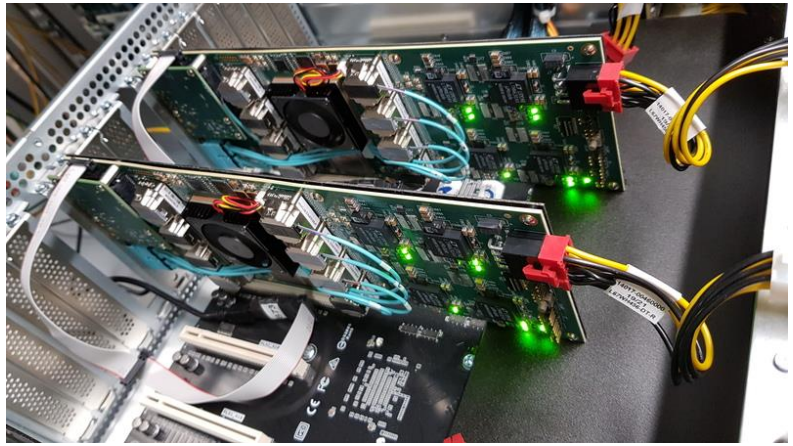
Prototype DAQ system for CBM



HELMHOLTZ
RESEARCH FOR GRAND CHALLENGES

David Emschermann

Streaming Readout Wokshop VII – BNL/Zoom – 17.Nov.2020

CBM

Outlook

- The FAIR facility and construction site
- Location of CBM at FAIR and mCBM at GSI
- The CBM data challenge
- The mCBM µTCA readout chain (2020)
- The mCBM CRI readout chain (2021)

The FAIR accelerator facility

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

Technical Challenges

- cooled beams
- rapid cycling superconducting magnets
- dynamical vacuum

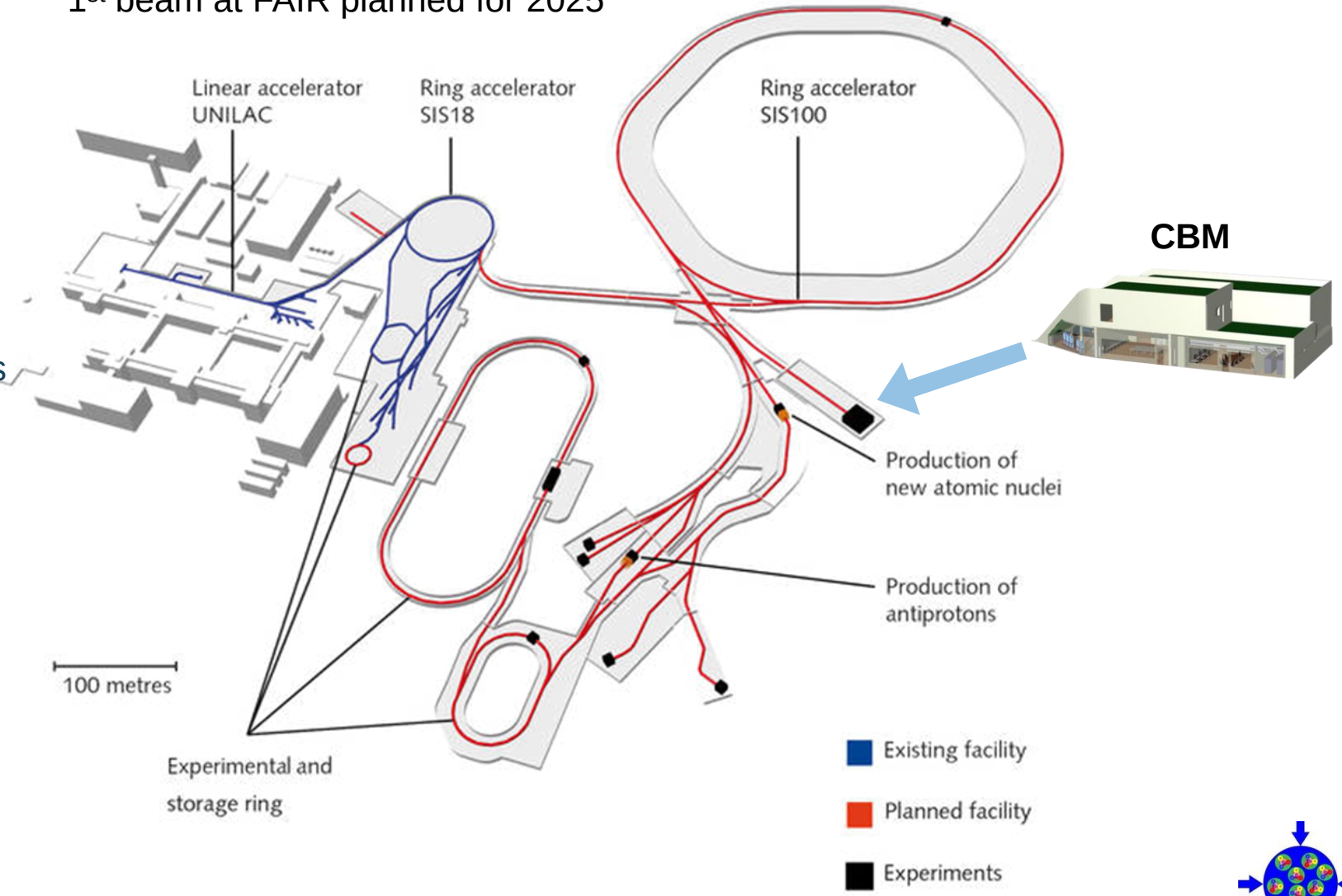
Secondary Beams

- radioactive beams up to 1.5 - 2 GeV/u; up to factor 10000 higher in intensity than presently
- antiprotons 3 - 30 GeV

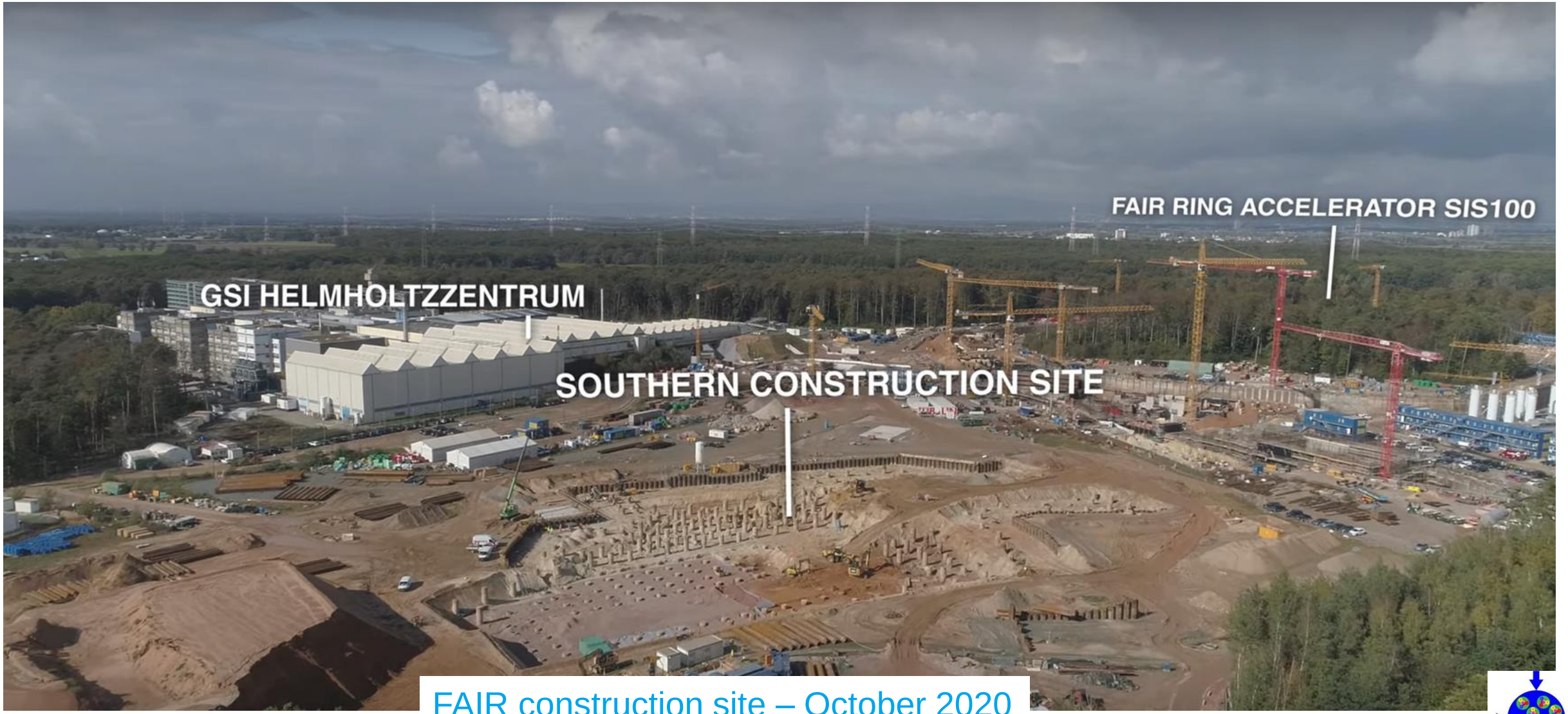
Storage and Cooler Rings

- radioactive beams
- 10^{11} antiprotons 1.5 - 15 GeV/c, stored and cooled

1st beam at FAIR planned for 2025



FAIR construction site – October 2020

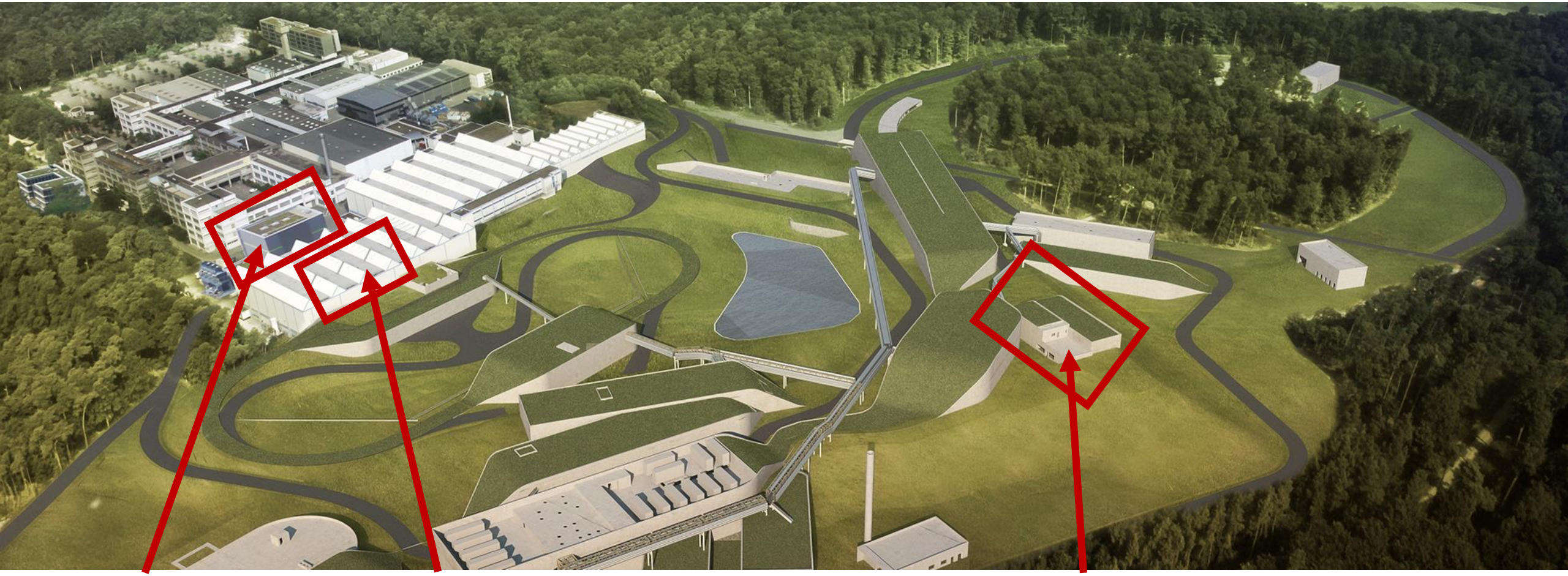


FAIR construction site – October 2020

GSI and completed FAIR campus in 2025

https://fair-center.eu

CBM related sites on the GSI and FAIR campus



Green IT Cube
data center (2016)

mCBM
test facility (2018)

CBM
experiment (2025)

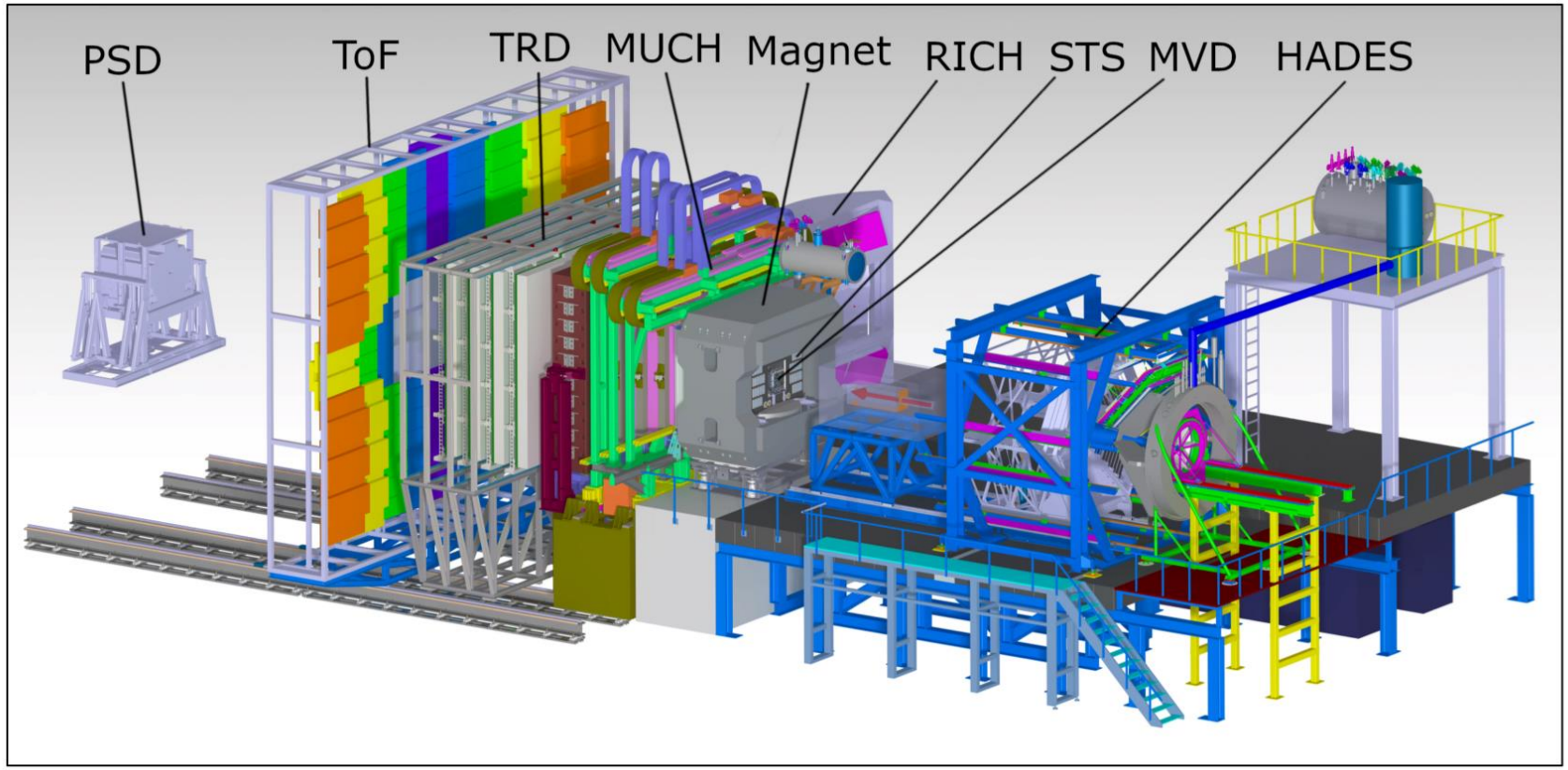
CBM cave construction – October 2020

Construction of CBM cave

The CBM experiment at FAIR

- Heavy-Ion fixed target experiment
- To be built on a beamline of the SIS100 synchrotron at the new FAIR facility in Darmstadt, Germany
- Physics program: investigate rare probes and potential phase transitions in the region of high baryon-densities
- Up to 10 AGeV Au
- Up to 30 GeV p
- Acceptance: $2° < \theta_{Lab} < 25°$
- “High precision High statistics”

