FAIR

Paolo Giubellino

Outline

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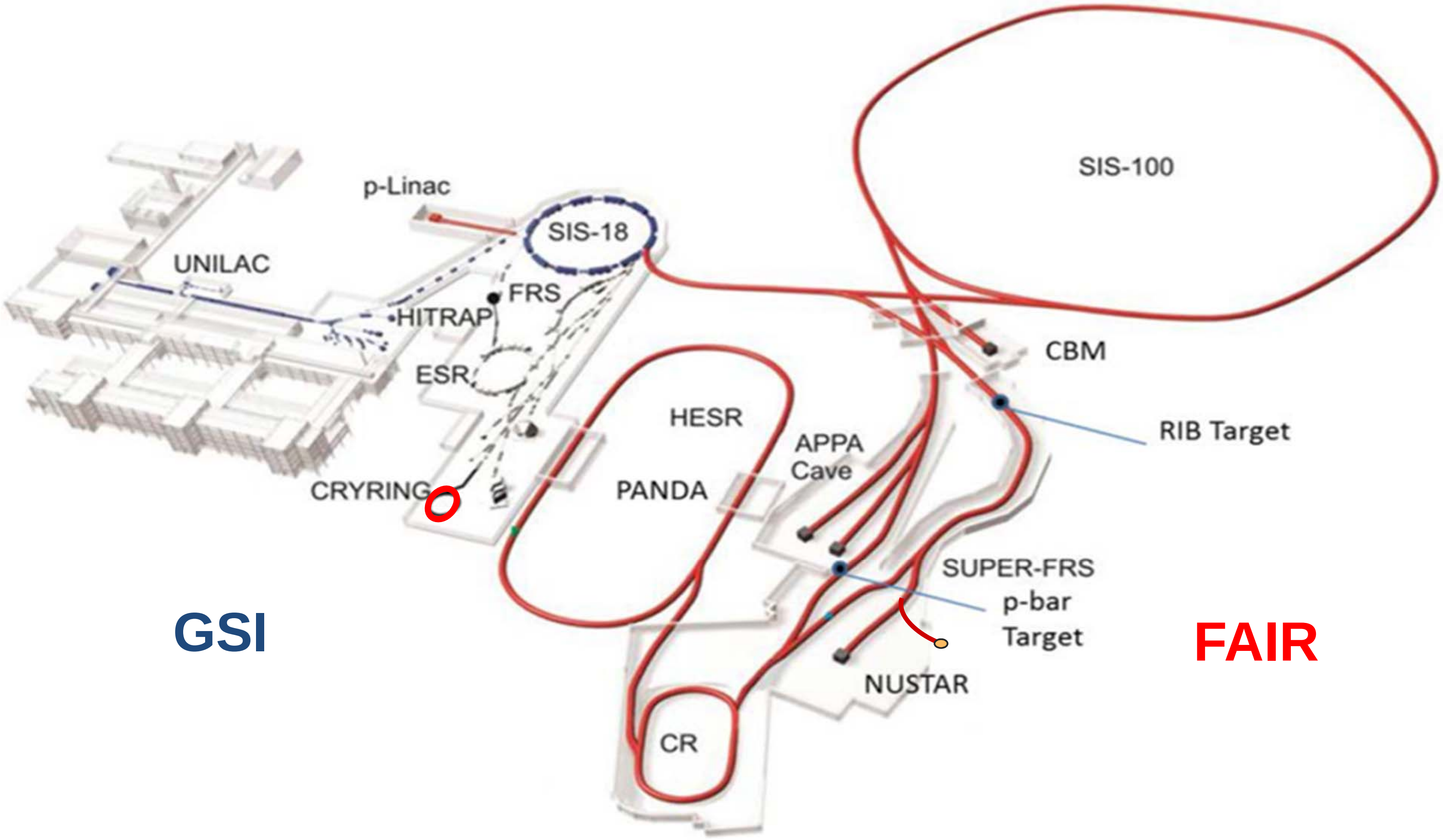
2. Major events and decisions
3. Civil construction – realization plan
4. Integrated Project Time Schedule
5. Progress achieved in the Accelerator Project
6. Progress of the Experiments
7. Research at GSI continues – beam time 2016 and recent research highlights
8. Intermediate research program FAIR Phase 0
9. Summary and outlook

FAIR Accelerator Complex



GSI

FAIR

FAIR Accelerator Complex

FAIR

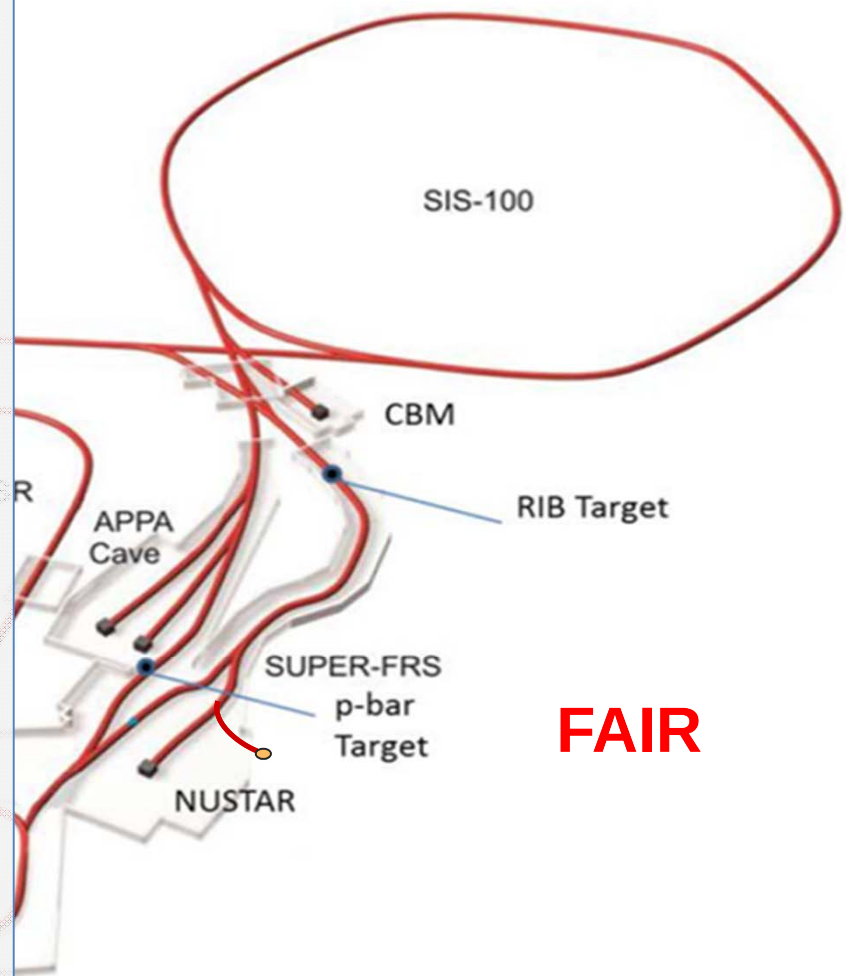
... accelerates particle beams from (anti)protons up to uranium ions with

- 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

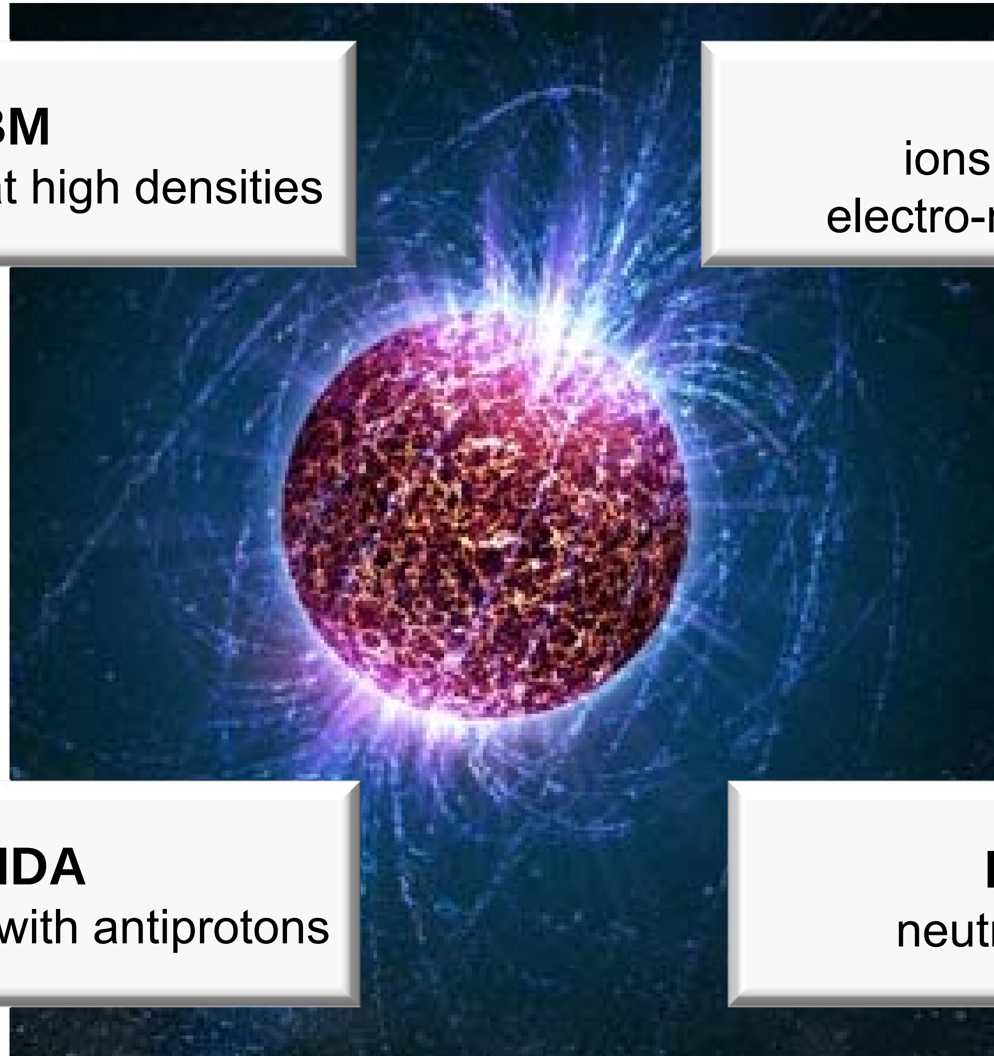
New Extreme States of Matter.



