The Wróblewski factor revisited for proton-proton at $\sqrt{s}\sim$10 GeV

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The Wróblewski Factor Acta Physica Polonica B16 (1985) 379

$$\lambda = \frac{\langle N_{s\bar{s}} \rangle}{\left(\langle N_{q\bar{q}} \rangle - \langle N_{s\bar{s}} \rangle \right)}$$

Note the energy scale shifted by two m_p

ON THE STRANGE QUARK SUPPRESSION FACTOR IN HIGH ENERGY COLLISIONS

BY A. WRÓBLEWSKI

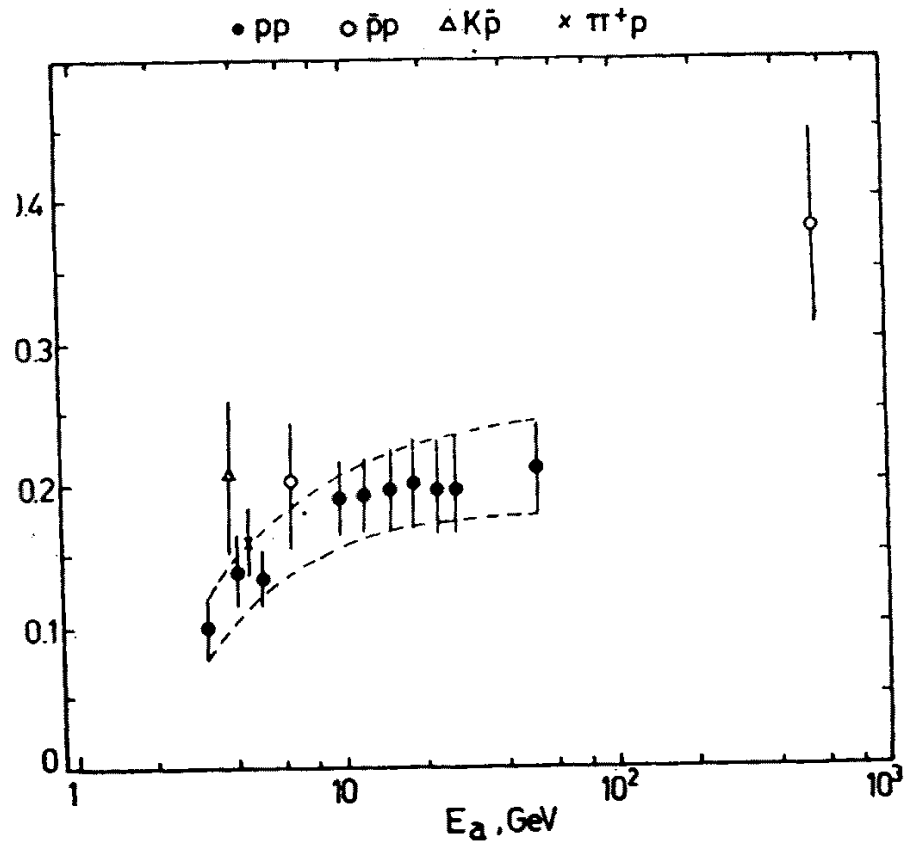
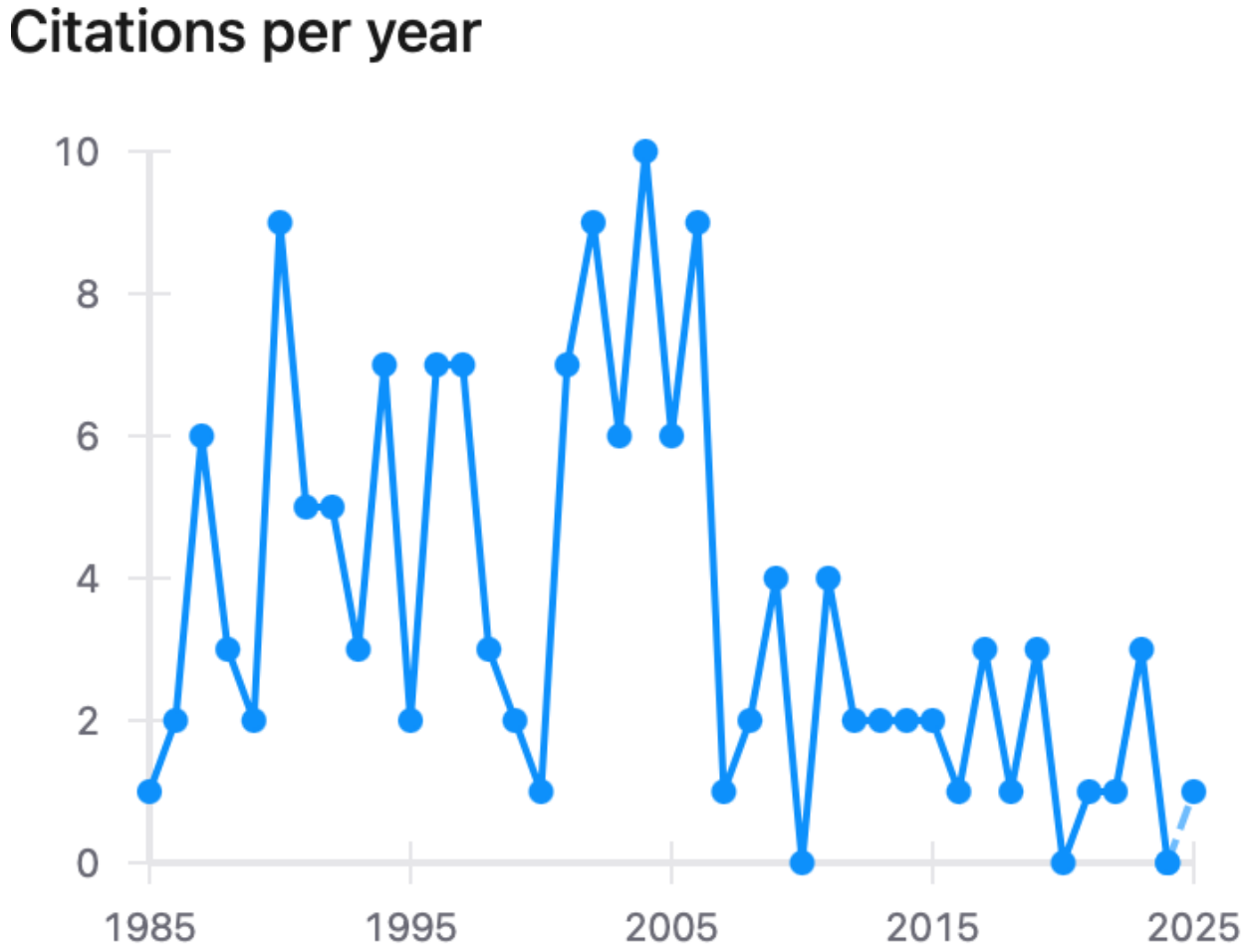


