Heavy Flavour Perspectives With the CBM Experiment

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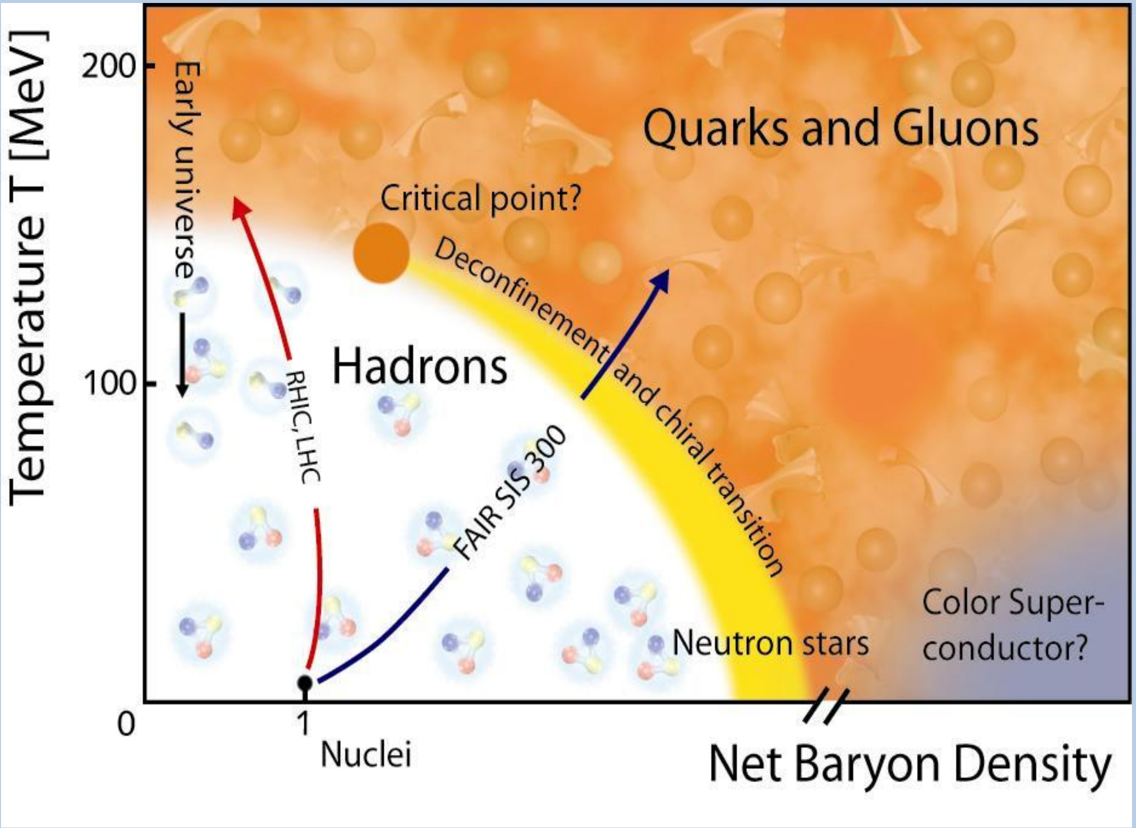
GSI Darmstadt

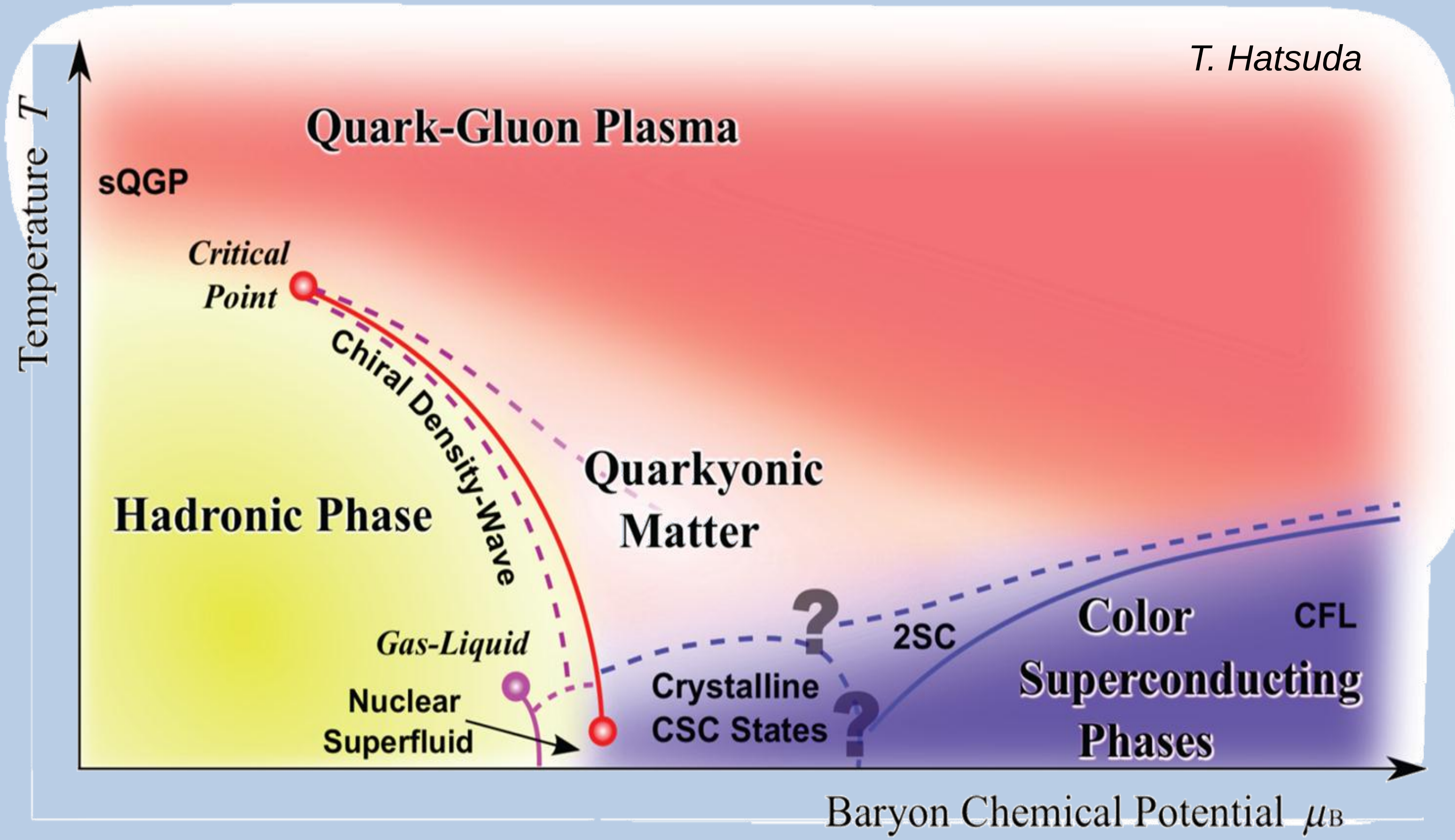
5th International Workshop on Heavy Quark Production in Heavy-Ion Collisions
Utrecht, 17 November 2012

QCD Phase Diagram: Canonical View



- μ_b = 0: crossover from hadronic to partomic medium
- RHIC + LHC domain: study the properties of the deconfined medium at highest availale energy densities
- Transition to partonic medium also expected for lower temperature but high baryon densities

QCD Phase Diagram: Contemporary View

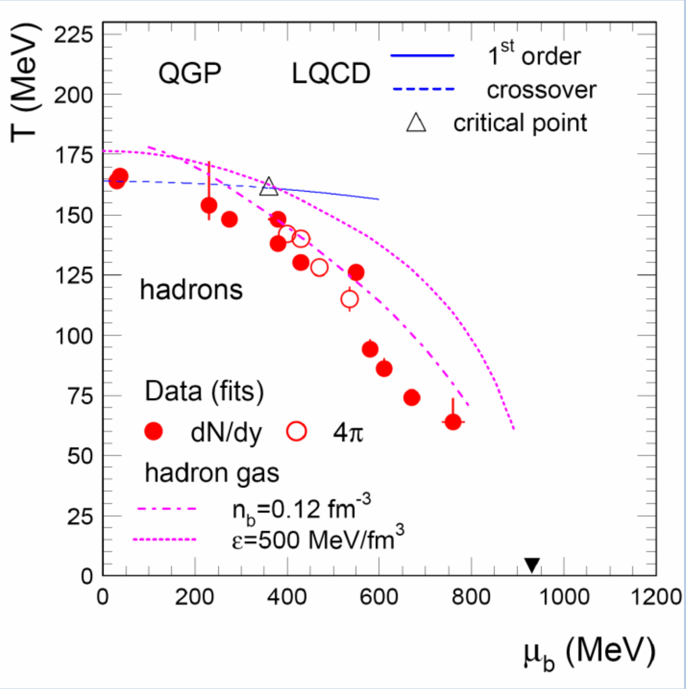


A rich structure of QCD at high densities!

