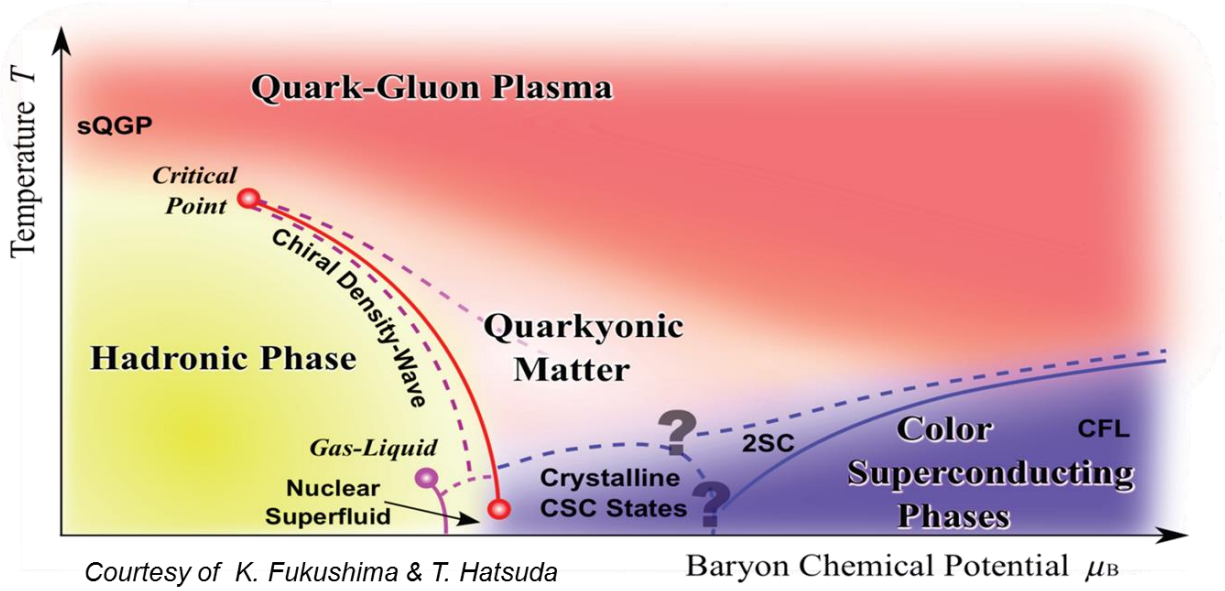
CBM Day-1 Physics

Outline:

- **CBM physics case**
- **Day-1 setup and program**
- **SIS100 beam requirements**

CBM – Goals



Courtesy of K. Fukushima & T. Hatsuda

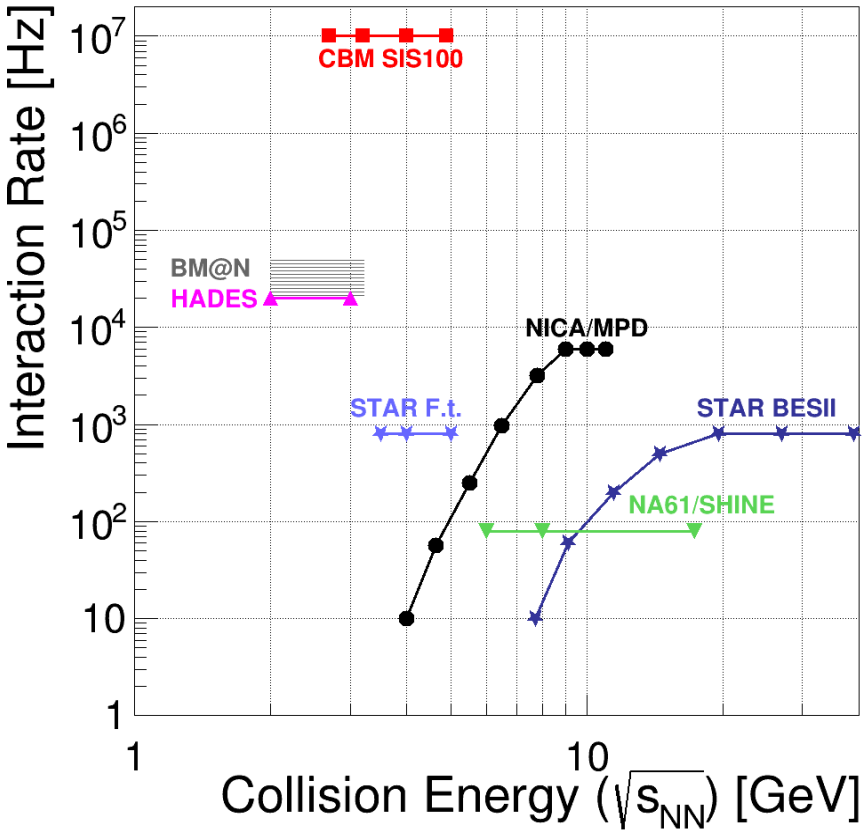
Mission:

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

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 typical running scenario:

1% target => 10^9 beam/s with slow extraction T_{spill} ~ 10 s

CBM physics and observables

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

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

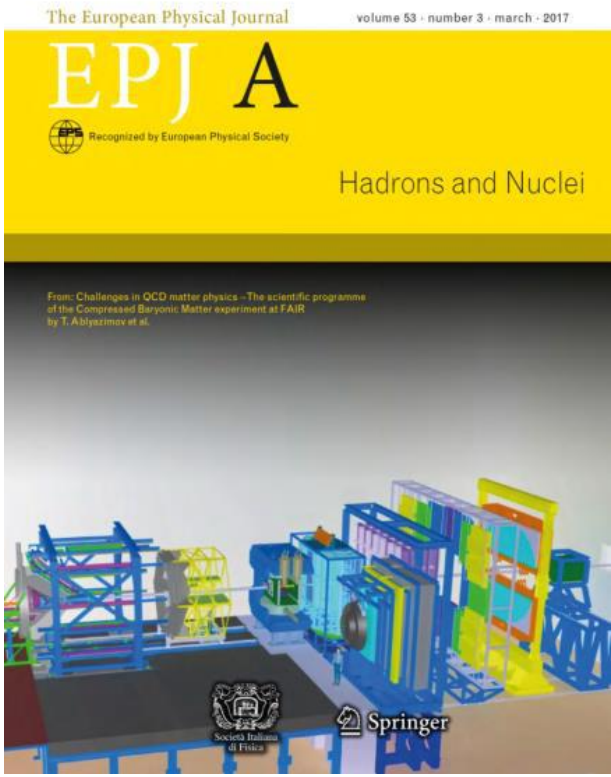
Critical point
- event-by-event fluctuations of conserved quantities

