L'expérience CBM à FAIR
détecteur et potentiel de physique

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Plan de l'exposé :

- Contexte général (FAIR)
- Objectifs scientifiques de CBM
- Système de détection
- Etudes de faisabilité et de performance
- Conclusions

FAIR – Facility for Antiproton and Ion Research

GSI - Darmstadt

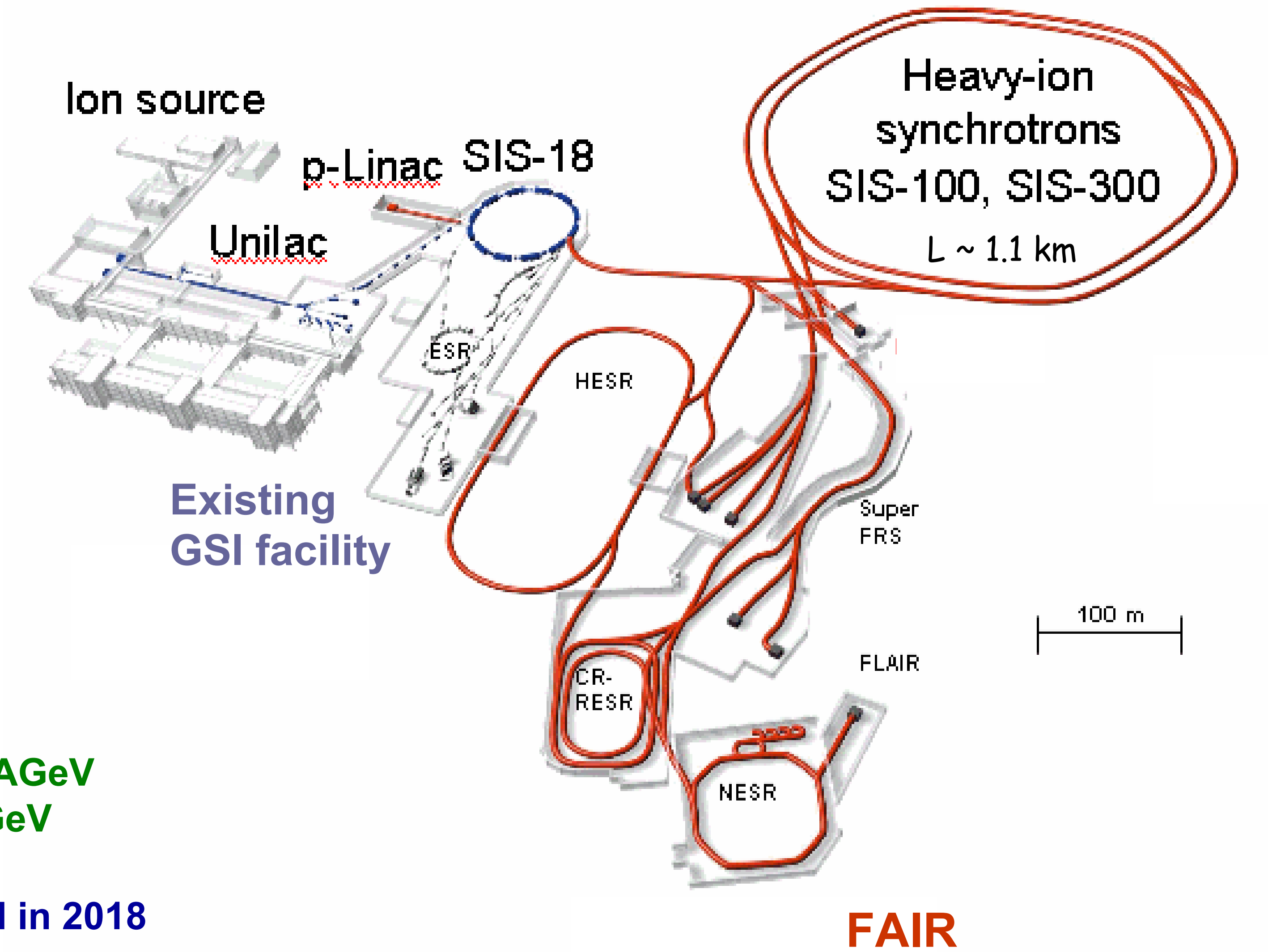
A large variety of high intensity primary and secondary beams

SIS-100
Ions : up to 14 AGeV
Protons : up to 29 GeV

SIS-300
Ions : up to 45 AGeV
Protons : up to 89 GeV

Secondary beams
Rare isotopes : up to 2 AGeV
Antiprotons : up to 30 GeV

→ First beams expected in 2018

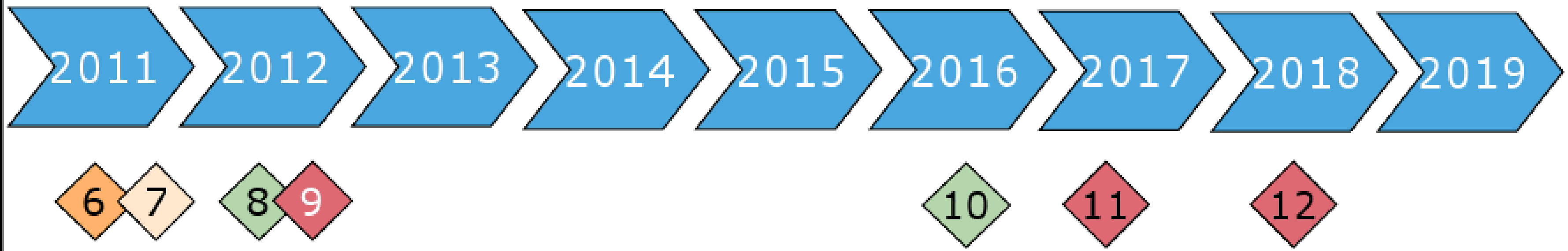


GSI and FAIR in 2018

FAIR is an international facility

- → **10 FAIR member states up to date:**
  Finland, France, Germany, India, Poland, Romania, Russia, Sweden, Slovenia, Spain
- → **Total construction cost ~ 1.27 Billion € (prices of 2005)**
  including ~210 Millions € for the experiments
- → **~70% from Germany and ~30% from foreign partners**

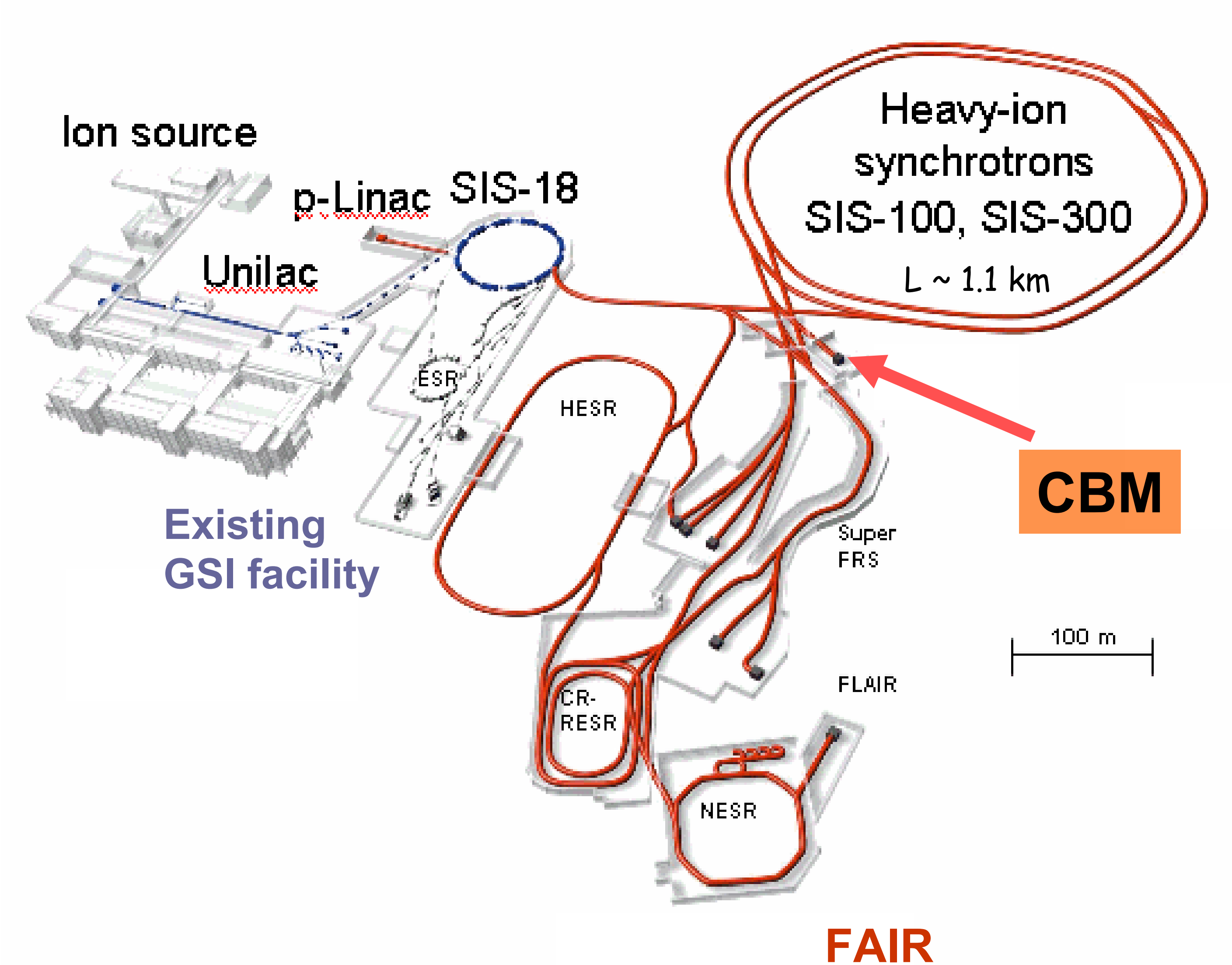
Timeline



- 6 Building permits
- 7 Site preparation
- 8 Civil construction contracts
- 9 Building of accelerator & detector components
- 10 Completion of civil construction work
- 11 Installation & commissioning of accelerators and detectors
- 12 Start Data taking

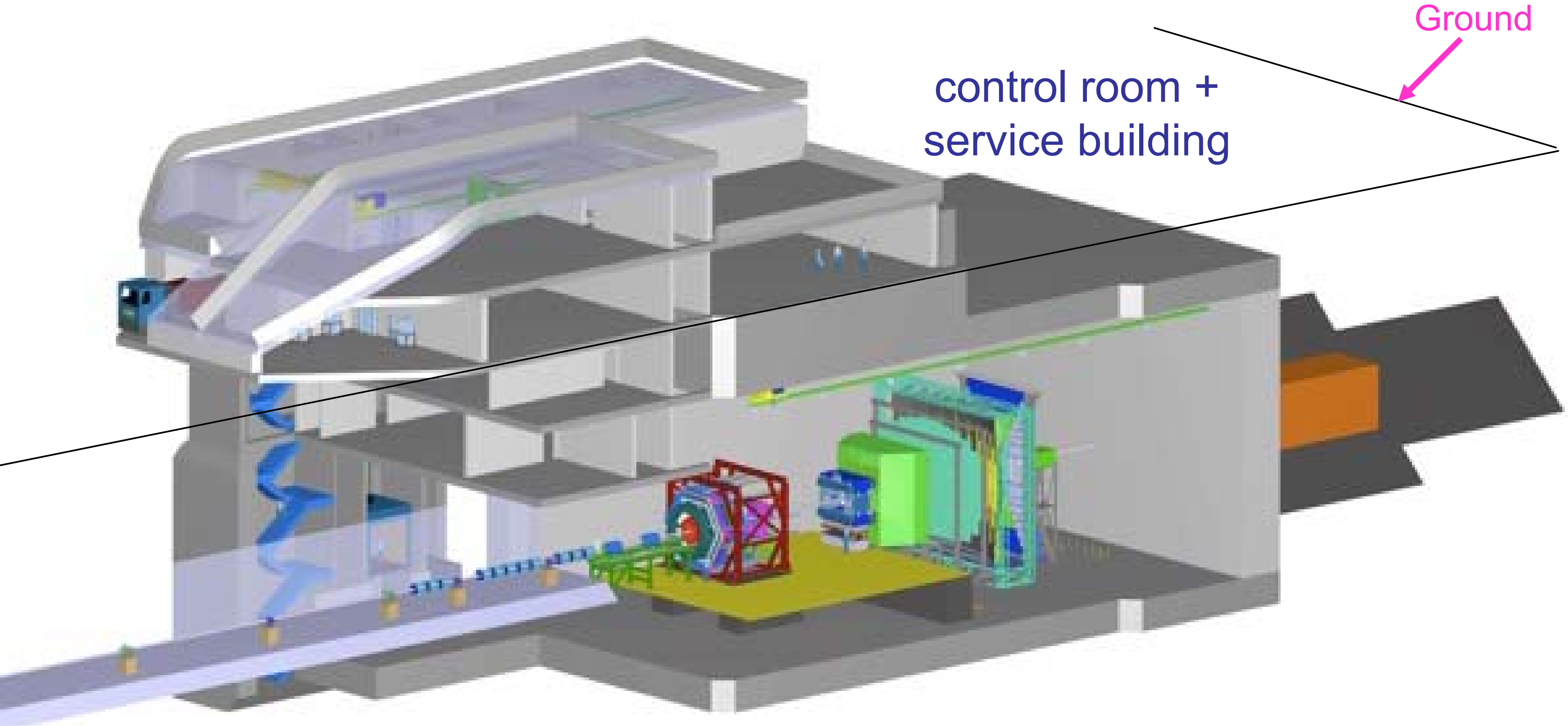
The Compressed Baryonic Matter (CBM) experiment

