First measurements with the LHCb experiment

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Outline

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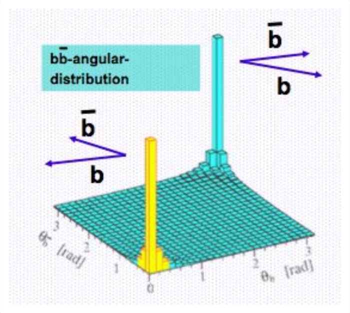
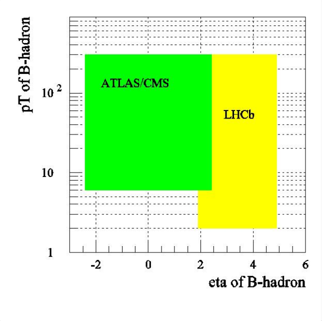
LHCb – an experiment at the LHC

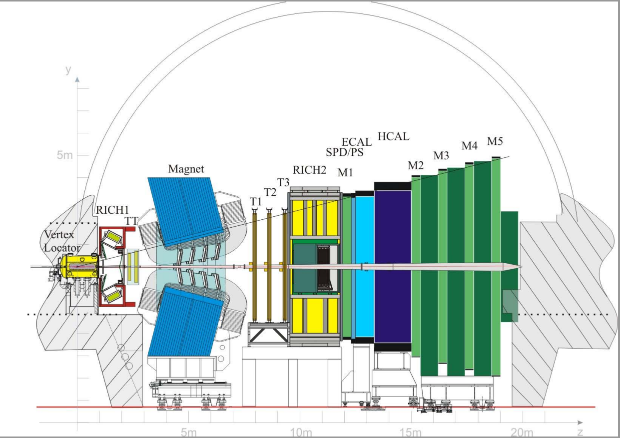
- precision measurements of CP violation & rare decays
- heavy flavor physics
- baryon asymmetry $\rightarrow$ more CP violation than in the SM
- sensitivity to new physics particles from loop diagrams
- most *b*s produced in forward (backward) direction
- forward spectrometer, pseudo rapidity $1.9 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





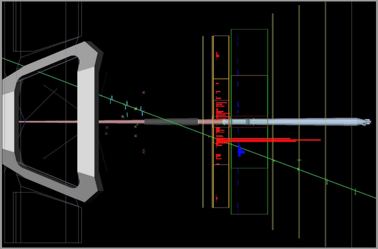
The LHCb experiment

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

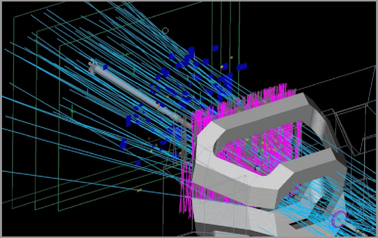


Selected results from commissioning

- used events
  - cosmics
  - beam–gas
  - beam on collimator



cosmic



beam–collimator

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- used events
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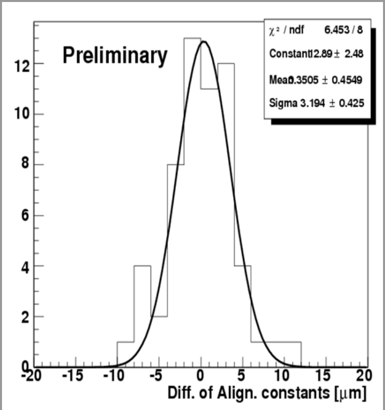
- VeLo alignment (beam on collimator)
  - consistent with survey to 10 μm
  - $\sim$ 5 μm x, y translations
  - $\sim$ 200 μrad z-rotation



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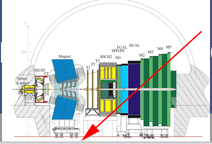
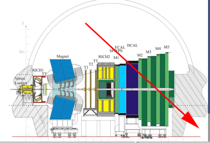
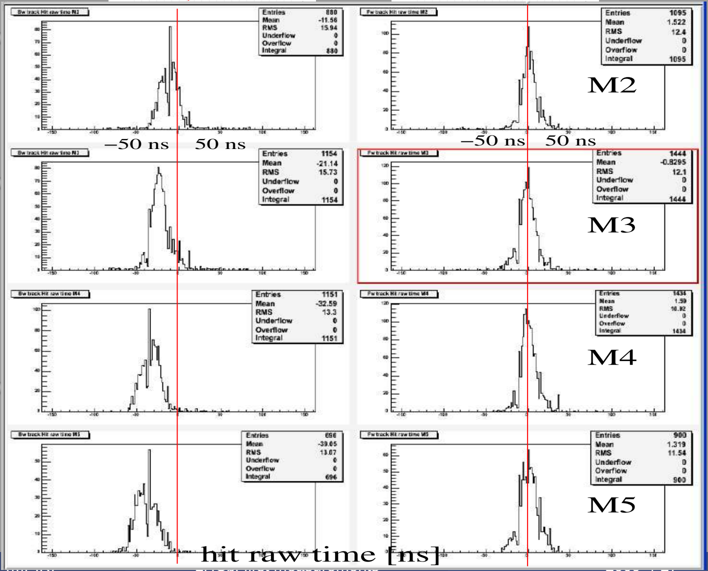
Selected ... com...







