Status of the CBM experiment

Christian Sturm, GSI
for the CBM Collaboration

Outline

CBM physics program at day 1

Status of the experiment preparation

- The full system test-setup mCBM@SIS18

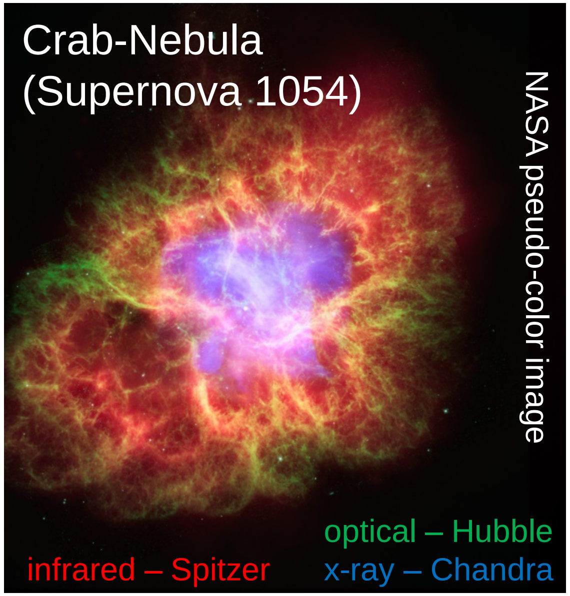
Compressed baryonic matter

Neutron stars

Temperature
T < 20 MeV

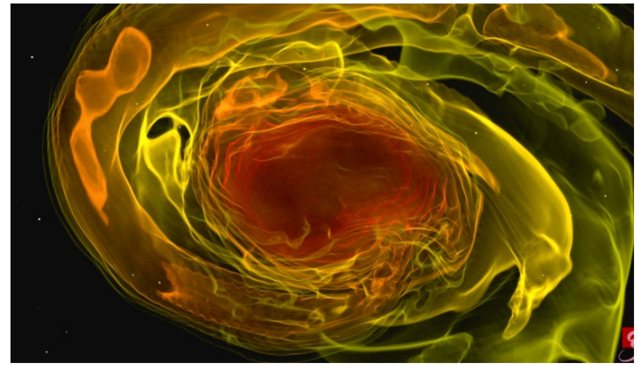
Core density
$\rho < 10\ \rho_0$

Lifetime
Δt ~ infinity



Crab pulsar T = 33.4 ms, Mass ~ 1.5 $M_{\odot}$

Neutron star merger



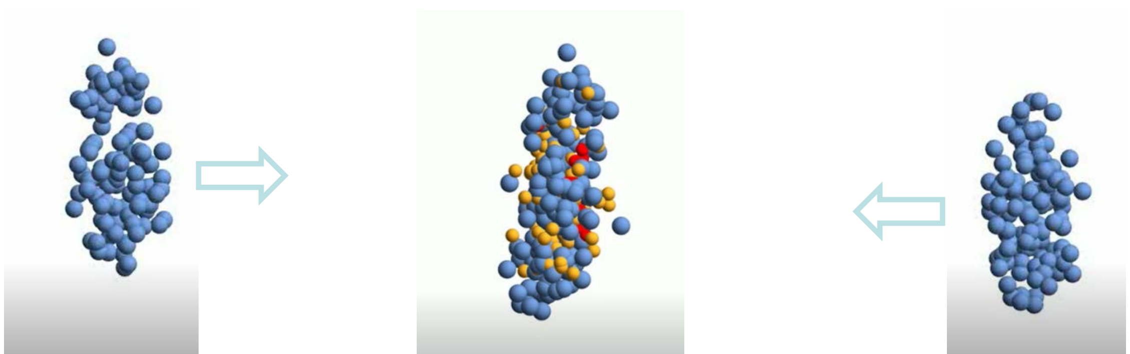
Temperature
T < 70 MeV

Density
$\rho < 2 – 6\ \rho_0$

Reaction time
Δt ~ 10 ms

numerical simulation, GW170817
T. Dietrich (Max Planck Institute for Gravitational Physics)

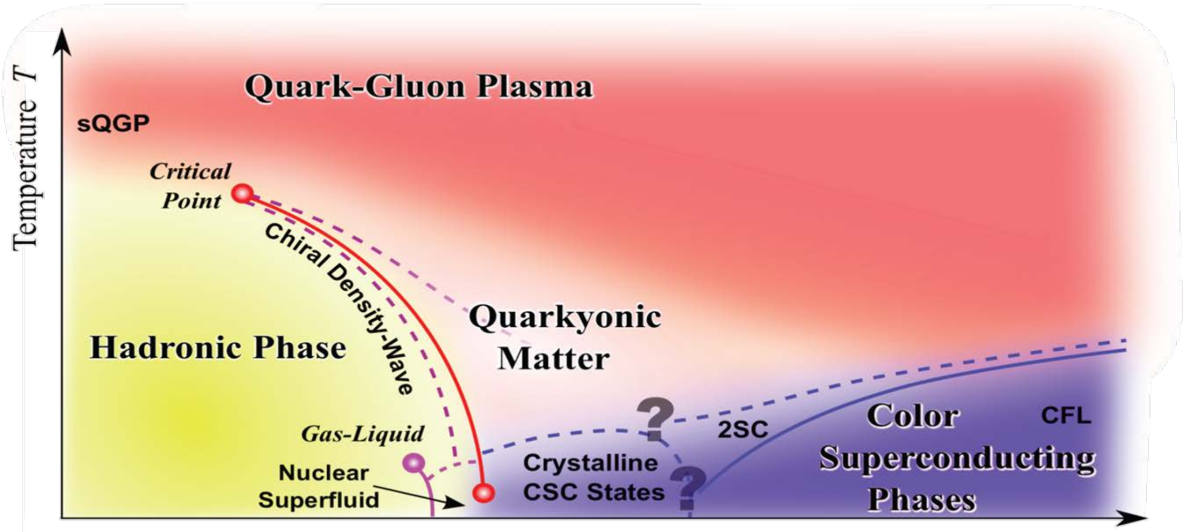
Relativistic nucleus-nucleus collisions at SIS100



Temperature
T < 120 MeV

Density
$\rho < 8\rho_0$

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



Courtesy of K. Fukushima & T. Hatsuda

Mission:

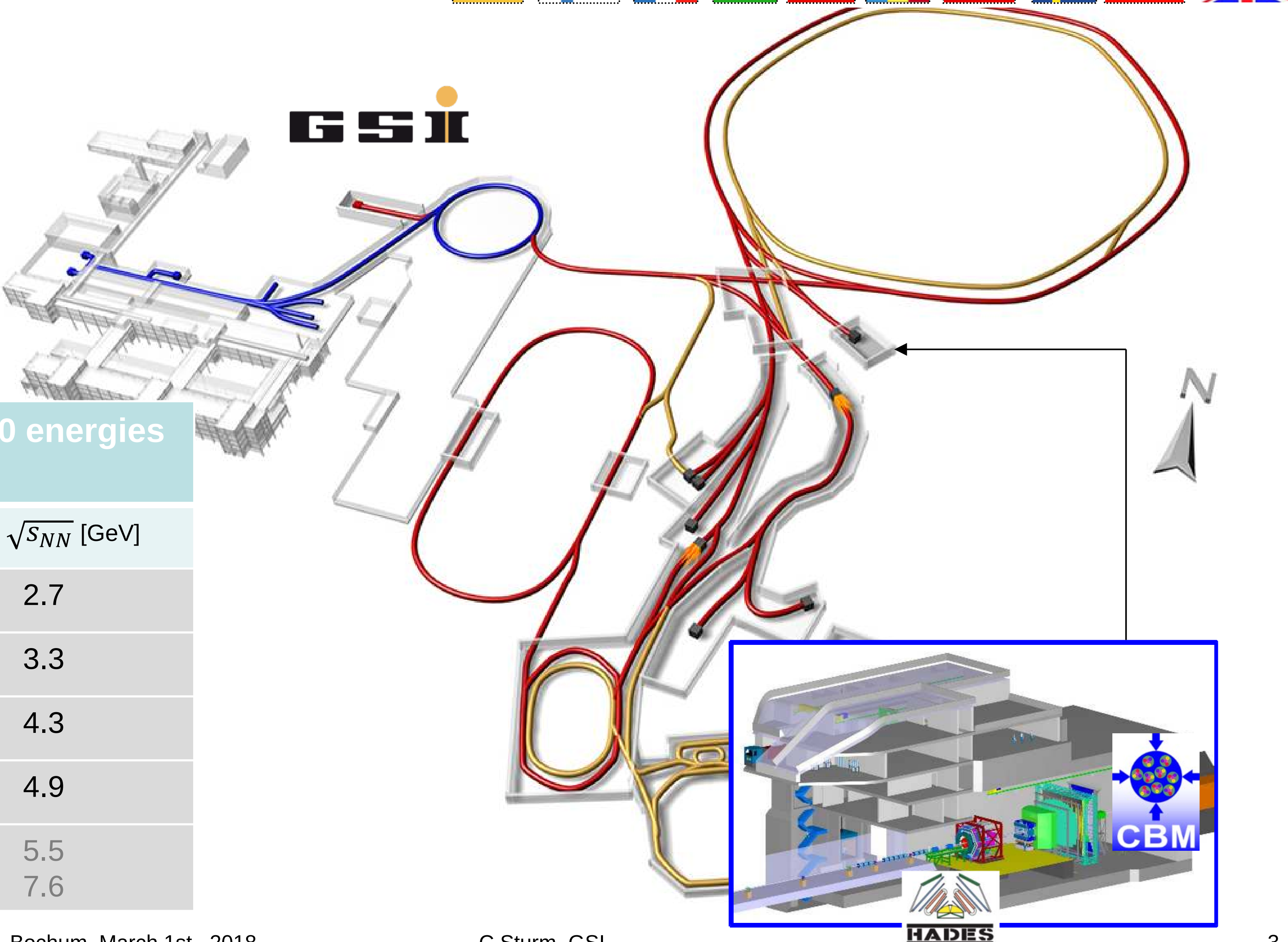
Systematically explore QCD matter at large baryon densities with high accuracy and rare probes.

Fundamental questions:

Equation-of-state of QCD matter at neutron star core densities
Phase structure of QCD matter
Chiral symmetry restoration at large densities
Bound states with strangeness

Field driven by experimental data !

The Facility for Antiproton and Ion Research



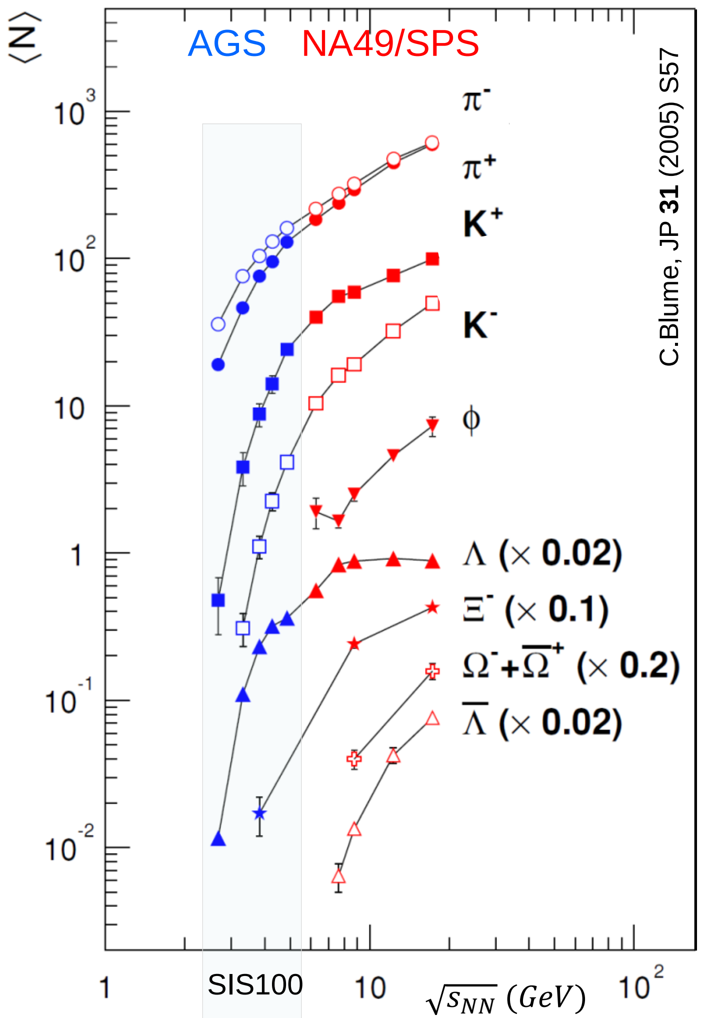
FAIR SIS100 energies
(Au ions)

