Perspectives for Heavy-Ion Collisions at Future Facilities

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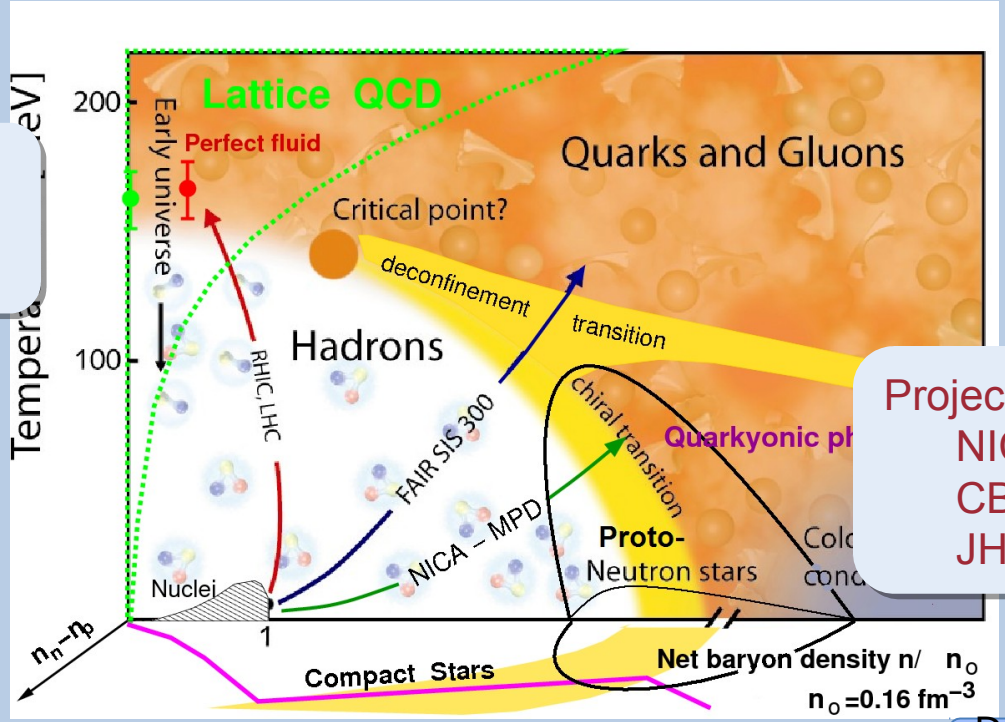
GSI Darmstadt

CPOD 2016, Wroclaw, 30 May 2016

What‘s It All About

Current players:
BES @ RHIC
NA61 @ SPS



Projects:
NICA @ JINR
CBM @ FAIR
JHITS @ J-PARC

Diagram: Courtesy A. Sorin

Searching for the features of the QCD phase diagram:

- Is there a critical point, and if yes, where?
- Where is deconfinement first reached?
- Is there a first-order phase transition?
- Is there a difference between chiral and deconfinement transition?

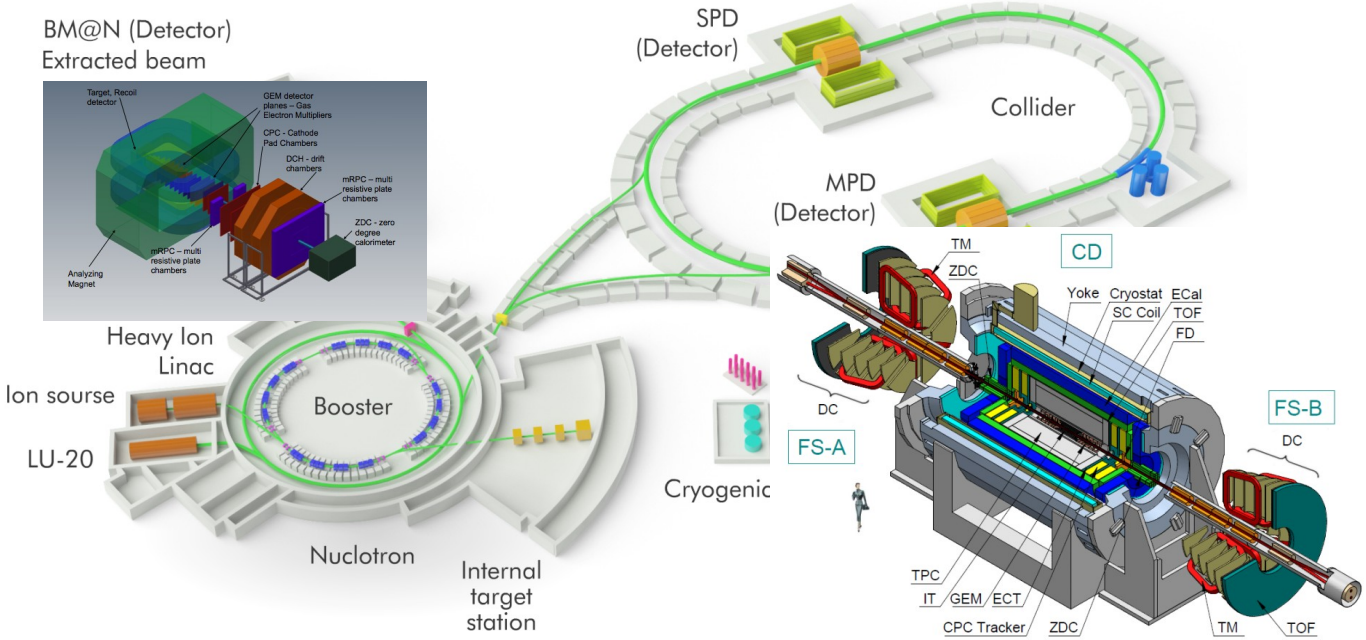
Experimental Handles

- Fluctuations: expected near the critical point
- Flow: access to the equation-of-state
- Strangeness: equilibration as signal for phase transition?
- Lepton pairs: thermal radiation as thermometer -> caloric curve
- Charm: probe of the early collision stage

Experimental knowledge on these below top SPS energies is scarce (limited to bulk probes, limited in statistics), or missing.

