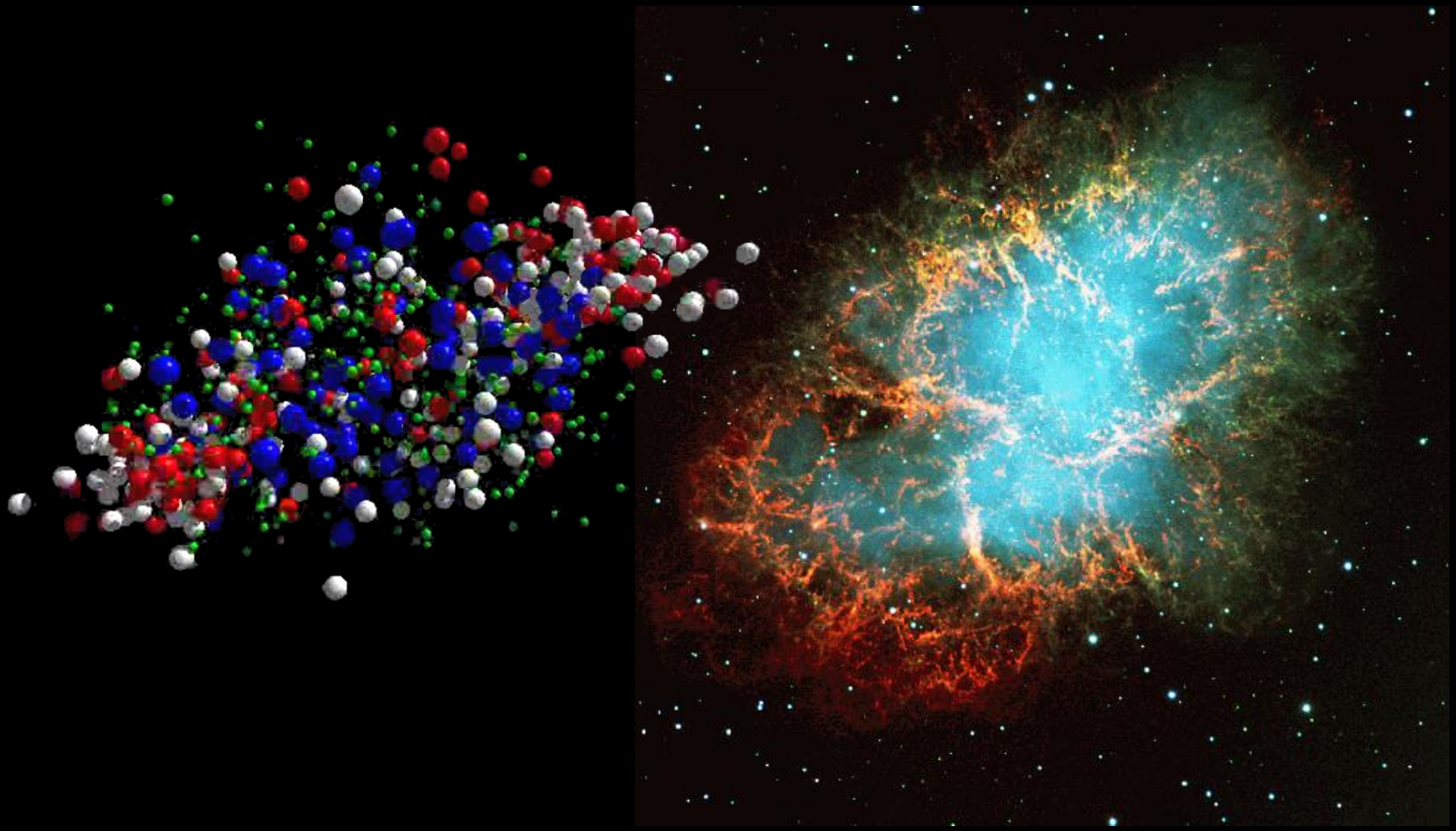
Status of the CBM Experiment at FAIR and its Silicon Tracking System

- *Compressed Baryonic Matter: The physics case*
- *Status of experiment preparation*
- *The Silicon Tracking System*
- *Funding and timeline*

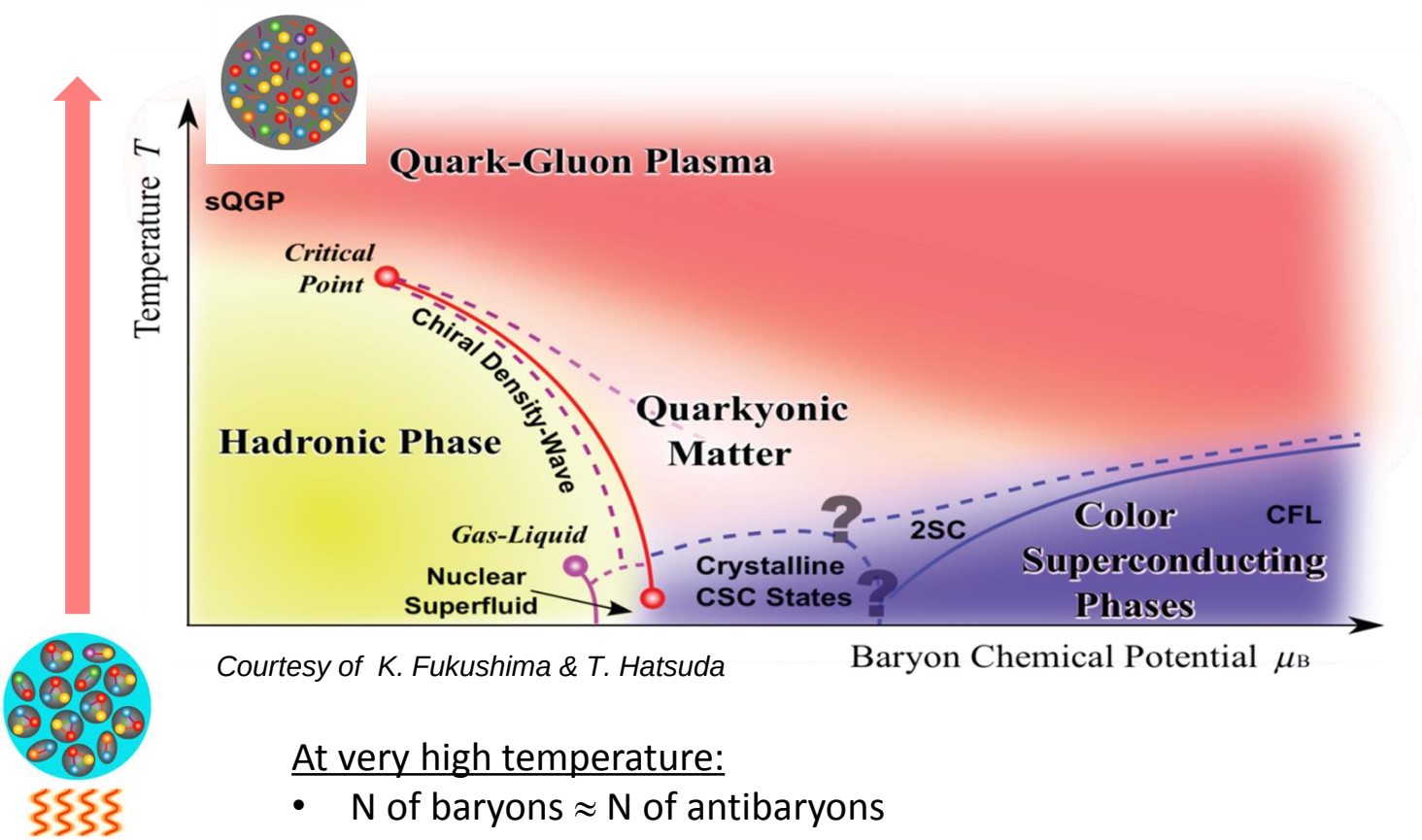
Johann M. Heuser
GSI Helmholtz Center for Heavy Ion Research, Darmstadt, Germany
for the CBM Collaboration

NICA Days 2015, Warsaw Technical University, Poland, 3-6 November 2015

Compressed Baryonic Matter



Exploring the QCD phase diagram

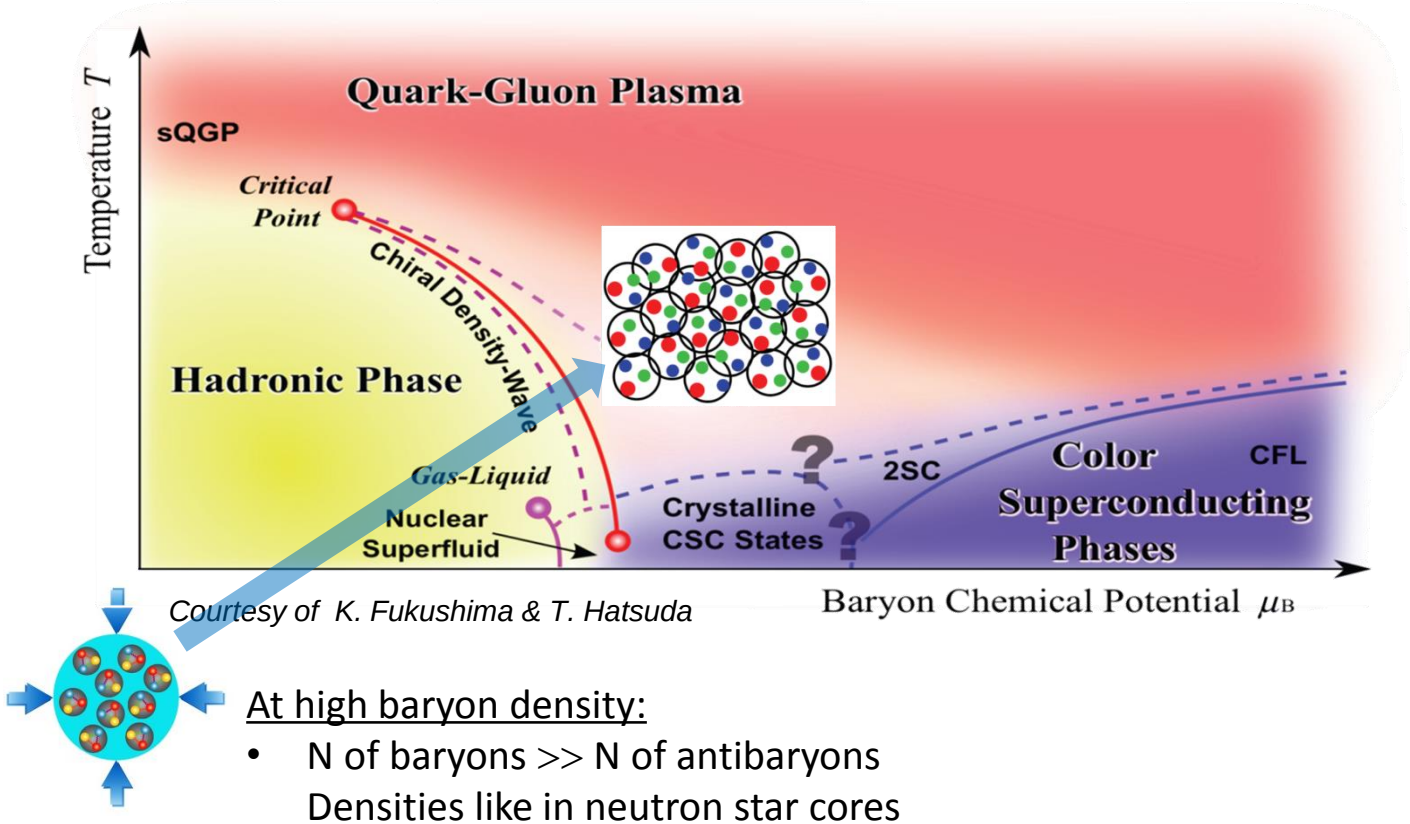


Courtesy of K. Fukushima & T. Hatsuda

<u>At very high temperature:</u>

- N of baryons ≈ N of antibaryons
  Situation similar to early universe
- L-QCD finds crossover transition between hadronic matter and Quark-Gluon Plasma
- Experiments: ALICE, ATLAS, CMS at LHC
  STAR, PHENIX at RHIC

