CETHENP 2022

15-17 November 2022

Strange particle production in hybrid UrQMD model for various particlization scenarios

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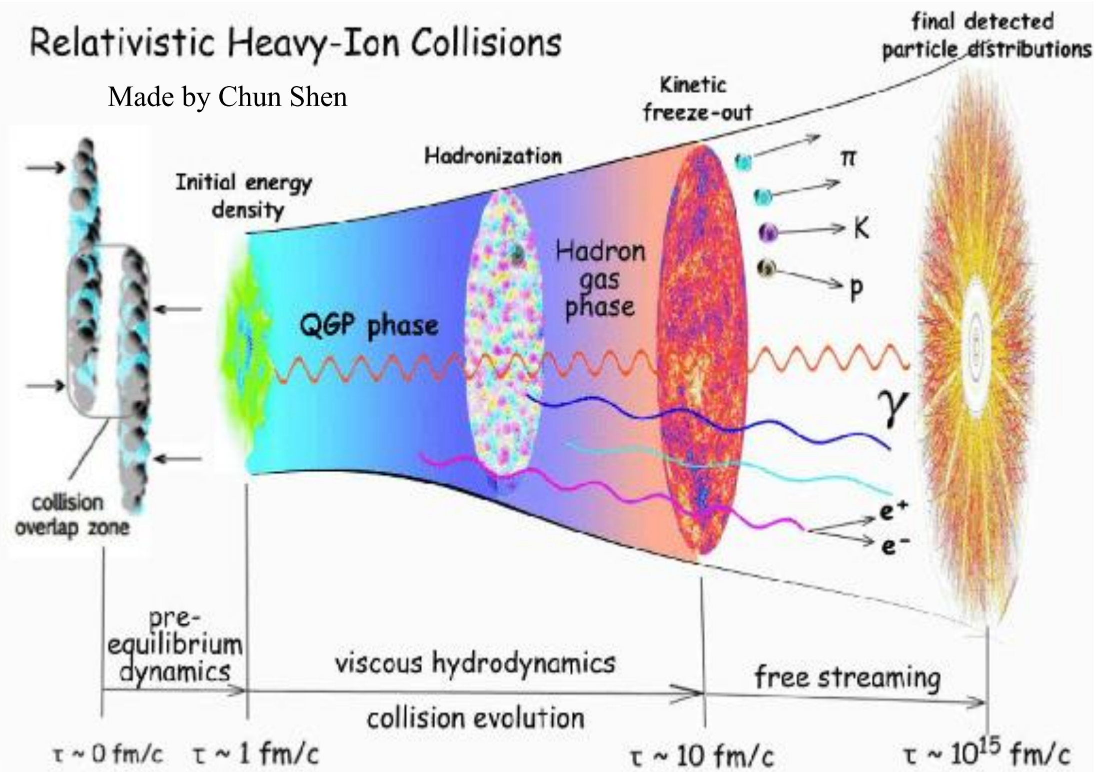
Outline:

- Motivation
- Model Description
- Different freeze-out prescriptions
- Results
- Summary

Motivation:



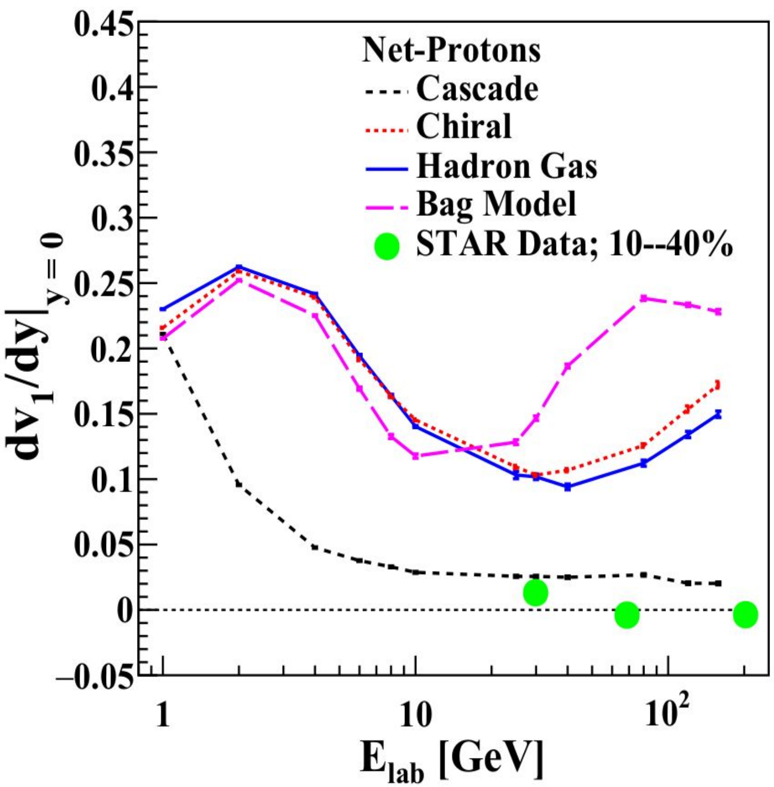
- Relativistic heavy ion collision produces a hot and dense fireball.
- Expansion of hot and dense fireball can be governed by EoS: crucial input to the hydrodynamic simulations.
- Hydrodynamic evolution followed by hadronization and then freeze-out: various prescriptions are available to mimic the real scenario.

- Strange particle production is sensitive to the QCD medium → Strangeness enhancement : A signature of QGP
- To study the impact of different EoS and freeze-out (particlization) models on strange particle production.

Model Description:

Phys. Rev. C 104 (2021) no.2, 024907

- Ultra-relativistic Quantum Molecular Dynamics (UrQMD) model in hybrid mode is used.
- Hybrid mode includes cascade + EoS.
- Three different EoS available:
  - Hadron Gas EoS (Mimics purely hadronic medium)
  - Bag Model EoS (Incorporates a first order phase transition between confined hadronic phase and deconfined partonic phase)
  - Chiral EoS (A smooth crossover transition between hadronic phase to QGP)



- Different variants of the UrQMD model, namely the pure transport(cascade) mode and the hybrid mode have been compared for Au–Au collision in mid-central (about 10-40% central) region for the beam energy range E_{lab} = 1A-158A GeV.