1st beam in 2025

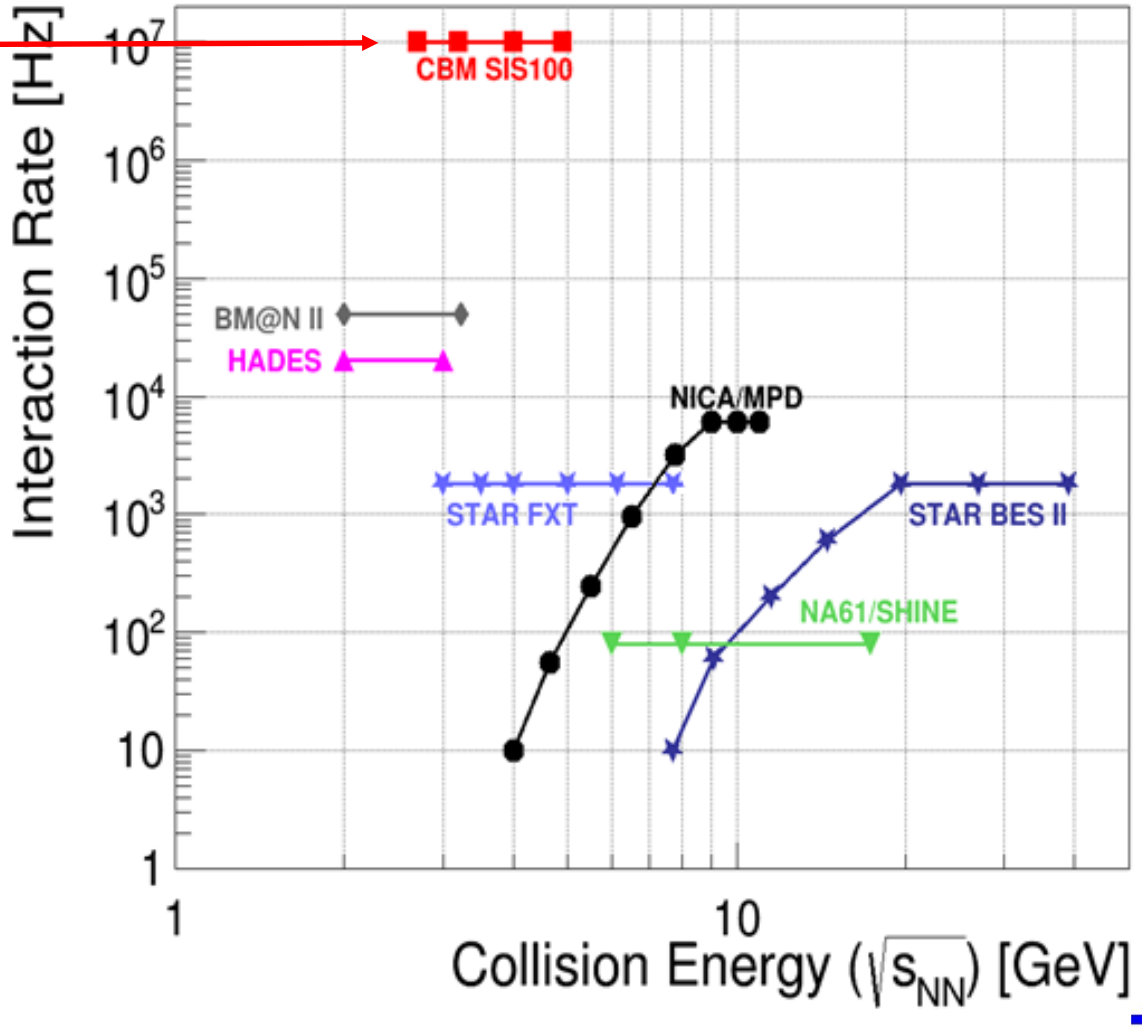


The CBM data challenge

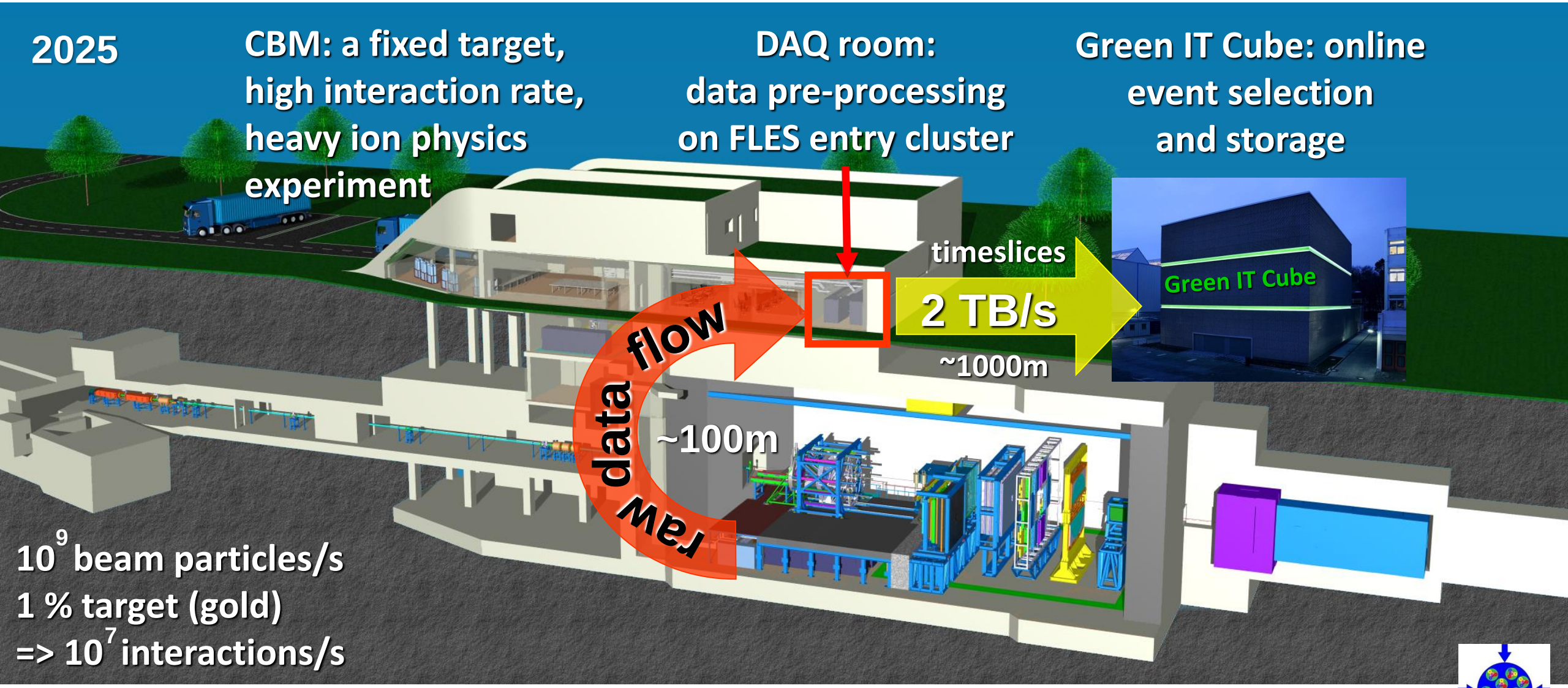
- Very high interaction rate environment:

  $10^5 – 10^7$/s (A+A), up to 10^9/s (p+A)

- Non-trivial criteria for event selection
- Fast detectors with radiation tolerant free-streaming readout electronics
- High-speed Data AQuisition (DAQ) system
- FPGA based readout chains
- About 1-2 TByte/s bandwidth to the High Performance computing farm, where the First Level Event Selector (FLES) is located
- State of the art computing infrastructure allowing for online event reconstruction
- Online event selection to reduce data by a factor 100-1000 for archiving at ~1 GByte/s



The CBM data flow



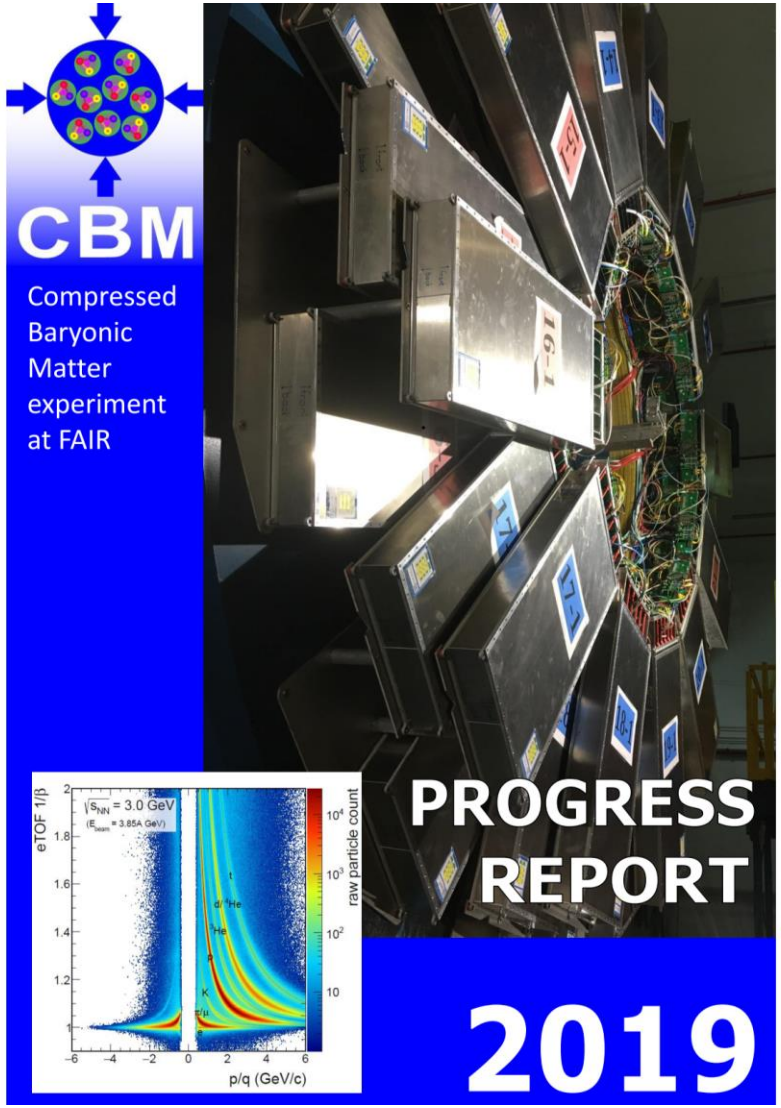
FAIR phase 0 activities

CBM streaming readout protoype setup - eTOF

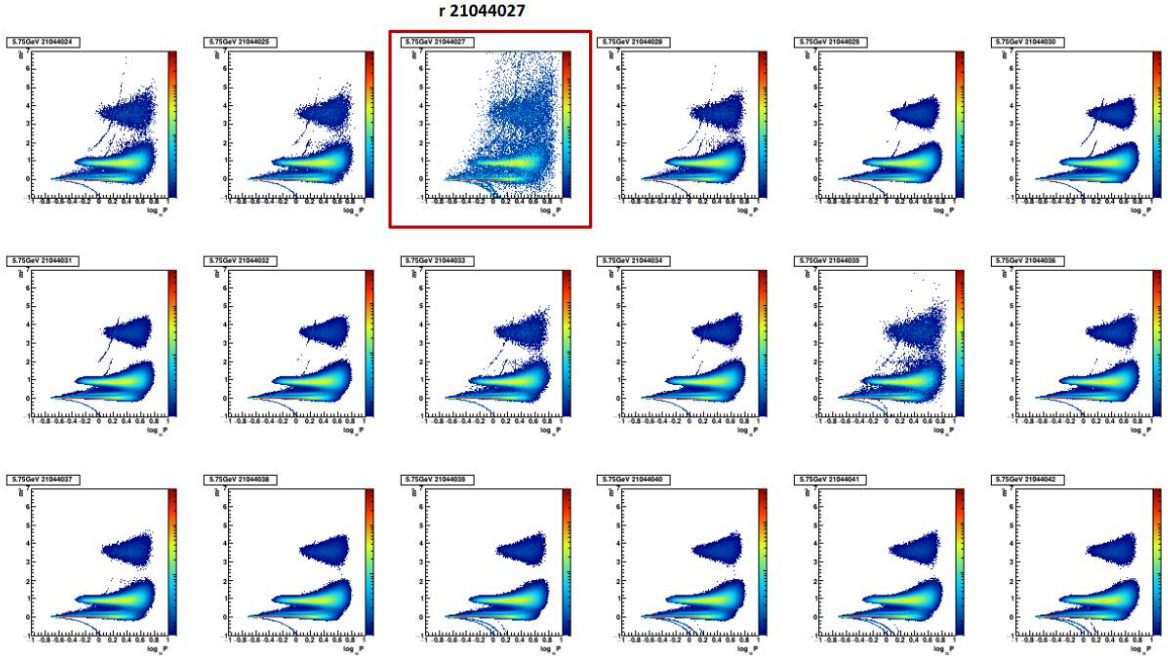
eTOF at STAR

presented at:

[Streaming Readout Workshop VI]



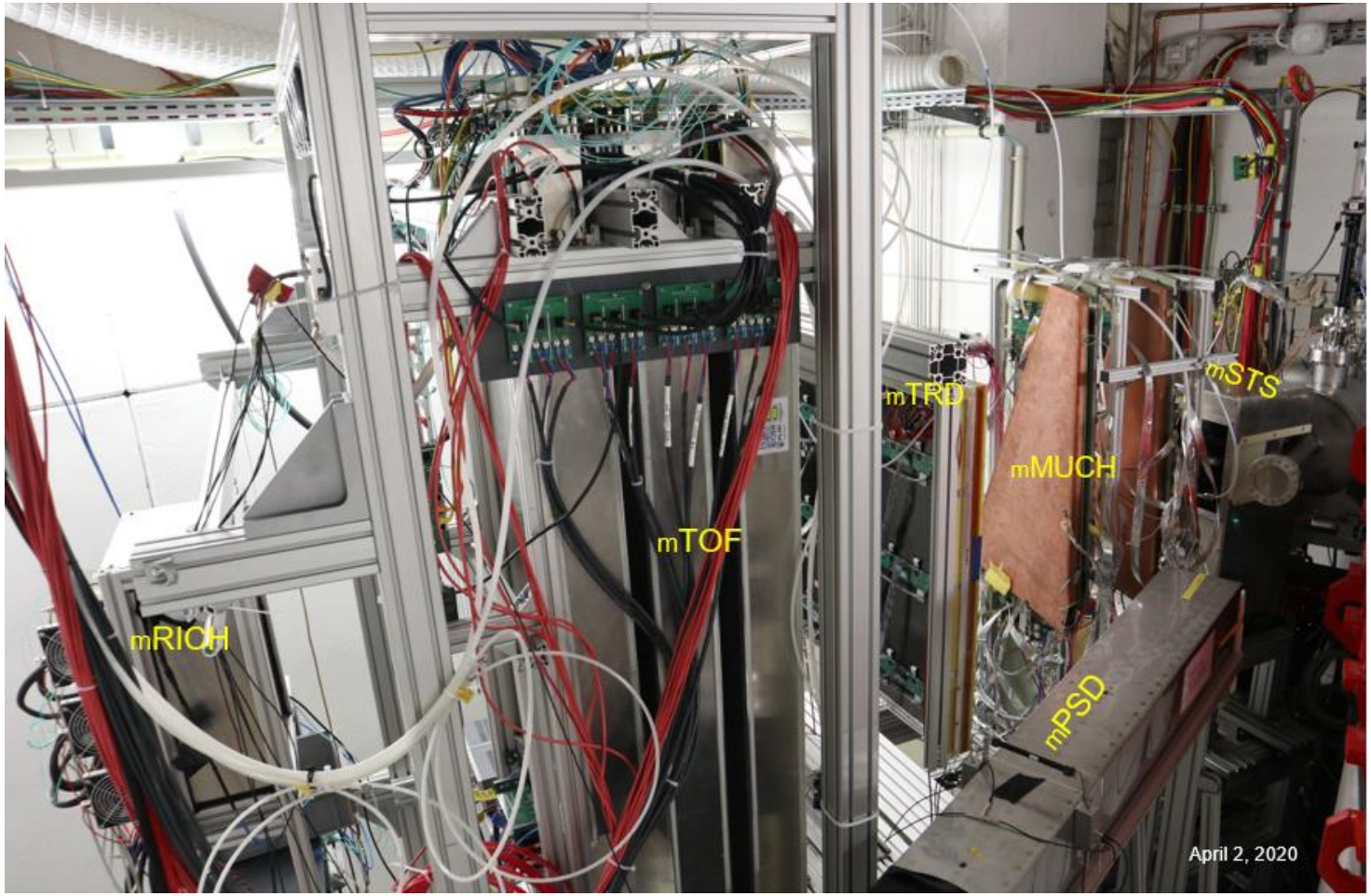
Run20 (Dec2019 – Sep2020) successfully completed



Run-by-Run online QA of eTOF Run20 data

Important step towards CBM control concept

CBM streaming readout protoype setup – mCBM @ SIS18



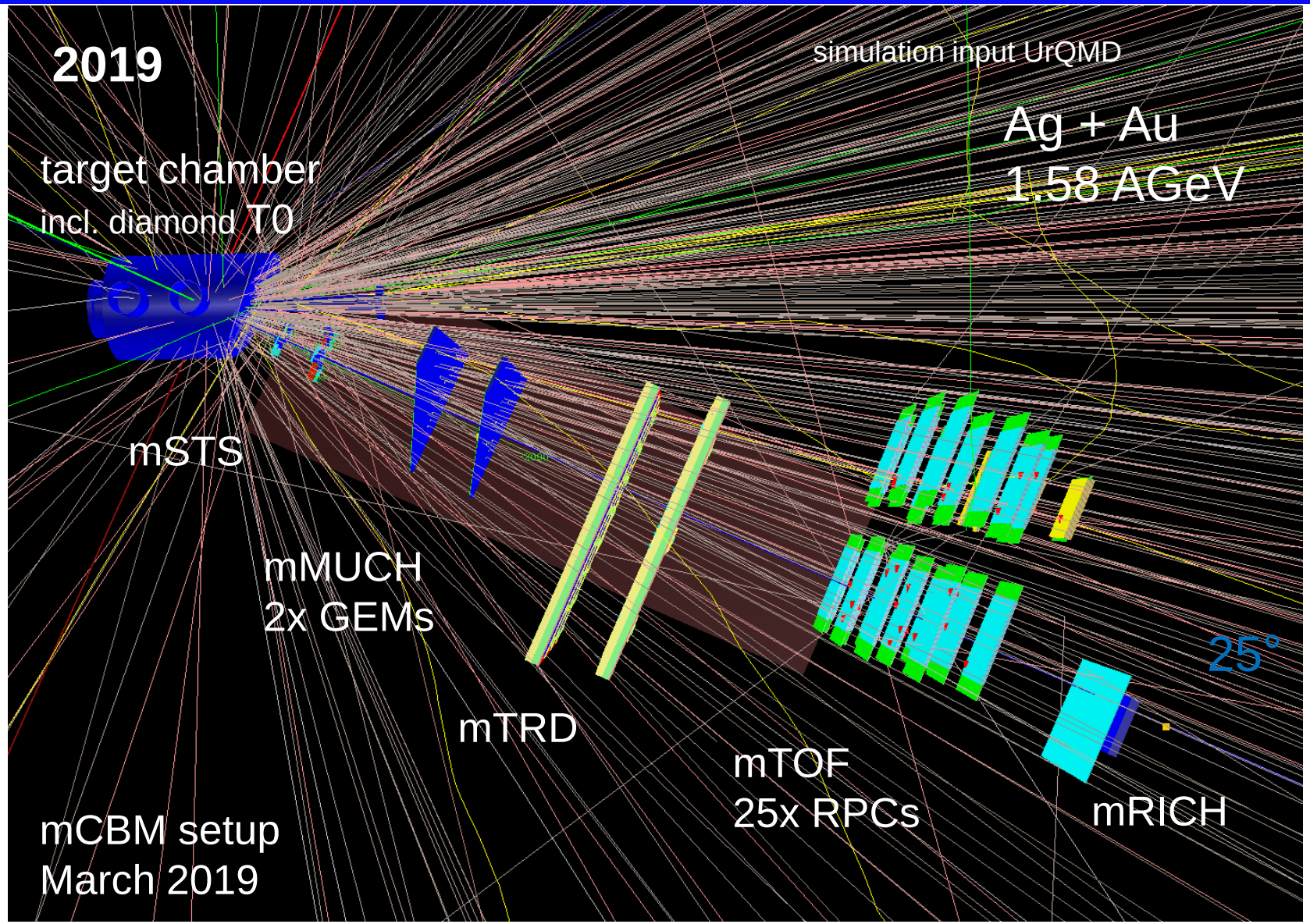
mCBM at GSI

presented today:

Streaming Readout Workshop VII

Proposal submitted to
G-PAC of GSI/FAIR , 10th June, 2020
→ fully granted !

mCBM as test bench



mCBM@SIS18

CBM full system test setup for high rate A-A collisions at the SIS18 facility

10^8 beam particles/s

10% gold target

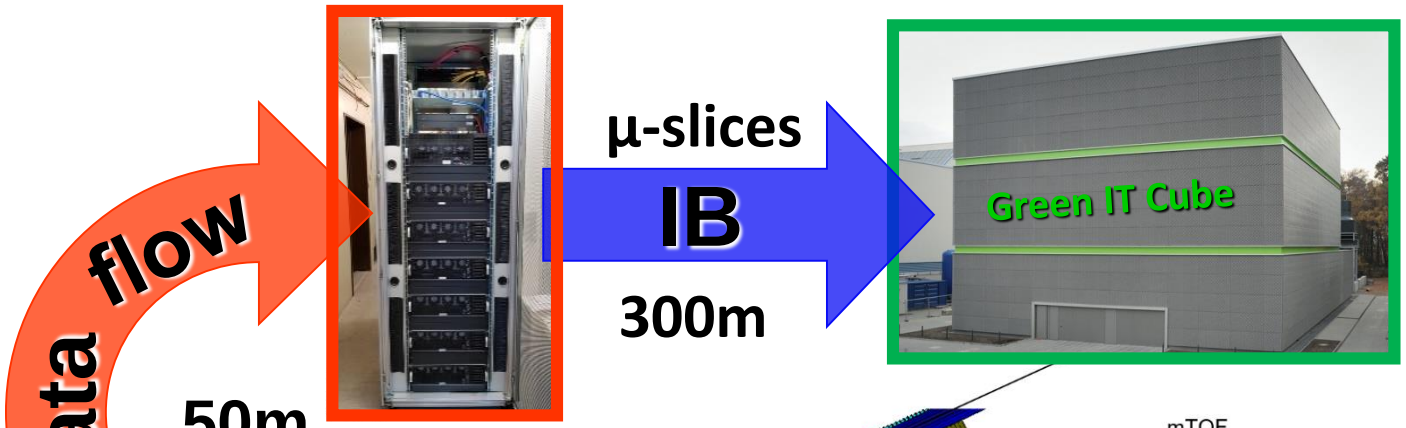
=> 10^7 interactions/s

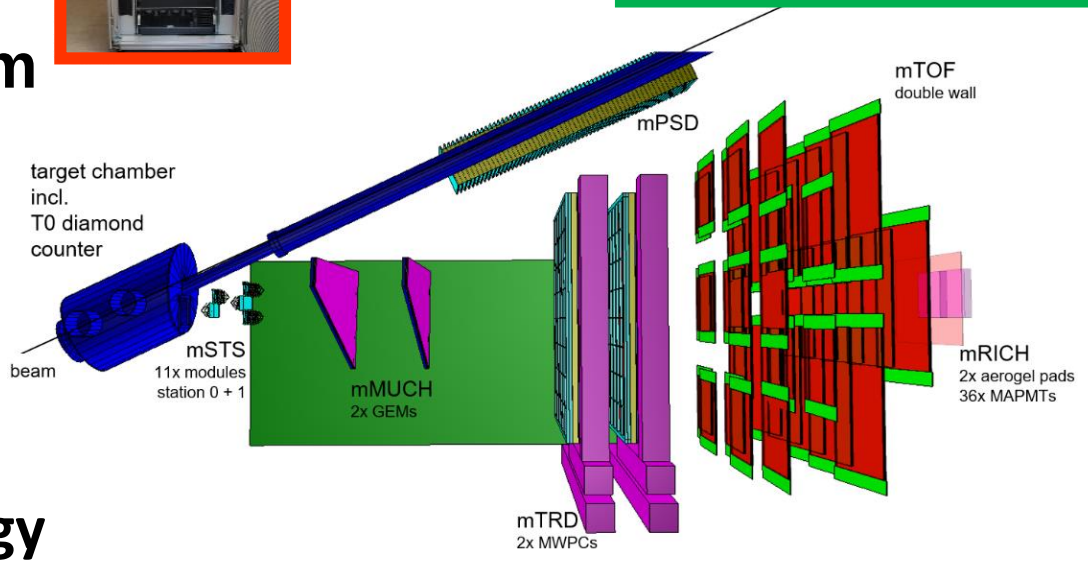
The mCBM experiment and readout chain in 2021

established 2018:
1st commissioning with beam
Dec 2018 / Mar 2019
2nd campaign
Nov 2019 / May 2020
3rd campaign – Λ study
Feb 2021 / May 2021

mCBM DAQ container:
data pre-processing
on FLES EN (CRI)

