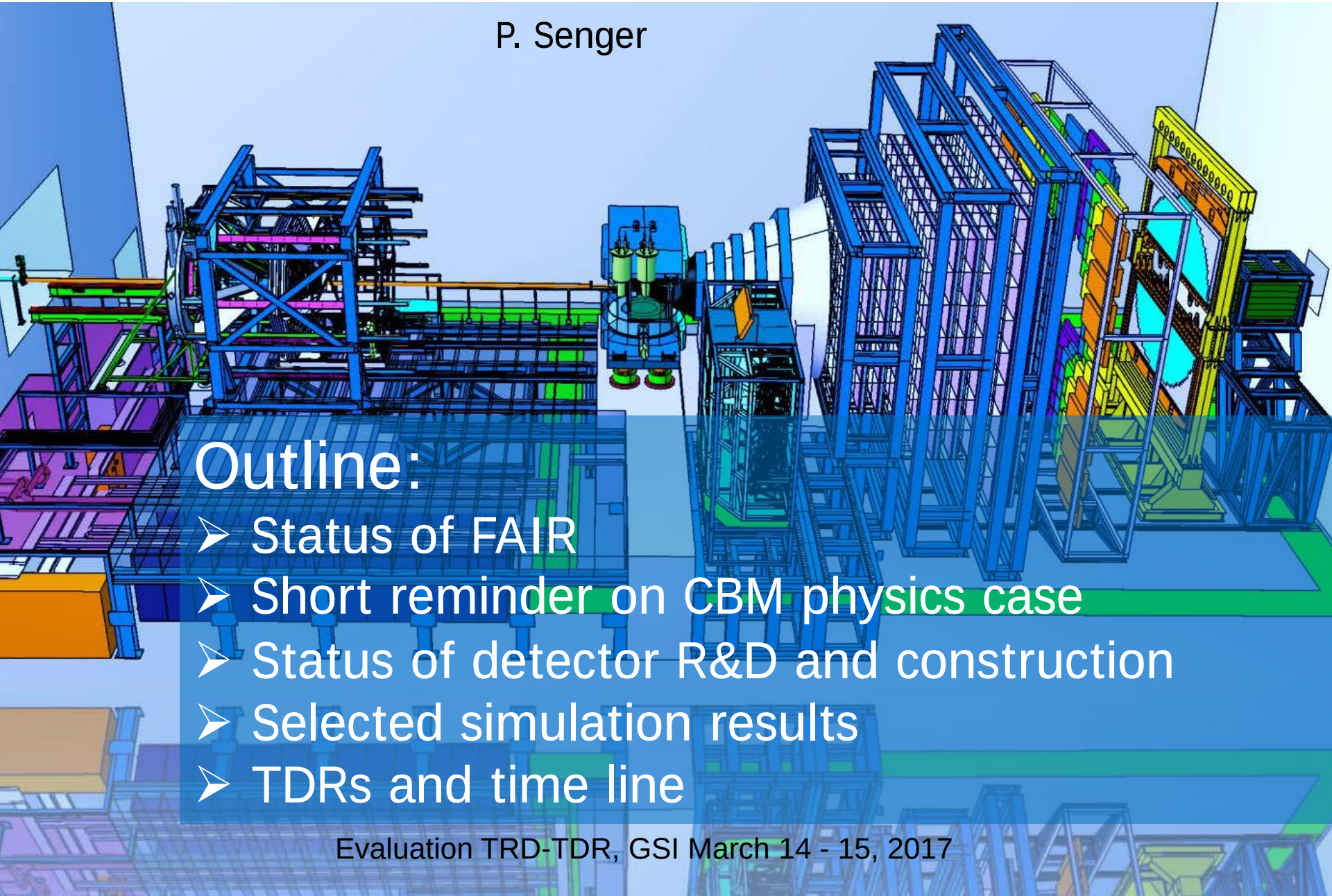
The Compressed Baryonic Matter experiment

P. Senger

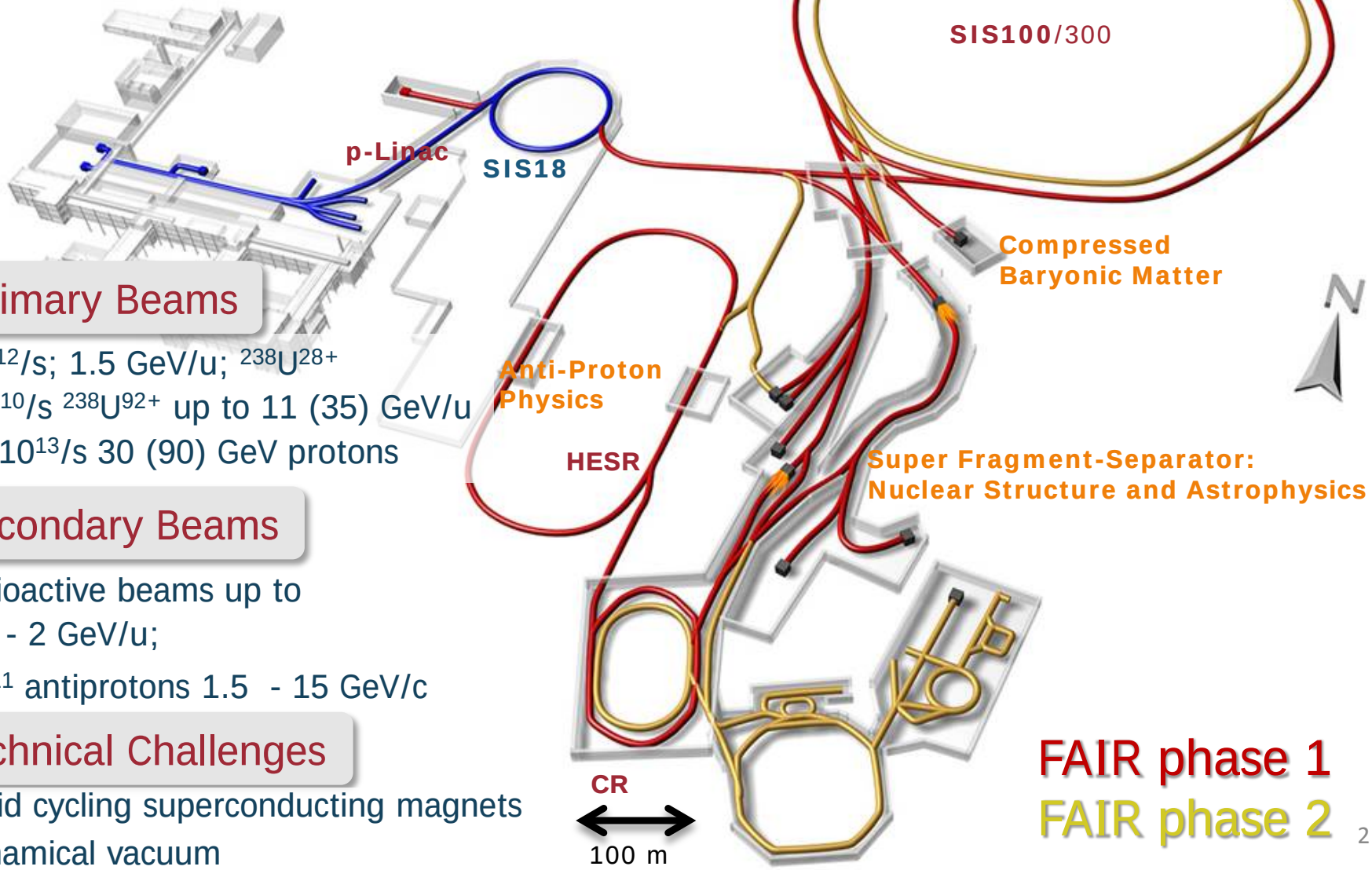


Outline:

- Status of FAIR
- Short reminder on CBM physics case
- Status of detector R&D and construction
- Selected simulation results
- TDRs and time line

Evaluation TRD-TDR, GSI March 14 - 15, 2017

Facility for Antiproton & Ion Research



Primary Beams

- 10^{12}/s; 1.5 GeV/u; $^{238}U^{28+}$
- 10^{10}/s $^{238}U^{92+}$ up to 11 (35) GeV/u
- 3x10^{13}/s 30 (90) GeV protons

Secondary Beams

- radioactive beams up to 1.5 - 2 GeV/u;
- 10^{11} antiprotons 1.5 - 15 GeV/c

Technical Challenges

- rapid cycling superconducting magnets
- dynamical vacuum

FAIR phase 1

FAIR phase 2

Facility for Antiproton & Ion Research

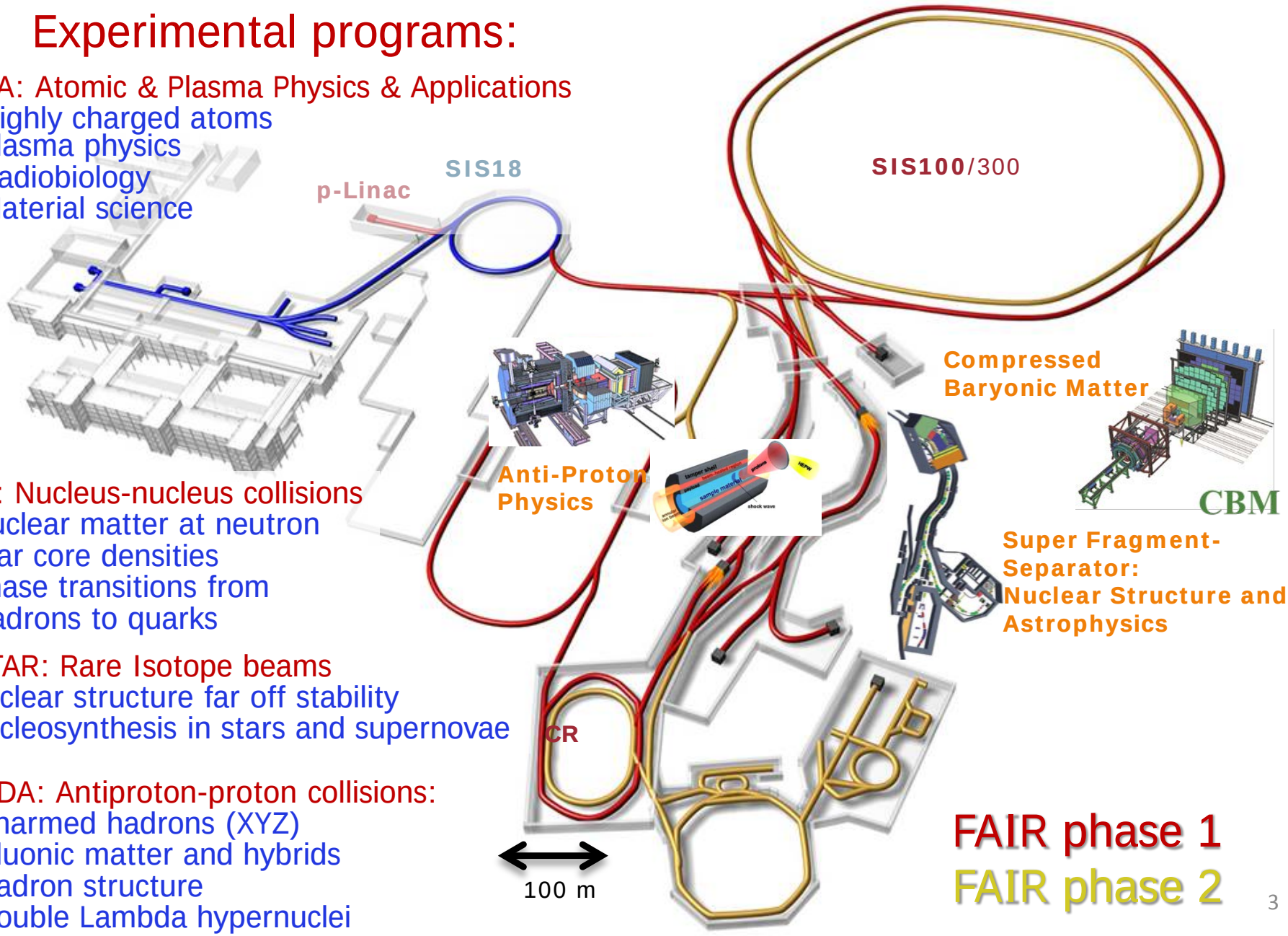
Experimental programs:

APPA: Atomic & Plasma Physics & Applications
- Highly charged atoms
- Plasma physics
- Radiobiology
- Material science

CBM: Nucleus-nucleus collisions
- Nuclear matter at neutron star core densities
- Phase transitions from hadrons to quarks

NUSTAR: Rare Isotope beams
- Nuclear structure far off stability
- Nucleosynthesis in stars and supernovae

PANDA: Antiproton-proton collisions:
- Charmed hadrons (XYZ)
- Gluonic matter and hybrids
- Hadron structure
- Double Lambda hypernuclei



FAIR phase 1

FAIR phase 2

Status of FAIR

On Sept. 13, 2016 BMBF gave green light and 203 M€ to start civil construction.

