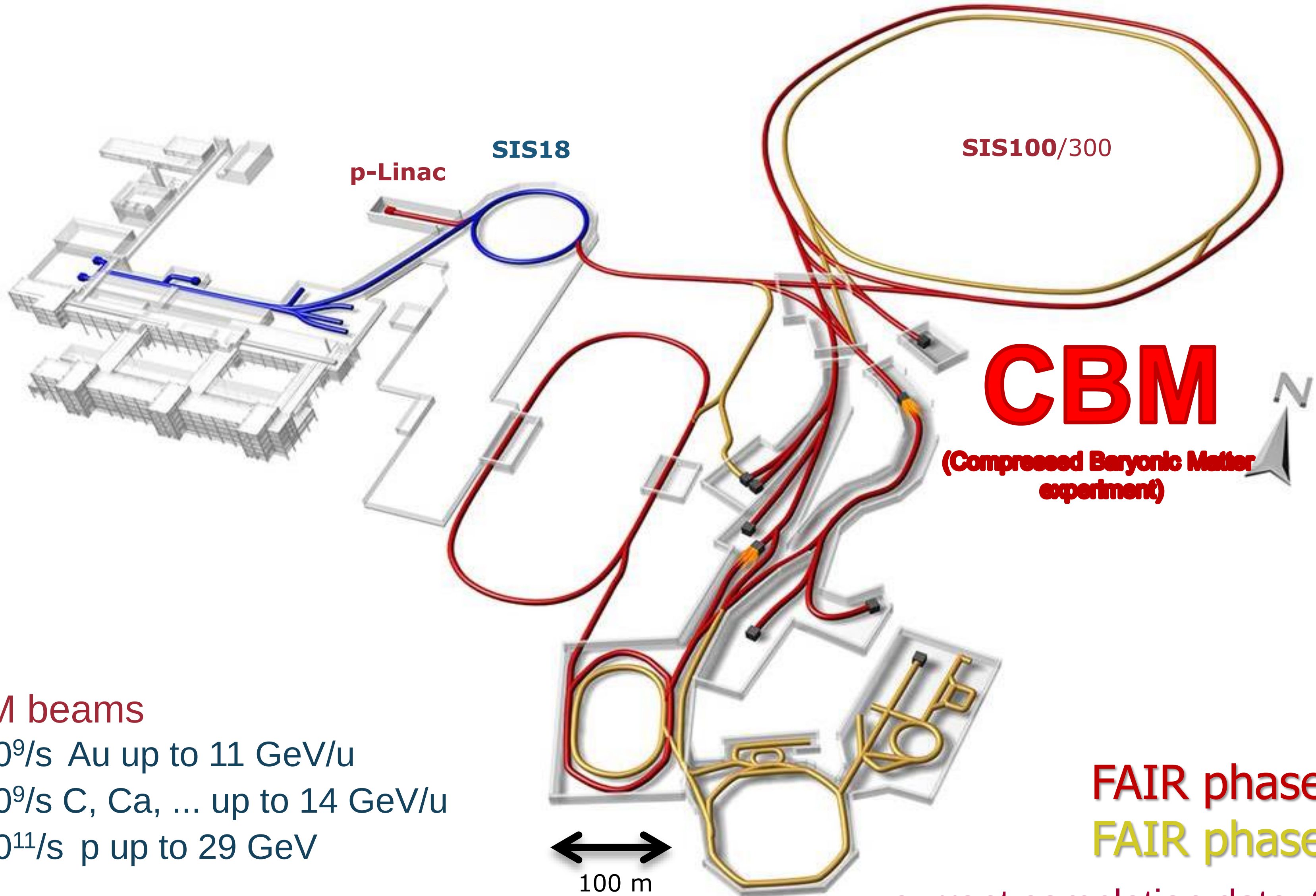
Status of CBM at FAIR

4^{th} CBM – China Workshop
Yichang
April 12 – 14, 2019

https://www.youtube.com/watch?v=ayrjkV8kr48

Facility for Antiproton & Ion Research



CBM beams

- 10^9/s Au up to 11 GeV/u
- 10^9/s C, Ca, ... up to 14 GeV/u
- 10^{11}/s p up to 29 GeV

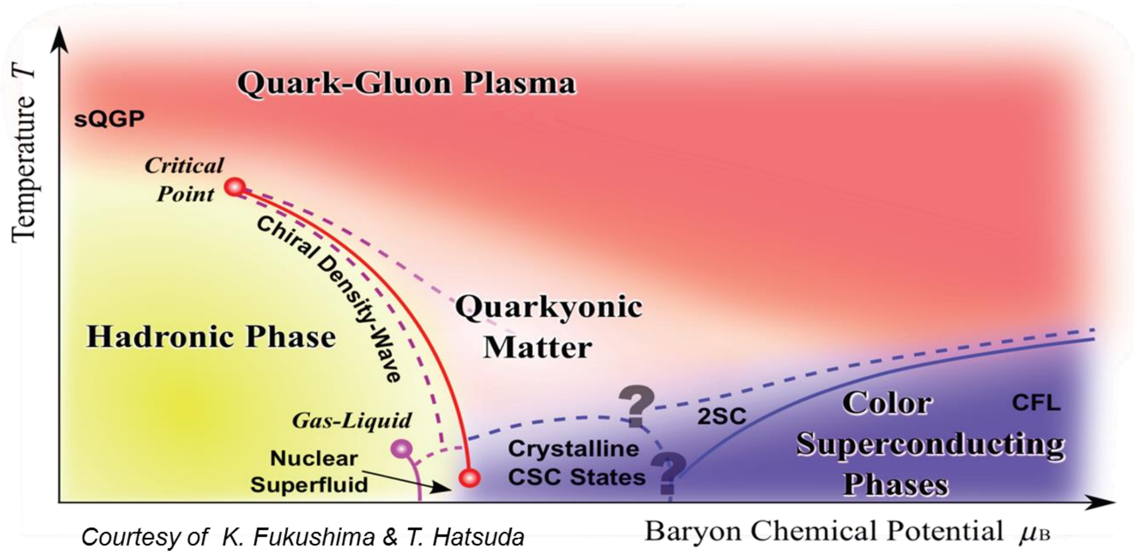
FAIR phase 1

FAIR phase 2

current completion date: 2025

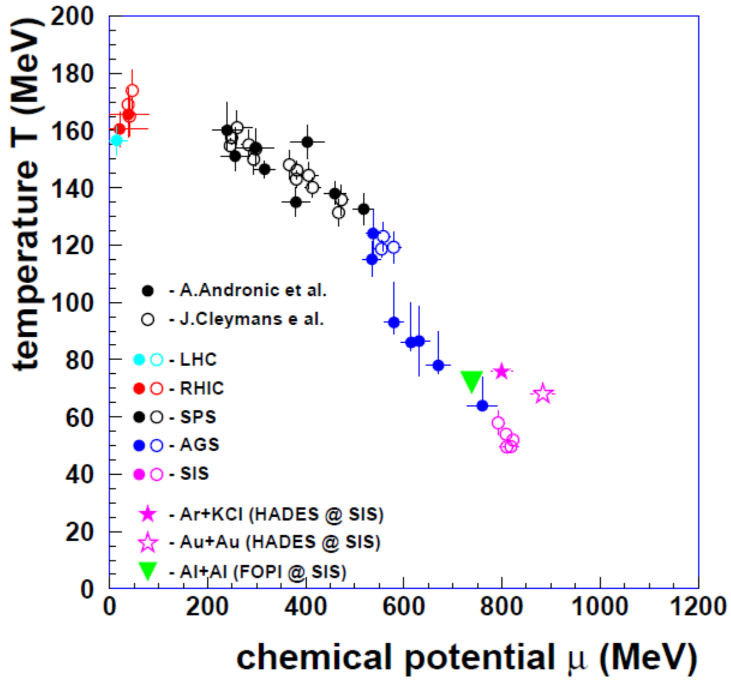
Motivation: QCD phase diagram

Theoretical expectations



Courtesy of K. Fukushima & T. Hatsuda

Experimental freeze-out data (SHM)



Outline:

CBM day-1 setup

CBM day-1 measurements

FAIR Phase-0 projects: (HADES)

mCBM

STAR

BM@N

CBM physics and observables

Eur.Phys.J. A53 (2017) 60

QCD equation-of-state
- collective flow of identified particles
- particle production at threshold energies

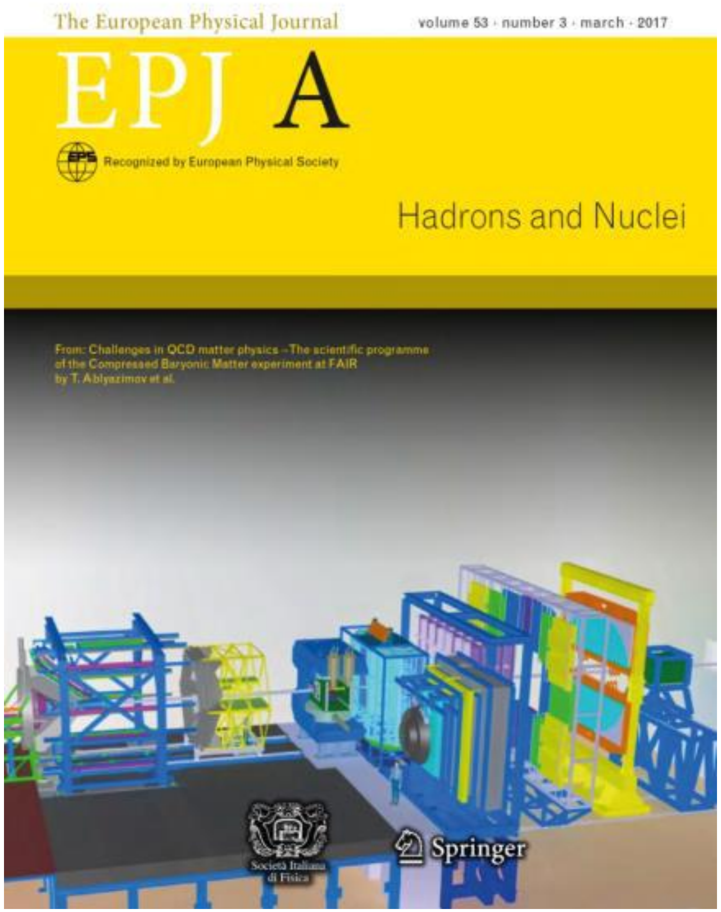
Phase transition
- excitation function of hyperons
- excitation function of LM lepton pairs

Critical point
- event-by-event fluctuations of conserved quantities

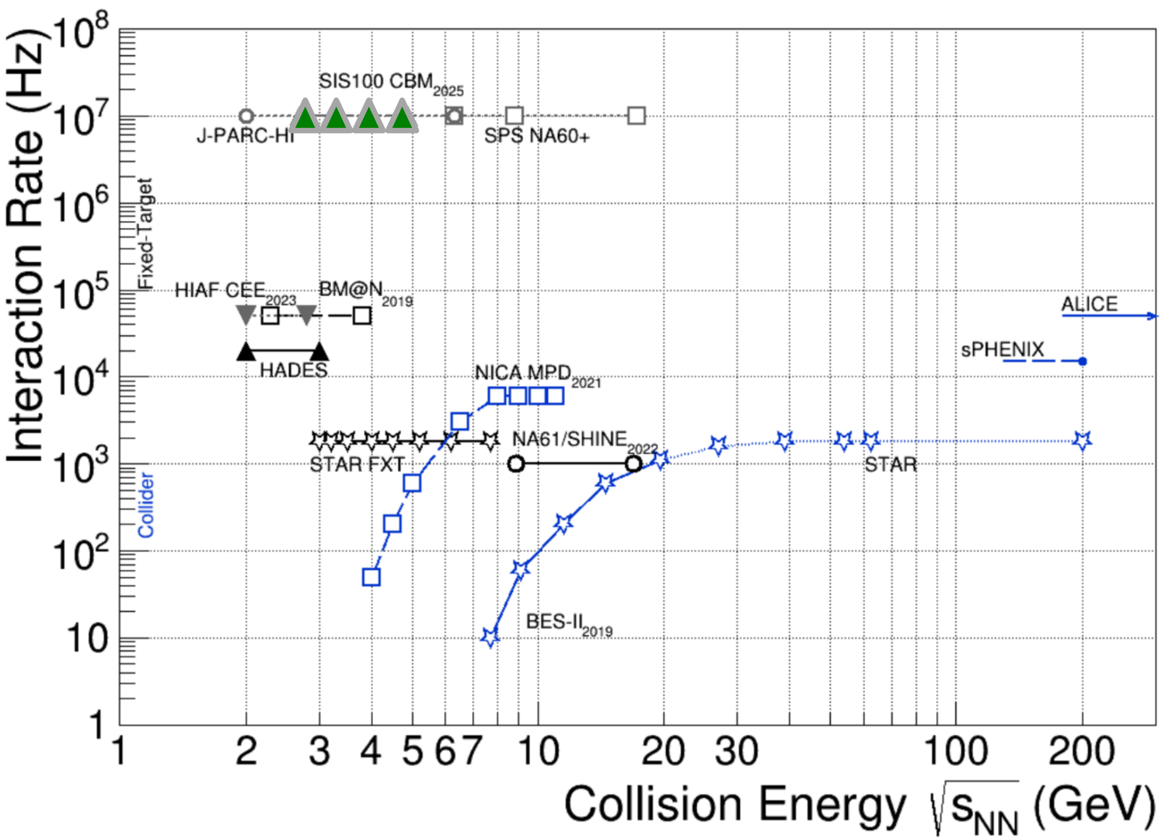
Chiral symmetry restoration at large μ_B
- in-medium modifications of hadrons
- meson-baryon coupling
- dileptons at intermediate invariant masses

Strange matter
- (double-) lambda hypernuclei
- Search for meta-stable objects (e.g. strange dibaryons)

Heavy flavour in cold and dense matter
- excitation function of charm production



Rate capability of experiments



Exploration of QCD phase diagram is an international effort:

NA61	@ SPS/CERN
BM@N	@ Nuclotron/JINR
STAR(FXT)	@ RHIC/BNL
MPD	@ NICA/JINR
CEE	*@ HIAF*
NA60+	*@ SPS/CERN* *
?	*@ J-PARC* *