E_{kin}^{lab} [A·GeV]	$\sqrt{s_{NN}}$ [GeV]
2	2.7
4	3.3
8	4.3
11	4.9
14 (Ca) 29 (p)	5.5 7.6

Strangeness at FAIR energies

CBM

Particle yields
from central Au + Au collisions



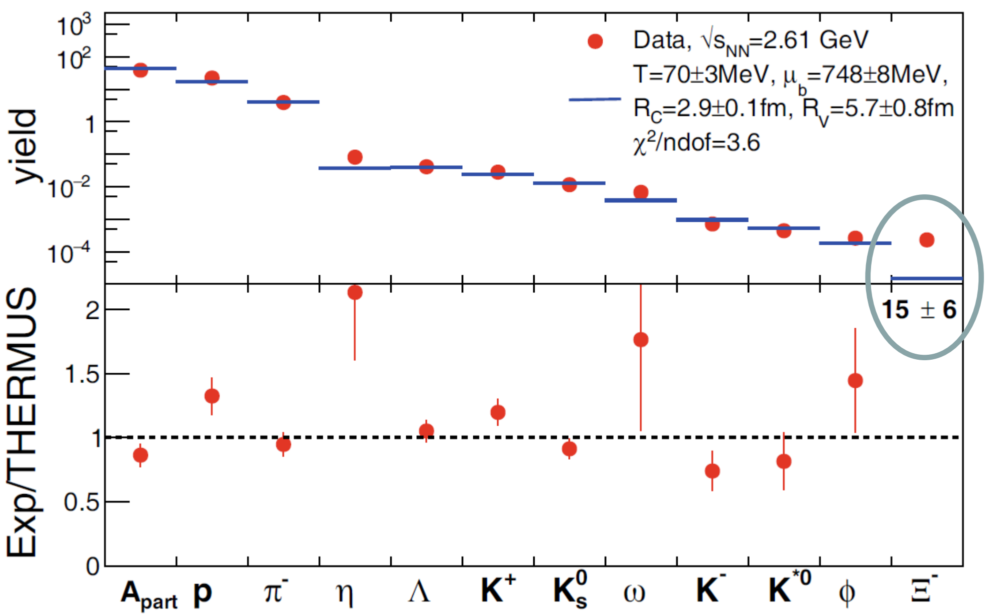
Particle production thresholds in pp - collisions

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

Little knowledge on **multi-strange hyperons** at energies T_{lab} < 10 AGeV

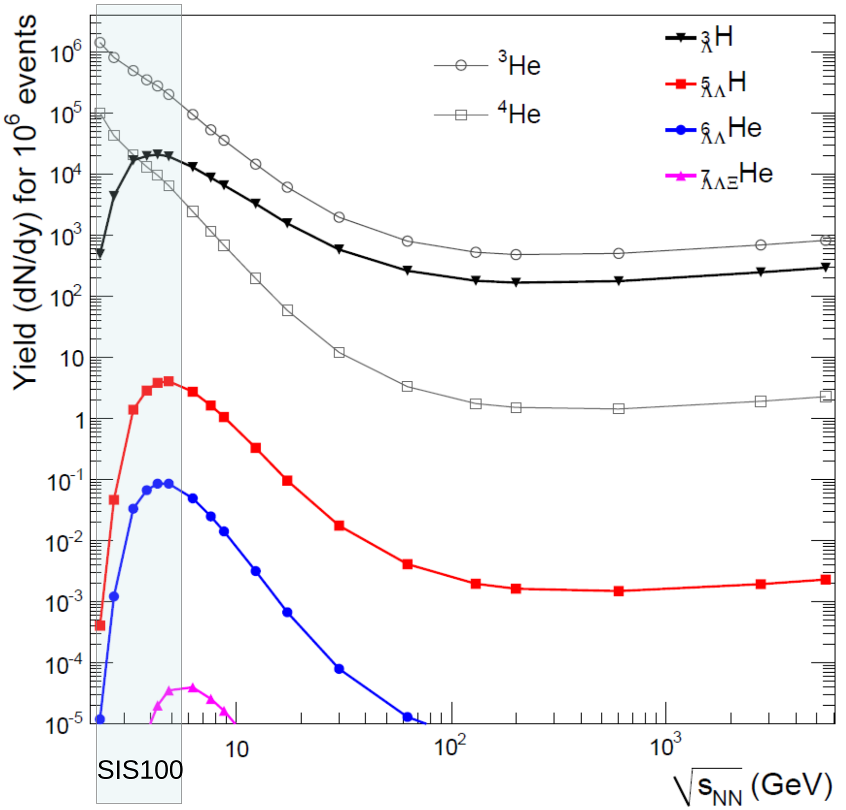
→ multi-stepproduction ?
→ production via strangeness exchange channels ?
→ enhanced production in dense medium ?

HADES data
Ar + KCl 1.76 A GeV
Phys. Rev. Lett. 103 (2009) 132301



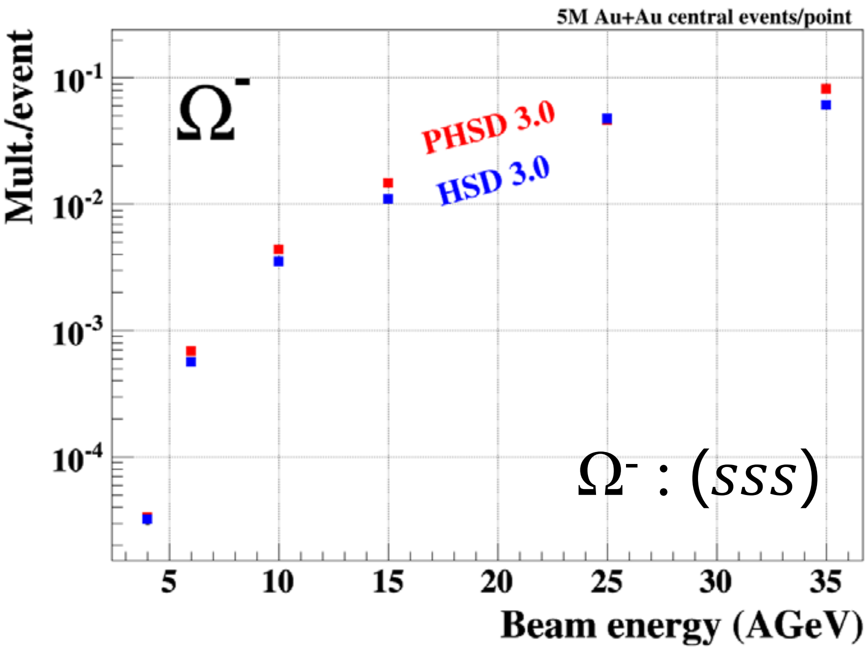
Statistical model fit, THERMUS v3.0
Eur. Phys. J. A (2016) 52 178

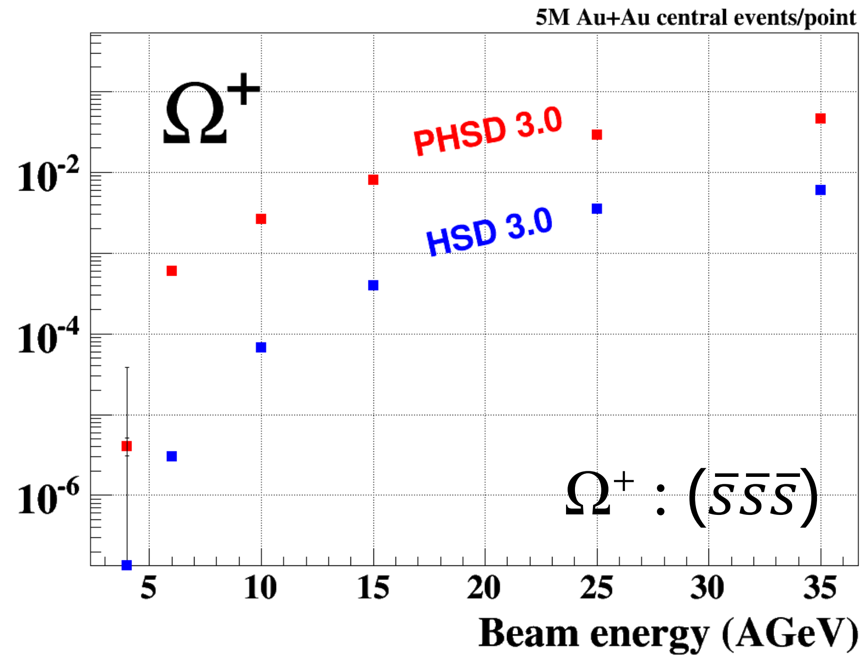
Statistical hadronisation model:
production of light nuclei and hypernuclei



A. Andronic, P. Braun-Munzinger, J. Stachel, H. Stöcker
Phys. Lett. B697 (2011) 203

PHSD: Transport code with partonic phase ($\varepsilon > 1$ GeV/fm^3)
HSD: Hadronic transport code

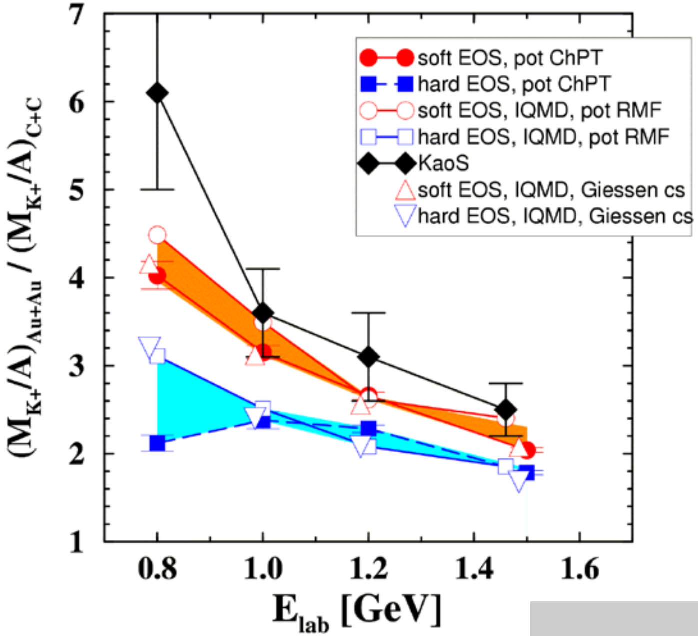




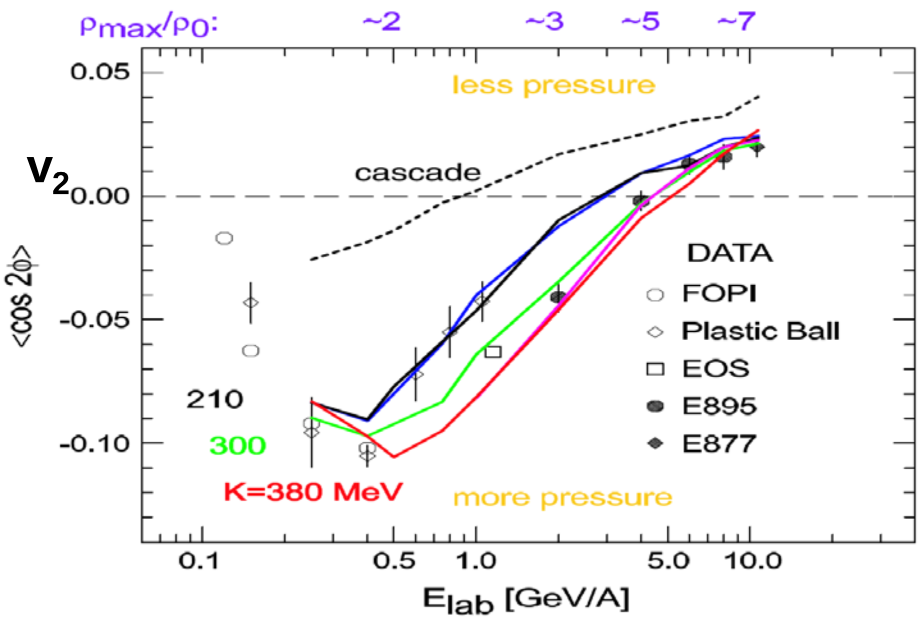
I. Vassiliev, E. Bratkovskaya, preliminary results

