Status report on CBM

C. Pauly, Wuppertal University
for the CBM collaboration

Contents:

CBM physics motivation

CBM detector setup

CBM-phase 0 activities:
- **mCBM**
- **HADES**

CBM motivation

Mission:

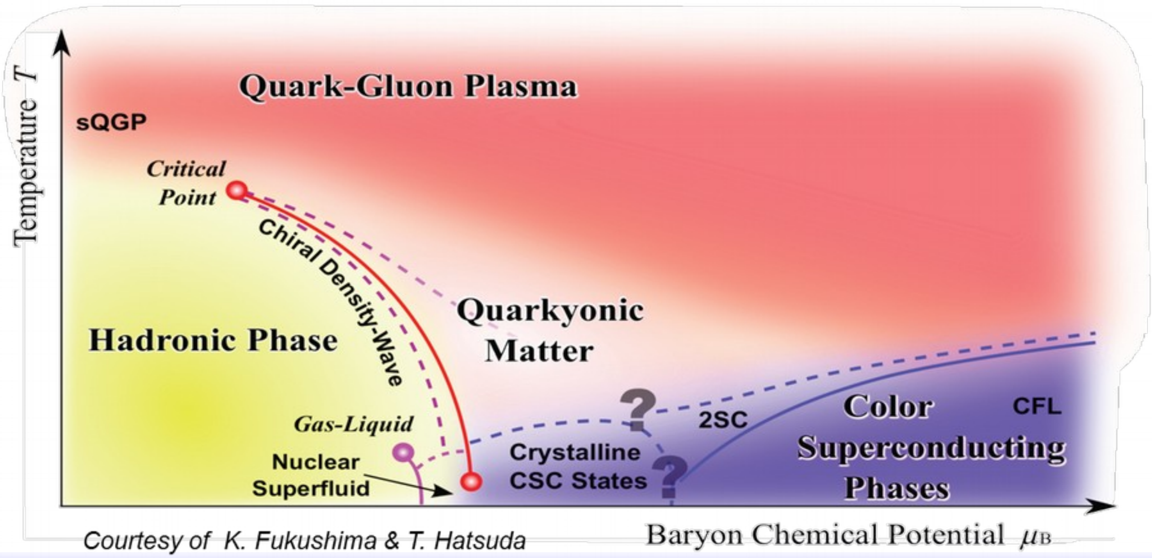
Explore the QCD phase diagram of baryonic matter at large baryon densities

Topics:

- QCD equation of state
- Search for exotic phases and 1^{st} order phase transition
- Critical endpoint
- Chiral symmetry restoration at high μ_B

CBM Probes:

- Collective Flow → nuclear matter EoS
- Event-by-Event fluctuations → critical endpoint
- Strangeness → signature of deconfinement
- (multi)-strange Hypernuclei → strange dimension of chart of nuclei
- Charm → early stages of collision, Debye-screening
- Dileptons



Courtesy of K. Fukushima & T. Hatsuda

Dileptons at CBM

Di-electron / Di-muon:

decouple from dense hadronic medium:
early system at high temperature and density

Low mass continuum: M_{ee} < 1 GeV/c²:

in medium ρ spectral function
→ chiral symmetry restauration at high μ_b
excess yield
→ fire ball space-time extension

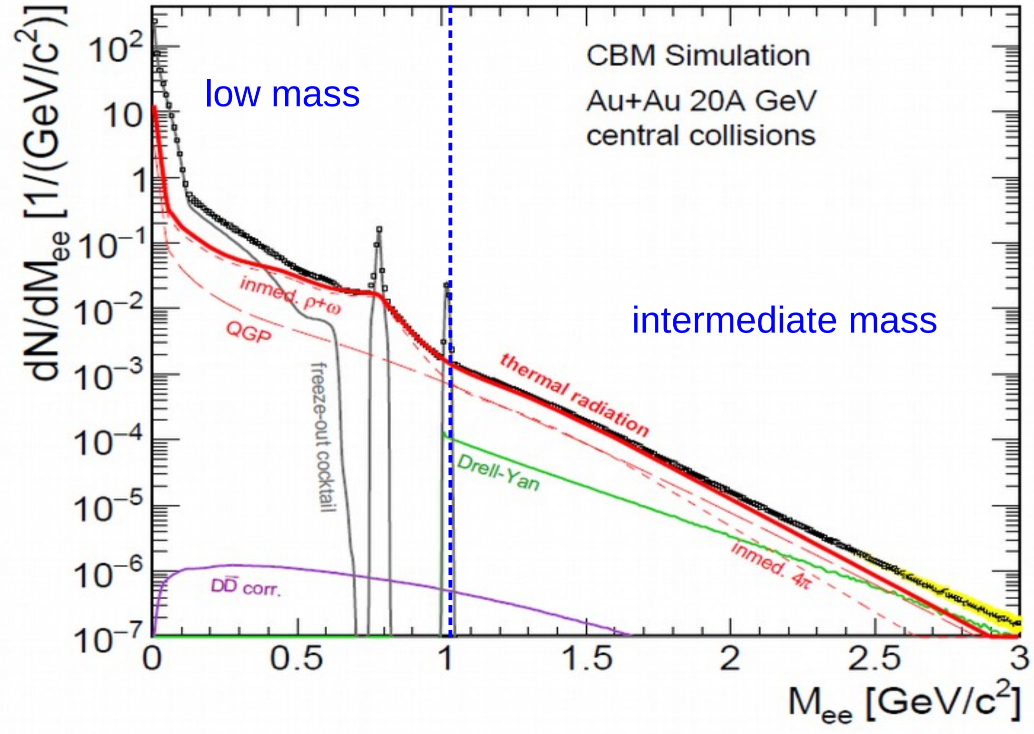
Intermediate mass range : 1 GeV/c² <M_{ee} < 2.5 GeV/c²:

reflects average fireball temperature
dileptons from multi-pion annihilation
→ ρ-a_1 scalar mixing

Challenges:

- very low signal cross sections
- branching ratios ~ 10^{-4}
- large combinatorial background

Dilepton invariant mass spectrum



R. Rapp, H. v.Hees, PLB 753 (2016) 586

no dilepton measurements between 2AGeV and 40 AGeV !

From neutron stars to heavy ion collisions

Crab-Nebula (Supernova 1054)

Temperature
T < 20 MeV

Core density
$\rho < 10\ \rho_0$

Lifetime
Δt ~ infinity

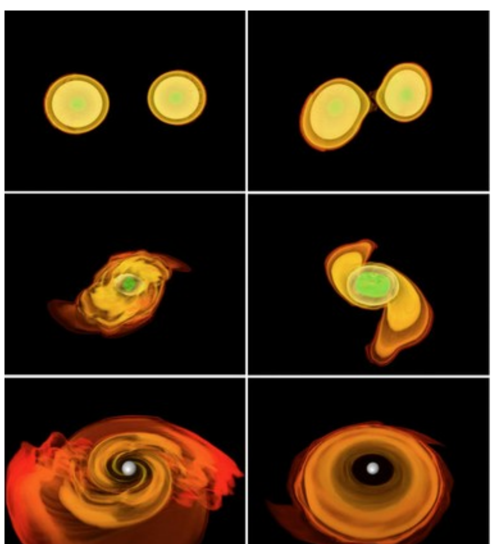
Crab pulsar T = 33.4 ms, Mass ~ 1.5 $M_\odot$
B0531+21

Neutron star merger (simulation)

Temperature
T < 70 MeV

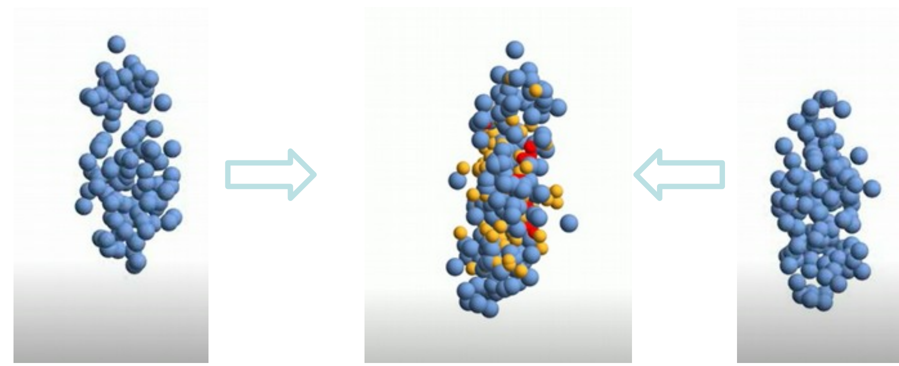
Core density
ρ ~ 2-6 ρ_0

Reactiontime
Δt ~ 10ms



Max Planck Institute for Gravitational Physics

Relativistic nucleus-nucleus collision SIS100



Temperature
T < 120 MeV

Density
$\rho < 8\ \rho_0$

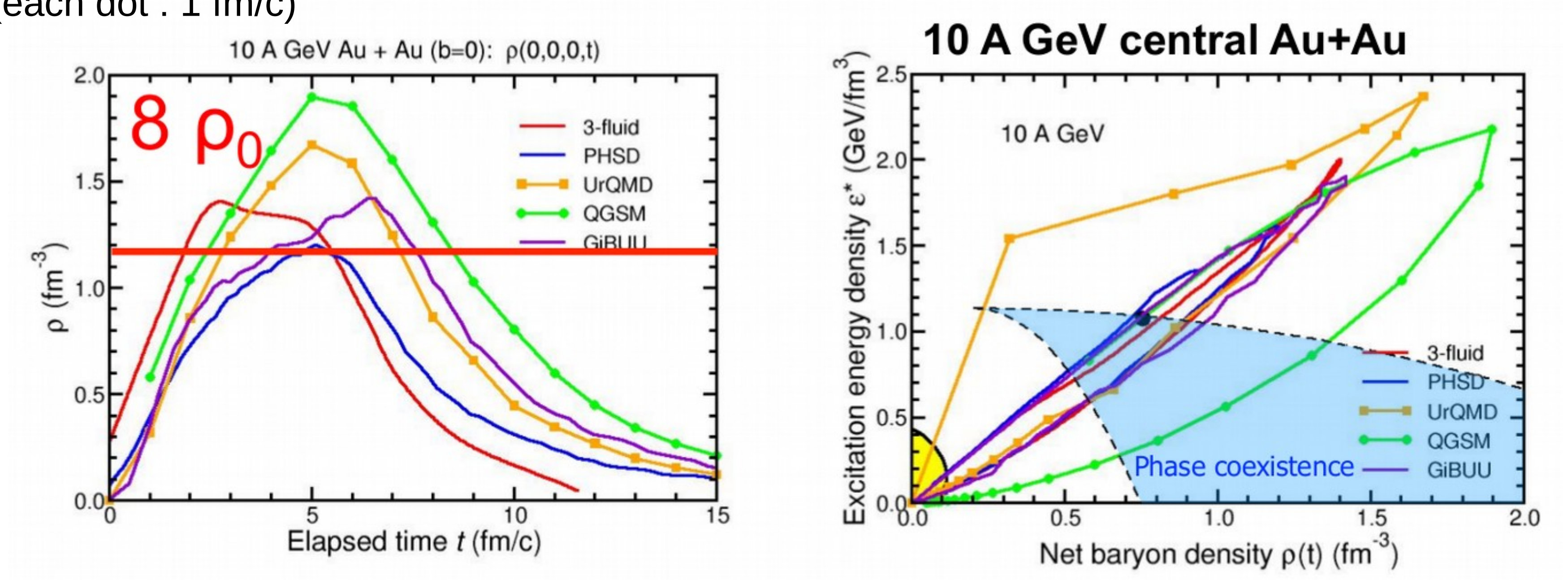
Reaction time
$\Delta t \sim 10^{-23}$ s

Creating dense matter in the lab

- Dense matter in the lab created in nucleus-nucleus collisions
- Maximum density and lifetime depends on beam energy

→ **FAIR SIS100 (SIS300) energy range ideally suited:**
Au+Au @ 11 AGeV (25 AGeV)

Phase space trajectories according to different transport calculations:
(each dot : 1 fm/c)



