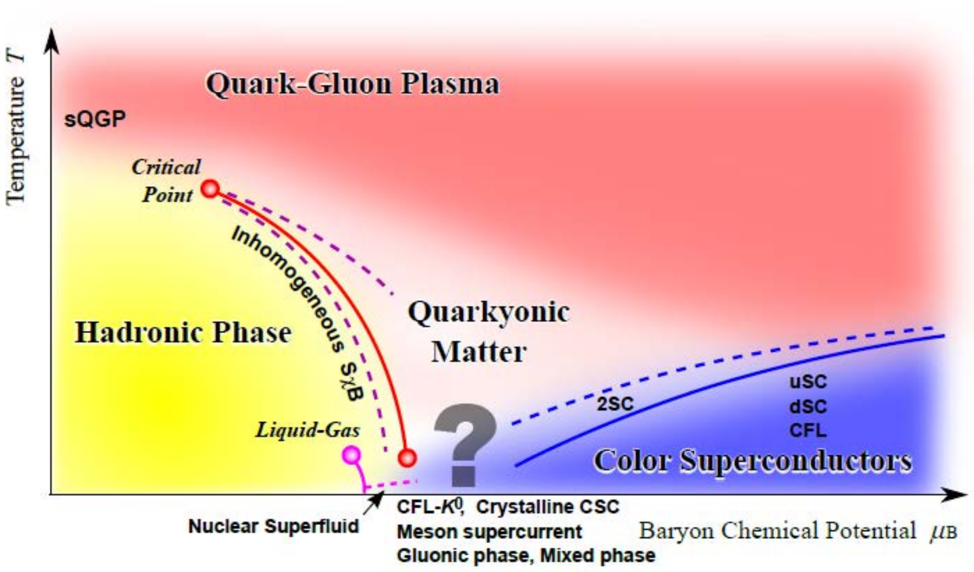
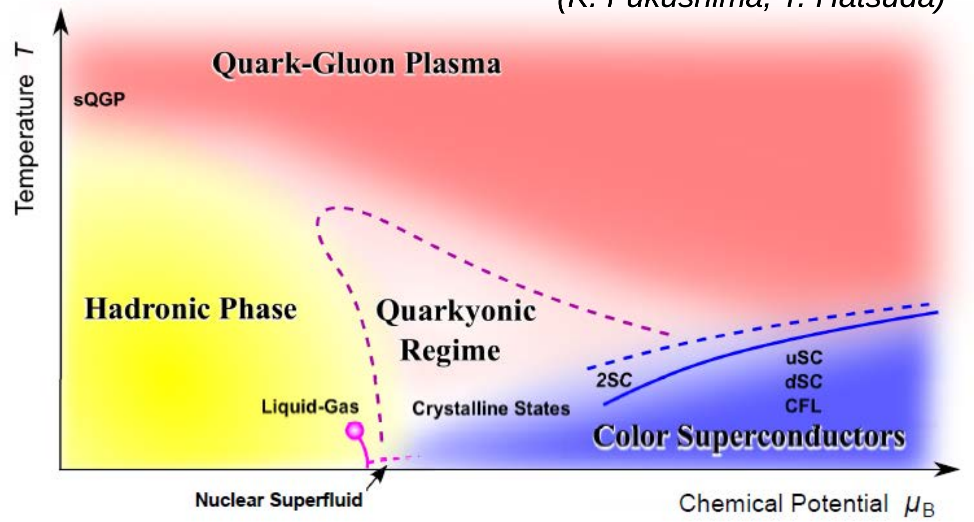
CBM – program and status



(K. Fukushima, T. Hatsuda)

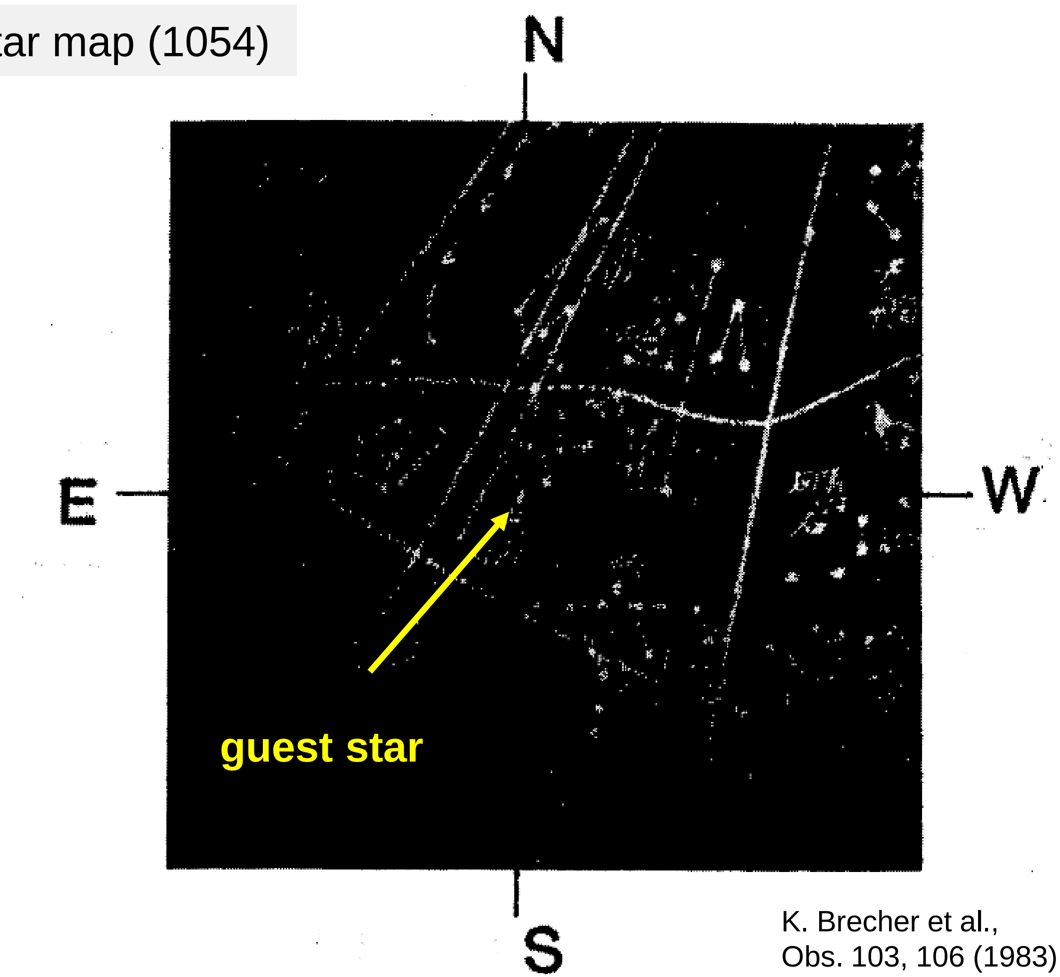


Outline:

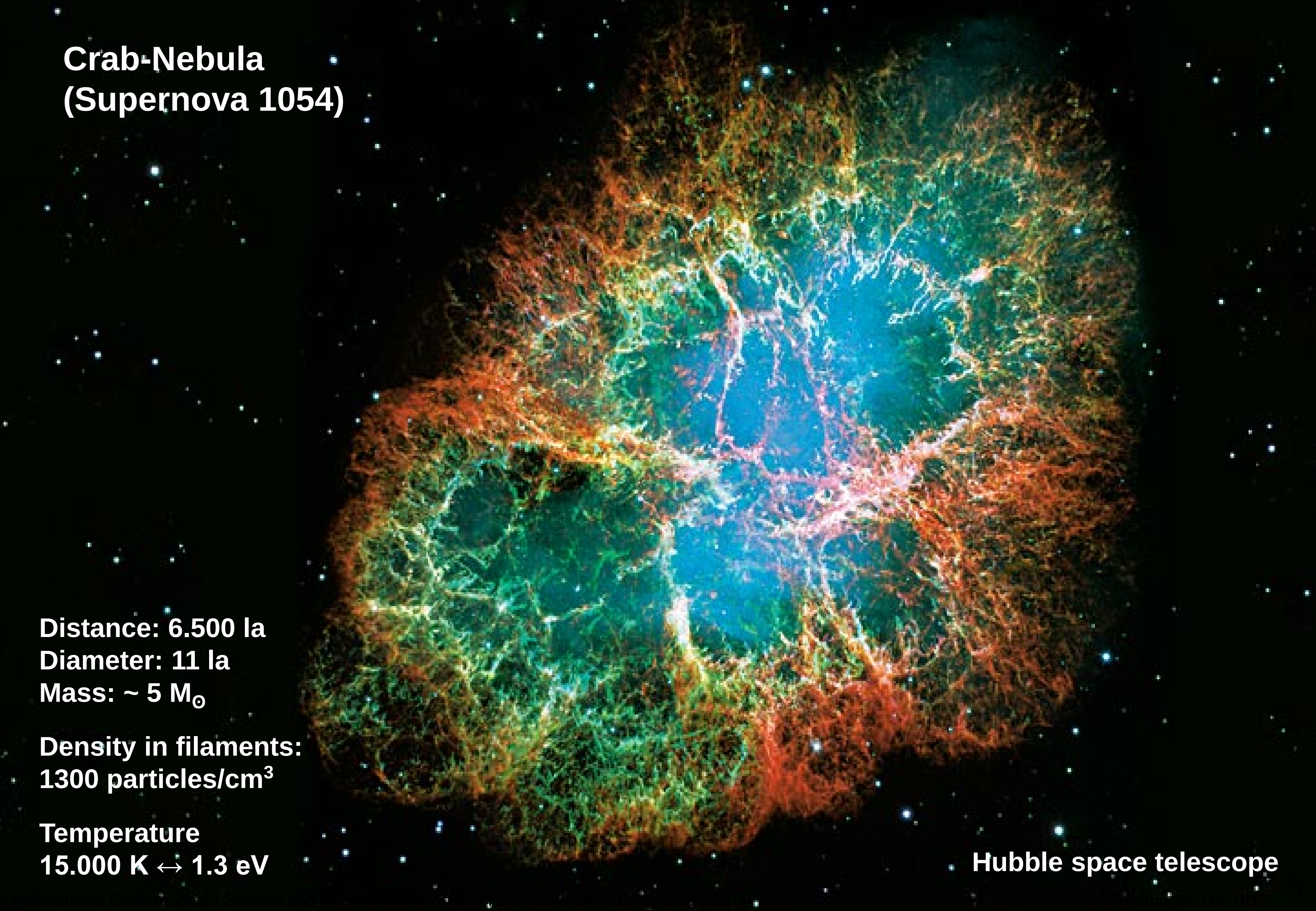
QCD – matter
Phase diagram and Freeze-out data
Equation – Of – State
In-medium modifications of hadrons
Dense matter observables at 'low energies'
Experimental strategy of CBM
Status of CBM
Conclusion

First Documented Observation of Strongly Interacting Matter

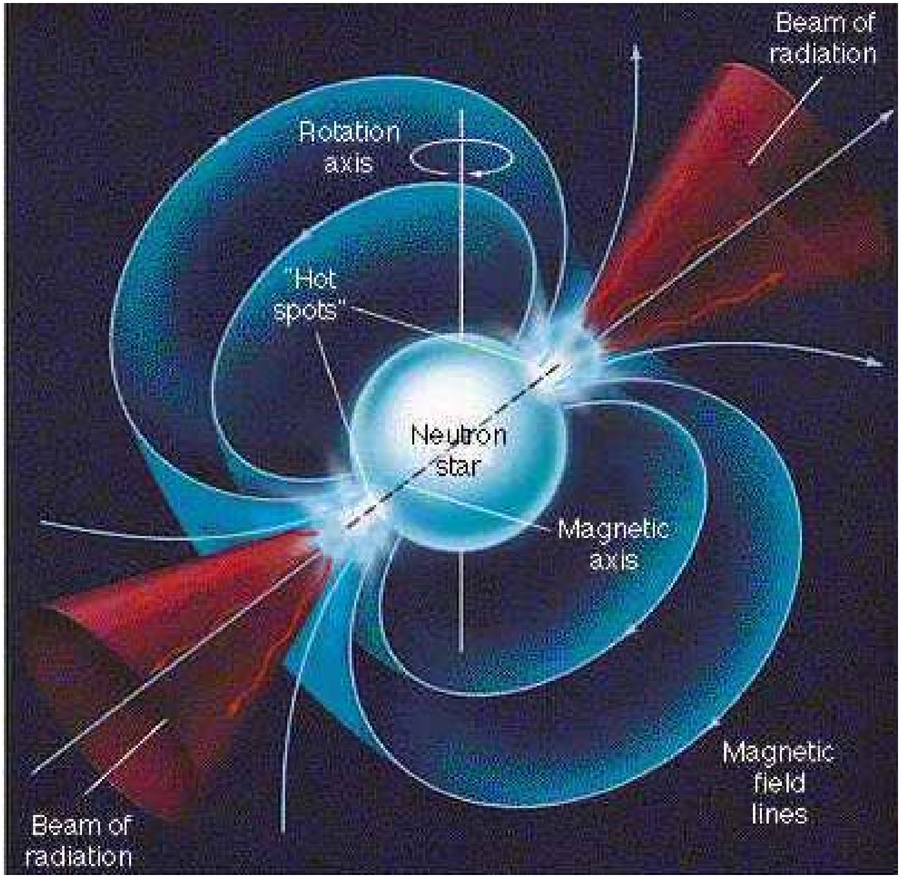
Rubbing of Suzhou star map (1054)



K. Brecher et al.,
Obs. 103, 106 (1983)


Crab-Nebula
(Supernova 1054)
Distance: 6.500 la
Diameter: 11 la
Mass: ~ 5 $M_\odot$
Density in filaments:
1300 particles/cm^3
Temperature
15.000 K ↔ 1.3 eV
Hubble space telescope

Pulsars



Pulsars are rotating neutron stars.

- **rotation frequency** **$f = 0.25 - 1000$ Hz**
- **magnetic field** **$B = 5 \cdot 10^{12}$ Gauss**

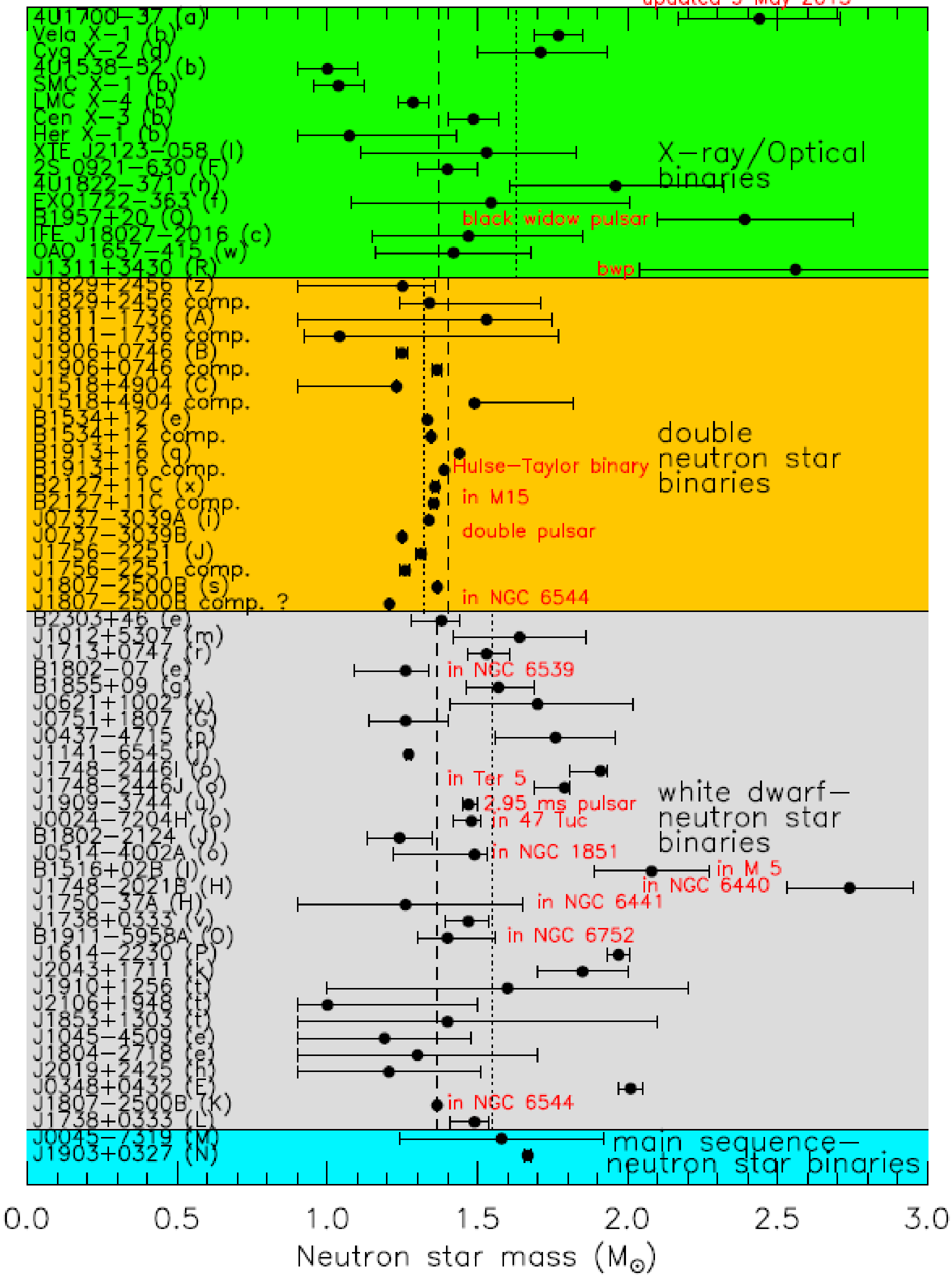
The rotating neutron star with a strong magnetic field emits synchrotron radiation from high energy electrons !

- **focused radiation (X-ray - radio)**
- **lighthouse behaviour**

Example: Crab pulsar

Discovery	**1968**
Rotation period	**$T = 33.4$ ms**
Slowing down rate	**$\Delta T/\Delta t = 3 \cdot 10^{-8}$ s/a**
Mass	**$\sim 1.5\ M_{\odot}$**
Radius	**~ 15 km**
Density	**$3 - 10\ \rho_0$**

Neutron star masses



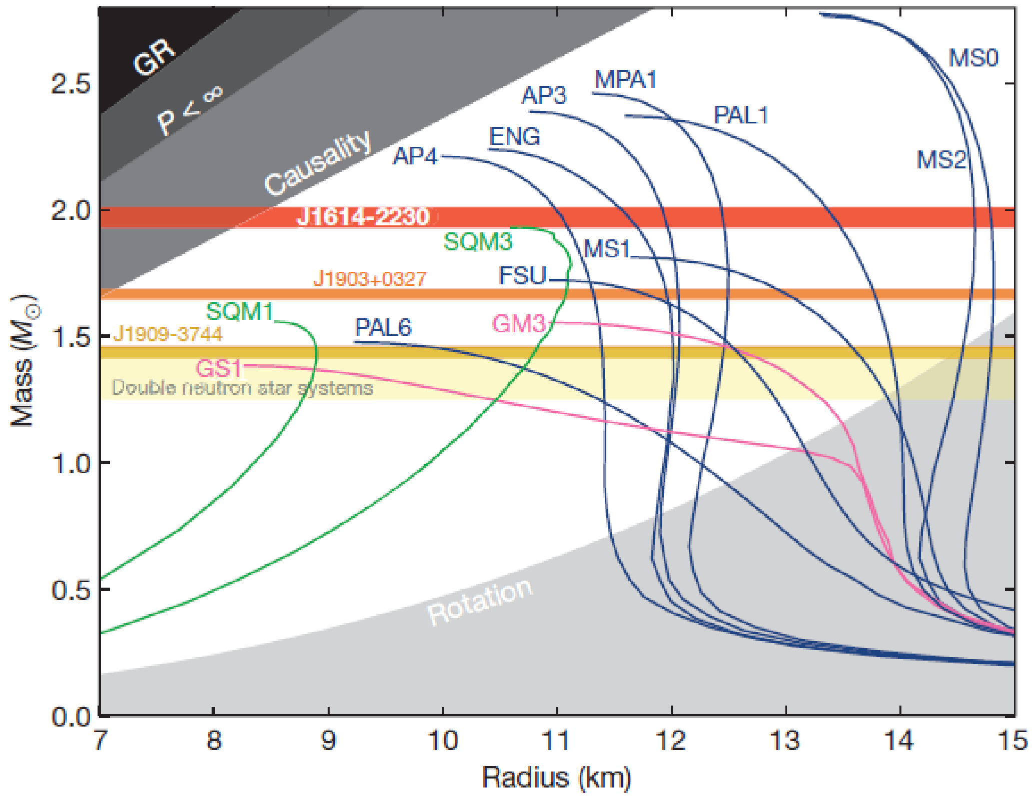
Compilation by Lattimer and Prakash

M. Prakash, [arXiv:1307.0397]

PSR J1614-2230

PSR J0348+0432

Mass – Radius Relation of Neutron Stars



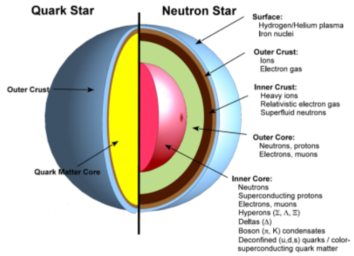
P.B. Demorest (2010)
doi:10.1038/nature09466

Curves given by different Equation – of – States (EOS): $P = P(\rho, T)$

(matter in β – equilibrium)

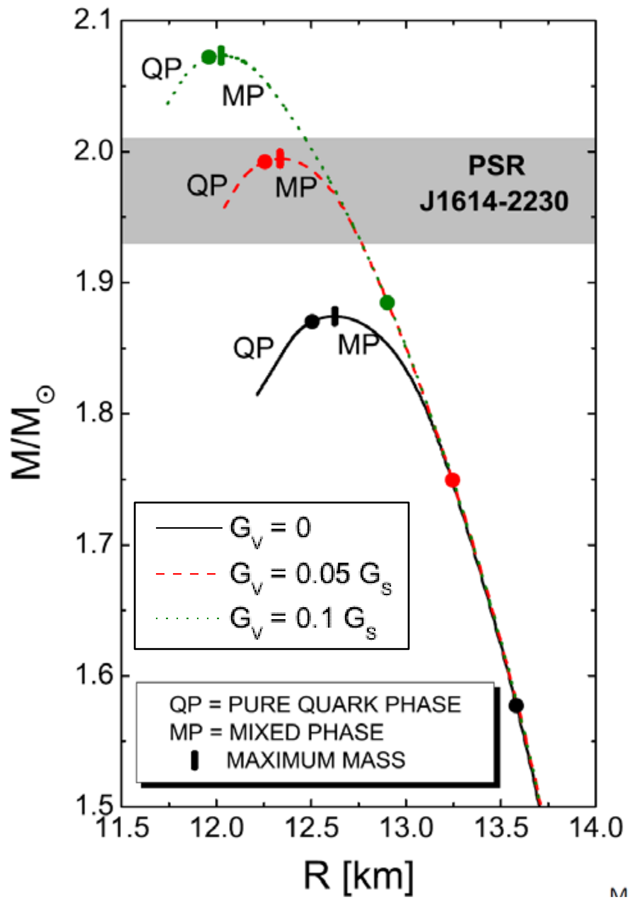
- **nucleons**
- **nucleons + exotic matter**
- **strange matter**