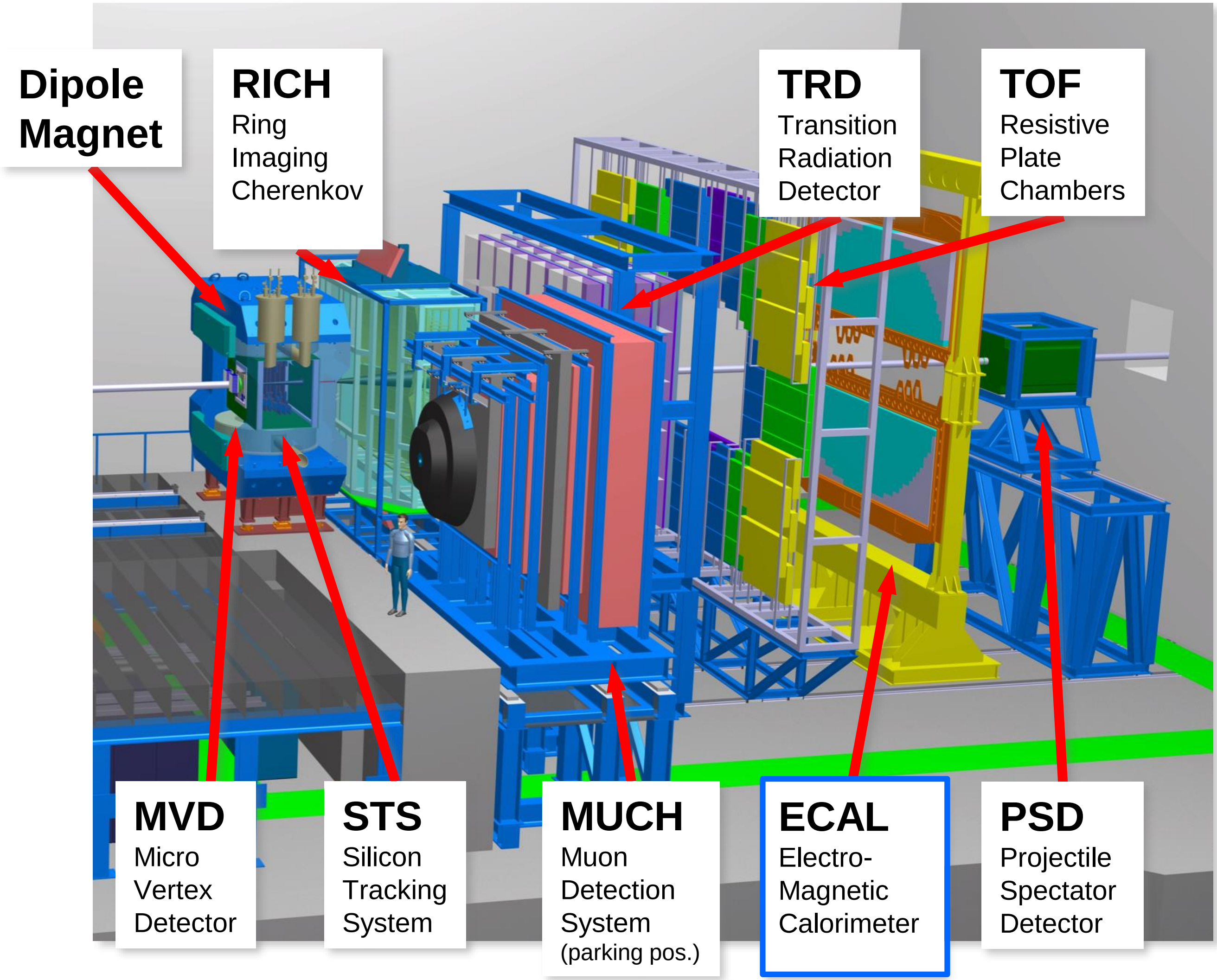
* *not yet funded*

Competitors for CBM:

BM@N	@ Nuclotron/JINR
STAR(FXT)	@ RHIC/BNL

CBM‘s unique feature:
High statistics measurement of rare probes

CBM Day-1 experimental setup



- Tracking acceptance: $2^o < \theta_{lab} < 25^o$
- Free streaming DAQ
- R_{int} = 10 MHz (Au+Au)

  $R_{int} \approx 0.5$ MHz
  full bandwith:
  Det. – Entry nodes
  reduced bandwidth
  Entry nodes – Comp. farm

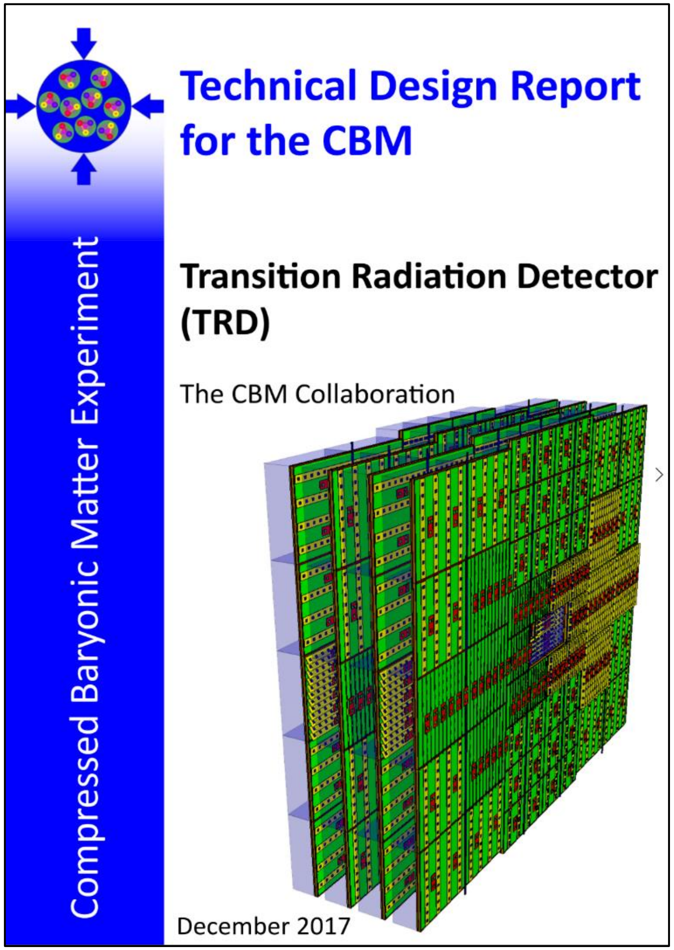
  with
  R_{int} (MVD)=0.1 MHz
- Software based event selection

Day-1 setup = MSV setup – Compute Performance - ECAL

Day-1 funding: ~ 90% secured

TDRs

#	Project	TDR Status
1	Magnet	approved 2013
2	STS	approved 2013
3	RICH	approved 2014
4	TOF	approved 2015
5	MuCh	approved 2015
6	PSD	approved 2015
7	TRD	approved 2018
8	MVD	submission 2020
9a	Online Systems: DAQ	submission 2020
9b	Online Systems: FLES	submission 2023
10	ECAL	submission t.b.d.

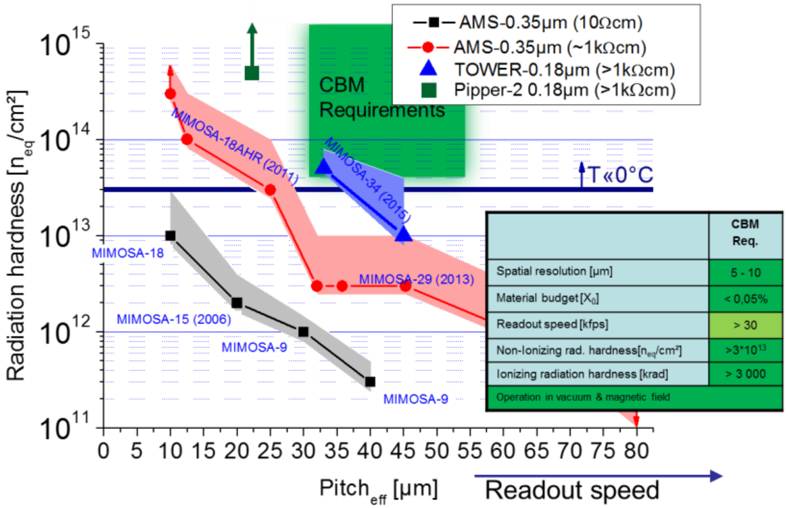


Day-1 target date: summer 2024

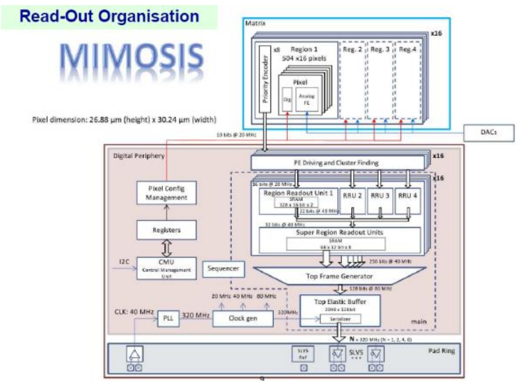
Micro Vertex Detector (MVD)

IKF Frankfurt, IPHC Strasbourg, Pusan National Univ. + CCNU Wuhan, IMP Lanzhou

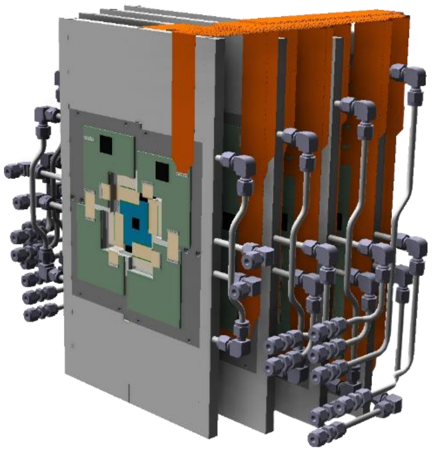
- Background suppression for di-electron measurements
- Determination of secondary vertices of open charm decays
- Improved tracking for hyperon-ID, enables missing mass method



	CBM Req.
Spatial resolution [µm]	5 - 10
Material budget [X_0]	< 0,05%
Readout speed [kfps]	> 30
Non-Ionizing rad. hardness[n_{eq}/cm^2]	>3*10^{13}
Ionizing radiation hardness [krad]	> 3 000
Operation in vacuum & magnetic field	



Sensor design inspired by ALPIDE



Status:

- MIMOSA sensor technology applicable after 10 years of joint development
- Steps toward final sensor identified:
  Q4,’17 MIMOSIS-0 diff pixel design, Q4,’19 MIMOSIS-1: 1st prototype of complete sensor
  Q2,’20 MIMOSIS-2: 2nd prototyp, 2021 MIMOSIS-3: final sensor pre-production
- TDR to be submitted in 2020

MVD: MIMOSIS-0/1

First generation sensor MIMOSIS-0 is being tested:

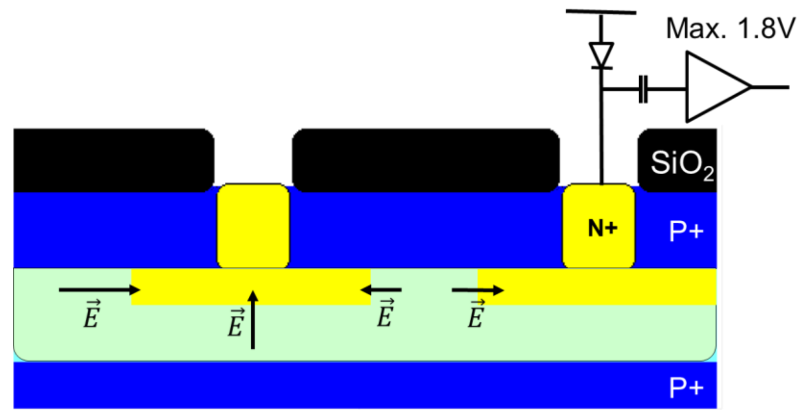
- Response to Fe-55 seems ok.
- Noise as expected.
- Signal shape as expected.
- Signal rise time: ~1µs
- Dead time: <10µs (more than readout time)

Radiation tolerance tests ongoing:

- Modest tuning of slow control parameters needed up to 1 Mrad.
- No substantial features for higher doses observed so far.
- Mild issue on DACs observed and understood, will be fixed.

Next steps (mid 2019):

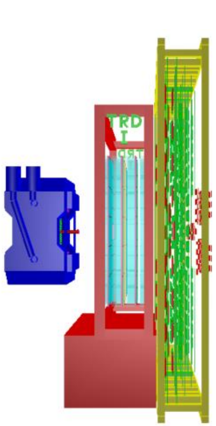
- CBM Internal sensor design review.
- Submission of full size prototype (MIMOSIS-1).
- Integrate stations based on MIMOSIS-1 to mCBM.
- Start extensive radiation tolerance (e.g. SEE) test program.

