Multiplicity dependence of strange and multi-strange particle in jets in pp collisions at $\sqrt{s} = 7$ TeV

authors

Abstract

Comprehensive results on the production of unidentified charged particles, $\pi^{\pm}$, $K^{\pm}$, p, K^0_S, K^{*0}, ϕ, Λ, $\Xi^{\pm}$, $\Omega^{\pm}$ hadrons in jets in proton-proton (pp) collisions at $\sqrt{s} = 7$ TeV are presented with two developed color reconnection models, the new color reconnection model and the rope hadronization model, in PYTHIA 8 generator. The observables are ratios of identified hadron yields as a function of the transverse momentum (p_T) and the final-state activity (the charged multiplicity).

1 Introduction

In heavy-ion collisions at ultra-relativistic energies, it is well established that a strongly coupled Quark-Gluon-Plasma (QGP) is formed [**? ? ? ? ?**]. Recent measurements in high multiplicity pp, p–A and d–A collisions at different energies have revealed strong flow-like effects even in these small collision systems [**? ? ? ? ? ? ? ? ? ? ?**]. The baryon-to-meson ratios p/π and Λ/K^0_S, in pp and p–Pb collision systems, exhibit a characteristic depletion at $p_T \sim 0.7$ GeV/c and an enhancement at intermediate p_T ($\sim$ 3 GeV/c), which is qualitatively similar to that observed in Pb–Pb collisions [**?**]. In a letter [**?**], the ALICE Collaboration reported the multiplicity dependent enhancement of strange (K^0_S, Λ and $\overline{\Lambda}$) and multi-strange (Ξ^-, $\overline{\Xi}^+$, Ω^- and $\overline{\Omega}^+$) particle in pp collisions at $\sqrt{s} = 7$ TeV. As well as, those results were complemented by the measurement of $\pi^{\pm}$, $K^{\pm}$, p, $\overline{p}$, K^{*0} and ϕ with ALICE [**?**]. Such behaviour cannot be reproduced by any of the MC models commonly used, suggesting that further developments are needed to obtain a complete microscopic understanding of strangeness production and indicating the presence of a phenomenon novel in high-multiplicity pp collisions.

In a recent study, to provide further insight into the particle production mechanisms in high-multiplicity pp and p–Pb events, the ALICE Collaboration has studied baryon-to-meson ratios with a new method: by studying the ratios in two parts of the events separately – inside jets and in the event portion perpendicular to a jet cone [**?**]. In contrast to the inclusive distribution, the p_T-differential Λ/K^0_S ratio within jets in pp and p–Pb collisions does not exhibit baryon enhancement at intermediate p_T. It is plausible that the baryon enhancement may therefore be attributable to the soft (low Q^2) component of the collision as discussed in [**?**].

In this work, inspired by this paper [**?**], we study the "strangeness to pion ratio increase with multiplicity" and the "baryon-to-meson ratio enhancement at intermediate p_T" with charged-particle jet probe by PYTHIA model. In this contribution we consider two of the models: the new colour reconnection (CR) model [**? ?**] and the colour rope model [**? ? ?**] in the PYTHIA 8 generator. Both considered colour reconnection models are built upon the Lund model for string hadronization [**? ?**]. In these models, outgoing partons are connected with string-like color fields, which fragment into hadrons when moving apart.

The paper is structured as follows: in Sec. 2 will give a brief introduction about the models we used, the results compared to data are provided in Sec. 3, the predictions results can be find in Sec. 4, and in the end, the paper will be summarized in Sec. 5,

2 Models

2.1 New color reconnection model

2.2 Color rope model

As rope formation is expected to give increased rates of strange particles and baryons, which may mimic effects of plasma formation, it makes signals for a phase transition more difficult to interpret. It has also been suggested that ropes may initiate the formation of a quark–gluon plasma [**? ? ? ?**]. At LHC energies many overlapping strings are also expected in pp scattering, where plasma formation normally is not expected.

3 Compare to data

The models performs as intended when comparing to existing data. The inclusive measurements on the charged particle pseudo-rapidity and multiplicity distributions are presented in Figure 1.