FAIR – the Universe in the Laboratory

CBM
nuclear matter at high densities

APPA
ions in extreme
electro-magnetic fields



PANDA
hadron physics with antiprotons

NUSTAR
neutron-rich nuclei

FAIR – four research pillars

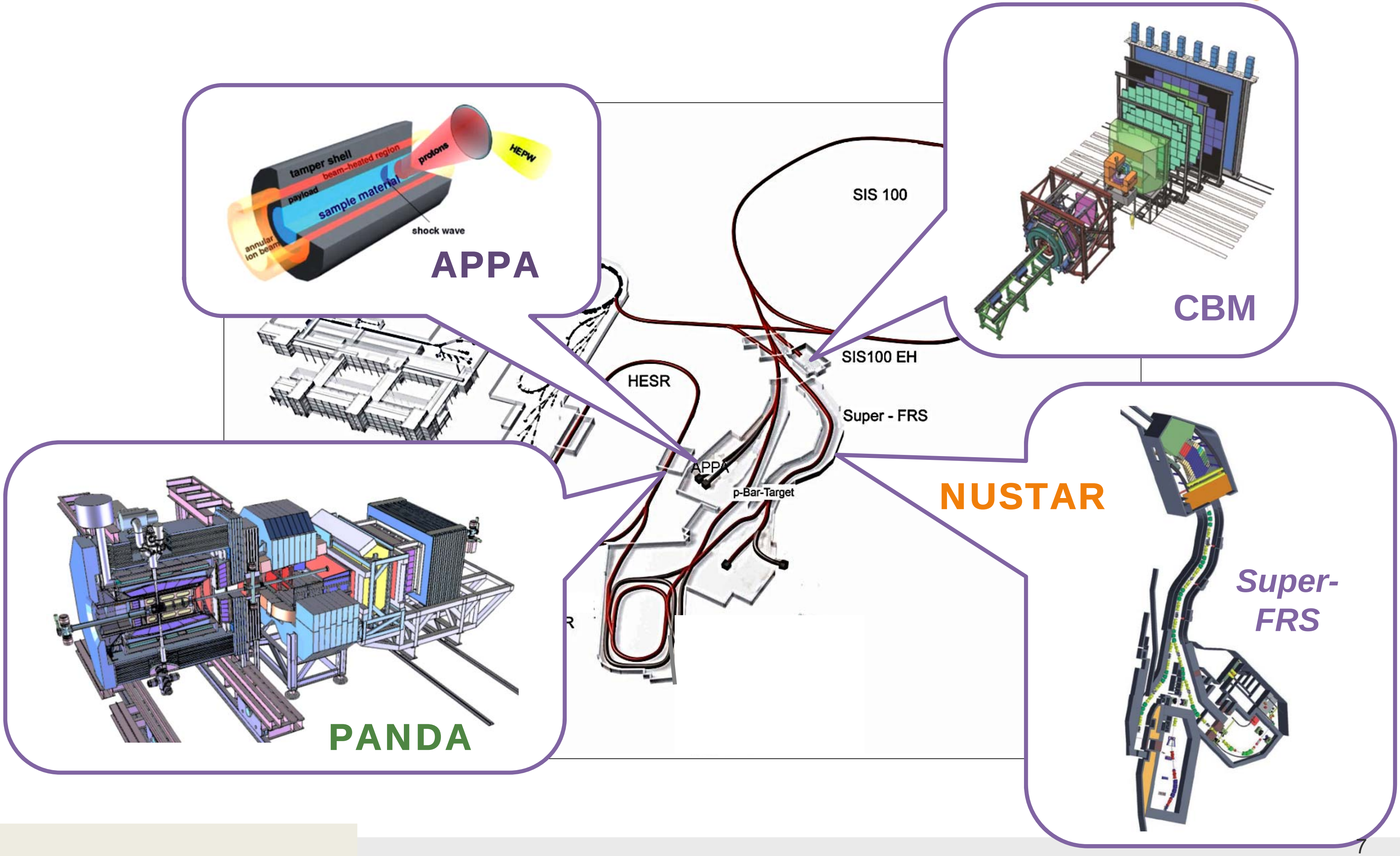
APPA
- Atomic Physics and Fundamental Symmetries,
- Plasma Physics,
- Materials Research,
- Radiation Biology,
- Cancer Therapy with Ion Beams / Space Res.

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 – four research pillars



International Participation in FAIR

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

Major events and decisions ...
... Council decisions from September 2015

- Despite the cost increase in civil construction Council confirmed in June 2015 the goal to realise the FAIR facility as outlined in the Convention → Modularised Start Version (MSV)
- MSV to be completed by 2025
- In September 2015, the Shareholders committed to confirm the first tranche of additional funding in 2016; commitments for the second tranche are to be made by 2019

Major events and recent decisions in 2016

- Confirmation of most FAIR partners to cover their share in the additional cost for civil construction has been received; the remaining confirmations are expected soon.
- 13 September 2016: BMBF approved funding for the civil construction of FAIR northern site area
- 26 September and 22 November 2016: Inquiry and contracting of civil construction has started; first calls for tender for ground water lowering, trench sheeting, excavation and building shell for construction have been launched.
- 7 December 2016: Full integrated planning for the FAIR construction and commissioning presented in the Council. Solid resource loaded plan for completion of the project by 2025.

Civil construction – realization plan

FAIR CC animation

Integrated Project Time Schedule: FAIR Buildings, Accelerators & Experiments

- Planning scope is the FAIR MSV
- Completion by 2025
- Full integration in planning of Civil Construction, Machine & Experiments is achieved
- A staged approach is realized ("Along the Beamline" / North & South) to speed up the start of experiments
- Installation windows prior finalization of Civil construction starting in 2021until 2024
- Components (Machine & Experiments) for this installation identified & respective dates set
- Continuous progress monitoring is defined and established

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
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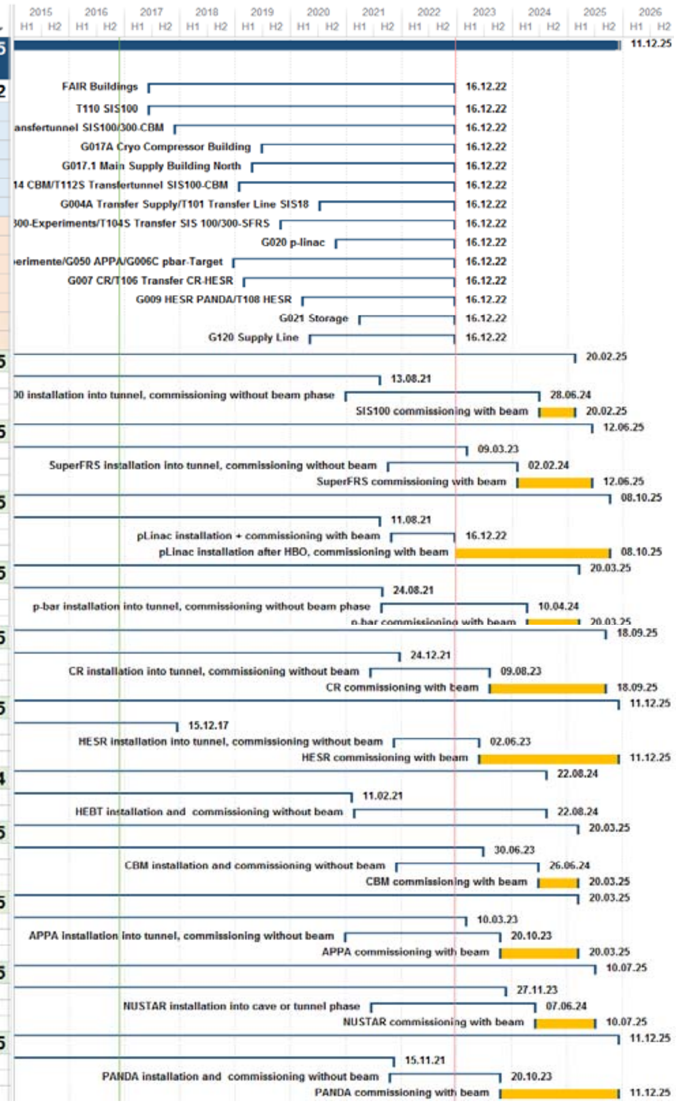
LEVEL_1



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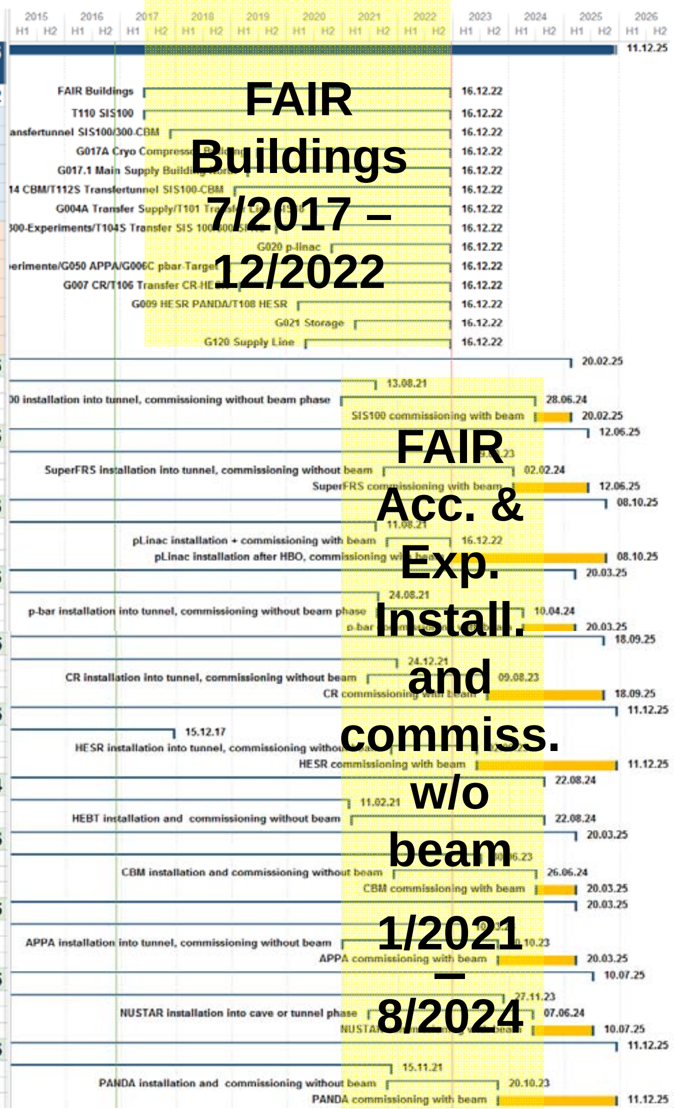
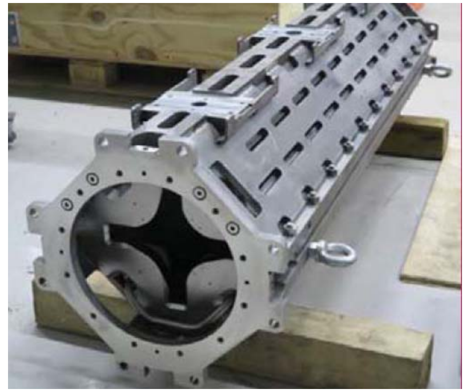


Progress achieved in the FAIR Accelerator Project

Procurement of the FAIR Accelerators SIS100

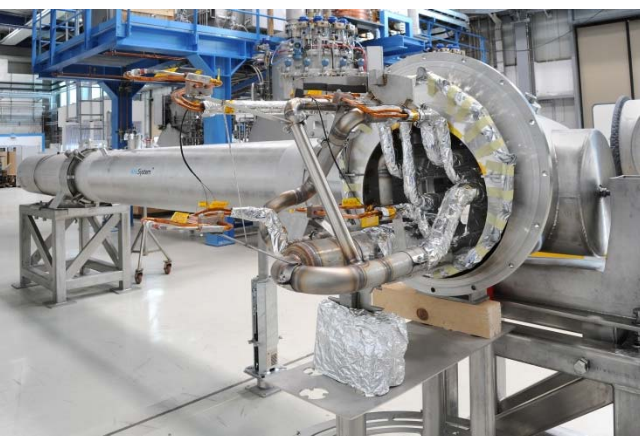
S.c. dipol magnet: Release of series production in July 2016 (Germany)



First SIS100 s.c quadrupole yoke and s.c. coil at JINR (Russia/Germany)

FoS bunch compressor for SIS100

First SIS100 bunch compressor cavity: SAT (on-site acceptance test) successful (Germany)



First cryogenic bypass line delivered and under cold testing at GSI (Poland)

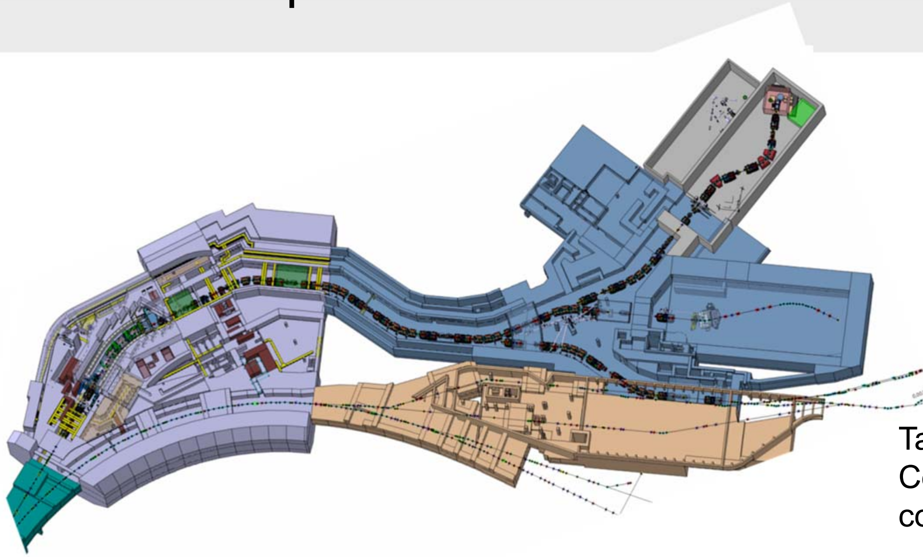
FOS (first of series) sextupole magnet delivered. SAT successful, Series released (Denmark).

