Measuring μ_B at the LHC with ALICE

Mario Ciacco, on behalf of the ALICE Collaboration

Politecnico di Torino and INFN

Quinto Incontro di Fisica Nucleare INFN 2022

Physics Motivation

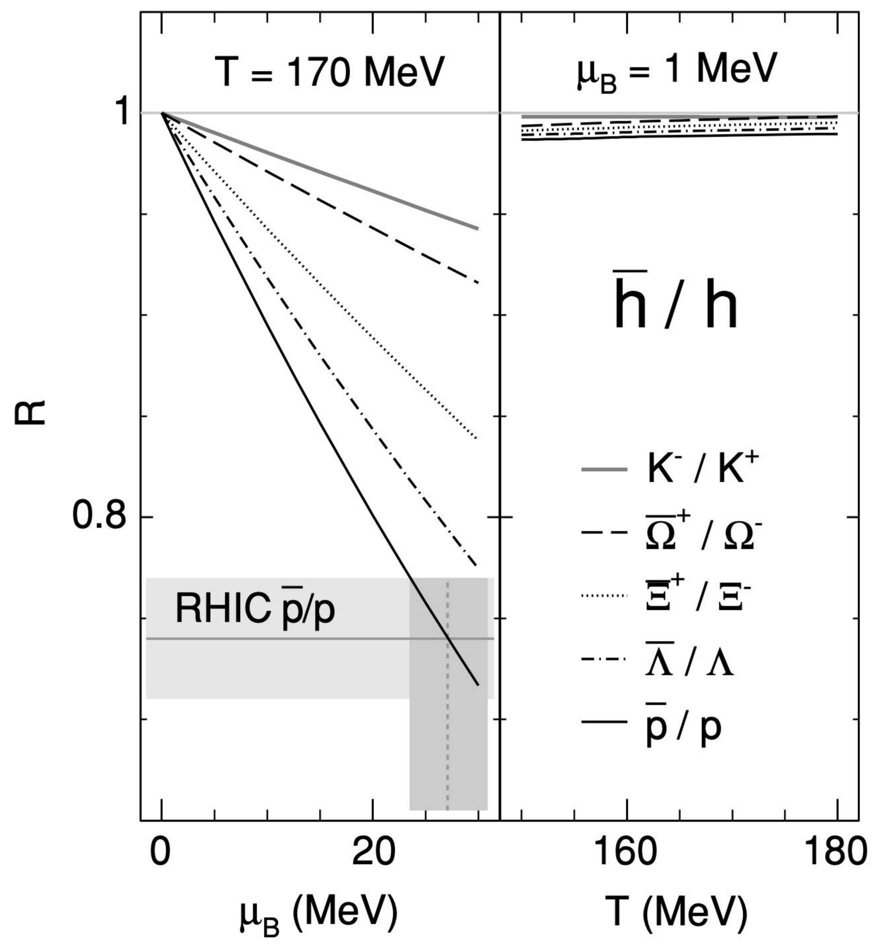
The Baryon Chemical Potential μ_B

- Chemical potential: internal energy variation (dU) due to variation in the particle number (dN)

$$\mu = \left(\frac{\mathrm{d}U}{\mathrm{d}N}\right)_{S,V}$$

- μ_B: associated with baryon number B determines antimatter-matter balance in hadron systems at thermal and chemical equilibrium
- In $\sqrt{s_{NN}}$ = 2.76 TeV Pb–Pb collisions at the LHC, μ_B = 0.7 ± 3.8 MeV [1]

figure from [2]



