"Measurement of Strange Particle Production in Underlying Events in proton-proton collisions at sqrt(s)=7 TeV"

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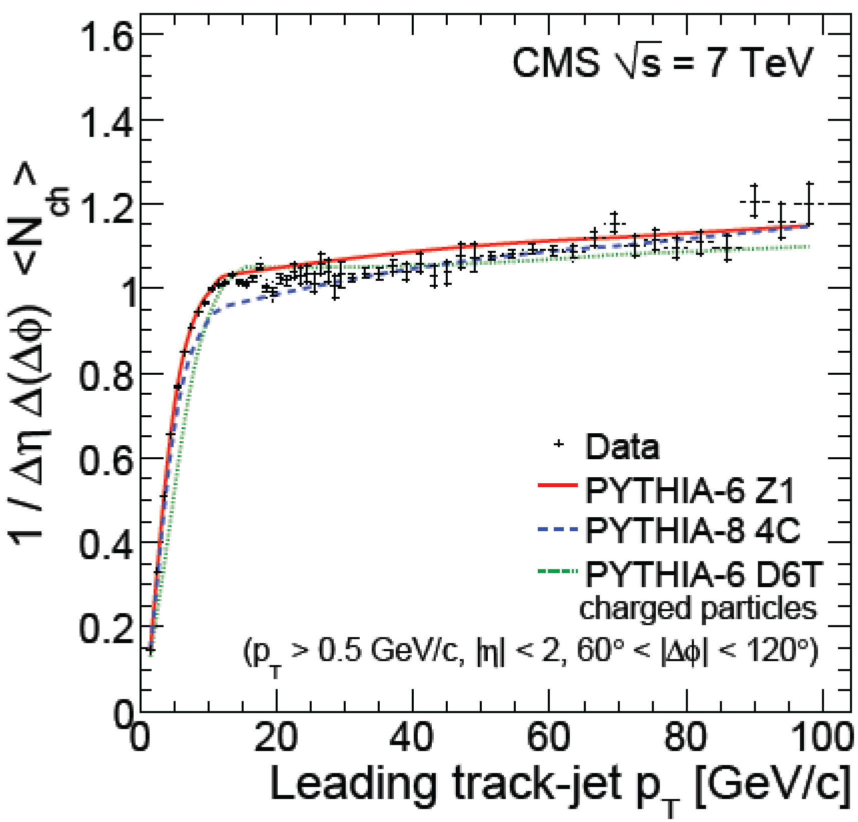
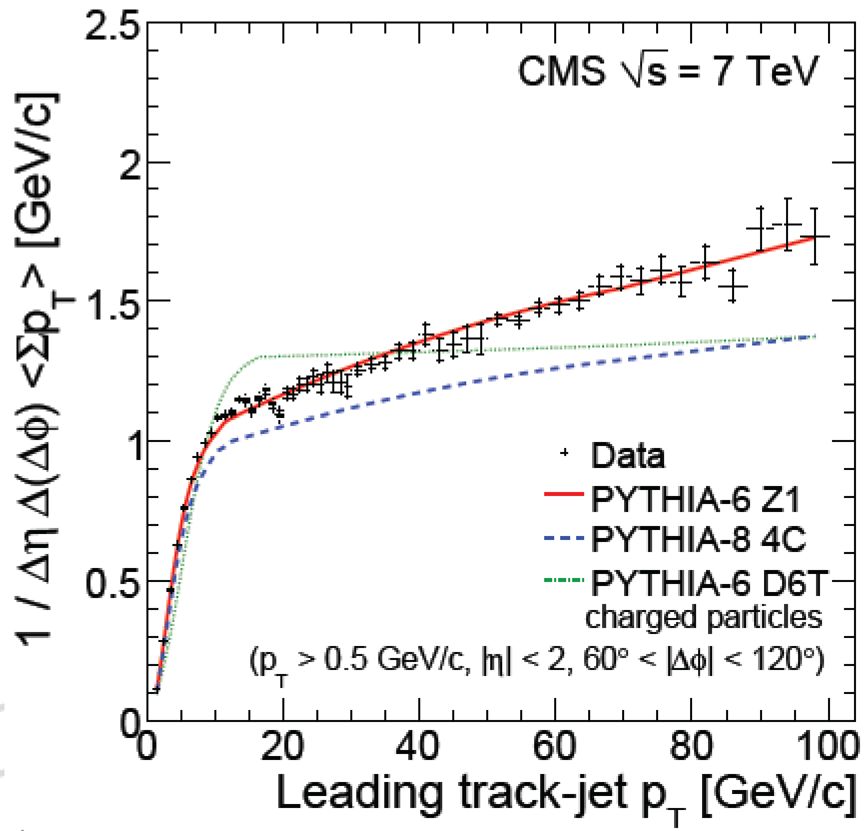
UE Activity

Several studies published by the CMS and ATLAS collaborations of the UE activity in charged primary particles as a function of different hard scales.

