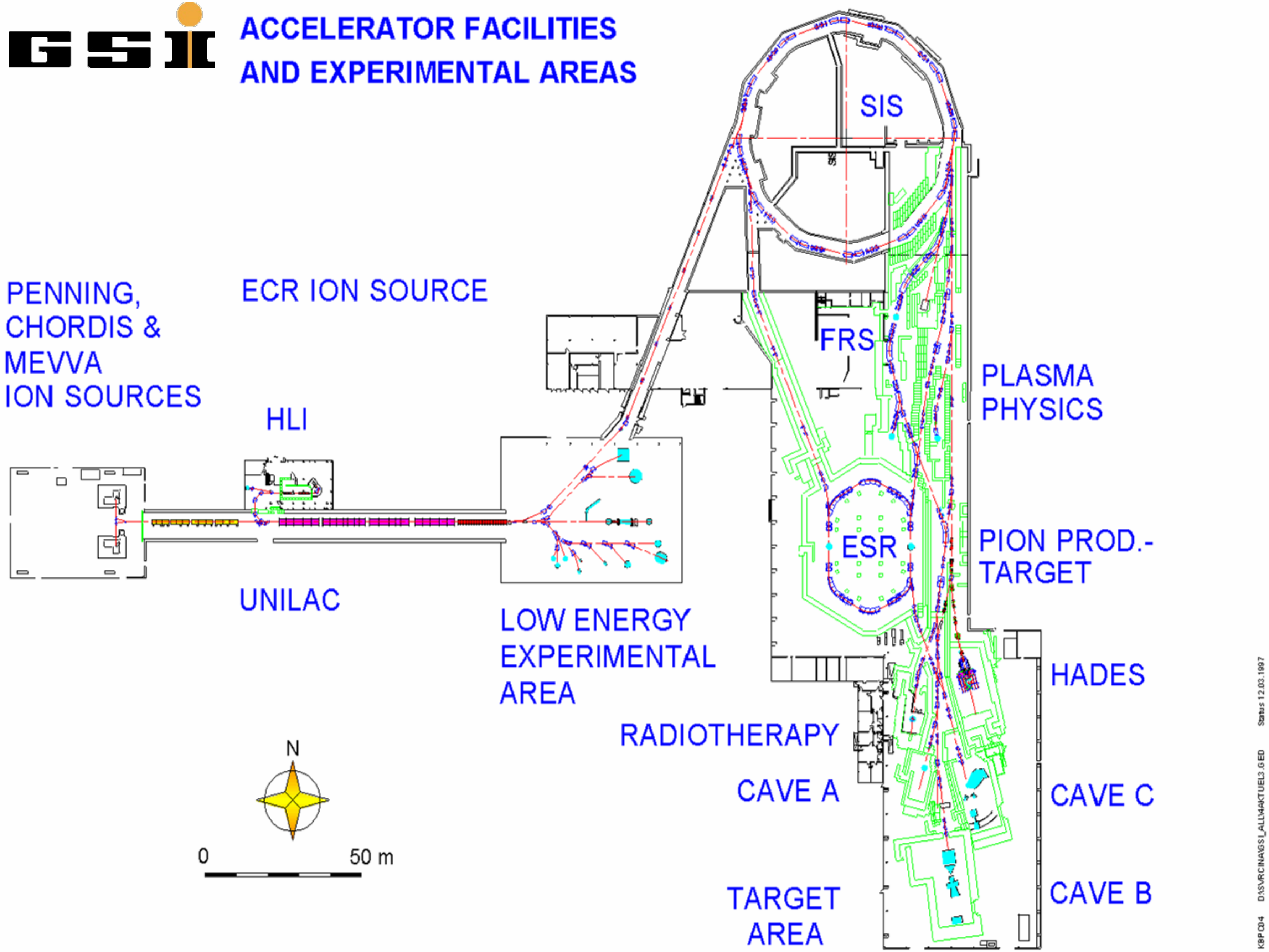
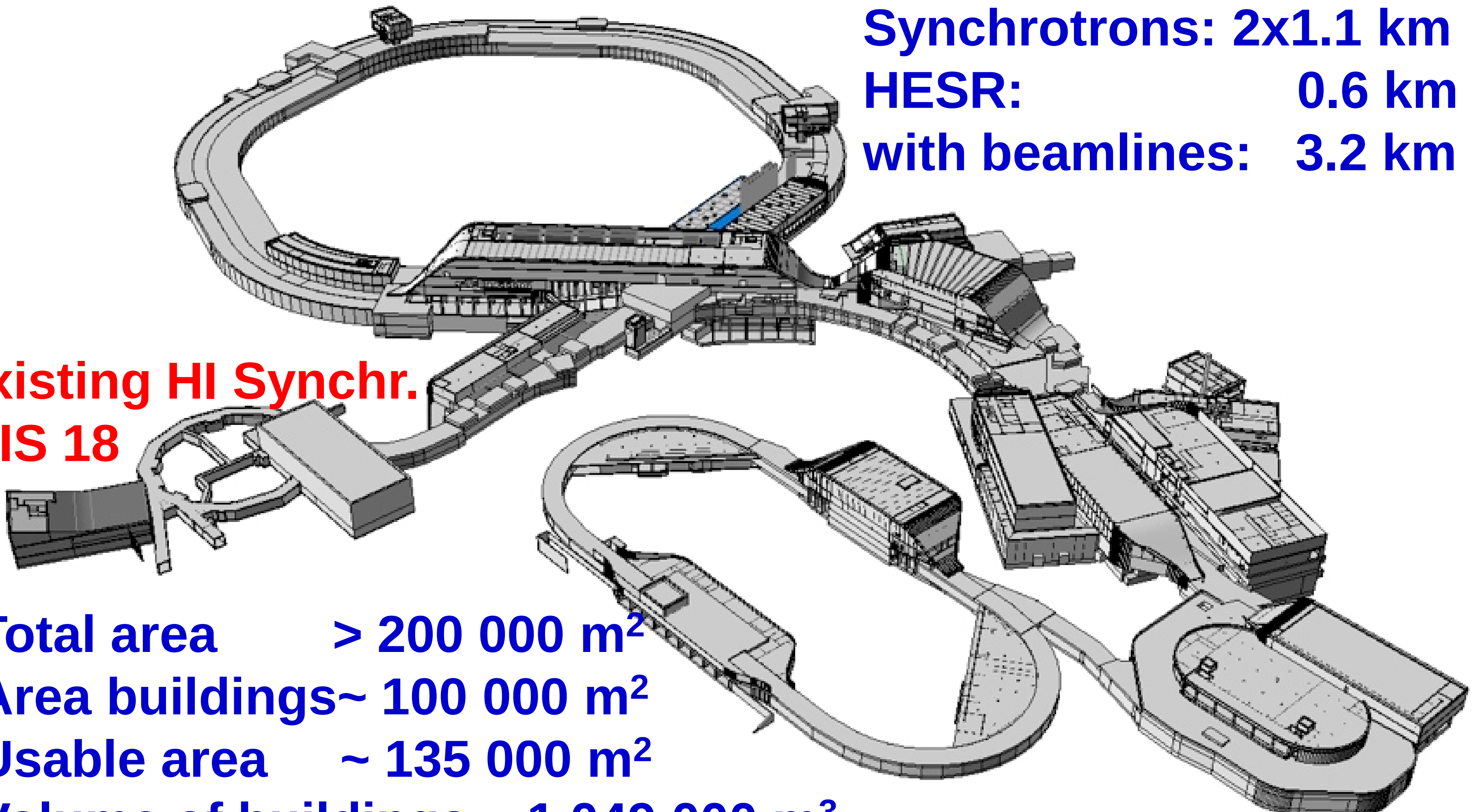
Discovery Physics at FAIR
Scientific and Technological Innovation Opportunities for South Africa

ACCELERATOR FACILITIES AND EXPERIMENTAL AREAS




Google Earth 7.12.2013

FAIR Civil Construction



Synchrotrons: 2x1.1 km
HESR: 0.6 km
with beamlines: 3.2 km

Existing HI Synchr.
SIS 18

Total area > 200 000 m^2
Area buildings~ 100 000 m^2
Usable area ~ 135 000 m^2
Volume of buildings ~ 1 049 000 m^3
Substructure:~ 1350 pillars, up to 65 m deep

The Big Challenge ...

Gain Factors

- Beam intensities up by factors of 100 - 10000
- Beam energies up by a factor 20
- Production of antiproton beams
- Factor 10000 in beam brilliance via cooling
- Efficient parallel operation of programs

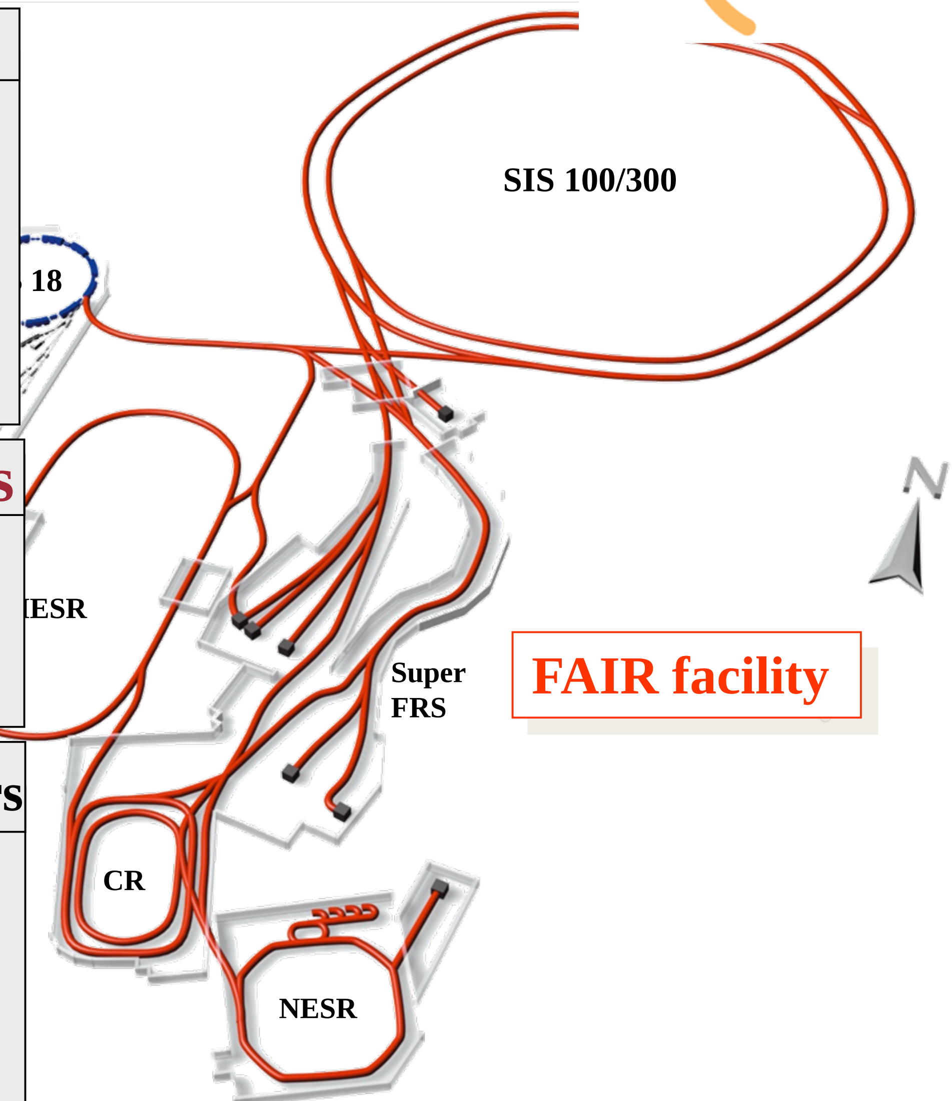
Construction Period, Cost, Users

- Construction of modules 1, 2, 3 until 2020
- Total cost 1.6 Giga €
- Scientific users: 2500 - 3000 per year

•Four pillars : APPA -CBM-NuSTAR-PANDA

Financing International Shareholders

- 30 % international Partners 12 Countries
- 10 % State of Hessen
- 25 % Helmholtz Gemeinschaft
- 35 % Federal Rep. Germany



FAIR facility

FAIR scientific opportunities: highest Ionbeam Intensity worldwide

+ FAIR under construction as an International Facility with 10 Ownerstates

Construction Budget: 1600+ Million Euro Invest – mostly in kind
Operating Budget: 160+ Million Euro annually … + detectors (collaborations)

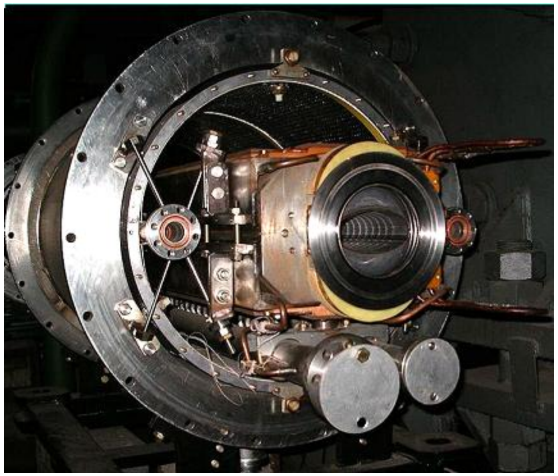
Four high intensity driver accelerators: Heavy Ion Linac UNILAC 20AMeV
⇒ 5 GeV Proton / 2 AGeV Uranium Synchrotron SIS 18 in operation at GSI
⇒ 30 GeV Proton / 10 AGeV Uranium Synchrotron SIS 100 under construction
⇒ 90 GeV Proton / 35 AGeV Uranium Synchrotron SIS 300 (still to be funded…)

Primary Proton and Ion beams on 4 primary targets

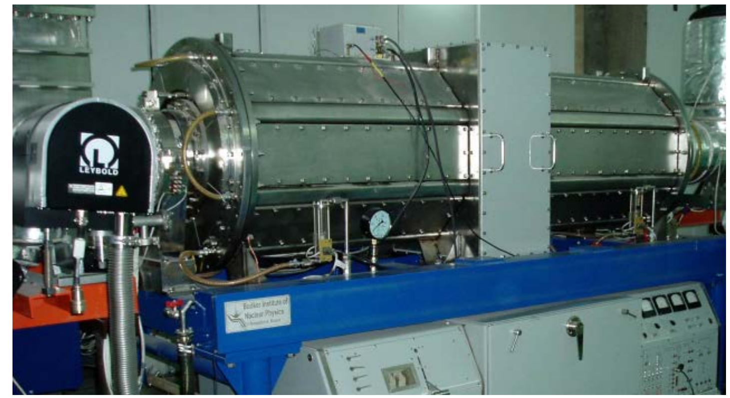
+ secondary beams: rare isotopes & Antiprotons in 4 Storage Rings HESR, CR, ESR
+ APPA: Atomic, applied , plasma, bio, material-science and FLAIR @ Cryring
+ NuSTAR: RIB, nuclear Astro, nuclear structure, multi-Hypernuclei
+ CBM: Relativistic Heavy Ions super- Dense Baryonic matter
+ PANDA: Massive Charmonium, X, Y, Z, Glueballs & Hybrids
+ Beauty-Baryon-AntiBaryon pairs in a pBar-p Collider option at HESR …

FAIR Accelerator Challenges

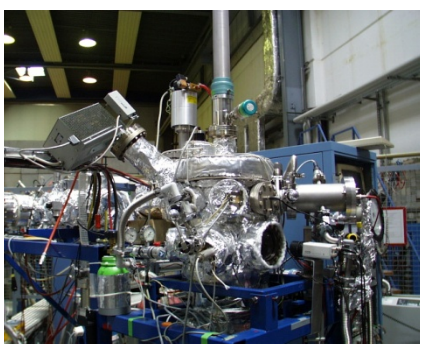
Compact & cost effective accelerators
Fast cycling superconducting magnets
dB/dt ~ 4T/s



Fast acceleration
High gradient, variable frequency
Ferrite & MA loaded cavities



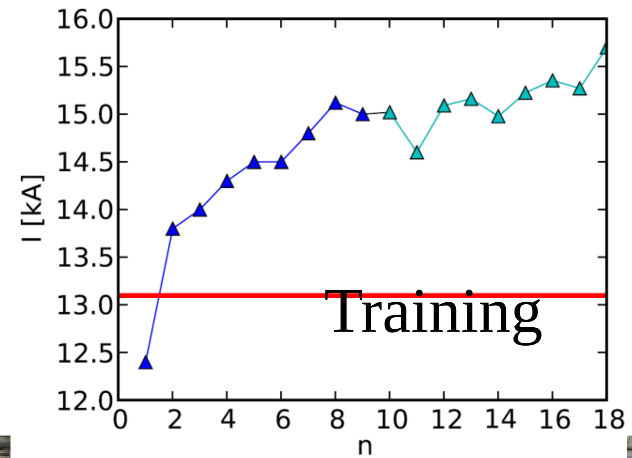
XHV @ high beam intensities
Extremely high vacuum ~10^{-13} mbar



Precision beams
Electron & stochastic cooling

SIS100 FOS Dipole-Tests

- **Cycle tests:**
  - B(Injection)→ B(max.)→ B(Injection)
  - Period T = 1.1 s achieved → minimum cycle time still to be checked

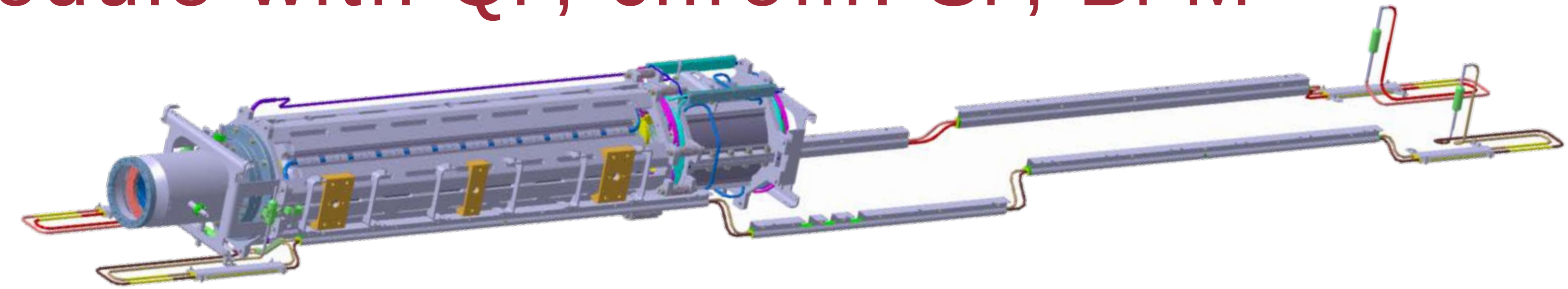


- **Magnetic field: DC measured**
  - Central field follows specific
  - Field higher-order componen measured

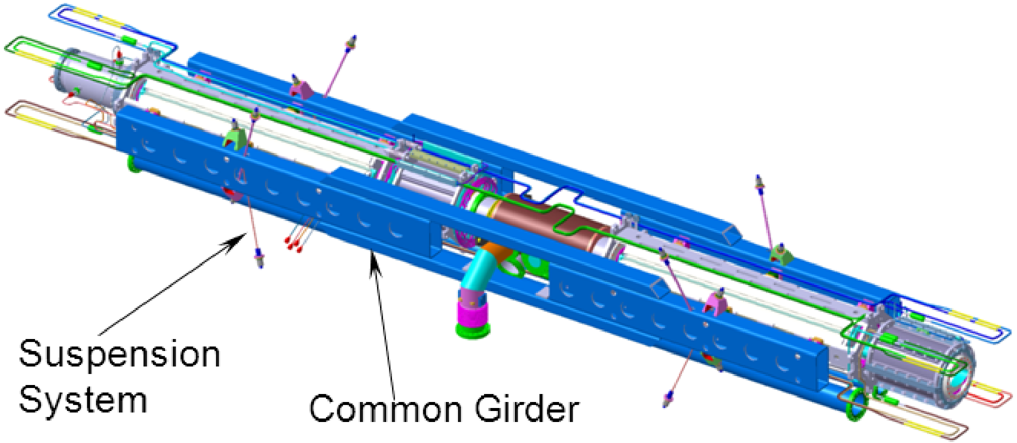
- **Next activities:**
  - Interpretation of measurem results
  - Measurements at cryogenic temperatures
  - Optimisation of yoke ends

SIS100 Quadrupole Module

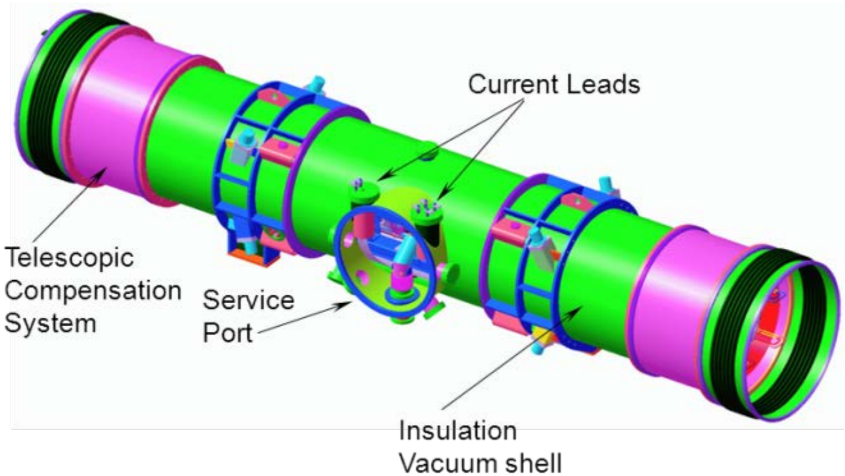
- Module with QP, chrom. SP, BPM



- Doublet with Cryo-Catcher module



Functional elements installed in common girder



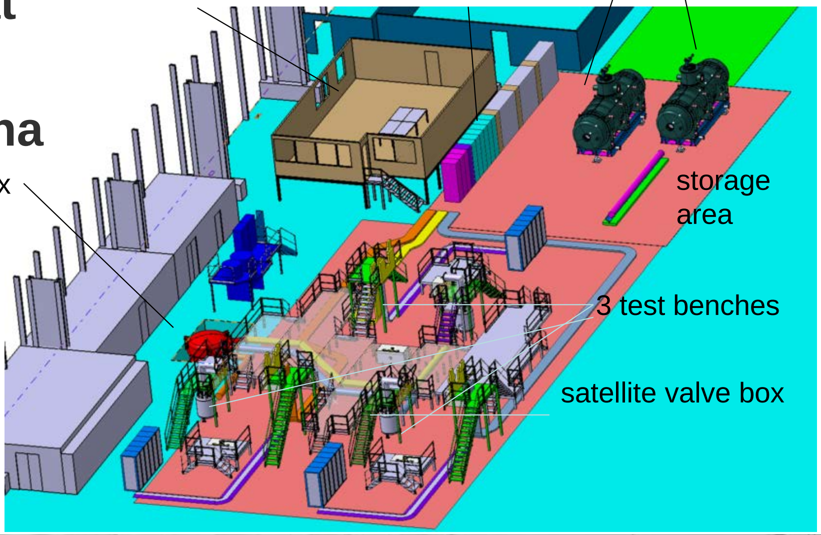
Fully integrated QP-Doublet: Cryostat with telescopic compens

Magnet testing facilities GSI / Dubna / CERN

- **Testing of SIS100 Dipoles and prototypes at GSI**
- **Testing of SIS100 Quadrupole units at Dubna**
- **Testing od Super-FRS magnets at CERN**

New series test facility at GSI

→ 2kW cryo plant in new building



Preparation at JINR/DUBNA

1600 m^2 main hall
700 m^2 auxiliary facilities

SIS100 dipole series test facility

Test station at GSI operating

- Cryogenic infrastructure procurement ongoing
- Power converters (2 pcs, 20 kA, 22/66 V) ordered
- HTS current leads: based on already tested ones
- Quench detection system ordered (1. test setup)

First delivery may 2014
Installation
commissioning August 2014

Status HEBT

- **Magnets:**

Almost all HEBT Magnets (338/356)
➔ Efremov Institute Russia

Magnets similar to CR Magnets (2+5)
➔ Budker institute

Super-FRS Quadrupoles (9) ➔ GSI in-kind

HEBT magnets distributed among the partners

- **Diagnostics:**

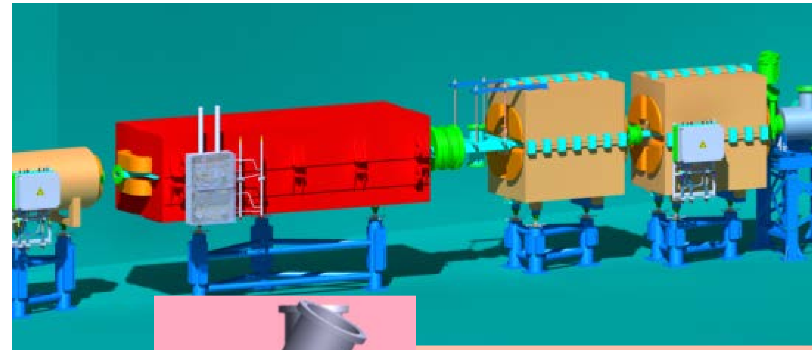
detailed, technical drawing and specification of all standard diagnostic and BPM chamber

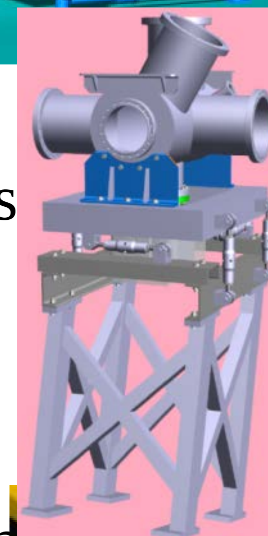
pre-series production of first diagnostic chamb

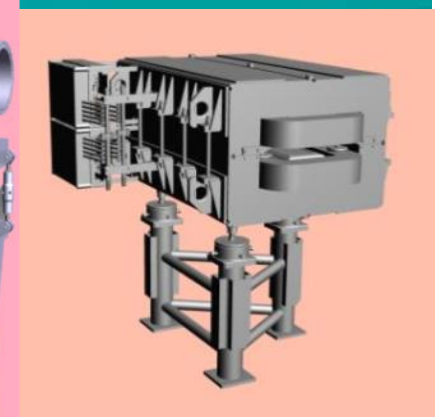
detailed, technical drawing of FAIR standard pneumatic drive

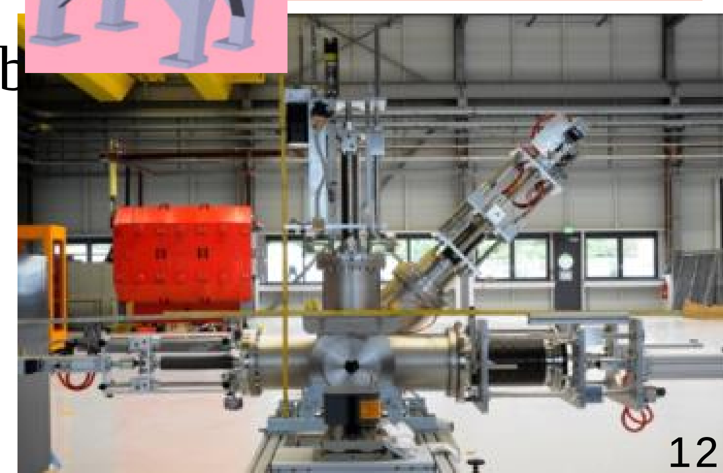
pre-series production of

first FAIR pneumatic drive



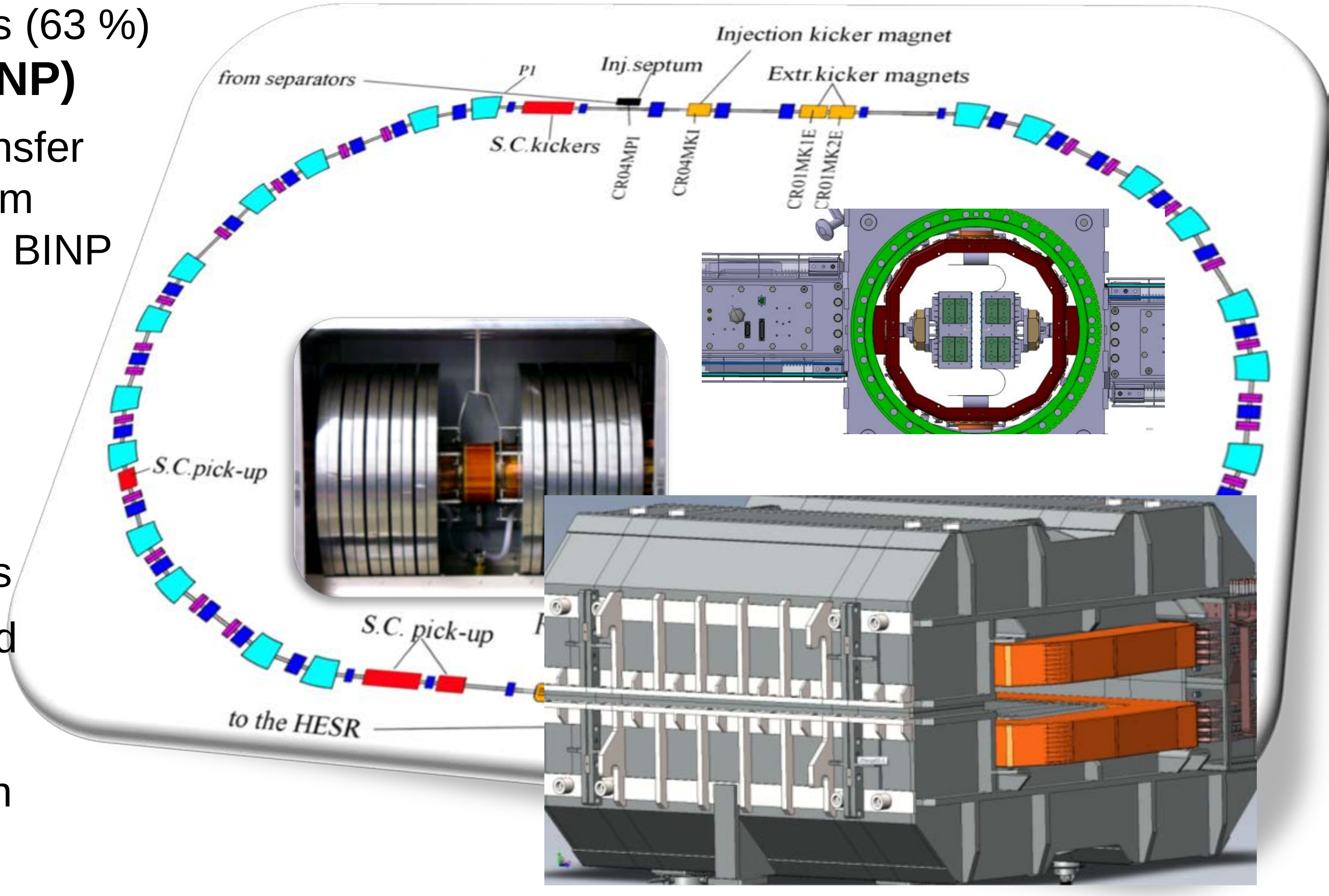




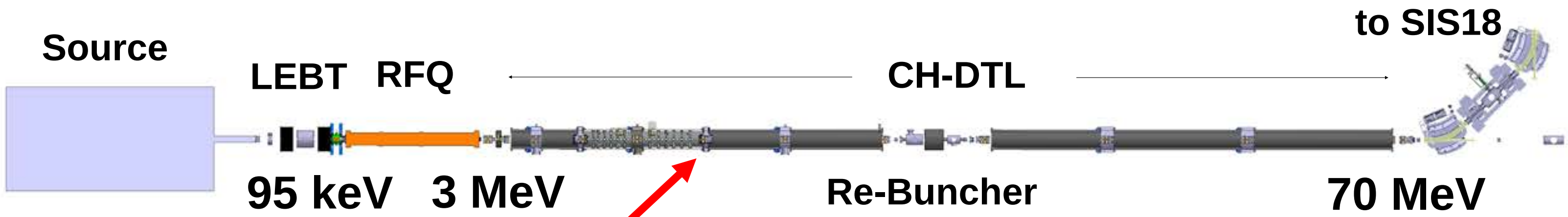


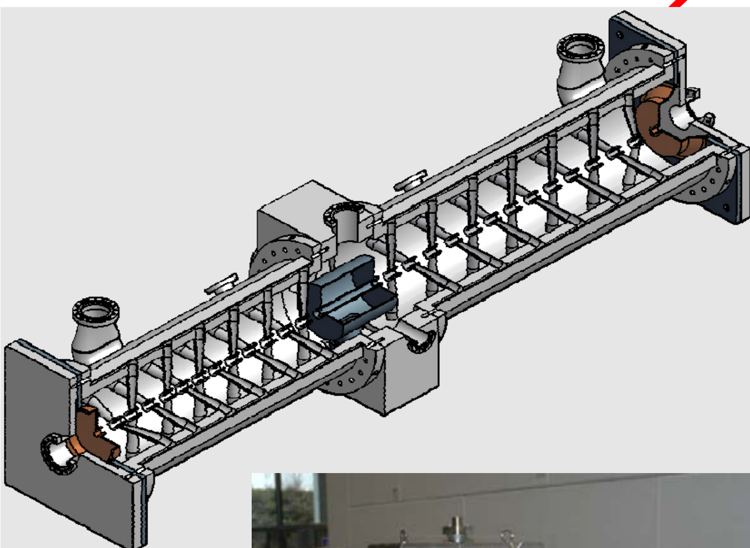
Collector Ring (CR) –> pBars and RIBs

- The TDR CR has been updated and approved in February 2014.
- IKRB assigns a major part of the CR components (63 %) to **Budker** **(BINP)**
- Contract on transfer of the CR system responsibility to BINP
- BINP and GSI make good progress in design and procurement of CR components
- RF-systems and stochastic cooling are GSI contribution



