEP Moscow
KRI, St. Petersburg
Kurchatov Inst., Moscow
LHEP, JINR Dubna
LIT, JINR Dubna
MEPHI Moscow
Obninsk State Univ.
PNPI Gatchina
SINP MSU, Moscow
St. Petersburg P. Univ.

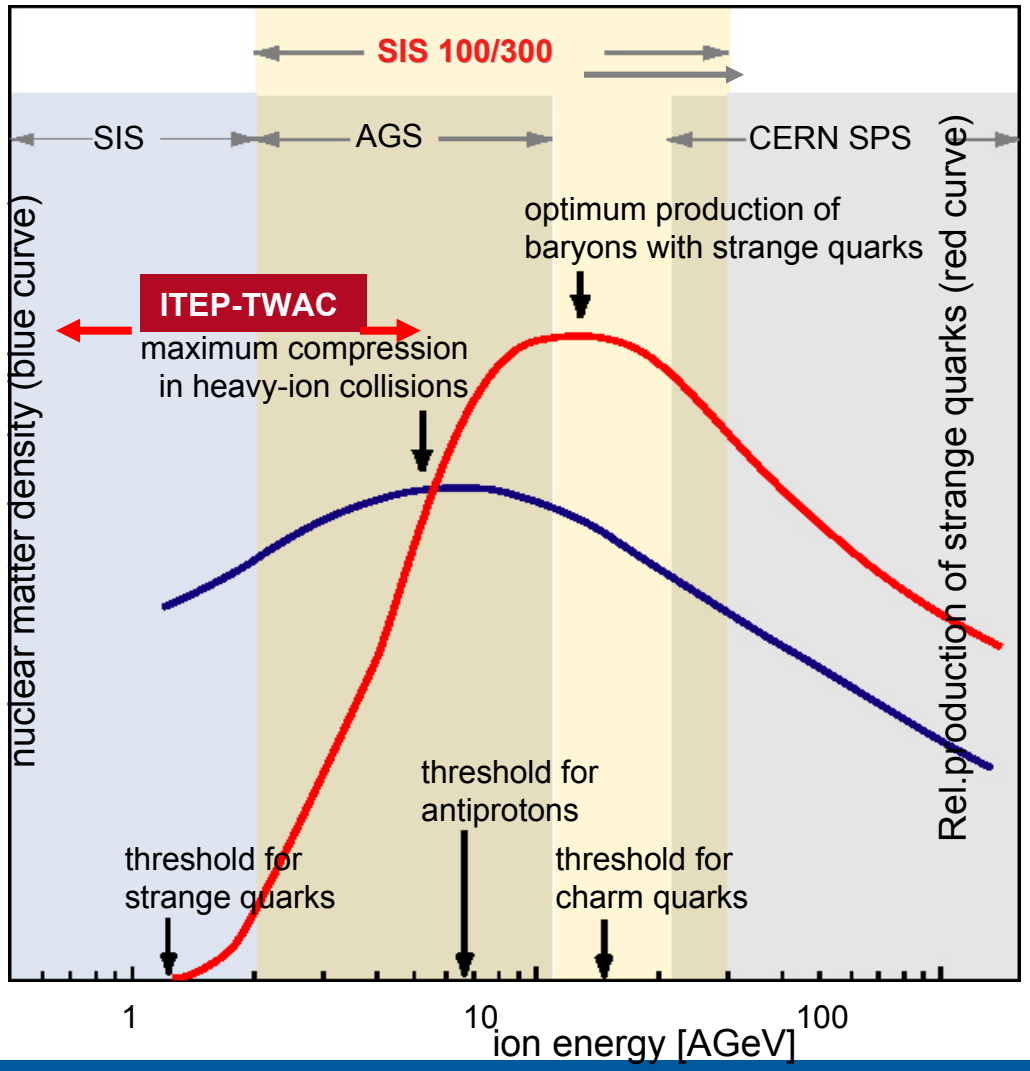
Ukraine:
T. Shevchenko Univ. Kiev
Kiev Inst. Nucl. Research

14st CBM Collaboration meeting
5-9 Oct. 2009, Split, Croatia

Relativistic Nuclear Physics

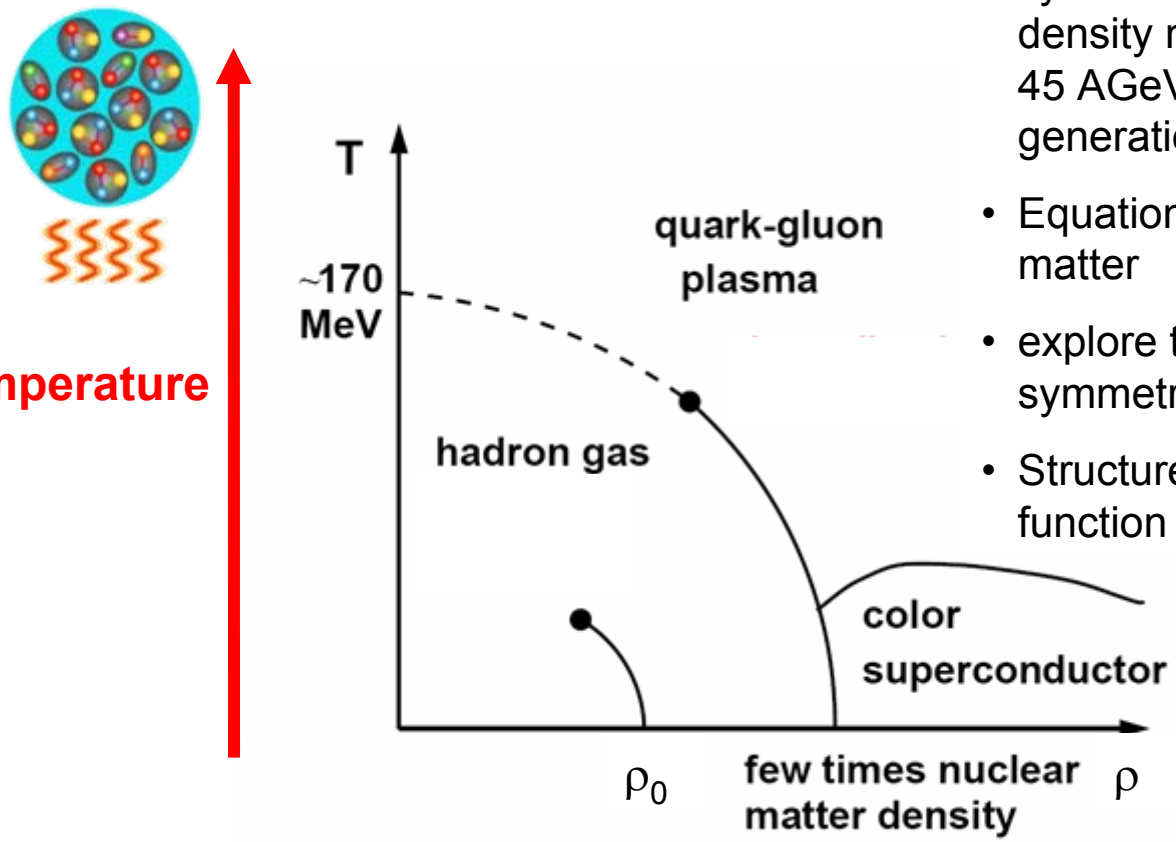
Studies of hadronic matter at high densities

