First ATLAS results on charm production

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**Introduction**

**Aim:**
- measurement of charm (and beauty) production
- either full or partial D meson reconstruction
- b/c separation

**Charm (and beauty) production at LHC, pp → QQX**
- **Flavour Creation (FC):**
  - $g + g \rightarrow Q + Q$
  - $q + q \rightarrow Q + Q$
- **Flavour Excitation (FE):**
  - $Q + g \rightarrow Q + g$
  - $Q + q \rightarrow Q + q$
- **Gluon Splitting (GS):**
  - $g \rightarrow Q + Q$

Production in pp collisions @ $\sqrt{s} = 7$TeV:
- $\sigma(cc) \sim 4.4mb$
- $\sigma(bb) \sim 0.24mb$

Reconstruction already feasible in ATLAS with the first LHC data due:
- large cross-section values
- clean D meson signatures
- very good ATLAS tracking
The ATLAS detector

Length: ~46 m
Radius: ~12 m
Weight: ~7 Ktons

**Inner Detector**
(|η|<2.5, B=2T):
Si Pixels, Si strips,
Transition Radiation Tracker (straws).
Precise tracking and vertexing, e/π separation.

\[ \frac{\sigma}{p_t} \sim 3.8 \times 10^{-4} \ p_t \ (\text{GeV}) \pm 0.015 \]

**Muon Spectrometer**
(|η|<2.7) : air-core toroids (average 0.5T) with gas-based muon chambers.
Muon trigger and measurement with momentum resolution < 10% up to \( E(\mu) \sim 1 \text{ TeV} \)

**EM calorimeter**: Pb-LAr
Accordion. e/γ trigger, identification and measurement.
E-resolution: \( \sigma/E \sim 10\%/\sqrt{E} \)

**HAD calorimetry** (|η|<5): Fe/scintillator Tiles (central), Cu/W-LAr (fwd). Trigger and measurement of jets and missing ET.
E-resolution: \( \sigma/E \sim 50\%/\sqrt{E} \pm 0.03 \)
**Overall statistics for 7TeV collisions**

**Period:** 30 March – 8 June

Instantaneous luminosity $L$ derived from:
- MBTS (trigger scintillators at ±3.5m from IP) double-side coincidence trigger rate
- LAr offline event selection (coincidence of in-time end-cap energy deposits)
- Measurement from dedicated LUCID forward detectors, at ±17m from IP

Present overall $L$ scale uncertainty ~20% from systematic uncertainties (MC cross-section)

Total luminosity about 16 nb$^{-1}$; 89 % of the luminosity delivered by LHC

For our analysis: 1.4 nb$^{-1}$
Introduction to the analysis

Ingredients of this analysis:

- **Trigger**
  - Using the ATLAS Minimum Bias Trigger Scintillators (MBTS): > 99.5% for any track multiplicity
  - With higher luminosity, lepton trigger will be used

- **Tracking:**
  - Inner Detector ($|\eta| < 2.5$, $B=2T$)
  - Precise tracking and vertexing
  - Pixel Detector
  - Semiconductor Tracker (SCT)
  - Transition Radiation Tracker (TRT)
Pixel Detector:
3 barrel layers, 2 x 3 end-cap discs
\( \sigma_{r\phi} \sim 10 \, \mu\text{m}, \sigma_z \sim 115 \, \mu\text{m} \)

Silicon Strip Detector (SCT)
4 barrel layers, 2 x 9 end-cap discs
\( \sigma_{r\phi} \sim 17 \, \mu\text{m}, \sigma_z \sim 580 \, \mu\text{m} \)

Transition Radiation Tracker (TRT)
73 barrel straw layers, 2x160 end-cap radial straw discs
\( \sigma_{r\phi} \sim 130 \, \mu\text{m} \)

<table>
<thead>
<tr>
<th>Subdetector</th>
<th>Number of Channels</th>
<th>Approximate Operational Fraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pixels</td>
<td>80 M</td>
<td>97.5%</td>
</tr>
<tr>
<td>SCT Silicon Strips</td>
<td>6.3 M</td>
<td>99.3%</td>
</tr>
<tr>
<td>TRT Transition Radiation Tracker</td>
<td>350 k</td>
<td>98.0%</td>
</tr>
</tbody>
</table>

All components operational > 97.5%!
Dedicated care that Monte Carlo samples reflect conditions during data taking (beam spot position, inactive modules, noisy channels)

In general, there is an excellent agreement between data and MC
ATLAS vertex reconstruction

Longitudinal Plane distribution for events with at least 10 tracks

Transverse Plane distribution for events with at least 10 tracks

Excellent primary vertex reconstruction
Analysis strategy

- D-meson selection:
  - hard nature of charm production \( p_t(D), p_t(K, \pi) \)
  - hard nature of charm fragmentation \( p_t(D)/E_t \)
  - relatively large D-mesons’ life-time (decay length \( L_{xy} \))
  - “spin” angular behaviour of D-mesons’ decays (\( \cos \theta^*, \cos \theta' \))[1]

- Goals:
  - use widest kinematic range where signals can be measured \([p_t(D) > 3.5 \text{ GeV}, |\eta(D)| < 2.1]\)
  - make signals as clean (significant) as possible in the kinematic range

