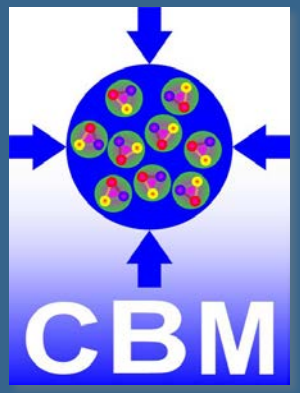
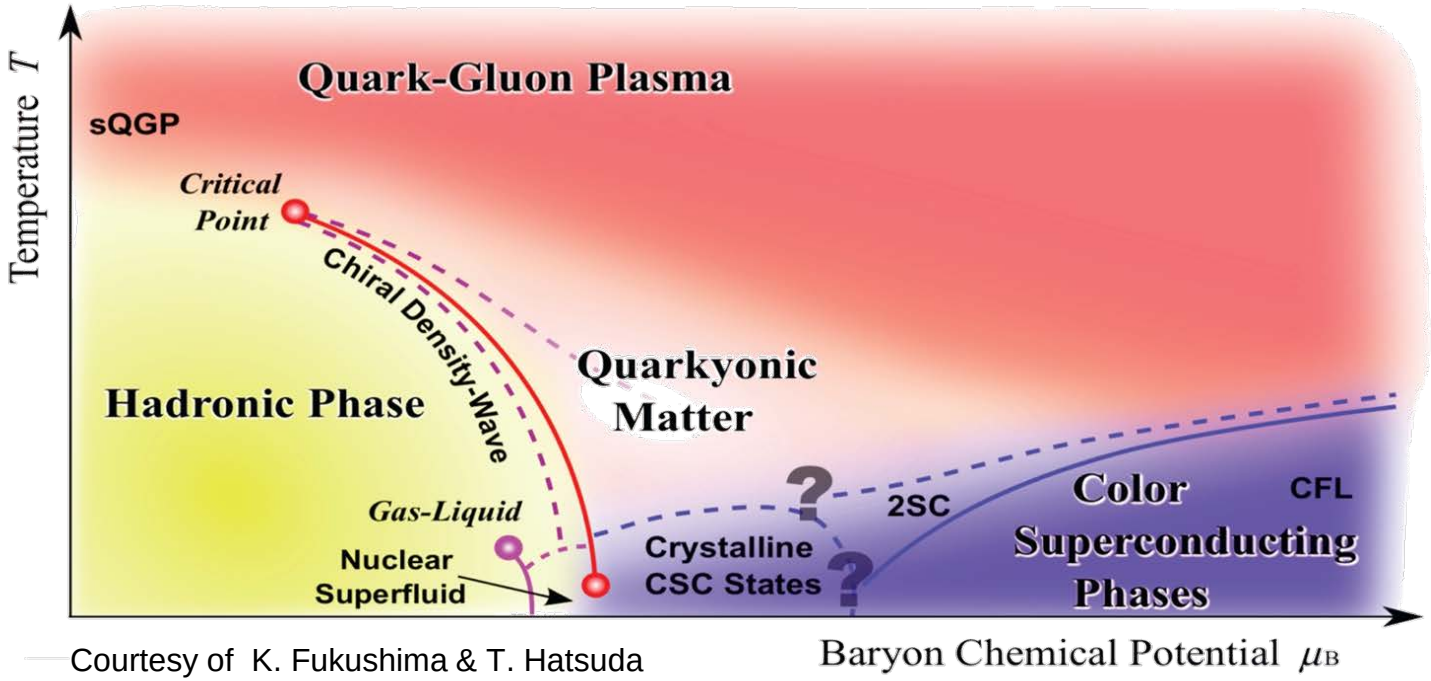
Bericht zu CBM



KHuK Jahrestagung
Bad Honnef
1.+ 2. Dezember 2016

Christoph Blume
Goethe-Universität Frankfurt

Physics Program
QCD Phase Diagram



Courtesy of K. Fukushima & T. Hatsuda

Probing the QCD phase diagram at high net-baryon densities

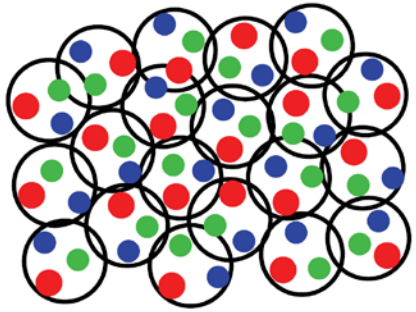
Phase transitions: deconfinement + chiral symmetry

Critical end point + phase coexistence

New phases (quarkyonic matter, …)

Physics Program
New Phases at High Densities

Net-baryon densities
More than $6 \times \rho_0$ already at 5 AGeV

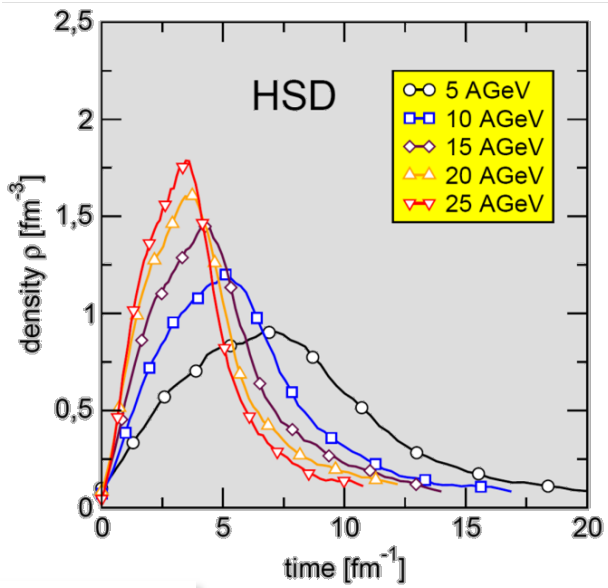


New phases of strongly interacting matter
E.g. quarkyonic phase

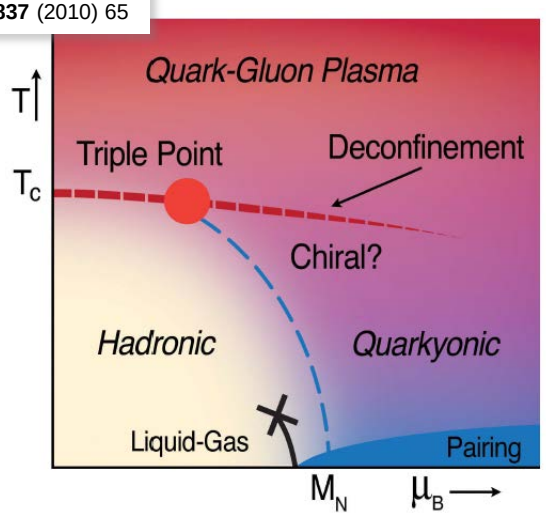
Observables
Di-lepton pairs

Strangeness (K, Λ, Ξ, Ω)

Excitation function and flow



A. Andronic et al., Nucl. Phys. **A837** (2010) 65



Physics Program
Matter Properties

Susceptibilities

Probing the medium response to external perturbations

Sensitive to matter properties

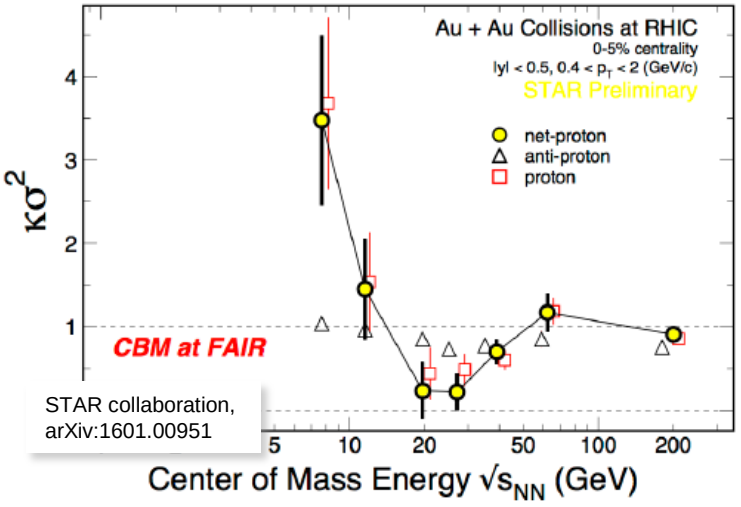
Related to phase structure of hot and dense matter

Search for the critical point

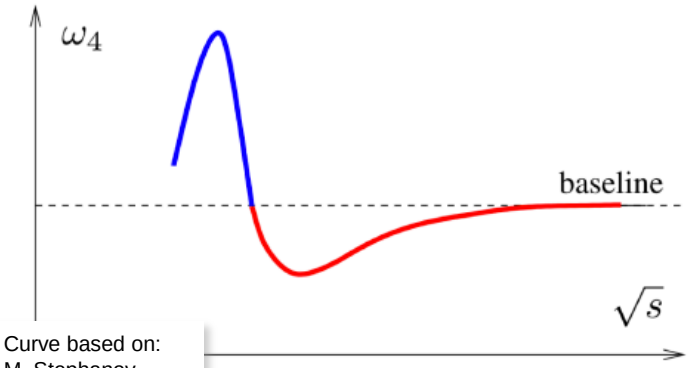
Observables

Event-by-event fluctuations of conserved quantities (e.g. *Q*, *S*, *B*)

Energy dependence of higher moments



STAR collaboration, arXiv:1601.00951

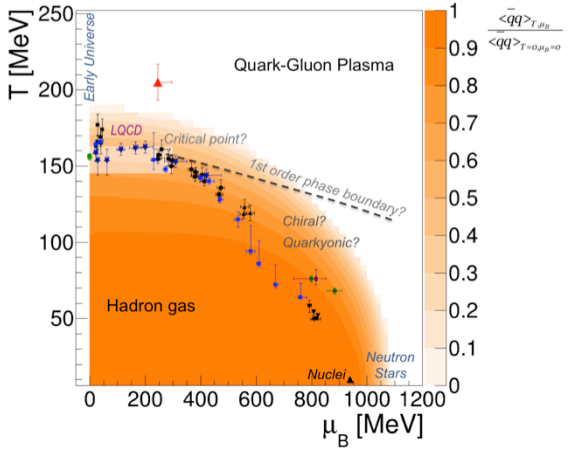


Curve based on: M. Stephanov, Phys. Rev. Lett. **107** (2011) 052301

Physics Program
Chiral Symmetry

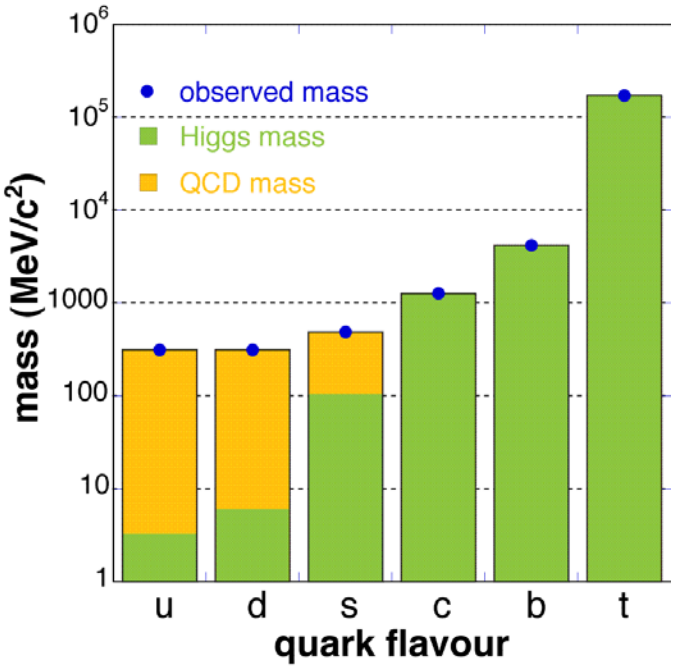
Origin of QCD mass
Medium modification of hadrons

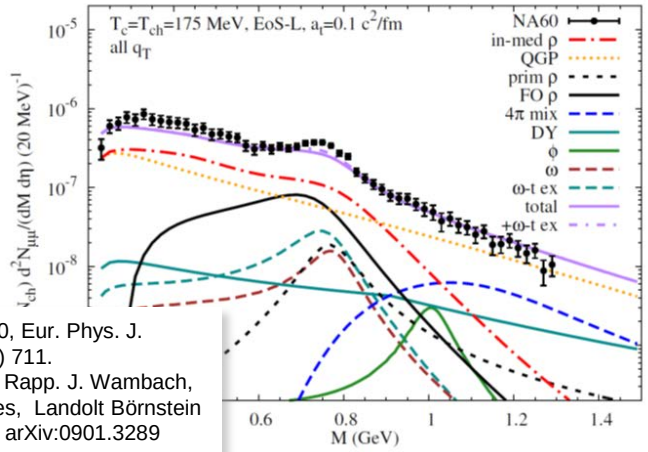
Restoration of chiral symmetry



Observables
Di-leptons: LMR (ρ), IMR (ρ-a_1-mixing)

Muon and electron decay channel

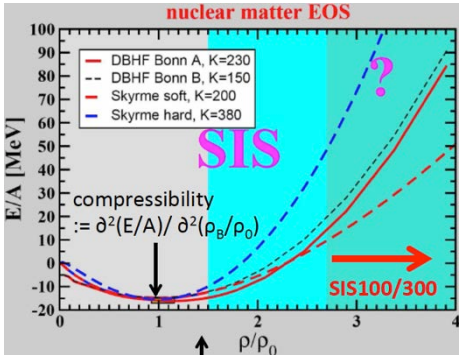




Data: NA60, Eur. Phys. J. **C61** (2009) 711.
Theory: R. Rapp. J. Wambach, H. van Hees, Landolt Börnstein (Springer), arXiv:0901.3289

