Analysis of first data at LHCb

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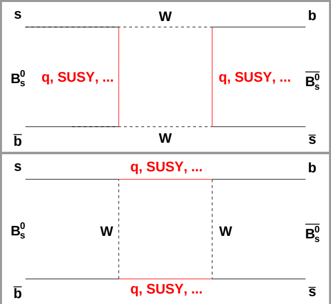
Outline

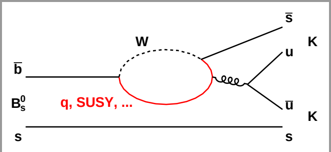
1. Introduction
2. Cross-section ratios
3. Cross-sections
4. Conclusion and outlook

Outline

LHCb – an experiment at the LHC

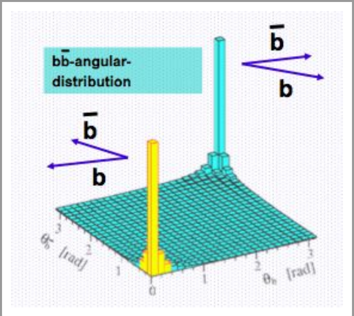
- precision measurements of CP violation & rare decays
- baryon asymmetry $\rightarrow$ more CP violation than in the SM
- heavy flavor physics
- sensitivity to terascale particles in box/loop diagrams

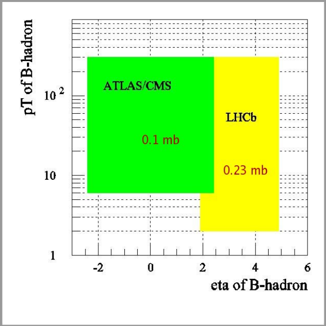




LHCb – an experiment at the LHC

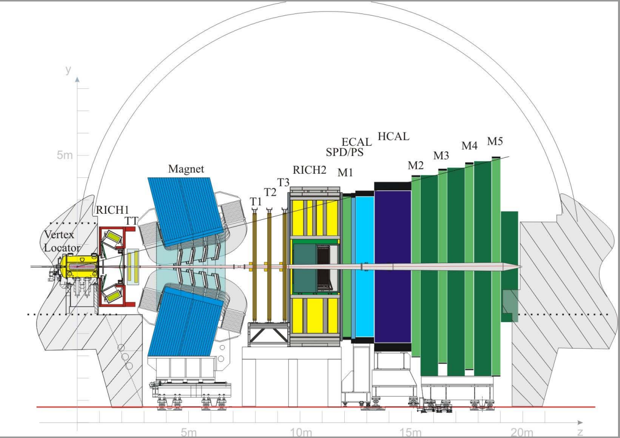
- precision measurements of CP violation & rare decays
- baryon asymmetry $\rightarrow$ more CP violation than in the SM
- heavy flavor physics
- sensitivity to terascale particles in box/loop diagrams
- most *b*s produced in forward (backward) direction
- forward spectrometer, pseudo rapidity $1.9 < \eta < 4.9$





The LHCb experiment

- good vertex resolution
- dedicated triggers
- good particle identification (PID)



The LHC conditions

Nominal conditions:

- LHC: *pp*-collider, $\sqrt{s} = 14$ TeV
- 2808 bunches filled
- nominal luminosity: 10^{34} cm^{-2}s^{-1}
- less strong focusing for LHCb: $2 \cdot 10^{32}$ cm^{-2}s^{-1}

Expected 2009/2010 conditions:

- $\sqrt{s} = 7 - 10$ TeV
- up to 414 bunches filled
- luminosity, up to: $\sim 10^{32}$ cm^{-2}s^{-1}

$\rightarrow$ start of full LHCb physics program possible in 2009/2010

First measurements with minimum bias data

Following: Focus on minimum bias day one physics

- $\sqrt{s} = 7$ TeV
- random trigger (or minimum bias trigger)
- logging rate of 2 kHz
- first collisions: expect 10^8 events recorded in a few days
- MC used here: $9.5 \cdot 10^6$ events, produced 2006, 14 TeV
- selection: use only tracking, no PID
- particle ratios (charged tracks, K_s^0, Λ, D)
  $\rightarrow$ most systematics cancel, no luminosity needed
- J/ψ, K_s^0, Λ, D cross-section, p_t spectra

