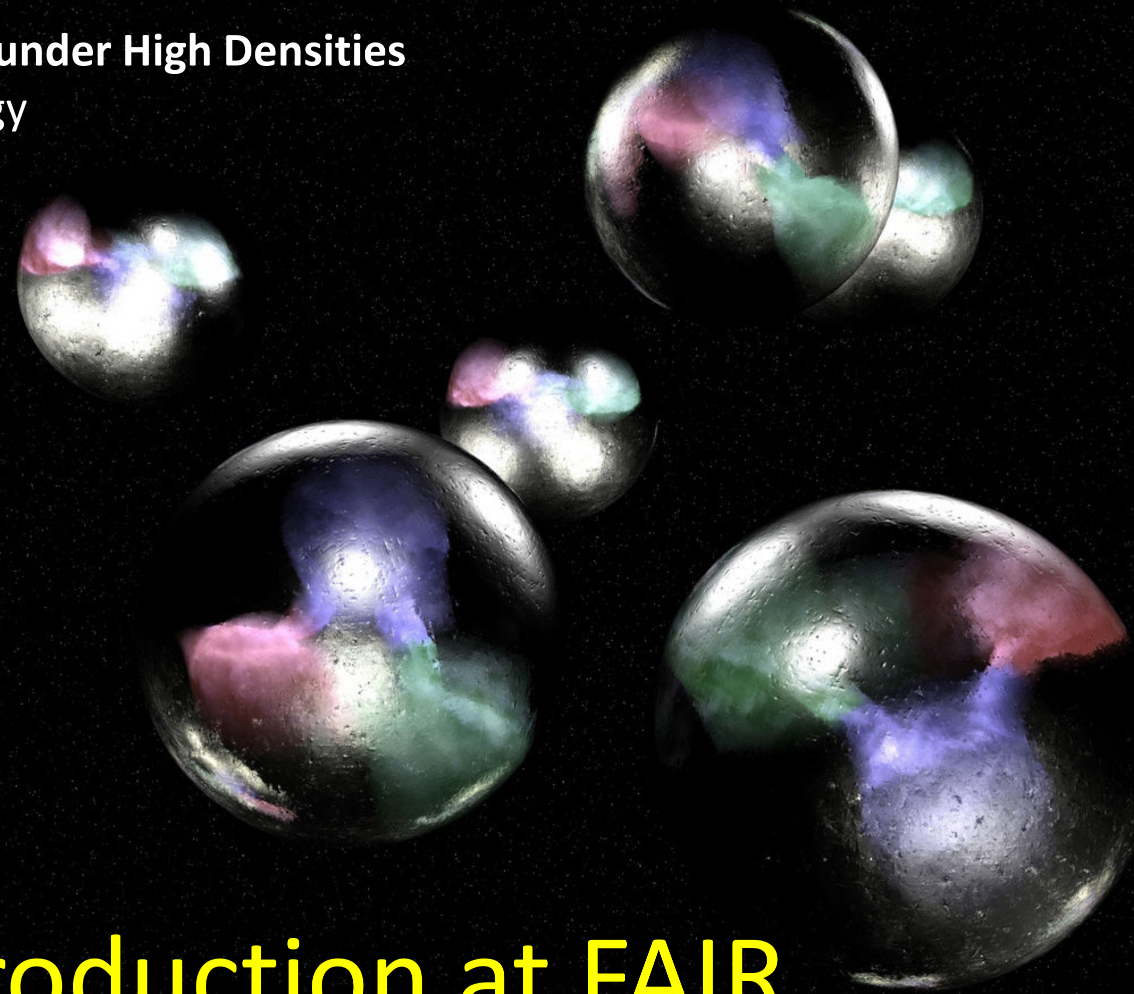
International Conference on Matter under High Densities
Sikkim Manipal Institute of Technology
Rangpo, Sikkim
India



Charm production at FAIR

Anna Senger
for CBM collaboration

Outline

- Motivation
- UrQMD model
- CBM
- Simulations
- Conclusions

Motivation

Helmut Satz

HICforFair Workshop "Heavy flavor physics with CBM" May 26-28, 2014

Why study charmonium production in nuclear matter?

- Charmonium interactions:

  Normal hadrons (u,d,s): large ($\sim$ 1 fm), all of same size

  Charmonia ($c\bar{c}$) : small, different sizes, different binding

  Effect of size and binding on interaction with normal hadrons?

- Charmonium formation:

  Charmonia formed in medium, evolution from $c\bar{c}$ to physical resonance

  In-medium behavior of charmonia of different momenta probes different evolution stages

Possible processes in dense matter

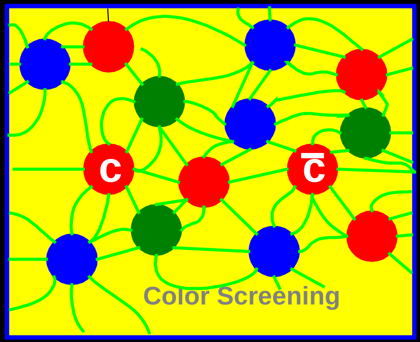
Suppression by comover hadrons

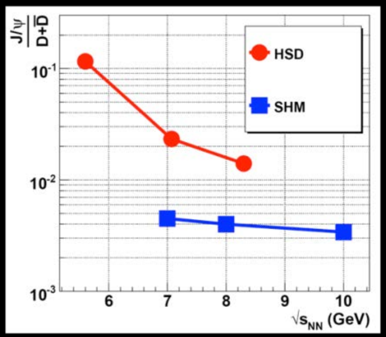
Charmonium can be dissociated through interactions with hadrons in the medium formed in the collisions

- *Main feature: smooth dependence on centrality*

Suppression by color screening

- *Onset for the suppression*





Enhancement by recombination

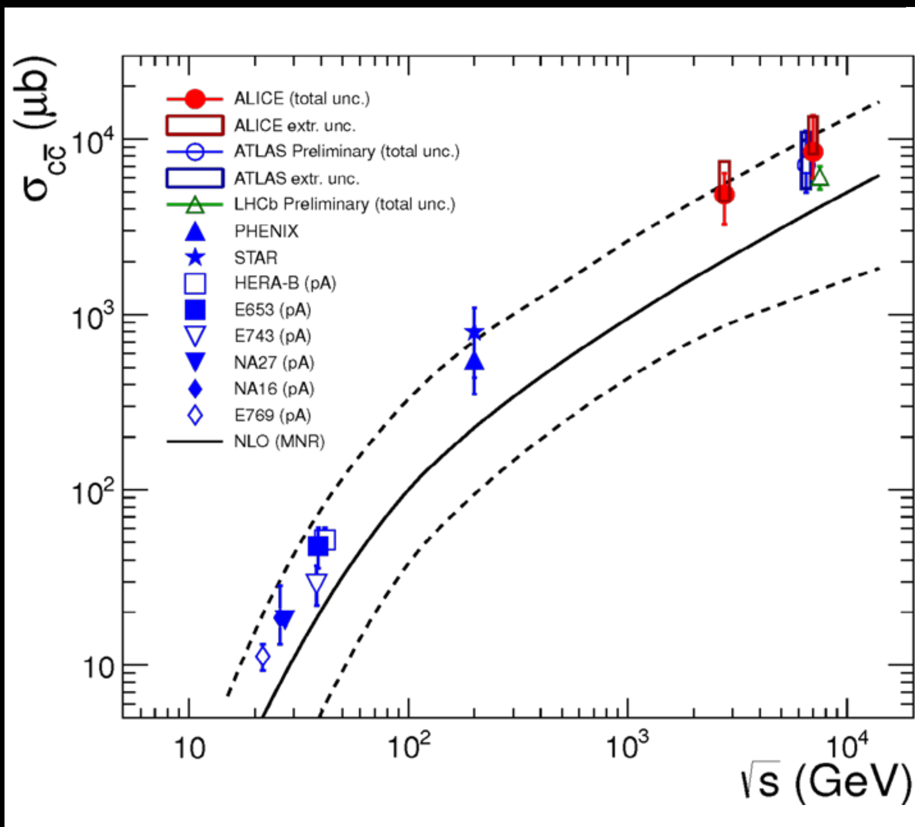
In the QGP hadronization, charmonium formation can occour by binding a c and a cbar from different nucleon-nucleon collisions, as well as from the same. This recombination is possible only if heavy quark multiplicity is high (LHC energies)

