Lambda-hyperon production in p+p and C+C collisions at NICA energies

(comments to BM@N results on Λ from C+C)

V.I. Kolesnikov
VBLHEP, JINR

The content of the talk is an attempt of relating p+p data on Λ production to C+C

Plan:

1. Excitation function of Λ production in p+p (as a starting point)
2. Transform p+p data into isospin averaged nucleon-nucleon results
3. Extrapolation from p+p to C+C: N_{part}-scaling using Glauber estimates
4. Error estimates for the N_{part}-scaling procedure
5. BM@N data and extrapolation: comparison & discussion
6. Conclusions and Outlook

Note: what follows is regarding the total multiplicity of Lambdas!

13th Collaboration meeting of the BM@N Experiment
JINR, Dubna, Russia, 08-10 October 2024

1. Excitation function of Λ production in p+p

ISSN 1547-4771, Physics of Particles and Nuclei Letters, 2020, Vol. 17, No. 2, pp. 142–153. © Pleiades Publishing, Ltd., 2020.

PHYSICS OF ELEMENTARY PARTICLES AND ATOMIC NUCLEI. EXPERIMENT

A New Review of Excitation Functions of Hadron Production in *pp* Collisions in the NICA Energy Range

V. Kolesnikov[a, *], V. Kireyeu[a], V. Lenivenko[a], A. Mudrokh[a], K. Shtejer[a], D. Zinchenko[a], and E. Bratkovskaya[b]

In addition, we used a parameterization based on the Lund–String–Model (LSM) from [20] (*Fit2*) given by

$$\langle n \rangle = a(x-1)^b (x)^{-c}, \qquad (2)$$

where $x = s/s_0$, s is the square of the center-of-mass energy, s_0 is the square of the production threshold, and (a, b, c) are the fit parameters.

$$\sigma = \langle n \rangle \sigma_{in}$$

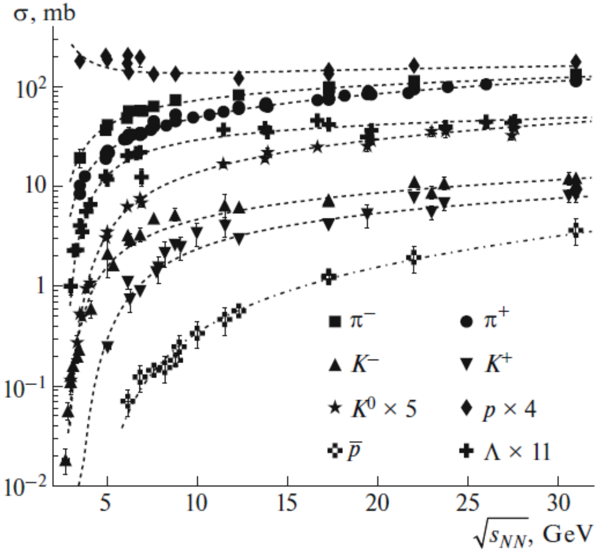


Fig. 4. Inclusive hadron production cross-sections from *pp* interactions as a function of the center-of-mass energy. Dashed lines are parameterizations to Eq. (2).

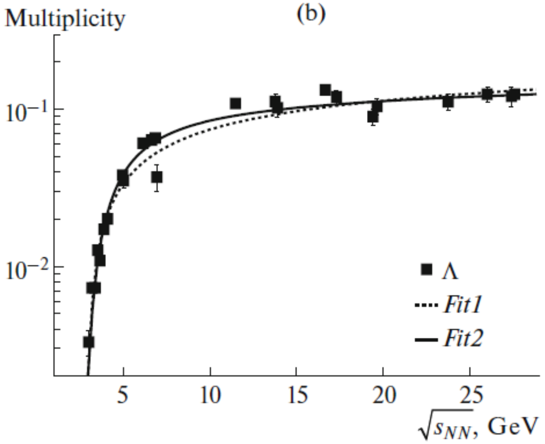


Table 6. Parameterization parameters (according to Eq. (2)) for the hadron production cross-sections