- First-order deconfinement transition + critical point
- Chiral restoration ≠ deconfinement: quaryonic phase?
- Exotic phases

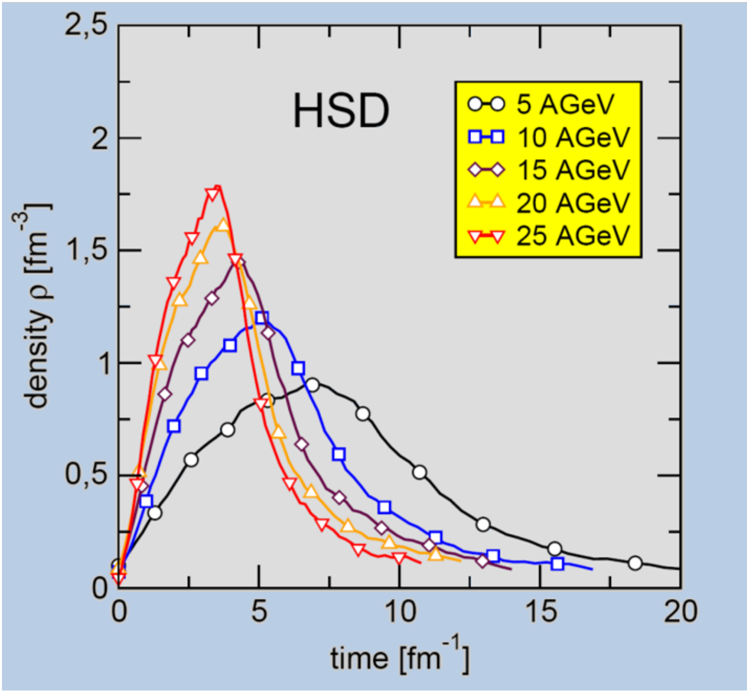
Accessing Dense QCD Matter

A. Andronic et al., Phys. Lett. B 673 (2009)



Freeze-out points from hadron gas models

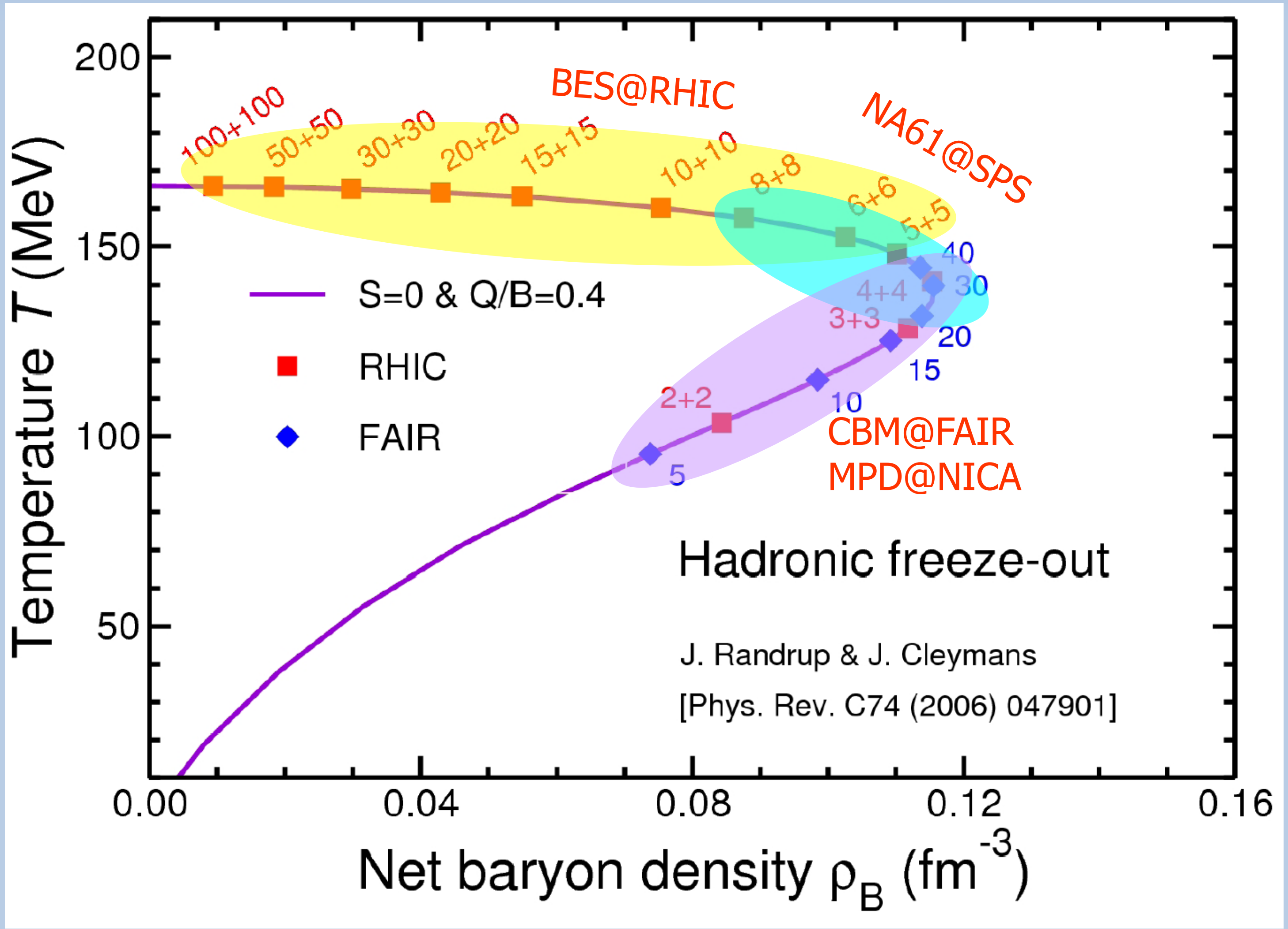
E. Bratkovskaya, W. Cassing



Hadronic transport

The high density regime of QCD is accessible with heavy-ion collisions at moderate collisions energies.

Covering the High Density Regime



Maximal net-baryon density (from hadron gas model): E_{beam} ≈ 30A GeV ($\sqrt{s_{NN}}$ ≈ 8 GeV)

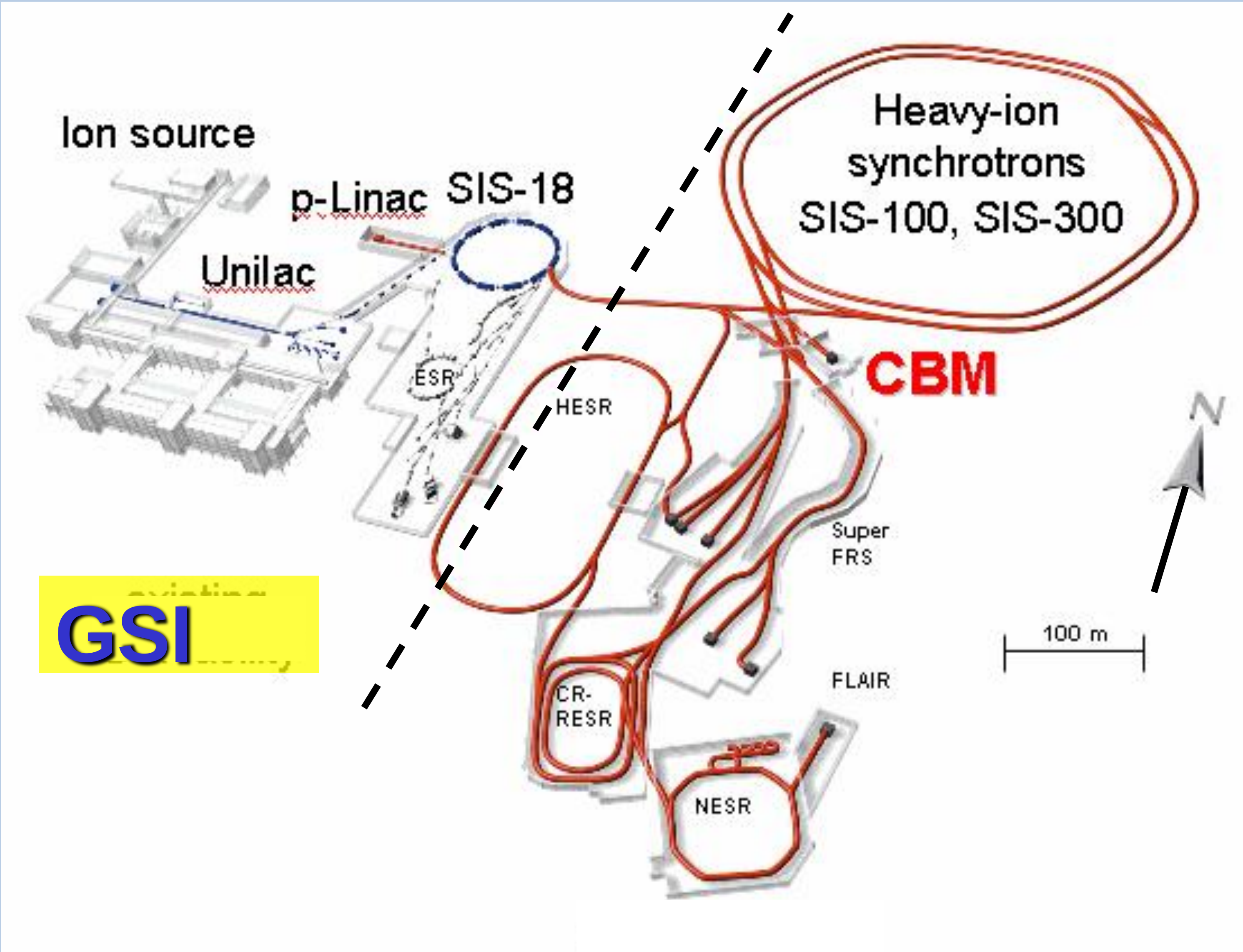
Experimental Programmes

	Fixed Target	Collider
Existing	NA61 @ CERN-SPS E_{beam} = 20 – 160 AGeV $\sqrt{s_{NN}}$= 6.4 – 17.4 GeV	BES @ BNL-RHIC $\sqrt{s_{NN}}$= 7 – 200 GeV
Planned / Under Constuction	CBM @ GSI-FAIR E_{beam} = 2 – 35 AGeV $\sqrt{s_{NN}}$= 2.7 – 8.3 GeV	MPD @ JINR-NICA $\sqrt{s_{NN}}$= 4 – 11 GeV

