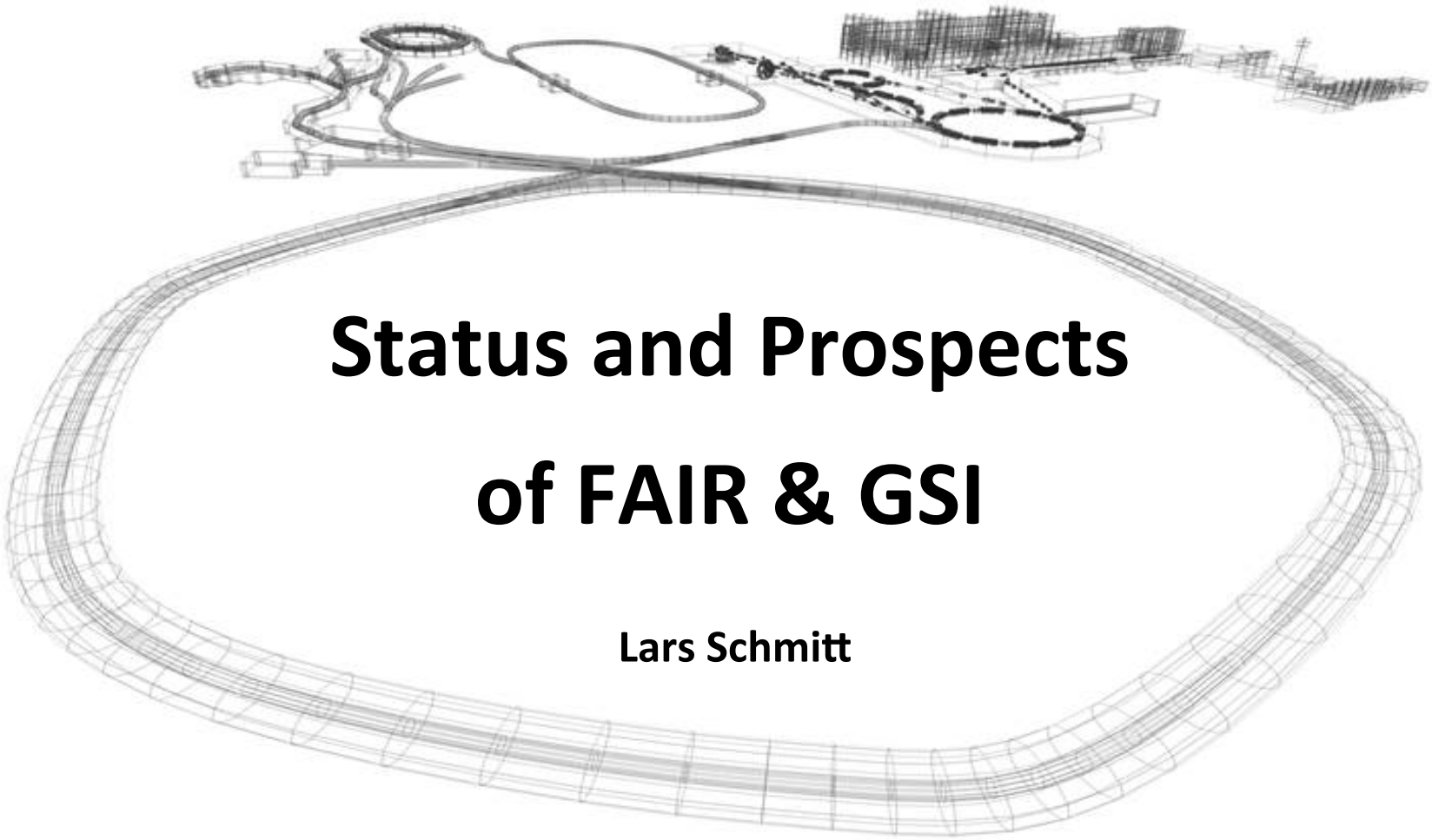
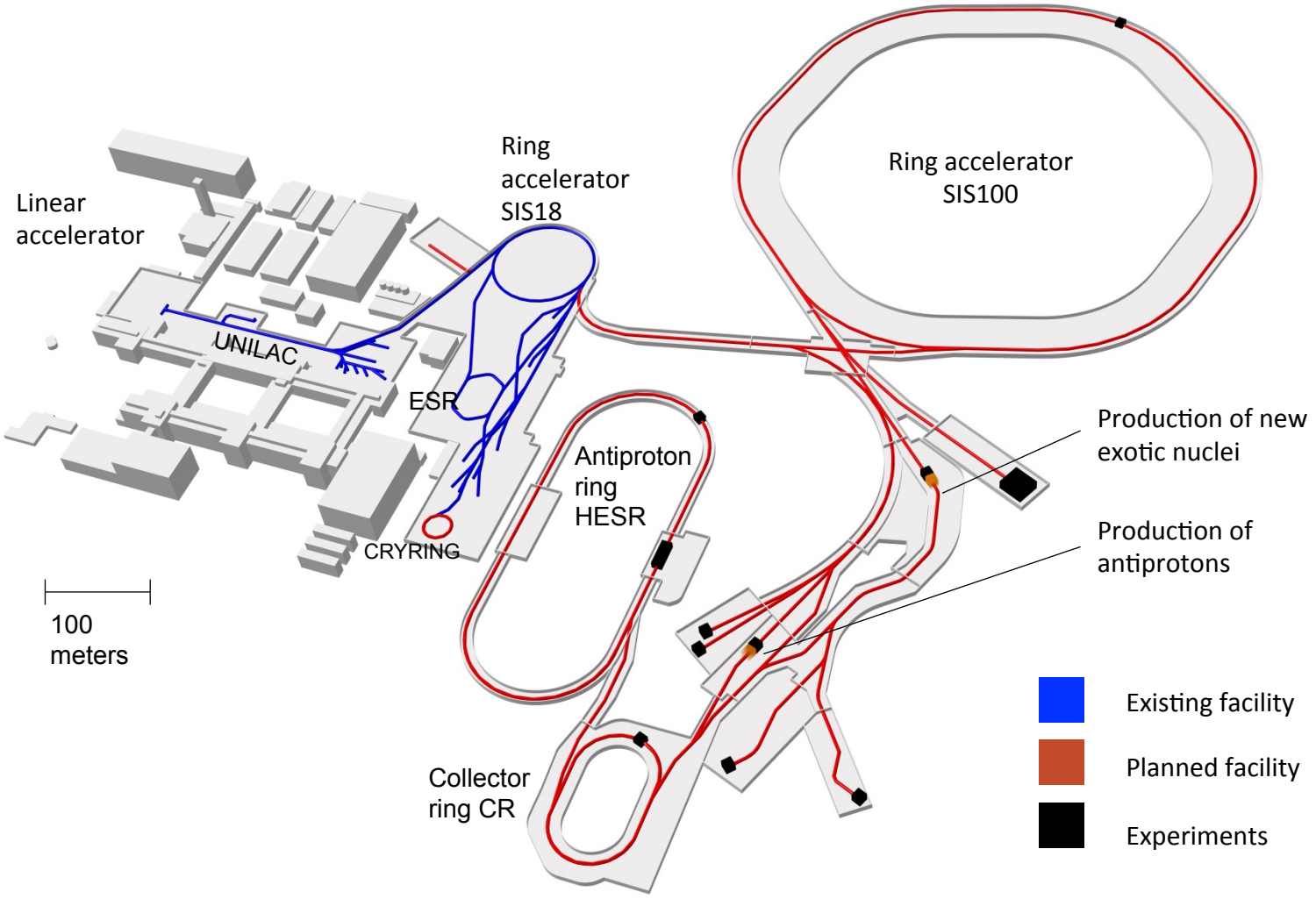


Status and Prospects of FAIR & GSI

Lars Schmitt

FAIR – The Facility



FAIR – The Facility

FAIR

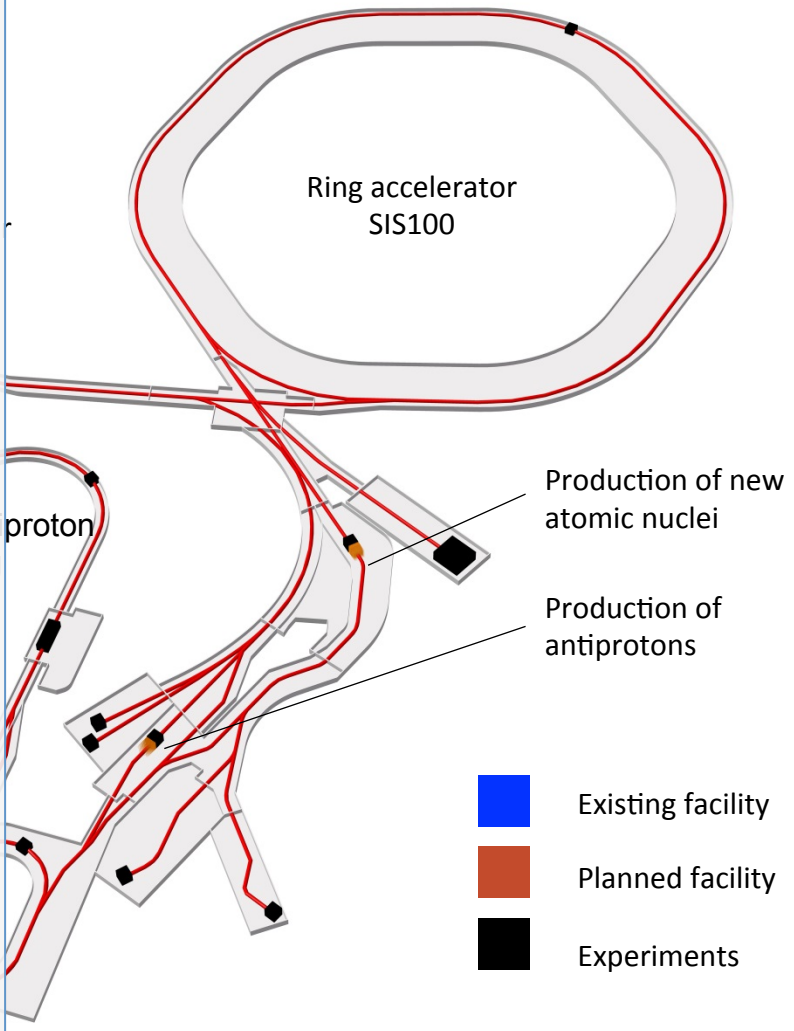
... accelerates particle beams from (anti)protons up to uranium ions with

- very high intensities
  - up to a factor of ~100 increase for primary Uranium beams (~ 5 x 10^{11} U^{28+} ions /s),
  - up to a factor of ~10.000 increase for secondary rare isotope beams
- high pulse power (up to ~ 50 kJ / 50 ns)
- suite of storage cooler rings equipped with stochastic and electron cooling for brilliant beam quality

