

KHuK Report

prepared for the
KAT Meeting in Karlsruhe
30 Sep – 1 Oct 2014

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University of Bochum

Challenges in Nuclear and Hadron Physics

- Hadron Physics
 - from quarks to hadrons, masses of hadrons, spin of the nucleons, exotic bound states, matter/anti-matter asymmetry
- Heavy Ion Physics
 - exploration of the QCD phase diagram: nature of the phase transition, properties of the quark-gluon plasma at high temperature or large density, exotic phases of QCD matter
- Nuclear Structure
 - existence of super-heavy elements, properties and formation of exotic nuclei, limits of nuclear stability, formation of heavy elements in the universe, neutron matter

dedicated support for theory on related to the experimental program



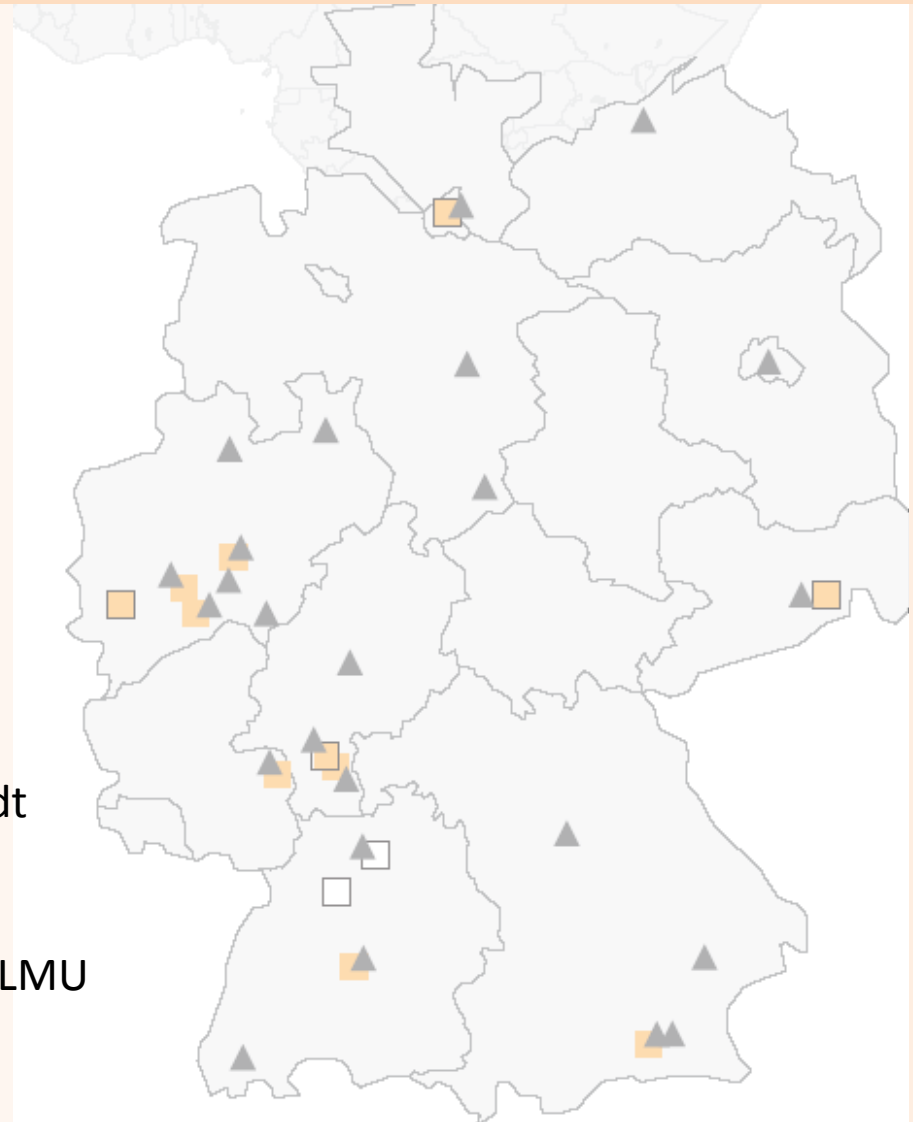
Nuclear and Hadron Physics in Germany

Facilities for Hadron and Nuclear Physics:

COSY, Jülich
DESY, Hamburg
ELBE, Dresden-Rossendorf
ELSA, Bonn
FRM-II, Munich
GSI, Darmstadt
MAMI, Mainz
TRIGA Mark II, Mainz
S-Dalinac, Darmstadt

Universities involved:

- Berlin • Bielefeld • Bochum • Bonn • Darmstadt
- Dresden • Erlangen • Frankfurt • Freiburg
- Giessen • Greifswald • Heidelberg (U + MPI)
- Jena • Karlsruhe IT • Köln • Mainz • München LMU
- München TU • Münster • Regensburg
- Rostock • Tübingen • Wuppertal





Research Priorities

- as spelled out in the strategy document
 - construction and completion of the Facility for Antiproton and Ion Research (FAIR) in Darmstadt
 - full exploitation of existing research infrastructures for the study of the properties and structure of matter under extreme conditions
 - initiative to secure the promotion of young scientists in the field of hadron and nuclear physics

in line with NuPECC Long-Range Plan for Europe

FAIR – Facility for Antiproton and Ion Research

Nuclear Structure & Astrophysics
(Rare-isotope beams)