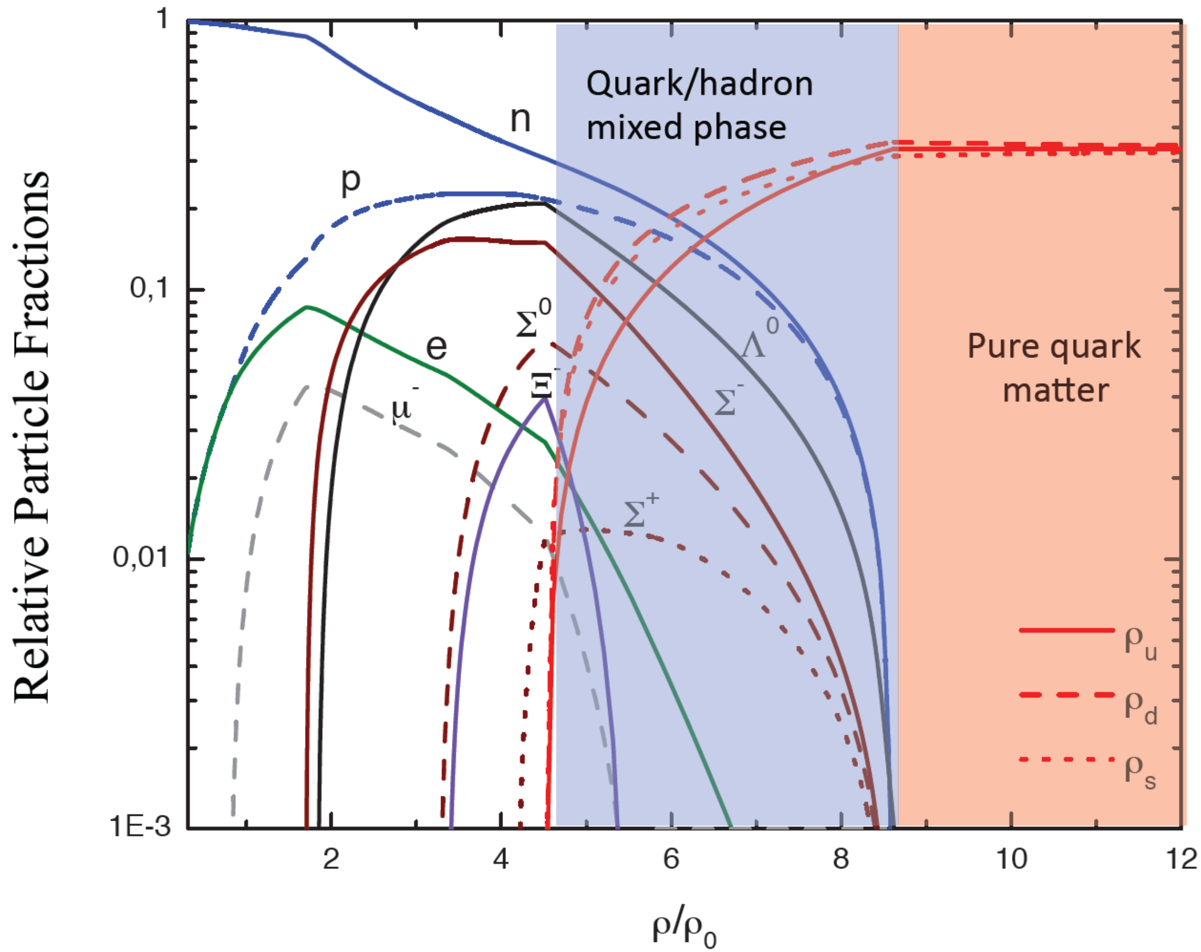
Equation – of – State of Neutron Stars



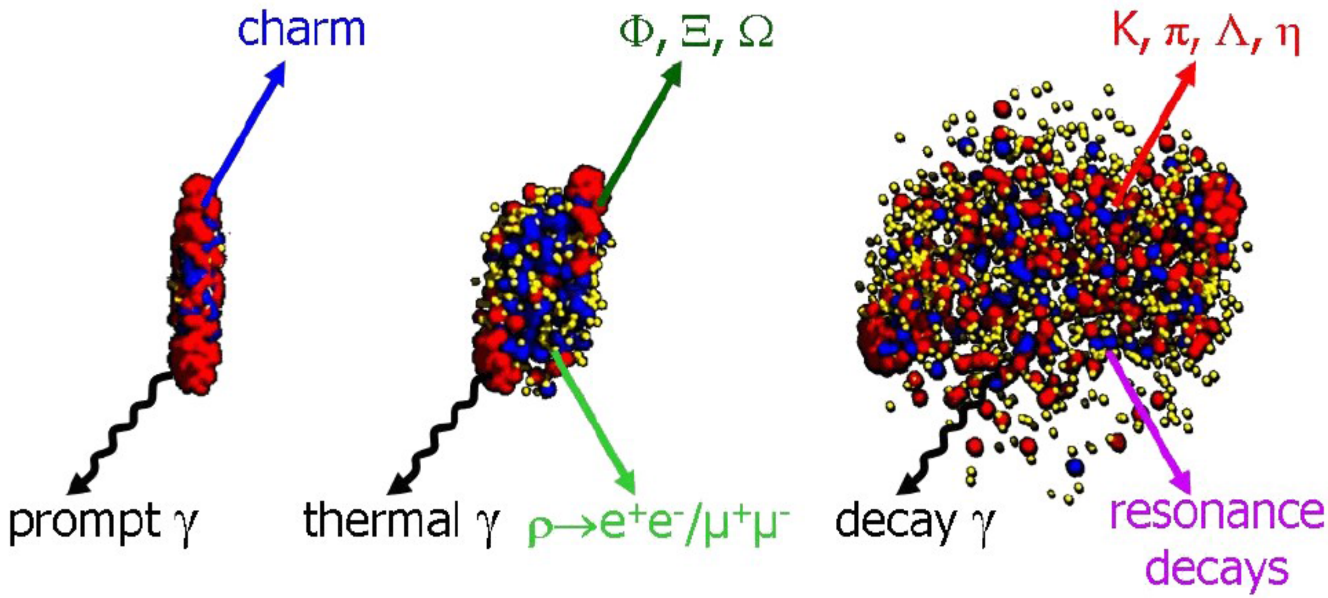
Equation-of-state: Non-local SU(3) NJL with vector coupling

M. Orsaria, H. Rodrigues, F. Weber, Phys.Rev. D87 (2013) 023001





Heavy – Ion Collisions



Hard probes
(initial state)

Penetrating probes
(integrate over collision history)
Relicts
(produced in dense phase)

Freeze-out
(final state particles)

Thermalized (?) hadrons

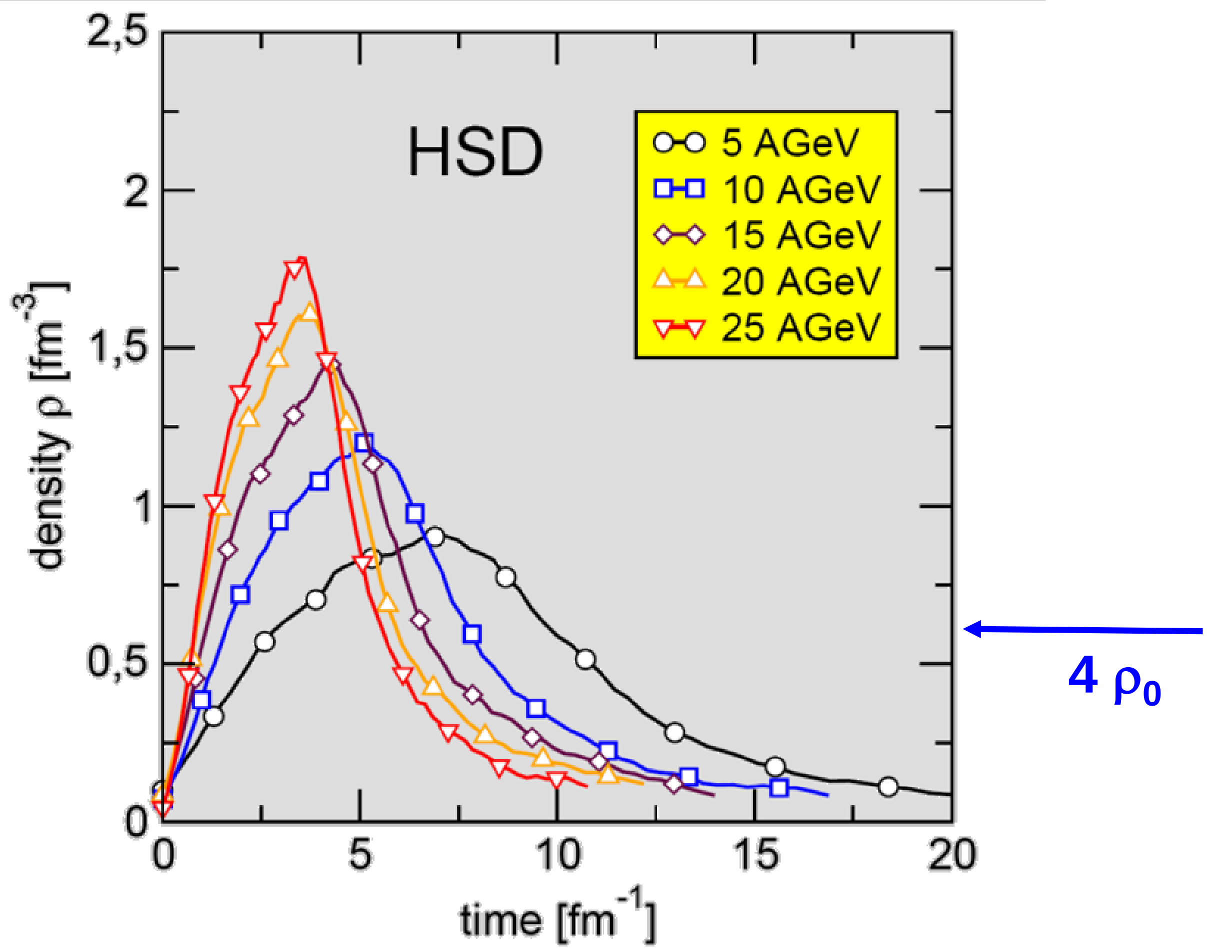
Differences to NS – research: **short system lifetime (no β – equilibrium)**
small systems
high temperatures

History of QCD – matter research

Bevalac @ LBNL, Berkeley	1980 - 1990	$\sqrt{s_{NN}}$= 1.15 GeV	E/A = 2.4 GeV
AGS @ BNL, Upton	1985 - 1995	$\sqrt{s_{NN}}$= 4.8 GeV	E/A = 10.5 GeV
SPS @ CERN, Geneva	1987 – 2004 2011 – …	$\sqrt{s_{NN}}$= 17.3 GeV	E/A = 157 GeV
SIS-18 @ GSI, Darmstadt	1989 – …	$\sqrt{s_{NN}}$= 1.5 GeV	E/A = 2.5 GeV
RHIC @ BNL, Upton	2000 – …	$\sqrt{s_{NN}}$ =12-200 GeV	E/A = 6-100 GeV
LHC @ CERN, Geneva	2010 – …	$\sqrt{s_{NN}}$= 15400 GeV $\sqrt{s_{NN}}$= 2760 GeV	E/A = 7700 GeV E/A = 1380 GeV
SIS-100@ FAIR, SIS-300@FAIR, Darmstadt	~ 2019 – …	$\sqrt{s_{NN}}$= 1.9-4.5 GeV $\sqrt{s_{NN}}$= 4.2-9 GeV	E/A = 2-11 GeV E/A = 10-45 GeV
NICA@JINR, Dubna	~ 2018 – …	$\sqrt{s_{NN}}$= 1.9-3.2 GeV	E/A = 2-6 GeV

Expectation of baryon density

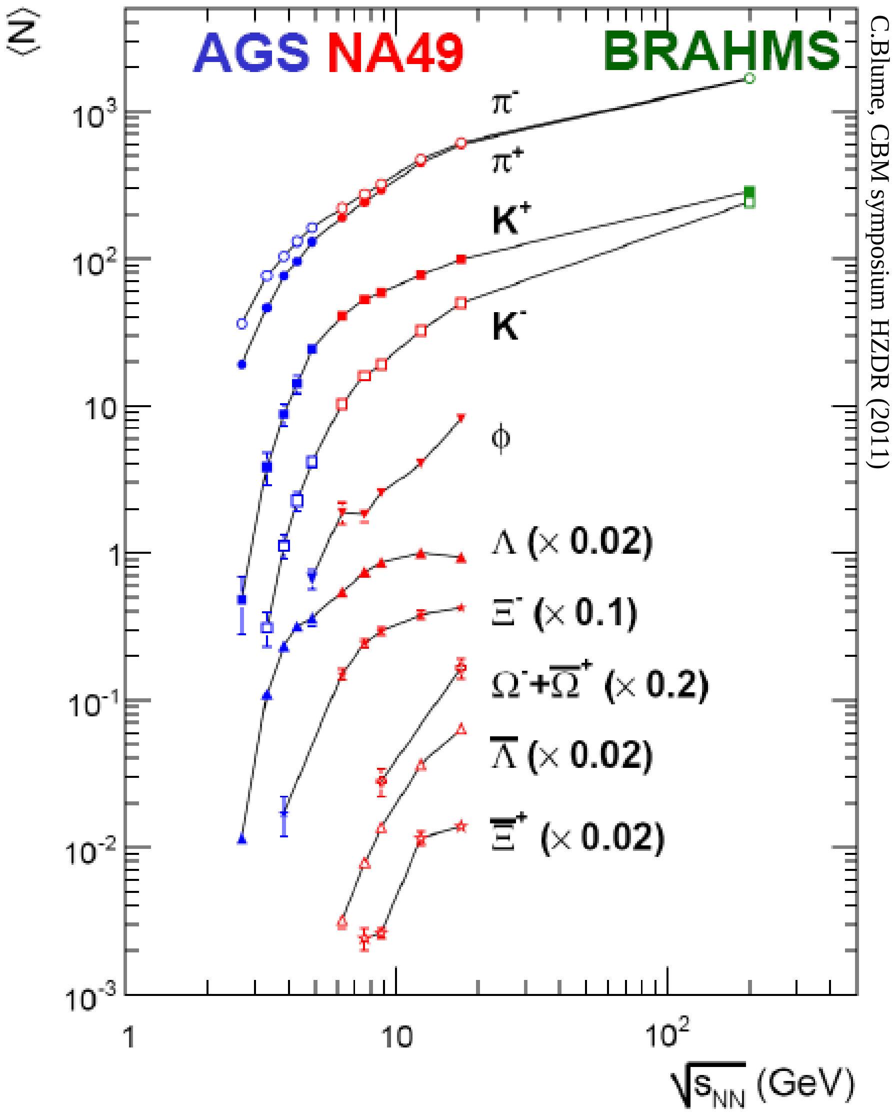
HSD transport model (W.Cassing, E. Bratkovskaya) calculations for central Au + Au collisions



Large baryon densities can be probed already at SIS100.

Final state particle abundance

Particle yield ratios from central Au + Au collisions



Knowledge about strange baryons and antibaryons in FAIR energy range is rather limited.

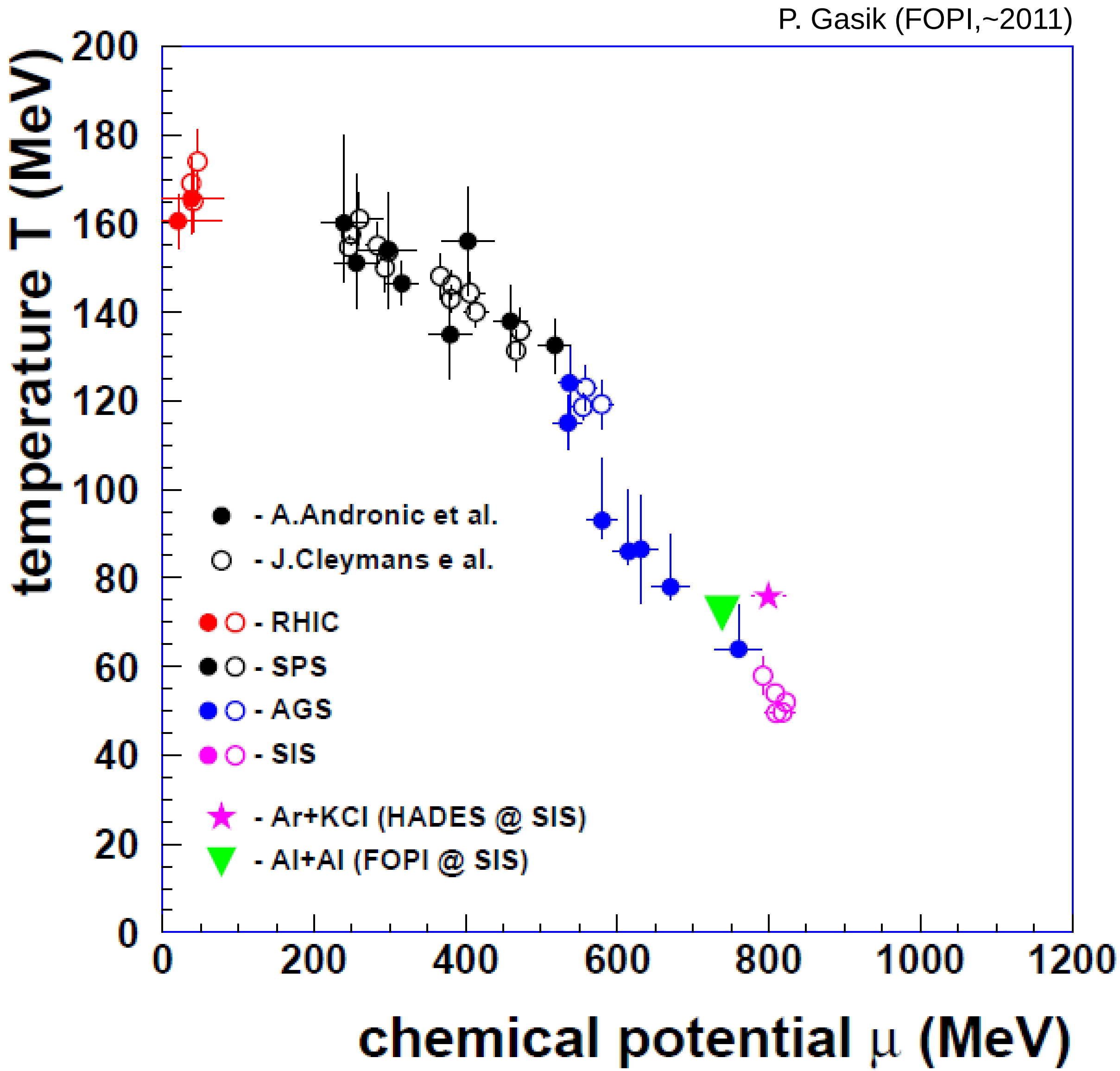
Note:

Direct multi-strange hyperon production:

$pp \rightarrow \Xi^- K^+ K^+ p$ (E_{thr} = 3.7 GeV)

$pp \rightarrow \Omega^- K^+ K^+ K^0 p$ (E_{thr} = 7.0 GeV)

Chemical Freeze-out data



Assumption:
thermodynamic equilibrium

Errors include systematic errors (when given).

Data sources:

A. Andronic, P. Braun-Munzinger, J. Stachel, Nucl. Phys. A772 (2006) 167

J. Cleymans, H. Oeschler, K. Redlich, S. Wheaton, Phys. Rev. C73 (2006) 034905

G. Agakishiev et al. (HADES), Eur. Phys.J. A47 (2011) 21

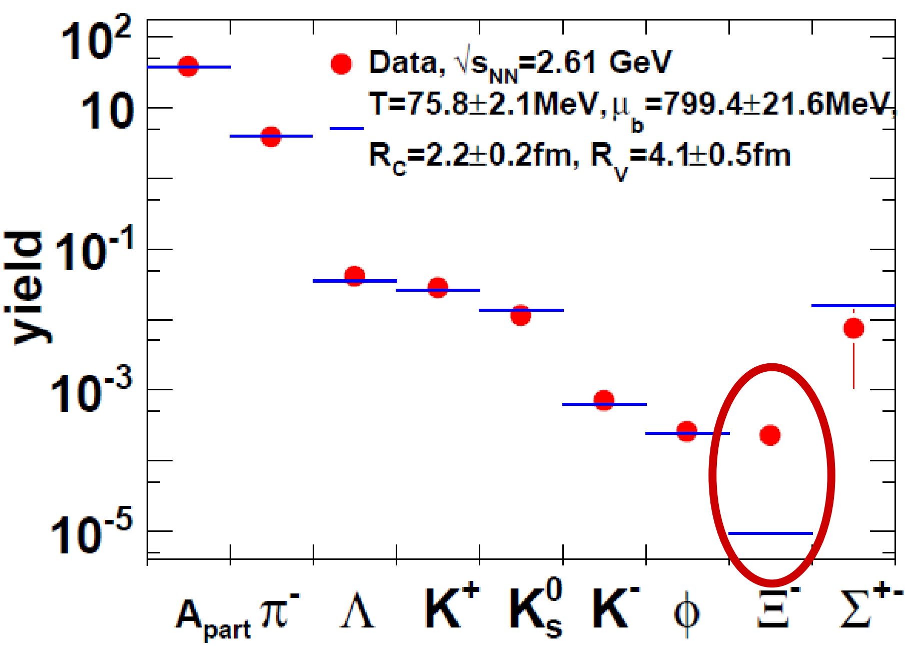
At lower energies canonical ensemble has to be used.

Equilibrium as signature for phase transition?

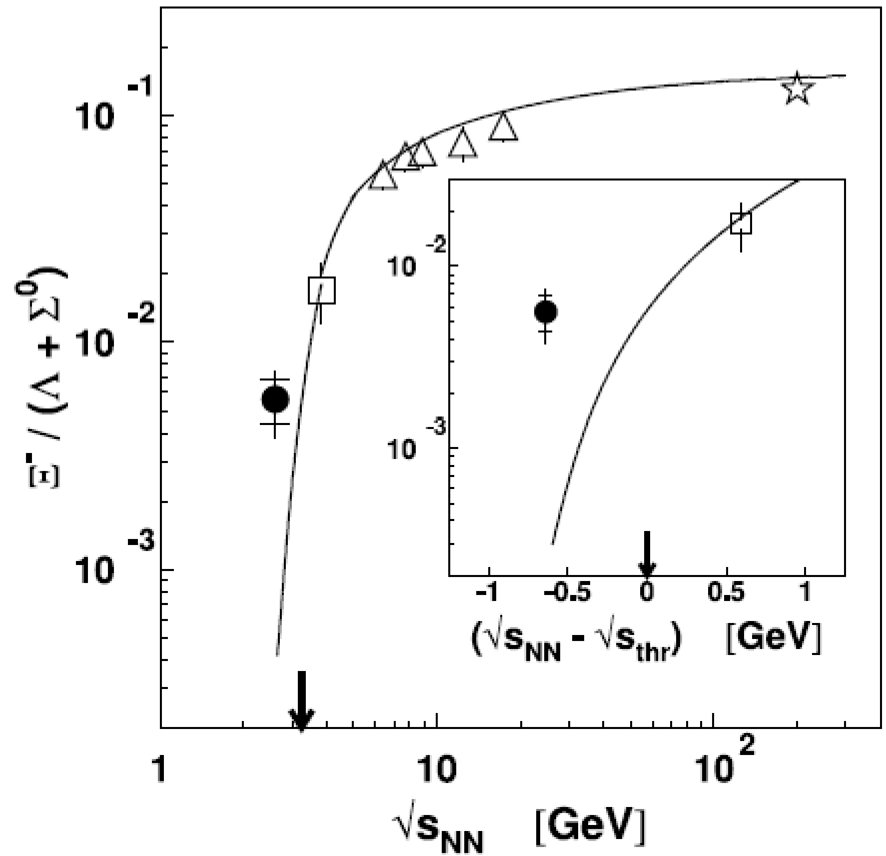
HADES: Sub-threshold Ξ^- - production

Ar+KCl reactions at 1.76A GeV

- Ξ^- yield by appr. factor 25 higher than thermal yield
- strangeness exchange reactions like
  $\bar{K}Y \rightarrow \pi\Xi$ (Y=Λ,Σ) ?