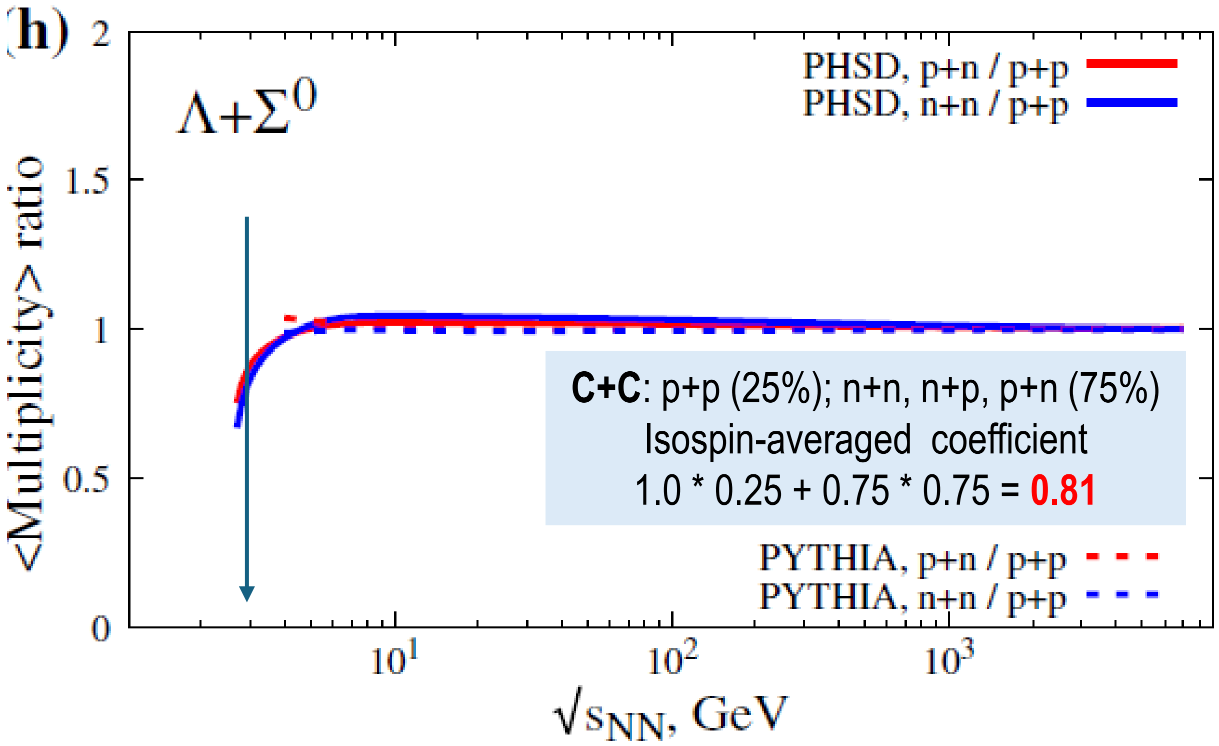
Hadron	a	b	c	s_0 (GeV^2)	χ^2/NDF
π^-	18.79 ± 0.554	1.998 ± 0.089	–.653 ± 0.095	4.64	0.5
π^+	43.046 ± 13.69	2.366 ± 1.386	2.168 ± 1.454	4.07	0.5
K^-	1.509 ± 0.363	5.138 ± 0.801	4.783 ± 0.853	8.2	2.0
K^+	2.176 ± 0.26	2.63 ± 0.155	2.285 ± 0.181	6.49	2.4
K_S^0	1.151 ± 0.087	3.697 ± 0.122	3.284 ± 0.139	6.49	1.9
p	19.49 ± 1.824	–8.717 ± 0.054	–8.823 ± 0.054	0	1.3
$\bar{p}$	0.122 ± 0.004	3.511 ± 0.291	2.69 ± 0.271	14.08	0.8
Λ	2.066 ± 0.161	2.625 ± 0.102	2.468 ± 0.121	6.49	4.1

2. p+p data and isospin-averaged nucleon-nucleon results

- In nucleon-nucleon interactions proton-involved and neutron-involved reaction have different production channels for Lambda due to isospin
- The ratio of the production rates p+n(n+n) / p+p ~ 0.75 at 3 GeV (*Eur. Phys. J. A (2020) 56:223*)

Eur. Phys. J. A (2020) 56:223
https://doi.org/10.1140/epja/s10050-020-00232-7
THE EUROPEAN PHYSICAL JOURNAL A
Check for updates
Review

Hadron production in elementary nucleon–nucleon reactions from low to ultra-relativistic energies

