PANIC11

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Massachusetts Institute of Technology
Cambridge, MA, USA

"B and D Hadron Production and Prospects"

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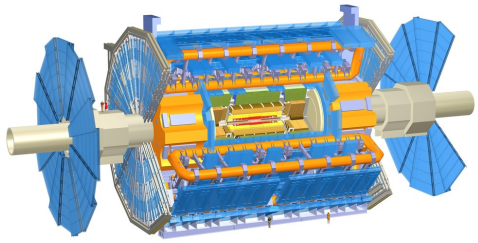
On behalf of ATLAS Collaboration

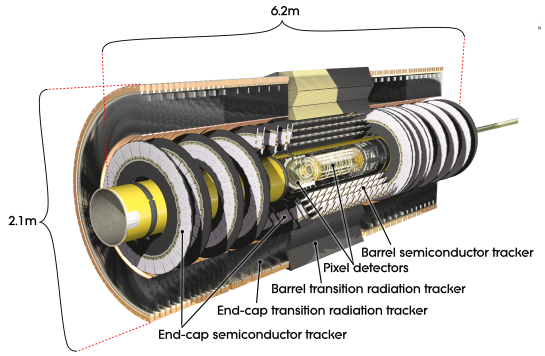
The ATLAS detector

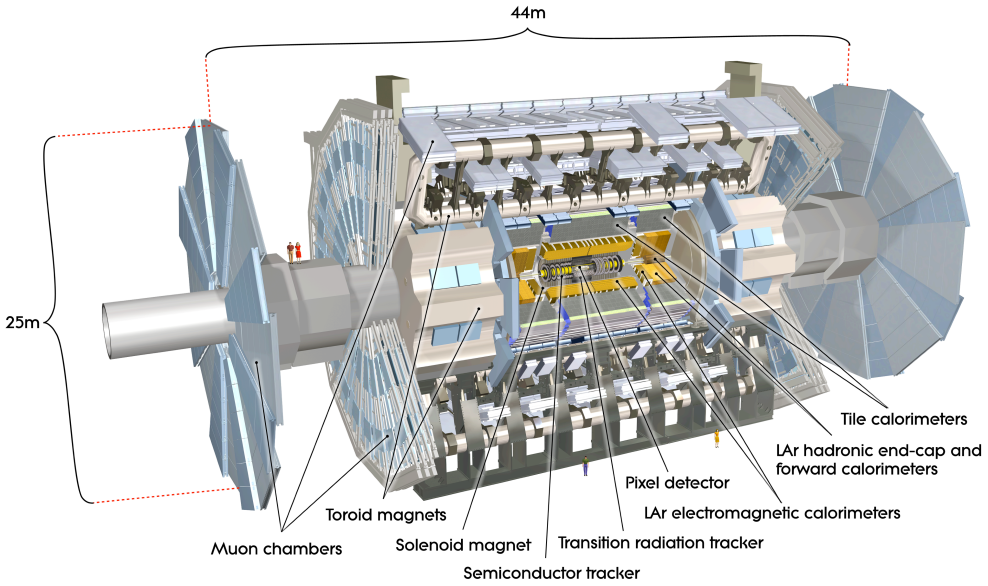
B-physics measurements with ATLAS

Large b production cross-section [few100 μ b]

Excellent muon detection and tracking performance







Inner Detector

- $|\eta|<2.5$,
- Solenoid B=2T
- Si Pixels,
- Si strips,
- Transition Radiation Tracker (TRT)
- $\sigma/p_T \sim 3.4\times10^{-4}\, p_T + 0.015$ for ($|\eta|<1.5$)
- Used for Tracking and Vertexing