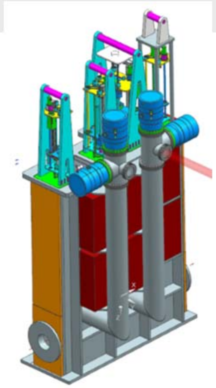
Parts for FOS acceleration cavity produced. Assembly started. FAT (factory acceptance test) in Dec. 2016 (Germany)

Procurement of the FAIR Accelerators

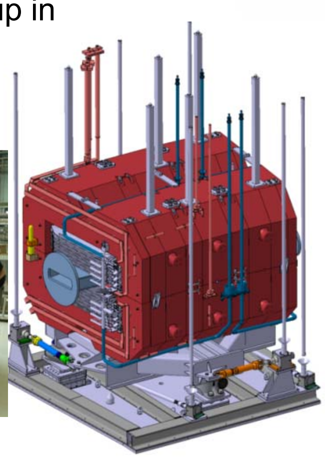
Super-FRS

FOS s.c multiplett: PDR approved in July. Steel and wire orderd. Coil mock-up in production (Italy).



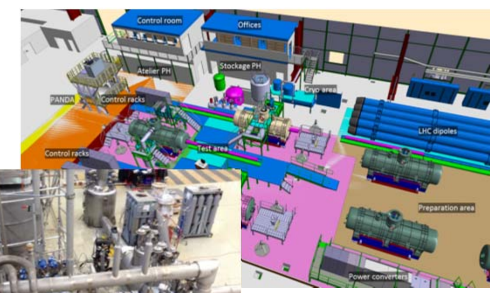


Target chamber with plug ins. Collaboration and R&D contracts with KVI-CART (NL)



Radiation hard dipole. Prototype testing almost completed. Tendering on short term (Russia)

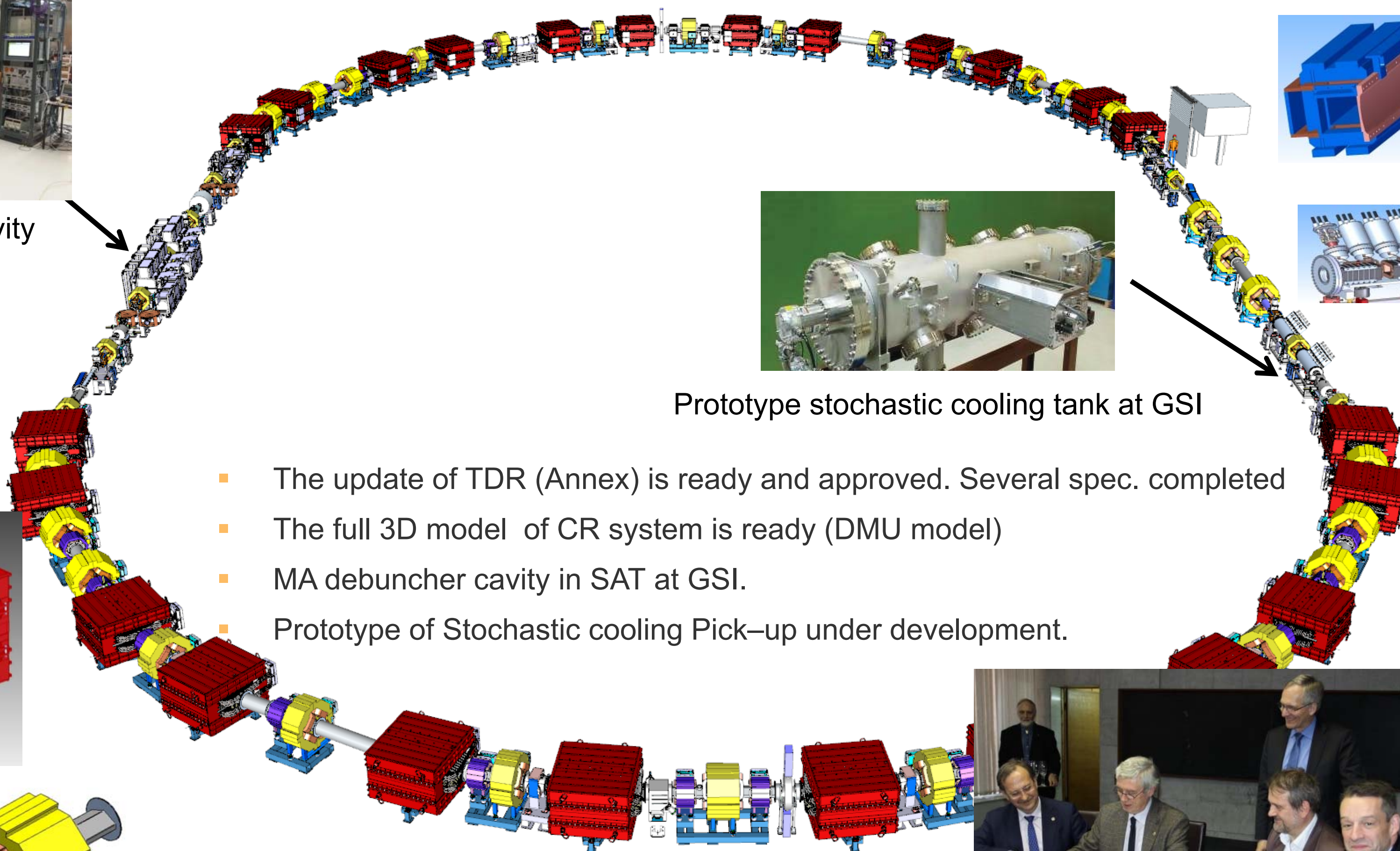
Collaboration agreement signed with CEA, including design and technical follow-up (France)



Set-up of test facility started at CERN, Commissioning of cryogenics system in 2016. First magnet end of 2017.

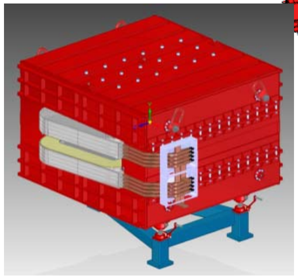
Procurement Highlights of the FAIR Accelerators
CR

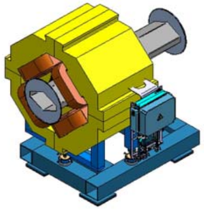
FOS debuncher cavity SAT ongoing.



Prototype stochastic cooling tank at GSI

- The update of TDR (Annex) is ready and approved. Several spec. completed
- The full 3D model of CR system is ready (DMU model)
- MA debuncher cavity in SAT at GSI.
- Prototype of Stochastic cooling Pick–up under development.





December 2016: Collaboration contract signed for the dipole magnets (production until 2021) and potentially for all other components with BINP, Novosibirsk (Russia)

Procurement of the FAIR Accelerators

HESR

First stochastic cooling pick-up and kicker installed in COSY. Amplifier expected end of the year

13 dipole magnets delivered to GSI after integration of UHV chamber

Large amount of dipole and quadrupole delivered to FZJ (Sigma Phi France):

- 36 von 46 dipole
- 56 of 84 quadrupoles magnets at FZJ. Last quadrupole expected until Q2 2017
- First sextupole parts built in Romania until Dec. 2016
- Injection kicker FAT started (Sigma Phi France)

All dipole chambers delivered and shipped to GSI for NEG coating and send back to FZJ.

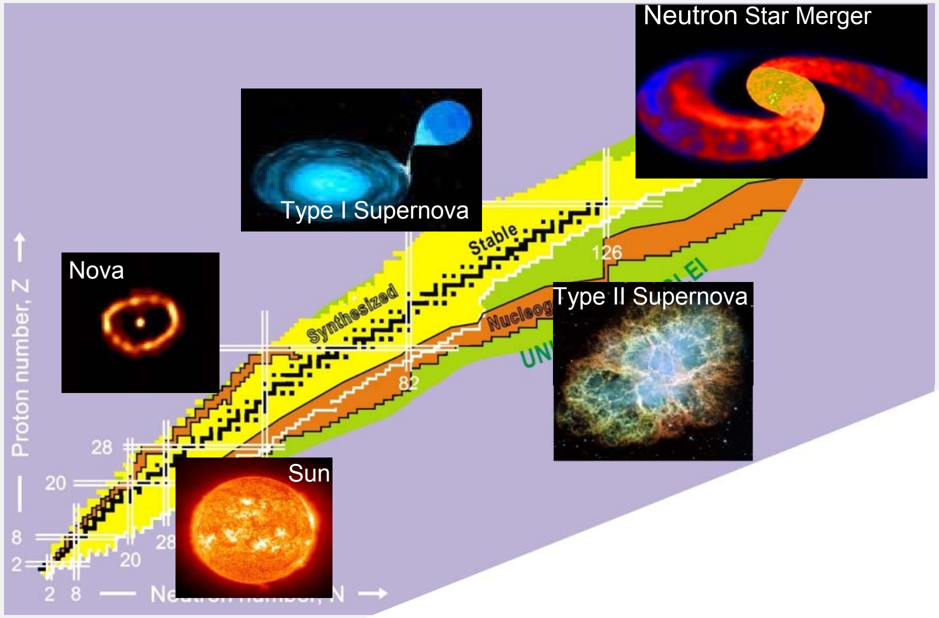
Final dipole PC produced according to schedule of buildings. All quadrupole PCs delivered to FZJ by Sigma Phi