Different freeze-out (fluid to particle transition) prescriptions:

Each hydrodynamical approach can be functioned by three different particlization models available in UrQMD:

1. **Gradual Freezeout (GF):** 0.2 fm thick transverse slices are particlized when energy density in all cells of each individual slice drops below the critical value (~730 MeV/fm^3).
2. **Isochronous Freezeout (ICF):** All hydrodynamic cells are mapped onto particles at the same time, provided the energy density drops below the critical value (~730 MeV/fm^3) in all cells.
3. **Iso-Energy density Freezeout (IEF):** The energy density hypersurface is constructed numerically using Cornelius routine (*Eur. Phys. J. A* **48,** 171 (2012)). Individual cells are mapped onto particles, provided the energy density drops below the assigned critical value.

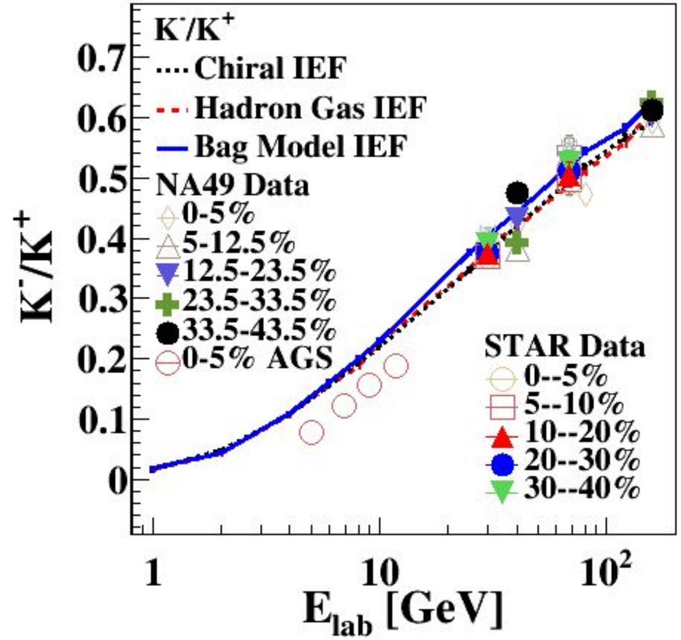
Observables and Motivations:

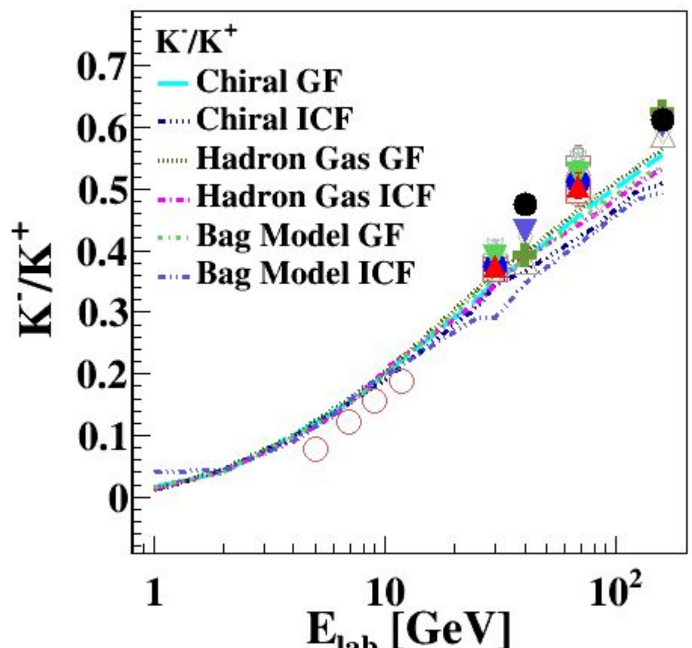
1. Particle ratio for strange anti-meson to meson (K^-/K^+), Strange anti-baryon to baryon ($\bar{\Lambda}/\Lambda$), strange to non-strange meson (K^-/π^-, K^+/π^+), strange to non-strange baryon (Λ/p, $\bar{\Lambda}/\bar{p}$), strange baryon to meson ($\bar{\Lambda}/K^-$).
2. Validation of coalescence sum rule.
3. Possibly sensitive to different freeze-out criteria.
4. Au–Au collisions in mid-central (about 10-40% central) region for the beam energy range E_{lab} = 20A-158A GeV.

Results-

Strange to anti-strange meson ratio:

- Similar results with all EoS irrespective of particlization scenario.
- However, IEF gives slightly better comparison.
- Expect negligible effect of core-corona separation → because of the ratio.