Exploring the QCD phase diagram

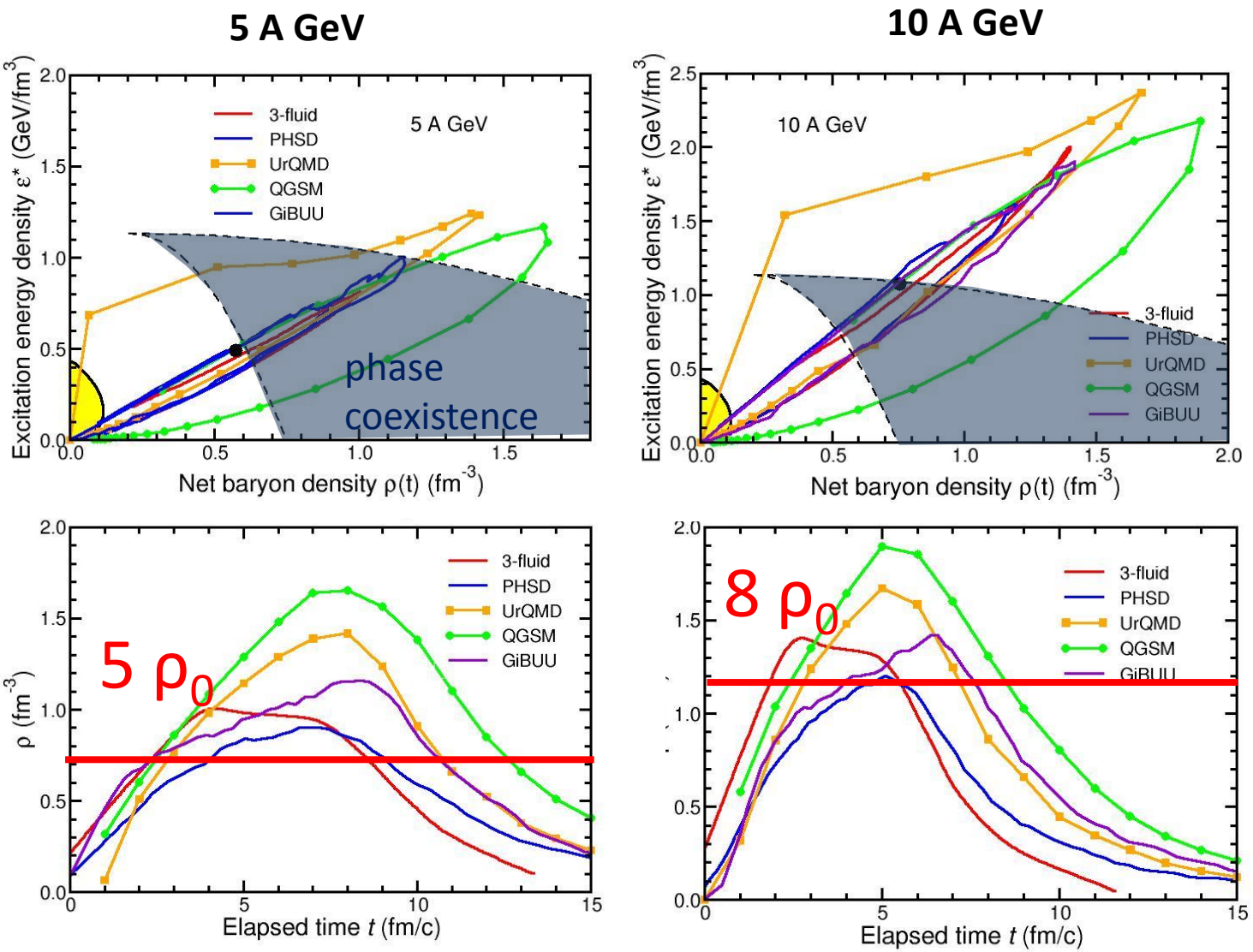


<u>At high baryon density:</u>

- N of baryons >> N of antibaryons
  Densities like in neutron star cores
- L-QCD not (yet) applicable
  Models predict first order phase transition
  with mixed or exotic phases
- Experiments: BES at RHIC, NA61 at CERN SPS,
  CBM at FAIR, NICA at JINR

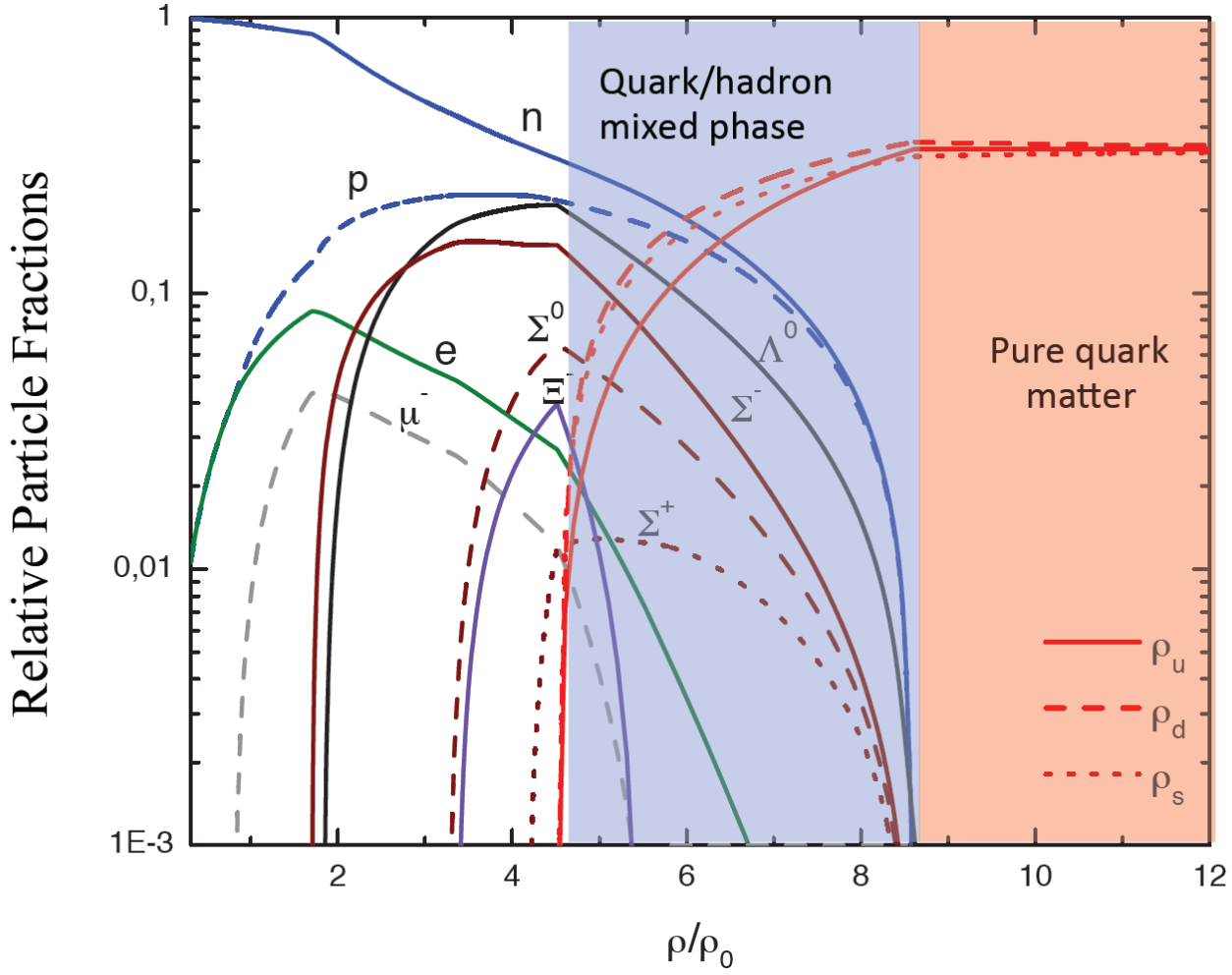
Baryon densities in central Au+Au collisions

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



Quark matter in massive neutron stars?

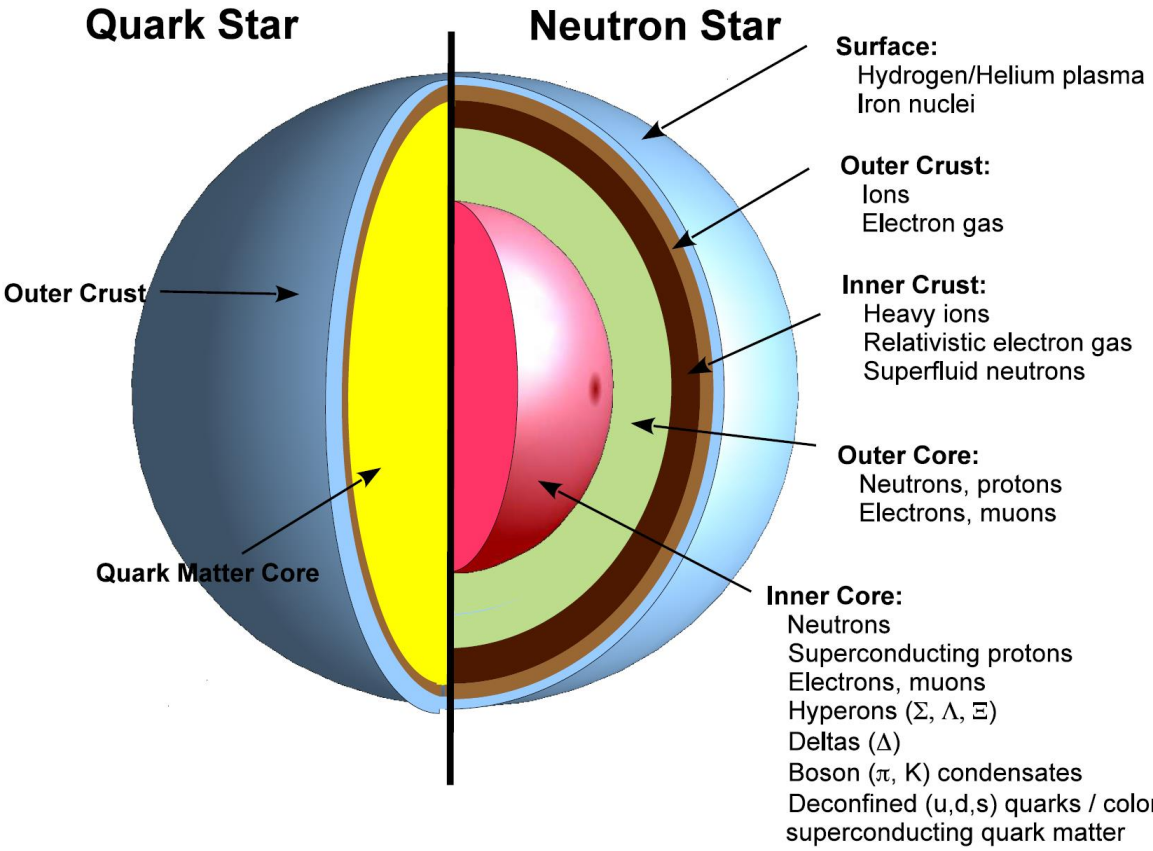
Equation-of-state: Non-local SU(3) NJL with vector coupling
M. Orsaria, H. Rodrigues, F. Weber, G.A. Contrera, arXiv:1308.1657



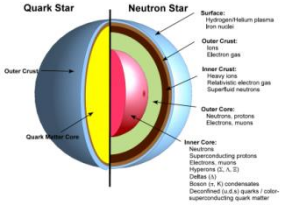
CBM physics case and observables

The equation-of-state at neutron star core densities

- collective flow of hadrons (driven by pressure)
- particle production at threshold energies (multi-strange hyperons)



CBM physics case and observables

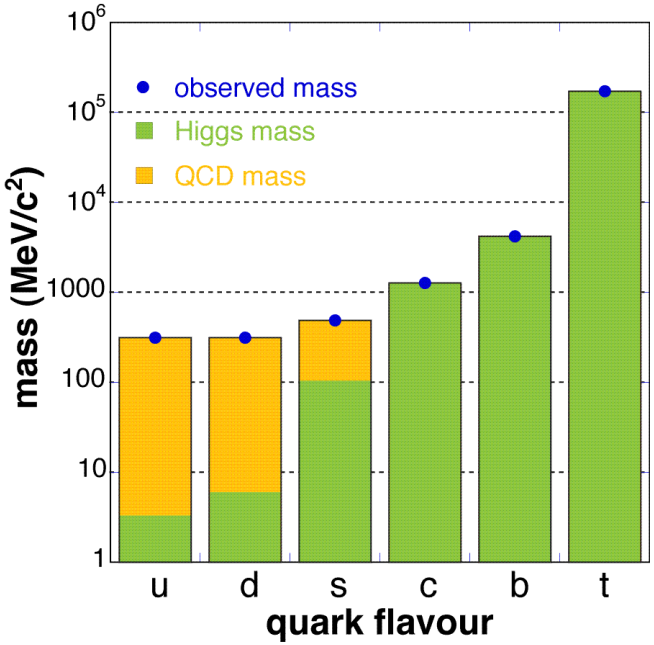


The equation-of-state at neutron star core densities

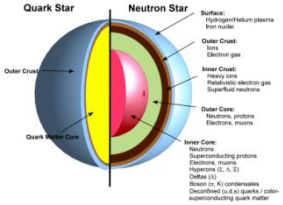
- collective flow of hadrons (driven by pressure)
- particle production at threshold energies (multi-strange hyperons)

Onset of chiral symmetry restoration at high ρ_B

- in-medium modifications of hadrons ($\rho,\omega,\phi \rightarrow e^+e^-(\mu^+\mu^-)$)
- dileptons at intermediate invariant masses: ρ-a_1 chiral mixing

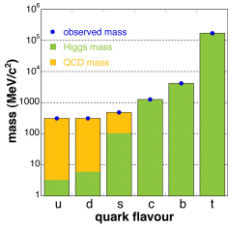


CBM physics case and observables



The equation-of-state at neutron star core densities

- collective flow of hadrons (driven by pressure)
- particle production at threshold energies (multi-strange hyperons)

