Report on CBM

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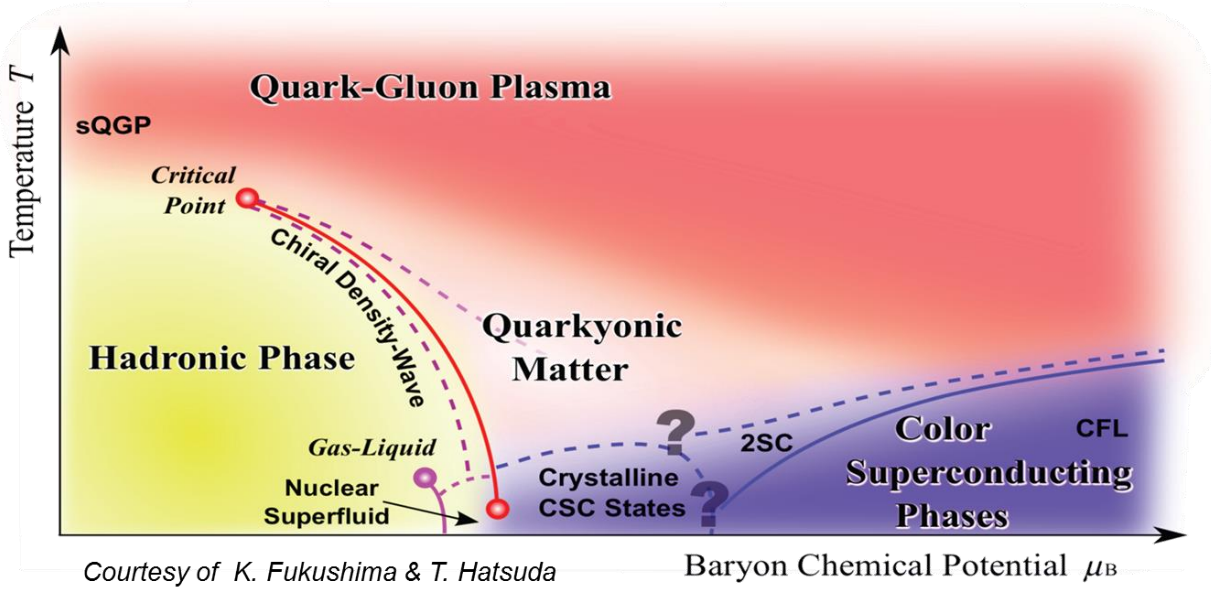
Heidelberg Univ.

CBM – Goals



Courtesy of K. Fukushima & T. Hatsuda

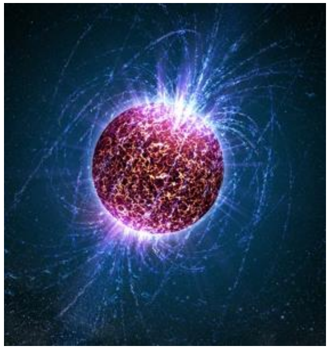
Mission:

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

Fundamental questions:

Equation of State of QCD matter at neutron star densities
Phase structure of QCD matter
Chiral symmetry restoration at large densities
Bound states with strangeness
Charm in dense baryonic matter

Dense Baryonic Matter



Neutron stars

Temperature

T < 20 MeV

Density

$\rho < 10\ \rho_0$

Lifetime

T ~ infinity

Neutron star merger

Temperature

T < 70 MeV

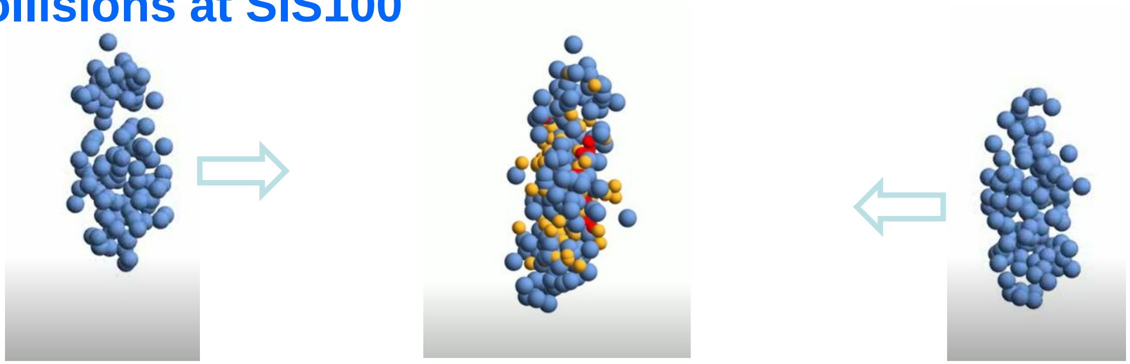
Density

$\rho < 3\rho_0$

Reaction time (GW170817)

