IS THERE A VIOLATION OF ISOSPIN SYMMETRY IN THE KAON SECTOR IN HIC?

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based on e-Print: 2503.10493 [nucl-th], Phys.Lett.B 873 (2026) 140170

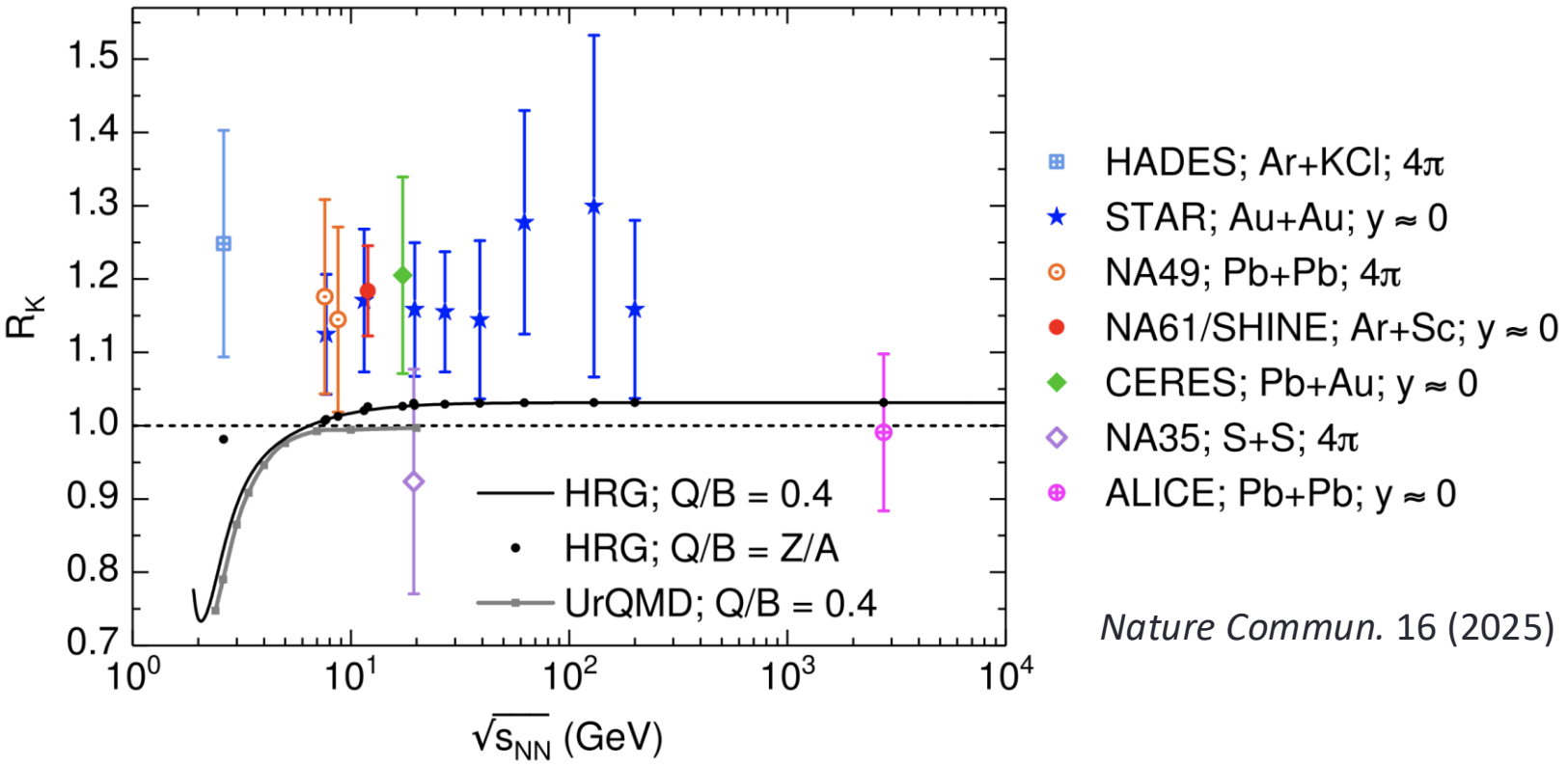
What do we expect?

- Collision of Au+Au
- → 2 x 79 protons (uud), 2 x 118 neutrons (udd)
- → 552 u-quarks, 630 d-quarks + pair produced s-sbar,...
- → yield of u-sbar (K^+) < d-sbar (K^0)

- Define $R_K = (K^+ + K^-) / (K^0 + \text{anti-}K^0) = (K^+ + K^-) / (2\, K^0_{short})$

- → $R_K < 1$

The question: Why is R_K>1???



Nature Commun. 16 (2025) 1, 2849

- Is there any way to explain the data?
  (asymmetry in phi decay not implemented in UrQMD!)