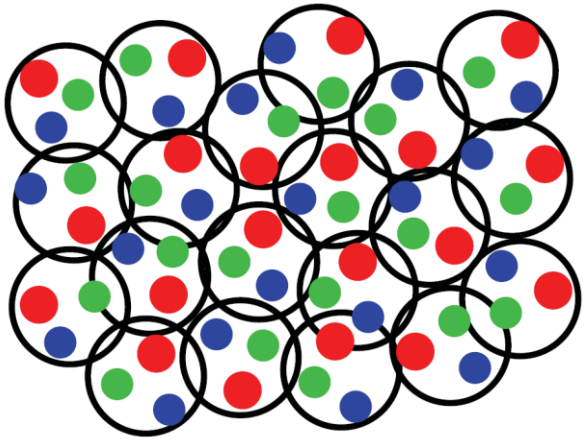


Onset of chiral symmetry restoration at high ρ_B

- in-medium modifications of hadrons ($\rho,\omega,\phi \rightarrow e^+e^-(\mu^+\mu^-)$)
- dileptons at intermediate invariant masses: ρ-a_1 chiral mixing

New phases of strongly-interacting matter

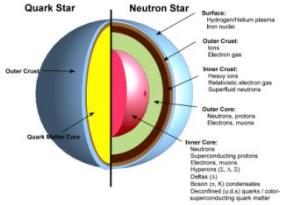
- excitation function and flow of lepton pairs
- excitation function and flow of strangeness (K, Λ, Σ, Ξ, Ω)



CBM physics case and observables

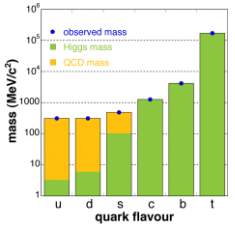
The equation-of-state at neutron star core densities

- collective flow of hadrons (driven by pressure)
- particle production at threshold energies (multi-strange hyperons)



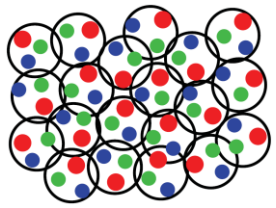
Onset of chiral symmetry restoration at high ρ_B

- in-medium modifications of hadrons ($\rho,\omega,\phi \rightarrow e^+e^-(\mu^+\mu^-)$)
- dileptons at intermediate invariant masses: ρ-a_1 chiral mixing



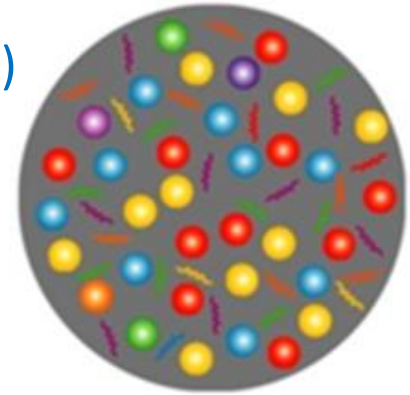
New phases of strongly-interacting matter

- excitation function and flow of lepton pairs
- excitation function and flow of strangeness (K, Λ, Σ, Ξ, Ω)



Deconfinement phase transition at high ρ_B

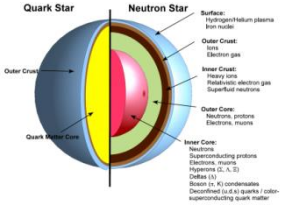
- excitation function and flow of charm (J/ψ, ψ', D^0, $D^{\pm}$, Λ_c)
- anomalouus charmonium suppression



CBM physics case and observables

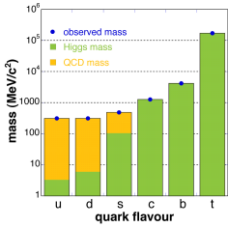
The equation-of-state at neutron star core densities

- collective flow of hadrons (driven by pressure)
- particle production at threshold energies (multi-strange hyperons)



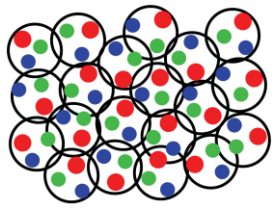
Onset of chiral symmetry restoration at high ρ_B

- in-medium modifications of hadrons ($\rho,\omega,\phi \rightarrow e^+e^-(\mu^+\mu^-)$)
- dileptons at intermediate invariant masses: ρ-a_1 chiral mixing



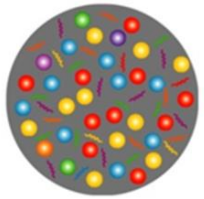
New phases of strongly-interacting matter

- excitation function and flow of lepton pairs
- excitation function and flow of strangeness (K, Λ, Σ, Ξ, Ω)



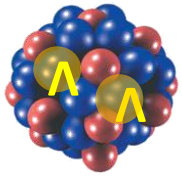
Deconfinement phase transition at high ρ_B

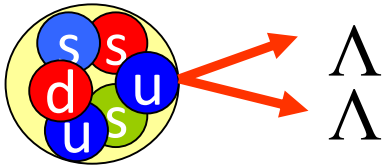
- excitation function and flow of charm (J/ψ, ψ', D^0, $D^{\pm}$, Λ_c)
- anomalouus charmonium suppression

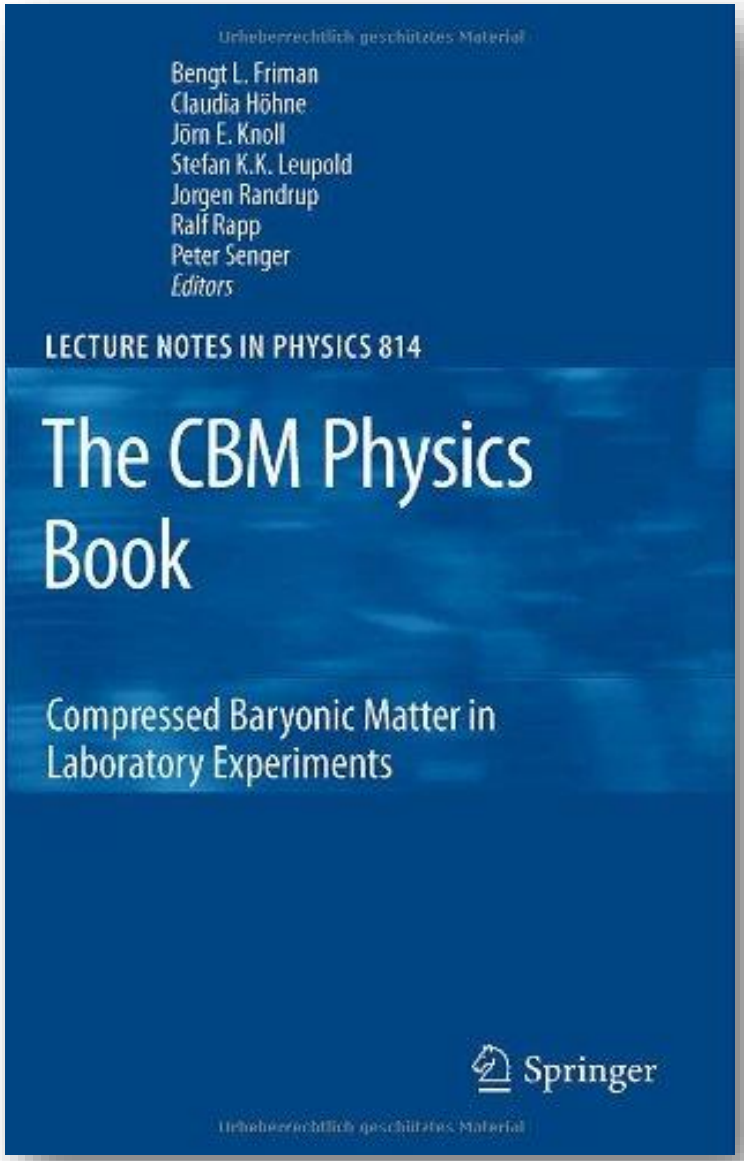


Strange matter

- (double-) lambda hypernuclei
- strange meta-stable objects (e.g. strange dibaryons)







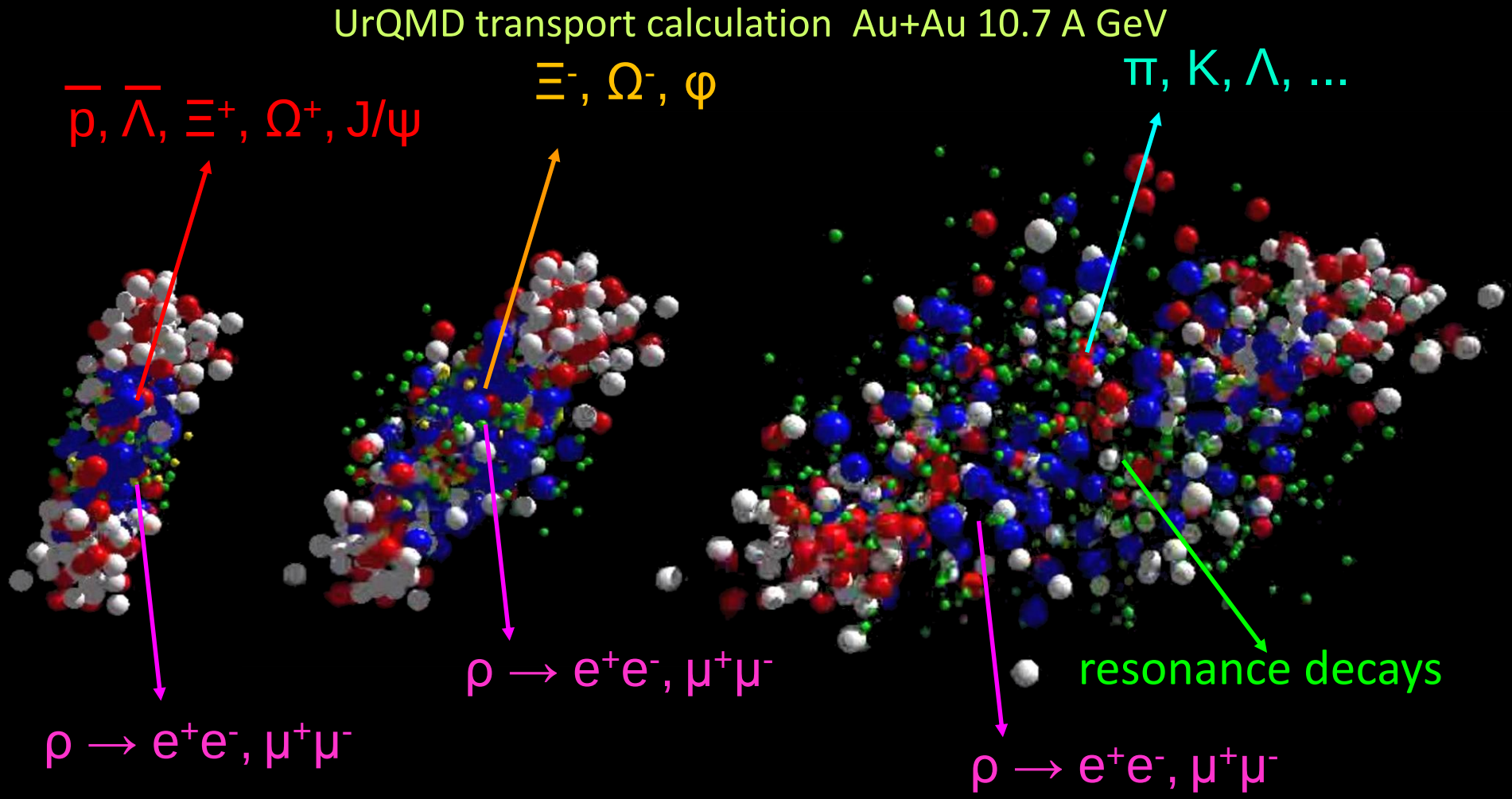
The CBM Physics Book

Foreword by Frank Wilczek

Springer Series:
Lecture Notes in Physics, Vol. 814
1st Edition., 2011, 960 p., Hardcover
ISBN: 978-3-642-13292-6