Precise momentum and lifetime measurements

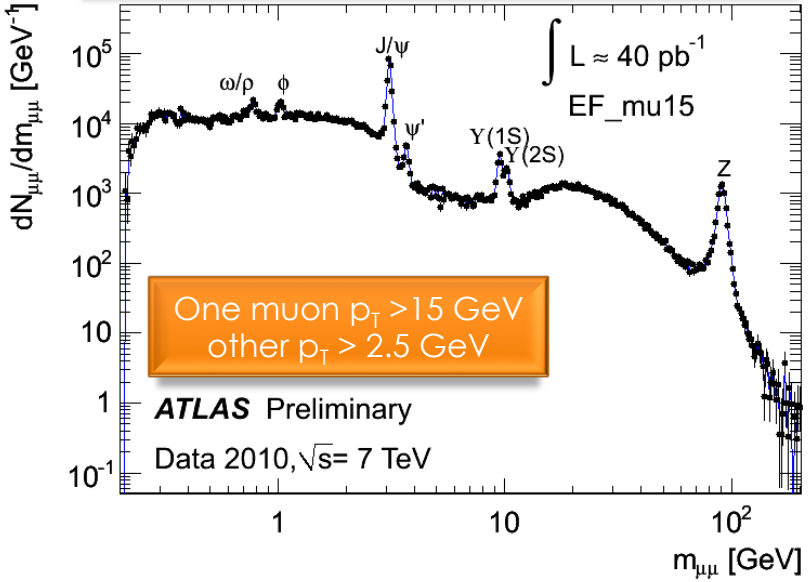
Muon Spectrometer

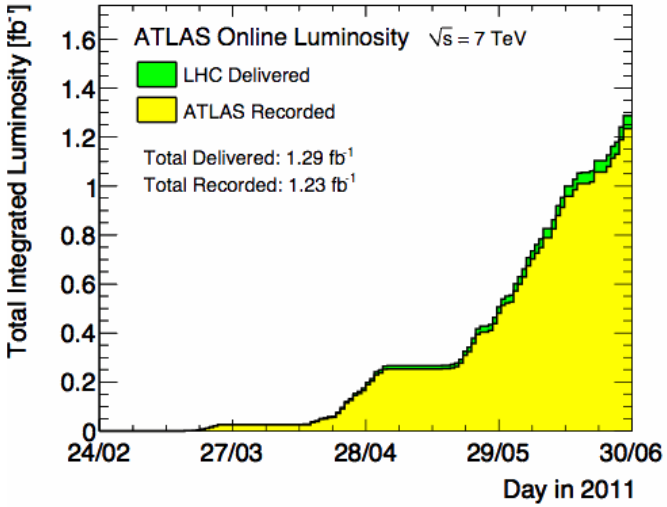
- $|\eta|<2.7$
- Toroid B-Field, average ~0.5 T
- Muon Momentum resolution
  $\sigma/p < 10\%$ up to ~ 1 TeV

Muon Trigger and Performance

- ✓ Muon identification is key to many B-physics analyses: clean trigger signature.
- ✓ Ever increasing instantaneous luminosity requires prescales & use of number of triggers to maximise statistics. Early period of data-taking essential to study, as access to low-p_T region:
  - ✓ **D mesons: minimum bias**
    - ✧ **Fully efficient, prescaled beyond first data**
  - ✓ **B mesons: single muon and dimuon**
    - ✧ **Thresholds 0-10 GeV**

Di-muon invariant mass distribution passing a p_T >15 GeV muon trigger.



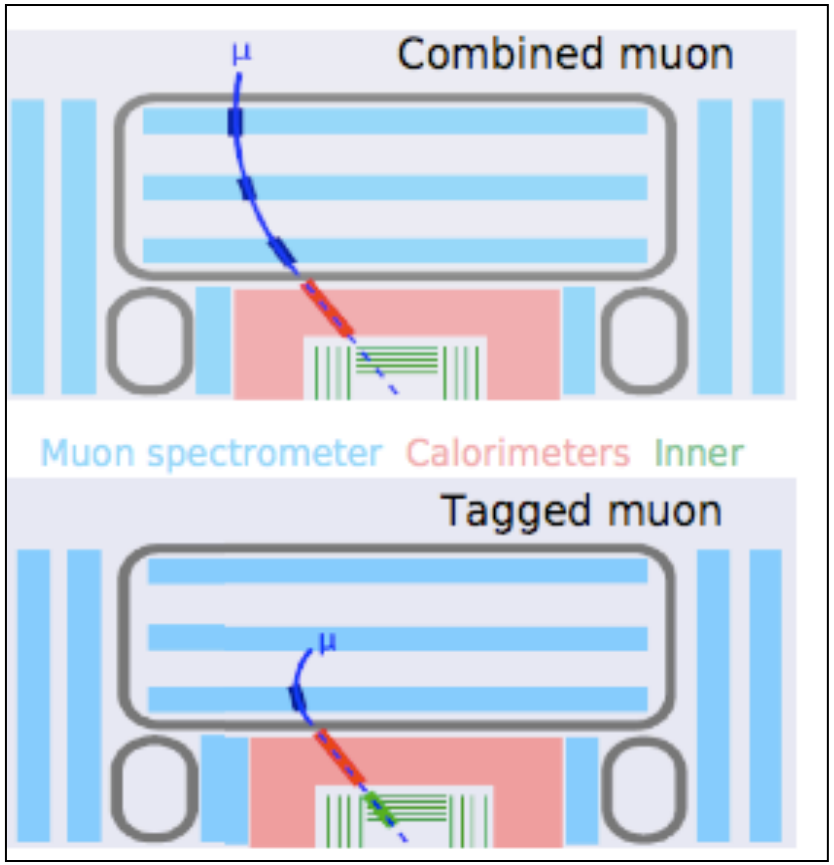


- ✧ 1.23 fb^{-1} integrated in 2011
- ✧ 1.26E33 cm^{-2} s^{-1} peak luminosity
- ✧ Overall data taking efficiency >95%
- ✧ All subsystems >90%
- ✧ Expect >10 fb^{-1} by 2012
- ✧ Results discussed based on 2010 (~40 pb^{-1}) data