Motivation for NN collisions at 2-40 AGeV



Phasediagram of strongly interacting matter

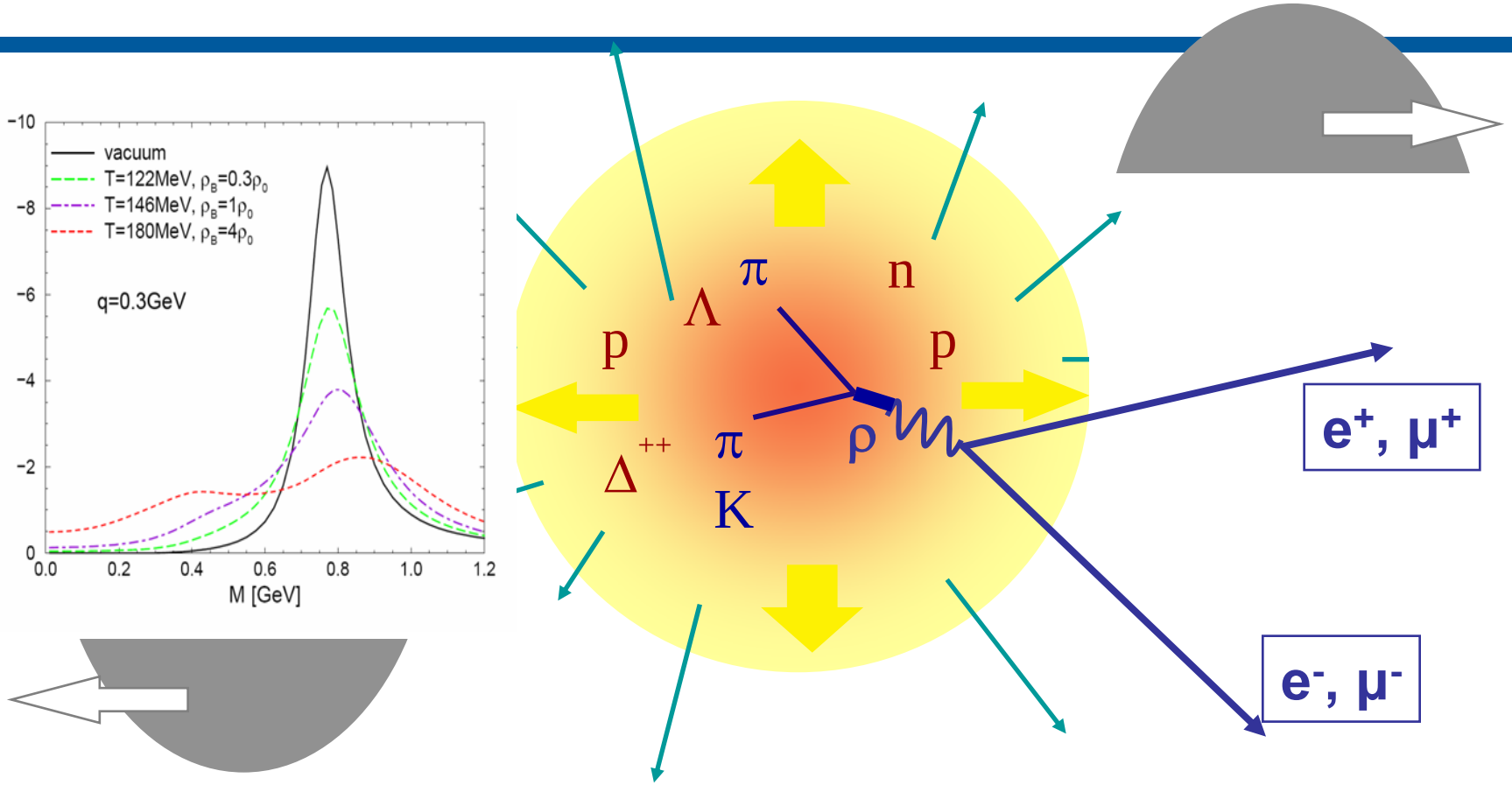
Fundamental questions of QCD



CBM and HADES at SIS 100 and SIS 300

- systematic exploration of high baryon density matter in A+A collisions from 2 – 45 AGeV beam energy with 2nd generation experiments
- Equation of state of strongly interacting matter
- explore the QCD phase diagram, chiral symmetry restauration
- Structure of strongly interacting matter as function of T and ρ_B?

Looking into the fireball ...



... using penetrating probes: short-lived vector mesons decaying into electron-positron pairs

Atomic, Plasma Physics and Applied Physics (APPA)

Plasma-physics

- 246 scientists
- 55 institutions
- 16 countries

BIOMAT

- 110 scientists
- 28 institutions
- 12 countries

SPARC

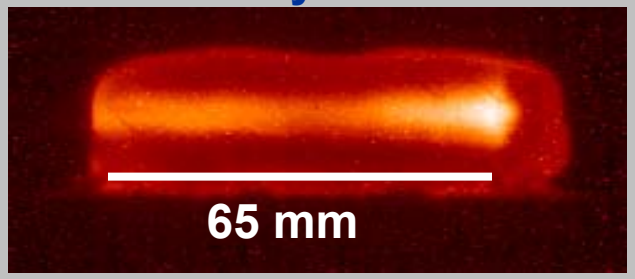
- 284 scientists
- 83 institutions
- 26 countries

FLAIR

- 144 scientists
- 49 institutions
- 15 countries

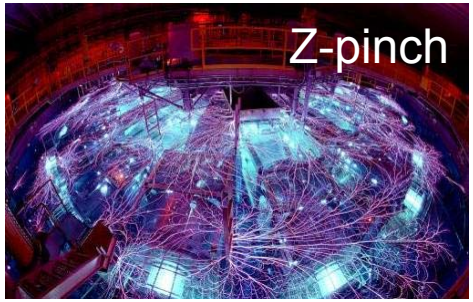
The uniqueness of heavy ion beams compared to other techniques (Laser, Z-pinch)

intense, energetic beams of heavy ions



Ne^{10+} 300 MeV/u; Kr crystal

- large volume of sample (mm^3)
- fairly uniform physical conditions
- thermodynamic equilibrium
- any material

