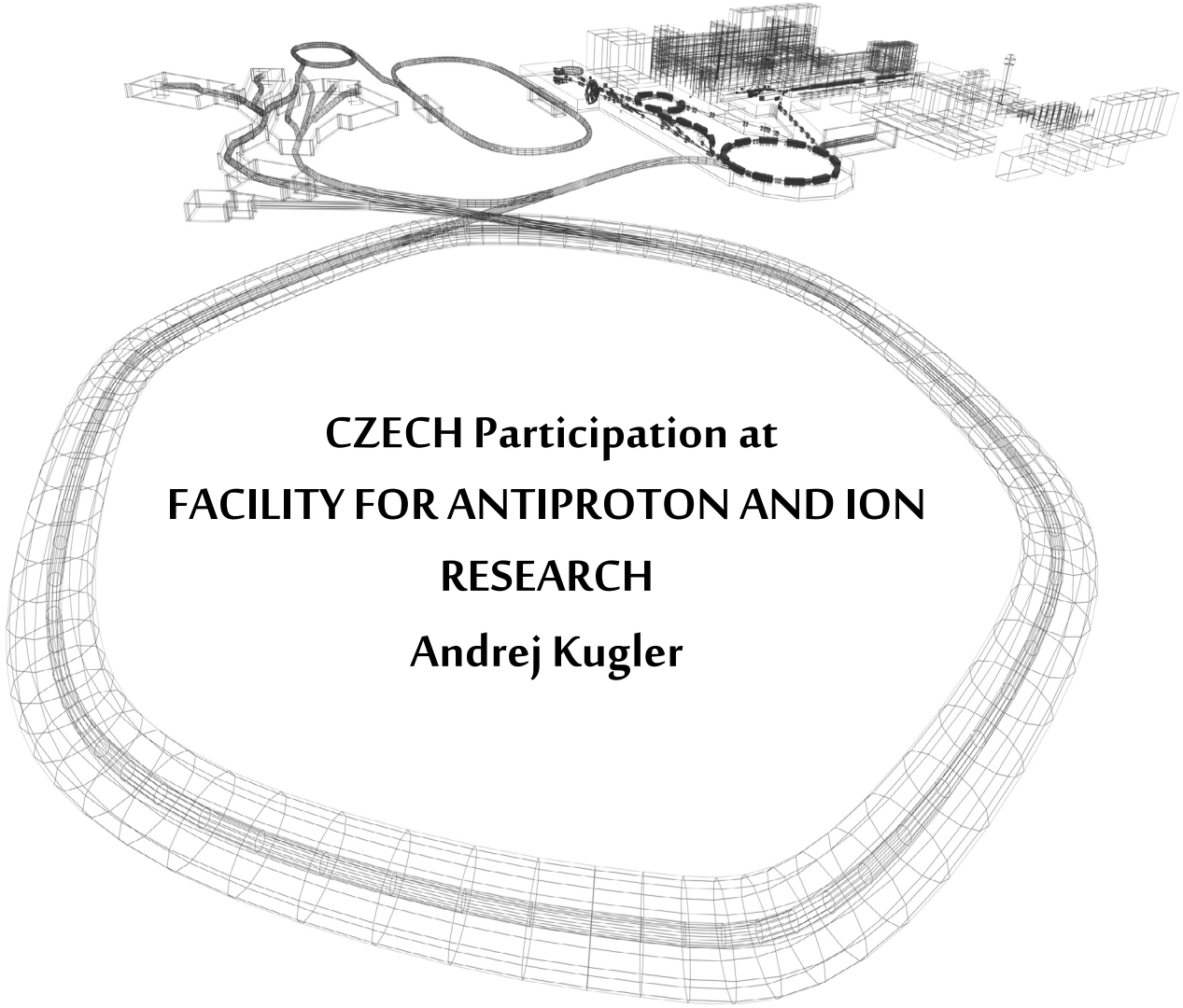


CZECH Participation at FACILITY FOR ANTIPROTON AND ION RESEARCH

Andrej Kugler

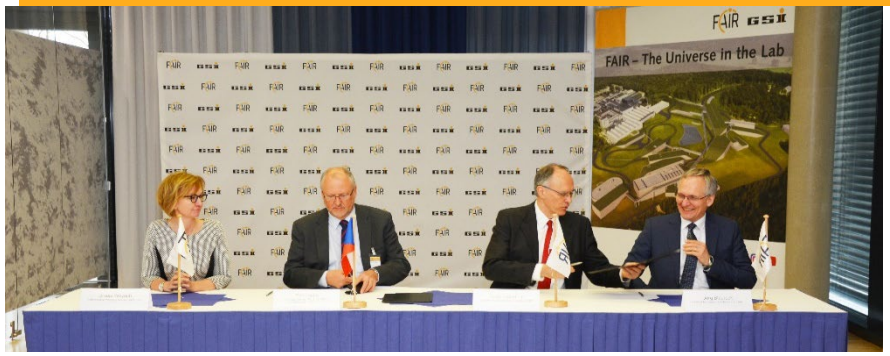
Czech groups collaborations with GSI/FAIR

- NPI **R**elativistic **H**eavy **I**on **C**ollisions group collaborated within TAPS participating in experiments at GSI, GANIL and KVI since 1989
- NPI RHIC group is between founding members of HADES (1995) and later CBM@FAIR (2004)
- CTU and CU groups are full members of PANDA since 2015
- SU Opava group is founding member of EXPERT experiment (NuSTAR)

FAIR-CZ Large Research Infrastructure is founded at 2015 with the aim to facilitate participation of Czech community in FAIR

- the support of operational costs –project MEYS LM2015049 funded since 01/2016 till 12/2019
- the support of investment cost from OP VVV (Structural funds) approved – project started in November 2016 (kick off meeting 14.12.2016), ends in 12/2019
- FAIR-CZ SAC established, meetings in 29.11.2016 Darmstadt and 19.1.2017 Prague

Czech Republic joins FAIR as "Aspirant Partner" at 25th March 2019
We promised in-kind contributions worth of about 2 MEUR



The contract has been signed by the managing directors of GSI and FAIR, Professor Paolo Giubellino, Ursula Weyrich and Jörg Blaurock, as well as by **Dr. Petr Lukáš, Director of the NPI**. Czech partners in FAIR-CZ consortium – represented by **Prof. Vojtěch Petráček, Rector of the Czech Technical University in Prague**, **Prof. Gabriel Török, Vice-Rector of the Silesian University in Opava**, **Prof. Jan Kratochvíl, Dean of the Faculty of mathematics and physics, Charles University** (FMP CU), Prof. Vladimír Baumruk, Vice-Dean of the FMP CU, and **Dr. Andrej Kugler, FAIR-CZ coordinator** – took part at the signing .

FAIR SIS100 will provide heavy ion beams with **world wide unique high intensities** as well as **secondary radioactive beams** and **antiprotons**. It will start operation in 2028

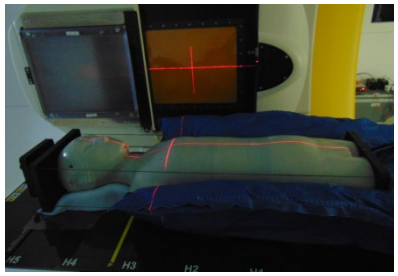
New international research laboratory FAIR is under construction at GSI campus near to Darmstadt, Germany, to explore the nature and evolution of matter in the Universe.

