

Prompt K_S production at $\sqrt{s} = 900$ GeV

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on behalf of the LHCb collaboration

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Outline

- the LHCb experiment
- outline of the $K_S \rightarrow \pi\pi$ analysis
- analysis details
- preliminary results
- summary and outlook

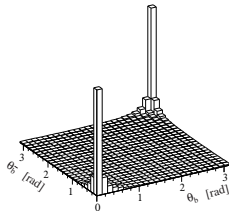
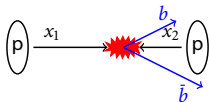
LHCb: A dedicated b physics experiment at the LHC

- first physics result expected soon in
 - charm physics
 - $B_s \rightarrow \mu\mu$
 - $B_s \rightarrow J/\psi\phi$
 - $B \rightarrow K^* \mu\mu$
- many interesting analyses ahead
 - measurement of γ in trees and penguins
 - $b \rightarrow s\gamma$ transitions
 - ...



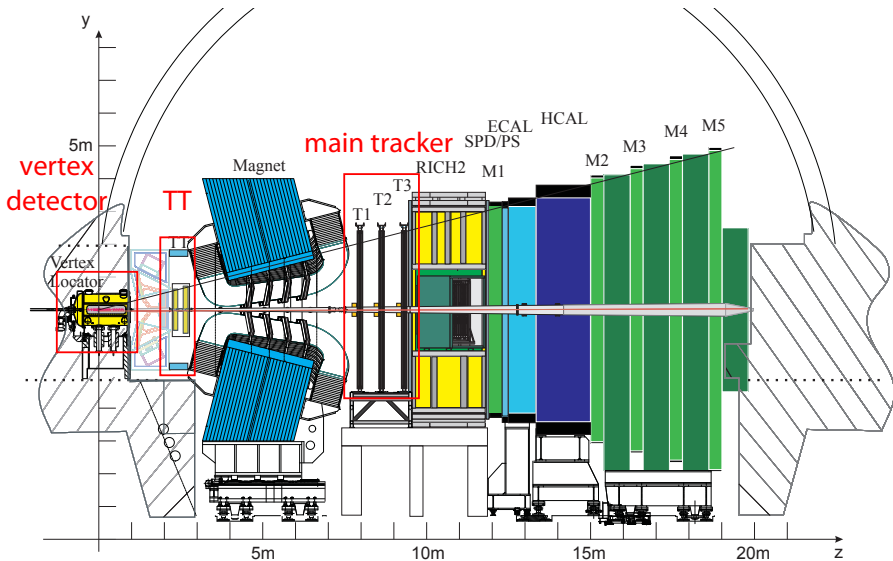
LHCb: A dedicated b physics experiment at the LHC

- expect to produce $10^{12} b\bar{b}$ pairs per nominal year ($\sqrt{s} = 14$ TeV, $L = 2 \cdot 10^{32} \text{cm}^{-2} \text{s}^{-1}$)
- $b\bar{b}$ pairs go either both in forward or both in backward direction:



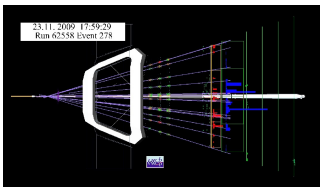
⇒ built as single arm forward spectrometer

LHCb detector

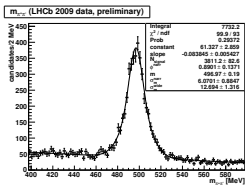




Some recent LHC(b) "history"

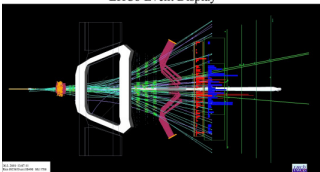


November 23th 2009
first $\sqrt{s} = 900$ GeV collision

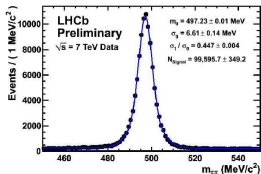


December 18th 2009
end of 2009 run

LHCb Event Display



March 30th 2010
first collisions at $\sqrt{s} = 7$ TeV



- since March 30th, about 28 M events taken and analyzed at $\sqrt{s} = 7$ TeV (last Friday)



