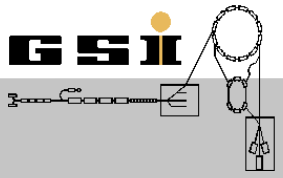
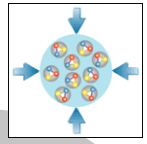




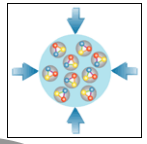
Exploring dense QCD matter with the CBM experiment

Volker Friese

Gesellschaft für Schwerionenforschung
Darmstadt

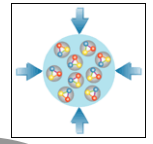
ICTDHEP – Jammu – 10 September 2013

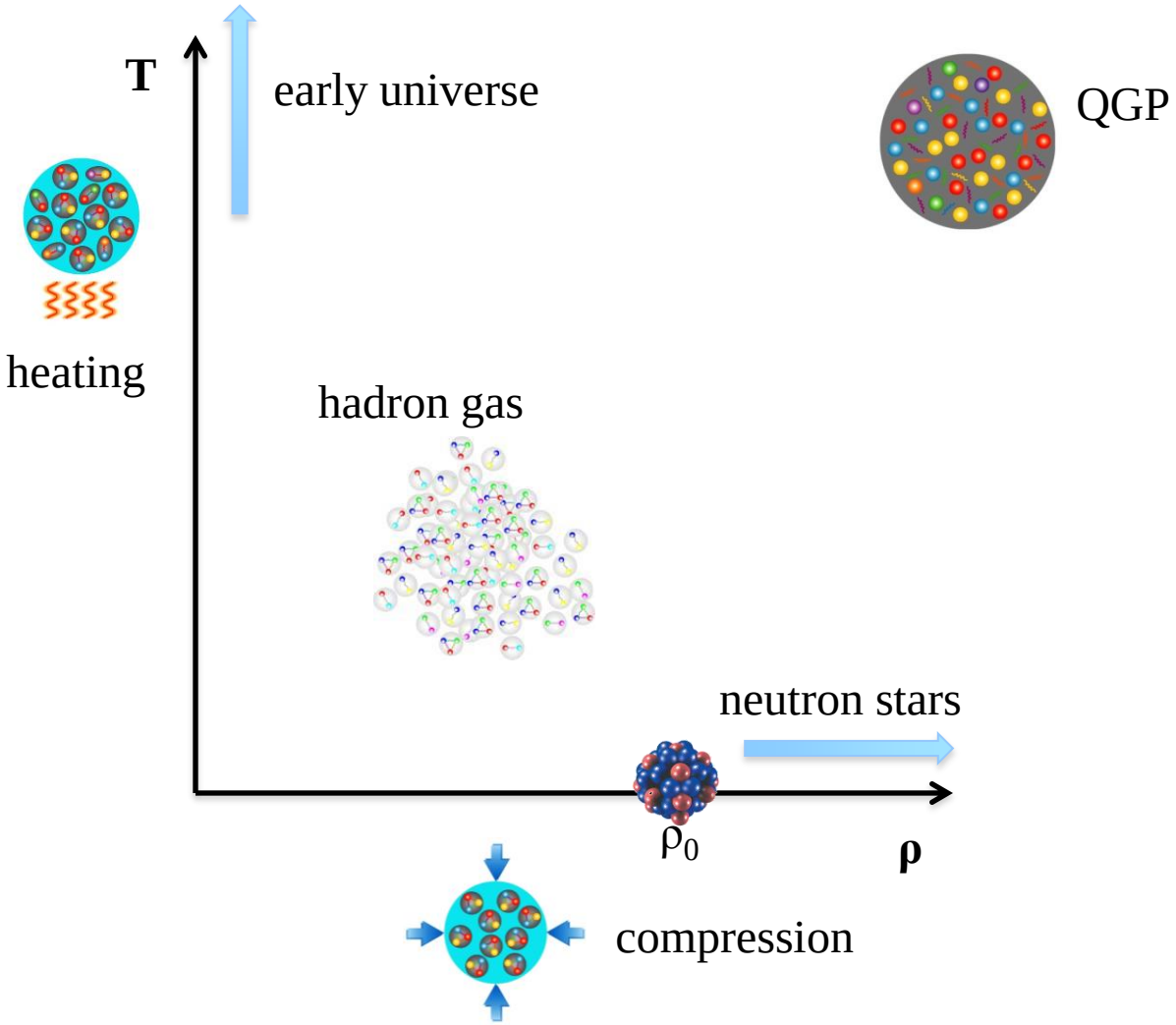
Outline



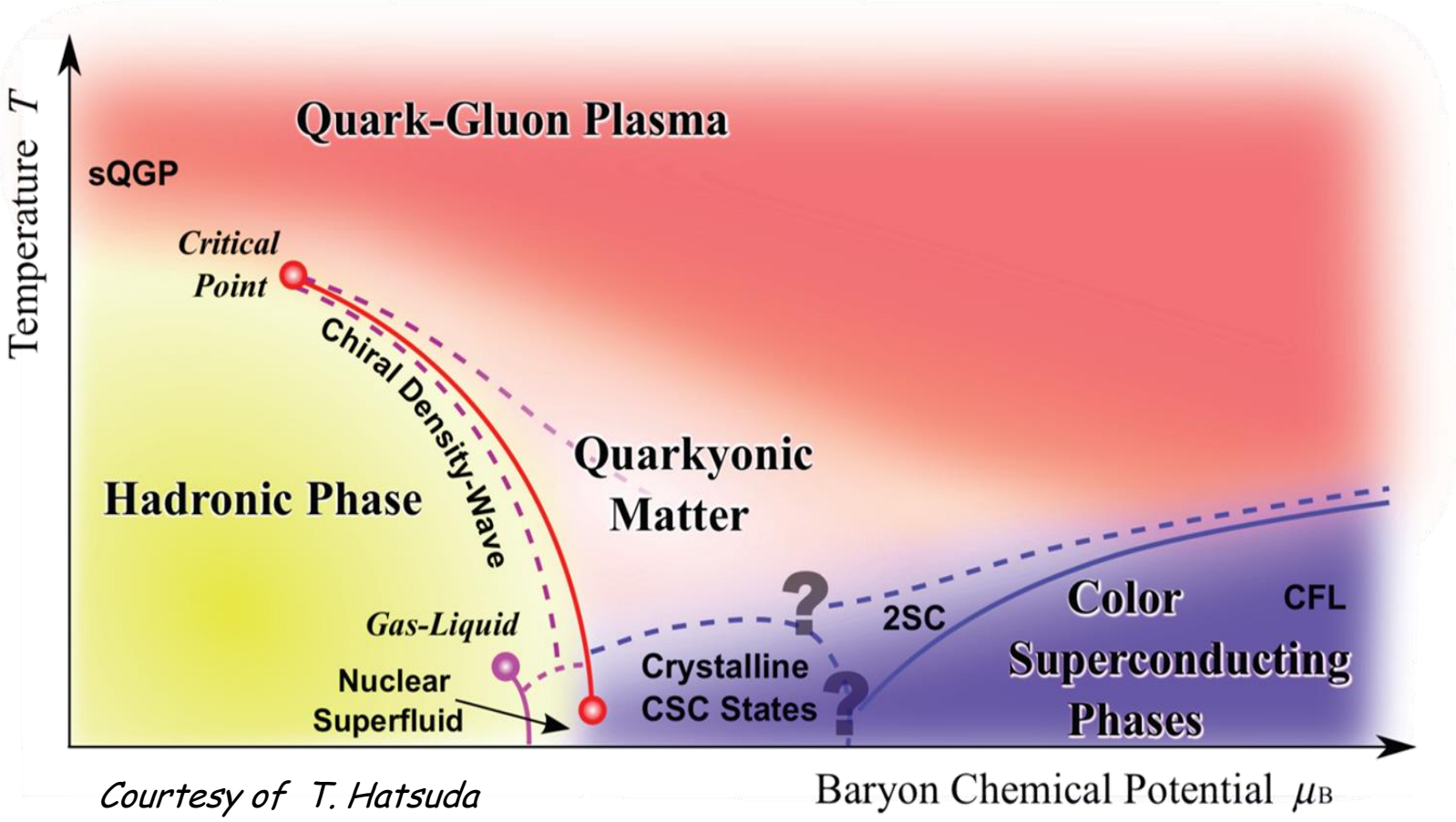
- Physics case
- Experiment
- Physics programme
- FAIR and CBM

Matter at extreme conditions



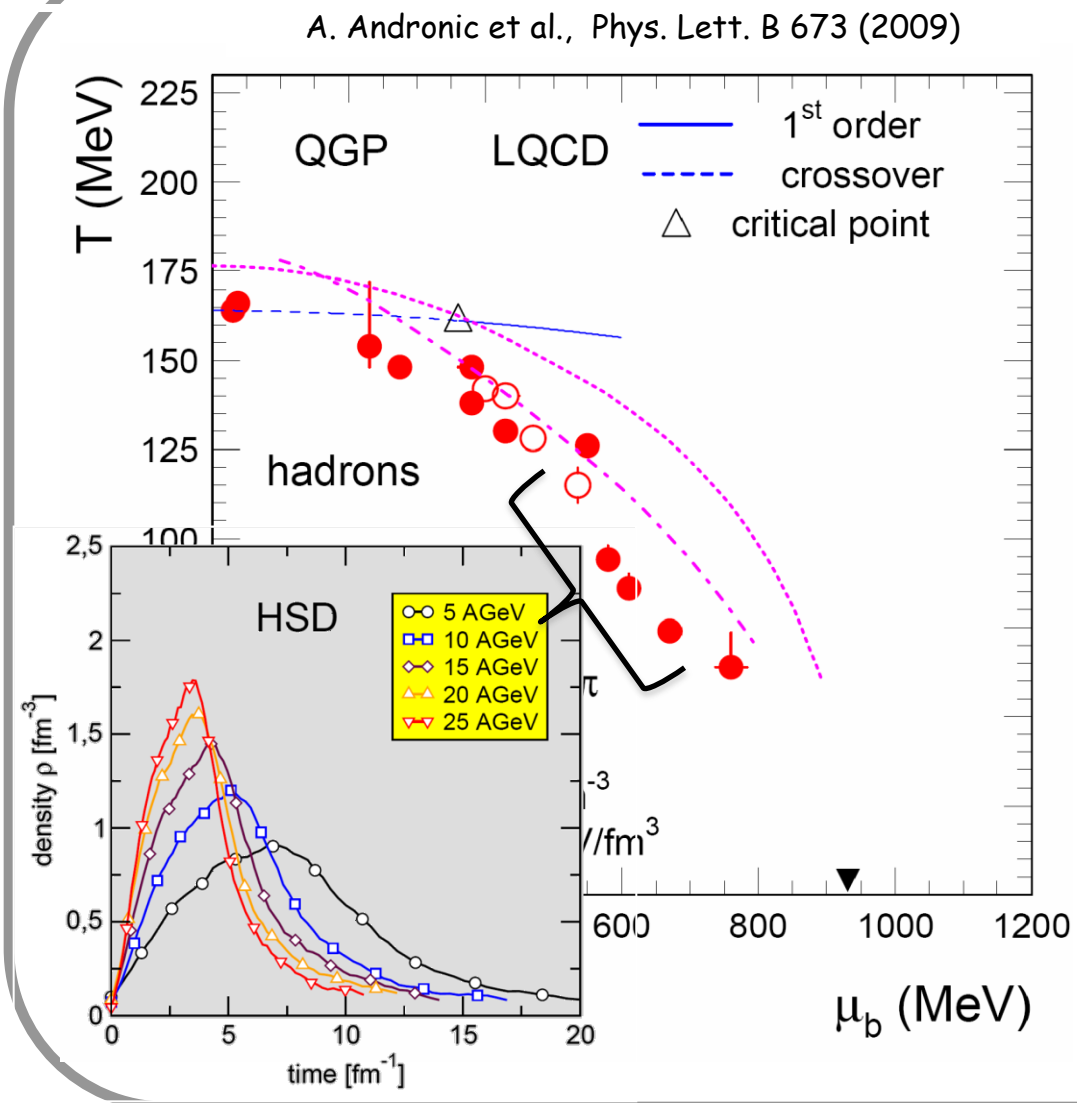


Suggestions from theory



High-densitiy regime:
An unexplored and potentially structure-rich region

What experiments tell



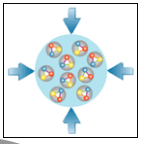
Freeze-out points of nuclear collisions lie on smooth curve

Varying the collision energy allowd to probe different regions of the phase diagram

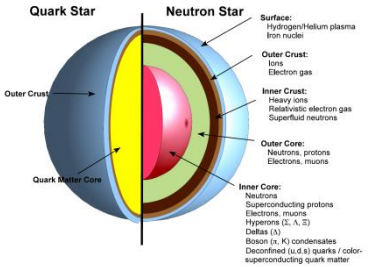
High energies (RHIC, LHC): net-baryon free system, highest T

Lower energies:high-density region, moderate T

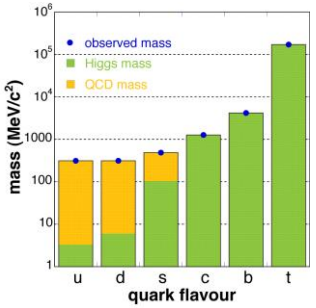
Questions



- What are the equation of state and the degrees of freedom of matter at extreme densities? Which implication are there for the structure of neutron stars?

