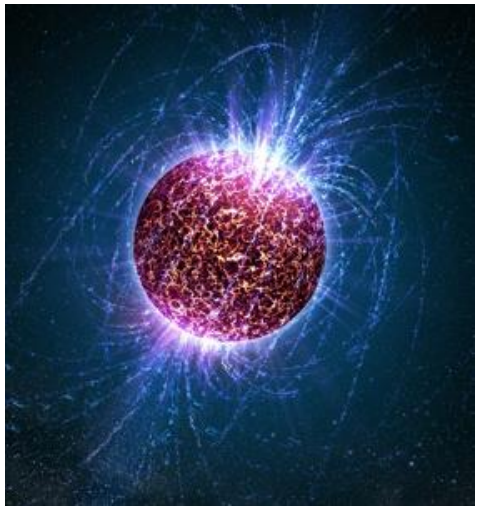
Status of the CBM Experiment at FAIR

Norbert Herrmann
Heidelberg Univ.

SIS100 construction site

WFJM, February 7th, 2018

Dense Baryonic Matter



Neutron stars

Temperature
T < 20 MeV

Density
$\rho < 10\ \rho_0$

Lifetime
T ~ infinity

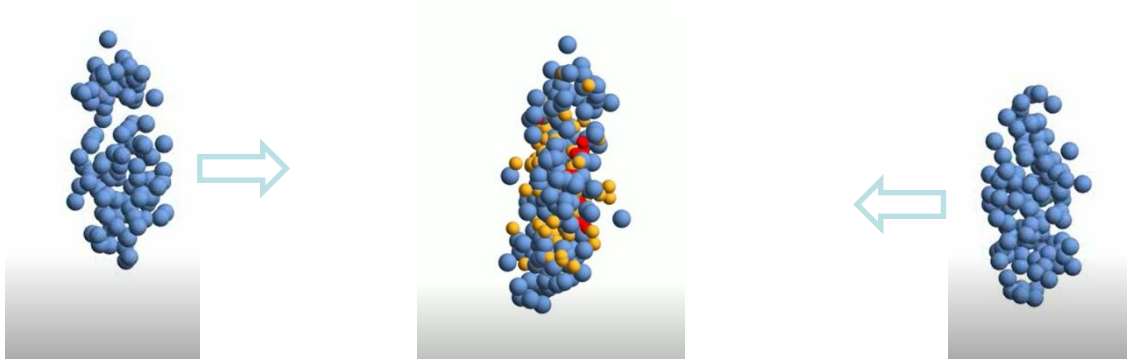
Neutron star merger

Temperature
T < 70 MeV

Density
$\rho < 2 - 6\ \rho_0$

Reaction time
(GW170817)
T ~ 10 ms

Heavy ion collisions at SIS100



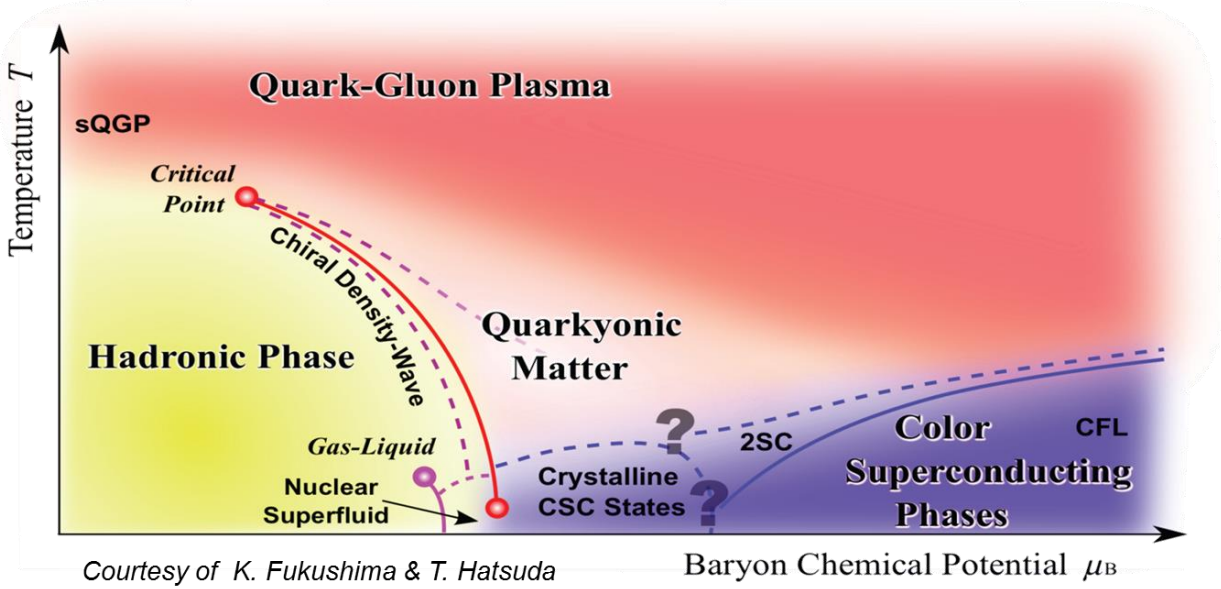
Temperature
T < 120 MeV

Density
$\rho < 8\rho_0$

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

Compressed Baryonic Matter

CBM – Goals



Courtesy of K. Fukushima & T. Hatsuda

Mission:

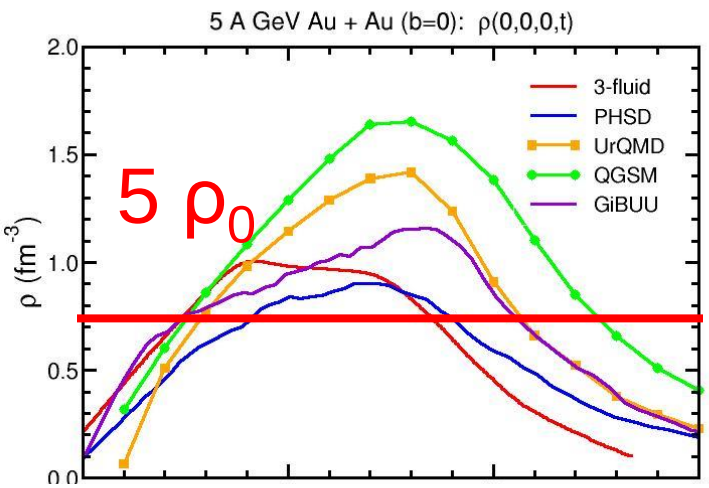
Systematically explore QCD matter at large baryon densities with high accuracy and rare probes.

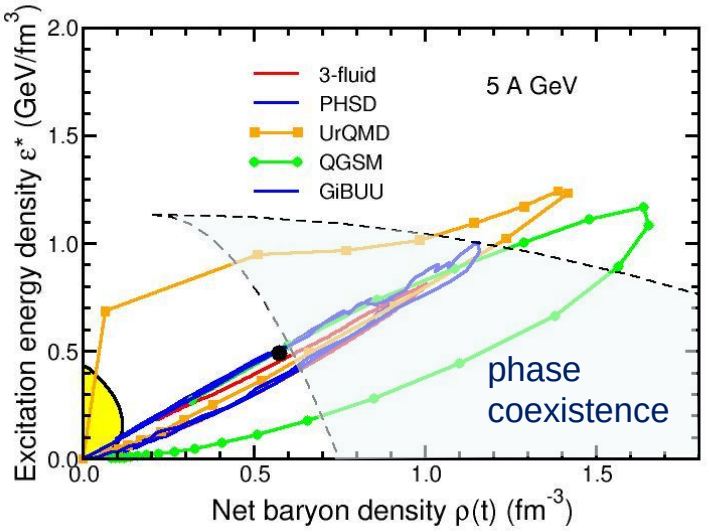
Outline:

CBM experiment's strategy
Experiment setup
Status of subsystems
Fair Phase-0 and Day-1 measurements

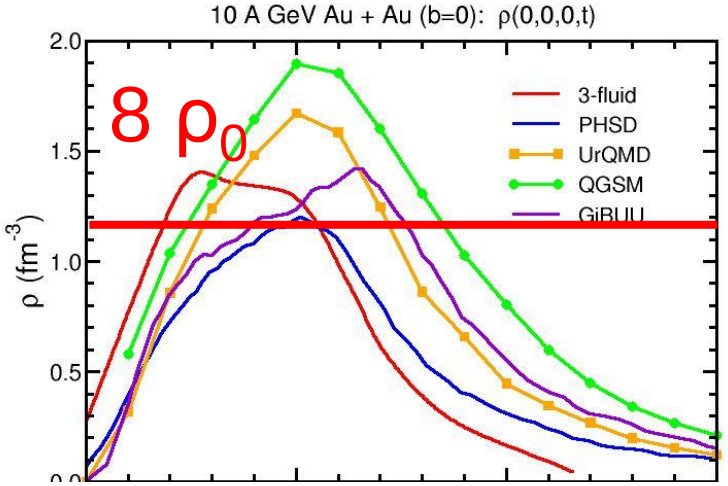
Baryon densities in central Au+Au collisions