Green IT Cube:
online timeslice building - FLES PN
storage to Lustre - GSI CN

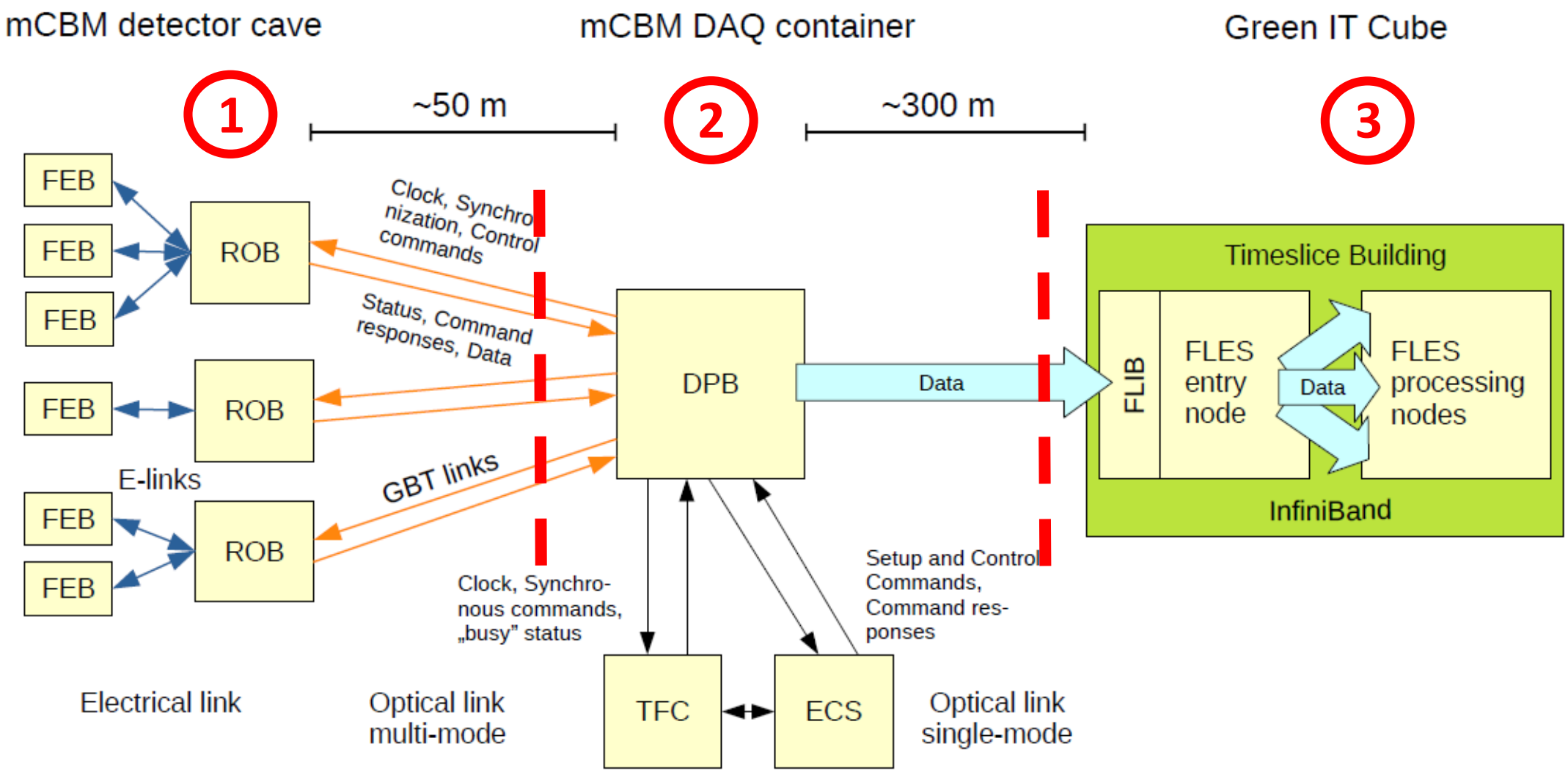




mCBM:
a fixed target,
high interaction rate,
heavy ion physics
experiment and
test-site for CBM technology

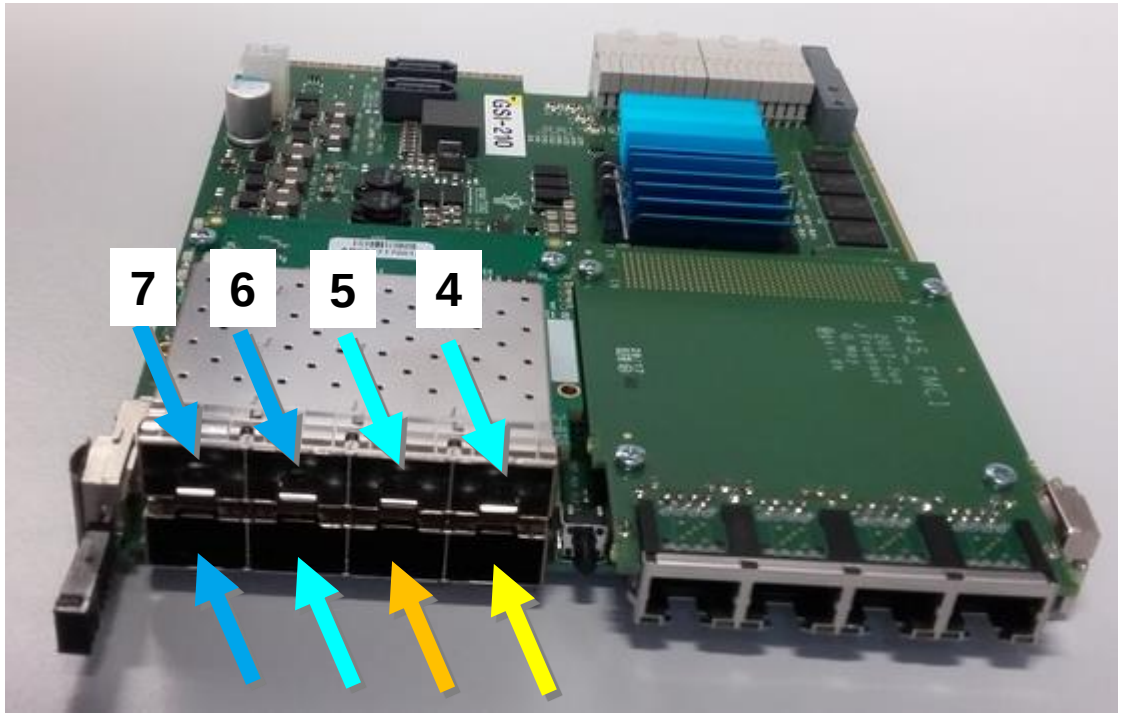
CBM cave construction – October 2020

The mCBM readout and control architecture (DPB)



DPB board configuration

2



3 2 1 0 FMC channel number

GBTx ROB #1 - links

GBTx ROB #2 - links

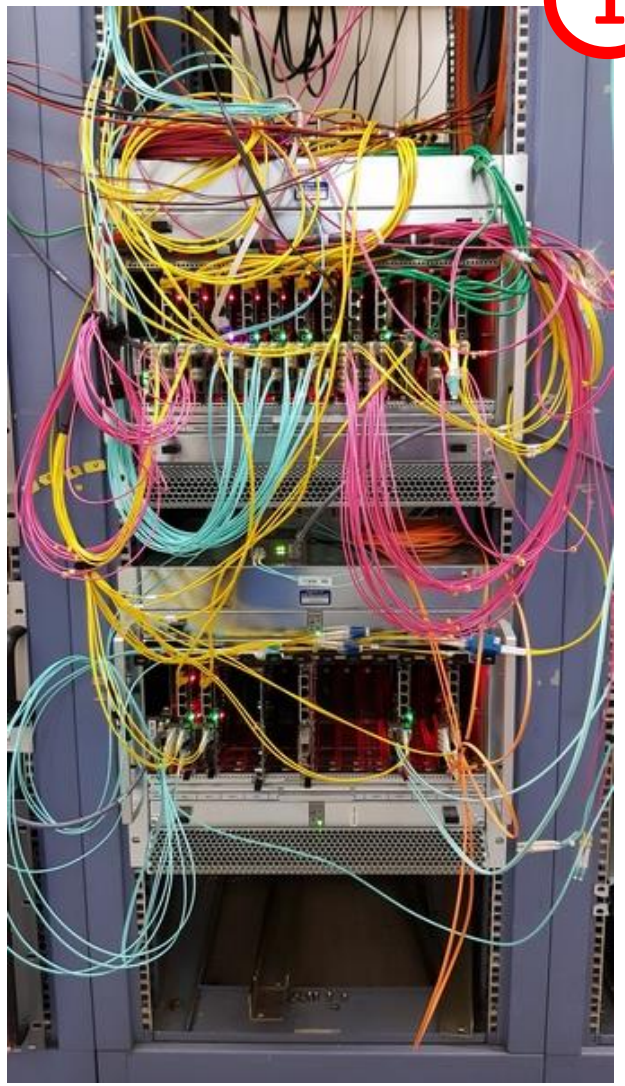
FLIM – link #1

FLIM – link #2

- AFCK board (Creotech, Poland)
- Xilinx Kintex 7 FPGA (325T FFG900)
- Receives several GT links at 4.8 Gbps (multimode fiber, 50 m)
- Indexes data in timeslices
- Allows for data pre-rpocessing
- Sends one single FLIM link at 10 Gbps (singlemode fiber, 300 m)

mCBM readout chain 2020

mCBM DAQ container



1

Green IT Cube

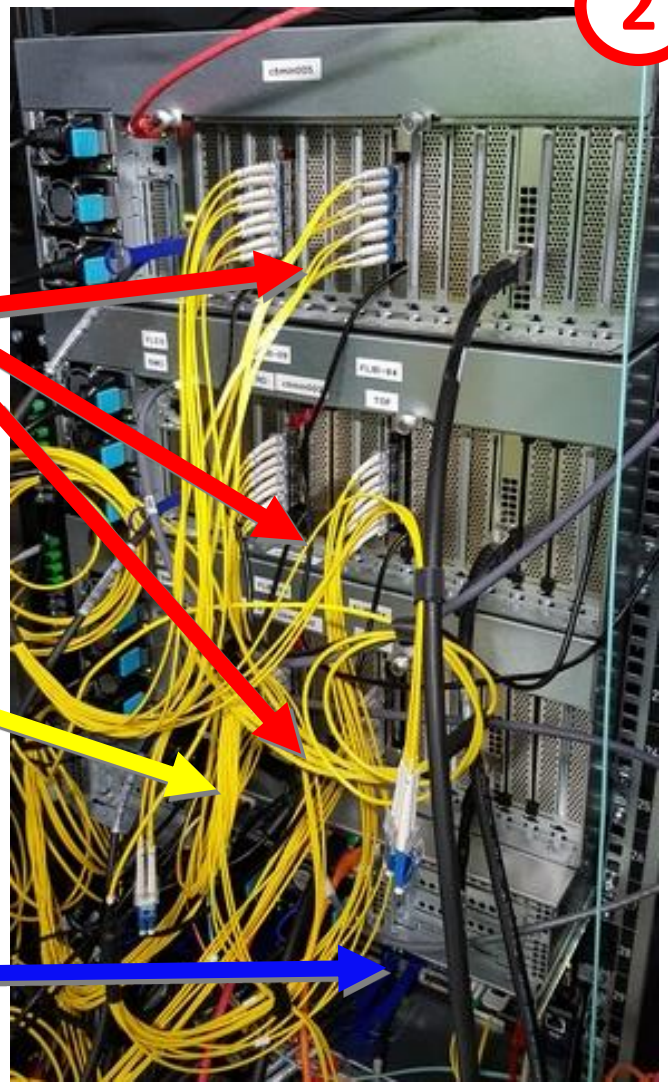
3x mFLES entry nodes

48x out of 144x OS2 fibers

Infiniband switch

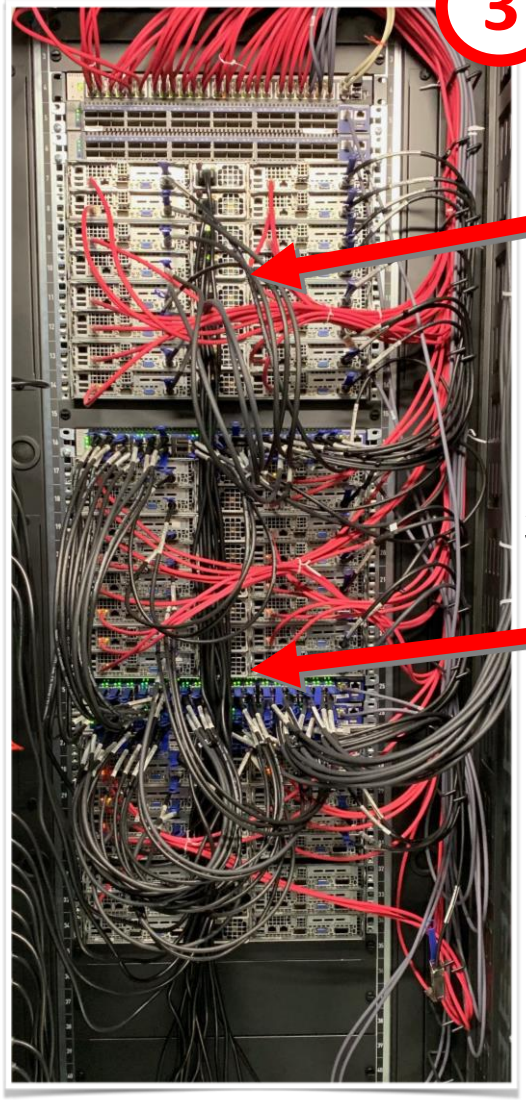
Rack GC-5A60

2



Rack GC-5A61

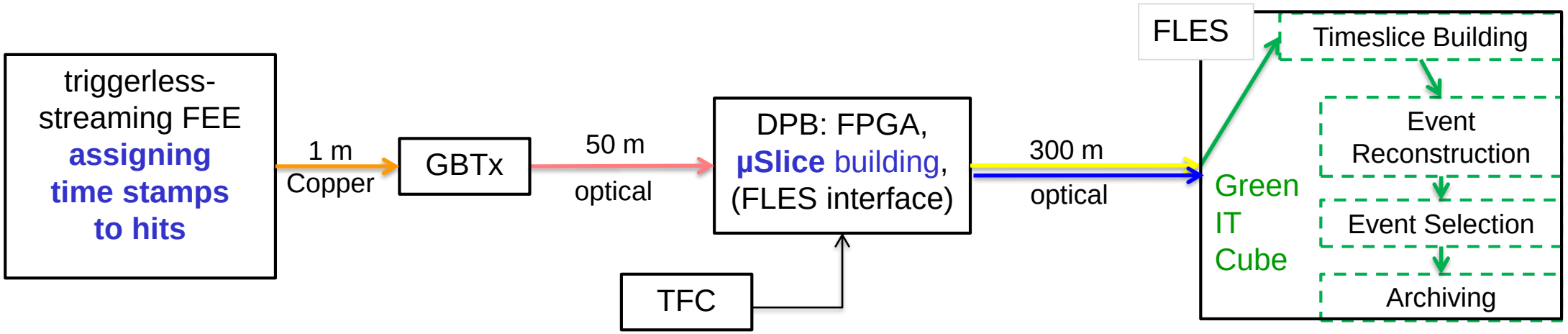
3



Infiniband switches to be cabled with nodes

36x mFLES compute nodes are online

Acronyms used in the mCBM readout



Acronyms

FPGA : Field Programmable Gate Array

DPB : Data Processing Board

TFC : Timing and Fast Control Syst.

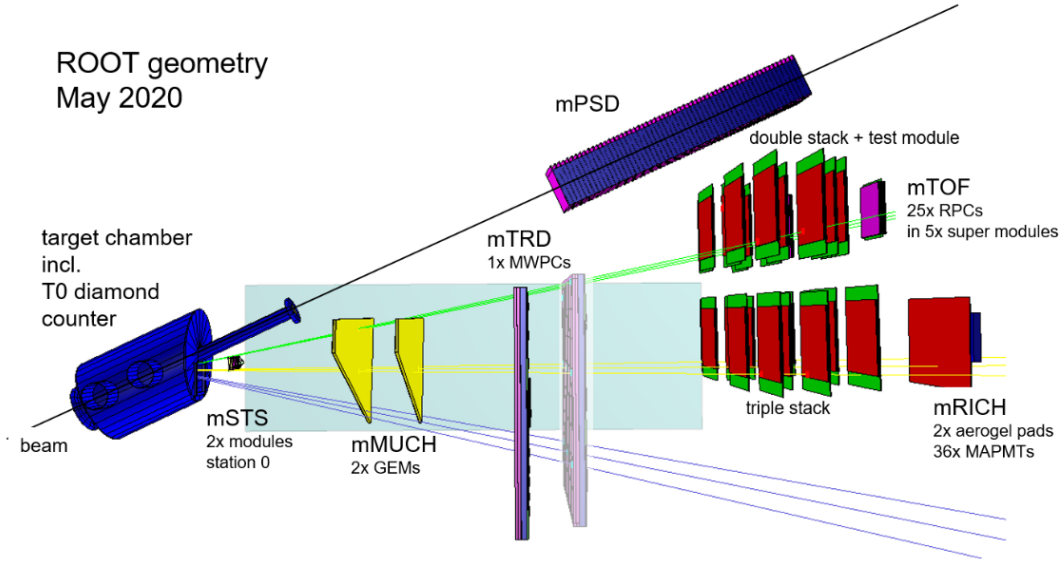
FLES : First Level Event Selector

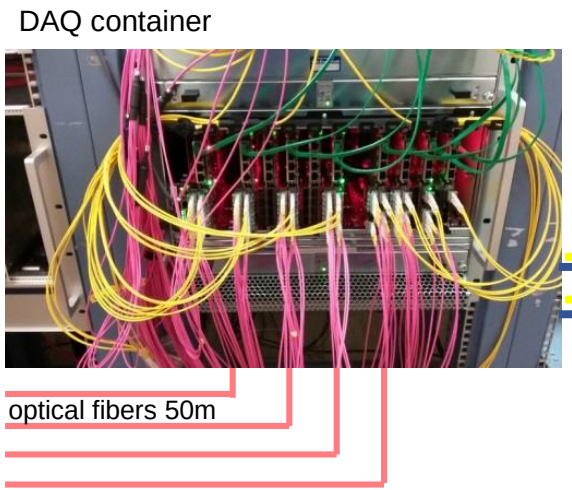
GBTx : CERN rad.-hard interface ASIC

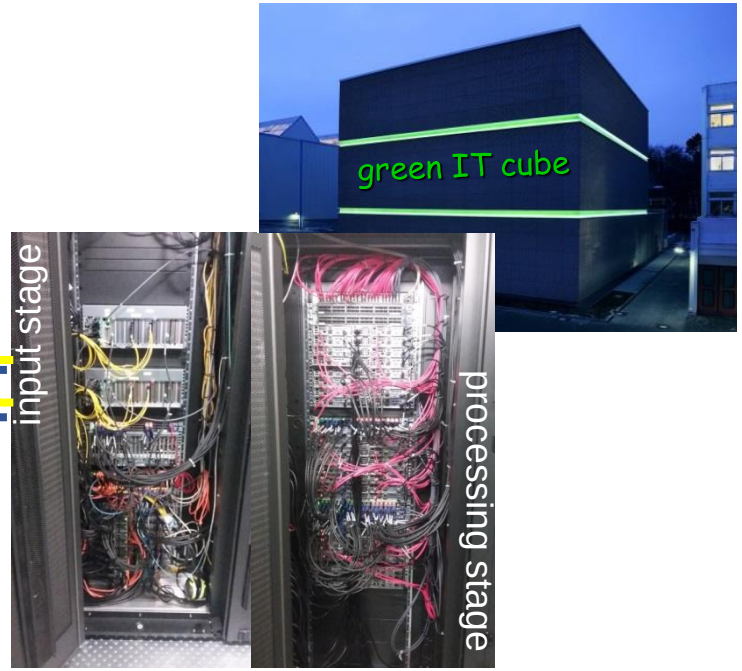
µSlice (µS) : Self contained data block for a subset of the experiment, minimal size depends on degree of data time sorting.