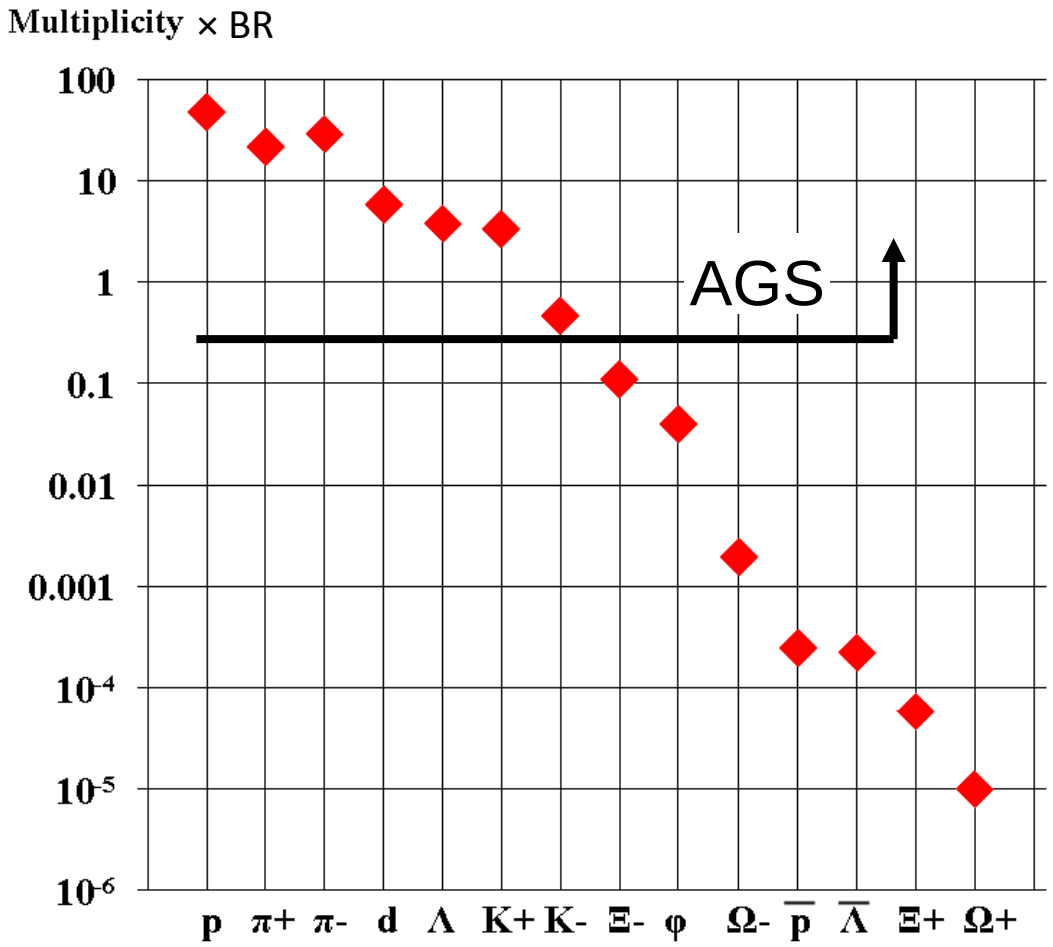
Electronic Authors version:
http://www.gsi.de/documents/DOC-2009-Sep-120-1.pdf

Messengers from the dense fireball: CBM at SIS100

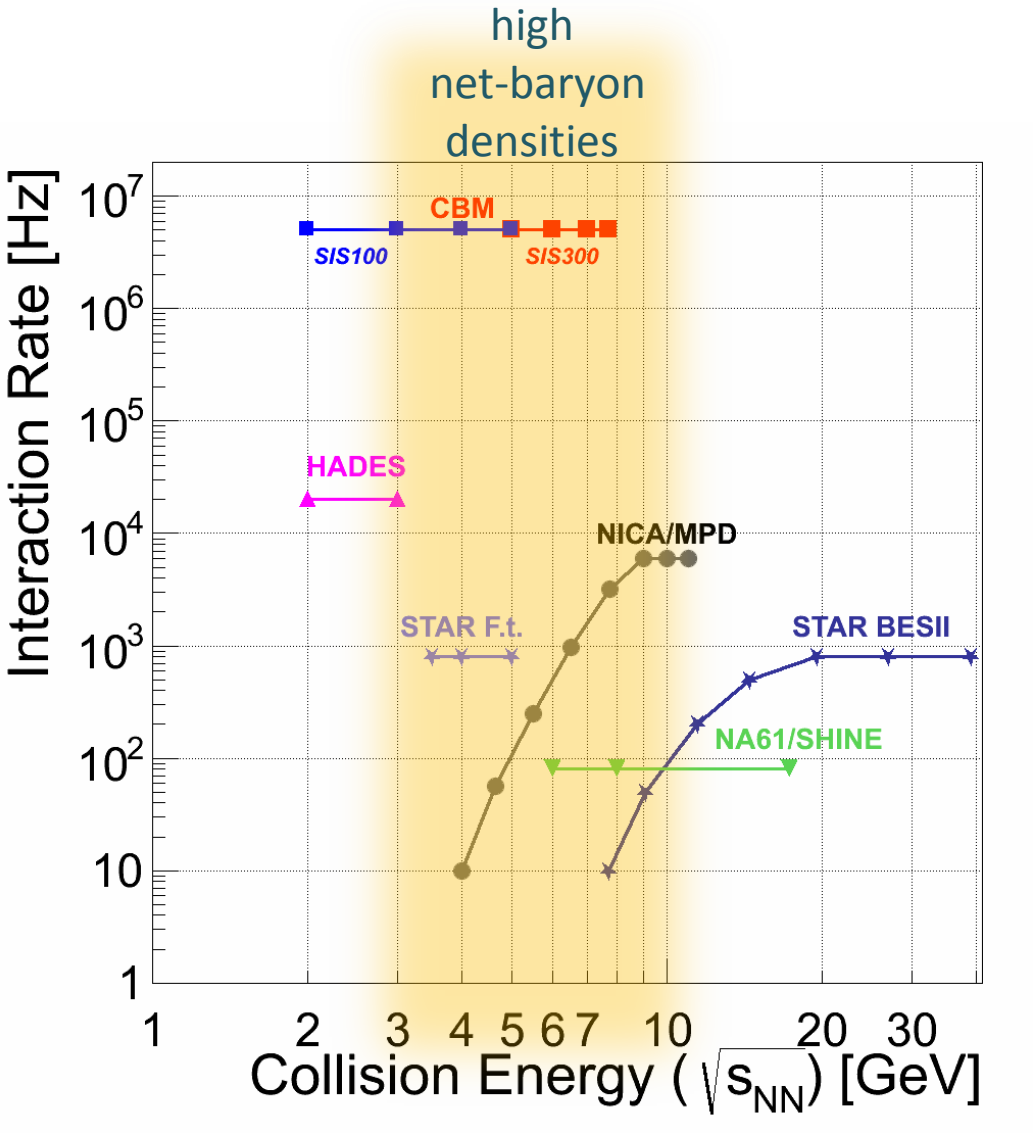


Experimental challenges

Particle yields in central Au+Au 4 A GeV



Experiments exploring dense QCD matter

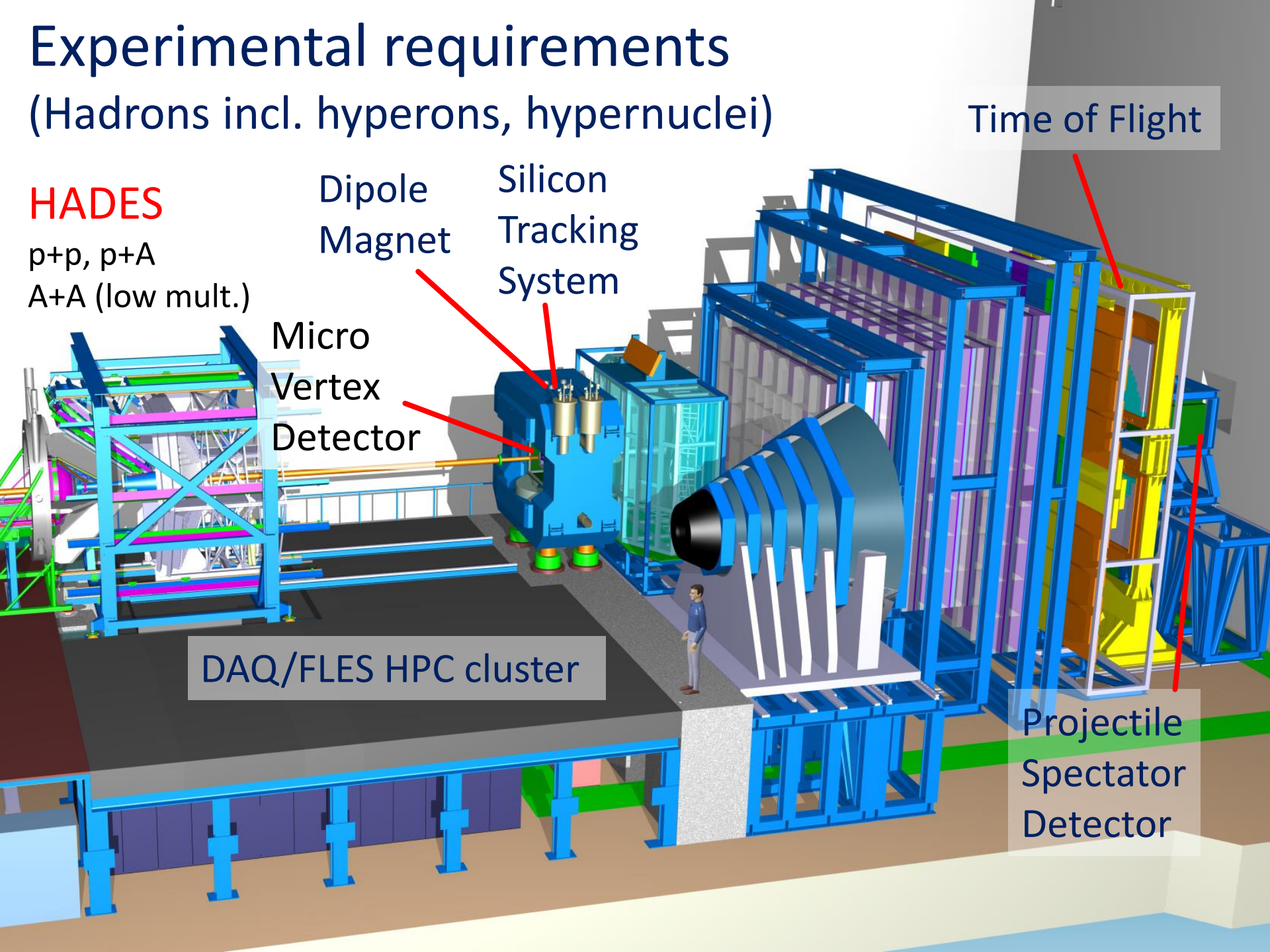


Experimental requirements

- 10^5 - 10^7 Au+Au reactions/sec
- determination of displaced vertices ($\sigma \approx 50\ \mu m$)
- identification of leptons and hadrons
- fast and radiation hard detectors
- free-streaming readout electronics
- high speed data acquisition and high performance computer farm for online event selection
- 4-D event reconstruction

Experimental requirements

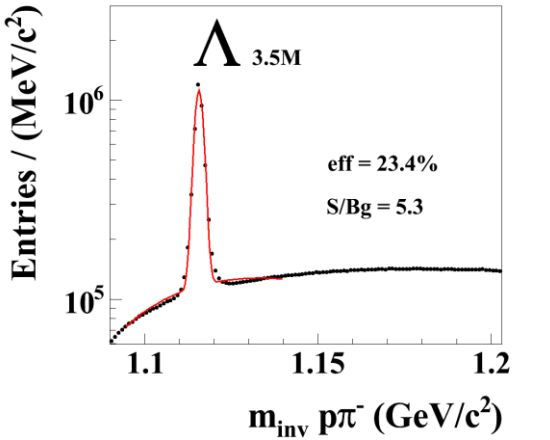
(Hadrons incl. hyperons, hypernuclei)

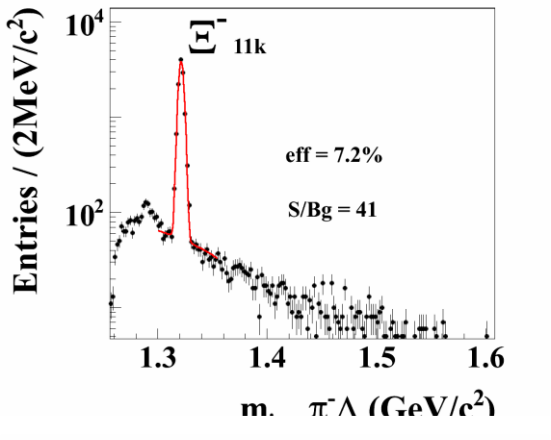


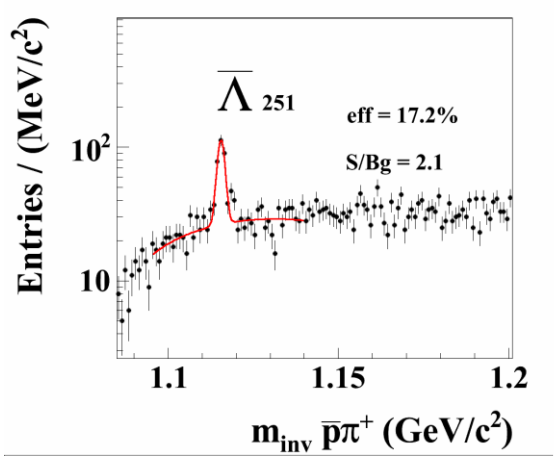
Hyperons in CBM at SIS100

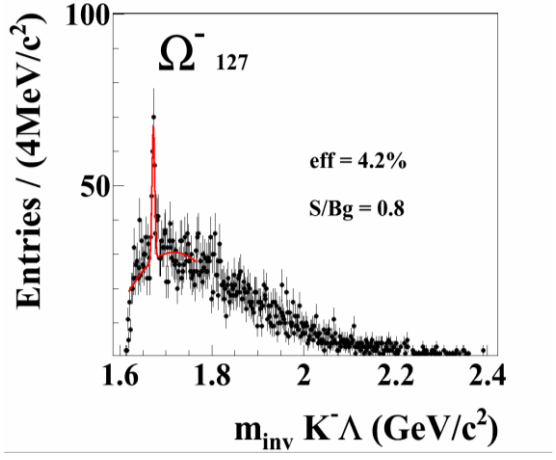
Running scenario: Au+Au, C+C at 4, 6, 8, 10 A GeV

