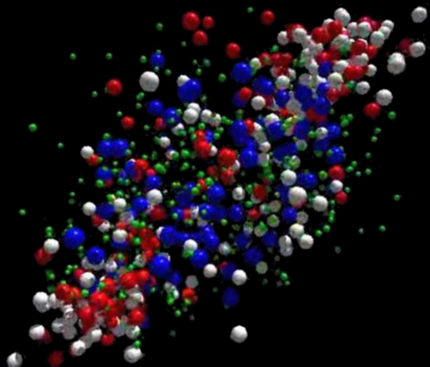
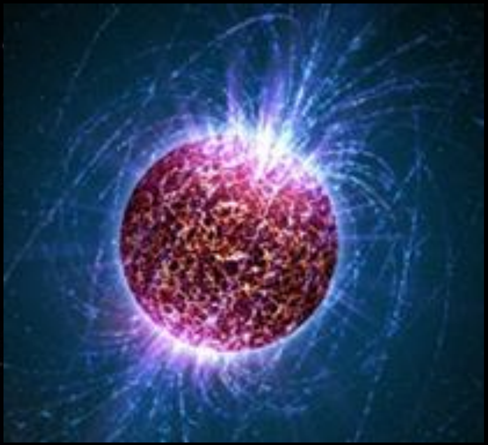
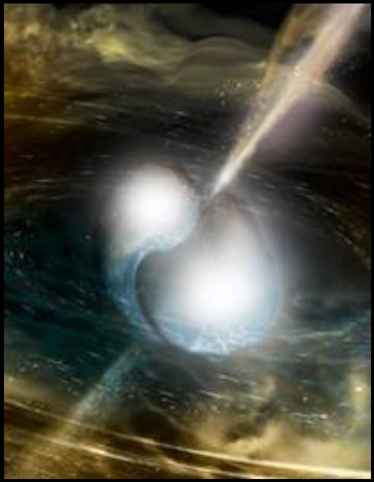






QCD matter physics at the future Facility for Antiproton and Ion Research

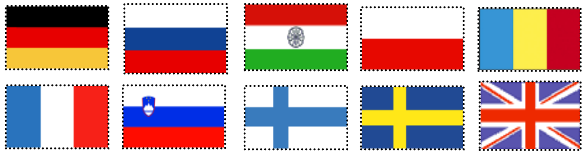
Peter Senger

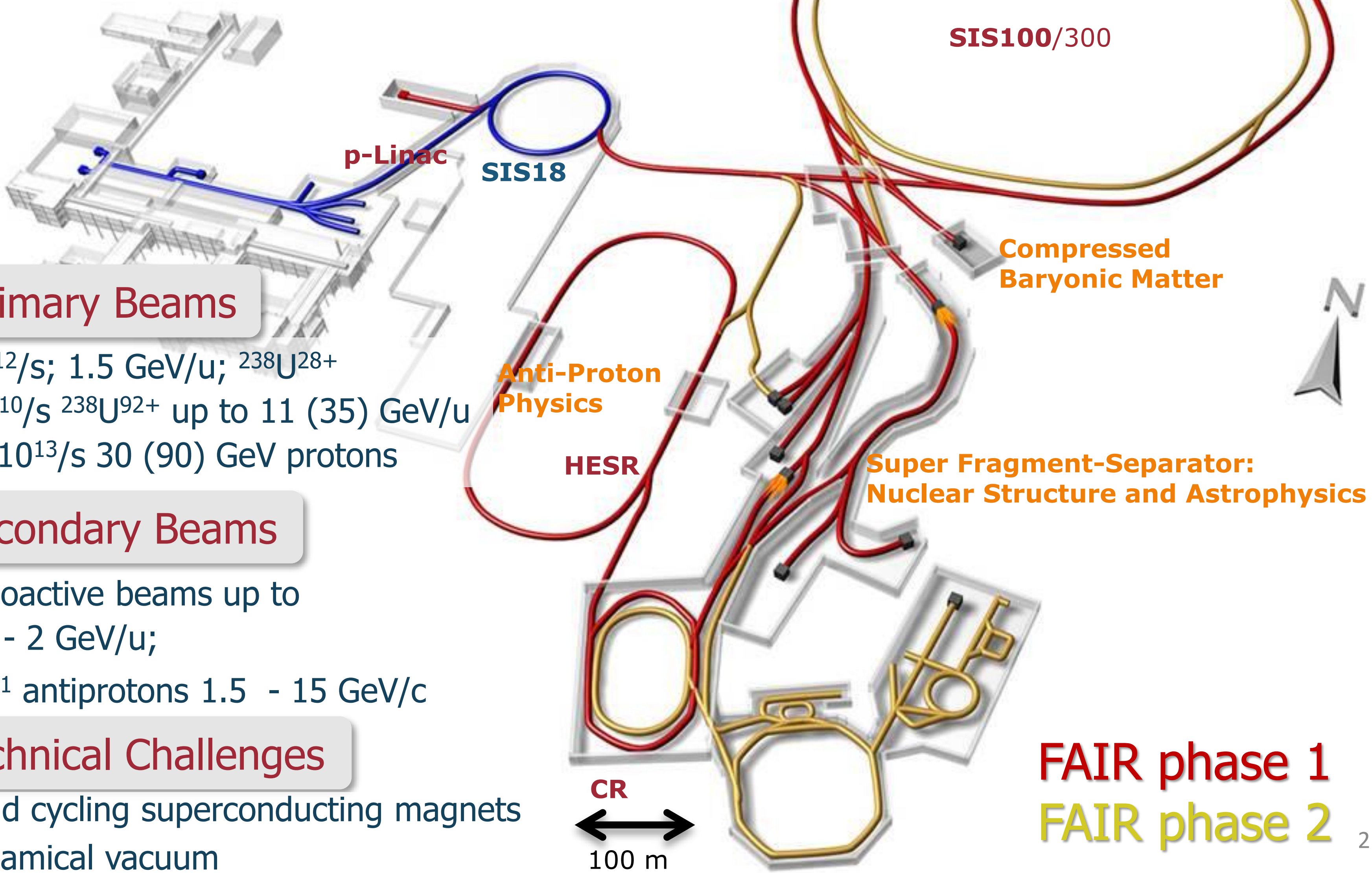
Outline:

- ➢ The Facility on Antiproton and Ion Research
- ➢ Exploring cosmic matter in the laboratory:
  - the high-density nuclear matter equation-of-state
  - the QCD phase diagram
- ➢ The Compressed Baryonic Matter (CBM) experiment

13th International Conference on Nucleus-Nucleus Collisions, Saitama, Japan, Dec. 4 – 8, 2018

Facility for Antiproton & Ion Research





Primary Beams

- 10^{12}/s; 1.5 GeV/u; $^{238}U^{28+}$
- 10^{10}/s $^{238}U^{92+}$ up to 11 (35) GeV/u
- 3×10^{13}/s 30 (90) GeV protons

Secondary Beams

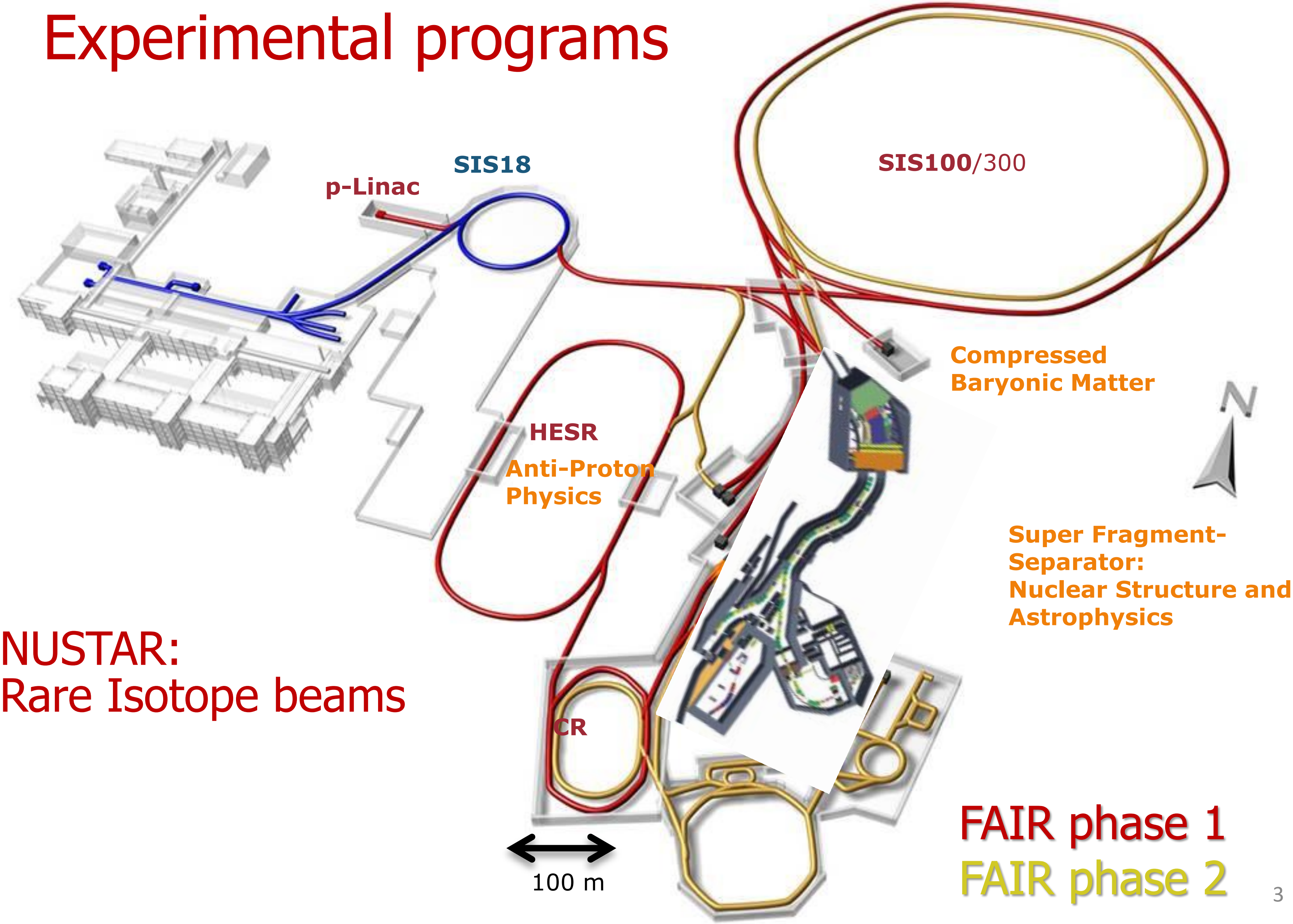
- radioactive beams up to 1.5 - 2 GeV/u;
- 10^{11} antiprotons 1.5 - 15 GeV/c

Technical Challenges

- rapid cycling superconducting magnets
- dynamical vacuum

Facility for Antiproton & Ion Research

Experimental programs



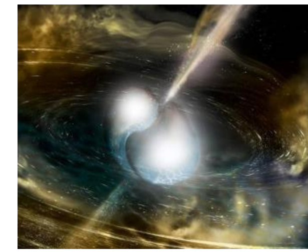
NUSTAR:
Rare Isotope beams

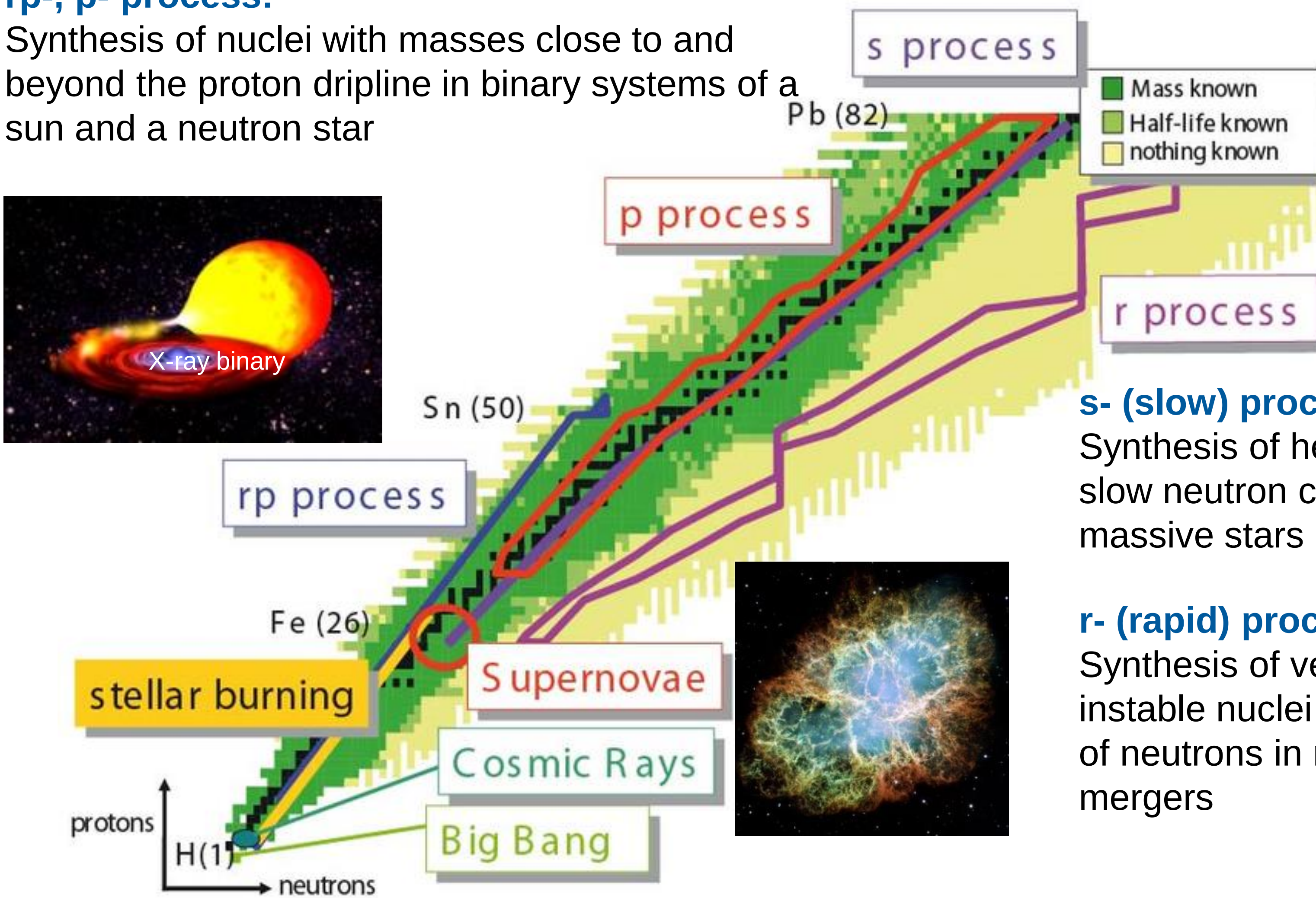
FAIR phase 1
FAIR phase 2

Nuclear astrophysics: The origin of elements

Measurements in the laboratory: Mass, lifetime, decay channels, structure of very rare instable (neutron or proton rich) nuclei

rp-, p- process:
Synthesis of nuclei with masses close to and beyond the proton dripline in binary systems of a sun and a neutron star



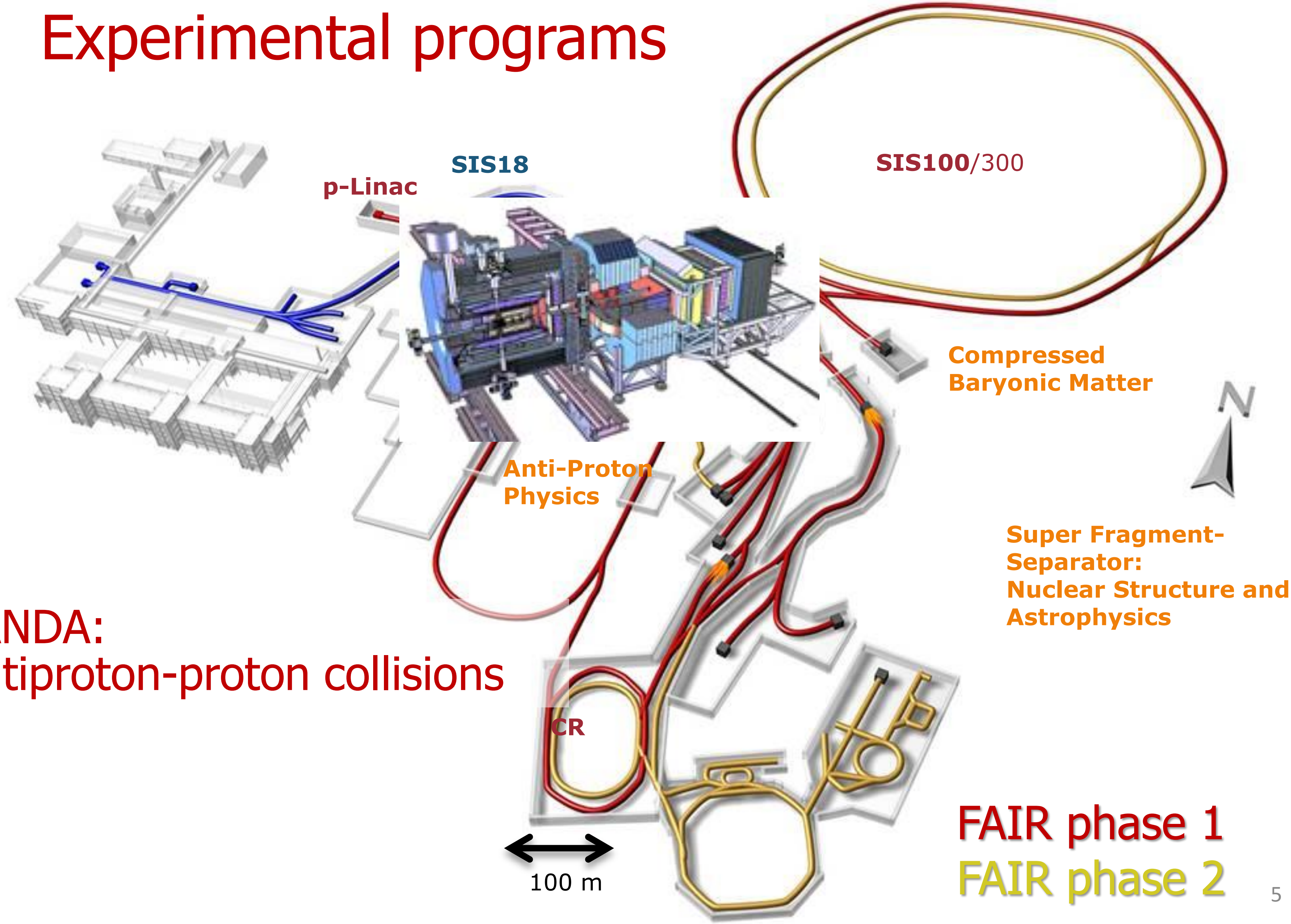


s- (slow) process:
Synthesis of heavy nuclei via slow neutron capture in very massive stars

r- (rapid) process:
Synthesis of very neutron-rich instable nuclei via rapid capture of neutrons in neutron star mergers

Facility for Antiproton & Ion Research

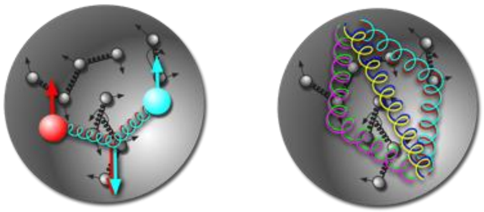
Experimental programs



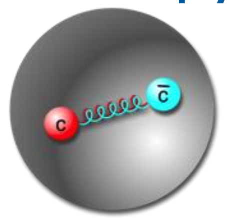
PANDA:
Antiproton-proton collisions

Hadron Physics with antiprotons at FAIR

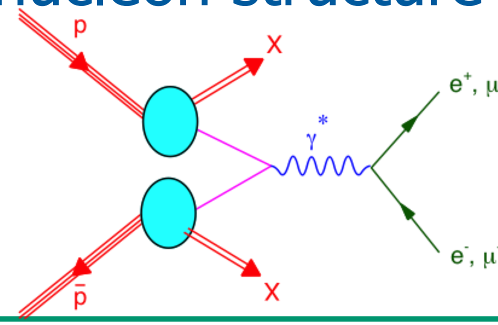
Gluonic excitations: Hybrids, glueballs



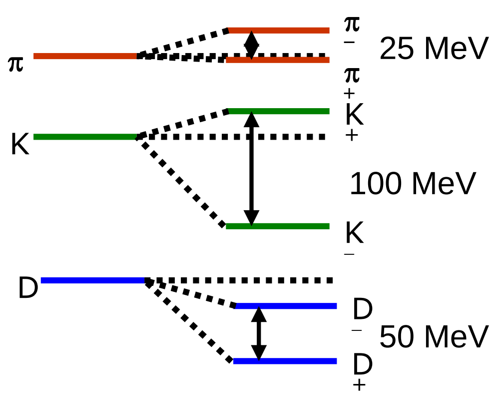
Charmonium states: Precision spectroscopy



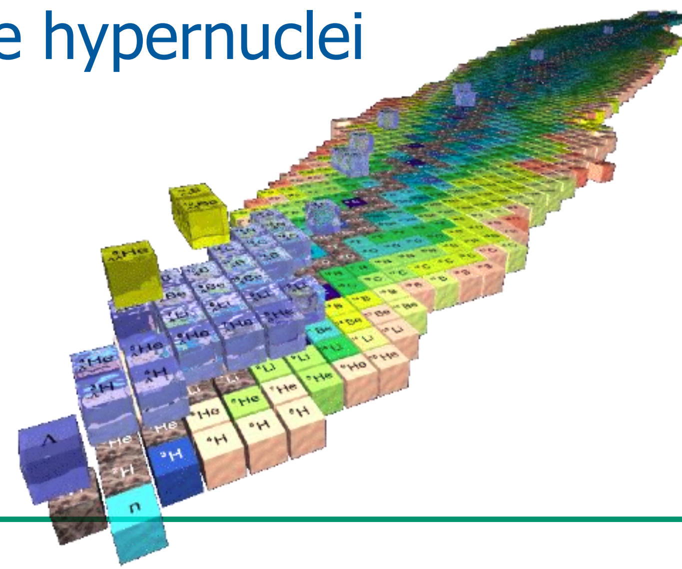
Time-like form factors, nucleon structure