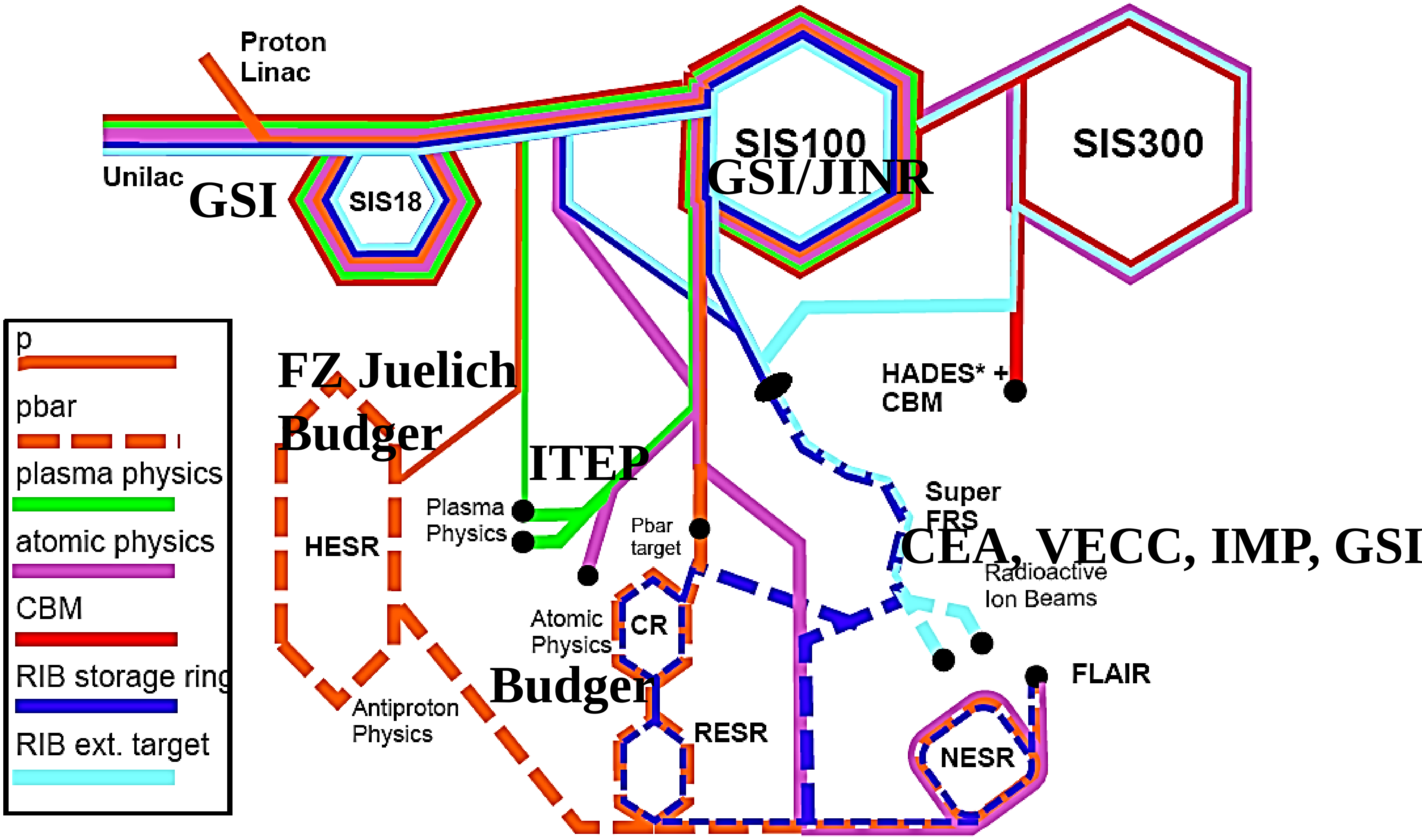
p-Linac DTL overview





CH-cavity

Parallel Operation of Accelerator Complex



FAIR

Nuclear Structure & Astrophysics
(RIBS Rare-isotope beams)

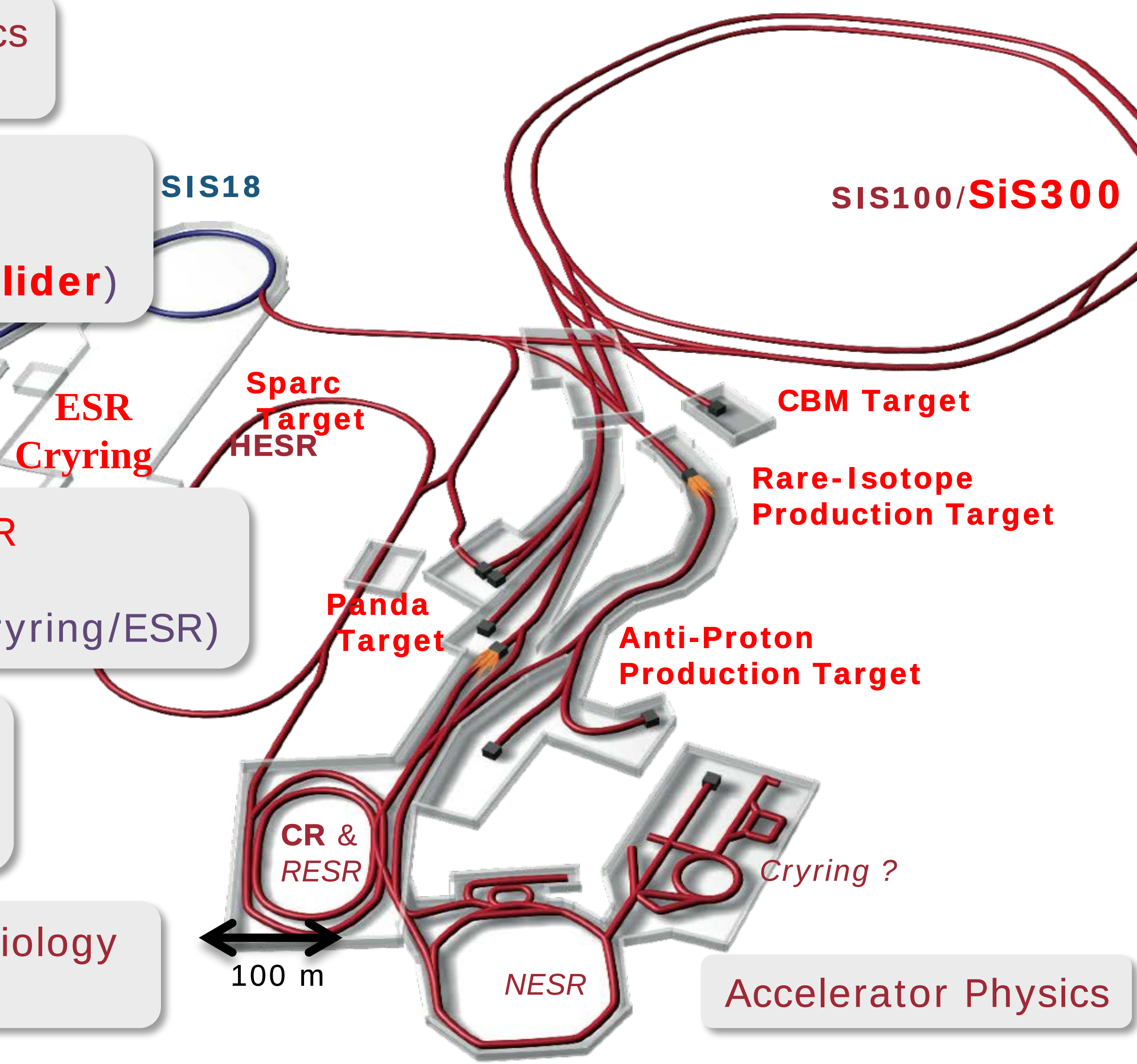
Hadron Physics
(Stored and cooled
14 GeV/c anti-protons /**p-$\bar{p}$ collider**)

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

Fundamental Symmetries FLAIR
& Ultra-High EM Fields
(Antiprotons & naked ions in Cryring/ESR)

Dense Bulk Plasmas
(Ion-beam bunch compression
& Petawatt-laser , Prior)

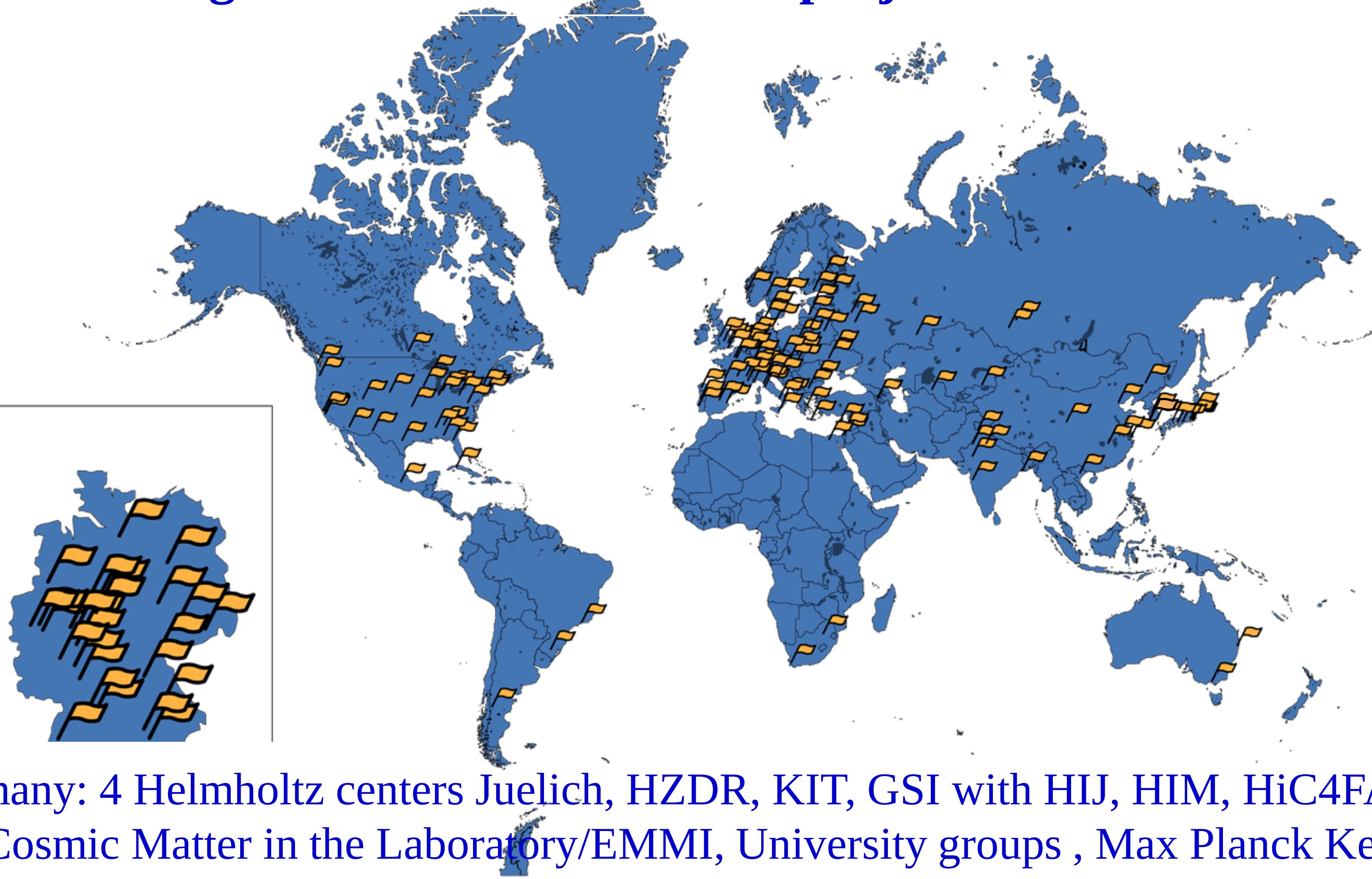
Materials Science & Radiation Biology
(Ion- & antiproton beams)



Accelerator Physics

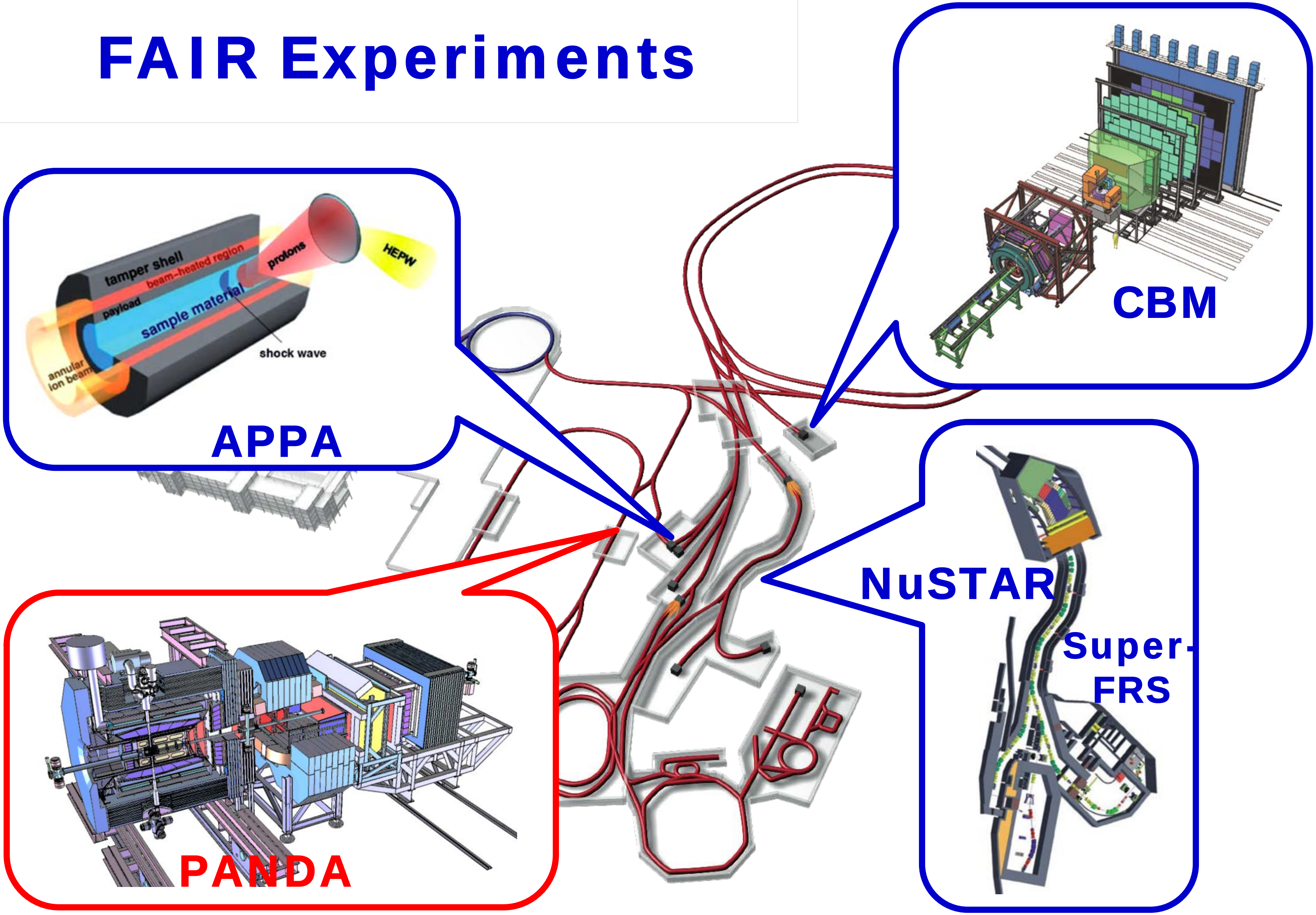
International Cooperation : 2400 FAIR users at 100+ Labs

… from more than 50+ countries, numbers rising -
World's largest fundamental science project of this decade …

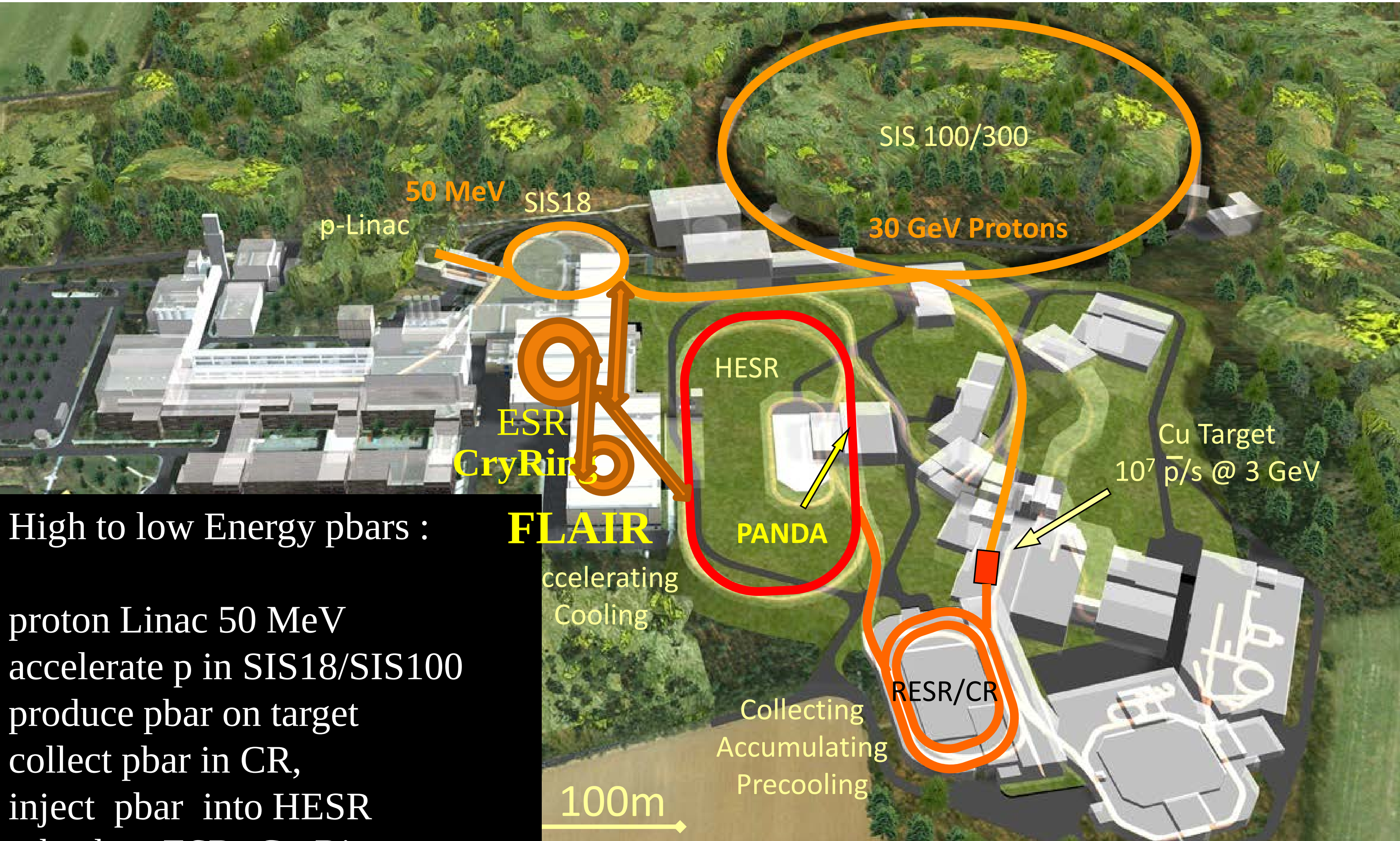


Germany: 4 Helmholtz centers Juelich, HZDR, KIT, GSI with HIJ, HIM, HiC4FAIR, HA Cosmic Matter in the Laboratory/EMMI, University groups , Max Planck Kernphys

FAIR Experiments



Brilliant Anti-proton beams
- Strange & Charm matter



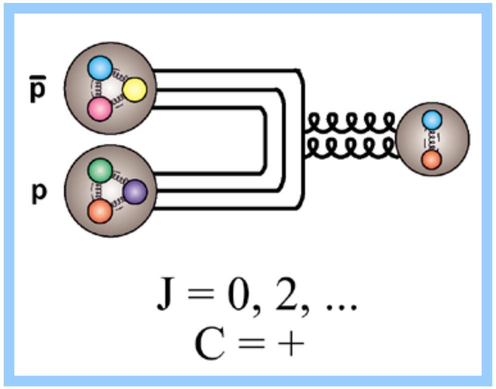
High to low Energy pbars :

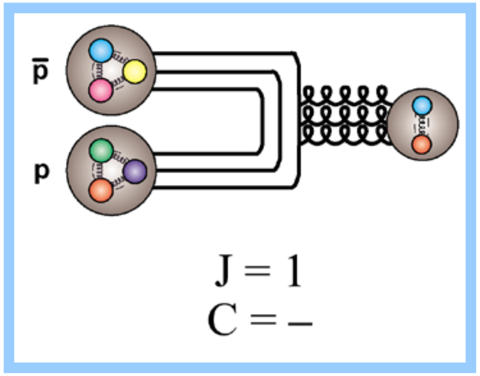
proton Linac 50 MeV
accelerate p in SIS18/SIS100
produce pbar on target
collect pbar in CR,
inject pbar into HESR
+ back to ESR+CryRing:
FLAIR!

Courtesy Jim Ritman, FZ Juelich

Particle production in $\bar{p}p$ collisions

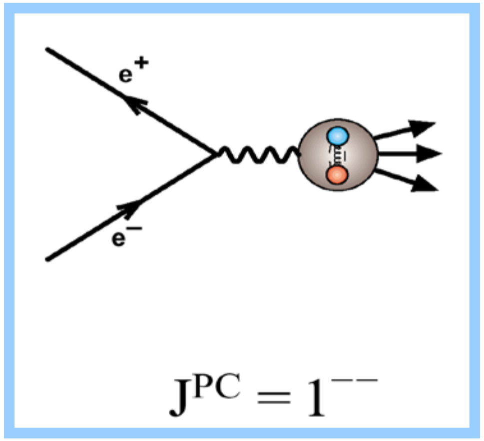
Formation:





All J^{PC} allowed for $(q\bar{q})$ accessible in $p\bar{p}$

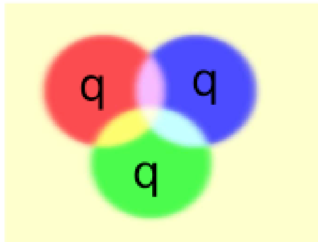
c.f.

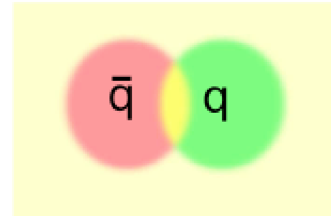


Only $J^{PC} = 1^{--}$ allowed in e^+e^-
(to 1st order)

Beyond standard quark configurations

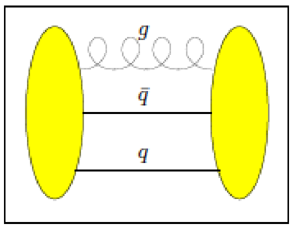
- QCD allows much more than what we have observed:



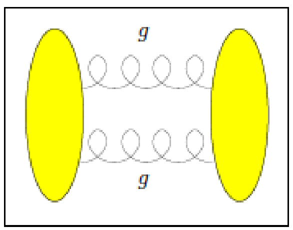


Mesons

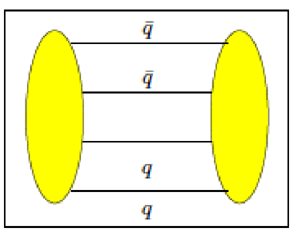
Exotica



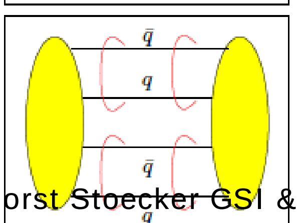
hybrid:
with gluon excitation



glueball:
pure gluon state



4 quark state:
compact 4–quark state

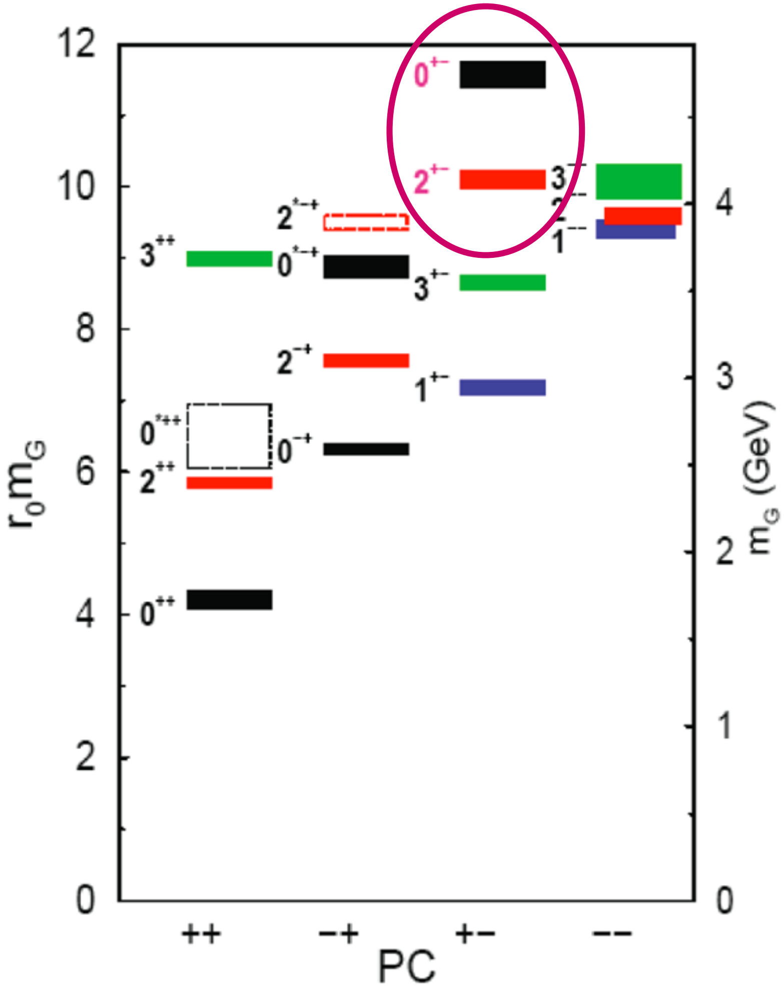


hadronic molecule:
bound state of two mesons

} may have J^{PC} not allowed for $q\bar{q}$

Courtesy C. Hanhart

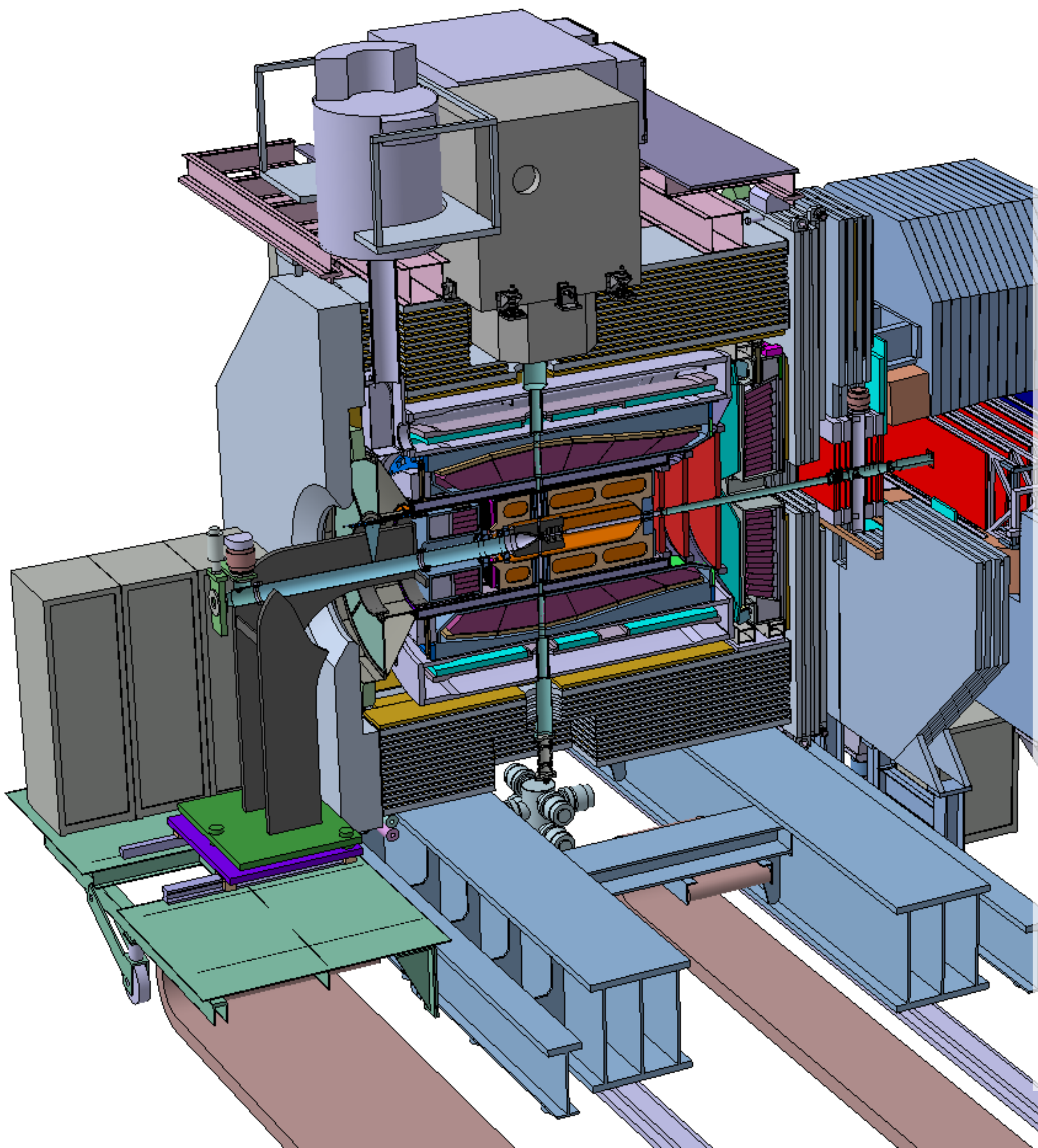
Search for Heavy Glueballs



Morningstar & Peardon, PRD60(1999)34509
Morningstar & Peardon, PRD56(1997)4043

- **Charmed glueballs**
  - flavour blind decays
    - charmed final states
  - only a few charmed mesons around 3 - 4 MeV/c^2
    - less mixing
- **Exotic glueballs (oddballs), no mixing!**
  - $m(2^{+-})$ = 4140(50)(200) MeV
  - $m(0^{+-})$ = 4740(70)(230) MeV
  - decay modes $\phi\phi$, $\phi\eta$, $J/\psi\eta$, $J/\psi\phi$
  - Narrow widths predicted