Obvious (wrong) answers

- I do not see the problem, anti-quarks are suppressed at high μ_B, R_K should be above 1
- Data is wrong
- Neutral Kaons oscillate (easy to get a factor 2)
- Charged Kaons couple to the electric field this enhances them somehow
- Its isospin, like in the case of the $\rho^0 \rightarrow \pi^+\pi^-$
- Its the mass difference between neutral and charged Kaons (indeed a bit, that's why the ϕ decays more to charged Kaons)

CAN WE EXPLANATION THE OBSERVED VIOLATION OF ISOSPIN SYMMETRY?

MOVING OUR NON-UNDERSTANDING TO SOMEWHERE ELSE...

What inspired us to look into e^+e^-

Table 53.1: Average hadron multiplicities per hadronic e^+e^- annihilation event at $\sqrt{s} \approx 10$, 29–35, 91, and 130–200 GeV. The rates given include decay products from resonances with $c\tau < 10$ cm, and include the corresponding anti-particle state. Correlations of the systematic uncertainties were considered for the calculation of the averages. Quoted errors are not increased by scale factor S.

Particle	$\sqrt{s} \approx 10$ GeV	$\sqrt{s} = 29$–35 GeV	$\sqrt{s} = 91$ GeV	$\sqrt{s} = 130$–200 GeV	References
Pseudoscalar mesons:					
π^+	6.52 ± 0.11	0.3 ± 0.4	17.02 ± 0.19	21.24 ± 0.39	[8–17]
π^0	3.2 ± 0.3	5.83 ± 0.28	9.42 ± 0.32		[12, 18–23]
K^+	0.953 ± 0.018	1.48 ± 0.09	2.228 ± 0.059	2.82 ± 0.19	[9–17, 24, 25]
K^0	0.91 ± 0.05	1.48 ± 0.07	2.049 ± 0.026	2.10 ± 0.12	[12, 17, 20, 26–36]
η	0.20 ± 0.04	0.61 ± 0.07	1.049 ± 0.080		[12, 18, 19, 22, 23, 37–40]
$\eta'(958)$	0.03 ± 0.01	0.26 ± 0.10	0.152 ± 0.020		[20, 39, 41–43]
D^+	$0.194 \pm 0.019^{(a)}$	0.17 ± 0.03	0.175 ± 0.016		[12, 44–47]
D^0	$0.446 \pm 0.032^{(a)}$	0.45 ± 0.07	0.454 ± 0.030		[12, 44–47]
D_s^+	$0.063 \pm 0.014^{(a)}$	$0.45 \pm 0.20^{(b)}$	0.131 ± 0.021		[8, 39, 44, 47–49]
$B^{(c)}$	—	—	$0.134 \pm 0.016^{(d)}$		[46, 50]
B^+	—	—	$0.141 \pm 0.004^{(d)}$		[51]
B_s^0	—	—	$0.054 \pm 0.011^{(d)}$		[52, 53]

PDG

- Also in e^+e^-, $K^+/K^0>1$ (!), also $D^0/D^+>1$ (D^0=ubar c, D^+=dbar c)
  BUT asymmetry due to D* decay: $D^{0*} \rightarrow D^0+x$ (100%), also $D^{+*} \rightarrow D^0+x$ (67%)
- → maybe u (ubar) quarks are more often produced?!