Exclusive B meson reconstruction

- ✓ Aim to study flavour tagging, mixing, CP violation, branching ratios
- ✓ Initial studies test detector and trigger performance
- ✓ Use $B \rightarrow J/\psi(\mu^+\mu^-) + X$ decays

Muon reconstruction



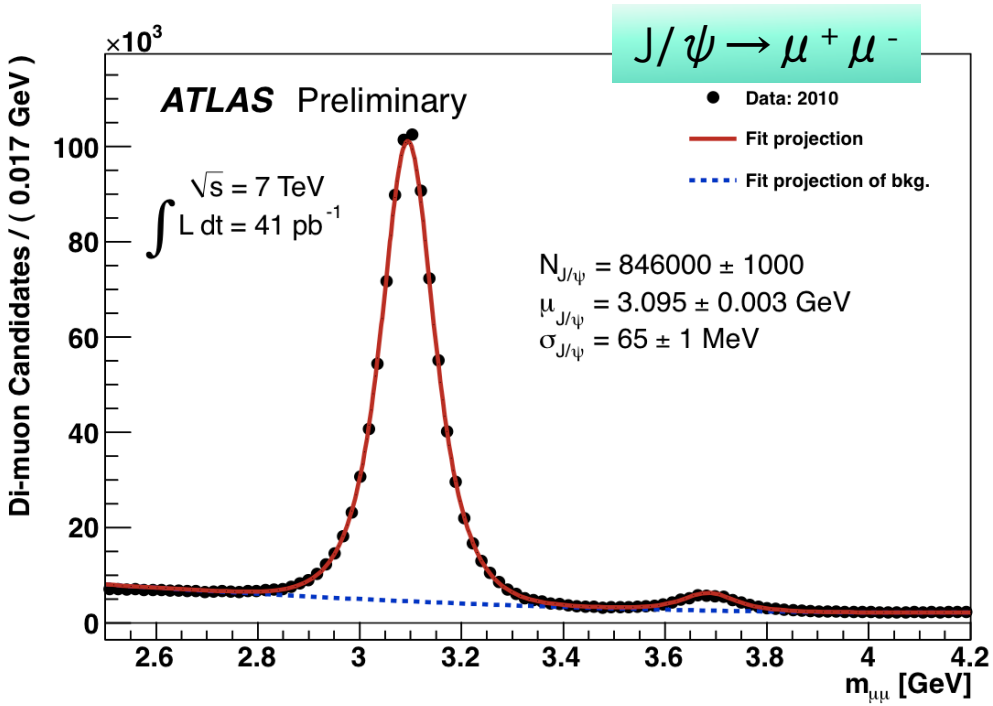
Combined Muons: Muons with an Inner Detector track matched to a Muon Spectrometer track and refitted through the detector to give the best measurement.

Tagged Muons: Muons with an Inner Detector track matched to a segment when extrapolated to the Muon Spectrometer. Such muons generally have low momentum.

Charmonium Observations

J/ψ events selection:

- At least 1 primary vertex with 3 tracks associated
- Quality cuts on the Inner Detector tracks to remove the badly measured muons
- Opposite charge muon pairs with successful vertex fit.
- One of the muon candidates needs to be combined
- Momentum Cut:
  $p_T(\mu_1) > 4$ GeV
  $p_T(\mu_2) > 2.5$ GeV
- $|\eta(\mu)| < 2.5$



J/ψ observation with L= 41pb^{-1} measured mass and width in agreement with PDG

$M_{J/\psi}$ = **3.095 ± 0.003 GeV**

$\sigma(m_{J/\psi})$ = **65 ± 1 MeV**

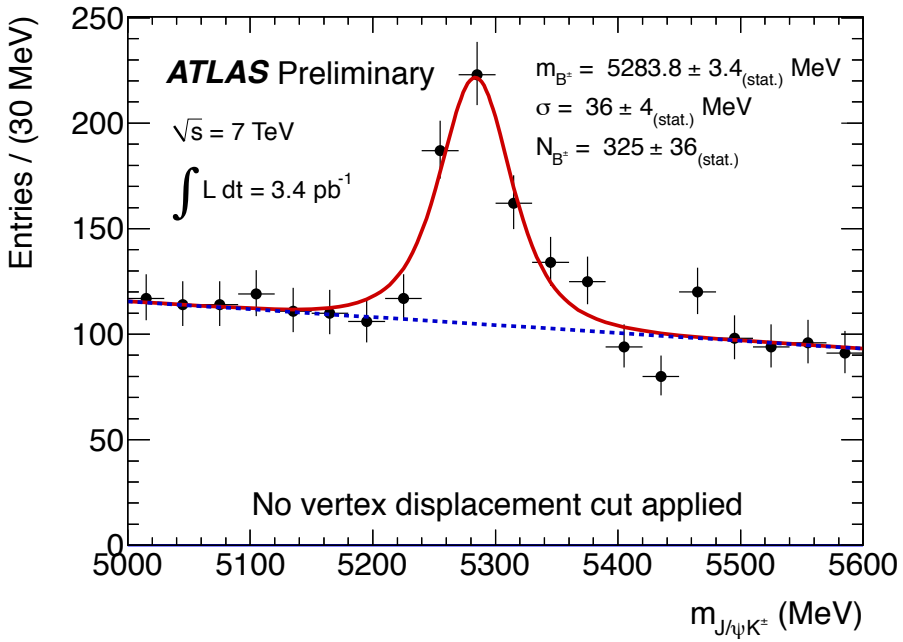
Observation of $B^{\pm}$ mesons: $B^{\pm} \rightarrow J/\psi(\mu\mu)K^{\pm}$

