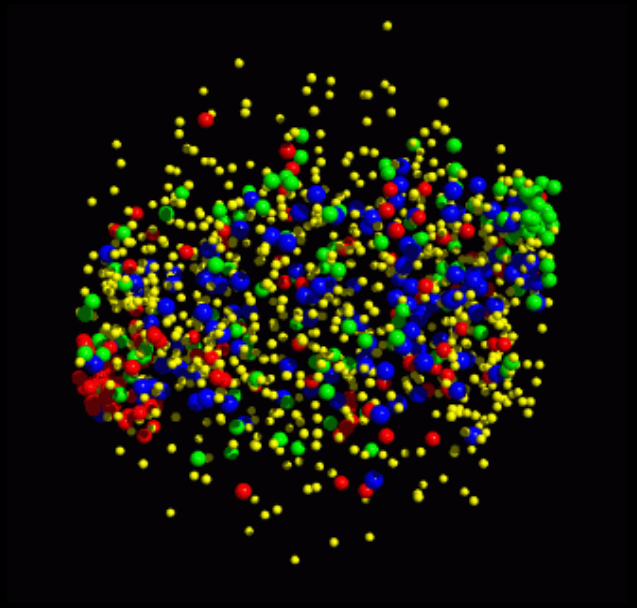
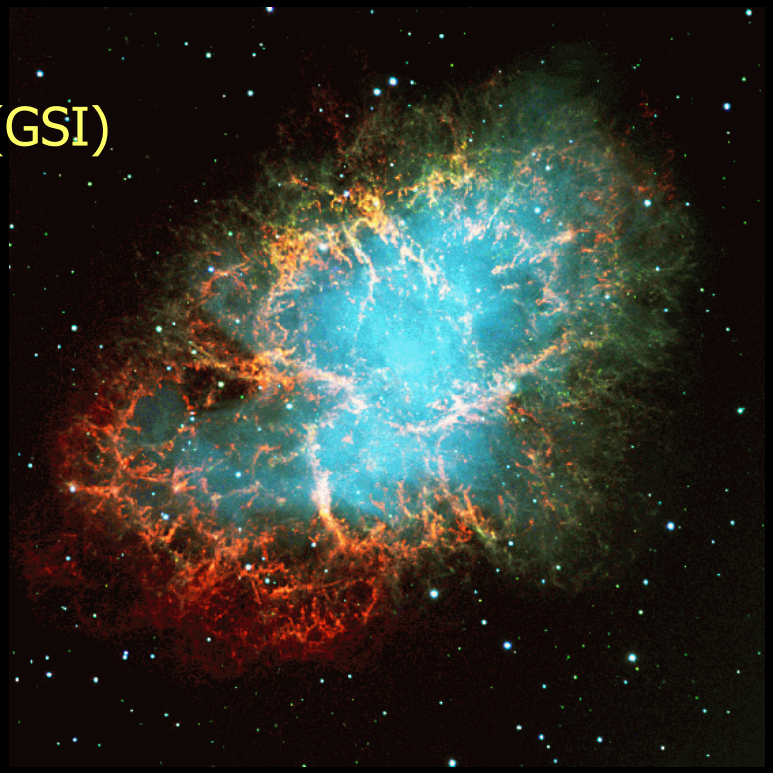
The Compressed Baryonic Matter Experiment



Peter Senger (GSI)

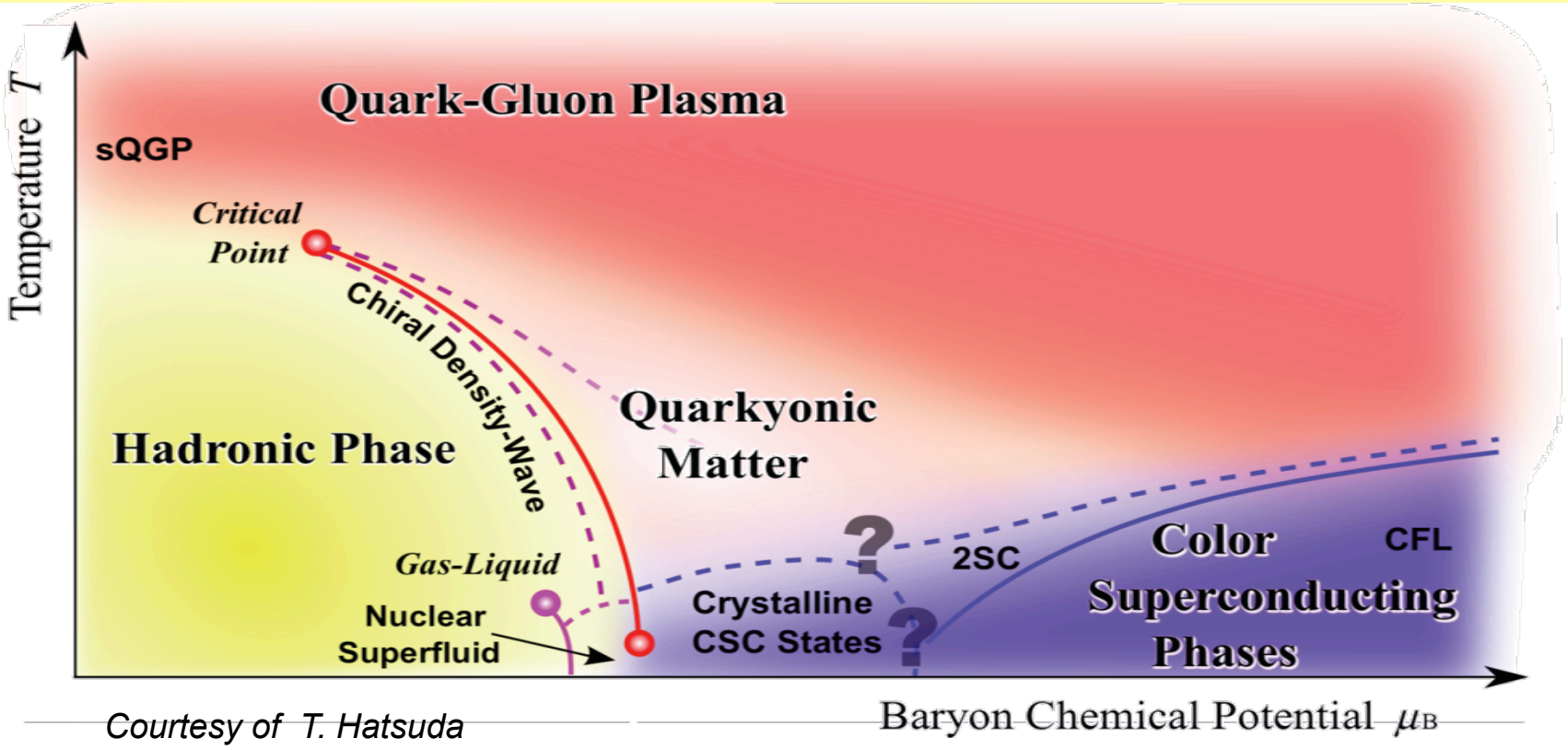


Outline:

- Physics case
- Status R&D
- Planning

FAIR Expert Committee Experiments, November 19, 2012, GSI

Exploring the QCD phase diagram

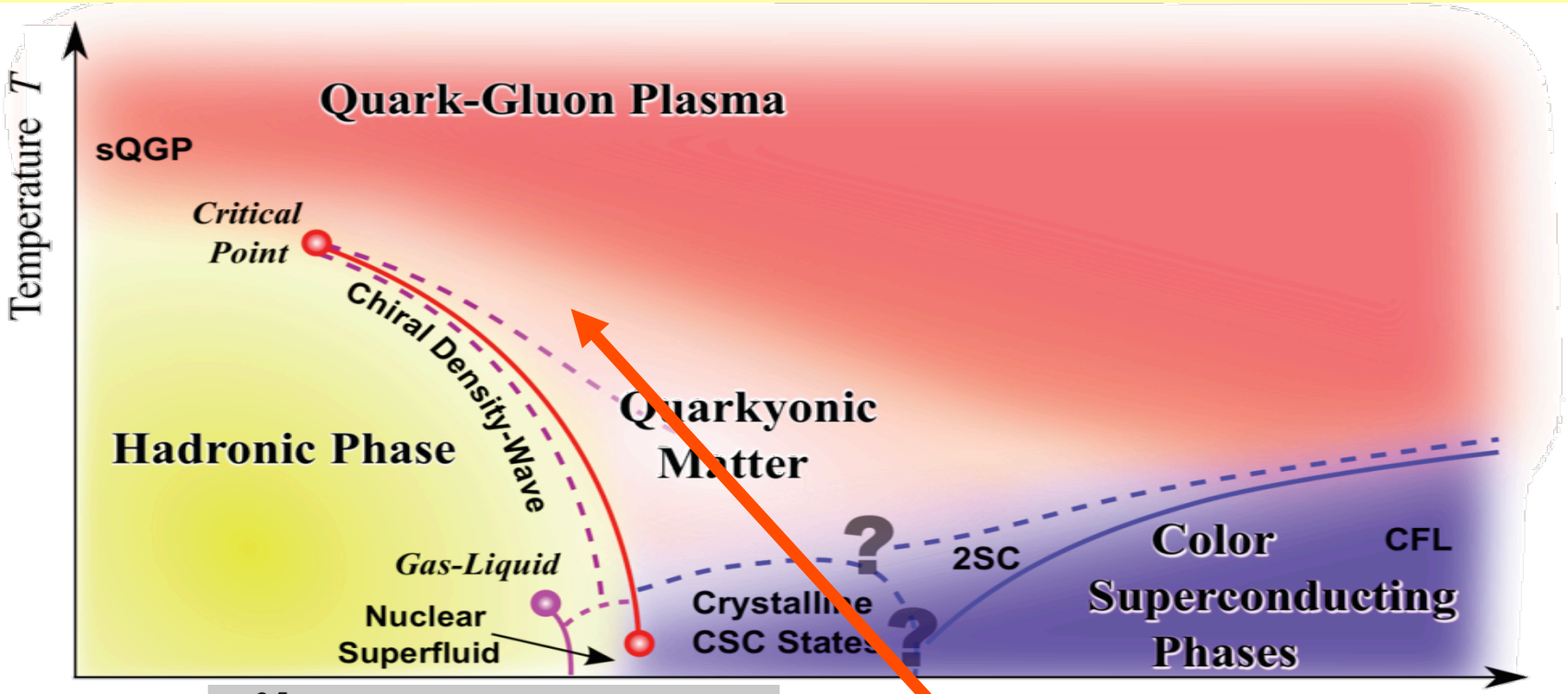


Courtesy of T. Hatsuda

Probing the QCD diagram at very high T and $\rho_B \sim 0$ (early universe):
ALICE, ATLAS, CMS at LHC
STAR, PHENIX at top RHIC energies

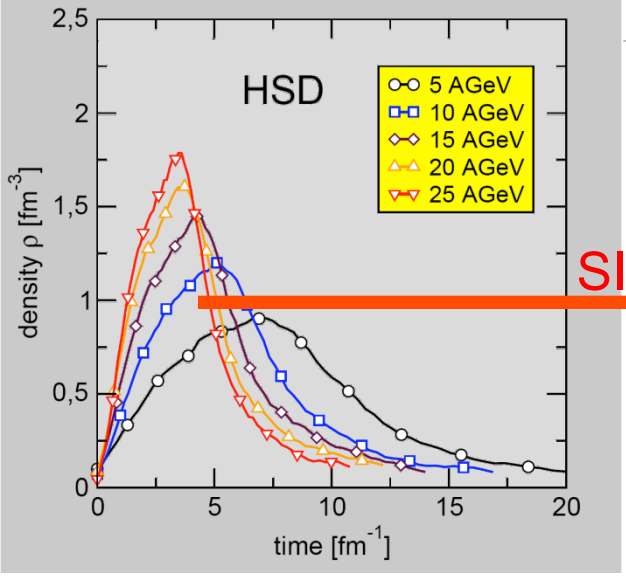
Probing the QCD diagram at moderate T and very high ρ_B:
Beam energy scan at RHIC, NA61 at CERN SPS, CBM at FAIR, MPD at NICA

Exploring the QCD phase diagram

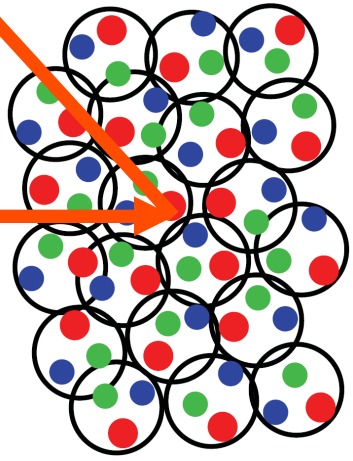


Courte

Baryon density in central Au+Au collisions

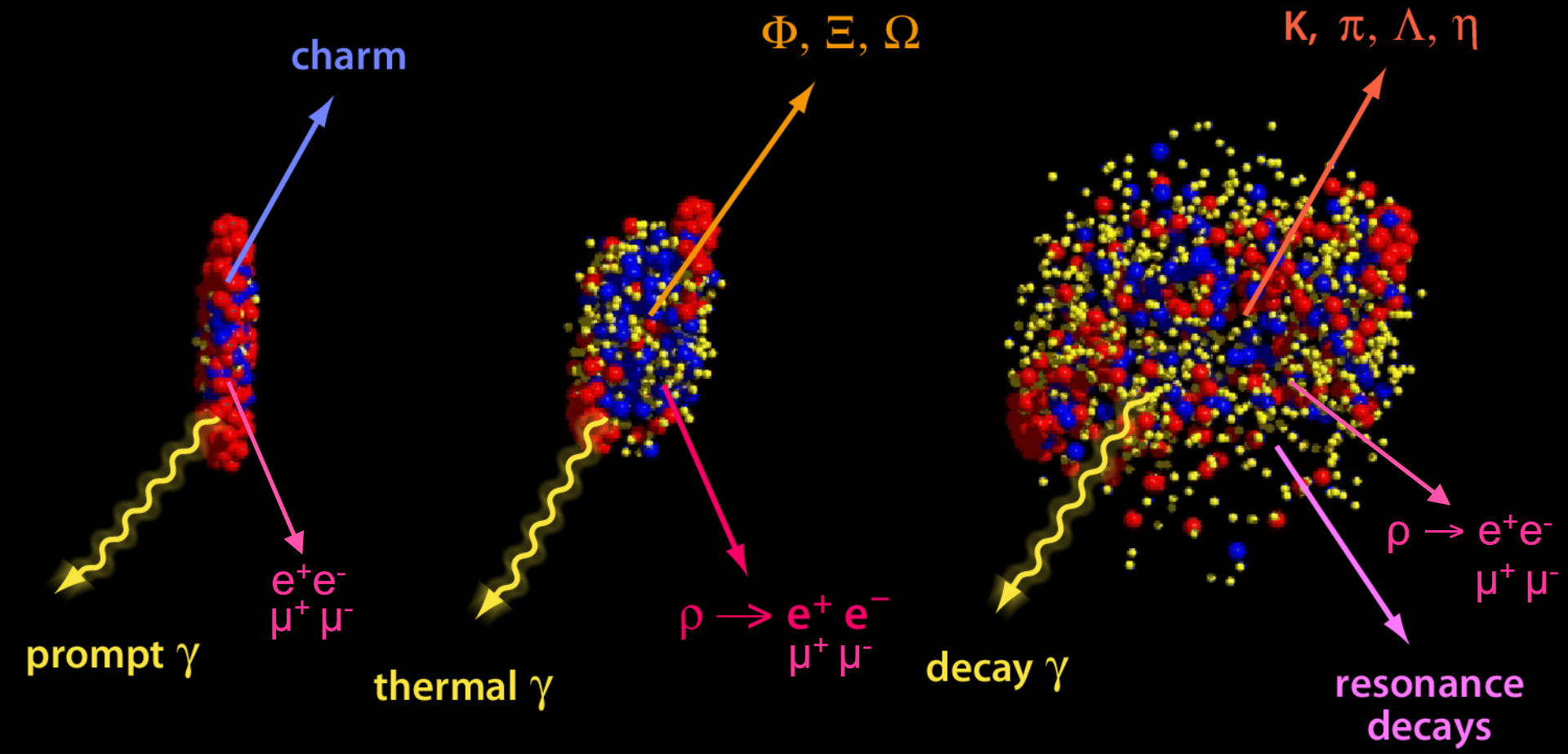


SIS100



Messengers from the dense fireball

UrQMD transport calculation U+U 23 AGeV



CBM physics case and observables

The equation-of-state at high ρ_B (SIS100/300)