e+ e- vs a proton string

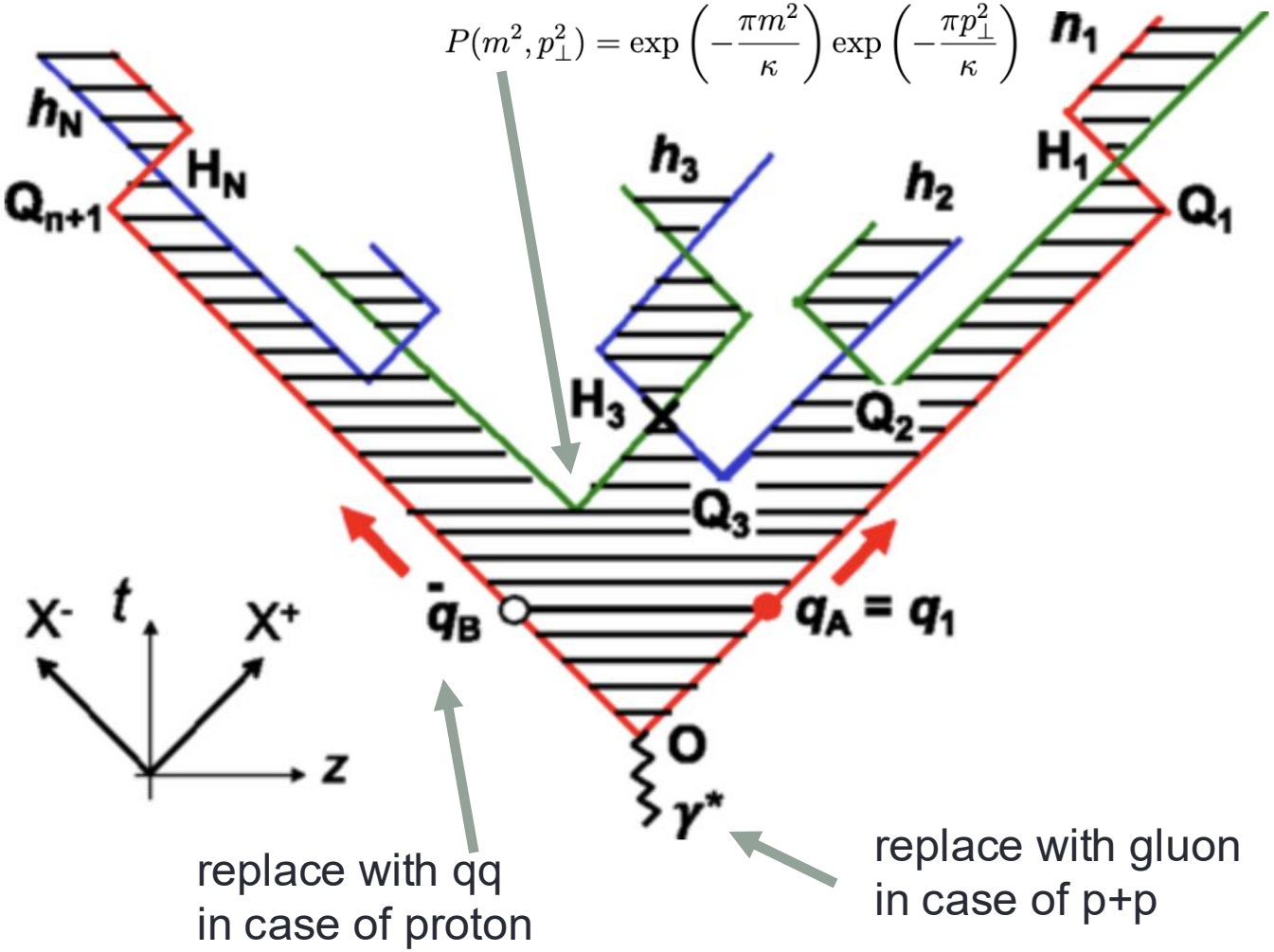
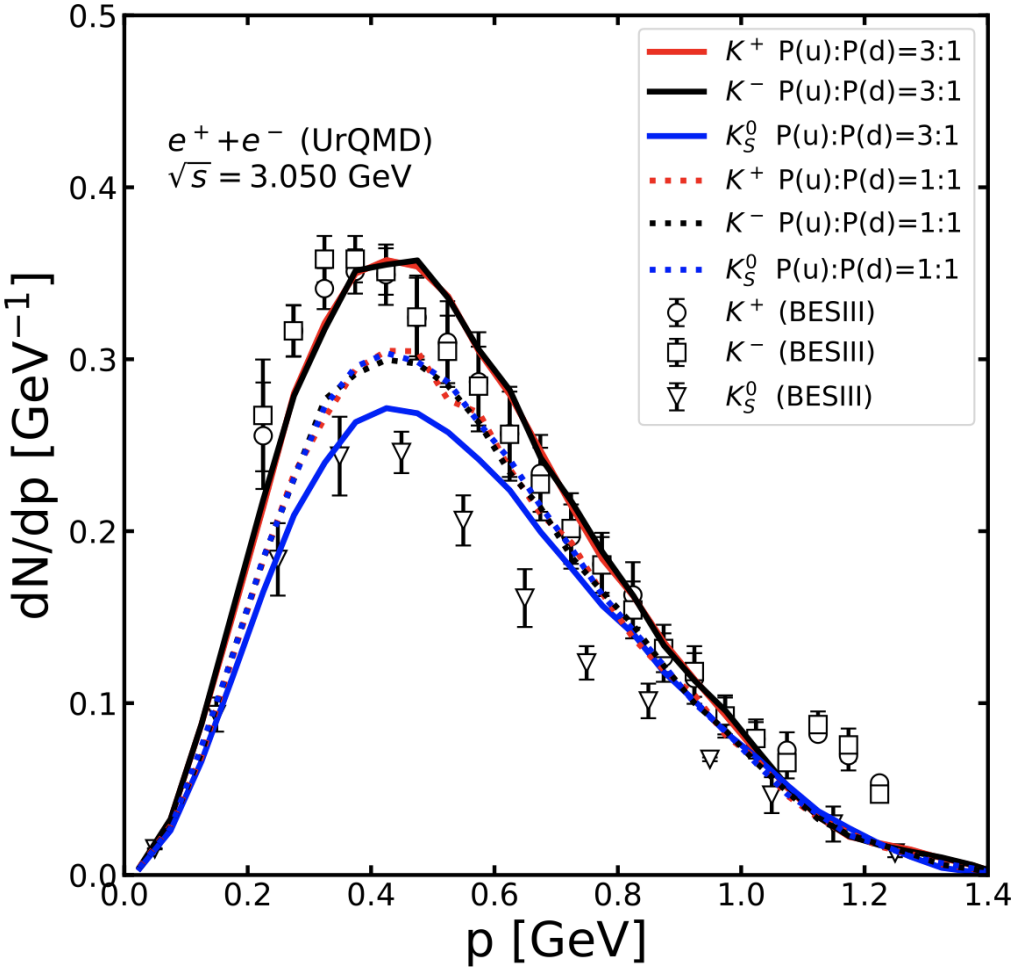


