



Compressed Baryonic Matter  
experiment at FAIR

CBM



# CBM: status & response to the "First-Science and Staging Review of the FAIR Project"

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Piotr Gasik  
for the CBM Collaboration

KHuK Jahrestagung / Annual Meeting 2022  
Physikzentrum Bad Honnef, 8-10 Dezember 2022





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# REVIEW

## Limited attendance session at Sc. Review

Friday Jun 24, 2022, 8:30 AM → 4:30 PM Europe/Berlin


Main lecture theatre (GSI/FAIR)

1:30 PM → 3:00 PM 1: CBM

1:30 PM

### CBM science

Speaker: Tetyana Galatyuk (TU Darmstadt / GSI)


 galatyuk\_CBM\_FAIR\_

30m

2:15 PM

### CBM detectors

Speaker: Piotr Gasik (GSI Helmholtzzentrum für Schwerionenforschung GmbH(GSI); Facility for Antiproton and Ion Research in Europe GmbH (FAIR))

 gasik\_CBM\_FAIR\_R\_

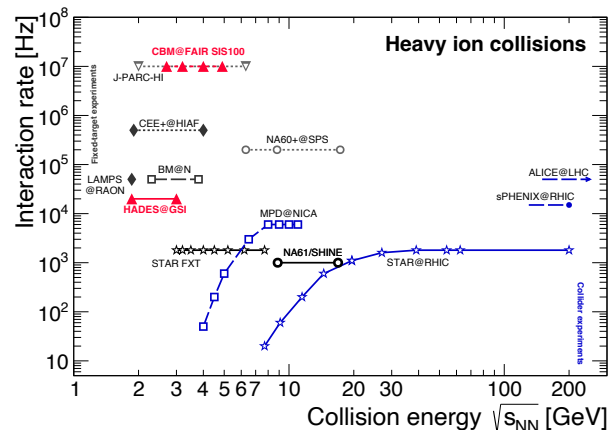
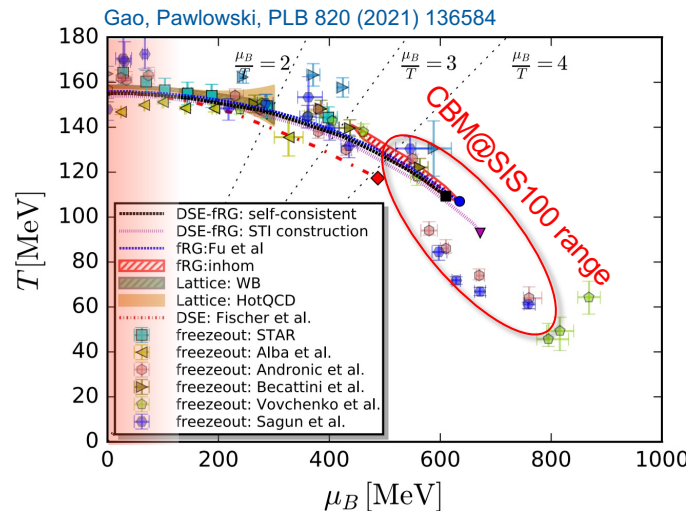
30m

## CBM Mission Statement:

- Systematically explore QCD matter at large baryon densities with high accuracy and rare probes.

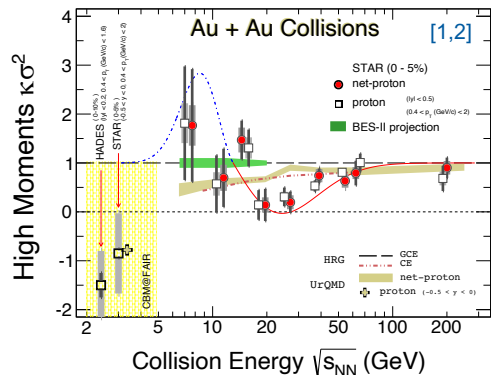
## Experimental challenge:

- Locate the onset of new phases of QCD
- Detect the conjectured QCD critical point
- Probe microscopic matter properties

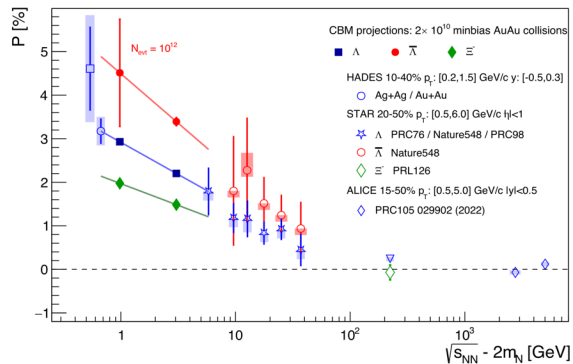


# Highlighted future directions

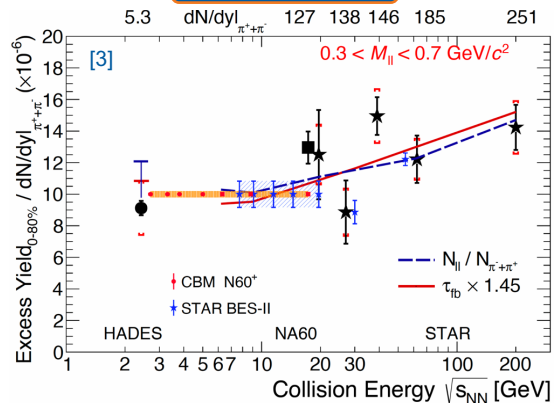
## Criticality



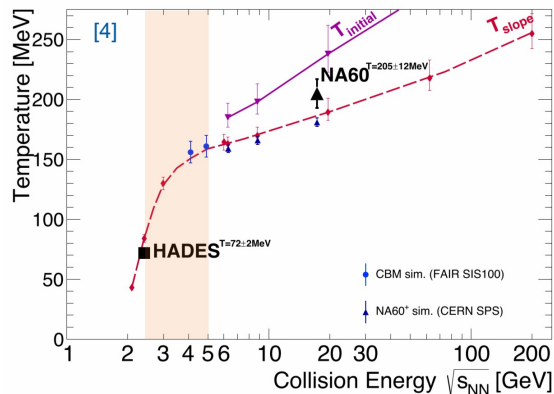
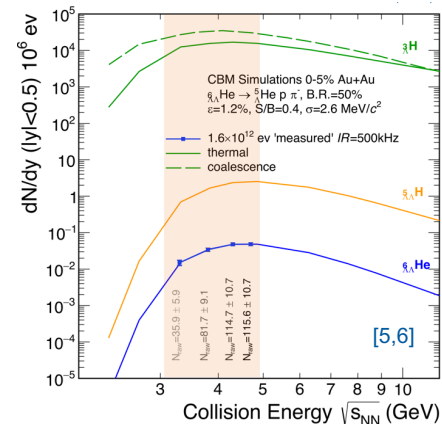
## Vorticity