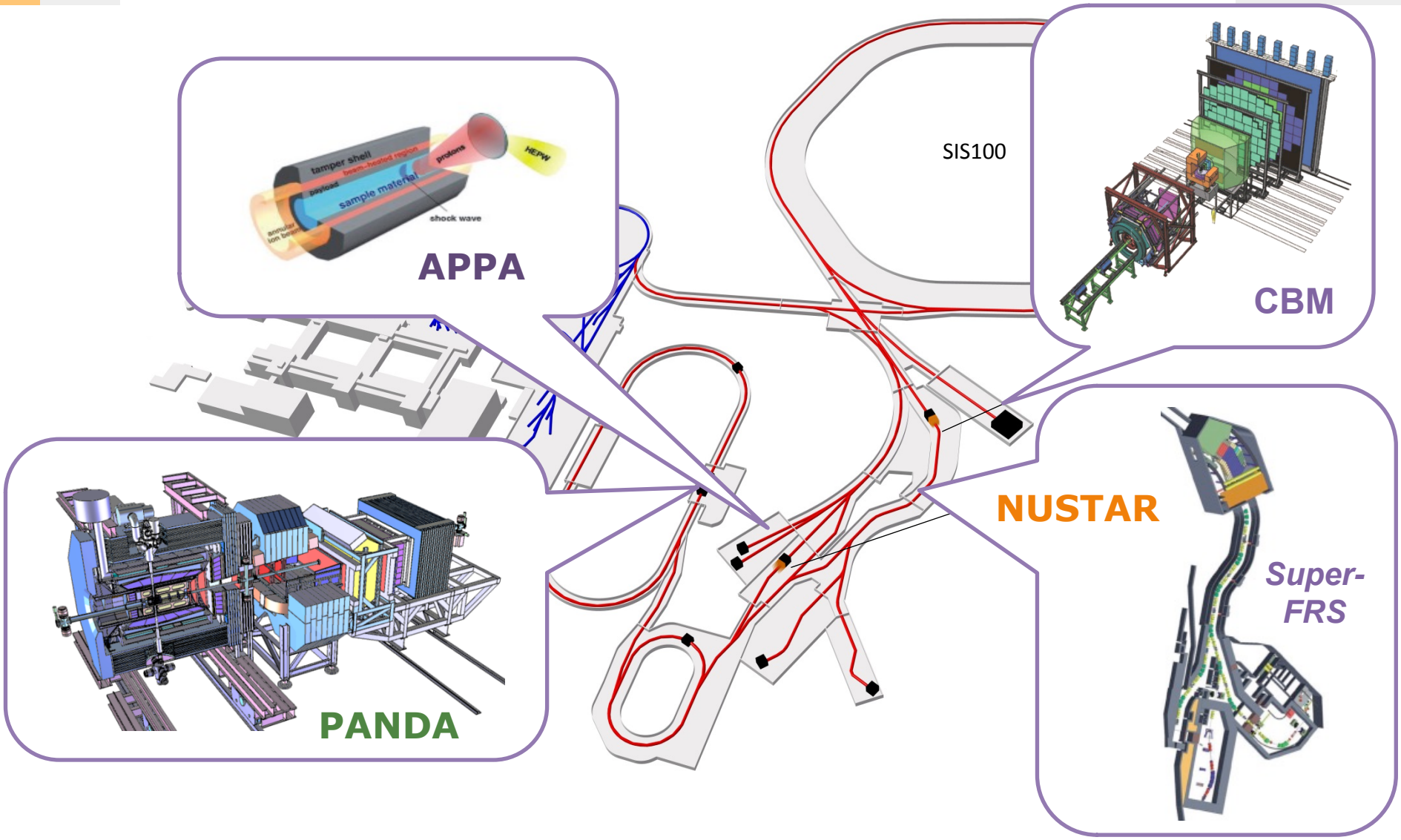
... develops and exploits innovative particle separation and detection methods, as well as novel computing techniques

... to perform forefront experiments towards the production and investigation of

New Extreme States of Matter.



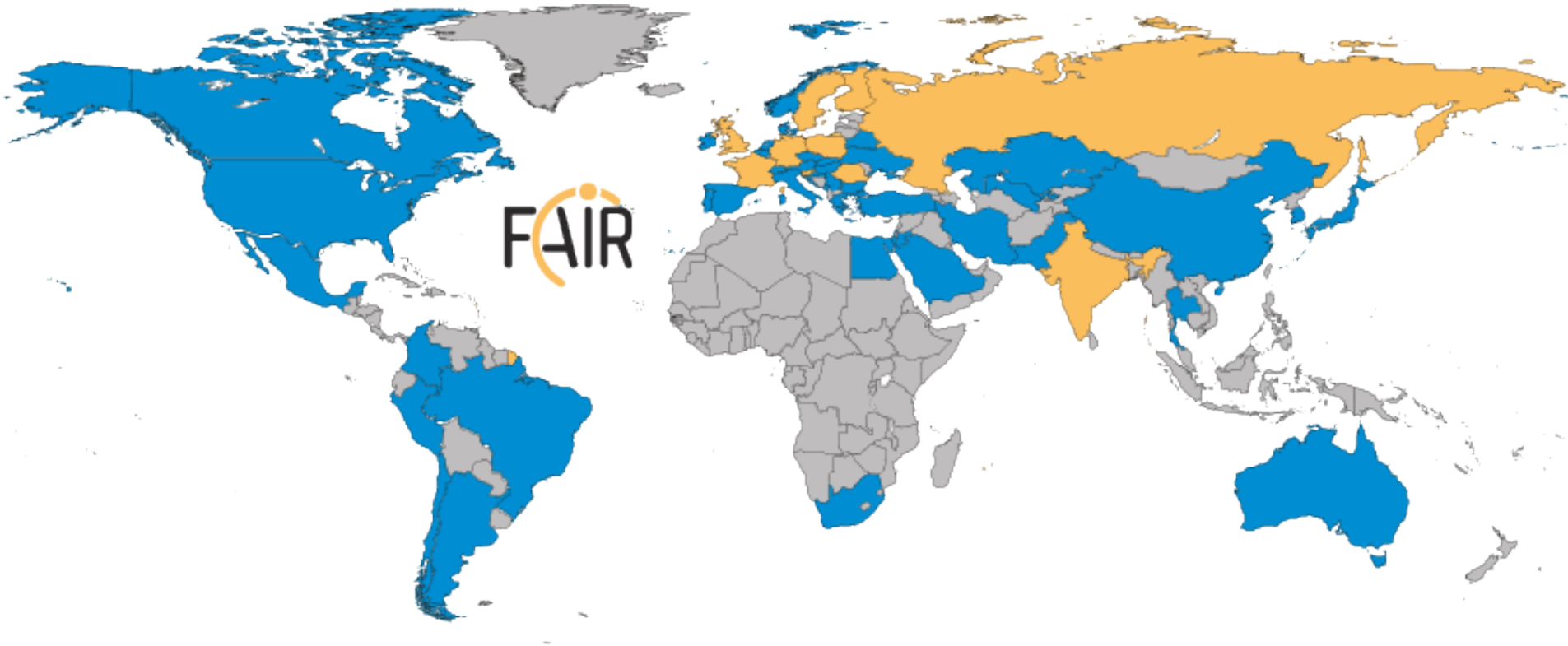
FAIR – four research pillars



Four Scientific Collaborations

APPA	▪ Atomic Physics and Fundamental Symmetries, ▪ Plasma Physics, ▪ Materials Research, ▪ Radiation Biology, ▪ Cancer Therapy with Ion Beams / Space Res.
CBM	▪ Dense and Hot Nuclear Matter
NUSTAR	▪ Nuclear Structure far off stability, Physics of Explosive Nucleosynthesis (r process)
PANDA	▪ Hadron Structure & Dynamics with cooled antiproton beams

FAIR: International Cooperation

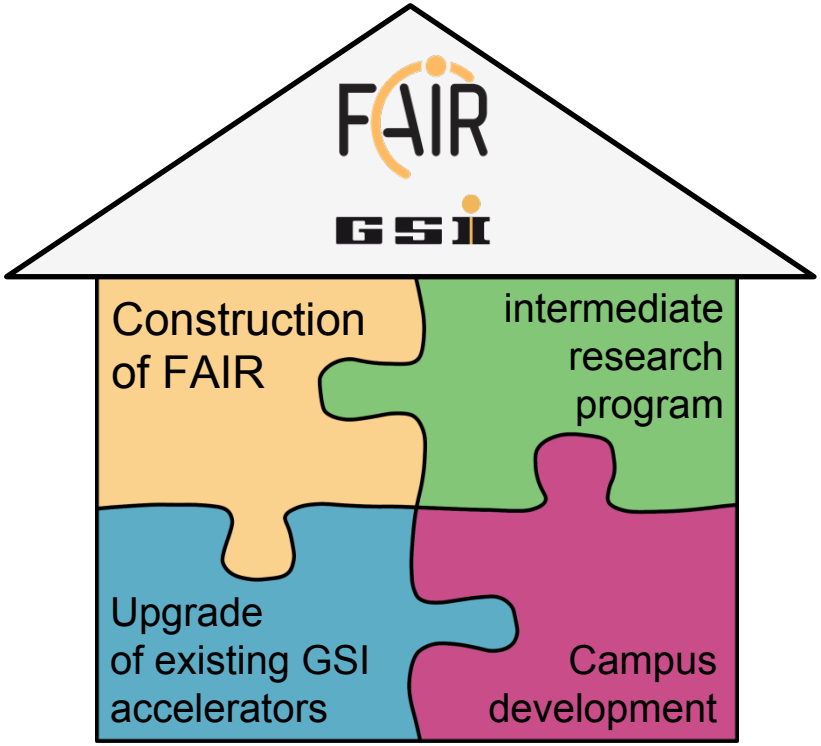


- Realization and operation in international cooperation
- Nine international shareholders
- Participation of 3.000 scientists from all continents

Challenges and Priorities in the Forthcoming Years

- Build FAIR and develop GSI for FAIR - in time and to budget

- Making FAIR a success requires:
  - a strong host laboratory with world-class facilities and a leading role in the international scientific arena
  - a vibrant scientific community, in particular young researchers, performing a first-class intermediate research program
  - a modern campus with appropriate infrastructure for the employees and the international users



FAIR Civil Construction

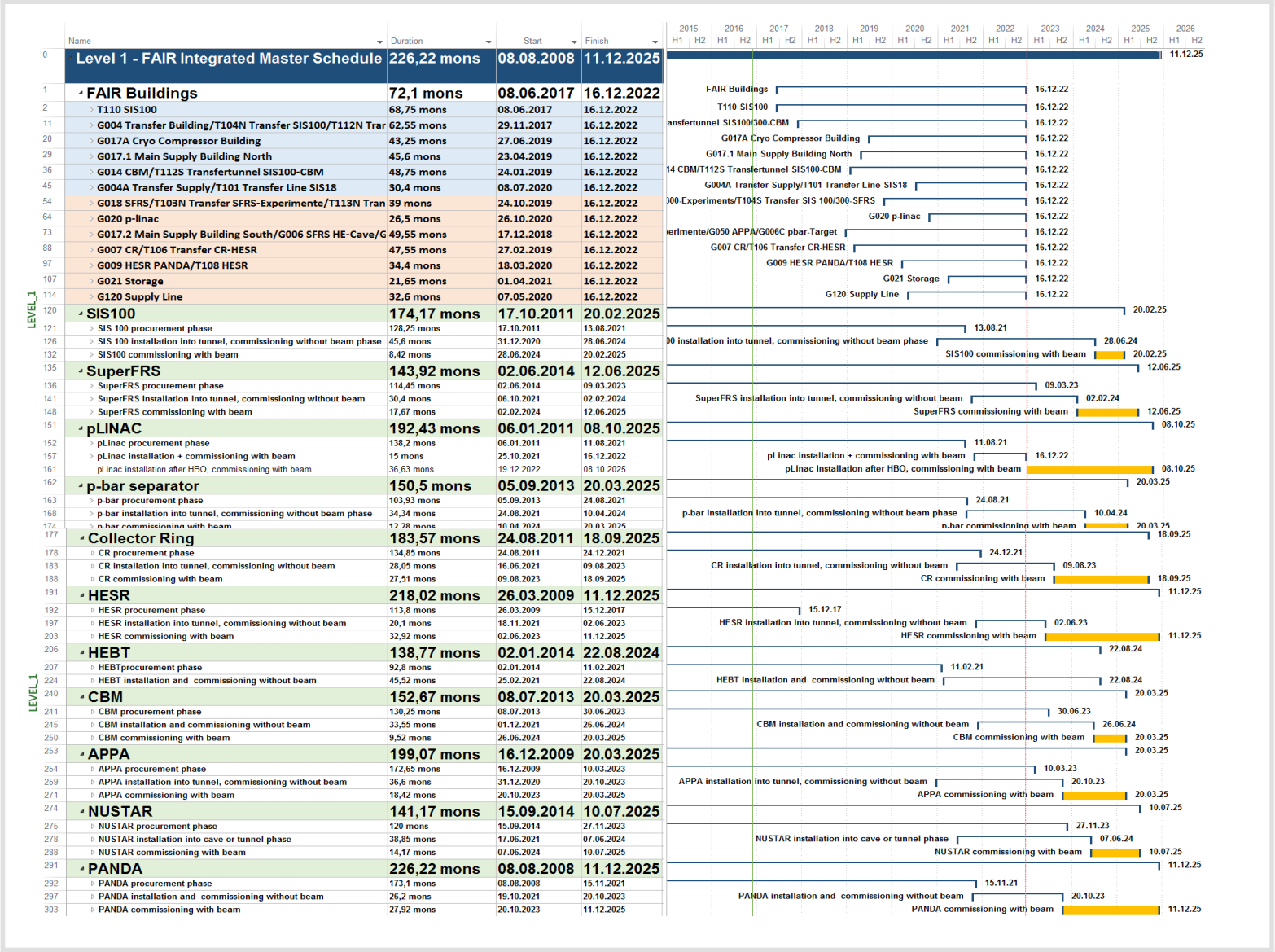
FAIR Civil Construction: Next Steps

- Inquiry for ground works for construction area north
  - published EU wide on 26th September 2016 -done✓
  - contract award scheduled for May 2017-done✓
  - start of site works in summer 2017
    ground breaking ceremony July 4, 2017
- Inquiry for building shell for construction area north
  - published EU wide in November 2016 -done✓
  - prequalification of bidders in Q1/2017-done✓
  - contract award in Q4/2017
  - start of site works on building shell end Q1/2018
- Further inquiries and contract awards as per project master time schedule