- observables measured: **average rate and average pT sum in the transverse region**
- **steep rise with increasing track-jet pT, followed by a slow rise**
  - **increased MPI activity with increasing event centrality**

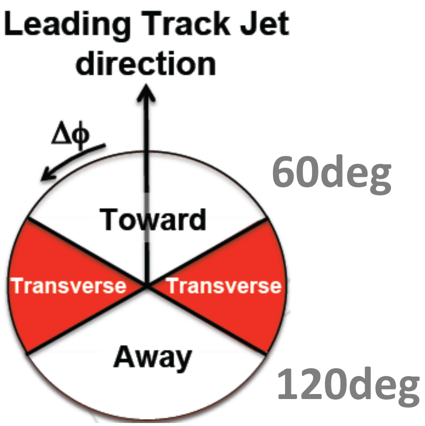




Analysis Aim

The present analysis considers identified neutral strange particles as additional probes to study the underlying event and its description by recent PYTHIA tunes.

- **Use strangeness to study UE**
  - K^0_S, Λ and anti-Λ at 7 TeV vs. hard scale given by leading track-jet p_T
  - compare with measurements with charged primary particles
  - compare with simulations



- **Study strange particle production in UE**
  - compare with simulations

Simulations are performed with versions of PYTHIA that include MPI:

- pre-LHC PYTHIA6 D6T tune
- Z1 and Z2 tunes, which include pT ordering of the parton showers and a new PYTHIA MPI model
- PYTHIA8 Tune 1, which includes hard diffraction in addition to the new MPI model

Event selection

Data collected in early 2010, low PU

Minimum bias Trigger selection:

- at L1: activity in Beam Scintillator Counters (BSC), in coincidence with beams in the Beam Pick-up Timing for eXperiments (BPTX) devices.
- at HLT: presence of at least one track segment in the pixel detector with pT > 200MeV/c.

Primary vertex:

- single vertex with quality cuts

Leading Track-jet:

- Defined using Anti-k_T $\Delta R = 0.5$
- Main track selection:
  - $p_T > 0.5$ GeV/c, $|\eta|<2.5$
- Leading track-jet:
  - $p_T>1$ GeV/c, $|\eta|<2$

Leading Track-jet corrections:

- pT corrected for detector response using simulations; **avg. correction: 1.01**
- Correction to gen-level: trackjet from leading parton not reconstructed as leading due to tracking inefficiencies; **correction between 5 – 10%**

V^0 reconstruction and selection

Decay tracks:
$|\eta| < 2.5$, $p_T > 0.3$ GeV , quality cuts

Secondary vertex:
Transverse flight distance $d_T > 8\,\sigma(d_T)$, quality cuts

V^0 candidates:
$|\eta| < 2.0$
K^0_S: $p_T > 0.6$ GeV/c
Λ, Anti-Λ: $p_T > 1.5$ GeV/c
Transverse flight distance > 1 cm

Kinematic fit:

- To identify primary V0
- Vertex constraint
- Mass constraint to PDG value
- V^0 momentum pointing from primary to secondary vertex

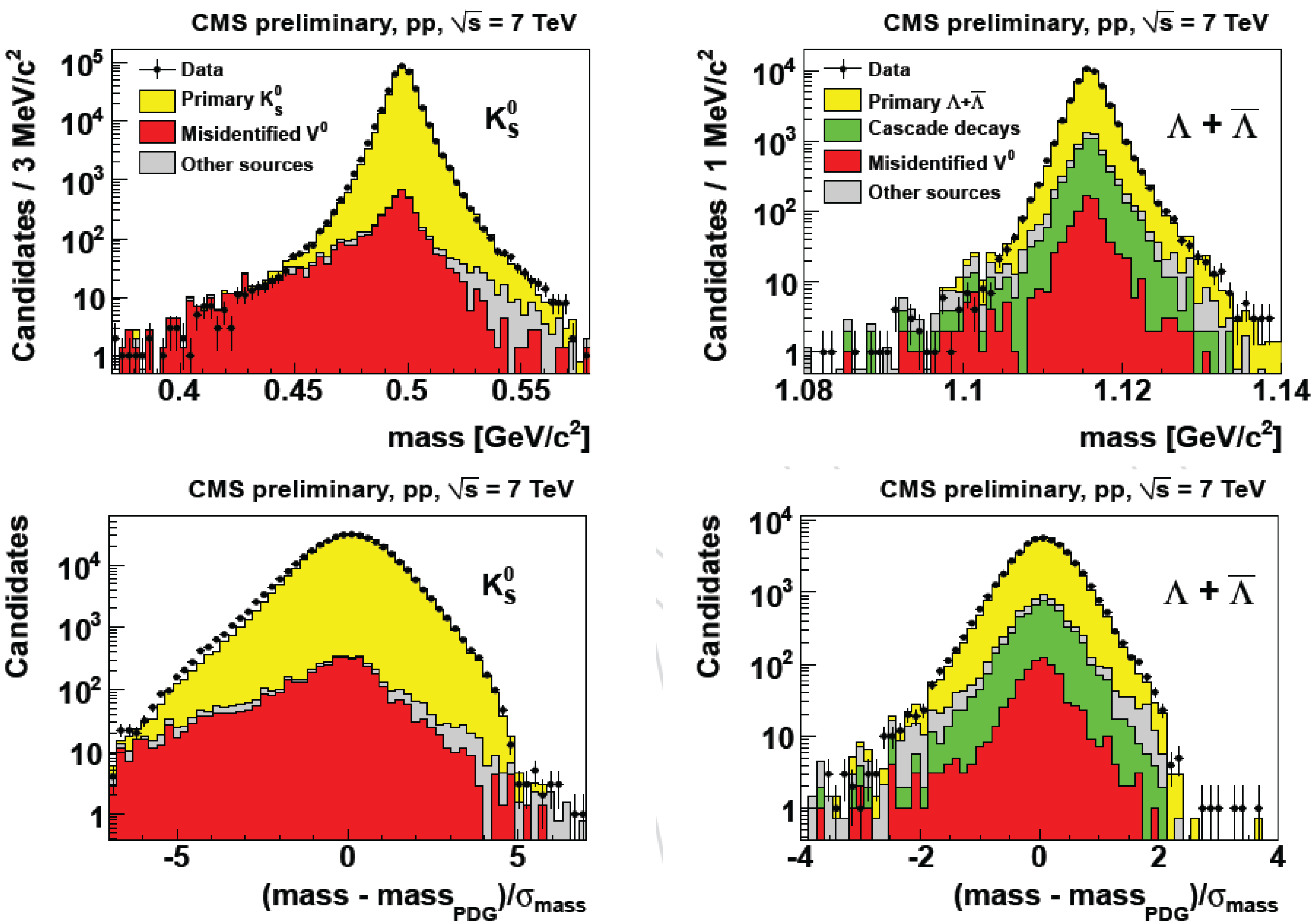
V^0 selection:
Hypotheses tested:

- $K^0_S \rightarrow \pi^+\pi^-$
- $\Lambda \rightarrow \pi^- p$
- Anti-Λ -> π^+anti-p

Hypothesis with largest $P(\chi^2$, Ndf) of kinematic fit retained

V0 Description

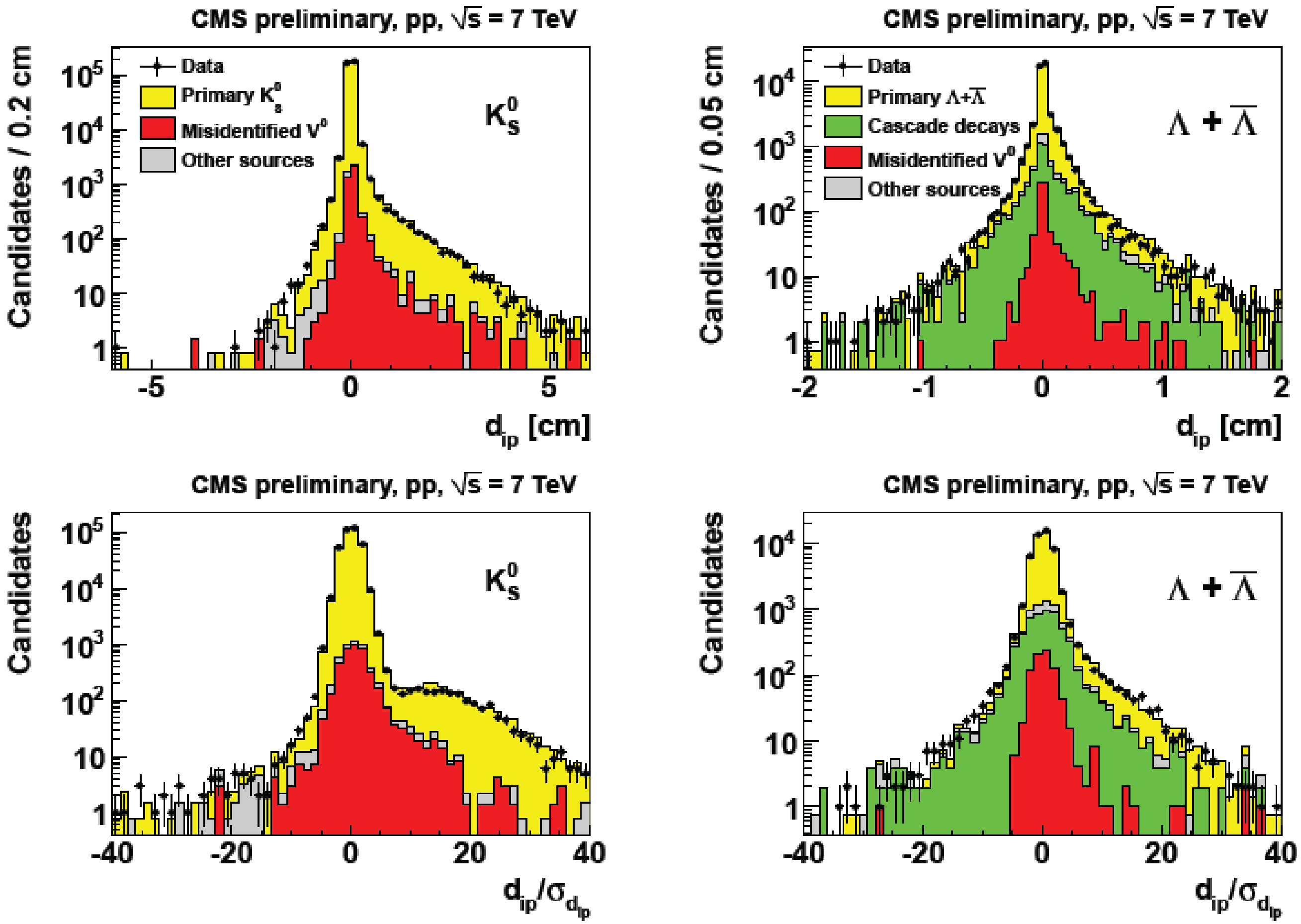
- V0 selection and efficiency determined by simulations: good description of kinematic fit input parameters essential