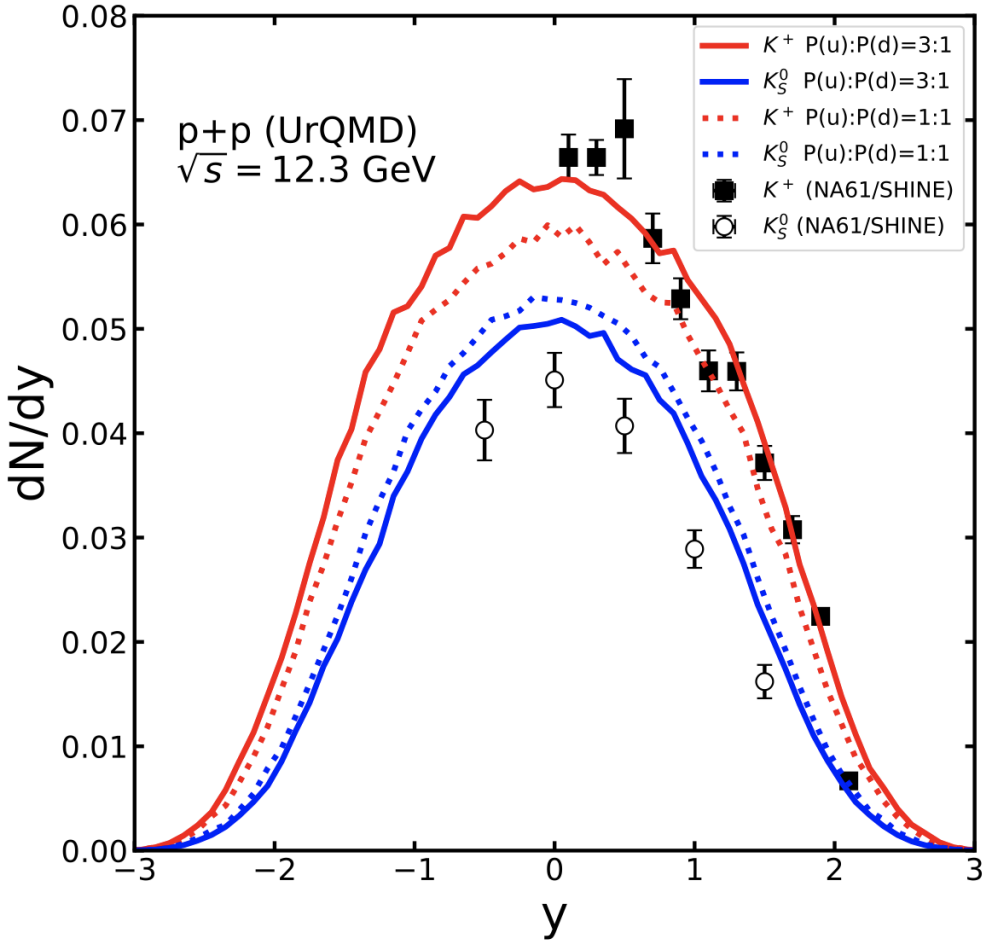
Figure taken from Phys. Rev. D **97**, 074010

Deeper analysis of e^+e^-



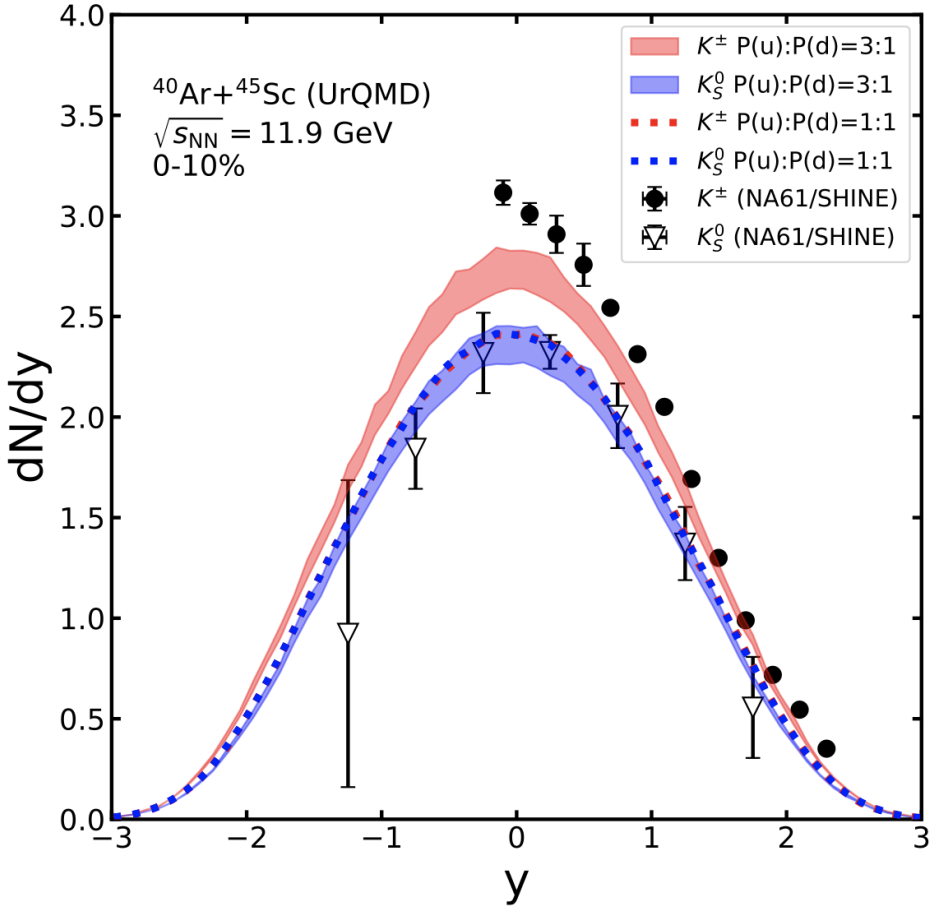
- String mass of 3GeV, compatible with typical excitation energy of proton strings (at all energies)
- K^+ (K^-) yields are higher than K^0 yields
- Not compatible with u:d=1:1 probability in string break
- Needs u:d=3:1