Pioneering: AGS (2 – 11 AGeV), NA49 (20 – 158 AGeV)

but only first glance with limited phase space and/or statistics

The FAIR Project



SIS-100/300:

protons:
max: 90 GeV

ions:
max. 45 GeV
up to Z/A=0.5
(35 AGeV Au)

intensities:
up to 10^9 ions per second at CBM

The FAIR Project

Facility for Anti-Proton and Ion Research

At GSI, Darmstadt

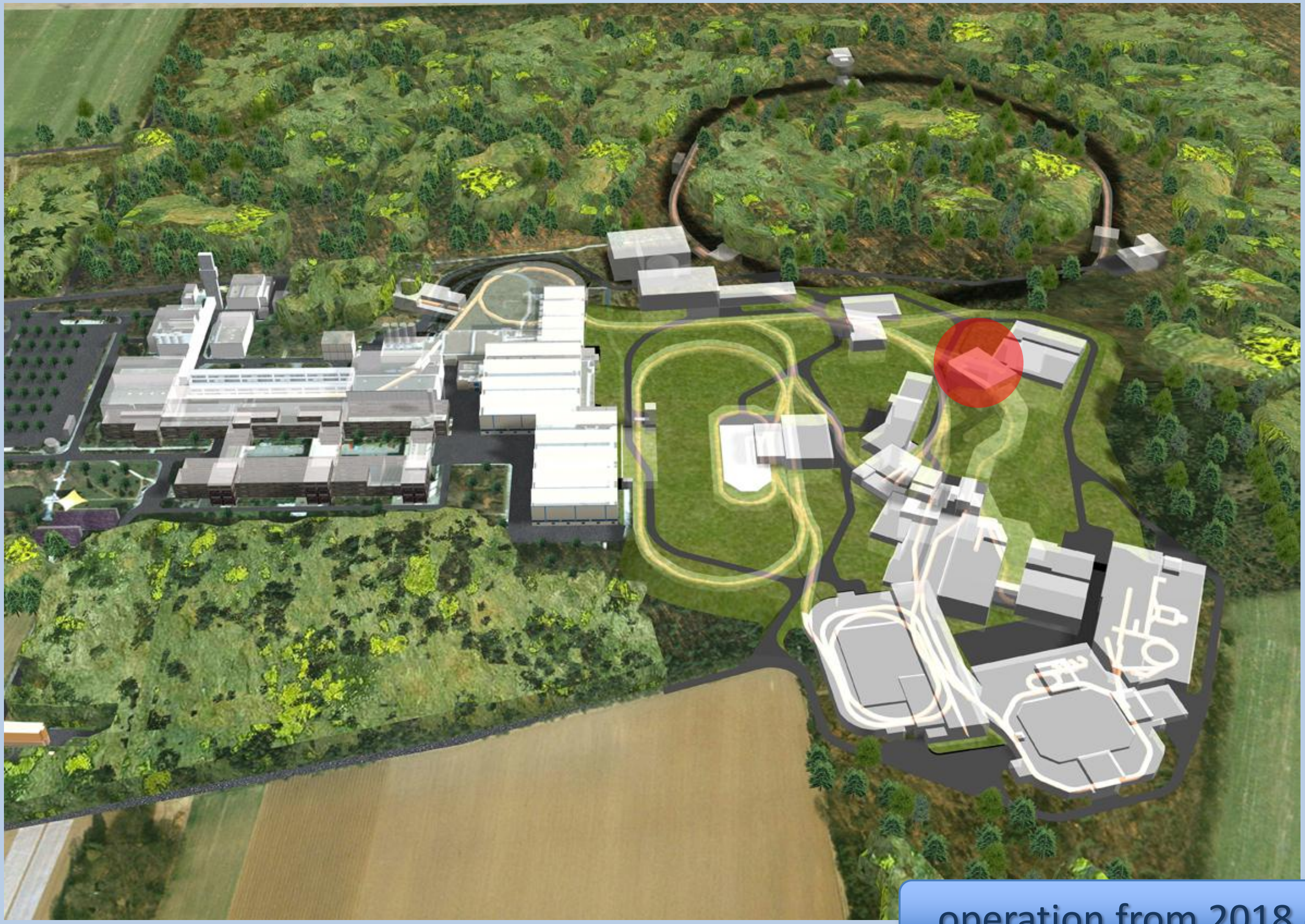
Hadron physics with anti-proton beams

Nuclear structure physics with rare isotope beams

Plasma physics with short-pulsed heavy-ion beams

Atomic physics with highly charged ions and low-energy anti-protons

Nuclear collisions:
CBM
Ion beams 10^9/s
10 – 45 AGeV



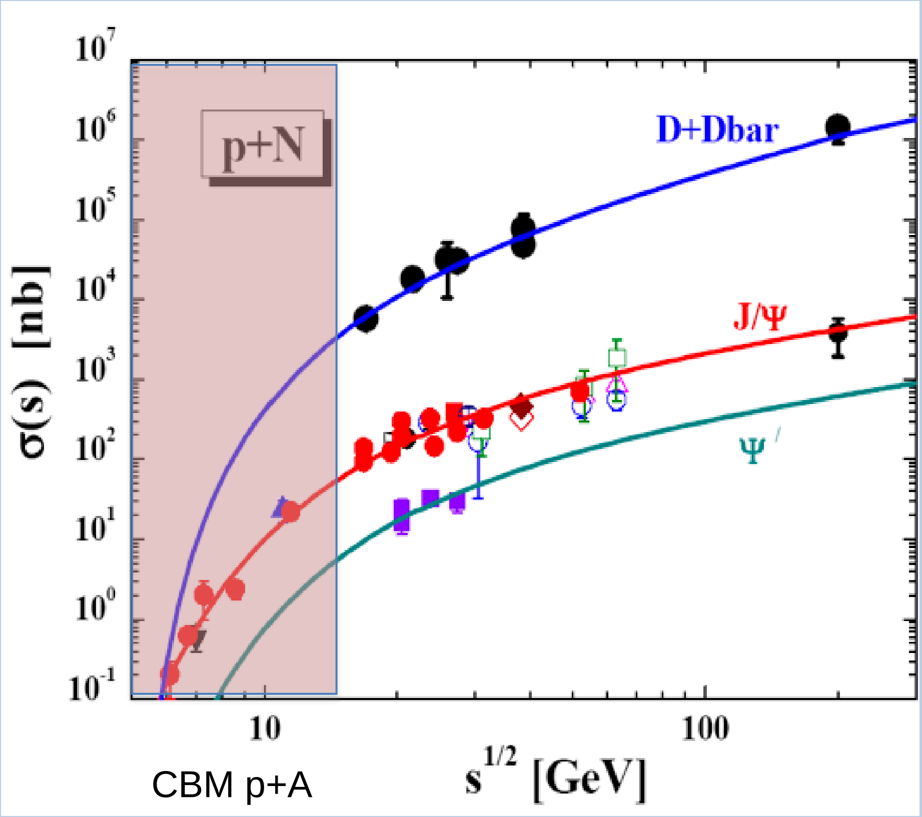
operation from 2018 on

Exploring Dense Matter

- Only vague guidance by theory:
  - present lattice QCD does not extend into this regime
  - rely on effective QCD models
- Characterise the medium systematically in terms of collision energy and system size:
  - strangeness, charm, flow, fluctuations
- Look for discontinuities signalling phase transitions or critical behaviour

The Role of Charm

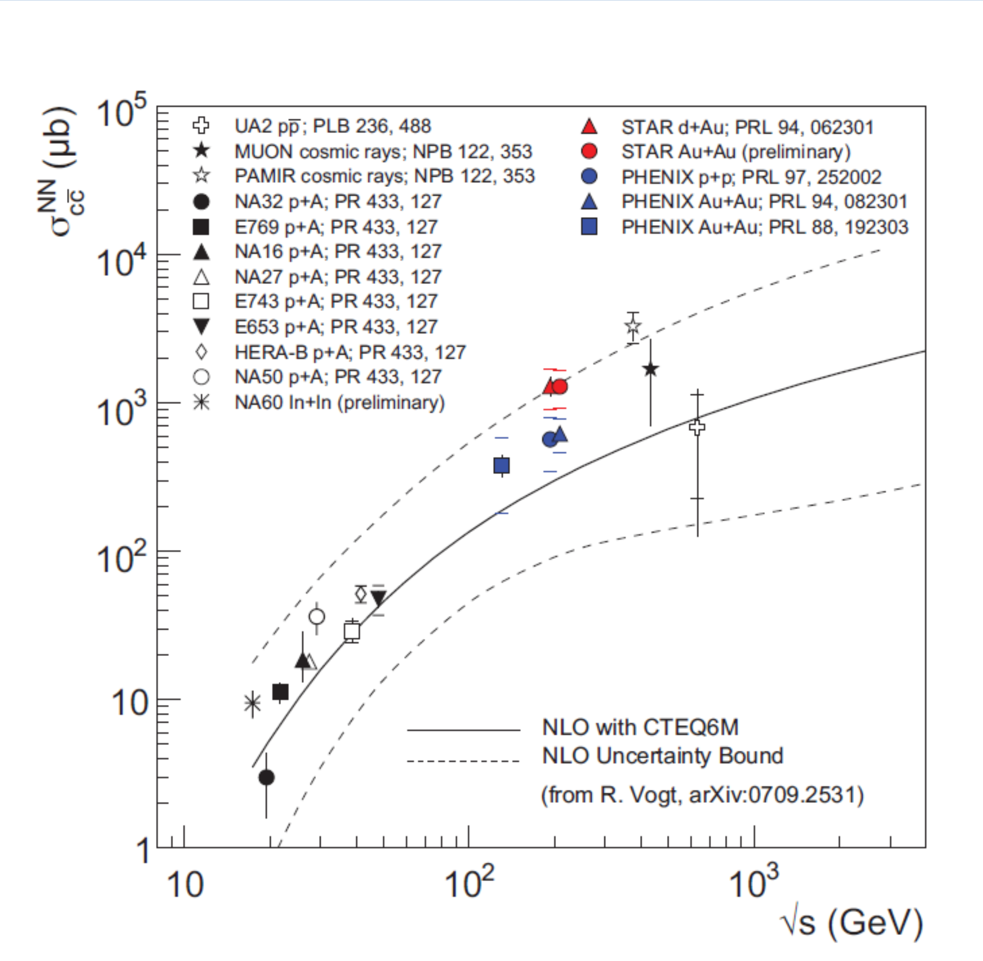
O. Lynnek et al., Nucl. Phys. A 786 (2007) 183



- Close to kinematic production threshold: total charm cross section experimentally unknown
- Both hidden and open charm are expected to contribute to the total charm production
- Predictions for A+A rely on parametrisation of experimental data: large uncertainties towards threshold