## Emmissivity



## Hypernuclei



## CBM performance after 3y of running

- [1] STAR, PRL 128 (2022) 20, 202303
- [2] HADES, PRC 102 (2020) 2, 024914
- [3] T. Galatyuk, JPS Conf.Proc. 32 (2020) 010079
- [4] [https://github.com/tgalatyuk/QCD\\_caloric\\_curve](https://github.com/tgalatyuk/QCD_caloric_curve)
- [5] Thermal: Andronic et al., PLB 697 (2011)
- [6] Coalescence: Steinheimer et al., PLB 714 (2012)



# Competitiveness statements

## 3 year

Competitiveness with respect to STAR FXT and BM@N after 3 years of running

- The CBM data will **improve** the statistical errors of the STAR measurements in the SIS100 energy range **by at least a factor of 10**.
- BM@N will have hadron data available comparable to CBMs HADR setup in the beam energy range below 4.5 AGeV with an event sample size of max.  $1 \cdot 10^{11}$ .

## 8 year

In the years 4 - 8, high-statistics measurements are foreseen, aiming for IMR studies of di-lepton spectra and ultra-rare probes such as multi-strange hypernuclei and charmed hadron production.

Around that time an upgrade of the silicon trackers (MVD and STS) will be plausible with novel pixel detector technology with high-rate readout capabilities. Increased rate capabilities of the electron setup and extended beamtime periods will allow to increase **the collected statistics by another factor of 10** allowing us to reach data samples of  $10^{12}$  events for heavy collision systems necessary for significant studies of the IMR of the di-lepton spectra. Studies of charmed hadron interaction with cold nuclear matter in pA and intermediate mass collision systems like Ni+Ni become feasible.

This part of the CBM program has currently no competitors and is world-wide unique.

# Competitiveness = attractiveness

**QCD Phase Structure and Interactions at High Baryon Density:**

**Completion of BES Physics Program with CBM at FAIR**

D. Almaalol, M. Hippert, J. Noronha-Hostler, J. Noronha, and E. Speranza  
*University of Illinois at Urbana-Champaign, Urbana, IL 61801*

G. Basar  
*University of North Carolina, Chapel Hill, NC 27599*

S. Bass  
*Duke University, Durham, NC 27708*

D. Cebra  
*University of California, Davis, CA 95616*

V. Dexheimer, D. Keane, S. Radhakrishnan, A.I. Sheikh, M. Strickland and C.Y. Tsang  
*Kent State University, Kent, OH 44242*

X. Dong, V. Koch, G. Odyniec and N. Xu  
*Lawrence Berkeley National Laboratory, Berkeley, CA 94720*

F. Geurts  
*Rice University, Houston, TX 77005*

D. Hofman, M. Stephanov, G. Wilks and Z.Y. Ye  
*University of Illinois at Chicago, Chicago, IL 60607*

H.Z. Huang and G. Wang  
*University of California, Los Angeles, CA 90095*

J.Y. Jia  
*Stony Brook University, Stony Brook, NY 11794*

H.S. Li and F.Q. Wang  
*Purdue University, West Lafayette, IN 47907*

J.F. Liao  
*Indiana University, Bloomington, IN 47408*

M. Lisa  
*The Ohio State University, Columbus, OH 43201*

L. McLerran and A. Sorensen  
*Institute for Nuclear Theory, University of Washington, Seattle, WA 98195*

C. Plumberg  
*Pepperdine University, Malibu, CA 90263, USA*

S. Mukherjee, R. Pisarski, B. Schenke and Z.B. Xu  
*Brookhaven National Laboratory, Upton, NY 11973*

S. Pratt  
*Michigan State University, East Lansing, MI 48824*

C. Ratti and V. Vovchenko  
*University of Houston, Houston, TX 77204*

T. Schäfer  
*North Carolina State University, Raleigh, NC 27695*

C. Shen  
*Wayne State University, Detroit, MI 48201*

(Dated: September 13, 2022)

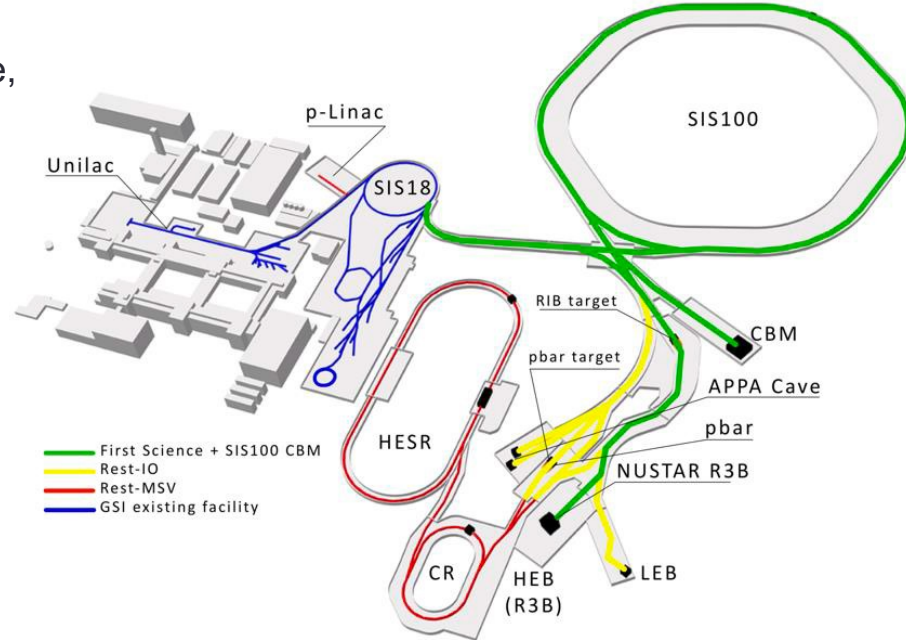
arXiv: [2209.05009v1](https://arxiv.org/abs/2209.05009v1) [nucl-ex]

arXiv:2209.05009v1 [nucl-ex] 12 Sep 2022

*It should be emphasized that timely completion of SIS100 is critical because it will provide a truly unique opportunity in the world for CBM to carry out its heavy-ion science program.*