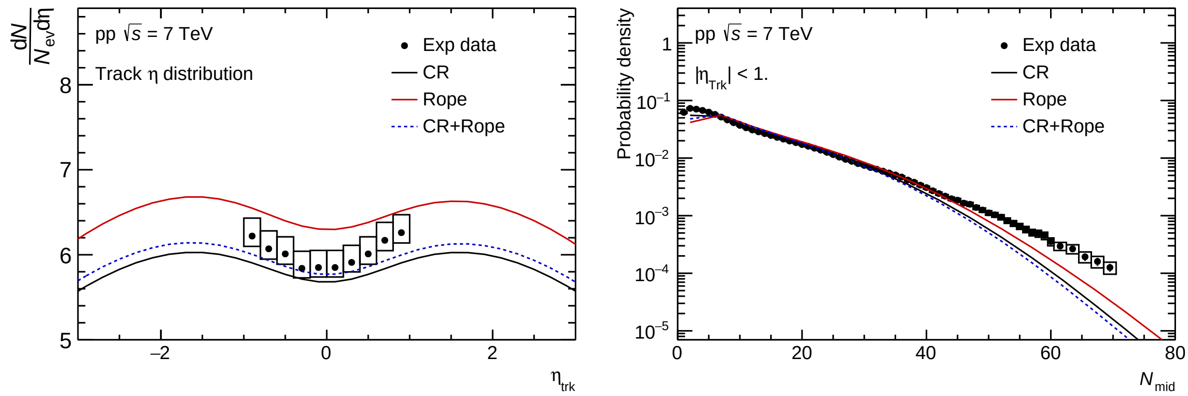

Figure 1: Charged particle pseudo-rapidity ($\eta_{\rm trk}$)(left) and number of mid-rapidity tracks ($N_{\rm mid}$) (right) distribution for pp collisions at $\sqrt{s} = 7$ TeV. The experimental data are taken from [**?**].

The average charged densities in each event for different string tension implementations are presented in Table A.3.

The $p_{\rm T}$-integrated yields of $\rm K^0_S$, $\rm K^{*0}$, Λ, Ξ, Ω and ϕ, are shown in figure 2. All of those three configurations can quantitatively describe the trends observed in the experiment data. For $\rm K^0_S$ and ϕ mesons, all the configurations tend to under estimate the data results. The $\rm K^{*0}$ yields are described well by all the models. For Λ, the Rope model is slightly underestimated the yields. For the multi-strange baryons (Ξ and Ω), only the CR + Rope configuration give the best descriptions.

The corresponding hadron to π ratios, $\rm K^0_S/\pi$, Λ/π, Ξ/π, Ω/π and ϕ/π, as functions of $\langle {\rm d}N_{\rm ch}/{\rm d}\eta\rangle$ distributions are shown in Figure 3. All those models can quantitatively describe the experiment results well. For multi-strange baryon to π ratios, the CR + Rope gives the best description. But this configuration overestimate the Λ/π ratio and Rope describe the ratio well. For $\rm K^0_S/\pi$ and ϕ/π ratios, all the configuration slightly underestimate the data results.