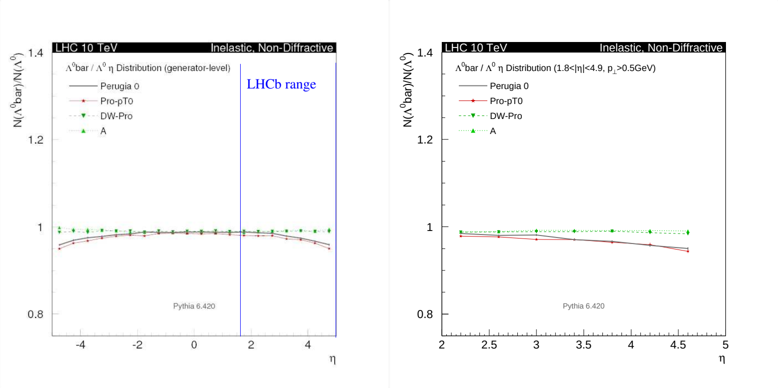
Physics topics

- commissioning for physics analyses:
  - inclusive production
  - strangeness production
  - charm signals
- stepping stone to terascale physics:
  - B-decays with K_s^0 as daughter ($e.g.$, $B_d^0 \to J/\psi K_s^0$, $B_s^0 \to K_s^0 K_s^0$)
  - radiative b-decays ($\Lambda_b \to \Lambda\gamma$)
  - B-decays with charming daughters ($e.g.$, $B_s^0 \to J/\psi\phi$, $B_d^{\pm} \to D^0 K^{\pm}$)
  - D^0–$\overline{D^0}$ mixing
- input for Monte Carlo tuning for **all** LHC experiments $\to$ underlying event for **higgs and SUSY** searches
- test fragmentation models for multi particle production

Fragmentation models

- there are different fragmentation models on the market
- strangeness is unique probe for fragmentation (created in fragmentation, medium *s*-quark mass)
- some new models predict the beam baryon number to reach lower η (at low p_t)
  - look for strange baryon to anti-baryon ratios at low p_t and medium η
  - this is the regime of LHCb!

Example: predictions for $\frac{\bar{\Lambda}}{\Lambda}$



→ less than ∼ 5 % error needed in LHCb regime

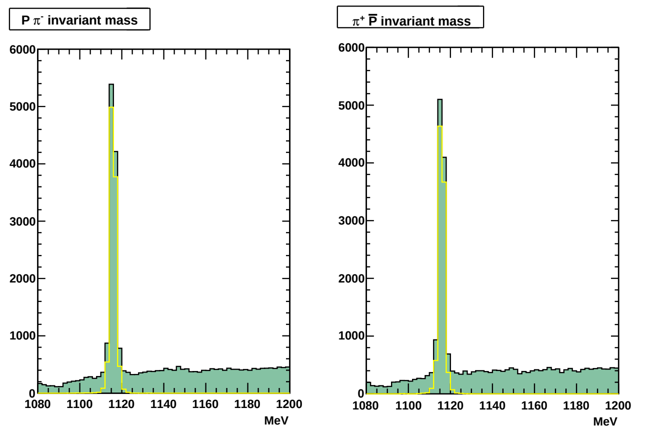
taken from
`http://home.fnal.gov/~skands/leshouches-plots/`
Thanks to Peter Skands

Outline

Strange particle selection

- use decays $K_s^0 \to \pi^+\pi^-$, $\Lambda \to p\pi^-$, $\bar{\Lambda} \to \bar{p}\pi^+$
- candidates are pairs of oppositely charged tracks
- two selection variants:
  - here: no significance ($\frac{x}{\sigma_x}$) cuts
  - later: use cuts on significances to improve sensitivity
- minimal requirements: working vertex detector (VeLo) and main tracker
- check of momentum calibration
- important for RICH calibration

E.g., Λ, $\bar{\Lambda}$ signals



Cuts: DoCA $\leq$ 0.3 mm, $ct \geq$ 4 mm, IP $\leq$ 0.1 mm, $p_{t,\text{wrt mother}} \geq$ 10 MeV