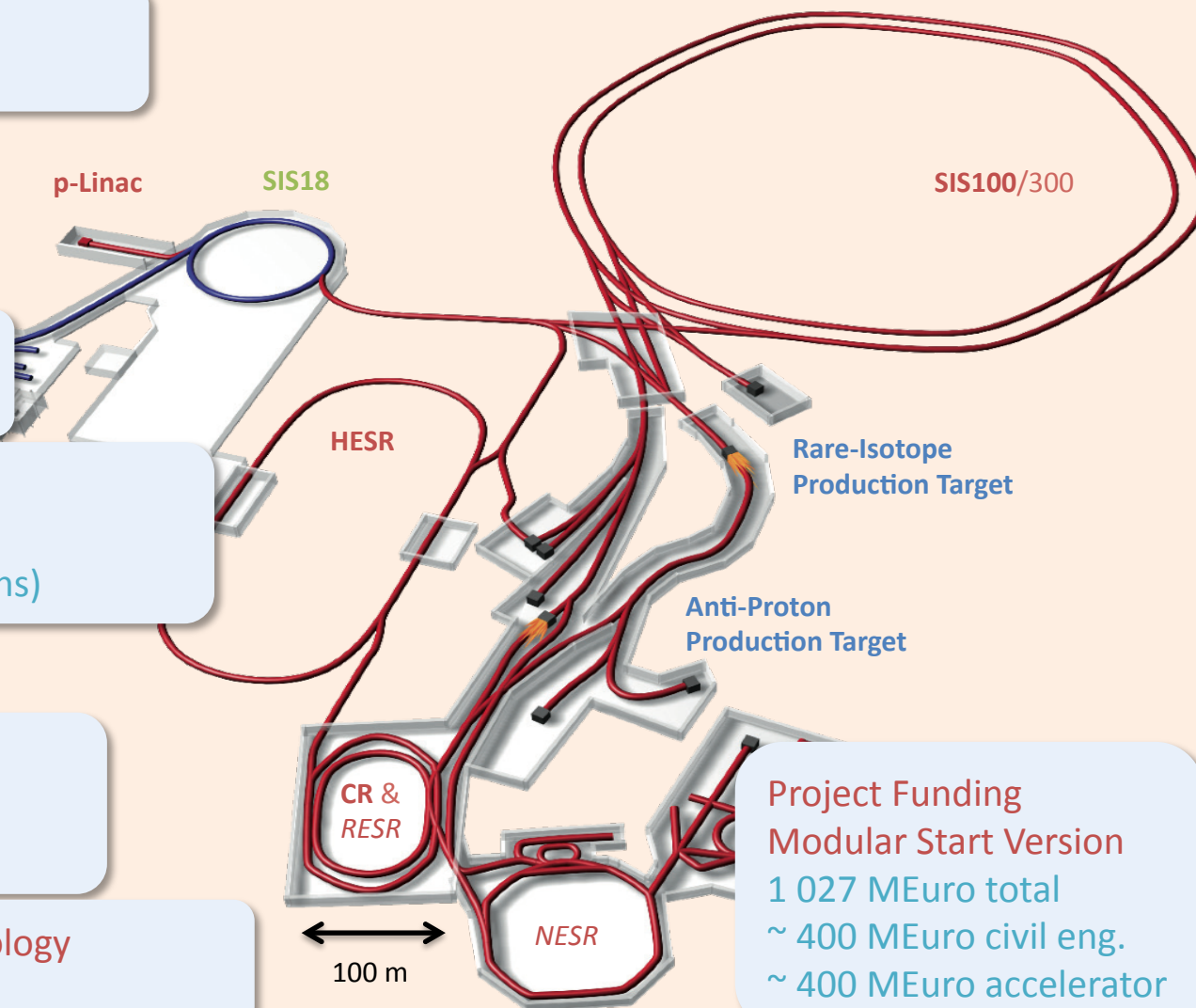
Hadron Physics
(Stored and cooled
14 GeV/c anti-protons)

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

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

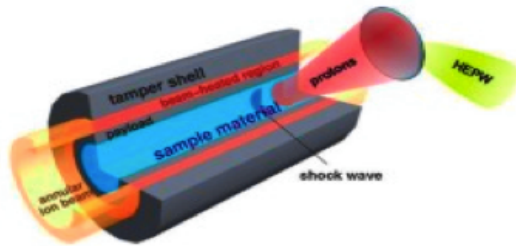
Dense Bulk Plasmas
(Ion-beam bunch compression
& petawatt-laser)

Materials Science & Radiation Biology
(Ion & antiproton beams)

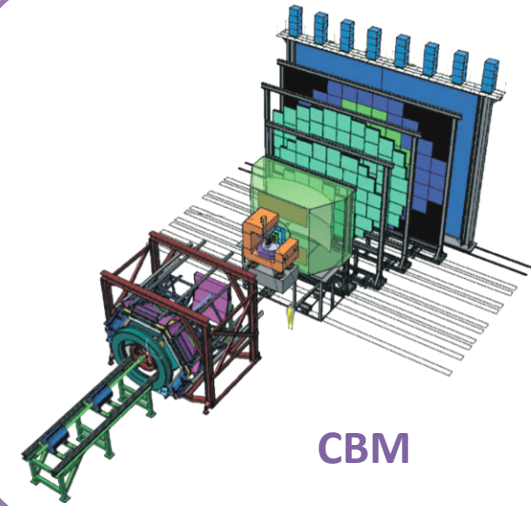


Project Funding
Modular Start Version
1 027 MEuro total
~ 400 MEuro civil eng.
~ 400 MEuro accelerator