T ~ 10 s

Heavy ion collisions at SIS100



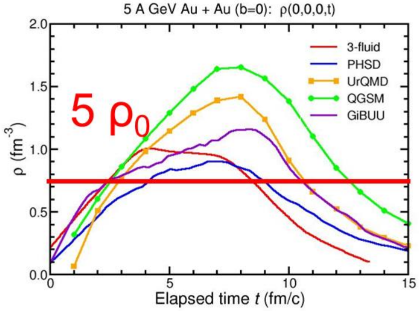
Temperature

T < 120 MeV

Reaction time

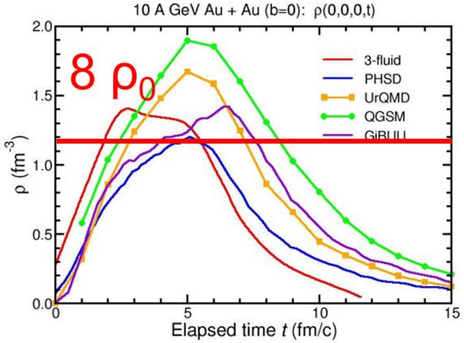
$t \sim 10^{-23}$ s

5 A GeV



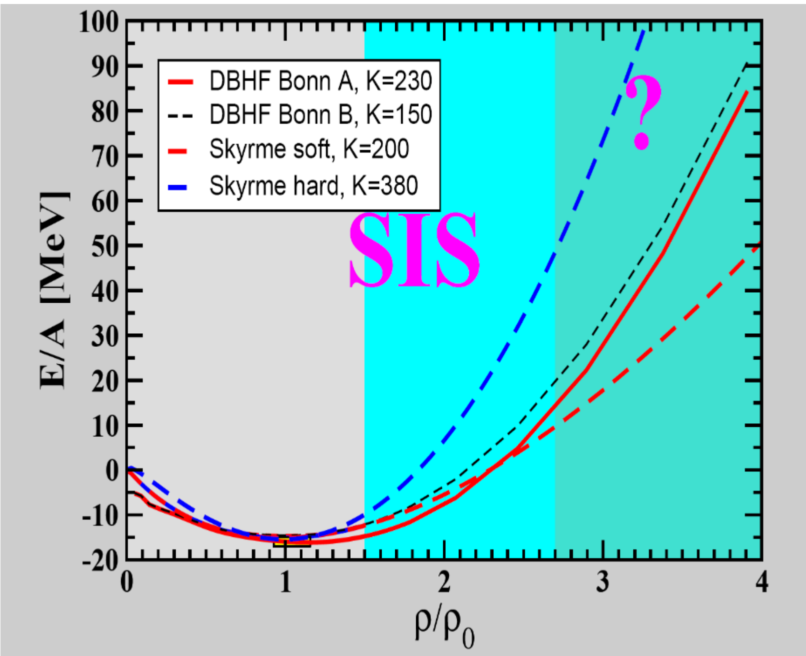
Compressed **B**aryonic **M**atter

10 A GeV

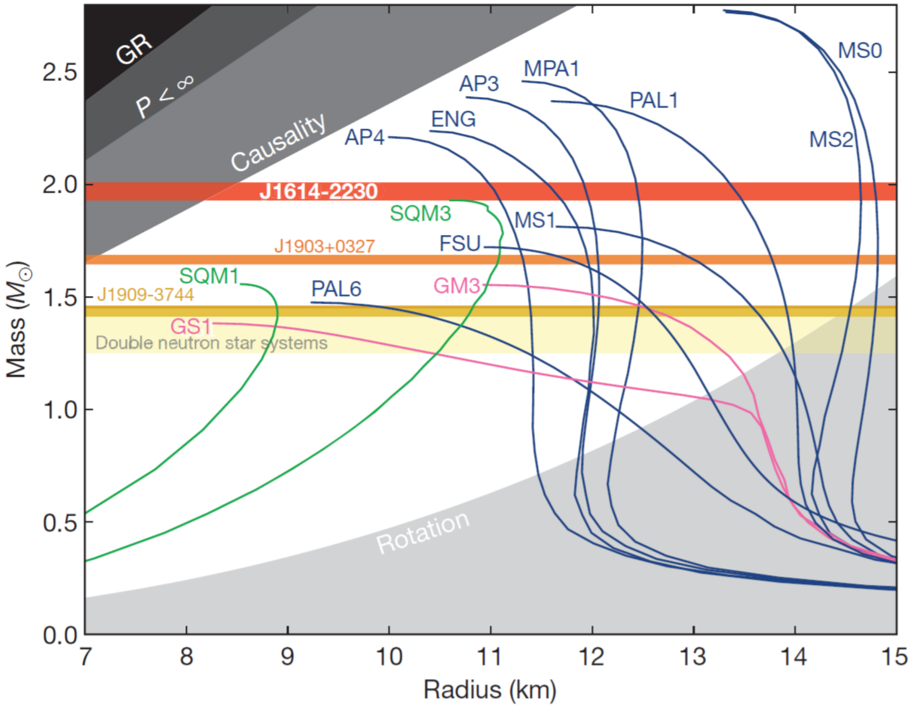


Equation of State & Neutron stars

C. Fuchs,
Prog. Part. Nucl. Phys. 56 (2006) 1



P.B. Demorest (2010)
doi:10.1038/nature09466



EOS is soft (K=200MeV) for densities $\rho/\rho_0 < 2.5$ (SIS18),
Soft EOS not repulsive enough to allow for a neutron star with $2M_\odot$,

Stiffening of EOS must occur in the SIS100 energy range.

CBM physics and observables

Eur.Phys.J. A53 (2017) 60

QCD equation-of-state
- collective flow of identified particles
- particle production at threshold energies

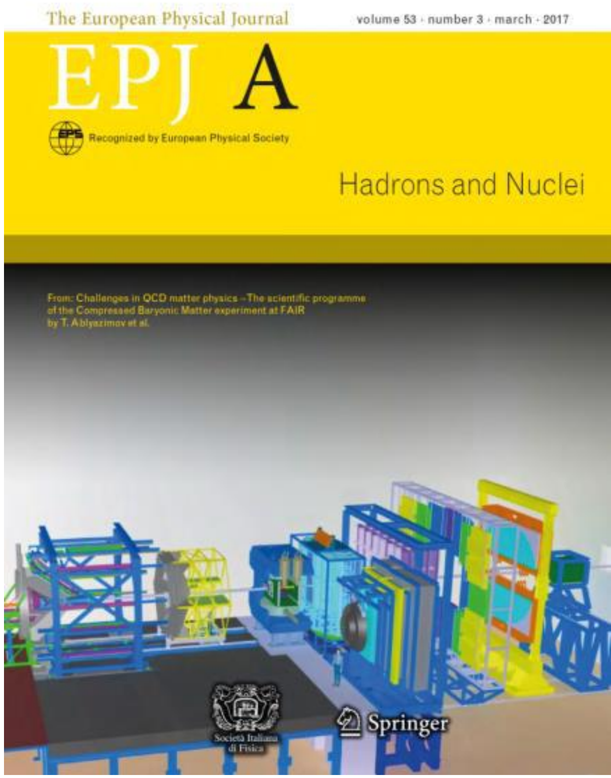
Phase transition
- excitation function of hyperons
- excitation function of LM lepton pairs

Critical point
- event-by-event fluctuations of conserved quantities

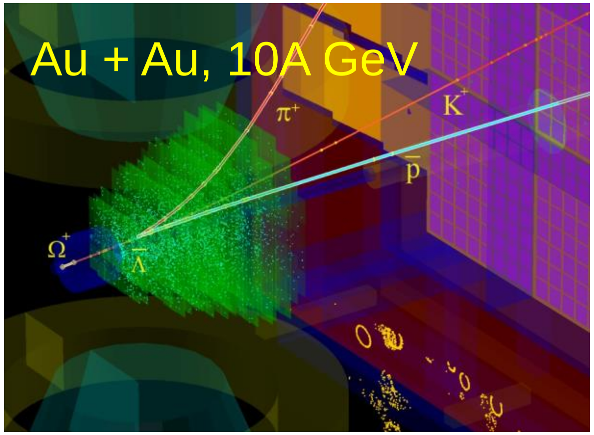
Chiral symmetry restoration at large ρ_B
- in-medium modifications of hadrons
- dileptons at intermediate invariant masses

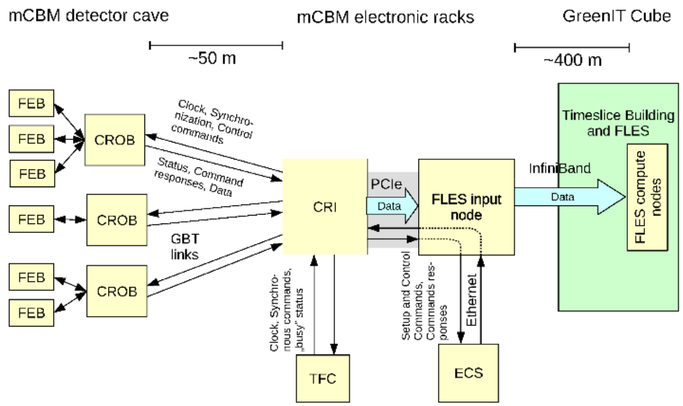
Strange matter
- (double-) lambda hypernuclei
- Search for meta-stable objects (e.g. strange dibaryons)

Heavy flavour in cold and dense matter
- excitation function of charm production



CBM data processing system





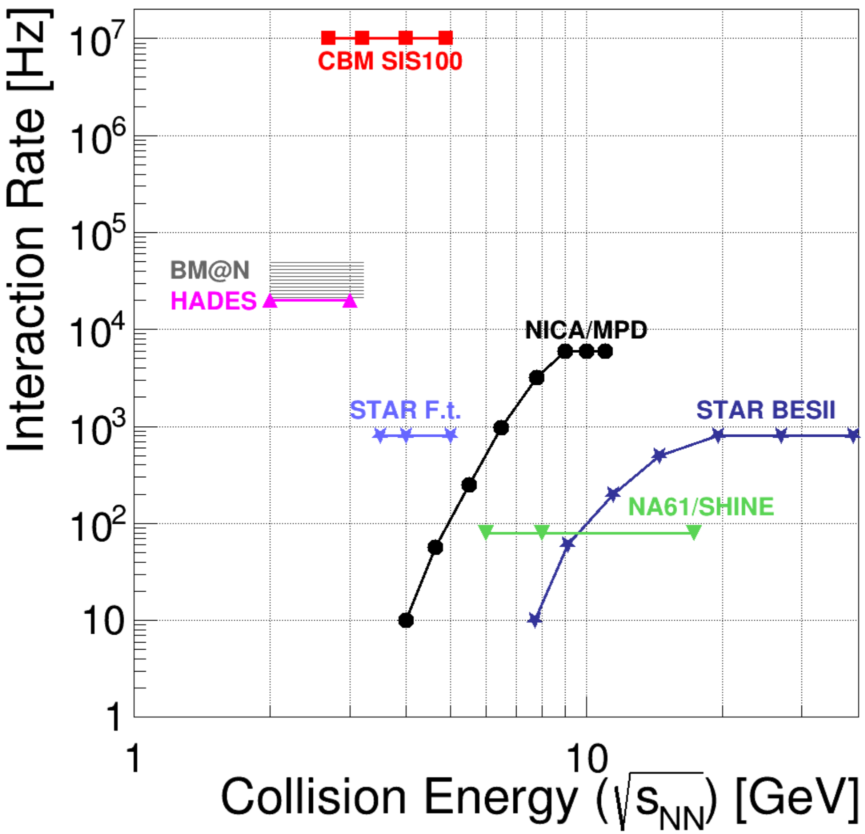
Reaction rate: Au + Au, 10^7 collisions per second

