Report from 'Hadrons and Nuclei' community EMMI, ALICE, FAIR,...

- Introduction, KHuK Research priorities
- status and future of EMMI
- selected results and future prospects – ALICE
- FAIR status

FIAS Frankfurt Institute for Advanced Studies

8th Terascale Meeting
DESY, Hamburg, Dec. 1 – 3, 2014

Hadrons and Nuclei – Survey

Research Priorities

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

    in line with NuPECC Long-Rangle Plan for Europe

ExtreMe Matter Institute EMMI

Helmholtz Alliance
„Cosmic Matter in the Laboratory“

www.gsi.de/emmi

Helmholtz Alliance

Cosmic Matter in the Laboratory

HELMHOLTZ ASSOCIATION

Alliance on Cosmic Matter in the Laboratory

- 18.75 MEuro for 6 years, starting April 2008
- 54 MEuro as matching funds from Partners
- ExtreMe Matter Institute EMMI founded at GSI
- now extended until Dec 2014
- sustained continuation planned

Coordinating Helmholtz Centre:
GSI Helmholtz Centre for Heavy Ion Research

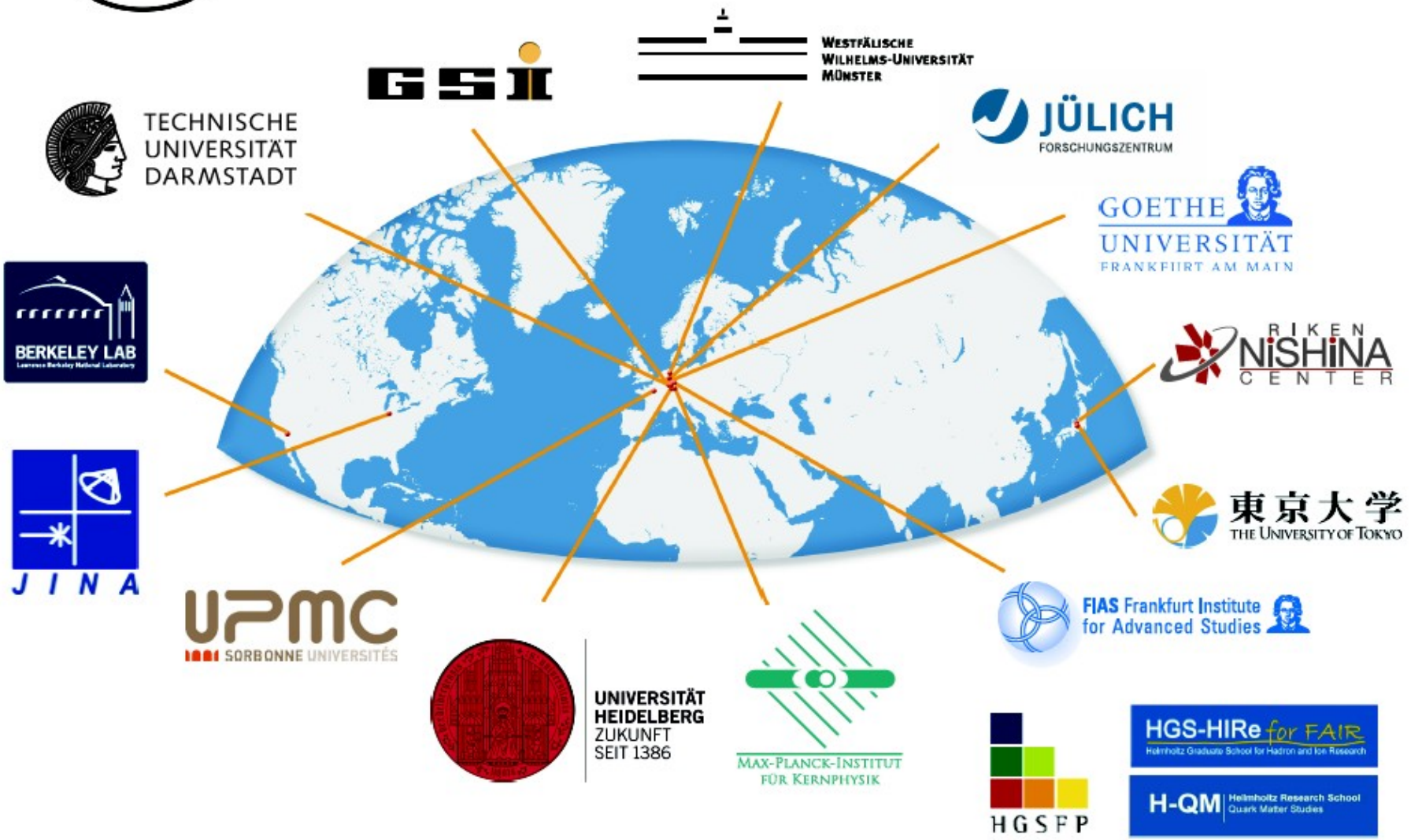
HELMHOLTZ ASSOCIATION

GSI

Partner Institutions

- GSI Helmholtz Centre for Heavy Ion Research
- Forschungszentrum Jülich
- Technische Universität Darmstadt
- Goethe-Universität Frankfurt
- Ruprecht-Karls-Universität Heidelberg
- Universität Münster
- Max-Planck-Institut für Kernphysik (MPIK), Heidelberg
- FIAS Frankfurt Institute for Advanced Studies
- Université VI (Pierre et Marie Curie), Paris
- Lawrence Berkeley National Laboratory, Berkeley
- Joint Institute for Nuclear Astrophysics (JINA)
- University of Tokyo
- RIKEN, Saitama

... and its Partners



Organisation

13 **Partner Institutions**

Management:

Scientific Director: Peter Braun-Munzinger

Scientific Coordinator: Carlo Ewerz

+ administrative support

32 further experts as **Associated Partners**

Scientific Council (representatives of Partners)
as main steering body

Program Advisory Committee (8 external experts)

Goals of the Alliance

Central Goal:
establish the ExtreMe Matter Institute EMMI as a

Think Tank for extreme matter research

aiming at:

- interdisciplinary scientific programs of highest quality
- strong promotion of young researchers
- new network among two Helmholtz centres and eleven top national and international laboratories and universities

complementary to HICforFAIR

Main Research Areas of EMMI

Matter under extreme conditions of temperature, density and pressure, in particular

- quark-gluon plasma and phase diagram of QCD
- neutron matter
- plasma physics
- atomic physics and ultracold gases

Vision:
bringing together the best minds from these communities

Emergence of common concepts

Common structures and underlying theoretical concepts for these strongly coupled systems, for example

- from BEC to BCS
- from QGP to ultracold Fermi gases
- from conformal field theory to QCD via black holes
- from neutron star matter to strongly coupled electromagnetic plasmas
- hydrodynamics, turbulence, ...
- ...

EMMI Scientists

- more than 100 senior researchers participating in the Alliance, more than 400 scientists in total
- 16 new positions (incl. professorships / tenure track) created and filled by partners:
  - 12 at TUD, F, MPI-K, MS, HD, FIAS, FZJ, LBNL
  - 4 EMMI Fellow positions at GSI
- EMMI supported PhD students associated with surrounding graduate schools (H-QM, HGS-HIRe, HGSFP)

EMMI Programs

- EMMI Workshops
- EMMI Programs
- EMMI Rapid Reaction Task Force meetings (RRTFs)

- Visiting Professor program

Sustained Continuation of EMMI

- 500 kEuro / year from GSI foreseen
- Workshops, RRTFs, Visiting Professorships
- with 2 other alliances embedded in new network for Helmholtz research field *Matter* / *Matter and Universe:* MUTLink - Matter Universe Technology Link

  in particular: RRTFs also in particle and astroparticle physics

ExtreMe Matter Institute EMMI

EMMI Workshops and EMMI Programs

Call for Proposals

The ExtreMe Matter Institute EMMI at GSI invites proposals for workshops and research programs in the four main research areas of EMMI:

- quark-gluon plasma
- neutron matter
- electromagnetic plasmas of high energy density
- ultra-cold quantum gases and extreme states in atomic physics,