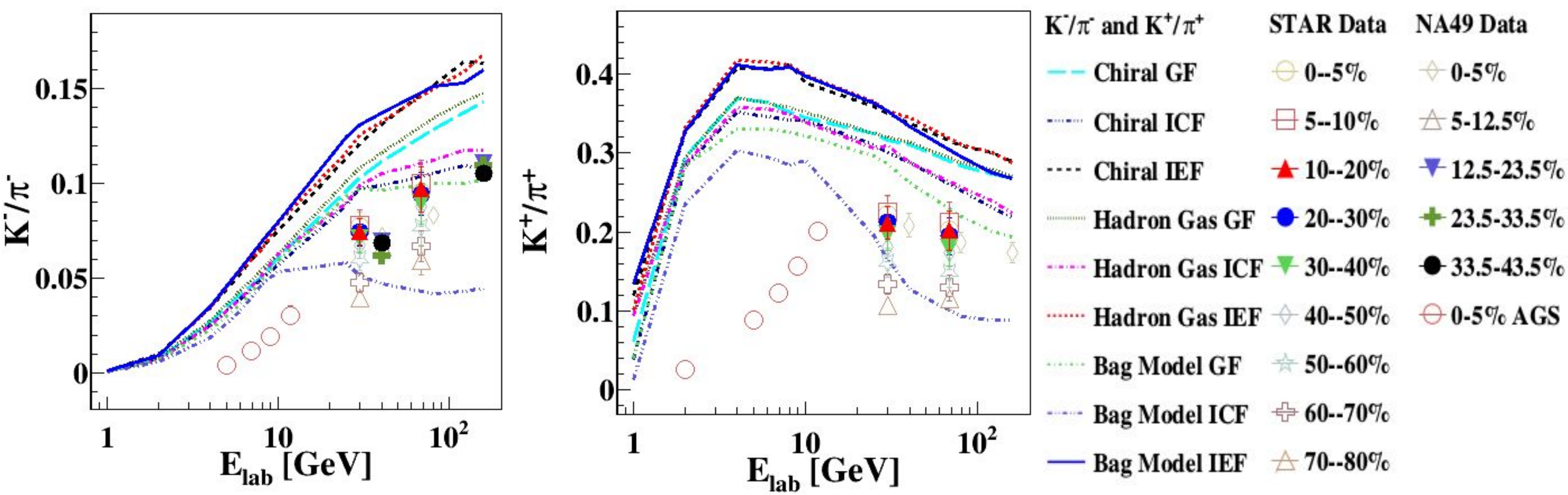




Results-

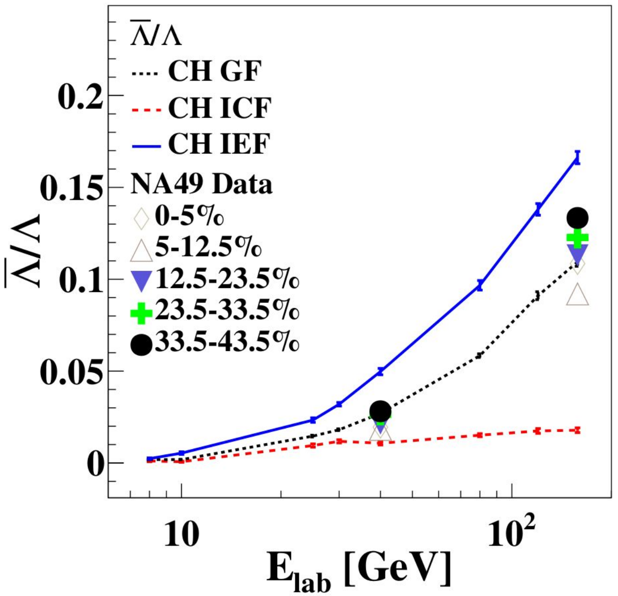
Strange to non-strange meson ratio:

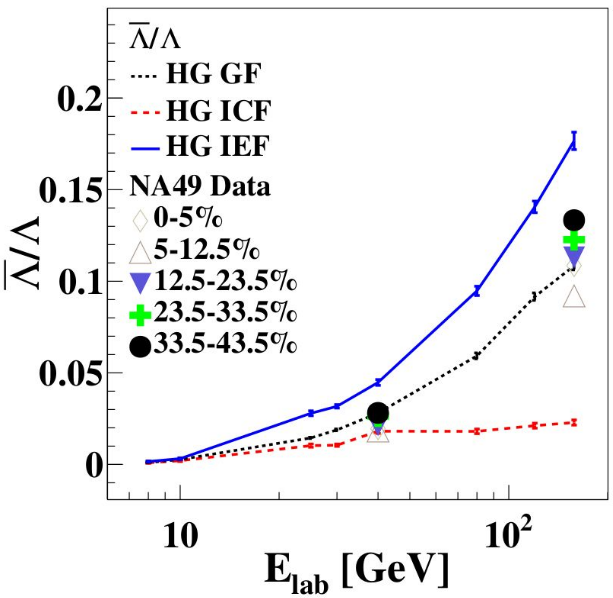
- Sensitive to the different particlization scenarios as expected.
- IEF results are able to reproduce the trend of the data for all three EoS.
- May have some effect of core-corona separation → Need to check.

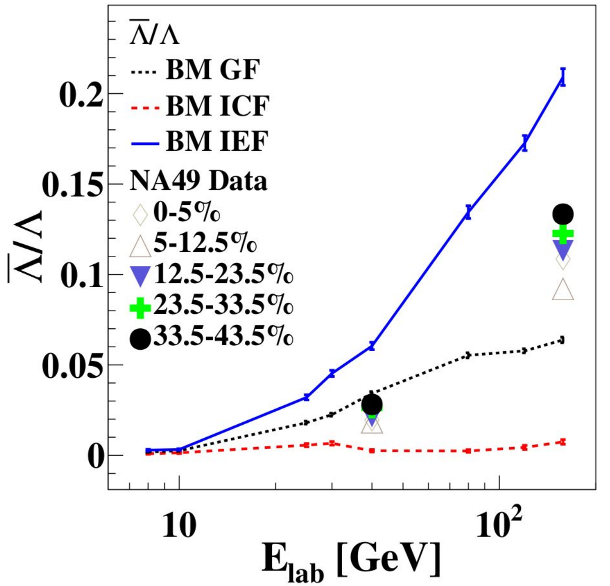


Results- Strange anti-baryon to baryon ratio:

- Almost same results with chiral and hadron gas EoS irrespective of particlization scenario.
- GF and IEF forms lower and upper bound respectively in all EoS → measurements lie on lower edge.
- Slightly wider range of the bound in Bag model.
- ICF: Not practical results observed.
- Expect negligible effect of core-corona separation → because of the ratio.