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- time alignment of muon chambers (cosmics)
  - backward tracks skewed
  - forward tracks time aligned
  - resolution $\sim$ 1 ns

Full Experimental System Test (FEST)

- inject raw Monte Carlo events into data acquisition chain as if coming from readout boards
- test everything except for the detector itself
- including:
  - run control
  - data stream, event building and high level trigger
  - data monitoring
  - databases
  - data storage
- 1.9 kHz data logging achieved steadily

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:

- $\sqrt{s} = 8 - 10$ 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

Commissioning for physics analyses

- early analyses as stepping stone for heavy flavor
- interesting in its own right
- basis for further investigations (e.g., MC tuning for all LHC experiments)

See also other LHCb contributions on this conference:

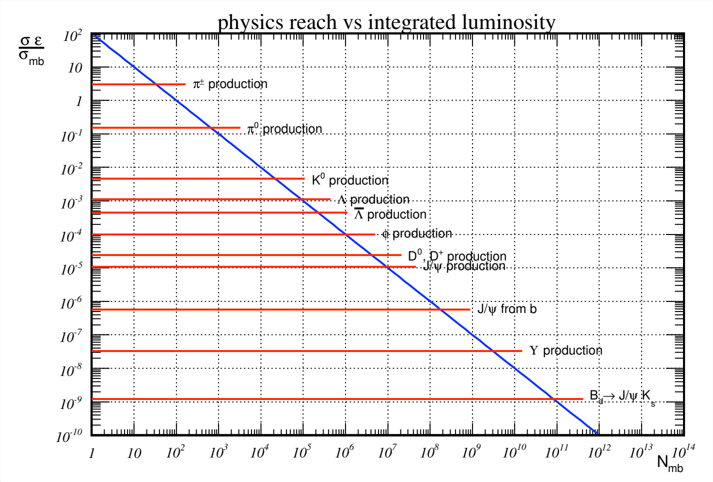
- luminosity determination: F. De Lorenzi
- low-x physics: J. Anderson
- W/Z production: S. Traynor
- heavy quark physics: J. He, J. Albrecht, M. Needham

Following: Focus on minimum bias day one physics

First measurements with minimum bias data

- w/o trigger (minimum bias trigger)
- logging rate of 2 kHz
- first collisions: expect 10^8 events recorded in a day
- use only tracking, no particle identification (PID)
- particle ratios (charged tracks, K_s^0, Λ, D)
  $\rightarrow$ most systematics cancel, no luminosity needed
- MC used here: $9.5 \cdot 10^6$ events, produced 2006, 14 TeV

Prospects for minimum bias physics



σ – corresponding cross section, σ_{mb} – minimum bias cross section, ε – efficiencies

Outline

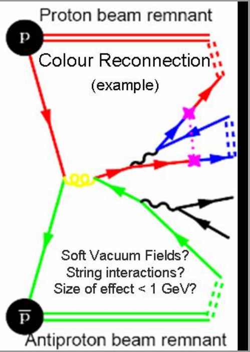
Physics topics

- inclusive production
- strangeness production
- charm signals

- stepping stone to:
  - B-decays with K_s^0 as daughter
  - radiative b-decays ($\Lambda_b \to \Lambda\gamma$)
  - b-baryon spectroscopy
- input for Monte Carlo tuning
- test fragmentation models for multi particle production

Elements of multi particle production

- multiple parton interaction (MPI) – important at LHC
- fragmentation
- color (re)connection
- new models exist