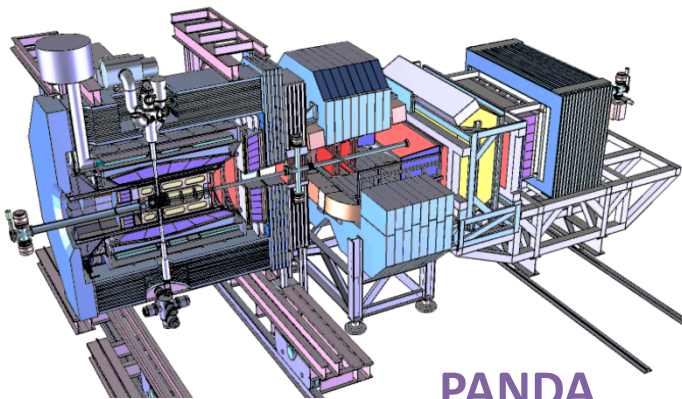
FAIR Experiments



APPA



CBM



PANDA

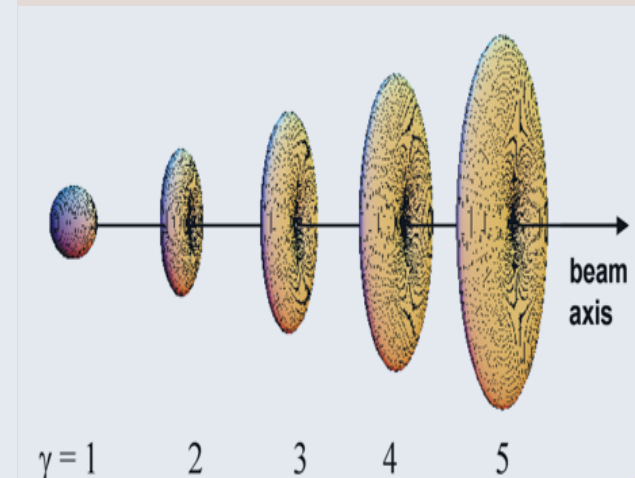
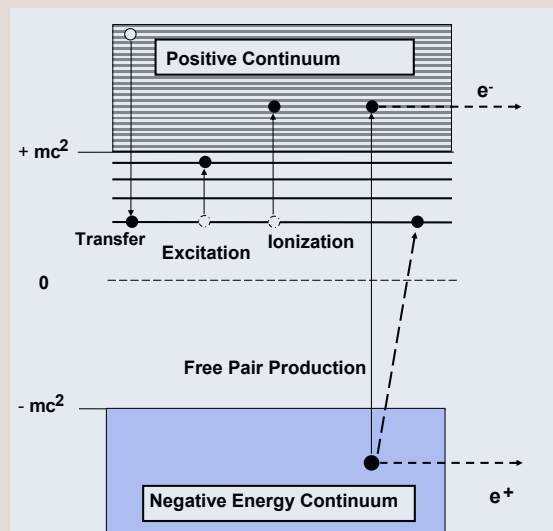
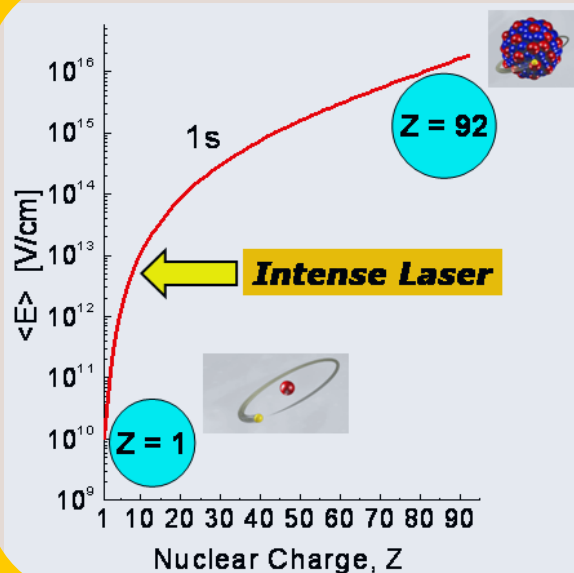


Super-FRS

NuSTAR

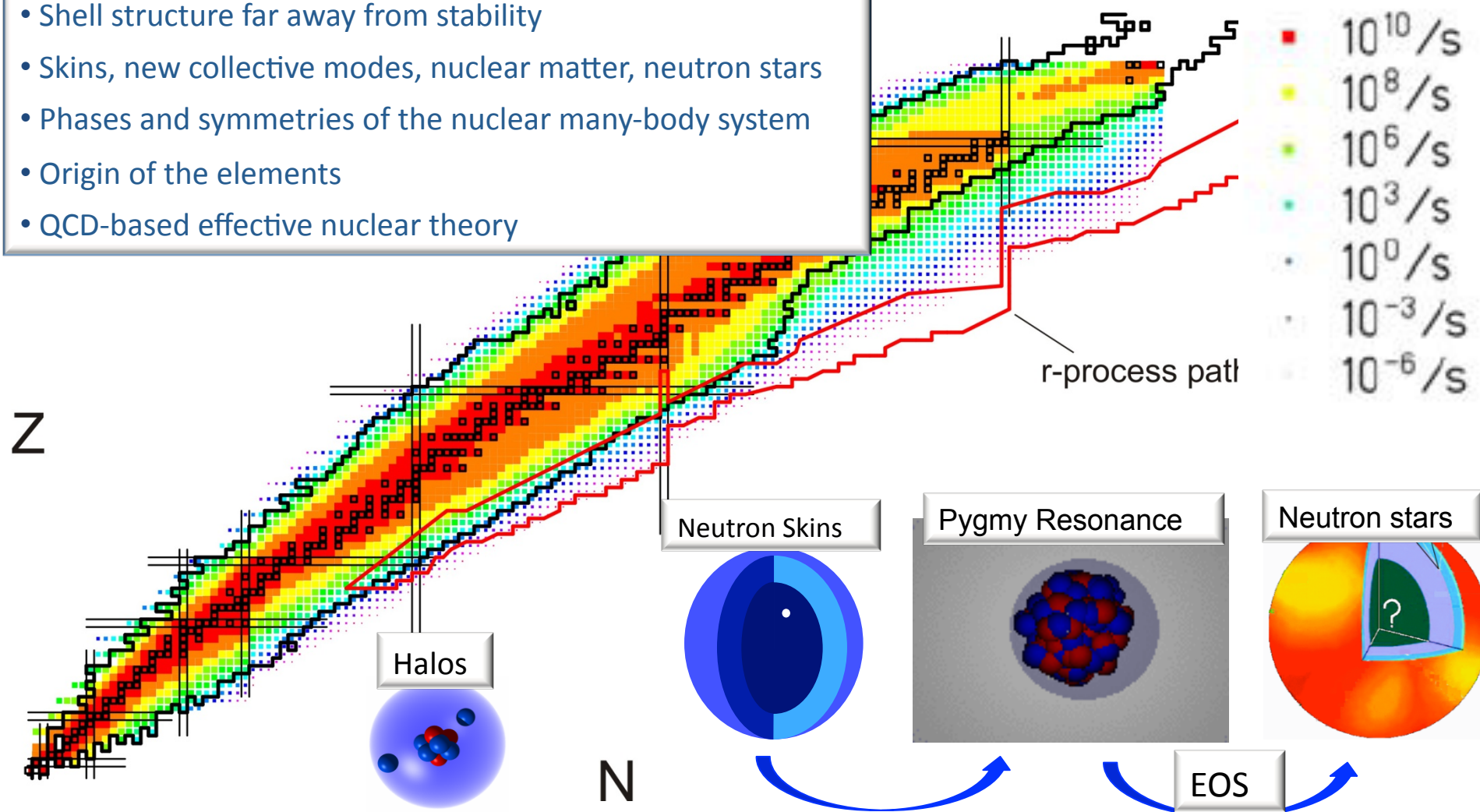
APPA – Atomic/Plasma Physics & Applications

- SPARC Stored Particles Atomic physics Research Collaboration
 - QED in non-pert. regime, precision measurement of fundamental constants, influence of atomic structure on nuclear decay
- FLAIR Facility for Low-energy Antiproton Ion Research
 - tests of CPT and QED with antiprotonic atoms and anithyogen
- HEDgeHOB Plasma physics
 - heavy ion heating and expansion (uniform heating of large-volume dense target, isentropic expansion)
 - laboratory for planetary science (ring-shaped beam implodes a heavy tamper shell)
- BIOMAT
 - material science, radiation hardness
 - anti-proton therapy