→ One of the major experiments at FAIR



The Compressed Baryonic Matter (CBM) experiment

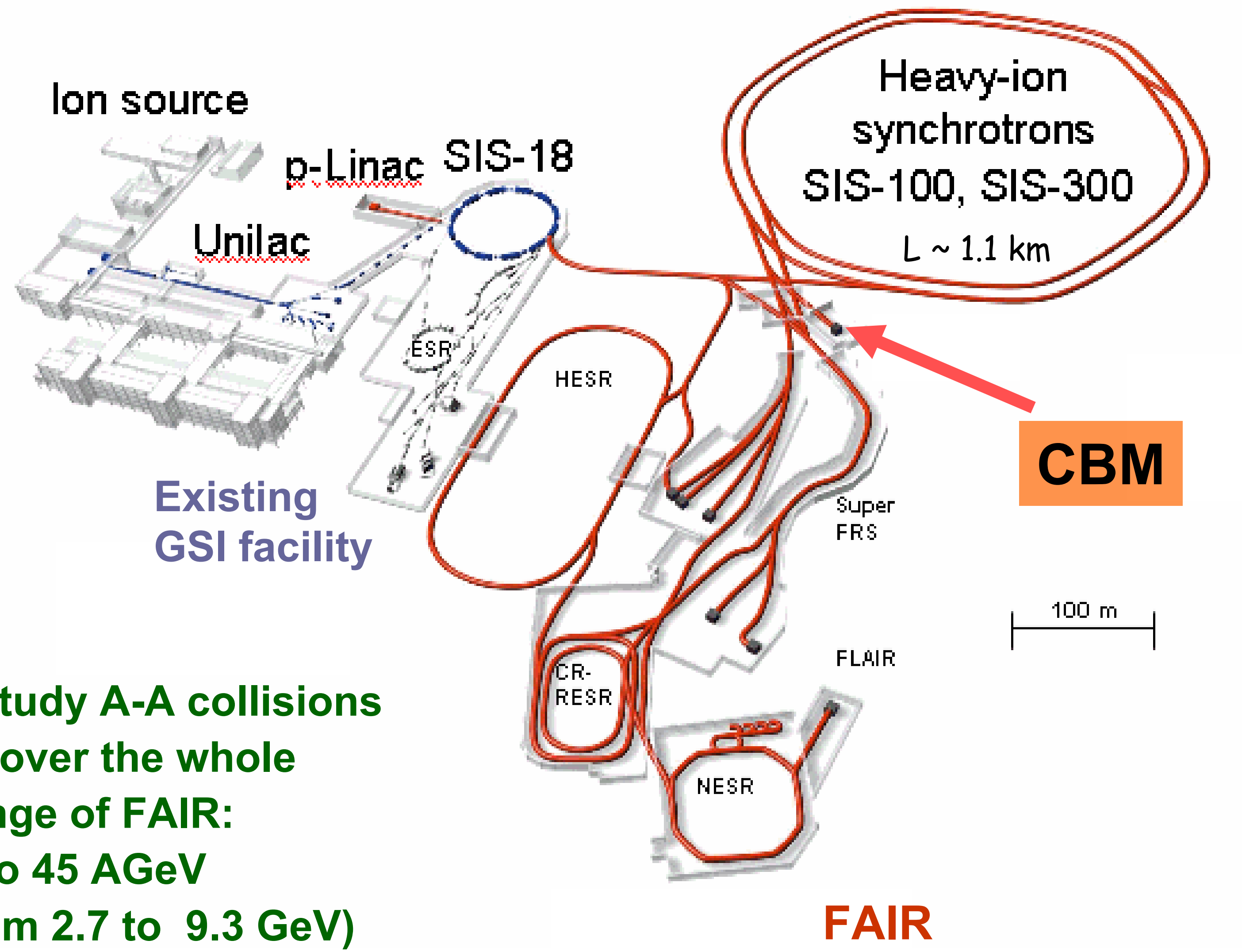
CBM in the underground hall



underground hall: length: 37 m
width: 27 m
height: 17 m

The Compressed Baryonic Matter (CBM) experiment

→ One of the major experiments at FAIR



→ CBM will study A-A collisions collisions over the whole energy range of FAIR:

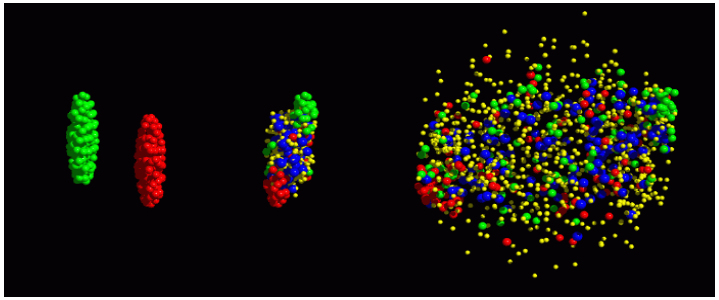
2 to 45 AGeV

($\sqrt{S_{NN}}$ from 2.7 to 9.3 GeV)

High Energy Heavy-Ion Collisions at FAIR

Specificity of the FAIR energy range (2 to 45 AGeV)

⇒ High net-baryon densities in A-A collisions



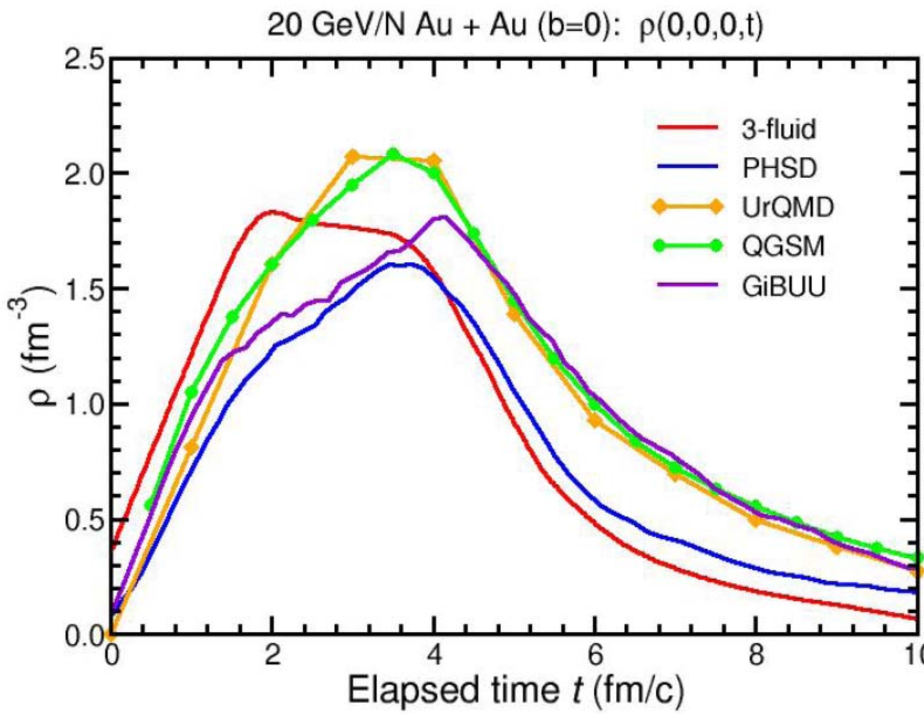
Theoretical models

→ **Net baryon densities up to ~$10\times\rho_0$ can be achieved**

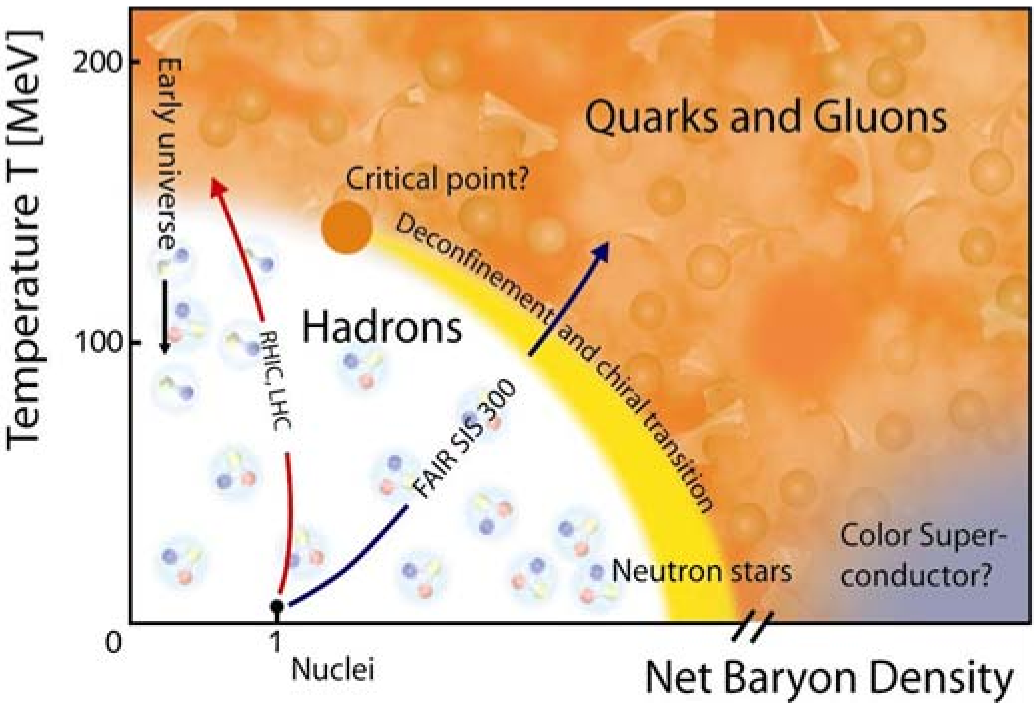
→ **High density phase lasts for a time span of 3-4 fm/c**

⇒ A-A collisions in the FAIR energy range will allow exploring a broad region of the QCD phase diagram extending up to very high baryon densities

Compilation by J. Randrup
The CBM Physics Book (2011)
Springer Series: Lecture Notes in Physics, Vol. 814



Exploring the QCD phase diagram at high ρ_B



- Deconfinement phase transition
  → 1st order phase transition
  → QCD critical endpoint
- In-medium modifications of hadrons (at high baryon densities)
  → chiral symmetry restoration
- Equation of state at high ρ_B

Main physics cases of the CBM experiment

Goal: map out the structure of the QCD phase diagram (of fundamental importance)

→ Related to basic features of QCD:
- Confinement
- Chiral symmetry restoration (origin of hadron masses)

→ Complementarity with RHIC et LHC (high T and low ρ_B)

→ Nuclear matter at high ρ_B of particular interest in the study of compact astrophysical objects (neutron stars)

Present and future experiments at high ρ_B

Experiment	Timeline	Energy range (Au/Pb beams)	Reaction rates Hz
STAR@RHIC BNL	BES-I: ongoing BES-II: 2018-2021	$\sqrt{s_{NN}}$ = 7 – 200 GeV BES-II: < 20 GeV	1 – 800 (*) (limitation by luminosity)
NA61@SPS CERN	2009-2015	E_{kin}= 20 – 160 A GeV $\sqrt{s_{NN}}$= 6.4 – 17.4 GeV	80 (limitation by detector)
MPD@NICA Dubna	Not yet funded > 2018 ?	$\sqrt{s_{NN}}$= 4.0 – 11.0 GeV	~1000 (design luminosity of 10^{27} $cm^{-2}s^{-1}$ for heavy ions)
CBM@FAIR Darmstadt	Start: 2018	E_{kin}= 2.0 – 35 A GeV $\sqrt{s_{NN}}$= 2.7 – 8.3 GeV	up to10^7

Bulk observables

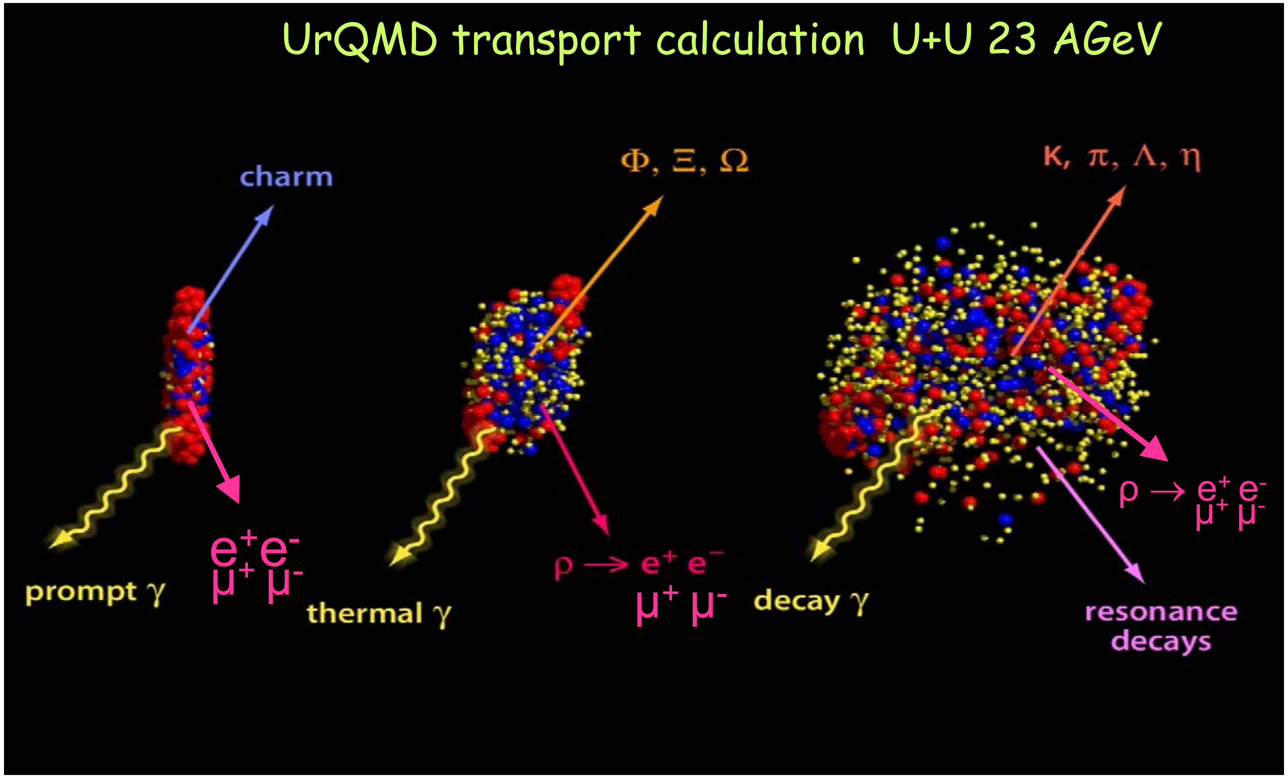
+

Rare probes (new)

(*) before luminosity upgrade
limitation to 800 due to TPC

Particularly sensitive to phase transitions and high baryon density effects

Messengers from the dense fireball



- Particles produced early in the collision are much more sensitive to the high density phase (fireball)
  - → Charmed particles formed very early (hard processes)
  - → Lepton pairs from the decay of light vector mesons are unperturbed by the effect of final state interactions (messengers from the fireball)
- These particles are produced with very low production yields → rare probes

⇒ CBM will measure them for the first time in the FAIR energy range ($\sqrt{S_{NN}}$ < 10 GeV)

The CBM physics program: Main topics and observables

Deconfinement phase transition at high ρ_B & QCD critical point

- 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 dynamical event-by-event fluctuations

Chiral symmetry restoration at high ρ_B

- in-medium modifications of hadrons
  - → dileptons from the decay of light vector mesons, in both e^+e^- and $\mu^+\mu^-$
  - → production yield of D-mesons (at threshold)

The equation-of-state at high ρ_B

- excitation function of the collective flow of hadrons
- production of multi-strange baryons (Ξ, Ω) at threshold

