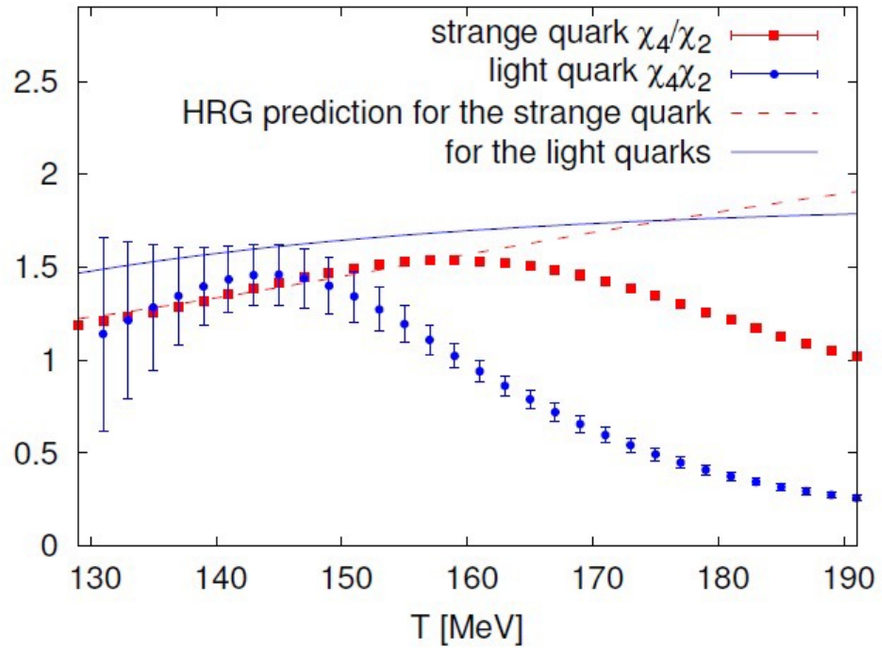
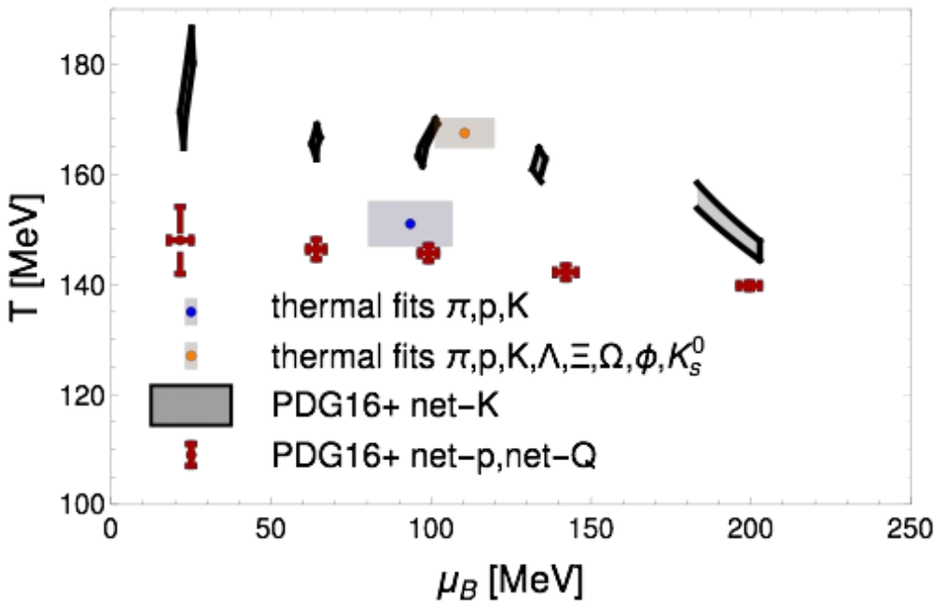
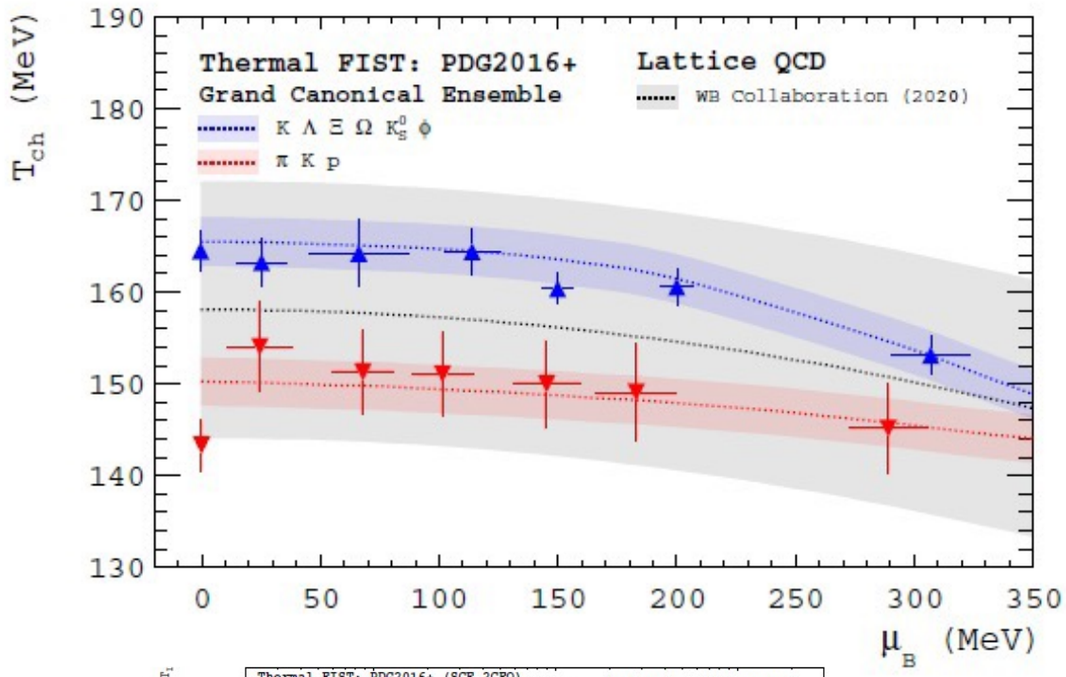
Particle Production and freeze-out
Q1: flavor dependent freeze-out