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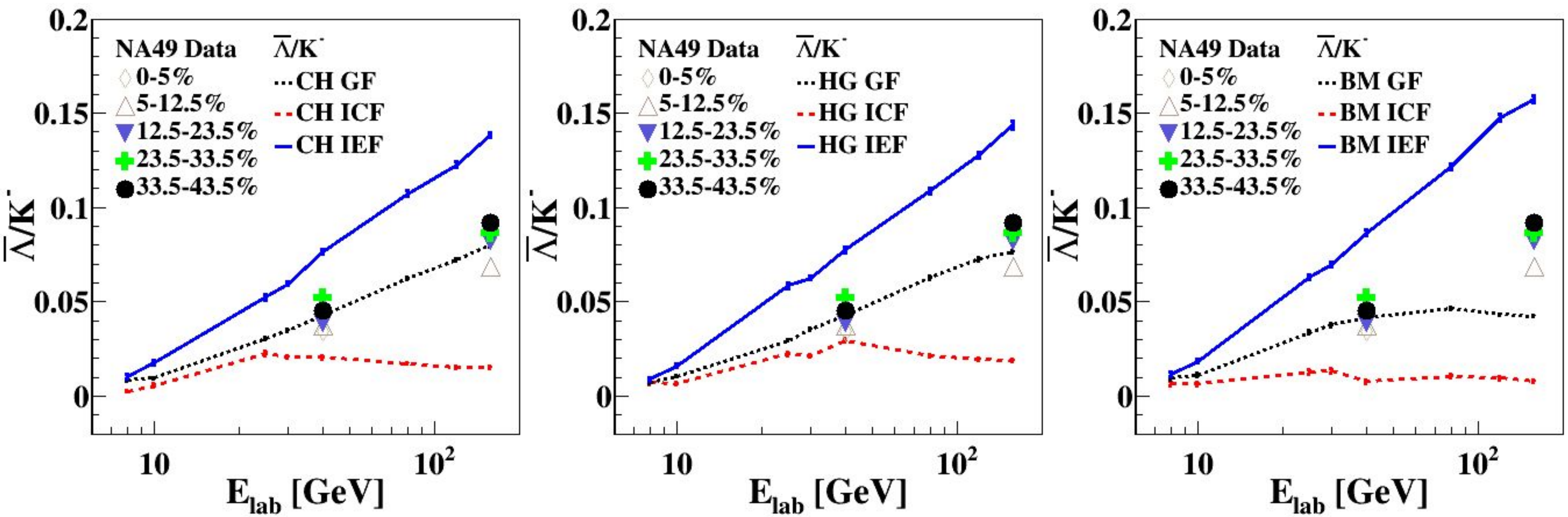
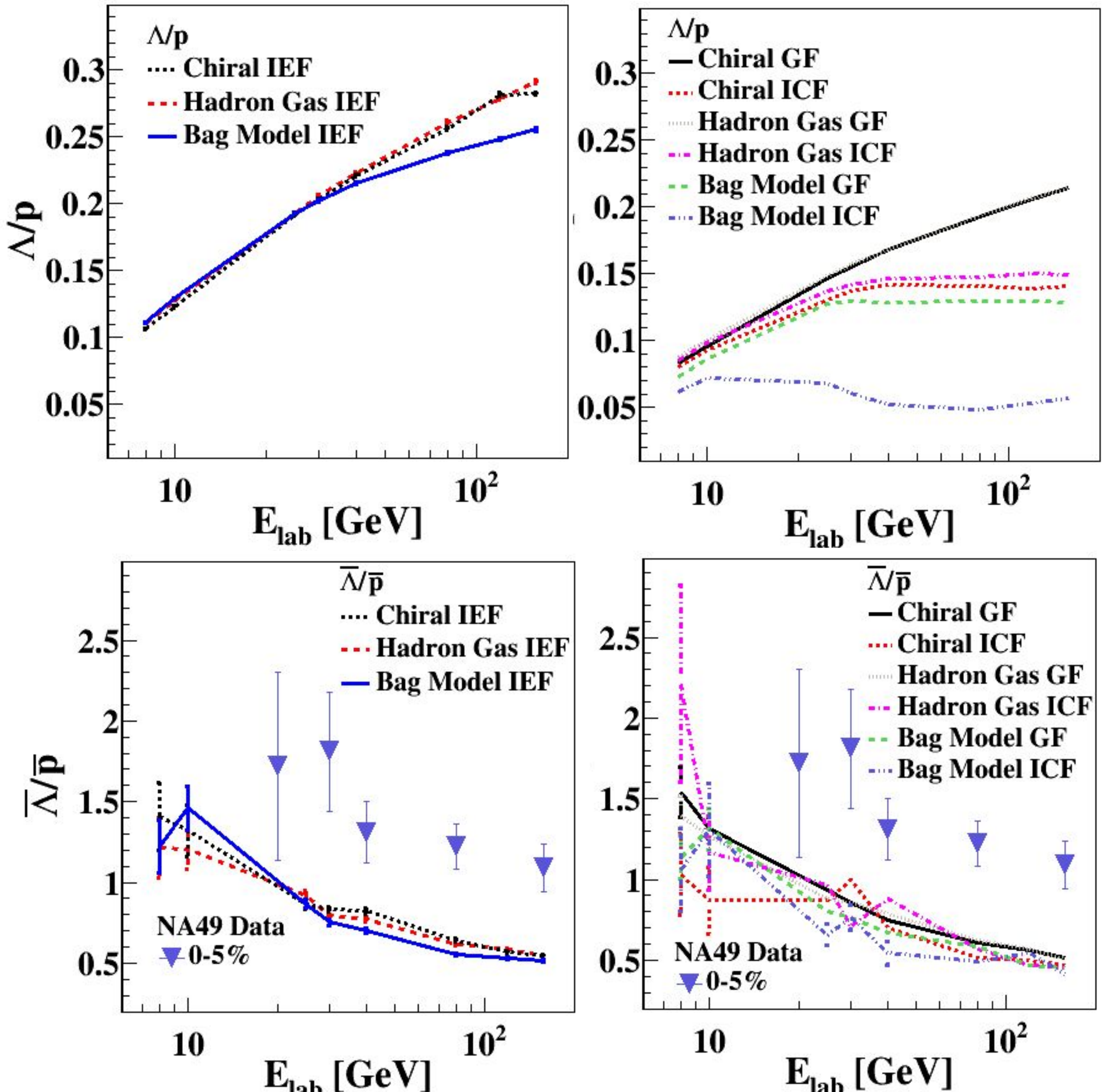