FAIR is governed by international convention
- 9 shareholders + 1 assoc. partner (UK) +1 aspirant partner (Czech Republic)

Scientists from all over the world are engaged
- more than 200 institutions from 53 countries are involved with their scientists

FAIR is included in **ESFRI road map** since 2006

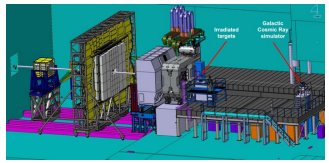
The coverage of broad range of both applied and basic science is unique feature of FAIR/ FAIR-CZ

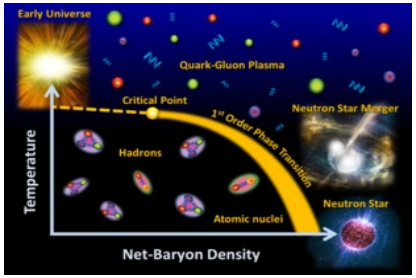


Atomic & Plasma Physics & Applied Sciences

- Highly charged atoms (SPARC@FAIR)
- Plasma physics (HED@FAIR)
- Radiobiology (BIOMAT@FAIR)
- Space radiation protection (ESA)
- Material science (BIOMAT@FAIR)

APPA

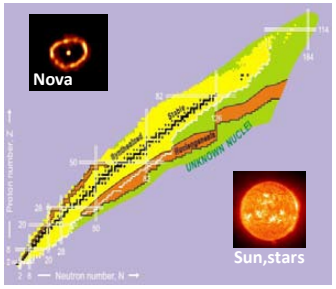




Compressed Baryonic Matter

CBM/HADES

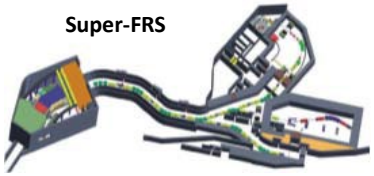
- Phase transitions from hadrons to quarks
- Equation-of-state of matter
- Electro-magnetic radiation from the dense fireball
- Chiral symmetry restoration in dense baryonic matter
- Hypernuclei: Λ-N, Λ-Λ interaction

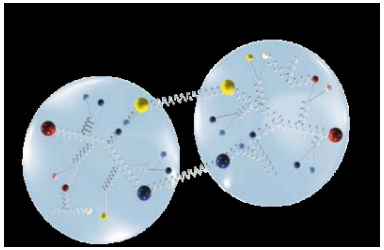


Nuclear structure and nuclear astrophysics

NuSTAR

- r-process nucleosynthesis
- nuclear landscape beyond driplines
- Super heavy elements
- Exotic nuclei



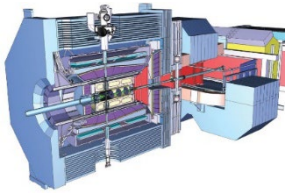


Hadron structure and dynamics

PANDA

- Exotic particles
- Gluonic matter and hybrids
- Hadron structure
- Hadrons in matter
- Double Lambda hypernuclei

*Participation of the Czech scientists



CBM cave

Topics and activities of the Biophysics Collaboration

Space radiation protection

ESA ground-based facility for European studies on space radiation risk and countermeasures (IBER)

Unique worldwide facility for simulation of the full GCR including very high energy heavy ions

Particle therapy

First European clinical tests of heavy ions and research on C ions

- High-energy particle radiography (theranostics)
- High-intensity (FLASH) radiotherapy
- Radioactive ion beams for therapy (10C, 14O and 8He, 8Li)
- Non-cancer diseases (heart arythmia)

BIO @CBM: the science case

Life **2014**, *4*, 491-510; doi:10.3390/life4030491

OPEN ACCESS

life

ISSN 2075-1729

www.mdpi.com/journal/life

Review

Space Radiation: The Number One Risk to Astronaut Health beyond Low Earth Orbit

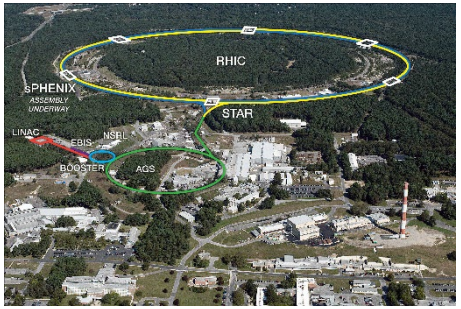
Jeffery C. Chancellor [1,2], Graham B. I. Scott [1,3] and Jeffrey P. Sutton [1,4,*]

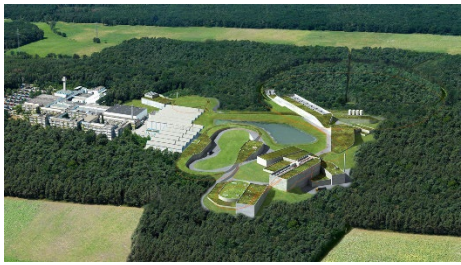
1 National Space Biomedical Research Institute (NSBRI), and Center for Space Medicine, Baylor College of Medicine, 6500 Main Street, Suite 910, Houston, TX 77030-1402, USA; E-Mails: jeff.chancellor@bcm.edu (J.C.C.); graham.scott@bcm.edu (G.B.I.S.)

2 Department of Materials Science and Engineering, Dwight Look College of Engineering, Texas A&M University, 3003 TAMU, College Station, TX 77843-3003, USA

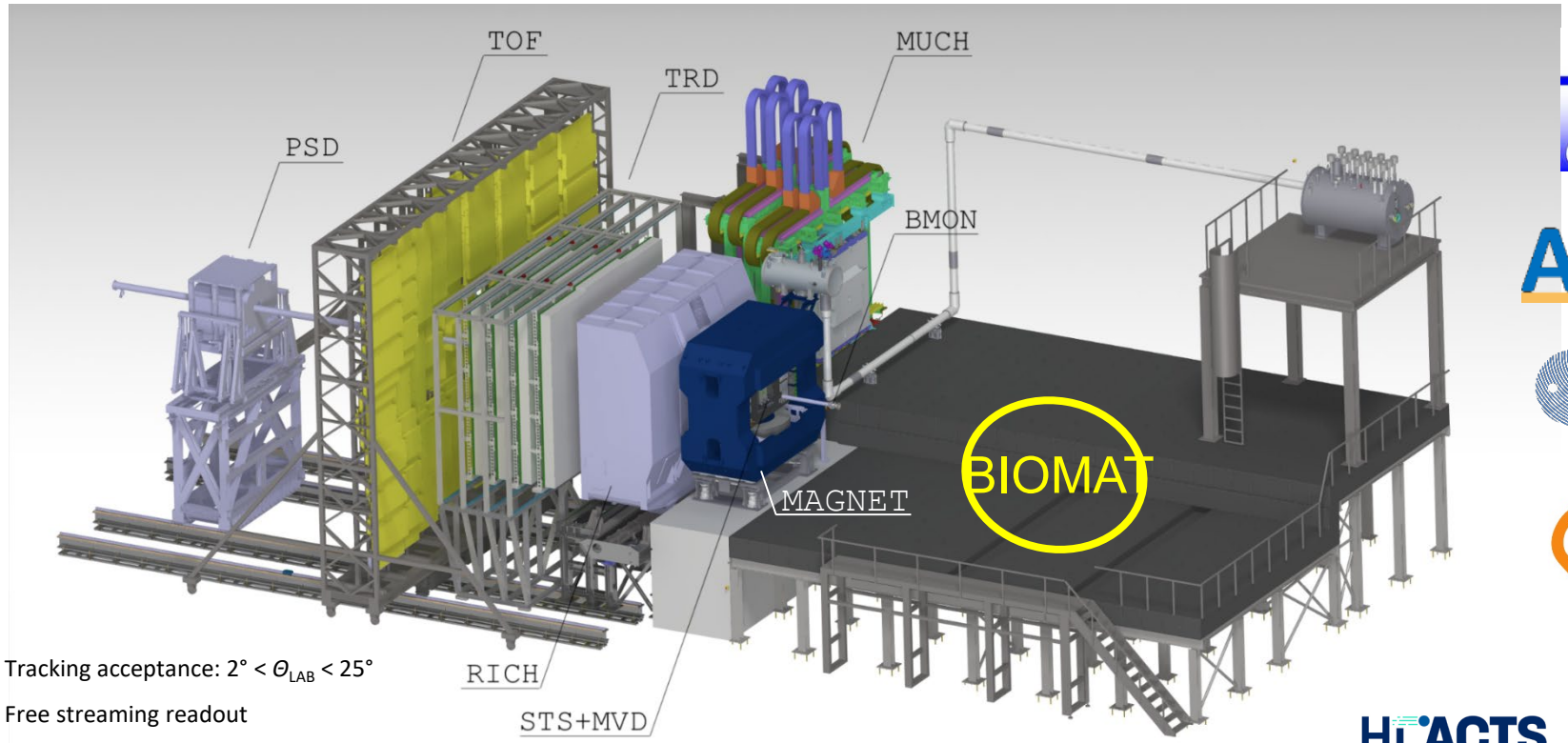
3 Department of Molecular and Cellular Biology, Baylor College of Medicine, 6500 Main Street, Suite 910, Houston, TX 77030-1402, USA