The Experiments

APPA,
CBM,
NUSTAR,
PANDA

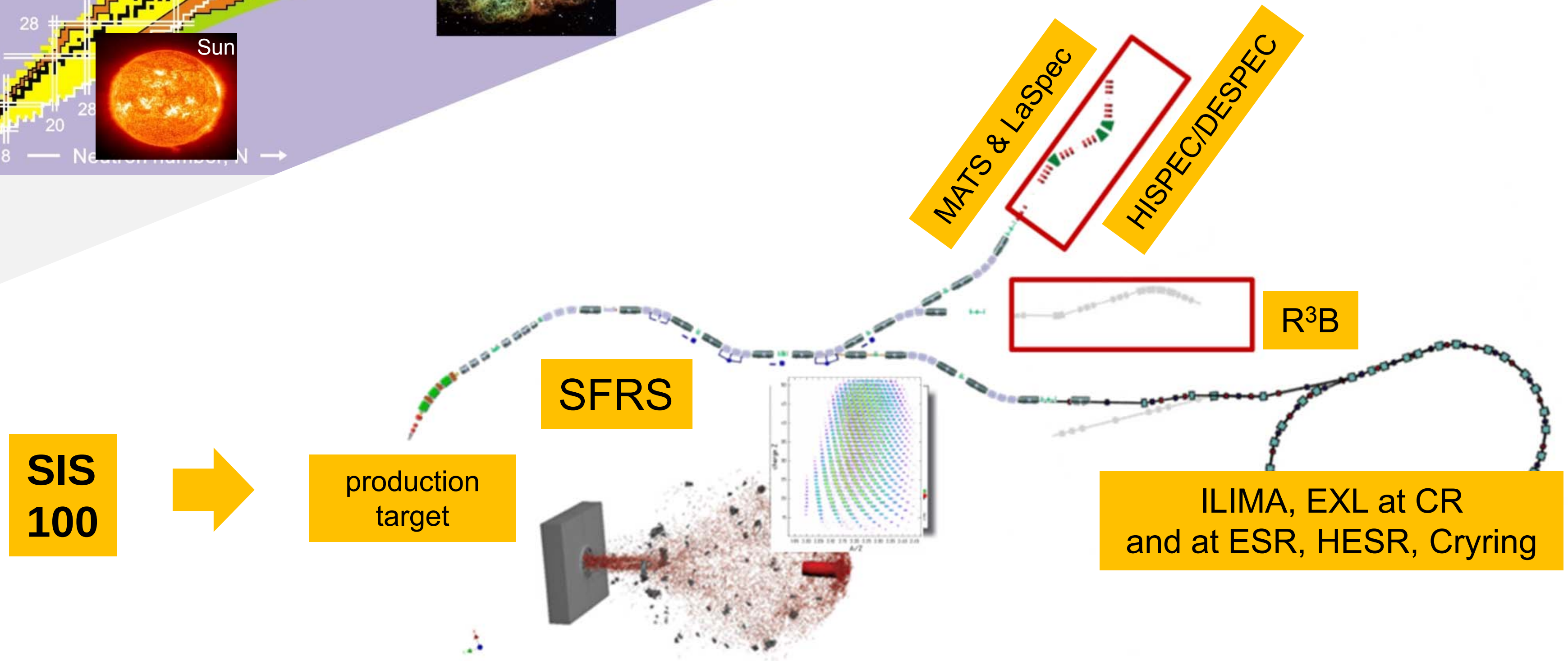
NUSTAR

NUSTAR - Origin of elements in the universe

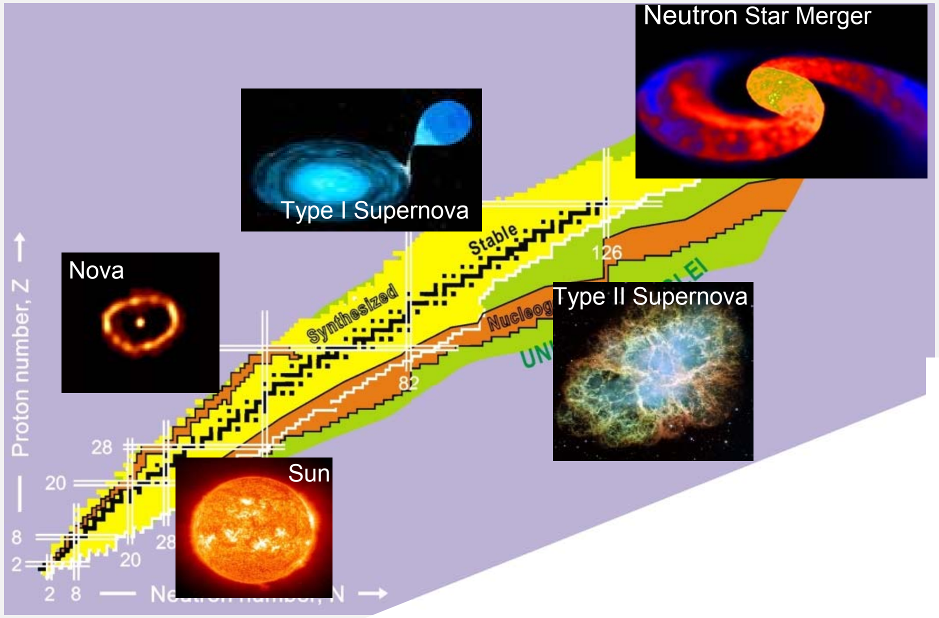


„Nucleosynthesis sites“ in the universe

„Nucleosynthesis sites” at FAIR

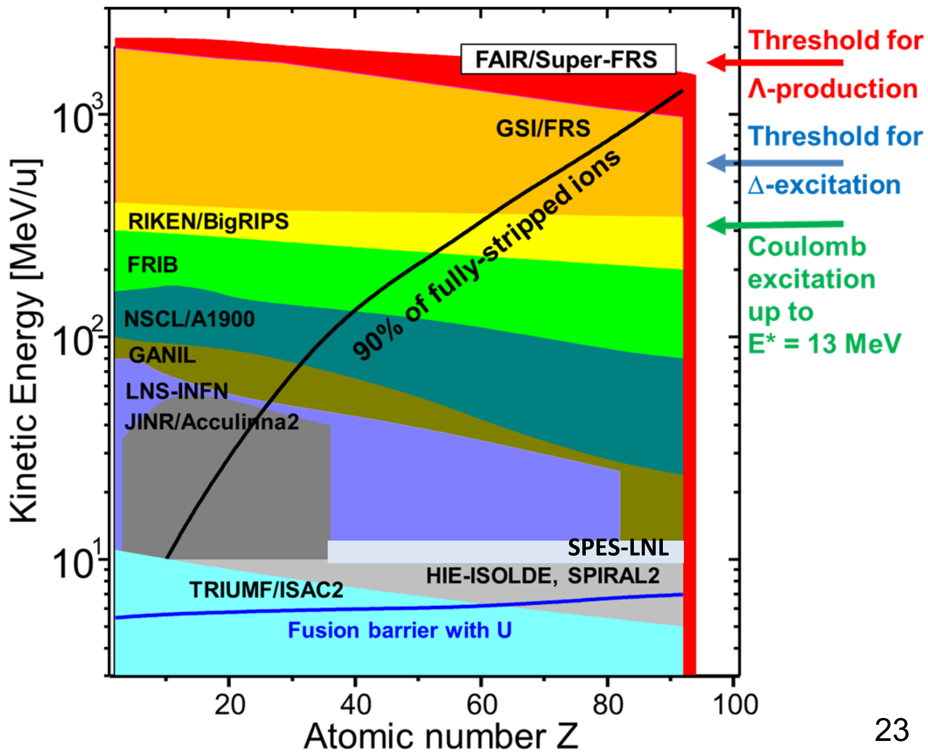


NUSTAR - Origin of elements in the universe



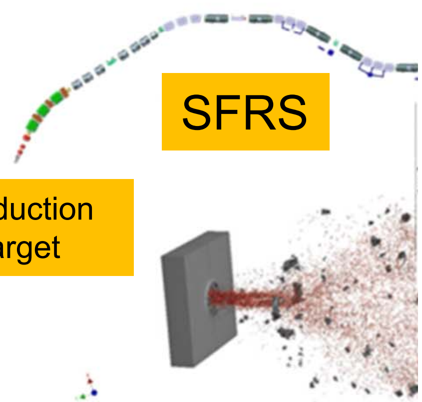
„Nucleosynthesis sites“ in the universe

High SIS100 energies + SFRS: superior charge separation and beam quality



SIS 100

production target



Physics goals/ highlights of the NUSTAR program

- Understanding the 3^{rd} 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.

Progress in preparing the NUSTAR experiments: SC R^{3}B Dipole GLAD installed at GSI

GLAD magnet (French in-kind contribution)

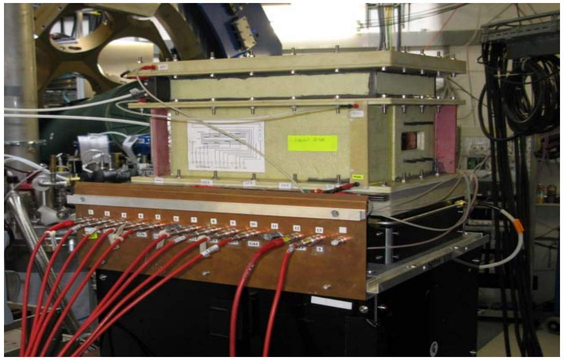
Commissioning und first tests 2016/17

In 2018, start of physics program with GLAD

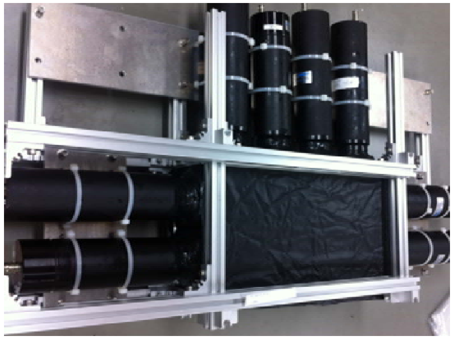
using beams from SIS18 and FRS at 1 GeV/u

Novel detectors developed for NUSTAR

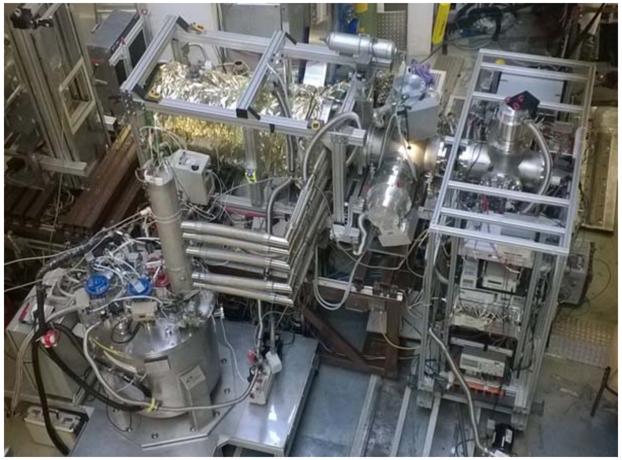
O-TPC: discovered β-delayed 3p-emission of ^{31}Ar



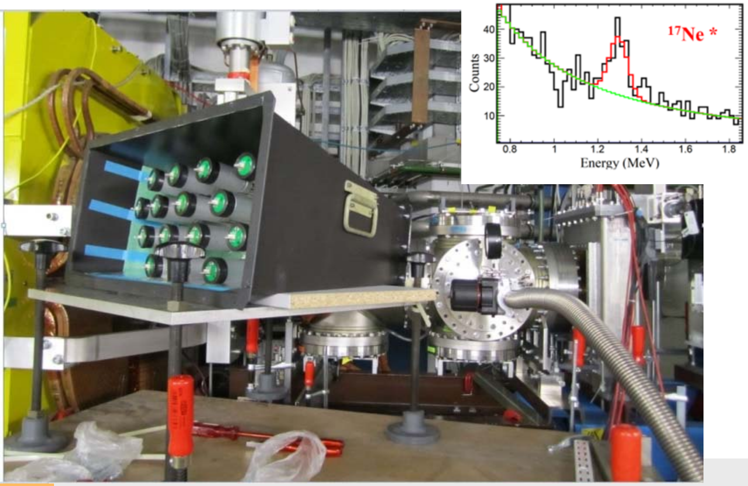
Backward-angle neutron detector for tensor-force experiments



Ion Catcher → LEB-MATS/LASPEC

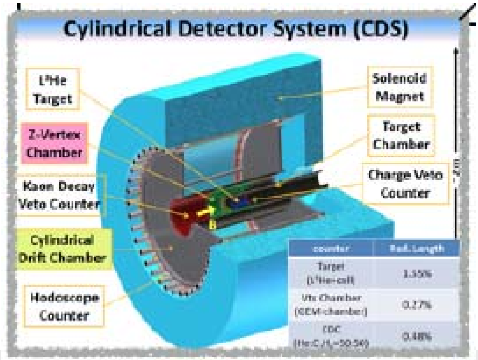


GADAST prototype measurements at S2



Full integrated S2 fiber tracker

Simulations for a pion detector integrated at S2



From the WG Draft Report on "Nuclear Structure and Reaction Dynamics":

FAIR will be the European flagship facility for the coming decades. The unique accelerator and experimental facilities will allow for a large variety of unprecedented fore-front research in physics and applied science.

The main thrust of FAIR research focuses on the structure and evolution of matter on both a microscopic and on a cosmic scale, deepening our understanding of fundamental questions.

The urgent completion of FAIR, the Super-FRS and NUSTAR@FAIR, are of utmost importance for the community.

In the interim period it is vital that a high-level research programme and use of the new detectors for FAIR at GSI continues using the existing beams and facilities.

From the WG Draft Report on "Nuclear Astrophysics":

... In the future, a major step will be made with the FAIR-NUSTAR facility, which is expected to give access, for the first time, to many of the r-process path nuclei at N=126 by means of fragmentation of high-intensity and high-energy 238U-beam.

Thus, a change of paradigm can be expected in the near future, providing first experimental data in a yet unknown region of the nuclear chart, and very stringent constraints for the r-process nucleosynthesis of the heaviest stable nuclei. ...

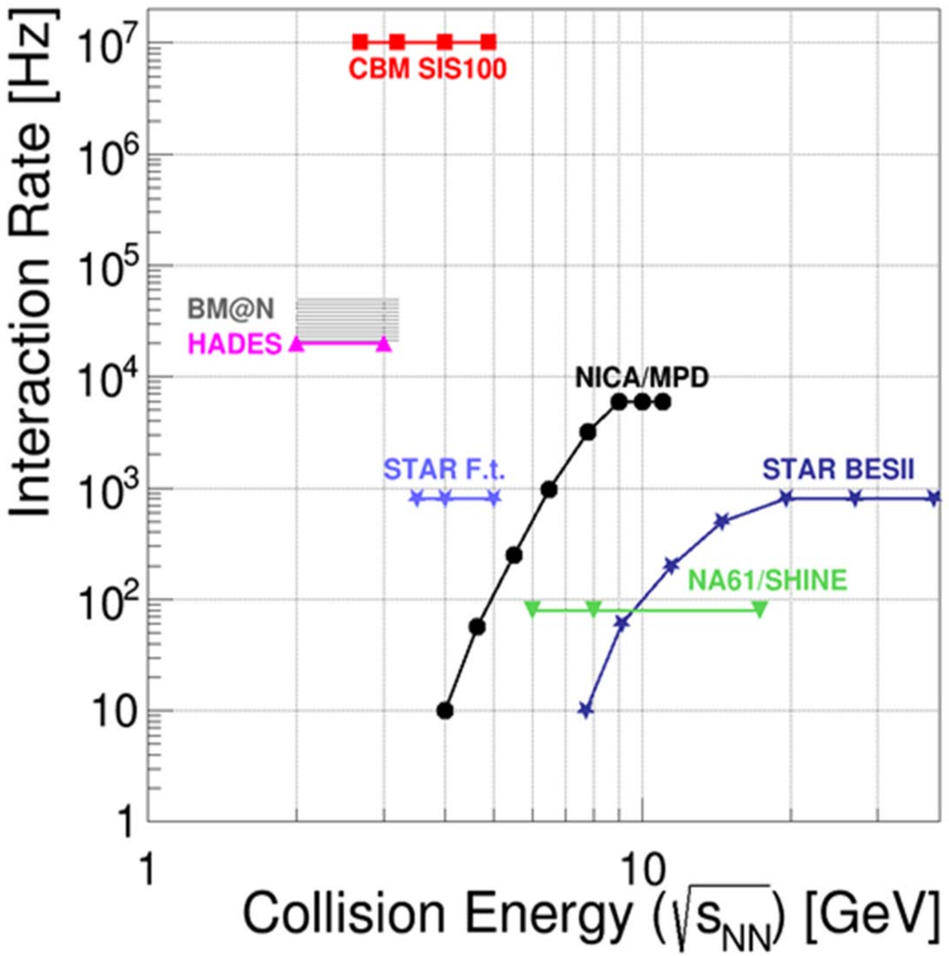
CBM: FAIR delay and competing experiments