## Review results

- The international review panel has issued its report, publicly available [here](#)
- Given the financial constraints, a start configuration including SIS 100, SFRS with the High Energy cave, and CBM is recommended (Scenario 3)
  - Early Science (SIS18 to SFRS)
  - First Science (SIS100 to SFRS)
  - First Science+ (SIS100 to CBM)
- The realization of Scenario 3 will be started in full
- Decision by next FAIR Council
- Re-baselining in January - March 2023





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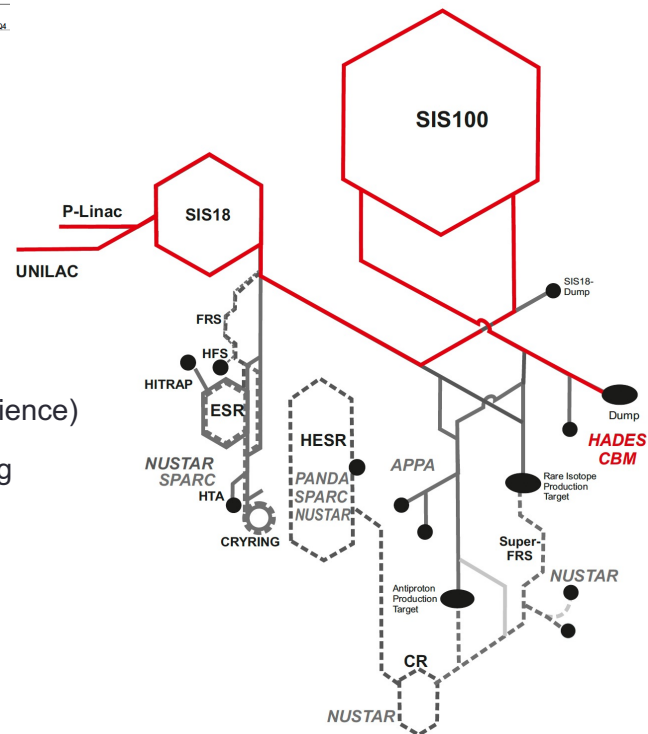
CBM



# CBM STATUS

## Level 1 - FAIR - project overview

data date: 16.05.22

[illegible]

- SIS100 ready for beam in Q2.2028, commissioning w/ beams till Q3.2028 (ready for science)
- CBM ready for beam in Q2.2027, ~12 months contingency for CBM global commissioning

