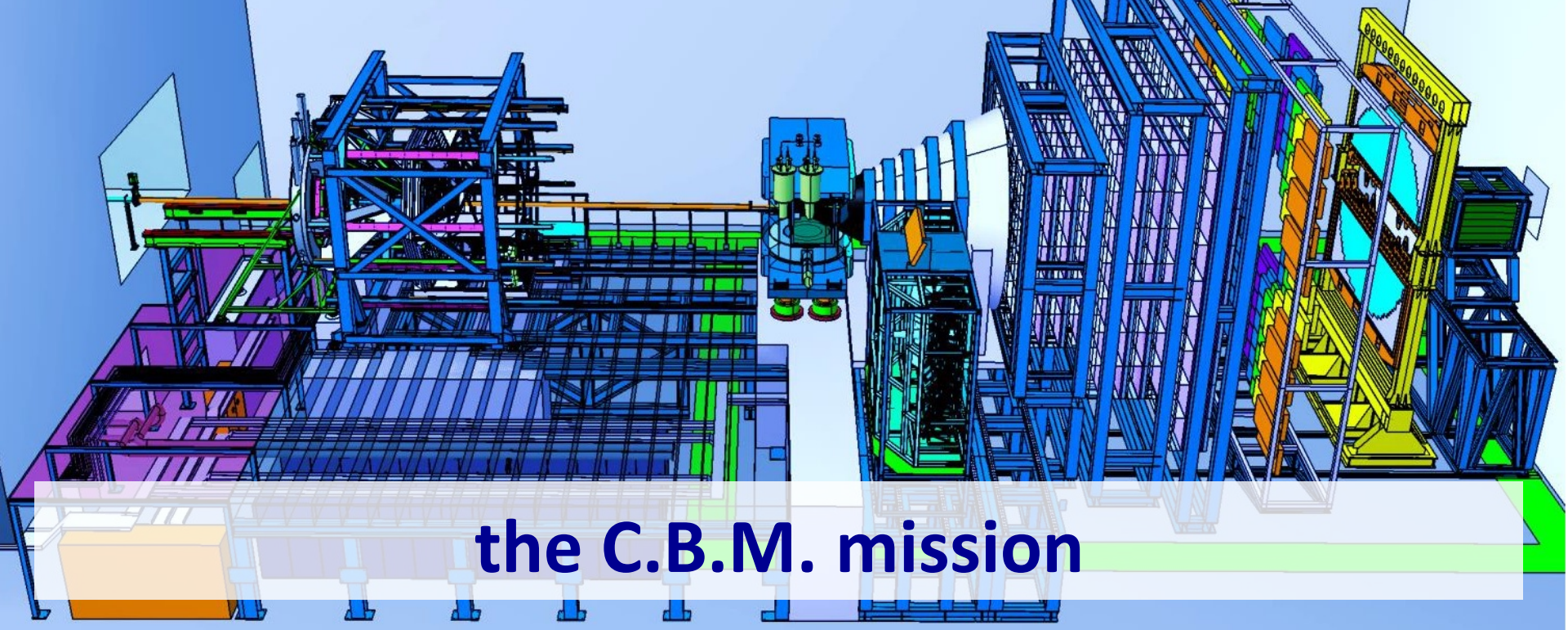
Compressed Baryonic Matter

at GSI and FAIR with

CBM and HADES

Joachim Stroth
for the CBM and HADES collaborations
Bad Honnef, 5. Dezember 2015



the C.B.M. mission

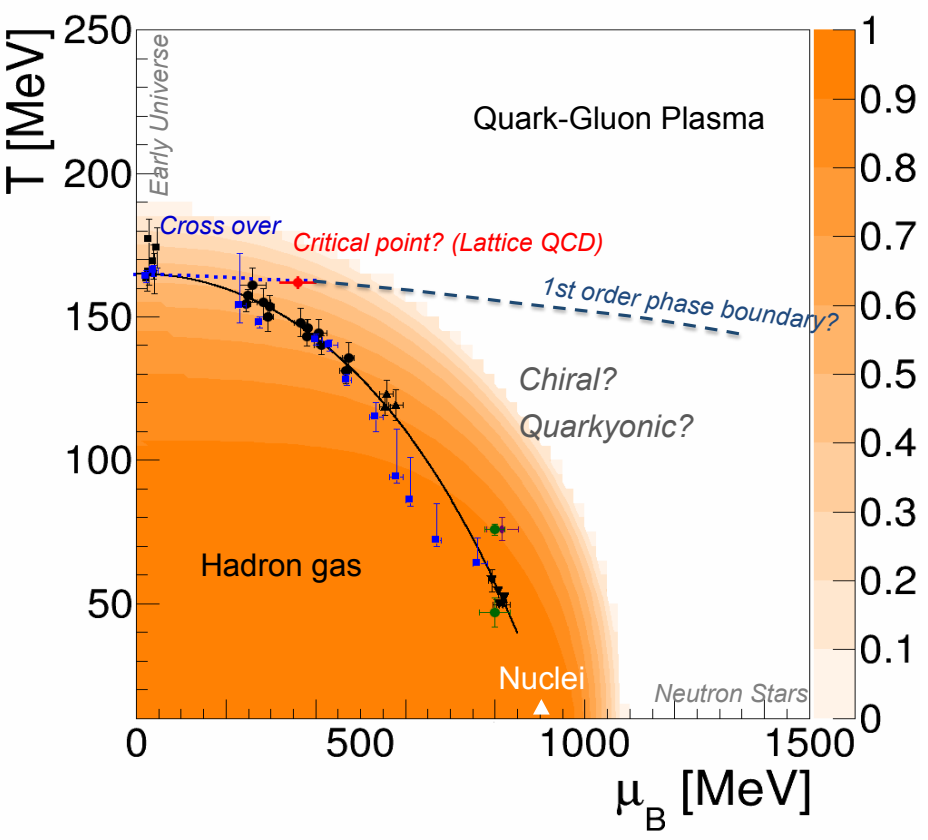
Explore Compressed Baryonic Matter with rare and penetrating probes:

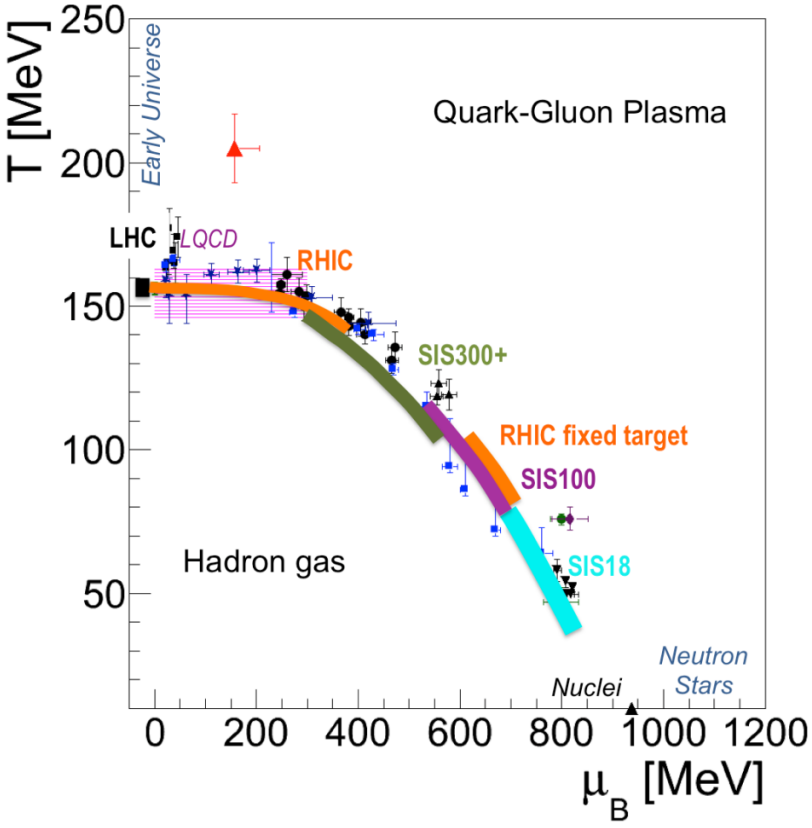
- **EOS** of (baryon) dense and hot QCD matter
- Search for **exotic quark matter** phases and rare strange matter
- Study the **limit of hadronic existence**