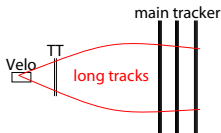
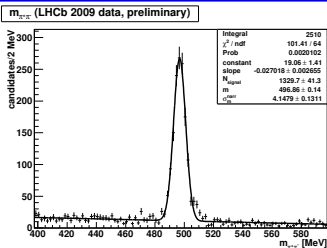
Analysis idea

- V0 production not yet measured in the LHCb y range at $\sqrt{s} = 900$ GeV
 - interesting input for tuning hadronization/fragmentation models
 - go for K_s first, it's the easiest to measure in 2009 data
- measure in bins of p_T and y

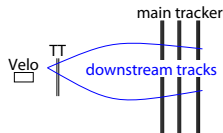
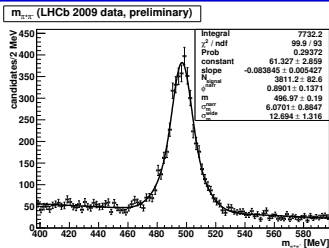
$$\mathcal{L} \sigma_{K_s}(p_T, y) = BR(K_s \rightarrow \pi\pi)^{-1} \varepsilon_{rec.}^{-1}(p_T, y) \varepsilon_{trig}^{-1}(p_T, y) N(p_T, y)$$

- from data:
 - $N(p_T, y)$
 - take $\mathcal{L} = 6.8 \pm 1.0 \mu\text{b}^{-1}$ (preliminary)
direct beam profile measurement by LHCb, bunch currents from machine
(see talk by Dermot Moran on Thursday)
 - from MC: $\varepsilon_{rec}(p_T, y)$
 - from data and/or MC: $\varepsilon_{trig}(p_T, y)$
 - from PDG: $BR(K_s \rightarrow \pi\pi)$
- need to make sure that MC describes data

Long vs Downstream Tracks



lower statistics, higher resolution



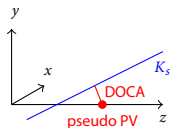
lower resolution, higher statistics

- most K_S decay after Velo \implies larger statistics with downstream tracks
- open Velo causes acceptance loss for long tracks
- long track mass resolution much better than downstream one

\implies two complementary analyses, concentrate on down-down in this talk

Data samples, selection

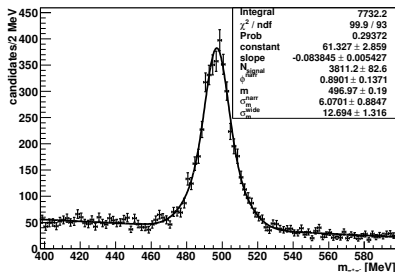
- 13 runs taken December 11-15, 2009
- only minbias events triggered by calorimeters
 - $E_T(\text{hadronic calo.}) > 240$ MeV
 - more than 2 preshower (SPD) hits
- selection
 - use "PV-less" selection (to be more independent of Velo)



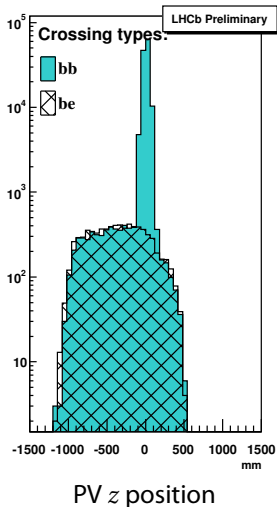
total K_S yield: 3811 ± 83 candidates

$m_{\pi^+\pi^-}$ (LHCb 2009 data, preliminary)

cut	value
πp	< 2 GeV
πp_T	< 50 MeV
π red. track χ^2	< 25
π IP	> 3 mm
K_S red. vertex χ^2	< 25
K_S dec. vertex z	< 2200 mm
K_S IP	< 150 mm
K_S DIRA	> 0.99995
$K_S ct$	> 5 mm
$ \Delta m $	< 50 MeV