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

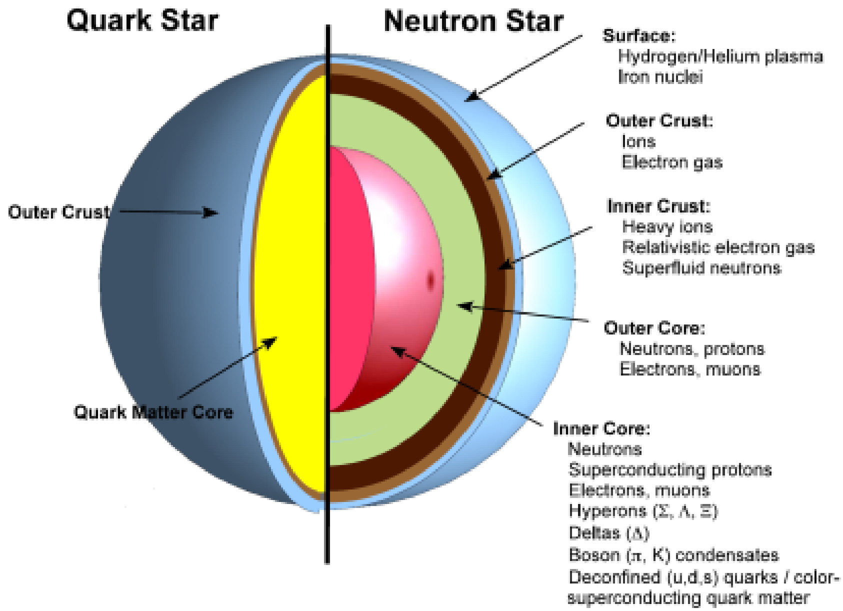
- STAR at RHIC-BNL (BES)
- NA61 at CERN-SPS
- MPD at JINR-NICA
- BM@N at JINR



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

Consequences of the FAIR evaluation for 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

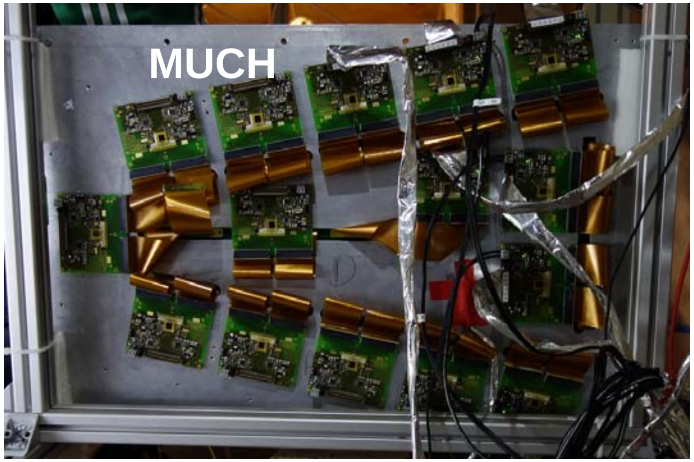
Detector optimization:

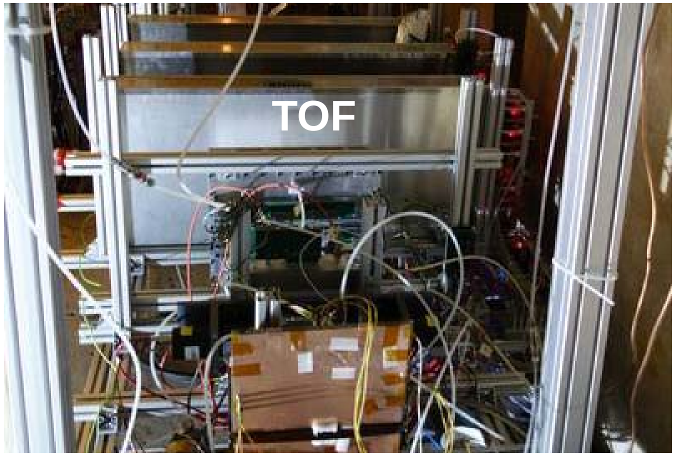
- Compact detector configuration to increase acceptance
  - Reduction of detector layers for TRD and Muon system

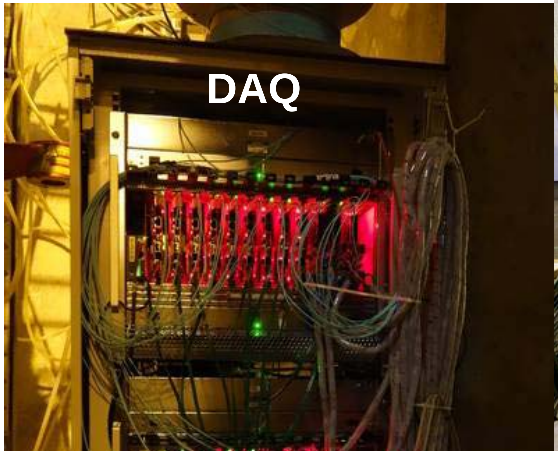
  Adoption to larger beam deflection at lower energies:
  - Horizontal displacement of forward hadron calorimeter
  - Horizontal adjustment of beam pipe
  - Larger acceptance of beam dump

CBM 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







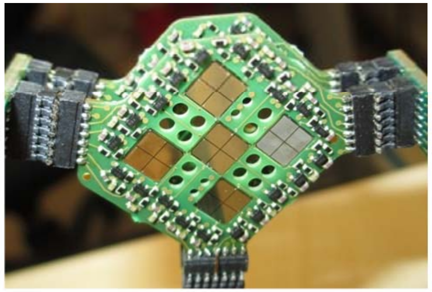
HADES Preparation for FAIR

Detector upgrades

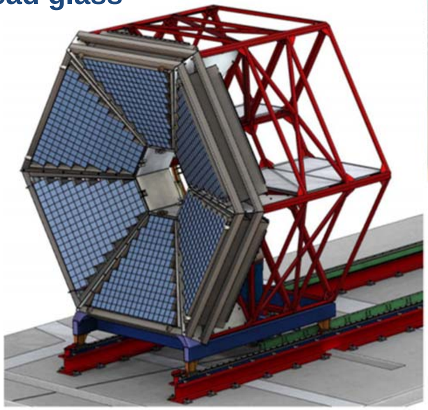
- ECAL (PSP 1.1.2.3)
- RICH-700 (synergy with CBM – UV detector)
- MDC-FEE (PSP 1.1.2.4, 1.1.2.5)
- FW-Tracker (synergy with PANDA – straws)
- FW-RPC (for excellent TOF and good charge resolution)
- FW-Wall (synergy with CBM – PSD)
- START (synergy with CBM – t_0 detector)

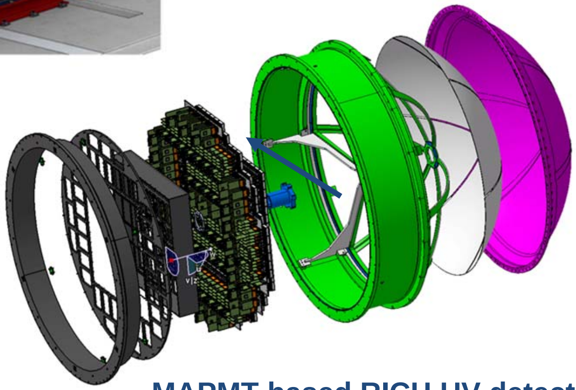
Up to 50 kHz interaction rate, improved electron-id, detection of photons, large acceptance for exclusive processes.

sc-CVD diamond start detector



ECAL based on OPAL lead glass





MAPMT based RICH UV detector

From the WG Draft Report on "Properties of Strongly Interacting Matter":

CBM at FAIR will measure both hadronic and leptonic probes with a large acceptance in fixed-target mode. For this next-generation experiment, the emphasis is put on very high rate capability, with the ambitious design goal of 10 MHz peak rate.

Such high interaction rates will overcome the limitations in statistics suffered by current experiments and permit the measurement of extremely rare probes like e.g., yields and flow of identified anti-baryons, in particular multi-strange hyperons, intermediate-mass lepton pairs, and particles containing charm quarks.

The combination of high-intensity beams with a dedicated high-rate detector system provides worldwide unique conditions for a comprehensive study of QCD matter at the highest net-baryon densities achievable in the laboratory.

$\bar{p}$anda

Science Case

- PANDA physics program now focused onto:
  - *Strangeness:* High statistics sample of unexplored territory hyperon ($\Lambda*$, $\Sigma*$, $\Xi*$, $\Omega*$) spectroscopy
  - *Charm(-like):*
    X,Y,Z-factory, high statistics allow new approach to lineshapes, transitions, nature of the states
    Heavy-light mesons unexplored high spin states, lineshape
  - *Nucleon Structure:*
    highest rates at lower q^2 for G_E, G_M, TDA, WACS, TMD
  - *Hypernuclei and nuclear targets:*
    Hyperon-potential in nuclei, excited states of $\Lambda\Lambda$-hypernuclei

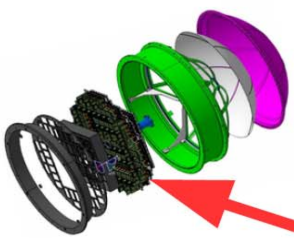
Strategy of PANDA

- After intense discussion with the scientific community, there is
  – a focusing of the first key experiments
  – a definition of the start setup
  – a proposal for intermediate experiments/activities

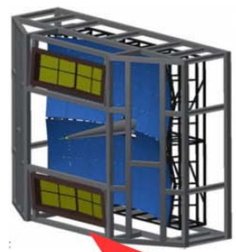
- And in addition:
  - Development of dedicated analysis methods at ELSA, MAMI, BESIII, Jlab, COMPASS to ensure a quick start of PANDA.
  - Application of modern PANDA technologies at present and future facilities, e.g. Trackers, Cherenkov (DIRC), EMC, Photon readout, Readout electronics

DiRICH MAPMT/MCP readout chain

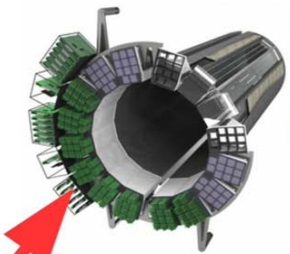
common development for **HADES**, **CBM** and **PANDA**



HADES RICH
28k channels
MAPMT readout
First beam 2018
FAIR phase-0 !



CBM RICH
55k channels
MAPMT readout

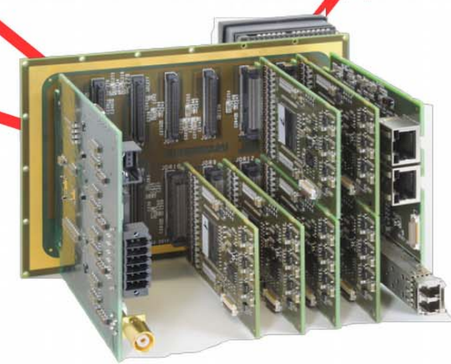


PANDA
Barrel-DIRC
11k channels
MCP readout

DiRICH 3x2 PMT readout module

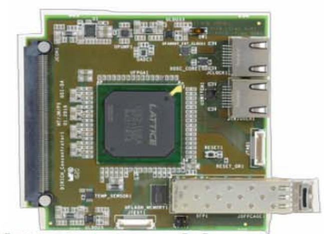
- Perfect synergy between FAIR experiments
- **Based on TRB3 project** (GSI development)
- Development funded by BMBF

- **prototypes** of all modules **available** and under evaluation (06 / 2016)
- **Very promising first results**



DiRICH Front-end
- **32ch** low-power preamp,
- **discrimination** (FPGA)
- high precision **FPGA-TDC**
- Time+ToT measurement
- **< 50ps RMS precision**

DiRICH Power
- Common LV+HV supply



DiRICH Combiner
- 12 DiRICH → single fiber

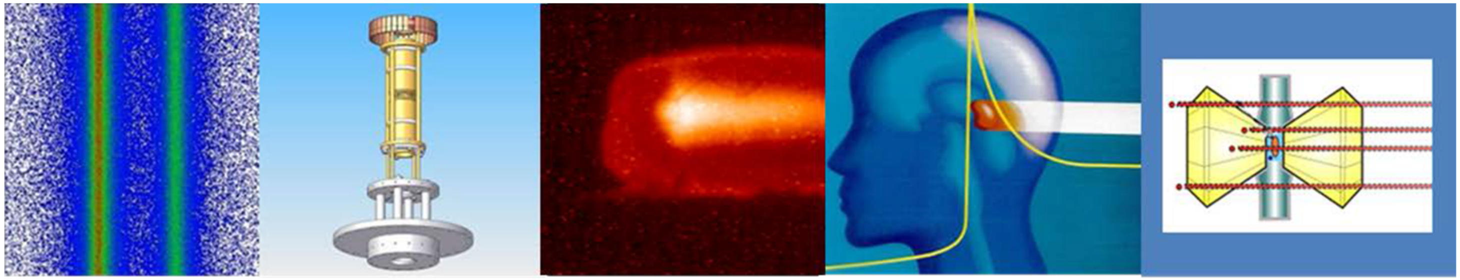
From the WG Draft Report on “Hadron physics”:

... FAIR is expected to provide ... a unique research environment for all aspects of hadron physics coming from experiments with antiprotons.