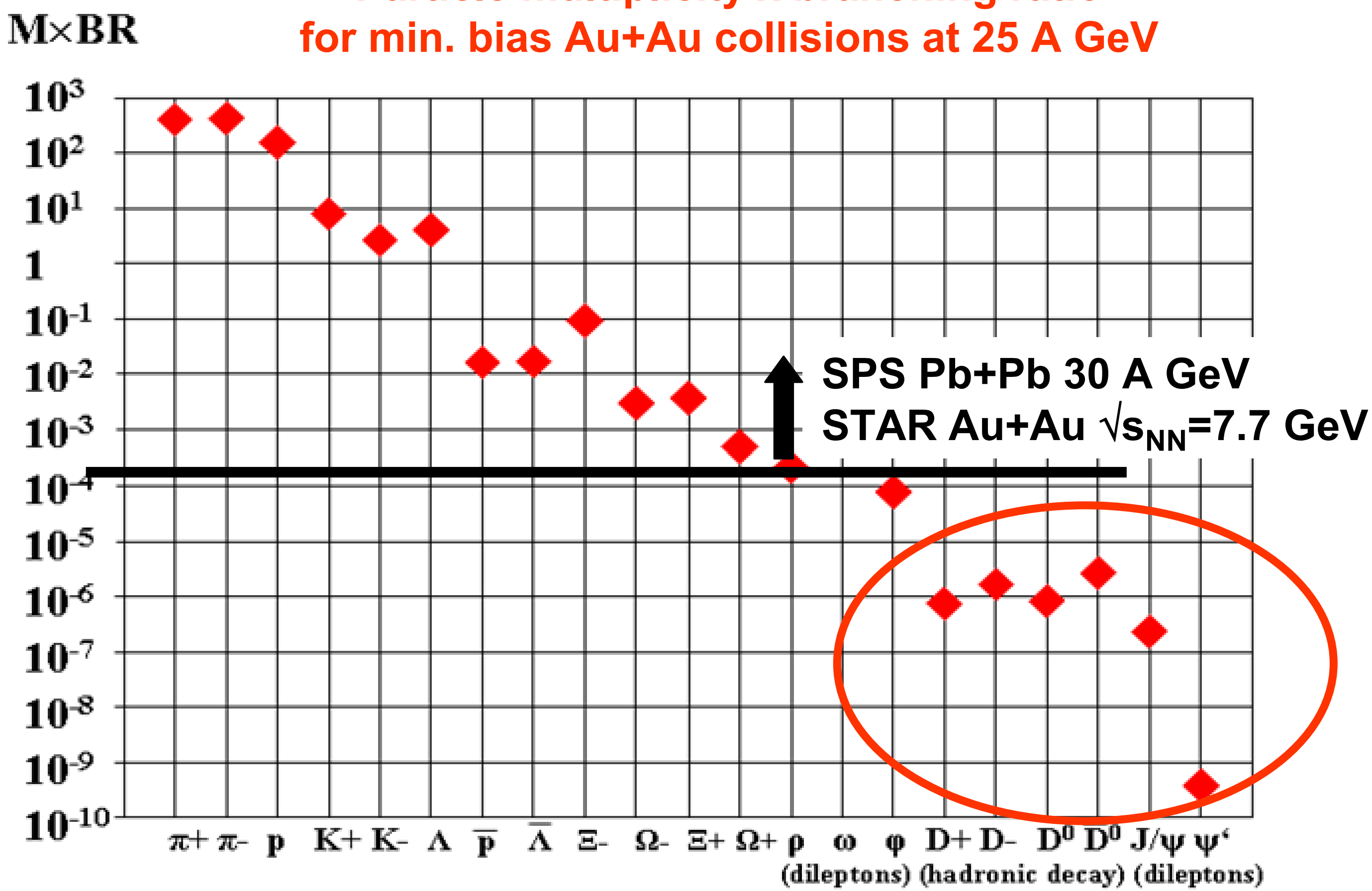
CBM will measure all these observables in:

- A-A collisions from 2 to 45 AGeV
- p-A and p-p collisions up to 90 GeV

⇒ Requires a large acceptance detector able to measure both hadrons and leptons and to operate at very high collision rates (↔ rare probes)

Experimental challenges

Particle multiplicity x branching ratio
for min. bias Au+Au collisions at 25 A GeV



- Rare probes requires very high collision rates: $10^5 - 10^7$ collisions/sec

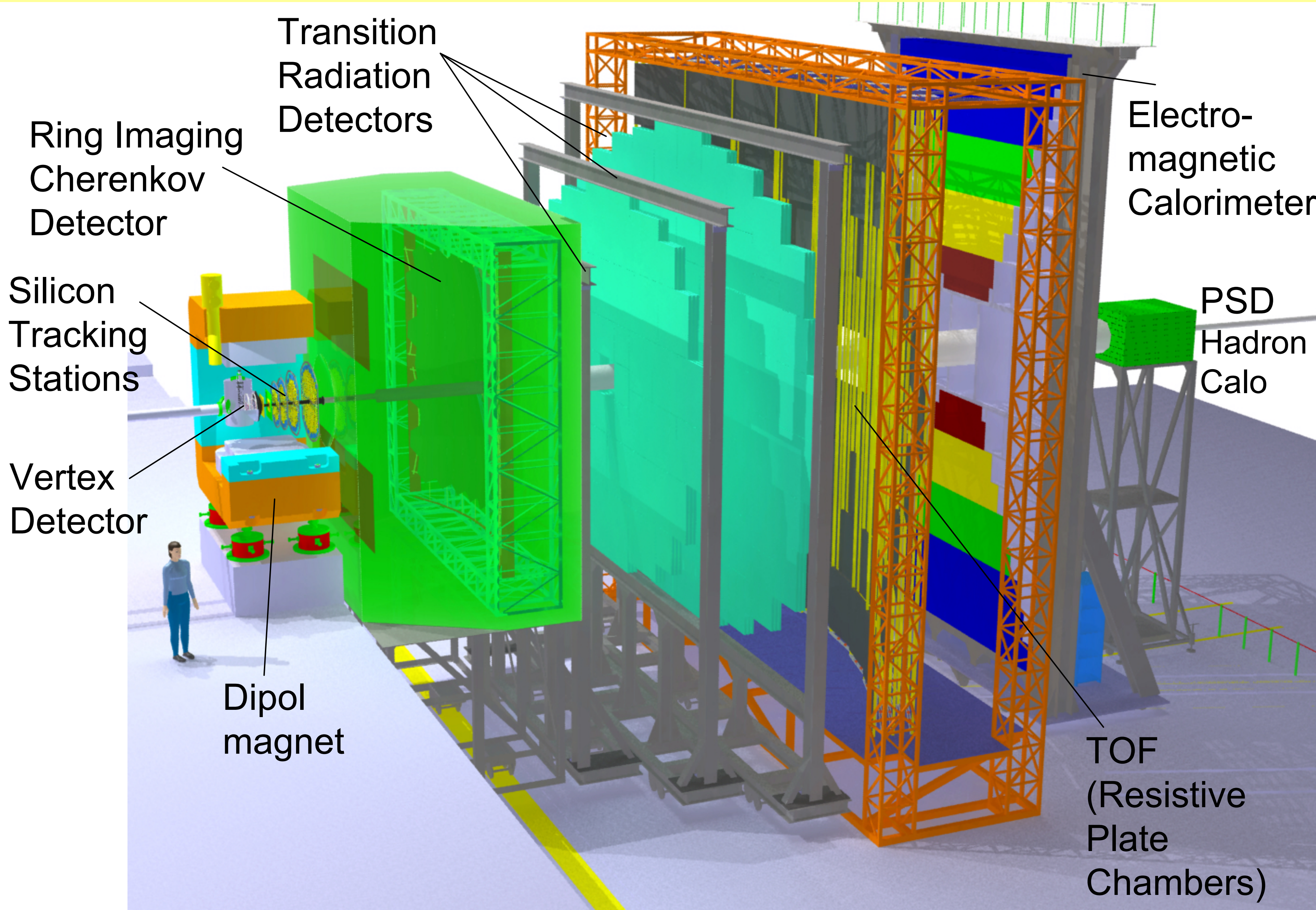
  → imposes strong constraints on the detector system: must be extremely fast and tolerant to high radiation doses + high precision vertex reconstruction

  → strong constraints also on the readout electronics and the DAQ system

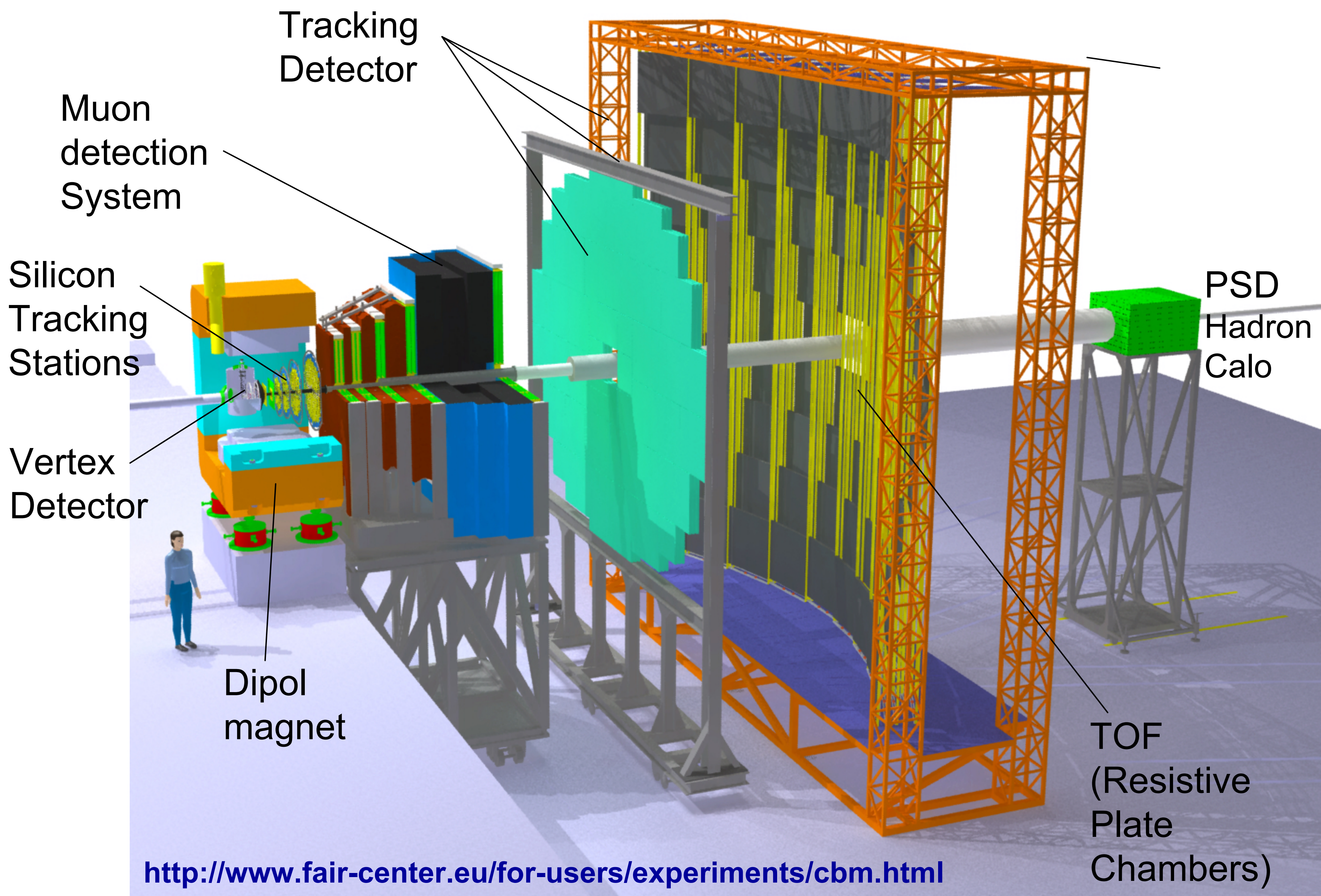
The CBM Collaboration: 56 institutions, 450 members

19th CBM Collaboration Meeting, March 26-30, 2012, GSI Darmstadt

The Compressed Baryonic Matter Experiment



The Compressed Baryonic Matter Experiment



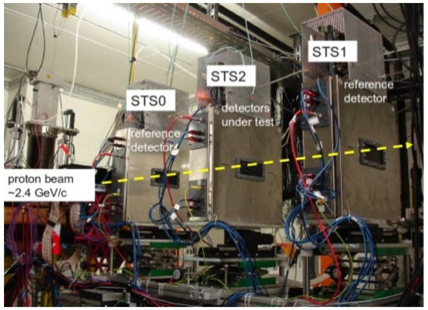
http://www.fair-center.eu/for-users/experiments/cbm.html

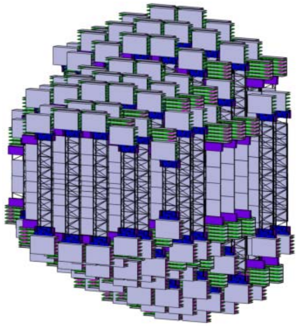
CBM technical developments

SC Magnet: JINR Dubna

Micro-Vertex Detector:
Frankfurt, Strasbourg

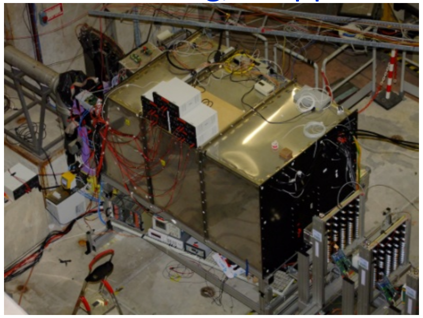
Silicon Tracking System: Darmstadt, Dubna, Krakow, Kiev, Kharkov, Moscow, St. Petersburg, Tübingen



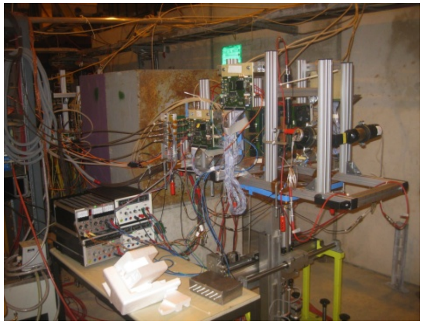


MRPC ToF Wall: Beijing, Bucharest, Darmstadt, Frankfurt, Hefei, Heidelberg, Moscow, Rossendorf, Wuhan, Zagreb

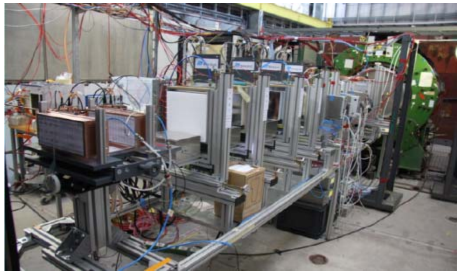
RICH Detector:
Darmstadt, Giessen, Pusan, St. Petersburg, Wuppertal



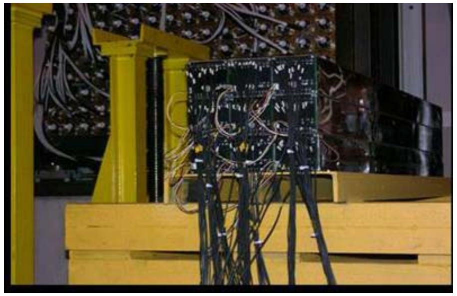
Muon detector:
Kolkata + 13 Indian Inst., Gatchina, Dubna