Dedicated experiment facility at FAIR with next generation high-rate fix-target experiment CBM:

- HI and p/d beams (π beams at SIS18)
- Flexible detector setup to optimally address **all relevant observables**
- Use high-acceptance **HADES** spectrometer for important reference measurements (cold-matter physics)

experimental approach to QCD phases

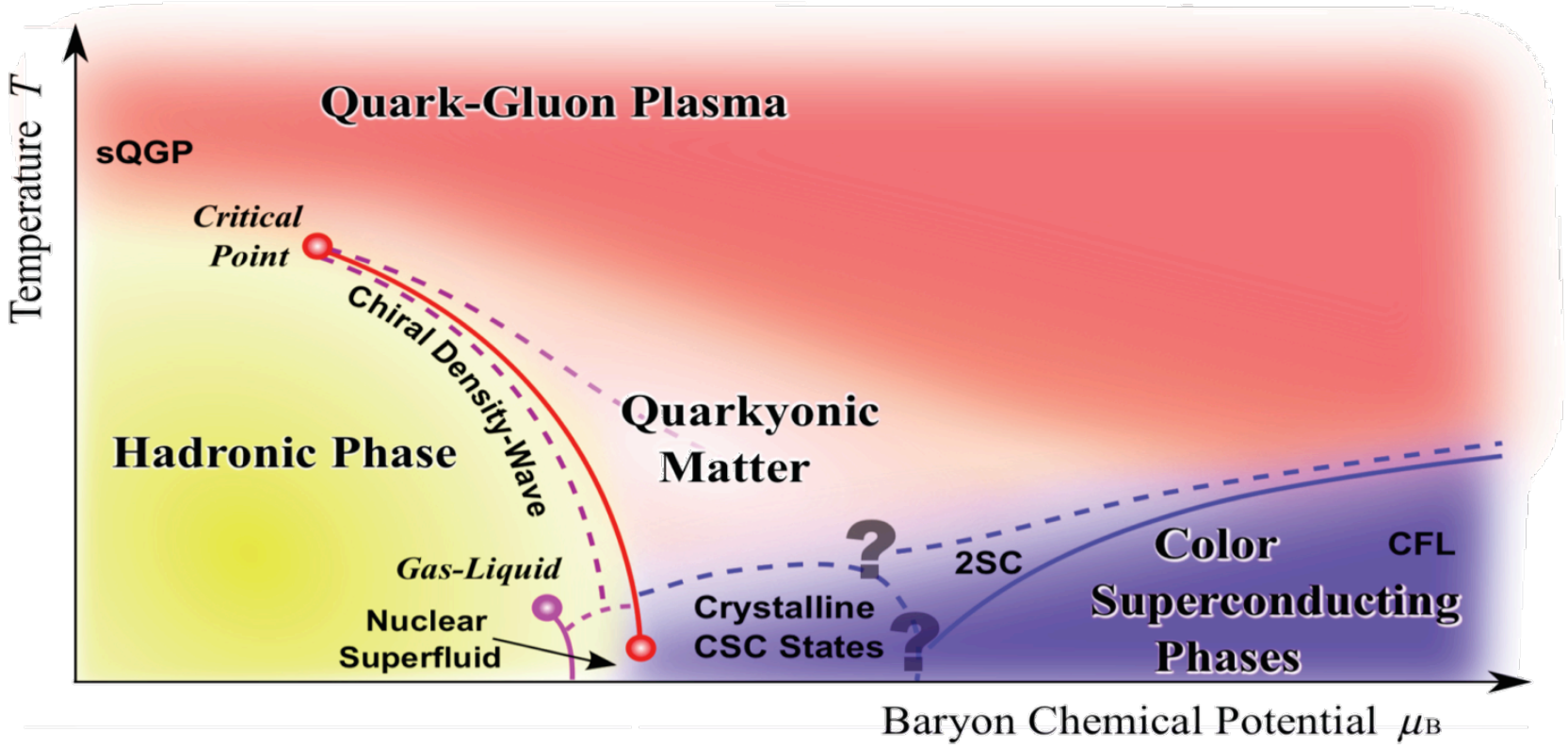




LQCD: Z. Fodor et al., hep-lat/0402006
Condensate: B.J. Schaefer and J. Wambach, private communication
HADES data: M. Lorenz et al., Nucl. Phys. A (2014) QM14
A. Andronic et al., Nucl. Phys. A 837 (2010) 65
J. Cleymans et al. , Phys. Rev. C 60 (1999) 054908

conjectured QCD phase structure

Recent Conception by Hatsuda and Fukushima



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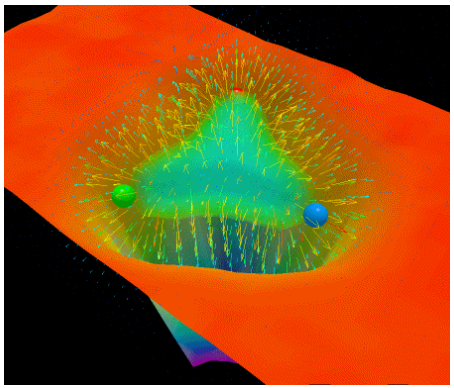
Cloudy Bag Model (for the nucleon)

Chirally restored valence quarks surrounded by a cloud of virtual pions (G. Brown and M. Rho, 1979)

➢ **R_{bag}= 0.82 fm → bags touch at $\rho \simeq 3\ \rho_0$**

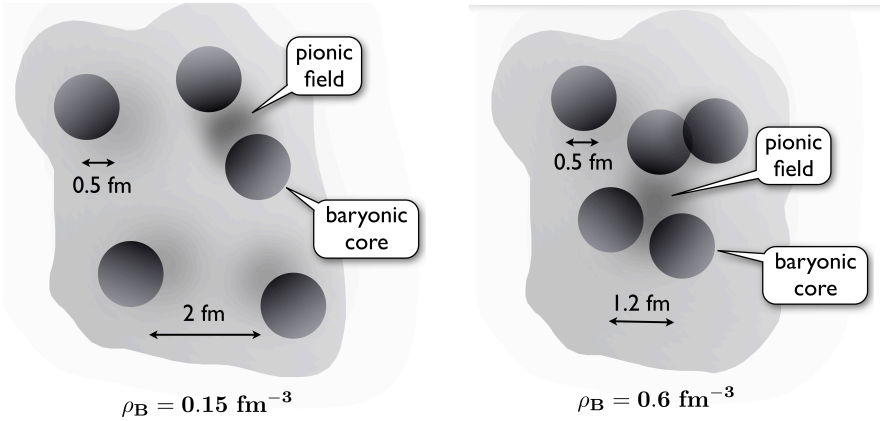
An old model but very instrumental in planning experiments (A.W. Thomas, MENU 2013)



Lattice-QCD vacuum action on the presence of static quarks!

http://www.physics.adelaide.edu.au/theory/staff/leinweber

- Not much guidance yet from lQCD at finite μ_B!