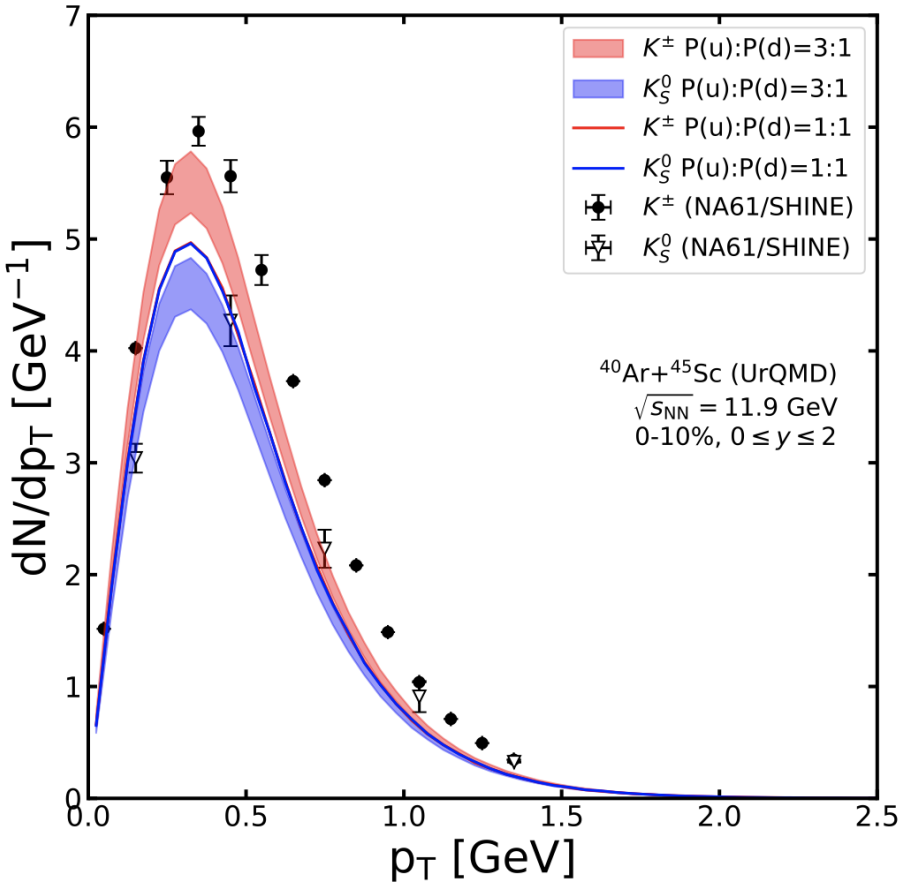
Extrapolation to p+p



- Same parameters as in e^+e^- (!)
- Splitting in p+p also increases
- Compatible with data
- Note: Splitting also increases in n+n