The Unknown Territory

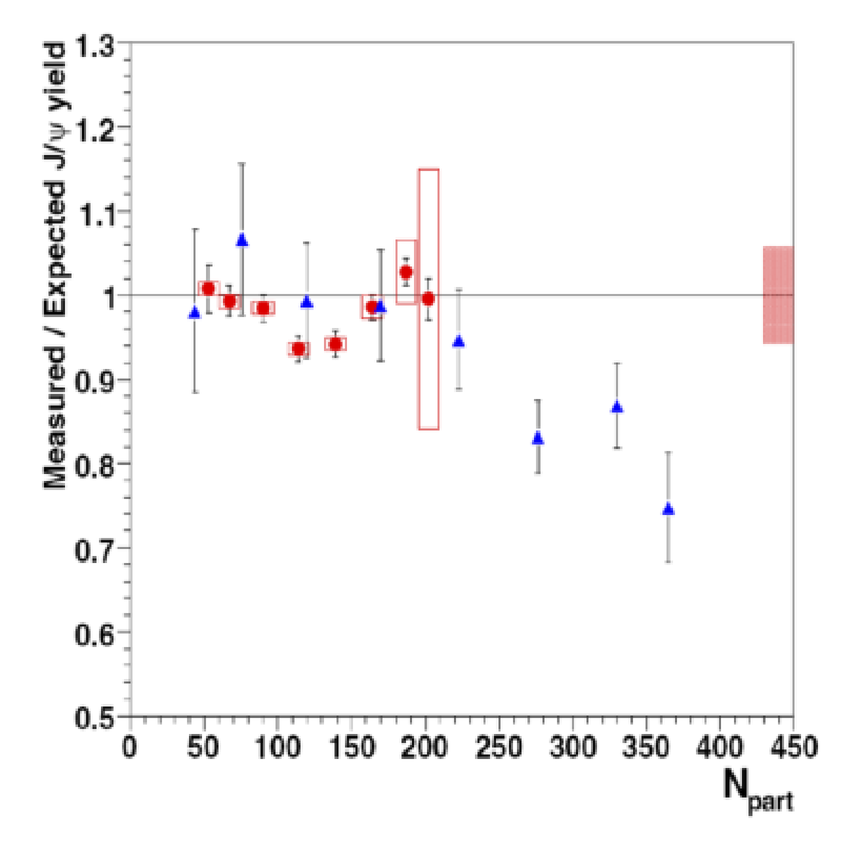
A. Frawley, T. Ulrich, R. Vogt, Phys. Rept. 462:125-175, 2008



- Large uncertainties in pQCD
- Experimental data close to threshold highly desirable
- No p+N data below 20 GeV
- No A+A data below top SPS (charmonium) / RHIC (open charm)

Charmonium: The QGP Signal

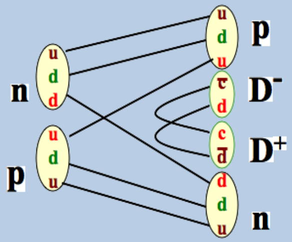
R. Arnaldi et al. (NA60), Nucl. Phys. A 830 (2009) 345c



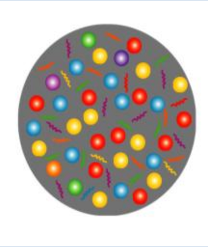
- Dissociation of bound c-cbar pairs due to Debye screening in presence of free colour charges
- Anomalous suppression (on top of nuclear absorption): observed first at SPS for most central Pb+Pb
- Many discussion, many effects (comover absorption, regeneration)
- Precision reference data in p+A indispensable
- Stays a prime messenger of a deconfined phase
- Can we see an onset of J/ψ suppression at lower energies?

Scenarios of Charm Production in A+A

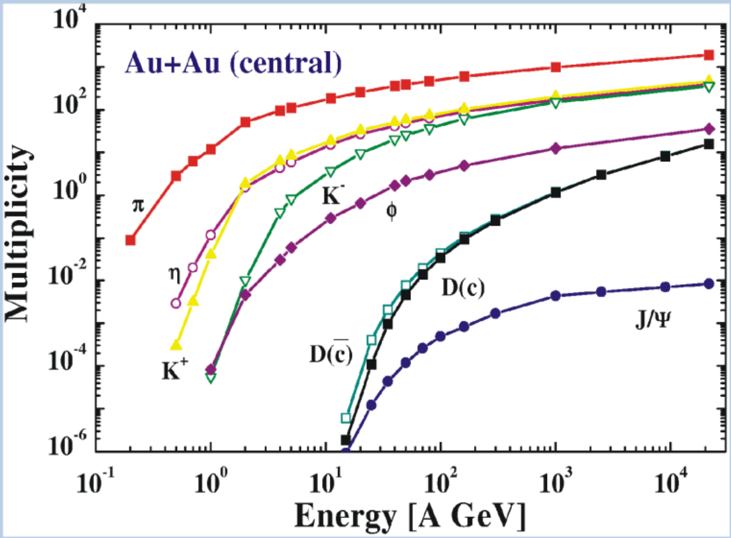
hadronic



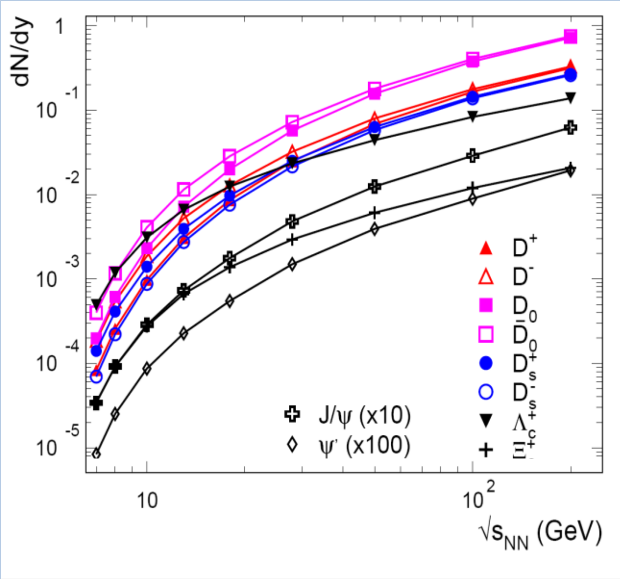
partonic:
pQCD +
statistical
hadronisation



W. Cassing et al., Nucl. Phys. A 691 (2001) 753



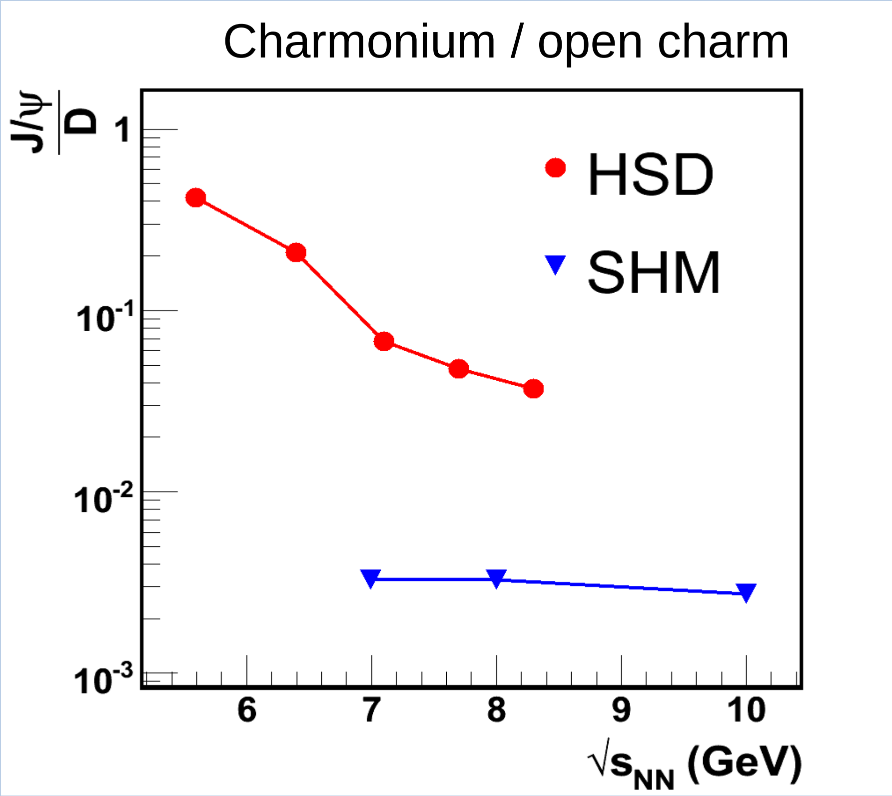
A. Andronic, et al., PLB 659 (2008) 149



Quite different predictions from hadronic and partonic models:

charm production is sensitive to the phase of matter

Predictions of Charm Production



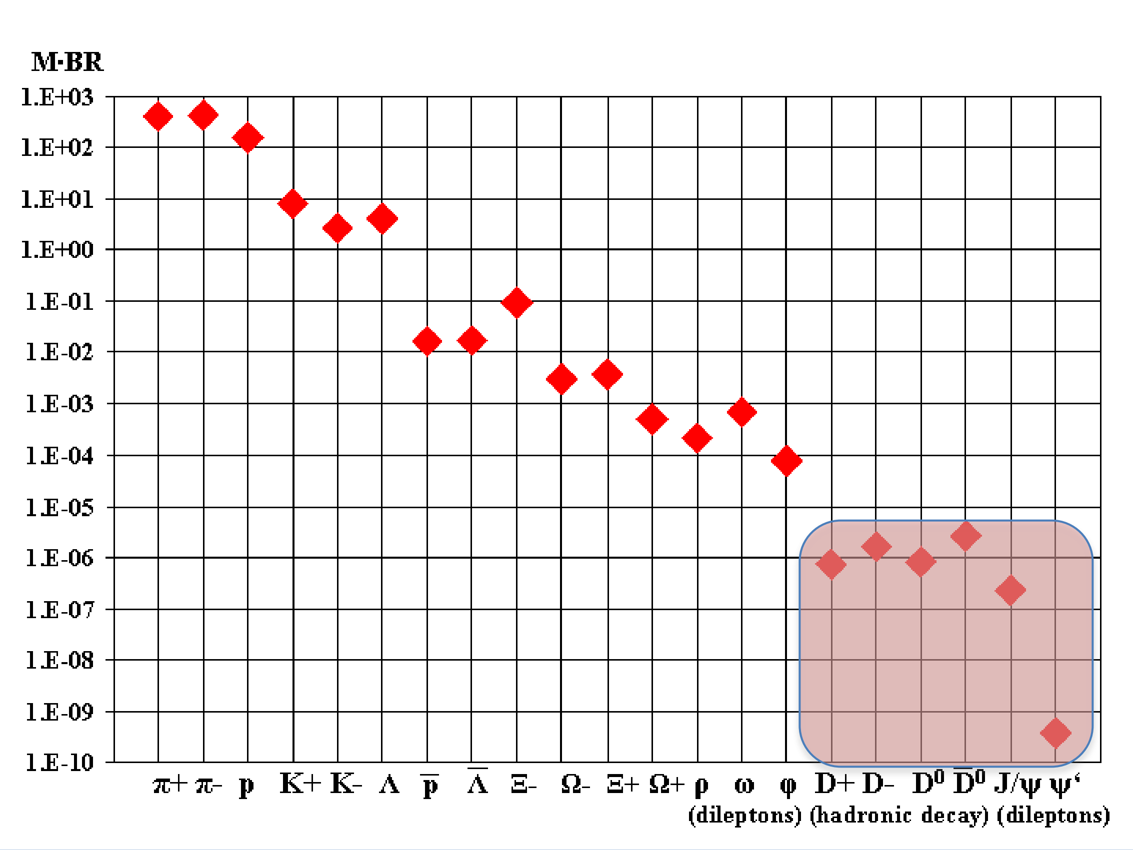
HSD: O. Linnyk et al., Nucl. Phys. A786 (2007) 183

SHM: A. Andronic et al., Phys. Lett. B 659 (2008) 149

The ratio of hidden to open charm seems a very promising probe of the production process!