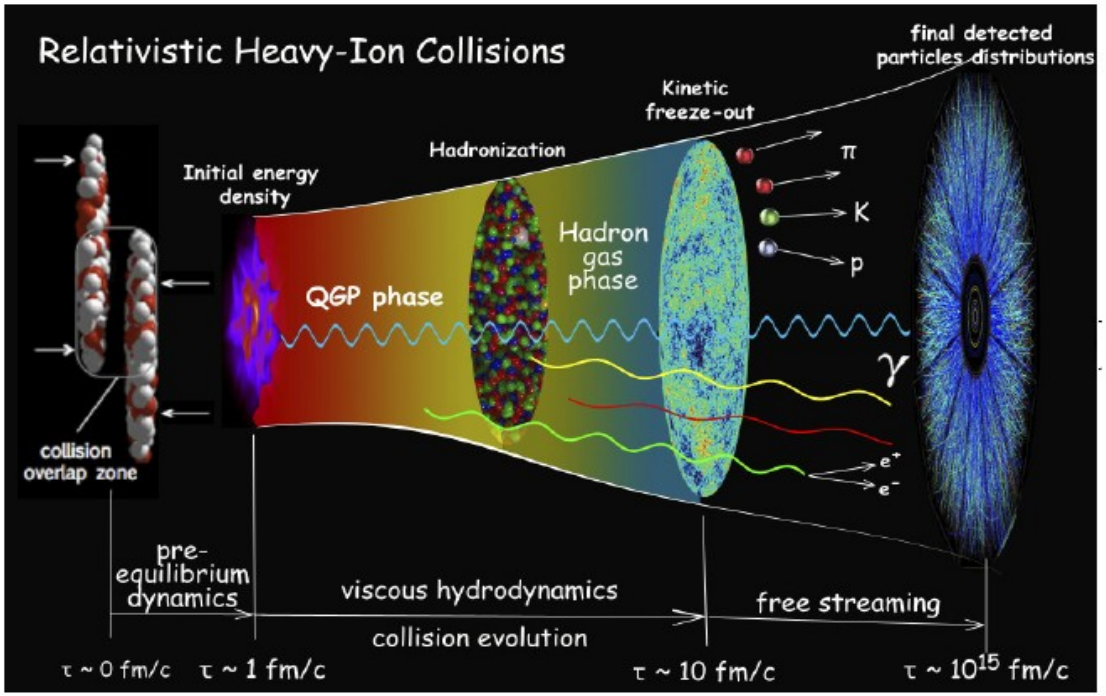
all understood in a broad sense.

Further information at www.gsi.de/emmi

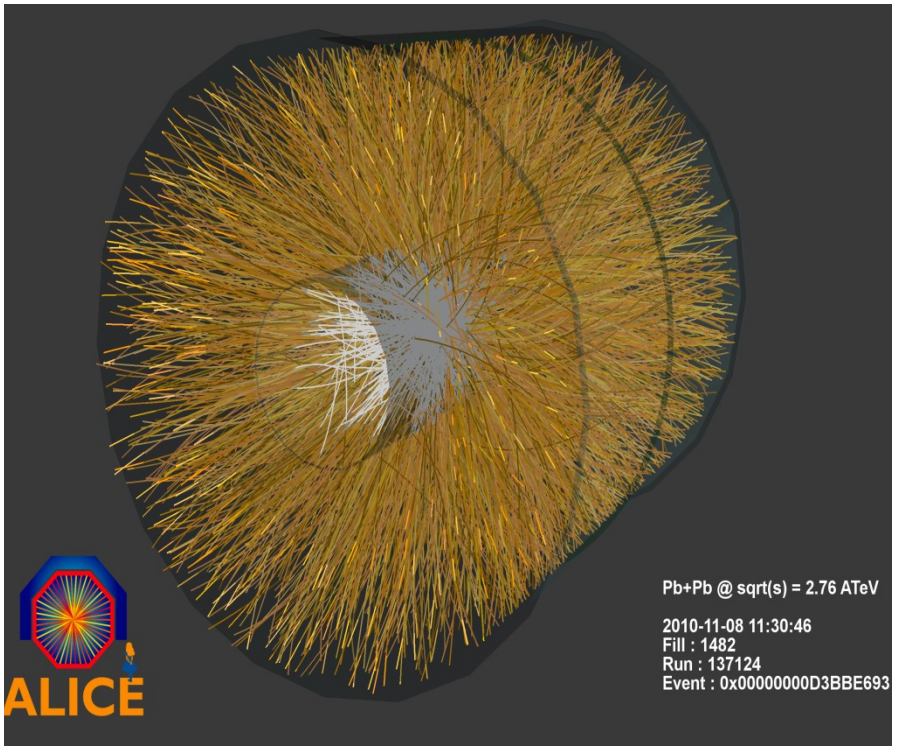
ALICE, Hadron production and the QCD phase boundary

Work performed in collaboration with Anton Andronic, Krzysztof Redlich and Johanna Stachel

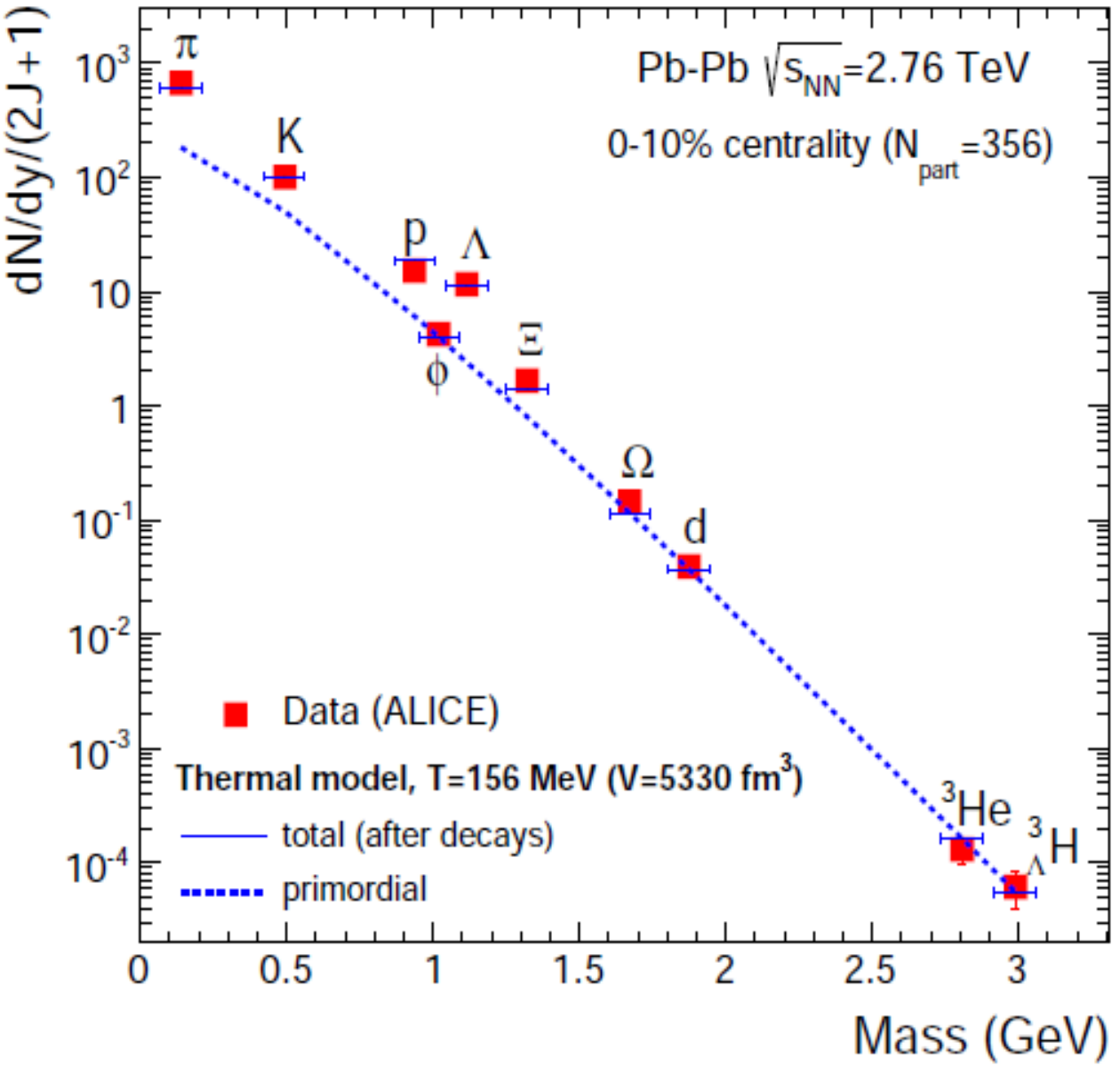
The Quark-Gluon Plasma formed in Nuclear Collisions at very high Energy