Example: Au+Au at 8 A GeV, 10^6 central collisions









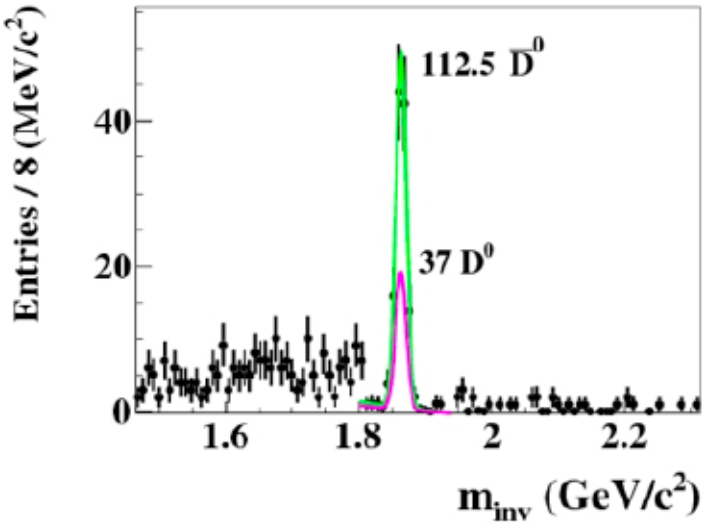
- In addition:
  K*,Λ*,Σ*,Ξ*,Ω*
- Event rate:
  100 kHz to 1 MHz

Open charm in CBM at SIS100

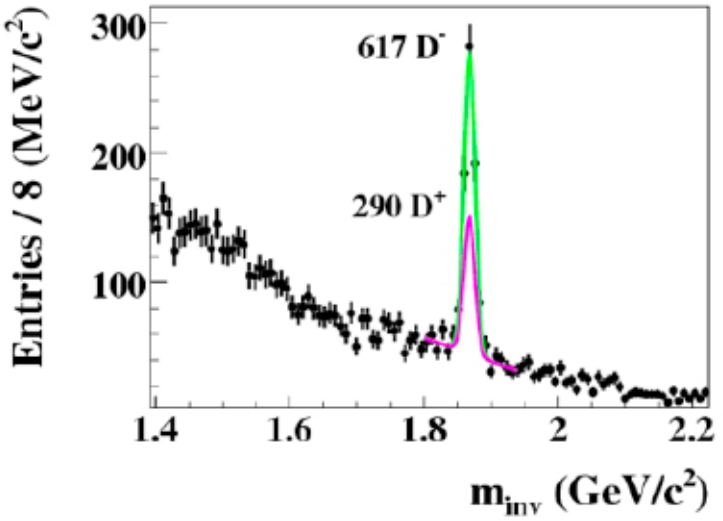
- Charm production cross sections at threshold energies
- Charm propagation in cold nuclear matter

30 GeV p + C

$D^0 \rightarrow K\pi\pi\pi$

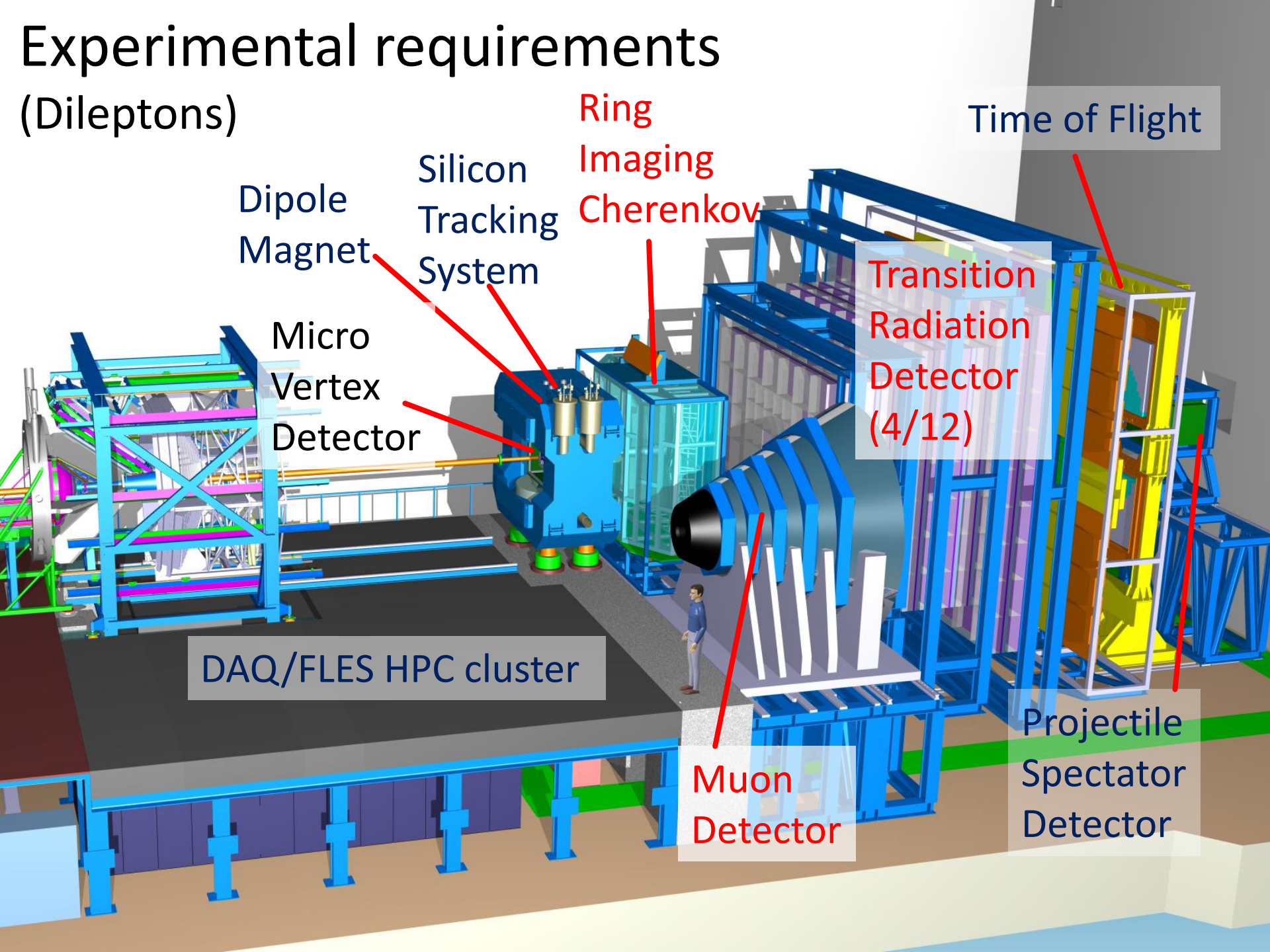


$D^{\pm} \rightarrow K\pi\pi$



Experimental requirements

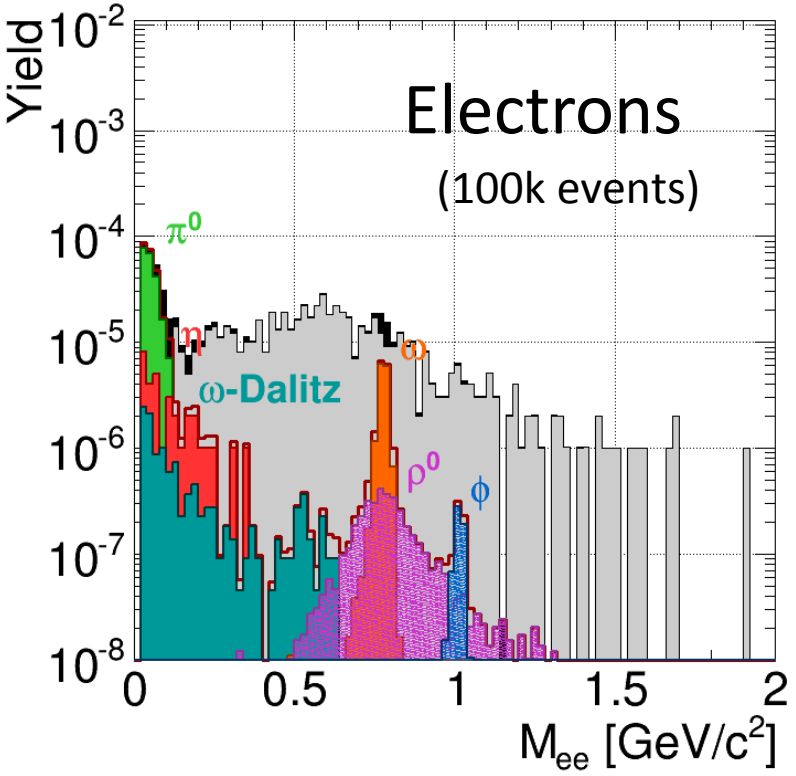
(Dileptons)

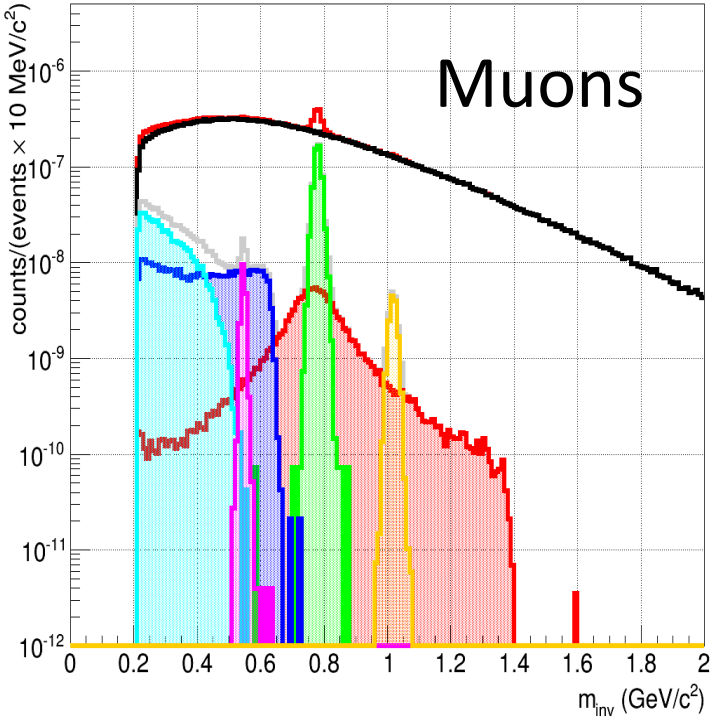


Leptons in CBM at SIS100

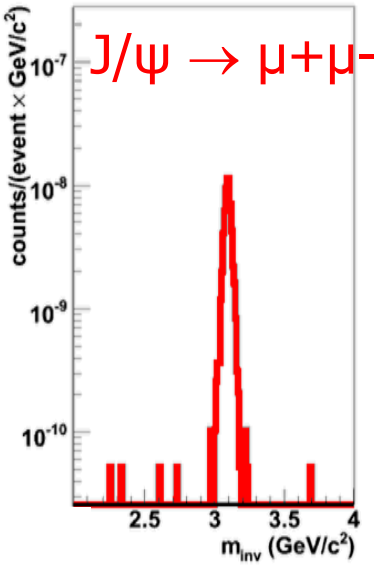
Simulation: Signal yields from HSD, Background from UrQMD

central Au+Au at 8 A GeV: 2×10^6 ω in 2 weeks





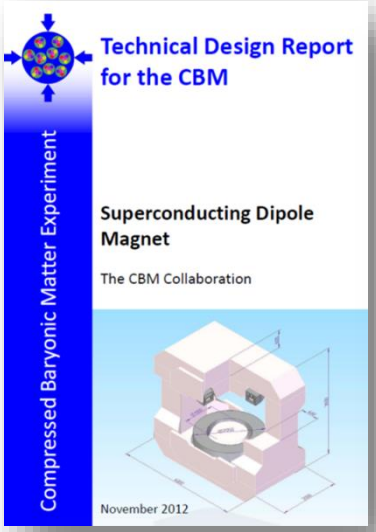
30 GeV p+Au

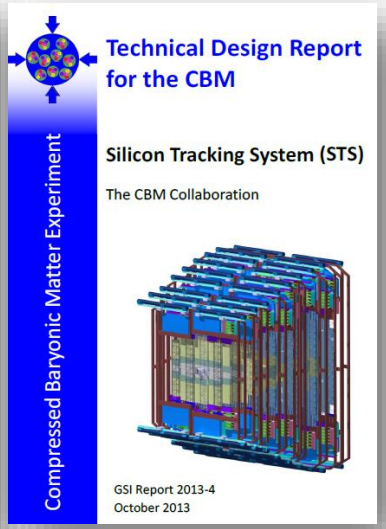


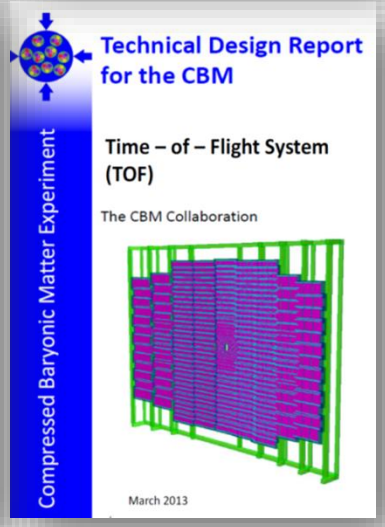
1000 J/ψ
in 10^{12} events
(1 day)