FAIR Civil Construction: Onsite Preparations

- Transformer stations North & South: Construction of transformer building
- Retaining wall at SIS 18: Concrete works of wall sections
- GSI attachment to FAIR (GAF):
  - Drilling of piles & wall cutting for tunnel 110
  - Concrete bars of SIS18 table
  - Opening of the tunnel SIS 18

Integrated Project Time Schedule – Level 1: FAIR Buildings, Accelerators & Experiments

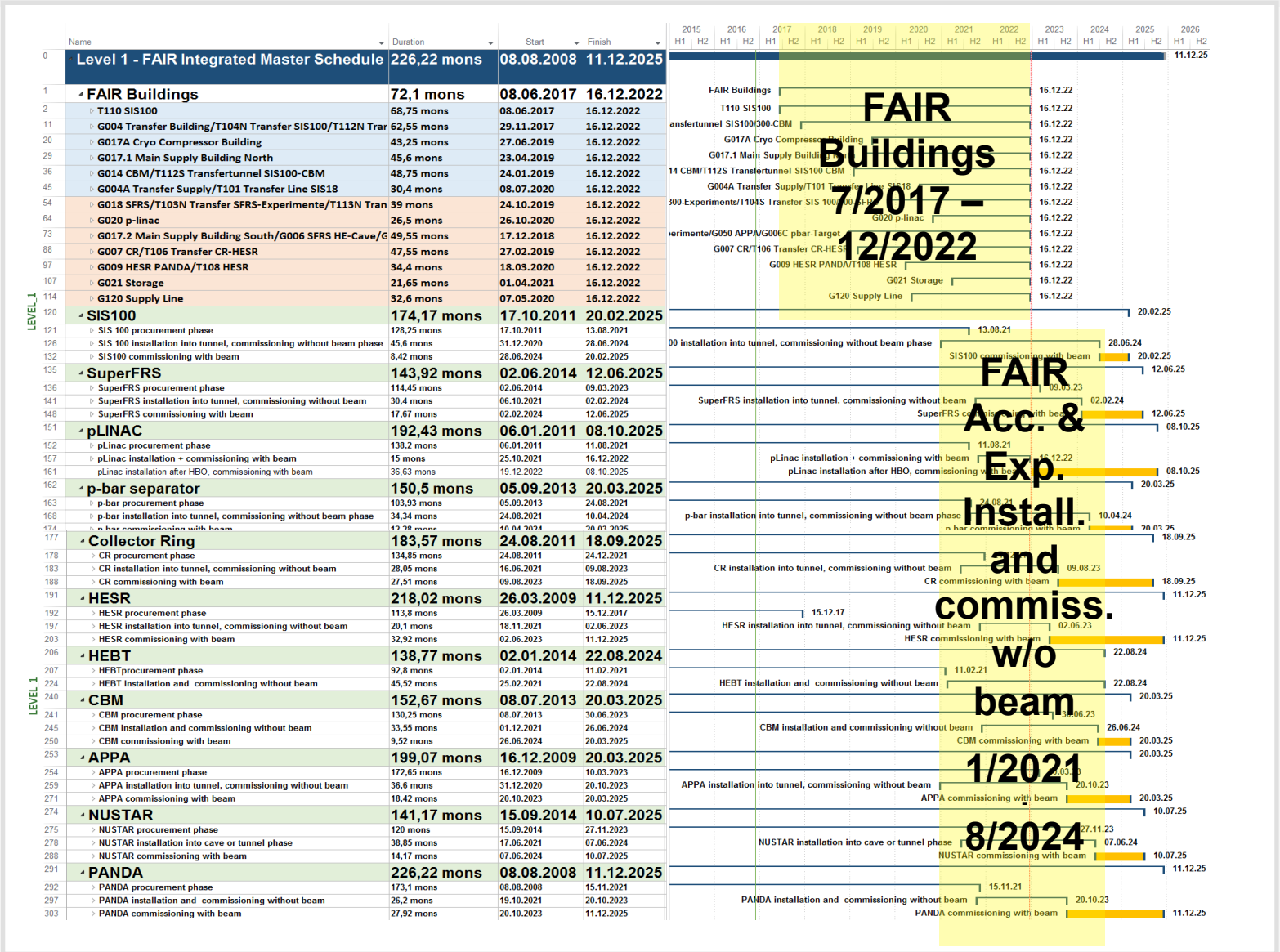


	Name	Duration	Start	Finish
0	**Level 1 - FAIR Integrated Master Schedule**	**226,22 mons**	**08.08.2008**	**11.12.2025**
1	**FAIR Buildings**	**72,1 mons**	**08.06.2017**	**16.12.2022**
2	T110 SIS100	68,75 mons	08.06.2017	16.12.2022
11	G004 Transfer Building/T104N Transfer SIS100/T112N Trar	62,55 mons	29.11.2017	16.12.2022
20	G017A Cryo Compressor Building	43,25 mons	27.06.2019	16.12.2022
29	G017.1 Main Supply Building North	45,6 mons	23.04.2019	16.12.2022
36	G014 CBM/T112S Transfertunnel SIS100-CBM	48,75 mons	24.01.2019	16.12.2022
45	G004A Transfer Supply/T101 Transfer Line SIS18	30,4 mons	08.07.2020	16.12.2022
54	G018 SFRS/T103N Transfer SFRS-Experimente/T113N Tran	39 mons	24.10.2019	16.12.2022
64	G020 p-linac	26,5 mons	26.10.2020	16.12.2022
73	G017.2 Main Supply Building South/G006 SFRS HE-Cave/G	49,55 mons	17.12.2018	16.12.2022
88	G007 CR/T106 Transfer CR-HESR	47,55 mons	27.02.2019	16.12.2022
97	G009 HESR PANDA/T108 HESR	34,4 mons	18.03.2020	16.12.2022
107	G021 Storage	21,65 mons	01.04.2021	16.12.2022
114	G120 Supply Line	32,6 mons	07.05.2020	16.12.2022
120	**SIS100**	**174,17 mons**	**17.10.2011**	**20.02.2025**
121	SIS 100 procurement phase	128,25 mons	17.10.2011	13.08.2021
126	SIS 100 installation into tunnel, commissioning without beam phase	45,6 mons	31.12.2020	28.06.2024
132	SIS100 commissioning with beam	8,42 mons	28.06.2024	20.02.2025
135	**SuperFRS**	**143,92 mons**	**02.06.2014**	**12.06.2025**
136	SuperFRS procurement phase	114,45 mons	02.06.2014	09.03.2023
141	SuperFRS installation into tunnel, commissioning without beam	30,4 mons	06.10.2021	02.02.2024
148	SuperFRS commissioning with beam	17,67 mons	02.02.2024	12.06.2025
151	**pLINAC**	**192,43 mons**	**06.01.2011**	**08.10.2025**
152	pLinac procurement phase	138,2 mons	06.01.2011	11.08.2021
157	pLinac installation + commissioning with beam	15 mons	25.10.2021	16.12.2022
161	pLinac installation after HBO, commissioning with beam	36,63 mons	19.12.2022	08.10.2025
162	**p-bar separator**	**150,5 mons**	**05.09.2013**	**20.03.2025**
163	p-bar procurement phase	103,93 mons	05.09.2013	24.08.2021
168	p-bar installation into tunnel, commissioning without beam phase	34,34 mons	24.08.2021	10.04.2024
174	p-bar commissioning with beam	12,28 mons	10.04.2024	20.03.2025
177	**Collector Ring**	**183,57 mons**	**24.08.2011**	**18.09.2025**
178	CR procurement phase	134,85 mons	24.08.2011	24.12.2021
183	CR installation into tunnel, commissioning without beam	28,05 mons	16.06.2021	09.08.2023
188	CR commissioning with beam	27,51 mons	09.08.2023	18.09.2025
191	**HESR**	**218,02 mons**	**26.03.2009**	**11.12.2025**
192	HESR procurement phase	113,8 mons	26.03.2009	15.12.2017
197	HESR installation into tunnel, commissioning without beam	20,1 mons	18.11.2021	02.06.2023
203	HESR commissioning with beam	32,92 mons	02.06.2023	11.12.2025
206	**HEBT**	**138,77 mons**	**02.01.2014**	**22.08.2024**
207	HEBTprocurement phase	92,8 mons	02.01.2014	11.02.2021
224	HEBT installation and commissioning without beam	45,52 mons	25.02.2021	22.08.2024
240	**CBM**	**152,67 mons**	**08.07.2013**	**20.03.2025**
241	CBM procurement phase	130,25 mons	08.07.2013	30.06.2023
245	CBM installation and commissioning without beam	33,55 mons	01.12.2021	26.06.2024
250	CBM commissioning with beam	9,52 mons	26.06.2024	20.03.2025
253	**APPA**	**199,07 mons**	**16.12.2009**	**20.03.2025**
254	APPA procurement phase	172,65 mons	16.12.2009	10.03.2023
259	APPA installation into tunnel, commissioning without beam	36,6 mons	31.12.2020	20.10.2023
271	APPA commissioning with beam	18,42 mons	20.10.2023	20.03.2025
274	**NUSTAR**	**141,17 mons**	**15.09.2014**	**10.07.2025**
275	NUSTAR procurement phase	120 mons	15.09.2014	27.11.2023
278	NUSTAR installation into cave or tunnel phase	38,85 mons	17.06.2021	07.06.2024
288	NUSTAR commissioning with beam	14,17 mons	07.06.2024	10.07.2025
291	**PANDA**	**226,22 mons**	**08.08.2008**	**11.12.2025**
292	PANDA procurement phase	173,1 mons	08.08.2008	15.11.2021
297	PANDA installation and commissioning without beam	26,2 mons	19.10.2021	20.10.2023
303	PANDA commissioning with beam	27,92 mons	20.10.2023	11.12.2025

LEVEL 1

LEVEL 1

Integrated Project Time Schedule – Level 1: FAIR Buildings, Accelerators & Experiments