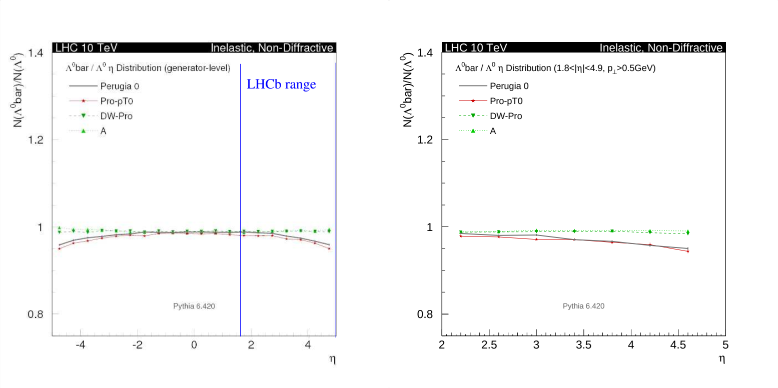


plot by Peter Scands

Experimental approach

- 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 $\frac{\bar{\Lambda}}{\Lambda}$



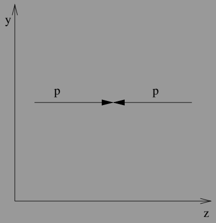
$\rightarrow$ less than $\sim$ 5 % error needed in LHCb regime

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

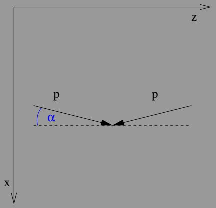
Outline

Charged track ratios

- 1 million minimum bias events used
- range 100 MeV $< p_t <$ 8000 MeV, $1.8 < \eta < 5.1$
- minimal requirement: working main tracker
- vital for understanding charge asymmetries
- use for Monte Carlo tuning, comparison w/ fragmentation models
- studies assume beam crossing angle of $2 \cdot 0.285$ mrad



side view



top view

Compare MC truth to reconstructed

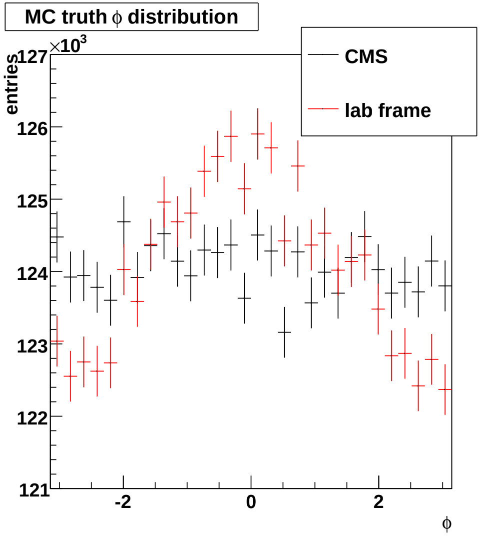
MC truth used:

- only events with exactly one primary vertex (PV)
- no elastic and single diffractive events
- long lived particles ($\tau > 1$ ns)
- coming from PV or from short lived particle from PV

Selecting reconstructed tracks:

- only events with exactly one PV
- tracks from PV (impact parameter < 0.15 mm)
- tracks with hits in both VeLo and main tracker