4 Department of Medicine, Baylor College of Medicine, 6500 Main Street, Suite 910, Houston, TX 77030-1402, USA





BIOMAT in First Science+ (FS+)



Tracking acceptance: $2° < \Theta_{LAB} < 25°$

Free streaming readout

Front-end connectivity up to R_{int} = 10 MHz

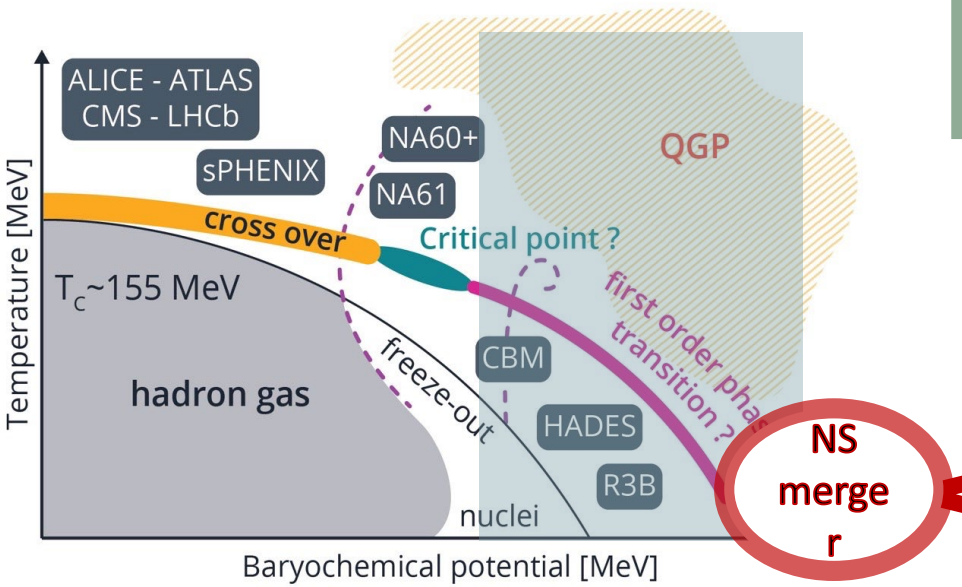
Software-based event selection

HI ACTS | Helmholtz Innovation Platform for Accelerator-based Technologies and Solutions

Compressed baryonic matter
The science case

ALICE/STAR Low μ_B ,hight *T*:

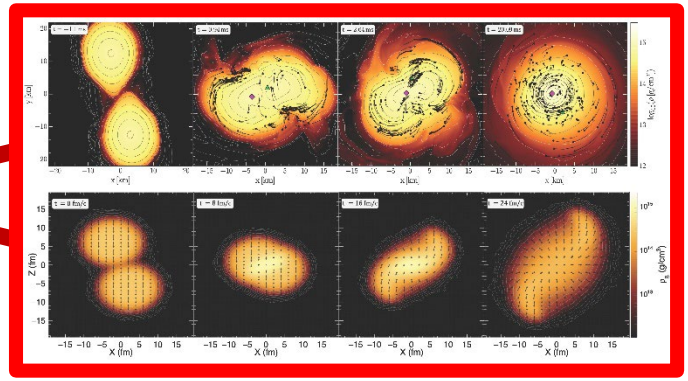
- **Cross-over** transition from hadronic to quark matter - comprehensive studies of **QGP** properties
- No **critical point** anticipated for $\mu_B/T < 3$ (QCD)



HADES/CBM High μ_B ,low *T*:

- Unknown **phase structure** (first-order phase transition, critical point possible, mixed phases, new phases, …)
- Properties of matter to determine
- Characteristics of hadrons
- Equation of State (**EoS**) to establish

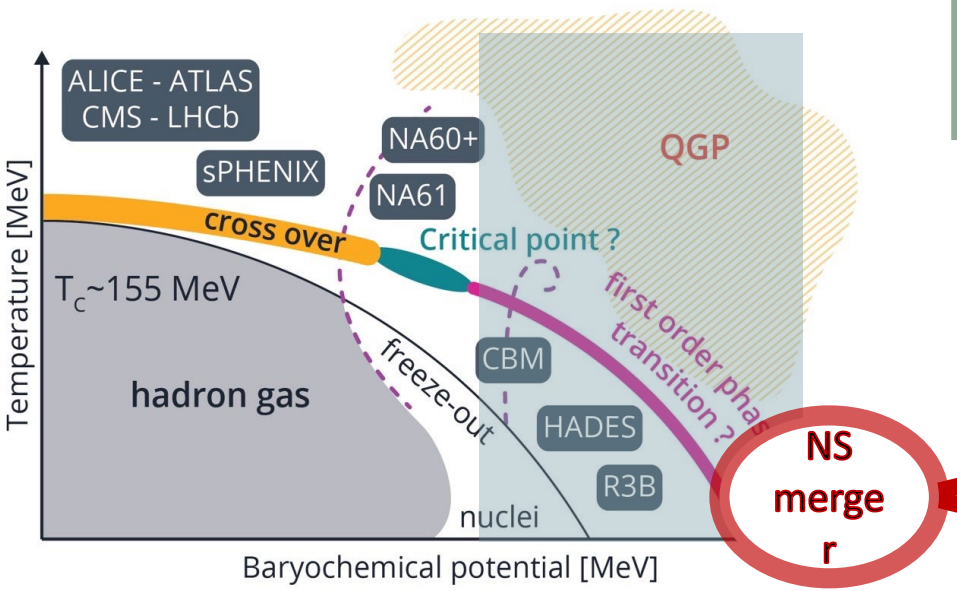
HADES collaboration, Nature Physics 15 (2019) 1040