Beamgas subtraction



- compare shapes of PV distributions for beam-beam and beam-empty events
- determine factor β from non-collision region ($z_{PV} < -200$ mm)

$$N_{collisions} = N_{bb} - \beta \cdot N_{be}$$

with $\beta = 0.916 \pm 0.019$, valid for the data sample used in this analysis

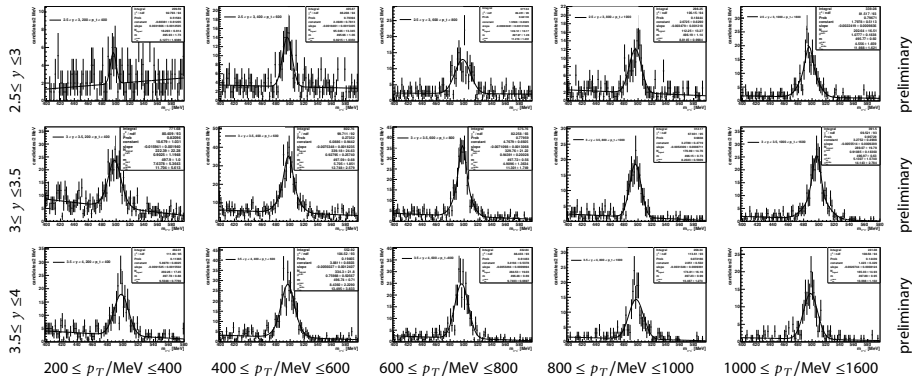
- not an important effect: 3% correction to K_S yields after selection
 - effect will become even smaller when the bunch currents increase this year

Signal extraction in bins of γ and p_T

$$\mathcal{L} \sigma_{K_s}(p_T, \gamma) = BR(K_s \rightarrow \pi\pi)^{-1} \varepsilon_{rec.}^{-1}(p_T, \gamma) \varepsilon_{trig}^{-1}(p_T, \gamma) N(p_T, \gamma)$$

Signal extraction in bins of γ and p_T

- fit model: lin. BG + double Gaussian (single for low statistics bins)
- fit model uncertainties: 4%



- table with numbers in backup



Tracking efficiencies

$$\mathcal{L} \sigma_{K_s}(p_T, y) = BR(K_s \rightarrow \pi\pi)^{-1} \varepsilon_{rec.}^{-1}(p_T, y) \varepsilon_{trig}^{-1}(p_T, y) N(p_T, y)$$



Tracking efficiencies

- turn off known dead channels in MC ($< 1\%$)
- not enough: use effective hit efficiency to account for hits not picked up

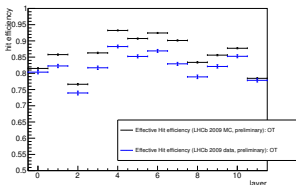


- affected by true (hit) inefficiencies, alignment, pattern recognition
 - not real inefficiency: hits are in detector but not found due to misalignment
 - few cosmics for LHCb, so alignment efforts still ongoing
- pattern reco does not really care for which of these reasons a hit is absent
- reprocess MC with the "right" fraction of hits dropped

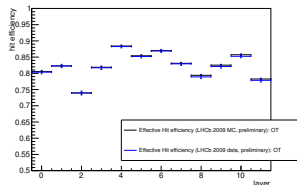


Tracking efficiencies

- data blue, MC black (e.g. for Outer Tracker)



drop fraction
blue curve
black curve
in each layer

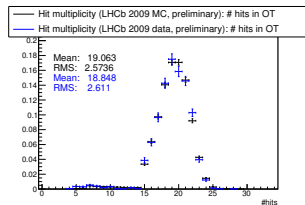


- check number of hits per subdetector after correction

- for systematics, look at variation of ratio
 $\frac{\text{hits per track (data)}}{\text{hits per track (MC)}}$
 - in bins of p, ϕ, η, y , per quarter. . .