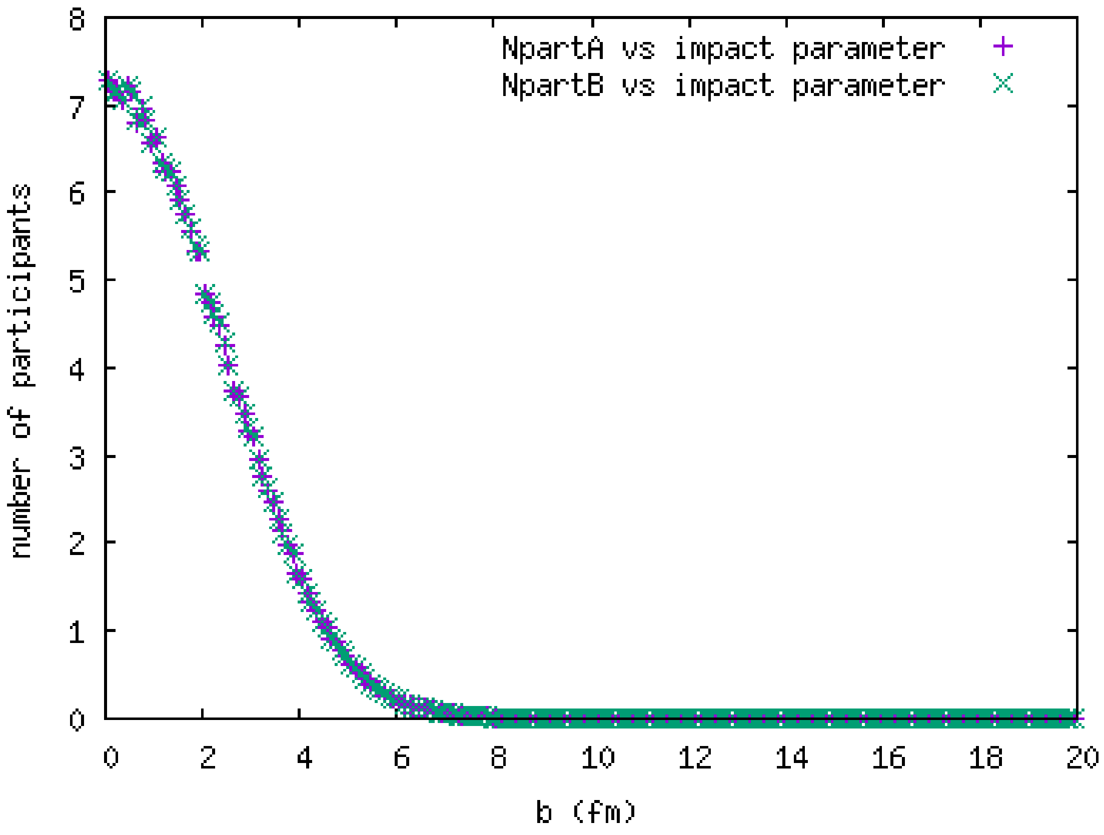


No.	pp→ reaction	$\sigma_0^{(id)}$ cross section [μb]	BR
		3-body channels	
1	$\Lambda p K^+$	$35.26 \pm 0.43\ ^{+3.55}_{-2.83}$	100%
2	$\Sigma^0 p K^+$	$16.5 \pm 20\%$	100%
3	$\Lambda \Delta^{++} K^0$	$29.45 \pm 0.08\ ^{+1.67}_{-1.46} \pm 2.06$	100%
4	$\Sigma^0 \Delta^{++} K^0$	$9.26 \pm 0.05\ ^{+1.41}_{-0.31} \pm 0.65$	100%
5	$\Lambda \Delta^+ K^+$	$9.82 \pm 20\%$	100%
6	$\Sigma^0 \Delta^+ K^+$	$3.27 \pm 20\%$	100%
7	$\Sigma(1385)^+ n K^+$	$22.42 \pm 0.99 \pm 1.57\ ^{+3.04}_{-2.23}$	94.05%
8	$\Delta(2050)^{++} n$	33% feeding for $\Sigma^* n K^+$	
9	$\Sigma(1385)^+ p K^0$	$14.05 \pm 0.05\ ^{+1.79}_{-2.14} \pm 1.00$	94.05%
10	$\Sigma(1385)^0 p K^+$	$6.0 \pm 0.48\ ^{+1.94}_{-1.06}$	88.3%
11	$\Lambda(1405) p K^+$	$9.2 \pm 0.9 \pm 0.7\ ^{+3.3}_{-1.0}$	33%
12	$\Lambda(1520) p K^+$	$5.6 \pm 1.1 \pm 0.4\ ^{+1.1}_{-1.6}$	19.55%
13	$\Delta^{++} \Lambda(1405) K^0$	$5.0 \pm 20\%$	33%
14	$\Delta^{++} \Sigma(1385)^0 K^0$	$3.5 \pm 20\%$	88.3%
15	$\Delta^+ \Sigma(1385)^+ K^0$	$2.3 \pm 20\%$	94.05%
16	$\Delta^+ \Lambda(1405) K^+$	$3.0 \pm 20\%$	33%
17	$\Delta^+ \Sigma(1385)^0 K^+$	$2.3 \pm 20\%$	88.3%
		4-body channels	
18	$\Lambda p \pi^+ K^0$	$2.57 \pm 0.02\ ^{+0.21}_{-1.98} \pm 0.18$	100%
19	$\Lambda n \pi^+ K^+$	from $\Lambda p \pi^+ K^0$	100%
20	$\Lambda p \pi^0 K^+$	from $\Lambda p \pi^+ K^0$	100%
21	$\Sigma^0 p \pi^+ K^0$	$1.35 \pm 0.02\ ^{+0.10}_{-1.35} \pm 0.09$	100%
22	$\Sigma^0 n \pi^+ K^+$	from $\Sigma^0 p \pi^+ K^0$	100%
23	$\Sigma^0 p \pi^0 K^+$	from $\Sigma^0 p \pi^+ K^0$	100%