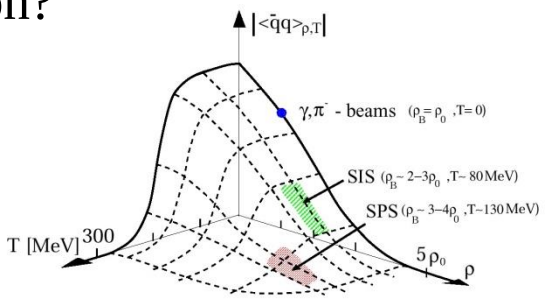


- What are the properties of hadrons in a dense medium? How is mass generated? Can we observe rstoration of chiral symmetry?

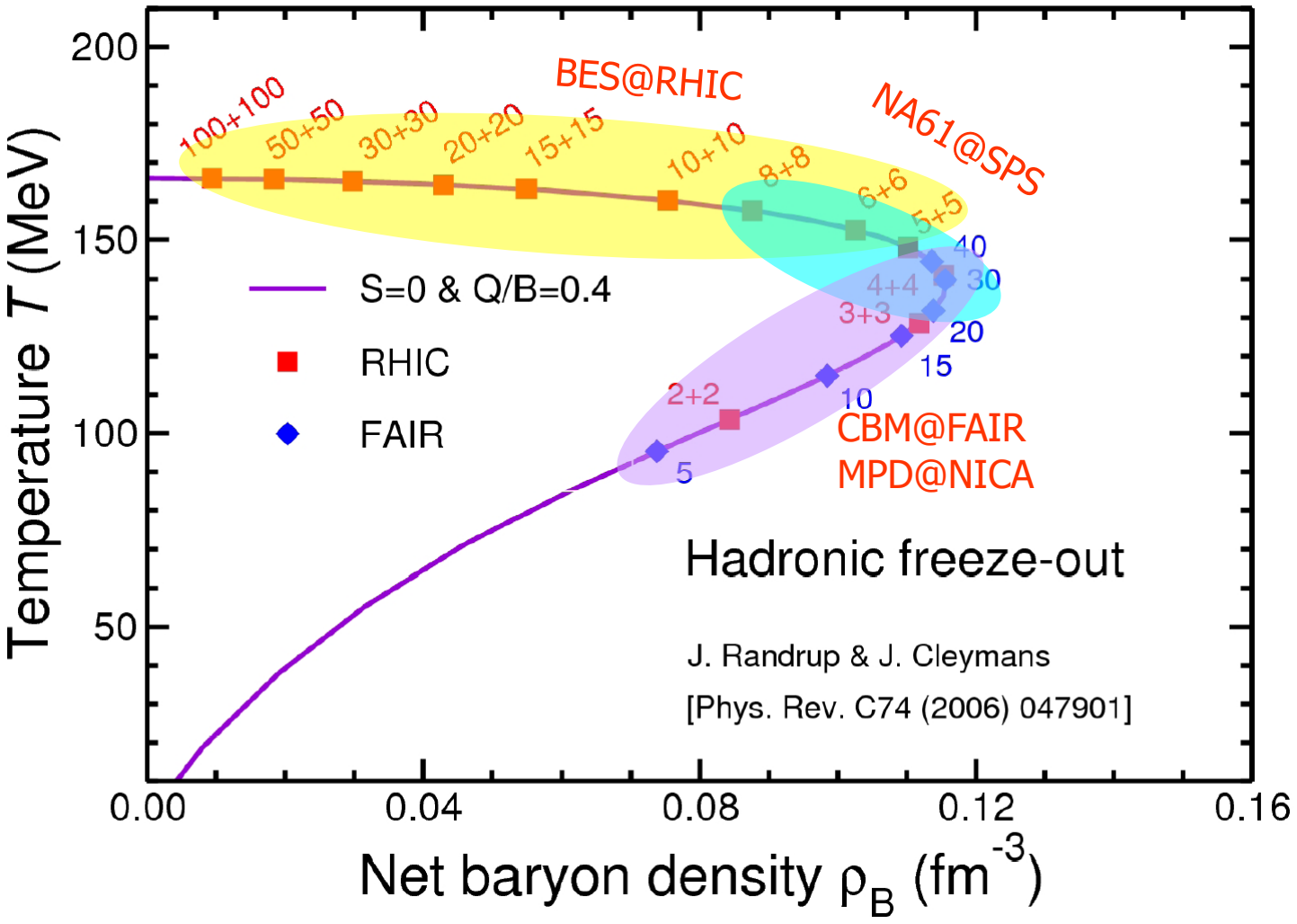


- Is there a first-order deconfinement phase transition?

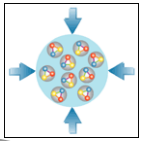
- Is there a QCD critical point, and if yes, where?



Experimental programmes



Experimental programmes

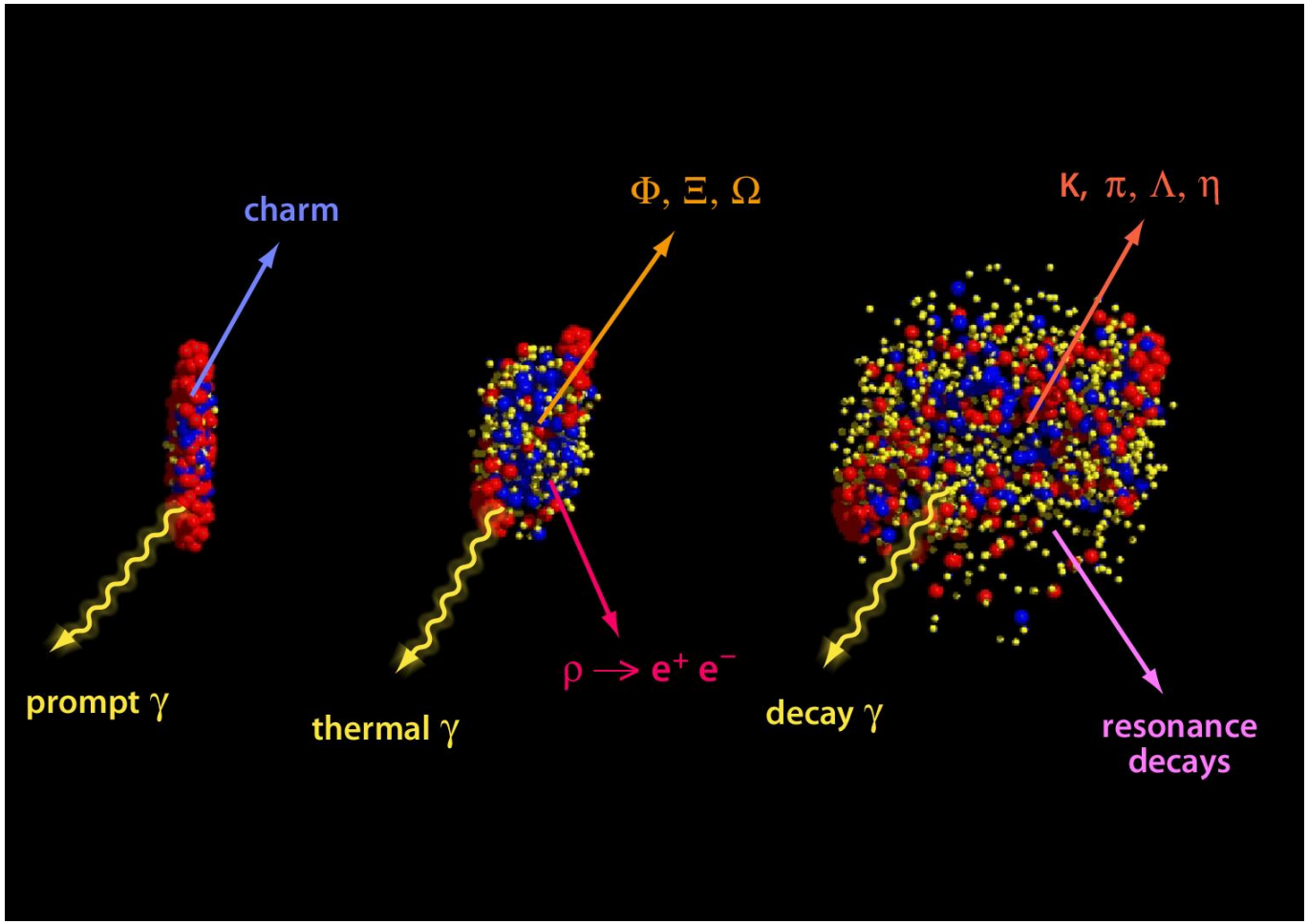


	Fixed Target	**Collider**
Existing	NA61 @ CERN-SPS E_{beam} = 20 – 160 AGeV $\sqrt{s_{NN}}$= 6.4 – 17.4 GeV Rate: 80 Hz	BES @ BNL-RHIC $\sqrt{s_{NN}}$= 7 – 200 GeV Rate : 1 - 800
Planned / Under Constuction	CBM @ GSI-FAIR E_{beam} = 2 – 35 AGeV $\sqrt{s_{NN}}$= 2.7 – 8.3 GeV Rate: 10^5 - 10^7	MPD @ JINR-NICA $\sqrt{s_{NN}}$= 4 – 11 GeV Rate: ~1000