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

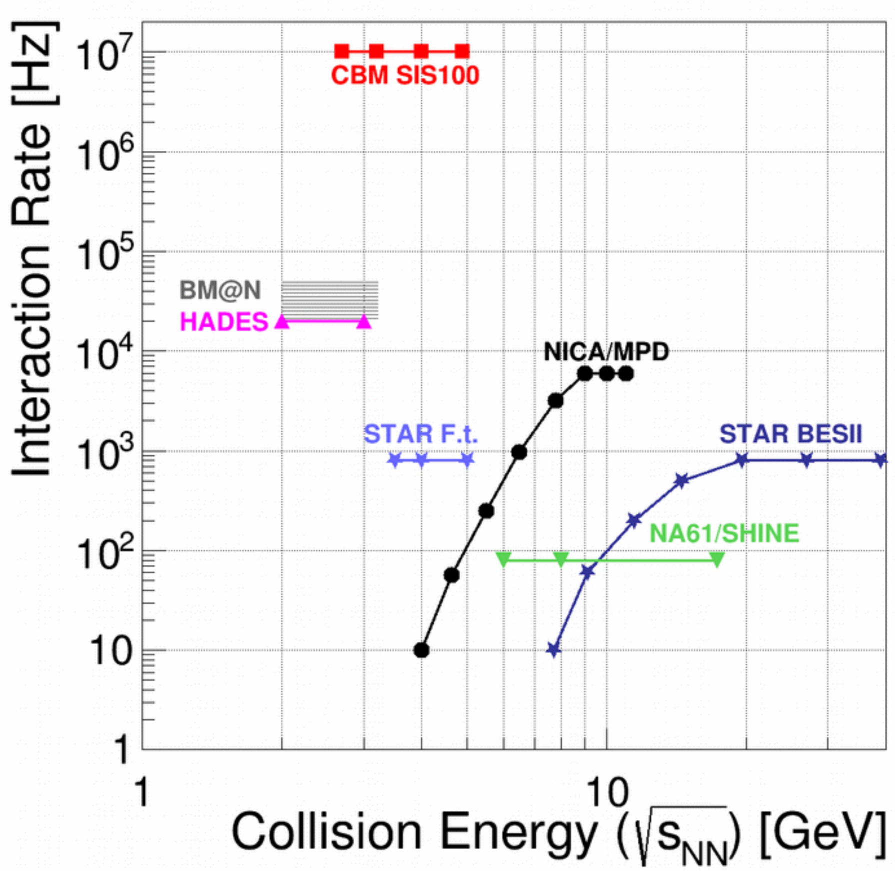
exploring dense matter: the rate challenge

- **NA61 / SHINE**, CERN-SPS
  light + medium heavy ion beams
  max 80 Hz event rate

- **BM@N**: Baryonic Matter @ Nuclotron, JINR
  Au up to 4 AGeV
  start: 2019

- **MPD@NICA**:
  Nuclotron based Heavy Ion Collider Facility NICA
  Au+Au. $\sqrt{S_{NN}}$ = 4 to 11 GeV, 10 Hz – 6 kHz
  start: 2021

- **STAR@RHIC:**
  Beam Energy Scan BESII
  STAR fixed target
  start: 2019



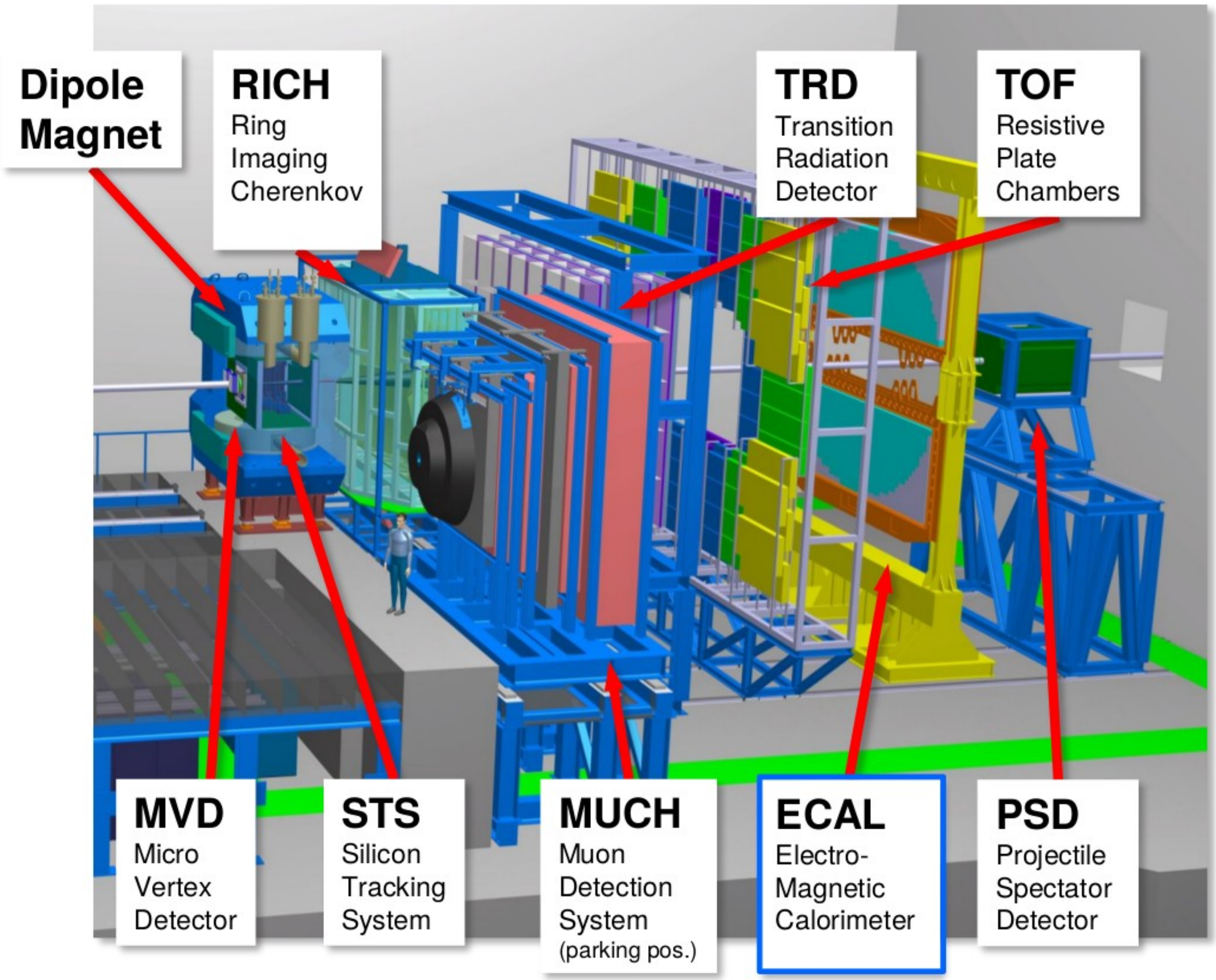
CBM collaboration, EPJ. A53(2017) no. 3, 60

Needed:

- large acceptance, fast detector
- high speed readout system
- high luminosity beams

CBM @ SIS100 energies
Au beam up to 11 AGeV, $\sqrt{S_{NN}}$ = 4.69 GeV
p beam up to 30 GeV

CBM @ SIS100

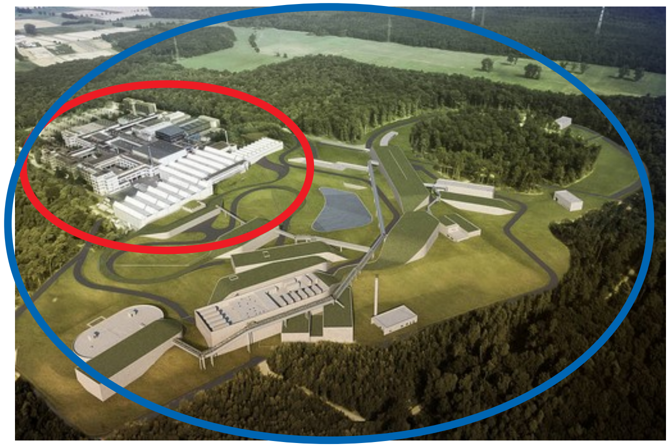


- fixed target
- geometrical acceptance: $2° < \theta_{lab} < 25°$
- free-streaming DAQ
- electron ↔ muon setup
  → same physics, diff. detector
- online event reconstruction

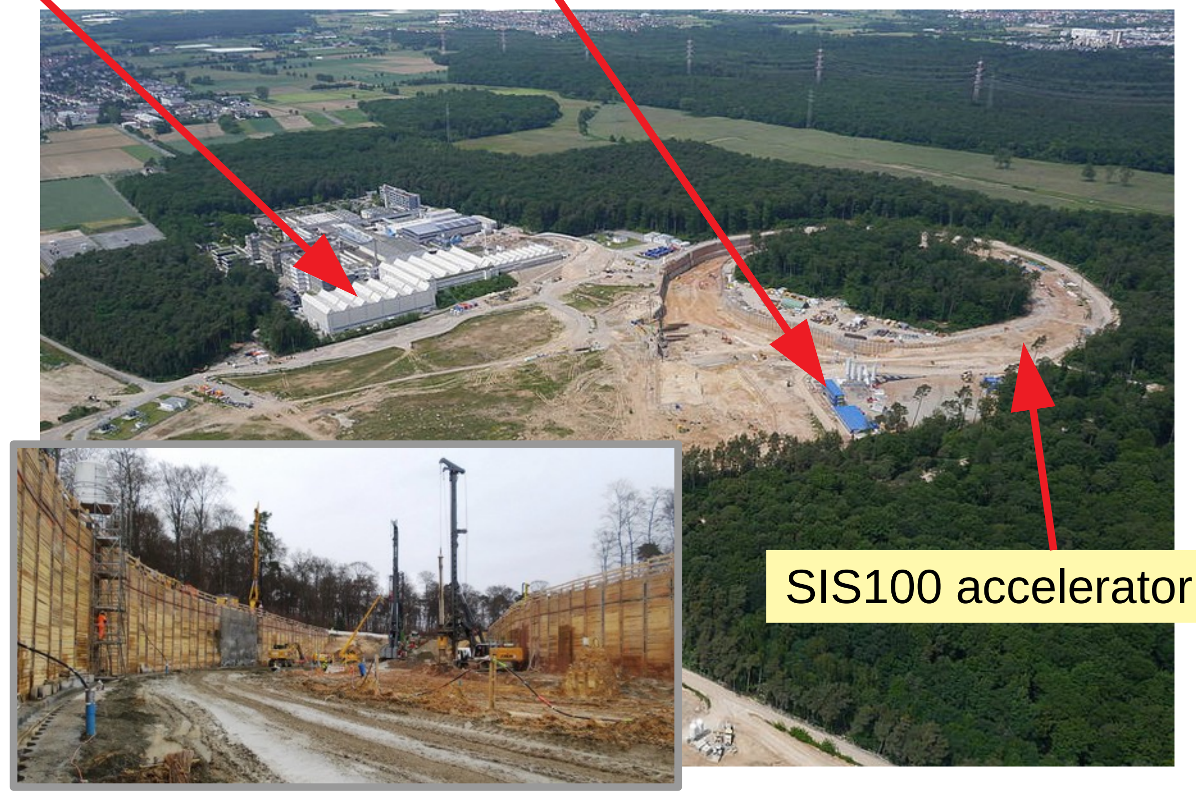
day1 setup: R_{int} = 0.5 MHz (0.1 MHz with MVD), w/o ECAL

phase1 setup: day1 + ECAL + ComputePerformance ↗ $R_{int,nax}$ = 10 MHz

FAIR – home of CBM and HADES



The future FAIR facility



The FAIR construction site as it looks today

- FAIR civil construction started 4th of July 2017

  Much progress during last year !
  Beam back in GSI SIS18
  after 4 year shutdown for upgrades