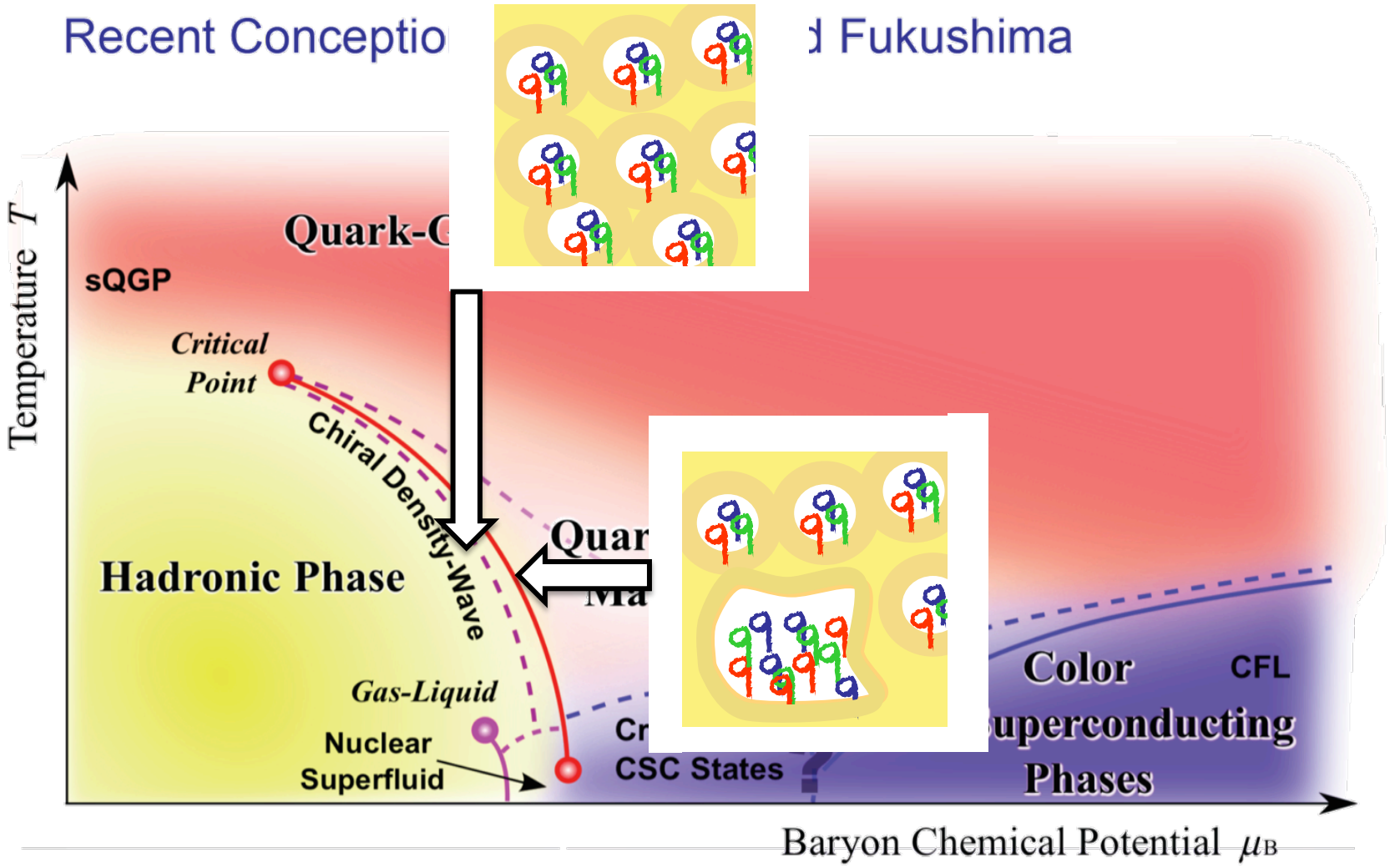


Nuclear matter from in-medium **Chiral Perturbation Theory!**

J.W. Holt, M. Rho, W. Weise arXiv1411.6681 (Phys. Rep. 2015)

- Provides prediction for chiral order parameter a.f.o. baryon density
- Possibility to connect CBM measurements to NS-core matter EOS

conjectured QCD phase structure



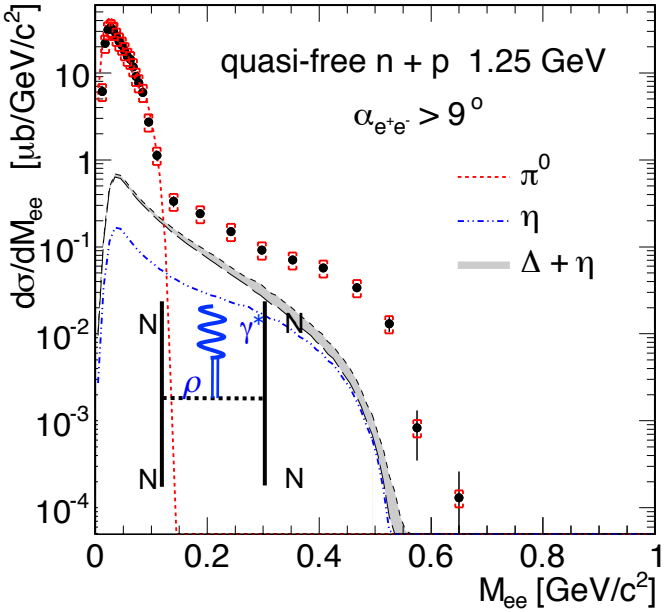
effects of the cloud in HADES data

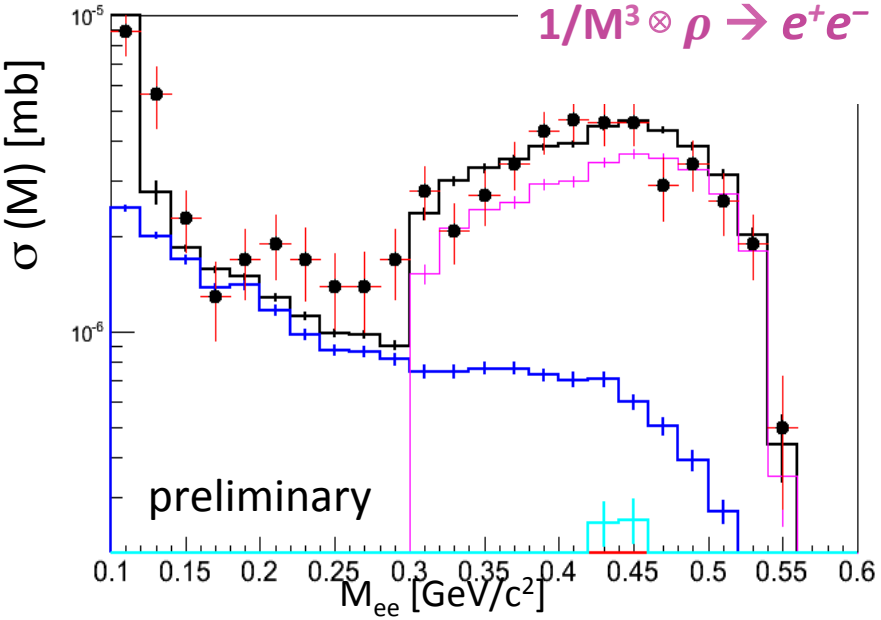
(p)n+p collisions

- strong overshoot towards larger invariant masses
- Can be explained by "emission from the internal charged pion line" (off-shell $\pi^-+\pi^+ \rightarrow \rho$)

