Chapter 7 | Discussion and conclusion

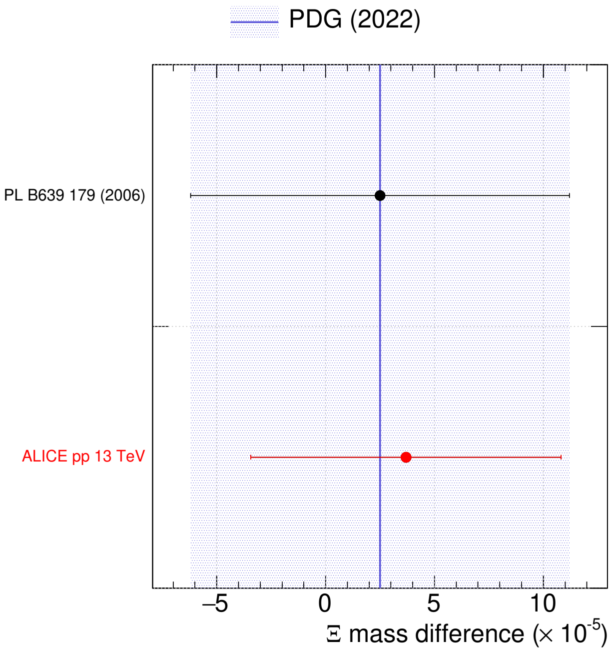
~~At the~~ beginning of this three-year PhD, in 2020, ~~the LHC is in~~ the middle of the ~~its~~ second long shutdown. For an experiment installed on the collider, such as ALICE, this is a decisive moment: the experiment has to carry out its major upgrade programme ~~on time~~ for the beginning of the LHC Run-3 and, ~~at the same time,~~ it must finalise the physics analyses of the previous data taking period. The present thesis contributes to the latter. In particular, it proposes to push the data analysis to the limits of ALICE during the LHC Run-2, by performing precision measurements in the light flavour sector, with multi-strange baryons. In that regard, two analyses have been performed.

Particle	Measured mass (MeV/c^2)	Uncertainty stat. (MeV/c^2)	Uncertainty syst. (MeV/c^2)	Measured mass difference ($\times 10^{-5}$)	Uncertainty stat. ($\times 10^{-5}$)	Uncertainty syst. ($\times 10^{-5}$)
Ξ^-	1321.968	0.025	0.070	-3.34	2.67	6.61
$\overline{\Xi}^+$	1321.918	0.025	0.075			
Ω^-	1672.520	0.033	0.102	3.44	3.00	1.91
$\overline{\Omega}^+$	1672.571	0.033	0.101			

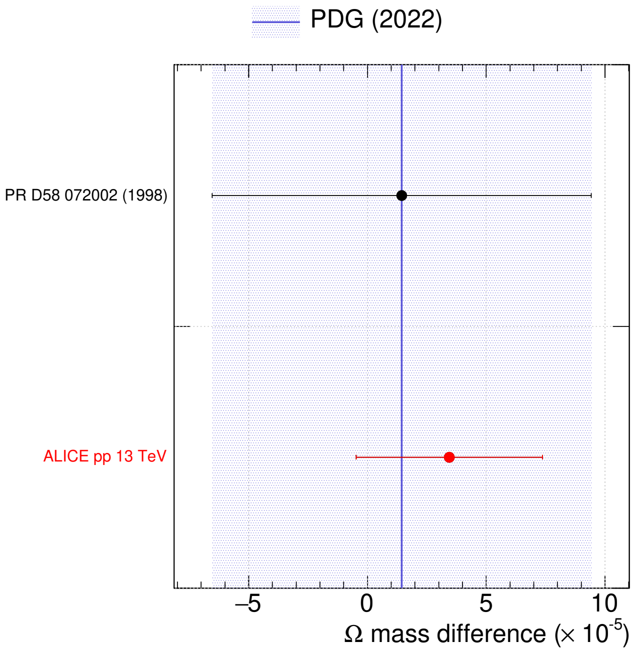
Table 7.1: Final measured masses and relative mass differences Ξ and Ω, with their associated statistical and systematic uncertainties.

The first analysis of this thesis consists in a precise measurement of the Ξ^-, $\overline{\Xi}^+$, Ω^- , $\overline{\Omega}^+$ masses and mass differences between particle and antiparticle. The main motivation is that the last mass measurements of such ~~nature~~ have been performed 17 and 25 years ~~ago,~~ and rely on a low statistics. In contrast, the present analysis makes use of the excellent reconstruction capabilities of ALICE during the LHC Run-2, and the abundant production of strange hadrons in pp collisions at centre-of-mass energy of 13 TeV: about 2 500 000 ($\Xi^- + \overline{\Xi}^+$) and approximately 133 000 ($\Omega^- + \overline{\Omega}^+$).