Compressed baryonic matter
The science case

ALICE/STAR Low μ_B ,hight *T*:

- **Cross-over** transition from hadronic to quark matter - comprehensive studies of **QGP** properties
- No **critical point** anticipated for $\mu_B/T < 3$ (QCD)

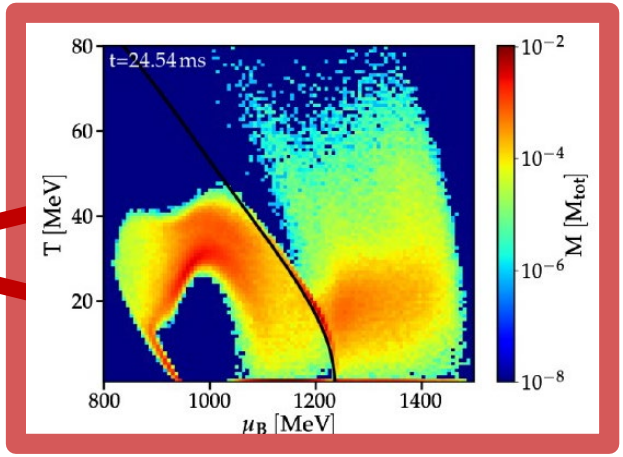


HADES/CBM High μ_B ,low *T*:

- Unknown **phase structure** (first-order phase transition, critical point possible, mixed phases, new phases, …)
- Properties of matter to determine
- Characteristics of hadrons
- Equation of State (**EoS**) to establish

Model of Neutron Star (NS) merger

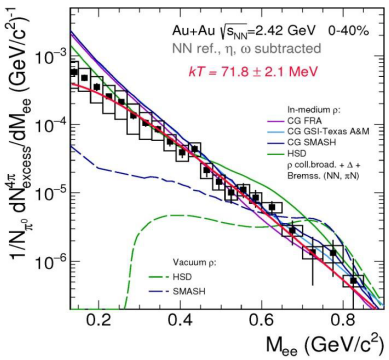
Bauswein , QCD at FAIR workshop 2024

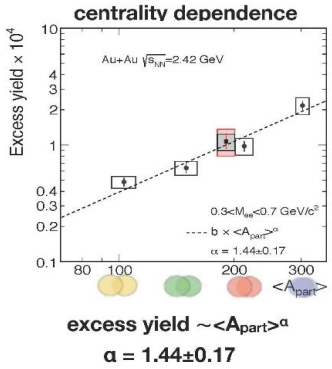


NPI in HADES - Dileptons

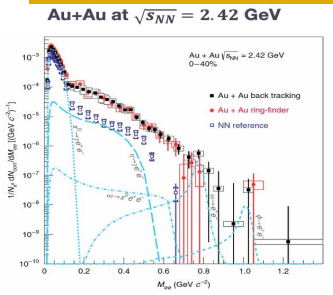
In-medium hadron properties at medium-to heavy ion collisions
Au+Au results summarized in
„Probing dense baryon-rich matter with virtual photons, HADES collaboration, Nature Physics 15 (2019) 1040“

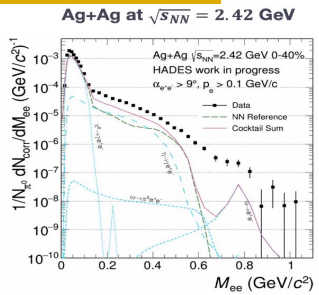
Au+Au beam energy scan E/A=400-800 MeV started in 2024-2025





Continued these studies with Ag+Ag

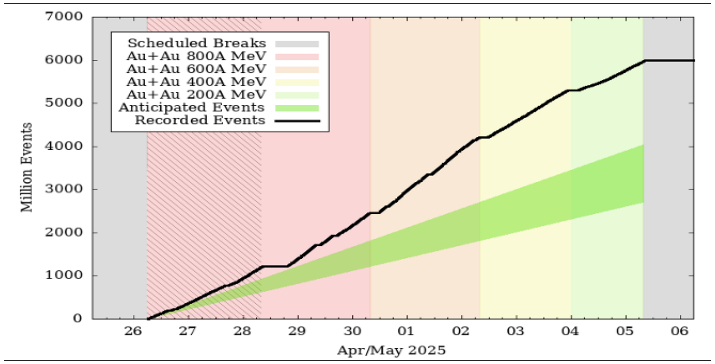




HADES G22-022 (Au+Au BES, 75 shifts “A”) in 2024

- C+C: Feb. 7 and 8 (6 shifts) •
- Au+Au: Feb. 28 until Mar. 22 (69 shifts) •
- Compressor failure March 4, termination of cool-down attempt up to March 17 (not enough liquid He).

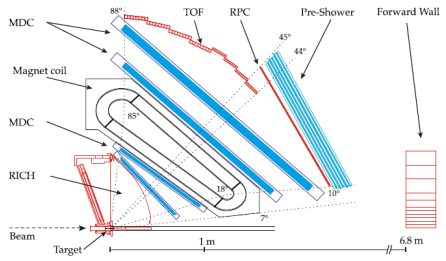
2025

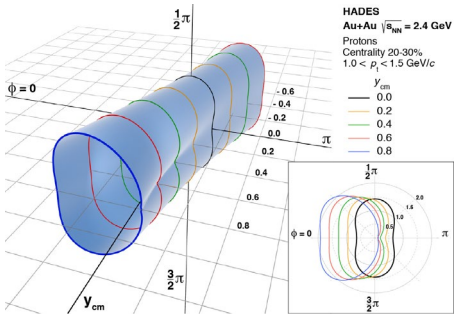


Coloured bands: 800, 600, 400 200 A MeV (from red to light green) Hatched area: weekend before scheduled beam time Green wedge (anticipated statistics): lower boundary rate assumed in proposal (w/o SOS and FEE upgrade), upper boundary includes maximum expected gain after upgrade of FEE (w/o SOS).

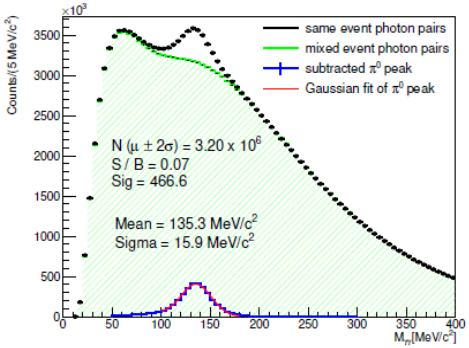
NPI in HADES
Production of hadrons and their flow

Proton, deuteron and triton flow measurements in Au+Au collisions at √sNN= 2.4 GeV
Phys.Rev.Lett. 125 (2021) 26, 262301 & Eur. Phys. J. A (2023) 59:80