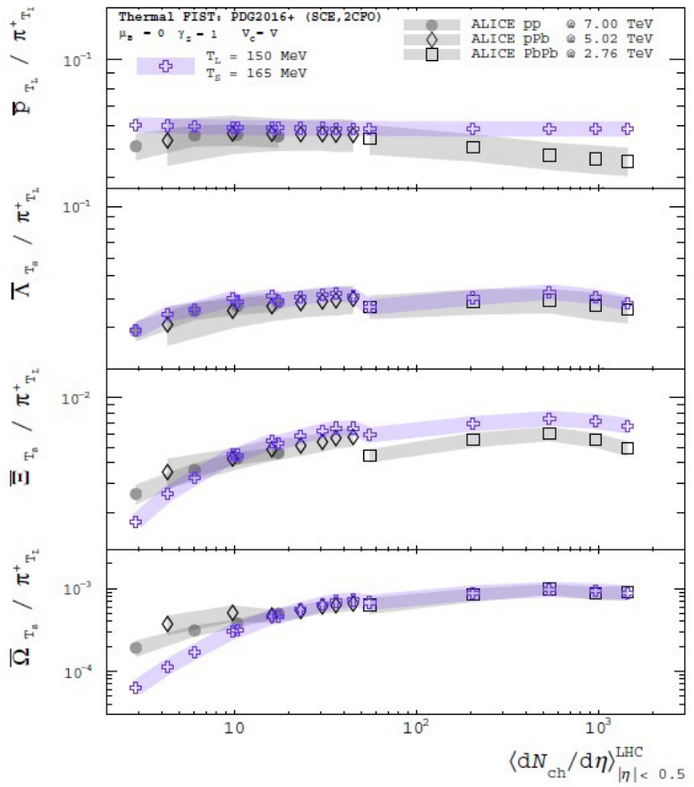
- First principle calculation & fluctuation measurements (PRL 111 (2013) 202302 & *Phys.Rev.C* 99 (2019) 3, 034912





- Experimental evidence from yields and strangeness enhancement *Phys.Lett.B* 814 (2021) 136098 & *Phys.Lett.B* 834 (2022) 137473