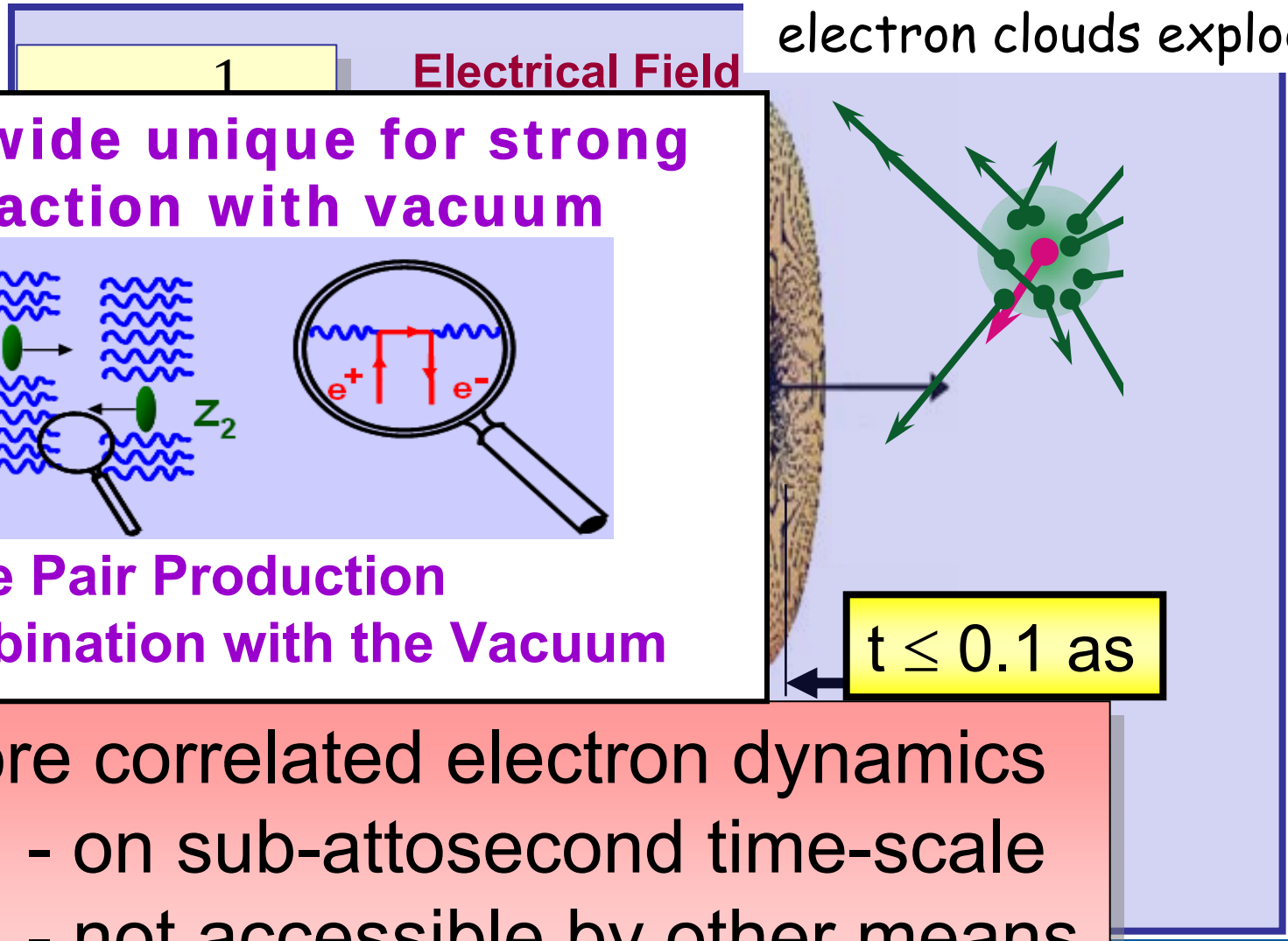


Already within module 1: Compared to GSI, FAIR will provide an ***intensity and energy density increase by a factor of 100.***

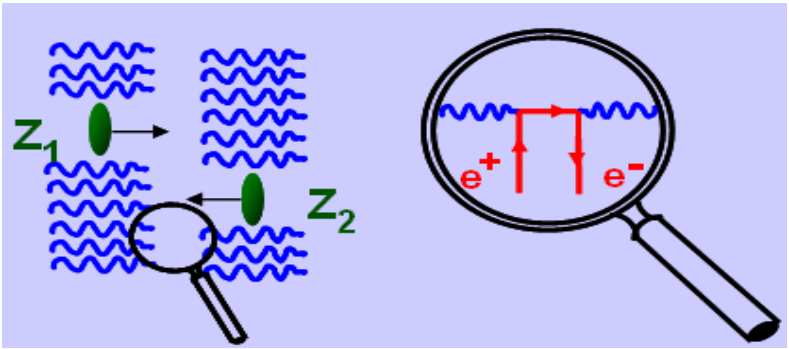
WDM-parameters: **T:** up to 10 eV **ρ:** ~ solid **P:** up **to 1** Mbar

SPARC Module 1: Relativistic Collisions @SIS100

"Heisenberg's dream"
shoot out the nucleus, let electron clouds explode



World-wide unique for strong interaction with vacuum



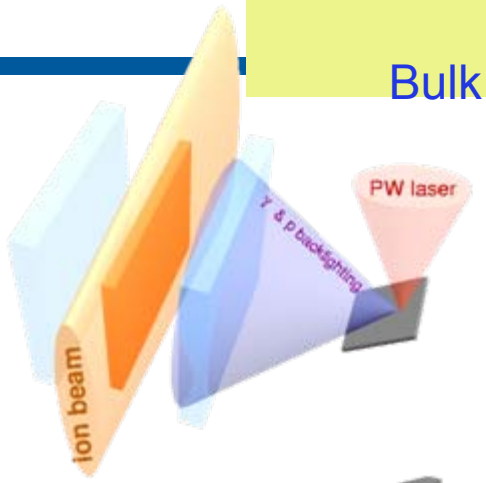
- **Multiple Pair Production**
- **Recombination with the Vacuum**

Explore correlated electron dynamics
- on sub-attosecond time-scale
- not accessible by other means

Proposed experiments on Plasma Physics

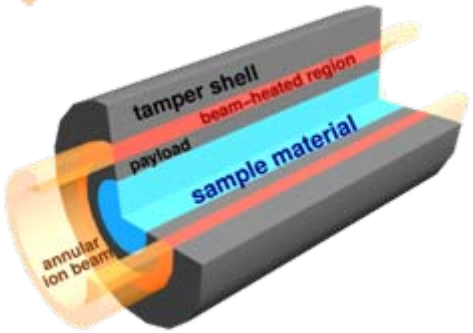
with highly Bunched Beams

Bulk matter at very high pressures, densities, and temperatures



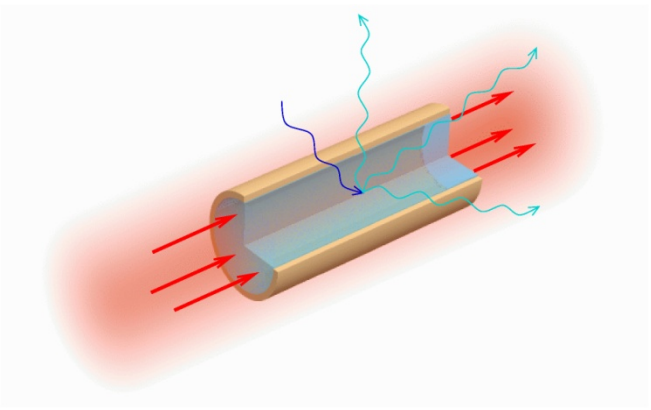
HIHEX: Heavy Ion Heating and Expansion

(HEDgeHOB)