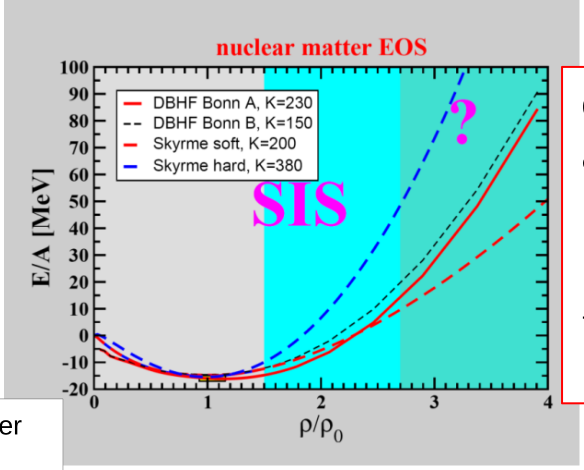
Nuclear equation-of-state at high net-baryon densities

Experiment: Phys. Rev. Lett. 86 (2001) 39
Theory: QMD C. Fuchs et al., Phys. Rev. Lett. 86 (2001) 1974
IQMD Ch. Hartnack, J. Aichelin, J. Phys. G 28 (2002) 1649



P. Danielewicz et al., Science 298 (2002) 1592



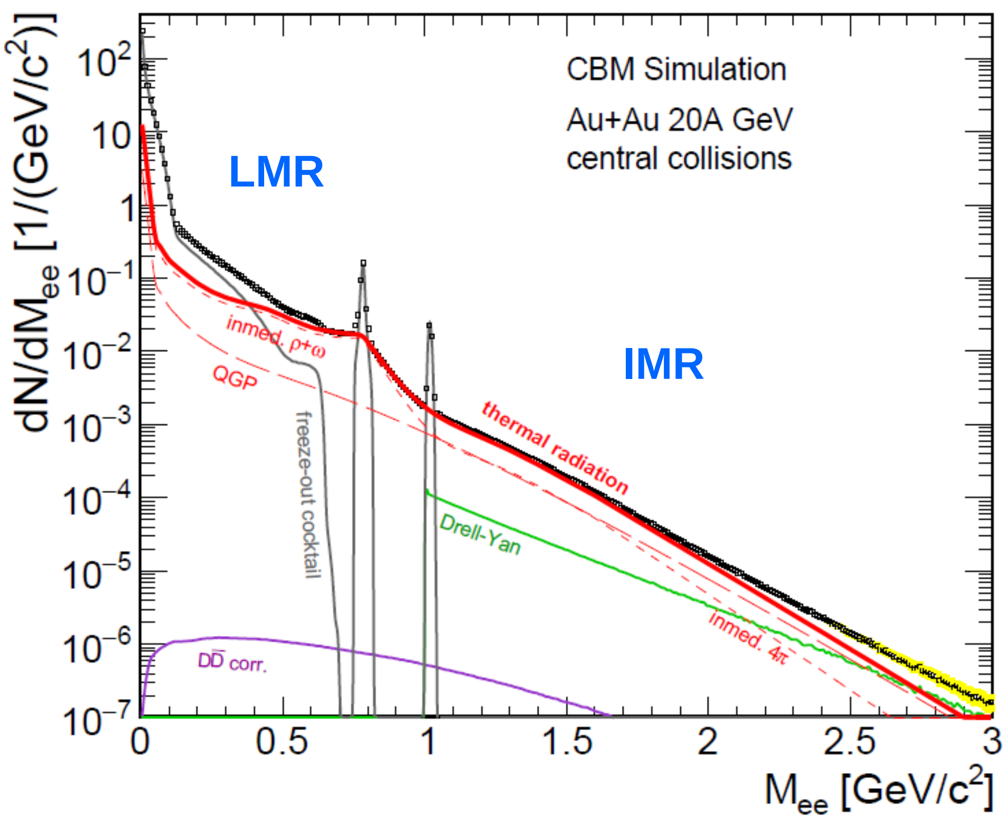


DBHF: E. N. E. van Dalen, C. Fuchs, A. Faessler
EPJ. A 31,29 (2007)

equation-of-state
at
neutron star core densities ?

→ subthreshold $\Omega^+(\bar{s}\bar{s}\bar{s})$ production
at FAIR SIS100 energies

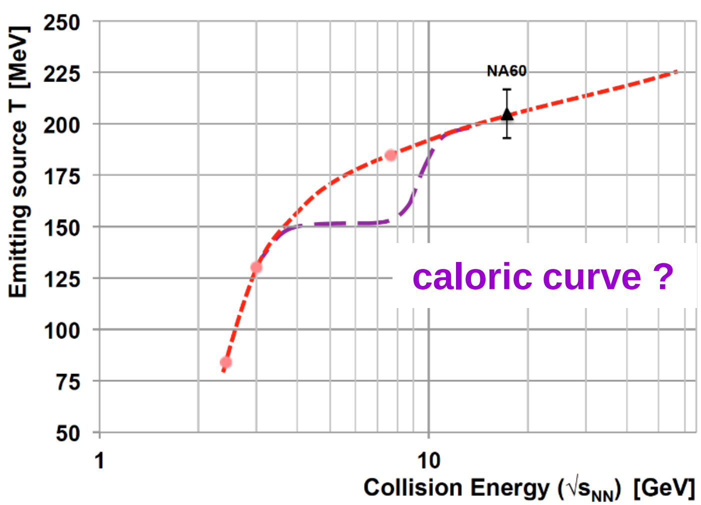
R. Rapp, H. v.Hees, PLB 753 (2016) 586



LMR (low mass region) **:**
ρ – chiral symmetry restoration
fireball space – time extension

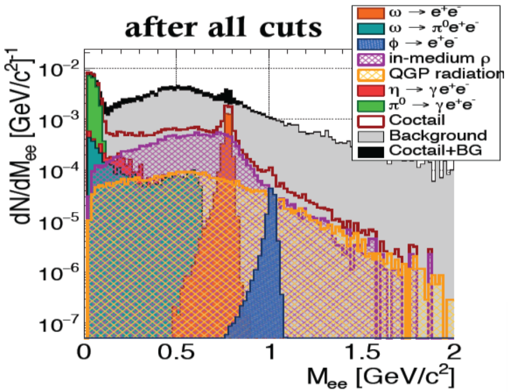
IMR (intermediate mass region) **:**
access to fireball temperature
ρ-a_1 chiral mixing

Fig. by T.Galatyuk & EPJA 52 (2016) 131



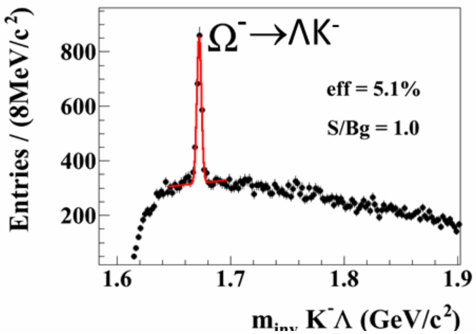
Measurement program:
e.g. excitation function of IMR–slope

Summary: unique measurements with CBM at day 1

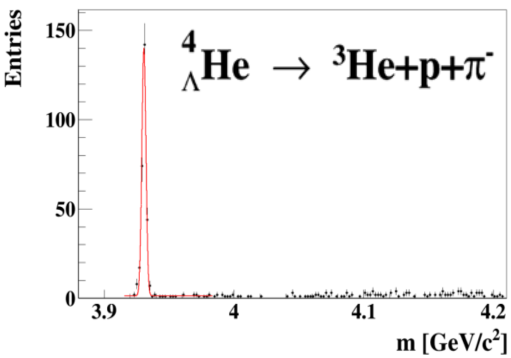


Au+Au, 8A GeV,

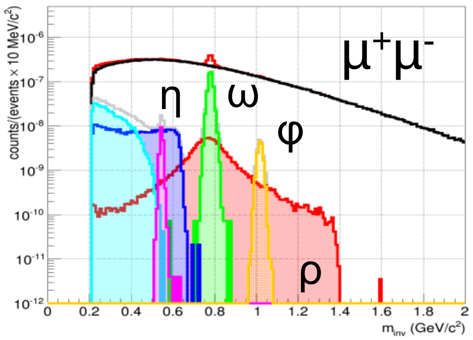
Di-electron measurement
Full performance,
(uses MVD, limited to 100 kHz)



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



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

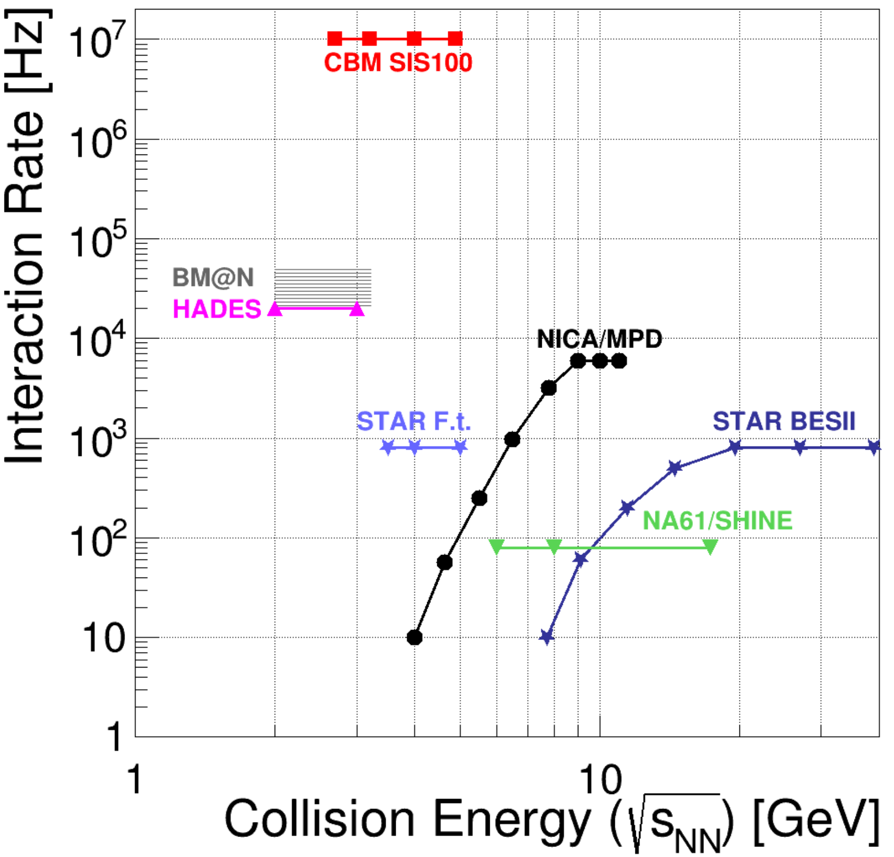


Di-muon
LM measurement at 8A GeV
= complementary measurement to e^+e^-
with different systematic errors