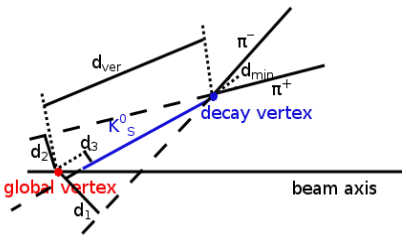


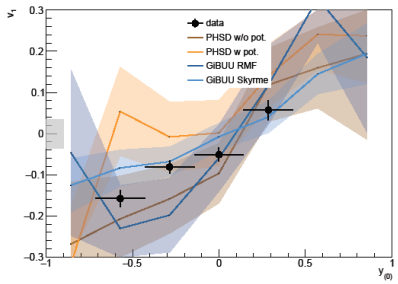


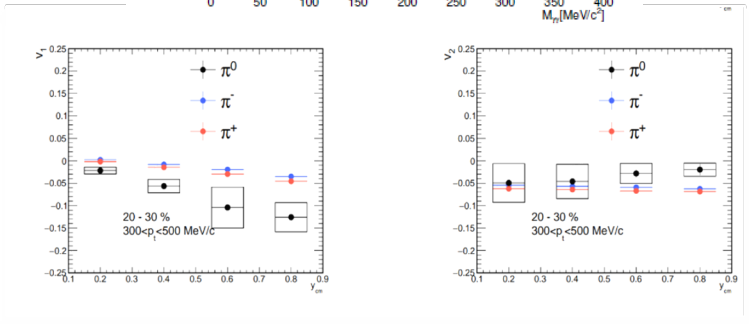
Neutral pion flow in Ag+Ag
PhD thesis of A.Prozorov (CU+NPI), 2023



Kaon flow considered to be a good probe of in-medium potentials
PhD thesis of L. Chlad (CU+NPI), 2021





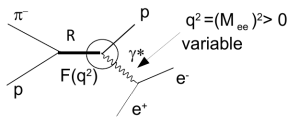


NPI in HADES – π induced reactions

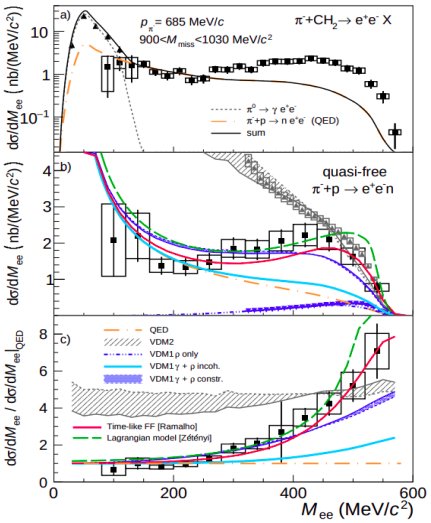
First information on the timelike electromagnetic structure of baryons in the second resonance region
PhD thesis of P.Rodriguez-Ramos (CTU+NPI) 2021

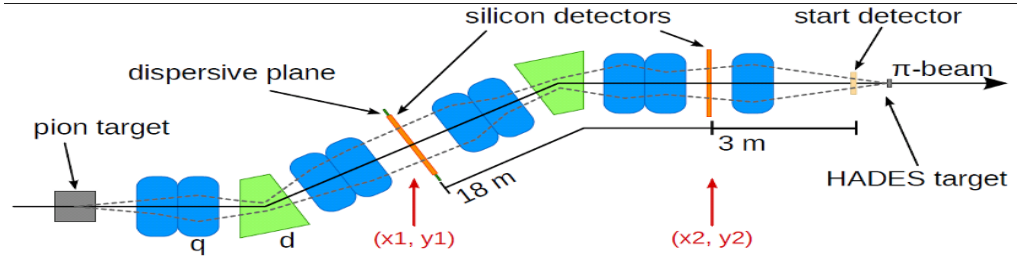
Hadron properties in cold nuclear matter in π induced reactions
HADES proposal for 2025-2026

Time-like electromagnetic form factors



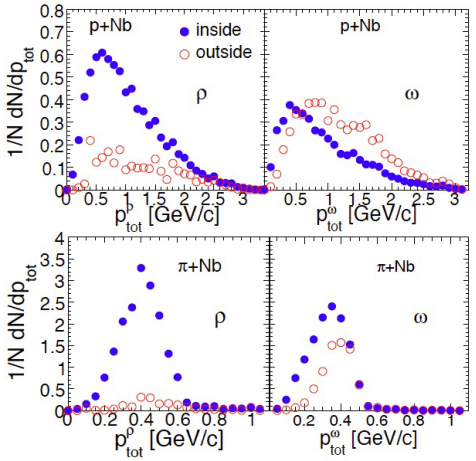
No data are available



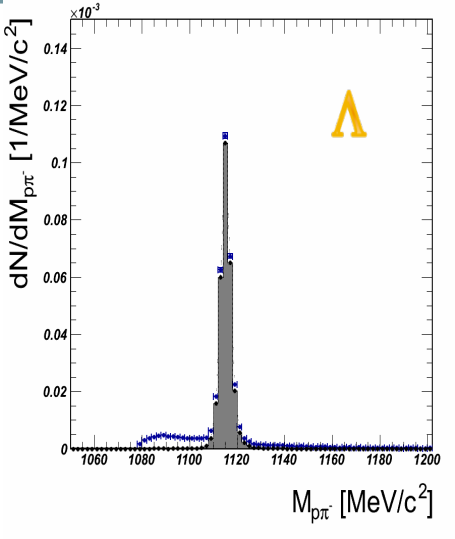


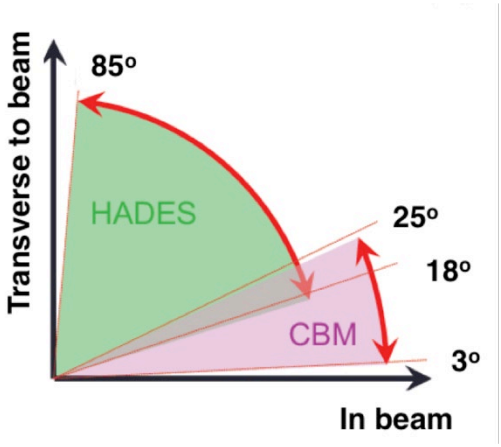
Was 21 shifts, DAQ$_{rate}$: 1kHZ

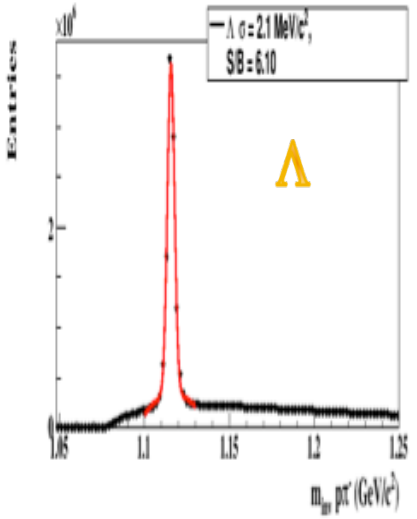
Expected for 2026:
42 shifts,
DAQ$_{rate}$: 45 kHz
gain factor: f$_{shift}$ 2 ・ f$_{DAQ}$ 45 = 90!