- simulations normalized to data
- excess of data in K0s mass pull: consistent with larger contribution from misidentified baryons

V0 Description

- **The pointing requirement of kinematic fit constrains the signed impact parameter of the V0 with respect to the primary vertex**



- **simulations normalized to data**
- **features well reproduced**
- **large pulls for secondary baryons from cascade decays allow suppression of this background by the kinematic fit**

V0 Background

- Background to K^0_S, Λ and anti-Λ is estimated using two methods

Simulation-based method (Pythia6 D6T):

- V0 candidates not matched to a generated primary V0 of the same type
- Known deficit of strange particles in simulation is accounted for by reweighting

Data-driven method:

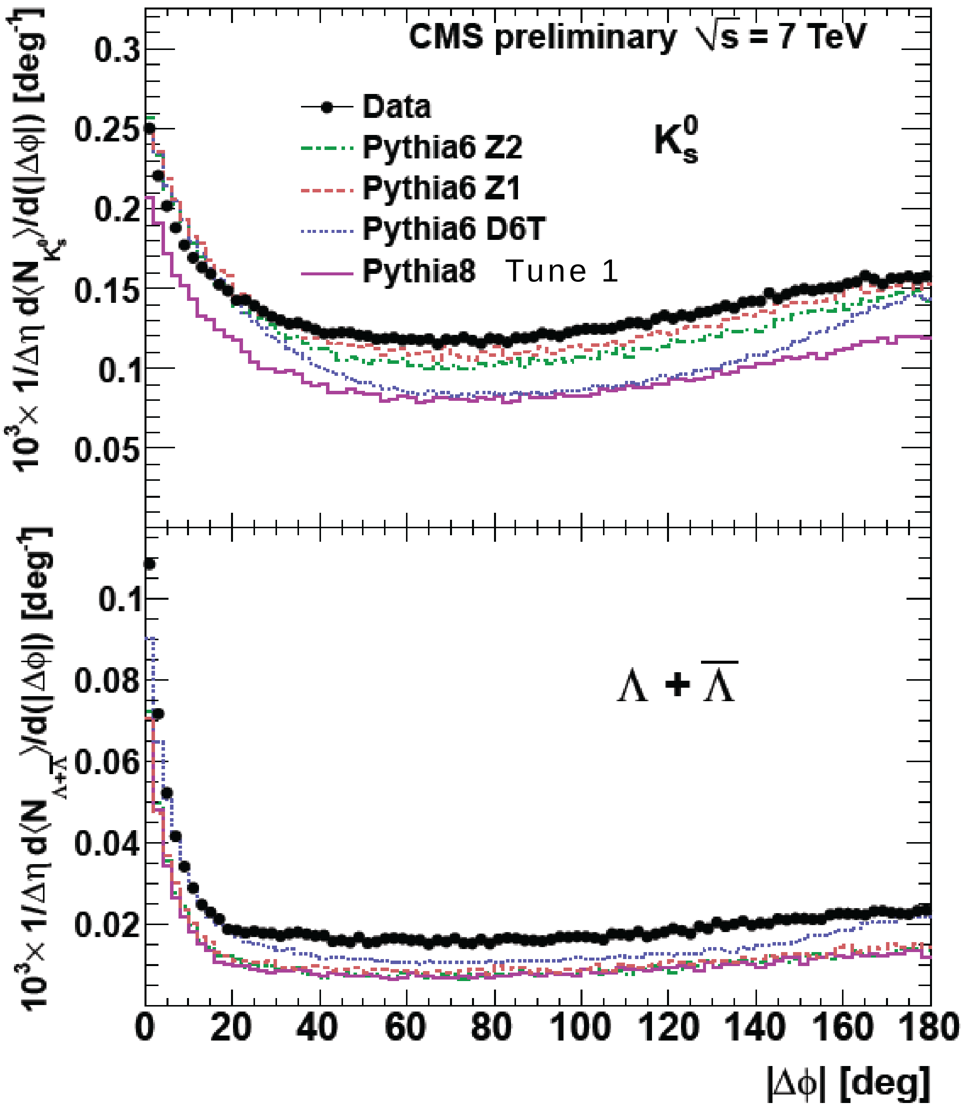
- signal and background contributions are extracted from a fit to the distribution of the kinematic fit χ^2-probability, with signal and background shapes obtained from simulations

