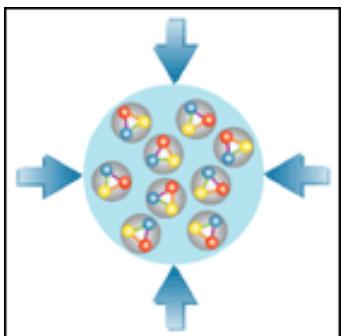


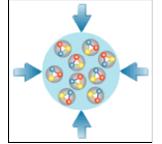
CBM Detector Systems Overview



Walter F.J. Müller
CBM Technical Coordinator
FAIR, Darmstadt

H4F WS Detectors & Accelerators
29-31 July 2015

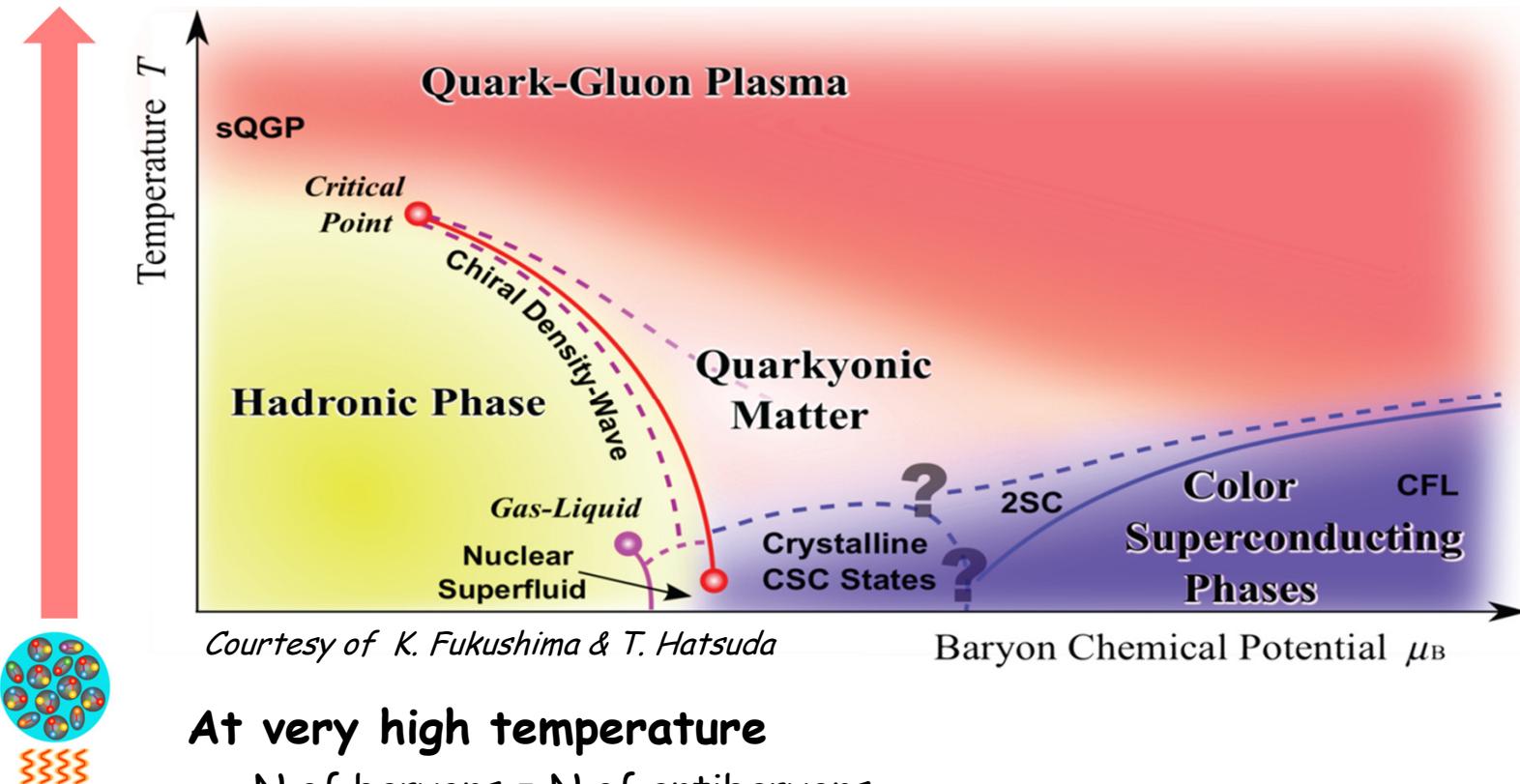
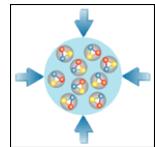




The CBM Physics Case



Exploring the QCD Phase Diagram



Courtesy of K. Fukushima & T. Hatsuda

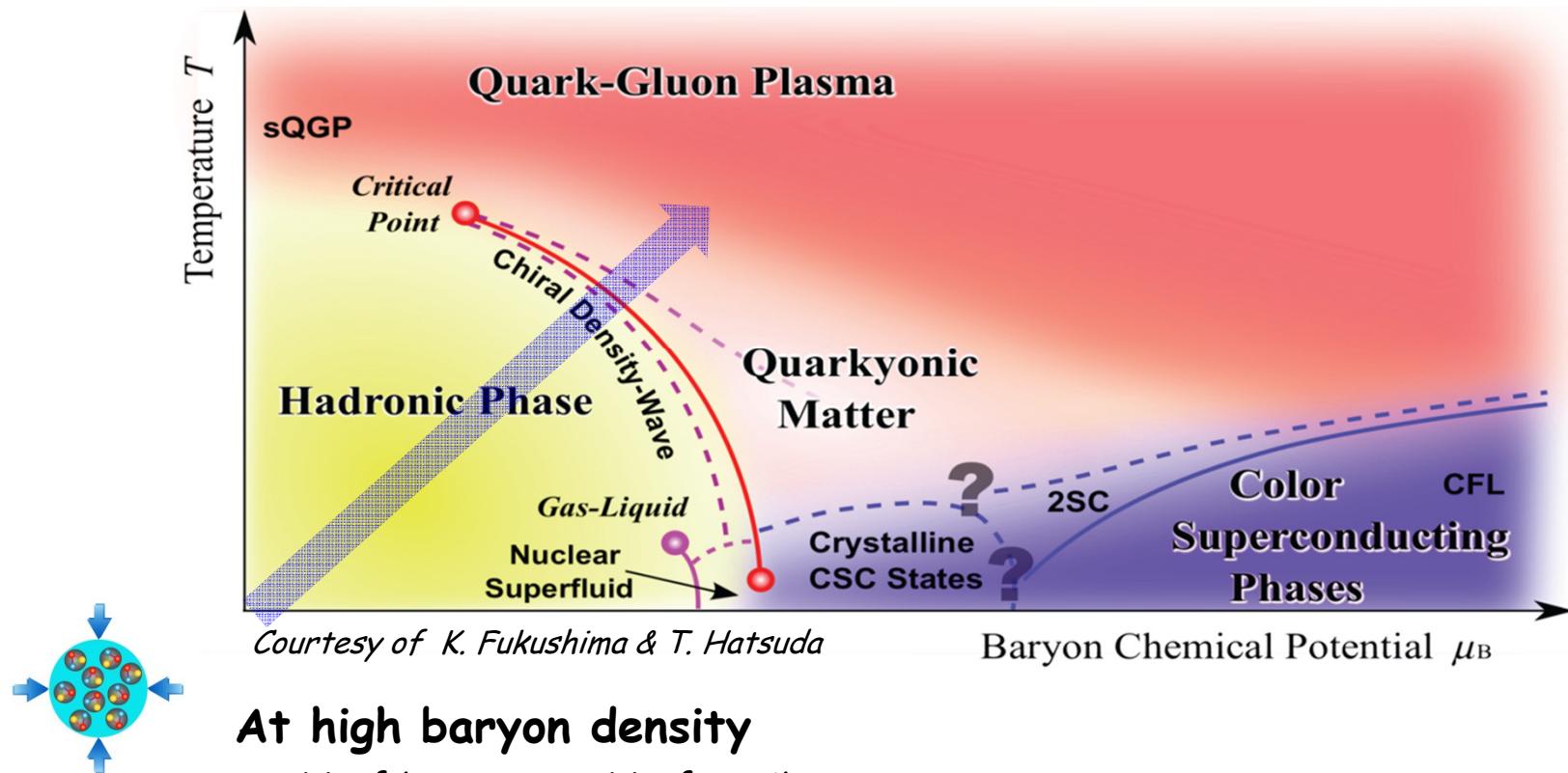
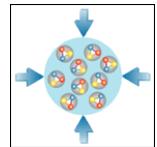
Baryon Chemical Potential μ_B

At very high temperature

- ❑ N of baryons = N of antibaryons
Situation similar to early universe
- ❑ L-QCD finds crossover transition between hadronic matter and quark gluon plasma.
- ❑ Precision experiments:
ALICE, ATLAS, CMS @ LHC; STAR, PHENIX @ RHIC;



Exploring the QCD Phase Diagram

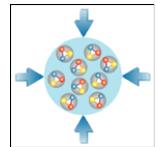


At high baryon density

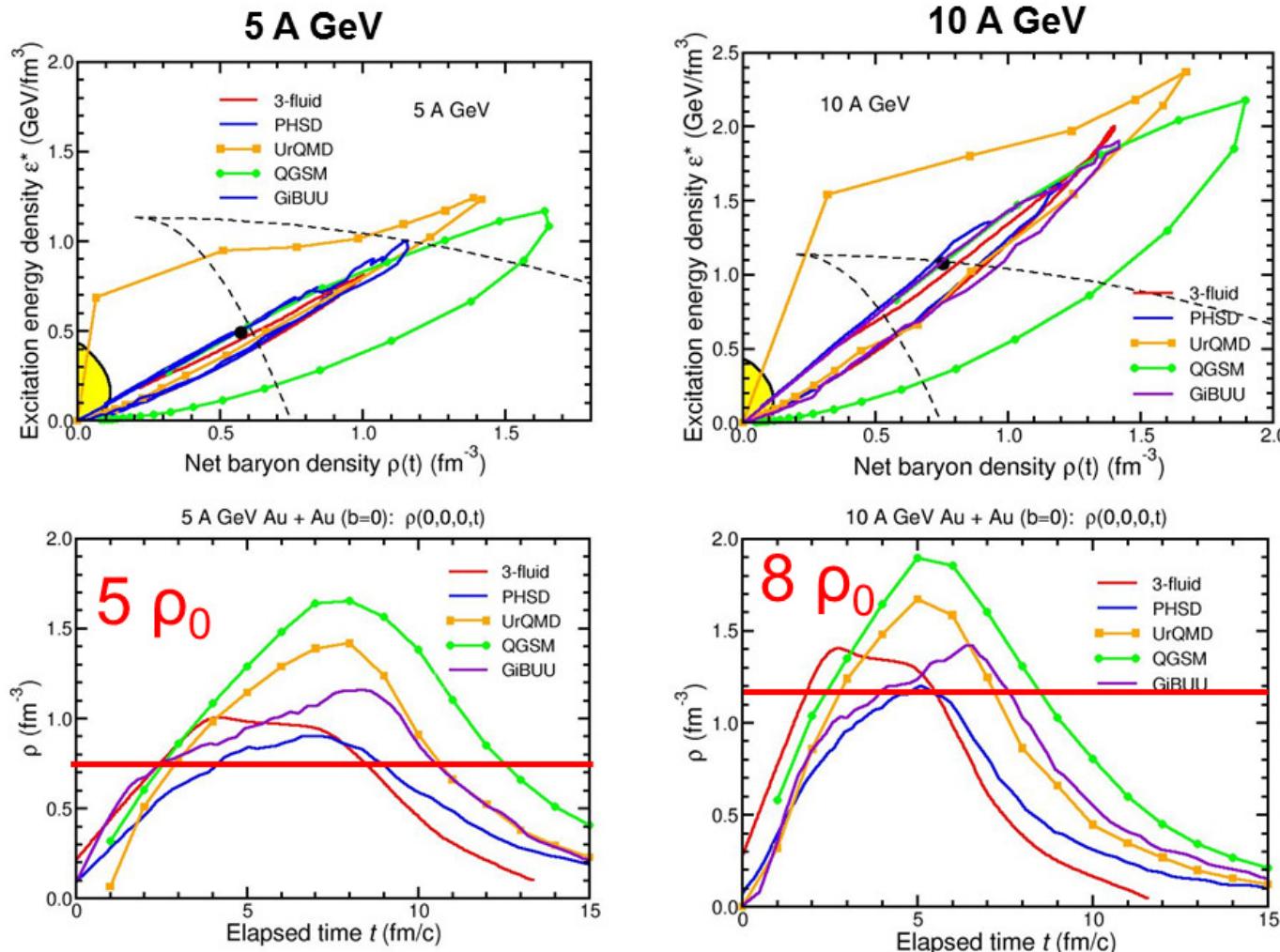
- ❑ N of baryons \gg N of antibaryons
Baryon densities like in neutron star cores
- ❑ L-QCD not (yet) applicable
- ❑ Models predict 1st order phase transition with mixed or exotic phases
- ❑ Experiments:
STAR(BES) @ RHIC; NA61 @ SPS; NICA @ JINR; CBM @ FAIR



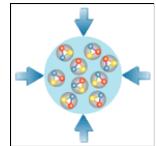
Baryon Densities for central Au+Au



I.C. Arsene et al., Phys. Rev. C 75, 24902 (2007), V. D. Toneev et al., Eur. Phys. J. C32 (2003) 399



CBM Physics Program at SIS100



■ Physics case

- Nuclear matter equation-of-state at high net baryon density
- In-medium modifications of hadrons
- Search for quarkyonic matter or for phase coexistence
- Exploring chiral symmetry restoration
- Strangeness in nuclear matter and (multi-)strange objects
- Charm production and propagation in cold and in dense matter

■ Observables

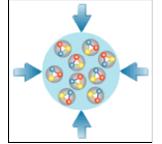
- Collective flow, correlations, fluctuations
- Strangeness
- Hypernuclei
- Charm
- Dileptons