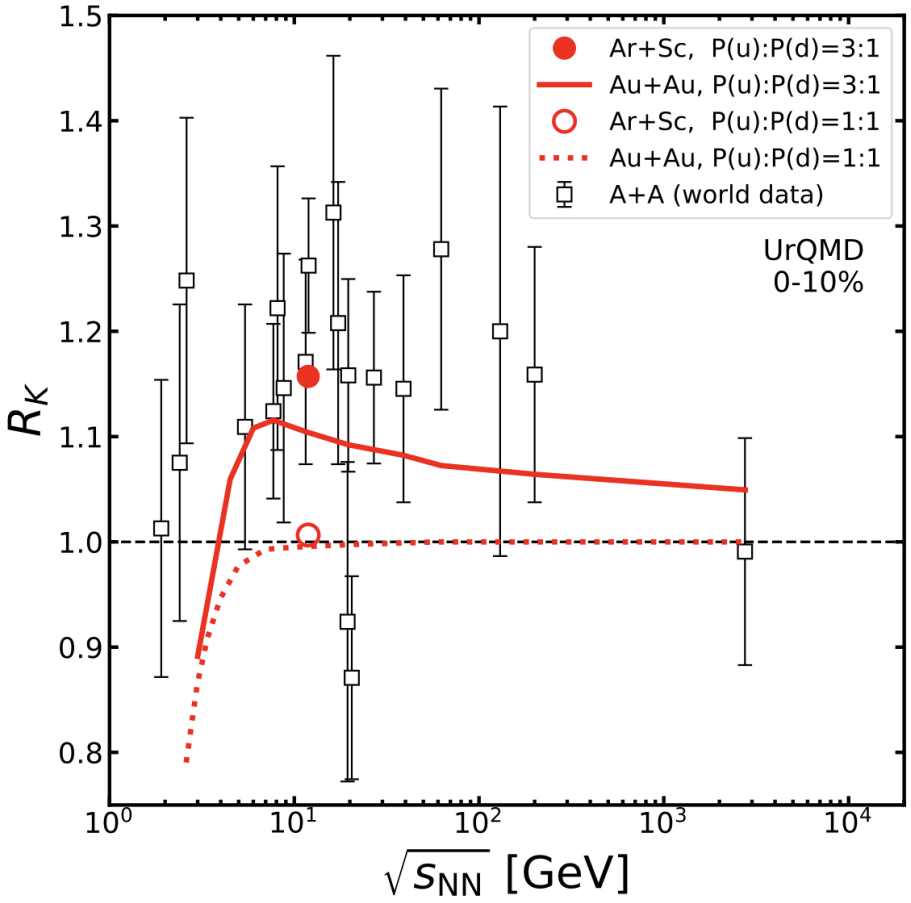
Translates directly to A+A





- Before: $K^+/K^0 = 1$
- With asymmetric u-quark production, ratio becomes compatible with data