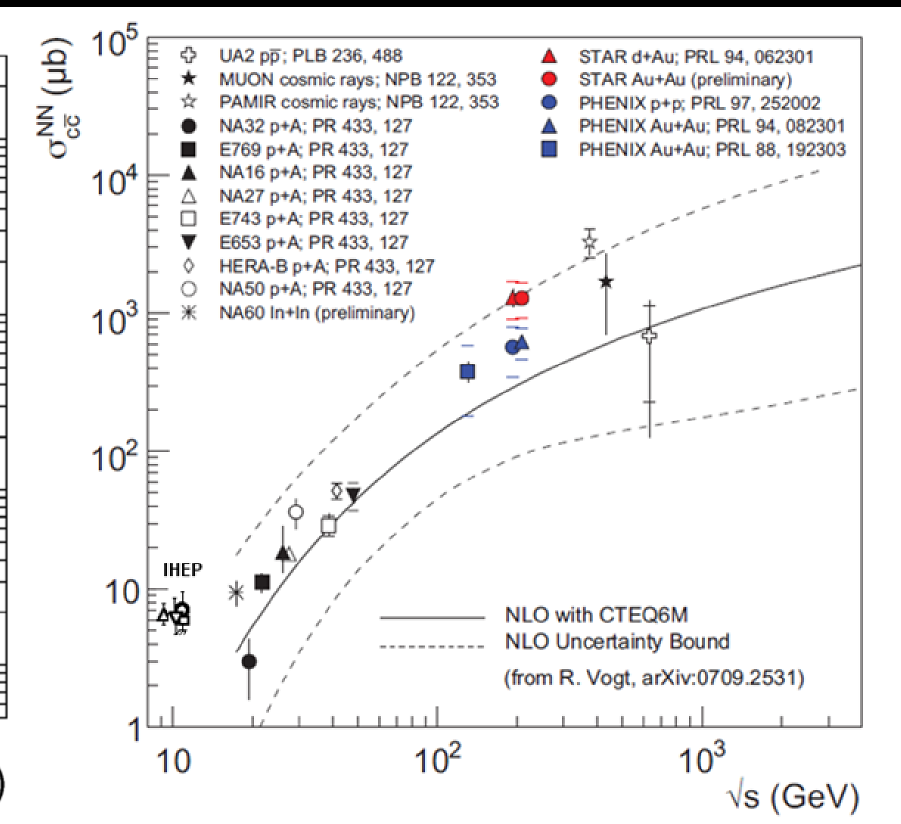
- *Enhancement of J/ψ production*

Subthreshold production

Possible production due to secondary interactions of heavy resonances (FAIR SIS100 energies)

Charm production at threshold energies in cold and dense matter





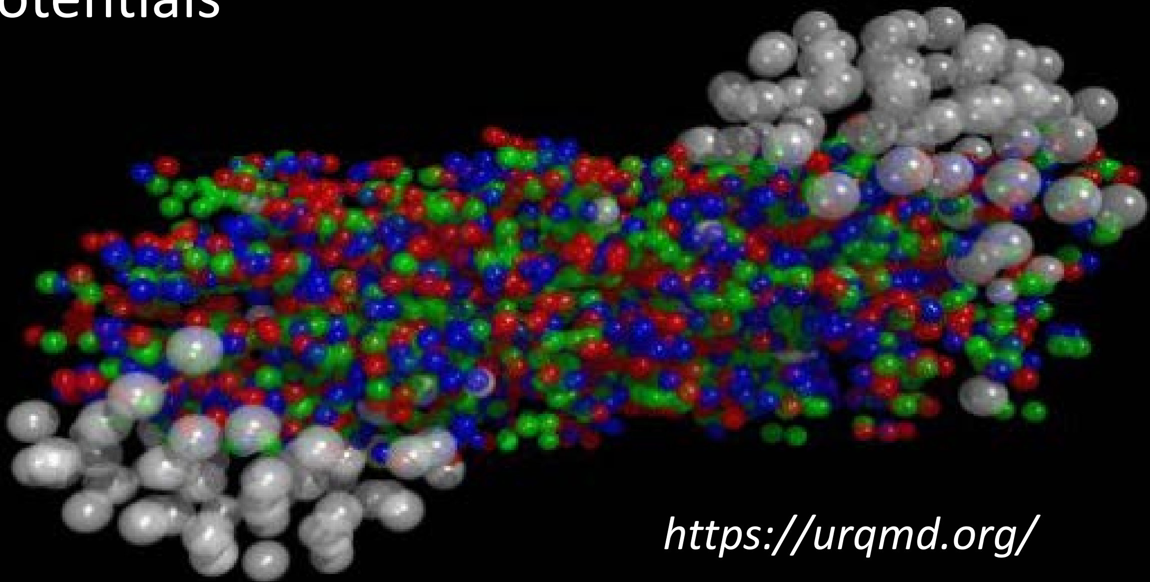
ALICE JHEP 1207 (2012) 191, arXiv:1205.4007

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

UrQMD model

UrQMD is a microscopic transport model:

- calculates the space-time trajectories of „real“ particles
- follows particles with a straight line trajectories until they scatter
- does not have long range interactions like potentials



https://urqmd.org/

Particle production in UrQMD

UrQMD is a microscopic transport model:

- bases on point like “real” hadrons with conserved energy-momentum, quantum numbers
- has only strong interactions. No electro-weak processes
- allows only $2 \leftrightarrow 2$, $2 \leftrightarrow 1$, $2 \rightarrow N$ and $1 \rightarrow N$ interactions
- hadrons interact via scattering according to geometrical interpretation of cross section
- has resonance decays according PDG values + guesstimates
- has detailed balance (violated in string excitations, annihilations and some decays)

Hadron production in UrQMD

Particle production only via:

- resonance excitation:

  N + N → X

  N + M → X

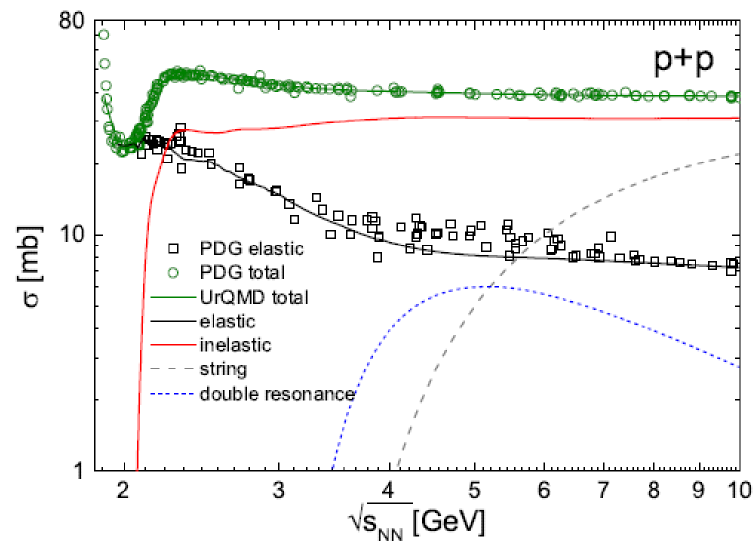
  M + M → X

- annihilation: B + B → X

- string excitations

Relevant channels:

1. $NN \to N\Delta_{1232}$
2. $NN \to NN^*$
3. $NN \to N\Delta^*$
4. $NN \to \Delta_{1232}\Delta_{1232}$
5. $NN \to \Delta_{1232}N^*$
6. $NN \to \Delta_{1232}\Delta^*$
7. $NN \to R^*R^*$



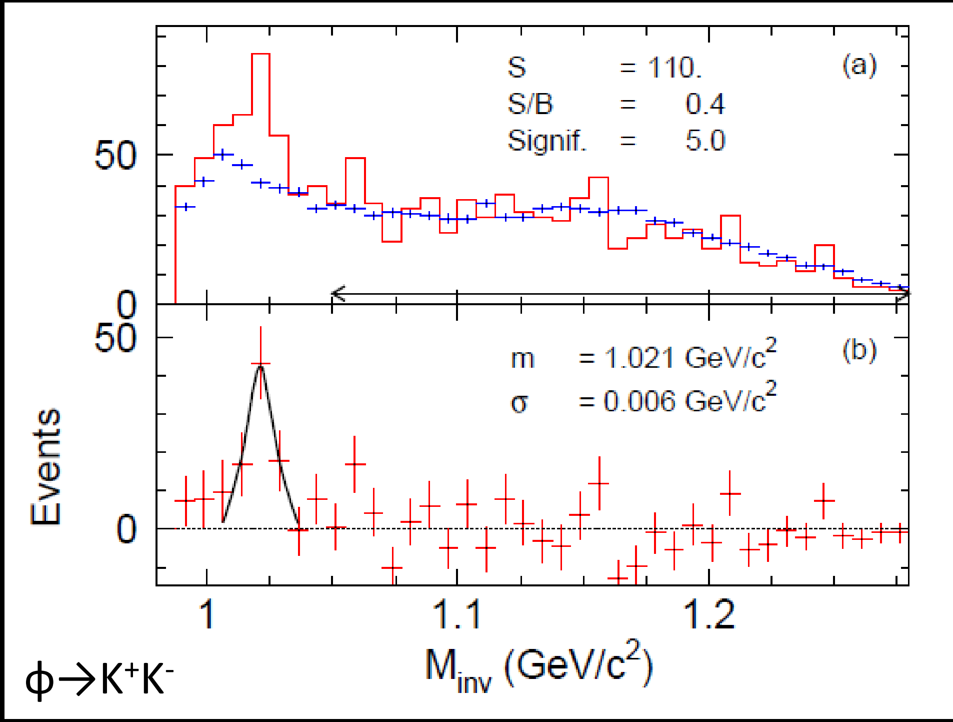
Sub-threshold φ and Ξ⁻ production by high mass resonances with UrQMD

