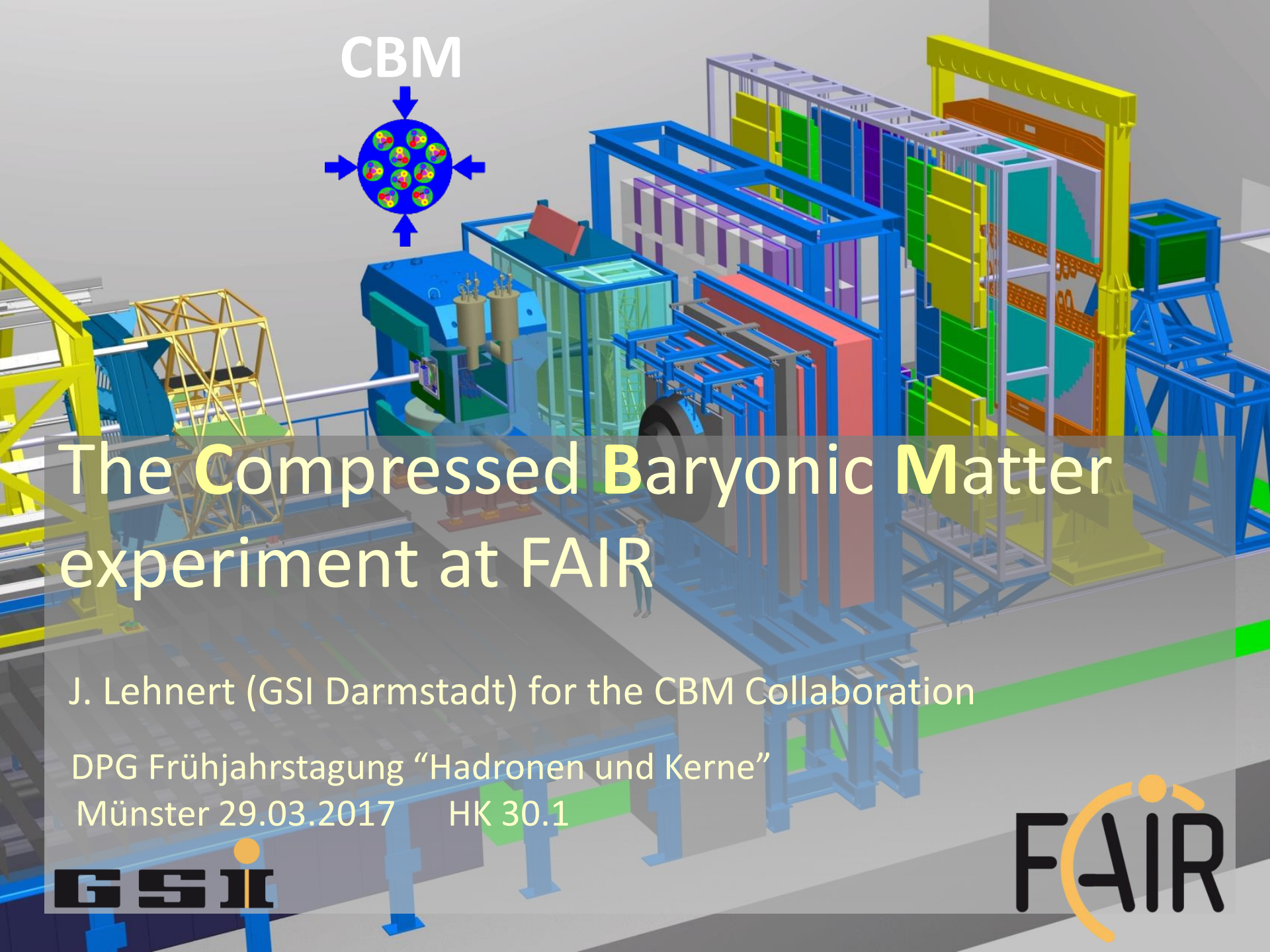


The Compressed Baryonic Matter experiment at FAIR

J. Lehnert (GSI Darmstadt) for the CBM Collaboration

DPG Frühjahrstagung “Hadronen und Kerne”
Münster 29.03.2017 HK 30.1

Outline

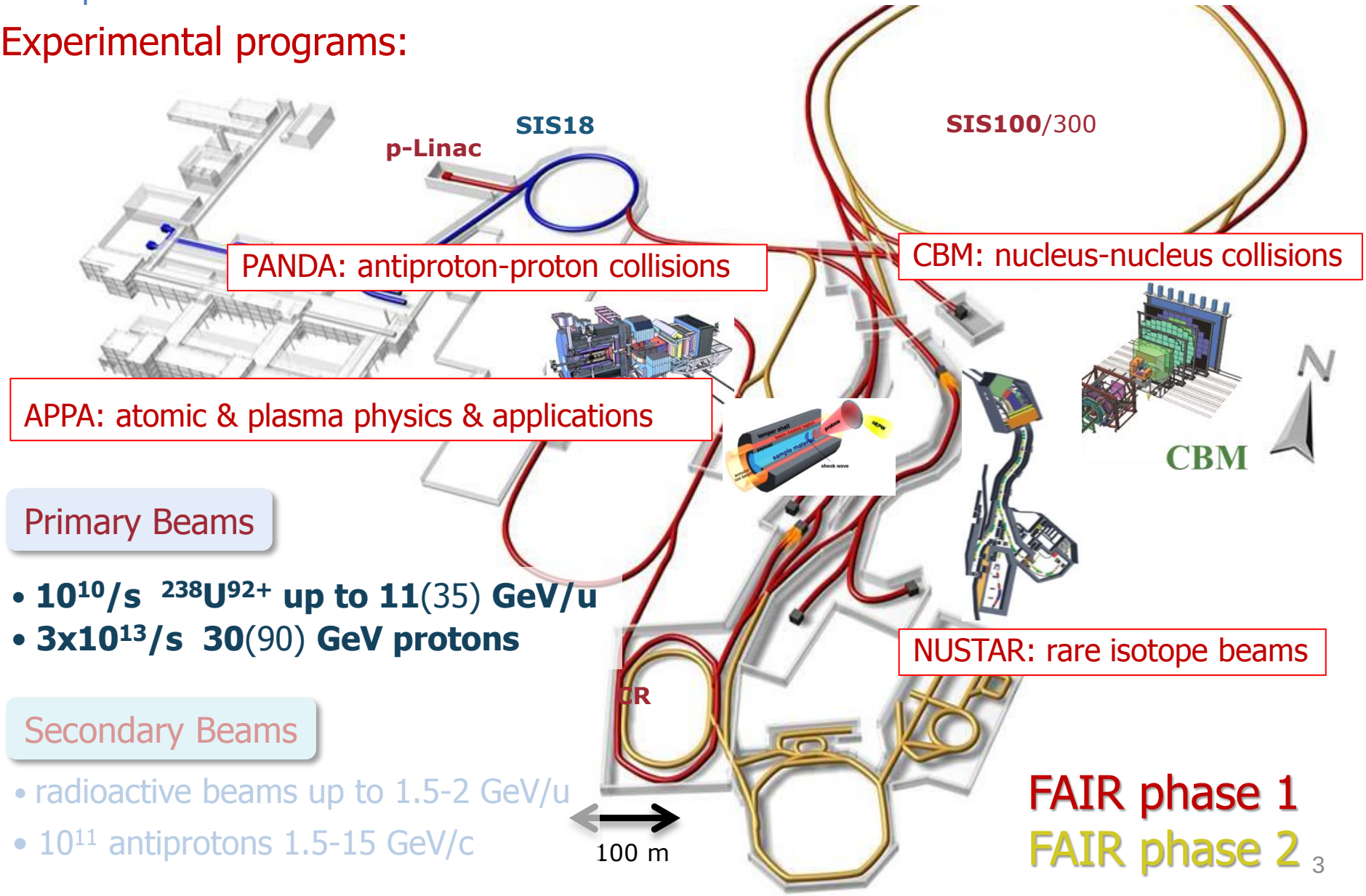
- CBM at FAIR
- Physics Motivation
- Detector Overview

- Status and Progress
  - subsystems
  - common activities: readout, test beam, DAQ
  - simulation and reconstruction

- FAIR Phase0 Experiments

FAIR - Facility for Antiproton & Ion Research

Experimental programs:



Primary Beams

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

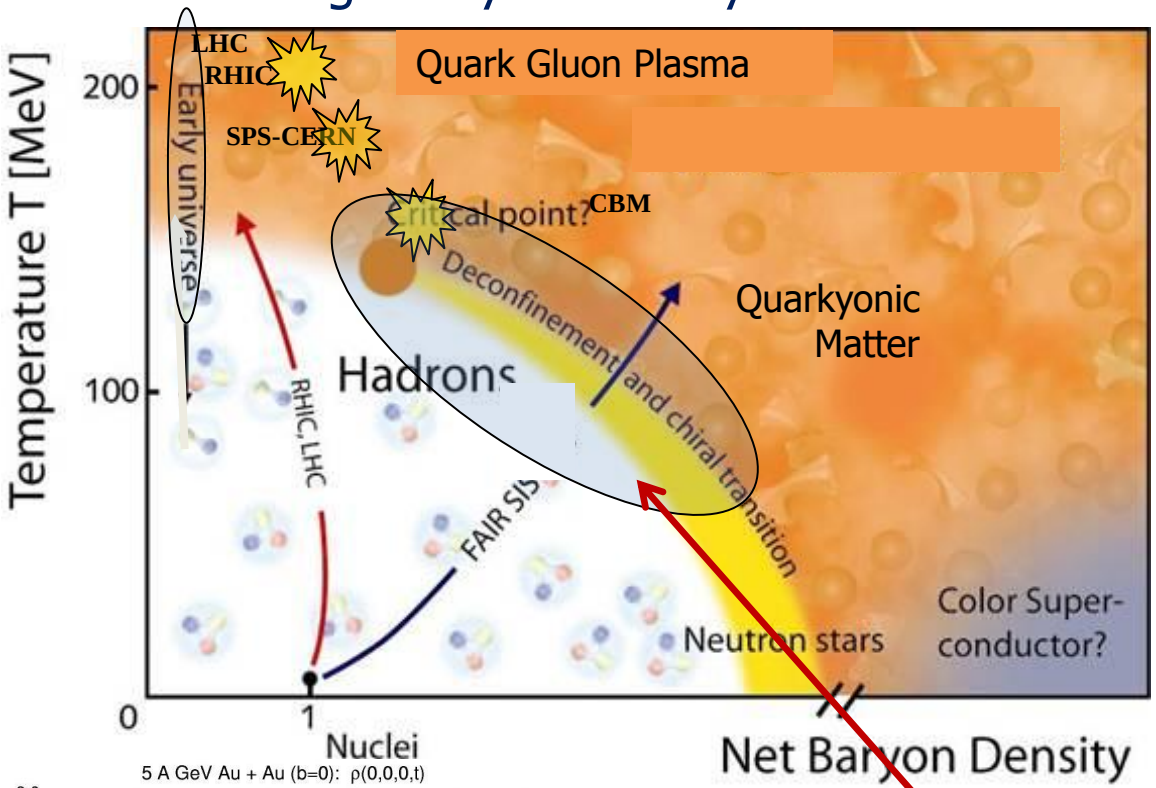
Secondary Beams

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

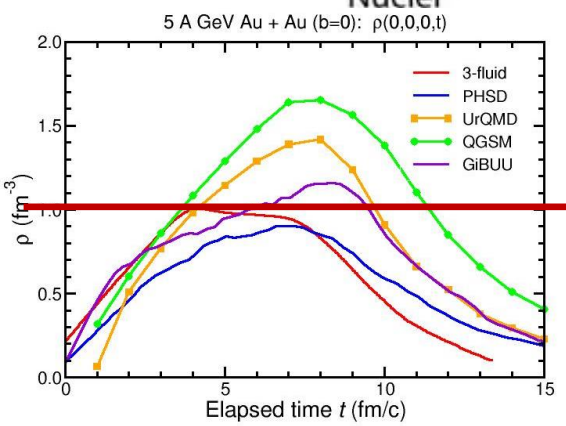
FAIR phase 1
FAIR phase 2

CBM: Exploring the QCD Phase Diagram

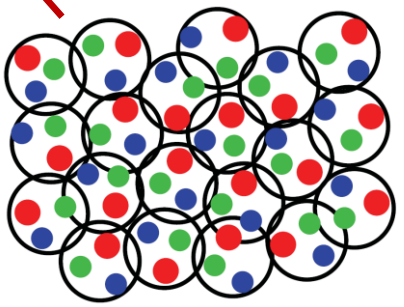
... at high baryon density



Au+Au
5 AGeV

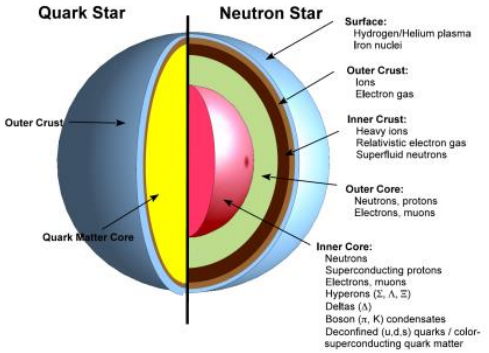


5 ρ_0



Physics Cases and Observables

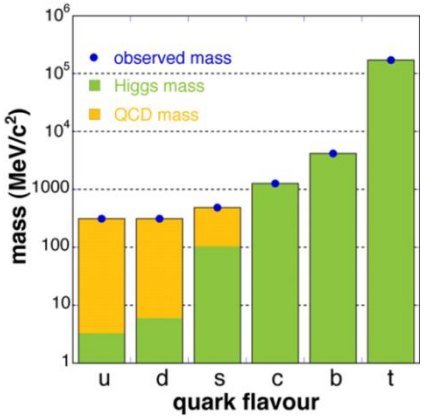
The equation-of-state at high ρ_B
- collective flow of hadrons
- particle production at threshold energies:
  open charm, multi-strange hyperons



Deconfinement phase transition at high ρ_B
- excitation function and flow of strangeness (K, Λ, Σ, Ξ, Ω) and charm (J/ψ, ψ', D^0, D_s, $D^{\pm}$, Λ_c)

Charmonium suppression for **J/ψ** and **ψ**

QCD critical endpoint
- excitation function of event-by-event fluctuations:
  K/π, ... Ξ/ π, Ω/ π



Onset of chiral symmetry restoration at high ρ_B
- in-medium modifications of hadrons (ρ,ω,ϕ)

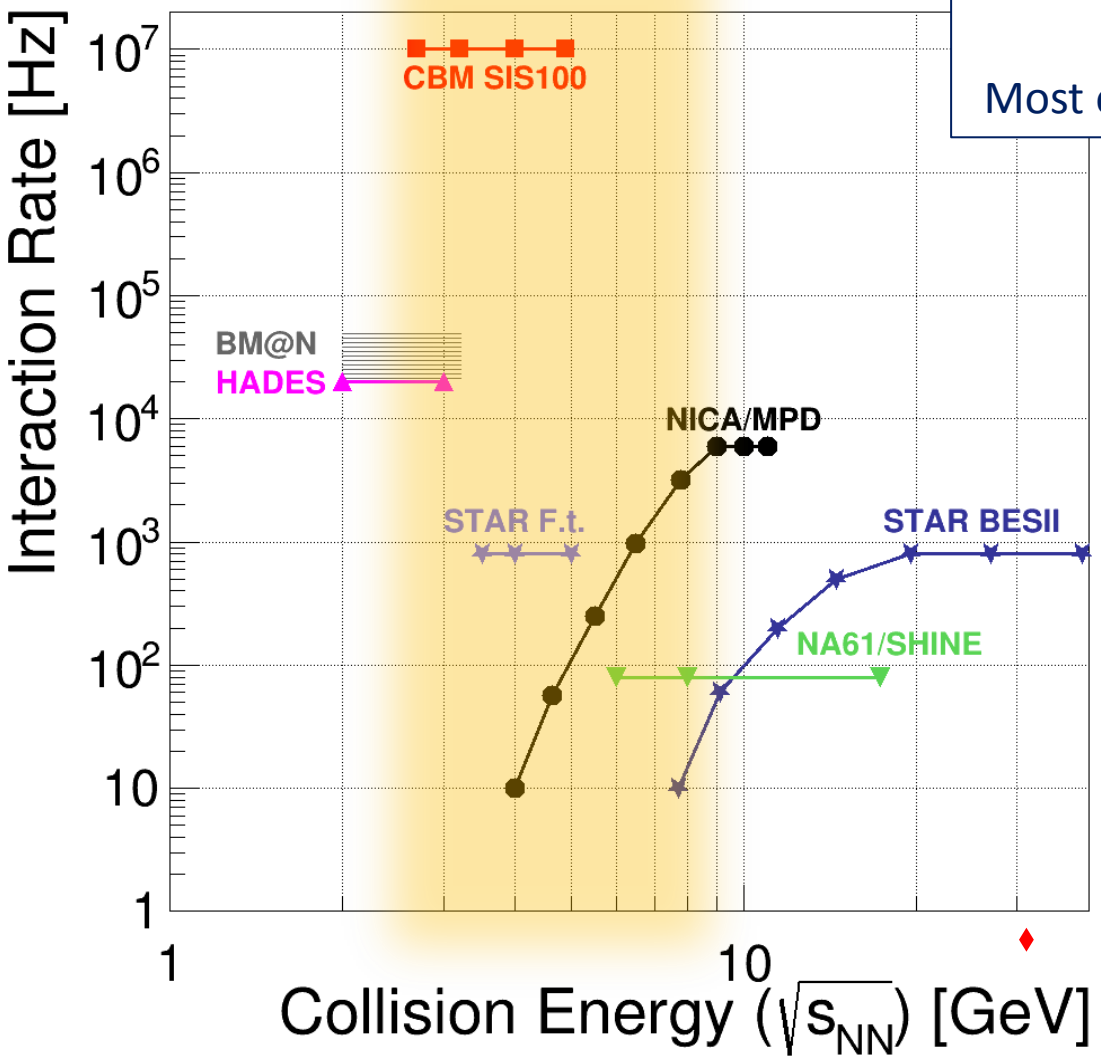
N-Λ, Λ-Λ interaction (hyperon puzzle in neutron stars) and strange matter
- (double) Λ hypernuclei