Fig. 6. The values of the strange quark suppression factor λ calculated from formula (1) as a function of the available energy $E_a = \sqrt{s} - m_{\text{beam}} - m_{\text{target}}$. Included is the UA5 result obtained in Ref. [4] for non single-diffractive events. The hand-drawn dashed lines indicate approximate limits of λ in pp collisions between 12 and 1500 GeV/c

ON THE STRANGE QUARK SUPPRESSION FACTOR IN HIGH ENERGY COLLISIONS

By A. Wróblewski



The Wróblewski Factor

$$\lambda_S = \frac{2(\langle s \rangle + \langle \bar{s} \rangle)}{\langle u \rangle + \langle \bar{u} \rangle + \langle d \rangle + \langle \bar{d} \rangle}$$

R. Stock 2004 J. Phys. G: Nucl. Part. Phys. **30** S633

F.Beccatini, M.Gaździcki, A.Keranen, J.Manninen, R.Stock PHYSICAL REVIEW C **69**, 024905 (2004)

H.Oeschler, Acta Phys. Pol. B35 (2004) 1067

V. Friesen, Y. Kalinowsky, V.D. Toneev, Physics of Particles and Nuclei Letters, 2019, Vol. 16, p. 681

- <N> - multiplicity of **newly formed** quarks at chemical freezeout

- *Wróblewski factor around 0.25 for pp, twice as large for AA (R. Stock)*

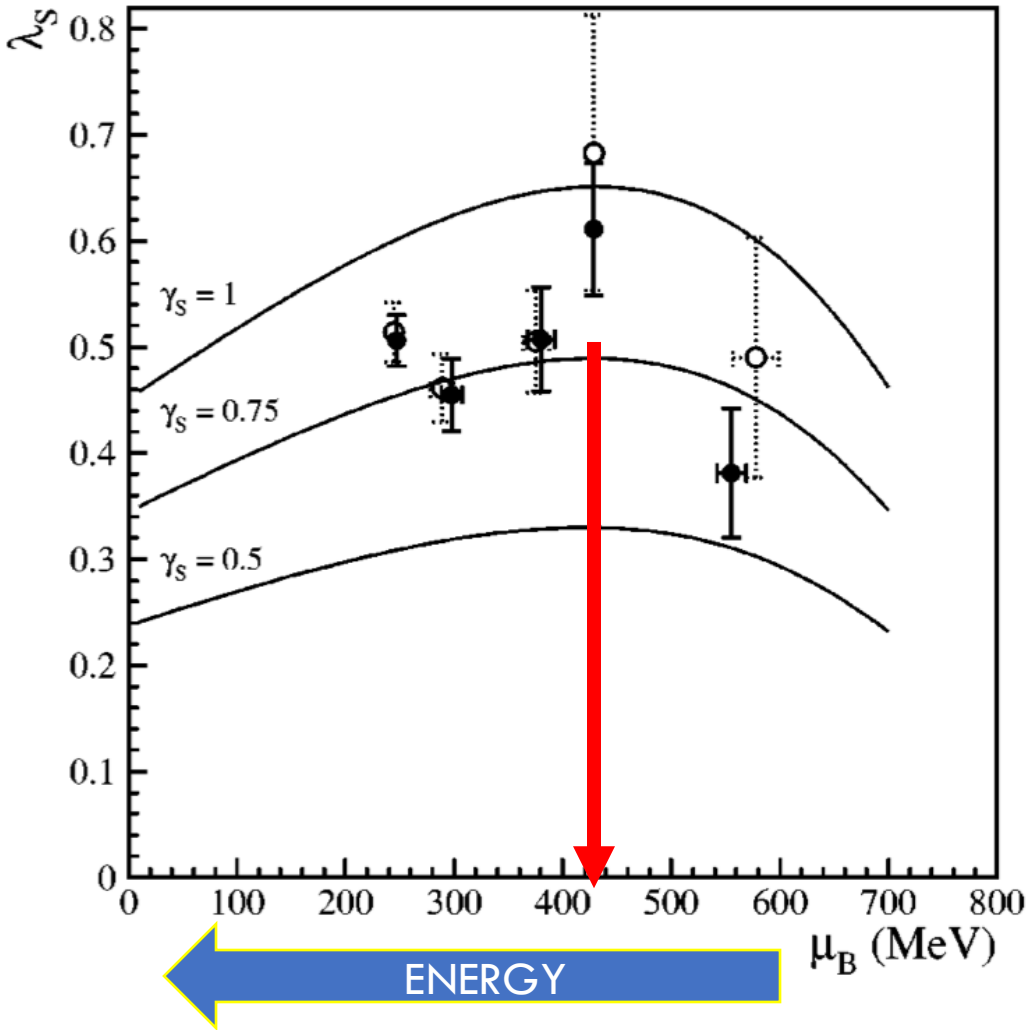


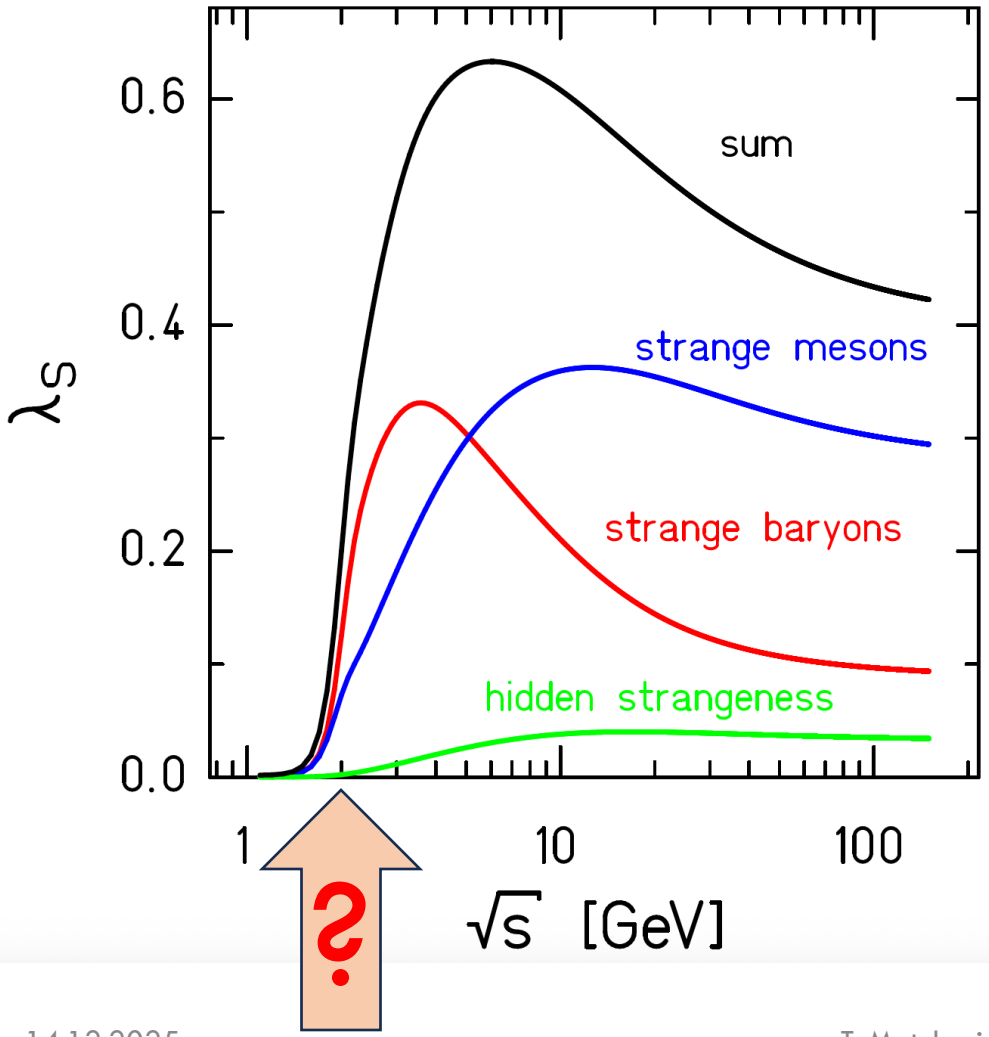
FIG. 14. λ_S estimated from the fits A (full dots) and B (hollow dots) as a function of the fitted baryon-chemical potential. Also shown are the theoretical values for a hadron gas along the fitted chemical freeze-out curve shown in Fig. 11, for different values of γ_S.

Peak in K^+/π^+ $\rightarrow$ peak in λ_S

- HRG fit to Pb+Pb multiplicities of π^+ K^+, K^- Λ Λ-bar
- Red arrow indicates 30A GeV/c

- From F.Beccatini, M.Gaździcki, A.Keranen, J.Manninen, R.Stock PHYSICAL REVIEW C **69**, 024905 (2004)