Physics Program
Equation-of-State

Neutron star core densities
Compressibility of nuclear matter

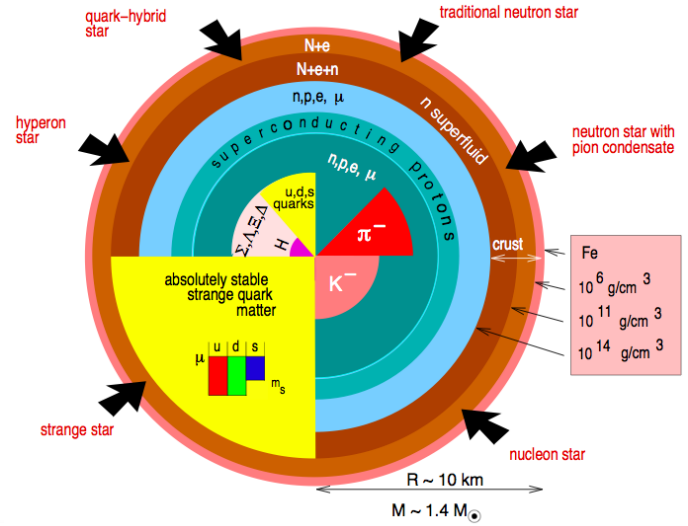


Interactions between strange baryons

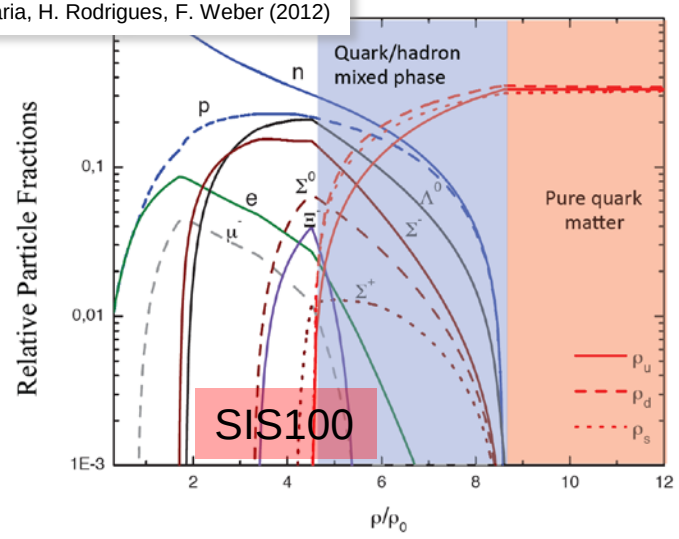
Observables
Collective flow of hadrons

Particle production at threshold (multi-strange hadrons)

Strange baryon correlations

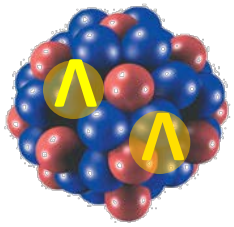


Equation-of-state:
Non-local SU(3) NJL with vector coupling
M. Orsaria, H. Rodrigues, F. Weber (2012)



Physics Program
Rare Strange Objects

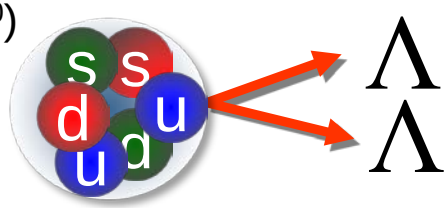
3rd axis of nuclide chart
(Double-) hypernuclei



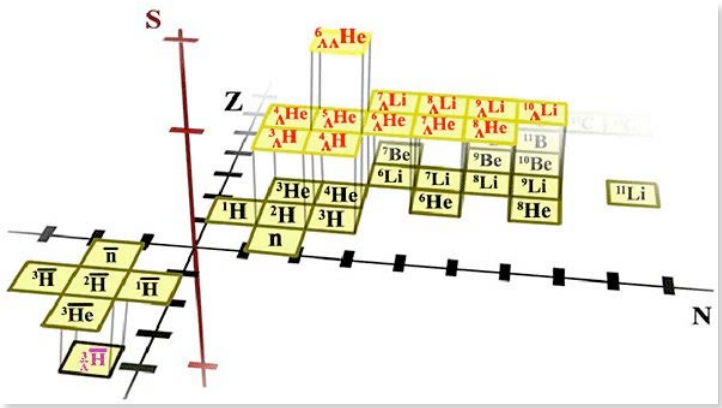
Information on ΛΛ interaction
(→ neutron stars)

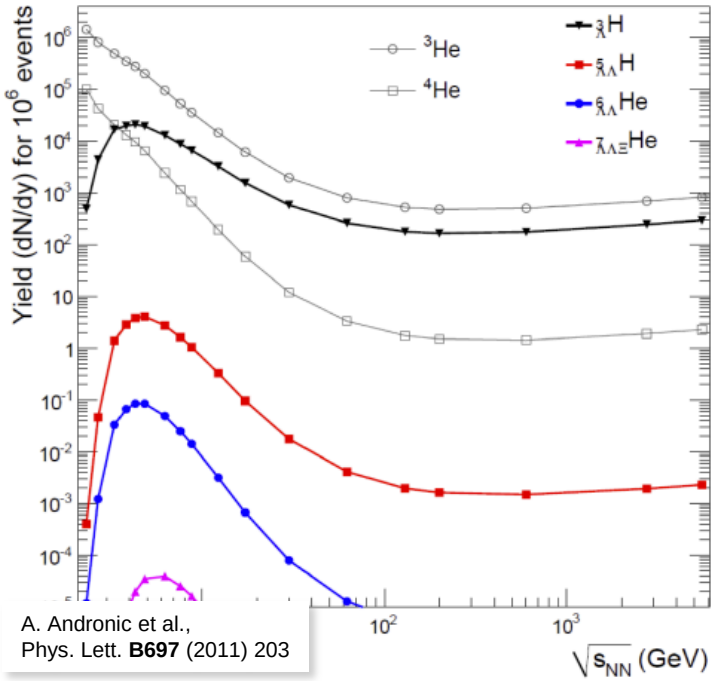
High event statistics needed
Production favored by high ρ_B

Strange matter
Di-baryons (e.g. H^0)



Meta-stable Exotic Multi-hypernuclear Objects (MEMOs)





A. Andronic et al.,
Phys. Lett. **B697** (2011) 203

Physics Program
Existing Measurements

Low data rates

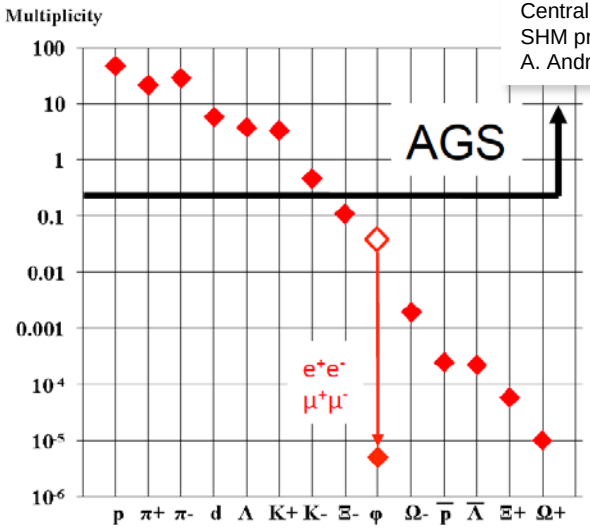
Mostly limited to bulk observables

No rare (anti-)particles (Ξ^-, Ω^-)

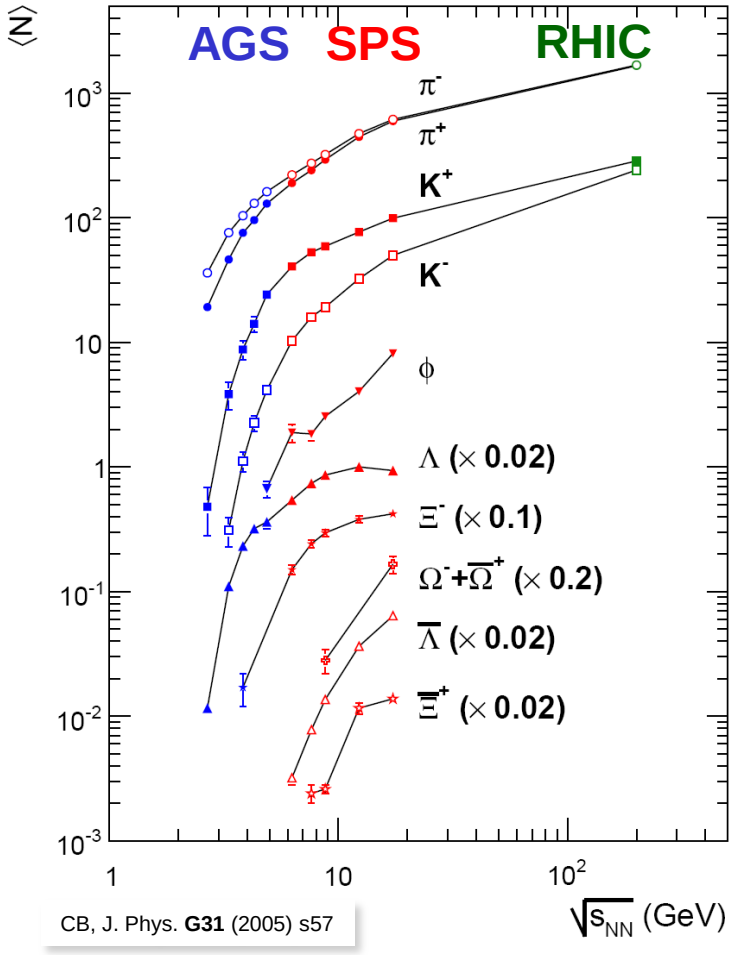
Heavy flavor (J/ψ, D) not addressed

Systematic di-lepton measurements missing

Lack of multi-dimensional studies



Central Au+Au at 4 *A*GeV
SHM prediction
A. Andronic, priv. comm.



CB, J. Phys. **G31** (2005) s57

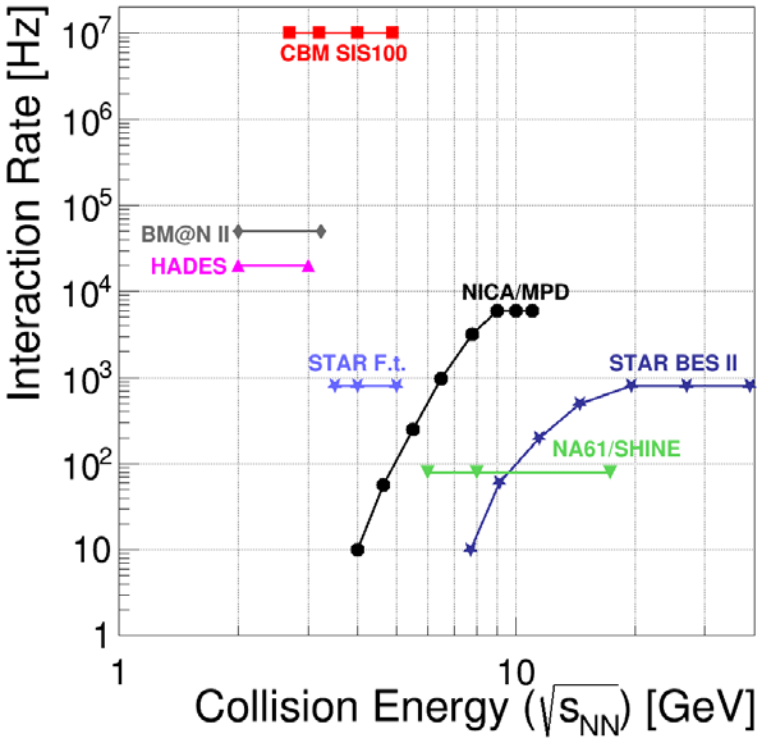
Physics Program
Data Rates

Highest data rates
Independent of centre-of-mass energies

Systematic studies with rare probes possible at SIS100

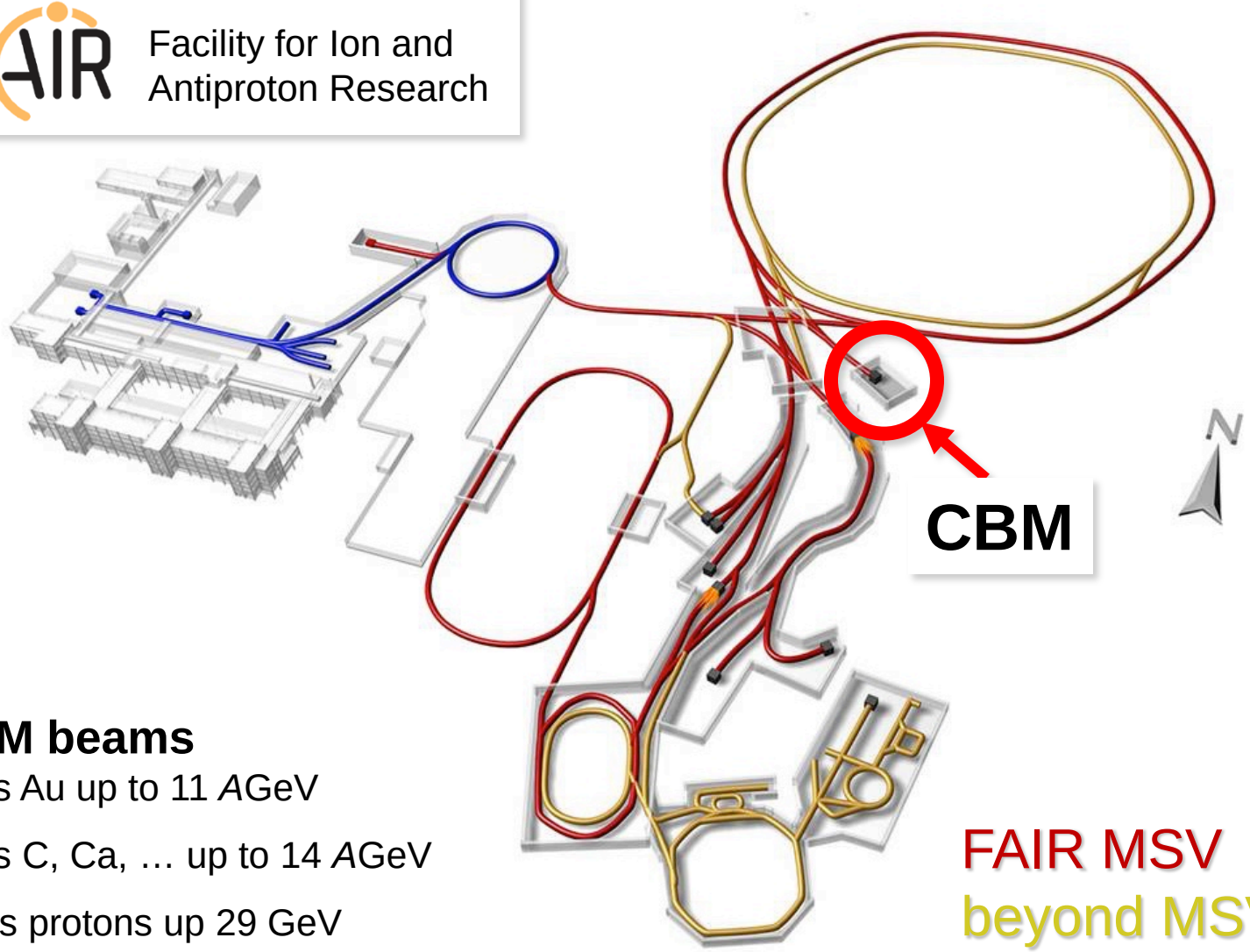
Colliders experiments not competitive to fixed target in terms of interaction rates