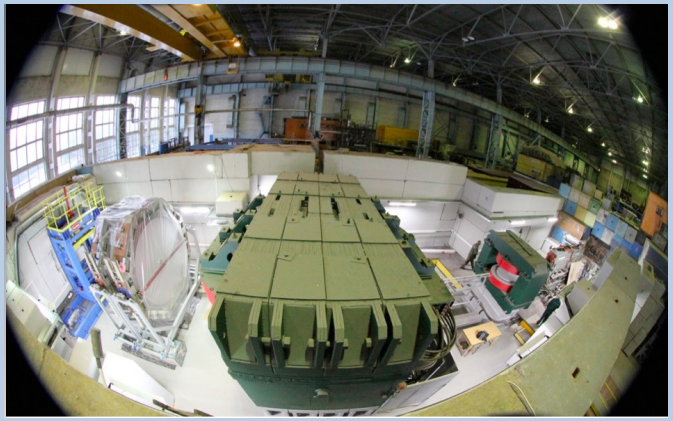
Future experiments must improve the data situation decisively!

The NICA Project



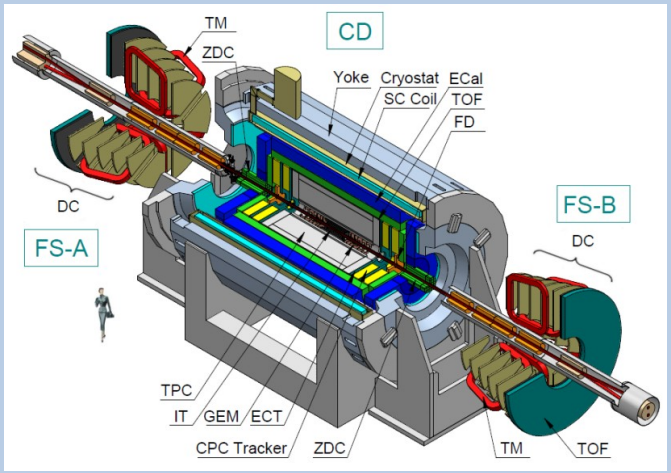
Collider luminosity (Au beams): 10^{27} $cm^{-2}s^{-2}$
Extracted beams for fixed-target experiments
Polarized p and d beams

QCD Matter Physics at NICA



BM@N:

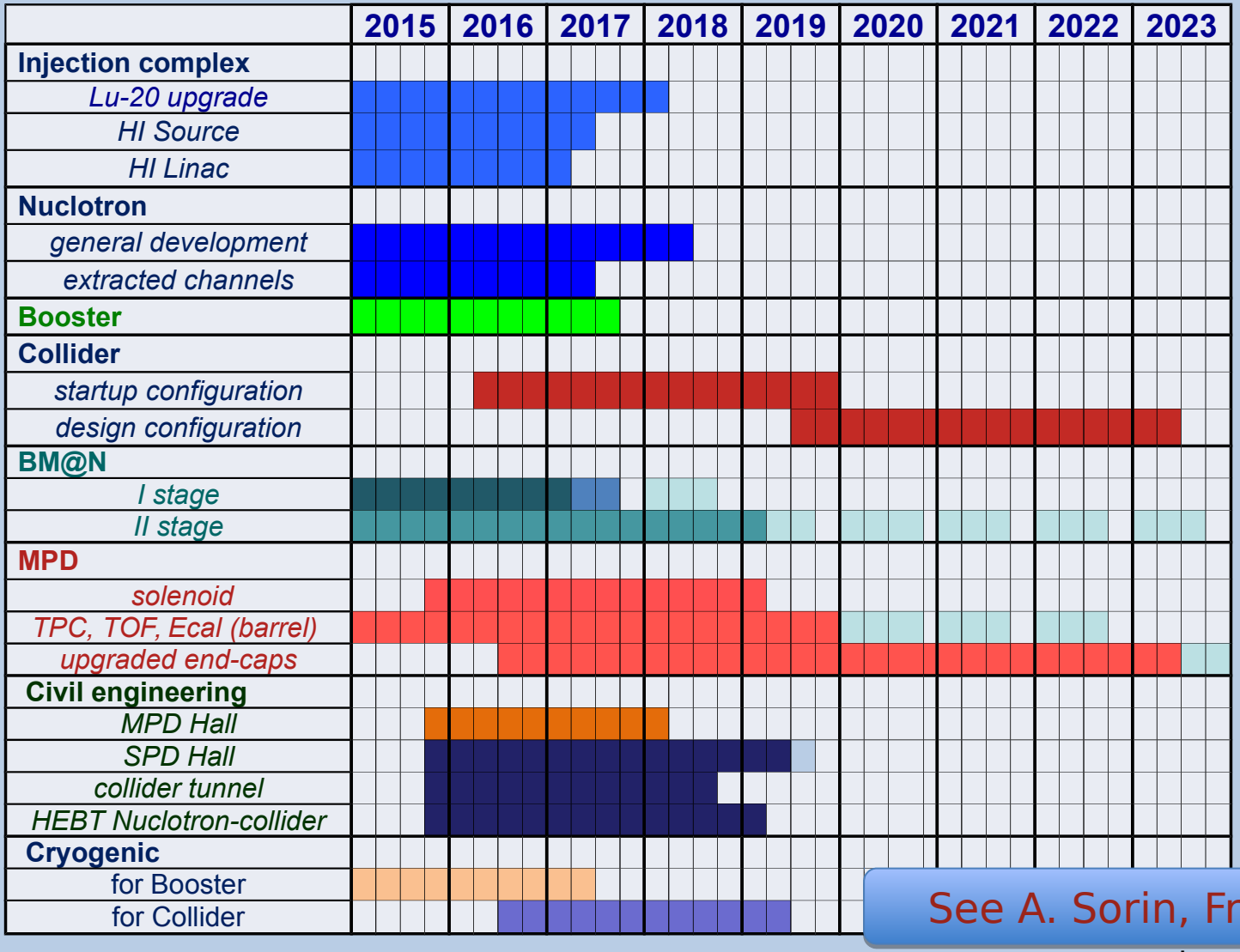
- Fixed-target, E_{beam} = 1A – 4.5A GeV from Nuclotron
- Interaction rates up to 50 kHz
- Measurement of hadrons
- Time line: light ion beams 2017, heavy ion beams 2019



MPD:

- Collider experiment, sqrt(s_{NN}) = 4 – 11 GeV
- Interaction rate up to 10 MHz (depending on energy)
- Hadron and lepton measurements
- Time line (staged): 2019 - 2013

NICA Timelines



See A. Sorin, Friday

operation

The FAIR Project

Nuclear Structure & Astrophysics
(Rare-isotope beams)