Experiments Exploring Dense QCD Matter

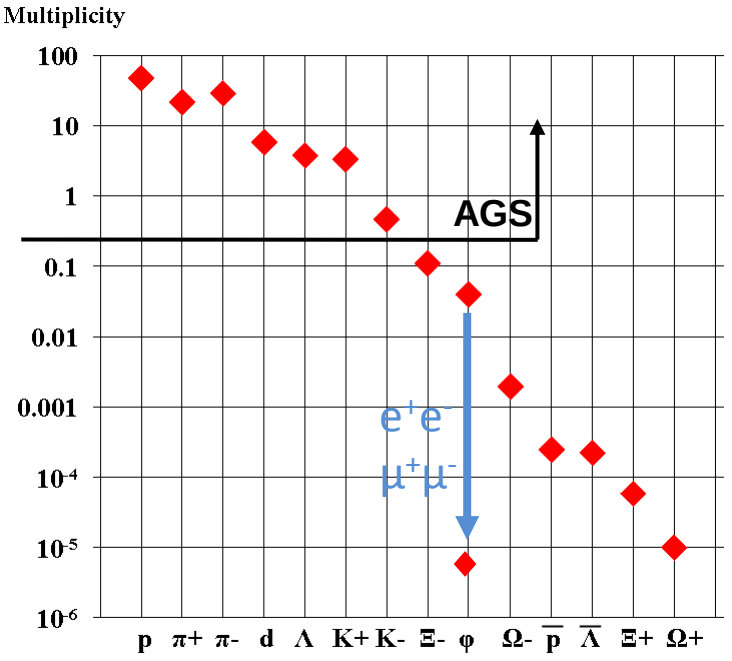
high net-baryon densities

CBM: bulk and **rare observables, high statistic**

Most experiments: bulk observables



Particle yields in central Au+Au 4 A GeV

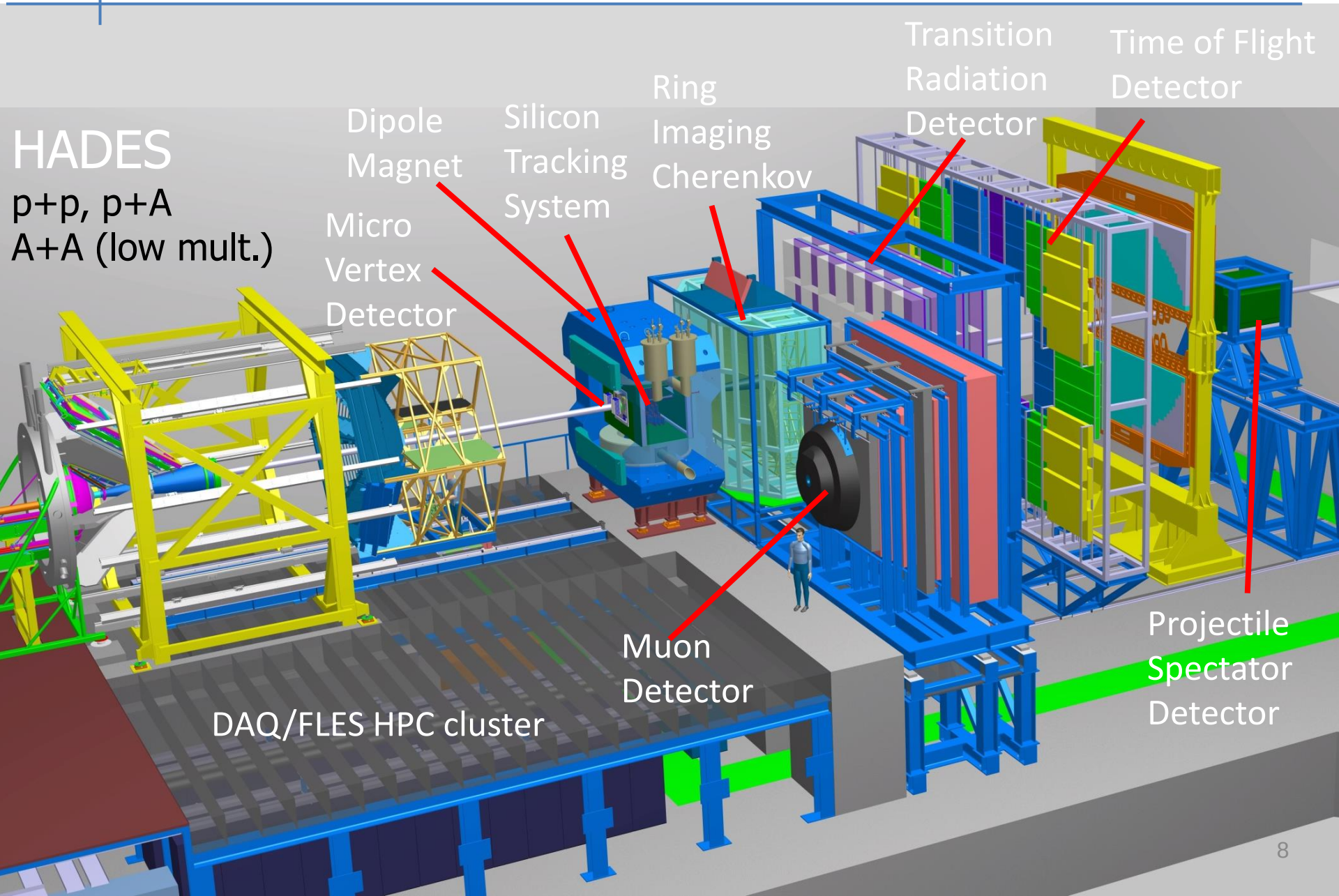


Statistical model, A. Andronic

CBM Experimental Challenges

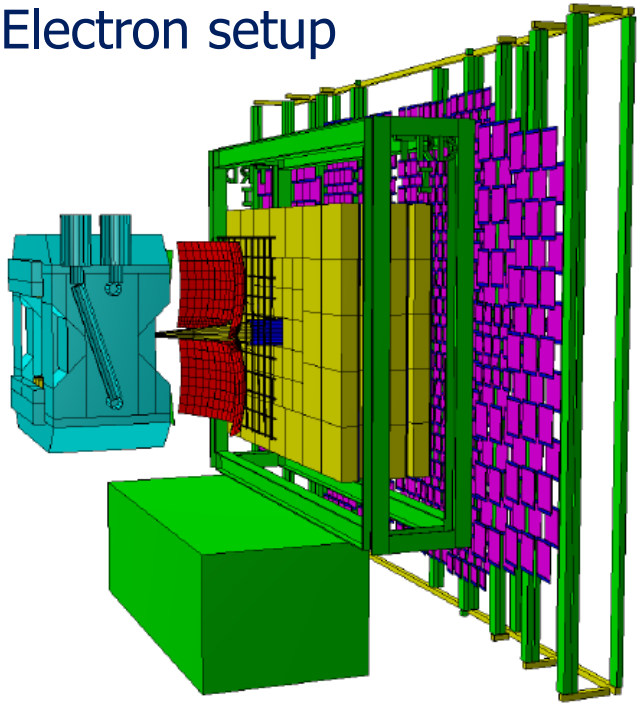
- 10^5 - 10^7 Au+Au reactions/sec
- determination of displaced vertices ($\sigma \approx 50$ μm)
- identification of leptons and hadrons
- fast and radiation hard detectors
  self triggering frontend electronics
- free-streaming readout system
- > 1TByte/sec of raw data
- high speed data acquisition and high performance computer farm
  - 4-D event reconstruction
  - online event selection

CBM Detector Assembly

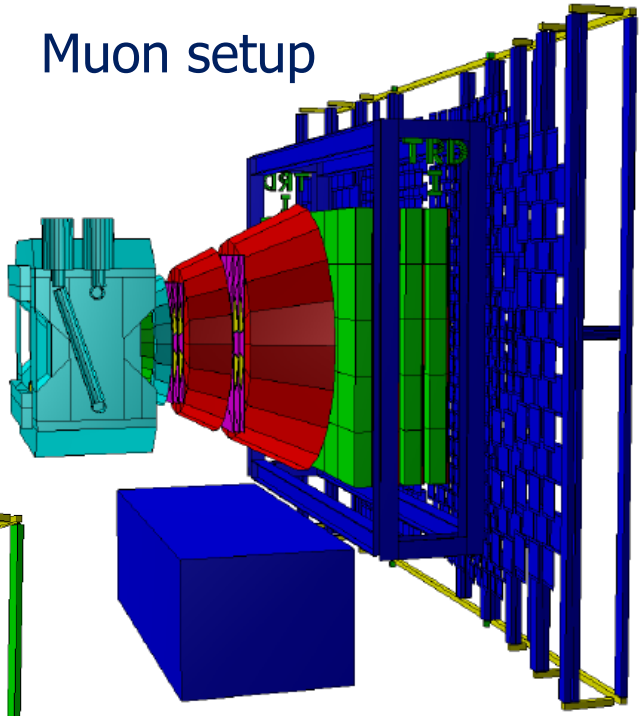


CBM Experimental Setups

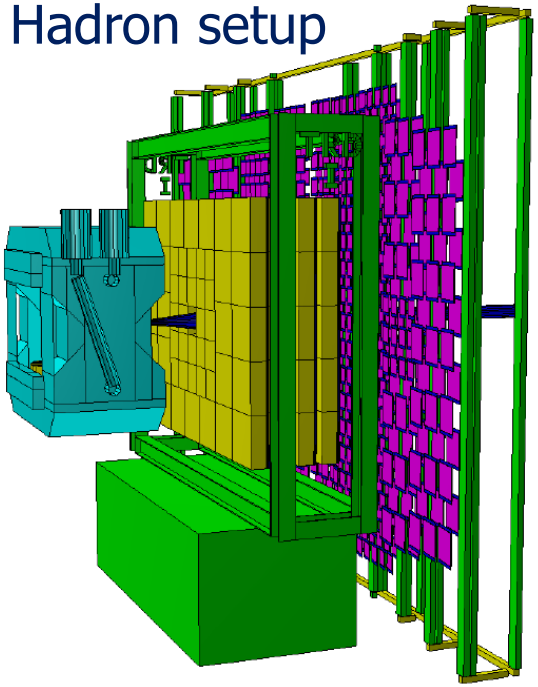
Electron setup



Muon setup



Hadron setup



Status & Progress

Status of FAIR

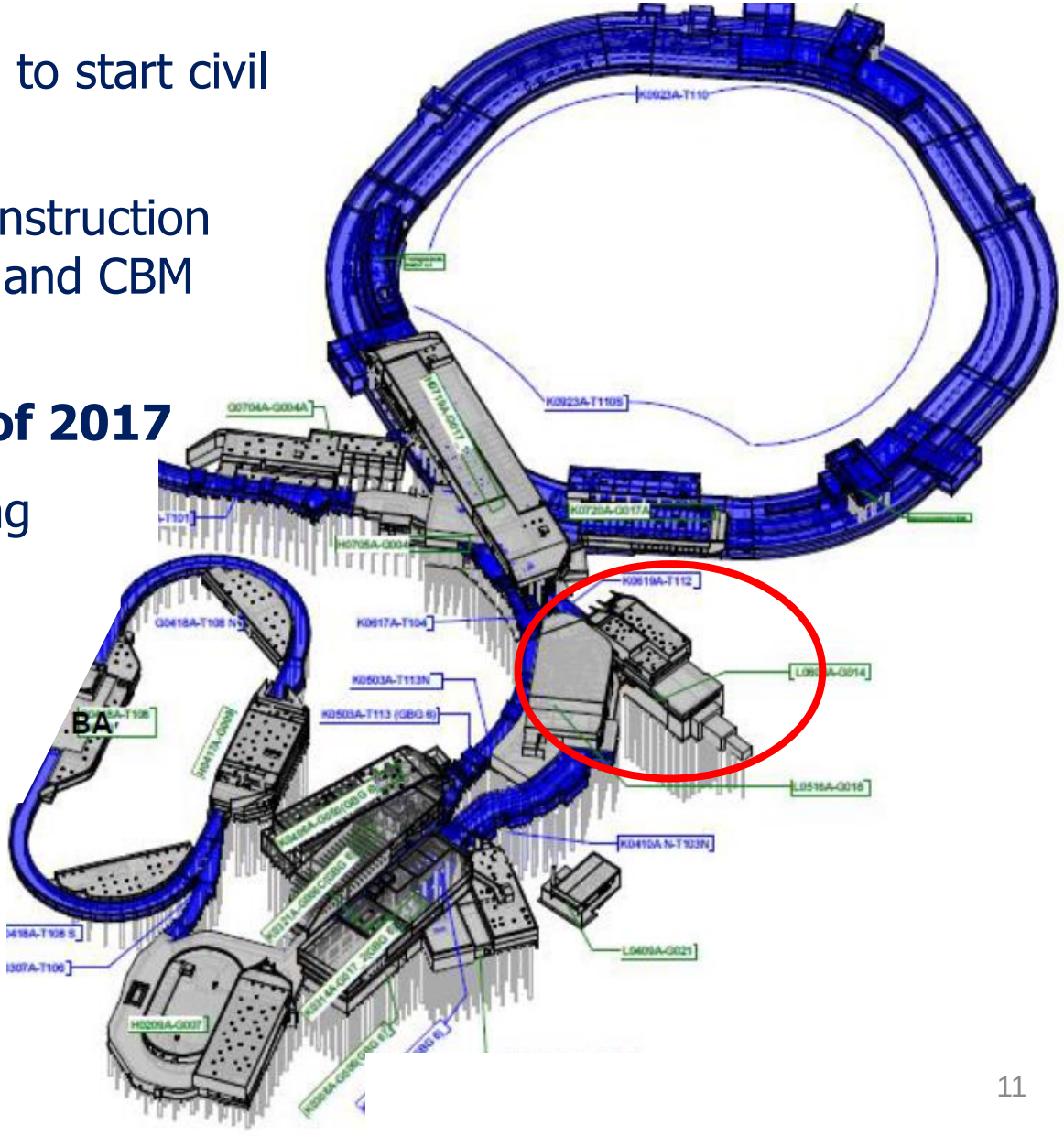
Sep. 2016: first BMBF funding to start civil construction.

Nov. 2016: tender for shell construction ‘north area’, including SIS100 and CBM cave

Start of construction mid of 2017

Installation incl. commissioning of the experiments is planned during 2022-2024

Full completion of FAIR by 2025

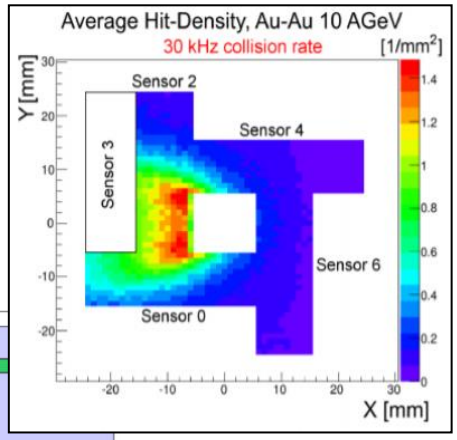


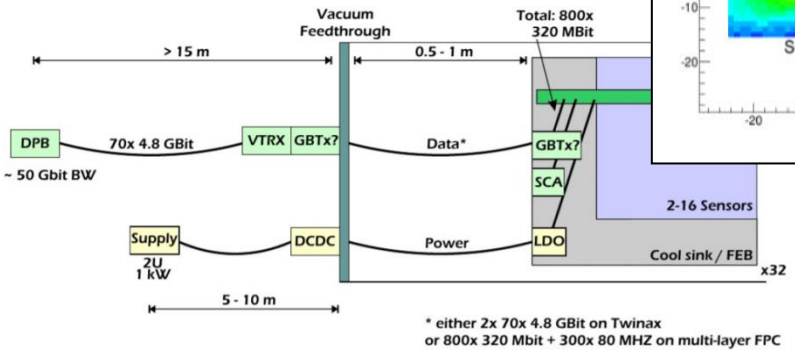
Planned Cave + Building Infrastructure

Tracking Detectors – Sensors & Readout

Micro Vertex Detector (MVD)