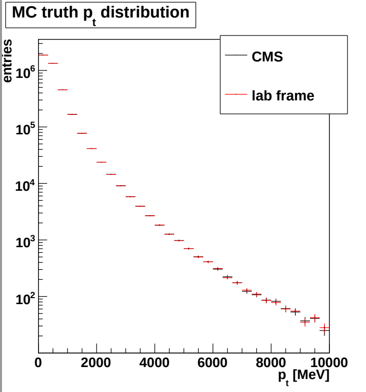
MC true azimuthal angle distribution

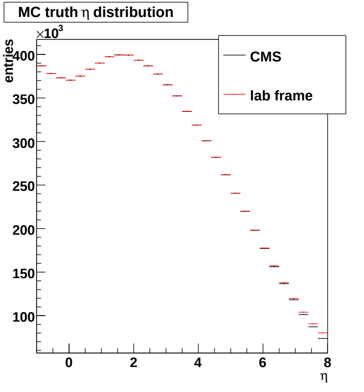


MC true p_t, η distributions

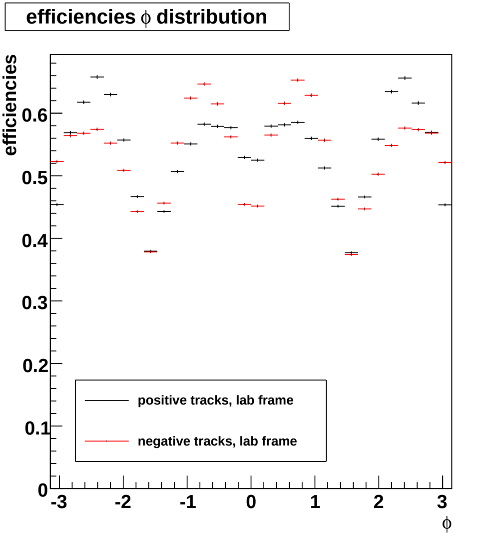
LHCb, first measurements

Markward Britsch





Reconstruction efficiencies in azimuthal angle



Reconstruction efficiencies

LHCb, first measurements

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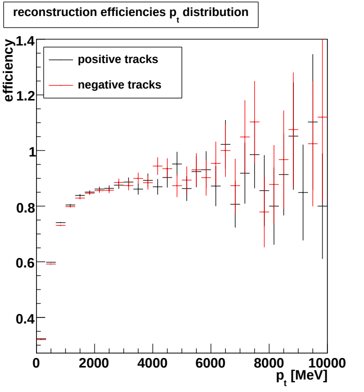
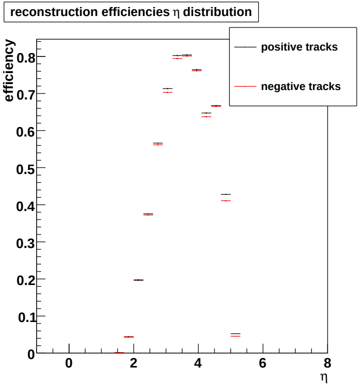
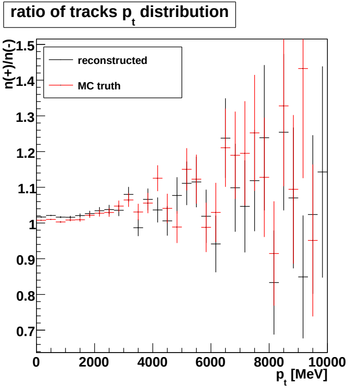
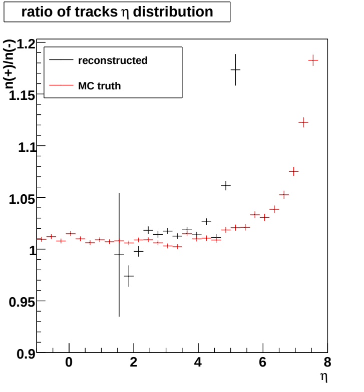




[in center of mass frame]

Charged track ratios





[in center of mass frame]

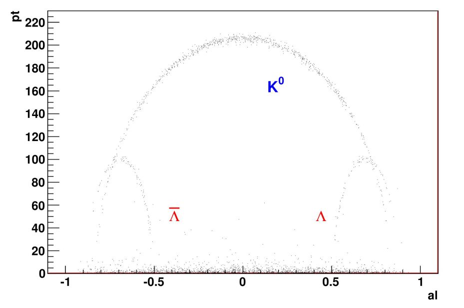
For most bins a MC efficiency correction of $\lesssim$ 5 % needed. Even if we would trust the MC only to 20 % this would give a systematic error of $\sim$ 1 %.

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
- 9.5 million minimum bias events used
- minimal requirements: working vertex detector (VeLo) and main tracker
- check of momentum calibration
- important for RICH calibration

Armenteros-Podolanski plot

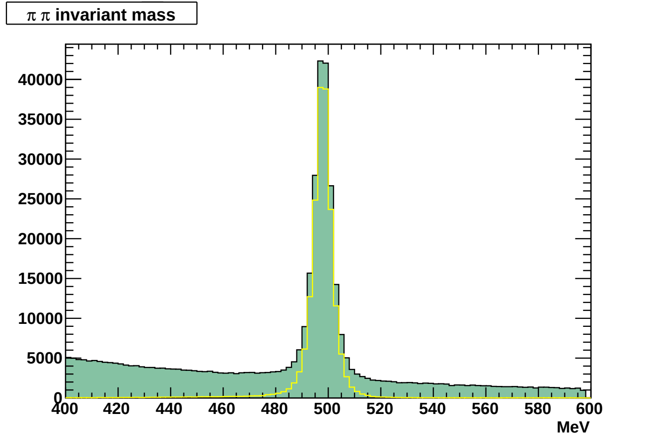


- $p_{t,\text{wrt mother}}$ of decay products
- asymmetry of longitudinal momenta of decay products, *i.e.*, (+,-)–track: $al = \alpha = \frac{p_L^+ - p_L^-}{p_L^+ + p_L^-}$