NuSTAR – Nuclear STructure, Astrophysics and Reactions

- Quest for the limits of existence
- Halos, open quantum systems, few-body correlations
- 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
- QCD-based effective nuclear theory



Non-GSI/FAIR Nuclear Structure Activities

Superconducting Darmstadt Linear
Electron Accelerator (S-DALINAC)
DFG-Center SFB 634 „Nuclear Structure, Nuclear
Astrophysics at the S-DALINAC“

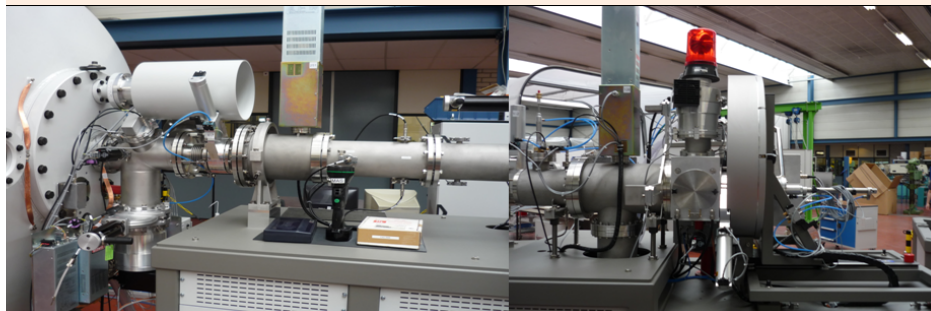


Munich
Emperor-TANDEM
Instrument of
DFG-Excellence
Cluster „Universe“



AGATA
significant
contribution
to detector and
experiments in
NuSTAR

Cologne FN-TANDEM
new AMS-TANDEM 6 M€ from DFG



ISOLDE @ CERN
funded by BMBF



PANDA – Antiproton Annihilation

Micro Vertex Detector

Straw Tube Tracker

GEM Detectors

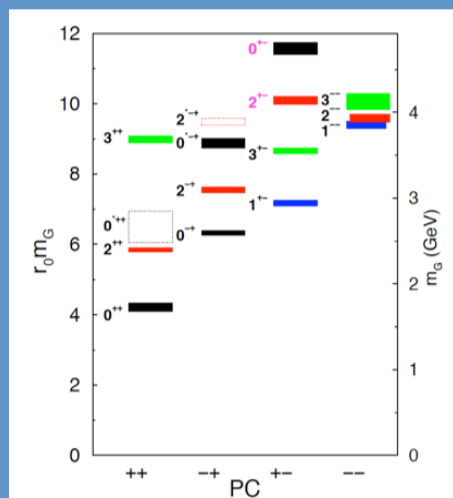
Forward Tracking System

Shashlyk Calorimeter

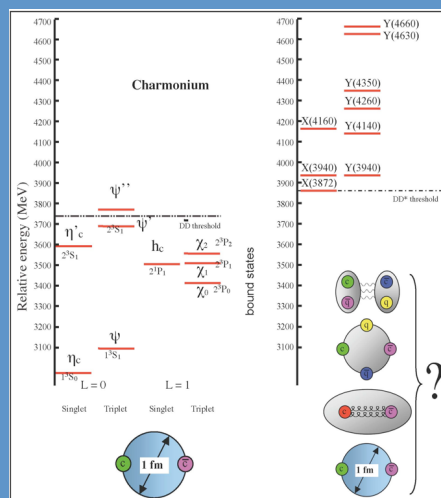
Muon Range System

Targetsystem

QCD exotics

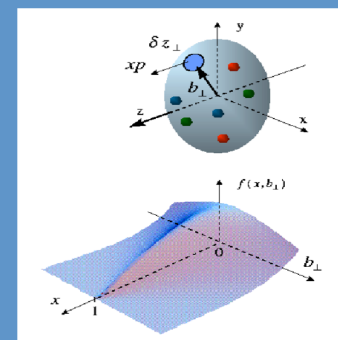


Glueballs
of all q.n.

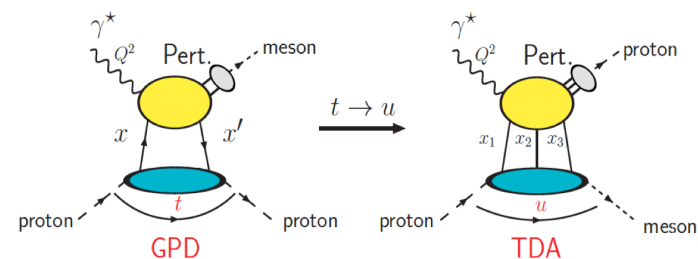


XYZ states
and their properties

Nucleon structure



From GPDs to TDAs



Muon Detection

EM Calorimeter

Barrel DIRC

KHUK Hadron Physics Facilities

Electron stretcher ELSA
 $E_{\max}=3.5$ GeV
 DFG TR 16, Subnuclear
 Structure of Matter
 Polarized photon beam



Univ. Bonn

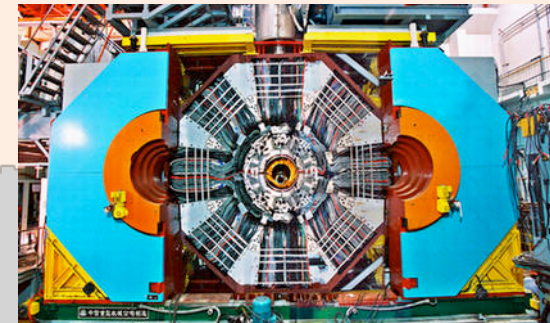
Muon and hadron beams
 SPS 160/190 GeV
 fixed target (polarized)



CERN

Univ. Mainz

e+e- collider BEP-C II with
 $\sqrt{s} = 2 \dots 4.5$ GeV (' τ -charm-factory')



BES-III/Beijing IHEP

OLYMPUS
 Olympus/DESY
 Fixed target e

scattering
 at DORIS ring

COSY/Jülich

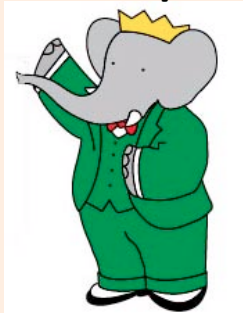


Cooled proton synchrotron
 COSY $p_{\max}=3.7$ GeV/c,
 Internal/external expts.