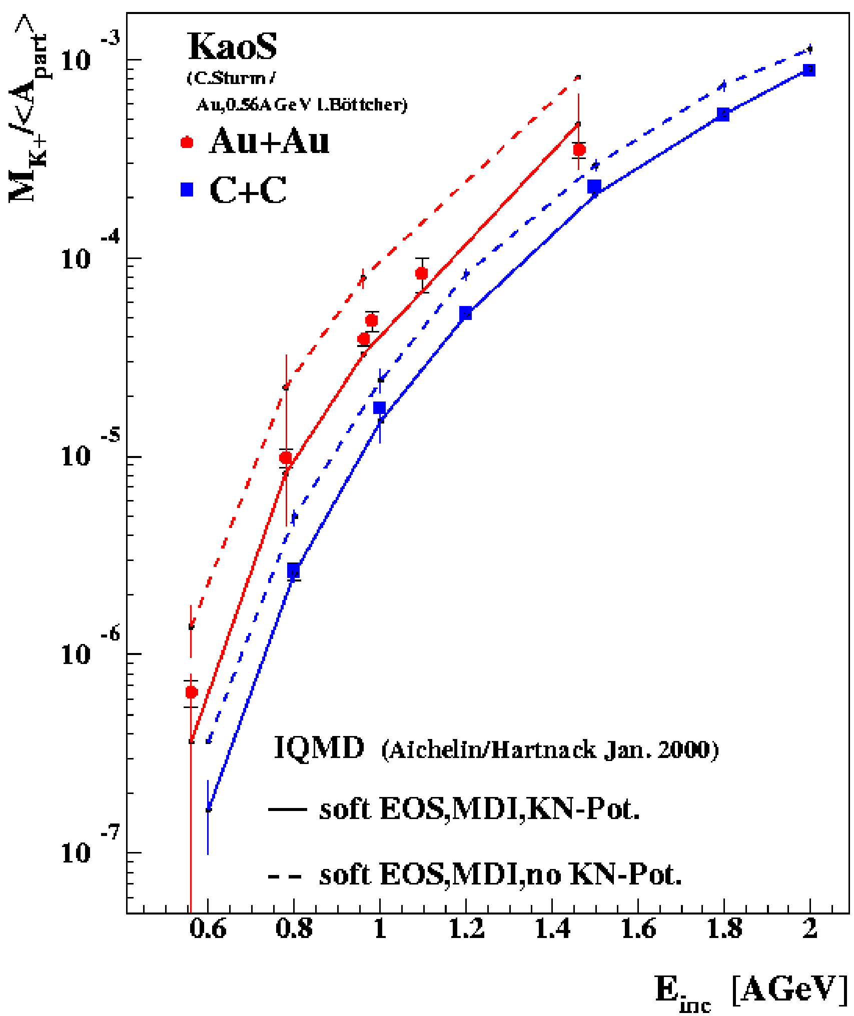


G. Agakishiev et al. (HADES), PRL103, 132301, (2009)

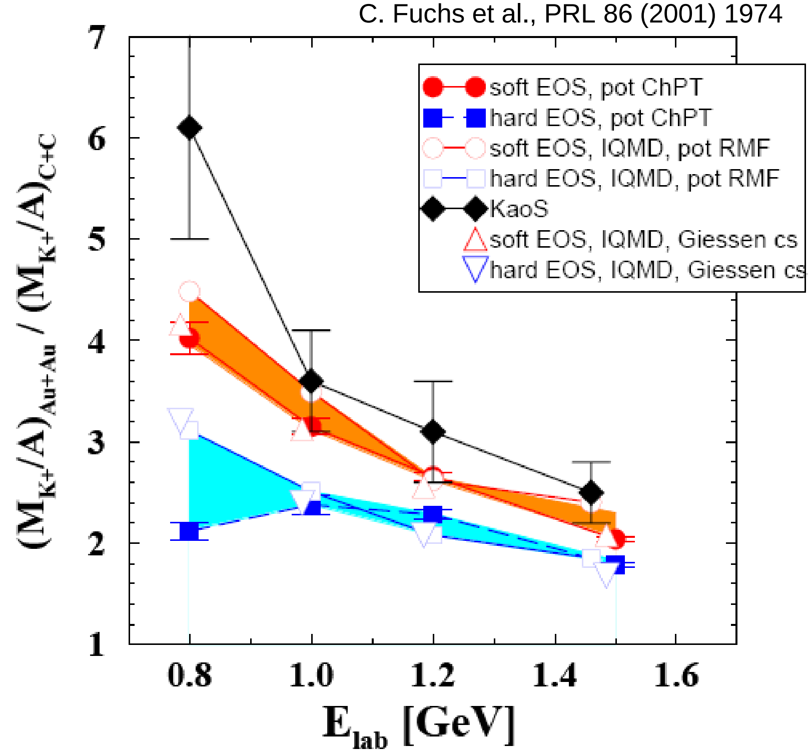


Reminder: Subthreshold Kaon – measurements (KAOS)

C.Sturm et al. (KaoS), PRL 86 (2001) 39



C. Fuchs et al., PRL 86 (2001) 1974

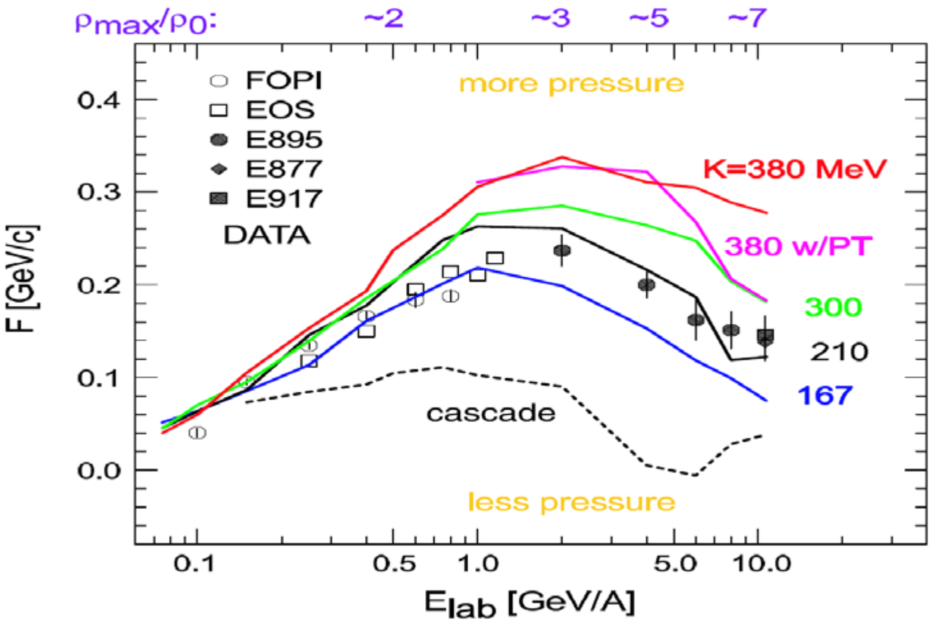


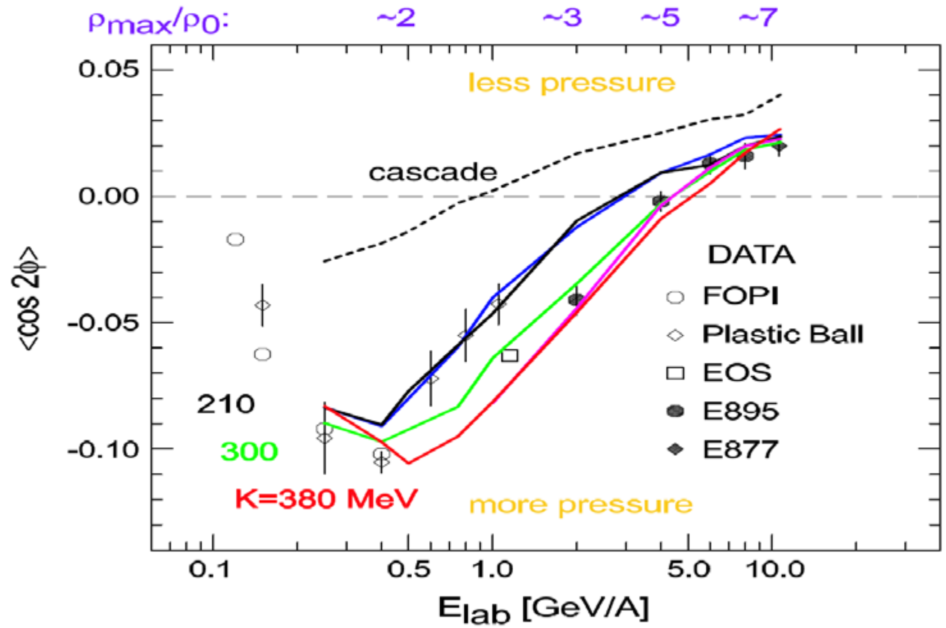
Strong sensitivity to EOS due to multistep production (formation of nucleon resonances)
=> soft EOS (K=200)

Excitation function of flow variables

$$F = \frac{d\langle p_x / A\rangle}{d(y/y_{cm})}$$

P. Danielewicz et al.
nucl-th/0112006 (2001),
Science 298, 1592 (2002)





- **No consistent model description available so far.**
- **Largest sensitivity to model parameters (EOS) in energy range 2 – 5 AGeV.**
- **Uncertainty in data at 1 GeV/A corresponds to uncertainty in K of 150 MeV.**

Flow of charged kaons

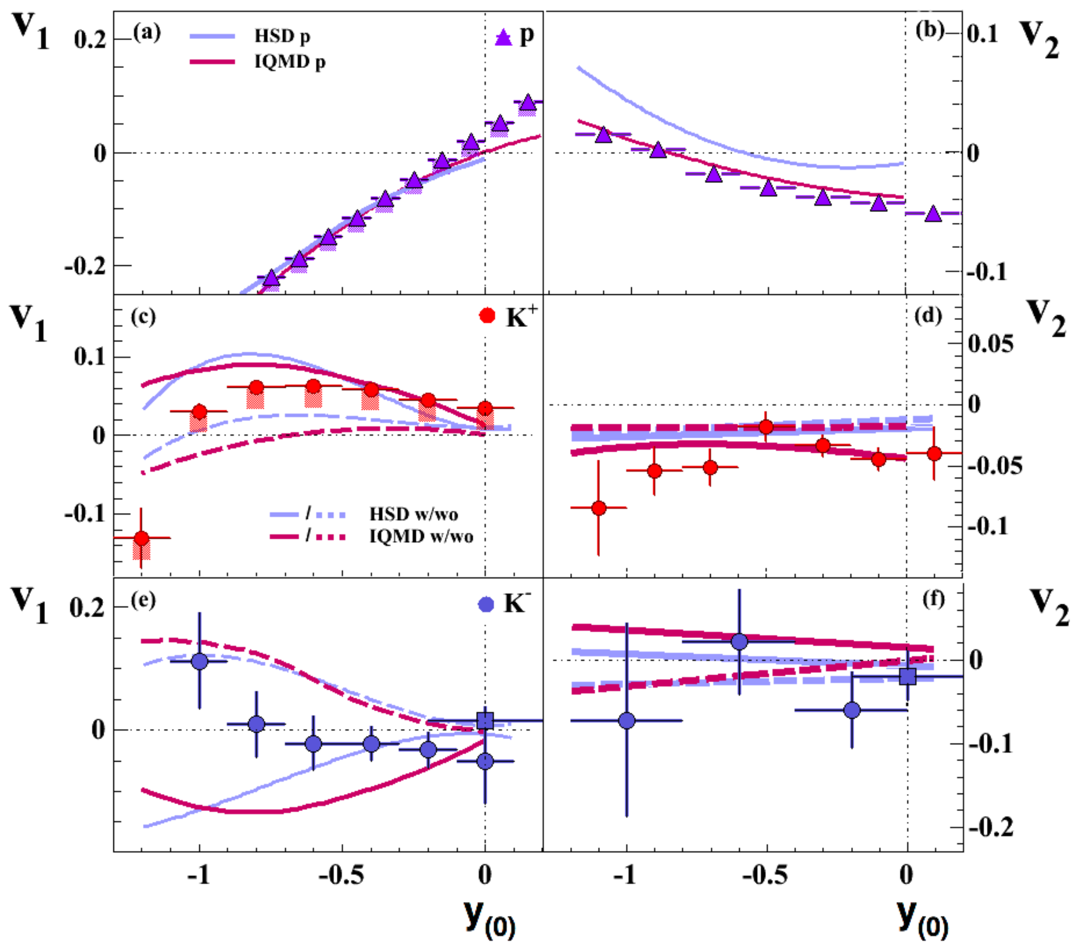
Ni+Ni at 1.91 AGeV
(S325 + S325e data)
σ = 1.5 b

Models with FOPI acceptance filter

Potentials with linear density dependence.

At $\rho=\rho_0$:

$U_{HSD}(K^+)$	20 MeV
$U_{IQMD}(K^+)$	40 MeV
$U_{HSD}(K^-)$	-50 MeV
$U_{IQMD}(K^-)$	-90 MeV

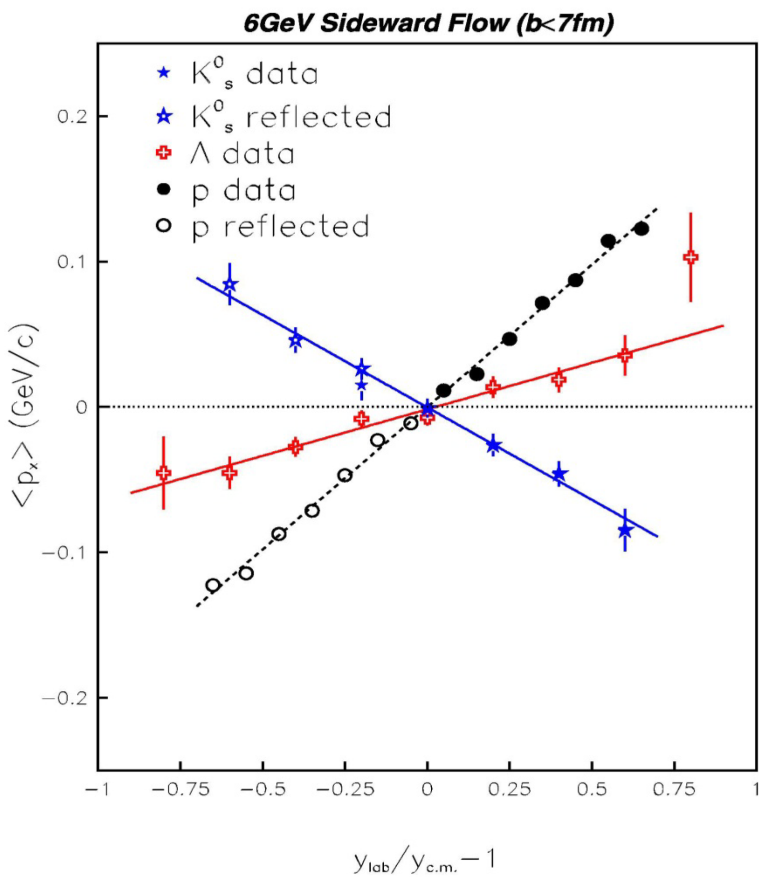


V.Zinyuk et al. (FOPI)
PRC 90 (2014) 025210

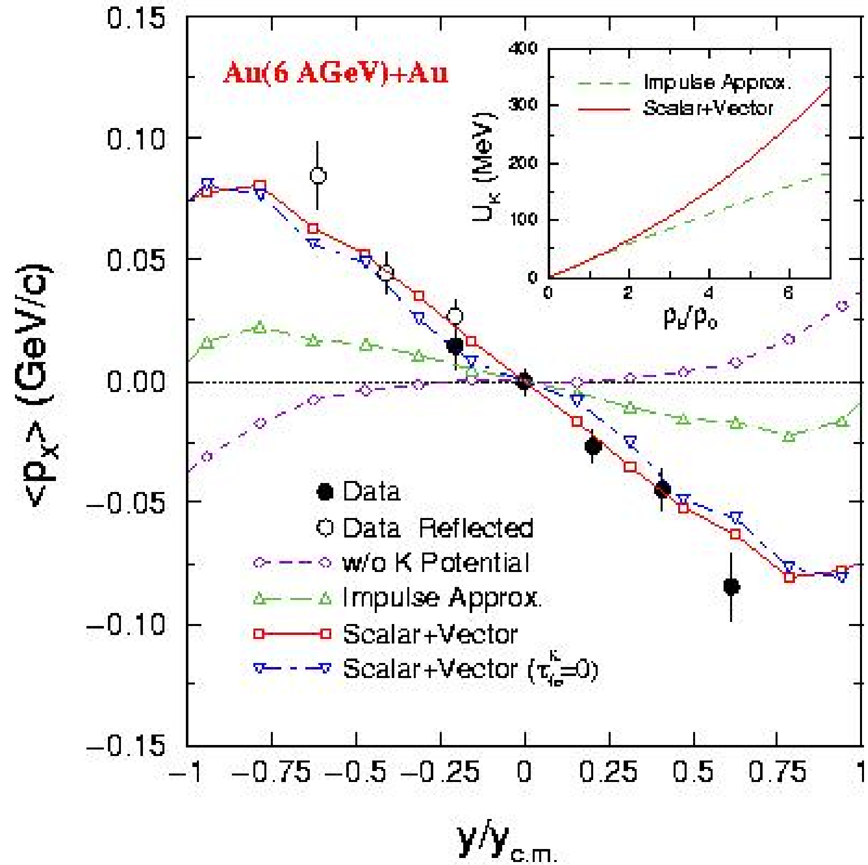
K^+ sideflow indicative for repulsive potential.
K^- sideflow indicative for attractive potential.
Transport model calculations need to be refined.

AGS: K^0 – flow

Data: P. Chung et al, (E895), PRL85, 940 (2000)



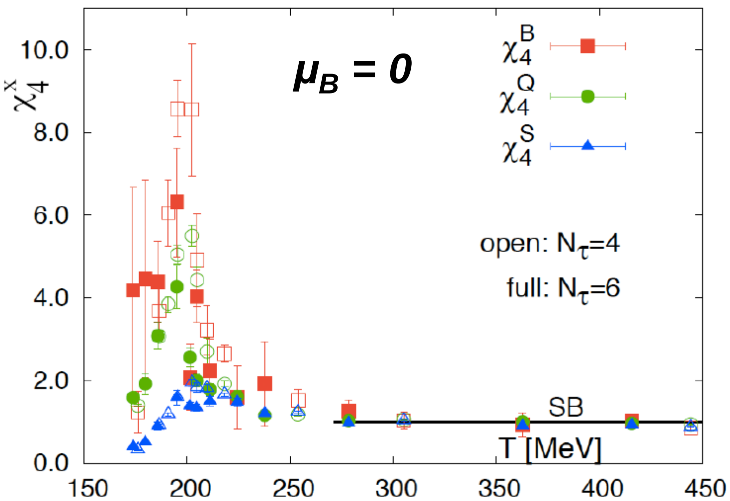
Theo: S. Pal et al., Phys.Rev.C62:061903, (2000)

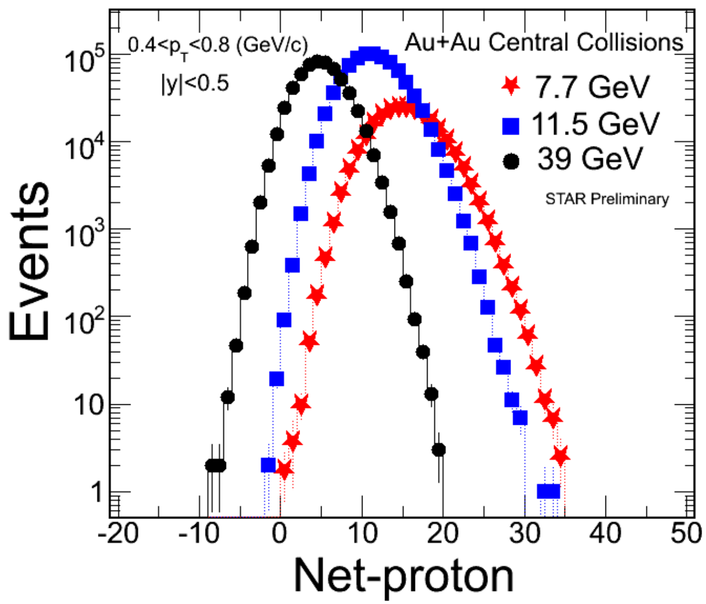


Kaon flow as barometer in HI collisions?
Calibrate probe by systematic measurements

- **centrality**
- **system size**
- **incident energy**

Fluctuations and critical point





Event-by-event fluctuations of conserved quantities like strangeness, baryons, and net-charge are related to susceptibilities χ and correlation length ξ .

$$\delta N = N - \langle N \rangle$$

$$\left\langle (\delta N)^2 \right\rangle \approx \xi^2, \left\langle (\delta N)^3 \right\rangle \approx \xi^{4.5}, \left\langle (\delta N)^4 \right\rangle \approx \xi^7$$

$$S\sigma \approx \frac{\chi_B^3}{\chi_B^2}, \qquad \kappa\sigma^2 \approx \frac{\chi_B^4}{\chi_B^2}$$

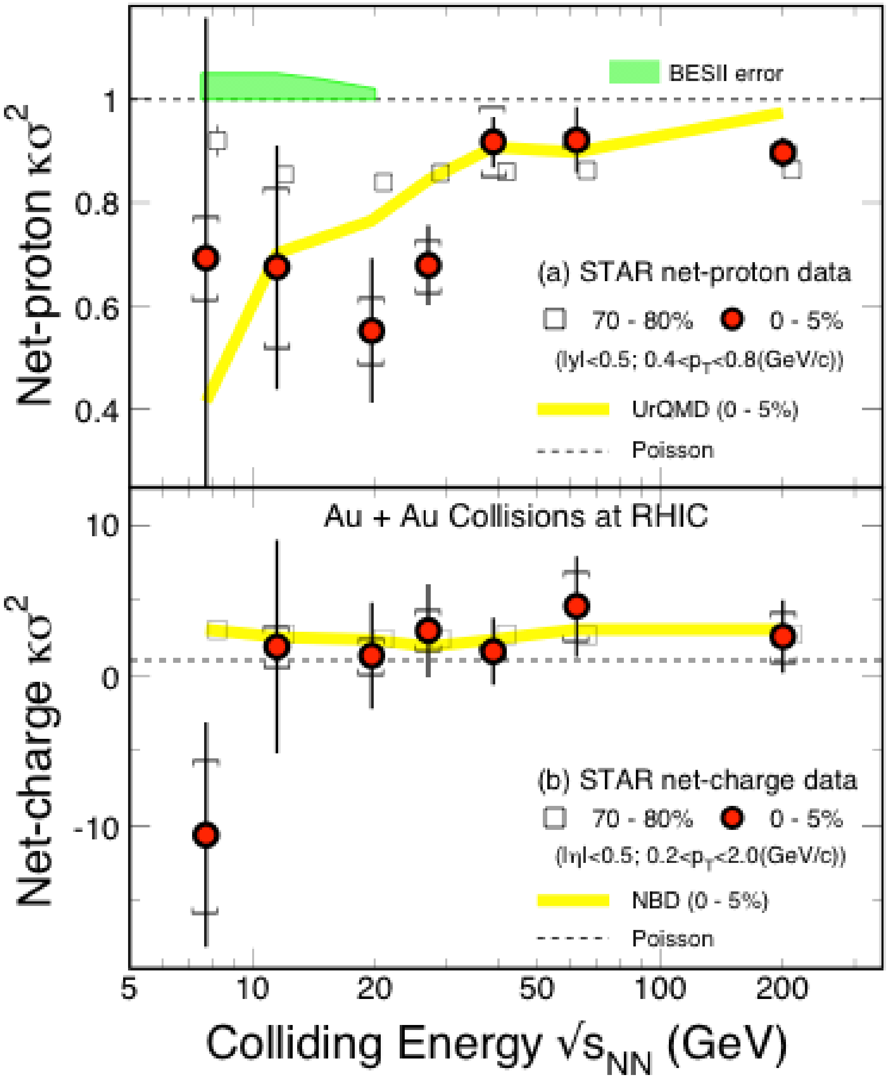
Sensitive to tails of multiplicity distributions (centrality selection, detector biases, …)