CBM strategy

Exploration of the 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:

ultimate rate capability for high statistics measurement of rare probes

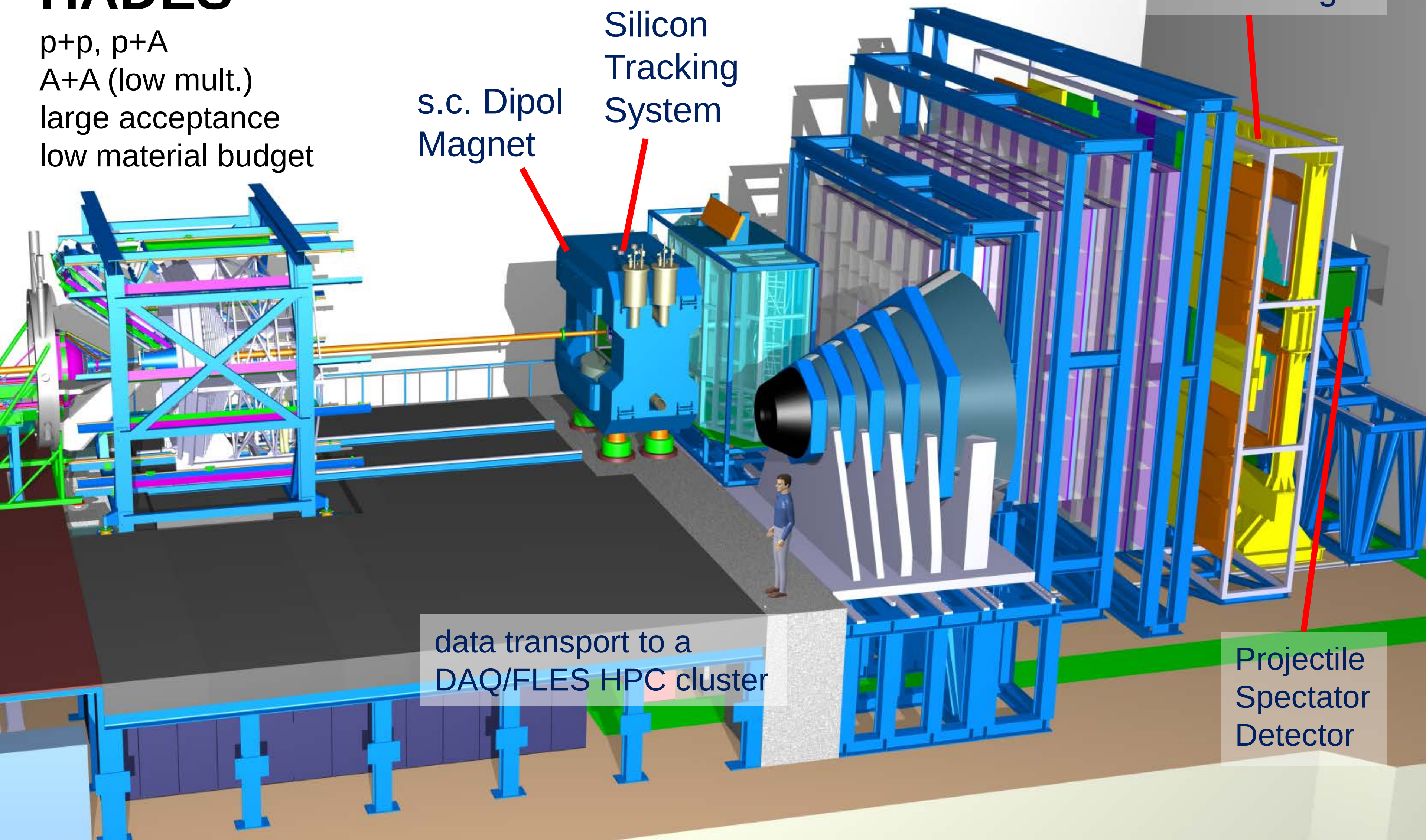
→ fast and radiation tolerant detectors
→ free-streaming read-out electronics
→ high speed data acquisition and high performance computer farm for online event reconstruction and selection

HADES

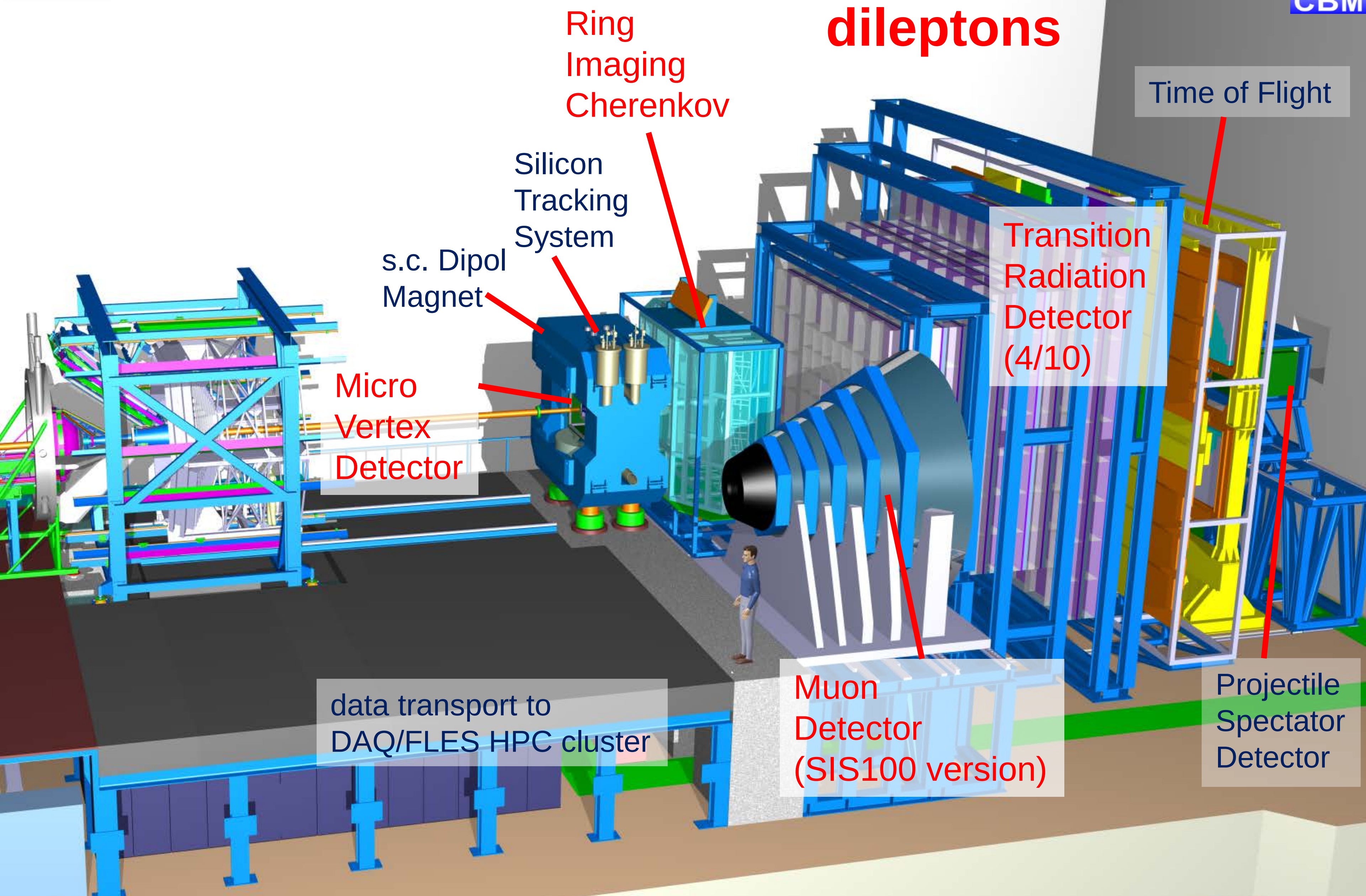
p+p, p+A
A+A (low mult.)
large acceptance
low material budget

CBM

hadrons



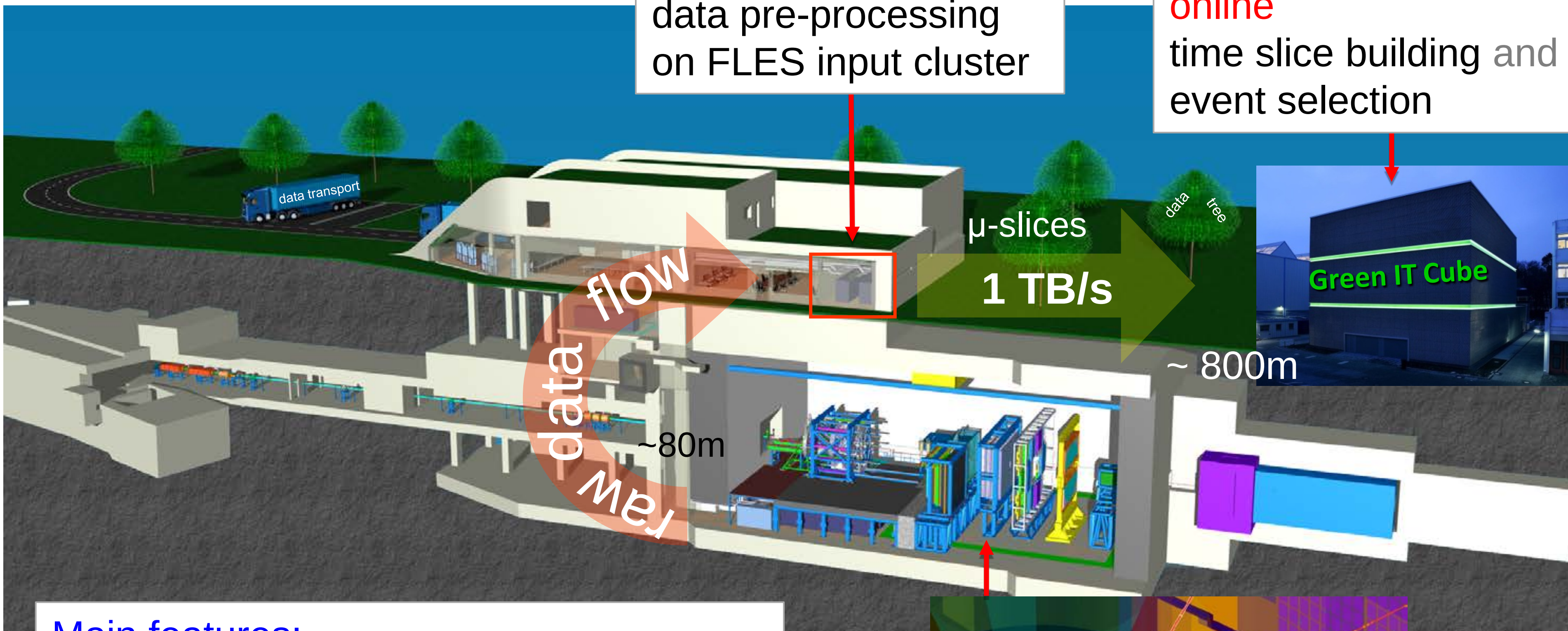
CBM
dileptons



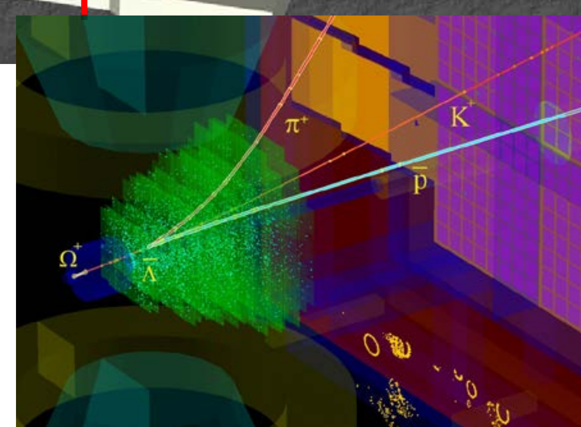
The high-performance free-streaming DAQ system of CBM

DAQ room:
data pre-processing
on FLES input cluster

Green IT Cube:
online
time slice building and
event selection



Main features:
- radiation tolerant detectors and front-end electronics
- free-streaming DAQ system
  - all detector hits with time stamps,
  - software based event selection



A CBM full-system test-setup at GSI/FAIR: *mCBM@SIS18*

concept:

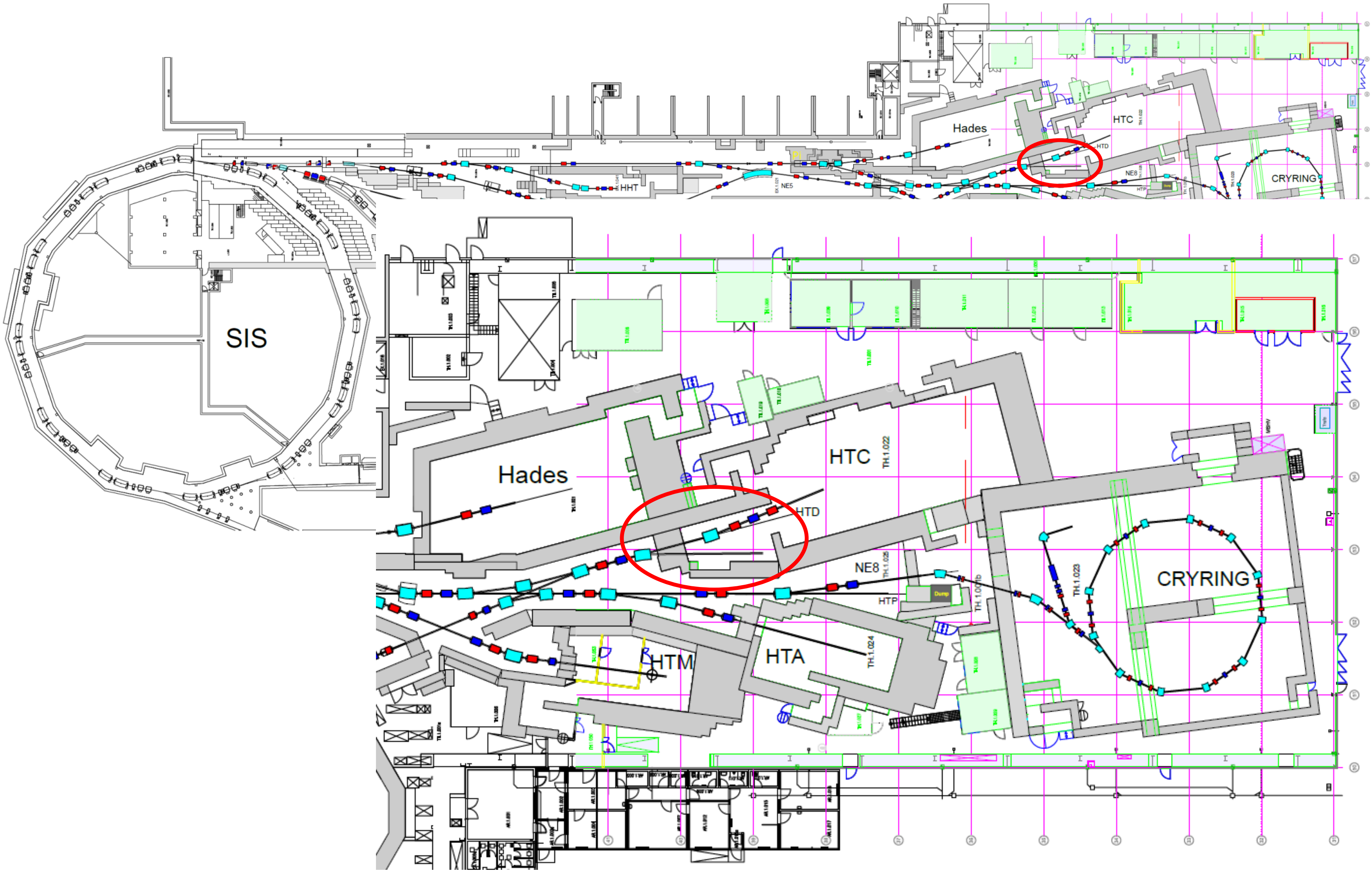
a permanent test-setup at the host lab

- **detector prototypes** at $\theta_{lab} \approx 20°$
- collision rates up to 10 MHz
- compact setup (< 5m)
- no B-field $\rightarrow$ straight tracks
- high resolution TOF (T_0 – TOF stop wall)

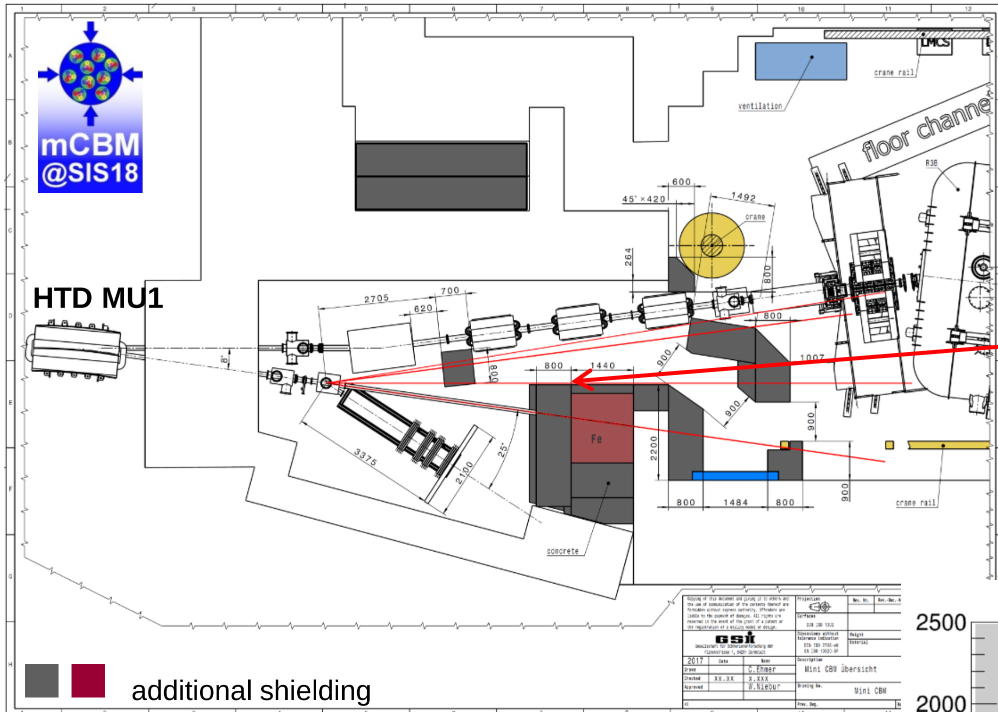
Topics to be addressed

- free streaming read-out and data transport to the mFLES
- online reconstruction
- offline data analysis
- controls
- detector tests of final detector prototypes

mCBM @ SIS18 facility

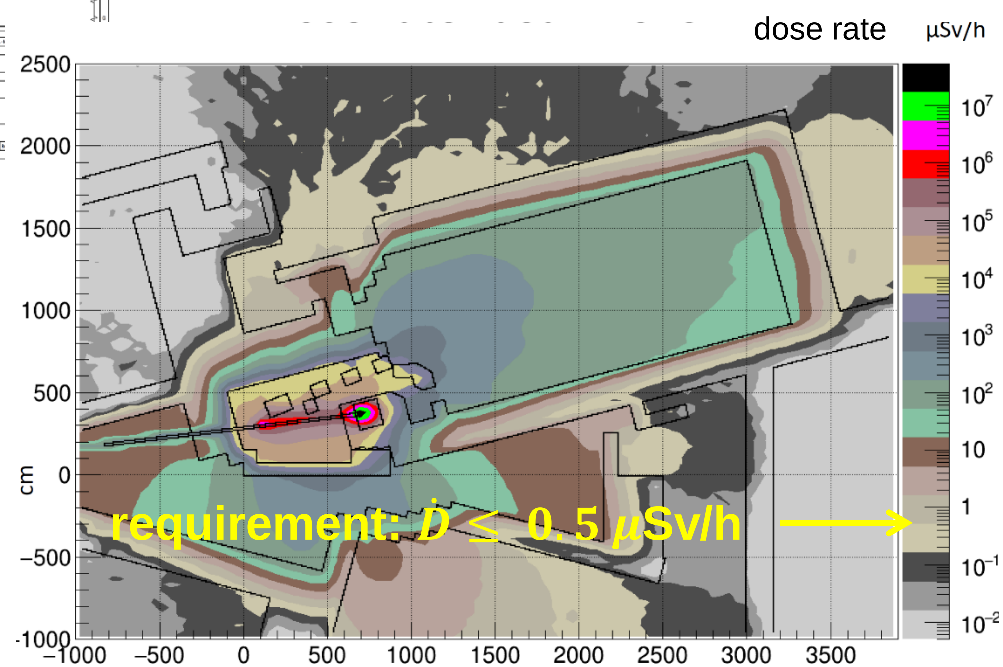


mCBM Cave (HTD @ SIS18 facility)

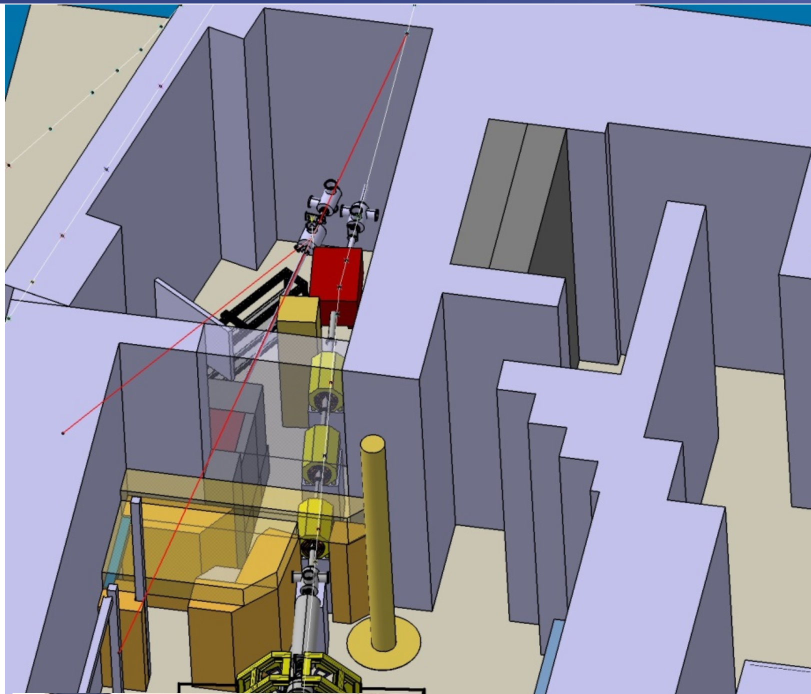


- modified switching magnet (HTD MU1)
- new beam dump
- additional shielding

FLUKA calculations (right fig.):
10^8 Au ions s^{-1}, 1.24 AGeV,
2.5 mm Au target (P_{int} = 10%)
vertical section: **beam level**