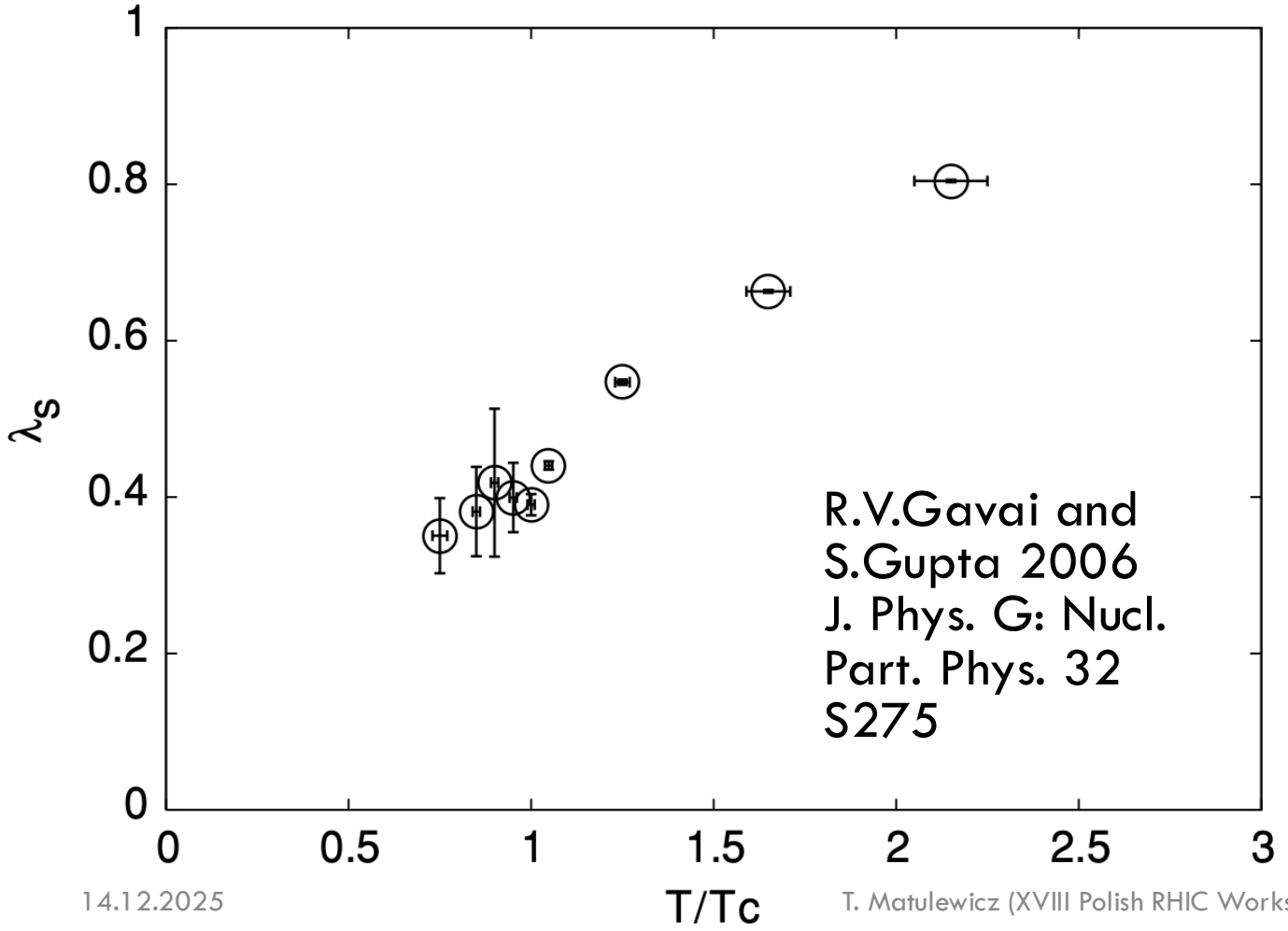
Decomposition of Wróblewski Factor



the freeze-out of an ideal hadron gas

H.Oeschler, J.Cleymans, K.Redlich, S.Wheaton Journal of Physics G: Nuclear and Particle Physics, Volume 32, p. S223

Lattice QCD results on strangeness and quasi-quarks in heavy-ion collisions



„We presented first full (two light dynamical quarks) QCD results for the Wróblewski parameter $\lambda_s(T)$. Near T_C these are found to be in agreement with the RHIC and SPS results."