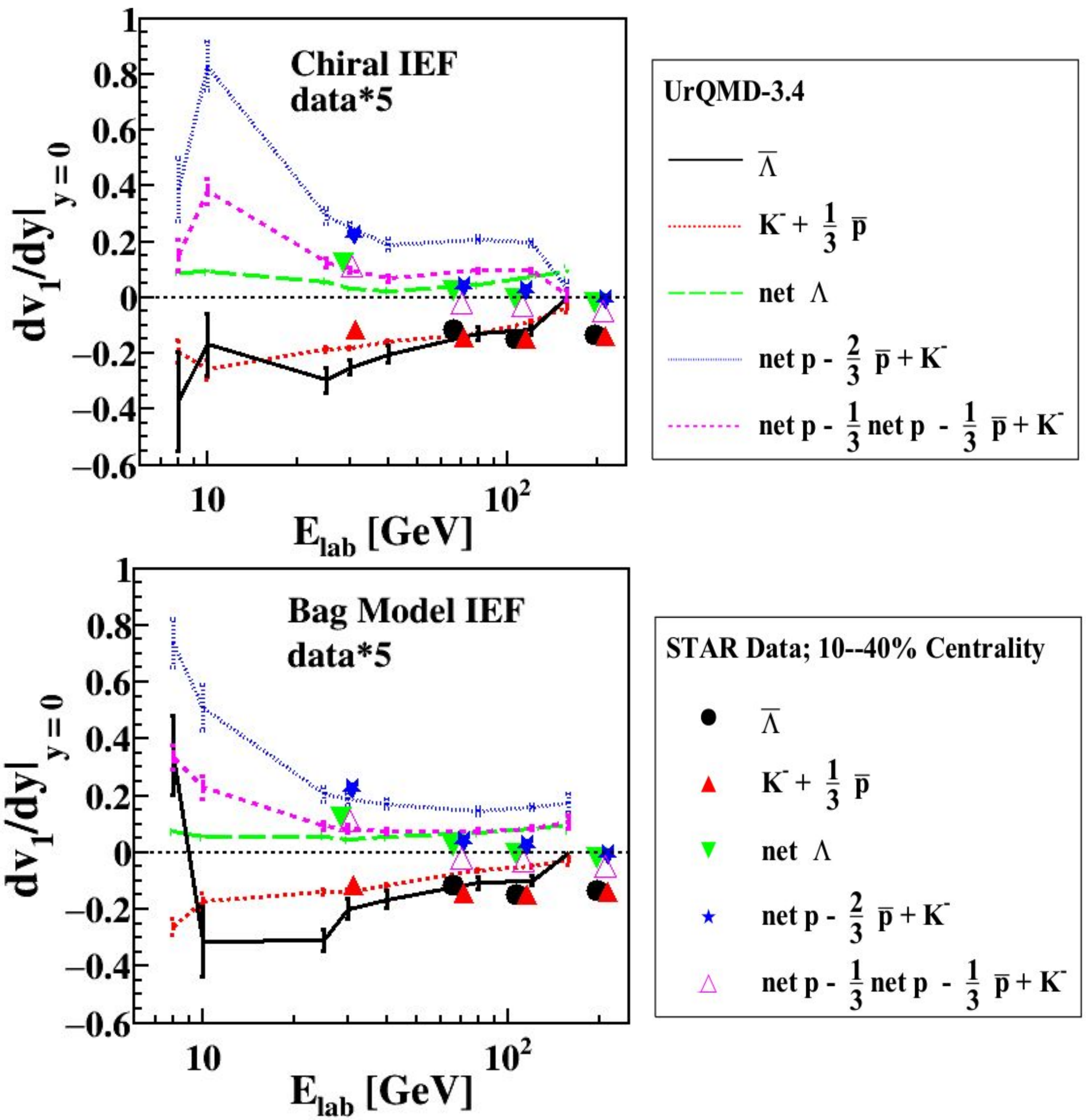
Results-

Strange to non-strange baryon ratio:

- Lambda to proton ratio: IEF shows spilling around ~ 30 GeV.
- GF and ICF: ratio becomes flat at higher energies.
- Anti-lambda to anti-proton ratio: Seems insensitive to the EoS and freeze-out scenarios.



Results- Slope of directed flow:



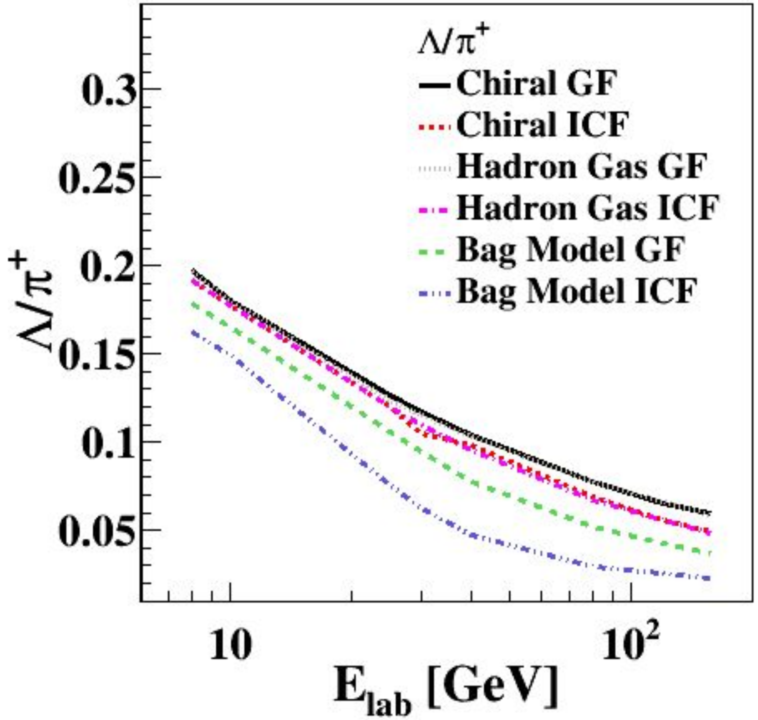
- Qualitative reproduction of the trend in experimental measurements.
- No significant difference is found with different particlization scenario.

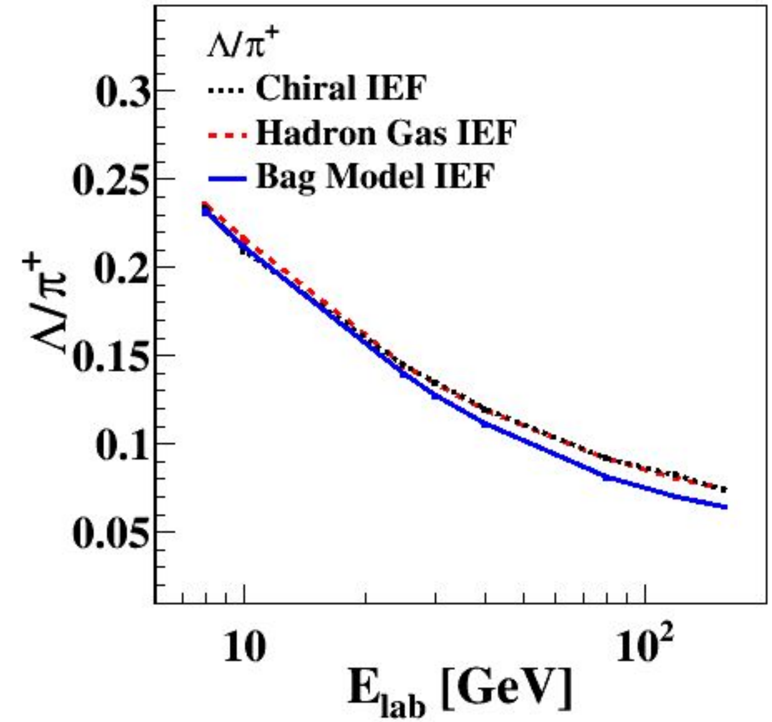
Summary and Outlook:

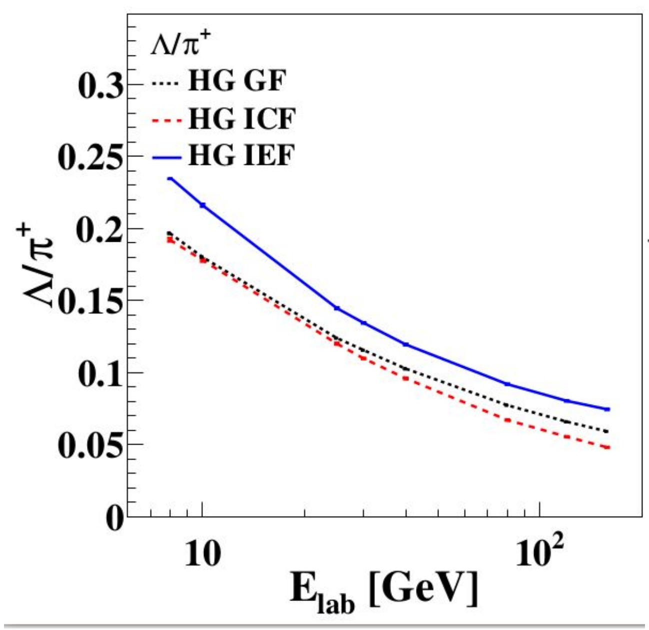
- Strange particle production in non-central nucleus-nucleus collisions is studied for different particlization model and EoS using UrQMD model.
- The results were compared with experimental measurements wherever available.
- Negligible effect of core-corona separation is expected in ratio of similar species, however, effect seen in ratio of different species.
- This study may help in addressing the shortcomings of the model.
- Σ and Ξ will be explored in future with higher statistics.