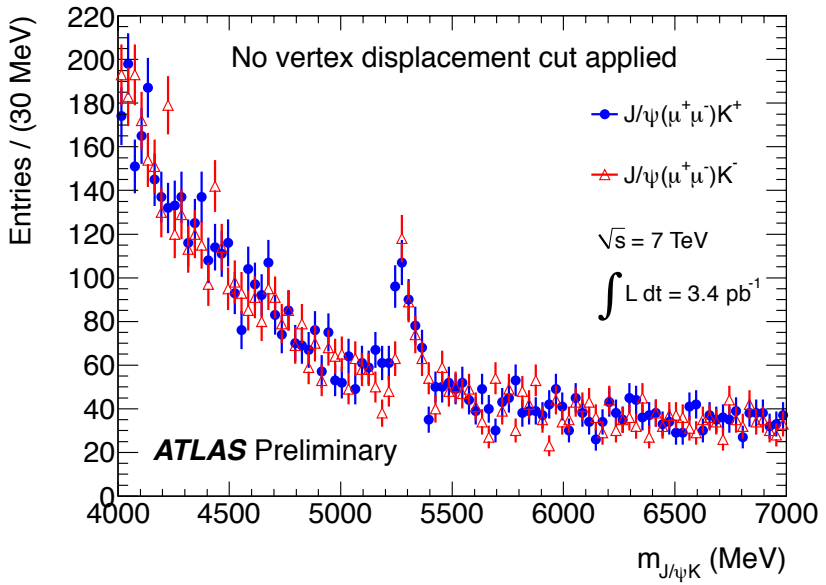
ATLAS-CONF-2010-098

Reference channel for other B decay measurements.
Cross section measurement imminent.

Data taken from June to August 2010, using single- and di-muon triggers:

- ✓ Di-muon in the J/ψ mass range combined with a third track (kaon mass assigned).
- ✓ Fitted 3-track vertex, with J/ψ mass constraint on di-muon
- ✓ Unbinned maximum likelihood fit : Gaussian signal, linear background