Detection by decay pattern:
→ tracking trigger

Rare Probes:
→ high rates

Investigate e^+e^- and $\mu^+\mu^-$:
→ e-PID and μ -PID

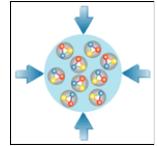




The CBM Detector Setup



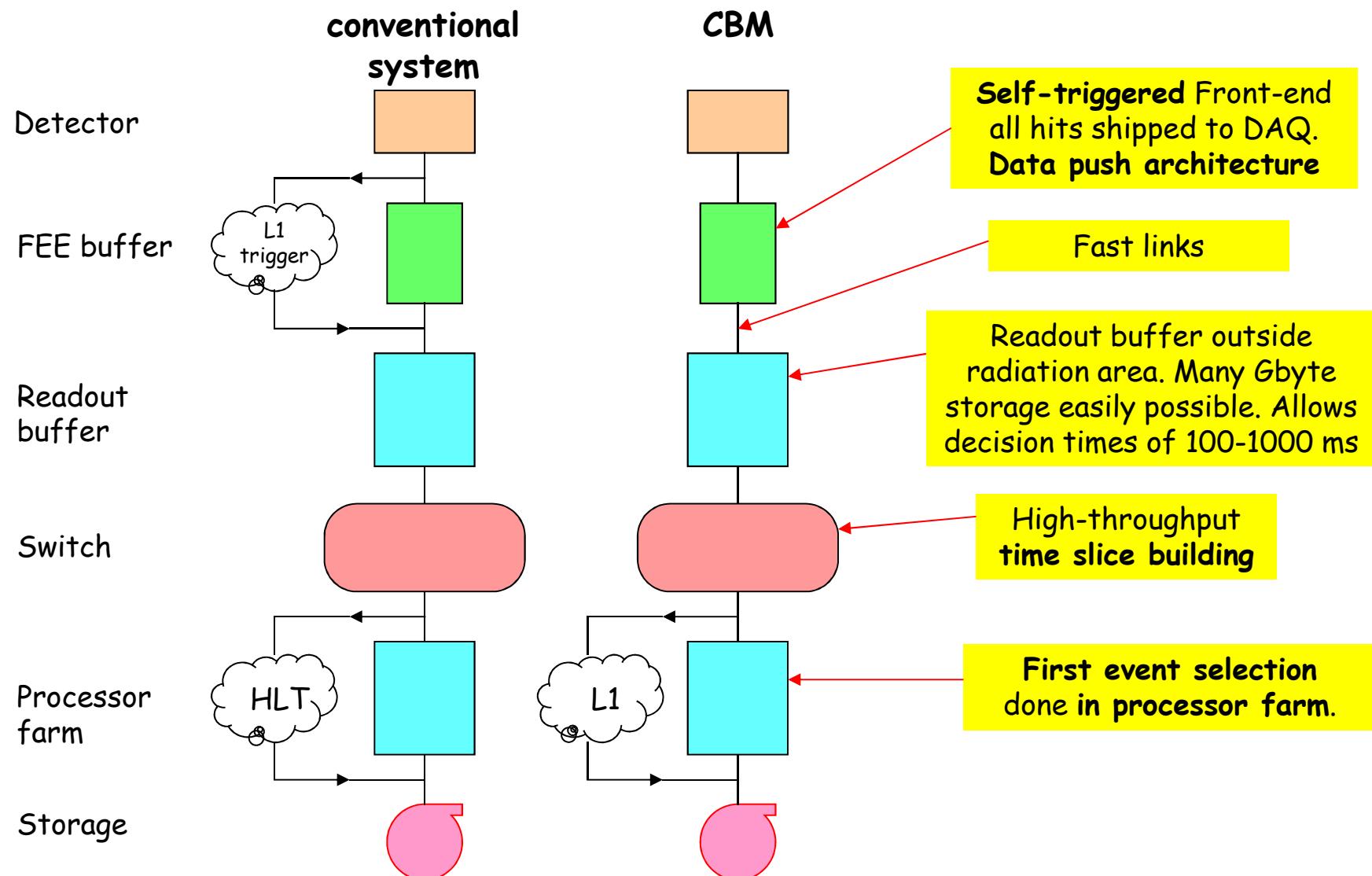
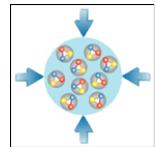
Rare Probes → High Rates



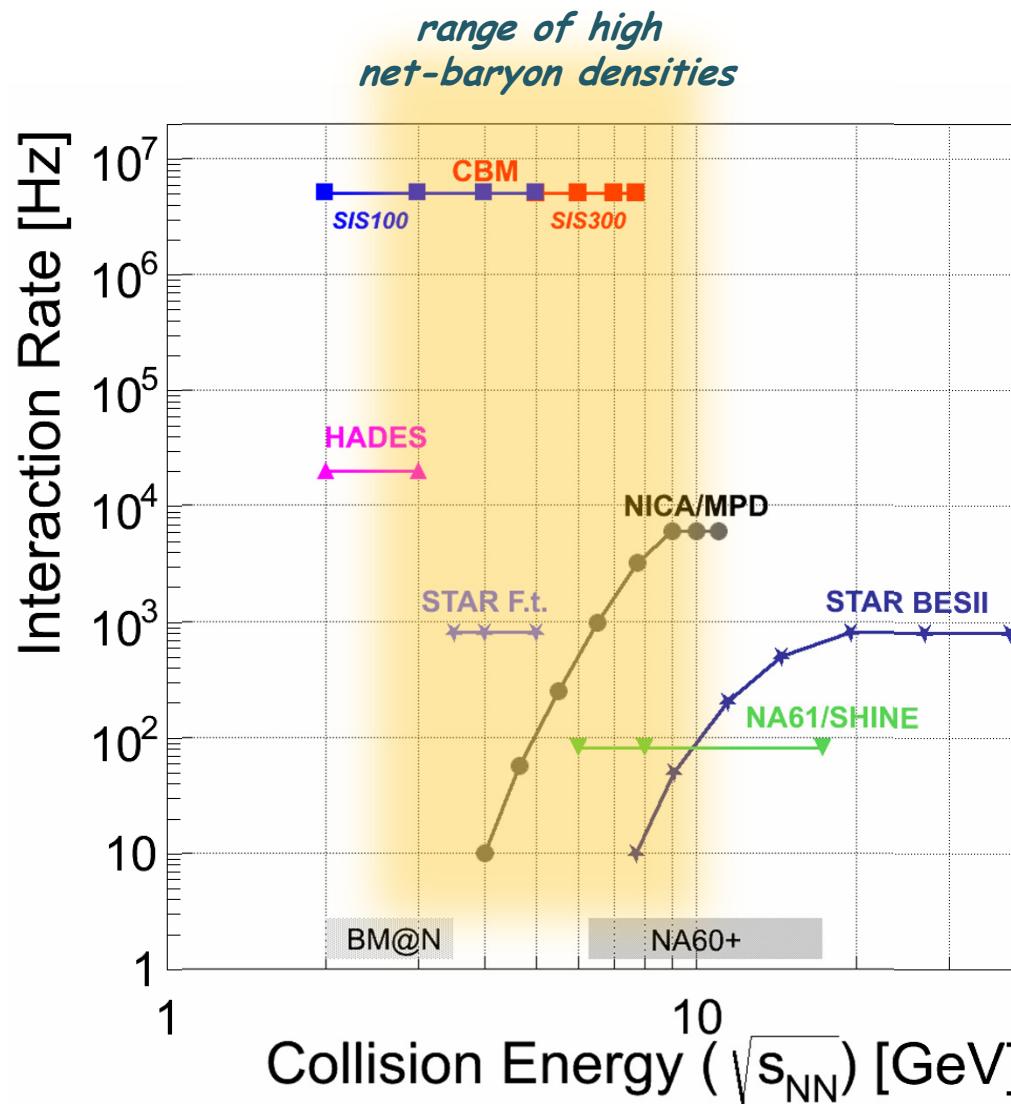
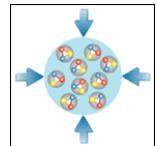
- Key observables are rare probes
 - either low cross section (e.g. Ω^+, d , or J/Ψ)
 - or low branching ratio (e.g. $\rho, \omega, \phi \rightarrow e^+e^-$)
- High interaction rate
 - design point: 10^7 Au+Au int/sec @ 11 A GeV
 - high count rate detectors
 - significant radiation level for FEE
- Selective triggers
 - key triggers are 'tracking triggers' (decay topology)
 - no hardware trigger, 'data push' architecture
 - event selection in software
 - high DAQ bandwidth
 - high computing requirements



CBM DAQ Architecture



The Interaction Rate Landscape



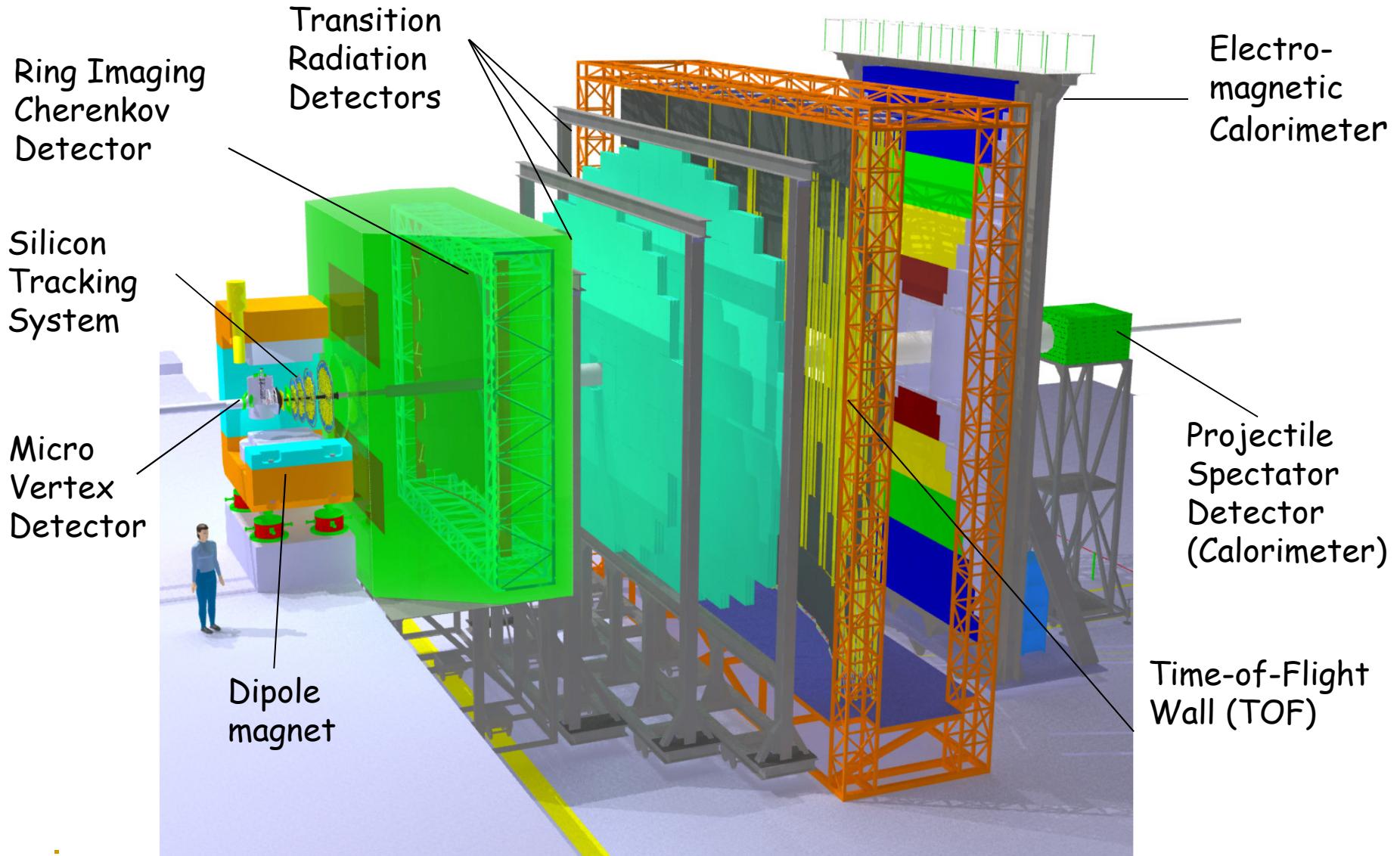
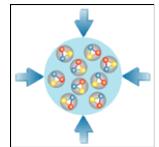
Shown are run average rates