LAPLAS: Laboratory Planetary Sciences

(HEDgeHOB)



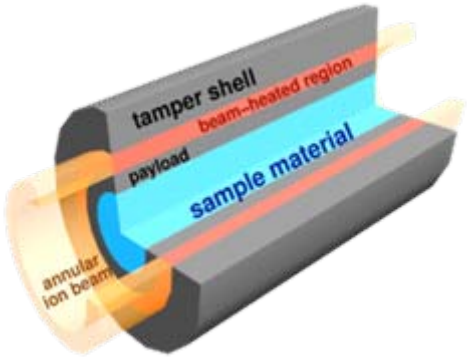
WDM: Warm Dense Matter

High Energy Density experiments of HEDgeHOB collaboration

HIHEX
Heavy Ion Heating and Expansion

- uniform quasi-isochoric heating of a large-volume dense target, isentropic expansion in 1D plane or cylindrical geometry

LAPLAS
Laboratory Planetary Sciences

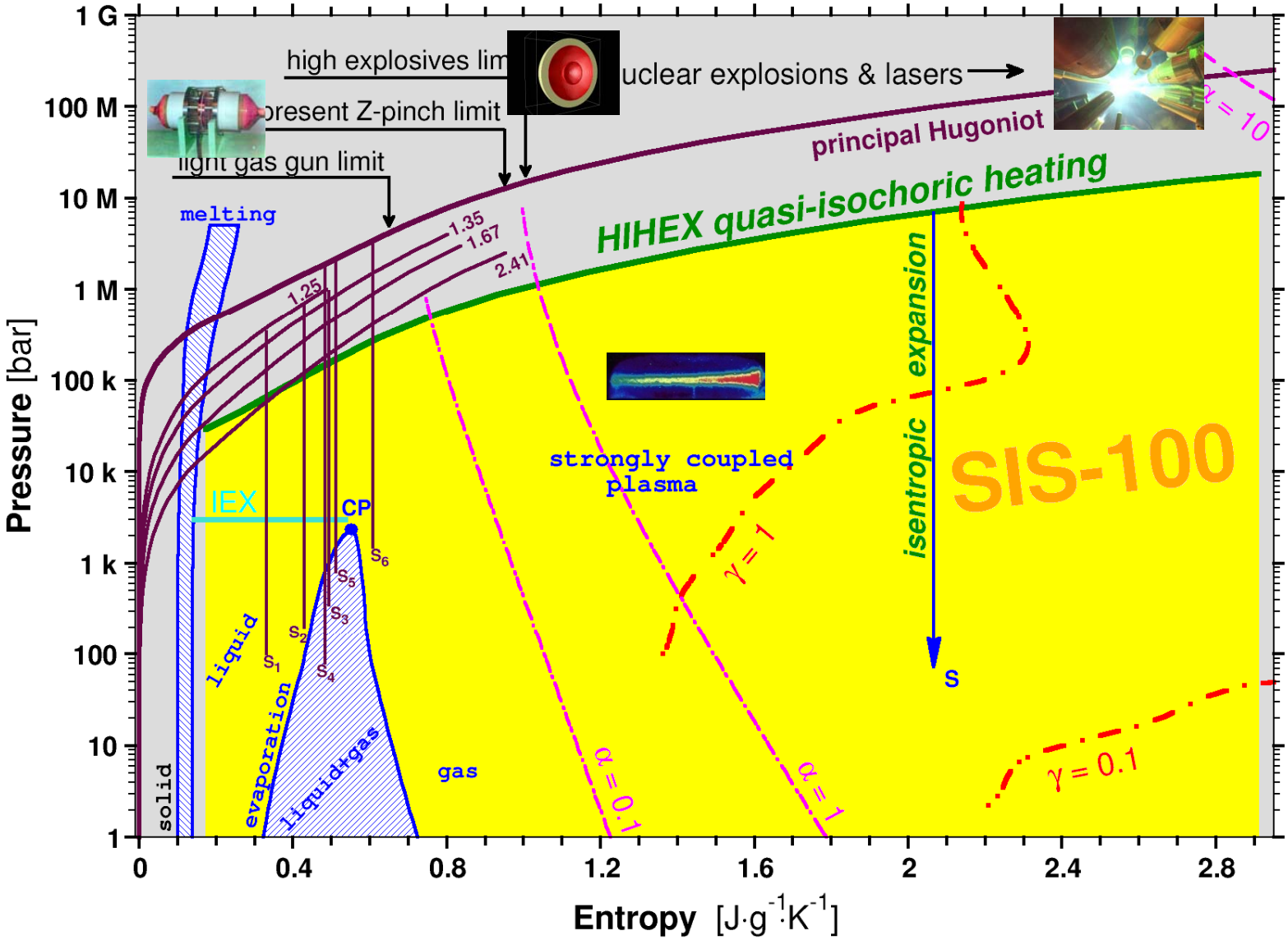


- hollow (ring-shaped) beam heats a heavy tamper shell cylindrical implosion and low-entropy compression

Numerous high-entropy HED states:
EOS and transport properties of e.g., non-ideal plasmas, WDM and critical point regions for various materials

Mbar pressures @ moderate temperatures:
high-density HED states, e.g. hydrogen metallization problem, interior of Jupiter and Saturn