Hadron Physics
(Stored and cooled
14 GeV/c anti-protons)

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

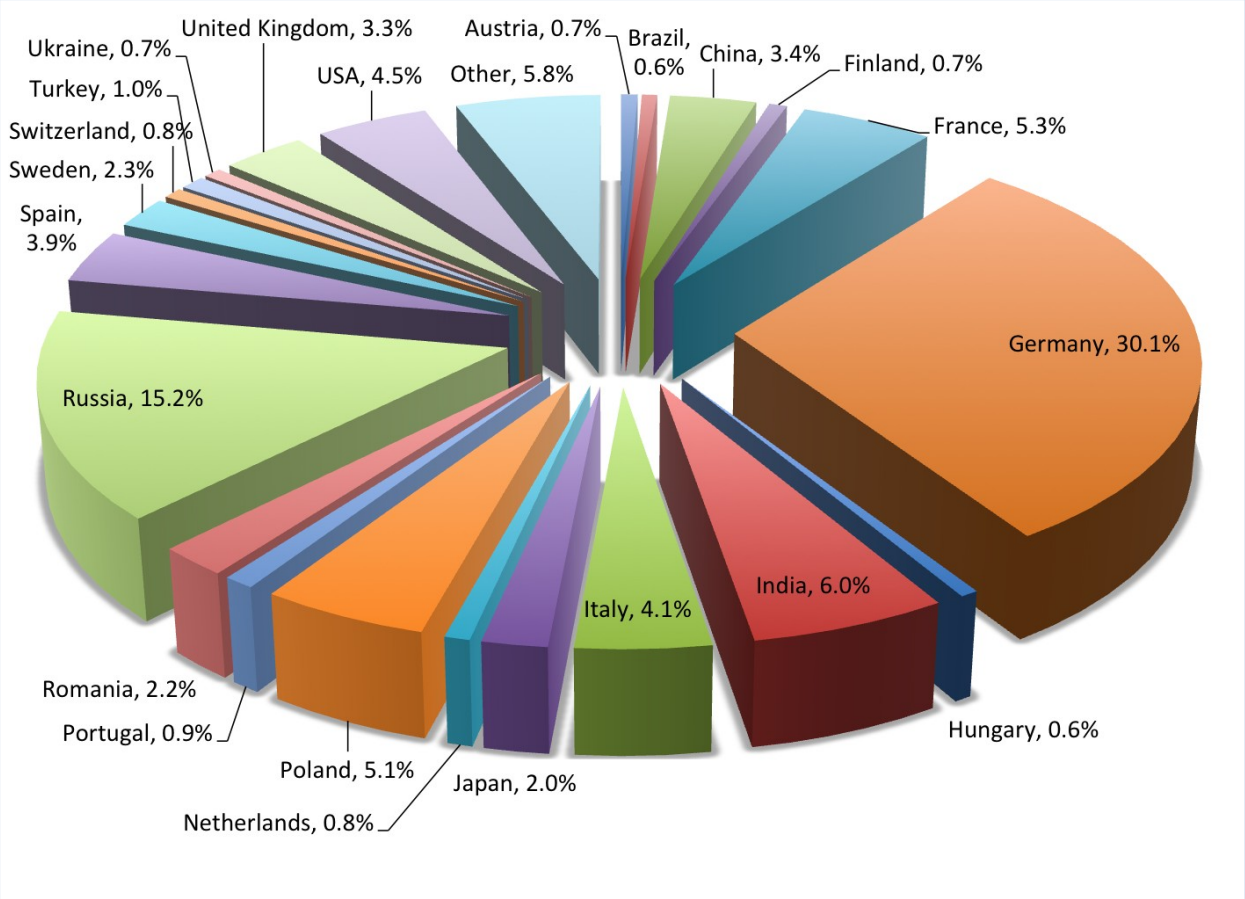
Fundamental Symmetrie
& Ultra-High EM Fields
(Antiprotons & highly str

Dense Bulk Plasmas
(Ion-beam bunch compre
& petawatt-laser)

Materials Science & Radiation Biology
(Ion & antiproton beams)