In medium mass modifications: Extension to the charm sector

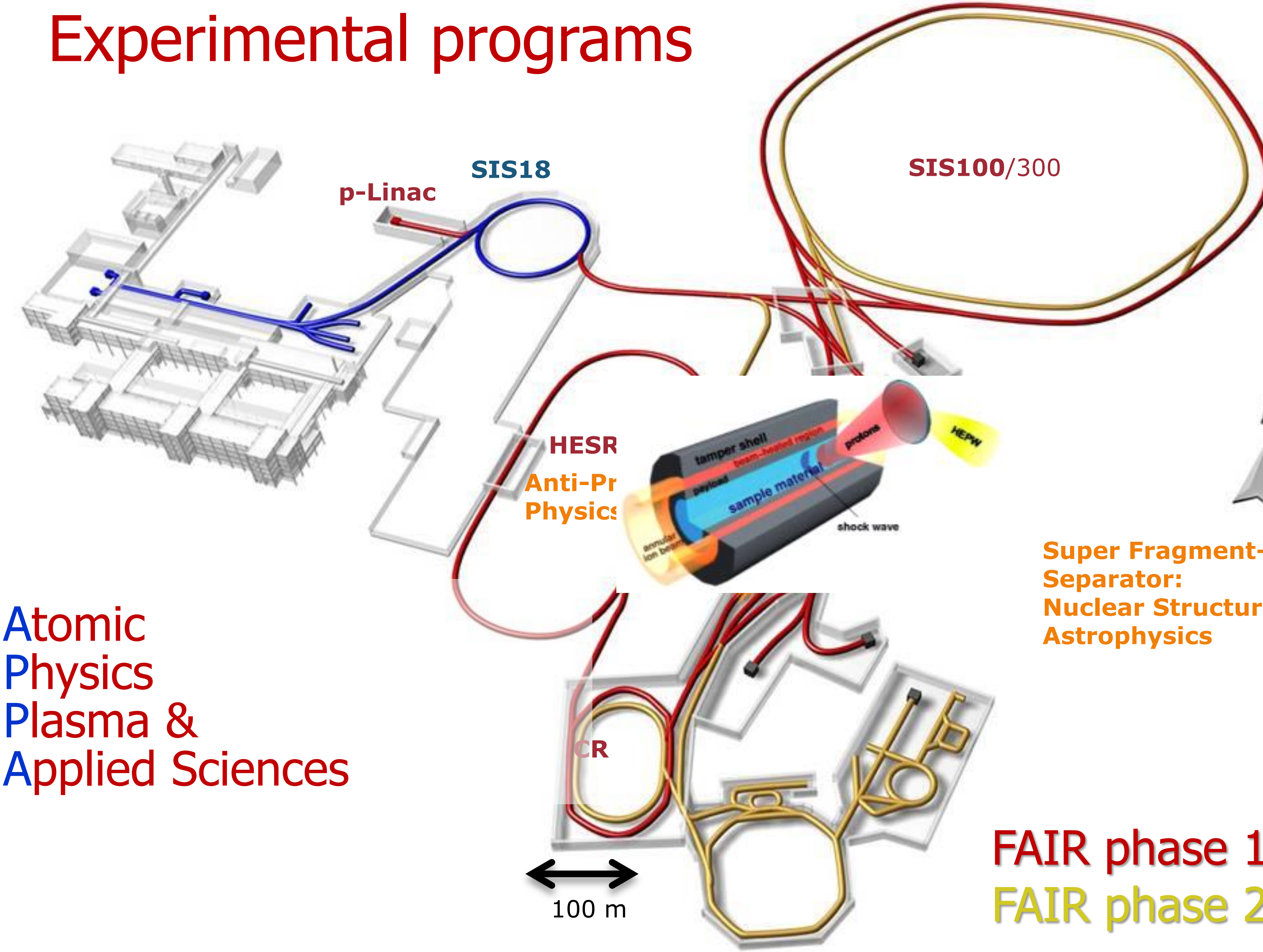


Extension of nuclear chart: Double hypernuclei



Facility for Antiproton & Ion Research

Experimental programs

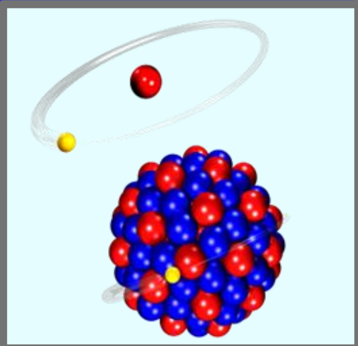
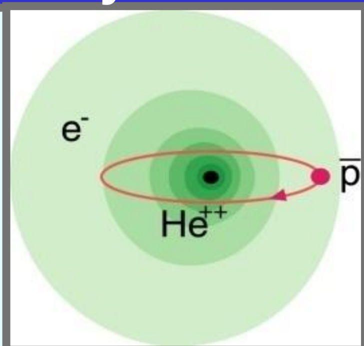
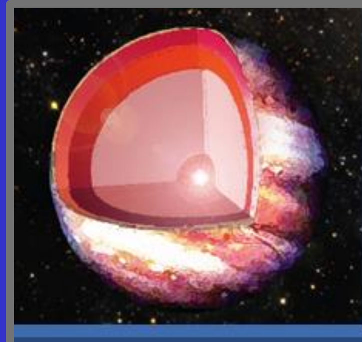
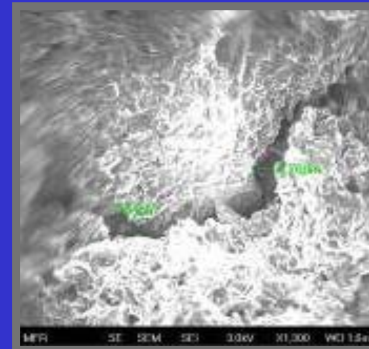


Atomic
Physics
Plasma &
Applied Sciences

Super Fragment-Separator: Nuclear Structure and Astrophysics

FAIR phase 1
FAIR phase 2

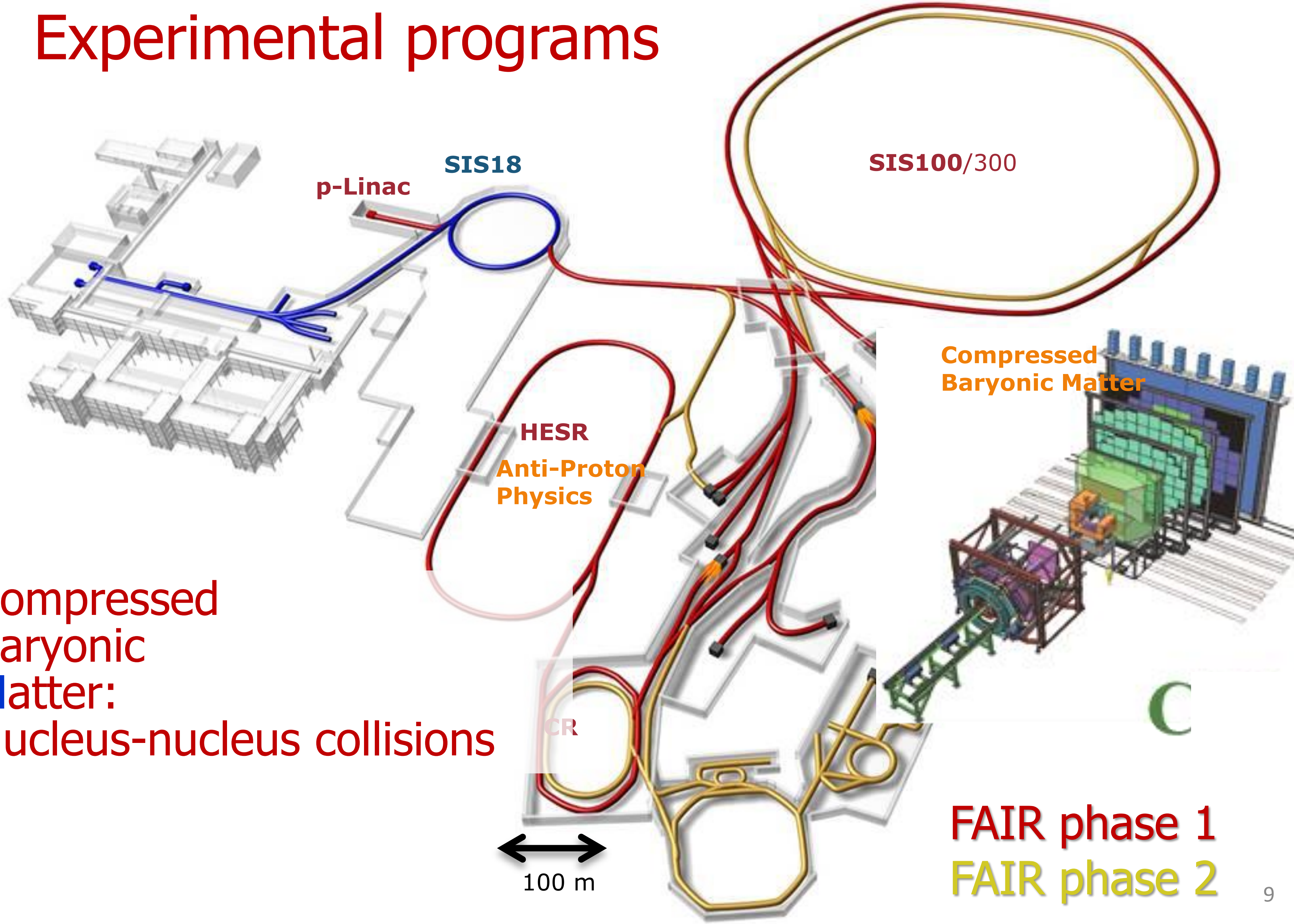
Atomic Physics, Plasma and Applied Sciences

Atomic Physics		Plasma	Materials	Bio
				
SPARC	FLAIR	HEDgeHOB/WDM	MAT/BIOMAT	BIO/BIOMAT
strong field research ... probing of fundamental laws of physics	**anti-matter** ... matter / anti-matter asymmetry	**planetary interiors** ... states of matter common in astrophysical objects	**extreme conditions** ... radiation hardness and modification of materials	**aerospace engineering** ... radiation shielding of cosmic radiation

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

Facility for Antiproton & Ion Research

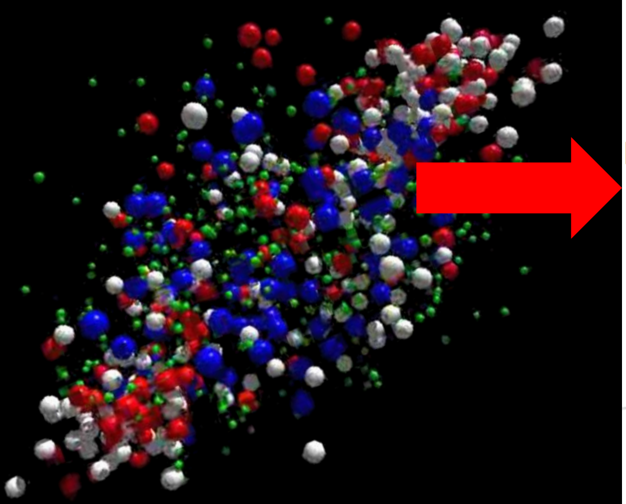
Experimental programs

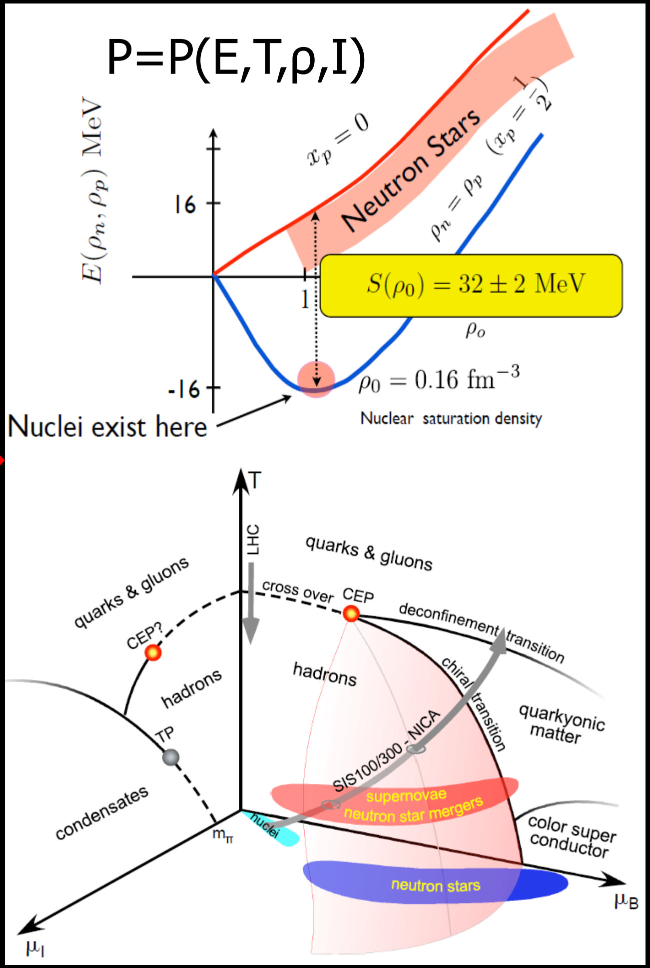


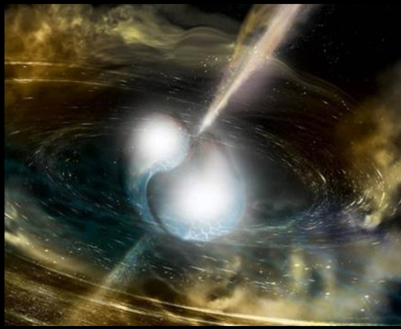
Compressed
Baryonic
Matter:
Nucleus-nucleus collisions

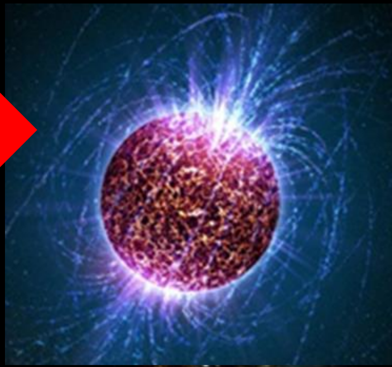
FAIR phase 1
FAIR phase 2

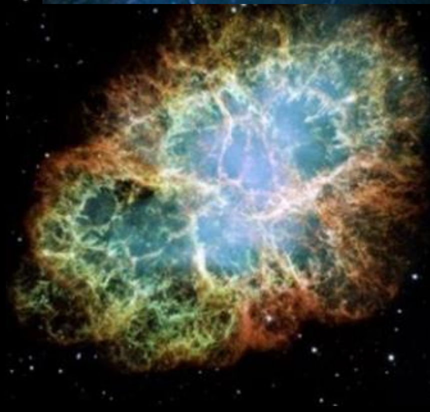
QCD matter physics



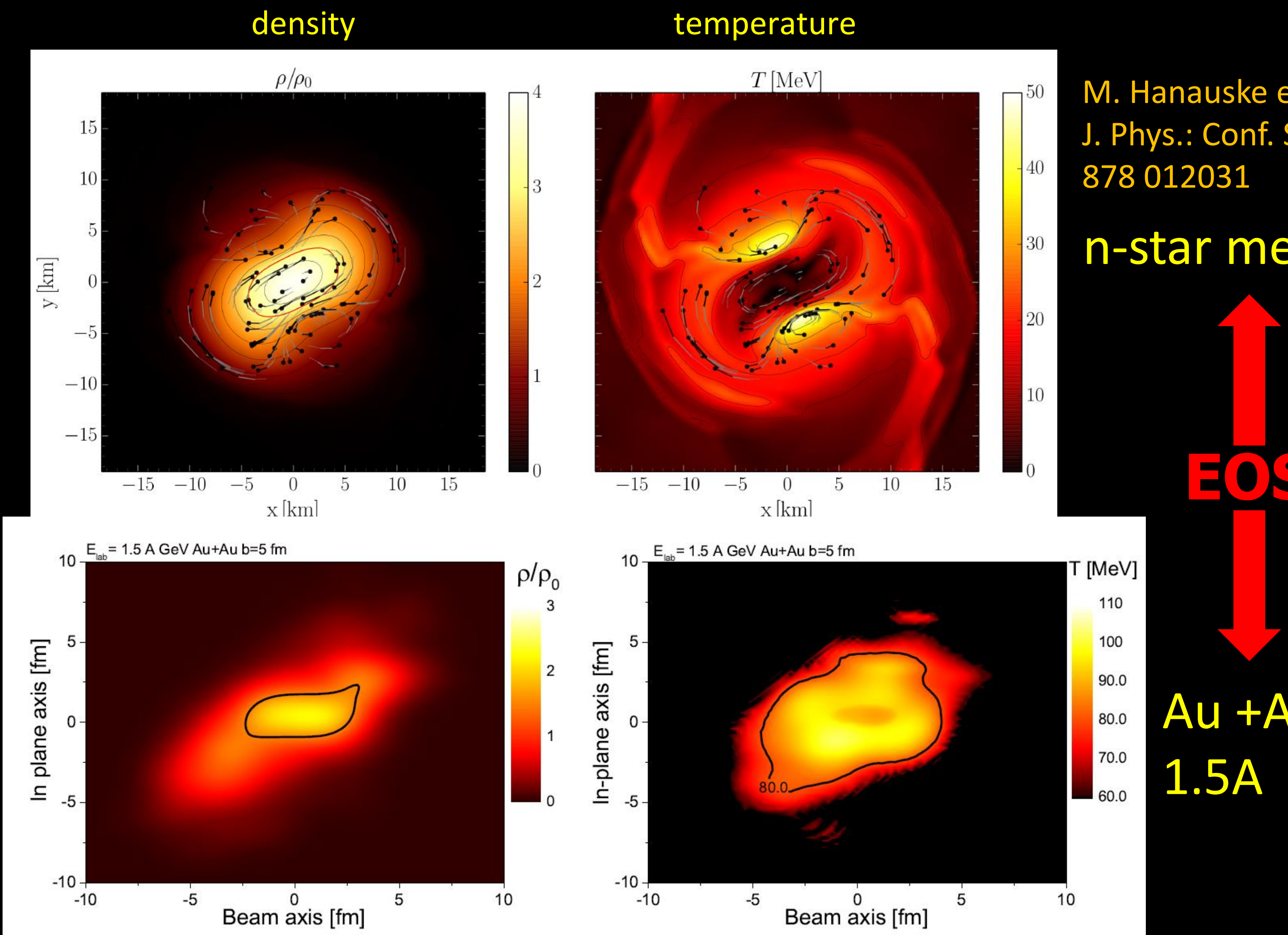








Neutron star mergers and heavy-ion collisions



M. Hanauske et al., J. Phys.: Conf. Ser. 878 012031

n-star merger

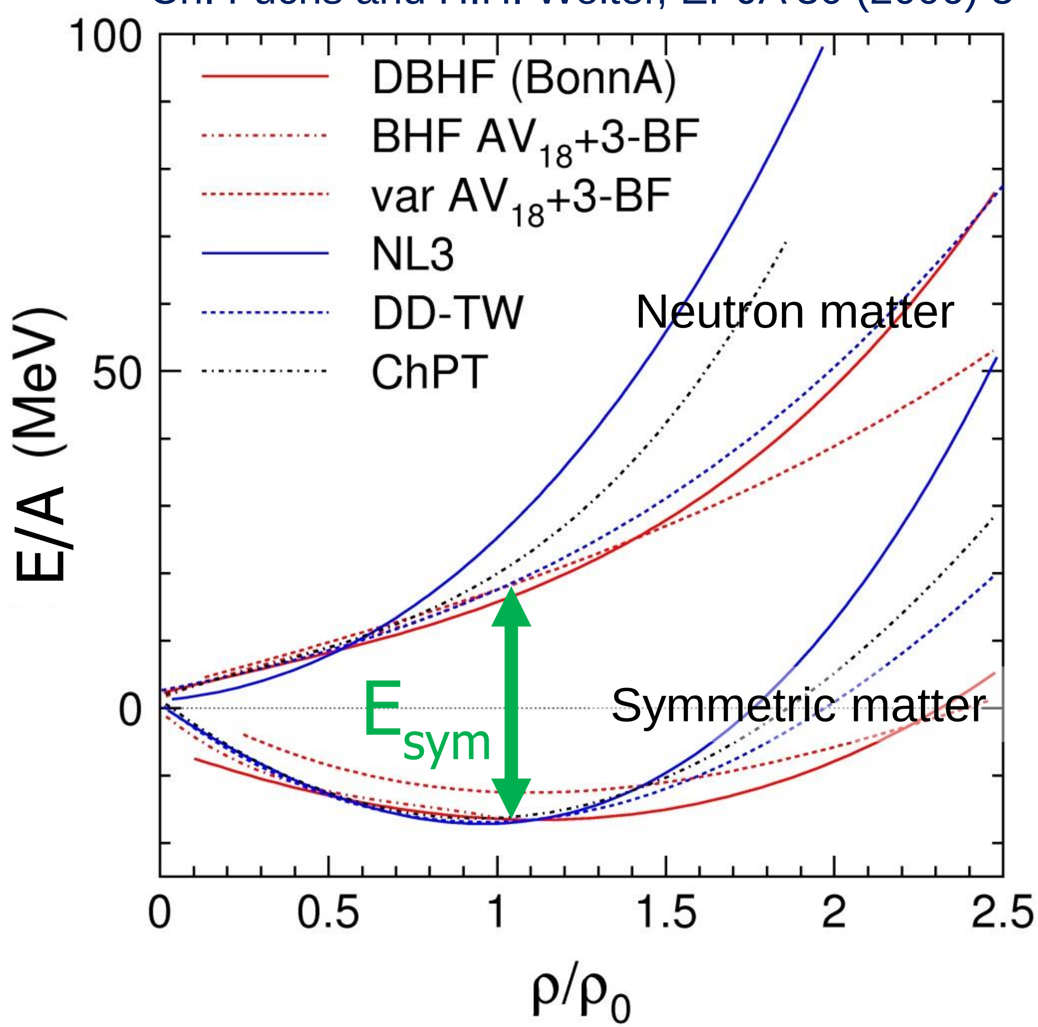
Au +Au 1.5A GeV

The nuclear matter equation-of-state

The nuclear matter equation of state (EOS) describes the relation between density, pressure, temperature, energy, and isospin asymmetry

$P = \delta E/\delta V \,|_{T=const}$
$V = A/\rho$
$\delta V/\delta\rho = -A/\rho^2$
$P = \rho^2\, \delta(E/A)/\delta\rho \,|_{T=const}$

Ch. Fuchs and H.H. Wolter, EPJA 30 (2006) 5



$E_A(\rho,\delta) = E_A(\rho,0) + E_{sym}(\rho)\cdot\delta^2$
with $\delta = (\rho_n - \rho_p)/\rho$