Data rate: ~ 1 TB/s

Main features:

- radiation tolerant detectors and front-end electronics
- free streaming (triggerless) data,
- all detector hits with time stamps,
- software based event selection

CBM – Strategy



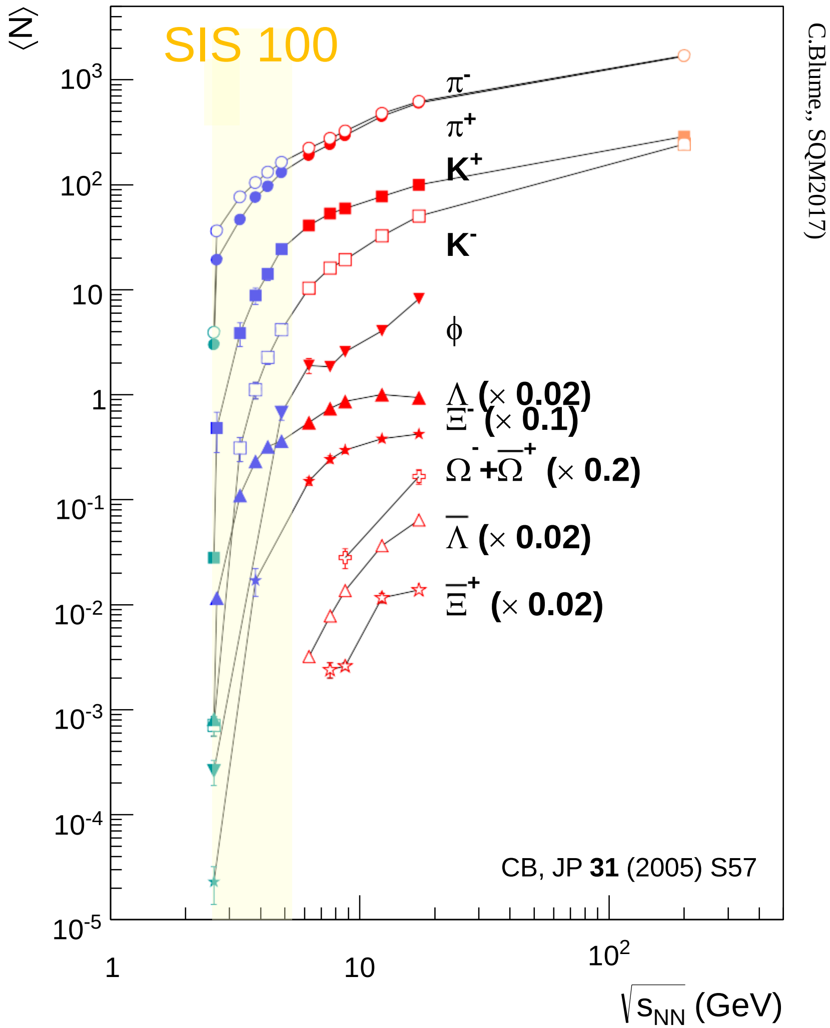
Exploration of QCD phase diagram
as international effort:

NA61	@ SPS / CERN
BM@N	@ Nuclotron/JINR
STAR (F.t.)	@ RHIC/BNL
MPD	@ NICA / JINR

CBM‘s unique feature
High statistics measurement of rare probes

Final state particle abundance

Particle yields from central Au + Au collisions



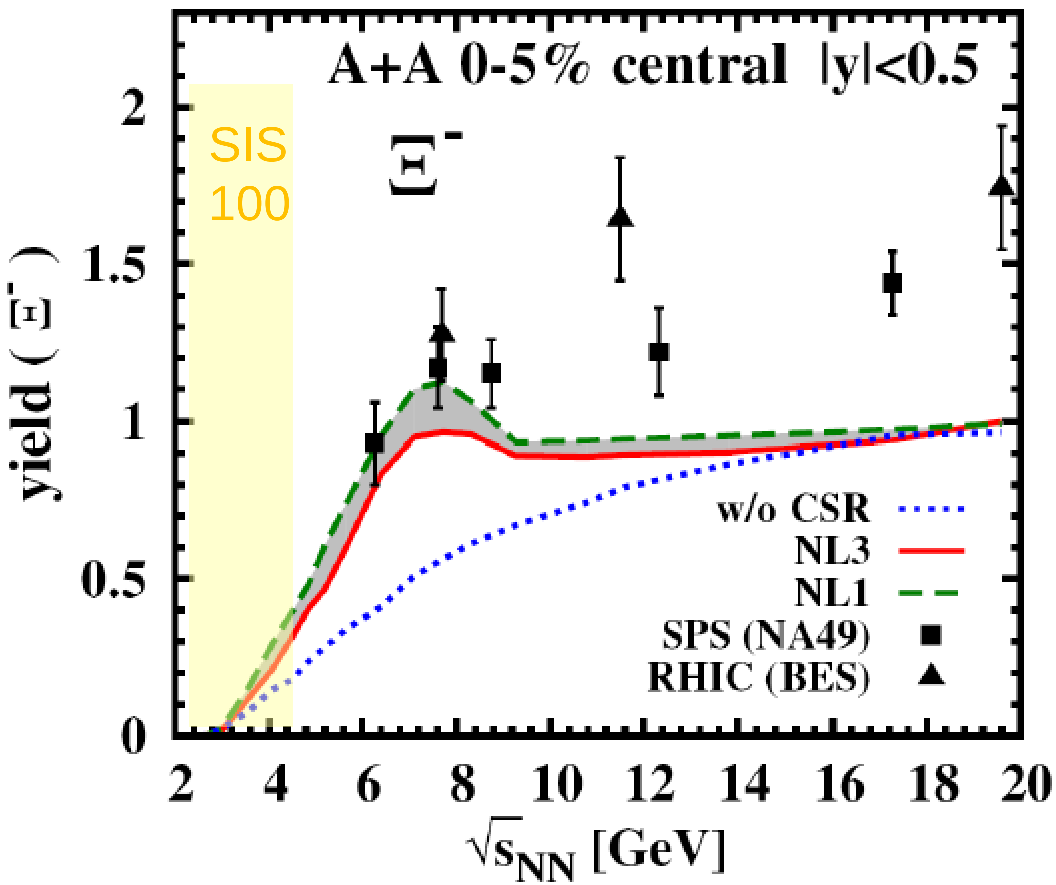
Strange and charmed particle production thresholds in pp - collisions

reaction	$\sqrt{s}$ (GeV)	T_{lab}(GeV)
$pp \rightarrow K^+\Lambda p$	2.548	1.6
$pp \rightarrow K^+K^-pp$	2.864	2.5
$pp \rightarrow K^+K^+\Xi^-p$	3.247	3.7
$pp \rightarrow K^+K^+K^+\Omega^-n$	4.092	7.0
$pp \rightarrow \Lambda\bar{\Lambda}pp$	4.108	7.1
$pp \rightarrow \Xi^-\bar{\Xi}^+pp$	4.520	9.0
$pp \rightarrow \Omega^-\bar{\Omega}^+pp$	5.222	12.7
$pp \rightarrow J/\Psi\, pp$	4.973	12.2