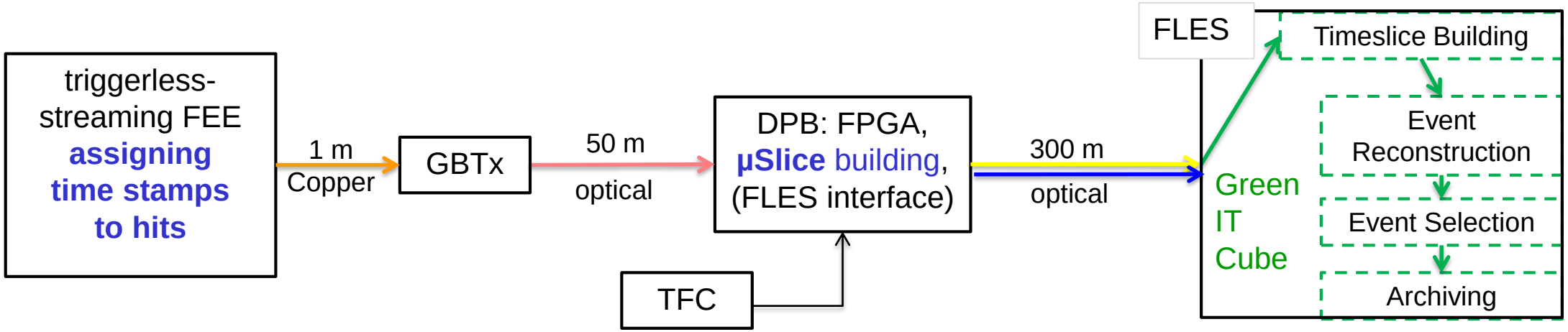
Timeslice : Collection of µS, self contained data block for the full experiment and a given time interval, includes overlap to avoid edge losses.

The mCBM data path

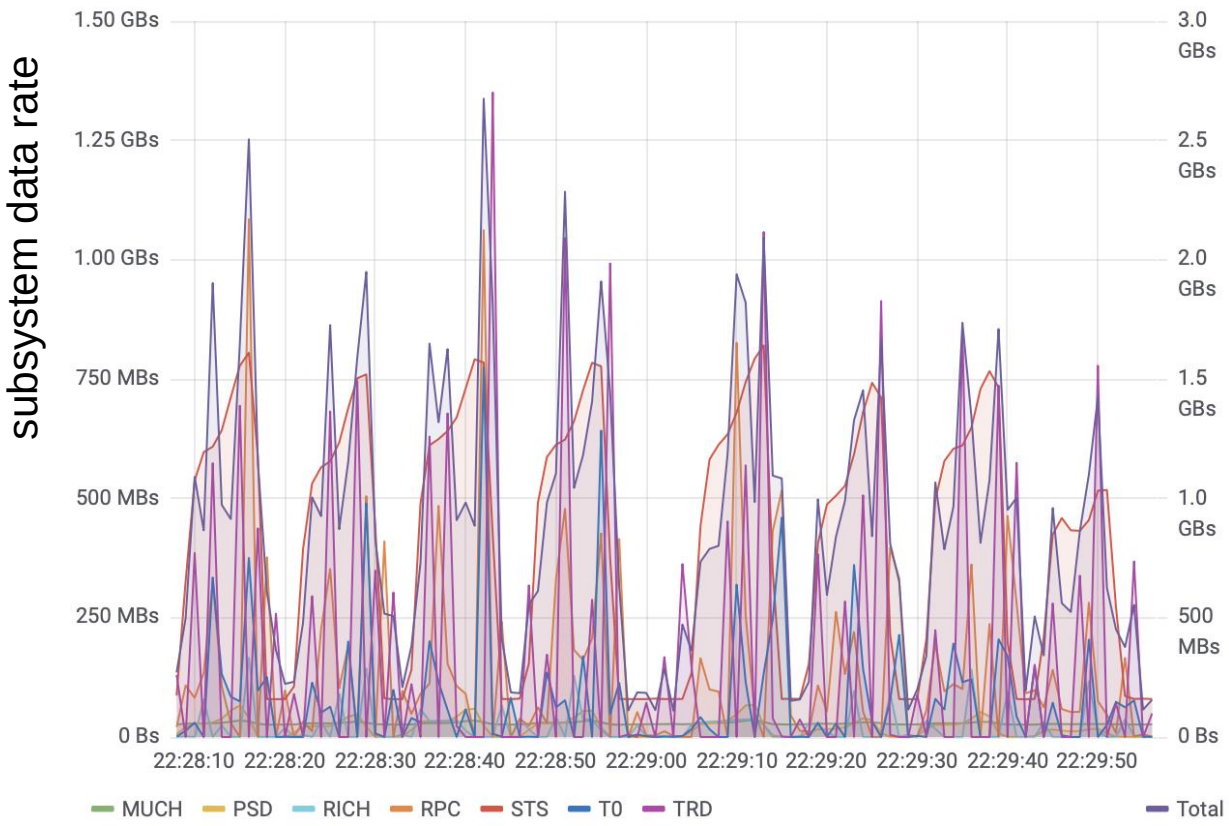






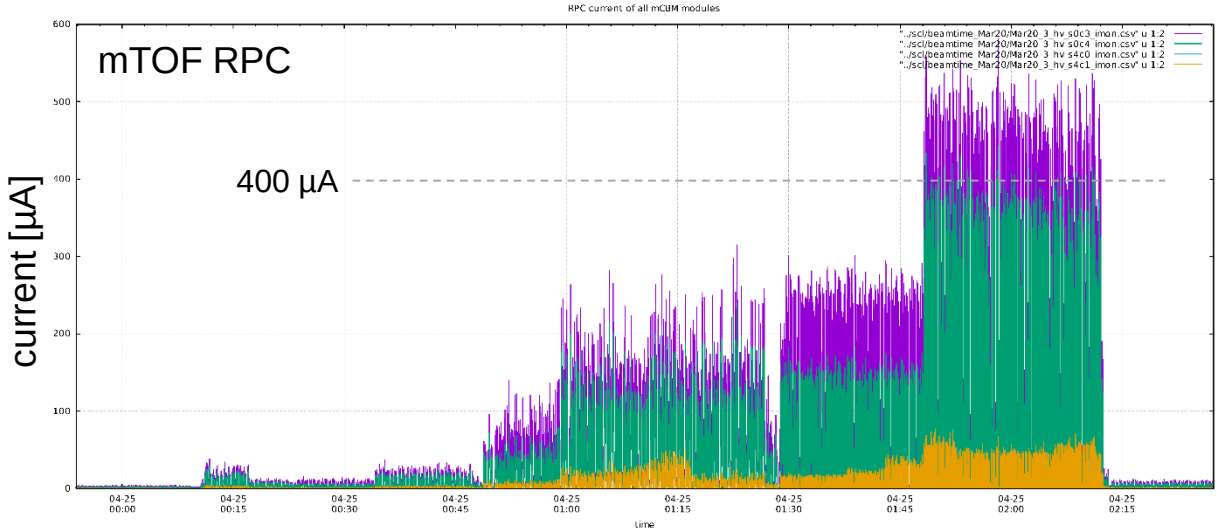


mCBM commissioning with beam, first results

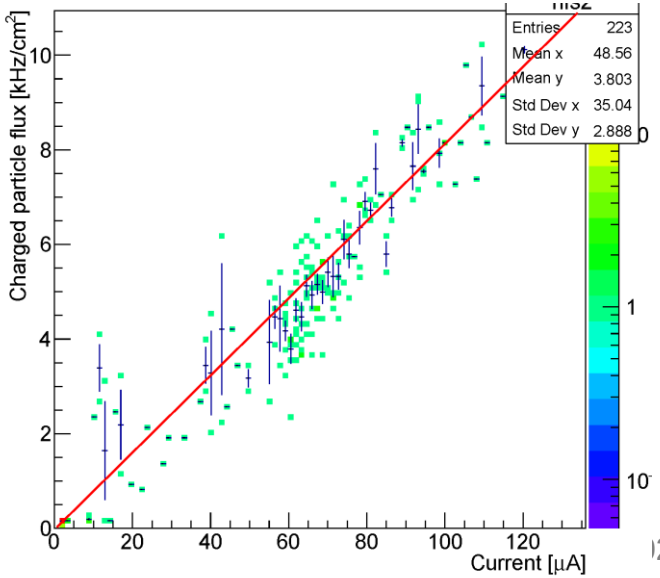


May 4th, 2020, run 858
^{208}Pb + Au, 1.060 AGeV, 1.1 MHz averaged collision rate

March 27 - May 24, 2020 campaign:
- max. collision rate: 4 MHz
- max. total data rate: 3 GB/s
- 20 TB data taken



charged particle flux - RPC current calibration



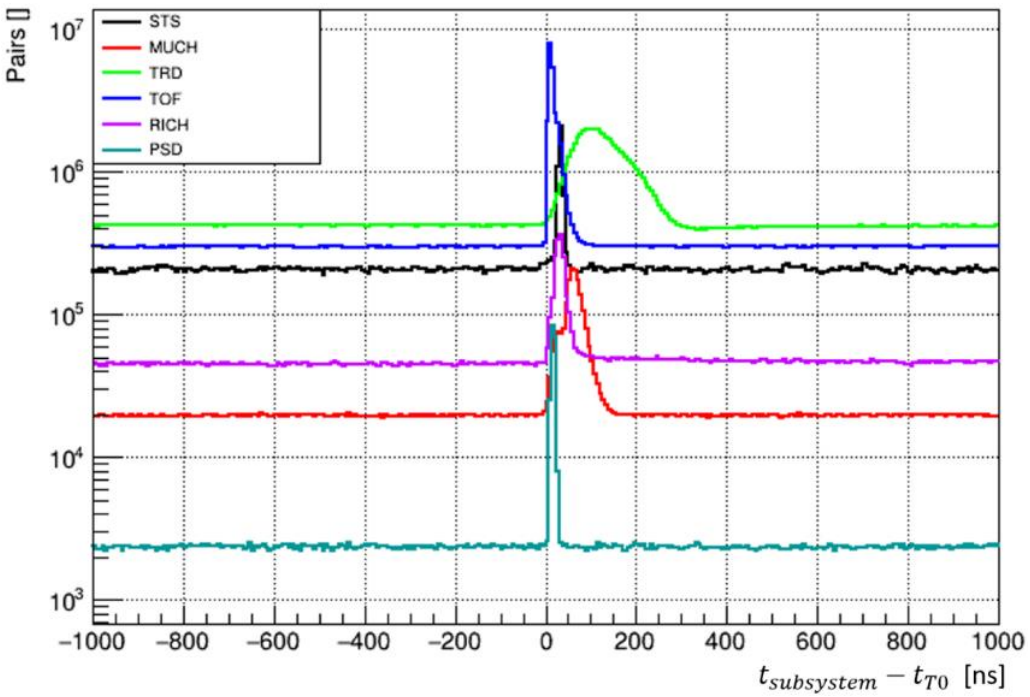
100 µA → 8 kHz/cm^2

↓

peak fluxes > 30 kHz/cm^2

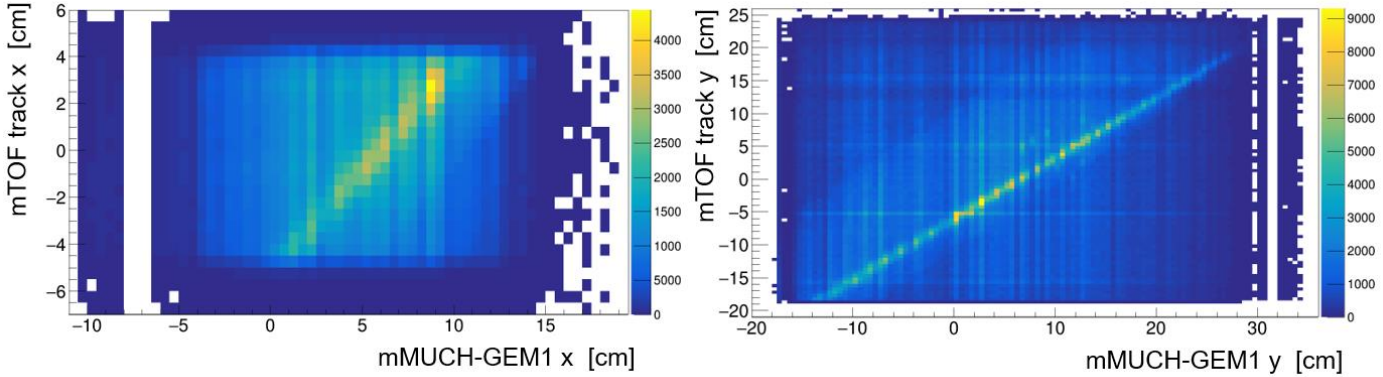
(CBM TOF design limit: 25 kHz/cm^2)

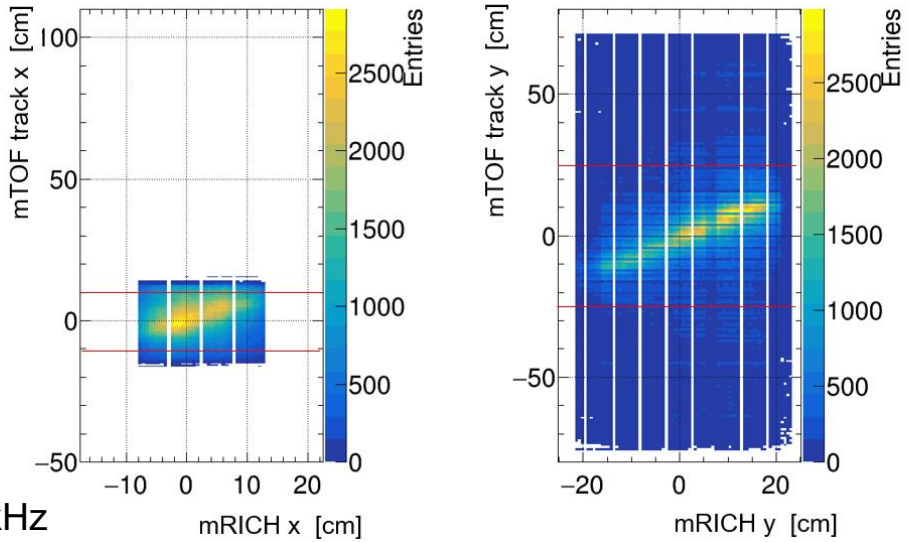
mCBM commissioning with beam, first results



subsystem time offset corrected

Observed time and spatial correlations between detector subsystems:
first conceptual verification of the triggerless-streaming DAQ system of CBM
→ **to be verified up to the CBM design limit of 10 MHz collision rate.**

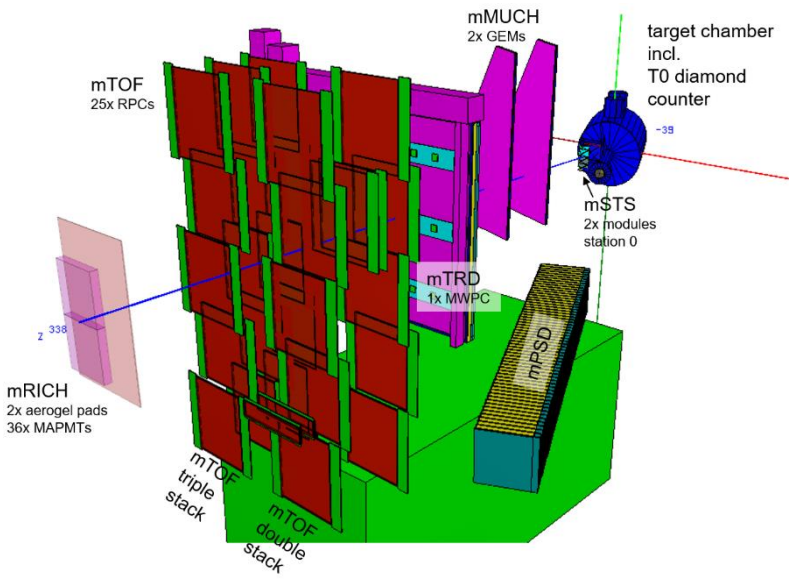


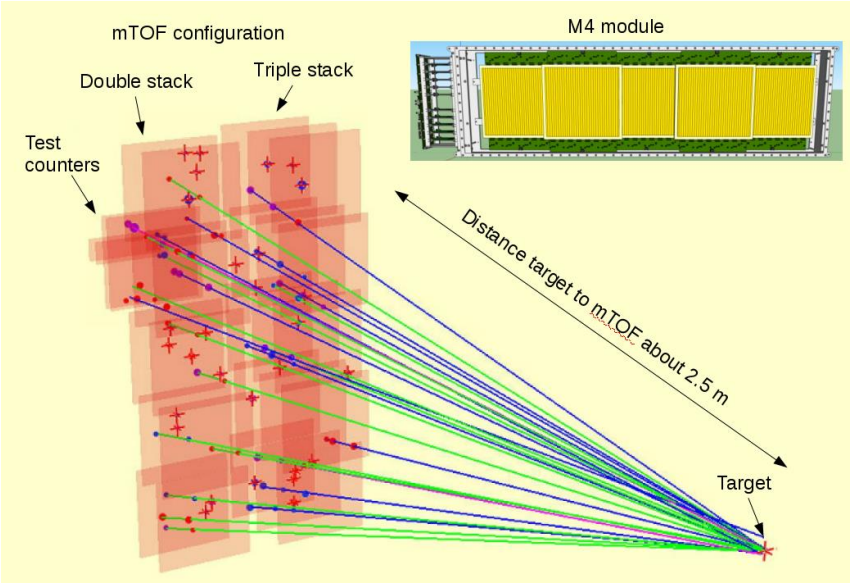


preliminary - May 2020 data

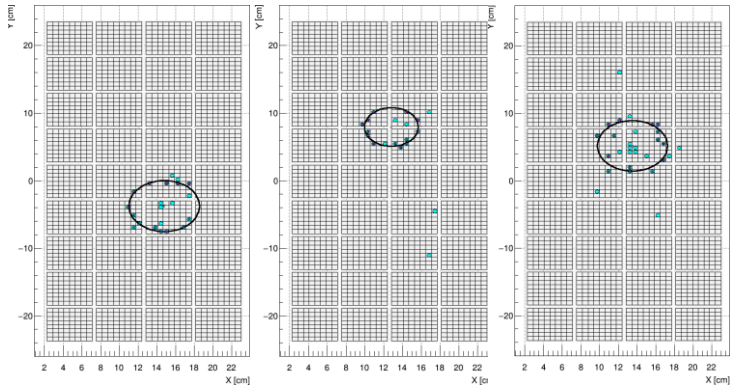
data:
run 831, May 4th, 2020
^{208}Pb + Au, 1.060 AGeV
"low" collision rate ≈ 20kHz