- vary effective hit efficiencies by
TT $\pm 2\%$, IT $\pm 5\%$, OT $\pm 1\%$

⇒ about 8% systematic uncertainties on yields





Total reconstruction efficiency

- total efficiency low (LHCb is not a 4π detector)

$p_T[\text{MeV}]/y$	2.5 - 3.0	3.0 - 3.5	3.5 - 4.0
200 - 400	$0.9 \pm 0.1 \pm 0.1$	$5.7 \pm 0.2 \pm 0.5$	$5.8 \pm 0.2 \pm 0.6$
400 - 600	$2.8 \pm 0.2 \pm 0.3$	$9.6 \pm 0.3 \pm 0.8$	$9.2 \pm 0.3 \pm 1.2$
600 - 800	$5.1 \pm 0.3 \pm 0.7$	$12.9 \pm 0.4 \pm 1.0$	$12.0 \pm 0.5 \pm 1.3$
800 - 1000	$8.7 \pm 0.5 \pm 0.5$	$14.5 \pm 0.7 \pm 1.4$	$11.0 \pm 0.7 \pm 1.4$
1000 - 1600	$11.7 \pm 0.6 \pm 1.3$	$15.4 \pm 0.8 \pm 1.6$	$9.6 \pm 0.8 \pm 0.9$

(numbers in percent, preliminary)

- treat data and MC exactly alike
- breakdown for $600 \leq p_T/\text{MeV} < 800, 3.0 \leq y < 3.5$:
 $\epsilon_{\text{decay}} = 69\%$, $\epsilon_{\text{acceptance}} = 49\%$, $\epsilon_{\text{reco}} = 74\%$, $\epsilon_{\text{sel}} = 49\%$



Trigger efficiency

$$\mathcal{L} \sigma_{K_s}(p_T, y) = BR(K_s \rightarrow \pi\pi)^{-1} \varepsilon_{rec.}^{-1}(p_T, y) \varepsilon_{trig}^{-1}(p_T, y) N(p_T, y)$$

Trigger efficiency

- trigger efficiency can be measured on data
 - two uncorrelated classes of events:
 - trigger on signal (TOS)
 - trigger independent of signal (TIS)

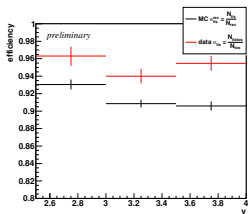
$$\varepsilon_{TIS}(p_T, y) = \frac{N_{TISTOS}(p_T, y)}{N_{TOS}(p_T, y)}$$

- not enough statistics for measurement in bins of p_T and y
- use trigger emulation of MC, crosscheck with data in 1D projections

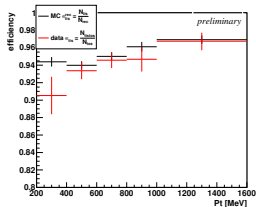
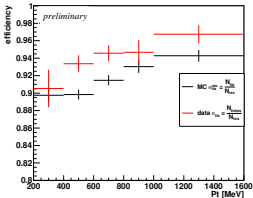
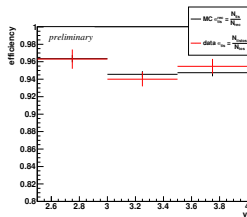
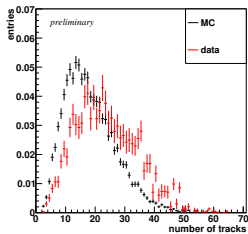