CW electron/photon facility MAMI
 $E_{\max}=1.6$ GeV,
 High beam intensity,
 resolution, polarization
 DFG-Center SFB 1044: The Low-
 Energy Bound of the Standard
 Model – From Quarks and Gluons
 to Hadrons and Nuclei
 PRISMA – Cluster of Excellence

BABAR/SLAC



e+e- collider PEP-II with
 $\sqrt{s} = 10.6$ GeV ('B-factory')

KHUK Hadron Physics Topics

- baryon spectroscopy
- chiral dynamics and nuclear effective field theory



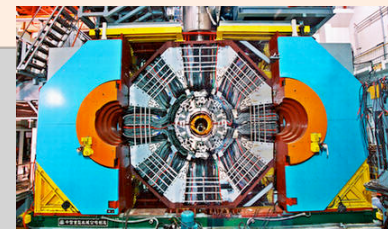
Univ. Bonn

- deep inelastic muon scattering
- bound states
- gluonic excitations
- hadron structure at low Q^2

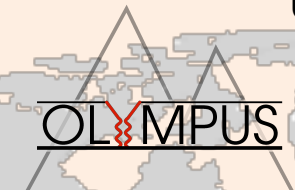


CERN

- charm(onium) and light quark spectroscopy, exotic bound states
- low-energy QCD, el.magn. FFs
- open charm flavour physics
- precision tests of the SM



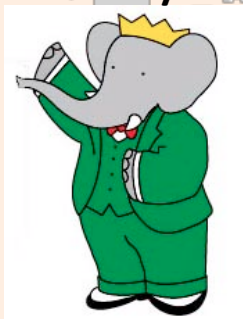
↖ BES-III



Olympus/DESY

- two-photon contribution to e p scattering

↖ BABAR/SLAC



- flavor physics (B, D mesons, τ),
- charm(onium) and light quark spectroscopy,
- low-energy QCD, el.magn. FFs
- precision tests of the SM

COSY/Jülich



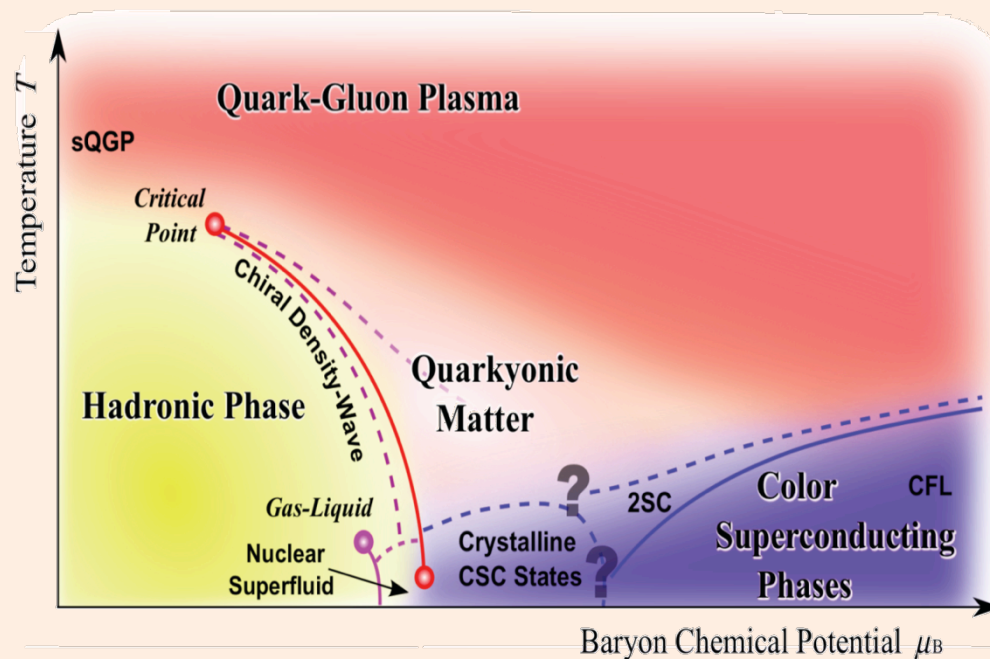
- production and decay of light mesons
- baryon spectroscopy
- spin physics