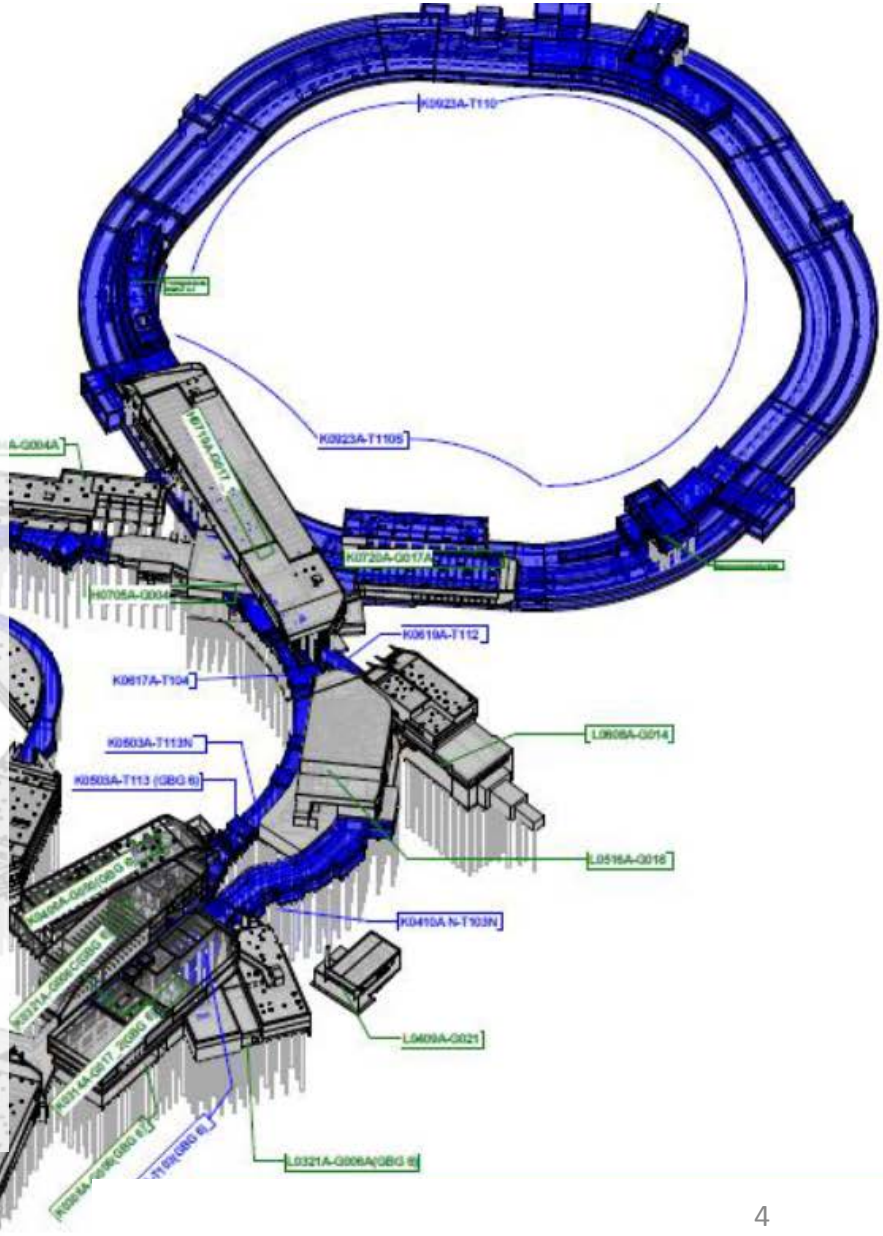
1st call for tender Sept. 26, 2016: water management and excavation

2nd call for tender Nov. 22, 2016: shell construction ‘north area’, includes SIS100 and CBM cave

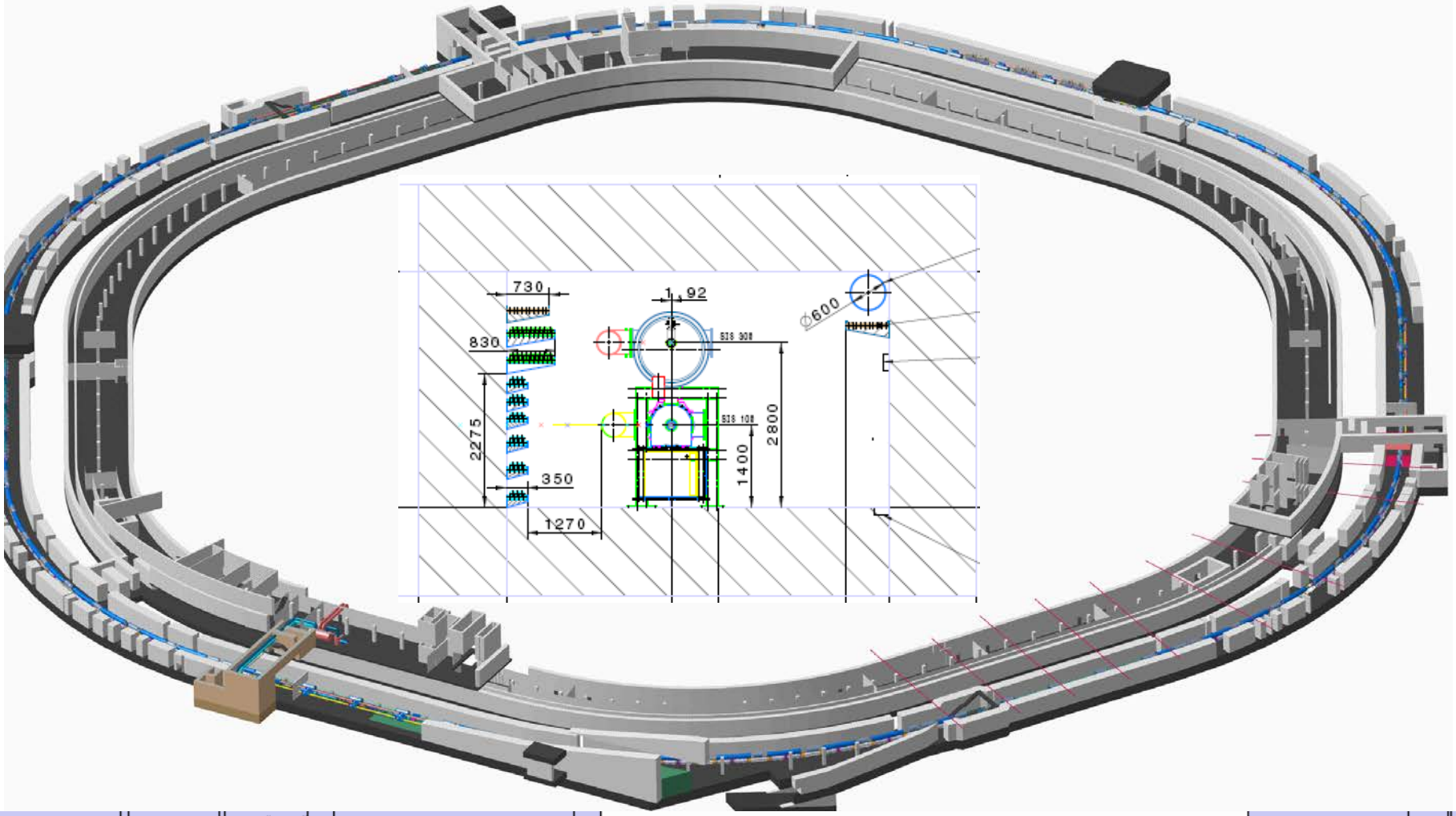
Start of construction mid of 2017

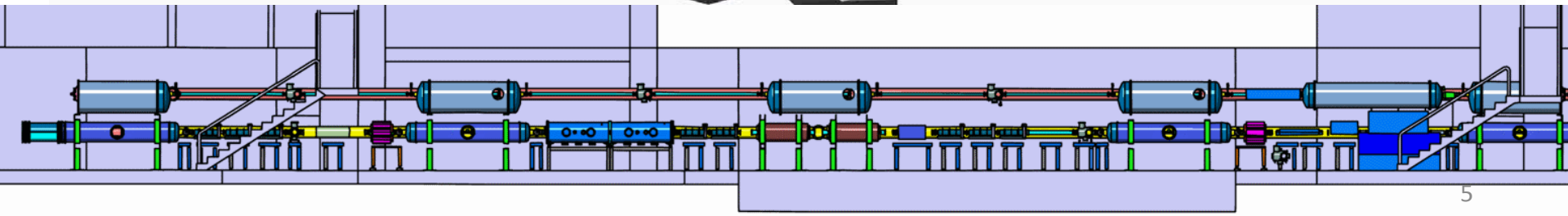
Installation incl. commissioning of the experiments is planned during 2021-2024

Full completion of FAIR by 2025



Tunnel for SIS100/300

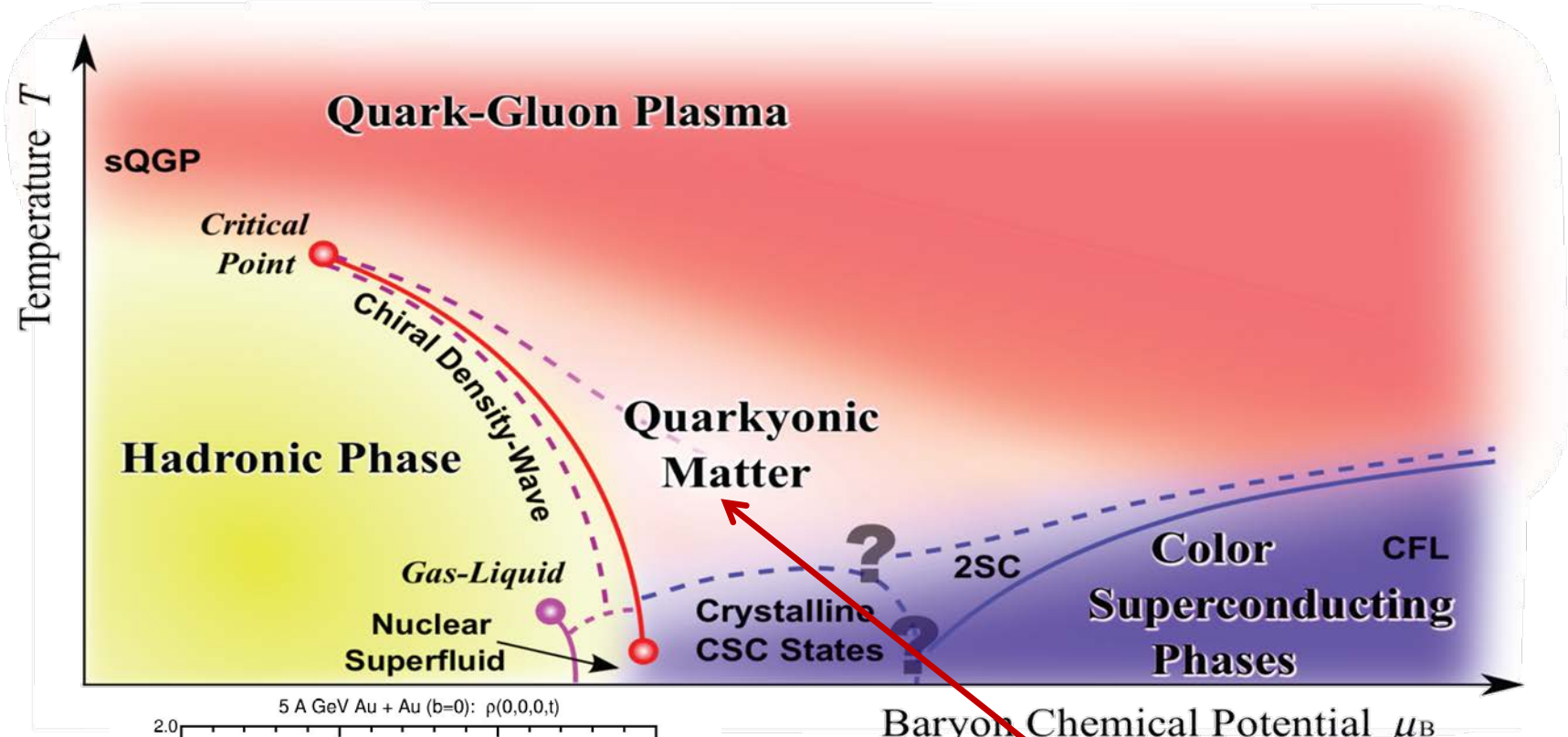




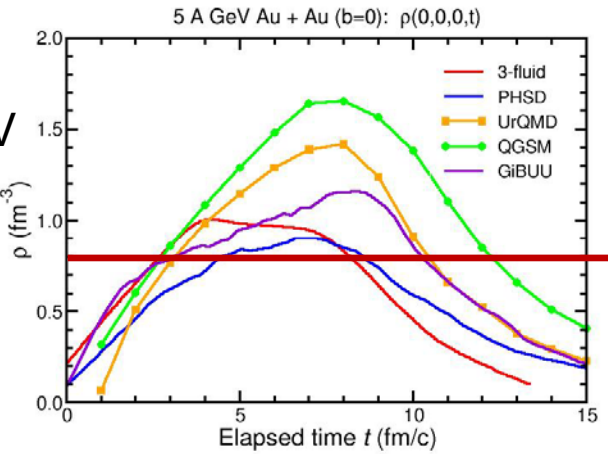
The Compressed Baryonic Matter (CBM) experiment