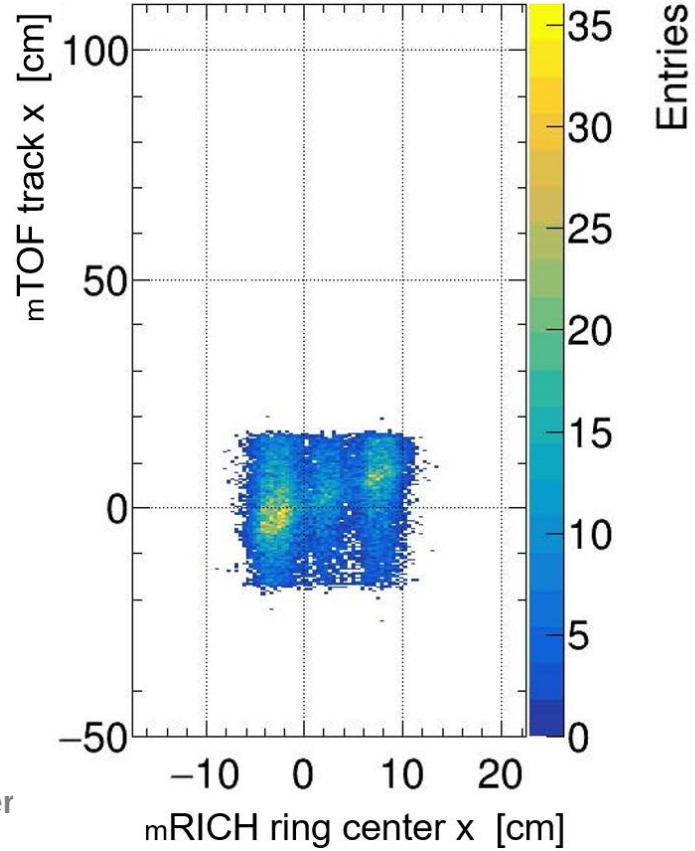
mCBM commissioning with beam, first results

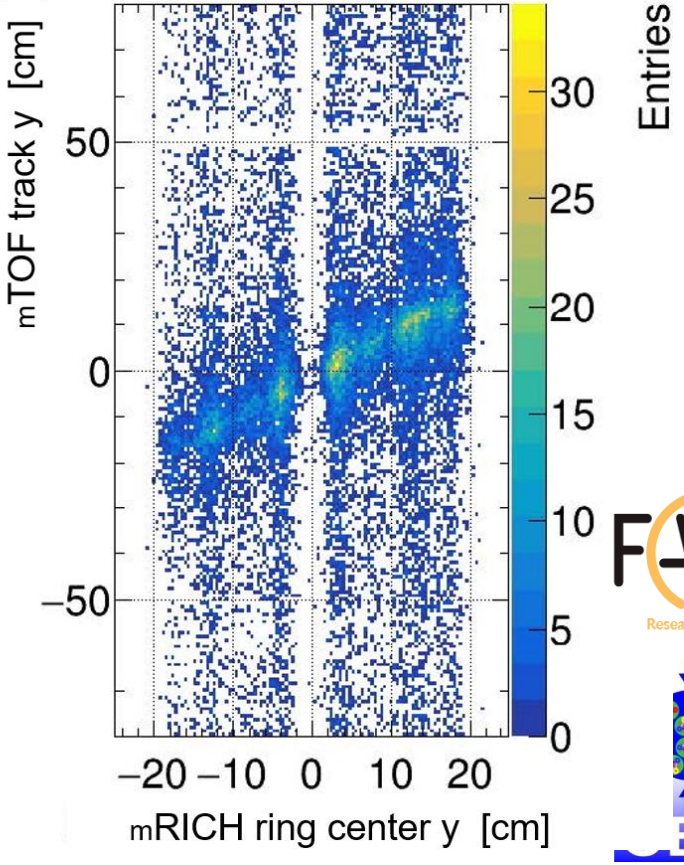




incl. ring recognition







preliminary - May 2020 data

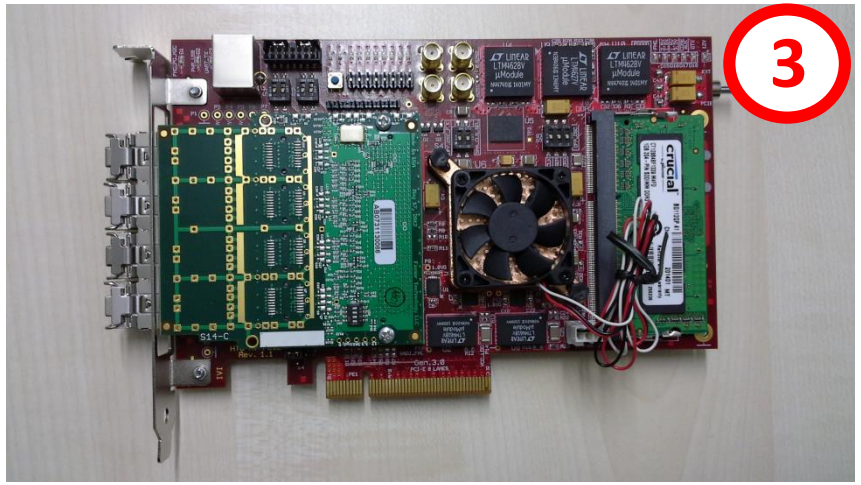
DPB, FLIB and CRI

2020

GBTx-DPB

Xilinx Kintex-7 XC7K325T

FLIB-4/8



Xilinx Kintex-7 XC7K325T

2021

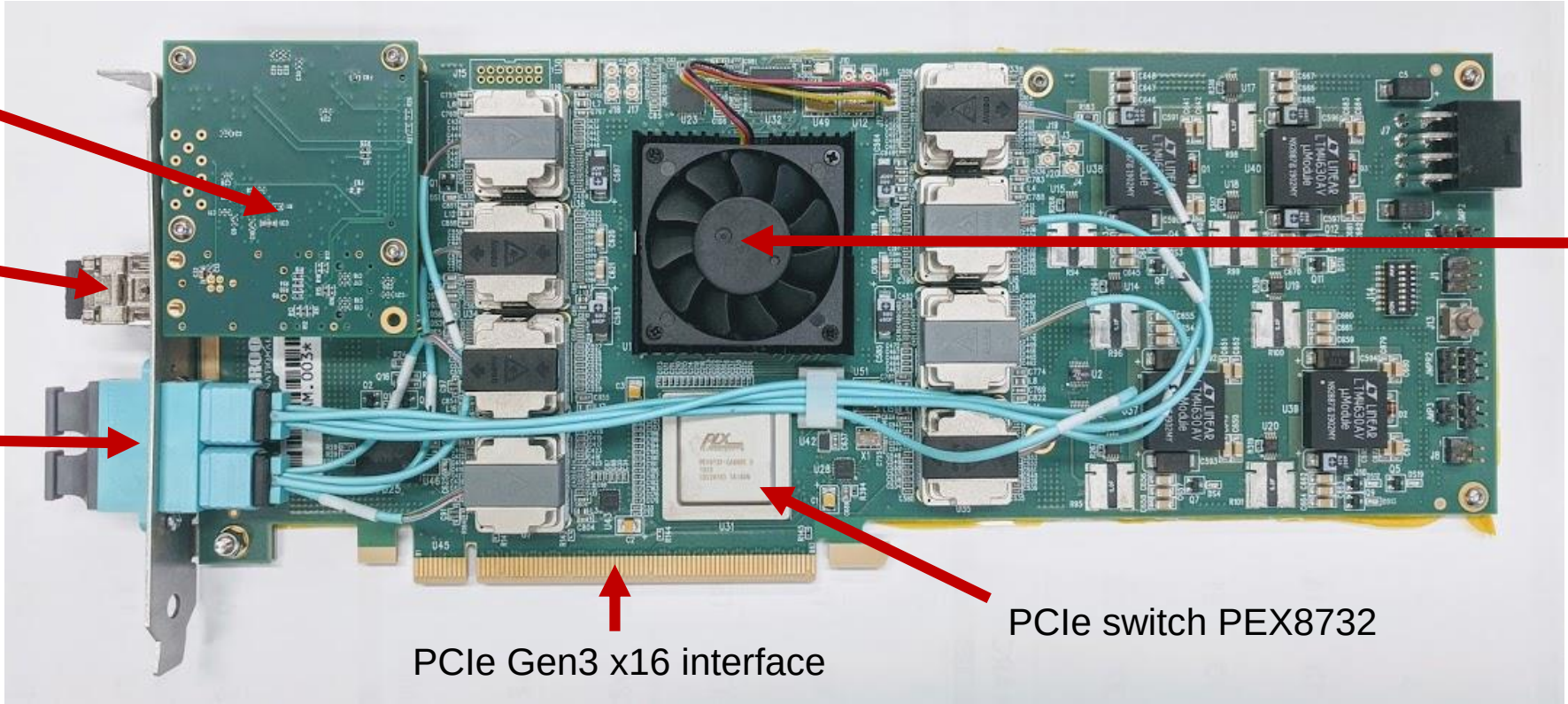
BNL-712 as CRI

Xilinx Kintex Ultrascale XCKU115

Common Readout Interface card 1.0

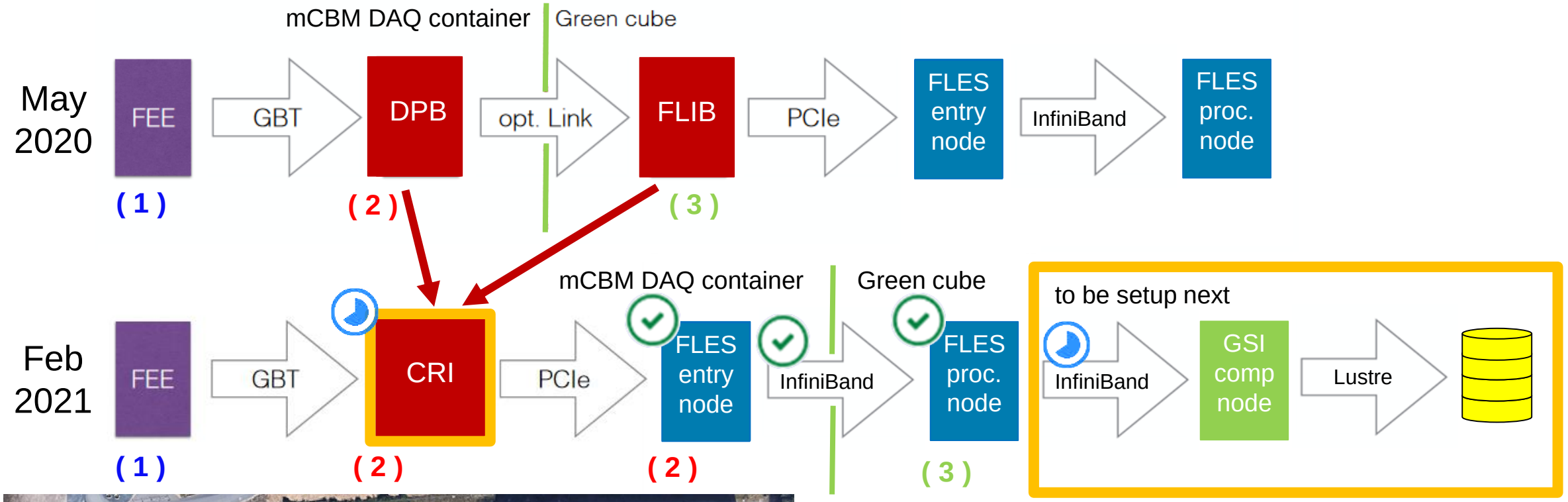
- Joint production of BNL-712 cards with sPHENIX/BNL
- This is the Common Readout Interface card (CRI-1.0)

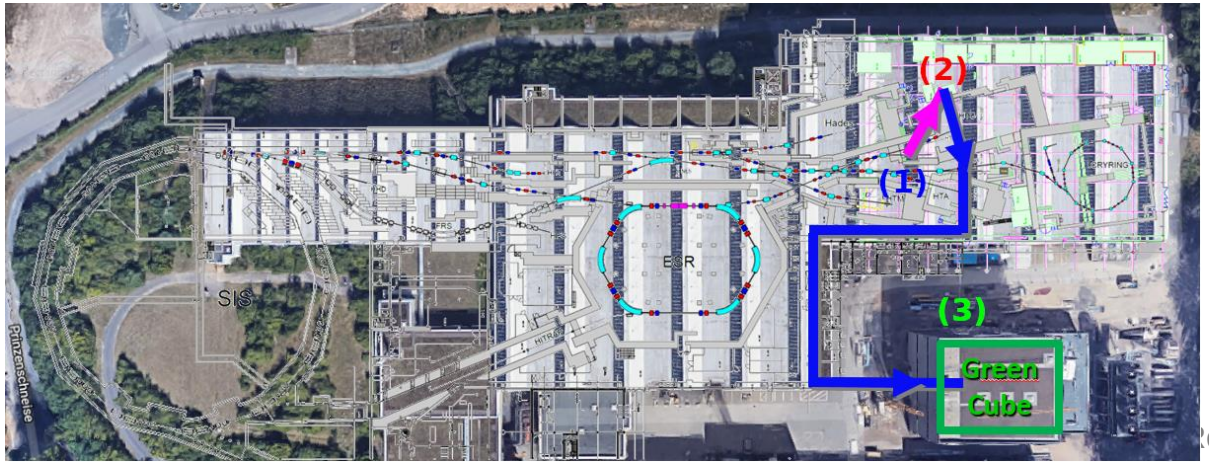
CBM will have 36 CRI by 2022



- Every subsystem in mCBM will use this card from 2021 to transfer data to the FLES
- The CRI card is also the core element of the TFC system

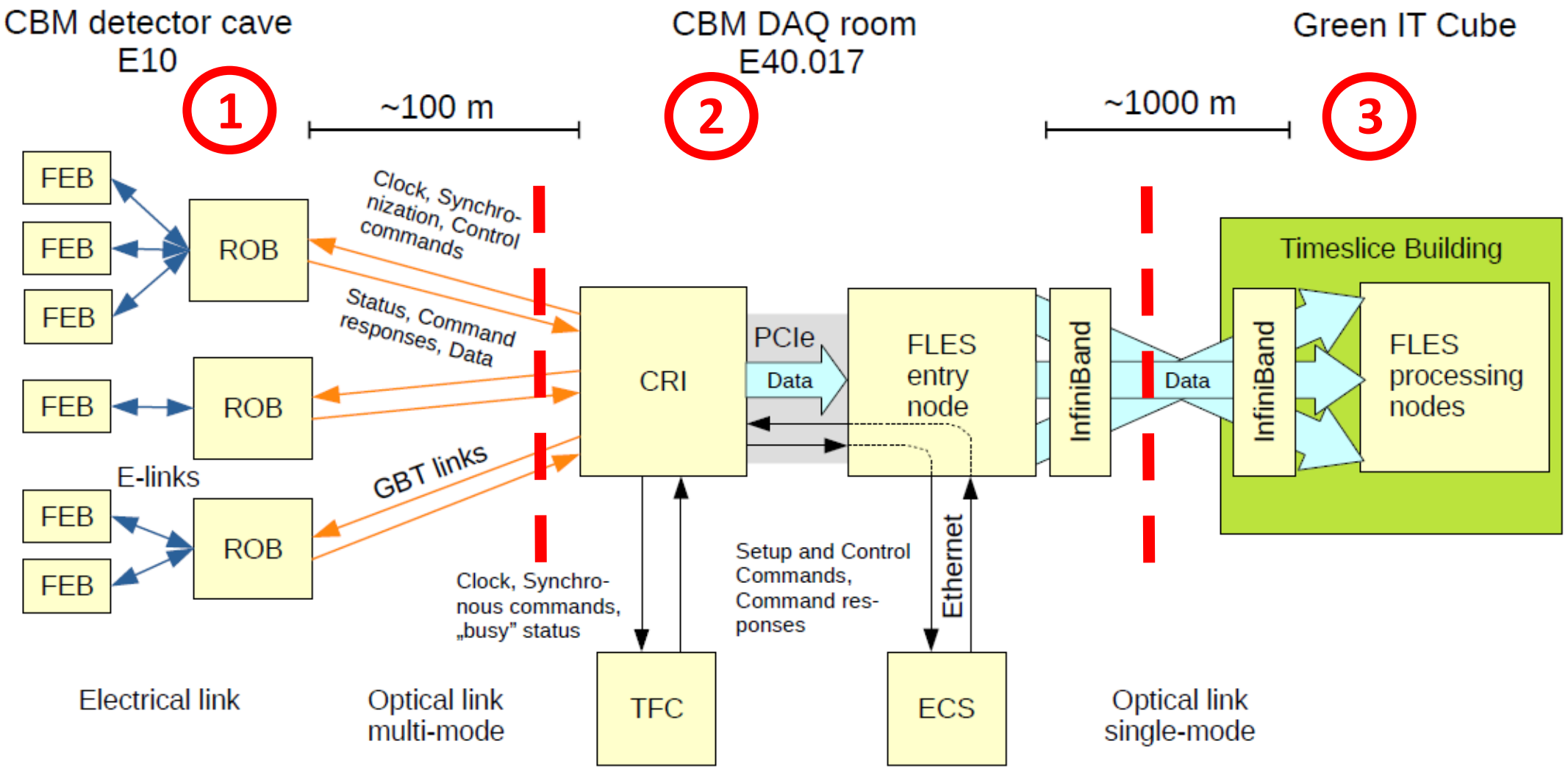
DAQ chain evolution at mCBM





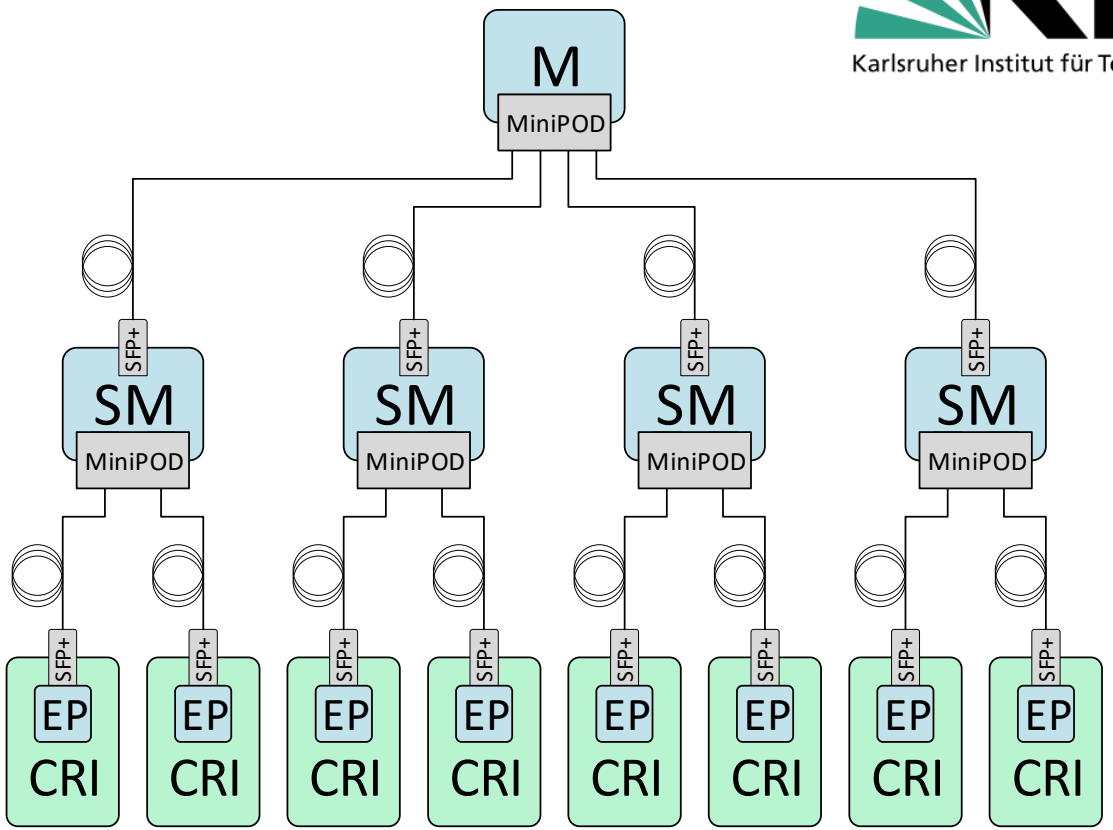
FLES EN – entry node
FLES PN – processing node
GSI CN – compute node