The strategic importance of PANDA for hadron physics cannot be overestimated. It provides a unique opportunity for a comprehensive research programme in hadron spectroscopy, hadron structure and hadronic interactions.

The combination of PANDA’s discovery potential for new states, coupled with the ability to perform high-precision systematic measurements is not realised at any other facility or experiment in the world.

... PANDA continues to be viewed as a major flagship experiment, which attracts a large international community.



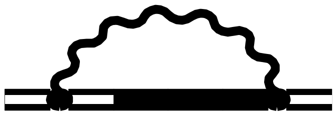
**From fundamental to applied research –
Atomic physics, Plasma Physics, Application**

APPA

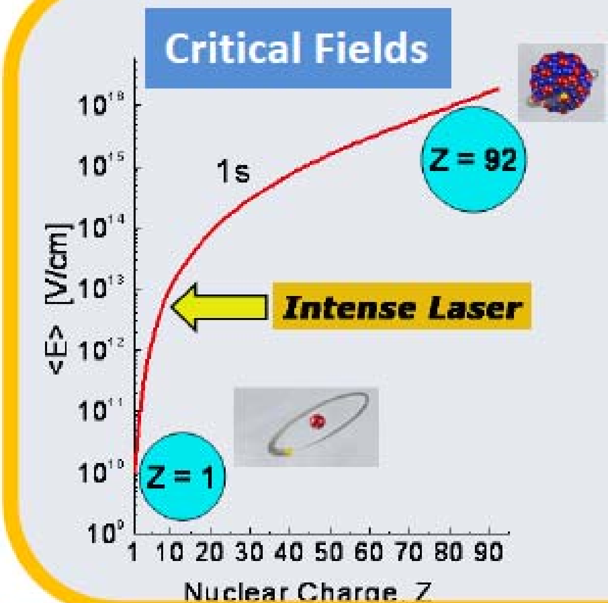
Atomic & Fundamental Physics

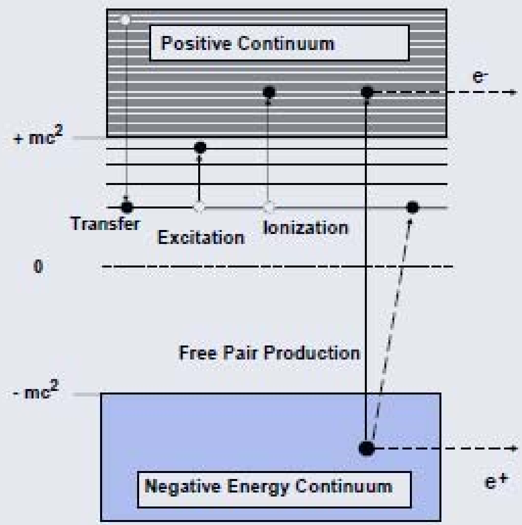
Interplay between Relativity, Correlation, and QED in the Non-Perturbative Regime

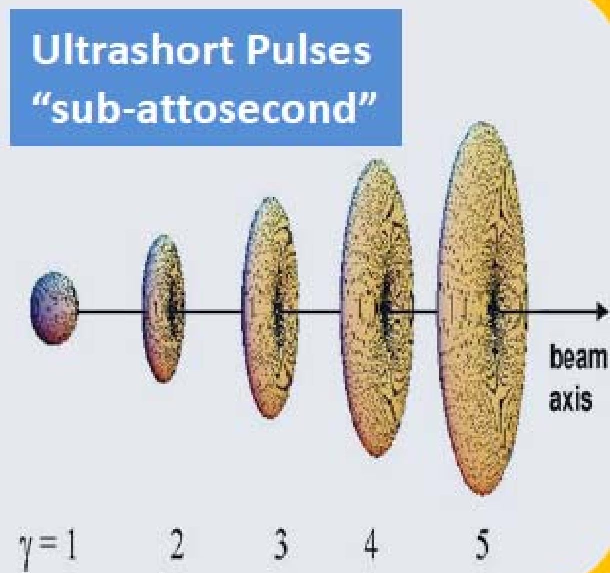
$$\alpha Z \approx 1$$



- **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**







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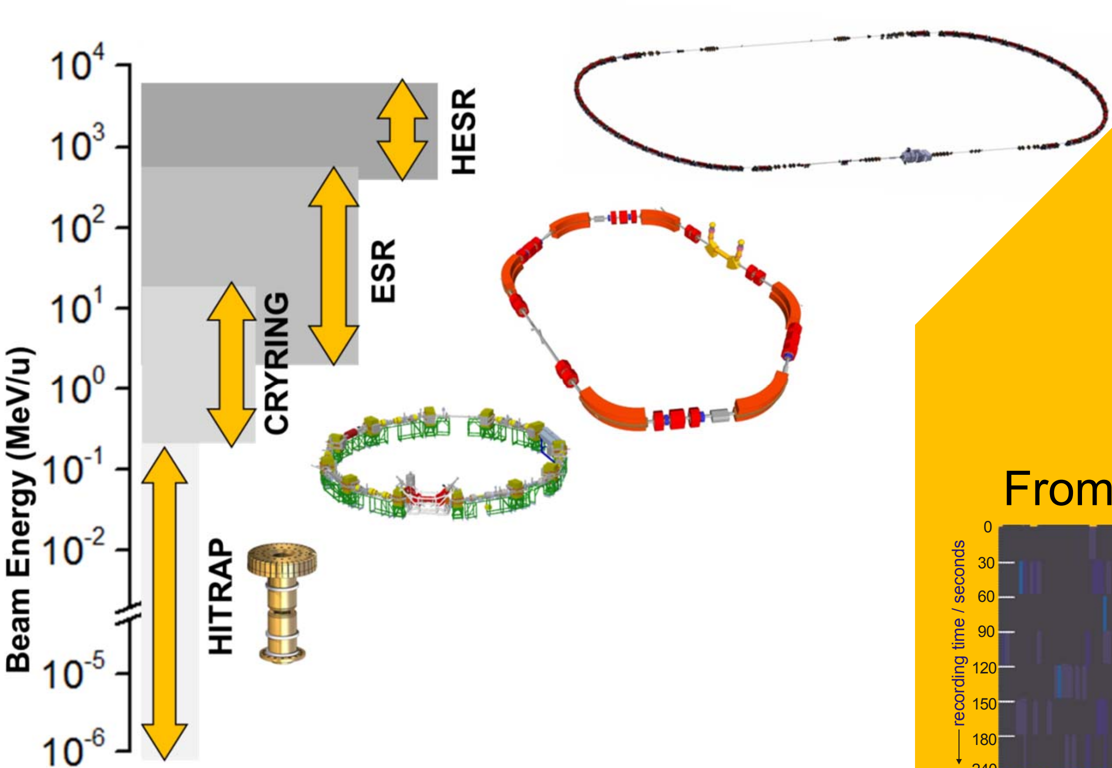
Ion Beam Facilities / Trapping & Storage

Worldwide Unique

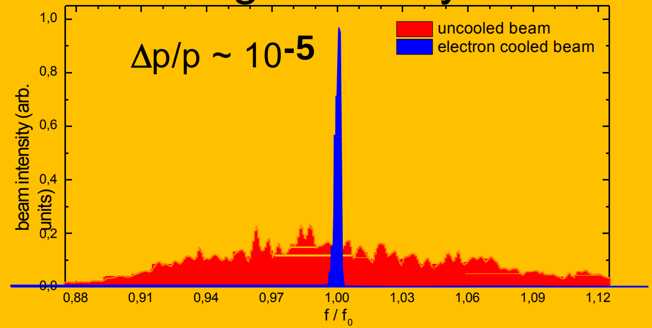
Stored and Cooled

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

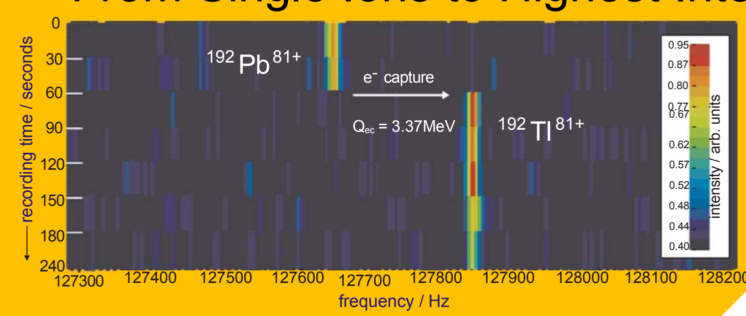
From Rest to Relativistic Energies (up to 4.9 GeV/u)



Cooling: The Key for Precision



From Single Ions to Highest Intensities



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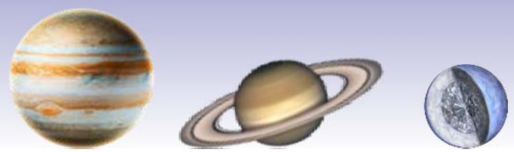
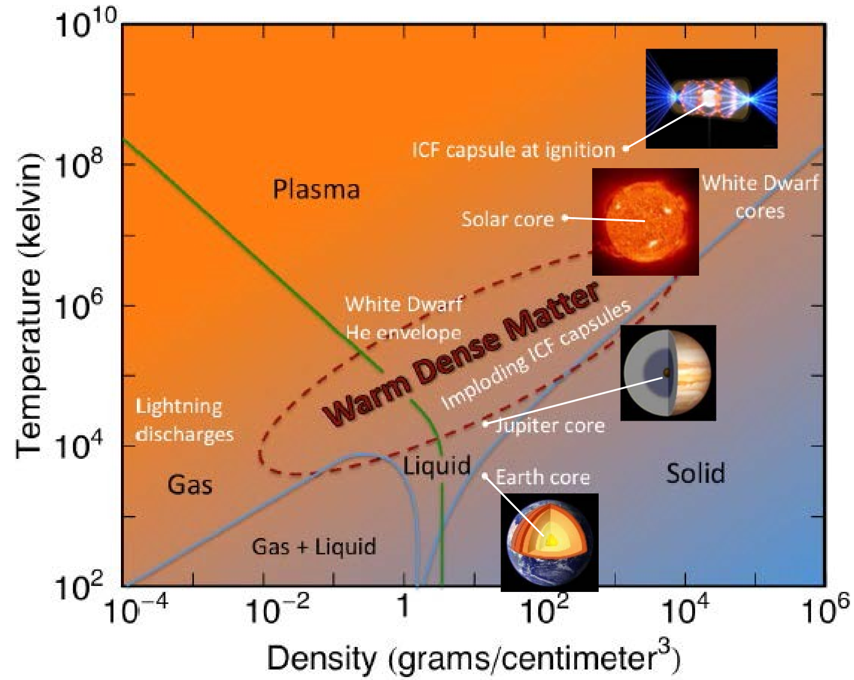
High-Energy Density Science

Dense plasmas

- Temperatures $10^3 \ldots 10^6$K
- Densities 0.1...1000x solid
- Pressures kbar...Gbar





A great challenge for theory:

- Strong coupling: $E_{pot} \geq k_B T$
- Quantum effects: $E_F \sim k_B T$
- Collisions (conductivity, heat transport): Λ_C<0
- Partial ionization
- Continuum lowering
- ...