The PANDA Spectrometer at FAIR



Detector requirements:

4π acceptance

High rate capability:
$2 \times 10^7\ s^{-1}$ interactions

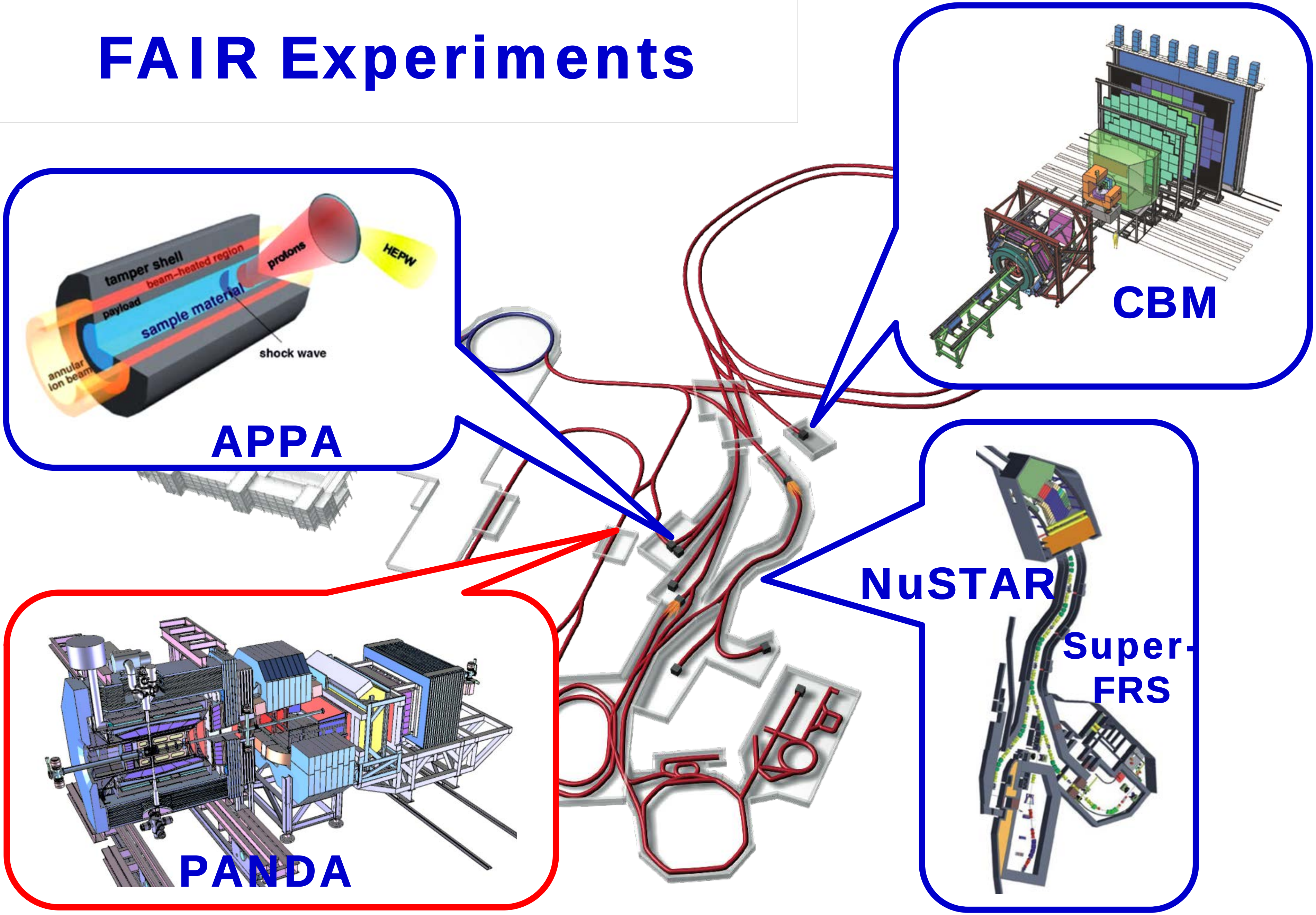
Efficient event selection
➔ *Continuous acquisition*

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

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

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

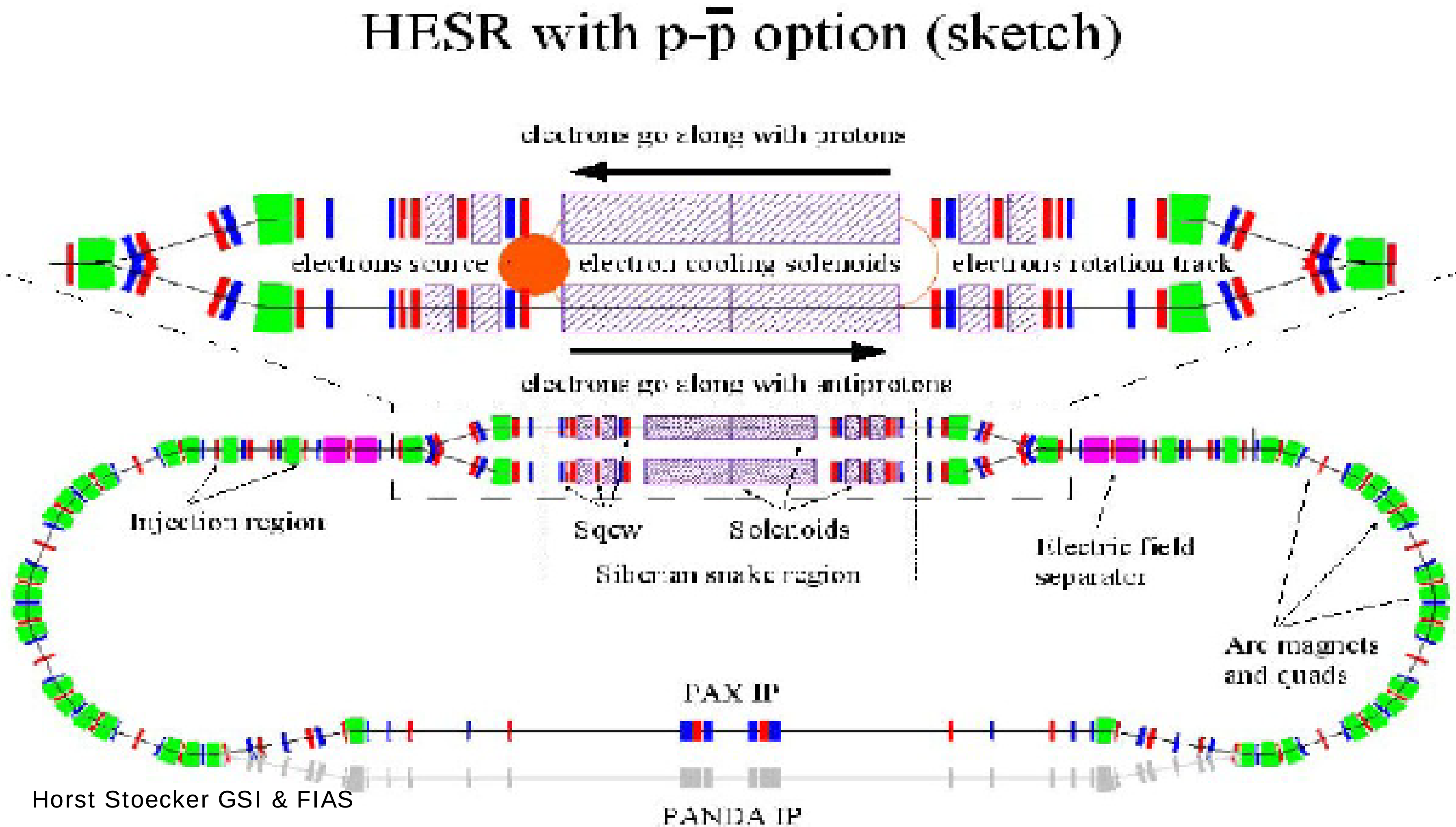
FAIR Experiments



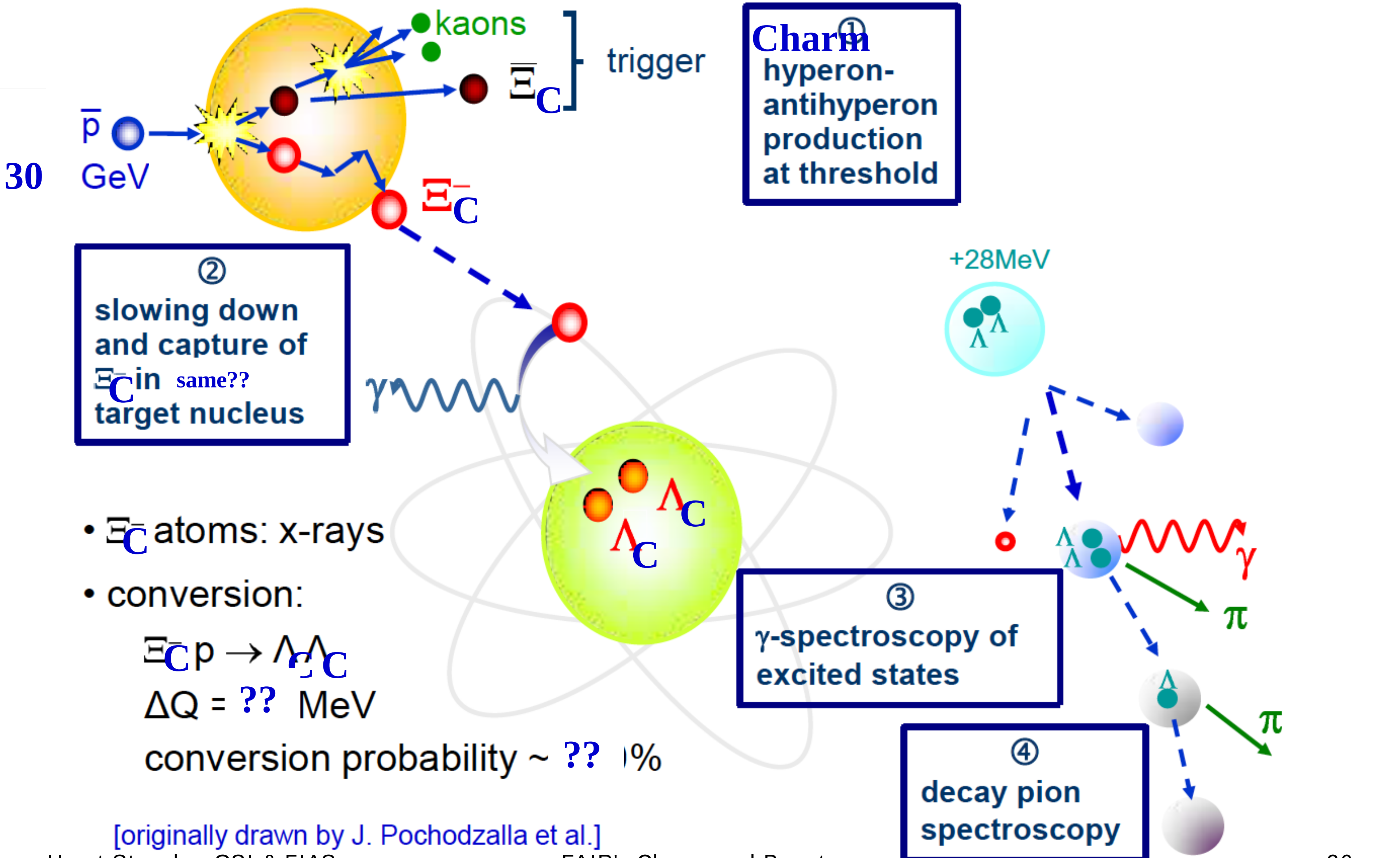
HESR in **pBar-p collider** mode (R. Maier, FZ Juelich) : 2. electron co

L= 3x30 with sqrt(s) = 30 GeV : **BEAUTY** baryon pairs +/- bcs.

Beauty xyz- mesons Xb, Yb, Zb with M >12 GeV



Beauty baryon pairs and multi-Charm-nuclei in Panda @ pBar-p collider: analogous to Hypernuclei ?!



- Ξ^-_C atoms: x-rays
- conversion:

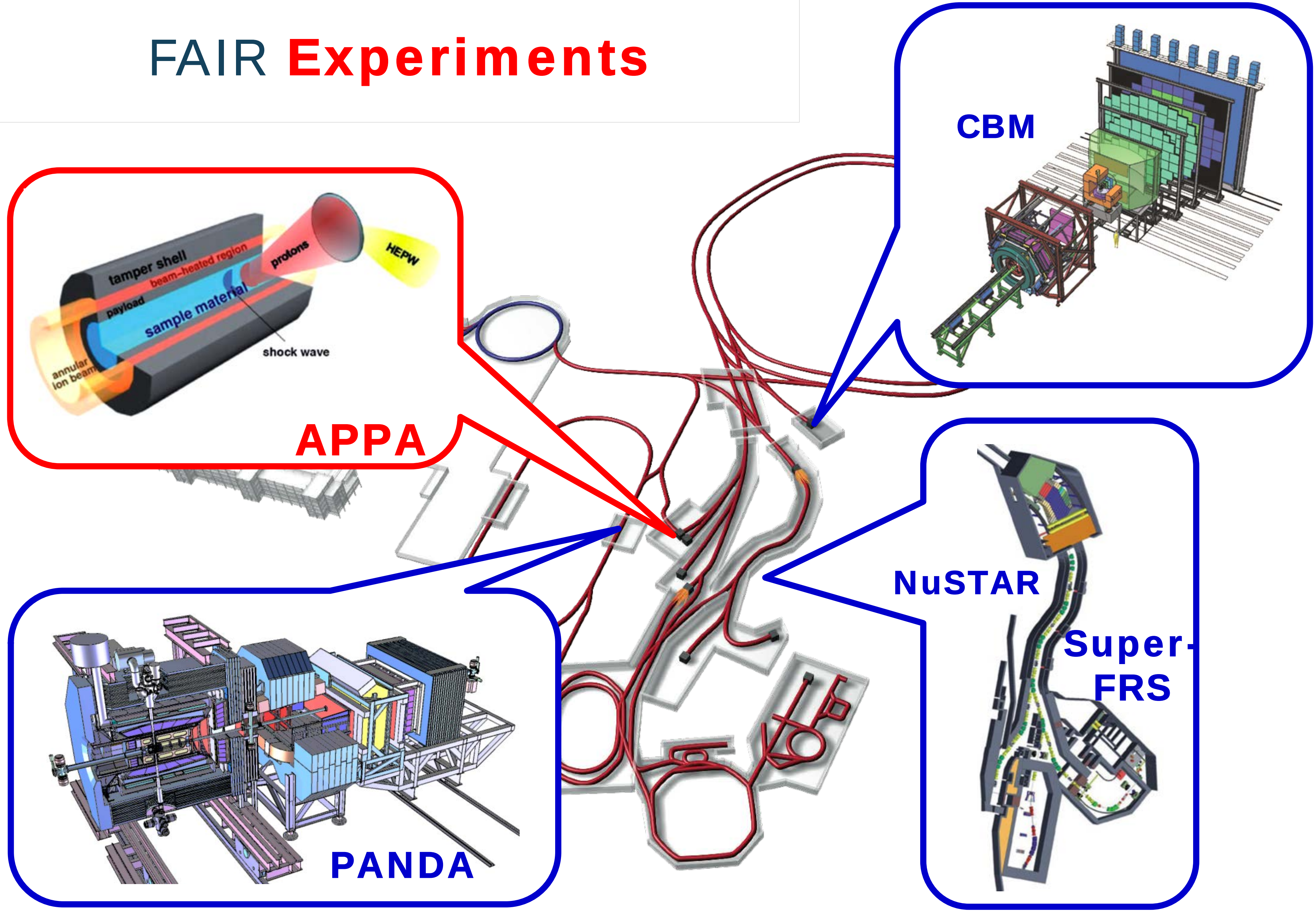
  $\Xi^-_C p \rightarrow \Lambda_C \Lambda_C$

  ΔQ = ?? MeV

  conversion probability ~ ?? %

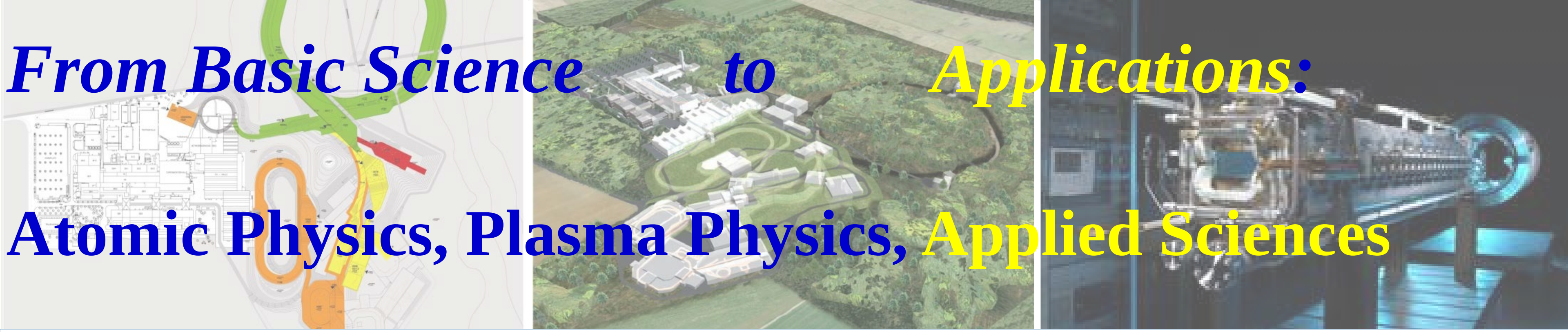
[originally drawn by J. Pochodzalla et al.]

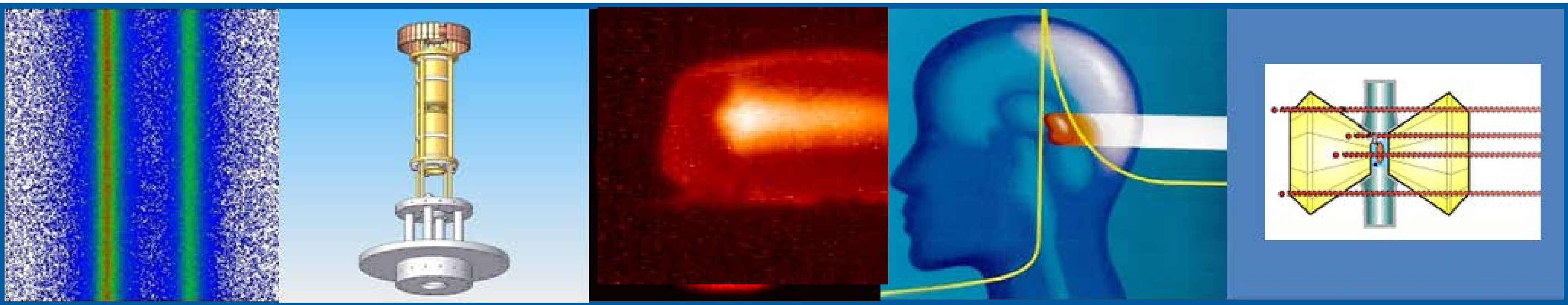
FAIR **Experiments**



From Basic Science to Applications:

Atomic Physics, Plasma Physics, Applied Sciences





APPA@ FAIR

Courtesy of Reinhold Schuch

Physics Department, Stockholm University, Sweden

APPA Collaborations @ FAIR > 600 scientists many exp.

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

SPARC — 337 scientists

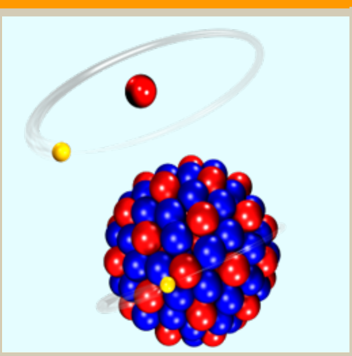
FLAIR (Facility for Low-energy Antiproton and Ion Research) — 144 scientists

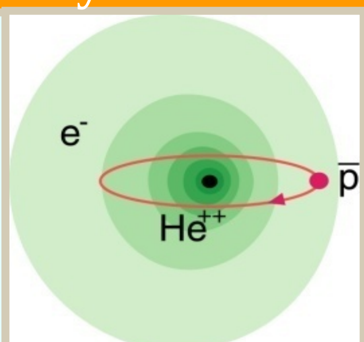
HEDgeHOB — 175 scient.

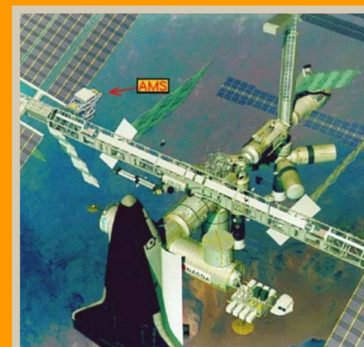
WDM — 71 scient.

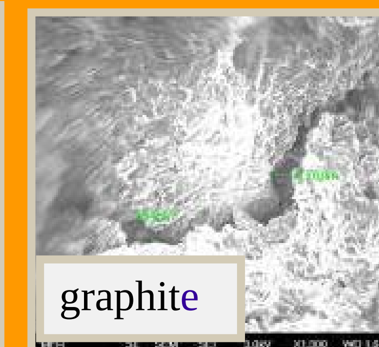
BIO*MAT — 136 scientists

Atomic Physics | **Plasma** | **Bio** | **Materials**









strong field research...
Probing fundamental laws of physics

anti-matter
... matter / anti-matter asymmetry (not MSV)

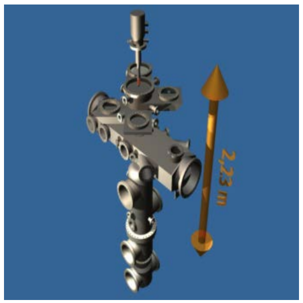
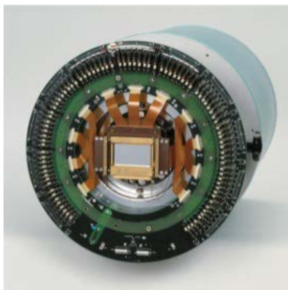
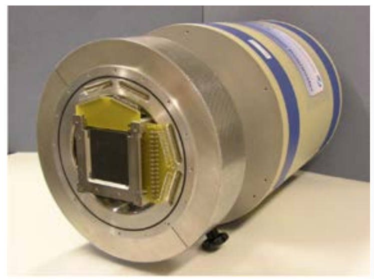
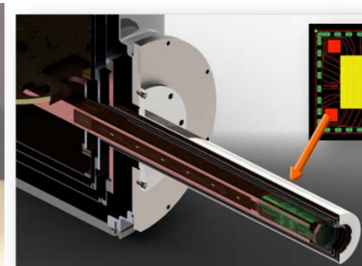
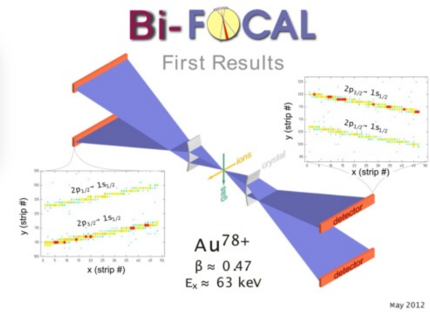
planetary interiors
... states of matter such as in astrophysical objects

aerospace
... shielding of cosmic radiation
medical
radiation treatment

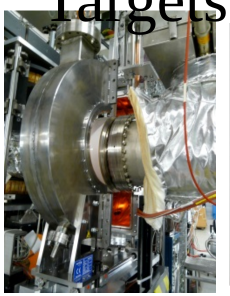
radiation hardness
degradation of materials

APPA: **Sophisticated & Versatile Instrumentation**

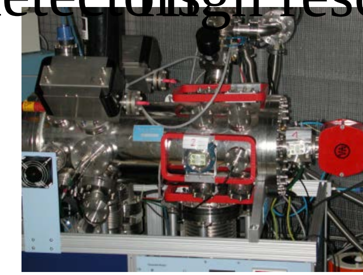
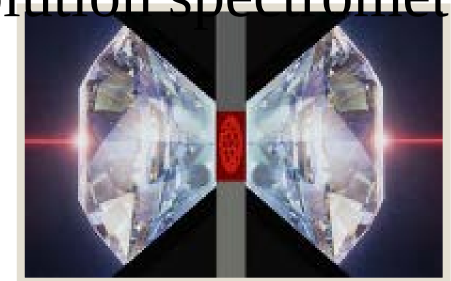
Observables: Photons, electrons, positrons, ions

Targets Position sensitive solid state detect High resolution spectromet

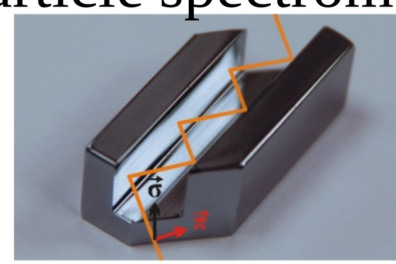
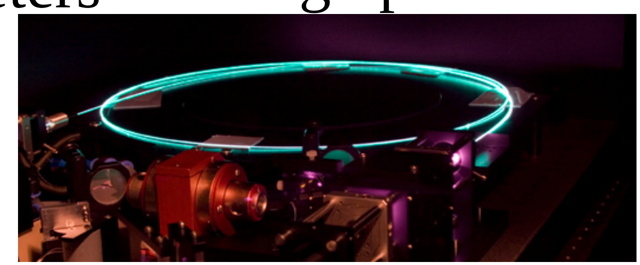




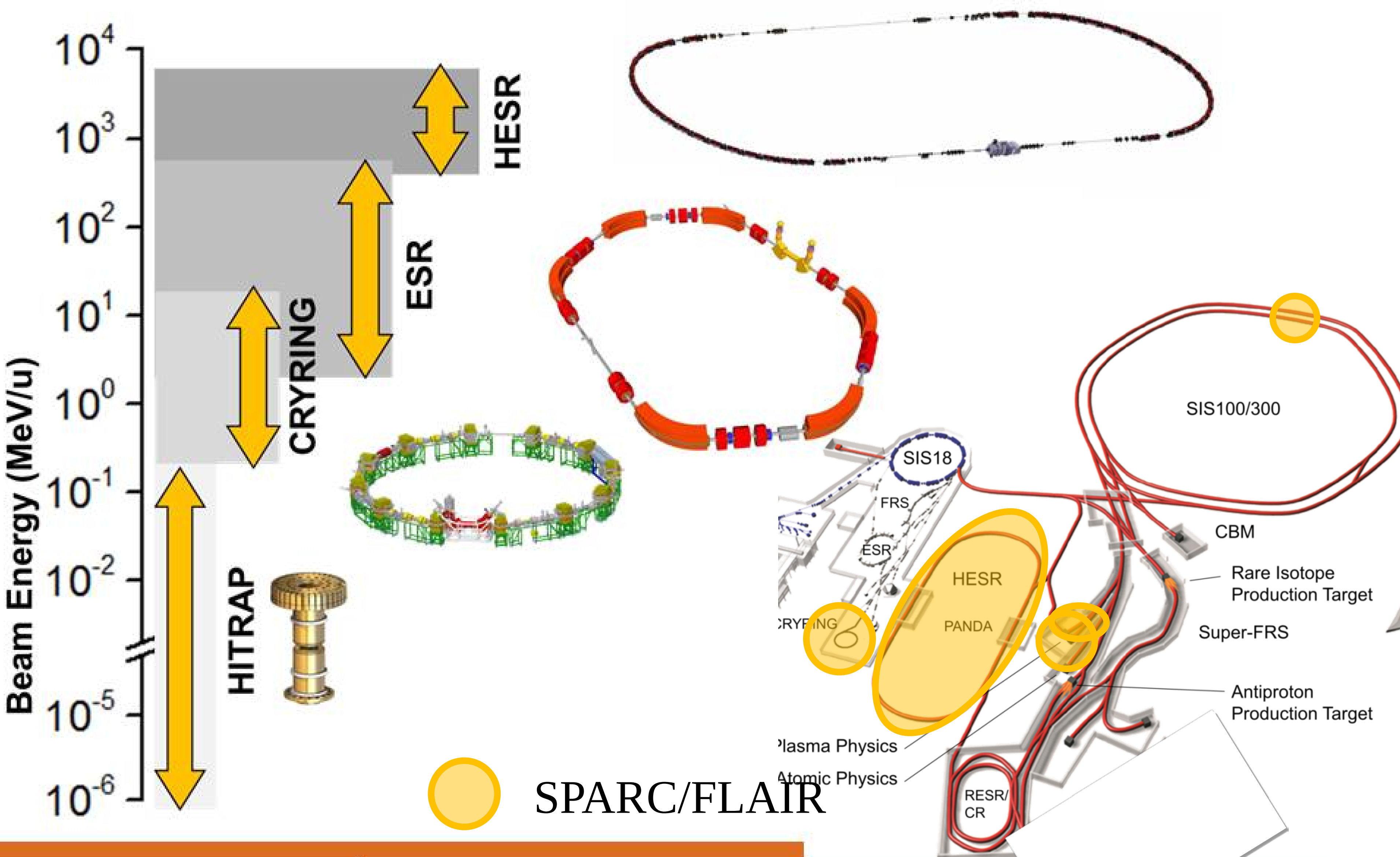
Particle detectors Particle spectrometers High pressure c



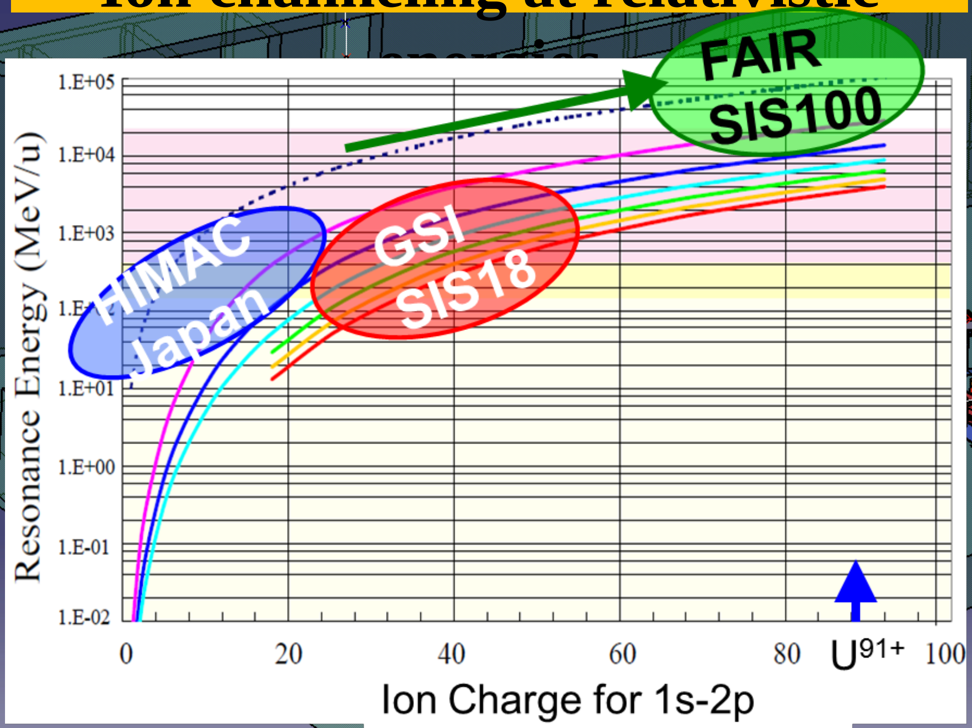




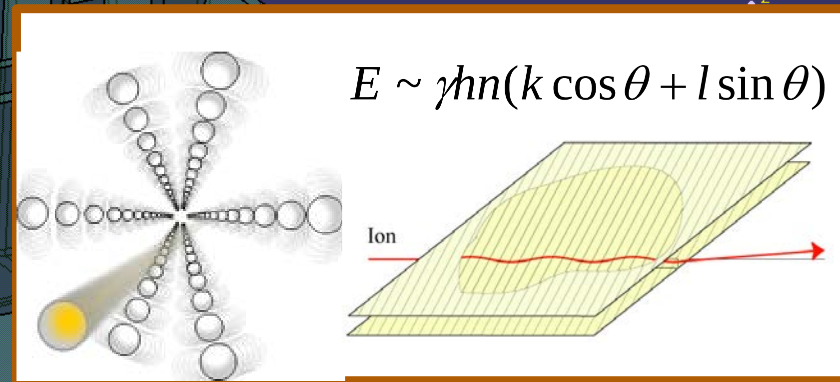
Traps X-ray optics, channel cut crystalls Laser systems