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

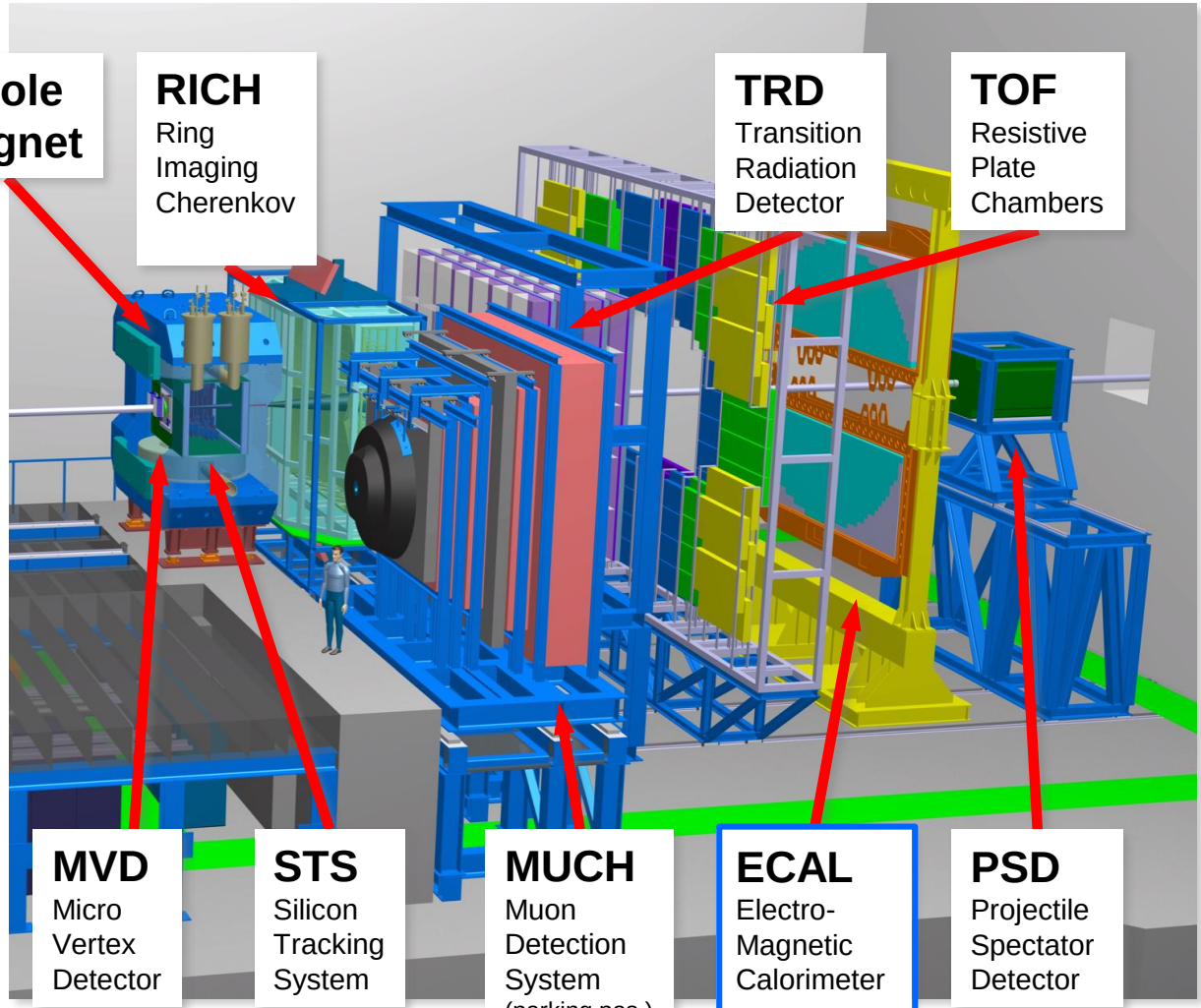
Strange matter
- (double-) lambda hypernuclei
- Search for meta-stable objects (e.g. strange dibaryons)

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

Eur.Phys.J. A53 (2017) 60



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

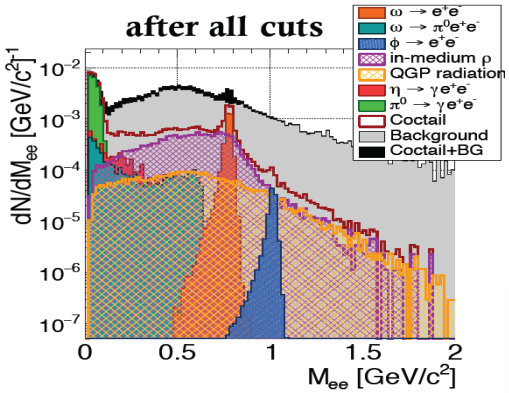
Day-1 setup = MSV setup – Compute Performance - ECAL