They determine sensitivity

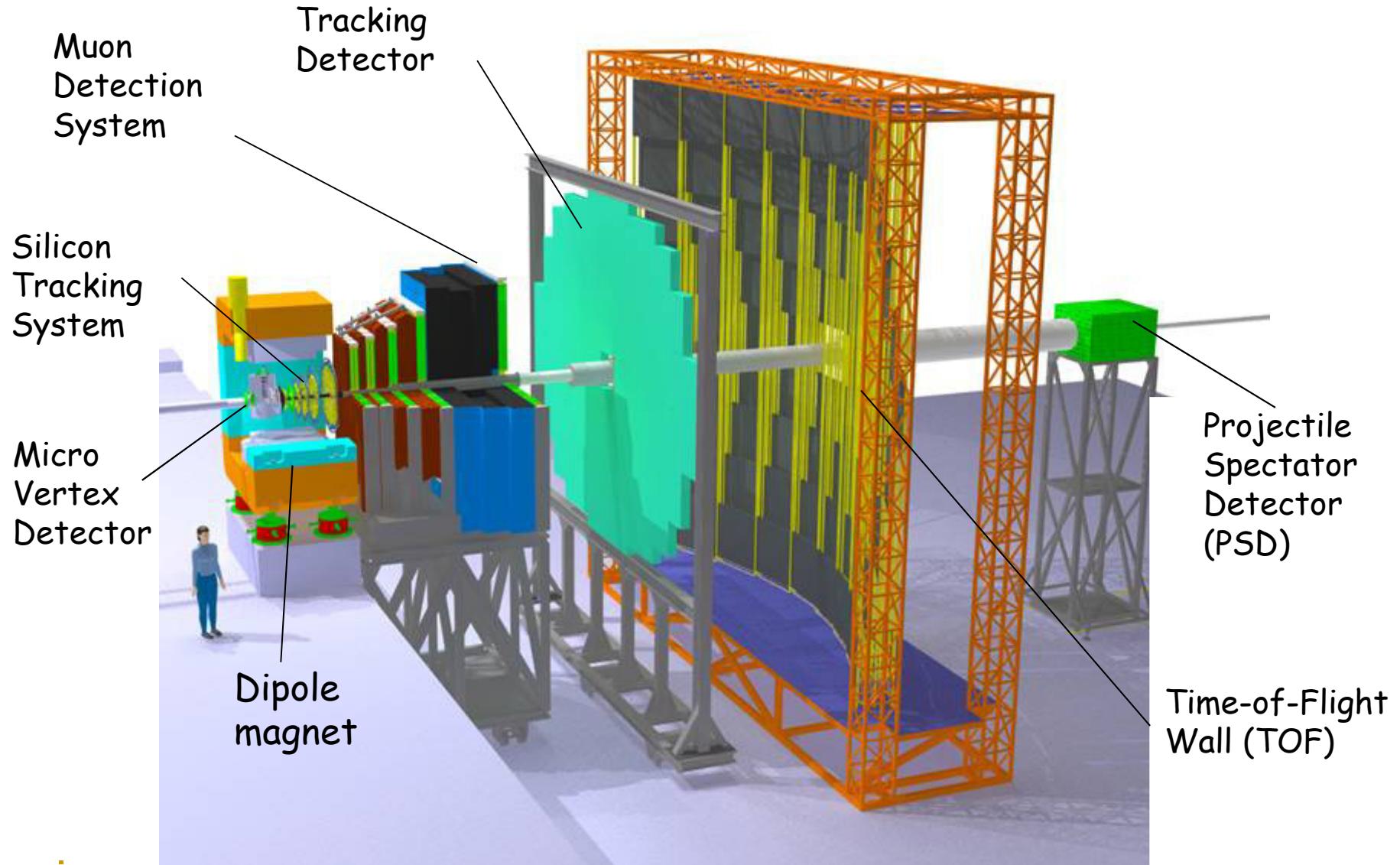
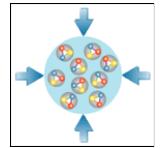
Detectors + FEE must be designed for peak rate !



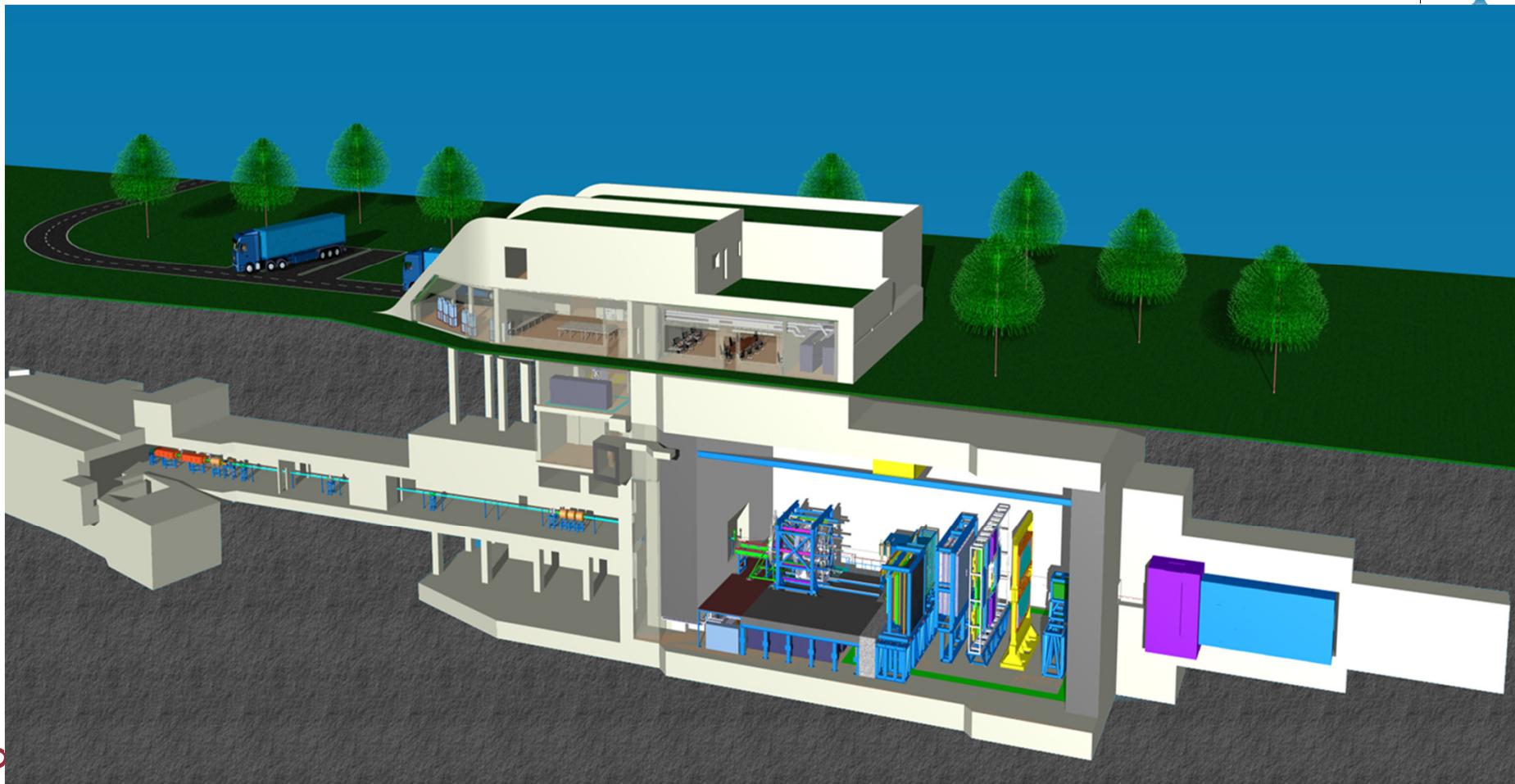
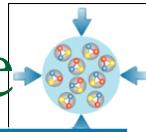
CBM – Hadron - Electron Configuration



CBM – Muon Configuration



Required FAIR Infrastructure: SIS100+Cave



P

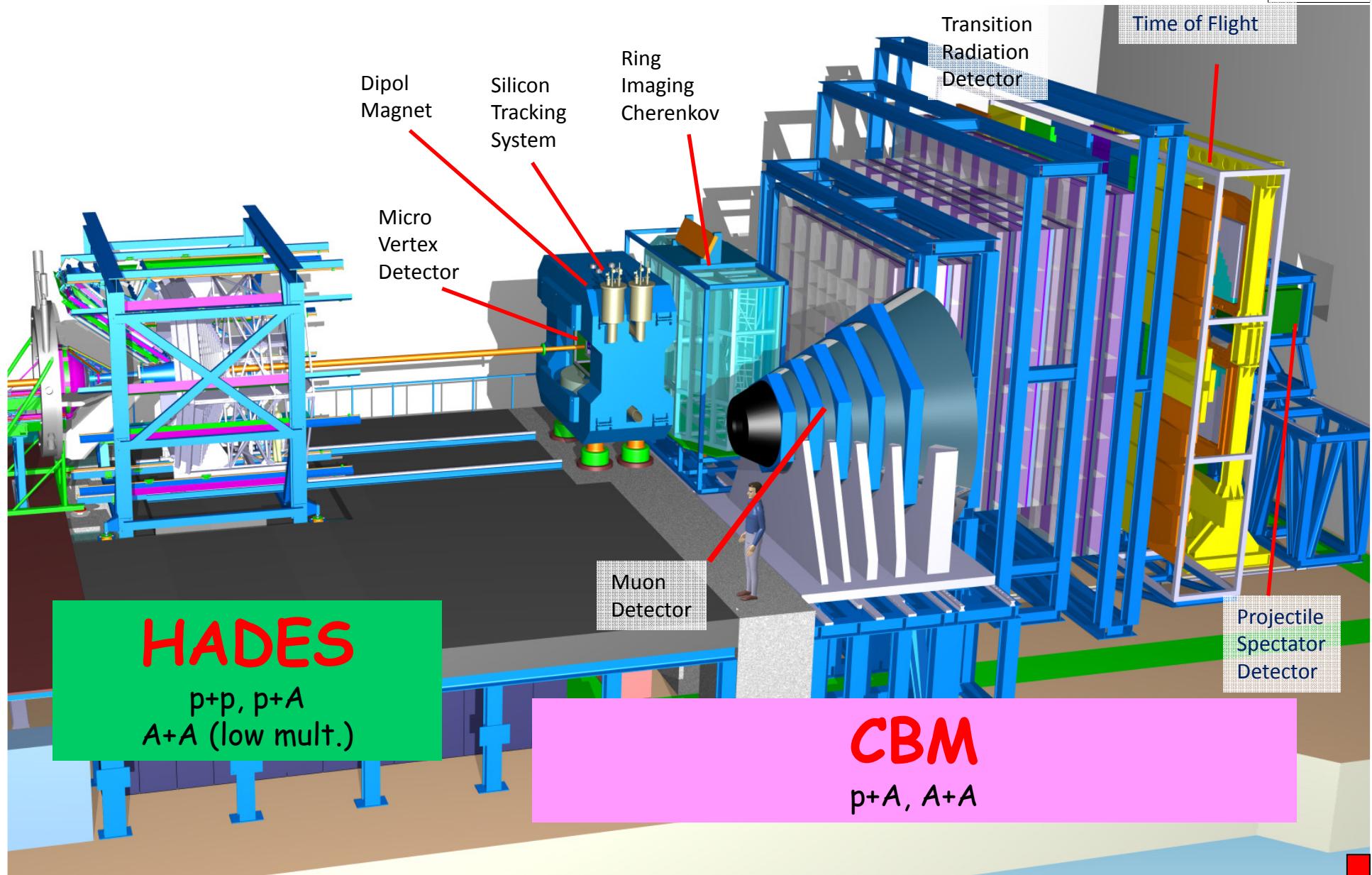
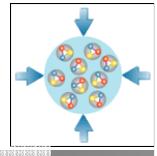
- $10^9/\text{s}$ Au up to 11 GeV/u
 - $10^9/\text{s}$ C, Ca, ... up to 14 GeV/u
 - $10^{11}/\text{s}$ p up to 29 GeV
- more by Ch. Sturm



FAIR phase 1
FAIR phase 2

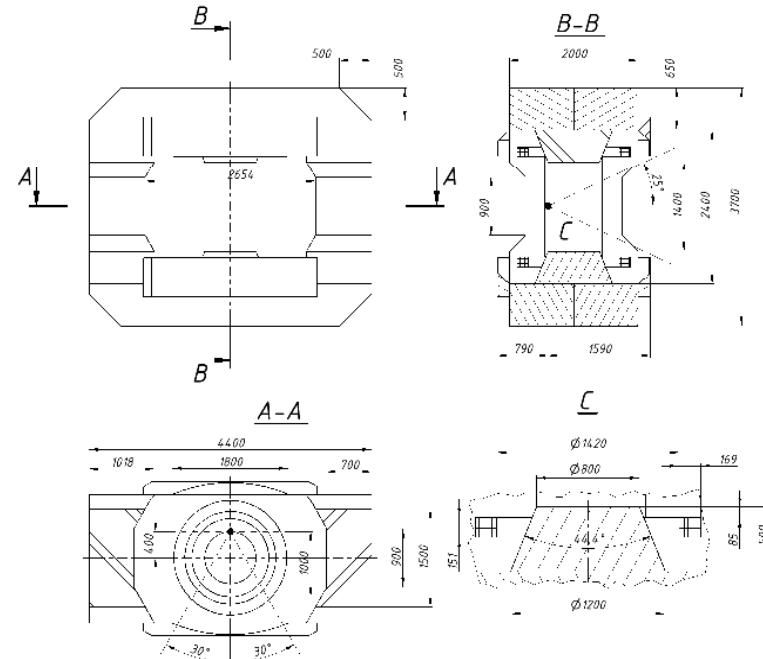
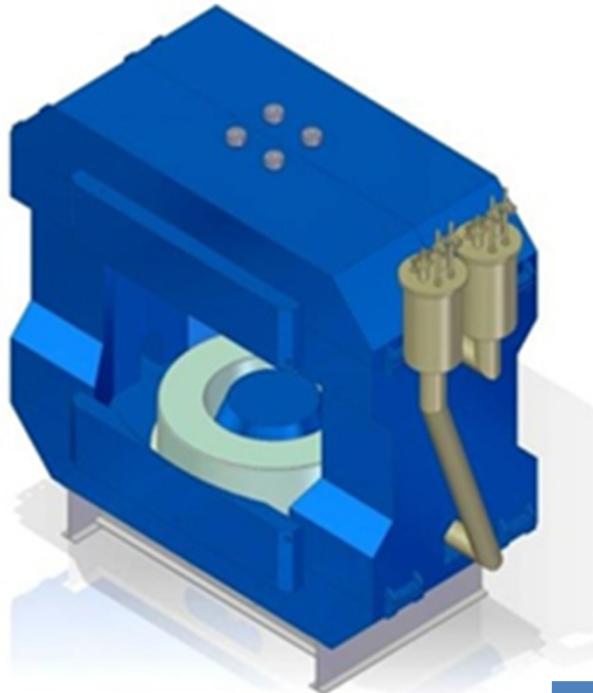


Full HADES+CBM Setup in CBM Cave



Superconductive Dipole Magnet

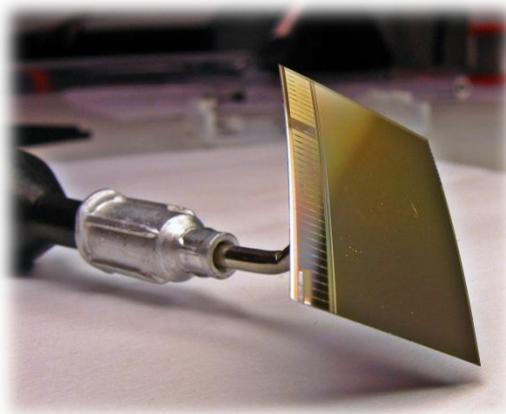
SC Magnet: JINR Dubna



Parameter	CBM dipole magnet
Type	H-type
Pole	Diameter 1 m, gap 1.4 m
Maximum field	1 T
Maximum field integral	1 Tm
Stored energy	5.15 MJ
Total weight	160 ton