4000 tons of steel plates transported from KIT to FAIR for the CBM beam dump

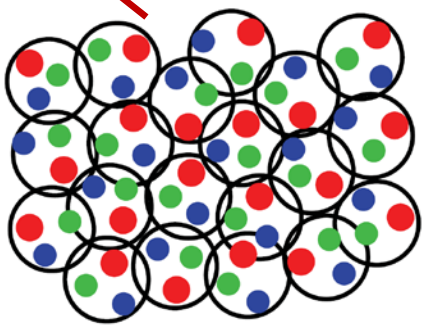
Exploring the QCD phase diagram



Au+Au
5 A GeV

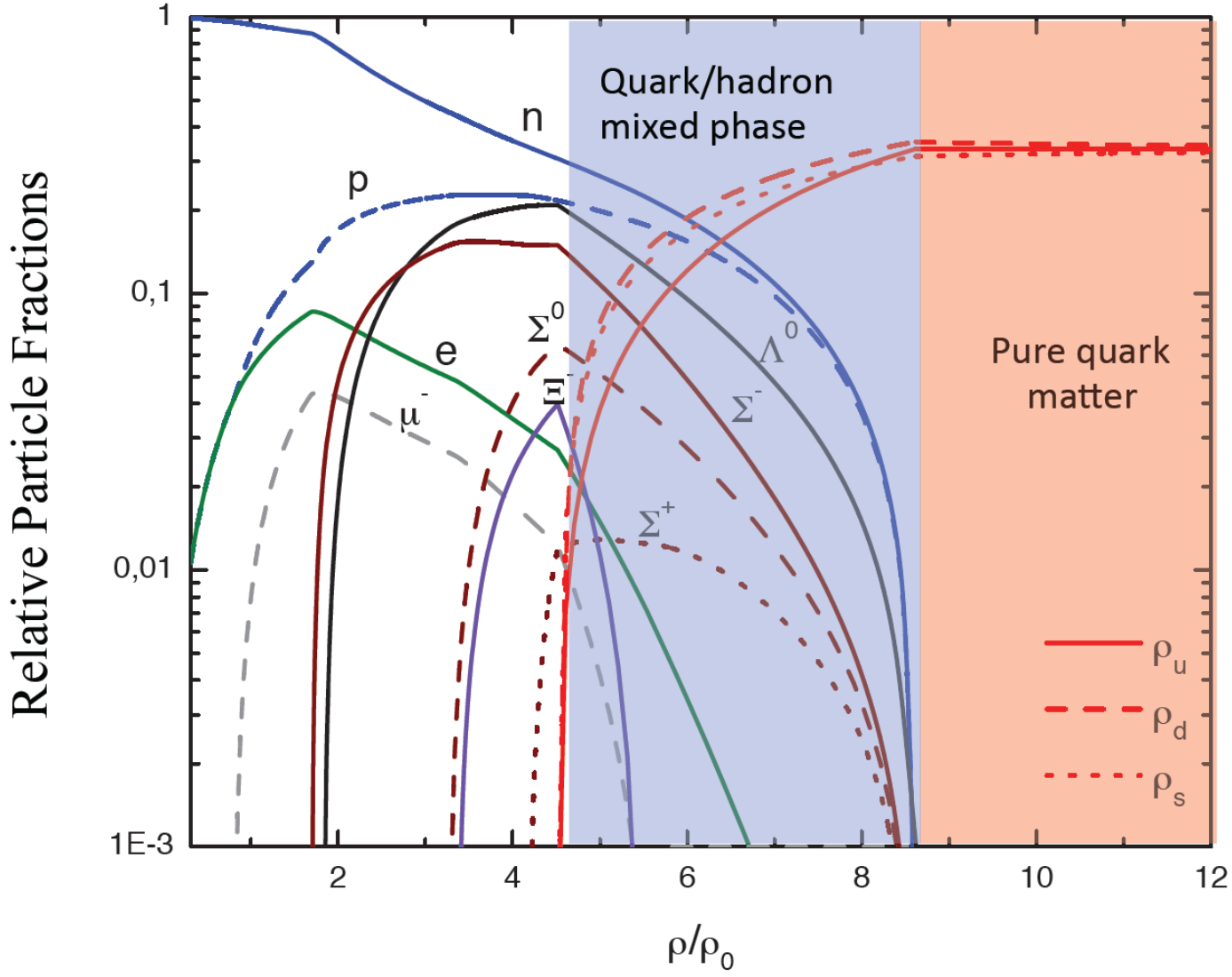


5 ρ_0



Quark matter in massive neutron stars?

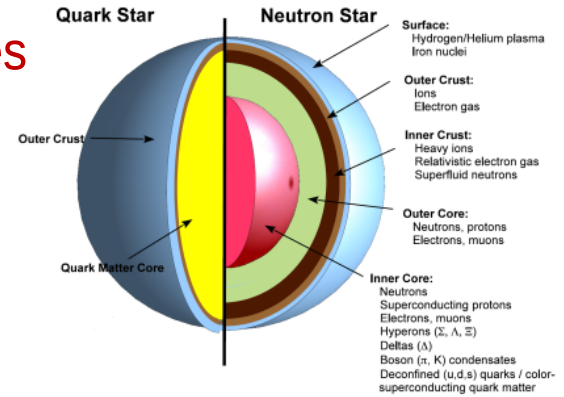
M. Orsaria, H. Rodrigues, F. Weber, G.A. Contrera, arXiv:1308.1657
Phys. Rev. C 89, 015806, 2014



CBM physics case and observables

The QCD equation-of-state at neutron star core densities

- collective flow of identified particles (π,K,p,Λ,Ξ,Ω,...) driven by the pressure gradient in the early fireball
- particle production at threshold energies via multi-step processes (multi-strange hyperons, charm)



Phase transitions from hadronic matter to partonic/quarkyonic matter at high ρ_B,

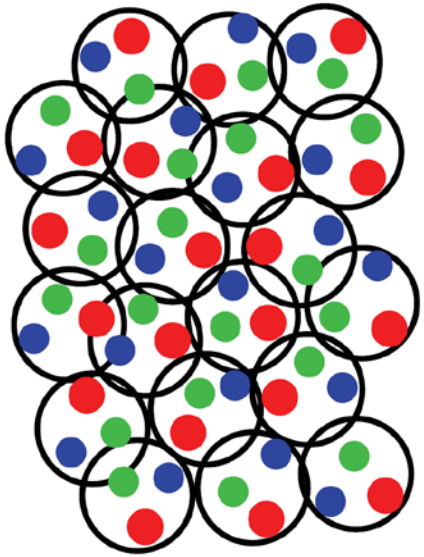
- excitation function of strangeness: $\Xi^-(dss)$,$\Xi^+(\overline{dss})$,$\Omega^-(sss)$,$\Omega^+(\overline{sss})$
  $\rightarrow$ chemical equilibration at the phase boundary

Phase coexistence

- excitation function (invariant mass) of lepton pairs: Thermal radiation from fireball, “caloric curve”
- anisotropic azimuthal angle distributions: ”spinodal decomposition”

Critical point

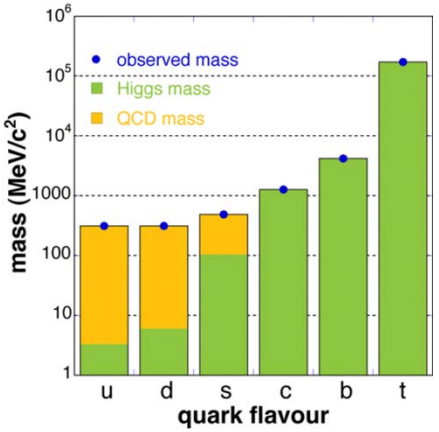
- event-by-event fluctuations of conserved quantities: ”critical opalescence”



CBM physics case and observables

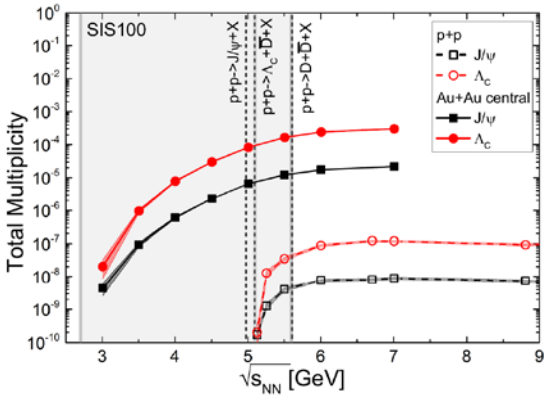
Onset of chiral symmetry restoration at high ρ_B

- in-medium modifications of hadrons ($\rho,\omega,\phi \rightarrow e^+e^-(\mu^+\mu^-)$)
- dileptons at intermediate invariant masses: 4 π → ρ-a_1 chiral mixing



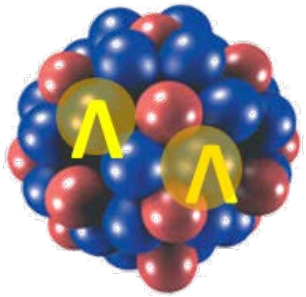
Charm production at threshold energies in cold and dense matter

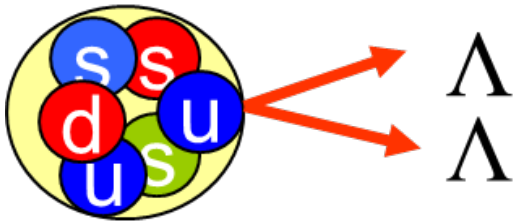
- excitation function of charm production in p+A and A+A (J/ψ, D^0, $D^{\pm}$)



N-Λ, Λ-Λ interaction (hyperon puzzle in neutron stars), strange matter

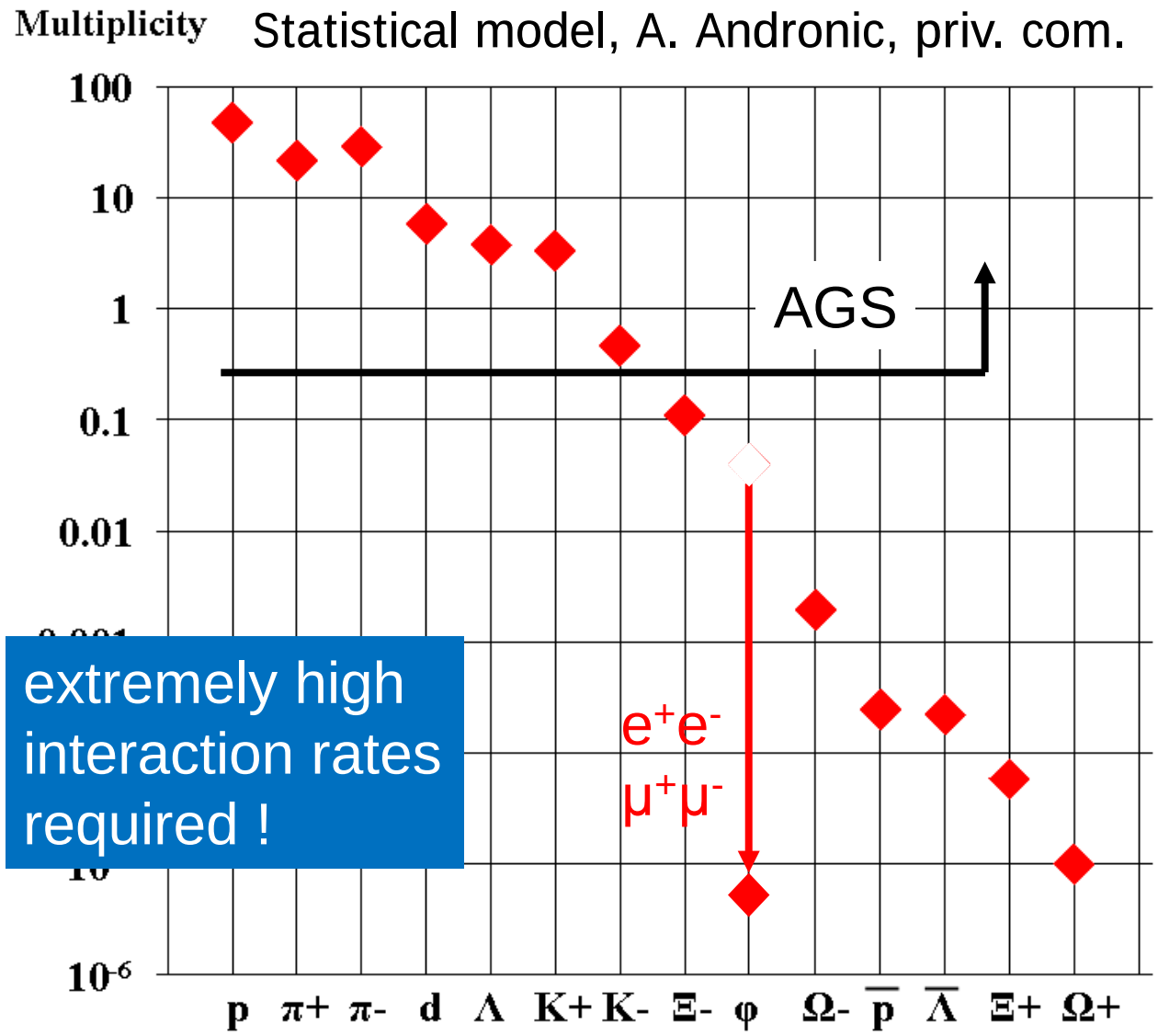
- (double-) lambda hypernuclei
- meta-stable objects (e.g. strange dibaryons)