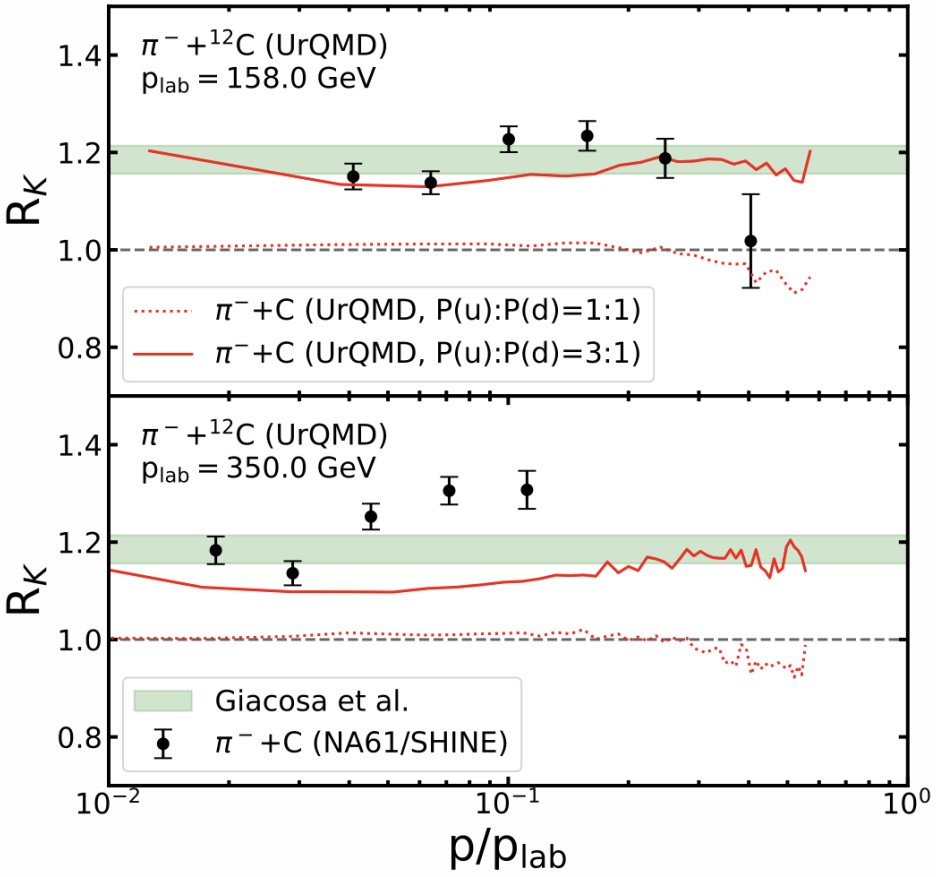
Energy dependence

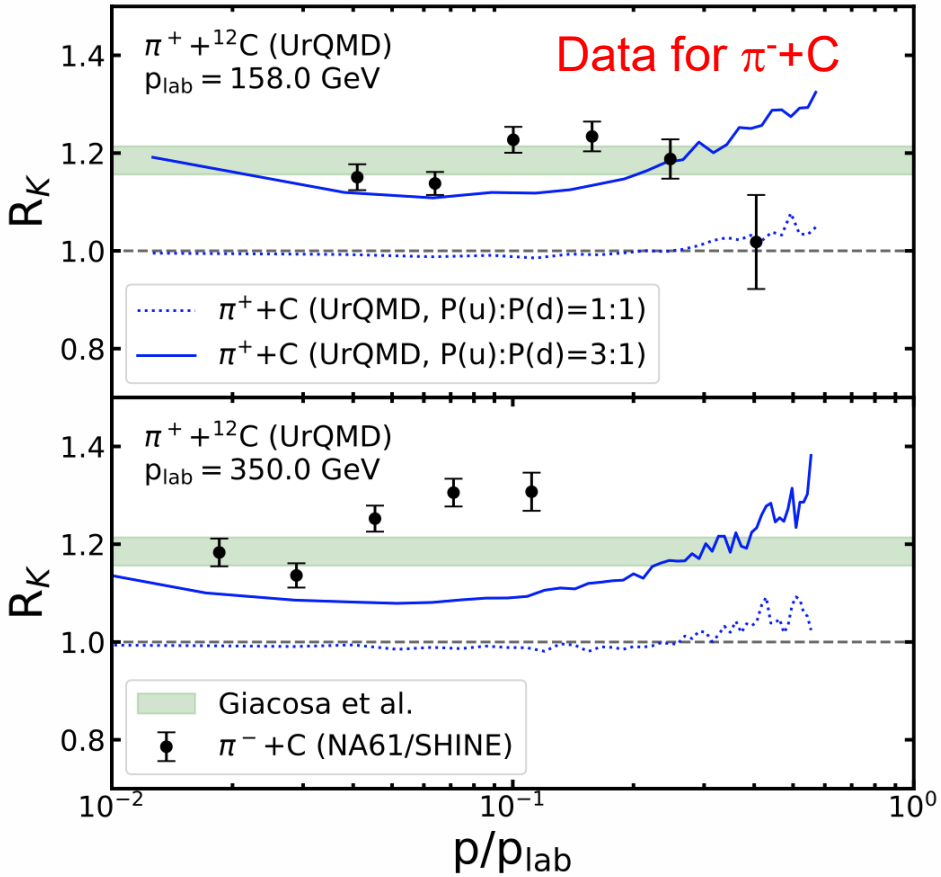


- Same parameters as in e^+e^- (!)
- Description of the data is “OK”
- Decrease towards lower energies, because effect only implemented in string break-up
- Washed out at high energies (more K* contribution, $K^{*0} \rightarrow K^+$, BR=66%!!)

- Some further predictions...