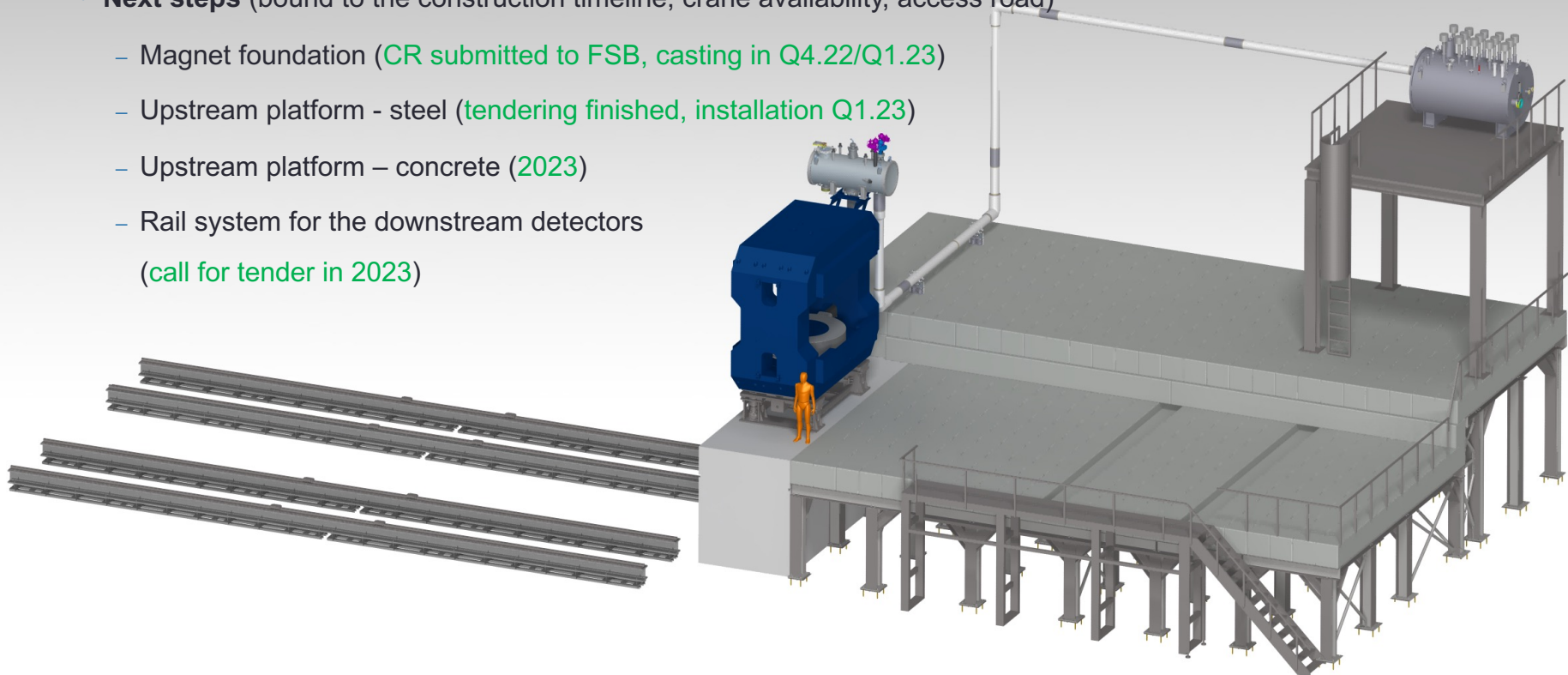


## CBM Cave & Building



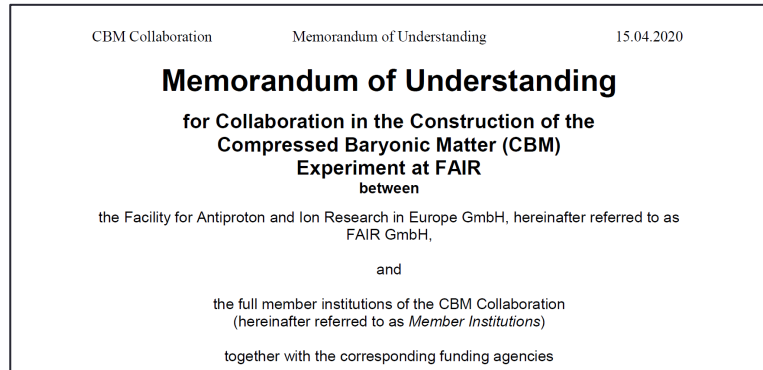
# Cave: common infrastructure, installation

- **Next steps** (bound to the construction timeline, crane availability, access road)
  - Magnet foundation (CR submitted to FSB, casting in Q4.22/Q1.23)
  - Upstream platform - steel (tendering finished, installation Q1.23)
  - Upstream platform – concrete (2023)
  - Rail system for the downstream detectors  
(call for tender in 2023)



# First FAIR experiment with signed Construction MoU

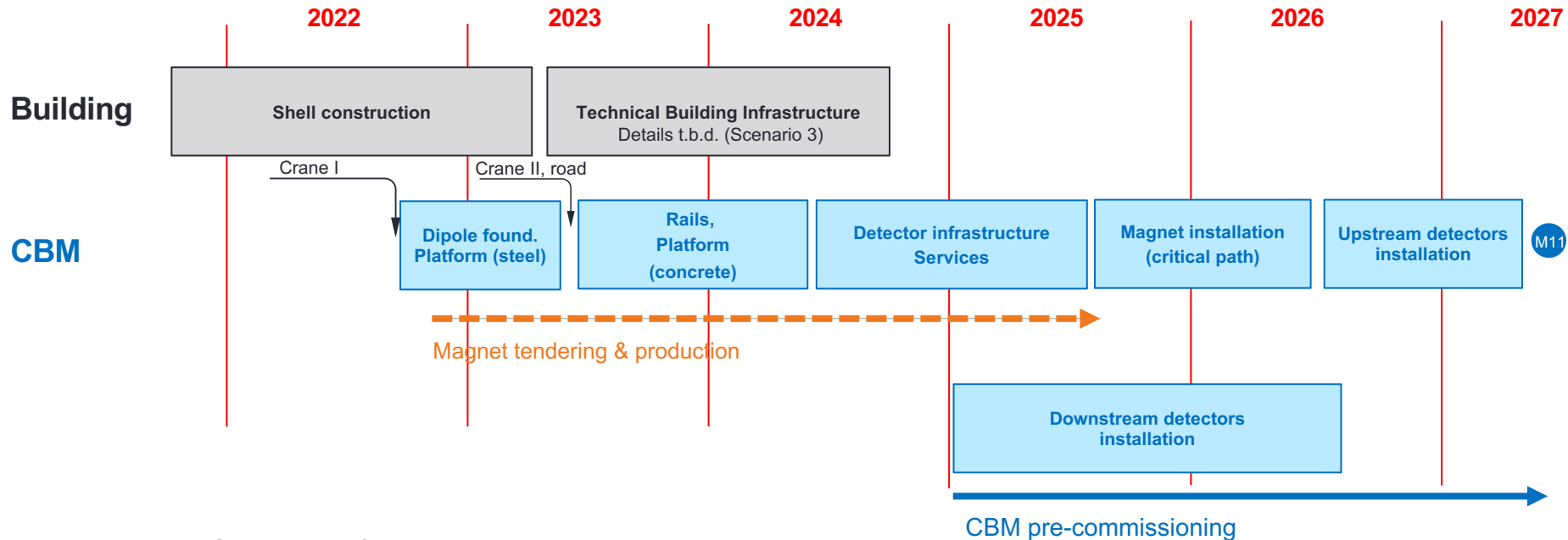
- CBM C-MoU defines the (In-Kind) contributions of the CBM member institutes to the construction of the CBM experiment
- Establishes the CBM Common Fund for the financing of the CBM common infrastructure (evaluated by ECSG and ECE)
- CBM Construction MoU agreed by CBM member institutes and all Funding Agencies in the FAIR Resource Review Board



- Signing has started (GSI/FAIR) in August 2020
- The majority of the funding agencies and of the CBM member institutions have signed the CBM Construction MoU already!
- Signing of Construction MoU by Russian institutions/funding agency not expected anymore (~20 % contribution to CF)



# Installation plan



- We plan CBM ready for beam in mid 2027
- ~ 1y contingency until SIS100 commissioning with beams (used for CBM global commissioning)
- Magnet on the critical path → plans will clarify after tendering.