J. Steinheimer and M. Bleicher

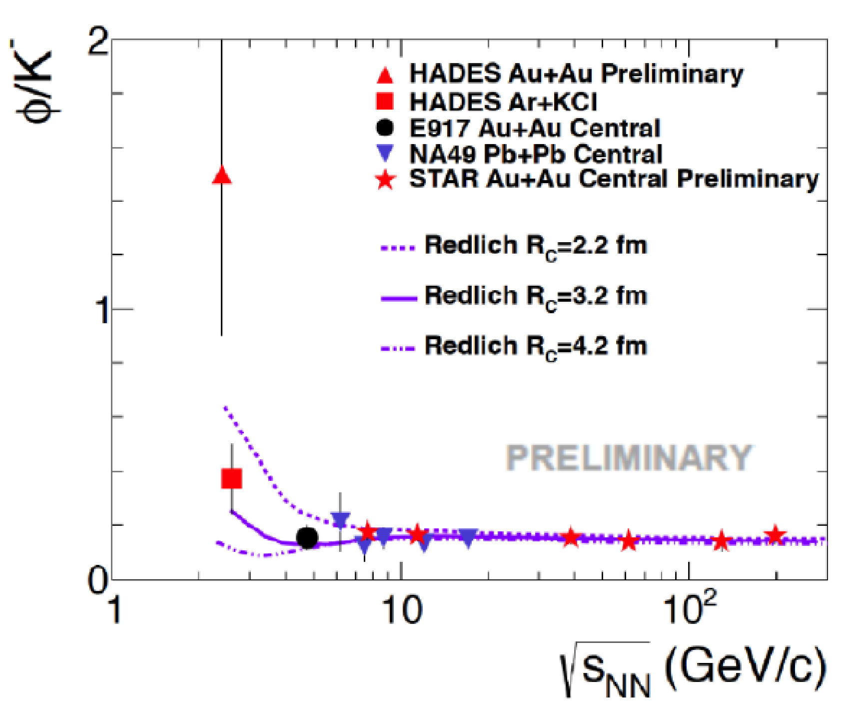
arXiv:1503.07305v2 [nucl-th] 26 Nov 2015

Motivation for UrQMD update

Centrality dependence of subthreshold φ meson production in Ni+Ni collisions at 1.9A GeV
FOPI collaboration
arXiv:1602.04378v2 [nucl-ex] 9 Jun 2016



Strange hadron production at SIS energies: an update from HADES
HADES Collaboration
doi:10.1088/1742-6596/668/1/012022



Update of UrQMD

Sub-threshold φ and Ξ^- production by high mass resonances with UrQMD

J. Steinheimer and M. Bleicher , arXiv:1503.07305v2 [nucl-th] 26 Nov 2015

Newly introduced baryonic resonances

Name	Mass [GeV]	Width [GeV]	Spin
N*(2600)	2.600	0.65	11/2
N*(2700)	2.700	0.40	13/2
N*(3100)	3.100	1.30	15/2
N*(3500)	3.500	1.30	17/2
N*(3800)	3.800	1.30	17/2
N*(4200)	4.200	1.30	19/2
Δ*(2420)	2.420	0.40	11/2
Δ*(2750)	2.750	0.40	13/2
Δ*(2950)	2.950	0.50	15/2
Δ*(3300)	3.300	1.00	17/2
Δ*(3500)	3.500	1.00	19/2
Δ*(3700)	3.700	1.00	19/2
Δ*(4200)	4.200	1.00	21/2

