

CMS Analysis Note

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Strangeness production in underlying event in proton - proton collisions at 7 TeV

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Abstract

Note based on presentations at CERN:

<https://indico.cern.ch/contributionDisplay.py?contribId=4&confId=131069>

<https://indico.cern.ch/contributionDisplay.py?contribId=8&confId=139037>

1 Introduction

2 Data samples

Datasets used for the present analysis are shown in Tab. 1 and 2. Adopted CMSSW release is *CMSSW_3_6_3*. Certified and signed-off run ranges and luminosity sections in real data have been considered using the JSON file *Cert_132440-137028_7TeV_June14thReReco_Collisions10_JSON.txt* as provided by the Physics Validation Team. The analyzed data correspond to 24671 selected lumisections and 12.9 pb^{-1} (?) recorded integrated luminosity.

Dataset	Detector conditions (Global tag)	Run numbers	Luminosity [pb-1]	#Events
/MinimumBias/Commissioning10 -Jun14thReReco_v1/RECO	GR_R_36X_V12A::All	32440-137028	12.9	570,870,002

Table 1: Data sample.

Dataset	Detector conditions (Global tag)	CMSSW version	#Events
/MinBias_TuneD6T_7TeV-pythia6/ Summer10-START36_V10_SP10-v1/ GEN-SIM-RECODEBUG	START36_V10::All	3_6_3	54,235,060

Table 2: Monte Carlo samples.

3 Event Selection

The minimum biasing trigger used in the analysis is the `HLT_MinBiasPixel_SingleTrack`. This trigger is simulated in the MC sample and requires a single reconstructed track in pixel detector with a minimum momentum of 0.2 GeV. Beam scraping filter is applied to the triggered events.

Event selection further requires exactly one primary vertex candidate from the `offlinePrimaryVertices` collection. Such a vertex is also requested to be valid, i.e. with coordinates different with respect to the ones of the beam spot (which are assigned by default in the case of failure of the vertex finding algorithm). The transverse distance of the primary vertex from the beam spot is required to be within 2 cm and the longitudinal distance (z position) within 10 cm. The number of degrees of freedom of the primary vertex reconstruction is required to be greater than four. The event selection is summarized in Table 3.

3.1 TrackJet Reconstruction

The hard scale of the event is provided by the transverse momentum of the leading TrackJet, i.e. a jet reconstructed using the information from tracks only. The `generalTracks` collection is used for the jet reconstruction algorithm, in addition requiring to be of `highPurity`, secondary decays are removed by requiring that the impact parameter significance, $d_0/\sigma(d_0)$ and significance of z separation between the track and primary vertex, $d_z/\sigma(d_z)$, each to be less than 3. Each track is required to be within $|\eta| < 2.5$ and to have a transverse momentum of at least 0.5 GeV, with the relative p_T error, $\sigma(p_T)/p_T$, of less than 5%.

TrackJet is reconstructed using the Anti-Kt algorithm, with $R = 0.5$ and is required to have a transverse momentum, $p_T > 1 \text{ GeV}$ and a pseudorapidity $|\eta| < 2$ units.

3.1.1 TrackJet p_T Correction

For study of the TrackJet p_T correction, the reconstructed leading TrackJet was matched to the closest generated TrackJet (ChargedGenJet) within $\Delta R = \sqrt{(\Delta\phi^2 + \Delta\eta^2)}$ of 0.3. The same jet algorithm (Anti-Kt) was applied to charged stable MC truth particles to obtain ChargedGenJets. The MC particles are required to have $p_T > 0.5 \text{ GeV}$ and $|\eta| < 2.5$ and the reconstructed ChargedGenJet is required to have $p_T > 1 \text{ GeV}$ and $|\eta| < 2$ units.