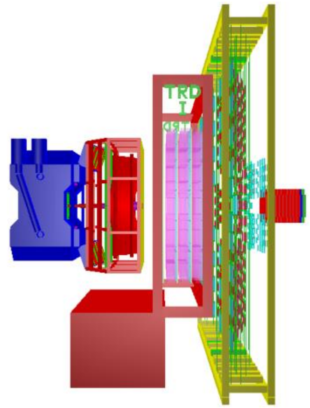


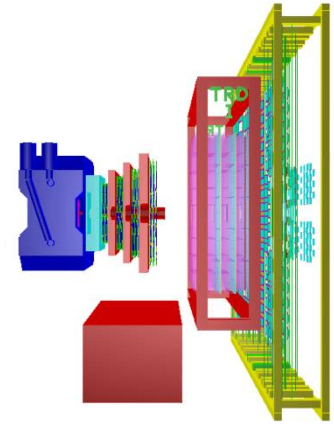
„Double modified process“:
- Add shaped deep n-implantation

=> Full depletion + lateral fields.
=> May allow for >>10^{14} n_{eq}/cm^2 rad. tolerance

CBM MSV vs. Day-1





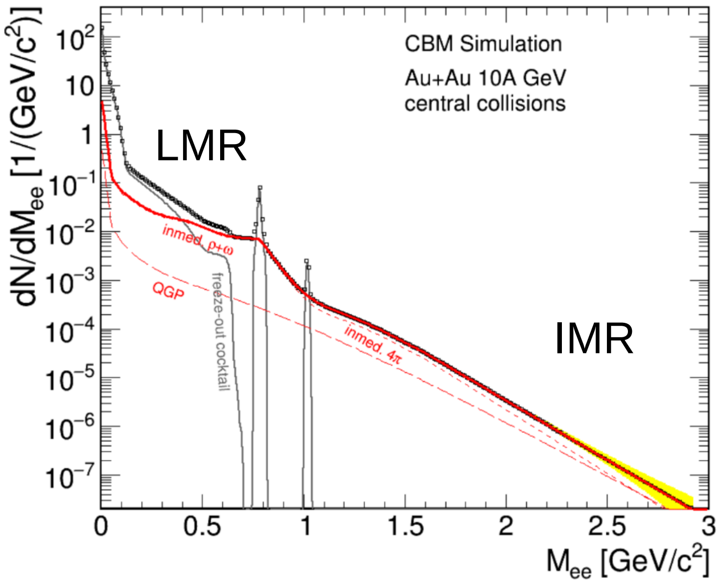


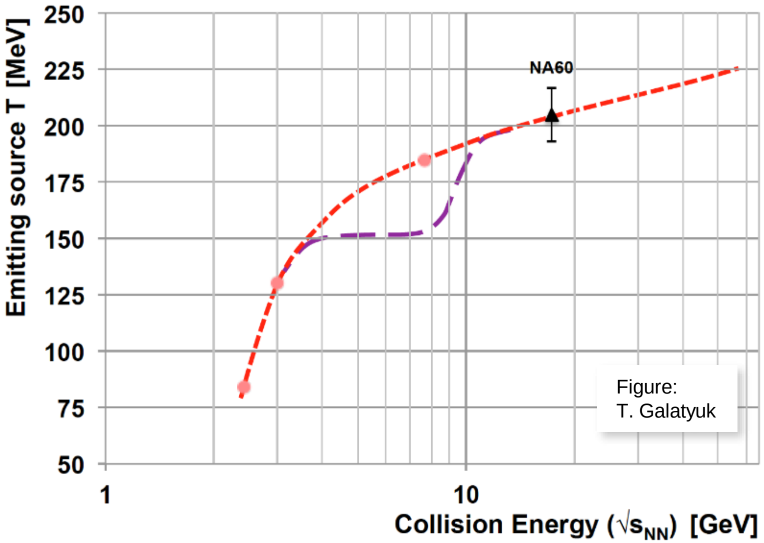
Setup	Subsystems	Average Rate (max)		Event size
		MSV	Day-1	
Hadron	STS, TRD, TOF	5 MHz	0.5 MHz	50 kB
Electron/ Hadron	MVD, STS, RICH, TRD, TOF, PSD	0.1 MHz	0.1 MHz	75 kB
Muon	STS, MUCH, TRD, TOF	5 MHz	0.5 MHz	30 kB

Day-1 electron setup offers final rate capability for di-electrons (due to MVD rate limitations).
No sophisticated online selection (trigger) planned for Day-1.

Dileptons as probes for dense matter (Day-1)

[R. Rapp, H. v.Hees, PLB 753 (2016) 586]





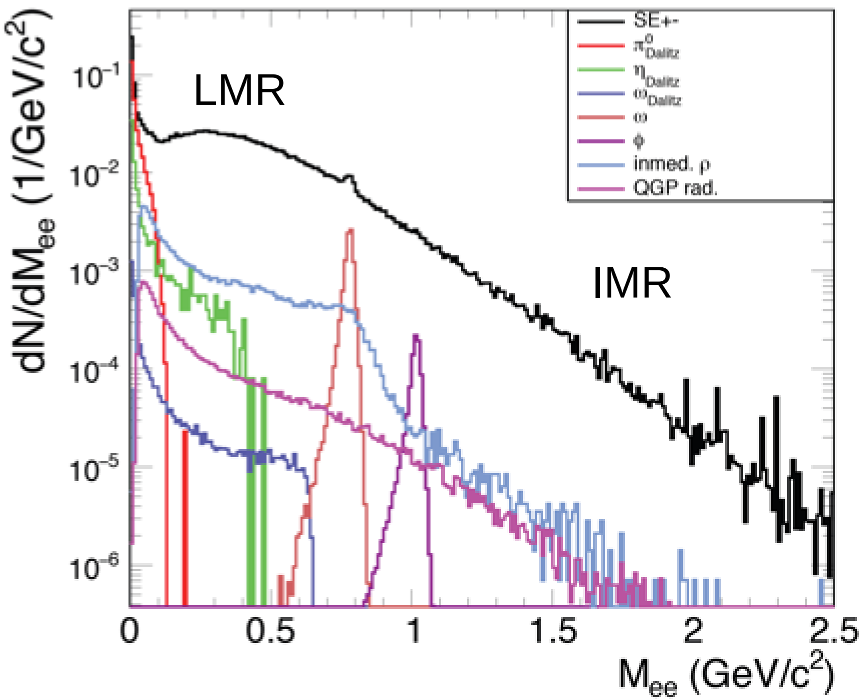
LMR: ρ – chiral symmetry restoration
fireball space – time extension

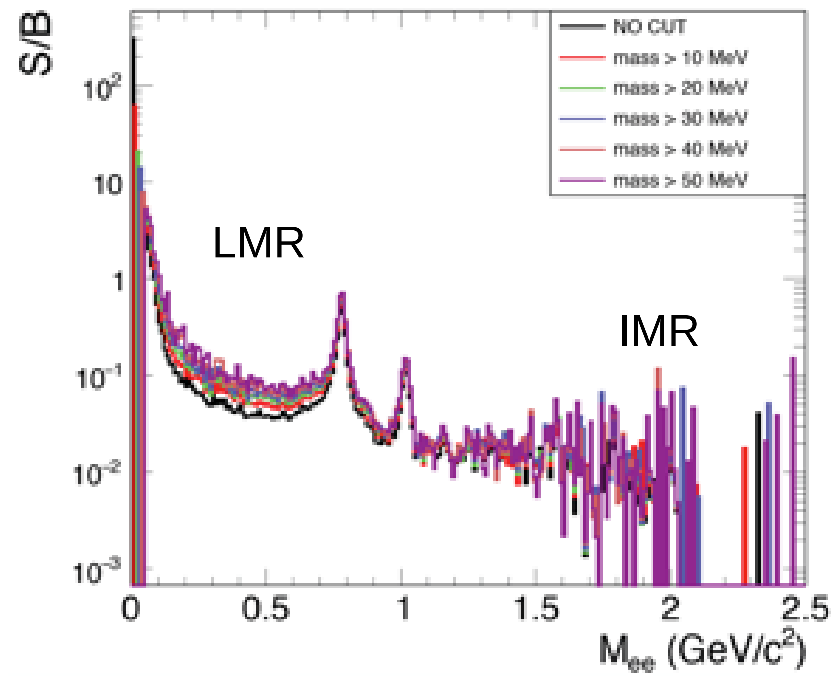
IMR: access to fireball temperature
ρ-a_1 chiral mixing

Measurement program:
excitation function of LMR – excess
excitation function of IMR – slope (non – monotonic behavior ?)

Day-1 di-electron measurement

Physics Topic: Chiral Symmetry restoration, phase transition



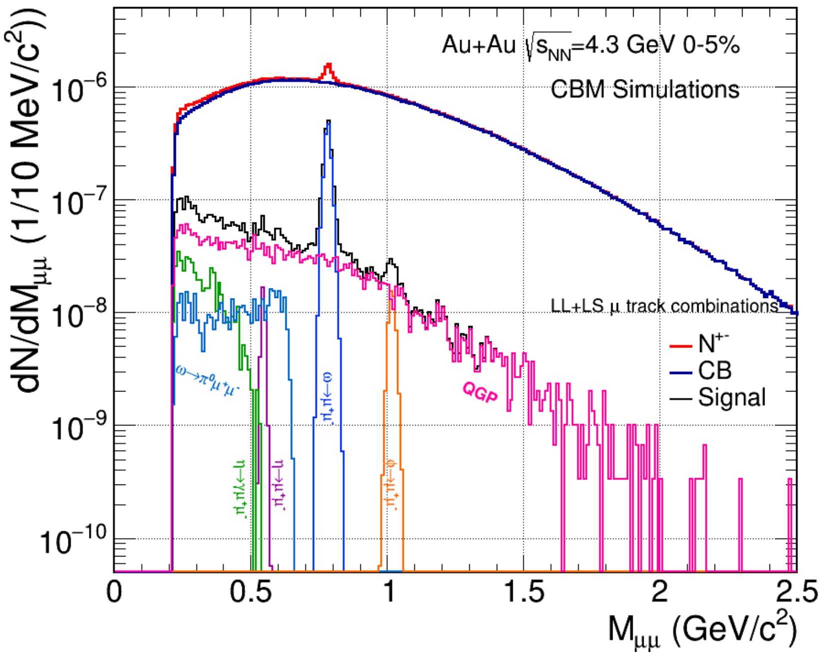


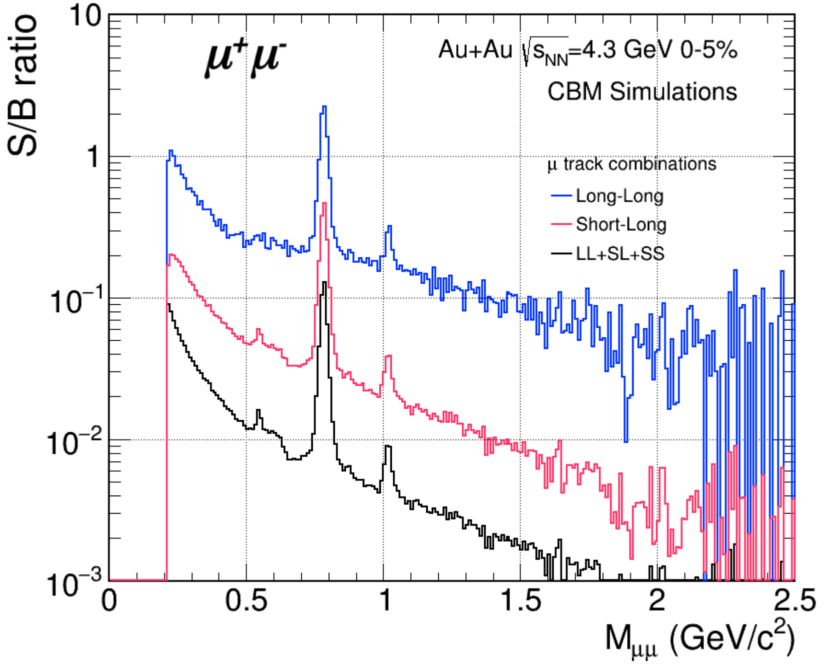
- 1M Au+Au (b=0 fm), 8A GeV
- IMR: S/B > 1/100
- Statistical accuracy for T_{eff} of 10% requires 10^{11} events, ~ 20 days of beamtime

- CBM will be the first experiment to use di-leptons for systematic measurements.

Day-1 di-muon measurement

Physics Topic: Chiral Symmetry restoration, phase transition

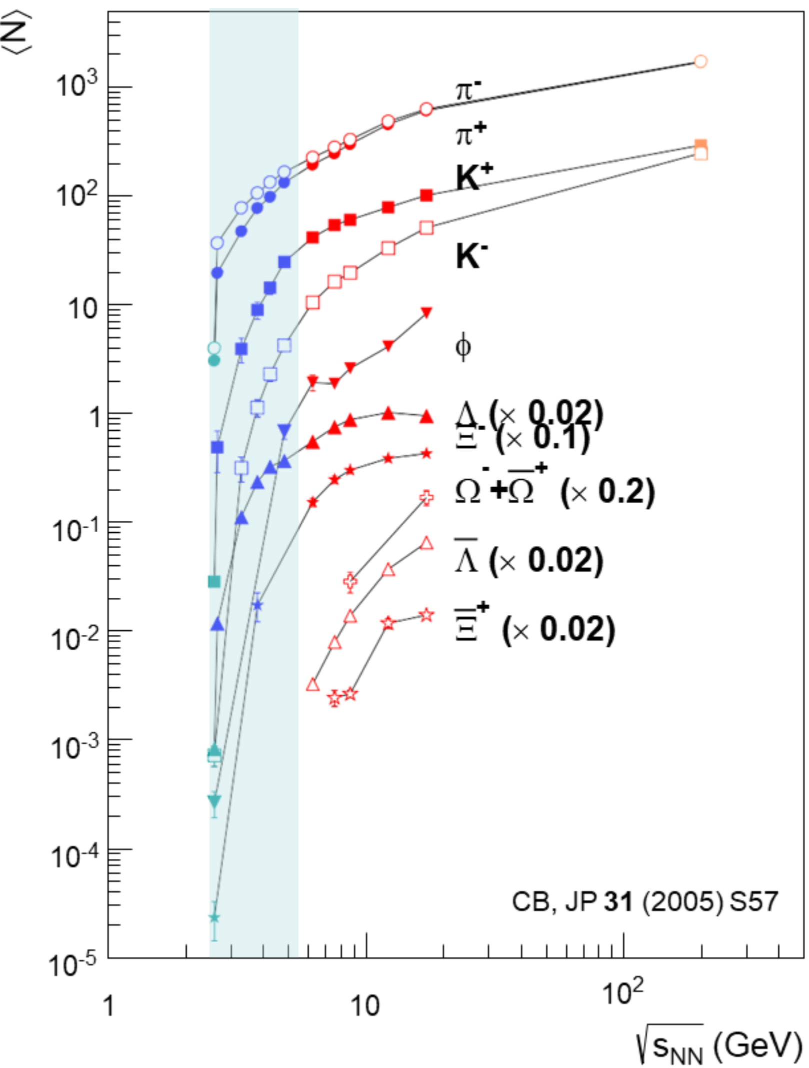




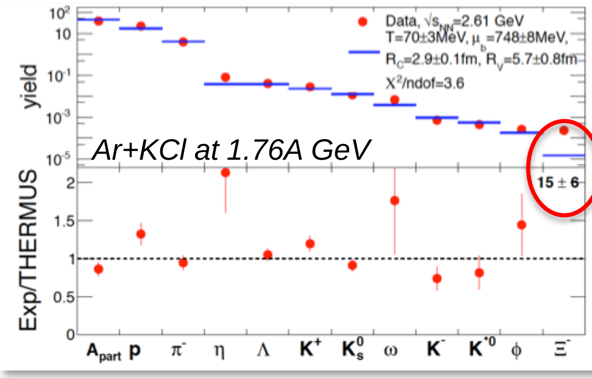
- Performance similar to di-electron setup
- First measurement in SIS100 energy range
- Different systematic errors from di-electron setup <-> cross check of results