Micro-Vertex Detector (MVD)

Task: determination of secondary vertices
of open charm decays ($\tau = 10^{-12}\text{-}10^{-13}$ s)



Monolithic Active
Pixel Sensors
(MAPS)

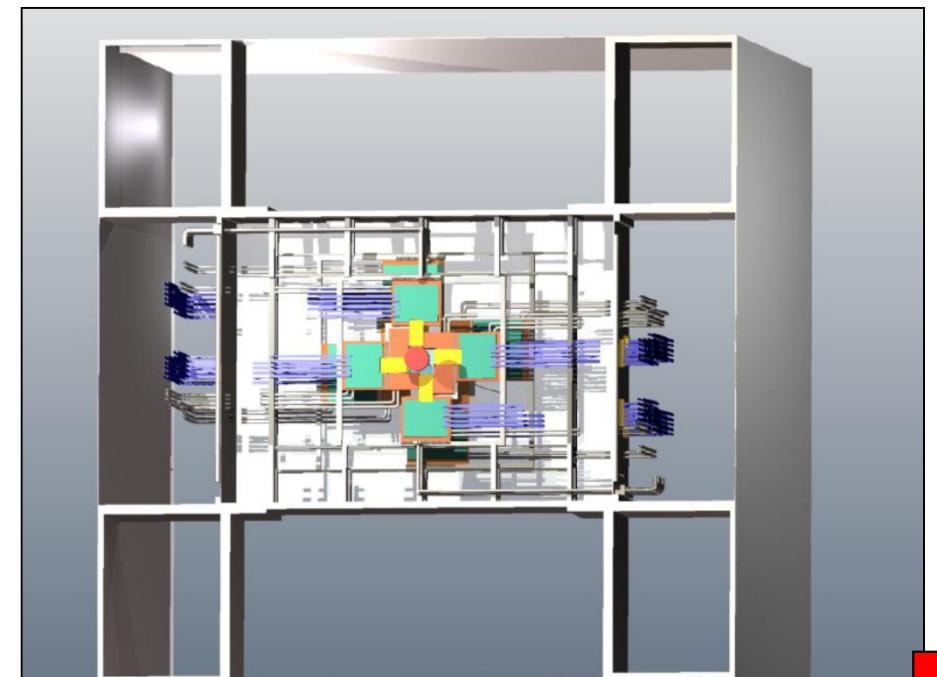


Sensor MIMOSA-26 or Alpide:
600 kPixel, zero suppression
thinned to 50 μ m, at IKF Frankfurt

Micro Vertex Detector:

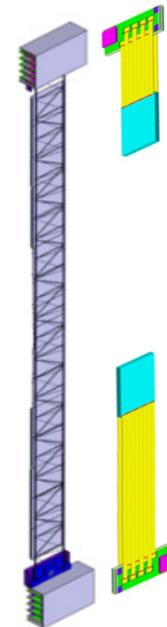
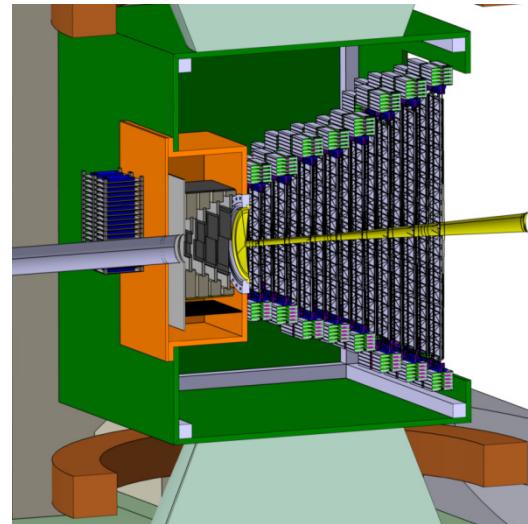
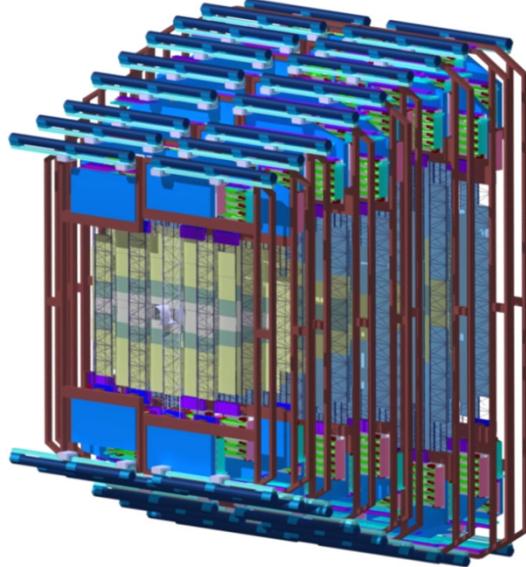
- Pixel size about $20\times 20\text{ }\mu\text{m}^2$
- Position resolution $\sigma = 4\text{ }\mu\text{m}$
- Vertex resolution $50\text{-}100\text{ }\mu\text{m}$ (beam axis)
- Total material budget $300\text{ -- }500\text{ }\mu\text{m}$
silicon equivalent
- 3 stations at 5, 10, 15 cm from target

Univ. Frankfurt, IPHC Strasbourg



The Silicon Tracking System (STS)

GSI, Dubna, Karlsruhe, Krakow, Kiev, Kharkov, St. Petersburg, Tübingen, Warsaw



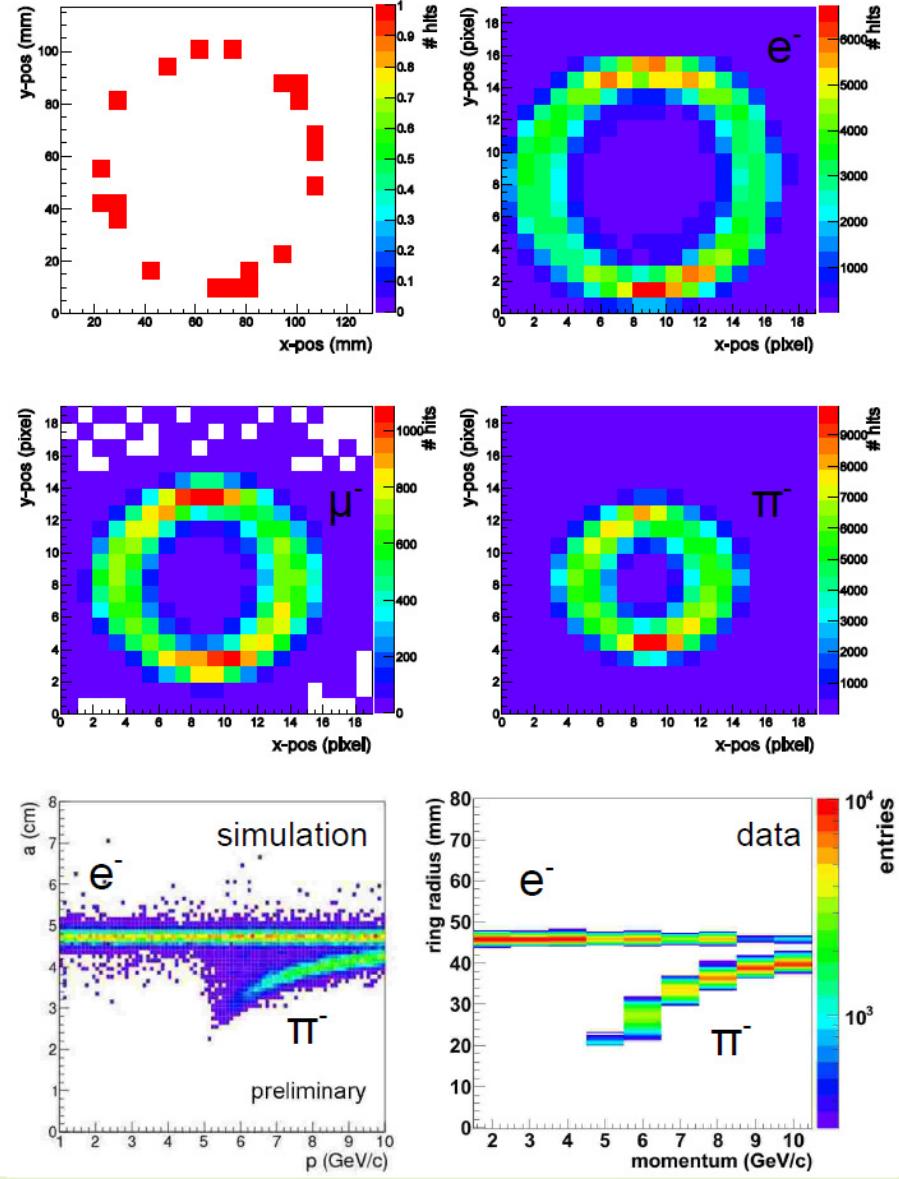
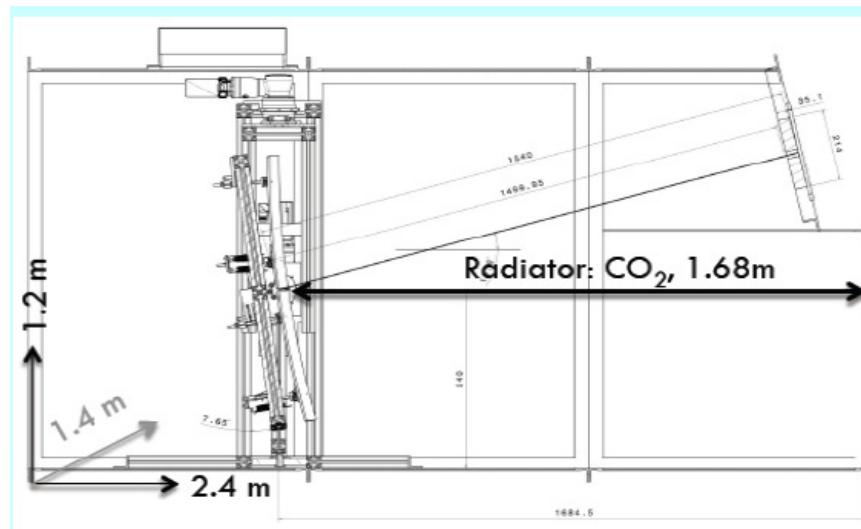
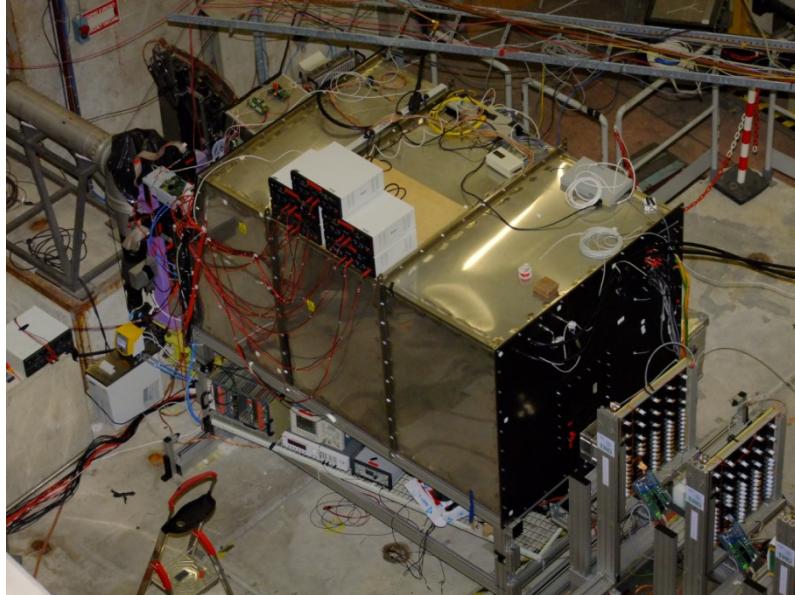
Silicon Tracking System:

- 8 stations, active area from $45 \times 30 \text{ cm}^2$ to $100 \times 100 \text{ cm}^2$
- Double-sided Silicon microstrip sensors , $58 \mu\text{m}$ pitch,
 1024 strips at both sides, 7.5° stereo angle
- Low-mass micro cables from sensor to FEE
- Ultra-light carbon support structures
- selftriggering ASIC
- 1.8 Mio channels, cooling power $\sim 40 \text{ kW}$
- Requirement: $\varepsilon > 95\%$, $S/N > 15$



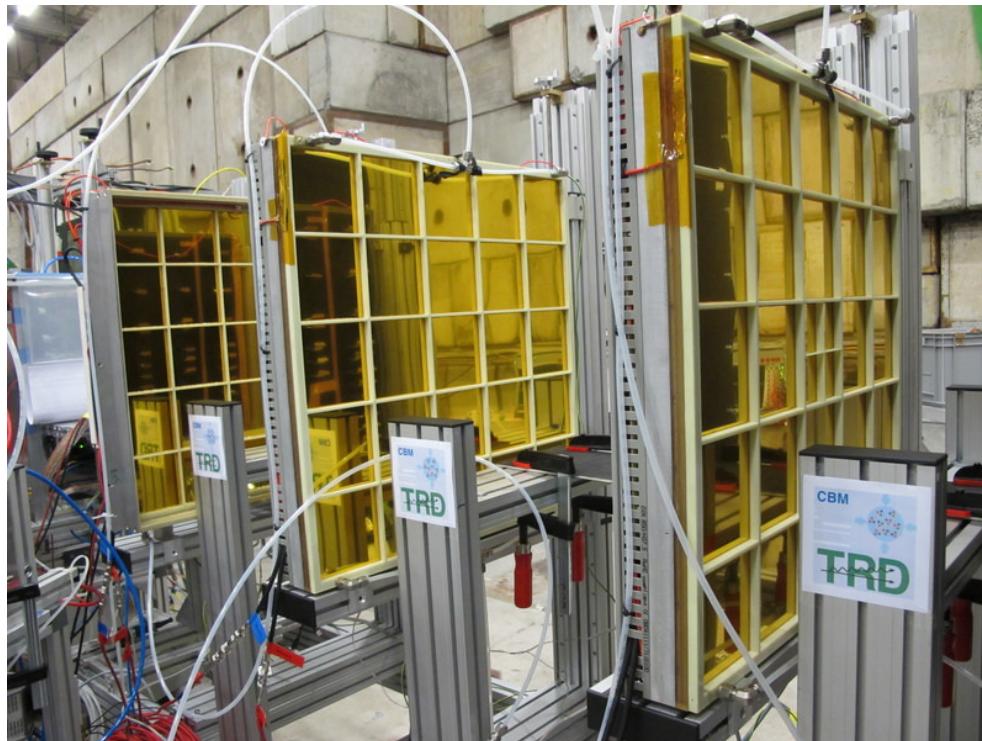
The Ring-Imaging Cherenkov (RICH) Detector

Univ. Gießen, Univ. Wuppertal, Gatchina, Pusan Natl.Univ.