PID by relativistic kinematics – RICH calibration

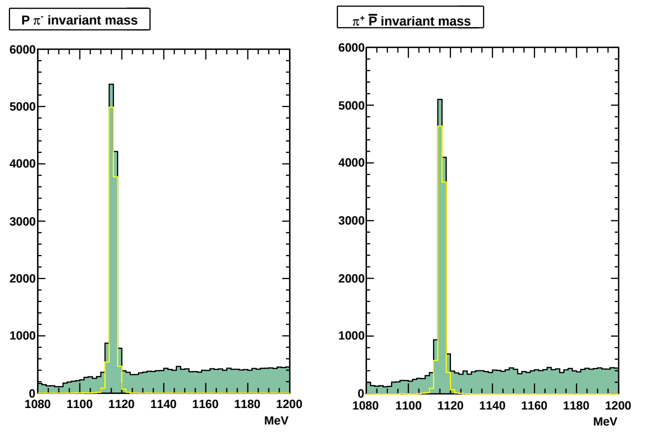
Cuts: distance of closest approach (DoCA) < 0.1 mm, $ct \geq 4$ mm, impact parameter (IP) ≤ 0.1 mm

K_s^0 signals



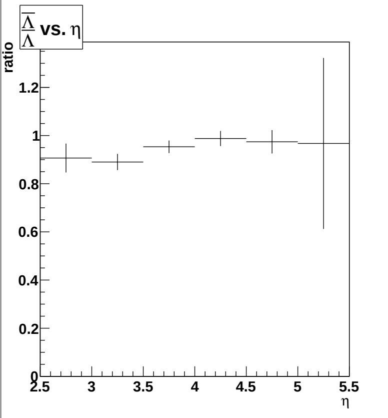
Cuts: DoCA $\leq$ 0.2 mm, $ct \geq$ 4 mm

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

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



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

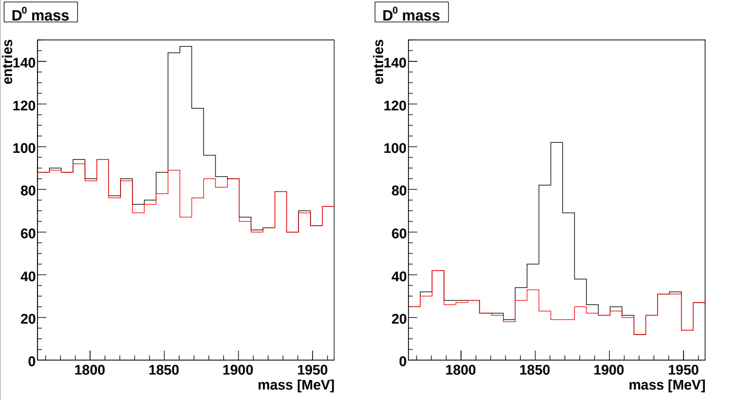
$\Rightarrow$ we will be able to decide between new and old models

D-meson selection

- similar to 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 working VeLo, main tracker
- only geometric and kinematic cuts (no significances)
- still no PID used!

[1] Britsch, Gagunashvili, Schmelling ACAT 2008

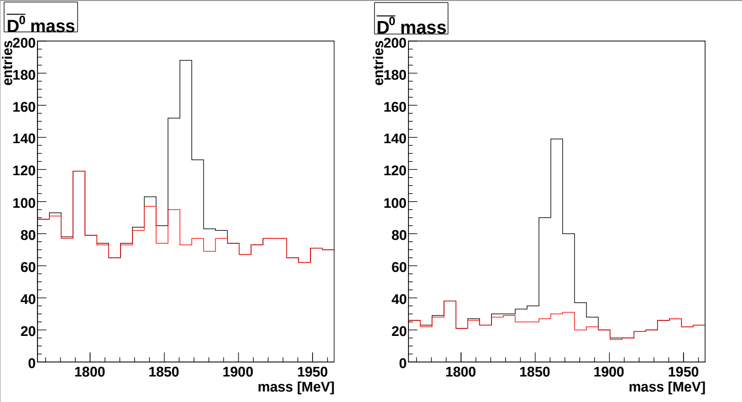
$D^0 \to K^-\pi^+$, 9.5 M events



cuts based

multivariate analysis
(for same signal yield)