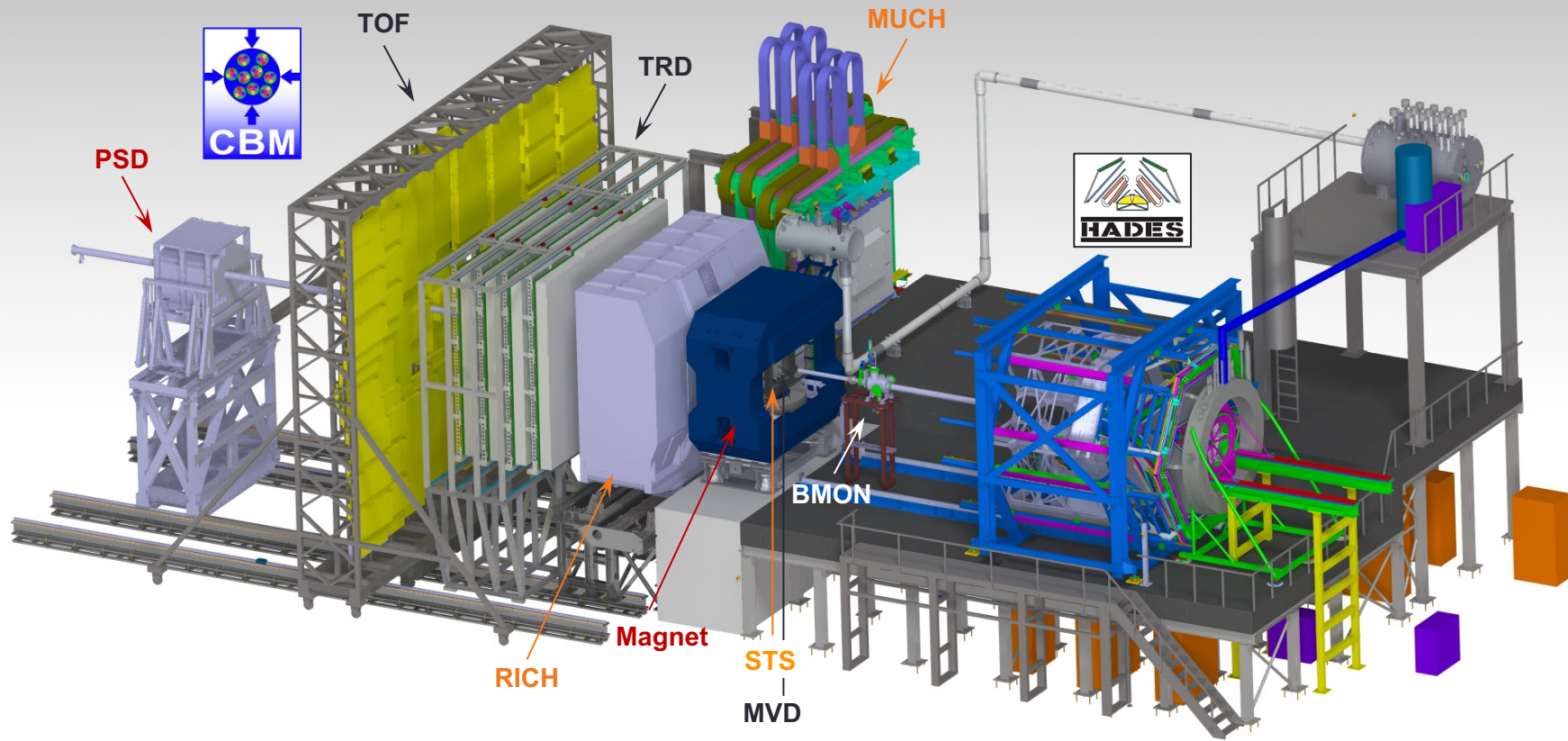


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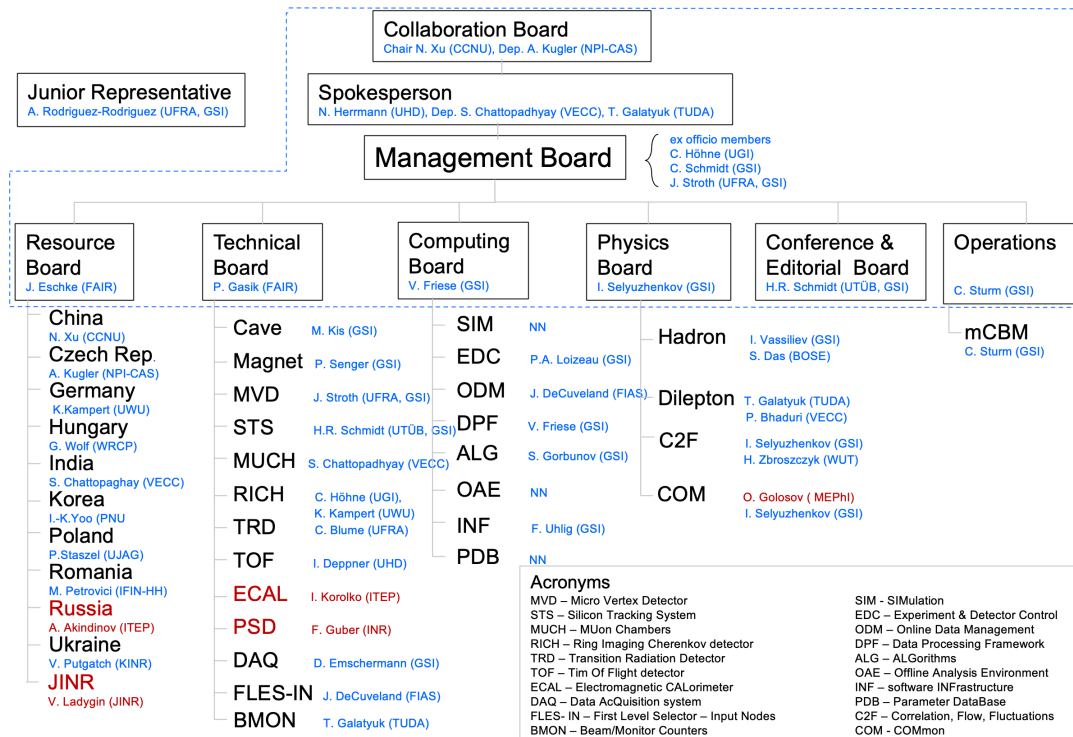
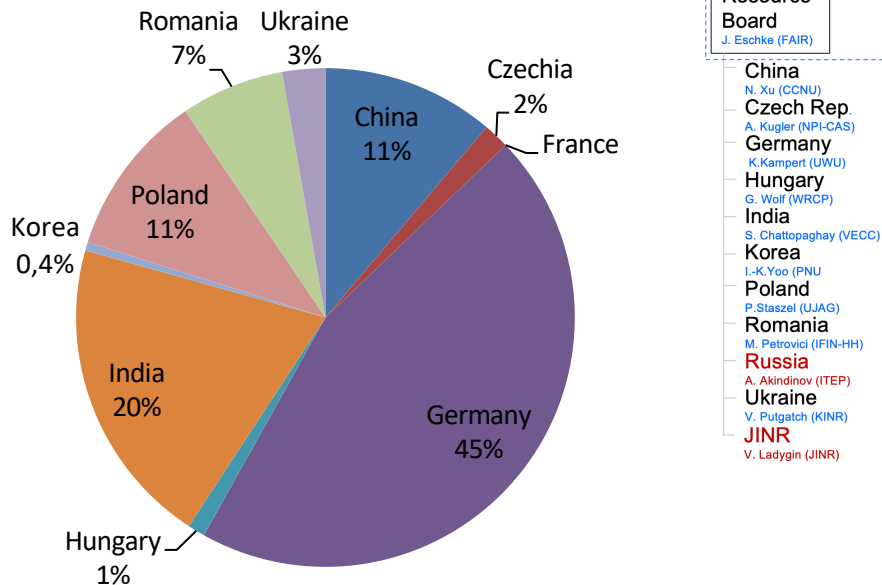