The p_T ratio between the reconstructed TrackJet and the matched ChargedGenJet, together with the correction factors is shown in Figure 1. The p_T correction is applied on the bin-by-bin basis for TrackJet $p_T < 15 \text{ GeV}$ and

cut	value	events selected (%)
primary vertex	1	
primary vertex	not fake	
transv. distance (primary vertex, beam spot)	2 cm	
longit. distance (primary vertex, beam spot)	10 cm	
primary vertex ndf	> 4	
leading TrackJet p_T	1 GeV	
leading TrackJet $ \eta $	< 2	
leading TrackJet tracks	highPurity	
$d_0/\sigma(d_0)$	< 3	
$d_z/\sigma(d_z)$	< 3	
TrackJet track p_T	500 MeV	
TrackJet track $\sigma(p_T)/p_T$	< 5%	
TrackJet track $ \eta $	< 2.5	

Table 3: Event selection summary and efficiency.

is set to 0.74 for $p_T > 15$ GeV (result of the constant fit), where the error on the correction is too big.

4 V_0 Reconstruction And Selection

We use the standard V_0 reconstruction and preselection as implemented in the CMSSW, with V_0 decay tracks extrapolated to the fitted secondary vertex. Tracks must have at least 3 hits, $\chi^2 / \text{ndf} < 5$ and the transverse impact point significance $> 1.5\sigma$. The distance of the closest approach of the decay tracks to the secondary vertex must be less than 1 cm. Distance in the transverse plane between the V_0 vertex and the primary vertex must be at least $8\sigma_{pv}$, where σ_{pv} accounts for the primary vertex, secondary vertex and beam spot errors. Mass of the reconstructed pion pair is requested to be below 600 MeV.

In addition to this standard V_0 selection, further requirements are used for the V_0 and decay particles as well. The transverse momentum of the decay products must be above 300 MeV and $|\eta|$ of each track must be within 2.5 units. Transverse momentum of the reconstructed V_0 must be between 0.5 GeV and 4 GeV and in case of Monte Carlo, matching of the reconstructed V_0 to its simulated particle is required within $\Delta R < 0.1$, where $\Delta R = \sqrt{\Delta\eta^2 + \Delta\phi^2}$. The pseudorapidity of the V_0 is required to be within $|\eta| < 2$. The transverse distance of the reconstructed secondary vertex from the primary vertex is required to be at least 1 cm. The V_0 selection summary is shown in Table 4.

cut	value
decay track hits	≥ 3
decay track χ^2 / ndf	< 5
decay track transv. impact point signif.	$> 1.5\sigma$
decay track DCA to the secondary vertex	< 1 cm
decay track p_T	300 MeV
decay track $ \eta $	< 2.5
$V_0 p_T$	0.5 – 4 GeV
$V_0 \eta $	< 2
matching ΔR	< 0.1
transverse dist. (sec.vertex, primary vertex)	> 1 cm
transverse dist. (sec.vertex, primary vertex)	$\geq 8\sigma_{pv}$
$m_{\pi\pi}$	< 600 MeV

Table 4: V_0 selection summary.

5 V^0 kinematic fitting

The kinematic fit is used for the V_0 identification and the background estimation. In the kinematic fit, we estimate the momentum components (p_x, p_y, p_z) of the strange particle, and improve the estimation of its decay