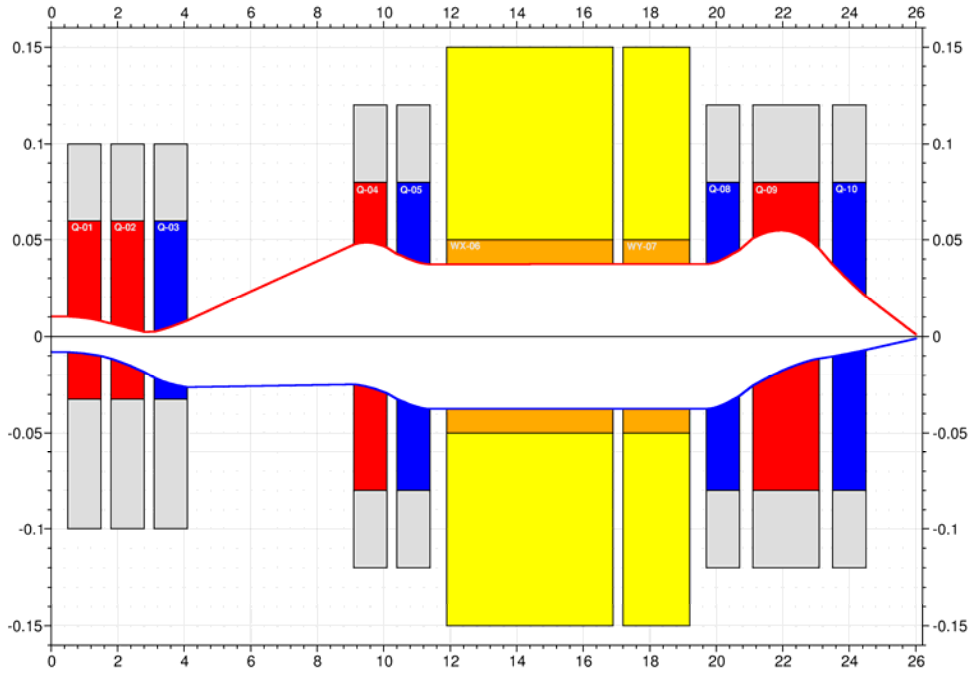
"Terra Incognita" regions of the phase diagram accessible in **HEDgeHOB** experiments at FAIR



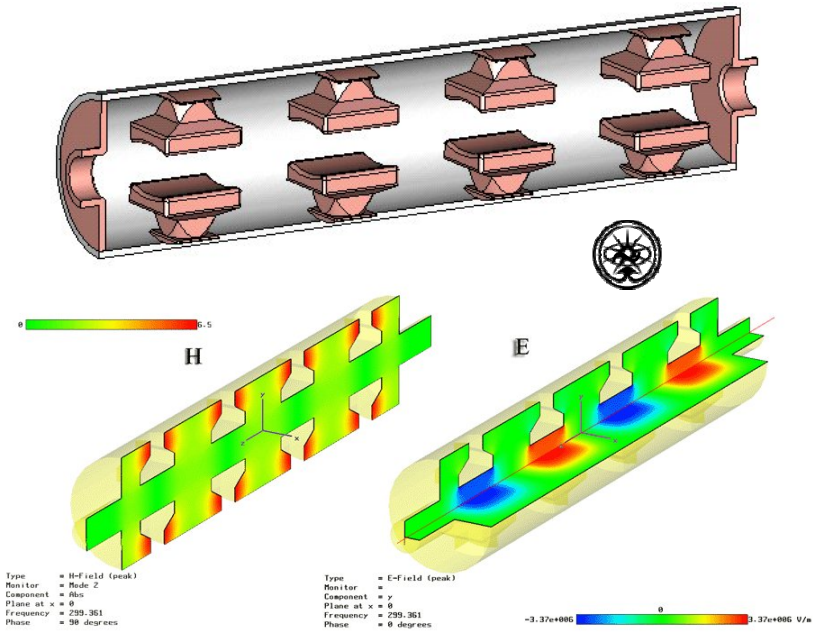
D.H.H. Hoffmann, V.E. Fortov et al. Phys. Plasmas 9 (2002) 3651.

P6.1&6.2: Ion optical design of the **LAPLAS** beam line: focusing and rf beam deflector (wobbler), ITEP design.

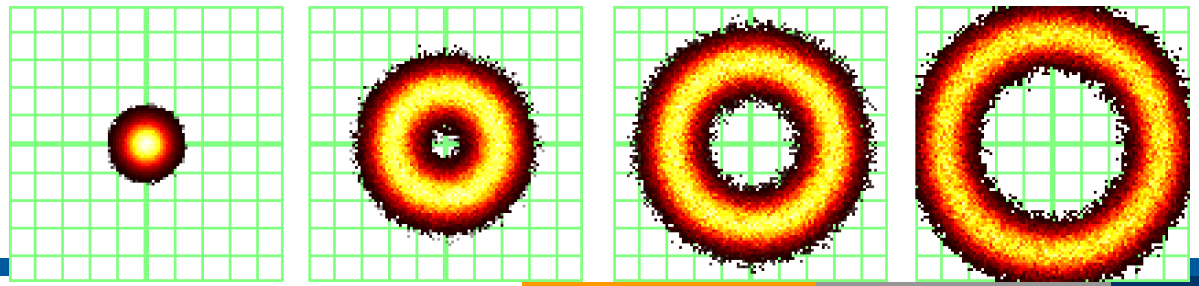
Layout of the **LAPLAS** beam line



Design of rf beam deflector (wobbler)



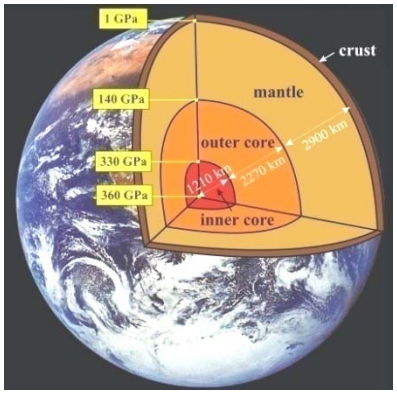
Transverse beam intensity distribution in the focal spot



BIOMAT

Full Program at SIS 100 - Module 1

Materials research



- **Exposure of matter to relativistic ions and high pressure:** phase transitions in mineralogy and geophysics
- **Ion-matter interaction at FAIR Energies:** energy-deposition and short-time processes at relativistic projectile velocities
- **Radiation hardness of materials:** requirements for accelerator and spacecraft-components

Biophysics

- **Cosmic radiation:** the main hindrance toward manned space exploration
- **Widely unknown biological effects of heavy ions**
- **A large experimental campaign in space radiation biophysic was started**

The Collaboration

At present 410 physicists from 53 institutions in 16 countries

Basel, Beijing, Bochum, IIT Bombay, Bonn, Brescia, IFIN Bucharest, Catania, IIT Chicago, Cracow, IFJ PAN Cracow, Cracow UT, Edinburgh, Erlangen, Ferrara, Frankfurt, Genova, Giessen, Glasgow, GSI, FZ Jülich, JINR Dubna, Katowice, KVI Groningen, Lanzhou, LNF, Lund, Mainz, Minsk, ITEP Moscow, MPEI Moscow,TU München, Münster, Northwestern, BINP Novosibirsk, IPN Orsay, Pavia, IHEP Protvino, PNPI St.Petersburg, KTH Stockholm, Stockholm, Dep. A. Avogadro Torino, Dep. Fis. Sperimentale Torino, Torino Politecnico, Trieste, TSL Uppsala, Tübingen, Uppsala, Valencia, SINS Warsaw, TU Warsaw, AAS Wien