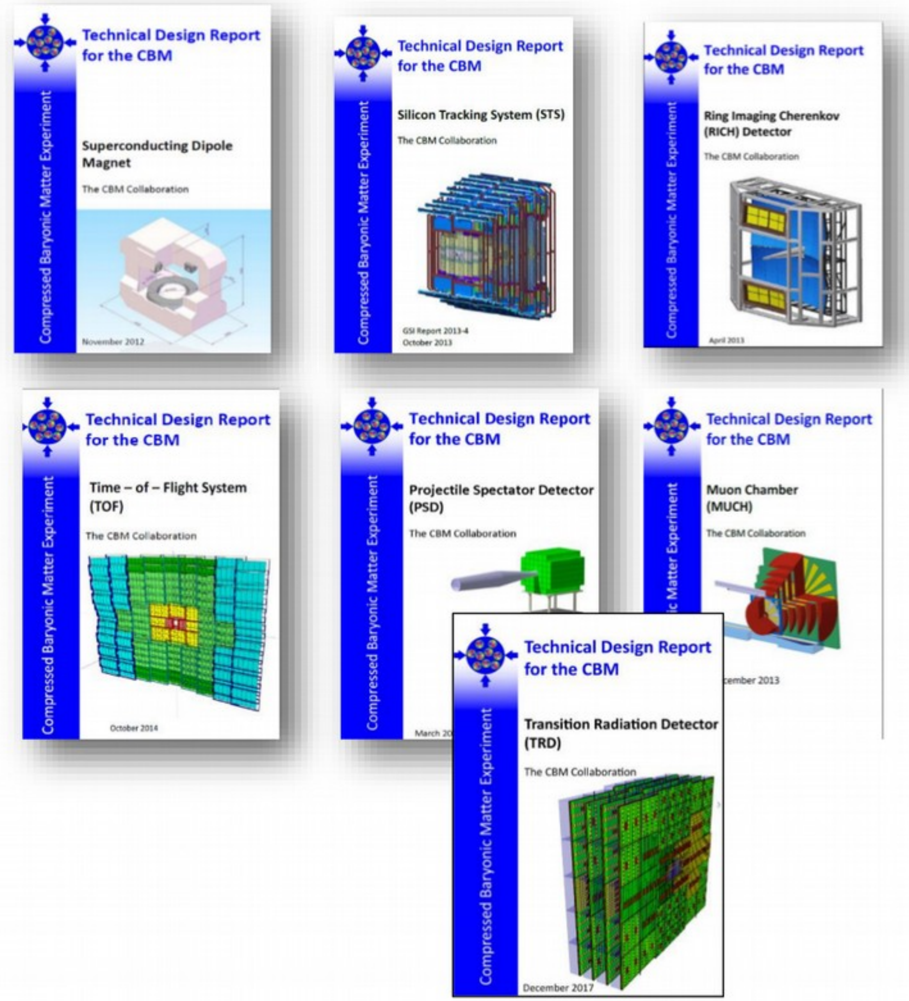
- Just last week :
  First beam on target mCBM + HADES

- **HADES physics run March 2019**

Bilder: GSI Helmholtzzentrum für Schwerionenforschung

CBM entering construction phase

#	Project	TDR status
1	Magnet	approved 2013
2	STS	approved 2013
3	RICH	approved 2014
4	TOF	approved 2015
5	MUCH	approved 2015
6	PSD	approved 2015
7	TRD	approved 2018
8	MVD	submission 2019
9a	Online Systems: DAQ	submission 2019
9b	Online systems: FLES	submission 2020
10	ECAL	t.b.d.



TDRs approved for nearly all major subdetector systems by FAIR ECE

CBM subdetector status-highlights

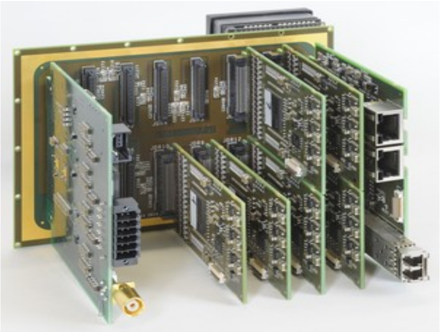
STS:

- **start sensor series production:** early 2019
- carbon fiber ladder supports ready for series production
- module assembly procedure defined (GSI, JINR)

first STS module with full 2-sided readout

RICH:

- **All Photomultipliers obtained**, series tested, characterized
  FPGA-based frontend chain developed, tested now in HADES-RICH
- construction of gas system: starting 2019
- large scale prototypes of mirror structure, photon camera



6 MAPMT readout module

MUCH:

- prototype GEM chamber build, tested at SPS/CERN
- **2 modules ready for mini-CBM setup**

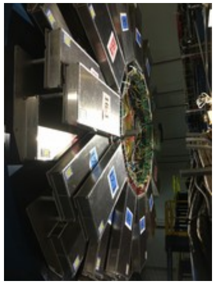
TRD:

- **2 full-size TRD modules incl. readout installed in mCBM**
  final version of frontend ASIC SPADIC 2.2 submitted

TOF:

- **36 MRPC modules (10% of CBM total) installed in STAR@RHIC**
- pre-mass production of 25 MRPC counters for mTOF finished

mTOF wall, 25 RPC sensors



eTOF@STAR

PSD:

- **46 PSD modules already build and QA tested**
  -> to be used first in mCBM, BM@N, NA61
- construction and delivery of CBM PSD mechanics 2019

mCBM@SIS18

mCBM serves as a **demonstrator** of the complete CBM free-streaming readout, including data transport to mFLES @ GreenITCube

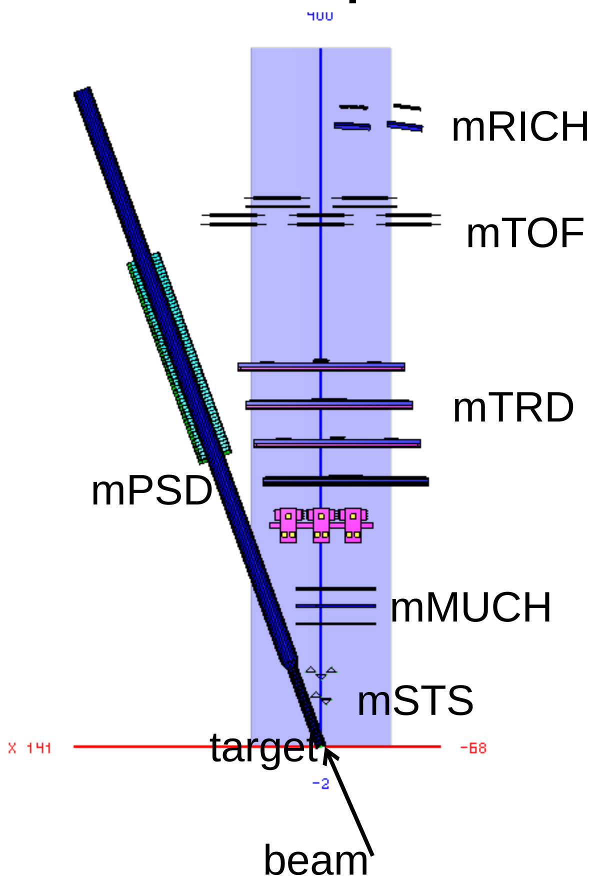
Concept:

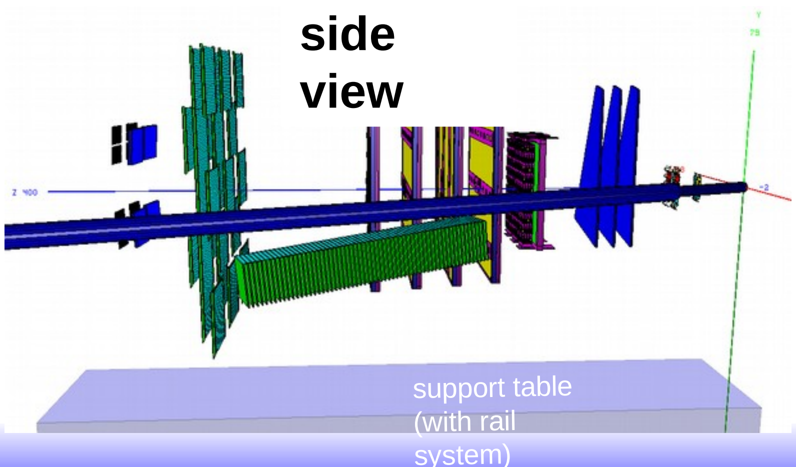
- permanent setup at host lab: **SIS 18**
- fixed target, ~ 25° scattering angle
- collision rates up to 10 MHz
- no B-field → straight tracks

Stepwise approach:

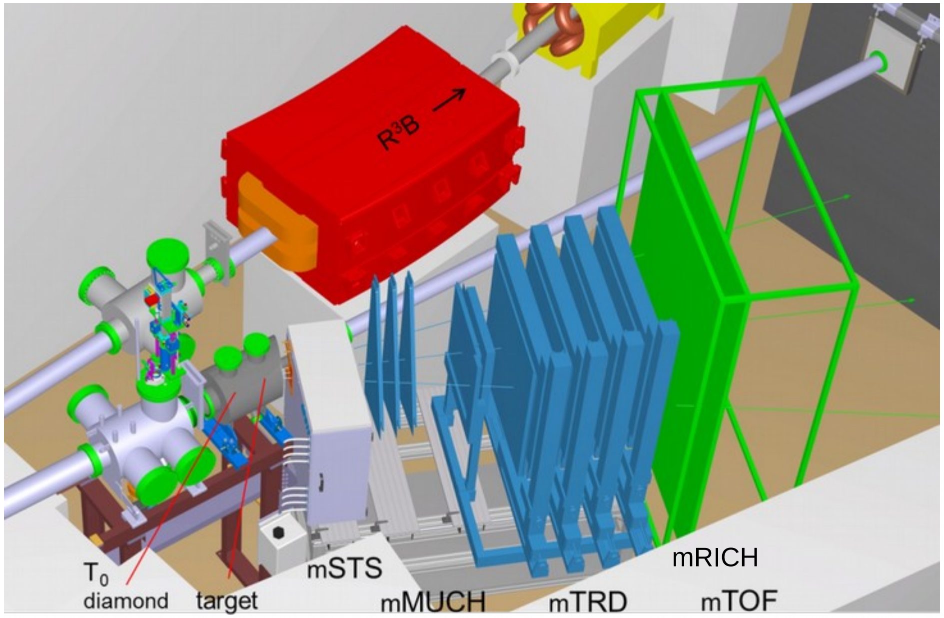
2019 : proove functionality
2020 : proove full rate capability } beamtime already granted by GPAC
2021 : benchmark observable : λ reconstruction
2022 : λ excitation function