3. C+C: N_{part} estimates from a Glauber approach

- Minbias (say, 0-80% central) C+C, σ_{NN} = 27 mb, σ_{tot} ~ 923 mb (830 mb in the Ksenia's analysis, i.e. -11%)

NN cross-sections: pdg.lbl.gov/2022/hadronic-xsections/rpp2022-pp_total.dat

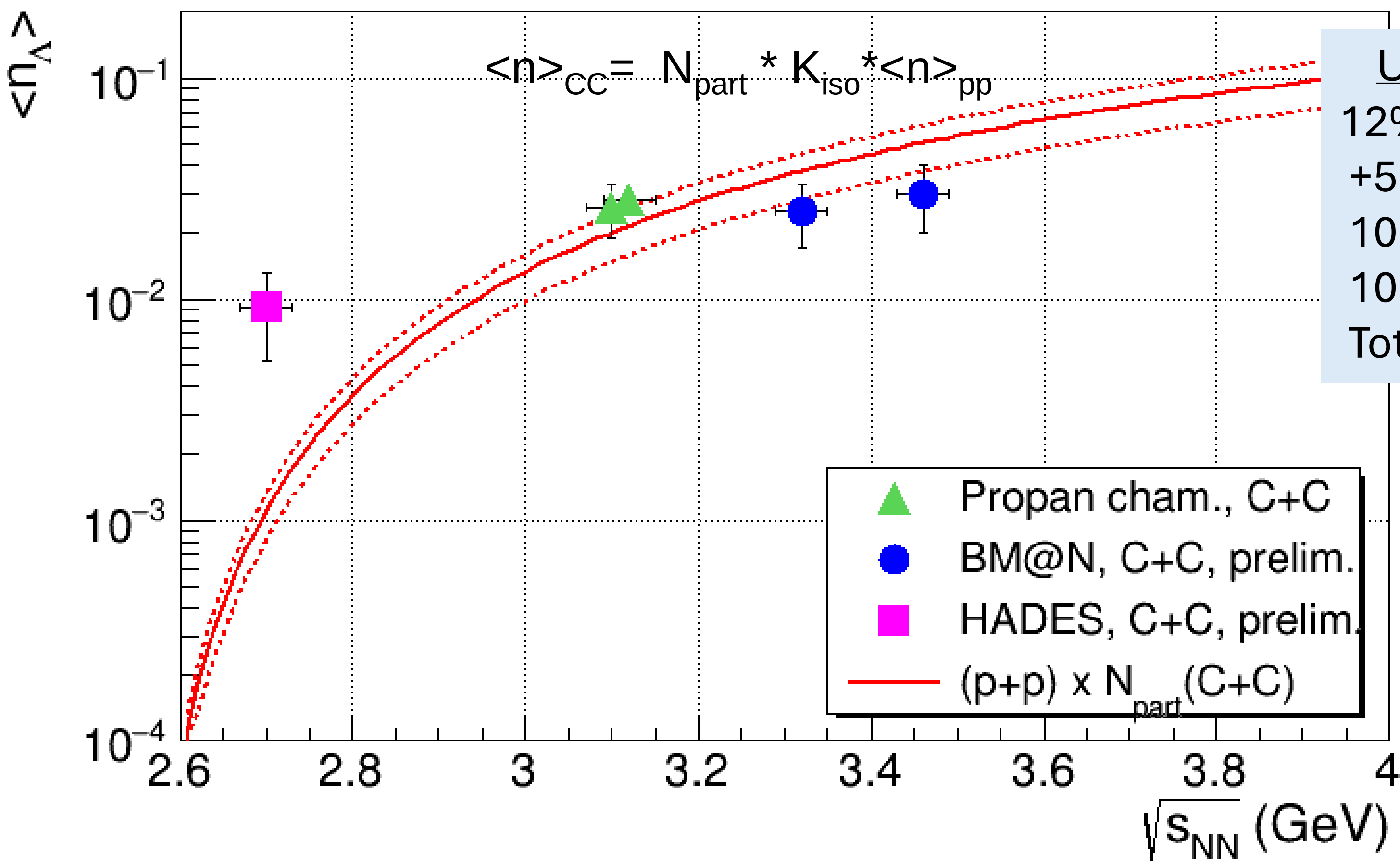


Glauber:

- b = 0-5 fm, N_{part} ~ 6
  that is close to a naive estimate $N_{part} = (A_p+A_T) / 4$

4-5. Lambda yields in C+C (param vs. data comparison and errors)

- BM@N data for the total yields in minbias C+C are compared with the parameterization of p+p (scaled to C+C) from *PEPAN Letters (2020), Vol. 17, №2, pp. 142-153*
- Dashed lines indicate the uncertainties in the predicted excitation function (~20-25%)



<u>Uncertainties (param.) :</u>
12% (fit function)
+5 .. -15% (cross-section)