Hyperons as probes of dense matter

PHSD interpretation of Ξ⁻ - production

A. Palmese et al. Phys.Rev. C94 (2016) no.4, 044912



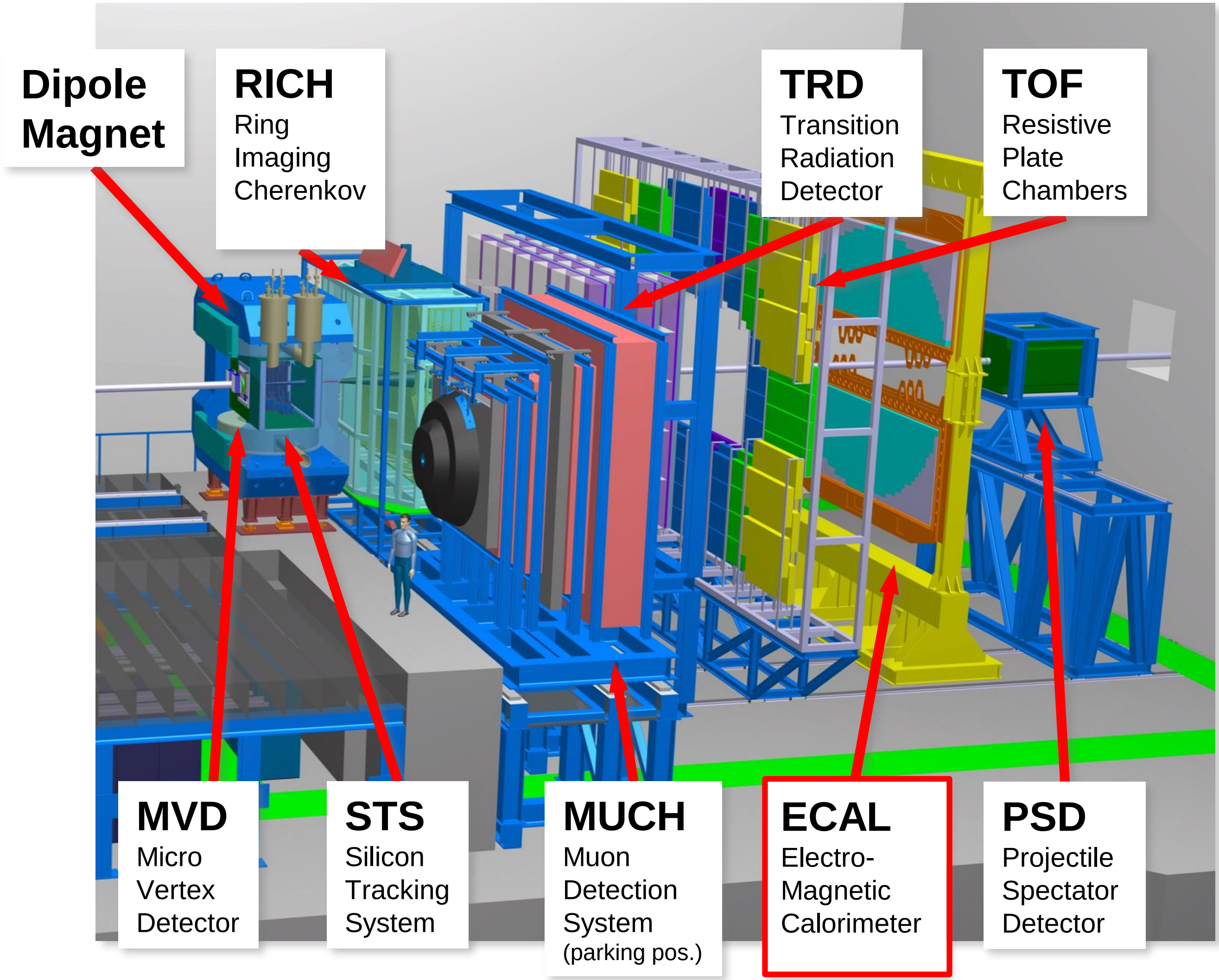
Predicted sensitivities of production yields:

strong dependence on Chiral Symmetry Restoration (CSR)

Measurable dependence on Equation of State (NL1, NL3)

Strong theoretical support necessary to link observables to matter properties.

CBM experimental setup (day-1)



- Tracking acceptance: $2^o < \theta_{lab} < 25^o$
- Free streaming DAQ
- R_{int} = 10 MHz (Au+Au)

  $R_{int} \approx$ 0.5 MHz
  full bandwith:
  Det. – Entry nodes
  reduced bandwidth
  Entry nodes – Comp. farm

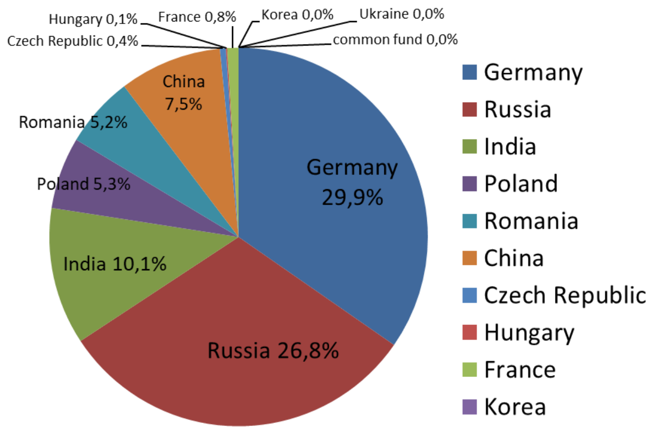
  with
  R_{int} (MVD)=0.1 MHz
- Software based event selection

Day-1 setup = MSV setup – Compute Performance - ECAL
Phase-1 = Day1 with full Compute Performance + ECAL

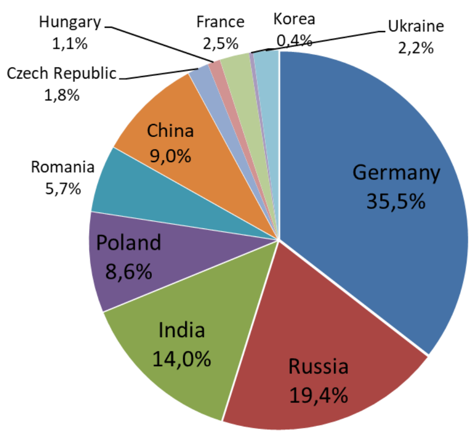
Day-1 funding: ~ 90% secured

German contributions to CBM

CBM day 1 setup
percentage secured funding



CBM collaboration
percentage PhD holders



Participating German University Groups

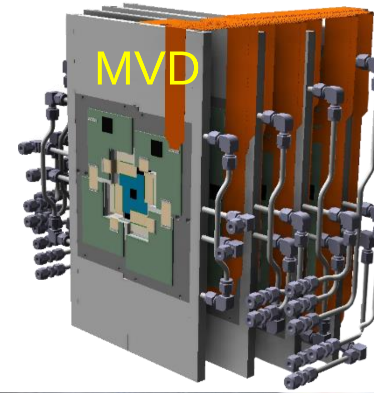
Sub-system	Institution	Group Leader
MVD	Univ. Frankfurt	Prof. J. Stroth *
STS	Univ. Tübingen	Prof. H.R. Schmidt *
RICH	Univ. Giessen Univ. Wuppertal	Prof. C. Höhne * Prof. K.H. Kampert *
TRD	Univ. Frankfurt Univ. Heidelberg Univ. Münster	Prof. C. Blume * Prof. P. Fischer Nf. Wessels
TOF	Univ. Heidelberg TU Darmstadt	Prof. N. Herrmann * Prof. T. Galatyuk
DAQ/FLES	KIT Karlsruhe Univ. Frankfurt Univ. Frankfurt Univ. Frankfurt Zuse Inst. Berlin Univ. Frankfurt	Prof. J. Becker Prof. U. Kebschull Prof. I. Kisel Prof. V. Lindenstruth * Prof. A. Reinefeld Prof. A. Toia

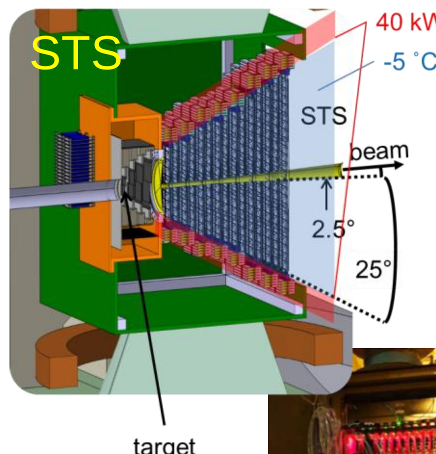
* Project leadership within the group

Timeline and activities

Target date for Day-1: Jun 2024 Commissioning beam from SIS100

#	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	submission 2017
8	MVD	submission 2018
9a	Online Systems: DAQ	submission 2018
9b	Online Systems: FLES	submission 2020
10	ECAL	submission 2018