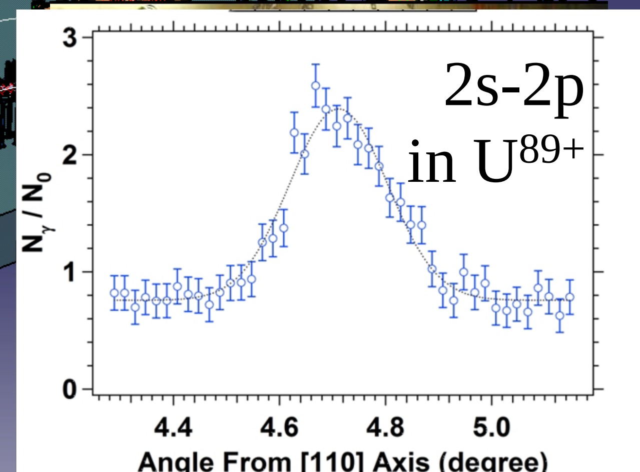
SPARC@FAIR: Storage and Trapping



Ion channeling at relativistic



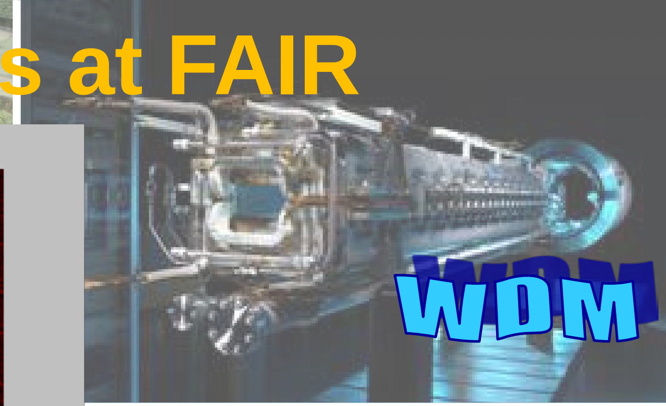




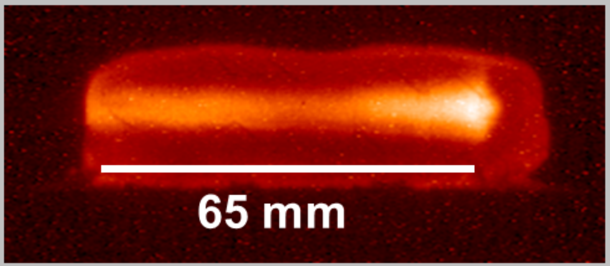
Test experiment performed at SIS 18 and ESR (2012/2014)

T. Azuma et al.

at APPA cave: excitation of 1s-2p in U^{91+} possible for first time



Plasma Physics at FAIR

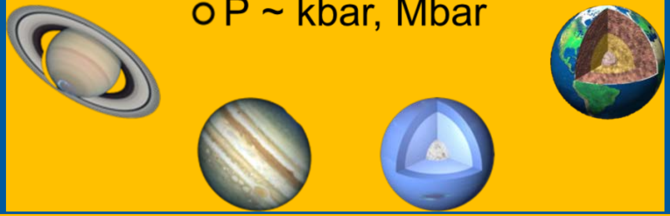


Ne^{10+} 300 MeV/u; Kr crystal

Interaction of ions and photons with plasmas
Equation of state, phase transitions, transport phenomena
Matter under high pressure
Coupling of intense light with matter

Warm Dense Matter

- T ~ 0.2 – 10 eV
- ρ ~ solid density
- P ~ kbar, Mbar

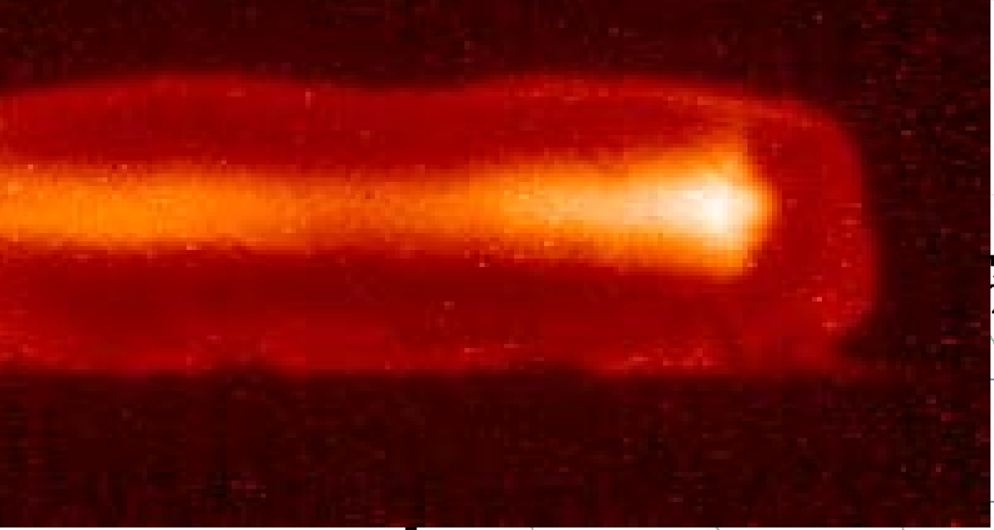


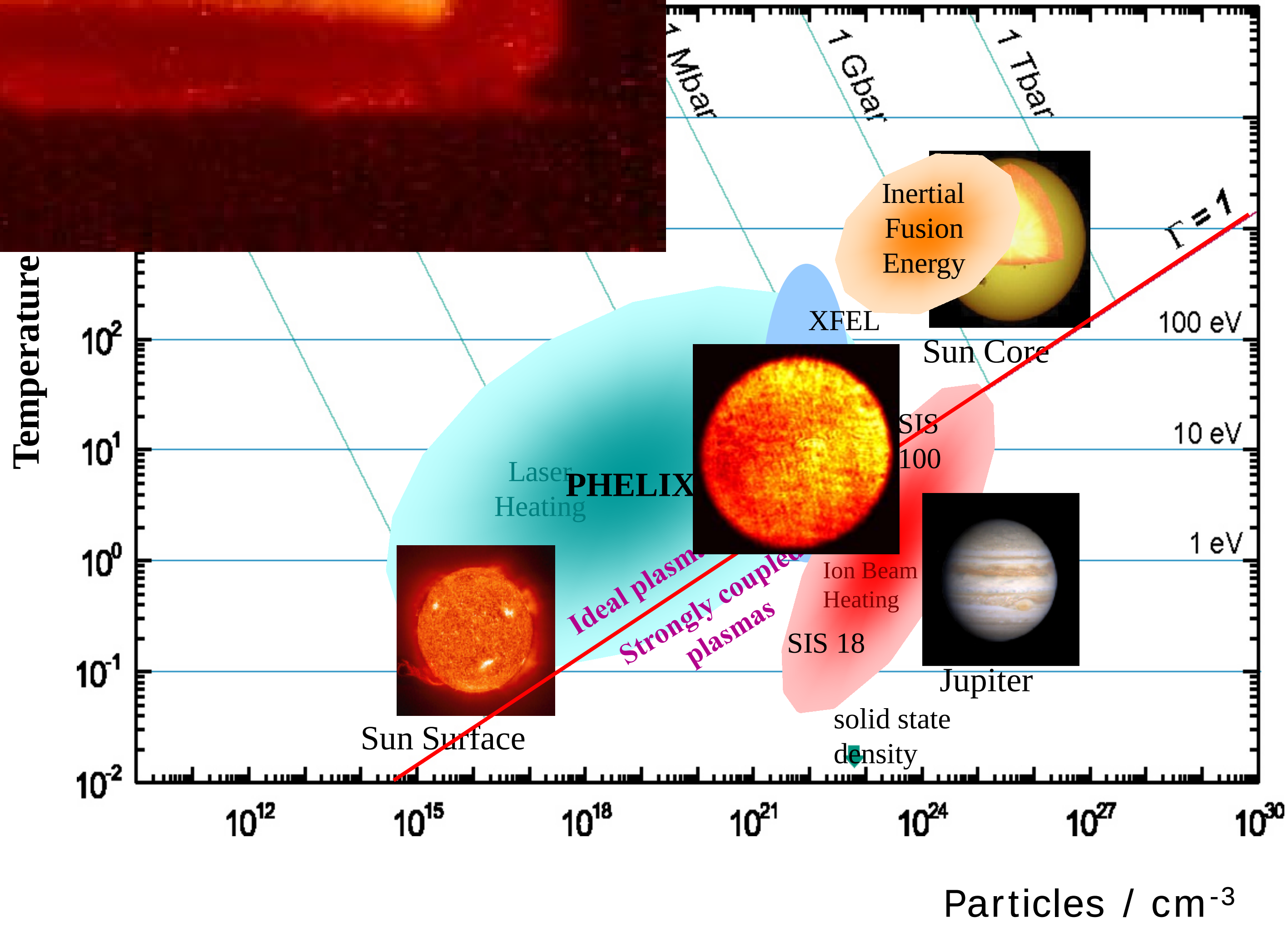
- large volume of sample (mm^3)
- fairly uniform physical conditions
- high entropy @ high densities
- high rep. rate and reproducibility
- any target material

Compared to GSI, FAIR will provide a specific intensity and energy deposition increase by a factor of 100 !

FAIR

Plasmas



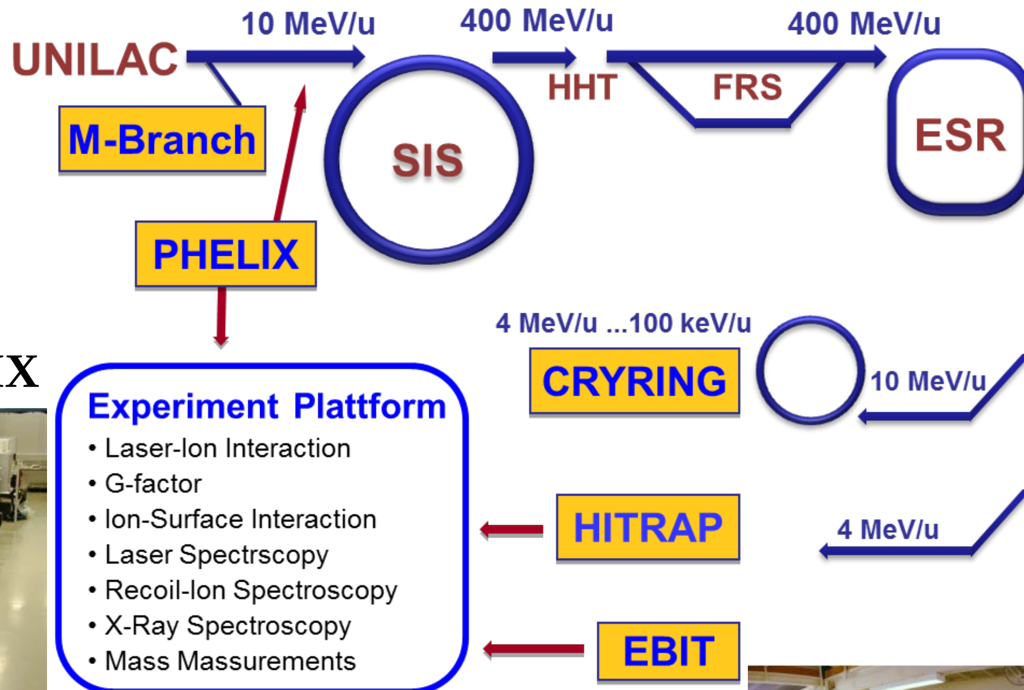

1 Mbar
1 Gbar
1 Tbar
Γ = 1
100 eV
10 eV
1 eV
Inertial Fusion Energy
Sun Core
XFEL
SIS 100
Laser Heating
PHELIX
Ideal plasma
Strongly coupled plasmas
Ion Beam Heating
SIS 18
Jupiter
solid state density
Sun Surface
Temperature
10^2
10^1
10^0
10^{-1}
10^{-2}
10^{12}
10^{15}
10^{18}
10^{21}
10^{24}
10^{27}
10^{30}
Particles / cm^{-3}

Ions at GSI & FAIR : challenges and strategies

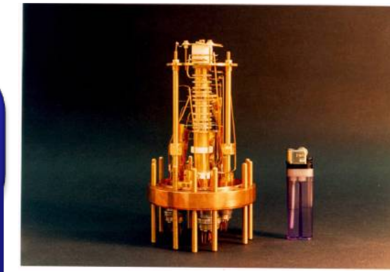
MML Facilities at GSI

M-branch UNILAC

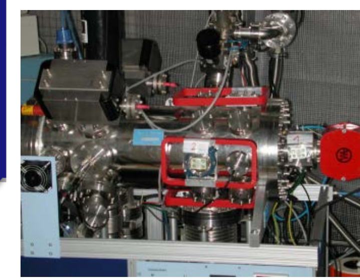
petawatt laser PHELIX



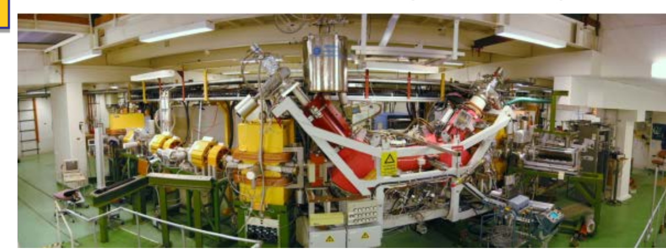
ion trap facility HITRAP



Super-EBIT



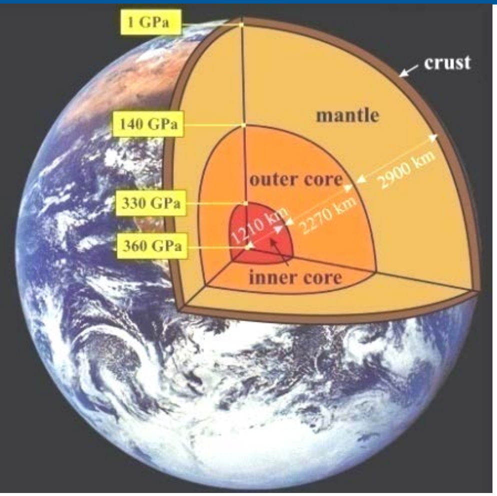
CRYRING



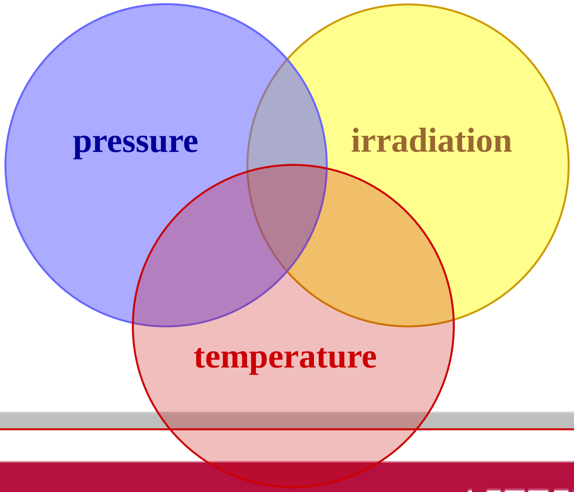
- **GSI: Serving the user communities**

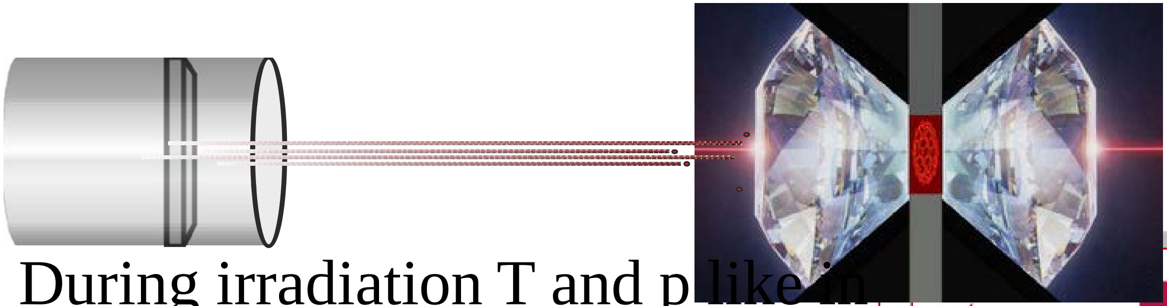
  UNILAC, PHELIX, EBIT, and CRYRING in operation -> FLAIR
- **R&D beam experiments for FAIR**
- **building novel instrumentation for FAIR**

Matter under extreme conditions

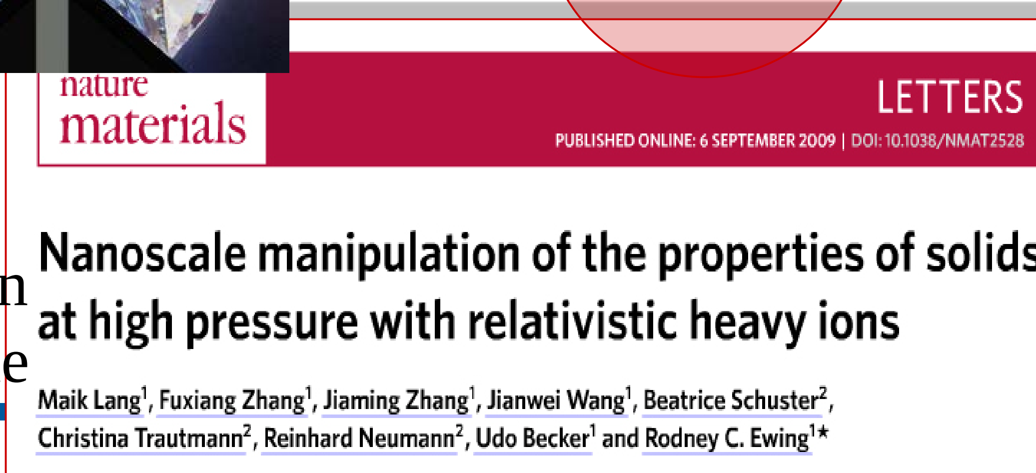


- **Simulating geological processes in the inner Earth**
- **Ion-beam stabilized high pressure phases**





During irradiation T and p like in the inner earth is applied to minerals.
+ tracks induced by natural fission fragments as in the minerals of the inner earth can be simulated.


nature materials

LETTERS

PUBLISHED ONLINE: 6 SEPTEMBER 2009 | DOI: 10.1038/NMAT2528

Nanoscale manipulation of the properties of solids at high pressure with relativistic heavy ions

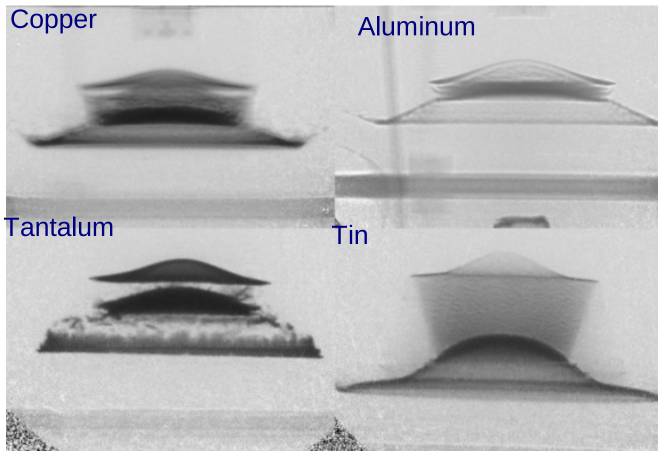
Maik Lang[1], Fuxiang Zhang[1], Jiaming Zhang[1], Jianwei Wang[1], Beatrice Schuster[2], Christina Trautmann[2], Reinhard Neumann[2], Udo Becker[1] and Rodney C. Ewing[1]*

PRIOR – Proton Microscope for FAIR

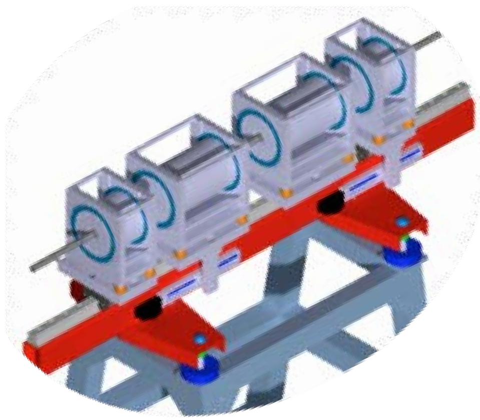
Pump-Probe: Ion and Proton beams

- the worldwide unique high energy proton microscopy facility PRIOR (10 µm / 10 ns resolution, sub-percent density reconstruction) will be integrated into the HEDgeHOB beam line
- using high-energy (5 – 10 GeV), high intensity ($5 \cdot 10^{12}$) SIS-100 proton beams

Material spall and fragmentation at micrometer level



courtesy of LANL



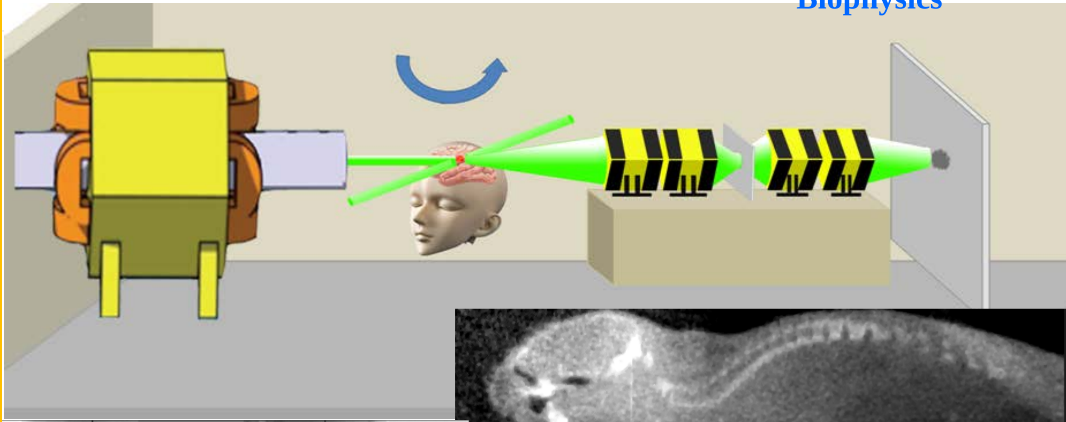
- joint multidisciplinary research of HEDgeHOB and BIOMAT **during FAIR MSV**:
  - materials at extreme dynamic environments generated by external drivers (plasma physics and materials research)
  - PaNTERA (Proton therapy and radiography) project (biophysics)

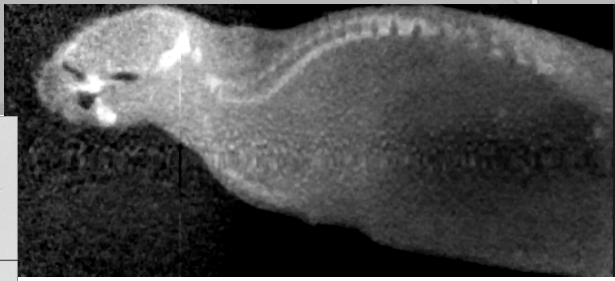
- PRIOR setup beam time commissioning at GSI: 2013/2014

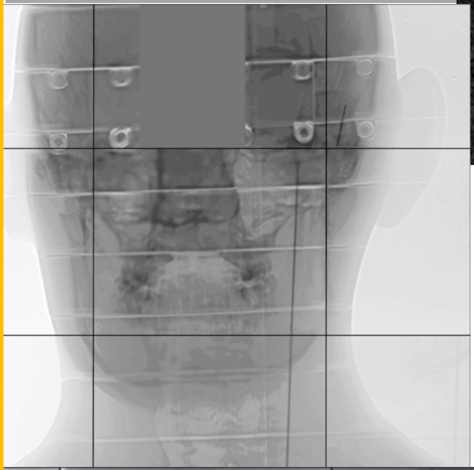
Particle Therapy at FAIR

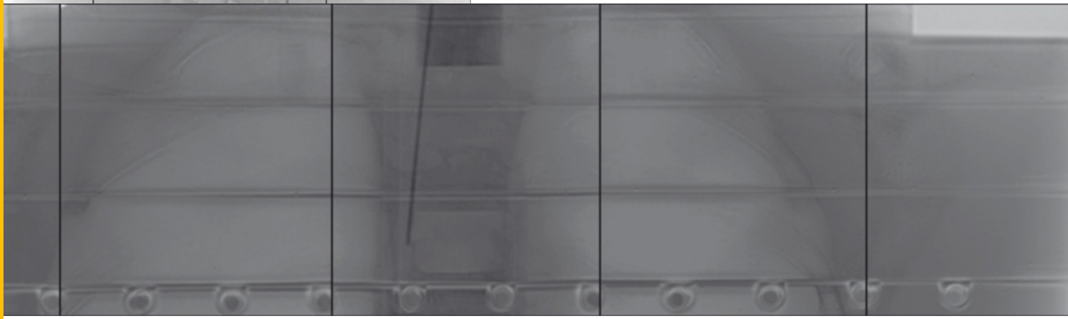
BIO*MAT
Biophysics

- New project (**PANThERA**) within APPA to exploit the PRIOR setup for Diagnostics and Therapy
- **Relativistic protons (4.5 GeV) for image-guided, high-resolution, realtime, stereotactic radiosurgery** - proton theragnostics, PRIOR setup
- Images of an antropomorphic phantom and a mouse recorded at LANL (800 MeV)
- Investigating also to use high-energy antiprotons for Theragnostics (together with FLAIR)



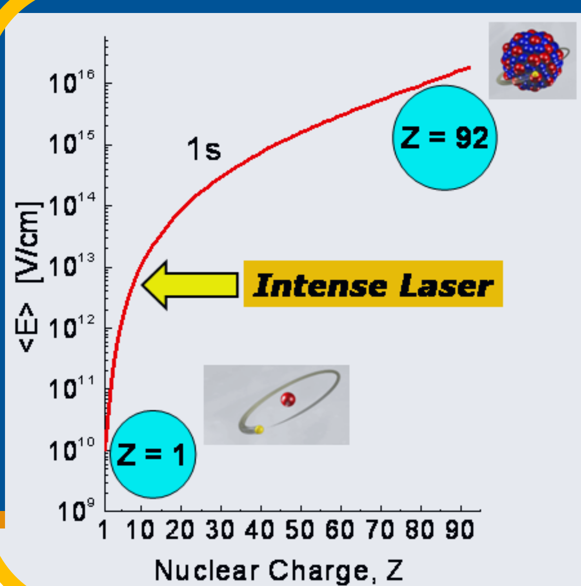


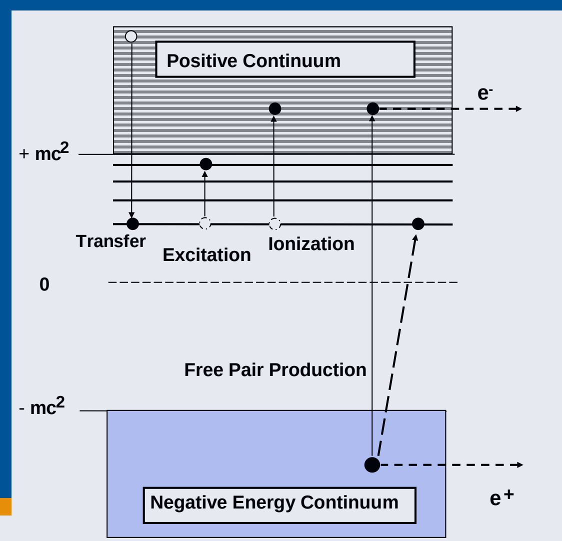


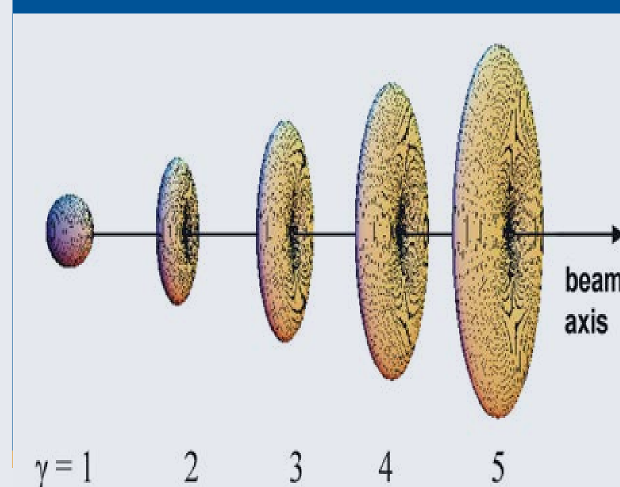


Atomic & Fundamental Physics

QED 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
Fundamental physics and antimatter



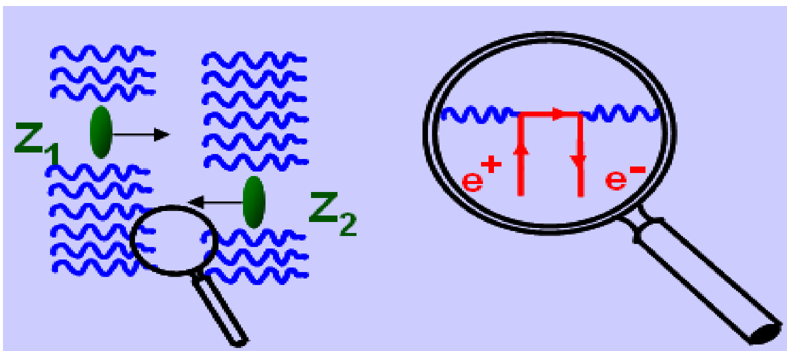




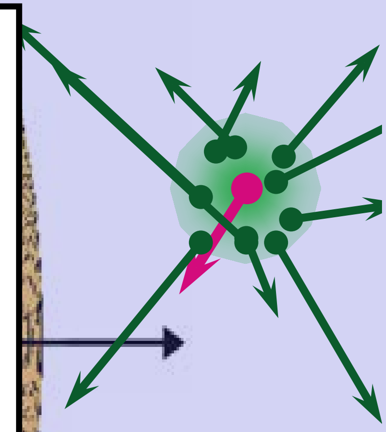
SPARC Challenges & Opportunities

"Heisenbergs dream"
shot out the nucleus,
let electrons explode !