Antiparticle-to-particle Ratios

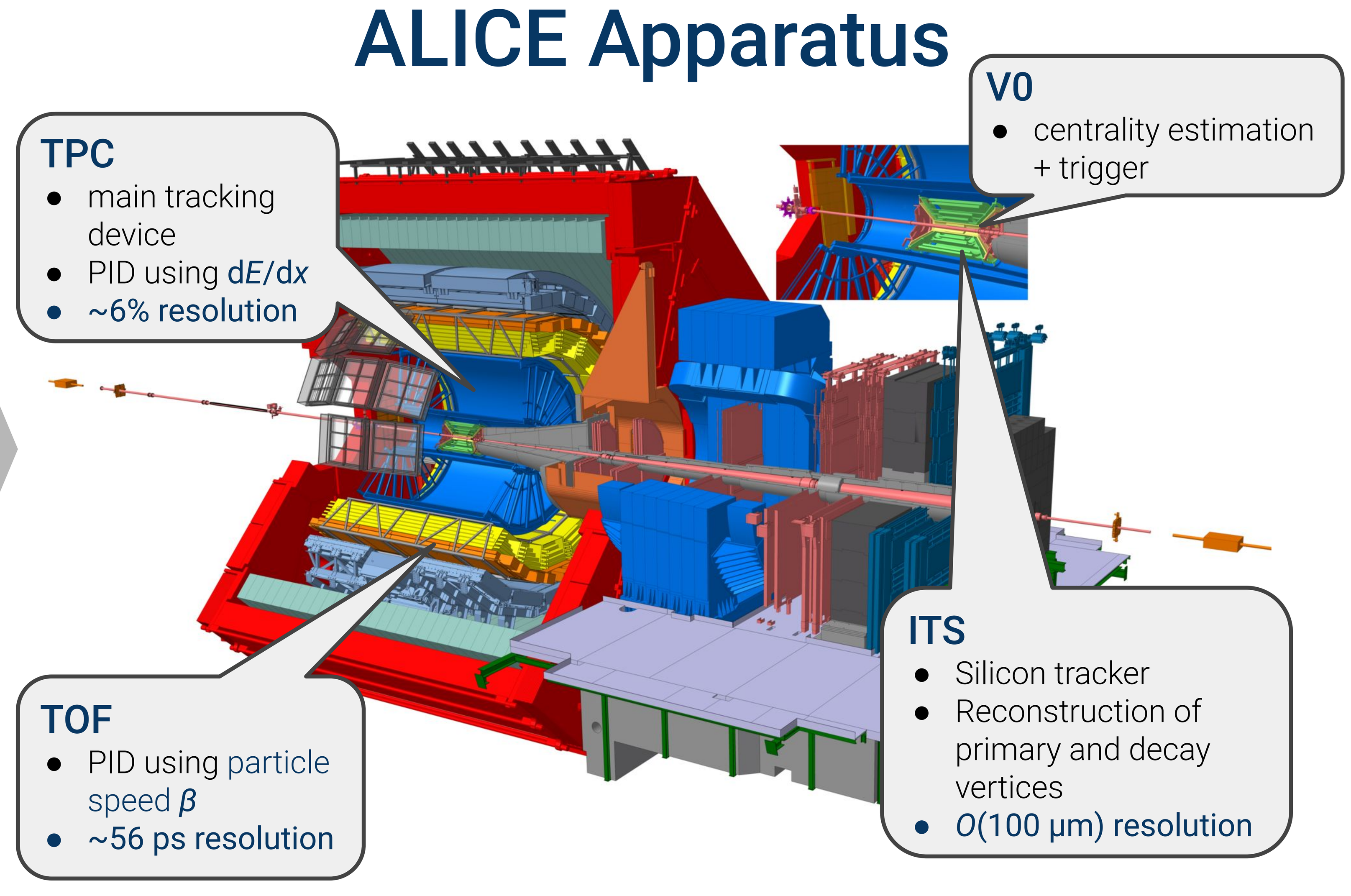
- From the Statistical Hadronisation Model (SHM) [2, 3]

$$\bar{h}/h \propto \exp\left[-2\left(B+\frac{S}{3}\right)\frac{\mu_B}{T} - 2I_3\frac{\mu_{I_3}}{T}\right]$$