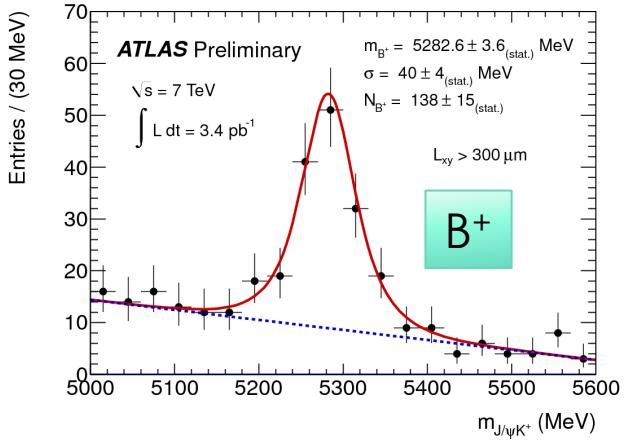


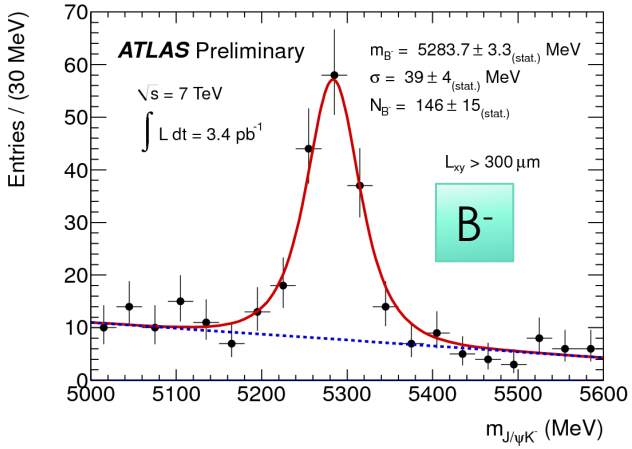


$B^{\pm} \rightarrow J/\psi(\mu\mu)K^{\pm}$

ATLAS-CONF-2010-098

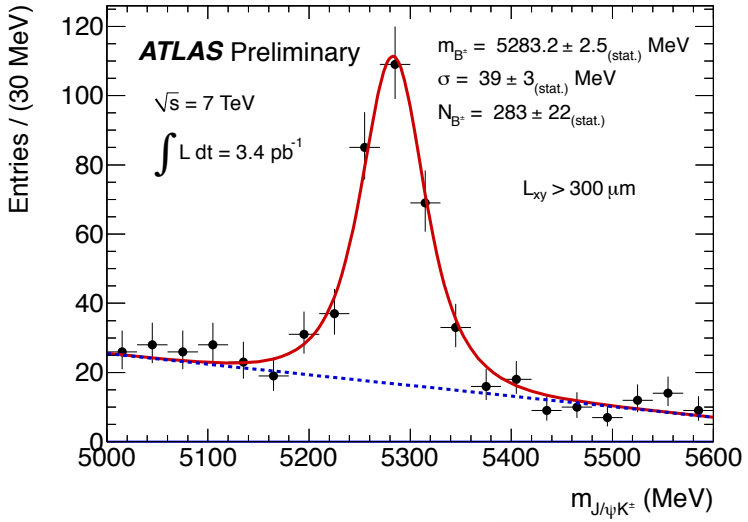
Positive and negative states are observed with consistent fitted parameters

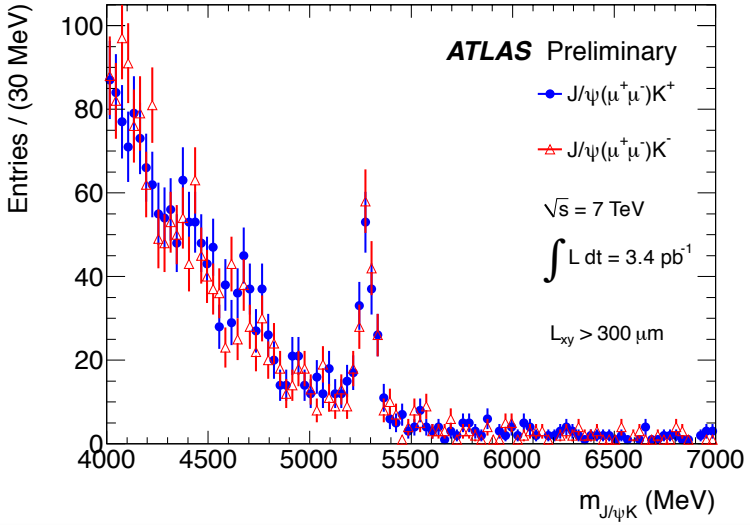




Background suppression by applying a cut on transverse decay length L_{xy} > 0.3 mm

Factor of 6 reduction in background with ~13% loss of signal.





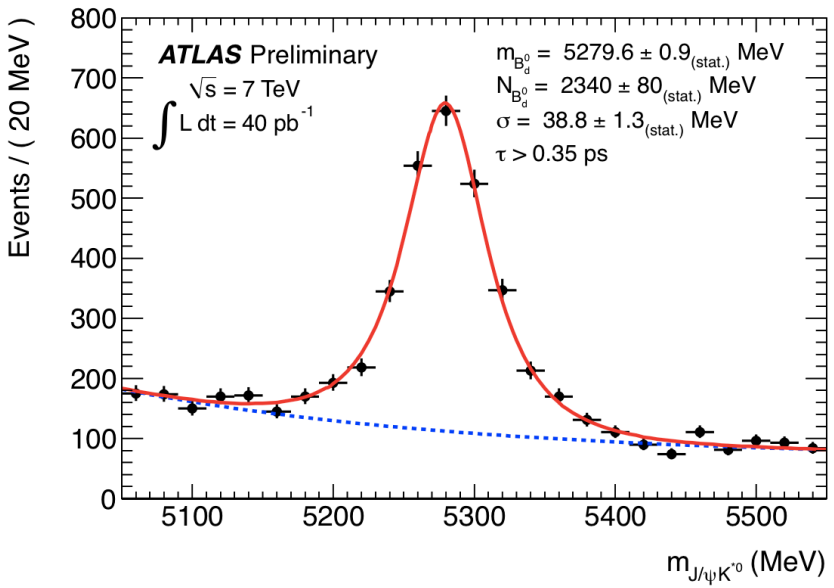
Mass compatible with PDG value:

ATLAS: M(B) = 5283.2 ± 2.5 MeV PDG: M(B) = 5279.17± 0.29MeV

$B^0_d \to J/\psi K^{0*}$ and $B^0_s \to J/\psi \phi$

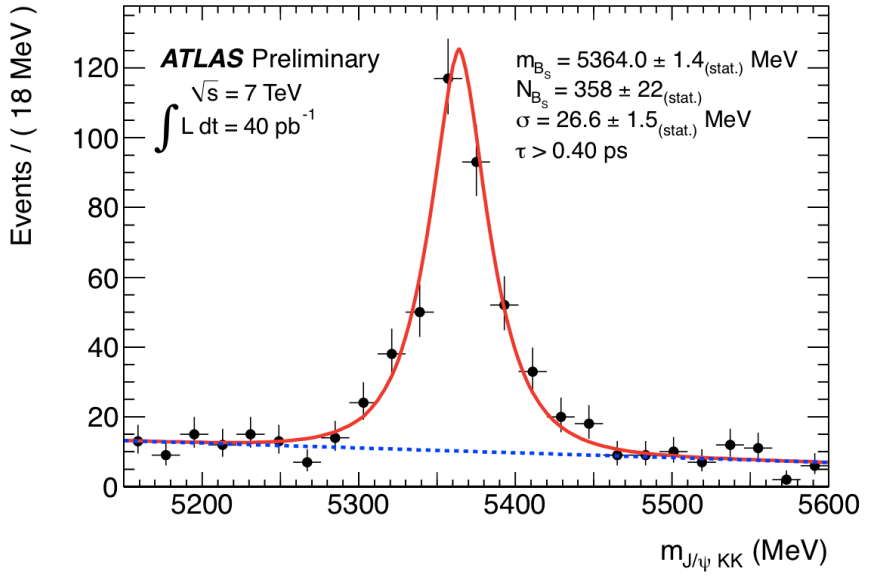
Select 2 additional tracks, assume $K^{*0} \to K^+ \pi^-$ or $\phi \to K^+K^-$
Fit 4-track vertex; constrain $\mu^+\mu^-$ to $M(J/\psi)$
Apply cuts on $M(\phi)$ or M(K*0)
Unbinned maximum likelihood fit: Gaussian signal, linear background

$B^0_d \to J/\psi K^{0*}$ and anti-$B^0_d \to J/\psi K^{0*}$



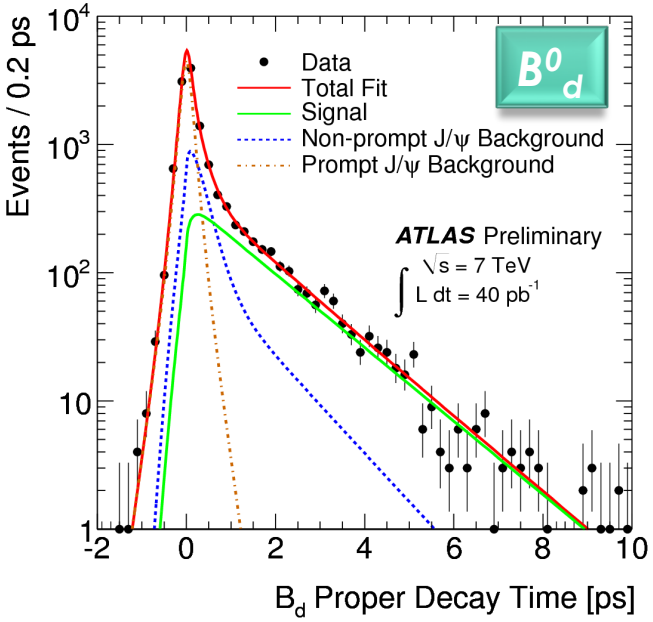
The solid line is the projection of the result of the unbinned maximum likelihood fit to all candidates in the mass range from 5050 MeV to 5550 MeV.

$B^0_s \to J/\psi \phi$



The solid line is the projection of the result of the unbinned maximum likelihood fit to all $J/\psi(\mu^+\mu^-)\phi(KK)$ candidates in the mass range from 5150 MeV to 5600 MeV.

The B^0_d and B^0_s lifetimes in the decay modes $B^0_d \to J/\psi K^{0*}$ and $B^0_s \to J/\psi \phi$



data

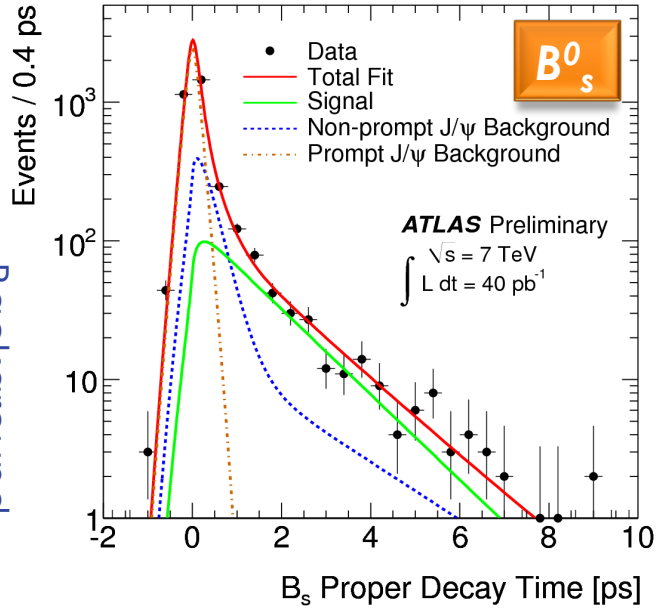
signal

lifetime projection of the simultaneous mass and lifetime fit

the proper decay time functions of the promptly produced J/ψ

the proper decay time functions of the non-prompt J/ψ

Background



B^0_d lifetime: $\tau_{Bd} = 1.51 \pm 0.04\,(stat) \pm 0.04\,(syst)$ ps

B^0_s lifetime: $\tau_{Bs}\,single = 1.41 \pm 0.08\,(stat) \pm 0.05\,(syst)$ ps

The fitted lifetimes of both *B* mesons are consistent with the world average values