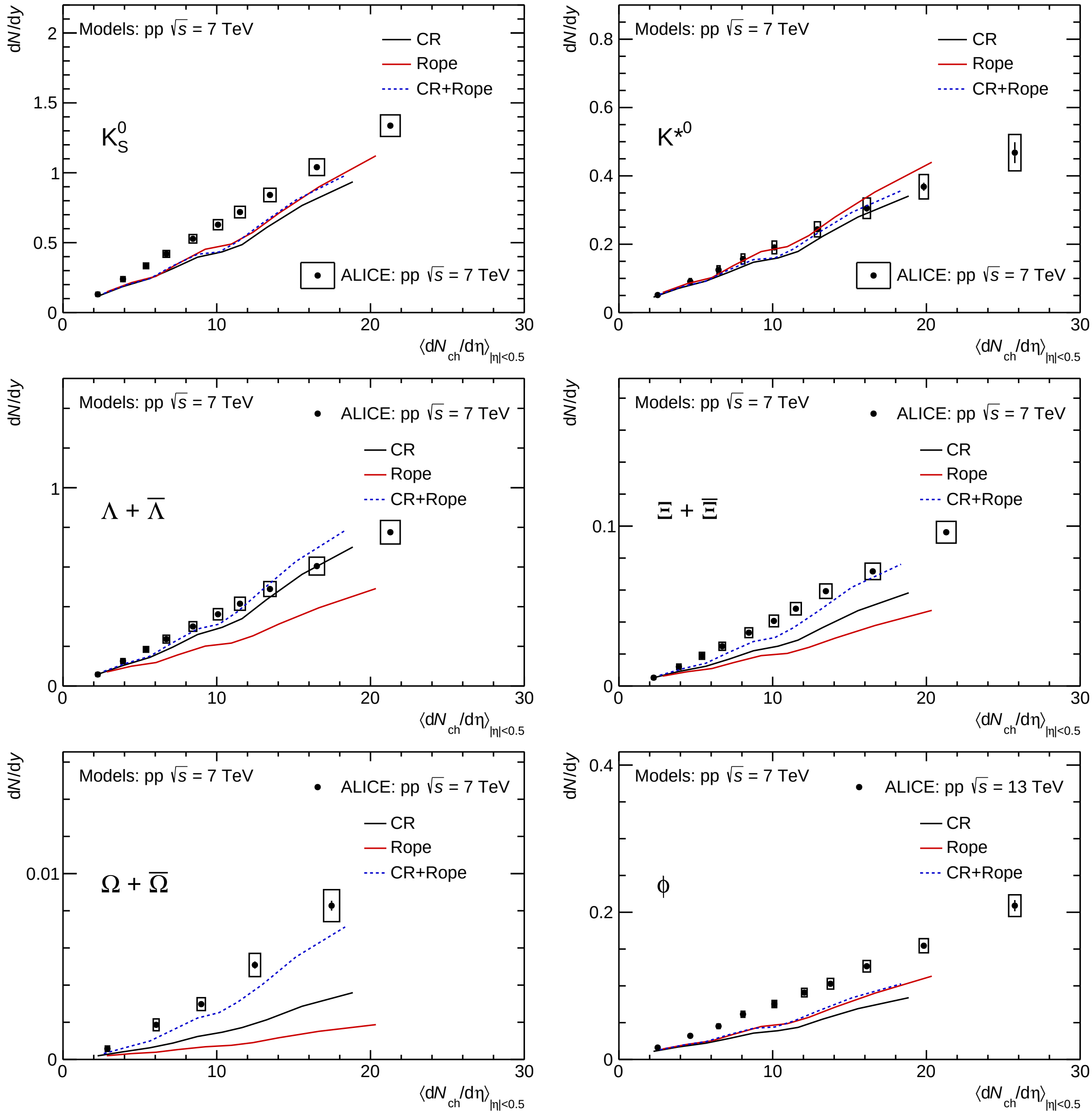

Figure 2: p_{T}-integrated yields dN/dy of various hadrons, $\mathrm{K^0_S}$, $\mathrm{K^{*0}}$, Λ, Ξ, Ω and ϕ, as functions of $\mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta_{|\eta|<0.5}$. Model results are show for pp collisions at $\sqrt{s}$ = 7 TeV, data for pp collisions at $\sqrt{s}$ = 7 TeV and $\sqrt{s}$ = 13 TeV (only for ϕ particle). The data point are taken from [**? ?**].