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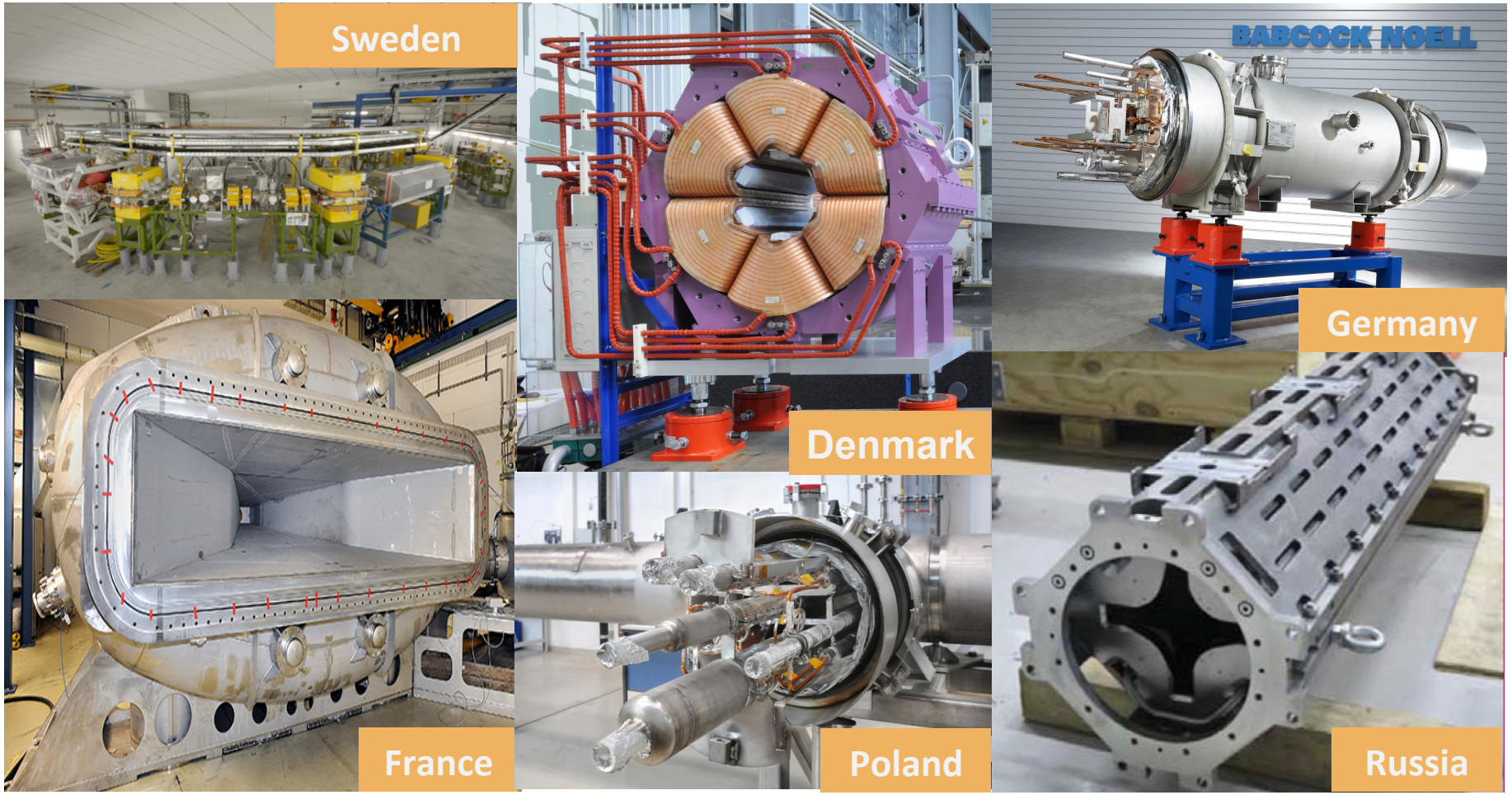
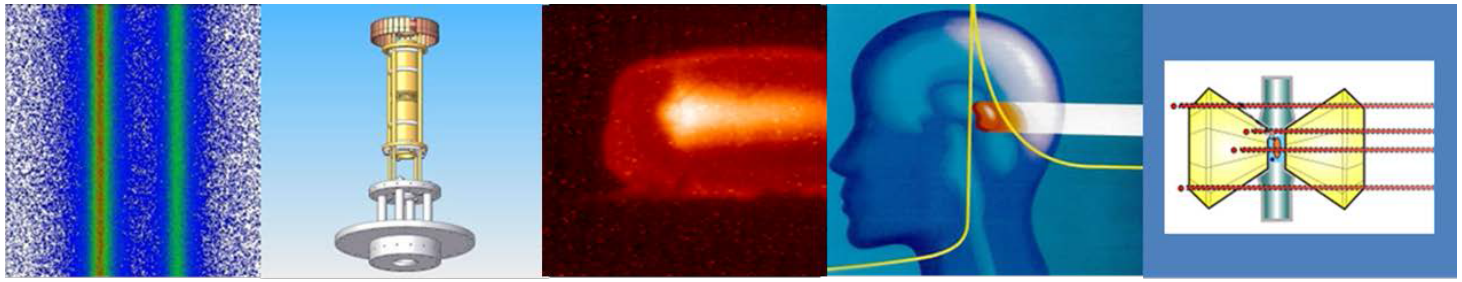
Procurement of FAIR components is in full swing ...



- Accelerator and detector contributions from many different partner institutions

The experiments advance!



From fundamental to applied research – Atomic physics, Plasma Physics, Application

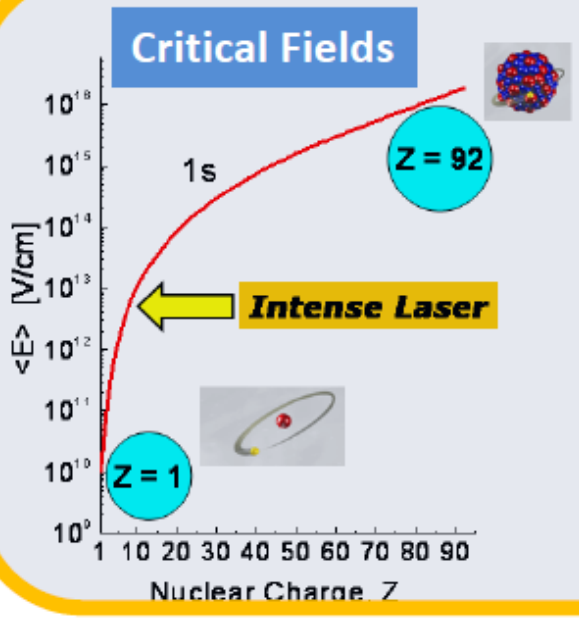
APPA

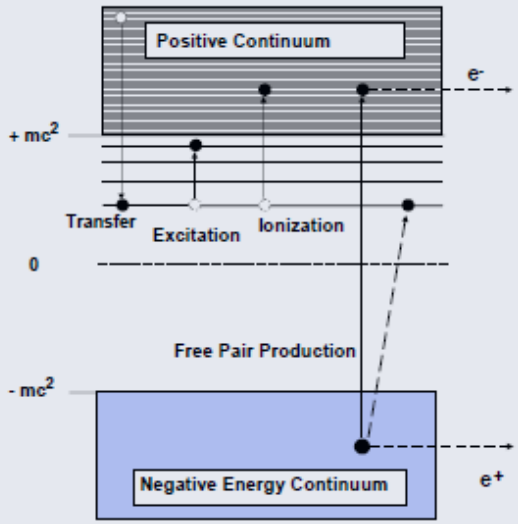
Atomic & Fundamental Physics

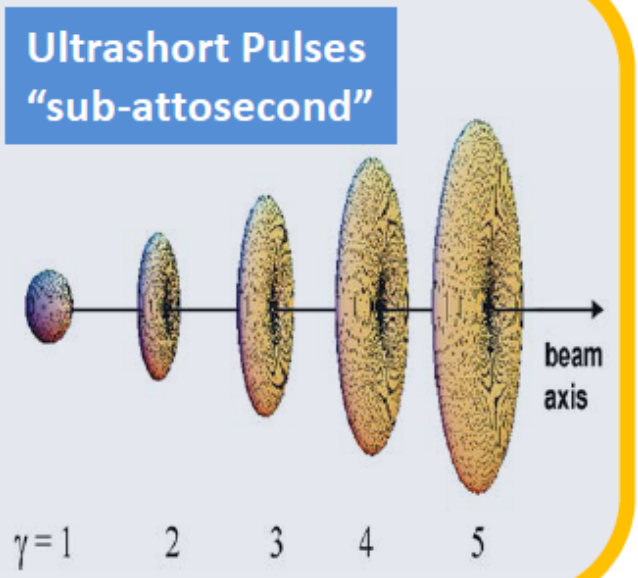
Interplay between Relativity, Correlation, and QED in the Non-Perturbative Regime

$$\alpha Z \approx 1$$

- Radiative corrections in the non-perturbative regime
- Correlated multi-body dynamics for atoms and ions
- Precision determination of fundamental constants
- Influence of atomic structure on nuclear decay properties







16

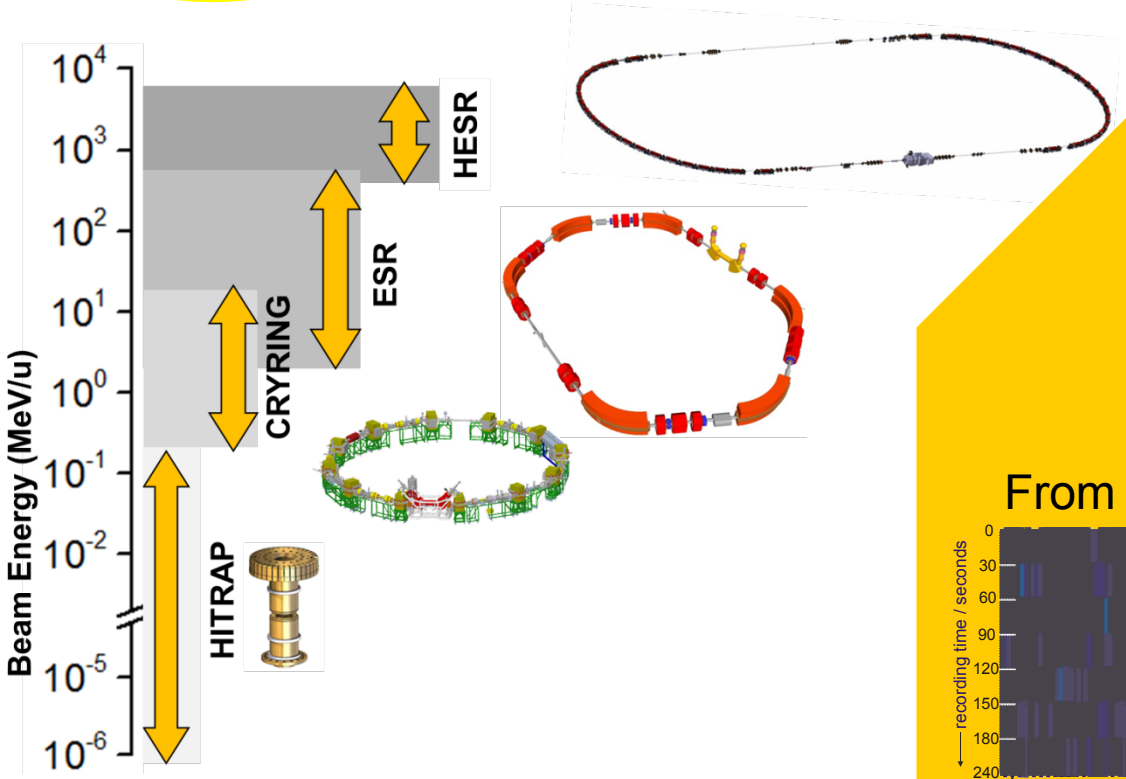
Ion Beam Facilities / Trapping & Storage

Worldwide Unique

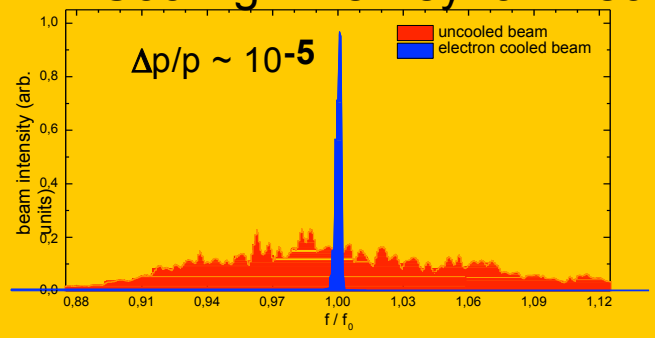
Stored and Cooled

Highly-Charged Ions (e.g. U^{92+}) and Exotic Nuclei

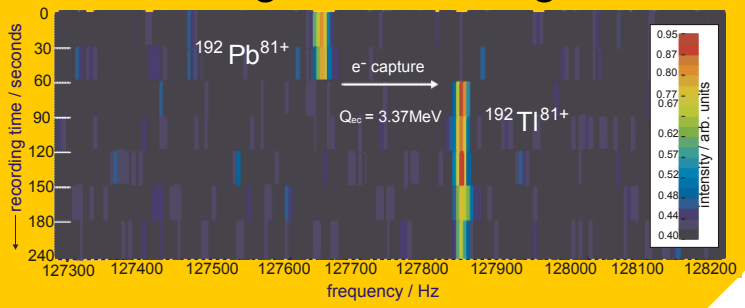
From Rest to Relativistic Energies (up to 4.9 GeV/u)