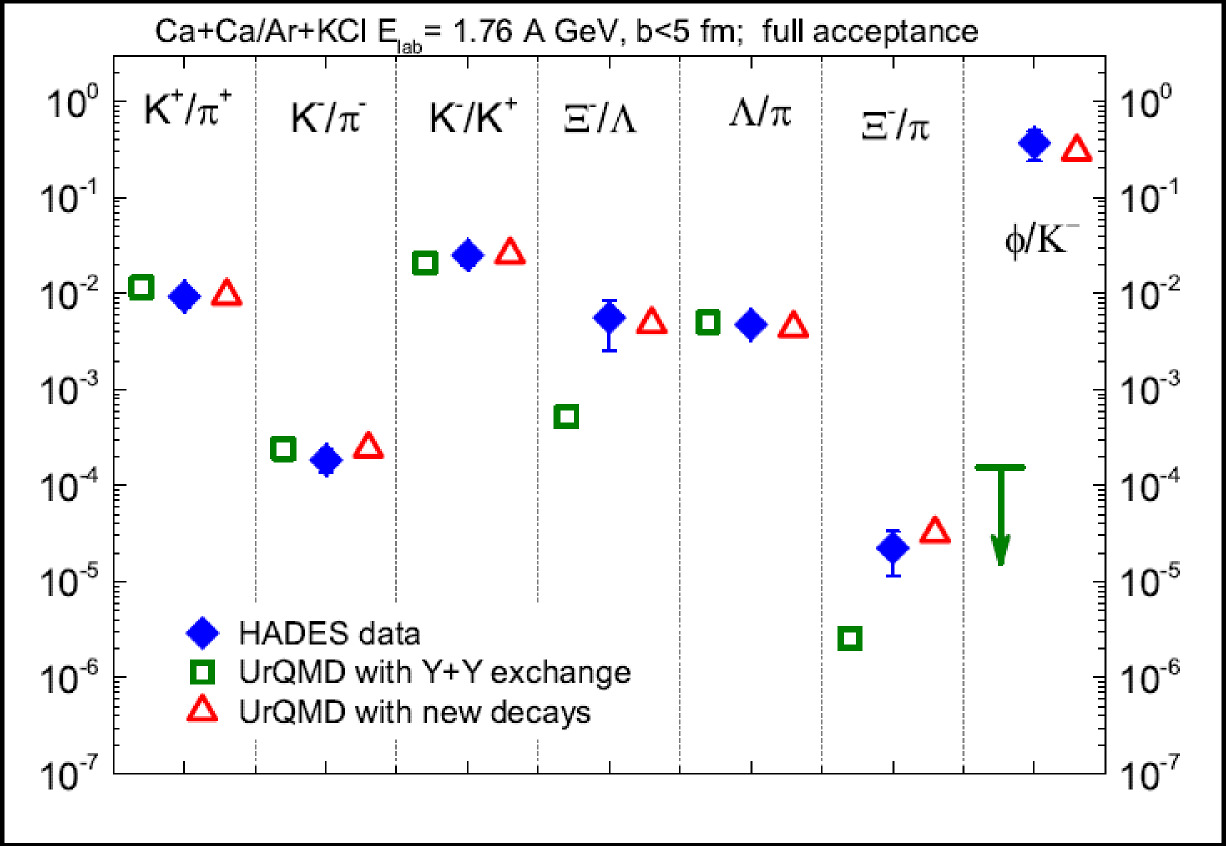
Subthreshold production via

$N^* \rightarrow N + \phi$

$N^* \rightarrow \Xi + K + K$

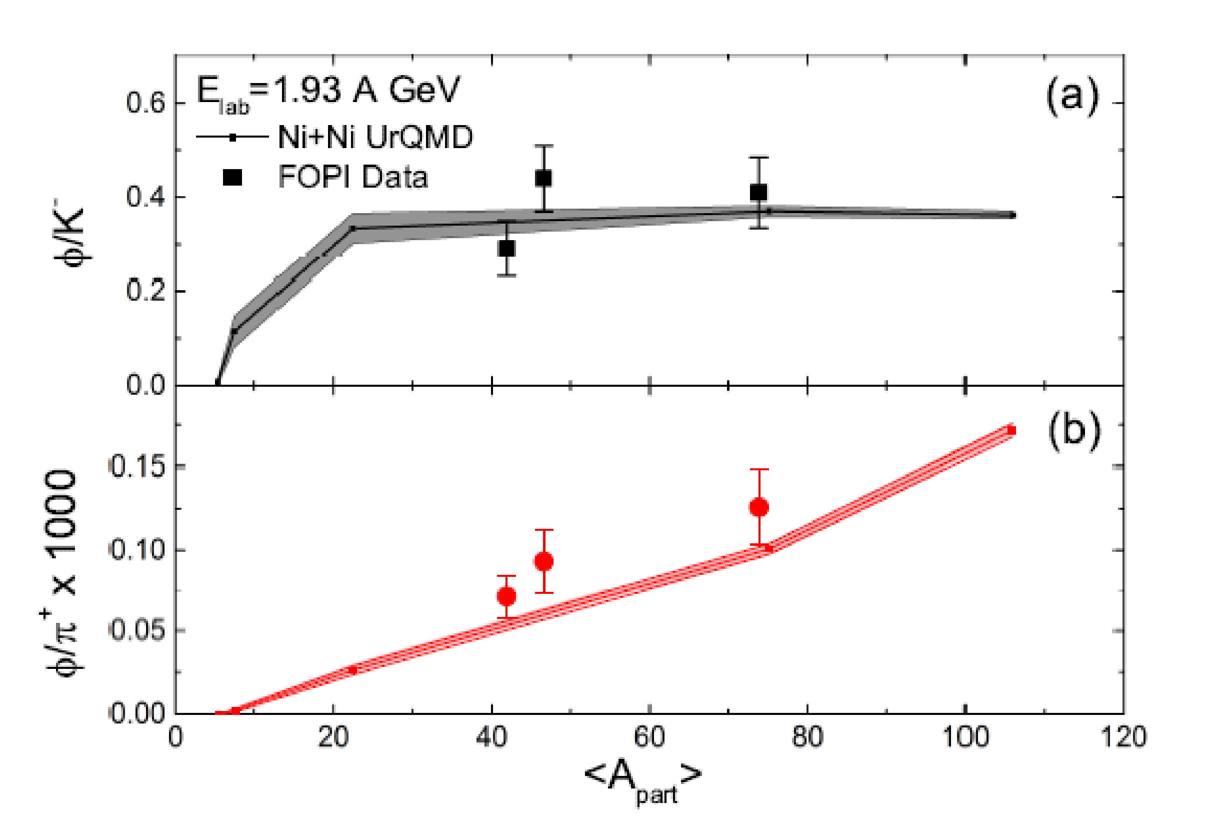
HADES data

Sub-threshold φ and Ξ⁻ production by high mass resonances with UrQMD
J. Steinheimer and M. Bleicher
arXiv:1503.07305v2 [nucl-th] 26 Nov 2015



FOPI data

Heavy baryonic resonances, multi strange hadrons and equilibration at SIS18 energies
J. Steinheimer, M. Lorenz, F. Becattini, R. Stock and M. Bleicher
arXiv:1603.02051v1 [nucl-th] 7 Mar 2016



Update of UrQMD

Sub-threshold charm production in nuclear collisions

J. Steinheimer, A. Botvina, M. Bleicher arXiv:1605.03439

Newly introduced baryonic resonances

Name	Mass [GeV]	Width [GeV]	Spin
N*(2600)	2.600	0.65	11/2
N*(2700)	2.700	0.40	13/2
N*(3100)	3.100	1.30	15/2
N*(3500)	3.500	1.30	17/2
N*(3800)	3.800	1.30	17/2
N*(4200)	4.200	1.30	19/2
Δ*(2420)	2.420	0.40	11/2
Δ*(2750)	2.750	0.40	13/2
Δ*(2950)	2.950	0.50	15/2
Δ*(3300)	3.300	1.00	17/2
Δ*(3500)	3.500	1.00	19/2
Δ*(3700)	3.700	1.00	19/2
Δ*(4200)	4.200	1.00	21/2

Subthreshold charm production via

$$N^* \rightarrow \Lambda_c + D$$
$$N^* \rightarrow N + J/\psi$$

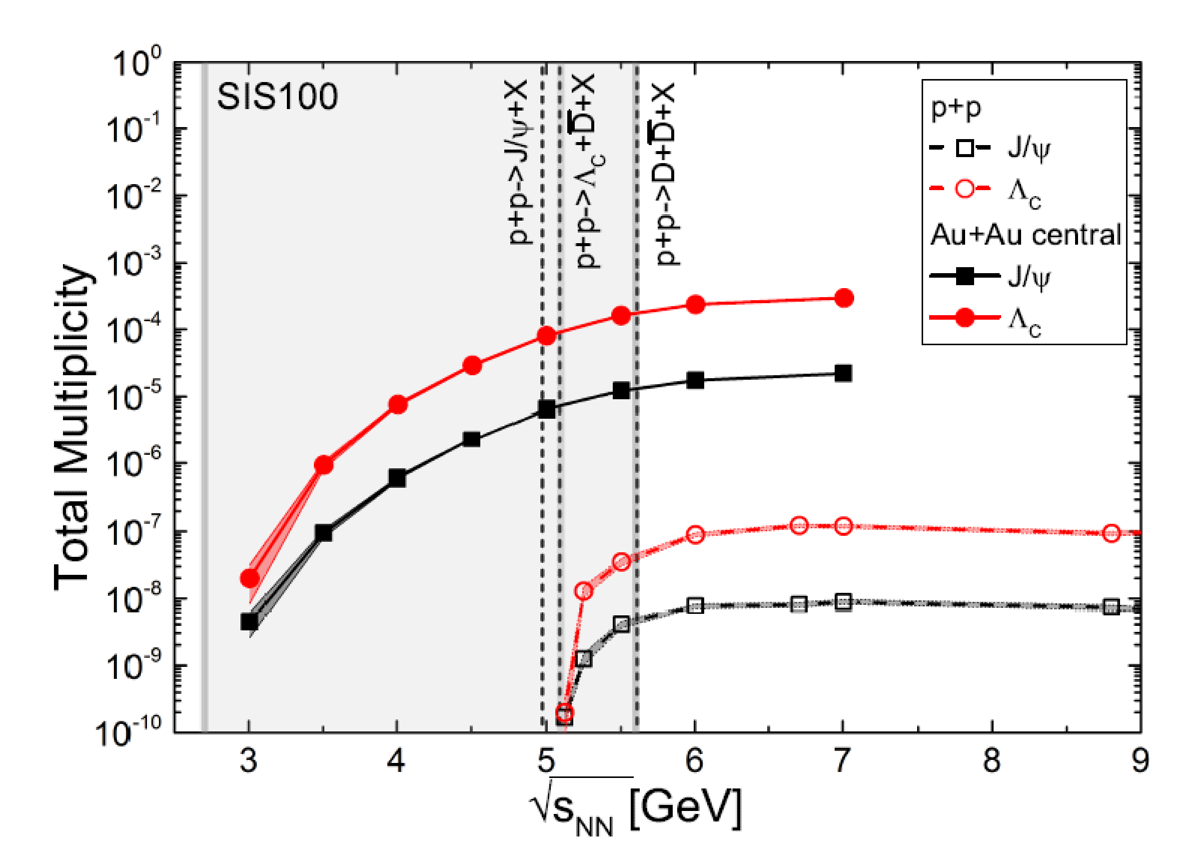
Note: does not (yet) include

- pair production $D + \bar{D}$
- charm pair production from string processes
- rescattering and absorption processes of the charmed hadrons in the hadronic medium

Charm subthreshold production

Subthreshold charm production via N* → Λ_c + D and N* → N +J/ψ

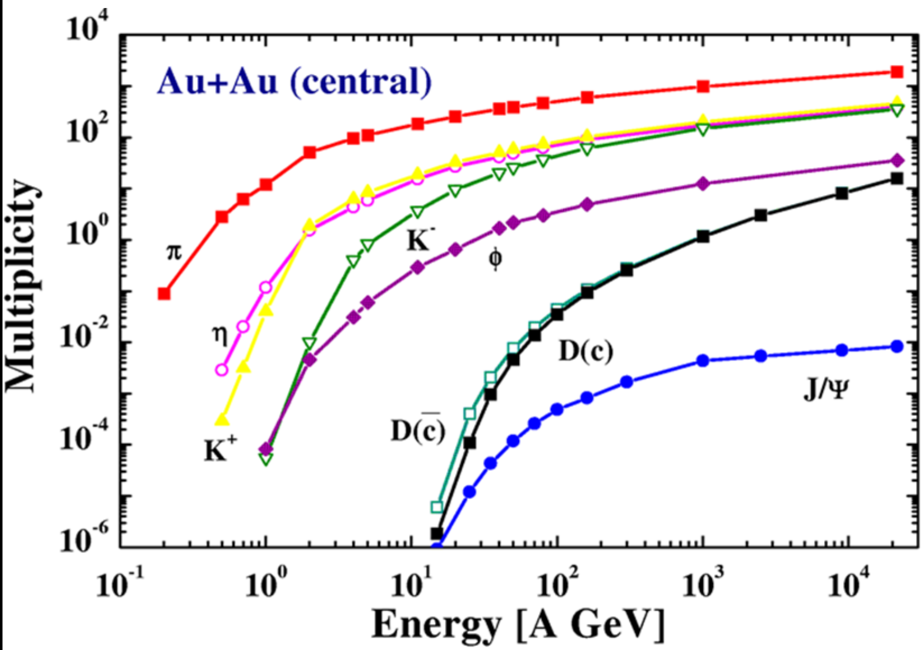
Sub-threshold charm production in nuclear collisions
J. Steinheimer, A. Botvina, M. Bleicher arXiv:1605.03439