References:

- STAR: *PRL*105, 22303(10); *ibid*, 032302(14)
- M. Stephanov: *PRL*102, 032301(09) // R.V. Gavai and S. Gupta, *PLB696*, 459(11) // F. Karsch et al, *PLB695*, 136(11) // S.Ejiri et al, PLB633, 275(06)
- A. Bazavov et al., PRL109, 192302(12) // S. Borsanyi et al., PRL111, 062005(13) // V. Skokov et al., PRC88, 034901(13)

Fluctuations in BES (STAR)

L. Adamczyk et al. (STAR Collaboration),
Phys. Rev. Lett. 112, 032302 (2014)



Net-proton results:

1) All data show deviations below Poisson for $\kappa\sigma^2$ at all energies. Larger deviation at $\sqrt{s_{NN}}$~20GeV

2) UrQMD model shows monotonic behavior in the moment products

STAR: PRL112, 32302(14)/arXiv: 1309.5681

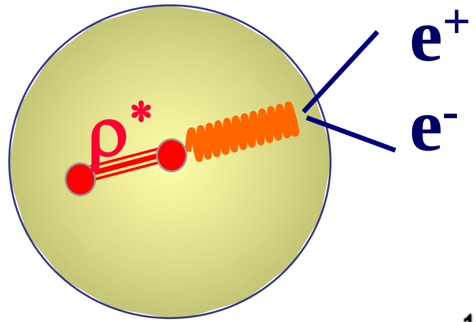
Net-charge results:

1) No non-monotonic behavior
2) More affected by the resonance decays

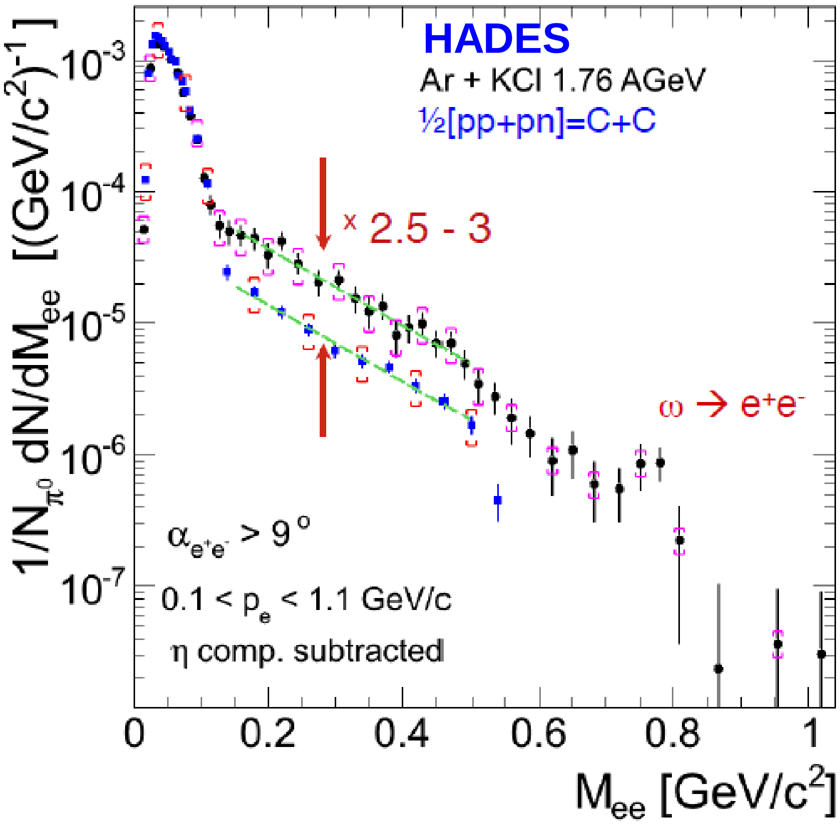
STAR: arXiv: 1402.1558
P. Garg et al, PLB726, 691(13)

'Low' energy data limited by statistics.

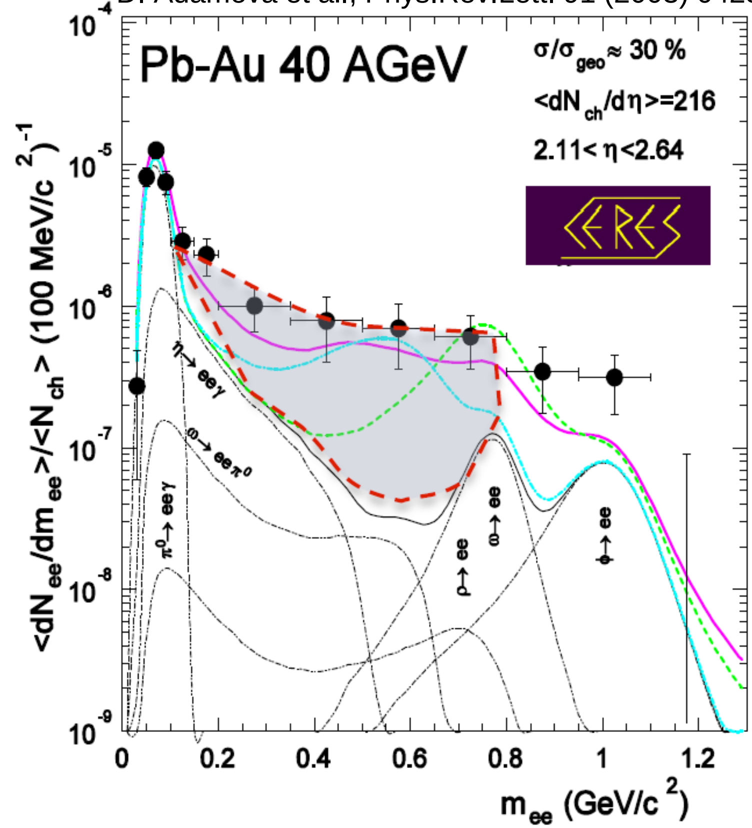
In – medium properties of light vector mesons



G. Agakishiev et al., Phys. Rev. C 84 (2011) 014902



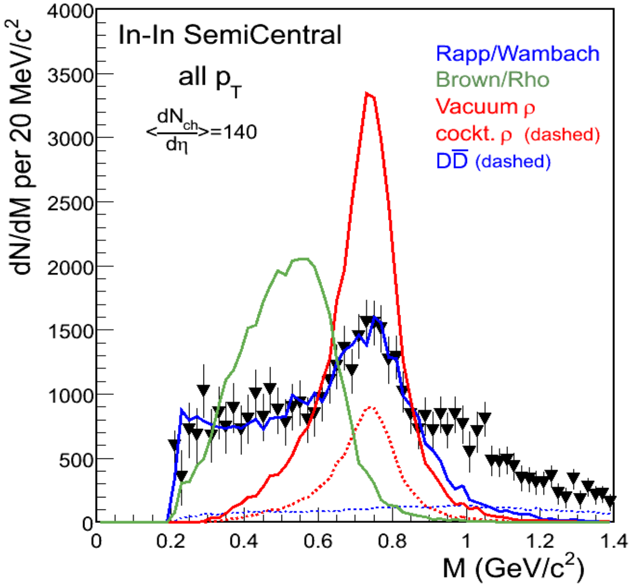
D. Adamova et al., Phys.Rev.Lett. 91 (2003) 042301

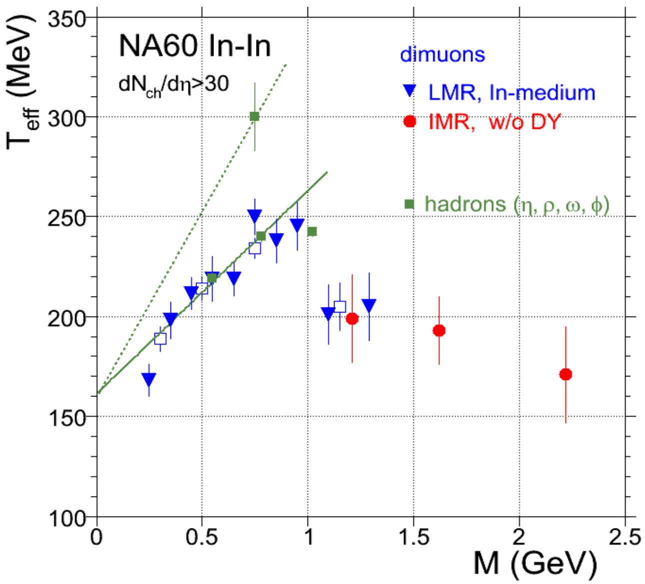


No data available in SIS100 / SIS300 energy range

Phase transition observables (?)

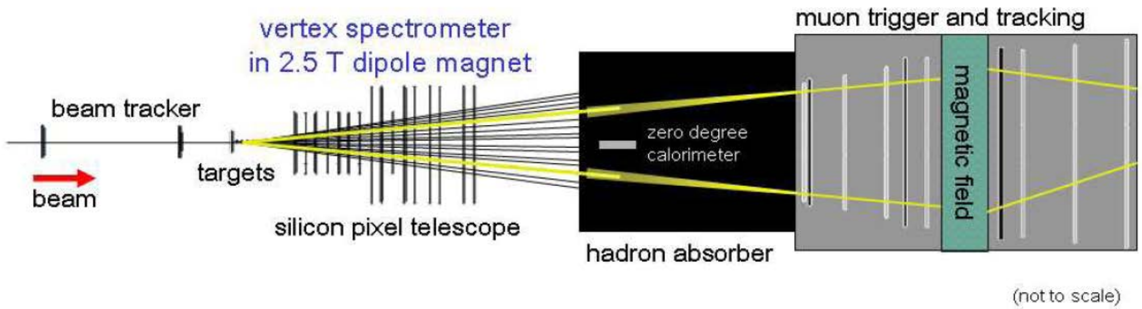
R. Arnaldi et al. (NA60), PRL 100 (2008) 022302





NA60

In + In collisions at 158 AGeV (SPS)



Clean measurement of ρ – meson spectral function.

Slope parameter of transverse momentum spectra in agreement with hadrons up to M ~ 1 GeV

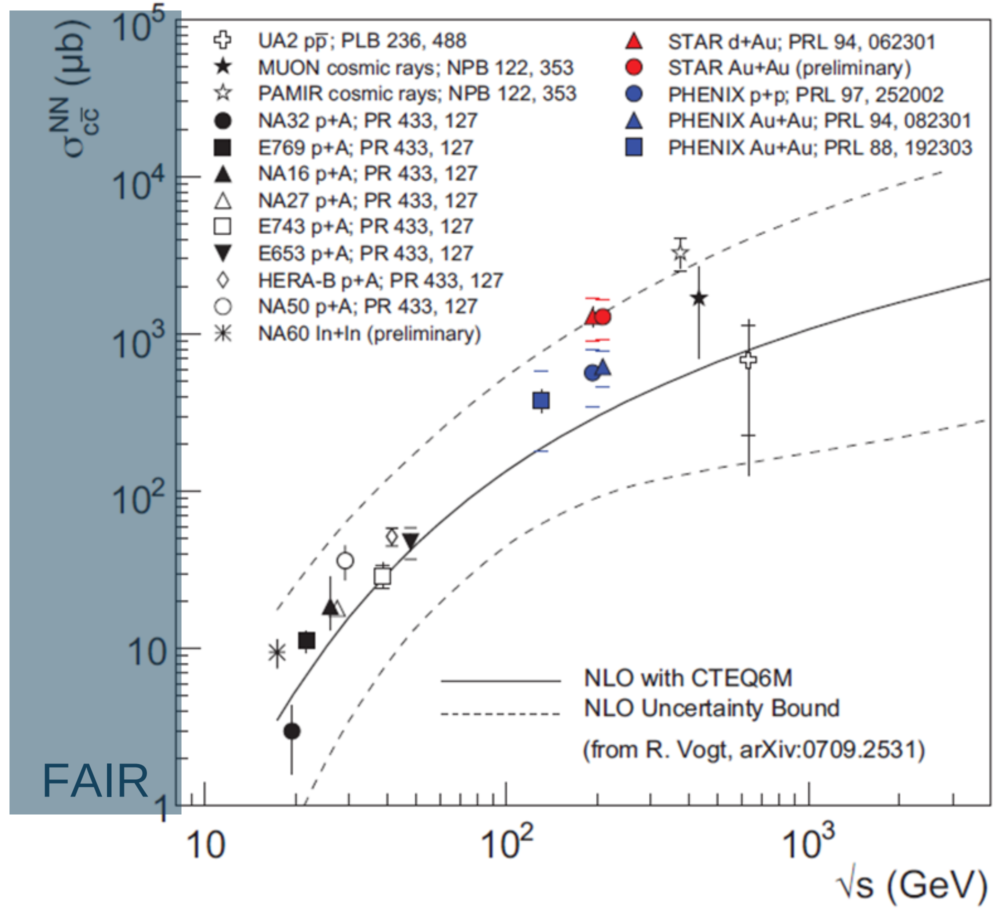
Spectra above 1 GeV are conjectured to originate from partonic source

Charm physics program

Physics case

- Charm production at threshold energies
- Charm propagation in (dense) nuclear matter
- Charmonium suppression in partonic matter

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



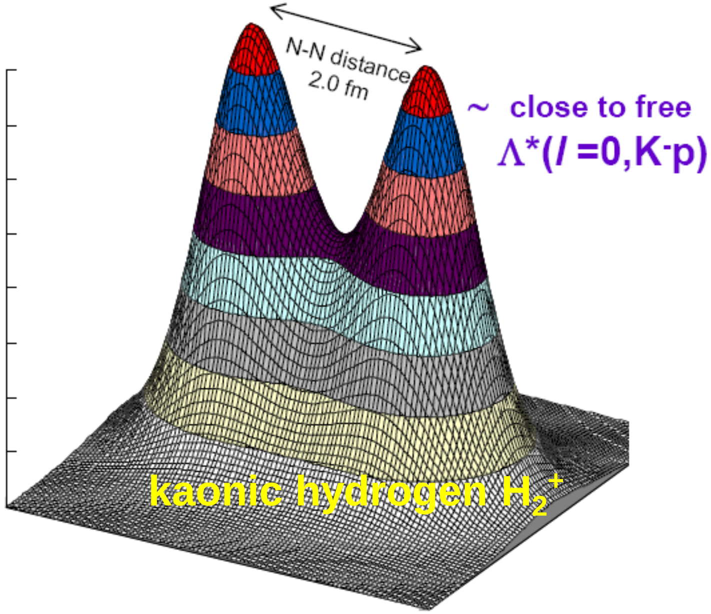
Experiments on dense baryonic matter

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	$5 \cdot 10^4$
CBM@FAIR Darmstadt	E_{kin}= 2.0 – 45 A GeV $\sqrt{s_{NN}}$= 2.7 – 8.3 GeV	$10^5 – 10^7$ (limitation by detector)

Relicts of high density phase(?)

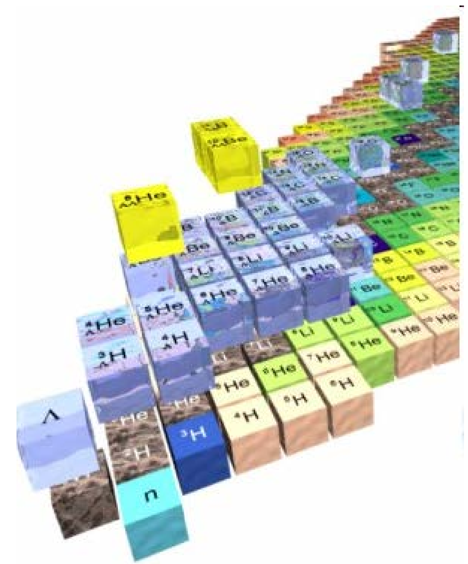
Kaonic molecules

T.Yamazaki and Y. Akaishi, Phys. Rev. C76 (2007) 045201
Y. Akaishi, T.Yamazaki, Phys.Rev.C65, 044005 (2002)
T.Yamazaki and Y. Akaishi, Phys.Lett.B535, 70 (2002)



$$\Psi = \phi_a + \phi_b$$

Hypernuclei



Decay by strong interaction

(ppK$^-$): $\left(ppK^-\right) \rightarrow \Lambda + p$

FINUDA M=2255±9 MeV, Γ=64±14 MeV
DISTO M=2265±2 MeV, Γ=118±8 MeV

Heavier clusters, e.g.: $\left(ppnK^-\right) \rightarrow \Lambda + d$

Decay by weak interaction

Production in HI – collisions?
Recently: STAR, ALICE

Double strange hypernuclei??

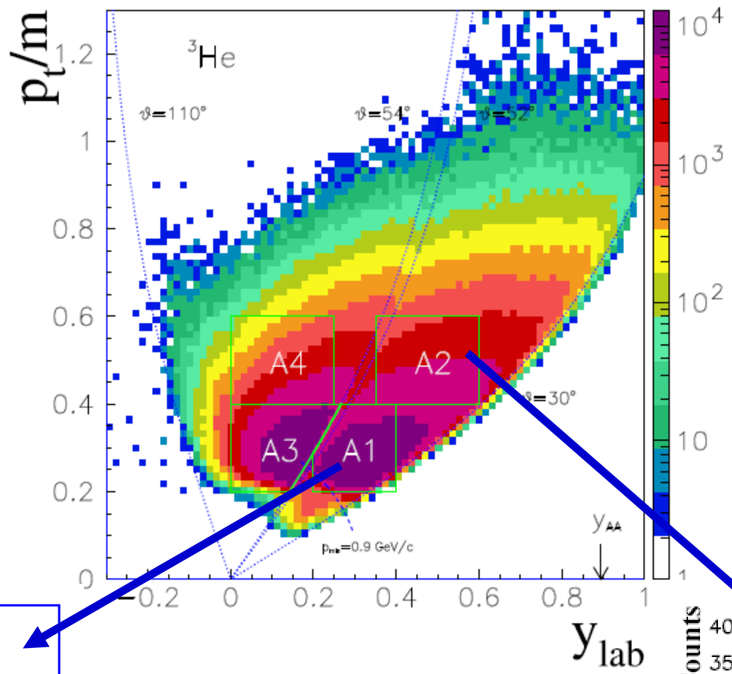
Hypertriton production in Ni+Ni at 2 AGeV

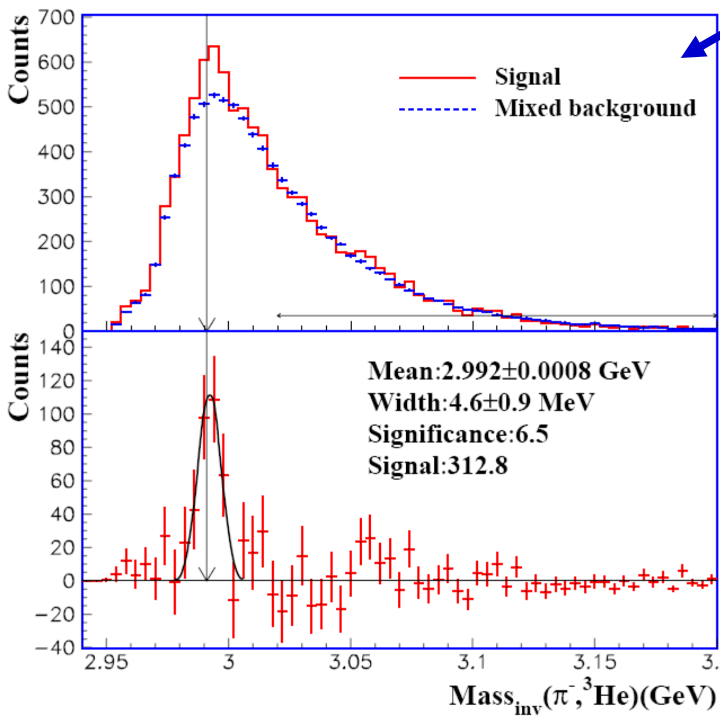
$$_{\Lambda}t \rightarrow {}^{3}He + \pi^{-}$$

