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, $pp \rightarrow QQX$

• 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
@ $\sqrt{s} = 7\text{TeV}$:

🏆 $\sigma(cc) \sim 4.4\text{mb}$

🏆 $\sigma(bb) \sim 0.24\text{mb}$

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

3-level trigger
reducing the rate
from 40 MHz to
 ~ 200 Hz

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

Inner Detector
($|\eta| < 2.5$, $B = 2$ T):
Si Pixels, Si strips,
Transition Radiation
Tracker (straws).
Precise tracking and
vertexing, e/μ
separation.
 p_t resolution:
 $\sigma/p_t \sim 3.8 \times 10^{-4} p_t$
(GeV) ± 0.015

Muon Detectors

Tile Calorimeter

Liquid Argon Calorimeter

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

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

Toroid Magnets

Solenoid Magnet

SCT Tracker

Pixel Detector

TRT Tracker

HAD calorimetry ($|\eta| < 5$): 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 ± 3.5 m 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 ± 17 m from IP
Present overall L scale uncertainty $\sim 20\%$ 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)

ATLAS Inner Detector

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
 $\sigma_{r\phi} \sim 130 \mu\text{m}$

Subdetector	Number of Channels	Approximate Operational Fraction
Pixels	80 M	97.5%
SCT Silicon Strips	6.3 M	99.3%
TRT Transition Radiation Tracker	350 k	98.0%

All components operational > 97.5%!

Tracking: data/MC agreement

Detailed studies comparing data/MC

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 π 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 π in the KK rest frame

D* reconstruction

- 🏆 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
 $p_t(D^*)/E_t > 0.02$

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

$$p_t(\pi_s) > 0.25 \text{ GeV}, p_t(K, \pi) > 1.0 \text{ GeV}$$

$$|\eta(K, \pi, \pi_s)| < 2.5, N^{\text{pix}} \geq 1, N^{\text{SCT}} \geq 4$$

$$d_0^{\text{PV}}(\pi_s) < 0.8\text{mm}, z_0^{\text{PV}}(\pi_s)\sin\theta < 1.5\text{mm}$$

$$d_0^{\text{PV}}(D^0) < 0.2\text{mm}, z_0^{\text{PV}}(D^0)\sin\theta < 0.5\text{mm}$$

$$\chi^2(D^0) < 5$$

$$144\text{MeV} < \Delta m < 147\text{MeV}$$

• $\sim 2000 D^{*\pm}$ in the signal

D⁺ reconstruction in 7TeV data

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

$p_t(\pi_{1,2}) > 0.8 \text{ GeV}, p_t(K) > 1.0 \text{ GeV}$
 $\max(p_t(\pi_{1,2})) > 1.0 \text{ GeV}$
 $|\eta(K, \pi_{1,2})| < 2.5, N^{\text{pix}} \geq 1, N^{\text{SCT}} \geq 4$
 $d_0^{\text{PV}}(D) < 0.15 \text{ mm}, z_0^{\text{PV}}(D) \sin\theta < 0.3 \text{ mm}$
 $\chi^2(D) < 6$

$L_{xy} > 1.3 \text{ mm}$
 $p_t(D)/E_t > 0.02$
 $\cos\theta^*(K) > -0.8$

Suppressing D* and Ds:

D* → D⁰ π → (K π) π vetoing $\Delta m < 150 \text{ MeV}$

D_s⁺ → φ π → (K K) π vetoing $|M(K \text{ "K"}) - M^{\text{PDG}}(\phi)| < 8 \text{ MeV}$

- ~1700 D[±] in the signal

D_s^+ reconstruction in 7TeV data

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

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

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

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

$$1.93 \text{ GeV} < M(KK\pi) < 2.01 \text{ GeV}$$

• $\sim 330 D_s^\pm$ in the signal

Conclusions

Clear $D^{*\pm}$, $D^\pm$ and $D_s^\pm$ signals reconstructed with the ATLAS detector in pp collisions @ 7TeV using $\int \mathcal{L}$ of 1.4nb^{-1} :

- $D^{*\pm}$: 2020 ± 120
- $D^\pm$: 1667 ± 86
- $D_s^\pm$: 326 ± 57

Confirm high performance of ATLAS detector for precision tracking measurements

Validate vertexing algorithms in ATLAS

Next step: measure cross-sections