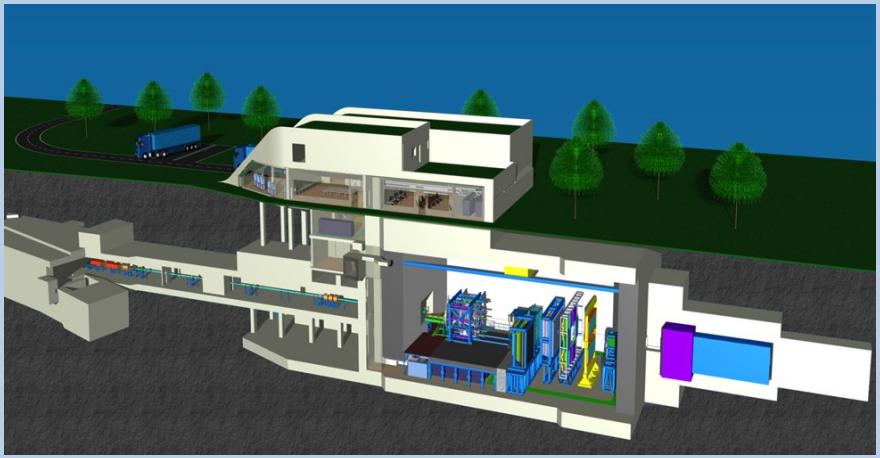
Accelerator Physic

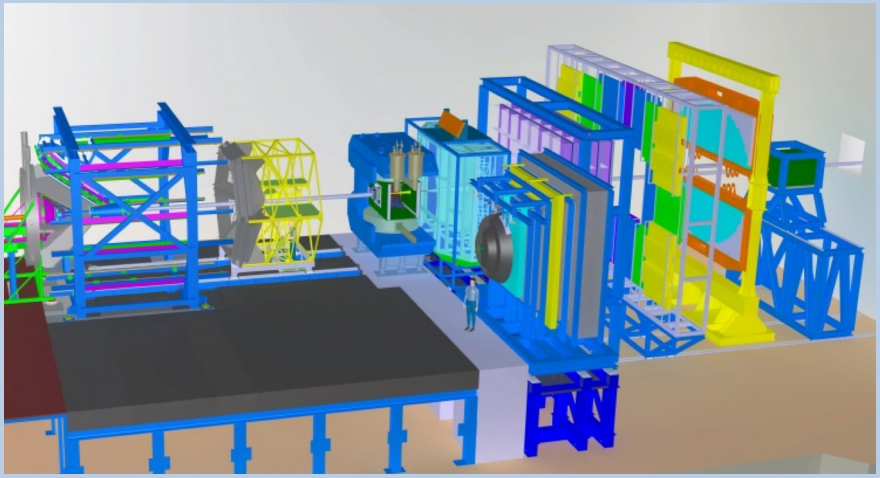
FAIR Scientific Community



1,800 senior scientists / 3,000 total

QCD Matter Physics at FAIR





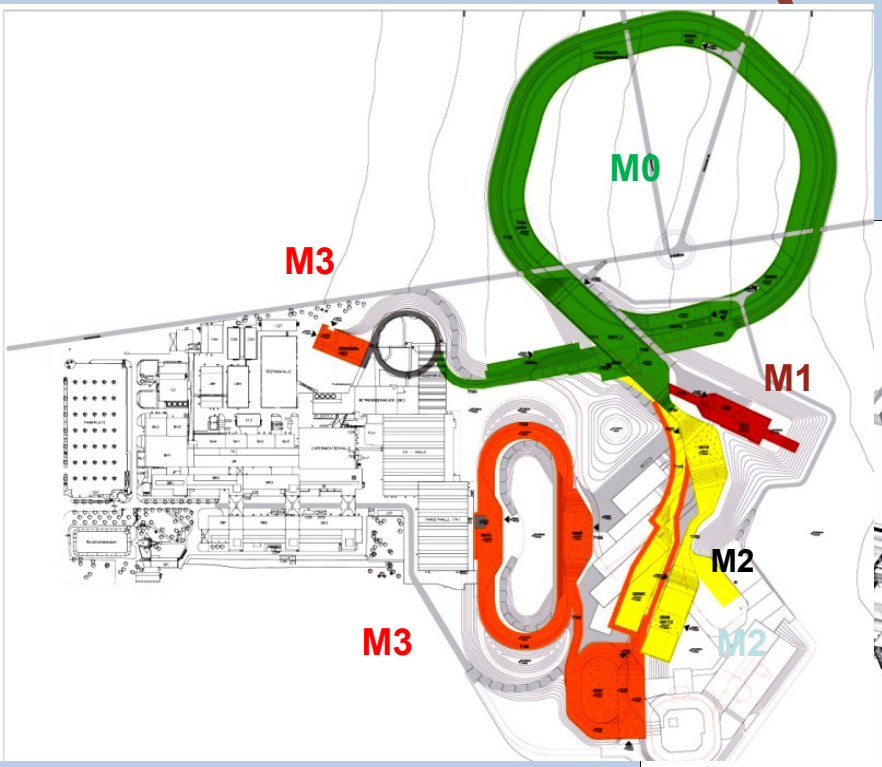
- Experiments: CBM and HADES (both fixed-target)
- HADES (existing): measurements with proton and medium-mass ion beams at lower SIS100 energies (up to 4A GeV)
- CBM (new):
  - Designed for p, light ions from SIS100/300 (35A GeV for Au, 45A GeV for symmetric nuclei)
  - Comprehensive research programme: hadrons, leptons, charm
  - [illegible]

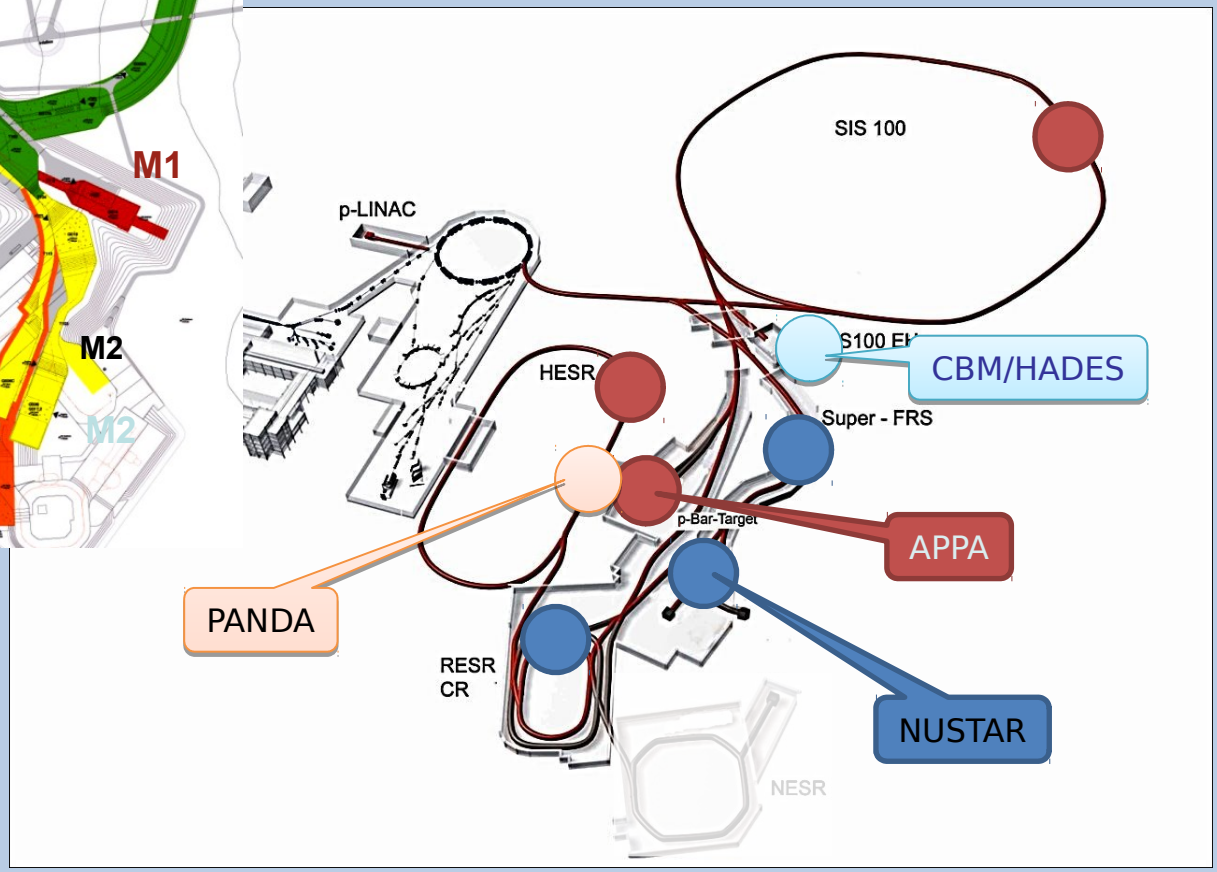
See C. Blume, Wednesday

FAIR Staging Plan

Baseline Technical Report 2005						
Start Version Phase A 2007 (SIS100)						**Phase B** (SIS300)
Modularised Start Version 2009						
Module **0**	Module **1**	Module **2**	Module **3**	Module **4**	Module **5**	
SIS100	**Exp. halls** *CBM & APPA*	**Super-FRS** *NuSTAR*	**Antiproton Facility** *PANDA & options NuSTAR*	**LEB, NESR, FLAIR** *NuSTAR & APPA*	**RESR** *PANDA, NuSTAR & APPA*	