pion p/C (PE) collisions

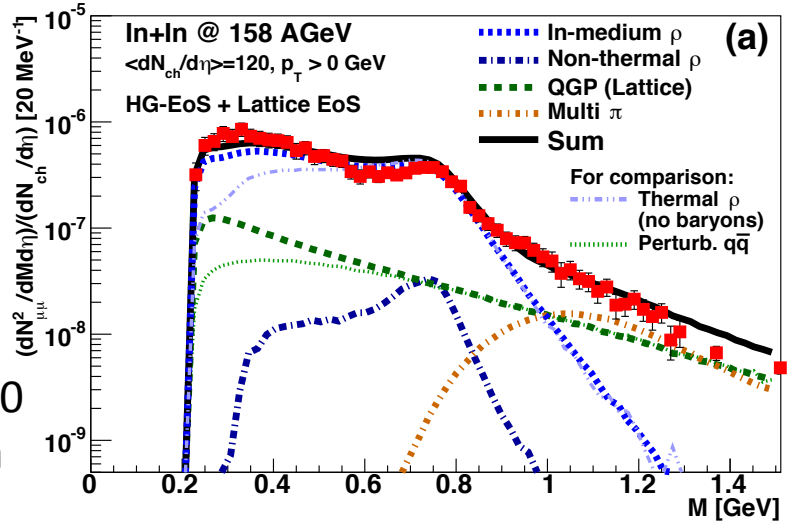
- preliminary, run 2014
- Cocktail constrained by exclusive measurement of hadronic final states (no free parameter)
- PWA (Bonn/Gatchina framework) analysis including electron and crystal barrel data



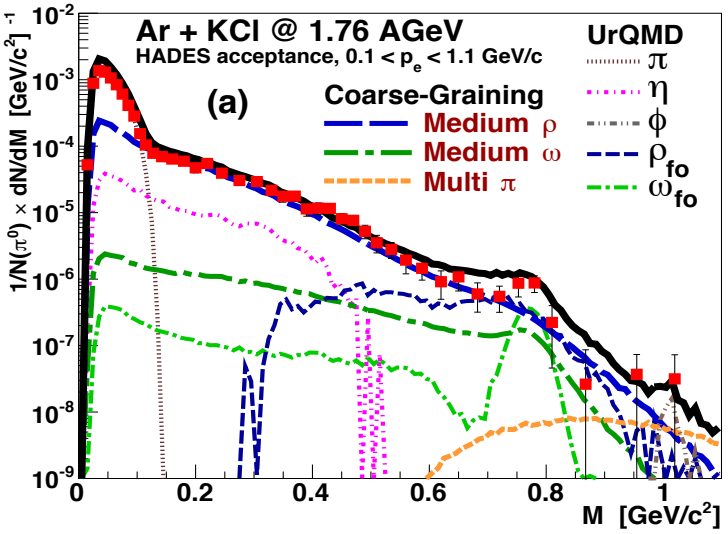


low-mass dilepton pairs

NA60 data



HADES data



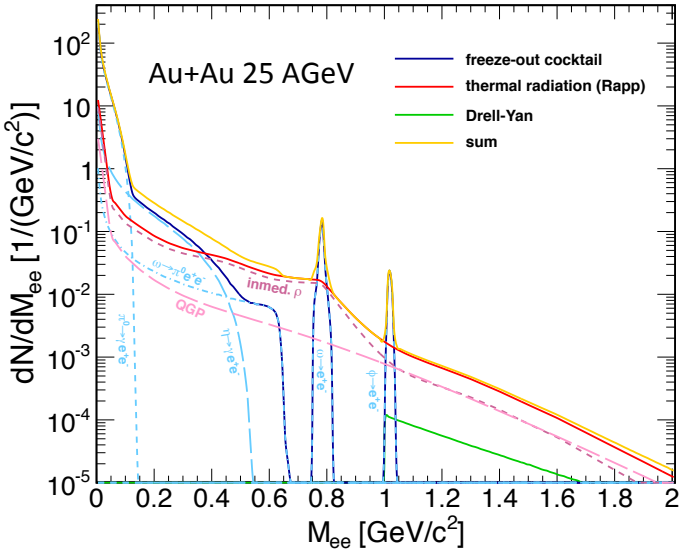
S. Endres et al. [arXiv:1412.1965,arXiv:1505.06131]

Thermal dilepton spectral distributions can be used as

- chronometer,
- thermometer and
- bar(y)ometer

of the dense phase (penetrating probe).

Model: coarse grained UrQMD with Rapp/Wambach thermal emission rates.



strangeness production

The "story" of the phi:

- supposed to be "special" because of the ss content (OZI).

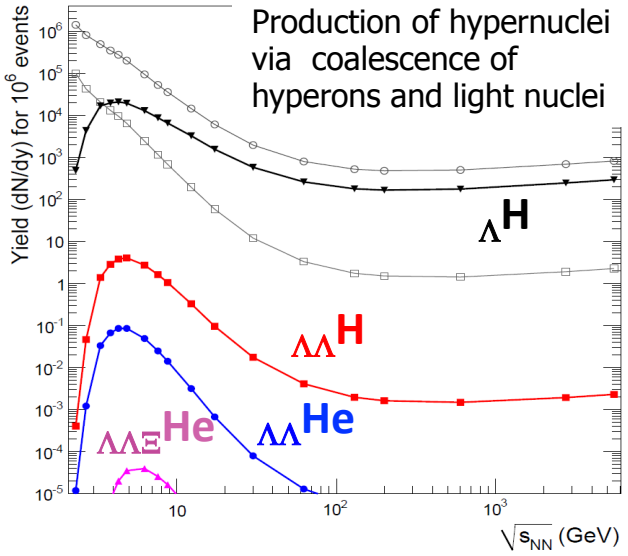
ϕ-Meson Production as a Probe of the Quark-Gluon Plasma

Asher Shor[a]
Lawrence Berkeley Laboratory, University of California, Berkeley, California 94720, and Department of Physics, University of California, Los Angeles, California 90024
(Received 24 August 1984)

The formation of the quark-gluon plasma in relativistic nuclear collisions may be determined by enhanced production of ϕ mesons. This enhancement would result from the absence of the Okubo-Zweig-Iizuka suppression which inhibits ϕ production in ordinary p-p and π-p collisions, and from a large abundance of strange quarks in the plasma. The ϕ will not rescatter significantly in the subsequent expanding hadronic phase and would thereby retain information on the conditions of the hot plasma.

but ...