Subthreshold particle production

World data

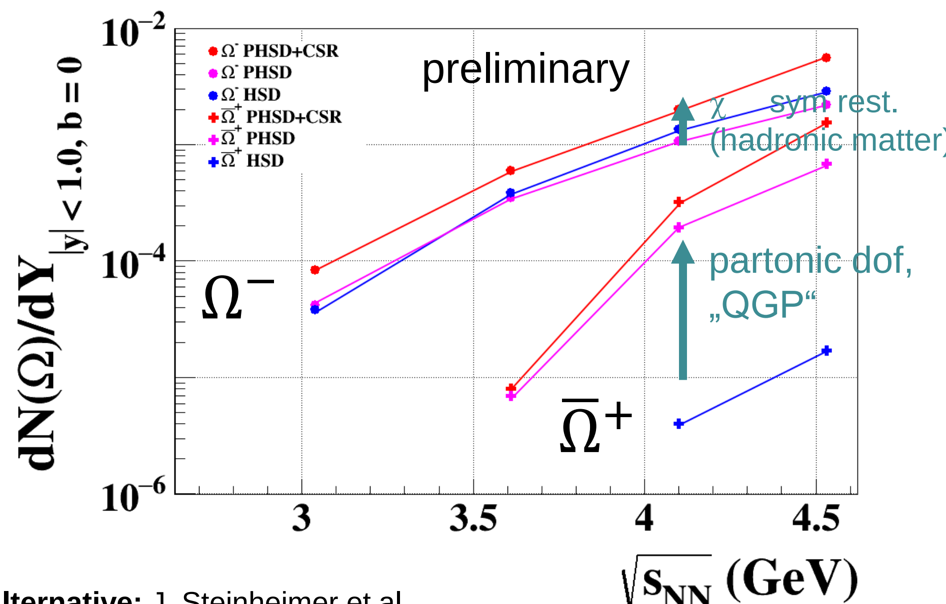


HADES:



Example of dependencies

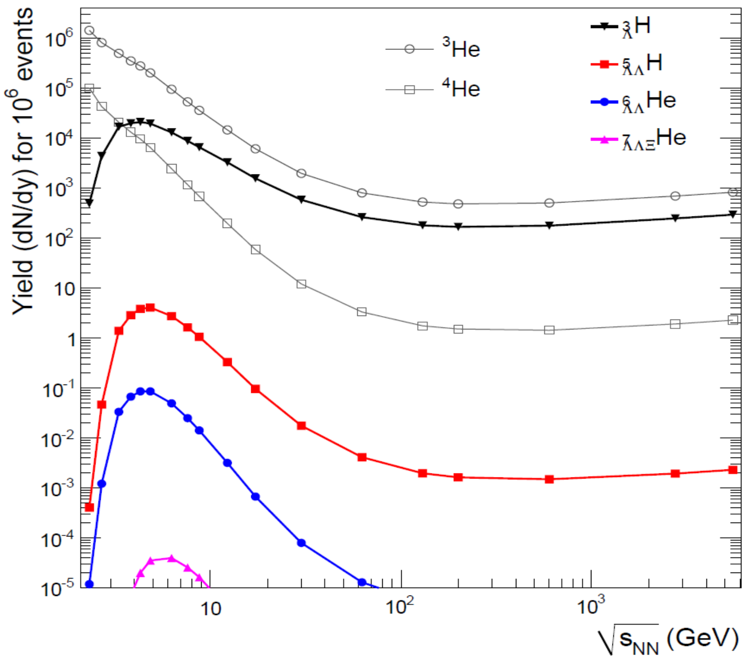
PHSD W. Cassing, E. Bratkovskaya et al., Phys.Rev. C93 (2016), 014902



Alternative: J. Steinheimer et al., resonance BRs

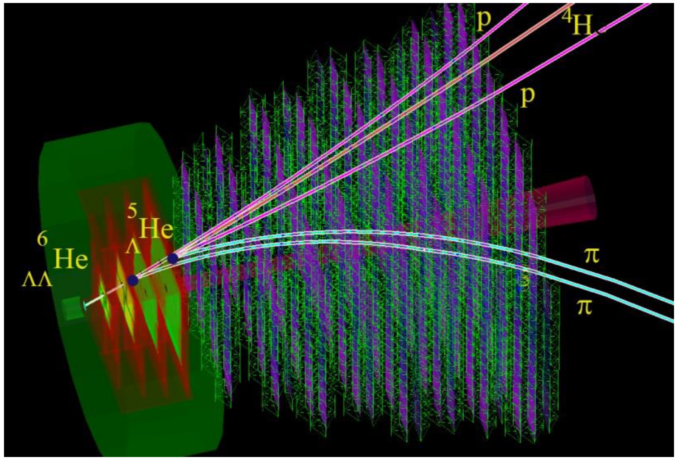
High rate case: ΛΛ - hypernuclei

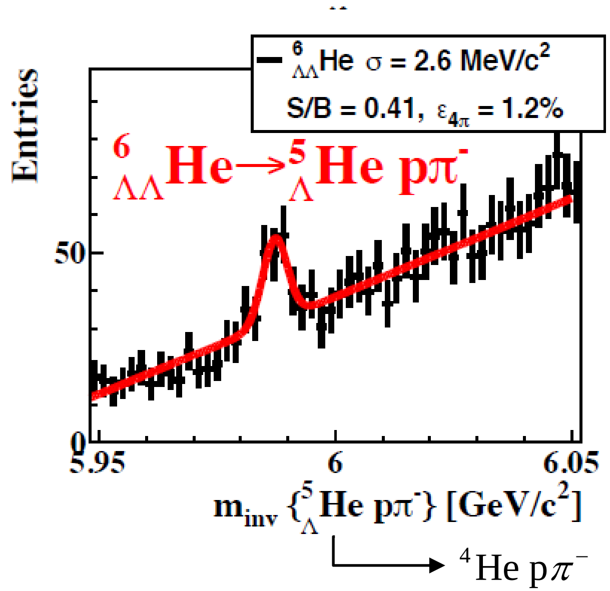
Thermal model prediction for Au+Au



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

Decay topology



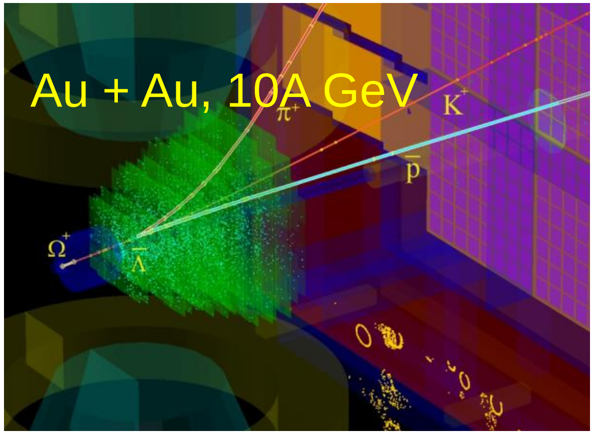


Runtime estimate at peak interaction rate of 10 MHz

Signal counts per week:

$$S_w = R_{peak} * f_{av} * \varepsilon_{duty} * P_{prod} * f_{mb/cen} * BR * \varepsilon_{reco} * \Delta T$$
$$= 10^7 * 0.5 * 0.7 * 10^{-7} * 0.25 * 0.1 * 0.012 * 6\ 10^5$$
$$= 60$$

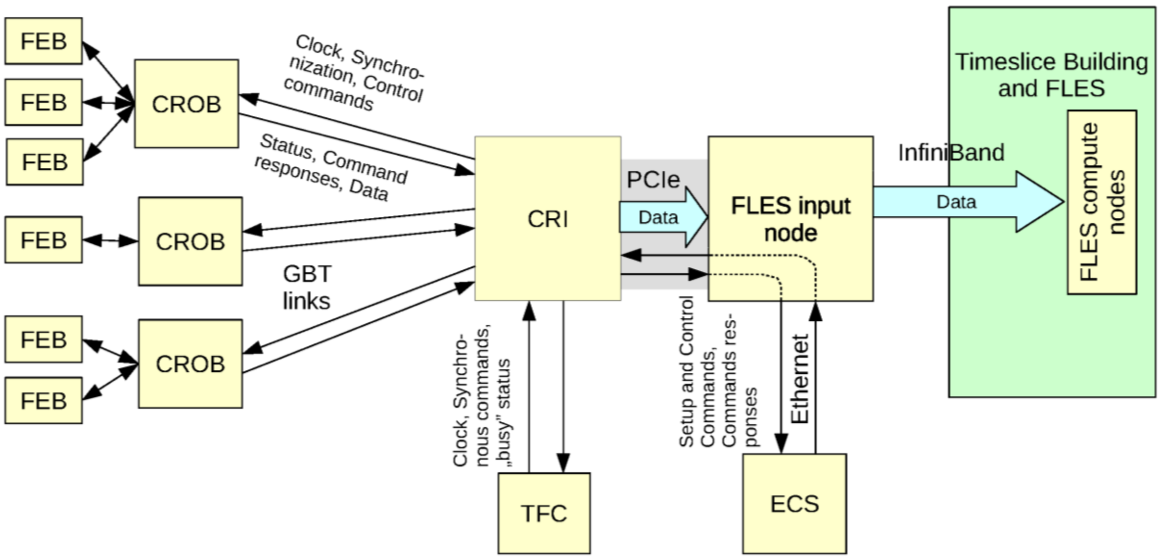
CBM data processing system



Reaction rate Au + Au:

10^7 collisions per second

Data rate: ~ 1 TB/s



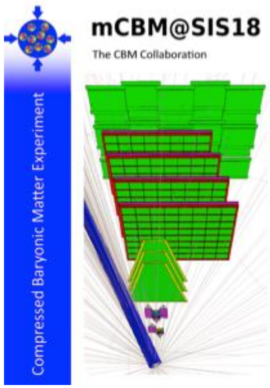
Main features:

- radiation tolerant detectors and front-end electronics
- free streaming (triggerless) data with time stamps,
- software based event selection

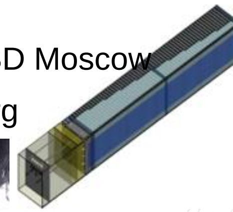
CBM Phase-0 Project: mCBM

Demonstrator for full CBMdata taking and analysis chain under full load (Au-Au, 10^7 interactions/s)

mFLES racks @ Green IT Cube

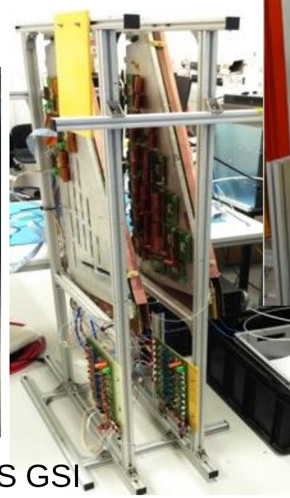


mPSD Moscow



mTOF Heidelberg

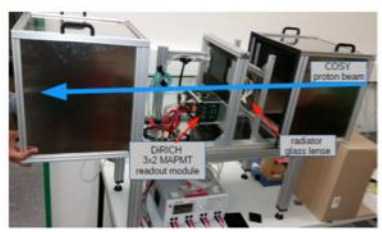
mTRD Münster, Frankfurt



mSTS GSI

mMVD$_{2020}$ Frankfurt

mMUCH VECC

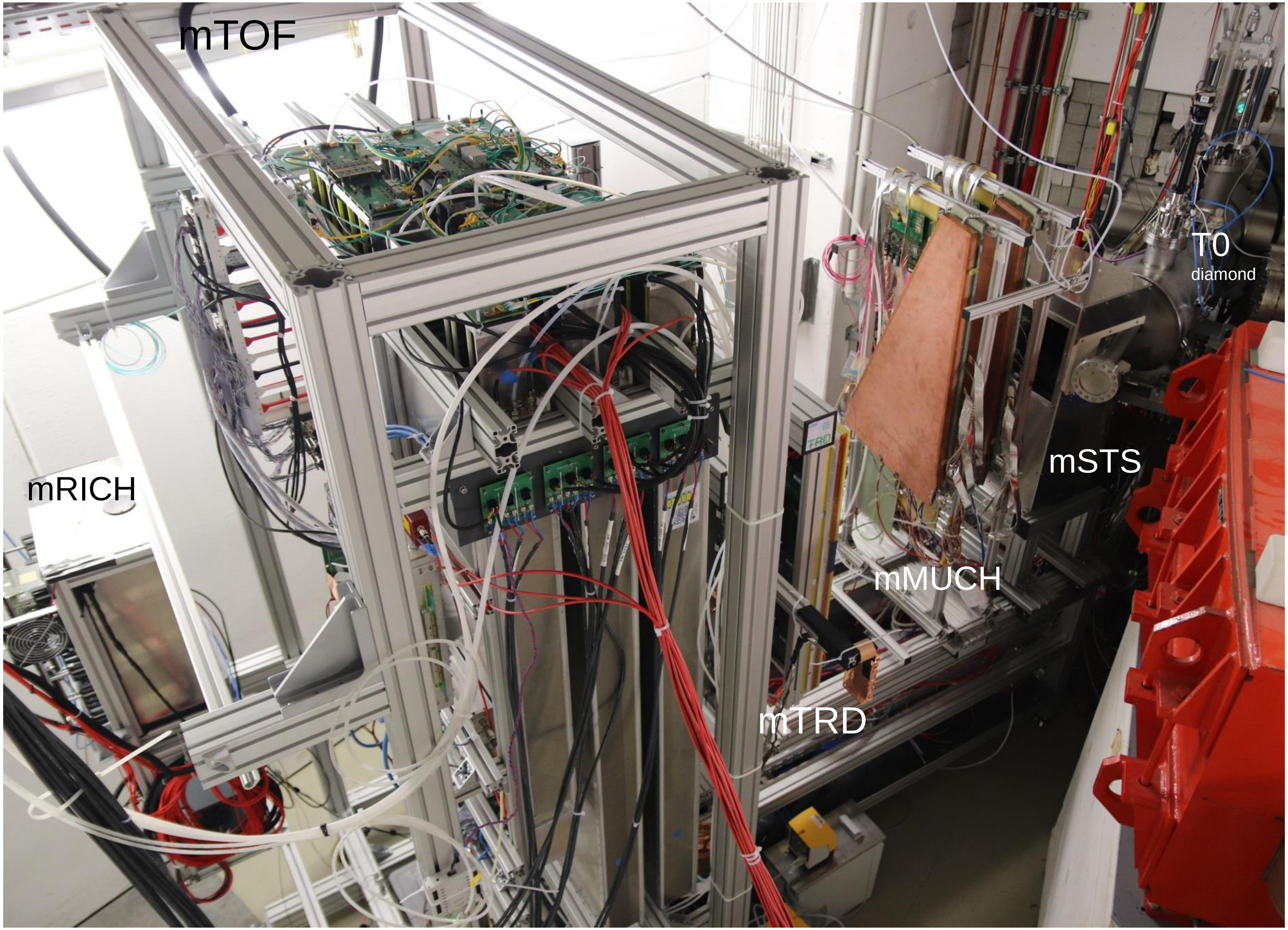


mCBM will focus on:

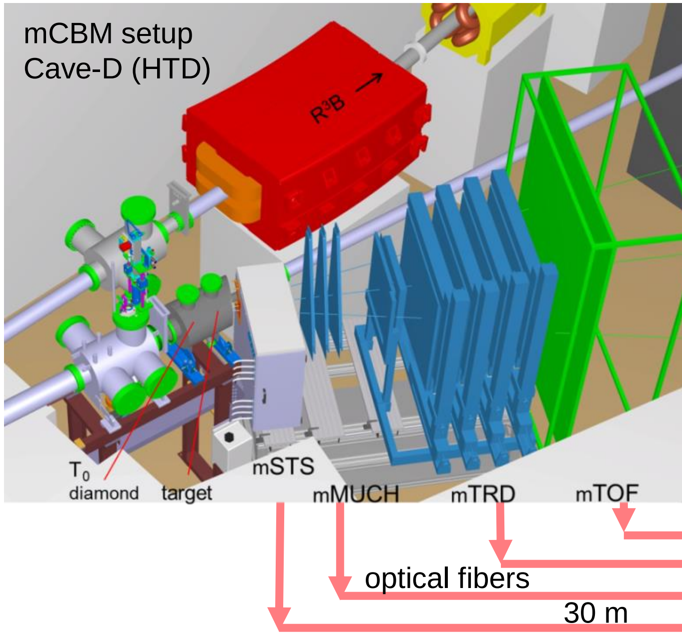
- Free streaming data transport to a computer farm
- Online reconstruction and event selection
- Offline data analysis

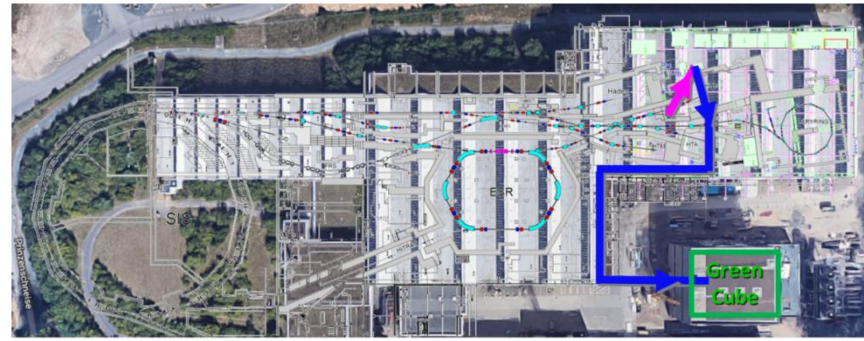
Requested beam time was fully granted by G-PAC

mCBM setup (as of March 25, 2019)



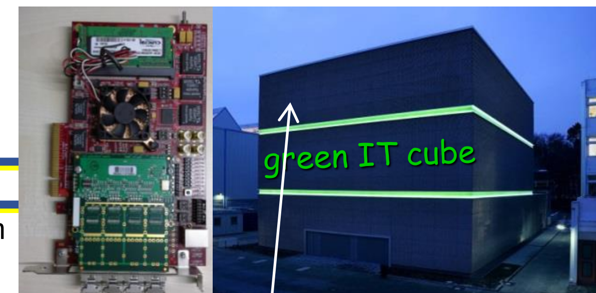
mCBM data transport

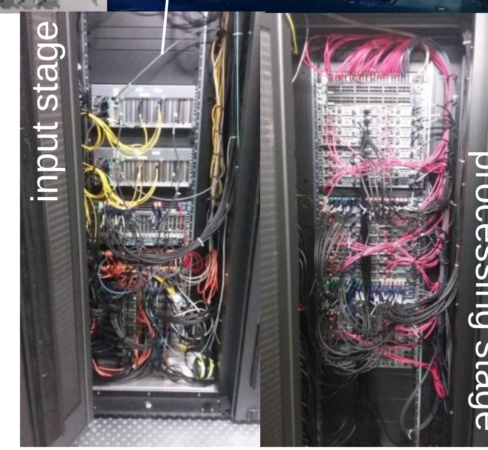




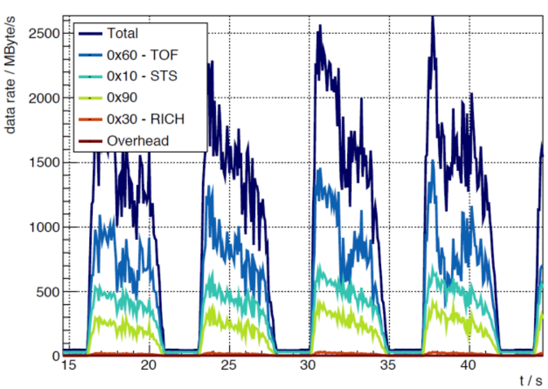
optical fibers

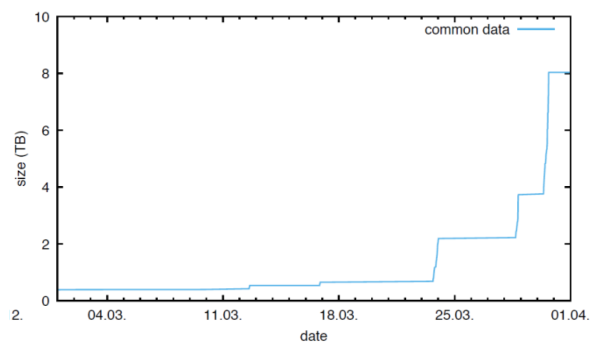
300 m





... operational !





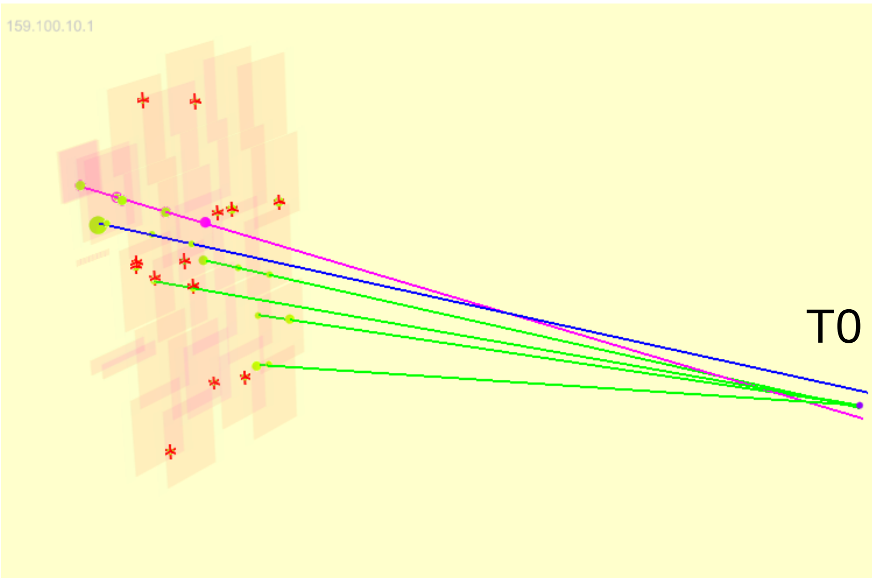
in total 8 TB
during March 2019

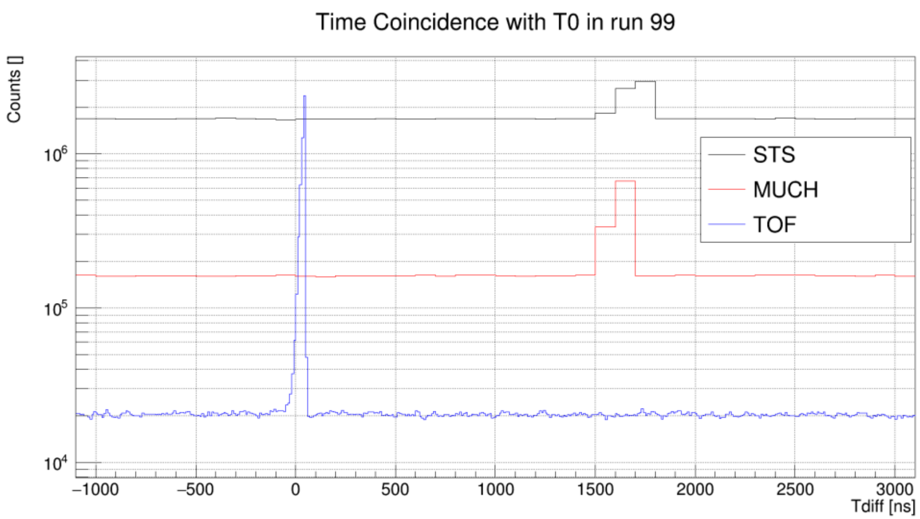
mSTS - Status

- demonstrator to validate
  - module and ladder assembly
  - read-out electronics
  - powering, electronics cooling
  - further integration aspects
  - first tracking station built in two steps (4 modules on 2 ladders)
- complete r/o chain, running in common mCBM data stream:
  - multiple FEB-8, C-ROBs, AFCK
- issues under study:
  - finite functional ASIC yield after ladder test and integration
  - noise in complete system
  - STS-XYTERv2.1 validation

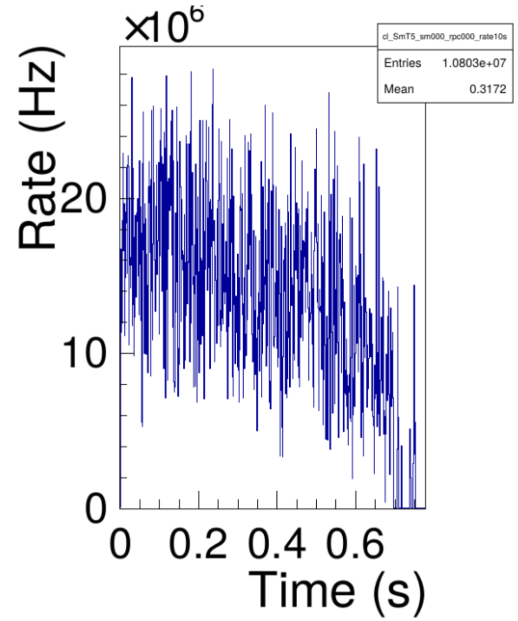
mCBM data 2019

High multiplicity mTOF event





Example of T0 (diamond) count rate



- Available interaction rate:
  $R_{int} > 2 \times 10^6$ Hz
- Synchronisation of active subsystems demonstrated

mCBM program:

Q1 2019 detector & daq commisioning

Q1 2020 high rate demonstrator

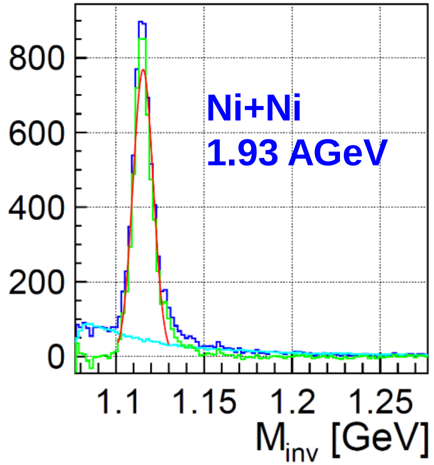
Q1 2021 physics benchmark (Λ – prod)

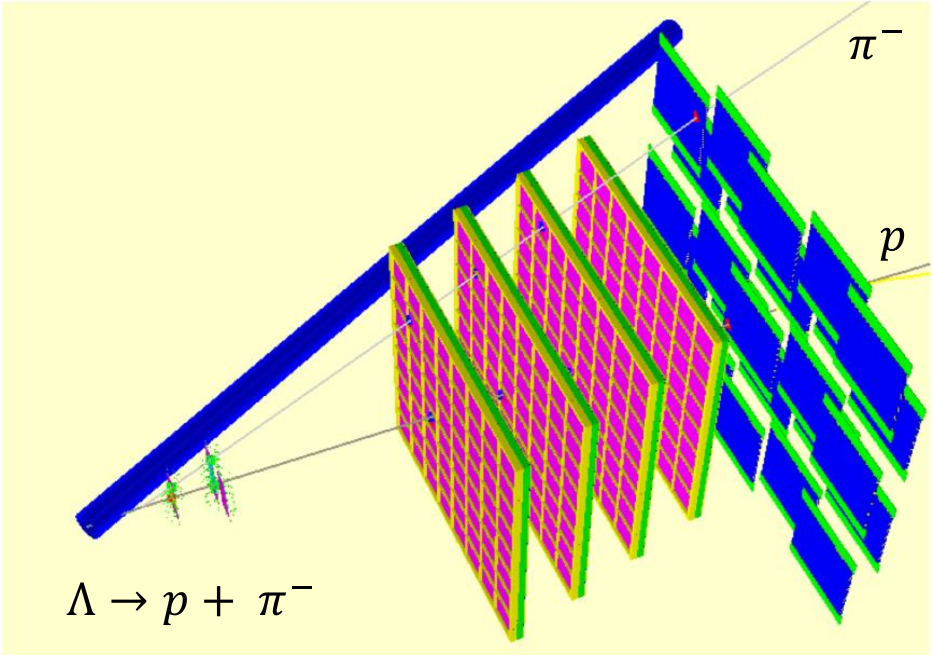
Q1 2022 Λ – excitation function

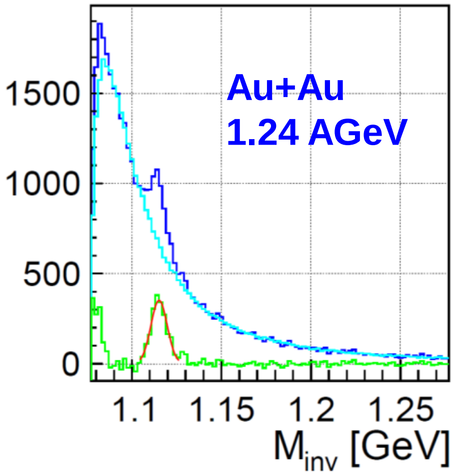
mCBM performance benchmark

(Sub)threshold Λ – baryon reconstruction.