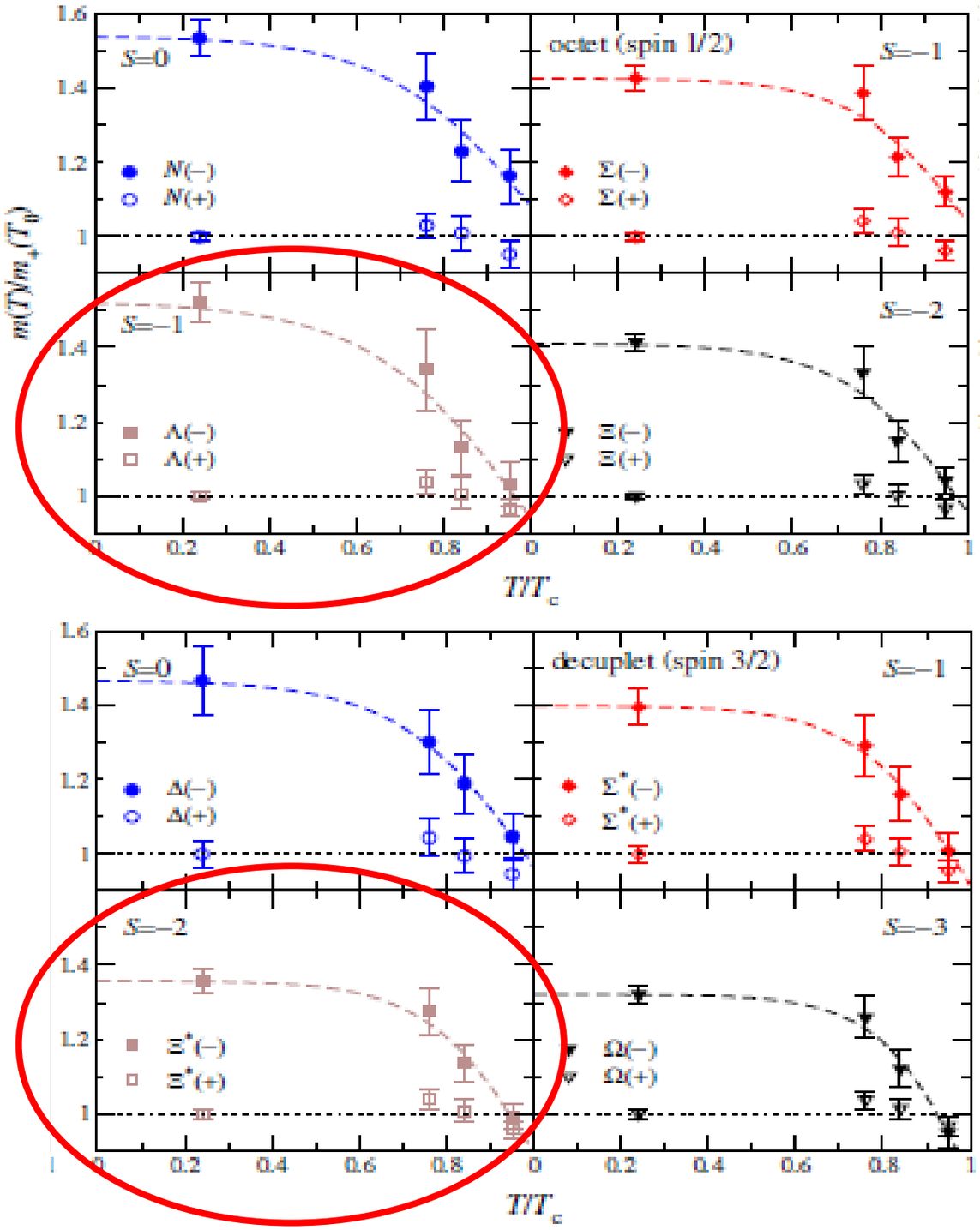


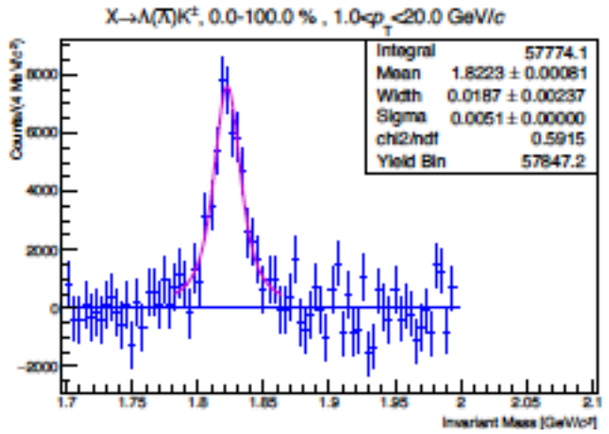


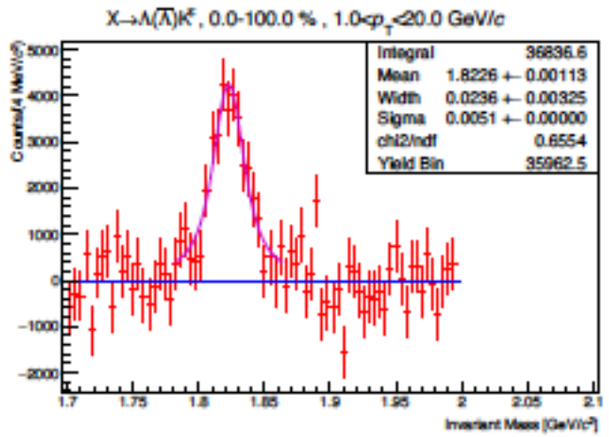
-> Future charm measurements

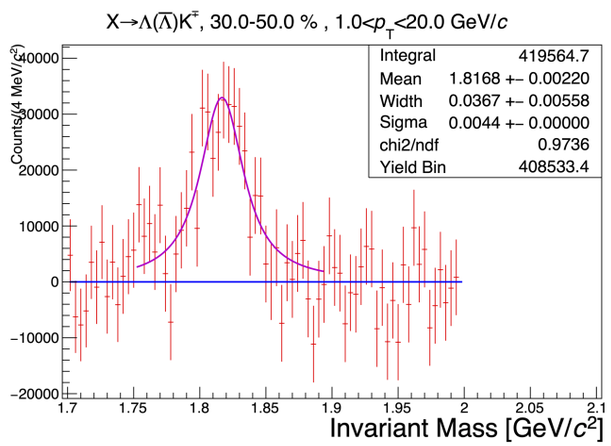
Particle Production and freeze-out
Q2: flavor dependent chiral symmetry restoration