Charm as a Challenge

Yield predictions for central Au+Au @ 25A GeV (HSD / thermal model)



At the energies under debate, charmed hadrons are extremely rare – O(10^{-6})

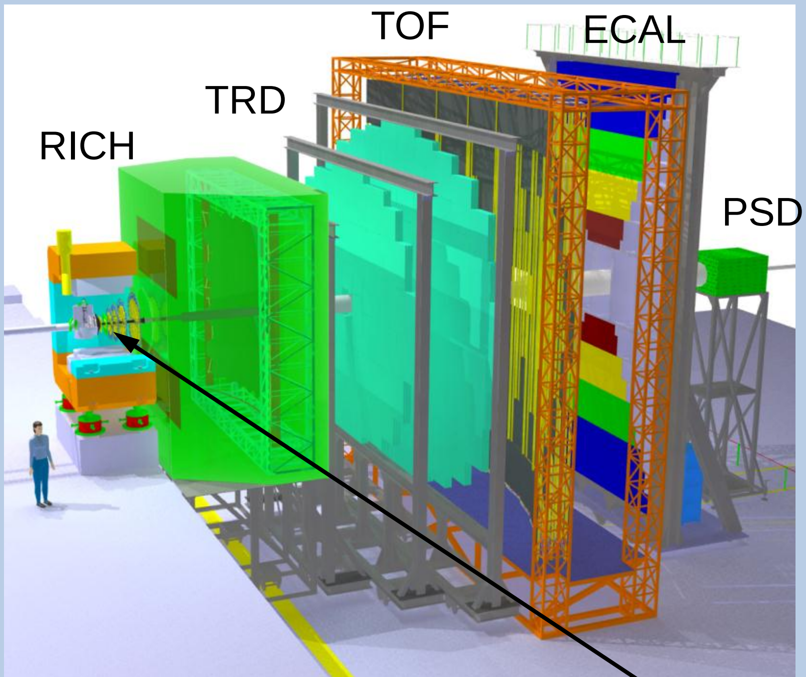
Are they experimentally accessible?

Rare Probes, High Rates

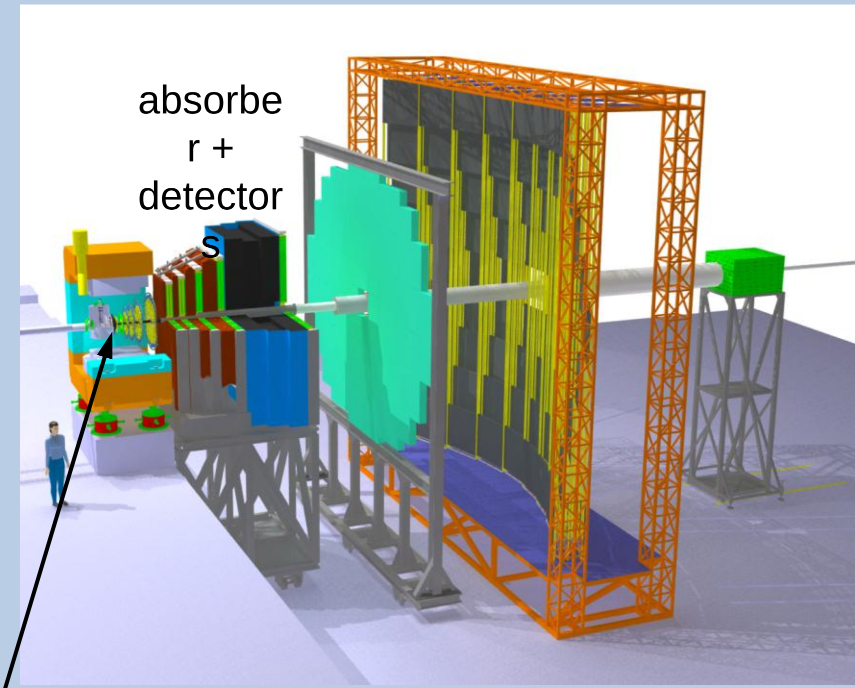
- The key to charm at FAIR energies is a high-rate experiment
  - typical rates of existing experiments: several 100 Hz
  - MHz rates nothing special in particle physics experiments
  - what prevents us from doing a MHz heavy-ion experiment?
- What we need:
  - fast and rate-capable detectors
  - fast read-out electronics
  - radiation-hard detectors and electronics
  - high-throughput data acquisition and efficient online data selection

CBM: experimental setup

Electron + Hadron setup



Muon setup



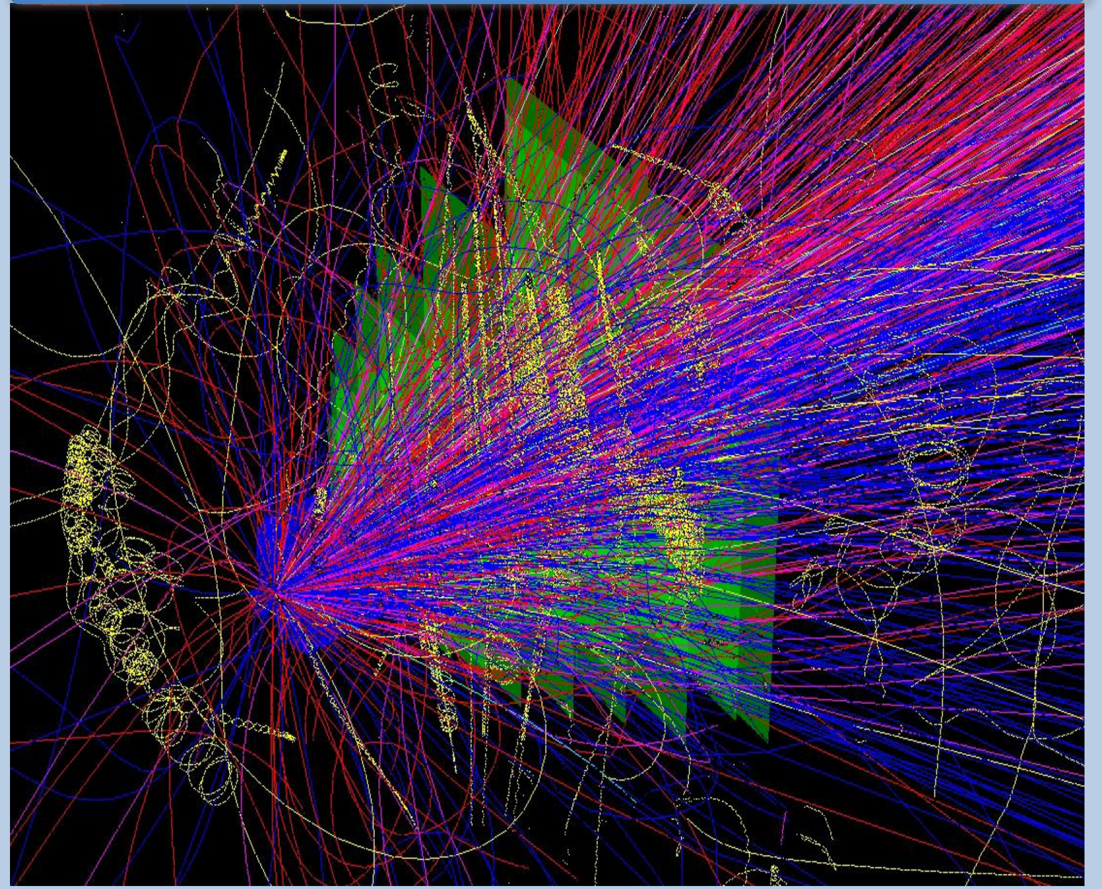
STS+MVD

Detector systems

- Main tracking device: STS
  - low-mass silicon strip detectors in magnetic diplole field
  - tracking efficiency > 90 %
  - momentum resolution ≈ 1%
- Micro-vertex detector for open charm: MVD
  - low-mass silicon pixel detector close to the target
  - high precision (resolution ≈ 3 µm)
- Electron identication: RICH and TRD
  - RICH with $C0_2$ radiator, two focal planes and MAPMT photo detection
  - several layers of thin TRDs with MWPC readout
- Hadron identification: TOF
  - RPC wall at 10 m flight distance, resolution <≈ 80 ps
- Muon identification: active absorber system
  - several absorber / GEM detector layers
- ECAL for photon and electron identification
  - lead/scinitillator sandwich
- Event characterisation: PSD
  - compensated forward calorimeter

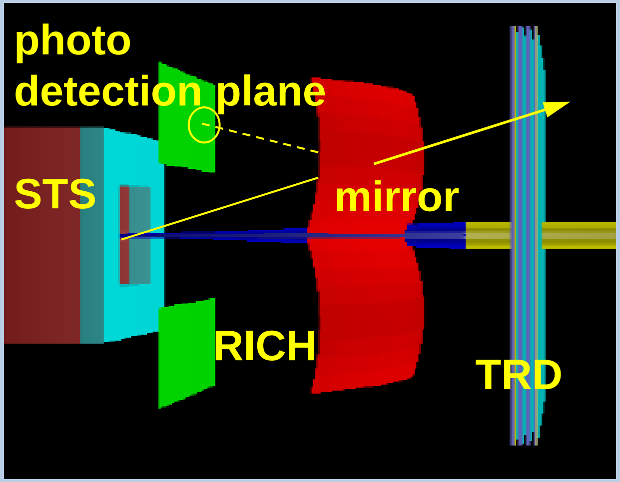
The challenge

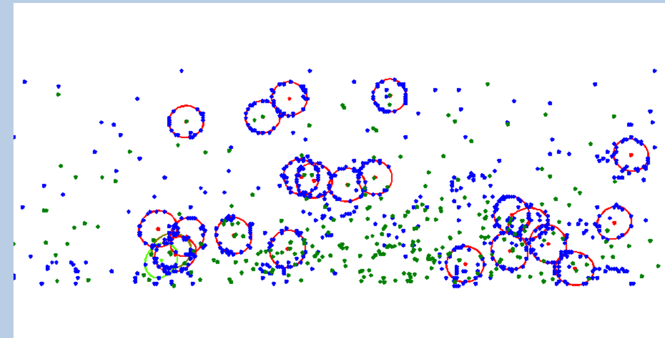
Central Au+Au collision at 25A GeV., simulated in the CBM detector