Event based MC simulation of 10^8 events
(equivalent beam-on-target time: 10 s)



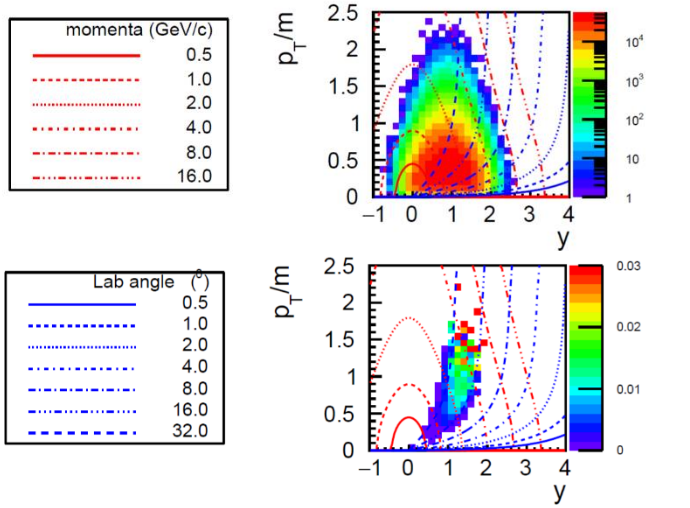




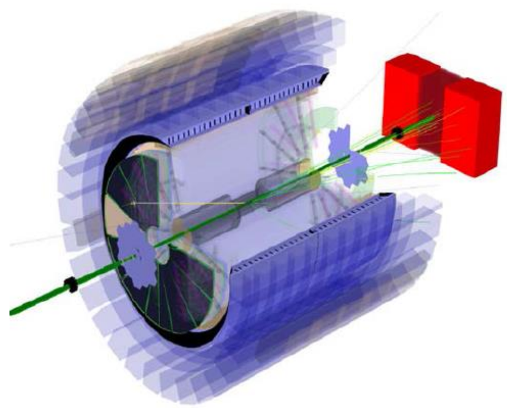
Acceptance

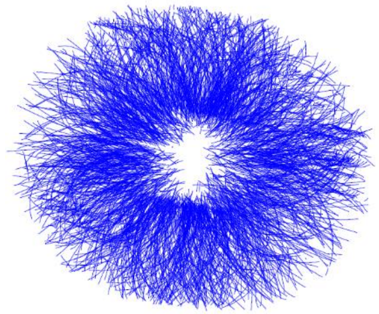
&

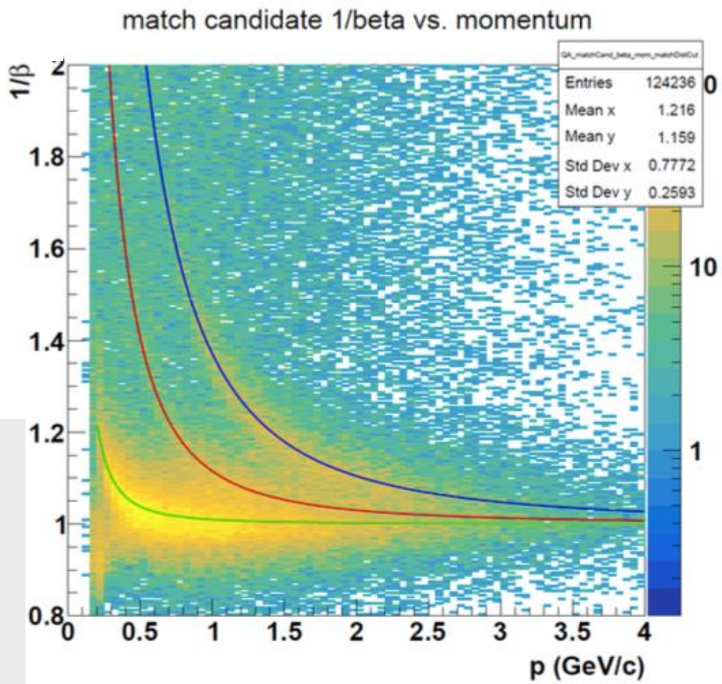
Efficiency

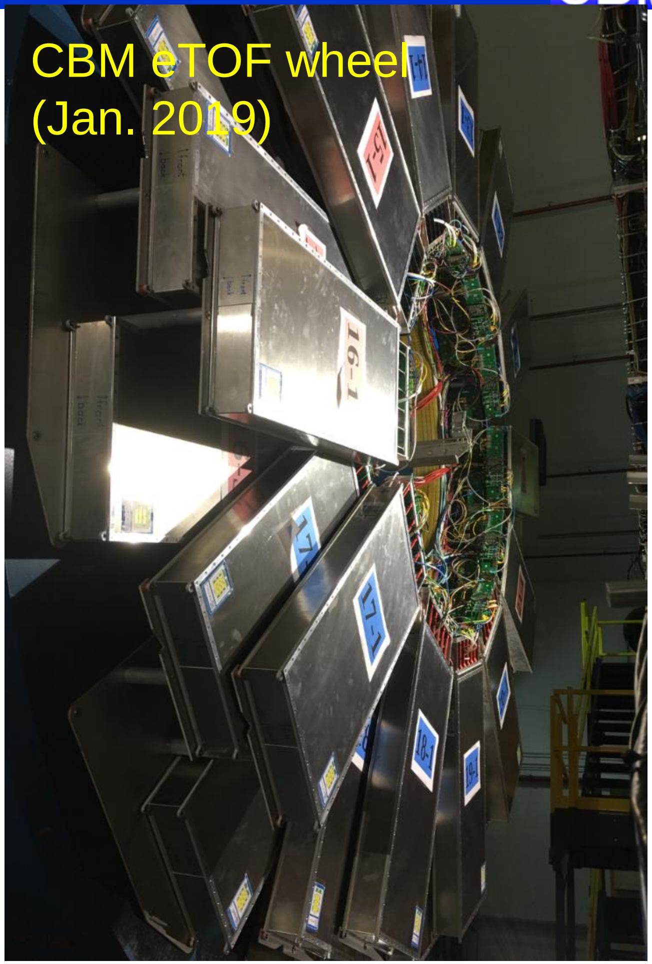


Phase-0: eTOF & HPC software in STAR (BNL)







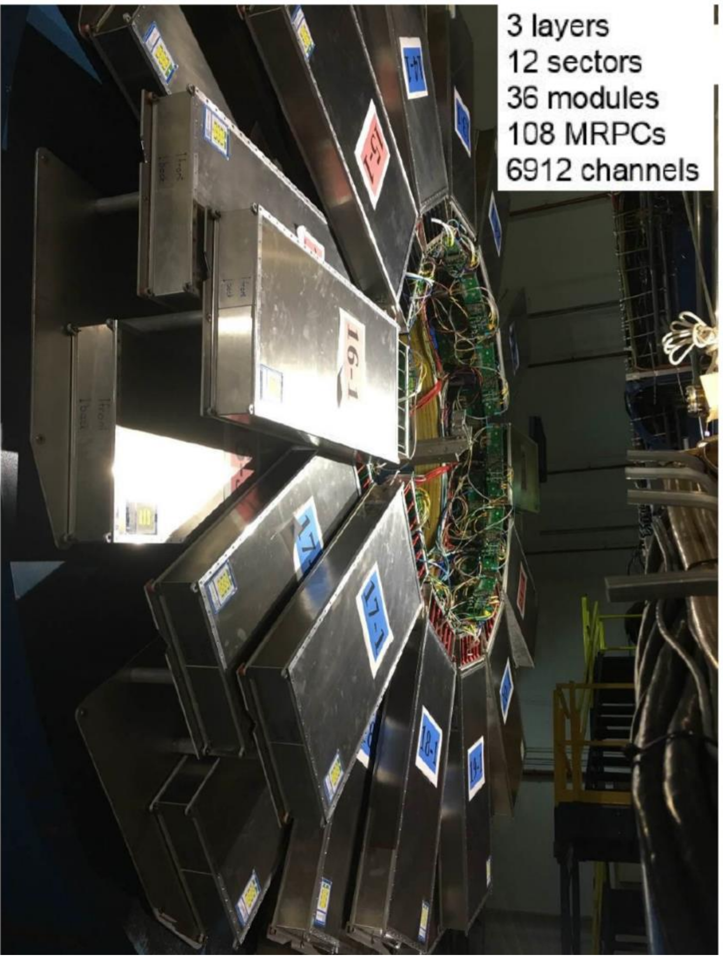


Correlation:
CBM-eTOF
with STAR TPC
from Run18

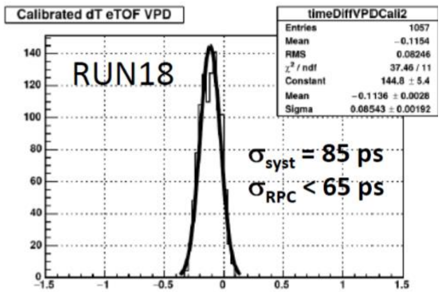
Participating CBM groups:
- Univ. Heidelberg,
- TU Darmstadt,
- GSI Darmstadt,
- Univ. Frankfurt,
- Tsinghua Univ. Beijing,
- USTC Hefei,
- CCNU Wuhan

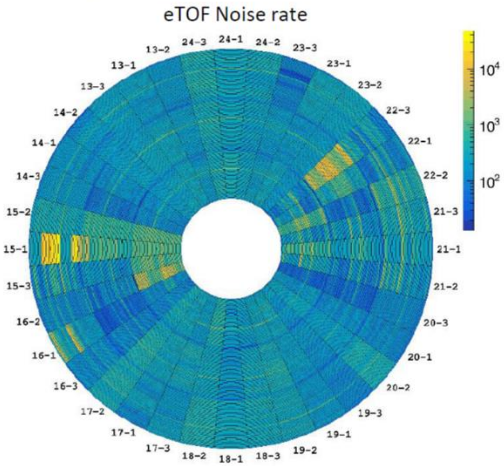
Test module operational	(Oct. 2016)
STAR DAQ interface	(Jan. 2017)
Full sector test	(Spring 2018)
Wheel installation	(Fall 2018)
BES II data taking	(2019/2021)
Transfer of modules to FAIR	(2022/23)

Status eTOF@STAR

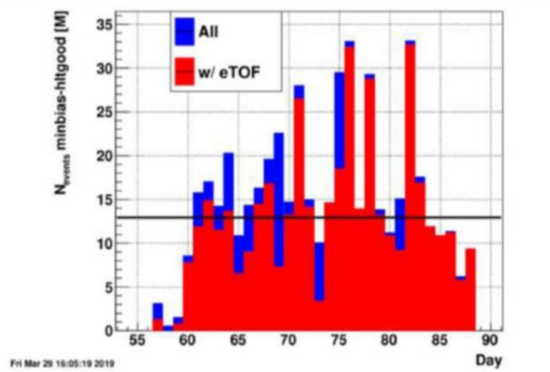


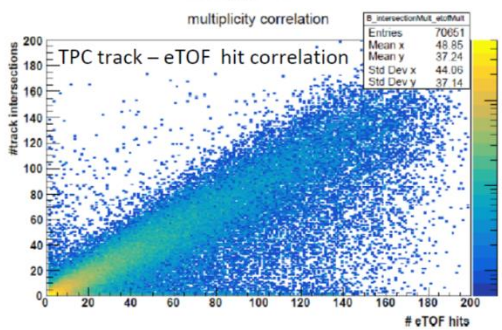
- eTOF@STAR is installed, commissioned and running
- BESII started in February
- Readout stability improves steadily
- PID capability demonstrated

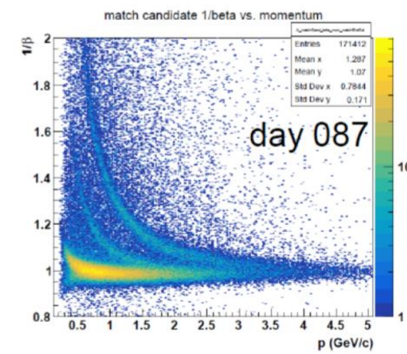




eTOF DAQ performance in the 19.6 GeV run



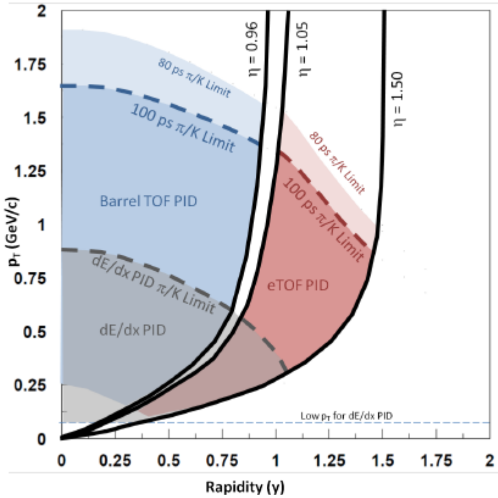


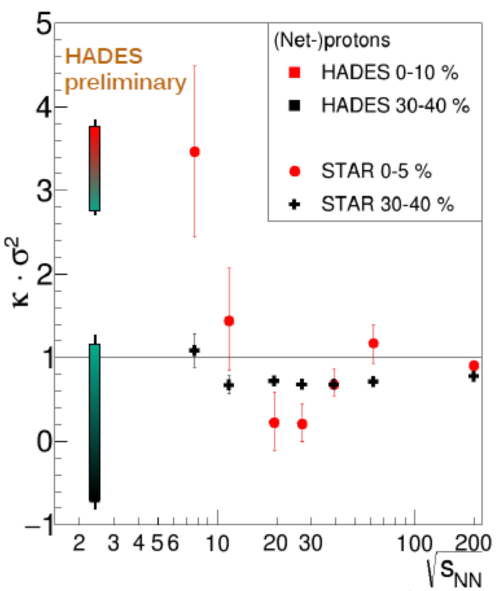


STAR – BES II physics program with eTOF

arXiv:1609.05102v1 [nucl-ex]