Transition Radiation Detector:
Bucharest, Dubna, Frankfurt, Heidelberg, Münster



Forward calorimeter:
Moscow, Prague, Rez



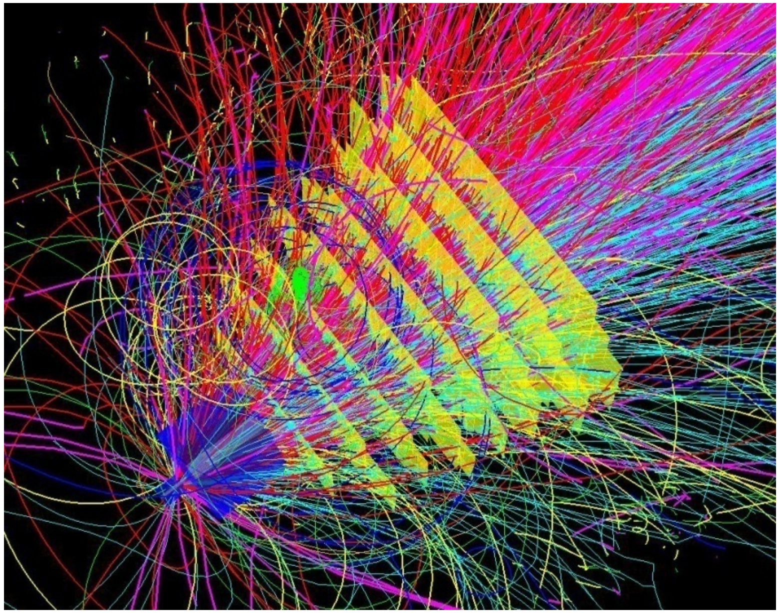
DAQ and online event selection:
Darmstadt, Frankfurt, Heidelberg, Kharagpur, Warsaw

Schedule CBM Technical Design Reports

Subsystem	Status	TDR submission
Magnet	Design ready	Dec. 2012
Micro-Vertex Detector	Prototype tests with beams	2014
Silicon Tracking System	Design ready, successful prototyp tests with beam	Dec. 2012
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	2013
Electromagnetic Calorimeter (ECAL)	Design ready established technology	2013/14
DAQ/FLES	Prototype tests with beams	2013 – 2016

Feasibility and Performance Studies

A central Au(25 AGeV) + Au collision in CBM



Realistic simulations (GEANT)

Next slides →

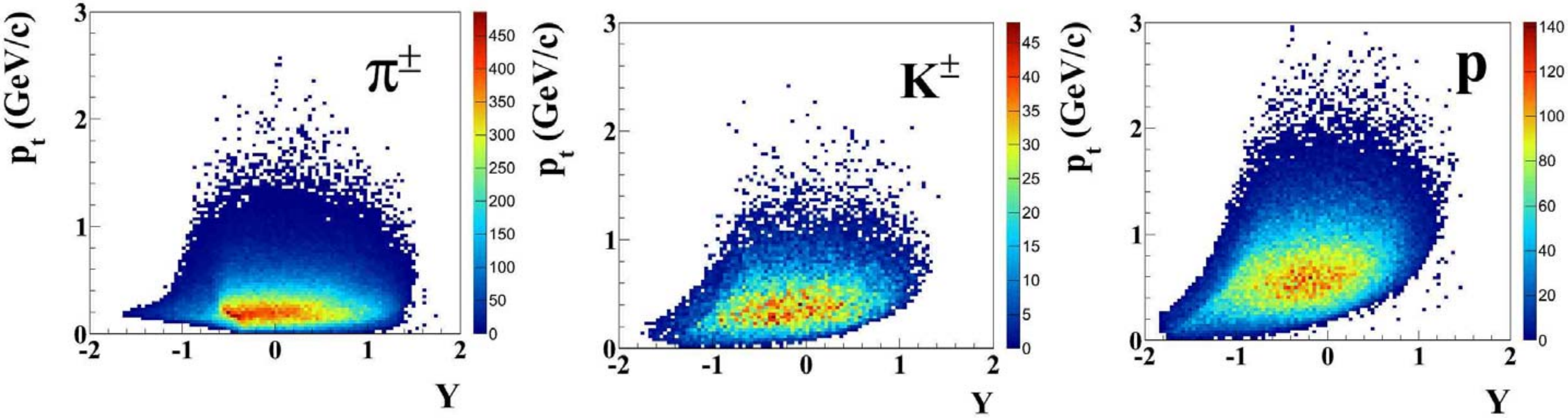
1- Detector acceptance

2- Tracking performances

3- Reconstruction of hyperons

4- Reconstruction of rare signals
- D-mesons
- Dileptons ($e^+ e^-$, $\mu^+ \mu^-$)

CBM acceptance for central Au+Au collisions at 25 AGeV



Y: center-of-mass rapidity / projectile rapidity

→ **Large coverage of the phase space**

→ **In particular, the mid-rapidity region**

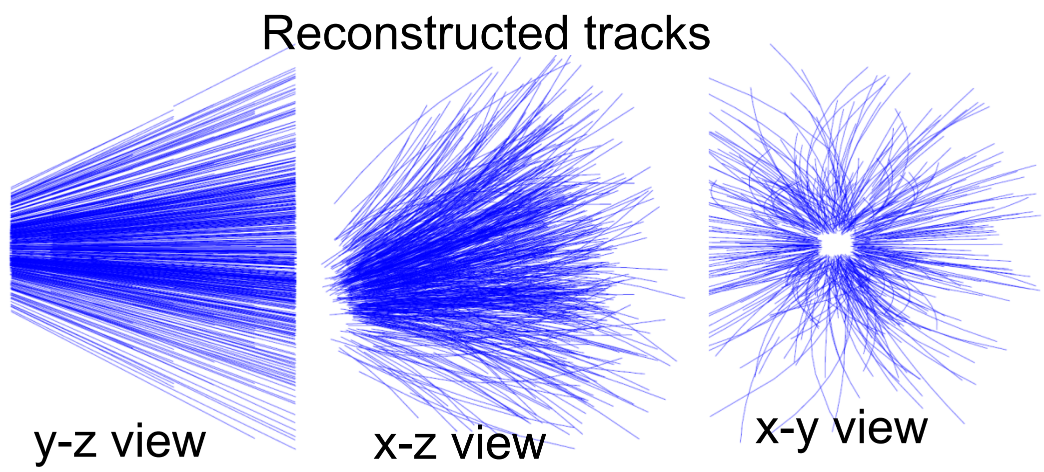
→ **Should allow the extrapolation to 4π with good precision.**

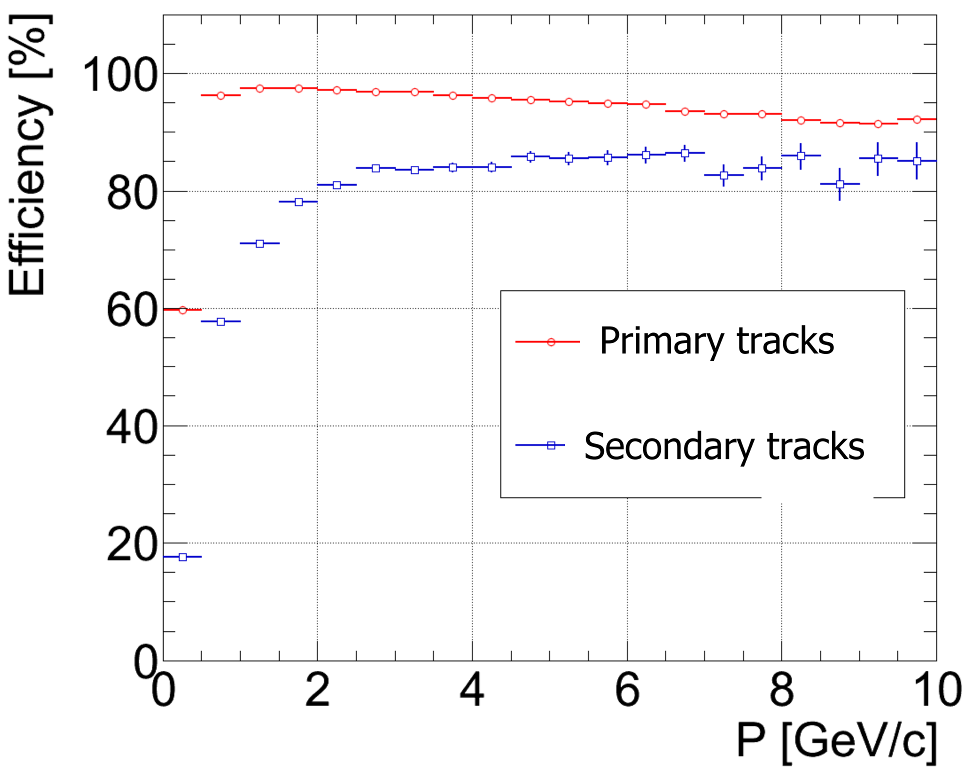
→ **Overall acceptance for charged hadrons (primary) at this energy is higher than 70%**

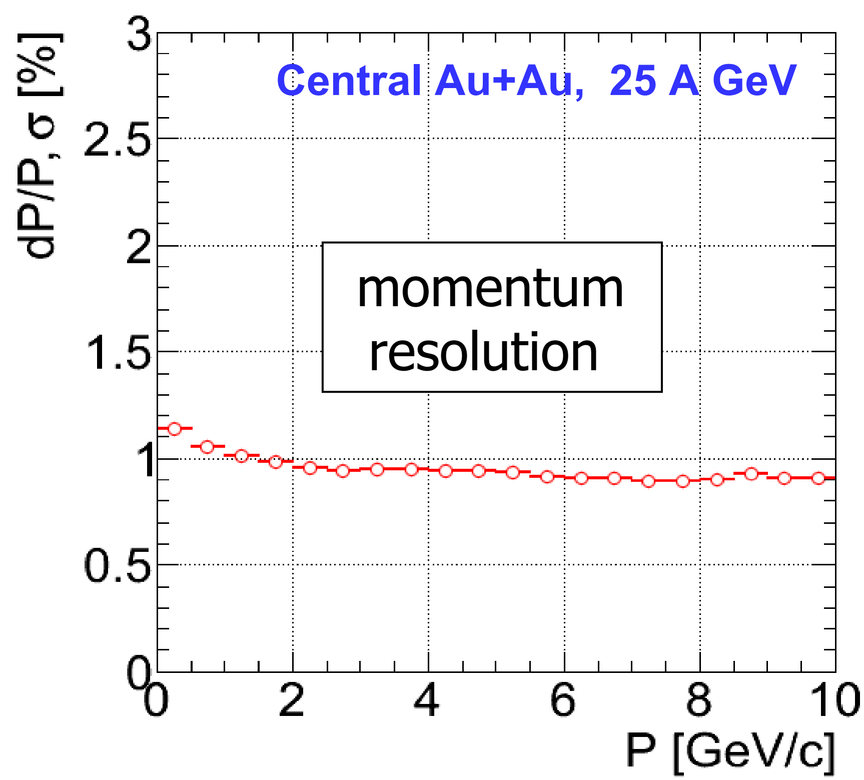
STS tracking performance

→ Track finding: Cellular Automaton

→ Track and vertex fitting: Kalman filter

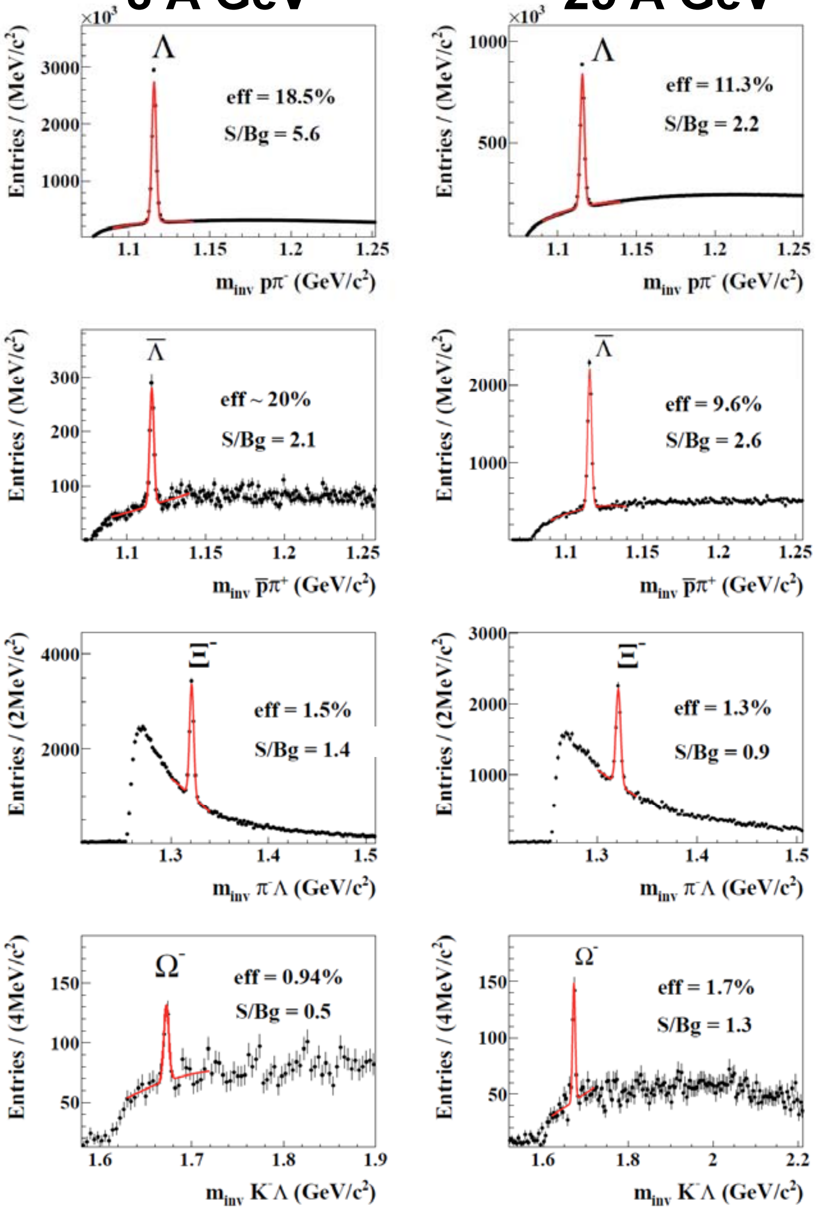






Hyperon reconstruction in central Au+Au collisions

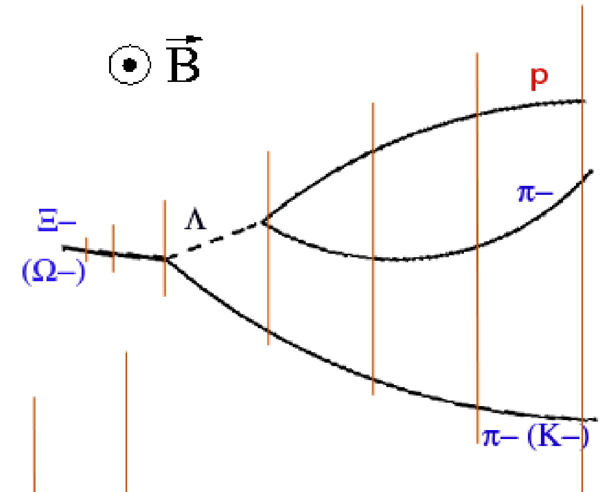
8 A GeV **25 A GeV**

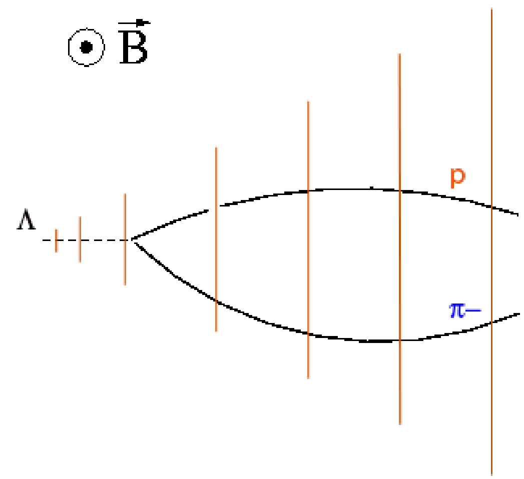


Simulations:

- STS with realistic geometry, material budget and detector response
- TOF at 10 m, time resolution 80 ps

- 8 A GeV: $5 \cdot 10^6$ events (~ 50 s beam)
  25 A GeV: $1 \cdot 10^6$ events (~ 10 s beam)





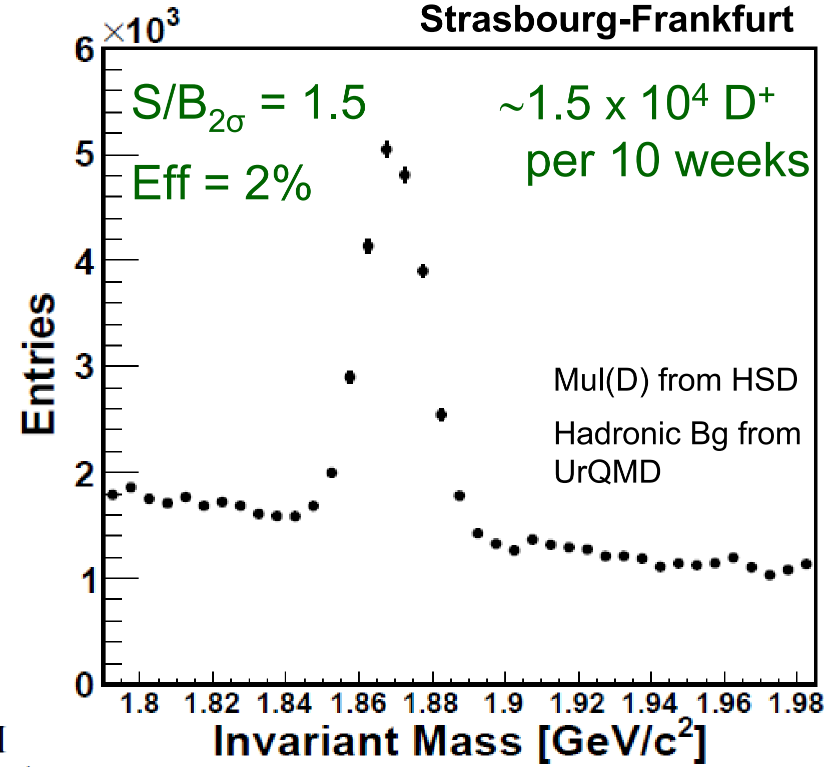
D-meson reconstruction in central Au + Au collisions

$D^+ \rightarrow \pi^+ \pi^+ K^-$ ($c\tau$ = 317 μm, BR = 9.5%)

in central Au+Au collisions at 25 AGeV

⇒ Excellent sec. vertex resolution ~ 70 μm (↔ high performances of the MVD)

S. Seddiki, PhD thesis
Strasbourg-Frankfurt



Expected D-meson statistics per 10 weeks of data taking (at 0.1 MHz) → typical CBM run

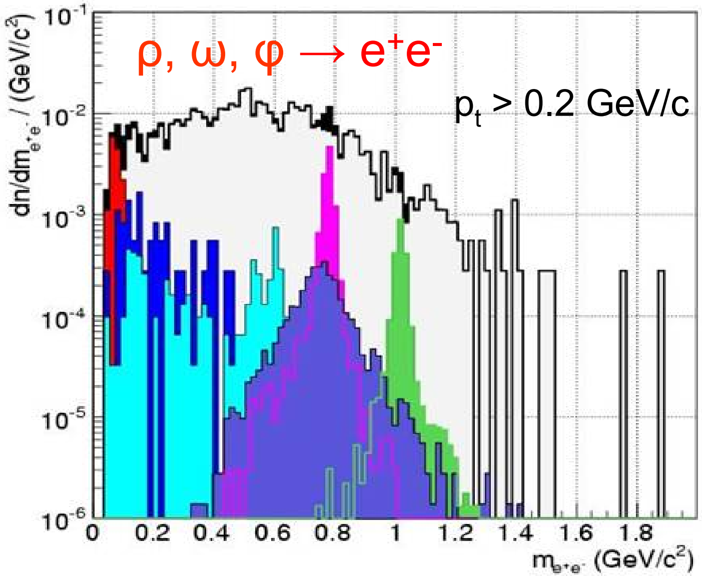
Decay channel	Multiplicity		BR	Reco.	Particles/run	
	HSD	SHM	[%]	eff. [%]	HSD	SHM
$D^+ \rightarrow \pi^+ \pi^+ K^-$	4.2×10^{-5}	8.4×10^{-5}	9.5	2.0	1.5×10^4	3.0×10^4
$D^- \rightarrow \pi^- \pi^- K^+$	8.9×10^{-5}	2.9×10^{-4}	9.5	1.4	2.3×10^4	7.5×10^4
$D^0 \rightarrow \pi^+ K^-$	3.7×10^{-5}	2.0×10^{-4}	3.9	2.0	5.8×10^3	3.2×10^4
$\bar{D}^0 \rightarrow \pi^- K^+$	1.1×10^{-4}	6.1×10^{-4}	3.9	2.0	1.7×10^4	9.6×10^4
$D^0 \rightarrow \pi^+ \pi^+ \pi^- K^-$	3.7×10^{-5}	2.0×10^{-4}	7.7	0.4	2.1×10^3	1.2×10^4
$\bar{D}^0 \rightarrow \pi^- \pi^- \pi^+ K^+$	1.1×10^{-4}	6.1×10^{-4}	7.7	0.4	6.4×10^3	3.5×10^4
$D_s^+ \rightarrow \pi^+ K^+ K^-$	5.4×10^{-6}	1.4×10^{-4}	5.3	1.0	5.8×10^2	1.5×10^4
Sum					6.9×10^4	3.0×10^5

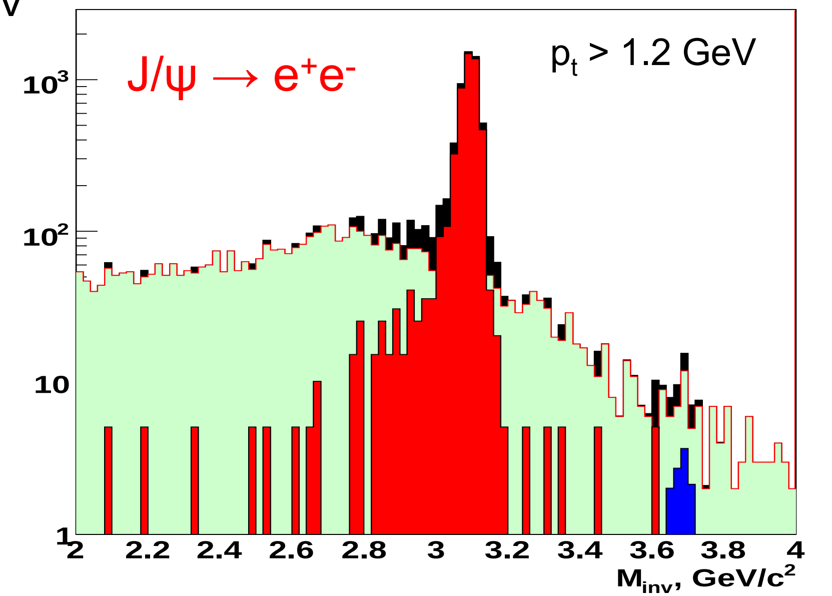
Statistics sufficient for detailed physics studies Including elliptic flow

Electron pairs

➢ **Electron id: TRD, RICH (combination → π suppression factor of 10^4)**

Central Au +Au
25 AGeV





25 µm target

➢ **Background dominated by (75%) by physical sources (mainly from π^0 Dalitz decays)**

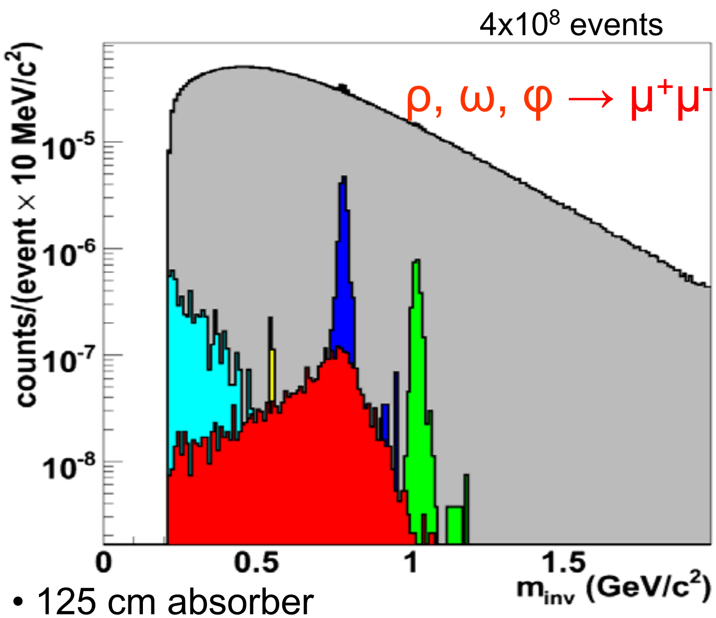
➢ **Expected statistics per 10 weeks (Min bias)**

  → Light vector mesons ~ few 10^6 each

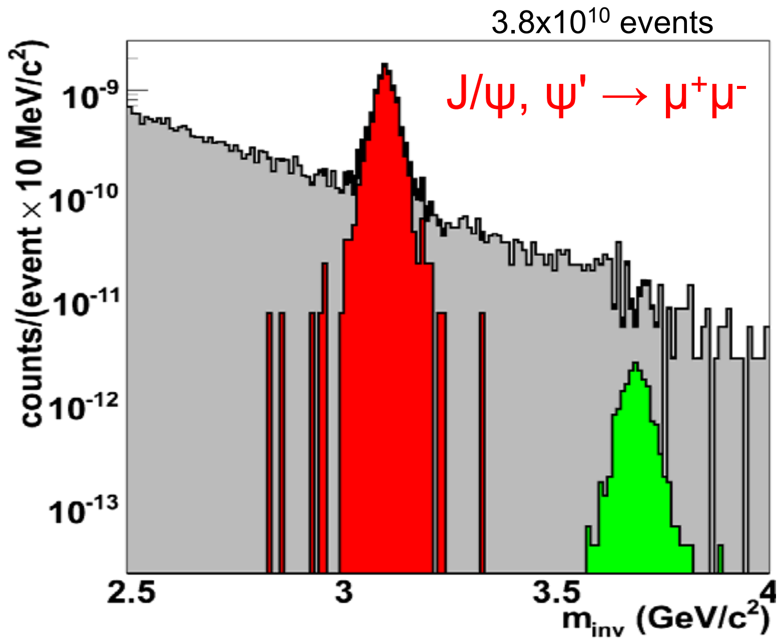
  → J/ψ ~ 2 x 10^6, ψ' ~ 3 x 10^3

Muon pairs

- Muon id: segmented hadron absorber + tracking stations
  - Iron absorber: 3x20 + 30 + 35 + 100 cm
  - 6 detector triplets: 3 GEM + 3 straw tubes



- 125 cm absorber
- intrinsic p>1.5 GeV cut



- 225 cm absorber
- p_t > 1GeV/c

- Background dominated by muons from π and K decay (0.13/event)
- Expected statistics per 10 weeks (Min bias)
  - → Light vector mesons ~ few 10^7 each
    - 10 x higher than with dielectrons
    - but exclude the mass range below $2m_\mu$ ~ 200 MeV/c² (close to the edge of ρ)
  - → J/ψ ~ 2 x 10^6, ψ' ~ 4 x 10^3

CBM: Estimated particle yields for minimum bias Au+Au collisions at 25 AGeV

particle, mass (MeV)	N	decay mode	BR	R/s (MHz)	T	ε (%)	Y/s	Y/10 w
η (547)	6.6	$\mu^+\mu^-$	$5.8 \cdot 10^{-6}$	0.25	y	3	0.28	$1.7 \cdot 10^{6}$
K^+ (494)	8	-	-	0.025	n	20	$4 \cdot 10^{4}$	$2.4 \cdot 10^{11}$
K^- (494)	2.6	-	-	0.025	n	20	$1.3 \cdot 10^{4}$	$7.8 \cdot 10^{10}$
K_s^0 (497)	5.4	$\pi^+\pi^-$	0.69	0.025	n	10	$9.3 \cdot 10^{3}$	$5.6 \cdot 10^{10}$
ρ (770)	4.6	e^+e^-	$4.7 \cdot 10^{-5}$	0.025	n	5.4	0.29	$1.8 \cdot 10^{6}$
ρ (770)	4.6	$\mu^+\mu^-$	$4.6 \cdot 10^{-5}$	0.25	y	2.7	1.4	$8.6 \cdot 10^{6}$
ω (782)	7.6	e^+e^-	$7.1 \cdot 10^{-5}$	0.025	n	7.2	1	$6 \cdot 10^{6}$
ω (782)	7.6	$\mu^+\mu^-$	$9 \cdot 10^{-5}$	0.25	y	3.7	6.3	$38 \cdot 10^{6}$
φ (1020)	0.256	e^+e^-	$3 \cdot 10^{-4}$	0.025	n	9.6	0.18	$1 \cdot 10^{6}$
φ (1020)	0.256	$\mu^+\mu^-$	$2.9 \cdot 10^{-4}$	0.25	y	6	1.	$6.7 \cdot 10^{6}$
Λ (1115)	6.4	$p\,\pi^-$	0.64	0.025	n	10.6	$1.1 \cdot 10^{4}$	$6.5 \cdot 10^{10}$
Ξ^- (1321)	0.096	$\Lambda\,\pi^-$	0.999	0.025	n	2.1	50.4	$3 \cdot 10^{8}$
Ω^- (1672)	0.0044	$\Lambda\,K^-$	0.68	0.025	n	1	0.75	$4.5 \cdot 10^{6}$
D^0 (1864)	$7.5 \cdot 10^{-6}$	$K^-\pi^+$	0.038	0.1	y	3.25	$8.5 \cdot 10^{-4}$	$5.1 \cdot 10^{3}$
D^0 (1864)	$7.5 \cdot 10^{-6}$	$K^-\pi^+\pi^+\pi^-$	0.075	0.1	y	0.37	$2.1 \cdot 10^{-4}$	$1.3 \cdot 10^{3}$
$\bar{D}^0$ (1864)	$2.3 \cdot 10^{-5}$	$K^+\pi^-$	0.038	0.1	y	3.25	$2.6 \cdot 10^{-3}$	$1.6 \cdot 10^{4}$
D^+ (1869)	$8 \cdot 10^{-6}$	$K^-\pi^+\pi^+$	0.092	0.1	y	4.2	$3.1 \cdot 10^{-3}$	$1.9 \cdot 10^{4}$
D^- (1869)	$1.8 \cdot 10^{-5}$	$K^+\pi^-\pi^-$	0.092	0.1	y	4.2	$7 \cdot 10^{-3}$	$4.2 \cdot 10^{4}$
Λ_c(2285)	$4.9 \cdot 10^{-4}$	$pK^-\pi^+$	0.05	0.1	y	0.5	$1.2 \cdot 10^{-2}$	$7.4 \cdot 10^{4}$
J/ψ (3097)	$3.8 \cdot 10^{-6}$	e^+e^-	0.06	1-10	y	14	0.032 - 0.32	$1.9 \cdot 10^{5-6}$
ψ' (3686)	$5.1 \cdot 10^{-8}$	e^+e^-	$7.3 \cdot 10^{-3}$	1-10	y	15	$5.6 \cdot 10^{-(5-4)}$	$3.4 \cdot 10^{2-3}$
J/ψ (3097)	$3.8 \cdot 10^{-6}$	$\mu^+\mu^-$	0.06	10	y	16	0.36	$2.2 \cdot 10^{6}$
ψ' (3686)	$5.1 \cdot 10^{-8}$	$\mu^+\mu^-$	$7.3 \cdot 10^{-3}$	10	y	19	$7.1 \cdot 10^{-4}$	$4.3 \cdot 10^{3}$