- collective flow of hadrons (driven by pressure)
- production of multi-strange hyperons at threshold energies (sensitive to density)

New phases of strongly-interacting matter (SIS100)

Deconfinement phase transition at high ρ_B (SIS300)

- excitation function and flow of strangeness (K, Λ, Σ, Ξ, Ω)
- excitation function and flow of charm (J/ψ, ψ', D^0, $D^{\pm}$, Λ_c)
- excitation function of low-mass lepton pairs

QCD critical endpoint (SIS300)

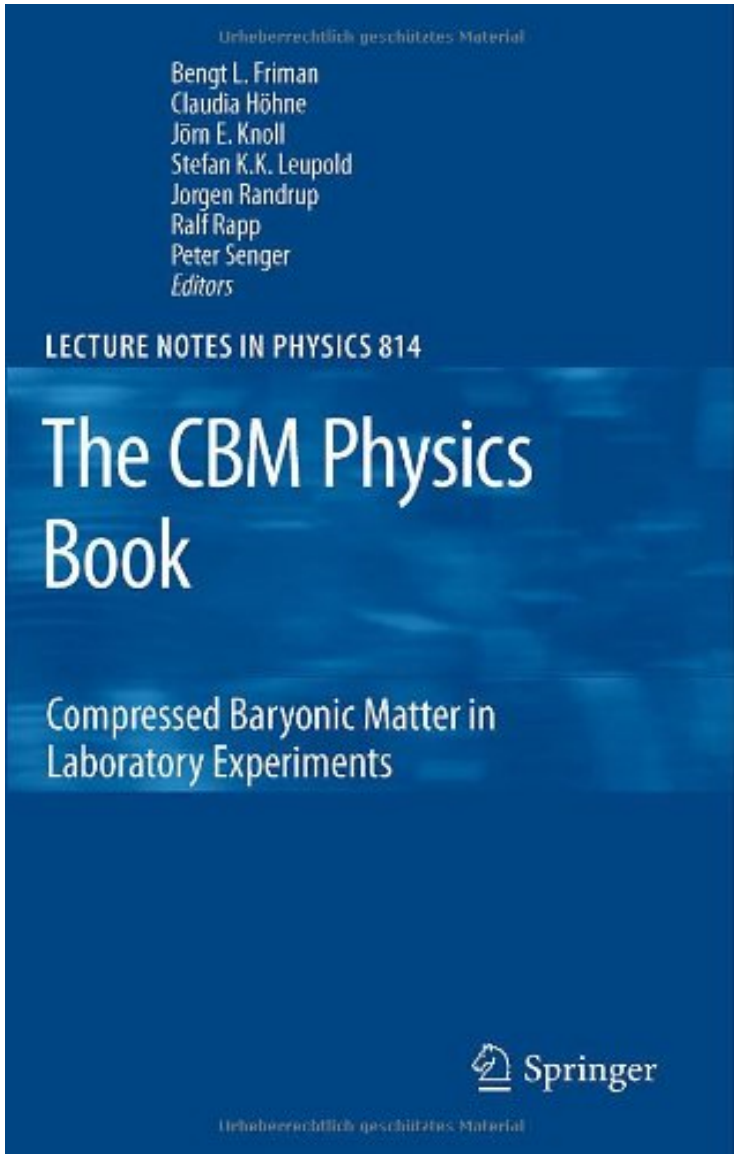
- excitation function of dynamical event-by-event fluctuations

Onset of chiral symmetry restoration at high ρ_B (SIS100/300)

- in-medium modifications of hadrons ($\rho,\omega,\phi \rightarrow e^+e^-(\mu^+\mu^-)$, D)

Strange matter (SIS100/300)

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



The CBM Physics Book

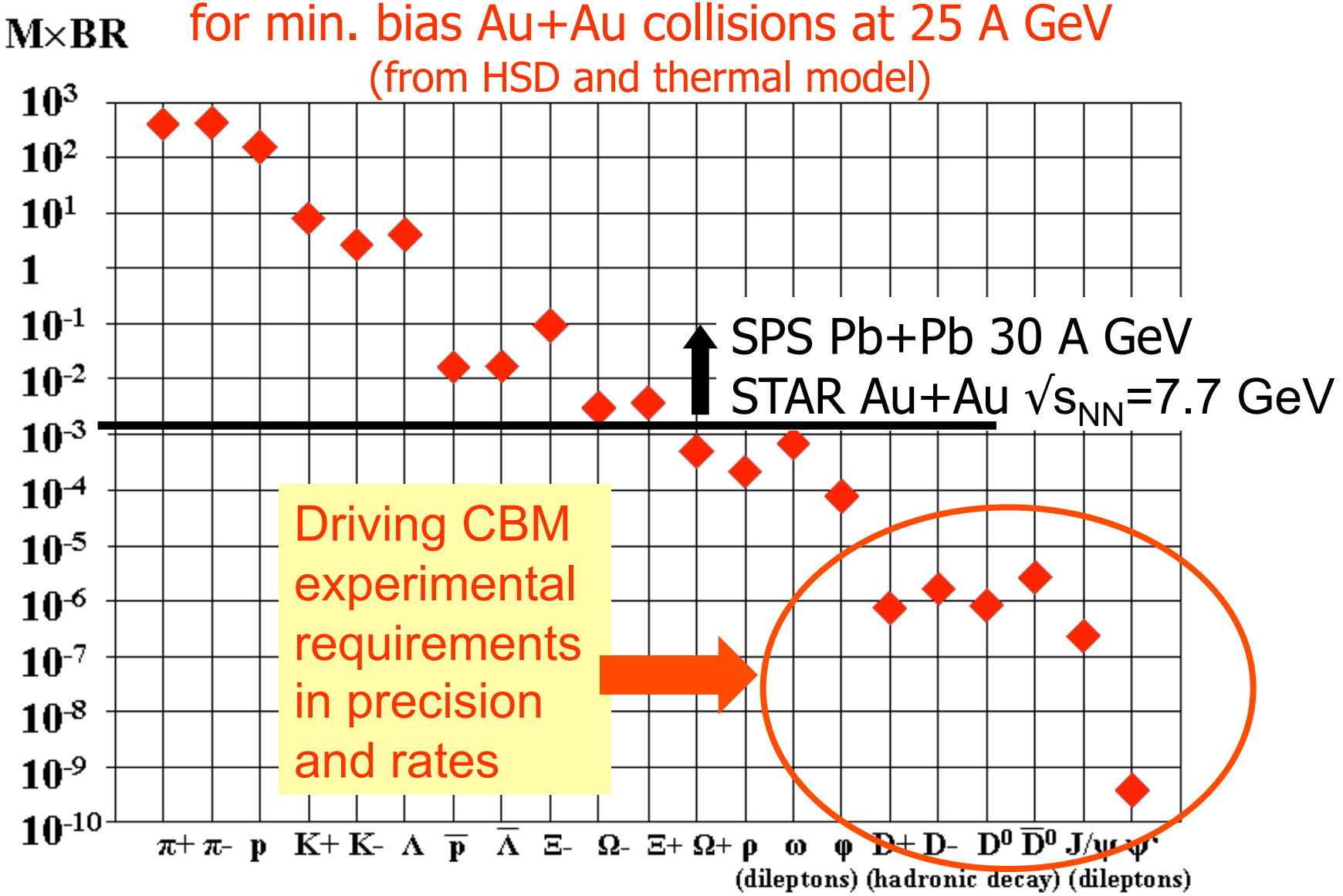
Foreword by Frank Wilczek

Springer Series:
Lecture Notes in Physics, Vol. 814
1st Edition., 2011, 960 p., Hardcover
ISBN: 978-3-642-13292-6

Electronic Authors version:
http://www.gsi.de/documents/DOC-2009-Sep-120-1.pdf

Experimental challenges

Particle multiplicity x branching ratio
for min. bias Au+Au collisions at 25 A GeV
(from HSD and thermal model)



Experiments on superdense nuclear matter

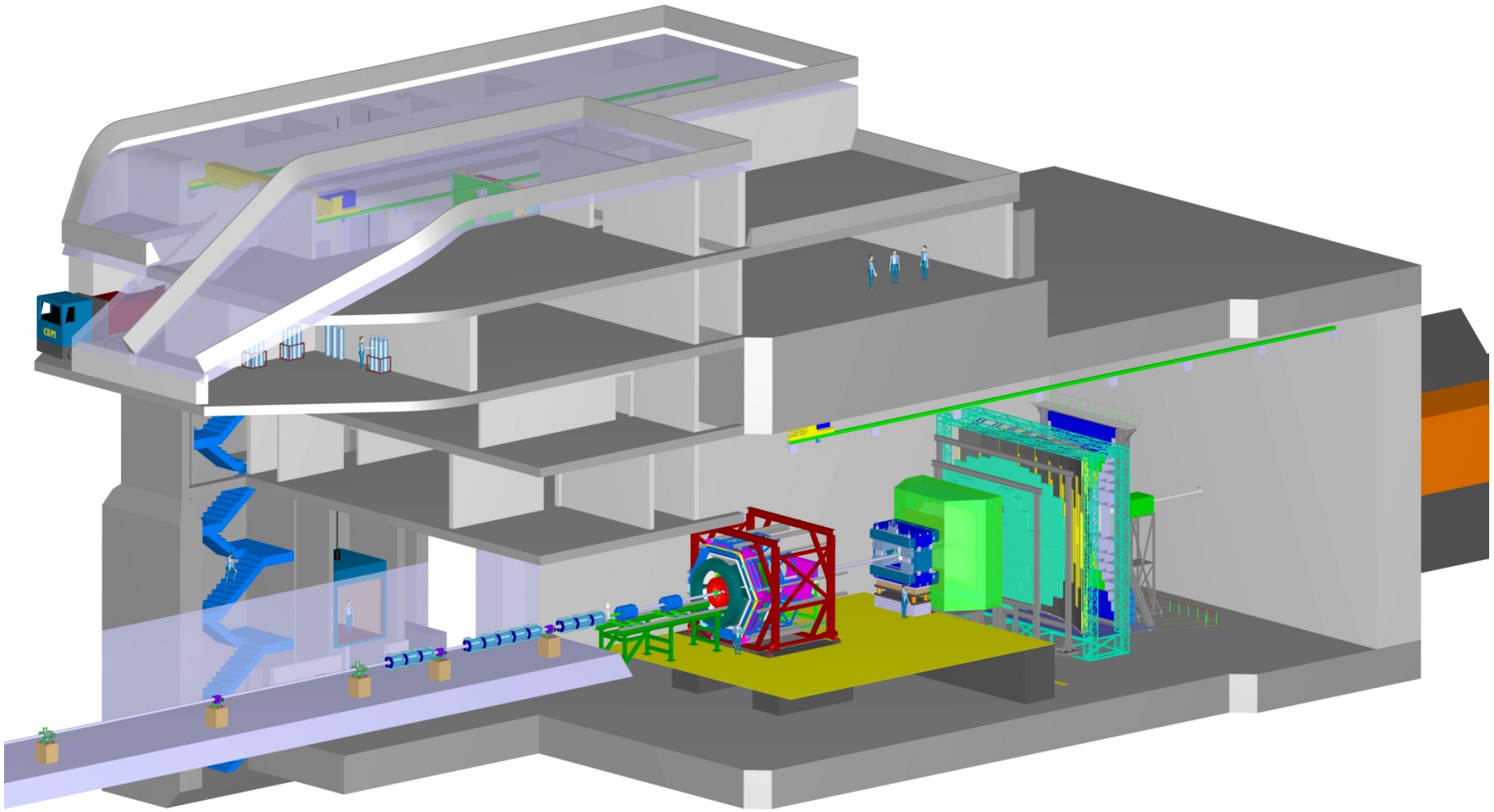
Experiment	Energy range (Au/Pb beams)	Reaction rates Hz
STAR@RHIC BNL	$\sqrt{s_{NN}}$ = 7 – 200 GeV	1 – 800 (limitation by luminosity)
NA61@SPS CERN	E_{kin}= 20 – 160 A GeV $\sqrt{s_{NN}}$= 6.4 – 17.4 GeV	80 (limitation by detector)
MPD@NICA Dubna	$\sqrt{s_{NN}}$= 4.0 – 11.0 GeV	~1000 (design luminosity of 10^{27} $cm^{-2}s^{-1}$ for heavy ions)
HADES@SIS100	1.5 A GeV Au+Au 8 A GeV Ni+Ni	510^4
CBM@FAIR Darmstadt	E_{kin}= 2.0 – 35 A GeV $\sqrt{s_{NN}}$= 2.7 – 8.3 GeV	10^5 – 10^7 (limitation by detector)

Technological challenges

Central Au+Au collision at 25 AGeV (UrQMD + GEANT4):
160 p 400 π^- 400 π^+ 44 K^+ 13 K^-