Status of the cave reconstruction

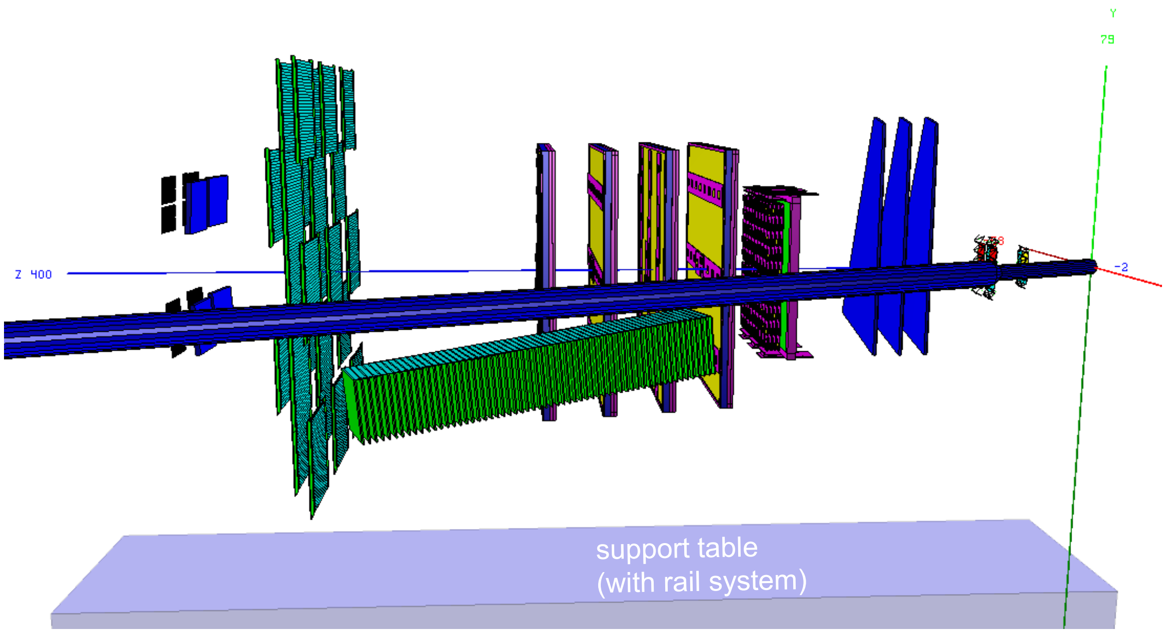


mCBM
@SIS18

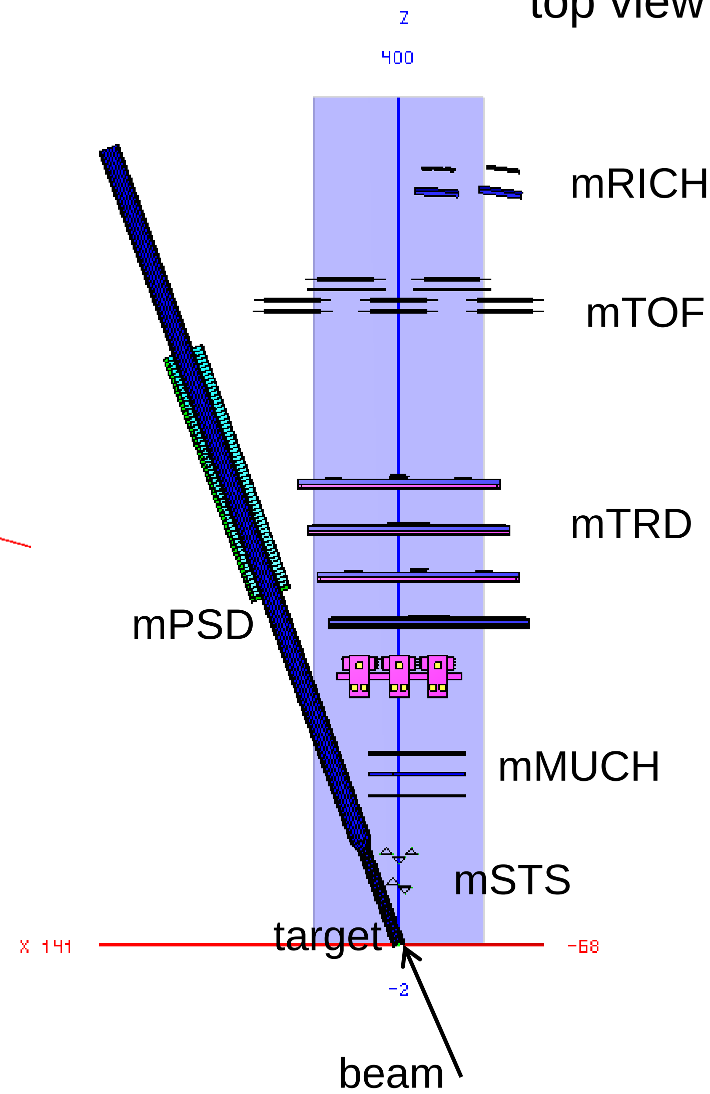
Design of the mCBM test-setup

mCBM @SIS18

side view



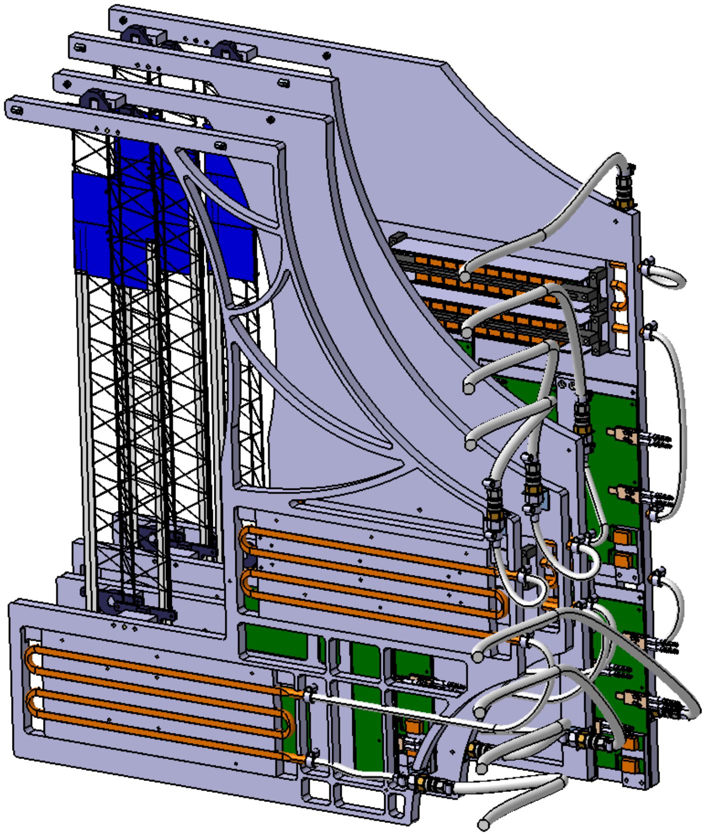
top view

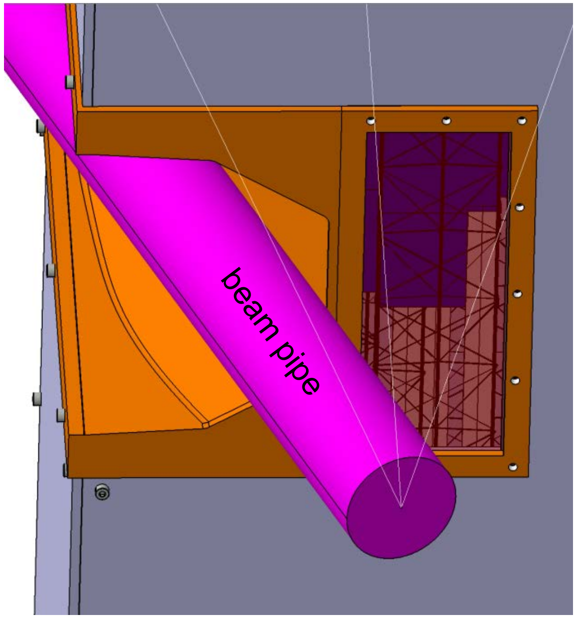


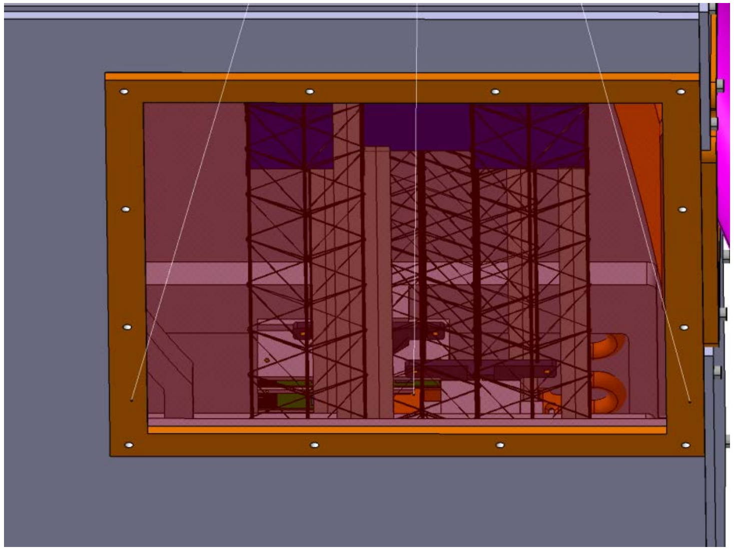
Example: mSTS integration

4 C-frames ("Units")

- holding the ladders with modules
- holding the read-out and powering electronics (FEB, C-ROB, POB) on cooling plates

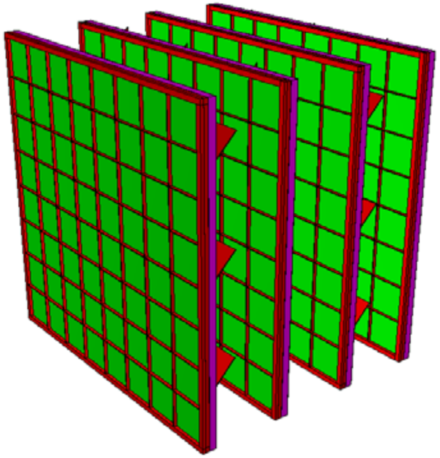


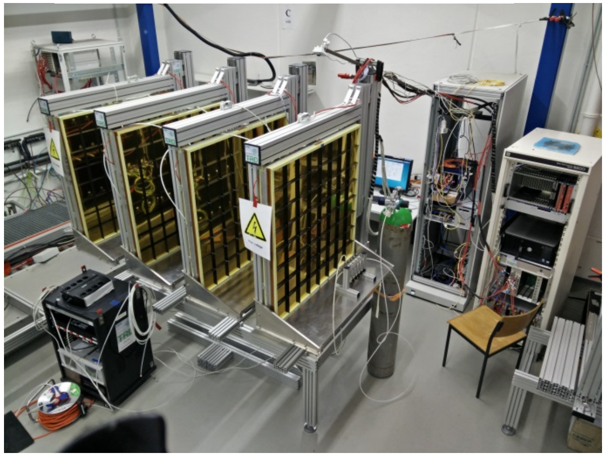




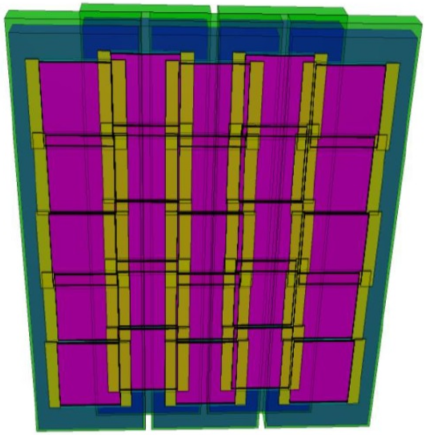
The mTRD and mTOF subsystems

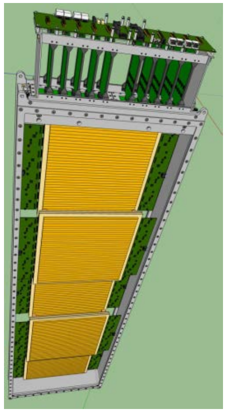
mTRD setup
4 layers
TRD modules
from DESY/CERN tests 2017

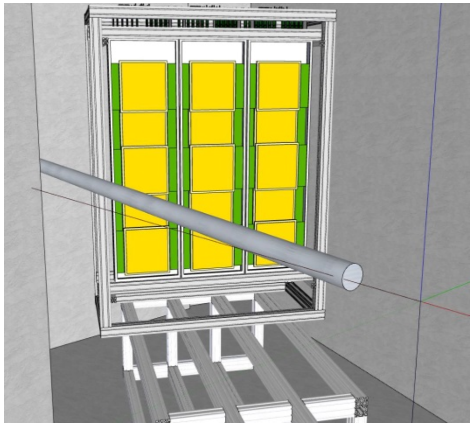


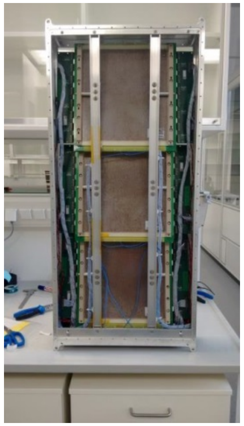


mTOF setup
25 MRPC(3a) counters
(= 5x STAR modules)
150 x 120 cm^2 active area
1600 readout channels

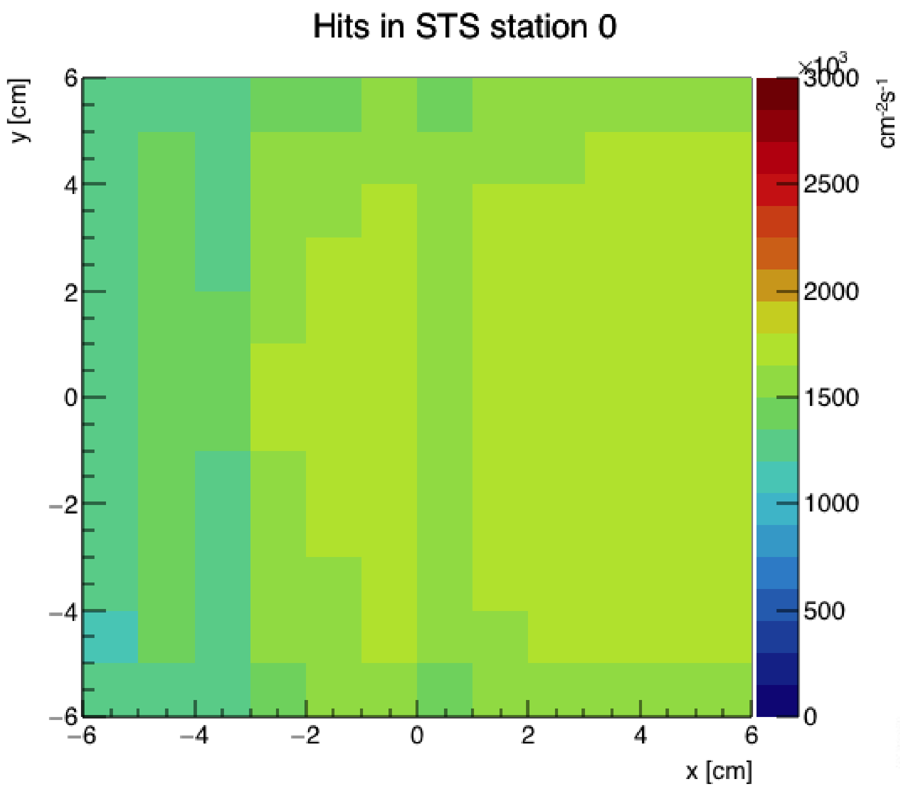








Hit rates at mCBM (simulation)