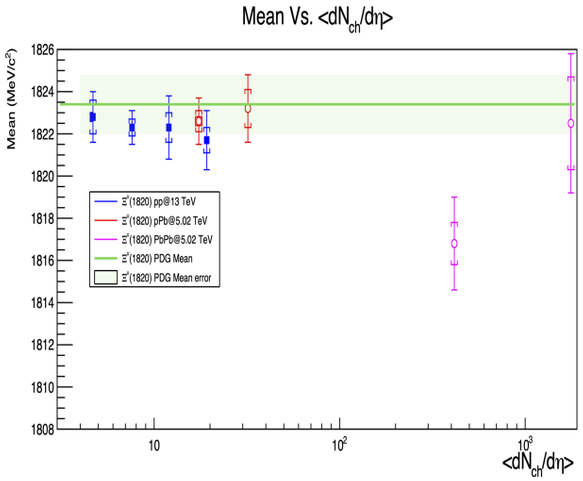
- Lattice QCD calculation (JHEP 06 (2017) 034)
- Experimental evidence (UH thesis – Myers)

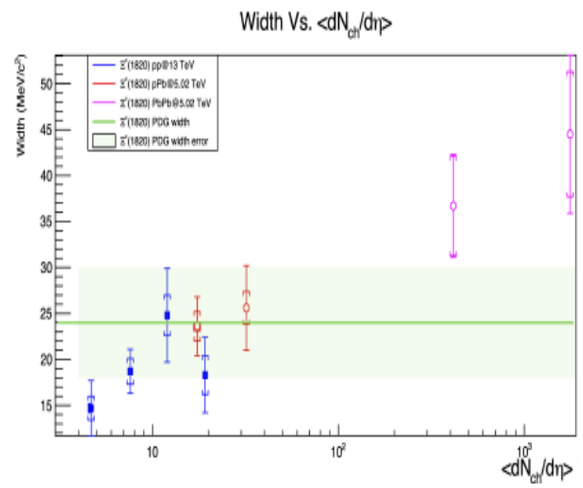