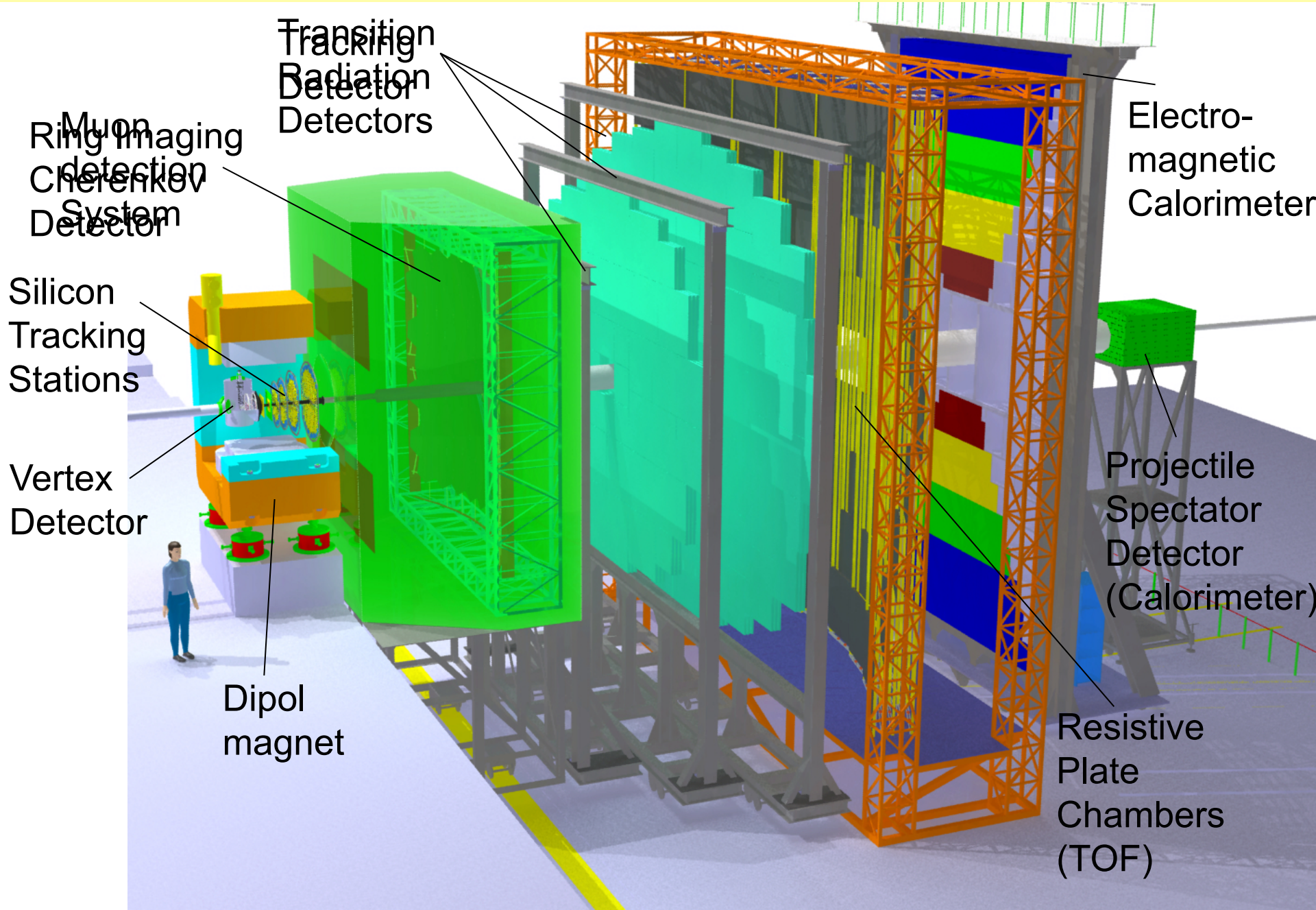
- 10^5 - 10^7 Au+Au reactions/sec
- determination of (displaced) vertices ($\sigma \approx 50$ μm)
- identification of leptons and hadrons
- fast and radiation hard detectors
- free-streaming readout electronics
- high speed data acquisition and high performance computer farm for online event selection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

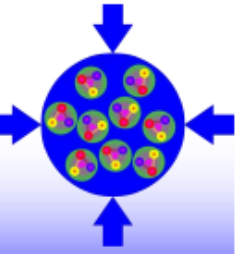
CBM/HADES Cave



Physics program with HADES: hadrons and electron-positron pairs
in Au+Au collisions up to 1.5 A GeV, and Ni+Ni collisions up to 8 A GeV

The Compressed Baryonic Matter Experiment





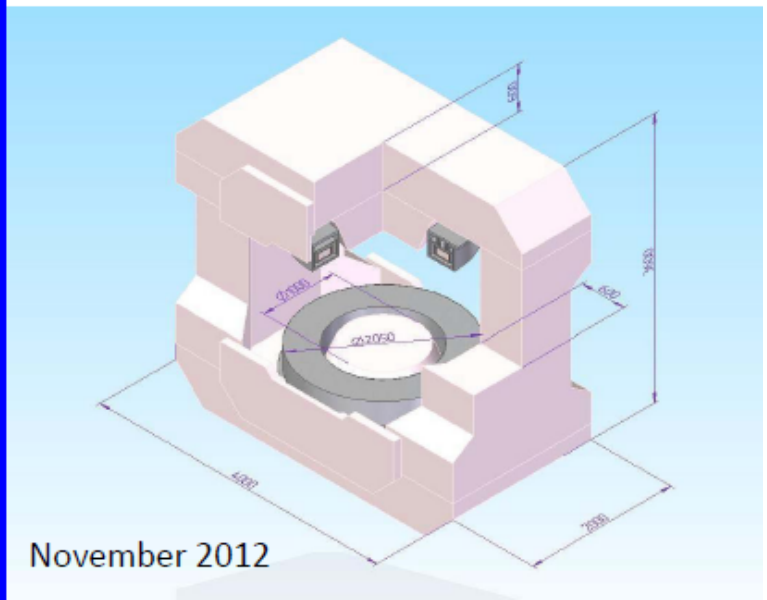
Compressed Baryonic Matter Experiment

Technical Design Report for the CBM

Responsible Institute:
JINR Dubna

Superconducting Dipole Magnet

The CBM Collaboration



November 2012

Review Board:

P. Fabbricatore, INFN Genova, Italy
B. Gastineau, CEA Saclay, France
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D. Swoboda, CERN
D. Tommasini, CERN
F. Toral, CIEMAT Madrid, Spain
A. Zeller, MSU, USA

Experts from GSI:

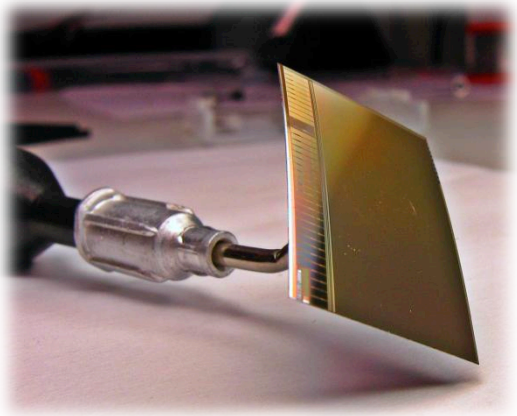
E. Floch, I. Lehmann, H. Leibrock,
J. Lühning, G. Moritz, C. Mühle, C. Will

Meetings:
January 11-12, 2012
June 18-19, 2012
November 5-6, 2012

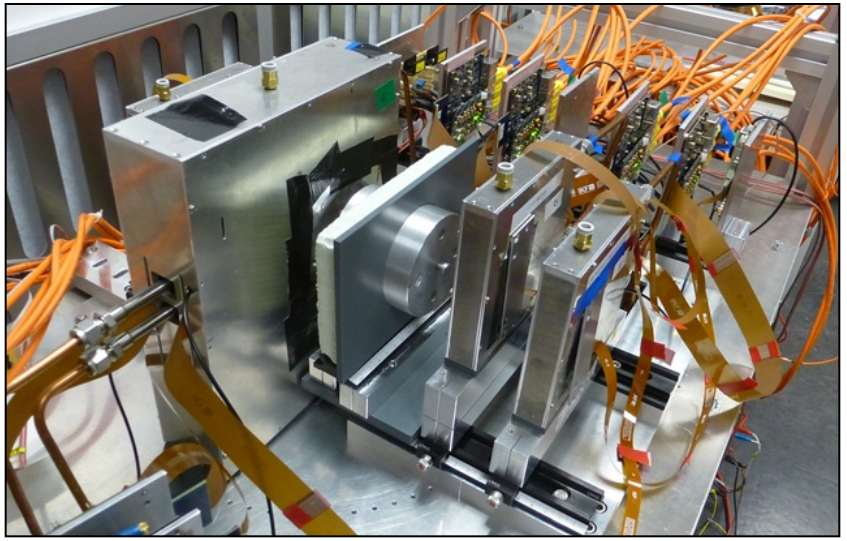
Micro-Vertex Detector

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

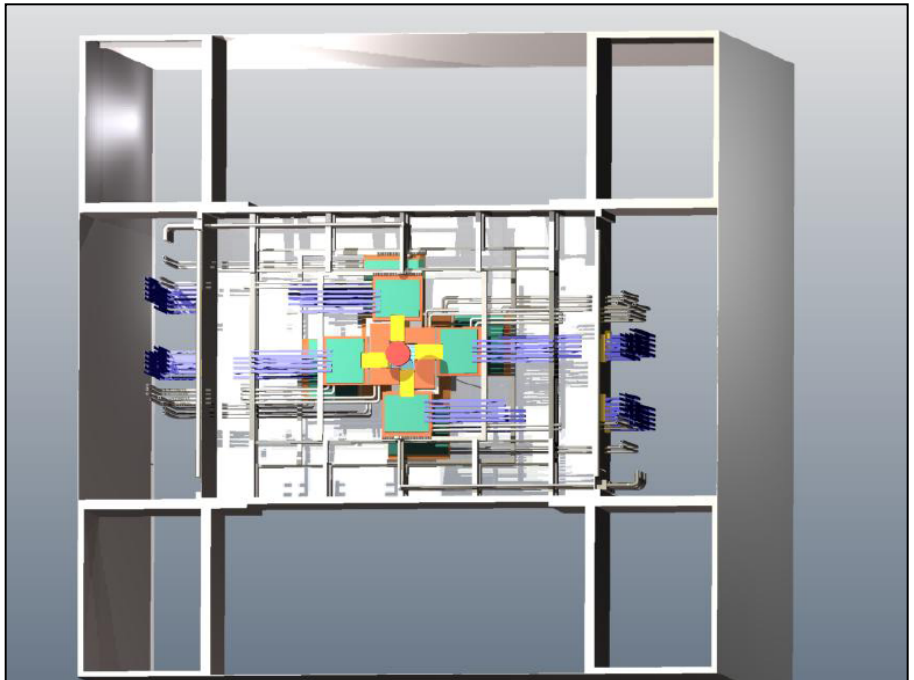
Univ. Frankfurt, IPHC Strasbourg



Monolithic Active Pixel Sensors (MAPS)



MIMOSA-26 :
600 kPixel, 10^4 frames/s, zero suppression
thinned to 50µm, at IKF Frankfurt



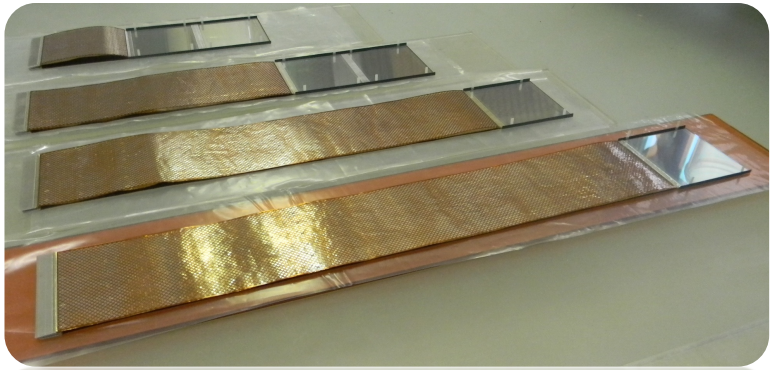
Micro Vertex Detector:

- Pixel size about 20x20 µm^2
- Position resolution σ = 4 µm
- Vertex resolution 50-100 µm (beam axis)
- Total material budget 300 – 500 µm silicon equivalent
- 3 stations at 5, 10, 15 cm from target

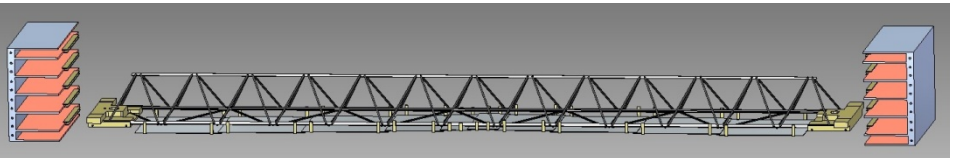
The CBM Silicon Tracking System

Silicon sensors:
double-sided micro-strips,
1024 strips on each side,
58 μm pitch, stereo angle 0°, 7.5°
width 60 mm, height 20, 40, 60 mm