⇒ Unique position of CBM



Numbers taken from:
NICA: A. Sorin, CPOD 2014
RHIC: C. Montag, D. Cebra, CPOD 2014
STAR-FT: G. Odyniec, CPOD 2013
SPS: G. Usai, TPD workshop 2014
NA61: M Gazdzicki, CBM Symposium 2014
HADES: J. Michel et al.,
IEEE Trans Nucl. Sci. **58** (2011)

Facility for Ion and Antiproton Research



CBM beams

10^9/s Au up to 11 *A*GeV

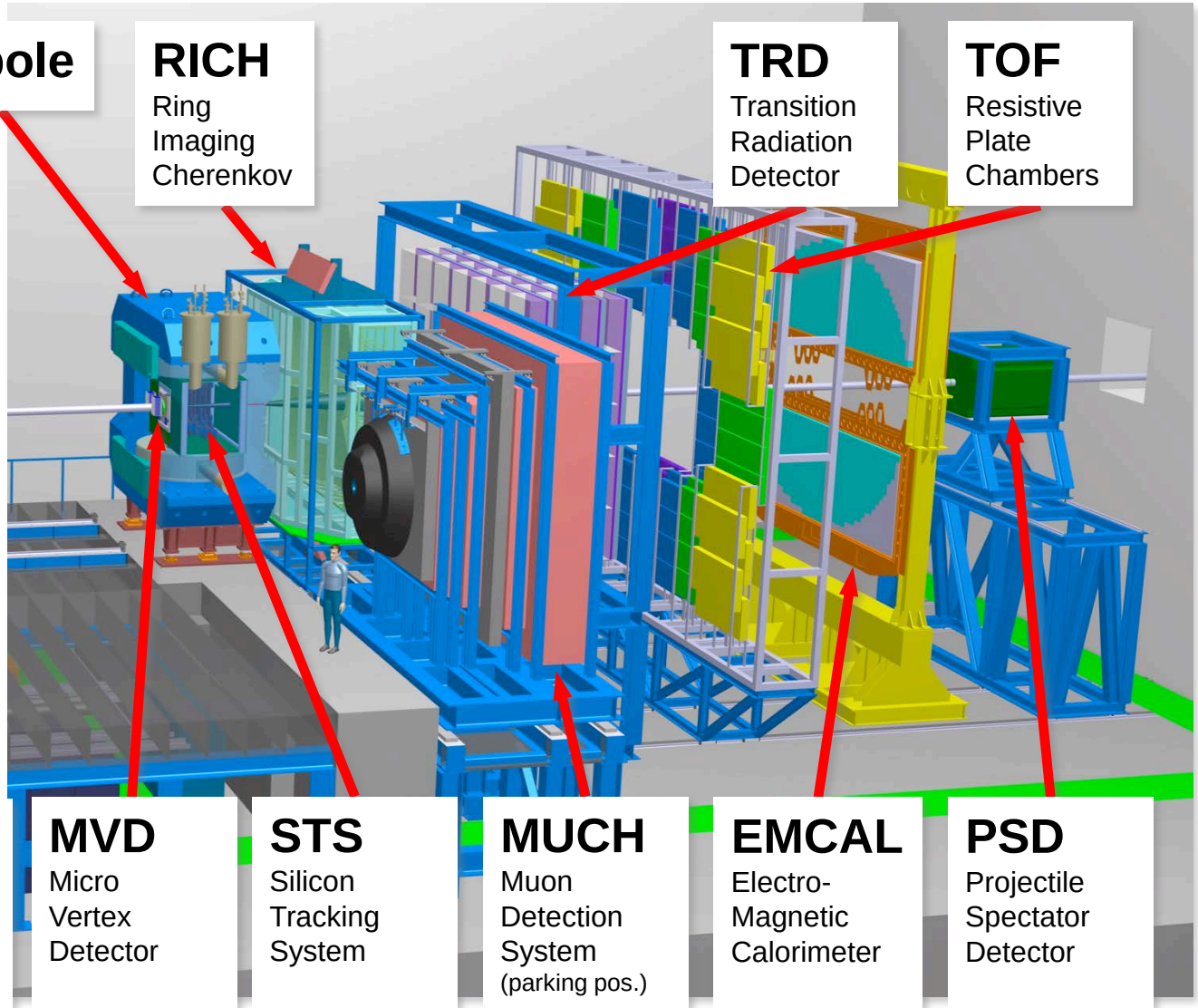
10^9/s C, Ca, … up to 14 *A*GeV

11^{11}/s protons up 29 GeV

FAIR MSV

beyond MSV

Experimental Setup
CBM Detector Components



Dipole

RICH
Ring Imaging Cherenkov

TRD
Transition Radiation Detector

TOF
Resistive Plate Chambers

MVD
Micro Vertex Detector

STS
Silicon Tracking System

MUCH
Muon Detection System
(parking pos.)

EMCAL
Electro-Magnetic Calorimeter

PSD
Projectile Spectator Detector

Acceptance
$p_t > 0$

Forward rapidities

Experimental Setup
Technological Challenges

High interaction rates
10^5 – 10^7 Au+Au collisions/sec.

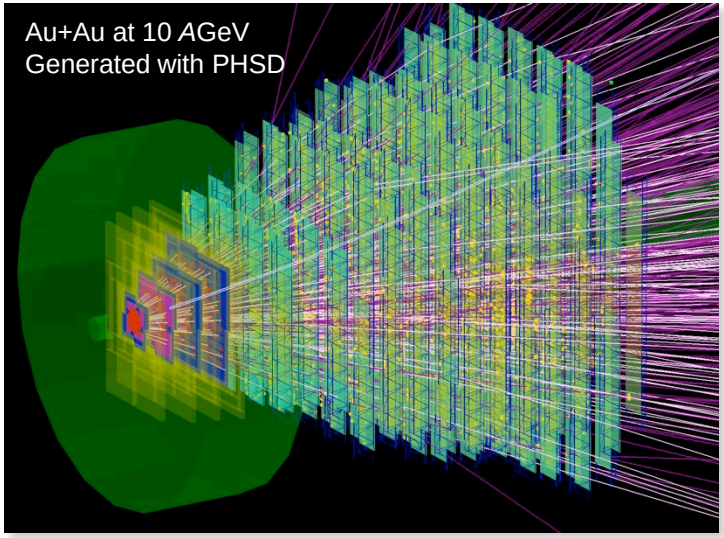
Fast and radiation hard detectors

Free streaming read-out electronics

High speed data acquisition

Computing farm for online event selection

4D reconstruction



Particle identification
Hadrons (π, K, p, fragments) and leptons ($e^{\pm}$, $\mu^{\pm}$)

Vertexing for open charm
Resolution for (main and secondary) vertices $\sigma \approx 50\mu m$

Experimental Setup
Particle Identification

Hadrons
$\pi^{\pm}$, $K^{\pm}$, p

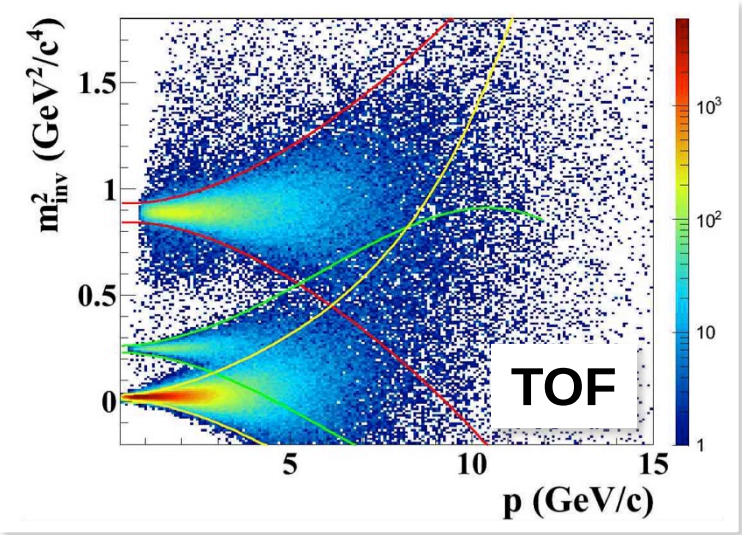
Fragments
TOF + TRD

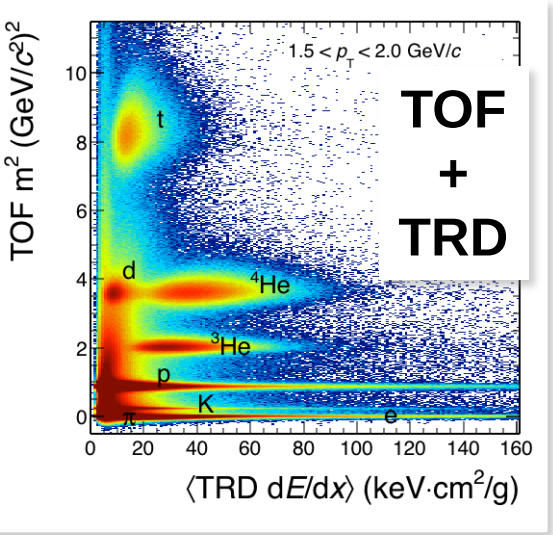
Electrons
RICH + TRD

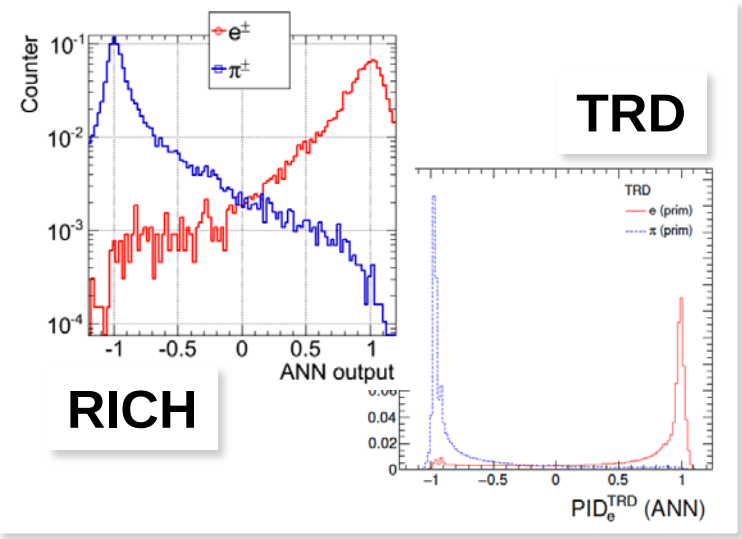
Muons
MUCH
with hadron absorber

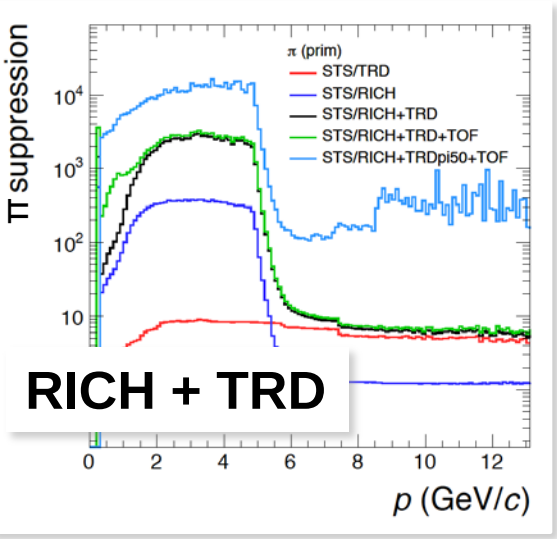
Photons
EMCAL

Conversion









CBM Status
Involvement of German Universities

Subsystem	Involved German groups
STS	Prof. H.R. Schmidt (Univ. Tübingen)
MVD	Prof. J. Stroth (Univ. Frankfurt)
RICH	Prof. C. Höhne (Univ. Giessen) Prof. K-H. Kampert (Univ. Wuppertal)
TRD	Prof. H. Appelshäuser (Univ. Frankfurt) Prof. C. Blume (Univ. Frankfurt) Prof. P. Fischer (Univ. Heidelberg) Nachfolger J. Wessels (Univ. Münster)
TOF	Prof. N. Herrmann (Univ. Heidelberg) Prof. T. Galatyuk (TU Darmstadt)
DAQ/FLES	Prof. U. Kebschull (Univ. Frankfurt) Prof. I. Kisel (Univ. Frankfurt) Prof. J. Becker (KIT Karlsruhe) Prof. V. Lindenstruth (Univ. Frankfurt) Prof. A. Reinefeld (Zuse Inst. Berlin) Prof. A. Toia (Univ. Frankfurt)