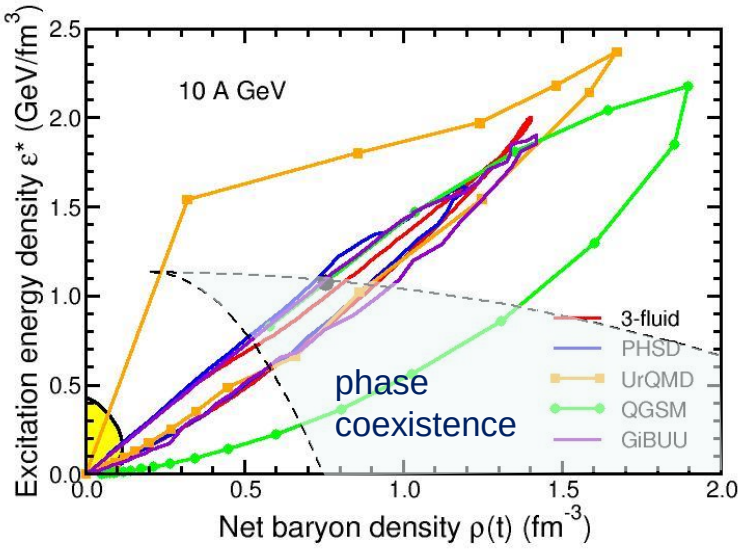
5 A GeV





10 A GeV

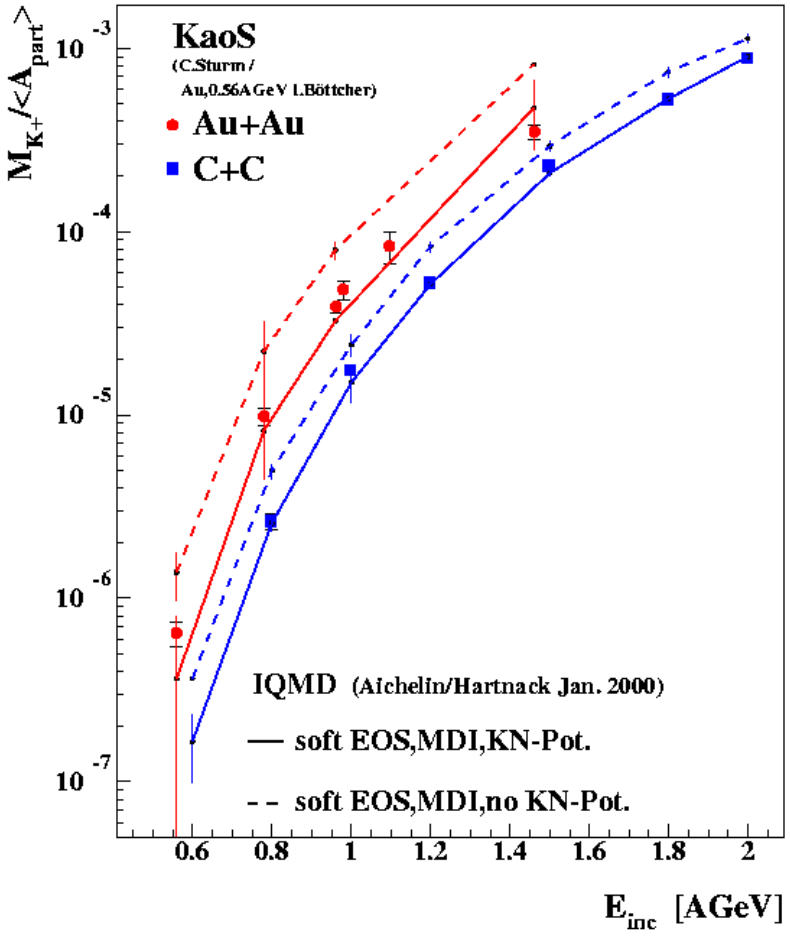




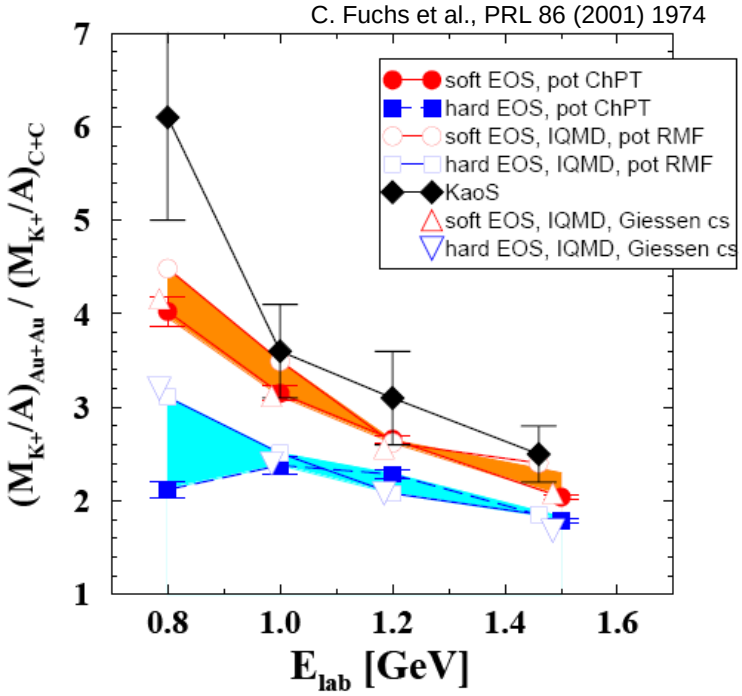
I.C. Arsene et al., Phys. Rev. C 75, 24902 (2007)

Reminder: Subthreshold Kaon – measurements (KAOS at SIS18)

C.Sturm et al. (KaoS), PRL 86 (2001) 39



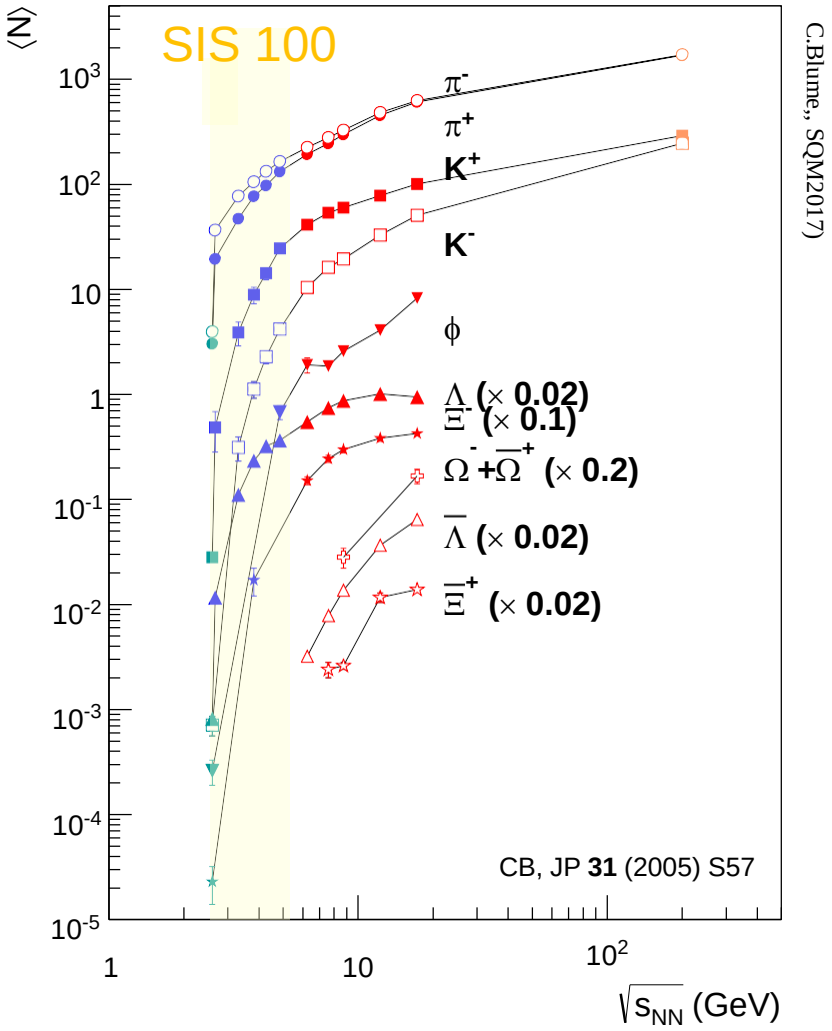
C. Fuchs et al., PRL 86 (2001) 1974



Strong sensitivity to Equation Of State
due to multistep production
(formation of nucleon resonances)
=> soft EOS (K=200 MeV)

Final state particle abundance

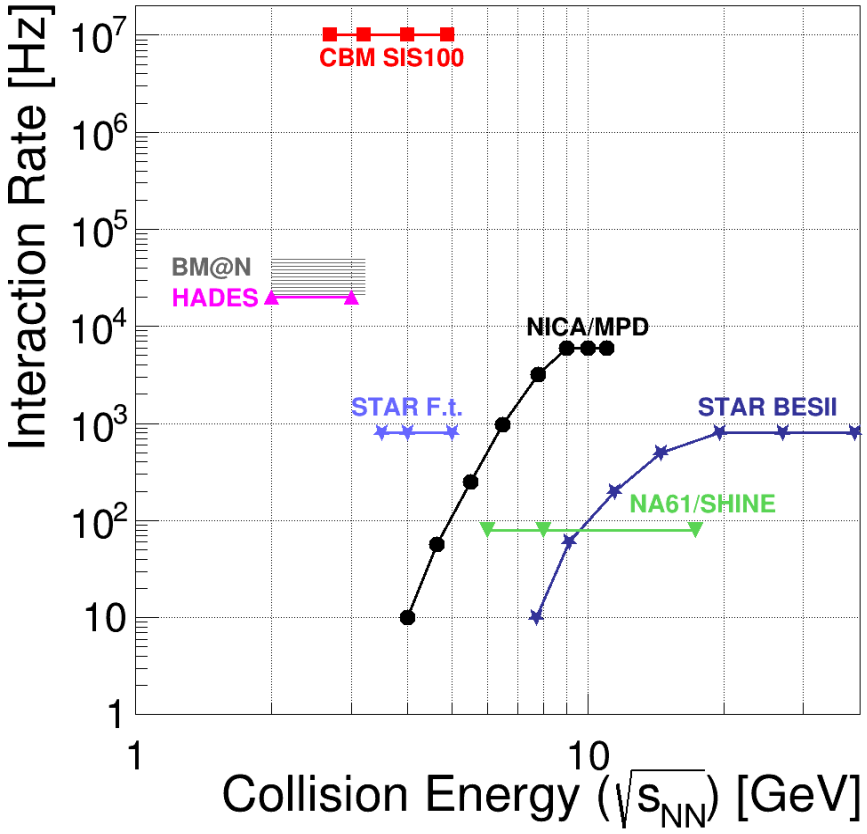
Particle yields from central Au + Au collisions