Paul Sorensen and Chun Shen

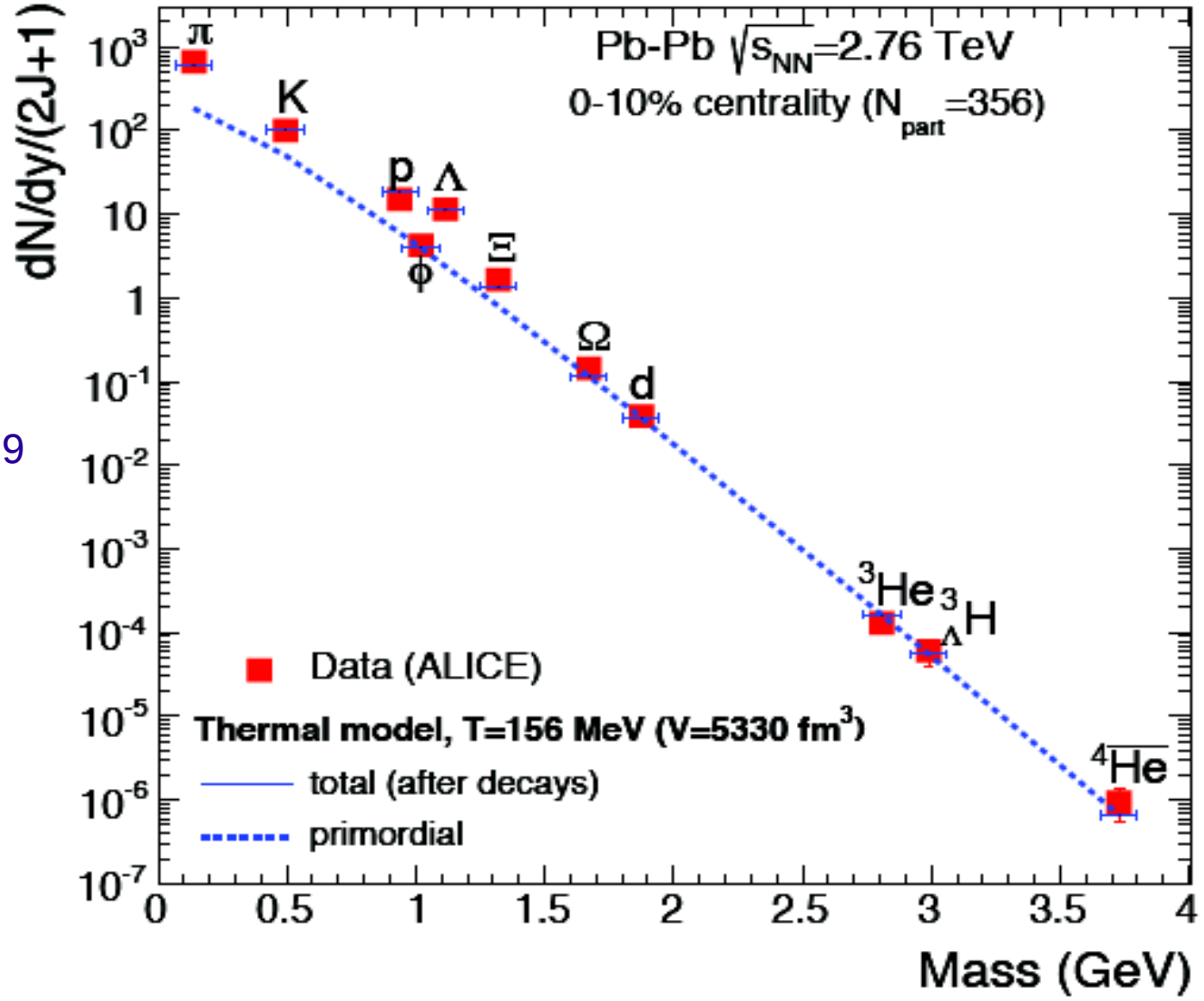


Mass dependence of primordial and total yield compared to LHC data



… and also including anti-alphas

agreement over 9 orders of magnitude with QCD statistical operator prediction



yield of light nuclei predicted in: pbm, J. Stachel, J.Phys. G28 (2002) 1971-1976, J.Phys. G21 (1995) L17-L20

Charmonium as a probe for the properties of the QGP

the original idea: (Matsui and Satz 1986) implant charmonia into the QGP and observe their modification, in terms of suppressed production in nucleus-nucleus collisions with or without plasma formation – sequential melting

new insight (pbm, Stachel 2000) QGP screens all charmonia, but charmonium production takes place at the phase boundary, enhanced production at colliders – signal for deconfined, thermalized charm quarks

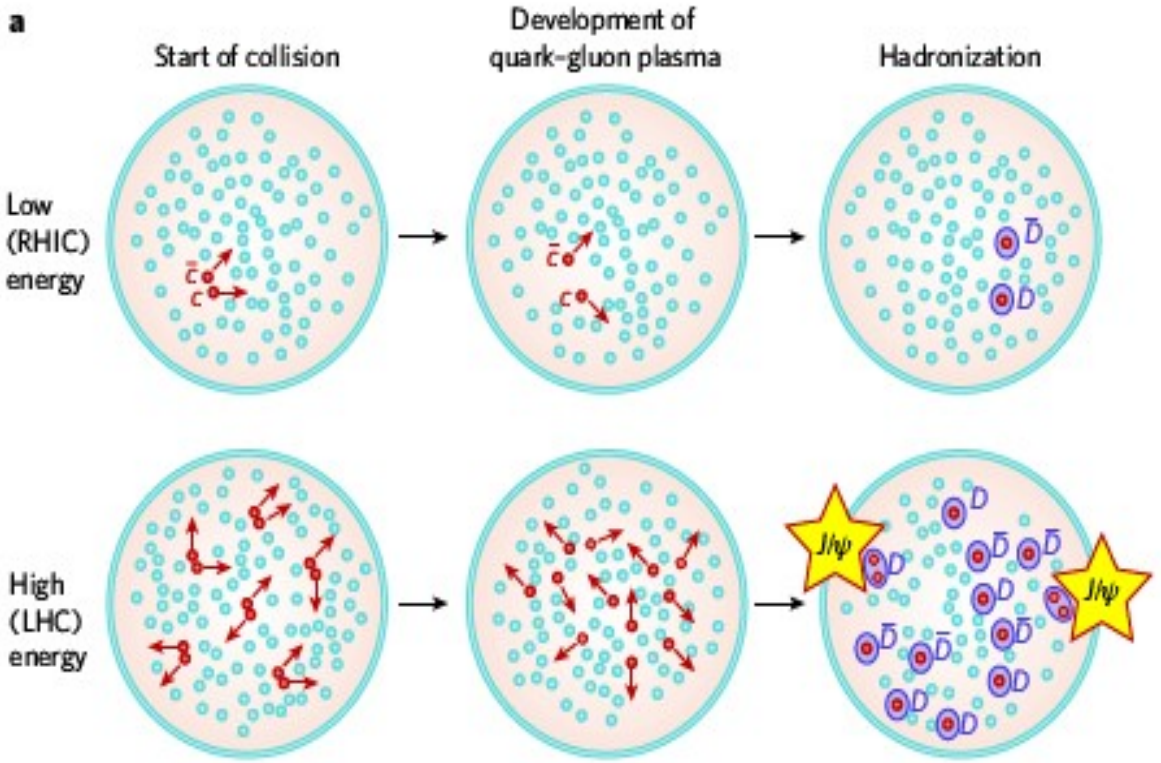
recent reviews: L. Kluberg and H. Satz, arXiv:0901.3831