The EOS of (symmetric) nuclear matter

$$E_A(\rho,\delta) = E_A(\rho,0) + E_{sym}(\rho)\cdot\delta^2 + O(\delta^4)$$

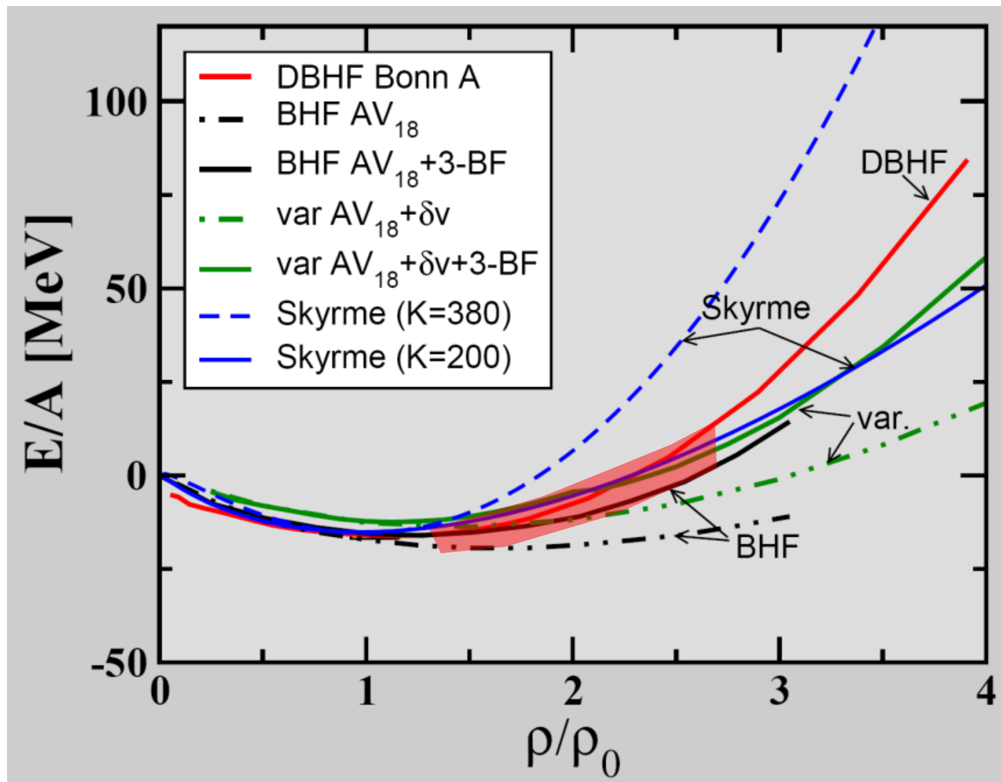
C. Fuchs, Prog. Part. Nucl. Phys. 56 (2006) 1

T=0: $E/A = 1/\rho \int U(\rho)d\rho$

Effective NN-potential:

$U(\rho)=\alpha\rho+\beta\rho^{\gamma}$

- $E/A(\rho_o)$ = -16 MeV
- slope $\delta(E/A)(\rho_o)/\delta\rho = 0$
- curvature $K_{nm} = 9\rho^2\ \delta^2(E/A)/\delta\rho^2$ (nuclear incompressibility)



Measurements at GSI SIS18:

- elliptic flow of light fragments
- subthreshold kaon production

A. Le Fevre et al., Nucl. Phys. A945 (2016) 112
C. Sturm et al., (KaoS Collaboration) Phys. Rev. Lett. 86 (2001) 39
Ch. Fuchs et al., Phys. Rev. Lett. 86 (2001) 1974

K_{nm} = 200 MeV: "soft" EOS

K_{nm} = 220 ± 40 MeV: "soft" EOS

K_{nm} = 380 MeV: "stiff" EOS

The nuclear symmetry energy

$$E_A(\rho,\delta) = E_A(\rho,0) + E_{sym}(\rho)\cdot\delta^2$$

$$E_{sym}(\rho) = E_{sym}(\rho_0) + \frac{L}{3}\left(\frac{\rho-\rho_0}{\rho_0}\right) + \frac{K_{sym}}{18}\left(\frac{\rho-\rho_0}{\rho_0}\right)^2$$

Empirical value $E_{sym}(\rho_0) \approx 30$ MeV

slope $$L = 3\rho_0 \left.\frac{\partial E_{sym}(\rho)}{\partial \rho}\right|_{\rho=\rho_0}$$

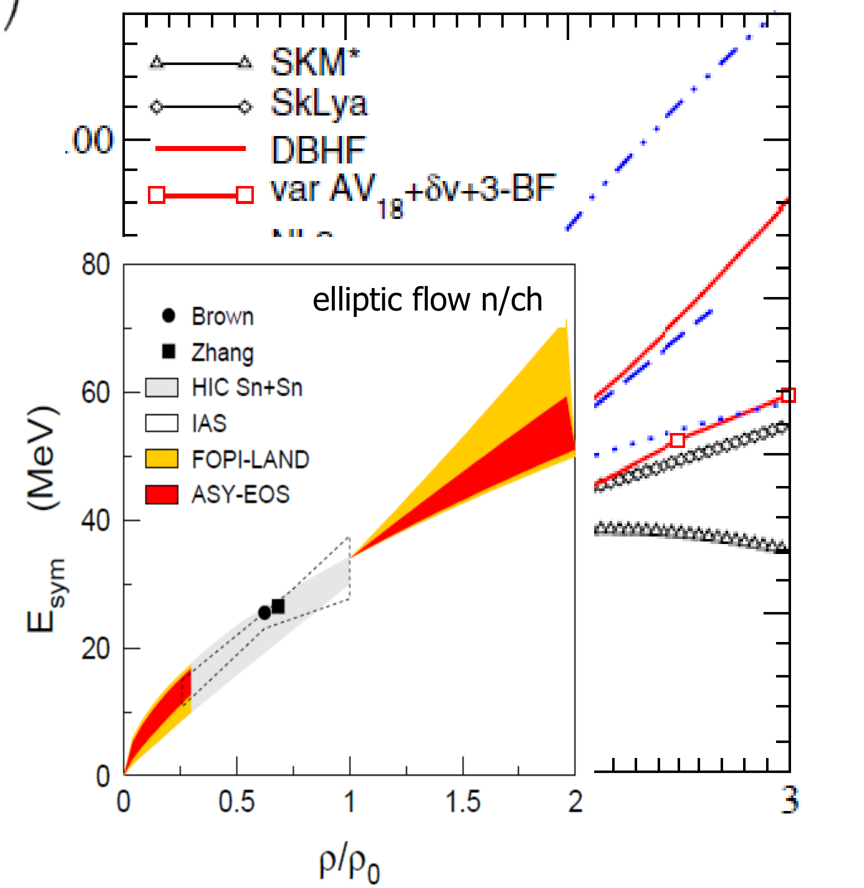
theoretical value $L(\rho_0) \approx 60$ MeV

B.A. Li and X. Han, Phys. Lett. B 727 (2013) 276

curvature $$K_{sym} = 9\rho_0^2 \left.\frac{\partial^2 E_{sym}(\rho)}{\partial^2 \rho}\right|_{\rho=\rho_0}$$

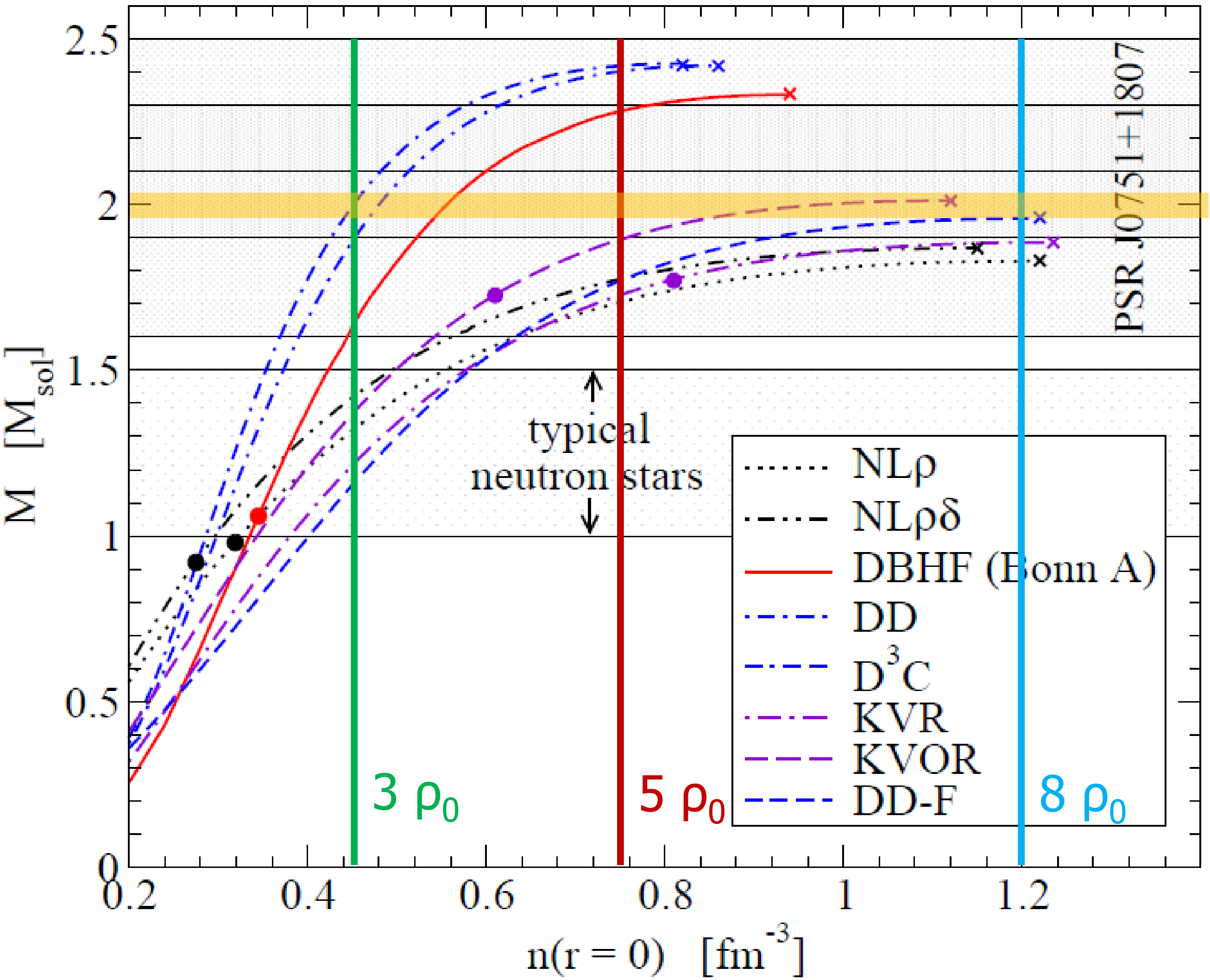
theoretical value K_{sym} = -700 to 470 MeV

Ch. Fuchs and H.H. Wolter, EPJA30 (2006) 5



P. Russotto et al., Phys. Rev. C 94, 034608 (2016)

Mass-density relation of neutron stars for different EOS



T. Klaehn et al., Phys. Rev. C74: 035802, 2006

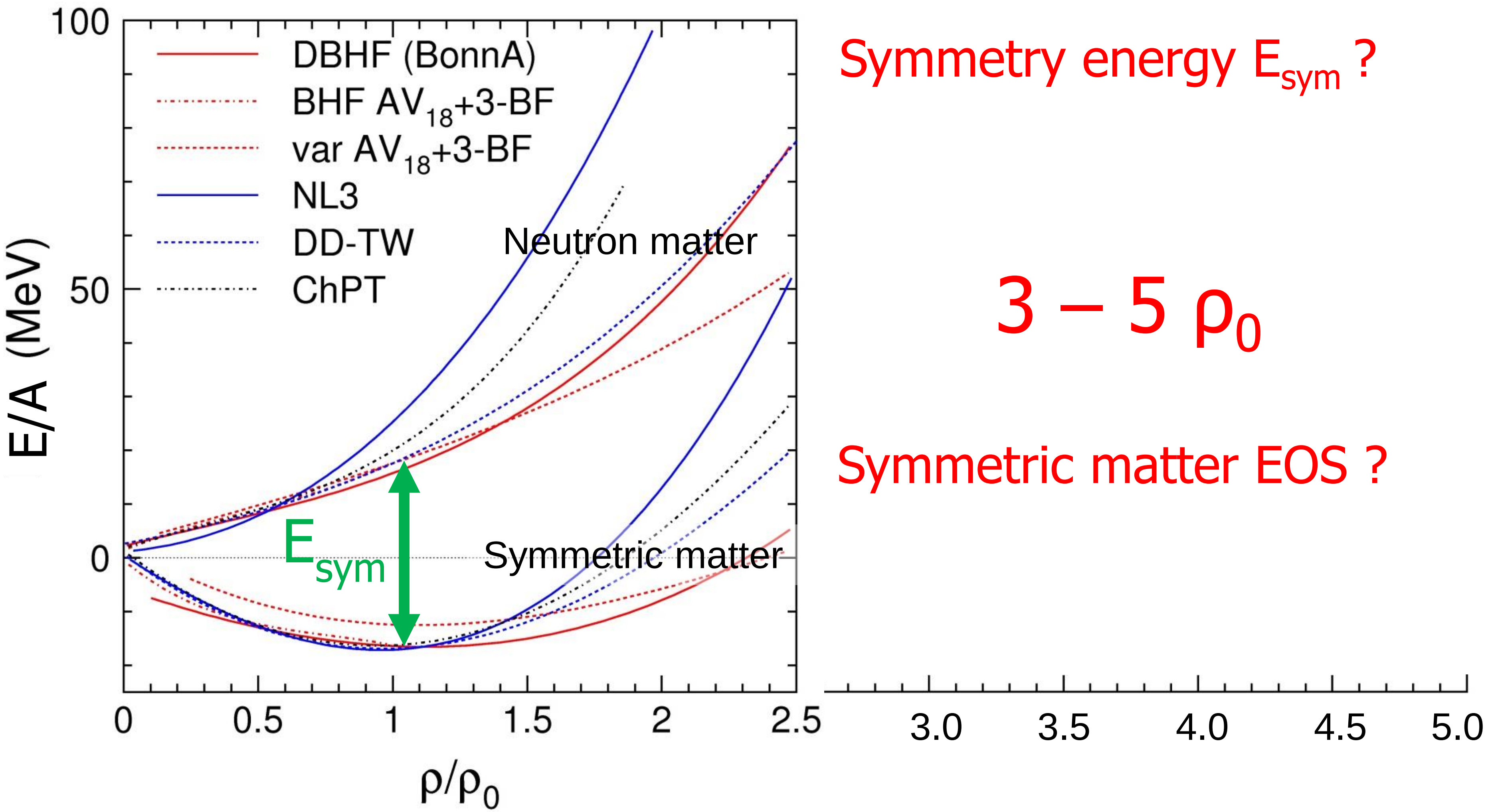
PSR J1614-2230
M = 1.97±0.04 M_{sun}

P. Demorest et al., Nature 467, 1081 (2010)

PSR J0348+0432
M = 2.01±0.04 M_{sun}

J. Antoniadis et al., *Science* ***340****, 6131 (2013)*

The high-density nuclear matter equation-of-state



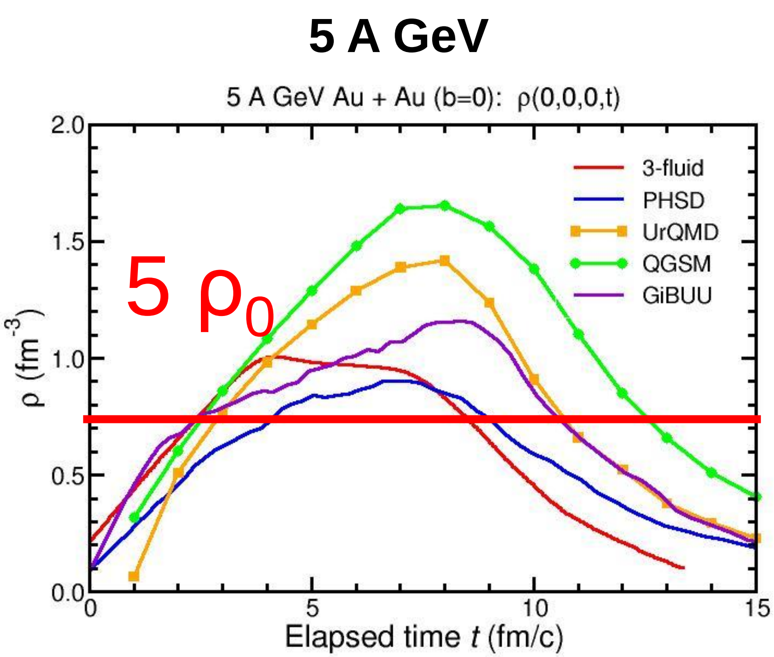
Symmetry energy E_{sym} ?

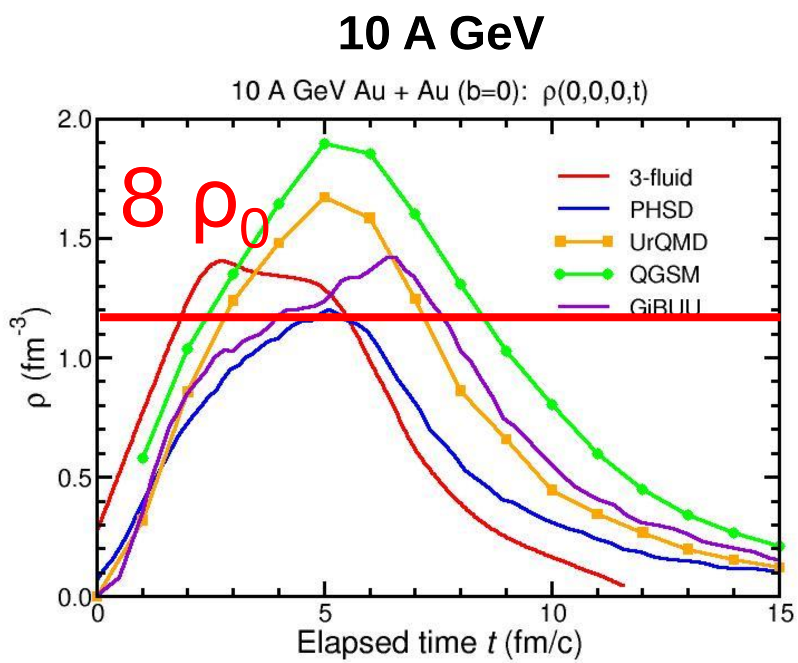
$3 – 5\ \rho_0$

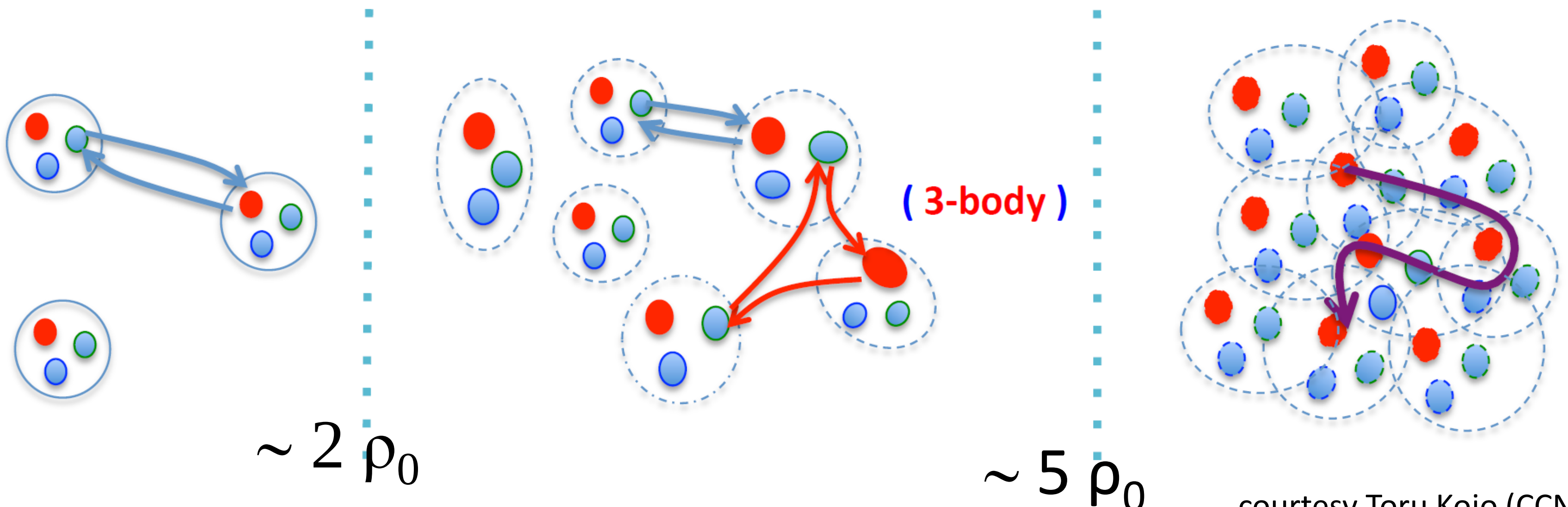
Symmetric matter EOS ?

Baryon densities in central Au+Au collisions

I.C. Arsene et al., Phys. Rev. C 75, 24902 (2007)







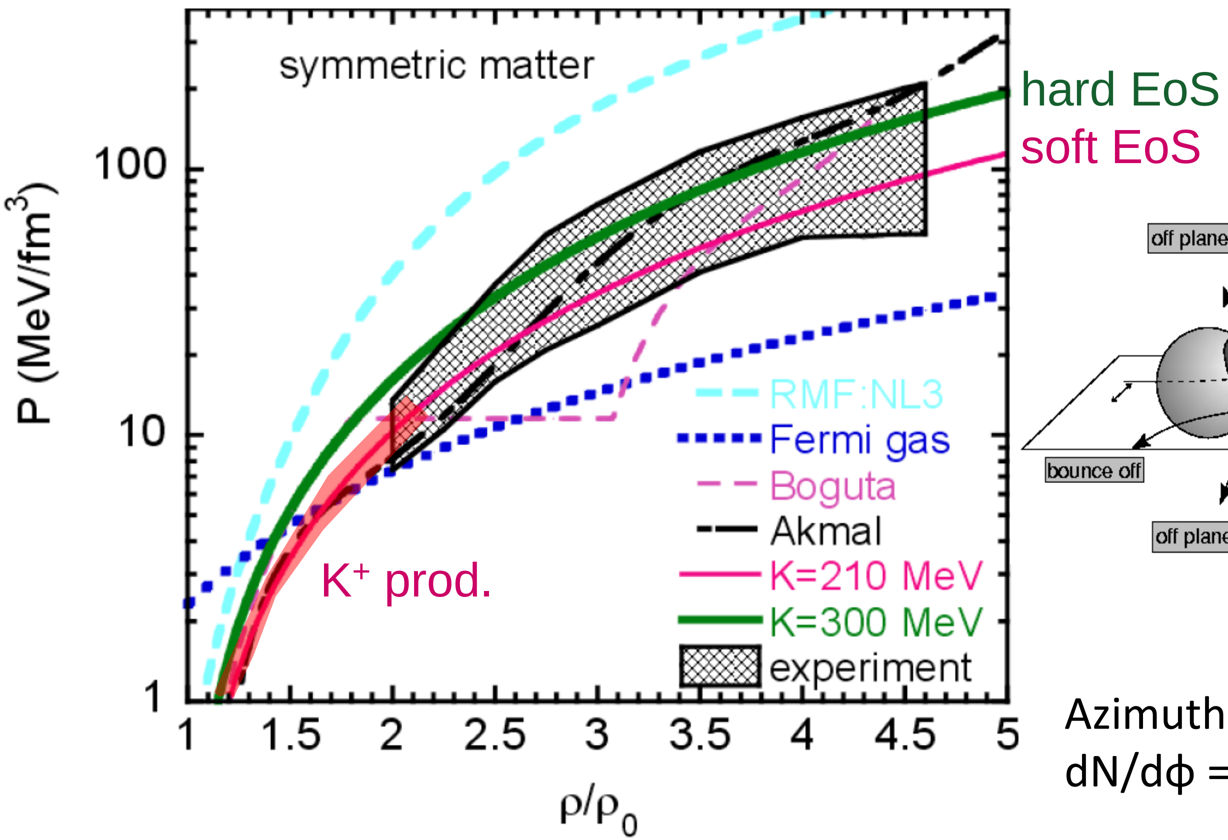
courtesy Toru Kojo (CCNU)

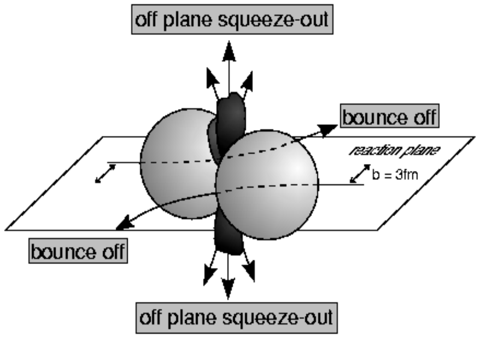
CBM physics case and observables

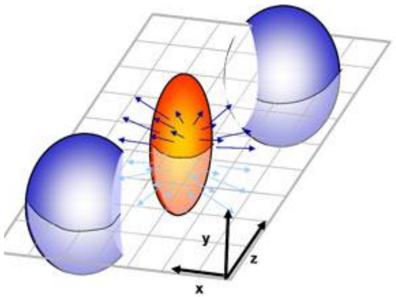
The QCD matter equation-of-state at neutron star core densities

- collective flow of identified particles (π,K,p,Λ,Ξ,Ω,...) driven by the pressure gradient in the early fireball

EOS of symmetric matter extracted from proton flow in Au+Au collisions measured at AGS for beam energies from 2 to 11A GeV.