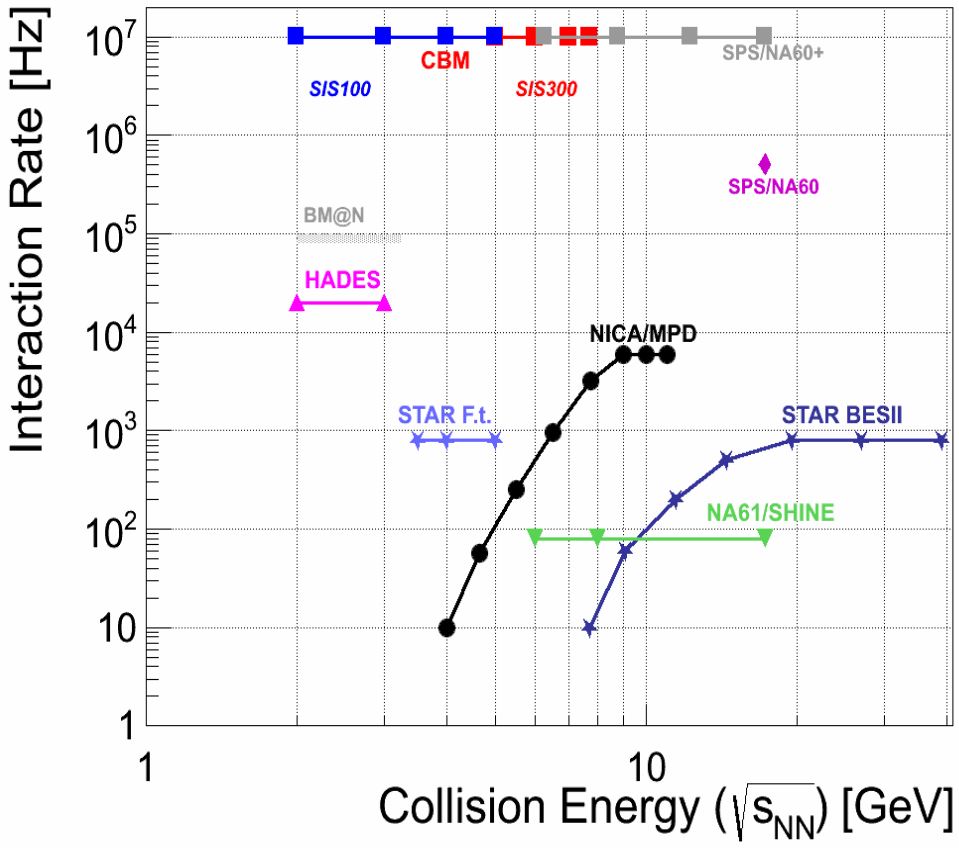
- DISTO: phi production in p+p 10 times above OZI expectation! (PRL 81, 21 (1998))
- ANKE: in-medium cross section 14-21 mb (almost like pion)! (arXiv:1201.3517v1)
- HADES: production in HI as if it has no strangeness content! (arXiv:1010.1675)



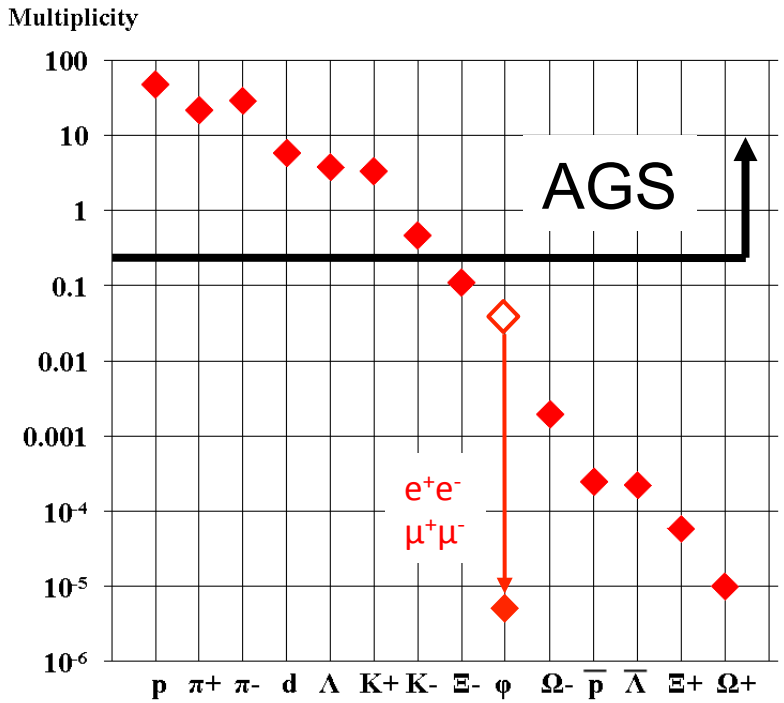
A. Andronic, P. Braun-Munzinger, J. Stachel, H. Stöcker, Phys. Lett. B697 (2011) 203

- **Excitation function of multi-strange baryons**
  - Important observable hardly addressed at SIS/AGS energies
- **Multi-strange hypernuclei**
  - Make use of the high rate capability and on-line data reduction

experiments exploring dense QCD matter



Particle yields in central Au+Au 4 A GeV from SHM (A. Andronic priv. com.)