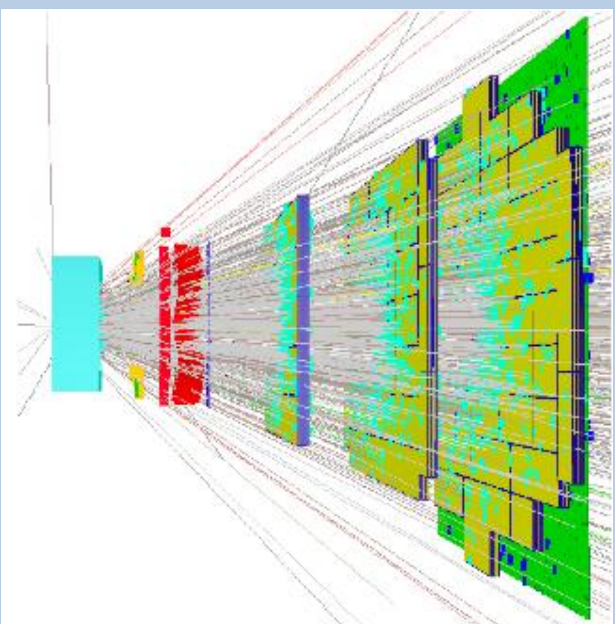
- typical CBM event: about 700 charged tracks in the acceptance
- strong kinematical focusing in the fixed-target setup: high track densities
- up to 10^7 of such events per second
- to be reconstructed precisely, fast and with high efficiency

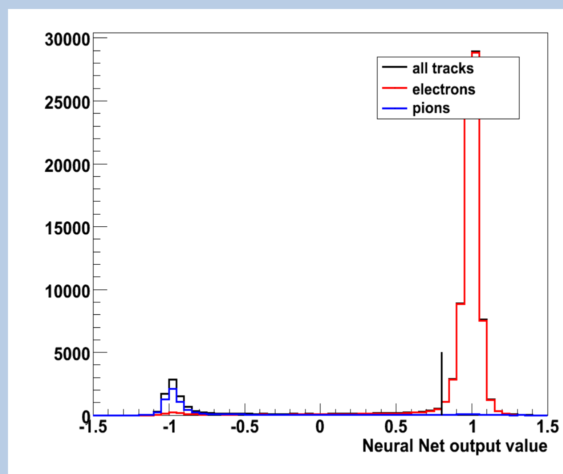
$J/\psi \to e^+e^-$





Proximity-focusing RICH with granular MAPMT readout

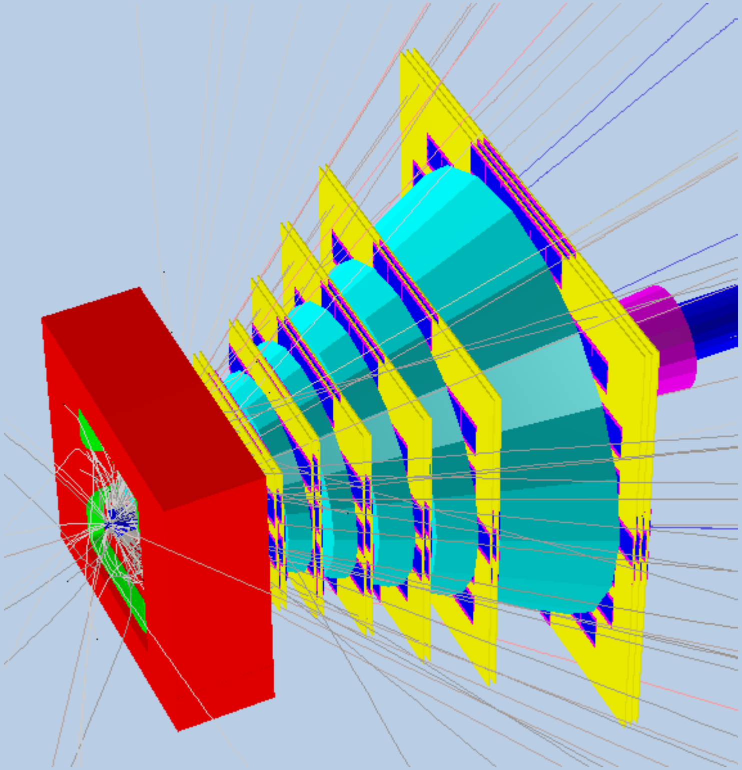


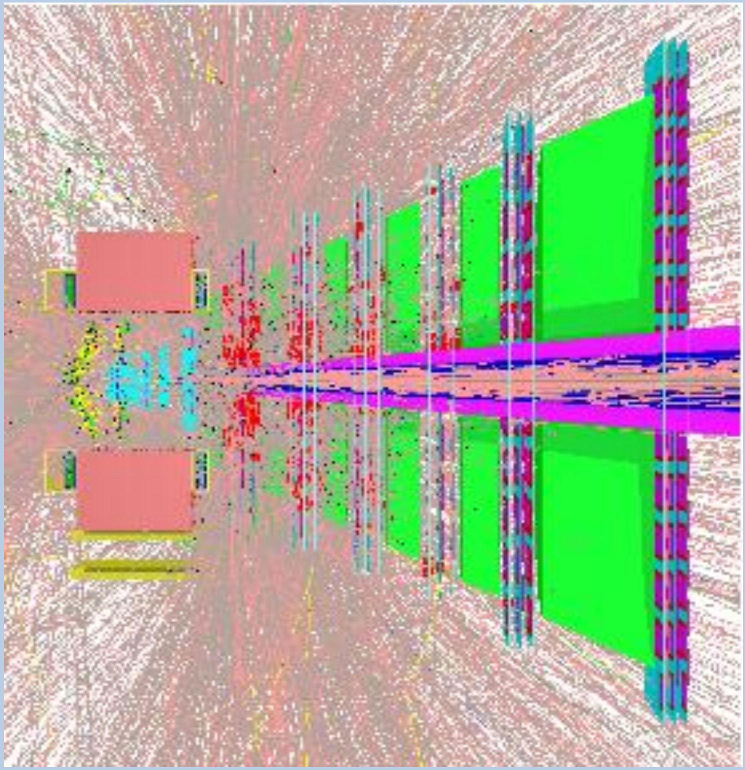


10-layer TRD with MW pad readout

Combined RICH+TRD pion suppression ≈ 10^4

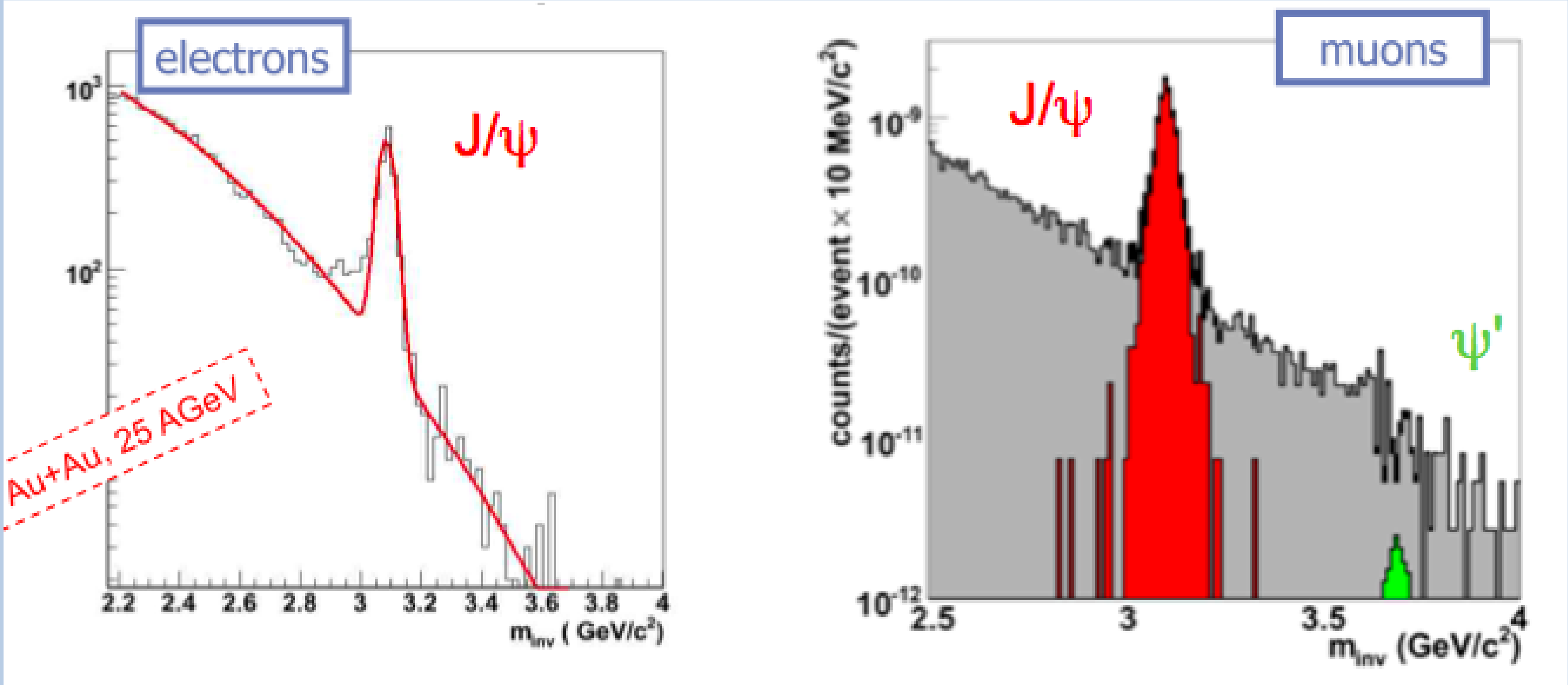
J/ψ -> $\mu^+\mu^-$





Instrumented absorber (225 cm Fe total, 6 x 3 GEM / straw tube detector layers)
Allows tracking through the system