Phase-1 = Day1 with full Compute Performance + ECAL

Day-1 funding:
~ 90% secured

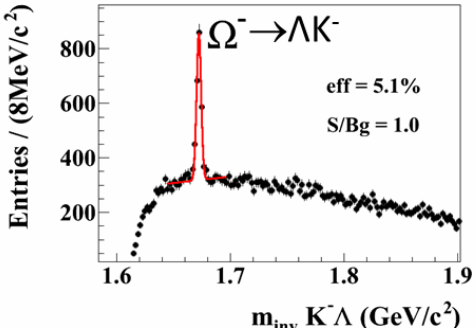
CBM Day 1 – unique measurements

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

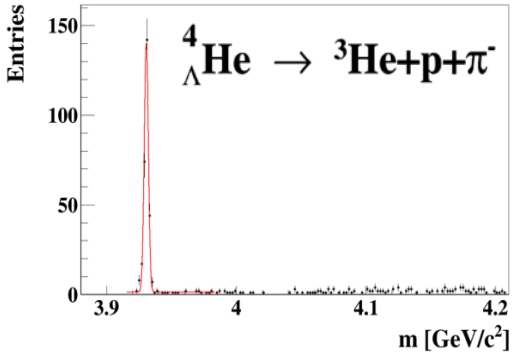


Au+Au, 8A GeV,

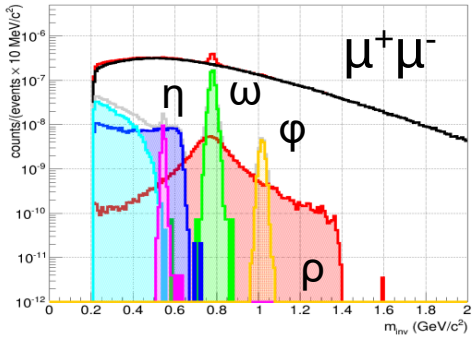
Hyperon measurements, e.g. Au+Au at 10A GeV :