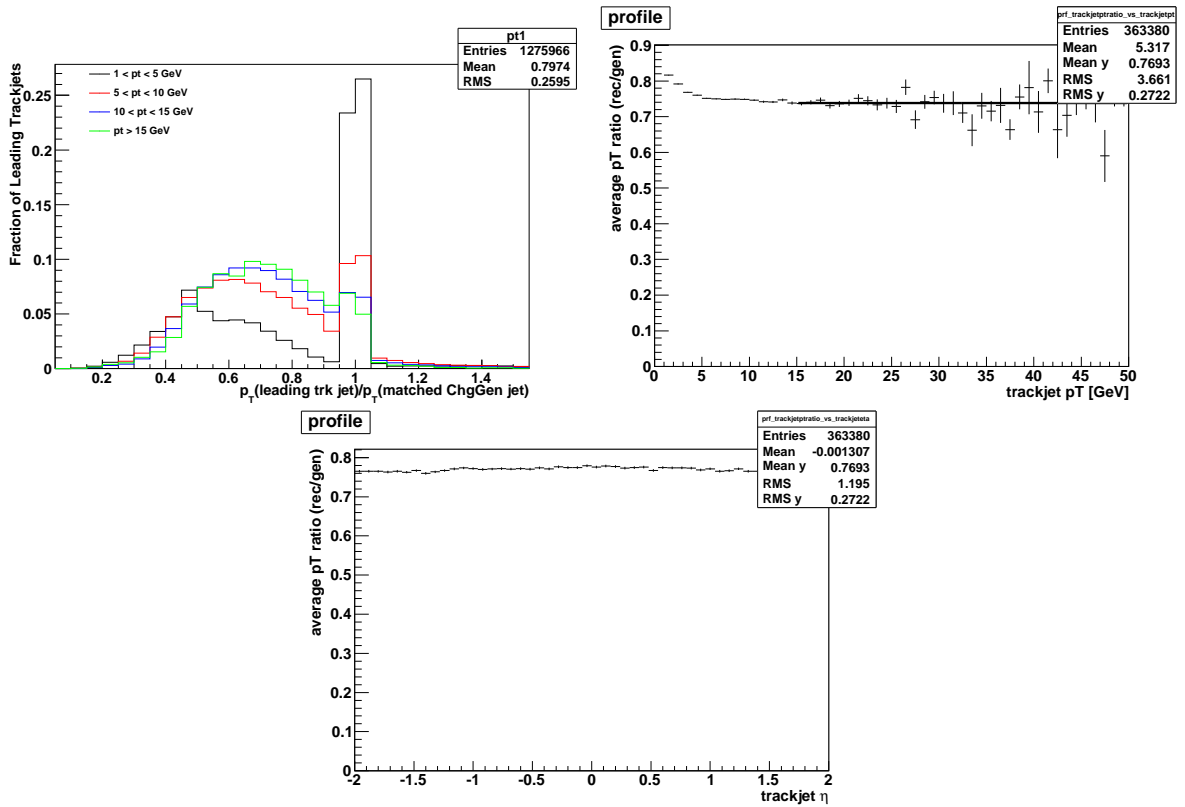


Figure 1: a) p_T ratio (p_T^{rec}/p_T^{gen}) of reconstructed TrackJet and matched ChargedGenJet for different bins of trackjet p_T ; b) p_T correction factor as a function of the reconstructed TrackJet; c) p_T correction as a function of TrackJet η .

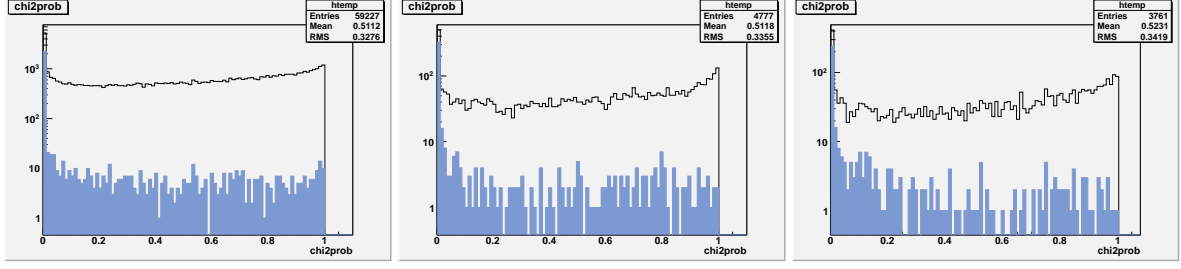


Figure 2: a) χ^2 probability for K_s^0 hypothesis; b) for Λ and c) $\bar{\Lambda}$ hypothesis. Full histogram represents V0s not matched to the generated V0 [redo with full stat].

vertex (x_s, y_s, z_s) and of daughter track parameters $(\rho^+, \theta^+, \phi^+)$ and $(\rho^-, \theta^-, \phi^-)$, by imposing the following constraints:

- the daughter tracks are constrained to originate from the same space point, the secondary vertex, whose coordinates are free parameters of the fit;
- the invariant mass of the pair of daughter tracks is constrained to be equal to the well-known mass m of the decaying particle (497.614 MeV for K_s^0 , 1.115683 GeV for Λ and $\bar{\Lambda}$ [?]);
- the momentum vector of the decaying particle is required to point from the secondary vertex towards the reconstructed primary vertex (x_p, y_p, z_p) .