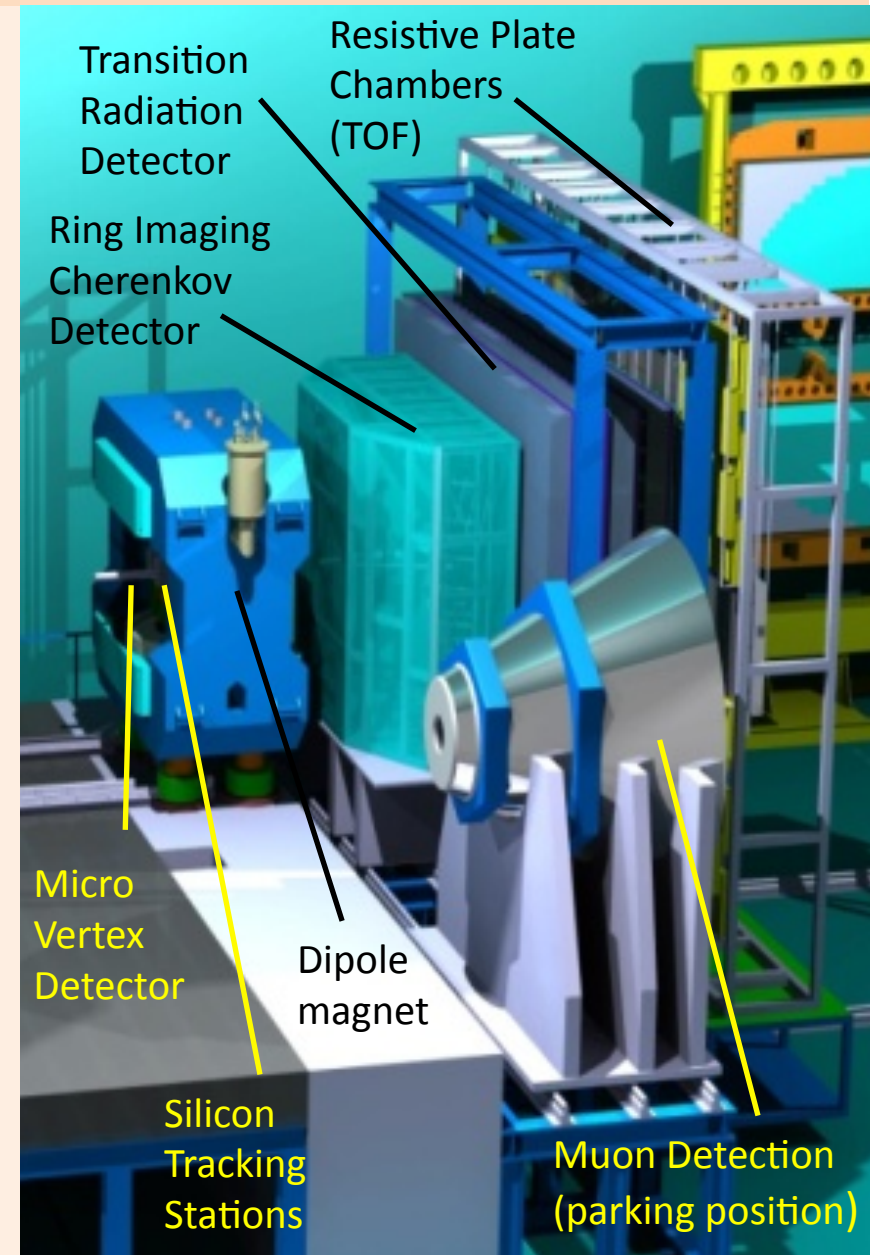
Univ. Mainz

- low-energy QCD
- el.magn. FFs and polarizabilities
- baryon spectroscopy, meson decays
- few-body physics, Hypernuclei
- dark photons
- precision tests of the SM ($\sin^2\Theta_W$)

CBM – Compressed Baryonic Matter



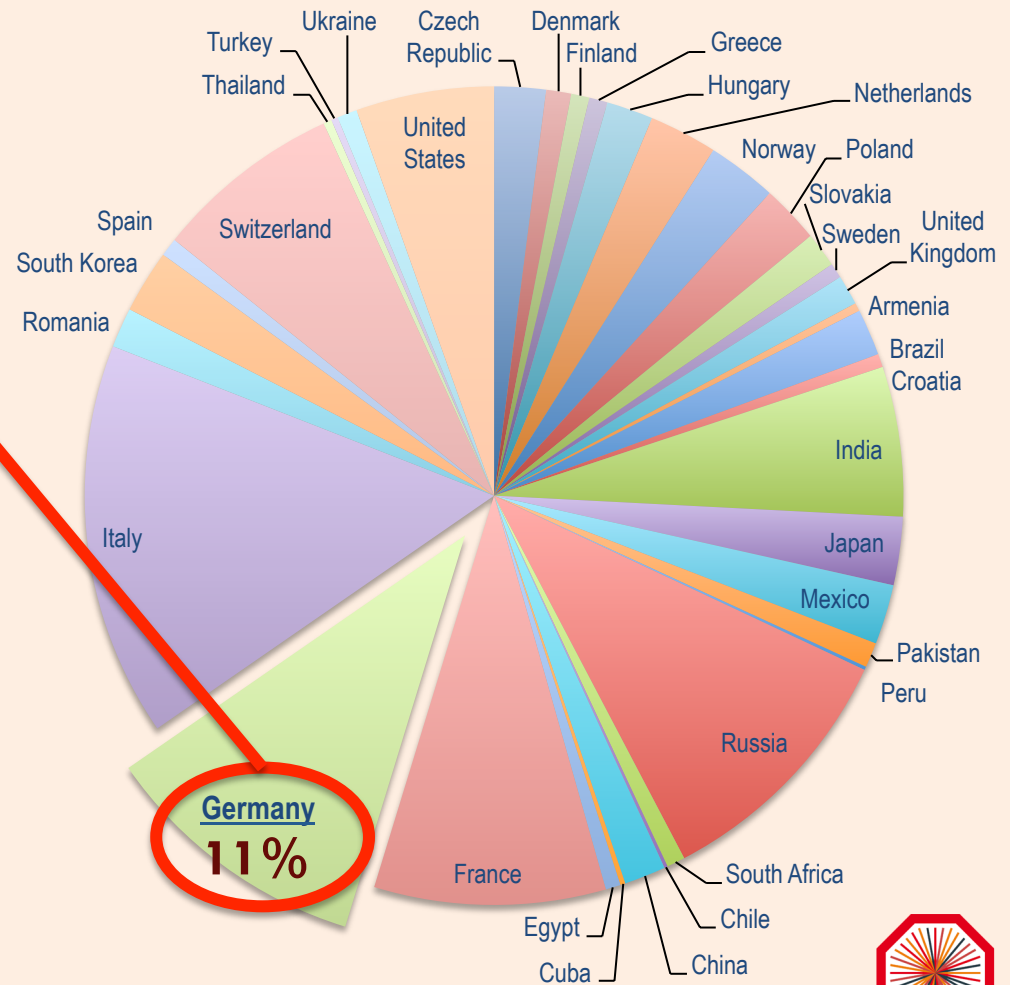
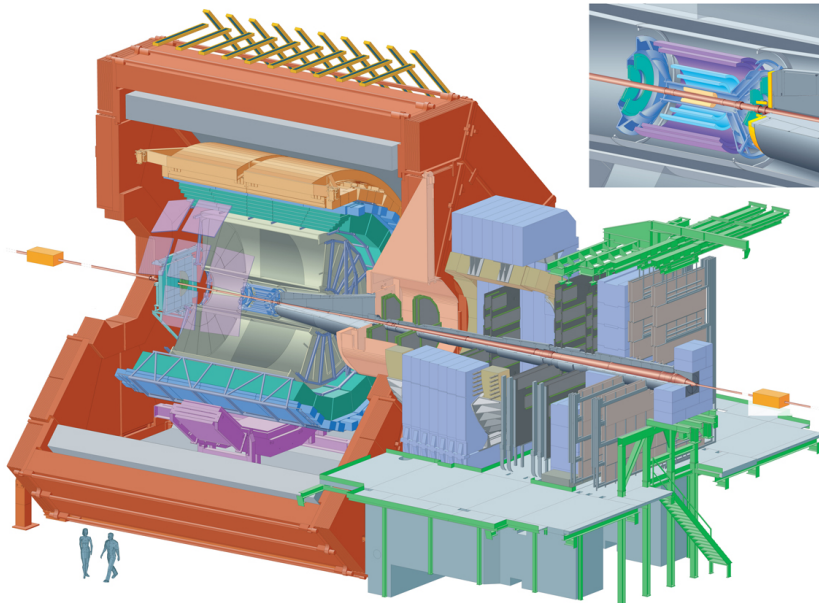
- Equation-of-state of matter at neutron star core densities.
- Phase transitions from hadronic matter to quarkyonic or partonic matter at high net-baryon densities.
- Electro-magnetic radiation from the dense fireball.
- Chiral symmetry restoration in dense baryonic matter.
- Charm production in (dense) nuclear matter at threshold energies.
- Hypernuclei, strange dibaryons, massive strange objects.
- Challenge: 10 MHz interaction rate on fixed target