Micro cables from sensors to FEBs

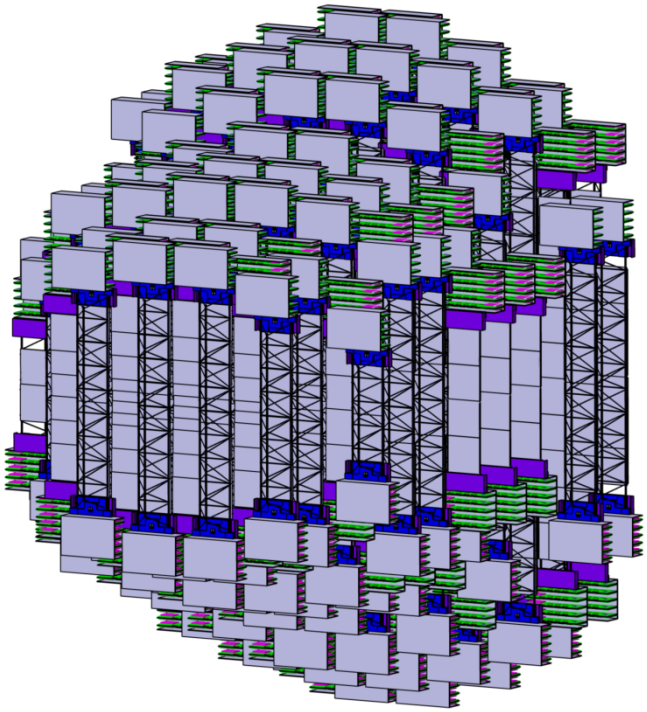


Light weight carbon fibre ladders

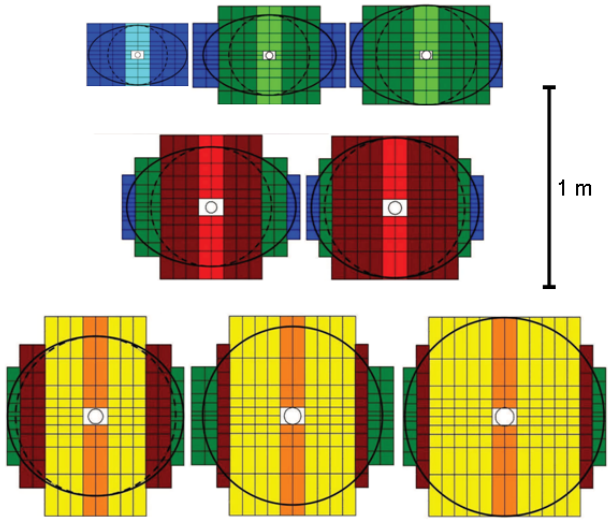


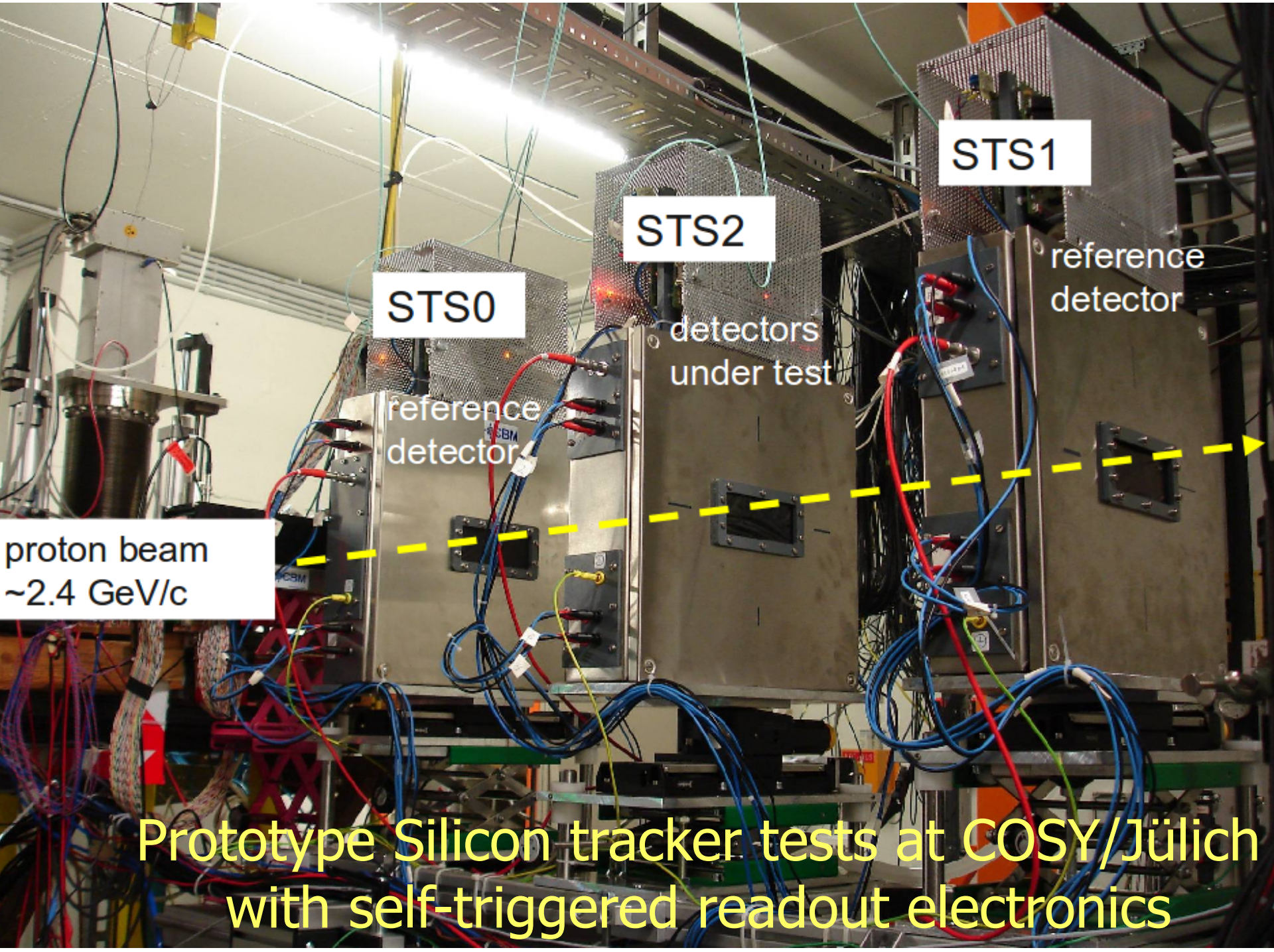
ASIC:
free streaming, hits with time stamp

FEB cooling: CO_2



8 STS stations, distance from target 30–100 cm





Prototype Silicon tracker tests at COSY/Jülich with self-triggered readout electronics

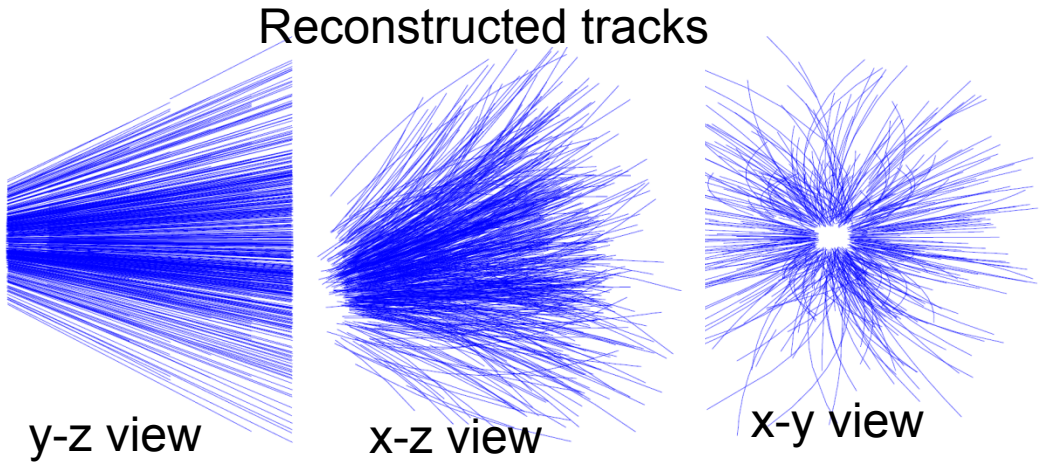
STS tracking performance

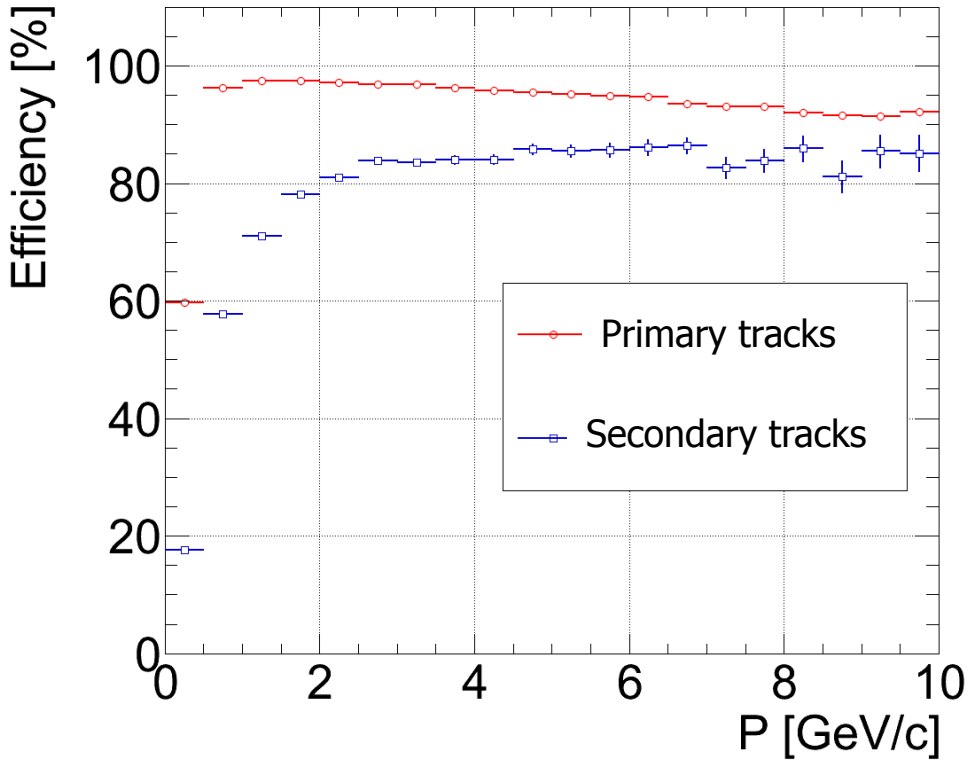
STS with realistic material budget
Central Au+Au collisions 25 A GeV

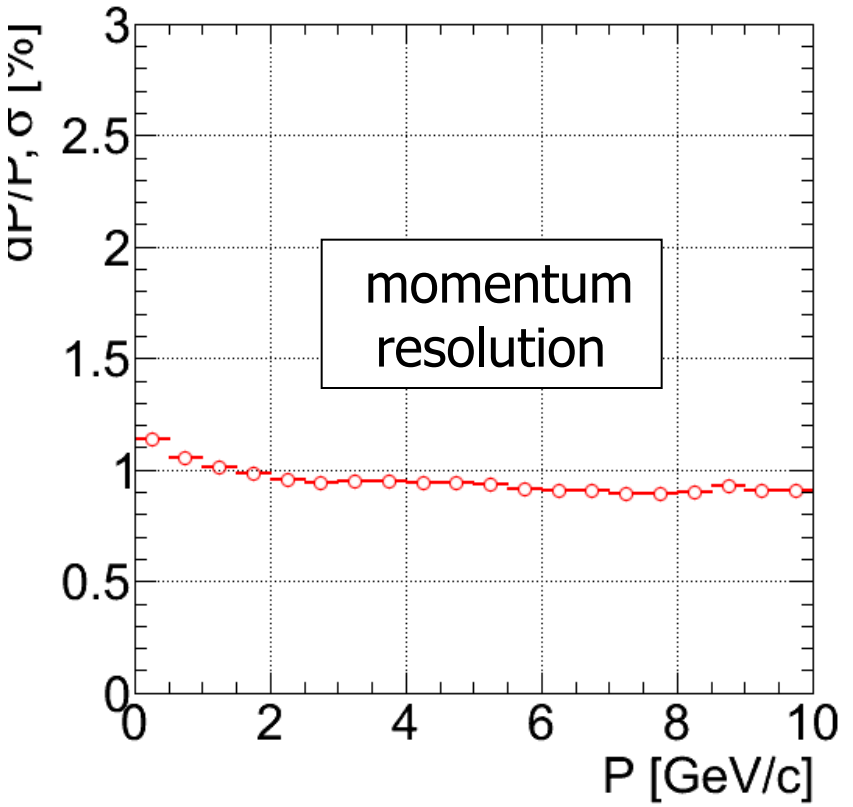
Track finding: Cellular Automaton

Track and vertex fitting:Kalman filter

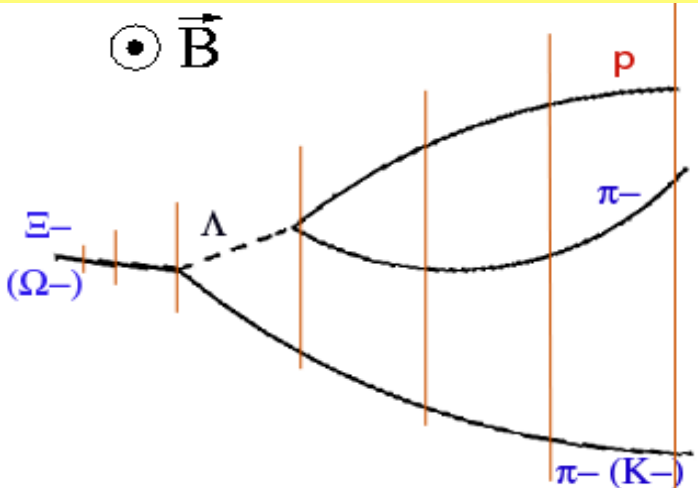
Running on many-core CPUs

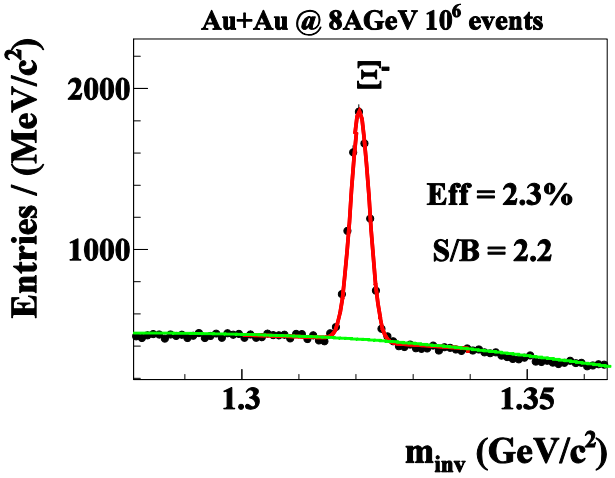


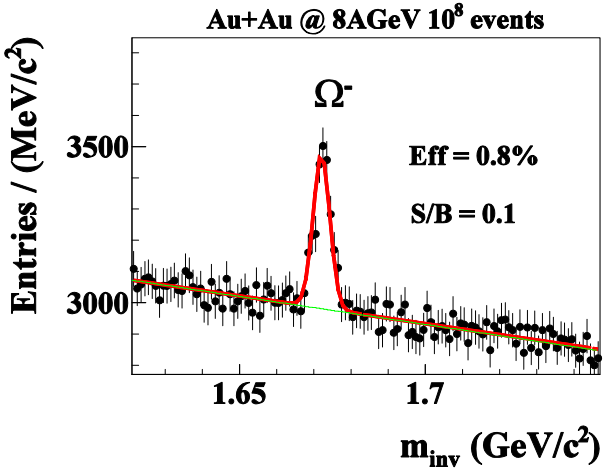




Hyperon production in 8 A GeV central Au+Au collisions



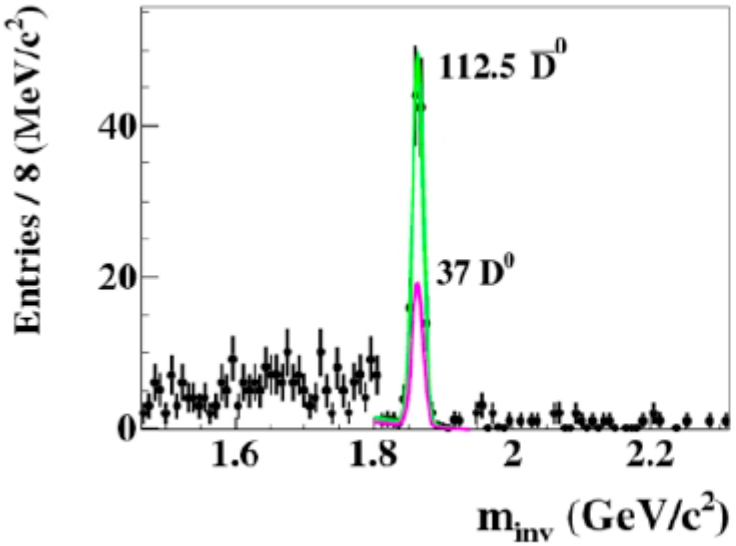




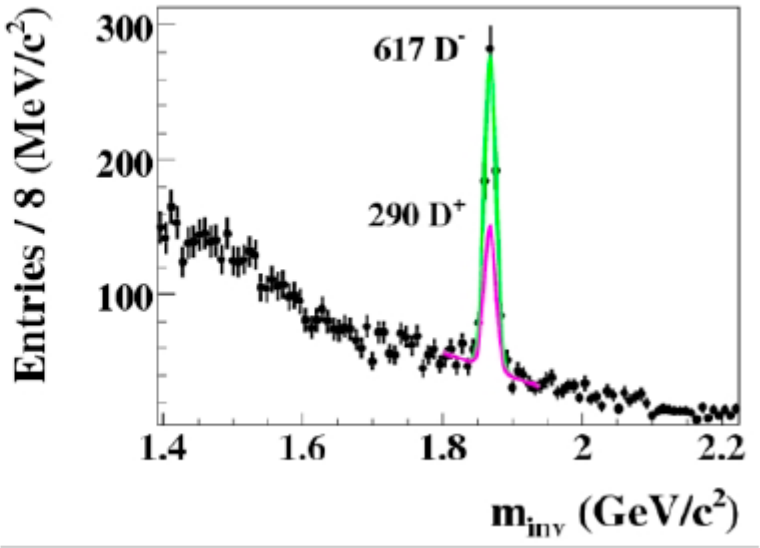
no particle identification by time-of-flight