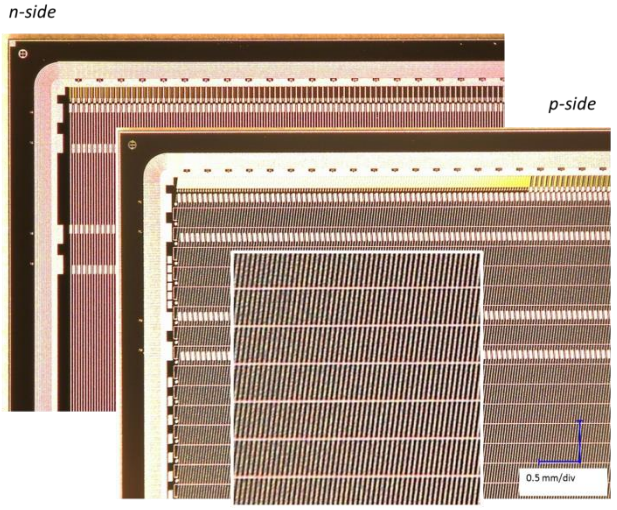
- Dedicated CBM sensor (MIMOSIS) in synergy with ALICE-ITS upgrade: improved in-pixel logic and data throughput, 200 kHz frame rate
- Detailed **studies of readout concept and data rates** for different physics cases
- Radiation studies with fully depleted MAPS

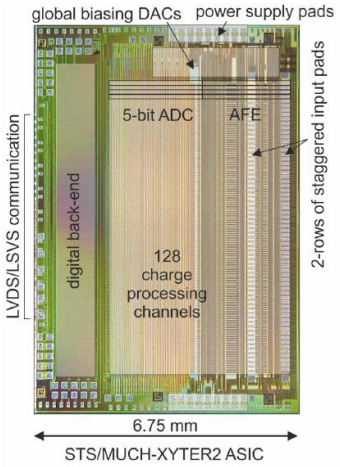




Silicon Tracking System (STS)

- **Sensor** layouts established with vendors, prototypes available
- Sensor QA and performance procedures defined
- Radiation tolerance of sensors tested up to n_{eq} (1 MeV) = 2×10^{14} /cm^2,
- STS-XYTERv2 **readout ASIC produced and being tested**; irradiation in test beam (SEU)

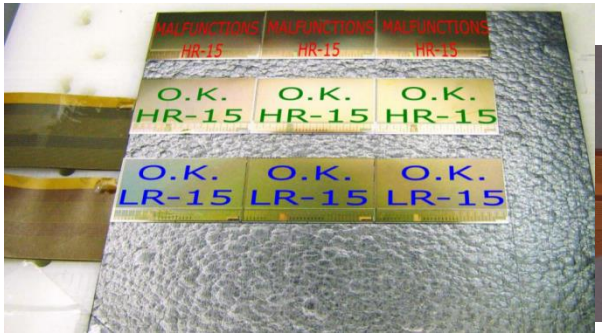


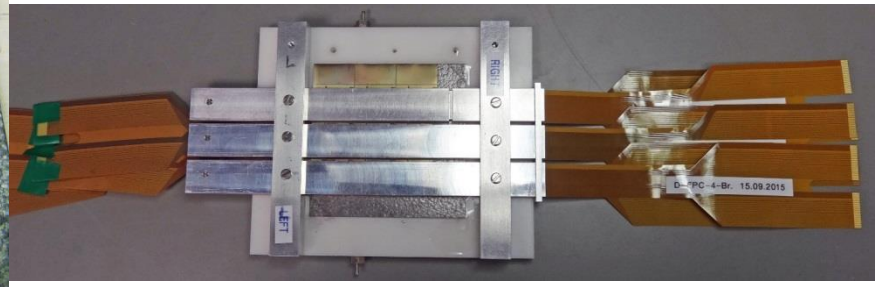


Tracking Detectors - Integration

Micro Vertex Detector (MVD)

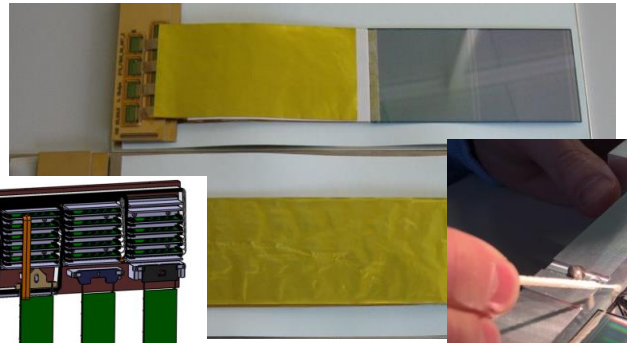
- Prototyping well advanced with **PRESTO module**: integration and operation of thinned pixel sensors on a carrier of Thermal Pyrolytic Graphite





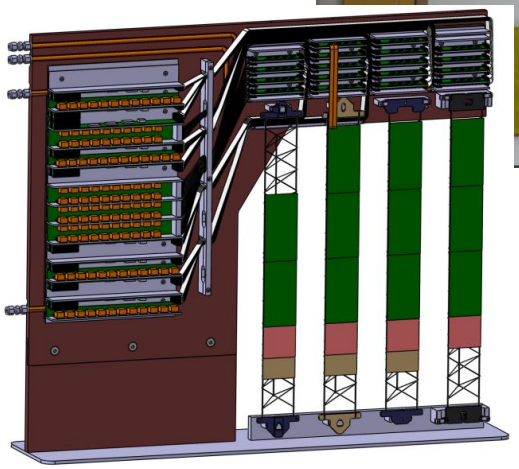
Superconducting Dipole Magnet

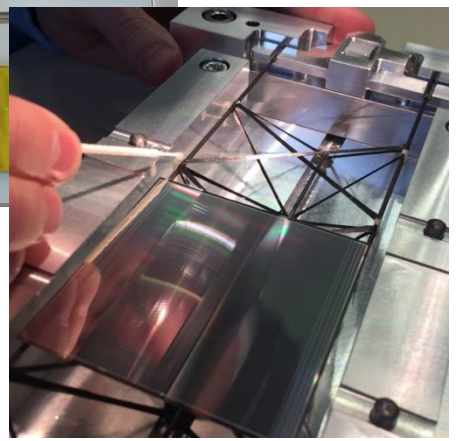
Collaboration contract with Budker Institute Novosibirsk signed Dec. 2016



Silicon Tracking System (STS)

- Progress in **establishing module and ladder assembly procedures** and **tooling** prototypes
- Progress in engineering design and system integration.
  - Quarter unit **mechanical mockup** for system integration studies





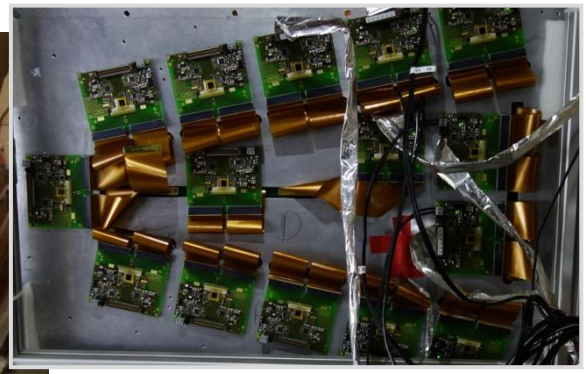
PID Detectors – Prototype Modules

MRPC Time-of-Flight Wall (TOF)

- Set of MRPCs successfully tested under realistic load conditions of beam rates up to several kHz/cm^2
- R&D for Beam Fragmentation T_0 Counter: ceramic RPC

Muon Chamber (MuCh)

- Full size GEM chamber tested with p beam (COSY), 2 large chambers tested at SPS
- Prototype Bakelite RPC detector (for 3rd, 4th plane) tested with cosmic rays



Transition Radiation Detector (TRD)

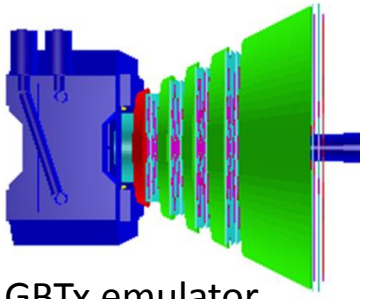
- Design and construction of four large detector modules (95 x 95 cm^2)
- Tested at CERN-SPS

Detectors – Misc.

Transition Radiation Detector (TRD)

- TDR completed, under review
- New versions of **readout ASIC**: SPADIC v1.1 and v2.0
- Successful test of a read-out chain employing the SPADIC v1.1 ASICs and FLES-DAQ.
- Simulations: intermediate mass di-electrons and identification of fragments via their energy loss

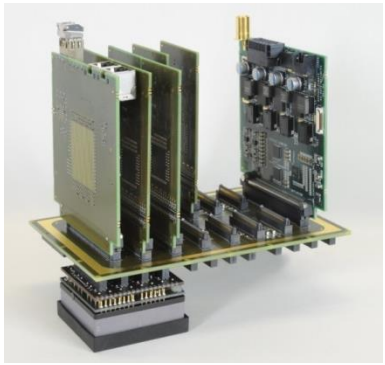
Muon Chamber (MuCh)



- MUCH-XYTER frontend ASIC produced and being tested
- Readout chain with GBTx emulator
- Prototype systems for mechanical mount, cooling, LV

Ring-Imaging Cherenkov (RICH) Detector

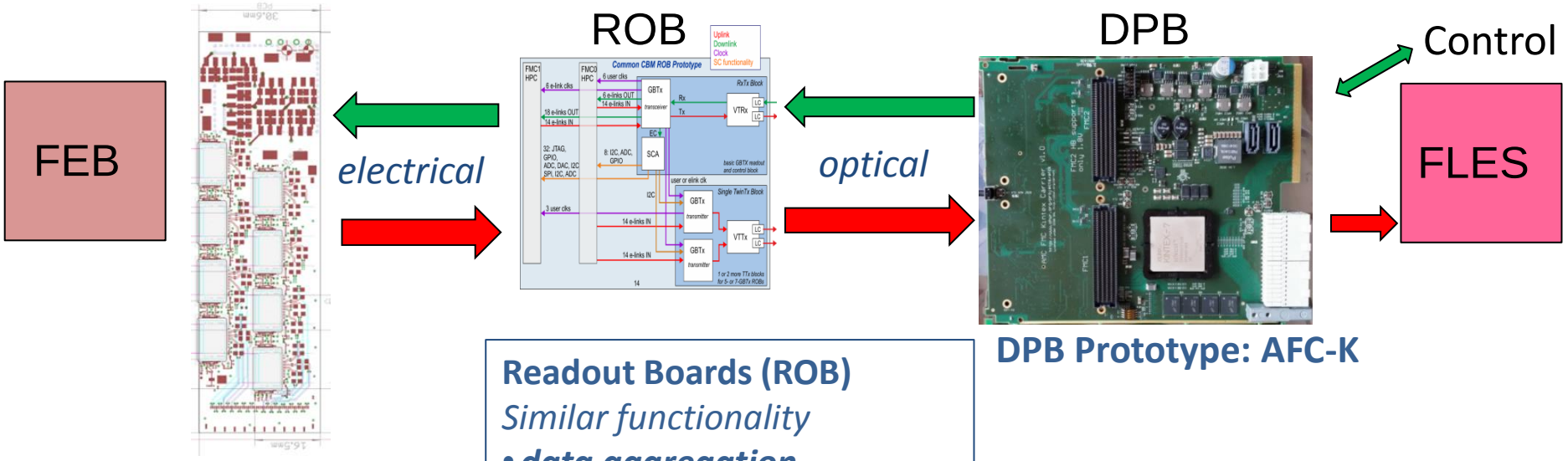
- New RICH geometry with cylindrical photodetector plane and better ring quality; fully implemented in simulations
- 70% of H12700 **MAPMTs delivered** and tested
- Concept for new structure of mirror wall with substantially reduced material budget
- **Prototype of full RICH readout chain** produced and under test