Cooling: The Key for Precision



From Single Ions to Highest Intensities



17

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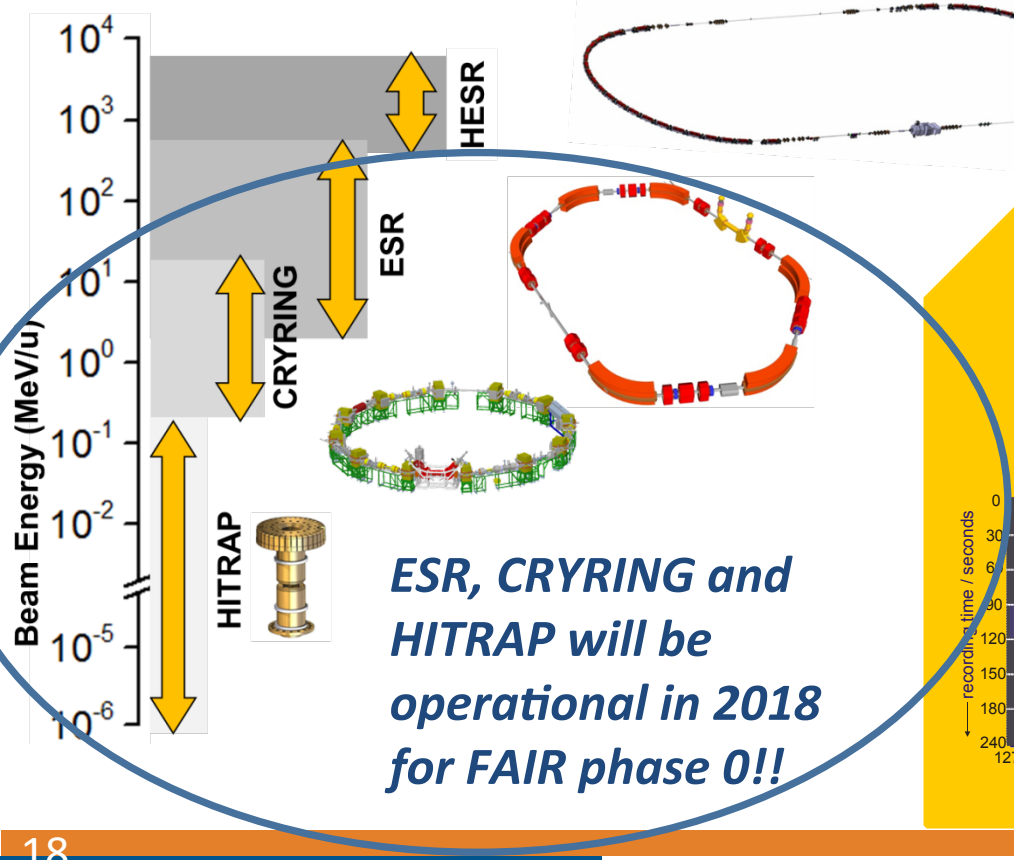
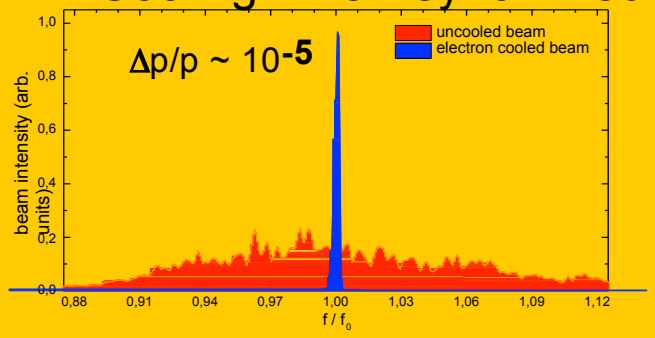
Highly-Charged Ions (e.g. U^{92+}) and Exotic Nuclei

From Rest to Relativistic Energies (up to 4.9 GeV/u)

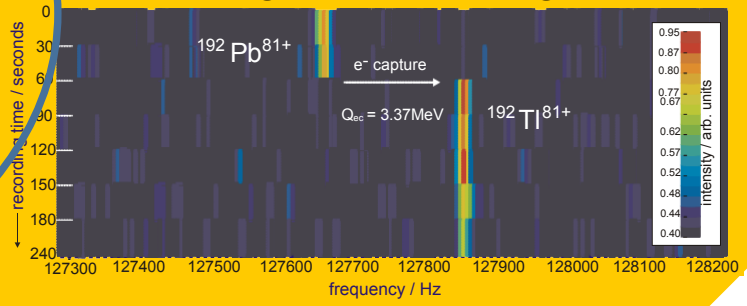


ESR, CRYRING and HITRAP will be operational in 2018 for FAIR phase 0!!

Cooling: The Key for Precision



From Single Ions to Highest Intensities

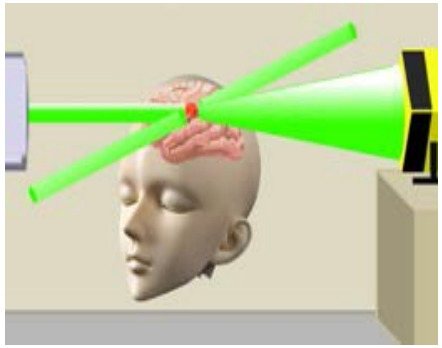


18

BIO*MAT

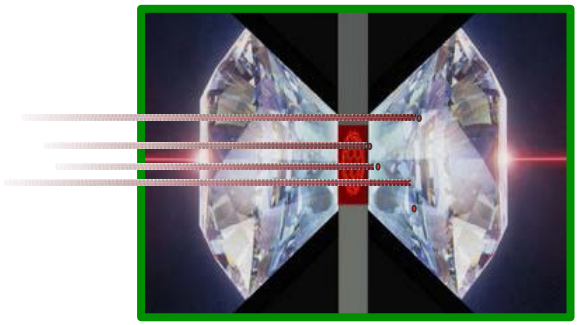
Research topics at FAIR

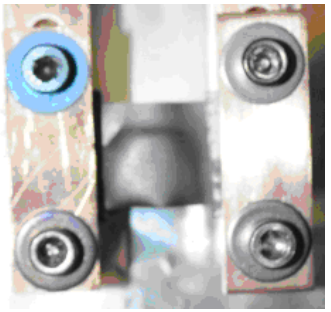
Biophysics



- Space radiation biophysics
- Biological effects of very high energetic ions
- Shielding measures: new materials
- Particle therapy: **“theranostics”** (use of high energetic proton beams for simultaneous diagnostics and therapy)

Materials Research





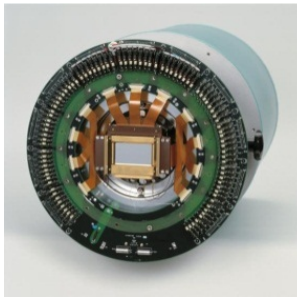
- Ion-matter interaction at highest energies and highest charge states
- Materials behavior under extreme conditions (high flux irradiations)
- Irradiations under multiple extremes (high pressure, temperature, dose)
- Radiation hardness of accelerator and spacecraft components

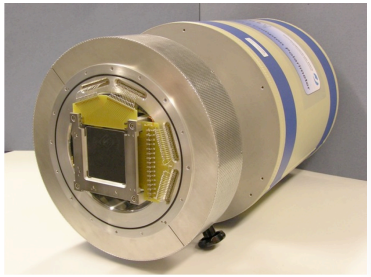
19

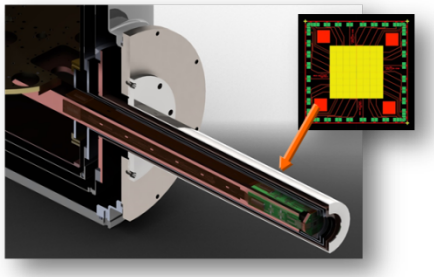
APPA
Sophisticated & Versatile Instrumentation

Observables: Photons, electrons, positrons, ions

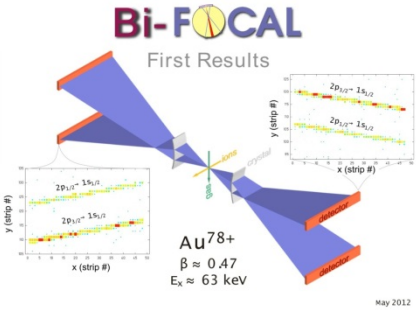
Targets



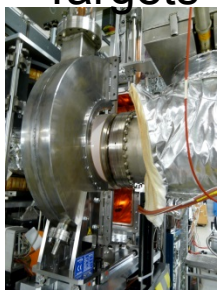


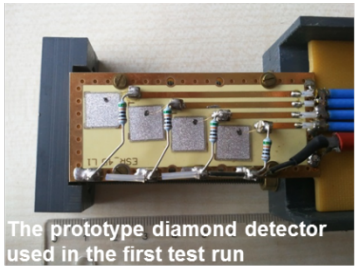


Position-sensitive solid-state detectors

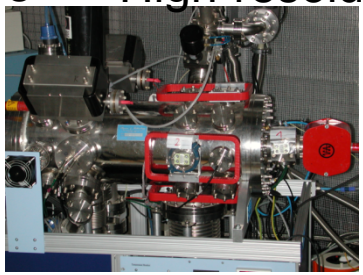


High-resolution spectrometers

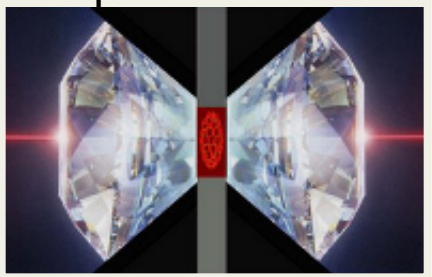




Particle detectors

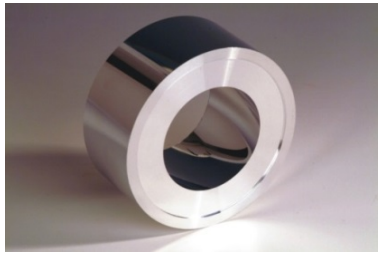


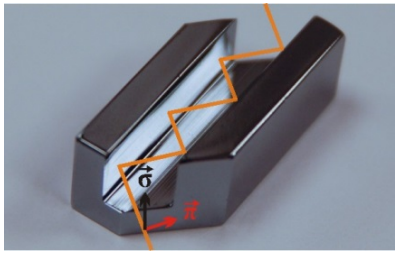
Particle spectrometers



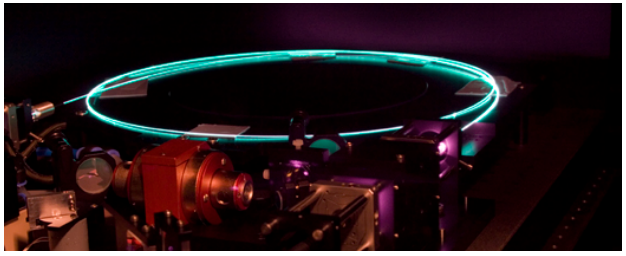
High pressure cell

Traps

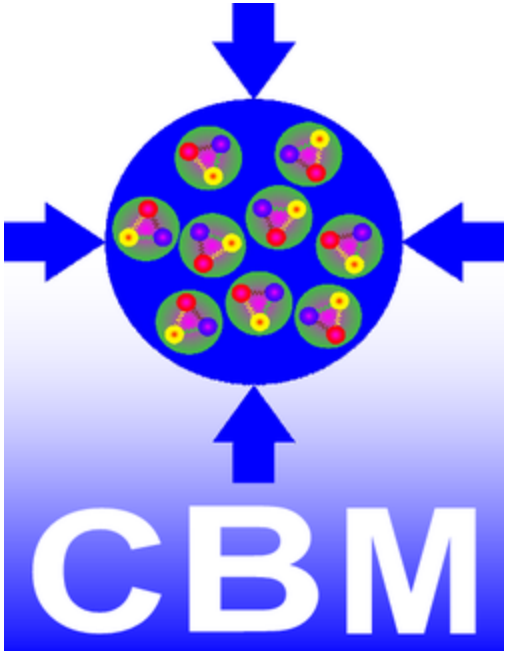




X-ray optics, channel-cut crystals



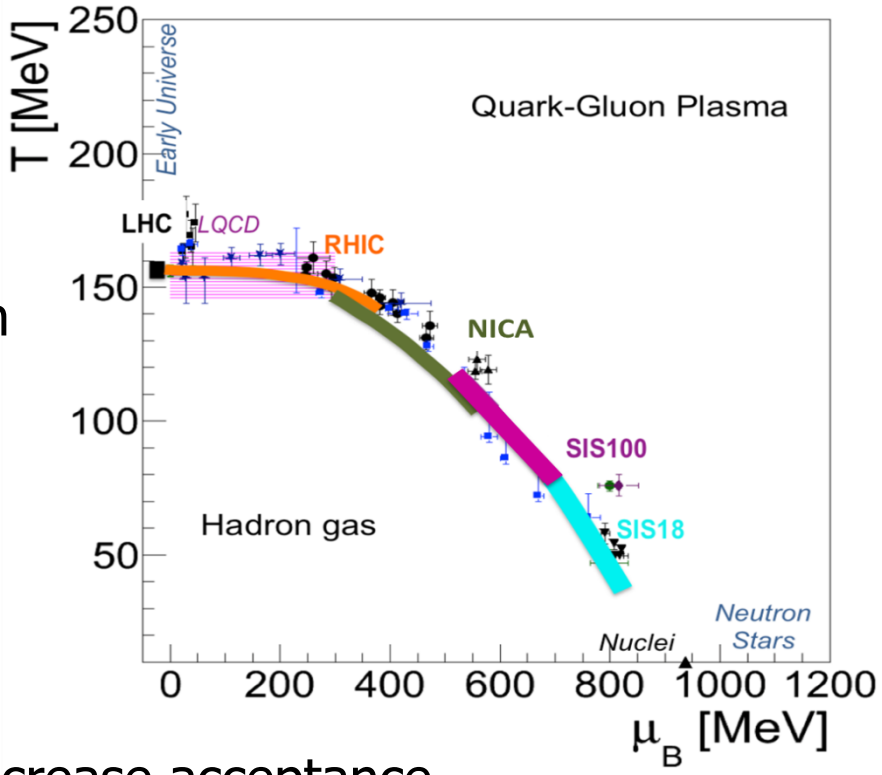
Laser systems


CBM

CBM: Focus on SIS100 beam energies

Physics program: Exploring QCD matter at neutron star core densities (> 5 ρ_0)