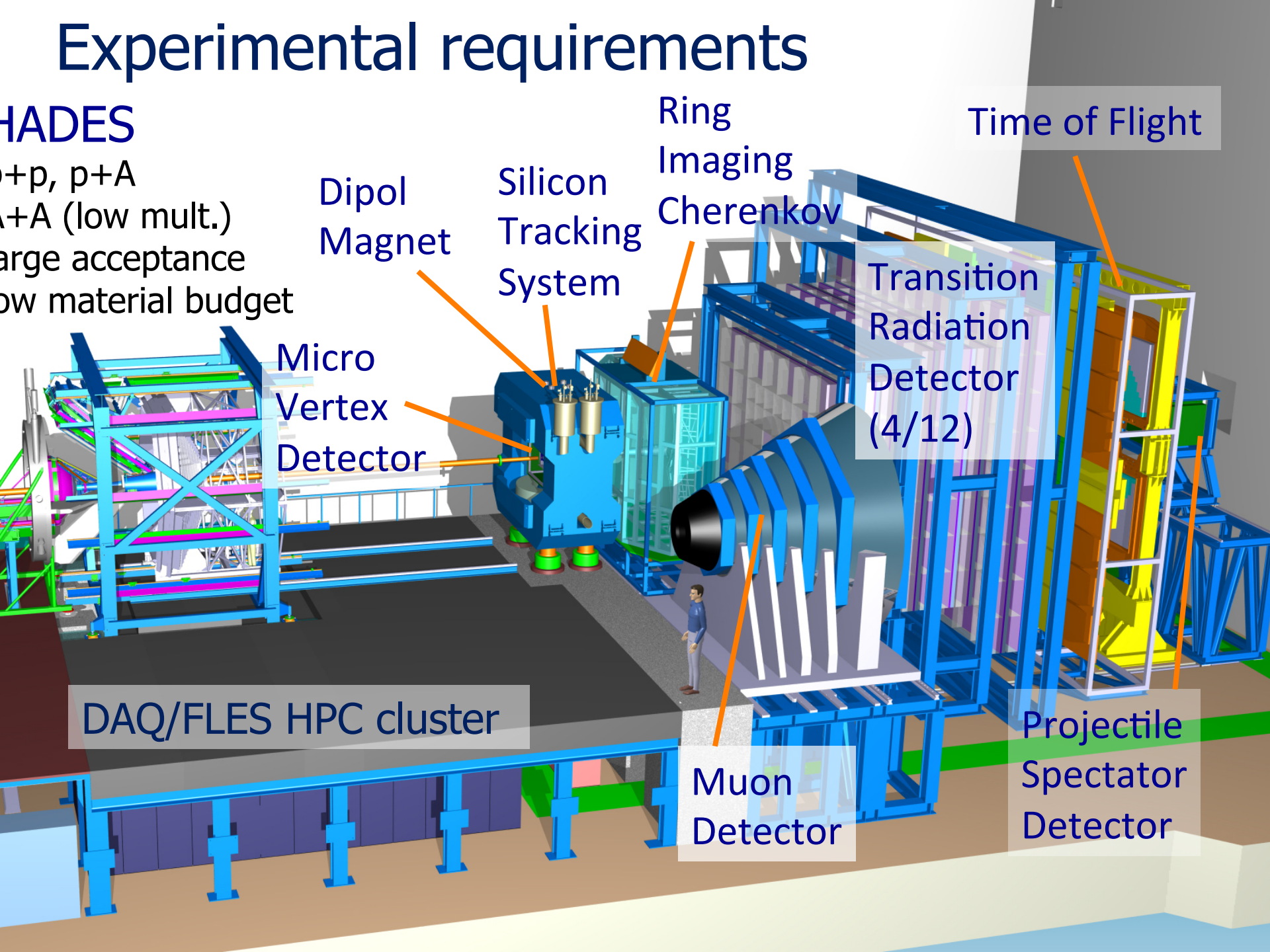


Rare and penetrating probes have not yet been systematically studied for exploring compressed baryonic matter!

Experimental requirements

HADES

p+p, p+A
A+A (low mult.)
arge acceptance
ow material budget



C.B.M. strategy

until 2018

- production readiness for all MSV relevant detector systems
- start of mass production for STS, TOF and RICH
- completion of HADES lead glass calorimeter

2018-2020 (phase 0)

- continue mass production of CBM detector components
- HADES experimental campaign at SIS18 (π, HI beam)
- operation of CBM **pre-series detectors*** in STAR, BM@N and HADES

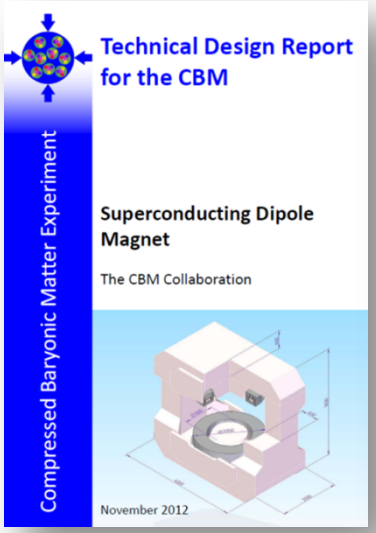
2021 on (phase 1)

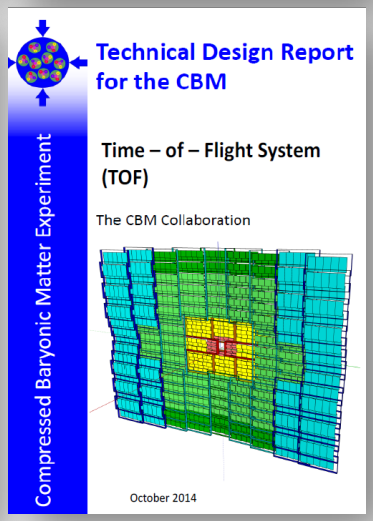
- Installation and commissioning of **CBM start version** to be **ready for day-one FAIR experiment** with SIS100 beam and CBM start version
- Completion of installation of CBM/MUCH,HADES and start of comprehensive research program

* provided core invest money is available in the running BMBF funding period

CBM Technical Design Reports

#	Project	TDR Status
1	Magnet	approved
2	STS	approved
3	RICH	approved
4	TOF	approved
5	MuCh	approved
6	HADES ECAL	approved
7	PSD	approved
8	MVD	submission 2016
9	DAQ/FLES	submission 2016
10	TRD	submission 2016





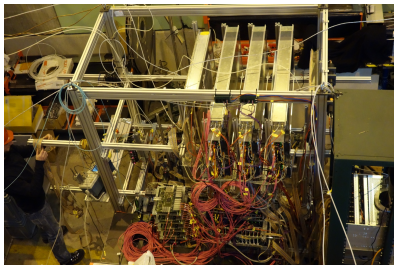
Ongoing R&D: Development of CMOS sensors (MVD), read-out ASIC for STS, and DAQ/FLES

R&D achievements

60 ps time-resolution for MIPS with **MRPC** modules with adjustable granularity

- Differential strip readout with varying strip length (4 – 30 cm)
- Adapted customized electronics (PADI, GET4)
- High rate capability by usage of doped glass with high conductivity (10^{11} Ωcm)

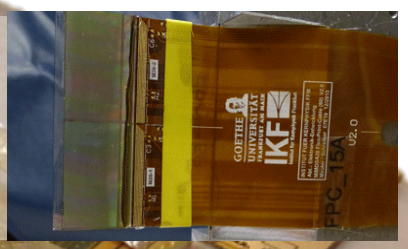
CBM-TOF collaboration, Journal of Instrumentation 7 (2012) P10008



Low-mas, vacuum-compatible pixel sensor integration

- double sided integration on CVD material - below 0.3 % X_0 in total
- 50 μm thinned **MAPS** with enhanced radiation tolerance (IPHC)

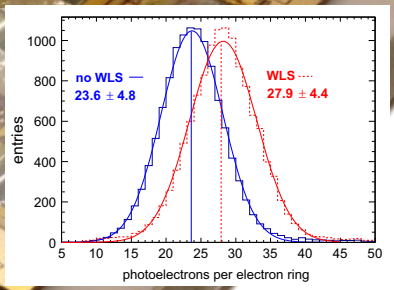
CBM-MVD collaboration: **Nucl.Instrum.Meth. A732 (2013) 515-518**



Wavelength shifting film enhanced UV photo efficiency

- Film applied by dip-coating method
- 20 % increase in mean detected photon per ring

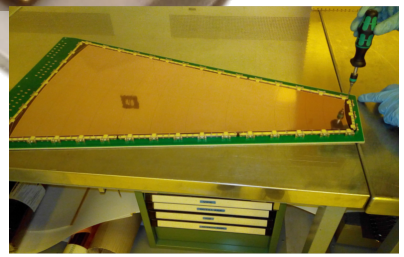
CBM-RICH/GSI collaboration: Nucl. Instrum. Meth. A 783 (2015) 43



High-rate modular muon detection system

- - Design based on instrumented absorbers completed
- - Large area prototype GEM detectors built and successfully tested

CBM-MUCH collaboration: S. Achmad et al., Nucl. Instrum. Meth. A775 (2014) 139-147



Background picture: STS module assembly with double-sided strip sensor, ultra-thin flex cables and front-end card.

just finished at CERN SPS

Full system test of CBM TOF system:

- Several MRPC modules under test: pad, multi-strip from 16 - 128 strips
- 1074 channels
- Full DAQ chain with PADI, FPGA TDC, TRB
- Diamond start detector