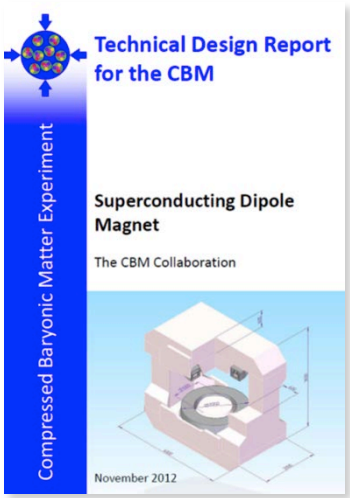
16 Professors

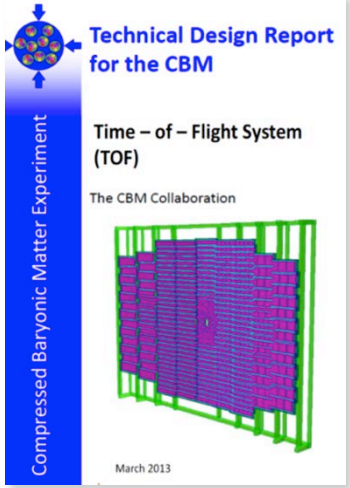
9 Universities

7 Project leaders

CBM Status
Technical Design Reports

Project	TDR Status
Magnet	approved
STS	approved
RICH	approved
TOF	approved
MUCH	approved
HADES ECAL	approved
PSD	approved
MVD	submission 2017
DAQ/FLES	submission 2017
TRD	submission 2017
ECAL	submission 2017



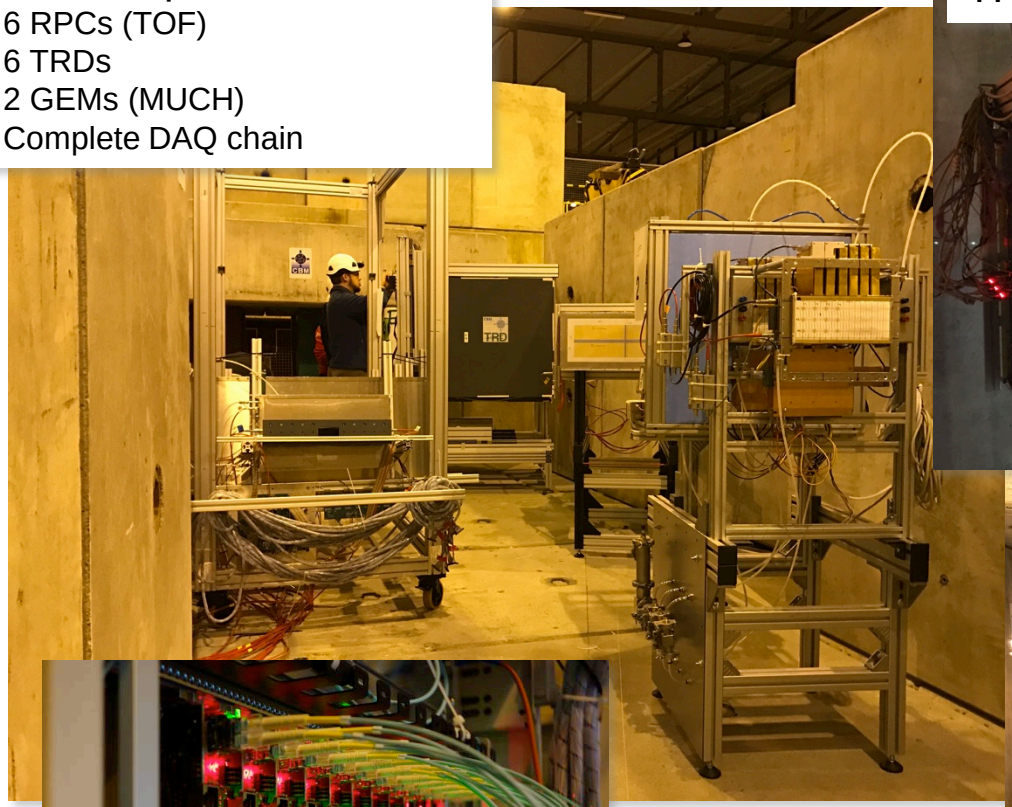


CBM Status
Milestones

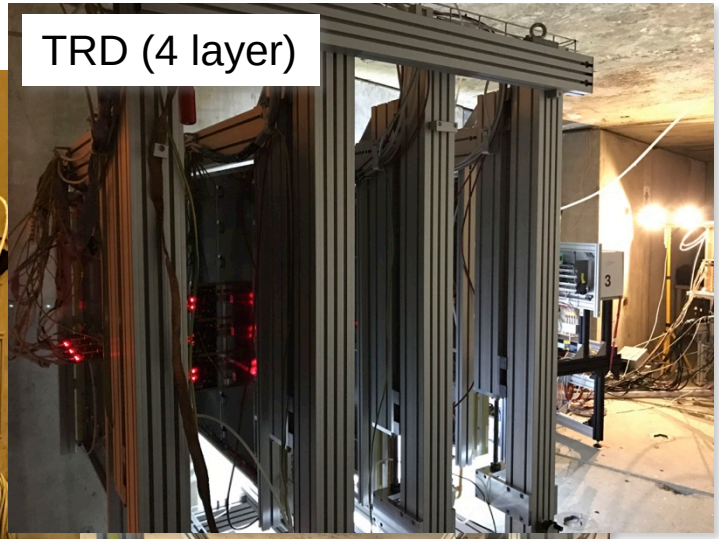
CBM subsystems	TDR approved	Start production	Ready for installation
Micro Vertex Detector (MVD)	01.11.17	30.06.18	31.09.21
Silicon Tracking System (STS)	05.07.13	30.06.17	31.12.21
Ring Imaging Cherenkov Detector (RICH)	07.01.14	30.06.17	31.12.20
Muon Detector (MUCH)	28.02.15	30.06.17	31.12.21
Transition Radiation Detector (TRD)	01.11.17	31.12.17	30.06.23
Time Of Flight System (TOF)	30.04.15	05.01.17	31.12.21
Electromagnetic Calorimeter (ECAL)	31.12.17	30.06.18	31.12.23
Projectile Spectator Detector (PSD)	28.02.15	30.06.16	31.12.21
Dipole Magnet	01.10.13	30.06.17	30.06.20
Online Systems (DAQ and FLES)	31.12.17	30.06.18	31.12.21

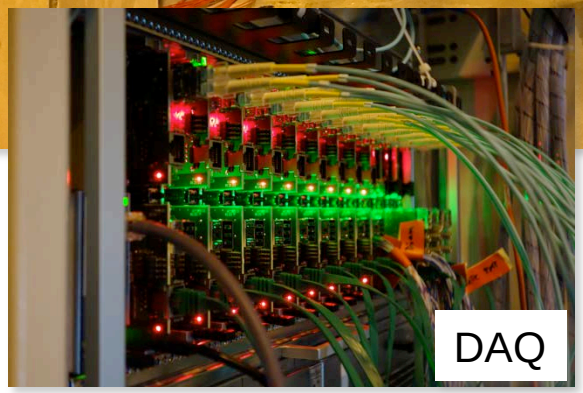
CBM Status
On-going Test Beam at CERN-SPS

Full setup at CERN-SPS
6 RPCs (TOF)
6 TRDs
2 GEMs (MUCH)
Complete DAQ chain



TRD (4 layer)





DAQ

RPCs + GEMs

CBM Status
Beam Dump

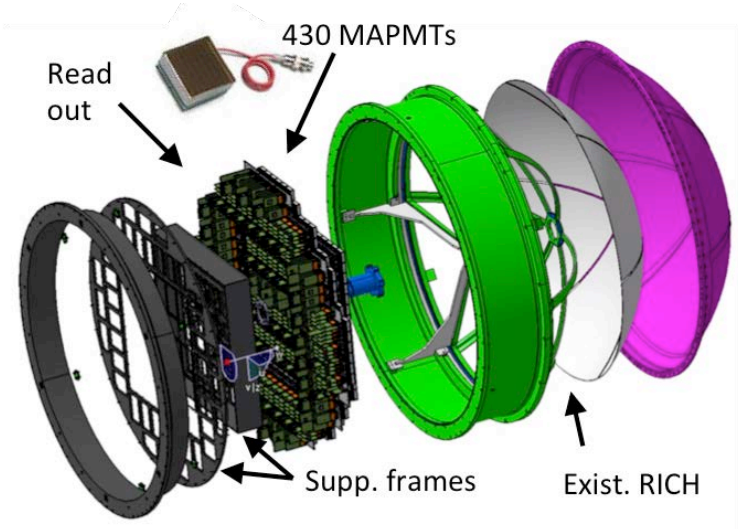
CBM Status
FAIR Phase-0 Experiments

MAPMTs for HADES-RICH
Joint CBM and HADES activity

430 out of 1100 Multi-Anode-PMTs for CBM-RICH installed in HADES-RICH

Provides experience in detector setup, calibration and data analysis

GSI research program 2018−2020

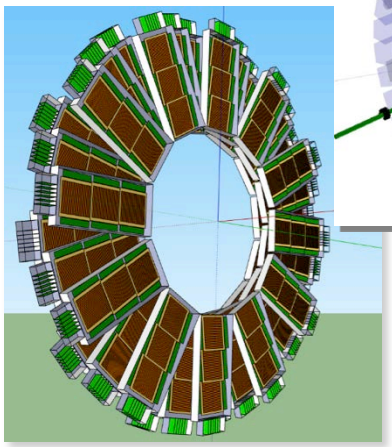


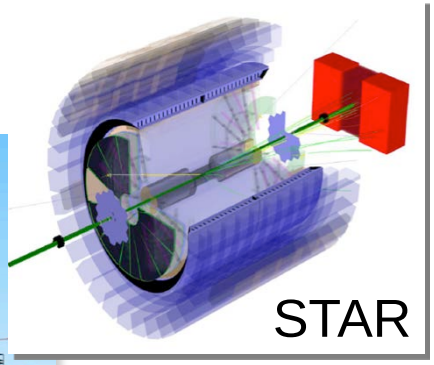
CBM-TOF modules in STAR
10% of total number of TOF modules

Participation in STAR-BES-II

Extends PID coverage to large rapidities

Large scale integration test and provides experience in MRPC operation



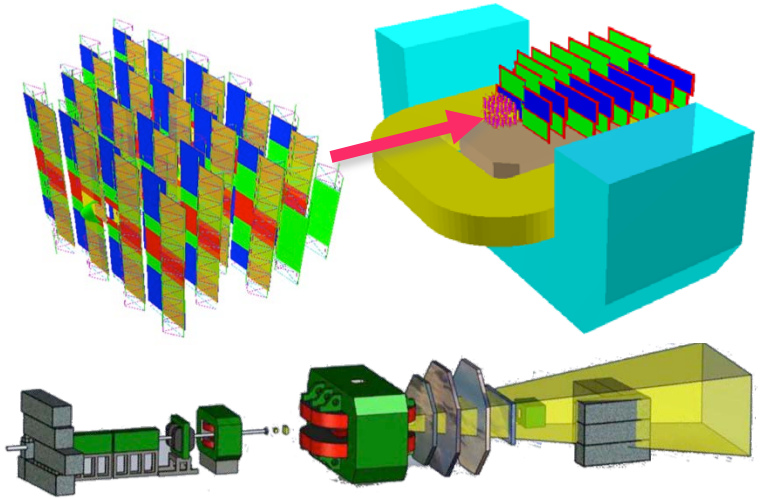


CBM Status
FAIR Phase-0 Experiments

STS + PSD for BM@N
Fixed target experiment
at the Nuclotron in JINR/Dubna

PSD in setup (2018)
Four layers STS in front of tracker (2020)

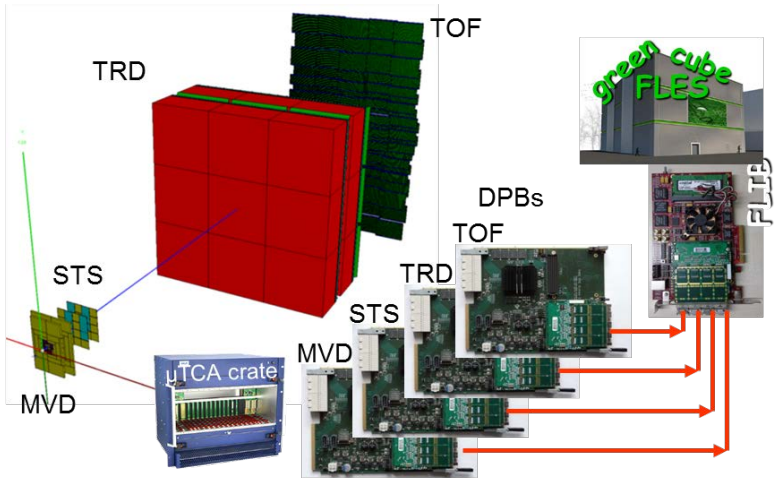
Au-beams up to 4.5 *A*GeV



CBM commissioning setup
High rate A+A collisions at SIS18/GSI

Full size detector modules
and read-out chain

Testing environment for:
Detector performance
Free streaming data transport
Online reconstruction