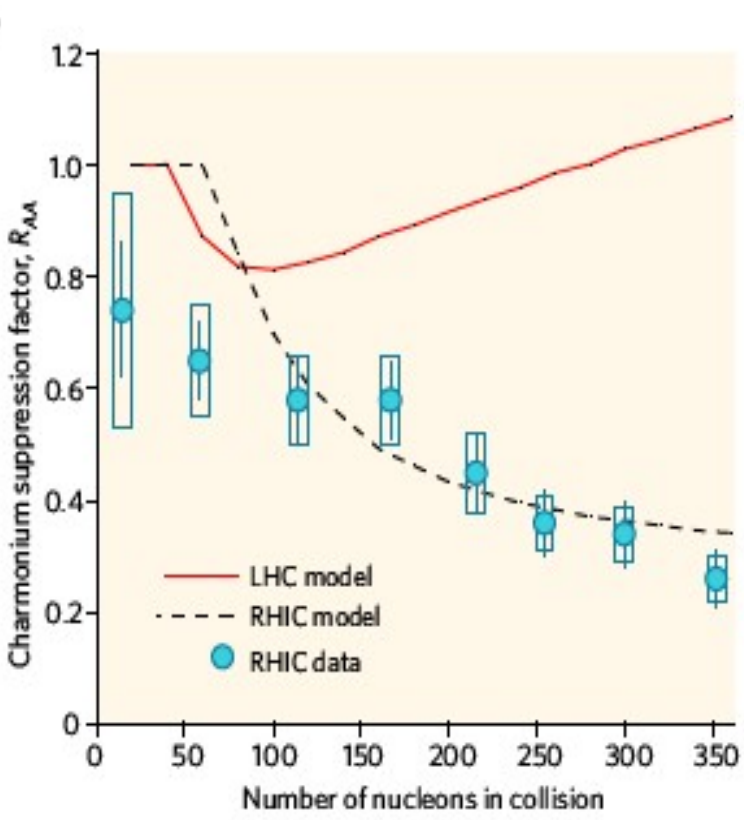
pbm and J. Stachel, arXiv:0901.2500

both published in Landoldt-Boernstein Review, R. Stock, editor, Springer 2010

quarkonium as a probe for deconfinement at the LHC
the statistical (re-)generation picture

P. Braun-Munzinger, J. Stachel, The Quest for the Quark-Gluon Plasma, Nature **448** Issue 7151, (2007) 302-309.

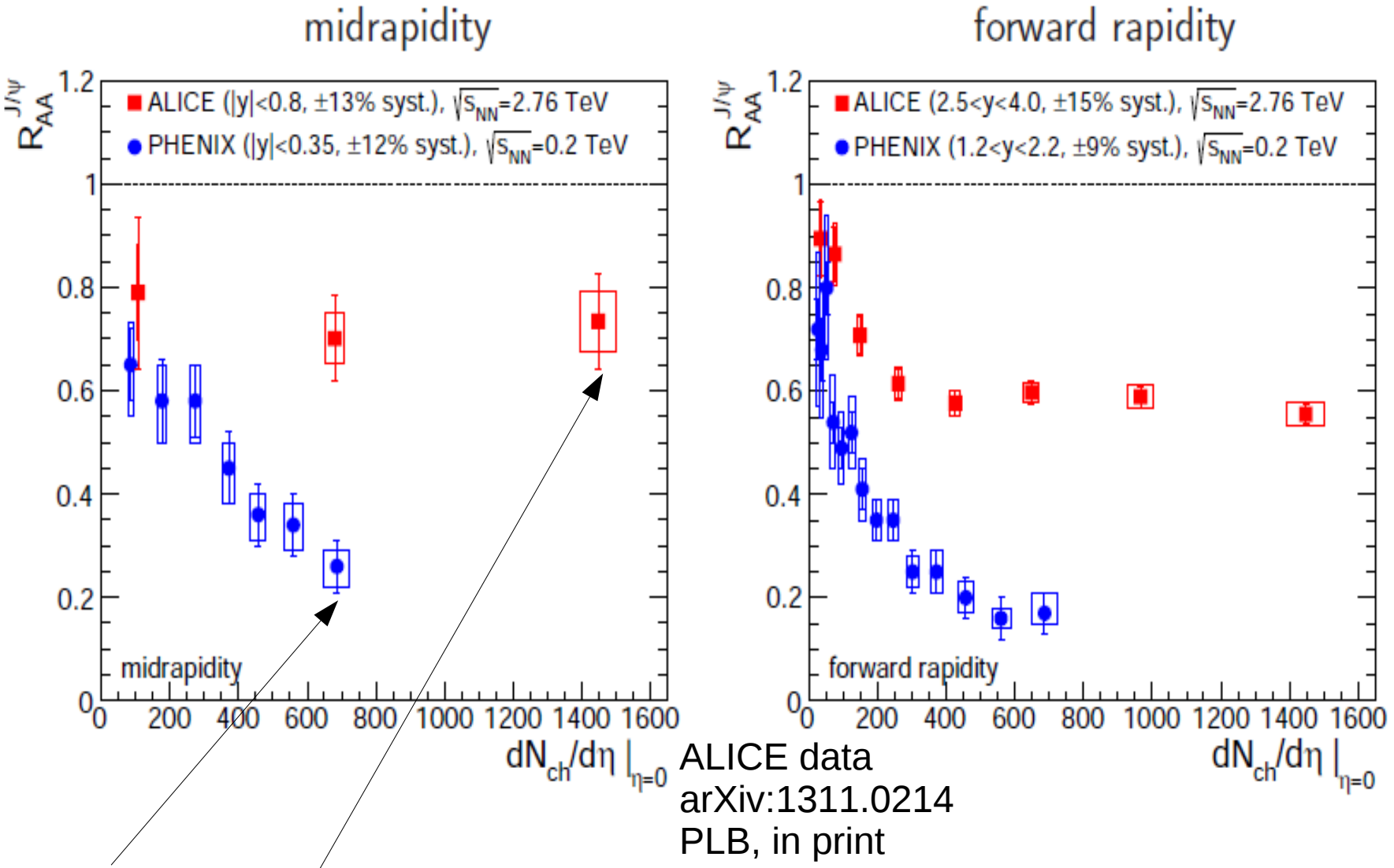




charmonium enhancement as fingerprint of color screening and deconfinement at LHC energy

pbm, Stachel, Phys. Lett. B490 (2000) 196
Andronic, pbm, Redlich, Stachel, Phys. Lett. B652 (2007) 659

less suppression when increasing the energy density



ALICE data
arXiv:1311.0214
PLB, in print

from here to here more than factor of 2 increase in energy density, but R_{AA} increases by more than a factor of 3

2007 prediction impressively confirmed by LHC data

Charmonium production at LHC energy: deconfinement,and color screening

- Charmonia formed at the phase boundary → full color screening at T_c

- Debye screening length < 0.4 fm near T_c

- Combination of uncorrelated charm quarks into J/psi → deconfinement

statistical hadronization picture of charmonium production provides most direct way towards information on the degree of deconfinement reached as well as on color screening and the question of bound states in the QGP