10% (Glauber)
10% (centrality)
Total: +20 .. -25%

- The parameterization of p+p scaled data is ~40-50% above the BM@N data (within the common uncertainties)
- HADES (preliminary) point is a factor of 10 above

BM@N points for $<n_\Lambda>$ are taken from K.Alishina's report this summer. The extrapolation to 4pi (model based, data based?) introduces an additional error (no estimates for them yet)!

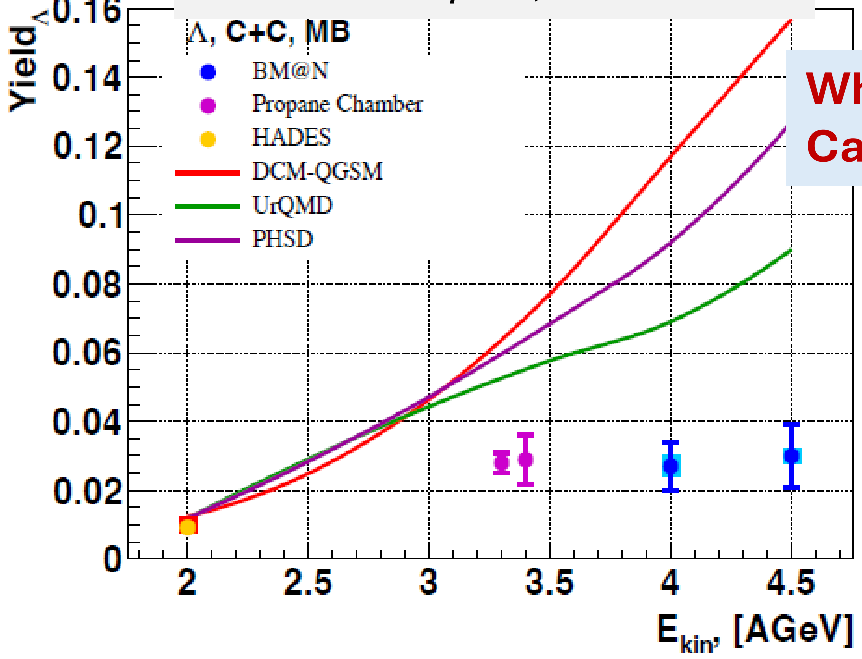
6. Conclusions and Outlook

- BM@N data on Λ yields in C+C at 4(.5)A GeV are close to the estimates based on p+p data scaled to C+C with a Glauber-based N_{part} scaling factor

- The difference between BM@N results and those from HADES and models(?!) is big, but this is the problem of HADES and models (my opinion!)