Thank You

Backup


Λ/π+
Chiral GF
Chiral ICF
Hadron Gas GF
Hadron Gas ICF
Bag Model GF
Bag Model ICF
Λ/π+
0.3
0.25
0.2
0.15
0.1
0.05
10
10^2
E_lab [GeV]


Λ/π+
Chiral IEF
Hadron Gas IEF
Bag Model IEF
Λ/π+
0.3
0.25
0.2
0.15
0.1
0.05
10
10^2
E_lab [GeV]


Λ/π+
HG GF
HG ICF
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0.3
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0
10
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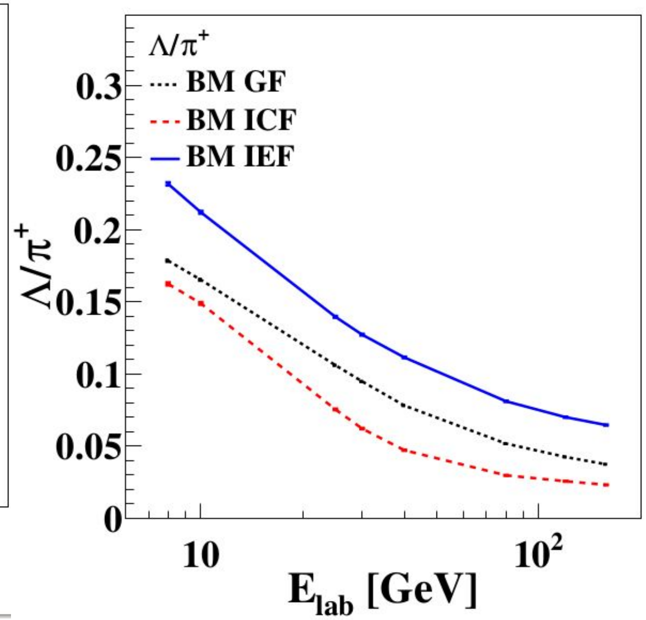
Λ/π+
BM GF
BM ICF
BM IEF
Λ/π+
0.3
0.25
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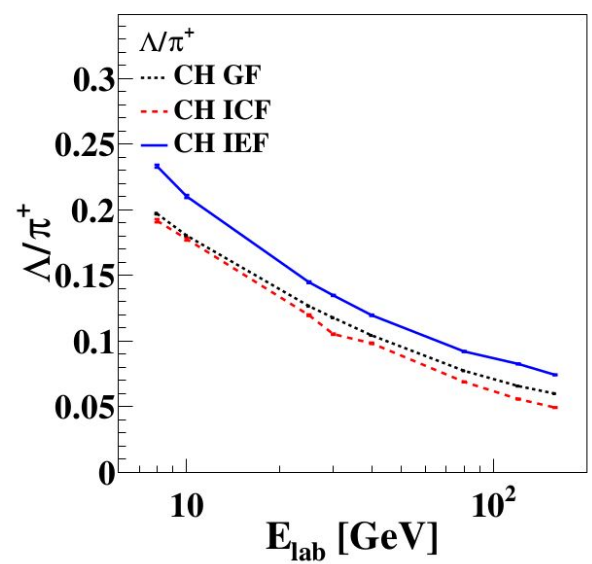
10
10^2
E_lab [GeV]