Y/10 w: Yield per 10 weeks

Huge statistics for bulk particles

10^4 – 10^6 for rare particles

Conclusions

- The CBM experiment offers new and excellent perspectives for the exploration of the QCD phase diagram in the region of high baryon densities
  - → large discovery potential: 1st order phase transition, Critical point, Chiral symmetry restoration, EOS
- The detector is designed to operate at very high collision rates (up to 10 MHz)
  - → Measurements for the first time of rare diagnostic probes, highly sensitive to the physics under study
- The preparation of the experiment is already well advanced
- Present status: close to the end of the prototyping phase for most sub-detectors
- Two TDRs (Tracker and Magnet) already submitted, others will follow soon
- The production phase will start in 2014
- Installation and commissioning expected in 2017-2018
- First physics data taking in 2019 at SIS100 → low energy part of the physics program (~ 5 years)
- The physics program will continue later at SIS300 to cover the high energy part

Backup slides

Research Areas at the FAIR Facility

→ **A multidisciplinary project involving several scientific communities**

- **Nuclear structure and nuclear astrophysics (rare isotope beams)**
- **Hadron physics (antiproton beams)**
- **High energy heavy-ion collisions (CBM)**
- **Physics of dense plasmas (ion-beam bunch compression and petawatt-laser)**
- **Atomic physics (highly stripped ions, antiprotons)**
- **Materials science and radiation biology (ion and antiproton beams)**

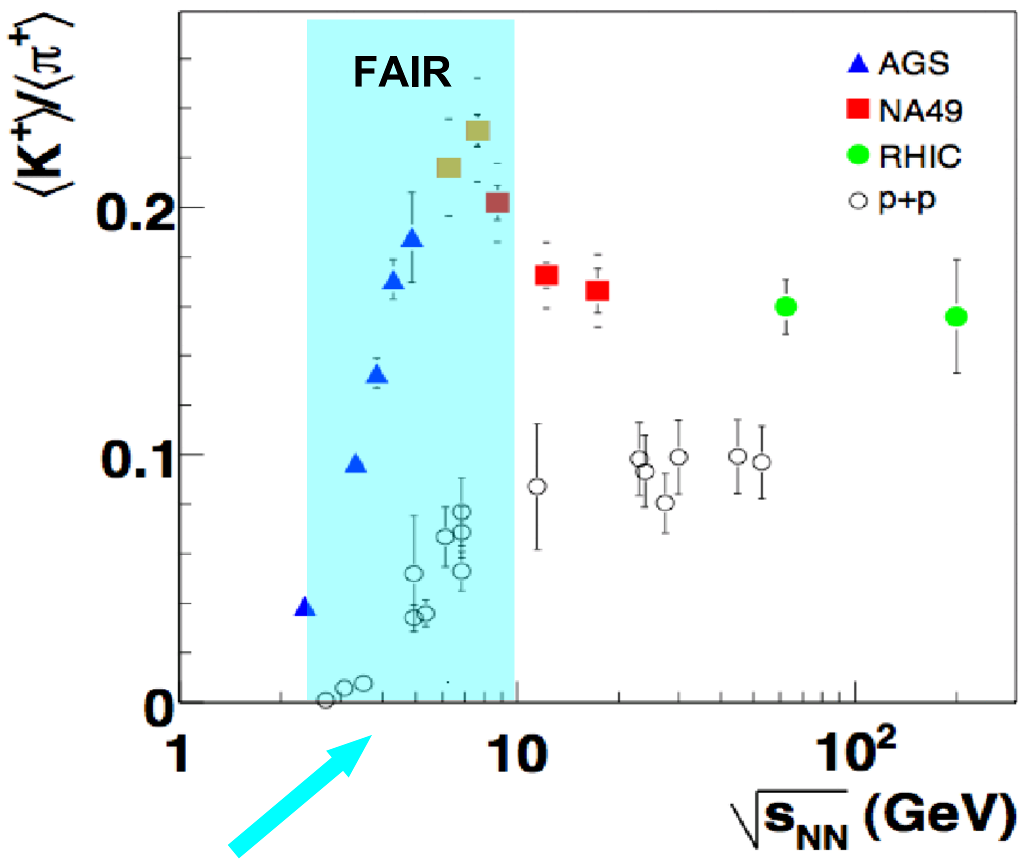
Efficient parallel operation
→ **FAIR will allow up to 5 experiments to run at the same time**
→ **High beam availability for experiments**

Onset of Deconfinement Phase Transition

- Structures in the excitation functions of several observables
- All at the same incident energy: ~ 30 AGeV ($\sqrt{S_{NN}}$ ~ 7 GeV)
- Typical of A-A collisions p-p → monotonic trend
- Cannot be reproduced by hadronic models

  → Onset of QGP formation?
- If due to QGP → 1st order phase transition

Results from SPS (NA49)



⇒ CBM will scrutinize this energy range with rare diagnostic probes (more sensitive to phase transition effects)

Results from BES-I at RHIC

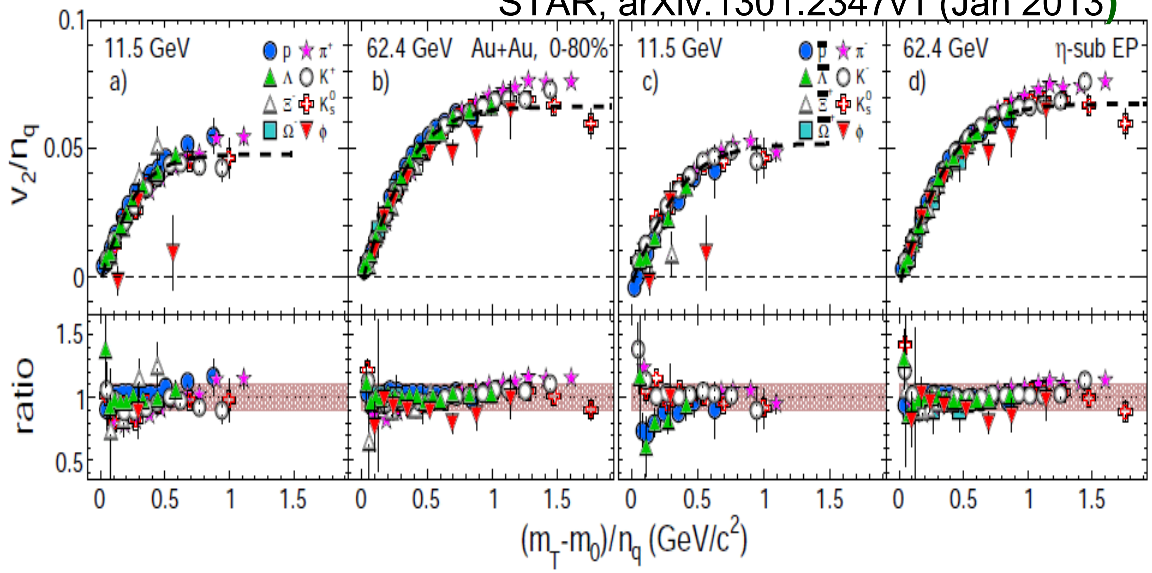
- RHIC performed a scan in energy from $\sqrt{S_{NN}}$ ~ 200 GeV (top energy) down to 7.7 GeV
- Results → QGP signatures seem to disappear below 20 GeV

→ Main observations:

- High pt suppression not observed below 20 GeV
- v_2(particles) ≠ v_2(anti-particles) below 20 GeV → deviation w.r.t. the NCQ scaling
- $v_2(\Phi)$ is relatively small at 11.5 GeV

→ Expected if predominant hadronic phase at 11.5 GeV, due to the small hadronic interaction x-section of Φ-mesons

STAR, arXiv:1301.2347v1 (Jan 2013)



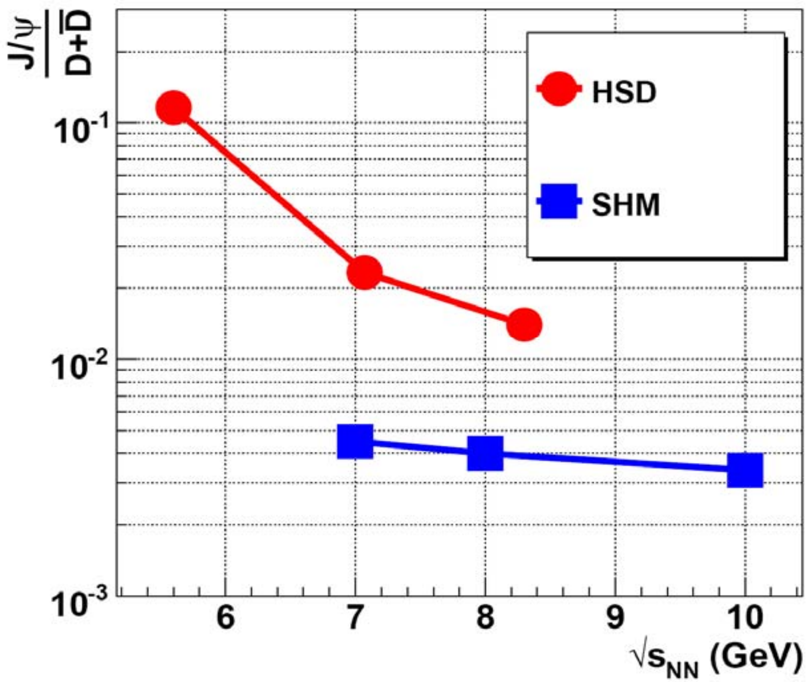
⇒ Needs to be confirmed with higher statistics measurements (BES-2)

⇒ CBM will extend these studies to multi-strange baryons and charmed particles

Deconfinement phase transition in CBM

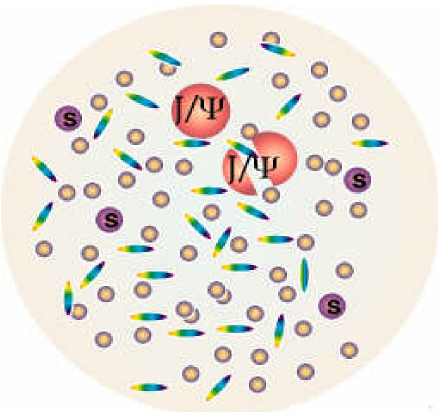
⇒ CBM will measure several observables relevant for the deconfinement phase transition:

- The excitation function of yields, spectra, and collective flow of strange particles, including multi-strange baryons (Ξ, Ω)
- The excitation function of yields, spectra, and collective flow of charmed particles
  - → Open charm particles via their hadronic decay
  - → Charmonium (will be measured in both di-muon and di-electron channels)



Charmonium to open charm ratio sensitive to the nature of the medium in the early stage of the collision
→ can be used as a signature of the deconfinement phase transition

Anomalous Suppression of Charmonium
Sequential Dissociation



Quarkonium dissociation temperatures: Lattice-based calculations(Digal, Karsch, Satz)

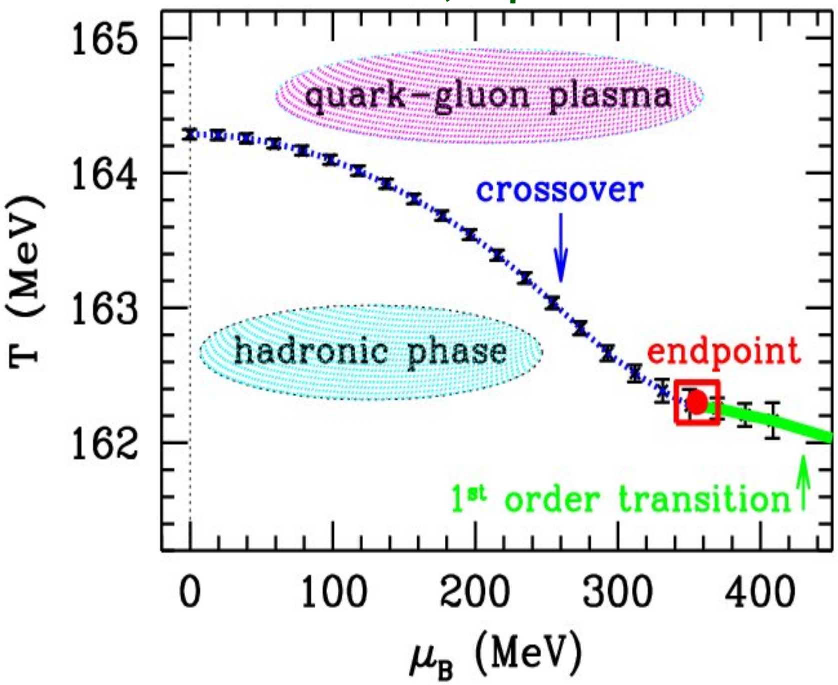
state	$J/\psi(1S)$	$\chi_c(1P)$	$\psi'(2S)$	$\Upsilon(1S)$	$\chi_b(1P)$	$\Upsilon(2S)$	$\chi_b(2P)$	$\Upsilon(3S)$
T_d/T_c	2.10	1.16	1.12	>4.0	1.76	1.60	1.19	1.17

Sequential dissociation?