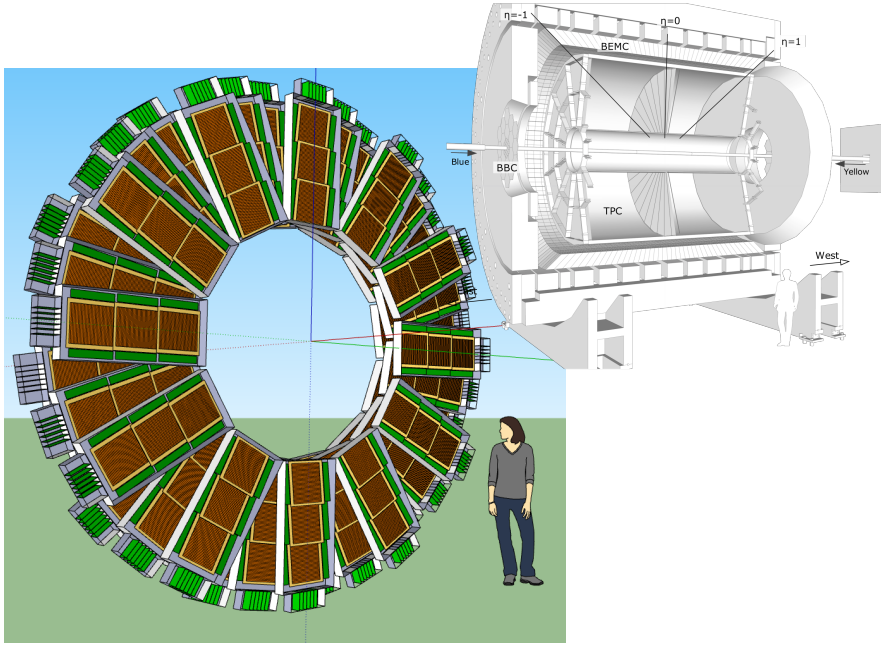
Pb+Pb collisions at at SPS

Beijing-Bucharest-GSI-Heidelberg-Wuhan Team

pre-series CBM detectors

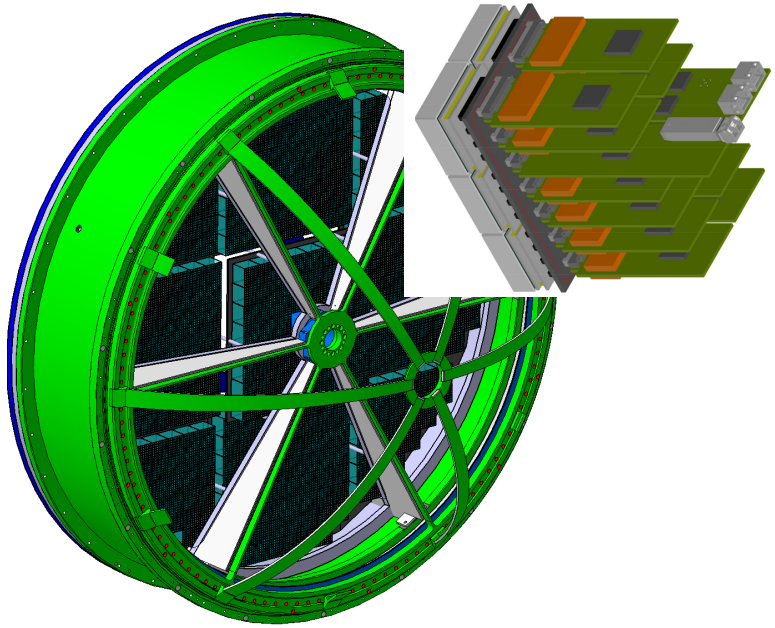
CBM MRPC's for STAR barrel TOF

- Extends STAR's PID capability to larger rapidity coverage
- Modules are produced by CCNU, ISTC and Tsinghua U. (Wuhan and Beijing)
- Provides large-scale integration test
- Gain experience in MRPC operation



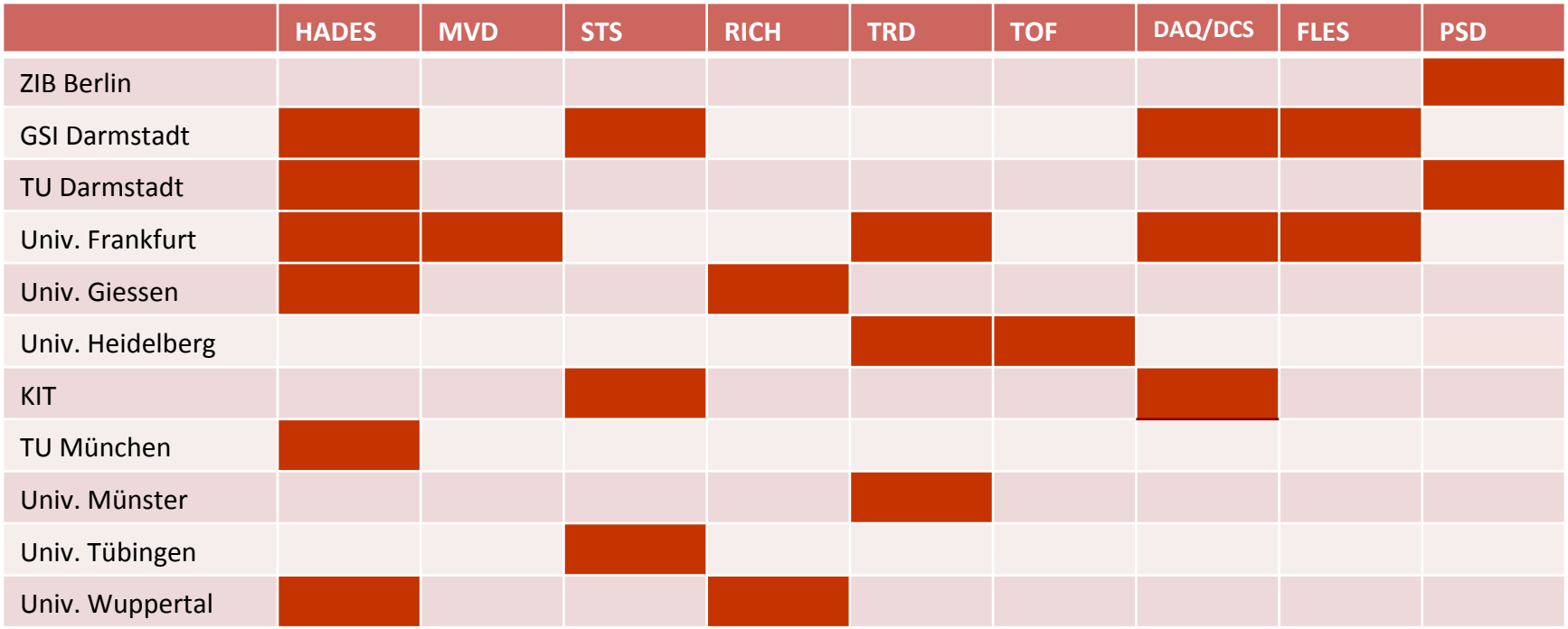
MAPMT UV photon detector for HADES

- Replaces aging solid CsI based UV photon detector
- Improves rate capability
- Joint development CBM and HADES
- Leaves the rest of the HADES-RICH untouched