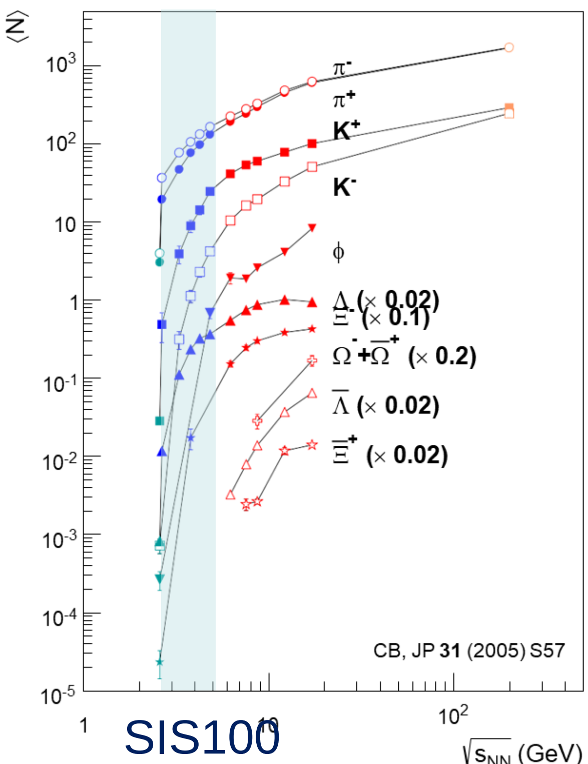




Observables: Strangeness and Dileptons

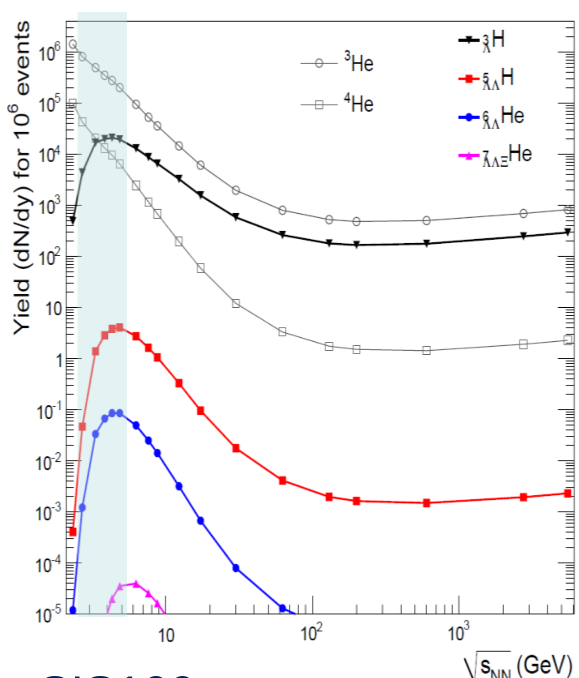
Excitation function of yields and phase-space distributions of
multi-strange hyperons and
lepton pairs in AA (C+C, Au+Au) collisions from 2-11 A GeV.
Search for hypernuclei (no data available in this energy range).

multi-strange hyperons



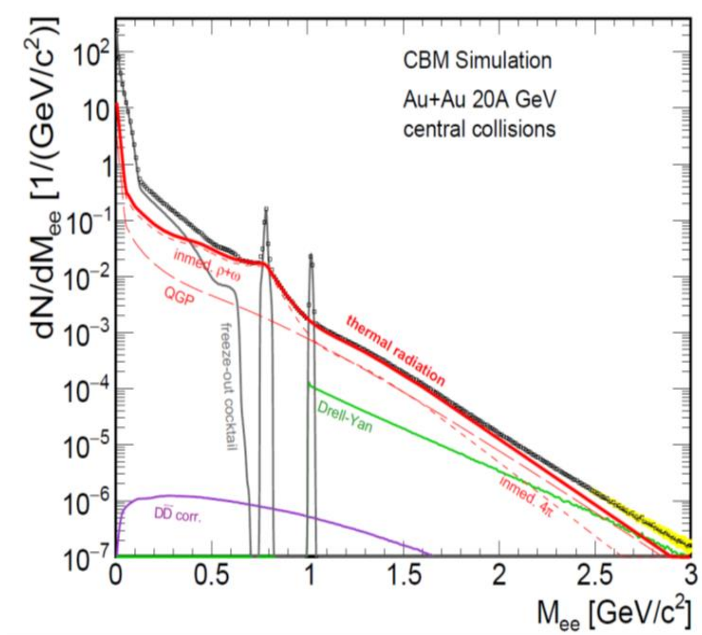
SIS100

hypernuclei



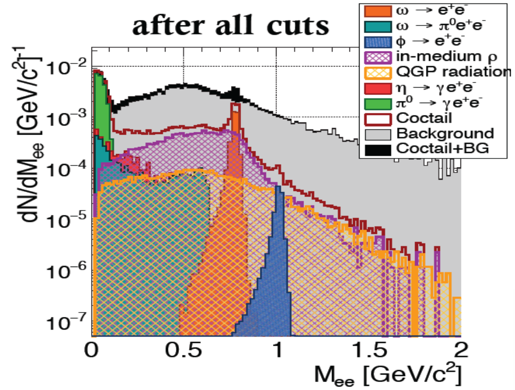
SIS100

dilepton invariant mass



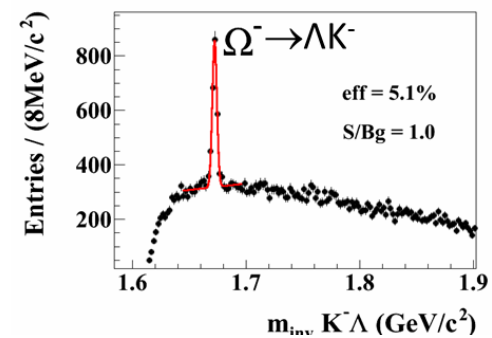
CBM Day 1 – unique measurements

Au+Au, 8A GeV,

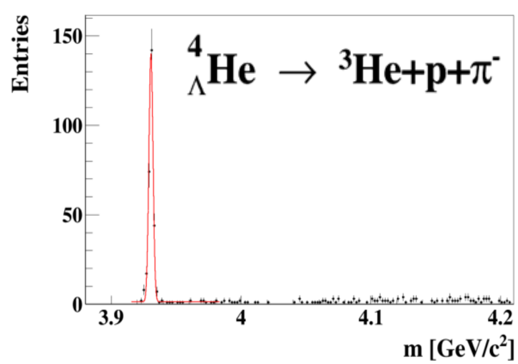


Di-electron measurement
Full performance,
uses MVD, limited to 100 kHz

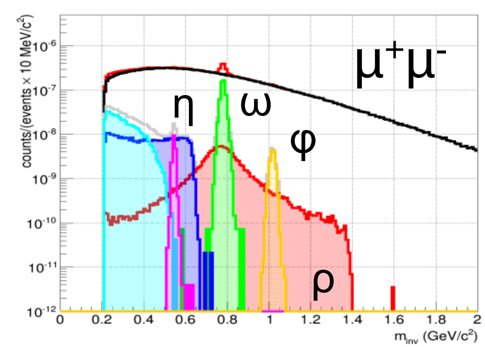
Hyperon measurements, e.g. Au+Au at 10A GeV :



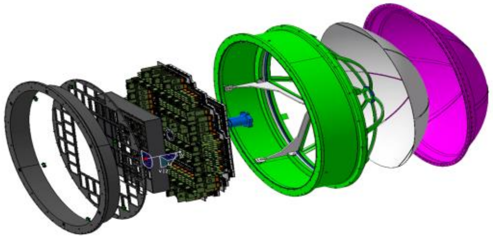
Hypernuclei measurement,
e.g. Au + Au at 10A GeV