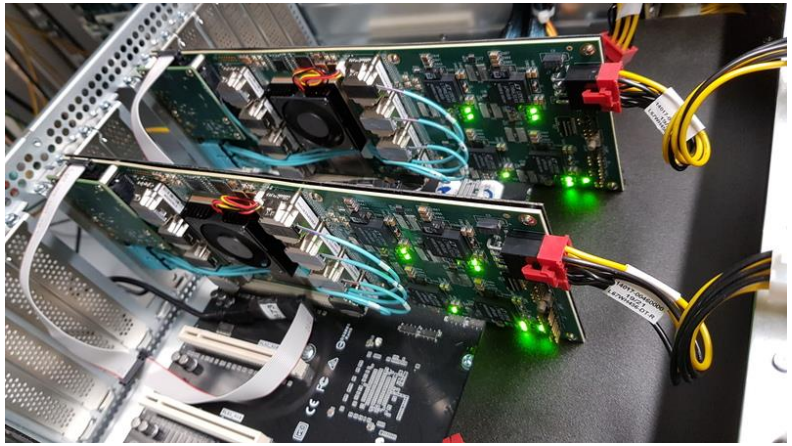
The CBM readout and control architecture (CRI)



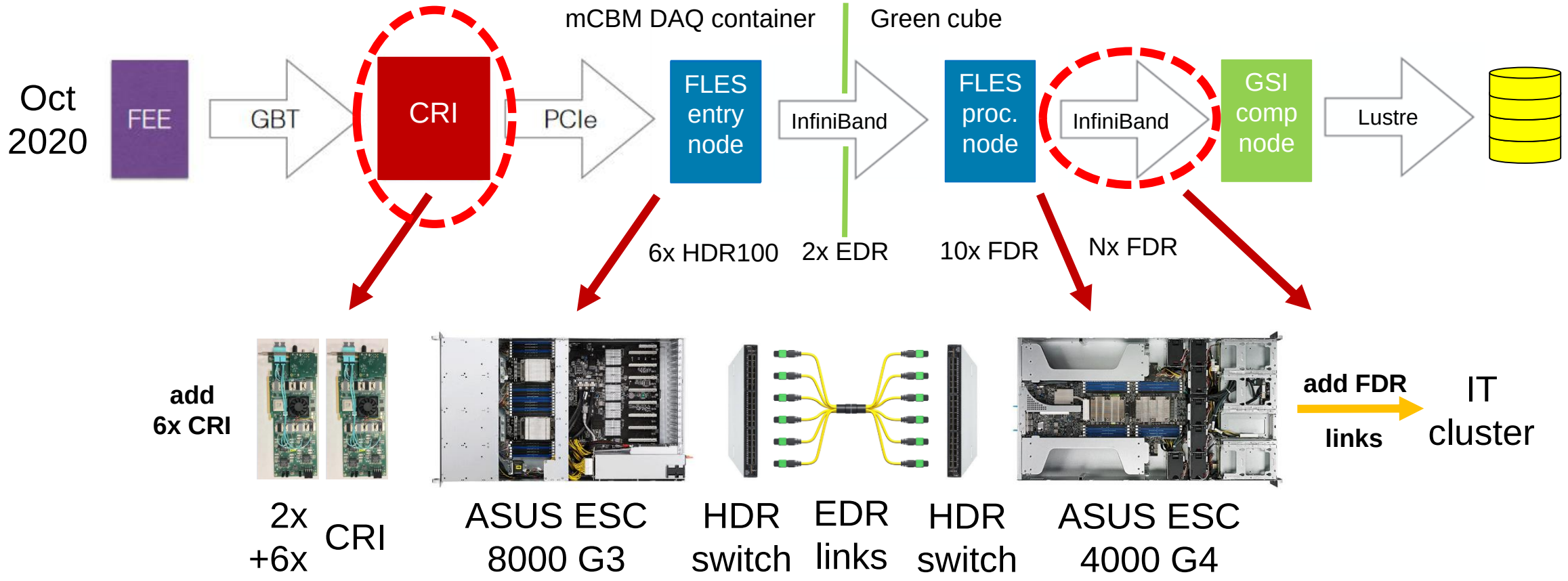
TFC Concept

- The Timing and Fast Control system (TFC) is meant to synchronise data processing electronics experiment-wide over optical fibres
- Organised as a hierarchical network for scalability
- Based on CRI cards
- Distributes timing information to endpoints (CRI)





The CBM readout chain in 2021



- next step: FDR extension of readout chain to the GSI IT cluster
- for more powerful online monitoring and online event selection and direct storage access to Lustre

The CRI DAQ rack prototype

- This is the CBM DAQ prototype rack (est. September 2020)
- all data from mCBM subsystems will transit here (replicate 24x at SIS100)
- the rack is it hosts the TFC system and FLES Entry Nodes fitted with CRI

mcbmcri - JTAG server

cbmin00x - 2x TFC-CRI

cbmin007 - 1x CRI

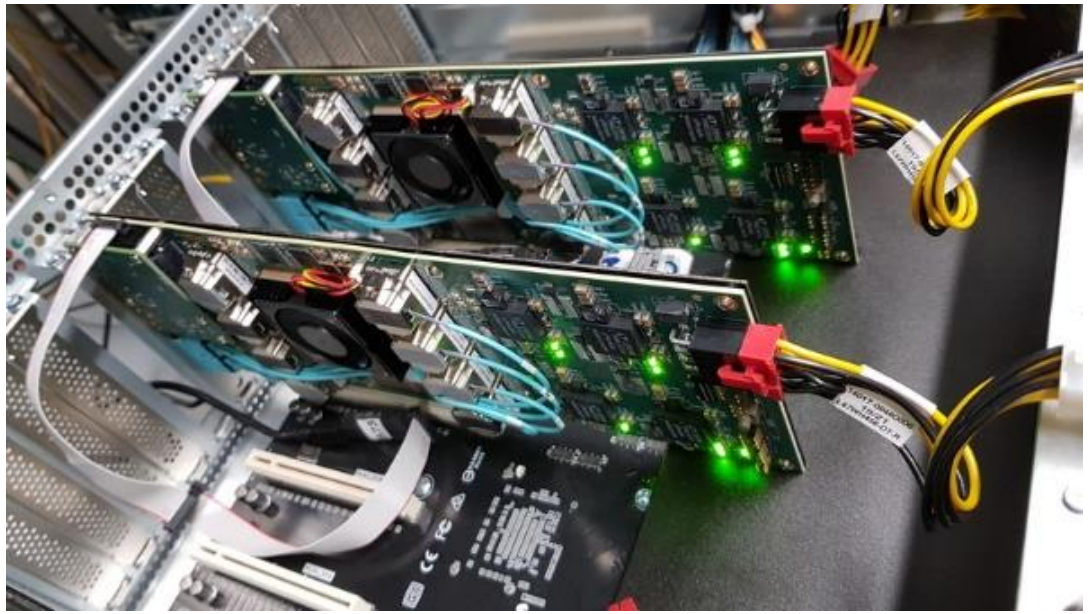
cbmin006 - 1x CRI

cbmin005 - 1x CRI

cbmin004 - 1x CRI

cbmin003 - 2x CRI

cbmin002 - 2x FLIB



2 CRI cards and 1 HDR HCA are installed in each Entry Node

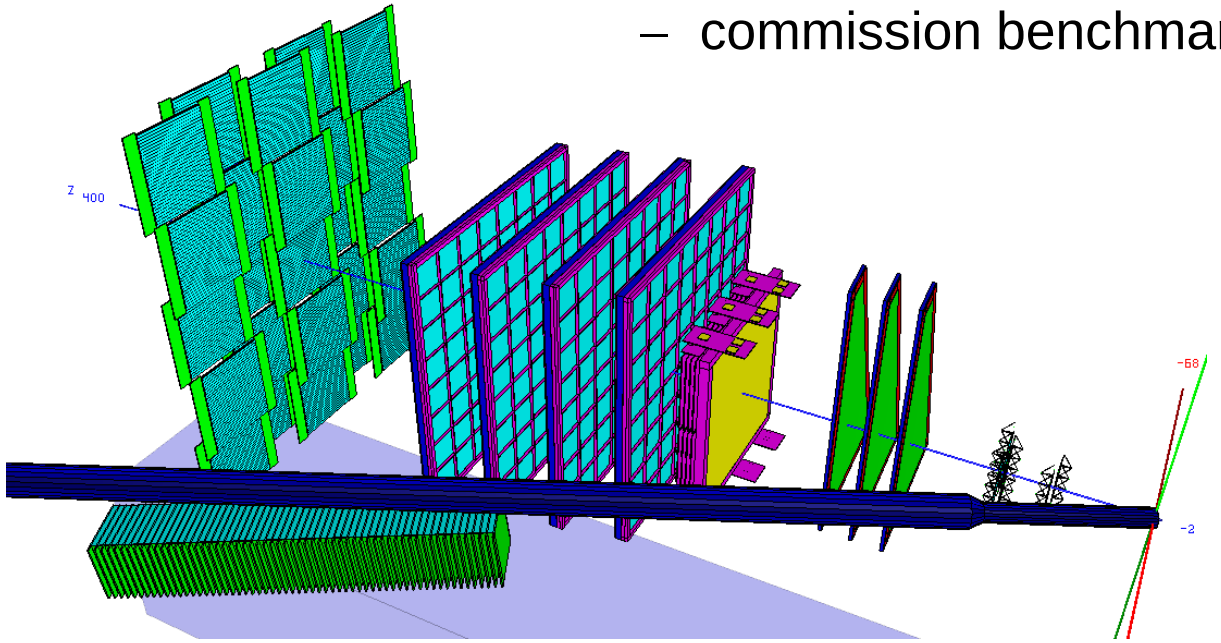
Milestones towards realization of full readout system for CBM

2020	✓ build a demonstrator rack for mCBM
	✓ move entry nodes from GC to the mCBM
	✓ take 300m long EDR InfiniBand link into operation
	✓ install CRI boards in entry nodes
	◕ introduce TFC system
2021	◕ upgrade processing node cluster (Kronos nodes)
	◕ control DAQ from ECS
	◕ prepare for data taking with beam
2023	◕ identify and procure final CRI+ board
	⏸ identify and procure final entry node server
2024	⏸ scale up to SIS100 system size
	⏸ introduce throttling to TFC
2025	⏸ 1st data taking with beam

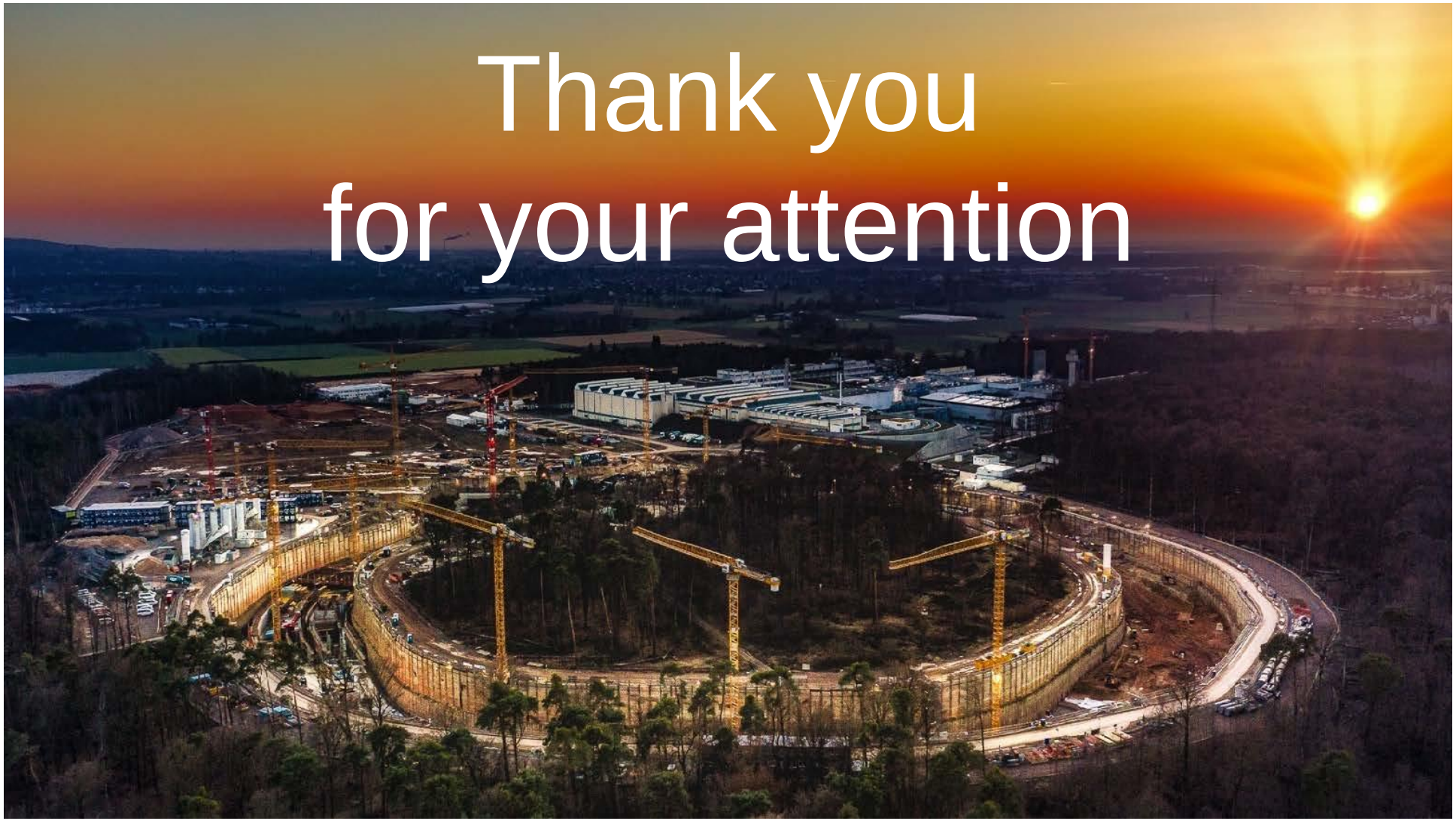
Summary

CBM

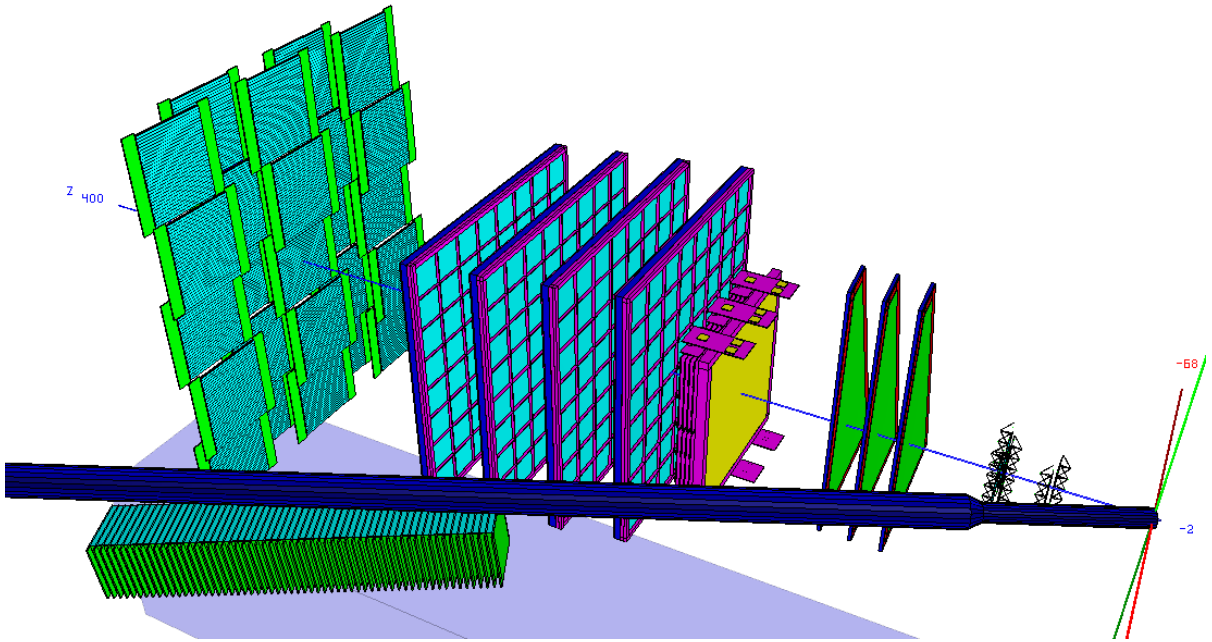
- Validate detector and DAQ concept with mCBM up to highest collision rates
  - upgrade to final DAQ hardware (CRI + TFC)
  - prepare for commissioning of new readout chain in Q1/2021
  - commission benchmark Λ – baryon measurement in Q2/2021