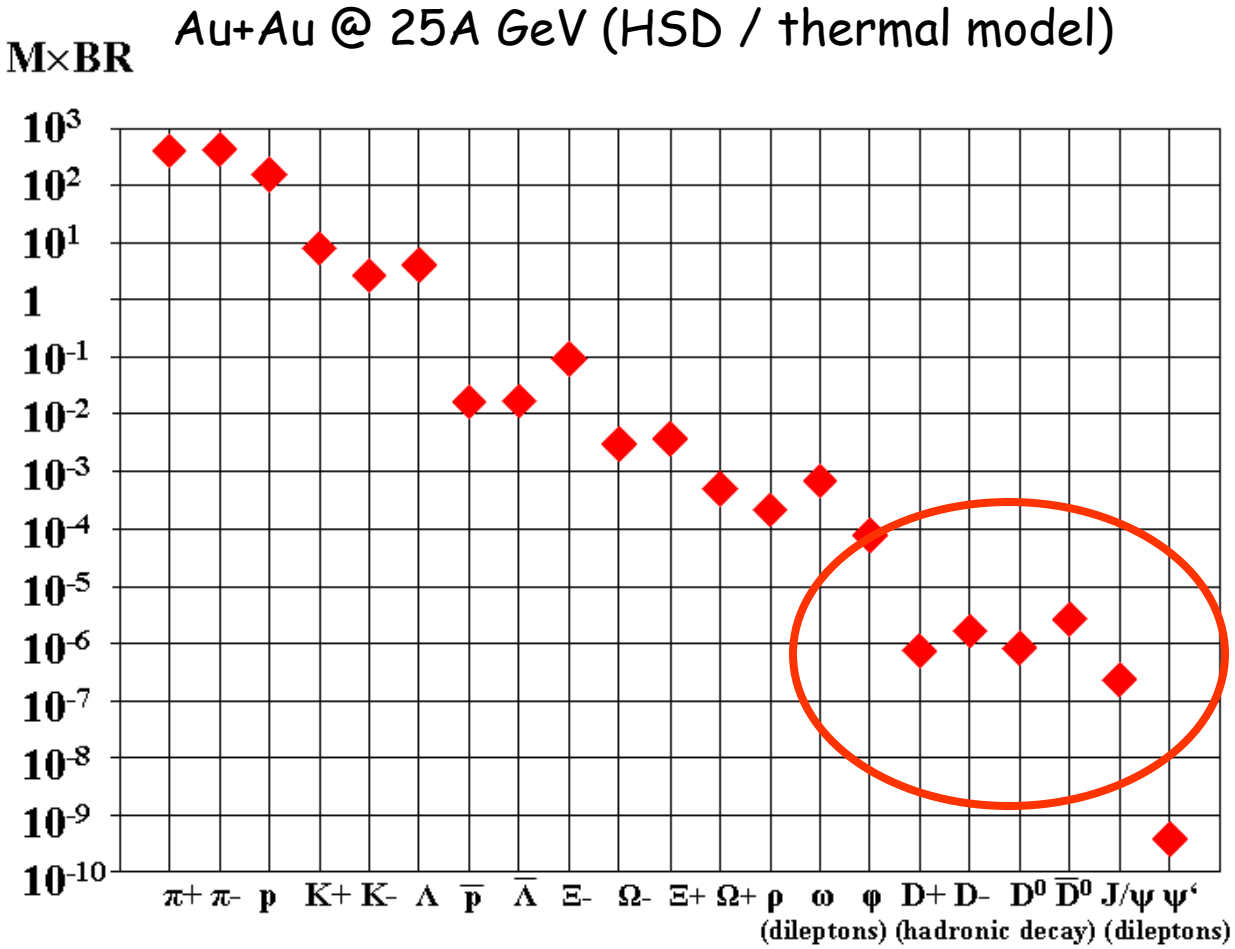
Pioneering: AGS (2 – 11 AGeV), NA49 (20 – 158 AGeV)

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

The messengers from the fireball

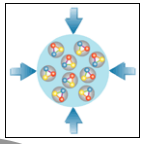


Multiplicities



CBM focuses on rare probes: drive experimental requirements

CBM: design features

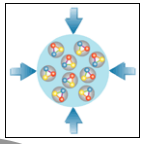


- p+p to Au+Au collision from 5 to 45 AGeV

- hadron identification
- lepton identification (electron and muon)
- event characterisation
- detection of displaced vertices (precision 50 μm) for open charm

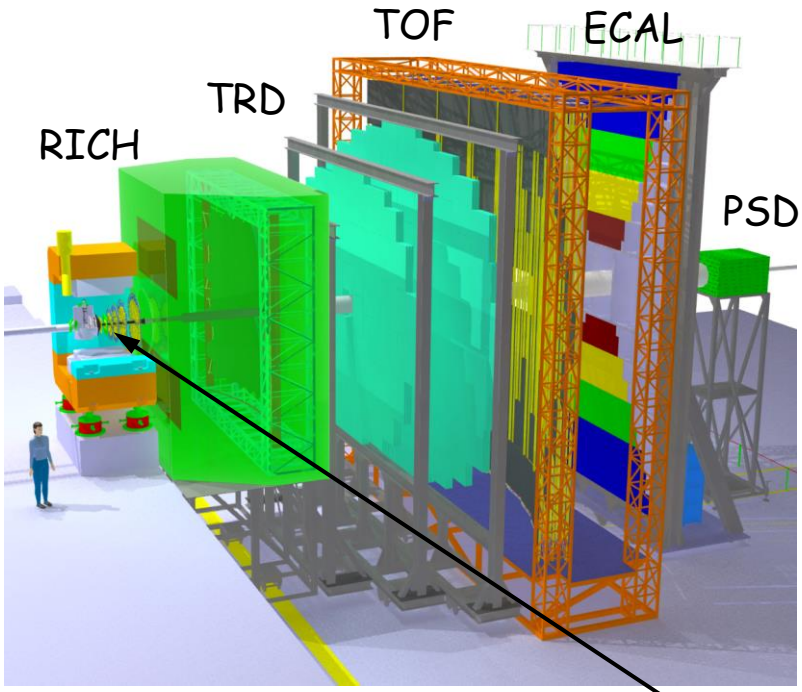
- in a large acceptance
- at very high rates:
- fast and radiation-hard detectors
- high-speed DAQ and online reconstruction