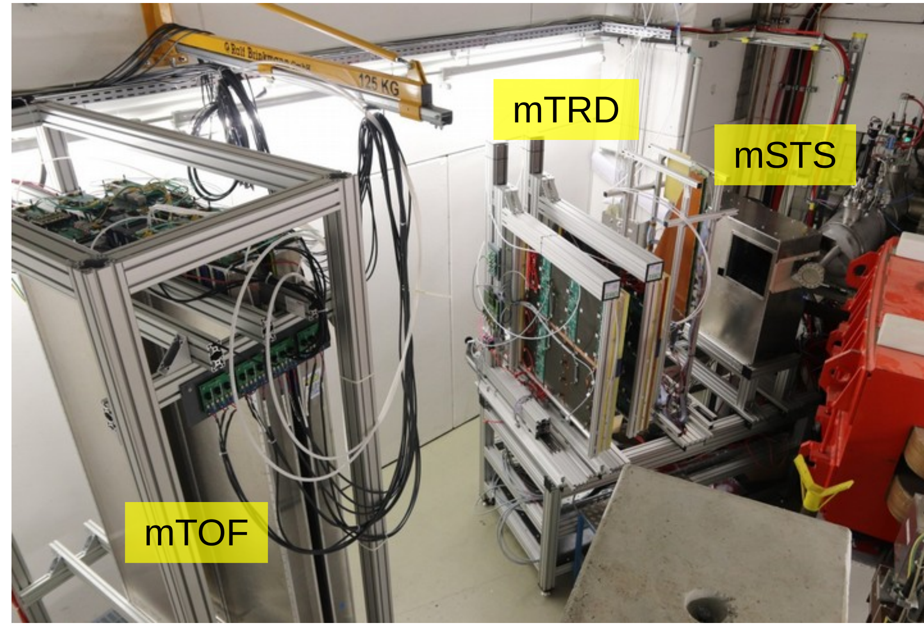
top view





mCBM @ SIS18 – phase 1





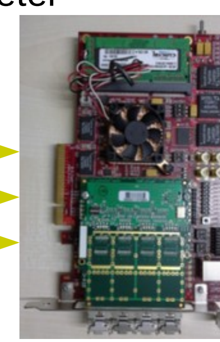
~50 meter

close to mCBM

DPB
data processing boards

~400 meter

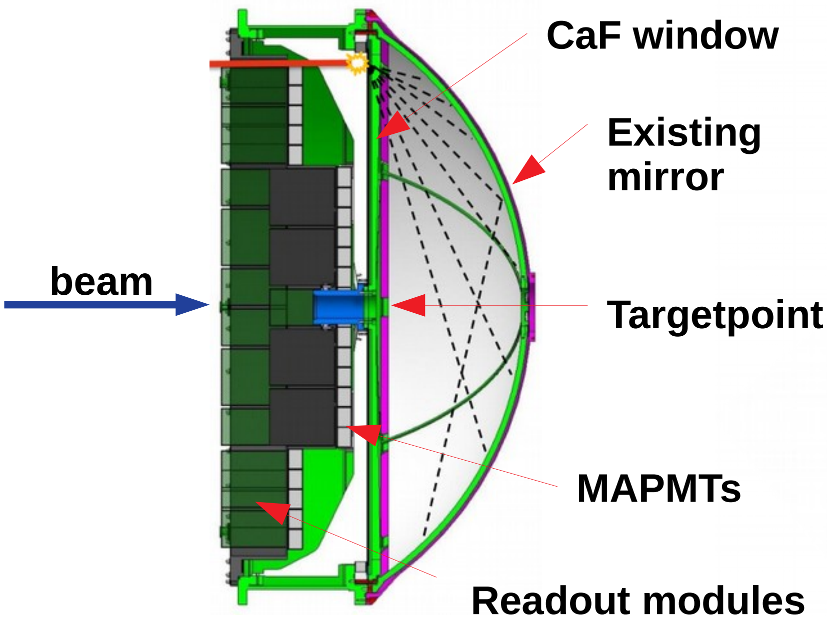
GreenITCube

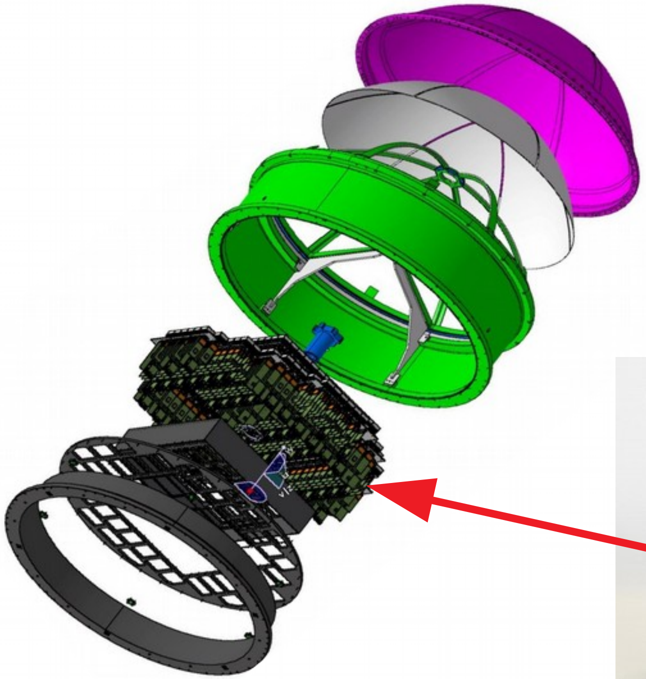


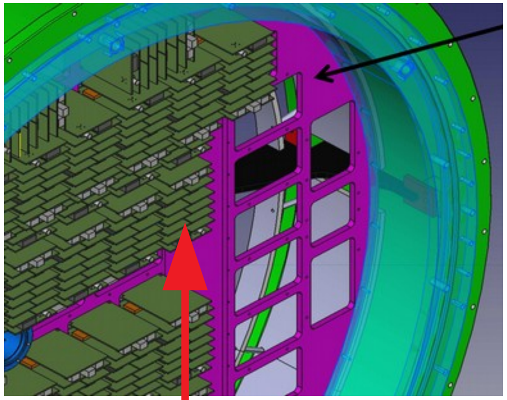
FLIB
1^{st} Level Input Board

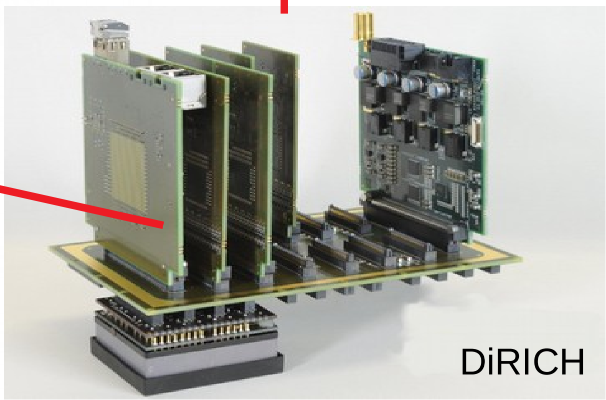
FLES
1^{st} level event selector

CBM Phase 0: HADES RICH upgrade









- Upgrade of HADES RICH photon detector using 50% of CBM RICH MAPMTs
- Common CBM/HADES development of FPGA-based readout chain for MAPMTs and MCPs

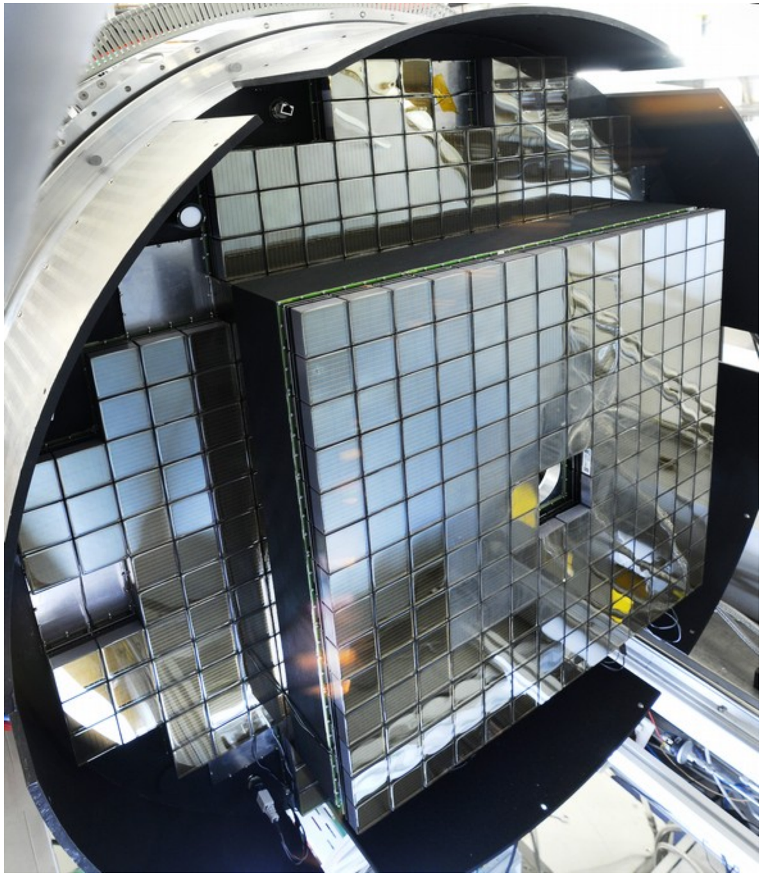
- Same readout will also be used by PANDA DIRC, PANDA fRICH

- **Perfect example for synergies due to FAIR phase 0 !**

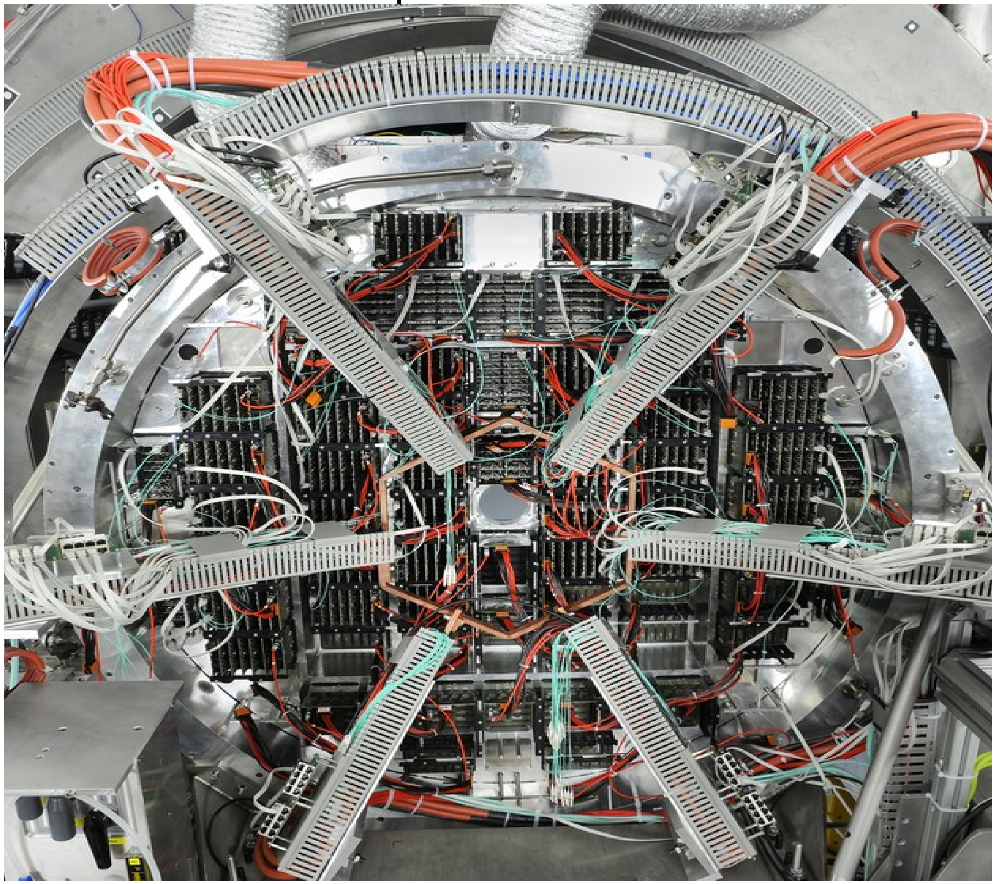
CBM groups:
GSI Darmstadt, Univ. Giesen, Univ. Wuppertal

New photon detector with MAPMTs

HADES RICH photon detector, Multianode PMTs



HADES RICH photon detector readout



➡ already 50% of CBM RICH photon detector !

Installation finished (summer 2018)
waiting for beam...

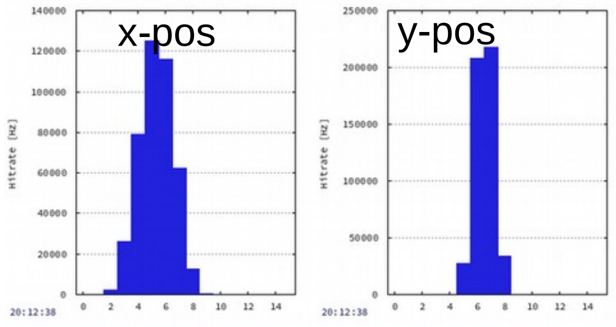
photos by G. Otto, GSI

CBM Phase0 @ GSI/FAIR has started !