World-wide unique for strong interaction with vacuum



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



$t \leq 0.1$ as

Explore correlated electron dynamics

- sub-attosecond time-scale
- not accessible by other means

CYRING@ESR

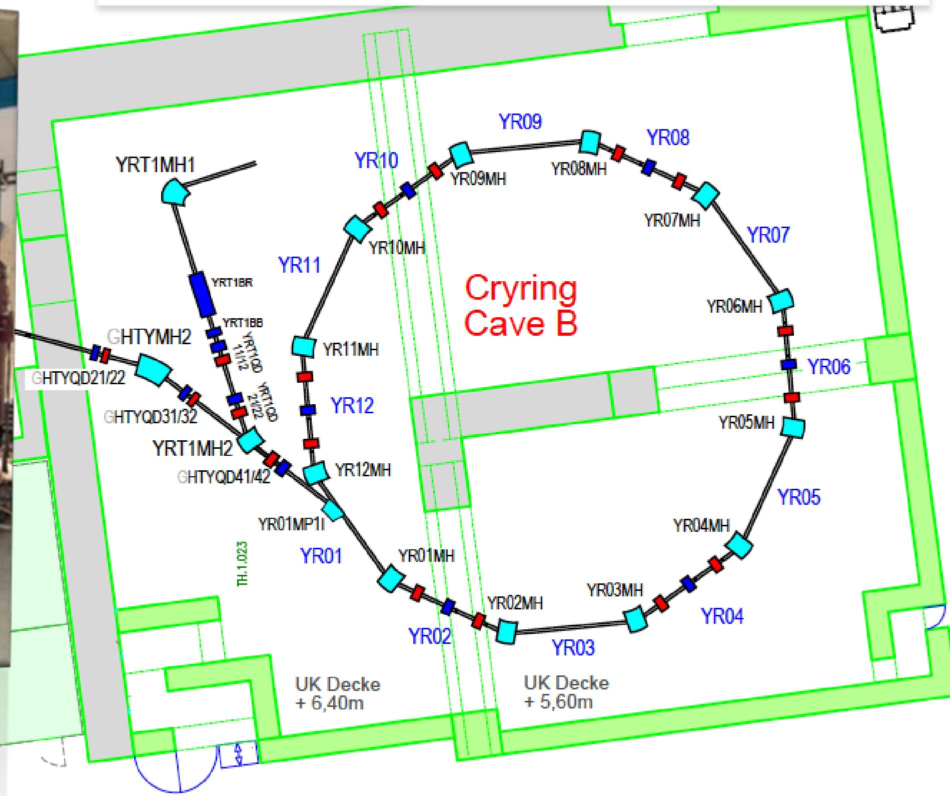
A collaboration of **FAIR@GSI**, **AP@GSI**, **GA@GSI**, **Stockholm Univ.**, **KVI Groningen**, **Cracow Univ.** , and the **SPARC Collaboration**

- **Cave reconstruction close to completion**
- **Component preparation ongoing**

FAIR Research & Development

FAIR type control system / Detectors and diagnostic systems / Training of operators on FAIR type system

Scientific Opportunities: Heavy, highly-charged ions – bridge the energy gap between the ESR (> 4 MeV/u) and HITRAP (<10 keV/u)

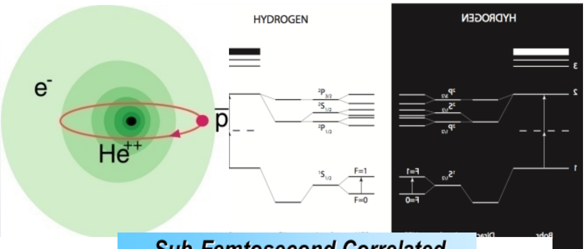


FLAIR

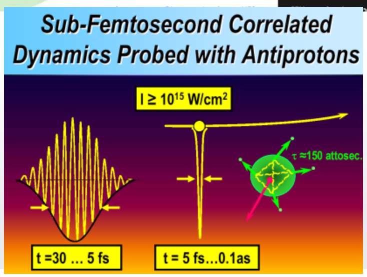
Facility for Low-energy Antiproton and Ion Research

Exp. With Low-Energy pBars

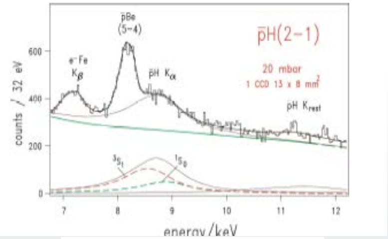
- **Spectroscopy for tests of CPT and QED**
  - Antiprotonic atoms (pbar-He, pbar-p), antihydrogen

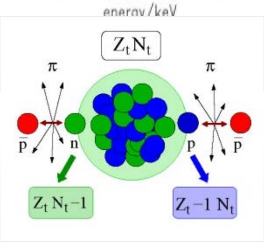


- **Atomic collisions**
  - Sub-femtosecond correlated dynamics: ionization, energy loss, antimatter-matter collisions

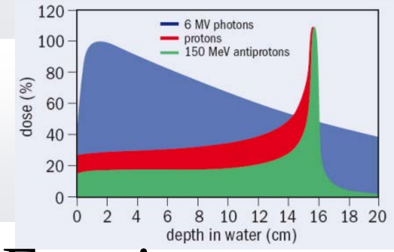


- **Antiprotons as hadronic probes**
  - X-rays of light antiprotonic atoms: low-energy QCD
  - X-rays of neutron-rich nuclei: nuclear structure (halo)
  - Antineutron interaction





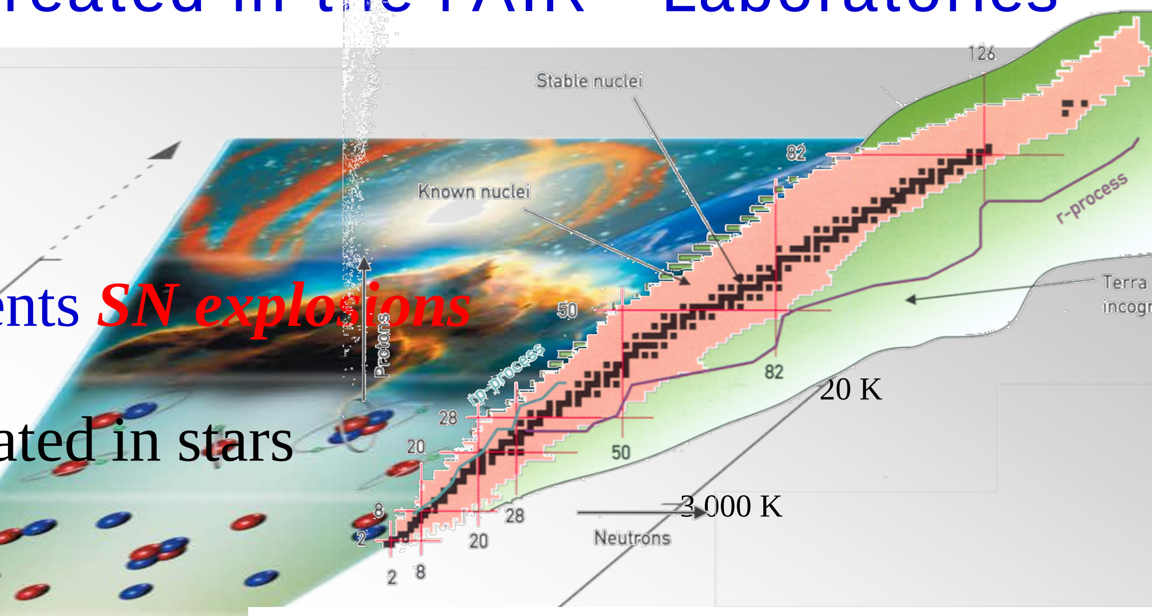
- **Medical applications: tumor therapy**
- **Material Science**



FLAIR collaboration uses low-E antiprotons at CERN-AD to

test decelerator schemes- initial experiments of FLAIR physics program

Big Bang, Supernovae, Neutron Stars :
Cosmic Matter – recreated in the FAIR - Laboratories



13 billion years

Creation of heavy elements ***SN explosions***

1 billion years

light nuclei created in stars

300.000 years

3 minutes

Anti-Protons, Neutrons, Hadrons disappear

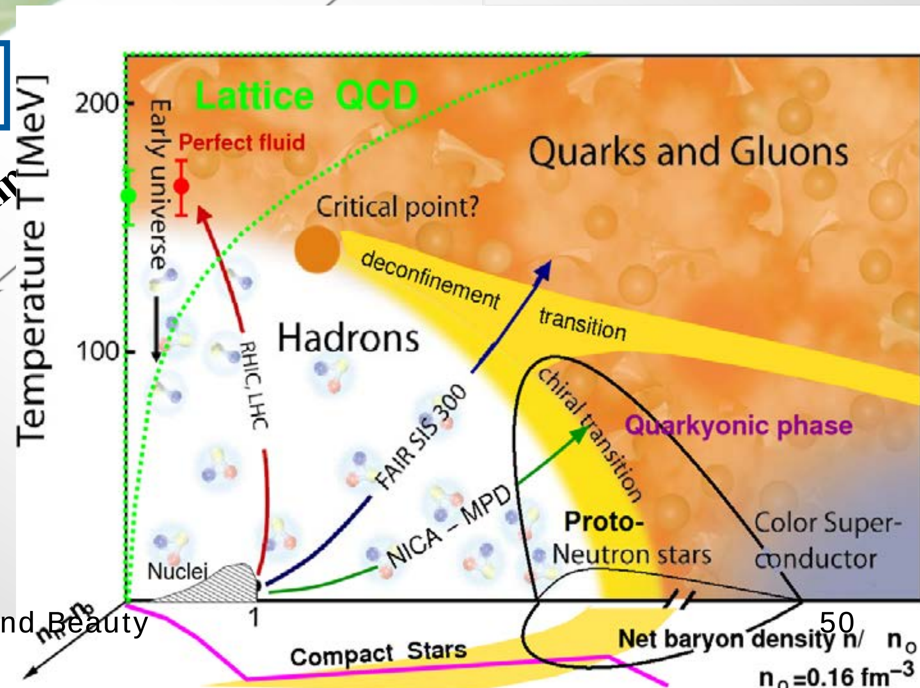
1 microsec

time

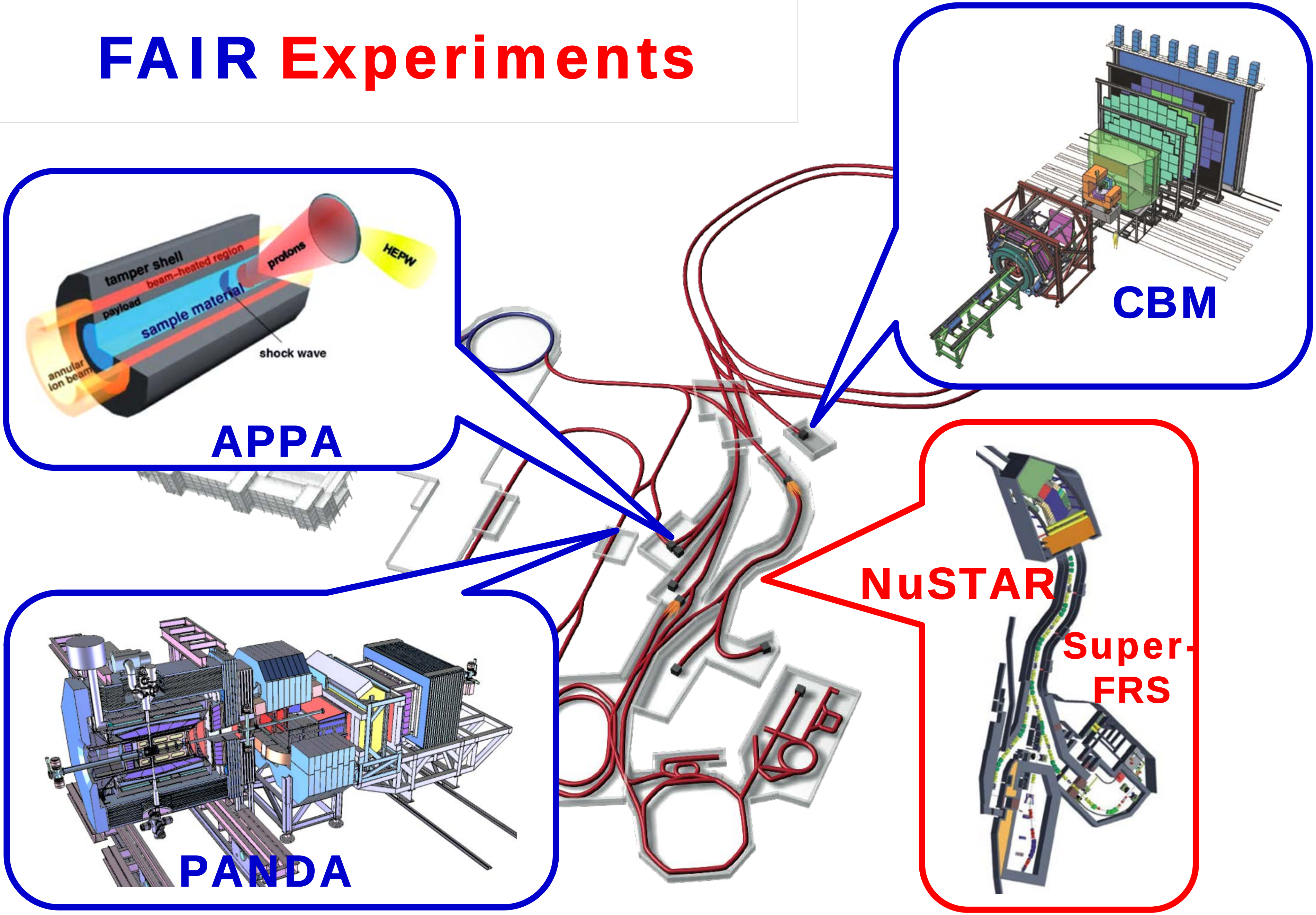
(Anti-) Baryons created

Gluons, quarks disappear

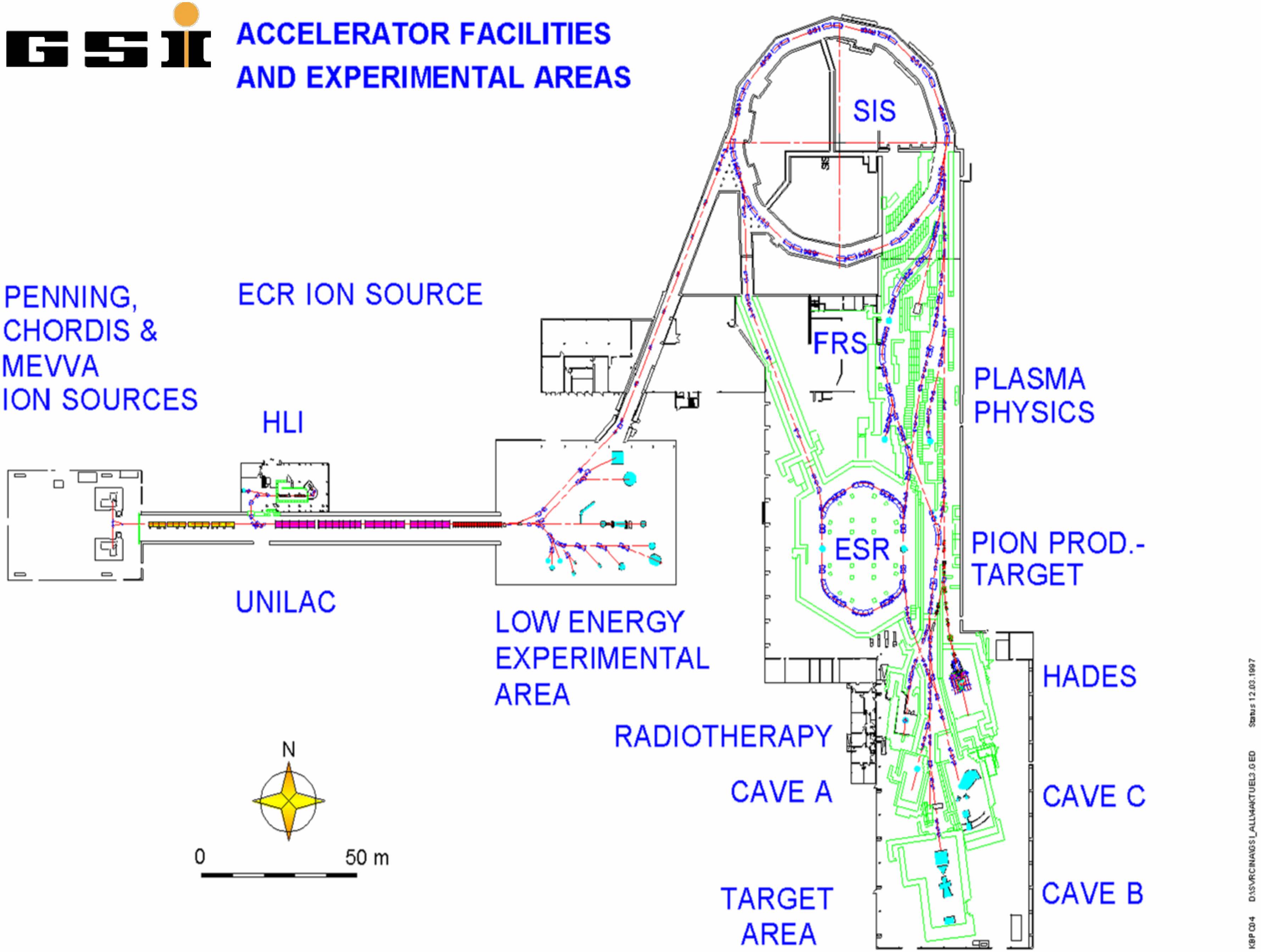
Genesis - Quarks, Leptons



FAIR Experiments



ACCELERATOR FACILITIES AND EXPERIMENTAL AREAS

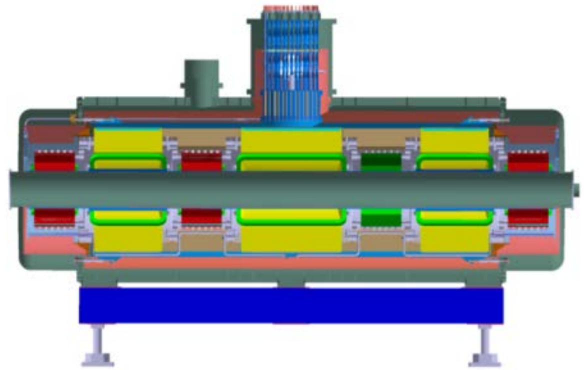


Super-FRS

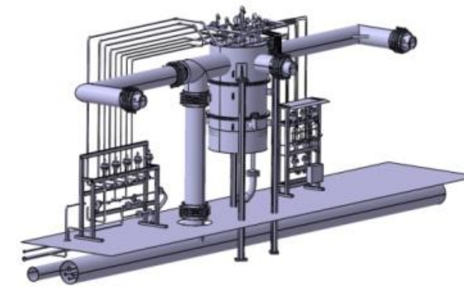
Remote Handling

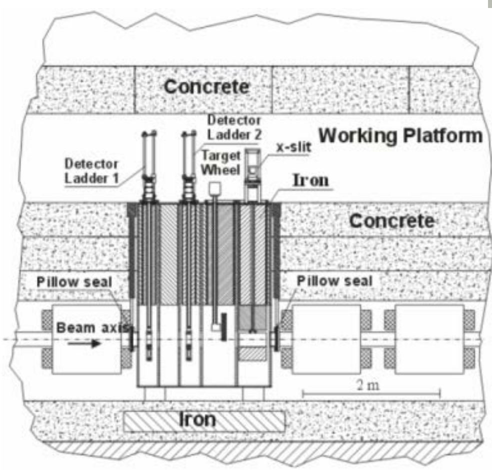
Target

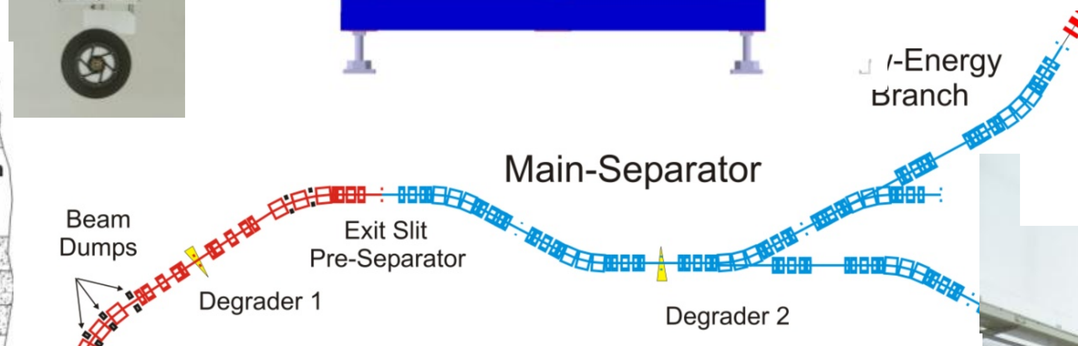
SC Multiplets



Local Cryogenics

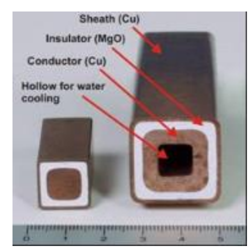






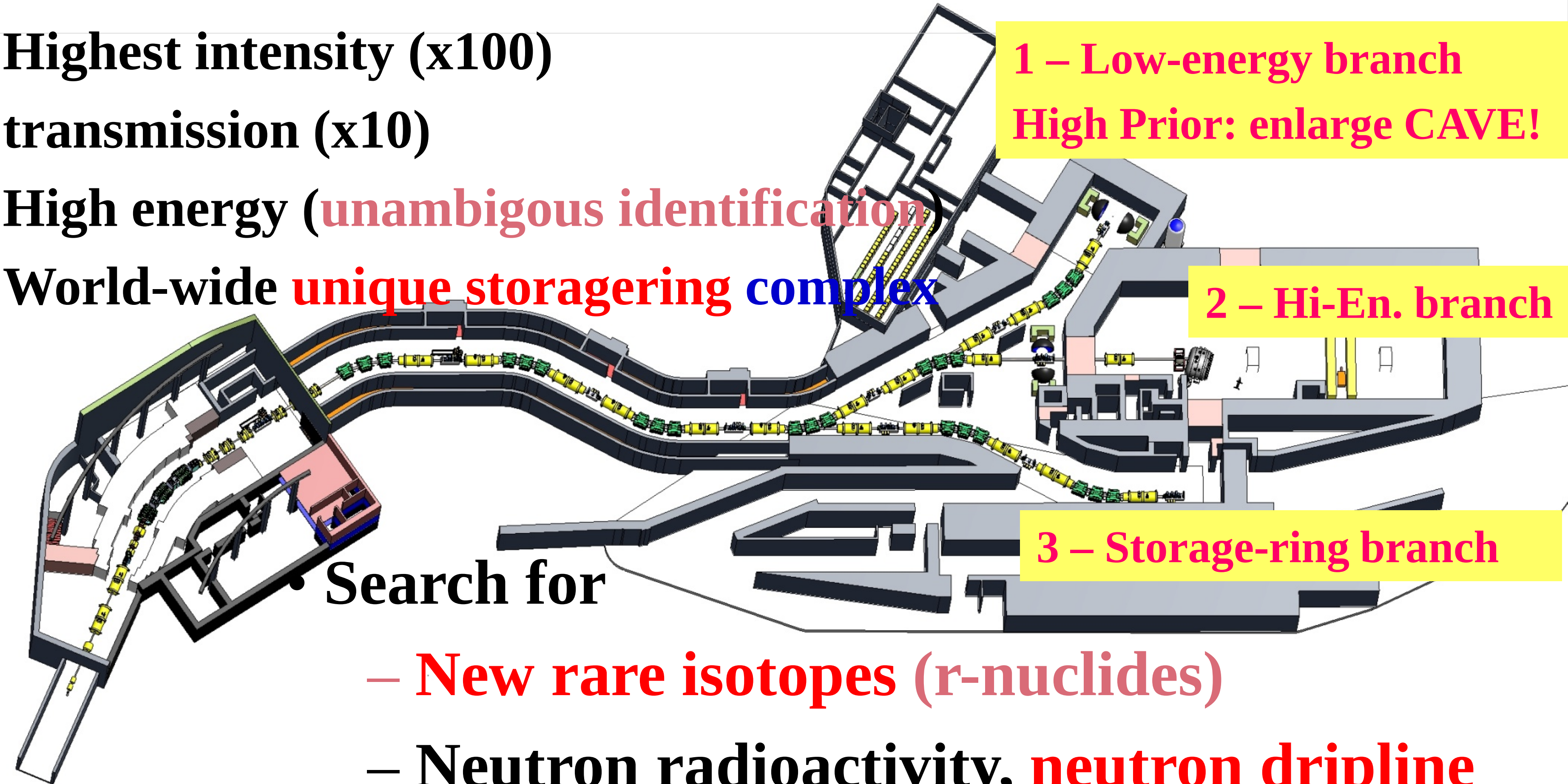
SC Dipoles

Radiation Resistant Magnets



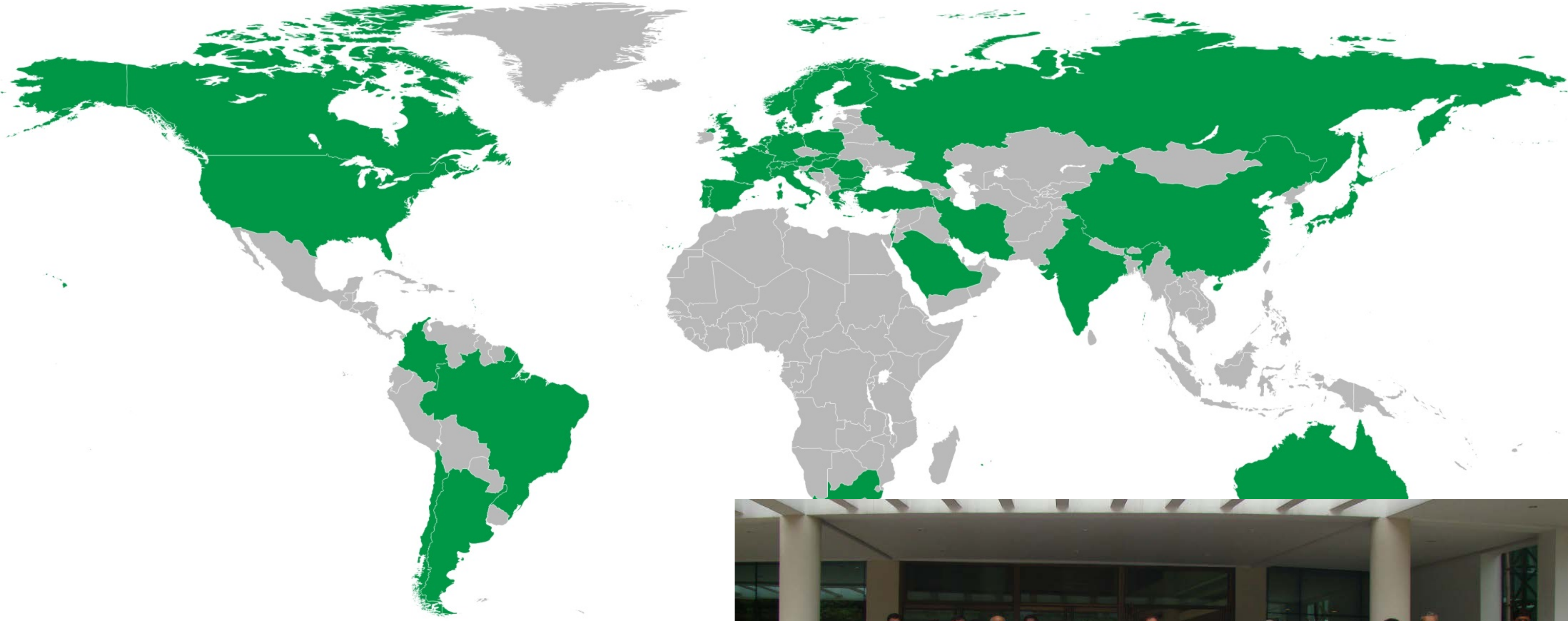
SuperFRS-facility and NuSTAR programme

- **Highest intensity (x100)**
- **transmission (x10)**
- **High energy (unambigous identification)**
- **World-wide unique storagering complex**



- **Search for**
  - **New rare isotopes (r-nuclides)**
  - **Neutron radioactivity, neutron dripline**
  - **Novel shell structure**
  - **New excitation modes**
  - **Unexpected observations and discoveries**

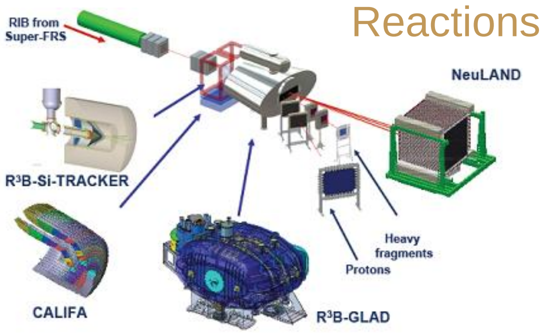
The NUSTAR collaboration

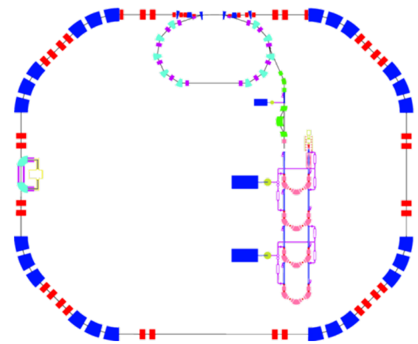


> 800 registered members
38 countries
180 institutes

The NUSTAR experiment facility at FAIR

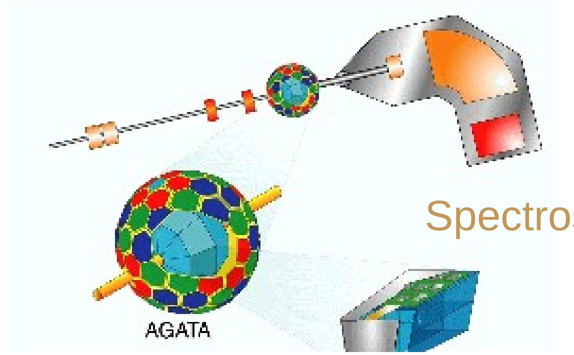
Reactions



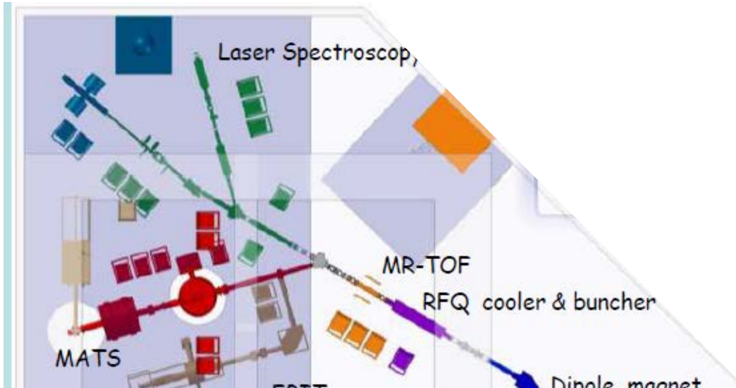


Stored-beam experiments

Super-FRS	Isotope identification and high-resolution spectrometer experiments
DESPEC	γ-, β-, α-, p-, n-decay spectroscopy
HISPEC	in-beam gamma-spectroscopy at low and intermediate energy
ILIMA	masses and lifetimes of nuclei in ground and isomeric states
LASPEC	Laser spectroscopy
MATS	in-trap mass measurements and decay studies
R^3B	kinematically complete reactions at high beam energy
ELISE	elastic, inelastic, and quasi-free e⁻A scattering