The end



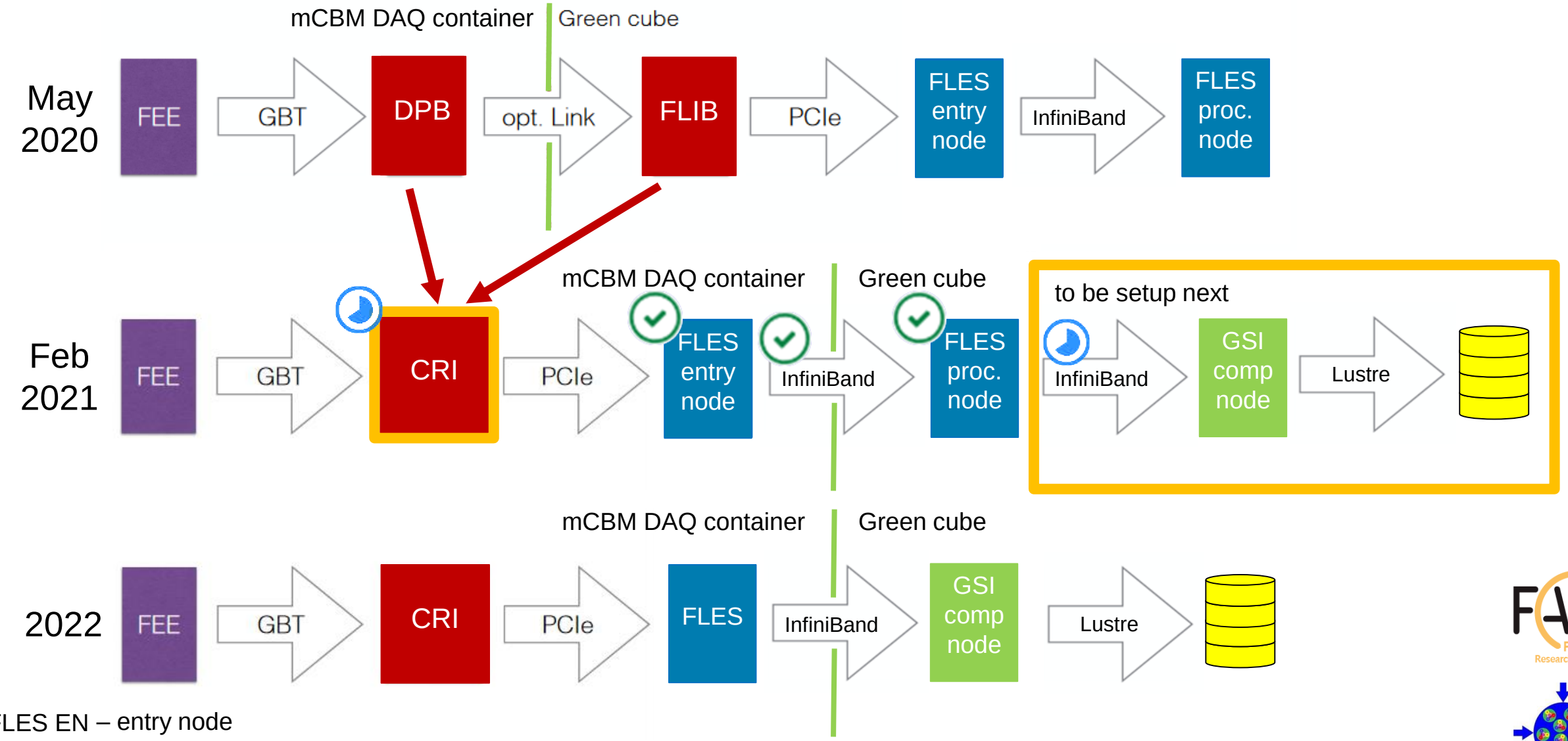
The end



Thank you
for your attention

Bonus slides

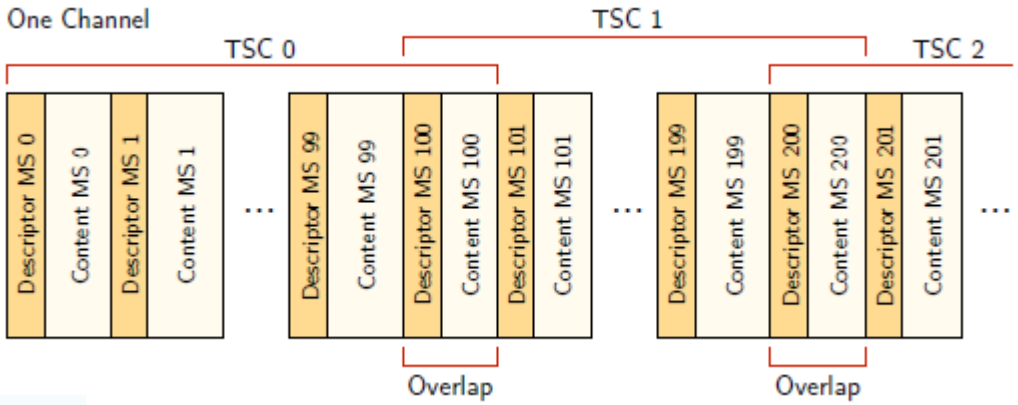
DAQ chain evolution at mCBM



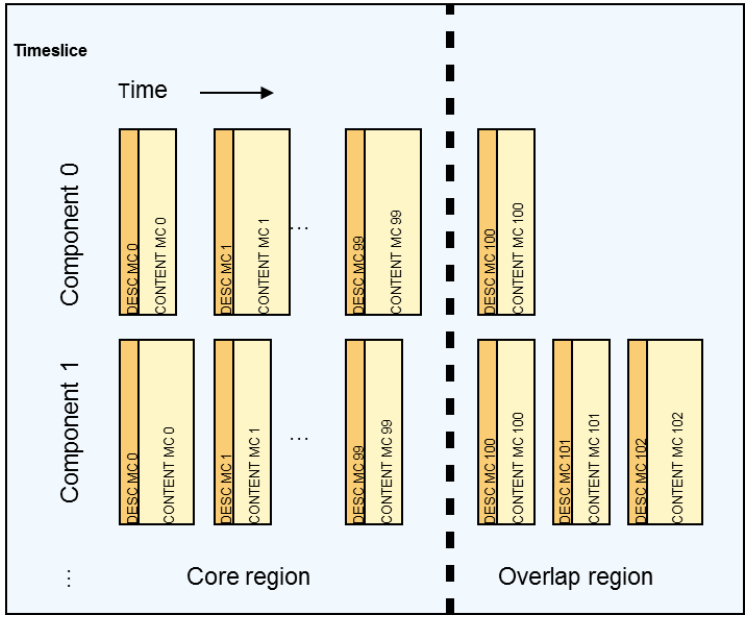
FLES EN – entry node
FLES PN – processing node
GSI CN – compute node

Timeslices and Microslices

- Definitions and concepts in the CBM readout chain



- MicroSlice (µS) = self-contained data container from a single CRI and for a fixed period of time
  - Output of the CRI in CBM => generated in FW
  - Constant length in experiment time
  - Typical period of time: 10's of µs to ms



- TimeSlice (TS) = container collecting the µS of all CRI cards in the setup and for a given number of µS
  - Assembled by FLESNET (CBM DAQ prototype) => generated in SW
  - Typical number of µS: 10-1000 => time range: ms to s
  - Includes an overlap µS
  - One TS for the full setup for each time interval

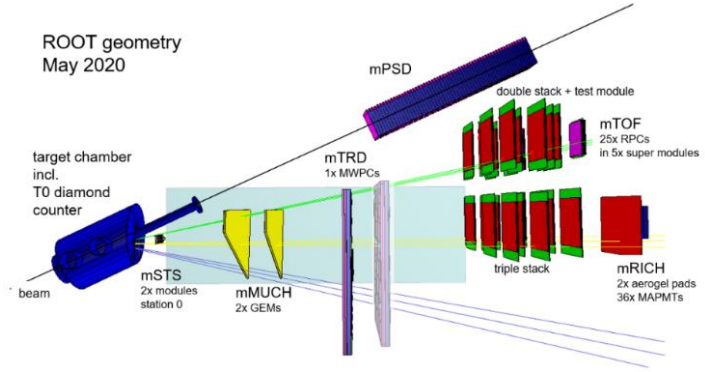
CBM streaming readout protoype setup - mCBM

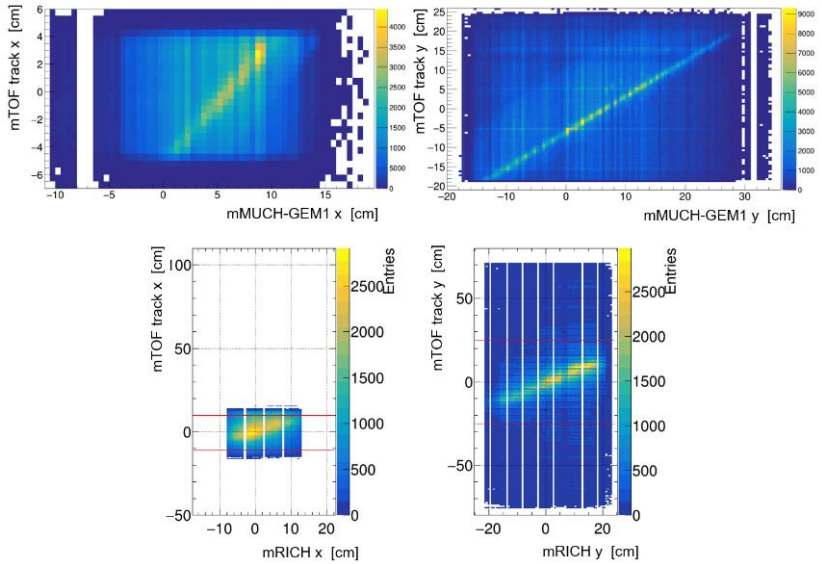
mCBM at GSI

presented today:

[Streaming Readout Workshop VII]

1st results from mCBM Run20
streaming readout setup with µTCA DAQ system



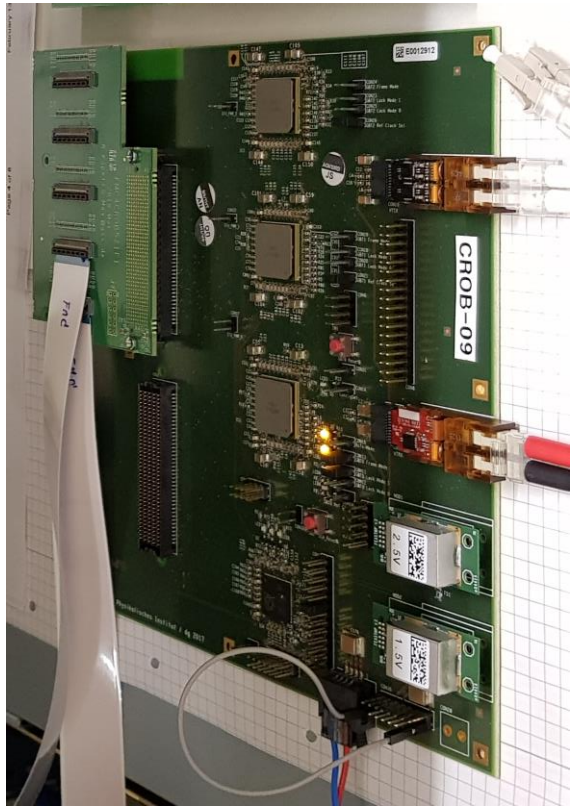


Common Readout Interface card for CBM

- BNL-712 card was developed for ATLAS
- also known as FLX-712 or FELIX
- CBM name: Common Readout Interface (CRI)
- core of CBM readout chain from 2021

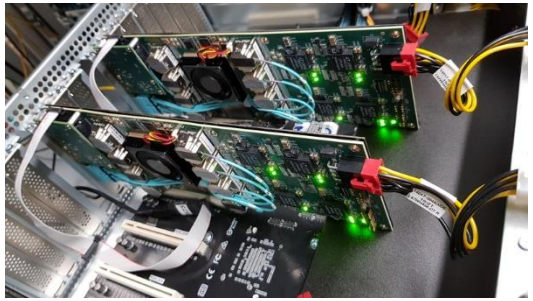
- Xilinx Kintex UltraScale XCKU115 FPGA
- 48 optical links (MiniPODs)
- PCIe Gen3 x16 (2x8 with switch)
- Separate TFC input via TMC

Fiber mapping on cave patch panel for 2021

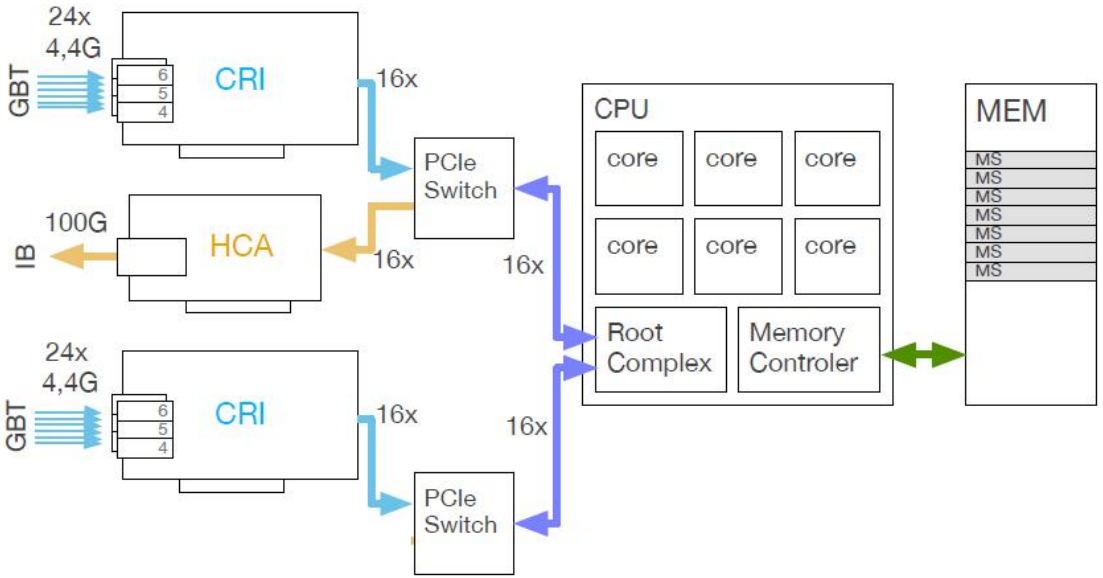


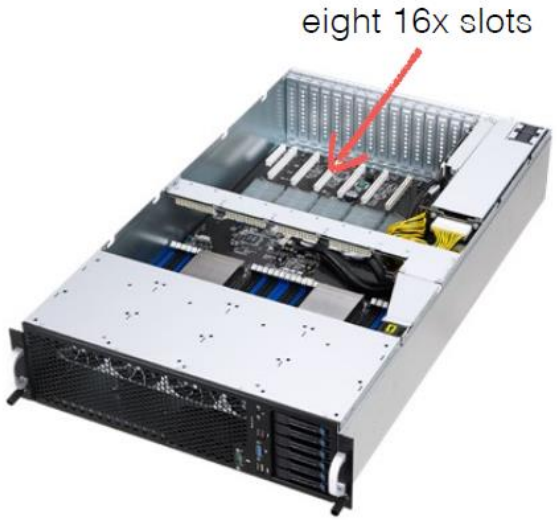
```
# 14.09.2020 - 12:30
# MTP cave patch panel
T0     | STS            | MUCH                    | TRD-I | TRD-O | TOF            | RICH   | PSD
1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 | 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 | 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1
Rx  Tx  Rx  Tx  Rx  Tx  Rx  Tx  Rx  Tx  Rx  Tx  Rx  Tx  Rx  Tx  Rx  Tx  Rx  Tx  Rx  Tx  Rx  Tx
```

Entry Node configuration - CRI data path



2 CRI cards installed in one entry node





ASUS ESC8000
-> prototype for mCBM

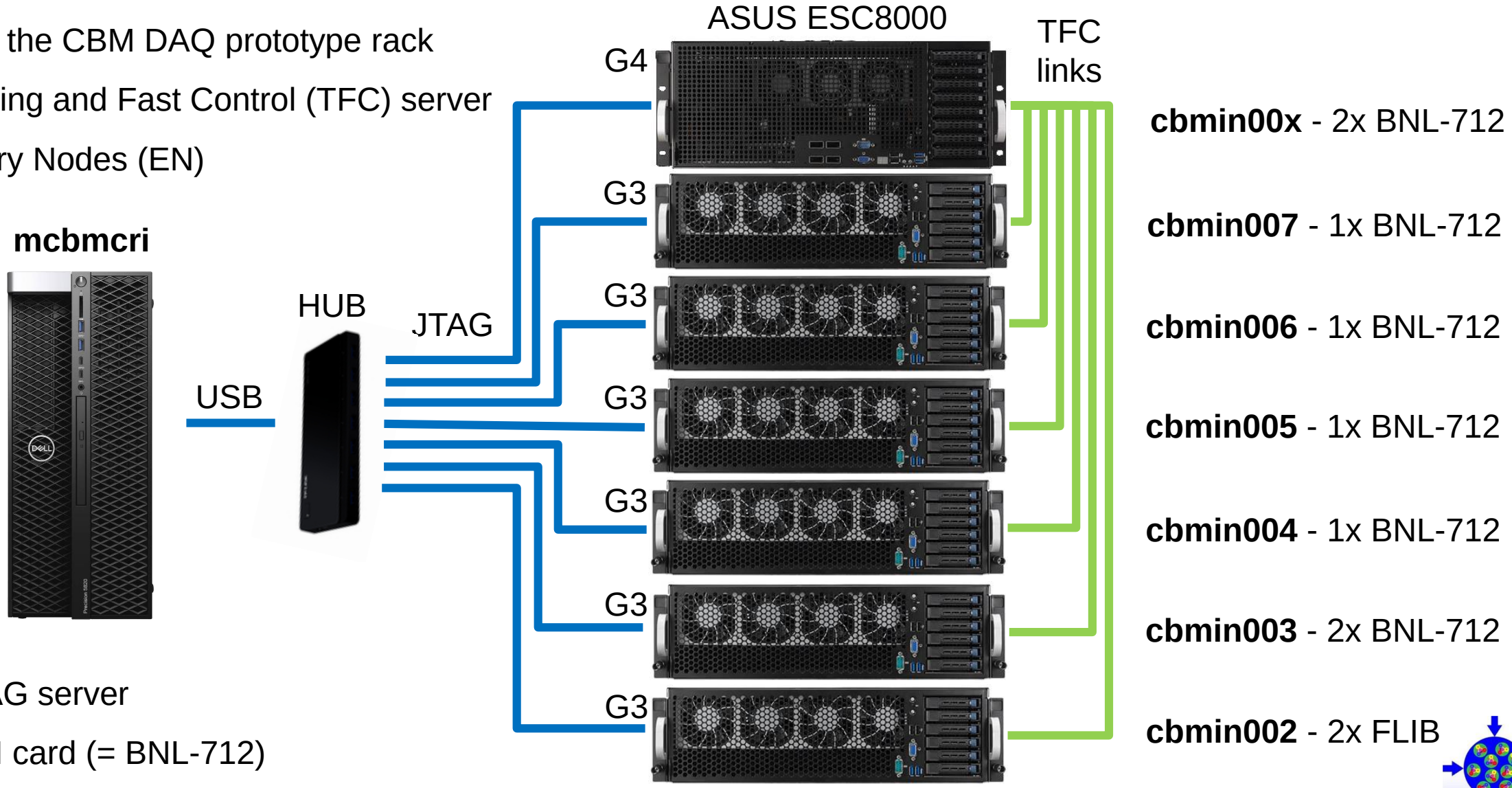
- 8x CRI boards are already installed
- 8x CRI boards to come in December 2020
- 18x CRI boards ordered for 2022

basic configuration of CRI entry nodes for 2021:

- 2x CRI - max 235 Gbps (in)
- 1x HDR HCA - max 120 Gbps (out)

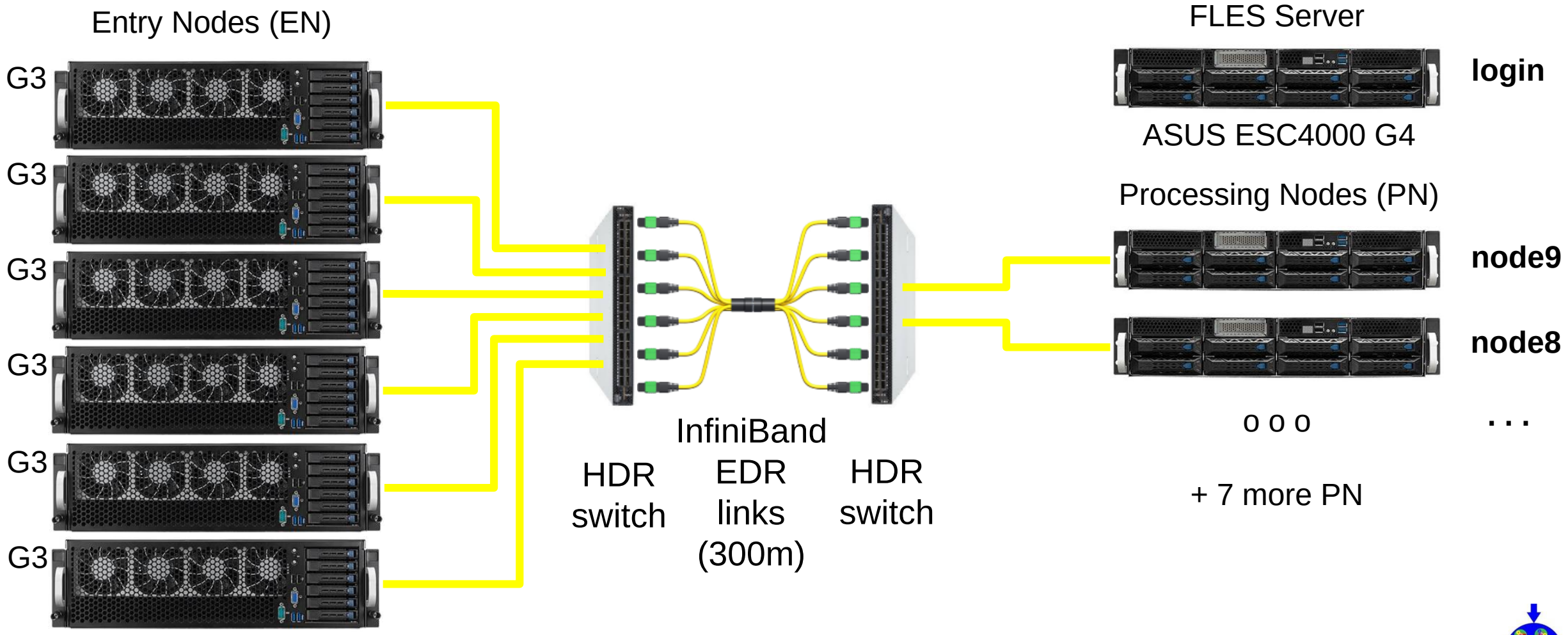
The CRI DAQ rack prototype

- This is the CBM DAQ prototype rack
- 1x Timing and Fast Control (TFC) server
- 6x Entry Nodes (EN)