Final background estimation

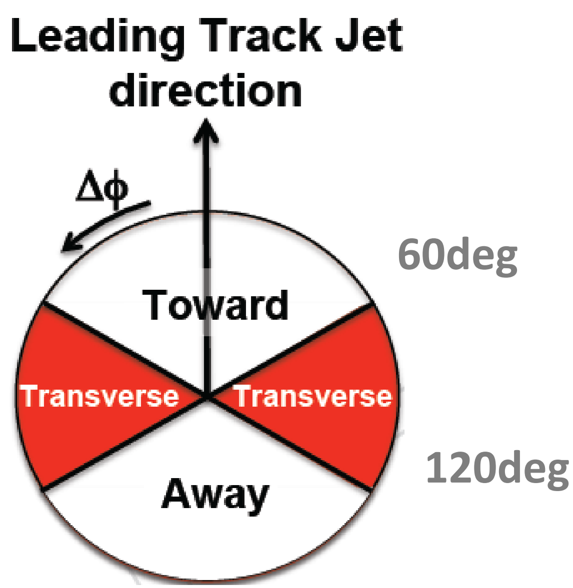
- final estimations by both methods are in reasonable agreement and exhibit the same dependence
- as function of track-jet pT for rate measurements
- as function of V0 pT for pT spectra and sums

Background to K^0_S : (1.5 +- 1.1)% at track-jet pT = 1 GeV/c to **(3.3 +- 1.7)%** at track-jet pT = 10 GeV/c, remaining constant at higher track-jet pT
Background to baryons: (8 +- 2)% independent of track-jet pT

Uncorrected rates vs. |Δϕ|



- Dependence with |Δϕ|qualitatively described by the used Pythia tunes
- Significant underestimation of rates in simulations
- Peak at |Δϕ|~ 0 more pronounced for baryons due to their harder pT selection



V0 Correction

- On top of background subtraction, V0 yield is corrected for acceptance times reconstruction efficiency = **fraction of generated primary V^0s matched to a selected V^0 within $\Delta R < 0.1$; $\Delta(p_T)/p_T < 0.1$**
  - computed in V0 (pT, η) bins using Pythia6 D6T

	K0s	Λ	anti-Λ
average correction x branch. ratio	**11.3%**	**8.4%**	**6.6%**
branch. ratio	69.2%	63.9%	63.9%

- **Weights are large, but known with good accuracy:**
  1) Acceptance is accurate (geometrical)
  2) Selection efficiency is cross-checked with data