D-mesons production

- ✓ *D-mesons are produced in c and b fragmentation*
- ✓ *c and b quark production are hard processes ($m_Q >> \Lambda_{QCD}$)*
- ✓ *Theoretical calculations available up to NLO+NNLO level*
- ✓ *Still large theoretical uncertainties (scales, multiple interactions)*

Reconstruction of *D-mesons already feasible with first ATLAS data* *due to:*

- ✧ *large cross-section values*
- ✧ *clean D-meson signatures*
- ✧ *precise ATLAS tracking and vertexing*

expected cc and bb cross sections in p-p collisions at $\sqrt{s}$ = 7 TeV:
σ (cc) ~ 4.4 mb σ (bb) ~ 0.24 mb
first charm processes reconstructed in ATLAS:

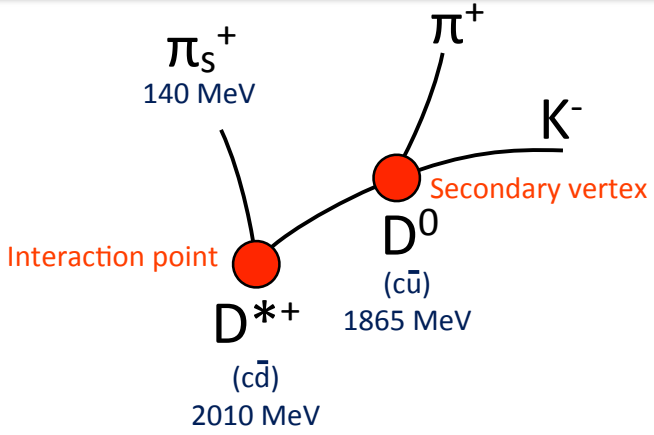
$D^{*+} \rightarrow D^0\pi^+ \rightarrow (K^-\pi^+)\pi^+ \ (+c.c.)$
$D^+ \rightarrow K^-\pi^+\pi^+ \ (+c.c.)$
$D_s^+ \rightarrow \Phi\,\pi^+ \rightarrow (K^-K^+)\pi^+ (+c.c.)$

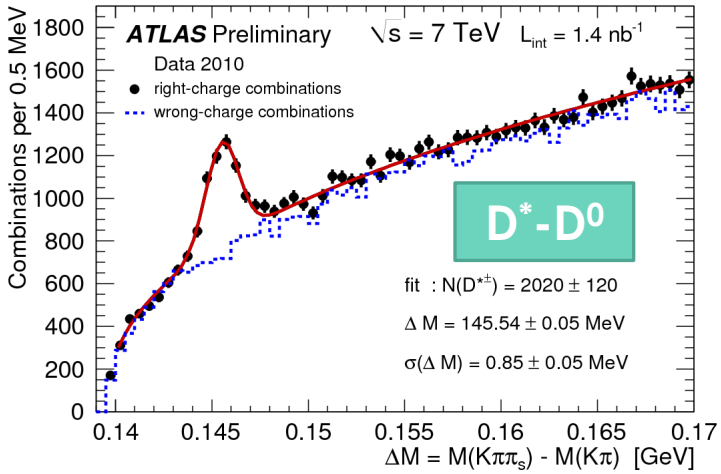
D-mesons production: D*

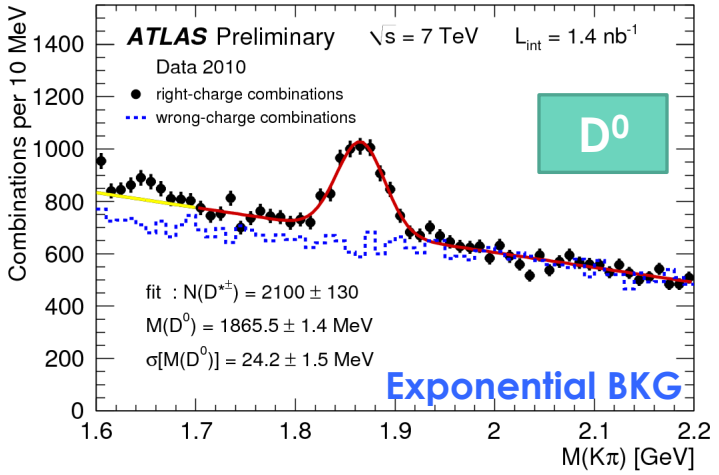
Build D^0 signal from M(Kπ) for $D^{*\pm}$ candidates
Additional discrimination from mass difference
$\Delta M = M(K\pi\pi_s)-M(K\pi)$