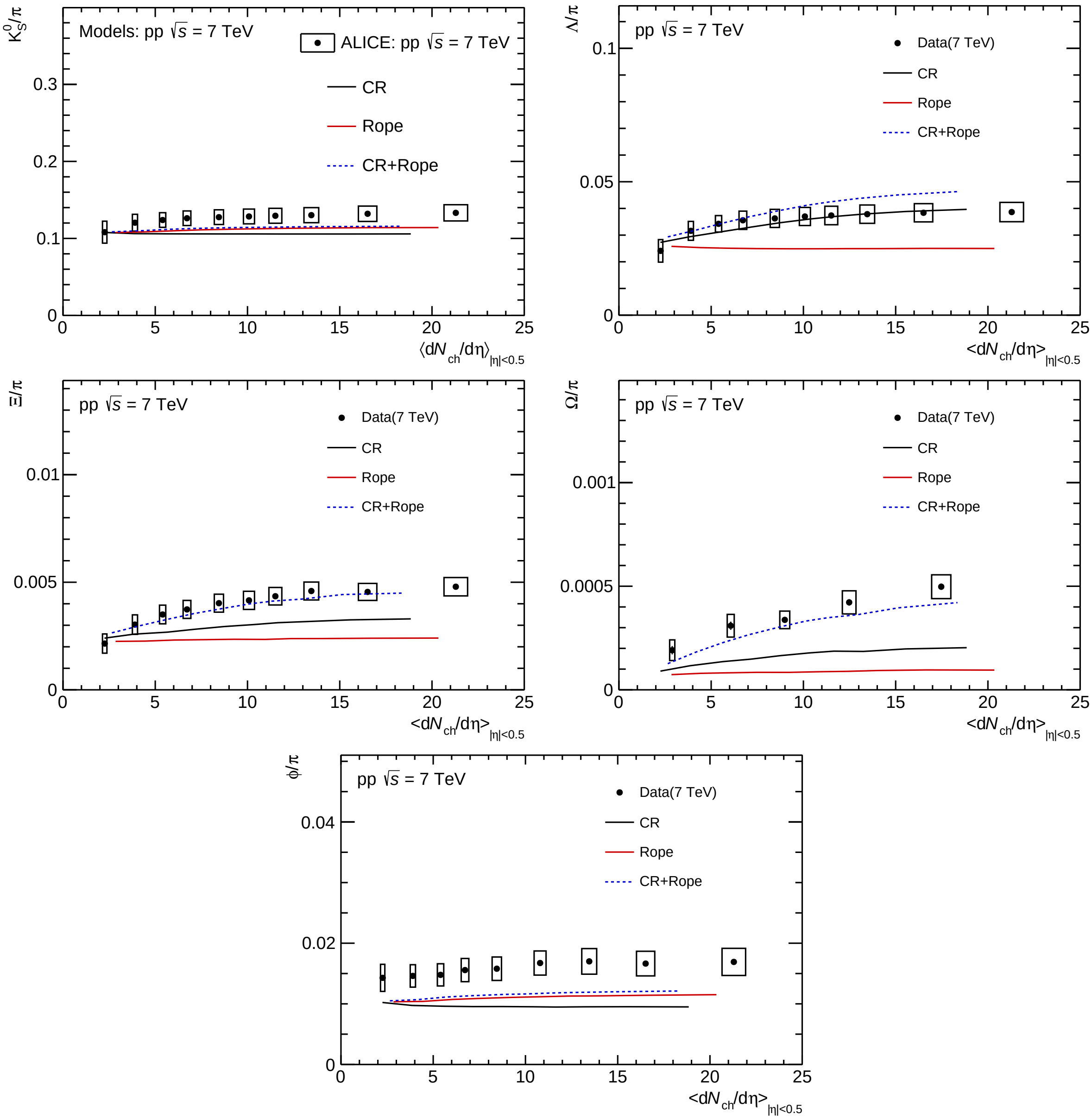

Figure 3: Particles to π p_{T}-integrated ratios, $\mathrm{K}^0_{\mathrm{S}}/\pi$, Λ/π, Ξ/π, Ω/π and ϕ/π in pp collisions at $\sqrt{s}$ = 7 TeV as functions of $\mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta_{|\eta|<0.5}$. The data point are taken from [**? ?**].

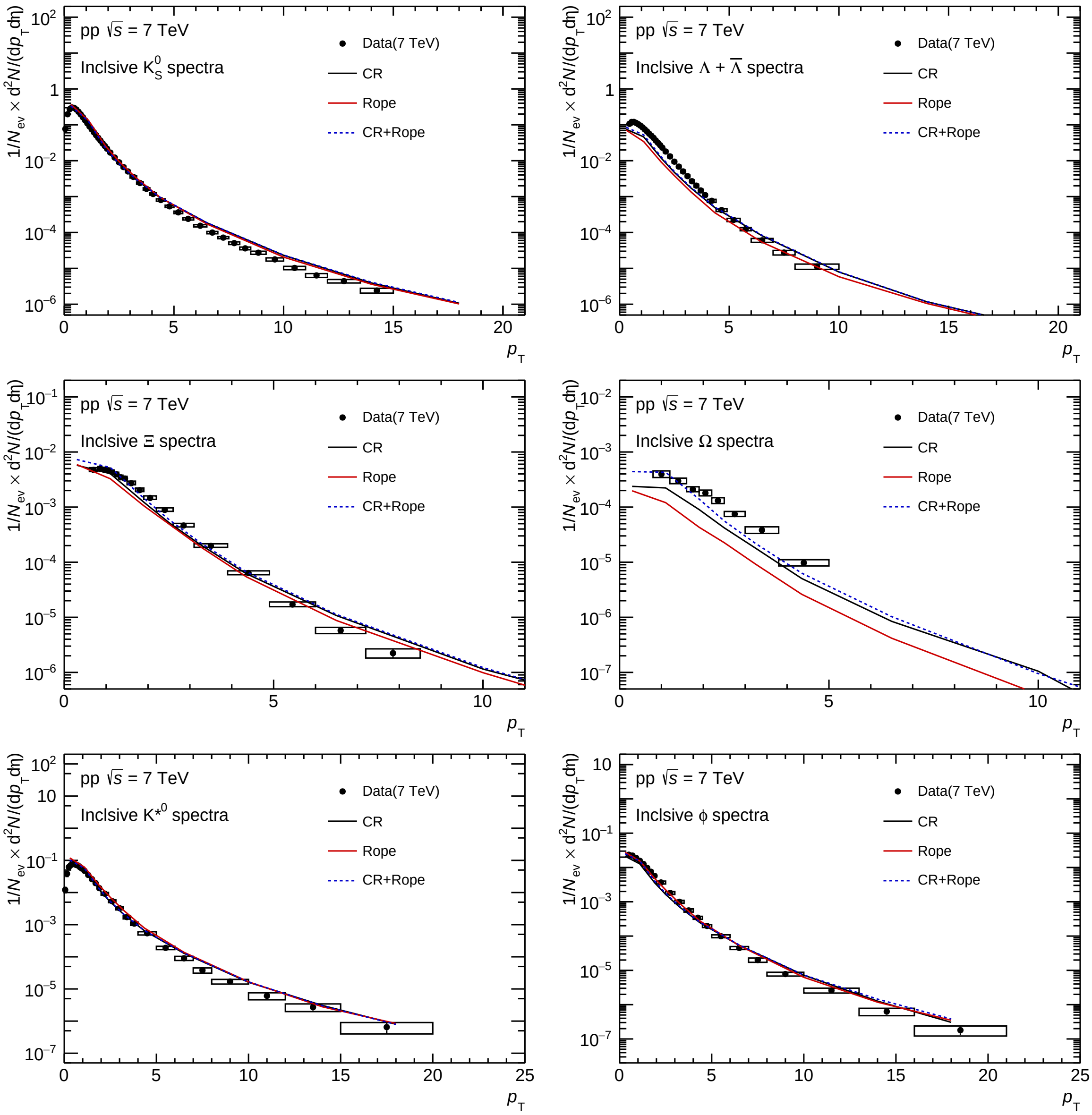

Figure 4: Inclusive particle p_T spectra. The different acceptance with data(for PYTHIA $|\eta| < 0.75$, data $|y| < 0.5$)(Data taken from arXiv:2005.11120, arXiv:1204.0292v3 and arXiv:1910.14410)