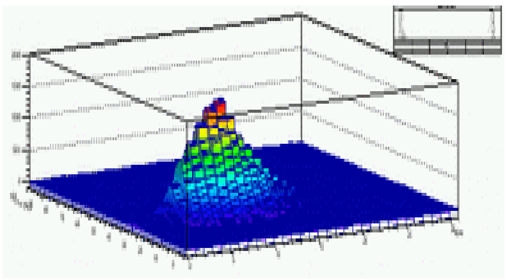
first SIS18 beam on target after 4 year shutdown

last week: HADES

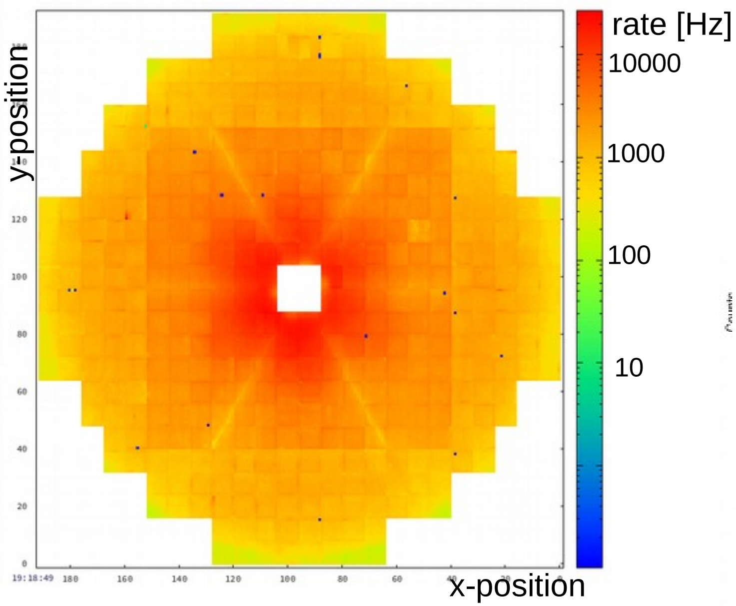
this week: mCBM



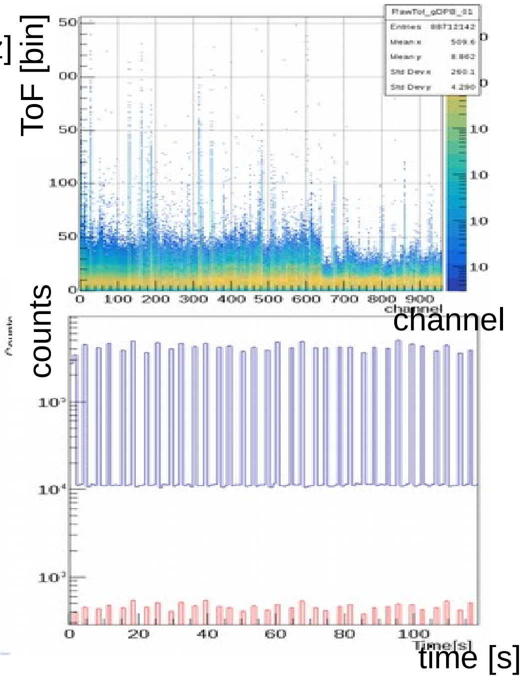
HADES beam spot on target (300 µm/bin)



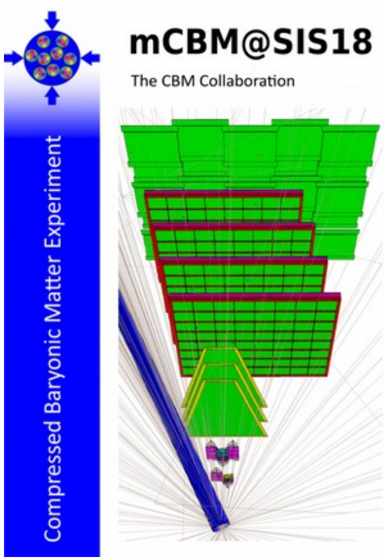
beam profile mCBM beam dump

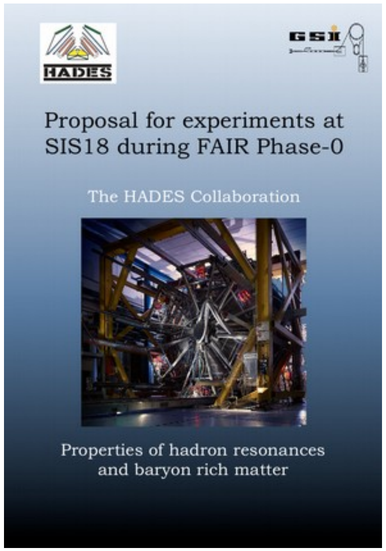


beam induced single photon hit rate on new HADES RICH photon detector



first beam data from mTOF





Detailed beamtime proposals:

mCBM and HADES @ SIS18
in 2019/2020
accepted by GPAC in 2017

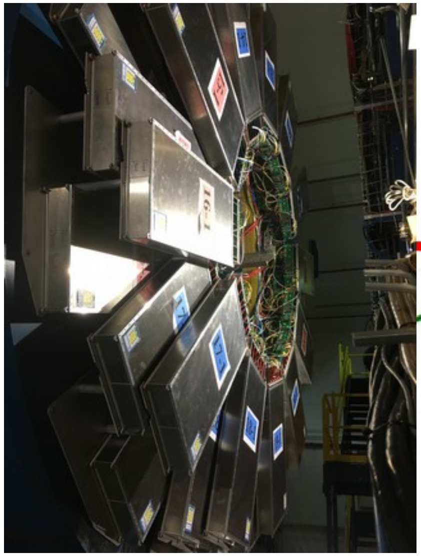
HADES:

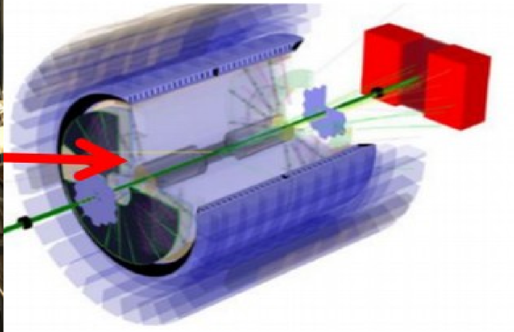
4 week production run
Ag+Ag @ 1.65 AGeV
in March 2019

mCBM:

parasitic beam, in parallel to HADES

further CBM-phase 0 activities:

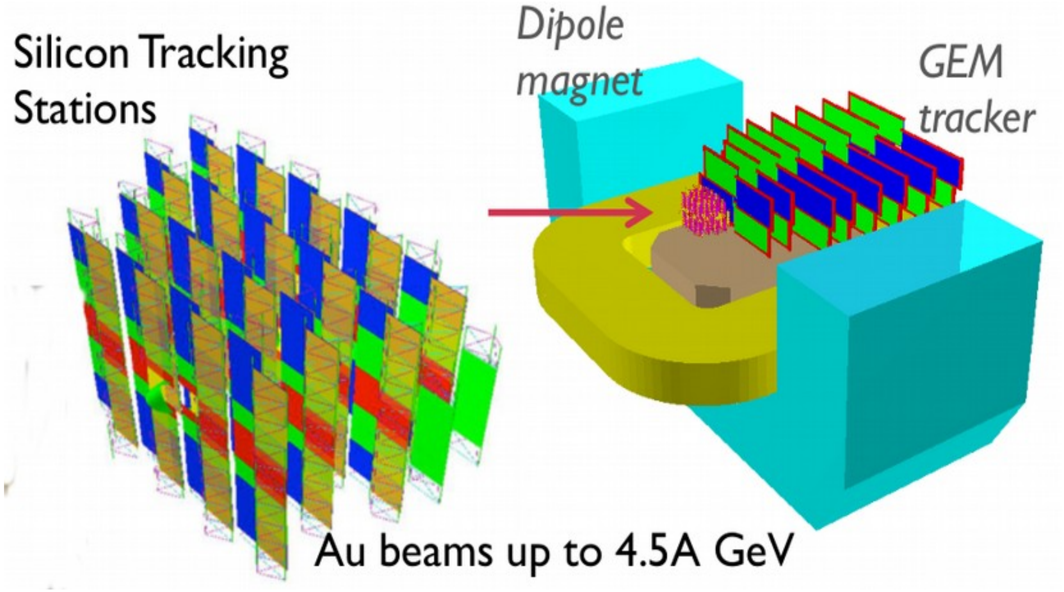




eTOF @ STAR:

36 MRPC modules (10% CBM total) installed last months including readout chain at **STAR/RHIC**, to be used in Beam Energy Scan **BES II 2019 / 2020**

CBM groups:
Univ. Heidelberg, TU Darmstadt,
GSI Darmstadt, Univ. Frankfurt,
Tsinghua Univ. Beijing, USTC Hefei, CCNU Wuhan



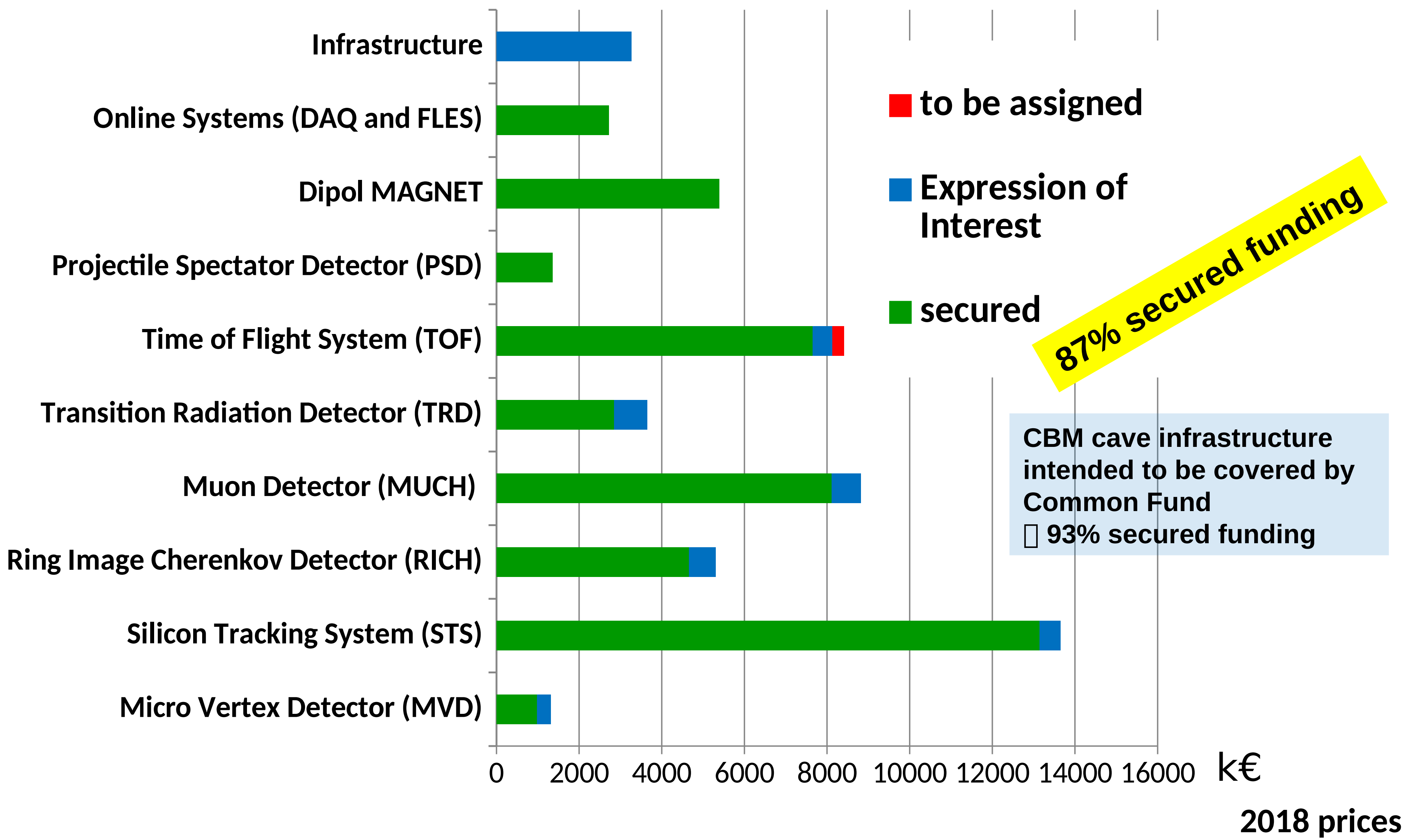
BM@N:

installation, commissioning and operation of
- **4 silicon stations of** CBM STS like design
- installation of **CBM PSD module**