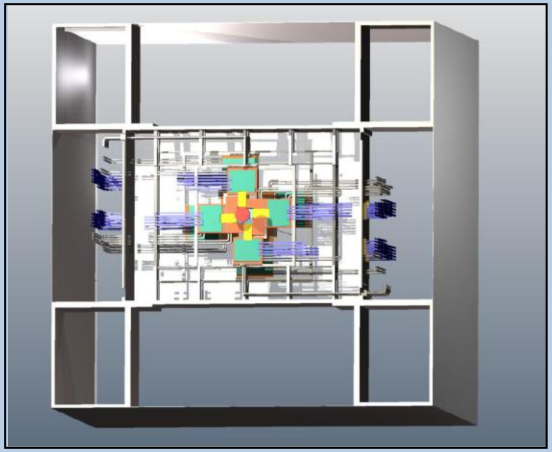
Performance for Charmonium



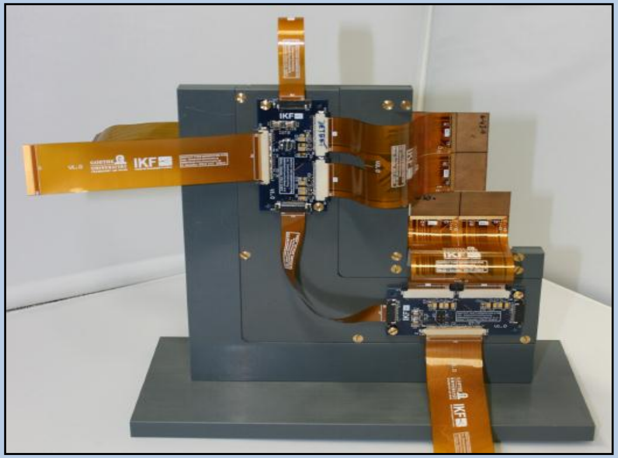
Comparable performance for electron and muon channels
Easier trigger signature for muons

Micro-Vertex Detector

MIMOSA 26



station design

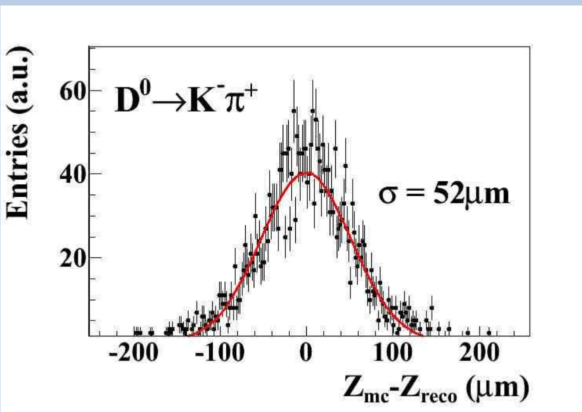


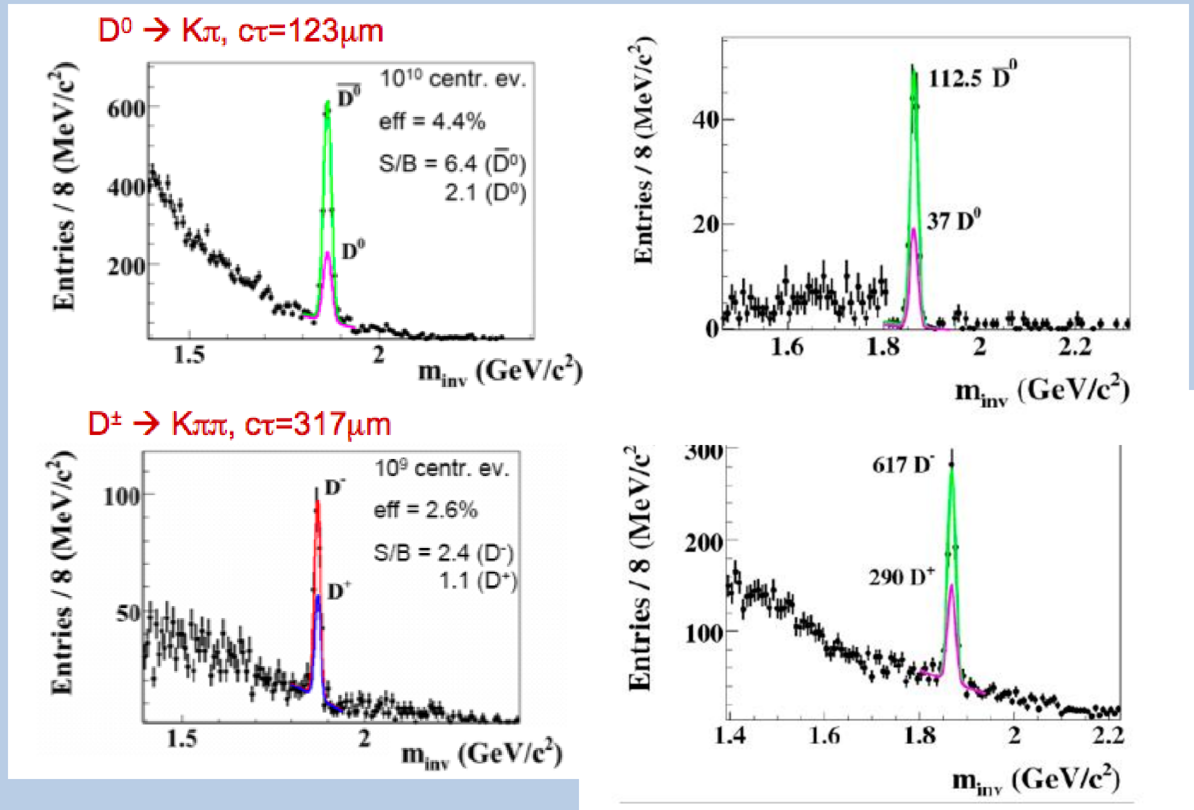
prototype

The key to open charm is a high-precision, ultra low-mass vertex detector

- MAPS: integrated electronics, very low material budget, very precise (3 µm)
- Not intrisically fast and radiation hard, but tremendeous progress: 40 µs r/o frame, stands up to 10^{13} n_{eq}/cm^2
- now almost „state of the art“ (STAR, ALICE. NA61 upgrades)

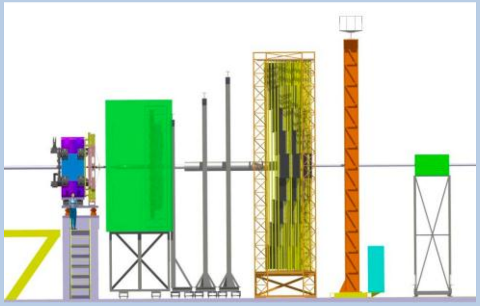
Performance for Open Charm





Secondary vertex resolution of ≈ 50 μm allows clean separation of open charm signals from combinatorial background

The Big Challenge: Data Reduction

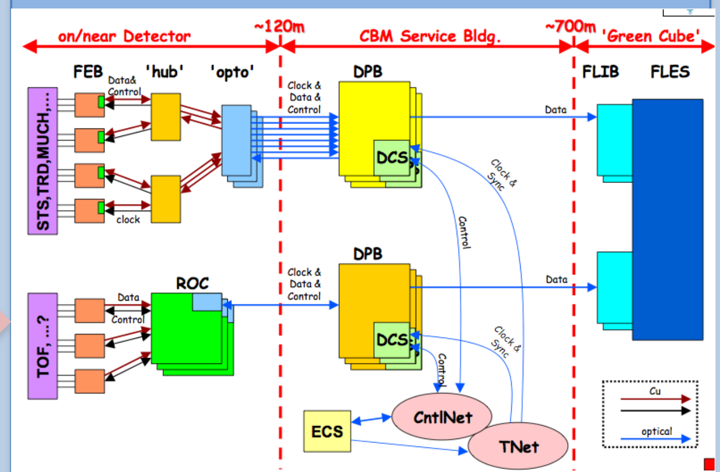


CBM FEE

At 10 MHz, online data reduction by ≈ 1000 is mandatory

Trigger signatures are complex (open charm) and require partial event reconstruction

1 TB/s

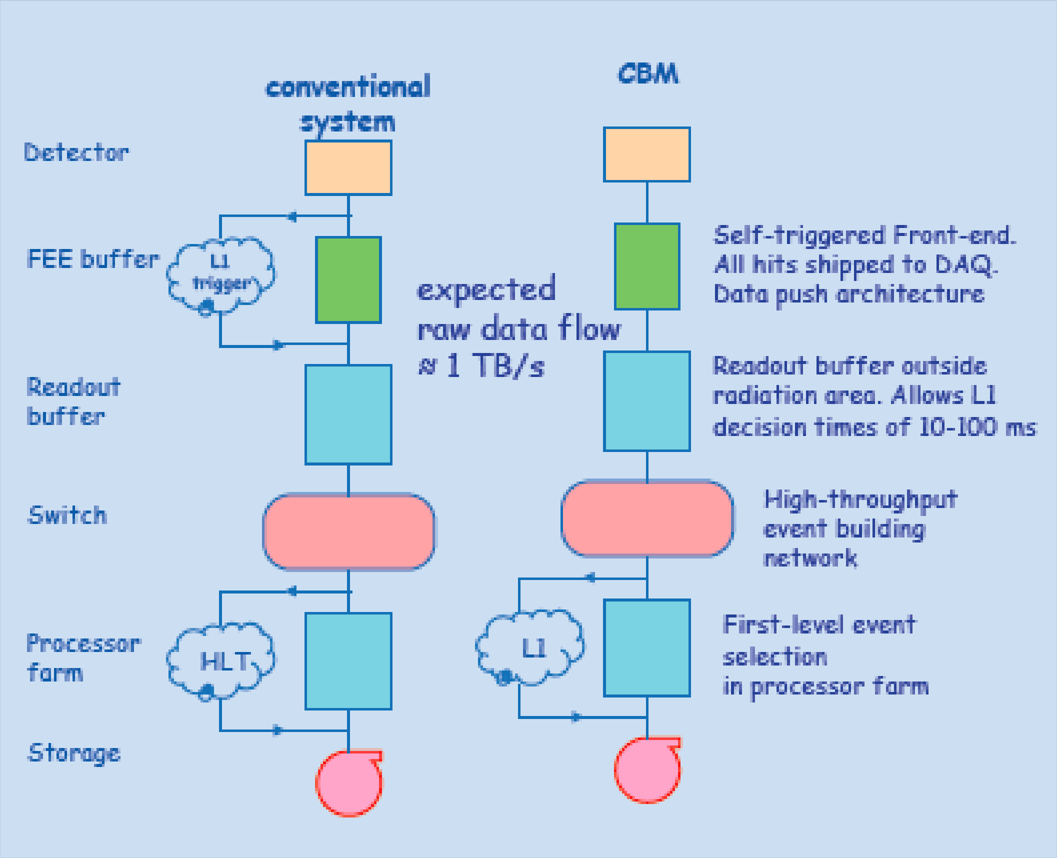


1 GB/s

Mass Storage

Need extremely fast reconstruction algorithms!