Debye mass, LQCD, and J/psi data

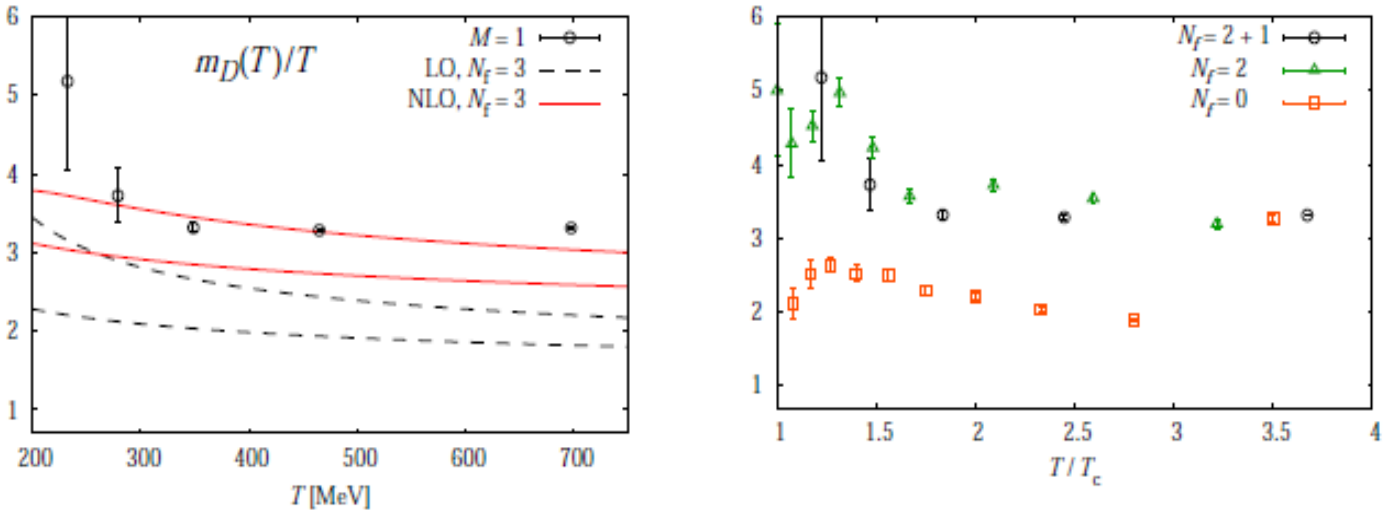


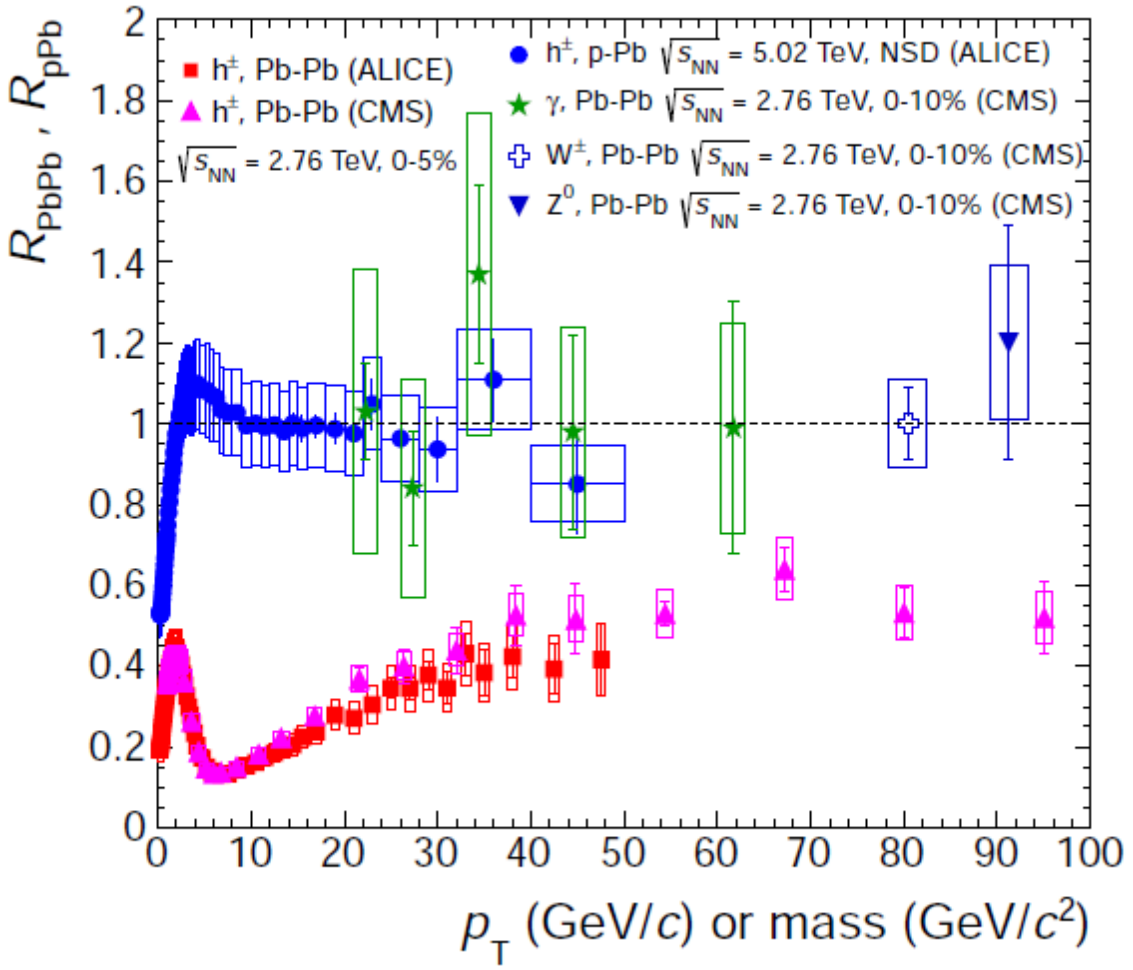
Fig. 6. (Left) The Debye screening mass on the lattice in the color-singlet channel together with that calculated in the leading-order (LO) and next-to-leading-order (NLO) perturbation theory shown by dashed-black and solid-red lines, respectively. The bottom (top) line expresses a result at $\mu = \pi T$ ($3\pi T$), where μ is the renormalization point. (Right) Flavor dependence of the Debye screening masses. We assume the pseudo-critical temperature for $2+1$-flavor QCD as $T_c \sim 190$ MeV.

arXiv:1112.2756 WHOT-QCD Coll.

from J/psi data and statistical hadronization analysis: $m_{Debye}/T > 3.3$ at T = 0.15 GeV

Synopsis of Energy Loss measurements for Strongly Interacting Hard Probes

no suppression in pPb, QGP opaque for high energy partons



Alice coll.,

arXiv:1405.2737

photons, Z and W scale with number of binary collisions in PbPb – not affected by medium

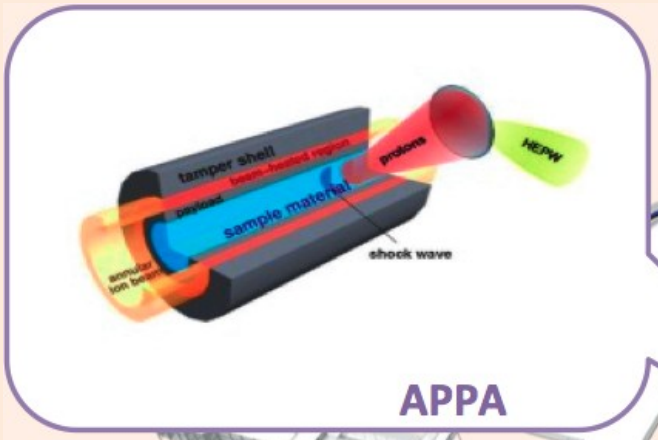
→ demonstrates that charged particle suppression is medium effect: energy loss in QGP

Now to FAIR

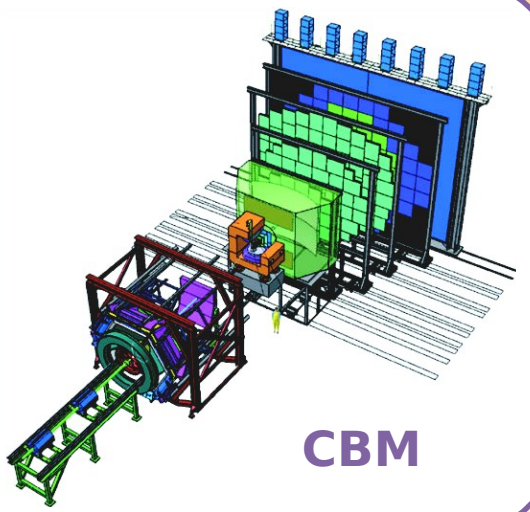
will focus on NUSTAR, CBM and PANDA, + schedule

exciting physics opportunities also for atomic physics, plasma physics, material science and biophysics – APPA pillar