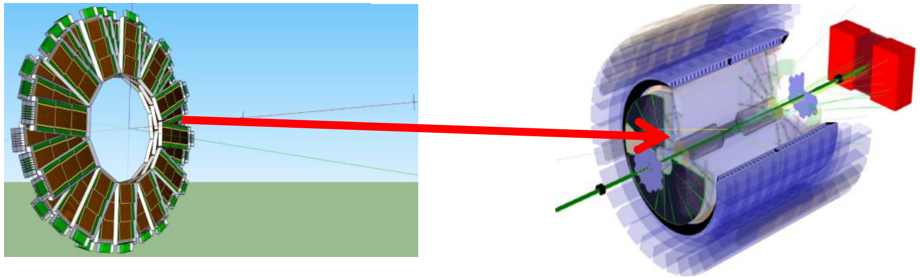
Di-Muon
LM measurement at 8A GeV



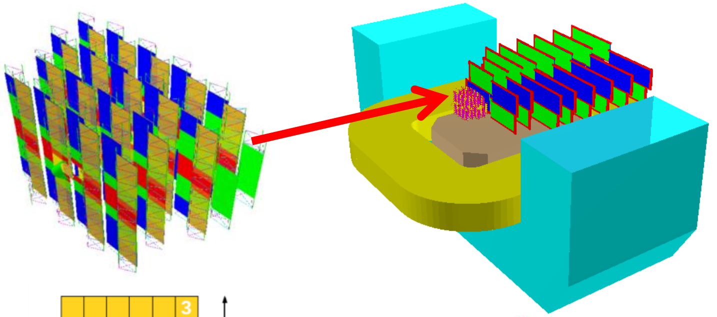
CBM – FAIR Phase 0 projects (2018 – 2022)



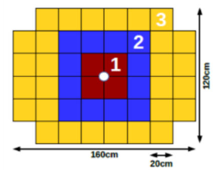
1. Install, commission and use 430 out of 1100 CBM RICH multi-anode photo-multipliers (MAPMT) including FEE in HADES RICH photon detector



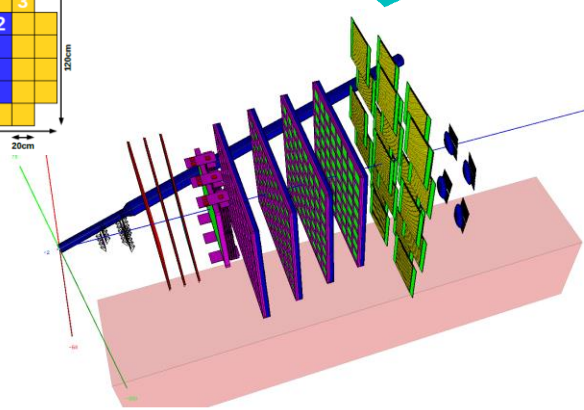
2. Install, commission and use 10% of the CBM TOF modules including read-out chain at STAR/RHIC (BES II 2019/2020)



3. Upgrade BM@N experiment with 4 Silicon stations of CBM/STS design in the BM@N experiment at the Nuclotron JINR/Dubna (Au-beams in late 2020)



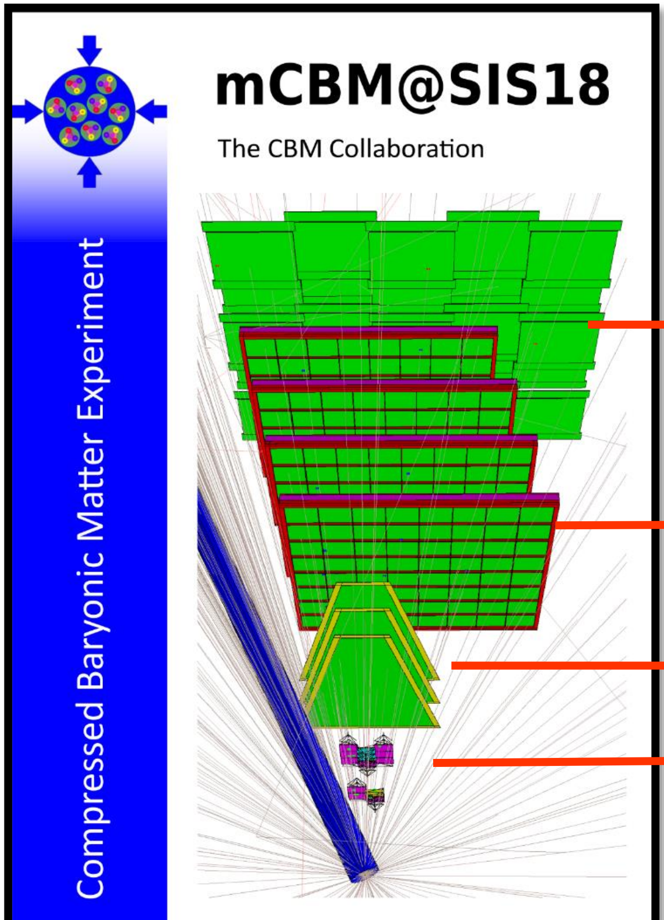
4. Install, commission and use the Project Spectator Detector at the BM@N experiment

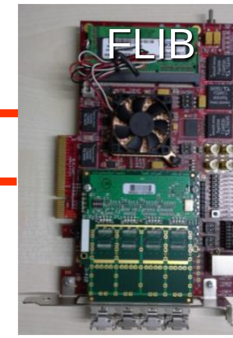


5. mini CBM (mCBM@SIS18) demonstrator for full CBM data taking and analysis chain

CBM FAIR Phase 0 project at SIS18: mCBM

Demonstrator for full CBM data taking and analysis chain





the mCBM test-setup (“mini-CBM”) will focus on

- test of final detector prototypes
- free streaming data transport to a computer farm
- online reconstruction and event selection
- offline data analysis

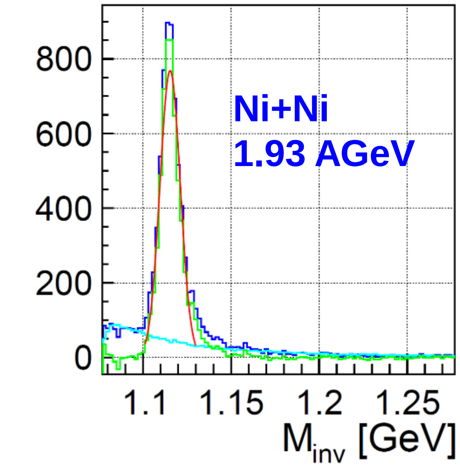
under full load conditions (Au + Au, 10^7 interactions/s)

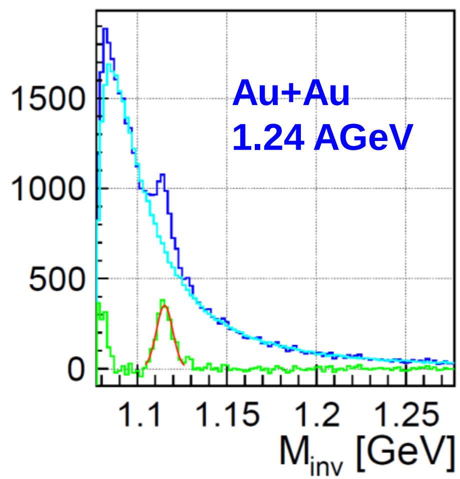
https://cbm-wiki.gsi.de/foswiki/pub/Public/Documents/
mcbm-proposal2GPAC-fullVersion.pdf