Conclusions

Diverse and exciting physics program (c.f. arXiv:1607.01487)

QCD phase diagram

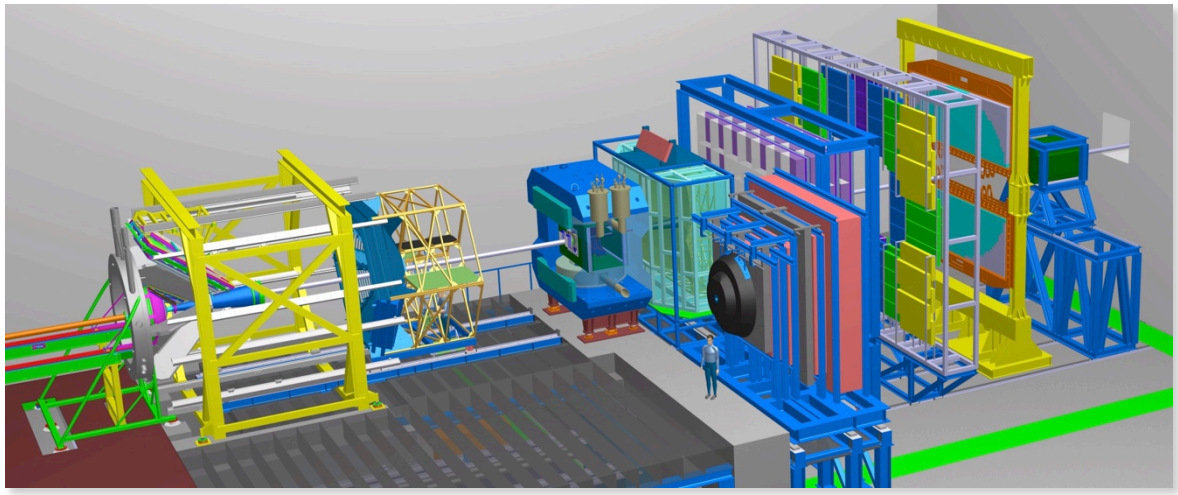
Exotic matter and particles

Many new observables accessible due to highest rates

E.g. di-leptons, heavy flavor, …

Systematic, multi-dimensional studies

Experiment will be ready for day-1 physics at the SIS100



The CBM Experiment
The Collaboration

China:
CCNU Wuhan
Tsinghua Univ.
USTC Hefei
CTGU Yichang

Czech Republic:
CAS, Rez
Techn. Univ. Prague

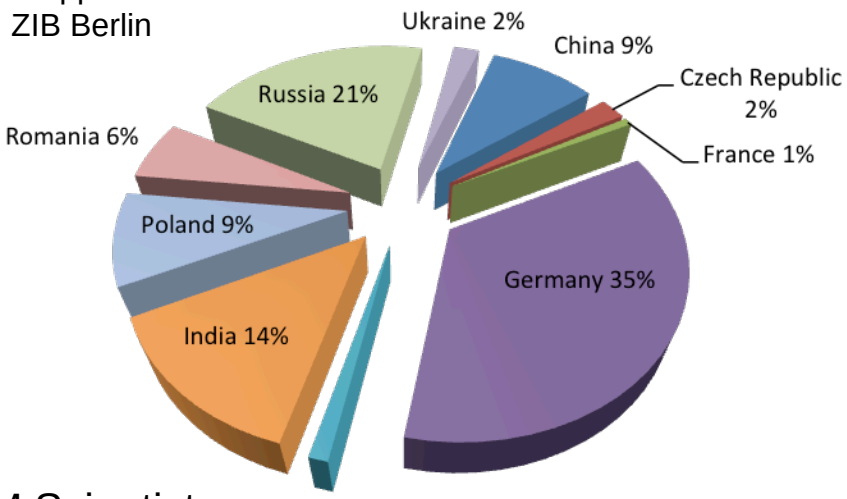
France:
IPHC Strasbourg

Hungary:
Wigner Inst. Budapest
Eötvös Univ.

55 institutions
460 members

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.
Rajasthan Univ.
Univ. of Jammu
Univ. of Kashmir
Univ. of Calcutta
B.H. Univ. Varanasi
VECC Kolkata
IOP Bhubaneswar
IIT Kharagpur
IIT Indore
Gauhati Univ.



CBM Scientists

Korea:
Pusan Nat. Univ.

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

Romania:
NIPNE Bucharest
Univ. Bucharest

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

The CBM Experiment
The Collaboration

Backup

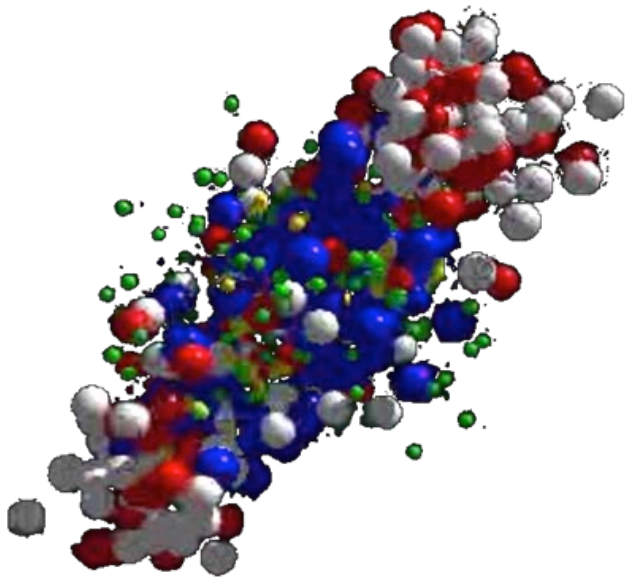
Outline

Physics program
QCD phase diagram
New phases and their properties
Chiral symmetry
Nuclear equation of state
Rare strange objects

Experimental setup
Technological challenges

Physics performance
Intermediate mass di-leptons
Hypernuclei

CBM status



CBM Status
Detector R&D

Recent R&D results

60ps time resolution (MIPS) for MRPCs

Low-mass, vacuum-compatible
pixel sensor integration

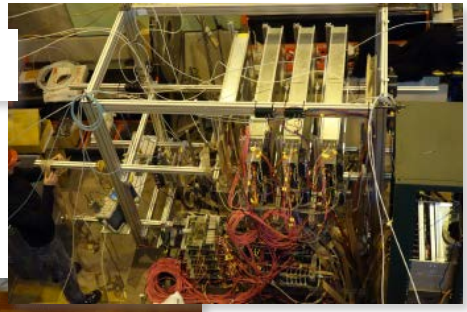
Enhanced UV photon efficiency
with wavelength shifting film

High-rate modular muon detection system

Test-beam activities

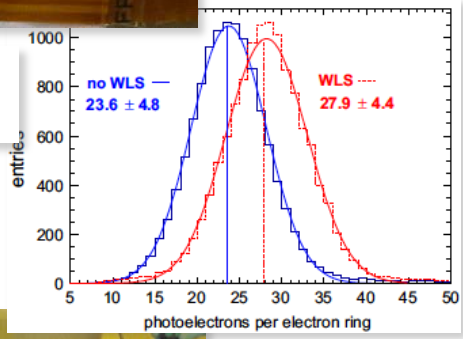
Many different activities
PS, SPS, COSY, …

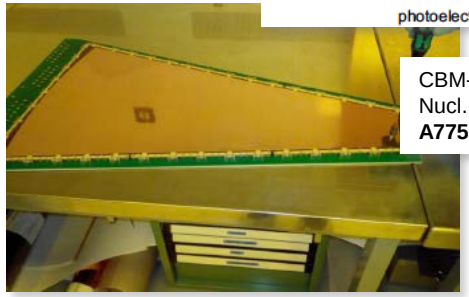
CBM-TOF collaboration:
J. Instrum. **7** (2012) R10008



CBM-MVD collaboration:
Nucl. Instrum. Meth.
A732 (2013) 515

CBM-RICH collaboration:
Nucl. Instrum. Meth.
A783 (2015) 543





CBM-MUCH collaboration:
Nucl. Instrum. Meth.
A775 (2014) 139

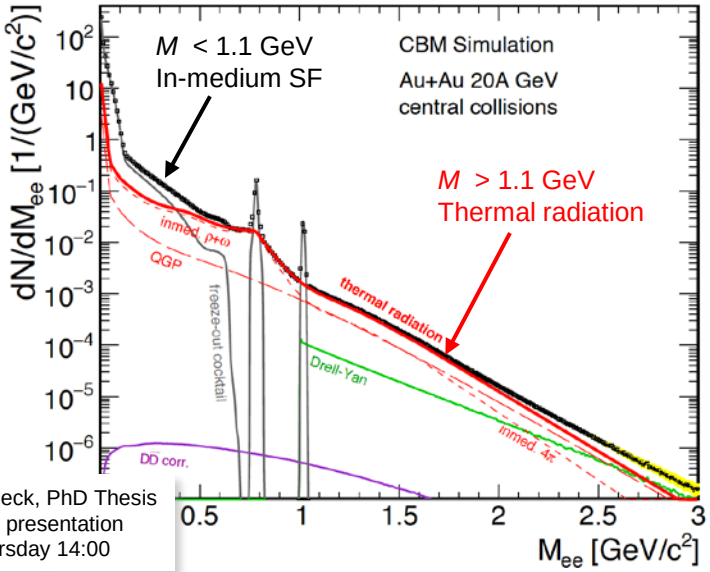
Physics Performance
Intermediate Mass Dileptons

Dilepton spectra
Space-time integral of EM radiation

Different collision stages accessible in different mass regions

Low mass region (M < 1.1 GeV)
Access to in-medium spectral functions

Intermediate mass region (M > 1.1 GeV)
Access to thermal medium radiation



F. Seck, PhD Thesis
See presentation
Thursday 14:00

Excitation function of IMR
Extract T_{slope} from mass spectra

Monotonous decrease or possible indications for 1st order phase transition?

Challenging measurement!

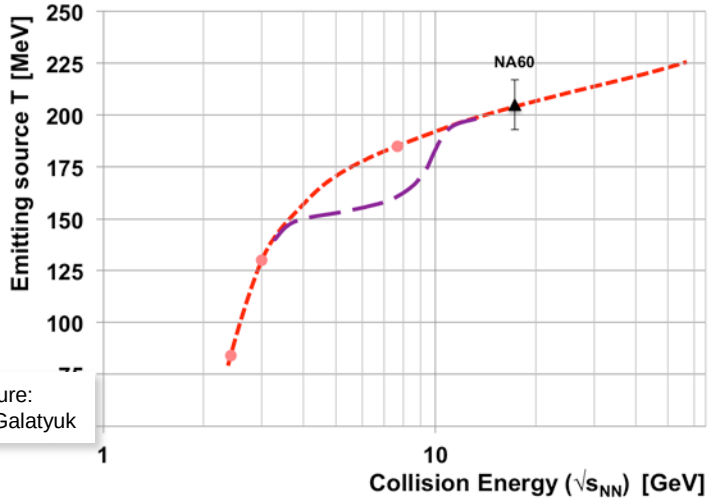


Figure:
T. Galatyuk

Physics Performance
Intermediate Mass Dileptons

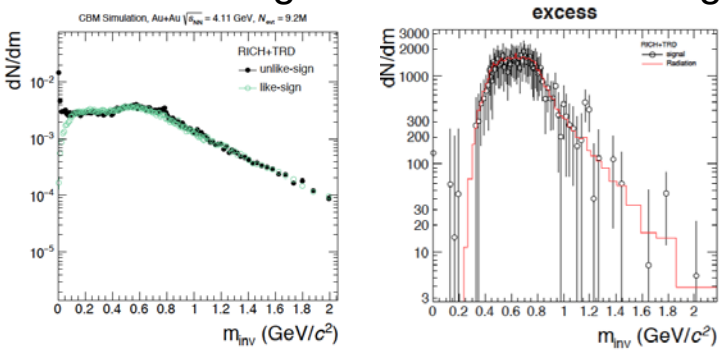
Dilepton spectra
Signal/background ratio essential

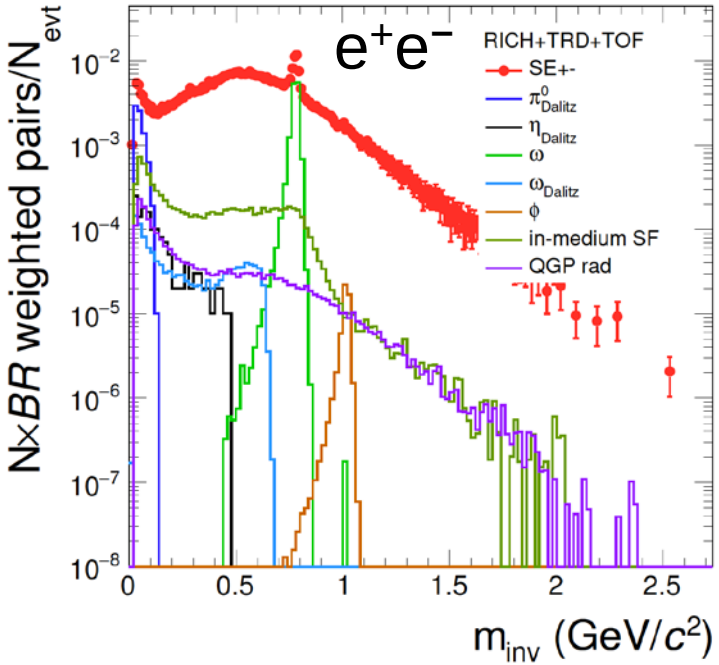
Physical sources: conversion, π^0-Dalitz
Rejection via topological cuts (MVD)