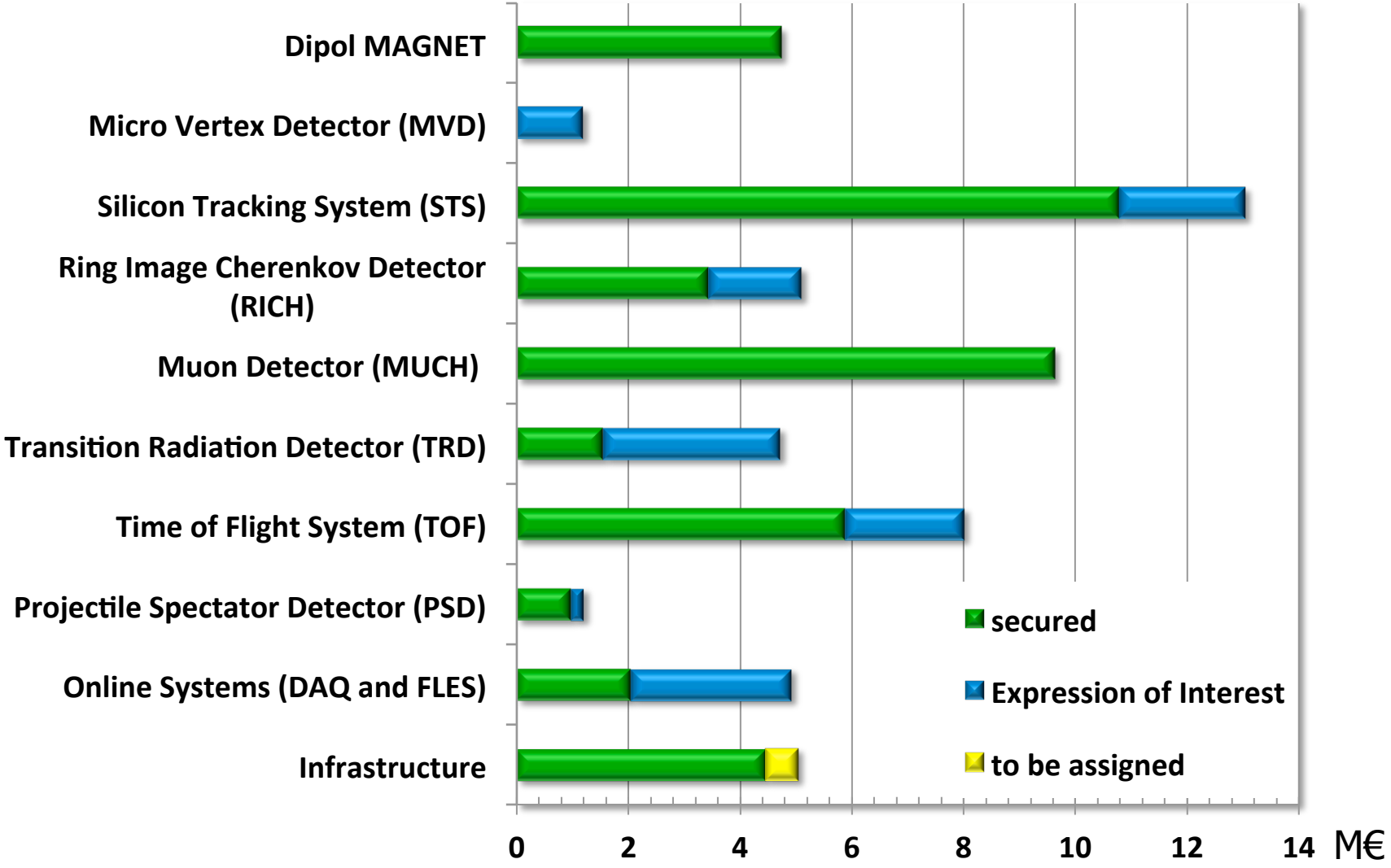
allows young members of the CBM collaboration to participate in experiments before 2022

German participation in C.B.M.



Konrad-Zuse-Zentrum Berlin	Prof. Reinefeld
GSI Darmstadt:	Prof. Senger, Dr. Schmidt, Dr. Sturm (FAIR: J. Eschke, W.F.J. Müller)
Technische Univ. Darmstadt:	JProf. Galatyuk
Univ. Frankfurt:	Prof. Blume, Prof.. Kebschull, Prof. Kisel, Prof. Lindenstruth, Prof. Stroth, Prof. Toia
Univ. Giessen:	Prof. Höhne, Prof.
Univ. Heidelberg:	Prof. Herrmann, Prof. Fischer
Karlsruhe Institute for Technology:	Prof. Becker
Technische Univ. München:	Prof. Fabbietti
Univ. Tübingen	Prof. Schmidt
Univ. Wuppertal:	Prof. Kampert

Costs and funding CBM day-1 version



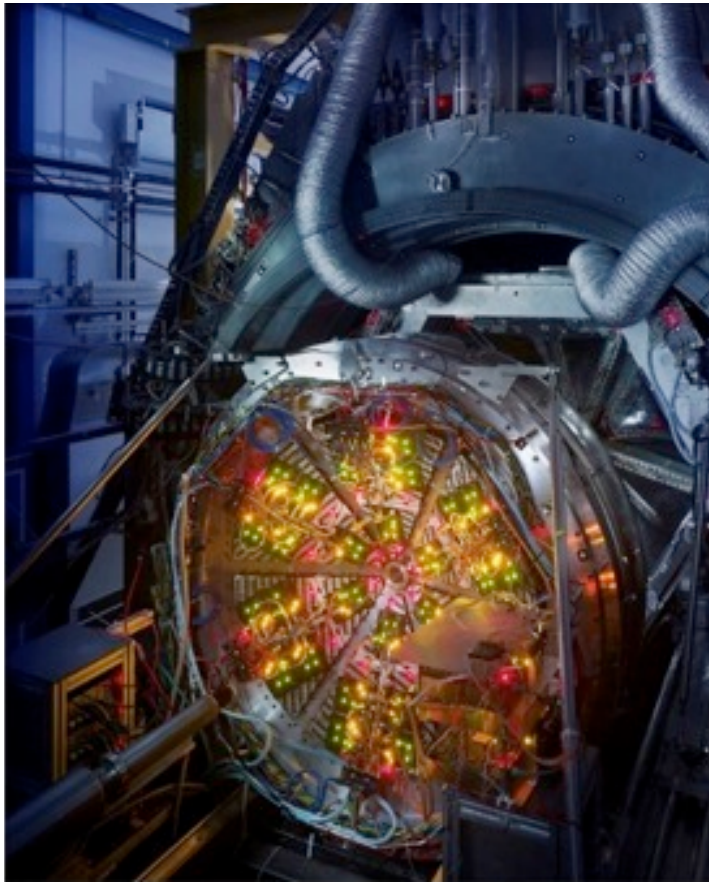

Vielen Dank für Ihre Aufmerksamkeit

back up

HADES run scenario at SIS18

Time line

- Upgrade program in 2016-2017 (no operation)
- Likely beam available from 2018 on (summer)
- Anticipated improved conditions
  - radiation protection
  - new slow extraction
  - improved intensities



Assume three long campaigns

i.e.

- π+PE/lH_2: baryon em transition form factors, baryonic resonances with strangeness
- p+A: strangeness/vector mesons in medium
- A+A: medium system at maximal energy

FAIR project plan