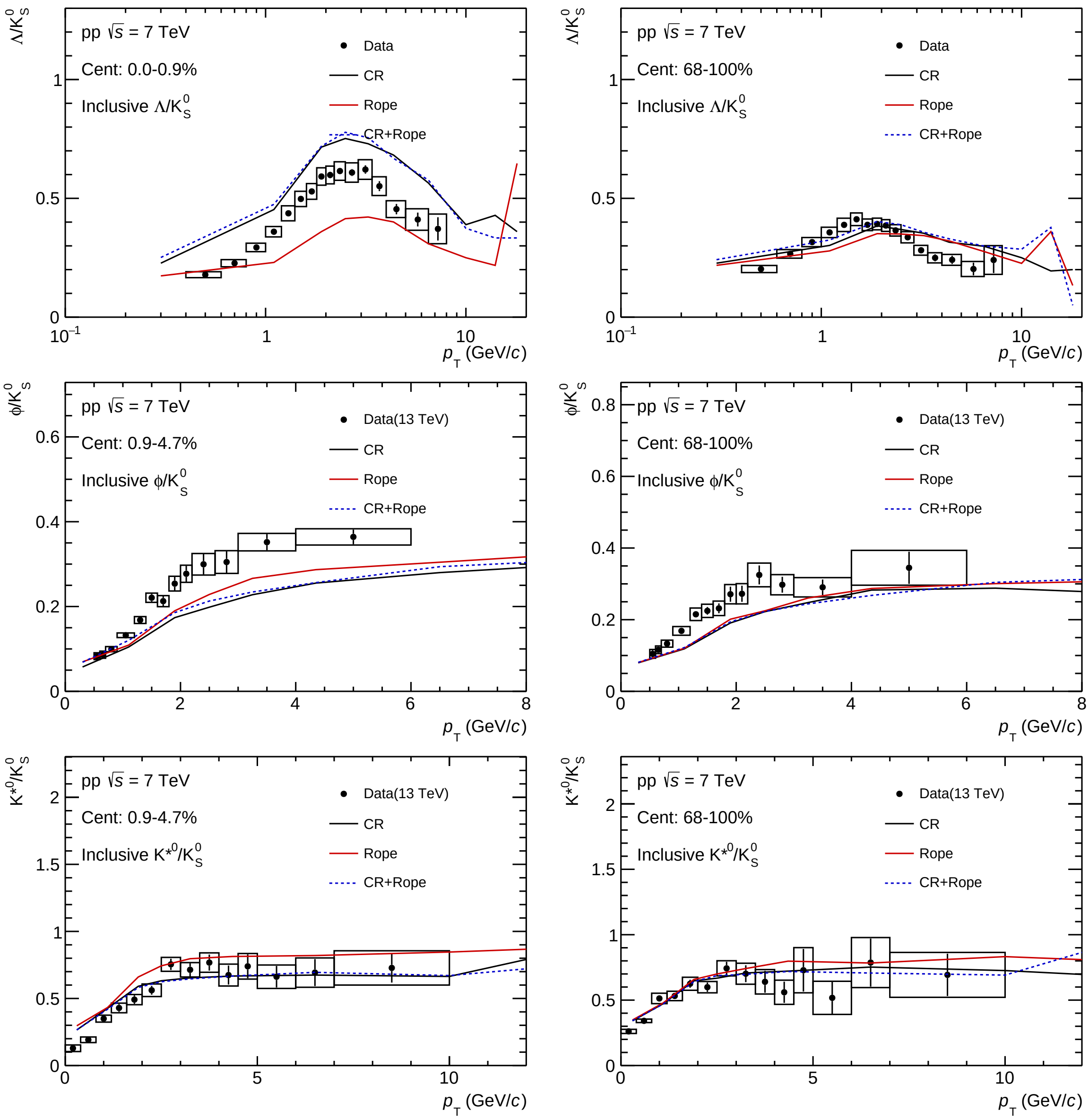

Figure 5: Ratios of particle yields, $\Lambda/\mathrm{K}^0_\mathrm{S}$, $\phi/\mathrm{K}^0_\mathrm{S}$ and $\mathrm{K}^{*0}/\mathrm{K}^0_\mathrm{S}$ as functions of p_T for high (II) and low (X) multiplicity classes. Data taken from arXiv:1807.11321v2 and arXiv:1910.14397v1