Azimuthal angle distribution:

$dN/d\phi = C\,(1 + v_1 \cos(\phi) + v_2 \cos(2\phi) + ...)$

P. Danielewicz, R. Lacey, W.G. Lynch, Science 298 (2002) 1592

CBM physics case and observables

The QCD matter equation-of-state at neutron star core densities

- particle production at (sub)threshold energies via multi-step processes (multi-strange hyperons, charm)

Direct multi-strange hyperon production:

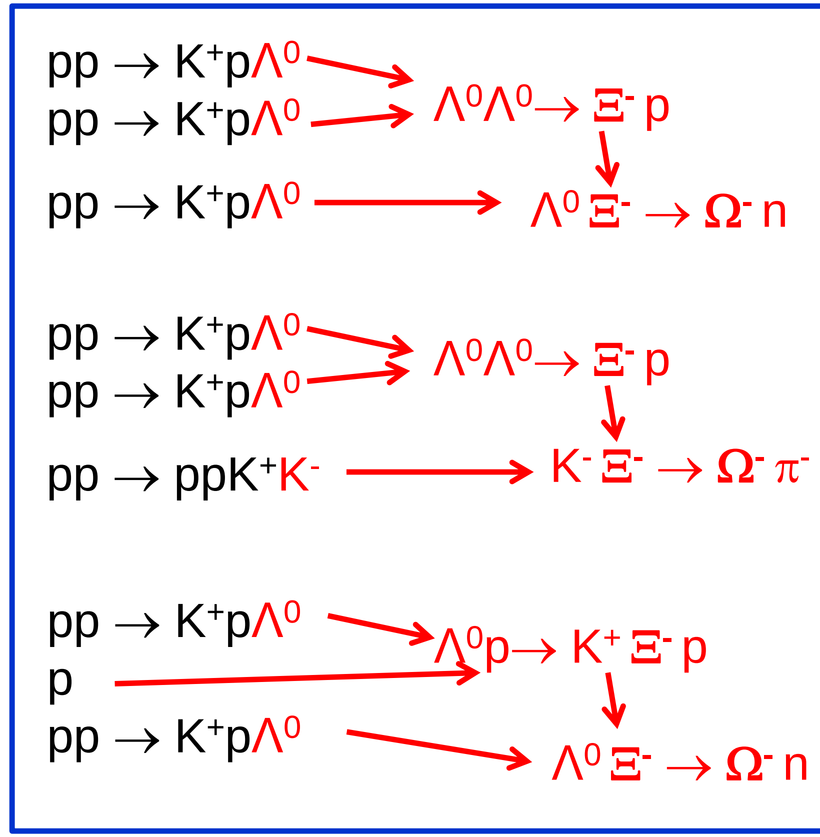
$pp \rightarrow \Xi^- K^+ K^+ p$ (E_{thr} = 3.7 GeV)
$pp \rightarrow \Omega^- K^+ K^+ K^0 p$ (E_{thr} = 7.0 GeV)
$pp \rightarrow \Lambda^0 \Lambda^0 pp$ (E_{thr} = 7.1 GeV)
$pp \rightarrow \Xi^+ \Xi^- pp$ (E_{thr} = 9.0 GeV)
$pp \rightarrow \Omega^+ \Omega^- pp$ (E_{thr} = 12.7 GeV

Hyperon production via multiple collisions

1. $pp \rightarrow K^+ \Lambda^0 p$, $pp \rightarrow K^+ K^- pp$,
2. $p\Lambda^0 \rightarrow K^+ \Xi^- p$, $\pi\Lambda^0 \rightarrow K^+ \Xi^- \pi$,
   $\Lambda^0\Lambda^0 \rightarrow \Xi^- p$, $\Lambda^0 K^- \rightarrow \Xi^- \pi^0$
3. $\Lambda^0 \Xi^- \rightarrow \Omega^- n$, $\Xi^- K^- \rightarrow \Omega^- \pi^-$

Antihyperons

1. $\Lambda^0 K^+ \rightarrow \Xi^+ \pi^0$,
2. $\Xi^+ K^+ \rightarrow \Omega^+ \pi^+$.



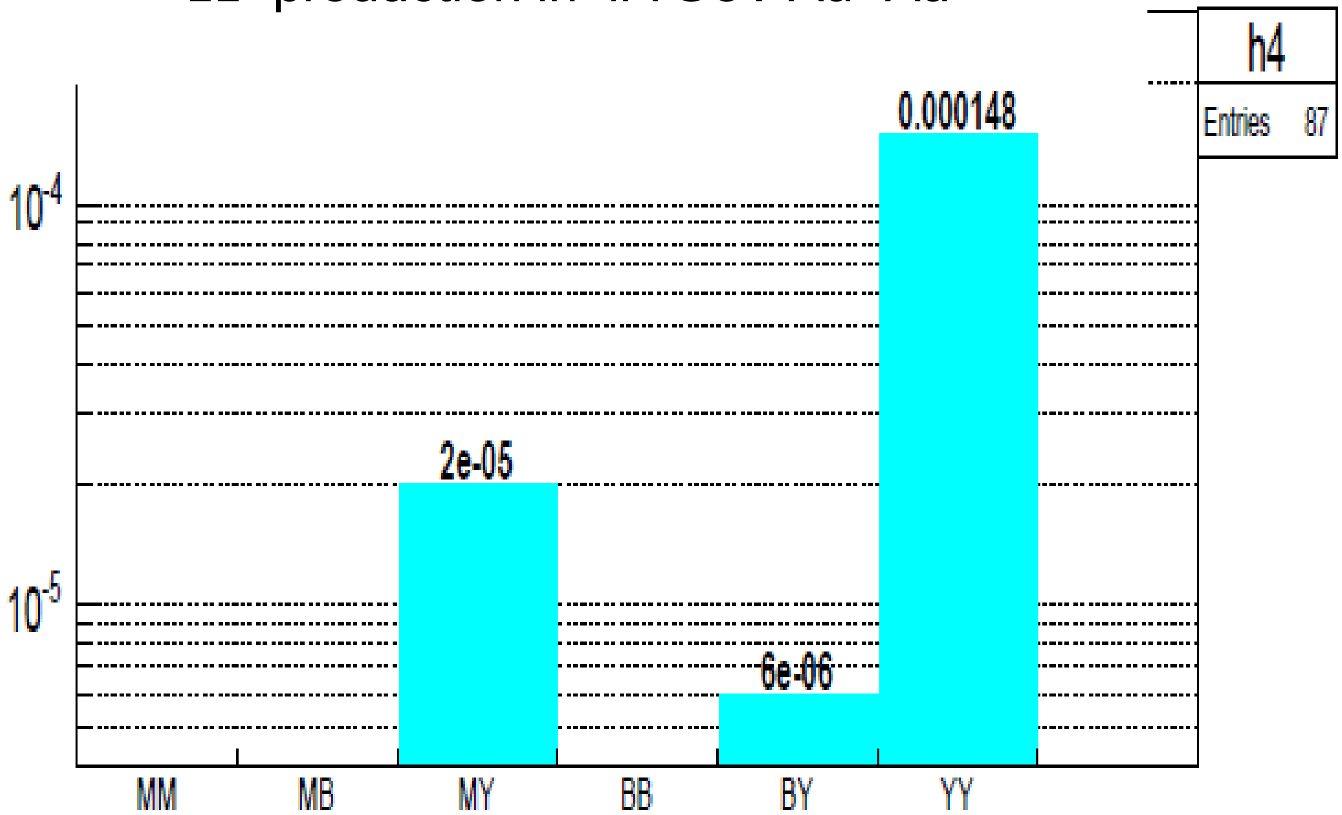
➡ Hyperon yield ~ multi-step collisions ~ density → EOS

CBM physics case and observables

The QCD matter equation-of-state at neutron star core densities

- particle production at (sub)threshold energies via multi-step processes (multi-strange hyperons, charm)

Ω^- production in 4A GeV Au+Au



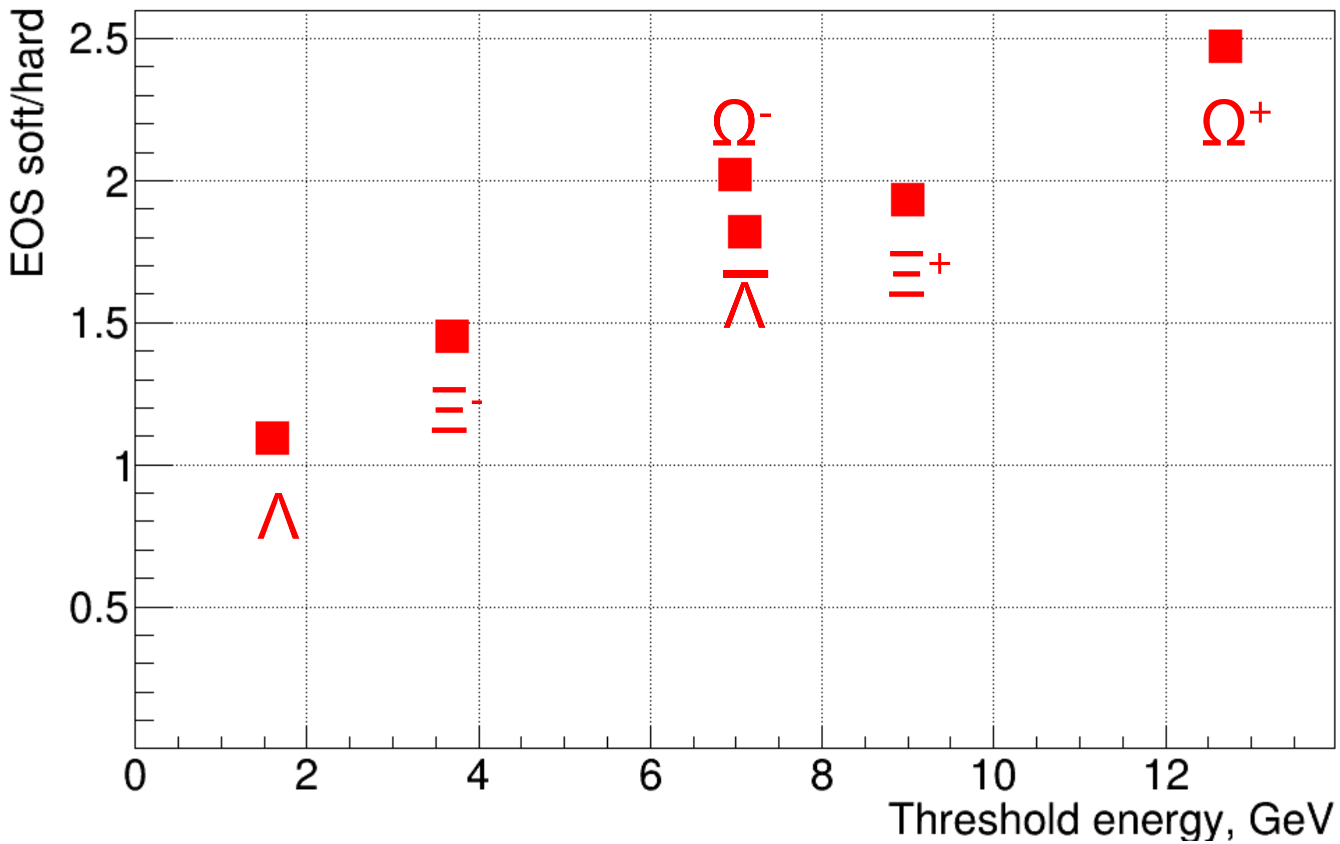
HYPQGSM calculations, K. Gudima, Y. Murin et al. , priv. comm.

CBM physics case and observables

The QCD matter equation-of-state at neutron star core densities

- particle production at (sub)threshold energies via multi-step processes (multi-strange hyperons, charm)

Hyperon yield in 4A GeV Au+Au:
soft EOS (K=240 MeV) / hard EOS (K=350) MeV

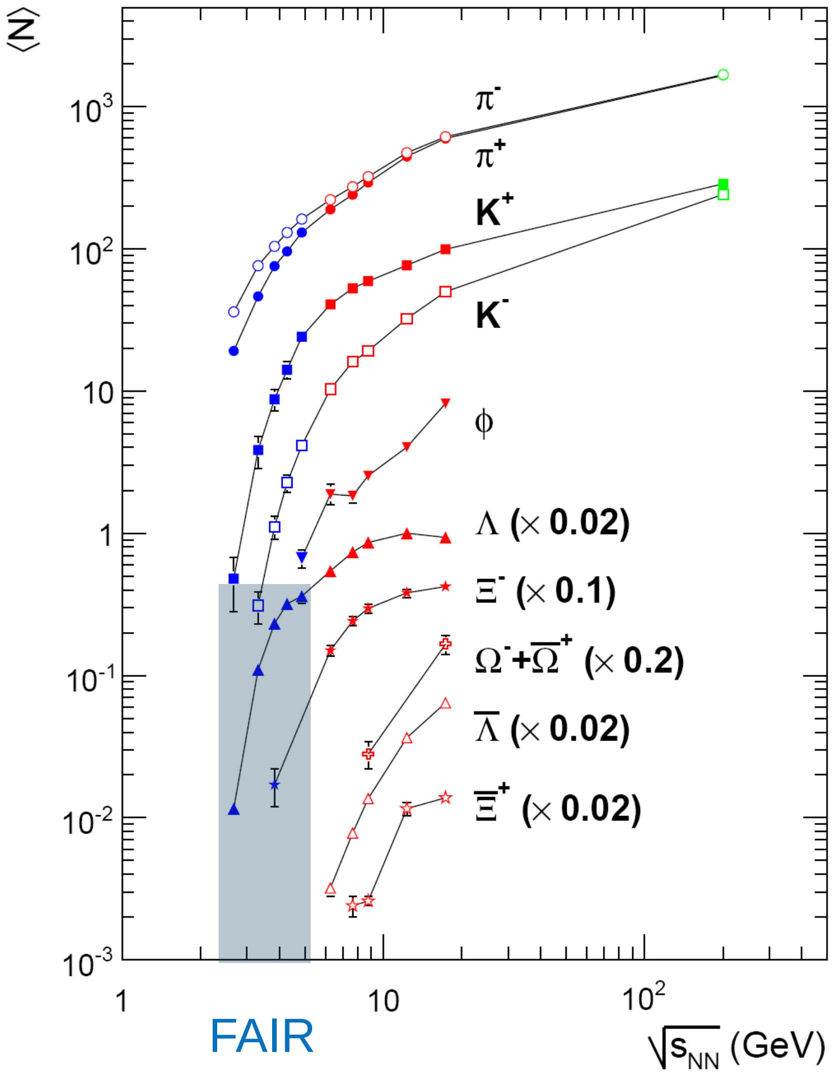


PHQMD calculations , V. Kireyeu et al., priv. comm.

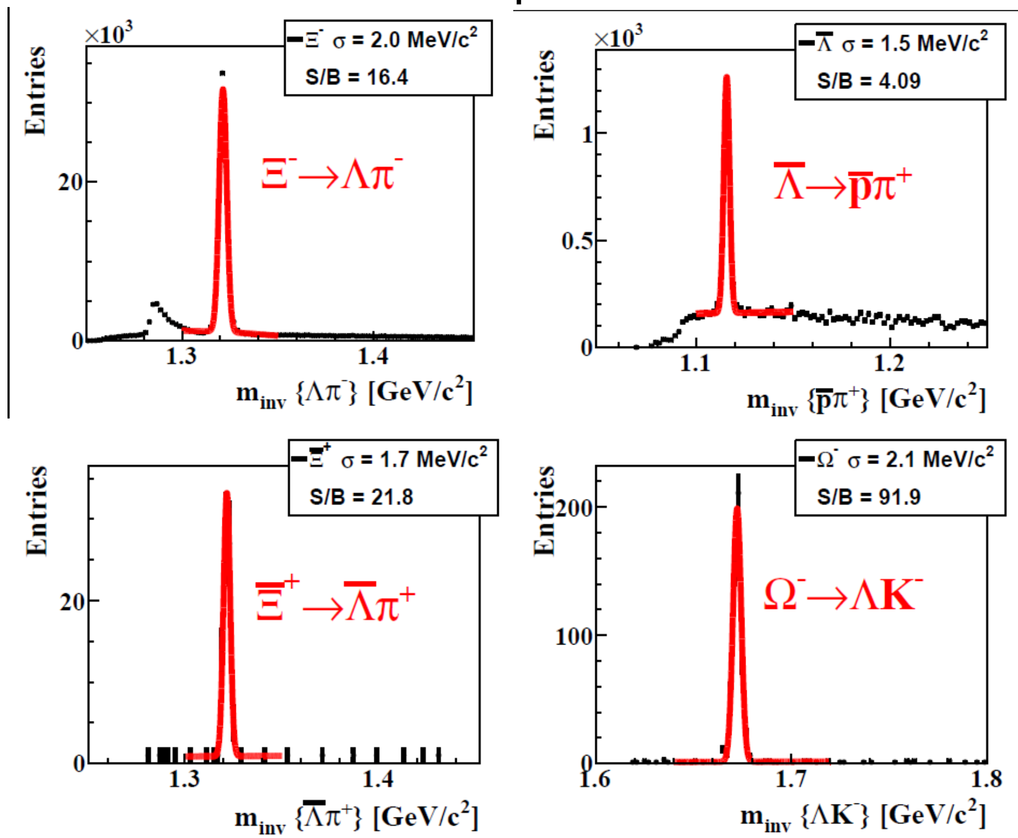
CBM physics case and observables

The QCD matter equation-of-state at neutron star core densities

- ➢ particle production at (sub)threshold energies via multi-step processes (multi-strange hyperons, charm)



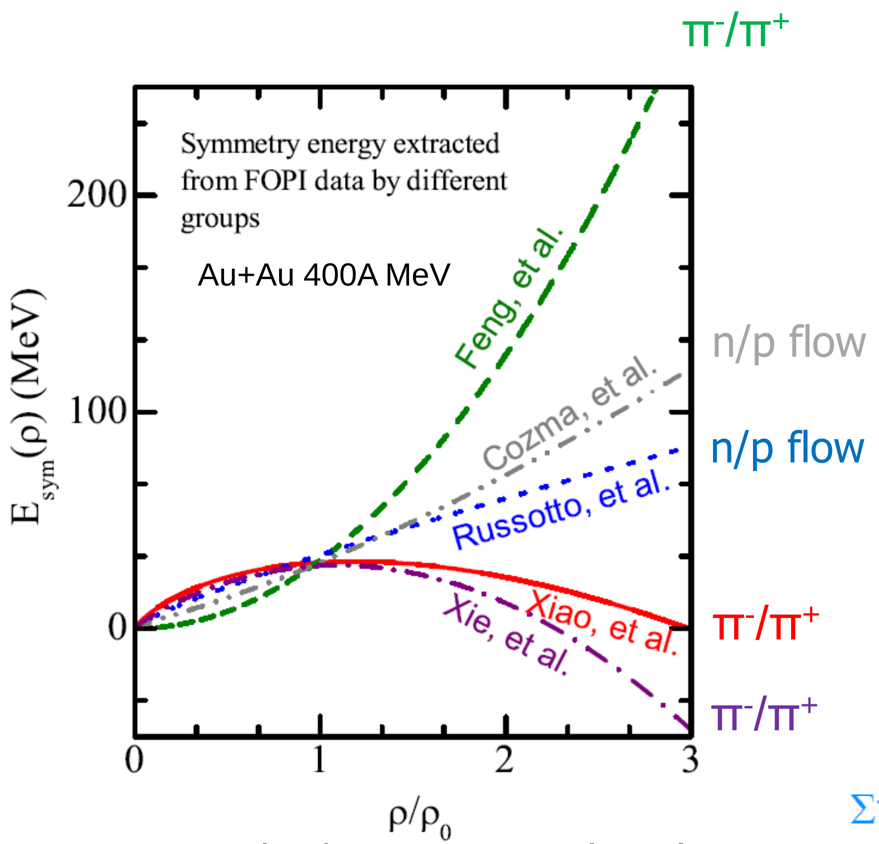
Simulations using the UrQMD event generator for central Au+Au collisions 10A GeV based on realistic detector responses



CBM physics case and observables

The symmetry energy E_{sym} at high density

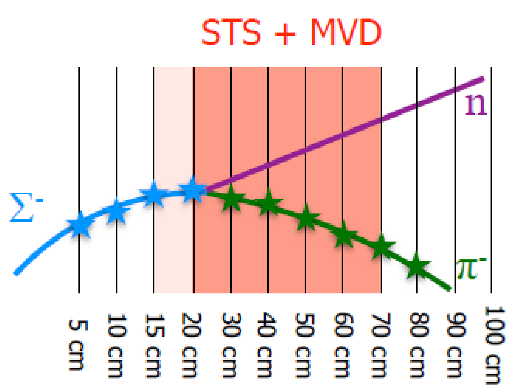
- Elliptic flow neutrons/protons (upgrade option)
- Particles with opposite isospin