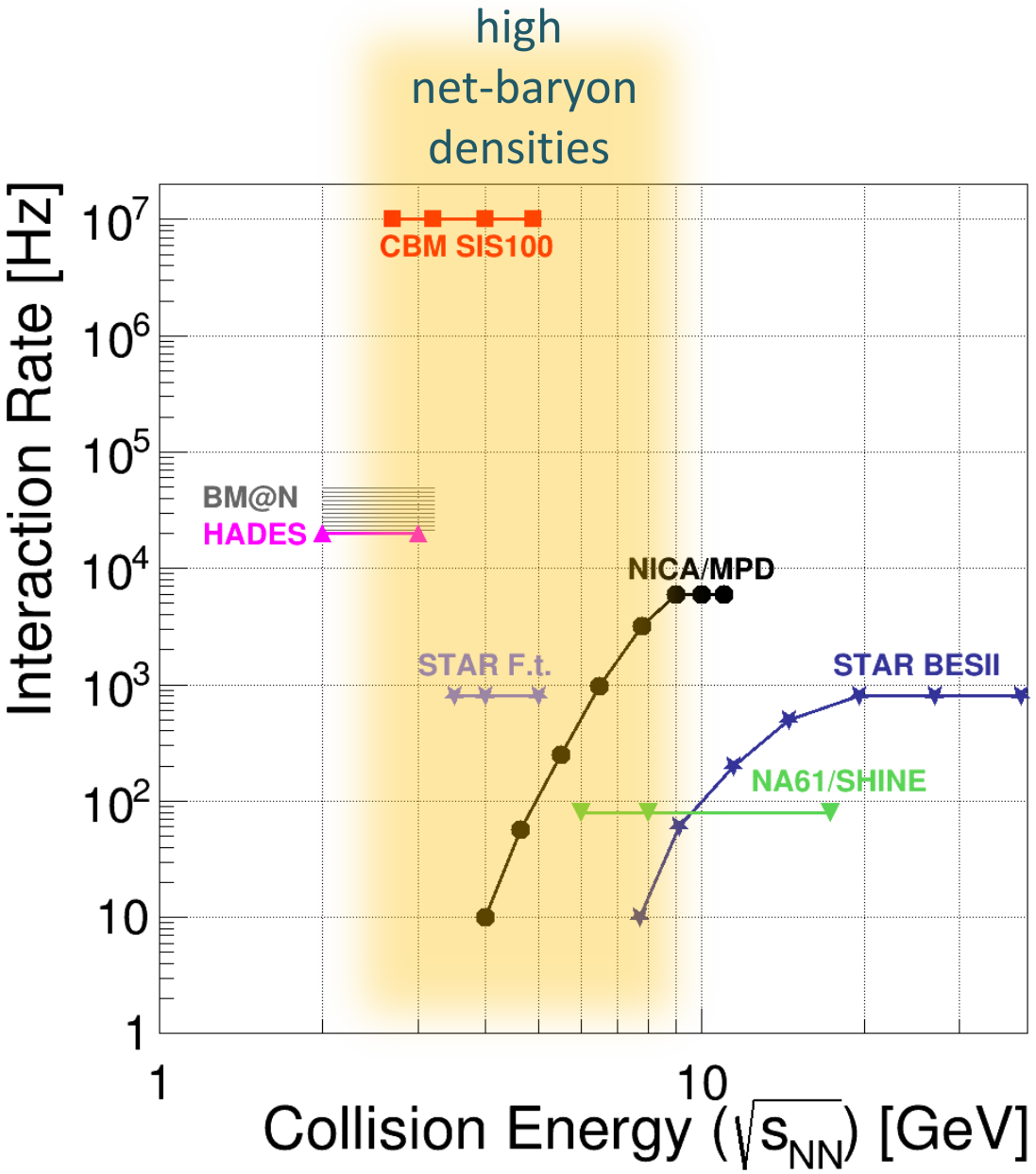
Experimental challenges

Particle yields in central Au+Au 4 A GeV

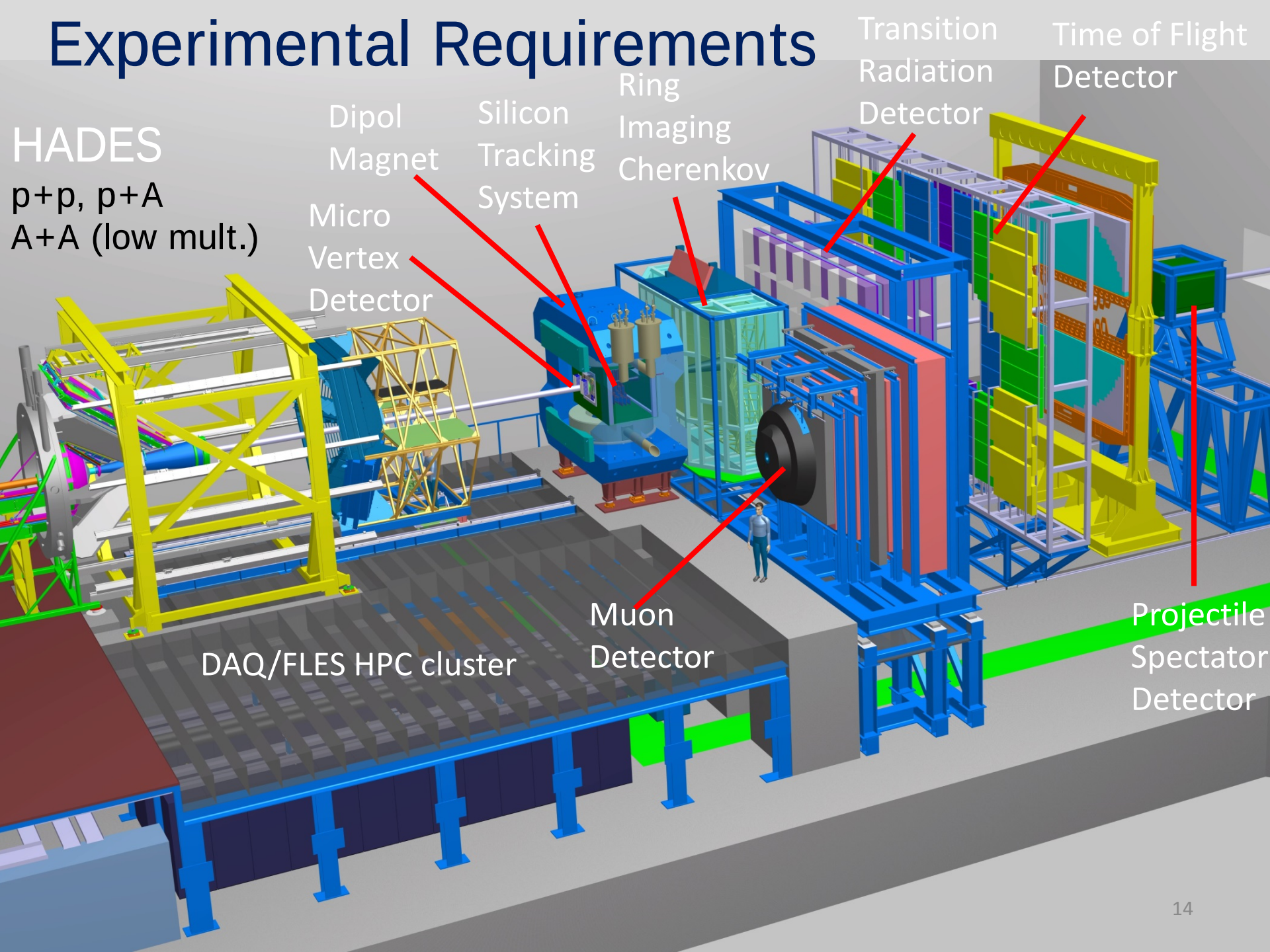


extremely high interaction rates required !

Experiments exploring dense QCD matter

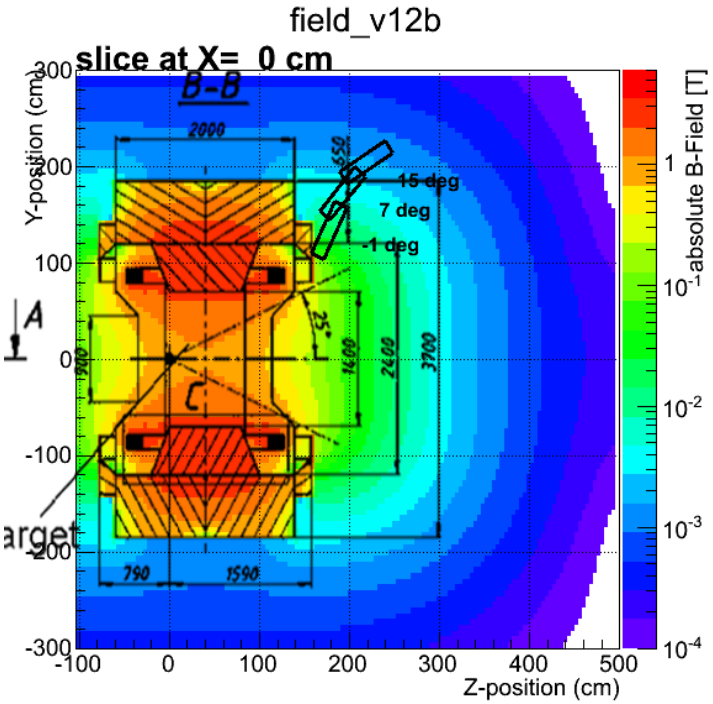


Experimental Requirements



Superconducting Dipole Magnet

SC Magnet: JINR Dubna, BINP Novosibirsk



Status:

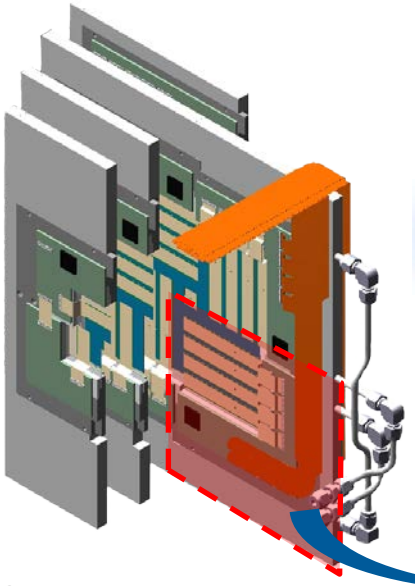
TDR approved by FAIR in January 2014

- Financed 100% by Russian Project funds (4.69 M€ in Euros of 2016)
- Collaboration Contract with Budker Institute Novosibirsk signed Dec. 2016
- Conceptional Design Review with internatl. experts in May 22-24, 2017

Micro Vertex Detector

Univ. Frankfurt, IPHC Strasbourg

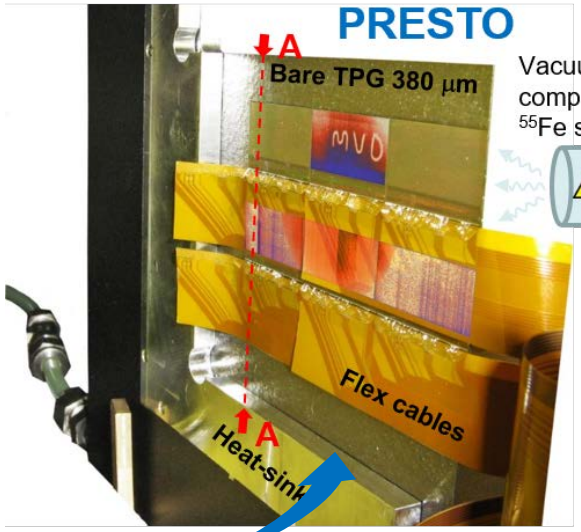
- Background suppression for di-electron measurements
- Determination of secondary vertices of open charm decays ($\tau = 10^{-12}$-10^{-13} s)
- Improved tracking for hyperon-ID

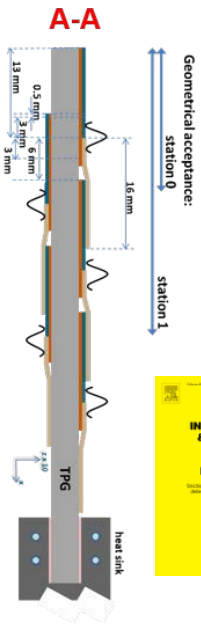


GOETHE UNIVERSITÄT FRANKFURT AM MAIN

MVD

IPHC Institut Pluridisciplinaire Hubert Curien STRASBOURG





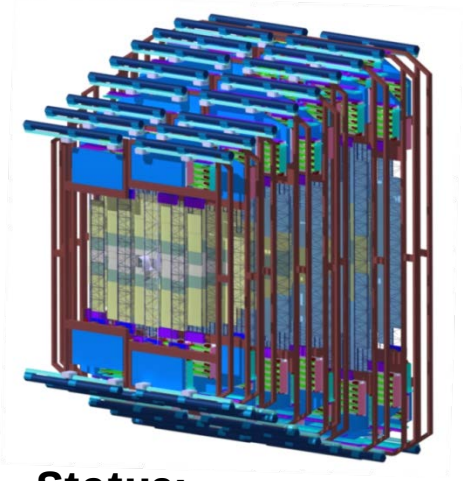
Status:

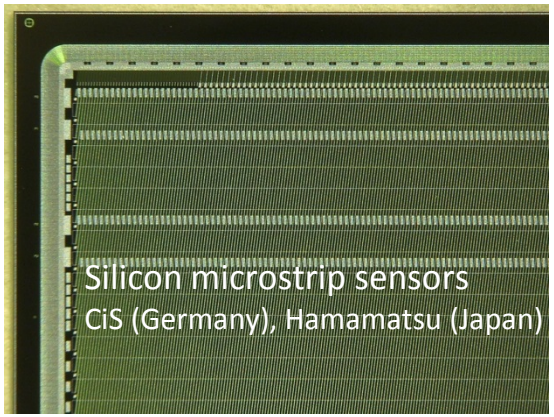
- Prototyping well advanced with PRESTO module: integration concept (vacuum operation / material budget) demonstrated
- Dedicated CBM sensor in synergy with ALICE-ITS upgrade: improved in-pixel logic and data throughput, R/O time ~ 5 µs.
- TDR to be submitted in 2017

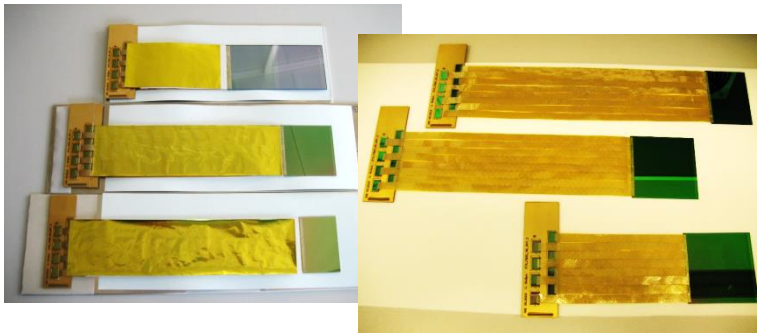
Silicon Tracking System

- Charged particle track reconstruction, momentum determination

Core teams: Darmstadt, Dubna, Karlsruhe, Krakow, Kiev, Tübingen, Warsaw







Module assembly at GSI and JINR

Status:

TDR approved by FAIR in July, 2013

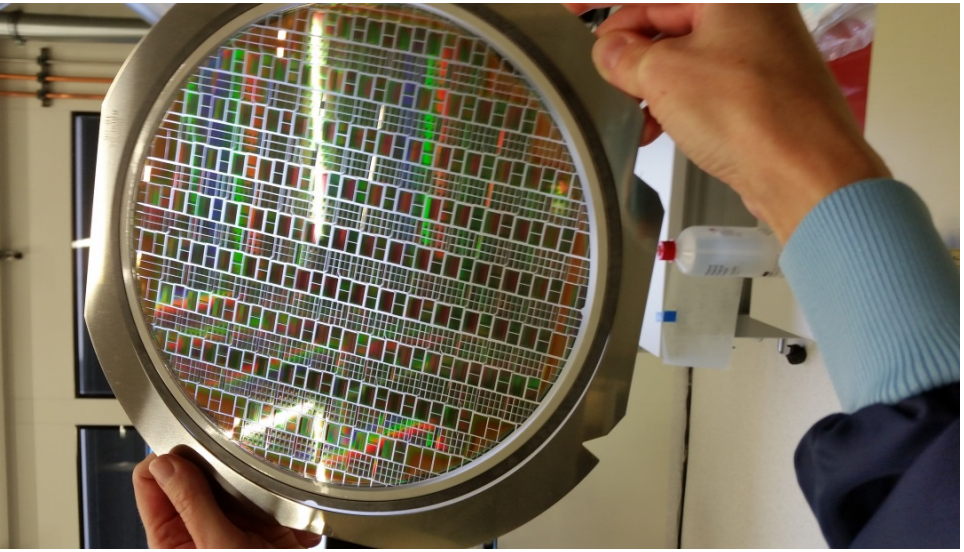
- Progress in establishing QA processes and module assembly procedures,
- Radiation tolerance of sensors tested up to n_{eq} (1 MeV) = 2 × 10^{14} /cm^2,
- Second design iteration of the STS-XYTER ASIC finalized,
- Progress in engineering design and system integration.

Contracts signed with:

- JINR/Dubna on production of 50 % of detector modules,
- KIT/Karlsruhe on production of 40% of detector modules,

Contract ready for signature with Polish groups on the development and production of ASIC and parts of the read-out chain.

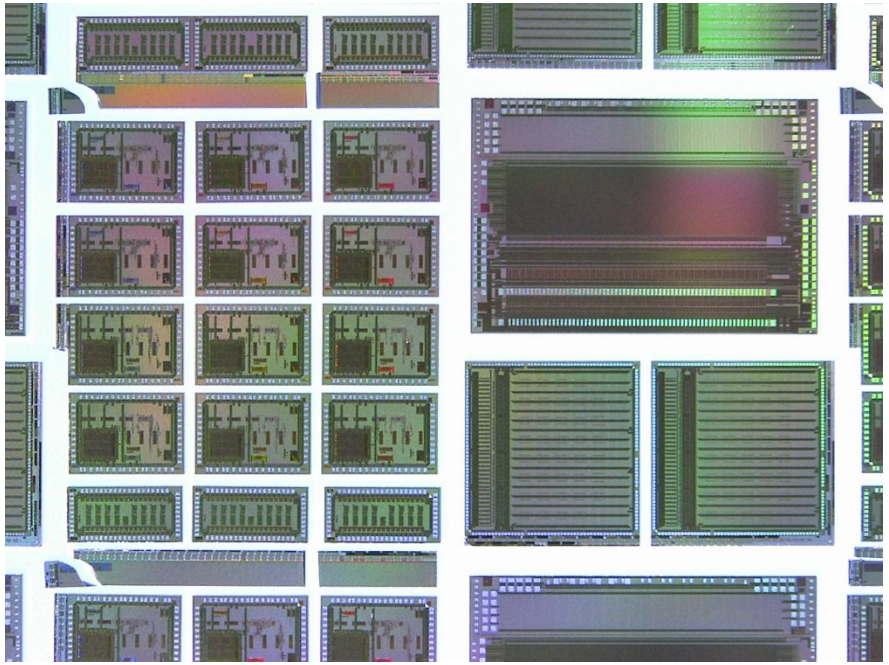
Successful Multi Project Chip Prototyping for CBM



5 final chip prototypes for CBM:

- STS-XYTER and Much-XYTER
- Get4 in two versions for TOF
- PADI production for CBM@STAR
- SPADIC for CBM-TRD

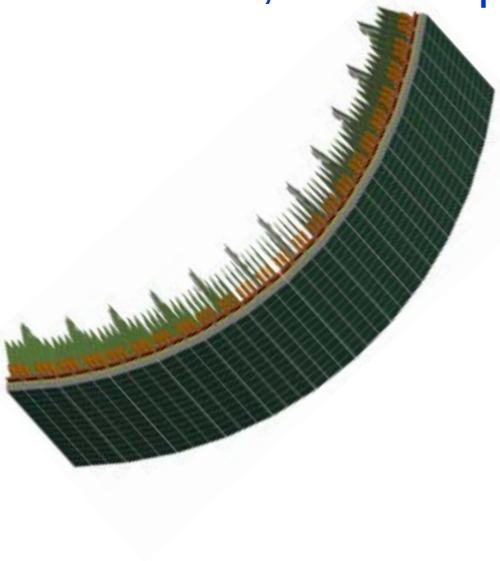
- CBM-TOF goes for FAIR Phase 0 at Star with Get4 and PADI
- CBM-STS can now do detector prototyping and go for production readiness
- CBM-TRD can now do detector prototyping

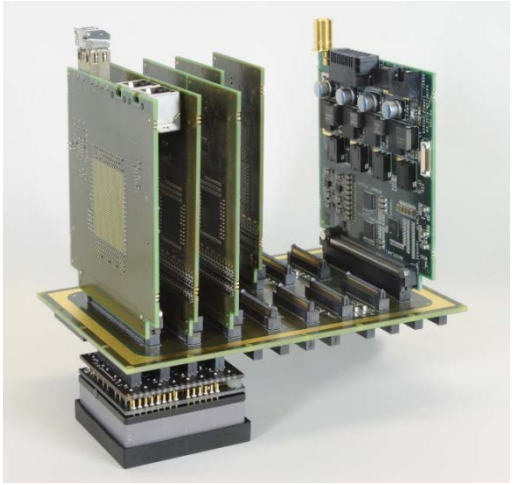


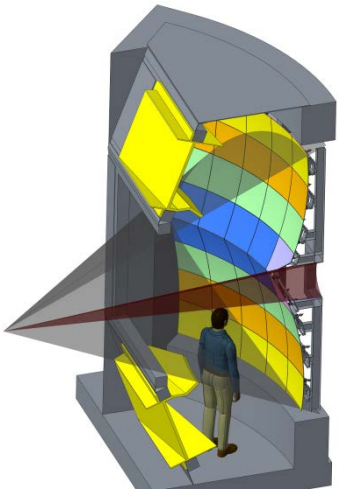
Ring-Imaging Cherenkov (RICH) Detector

- Electron identification

Univ. Gießen, Univ. Wuppertal, PNPI Gatchina, GSI







Status:

- RICH geometry with bended photodetector plane for optimized ring detection in large acceptance fully implemented in simulations
- First version of RICH readout chain produced, assembled, under test in lab
- 400 out of 1100 H12700 MAPMTs delivered and tested
- Concept for new structure of mirror wall with substantially reduced material budget
  First software correction cycle for mirror misalignments ready

Transition Radiation Detector (TRD)

- Electron identification, energy-loss measurements

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

Challenge:
$\varepsilon(e^{\pm}) = 90\%$
$\varepsilon(\pi) = 7.5\%$
at 100 kHz/cm^2

Prototype TRDs tested at the CERN-SPS in Nov.-Dec. 2016

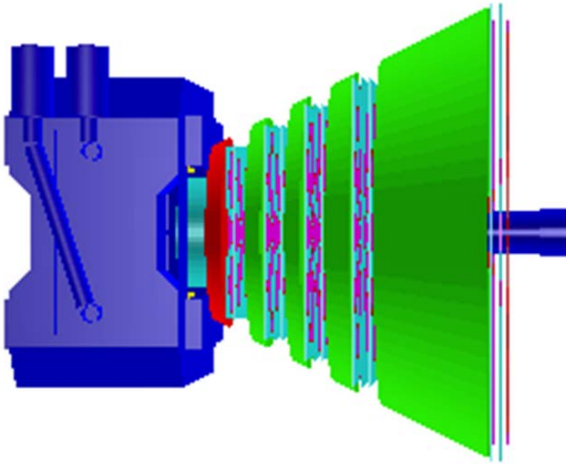
Status:

- New simulations: measurement of intermediate mass di-electrons and on the identification of fragments via their energy loss in the TRD gas.
- Design and construction of four large detector modules (95 x 95 cm^2), tested with heavy ion beams at the CERN-SPS in Nov. - Dec. 2016. Successful test of a realistic read-out chain employing the SPADIC v1.0 ASICs and FLES-DAQ.
- Internal evaluation of TDR by external experts March 14-15, 2017

Muon Chamber (MuCh) System

- Muon identification

VECC Kolkata + 12 Indian Inst., PNPI Gatchina, JINR Dubna



MuCh at SIS100: 2 GEM triplets,
2 tracking detector tripletts,TRD

Full size GEM detectors tested with free-streaming read-out electronics at the CERN-SPS Nov.-Dec. 2016

Bakelite trigger RPCs under investigation for stations 3 and 4.
Required for high rate (kHz) operation: low resistivity Bakelite

Status:

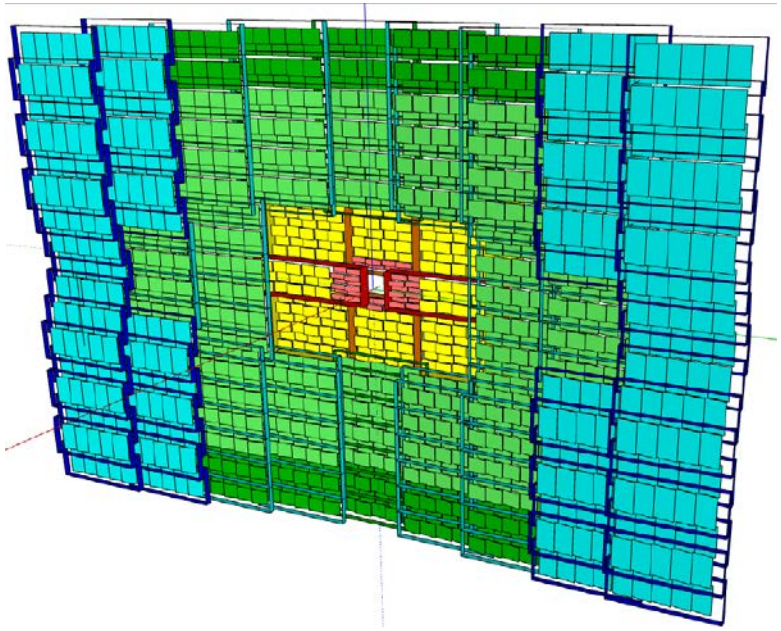
- TDR approved in Feb. 2015
- GEM construction sites are under preparation in India.
- The GBTx emulator was implemented and tested.
- In-kind Contract with VECC Kolkata and Collaboration Contract with PNPI St. Petersburg close to signature