Au beam in late 2020

CBM groups:
GSI Darmstadt, Univ. Tübingen, JINR

Funding CBM day-1 setup (RRB 8, 26. Nov. 2018)



CBM collaboration: 55 institutions, 470 members

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

Czech Republic:
CAS, Rez
Techn. Univ. Prague

France:
IPHC Strasbourg

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.
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 TU

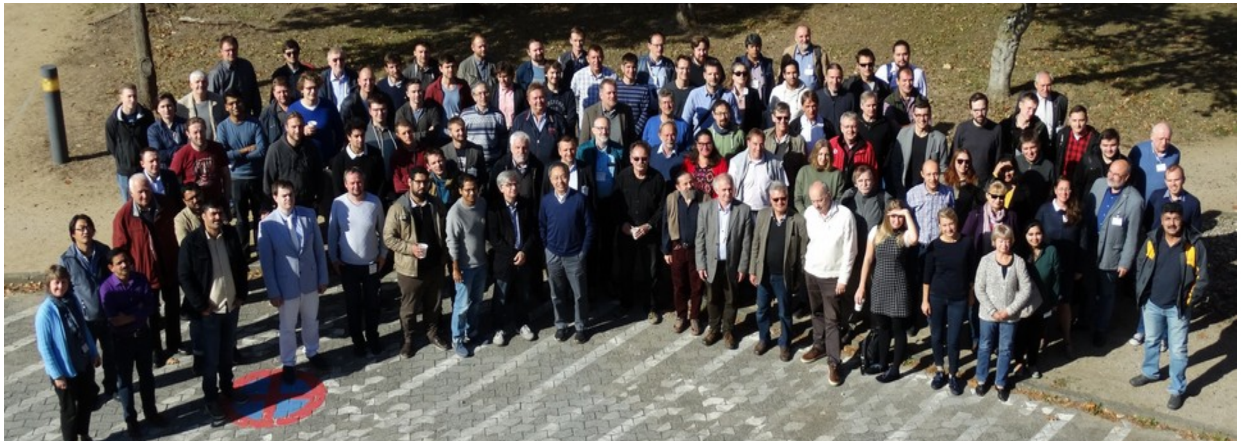
Romania:
NIPNE Bucharest
Univ. Bucharest

Hungary:
KFKI Budapest
Eötvös Univ.

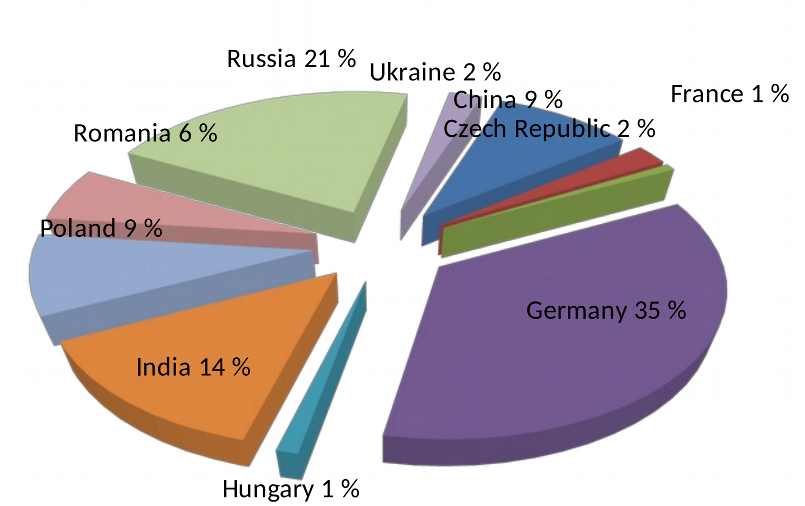
Russia:
IHEP Protvino
INR Troitzk
ITEP Moscow
Kurchatov Inst., Moscow
VBLHEP, JINR Dubna
LIT, JINR Dubna
MEPHI Moscow
PNPI Gatchina
SINP MSU, Moscow

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

32nd CBM collaboration meeting
GSI, Darmstadt, 01. -05.10. 2018



CBM Scientists



additional material

(some) CBM probes of dense matter

Collective flow of (identified) hadrons:

driven by preasure gradient in early fireball
v_1, v_2 : directed / elliptic flow
information on nuclear matter Equation-of-State

Event-by-event fluctuations of conserved quantities:

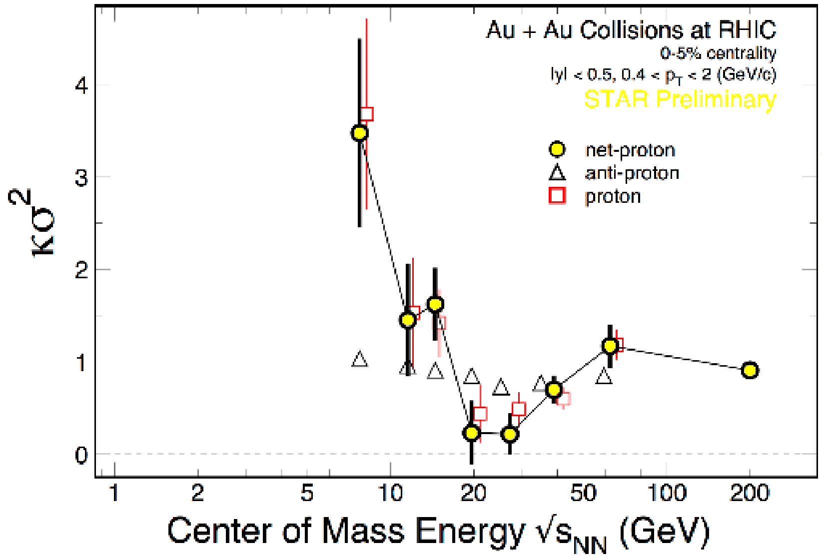
baryon number, strangeness, electric charge
cumulants sensitive to proximity of critical point
no data available at SIS100 energy range

(Multi) -strange hypernuclei:

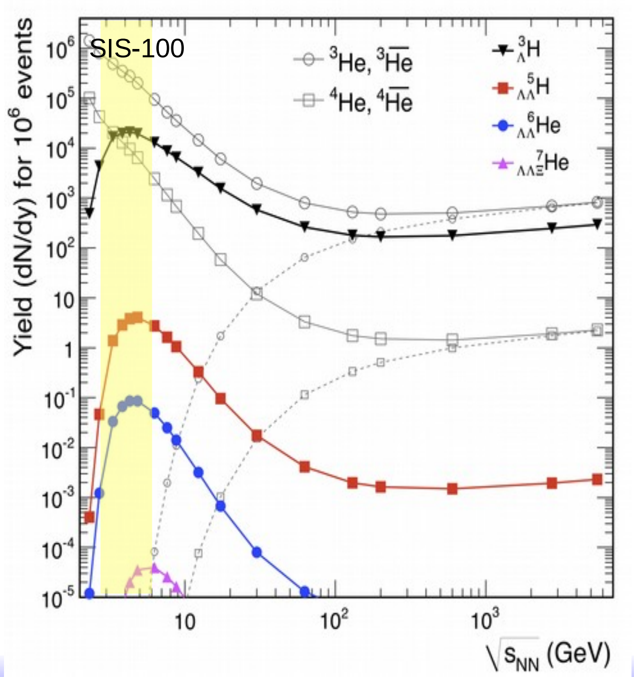
via coalescence of Λ with nucleon
SIS100 energy range particularly well suited
explore strange dimension of chart of nuclei
hyperon – hyperon / hyperon-nucleon interaction
→ neutron star models

Charm:

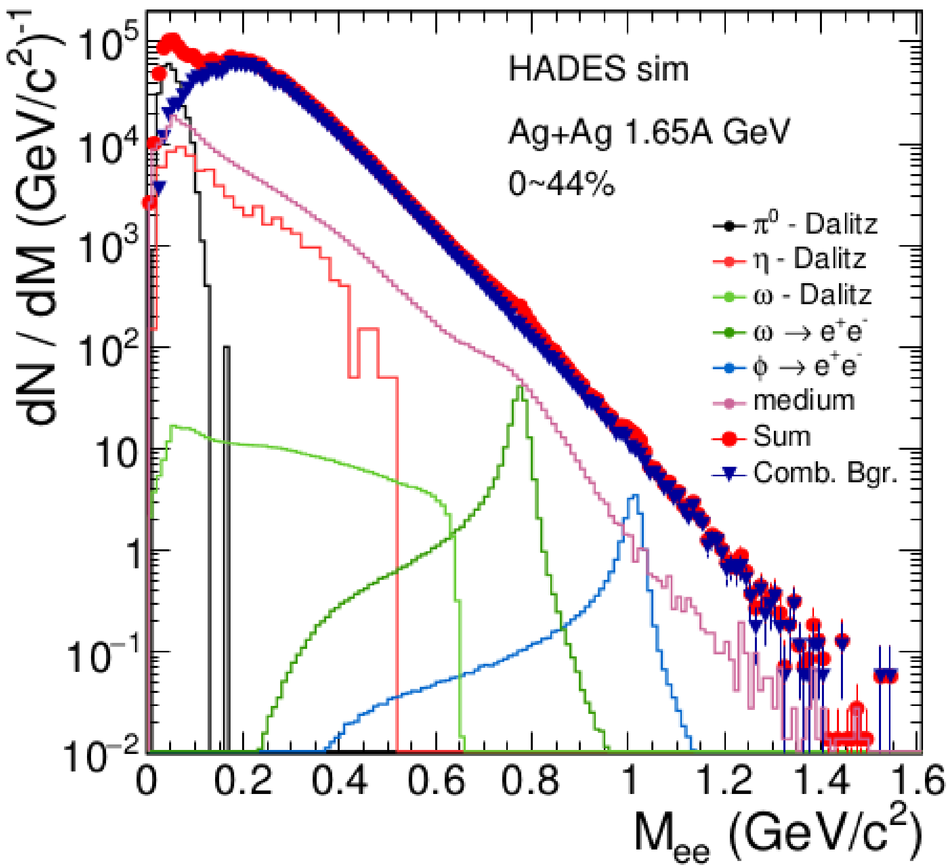
created early in collision process
J/Ψsuppression due to Debye-screening in partonic medium
→ good signature for quark gluon plasma
no data on open / hidden charm below RHIC / LHC energies