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

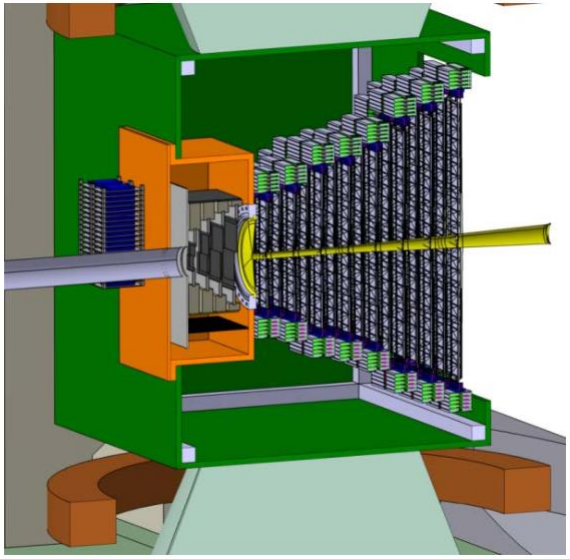


Di-Muon
LM measurement at 8A GeV



CBM beam requirements for Day-1

Max interaction rate: 500 kHz
Max beam intensity: $5 \cdot 10^7$ Au-ions/s



Beam focus & halo

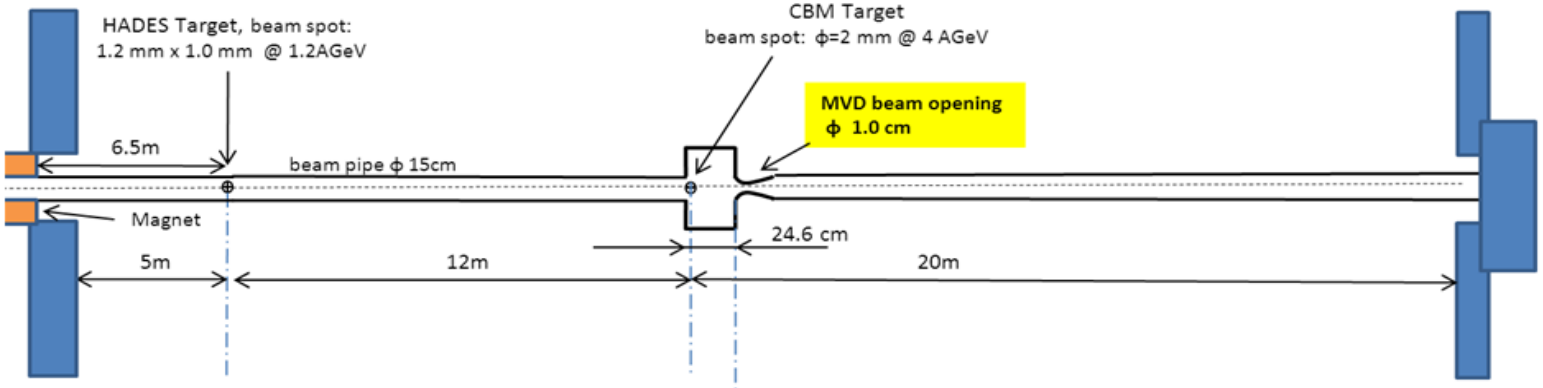


Figure 3. Schematically drawn beam line aperture in HADES/CBM cave (not to scale) for a case when CBM conducts experiments. The requested emittance is constrained by a long distance between the last magnet and a small beam spot on the CBM target.

CBM beam emittance requirements

CBM Internal Note, „Beam quality requirement for CBM/HADES experiments at SIS100/300”, V6.0, J. Pietraszko, W.F.J. Müller (07/2016)

1. **Beam spot** smaller than **2 mm** in diameter in both directions (99.73 % of the beam) for beam energies above 4 AGeV.
2. **CBM beam divergence** smaller than 6 mrad.

   (17 meters distance between the last focusing magnet and target point and only 70% of the beam line aperture will be filled)
3. **The CBM beam line aperture**: the smallest opening is 10 mm

   (MVD detector, 10.0 cm from the focal point)
4. **The requested beam emittance** is constrained by the beam divergence (6 mrad) and small beam diameter at the target point, 2 mm at 4 AGeV. Thus, the beam emittance should be 3 mrad * 1 mm = **3.0 mm mrad** at **4 AGeV.**
5. **The BEAM HALO** around the CBM focal point should be reduced **below 10^{-5}** of the total beam intensity at a distance greater than 5 mm away the beam symmetry axis.

+ Fast, fail-safe, beam abort system with reaction time of ~500 μs

CBM ion species and intensities for Phase 1

Phase 1 with full rate capability anticipated for +1a after first beam!

Isotope	Energies [AGeV] min-max	beam intensity in spill / s
p	2 – 29	10^{11} /s
^{12}C	3 – 14	10^{10} /s
^{40}Ca	3 – 14	$4*10^{9}$ /s
^{58}Ni	2[1] – 13	$4*10^{9}$ /s
$^{96}_{40}Zr$	2[1] – 12	$4*10^{7}$ /s
$^{96}_{44}Ru$	2[1] – 13	$4*10^{7}$ /s
^{107}Ag	2[1] – 12	$2*10^{9}$ /s
^{197}Au [2]	2[1] – 11	10^{9} /s
^{238}U	2[1] – 11	10^{9} /s

Table 2. A list of proposed beam isotopes, energies and requested beam intensities for CBM at SIS100 experiments.

Extraction: slow extraction, duty cycle better than 50%.

Beam emittance:

HADES at SIS100 - 5 mrad mm at 2 AGeV

CBM at SIS100 and SIS300 - 3.0 mm mrad at 4 AGeV.

Beam HALO: HADES and CBM:

below 10^{-5} of the total beam intensity at a distance greater than 5 mm

Spill structure:

Intensity fluctuations below a factor of 3 (integration time ≈ 30ns).

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 di-lepton production (full performance)
- excitation function of hyperons production
- study of hypernuclei

- initial intensity limited to max. interaction rate 0.5 MHz (Au+Au)
- full beam quality demands

CBM Phase 1 will address the full set of observables with full rate capability

- CBM‘s initial rate limitation will be overcome ~1 year after start of operation