Emission of strange particles from Baryonic Matter: HADES, CBM

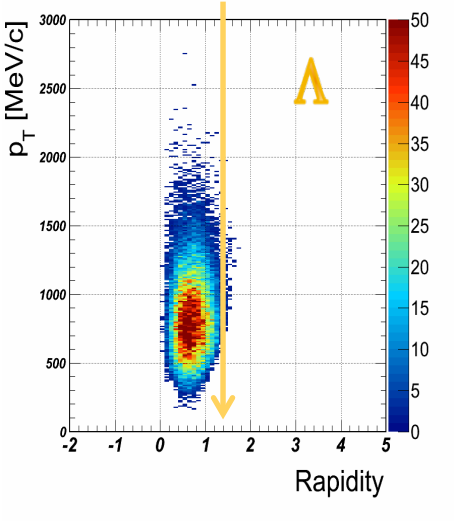


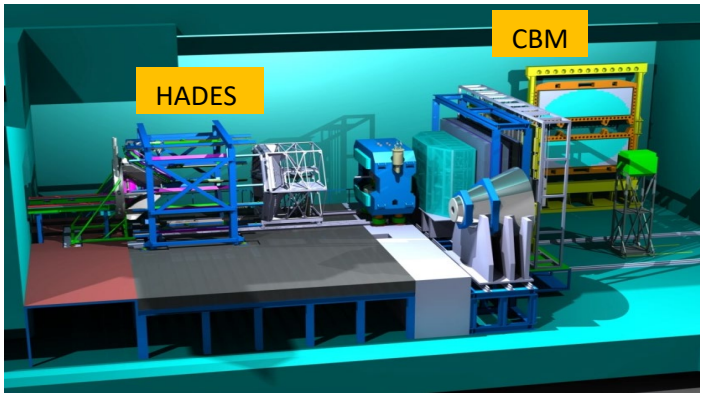




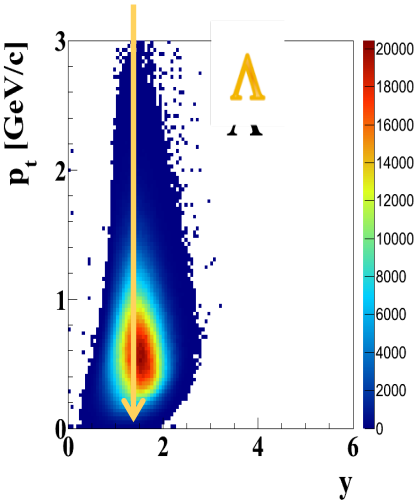
Phase space coverage (acceptance, reconstruction efficiency, secondary vertex cuts)

HADES Nb+Nb, 3.5A GeV



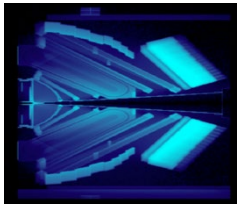


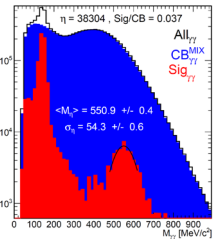
CBM Au+Au, 4A GeV

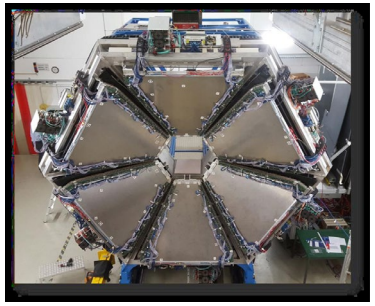


NPI in-kind contribution to HADES

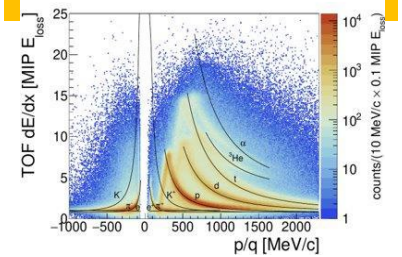
Electromagnetic Calorimeter (ECAL)
- 978 modules of lead glass + photomultiplier
- Detects two photons decays of neutral particles (mesons)

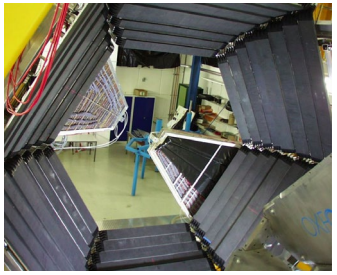


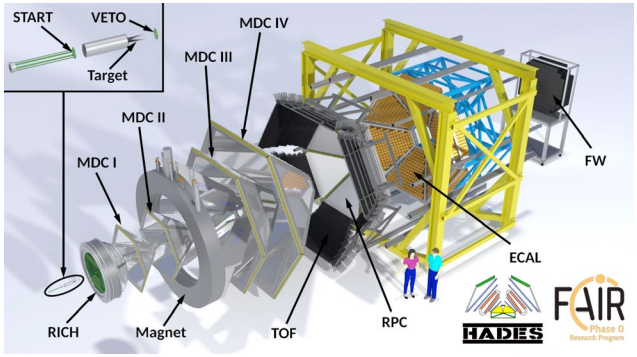




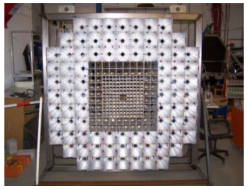
Time of Flight (TOF)
384 plastic rods + 768 photomultipliers

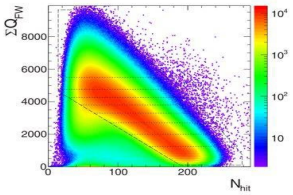






Forward Wall
288 plastic scintillators + 288 photomultipliers
- Size of cells 4x4, 8x8 and 16x16 cm^2
- Covering polar angle between 0.33°and 7.17°(7m distance from target)
- Provide rapidity separated measurement w.r.t. rest of HADES spectrometer
- Used for Centrality and Event Plane determination
- Very good resolution of the azimuthal angle of Event Plane allows to measure up to 6th order transverse flow harmonic(PRL 125, 262301 (2020))

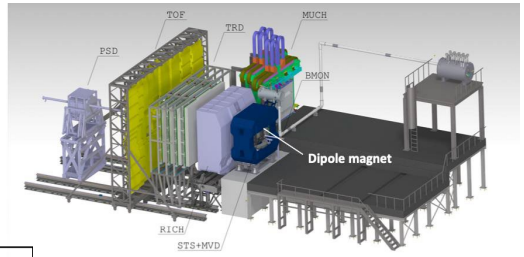




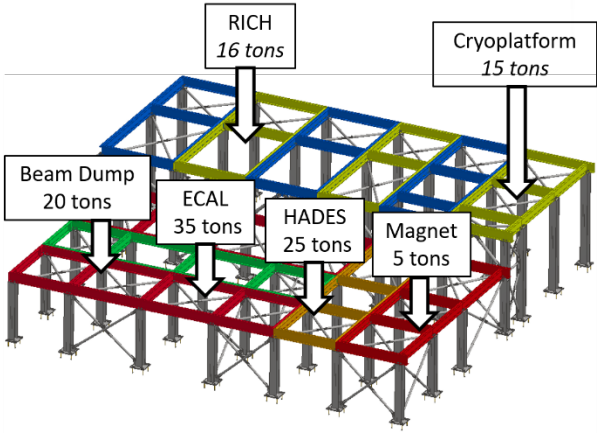
NPI and CTU in-kind contributions to CBM

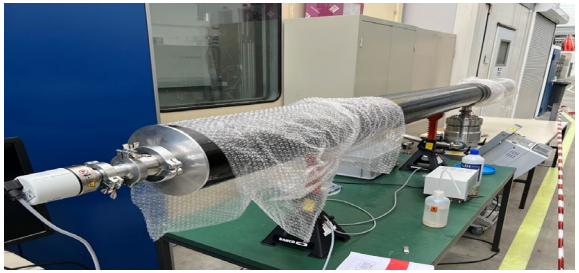
Compressed Baryonic Matter @ FAIR

CBM cave (CTU, NPI)
upstream platform -2023



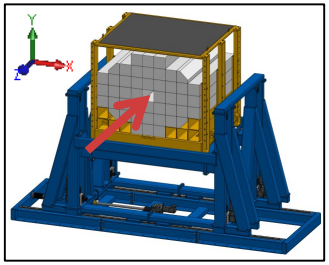
CBM cave (CTU, NPI)
Carbon beam pipe -2023
PhD thesis M.Smetana (CTU), 2024?
PhD thesis J.Kollarczyk (CTU+NPI), 2025?