ALICE – QCD Matter at the LHC

1472 People* – 148 Institutes – 36 Countries - 161 MCHF capital invest

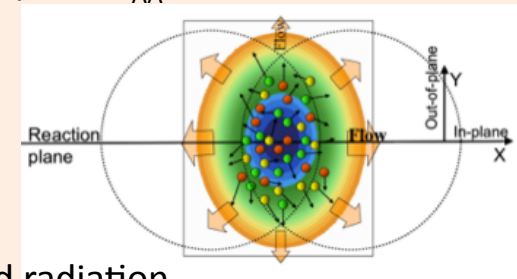
German contributions:
Time Projection Chamber (TPC)
Transition Radiation Detector (TRD)
High Level Trigger (HLT)
High Performance Computing Center (GridKA) German Tier-1



*Alice Collaboration Data Base (ACDB), January, 2014

ALICE – QCD Matter at the LHC

- **Run 1, Run 2**
 - established production of hottest, densest and longest-lived quark gluon plasma phase.
 - strong jet quenching: first indications of differences in quark mass and color transport in medium.
 - approved for 1/nb
- **Upgrade for precision measurements of QGP**
 - **Measurement of heavy-flavour transport parameters**
 - Diffusion coefficient (QGP eq. of state, h/s) \rightarrow HF azimuthal anisotropy and R_{AA}
 - In-medium thermalization and hadronization \rightarrow HF baryons
 - Mass dependence of energy loss \rightarrow HF R_{AA}
 - **Measurement of low-mass and low- p_t di-electrons**
 - Chiral symmetry restoration \rightarrow ρ spectral function
 - g production from QGP \rightarrow low-mass dilepton continuum
 - Space-time evolution of the QGP \rightarrow radial and elliptic flow of emitted radiation
 - **J/ψ , ψ' , and χ_c states down to zero p_t**
 - statistical hadronization vs. dissociation/recombination scenario
 - transition between low and high transverse momenta
 - density dependence – central vs. forward production
 - **Heavy nuclear states**
 - mass-4 and -5 (anti-)hypernuclei
 - search for H-dibaryon, Ln bound states, etc.



➡ **requires**
high statistics 10/nb
larger compression,
bandwidth (*10)
low p_T measurements

ALICE Upgrade During Long Shutdown 2

New Inner Tracking System (ITS)

- improved pointing resolution
- less material -> thinnest tracker at the LHC

Time Projection Chamber (TPC)

- new GEM technology for readout Chambers
- continuous readout
- faster readout electronics

New Central Trigger Processor

Data Acquisition (DAQ)/ High Level Trigger (HLT)

- new architecture
- online tracking & data compression
- 50kHz PbPb event rate

Muon Forward Tracker (MFT)

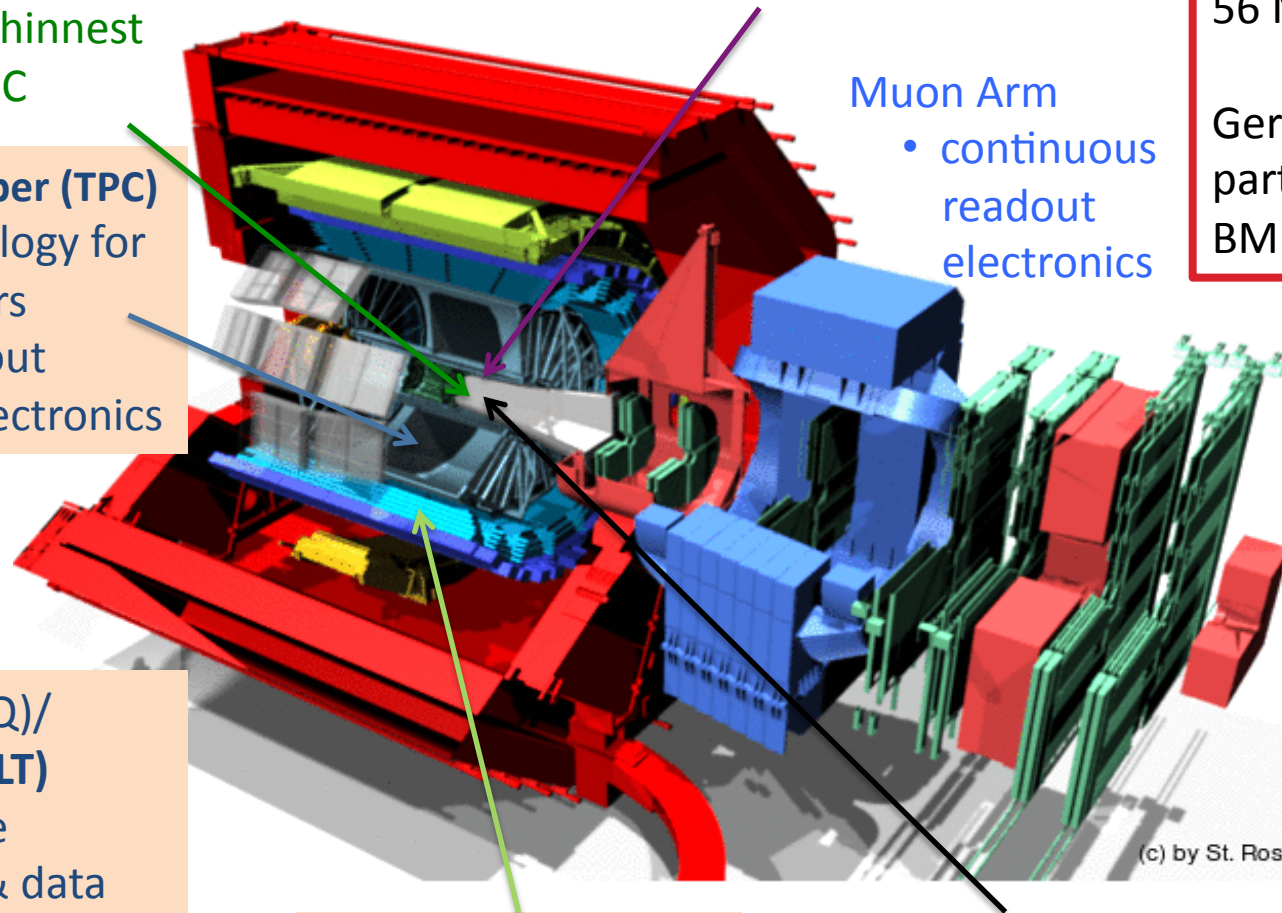
- new Si tracker
- Improved MUON pointing precision