- nuclear matter equation of state
- search for phase transition, phase coexistence, exotic phases
- onset of Chiral symmetry restoration
- hypernuclei, strange matter



Detector optimization:

- Compact detector configuration to increase acceptance
  - Reduction of detector layers for TRD and Muon system
    Adoption to larger beam deflection at lower energies:
  - Horizontal displacement of forward hadron calorimeter
  - Horizontal adjustment of beam pipe
  - Larger acceptance of beam dump

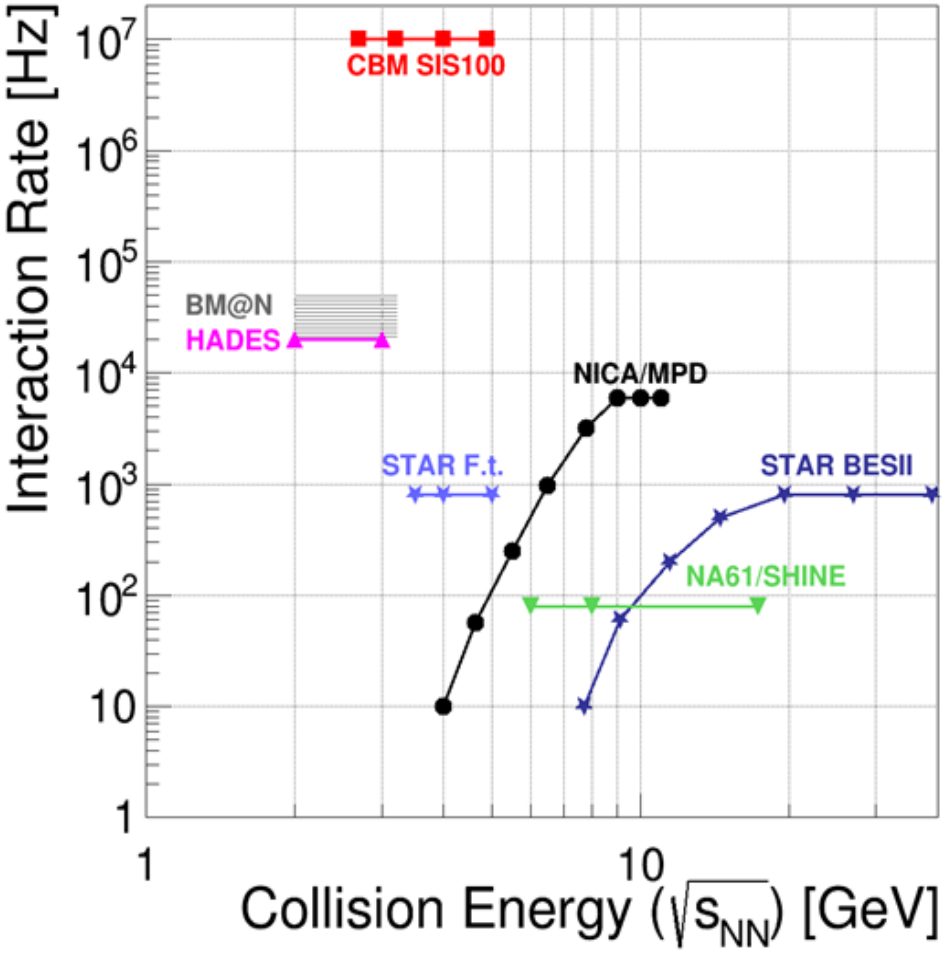
CBM: competing experiments

FAIR delay

Main objectives of the CBM physics program at SIS100 not affected by the delay of the MSV due to unrivalled rate capability of the CBM setup

Competing experiments

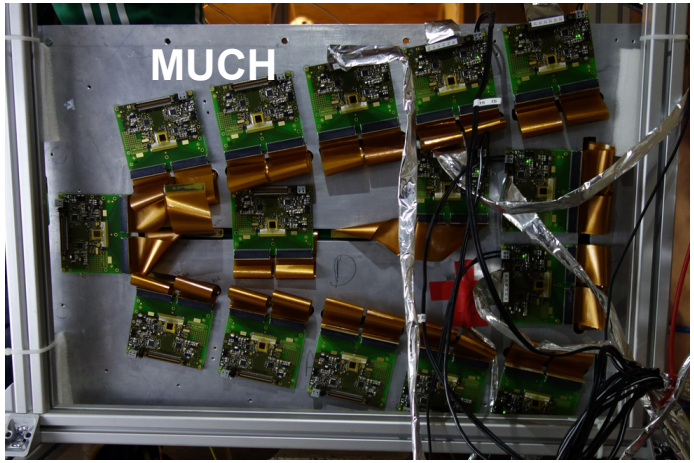
- STAR at RHIC-BNL (BES)
- NA61 at CERN-SPS
- MPD at JINR-NICA
- BM@N at JINR

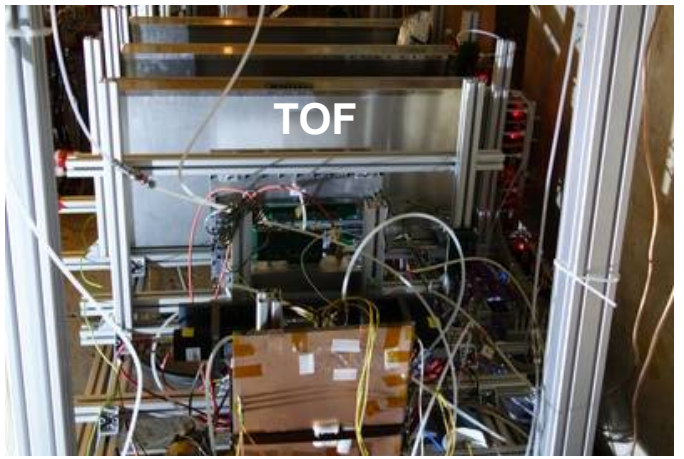


CBM: world wide unique high-precision measurements of rare diagnostic probes like multi-strange hyperons, hypernuclei, dileptons, charm, and multi-differential observables.

CBM detector and DAQ tests at CERN SPS

- Successfull operation of detectors and of the DAQ system
- Events successfully reconstructed from free-streaming data
- Data quality allows for investigation of detector performance





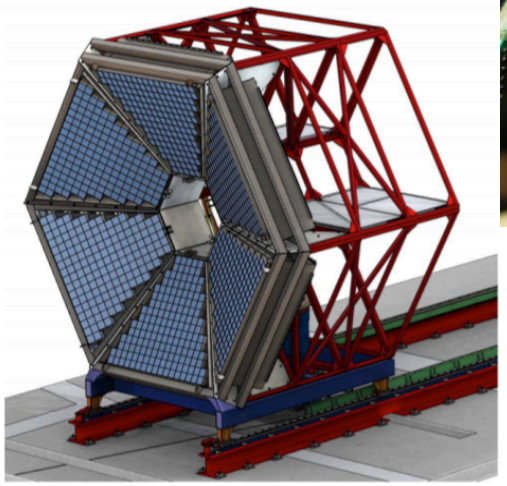
HADES Preparation for FAIR

Detector upgrades

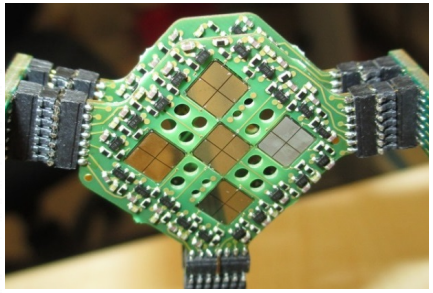
- ECAL
- RICH-700 (synergy with CBM – UV detector)
- MDC-FEE
- FW-Tracker (synergy with PANDA – straws)
- FW-RPC
- FW-Wall (synergy with CBM – PSD)
- START (synergy with CBM – t_0 detector)

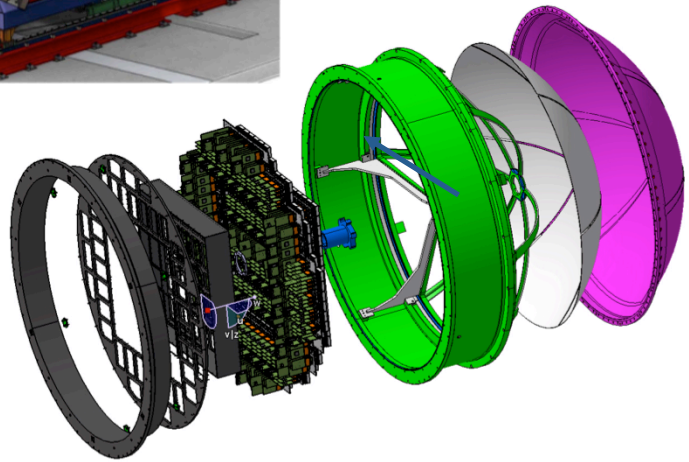
Up to 50 kHz interaction rate, improved electron-id, detection of photons, large acceptance for exclusive processes.