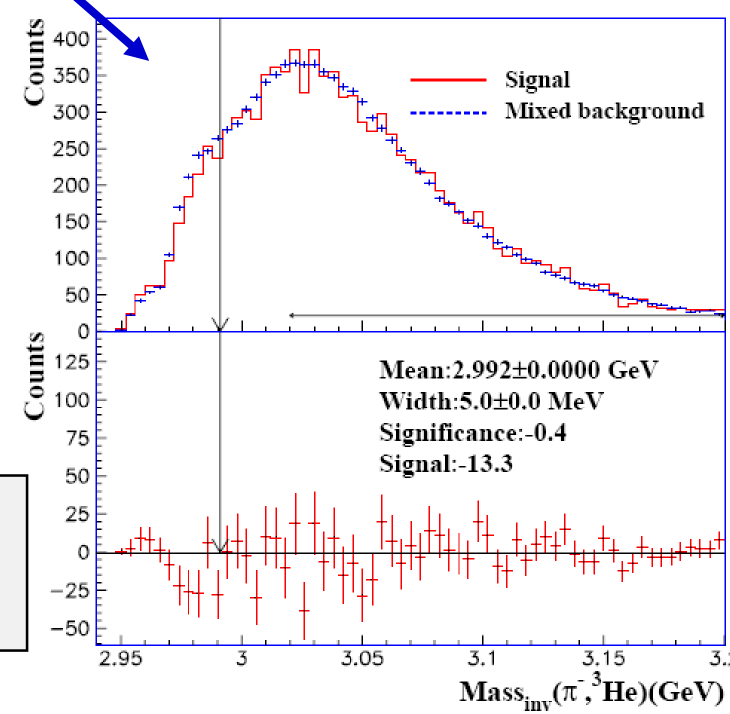
50 M events,

$\sigma_{triggered}$ = 0.5 . $\sigma_{reaction}$

Y.P. Zhang, PhD thesis, Heidelberg

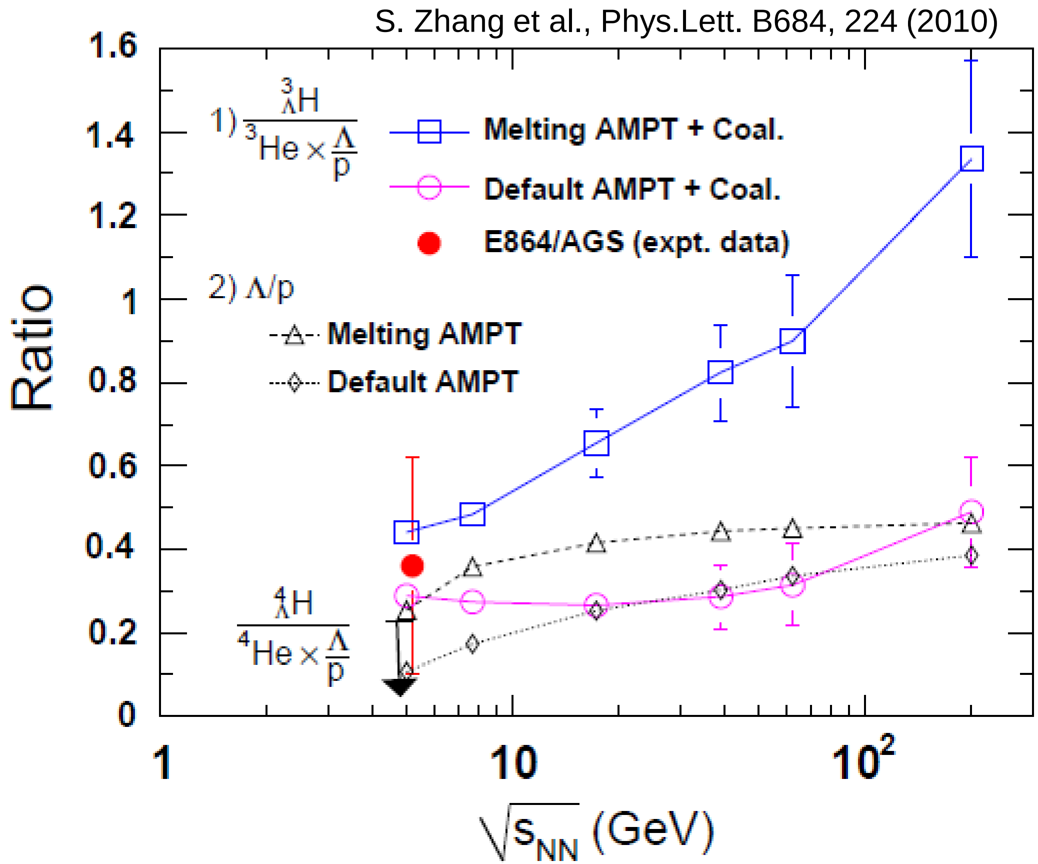






Excess over combinatorial background only in Phase space region A1

Baryon – Strangeness – Correlation

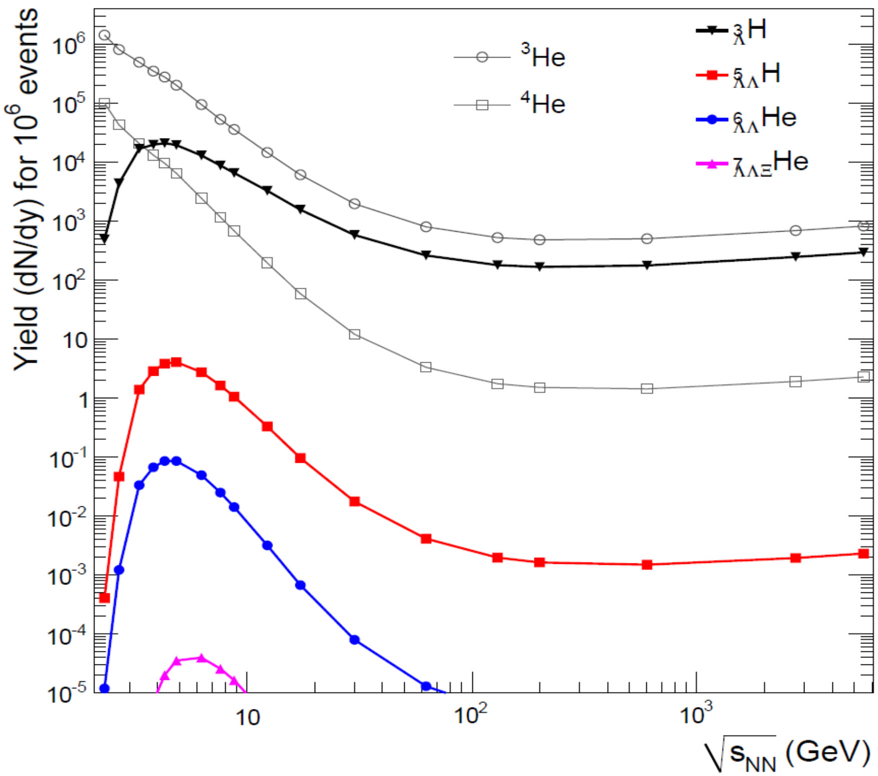


	Region A1	Region A2
$_\Lambda t/^3He$	0.029 +/- 0.002	<0.003 +/- 0.002
Λ/p	0.0020 +/- 0.0005	0.0028 +/- 0.0005
$_\Lambda t/^3He$ / Λ/p	10 +/- 3	< 0.95 +/- 0.6

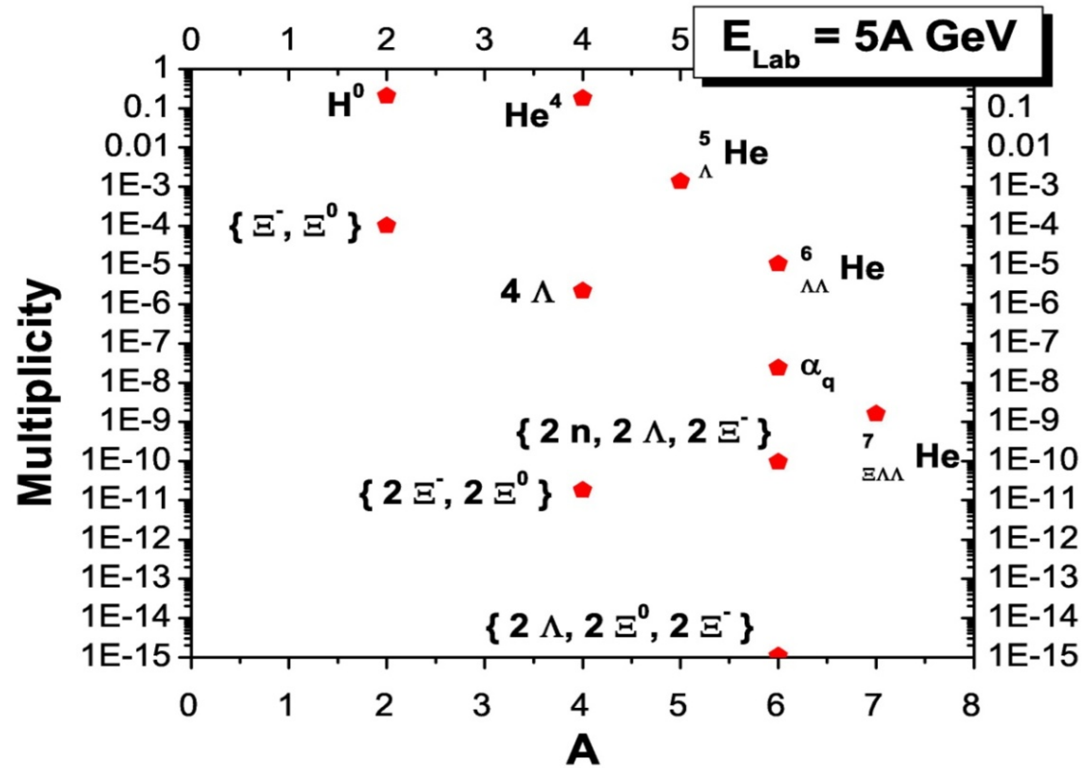
Strange baryonic bound states

- Single and double strange hypernuclei in heavy ion collisions at SIS100
- Strange matter in the form of strange dibaryons and heavy multi-strange short-lived objects.

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



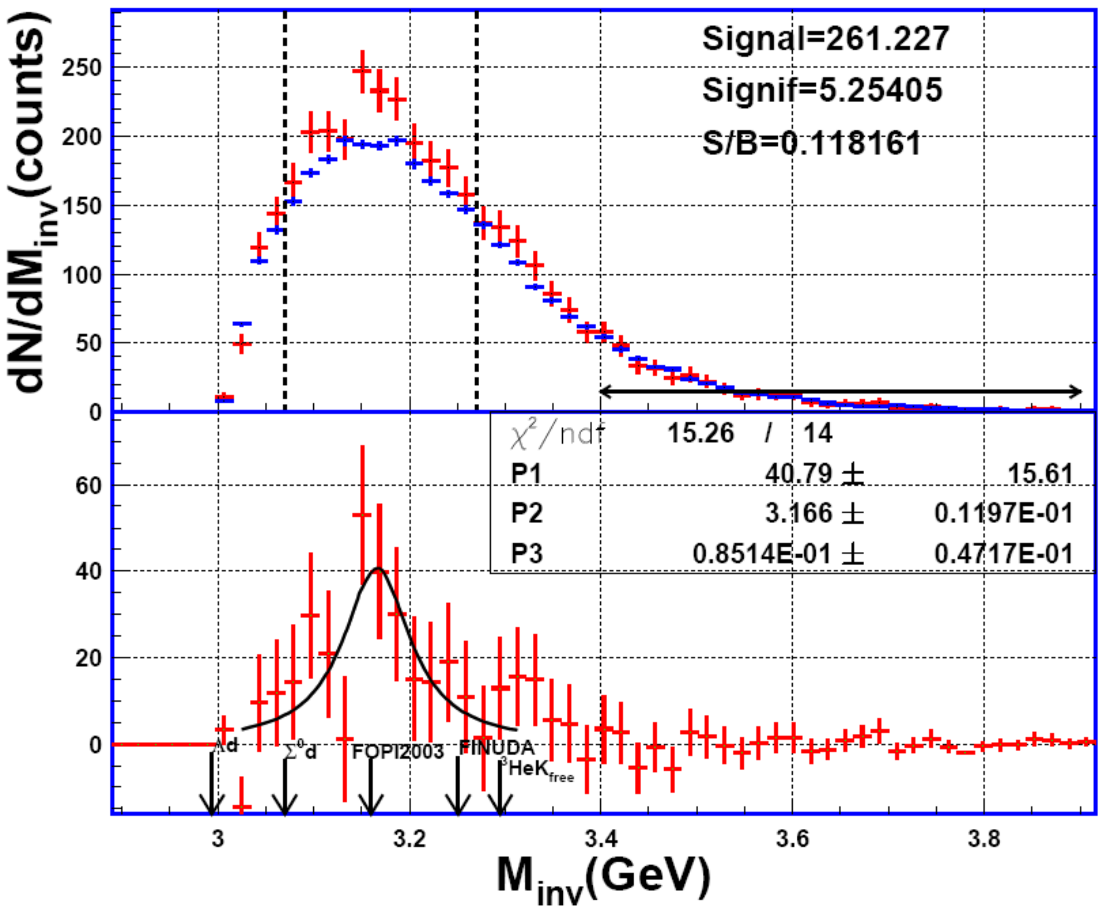
H. Stöcker et al., Nucl. Phys. A 827 (2009) 624c

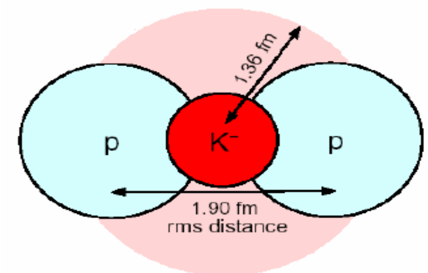


Λd – correlations

(FOPI, work in progress)

Ni+Ni at 1.91 AGeV (S325e data (2008))





$$\left(ppnK^-\right) \rightarrow \Lambda + d$$

FOPI 2003 and 2008 data are consistent,
Inconsistent with cusp (Σ – d – threshold) and FINUDA.

Current scenario:
Data taking: 2 weeks,
DAQ rate: 1kHz
Event sample: ~ 100 M events,
Statistical significance: ~ 5,
Production probability: P ~ 10^{-4}

Significance does not include
LEE – Look elsewhere effect (?)

Needed :
Sensitivity at level P ~ 10^{-6}
Significant increase of DAQ rate

CBM collaboration

China:
Tsinghua Univ., Beijing
CCNU Wuhan
USTC Hefei

Croatia:
University of Split

Czech Republic:
CAS, Rez
Techn. Univ. Prague

France:
IPHC Strasbourg

Hungaria:
Wigner IPNP, Budapest
Eötvös Univ. Budapest

Germany:
TU Darmstadt
Univ. Gießen
Univ. Heidelberg, Phys. Inst.
Univ. Heidelberg, ZITI
Univ. Frankfurt
FIAS Frankfurt
Univ. Münster
FZ Rossendorf
GSI Darmstadt
FAIR Darmstadt
Univ. Tübingen
Univ. Wuppertal

India:
Aligarh Muslim Univ., Aligarh
IOP Bhubaneswar
Panjab Univ., Chandigarh
Gauhati Univ., Guwahati
Univ. Rajasthan, Jaipur
Univ. Jammu, Jammu
IIT Kharagpur
SAHA Kolkata
Univ Calcutta, Kolkata
VECC Kolkata
Univ. Kashmir, Srinagar
Banaras Hindu Univ., Varanasi
Inst. of Tech., Indore, India

Korea:
Pusan National Univ.

Poland:
Krakow Univ.
Warsaw Univ.
Warsaw Univ. of Tech.
Silesia Univ. Katowice
Nucl. Phys. Inst. Krakow

Romania:
NIPNE Bucharest
Bucharest University

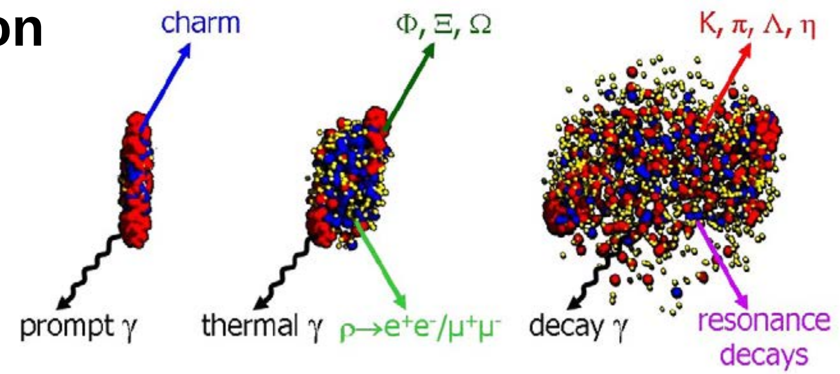
Russia:
IHEP Protvino
INR Moscow
ITEP Moscow
KRI, St. Petersburg
Kurchatov Inst. Moscow
VBLHEP, JINR Dubna
LIT, JINR Dubna
MEPHI Moscow
Obninsk State Univ.
PNPI Gatchina
SINP, Moscow State Univ.
St. Petersburg Polytec. U.

Ukraine:
KINR, Kiev
Shevchenko Univ. , Kiev

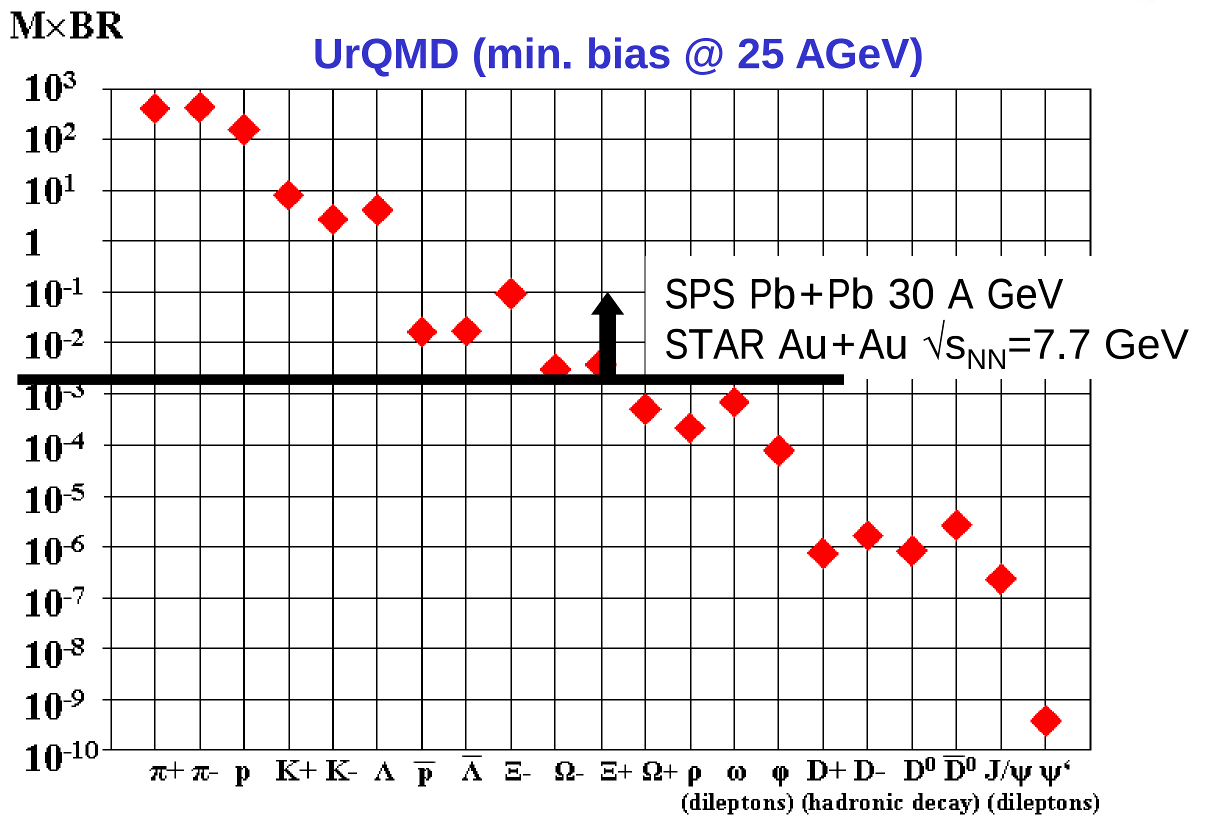
56 institutions, > 400 members

CBM - strategy

Systematic measurement of excitation function of <u>rare</u> probes with full event characterisation



- **Multiple strange hadrons**
- **Low mass vector mesons via dileptons**
- **Open charm**
- **Charmonia**



with min. bias event Inspection rate of

10 MHz (!)

by realizing free streaming DAQ concept.

CBM – Detector Concept

Different detector setups for muon & electron measurements:

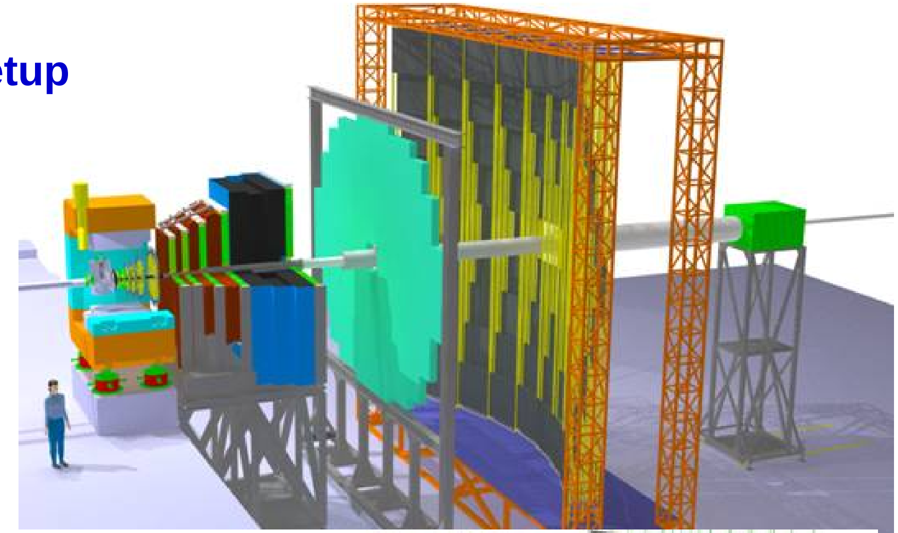
0) Core elements
- dipole magnet
- STS – silicon tracking system
- PSD – projectile spectator detector
- TOF – MRPC time-of-flight detector
- DAQ – data acquisition
- FLES – first level event selection

1) Muon setup
- MUCH – Muon detection system (active absorber)
- TRD – tracking station

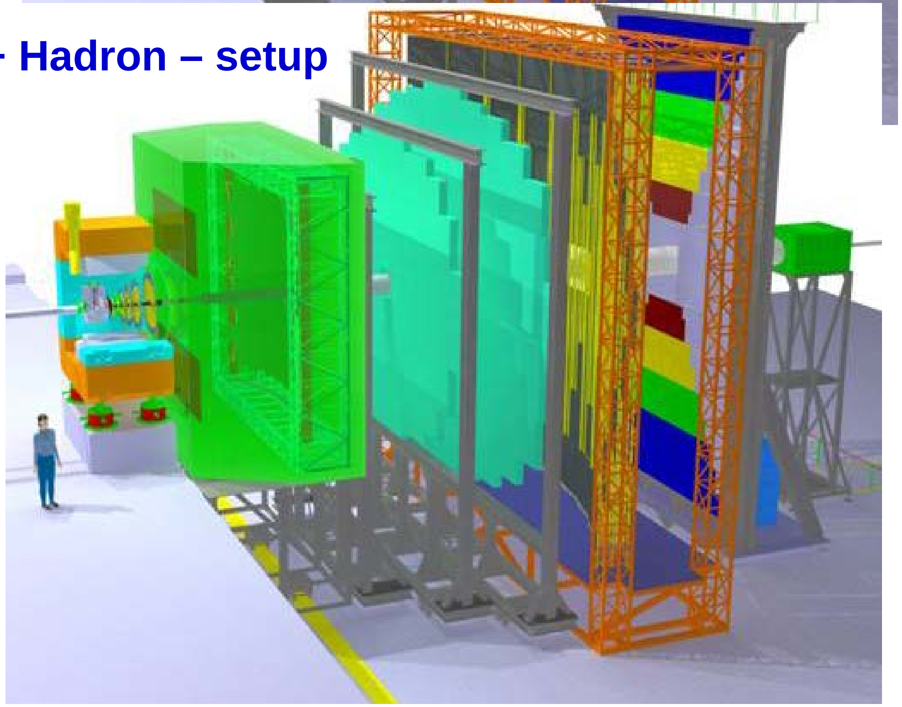
2) Electron/Hadron setup
- MVD – Micro vertex detector
- TRD – Transistion radidation detector
- ECAL – Electromagnetic calorimeter

All core components designed with self triggered FEE and free running DAQ for 10 MHz interaction rate.