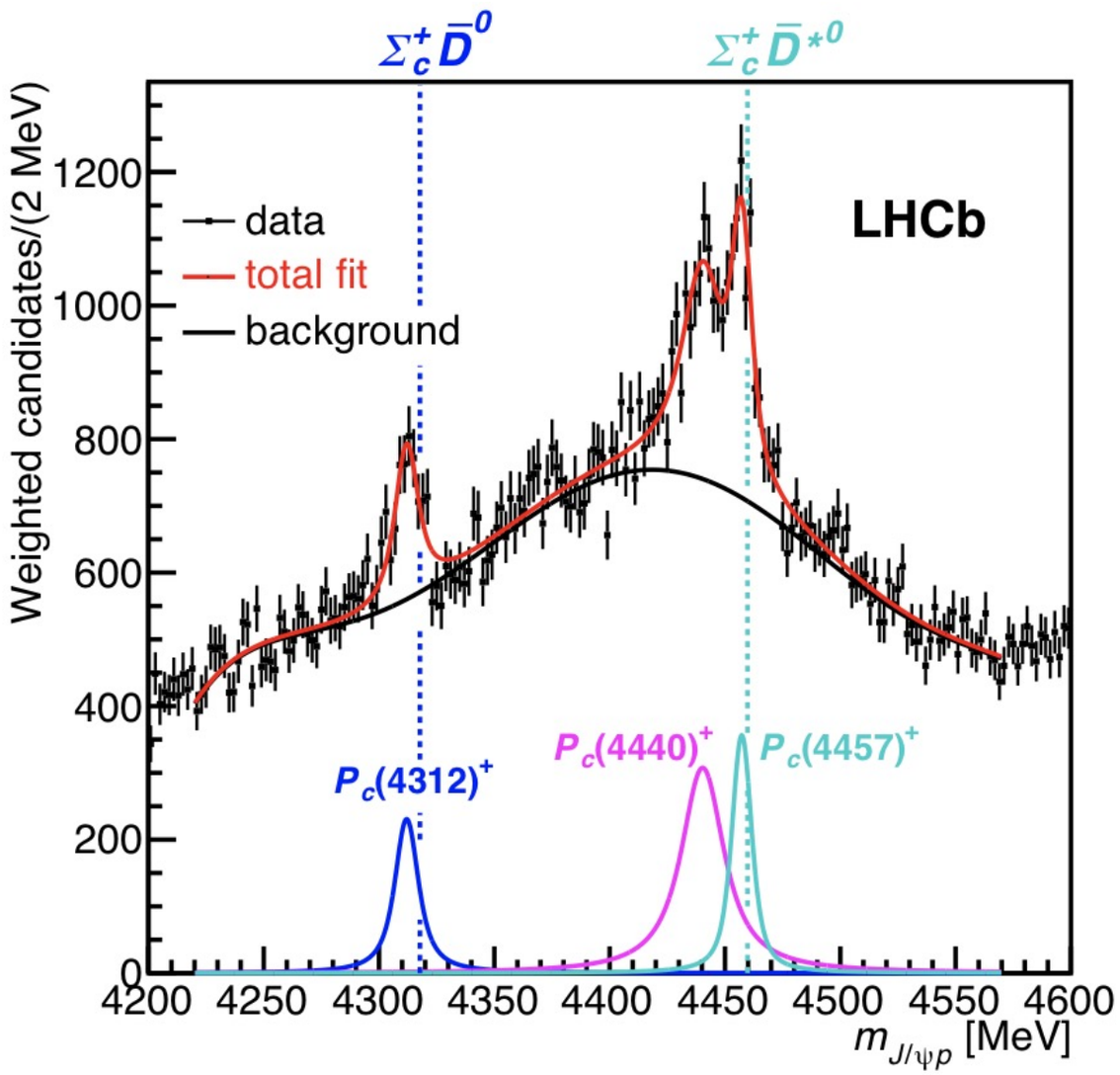




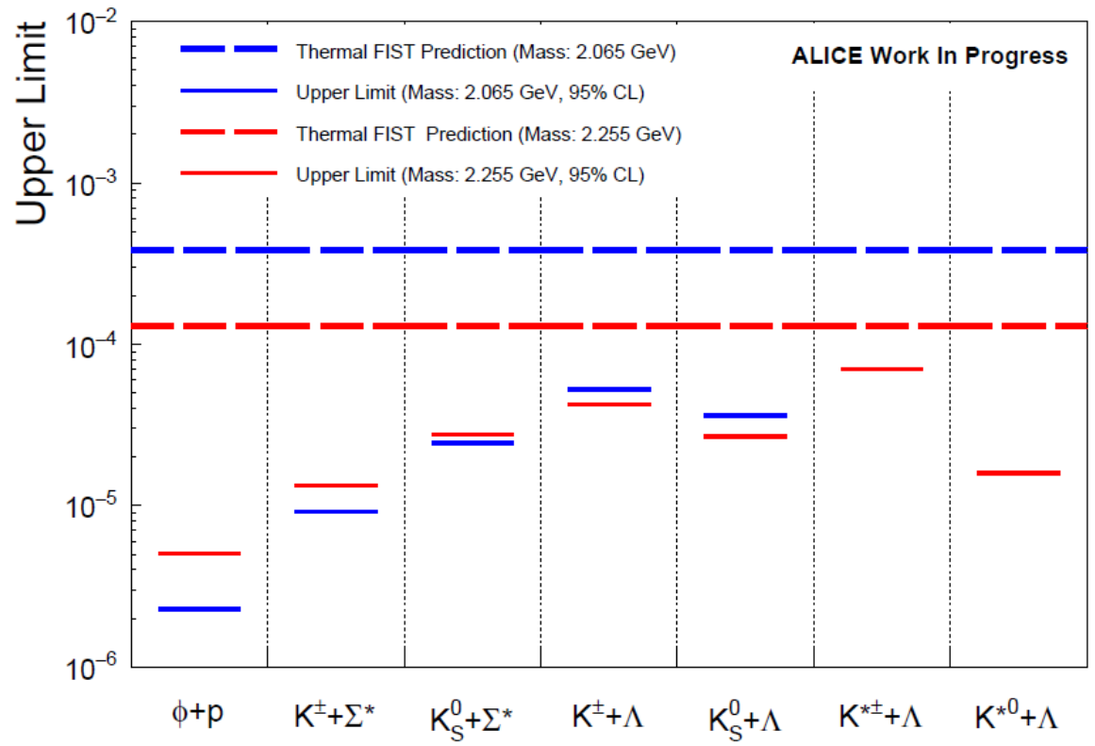


Particle Production and freeze-out
Q3: lack of multi-quark states in strange sector