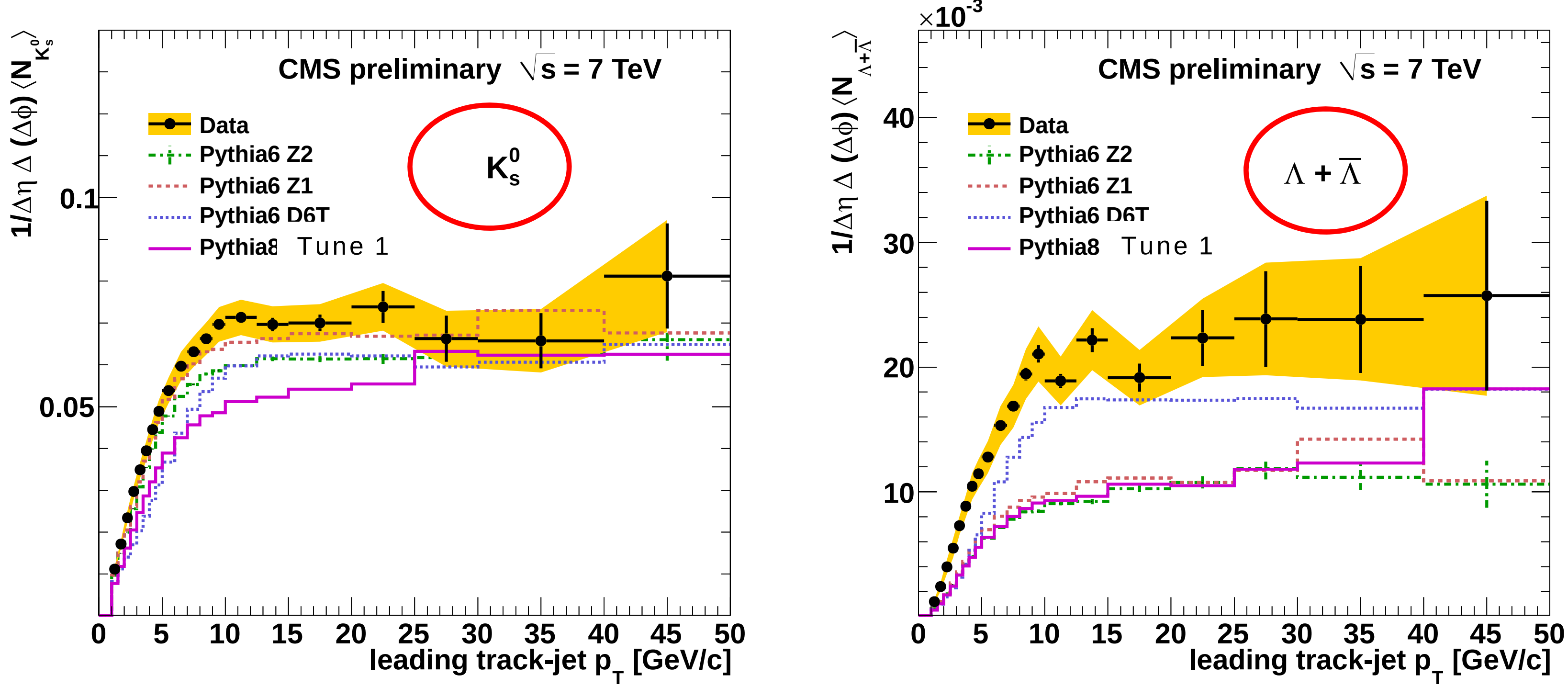
Summary on syst. uncertainties

Average rates		
source	K_S^0 (%)	$\Lambda + \overline{\Lambda}$ (%)
modelling of V^0 efficiency		
track-jet $p_T \leq 2.5\,\mathrm{GeV}/c$	3	10
track-jet $p_T > 2.5\,\mathrm{GeV}/c$	3	3
detector material	3	3
GEANT4 cross sections	-	5
beam spot position	0.2	0.2
background estimation		
track-jet $p_T = 1\,\mathrm{GeV}/c$	1.1	2
track-jet $p_T = 10\,\mathrm{GeV}/c$	1.7	2
statistical uncertainty on V^0 weights		
$600\,\mathrm{MeV}/c < p_{T,V^0} < 700\,\mathrm{MeV}/c$	0.1	-
$1.5\,\mathrm{GeV}/c < p_{T,V^0} < 1.6\,\mathrm{GeV}/c$	0.03	0.33
$6\,\mathrm{GeV}/c < p_{T,V^0} < 8\,\mathrm{GeV}/c$	1.4	8.3
correction to generated leading track-jet and correction non-closure	3	7

Average p_T sums		
source	K_S^0 (%)	$\Lambda + \overline{\Lambda}$ (%)
background estimation		
$p_{T,V^0} = 600\,\mathrm{MeV}/c$	0.1	-
$p_{T,V^0} = 1.5\,\mathrm{GeV}/c$	0.8	0.3
$p_{T,V^0} = 8\,\mathrm{GeV}/c$	3.6	4
other sources	same	same

Results: Production rates

Average multiplicity of K^0_S and Λ+anti-Λ in transverse region per unit η per radian



Activity vs. hard scale: similar characteristics as with primary charged particles

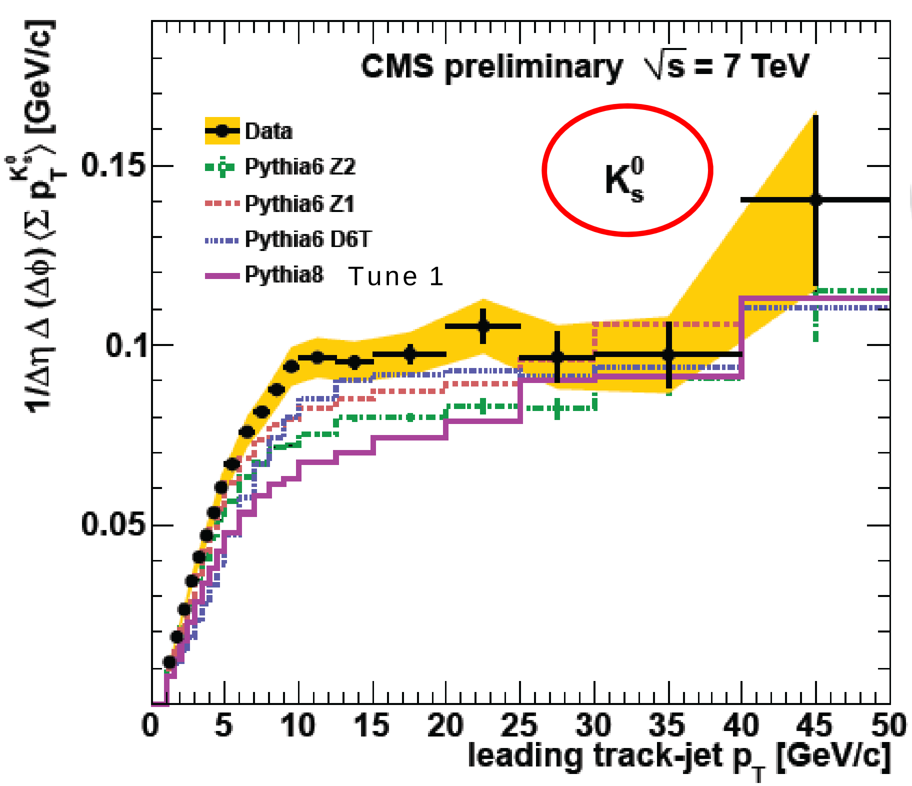
- steep rise up to track-jet p_T~10 GeV/c, then essentially constant
- qualitatively described by all PYTHIA tunes studied