Through the Chap. 5, it has been shown that a fine comprehension of the data reconstruction is required to perform such measurements, and quickly the limits of the detector calibration are reached. To overcome these limitations, a sizeable fraction of the statistics had to be sacrificed. Although, the final measurements – summarised in Tab. 7.1 – can still compete with the current values listed in the PDG, and improves them by a factor 1.20 and 2 for the relative mass difference of the Ξ and Ω baryons respectively (Fig. 7.1). Considering their precision, both ascertain the validity of the CPT invariance symmetry. The presented results are in their final state, and should lead to a publication in the future.



(a)



(b)

Fig. 7.1: Comparison of our mass difference values between the Ξ^- and $\overline{\Xi}^+$ (a), and the Ω^- and $\overline{\Omega}^+$, to the past measurements quoted in the PDG, as of 2023 [42]. The vertical line and the shaded area represent the PDG average and its associated uncertainty.

Based on the first analysis, this thesis work continues with a second one. However, the objective is no longer to measure the properties of multi-strange baryons, but to study their production mechanisms in proton-proton collisions at the LHC energies. This analysis aims at providing further experimental input in order to form continum of physics going from pp collisions to heavy-ion collisions.

In particular, this involves correlating a multi-strange baryon – either a Ξ or Ω– with a $\phi(1020)$ resonance. Such a measurement turns out to be rather challenging: the goal is to correlate two *identified* particles, with a relatively low production rate[1]. In contrast, while the first analysis targets high precision, this one clearly aims for high efficiency.

This experimental constraint is important to distinguish between different phenomelogical models. For instance, the Monash 2013 tune of Pythia predicts an enhancement of Ω abundancy in presence of a $\phi(1020)$ in the event that decreases with the charged particle multiplicity, while the colour reconnection and colour rope "tune"[2] anticipates an increase.

Preliminary results related to such correlation are presented in Chap. 6. They indicate that the available statistics in both Ω baryons and ϕ resonances remains too low in minimum-bias proton-proton collisions; concerning the Ξ hyperons, the angular and rapidity correlations have been studied separately, though no correlation can be observed at the moment.

This study has also been initiated in high multiplicity proton-proton collisions, as well as the comparison to different MC model predictions, mainly Pythia and Epos. These do not appear in the manuscript, as the results are not mature enough to draw any conclusion.

These two analysis put into perspective the limits of the ALICE detector during the LHC Run-2. On one hand, as shown in Chap. 5, the uncertainties on the mass and mass difference values are driven by the detector calibration. In particular, the dominant source of systematic bias comes from the residual mis-calibration. To keep it under control, a sizeable fraction of the data had to be discarded, resulting in high uncertainties. On the other hand, the second analysis lacks of statistics, making it impossible to draw any conclusions. The solution to these limitations may certainly be found in the LHC Run-3.

As mentioned in the introduction, the ALICE collaboration carried out a major upgrade of the experimental apparatus during the second long shutdown (2018-2022). The ITS have been replaced with a new Inner Tracking System, the ITS-2, with a better spatial resolution and a reduced material budget[3]. As opposed to its predecessor in the LHC Run-1 and Run-2, all the layers are equipped with the same technology (Monolithic Active Pixel Sensors), thus limiting the holes in the detector acceptance. Furthermore, ALICE deployed a new Online-Offline software to enable continuous readout of Pb-Pb collisions to interaction rate up to 50 kHz. Therefore, the experiment is now able to record much more data than ~~in~~ the LHC Run-2[4].

In turn, ALICE has become much more dependent on the quality of its calibration, and most particularly, the one in the TPC. However, this is also an opportunity, as it opens the way towards a potentially better calibration in the LHC Run-2.

[1]Over a thousand event, one can expect approximately 38 $\phi(1020)$, 20 Ξ and 2 Ω in pp collisions at $\sqrt{s} = 13$ TeV [142]. In addition, they must belong to the same event to be useful in the analysis.

[2]Strictly speaking, there exists no official tune in Pythia including the colour reconnection and colour rope mechanisms. The closest configuration to a tune is the one presented in App. 9.

[3]To that regard, the present author contributed to the commissionning of the ITS-2, and particularly to the pre-alignement of the detector.

[4]As a comparison, over the past six months, ALICE already recorded 300 times more data than ~~in~~ the LHC Run-2.