Spectroscopy



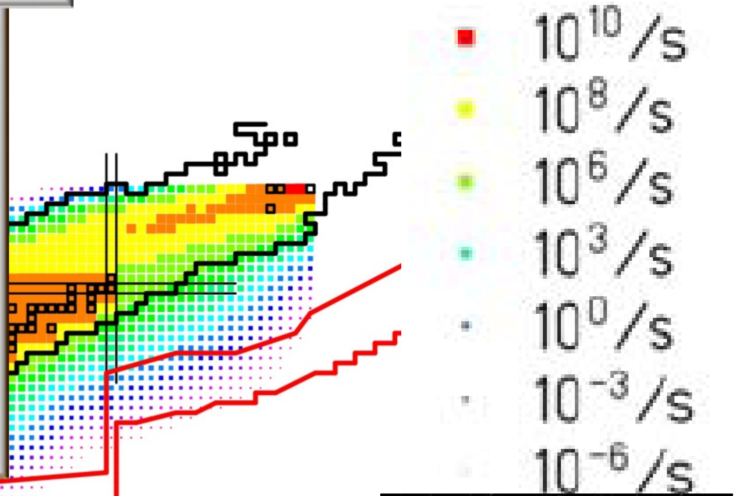
Nuclear Astrophysics at FAIR: NuSTAR

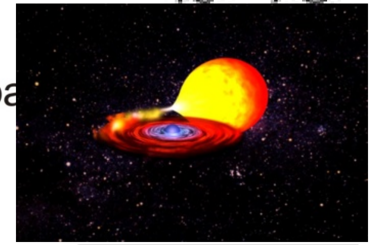
FAIR will provide unique access to many nuclei relevant in explosive nucleosynthesis

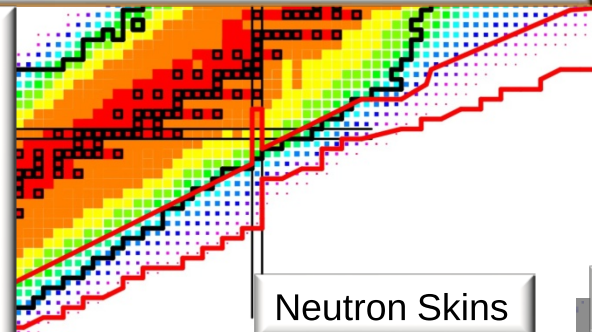
- Quest for the limits of existence
- Halos, Open Quantum Systems, Few Body Correlations
- Changing shell structure far away from stability
- Skins, new collective modes, nuclear matter, neutron stars
- Phases and symmetries of the nuclear many body system
- Origin of the elements

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

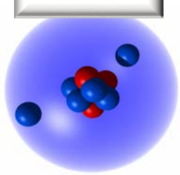
➔ Combine accurate **nuclear physics** with precision **astronomy** to **constrain astrophysical scenarios**



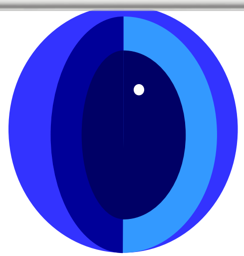




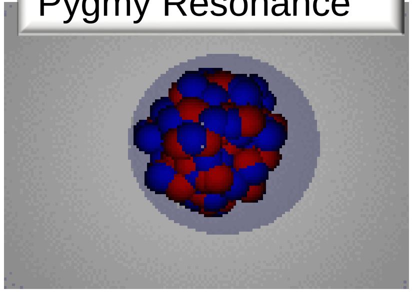
Halos



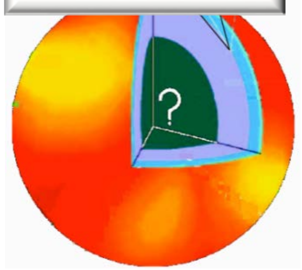
Neutron Skins



Pygmy Resonance



Neutron stars

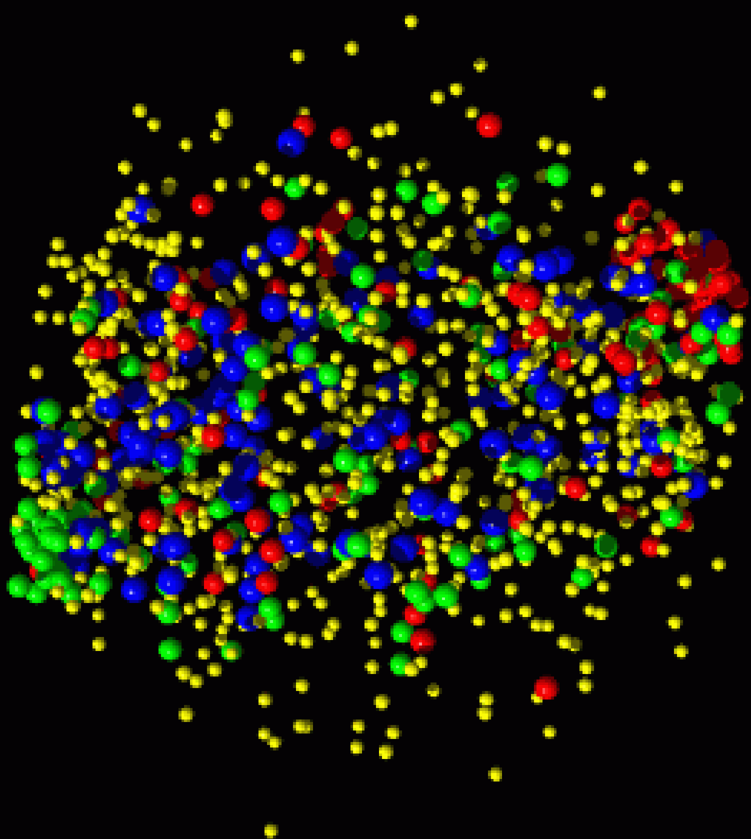


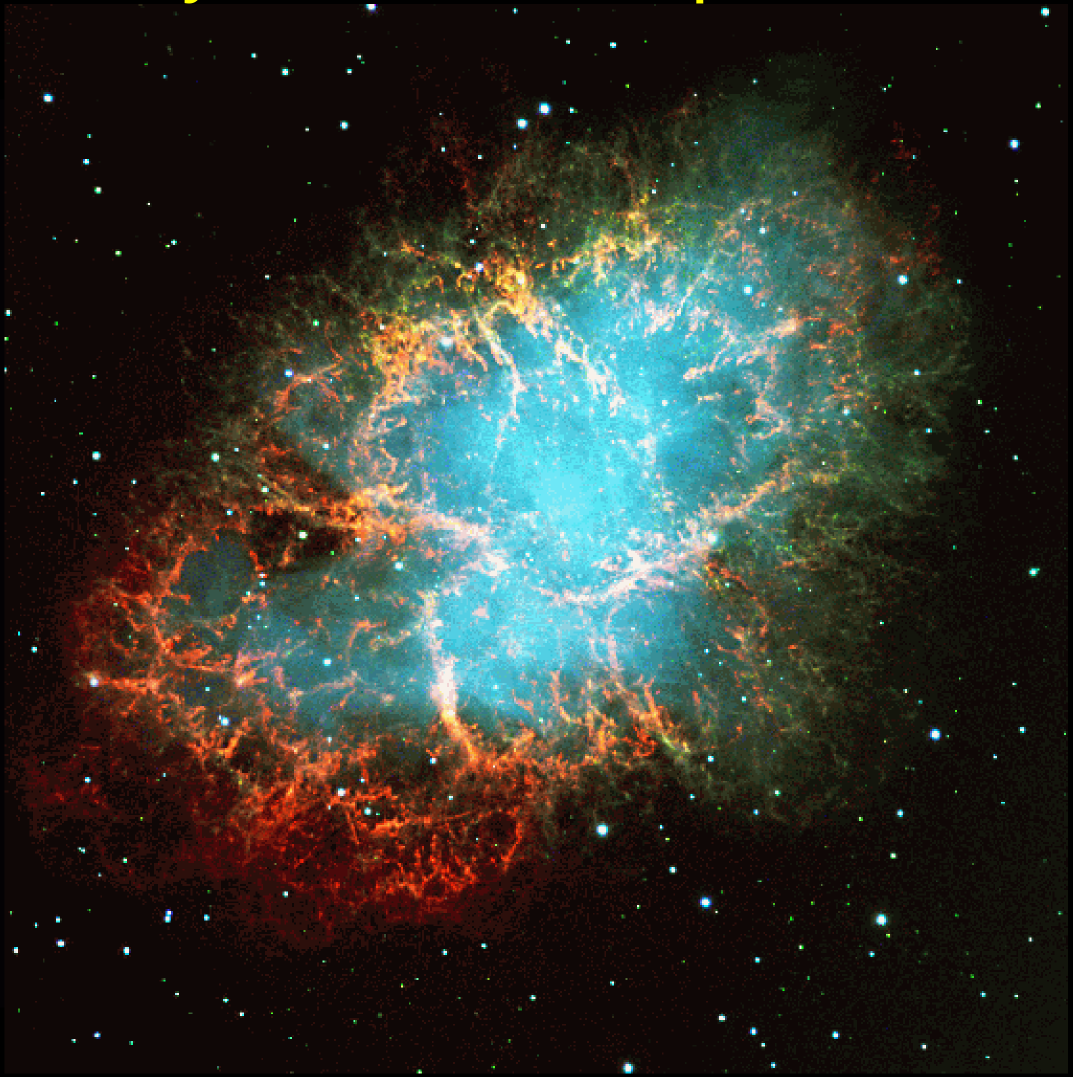
EOS

NuSTAR

Horst Stoecker GSI

CBM: The Compressed Baryonic Matter Experiment



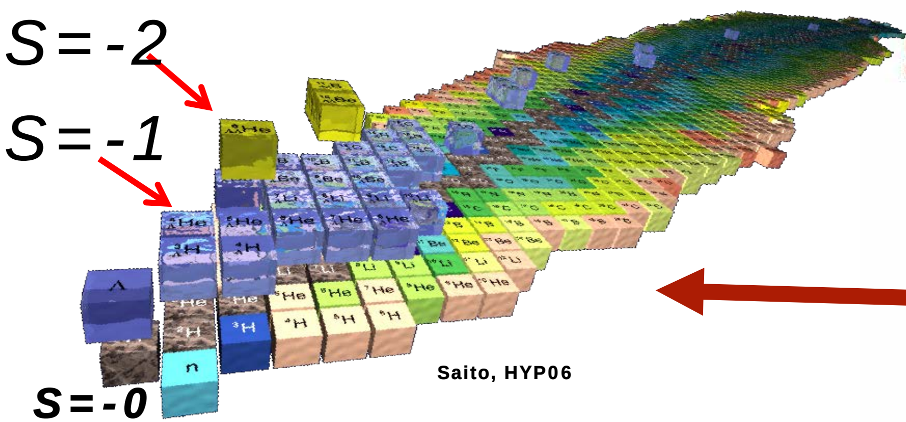


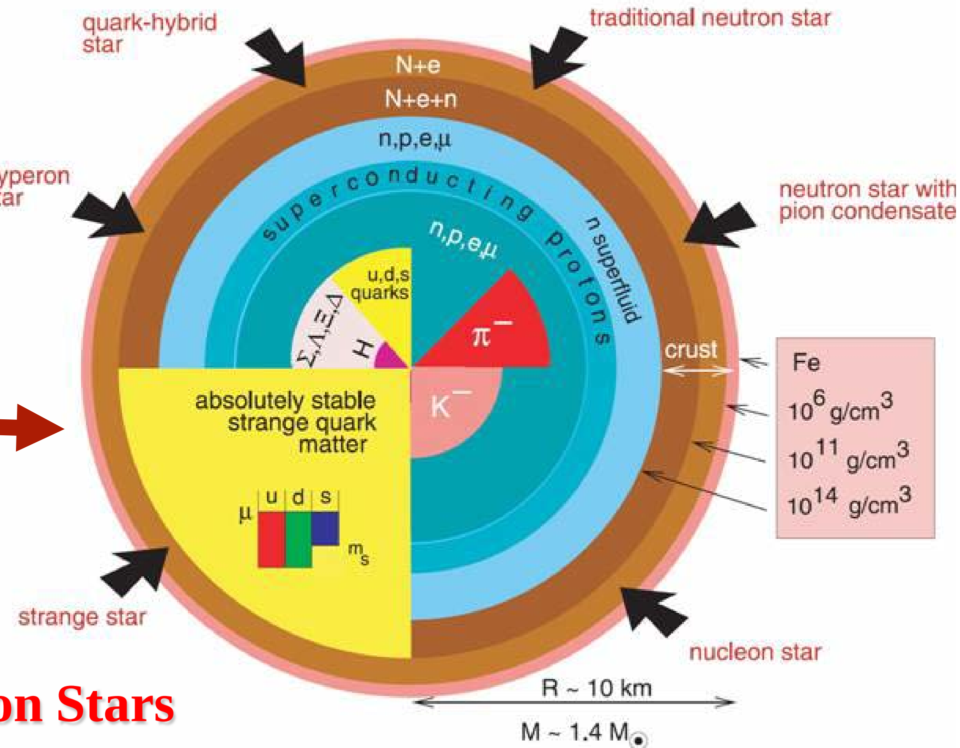
- Science case
- Status experiment preparation

Courtesy of Peter Senger (GSI)

From NuSTAR to CBM : Hypernuclei and Neutron Stars

hypernuclei ← Λ-B Interaction → Neutron Stars





Several possible configurations of Neutron Stars

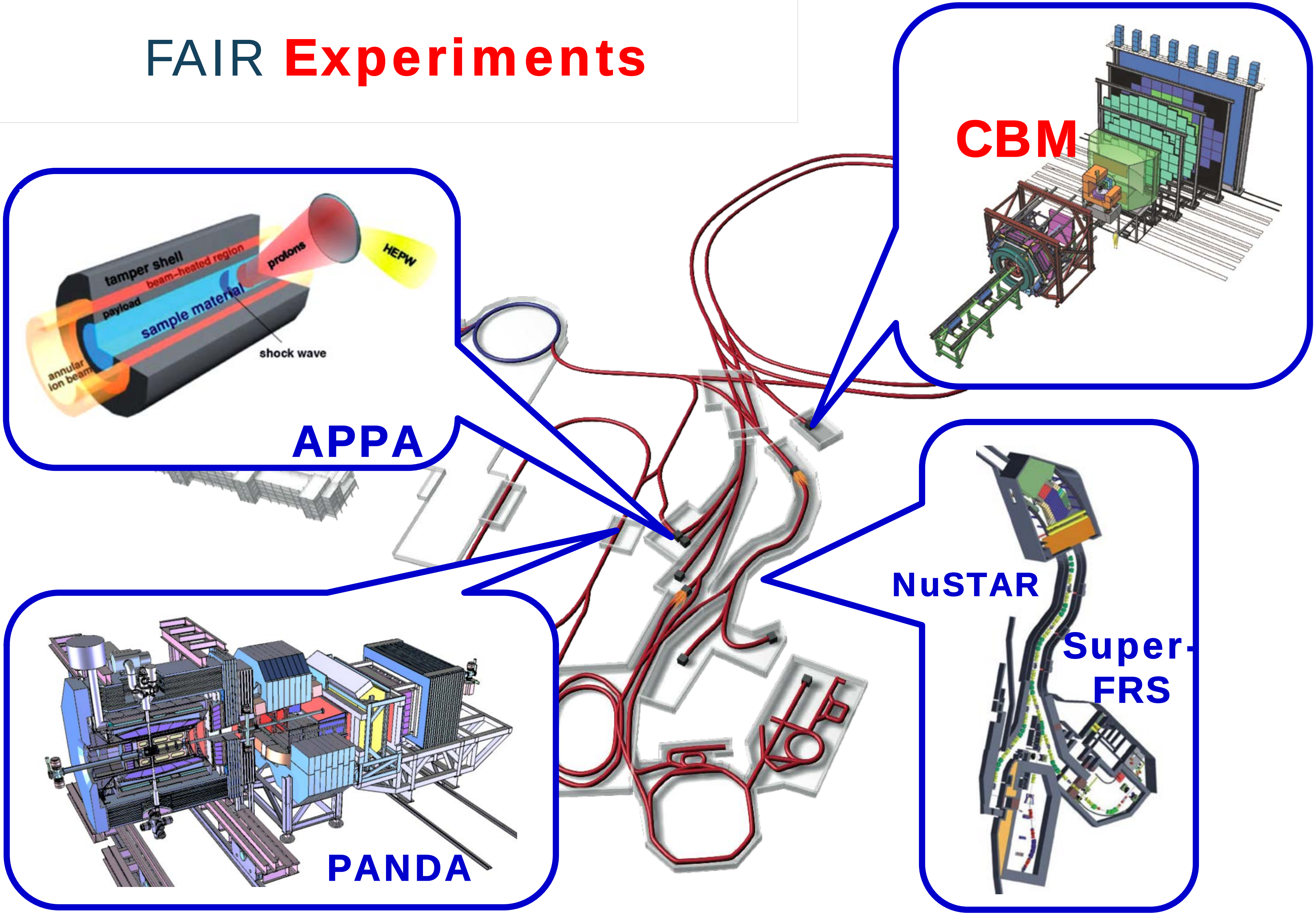
- **Kaon condensate, hyperons, strange quark matter**

J.M. Lattimer and M. Prakash,
"The Physics of Neutron Stars", Science 304
J. Schaffner and I. Mishustin, *Phys. Rev. C* 5
Hyperon-rich matter in neutron stars

Single **and** ***double*** **hypernuclei in the laboratory:**

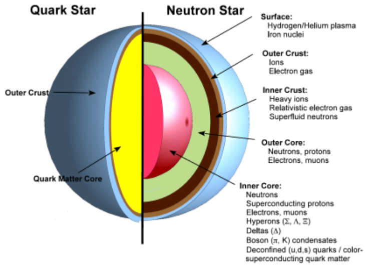
- **study the strange sector of the baryon-baryon interaction**
- **provide info on EOS of neutron stars**

FAIR Experiments

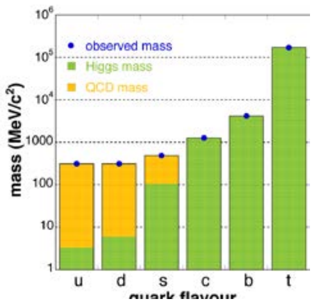


Fundamental Questions of (QCD-) Physics

- What is the structure of compact stars?

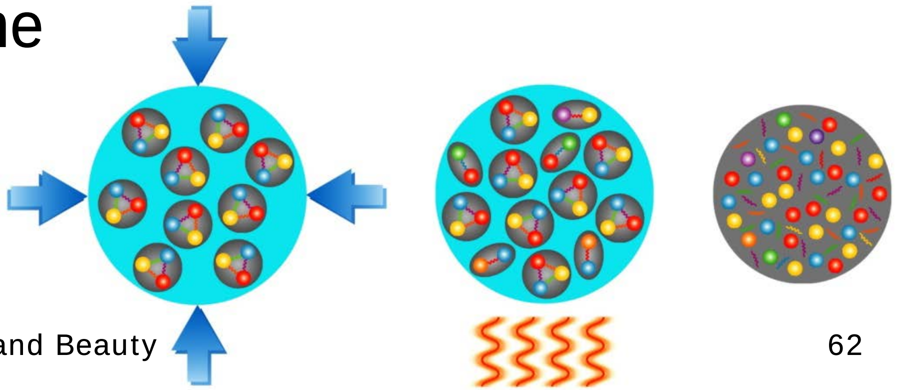


- What is the origin of the mass of the hadrons which determine the visible mass of the universe?



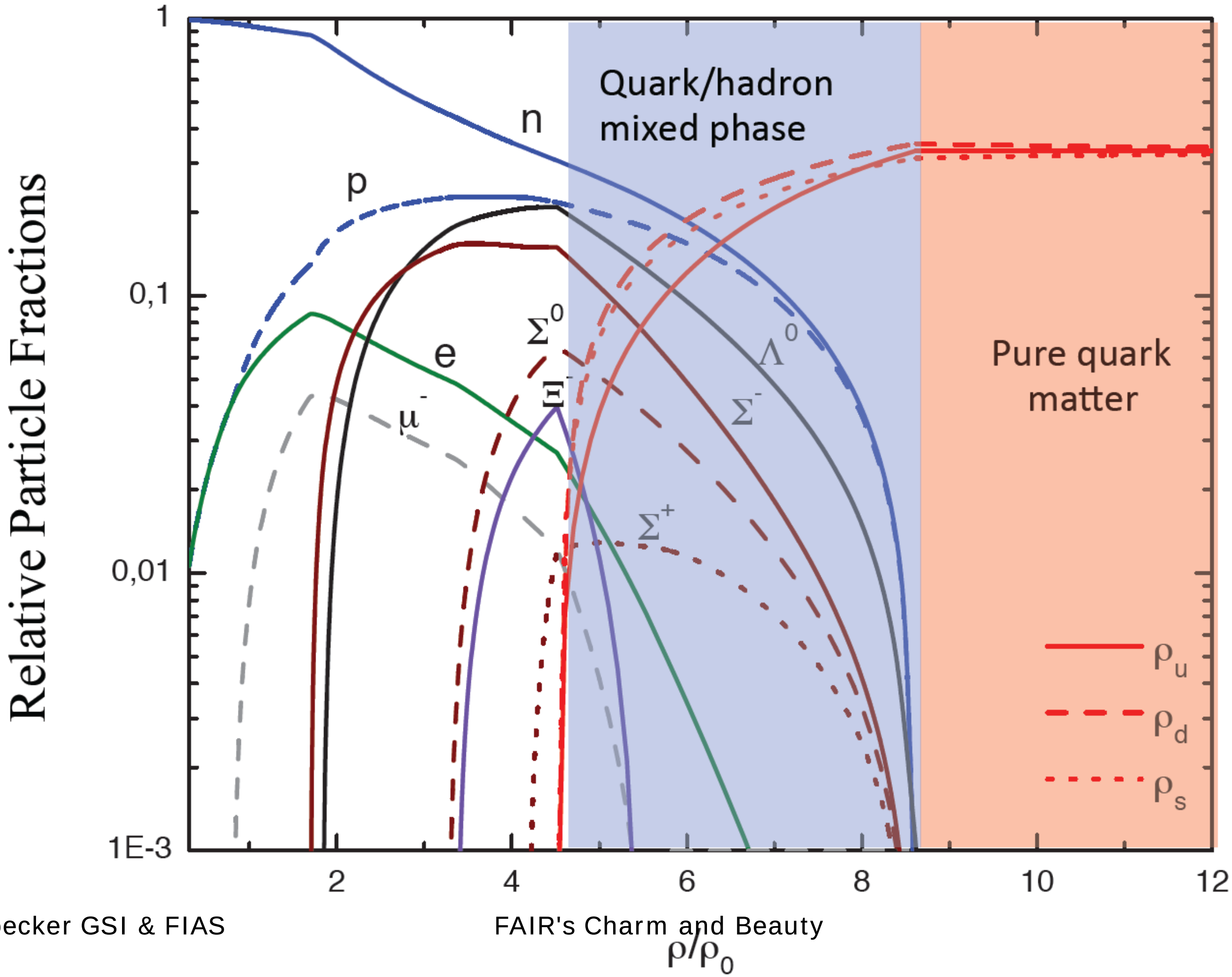
- Why do we not observe individual quarks, the elementary building blocks of matter?

- What are the properties and the degrees-of-freedom of nuclear matter under extreme conditions (high temperature and/or high density)?

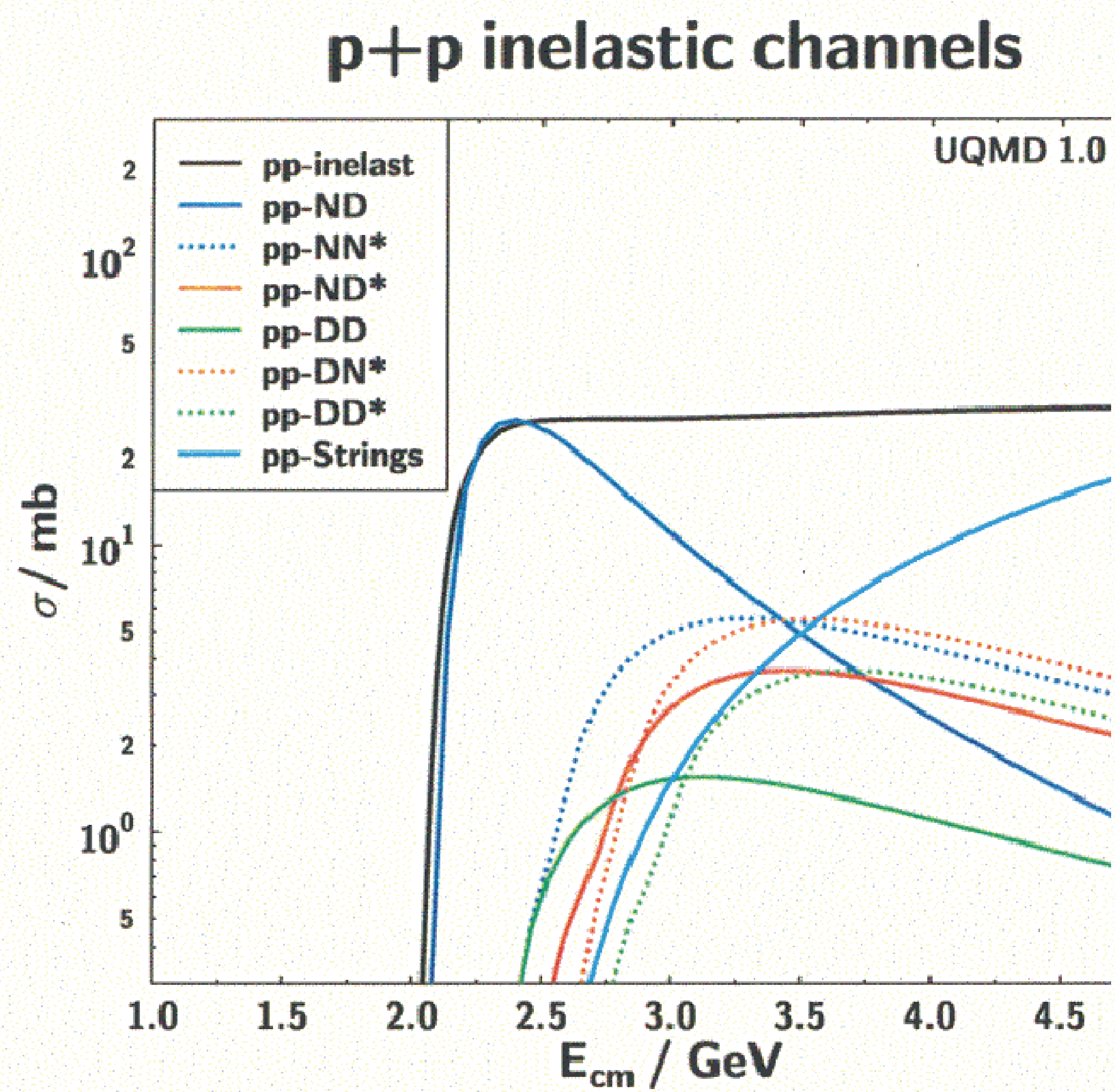


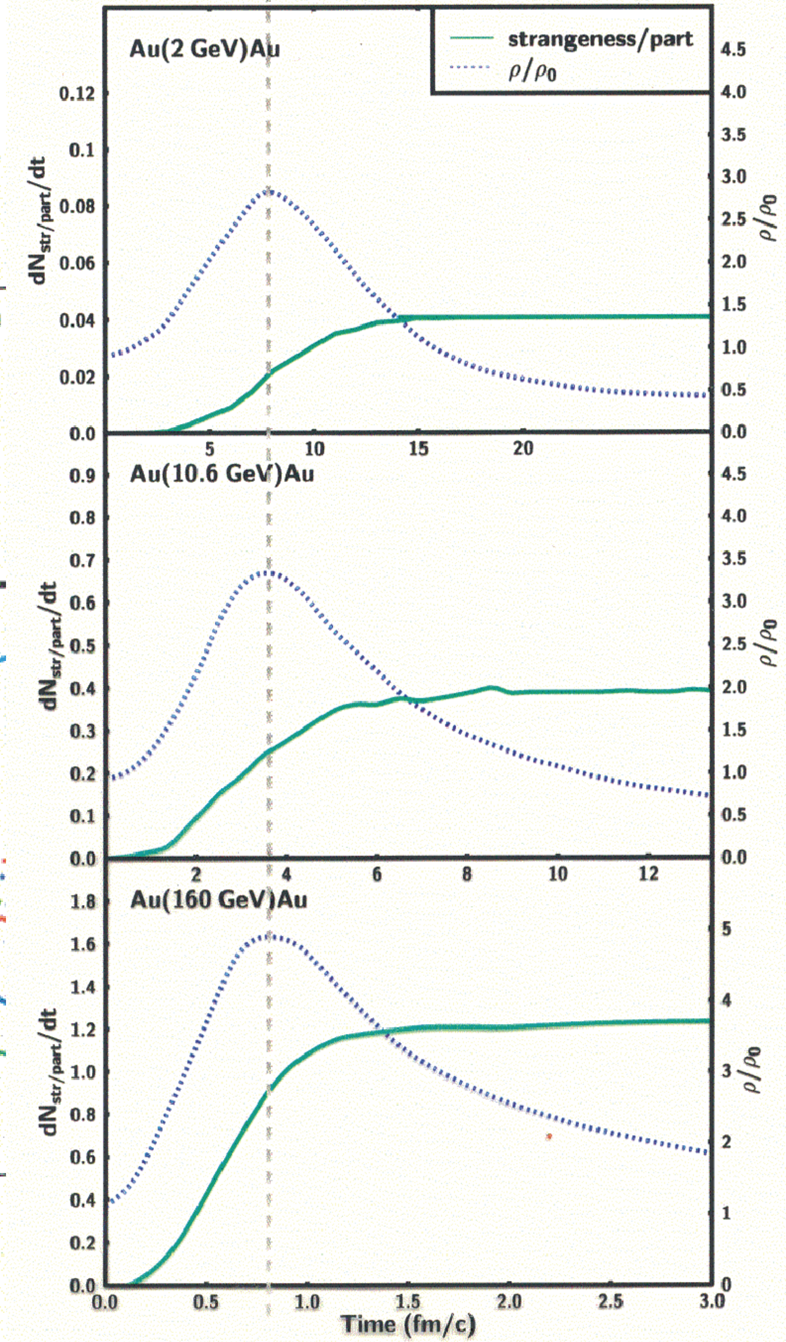
Quark/Hadron composition and mixed phase in neutron stars

M. Orsaria, H. Rodrigues, F. Weber (August 2012)

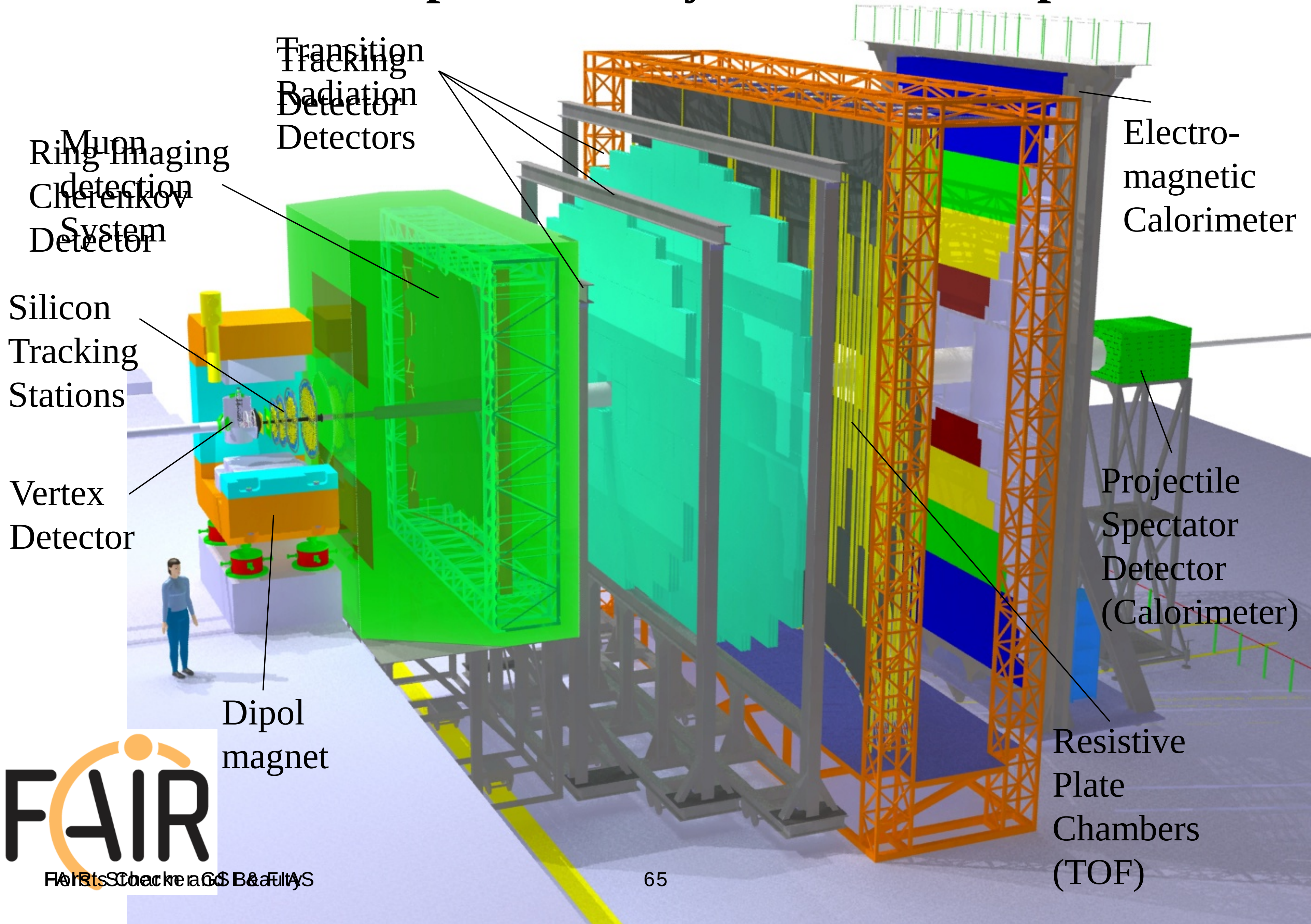


Heavy Ion Collisions: Hadron Composition and - densities match Neutron Star matter well …