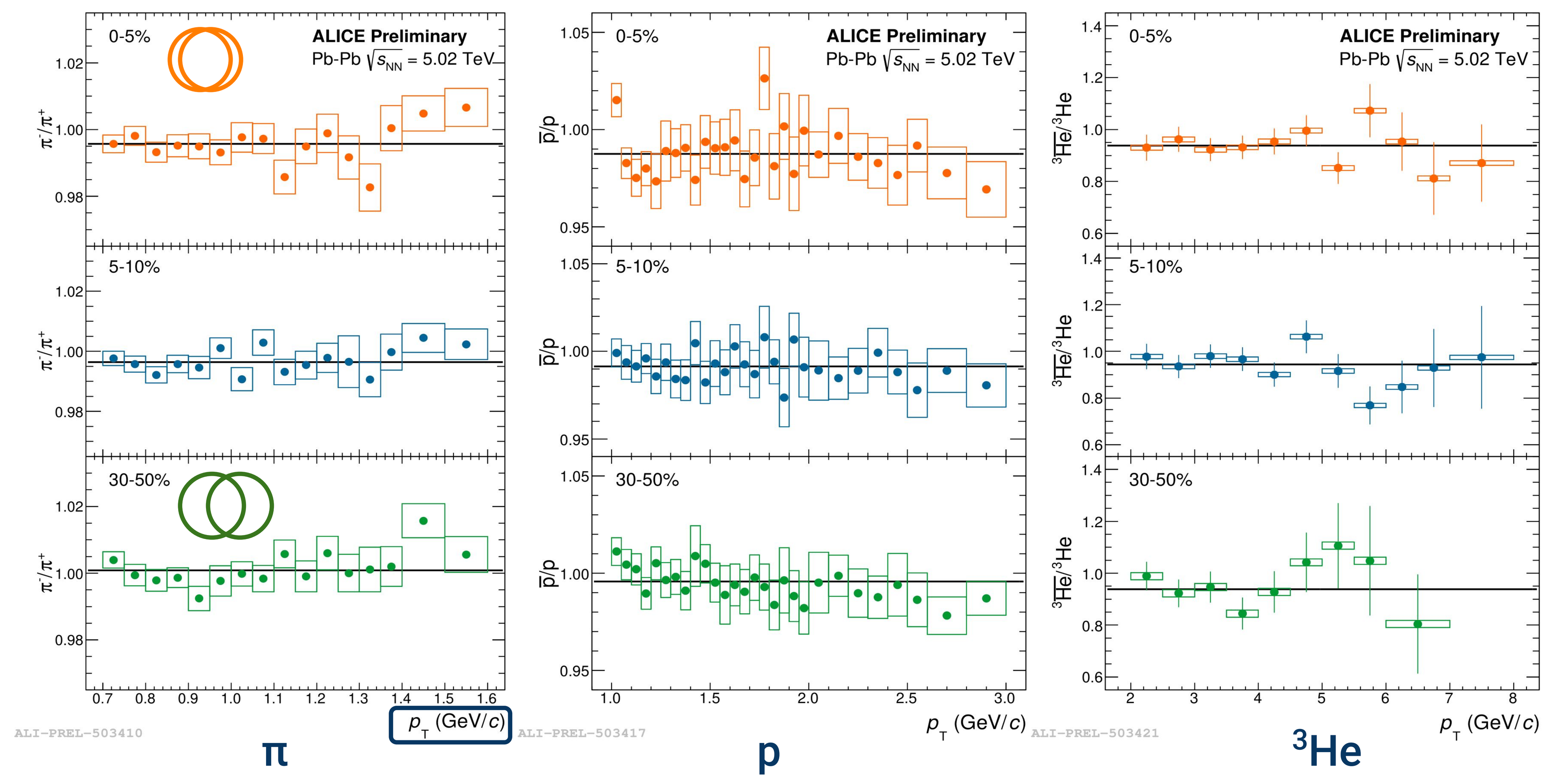
strangeness — isospin chemical potential

- Large $B + S/3$ → high sensitivity to μ_B → (anti)p, ^{3}He, $^3_\Lambda$H (and π± for μ_{I3})
- Small dependence on temperature T → fixed from SHM fit [1]
  → T = 156.5 ± 1.5 MeV
- Ratios → reduce systematic uncertainties → precise μ_B measurement

ALICE Apparatus



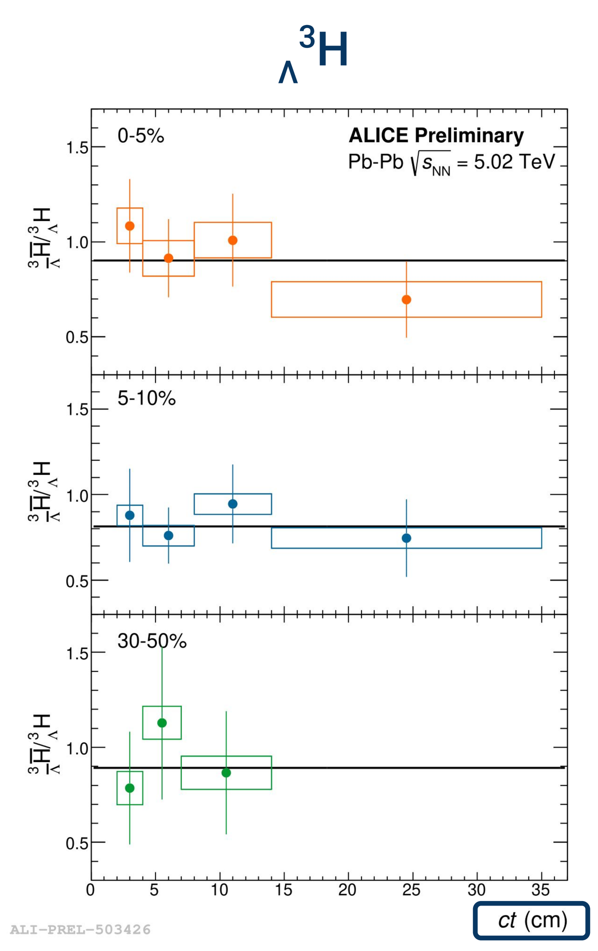
Antiparticle-to-particle Ratios



Pions, protons and helium

- Particle identification with **TOF** (pions, protons) and **TPC** (helium)
- Centrality from **V0** detector
- Standard selections applied to reconstructed tracks:
  - kinematic variables
  - track-reconstruction quality parameters
  - distance of closest approach to primary vertex → reject candidates originating from weak decays of Λ and $^3_\Lambda$H and inelastic interactions with material
- Ratios as a function of p_T in central and semicentral events
  → no dependence on p_T
  → weighted average of p_T-differential points