D-meson production in 30 GeV p+C collisions (SIS100)

no particle identification by time-of-flight



$D^0 \rightarrow K\pi\pi\pi\pi$



$D^{\pm} \rightarrow K\pi\pi\pi\pi$

Yields for 1MHz min. bias collisions 30 GeV p+C

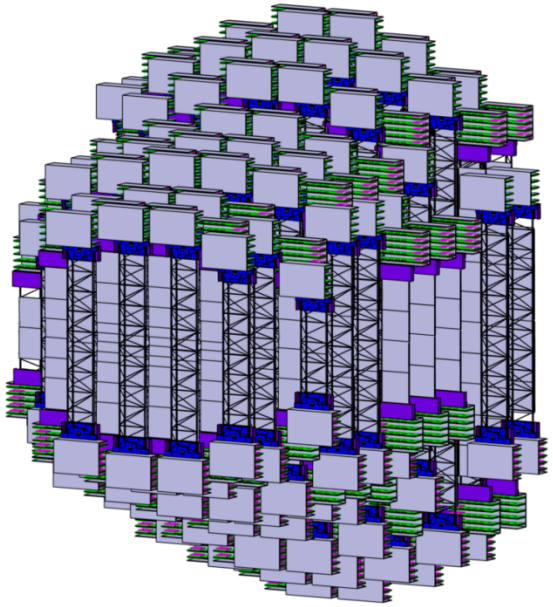
	D^+	D^-	D^0	$\overline{D}^0$
Decay channel	$K^+\pi^+\pi-$	$K^-\pi^-\pi^+$	$K^-\pi^-\pi^+\pi^+$	$K^+\pi^+\pi^-\pi^-$
Multiplicity central	$2.7 \cdot 10^{-8}$	$5.5 \cdot 10^{-8}$	$2.9 \cdot 10^{-8}$	$8.8 \cdot 10^{-8}$
Multiplicity min. bias	$9.0 \cdot 10^{-9}$	$1.8 \cdot 10^{-8}$	$9.7 \cdot 10^{-9}$	$2.9 \cdot 10^{-8}$
branching ratio	9.5%	9.5%	8.1%	8.1%
efficiency	13%	13%	1.7%	1.7%
yield per week	67	134	8	24

Compressed Baryonic Matter Experiment

Technical Design Report for the CBM

The Silicon Tracking System (STS)

The CBM Collaboration



Participating institutes:
GSI Darmstadt, JINR Dubna, Univ. Frankfurt, Silesia Univ. Katowice, SE SRTIIE Kharkov, KINR Kiev, AGH Krakow, Jag. Univ. Krakow, ITEP Moscow, Moscow State Univ., IHEP Protvino, Joffe Inst. St. Petersburg, St. Petersburg State Univ.
Univ. Tübingen

Review Board:

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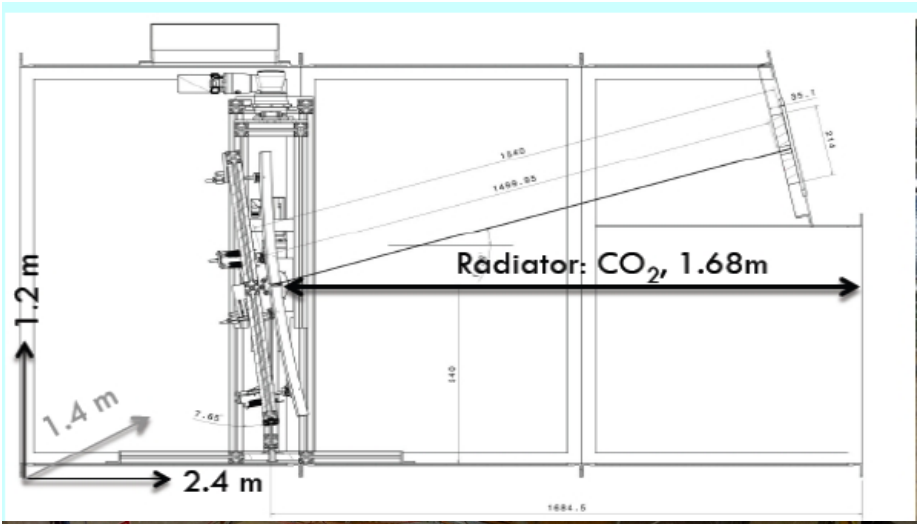
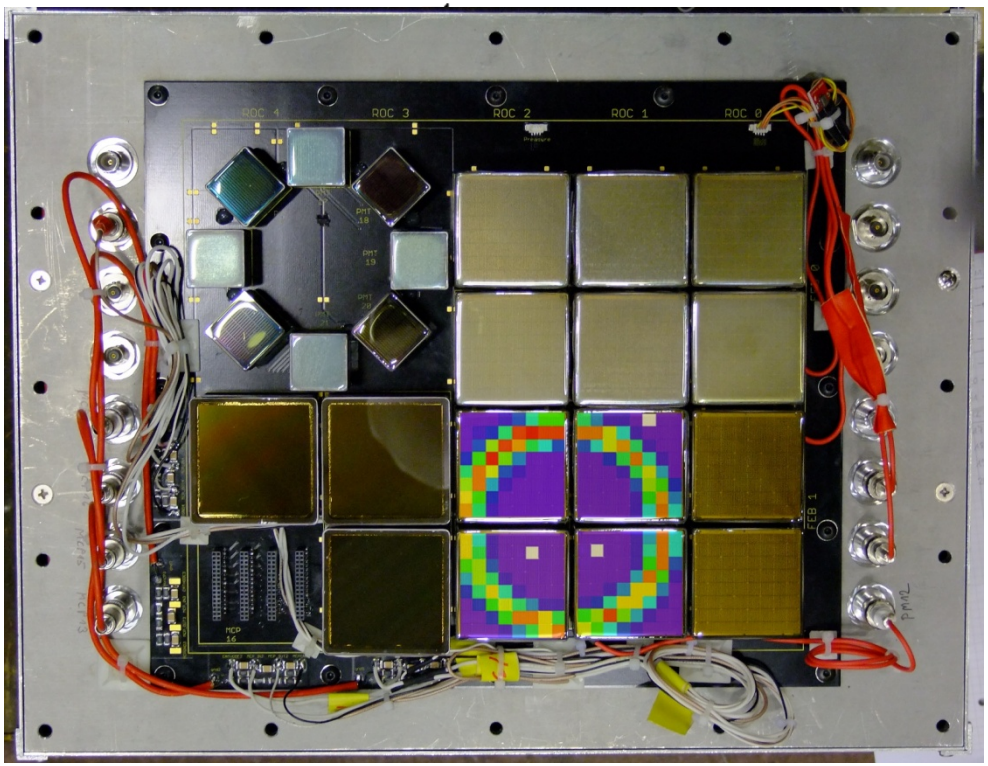
Luciano Musa, CERN, ALICE
Gerd-Jan Nooren, NIKHEF, ALICE
Ulrich Parzefal, Univ. Freiburg, ATLAS
Rainer Richter, MPI-HLL

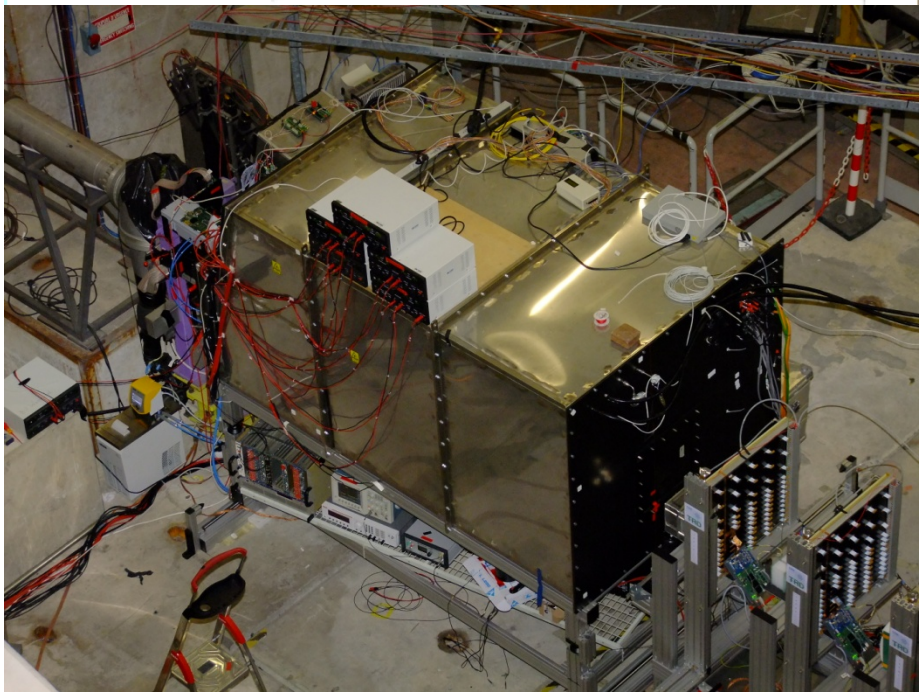
Meeting: Oct. 17-18, 2012

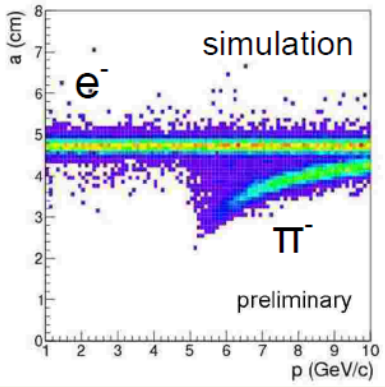
Prototype RICH beam test at CERN-SPS

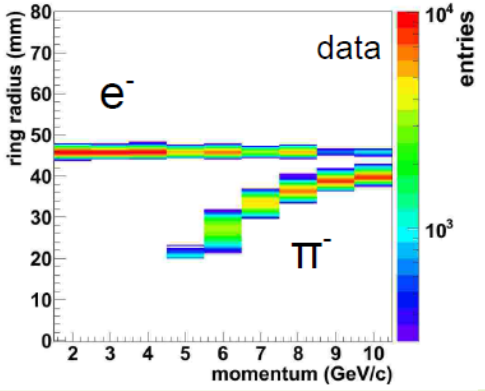
Univ. Gießen, Univ. Wuppertal, HS Esslingen, GSI, PNPI Gatchina, Pusan Natl. Univ.





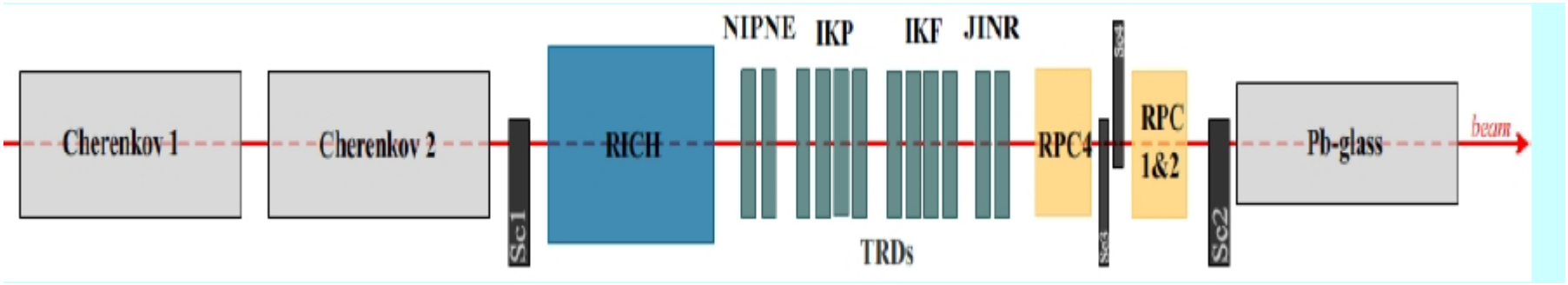


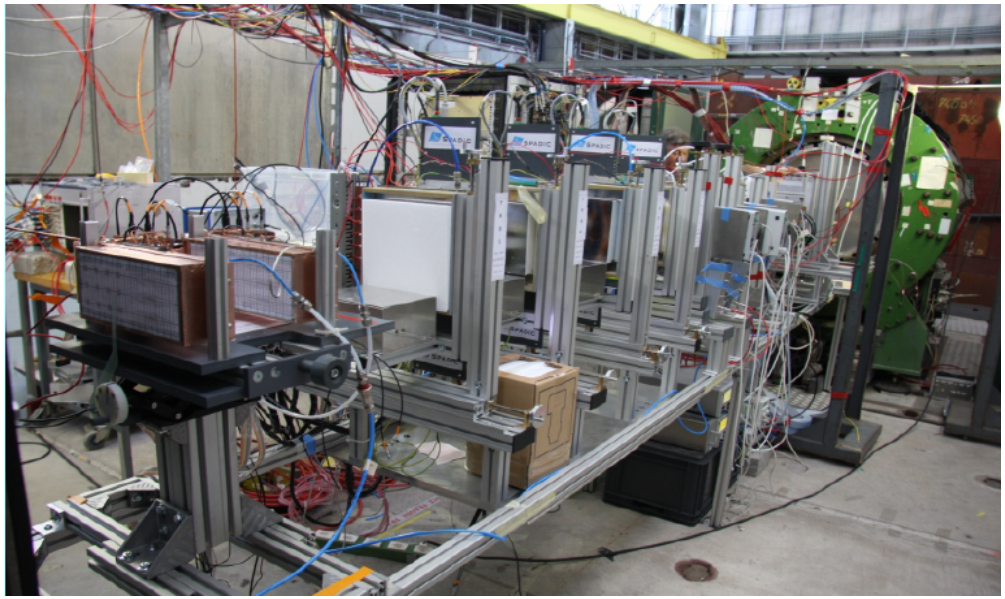




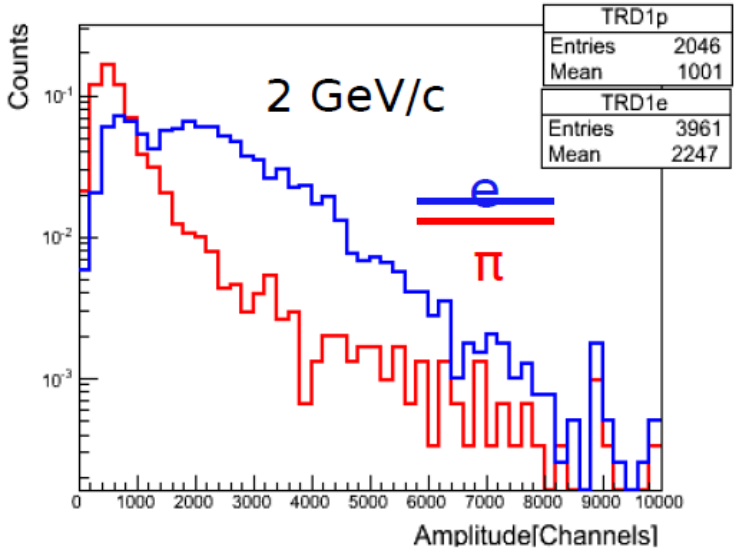
Prototype CBM detectors (RICH, TRDs, RPCs): Beam tests at CERN