CBM Technical Design Reports

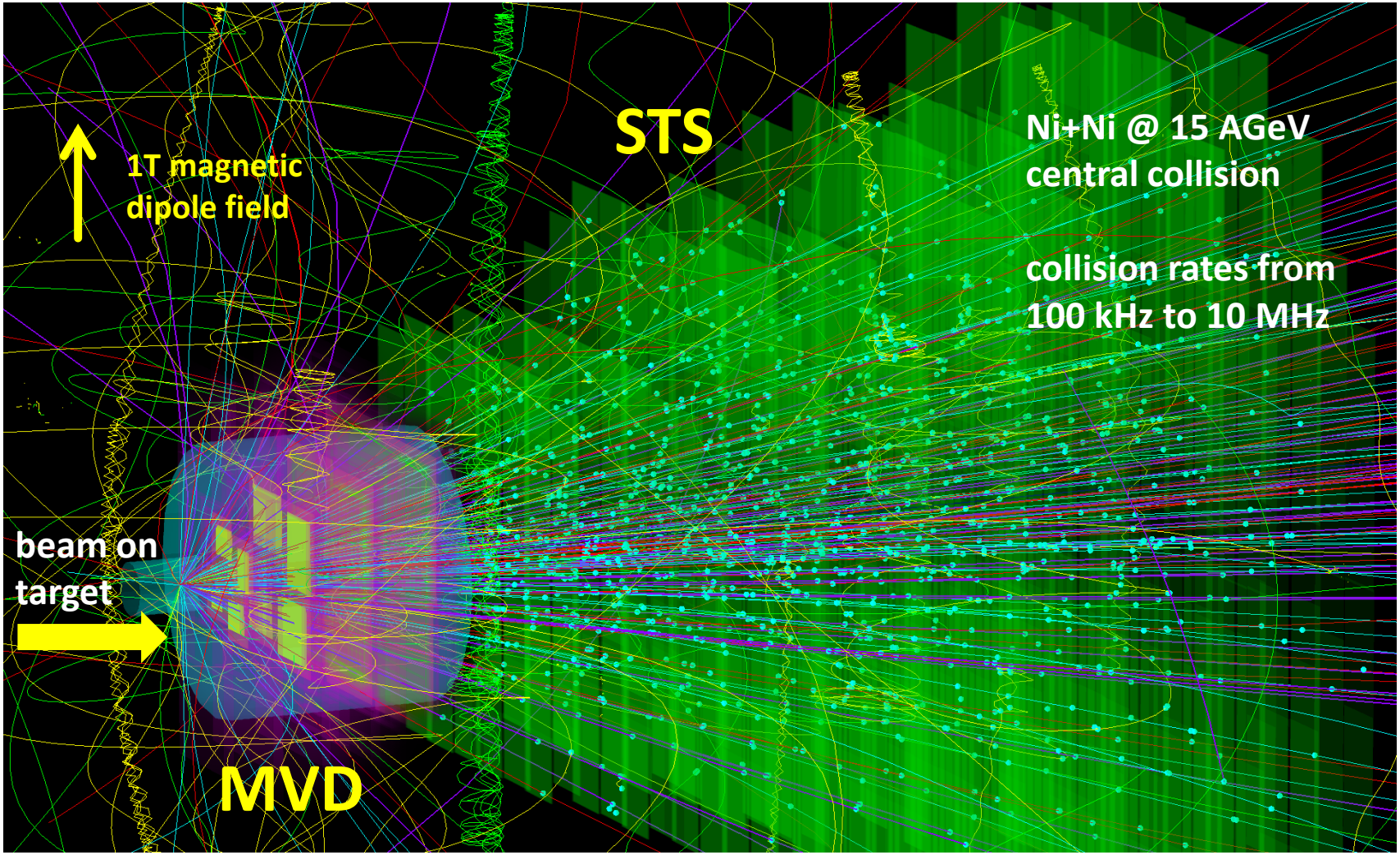
#	Project	TDR Status
1	Magnet	approved
2	STS	approved
3	RICH	approved
4	TOF	approved
5	MuCh	approved
6	HADES ECAL	approved
7	PSD	approved
8	MVD	submission 2016
9	DAQ/FLES	submission 2016
10	TRD	submission 2016
11	ECAL	submission 2016



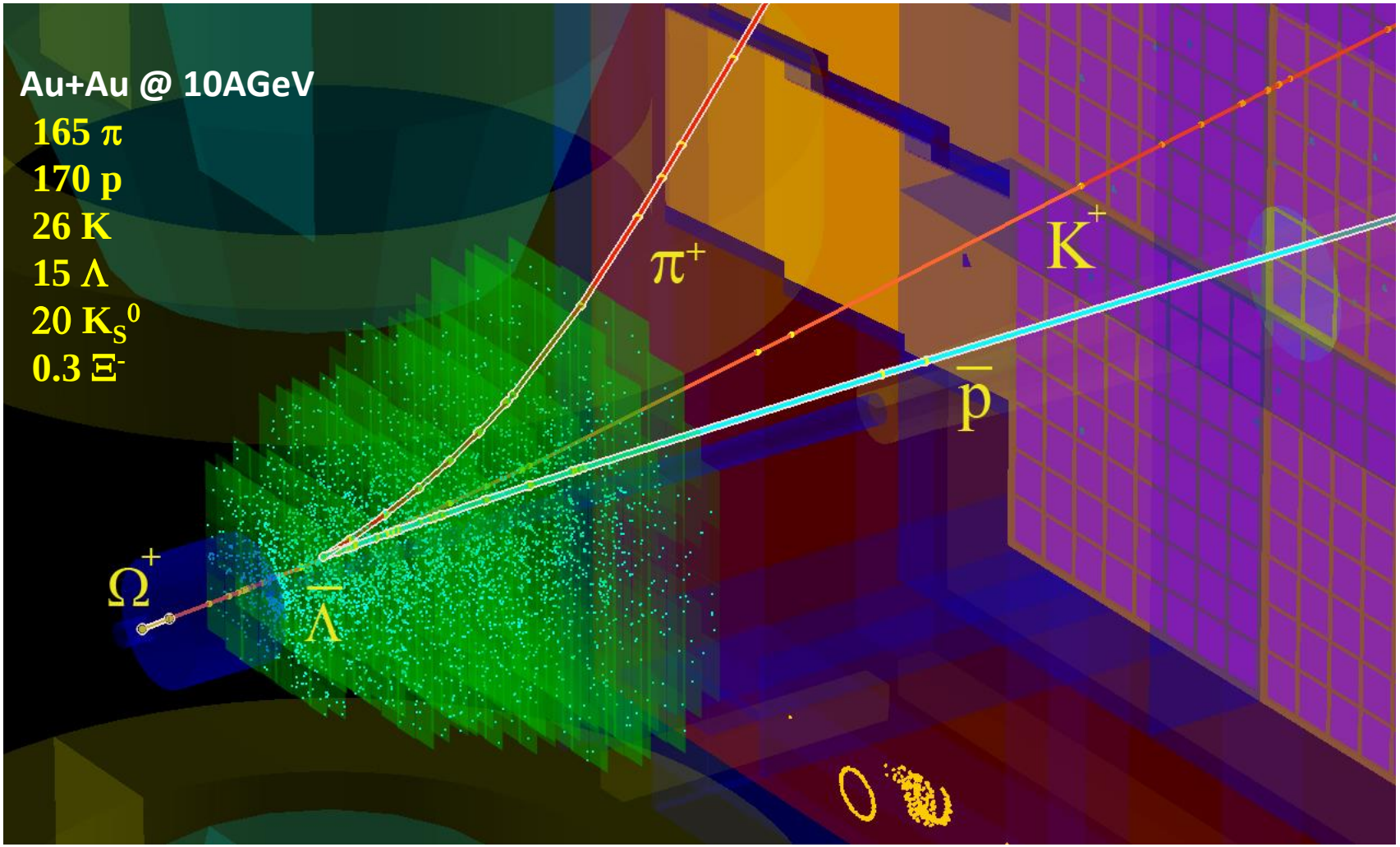




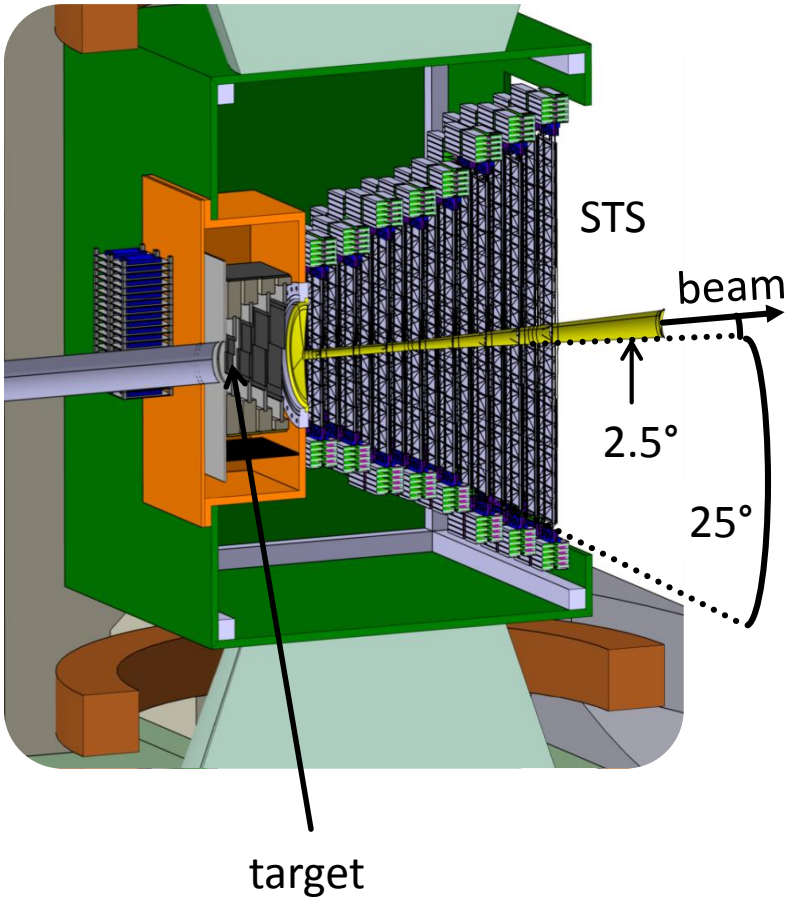
Tracking nuclear collisions

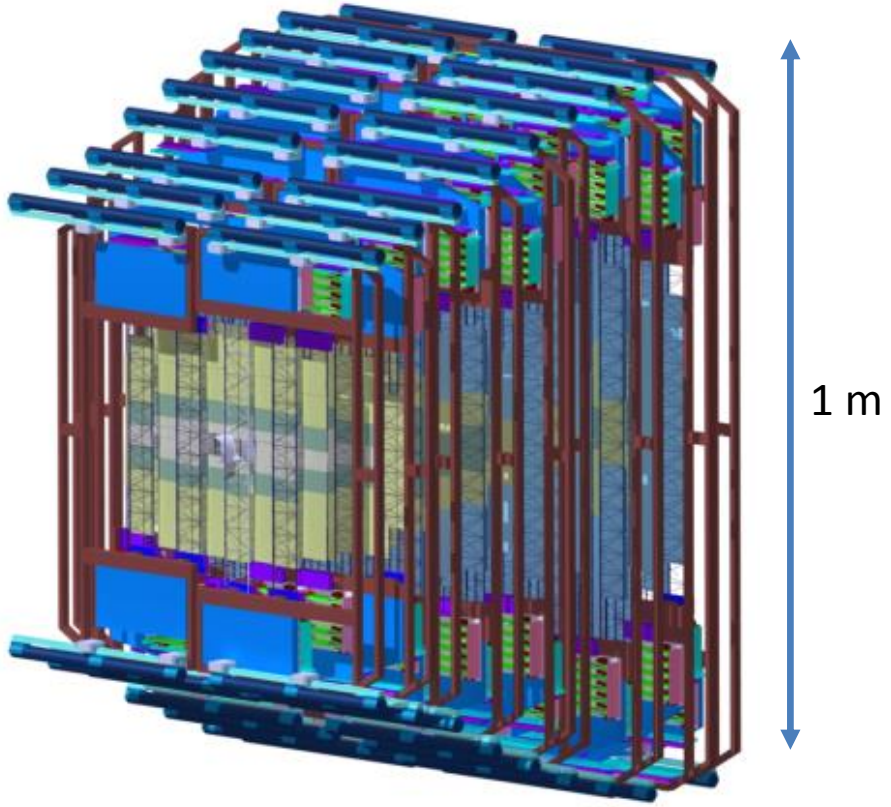


Physics signatures



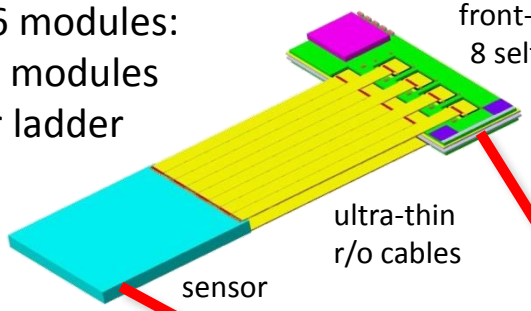
Silicon Tracking System



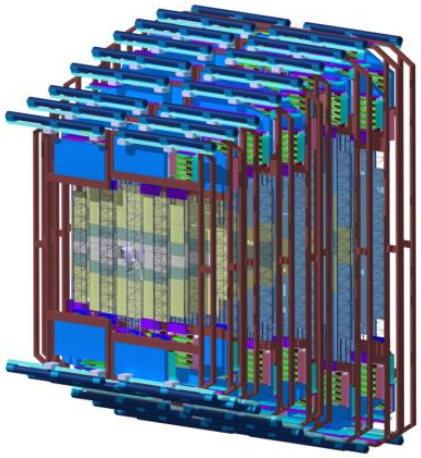


STS integration

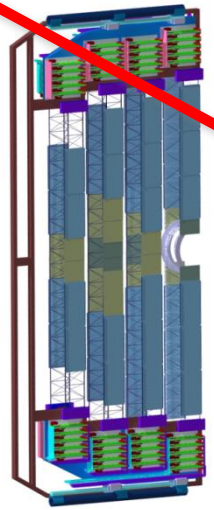
896 modules:
4-5 modules
per ladder



- 8 stations, volume 2 m^3, area 4 m^2
- 896 detector modules
  - 1220 double-sided microstrip sensors
  - ~ 1.8 million read-out channels
  - ~ 16 000 r/o STS-XYTER ASICs
  - ~ 58 000 ultra-thin r/o cables
- 106 detector ladders with 4-5 modules
- power dissipation: 42 kW (CO_2 cooling)