High precision beams of Antiprotons

..allow in collisions with protons and nuclei the formation of

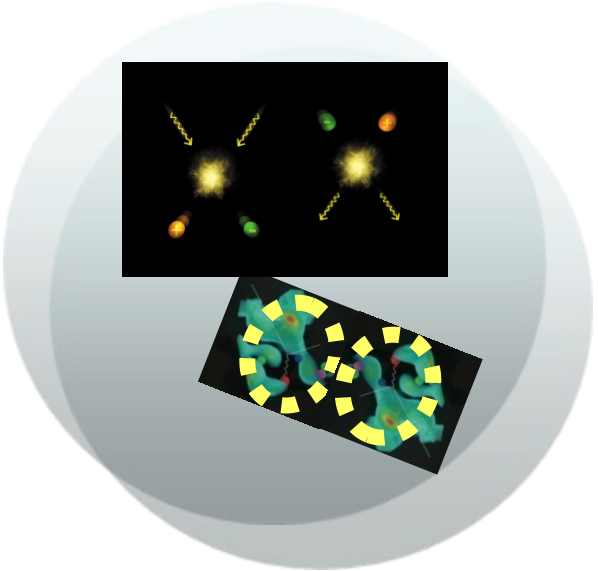
- pairs of sub-nuclear particles and their antiparticles
- high precision measurements of sub-nuclear masses and lifetimes

..allow at zero velocity the production of ***antihydrogen atoms and molecules***, the antimatter of hydrogen, and studies of, e.g.,

- gravity acting on ***antimatter***
- validity of our physics laws for ***antimatter***

⇒ ***At FAIR: 100 times more abundant than at CERN***

Structure and fundamental properties of anti-matter



Scientific program (Highlights)

- Charmonium (ccbar)/open charm (c+other non c-quark) spectroscopy
- Non-pertubative QCD dynamics
- Nucleon Structure via electro-magnetic processes

PHASE DIAGRAM OF MATTER

Lg P,Mbar

quark-gluon plasma

Relativism of nucleons

Nuclear Collisions (15.7)

Atomic nuclei (14.5)

Neutron Stars (6-9)

Red Giant(3-4)

White Dwarf (6-9)

FAIR

SUN(2.2)

ICF(2.3)

Jupiter(1.5)

Exoplanets

T-F

Relativism $T \sim mc^2$

Dynamics

Nuclear Explosions (2)

Electrons

Nucleons

Statics

Earth(1)

H-Fusion(-8.5)

High Temperatures

30 25 20 15 10 5 0 -5

-2 -1 0 1 2 3 4 5 6 7 8 9 10

Lg T,eV

04.10.2010 Castle Biebrich, Wiesbaden
Signing Ceremony of FAIR international Convention

Finland, France, Germany, India, Poland, Romania, Russia, Slovenia and Sweden

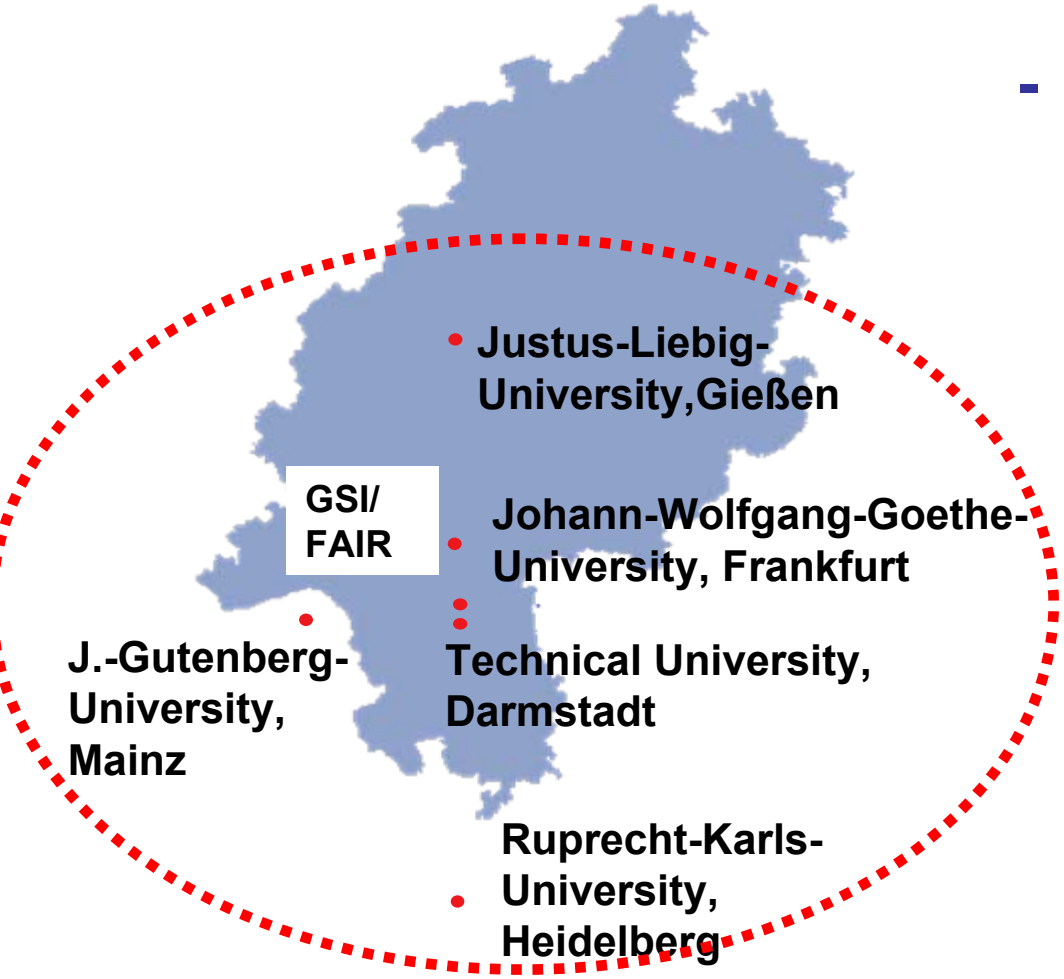
General MoU with CERN

signed on 18 November 2010

Rolf Heuer

Boris Sharkov

Concept of GSI / FAIR – Associated Universities



- **with 'founding univ.'**
  DA, F, GI, HD, and Mz ...

- Joint research & development projects related to GSI / FAIR
- Joint initiatives for graduate education at the universities

Expansion of this concept to further universities envisaged!

HIC4FAIR, HGS FAIR, EMMI ….