1) Muon – setup



2) Electron + Hadron – setup

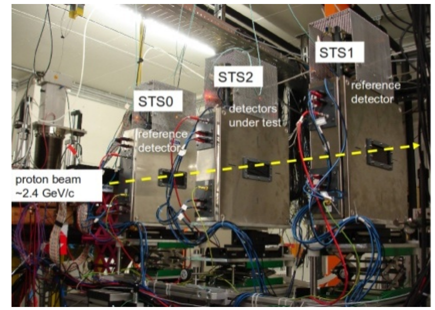


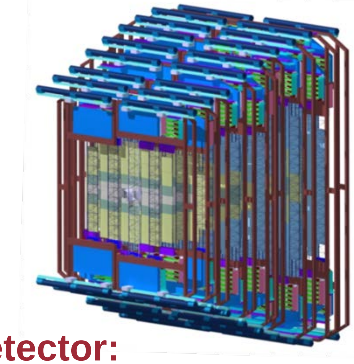
CBM Technical Developments

SC Magnet: JINR Dubna

Micro-Vertex Detector: Frankfurt, Strasbourg

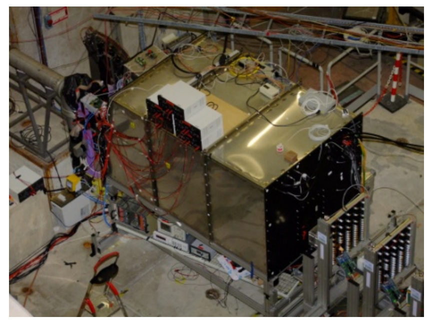
Silicon Tracking System: Darmstadt, Dubna, Krakow, Kiev, Kharkov, Moscow, St. Petersburg, Tübingen



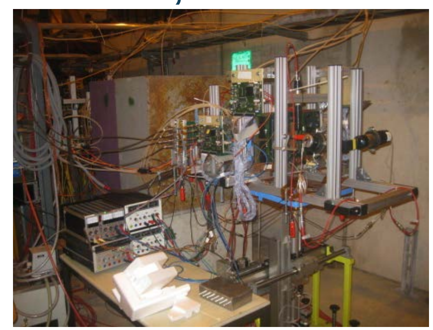


MRPC ToF Wall: Beijing, Bucharest, Darmstadt, Frankfurt, Hefei, Heidelberg, Moscow, Rossendorf, Wuhan

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



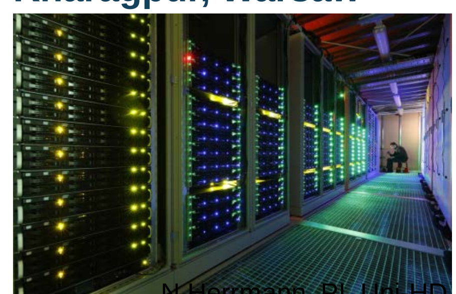
Muon detector: Kolkata + 13 Indian Inst., Gatchina, Dubna



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

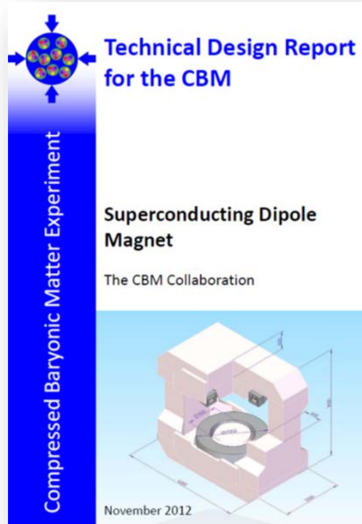
Forward calorimeter: Moscow, Prague, Rez

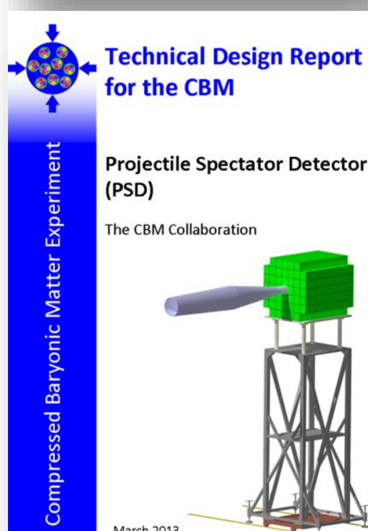
DAQ and online event selection: Darmstadt, Frankfurt, Heidelberg, Kharagpur, Warsaw

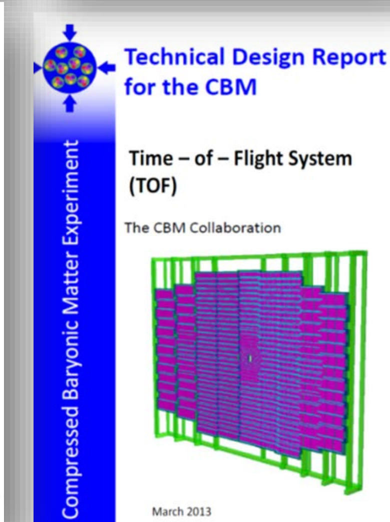


CBM Technical Design Reports

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



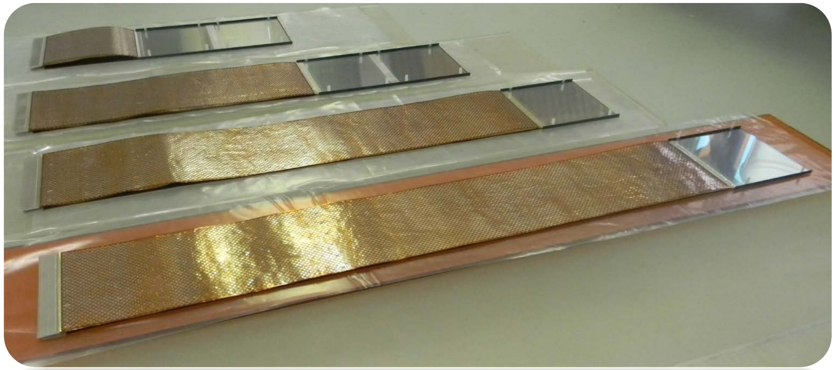


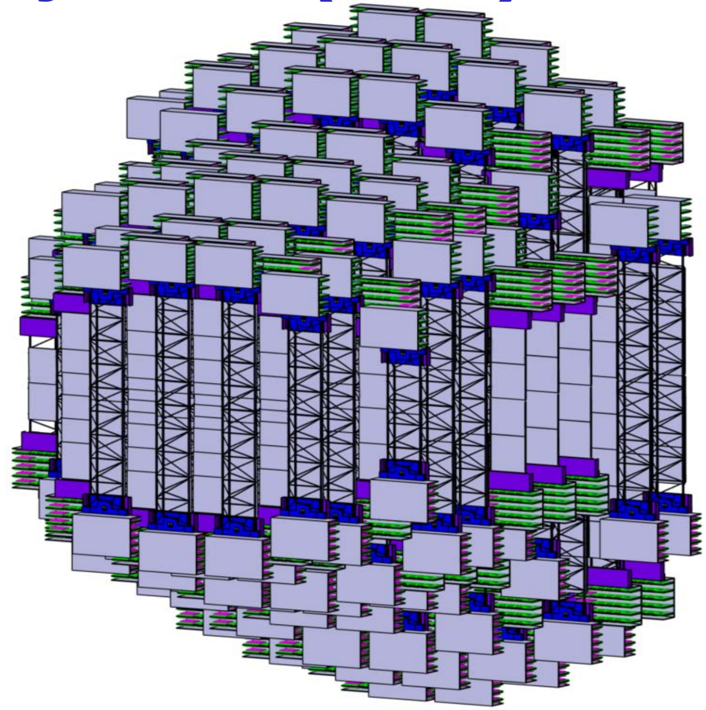


CBM Silicon Tracking System (STS)

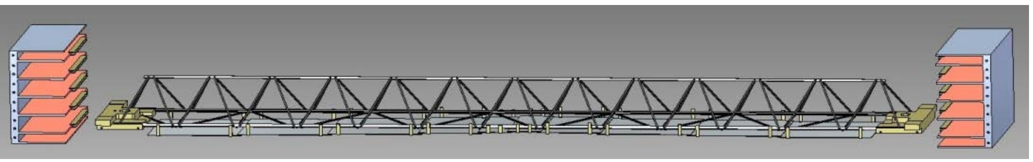
Silicon sensors:
double-sided micro-strips,
1024 strips on each side,
58 µm pitch, stereo angle 0°, 7.5°
width 60 mm, height 20, 40, 60 mm

Micro cables from sensors to FEBs

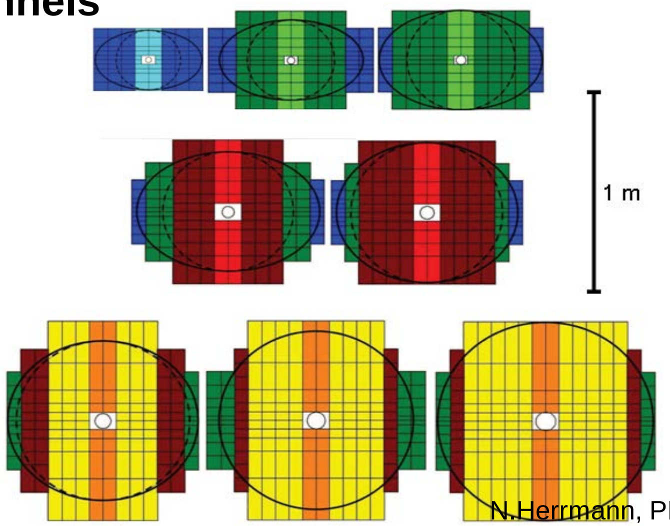




Light weight carbon fibre ladders



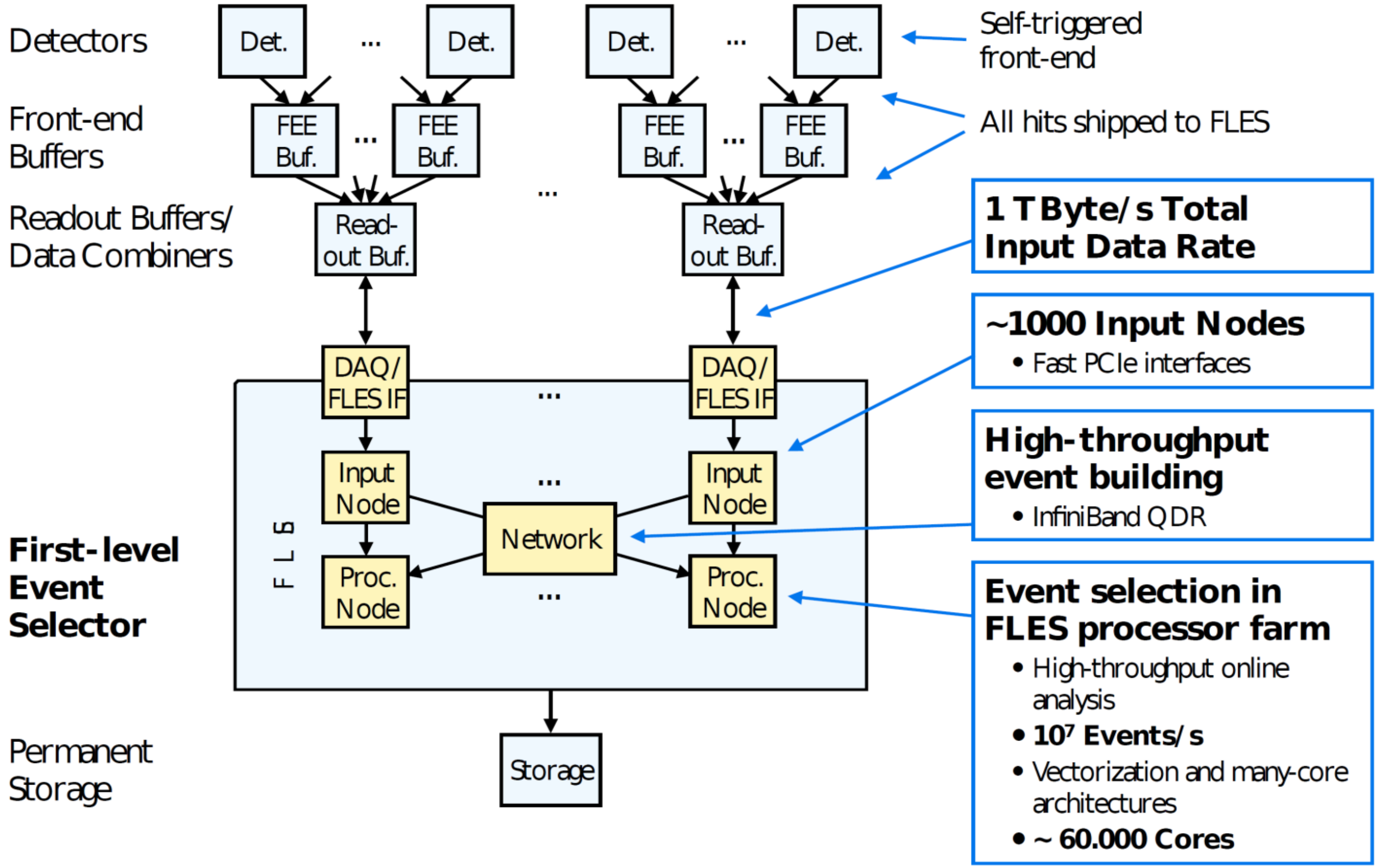
8 STS stations, distance from target 30–100 cm
2.133 M channels



ASIC:
free streaming, hits with time stamp

FEB cooling: CO_2

Free streaming data read-out & online event selection

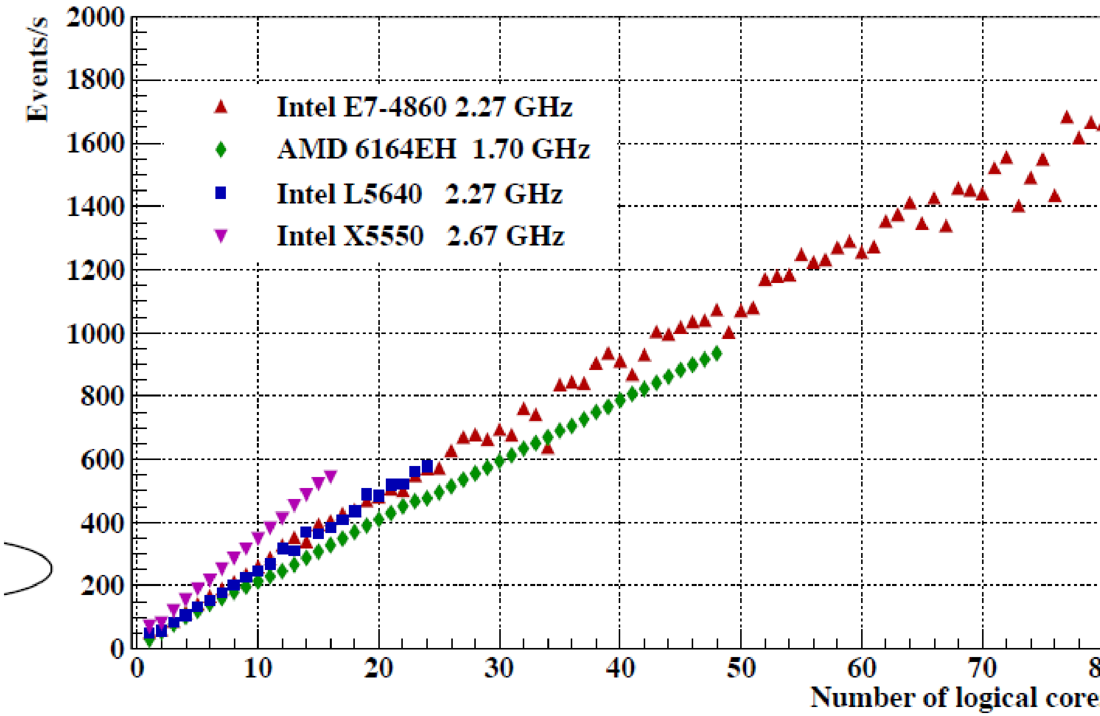


All CBM – event selection is done in software.

Challenges: **Sufficient bandwidth and compute power for operation at 10 MHz,**
Robust detector technologies,
Stable operation,
Online calibration and alignment.

FLES Reconstruction Software

GSI „Minicube“ with 10.000 cores

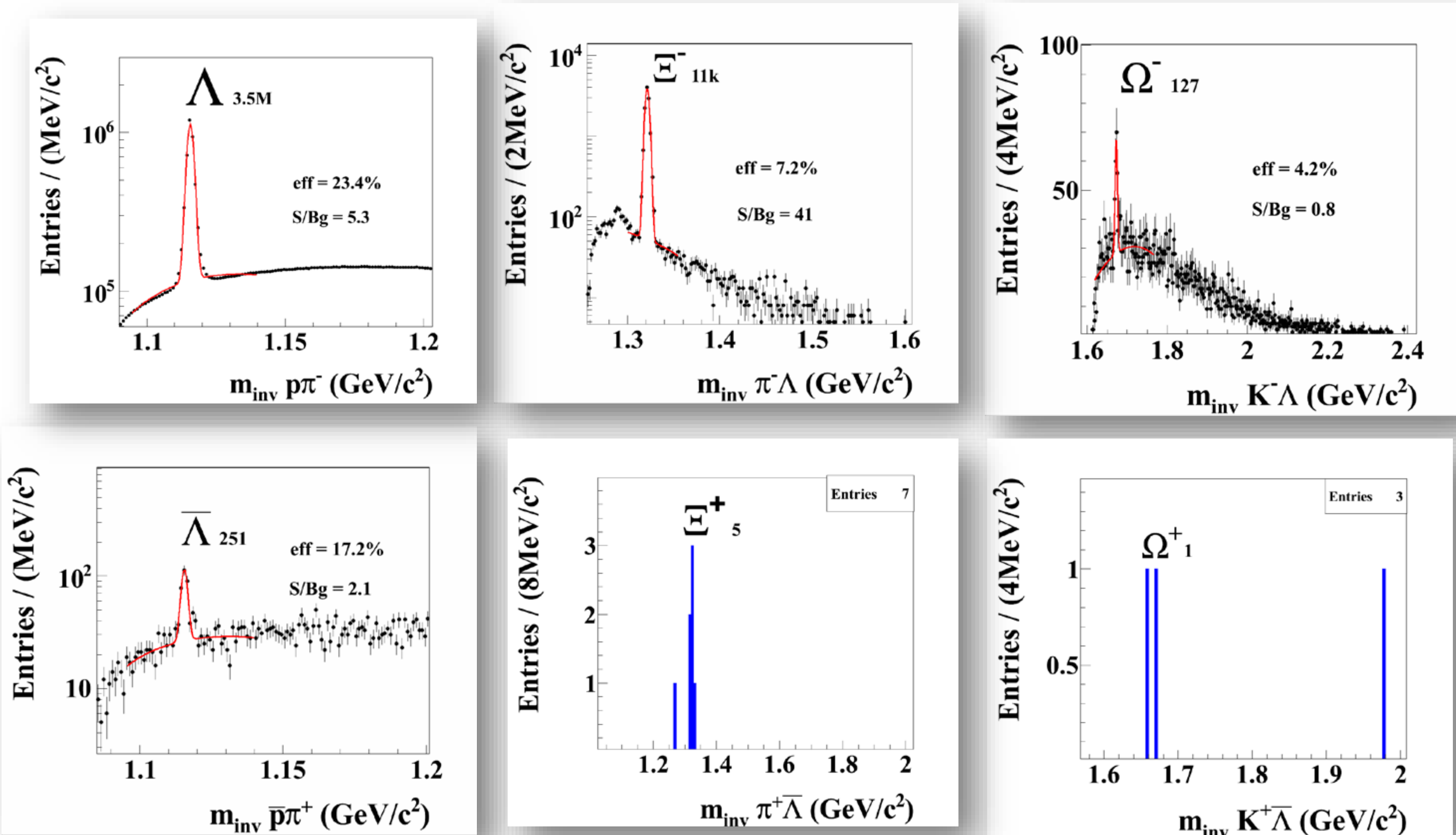


Given n threads each filled with 1000 events, run them on specified n cores, thread/core.

Full online track reconstruction,
event reconstruction,
particle analysis,
event selection, and storage.

The FLES package is vectorized, parallelized, portable and scalable.

Hyperon reconstruction: Au + Au at 8 AGeV
10^6 central events



The high rate case at SIS100

Example:

Ξ^+- flow measurement with ε = 5 / 10^6 central events

Requirement for high precision measurement: **N(Ξ^+) = 10^5 / event sample**

Rate of Ξ^+- detection in CBM acceptance:

$$R(\Xi^+) = R_{ev} \cdot f_{ev} \cdot \epsilon = 10^5 \cdot 0.1 \cdot 5.10^{-6}\ s^{-1} = 5.10^{-2}\ s^{-1}$$

Time for CBM running without selection (R_{ev}=100 kHz):

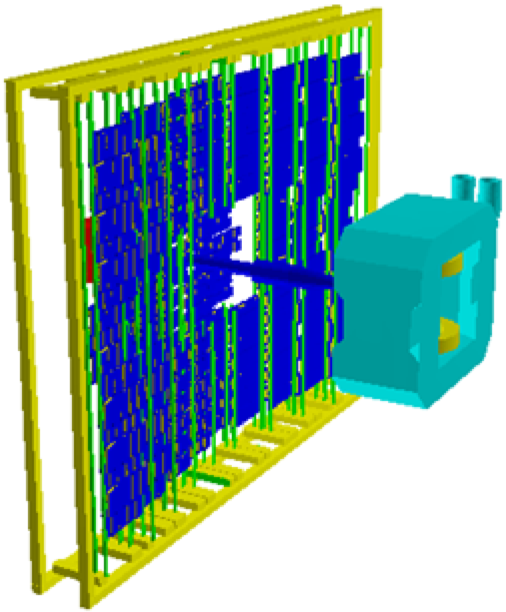
ΔT = N / $R(\Xi^+)$= $2.10^6 s$ = 555 h = 23 d **(no systematic studies possible)**

Time for CBM running with FLES (10MHz):

$$R_{ev} = 10^7\ s^{-1}$$

ΔT = N / $R(\Xi^+)$= $2.10^4 s$ = 5.55 h **(systematic studies possible !)**

Generic anti-particle selection: $\bar{p}$ - candidates



Central Au+Au at 10 AGeV from UrQMD
current global track – TofHit matching performance

total efficiency: $\varepsilon = 0.36$

contamination: $\kappa = 4.$

Event selection rate: $\mathrm{R} = \mathrm{R}_{ev} \cdot f_{cen} \cdot \mathrm{P}_{probe} \cdot \varepsilon \cdot (1+\kappa)$

@10MHz: $\mathrm{R} = 10^7 \cdot 0.1 \cdot 7 \cdot 10^{-3} \cdot 0.36 \cdot 5.\mathrm{Hz}$

$= 12.6\ \mathrm{kHz}$

$\Delta T(10^5\ \bar{p}) = 40\ s$ **time on target to archive 100.000 $\bar{p}$.**

Extrapolation to central Au+Au at 4 AGeV:

Run time in 10 MHz mode:

total efficiency: $\varepsilon = 0.55$

contamination: $\kappa = 1000.$

background scaled with total multiplicity

Event selection rate: $\mathrm{R} = \mathrm{R}_{ev} \cdot f_{cen} \cdot \mathrm{P}_{probe} \cdot \varepsilon \cdot (1+\kappa)$

@10MHz: $\mathrm{R} = 10^7 \cdot 0.1 \cdot 1.5 \cdot 10^{-5} \cdot 0.55 \cdot 1.10^3\,\mathrm{Hz} = 8.2\ \mathrm{kHz}$

$\Delta T(10^5\ \bar{p}) = 3.5\ h$

Run time in 100 kHz mode:

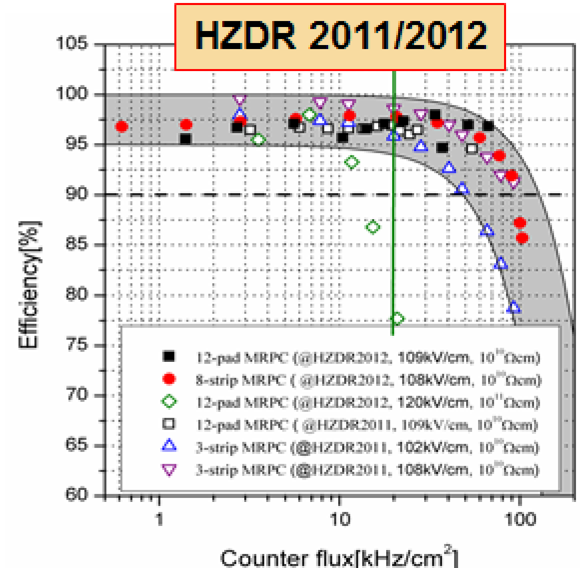
@100kHz: $\mathrm{R} = 10^5 \cdot 0.1 \cdot 1.5 \cdot 10^{-5} \cdot 0.55\,\mathrm{Hz} = 8\ \mathrm{Hz}$

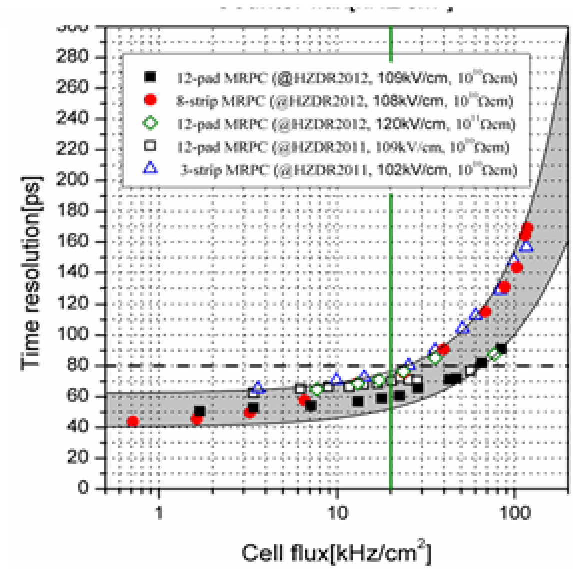
$\Delta T(10^5\ \bar{p}) = 350\ h = 14\ d$

Load test of full size RPC prototypes at SIS18

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

Single particle response:





Oct. 2012

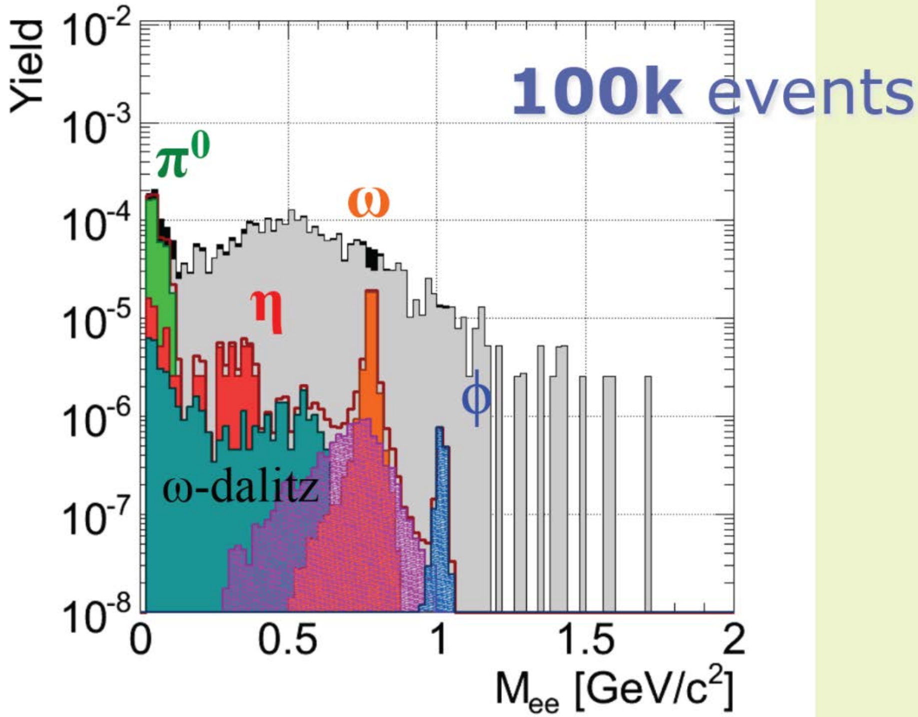
Kr + Pb (2% target) @ 1.2 AGeV in Cave B

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

Availability of heavy – ion test beams in 2015 - 2017 ?