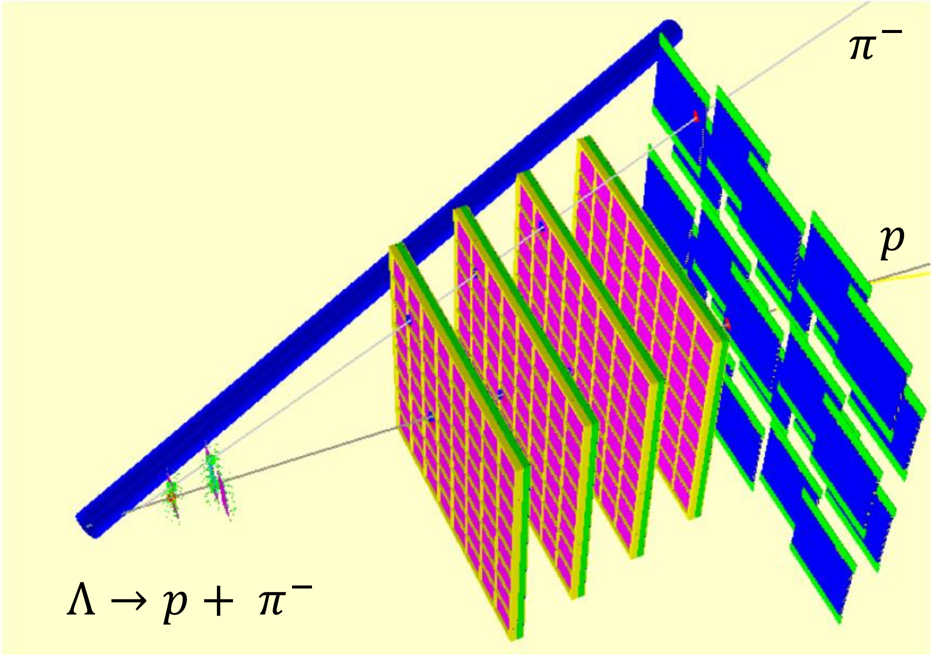
mCBM performance benchmark

(Sub)threshold Λ – baryon reconstruction.

Event based MC simulation of 10^8 events
(measurement time: 10 s)



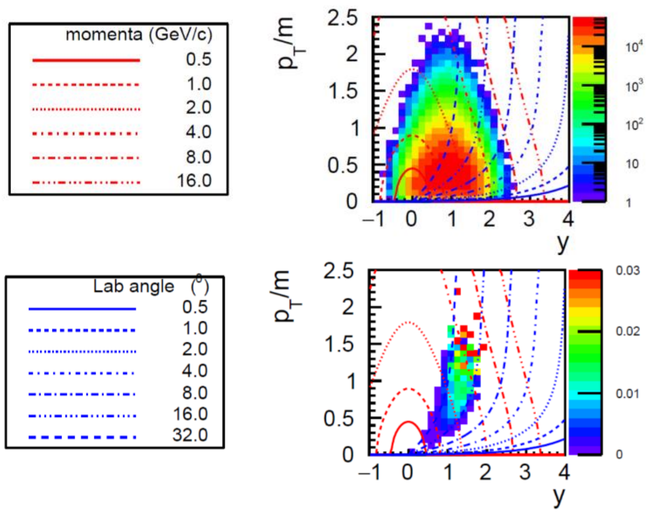




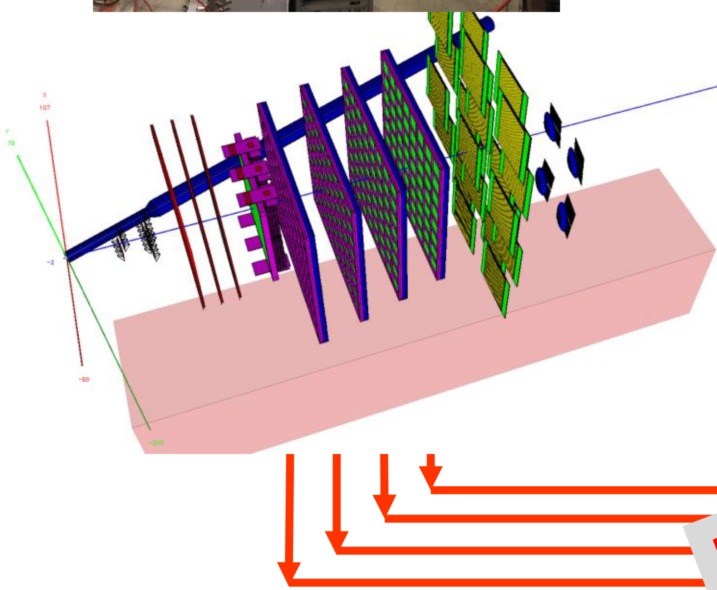
Acceptance

&

Efficiency



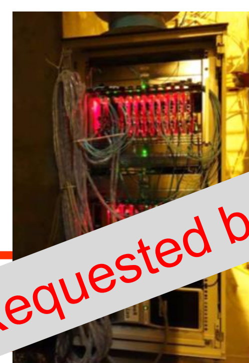
Schedule of mCBM construction



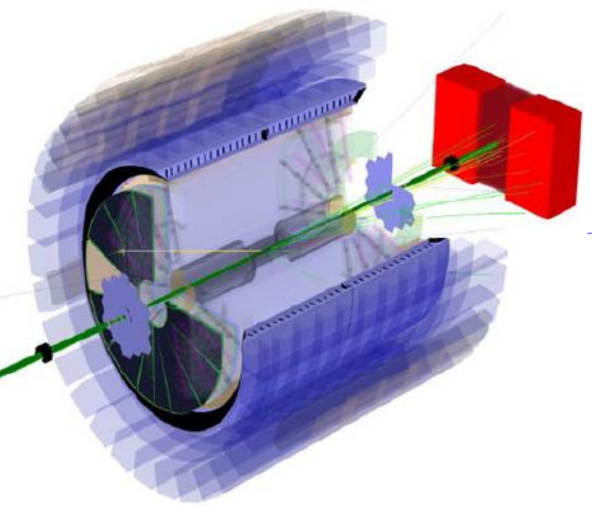
Schedule

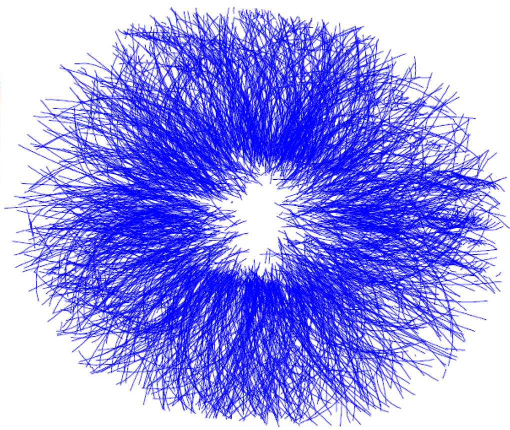
10/2017	cave & beam line: reconstruction started, procurement started
11/2017	µDAQ test stand @ Heidelberg operational
12/2017	beam dump mounted
03/2018	cave reconstruction completed
04/2018	mFLES cluster @ Green IT Cube installed
05/2018	beam line installed and commissioned
05/2018	installation of detector stations
06/2018	start commissioning w/o beam
08/2018	start commissioning with beam

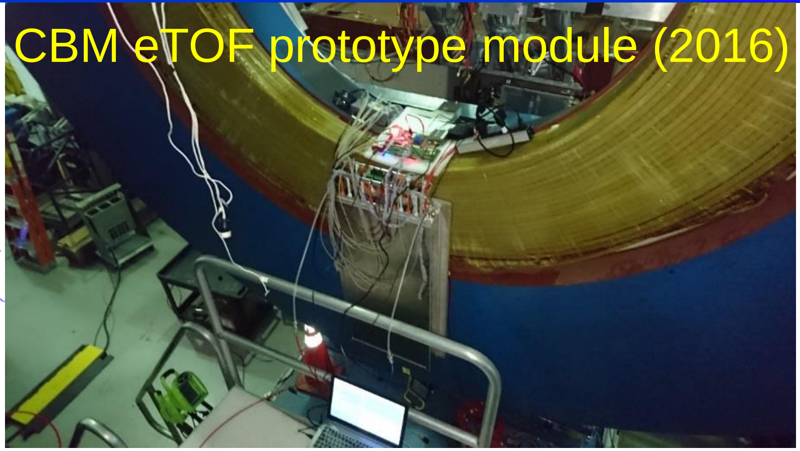
Requested beamtime was fully granted by G-PAC

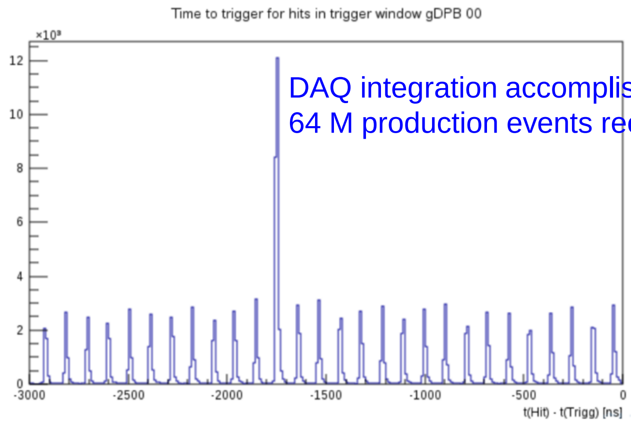


eTOF & HPC software in STAR at RHIC (BNL)









DAQ integration accomplished (Spring ´17)
64 M production events recorded

Participating CBM groups:

- Tsinghua Univ. Beijing
- GSI Darmstadt
- TU Darmstadt
- Univ. Frankfurt
- Univ. Heidelberg
- USTC Hefei
- CCNU Wuhan

Participation of German groups
In BES II secured by additional
funds (Germany VF).