The high-rate MRPC TOF wall

- Particle identification

Challenge: Time resolution 50 ps up to 25 kHz/cm^2. Total area 100 m^2

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



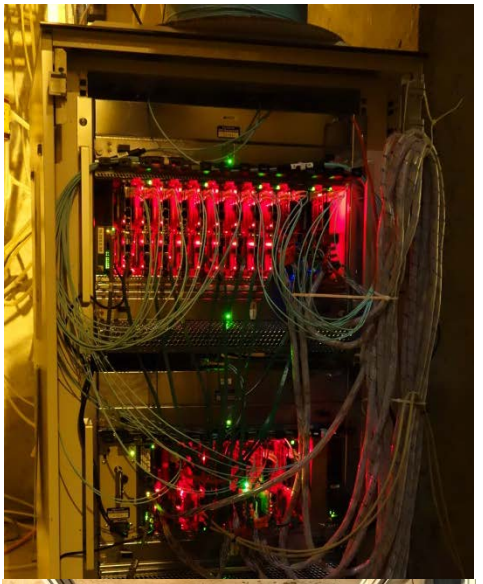
ToF MRPC detectors tested with free-streaming read-out electronics at the CERN-SPS Nov.-Dec. 2016

Status:

- TDR approved Feb. 2015
- A stack of mRPCs with more than 1000 readout channels (1% of TOF setup for SIS100) was successfully tested at rates up to several kHz/cm^2

Test beam at CERN Nov.-Dec. 2016

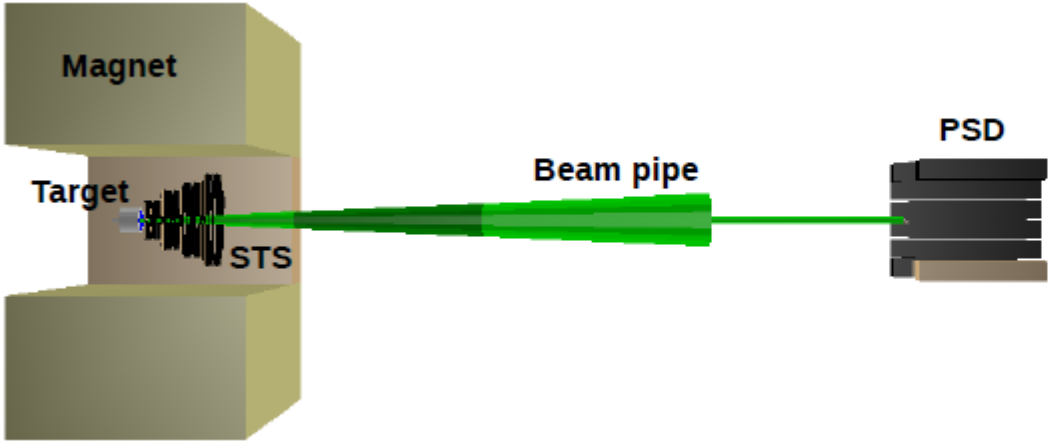
- Prototype TOF, MuCh-GEM, TRD and diamond detectors with common free-streaming readout system and DAQ.
- Pb+Pb collisions at 13, 30 and 160 A GeV.
- 3 weeks in Nov. – Dec. 2016
- Teams from China, Germany, India, Romania



Projectile Spectator Detector

- determination of collision centrality and orientation of the reaction plane

INR Moscow, TU Darmstadt, Prague, Rez




Fully assembled PSD module at INR Moscow

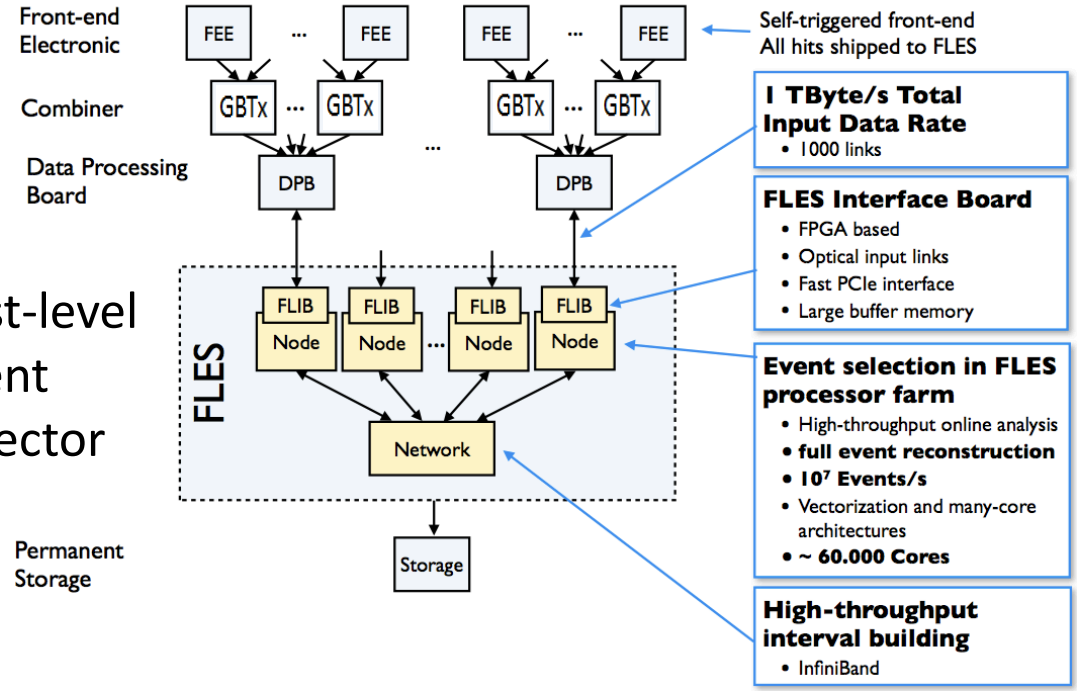
Status:

- TDR approved Feb. 2015,
- A few versions of PSD readout electronics tested at CERN (Nov. 2015 – April 2016),
- 19 PSD modules (out of 45) have been fully assembled, and tests with cosmic rays at INR Moscow are ongoing,
- Reconstruction algorithms for the reaction plane and centrality determination were developed and used in the analysis of NA61 data for Pb-Pb at 30 AGeV. New centrality reconstruction algorithm has been proposed.

CBM online systems

Univ. Frankfurt, FIAS, GSI Darmstadt, KIT Karlsruhe, IIT Kharagpur, Warsaw UT

First-level Event Selector

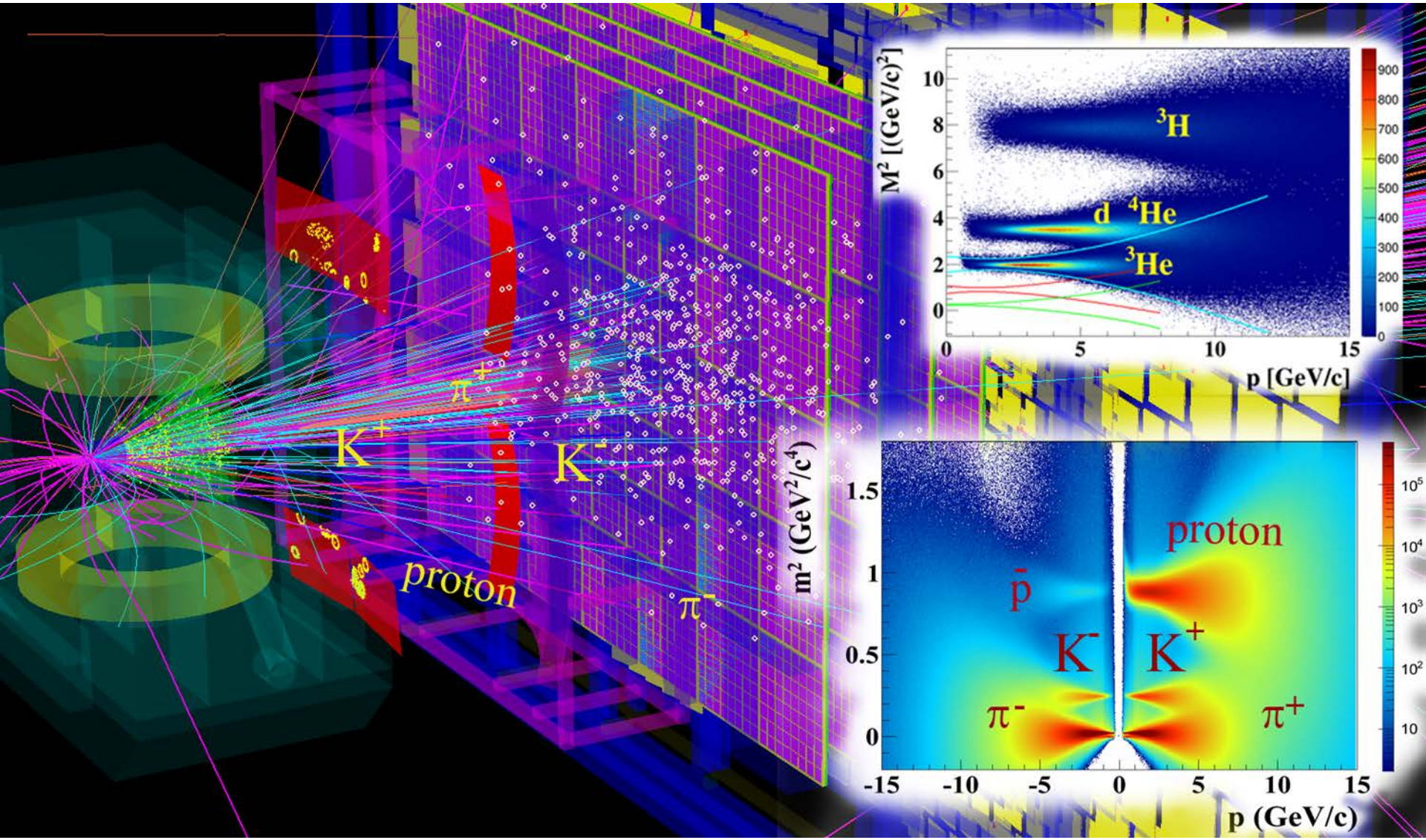


Novel readout system: no hardware trigger on events, detector hits with time stamps, full online 4-D track and event reconstruction.

Status:

- FLES input interface designed
- FLESnet software successfully applied in beam tests with detectors
- TDR to be submitted in 2017.