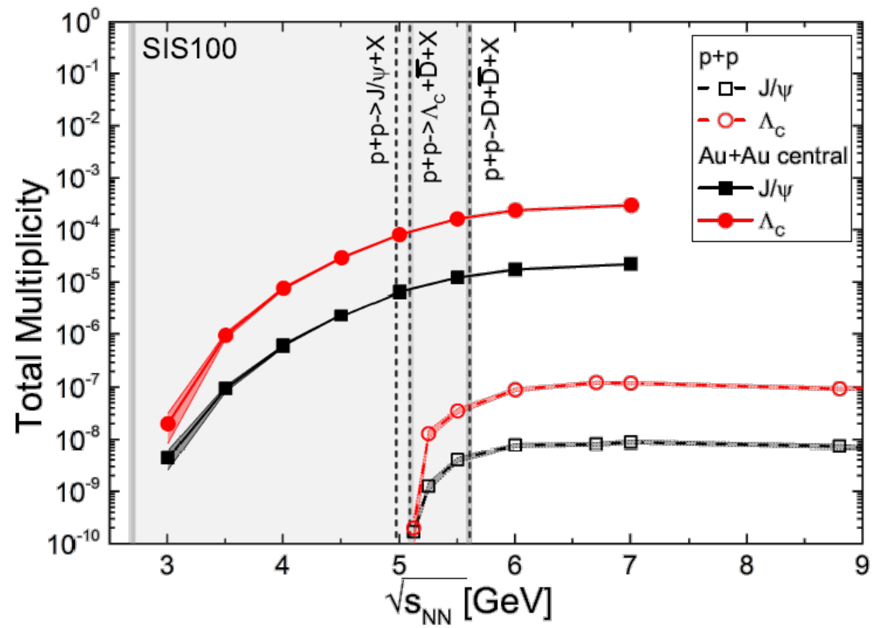


UrQMD vs. HSD

W. Cassing, E. Bratkovskaya, A. Sibirtsev
Nucl. Phys. A 691 (2001) 753

J. Steinheimer, A. Botvina, M. Bleicher
arXiv:1605.03439v1





HSD calculation

http://fias.uni-frankfurt.de/~phsd-project/HSD

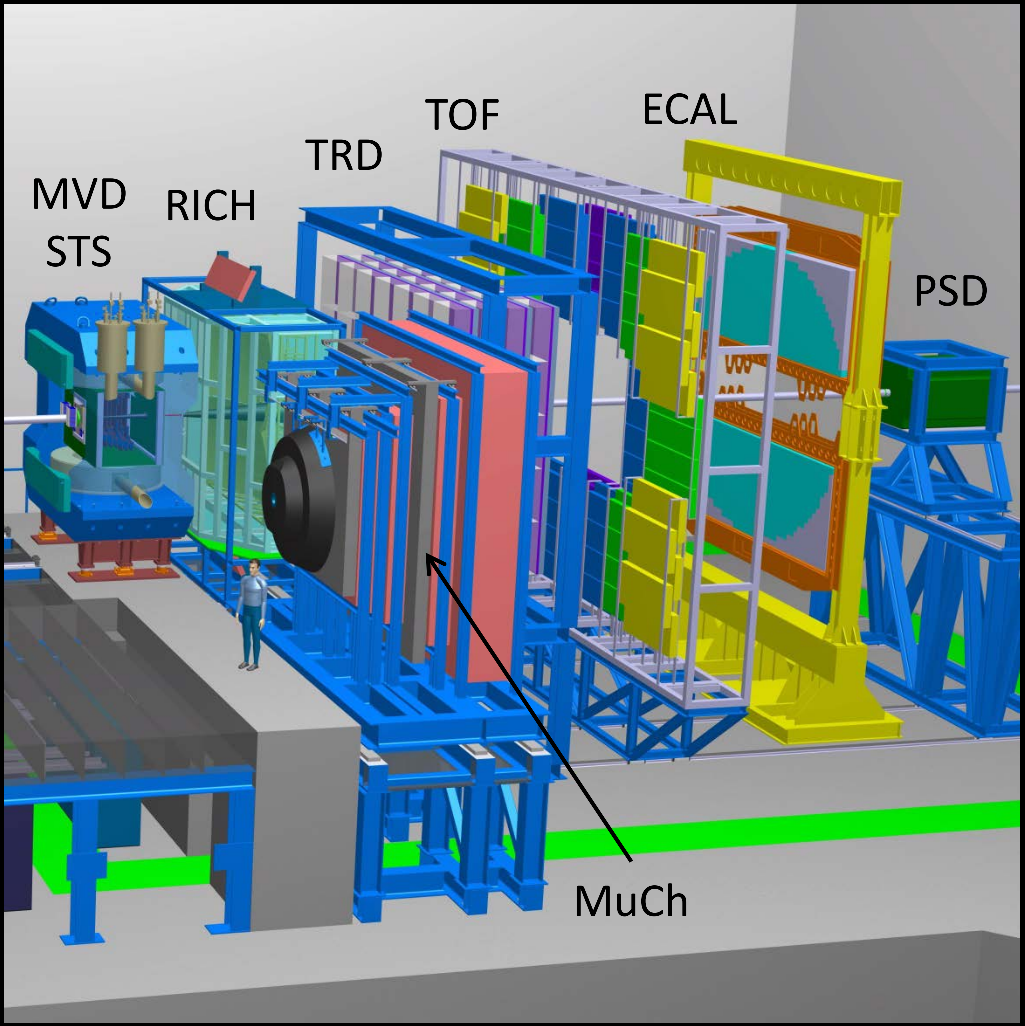
Central Au+Au collisions 10 A GeV : $M_{J/\psi} = \underline{1.7 \cdot 10^{-7}}$

UrQMD calculation
including subthreshold charm production via
$N^* \rightarrow \Lambda_c + D$ and $N^* \rightarrow N + J/\psi$