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

CBM – Strategy

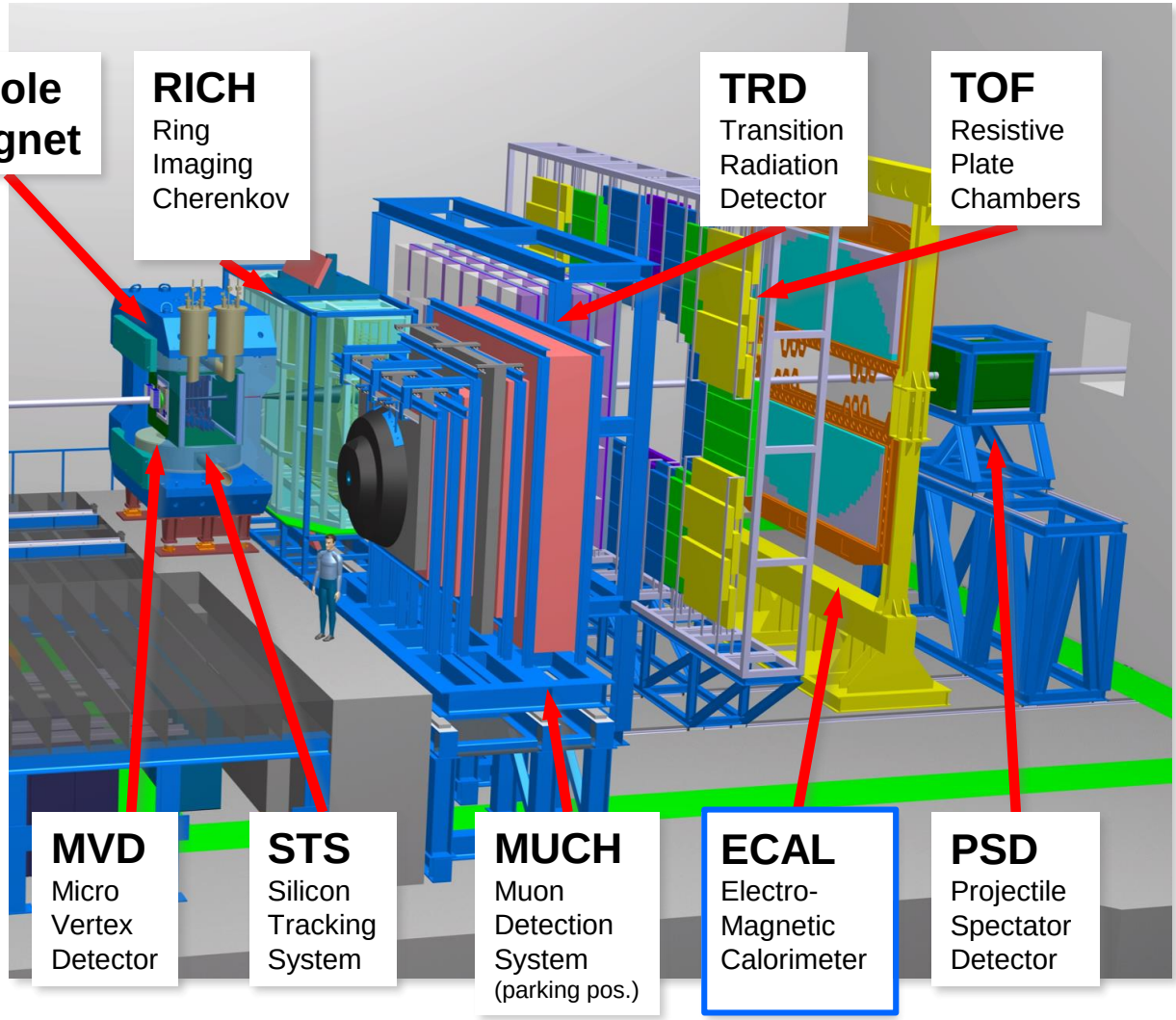


Exploration of QCD phase diagram
as international effort:

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

CBM experimental setup (day-1)



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

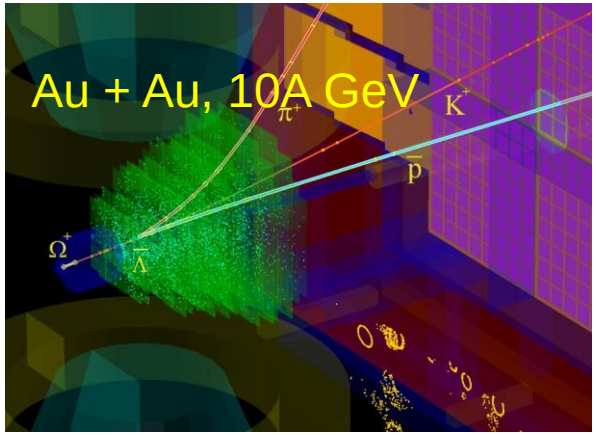
  $R_{int} \approx 0.5$ MHz
  full bandwith:
  Det. – Entry nodes
  reduced bandwidth
  Entry nodes – Comp. farm

  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

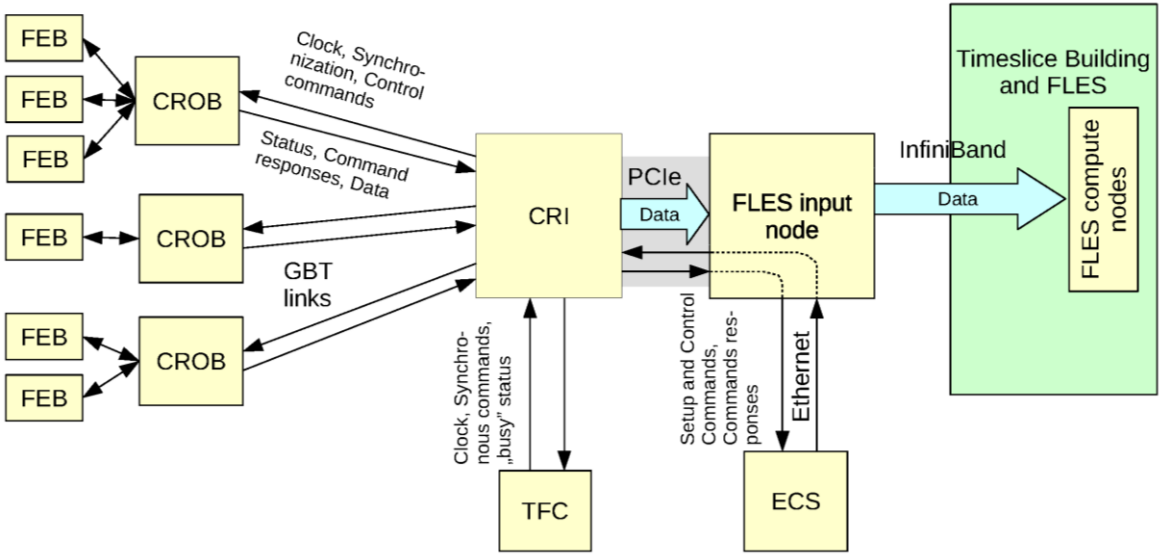
CBM data processing system



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 with time stamps,
- software based event selection

CBM physics and observables

Eur.Phys.J. A53 (2017) 60

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

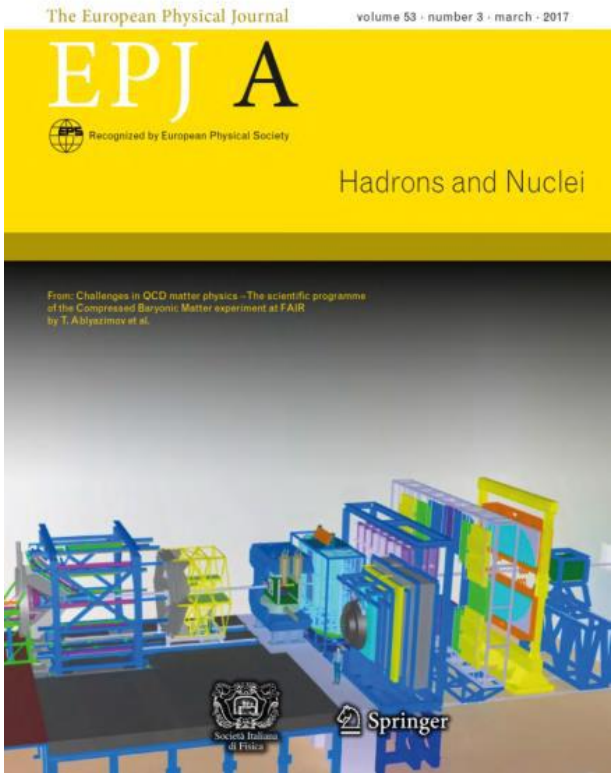
Phase transition
- excitation function of hyperons
- excitation function of LM lepton pairs