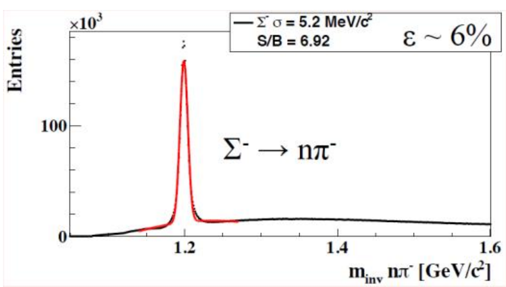


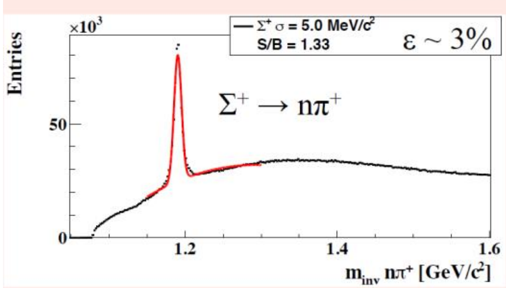
W.-M. Guo et al., Phys. Lett. B738 (2014) 397

I_3	particle	production	E_{thr} GeV	decay
+1	$\Sigma^+(uus)$	$pp \to \Sigma^+K^+n$ $pp \to \Sigma^+K^0p$ $pn \to \Sigma^+K^0n$	1.8	$\Sigma^+ \to p\pi^0$ $\Sigma^+ \to n\pi^+$
-1	$\Sigma^-(dds)$	$pn \to \Sigma^-K^+p$ $nn \to \Sigma^-K^+n$	1.8	$\Sigma^- \to n\pi^-$

Missing mass method

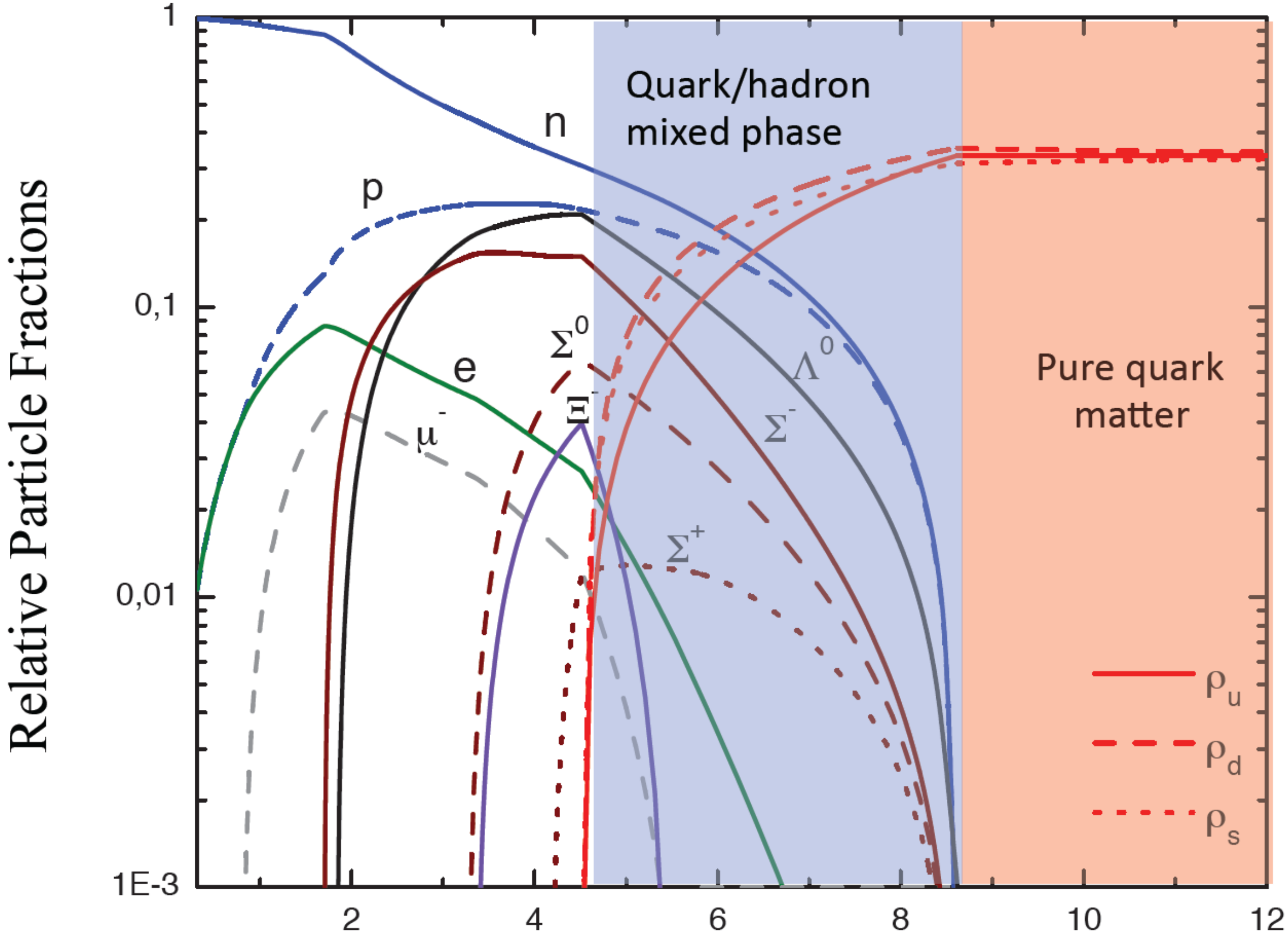






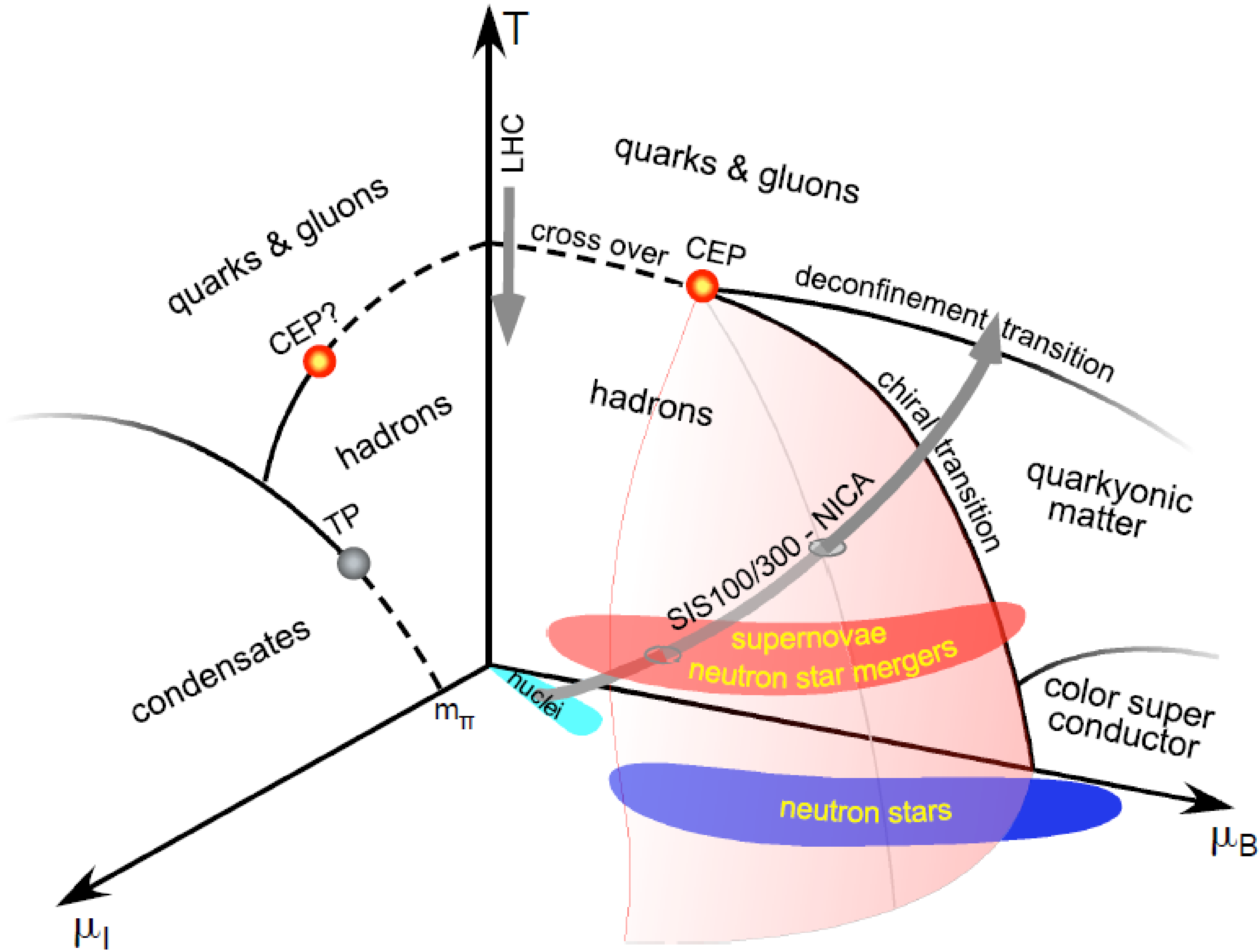
Quark matter in massive neutron stars?

M. Orsaria, H. Rodrigues, F. Weber, G.A. Contrera, arXiv:1308.1657
Phys. Rev. C 89, 015806, 2014



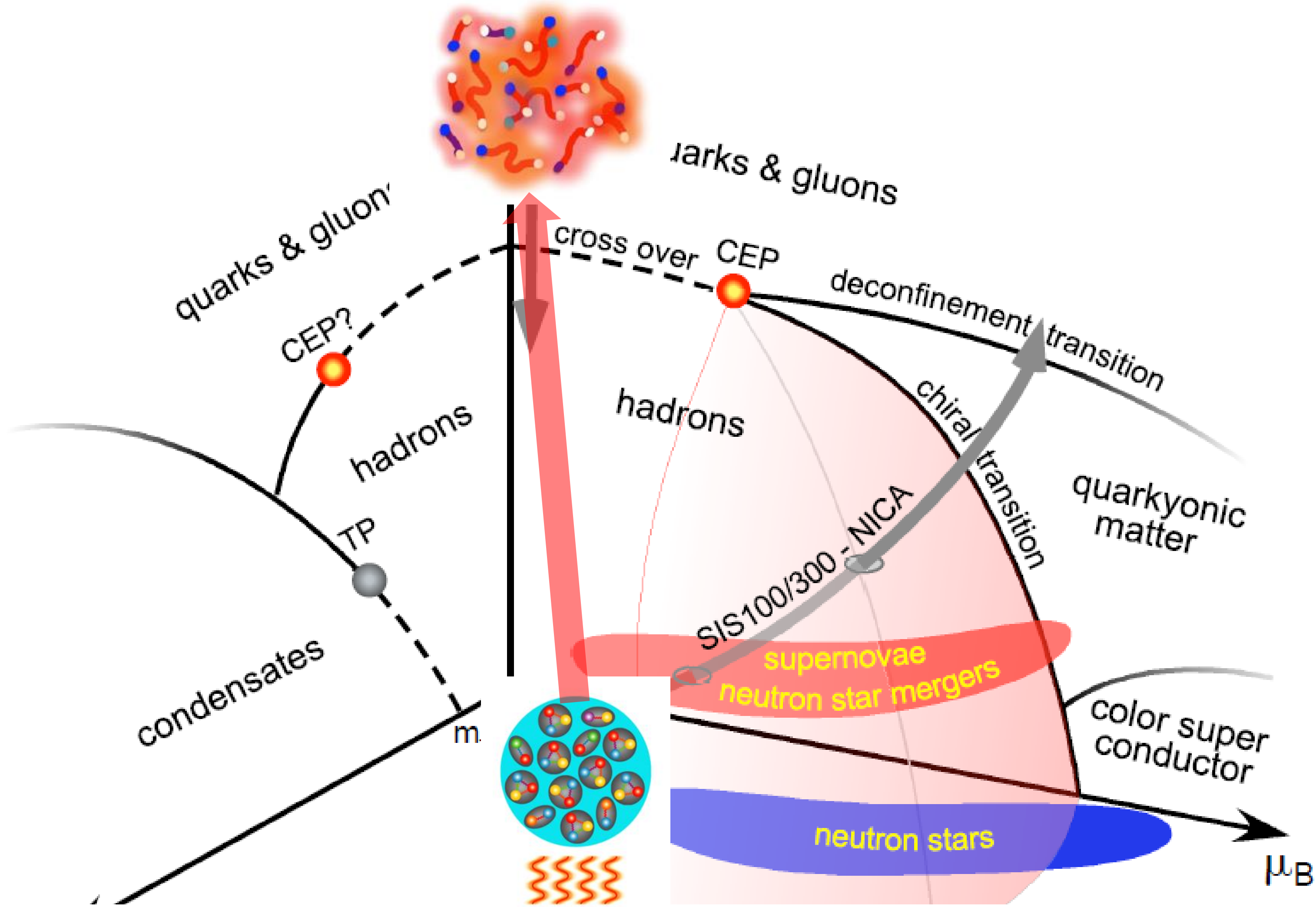
QCD phase diagram

Exploring the QCD phase diagram



NUPECC Long Range Plan 2017

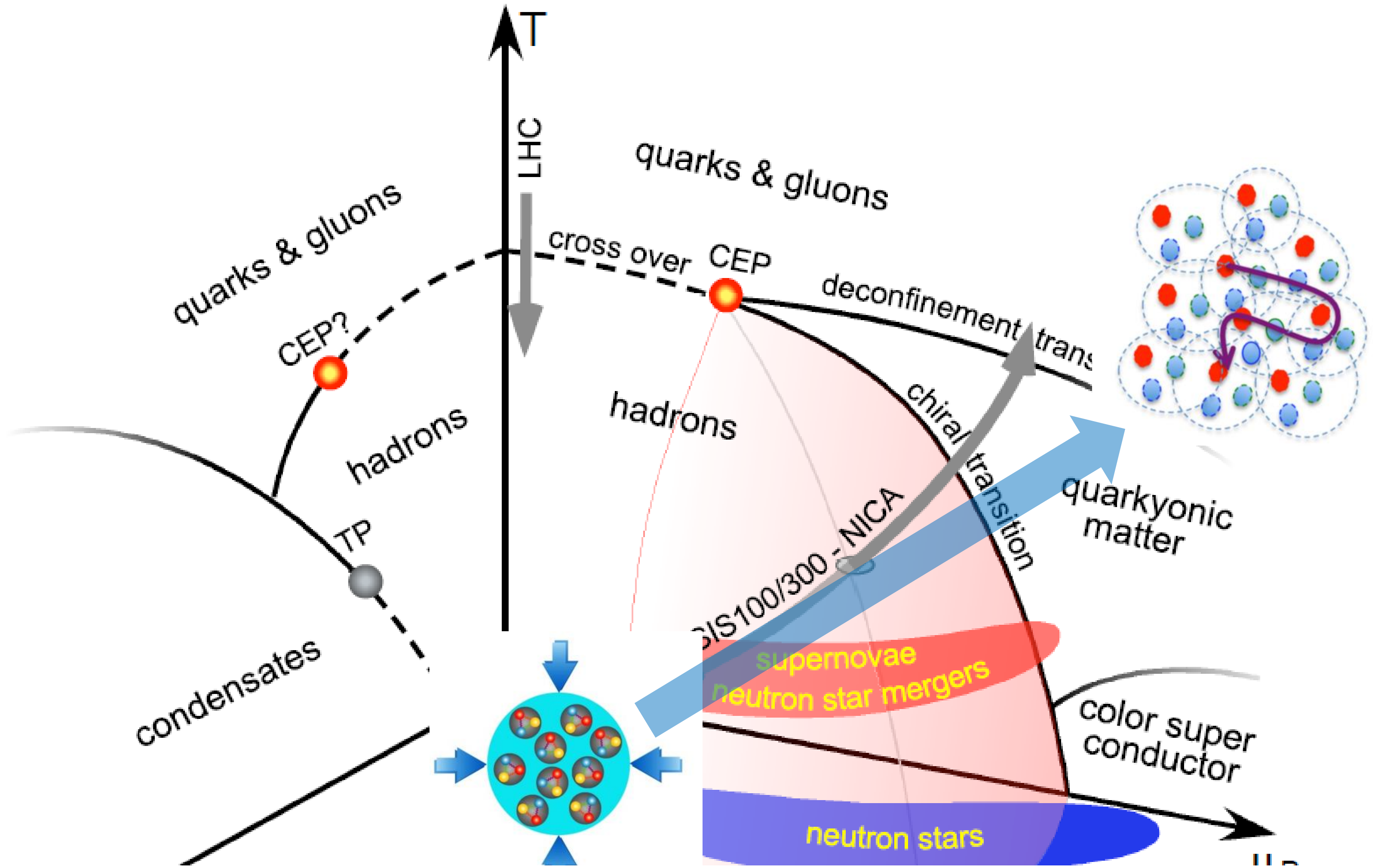
Exploring the QCD phase diagram



<u>At very high temperature:</u>

- N of baryons ≈ N of antibaryons, situation similar to early universe
- L-QCD finds crossover transition between hadronic matter and Quark-Gluon Plasma
- Experiments: ALICE, ATLAS, CMS at LHC, STAR, PHENIX at RHIC

Exploring the QCD phase diagram



<u>At high baryon density:</u>

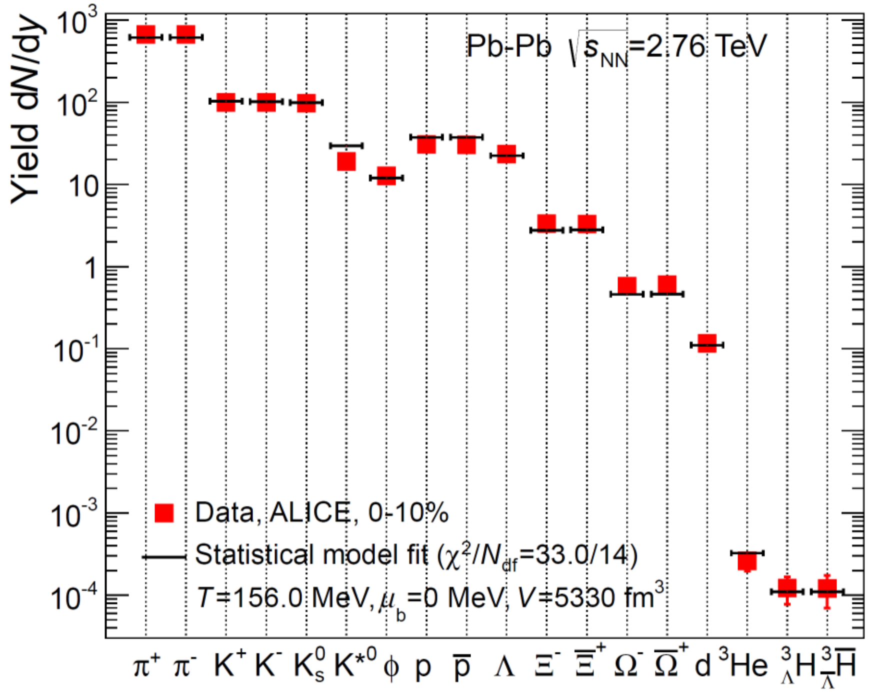
- N of baryons >> N of antibaryons , densities like in neutron star cores
- L-QCD not (yet) applicable, models predict phase transitions and exotic phases
- Experiments:
  BES at RHIC, NA61 at CERN SPS, CBM at FAIR, MPD/BM@N at NICA, CEE at HIAF

Linking hadron production in heavy-ion collisions to the QCD phase diagram: Statistical Hadronization Model

Particle density:

$$n_i = N_i/V = -\frac{T}{V}\frac{\partial \ln Z_i}{\partial \mu} = \frac{g_i}{2\pi^2}\int_0^\infty \frac{p^2 \mathrm{d}p}{\exp[(E_i - \mu_i)/T] \pm 1},$$

N_i: number of particles i
V: volume
T: temperature
Z_i: partition function
μ: chemical potential
$g_i = (2J_i + 1)$: spin degeneracy factor
$E_i = \sqrt{(p^2 + m_i^2)}$: total energy



A. Andronic et al., Jour. Phys. G38 (2011)

Assumptions:

- chemical equilibrium
- simultaneous freeze-out of all particles

Linking hadron production in heavy-ion collisions to the QCD phase diagram: Statistical Hadronization Model

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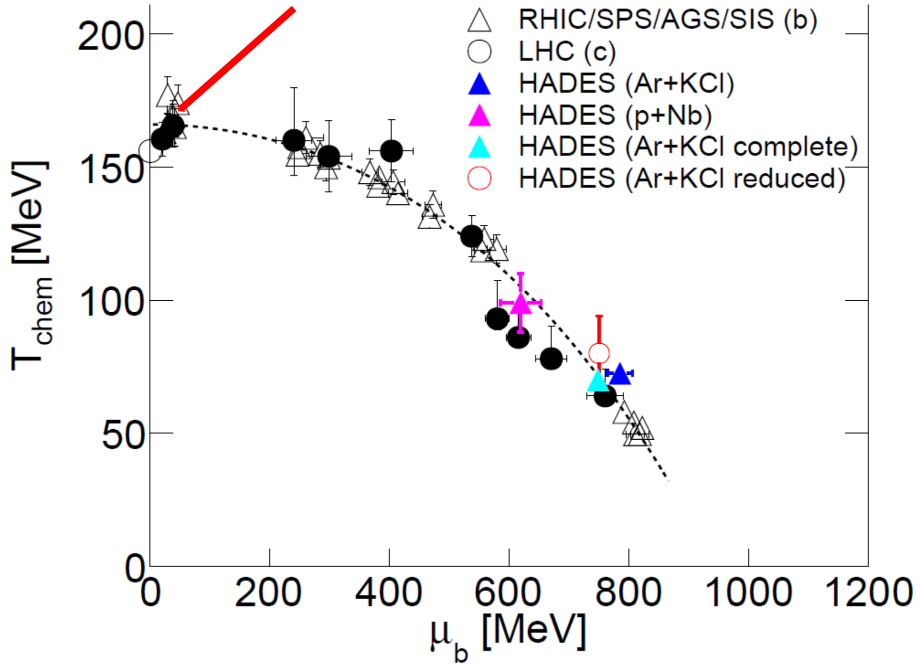
$g_i = (2J_i + 1)$: spin degeneracy factor
$E_i = \sqrt{(p^2 + m_i^2)}$: total energy

Cross-over transition at $\mu_B \approx 0$ with pseudo-critical temperature of $T_c = 156.5 \pm 1.5$ MeV