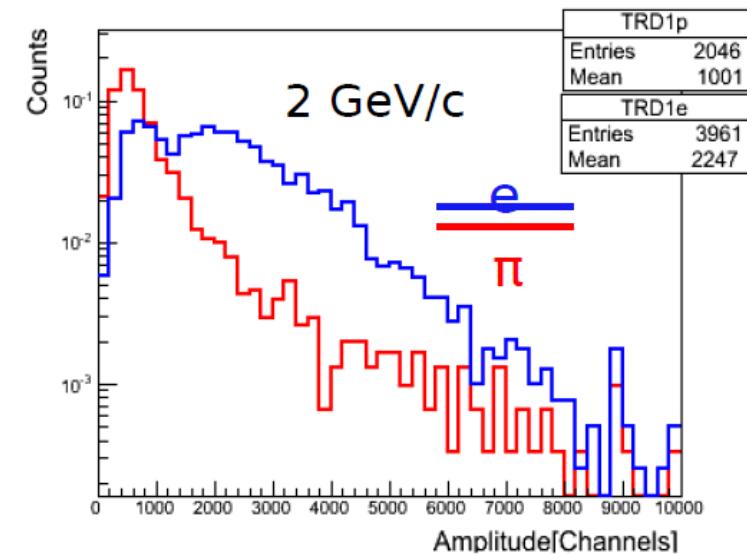


The Transition Radiation Detector (TRD)

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



Energy loss in
Transition Radiation Detectors

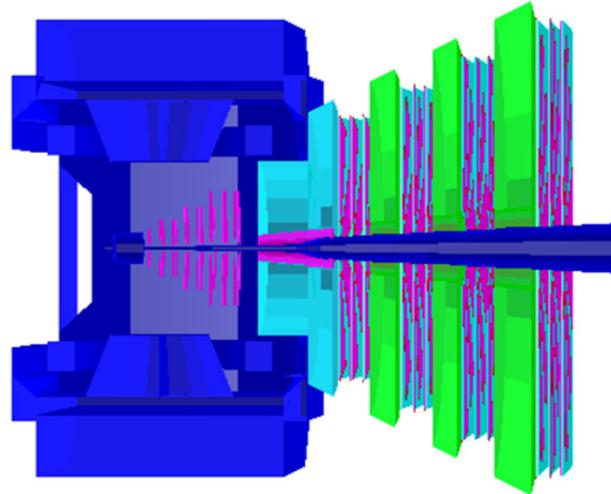


TRD requirements: 100 kHz/cm², 700 m²



The Muon Detection System (MUCH)

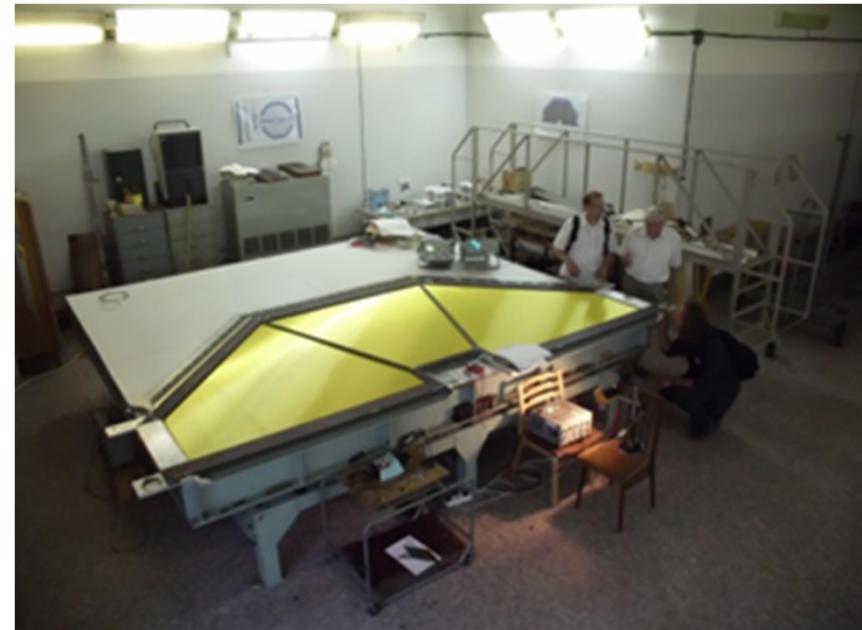
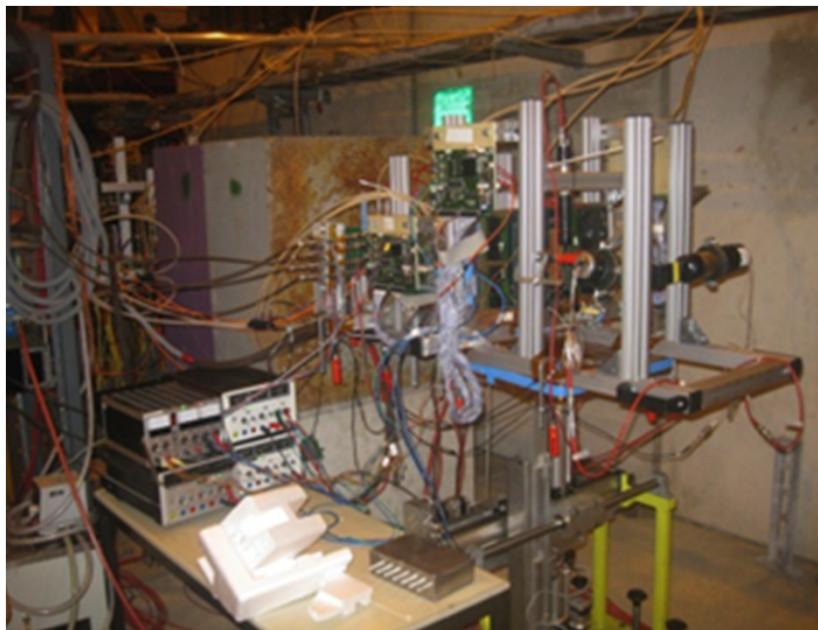
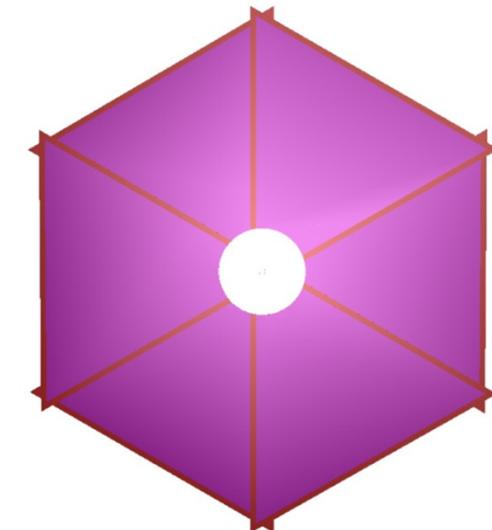
Kolkata + 13 Indian Inst., Gatchina, Dubna



The muon detection system:

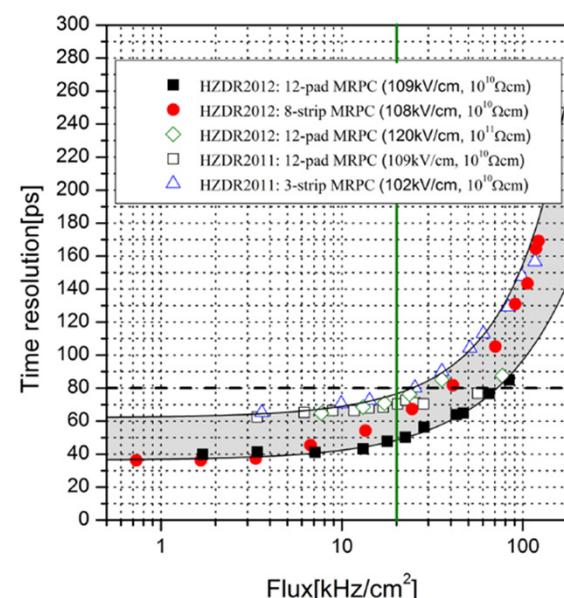
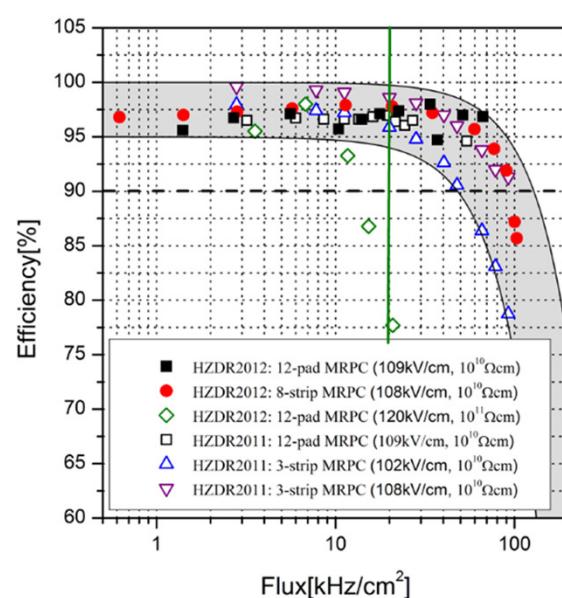
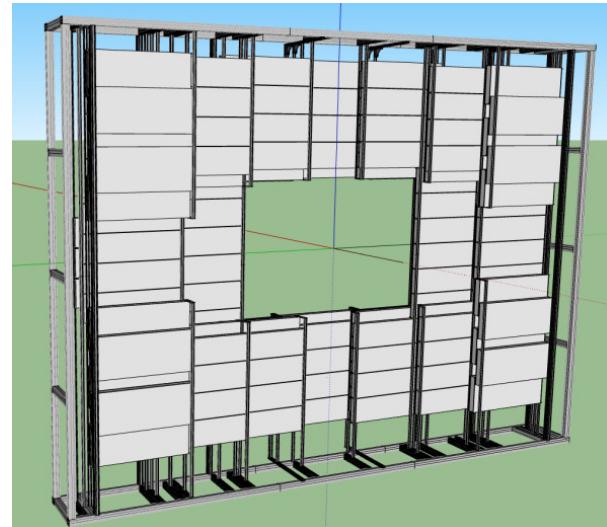
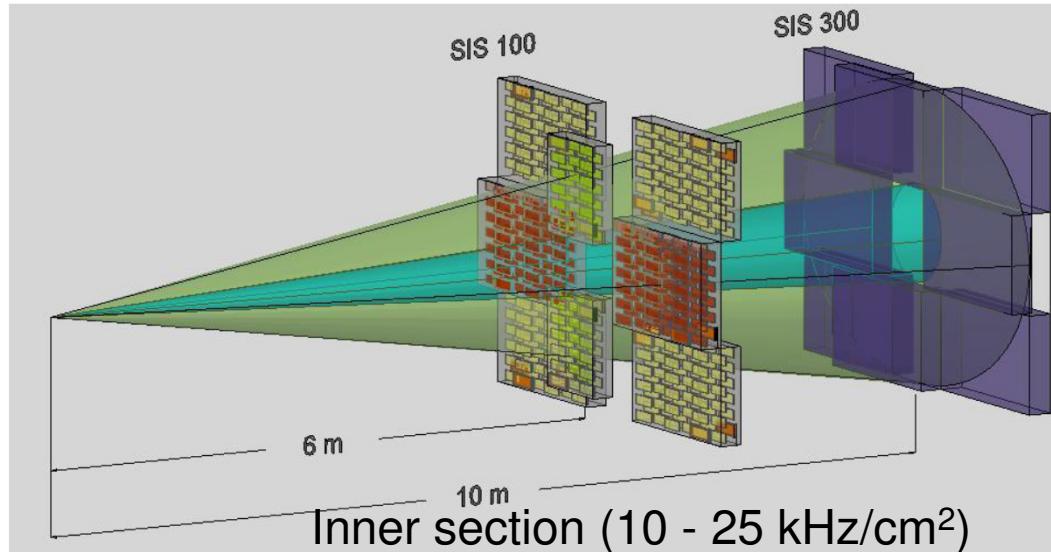
Hadron absorbers: C, Fe