LHCb, first measurements

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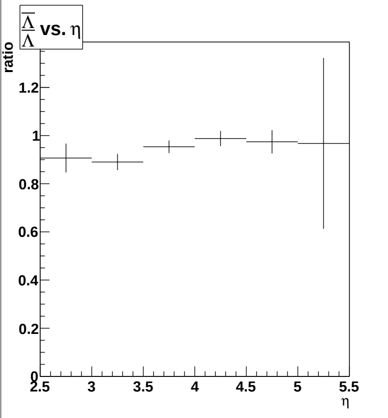
$\frac{\bar{\Lambda}}{\Lambda}$ versus η



$\sim$ 4 % statistical error for ratios $\rightarrow$ 1.3 % error when extrapolated to 100 M events

$\Rightarrow$ we will be able to decide between new and old models

D-meson selection

LHCb, first measurements

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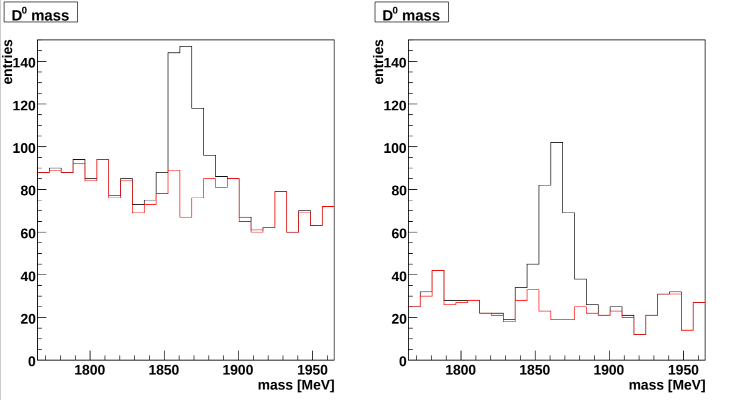
- D selection similar to that of strange particles
- $D^0 \to K^-\pi^+$ and cc, $D^\pm \to K^\mp\pi^\pm\pi^\pm$
- use cuts based and multivariate analysis (MVA)[1]
- minimal requirement: well aligned VeLo, main tracker
- only geometric and kinematic cuts (no significances)
- still no particle identification used!

[1] Britsch, Gagunashvili, Schmelling ACAT 2008

$D^0 \to K^- \pi^+$, 9.5 M events



cuts based

multivariate analysis
(for same signal yield)

Expected sensitivity on charm selection

- about 200 particles for each *D*-meson species
- 2000 each, expected for 100 M events
- MVA can reduce the background by a factor of ~ 3

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For $p_t < 12$ GeV, $1.8 < y < 4.5$, 100 M events:

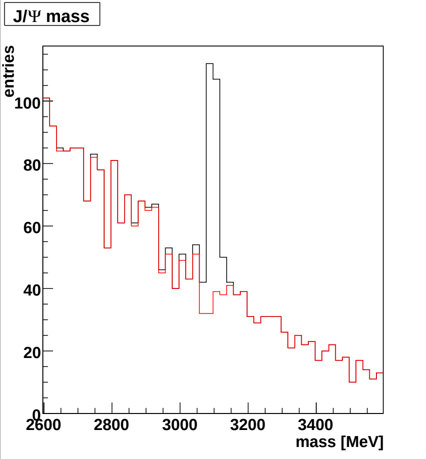
Expect error on D-meson ratios: ~ 5 %

Outline

Cross-sections

- probing more details of the production mechanism
- K_s^0, Λ, D: p_t^2 spectra in bins of y
  probes the kinematic dependence of the production, getting rid of the phase space factor
- with luminosity determination:
  - K_s^0, Λ, D: cross-sections
  - $J/\Psi(1S)$ cross-sections
    ($J/\Psi \to \mu^+\mu^-$, using muon chambers)

J/Ψ, 9.5 M events



174 J/Ψ, 197 BG, $\rightarrow$ 100 M events: 2000 J/Ψ, 2000 BG

Outline

Conclusion and outlook

With first 10^8 minimum bias events (few days of running):

- stepping stone to terascale physics
- probe fragmentation models by strange particle ratios
- also important for MC tuning for all LHC experiments
- $\sim$ 2000 $D^{0/\pm}$, J/ψ, ratios with $\sim$ 5 % error

Conclusion and outlook

With first 10^8 minimum bias events (few days of running):