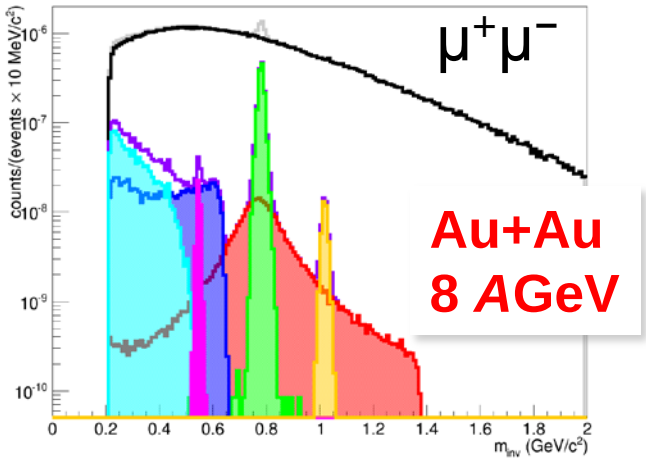
Mass Range [GeV/c^2]	S/B	S/√(S+B)
0.0-0.15	7.51 ± 0.53	39.1 ± 0.55
0.15-0.6	0.28 ± 0.02	9.34 ± 0.43
0.6-1.2	0.30 ± 0.02	8.37 ± 0.44
ω	0.88 ± 0.11	7.86 ± 0.55
φ	0.23 ± 0.09	1.24 ± 0.40

T. Galatyuk, ECT*-Dilepton Workshop, Trento 2015

Extraction of T_{slope}
Residual background via event mixing





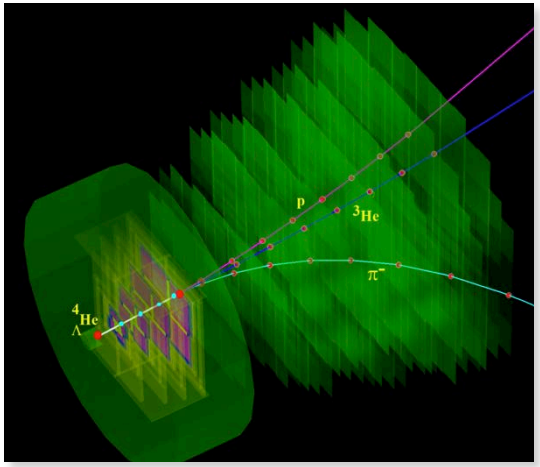


Physics Performance
Hypernuclei

Hypernuclei in heavy-ions

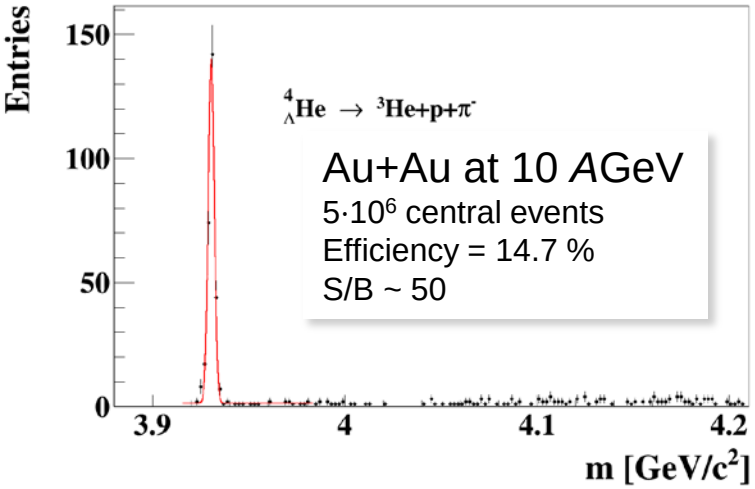
$^{4}_{\Lambda}He \rightarrow {}^{3}He + p + \pi^-$

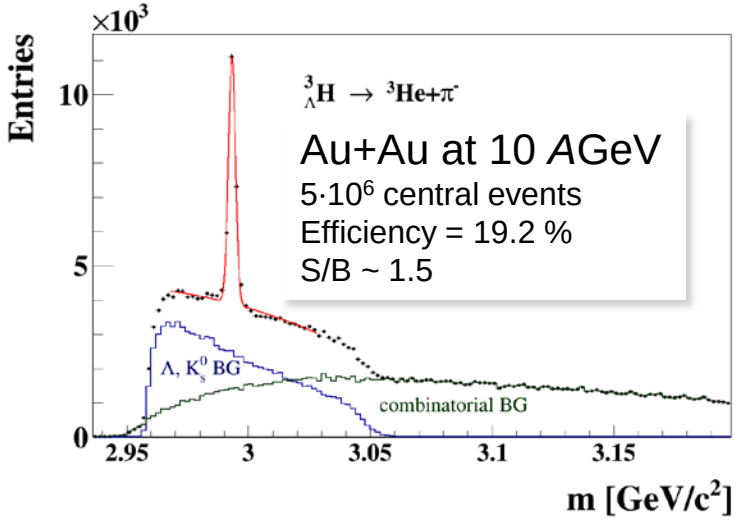
3-prong decay from detached vertex



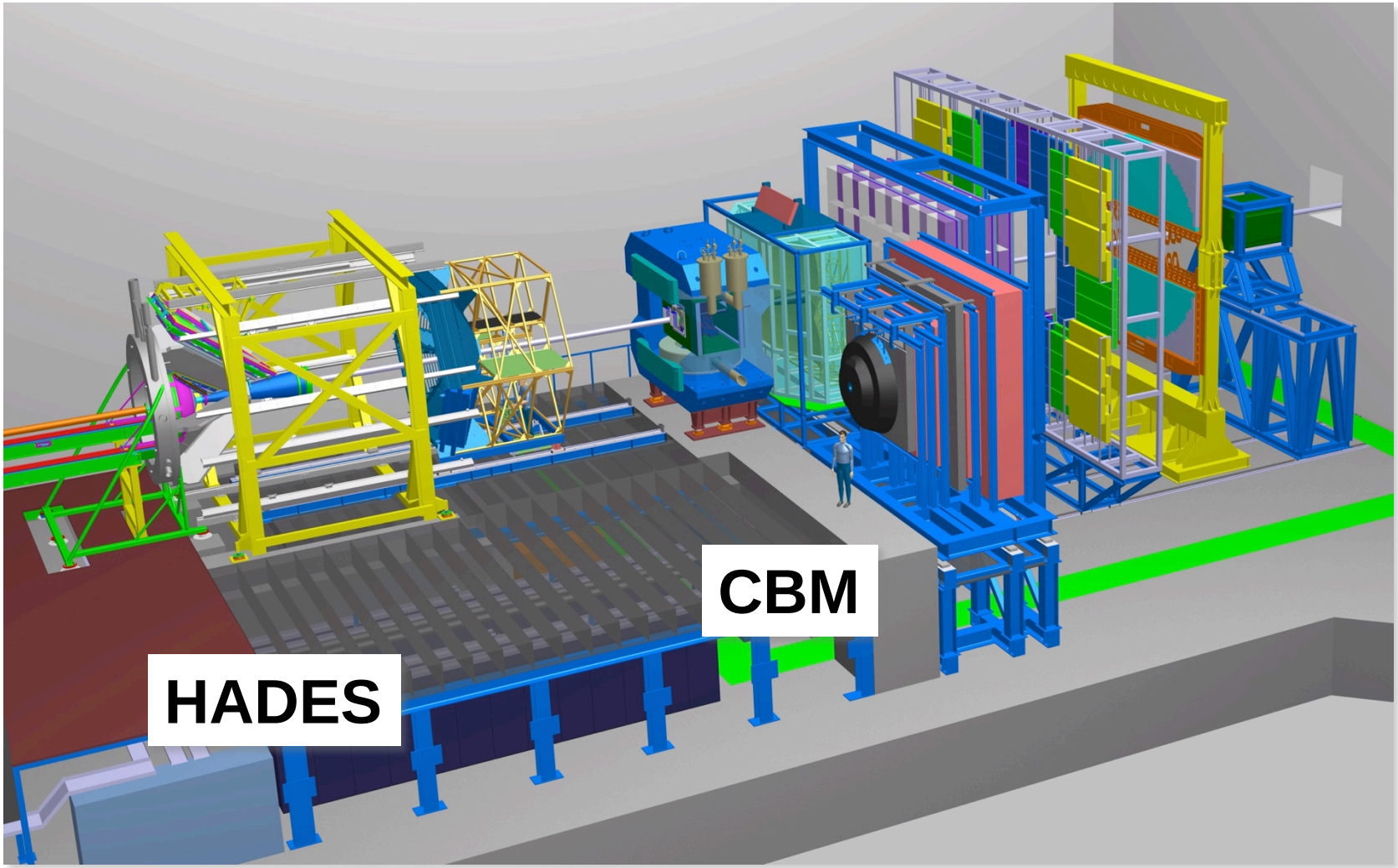
$^{3}_{\Lambda}H \rightarrow {}^{3}He + \pi^-$

Input to simulations:
J. Steinheimer et al., Phys. Lett. **B714** (2012) 85
H. Kameda et al., Phys. Rev. **C57** (1998) 1595
A. Andronic et al., Phys. Lett. **B697** (2011) 203
H. Stöcker et al., Nucl. Phys. **A827** (2009) 624c