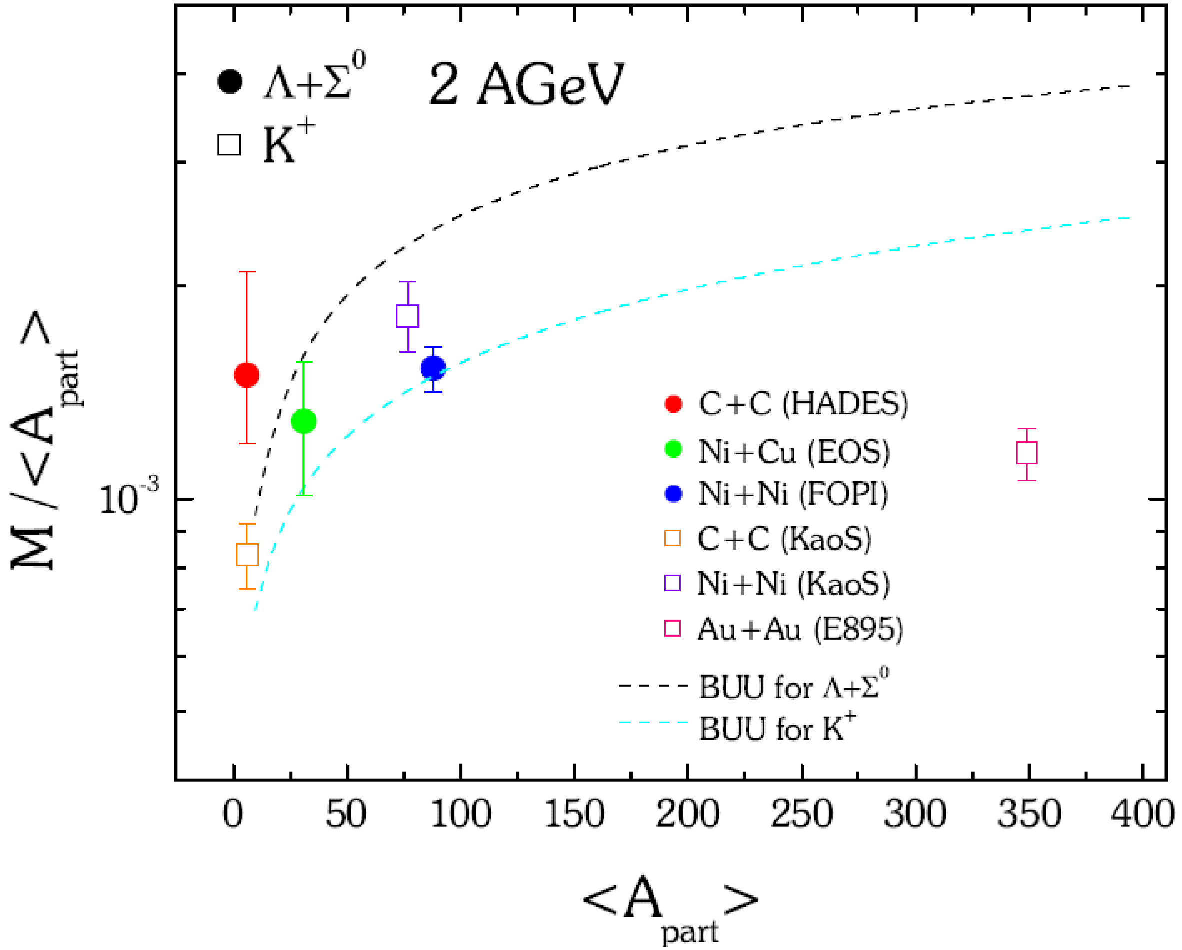
- System size dependence of Λ-hyperon production in A+A collisions at 2-4A GeV is not fully understood: more measurements are needed with a higher statistics!

K.Alishina report, 27.06.2024



Who did this comparison?
Can it be reproduced?

Spires



Λ+Σ⁰
2 AGeV
K⁺
C+C (HADES)
Ni+Cu (EOS)
Ni+Ni (FOPI)
C+C (KaoS)
Ni+Ni (KaoS)
Au+Au (E895)
BUU for Λ+Σ⁰
BUU for K⁺
M /<A_part>
10⁻³
0
50
100
150
200
250
300
350
400
<A_part>