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



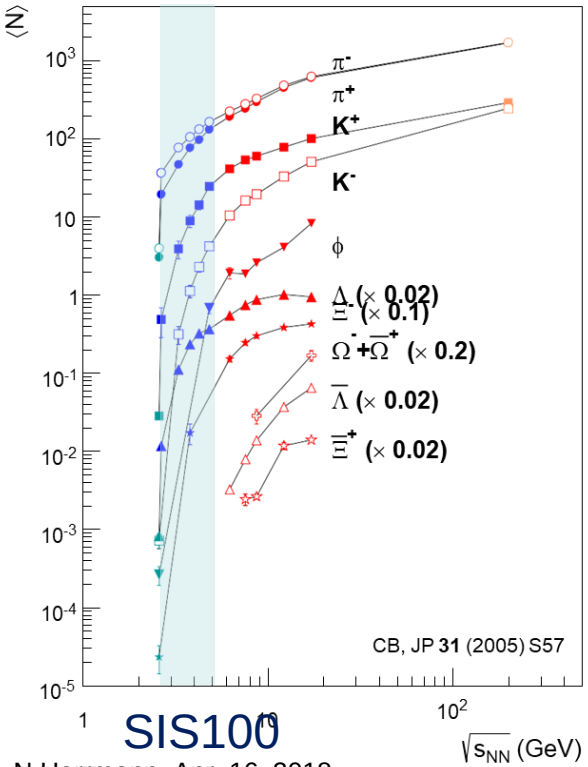
→ **V. Friese**

CBM day-1 – program

Observables: Strangeness and Dileptons

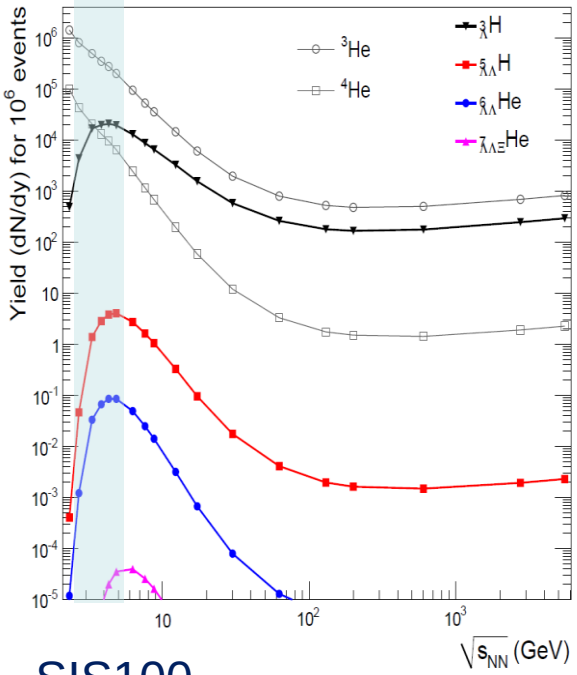
Excitation function of yields and phase-space distributions of
multi-strange hyperons and
lepton pairs in AA (C+C, Au+Au) collisions from 2-11 A GeV.
Search for hypernuclei (no data available in this energy range).

multi-strange hyperons



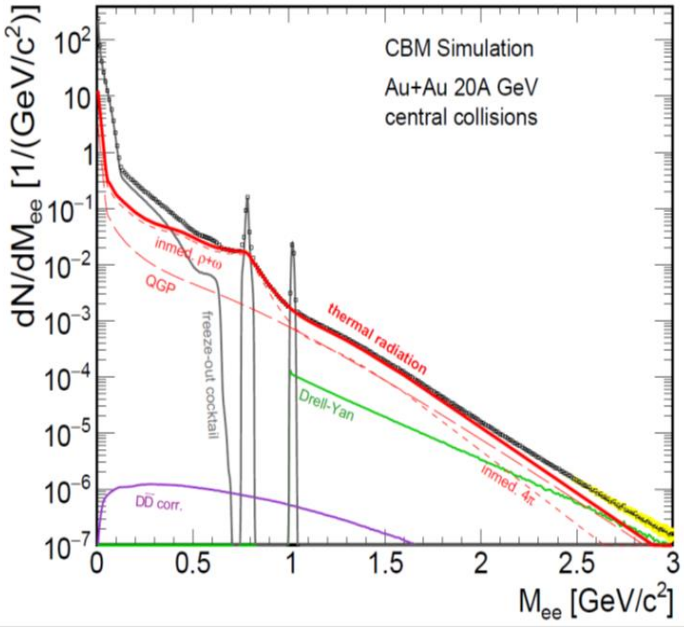
SIS100

hypernuclei



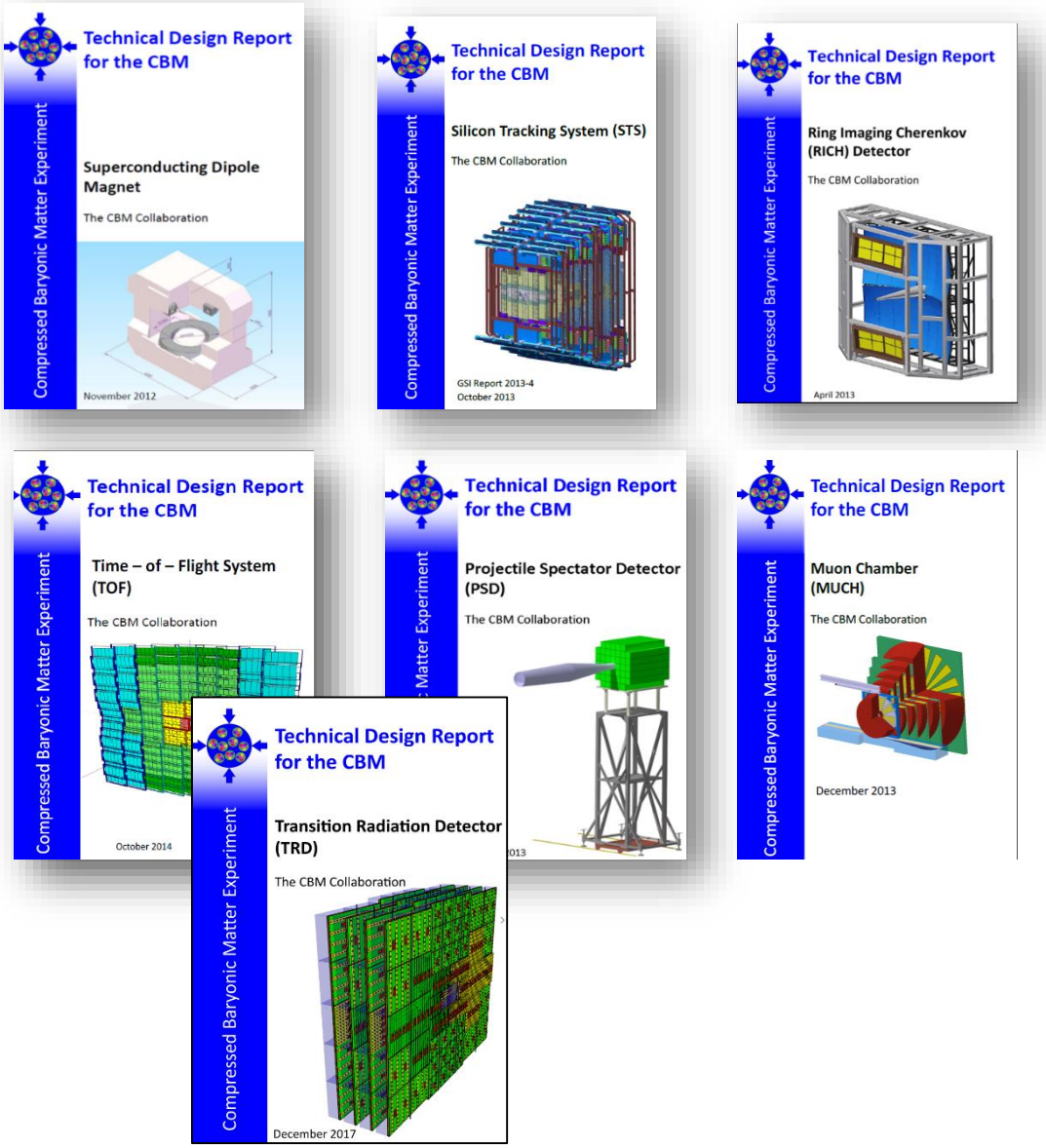
SIS100

dilepton invariant mass



Technical Design Reports

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

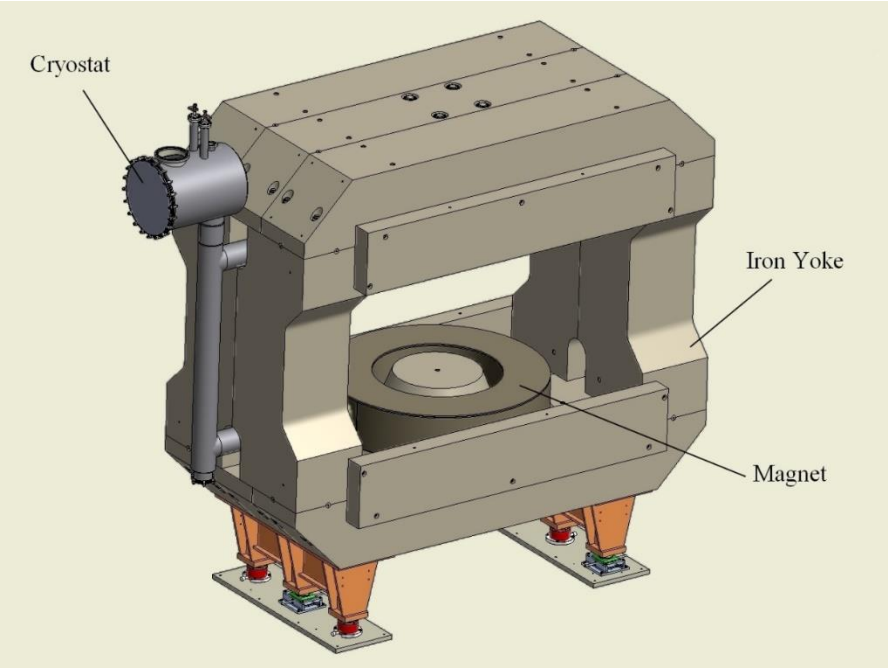


Day-1 target date: summer 2024

Superconducting Dipole Magnet

GSI Darmstadt, BINP Novosibirsk, JINR Dubna

- momentum determination of charged particles



Magnet gap 1.44 m
Field integral 1 Tm
Acceptance:
vertical: 25°
horizontal: 30°

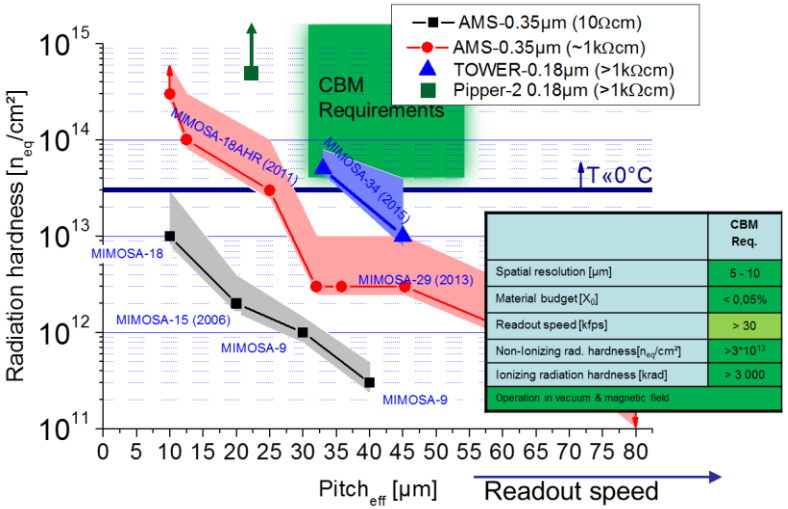
Status:

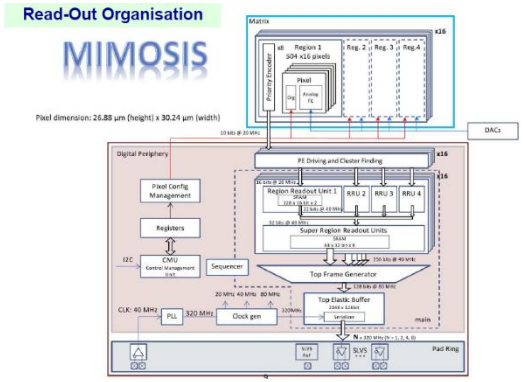
- TDR approved by FAIR in January 2014
- Collaboration Contract with Budker Institute Novosibirsk signed Dec. 2016
- Design and realization reviewed/supervised by internatl. expert committee
- CDR: April 2018

Micro Vertex Detector (MVD)

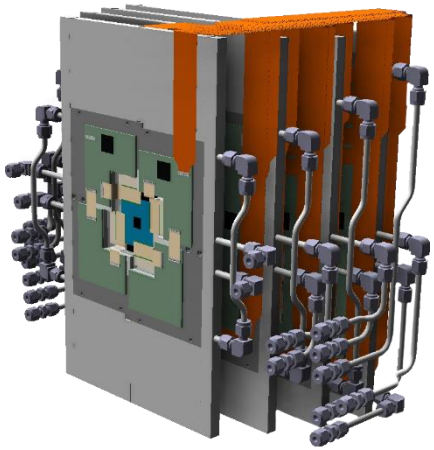
IKF Frankfurt, IPHC Strasbourg, Pusan National Univ.

- Background suppression for di-electron measurements
- Determination of secondary vertices of open charm decays
- Improved tracking for hyperon-ID





Sensor design inspired by ALPIDE



Status:

- MIMOSA sensor technology applicable after 10 years of joint development
- Steps toward final sensor identified:
  Q4,'17 MIMOSIS-0 diff pixel design, Q2,'18 MIMOSIS-1: 1st prototype of complete sensor
  Q2,'19 MIMOSIS-2: 2nd prototyp, 2020 MIMOSIS-3: final sensor pre-production
- TDR to be submitted in 2018

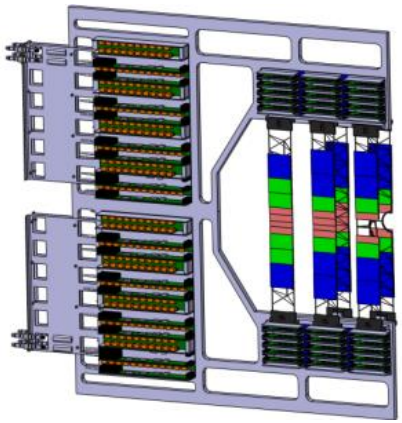
Silicon Tracking System (STS)

GSI Darmstadt, JINR Dubna, KIT Karlsruhe, JU Crakow, AGH Crakov, KINR Kiev, Univ. Tübingen, Warsaw UT

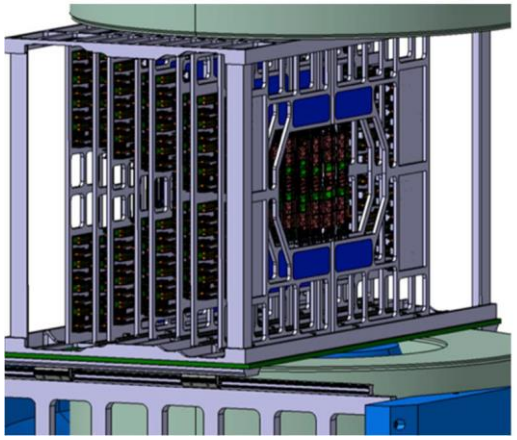
- Charged particle track reconstruction, momentum determination

Integrated module

Engineering design of station



8 STS in thermal enclosure, 2.133 M channels



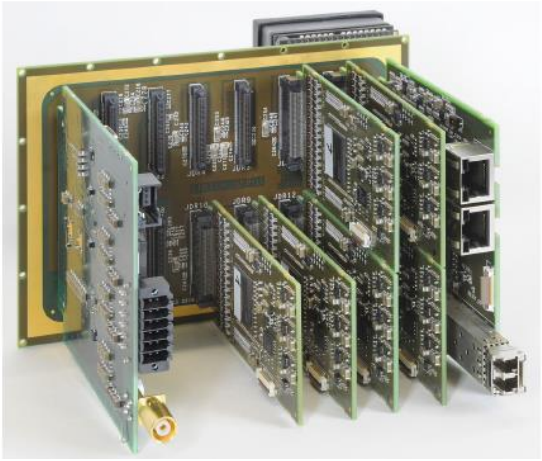
Status:

- TDR approved by FAIR in July, 2013
- Radiation tolerance of sensors tested up to n_{eq} (1 MeV) = 2×10^{14} /cm^2,
- Readout ASICS STS-XYTER V 2.0 produced,
- Sensor procurement: Q2 2018
- System integration concept close to final.

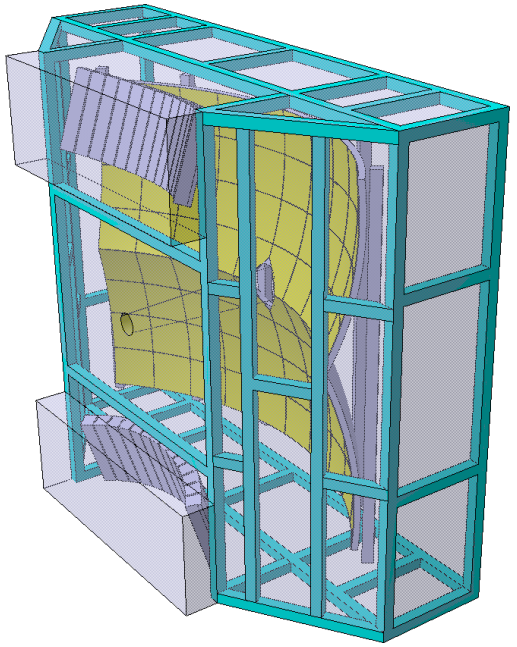
Ring Imaging Cherenkov Detector (RICH)

Univ. Giessen, Univ. Wuppertal, PNPI Gatchina, GSI Darmstadt

- Electron identification



3x2 MAPMT readout cluster



mechanical design

Status:

- TDR approved by FAIR in July 2013
- 1100 MAPMTs (Hamamatsu H12700) tested
- Geometry optimized (curved PMT surface)
- New shielding box design
- Readout chain set up for Phase-0 program with HADES

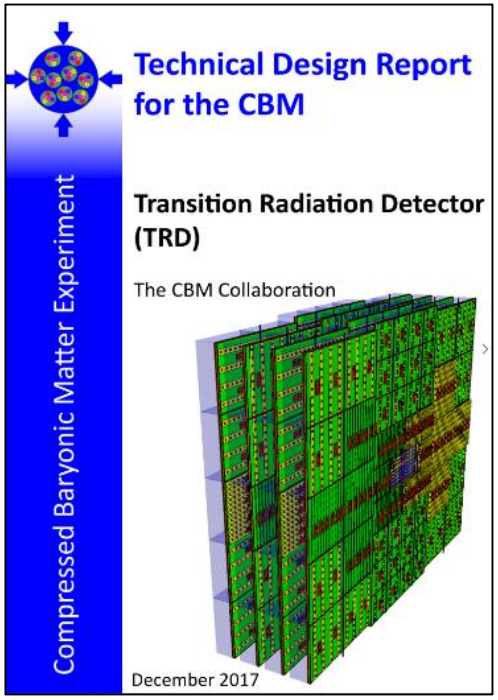
Transition Radiation Detector (TRD)

NIPNE Bucharest, Univ. Frankfurt, Univ. Heidelberg, Univ. Münster

- Electron identification, energy-loss measurements

TRD Test Setup at SPS 2016

TRD Test Setup at DESY 2017



~ 330.000 readout channels

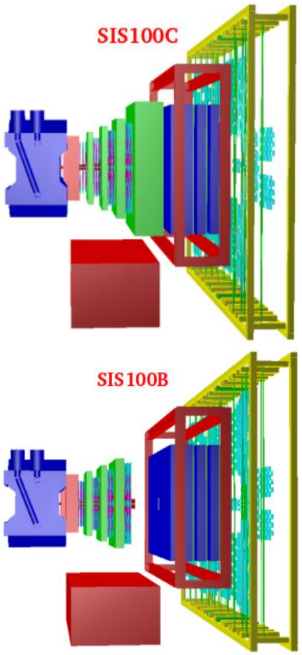
Status:

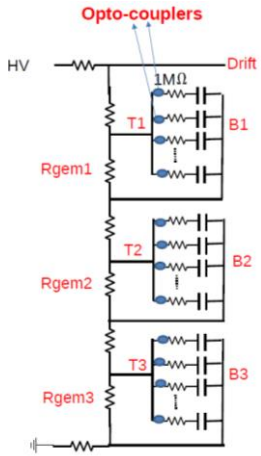
- System optimization done, alternative designs identified,
- Performance study done, 4 layers are sufficient for electron – pion separation,
- TDR submitted in Dec. 2017,