- Experimental evidence in charm sector



- Lack of experimental evidence in strange sector

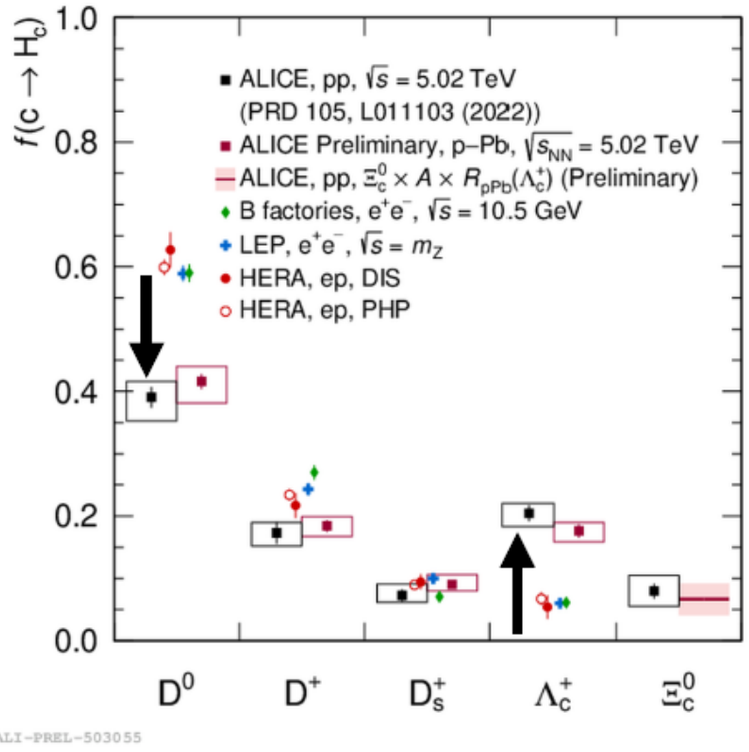


State	Mass (MeV/c^2)	Width (MeV/c^2)	S-wave threshold (MeV/c^2)	Coupled Channels
X(3872) [226]	3872.0 ± 0.2	1.19 ± 0.21	$D^{*0}\bar{D}^0(-0.04)$, $D^{*+}\bar{D}^-(-8.11)$	$\pi^+\pi^- J/\psi$, $\pi^+\pi^-\pi^0 J/\psi$
X(3940) [226]	3942 ± 9	37	$D^*\bar{D}^*$ (-75 ±9)	$D^*\bar{D}$
X(4140) [226]	4147.0 ± 4.5	83 ± 21	$D_s\bar{D}_s^*$ ($-66^{+4.9}_{-3.2}$)	$\phi J/\psi$
X(4274) [226]	4273.0 ± 8.3	56 ± 11	$D_s\bar{D}_s^*$ ($-49.1^{+19.1}_{-9.1}$)	$\phi J/\psi$
$Z_b(10610)$ [226]	$10\,607.0 \pm 2.0$	18.4 ± 2.4	$B\bar{B}^*(4 \pm 3.2)$	$\pi^\pm\Upsilon(nS)$ $\pi^\pm h_b(nP)$
$Z_b^\pm(10650)$ [226]	$10\,652.2 \pm 1.5$	11.5 ± 2.2	$B^*\bar{B}^*(+2.9)$	$\pi^\pm\Upsilon(nS)$ $\pi^\pm h_b(nP)$
$P_c^+(4312)$ [83]	$4311.9 \pm 0.7^{+6.8}_{-0.6}$		$\Sigma_c\bar{D}(-9.7)$	pJ/ψ
$P_c^+(4440)$ [83]	$4440.3 \pm 1.3^{+4.1}_{-4.7}$	$20.6 \pm 4.9^{+8.7}_{-10.1}$	$\Sigma_c\bar{D}^*(-21.8)$	$pJ/\psi, \Sigma_c\bar{D}\Sigma_c^*\bar{D}$
$P_c^+(4457)$ [83]	$4457.3 \pm 0.6^{+4.1}_{-1.7}$	$6.4 \pm 2.0^{+5.7}_{-1.9}$	$\Sigma_c\bar{D}^*(-4.8)$	$pJ/\psi, \Sigma_c\bar{D}\Sigma_c^*\bar{D}$
T_{cc}^+ [57]	3874.827	0.410	$D^{*+}\bar{D}^0(-0.273)$, $D^{*0}\bar{D}^+(-1.523)$	$D^0D^0\pi^+$

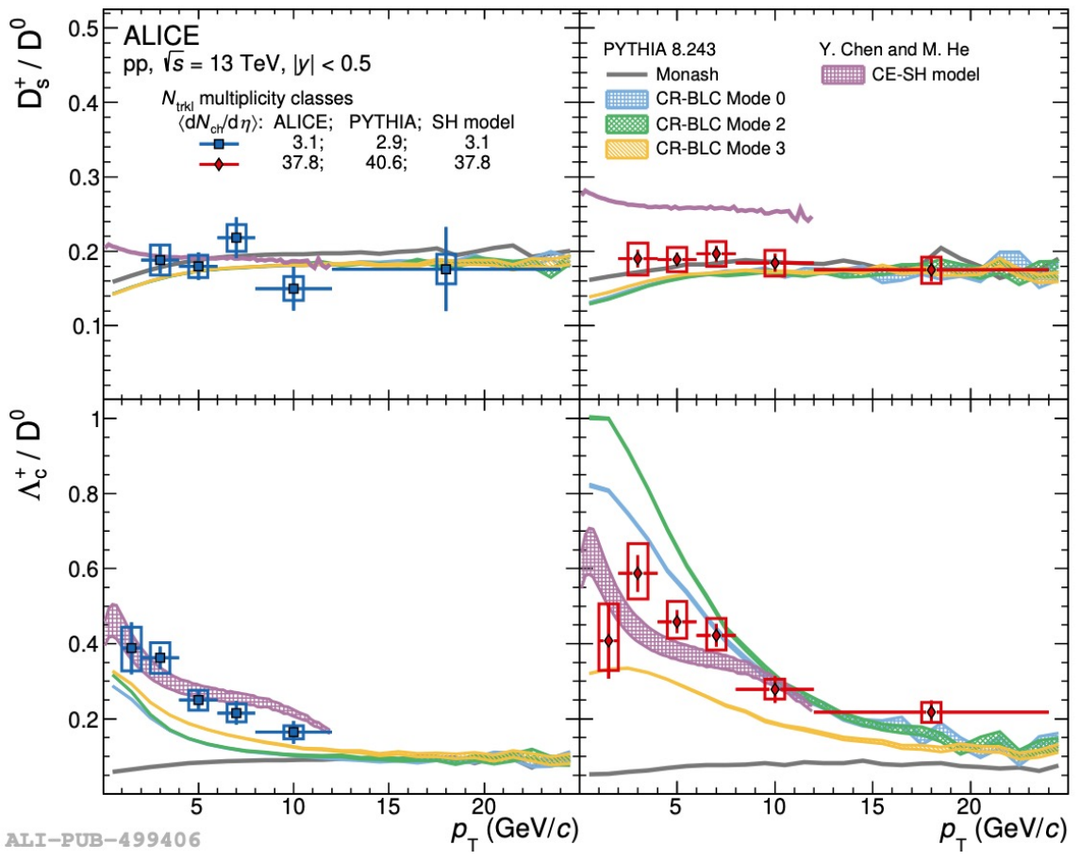
Table 5: Selection of candidates for hadronic molecules with a mass close to a hadron-hadron mass threshold [57, 83, 226].