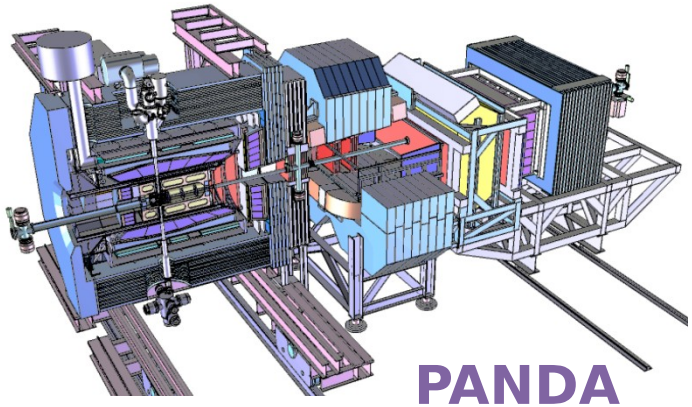
FAIR Experiments



APPA



CBM



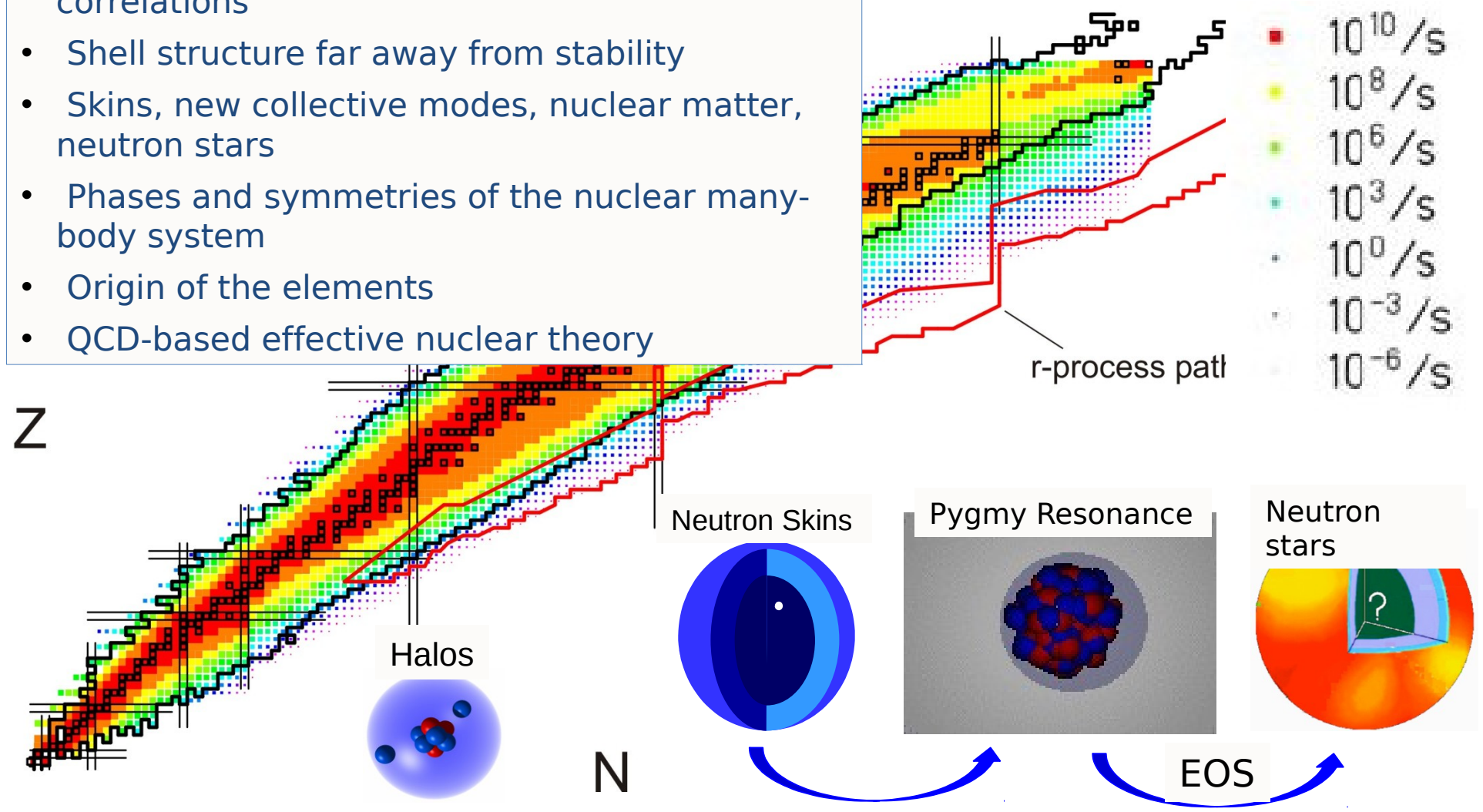
PANDA

Super-FRS

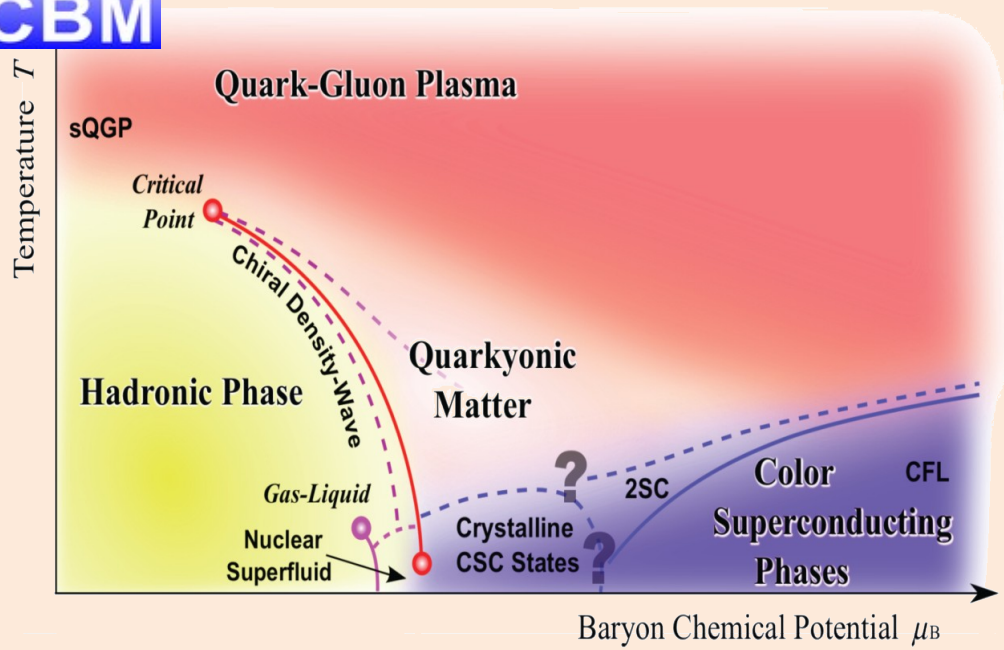
NuSTAR

NuSTAR – Nuclear STructure, Astrophysics and Reactions

- Quest for the limits of existence
- Halos, open quantum systems, few-body correlations
- Shell structure far away from stability
- Skins, new collective modes, nuclear matter, neutron stars
- Phases and symmetries of the nuclear many-body system
- Origin of the elements
- QCD-based effective nuclear theory