Exotic states, complex properties:

- Equation of state, melting + phase transitions, transport properties, metallization,...
- Transport properties (heat, radiation), equilibration,...., non-equilibrium states
- Interaction of ions and photons with plasma
- Atomic & nuclear physics in dense plasmas

Dense plasmas are stongly correlated many particle quantum systems

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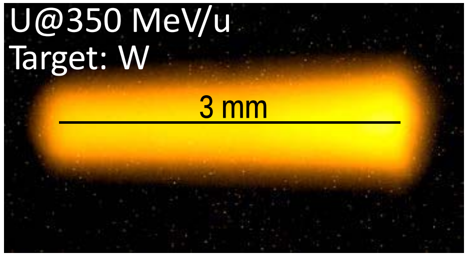
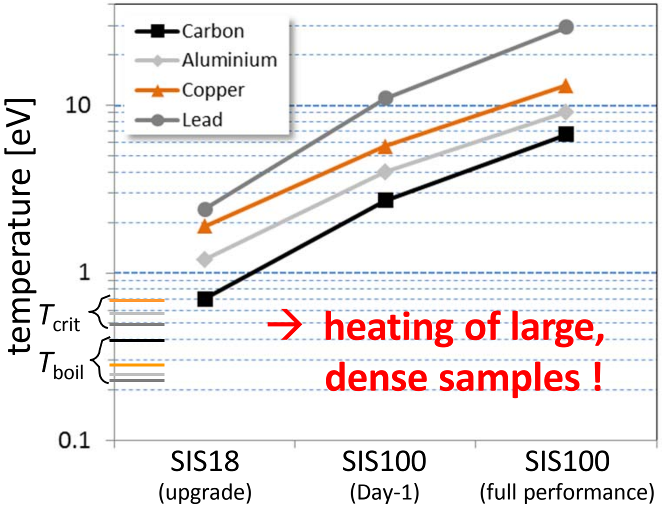
FAIR will offer exciting new possibilities for research in High-Energy Density Science

Unique properties of heavy-ion driven plasmas

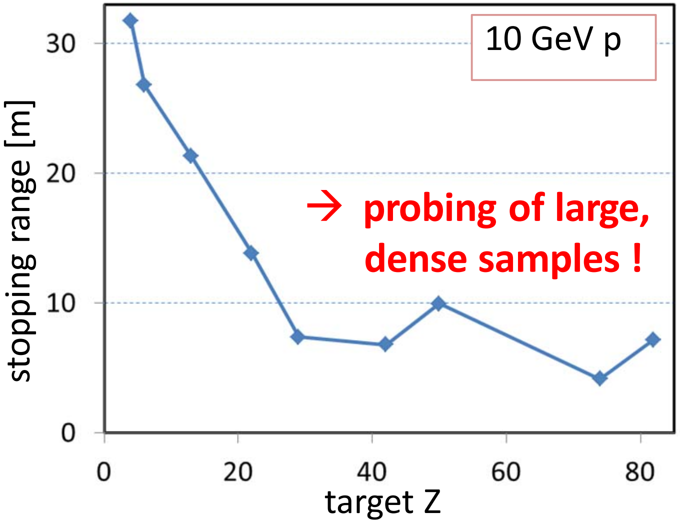
- large volumes (mm^3)
- uniform conditions
- thermal equilibrium
- any target material
- rep. rate, reproducibility





Protons as dense matter probe

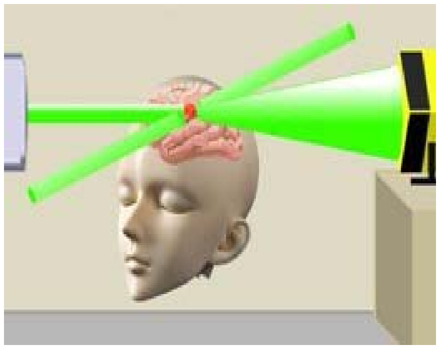
- Long range (~m) of relativistic protons
- High-resolution imaging of small angle deflection →accurate density meas.
- Ultra-intense proton pulses allow for short (~10ns) time exposure



- **FAIR will produce the worlds largest volumes of uniform HED matter** (x100 increase in specific energy deposition over GSI)
- **FAIR will host the worlds highest resolution proton microscope**

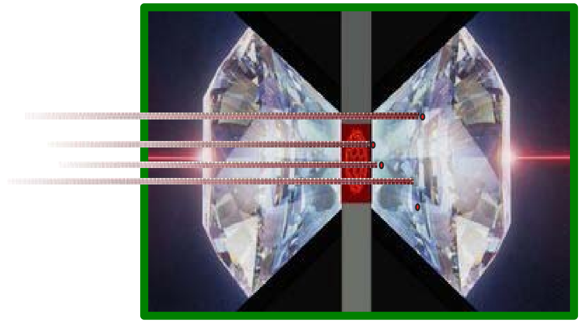
Research topics at FAIR

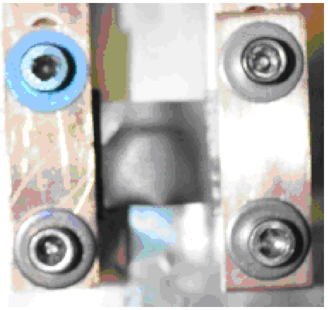
Biophysics



- **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**

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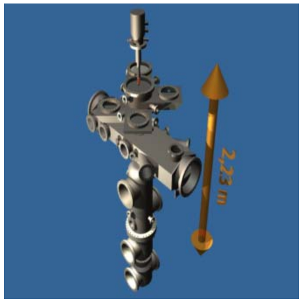
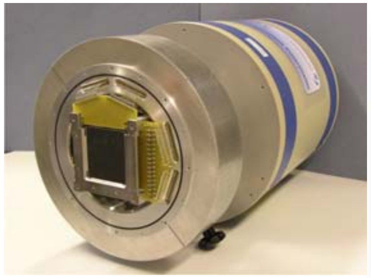
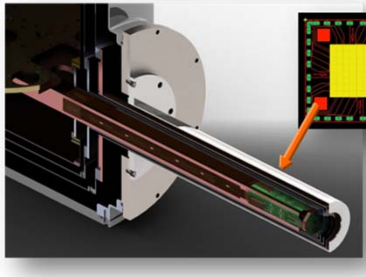
Progress in preparing the APPA experiments: Sophisticated & Versatile Instrumentation

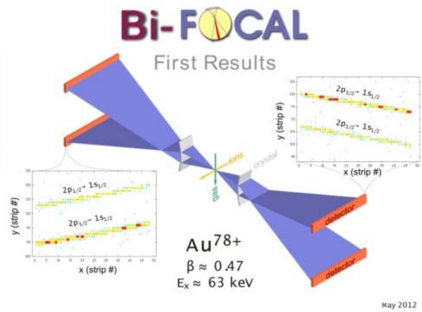
Observables: Photons, electrons, positrons, ions



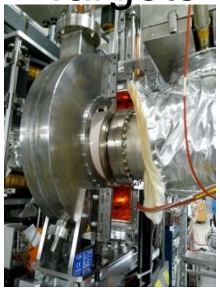
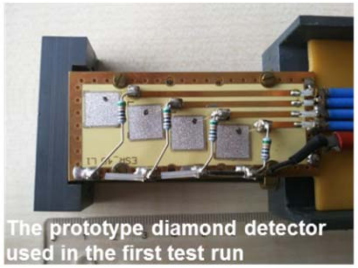
Targets

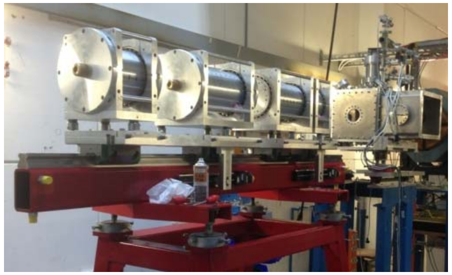
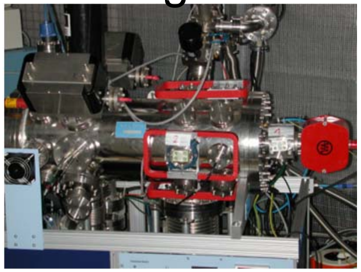
Position-sensitive solid-state detectors



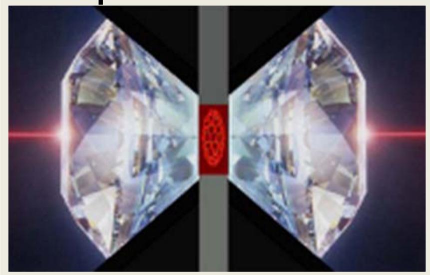
High-resolution spectrometers

Particle detectors

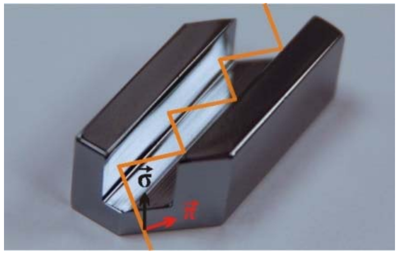



Particle spectrometers

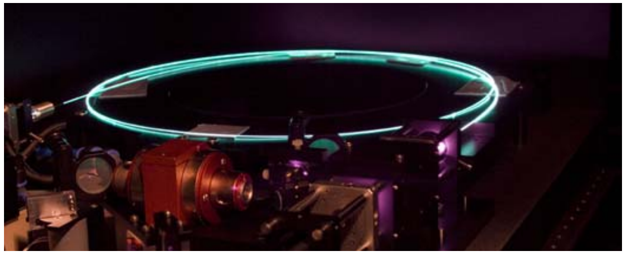


High pressure cell


Traps

X-ray optics, channel-cut crystals



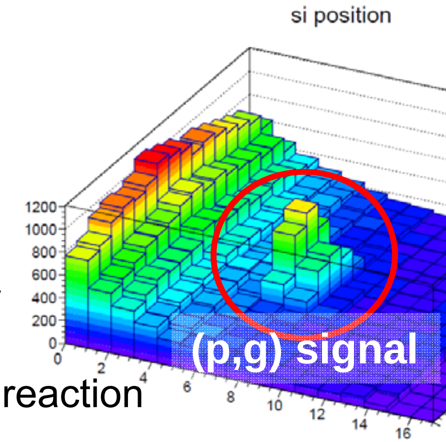
Laser systems

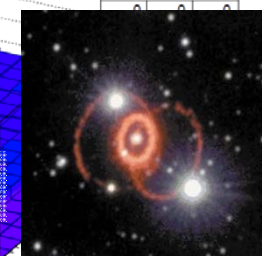
Research at GSI continues ...

- Beam Time 2016
  - 3 months during the first half year
  - Global machine availability about 75% for parallel operation
  - Very efficient parallel operation at SIS/ESR:
    on average beam delivery to three experiments in pulse-to-pulse operation
  - Instrumental highlight: start of commissioning of the Cryring
  - Physics highlight: pioneering measurements of proton-capture reactions at the internal target of ESR
    → demonstrating the feasibility of precision studies of astrophysical reactions at storage rings.