$^3_\Lambda$H



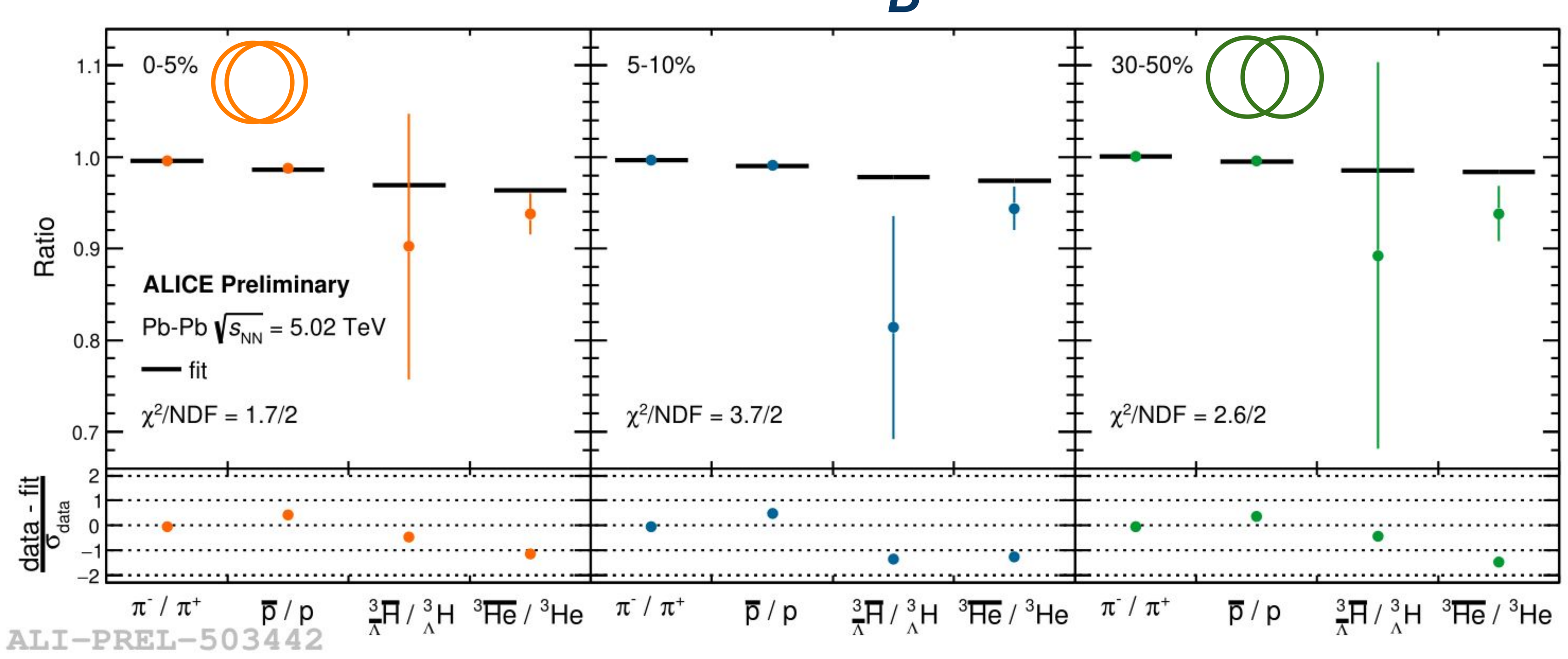
Hypertriton

- Reconstructed via 2-body mesonic decay

$$^3_\Lambda\mathrm{H} \to {}^3\mathrm{He} + \pi^- (+\text{ c.c.})$$

- Pion yield → ~10^7x helium yield → large combinatorial background
  → BDT candidate selection using *XGBoost* [5, 6]
- Variables used to train the classifiers:
  - topological and kinematic variables of reconstructed hypertriton candidate
  - reconstruction quality and PID of daughter particles
- Ratios as a function of proper decay length ct