FAIR Modularized Start Version (MSV)





Modules

M0: SIS100

M1: APPA

M1: CBM/HADES

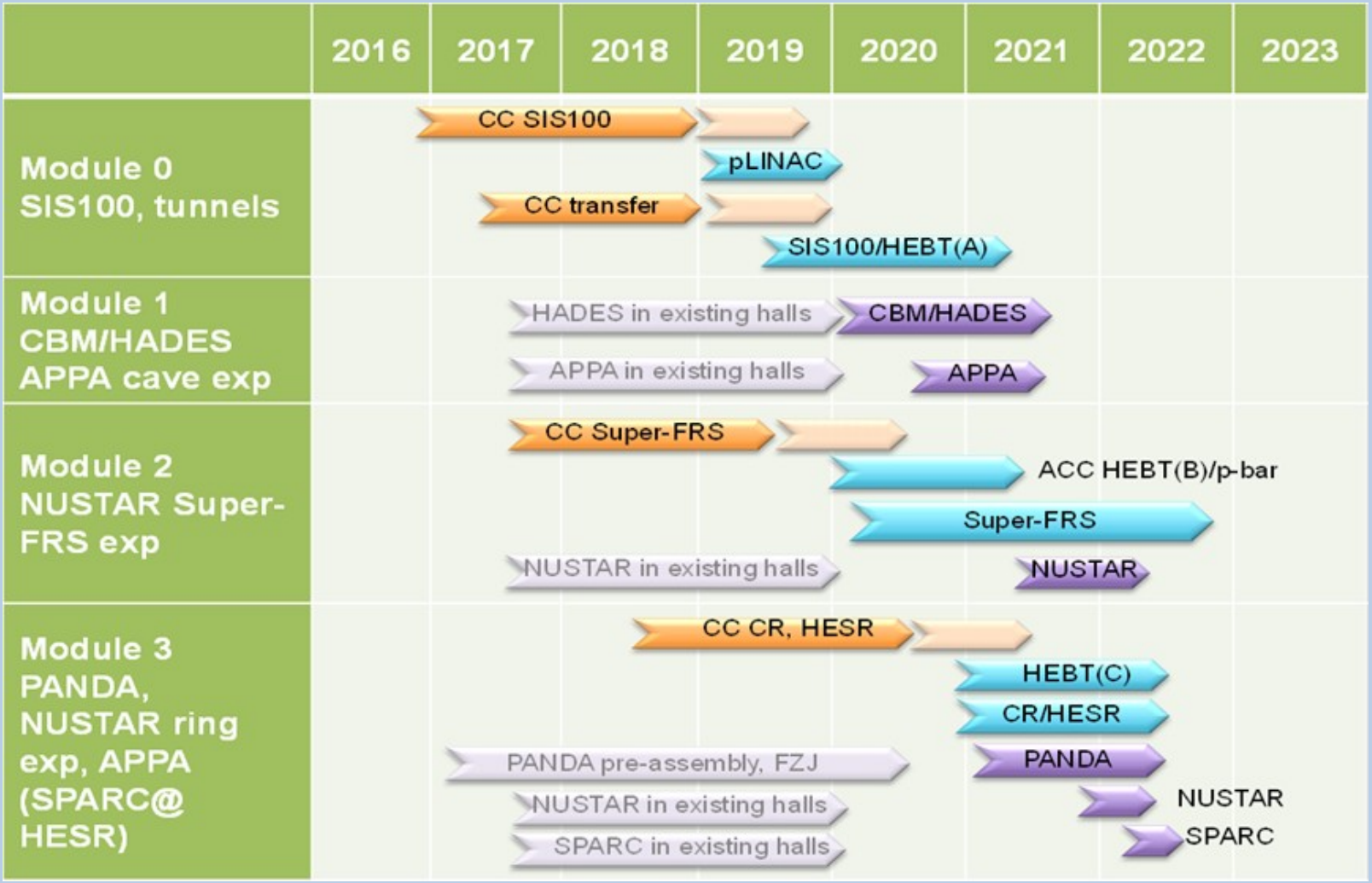
M2: NUSTAR

M3: PANDA, NuSTAR, APPA

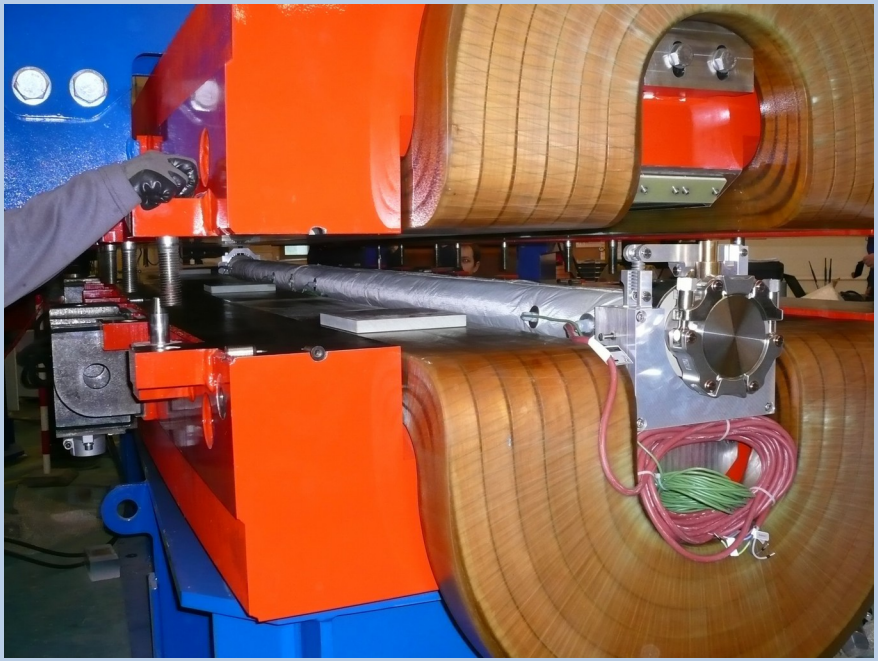
Developments 2015

- Severe problems with civil construction
  - Substantial cost increase
  - Delay of construction start
- Re-assessment of physics cases / experiments in view of delay
  - Scientific merit, discovery potential, competitiveness, funding
  - Outcome: the scientific cases of all four FAIR pillars are compelling
  - The MSV is considered to offer the best science-to-cost ratio
- Decision by the FAIR Council September 2015:
  - MSV will be realised; start of construction as soon as possible
  - Additional funding will be raised by the FAIR member states