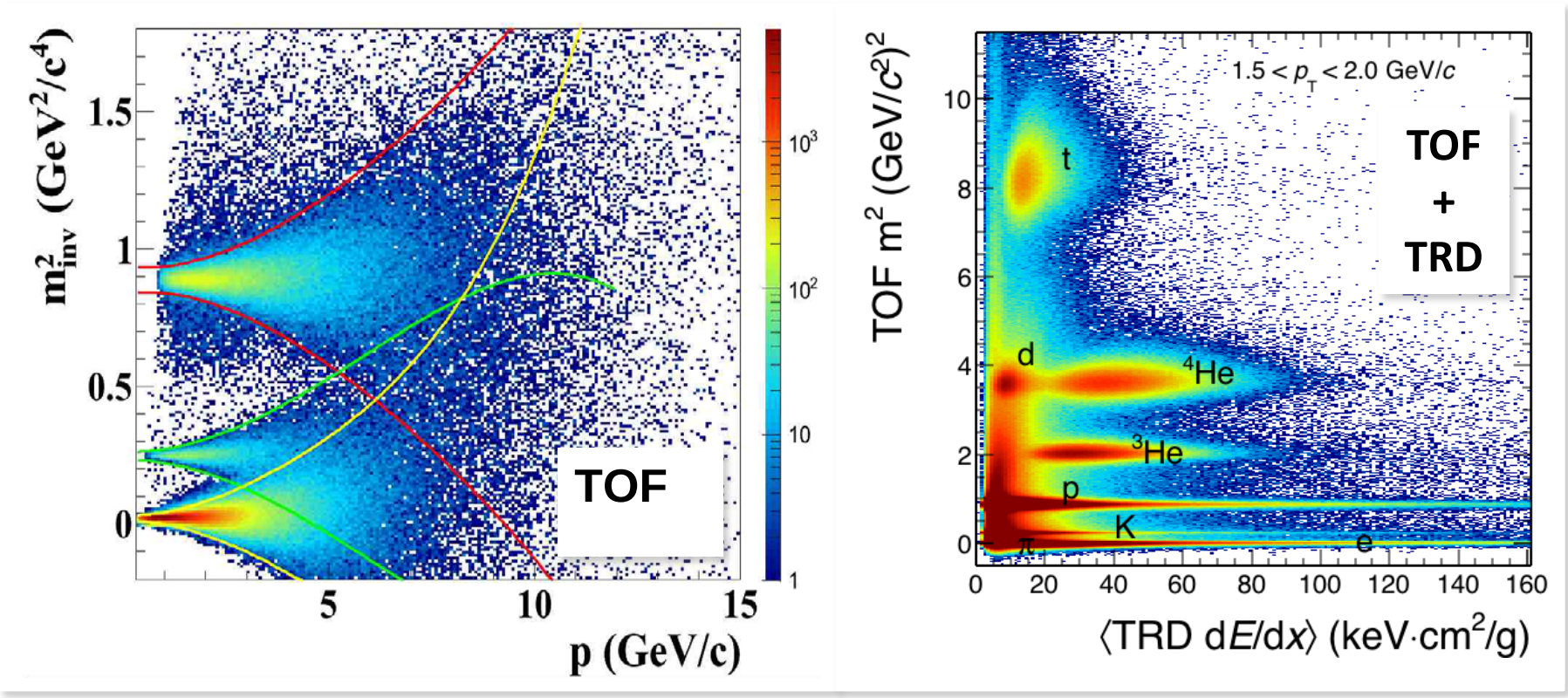
Simulation and reconstruction



Simulation and reconstruction

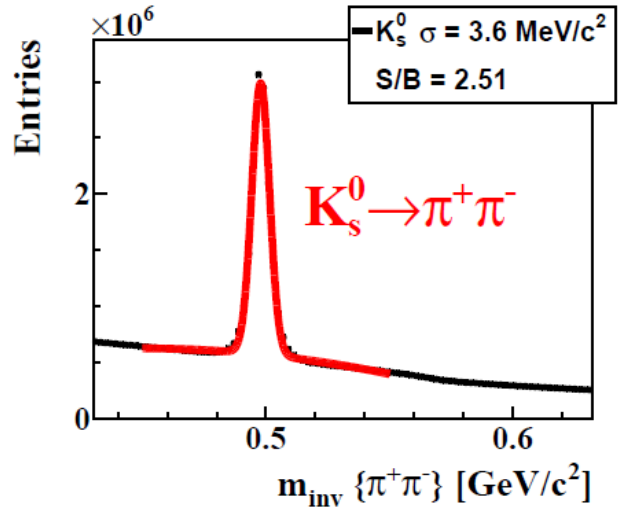
Particle Identification

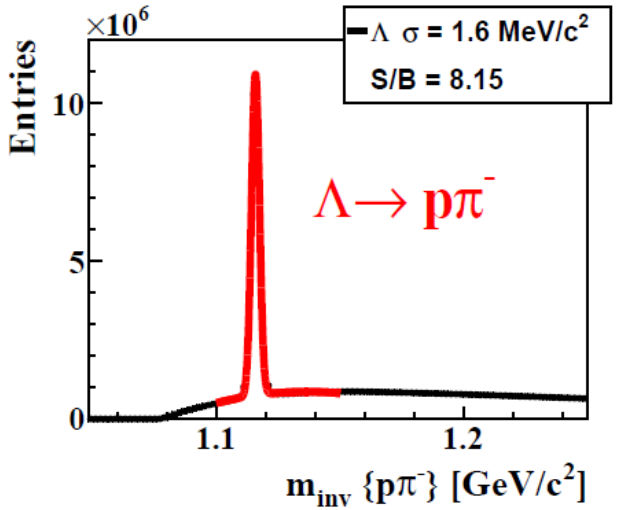
Detectors used: STS, TOF, TRD

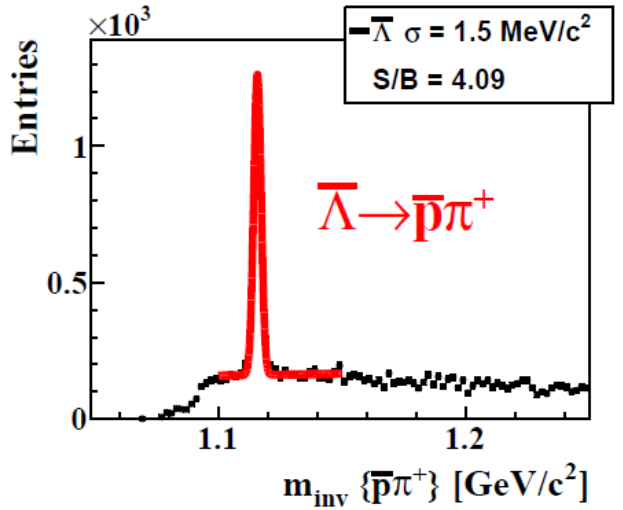


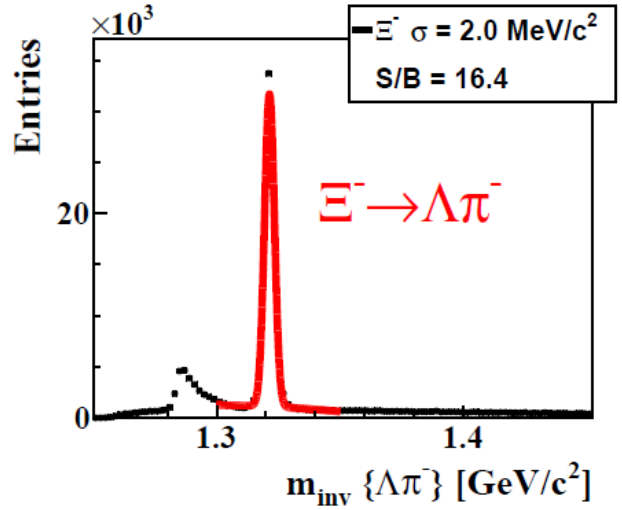
Simulation and reconstruction

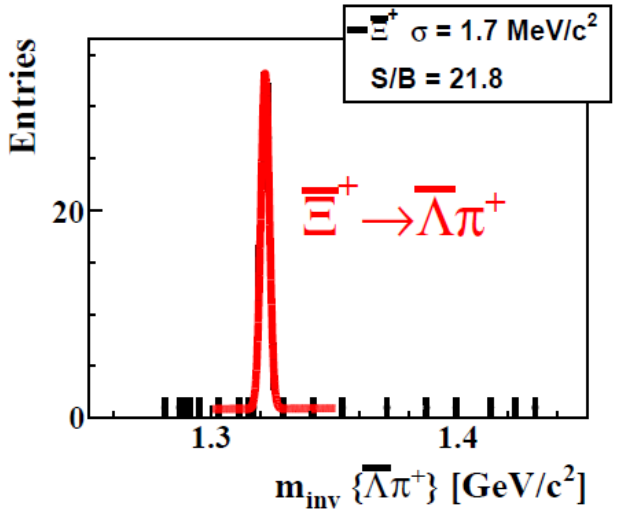
Strange hadrons in central Au+Au 10 AGeV