Physics Program for the STAR/CBM eTOF Upgrade



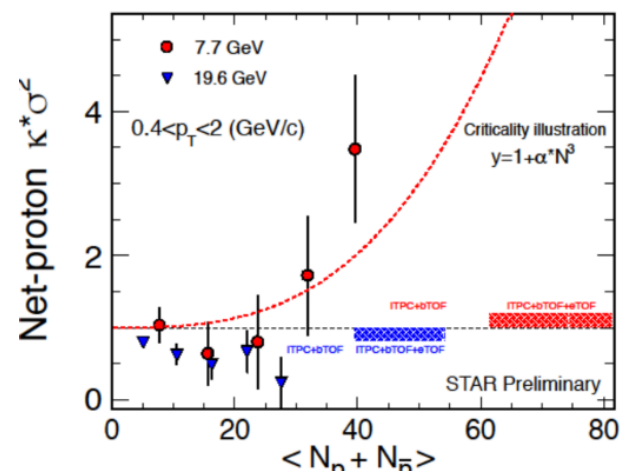


HADES: M. Lorenz, QM 2017
STAR: X. Luo et al, CPOD 2014

Topics to be studied with extended acceptance in energy range $\sqrt{s_{NN}} = 3 - 62$ GeV:

- Excitation function and phase-space distributions of hyperons, hypernuclei, anti-protons, ...
  → Equilibration, phase transitions
- Collective Flow (v1, v2)
  → Equation-of-State, phase transitions
- Dilepton yields
  → Chiral symmetry restoration
- Fluctuations of conserved quantum numbers (baryon, charge, strangeness)
  → Critical point

Expected increase in signal strength:

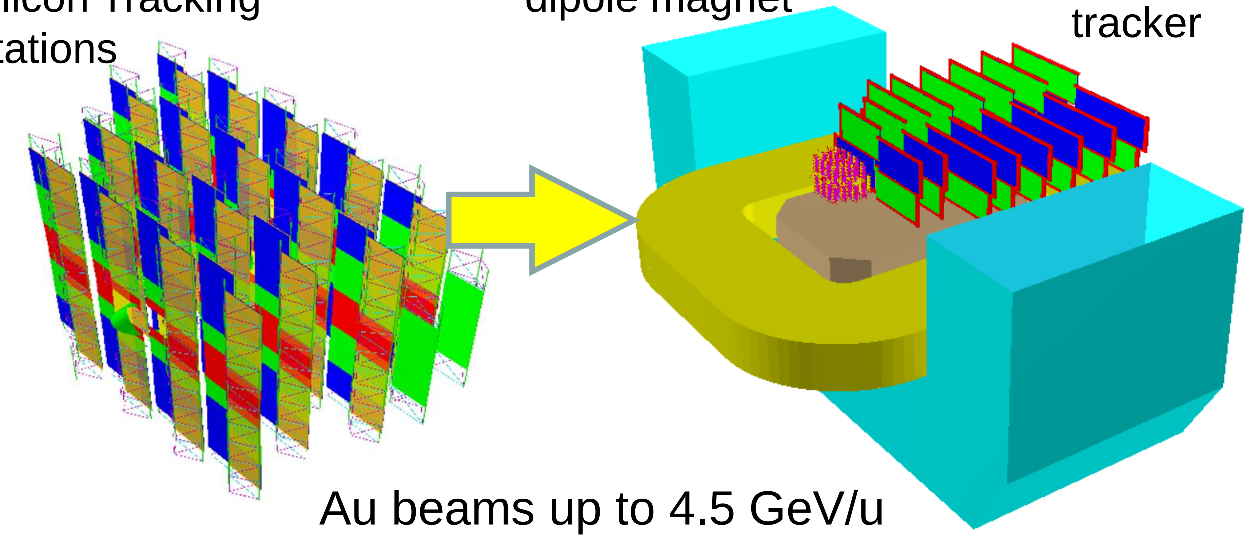


Phase-0: STS & PSD in BM@N (JINR)

Silicon Tracking Stations

dipole magnet

GEM tracker



Au beams up to 4.5 GeV/u

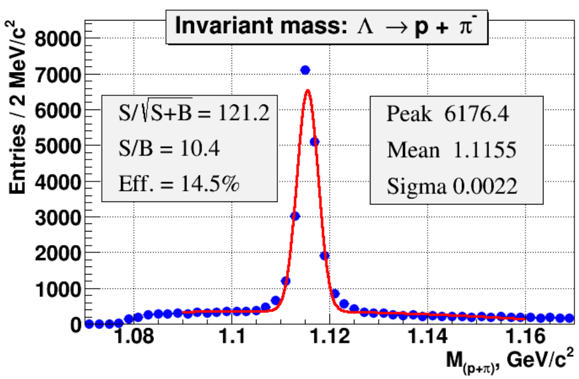
PSD calorimeter (synergies with usage in NA61/shine)

BM@N timeline: NICA white paper
(Eur. Phys. J. A (2016) 213

2018 Installation of PSD detector (MoU signed)

2022 Au beams from Nuclotron
Installation of 4 Si Tracking Stations (MoU signed)

Improvement in efficiency & signal / backrgound



Participating CBM groups:
- GSI Darmstadt,
- Univ. Tübingen,
- JINR Dubna,
- INR Moscow

CBM – Collaboration: 63 institutions, ~500 members

China:
CCNU Wuhan
Tsinghua Univ.
USTC Hefei
CTGU Yichang
Chongqing Univ.

Czech Republic:
CAS, Rez
Techn. Univ. Prague

France:
IPHC Strasbourg

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
München TU
Münster Univ.
Tübingen Univ.
Wuppertal Univ.
ZIB Berlin

India:
Aligarh Muslim Univ.
Bose Inst. Kolkata
Panjab Univ.
Univ. of Jammu
Univ. of Kashmir
Univ. of Calcutta
B.H. Univ. Varanasi
VECC Kolkata
IOP Bhubaneswar
IIT Kharagpur
IIT Indore
Gauhati Univ.

JAPAN
KEK Tsukuba

Korea:
Pusan Nat. Univ.

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

Romania:
NIPNE Bucharest
Univ. Bucharest

Hungary:
KFKI Budapest
Eötvös Univ.

Russia:
IHEP Protvino
INR Troitzk
ITEP Moscow
Kurchatov Inst., Moscow
VBLHEP, JINR Dubna
LIT, JINR Dubna
MEPHI Moscow
PNPI Gatchina
SINP MSU, Moscow

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

Manpower situation

Severe shortage in key areas

- Firmware development
- Development of DPF (data processing framework): CBMROOT → CBMMQ
- Software QA

Strategy:

- Register working group members to coordinators / project leaders (PL)
- Coordinators / PL will maintain list of participants (relevant for author list)
- Coordinators / PL & MB will (have to) define priorities
- Enlarge workforce by participation in new initiatives (EU, bi-lateral, …)

Introduce service tasks → details to be worked out by MB

Conclusion

- CBM has well defined FAIR phase 0 programs preparing the operation at SIS100 combined with a rich physics potential:
  - HADES with CBM – RICH photon detector
  - CBM – TOF, CBM – HPC software in BES II run of STAR @ RHIC
  - CBM – STS, CBM – PSD in BM@N
  - mCBM at SIS18

- CBM Day-1 experiment offers start of unique measurements at SIS100:
  - Multiple strange hyperon measurements at higher SIS100 energies
  - Single Λ - hypernuclei properties (lifetime)
  - Dilepton excitation function measurements with initial focus on LMR

- CBM MSV addresses the complete set of physics observables

  to map out the phase structure of QCD in the SIS100 energy range and to search for exotic objects (e.g. double Λ – hypernuclei).

Acknowledgements

Bundesministerium für Bildung und Forschung

GSI

FAIR

HIC for FAIR
Helmholtz International Center

HELMHOLTZ GEMEINSCHAFT

ROSATOM

IFIN-HH
www.ifin.ro

DAE

FRRC
FAIR-Russia Research Center
FAIR

MŠMT
MINISTRY OF EDUCATION YOUTH AND SPORTS

Cremlin Connecting
Russian and European Measures for Large-scale Research Infrastructures

CSIR
Council of Scientific and Industrial Research

विज्ञान एवं प्रौद्योगिकी विभाग
DEPARTMENT OF SCIENCE & TECHNOLOGY

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Ministry of Science and Higher Education
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Ministry of Science and Technology of the People's Republic of China

NSFC
国家自然科学基金委员会
National Natural Science Foundation of China

MVD Highlights 10/18 – 3/19

MIMOSIS:

- MIMOSIS-0: Evaluation of analog and digital features, focus on radiation hardness
- **MIMOSIS-1: Preparation of a 1-day design review**

Geometries and detector layout

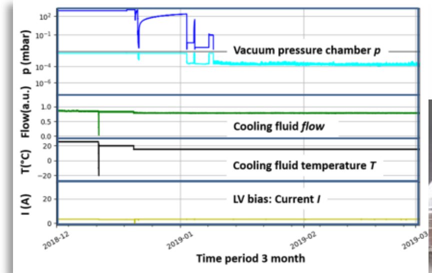
- CAD design of the detector in the target box
- Consolidating 2 MVD geometries (VX, TR)
- CBM Technical Note **TN-19004**

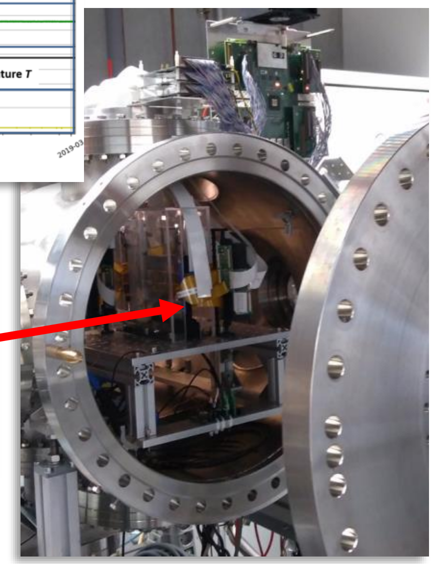
Simulations on hit rates

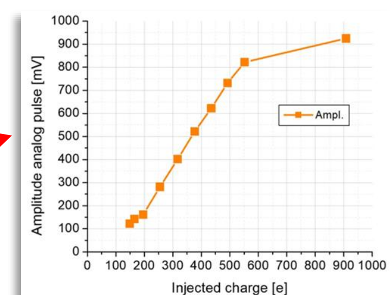
- CBM Technical Note **TN-19002**
- Employing actual geometries and sensor properties

Integration & DCS

- **PRESTO 24/7 in vacuum** (3 months)
- Continuous DCS ctrl & sensor (M26) r/o







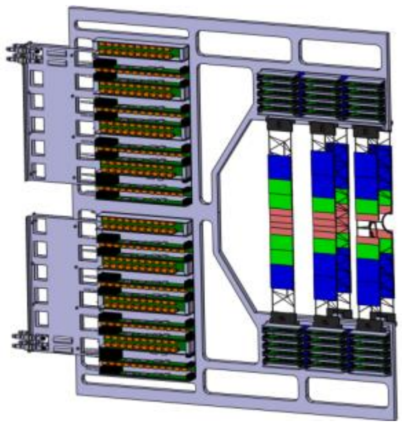
Silicon Tracking System (STS)

GSI Darmstadt, JINR Dubna, KIT Karlsruhe, JU Crakow, AGH Crakov, KINR Kiev, Univ. Tübingen, Warsaw UT

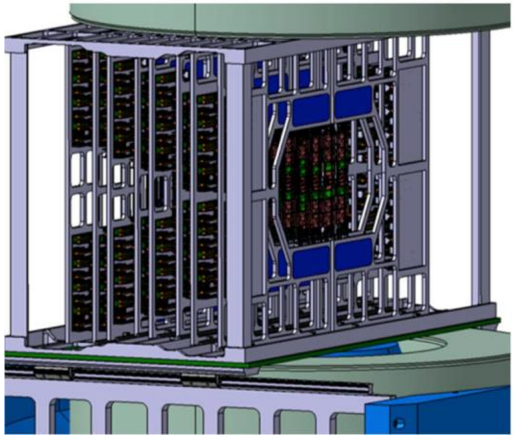
- Charged particle track reconstruction, momentum determination

Integrated module

Engineering design of station



8 STS in thermal enclosure, 2.133 M channels

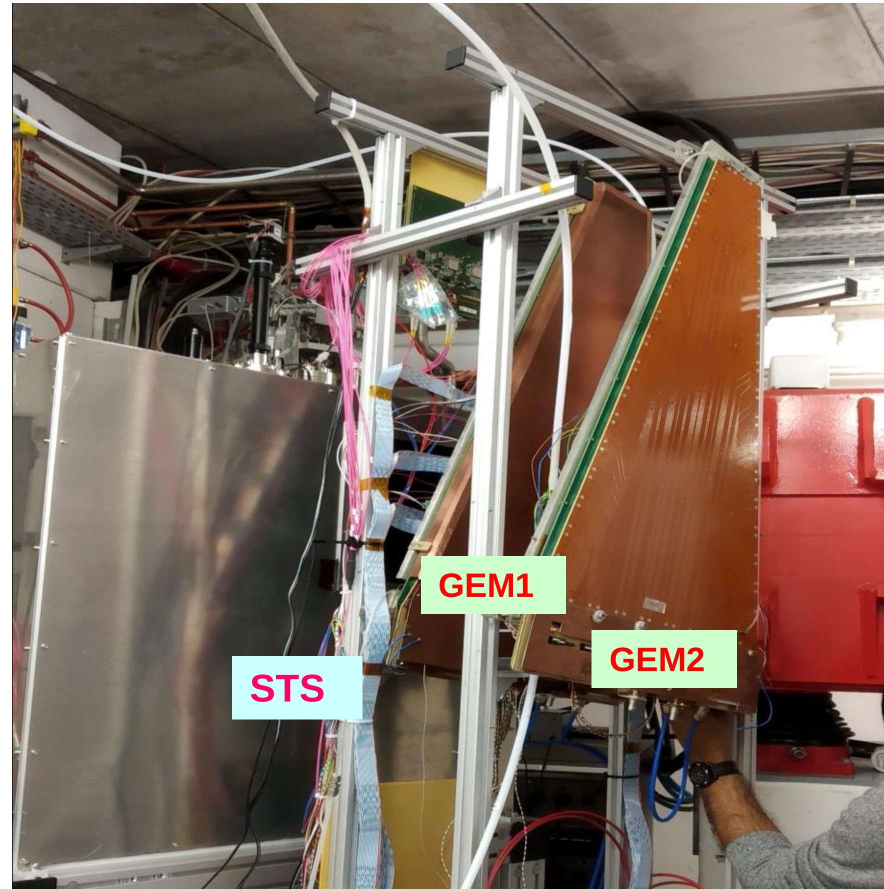


Status:

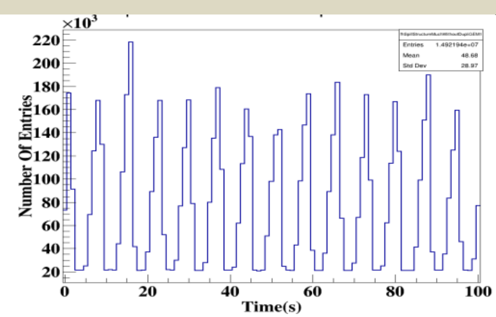
- TDR approved by FAIR in July, 2013
- Radiation tolerance of sensors tested up to n_{eq} (1 MeV) = 2×10^{14} /cm^2,
- Readout ASICS STS-XYTER V 2.1 produced,
- Sensors ordered (HAMAMATSU): Q2 2019
- System integration concept close to final.