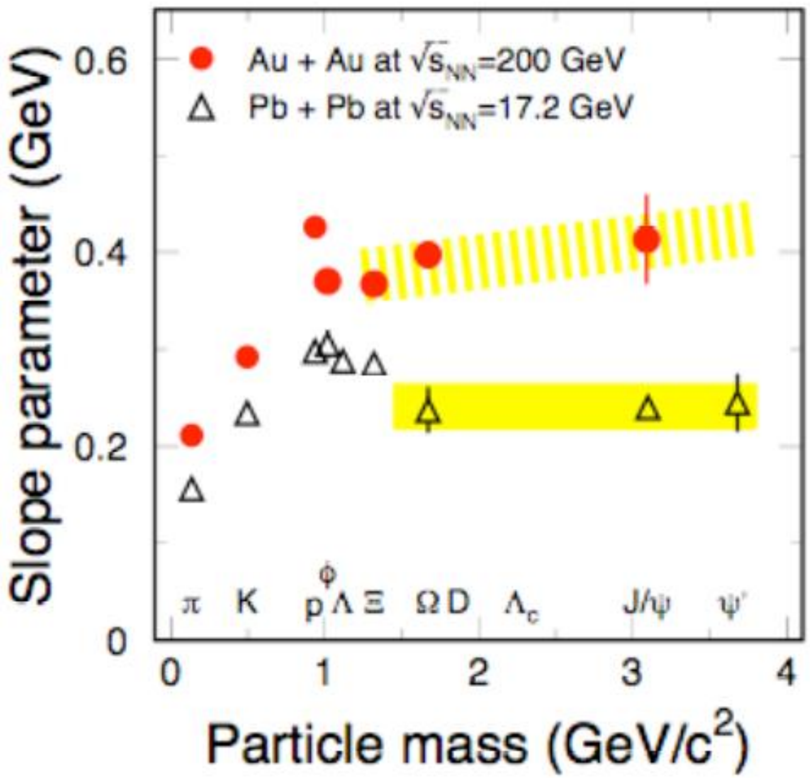
G. Agakishiev et al., arXiv:1512.07070

Assumptions:

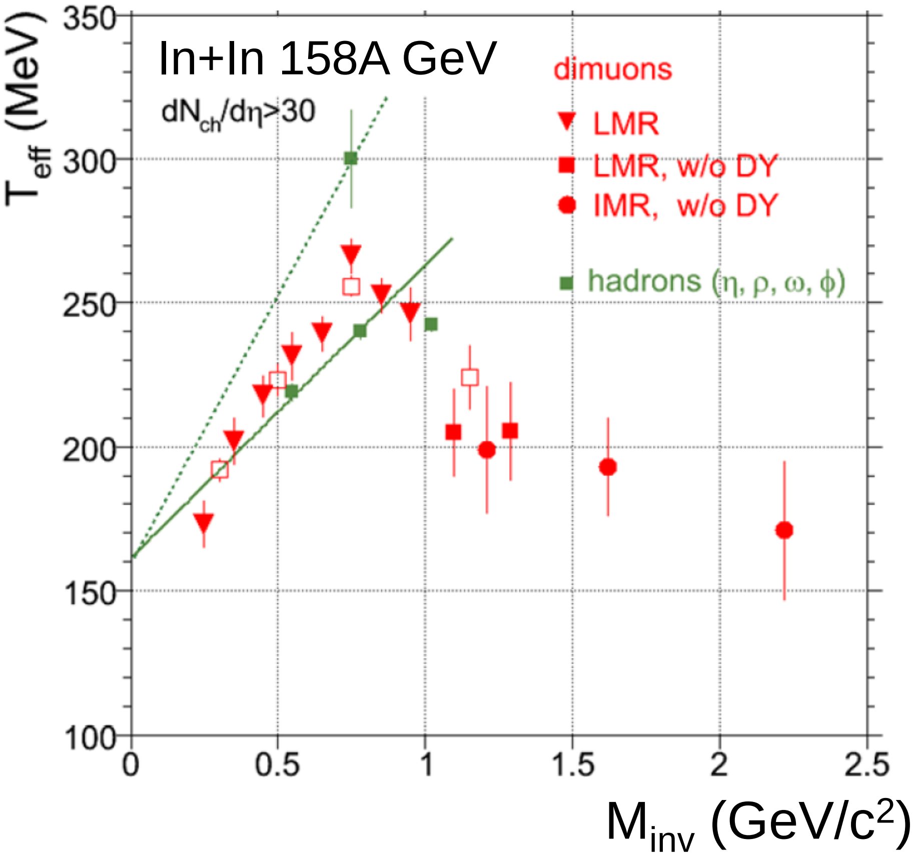
- chemical equilibrium
- simultaneous freeze-out of all particles

Slope of transverse mass distributions of particles and lepton pairs

Nu Xu priv. comm.



R. Arnaldi et. al., NA60 Collaboration
Phys. Rev. Lett. 100, 022302 (2008)



M < 1 GeV/c²: radial flow generated in the late hadronic phase

M > 1 GeV/c²: messengers from the early partonic phase ?

CBM physics case and observables

Phase transitions from partonic to hadronic matter

- excitation function of yields and slope parameters of hadrons (from π to Ω) and of lepton pairs (from M_{inv}= 0.2 to ~ 3 GeV) $\rightarrow$ separation of radial flow generated in late hadronic phase and early partonic phase

CBM physics case and observables

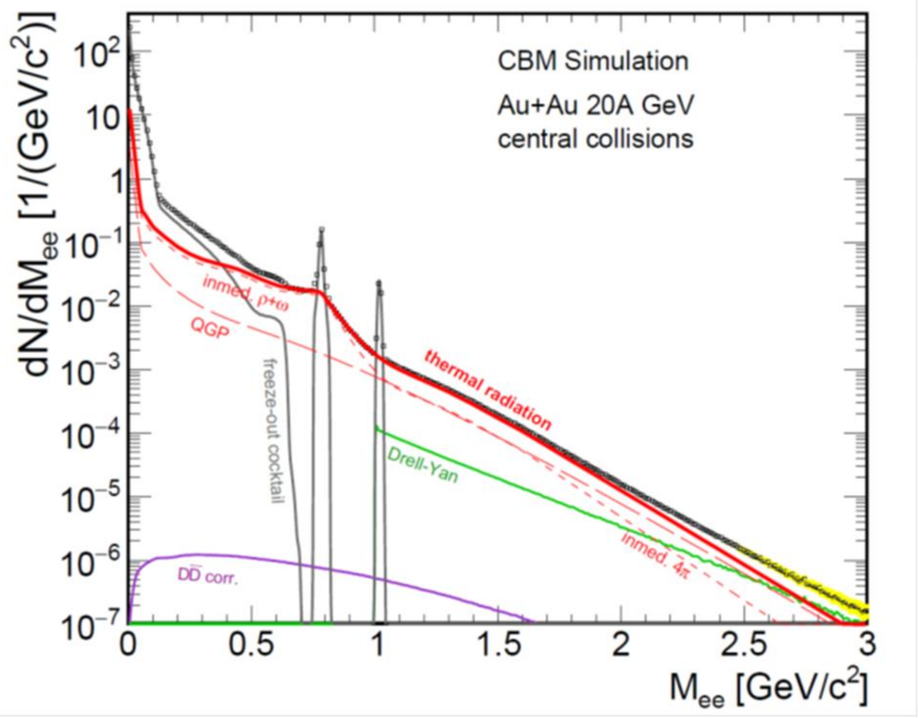
Phase transitions from partonic to hadronic matter

- excitation function of yields and slope parameters of hadrons (from π to Ω) and of lepton pairs (from M_{inv}= 0.2 to ~ 3 GeV) → separation of radial flow generated in late hadronic phase and early partonic phase

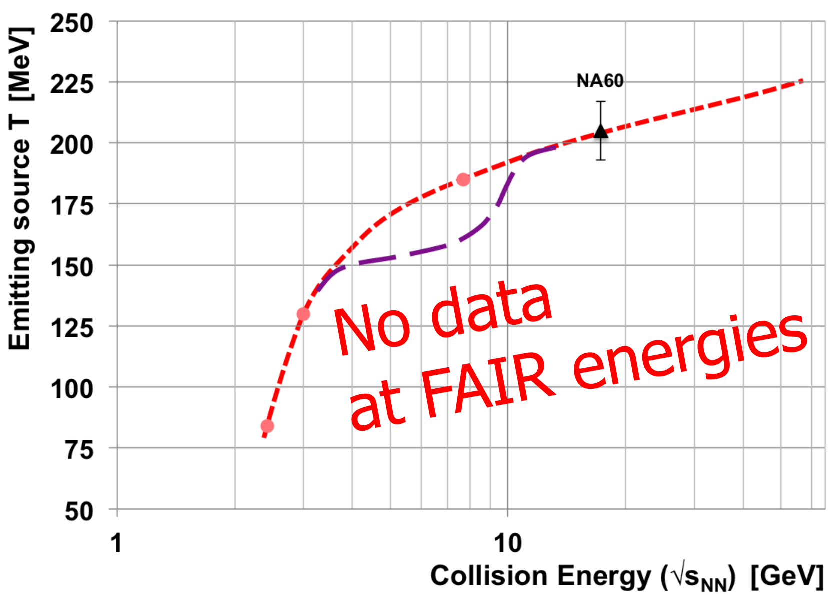
Phase coexistence

- excitation function (invariant mass) of lepton pairs:
thermal radiation from QGP, caloric curve

Invariant mass distribution of lepton pairs



Slope of dilepton invariant mass spectrum
$1\ GeV/c^2 < M_{inv} < 2.5\ GeV/c^2$



T. Ablyasimov et al., (CBM Collaboration)
Eur. Phys. J. A 53 (2017) 60

CBM physics case and observables

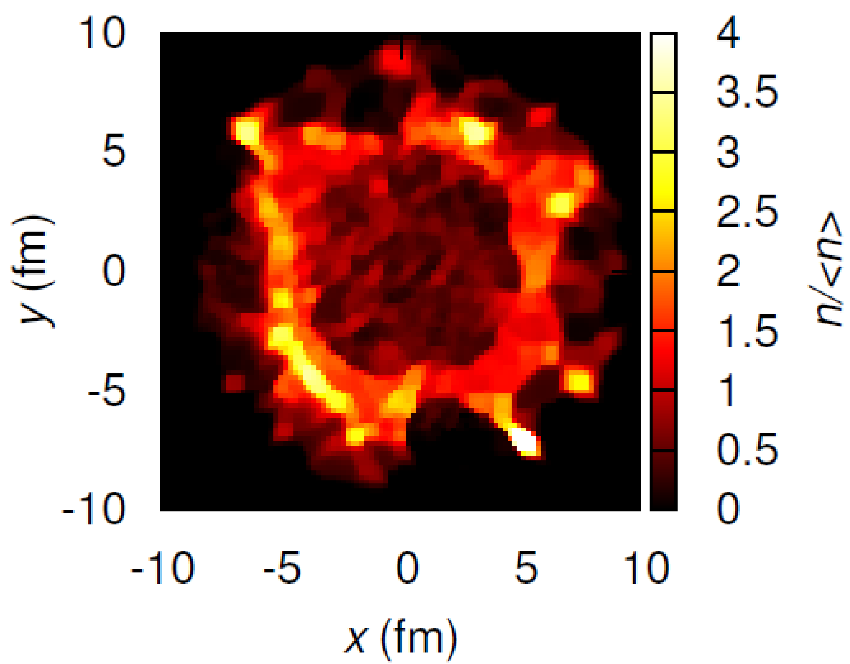
Phase transitions from partonic to hadronic matter

- excitation function of yields and slope parameters of hadrons (from π to Ω) and of lepton pairs (from M_{inv}= 0.2 to ~ 3 GeV) → separation of radial flow generated in late hadronic phase and early partonic phase

Phase coexistence

- excitation function (invariant mass) of lepton pairs: thermal radiation from QGP, caloric curve
- anisotropic azimuthal angle distributions: "spinodal decomposition"

Spinodal decomposition of the mixed phase: net baryon number density fluctuations



C. Herold, M. Nahrgang, I. Mishustin, M.Bleicher
Nuclear Physics A 925 (2014) 14

Jan Steinheimer, Jorgen Randrup
Phys. Rev. C 87, 054903 (2013)
Eur. Phys. J. A (2016) 52: 239

No data
at FAIR energies

CBM physics case and observables

Phase transitions from partonic to hadronic matter

- excitation function of yields and slope parameters of hadrons (from π to Ω) and of lepton pairs (from M_{inv}= 0.2 to ~ 3 GeV) $\rightarrow$ separation of radial flow generated in late hadronic phase and early partonic phase

Phase coexistence

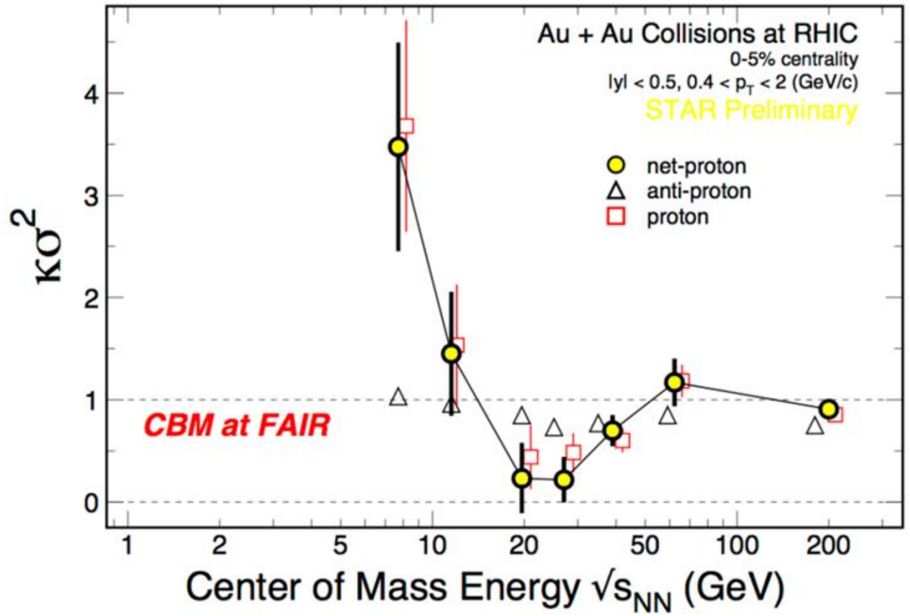
- excitation function (invariant mass) of lepton pairs: thermal radiation from QGP, caloric curve
- anisotropic azimuthal angle distributions: "spinodal decomposition"

Critical point

- event-by-event fluctuations of conserved quantities (B,S,Q) "critical opalescence"

4th moment of net-proton multiplicity distribution: critical fluctuations

No data at FAIR energies

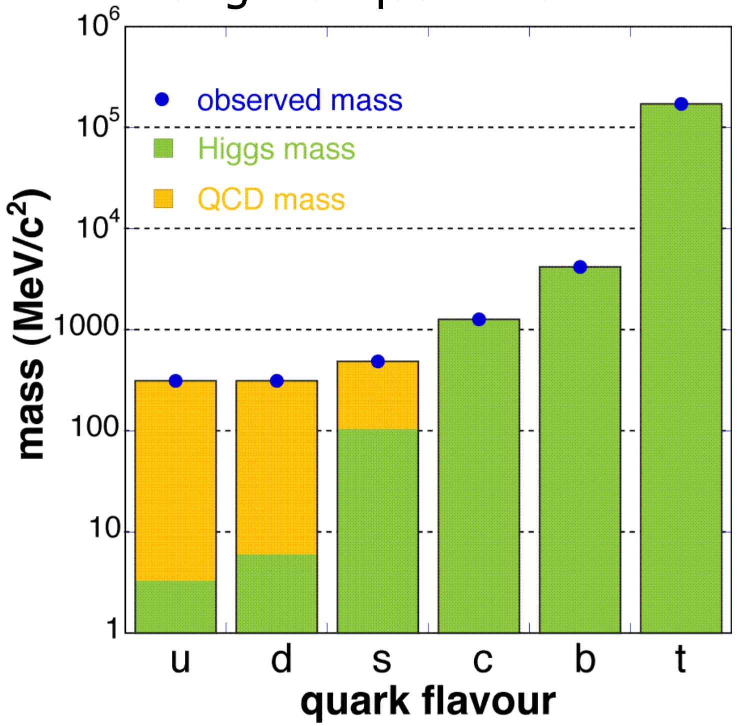


CBM physics case and observables

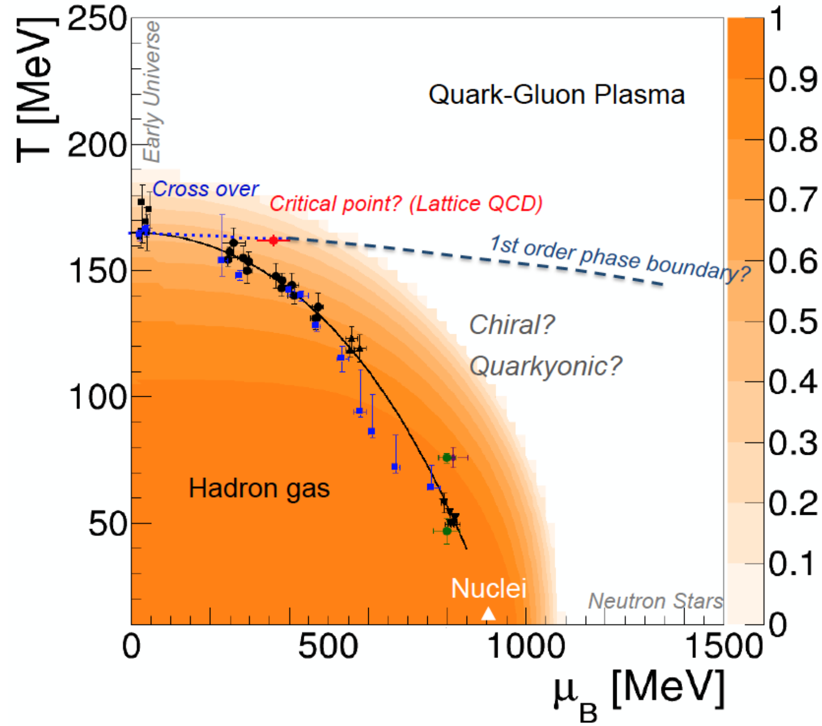
Onset of chiral symmetry restoration at high ρ_B

- in-medium modifications of hadrons: $\rho,\omega,\phi \rightarrow e^+e^-(\mu^+\mu^-)$
- dileptons at intermediate invariant masses: $4\pi \rightarrow \rho\text{-}a_1$ chiral mixing

Origin of quark masses



Orange region: Chiral condensate



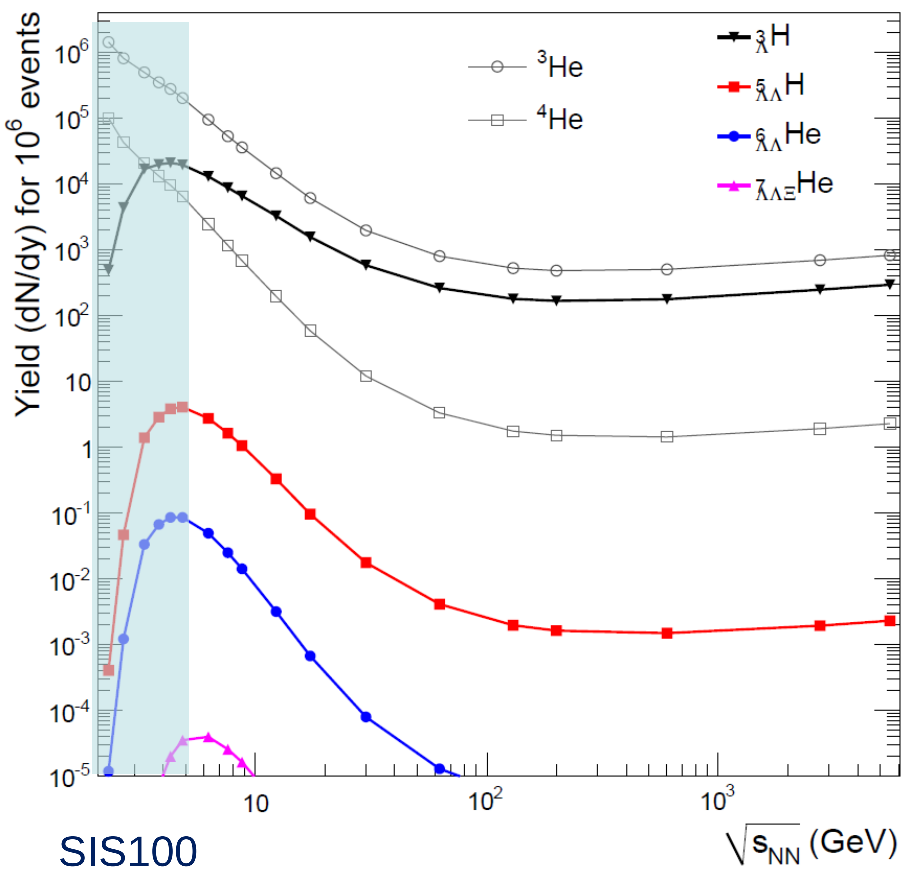
QCD mass generation by spontaneous/dynamical Chiral Symmetry breaking: Hadrons acquire mass by coupling to the virtual quark-antiquark pairs of the chiral condensate

CBM physics case and observables

N-Λ, Λ-Λ interaction, strange matter?