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





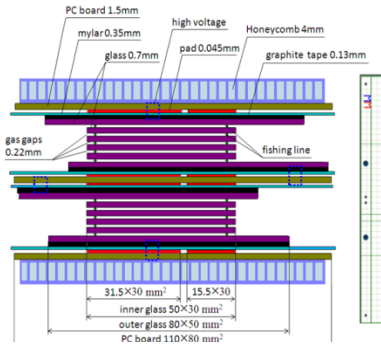
Energy loss in Transition Radiation Detectors



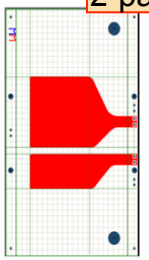
TRD requirements: 100 kHz/cm^2, 700 m^2

Time-of-Flight Detector: MRPCs with low-resistivity glass

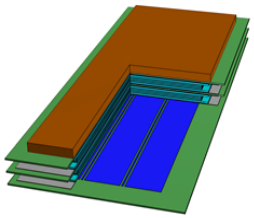
Prototype MRPC tests at ELBE (HZDR)

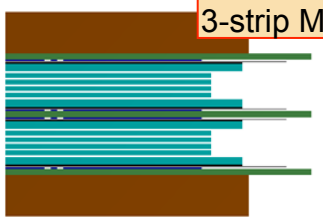


2-pad MRPC

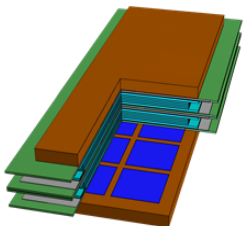


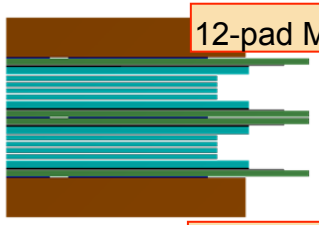
3-strip MRPC



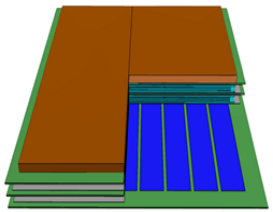


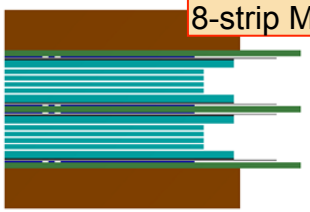
12-pad MRPC



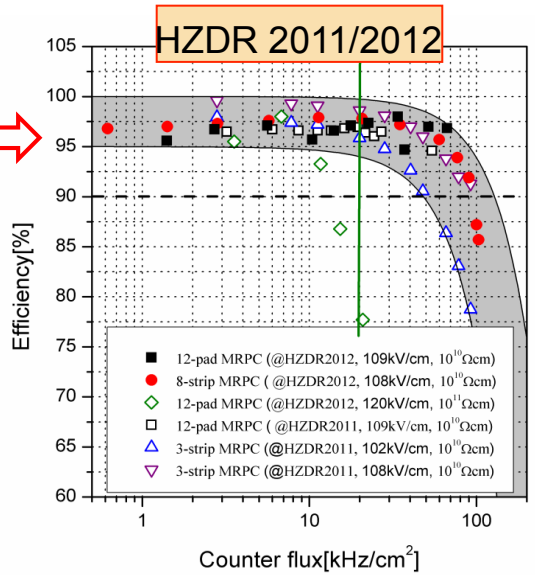


8-strip MRPC

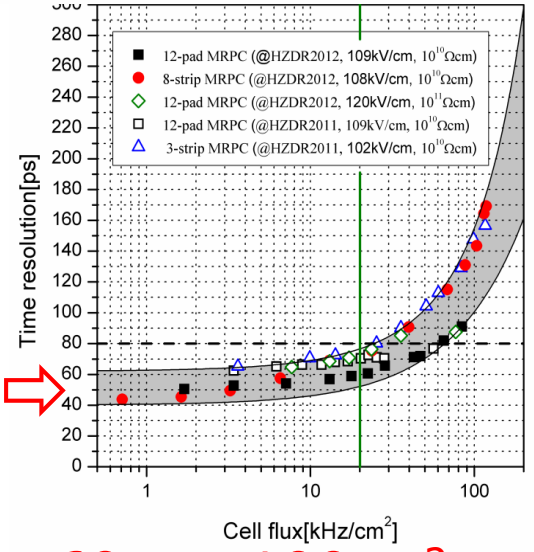




ε > 95% ⇨



σ= 40-60 ps ⇨



CBM requirements:
rates up to 25 kHz/cm², time resolution 60 ps, 100 m²

Load test of full size prototype MRPC at GSI

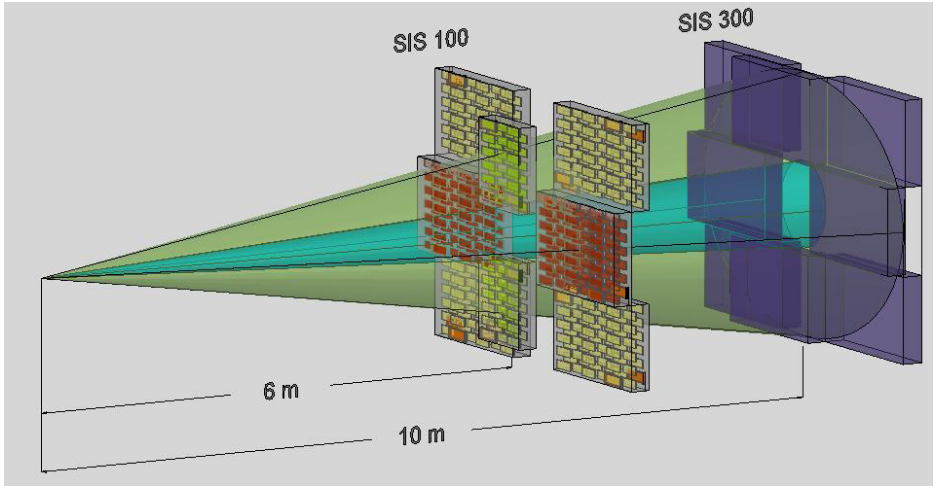
THU Beijing, NIPNE Bucharest, GSI Darmstadt, IRI Frankfurt, USTC Hefei, PI Heidelberg, INR Moscow, ITEP Moscow, HZDR Rossendorf, CCNU Wuhan, RBI Zagreb.

Kr + Pb (2% target) @ 1.2 AGeV

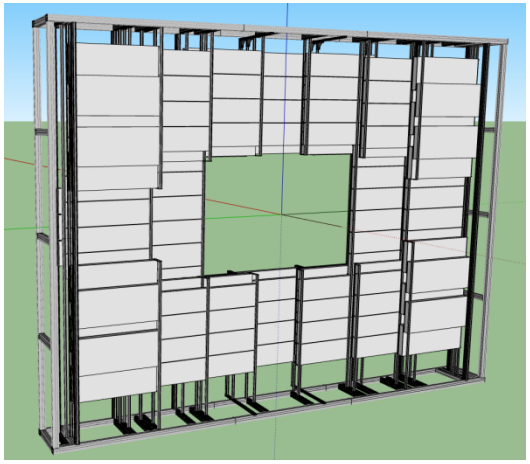
Flux with beam rates of
5 10^5/spill – (~) 5 10^7 /spill:
200 Hz/cm^2 – 100 kHz/cm^2

Layout of the MRPC TOF wall for CBM

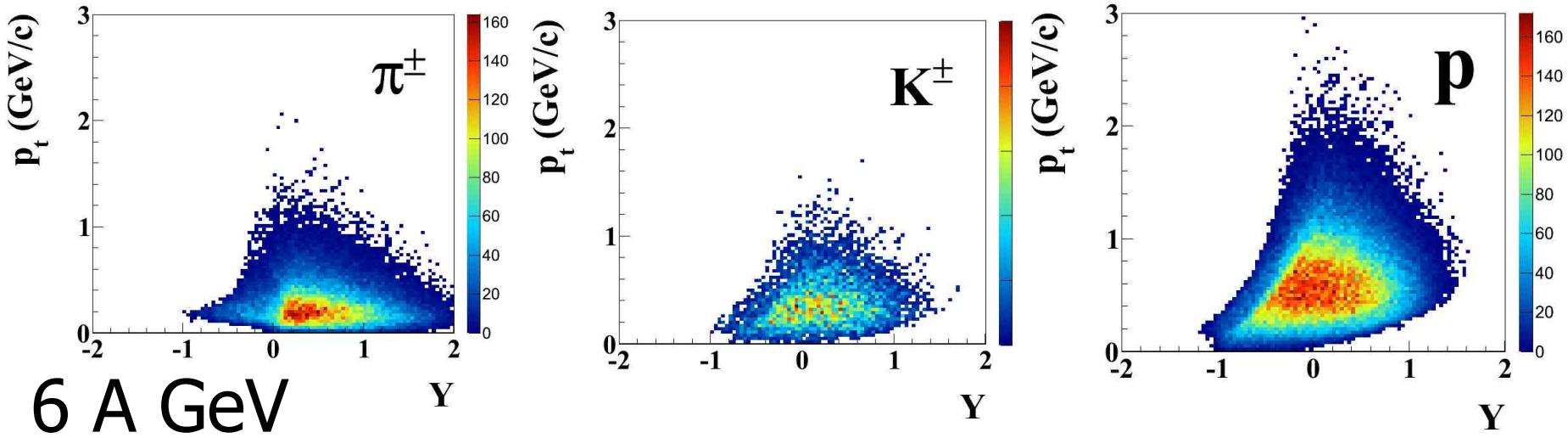
inner section (10 - 25 kHz/cm^2)



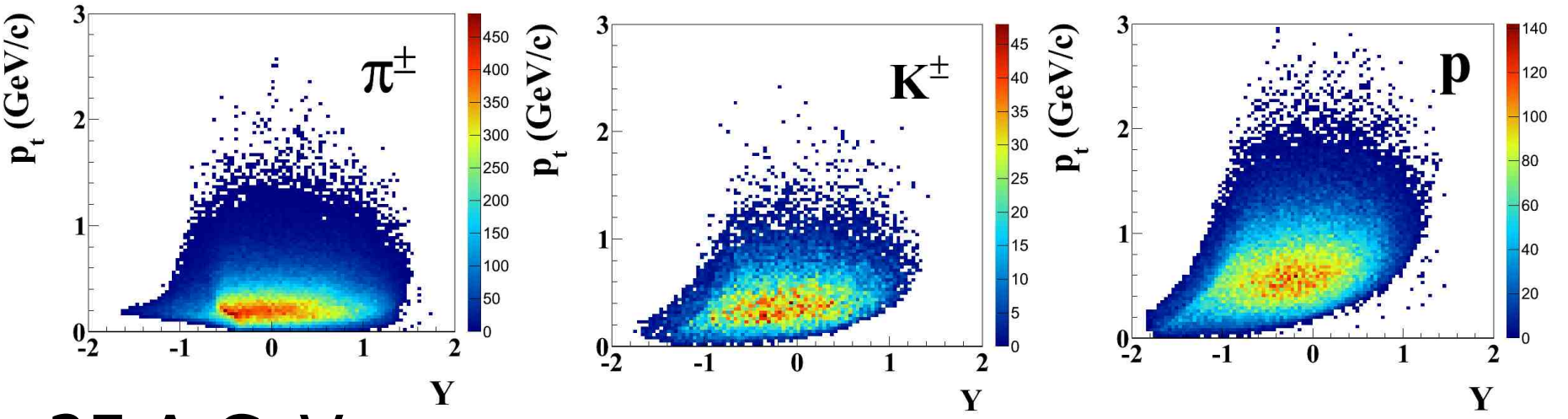
Outer section (2 – 10 kHz/cm^2)