MUCH; status report

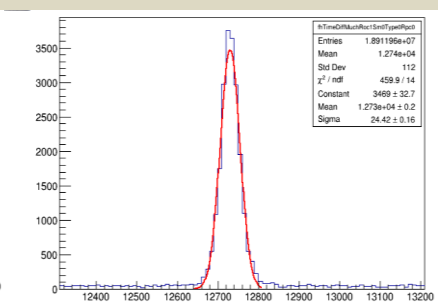
- Two GEM chambers took data in mCBM with MUCH-XYTER based readout and full DAQ; Prelim analyses show clear spill structure and time correlation
- Radiation resistant LV and HV distribution systems developed and deployed in mini-CBM
- Low-resistivity single-gap RPC tested with MUCH-XYTER in GIF++ as R&D for 3rd and 4th stations
- Design of the mechanical integration of the system is ongoing



Two GEM chambers in mini CBM



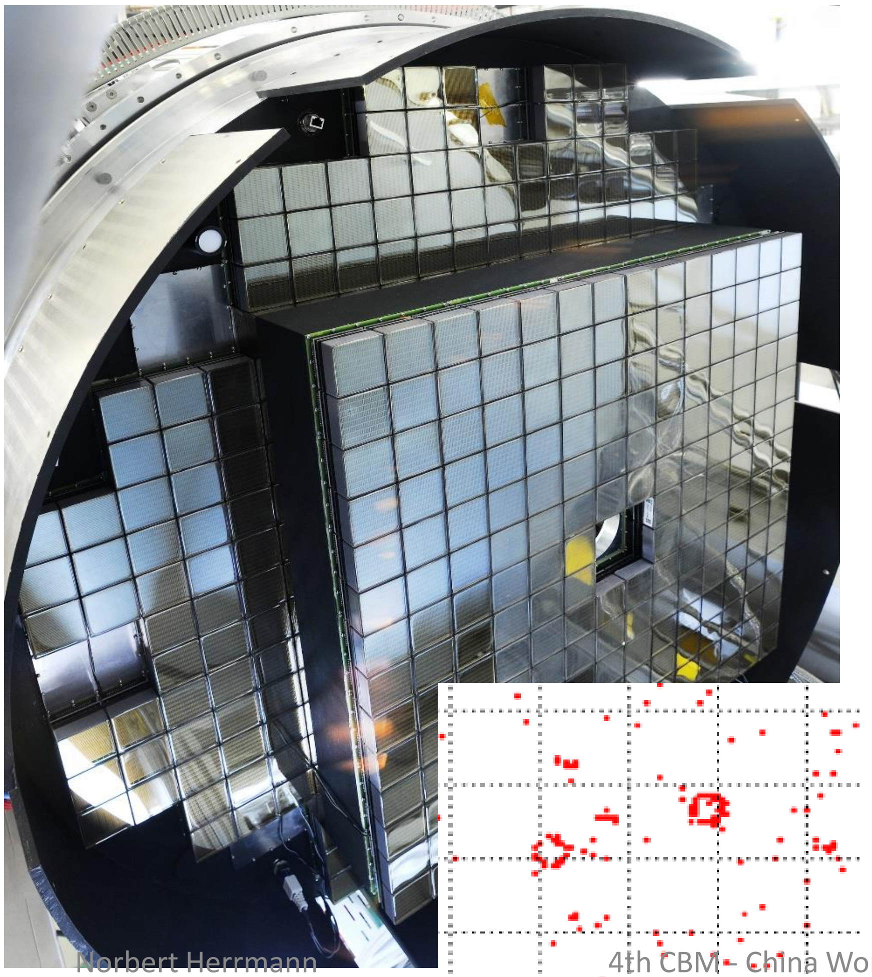
Spill structure by GEM

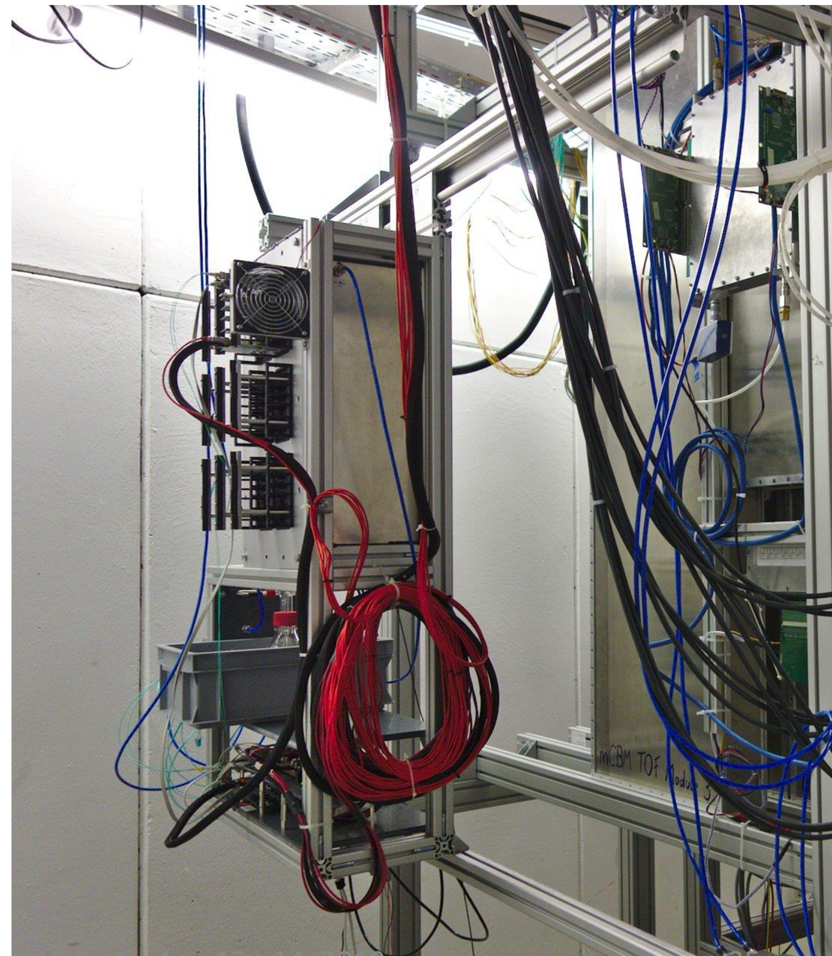


Time-correlation between TOF and GEM

RICH Detector

- Successful upgrade and full beamtime operation of the RICH detector in HADES
- Successful mRICH operation in mCBM
- Mechanical stability test of mirror wall, shielding box optimization



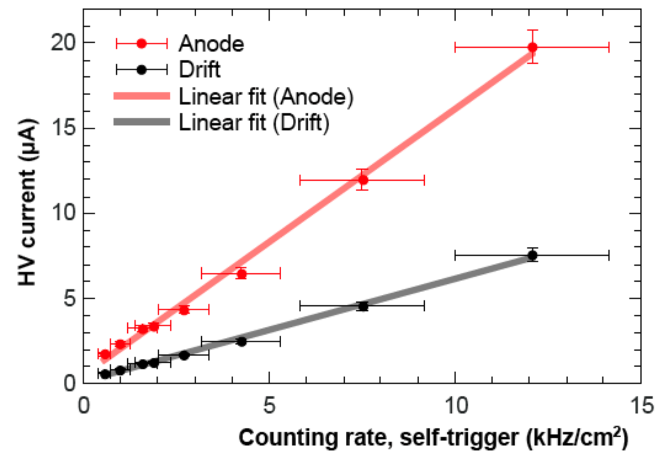


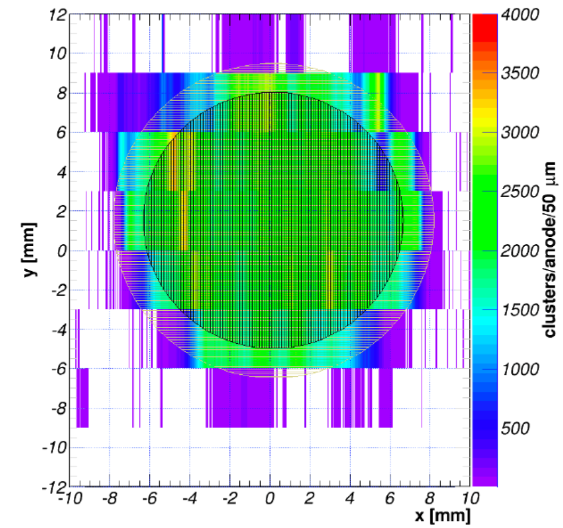
TRD: Recent Achievements

- Technical Design Report approved by ECE on October 9th, 2018

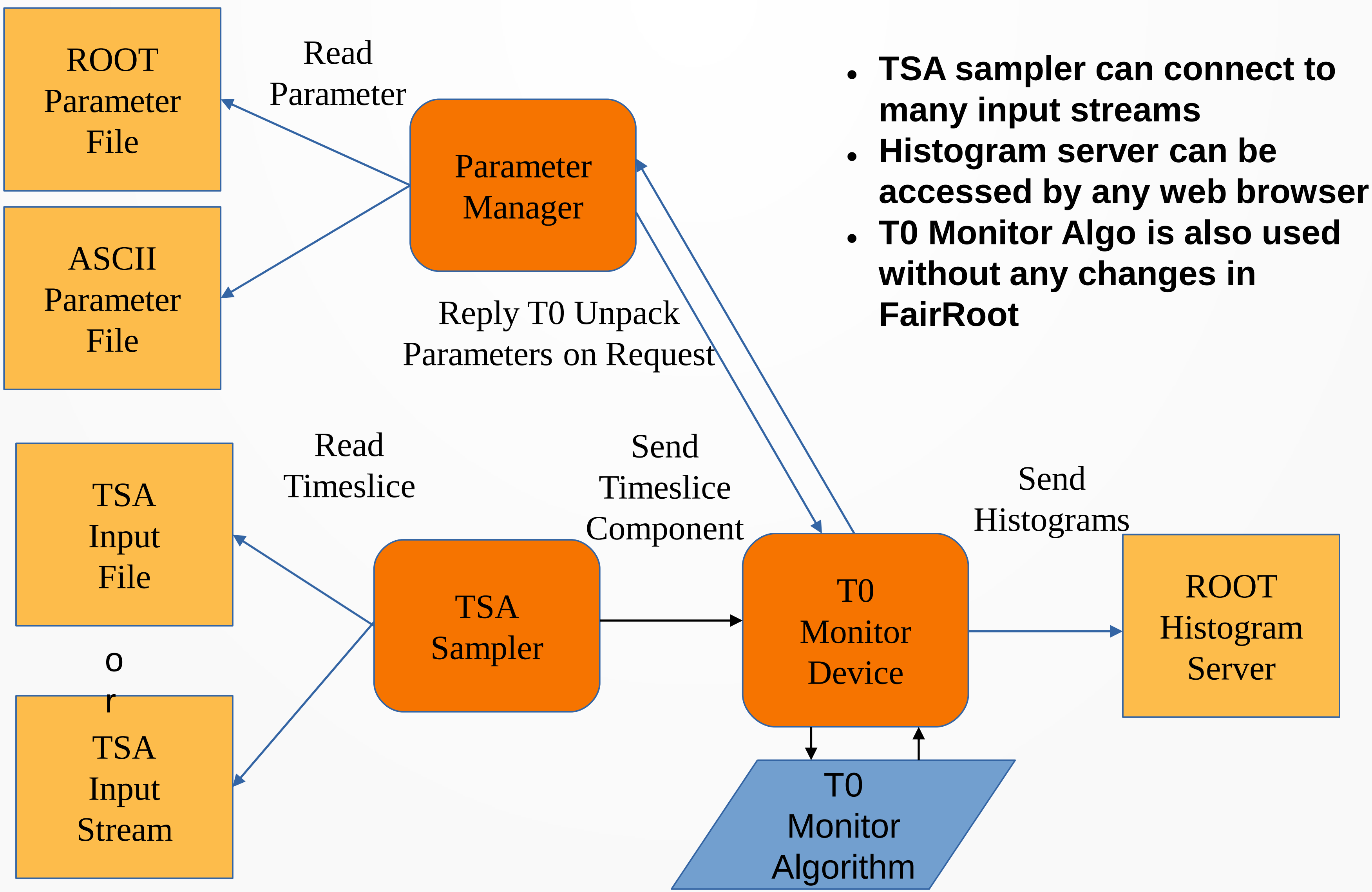
- CERN-GIF++:
  High rate gamma irradiation (^{137}Cs source).
  No deviation from expected linear increase of HV current with trigger rate seen (s. Fig.)

- X-ray test setup (Bucharest)
  High intensity x-ray setup with complete readout chain (FASPRO).
  2-D position reconstruction of irradiated area (s. Fig.)





FairMQ Based Online Monitor



- **TSA sampler can connect to many input streams**
- **Histogram server can be accessed by any web browser**
- **T0 Monitor Algo is also used without any changes in FairRoot**