CBM: experimental setup

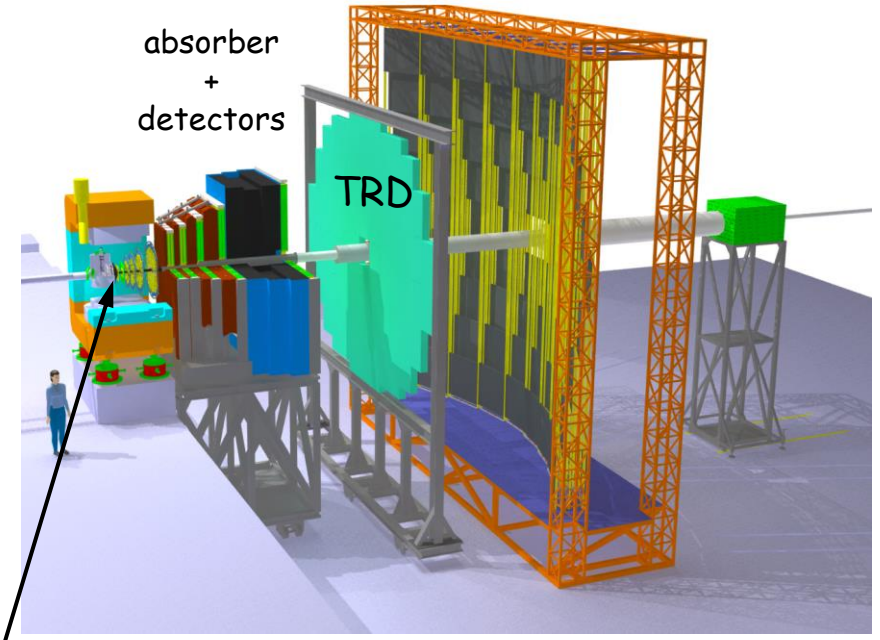


Two flavours: electron/hadron and muon setup

Electron + Hadron setup

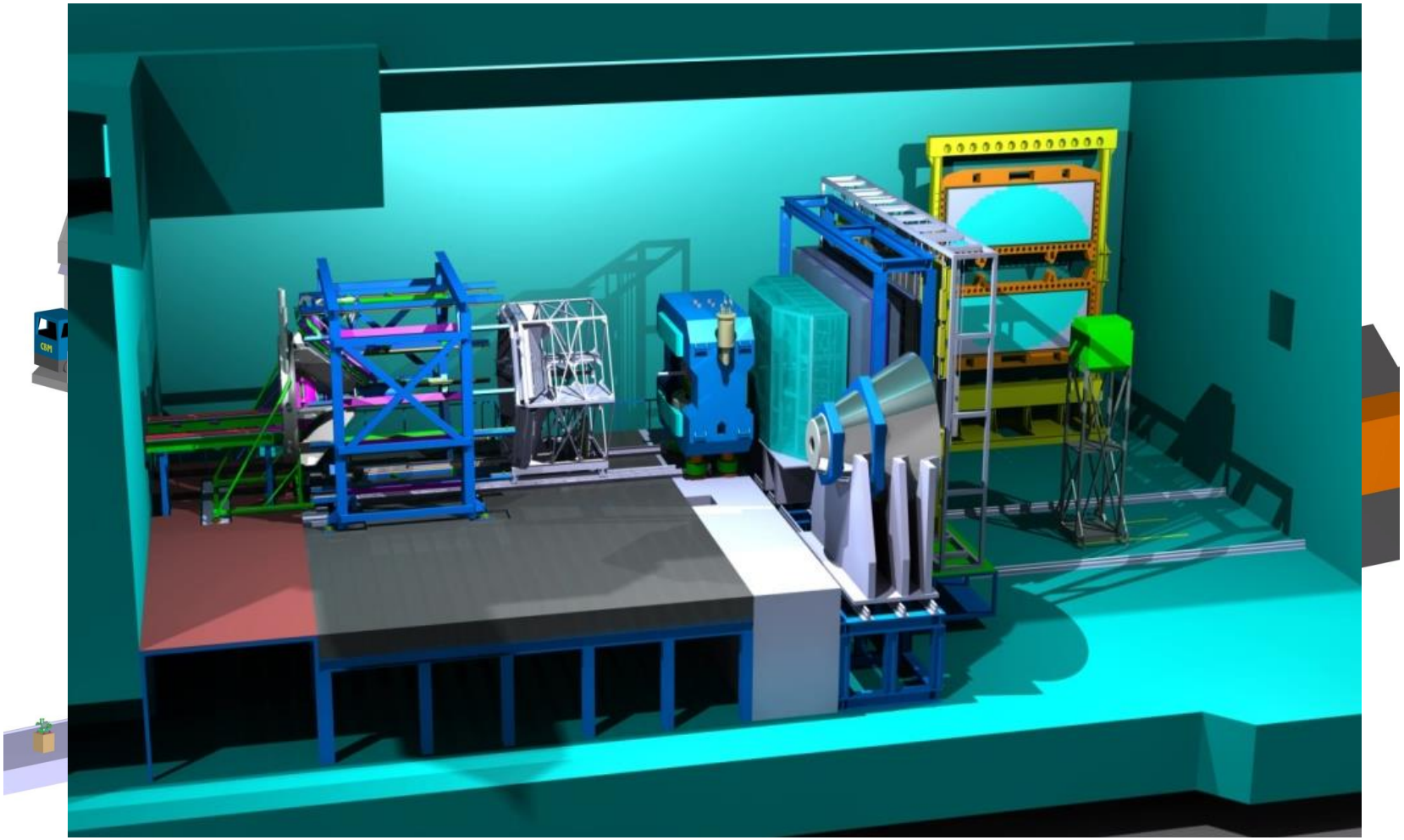


Muon setup

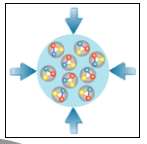


STS+MVD

CBM in its cave

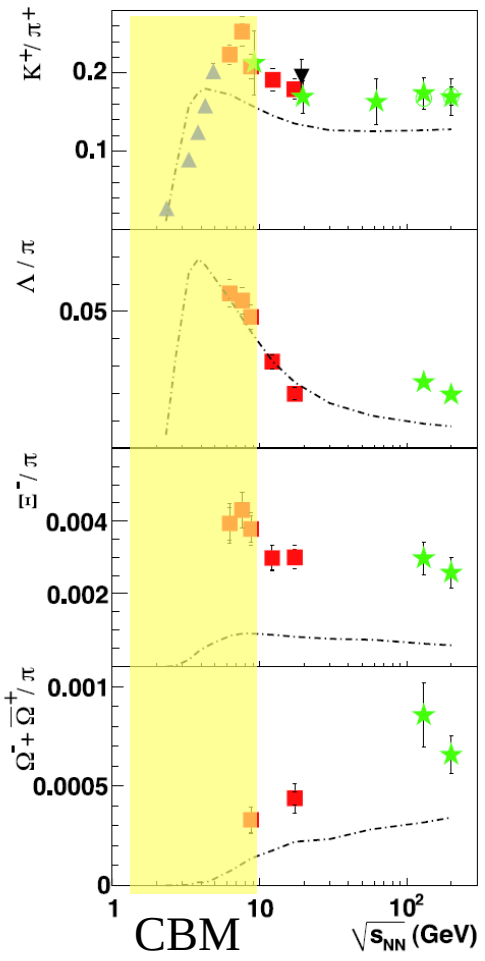


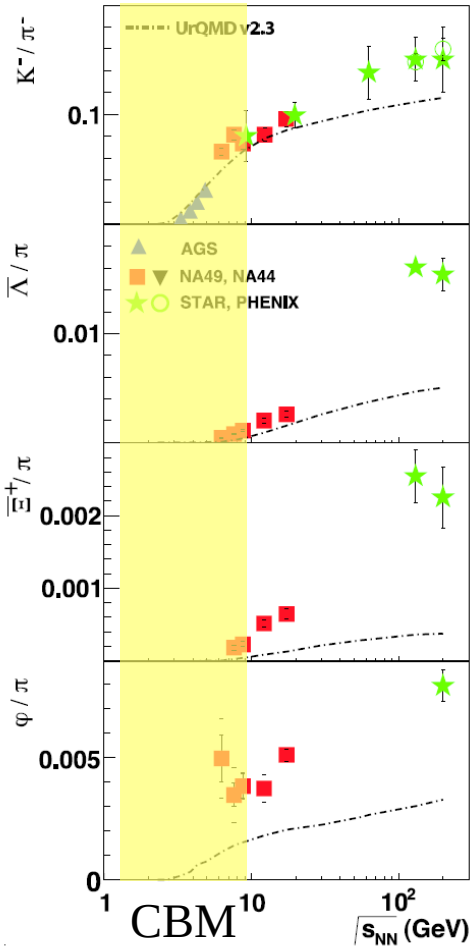
CBM: components



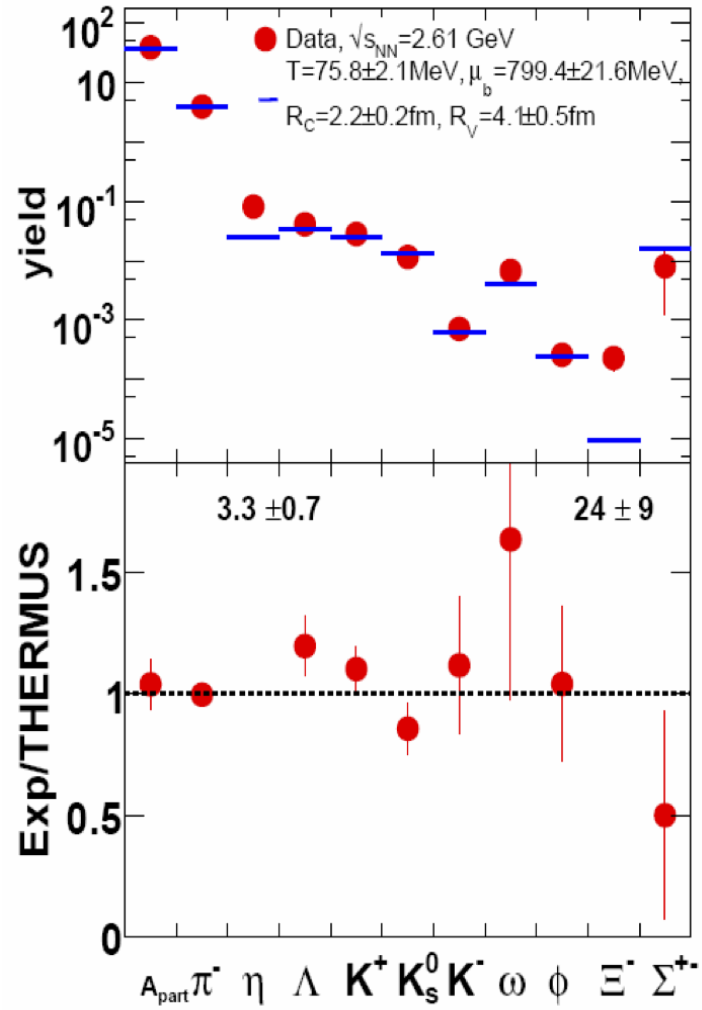
- MVD: Silicon pixel detectors (MAPS) for precision measurement of displaced vertices
- STS: Main tracking system. Silicon strip sensors.
- RICH: Cherenkov detector with MAPMT photo detectors in two focal planes
- TRD: for global tracking and electron identification by TR. MWPC pad readout.
- MUCH: muon identification in a segmented absorber system interlaid with GEM detectors, allowing to follow tracks through the absorber system.
- TOF: for hadron identification. RPC detector array with about 60 ps resolution.
- ECAL: Pb-Sci calorimeter for the measurement of neutral probes
- PSD: Compensated calorimeter for the detection of projectile spectators. For the determination of event centrality and event plane.

CBM Physics: Strangeness



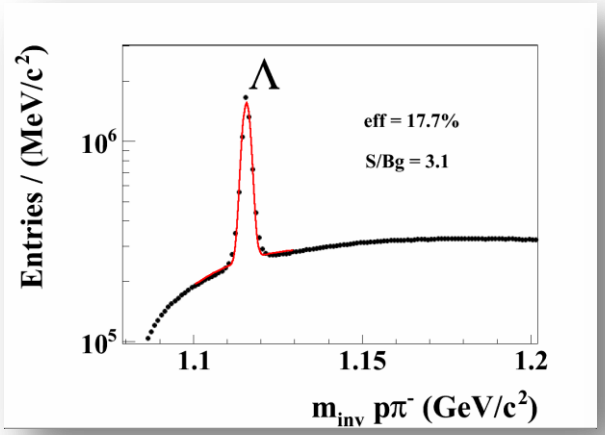


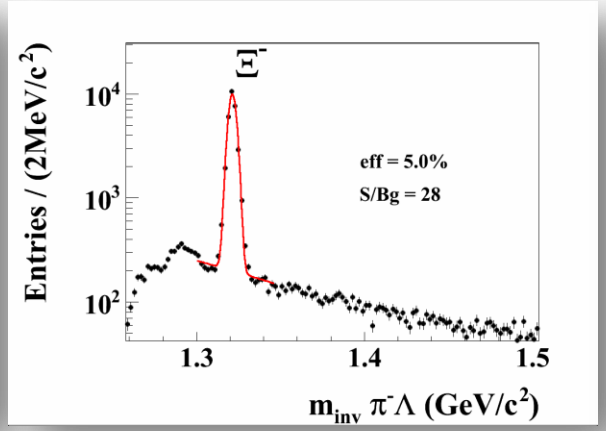
S. Wheaton and J. Cleymans, Comp. Phys. Comm. 180 (2009) 84

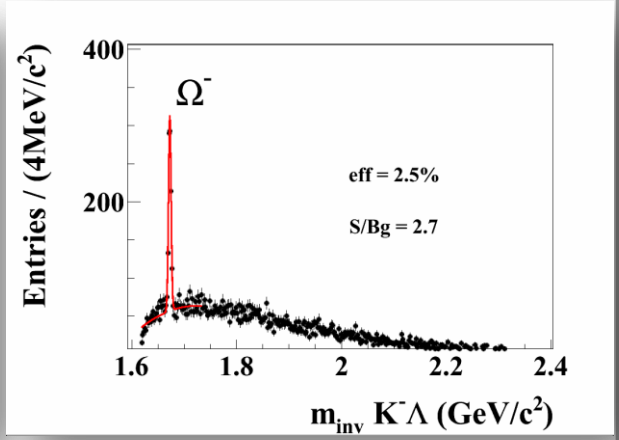


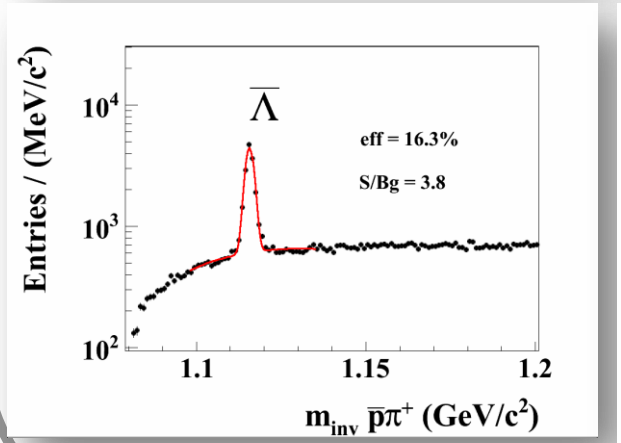
CBM performance: hyperons

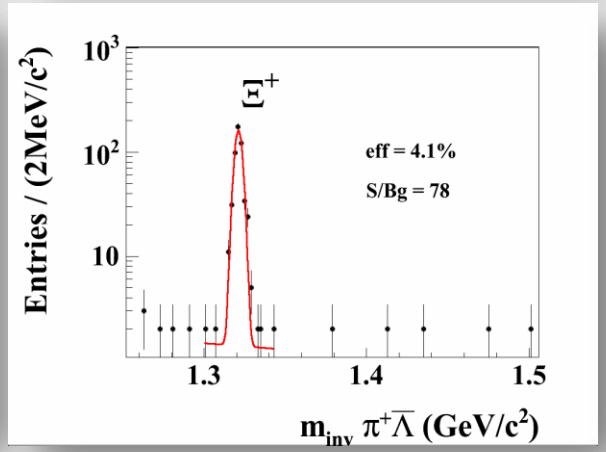
Hyperon yields (equivalent to 10 s CBM run)