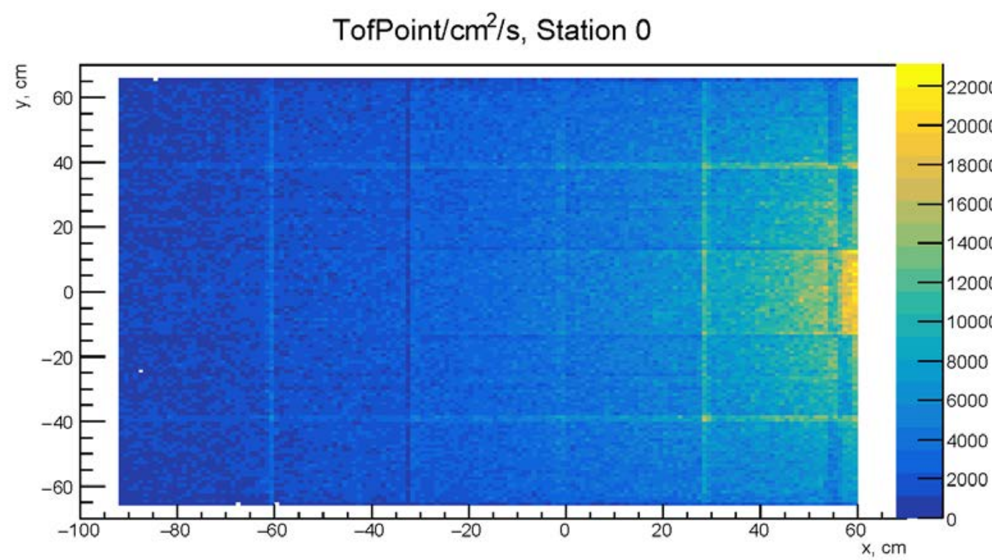


mSTS, 1st station

max. (design) rate: 1.5 MHz/cm²

mTOF

max. (design) rate: 20 kHz/cm²

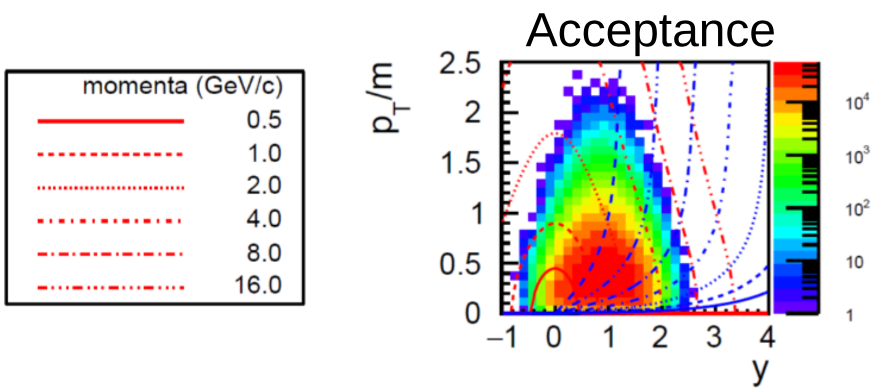


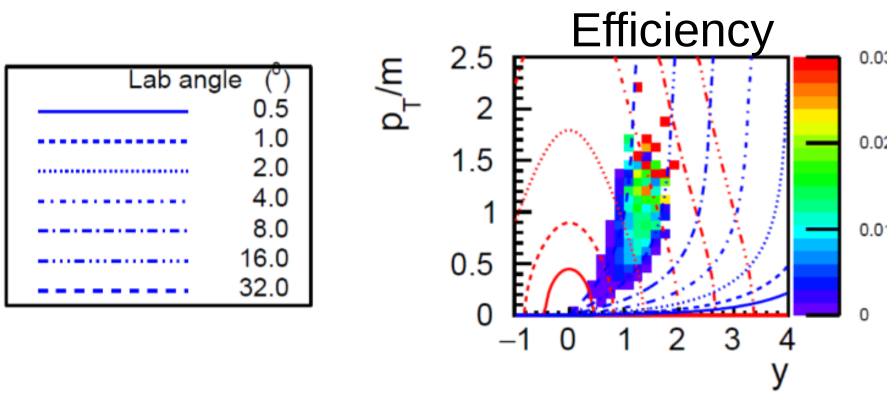
Input:

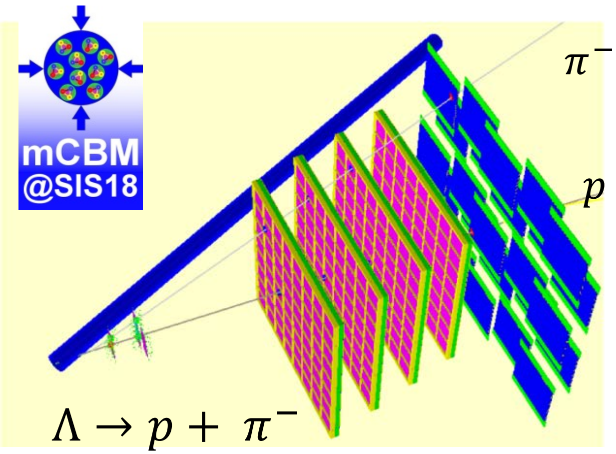
UrQMD, Au+Au 1.24 AGeV, mbias, incl. δ-electrons

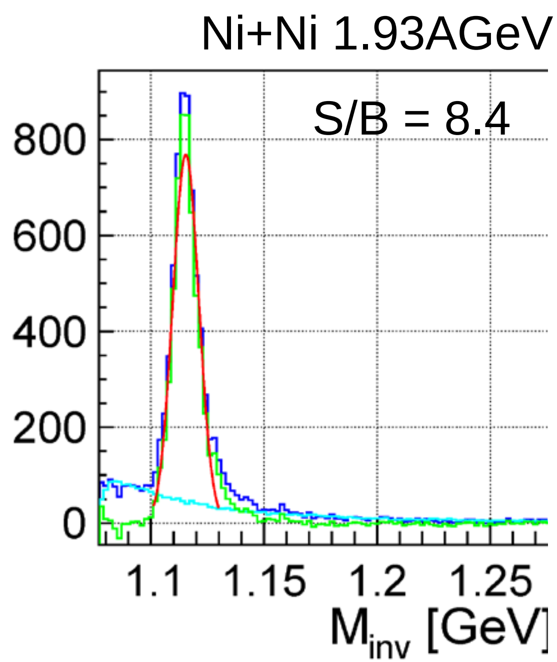
mCBM benchmark observable: Λ reconstruction

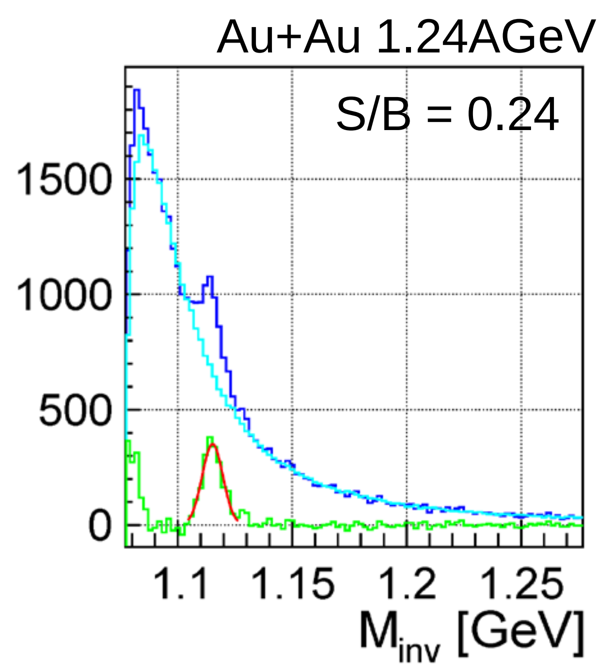
<u>Simulation input:</u> 10^8 UrQMD events, min. bias







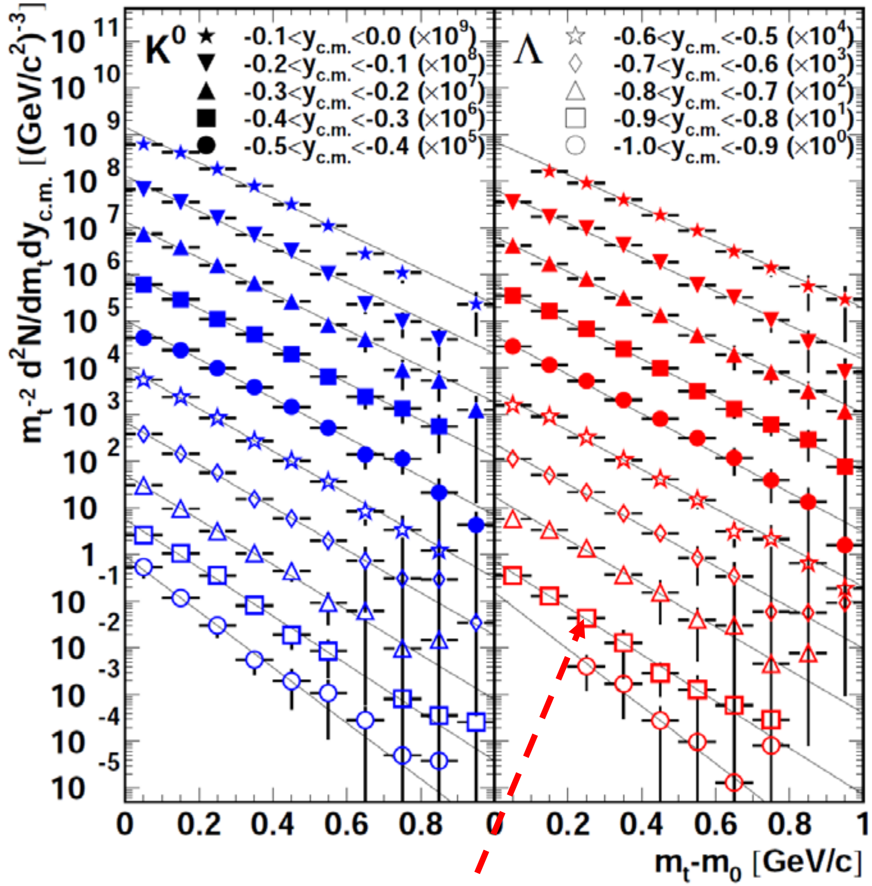




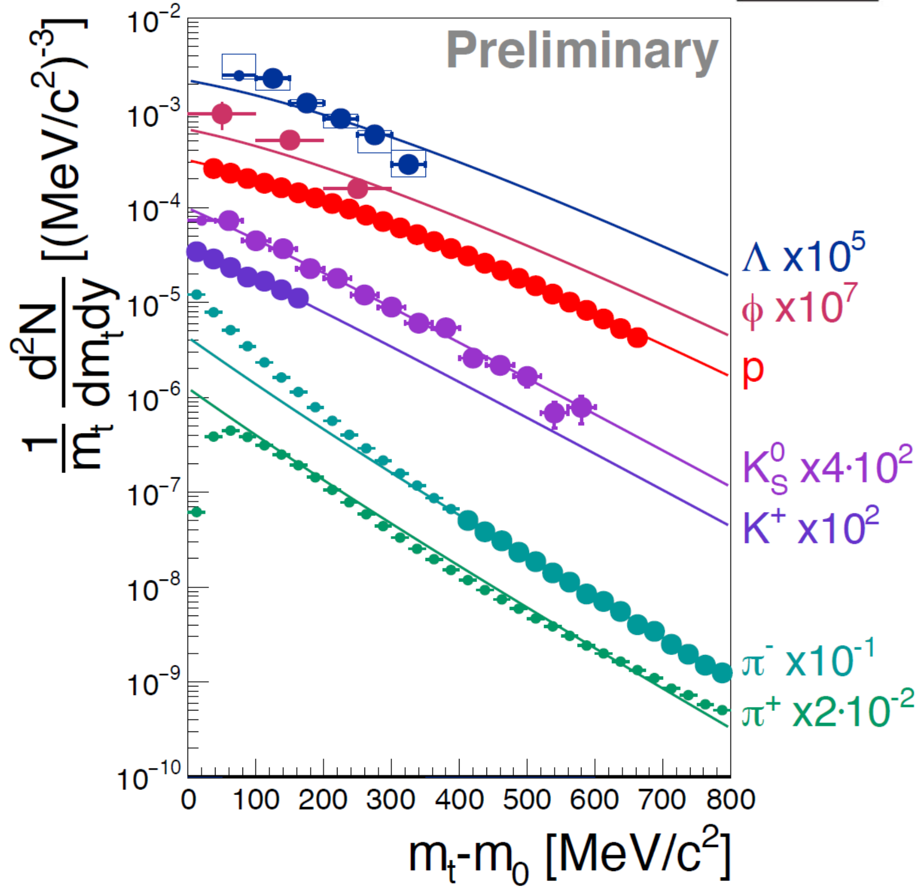
Λ production at SIS18 energies – mCBM reference data

