Reconstruction of D-mesons from three body hadronic decay

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Road Map

- **Physics Motivation**
  - why do we need many channels?

- **Simulation Strategy**
  - $D^+ \rightarrow K\pi\pi$
  - $D_s \rightarrow KK\pi$

- **Tools used for the Analysis**
  - Grid Analysis FrameWork

- **Summary**
Physics Motivation

✓ To measure charm yield more precisely, we need to measure as many channels as we can.

❖ reduces the systematic error on the absolute cross-section

✓ Study of different ways of hadronization:

❖ String fragmentation:
  \[ \frac{D_s^+ (cs)}{D^+ (cd)} \sim 1/3 \]
  it should be easier to take a light meson from vacuum than strange one.

❖ Recombination:
  \[ \frac{D_s^+ (cs)}{D^+ (cd)} \sim \frac{N(s)}{N(d)} (\sim 1 \text{ at LHC?}) \]
  recombination occurs inside the medium.
# D Mesons: Main features

<table>
<thead>
<tr>
<th></th>
<th>$D^0$</th>
<th>$D^+$</th>
<th>$D_s^+$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expected abundance per event (0-5% Pb-Pb at 5.5 TeV) from NLO pQCD + binary scaling ($</td>
<td>\eta</td>
<td>&lt;0.9$)</td>
<td>28</td>
</tr>
<tr>
<td>Decay Channel</td>
<td>$K^-\pi^+$</td>
<td>$K^-\pi^+\pi^+$</td>
<td>$K^-K^+\pi^+$</td>
</tr>
<tr>
<td>Branching Ratio</td>
<td>3.89%</td>
<td>9.2%</td>
<td>5.5%</td>
</tr>
<tr>
<td># charged body</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td># of combinations in full mass range for $dN/dy = 6000$ (with ideal PID)</td>
<td>$10^6$ pairs</td>
<td>$10^9$ triplets</td>
<td>$10^8$ triplets</td>
</tr>
<tr>
<td>Decay length</td>
<td>123μm</td>
<td>312μm</td>
<td>150μm</td>
</tr>
<tr>
<td>Resonant channel</td>
<td>$\square$</td>
<td>$\checkmark$</td>
<td>$\checkmark$</td>
</tr>
</tbody>
</table>

$D^+$ → $K^0\pi^+\rightarrow K^-\pi^+\pi^+$

$D_s^+$ → $\phi\pi^+\rightarrow K^-K^+\pi^+$

$D_s^+$ → $K^0K^+\rightarrow K^-K^+\pi^+$
D⁺ → Kππ: Selection Strategy: invariant-mass analysis of fully-reconstructed topologies originating from displaced vertices

- Various selection steps have been applied to extract the signal from the large combinatorial background

  - Distance between primary and secondary vertex ($d_{ps}$)

  - Cosine of pointing angle ($\cos\theta_p$), where $\theta_p$ is the angular distance between the reconstructed D⁺ momentum and D⁺ flight line.

  - Sum of squared impact parameters
    \[ s = d_{01}^2 + d_{02}^2 + d_{03}^2 \]

  - Max pt among the 3 tracks:
    \[ p_M = \text{Max}\{p_{T1}, p_{T2}, p_{T3}\} \]
Expected Result

Significance \((D^+ \rightarrow K\pi\pi)\)

✓ Significance \(S/\sqrt{S+B}\) normalized to \(10^7\) events for Pb-Pb and \(10^9\) events for pp
**D_s \rightarrow KK\pi: Selection Strategy**

- Five variables have been chosen to perform a final selection of the useful signal:
  
  - **Cosine of pointing angle** ($\cos\theta_p$). If the found vertex really corresponds to $D_s$ decay vertex, then $\theta_p \sim 0$ and $\cos\theta_p \sim 1$.
  
  - $\cos\phi_{\text{opening}}$, where $\phi_{\text{opening}}$ is the angle between two opposite sign tracks.
  
  - Sum of the squares of the three tracks impact parameters with respect to the primary vertex.
  
  - Distance between the primary and secondary vertices
  
  - Dispersion of secondary vertex (additional tuning)

**NB:** Before these, cuts on invariant mass of KK pair to select resonant decays through $\Phi$ or $K\pi$ (opposite sign) to select resonant decays through $K^0\pi$ is applied.
Significance ($D_s \rightarrow K\pi\pi$)

Significance $S/\sqrt{S+B}$ normalized to $10^7$ events for Pb-Pb and $10^9$ events for pp.
Software tools for the analysis on the Grid

- Three kinds of data analysis
  - **Fast pilot analysis** of the data “just collected” to tune the first reconstruction at CERN Analysis Facility (CAF)
  - **Scheduled batch analysis** on the Grid (ESDs and AODs)
  - **End-user interactive or batch analysis using GRID** (AODs and ESDs)
Final interactive analysis (Local desktop via TGrid & Alien Catalogue)