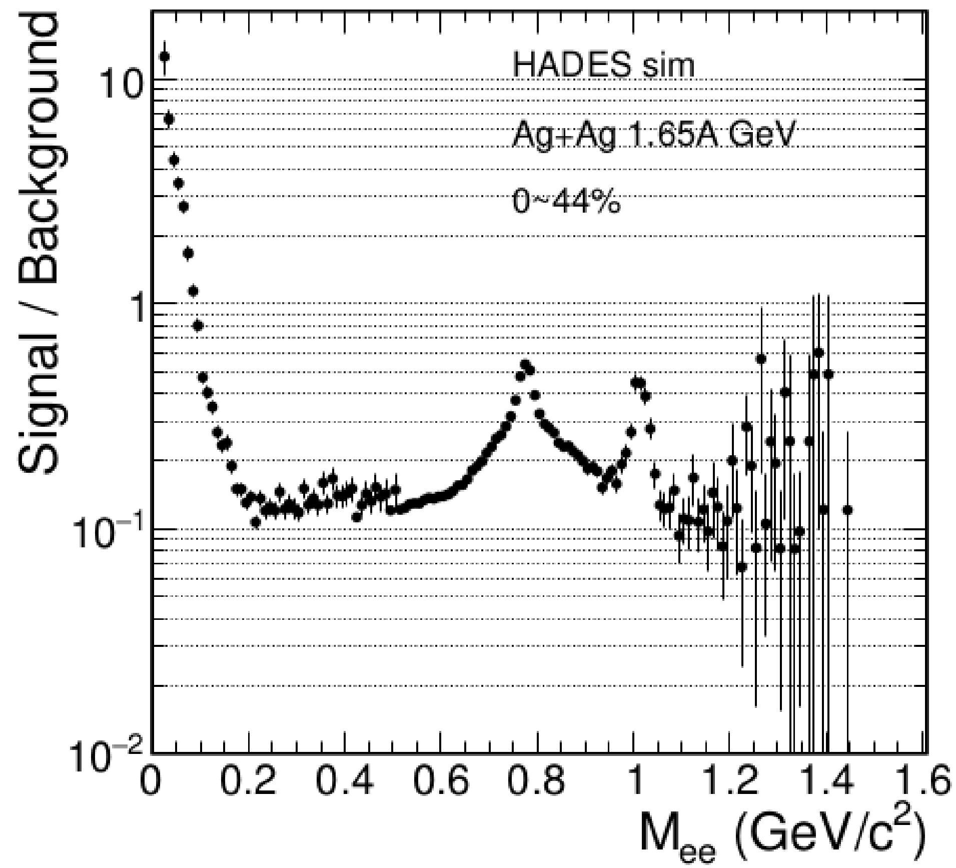


A. Andronic et al., Phys. Lett. B 697 (2011) 203

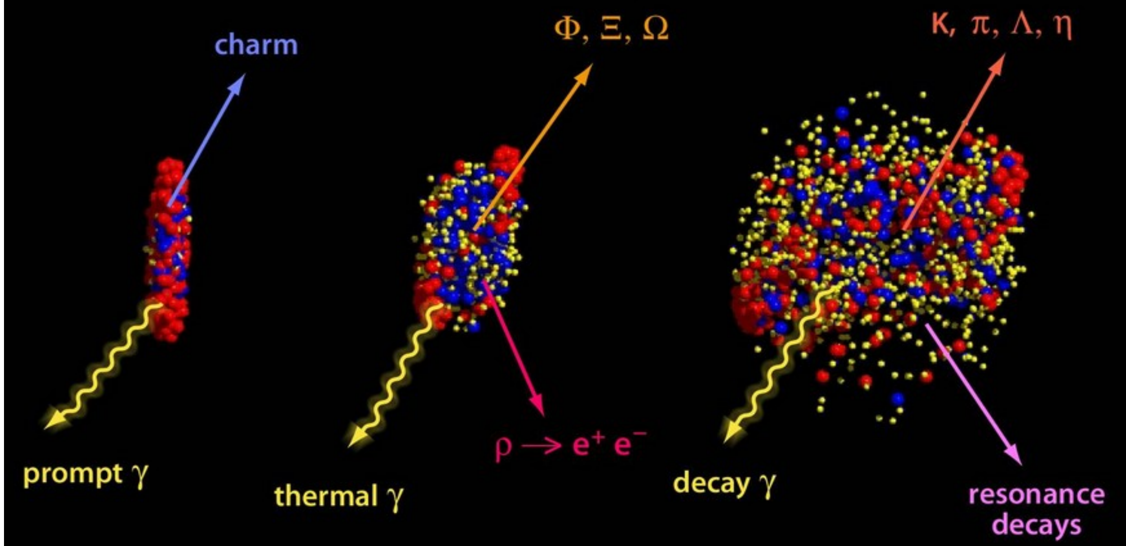


dilepton spectrum HADES (simulation)



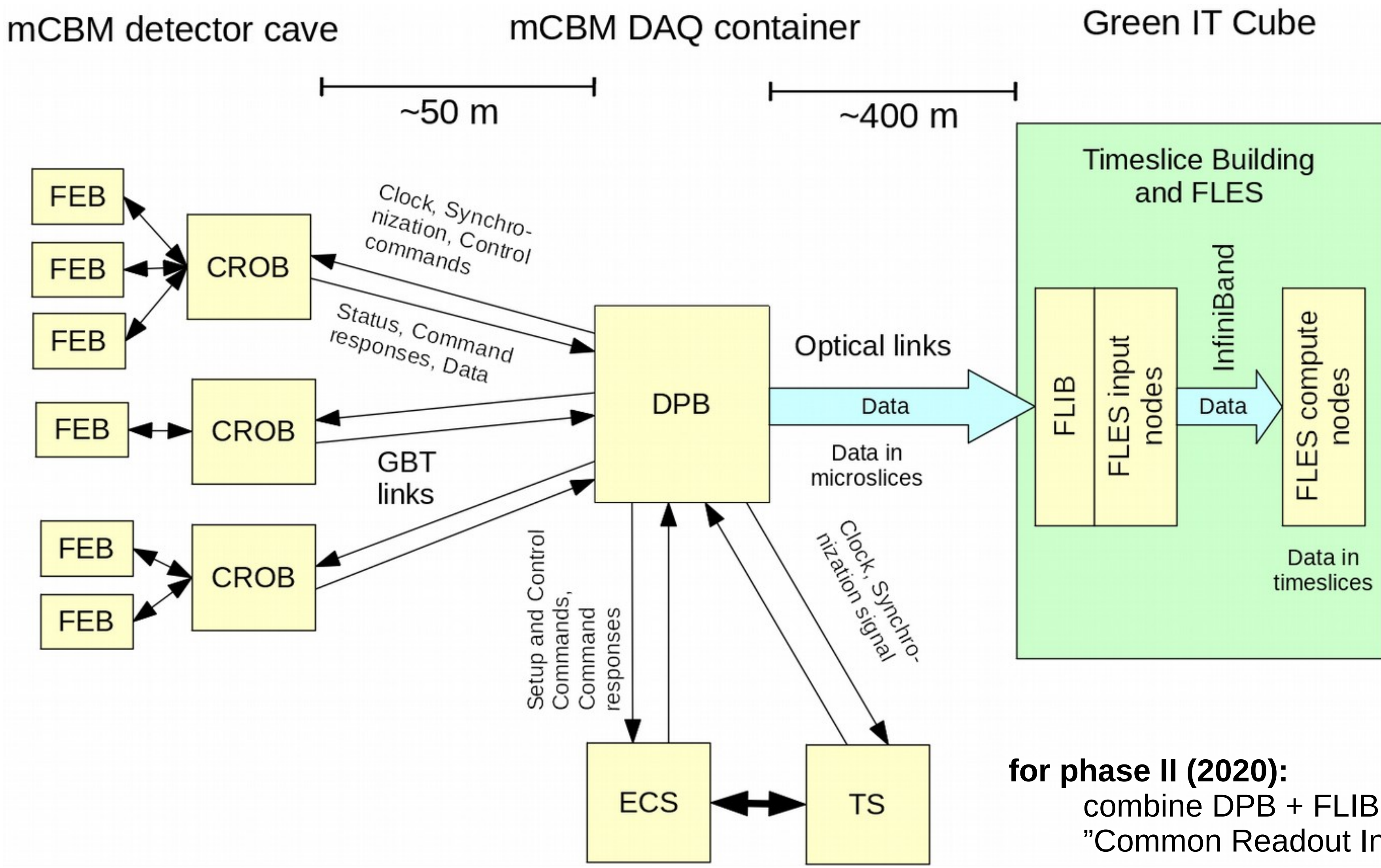


different stages of a heavy ion collision



U – U collision at 23 AGeV, evolution in time from UQMD

mCBM readout concept – Phase I (2019)

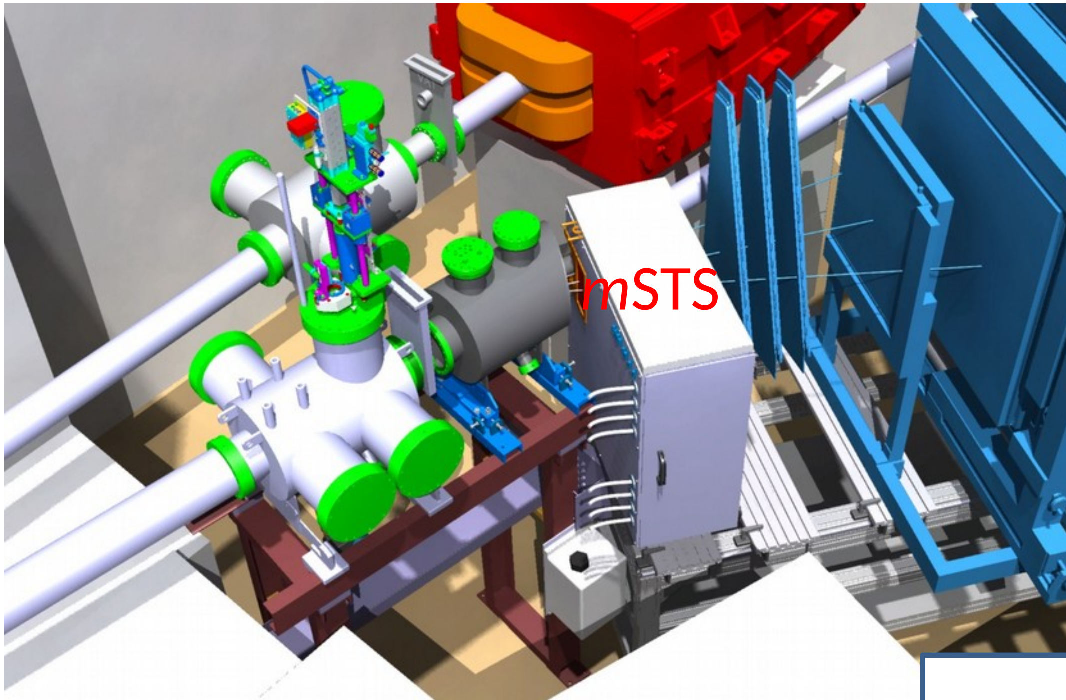


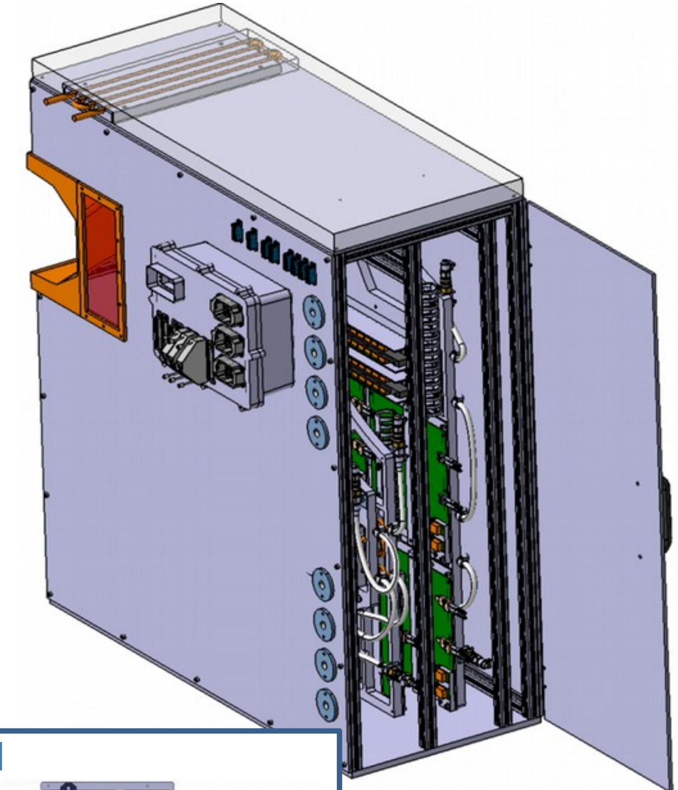
for phase II (2020):