ECAL based on OPAL lead glass

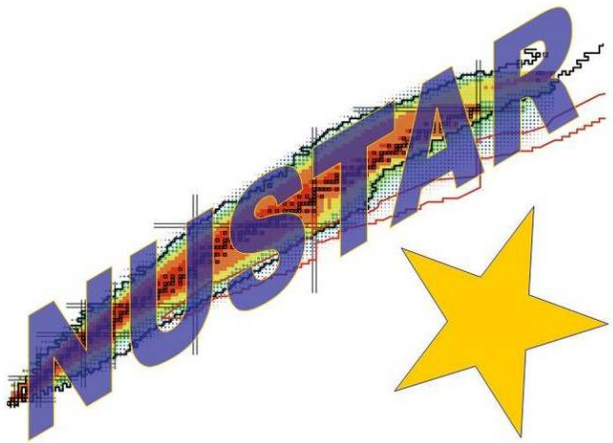


sc-CVD diamond start detector



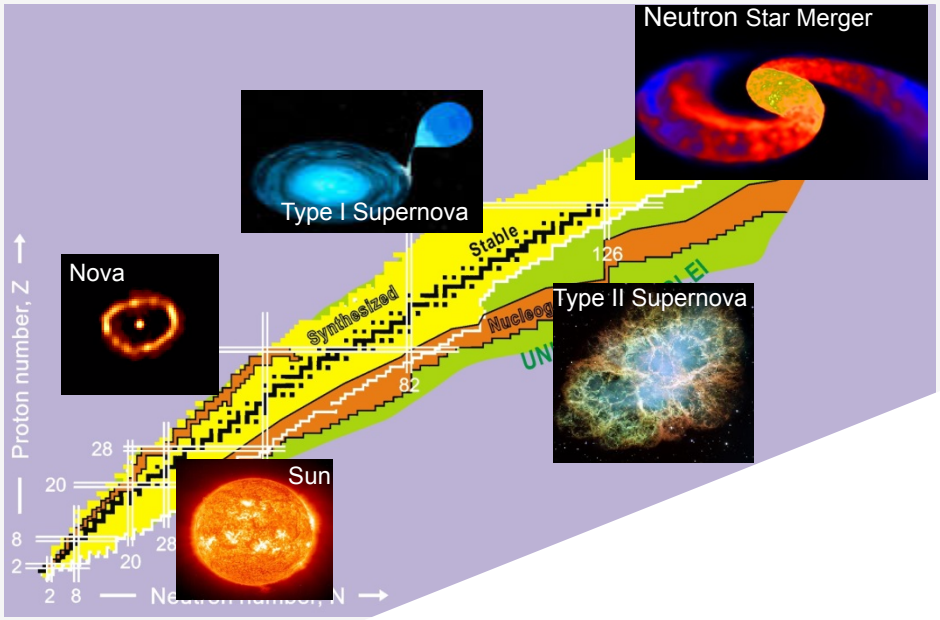


MAPMT based RICH UV detector


NUSTAR

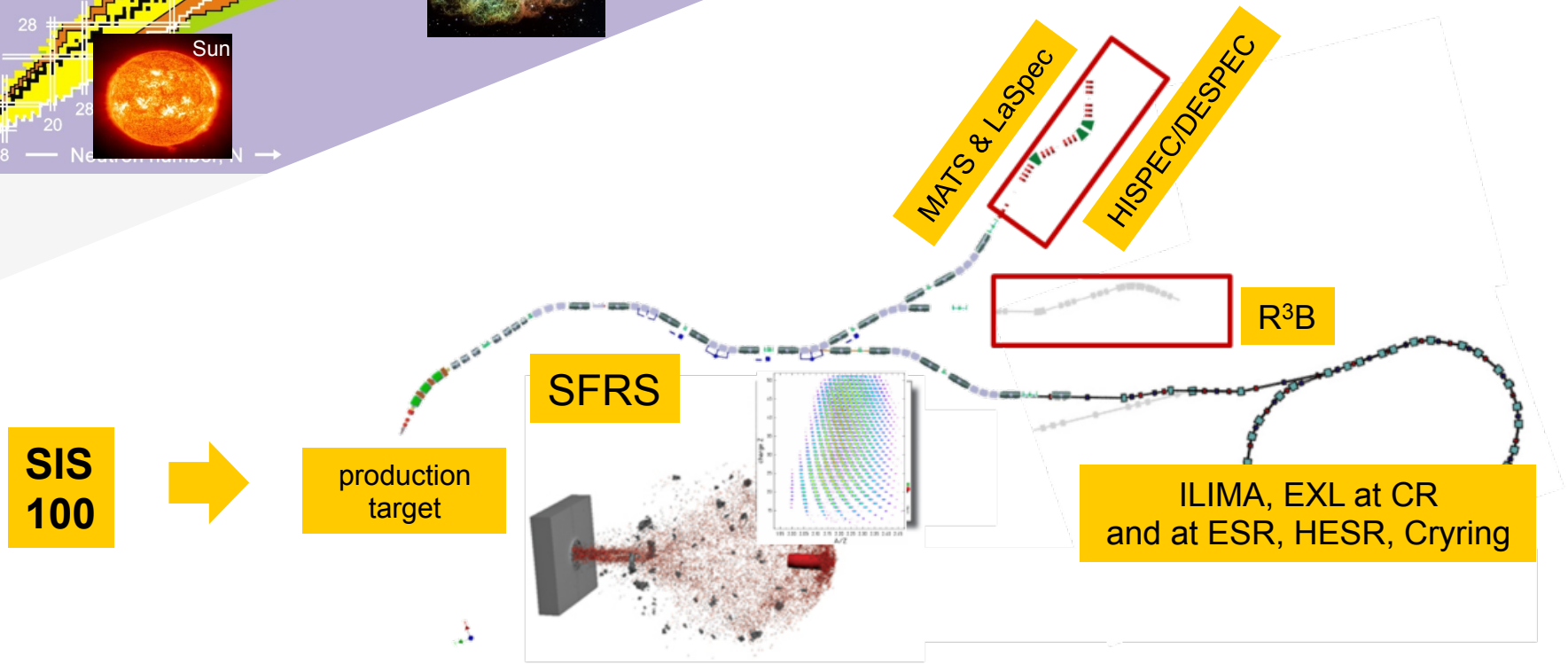
Synthesis of the chemical elements

NUSTAR - Origin of elements in the universe



„Nucleosynthesis sites“ in the universe

„Nucleosynthesis sites” at FAIR



Physics goals/ highlights of the NUSTAR program

- Understanding the 3rd r-process peak by means of comprehensive measurements of masses, lifetimes, neutron branchings, dipole strength, and level structure along the N=126 isotones;
- Equation of State (EoS) of asymmetric matter by means of measuring the dipole polarizability and neutron-skin thicknesses of tin isotopes with N larger than 82 (in combination with the results of the first highlight);
- Exotic hypernuclei with very large N/Z asymmetry.

SC R^3B Dipole GLAD installed at GSI for FAIR phase 0 experiments in 2018/19

GLAD magnet (French in-kind contribution)

In 2018, start of physics program with GLAD
using beams from SIS18 and FRS at 1 GeV/u


panda

Science Case

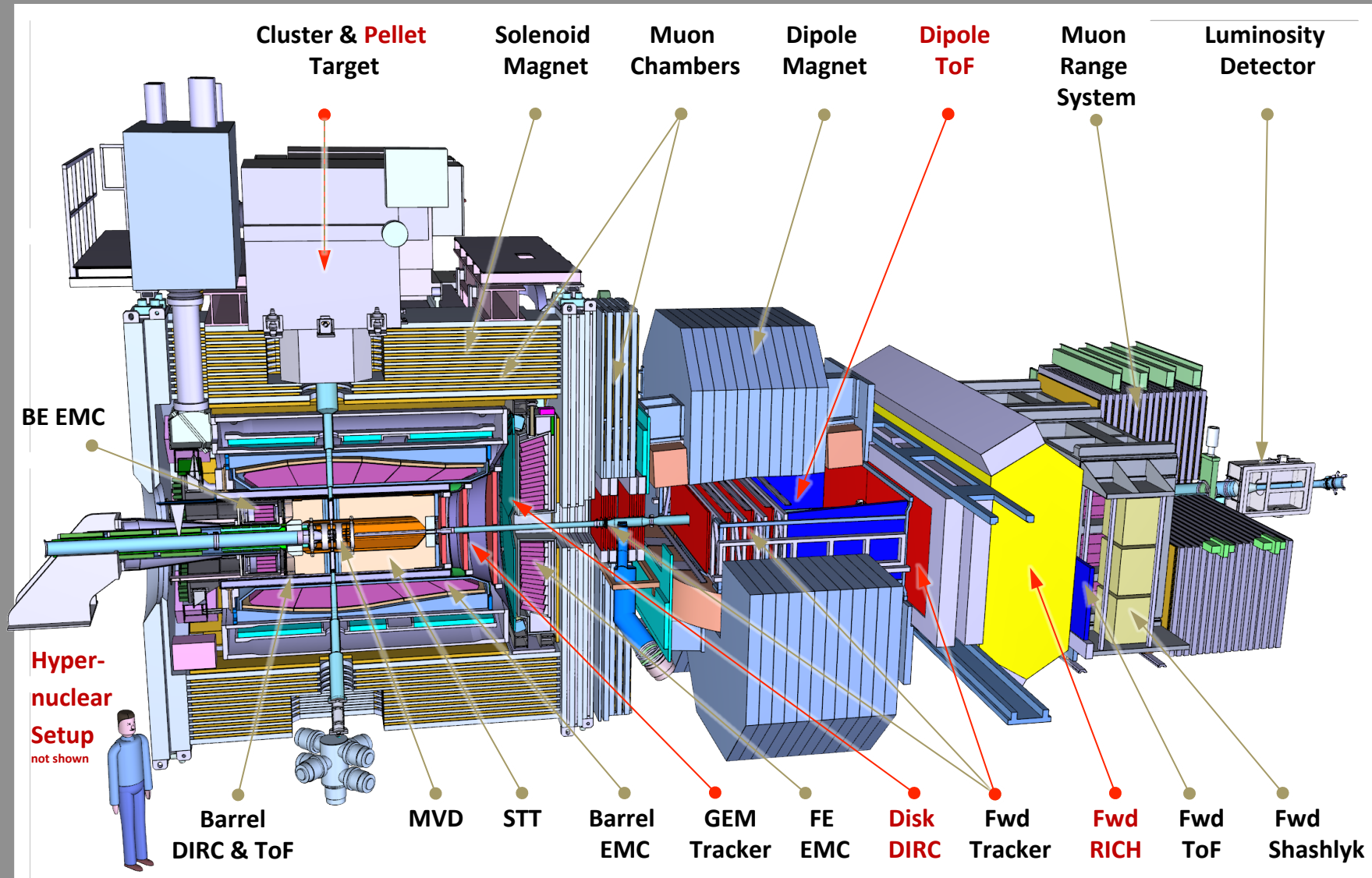
- PANDA physics program now focused on:

  - *Strange Baryons:* High statistics sample of unexplored territory of hyperon ($\Lambda*$, $\Sigma*$, $\Xi*$, $\Omega*$) spectroscopy
  - *Charm and strange mesons:*
    - X,Y,Z-factory, high statistics and resolution, lineshapes, transitions, nature of the states
    - Heavy-light mesons: unexplored high spin states, lineshape
  - *Nucleon Structure:*
    highest rates at lower q^2 for timelike formfactors G_E, G_M, TDA, WACS, TMD
  - *Hypernuclei and nuclear targets:*
    Hyperon-potential in nuclei, excited states of $\Lambda\Lambda$-hypernuclei

Technical Progress of PANDA

- TDR Status
  - 7 approved TDRs: EMC, Magnets, Target, STT, MVD, Muon, FSC
  - 3 TDRs in review by ECE: Barrel DIRC, Barrel ToF, Luminosity Det.
  - 3 more head for submission: Fwd TOF, Fwd Tracker, Disc
  - All remaining TDRs in drafting process
- PANDA Solenoid contract signed between FAIR/PANDA/BINP
  - Work on yoke production design started
  - Cold mass design from CERN
- Micro Vertex Detector: prototype ASICs, advanced system design
  - Prototype ASICs for pixel and strip parts
  - Advanced system design
  - Ongoing optimisation of Services
- Cluster Jet Target: PANDA setup in test at U Münster
  - System optimisation ongoing
  - Beam tests at COSY in preparation
- Infrastructure planning and detector Integration well under way

PANDA Setup

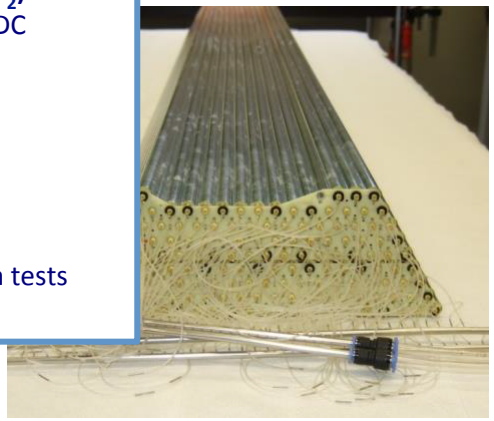

Cluster & Pellet Target
Solenoid Magnet
Muon Chambers
Dipole Magnet
Dipole ToF
Muon Range System
Luminosity Detector
BE EMC
Hyper-nuclear Setup
not shown
Barrel DIRC & ToF
MVD
STT
Barrel EMC
GEM Tracker
FE EMC
Disk DIRC
Fwd Tracker
Fwd RICH
Fwd ToF
Fwd Shashlyk