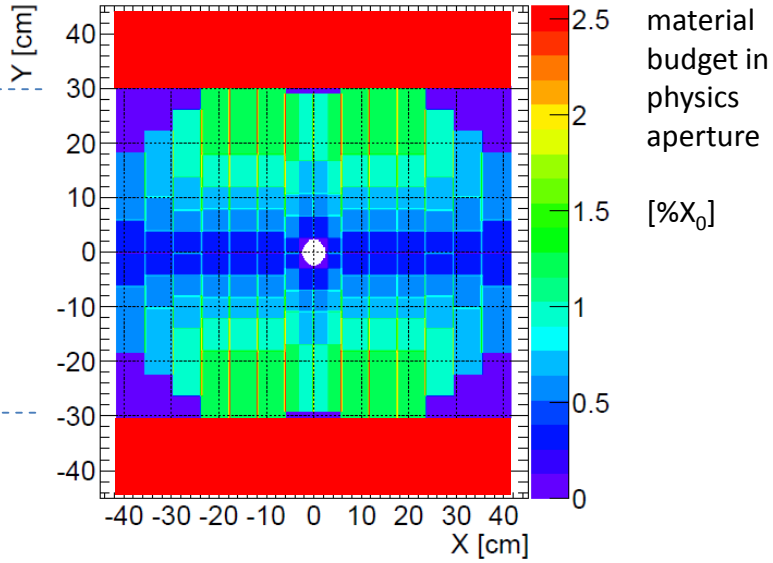


8 tracking stations



18 half-units

106 ladders



CBM-STS teams

17 groups from 4 countries

- ***Darmstadt, Germany, GSI Helmholtz Center (GSI)***
- *Karlsruhe, Germany, Karlsruhe Institute of Technology (KIT)*
- *Tübingen, Germany, Eberhard Karls University (EKU)*

- *Katowice, Poland, University of Silesia (Usilesia)*
- *Krakow, Poland, AGH University of Science and Technology*
- *Krakow, Poland, Jagiellonian University (JU)*
- *Warsaw, Poland, Warsaw University of Technology (WUT)*
- *Warsaw, Poland, University of Warsaw (UWarsaw)*

- ***Dubna, Russia, Joint Institute for Nuclear Research (JINR)***
- *Moscow, Russia, Inst. for Theoretical and Exp. Physics (ITEP)*
- *Moscow, Russia, Moscow State University (SINP-MSU)*
- *Protvino, Russia, Institute for High Energy Physics (IHEP)*
- *St. Petersburg, Russia, Ioffe Physical-Technical Institute (Ioffe)*
- *St. Petersburg, Russia, Khlopin Radium Institute (KRI)*
- *St. Petersburg, Russia, St. Petersburg State Polytechnic Univ. (SPbSPU)*

- *Kharkov, Ukraine, LED Technologies of Ukraine Ltd (LTU)* * Partner
- *Kiev, Ukraine, Kiev Institute for Nuclear Research (KINR)*

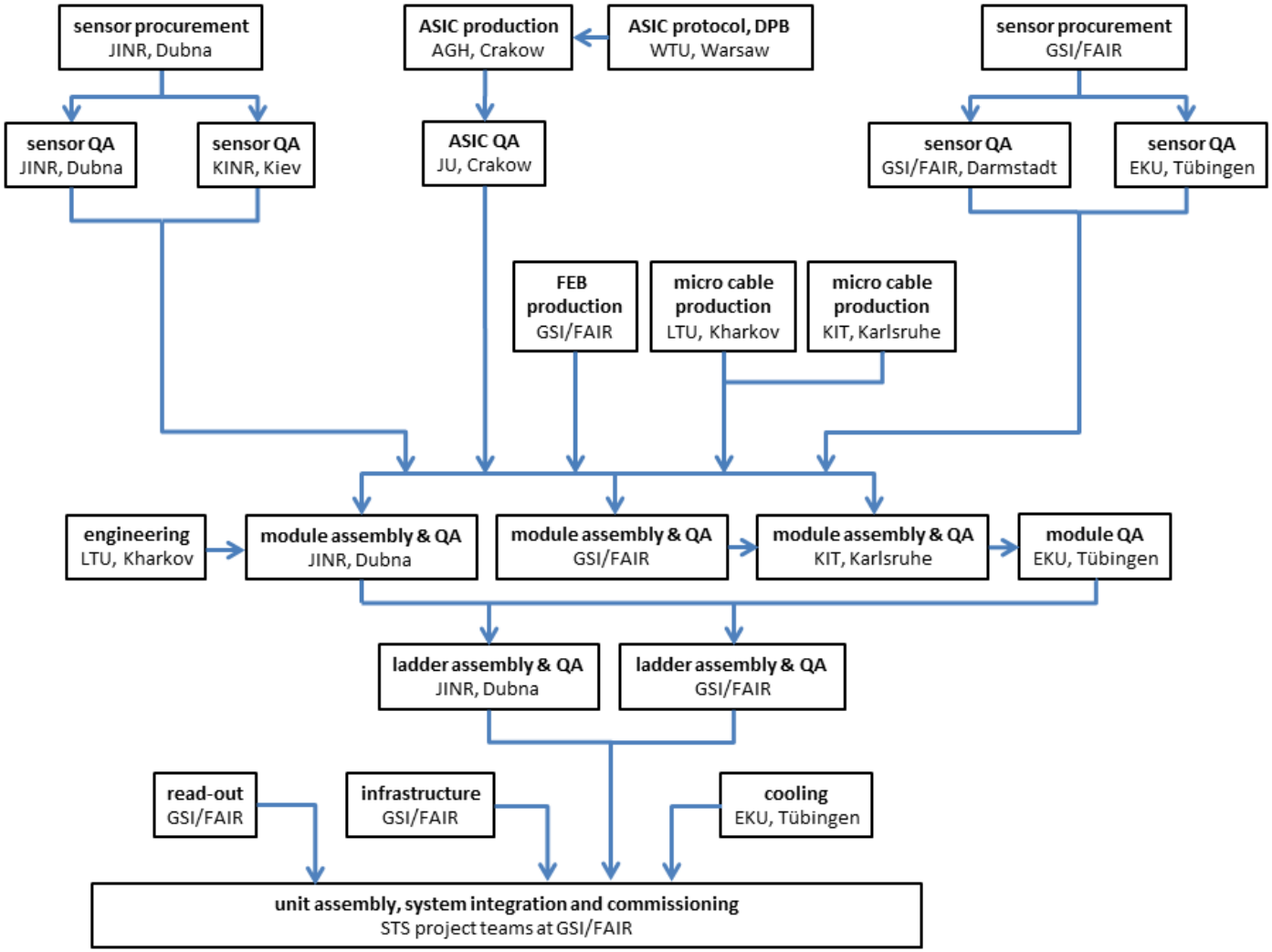
STS assembly centers: GSI and JINR


clean rooms, Solid State Section


realized in GSI + JINR cooperation with BMBF-JINR funding (2015)

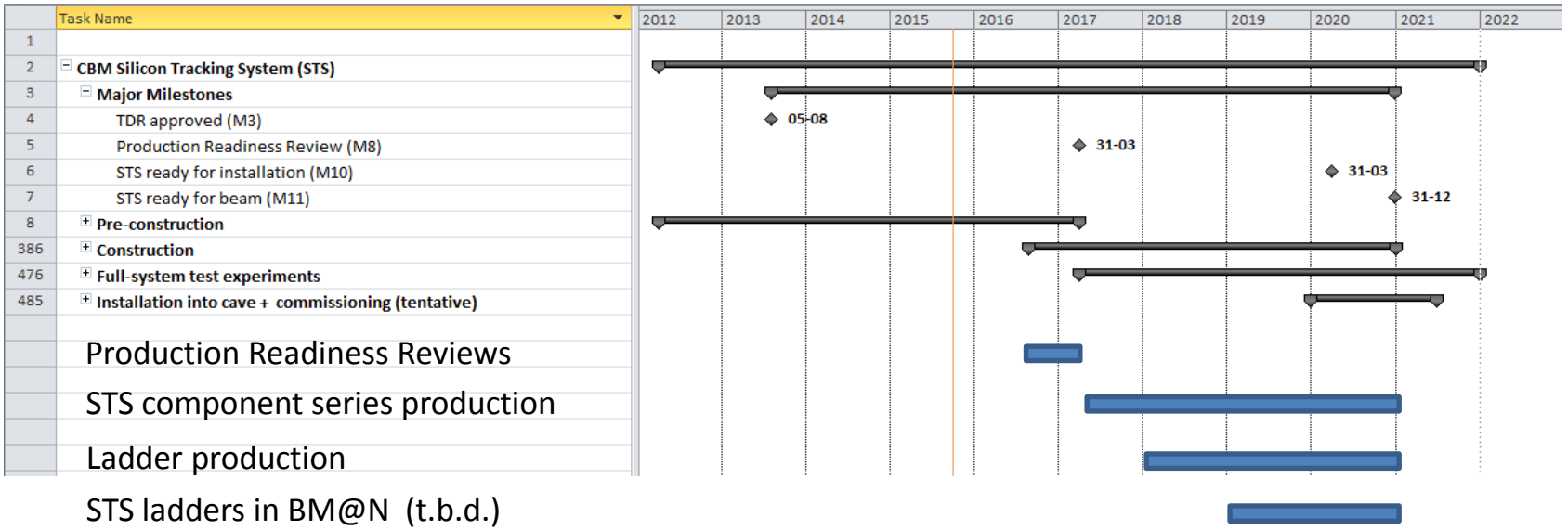
support by BMBF-JINR and EU-Horizon2020 CREMLIN grants