FAIR – Russia Research Center @ ITEP-Moscow

Strategic goal:

- Technical support of the Russian FAIR research activities and work packages
- Communication and cross-fertilization between the different Russian FAIR research communities
- Support for FAIR- related projects of masters, PhD students and post-docs in various fields of FAIR related fundamental and applied sciences

Seminar of FRRC Fellows 2009

Main results:

- **15 workshops, technical meetings and seminars on FAIR related issues**
- **23 in 2009 and 30 Fellows in 2010 representing 10 Russian Institutes and Universities and all FAIR collaborations**
- **2 regular lecture curses**
- **Basic analysis for White paper of Russian participation in FAIR project**

Hirschegg H/RA/HGS - FAIR school
12 – 17 Febr. 2011

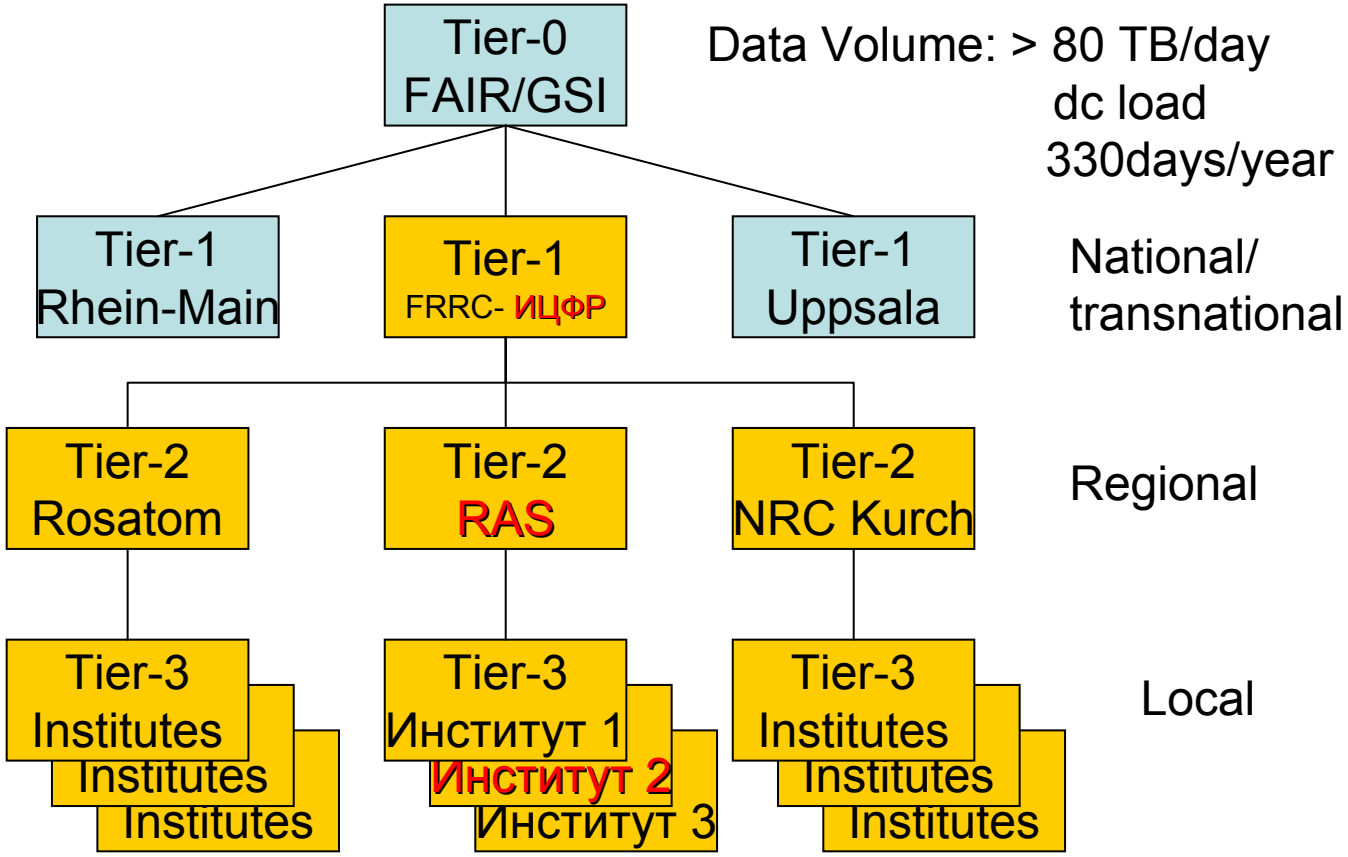
1st Joint Helmholtz-Rosatom School for Young Scientist at FAIR

Hirschegg – February 12 – 17, 2011

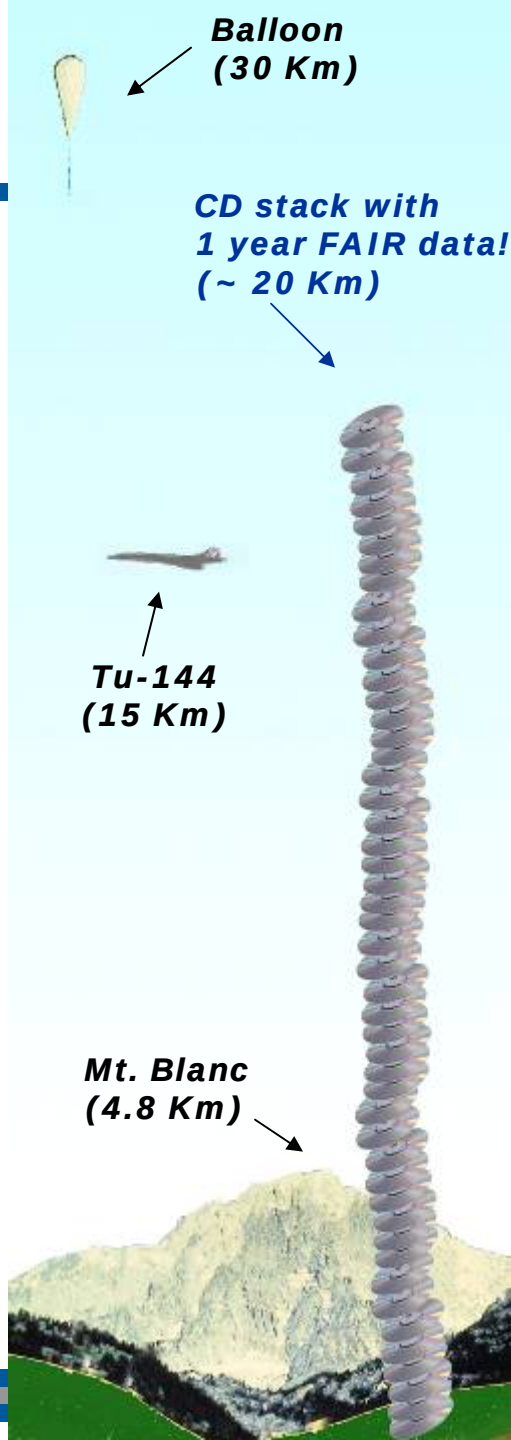
Waldemar Petersen Haus of TU Darmstadt

1st Joint Helmholtz-Rosatom School for Young Scientist at FAIR

FAIR Computing



Tier-1 & Tier-2 совместно с БАК (LHC GRID)