- (double-) lambda hypernuclei
- meta-stable objects (e.g. strange dibaryons)

No data at FAIR energies

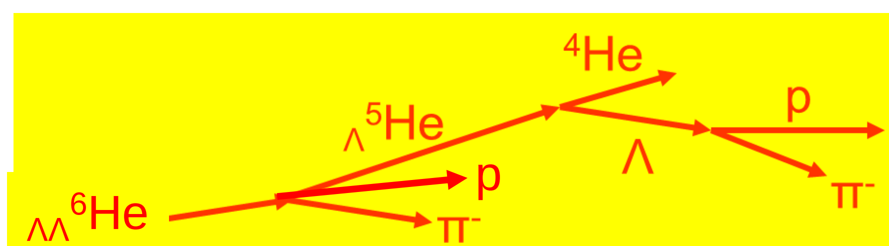


A. Andronic et al., Phys. Lett. B697 (2011) 203

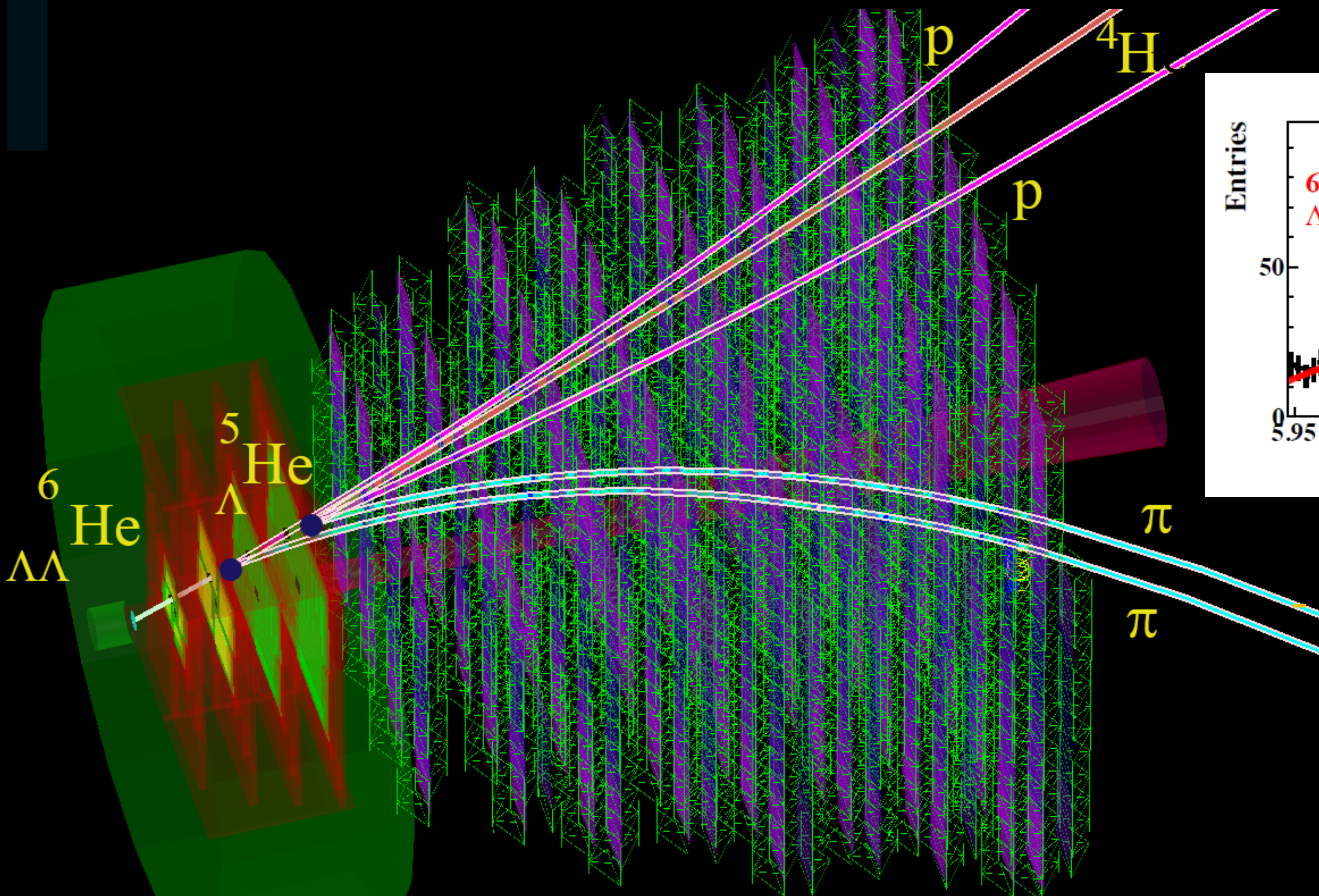
Central Au+Au collisions at 10 A GeV:

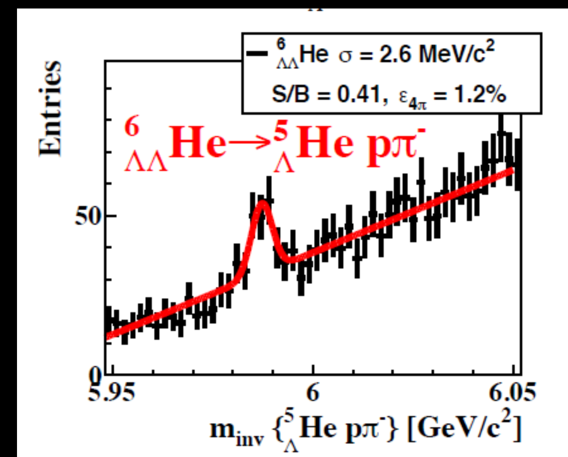
	Multiplicity	Yield in 1 week
$_{\Lambda\Lambda}{}^5$H	$5 \cdot 10^{-6}$	3000
$_{\Lambda\Lambda}{}^6$He	$1 \cdot 10^{-7}$	60

Reaction Rate 1 MHz, BR 10%, efficiency 1%

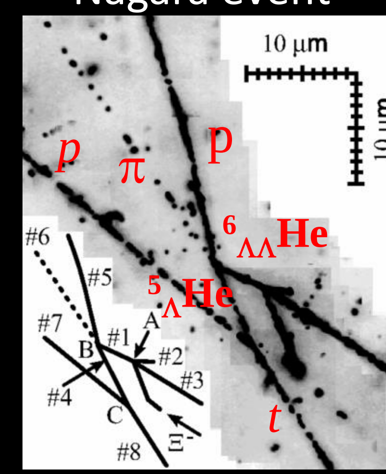


${}_{\Lambda\Lambda}^{6}He$ reconstruction in CBM detector





Nagara event



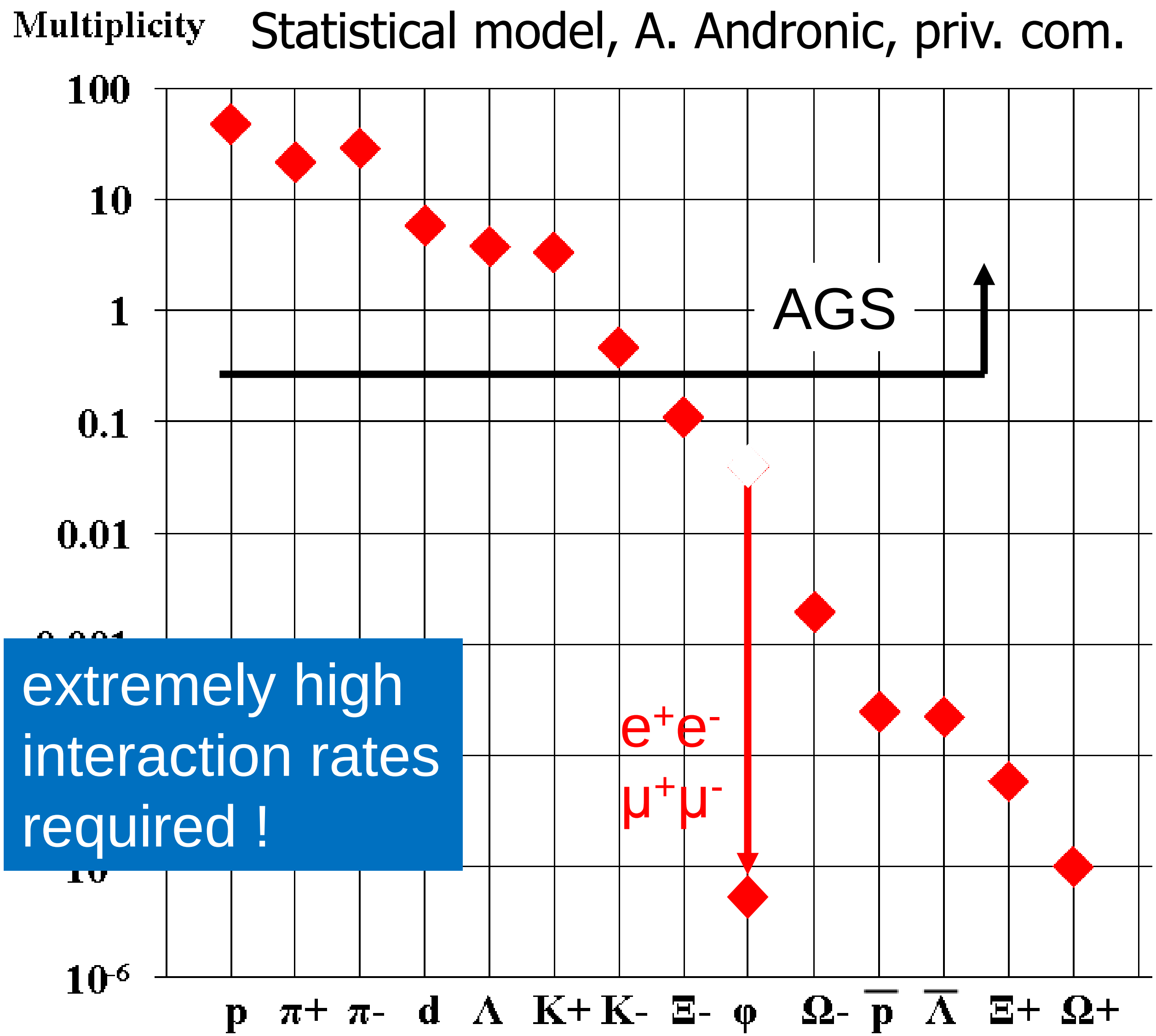
Micro Vertex Detector
(4 layers of
Monolithic Active
Pixel Sensors)

Silicon Tracking System
(8 layers of double-sided
micro-strip sensors)

Experimental challenges

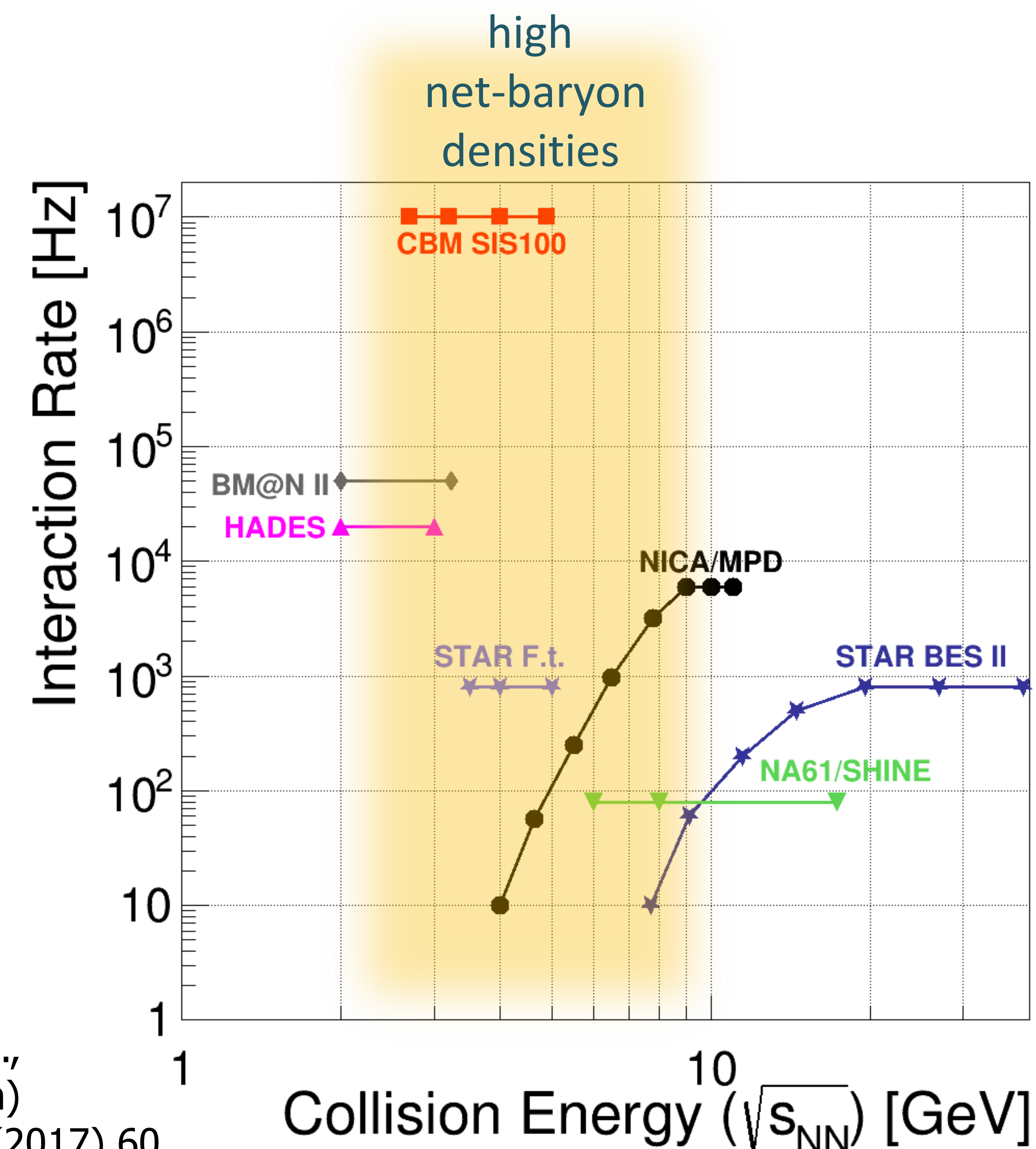
Particle yields in central Au+Au 4 A GeV

Statistical model, A. Andronic, priv. com.



extremely high interaction rates required !

Experiments exploring dense QCD matter



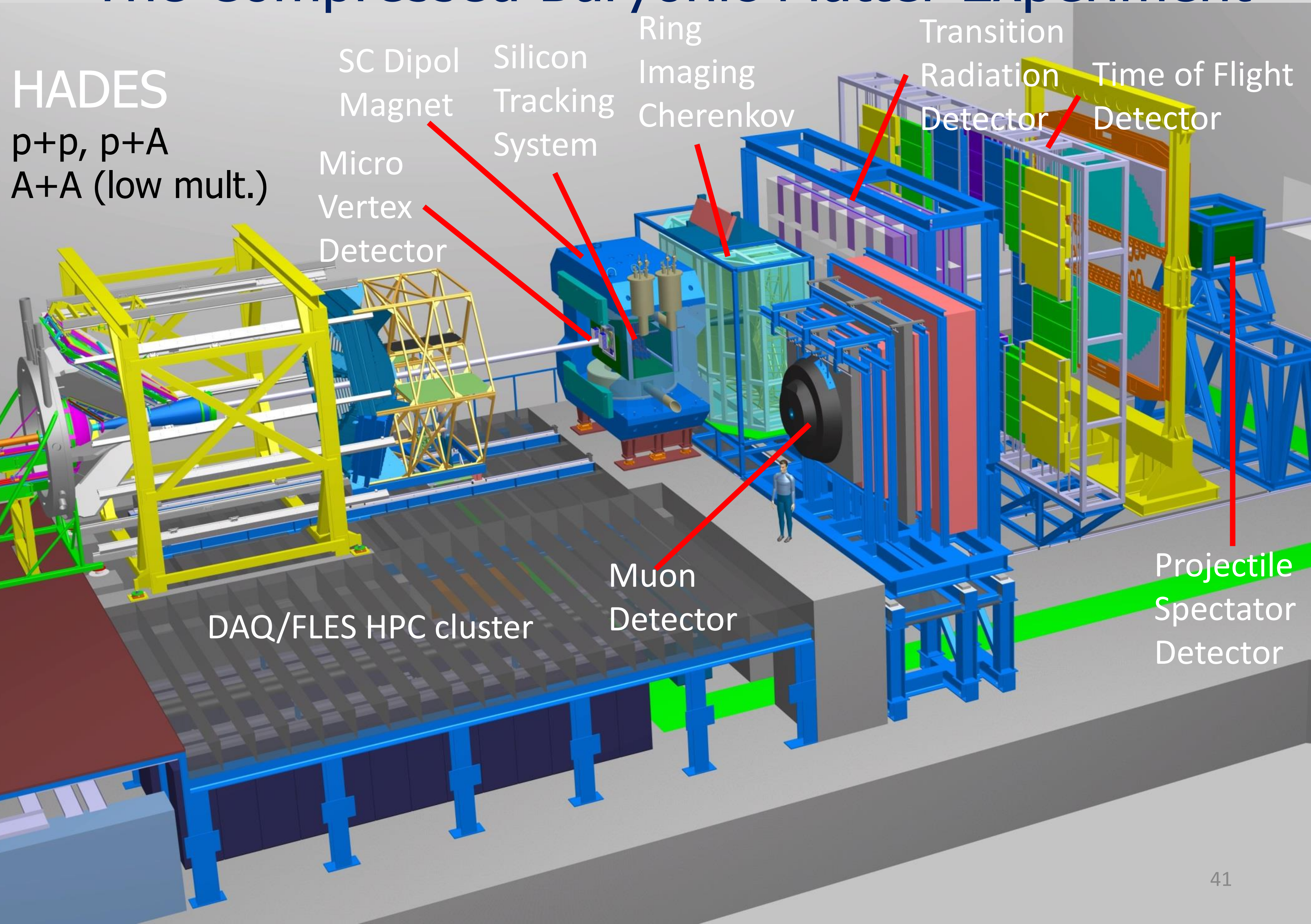
T. Ablyasimov et al.,
(CBM Collaboration)
Eur. Phys. J. A 53 (2017) 60

Experimental requirements

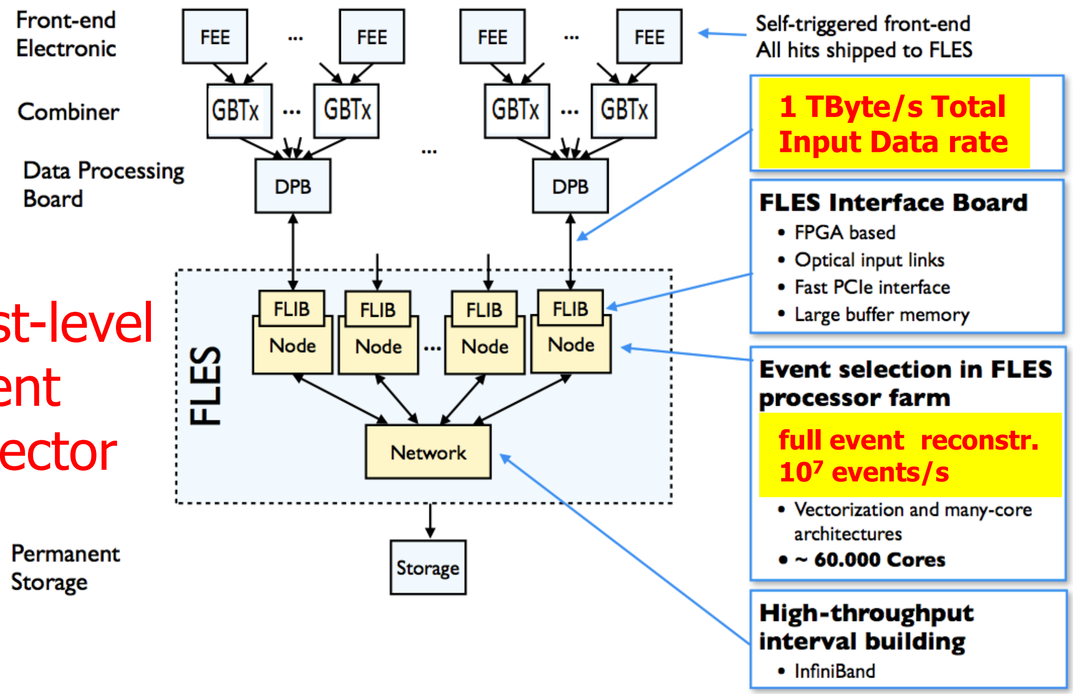
- 10^5 - 10^7 Au+Au reactions/sec
- determination of displaced vertices ($\sigma \approx 50\ \mu m$)
- identification of leptons and hadrons
- fast and radiation hard detectors and FEE
- free-streaming readout electronics
- high speed data acquisition and high performance computer farm for online event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

40

The Compressed Baryonic Matter Experiment



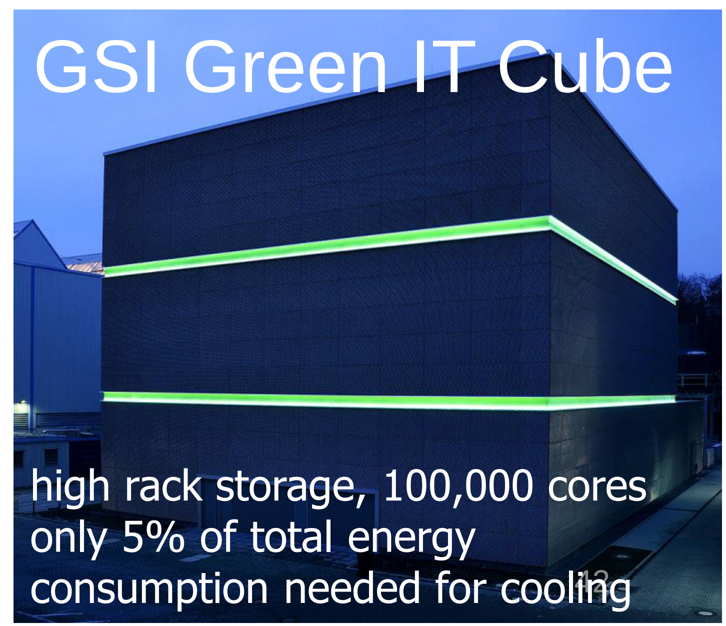
CBM DAQ and online event selection



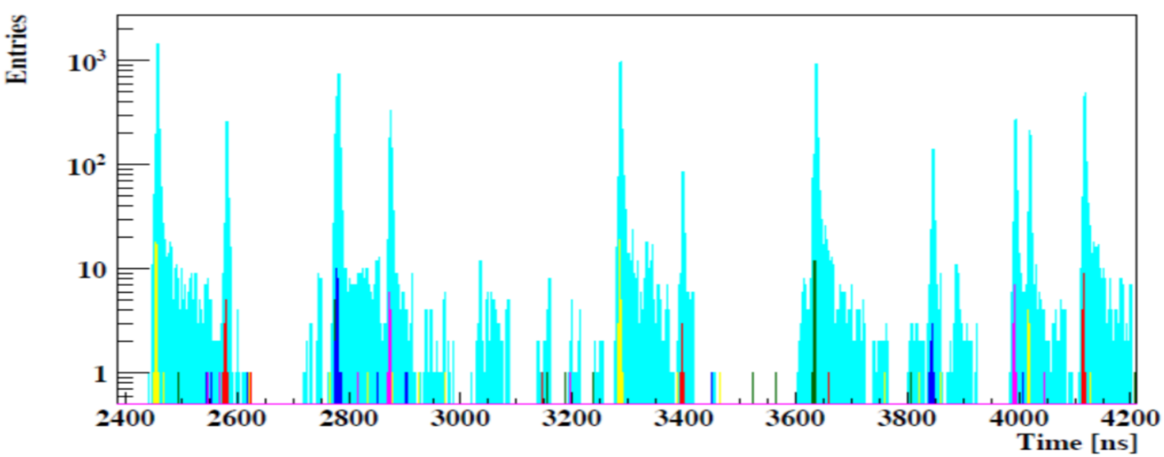
First-level Event Selector

Novel readout system:

- no hardware trigger on events
- detector hits with time stamps
- full online 4-D track and event reconstruction.