Tracking chambers:
GEMs , Straw tubes



The high-rate MRPC TOF wall

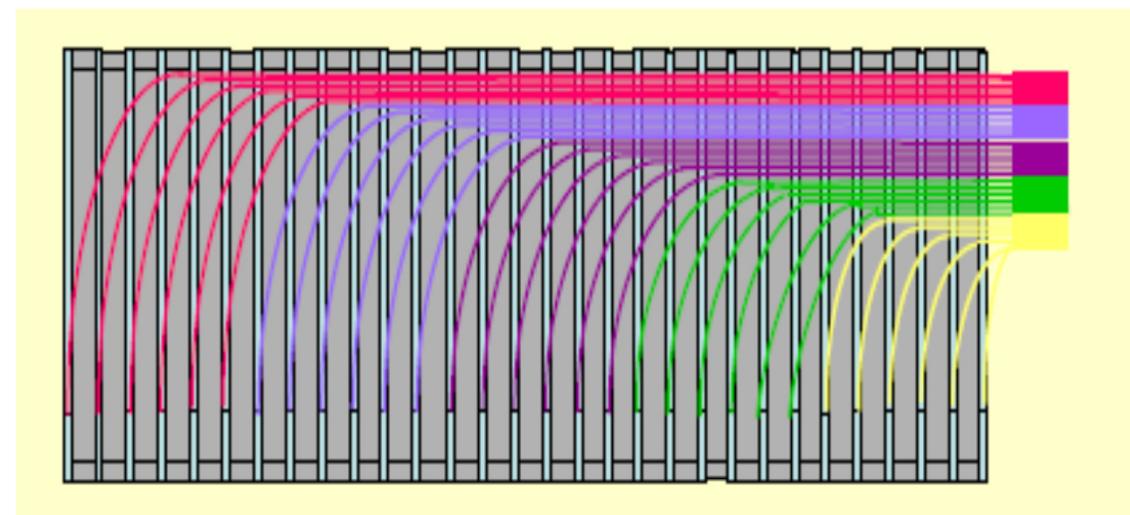
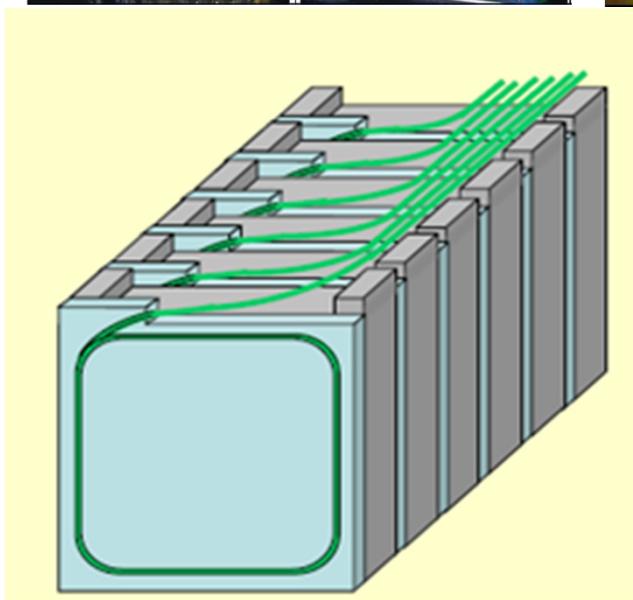
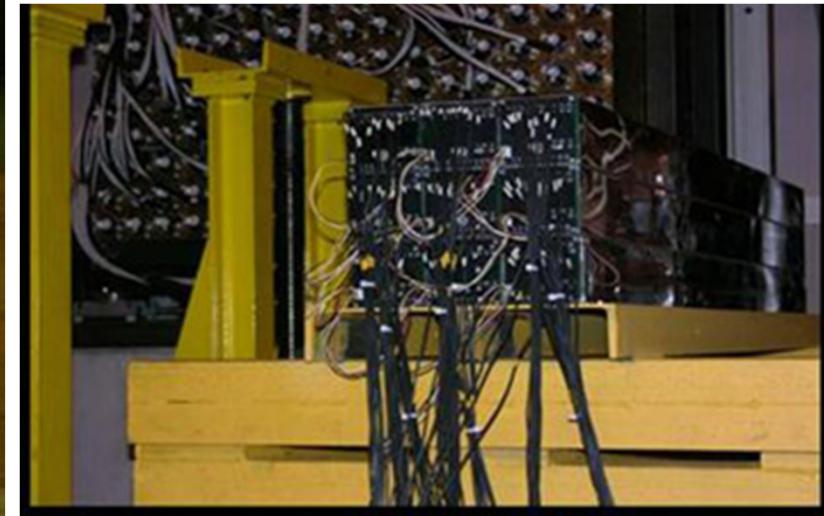
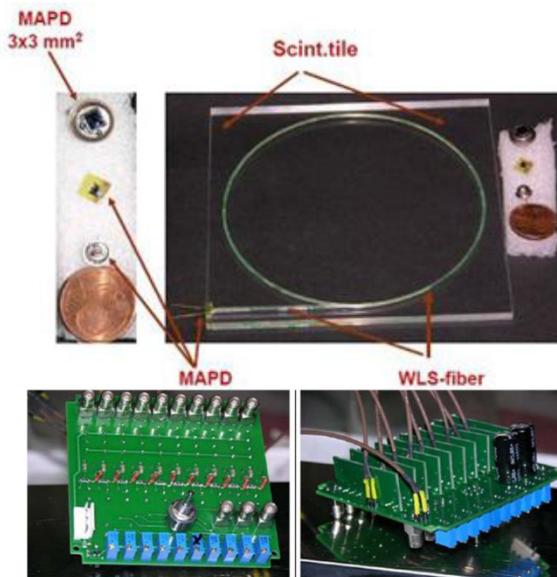
THU Beijing, NIPNE Bucharest, GSI Darmstadt, TU Darmstadt, IfI Frankfurt, USTC Hefei,
Univ. Heidelberg, INR Moscow, ITEP Moscow, HZDR Rossendorf, CCNU Wuhan.



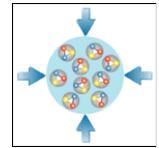
CBM requirements:
60 ps, 100 m²

Projectile Spectator Detector (PSD)

INR Moscow, Prague, Rez



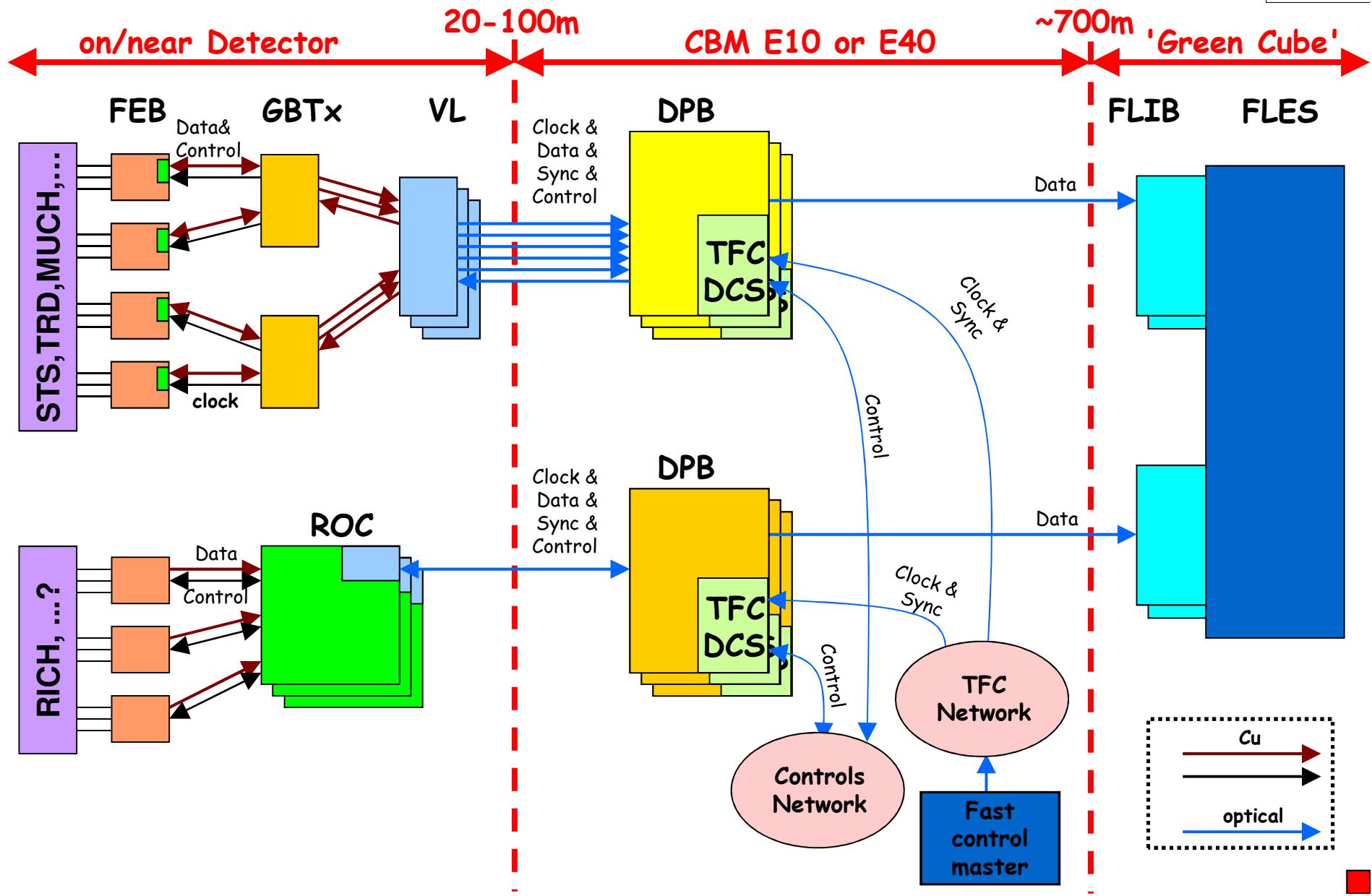
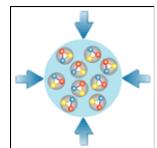
Detector → Electronics



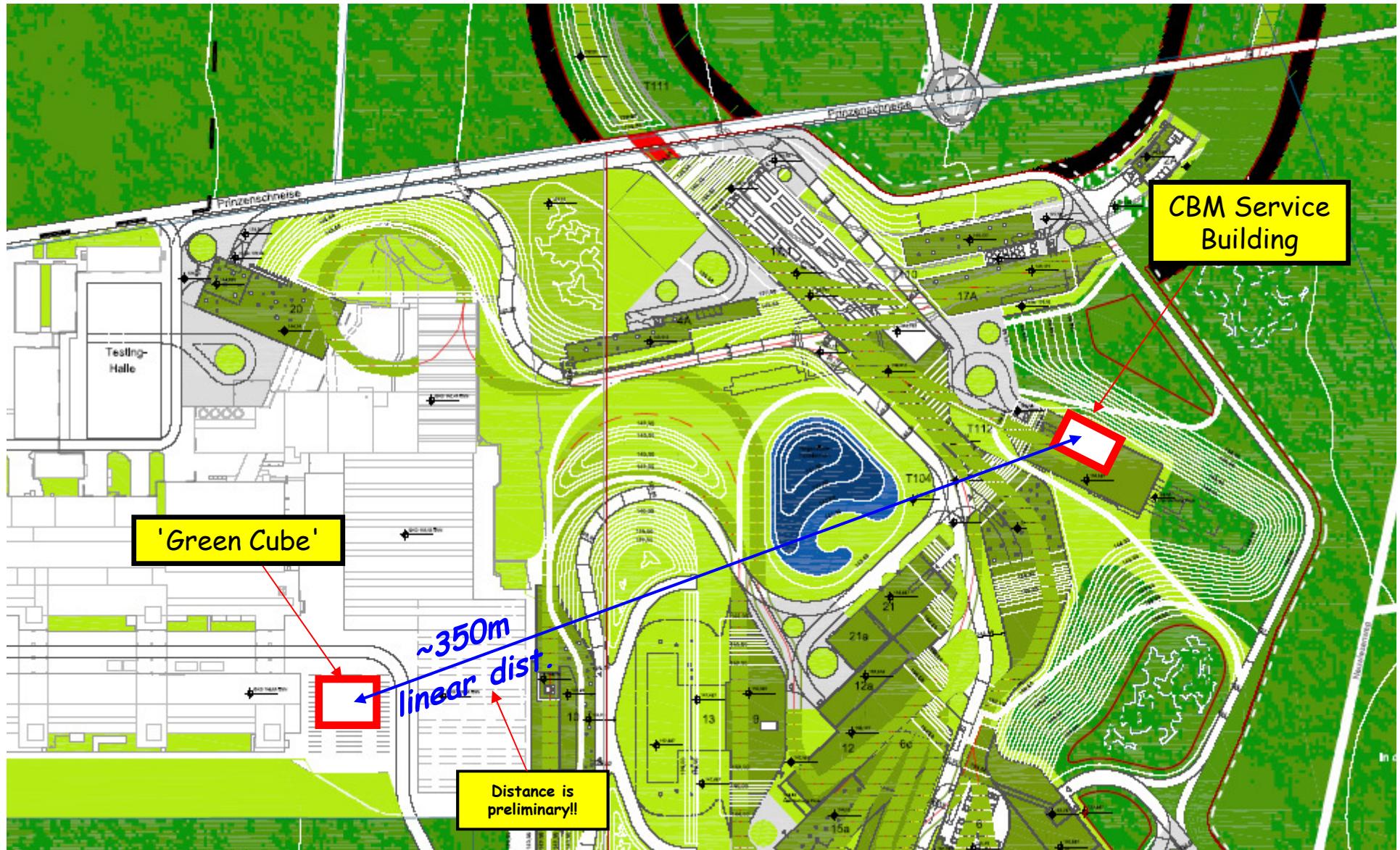
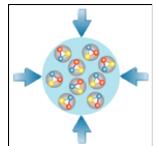
- Large R&D effort done on high rate detectors
 - TOF: 25 kHz/cm²
 - TRD: 100 kHz/cm²
- Complemented by high rate electronics
 - typ. shaping times ~30-80 ns
 - typ. buffer times ~25-100 μsec
- and high bandwidth readout
 - about 50.000 FEE ASICs (hottest have 1 Gbit/sec)
 - use CERN GBTx concentrator ASIC → 4.8 Gbps links
- Note: FEE and readout must be designed for peak rate
→ good beam time structure is essential !!