Proton-proton measurements

Momentum (GeV/c)	$\sqrt{s}$ (GeV)	Number of measured multiplicities
40	8.8	11
80	12.3	10 (*Λ missing*)
158	17.3	18 *(including NA49 results)*

HRG (ThermalFist) reproduces the experimental multiplicities with (4±17)% precision (Acta Phys. Pol. B54, 12-A1 (2023))

The remainig multiplicities from HRG model (ThermalFist)
V.Vovchenko, H.Stoecker, Computer Physics Communications 244, 295 (2019)
Assumed accuracy of HRG results: 20%.

Wróblewski Factor for proton-proton

Momentum (GeV/c)	$\sqrt{s}$ (GeV)	Wróblewski Factor λ
40	8.8	0.113 ± 0.007
80	12.3	0.131 ± 0.008
158	17.3	0.146 ± 0.008

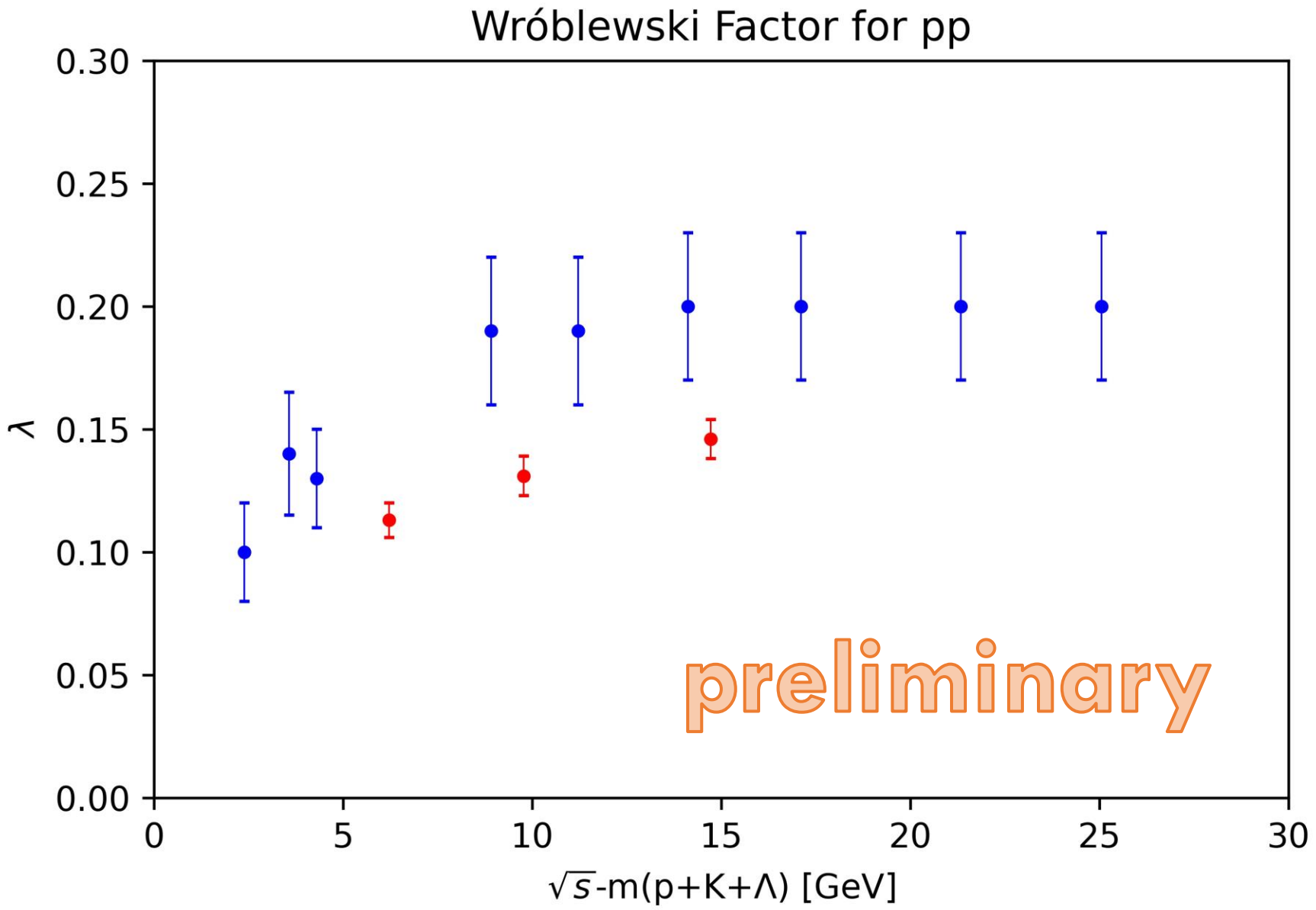
S=0 mesons (π, η, ρ, ϕ) |S|=1 mesons (K, K(892))