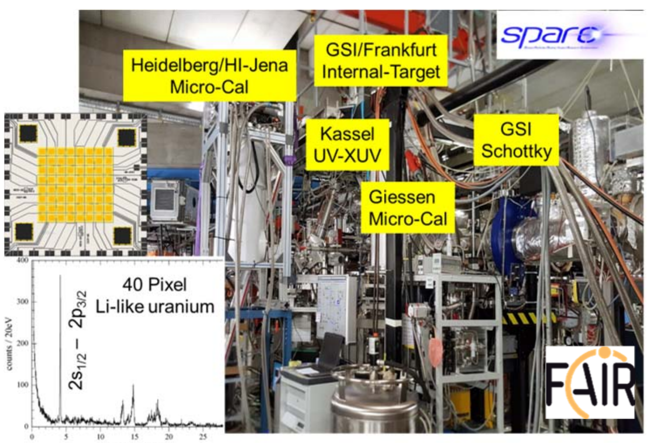
Highlights from 2016 Beam Time at GSI

- Successful start of commissioning of the Cryring@ESR (first turn achieved)



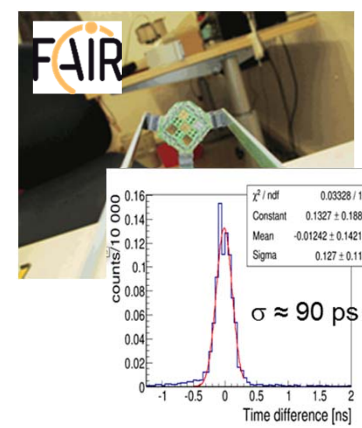


- Successful proof-of-concept of nuclear astrophysics studies in storage rings using the 124Xe (p,γ) nucleosynthesis reaction



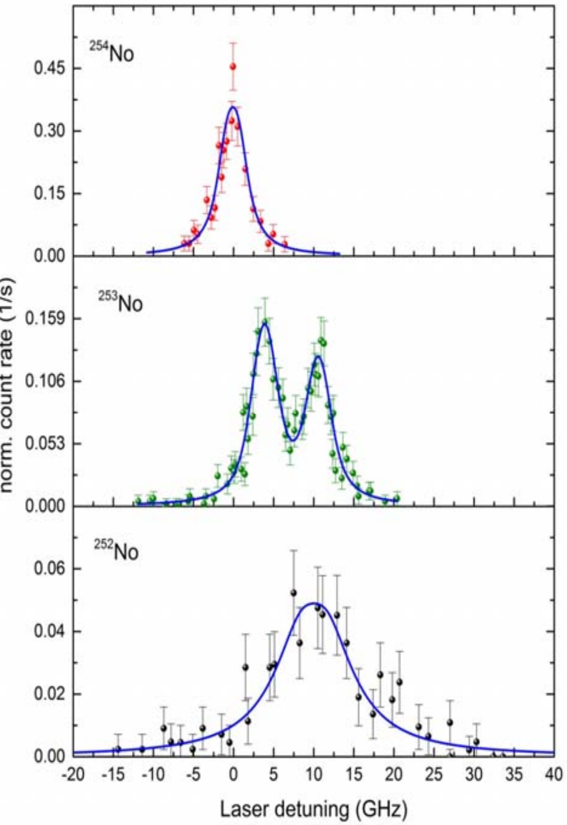
- Successful test of novel APPA / SPARC instrumentation

- Tests of CVD diamond detector
  - In vacuum operation without cooling
  - Rate capability up to 10^7 MIPs/s/mm2
  - Timing resolution (sigma) 90ps
  - Radiation hard material CVD diamond



Further research highlights

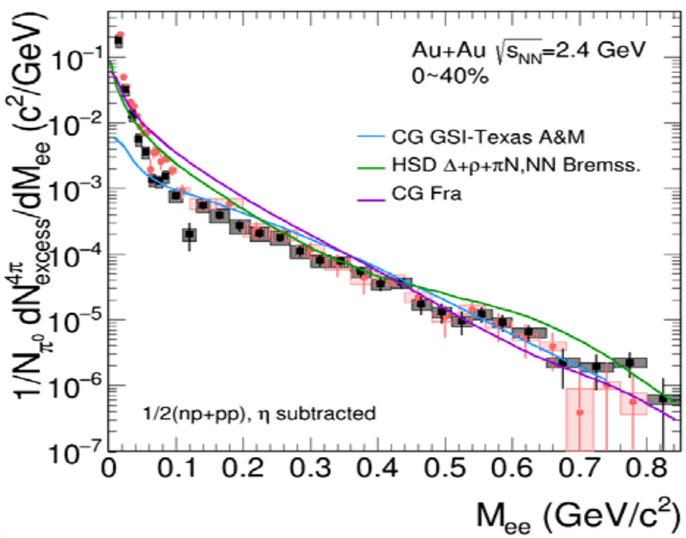
Laser Spectroscopy of Nobelium (Z=102)



nature

doi:10.1038/ nature19345, 9/16

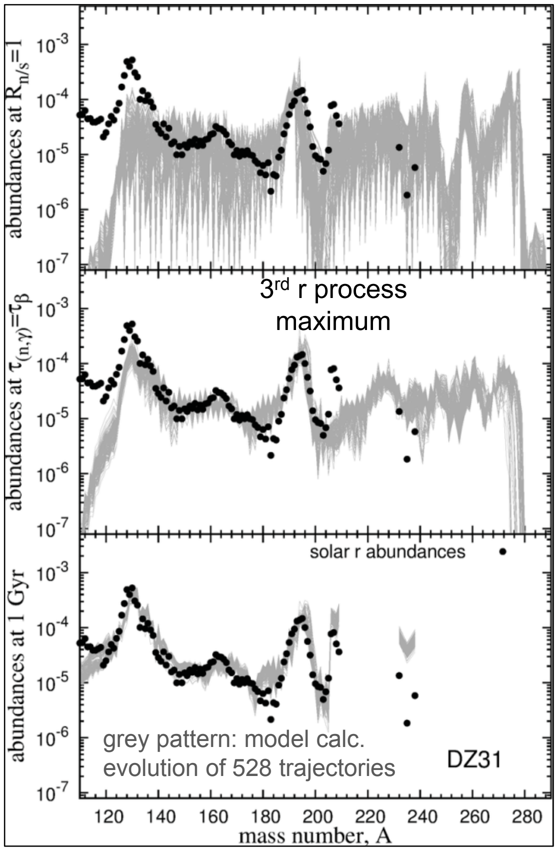
Virtual photon radiation from Au+Au collisions



- Inclusive excess mass spectrum
- all known sources subtracted
- fully corrected for acceptance
- Almost exponential spectrum up to vector meson region.
- Fit to dN / dM ∝ M3/2 × e−M/T →

$T_{emitting\ Source}$ = 95 ± 5 MeV

Theory r-process in neutron star mergers



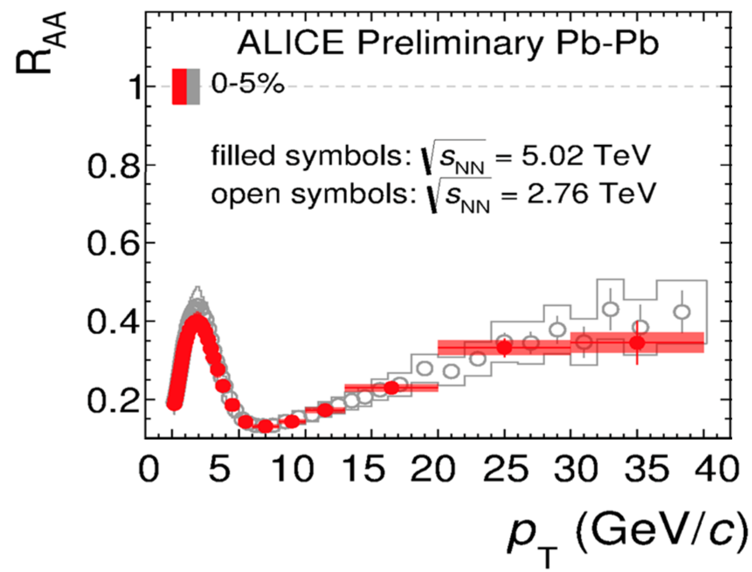
- Sensitive to properties of exotic nuclei and fission

G. Martinez-P., PRC **92**, 055805 (2015)

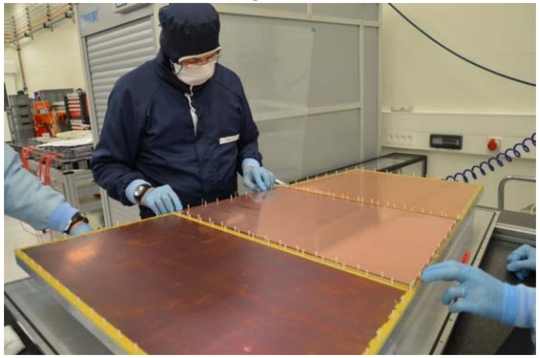
ALICE @ GSI

GSI continues to play a leading role in the ALICE Collaboration:

- Participation in the ongoing analysis
- Operation of the Tier 2 Center/ Analysis Center
- Contribution to high intensity upgrade for LHC Run 3



Nuclear modification factor of inclusive charged particles.



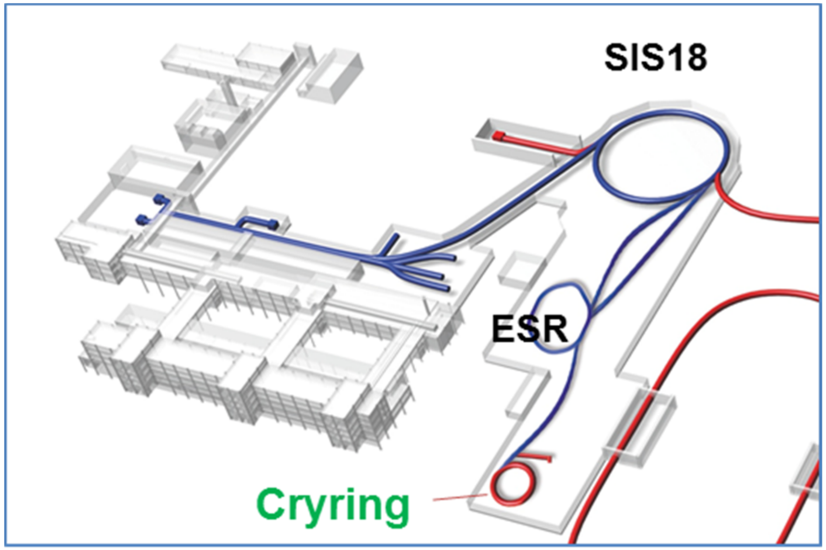
TPC upgrade: Outer ReadOut Chamber (OROC) pre-production

Intermediate Research Program FAIR Phase 0

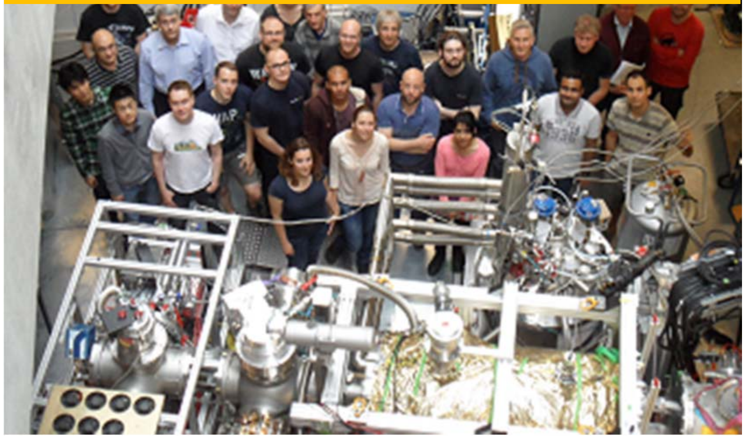
- Goals
  - Forefront research by employing and testing new FAIR detectors
  - Exploiting upgraded GSI accelerator facilities
    - ongoing upgrade of SIS18 completed by mid 2018
  - Education of young scientists
  - Maintain and extend skills and expertise
  - Serve national and international user community
- Plan
  - Establish an international Program Advisory Committee
  - 1st call for proposals for beam time slot 2018/19
    in spring 2017

FAIR Phase 0 Program

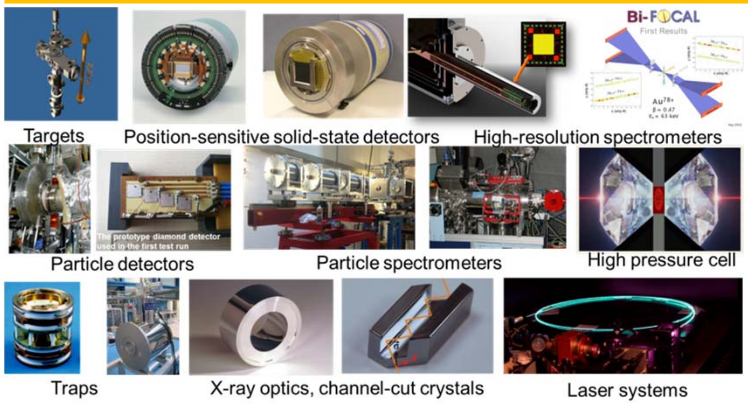
- Benefit from UNILAC and SIS18 upgrade
- Make use of Cryring, R3B magnet and other novel FAIR instrumentation



LEB Stopping Cell



SPARC instrumentation



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

APPA	Facility	Research Activity
SPARC SPARC	ESR-HITRAP- CRYRING	Strong field QED, atomic collisions, fundamental 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	External	Search for exotic states, charmonium and time-like form factors at BESIII/Beijing/IHEP. Magnetic moment of $\Delta(1232)$, e-m universality, multi pi0 prod. at MAMI

Summary and Outlook

FAIR is in good shape for full completion by 2025.

Installation incl. commissioning of the experiments is planned during 2021-2024

GSI/FAIR Research Strategy towards 2025:

- **R&D for and construction of the FAIR experiments**
- **FAIR phase 0 – intermediate research program** bridging the construction phase from 2018 until commissioning of the FAIR accelerators and experiments.

FAIR 2025