Particle Production and freeze-out
Q4: large small system vs small large system

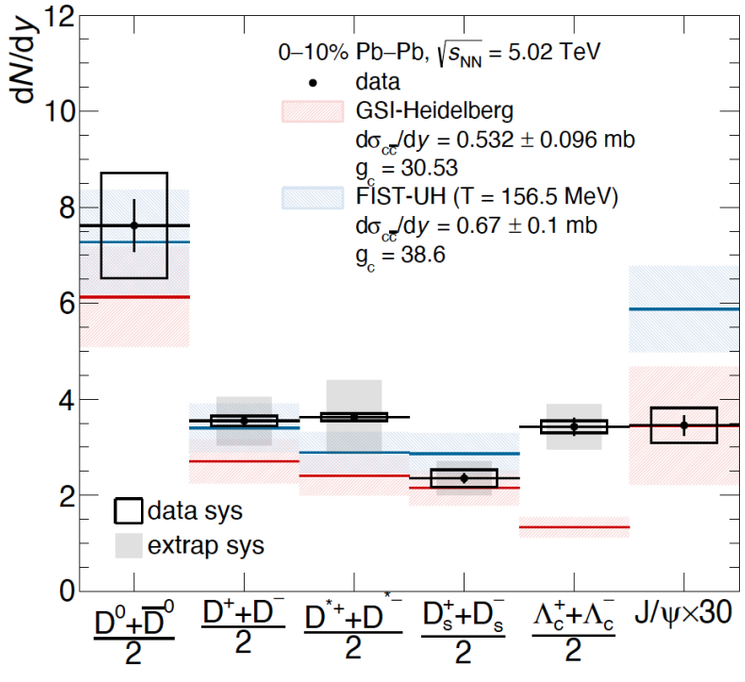
- Non-universality in charm sector ?

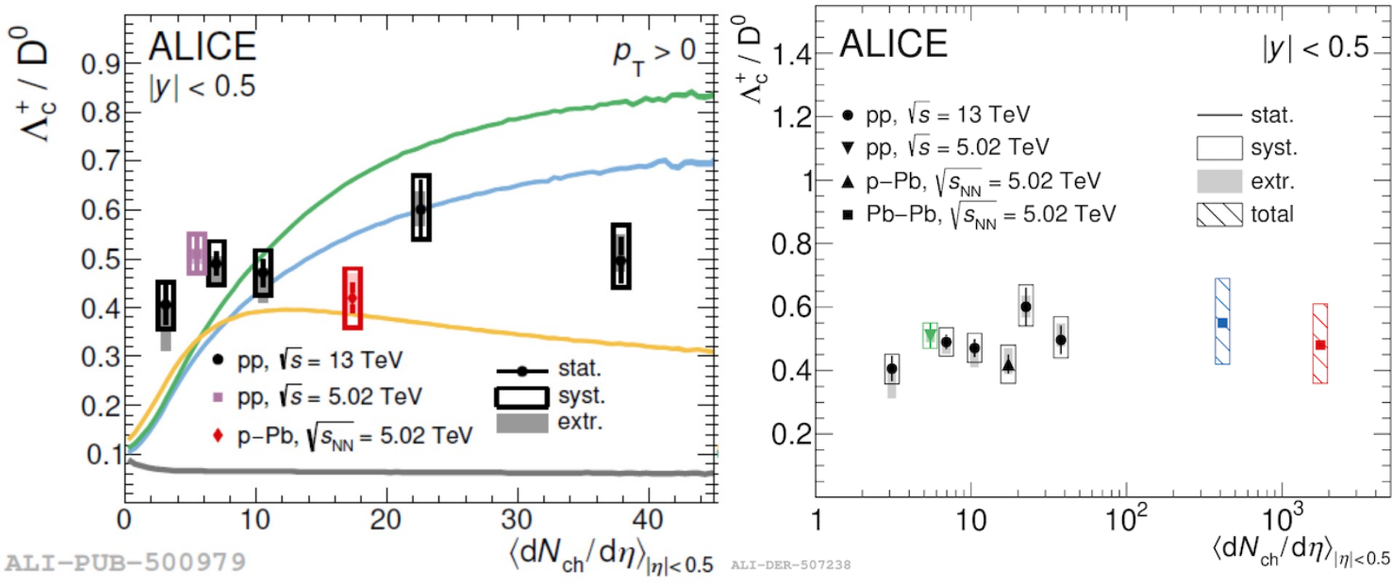


- CR vs. thermal production



- Common thermal production in heavy ions ?