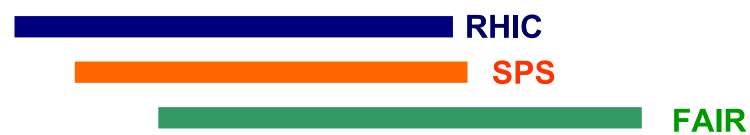
CBM → will measure both J/ψ and ψ' in p+p, p+A and A+A collisions

QCD critical point

LQCD calculations at $\mu_B \neq 0$
Fodor & Katz, hep-lat/0402006



Experimental program	$\sqrt{s_{NN}}$ range (GeV)	μ_B range (MeV)
RHIC (BES)	5 - 30	150 - 580
SPS	4.9 - 17.3	220 – 600
FAIR	2 – 9.3	300 – 800



μ_B coverage

→ Complementarity between RHIC, SPS and FAIR (+ overlap)

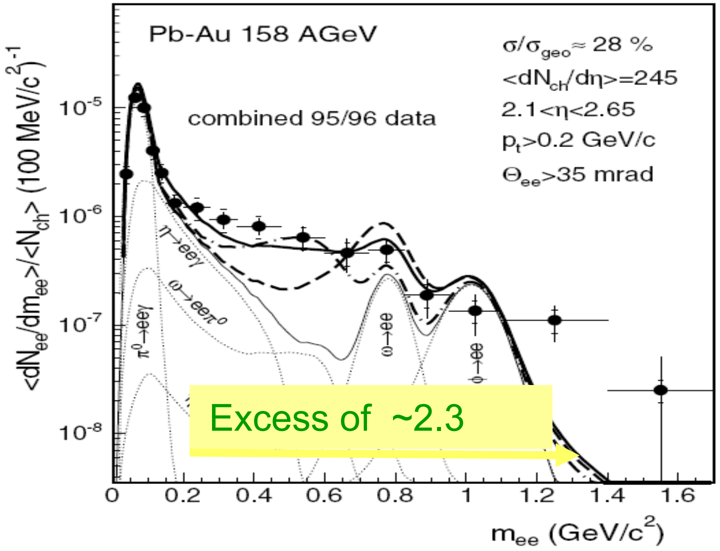
- Depends on assumptions made
  - → Number of quark flavours
  - → m_q
- Localisation of the Critical Point
  - → μ_B from 200 to 1000 MeV!
- Important to measure over a broad range in energy (→ broad range in μ_B)

Experimental observable:
Event-by-event fluctuations of conserved quantities like strangeness, net baryon number, and net-charge

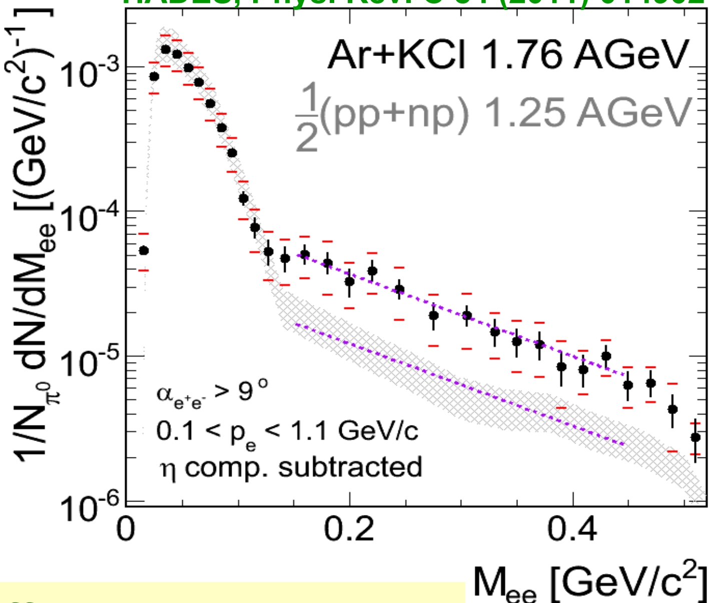
In-medium modification of hadron properties

- Indications on the chiral symmetry restoration ↔ origin of hadron mass
- A sensitive observable: light vector mesons (ρ, ω, Φ) in their leptonic decay channel
  - formed and decay inside the fireball (e.g. lifetime of ρ in vacuum = 1.3 fm/c)
  - leptons not affected by final state interactions → probe to study the properties of these mesons in a dense and hot medium
- Experimentally → measure dilepton spectra in the low mass region and compare to what is expected in the absence of medium effects (N-N reference)
- Measured at SPS (CERES, NA60) and at SIS18 (HADES)

CERES, Eur.Phys.J. C 41, 475 (2005)]



HADES, Phys. Rev. C 84 (2011) 014902

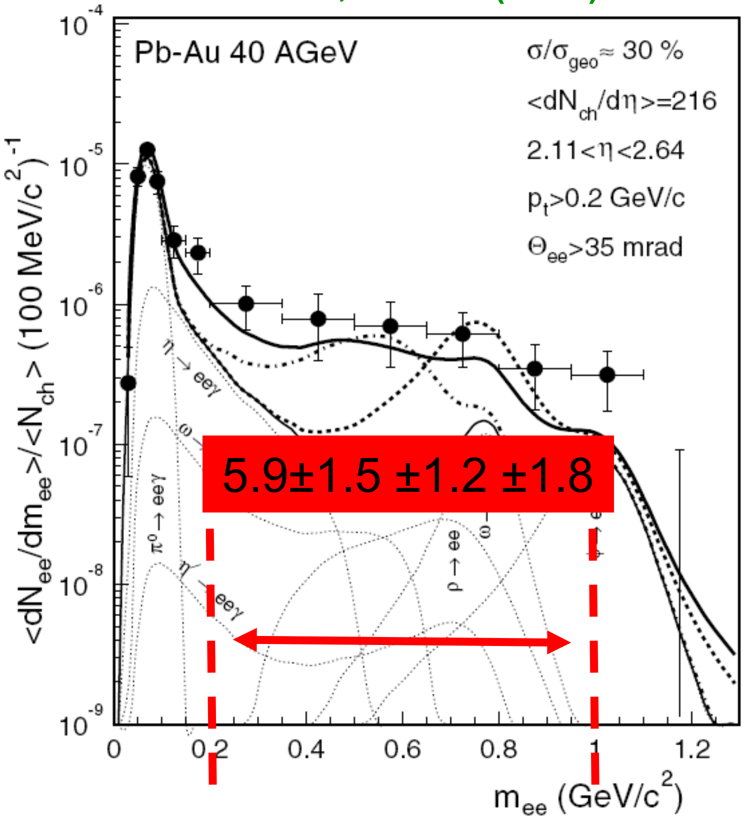


Recent theoretical studies indicate that these effects are more driven by baryon density than by temperature
⇒ Importance of high ρ_B measurements → FAIR energy range (CBM)

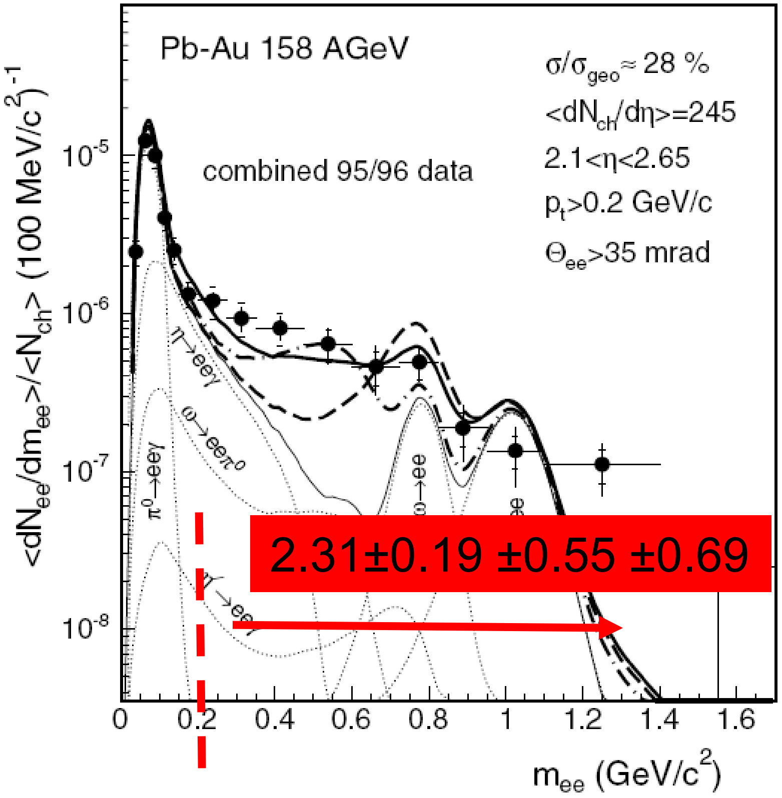
In-medium modification of hadron properties

CERES data → excess factor higher at lower energy

PRL 91, 042301 (2003)



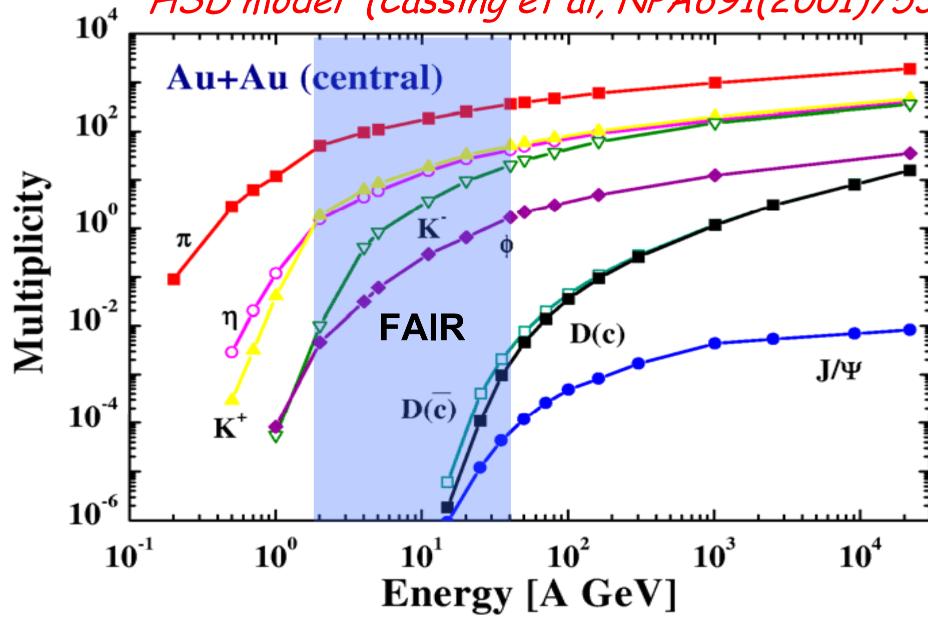
Eur.Phys.J.C 41, 475 (2005)

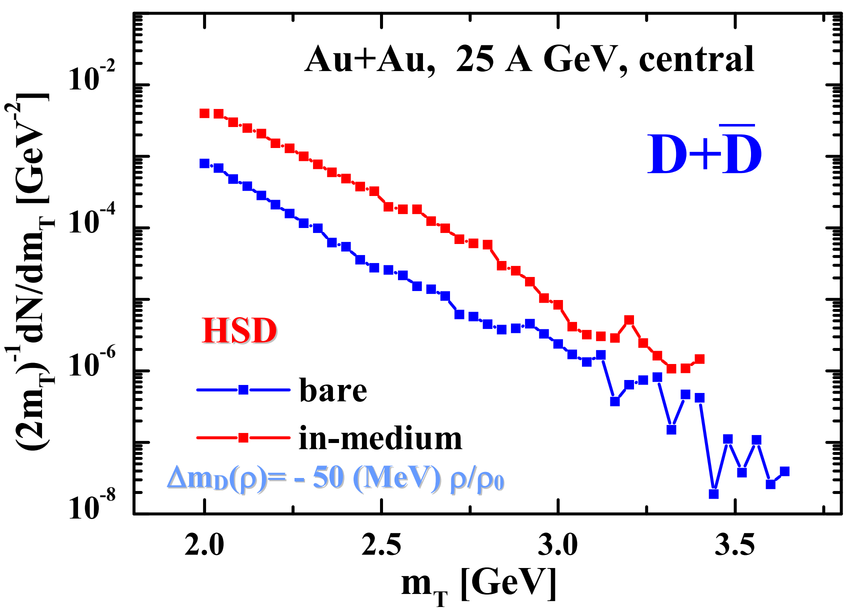


In-Medium Modifications of Hadron Properties
Open Charm

- Open charm particles are produced very early in the collision (dense environment)
- If their mass is modified in the dense medium
  - → Different production yield
  - → Strong sensitivity at FAIR energies (threshold production)

HSD model (Cassing et al, NPA691(2001)753)





CBM

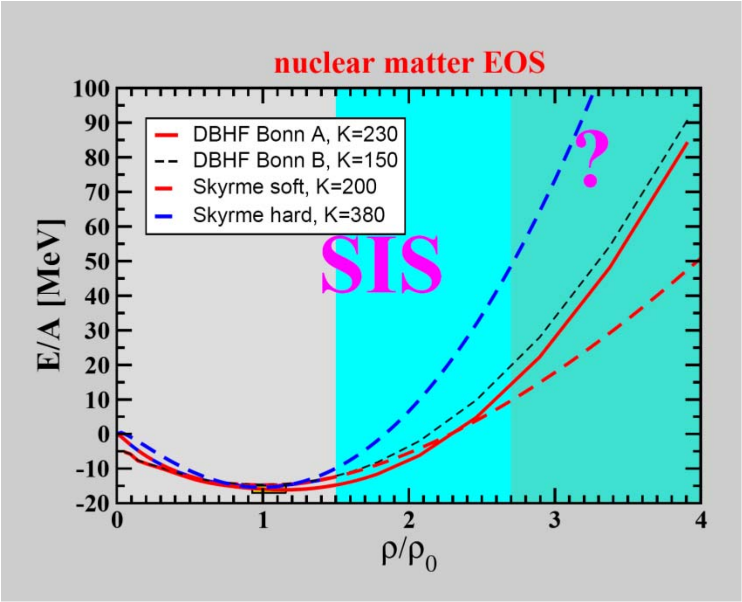
↓

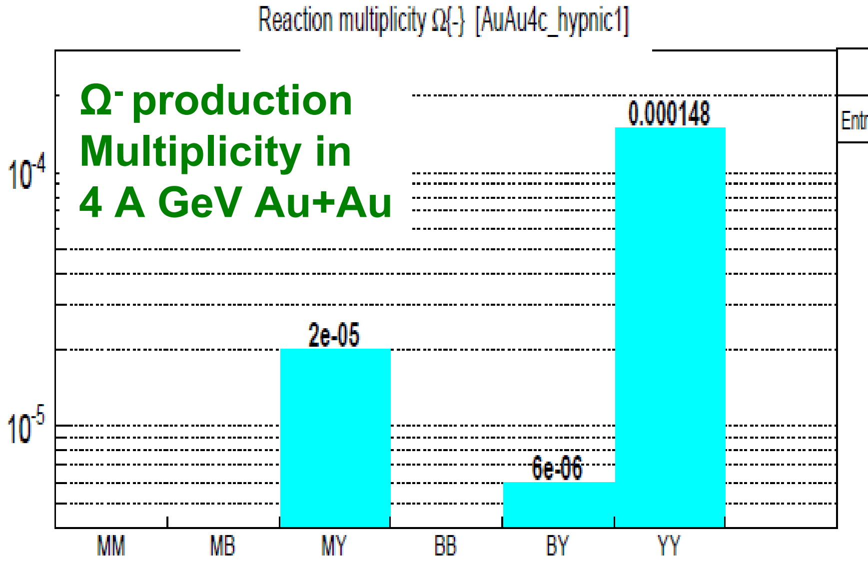
Detailed measurements of different types of open charm particles: D^+, D^-, D^0, Λ_c
→ Yields, p_t spectra and flow

Not measured so far in A-A collisions!