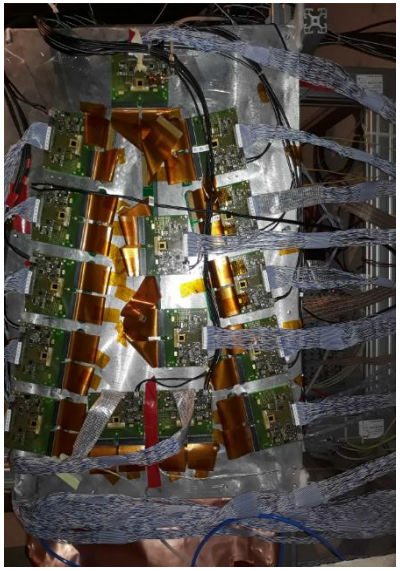
Muon Chamber System (MUCH)

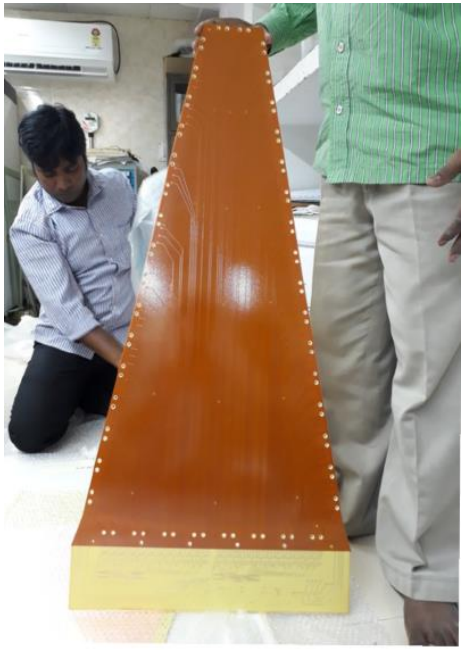
VECC Kolkata + 12 Indian Inst., PNPI Gatchina

- Muon identification









Status:

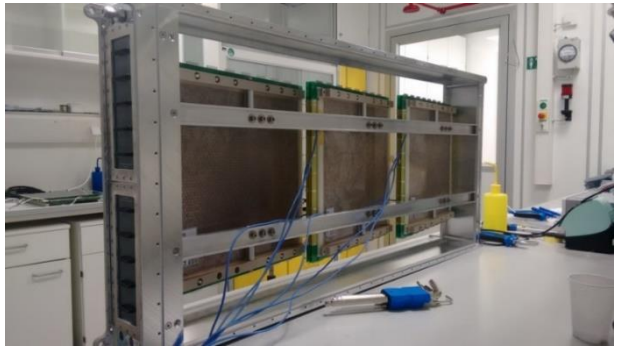
- TDR approved in Feb. 2015
- Real-size prototype GEM chamber was tested in Pb+Pb at SPS
- HV system designed
- Bakelite RPC for operation in 3rd and 4th plane under development

Time Of Flight Detector (TOF)

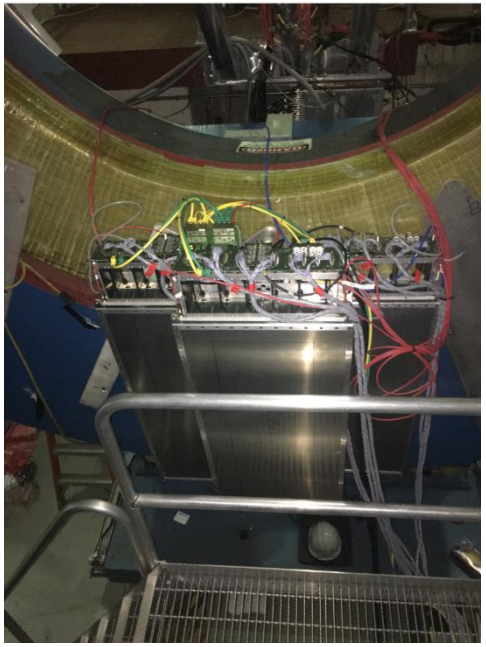
THU Beijing, NIPNE Bucharest, GSI Darmstadt, TU Darmstadt, USTC Hefei, Univ. Heidelberg, ITEP Moscow, HZDR Rossendorf, CCNU Wuhan

- Charged particle identification

Setup at SPS (2016)



Open CBM – TOF Module with 3 MRPCs



eTOF sector in STAR (2018)

Status:

- TDR approved Feb. 2015
- A stack of MRPCs was successfully tested with final streaming electronics at rates up to several kHz/cm^2 at CERN SPS.
- Mass production of modules for usage in STAR has started.
- CBM eTOF modules run stable in Star Run18 (streaming DAQ, gas mixture: no SF_6).

Projectile Spectator Detector (PSD)

INR Moscow, TU Darmstadt, CTU Prague, NPI Rez

- determination of collision centrality and orientation of the reaction plane

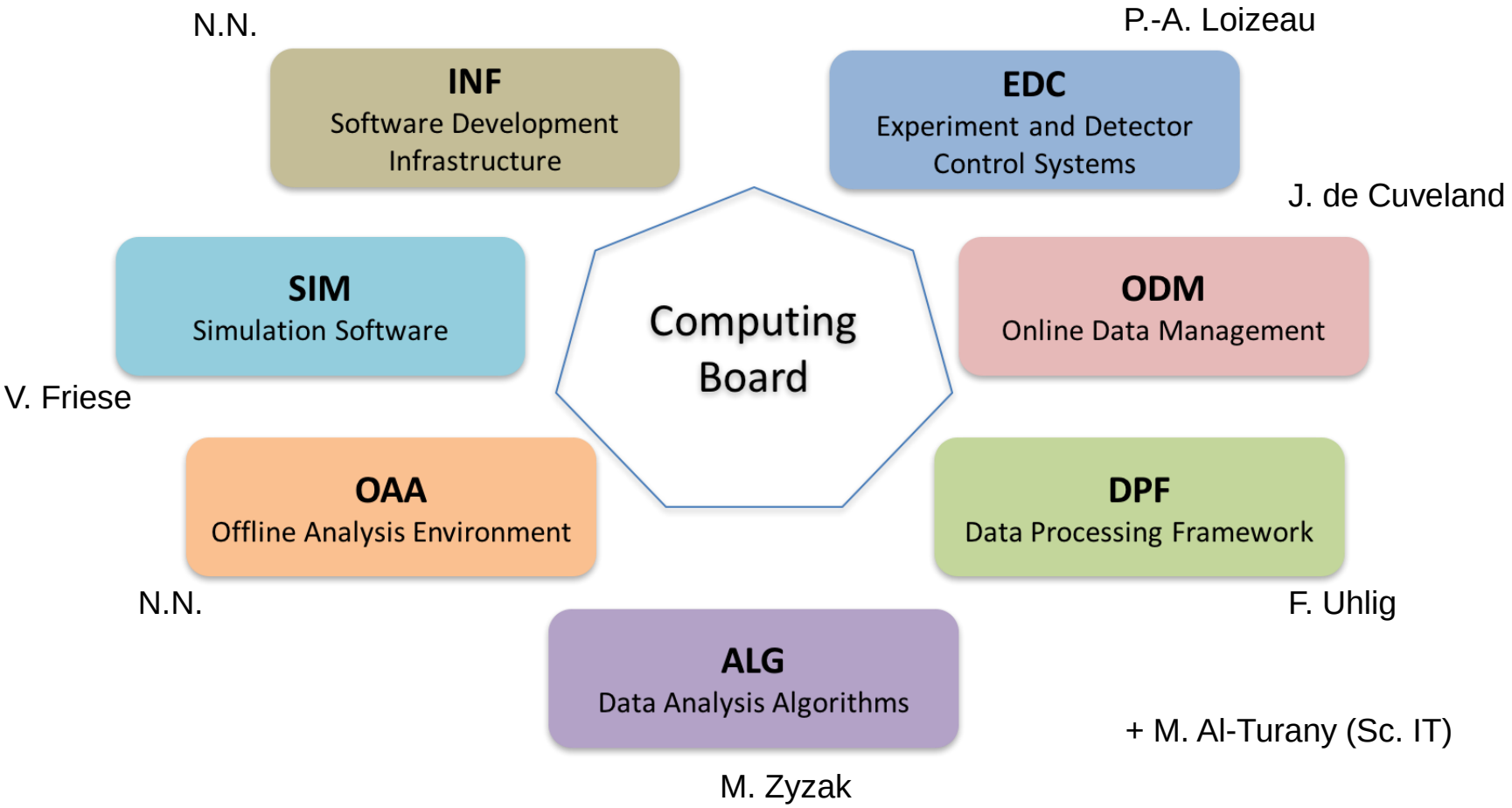
PSD module

PSD Supermodule at CERN PS (2017)

Status:

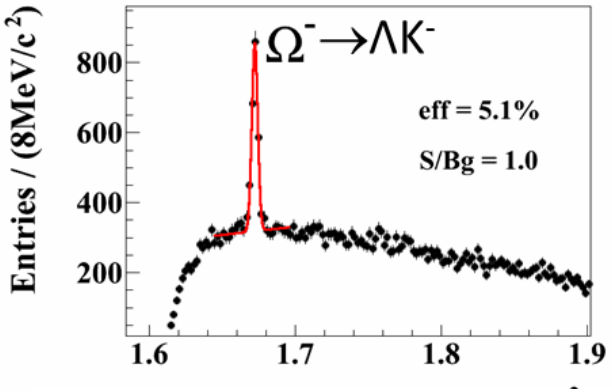
- TDR approved Feb. 2015,
- All 45 modules of CBM PSD have been assembled.
- Test of PSD Supermodule at CERN PS (T10).
- Expected energy resolution confirmed:
- PSD modules will be used in CBM Phase- 0 in various places.