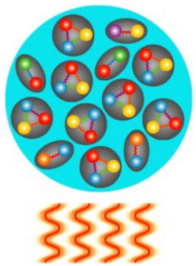


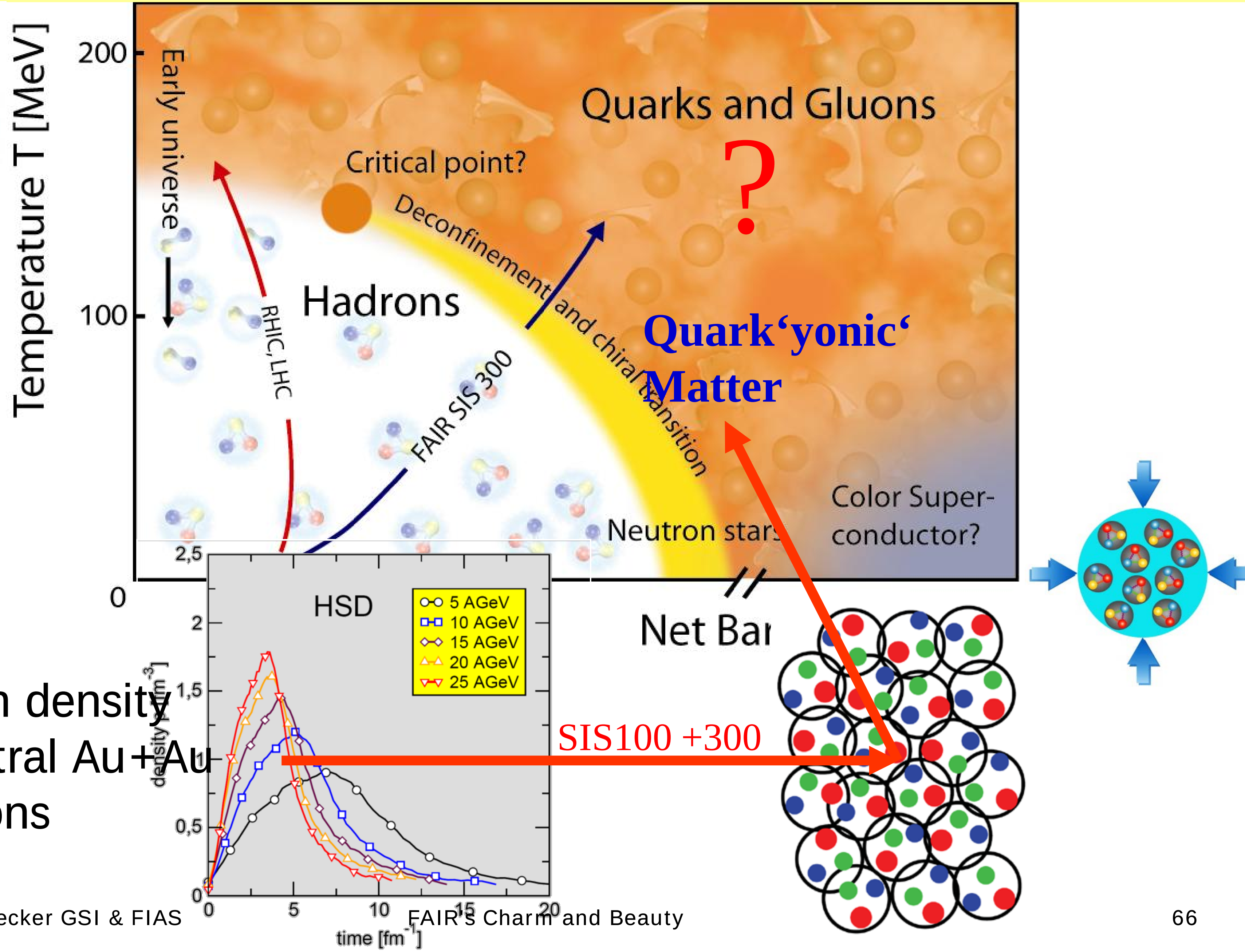


CBM: The Compressed Baryonic Matter Experiment



Exploring the QCD phase diagram

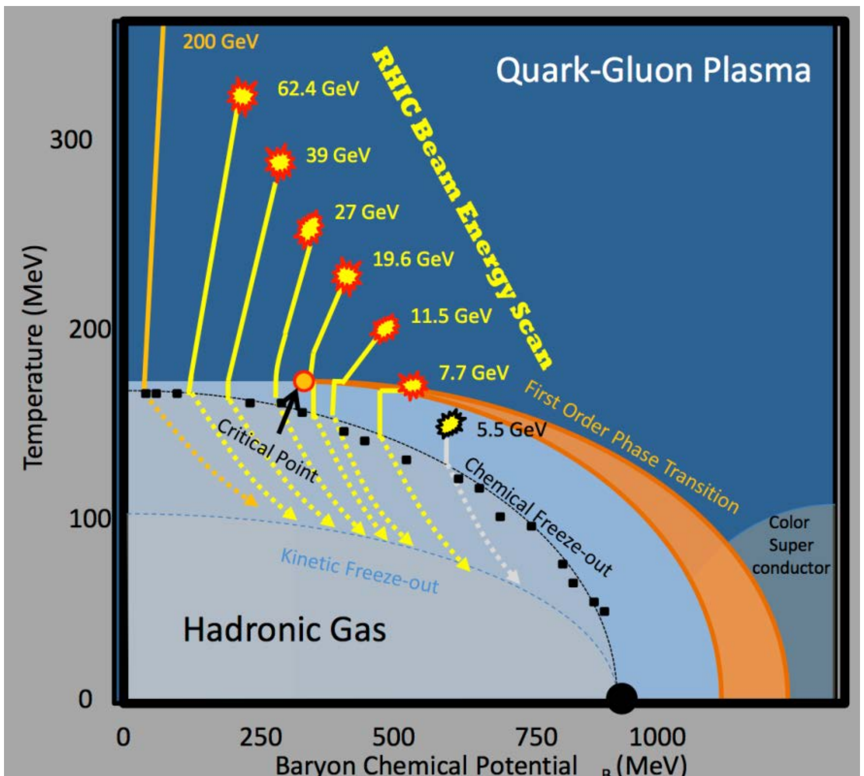


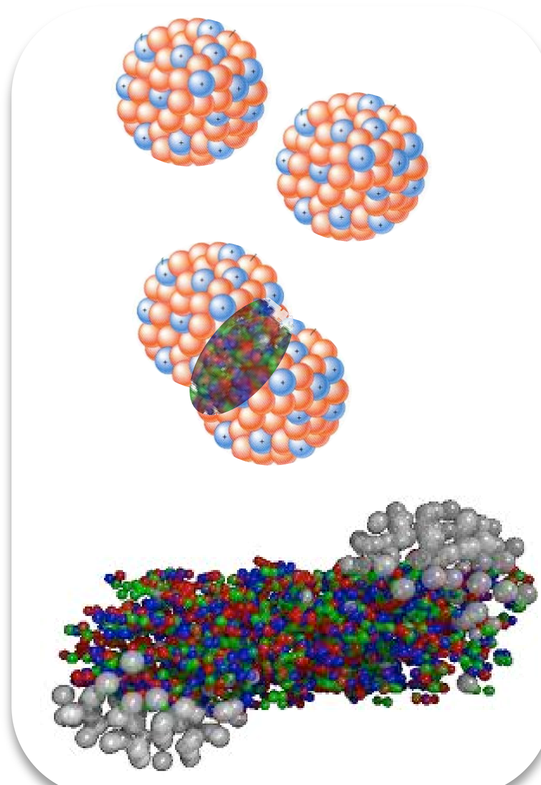


Baryon density in central Au+Au collisions

Directed flow: px/pt = v1

- **First form of flow predicted (one-fluid hydro, H.St. & W. Greiner)**
- **and observed at LB L (Plastic Ball, Streamer Chamber) in 1980's**
- **later less focus on v1 at higher energies, where**
  - **signal is smaller than v2**
  - **v2 stole the limelight**
  - **2D models cannot address this explicitly 3-D phenomenon**

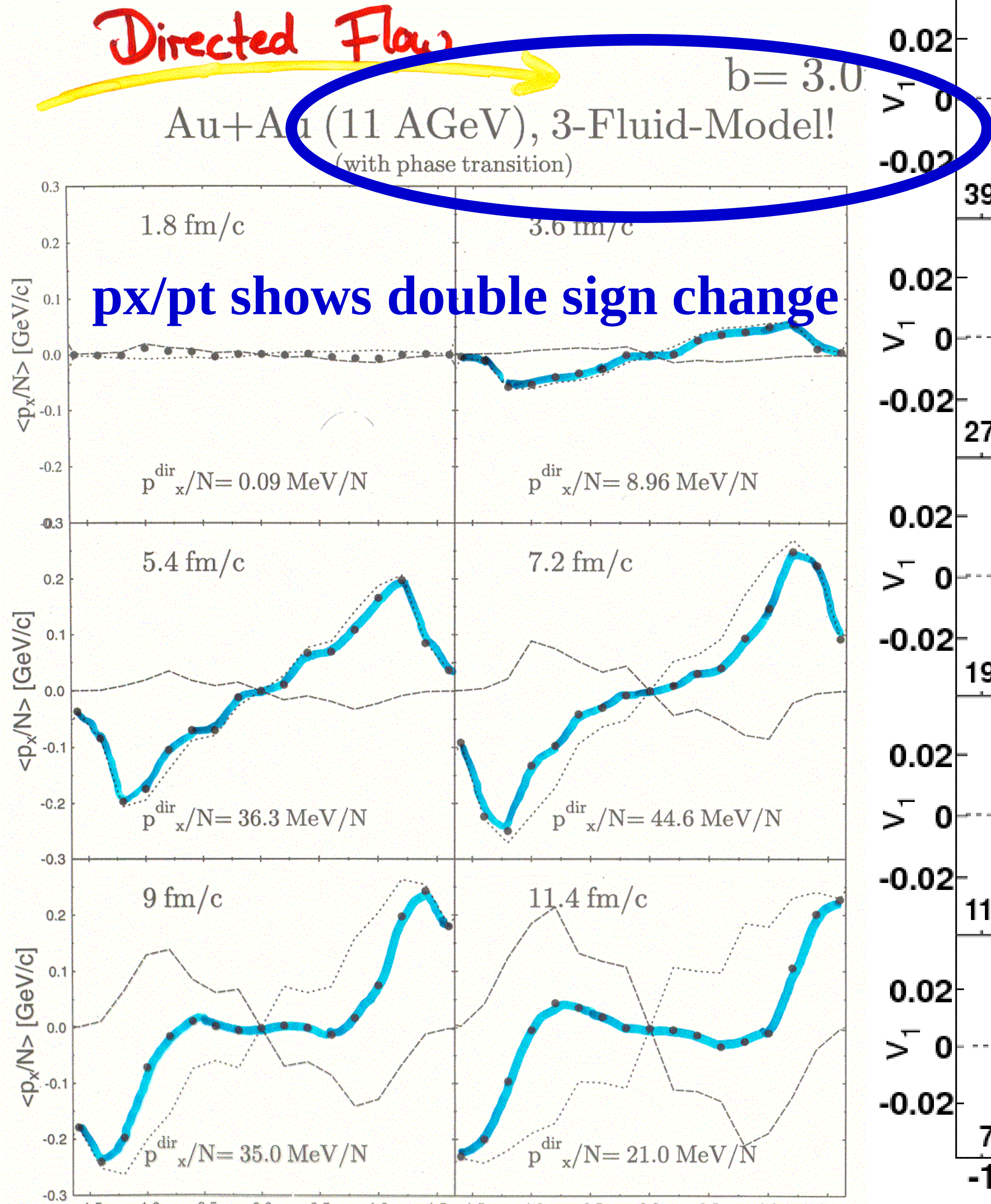


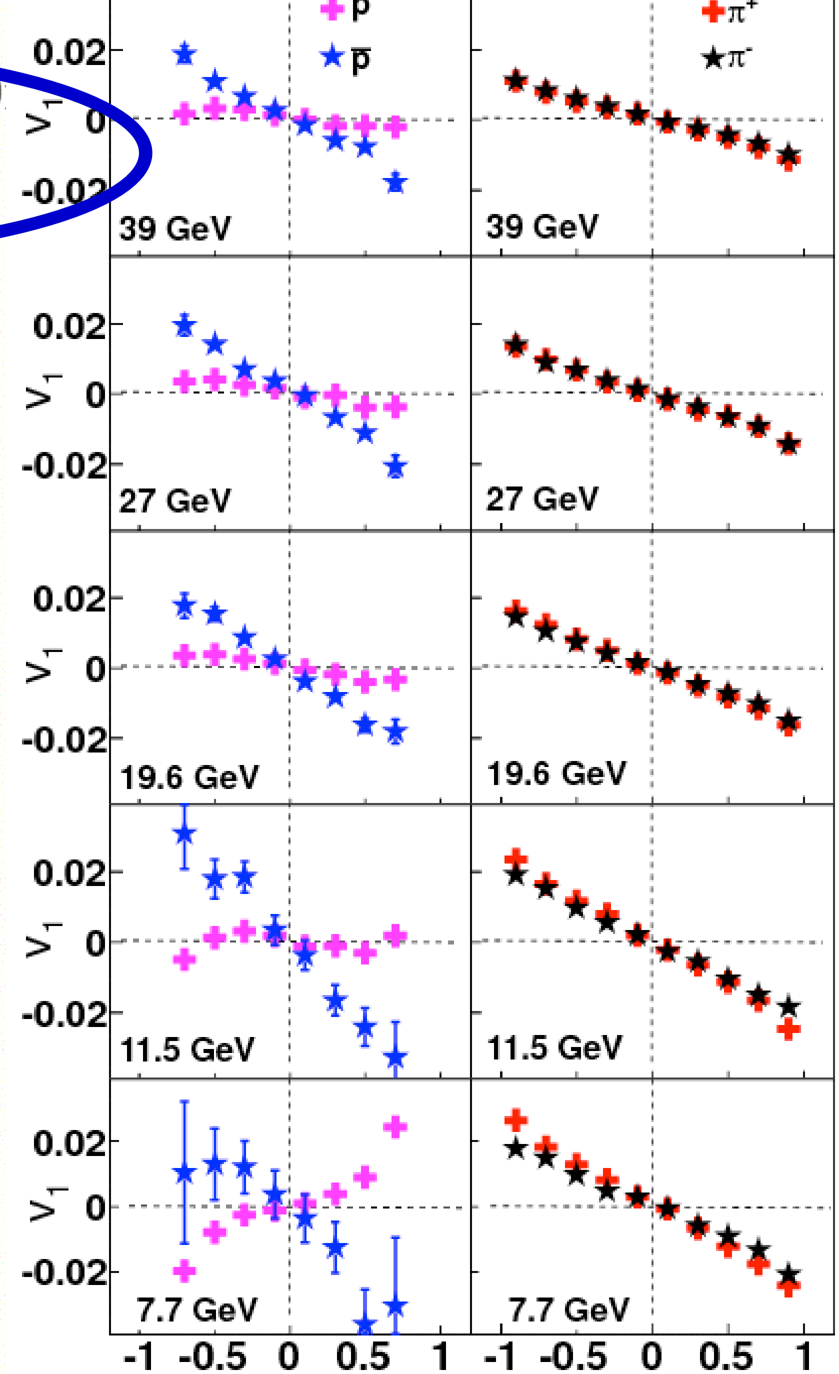


Geometrical seeds of directed flow imprinted during Interpenetration

→ early pressure signal !

Courtesy M. Lisa, STAR



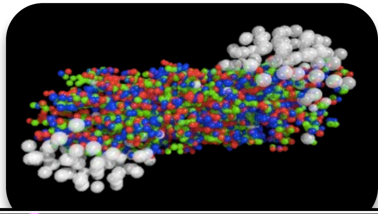


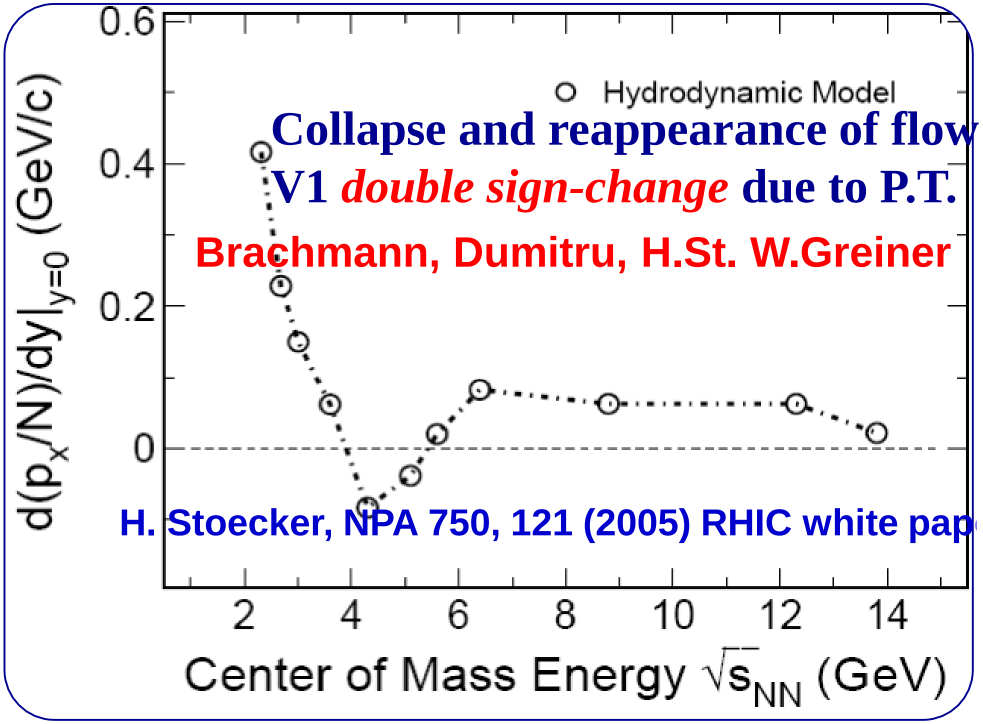
Brachmann, Dumitru, H.St., W.Greiner EPJC 2000

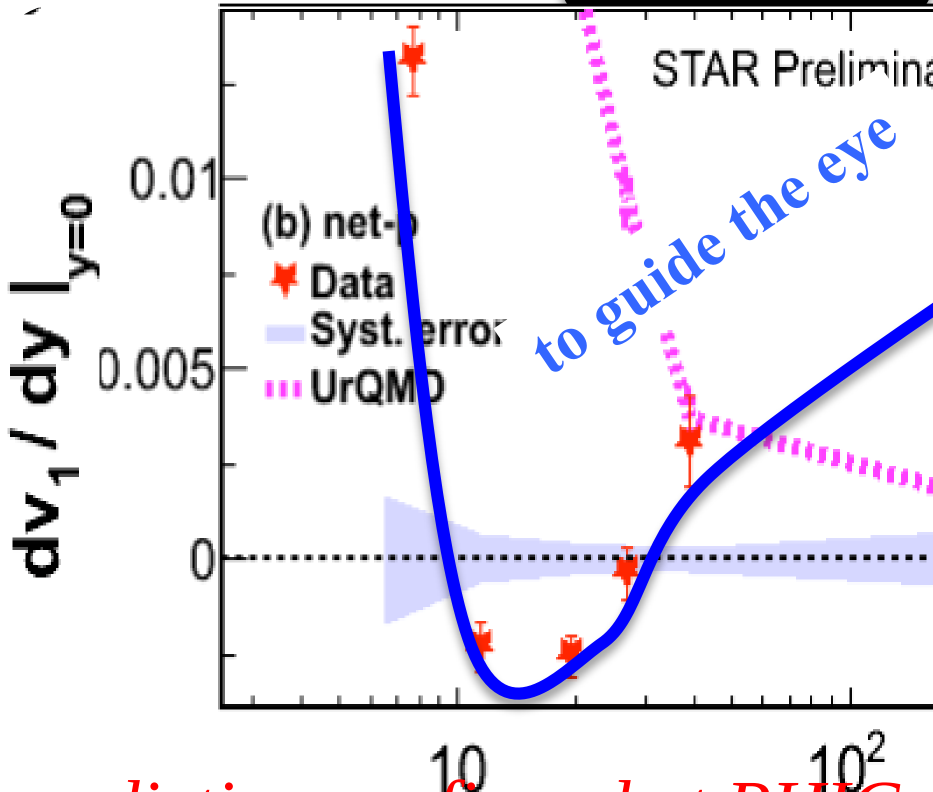
A.Schmah STAR

Directed flow v1 probes early pressure: "Bounce off as a Barometer for RHIC"

H. St., B. Mueller, W.Greiner 1979







Nontrivial qualitative soft-spot prediction confirmed at RHIC

(based on) D. Keane Confinement 2012

STAR BES results

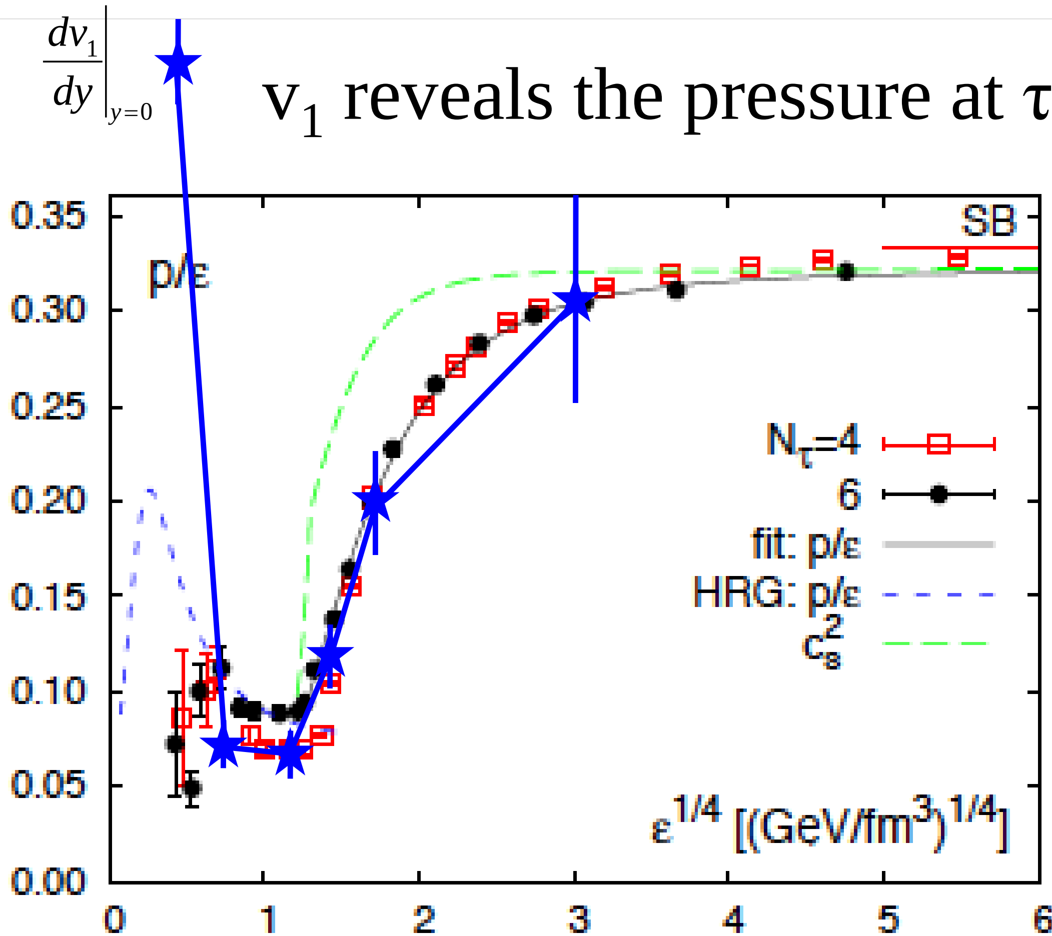
First-order anisotropy imprints itself on momentum space in first instants

- Promising soft-spot probe, due to rapid dynamics
- **Long-standing probe for 1st-order transition neglected in v2 @RHI**

P. Sorensen‘s Optimistic point of view

STAR : RHIC BES data

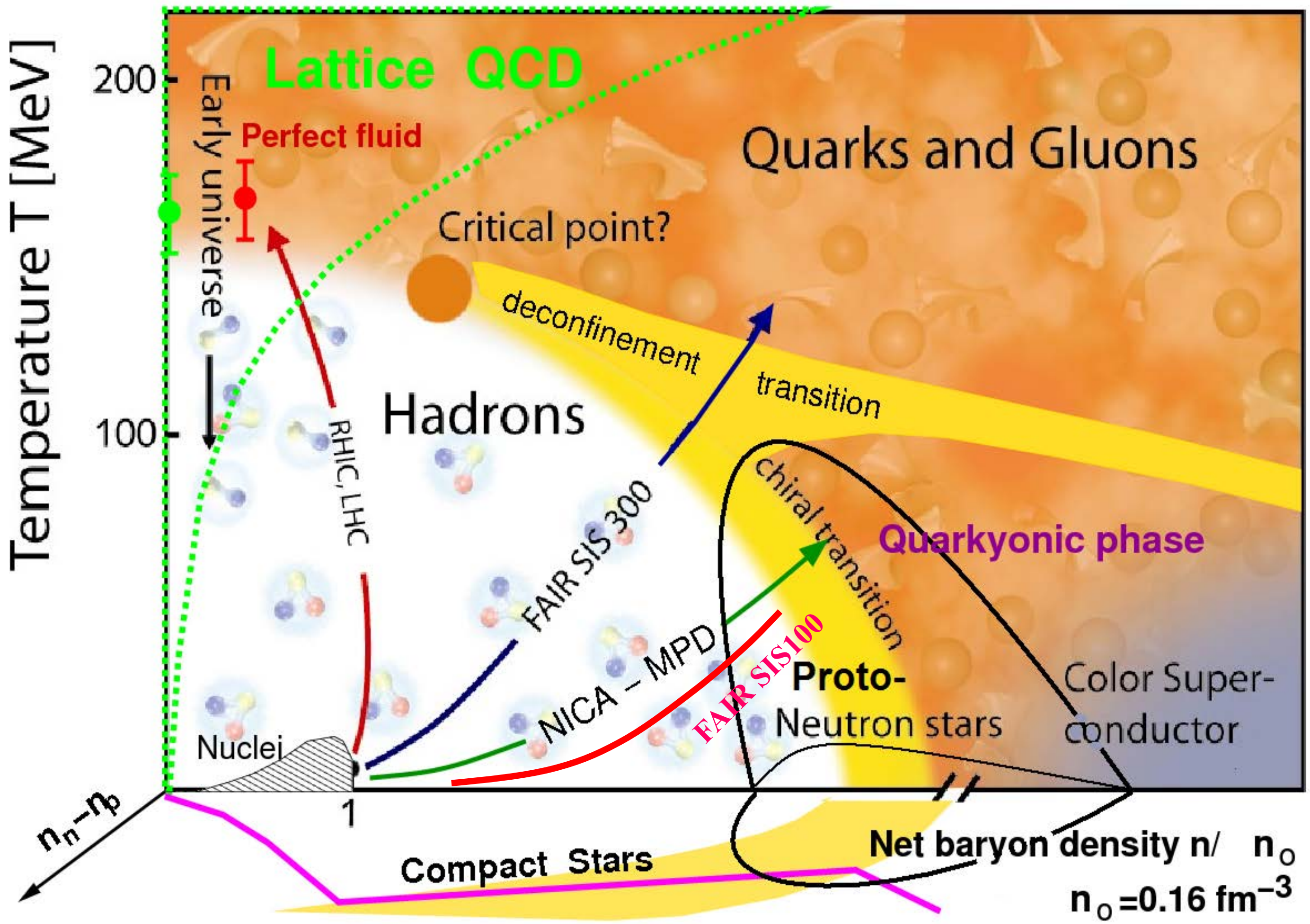
v_1 reveals the pressure at τ=0 !?



H.St, B. Mueller: „Bounce Off as Barometer“ 1979

dv$_1$/dy for net protons
very well may be the smoking gun we’ve been looking for.
It deserves more theoretical attention!

CBM : Big Bang and Neutron Star matter
- in the laboratory

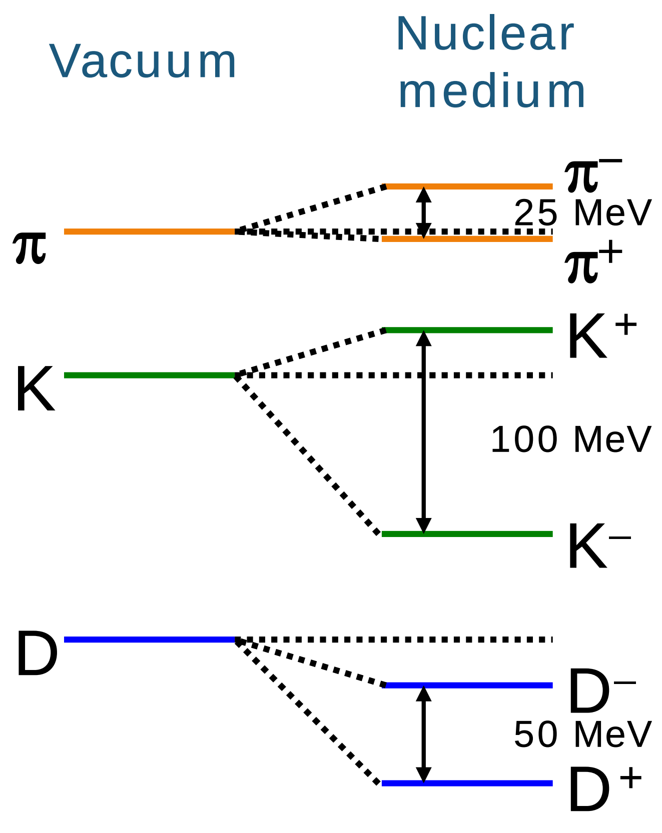


- deconfinement phase transition Quarks=> Proton
- Equation-of-state at neutron star densities, Multi-Strange Quarks
- in-medium properties of hadrons, hadron mass generation

Highest Proton Densities in the Universe !