Ni + Ni 1.93 AGeV

M. Merschmeyer et al. (FOPI), PRC 76, 024906 (2007)



Au + Au 1.23 AGeV



H. Schuldes et al. (HADES)
EPJ Web of Conferences 171, 01001 (2018), SQM2017

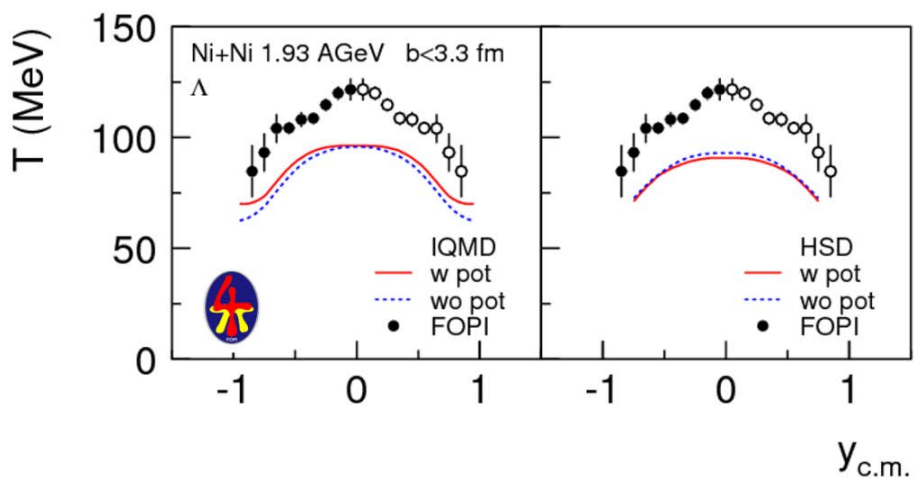
mCBM data taking

2018	**development & commissioning** data transport, data analysis, detector tests
2019	**approaching full performance** subsystems completed, high-rate data transport / processing → online reconstruction

requested beamtime was fully granted by GSI/FAIR G-PAC

2020	**1st benchmark run** Λ reconstruction production runs benchmark coll. systems: Ni+Ni 1.93AGeV & Au+Au 1.24AGeV
2021	**2nd benchmark run** Λ reconstruction in Ni+Ni and Au+Au collisions at various projectile energies → Λ production excitation function

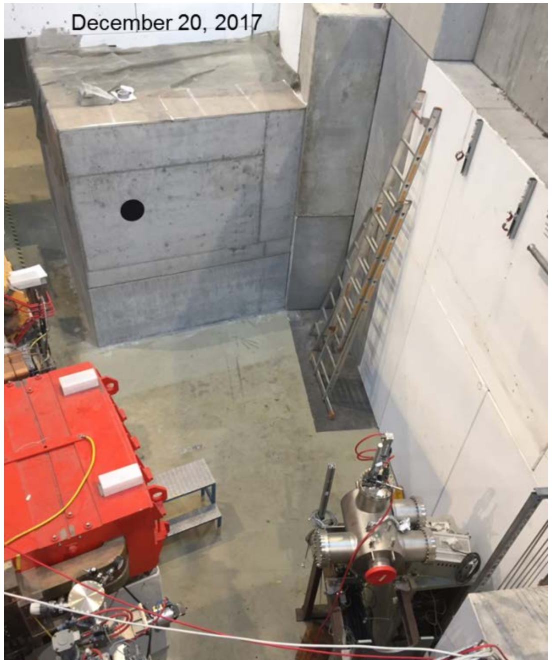
proposal to be submitted in 2019

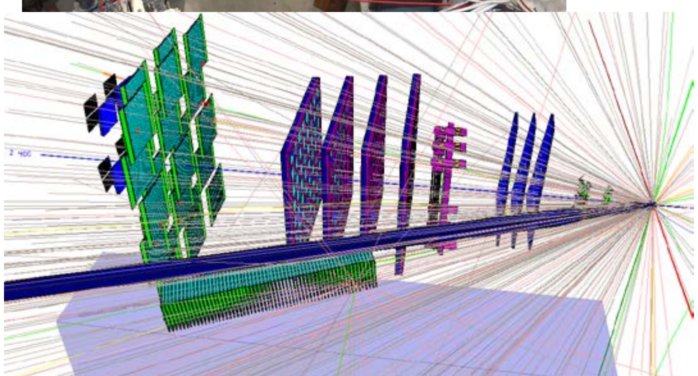


Λ - slope parameter:

- smaller than proton
- not explained by transport models
  reason unclear:
  - rescattering cross section ?
  - repulsive potential ?

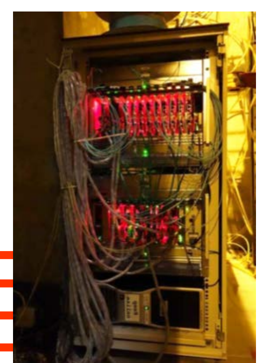
Schedule of mCBM@SIS18 construction

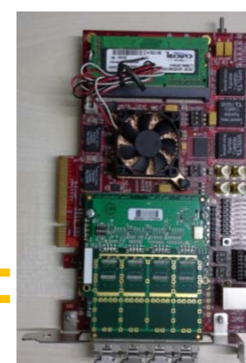




Schedule

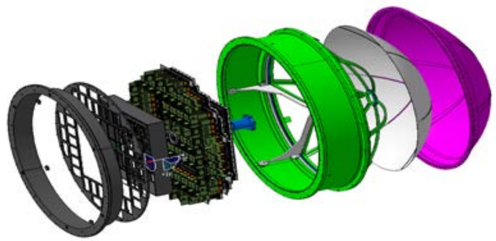
10/2017	cave & beam line: reconstruction started, procurement started
12/2017	mDAQ test stand @ Heidelberg operational
12/2017	beam dump mounted
03/2018	cave reconstruction completed
04/2018	mFLES cluster @ Green IT Cube installed
05/2018	beam line installed and commissioned
05/2018	installation of detector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



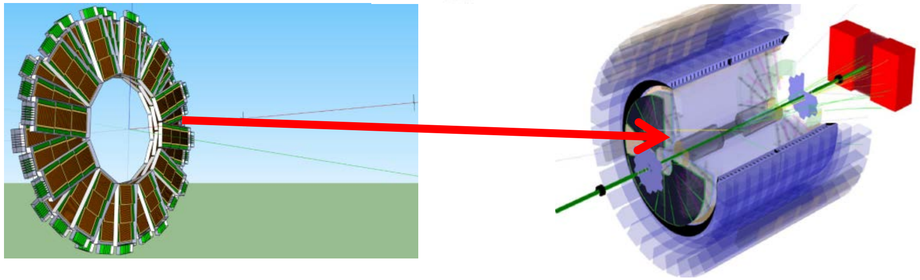


CBM – FAIR Phase 0 projects (2018 – 2022)

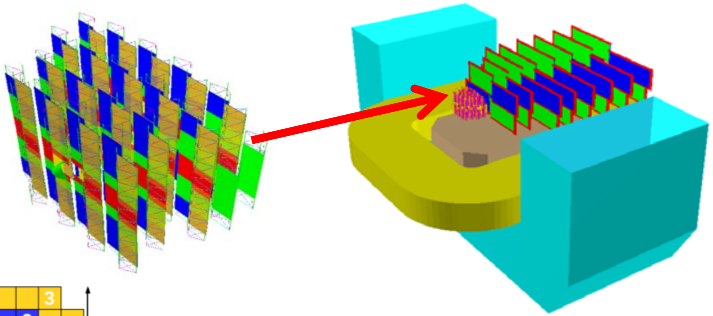
1. Install, commission and use 430 out of 1100 CBM RICH multi-anode photo-multipliers (MAPMT) including FEE in HADES RICH photon detector



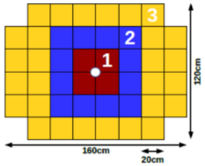
2. Install, commission and use 10% of the CBM TOF modules including read-out chain at STAR/RHIC (BES II 2019/2020)



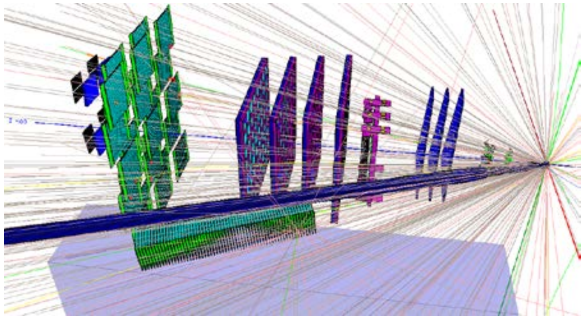
3. Upgrade BM@N experiment with 4 Silicon stations of CBM/STS design in the BM@N experiment at the Nuclotron JINR/Dubna (Au-beams in late 2020)



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

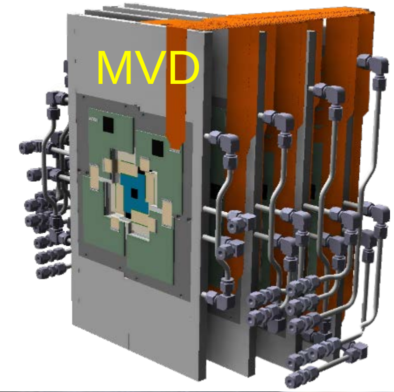


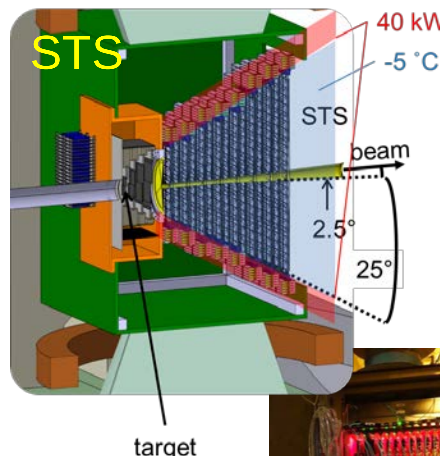
5. mCBM@SIS18: demonstrator for full CBM data taking and analysis chain

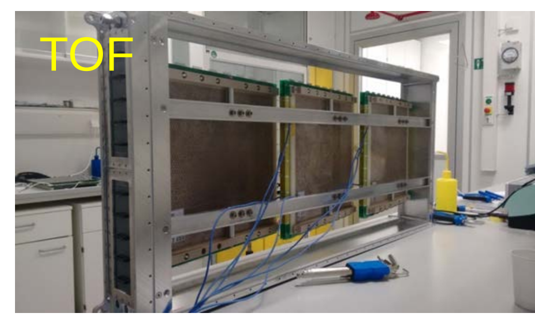


Status of the experiment preparation

#	Project	TDR Status
1	Magnet	approved
2	STS	approved
3	RICH	approved
4	TOF	approved
5	MuCh	approved
6	HADES ECAL	approved
7	PSD	approved
8	MVD	submission in 2018
9	DAQ/FLES	submission in 2018
10	TRD	submission in 2018
11	ECAL	submission in 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

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