S=0 baryons (p,n,d) |S|>0 baryons (Λ,Λ(1520),Ξ,Ξ(1530),Ω)

and antiparticles

Example from Wróblewski paper: $\lambda=0.19 \pm 0.03$ @100 GeV/c

Precision improved by factor 3 (only!)



Note the energy scale is shifted by the threshold energy equal to the sum of masses of:

1. proton
2. K^+
3. Λ

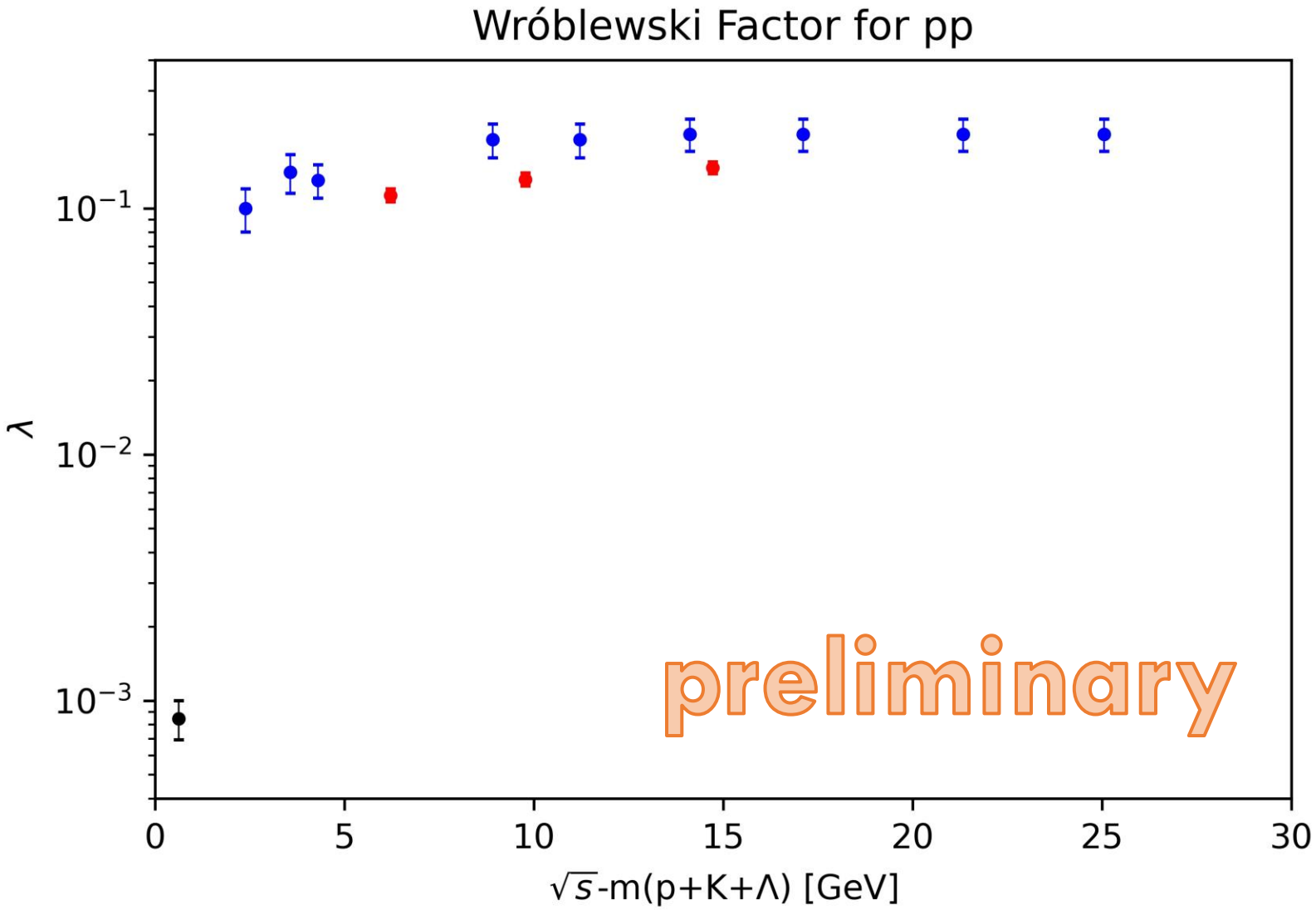
In the proces $pp \rightarrow pK^+\Lambda$ nothing but the $s\bar{s}$ pair is created.