Trigger efficiency

- track multiplicity different in data and MC: reweight
- trigger efficiency typically above 95% (full table in backup)
- trigger efficiency systematics: 2% (preliminary)



track multiplicity



Sources of uncertainties

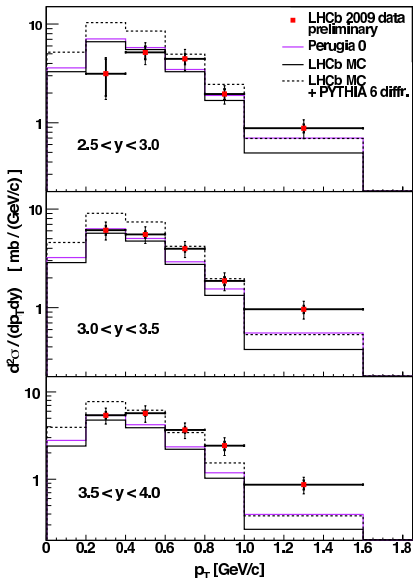
- statistical uncertainty: around 10% (depending on bin)
- systematics:

important systematics	minor effects
data/MC agreement (8%)	binning effects
fit stability (4%)	non-prompt K_s
stability of selection cuts (2.5%)	beam gas subtraction
trigger (2%)	branching ratio uncertainties

Preliminary results: K_s production in regions of rapidity

$$\mathcal{L} \sigma_{K_s}(p_T, y) = BR(K_s \rightarrow \pi\pi)^{-1} \varepsilon_{rec.}^{-1}(p_T, y) \varepsilon_{trig}^{-1}(p_T, y) N(p_T, y)$$

Preliminary results: K_S production in regions of rapidity



- data points: bold error bars: stat.; thin error bars: systematics (incl. 15% on lumi)
- black curve: LHCb Monte Carlo
- magenta curve: Perugia 0 Pythia tuning
- results reasonably consistent with MC



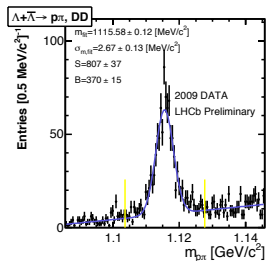
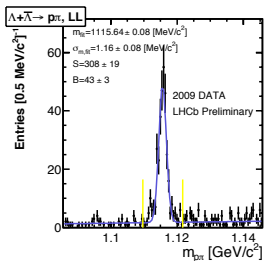
Summary/Outlook

- presented first (preliminary) physics results at LHCb: K_S production cross section
 - inelastic pp collisions, $\sqrt{s} = 900$ GeV, in range of $0.2 < p_T/\text{GeV} < 1.6$ and $2.5 < y < 4.0$
 - analysis with "minimal requirements": no PID, almost no Velo, no energy measurements



Summary/Outlook

- several analyses of 2009 data ongoing
 - 2 other K_s analyses ongoing
 - studying systematics
 - results consistent with the one presented here
 - $\Lambda/\bar{\Lambda}$ studies

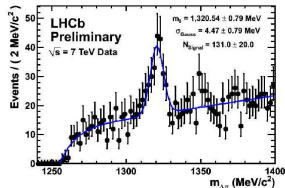
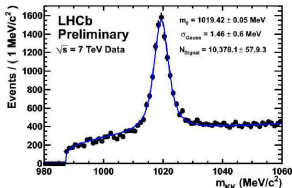
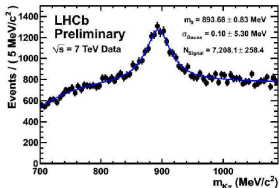
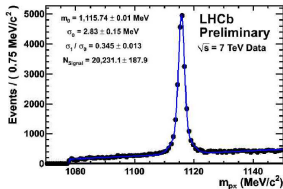
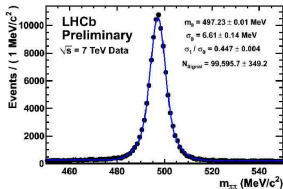


- jet structure of pp collisions at $\sqrt{s} = 900$ GeV in LHCb acceptance ($2 \leq \eta < 5$)
- inclusive charged particle production



Summary/Outlook

- LHCb has had a great start and is eagerly awaiting (more) 2010 data to do physics at $\sqrt{s} = 7$ TeV