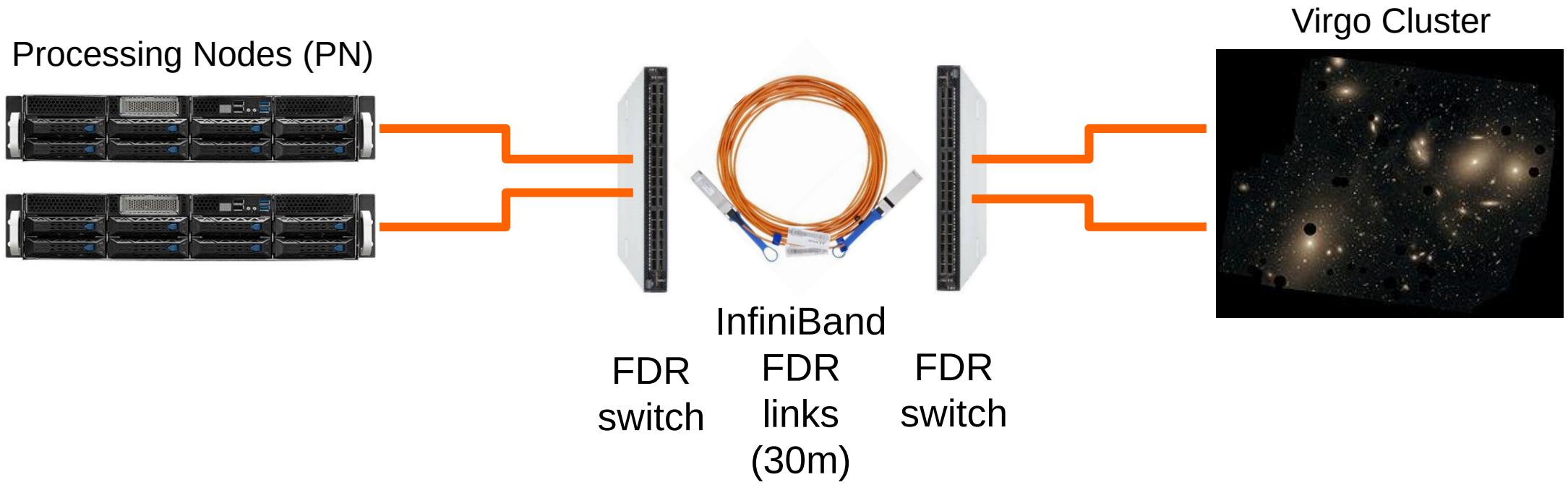


- 1x JTAG server
- 8x CRI card (= BNL-712)

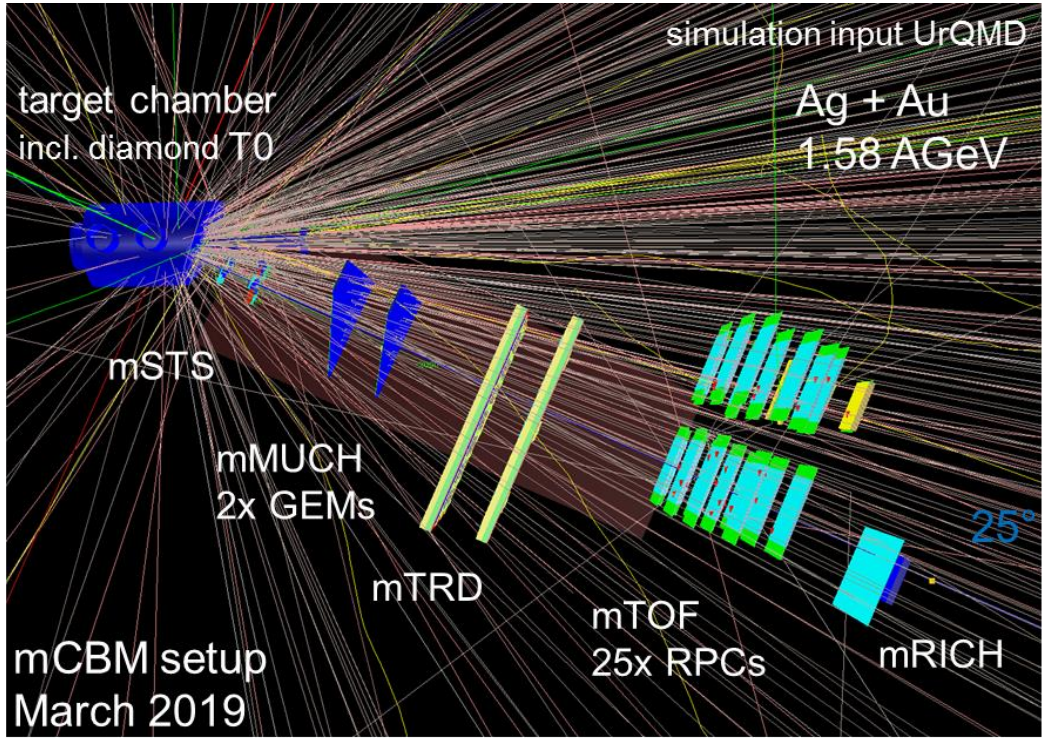
The Processing Node cluster

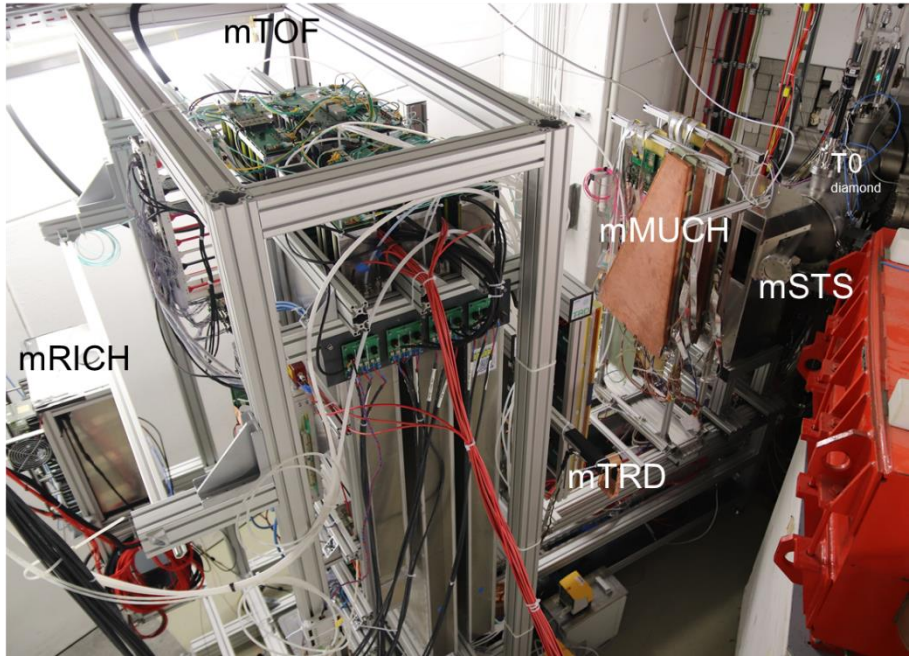


The link to Virgo / IT cluster



Commissioning of mCBM

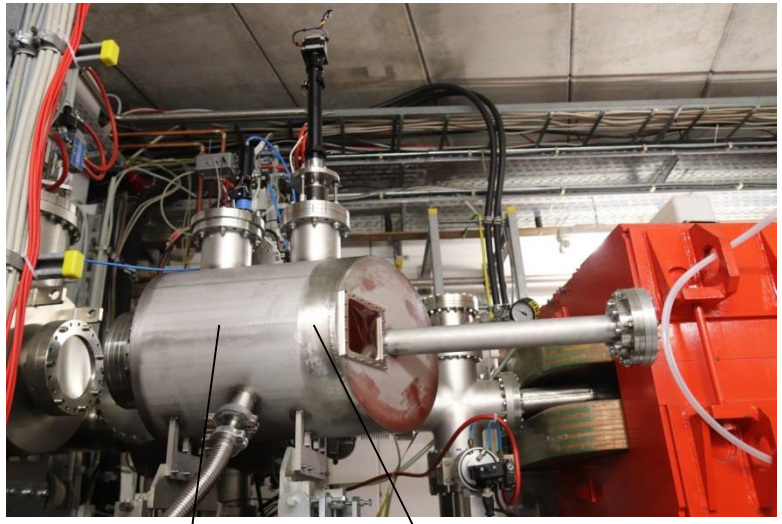


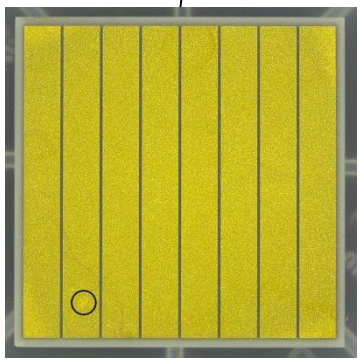


1st data campaign:
Nov./Dec. 2018 & March 2019

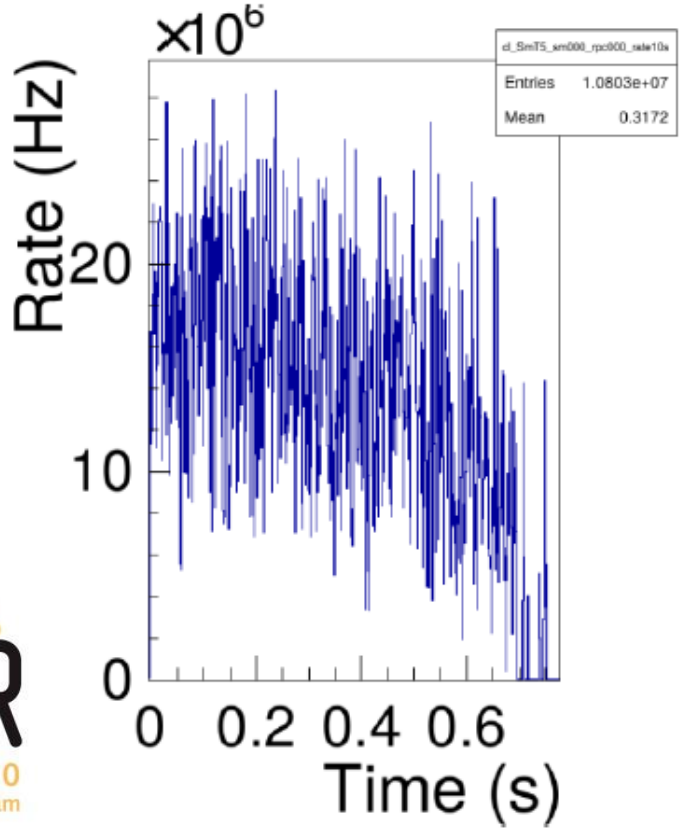
2nd data campaign:
Nov. 2019 & May 2020

Diamond T0 counter





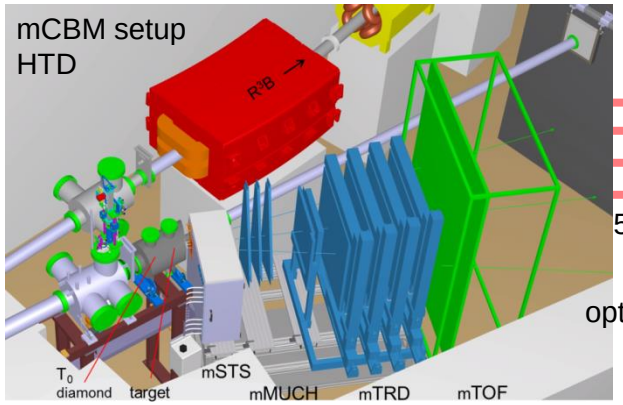
diamond counter:
8x strips
2mm width each



March 30, 2019:
beam intensity ≈ 10^8 Ag ions / s
⟶ T0 saturation

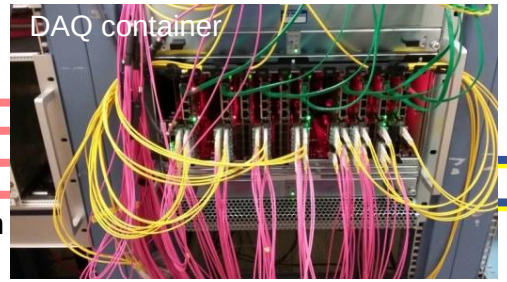
Commissioning of mCBM

March 2019 : 10^8 Ag ions/s (1.58 AGeV) + Au (2.5mm) → 10 MHz collision rate



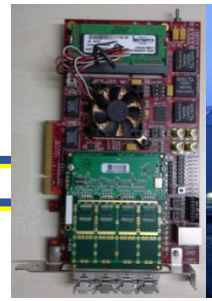
50 m

optical fibers



optical fibers

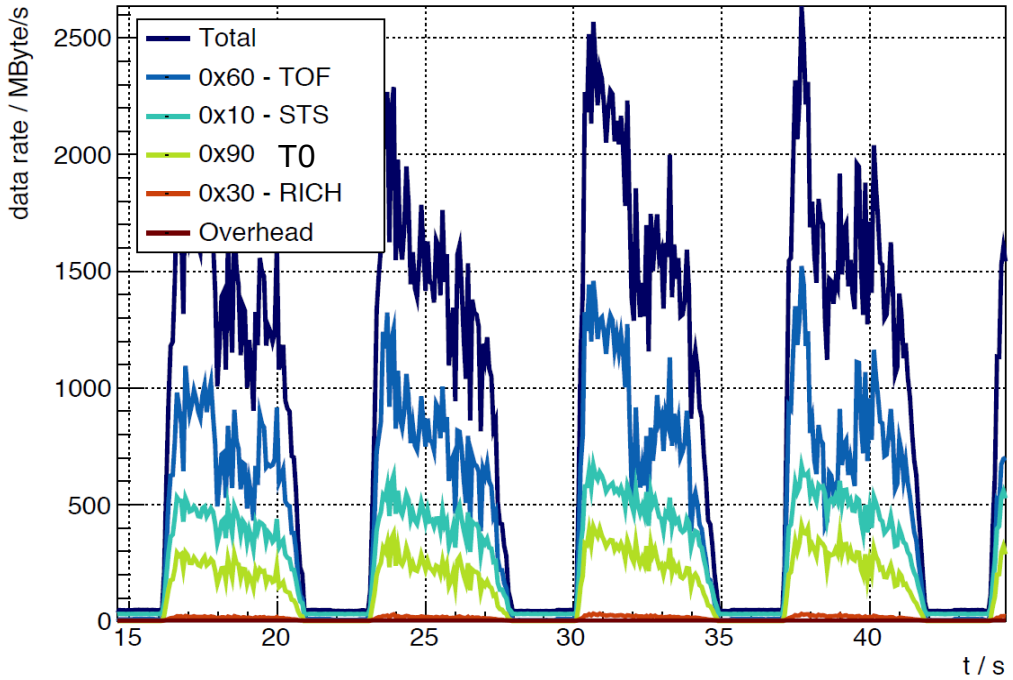
300 m



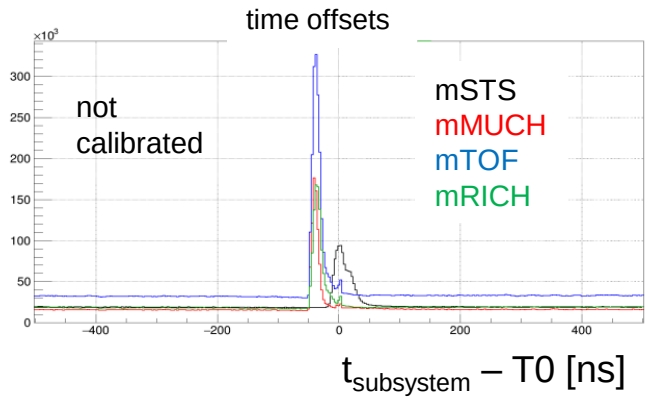
FAIR Phase 0 Research Program

total data rate
online

2.5 GB/s (max.)



Commissioning of mCBM



time

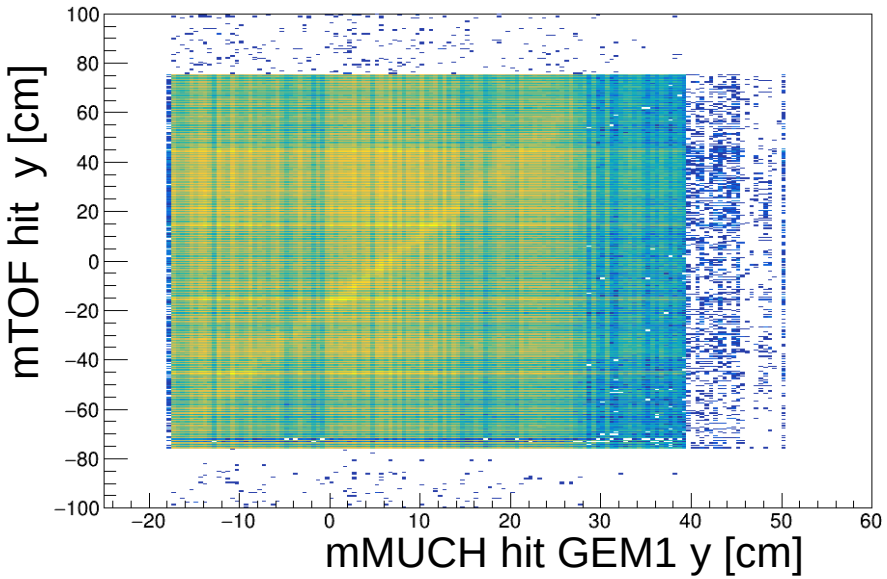
and

spatial correlations

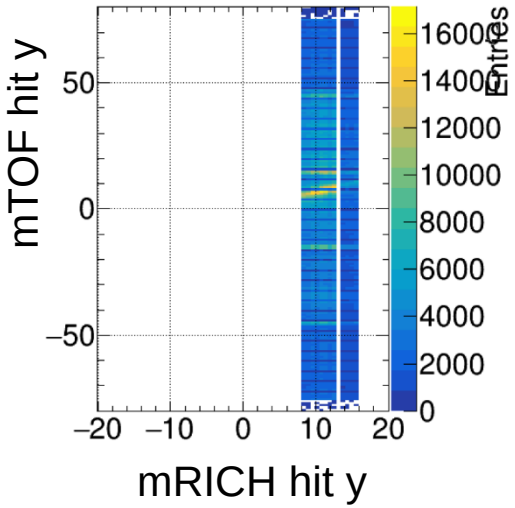
preliminary, March 2019 run
Ag + Au, 1.58 AGeV

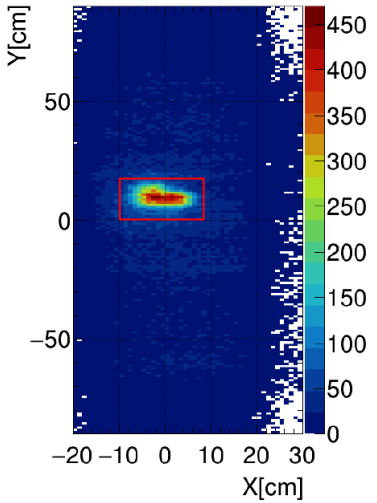
→ 1st proof of concept

mMUCH ↔ mTOF



mTOF ↔ mRICH





mTOF tracks with assigned mRICH hit

Trunk cables linking HTD cave to the DAQ container and to the Green Cube

2x 50 m long OM4 cable for HTD-DAQ

300 m long OS2 cable for DAQ-GC

144x core trunk fibers for mCBM

max bandwidth of MM connection with 4.8 Gbps GBT links:
144 * 4.8 Gbps = 691.2 Gbps

max bandwidth of SM connection with 100 Gbps (EDR) links:
72 * 100.0 Gbps = 7200.0 Gbps

The end

The end