FAIR-MSV Schedule



FAIR In Progress



Dipole series production started
19 / 46 specimen available (1 is delivered each two weeks)
Mounting of vacuum chambers started (FZ Jülich)
Completion of delivery expected Q2 / 2017

FAIR In Progress

Quadrupole reference magnet accepted March 2015
21 / 84 specimen available
Mounting of units at FZ Jülich
Completion of delivery expected Q2 / 2017

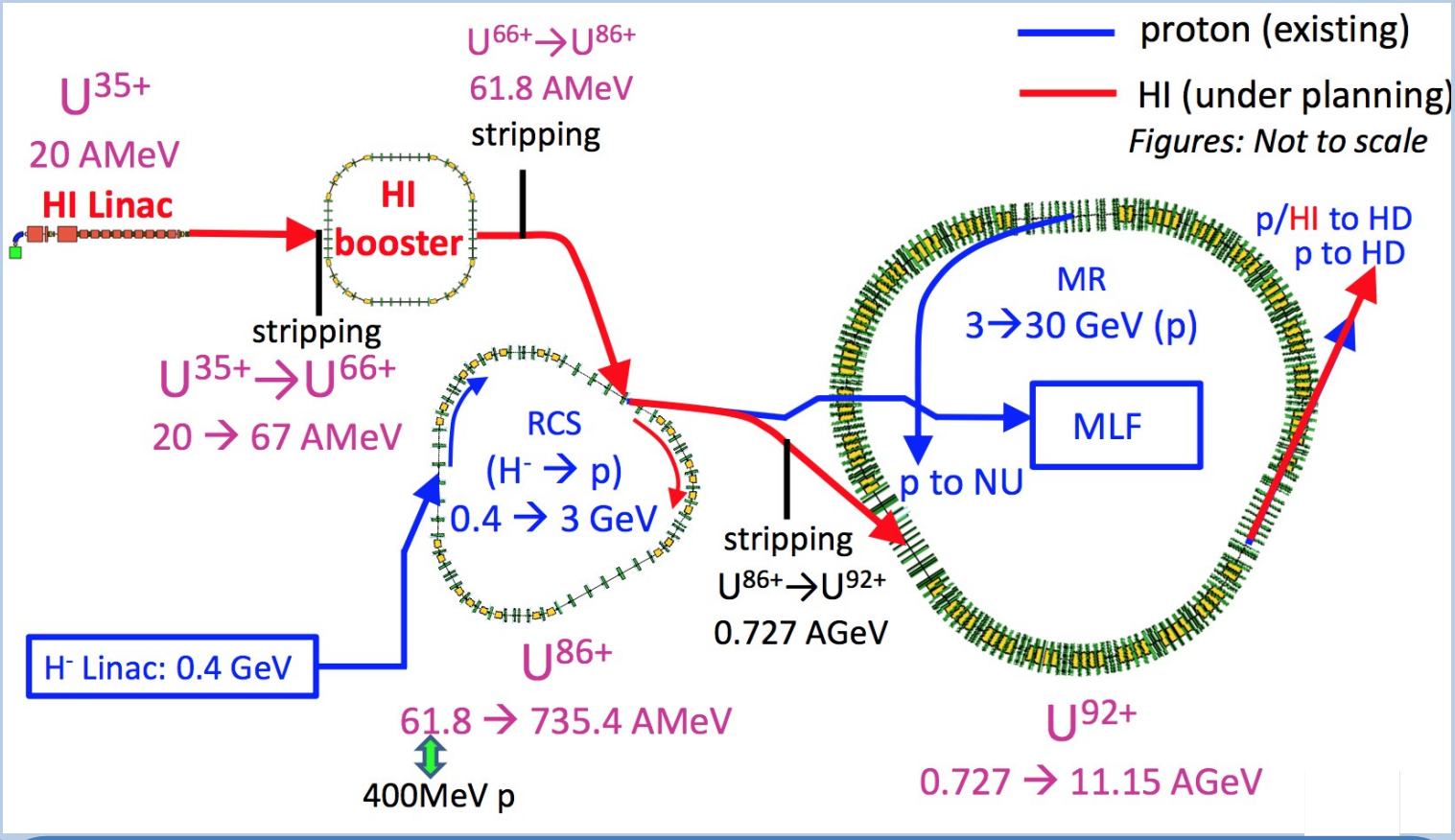
FAIR beyond MSV

- Intention: Reach full power of FAIR at the earliest possible

- Strategy:
  - Installation of RESR
    - Full luminosity for PANDA
  - Installation of SIS-300
    - Tunnel design unchanged; can be installed without major modifications
    - High energy (35A GeV Au) for CBM
    - Parallel operation of up to six experiments
  - Other programmes: FLAIR, EXL, ELISe