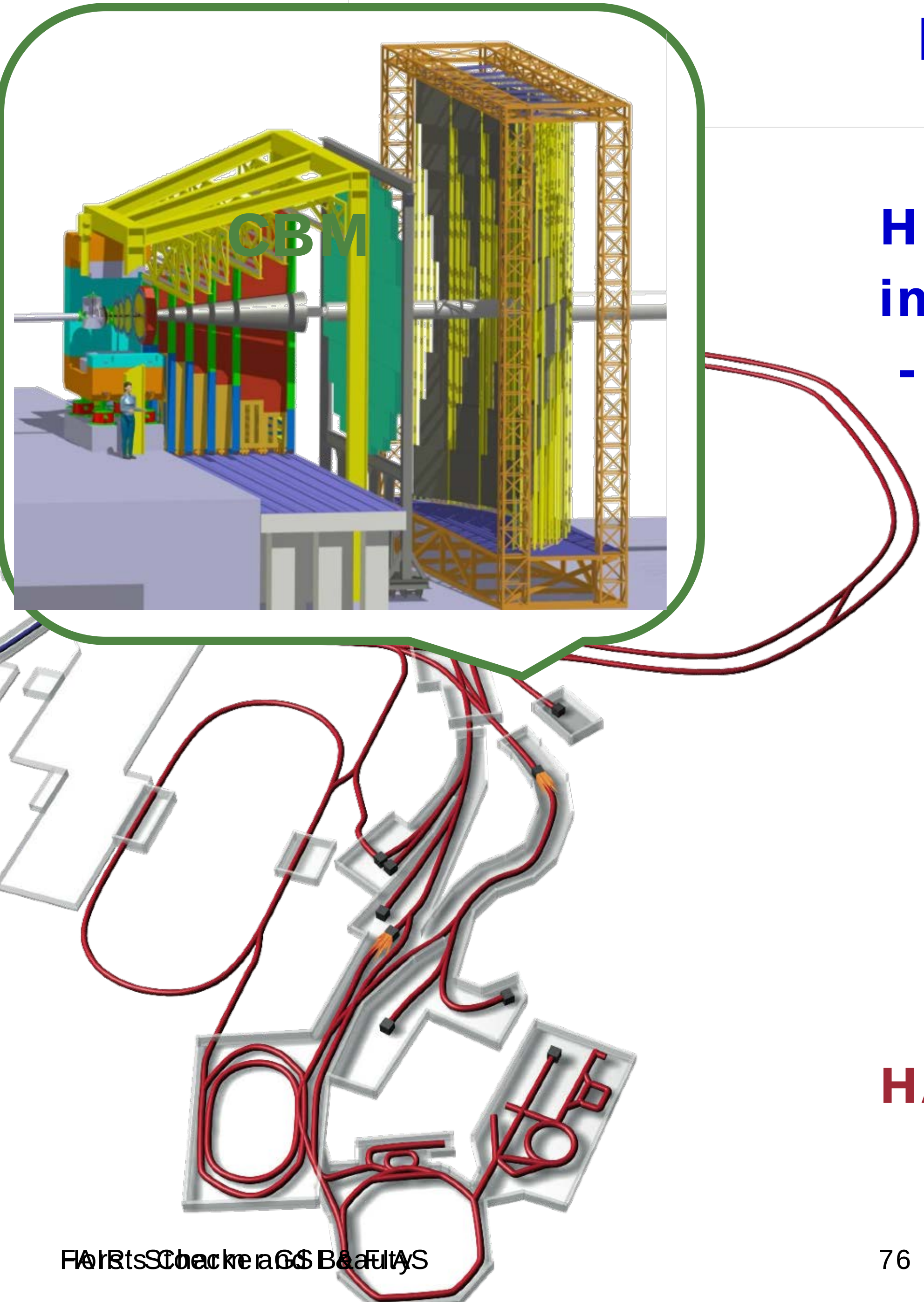
Hadrons in nuclear- / Neutronstar Matter

- Partial restoration of chiral symmetry in nuclear matter
  - Light quarks sensitive to quark condensate
- $(c\,\bar{c})$ states sensitive to gluon condensate
  - Small (5-10 MeV/c^2) in medium modifications for low-lying $(c\,\bar{c})$ $(J/\psi, \eta_c)$
  - Significant mass shifts expected for excited states: 40, 100, 140 MeV/c^2 for χ_{cJ}, ψ', $\psi(3770)$ resp.
- D mesons - QCD analogue of H-atom
  - Chiral symmetry to be studied on a single light quark
  - Theoretical calculations disagree in size and sign of mass shift (50 MeV/c^2 attractive – 160 MeV/c^2 repulsive)



Hayaski, PLB 487 (2000) 96
Morath, Lee, Weise, priv. Comm.

From Hades to CBM



CBM

Highest Baryon densities in the universe
- probing the center of neutron stars

HADES high multiplicity upgrade

Au+Au @ SIS18

Ag+Ag @ SIS100

CBM = Look deep into neutron stars !

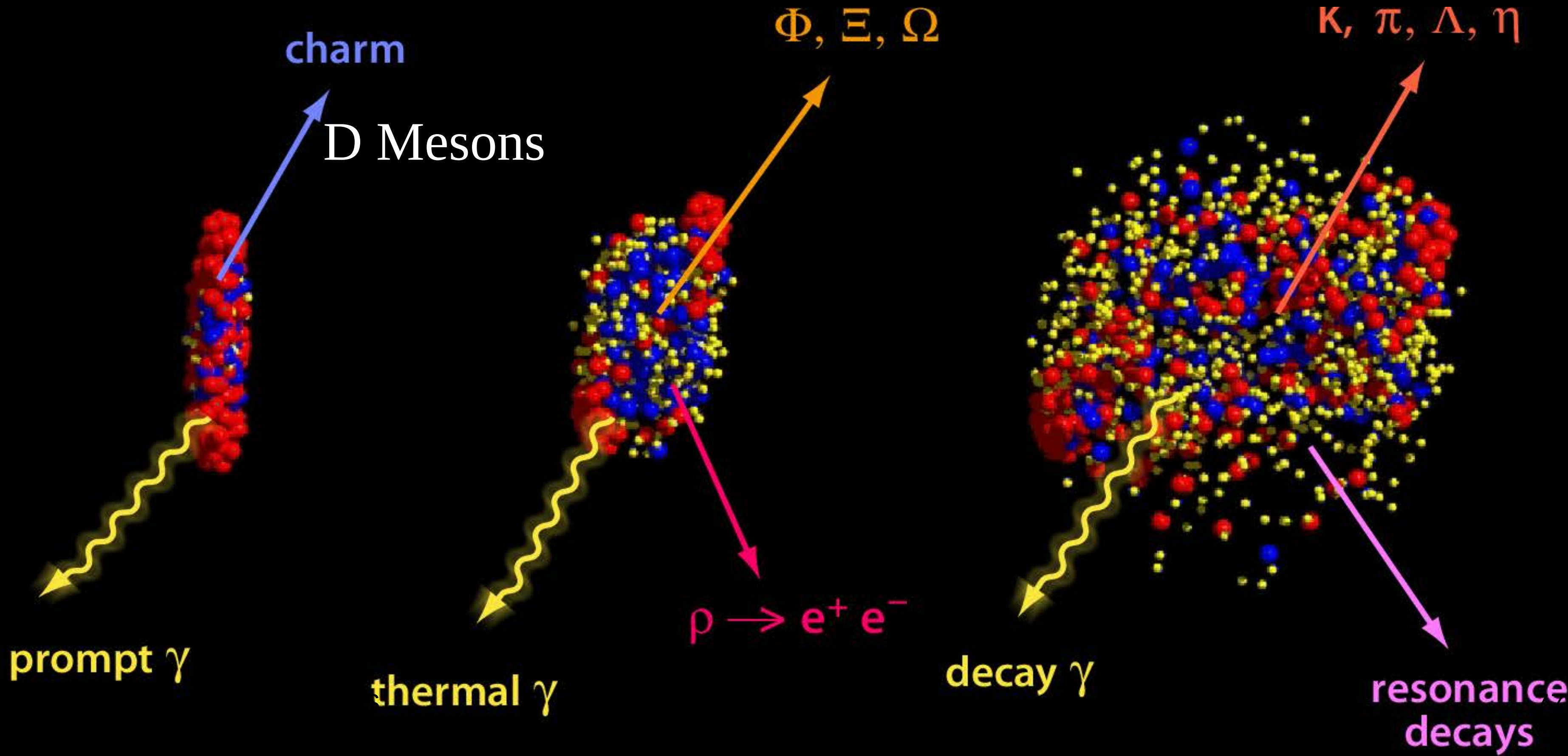
High density matter - EoS: collective explosive flow of protons

Quark-Hadron phase boundary @ high baryon density ρ_B:

- multi-strange + charm production

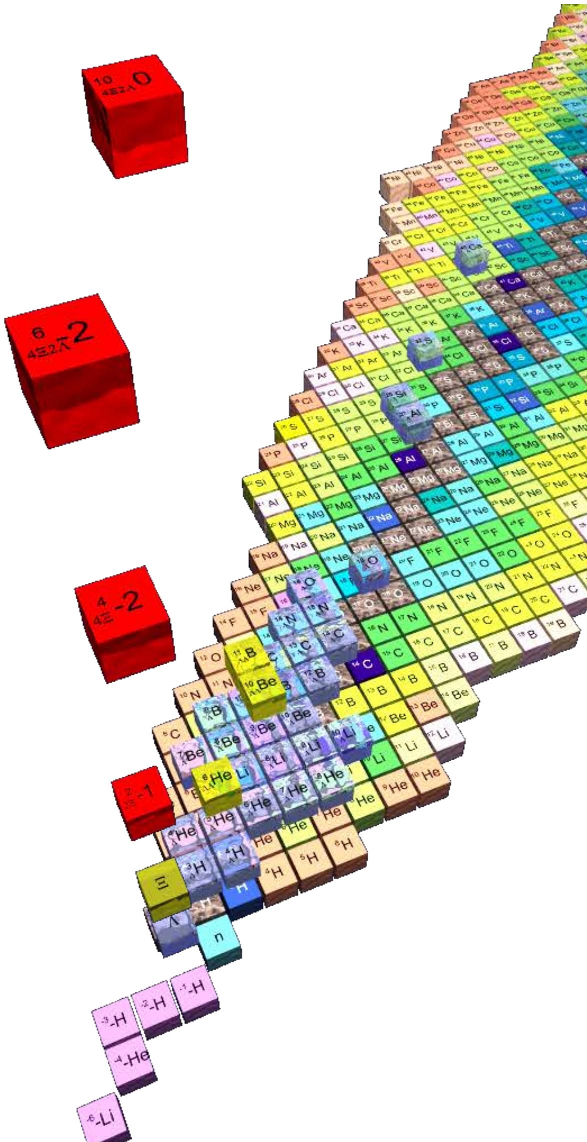
QCD critical point

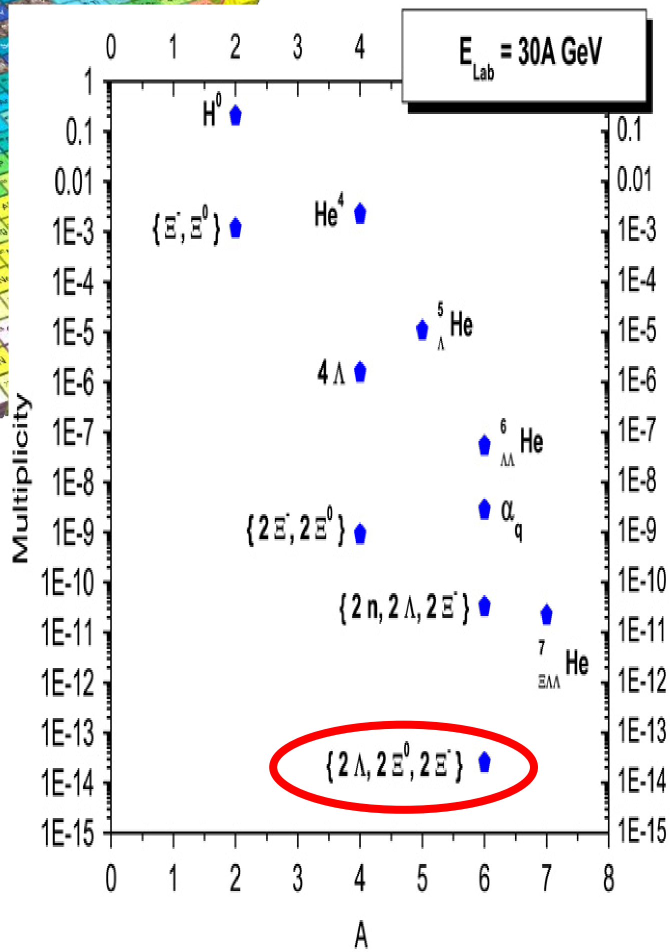
Chiral symmetry at high ρ_B: open charm, J/Psi, dilepton production

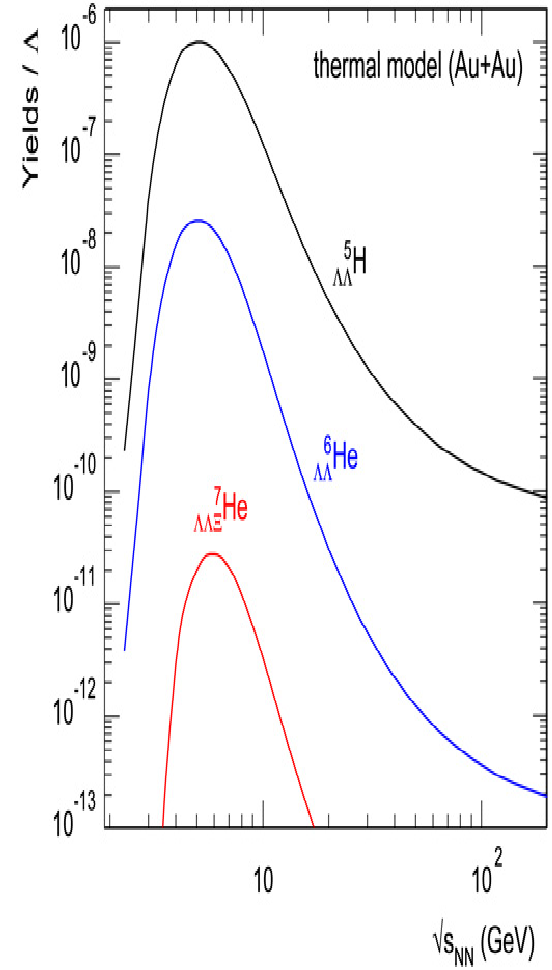


Hypernuclei and metastable multistrange matter

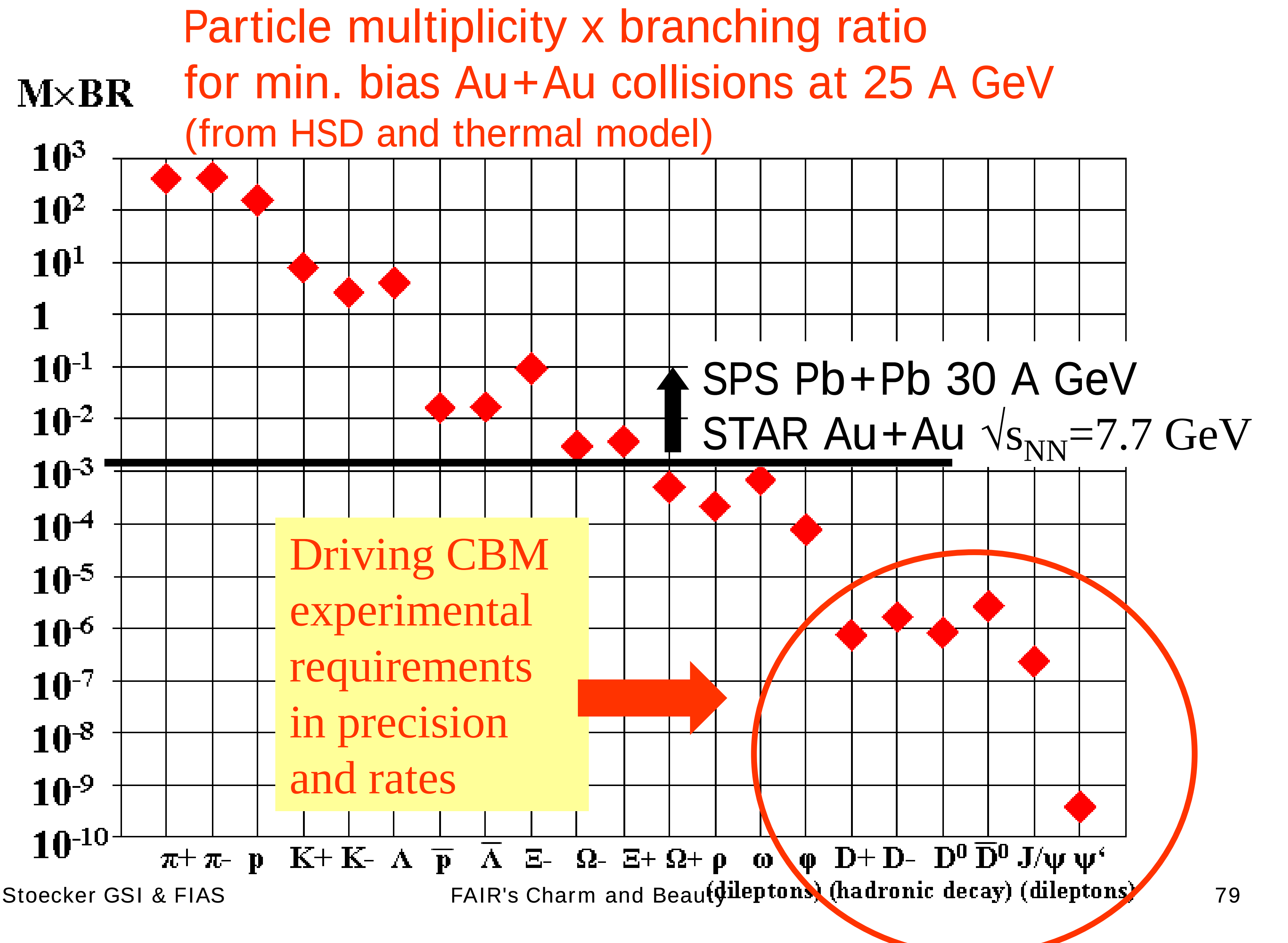
J. Steinheimer, P. Senger, H. Stöcker et. al.
Progress in Particles and Nuclear Physics
62 (2009) 313-317







Experimental challenge: 10000000x STAR-yields!!



Experiments on superdense nuclear matter

Experiment	Energy range (Au/Pb beams)	Reaction rates Hz
STAR@RHIC BNL	$\sqrt{s_{NN}}$ = 7 – 200 GeV	1 – 800 (limitation by luminosity)
NA61@SPS CERN	E_{kin}= 20 – 160 A GeV $\sqrt{s_{NN}}$= 6.4 – 17.4 GeV	80 (limitation by detector)
MPD@NICA Dubna	$\sqrt{s_{NN}}$= 4.0 – 11.0 GeV	~1000 (design luminosity of 10^{27} $cm^{-2}s^{-1}$ for heavy ions)
HADES@SIS100	1.5 A GeV Au+Au 8 A GeV Ni+Ni	$5\cdot10^4$
CBM@FAIR Darmstadt	E_{kin}= 2.0 – 35 A GeV $\sqrt{s_{NN}}$= 2.7 – 8.3 GeV	10^5 – 10^7 (limitation by detector)

CBM technological challenges

Central Au+Au collision at 25 AGeV (UrQMD + GEANT4):

160 p 400 π^- 400 π^+ 44 K^+ 13 K^-

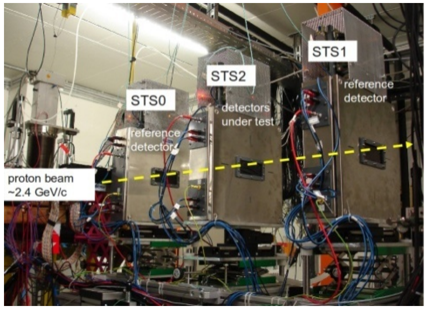
- 10^5 - 10^7 Au+Au reactions/sec
- determination of (displaced) vertices ($\sigma \approx 50\ \mu m$)
- identification of leptons and hadrons
- fast and radiation hard detectors
- free-streaming readout electronics
- high speed data acquisition and high performance computer farm for online event selection
- 4-D event reconstruction

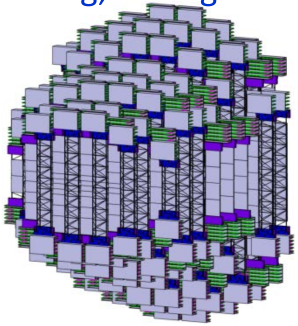
CBM technical developments

SC Magnet: JINR Dubna

Micro-Vertex Detector: Frankfurt, Strasbourg

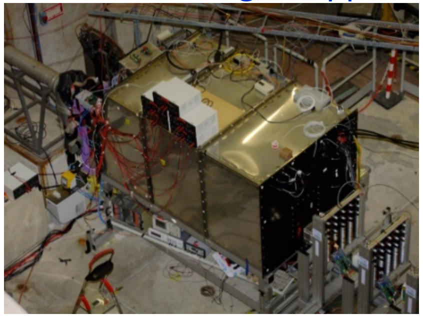
Silicon Tracking System: Darmstadt, Dubna, Krakow, Kiev, Kharkov, Moscow, St. Petersburg, Tübingen



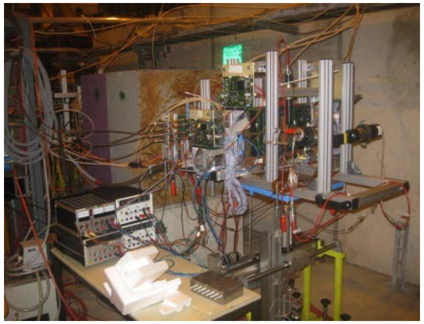


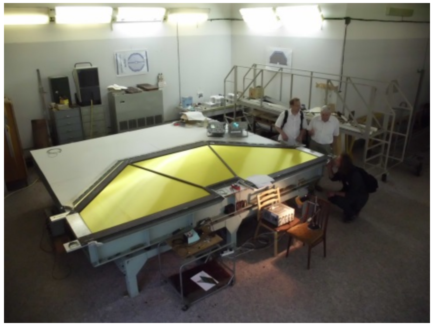
MRPC ToF Wall: Beijing, Bucharest, Darmstadt, Frankfurt, Hefei, Heidelberg, Moscow, Rossendorf, Wuhan, Zagreb

RICH Detector: Darmstadt, Giessen, Pusan, St. Petersburg, Wuppertal



Muon detector: Kolkata + 13 Indian Inst., Gatchina, Dubna





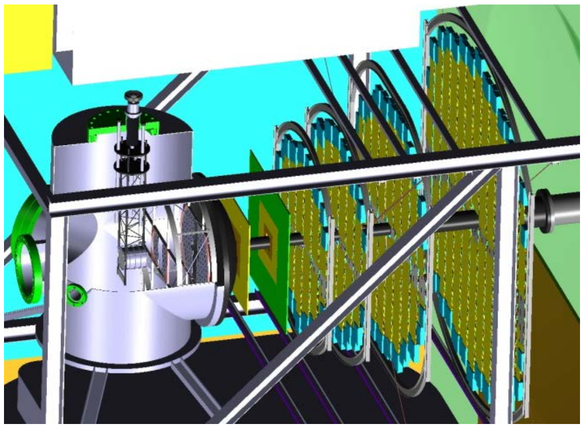
Transition Radiation Detector: Bucharest, Dubna, Frankfurt, Heidelberg, Münster

Forward calorimeter: Moscow, Prague, Rez

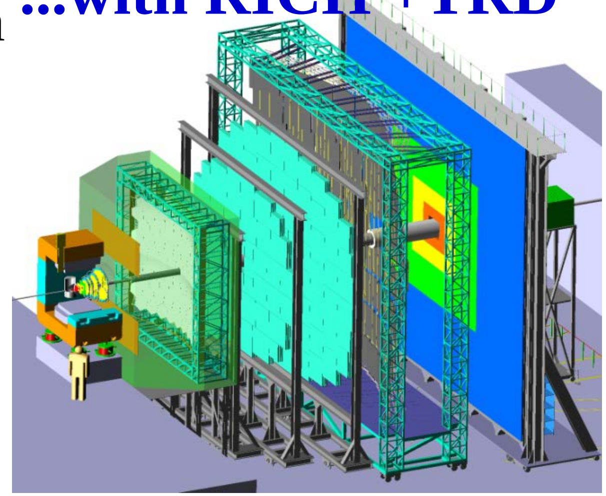
DAQ and online event selection: Darmstadt, Frankfurt, Heidelberg, Kharagpur, Warsaw

CBM: Dileptons from central Au+Au 25 AGeV : SiS 300 !!

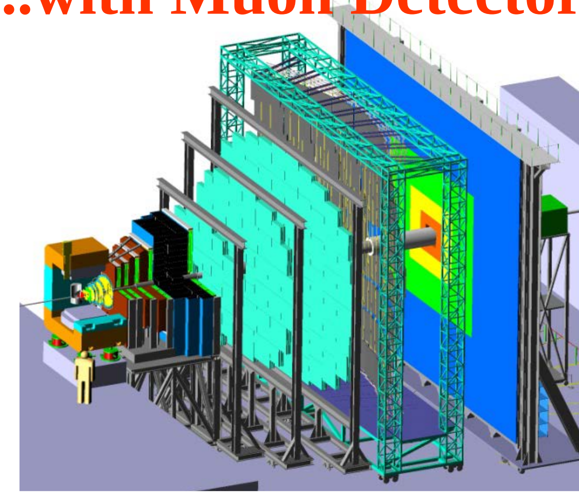
Micro-Vertex detector (MAPS)
+ Silicon-Microstrip System



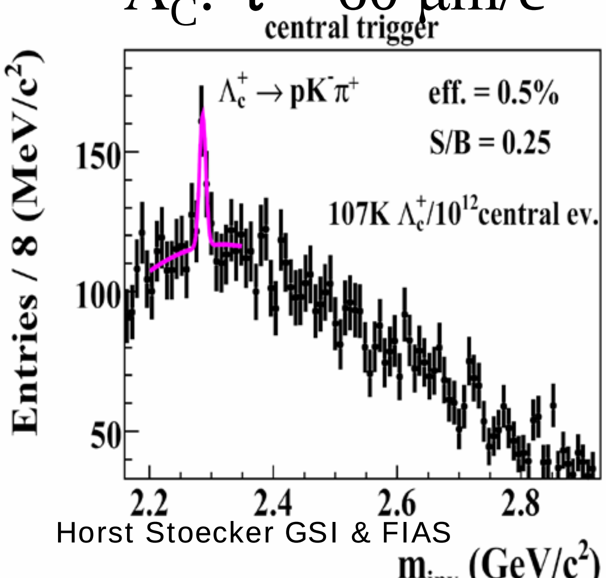
...with RICH +TRD



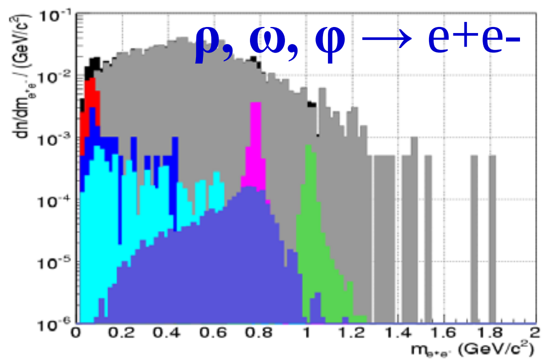
..with Muon Detector



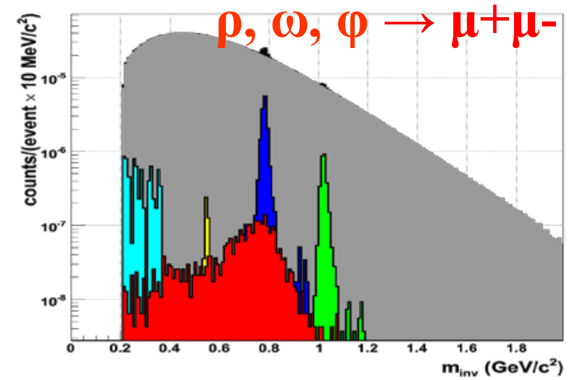
Λ_C: τ = 60 μm/c



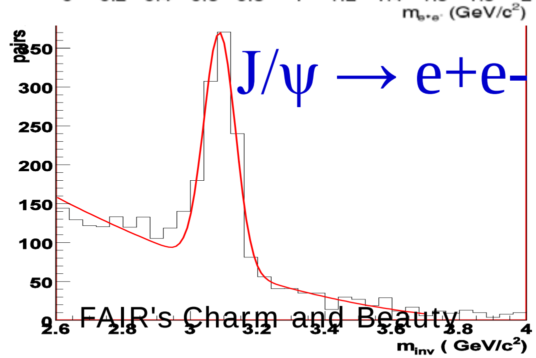
ρ, ω, φ → e+e-



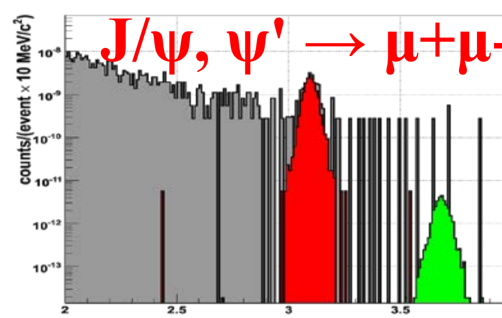
ρ, ω, φ → μ+μ-



J/ψ → e+e-



J/ψ, ψ' → μ+μ-



Extreme Computing Challenges
FAIR Tier 0 GreenCube Data Center

*****No. 1*** Green500***: Nov. 2014**

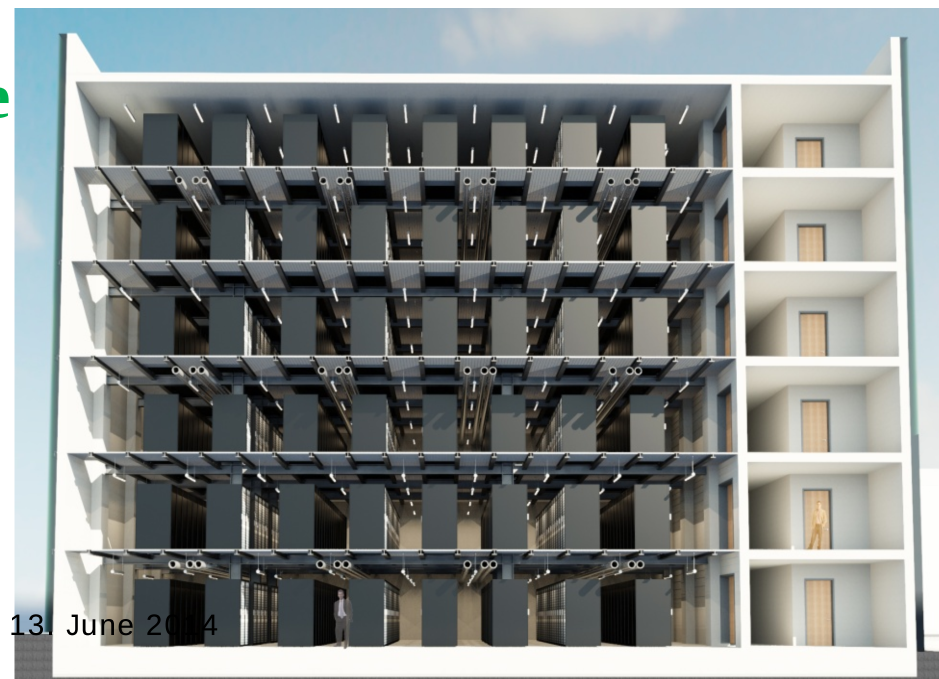
5.27 Gflops/Watt - World Record

L-CSC GSI Darmstadt PUE <1.07

powerefficient Supercomputer
AMD FirePro GPU, Intel Xeon CPU

Tier0 data center: FAIR **GreenCube**
Helmholtz funding 770 Racks 2.2m

- 12 M€ building cost
- 7 M€ initial HPC installation
- Completion of CC in Q4/2015
- Max cooling power 12 MW
- Fully redundand (N+1)



FAIR Collaborations want more South Africans ! Versatile Science and Technology Opportunities

Detector funding …by Collaboration