# CBM SUBSYSTEMS



# CBM collaboration

- 47 full / 10 associated member institutions
- 10 countries
- ~400 full members - 22% from Russia = ~ 310



Suspension of membership in CBM collaboration of Russian Institutions endorsed by the Collaboration Board on 18.05.22

# Highlights from the detector projects

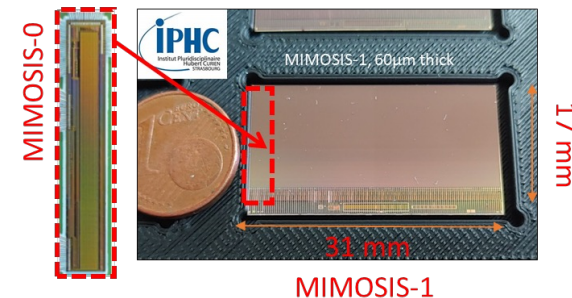
## BMON (TU Darmstadt)

- Start detector Concept for Day-1 based on pcCVD high-purity diamond sensors
- Successful implementation in mCBM
- A concept of the beam abort system being worked out (estimate manpower, invest)
- R&D on novel technologies (LGAD) ongoing



## MVD (U Frankfurt, GSI, IKF Frankfurt, IPHC Strasbourg, Pusan Nat'l Univ, Czech TU)

- TDR submitted and accepted by ECE in 2021
- MIMOSIS-1: extensive testing (9) and irradiation (3) campaigns
- MIMOSIS-2 submitted for production (first beam at DESY in Jul 2023)
- RO chain development, integration and services



## STS (GSI, KIT Karlsruhe, JU Crakow, AGH Crakov, KINR Kiev, Univ. Tübingen, Warsaw UT)

- Preproduction of the STS modules ongoing.
- 10 STS modules to be integrated into the J-PARC E16 experiment
- PRR in Spring 2023 for the full scale production
- 75 wafers of SMX\_V2.2 ASICs delivered
- 7.5 kW NOVEC cooling plant prototype and realistic thermal demonstrator





# Highlights from the detector projects

**MUCH** (U Aligarh Muslim, Bose Inst., U Panjab, U Jammu, U Kashmir, U Calcutta, B.H. U Varanasi, VECC, IOP Bhubaneswar, NISER Bhubaneswar, IIT Kharagpur, IIT Indore, U Gauhati)

- MUCH GEMs and RPCs installed in mCBM setup
- Production of Station 1 GEM chambers to be launched soon (GEMs available).
- Successful GIF++ and mCBM high-rate campaign for GEMs and RPCs

**RICH** (U Giessen, U Wuppertal, GSI Darmstadt)

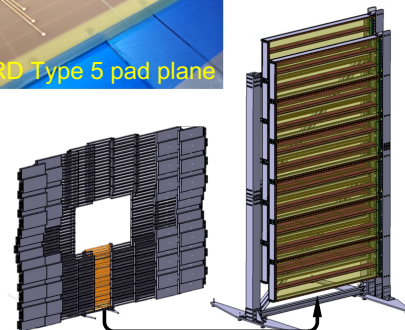
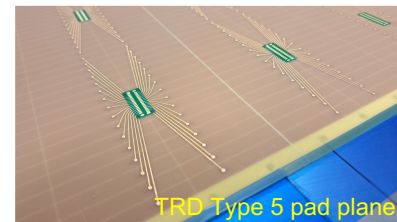
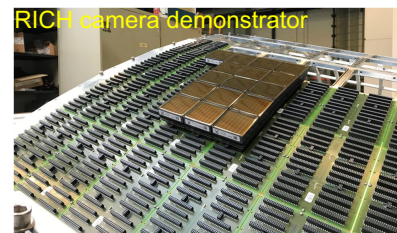
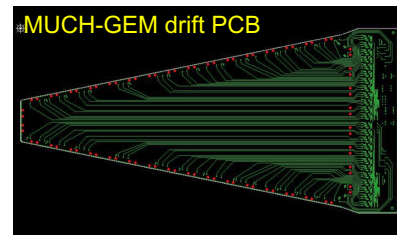
- Photocamera prototype → cooling concept verification ongoing
- Mirror production to be launched soon (2023)
- FEE production/assembly started.

**TRD** (NIPNE Bucharest, U Frankfurt, U Heidelberg, U Münster, IRI Frankfurt)

- Pre-production (modules type “5”) ongoing. Raw material for full production procured.
- SPADIC 2.3 ASIC tests ongoing → submission of successor ASIC early 2023
- Mechanical structure (frame) development. Prototype of gas supply.

**TOF** (THU Beijing, NIPNE Bucharest, GSI, USTC Hefei, U Heidelberg, CCNU Wuhan)

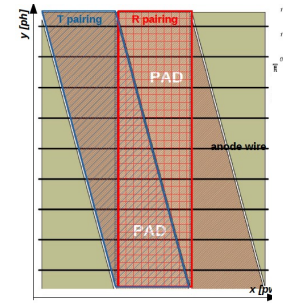
- Pre-production of MRPC launched in China. Pre-production module assembly in HD starts now.
- High-rate capabilities demonstrated in mCBM
- Mainframe CDR accepted – prototype frame being produced
- FEE PRR in Q1.2023!