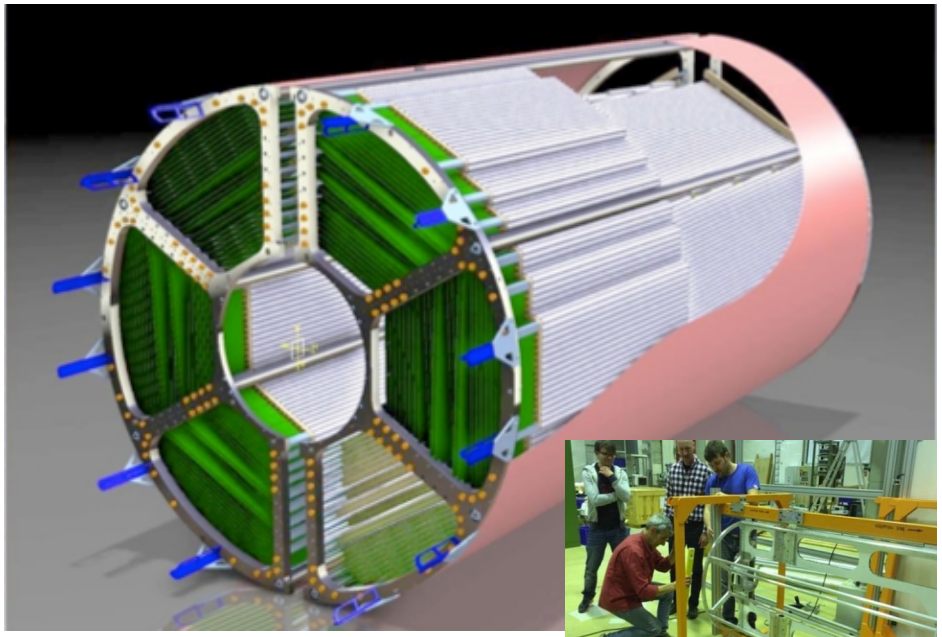
Straw Tube Tracker

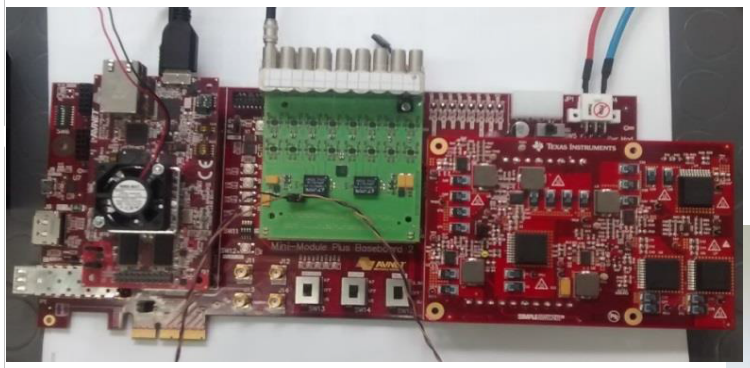
Detector Layout
4600 straws in 21-27 layers,
of which 8 layers skewed at ~3°
Tube made of 27 µm thin Al-mylar, Ø=1cm
R_{in}= 150 mm, R_{out}= 420 mm, l=1500 mm
Self-supporting straw double layers at ~1 bar overpressure (Ar/CO_2)
Readout with ASIC+TDC or FADC

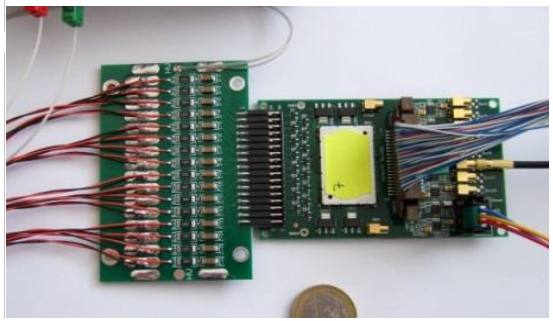
Material Budget
Max. 26 layers,
0.05 % X/X_0 per layer
Total 1.3% X/X_0

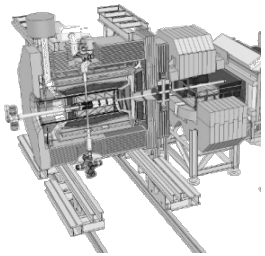
Project Status
7000 Straws produced
Readout prototypes and beam tests
Ageing tests: up to 1.2 C/cm^2







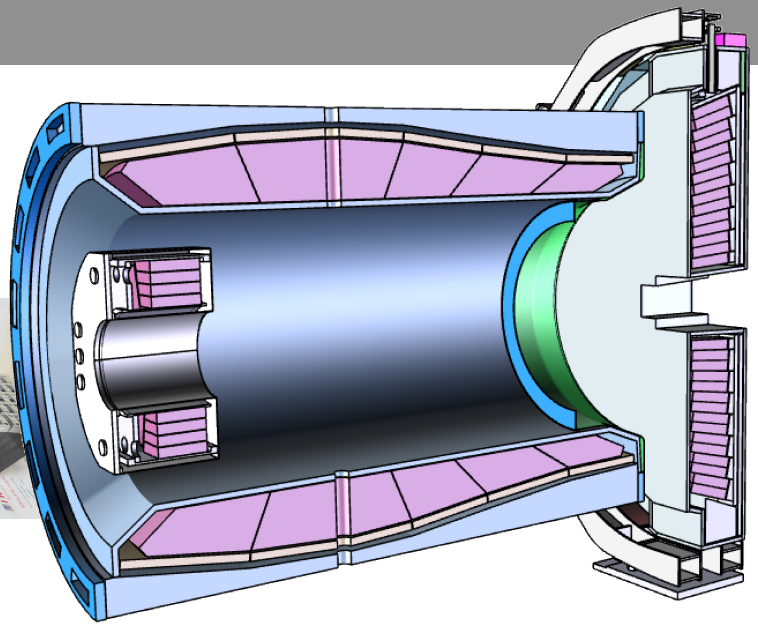


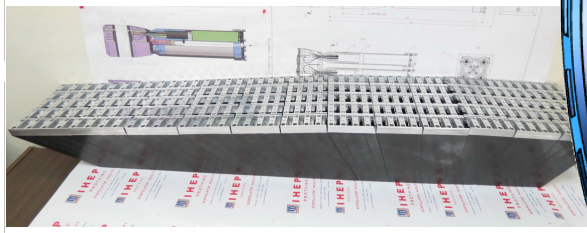


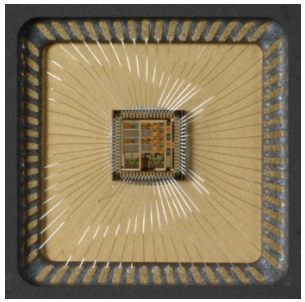
PANDA – Detector Progress

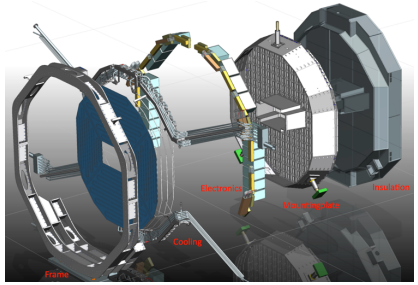
EM Calorimeter

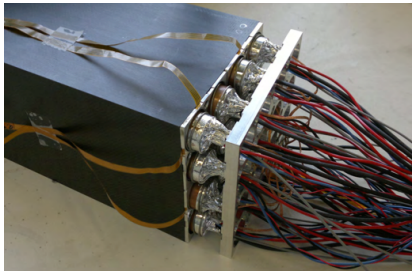
Crystals
1st lot of crystals delivered
New producer Crytur
Test production in 2016/17 (~100pc)
APD/Preamp/VPTT
Screening of 30000 APDs ongoing
ASIC preamp production complete
VPTT (Forward) characterized
Assembly
Forward-EMC full completion until 2018
Backward-EMC prototype-tests successful
Barrel-EMC: alveoles produced , 1st slice in construction

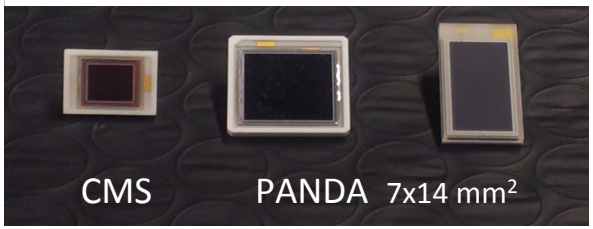


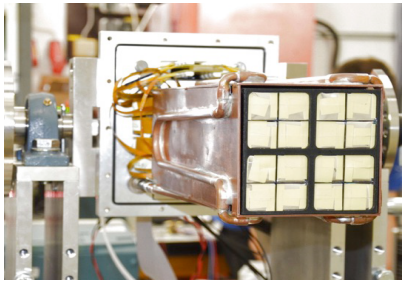


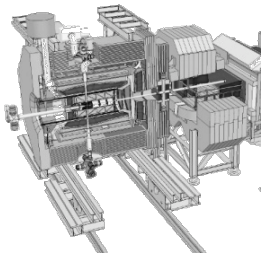








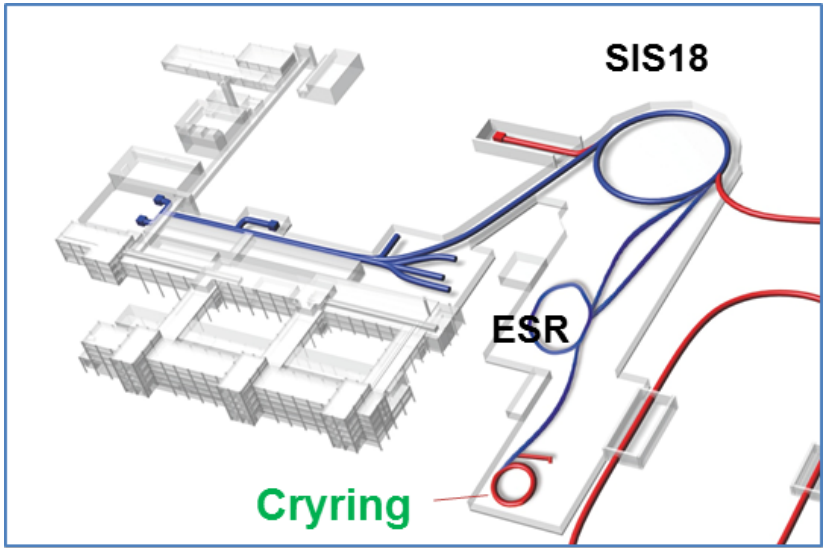




PANDA – Detector Progress

Intermediate Research Program FAIR Phase 0

- Goals
  - Forefront research by employing and testing new FAIR detectors
  - Exploiting upgraded GSI accelerator facilities
    - ongoing upgrade of SIS18 completed by mid 2018
    - Make use of Cryring
  - Education of young scientists
  - Maintain and extend skills and expertise
  - Serve national and international user community



FAIR Phase 0 – scientific opportunities for the four research pillars of FAIR

APPA	Facility	Research Activity
SPARC	ESR-HITRAP-	Strong field QED, atomic collisions, fundamental
SPARC	CRYRING	symmetries, border to nuclear physics
BIOMAT	M Branch, Z0/ A	Biophysics, heavy ion therapy, Material Science
WDM/HEDgeHOB	HHT/PRIOR	Equation-of-state studies; phase transitions in matter
WDM/HEDgeHOB	PHELIX	Laser plasma interaction and acceleration
CBM		
CBM/HADES	HADES@SIS18	Di-lepton production in pion-induced and HI reactions
miniCBM	miniCBM@SIS18	Test of subsystem plus data acquisition of CBM
CBM	External	Beam energy scan at STAR/RHIC (tests/ physics at NICA)
NUSTAR		
NUSTAR	FRS	Separator-/spectrometer expt.'s with exotic nuclei
NUSTAR	FRS-ESR	Nuclear physics with exotic beams in storage rings
NUSTAR	HISPEC/DESPEC	In-beam and stopped-beam spectroscopy experiments
NUSTAR	R3B@SIS18	Reactions with relativistic radioactive beams
NUSTAR	SHIP, TASCA	Physics and chemistry of SHE
PANDA		
PANDA	HADES	Hyperon Dalitz decays with HADES (use of PANDA F-TRK)
PANDA	BESIII	Search for exotic states, charmonium and TL form factors
	MAMI	Mag. moment of $\Delta(1232)$, e-m universality, multi π^0 prod (use PANDA BW Endcap EMC at MAMI A1)

Intermediate Research Program FAIR Phase 0

- Steps taken:
  - Beam time plan for 2018 adopted by GSI Management Board; draft beam time plan for 2019 in preparation
  - List of main possible beam parameters defined
  - International Program Advisory Committee is presently being established (Chair: Sydney Gales)
  - 1st call for proposals for beam time slot 2018/19 in spring 2017 has been published https://www.gsi.de/fileadmin/GF-wiss/Call_for_Proposals_2018-19.pdf

Summary and Outlook

- **Progress in Civil Construction**
- **Procurement of accelerators**
- **R&D and construction of all FAIR experiment pillars**

- **FAIR phase 0 – intermediate research program**
  - bridge construction phase from 2018 until FAIR commissioning
  - first-class experiments exploiting upgraded GSI accelerators
  - employ novel detector instrumentation developed for FAIR.
- **Beam time plan for 2018** adopted by GSI Management Board, **proposals received for beam time slot 2018/19** in first call

FAIR Construction Field

FAIR 2025