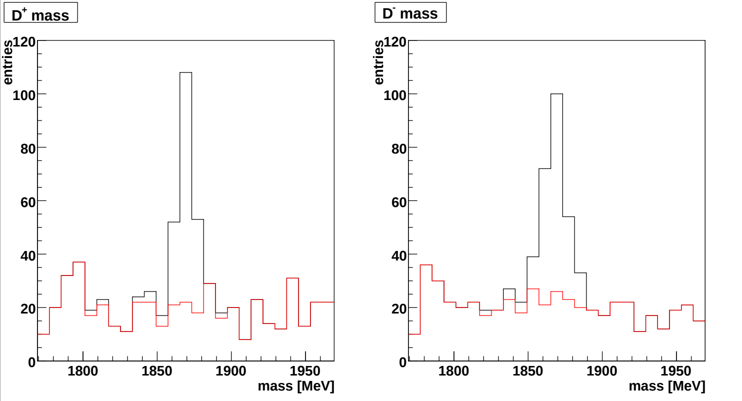
$\overline{D^0} \to K^+\pi^-$, 9.5 M events



cuts based

multivariate analysis (for same signal yield)

$D^{\pm} \to K^{\mp}\pi^{\pm}\pi^{\pm}$, 9.5 M events



both cuts based

Expected sensitivity on *D* selection

- about 200 particles for each charm species
- 2000 each expected for 100 M events
- MVA has reduced 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 $\frac{\overline{D^0}}{D^0}$ cuts based: 7 %
- expect error on $\frac{\overline{D^0}}{D^0}$ MVA: 5 %
- expect error on $\frac{D^-}{D^+}$ cuts based: 6 %

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More charm physics at LHCb, see talk by M. Needham, Heavy Flavors session, Wednesday

Outline

Conclusion and outlook

With first 10^8 minimum bias events (one day of running):

- get charged track ratio distributions with ~ 1 % error
- probe fragmentation models by strange particle ratios
- also important for MC tuning
- ~ 2000 $D^{0/\pm}$, ratios with ~ 5 % error

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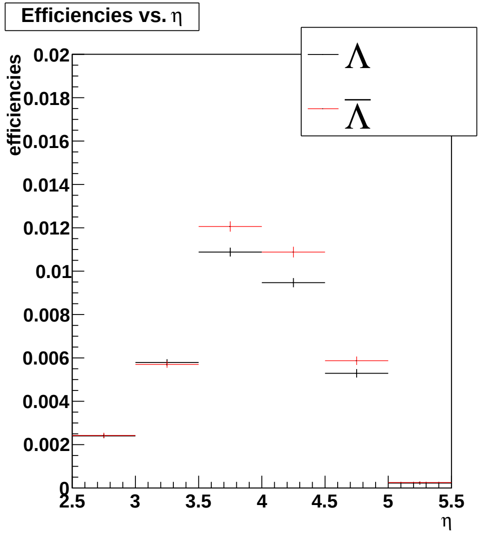
Outlook:

- more detailed MC studies
- cascades ratios (Ξ^-, Ω^-)
- look for b-baryons (Λ_b, Ξ_b, ...)
- cross section measurements

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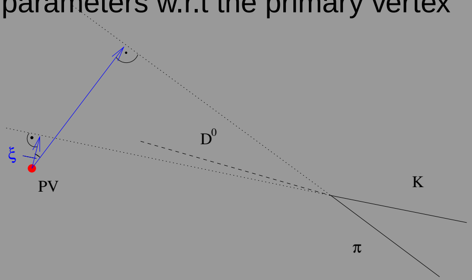
- introduce cost to change outcome
- the cost is introduced by weights
- use bagging to stabilize algorithm: produce a set of new training samples by drawing with replacement from original set

orig. sample	1	2	3	4	5
1^{st} iteration	2	5	1	1	4
2^{nd} iteration	5	3	2	2	4
⋮					
r^{th} 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
- $pt_{\mathrm{daughters}} > 500$ MeV
- $\cos\xi < -0.7$
- $FL > 1.5$ mm
- $DoCA < 0.07$ mm
- $\log \frac{DoCA}{FL} < -4.0$
- $IP < 0.08$ mm
- $IP_{\mathrm{daughters}} > 0.05$ 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
- $pt_{\text{daughters}} > 400$ 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
- $\log\left(\frac{IP_K^2 + IP_{\pi_1}^2 + IP_{\pi_2}^2}{IP^2}\right) > 3.5$