Particle Production and freeze-out
Q5: 'thermalization' from entanglement
initial entropy production = final particle production

- Bose condensate measurement

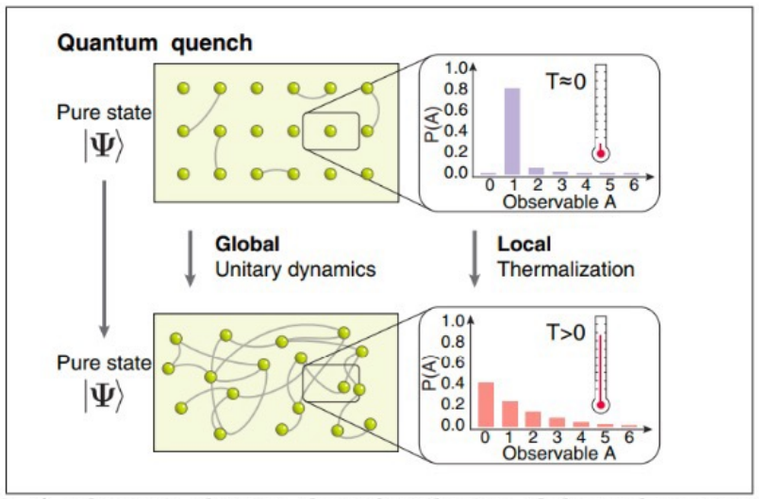
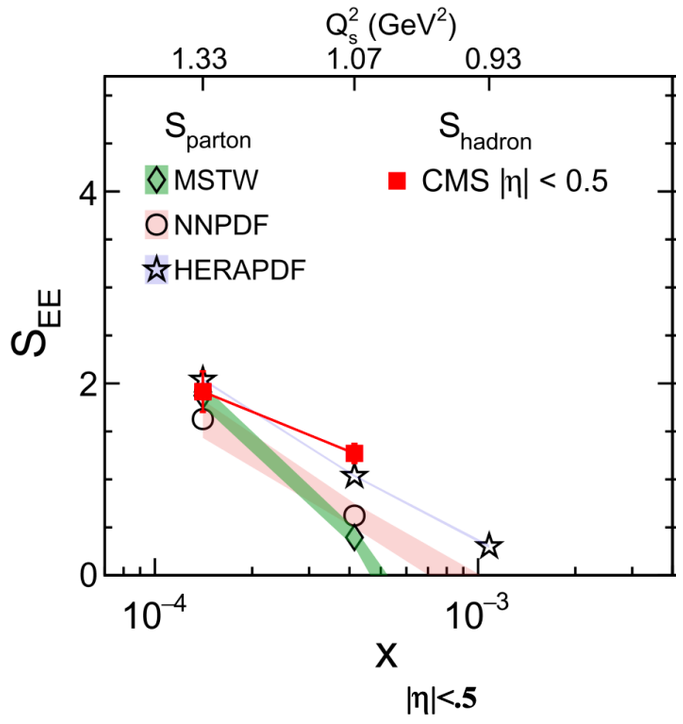


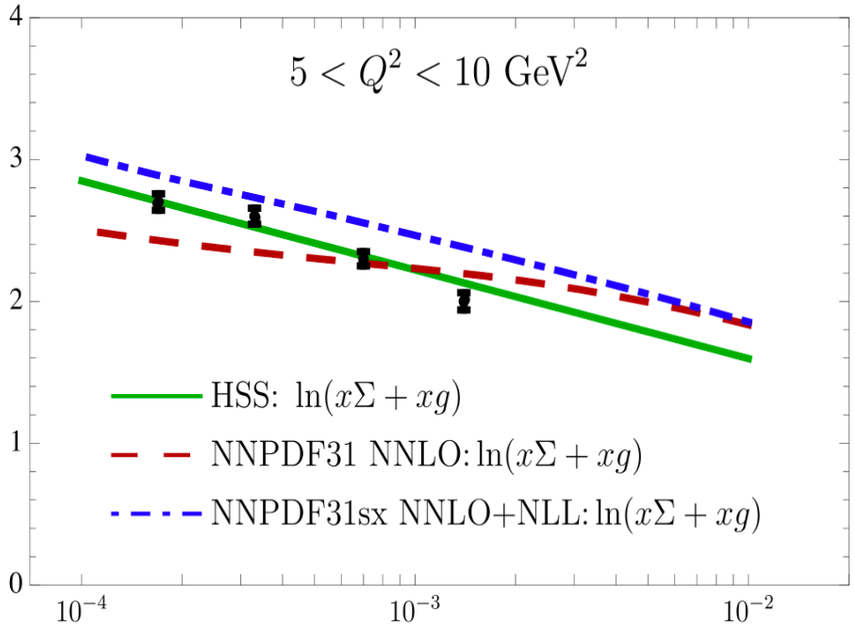
Figure 2. A schematic showing the redistribution of thermal energy in a pure state of entangled atoms. [5]

- Experimental evidence

pp collisions
(CMS data at
different energies)



ep collisions: (H1 data at different x-values)



pp collisions
(ALICE data at
different energies)