Central Au+Au collisions 10 A GeV: $M_{J/\psi} = \underline{5 \cdot 10^{-6}}$

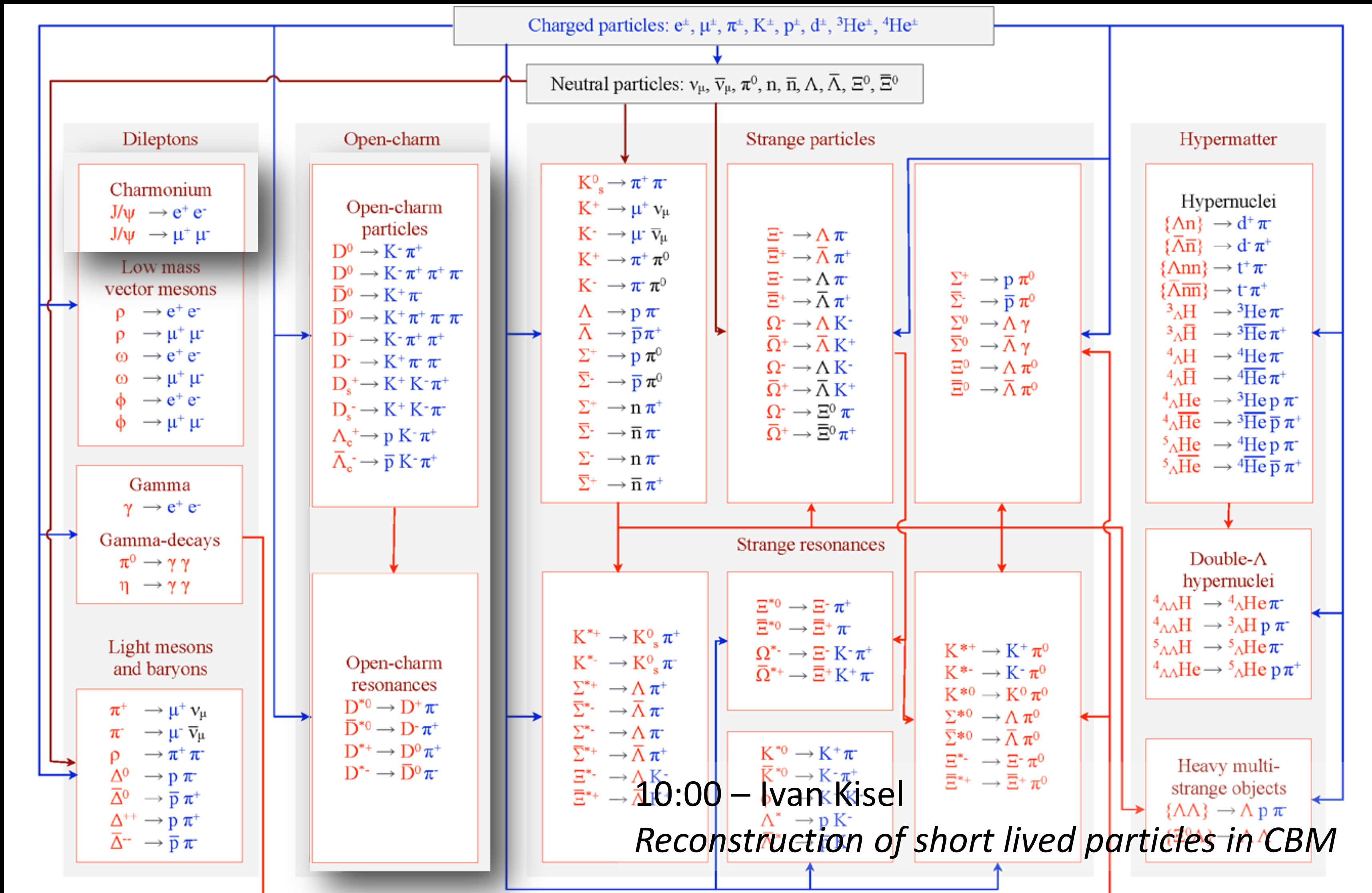
CBM detector

MVD
primary and secondary vertex reconstruction with high precision
STS
track, vertex and momentum reconstruction
***MuCh**
muon identification
RICH
electron identification
TRD
global tracking, electron identification
ToF
time-of-flight measurement and hadron identification
ECAL
electron and neutral particle identification
PSD
reaction plane and centrality determination



* *Muon Chamber system*

KFParticle package

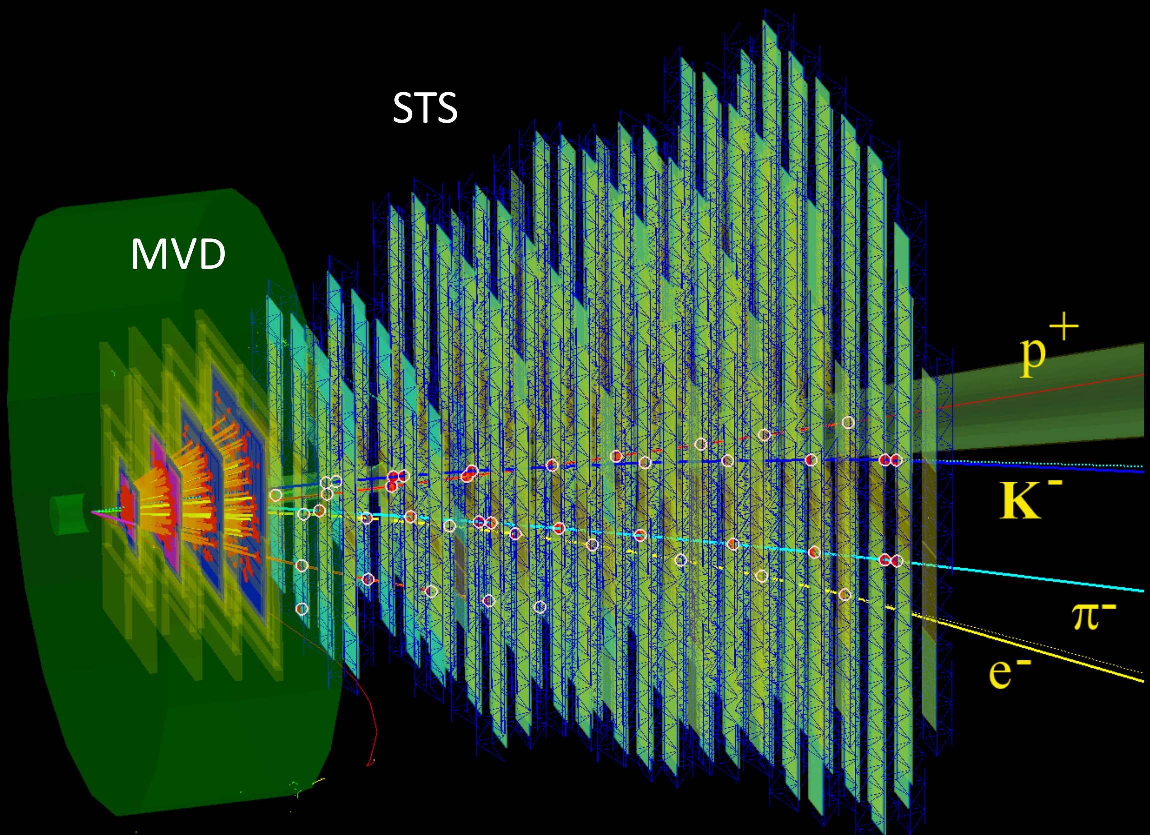


10:00 – Ivan Kisel

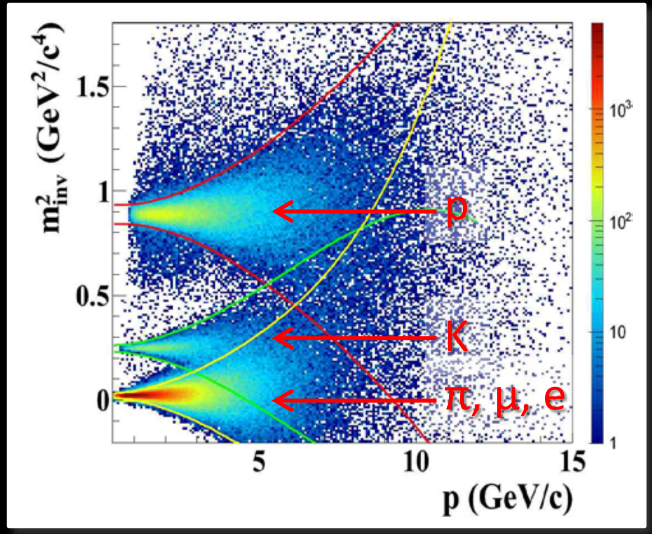
Reconstruction of short lived particles in CBM

D-meson setup

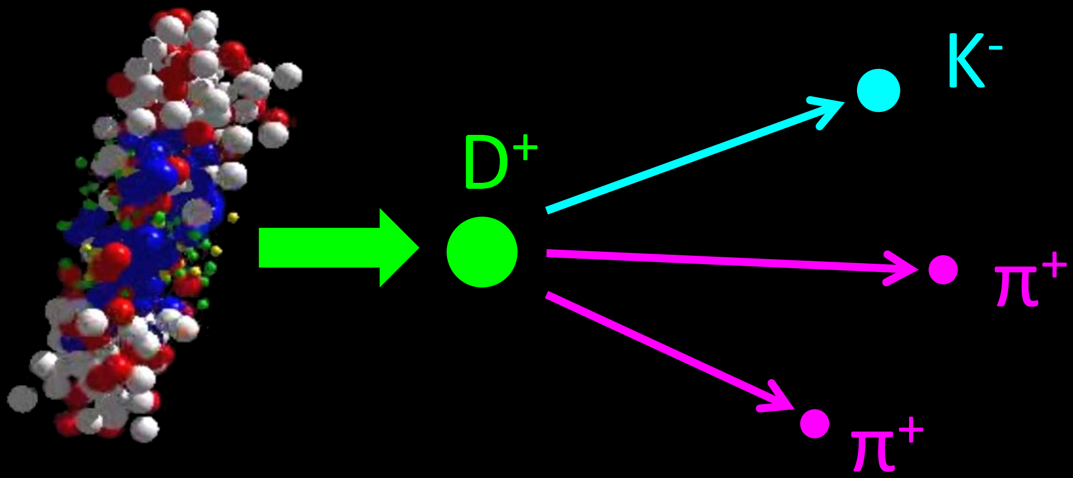
reconstructed tracks of 1 p+Ni collision @ 15 AGeV



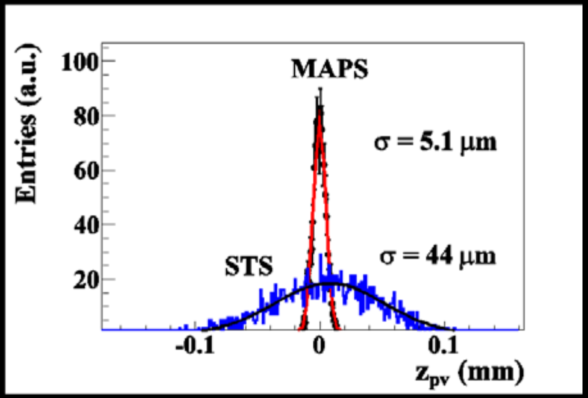
MVD
primary and secondary vertex reconstruction with high precision
STS
momentum reconstruction
ToF
hadron identification