Particle Spectator Detector (PSD)

19 of 45 modules assembled and tested

CBM Readout Scheme



DPB Prototype: AFC-K

Frontend Boards (FEB)
detector specific functionality and designs of ASICs and boards

Channel, signal, **timestamp**

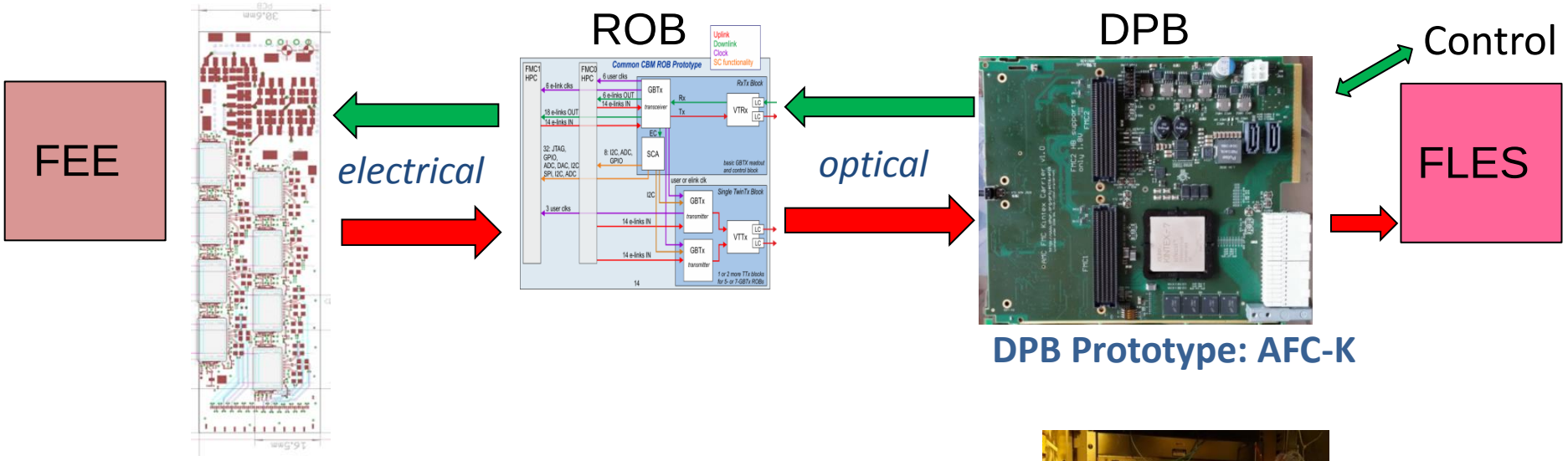
Integrated with or located close to detector elements

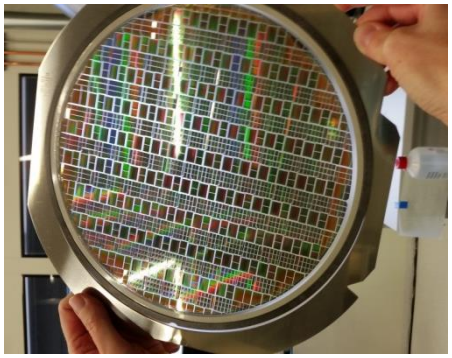
Readout Boards (ROB)
Similar functionality
- ***data aggregation***
  - ASICs: several ten thousand electrical links
- data readout
  - ***optical readout interface***
- FE ASIC control path
- clock distribution and synchronization

Implementation with radiation hard ***CERN GBTX and Versatile Link*** *components*

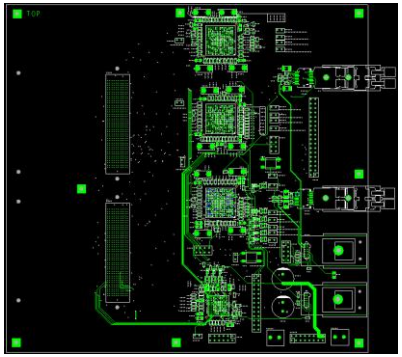
Data Processing Board (DPB)
CBM *common hardware platform*:
- FPGA based
  - data formatting
  - preprocessing
- timing and control interfaces
- interface to FLES (FLIB)
- in CBM building (surface)

CBM Readout Scheme





Common ASIC production for prototype FEBs

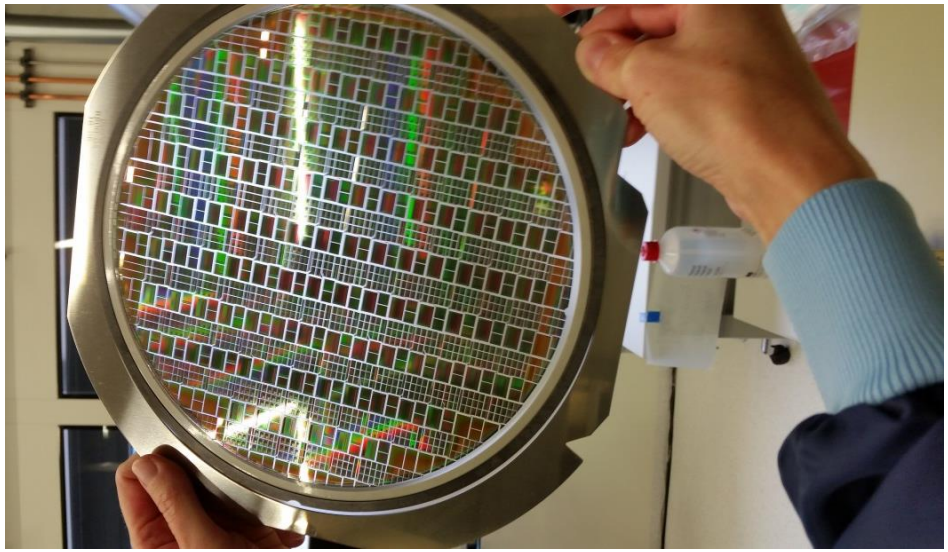


Common readout board prototype

Common free streaming readout system in test beamtime

Common ASIC Engineering Run

Engineering run (UMC180nm) of 20 wafers with multiple CBM ASICs.

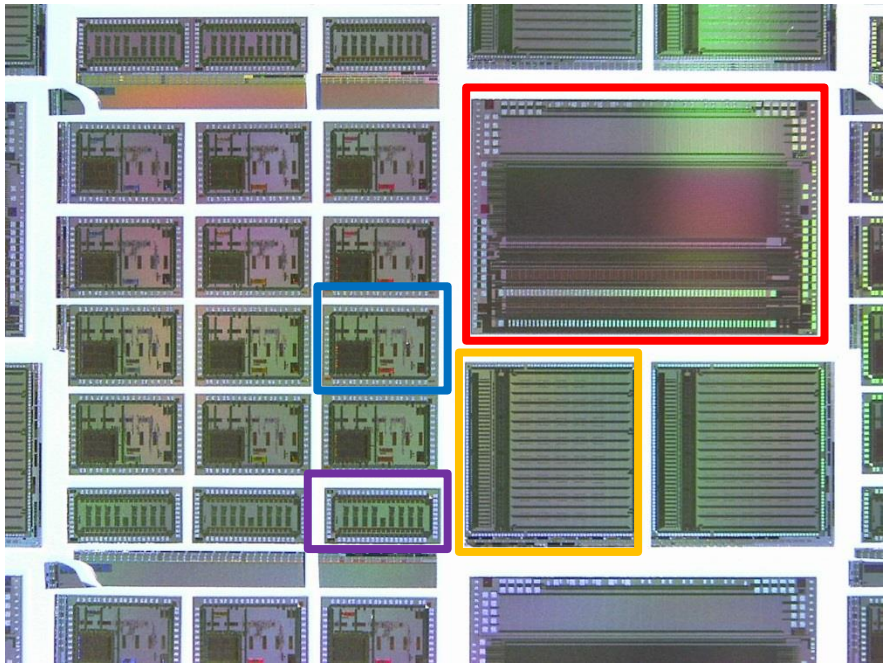


Evaluation, integration and application ongoing:

- TOF participates in FAIR Phase 0 at Star with Get4 and PADI
- STS proceeds with FEB & module prototyping & detector tests
  → production readiness
- TRD does readout prototyping

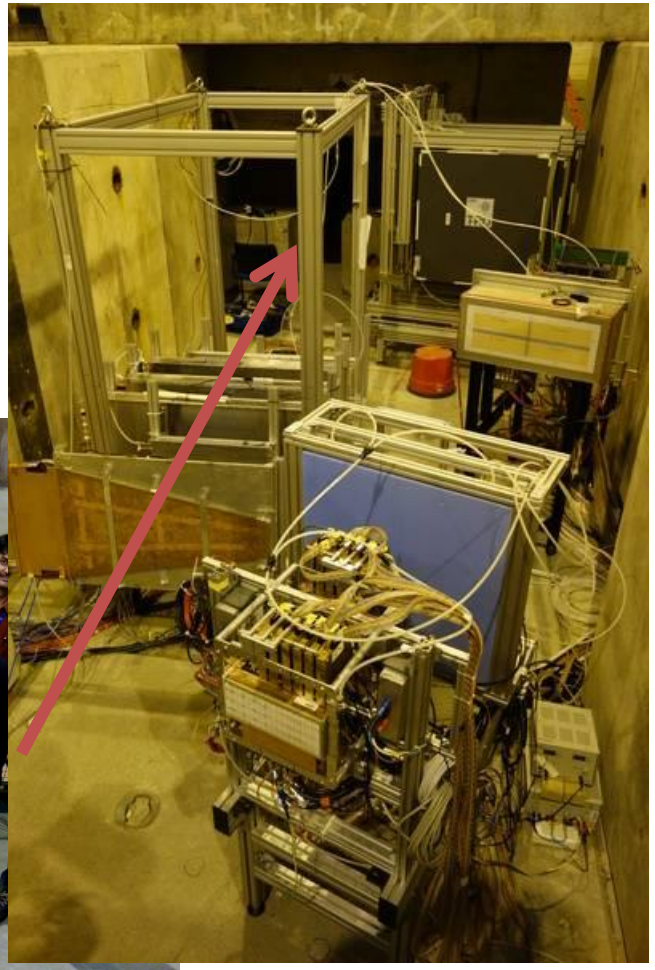
Prototype or engineering versions for:

- STS-XYTER and Much-XYTER v2.0
- Get4 TDC in two versions for TOF
- PADI production for CBM-TOF@STAR
- SPADIC for TRD