4 Predictions

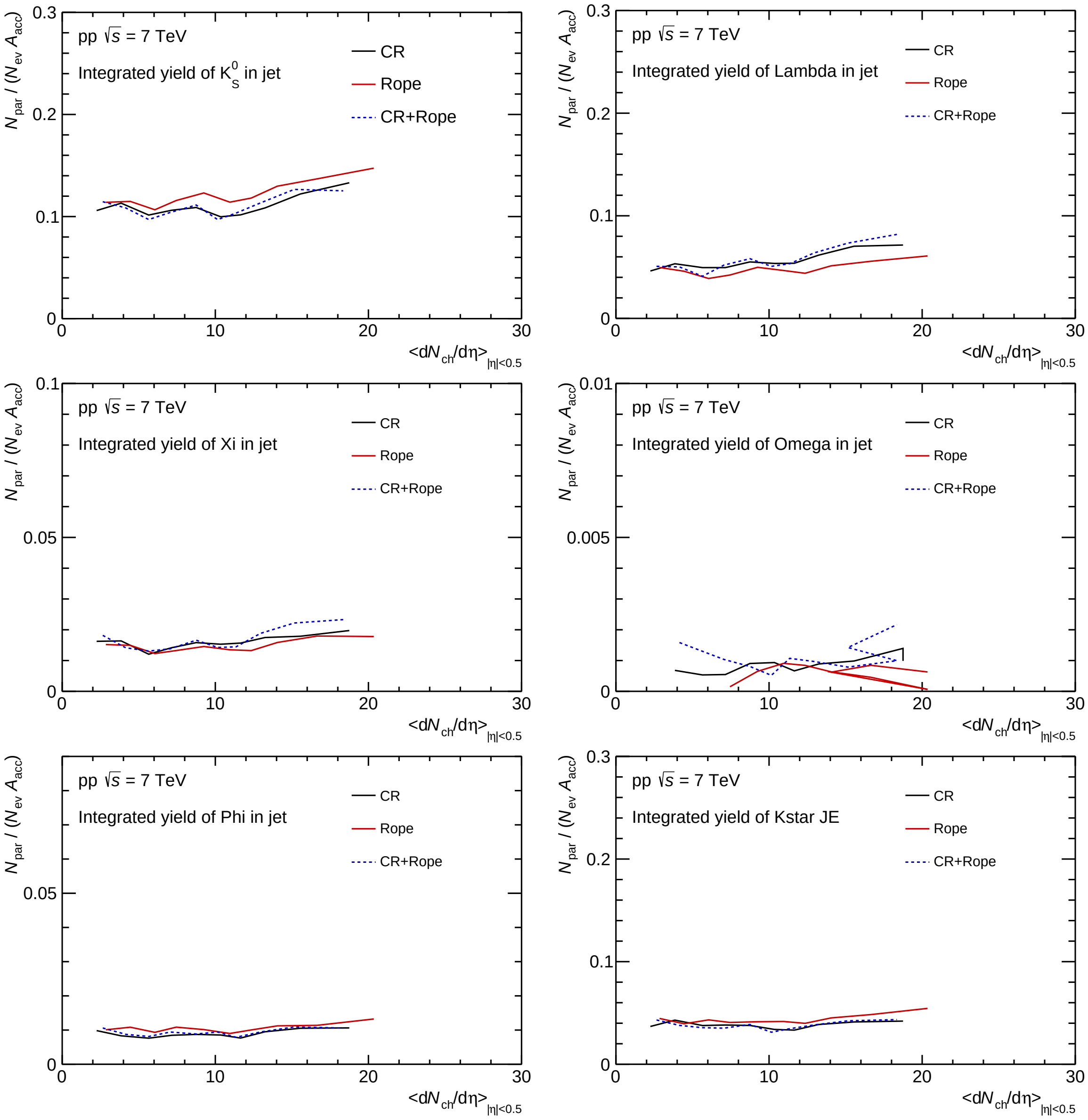

Figure 6: Integrated yields of particles in jet with $\langle dN_{ch}/d\eta \rangle$.(Data point at 13 TeV is used hadron-strange correlation method)