D-meson reconstruction



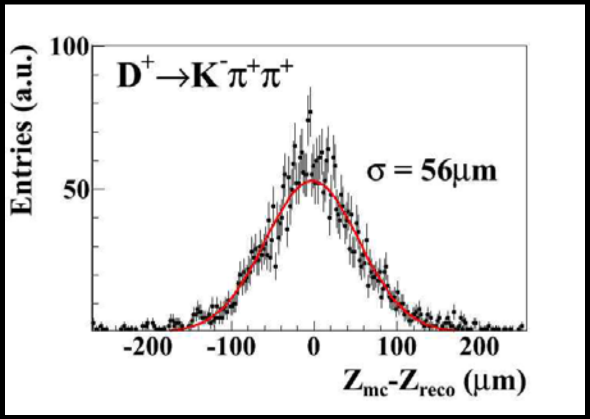
Precision of the primary vertex



Single track indentification:

- particle ID – ToF detector
- separation of primary and secondary particles (reconstruction of the primary vertex) – MVD + STS

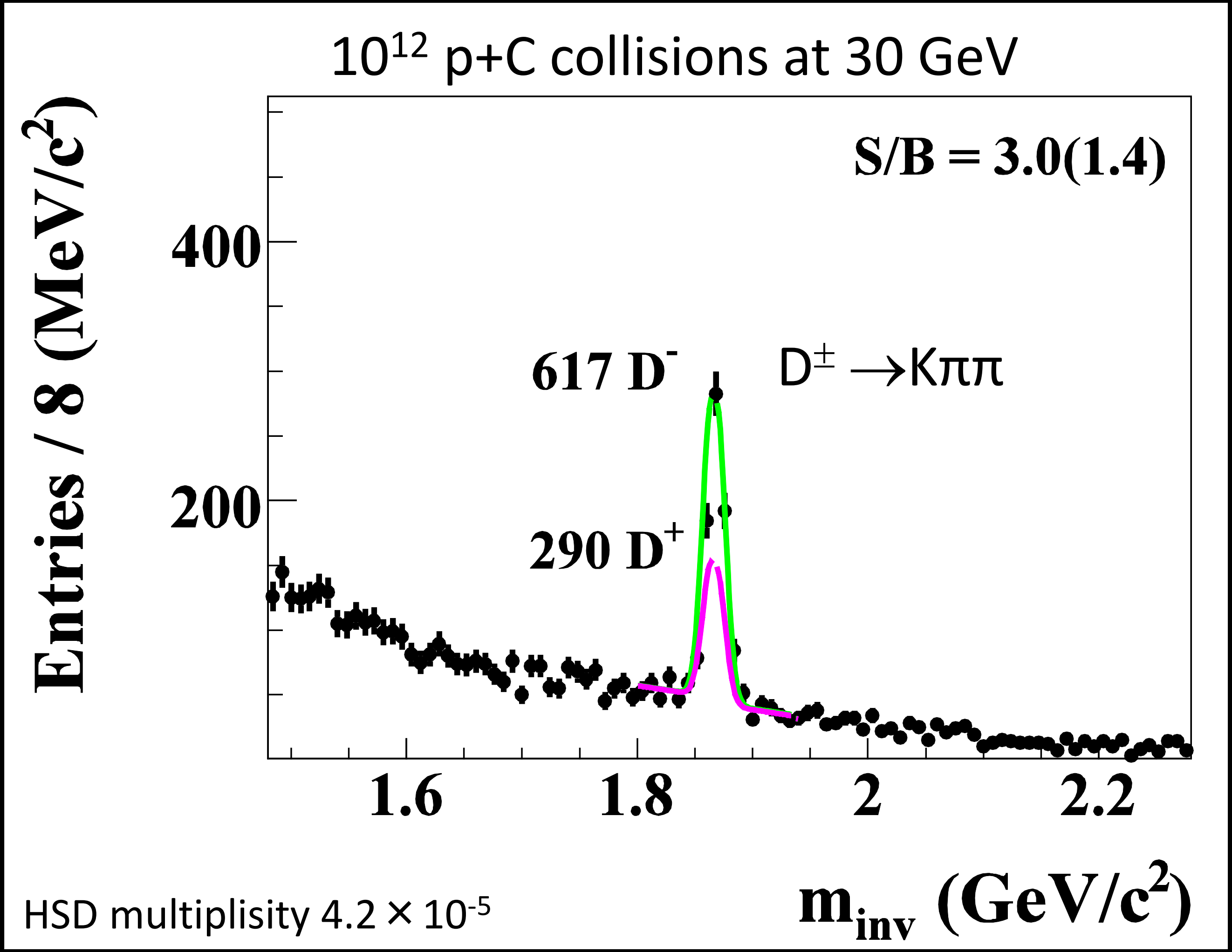
Precision of the secondary vertex



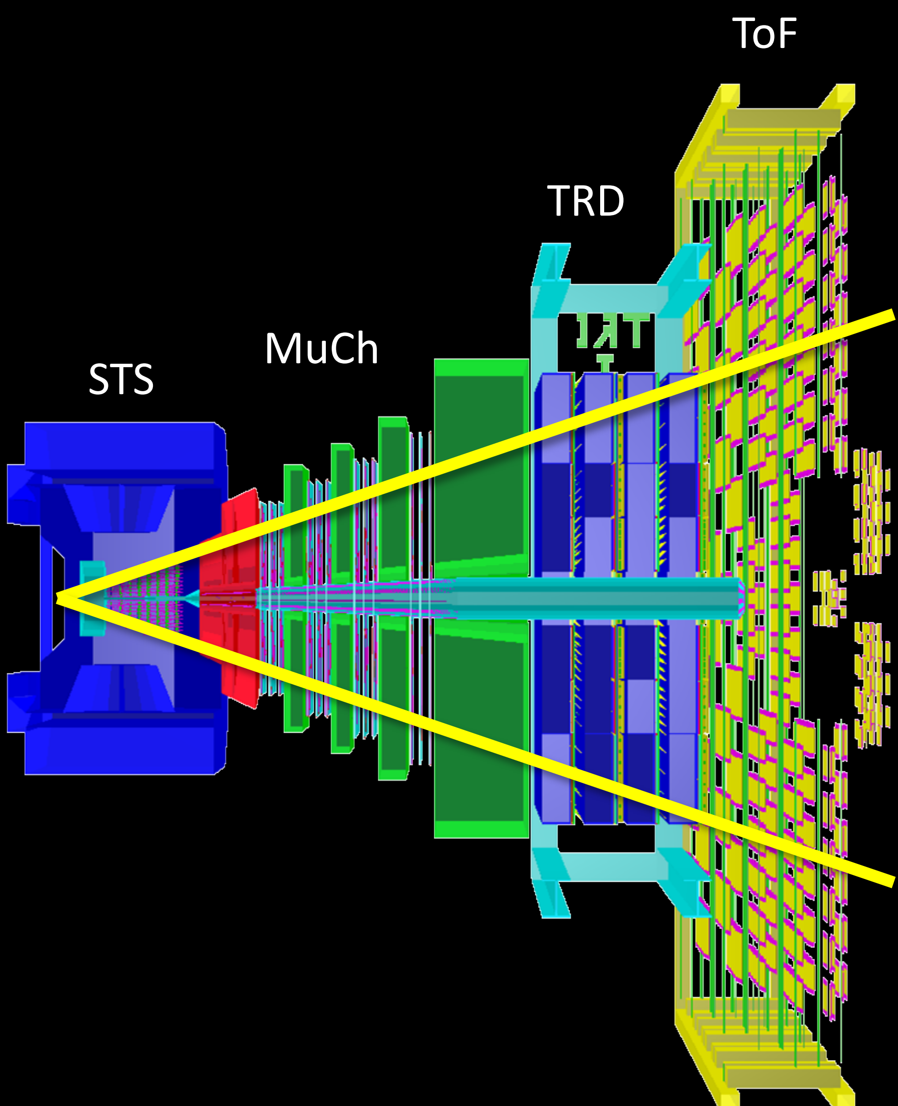
Decay chain reconstruction (KFParticle package):

- constrain of the secondary vertex and mother particle
- selection of the mother particles from the primary vertex