Software status

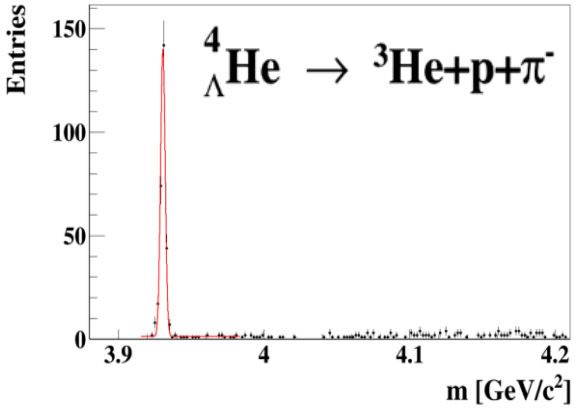


CBM Day 1 – performance

Hyperon measurements:



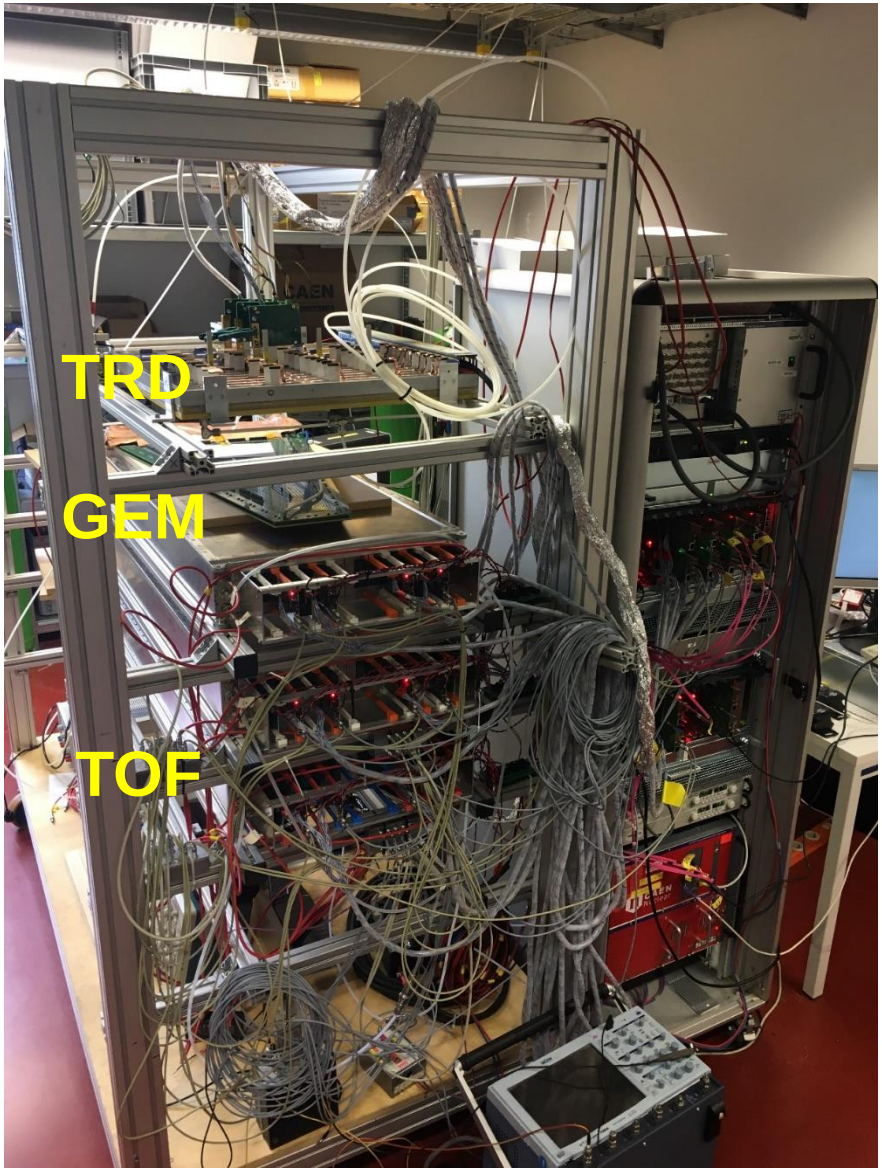
Hypernuclei measurement:



Au+Au at 10A GeV, ε_{duty} = 50%, R=100kHz
(time based analysis)

Particle	Multi-plicity	BR	ε (%)	yield (s^{-1})	yield in 1 week
Ω^- (1672)	$5.6 \cdot 10^{-3}$	0.68	5	1.64	$5 \cdot 10^5$
$^4_\Lambda$He (3930)	$1.9 \cdot 10^{-3}$	0.32	14.7	0.87	$3 \cdot 10^5$

Cosmic stand (μCBM) in Heidelberg



Hardware:
TRD, GEM, TOF, DAQ, FLES in place,

setup continuously running,

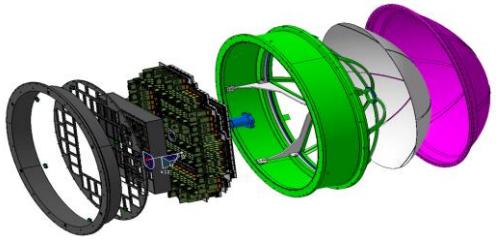
software under development,

unexpected features found,

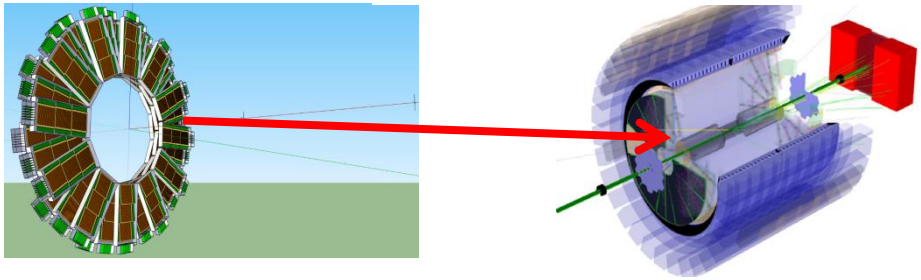
no combined data available yet!

CBM – FAIR Phase 0 projects (2018 – 2022)

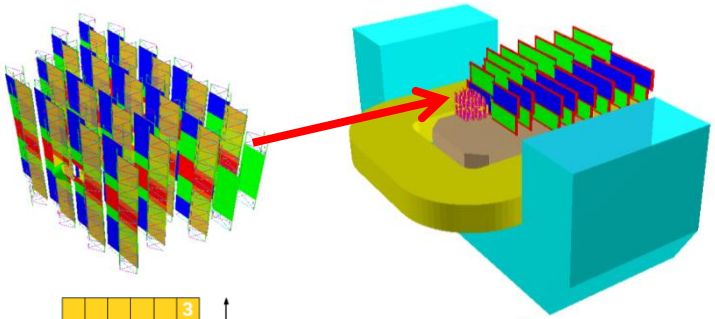
1. Install, commission and use 430 out of 1100 CBM RICH multi-anode photo-multipliers (MAPMT) including FEE in HADES RICH photon detector



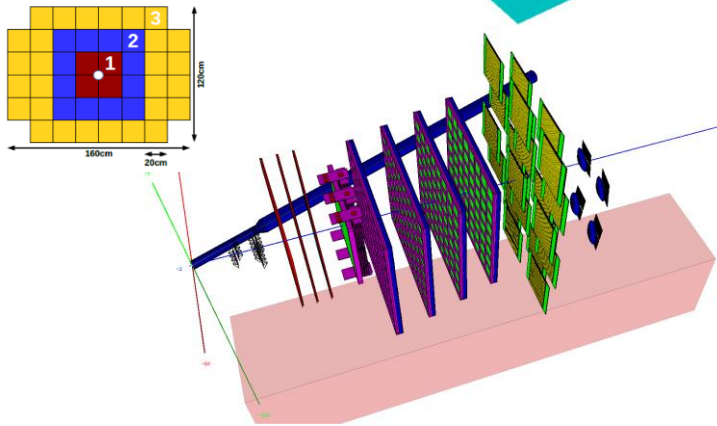
2. Install, commission and use 10% of the CBM TOF modules including read-out chain at STAR/RHIC (BES II 2019/2020)



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)