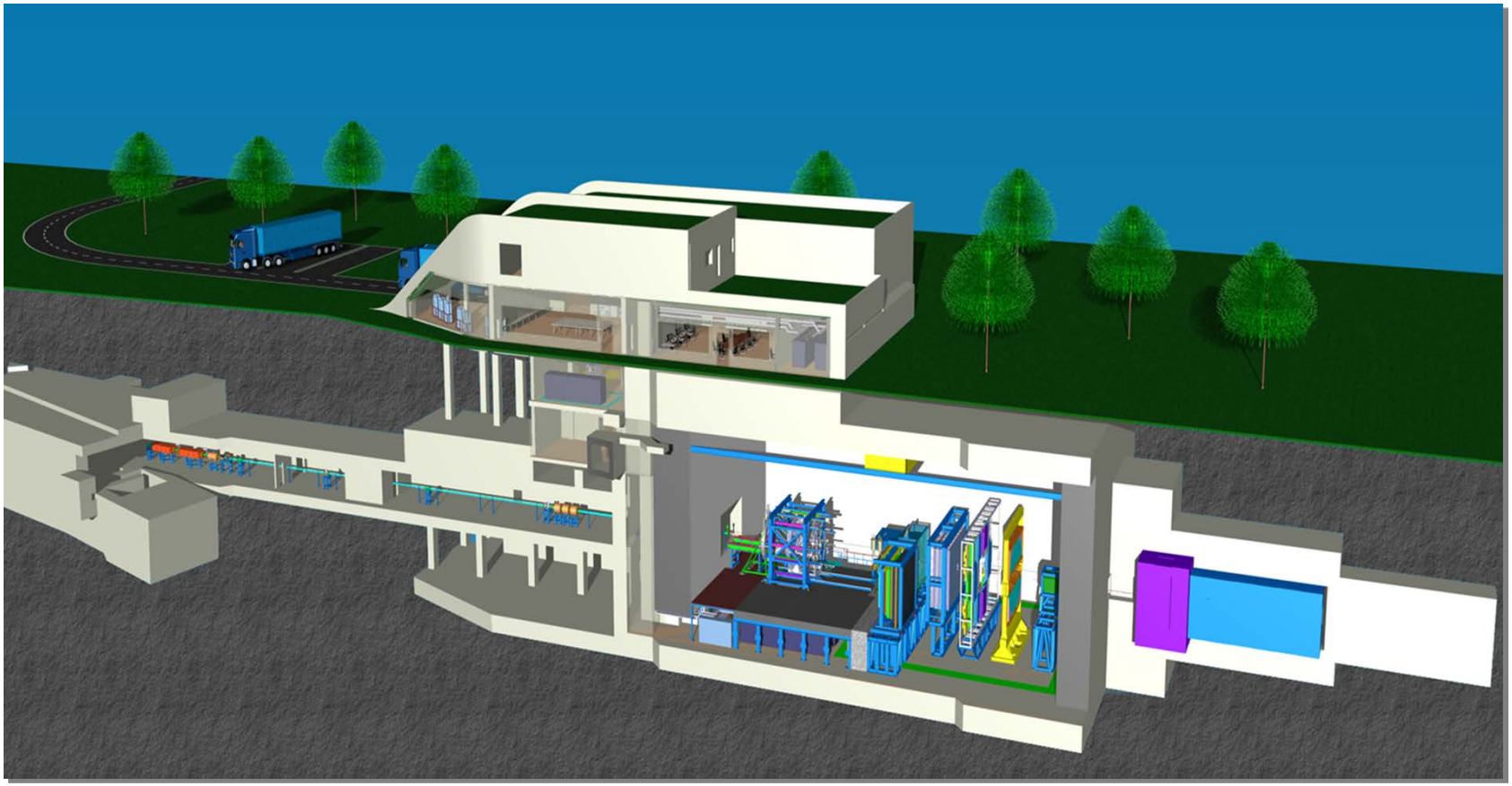


Experimental Setup
HADES + CBM

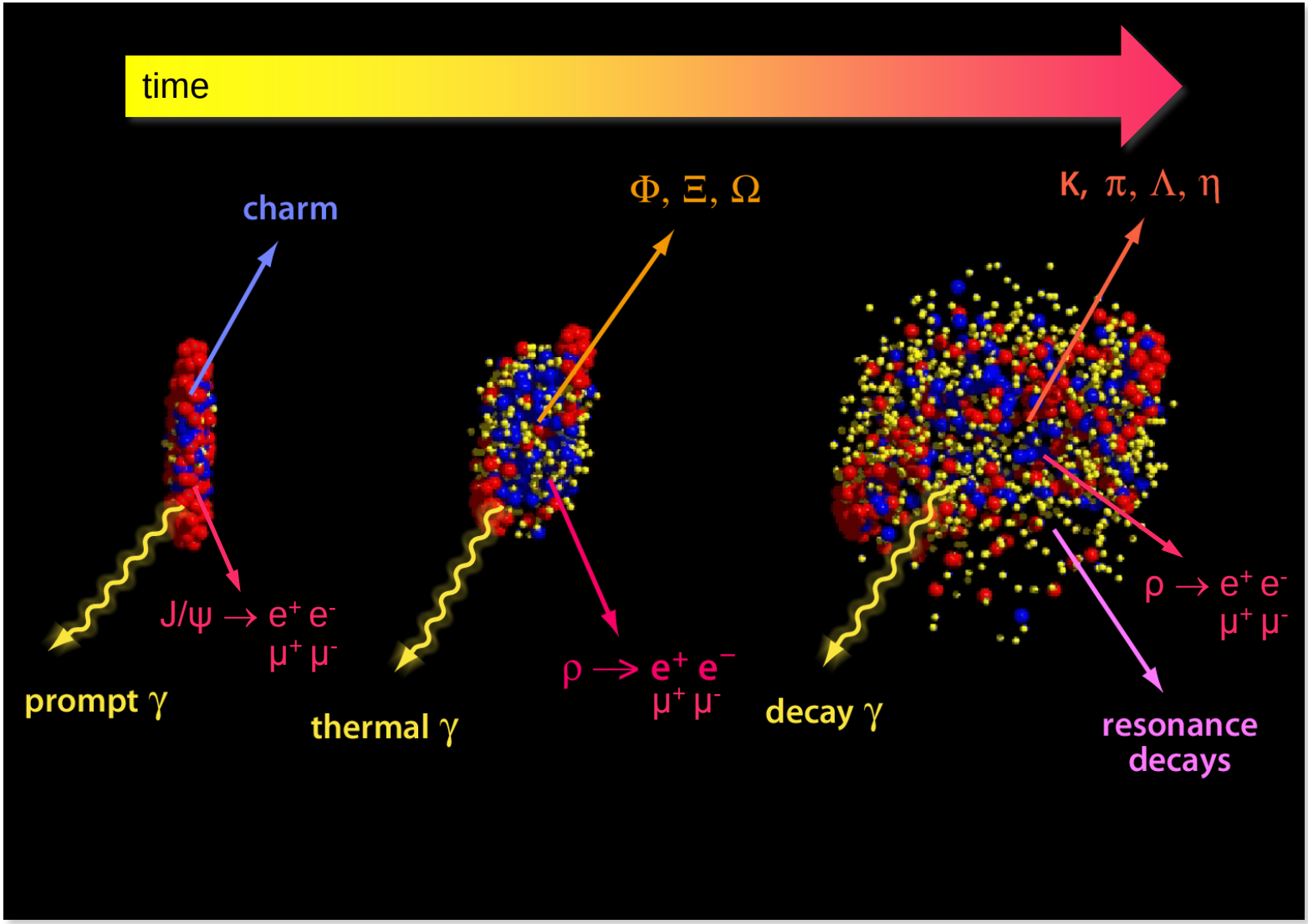


Experimental Setup

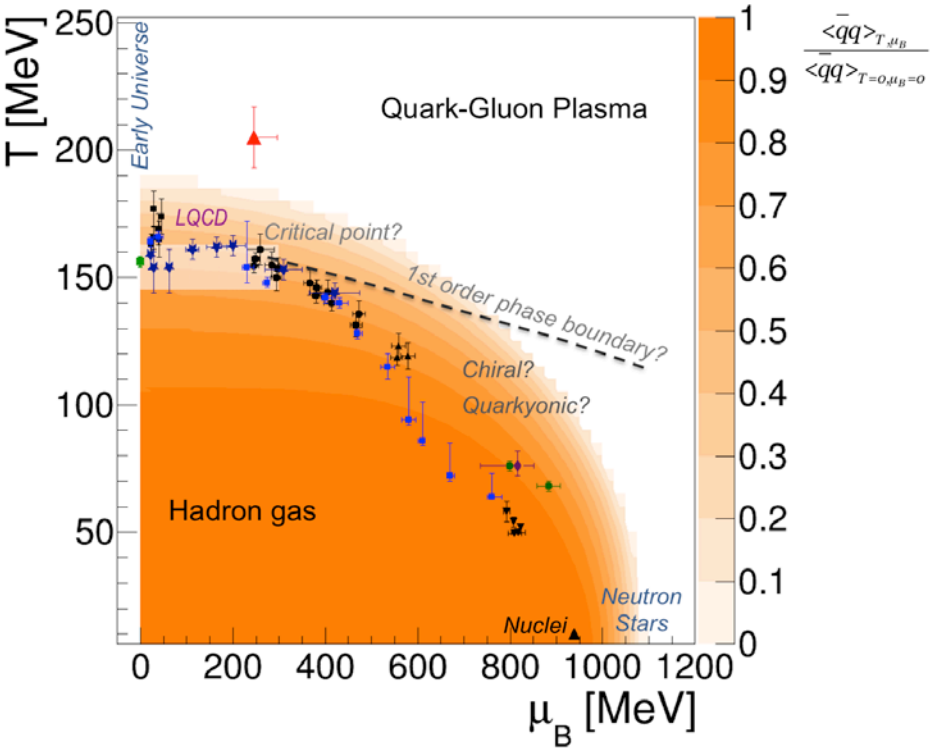
HADES + CBM in Cave

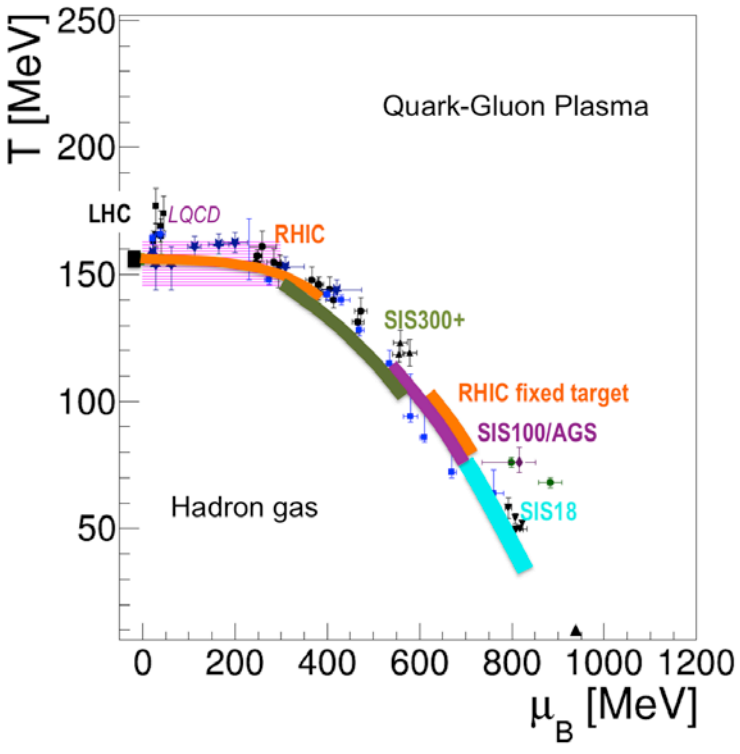


Physics Program
Observables



Physics Program
QCD Phase Diagram





Experimental and theoretical access to the phase diagram

Chemical freeze-out points from statistical model analyses

Lattice QCD: cross over transition at small μ_B

1st order at high μ_B and critical endpoint?

SHM : J. Cleymans: PRC 73 (2006) 034905, A. Andronic PLB 673 (2009) 142
ALICE : J. Stachel, arXiv:1311.4662
STAR : PRC 79 (2009) 034909
HADES : NPA 931 (2014)
FOPI : PRC 76 (2007) 052203
Lattice : $T_c(\mu_B) = 154(9)\ [1\text{-}0.0006(7)\ \mu_B^2]$ MeV

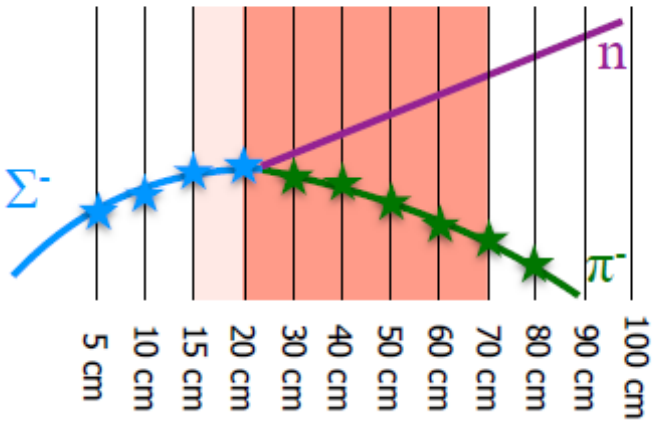
Physics Performance
Hyperons

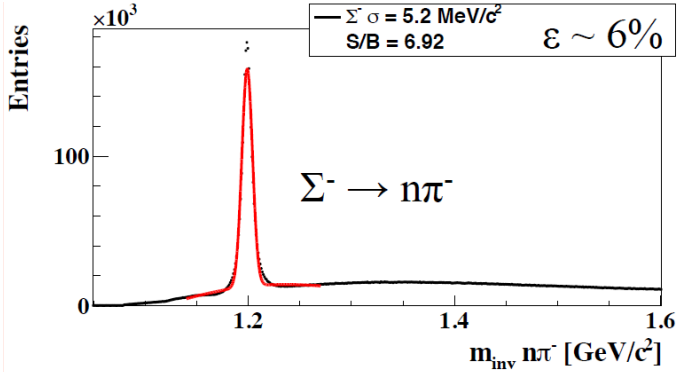
Σ-Hyperons in heavy-ions

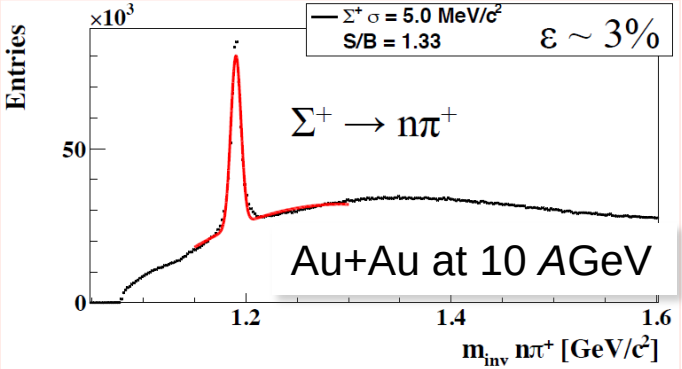
Neutral decay partner
via missing mass analysis

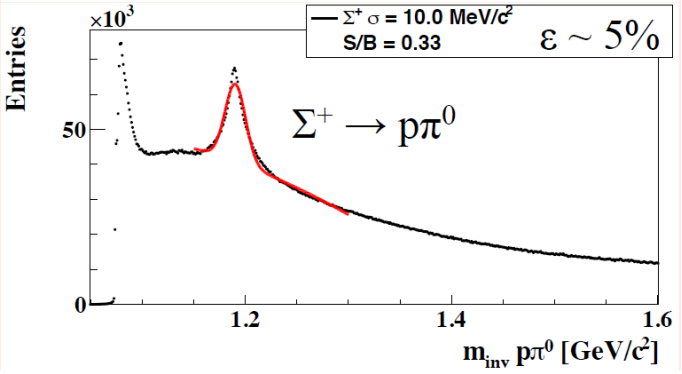
STS + MVD

KFParticleFinder Algorithm









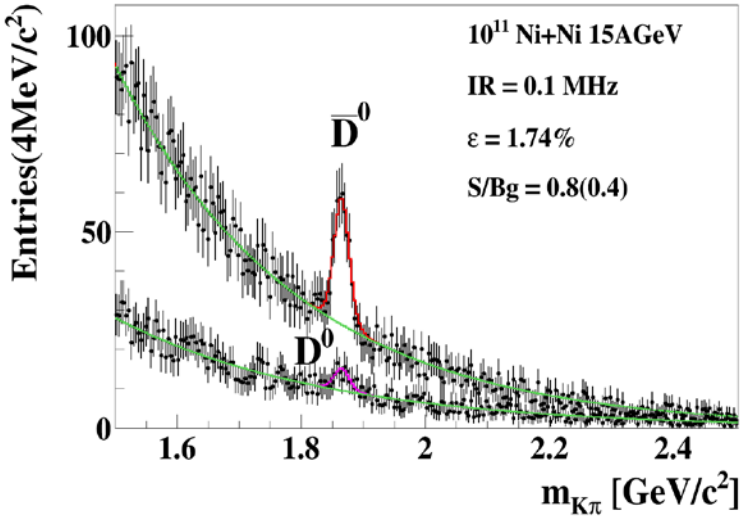
Physics Performance
Heavy-Flavour

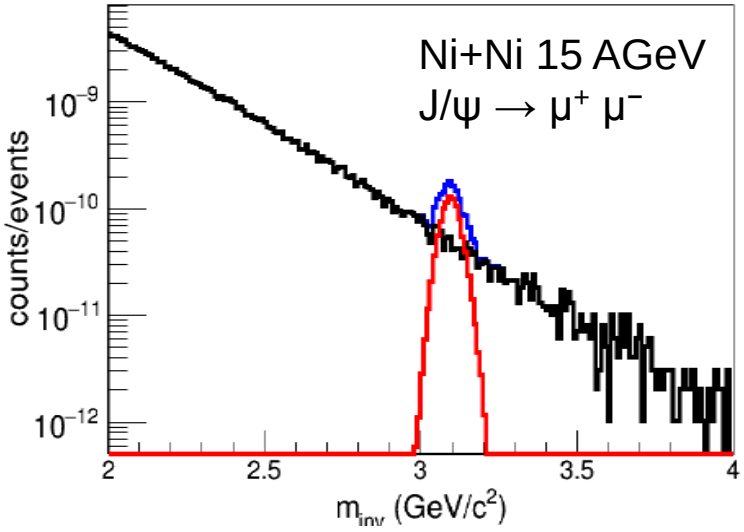
Ni+Ni collisions at 15 *A*GeV

D^0-mesons
Interaction rate = 0.1 MHz
260 $\bar{D}^0$ and 45 D^0 in ~ 2 weeks

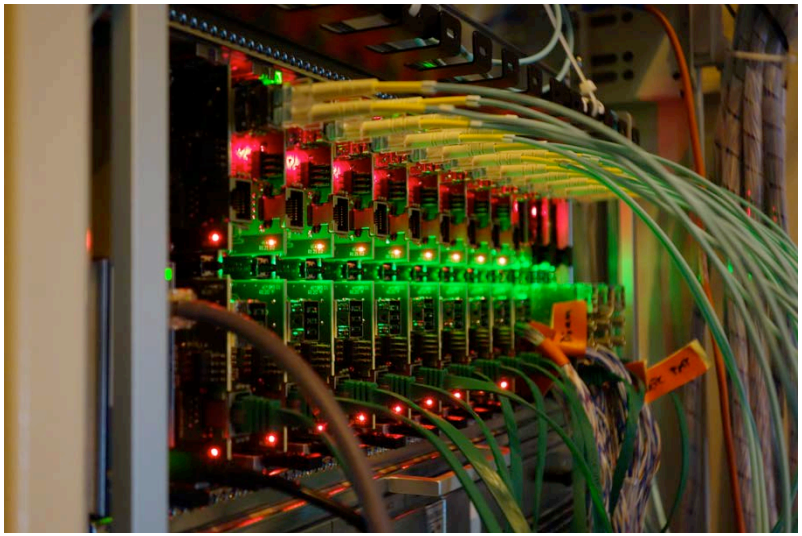
J/ψ via di-muons
Interaction rate = 1 MHz
3300 J/ψ in ~ 2 weeks