Common Beam Test at CERN SPS

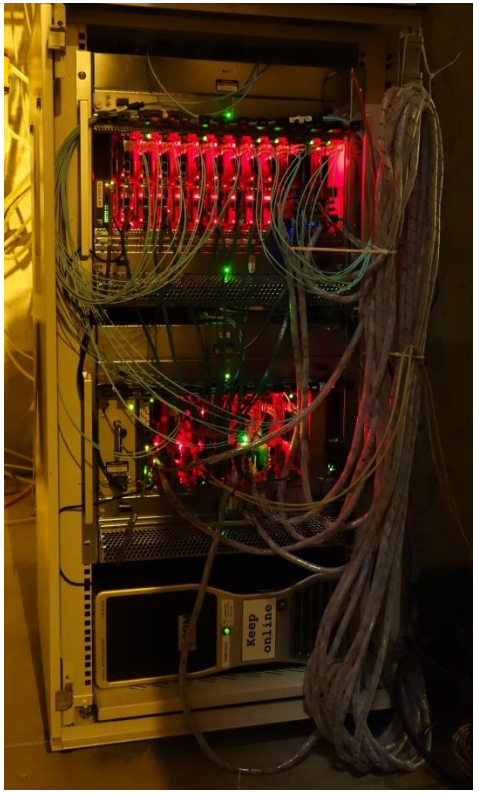
- 3 weeks in Nov. – Dec. 2016
- Pb+Pb collisions at 13, 30 and 160 A GeV.
- Teams from China, Germany, India, Romania
- Prototype detectors:
  - MuCh-GEM
  - TRD
  - TOF
  - diamond start detector
- Common free-streaming readout system and DAQ



Free-Streaming Readout Systems at SPS

Common Readout & DAQ System

- AFCK based, free streaming DAQ system for TOF & MUCH
- Modular readout chains
- Stable DAQ operation over a period of 4 weeks

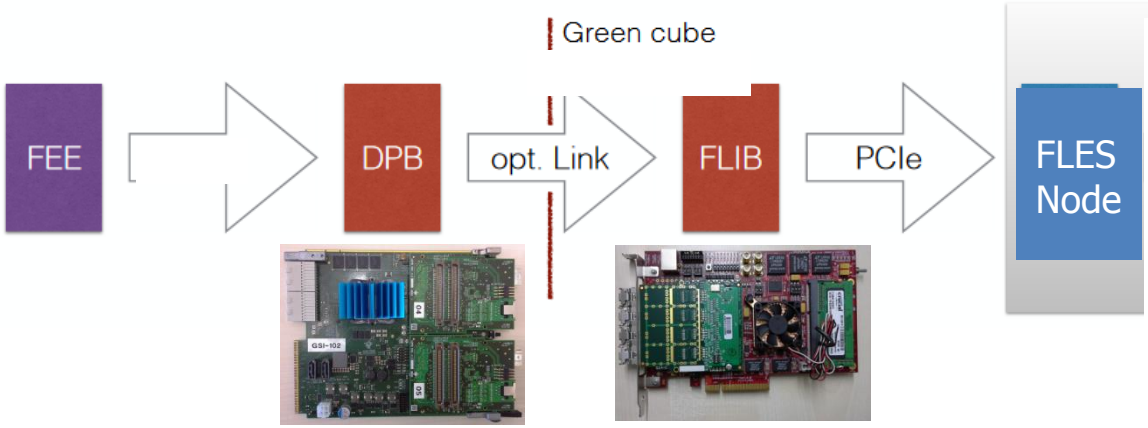


MuCH

Free-streaming read-out electronics with n-XYTER v2, AFCK

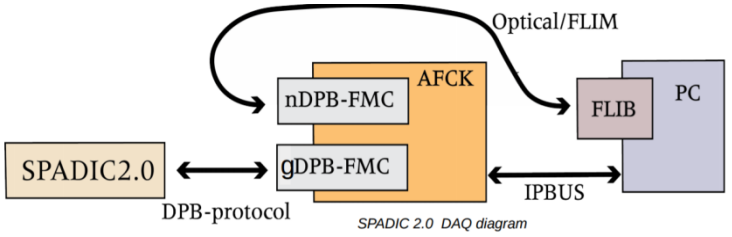
MRPC Time-of-Flight Wall (TOF)

Free streaming readout chain with PADI, GET4, AFCK



Transition Radiation Detector (TRD)

Successful test of a read-out chain employing the SPADIC v1.1 ASIC, AFCK and FLES-DAQ



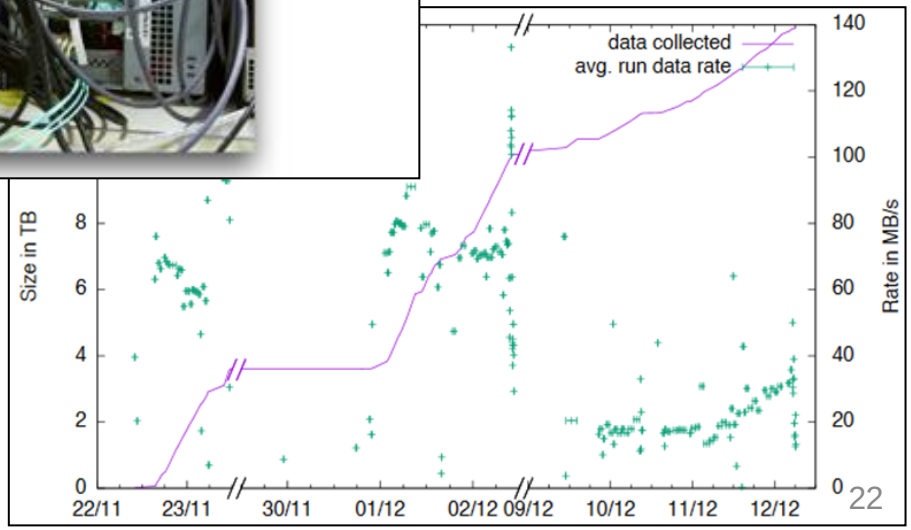
Common FLES-DAQ System at SPS

- First common FLES readout of multiple CBM detector systems
- Readout chain from DPB to timeslice like planed for the final system

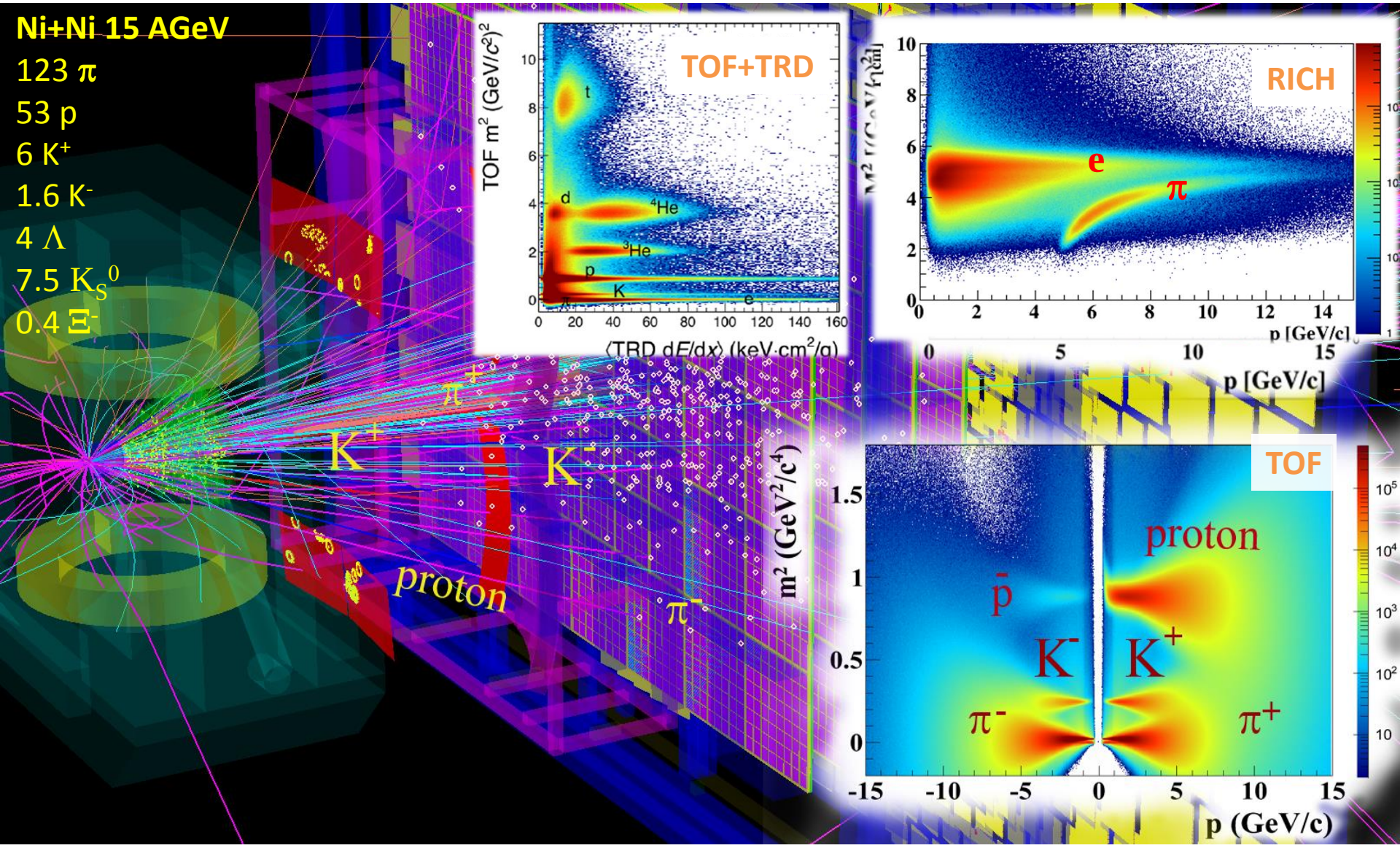
~20m

miniFLES

Data rate and data volume over full beamtime



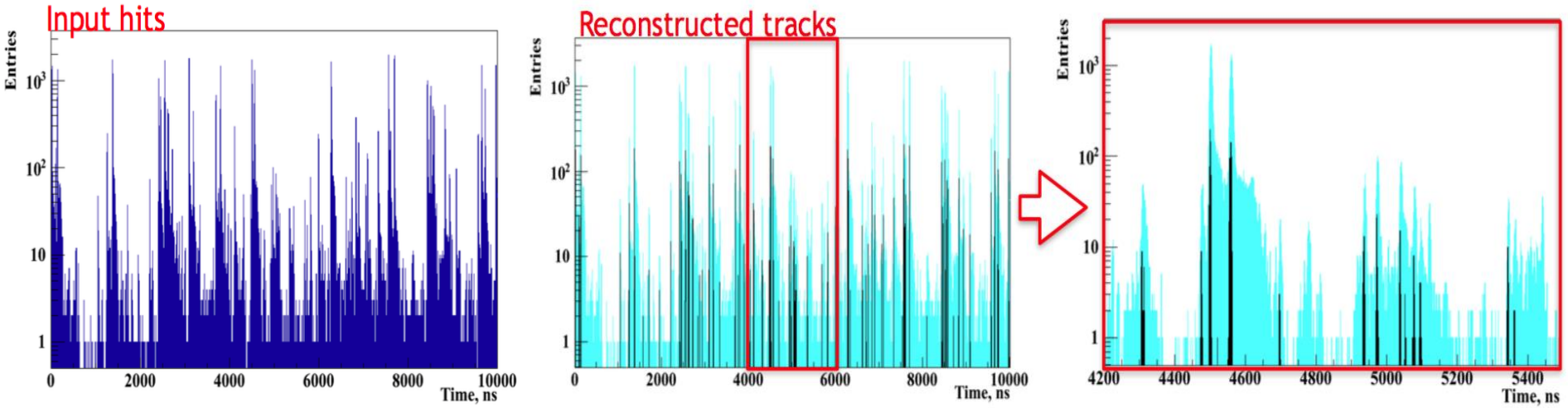
Simulation & Reconstruction: Particle ID



Sim. & Reco.: **4D** Track & Event Reconstruction

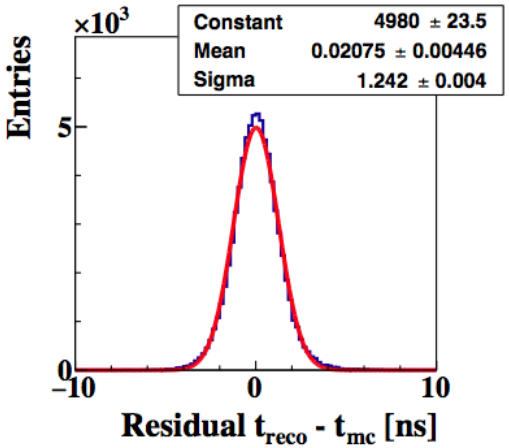
Challenge

- Reconstruct particles and events from the **untriggered, time-stamped data stream**.
- At high rates: events overlap in time at the hit level.