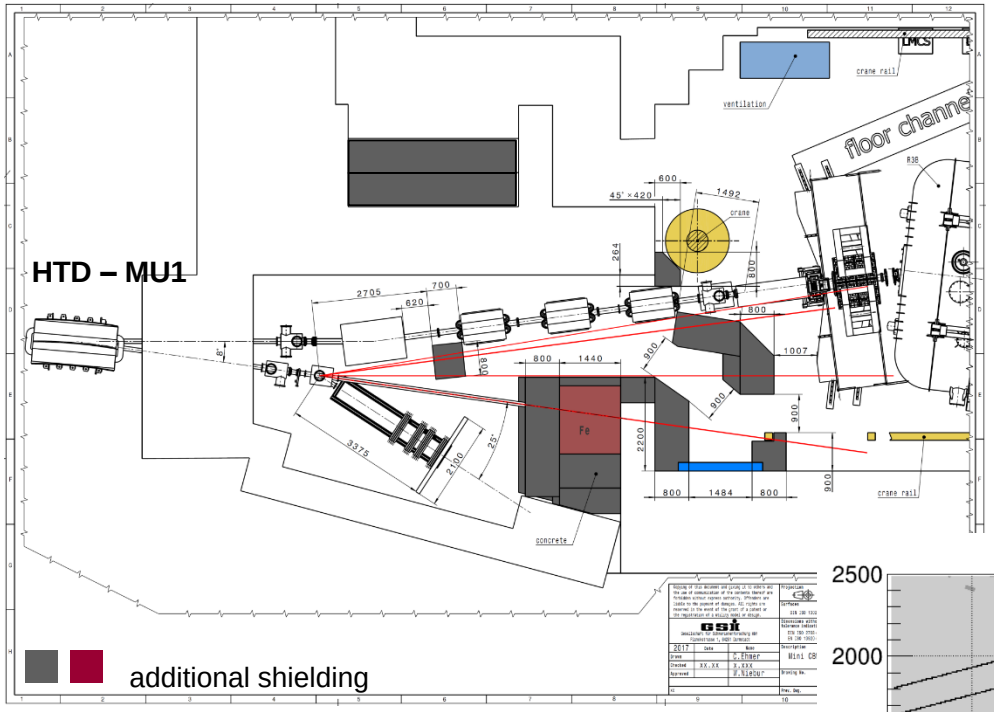


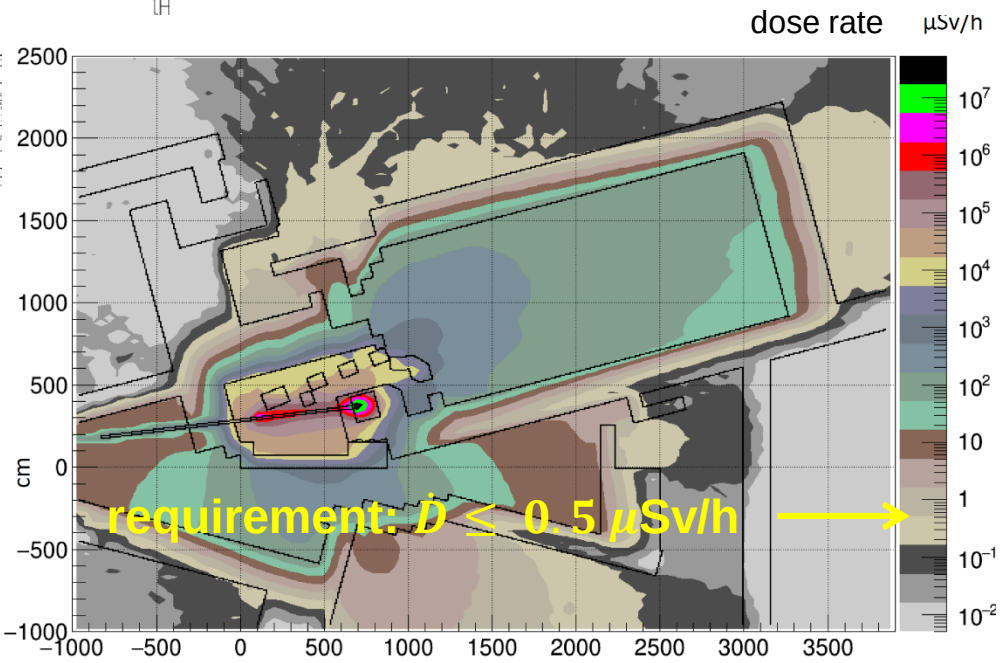
4. Install, commission and use the Project Spectator Detector at the BM@N experiment



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

mCBM Cave (HTD)

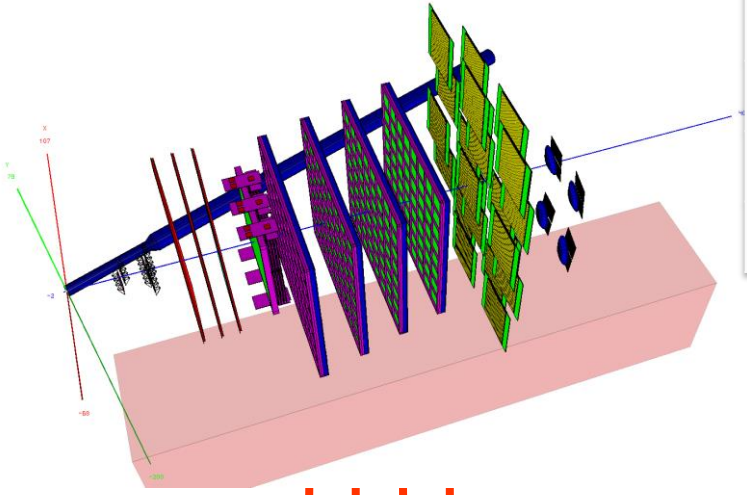




- Modified switching magnet
- New beam dump
- Additional shielding

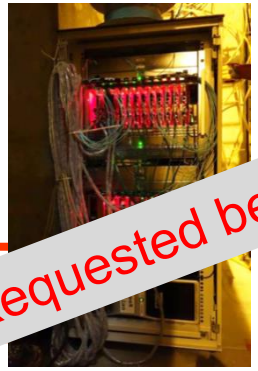
FLUKA calculations:
10^{8} Au ions s^{-1}, 1.24 AGeV,
2.5 mm Au target (P_{int} = 10%)

mCBM schedule



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
Q3/2019	first system high rate test

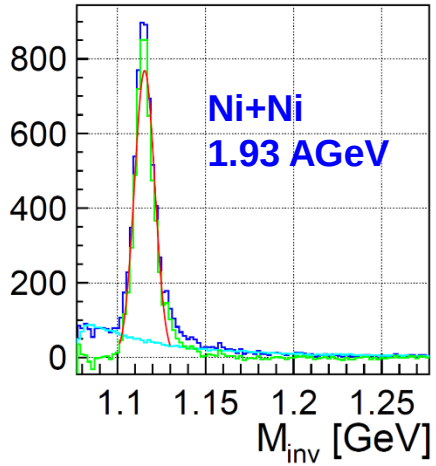


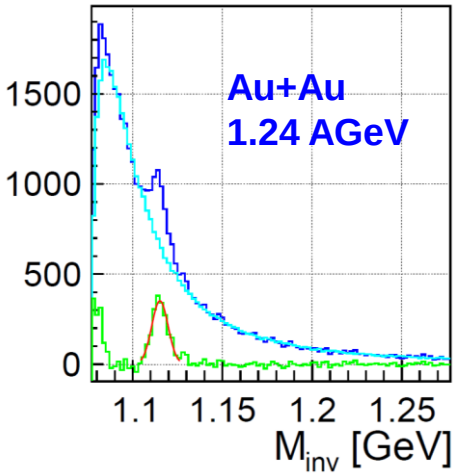
Requested beamtime was fully granted by G-PAC

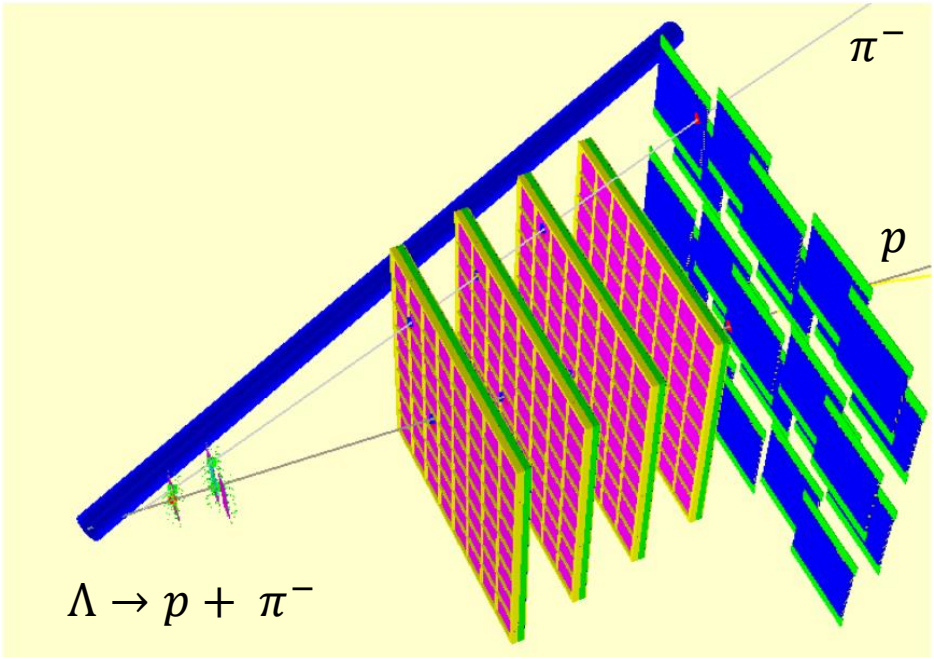
mCBM performance benchmark

(Sub)threshold Λ – baryon reconstruction.

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



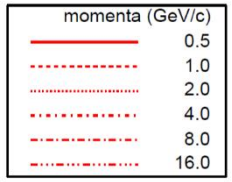


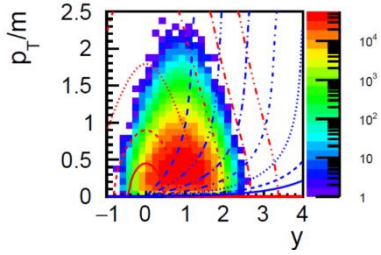


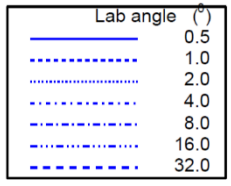
Acceptance

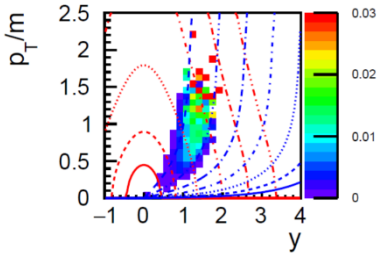
&

Efficiency









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

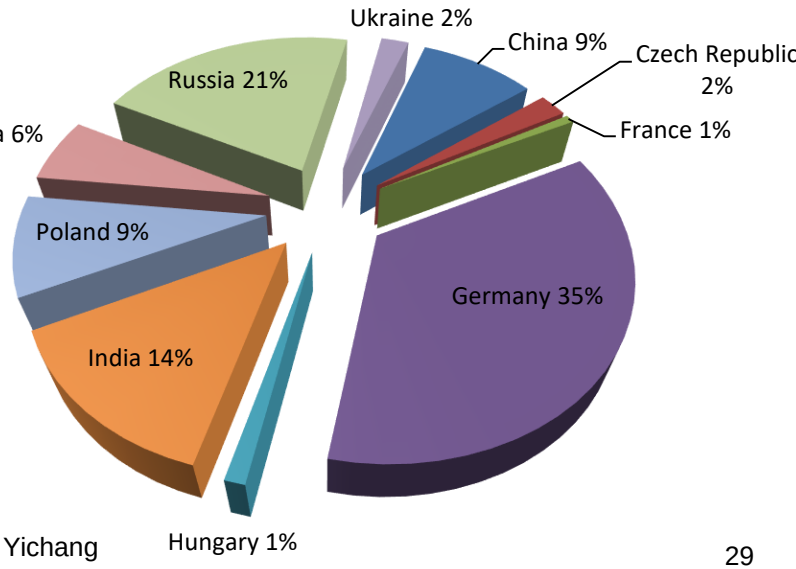
Romania:
NIPNE Bucharest
Univ. Bucharest

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

CBM Scientists



Conclusion

CBM scientific program at SIS100 is unique

- explore QCD matter at neutron star core densities
- employ high statistics capability
  - 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 relevant 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