CBM acceptance for central Au+Au collisions at SIS100 and SIS300 beam energies

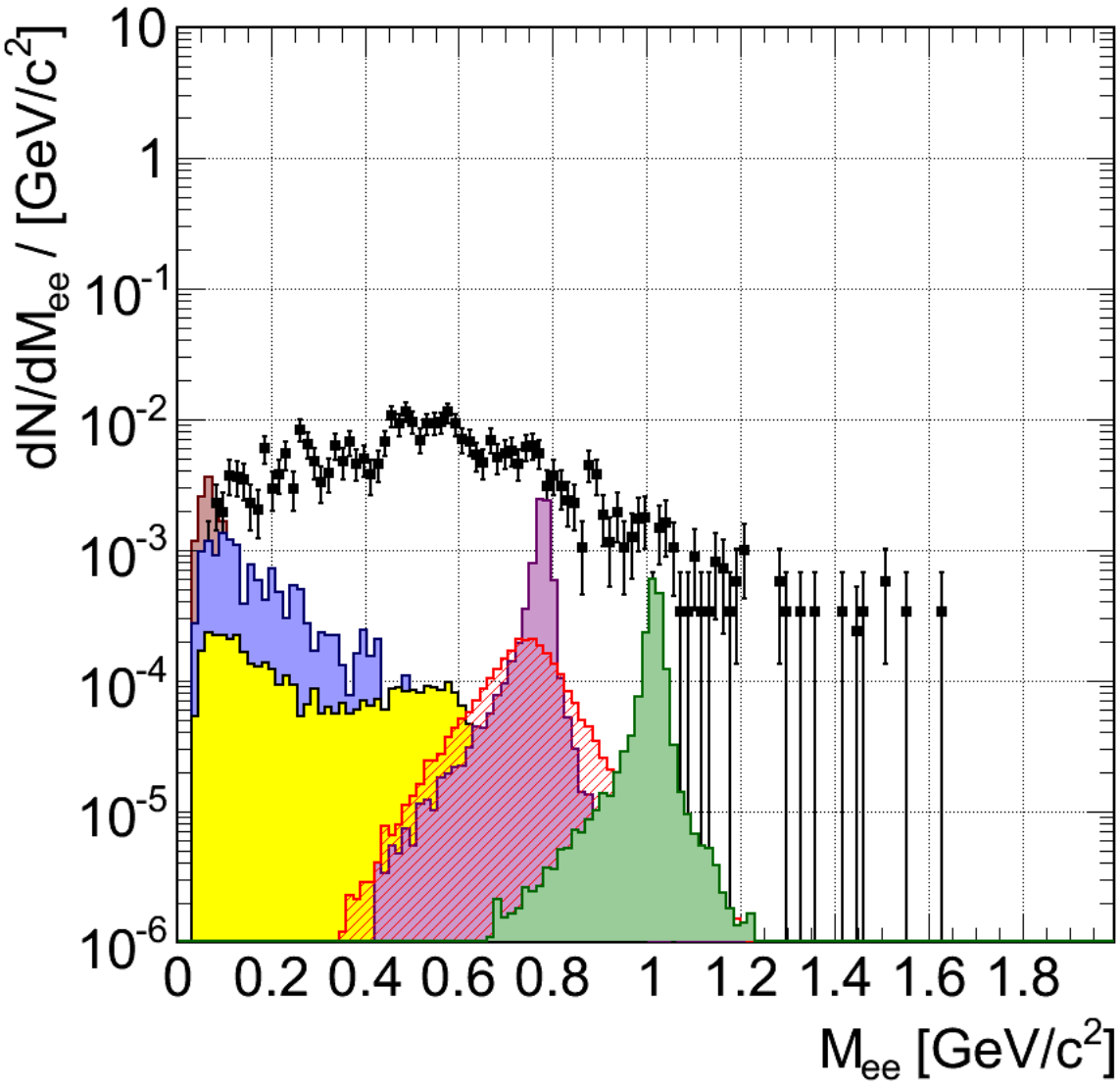


6 A GeV



25 A GeV

Dielectron invariant mass spectrum simulated for central 25 A GeV Au+Au collisions



<u>Setup:</u>

MVD

STS

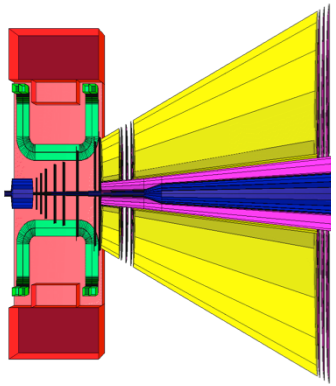
RICH

TRD

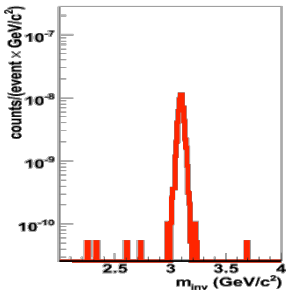
TOF

The Muon Detection System at SIS100

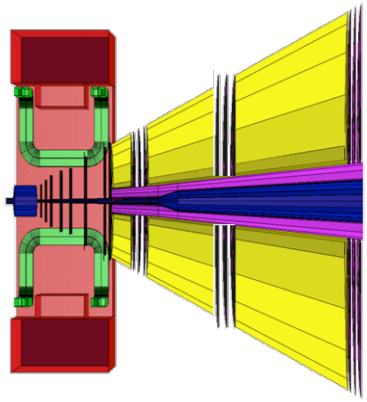
VECC Kolkata + Indian MUCH consortium (13 Inst.), PNPI Gatchina, JINR Dubna



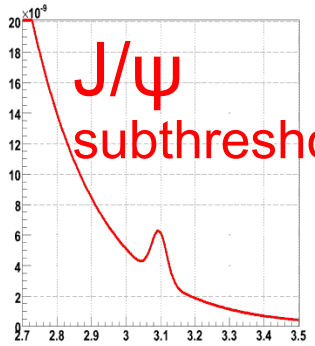
Start version I
25 GeV p+A → J/ψ
Iron absorber: 20+205 cm
2 detector triplets:
GEM + TRD



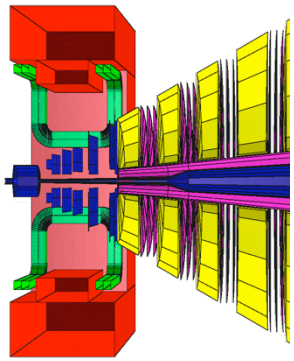
J/ψ



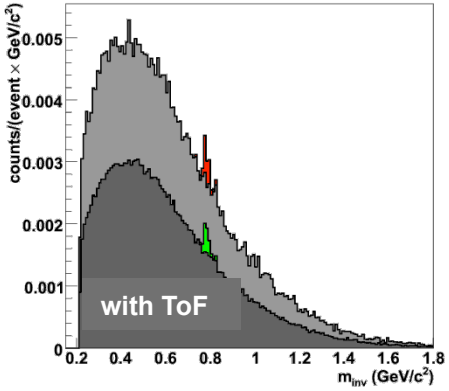
Start version II
10 A GeV Au+Au → J/ψ
Iron absorber: 20+70+135 cm
3 detector triplets:
GEM + straw tubes + TRD

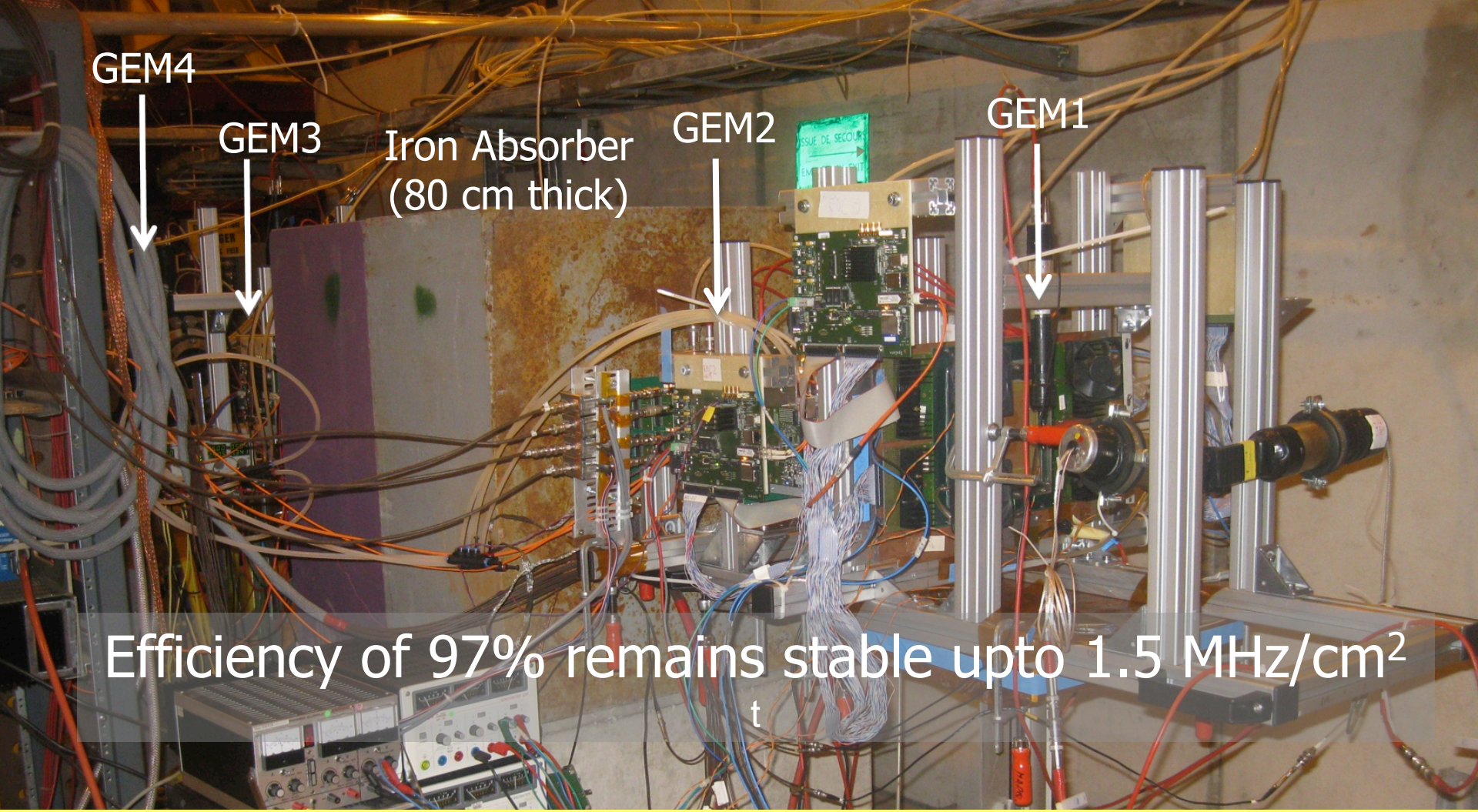


J/ψ
subthreshold !



Start version III
8 A GeV Au+Au → ω
Iron absorber: 3x20+30cm
4 detector triplets:
3 GEM + 1 straw tubes





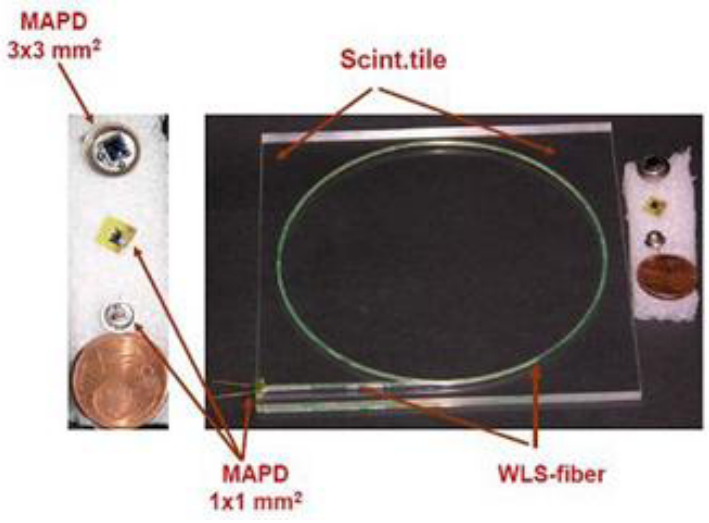
Prototype GEM detector tests with muon and pion beams at CERN using self-triggered readout electronics

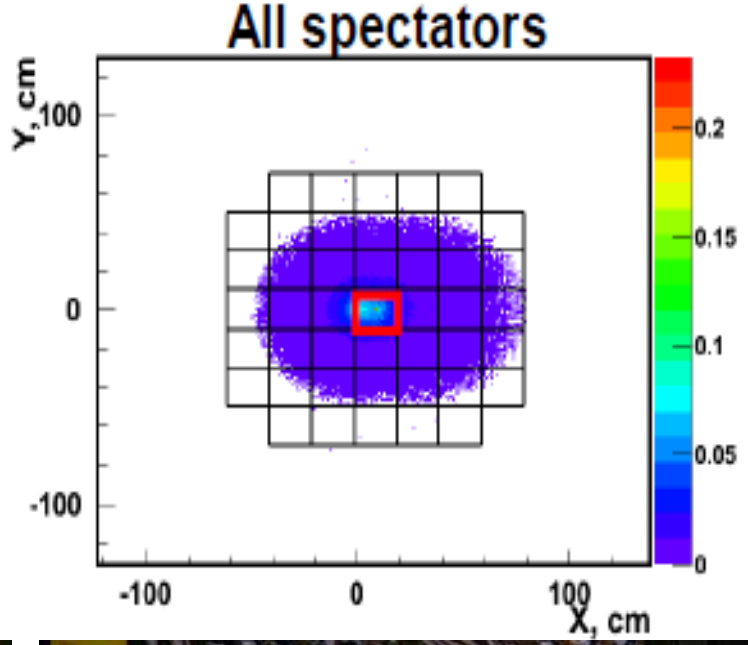
(VECC Kolkata, GSI, Univ. Tübingen)

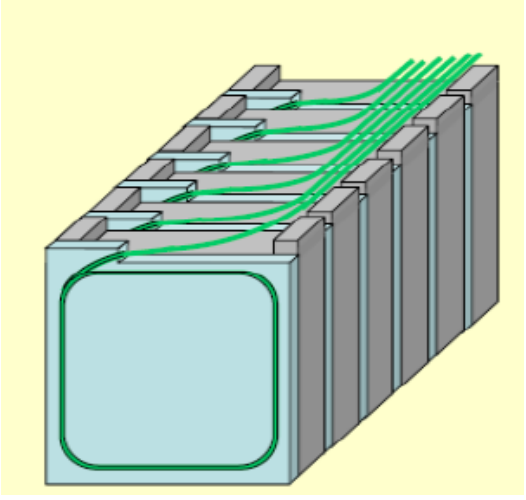
The Projectile Spectator Detector (PSD)

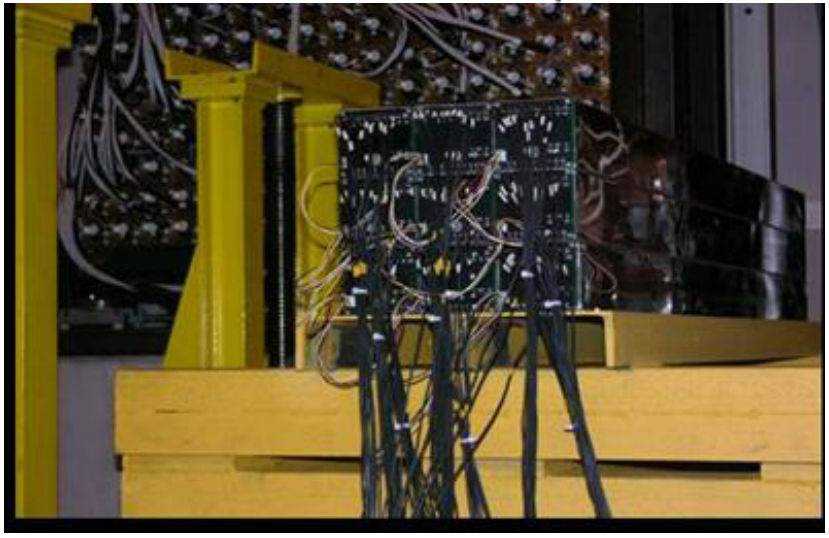
Task: determination of centrality and orientation of reaction plane