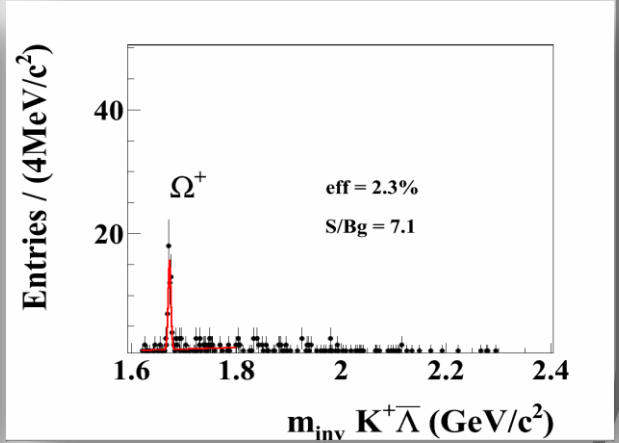




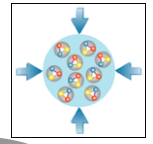




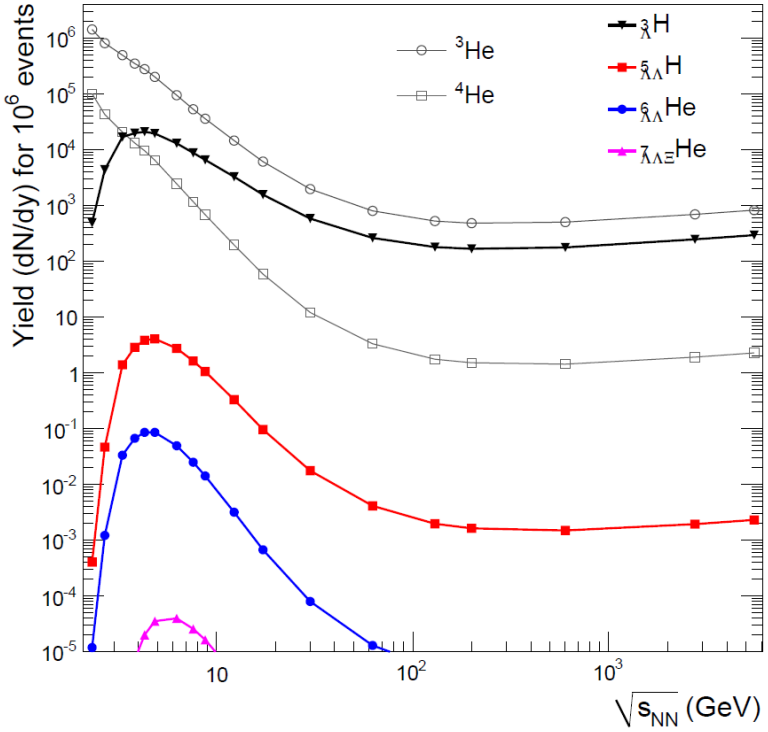




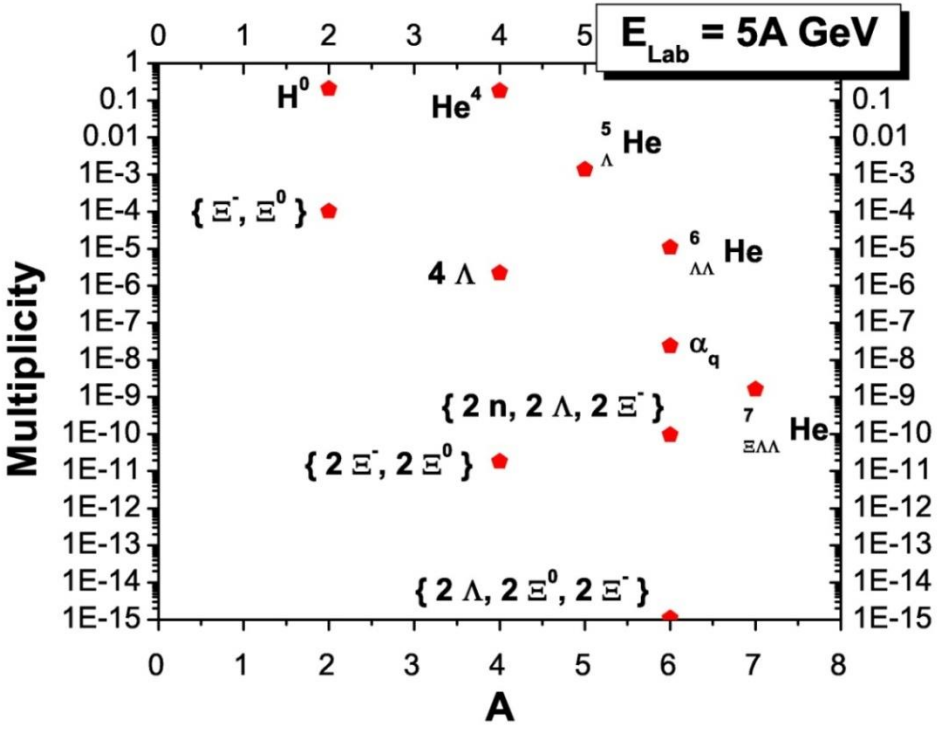
CBM physics: (double) hypernuclei and exotica



Production of hypernuclei via coalescence of hyperons and light nuclei
Strange di-baryons via ΛΛ or Ξp coalescence



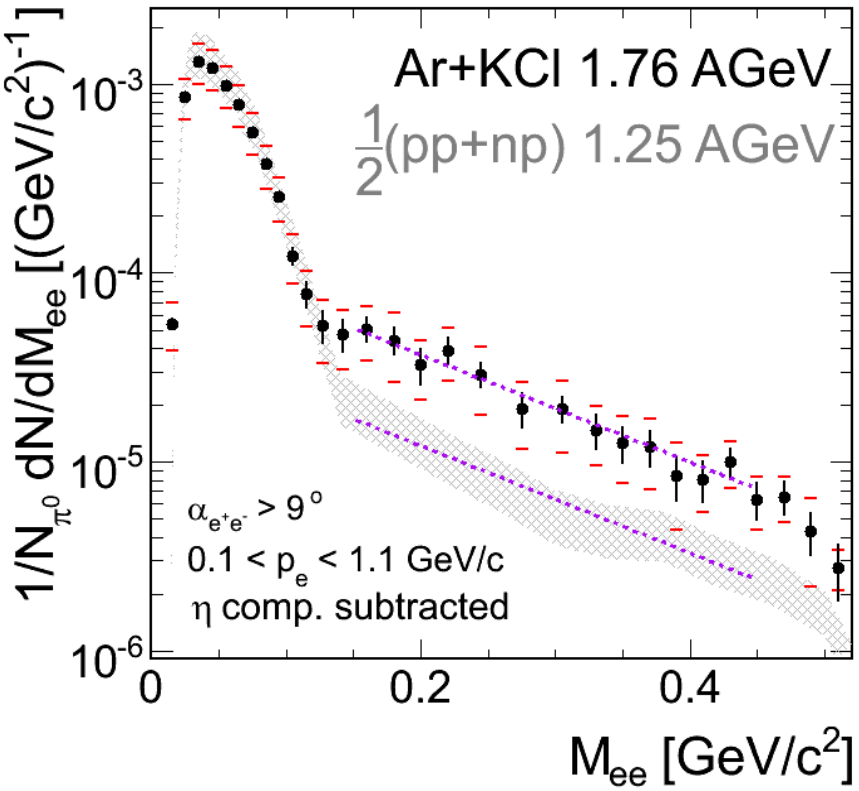
A. Andronic, P. Braun-Munzinger, J. Stachel, H. Stöcker, Phys. Lett. B697 (2011) 203



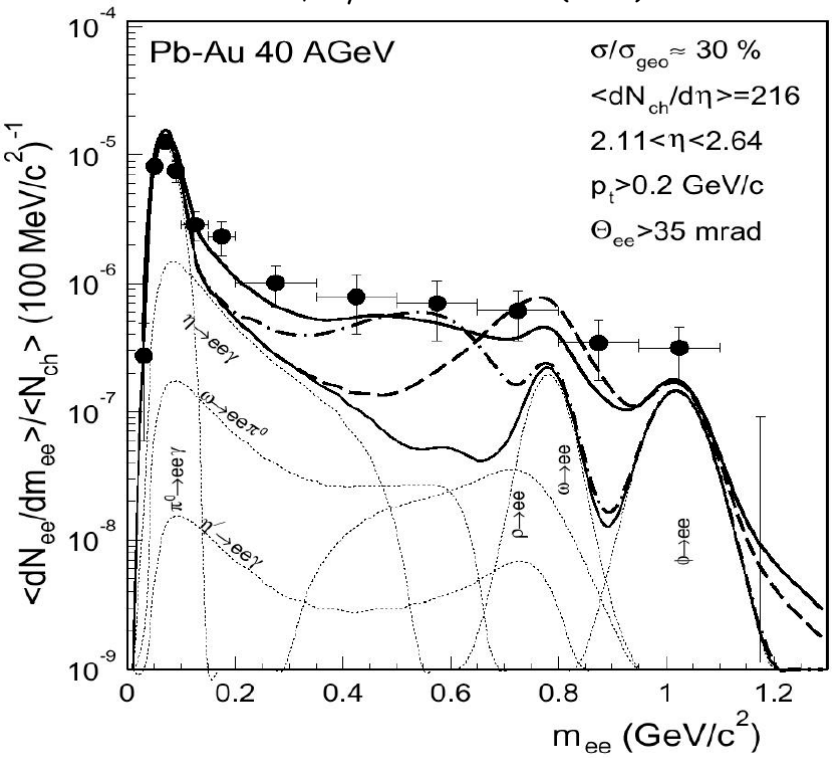
H. Stöcker et al., Nucl. Phys. A 827 (2009) 624c

Observables: Low-mass vector mesons

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



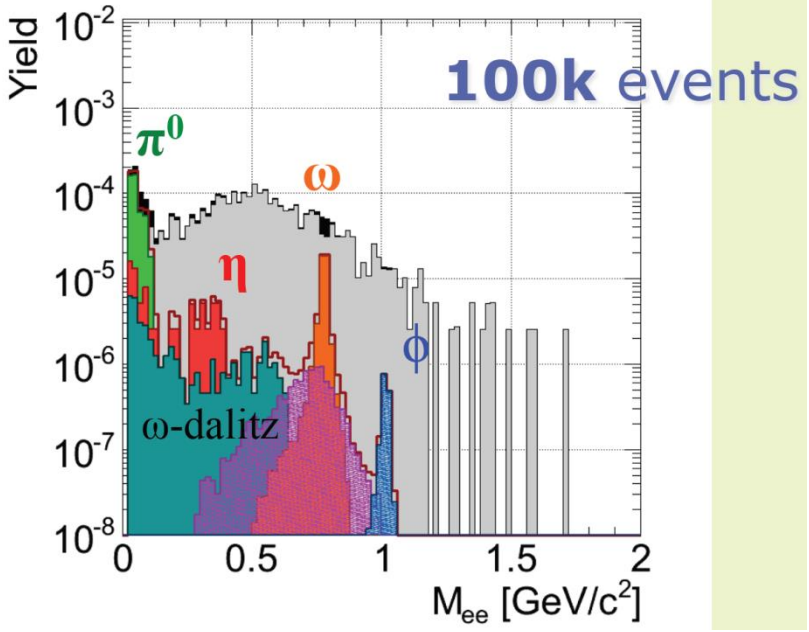
CERES, Phys. Rev. Lett. 91 (2003) 042301



Excess yield observed at SPS (CERES, NA60).
Also seen by HADES in Ar+KCl (but not in C+C).
No dilepton data between SIS-18 and SPS available. Study of low-mass dilepton spectra at highest baryon densities is mandatory.

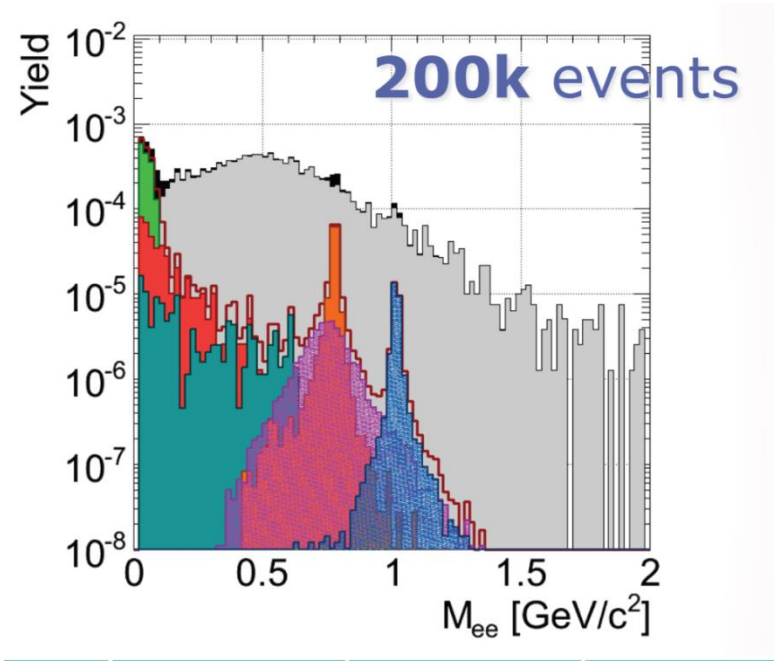
CBM performance: low-mass dileptons

8 AGeV: STS, RICH, TOF



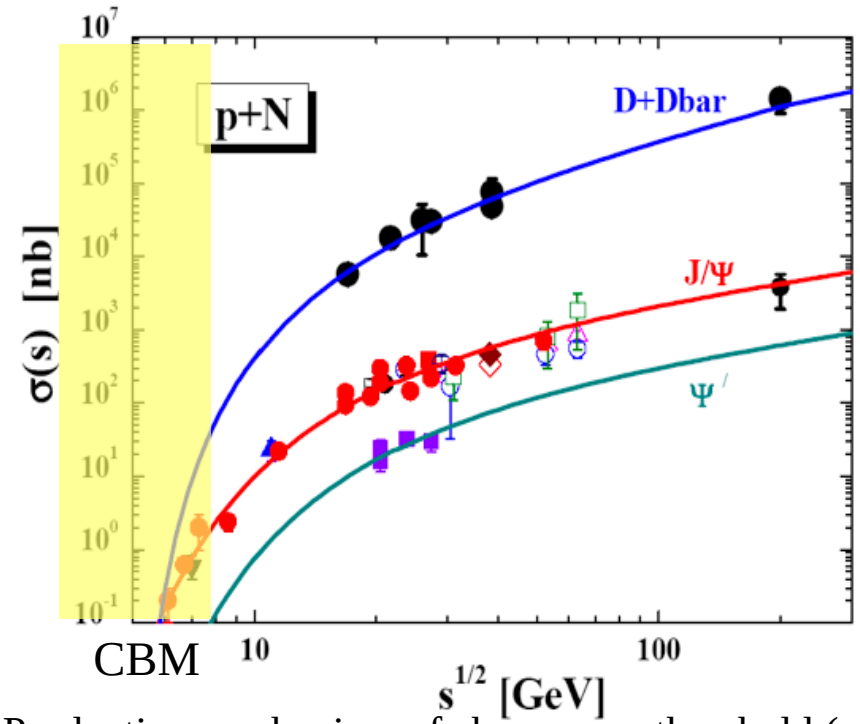
	ρ	ω	φ
eff.	3.12	4.11	4.89
S/BG	-	0.64	0.04