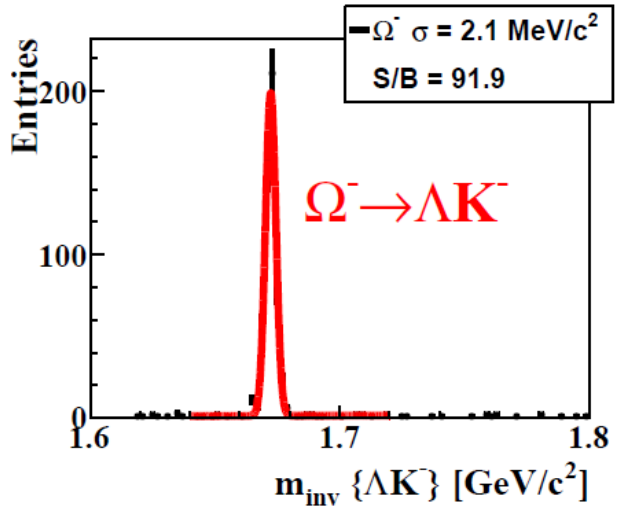








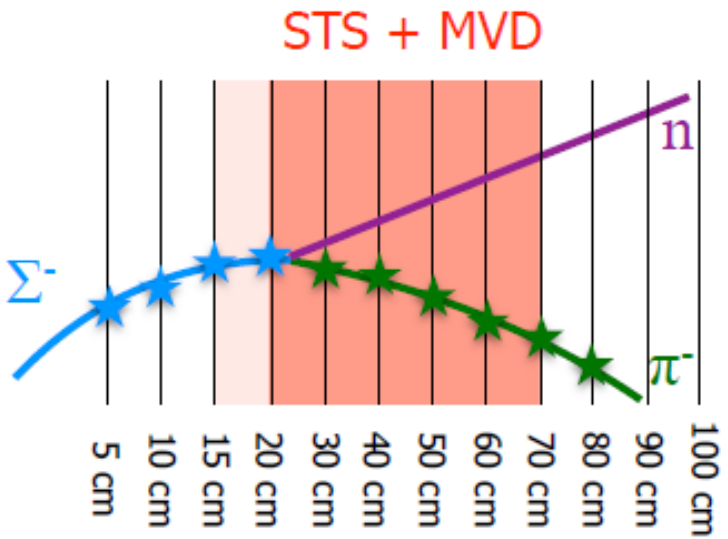


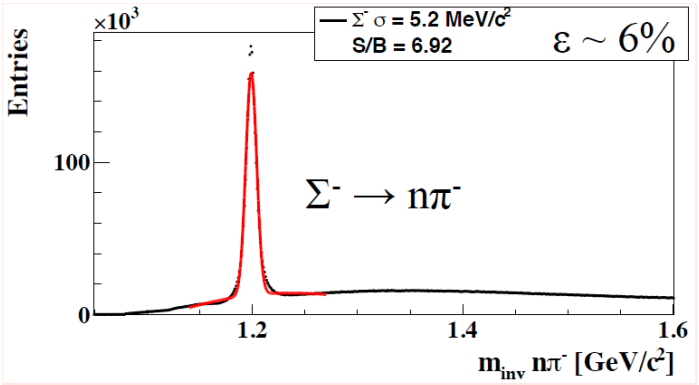


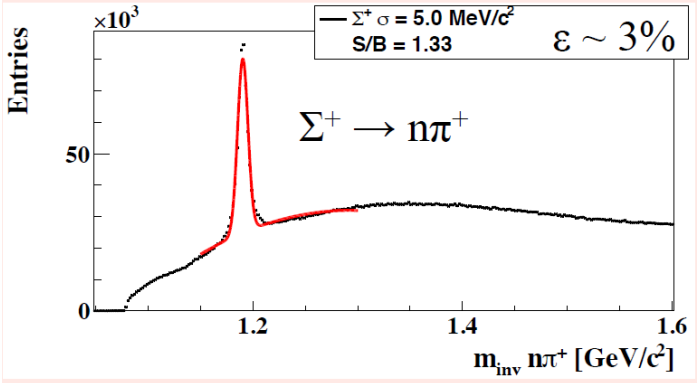
Simulation and reconstruction

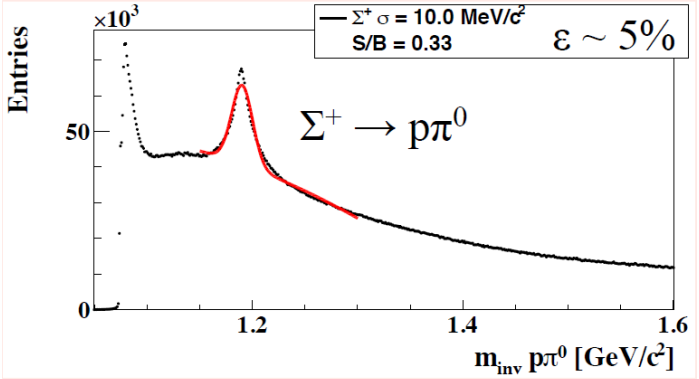
Hyperons in Au+Au 10 AGeV

missing mass analysis



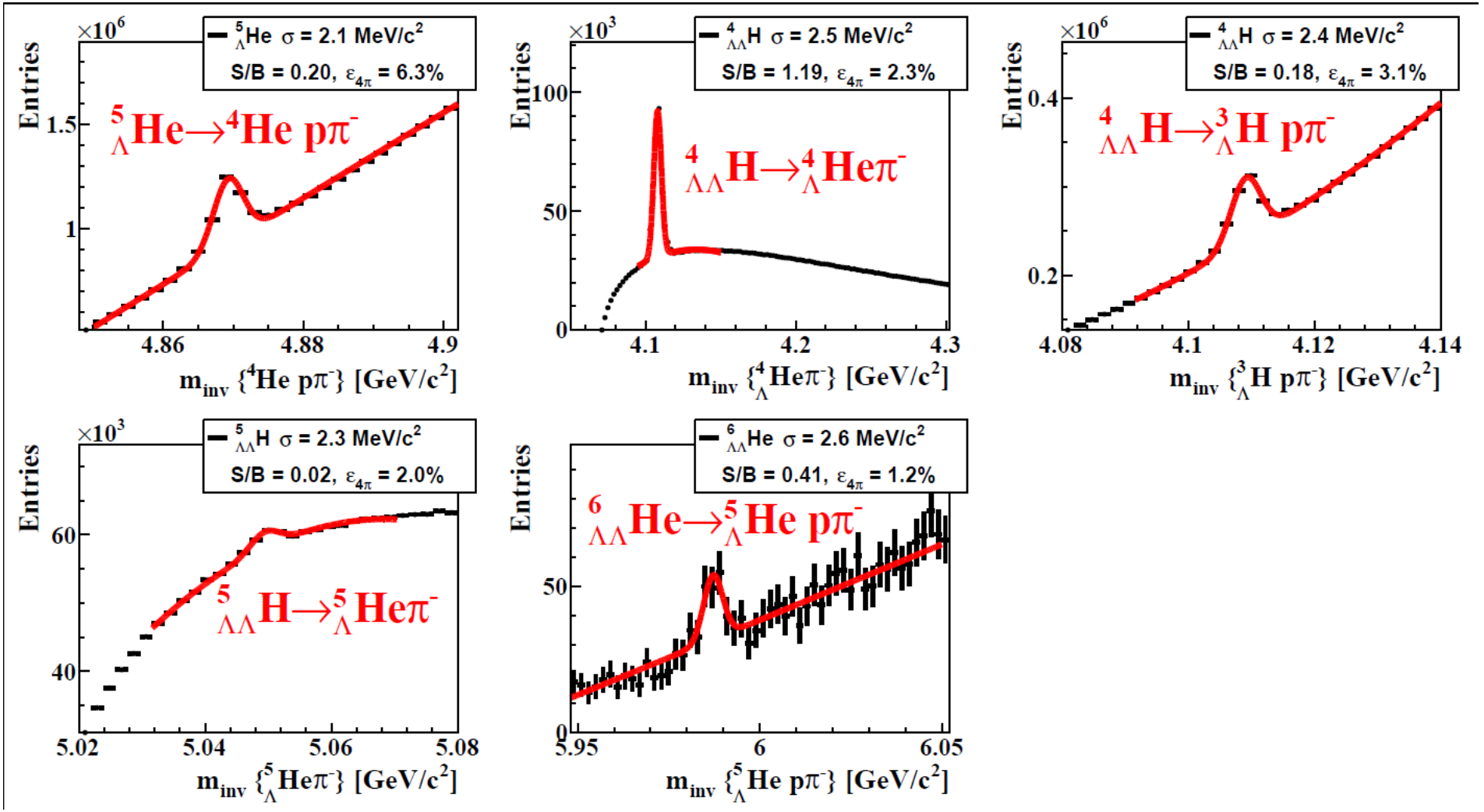






Simulation and reconstruction

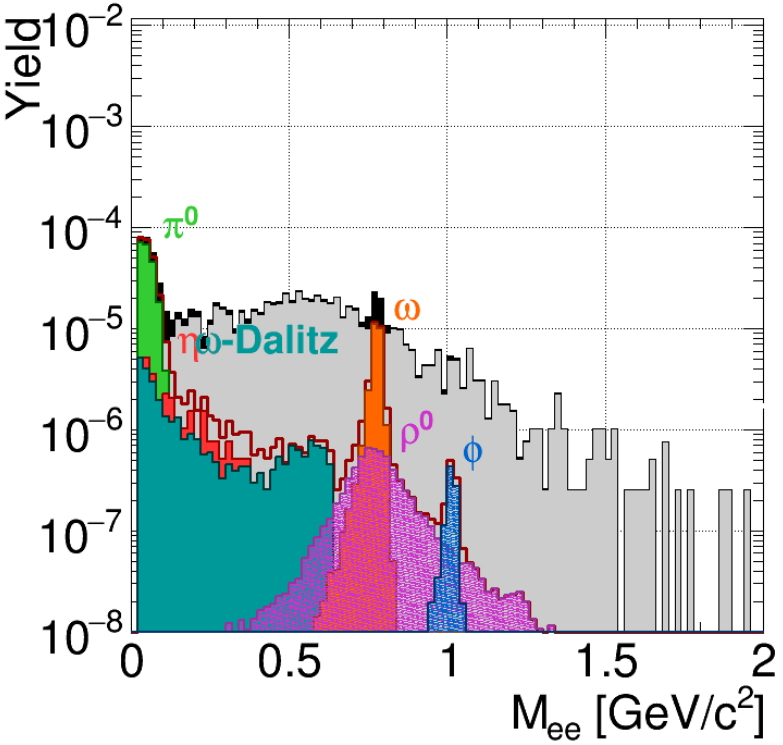
Hypernuclei in central Au+Au 10 AGeV



Simulation and reconstruction

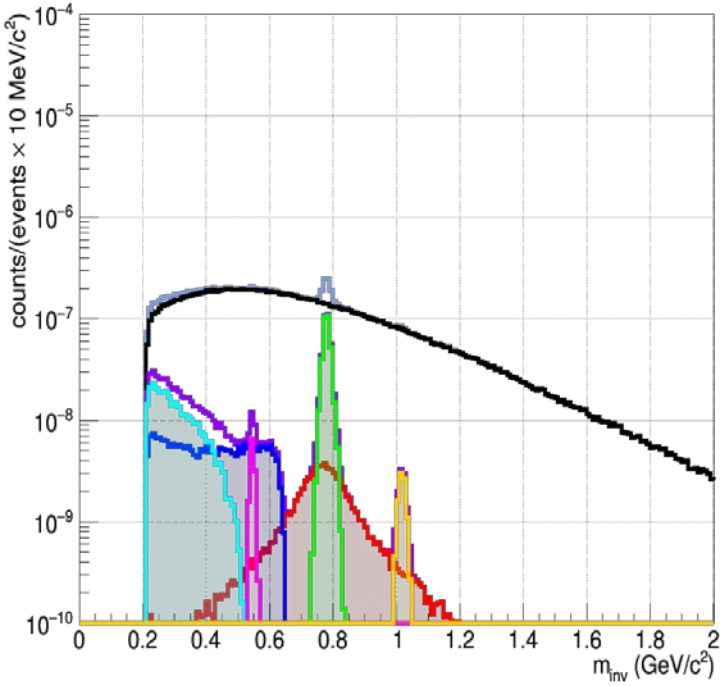
Dileptons in central Au+Au collisions at 8 A GeV

Electrons



Simulation STS, RICH, TRD, TOF:
RICH with mechanical structure
Hit smearing in TRD (4 layers)

Muons



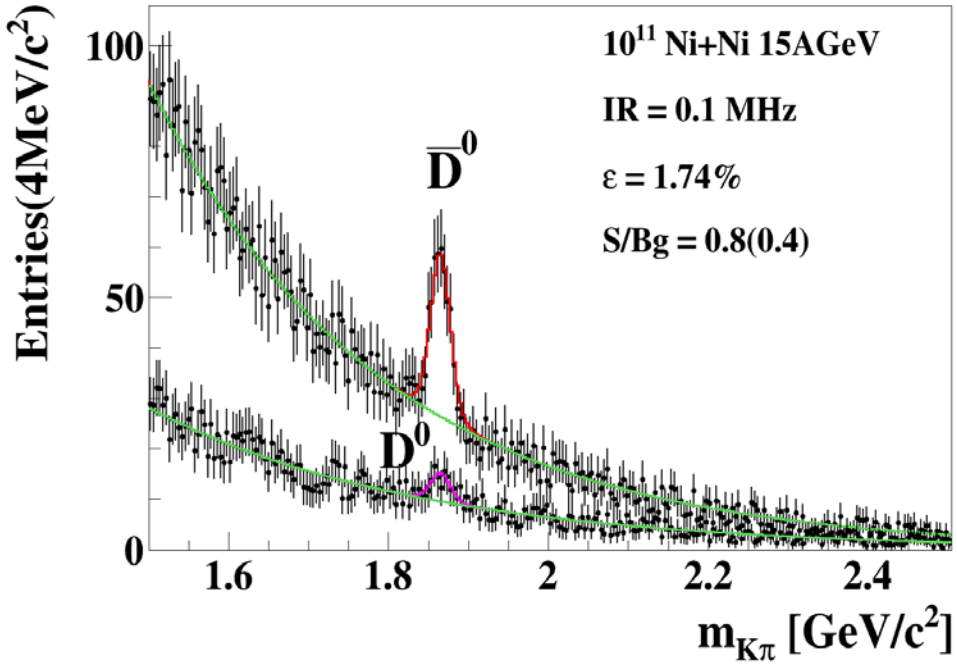
Simulation STS, MUCH with TRD, TOF:
Clustering in all detectors
(3 GEM stations + 4 layers TRD)

Simulation and reconstruction

Open and hidden charm in CBM at SIS100

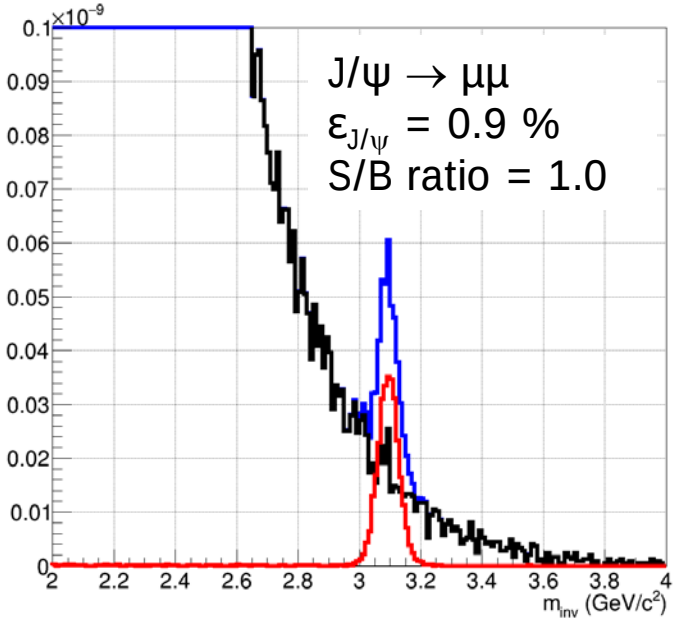
Ni + Ni central collisions at 15 A GeV

260 $\bar{D}^0$ and 45 D^0 in 2 weeks at IR = 0.1 MHz



Au + Au central collisions at 10 A GeV

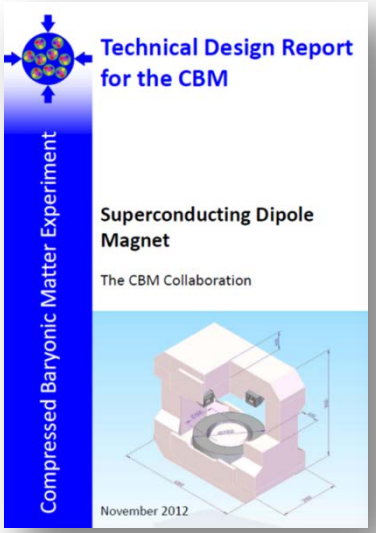
6480 J/ψ in 2 weeks at IR = 10 MHz

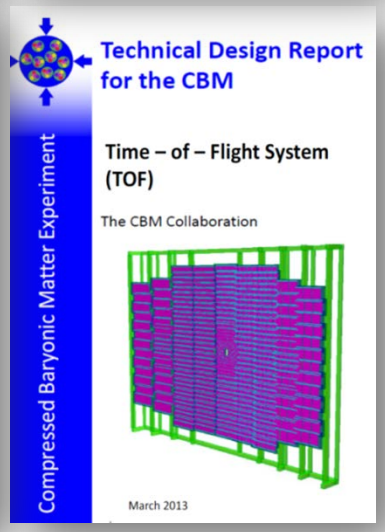


** Sub-threshold charm production in nuclear collisions* J. Steinheimer, A. Botvina, M. Bleicher arXiv:1605.03439

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 2017
9	DAQ/FLES	submission 2017
10	TRD	submission 2017
11	ECAL	submission 2017





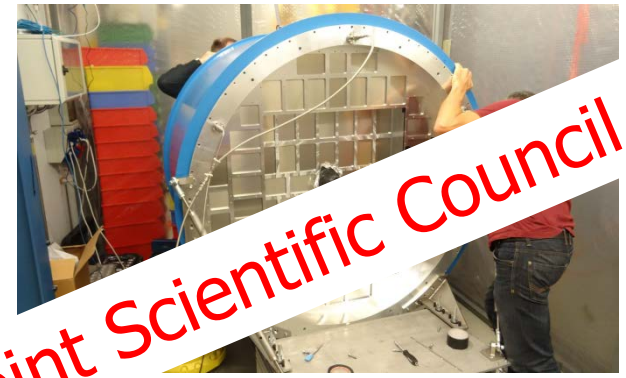
CBM mile stones (Nov. 2016)

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	31.03.18	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	30.09.16	31.12.21
Dipol 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 detectors will be in place
to take the first beams from SIS100

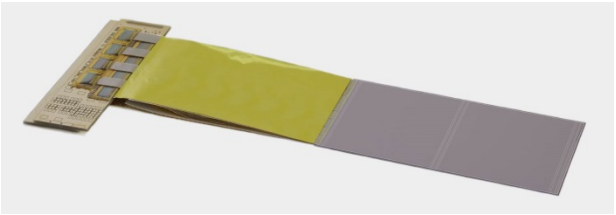
FAIR phase 0 experiments on dense QCD matter

1. Install, commission and use 430 out of 1100 CBM RICH multi-anode photo-multipliers (MAPMT) 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 [illegible])

3. Install [illegible] and use 4 Silicon [illegible]tations in the BM@N experiment at the Nuclotron in JINR/Dubna (start 2019 with Au-beams up to 4.5 A GeV)



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

Strongly endorsed by the 2nd FAIR/GSI Joint Scientific Council

The CBM Collaboration: 55 institutions, 460 members

China:
CCNU Wuhan
Tsinghua Univ.
USTC Hefei
CTGU Yichang

Czech Republic:
CAS, Rez
Techn. Univ. Prague

France:
IPHC Strasbourg

Hungary:
KFKI Budapest
Eötvös 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

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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.

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

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Univ. Bucharest

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ITEP Moscow
Kurchatov Inst., Moscow
VBLHEP, JINR Dubna
LIT, JINR Dubna
MEPHI Moscow
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SINP MSU, Moscow

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28th CBM Collaboration meeting in Tübingen
26-30 September 2016

CBM Scientists