CBM-STS assembly flow



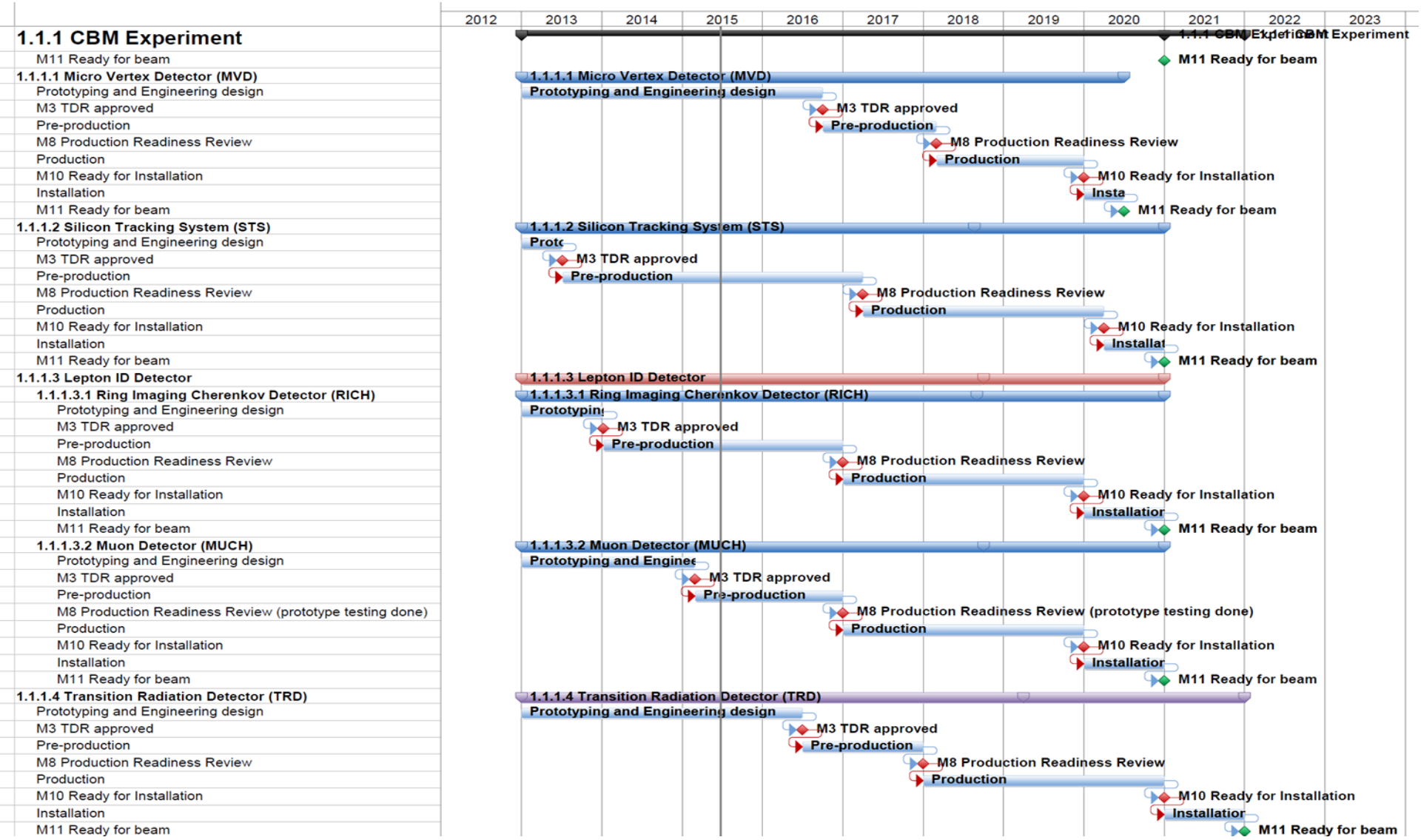
CBM-STS Workshops

CBM-STS project plan

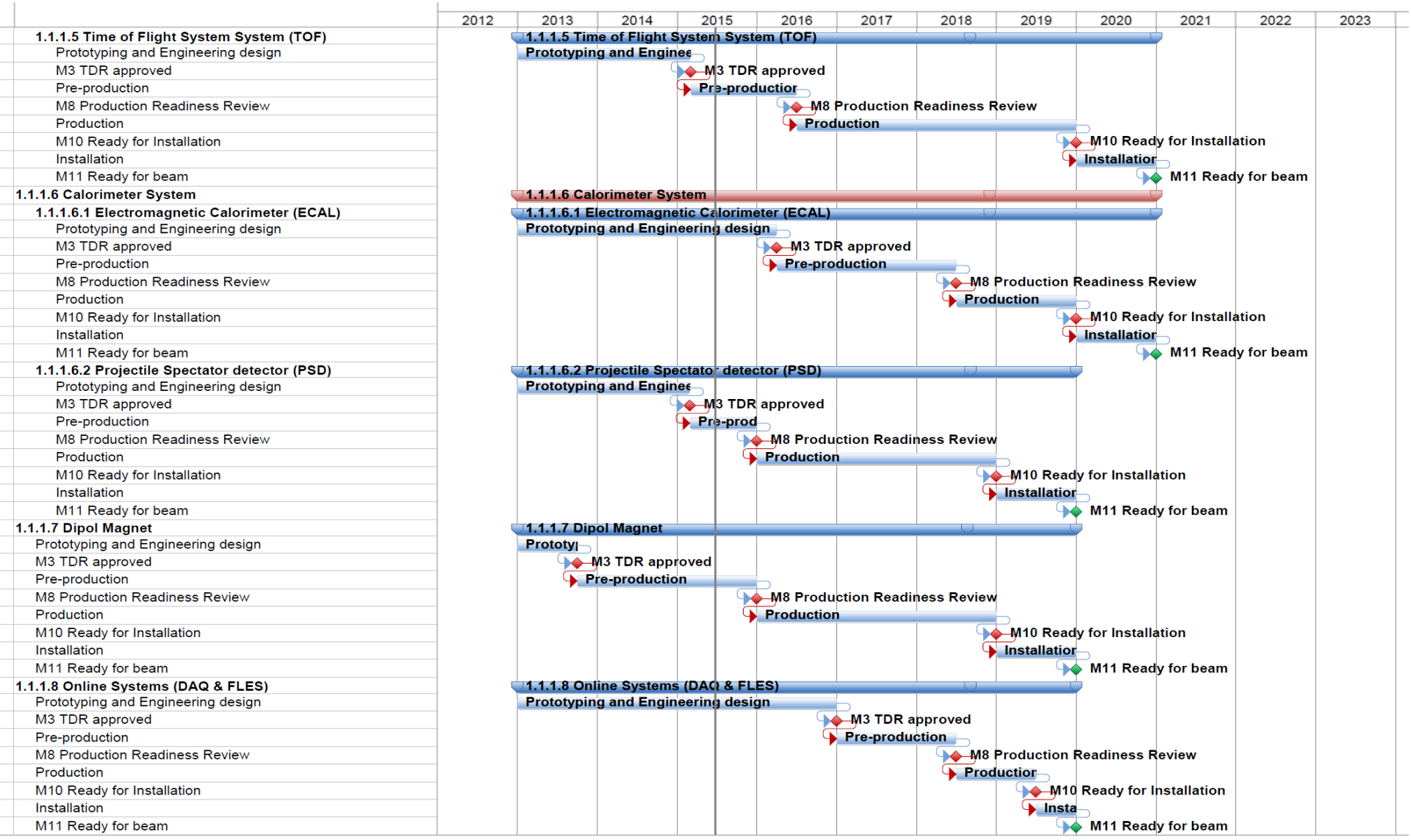


- Possible use of additional CBM-STS ladders in the BM@N experiment (t.b.d.)
- CBM-STS ladders can only be available after the start of component series production:
  - start of ladder production: early 2018
  - ladders in experiments: 2019 onwards

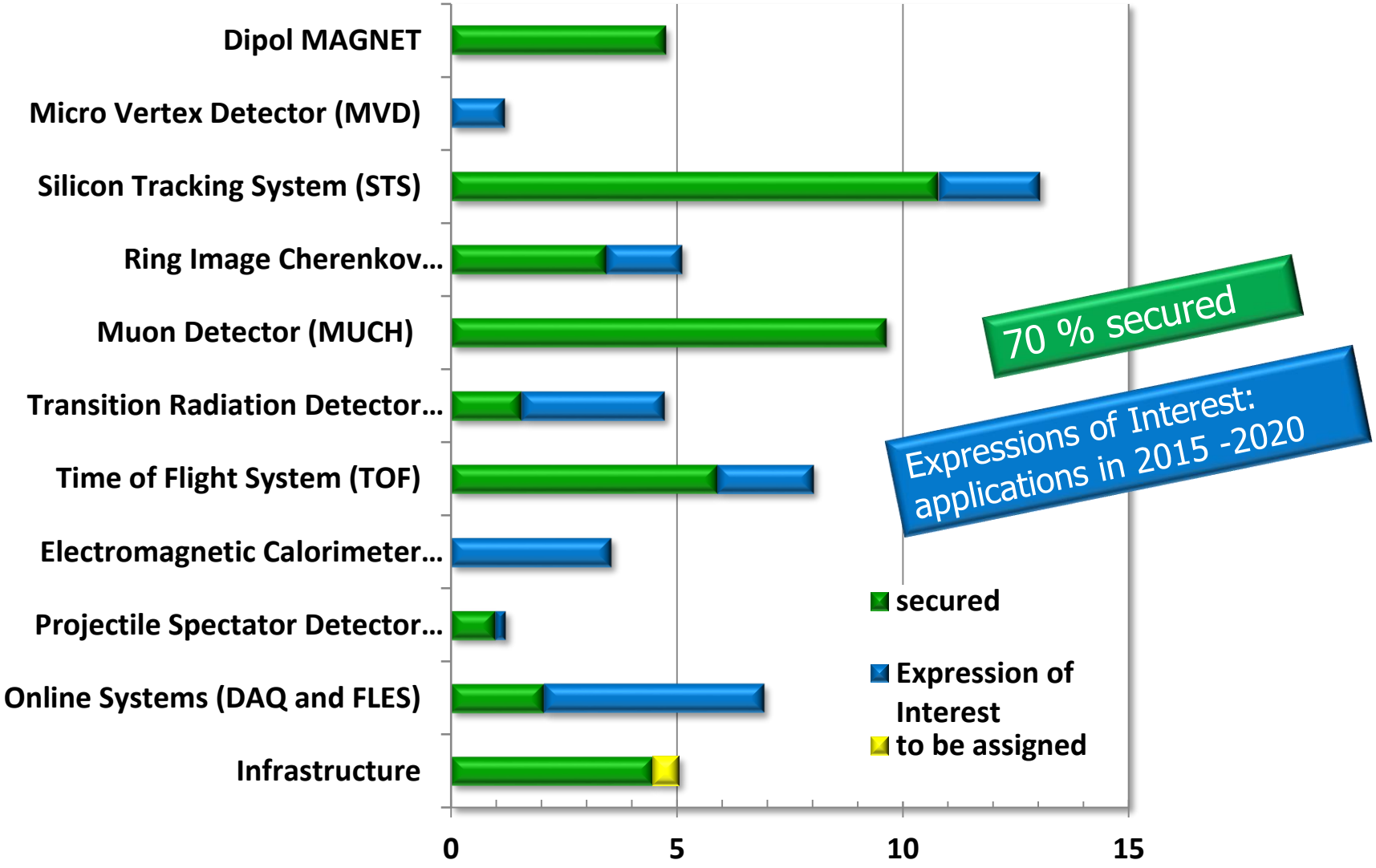
CBM time line



CBM time line



Costs and funding – CBM Start version



Facility for Antiproton & Ion Research

FAIR phase 1

FAIR phase 2

The CBM Collaboration: 60 institutions, 530 members

Croatia:
Split Univ.

China:
CCNU Wuhan
Tsinghua Univ.
USTC Hefei
CTGU Yichang

Czech Republic:
CAS, Rez
Techn. Univ.Prague

France:
IPHC Strasbourg

Hungary:
KFKI Budapest
Budapest Univ.

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.

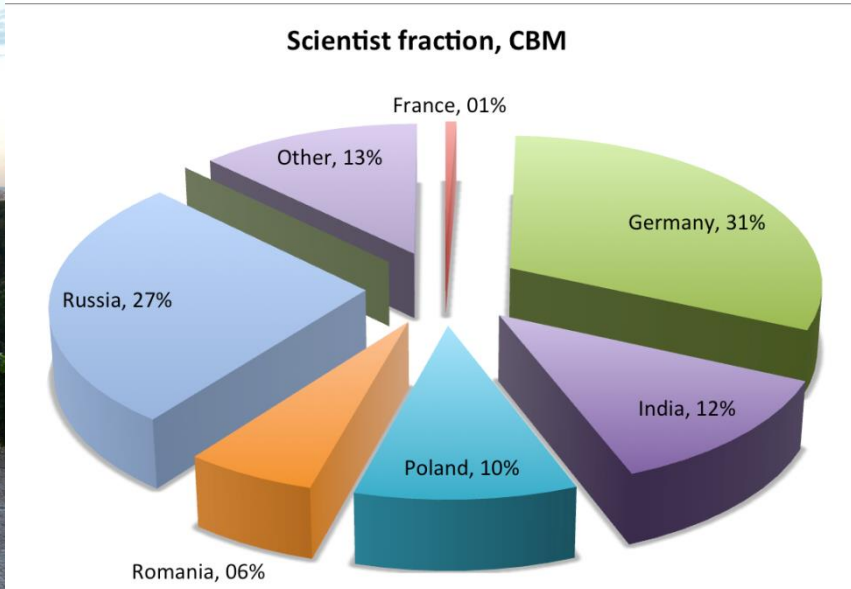
Korea:
Pusan Nat. Univ.

Romania:
NIPNE Bucharest
Univ. Bucharest

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

Russia:
IHEP Protvino
INR Troitzk
ITEP Moscow
Kurchatov Inst., Moscow
LHEP, JINR Dubna
LIT, JINR Dubna
MEPHI Moscow
Obninsk Univ.
PNPI Gatchina
SINP MSU, Moscow
St. Petersburg P. Univ.
Ioffe Phys.-Tech. Inst. St. Pb.

Ukraine:
T. Shevchenko Univ. Kiev
Kiev Inst. Nucl. Research



Summary

- **CBM scientific program at SIS100:**
  Exploration of the QCD phase diagram in the region of neutron star core densities
  $\rightarrow$ large discovery potential.
- **First measurements with CBM:**
  High-precision multi-differential measurements of hadrons incl. multistrange hyperons, hypernuclei and dileptons for different beam energies and collision systems $\rightarrow$ terra incognita.
- **Status of experiment preparation:**
  Prototype detector performances fulfill CBM requirements.
  7 TDRs approved, 4 TDRs in preparation.
- **Silicon Tracking System:**
  Central detector of the experiment: charged-particle tracking, momentum measurement.
  Development and construction in close cooperation of GSI and JINR. Electronics from Poland.
  Using part of the STS detector for system tests at GSI and/or physics runs at external labs is under consideration: $\rightarrow$ BM@N, JINR
- **Funding:**
  Substantial part of the CBM start version is financed (+ Expressions of Interest).
- **CBM time line:**
  Resource loaded schedules for most of the detectors.
  Ready to take first beam end of 2020.