Legend:
SE: storage element
CE: computing element
WN: Worker Node

Jobs ESD ➔ AOD

Output: AOD

Legend:
SE: storage element
CE: computing element
WN: Worker Node
AODs produced on the Grid

✓ 48M min-bias pp events (LHC09a4)

/alice/cern.ch/user/m/mgheata/analysisESD/output_train_default_28May2009_09h33/

✓ 7M pp charm, forced to hadronic decays, events(LHC09a5)

/alice/cern.ch/user/m/mgheata/analysisESD/output_train_LHC09a5_11Jun2009_10h07/

✓ 1.4M, pp beauty, B→J/Ψ→ee decay(LHC09a6)

/alice/cern.ch/user/m/mgheata/analysisESD/output_train_default_26May2009_16h30/
Analysis of candidates from AODs

- RunAnalysisAODVertexingHF.C (Prepared by A. Dainese): a steering macro to analyze the AODs (Standard + vertexingHF)

- This macro creates the analysis manager + event handlers, defines the input data and analysis mode.

- Each task provided by a macro AddTaskXXX.C.

- We have 12 tasks (wagons) included in RunAnalysisAODVertexingHF.C (Train)

  Eg. CompareHF (vertex resolution), D0InvMass, Dplus, Like Sign BKG ...
AddTaskDplus (To extract D\(^+\) from the background)

- The macro AddTaskDplus.C implements a method
  AliAnalysisTaskSEDplus *AddTaskDplus() which creates, configure and connect the task to an existing analysis manager

- AliAnalysisManager *mgr =
  AliAnalysisManager::GetAnalysisManager();
- AliAnalysisTaskSEDplus *dplusTask = new
  AliAnalysisTaskSEDplus("DplusAnalysis");
- mgr->AddTask(dplusTask);

- Produce some histogram as well as ntuple for signal and background (D\(^+\)) in the root files “InvMassDplus.root
  InvMassDplus_nt1.root, InvMassDplus_nt2.root”
P-P charm(\sim 4M) events (lhc09a5) \rightarrow loose cuts
(default ConfigVertexingHF.C)

\begin{itemize}
\item \textbf{Sig +bkg}:
\begin{itemize}
\item \textbf{D'} invariant mass:
\begin{itemize}
\item \textbf{Sig +bkg}:
\begin{itemize}
\item \textbf{Entries} 832076
\item \textbf{RMS} 0.6573
\end{itemize}
\end{itemize}
\end{itemize}
\begin{itemize}
\item \textbf{Signal}:
\begin{itemize}
\item \textbf{Entries} 4523
\item \textbf{Mean} 1.872
\item \textbf{RMS} 0.01544
\end{itemize}
\end{itemize}
\begin{itemize}
\item \textbf{BKG}:
\begin{itemize}
\item \textbf{Entries} 848857
\item \textbf{Mean} 1.585
\item \textbf{RMS} 0.05757
\end{itemize}
\end{itemize}
\begin{itemize}
\item \textbf{Pt D+}:
\begin{itemize}
\item \textbf{Entries} 4533
\item \textbf{Mean} 3.991
\item \textbf{RMS} 2.582
\end{itemize}
\end{itemize}
\end{itemize}
P-P charm (~4M) events (lhco9a5) \(\rightarrow\) with tighter cuts 
i.e. Pointing Angle > 0.97 and decay length > 0.1 cm
PP min bias (lhc09a4) ~17M events $\rightarrow$ loose cuts

D$^+$ invariant mass

Signal

BKG

Pt D$^+$

Background invariant mass - MC

Sig+BKG

fHistMass

Entries 7598854
Mean 1.866
RMS 0.05752

fHistSignal

Entries 325
Mean 1.871
RMS 0.01748

fHistBackground

Entries 7598529
Mean 1.866
RMS 0.05752

fPID

Entries 325
Mean 4.248
RMS 2.771
PP min bias (lhc09a4) events → with tighter cuts

Sig+BKG

Signal

BKG

M (GeV)

Pt (GeV/c)
Significance (lhc09a4) with tighter cuts

Decay Length
Like Sign Triplet

- For background subtraction, we are exploring the feasibility to use LS triplet

- Compare positive (+++) LS background with negative (---) background. They should provide the same result

- Compare LS background with OS (+--) background.
The shape of the distribution around the D+ mass is same.

OS is bit smaller (less statistics?)
Summary

- A huge statistics required to extract the signal from large background.

- Grid facilities provides the computing resources and disc space required.

- Analysis Train to analyze the data on the Grid has been developed and validated.

- Analysis is feasible with good significance of exclusive D-mesons reconstruction at wide pt range (1<pt<20 GeV/c) within 1 year of data taking at nominal luminosity.
Thanks