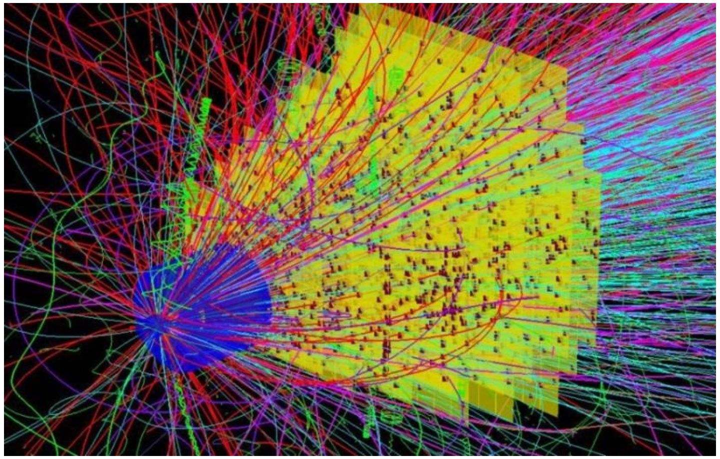


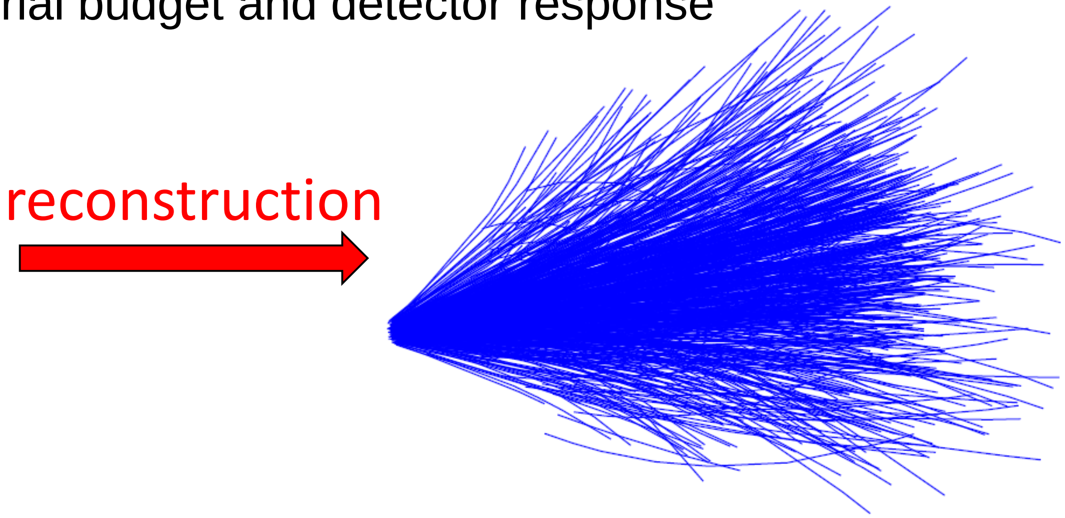
Hit and track time distribution for Au+Au 10A GeV collisions at 10 MHz (UrQMD)

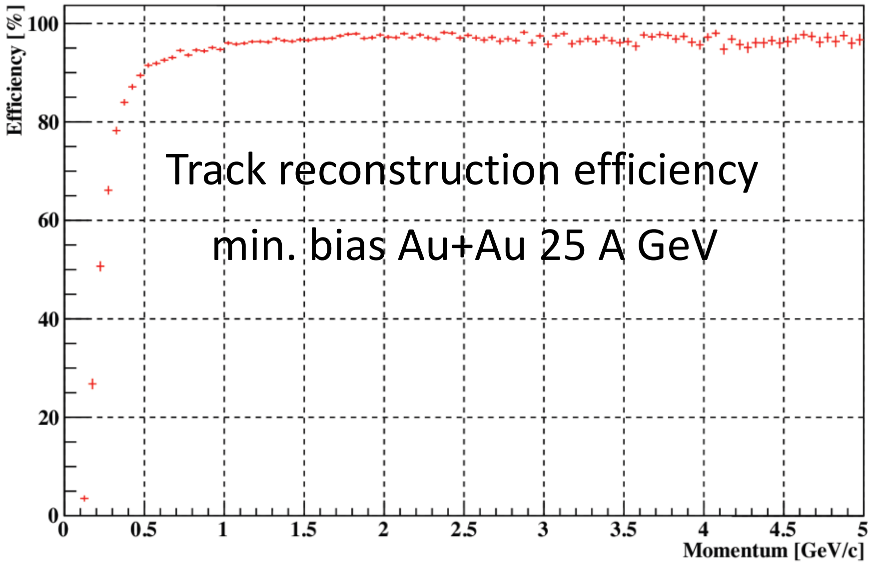


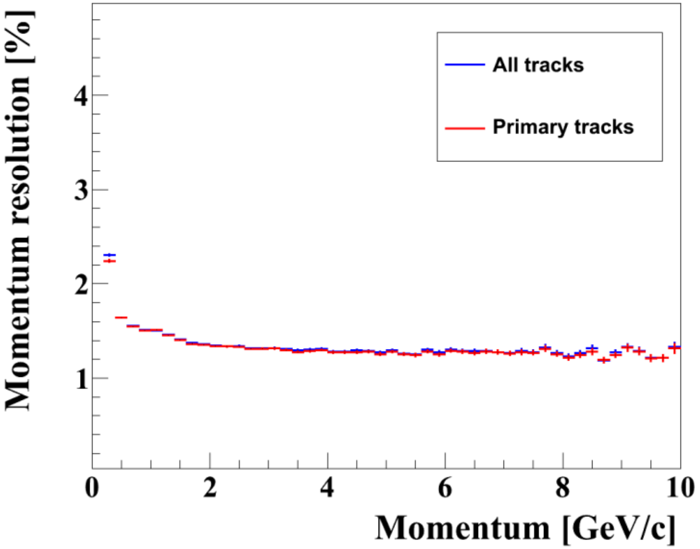
Simulation and reconstruction

Event generators UrQMD 3.3
Transport code GEANT3, FLUKA
Realistic detector geometries, material budget and detector response

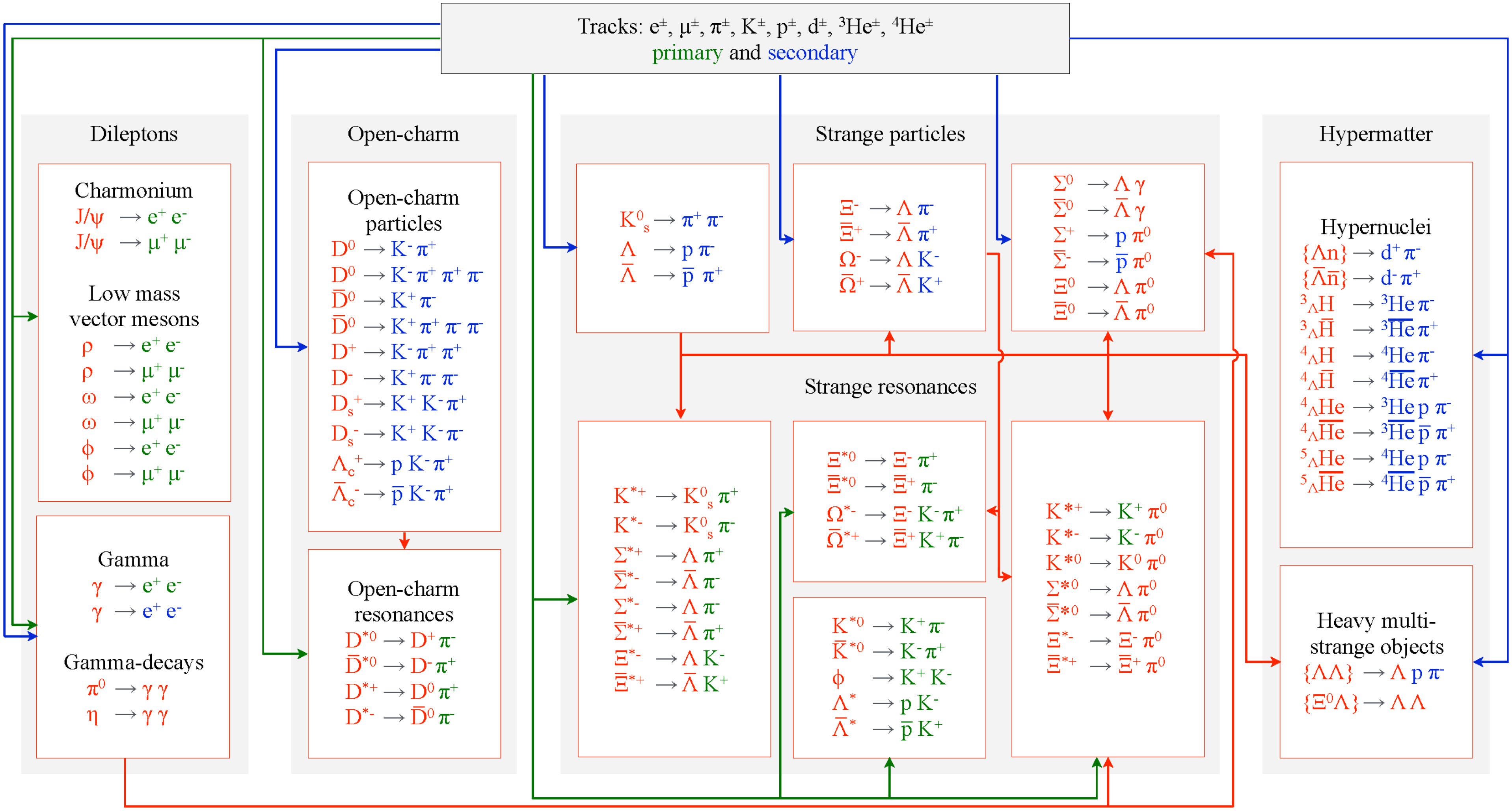








Online particle identification in CBM: The KF Particle Finder



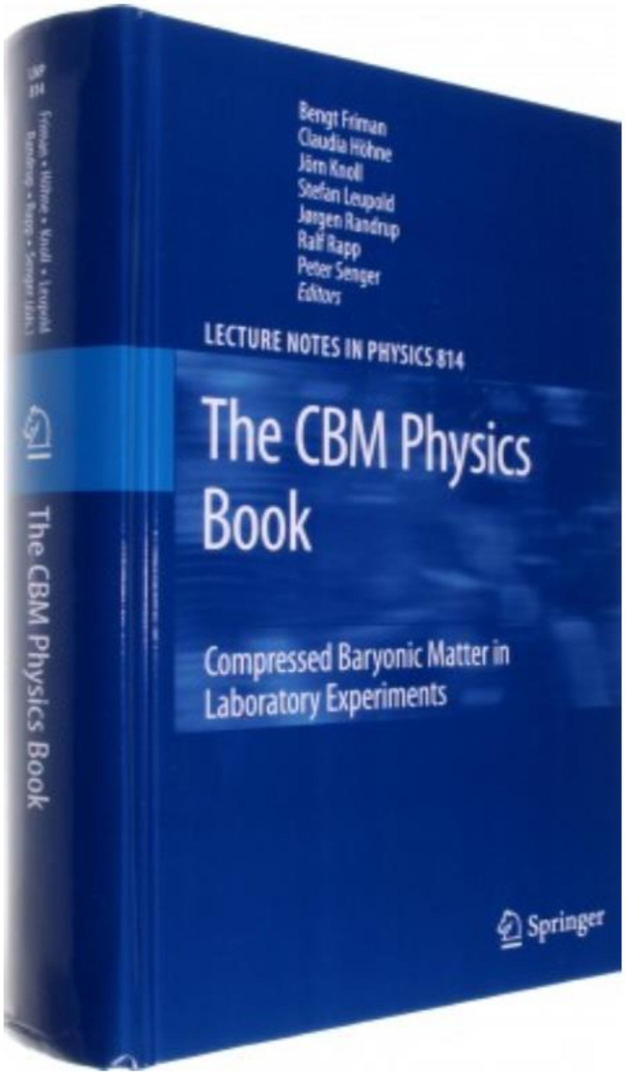
successfully used online in the STAR experiment at RHIC

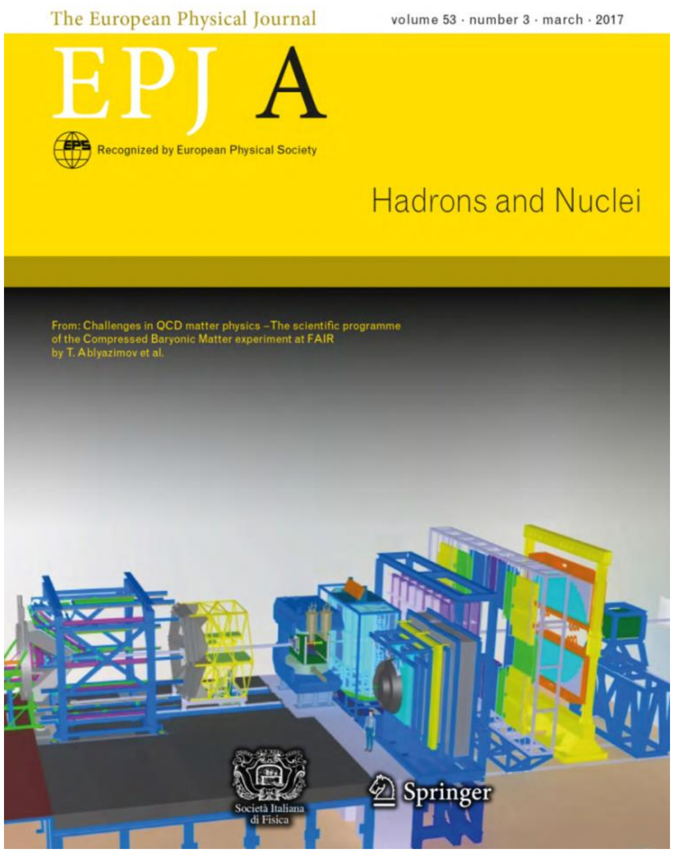
For further reading ...

The CBM Physics Book

Foreword by Frank Wilczek

Springer Series: Lecture Notes in Physics, Vol. 814
1st Edition., 2011, 960 p.,



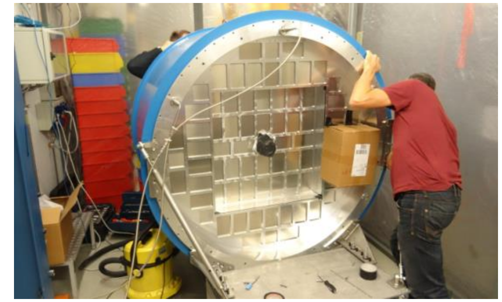


"Challenges in QCD Matter Physics – the scientific programme of the Compressed Baryonic Matter Experiment at FAIR"

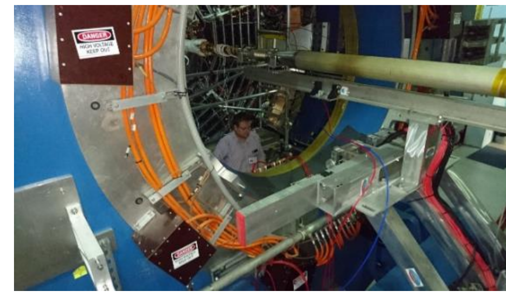
Ablyazimov, et al. Eur. Phys. J. A (2017) 53

Electronic Authors version:
http://www.gsi.de/documents/DOC-2009-Sep-120-1.pdf

FAIR phase 0 experiments on dense QCD matter

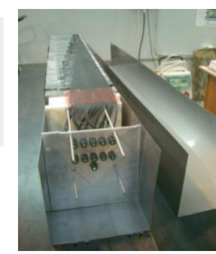


1. Install, commission and use 430 out of 1100 CBM RICH multi-anode photo-multipliers (MAPMT) in HADES RICH photon detector



2. Install, commission and use 10% of the CBM TOF modules including read-out chain at STAR/RHIC (BES II 2019/2020)

3. Install, commission and use 4 Silicon Tracking Stations and the Project Spectator Detector in the BM@N experiment at the Nuclotron in JINR/Dubna (start 2019 with Au-beams up to 4.5 A GeV)



4. Build miniCBM at GSI/SIS18 for a full system test with high-rate nucleus-nucleus collisions from 2018 - 2021

The CBM Collaboration: 56 institutions, > 460 members

China:
CCNU Wuhan
Tsinghua Univ.
USTC Hefei
CTGU Yichang
Chongqing Univ.

Czech Republic:
CAS, Rez
Techn. Univ. Prague

France:
IPHC Strasbourg

Hungary:
KFKI Budapest
Eötvös Univ.

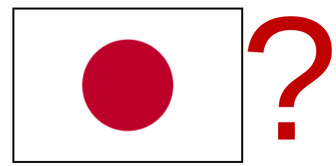
Germany:
Darmstadt TU
FAIR
Frankfurt Univ. IKF
Frankfurt Univ. FIAS
Frankfurt Univ. ICS
GSI Darmstadt
Giessen Univ.
Heidelberg Univ. P.I.
Heidelberg Univ. ZITI
HZ Dresden-Rossendorf
KIT Karlsruhe
Münster Univ.
Tübingen Univ.
Wuppertal Univ.
ZIB Berlin

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

Korea:
Pusan Nat. Univ.

Poland:
AGH Krakow
Jag. Univ. Krakow
Warsaw Univ.
Warsaw Univ. Tech.

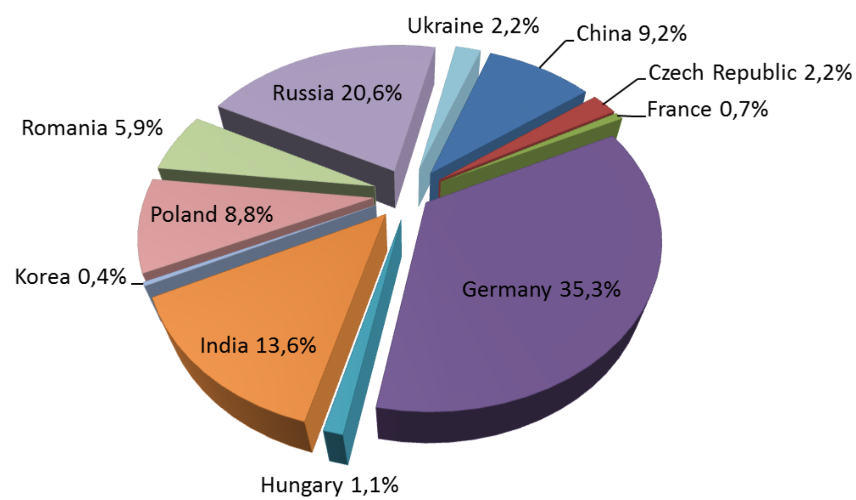
Romania:
NIPNE Bucharest
Univ. Bucharest



Russia:
IHEP Protvino
INR Troitzk
ITEP Moscow
Kurchatov Inst., Moscow
VBLHEP, JINR Dubna
LIT, JINR Dubna
MEPHI Moscow
PNPI Gatchina
SINP MSU, Moscow

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

CBM Scientists



FAIR Project Status 2018

- Comprehensive civil construction plan: completion of all buildings by 2022
- Full integrated planning for construction and commissioning of the entire project: Completion of the full FAIR facility by 2025.
- Civil construction as well as procurement of accelerators and realization of experiments are progressing well.

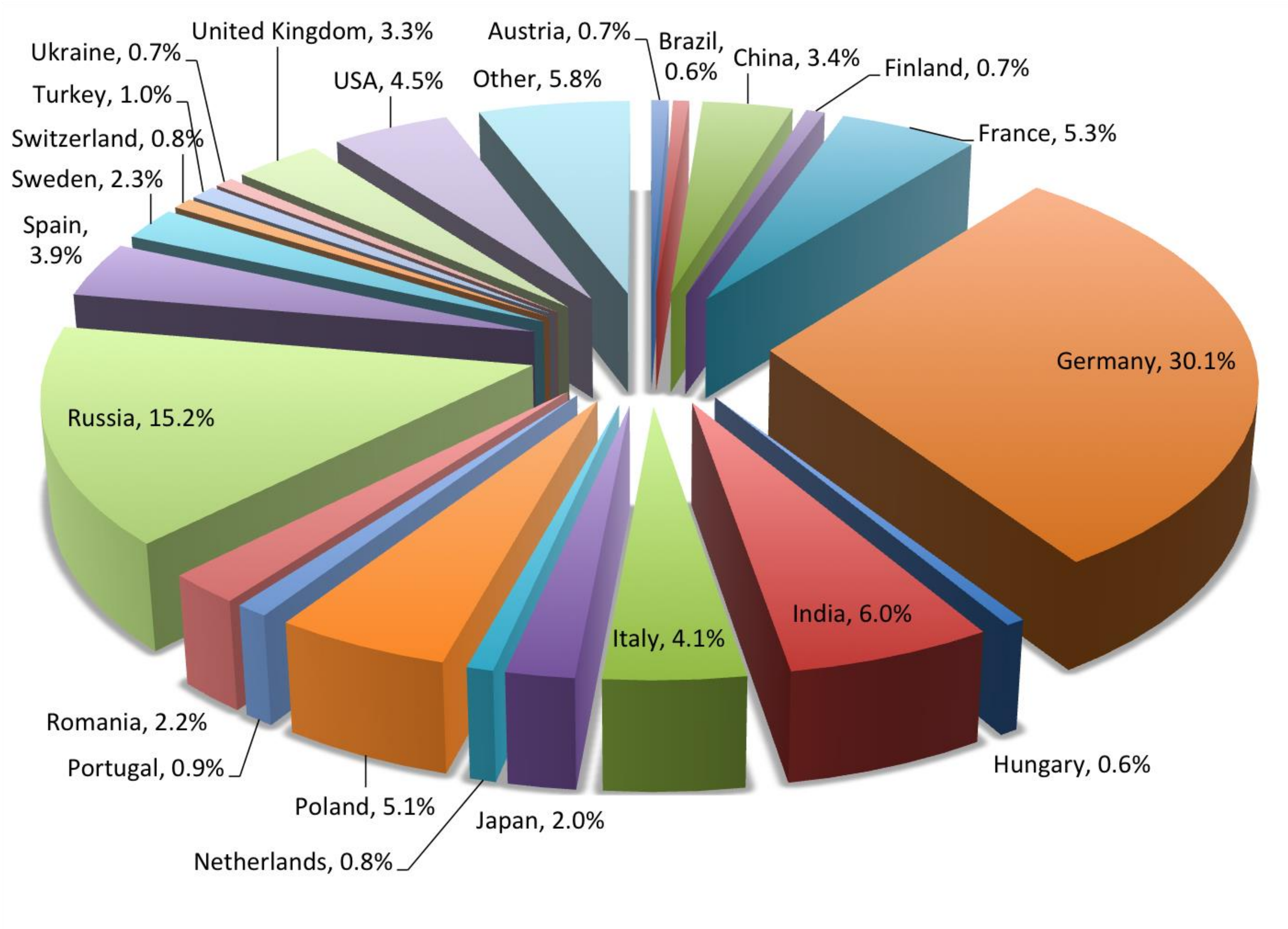
2014: 1350 pillars 60 m deep

Ground breaking - 4 July 2017

FAIR tunnel excavation August 2018

FAIR civil construction status Sept. 2018

FAIR Collaboration Members by Country



Instead of a summary: NuPECC recommendation

Key Summary Recommendation of the NuPECC Long Range Plan 2017 presented in Brussels on Nov 27th :

Complete urgently the construction of the ESFRI* flagship FAIR and develop and bring into operation the experimental program of its four scientific pillars APPA, CBM, NUSTAR and PANDA.

FAIR is a European flagship facility for the coming decades. Worldwide unique it will allow for a large variety of unprecedented fore-front research in physics and applied science. It focuses on the structure and evolution of matter. Its multi- faceted research opens a new era in our understanding of the fundamental building blocks of matter and the forces as well as of the evolution of our Universe: the new possibilities for research in Darmstadt are unique and are expected to produce ground breaking new insights for nuclear research.

*European Strategy Forum on Research Infrastructures