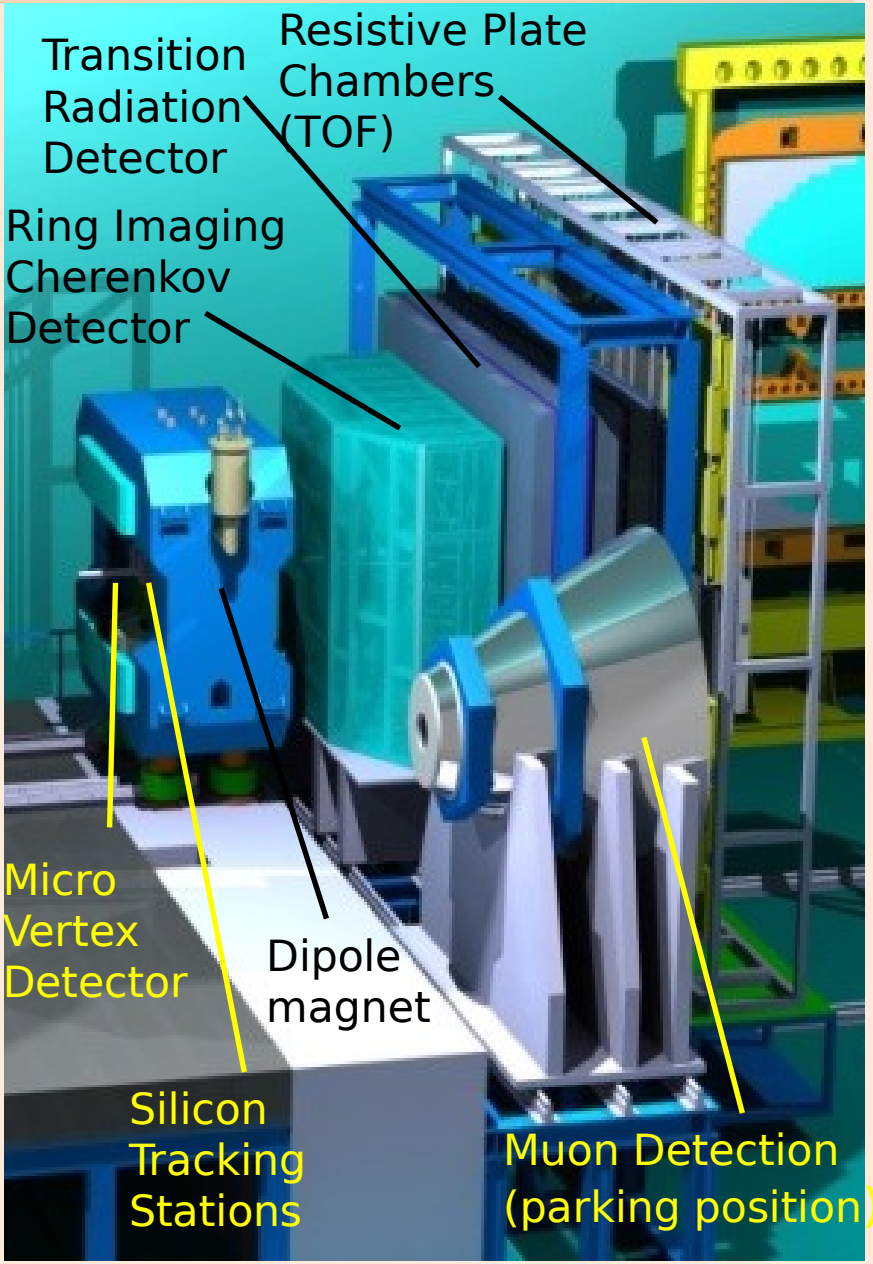


CBM – Compressed Baryonic Matter



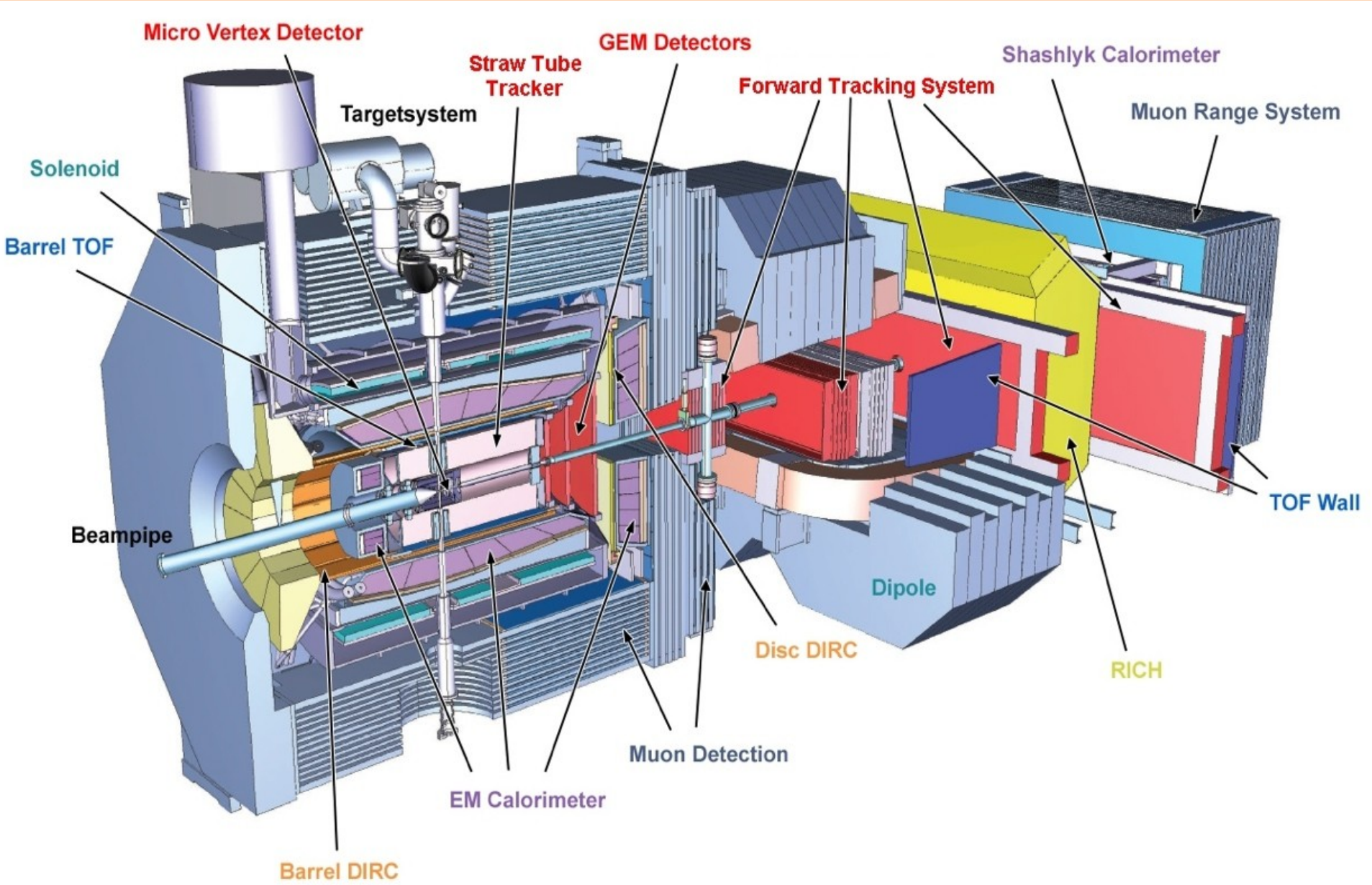
- Equation-of-state of matter at neutron star core densities.
- Phase transitions from hadronic matter to quarkyonic or partonic matter at high net-baryon densities.
- Electro-magnetic radiation from the dense fireball.
- Chiral symmetry restoration in dense baryonic matter.
- Charm production in (dense)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

- Challenge: 10 MHz interaction rate on fixed target



> 500 members

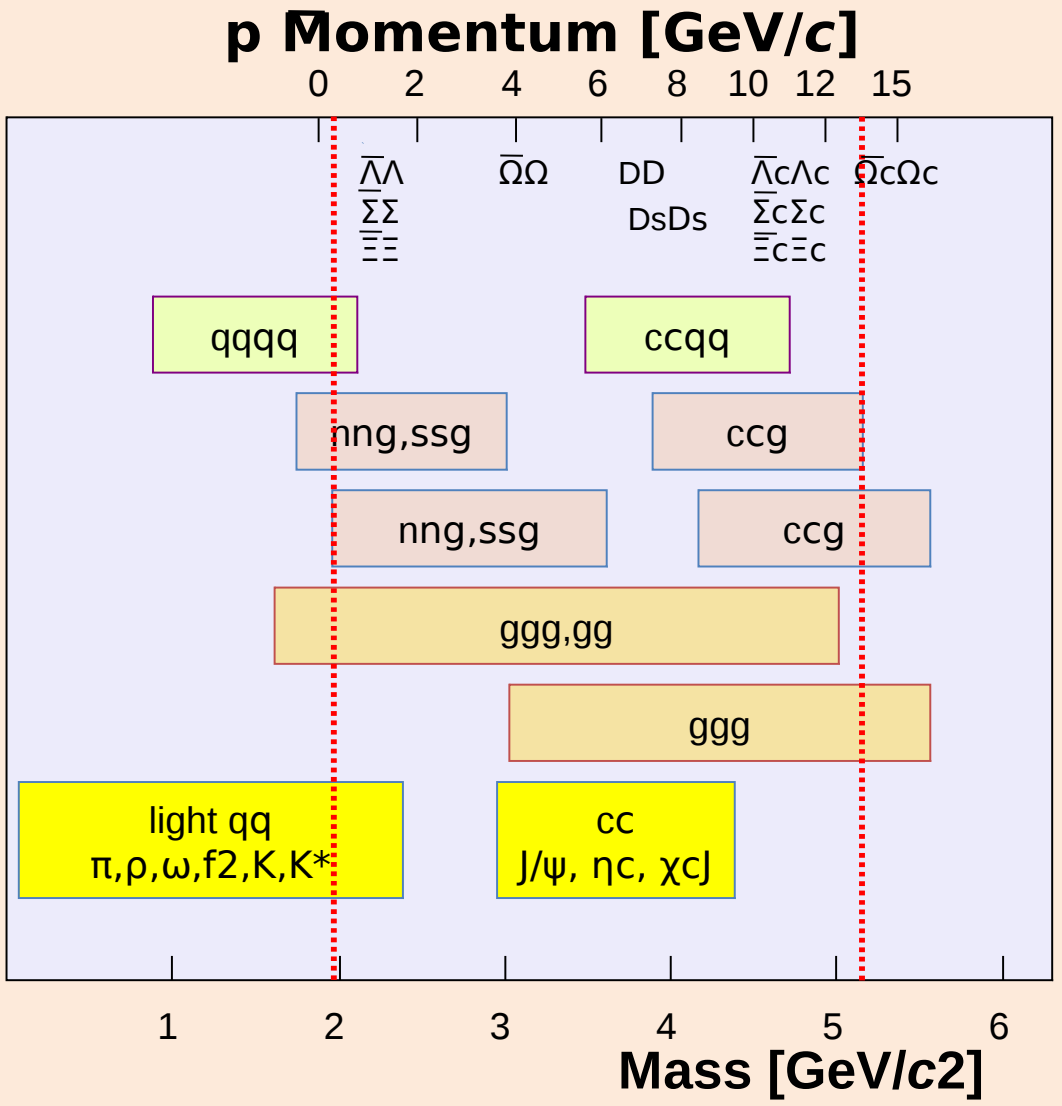
PANDA – Antiproton Annihilation



PANDA Scientific Pr

- Nucleon structure
  E.M. processes
-
- Meson spectroscopy
  - light mesons
  - charmonium
  - exotic states
- glueballs
- hybrids
- molecules/multiquarks
  - open charm