Comparison: π^++C and π^-+C



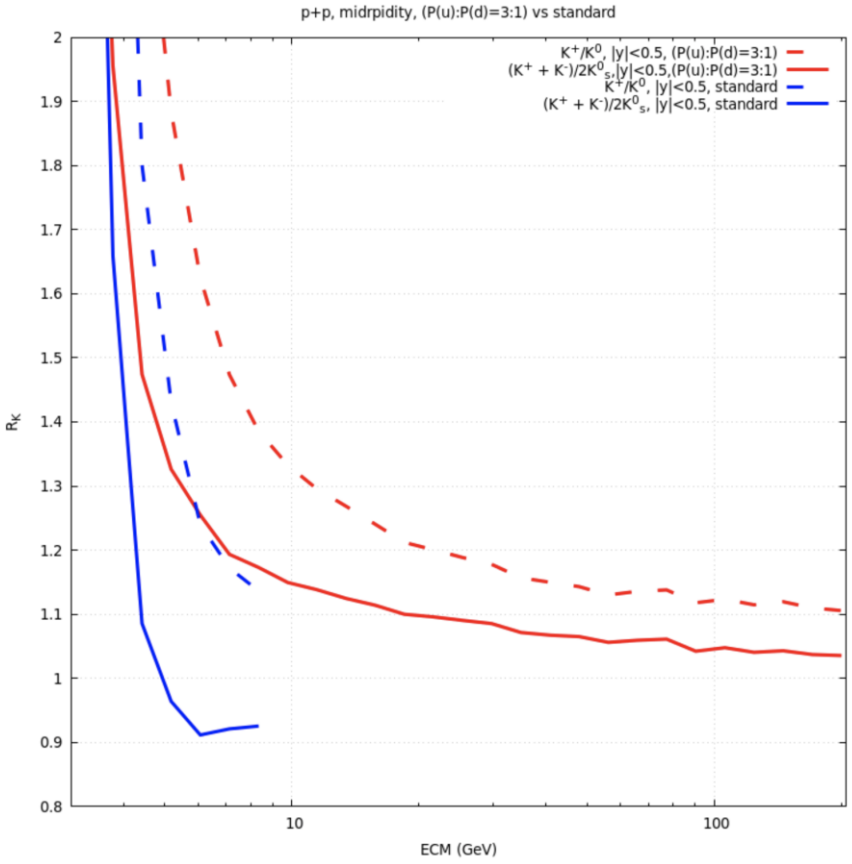


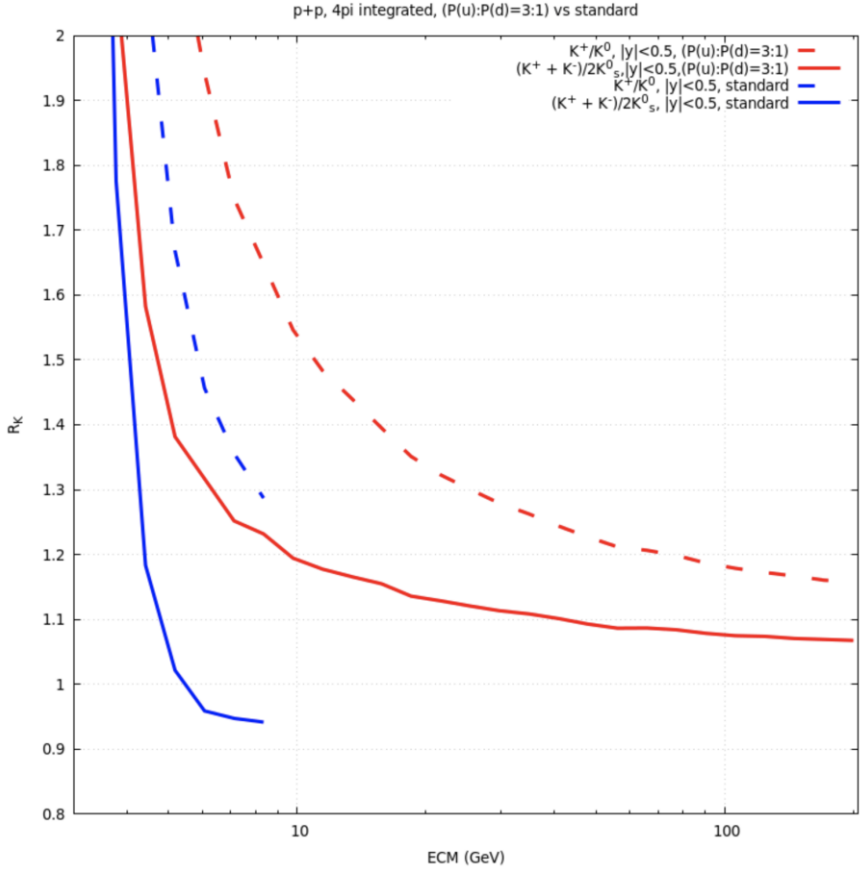
$K^+/K^0>1$ for both systems

T. Reichert, priv. comm.

p+p excitation function

- midrapidity ratios
- integrated ratios (4pi)

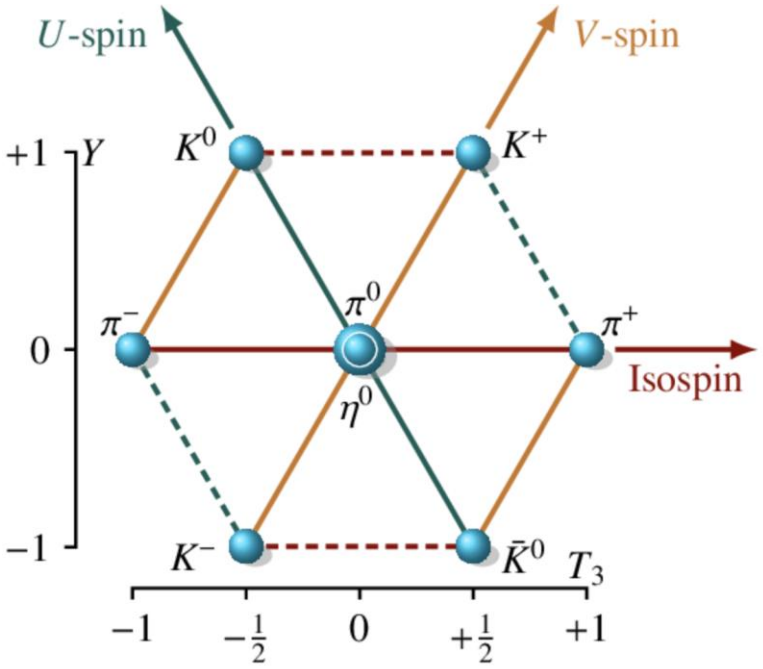




Increase towards low energy obvious: pp → Λ K^+ p has lowest threshold

Final thoughts

- No physics reason for such large asymmetry in u:d in vacuum or sea quarks or color field fragmentation
- However, SU(3) flavour symmetry (U-Spin!) is broken:



Apart from I-(so)spin, also the U- and V-spin pose constraints on possible decays

Lipkin argued, e.g. that U-Spin forbids the process e+e- → K^0 aK^0

"The experimental data should be checked for some qualitative indication of the SU(3) selection rule forbidding neutral-kaon pair production. This would appear as a suppression of production of neutral-kaon pairs relative to charged-kaon pairs resulting from some interference between the contributions of the isoscalar and isovector components of the photon." (*PRL* 31 (1973) 656)