Λ/π+
CH GF
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0.3
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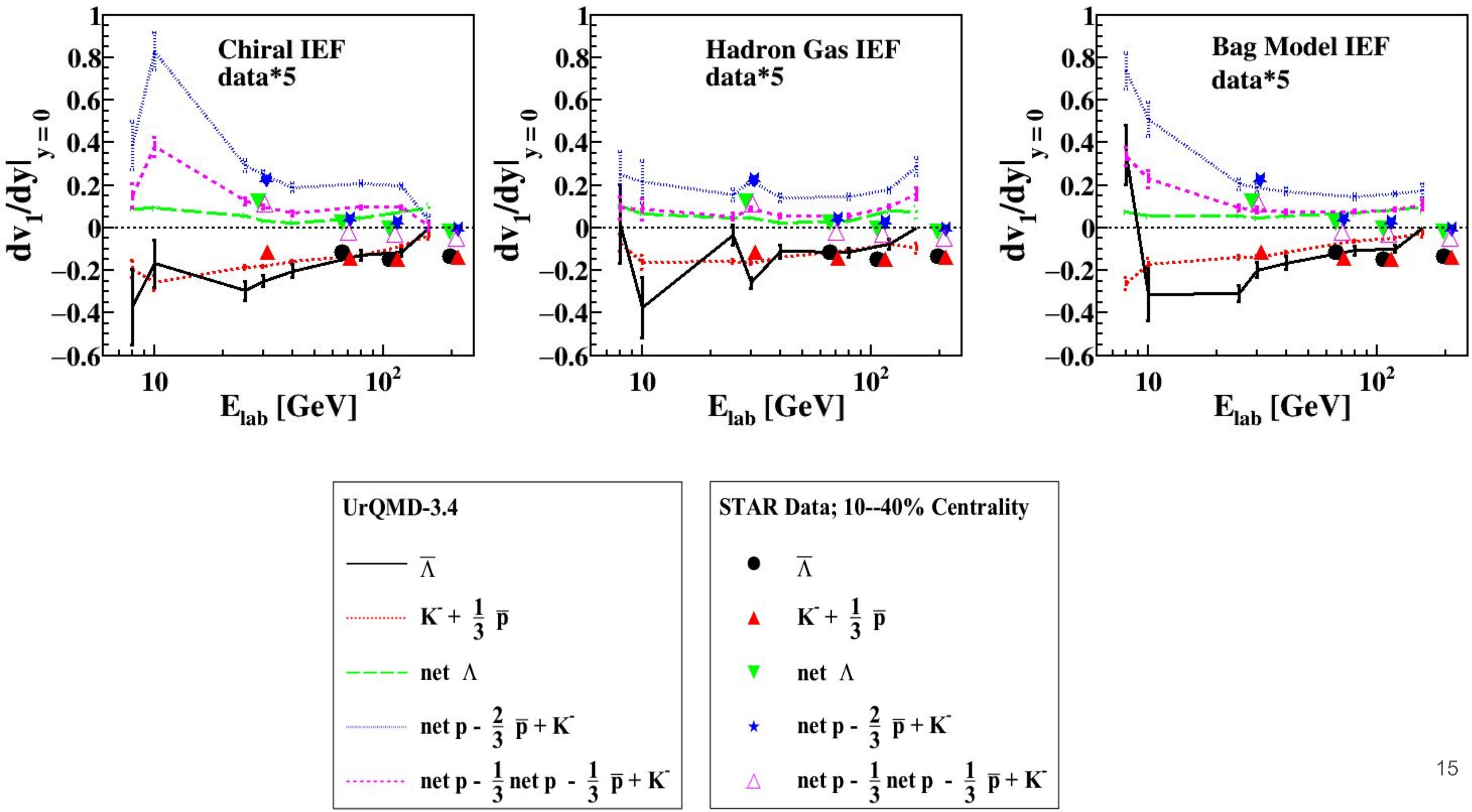
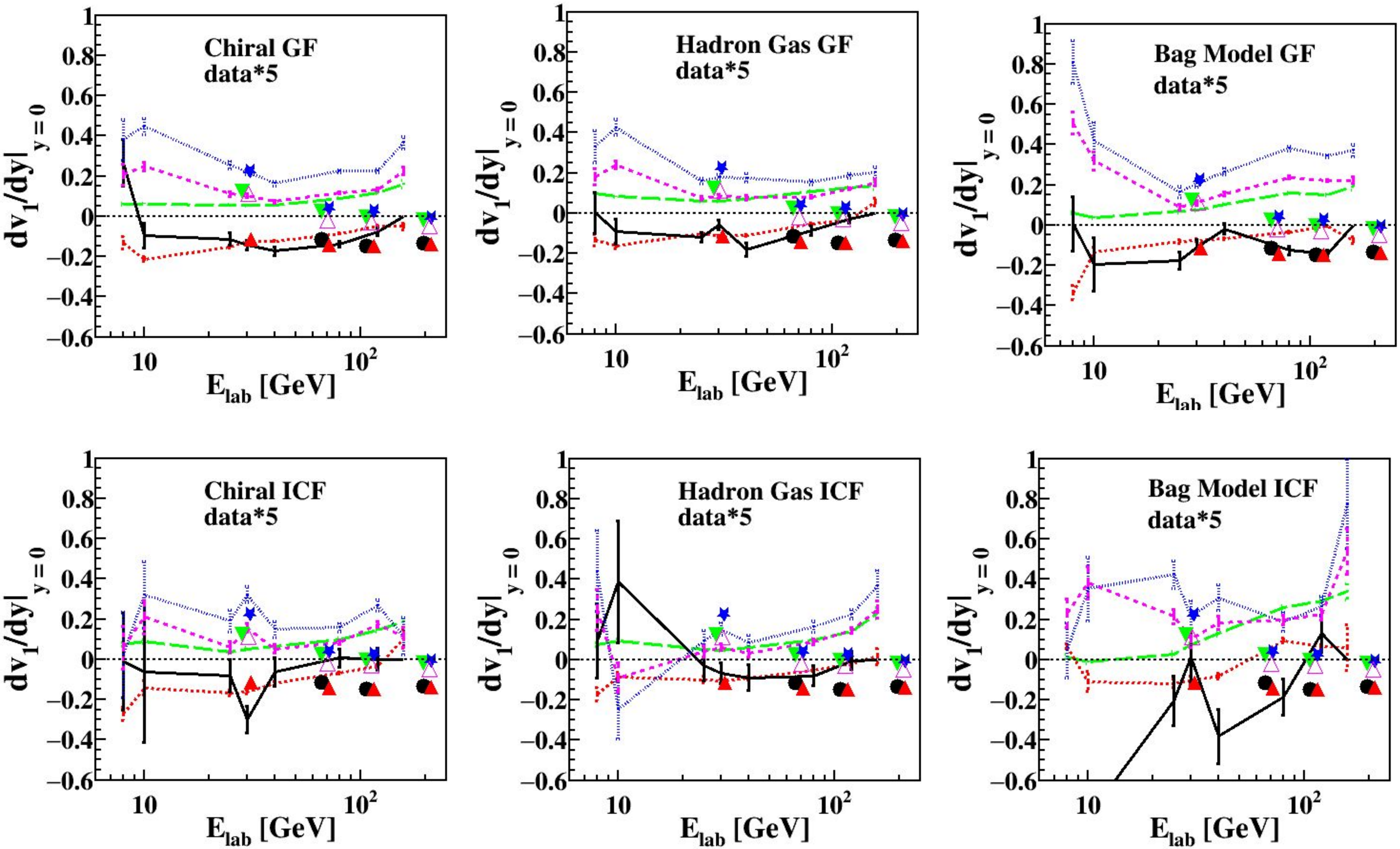
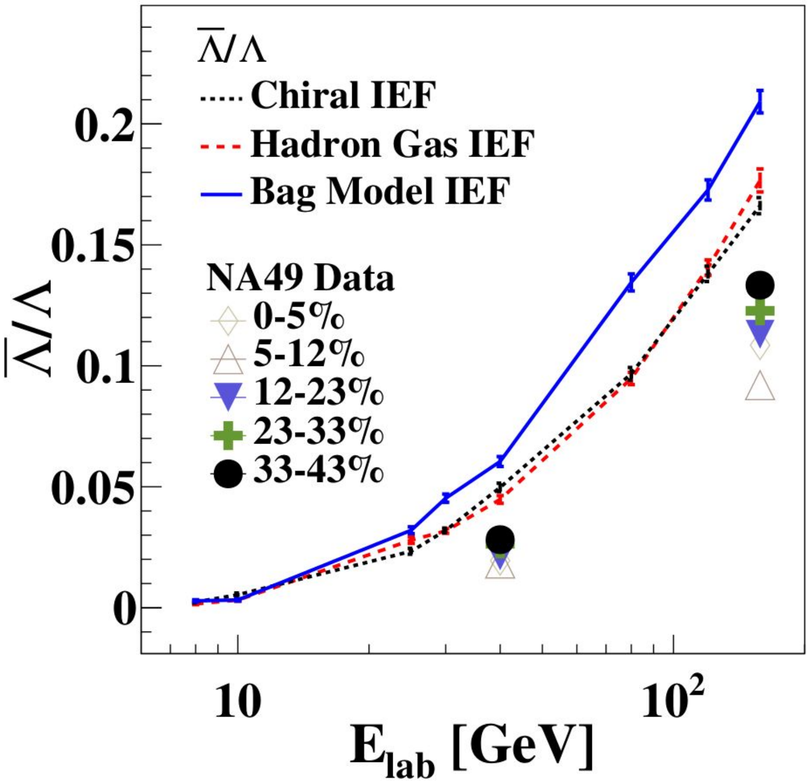
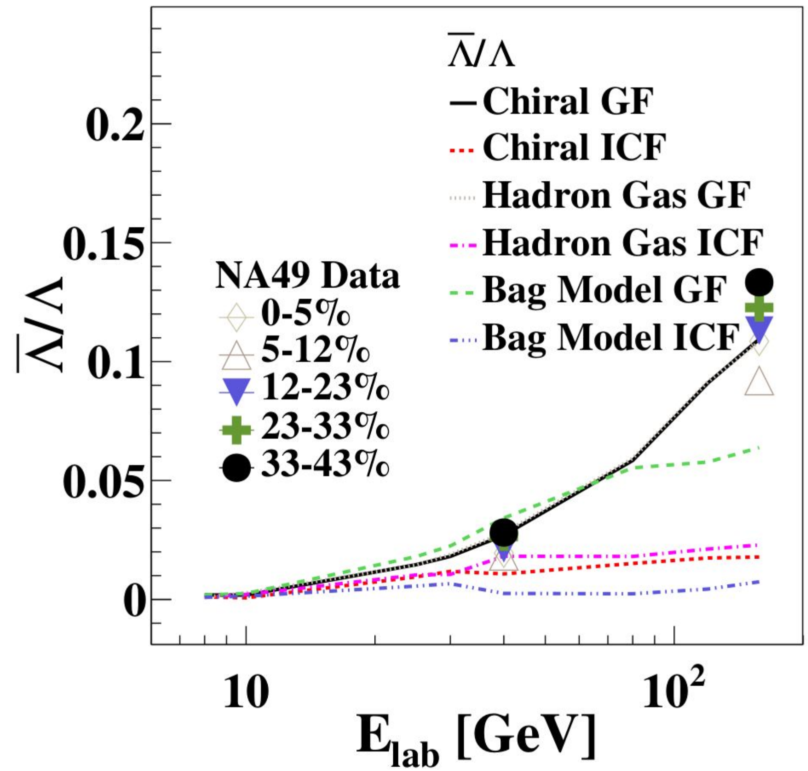