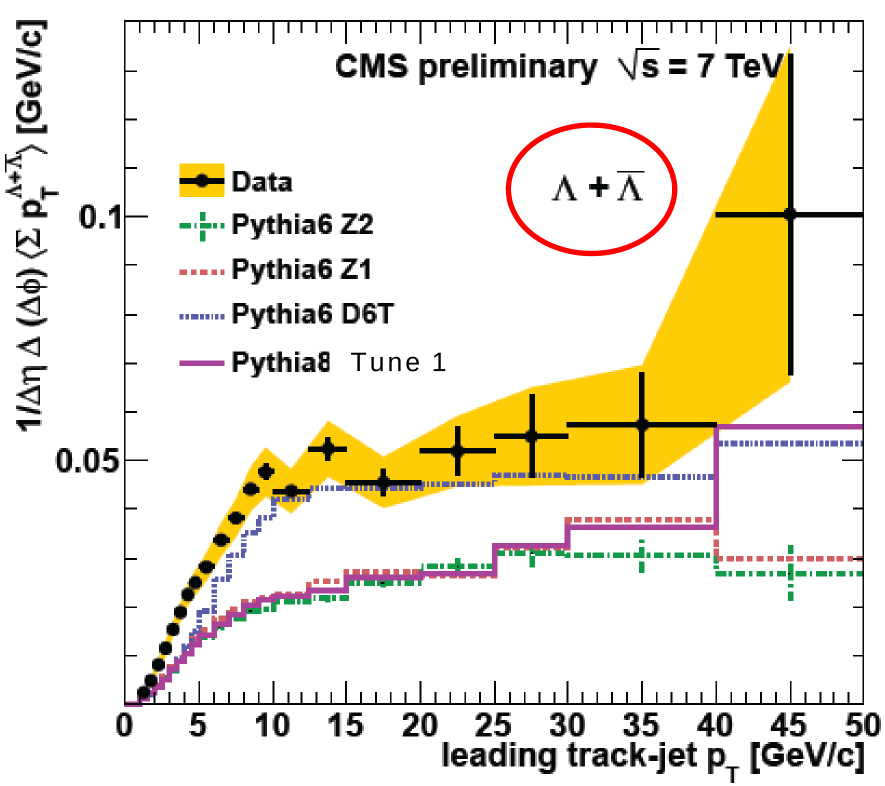
Production rate:

- deficit of K^0_S production ~15% (30)% for Z2 (P8) for track-jet p_T>10 GeV/c
- deficit of Λ+anti-Λ production ~50% for all tunes (except D6T)

Results: Scalar p_T sums

Average scalar p_T sum of K^0_S and Λ+anti-Λ in transverse region per unit η per radian