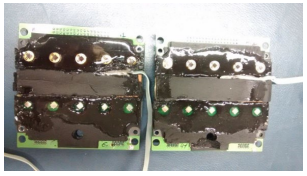


Radiation hardness and performance of the hadron calorimeter designed for Projectile Spectator Detection in the framework of international Collaboration CBM@FAIR

PhD thesis V.Mikhailov (CTU+NPI), 2021



PSD manipulator (CTU, NPI)
September 2020

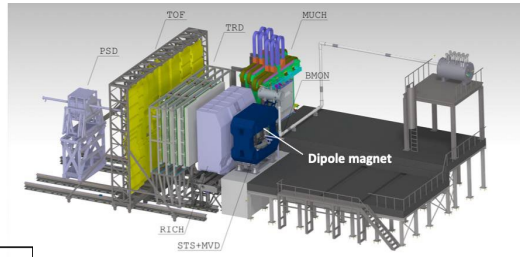


Neutron irradiation of SiPM for PSD at NPI Řež, up to 10^{12} neutrons/cm^2

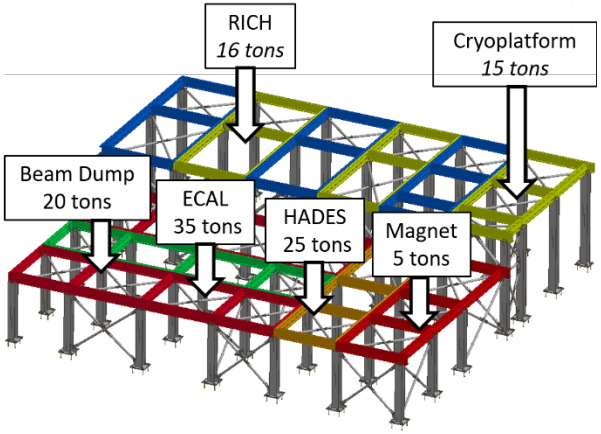
NPI and CTU in-kind contributions to CBM

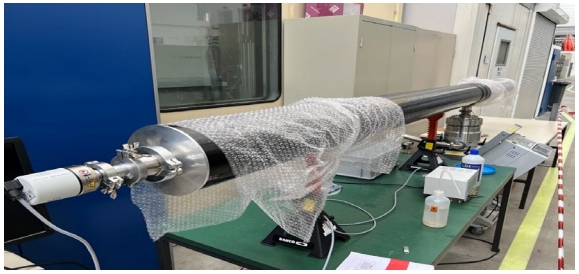
Compressed Baryonic Matter @ FAIR

CBM cave (CTU, NPI)
upstream platform -2023



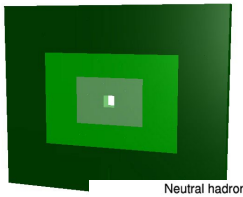
CBM cave (CTU, NPI)
Carbon beam pipe -2023
PhD thesis M.Smetana (CTU), 2024?
PhD thesis J.Kollarczyk (CTU+NPI), 2025?

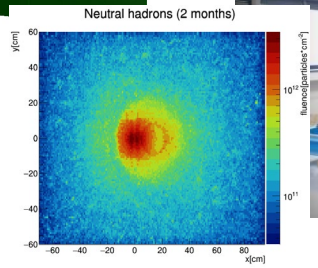




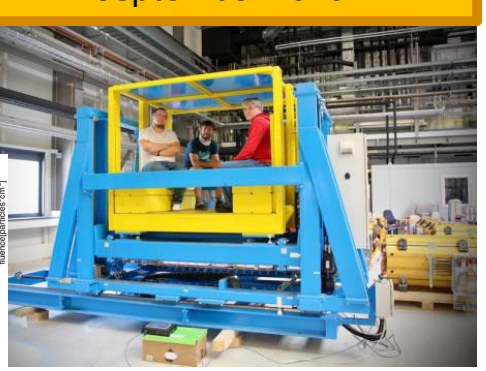
Radiation hardness and performance of the hadron calorimeter designed for Projectile Spectator Detection in the framework of international Collaboration CBM@FAIR

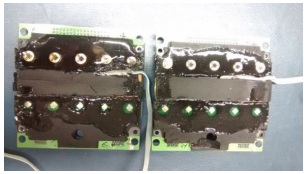
PhD thesis V.Mikhailov (CTU+NPI), 2021





FSD manipulator (CTU, NPI)
September 2020





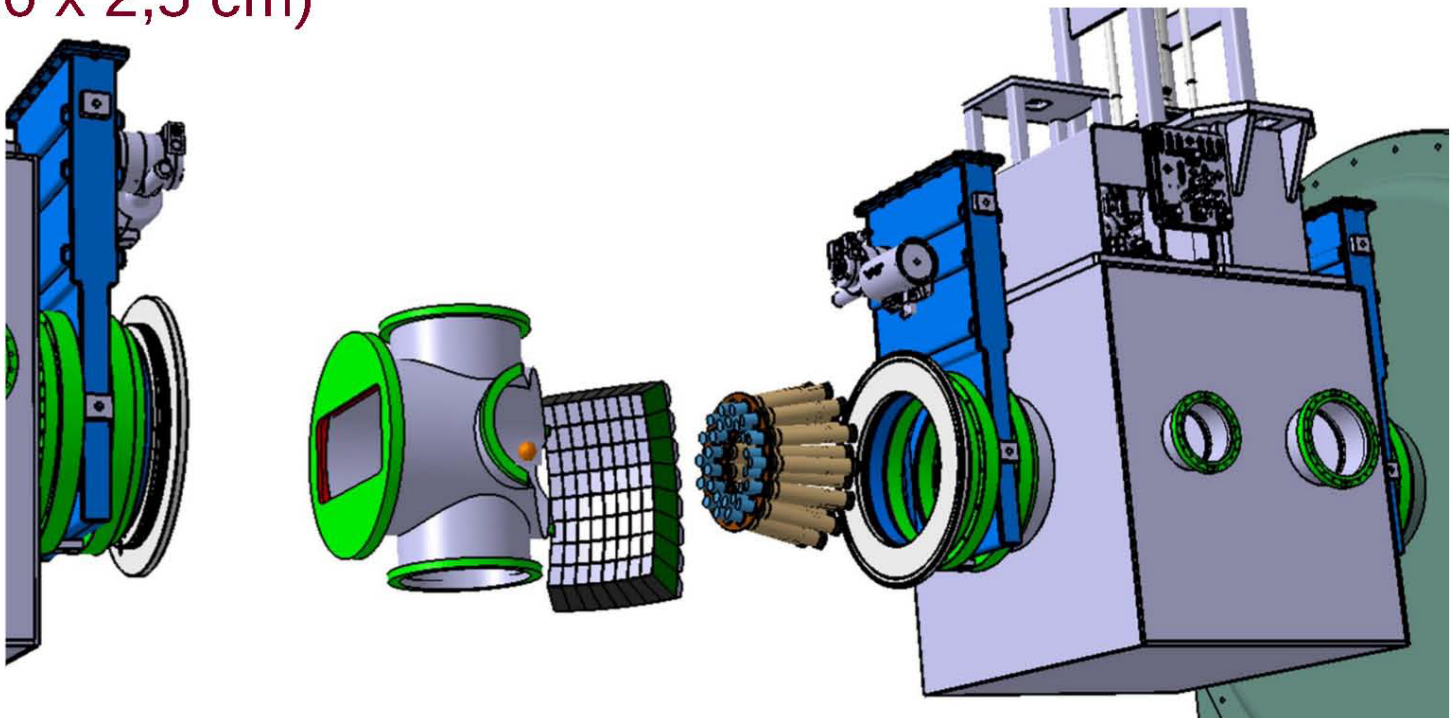
Neutron irradiation of SiPM for PSD at NPI Řež, up to 10^{12} neutrons/cm^2