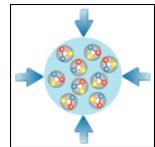
CBM Data Flow – Full Picture



FAIR T0 Centre as CBM FLES Location



CBM Technical Design Reports

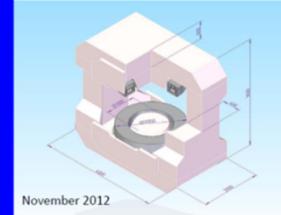


#	Project	TDR Status
1	Magnet	approved
2	STS	approved
3	RICH	approved
4	TOF	approved
5	MuCh	approved
6	HADES ECAL	approved
7	PSD	approved
8	MVD	submission 2016
9	DAQ/FLES	submission 2016
10	TRD	submission 2015
11	ECAL	submission 2015

Technical Design Report for the CBM

Superconducting Dipole Magnet

The CBM Collaboration

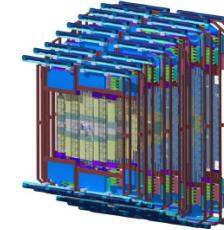


November 2012

Technical Design Report for the CBM

Silicon Tracking System (STS)

The CBM Collaboration

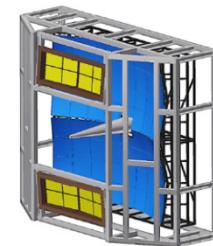


GSI Report 2013-4
October 2013

Technical Design Report for the CBM

Ring Imaging Cherenkov (RICH) Detector

The CBM Collaboration



April 2013

Technical Design Report for the CBM

Projectile Spectator Detector (PSD)

The CBM Collaboration

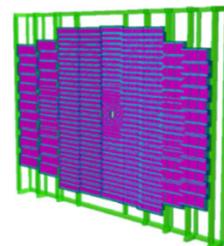


March 2013

Technical Design Report for the CBM

Time – of – Flight System (TOF)

The CBM Collaboration

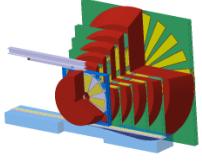


March 2013

Technical Design Report for the CBM

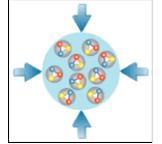
Muon Chamber (MuCh)

The CBM Collaboration



December 2013



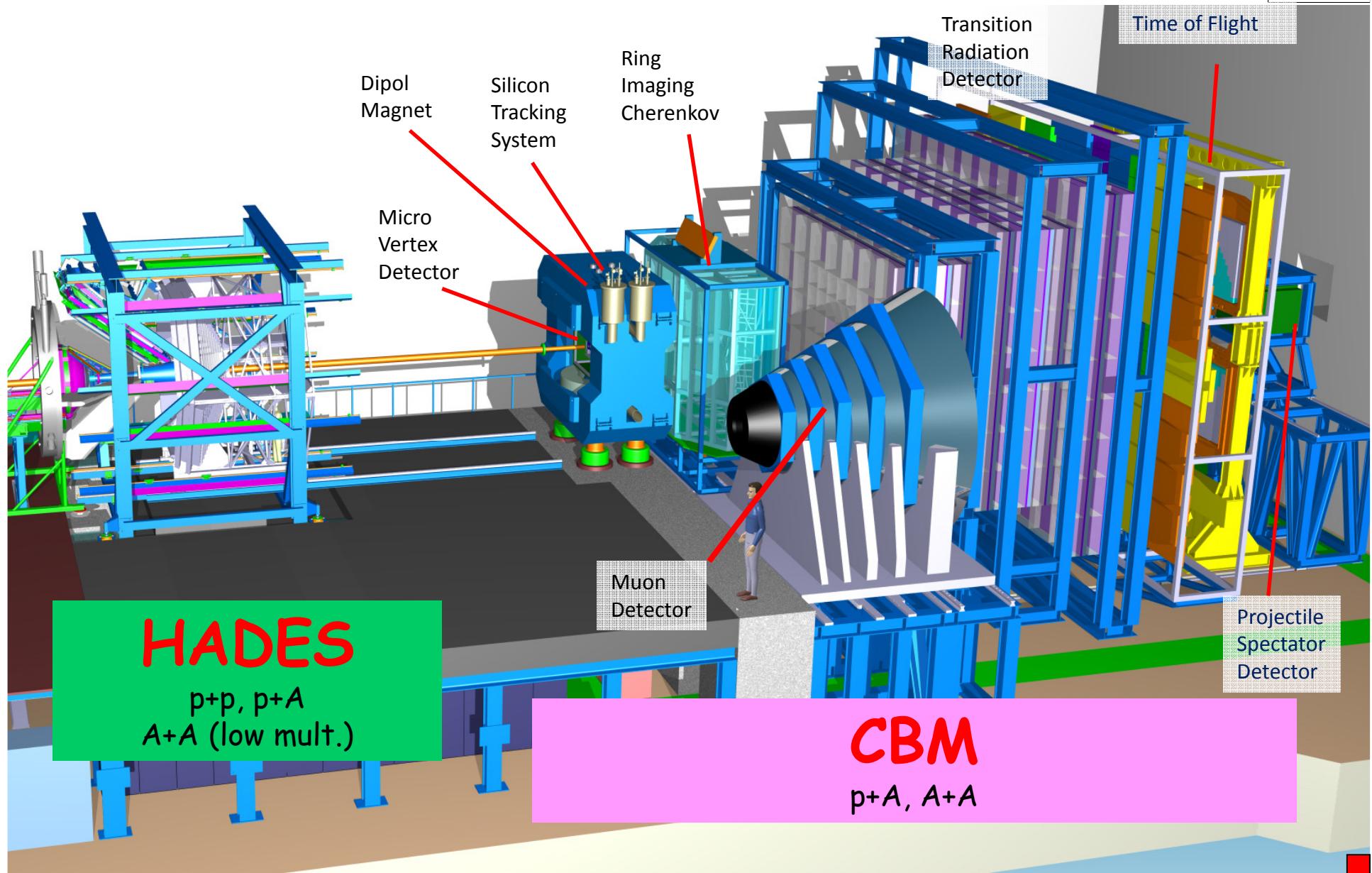
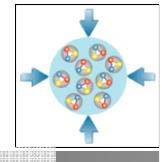


HADES

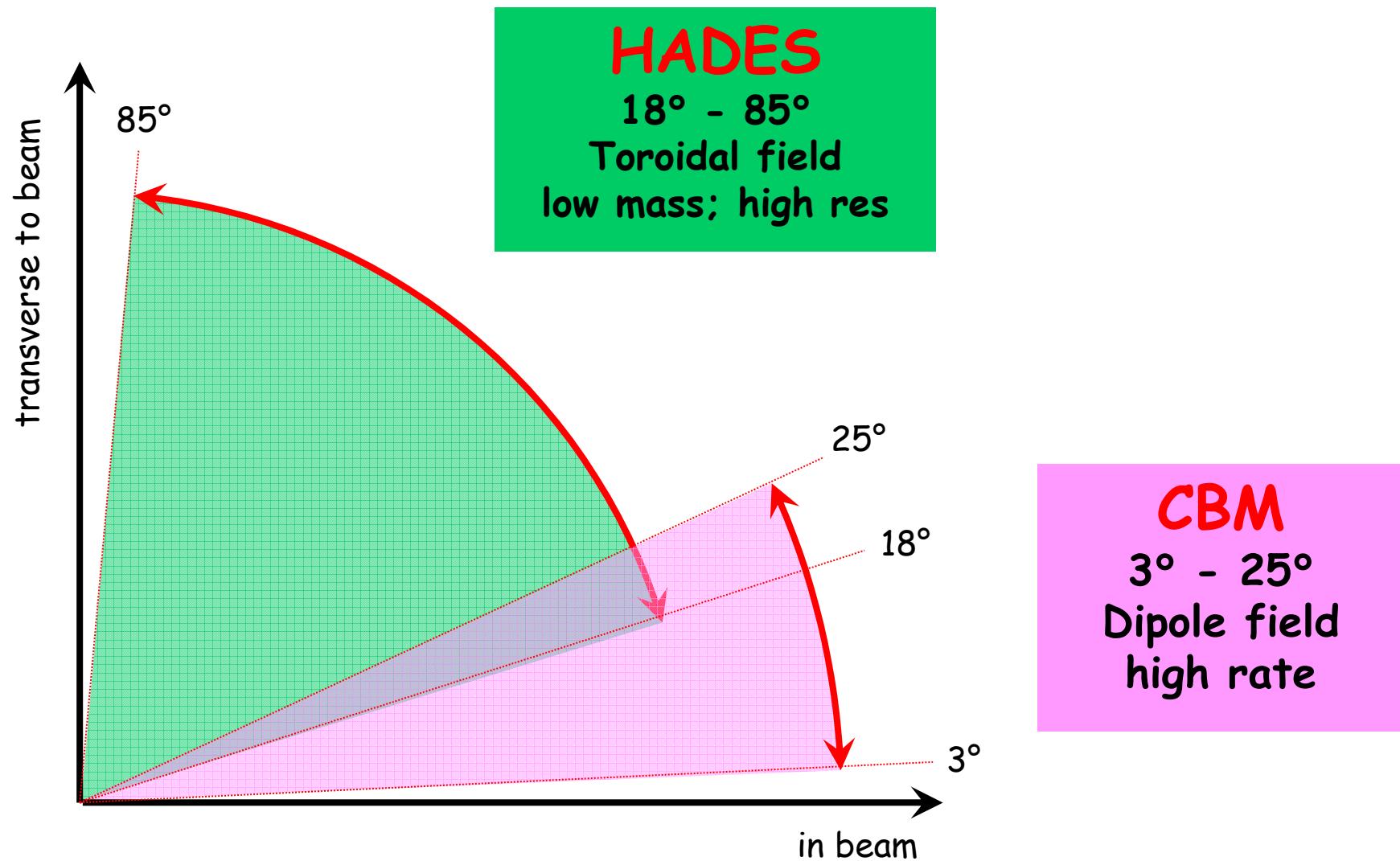
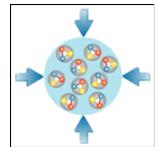
@ SIS-100



Reminder: Two Setups: HADES & CBM



HADES & CBM: Complementary Setups



HADES experiment status

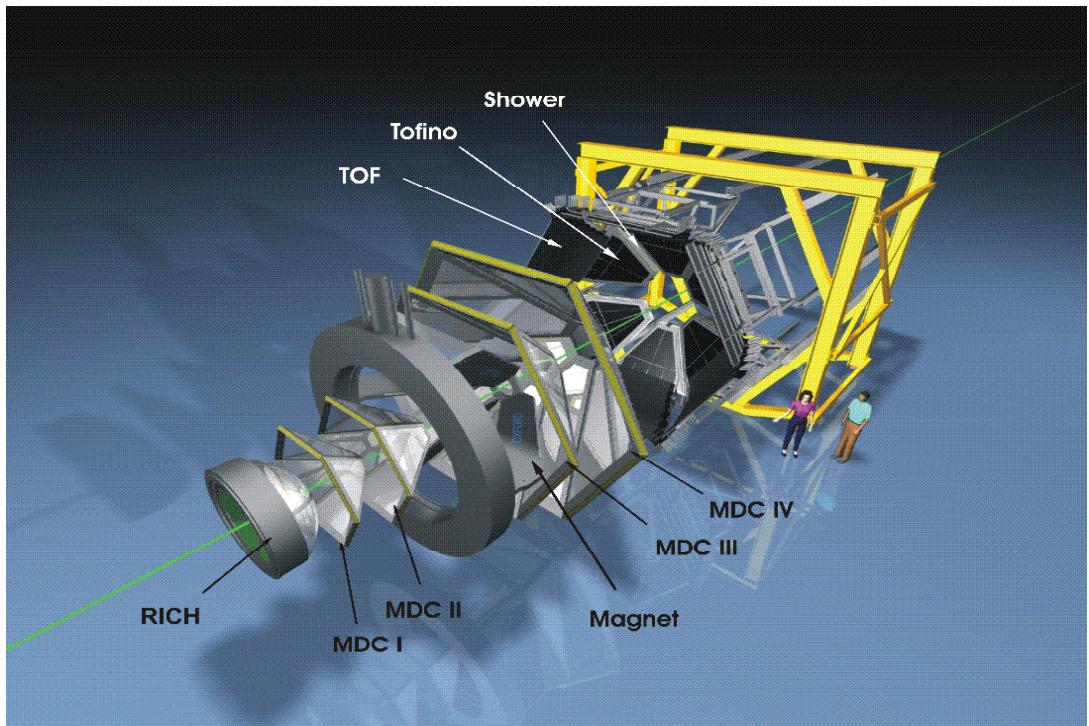
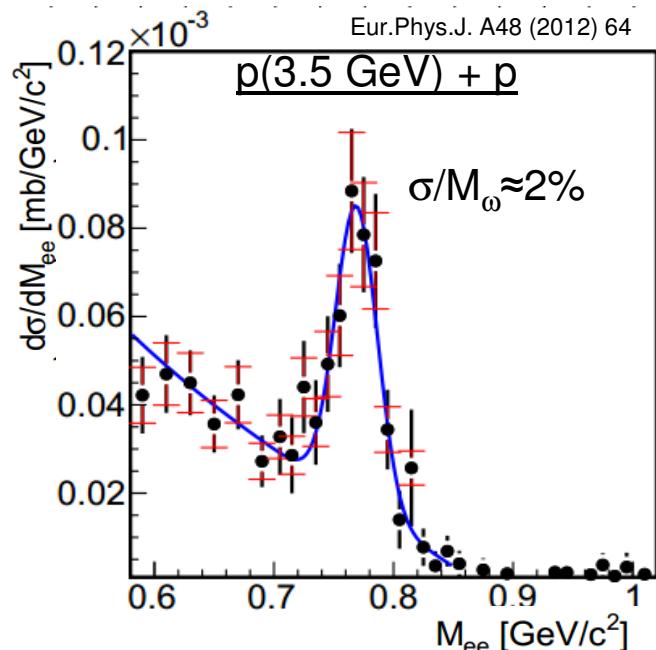
Key features:

- Di-electron pair acceptance
 $\approx 35\% \text{ (VM} \rightarrow e^+e^-)$
- Low mass spectrometer
 - RICH: $x/X_0 < 1\%$
 - MDC: $x/X_0 \approx 0.42\%$

Main focus:

Systematic di-electron and multi-strangeness measurements in heavy ion, proton and pion induced reactions (SIS18, SIS100)

→ See talk on Friday !!