5 Summary

References

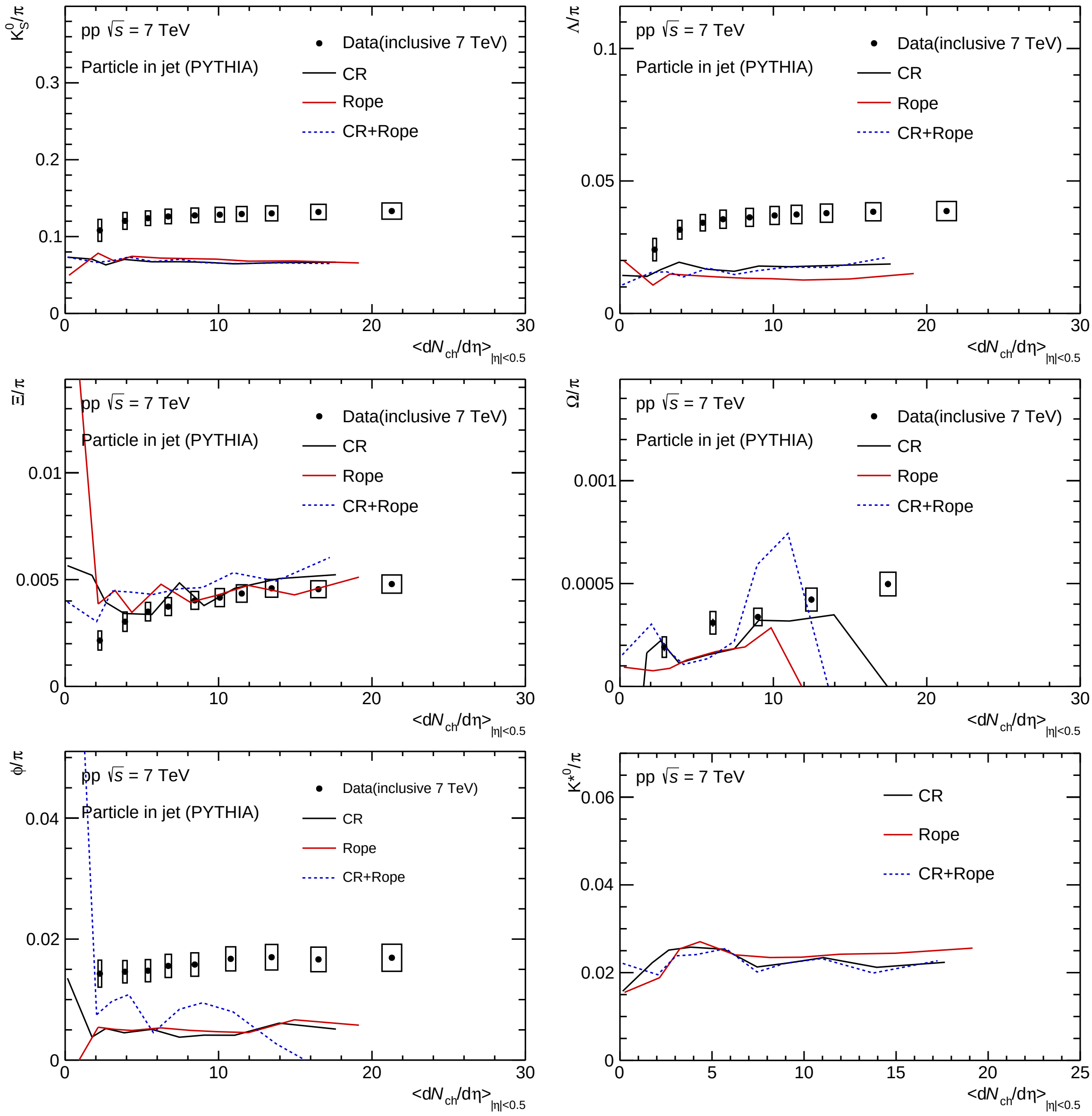

Figure 7: Integrated yields ratios in jet of strange particle to π with $\langle dN_{ch}/d\eta \rangle$. (Data taken from arXiv:1606.07424v2 and arXiv:1807.11321v2)