Free-streaming Data Acquisition



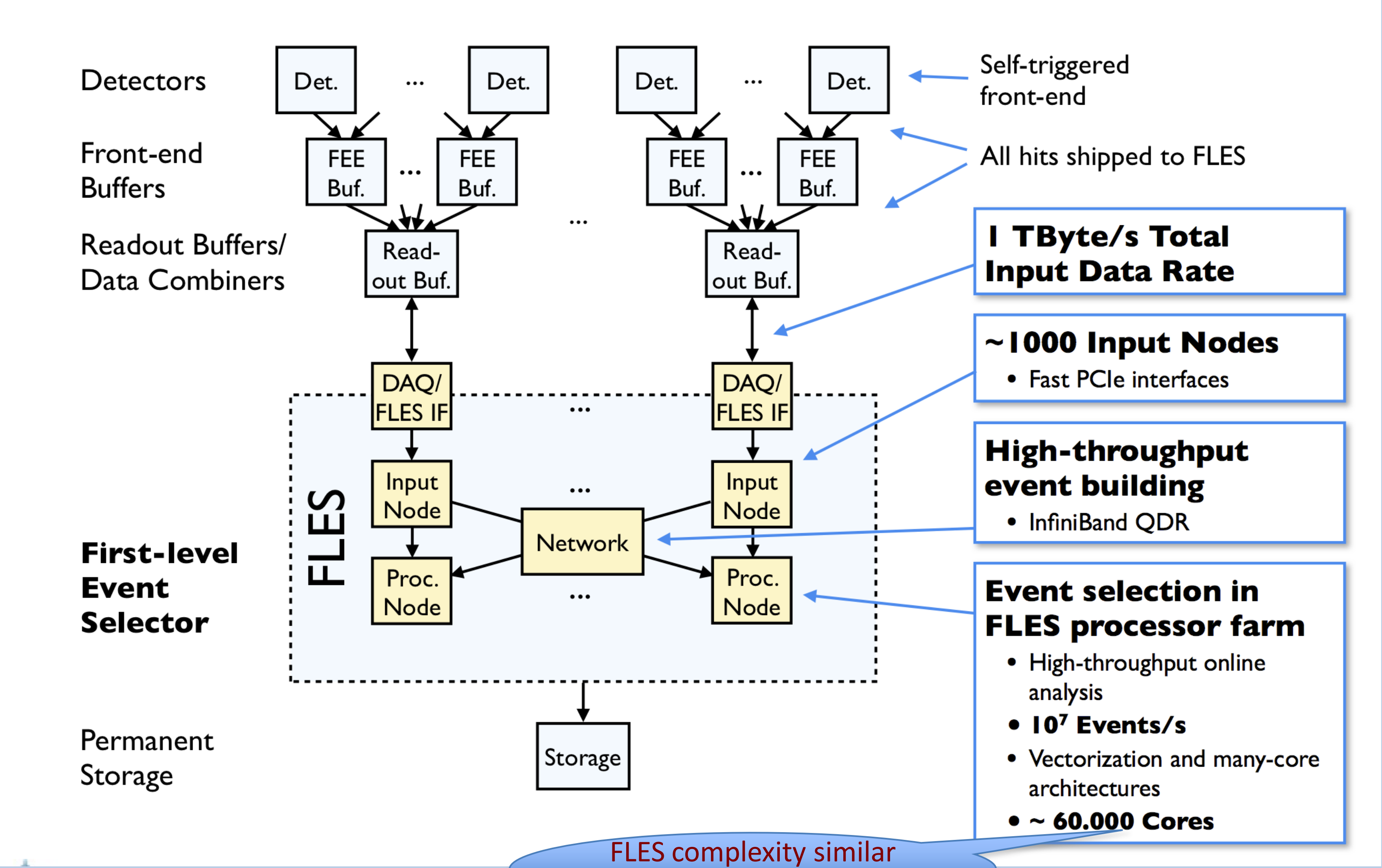
No hardware trigger; self-triggered, autonomous front-end

Signals get time stamp from system clock and are shipped to DAQ as they come

Data association, reconstruction and selection in software on FLES

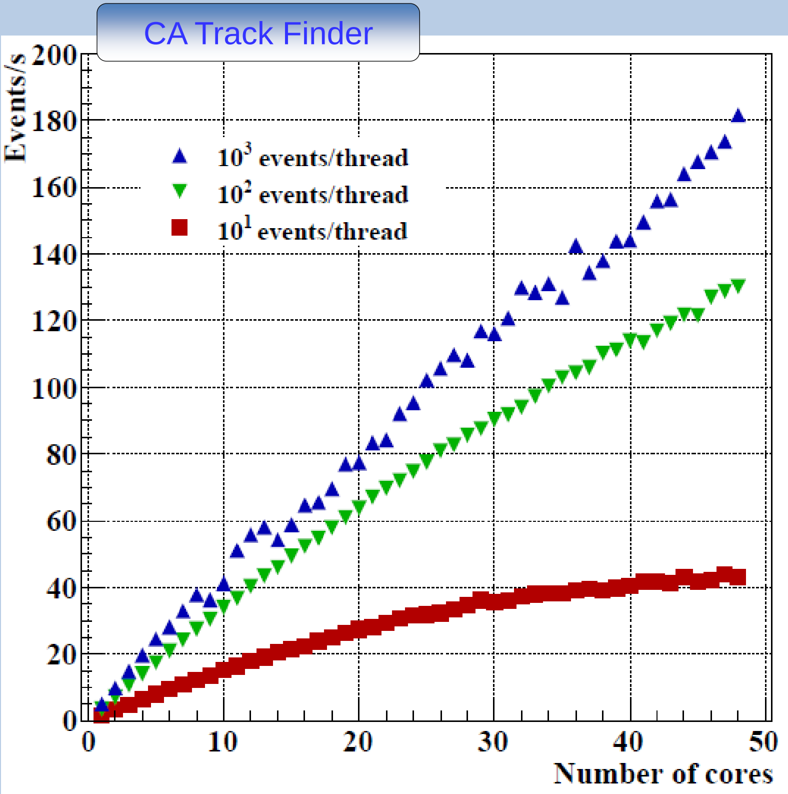
No a-priori association of signals to physical events!
„Event building“ becomes non-trivial at high rates

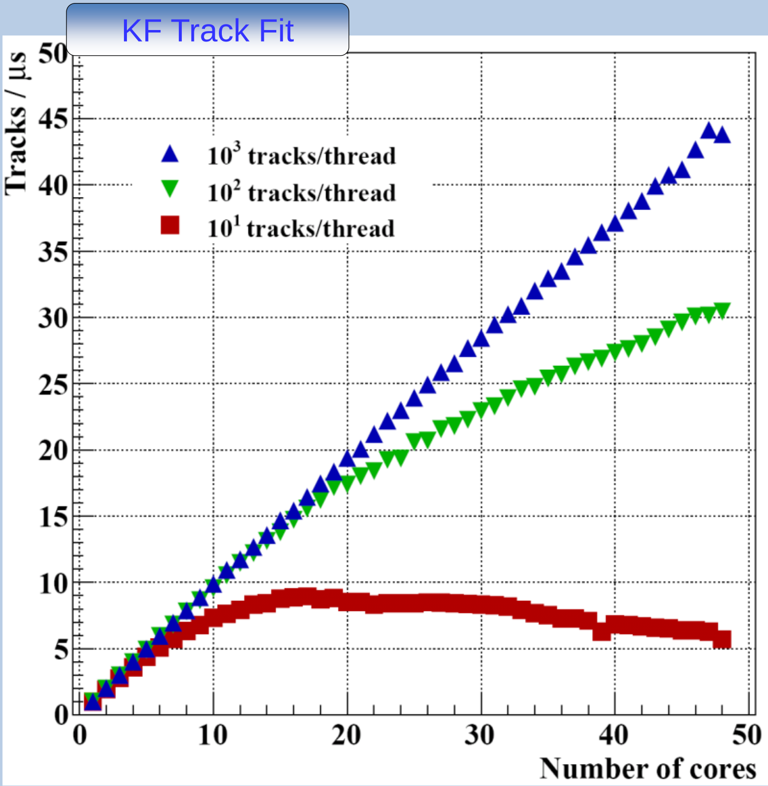
Online Data Processing



FLES complexity similar to LHCGrid

Fast Reconstruction





Highly parellel reconstruction codes are developed
Many-core scalability was demonstrated
Event reconstruction on ms level is already achieved
Still some way to go though….

CBM Time Line

Nr.	Vorgangsname	Anfang	Ende	2009–2019
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	Fr 29.04.16	Fr 29.04.16	29.04.
5	Ready to move in HEBT SIS100	Fr 29.04.16	Fr 29.04.16	29.04.
6	Ready to move in SIS100	Fr 29.04.16	Fr 29.04.16	29.04.
7	Ready to move in HEBT - T1X1...	Mo 01.05.17	Mo 01.05.17	01.05.
8	Ready to move in Multifunction Caves (CBM, HADES)	Mo 01.05.17	Mo 01.05.17	01.05.
9	Ready to move in HEBT -T1F1...	Fr 28.10.16	Fr 28.10.16	28.10.
10	Ready to move in Super-FRS	Fr 28.10.16	Fr 28.10.16	28.10.
11	Ready to move in HEBT TAP1 ...	Mo 23.01.17	Mo 23.01.17	23.01.
12	Ready to move in p-bar Target	Mo 23.01.17	Mo 23.01.17	23.01.
13	Ready to move in p-LINAC			29.04.
14	Ready to move in CR			23.01.
15	Ready to move in HESR			23.01.
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	01.06.
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)**	**Mo 01.06.09**	**Mi 01.03.17**	
103	**Super FRS**	**Mo 01.06.09**	**Do 22.02.18**	
188	**Systems Block 2 of Mod 0 - 3**	**Mo 01.06.09**	**Fr 28.09.18**	
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,T**	**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**			
614	**HEBT - TAP1, TAP2, TCR1, THS1**			
694	**p-bar Target**			
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

SIS100 ready: Oct. 13, 2017

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	

Instead of a Summary....

.... things are moving on!