Major upgrade projects (before 2018):

- Electromagnetic Calorimeter
- Photon detector in RICH
- Tracking system improvements

Electromagnetic Calorimeter ECAL

Purpose and Concept

- Based on OPAL lead-glass crystals combined with Hamamatsu 3" PMTs
- Will replace PRE-SHOWER detector
- Improves electron-to-pion suppression and enables photon measurements

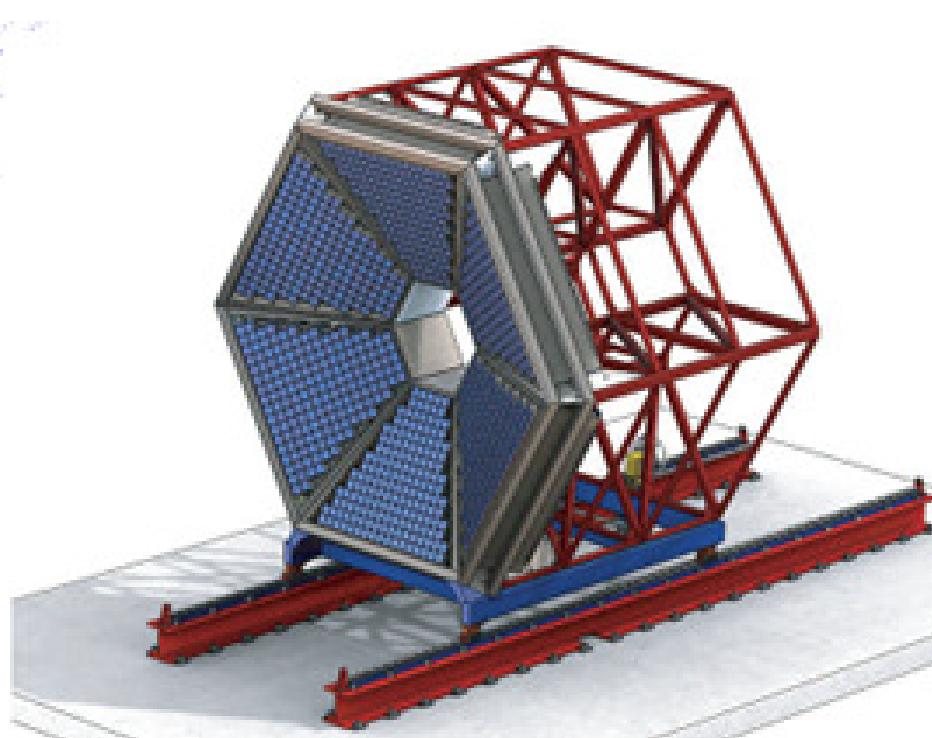
Participating groups

- TU Darmstadt, U Krakow, INR/RAS Moscow, INP/CAS Rez and GSI

Status

- Commissioning planned for Q4/2017
- Expected performance
 - $\Delta E/E = 5\%$ at 1.5 GeV (photons)
 - 978 modules ($94 \times 94 \times 420 \text{ mm}^3$), $L = 17 X_0$
 - 18 t total weight on rail system
- Total cost
 - 2.7 MEUR (1.3 MEUR spent, 1.4 missing)

	15	2016	2017	18
Mainframe				
Module assembly				
Sector assembly				
DAQ				
Installation				



MAPMT photon detector for the RICH

Purpose and Upgrade Concept

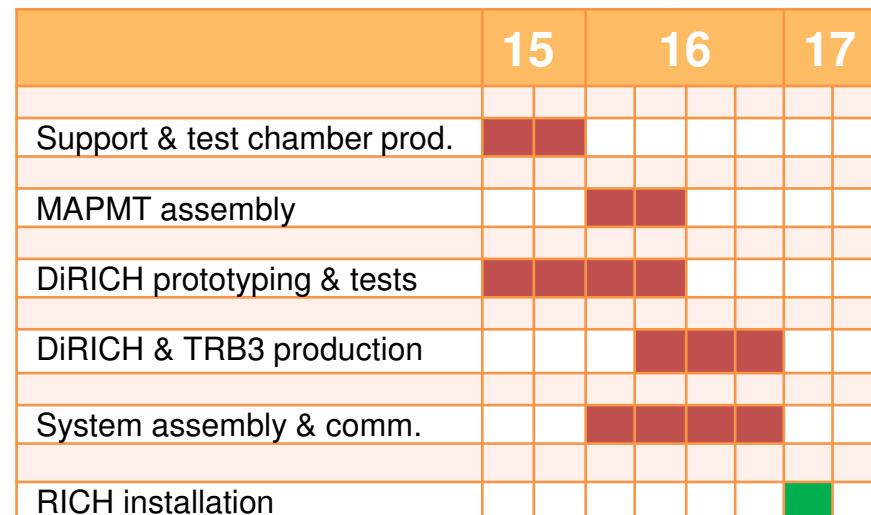
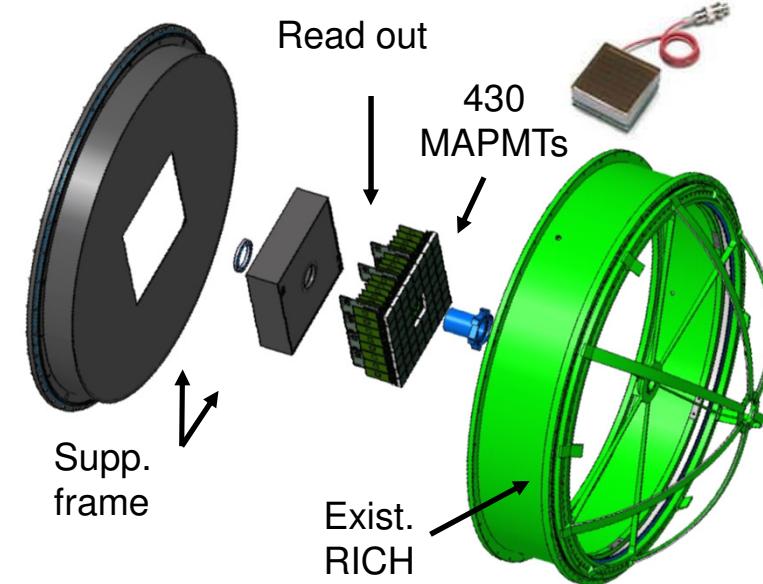
- e^+e^- - pair efficiency → ~ x3 - x4
 - CsI-based MWPC → high QE PMT
 - CBM comp. readout → DiRICH FE & TRB3 back end
- !! Joint endeavor with the CBM-RICH team

Participating groups

- *U Frankfurt, U Gießen, TU München, U Wuppertal, and GSI*

Status

✓ Funding:	secured
✓ MAPMT delivery:	11.2015
✓ Support & test ch.:	tender proc.
!! DiRICH & PCB design:	to start <u>asap</u>



Track Reconstruction with MDC

Purpose and Upgrade Concept

- High-precision tracking system, low material budget
- Improving sensitivity by replacing the frontend electronics
- Improving rate capability by replacing the 2nd detector plane
- Optimization of the gas mixture

Participating groups

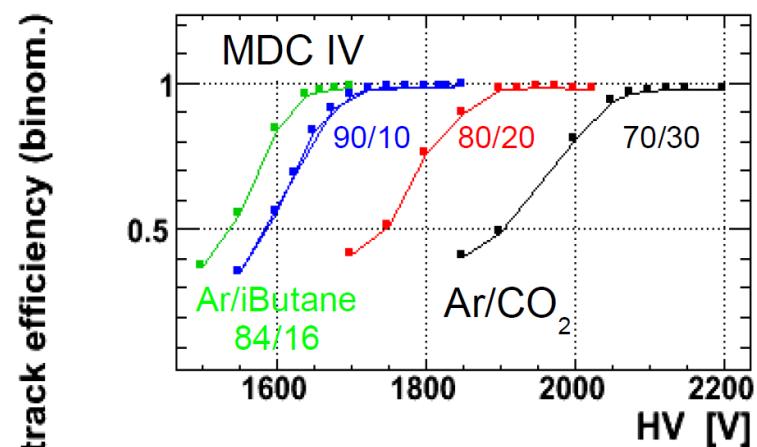
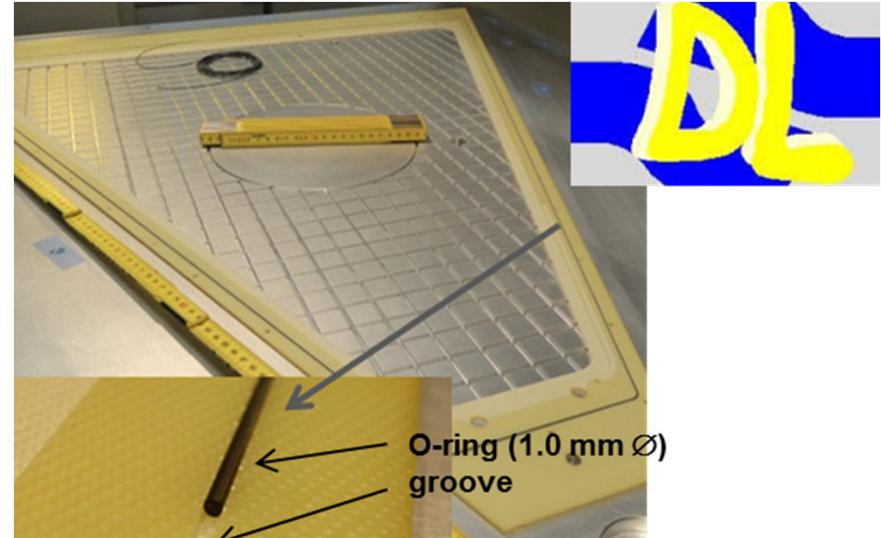
- GU Frankfurt, HZDR, IPNO Paris, JINR Dubna and GSI

Status

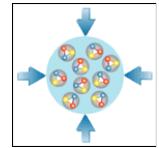
- Studies on CO₂-based gas mixtures concluded
- Preparation of a plane-I spare module in the GSI detector laboratory
- Work on FEE upgrade is pending,
- FEE R&D covered by a BMBF application (GUF)
- FEE mass production and plane II rebuild (7 chambers) not covered

Time plan

- Q2/2016: Finish plane I spare module
- Q4/2015-Q2/2016: Simulations on plane II rebuild (granularity and AutoCAD)
- Q3/2016-Q3/2018: Rebuild plane II
- Q4/2015-Q4/2016: R&D, prototyping FEE (digital)
- Q1/2016-Q1/2017: R&D, prototyping FEE (analog)
- Q1/2017-Q1/2018: FEE Production
- Q2-Q4/2018: FEE Installation in planes I, II, installation plane II



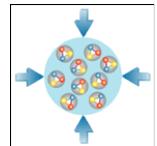
Compressed Baryonic Matter @ FAIR



- Two complementary detector setups on one cave
 - HADES
 - CBM
- Both with broad A-A and p-A program
→ *more on running scenario by Christian Sturm*
- Both require slow extraction with good time structure
→ *more on beam requirements by Jurek Pietraszko*
- And need SIS-18 in 2018-2020
 - CBM → pre-commissioning → *C.Sturm later today*
 - HADES → π -A physics run → *T.Galatyuk on Friday*



The CBM Collaboration



Croatia:

Split Univ.

China:

CCNU Wuhan

Tsinghua Univ.

USTC Hefei

CTGU Yichang

Czech Republic:

CAS, Rez

Techn. Univ. Prague

France:

IPHC Strasbourg

Hungary:

KFKI Budapest

Budapest Univ.

Germany:

Darmstadt TU

FAIR

Frankfurt Univ. IKF

Frankfurt Univ. FIAS

Frankfurt Univ. ICS

GSI Darmstadt

Giessen Univ.

Heidelberg Univ. P.I.

Heidelberg Univ. ZITI

HZ Dresden-Rossendorf

KIT Karlsruhe

Münster Univ.

Tübingen Univ.

Wuppertal Univ.

ZIB Berlin

India:

Aligarh Muslim Univ.

Bose Inst. Kolkata

Panjab Univ.

Rajasthan Univ.

Univ. of Jammu

Univ. of Kashmir

Univ. of Calcutta

B.H. Univ. Varanasi

VECC Kolkata

IOP Bhubaneswar

IIT Kharagpur

IIT Indore

Gauhati Univ.

Korea:

Pusan Nat. Univ.

Romania:

NIPNE Bucharest

Univ. Bucharest

Poland:

AGH Krakow

Jag. Univ. Krakow

Silesia Univ.

Katowice

Warsaw Univ.

Warsaw TU

in HADES only

+ IPNO Paris

+ TUM Munich

+ LIP Coimbra

Russia:

IHEP Protvino

INR Troitzk

ITEP Moscow

Kurchatov Inst., Moscow

LHEP, JINR Dubna

LIT, JINR Dubna

MEPHI Moscow

Obninsk Univ.

PNPI Gatchina

SINP MSU, Moscow

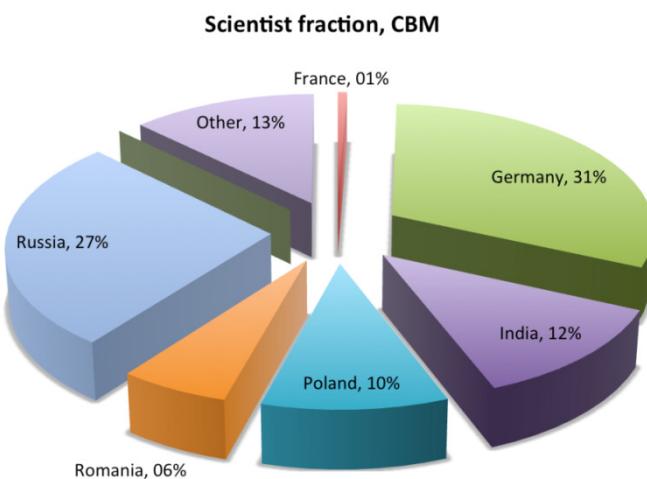
St. Petersburg P. Univ.

Ioffe Phys.-Tech. Inst. St. Pb.

Ukraine:

T. Shevchenko Univ. Kiev

Kiev Inst. Nucl. Research

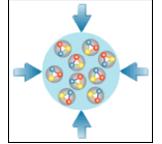


Countries: 12

Institutes: 61

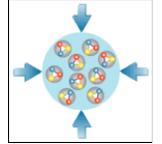
Members: 547

The End



Thanks for
your attention





Backup Slides