5 A GeV Au+Au collisions
PSD 6 m downstream of the target









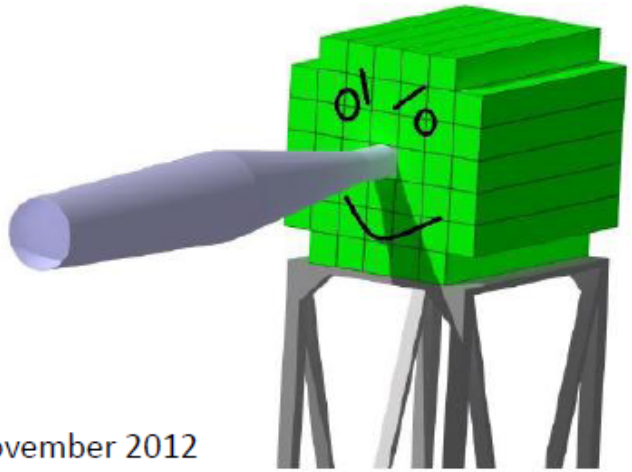
Compressed Baryonic Matter Experiment

Technical Design Report for the CBM

Participating Institutes:
INR Moscow,
CTU Prague,
NPI ASC Rez

Projectile Spectator Detector (PSD)

The CBM Collaboration



November 2012

Review Board:

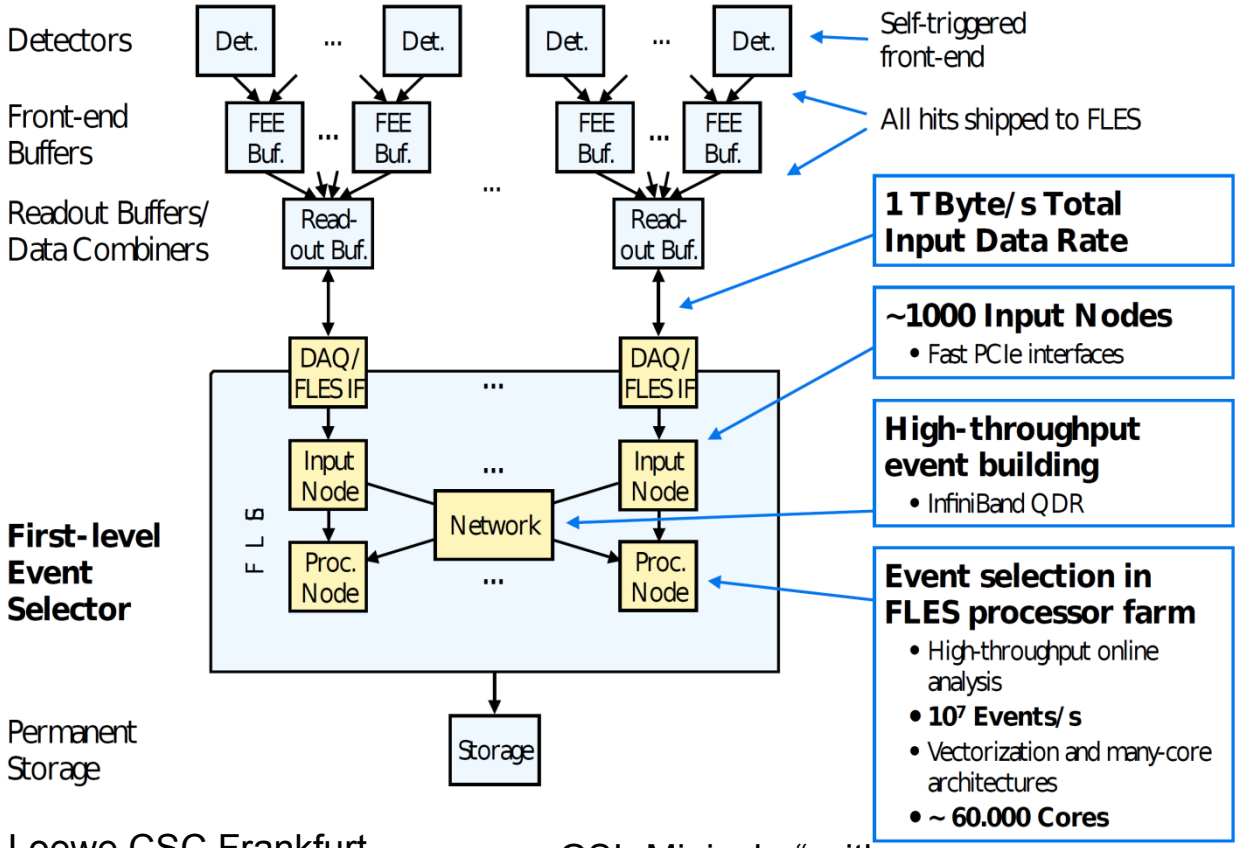
M. Kavatsyuk, Univ. Groningen
H.Ströbele, Univ. Frankfurt
C. Schwarz, GSI

Experts from GSI:

M. Traxler
J. Pietraszko

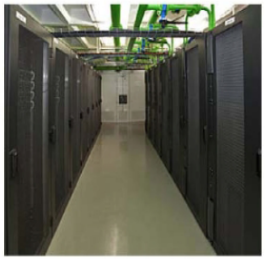
Meeting:
November 23, 2012

Free streaming data read-out + online event selection



Participating institutes:
FIAS Frankfurt,
IFI Univ. Frankfurt,
GSI,
ZITI Univ. Heidelberg
IIT Kharagpur
Warsaw University

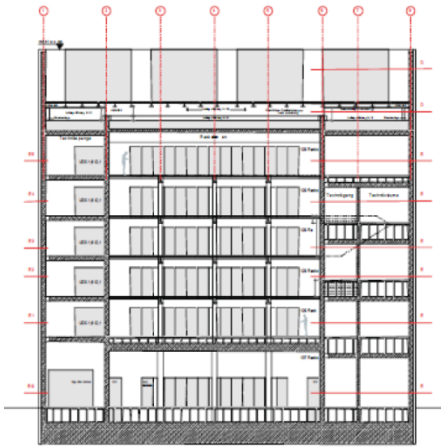
Loewe CSC Frankfurt



- rank 22 in the Top500 list of supercomputers
- ca. 800 nodes each with two 12-core processors and a GPU
- energy-efficient: cooling consumes less than 10 % of the total power
- highly optimized software required:
  parallelization, vectorization, and GPU-programming

GSI „Minicube“ with several 10.000 cores

„GreenIT cube“:
planned FAIR Tier-0 data center

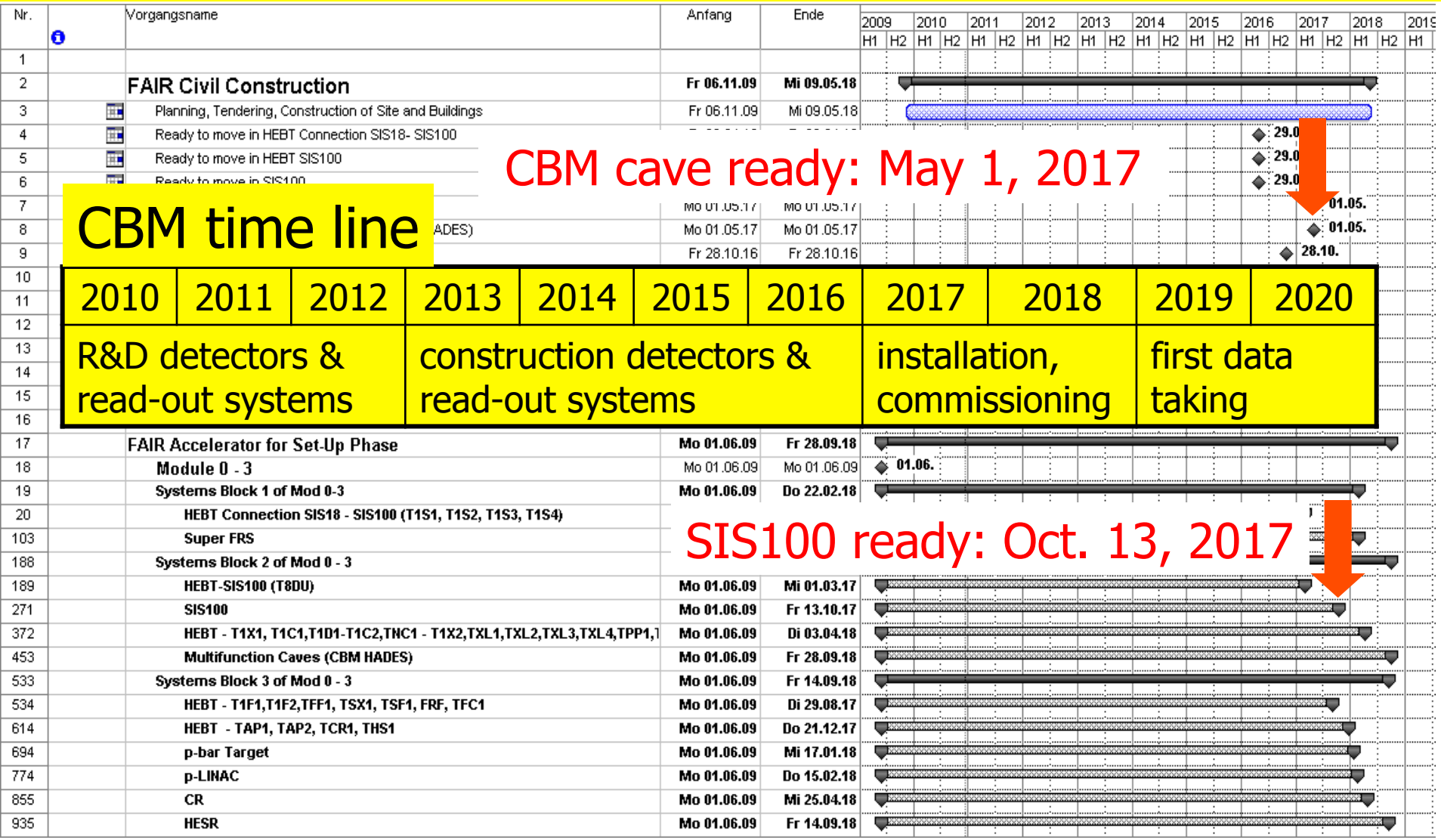


Schedule CBM Technical Design Reports

Subsystem	Status	TDR submission
Magnet	Design ready	Dec. 2012 / Jan. 2013
Micro-Vertex Detector	Prototype tests with beams	2014
Silicon Tracking System	Design ready, successful prototyp tests with beam	Dec. 2012 / Jan. 2013
Ring Imaging Cherenkov Detector	Design ready, successful prototyp tests with beam	Spring 2013
Time-of-Flight wall (Multi-gap RPCs)	Prototype MRPCs successfully tested.	2013
Transition Radiation Detector (TDR)	Prototype TDRs successfully tested	2014
Muon Tracking Chambers (MUCH)	Prototype MUCH successfully tested	End of 2013
Projectile Spectator Detector	Design ready established technology	Dec. 2012 / Jan. 2013
Electromagnetic Calorimeter (ECAL)	Design ready established technology	2013/14
DAQ/FLES	Prototype tests with beams	2013 - 2016

Schedule FAIR

Nr.	Vorgangsname	Anfang	Ende
1			
2	**FAIR Civil Construction**	**Fr 06.11.09**	**Mi 09.05.18**
3	Planning, Tendering, Construction of Site and Buildings	Fr 06.11.09	Mi 09.05.18
4	Ready to move in HEBT Connection SIS18- SIS100		
5	Ready to move in HEBT SIS100		
6	Ready to move in SIS100		
7		Mo 01.05.17	Mo 01.05.17
8	ADES)	Mo 01.05.17	Mo 01.05.17
9		Fr 28.10.16	Fr 28.10.16
10			
11			
12			
13			
14			
15			
16			
17	**FAIR Accelerator for Set-Up Phase**	**Mo 01.06.09**	**Fr 28.09.18**
18	**Module 0 - 3**	Mo 01.06.09	Mo 01.06.09
19	**Systems Block 1 of Mod 0-3**	**Mo 01.06.09**	**Do 22.02.18**
20	**HEBT Connection SIS18 - SIS100 (T1S1, T1S2, T1S3, T1S4)**		
103	**Super FRS**		
188	**Systems Block 2 of Mod 0 - 3**		
189	**HEBT-SIS100 (T8DU)**	**Mo 01.06.09**	**Mi 01.03.17**
271	**SIS100**	**Mo 01.06.09**	**Fr 13.10.17**
372	**HEBT - T1X1, T1C1,T1D1-T1C2,TNC1 - T1X2,TXL1,TXL2,TXL3,TXL4,TPP1,1**	**Mo 01.06.09**	**Di 03.04.18**
453	**Multifunction Caves (CBM HADES)**	**Mo 01.06.09**	**Fr 28.09.18**
533	**Systems Block 3 of Mod 0 - 3**	**Mo 01.06.09**	**Fr 14.09.18**
534	**HEBT - T1F1,T1F2,TFF1, TSX1, TSF1, FRF, TFC1**	**Mo 01.06.09**	**Di 29.08.17**
614	**HEBT - TAP1, TAP2, TCR1, THS1**	**Mo 01.06.09**	**Do 21.12.17**
694	**p-bar Target**	**Mo 01.06.09**	**Mi 17.01.18**
774	**p-LINAC**	**Mo 01.06.09**	**Do 15.02.18**
855	**CR**	**Mo 01.06.09**	**Mi 25.04.18**
935	**HESR**	**Mo 01.06.09**	**Fr 14.09.18**



CBM cave ready: May 1, 2017

CBM time line

2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
R&D detectors & read-out systems			construction detectors & read-out systems				installation, commissioning		first data taking	

SIS100 ready: Oct. 13, 2017

The CBM Collaboration: 56 institutions, 450 members

Croatia:
RBI, Zagreb
Split Univ.

China:
CCNU Wuhan
Tsinghua Univ.
USTC Hefei

Czech Republic:
CAS, Rez
Techn. Univ.Prague

France:
IPHC Strasbourg

Hungaria:
KFKI Budapest
Budapest Univ.

Germany:
Darmstadt TU
FAIR
Frankfurt Univ. IKF
Frankfurt Univ. FIAS
GSI Darmstadt
Giessen Univ.
Heidelberg Univ. P.I.
Heidelberg Univ. ZITI
HZ Dresden-Rossendorf
Münster Univ.
Tübingen Univ.
Wuppertal Univ.

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
SAHA Kolkata
IOP Bhubaneswar
IIT Kharagpur
Gauhati Univ.

Korea:
Korea Univ. Seoul
Pusan Nat. Univ.

Romania:
NIPNE Bucharest
Univ. Bucharest

Poland:
AGH Krakow
Jag. Univ. Krakow
Silesia Univ. Katowice
Warsaw Univ.

Russia:
IHEP Protvino
INR Troitzk
ITEP Moscow
KRI, St. Petersburg
Kurchatov Inst., Moscow
LHEP, JINR Dubna
LIT, JINR Dubna
MEPHI Moscow
Obninsk State Univ.
PNPI Gatchina
SINP MSU, Moscow
St. Petersburg P. Univ.

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

Conclusions

CBM physics program:

Exploration of the QCD phase diagram in the region of high baryon densities which is „terra incognita“

→ large discovery potential at SIS100/300.

Experimental approach:

High-precision measurements of multi-differential observables including particles with small cross sections for a variety of beam energies and collision systems.

Status of experiment preparation:

Prototype detector performances fulfil CBM requirements. TDRs will be submitted soon.

Funding:

Substantial part of the CBM start version for SIS100 is financed (incl. applied funding).