Raising New Funds

- New international Partners
  - Saudi Arabia
  - Brasilia
  - Turkey
  - Hungary . . .
- Increasing contributions to FAIR
  - China
  - Spain
  - India
  - Italy . . .
- EU Programme
- Costs optimisation, raising efficiency
  - Accelerator , CC , Experiments
    → implementation of MAC recommendations already in 2010

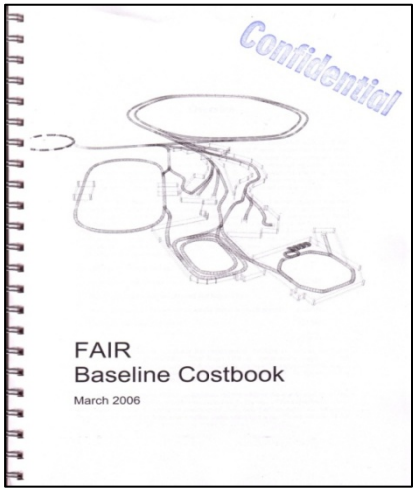
Construction Period, Cost, Users

- Construction until 2018
- Total cost 1.2 B€ (2005 prices)
- Scientific users: 2500 - 3000 per year

Financing

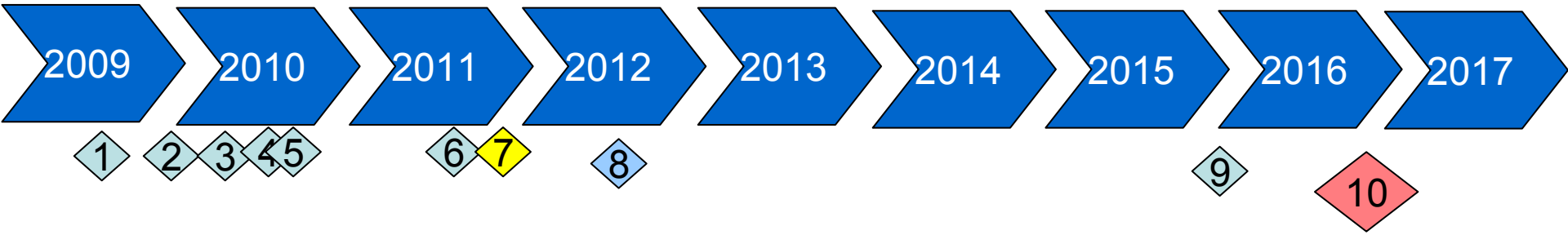
- up to 65 % Federal Government of Germany
- 10 % State of Hessen
- 25 % Partner Countries

⇨ **FAIR GmbH with International Shareholders**

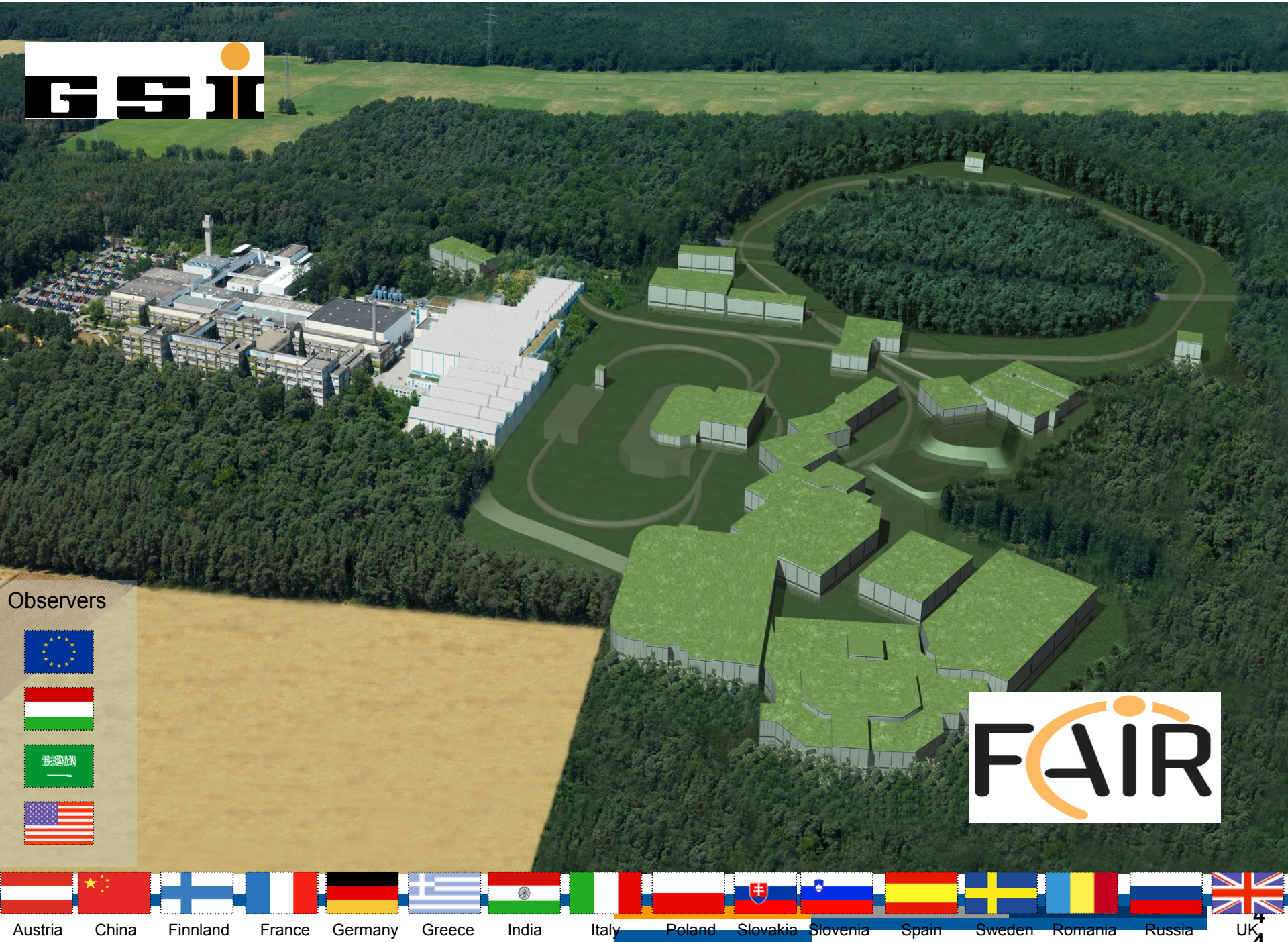


Operation cost will be negotiated in 3 years after FAIR GmbH will be established

Road Map FAIR Site & Buildings



1. Handing in of preplanning documents to hbm
2. Clarification of user requirements Modularized Start Version (MSV)
3. Start revised preplanning for MSV
4. Approval of revised planning for MSV
5. Preparation of documents for building permit
6. Expected approval for (partial) building permit
7. Start site preparation (clearing trees)
8. Award contracts on civil construction work lot 1 … n
9. Completion of civil construction work lot 1 … n
10. Start installation of accelerators and detectors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