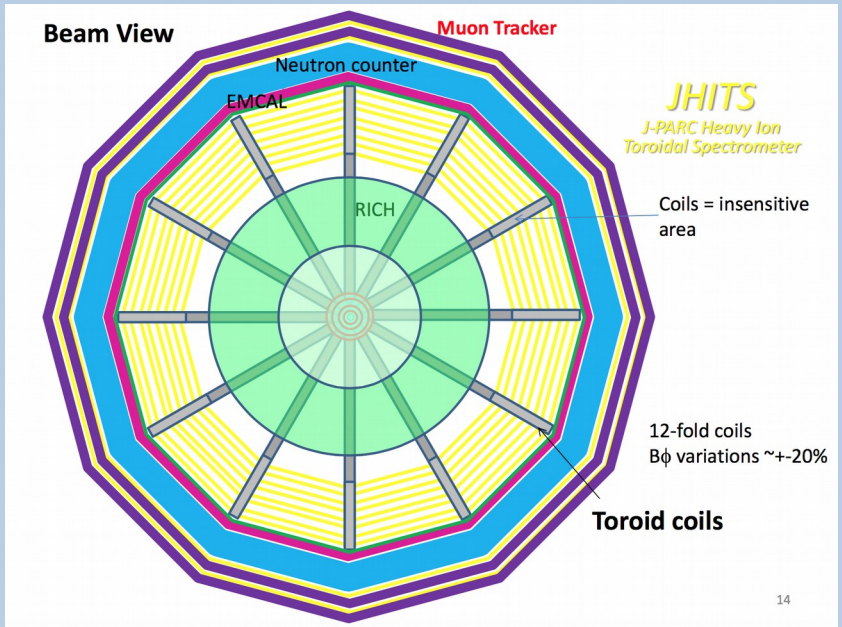
- Details to be refined closer to finalisation of MSV

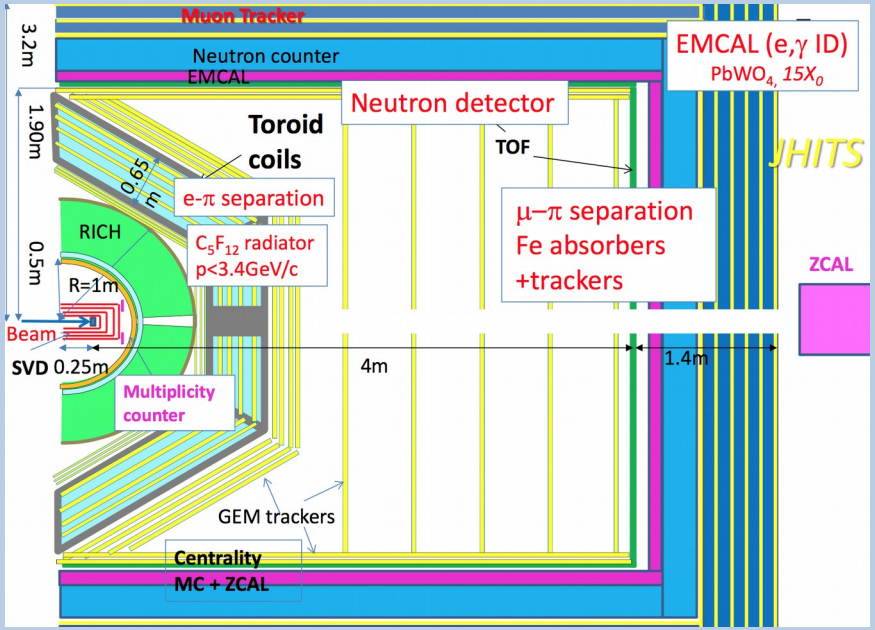
Plans at J-PARC



Additional ion acceleration scheme
Extracted beams for fixed-target experiments
Energy: 1A – 19A GeV
Extreme rates (4 x 10^{11} / cycle)

J-PARC: Ideas on a HI Detector





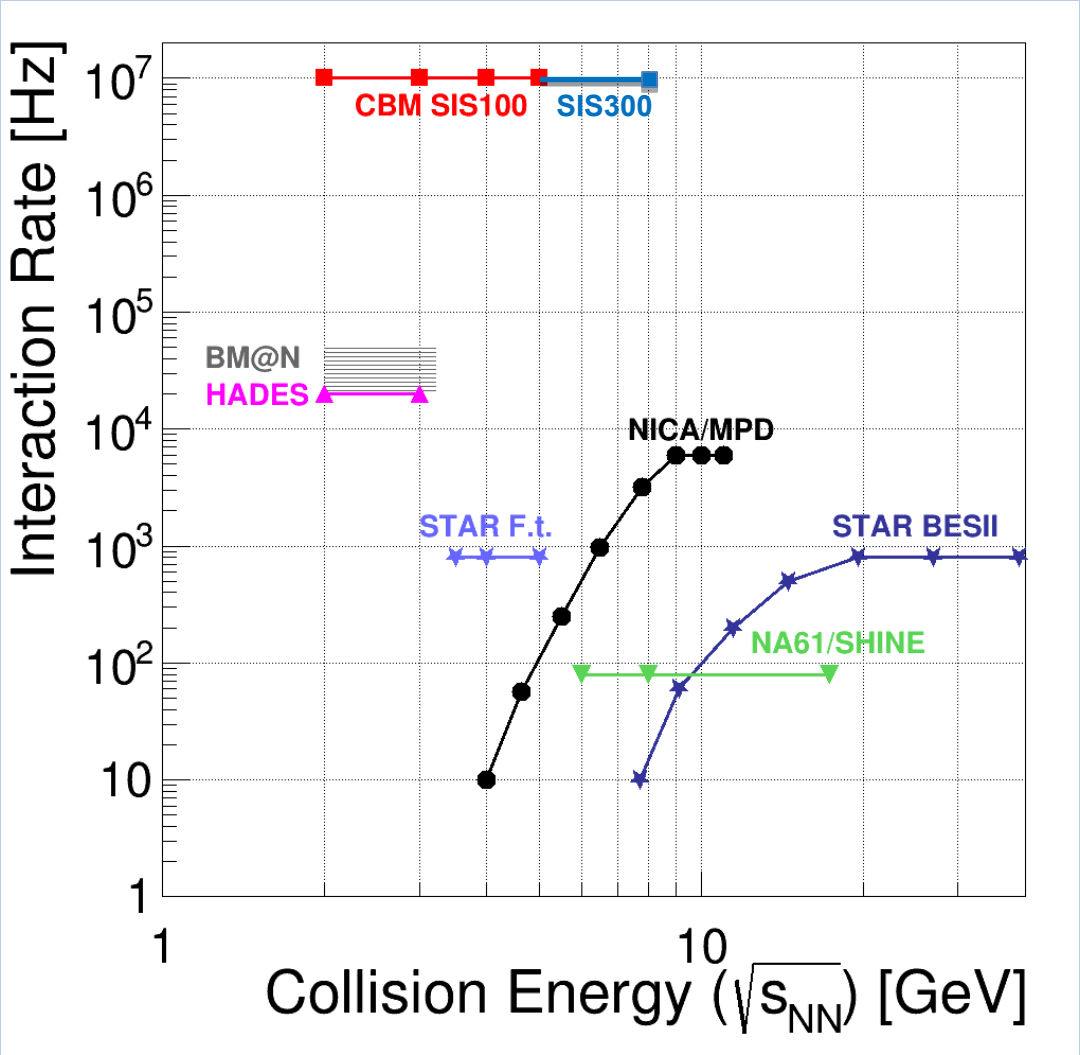
- Toroidal Spectrometer
  Interaction rates up to 10 MHz
- Measurement of hadrons, electrons, muons and neutral probes