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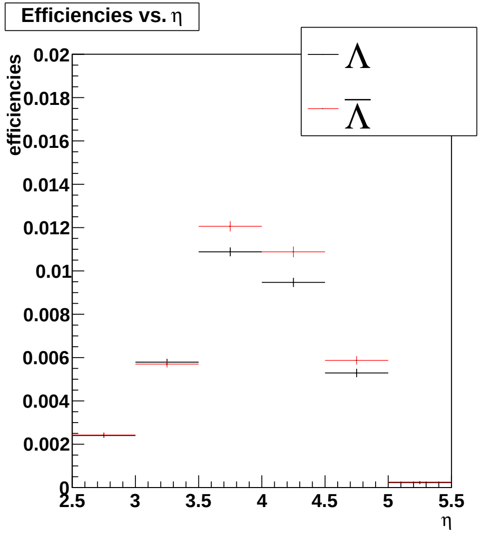
- $\sim 2000\ D^{0/\pm}$, J/ψ, ratios with ~ 5 % error

Outlook:

- more detailed MC studies
- cascade ratios (Ξ^-, Ω^-)
- with triggered data:
  - look for b-baryons (Λ_b, Ξ_b, ...)
  - $pp \to b\bar{b}$ cross-section from detached J/Ψ

backup slides

$\bar{\Lambda}$, Λ efficiencies



Used MVA-method

- using RIPPER classifier, rule based

```
(IPpi >= 1.039316) and (DoCA <= 0.307358)
and (IP <= 0.270767) and (IPp >=
0.800645)
=> class=Lambda
(IPpi >= 0.637403) and (DoCA <= 0.159043)
and (IP <= 0.12081) and (ptpi >=
149.2332) and (IP >= 0.003371)
=> class=Lambda
=> class=BG
```

Used MVA-method

- using RIPPER classifier, rule based
- introduce cost to change outcome

	pred. BG	pred. signal
tr. BG	0	$C(\mathrm{BG}, \mathrm{s})$
tr. signal	$C(\mathrm{s}, \mathrm{BG})$	0

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- the cost is introduced by weights

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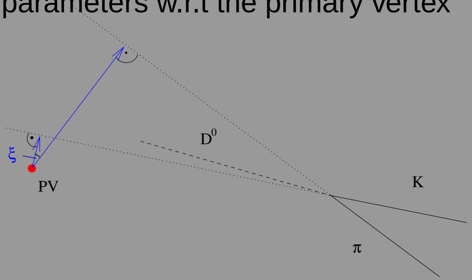
- using RIPPER classifier, rule based
- introduce cost to change outcome
- the cost is introduced by weights
- use bagging to stabilize algorithm: produce a set of new training samples by drawing with replacement from original set

orig. sample	1	2	3	4	5
1st iteration	2	5	1	1	4
2nd iteration	5	3	2	2	4
⋮					
rth iteration	1	1	5	1	4

D-meson cuts

- track hits
- transverse momenta
- flight-length, distance of closest approach (DoCA)
- impact parameters w.r.t the primary vertex
- cos ξ



$D^0 \to K^-\pi^+$-Cuts

- long tracks only
- pion/kaon track #LHCbIDs > 27
- $pt > 700$ MeV
- $pt_{\text{daughters}} > 500$ MeV
- $\cos\xi < -0.7$
- $FL > 1.5$ mm
- $DoCA < 0.07$ mm
- $\log \frac{DoCA}{FL} < -4.0$
- $IP < 0.08$ mm
- $IP_{\text{daughters}} > 0.05$ mm
- $\log\left(\frac{IP_K^2 + IP_\pi^2}{IP^2}\right) > 3.0$

ξ: angle between impact vectors

$D^{\pm} \to K^{\mp}\pi^{\pm}\pi^{\pm}$-Cuts

- long tracks only
- pion tracks #LHCbIDs > 30
- kaon track #LHCbIDs > 30
- $pt > 2000$ MeV
- $pt_{\mathrm{daughters}} > 400$ MeV
- $FL > 5.0$ mm
- $FL\frac{M}{E} > 0.2$ mm
- $DoCA < 0.1$ mm
- $\log\frac{DoCA}{FL} < -5.0$
- $IP < 0.1$ mm
- $IP_{\pi s} > 0.1$ mm
- $IP_K > 0.05$ mm
- $\log\left(\frac{IP_K^2+IP_{\pi_1}^2+IP_{\pi_2}^2}{IP^2}\right) > 3.5$