Backup

Signal extraction: uncorrected K_s yields

■ uncorrected K_s yields (preliminary)

$p_T [MeV]/y$	2.5 - 3.0	3.0 - 3.5	3.5 - 4.0
200 - 400	$18 \pm 7 \pm 1$	$222 \pm 22 \pm 9$	$202 \pm 17 \pm 10$
400 - 600	$95 \pm 13 \pm 6$	$339 \pm 25 \pm 5$	$334 \pm 22 \pm 5$
600 - 800	$149 \pm 16 \pm 9$	$330 \pm 21 \pm 10$	$285 \pm 19 \pm 5$
800 - 1000	$112 \pm 13 \pm 4$	$177 \pm 15 \pm 4$	$175 \pm 16 \pm 3$
1000 - 1600	$203 \pm 17 \pm 9$	$289 \pm 20 \pm 8$	$165 \pm 15 \pm 4$



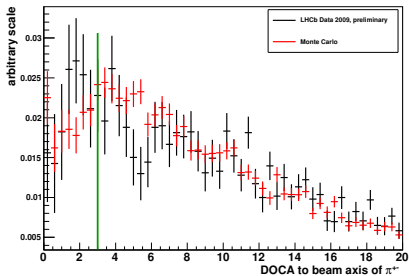
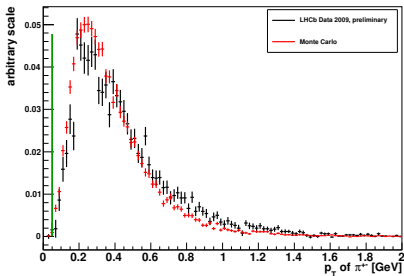
Trigger efficiencies

- trigger efficiencies in percent (preliminary)

$p_T [MeV]/y$	2.5 - 3.0	3.0 - 3.5	3.5 - 4.0
200 - 400	$93.5 \pm 4.1 \pm 2.0$	$93.8 \pm 1.2 \pm 2.0$	$94.7 \pm 1.0 \pm 2.0$
400 - 600	$96.4 \pm 1.4 \pm 2.0$	$93.9 \pm 1.0 \pm 2.0$	$93.5 \pm 1.0 \pm 2.0$
600 - 800	$96.6 \pm 1.3 \pm 2.0$	$95.1 \pm 1.0 \pm 2.0$	$95.1 \pm 1.0 \pm 2.0$
800 - 1000	$96.8 \pm 1.4 \pm 2.0$	$96.3 \pm 1.1 \pm 2.0$	$96.5 \pm 1.3 \pm 2.0$
1000 - 1600	$96.8 \pm 1.1 \pm 2.0$	$95.6 \pm 1.3 \pm 2.0$	$97.1 \pm 1.4 \pm 2.0$

Selection efficiencies

- systematics of selection come from data/MC disagreement
- check every variable by releasing only that cut (n-1)
- total systematics: 2.5% (preliminary)
- two examples: p_T and (pseudo-)IP of daughter π



Preliminary results: K_s production in regions of rapidity

■ K_s production in regions of rapidity

$p_T [MeV]/y$	2.5 - 3.0	3.0 - 3.5	3.5 - 4.0
200 - 400	$2139 \pm 870 \pm 270$	$4152 \pm 440 \pm 410$	$3678 \pm 337 \pm 429$
400 - 600	$3520 \pm 545 \pm 444$	$3761 \pm 304 \pm 328$	$3883 \pm 288 \pm 517$
600 - 800	$3024 \pm 373 \pm 458$	$2690 \pm 193 \pm 231$	$2497 \pm 198 \pm 279$
800 - 1000	$1330 \pm 173 \pm 94$	$1268 \pm 124 \pm 128$	$1649 \pm 185 \pm 214$
1000 - 1600	$1792 \pm 177 \pm 218$	$1963 \pm 172 \pm 215$	$1770 \pm 218 \pm 175$