Low energy supplement

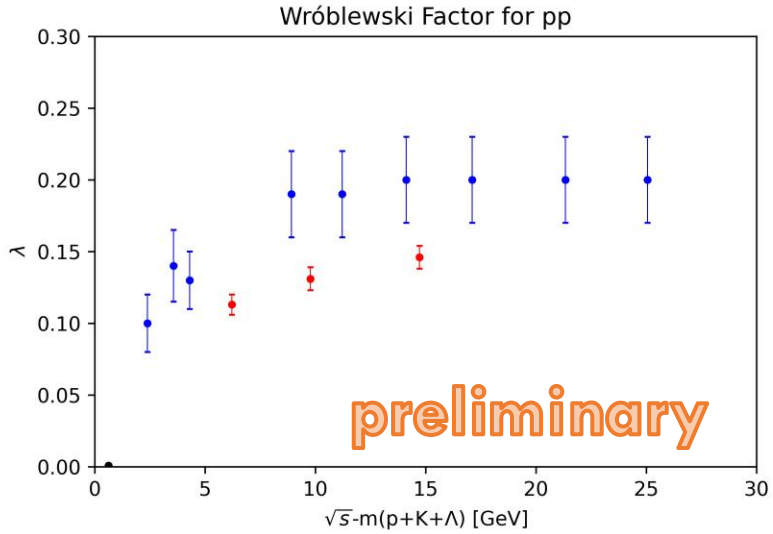
- HADES Collaboration (SIS18@GSI) measured pp at T_{KIN}=3.5 GeV
- Cross section for pp→p$K^+\Lambda = 38\mu$b (Physics Letters B 742 (2015) 242)
- Cross section for pp→NNπ, pp→NN$\pi\pi$ ... ≈ 30mb (PDG)
- Average multiplicity of (charged) π $<M_\pi>=1.5\pm0.2$

  (R.J. Piserchio and R.M. Kalbach, Il Nuovo Cimento XXVI, 729 (1962) „*PROTON-PROTON COLLISIONS AT 3.5 GeV*")
- Wróblewski Factor

$$\lambda = \frac{38\mu b}{30mb} \times \frac{2}{2 \times 1.5} = (8.4 \pm 1.5)10^{-4}$$



including HADES measurement (black) just above threshold



CONCLUSIONS

- Wróblewski Factor λ obtained for pp
- NA61/SHINE energy range (8 GeV$< \sqrt{s} <$ 17 GeV)

  results (~0.15) similar to the evaluation by Wróblewski (1985)
- HADES energy (E_{KIN}=3.5 GeV, $\sqrt{s}$ =3.17 GeV)

  $\lambda \approx 10^{-3}$, as very close to the threshold energy