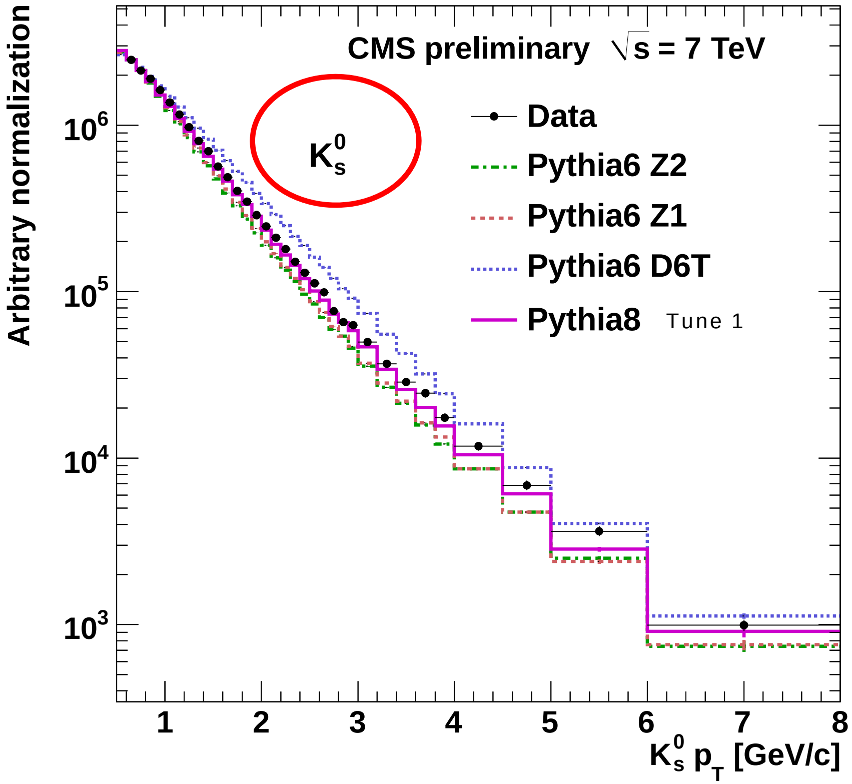


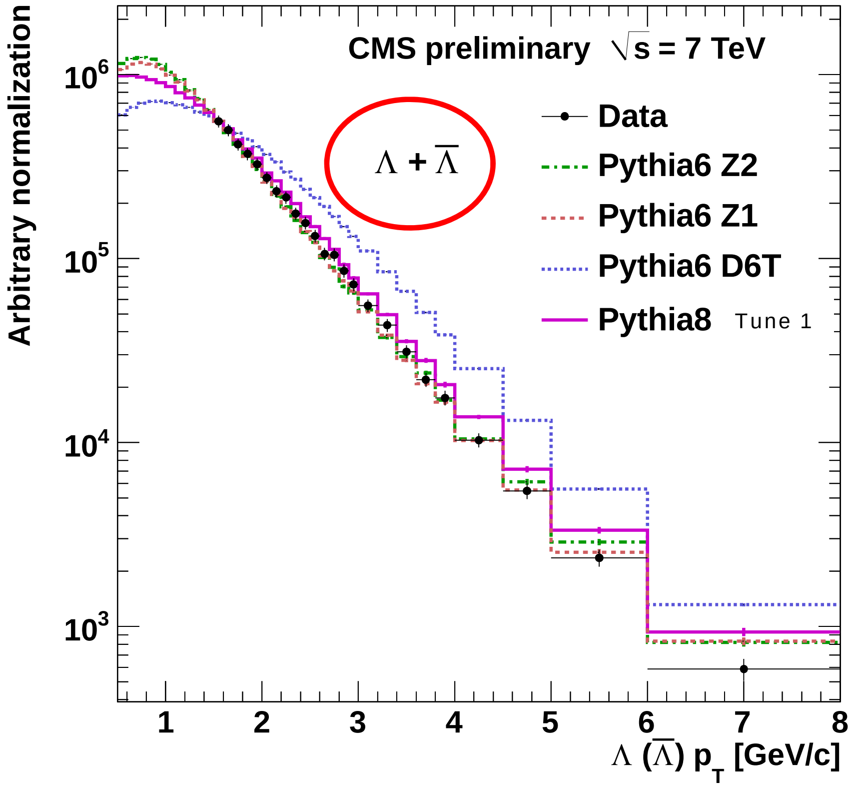


Activity vs. hard scale: same observation with p_T sums as with rates

Results: pT spectra

p_T spectra in MC and data for track-jet p_T > 3 GeV/c, in region transverse to reconstructed track-jet, normalized to 1st measured bin





- Notable differences
- D6T spectra harder - explains good description of rates and p_T sums within kinematic region of interest (more events for K^0_S p_T>0.6 GeV/c, baryon p_T>1.5 GeV/c)

Conclusions

- **Analysis of underlying event (UE) activity in primary strange particles K^0_S, Λ and Anti-Λ**, within $|\eta|<2$, with p_T K^0_S > 600 MeV/c, Λ+anti-Λ > 1.5 GeV/c

- UE studied in region transverse to the leading track-jet with p_T > 1 GeV/c, $|\eta|<2$, at sqrt(s) = 7 TeV

- **Measured $1/d\eta d\Delta\phi$ $\langle N_{V0}\rangle$ and $1/d\eta d\Delta\phi$ $\langle\Sigma p_T\rangle$ as function of hard scale** = leading track-jet p_T **and compared to PYTHIA simulations (D6T, Z1, Z2, P8 T1)**

- **Observed characteristics of the UE activity very similar to what is seen with primary charged particles**
  - Steep rise up to track-jet p_T~10 GeV, then essentially constant
  - Trend with track-jet p_T qualitatively described by all PYTHIA tunes studied

Conclusions (2)

- **Average rate of strange particles vs. leading track-jet p_T shows:**
  - **Deficit in PYTHIA simulations for all tunes, with discrepancies from 10% up to 30% for K^0_S and ~50% for Λ/Anti-Λ**
  - **Similar deficit of PYTHIA8 Tune1 predictions in UE as in NSD events**
  - **Less pronounced deficit of PYTHIA6 D6T in UE as in NSD events**
    - **Rate is averaged over V^0 p_T range studied (>0.6 GeV/c for K^0_S and 1.5 GeV/c for Λ/Anti-Λ)**
    - **p_T spectrum in D6T much harder than data p_T spectrum**

- **Results provide valuable input for generator tuning**