H. Sako, Reimei workshop 2015

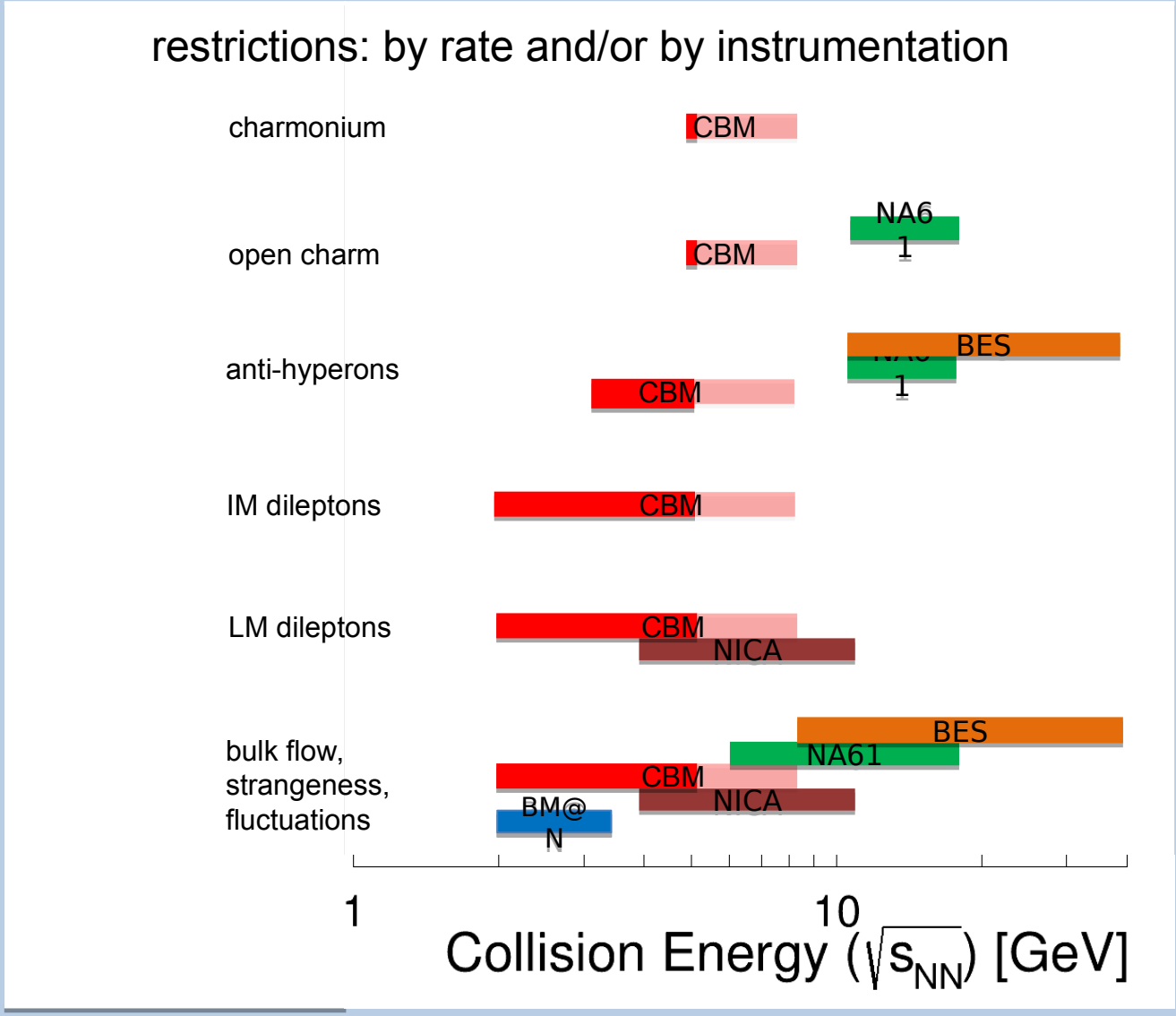
J-PARC HI Project: Status

- Currently, the project is in the conceptual stage
- Intentions:
  - White paper March 2016
  - Letter of Interest July 2016
- Timeline not fixed; goal: start within 10 years

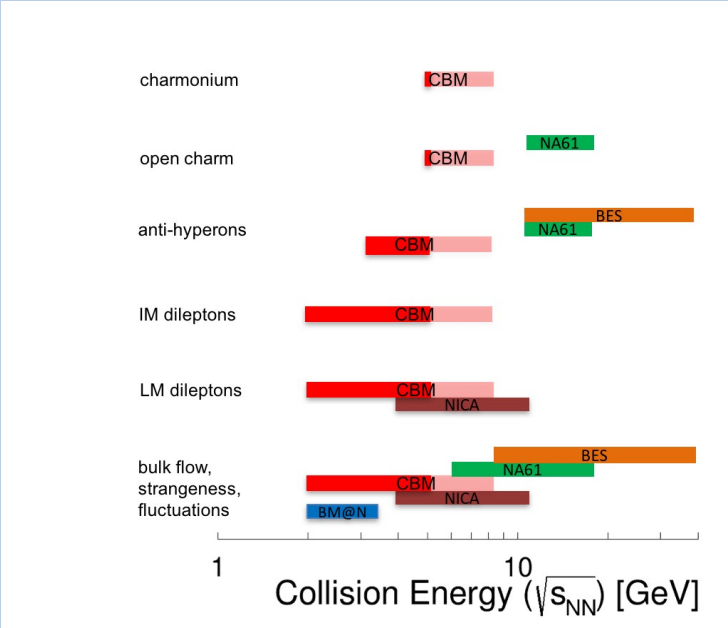
Comparison: Rates



Comparison: Observables



Summary



If the intended experiment programmes and their timelines become true: starting from the early 2020s, a wealth of data will decisively improve our knowledge on the QCD phase diagram at high net-baryon densities.