First, the constraint of the decay tracks pointing to the secondary vertex is made with the CMSSW implementation of the `KalmanVertexFitter` [?]. This vertex constraint is done before the simultaneous application of the invariant mass and pointing constraints. Inputs to the `KalmanVertexFitter` are parameters of the two daughter tracks and the output is the improved track parameters and the space coordinates of the secondary vertex. After the vertex fitting, the two vertex-fitted tracks and the covariance between the tracks and the secondary vertex is used as the input for the remaining part of the fit (when the mass and pointing constraints are applied in parallel).

The primary vertex is treated as fixed in the pointing constraint, but the secondary vertex uncertainty used in the fit includes error on the primary vertex as well. There are thus 12 parameters to estimate or improve: $(p_x, p_y, p_z, \rho^+, \theta^+, \phi^+, \rho^-, \theta^-, \phi^-, x_s, y_s, z_s)$ and 6 constraints: four momentum and energy conservation equations and two pointing equations. The 9×9 covariance matrix of the daughter track parameters and of the secondary vertex position is improved by the fit iteratively (number of iterations is limited to 100), whereas the 3×3 covariance matrix of the strange particle momentum components (p_x, p_y, p_z) is given as the output of the fit, see Appendix.

The estimated parameters are obtained by minimizing a χ^2 function where the constraints are added using the Lagrange multiplier technique [?, ?, ?]. The minimization is iterative, the constraints being linearized around the parameter estimates from the previous iteration and initially, the linearization is done around the vertex-fitted parameters. The algebra of the minimization is (will be) described in appendix. Number of degrees of freedom for the full fit is three: 9 independent measurements plus 6 constraint equations minus 12 adjustable parameters. Number of degrees of freedom for the mass-constrained fit only is one.

5.1 V0 Identification

For each V0 candidate, the kinematic fit is performed separately for the K_s^0 , Λ and $\bar{\Lambda}$ hypothesis and the three final χ^2 values are compared. Identification is based on the hypothesis with the highest χ^2 probability. Figure 2 shows the χ^2 probability distributions for the three hypotheses. V0 candidates with the highest χ^2 probability below 0.05 are rejected.

6 V0 Background

The remaining background is studied using the matching of MC truth primary V0s to the reconstructed V0 in the $\eta - \phi$ space within $\Delta R < 0.1$ and $\delta p_T/p_T < 0.1$. The signal V0 is defined as the one with matched MC truth V0. The background to the V0 sample (V0s not matched to MC) is 1% for K_s^0 , 4% for Λ and 6% for $\bar{\Lambda}$. This background is subtracted on the bin-by-bin basis from the measured rates in data.

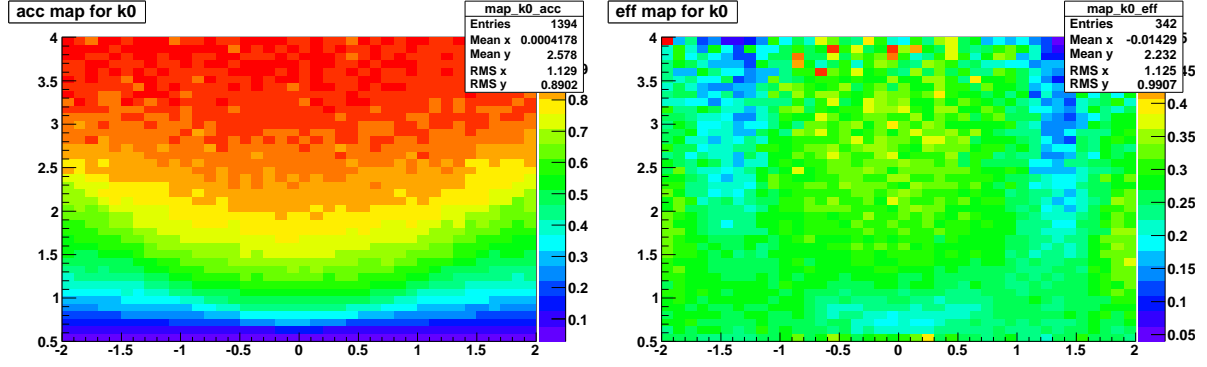


Figure 3: a) K_s^0 acceptance as a function of its p_T and η ; b) K_s^0 efficiency.