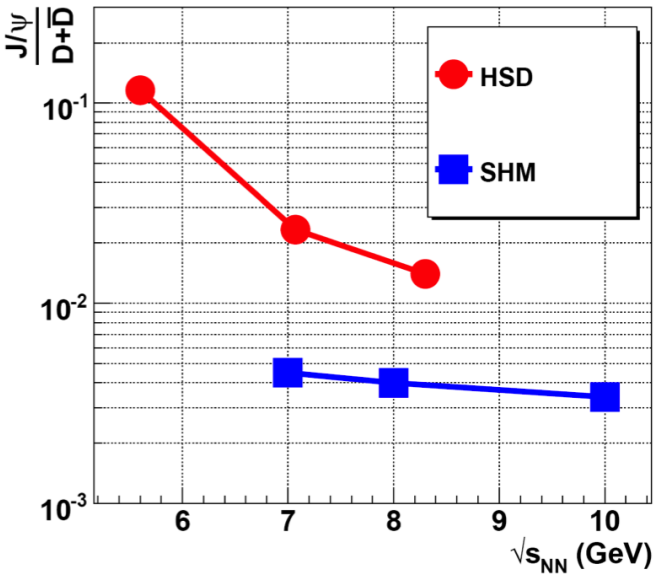
25 AGeV: STS, RICH, TRD, TOF

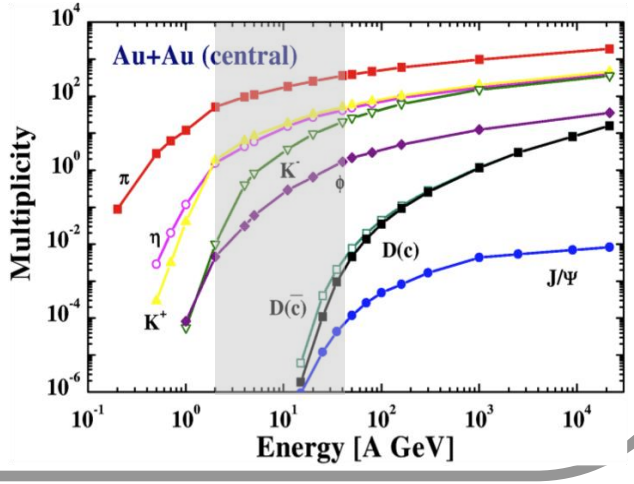


	ρ	ω	φ
eff.	4.39	5.53	7.08
S/BG	-	0.31	0.11

CBM physics: Charm near threshold







Production mechanism of charm near threshold (p+p)

Propagation in cold nuclear matter (p+A)

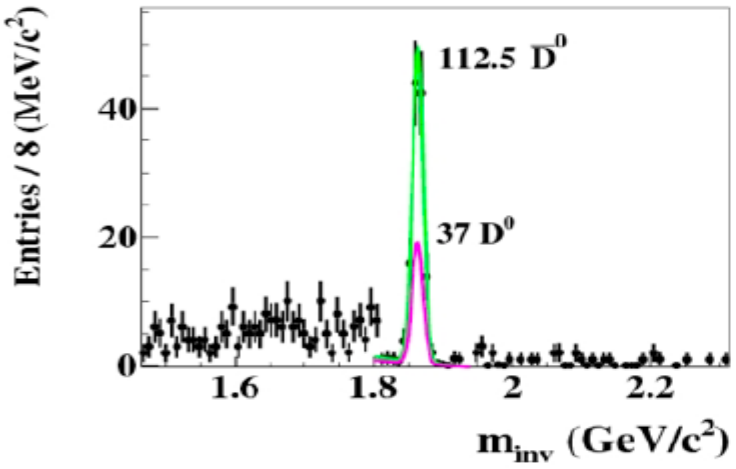
Open/hidden charm: sensitive to production scenario (A+A)

Extremely rare probe!

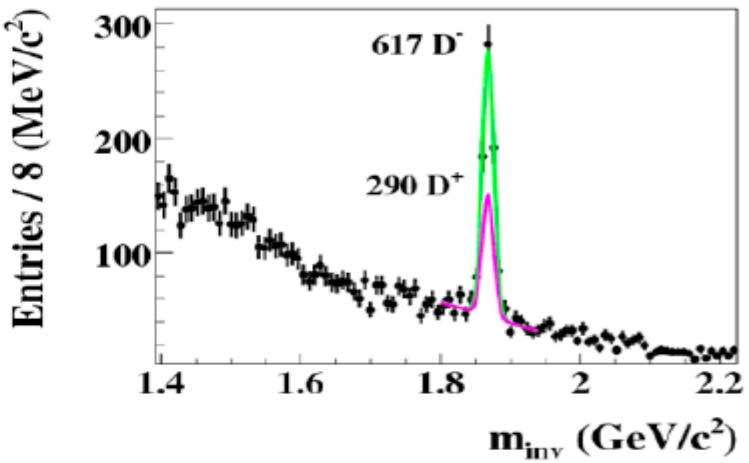
CBM performance: open charm

30 GeV p + C (SIS100)

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

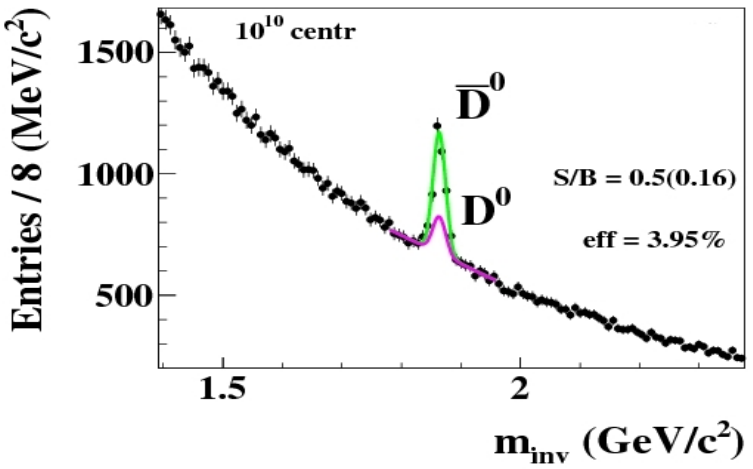


$D^{\pm} \rightarrow K\pi\pi\pi$

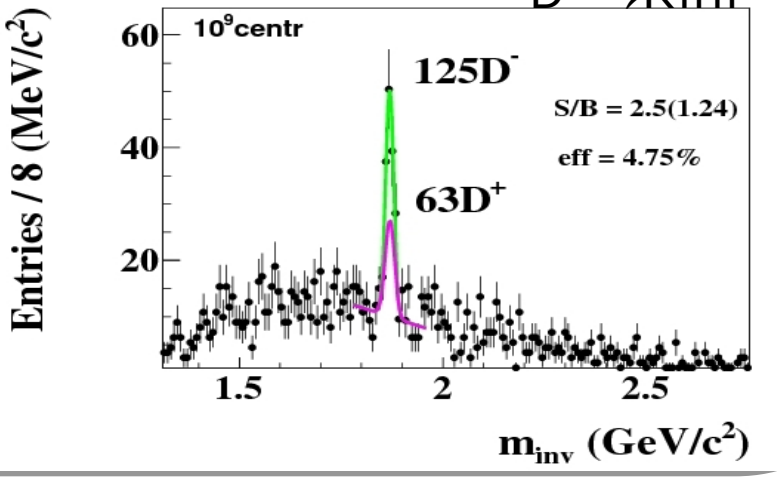


Au+Au 25 AGeV (SIS300)

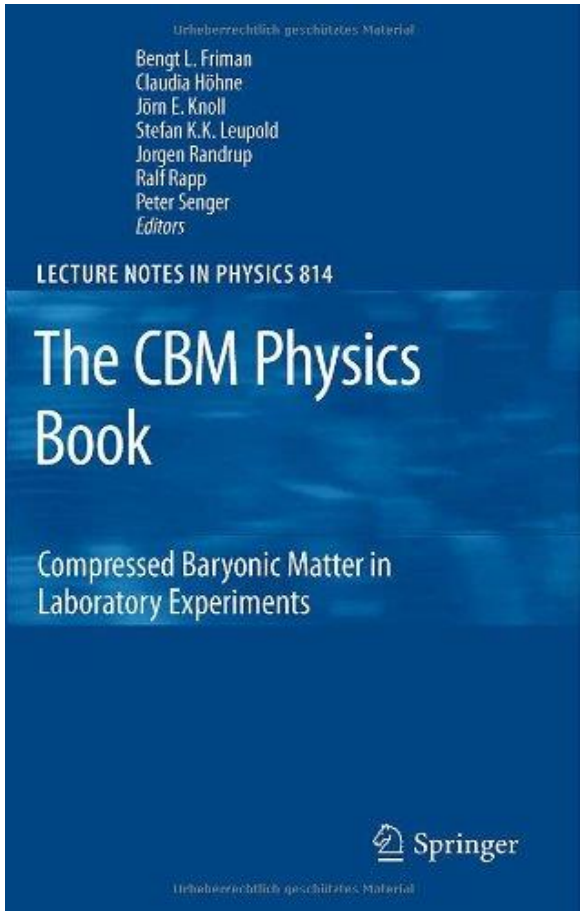
$D^0 \rightarrow K\pi\pi\pi\pi$



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



More physics? See:



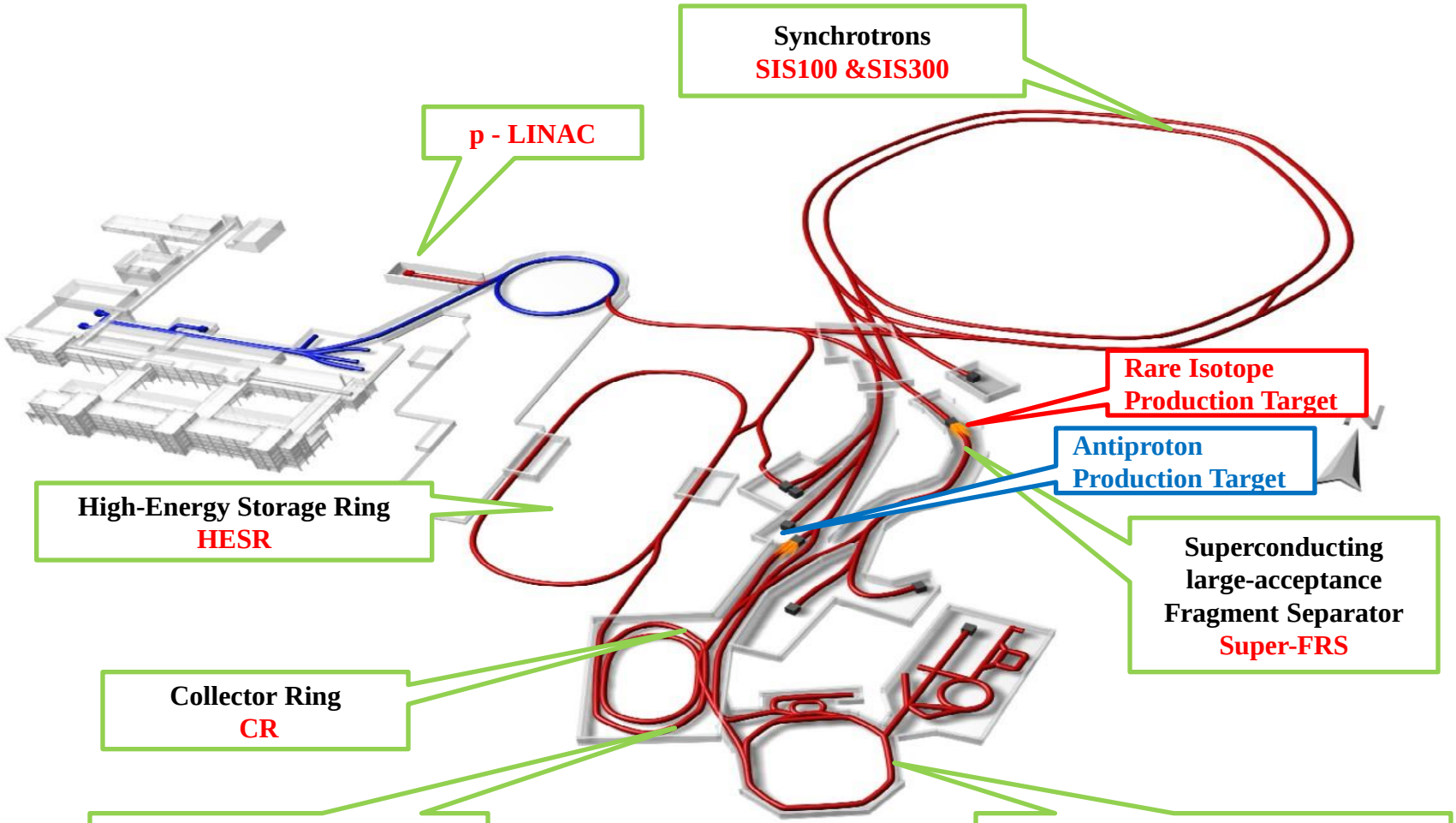
The CBM Physics Book

Foreword by Frank Wilczek

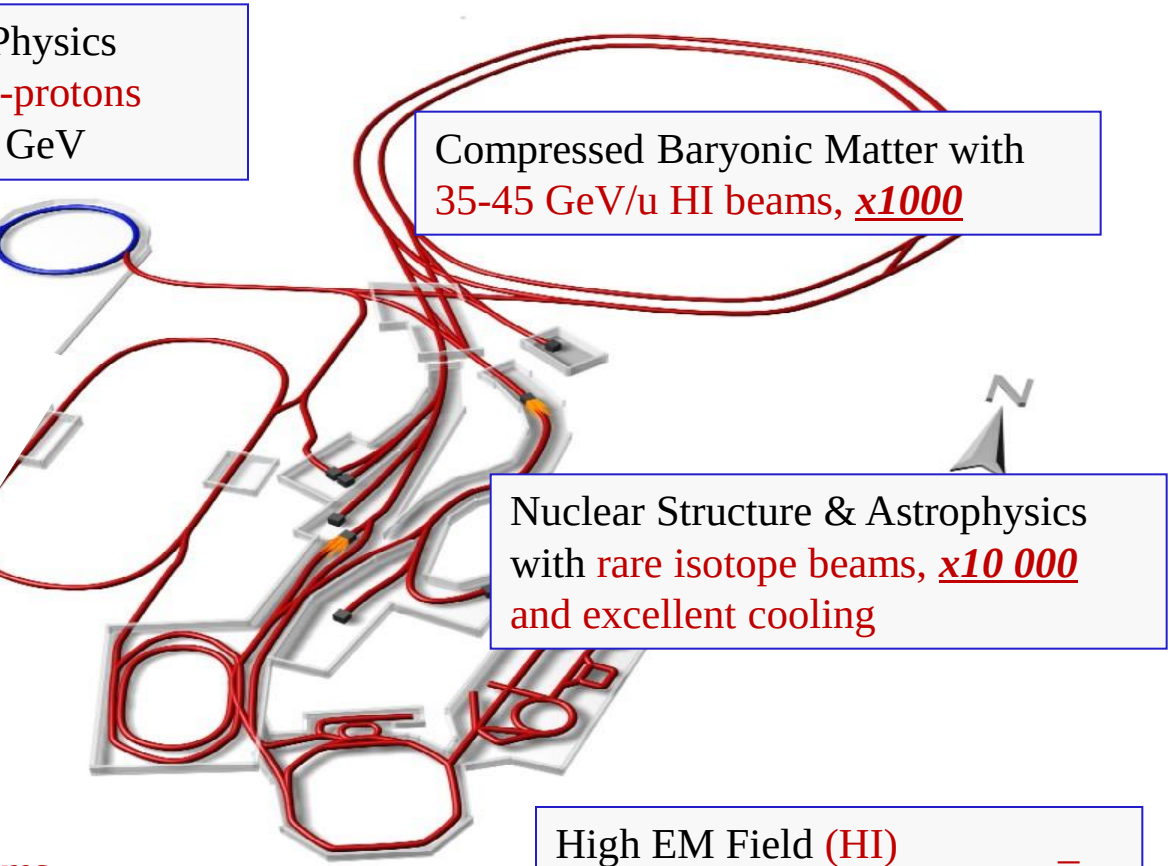
Springer Series:
Lecture Notes in Physics, Vol. 814
1st Edition., 2011, 960 p., Hardcover
ISBN: 978-3-642-13292-6

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

FAIR accelerator complex



FAIR physics programmes



Hadron Physics
with anti-protons
of 0 - 15 GeV

Compressed Baryonic Matter with
35-45 GeV/u HI beams, ***x1000***

Plasma Physics: ***x600***
higher target energy
density 600kJ/g

Nuclear Structure & Astrophysics
with rare isotope beams, ***x10 000***
and excellent cooling

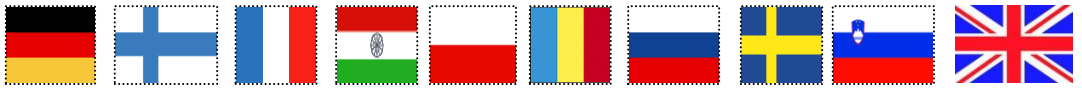
Special Features:

- 50ns Bunched beams
- Electron cooling of secondary beams
- SC magnets fast ramping
- Parallel operation

High EM Field (HI)
Fundamental Studies (HI & $\bar{p}$)
Applications (HI)

Scientific pillars of FAIR

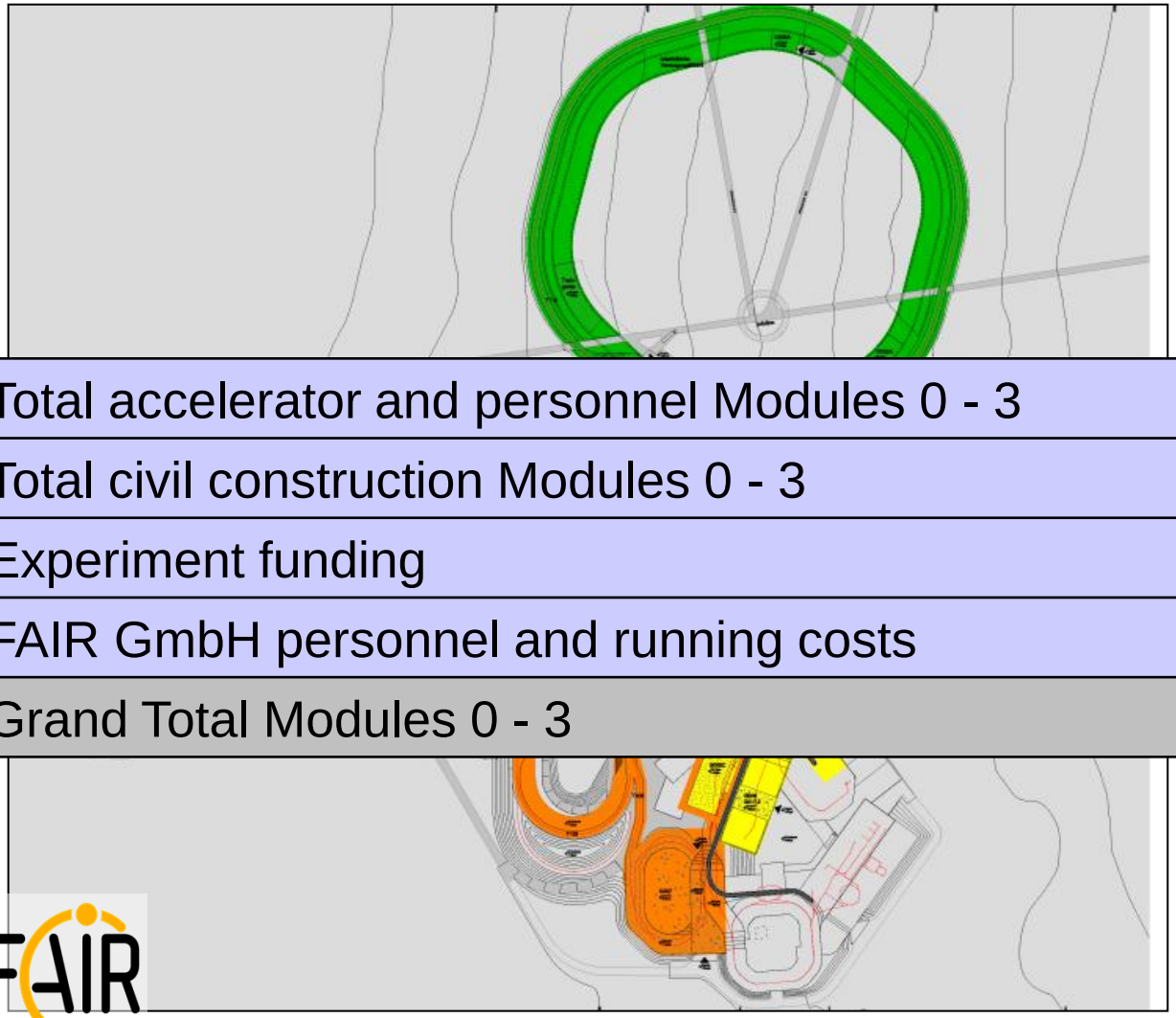
Partner States:



Finland, France, Germany, India, Poland, Romania, Russia, Slovenia, Sweden, United Kingdom

CBM	PANDA	NUSTAR	APPA
Nuclear Matter	anti-proton annihilations	nuclear structure, astro-physics reactions	atomic physics, plasma physics applications