Fit to Ratios and μ_B measurement

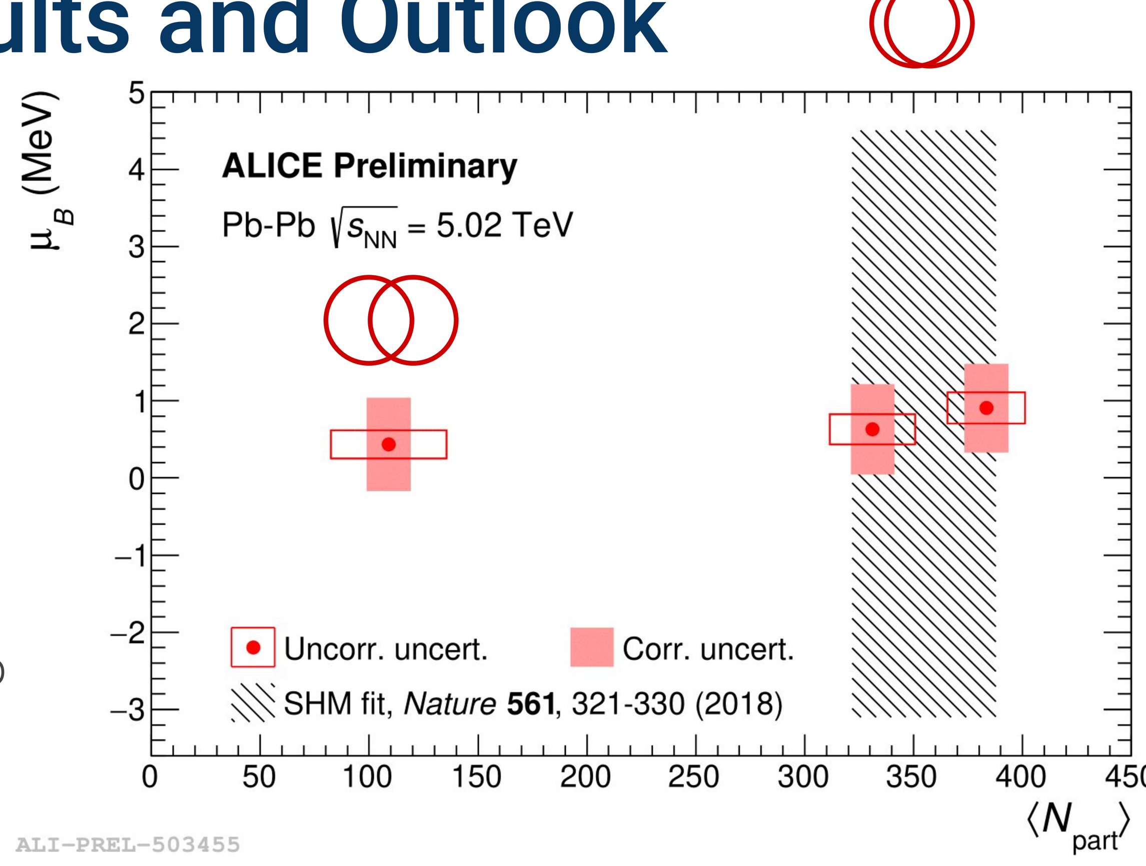


Fit to Ratios

- μ_B and μ_{I3} as fit parameters
- Strangeness neutrality → $\mu_S \approx \mu_B/3$
  → scaling of ratios with $B + S/3$ → verified

	π⁺	p	^{3}He	$^3_\Lambda$H
$B+S/3$	0	1	3	8/9
I_3	1	1/2	1/2	0

Results and Outlook



- Agreement with previous studies
- O(10) improvement in precision from previous studies → most precise measurement in Pb–Pb at TeV scale
- No significant dependence on centrality from central to semicentral collisions

Outlook

- Further test the statistical model description with additional species
  - Λ → precise test of strangeness dependence of ratios
  - Ω → $B + S/3 = I_3 = 0$ → expected ratio = 1
  - ^{3}H → $B + S/3 = 3$, I_3 = -½ → negative-isospin ^{3}He counterpart

References

[1] A. Andronic et al., Nature 561, 321-330 (2018)

[2] J. Cleymans *et al.*, Phys. Rev. C 74, 034903 (2006)

[3] J. Cleymans and H. Satz., Z. Phys. C 57, 135–147 (1993)

[4] ALICE Collaboration *et al* 2008 *JINST* 3 S08002T

[5] Chen et al., (2016 arXiv:1603.02754 [cs.LG]

[6] ALICE Collaboration, (2021) arXiv:2107.10627 [nucl-ex]