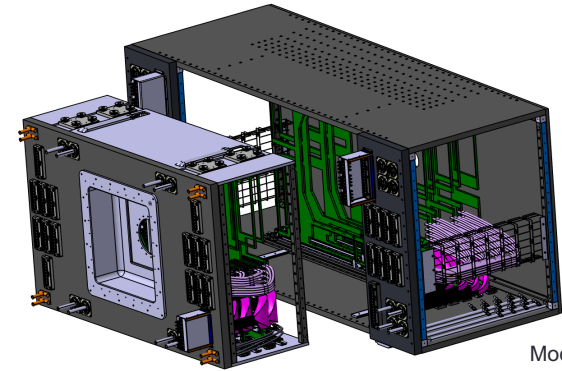
TOF prototype wall

# Ongoing improvements for Day-1

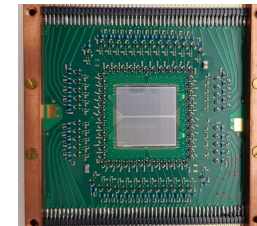
- **High-rate MWPCs with 2D readout for ultra-low  $p_t$  tracking for the inner-most TRD region**
  - TDR Addendum under review by the ECE
- **Prepare an upgrade path for STS with radiation hard pixel sensors**
  - Gain from the ongoing developments at CERN for the LS3 upgrades
  - Feasibility of the upgrade with the STS “3+5” modular setup
- **Start and HALO detectors based on LGAD sensors**
  - Currently employed by HADES START detector
  - Sensor development: Bruno Kessler Foundation;
  - Performance with high-intensity heavy ion beams to be shown



TRD 2D readout scheme



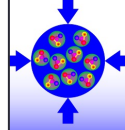
Modular STS setup



HADES START

# CBM Online Systems

- Free-streaming readout implemented and commissioned in mCBM
- Connection scheme, hardware, achieved occupancies  
close to the final CBM DAQ → can be scaled towards full CBM
- High-rate capabilities demonstrated
- TDR Online Systems – Part I (DAQ and FLES) **submitted** to ECE
- TDR Online Systems – Part II (Online analysis, event selection and controls)
  - last CBM TDR to be submitted




## Technical Design Report for the CBM

### Online Systems – Part I

DAQ and FLES Entry Stage

The CBM Collaboration



November 2022

commit date 2022-11-16  
commit hash 278fd34 (clean)

Compressed Baryonic Matter Experiment





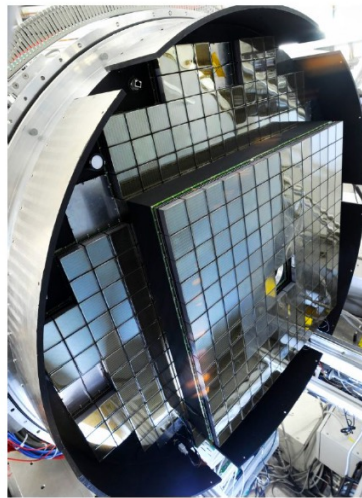
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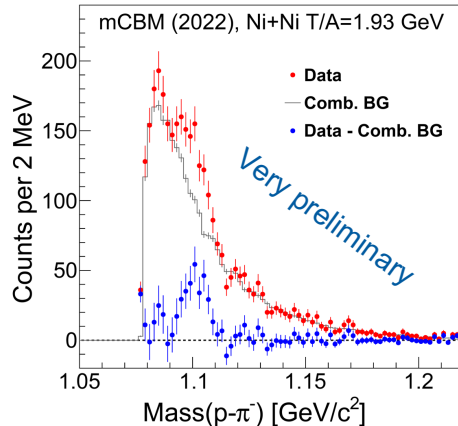
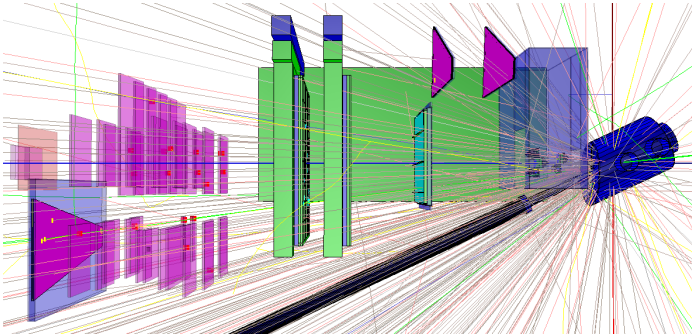
FAIR PHASE-0

# FAIR Phase-0 research program



- eTOF @ STAR is installed, commissioned and running
- Use 430 out of 1100 CBM RICH multi-anode photo-multipliers in HADES
- mCBM @ SIS18: high-rate detector tests, CBM DAQ development,  $\Lambda$  excitation function measurement

# mCBM @ SIS18 – CBM full system setup



## $\Lambda$ production benchmark runs 2022

### Ni + Ni, T = 1.93 AGeV

- May 26, 2022, total run duration: 5h 55m
- av. collision rate: 400 kHz
- av. data rate 1.5 GB/s to disc, 32 TB data collected

### Au + Au, T = 1.23 AGeV

- June 17-18, 2022, total run duration: 34h 33m
- av. collision rate: 200 – 300 kHz
- av. data rate 1.4 – 2.2 GB/s to disc, 180 TB data collected
- First results promising - work on calibration and alignment ongoing
- Further development of the readout chain and online analysis tools
- High-rate detector tests and  $\Lambda$  production runs in 2024-2025 approved by G-PAC (36/18 shifts as a primary/secondary user)



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# MISSING RUSSIAN CONTRIBUTIONS

# Superconducting magnet

BINP Novosibirsk

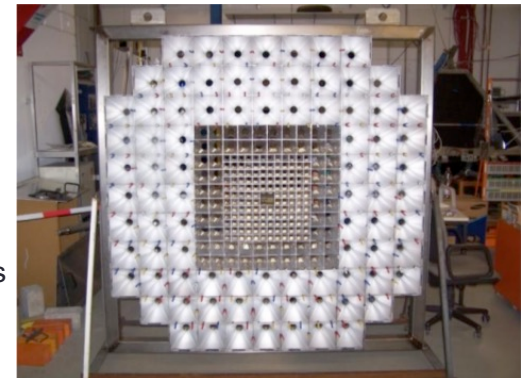
- **CBM Dipole** defined as an item for urgent re-procurement
  - Budget allocated!
  - Preparation for tender with FAIR purchasing department
  - Detailed Specifications under review until 16.12.2022
- **On the critical path for CBM installation and commissioning:**  
~3.5–4 years for tendering, production, installation and commissioning