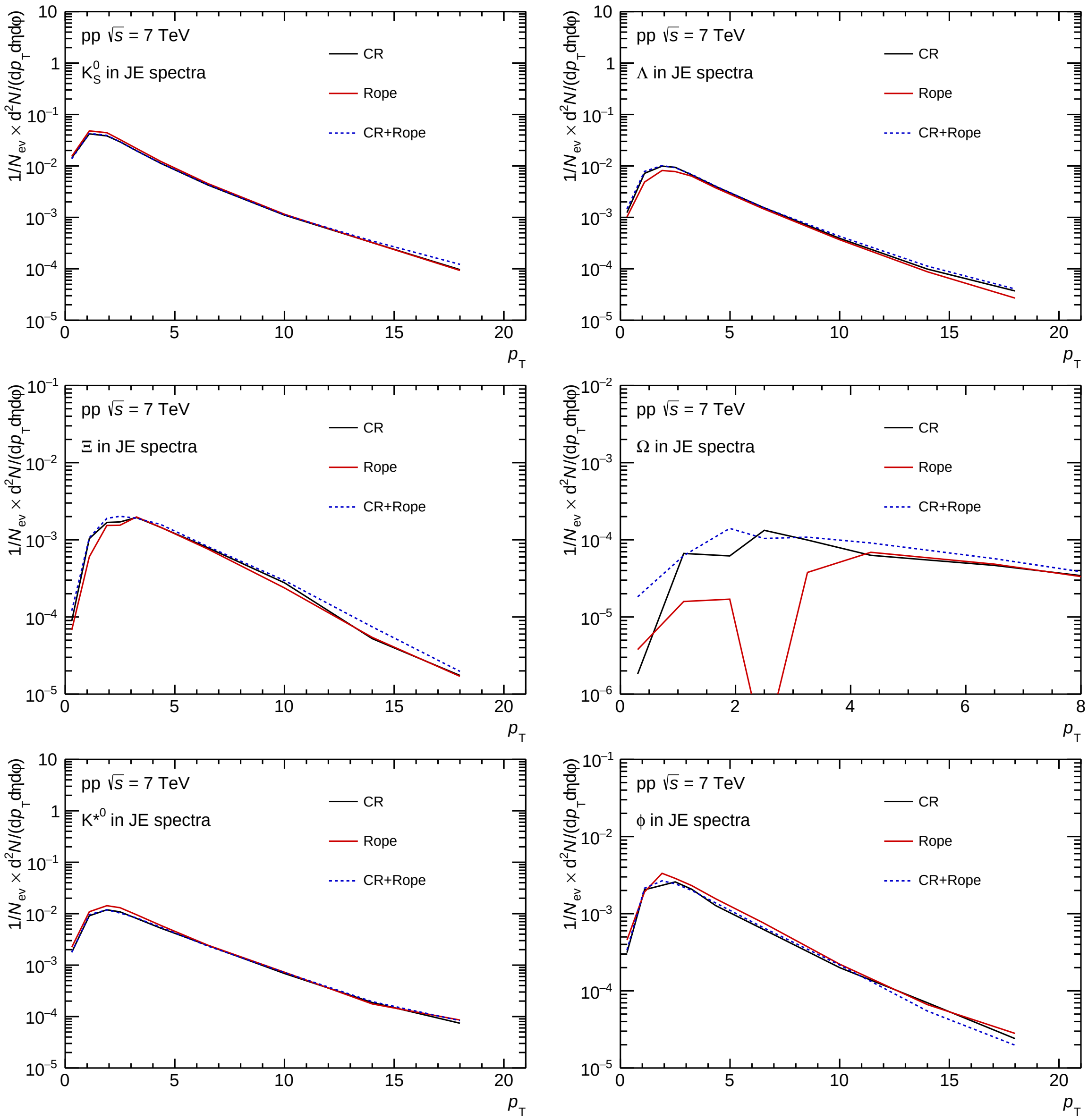

Figure 8: Particle in jet p_T spectra.

67 # A Model parameters

Parameters	Values
MultiPartonInteractions:pT0Ref	2.15
BeamRemnants:remnantMode	1
BeamRemnants:saturation	5
ColourReconnection:reconnect	on
ColourReconnection:mode	1
ColourReconnection:allowDoubleJunRem	off
ColourReconnection:m0	0.3
ColourReconnection:allowJunctions	on
ColourReconnection:junctionCorrection	1.2
; ColourReconnection:timeDilationMode	2
ColourReconnection:timeDilationPar	0.18

Table A.1: Colour reconnection model parameters

Parameters	Values
Ropewalk:RopeHadronization	on
Ropewalk:doShoving	on
Ropewalk:tInit	1.5
Ropewalk:deltat	0.05
Ropewalk:tShove	0.1
Ropewalk:gAmplitude	0.
Ropewalk:doFlavour	on
Ropewalk:r0	0.5
Ropewalk:m0	0.2
Ropewalk:beta	0.1

Table A.2: Rope hadronization model parameters

Table A.3: Definition of the event classes as fractions of the analyzed event sample and their corresponding $dN_{ch}/d\eta$ within $|\eta_{lab}| < 0.5$.

Event class	I	II	III	IV	V	VI	VII	VIII	IX	X
$\sigma/\sigma_{INEL>0}$	0-0.95%	0.95-4.7%	4.7-9.5%	9.5-14%	14-19%	19-28%	28-38%	38-48%	48-68%	68-100%
Exp data	21.3 ± 0.6	16.5 ± 0.5	13.5 ± 0.4	11.5 ± 0.3	10.1 ± 0.3	8.45 ± 0.25	6.72 ± 0.21	5.40 ± 0.17	3.90 ± 0.14	2.26 ± 0.12
CR	18.8	15.6	13.3	11.7	10.4	8.8	7.1	5.7	3.9	2.3
Rope	20.3	16.6	14.1	12.3	10.9	9.2	7.5	6.1	4.5	2.9
CR + Rope	18.3	15.2	12.9	11.4	10.2	8.7	7.0	5.7	4.2	2.6