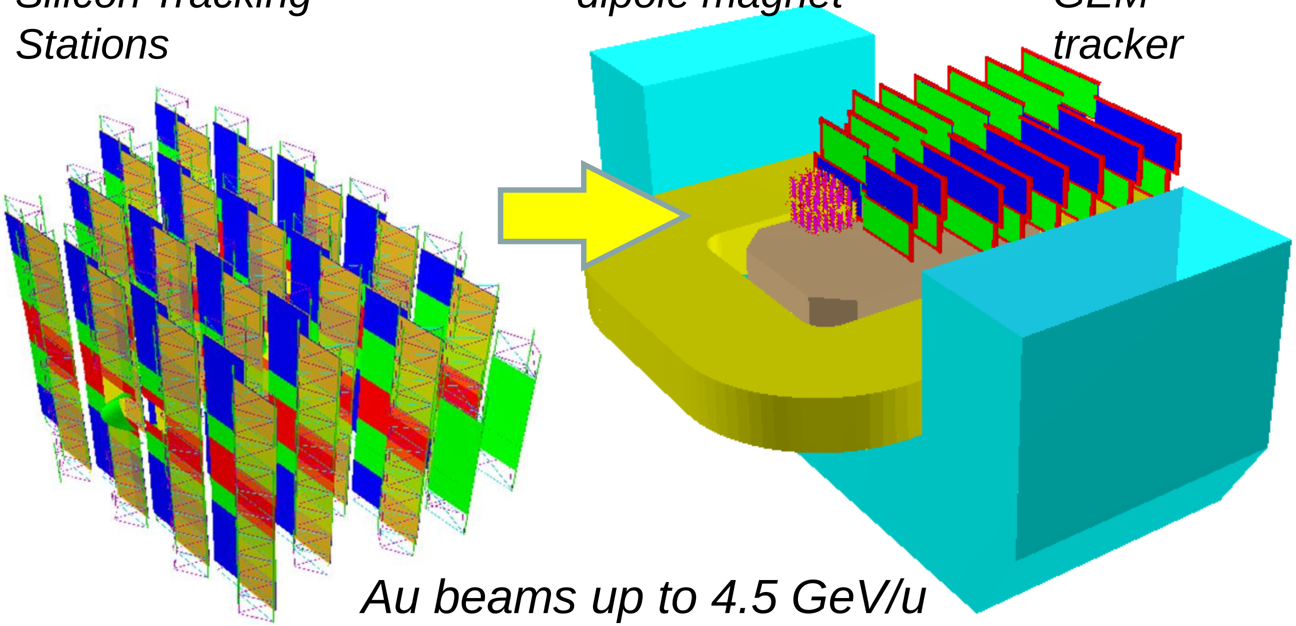
Test module installed	(Oct. 2016),
Module is operational	(Oct. 2016),
STAR DAQ interface	(Jan. 2017),
Full sector test	(Spring 2018),
Wheel installation	(Summer 2018),
BES II data taking	(2019/2020),
Transfer of modules to FAIR	(2021/22).

STS & PSD in BM@N (JINR)

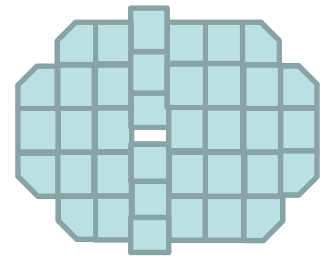
Silicon Tracking Stations

dipole magnet

GEM tracker

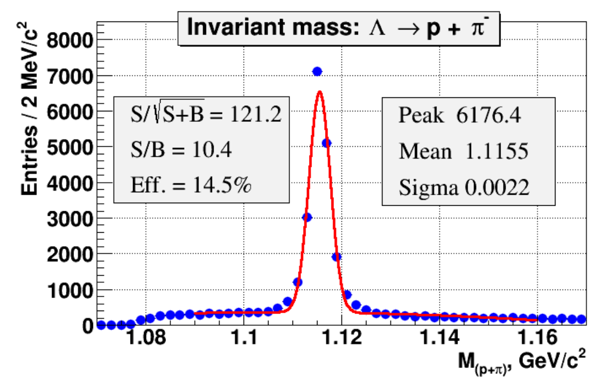


Au beams up to 4.5 GeV/u



PSD calorimeter

Improvement in efficiency & signal / backrgound



BM@N timeline: NICA white paper (Eur. Phys. J. A (2016) 213

2018	Installation of PSD detector (MoU signed
2020	Installation of 4 Si tracking stations (MoU signed)
2020	Au beams from Nuclotron

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.

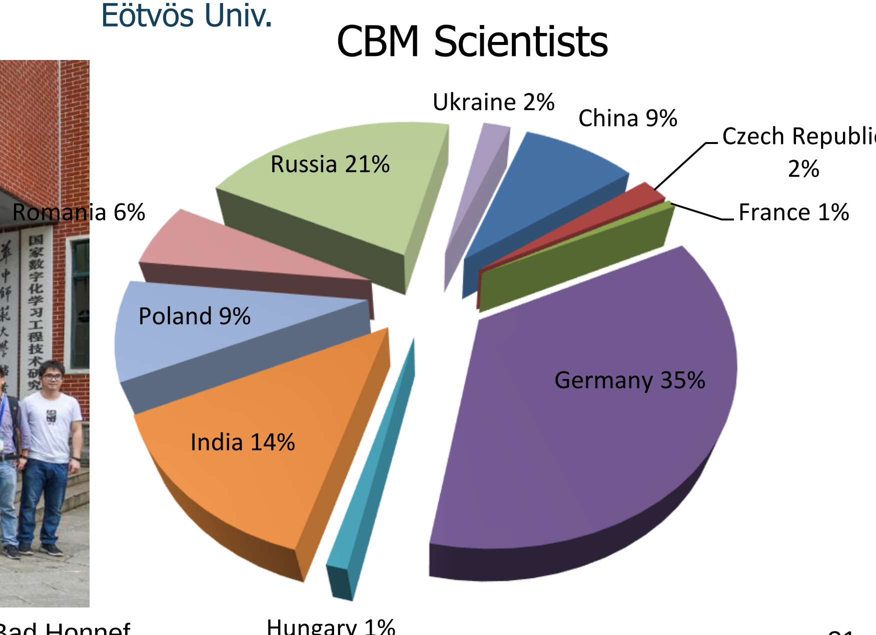
Poland:
AGH Krakow
Jag. Univ. Krakow
Warsaw Univ.
Warsaw TU

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



Summary / Conclusion

CBM scientific program at SIS100 is unique

- explore QCD matter at neutron star core densities
- employ high statistics capibility
  - to achieve high-precision of multi-differential observables
  - to enable rare processes as sensitive probes

CBM day-1 setup allows start of program with significant discovery potential

- excitation function of hyperons production
- excitation function of di-lepton production
- study of hypernuclei

CBM Phase 0 activities targeted towards usage and understanding of major components & production of visible physics results with CBM devices

- CBM – RICH sensors & readout in HADES at SIS18
- CBM – TOF and HPC software in STAR at RHIC/BNL
- CBM – PSD and CBM - STS in BM@N at Nuclotron/JINR
- Integration of all subsystems & FLES in mCBM at SIS18