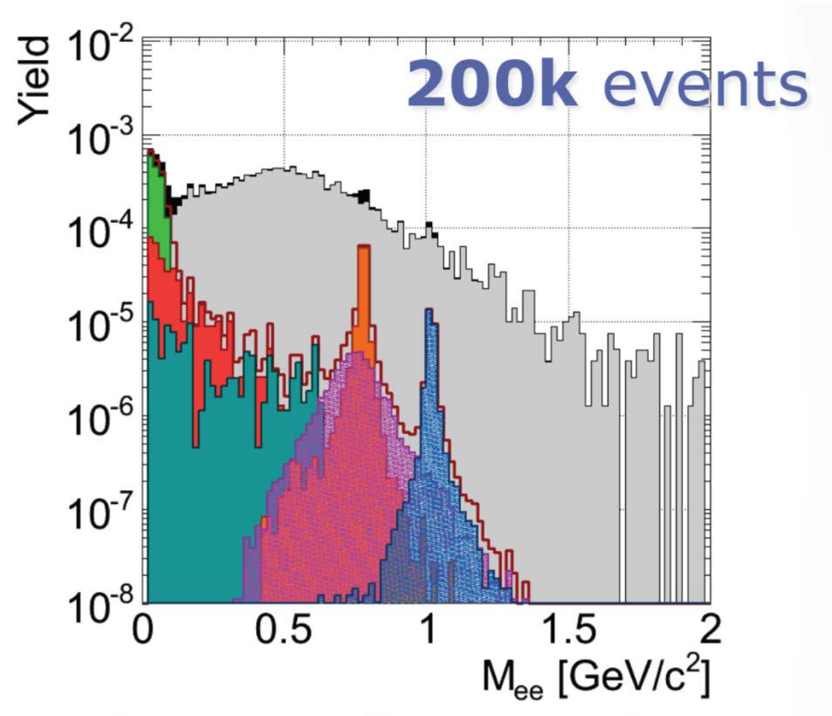
e^+e^- - invariant mass spectra in central Au+Au

8 A GeV: STS, RICH, TOF



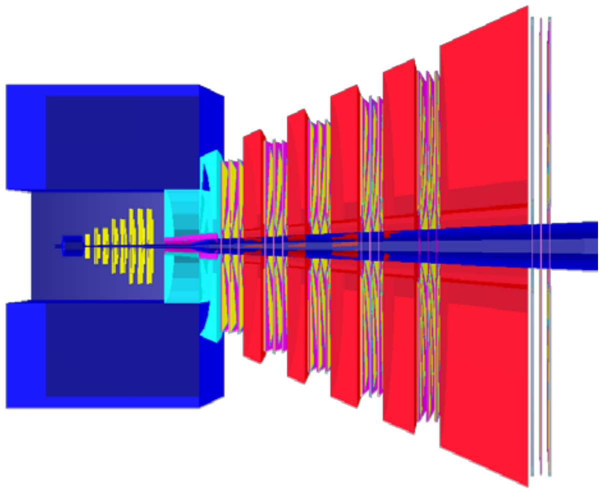
	ρ	ω	φ
eff.	3.12	4.11	4.89
S/BG	-	0.64	0.04

25 A GeV: STS, RICH, TRD, TOF

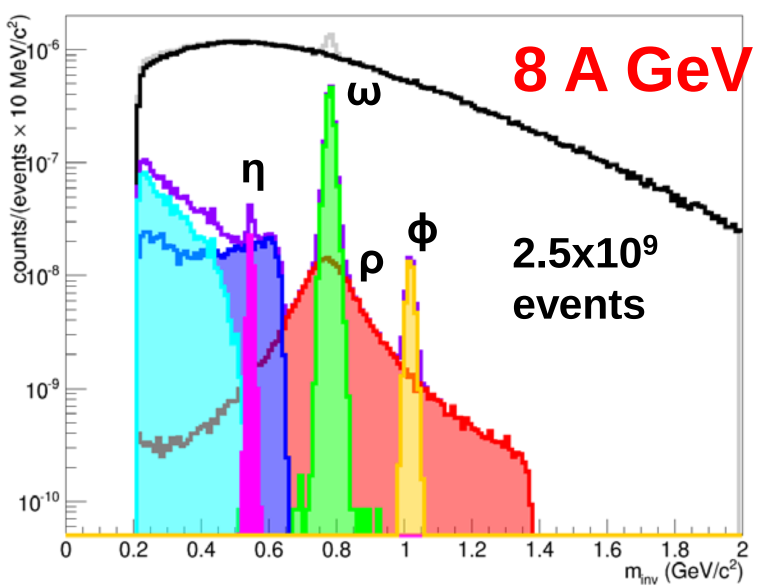


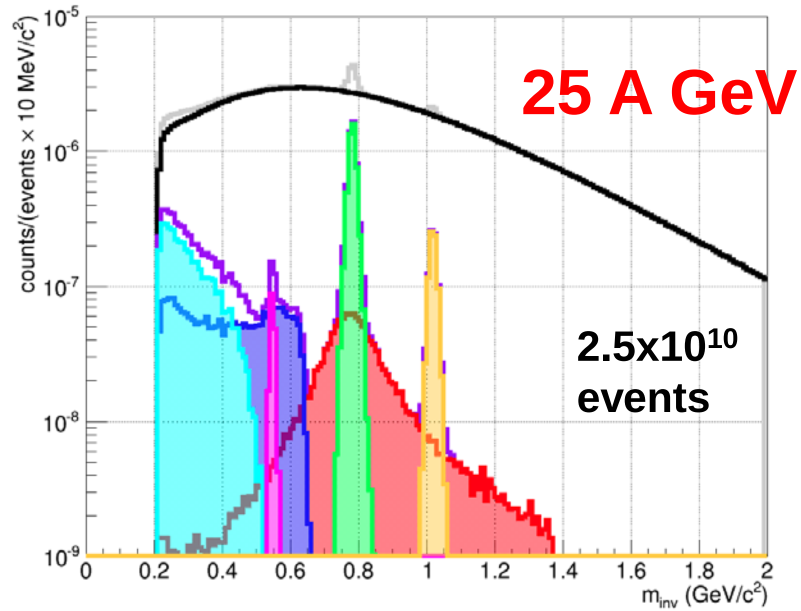
	ρ	ω	φ
eff.	4.39	5.53	7.08
S/BG	-	0.31	0.11

Muon Detection System

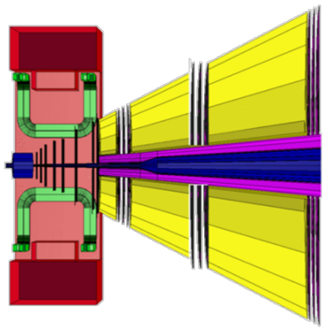


central Au + Au collisions at
8 A GeV and 25 A GeV

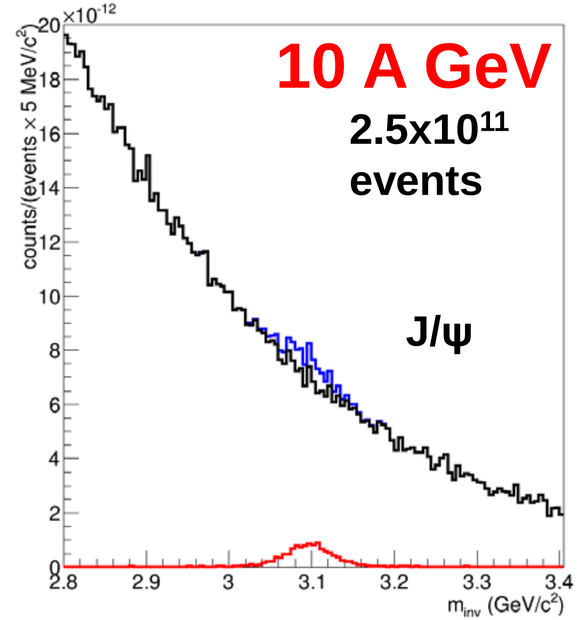


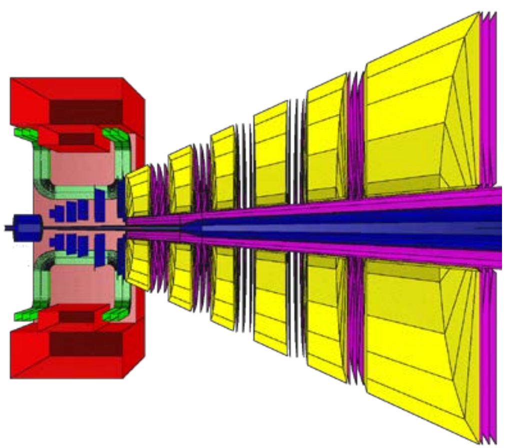


The Muon Detection System at SIS100/300

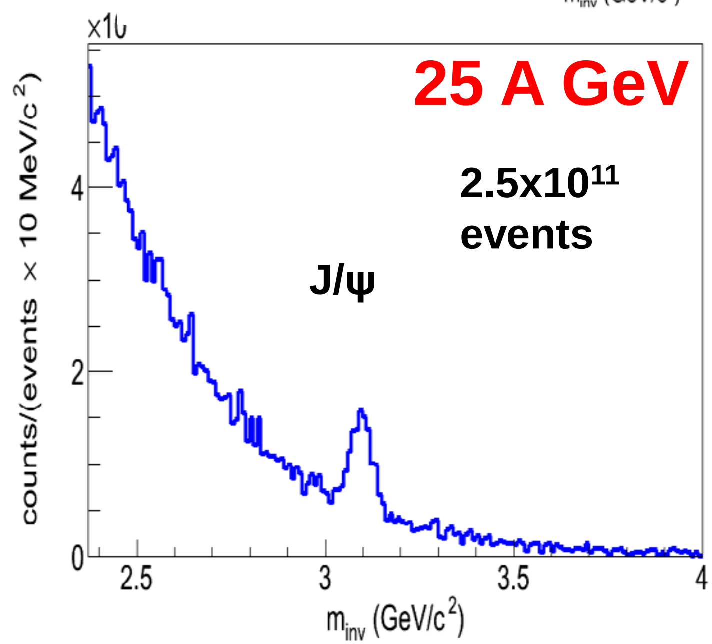


Start versio
10 A GeV Au+Au → J/ψ
Iron absorber: 20+70+135 cm
3 detector triplets:
GEM + straw tubes + TRD





Full version
35 A GeV Au+Au
Iron absorber:
2x20+3x30cm
6 detector triplets:
3 GEM+2 straw tubes
+TRD



Summary / Conclusion

- **Phase structure of QCD will not be revealed by a single measurement.**

- **QCD matter physics needs a facility for systematic studies. and a 3. generation experiment -> CBM**
  rate capability: 10 MHz interaction rate

- **CBM physics program**
  many open physics questions

  EOS
  in-medium modifications of hadrons
  phase transition to quarkyonic matter (?)

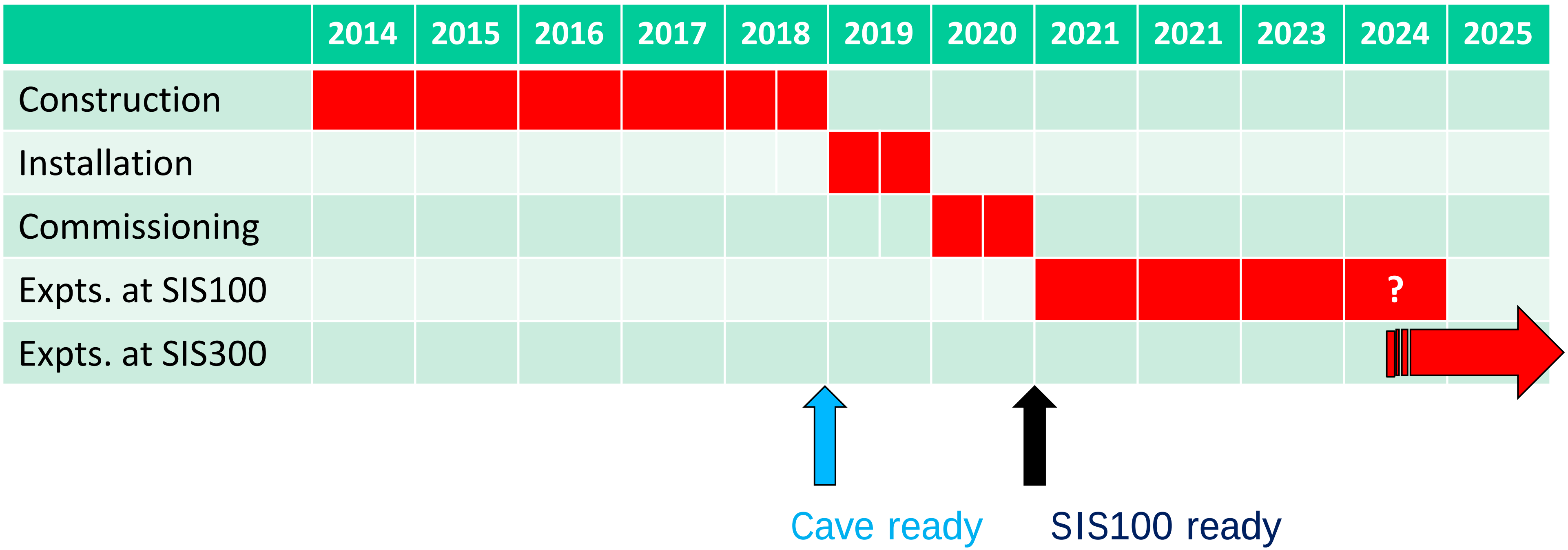
  substantial discovery potential at SIS100 / 300

- **CBM strategy**
  systematic measurement of multi-dimensional observables of (rare) probes
  use detector components as tool kit.

- **CBM status**
  well advanced with respect to overall FAIR timeline.

Thanks for your attention!

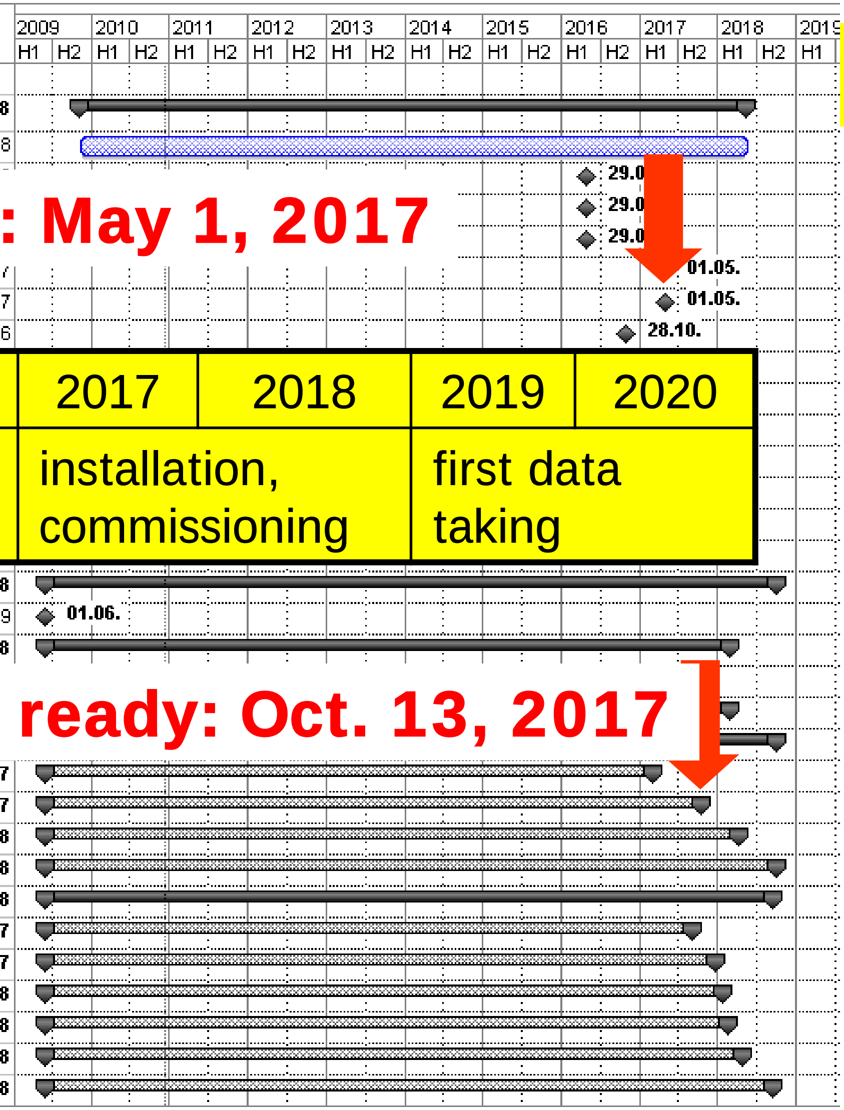
CBM time line



CBM time line

Schedule

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		ES)	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,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**	**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

SIS100 ready: Oct. 13, 2017

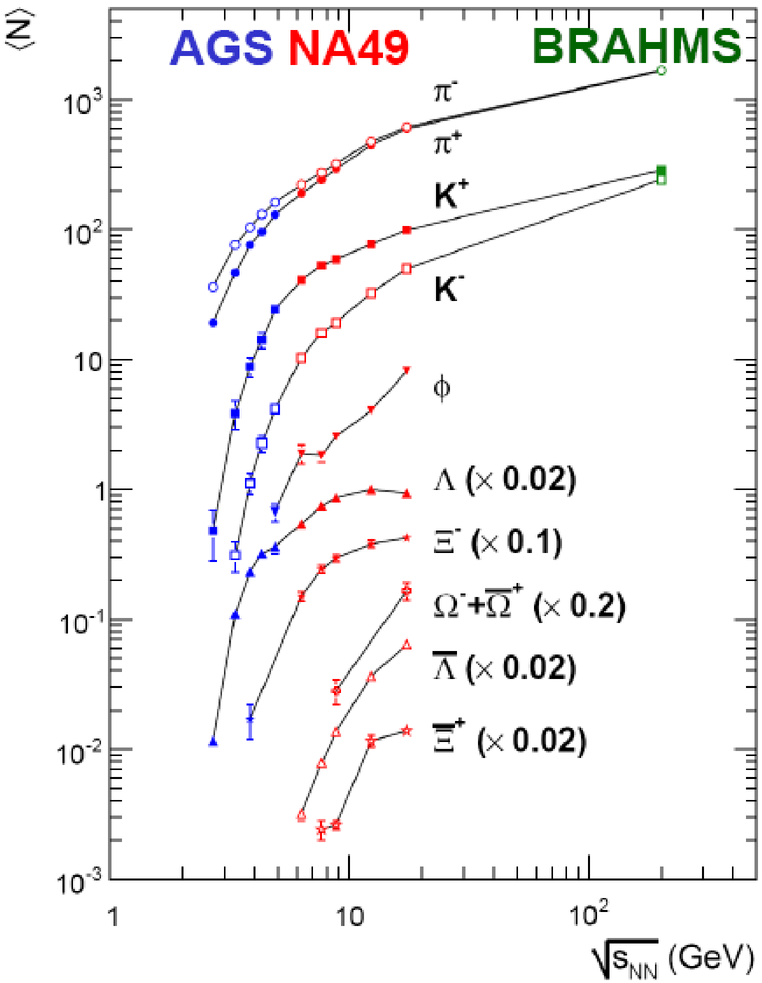
CBM time line

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	

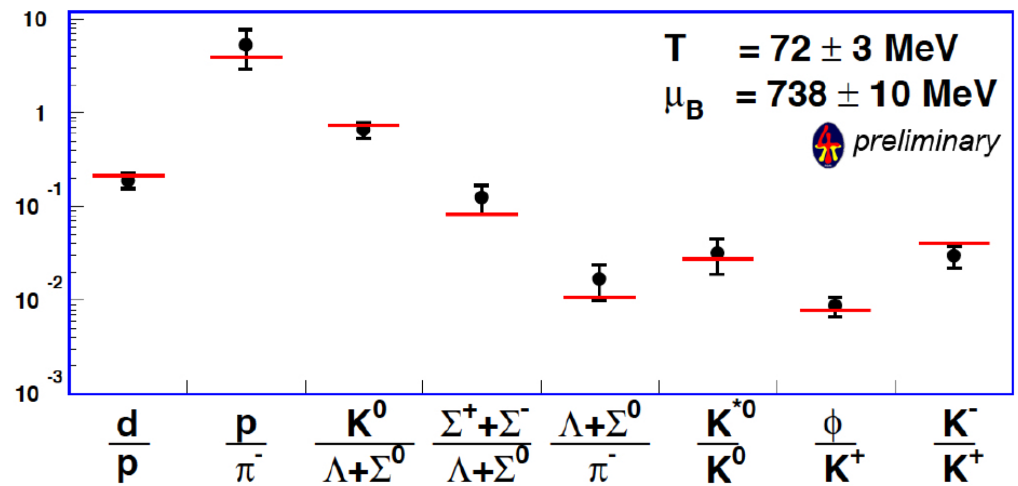
Excitation function of particle production

Central Au+Au collisions
4π yields

C.Blume, CBM symposium HZDR (2011)