Au+Au 25 AGeV @10 MHz; **STS only**

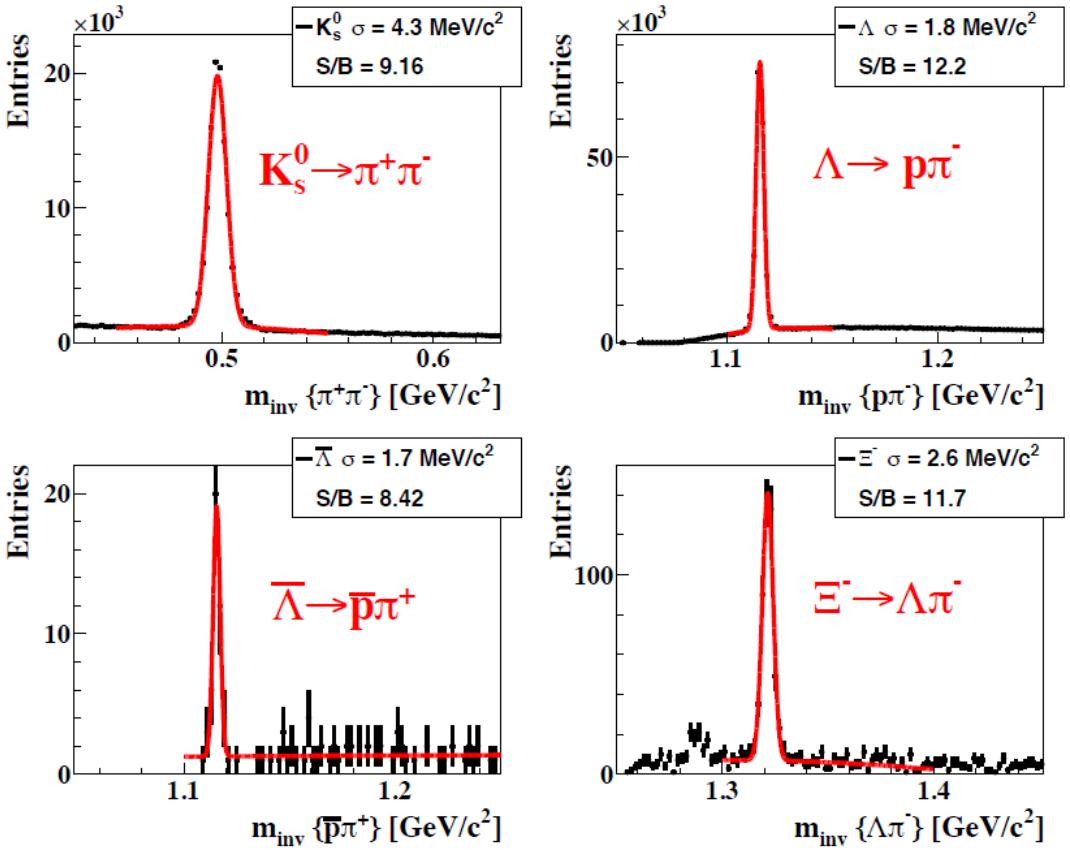
4D Track Fit (Kalman Filter):
(x, y, t_x, t_y, q/p) ->
(x, y, t_x, t_y, q/p, **t**)



- At 10 MHz event rate, about 80% of all events can be resolved at the track level.
- The remaining pile-up events require inclusion of TOF information and/or topological analysis (primary vertices).

Sim. & Reco.: 4D Physics Analysis

10 MHz, AuAu, 10 AGeV, 300k mbias UrQMD events, ideal PID



- 4D reconstruction chain from hit production to physics analysis established
- Ideal (Monte Carlo) PID used for track identification
- Physics performance stable up to 1MHz interaction rate
- Extreme case of 10MHz will require additional steps (TOF, primary vertex analysis)

FAIR Phase 0 Experiments

Intermediate research program until physics program starts at SIS100

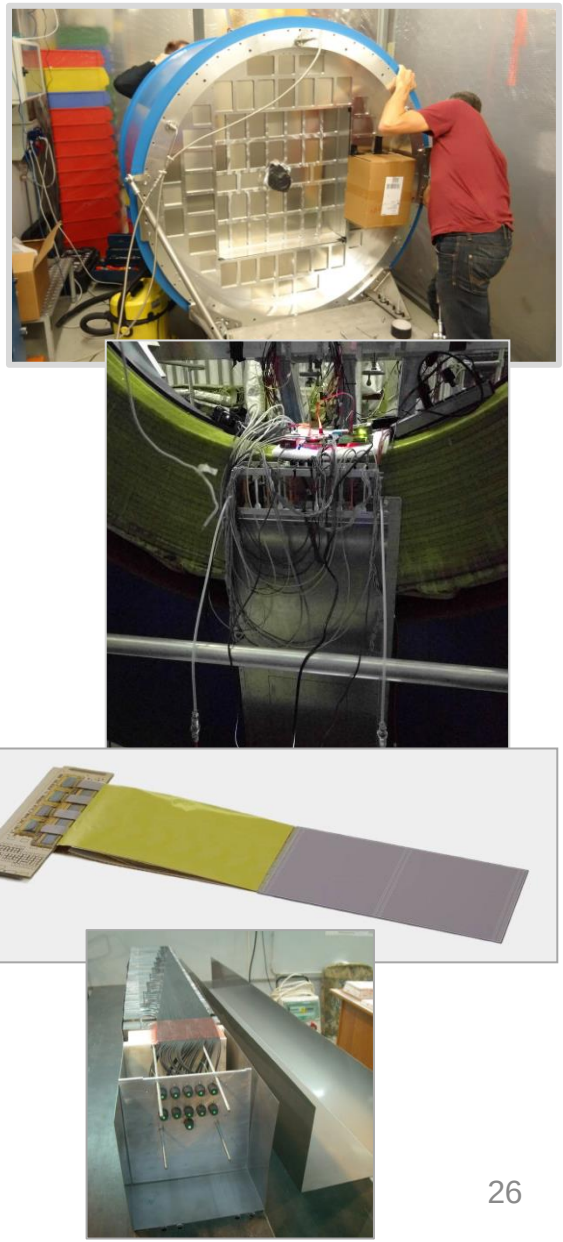
- Use subsystems in production environment
- Practice system operation, processing and analysis

1. Install, commission and use 430 out of 1100 CBM **RICH** multi-anode photo-multipliers (**MAPMT**) in **HADES RICH photon detector** at SIS18

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

3. Install, commission and use **4 Silicon Tracking Stations** 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 **Projectile Spectator Detector** at the **BM@N** experiment



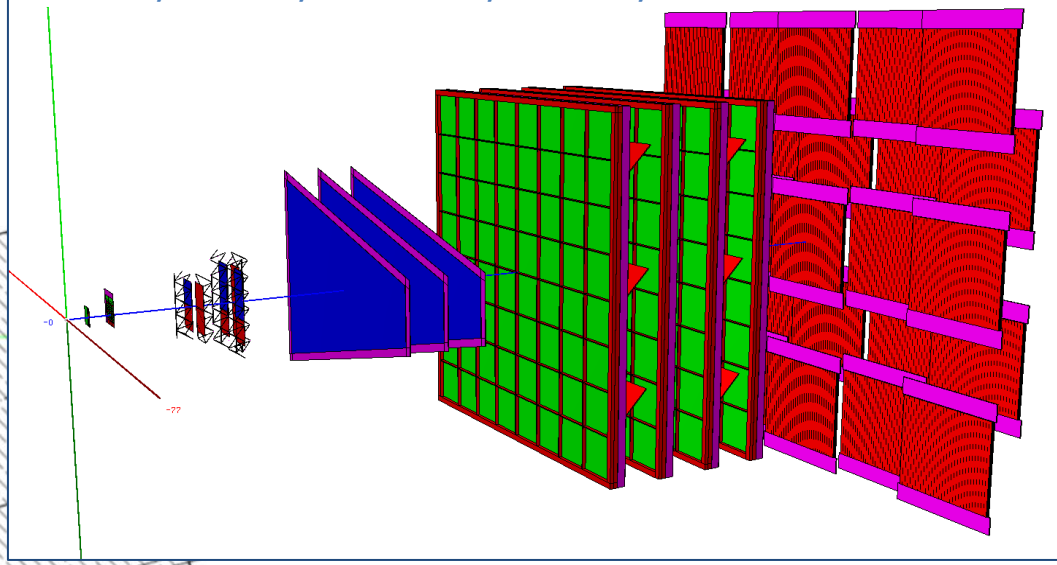
FAIR Phase0: miniCBM at GSI SIS18

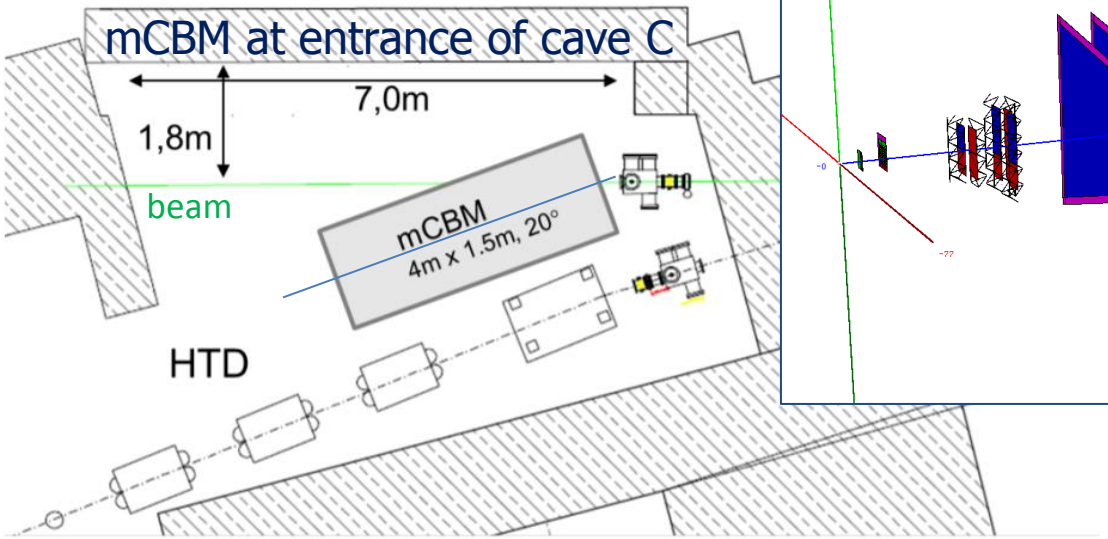
Dedicated full system testing with high-rate nucleus-nucleus collisions 2018-2021

Set-up with full size detector modules and read-out chain.
Test and optimization of:

- Detector performance under experiment conditions
- Free streaming readout and data transport to FLES
- Online reconstruction
- Data analysis (offline)

mCBM setup with
mMVD, mSTS, mMUCH, mTRD, mTOF





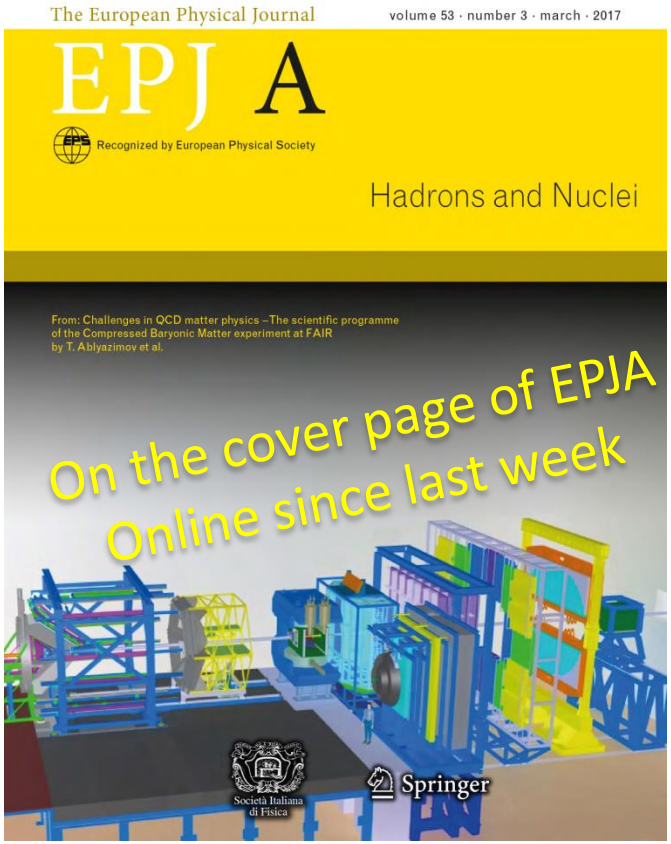
Conclusions

- FAIR: comprehensive civil construction plan; activities starting
  → CBM on well defined schedule for experiment readiness
- CBM Progress
  - Several close to final detector modules tested with beam (TOF, TRD, MUCH)
  - Development of prototypes and tools for detector assembly
  - Progresses in services, integration, ..
  - Components towards final and full readout chains become available
  - First common free streaming readout up to time slice building with multiple detectors in beam test
  - Simulation & reconstruction: 4D tracking and analysis become default approach; refinement ongoing
- Phase0 activities
  - will provide system experiences and physics from 2018/19

For Further Reading…

First Collaboration Paper:

"Challenges in QCD Matter Physics – the scientific programme of the Compressed Baryonic Matter Experiment at FAIR"



Ref.: Ablyazimov, T. et al. Eur. Phys. J. A (2017) 53: 60. doi:10.1140/epja/i2017-12248-y

Latest Progress Report:

https://repository.gsi.de/record/201318

ISBN 978-3-9815227-4-7

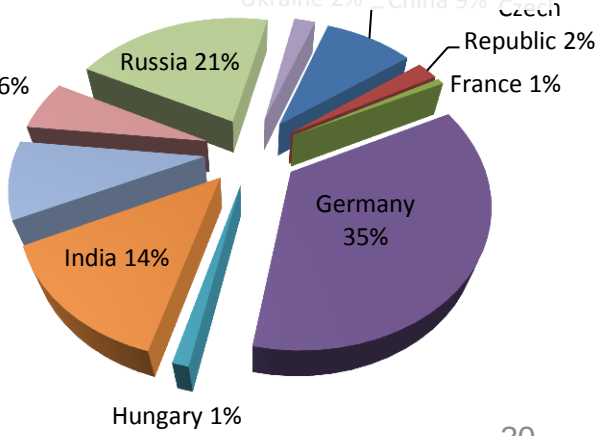
The Collaboration: 55 institutions, 460 members

23.03.2017: new CBM spokesperson:
Prof. Norbert Herrmann, Univ. Heidelberg

Successor of Prof. Peter Senger,
GSI/Univ. Frankfurt

29th CBM Collaboration meeting, GSI, Mar. 2017

CBM Scientists



CBM Presentations – Mon./Tue.

Mon, 17:30	HK 2.3	Performance of charged pions, kaons, protons and their anti-particles identification in the CBM experiment — •Viktor Klochkov	
Mon, 18:15	HK 2.6	Performance studies for electron measurement with the CBM-TRD — •Etienne Bechtel	Performance
Mon, 18:15	HK 6.7	Radiation Damage Caused by Neutron Capture in Boron Doped Silicon Pixel Sensors — •Benjamin Linnik	Rad. Effects
Mon, 18:45	HK 6.9	Read-Out Resilience in Radiation Environments — •Andrei-Dumitru Oancea	
Mon, 17:00	HK 9.2	The Silicon Tracking System of the CBM Experiment at FAIR — •Olga Bertini	
Mon, 17:30	HK 9.3	Proton beam tests of silicon microstrip sensors for the CBM experiment — •Maksym Teklishyn	
Mon, 18:00	HK 9.5	Hit position error estimation for the CBM Silicon Tracking System — •Hanna Malygina	STS
Mon, 18:15	HK 9.6	Progress with System Integration of the CBM Silicon Tracking Detector — •Johann M. Heuser	
Tue, 11:00	HK 12.1	Event reconstruction and selection in high-rate heavy-ion reactions in the CBM experiment at FAIR — •Maksym Zyzak	
Tue, 11:30	HK 12.2	Geometry independent Kalman filter based track fit — •Artemiy Belousov	Reco.
Tue, 12:15	HK 12.5	Performance of 4-Dimensional Cellular Automaton Track Finder in CBM — •Valentina Akishina	
Tue, 11:00	HK 15.1	The CBM First-level Event Selector — •Jan de Cuveland	
Tue, 12:00	HK 15.4	A prototype of the free-streaming data acquisition system for the Compressed Baryonic Matter experiment at FAIR — •David Emschermann	DAQ
Tue, 12:15	HK 15.5	mCBM@SIS18 - a CBM full system test-setup at GSI — •Christian Sturm	
Tue, 11:30	HK 16.2	The CBM Time-of-Flight wall — •Ingo Martin Deppner	
Tue, 12:05	HK 18.5	Evaluation of Innovative Cooling Concepts with High Performance Carbon Material for Vertex Detectors operated in Vacuum — •Daniela Mijatovic	
Tue, 14:45	HK 21.3	Reconstruction of neutral pions at CBM-RICH detector via conversion* — •Ievgenii Kres	TOF, RICH
Tue, 15:30	HK 26.6	Charakteristika von 700 HAMAMATSU H12700 MAPMTs* — •Jörg Förtsch	

18 oral presentations

Tue, 16:45	HK 27.24	Performance studies for J/ψ measurements in p+A collisions with CBM — •Daniel Giang
Tue, 16:45	HK 27.52	Track-based Misalignment Corrections for the CBM Silicon Tracking Detector — •Susovan Das
Tue, 16:45	HK 27.54	Construction of a neutron source for silicon detector irradiation — •Eduard Friske
Tue, 16:45	HK 27.65	Measurements with CBM-TRD Prototypes at the CERN SPS in 2015 — •Patrick Schneider and Dennis Spicker
Tue, 16:45	HK 27.69	Energy resolution measurements with the CBM-TRD using a 55Fe-Source — •Marcel Raabe
Tue, 16:45	HK 27.71	Investigation of CO2-based Cooling for the CBM Silicon Tracking System — •Kshitij Agarwal
Tue, 16:45	HK 27.93	The common GBTX based prototype readout board for CBM — •Jörg Lehnert

7 posters

CBM Presentations – Wed./Thu./Fri.

27 oral presentations still to come

Wed, 16:45	HK 30.1	The Compressed Baryonic Matter experiment at FAIR — •Jörg Lehnert	
Wed, 17:30	HK 33.3	Time based track reconstruction in the CBM experiment — •Timur Ablyazimov	Reco.
Wed, 17:45	HK 33.4	Speed up approaches in the Cellular Automaton (CA) track finder — •Grigory Kozlov	
Wed, 17:30	HK 34.3	Concept and design of an alignment monitoring system for the CBM RICH mirrors* — •Jordan Bendarouach	
Wed, 18:15	HK 35.7	Electrical quality assurance of silicon microstrip sensors for the CBM experiment — •Iaroslav Panasenko	QA
Wed, 18:30	HK 35.8	Optical quality assurance procedures for the sensors of the CBM Silicon Tracking System — •Evgeny Lavrik	
Wed, 17:15	HK 36.3	Studies of radiation field impact on microstrip sensors for the CBM Silicon Tracking System — •Ievgeniia Momot	
Wed, 18:30	HK 36.8	Radiation Tolerance of a Fully Depleted CMOS Monolithic Active Pixel Sensor — •Tobias Bus	Rad. Effects
Thu, 15:00	HK 40.5	Thermal dilepton emission as a fireball probe — •Florian Seck	
Thu, 14:45	HK 45.4	Status update of the Feature Extraction Framework for CBM-TRD — •Cruz de Jesus Garcia Chavez	Dileptons Hyperons
Thu, 17:15	HK 47.2	Multi-strange Hyperons and Hypernuclei reconstruction at the CBM experiment — •Iouri Vassiliev	
Thu, 18:45	HK 47.8	Online reconstruction of multi-strange hyperons with the CBM experiment — •Hamda Cherif	
Thu, 18:00	HK 50.6	Online data pre-processing for CBM-MVD — •Qiyan Li	
Thu, 18:45	HK 50.9	A parametric response model for the self-triggered MRPC readout scheme of the CBM time-of-flight system — •Christian Simon	
Thu, 16:45	HK 53.1	The CBM-MVD: Group Report — •Michal Koziel	
Thu, 17:45	HK 53.4	Design studies on the MimoSIS pixel sensor for the CBM-MVD — •Philipp Sitzmann	MVD
Thu, 18:30	HK 53.7	Finalizing the CBM-MVD Geometry: CAD and Simulation — •Philipp Klaus	
Fri, 14:45	HK 58.3	Reconstruction of short-lived particles with neutral daughter by the missing mass method — •Pavel Kisel	
Fri, 14:45	HK 62.4	Detector performance tests for the CBM TRD — •Martin Kohn	
Fri, 15:00	HK 62.5	Construction of large full-size MWPC prototypes for the CBM-TRD — •Susanne Gläessel	TRD
Fri, 15:15	HK 62.6	Development of a Gas System Prototype for the CBM-TRD — •Felix Fidorra	
Fri, 15:30	HK 62.7	An instrumented analysis and supply gas system prototype for the CBM TRD — •Philipp Munkes	
Fri, 15:45	HK 62.8	Spectra and Position Reconstruction on CBM-TRD Data from CERN-SPS Testbeam 2016 — •Philipp Kähler	
Fri, 14:15	HK 63.2	Test of the STS-XYTER2 frontend ASIC for the CBM Silicon Tracking System — •Adrian Rodriguez Rodriguez	
Fri, 14:45	HK 63.4	First measurements on the new FPGA-based DIRICH MAPMT readout* — •Vivek Patel	
Fri, 15:00	HK 63.5	DiRich - Readout Electronics for DIRC and RICH detectors at FAIR — •Jan Michel	Readout & DAQ
Fri, 15:15	HK 63.6	Evaluation of the CBM FLES input interface at 2016 CERN/SPS beam test — •Dirk Hutter	