- S=2,3 and C=1 (excited) Baryon/antibaryon spectroscopy
- Charm in nuclei
- Strangeness physics
  - S = -2 nuclear system
- Ξ− nuclei
- ΛΛ hypernuclei



FAIR Civil Construction (May, June 2014)

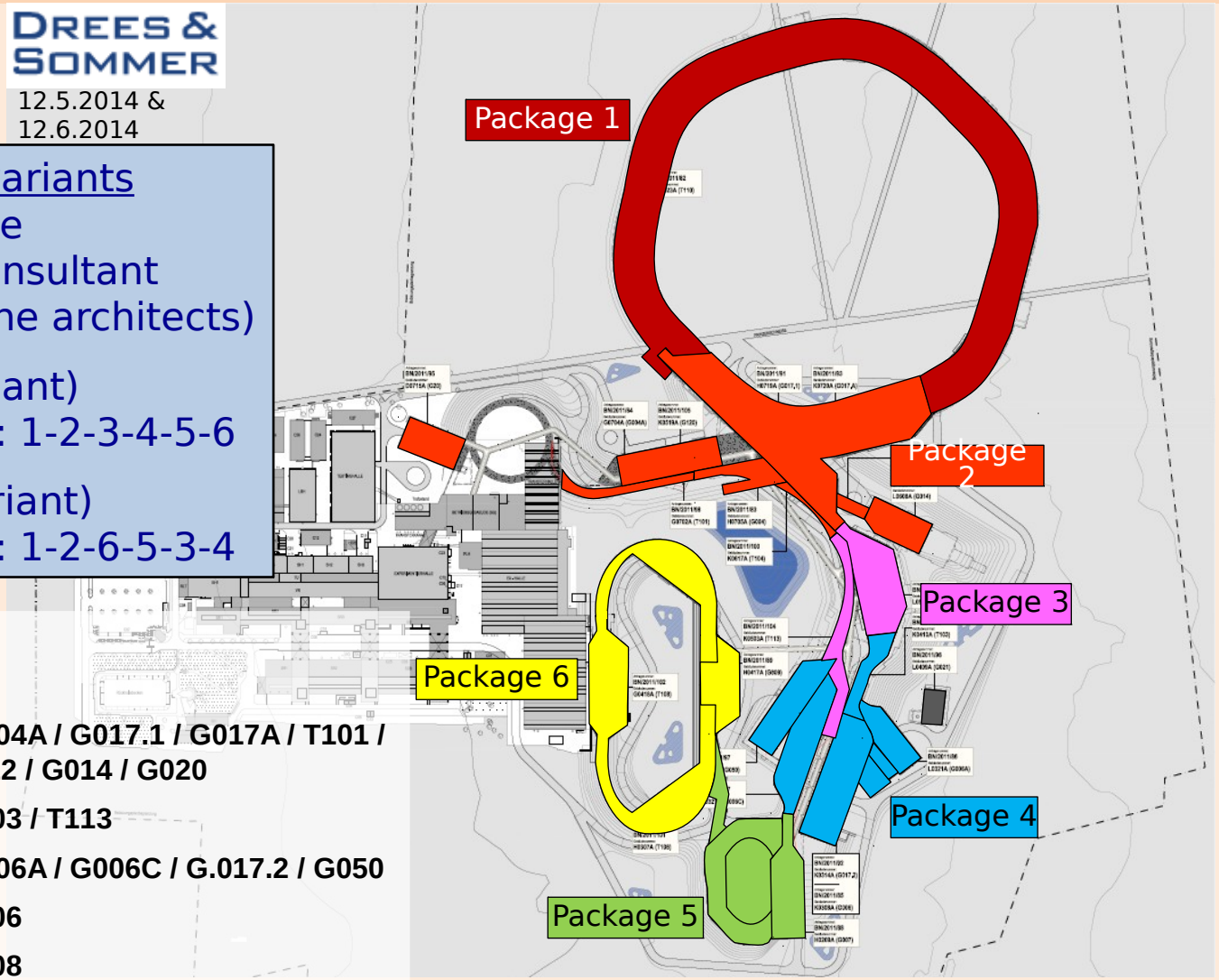
DREES & SOMMER

12.5.2014 &
12.6.2014

Civil construction variants
as suggested by the
Project Steering Consultant
(not approved by the architects)

12.5.2014 (1st variant)
Package Sequence: 1-2-3-4-5-6

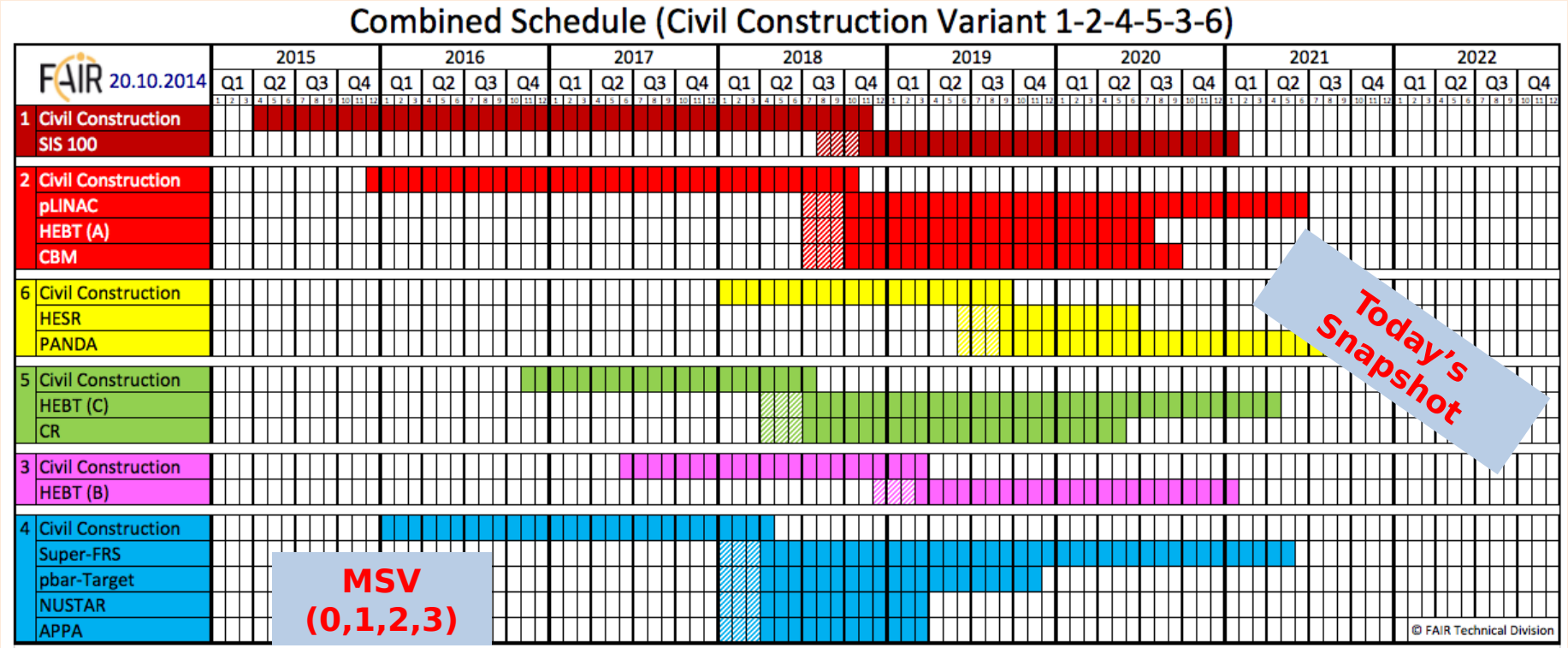
12.6.2014 (2nd variant)
Package Sequence: 1-2-6-5-3-4



Legend:

Package 1	**T110**
Package 2	**G004 / G004A / G017.1 / G017A / T101 / T104 / T112 / G014 / G020**
Package 3	**G018 / T103 / T113**
Package 4	**G006 / G006A / G006C / G.017.2 / G050**
Package 5	**G007 / T106**
Package 6	**G009 / T108**

FAIR Combined Schedule (20.10.2014) variant 3



FAIR Modularised Start Version (MSV) anticipated in 09/2021, compared to 02/2023 (variant 2). ⁼ **Preferred solution**