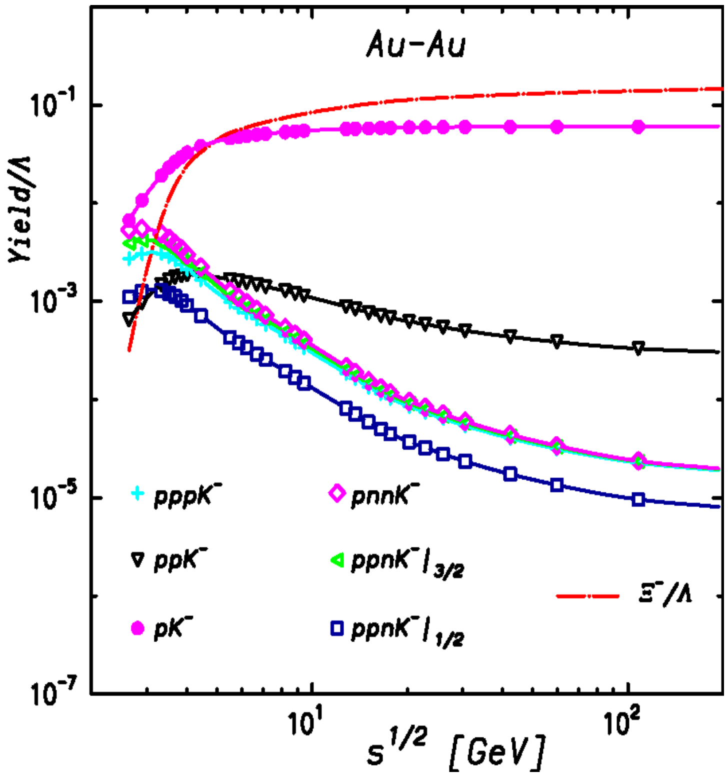


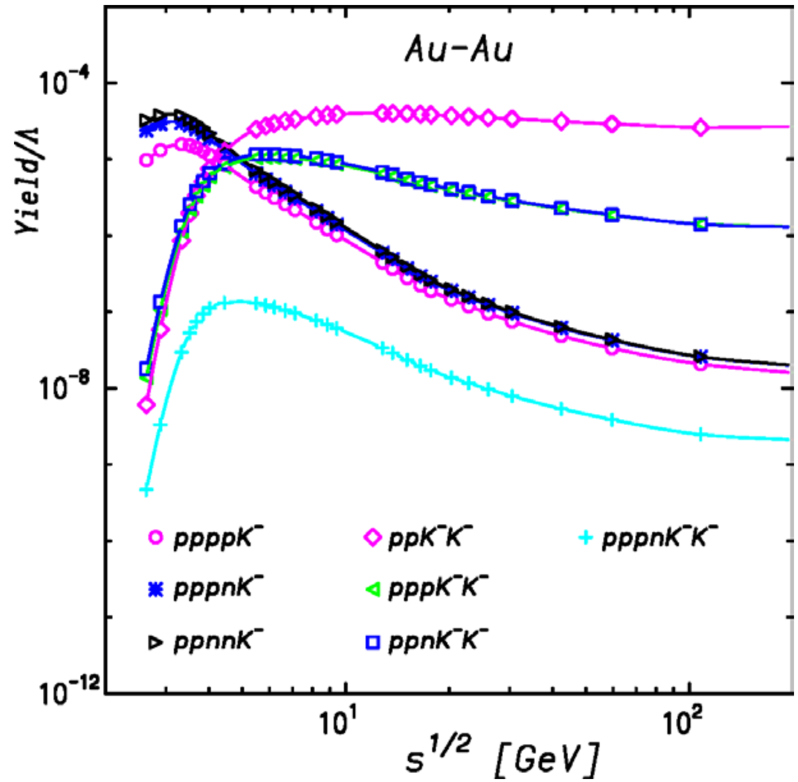
Low energies (SIS18): light systems only
Al + Al at 1.91 AGeV



Knowledge about multi-strange baryons at energies below 10 AGeV very limited.

Experimental strategy towards strange bound states





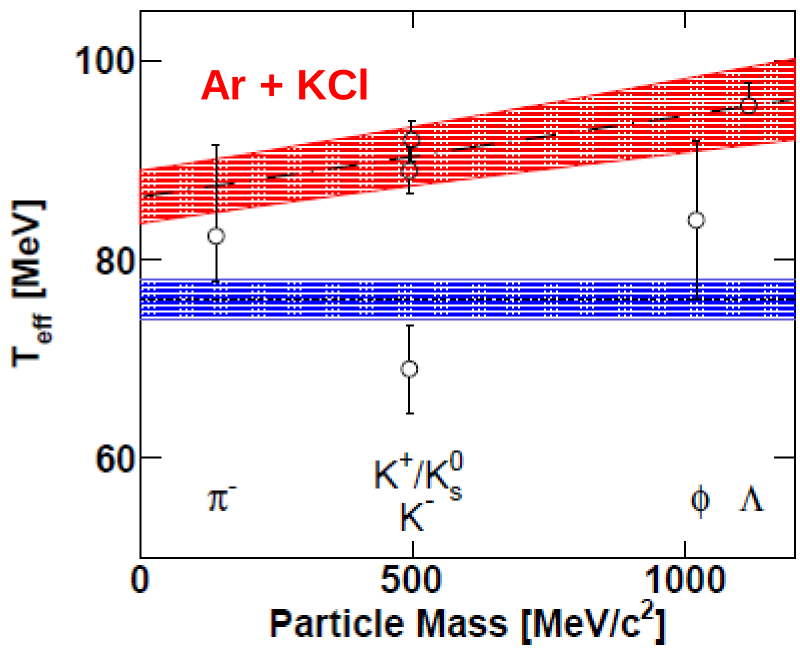
A.Andronic, PBM, K. Redlich (2005), nucl-th/0506083

Experimental strategy at beam energies < 10 AGeV:

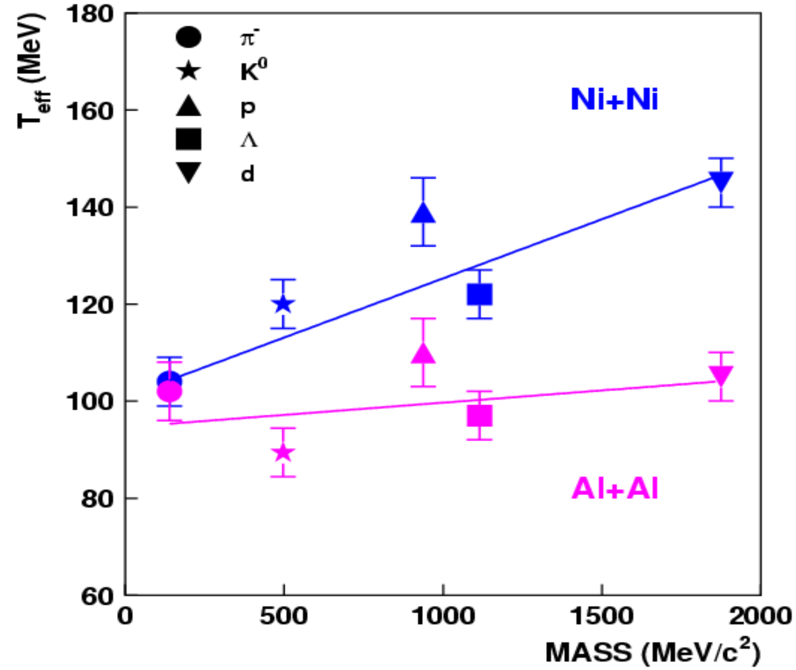
- allow for large event samples (P ~ 10^{-8}, N_{signal} > 1000 => N_{event}>10^{11}
- reduce combinatorial background as much as possible
- tag events for strangeness content (by K^+, (K^0))
- detect K^+ as efficiently as possible
- compact kaon PID

Kinetic freeze out

G. Agakishiev et al.(HADES),EPJ A47 (2011) 21



K. Piasecki et al.(FOPI), Act.Phys.Pol. B41 (2010) 405



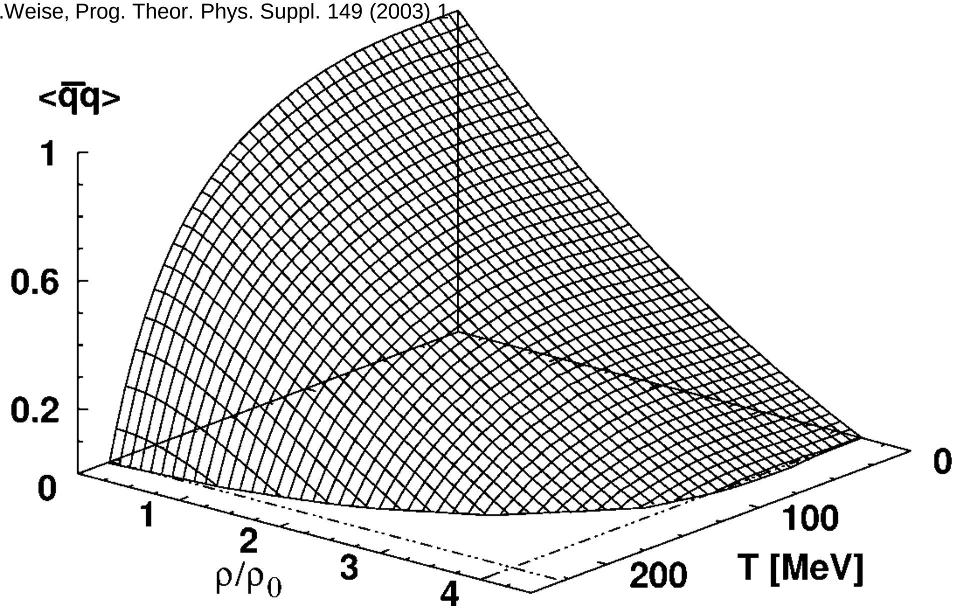
T_{kin} > 90 MeV > T_{chem} ≈ 75 MeV

Ordering counter intuitive for equilibrated systems.

No thermal equilibrium? -> Stochastic particle production
(Hadronic Unruh radiation?)
-> Non – equilibrium off-shell scattering (?)

Hadrons in Medium

W.Weise, Prog. Theor. Phys. Suppl. 149 (2003) 1



GOR – relation: $m_\pi^2 f_\pi^2 = - < m_q > \langle \bar{q} q \rangle$

In-medium effects in finite systems:

'Trivial'

Fermi motion
Pauli blocking
Collisional broadening

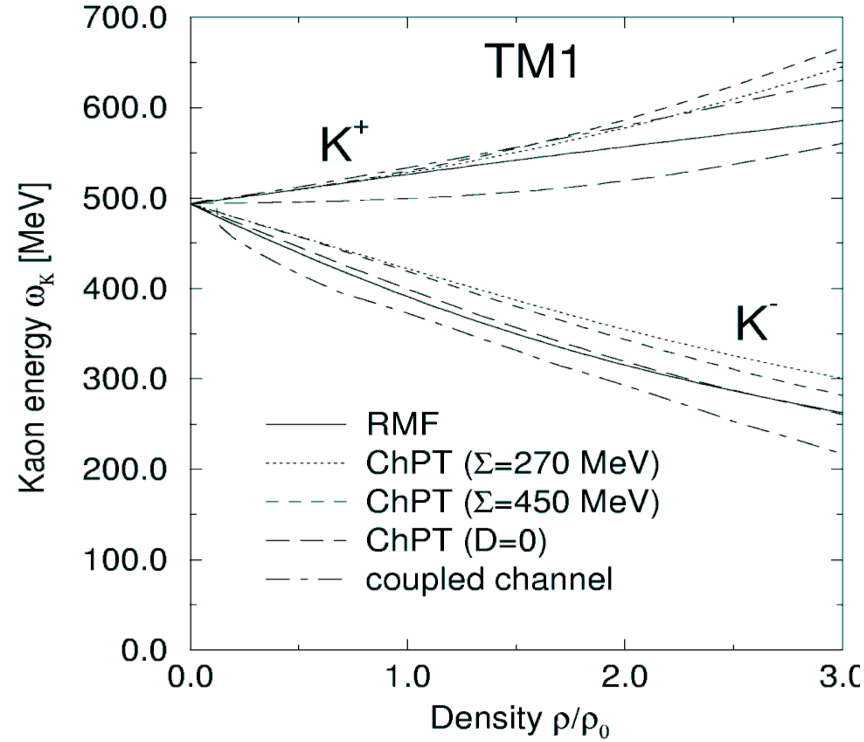
'Non-trivial'

Partial restoration of chiral symmetry
Meson – baryon coupling
Bound states

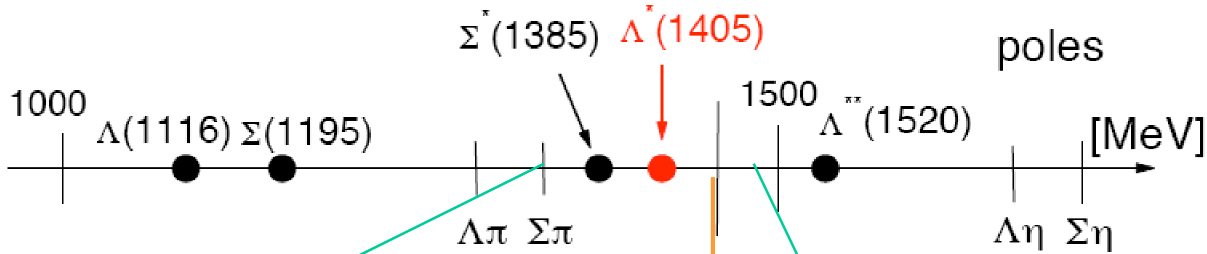
Modified properties of hadrons in dense baryonic matter?

$M^*(\rho)$	**(mass)**
$\Gamma^*(\rho)$	**(width)**
$\sigma^*(\rho)$	**(cross section)**

in-medium kaon energy



$\bar{K}$N – interaction

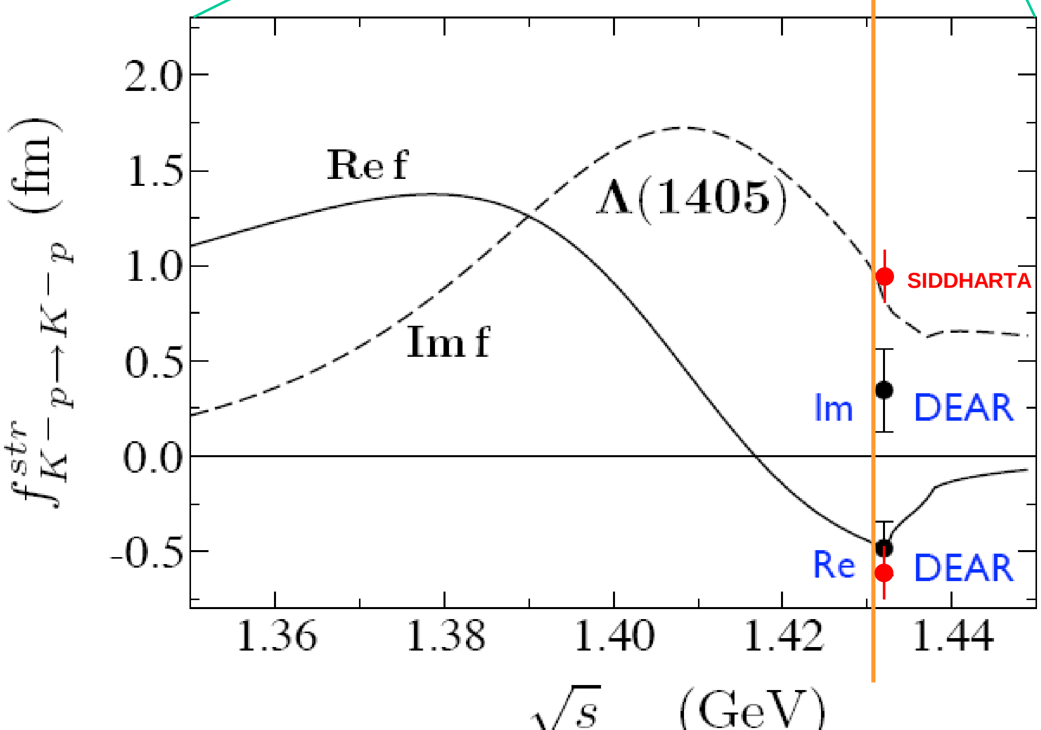


$$\sqrt{s} = \omega + m_N$$

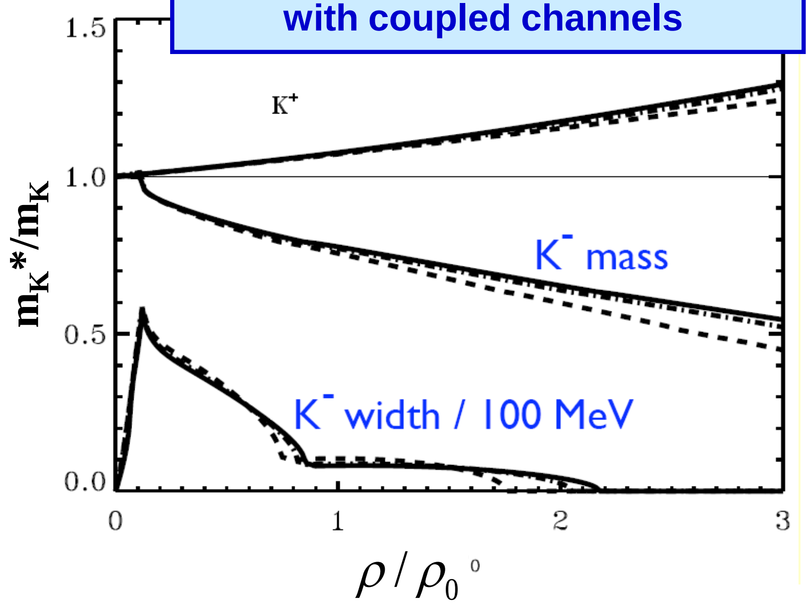
$\bar{K}$ – energy

due to presence of resonances
↓
non – perturbative problem
↓
chiral SU(3) effective field theory with coupled channels

Scattering amplitude f



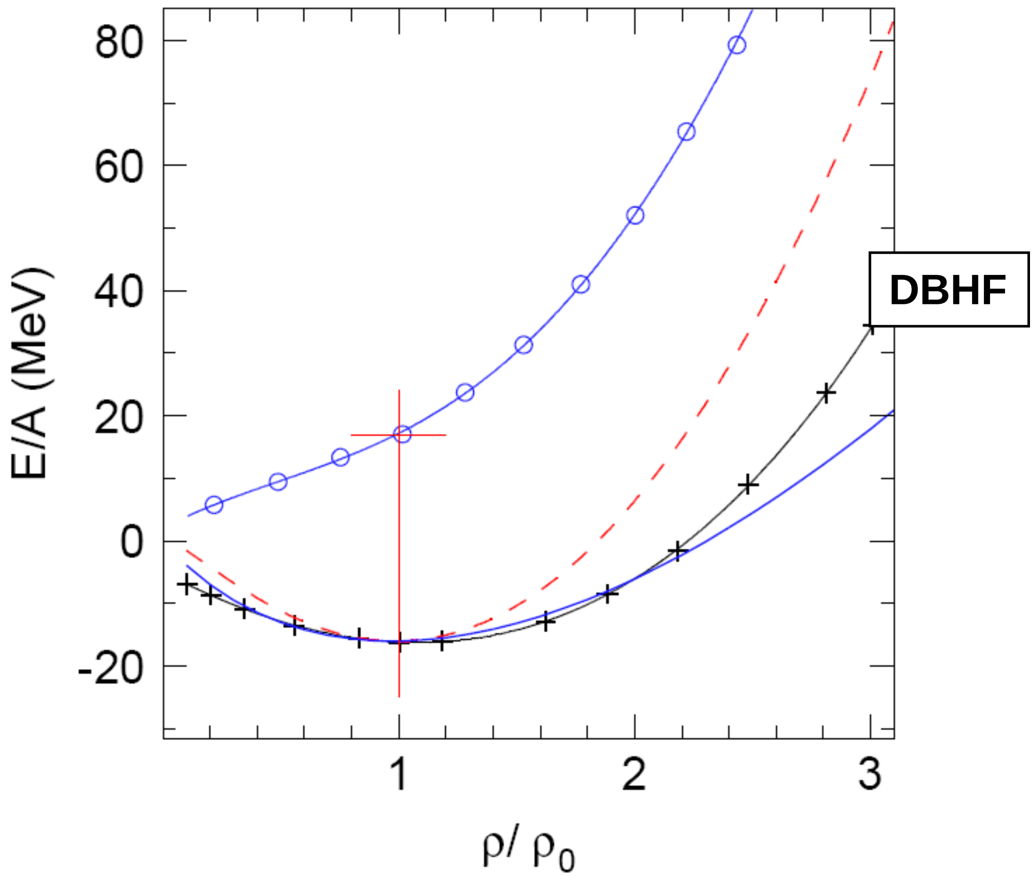
W.Weise et al.: PLB 379, 34 (1996), PRL 94, 213401 (2005)
Y.Ikeda et al. arXiV:1109:3005



$\bar{K}$N – interaction is attractive at finite densities, but strength (depth of potential) is unclear
Experimental signatures: flow of kaons
bound baryonic states

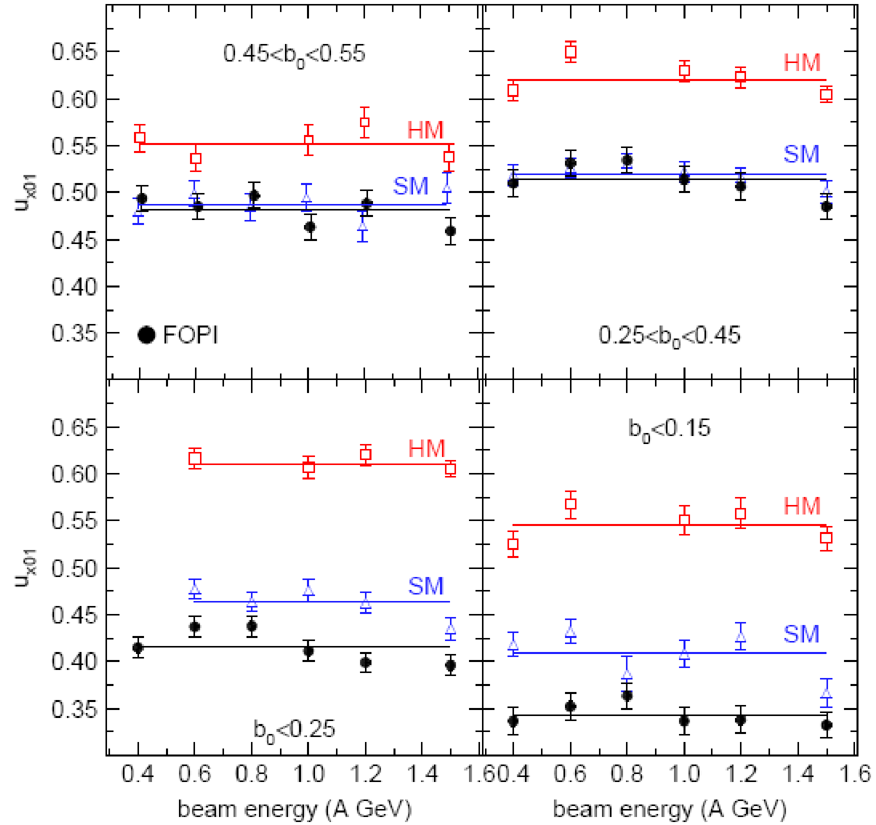
Equation – Of – State

DBHF: E. N. E. van Dalen, C. Fuchs, A. Faessler, EPJ. A 31,29 (2007)



Excitation function of deuteron sideflow

W. Reisdorf et al. (FOPI), NPA 876, 1 (2012)



The EOS is soft up to E_{beam}=1.5 AGeV (ρ_{max} = 2 – 2.5 ρ_0).

Soft EOS does not support neutron stars with $M_{NS}=2M_\odot$

Flow systematics at high energies

RHIC beam energy scan