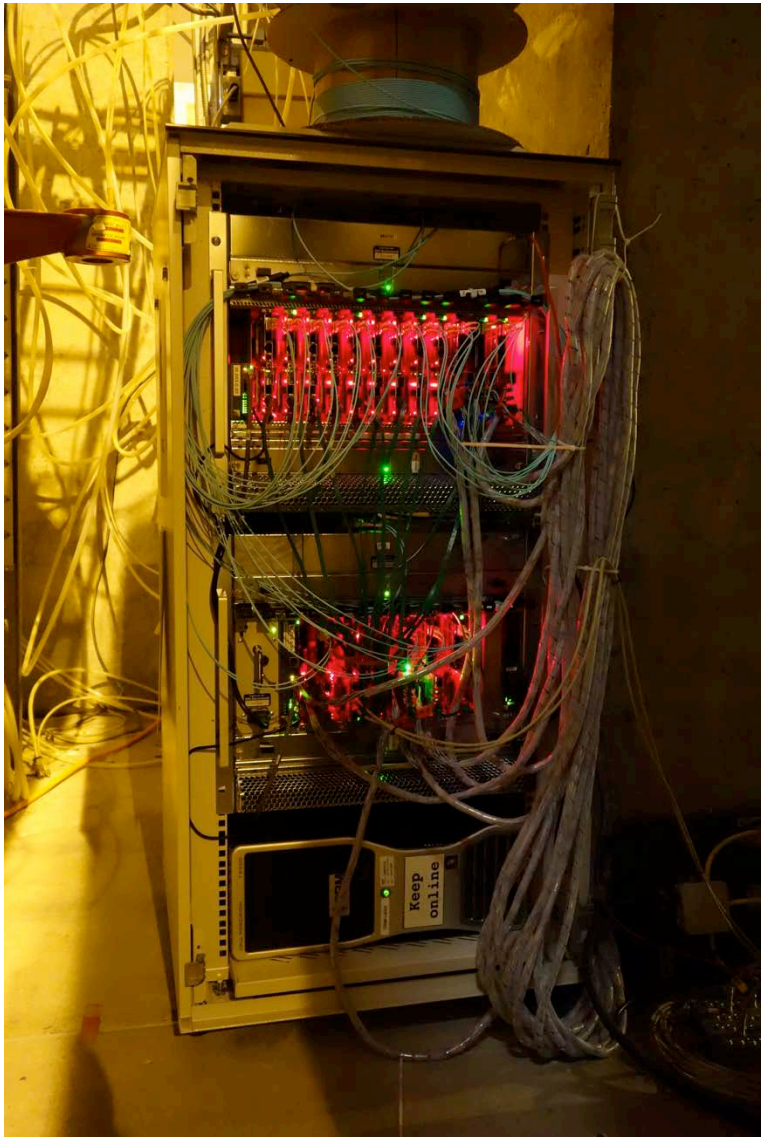
Objectives
Ratio open to hidden charm
Cold nuclear matter effects (p+A)



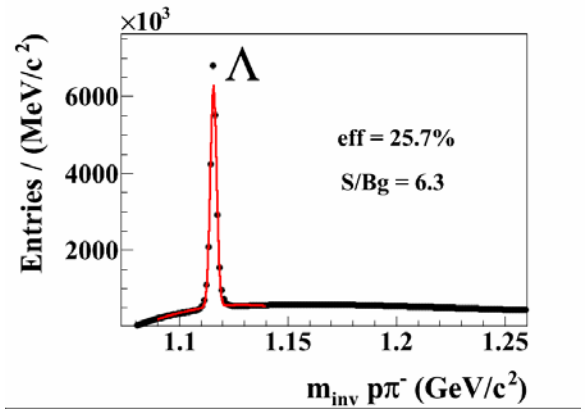


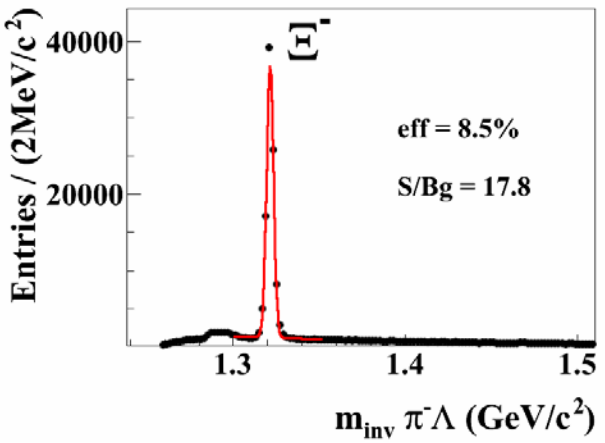
CBM Status
Test Beam at CERN-SPS

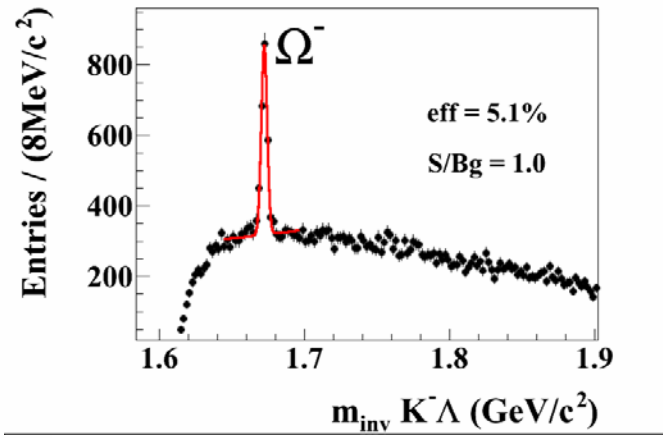


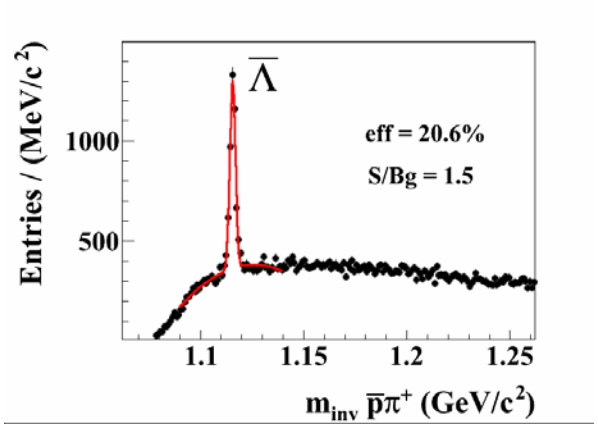


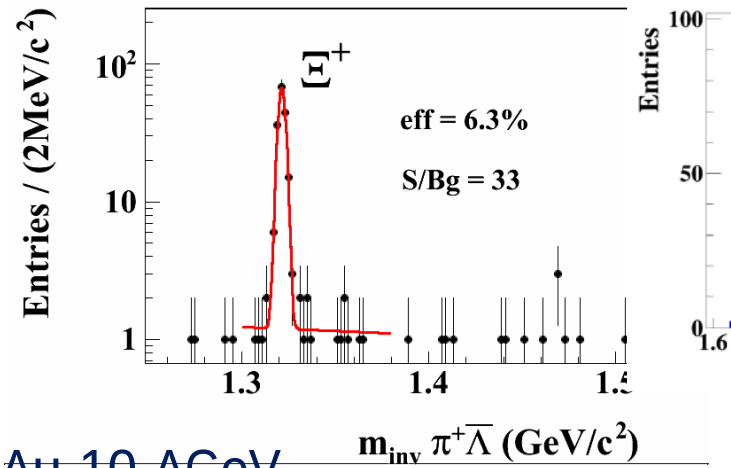
UrQMD

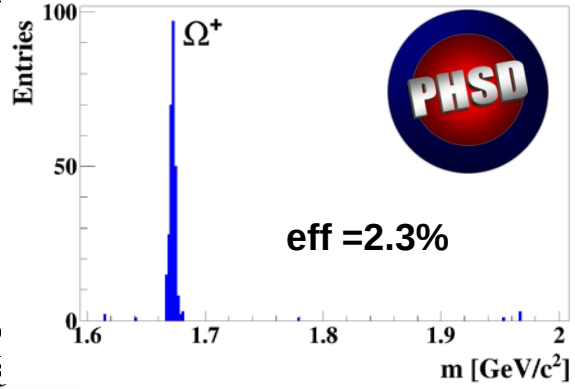




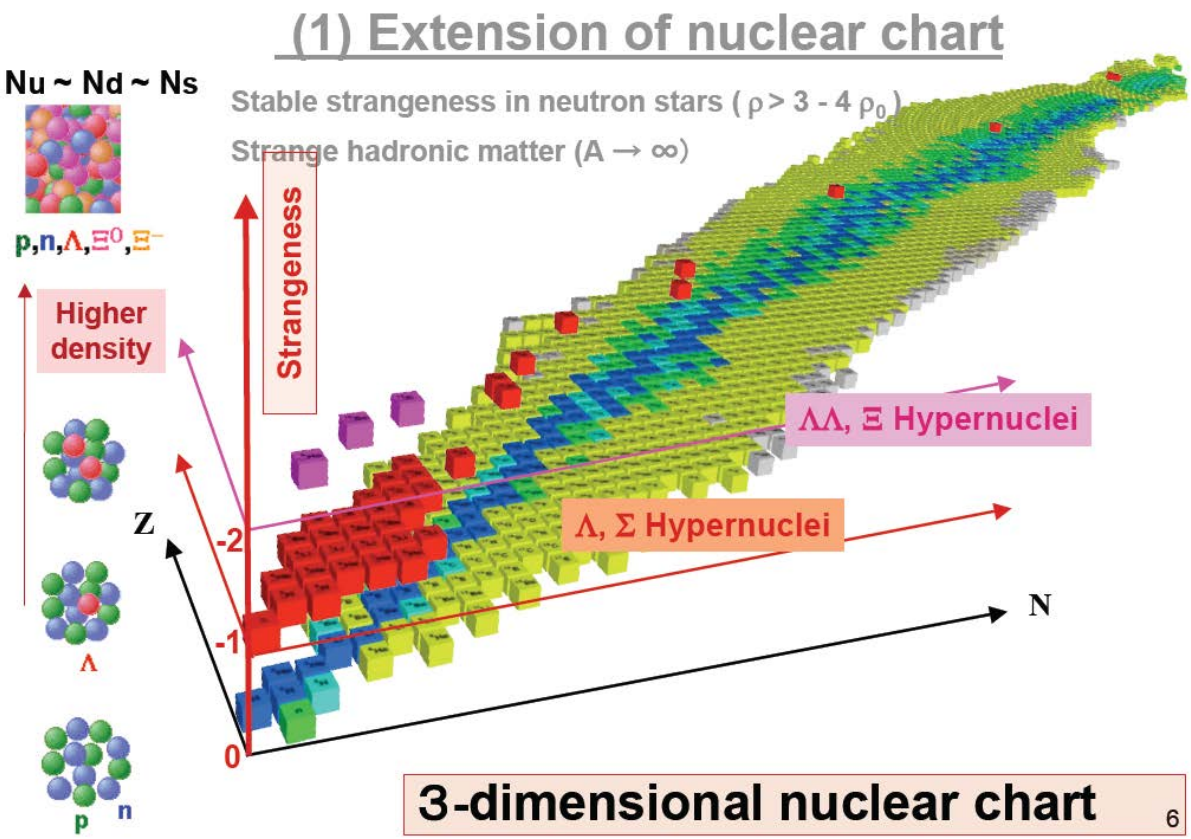








Hyperons in Au+Au 10 AGeV


(1) Extension of nuclear chart
Nu ~ Nd ~ Ns
Stable strangeness in neutron stars (ρ > 3 - 4 ρ0)
Strange hadronic matter (A → ∞)
p,n,Λ,Ξ0,Ξ−
Higher density
Strangeness
ΛΛ, Ξ Hypernuclei
Λ, Σ Hypernuclei
Z
N
-2
-1
0
Λ
p
n
3-dimensional nuclear chart
6