Background composition was studied by matching the V0 decay tracks at the simulation level using `TrackingParticles` collection, to the reconstructed tracks. Most of the background comes from the ambiguous identification of the kinematic fit, which assigns the highest probability to a wrong hypothesis. This corresponds to 40% (K_s^0) and 20% (Λ , $\bar{\Lambda}$) of the background. Photon conversions to e^+e^- pairs correspond to 20% for Λ , $\bar{\Lambda}$. nuclear interactions correspond to about 1% for all three V0 types considered. Note that 50% of the background composition has yet to be understood: even though no matched generated V0 particle of the given type has been found, the matched underlying particle from the `TrackingParticles` collection tells that the particle ID is correct.

7 V0 Correction

A weight is applied on selected V0s, depending on its type, p_T and η . In case of K_s^0 , this correction is factorized into acceptance and efficiency. Acceptance is defined as number of accepted V0s, N_{acc} , within V0s generated, N_{gen} , in the (η, p_T) bin, in the kinematic range of sufficient V0 selection efficiency. N_{gen} represents number of V0s generated in bins between $0.5 < p_T < 4$ GeV and $|\eta| < 2$ units. N_{acc} is a fraction of N_{gen} with both decay tracks p_T above 0.3 GeV and $|\eta| < 2.5$ units and generated transverse flight distance > 1 cm. In order to compute the decay quantities, an isotropic decay of generated K_s^0 was simulated. Efficiency, which is estimated with a detailed MC at the reconstructed level is defined as a ratio of reconstructed V0s, N_{rec} to accepted V0s, N_{acc} , where the reconstructed V0s pass the selection criteria of decay tracks $p_t > 0.3$ GeV and $|\eta| < 2.5$ units, V0 $p_T > 0.5$ GeV and V0 $|\eta| < 2$ units, transverse flight distance above 1 cm and χ^2 probability above 0.05.

K_s^0 acceptance and efficiency is shown in Figure 3 as a function of its p_T and η . The final V0 correction, acceptance times efficiency, or N_{rec}/N_{gen} , is shown in Figure 4, separately for K_s^0 , Λ and $\bar{\Lambda}$.

To check the factorization of the K_s^0 efficiency from the TrackJet p_T , we have defined three p_T bins and measured the V0 efficiency in each of them separately. Figure 5 shows the efficiency as a function of K_s^0 properties in different bins of TrackJet p_T .

8 Closure Test

Validity of the V0 correction is verified by performing the closure test, where the corrected MC V0 rates are compared to MC truth rates, as shown in Figure 6. The TrackJet p_T correction was checked by comparison of the MC Truth rates as a function of the generated TrackJet p_T and the MC reconstructed rates as a function of the corrected TrackJet p_T , as shown in Figure 7.

9 Analysis Results

Rates of K_s^0 , Λ and $\bar{\Lambda}$ are shown in Figure 8.