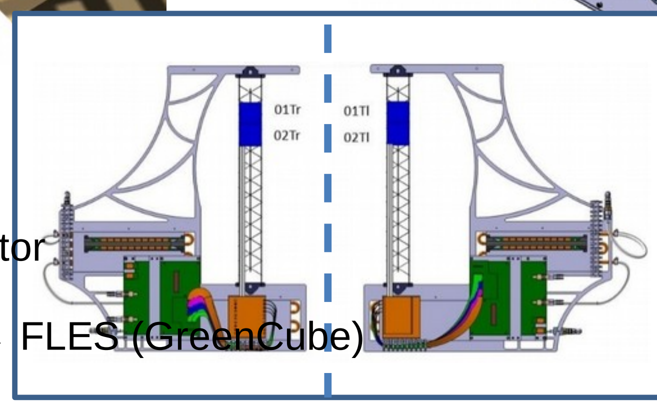
combine DPB + FLIB to CRI:
”Common Readout Interface”

→ **final CBM implementation**

mSTS at mCBM



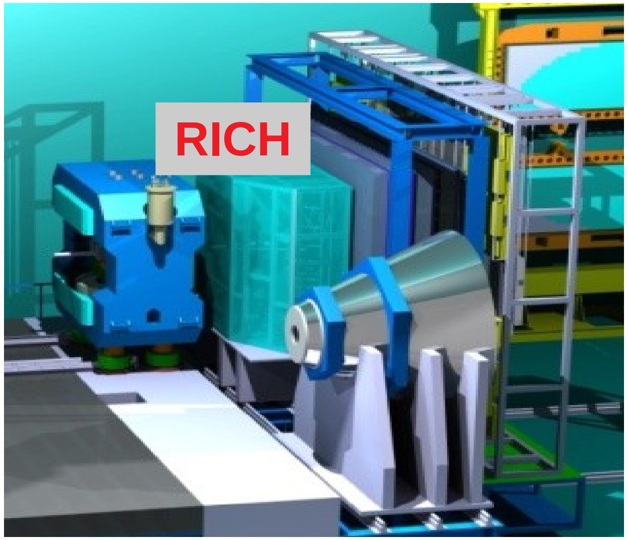


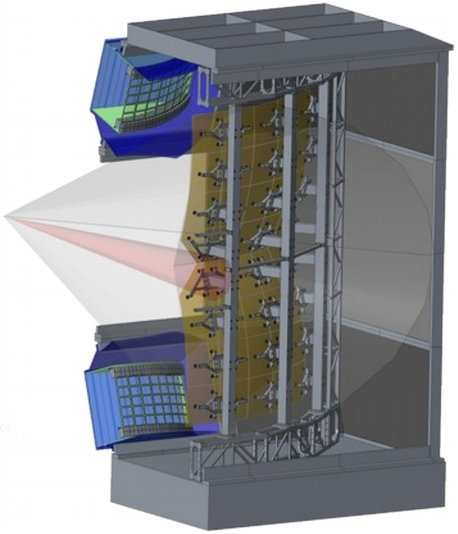


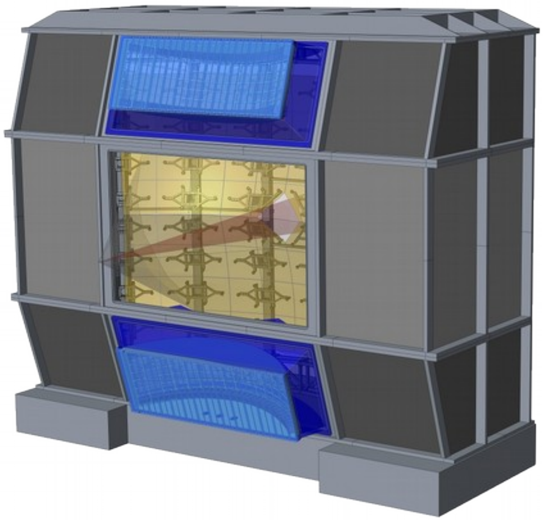
mSTS box with C-frames
holding carbon ladder with silicon strip detector
readout using full STS readout chain:
sts-Xyter → C-ROB (GBTx-based) → FLIB → FLES (GreenCube)

first station installed last week (2 ladders, 2 sensors each)
first beam this week
second station (3 ladders, 6 sensors) 2019

The CBM RICH detector







Facts:

- Dimensions: 2m x 5.14m x 3.93m (length x height x width)
- Acceptance: 0-35° / 0-25° (horizontal / vertical)

- **CO_2 gas radiator**
  - Pion threshold 4.5 GeV/c
  - UV cutoff <190 nm
  - 35 m^3 radiator gas volume, 1.7m radiator length

- 13m^2 segmented glass mirror, 80 tiles 40x40 cm^2, focal length 1.5m
- **MAPMT readout**: ~1000x Hamamatsu H12700, 64k channels

Updated CBM timeline:

2014	Technical Design Report approved
2019	Conceptual Design Review
2019	Production of first components
2022/23	**Installation in the cave**
2024	First beam

Challenges:

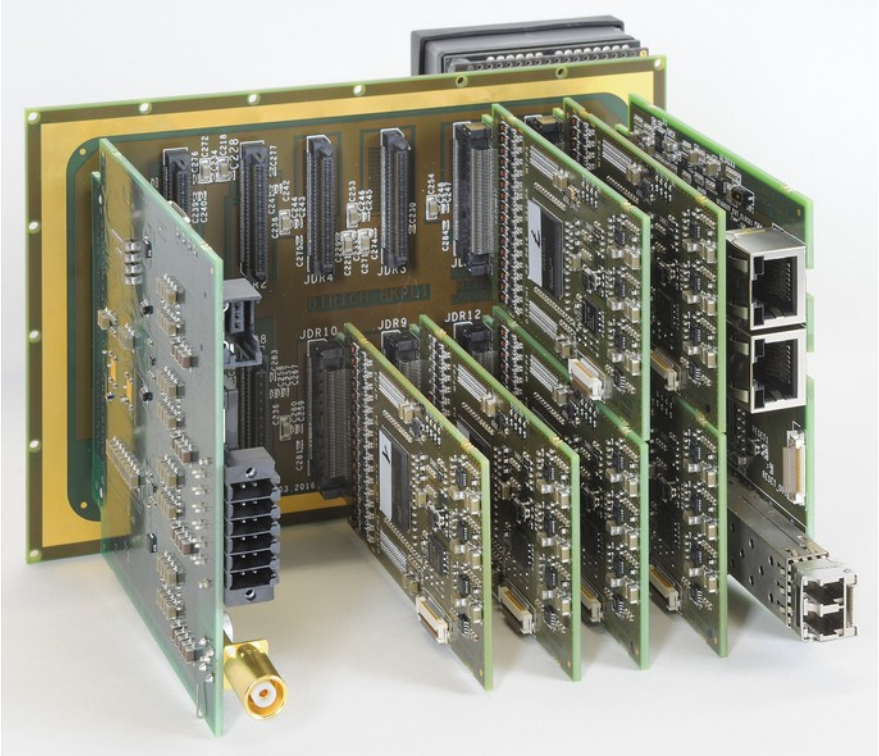
- High rate (up to 100 kHz photon rate per pixel)
- Magnetic stray field from CBM magnet (shielding box)
- RICH downstream of tracking system
- Free-streaming readout
- Moveable by crane

See **Poster #16** for more details:
"Development of a mirror supporting frame, mounting scheme and alignment monitoring system for CBM RICH"

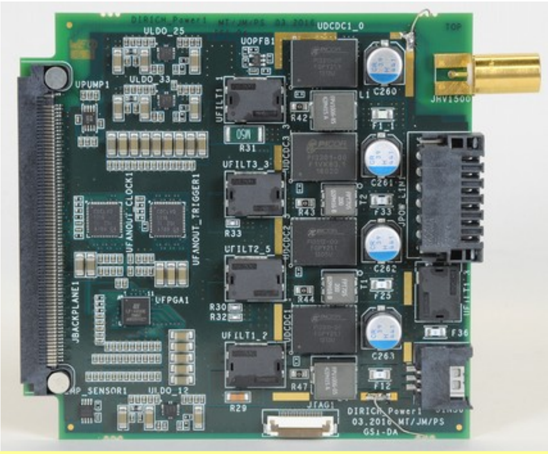
The DIRICH readout chain

Based on TRB development by
M. Traxler, C. Ugur, J. Michel et al (TRB collaboration)

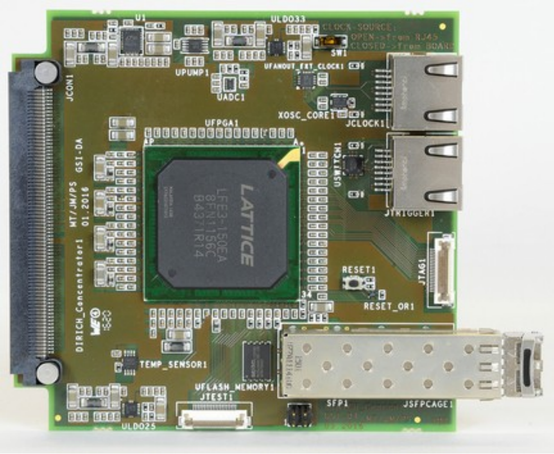
32ch DIRICH
frontend module



3x2 MAPMT backplane
(with few modules equipped)

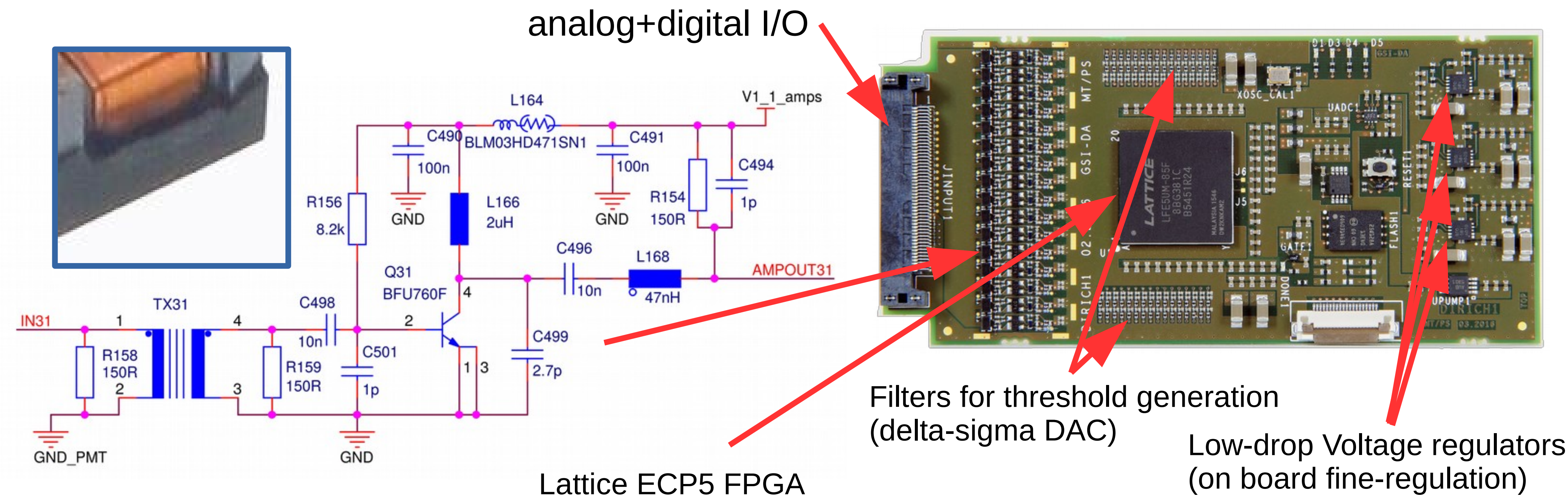


DIRICH-Power module
(LV + HV supply, DCDC)



DIRICH-Combiner module

DIRICH frontend module



- 32ch analog amplification, discrimination, leading+trailing edge TDC, digital control all implemented on single FPGA with few discrete elements only

- **Galvanically isolated inputs** to minimize noise and ground loops
- Single-stage transistor amplifier, amplitude **gain ~30**, **high band width (4 GHz) amplifier: only 10 mW per channel** (1.1V Vcc)
- Signal shaping to optimize time measurement

- **Leading+Trailing edge time measurement** on same channel using stretcher
- No signal integration: pure “amplitude measurement” (no charge measurement as on nXYter)
- Accurate **Time-Over-Threshold measurement** (for amplitude, walk corr.)

- Up to 50 MHz hit rate (burst)