[1] In the example of \( D_s^+ \rightarrow \phi \pi^+ \rightarrow (K^- K^+) \pi^+ \):

\( \theta^*(\pi) \): angle between the \( \pi \) in the KK\( \pi \) rest frame and the KK\( \pi \) line of flight in the laboratory frame

\( \theta'(K) \): angle between the \( K \) and the \( \pi \) in the KK rest frame
Tracks used satisfying the selection criteria

Vertexing has been used to combine the 2 oppositely charged tracks to a single vertex (secondary vertex) and combination of 3rd track

Apply D-meson selection criteria (in previous slide)

For D* the $\Delta m = M(K\pi\pi) - M(K\pi)$ variable is mostly discriminant
**D* reconstruction in 7TeV data**

\[ D^{*+} \rightarrow D^0 \pi_s^+ \rightarrow (K^- \pi^+) \pi_s^+ \]

Positive decay length

\[ p_t(D^*)/E_t > 0.02 \]

\[ |M(K\pi) - M^{PDG}(D^0)| < 35\text{MeV} \]

\[ 144\text{MeV} < \Delta m < 147\text{MeV} \]

- \[ p_t(\pi_s) > 0.25 \text{GeV} \]
- \[ p_t(K,\pi) > 1.0 \text{GeV} \]
- \[ |\eta(K,\pi,\pi_s)| < 2.5 \]
- \[ N^{pix} \geq 1 \]
- \[ N^{SCT} \geq 4 \]
- \[ d_0^{PV}(\pi_s) < 0.8\text{mm} \]
- \[ z_0^{PV}(\pi_s)\sin\theta < 1.5\text{mm} \]
- \[ d_0^{PV}(D^0) < 0.2\text{mm} \]
- \[ z_0^{PV}(D^0)\sin\theta < 0.5\text{mm} \]
- \[ \chi^2(D^0) < 5 \]

\[ \sim 2000 \ D^{*\pm} \ \text{in the signal} \]
D+ reconstruction in 7TeV data

\[ \text{D}^+ \rightarrow K^- \pi^+ \pi^+ \]

- \( p_t(\pi_{1,2}) > 0.8 \text{ GeV} \)
- \( p_t(K) > 1.0 \text{ GeV} \)
- \( \max(p_t(\pi_{1,2})) > 1.0 \text{ GeV} \)
- \( |\eta(K, \pi_{1,2})| < 2.5, N_{\text{pix}} \geq 1, N_{\text{SCT}} \geq 4 \)
- \( d_{0}^{\text{PV}}(D) < 0.15 \text{ mm}, z_{0}^{\text{PV}}(D) \sin \theta < 0.3 \text{ mm} \)
- \( \chi^2(D) < 6 \)
- \( L_{xy} > 1.3 \text{ mm} \)
- \( p_t(D)/E_t > 0.02 \)
- \( \cos \theta^*(K) > -0.8 \)

 Suppressing D* and Ds:
- \( \text{D}^* \rightarrow \text{D}^0 \pi \rightarrow (K \pi) \pi \) vetoing \( \Delta m < 150 \text{ MeV} \)
- \( \text{D}_{s}^{+} \rightarrow \phi \pi \rightarrow (K K) \pi \) vetoing \( |M(K "K") - M_{\text{PDG}}(\phi)| < 8 \text{ MeV} \)

\(~1700 \text{ D}^\pm \) in the signal
$D_s^+$ reconstruction in 7TeV data

$D_s^+ \rightarrow \varphi \pi^+ \rightarrow (K^- K^+) \pi^+$

- $L_{xy} > 0.4$ mm
- $p_t(D_s^+)/E_t > 0.04$
- $\cos\theta^*(\pi) < 0.4$
- $|\cos\theta'(K)|^3 > 0.2$

$M(KK) - M^{PDG}(\varphi) < 6$ MeV

1.93 GeV < $M(KK\pi) < 2.01$ GeV

- $\Delta E_{T}(K_{1,2}) > 0.7$ GeV
- $p_t(\pi) > 0.8$ GeV
- $|\eta(\pi, K_{1,2})| < 2.5$,
- $N^{pix} \geq 1$, $N^{SCT} \geq 4$
- $d_0^{PV}(D_s) < 0.15$ mm,
- $z_0^{PV}(D_s) \sin\theta < 0.3$ mm
- $\chi^2(D_s) < 6$

- $\sim 330$ $D_s^{\pm}$ in the signal

ATLAS Preliminary

$\sqrt{s} = 7$ TeV $L_{int} = 1.4$ nb$^{-1}$

- Data 2010

PDG: 1968.49 MeV

PDG: 1019.455 MeV

$\sigma(M(D_s^0)) = 24.0 \pm 3.8$ MeV

$M(D_s^0) = 1971.5 \pm 4.6$ MeV

$\sim 330$ $D_s^{\pm}$ in the signal
Conclusions

Clear D*±, D± and Ds± signals reconstructed with the ATLAS detector in pp collisions @ 7TeV using $\int L$ of 1.4nb⁻¹:
- D*±: 2020 ± 120
- D±: 1667 ± 86
- Ds±: 326 ± 57

Confirm high performance of ATLAS detector for precision tracking measurements

Validate vertexing algorithms in ATLAS

Next step: measure cross-sections