Simulation results



Muon setup



STS
track, vertex and momentum reconstruction

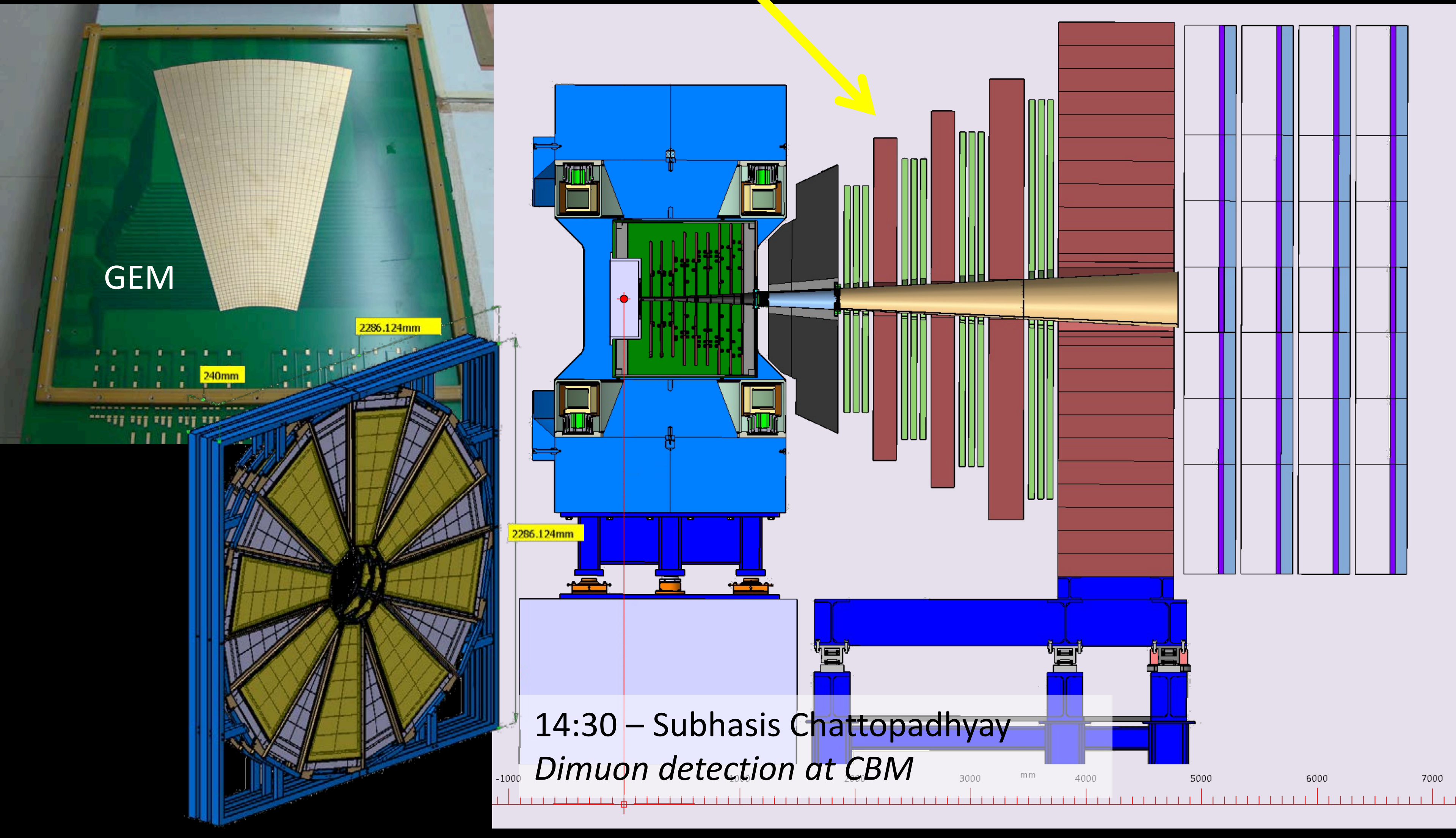
MuCh
muon identification

TRD
global tracking

ToF
time-of-flight measurement and particle identification

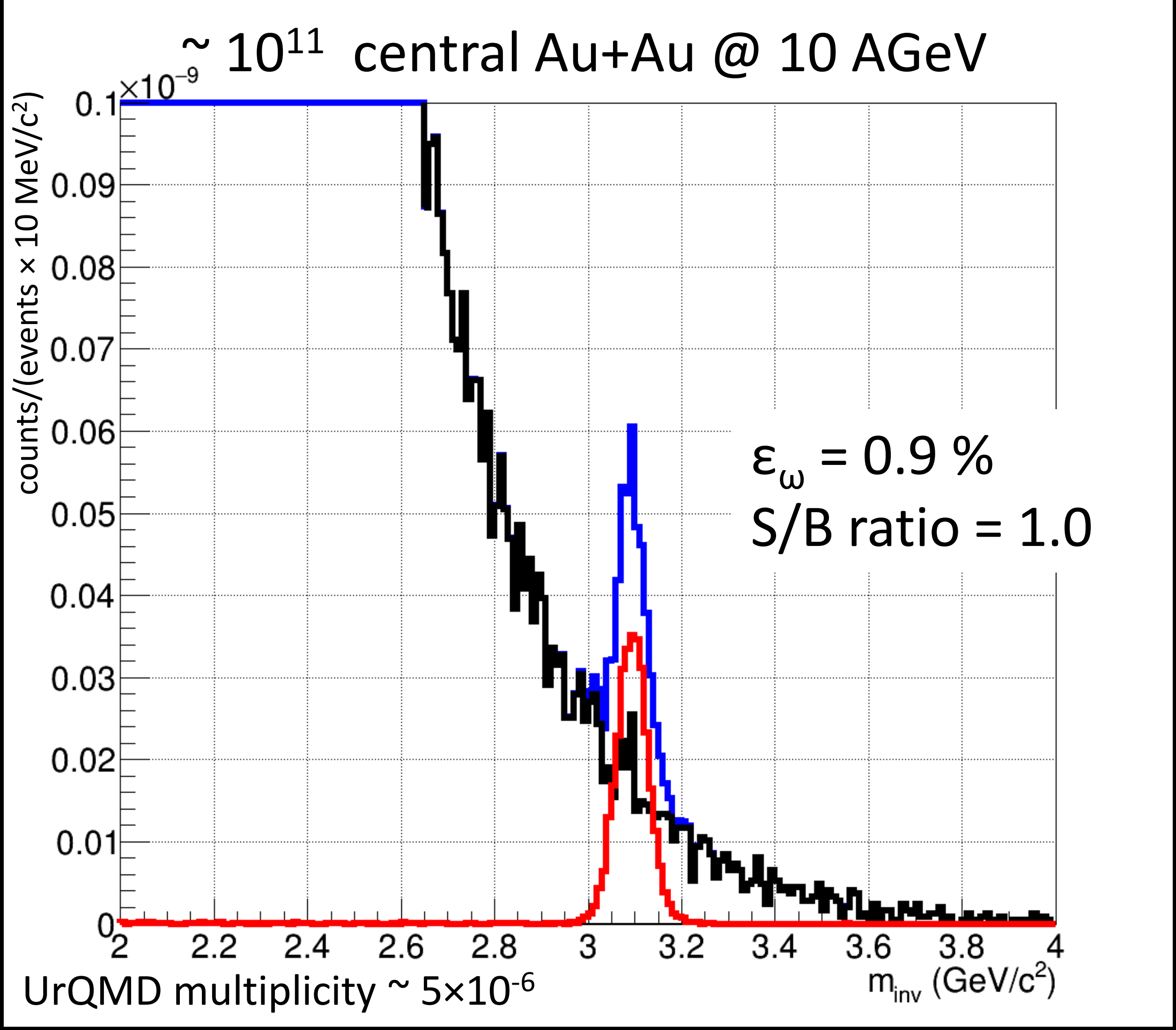
Muon reconstruction strategy:
primary tracks passing through STS, MuCh and TRD, and mass determination via TOF

MuCh system



14:30 – Subhasis Chattopadhyay
Dimuon detection at CBM

Simulation results



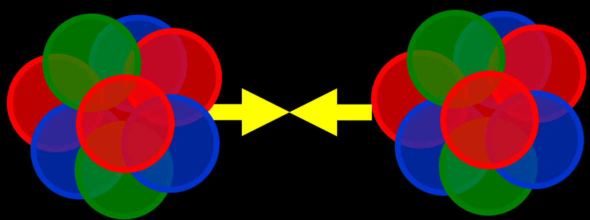
Conclusions

- CBM will provide first data on (open and hidden) charm production at beam energies close to the production threshold
- Measurement of production cross sections in p+p collisions
- Measurement of could nuclear matter effects on charm production in p+A collisions
- Measurements of charmonium as a probe of the hot medium in A+A collisions
- Important: Measurement of D mesons and J/ψ under the same conditions

BACKUP

Quarkonium measurements

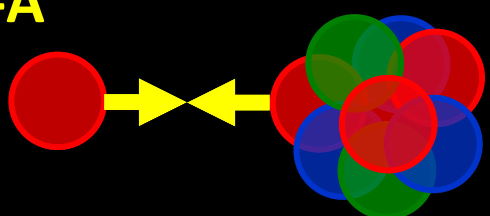
A-A



Quarkonium as a probe of the hot medium created in the collision (QGP)

Suppression vs regeneration

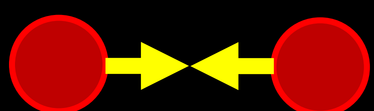
p-A



Investigation of cold nuclear matter effects (shadowing, energy loss…)

Crucial tool to disentangle genuine QGP effect is AA collisions

p-p



Reference process to understand behaviour in pA, AA collisions

Useful to investigate production mechanisms