Muon Arm

- continuous readout electronics

Total cost incl. R&D:
56 MCHF

German part via
BMBF, HGF



TOF, TRD

- Faster readout

New Trigger
Detectors (FIT)



KHUK Special Initiatives

- BMBF “Forschungsschwerpunkte”
 - special funding for collaborative efforts and outreach of BMBF funded large-scale projects (ALICE, NuSTAR, PANDA)
- Helmholtz initiatives
 - Alliance - ExtreMe Matter Institute (EMMI)
18.8 MEuro (6 years) focus on **interdisciplinary studies of matter under extreme conditions**: quark-gluon plasma and QCD phase diagram, neutron matter, plasma physics, atomic physics and ultra-cold quantum gases.
18 new tenured positions and 54 MEuro matching funds pledged by partners. -> will become part of the MUTlink Initiative
 - HIC4FAIR
Think tank for forefront theoretical and experimental research associated with FAIR. -> recommended for continuation by Helmholtz
Funding for 26 professorships at Hessian universities in conjunction with state excellence program LOEWE.
- EU – Horizon 2020
 - networking, joint research initiatives and access to research infrastructures (HadronPhysics HPH2020, Eurons, Ensar...)



Funding BMBF

- Shortly after the last call for proposals the BMBF decided to handle the grant administration via PT-DESY
- Following the 'Strategiegespräch' (14-15 May) the BMBF decided to issue a common call for proposals from KET and KHuK in order to facilitate easier communication within the ministry
- Decision was viewed with skepticism both by KHuK and KET
- Deadline for the call for proposals is November, 1
- A joint enlarged 'Gutachterausschuss' will handle the proposals from nuclear, particle and accelerator physics
- It has been agreed that the funding corridor for the different fields will remain unchanged
- Additional funding will be sought for the large LHC upgrades of ATLAS and CMS ('Schätzerkonferenz' to initiate additional funding has already taken place)

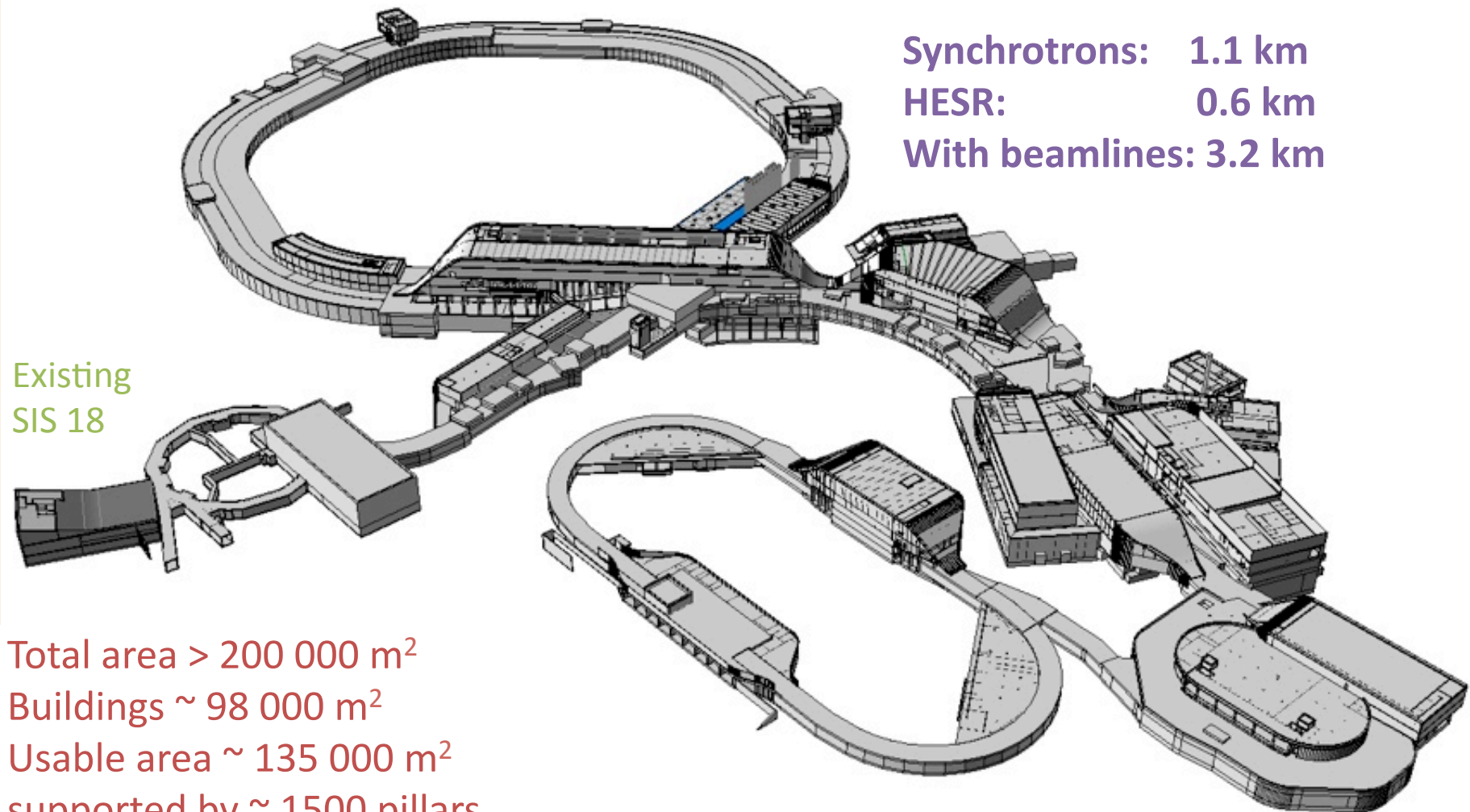
Backup

Mandate of KHUK

- Develop strategies for hadron and nuclear physics in Germany
- Provide access to national and international research infrastructures
- Coordinate interests of universities, national labs and Max-Planck institutes
- Representation of community in international bodies (NuPECC, etc.)
- Promotion of young academics
- Public outreach

Membership: elected members and representatives of other committees (particle physics, astroparticle physics, accelerator physics), DFG, DPG and NuPECC

FAIR – Civil Construction



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

Existing
SIS 18

Total area > 200 000 m²
Buildings ~ 98 000 m²
Usable area ~ 135 000 m²
supported by ~ 1500 pillars
up to 65 m deep

FAIR – Civil Construction Progress



FAIR – Timeline Experiments