FAIR – Modularised Start Version



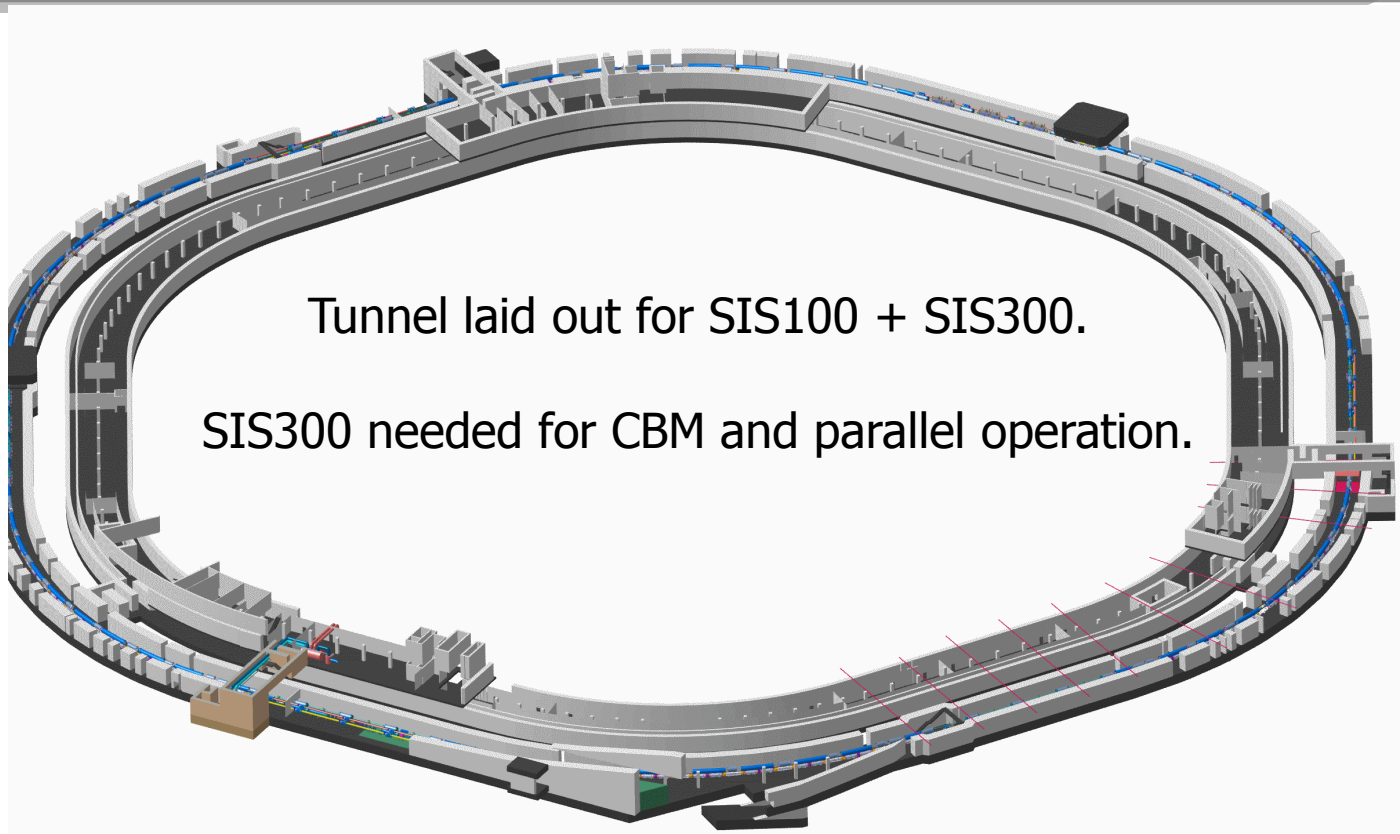
Modul 0
SIS100

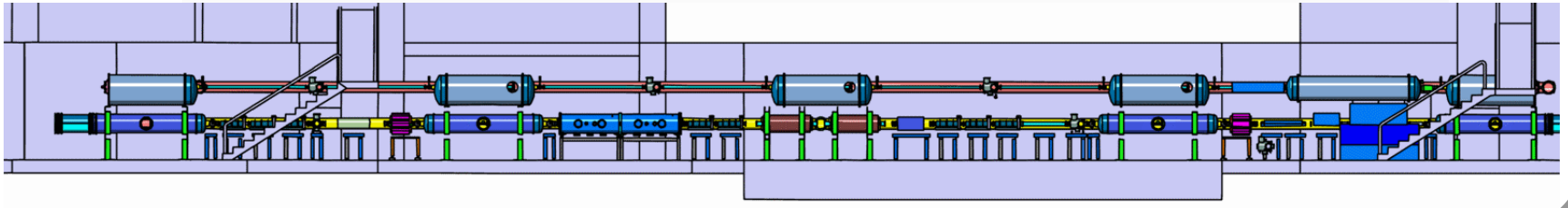
Modul 1
CBM,
APPA

p-Linac,
HESR

Total accelerator and personnel Modules 0 - 3	502
Total civil construction Modules 0 - 3	400
Experiment funding	78
FAIR GmbH personnel and running costs	47
Grand Total Modules 0 - 3	1027

SIS100/300 tunnel





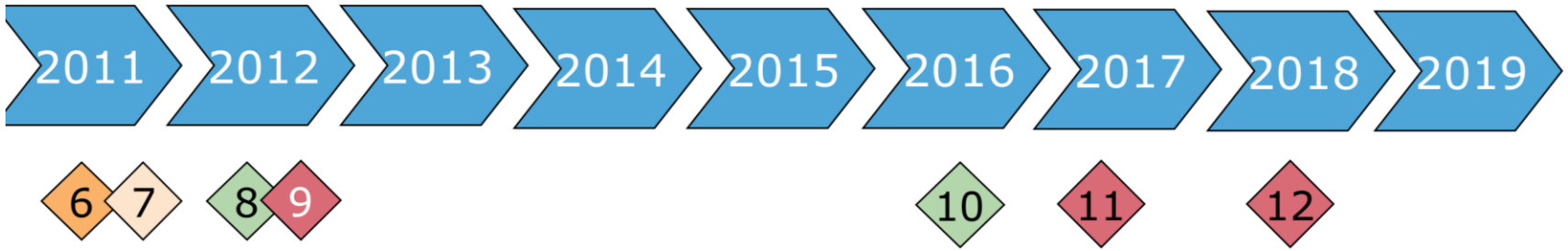
FAIR in 2018: artists view

FAIR construction site now

Web camera:

http://www.fair-center.eu/construction/webcam.html

FAIR timeline



6 Building permits

7 Site preparation

8 Civil construction contracts

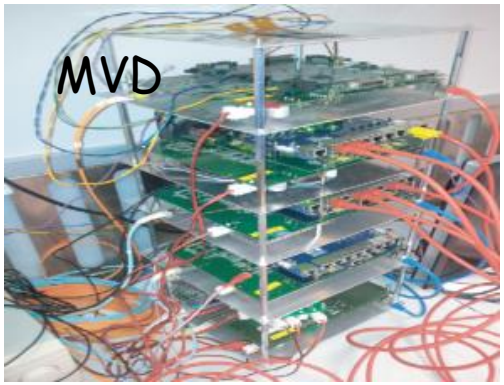
9 Building of accelerator & detector components

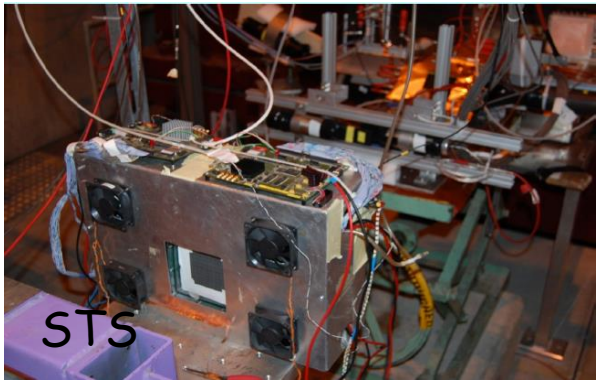
10 Completion of civil construction work

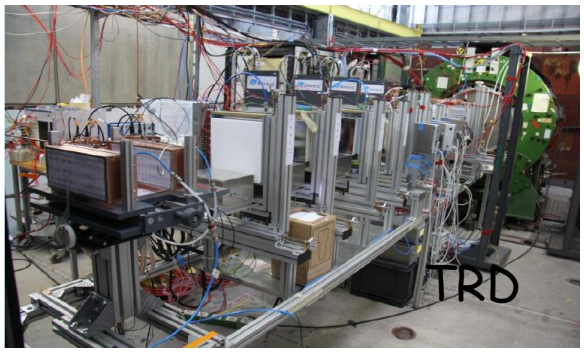
11 Installation & commissioning of accelerators and detectors

12 Start Data taking

Detector developments



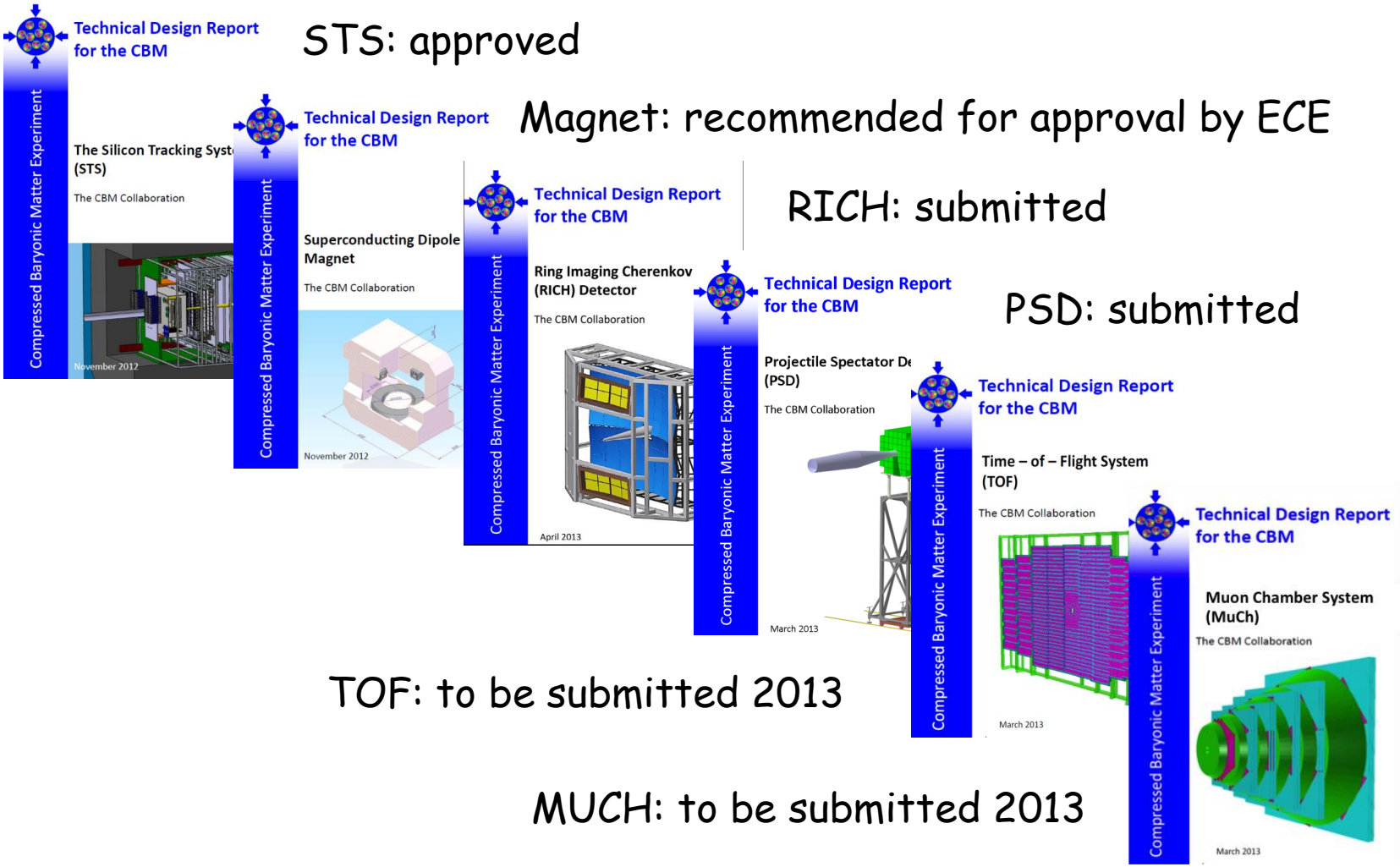




Prototypes for all detetcor systems were tested in beam

Technical Design reports will be delivered in the course of 2013

CBM: Status of preparations



STS: approved

Magnet: recommended for approval by ECE

RICH: submitted

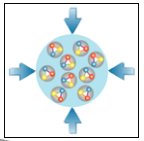
PSD: submitted

TOF: to be submitted 2013

MUCH: to be submitted 2013

MVD, TRD, ECAL: submission in 2014

Conclusion



- CBM: A+A collisions from 2A-45A GeV (p+p and p+A up to 90 GeV); fixed-target; large acceptance, very high rates
- hadrons, leptons, charm: yield, flow, correlations
- CBM is on track; so is FAIR. Operations will start 2018.
- There is an exiting physics programme already at SIS-100; however, the full potential of CBM will become available with the SIS-300 accelerator some years later.
- The discovery potential lies (apart from exotic matter) in a systematic investigation of nuclear collisions in terms of system sizes and, in particular, collision energy.

The study of excitation functions is the key to the understanding of the QCD phase diagram.

The Collaboration