# Projectile Spectator Detector

INR Moscow

- Original concept based on hadronic calorimeter (Pb/Scintillator)
- Discussion on **on plastic scintillator** based forward wall  
(a'la HADES forward hodoscope wall or STAR Event Plane Detector)
- Provides an **opportunity to improve performance** at low energies and high interaction rates
- Possible Czech contribution; new sub-project to be defined



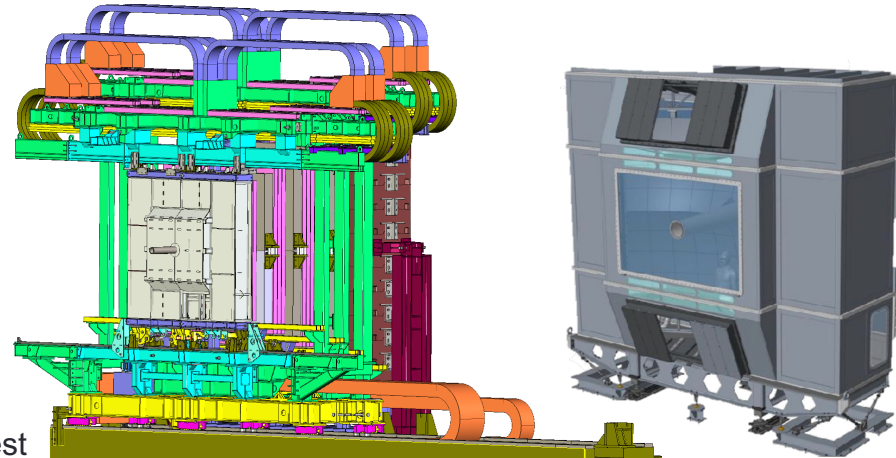


# Other in-kind contributions from Russia

## MUCH/RICH mechanics and gas systems

PNPI Gatchina

- RICH: gas box, support stand, mirror system
- MUCH: absorbers, superstructure, rails
- Funding needs to be clarified asap
- Engineering work must continue (manpower!)
- Gas system: discussion on the support from NICIT/Bucharest



## STS module assembly

JINR Dubna – contract not yet cancelled

- Majority of the IKC completed → all sensors delivered
- 40% of the STS modules to be assembled in JINR → needs to be accommodated at GSI and KIT





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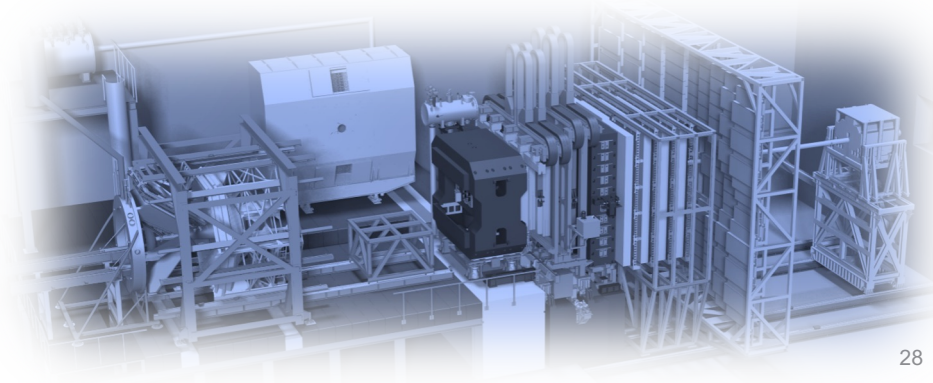
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# SUMMARY AND OUTLOOK

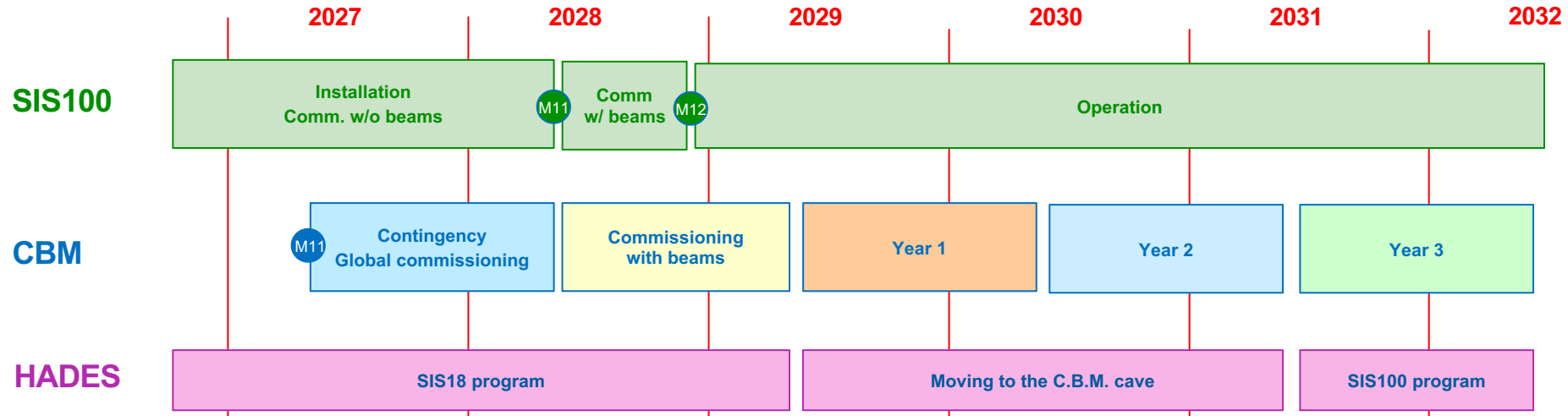
# Summary

- **Timely completion of SIS100:** unique physics program with CBM
- CBM is progressing well toward the science program with SIS100 beams
- Rich FAIR Phase-0 program
- High-rate capabilities achieved in the extensive R&D phase
- All subsystems on the verge of the series production
- Time-critical procurement of the CBM superconducting magnet to be initiated in December 2022
- Installation of CBM infrastructure in the cave starts in early 2023
- **CBM “ready for beam” in 2027!**





# Outlook



- **Preparing for a competitive program in 2028**
- CBM input submitted to NuPECC LRP: <https://indico.ph.tum.de/event/7050/contributions/6344/>



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THANK YOU!