Nuclear Matter Equation of State

CBM will contribute to the determination of the EOS in the region of high baryon densities



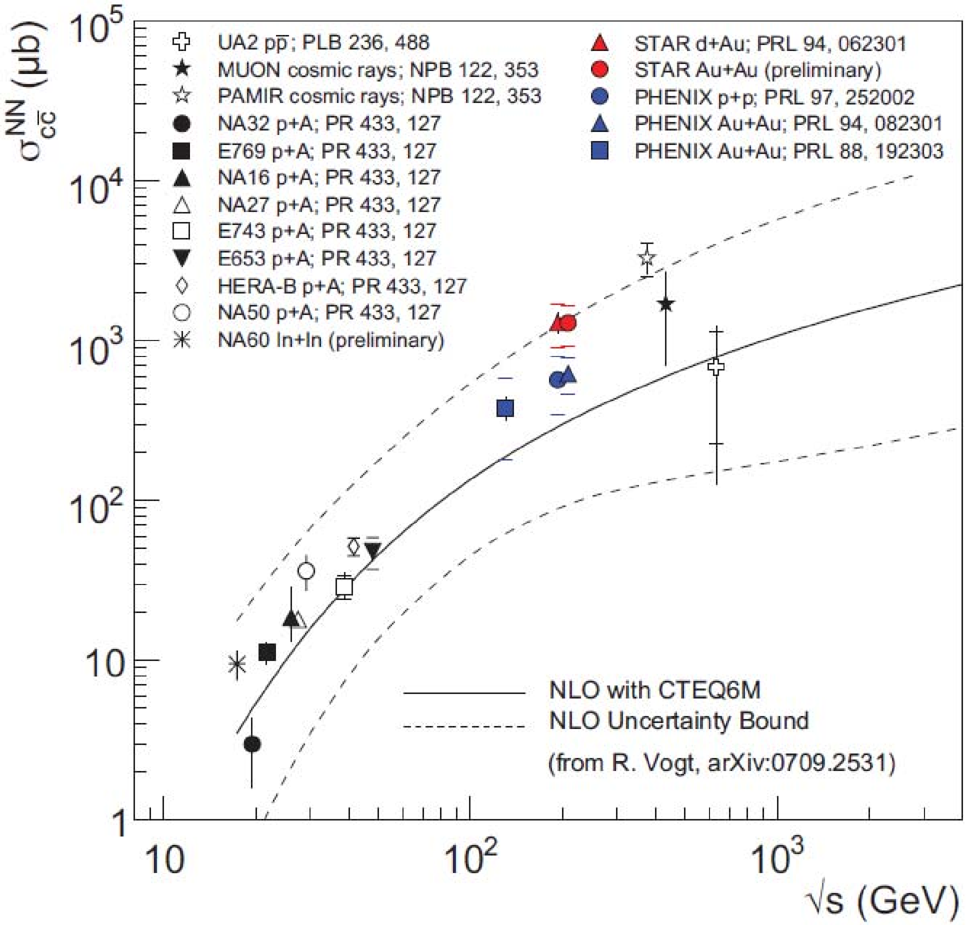


HYPQGSM calculations , K. Gudima et al.

To constrain the theory, CBM will measure two sensitive observables:

- **Collective flow of hadrons (driven by the pressure created in the early fireball)**
- **Production yield of multi-strange baryons at incident energies close to their kinematical threshold (2 to 10 A GeV)**

Charm production mechanisms

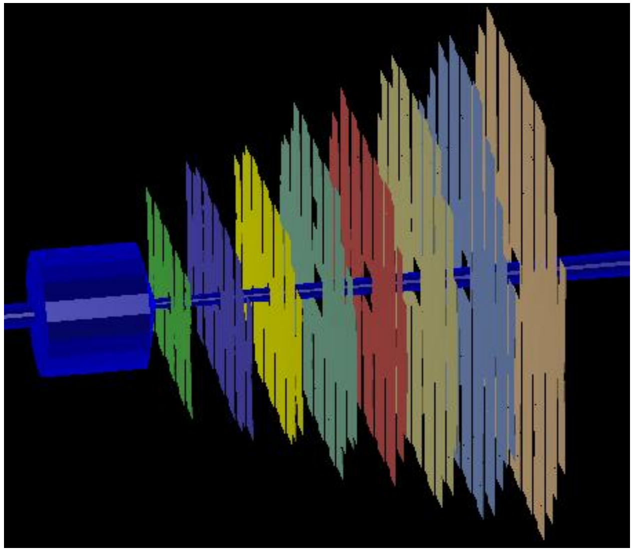


A. Frawley, T. Ulrich, R. Vogt, Phys.Rept.462:125-175,2008

The Silicon Tracking System (STS)

Main tasks:

- **Reconstruct particle tracks**
- **Measure their momentum with good accuracy**

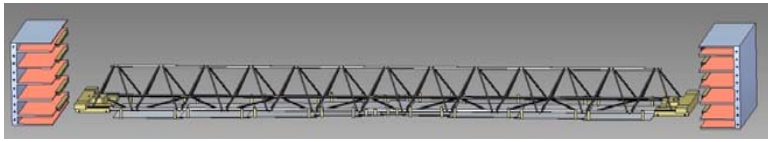


8 Silicon stations (in 1 T dipole magnet)
→ distance from target: 30 to 100 cm
→ total active area ~4 m^2

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
- thickness < 300 µm

- **Partners: GSI + several groups (Germany, Russia, Poland, Ukraine) + CiS (sensor development)**
- **Present status of the project:**
  - **→ R&D (sensors and system integration) being finalized**
  - **→ Prototypes being tested**
  - **→ TDR submitted (Dec 2012)**



Sensors mounted on light weight carbon fiber ladders

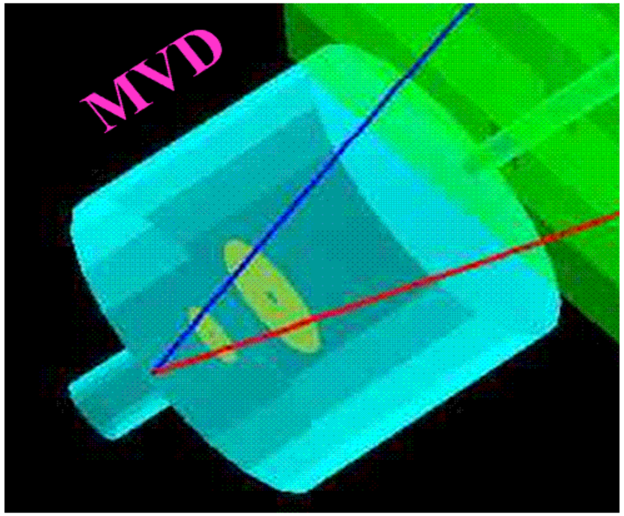
→ Material budget (per station) :
$\leq$ 1% X_0

The Micro Vertex Detector (MVD)

Main task: **Reconstruction of open charm particles**

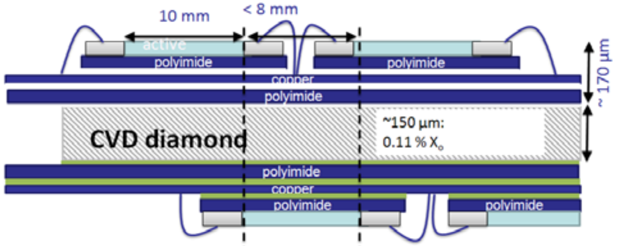
e.g. $D^0 \rightarrow K^- \pi^+$ ($c\tau$ = 123.4 μm)

- Requires an excellent resolution on their decay vertex (z-axis): better than **100 μm**
- **Can be achieved with Monolithic Active Pixel Sensors (MAPS)**



2 Si-pixel stations (in vacuum)
→ distance from target: 5, 10 cm
→ total active area ~20, ~80 cm^2
→ # of cells ~ 5 x 10^6, 5-20 x 10^6

- **Partners: IPHC-Strasbourg (R&D on MAPS)**
  IKF –Frankfurt (system integration)
- **Present status of the project:**
  → **R&D in progress**
  several breakthroughs in the last years
  → **Prototypes being tested**
  → **TDR expected in 2014**



Sensors mounted on ultra-thin carbon supports

→ Material budget (1st station) :
≤ 0.3% X_0

The Micro Vertex Detector (MVD)

Evolution of MAPS performances (PICSEL group of IPHC)

	MVD-1 (SIS100) (10^5 coll/s)	MAPS (2003)	MAPS (2012)	MAPS (expected 2015)
s.p. resolution	~ 5 µm	< 3.5 µm	< 3.5 µm	< 3.5 µm
Material budget	few 0.1% X_0	~ 0.1% X_0	~ 0.05% X_0	~ 0.05% X_0
Time resolution	~ 30 µs	~ 1 ms	~ 100 µs	~ 30 µs
Rad. hardness	few 10^{13} n_{eq}/cm^2	~$10^{12} n_{eq}/cm^2$	>$10^{13} n_{eq}/cm^2$	< 10^{14} n_{eq}/cm^2

(C. Dritsa, Ph-D thesis, Strasbourg-Frankfurt)

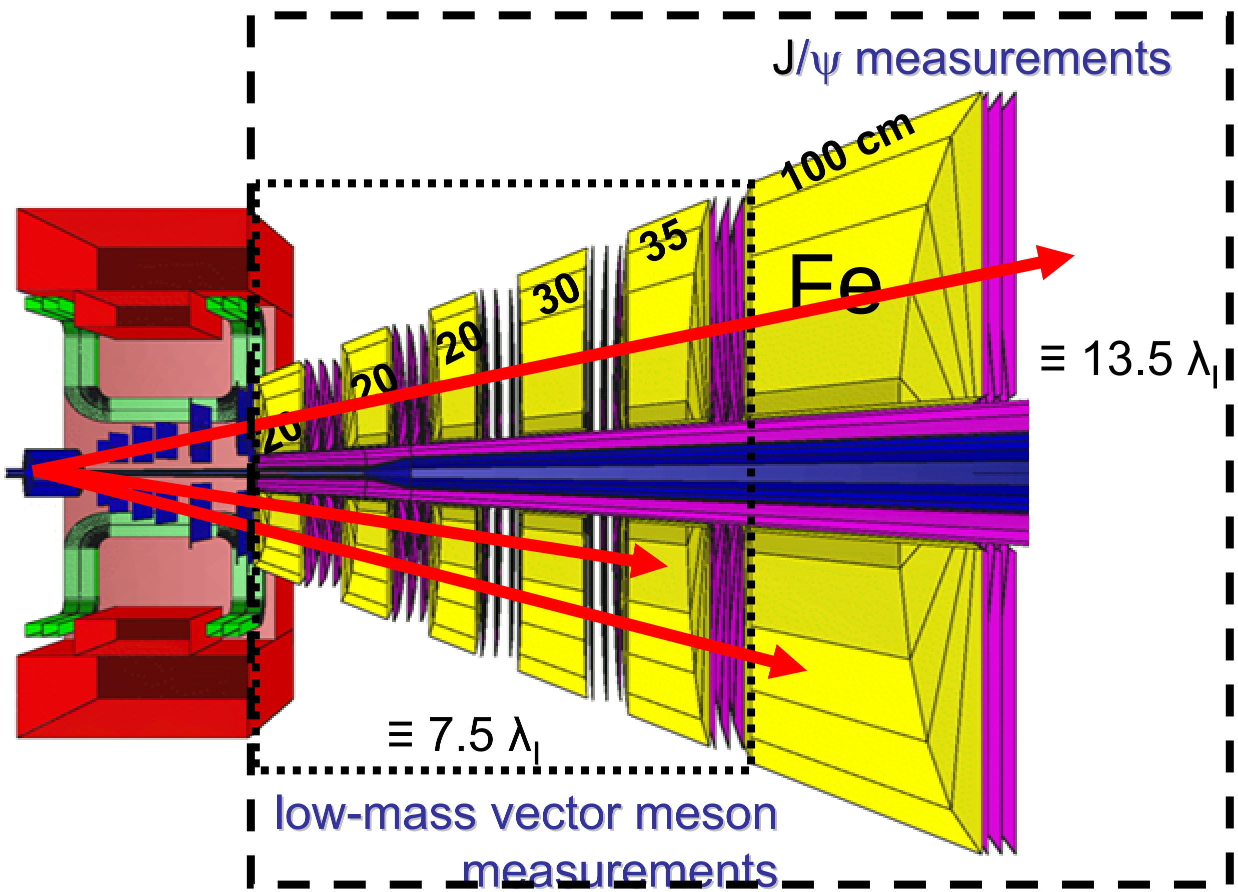
- Expected performances should fulfill the requirements (phase-1 MVD at SIS100)

- **Partners: IPHC-Strasbourg (R&D on MAPS)**
  IKF –Frankfurt (system integration)
- **Present status of the project:**
  - → R&D in progress
    several breakthroughs in the last years
  - → Prototypes being tested
  - → TDR expected in 2014

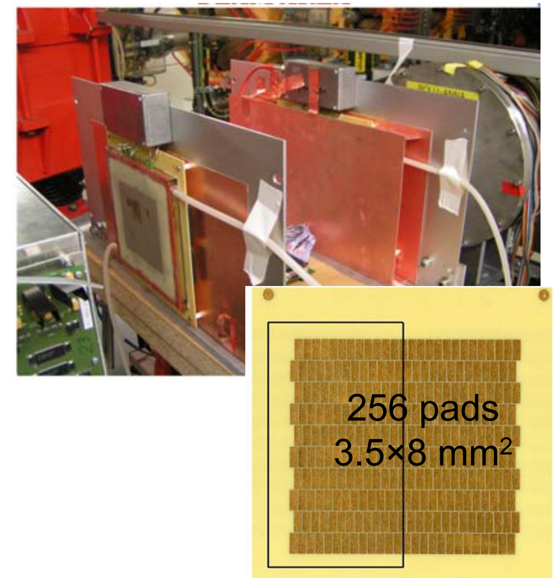
Muon detection

Segmented hadron absorber + tracking stations

- **Iron absorber: 3x20 + 30 + 35 + 100 cm**
- **6 detector triplets: 3 GEM + 3 straw tubes**



GEM detectors



→ **Total active area (all chambers) ~ 70 m^2 subdivided into ~ 0.5 x 10^6 channels**

→ **The challenge for the muon chambers and for the tracking algorithms is the huge particle density of up to 1 hit/cm^2 per event in the 1st detector layers after 20 cm of iron**

Funding CBM start version 2018 in Mio € (2009)

according to the CBM pre-construction MoU (September 2012)

Project	Costs full version	Costs start version	secured funding start version	applied funding start version	intended funding start version
MVD	2.1	2.1	0	2.0	0.1
STS	11.5	11.5	10.5	1.0	0
TRD*	9.6	4.0	1.3	2.5	0
RICH	5.6	5.6	0	3.3	2.3
TOF	6.8	6.8	4.6	1.5	0.5
DAQ*	3.9	3.0	0.5	1.9	0.6
FLES*	6.0	3.0	0	1.0	2.0
Magnet	4.3	4.3	4.3	0	0
MuCh*	10.6	4.0	4.0	0	0
PSD	1.0	1.0	1.0	0	0
Infrastr.	4.2	4.2	4.2	0	0
ECAL*	10.6	3.0	0	0	3.0
Sum in 2009 €	**76.4**	**52.5**	**30.4**	**13.2**	**8.5**
Sum in 2005 € (*1/1.04)	**69.2**	**47.6**	**29.2**	**12.7**	**7.7**

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

TDR*, DAQ*, FLES*, MuCh*, ECAL*: reduced for CBM start version 2018