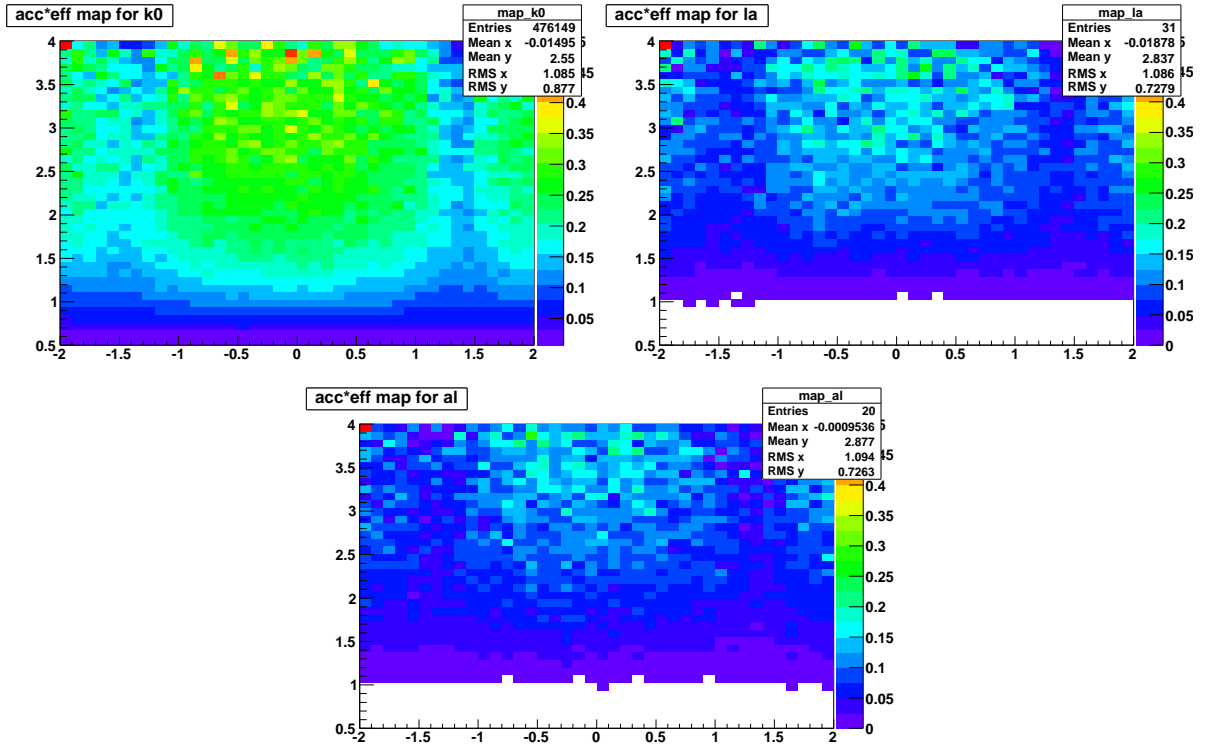


Figure 4: V0 correction as a function of its p_T and η for a) K_s^0 b) Λ c) $\bar{\Lambda}$.

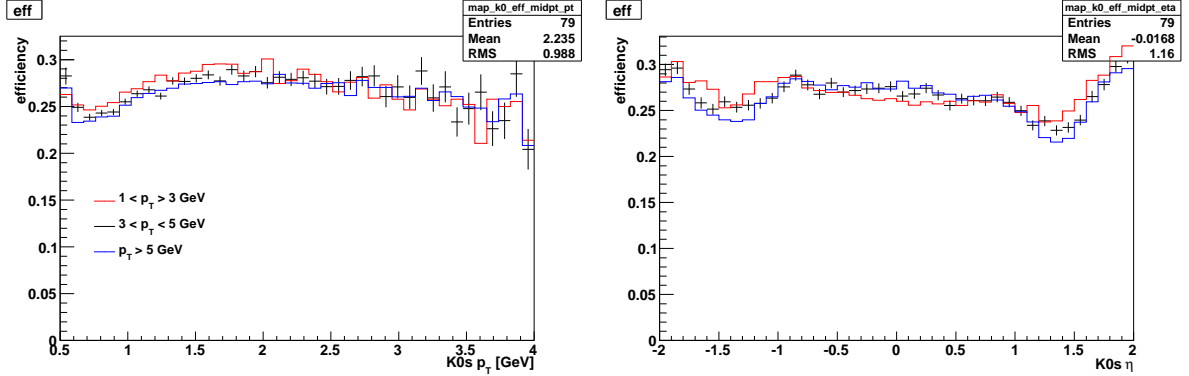


Figure 5: V0 efficiency as a function of a) $K_s^0 p_T$ b) and $K_s^0 \eta$ for three different bins in TrackJet p_T .

Figure 6: Corrected MC spectra compared to generated spectra, a) V0 rates, b) V0 scalar sum of p_T .

Figure 7: Corrected MC spectra (including the TrackJet p_T correction) compared to generated spectra, a) V0 rates, b) V0 scalar sum of p_T .

Figure 8: a) V0 rates and b) the scalar p_T sum, both in the transverse region.

10 Appendix A: Kinematic Fit Algebra

10.1 Validation of the kinematic fit

References