Chiral IEF
data*5
Hadron Gas IEF
data*5
Bag Model IEF
data*5
$dv_1/dy|_{y=0}$
E_{lab} [GeV]
UrQMD-3.4
$\bar{\Lambda}$
$K^- + \frac{1}{3}\ \bar{p}$
net Λ
net p - $\frac{2}{3}\ \bar{p} + K^-$
net p - $\frac{1}{3}$ net p - $\frac{1}{3}\ \bar{p} + K^-$
STAR Data; 10--40% Centrality
$\bar{\Lambda}$
$K^- + \frac{1}{3}\ \bar{p}$
net Λ
net p - $\frac{2}{3}\ \bar{p} + K^-$
net p - $\frac{1}{3}$ net p - $\frac{1}{3}\ \bar{p} + K^-$


Chiral GF
data*5
Hadron Gas GF
data*5
Bag Model GF
data*5
Chiral ICF
data*5
Hadron Gas ICF
data*5
Bag Model ICF
data*5
$dv_1/dy|_{y=0}$
E_{lab} [GeV]

Lambda bar to Lambda (strange to anti-strange baryon ratio)





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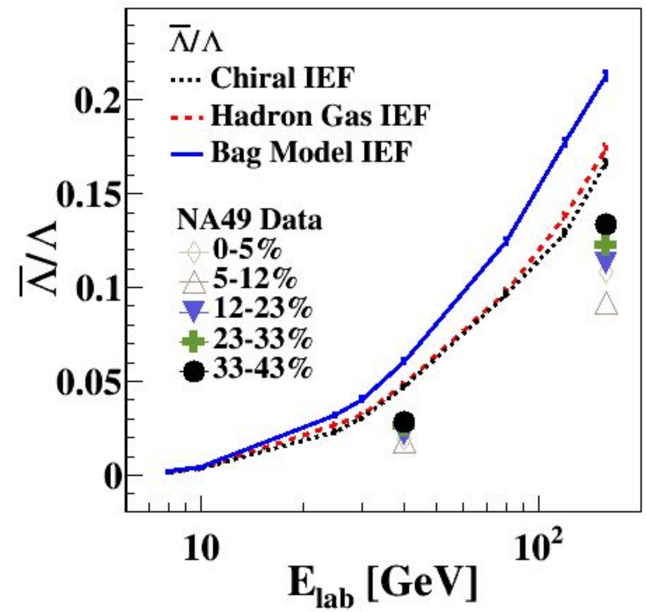

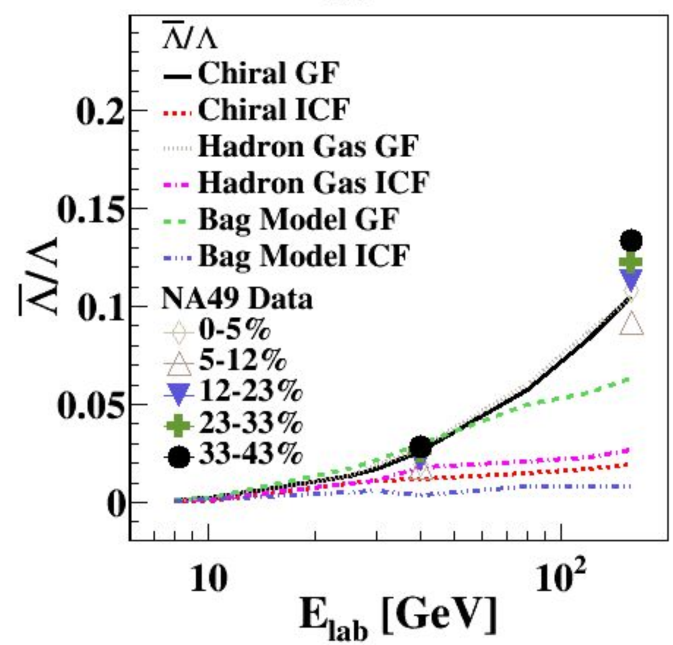

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