GADAST@EXPERT: Czech contributions

- tagging of gammas from 2p-radioactivity
- E_g ~ 100 keV – 2 MeV
- trapezoidal CsI(Tl) crystals (4.1 x 7.6 x 15 cm)
- cylindrical $LaBr_3$(Ce) crystals (10 x 2,5 cm)

in the middle of SuperFRS in FMF2

128 modules CsI(Tl)
32 modules $LaBr_3$(Ce)



Electromagnetic Calorimeter @ PANDA

based on high-quality PWO-II crystals: Czech contribution

Barrel of Electromagnetic Calorimeter (EMC)
8 500 $PbWO_4$ crystals , operated at -25°C,
read-out by APD
Crystals to be produced in CRYTUR

- physical goals of PANDA require further development

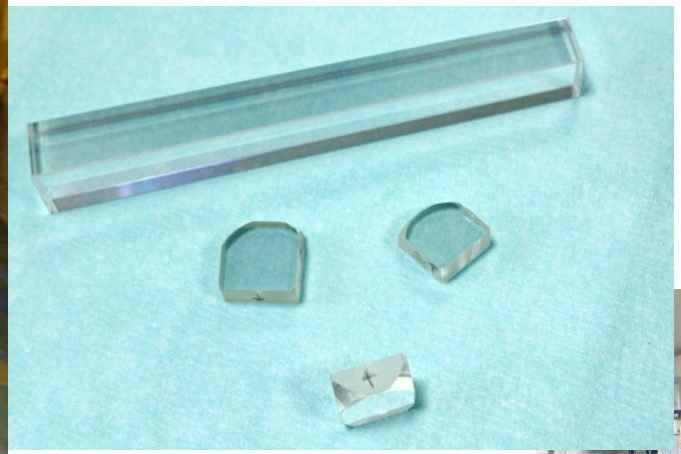
	PWO-I (CMS)	PWO-II (PANDA)
luminescence maximum, nm	420	420
La, Y concentration level, ppm	100	40
expected energy range of EMC	150MeV - 1TeV	10MeV - 10GeV
light yield, phe/MeV at room temperature	8-12	17-22
EMC operating temperature, °C	+18	-25
energy resolution of EMC at 1GeV, %	3,4	2,0

Test of radiation hardness of ingots @ Microtron Lab of NPI

- **irradiation of samples from the top and bottom part of the ingot by Bremstrahlung due to electrons from Microtron (5.5 MeV < E_e < 16.6 MeV)**
- **Samples are provided by CRYTUR**

MT25 Facility at Prague

- **homogeneous** illumination of the (rotated) sample
- **integral beam intensity** adjusted to irradiation γ-rays from ^{60}Co source (30Gy)
- illumination for 5-10 minutes
- immediate measurements of the **optical transmission** before and after irradiation (sample thickness ~ 10mm)



fast response for immediate reactions of CRYTUR

In-kind contributions of Czech Republic into FAIR (2016-2023-2026)

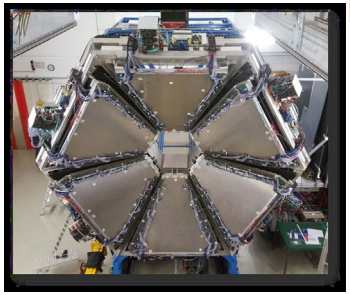
FAIR-CZ coordinates NPI, further partners are CU, CTU, SUO, UPO

2018

HADES (NPI)/Phase 0+1:
Electromagnetic Calorimeter -2023
ECAL upgrade will finish at 2026

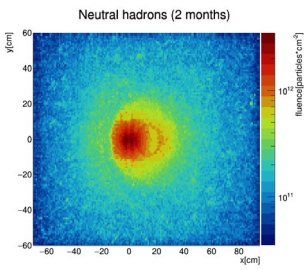
CBM (CTU, NPI):
PSD manipulator -2020
FSD (replacement of PSD) will finish at 2026

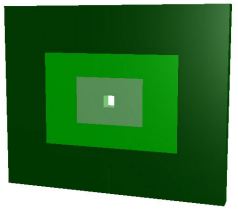
2019



PANDA (CU)
PbWO crystals -2023

April 2024

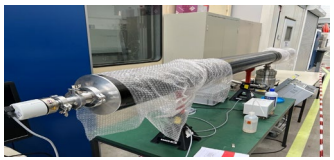


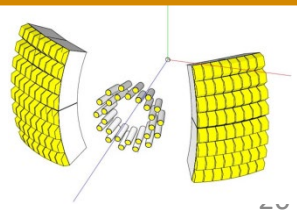


CBM cave (CTU, NPI)
Upstream platform -2023
Carbon beam pipe -2023
HEBT beam line finish at 2026

Artistic view 2028

NuSTAR GADAST (SUO) /Phase 0+1:
32 modules 2022
32 modules 2026





FAIR and FAIR-CZ future plans…

FAIR Phase 0 physics 2018-2025 experiments, Czech groups will participate in:

- ***HADES (CBM pillar)*** with participation of PANDA groups (RICH, TOF) plans to study Di-lepton production in pion-induced and HI reactions, as well as Hyperon Dalitz decays (PANDA),
- ***miniCBM*** tests of subsystems including FSD module prototypes plus data acquisition of CBM,
- ***NuSTAR EXPERT at FRS*** studies of new 2p radioactivity precursor and searches for new type of radioactivity - four proton one,
- ***NuSTAR SHE*** *studies of volatile carbonyls of seaborgium and bohrium*

- **FAIR civil construction finished in 2023. See** https://www.gsi.de/en/researchaccelerators/fair.htm
- **Start of FAIR Phase 1 NuSTAR , BIOMAT and CBM experiments at 2028+**
- **Start of FAIR Phase 1 PANDA experiments at 2032+**
- **R&D and installation of in-kind contributions to FAIR planned by Czech groups (OP JAK)**
  - upgrade of two sectors of HADES ECAL by replacing old 1,5" PMTs by new 3" PMTs –delivery will start at March 2025
  - install vacuum components on High Energy Beam line Transport in front of CBM cave - from 2025?
  - R&D of FSD and install of FSD into CBM cave at 2026
  - install 32 scintillation modules of the GADAST detector of EXPERT (NuSTAR pillar) at 2025 (32 modules delivered already before 2022) => full setup of 64 modules at 2026
  - Upgrade of local NPI cyclotron/microtron facilities – done 2024
  - Detector laboratory at CTU at 2025?

THANK YOU