Use presence of secondary vertex and properties of hard process to guide cut selection to enhance signal

$$D^{*+} \rightarrow D^0 \pi^+_{soft} \rightarrow (K^- \pi^+) \pi^+_{soft} \ (+c.c.)$$





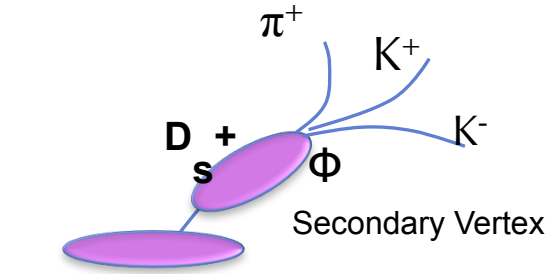


- Hard production and fragmentation cuts on $p_T(D^*)$, $p_T(K,\pi)$, $p_T(D^*)/\Sigma E_T$
- Charge constraints $q(K)=-q(\pi,\pi_s)$
- Vertex reconstruction $D^{*\pm}$, D^0
- Decay length $L_{XY}(D^0)>0$

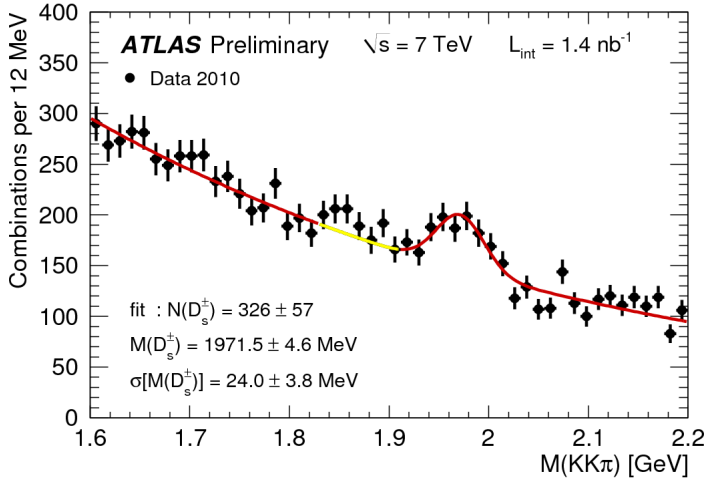
Mesons	PDG Mass (MeV)	ATLAS Mass (MeV)
$D^* - D^0$	145.42 ± 0.01	145.54 ± 0.05
D^0	1864.83 ±0.14	1865.5 ± 1.4

D-mesons production: D_s^+ and D^+

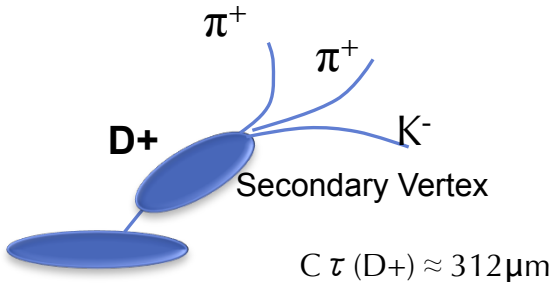
$D_s^+ \rightarrow \Phi\,\pi^+ \rightarrow (K^-K^+)\pi^+(+c.c.)$



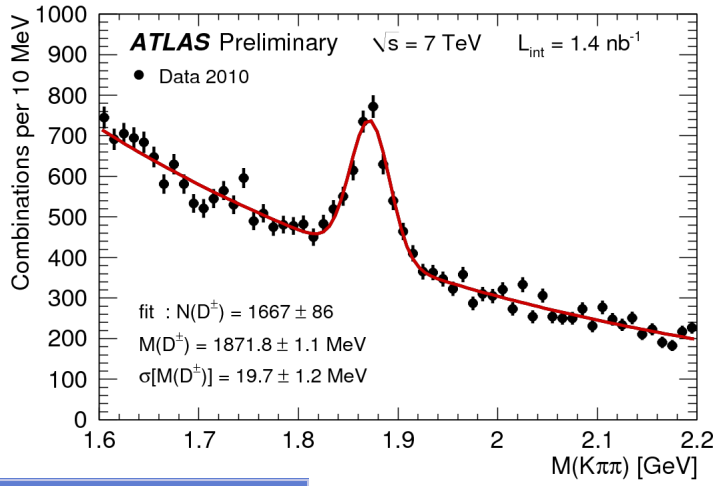
$C\,\tau\,(Ds^+) \approx 150\mu m$



$D^+ \rightarrow K^-\pi^+\pi+ (+c.c.)$

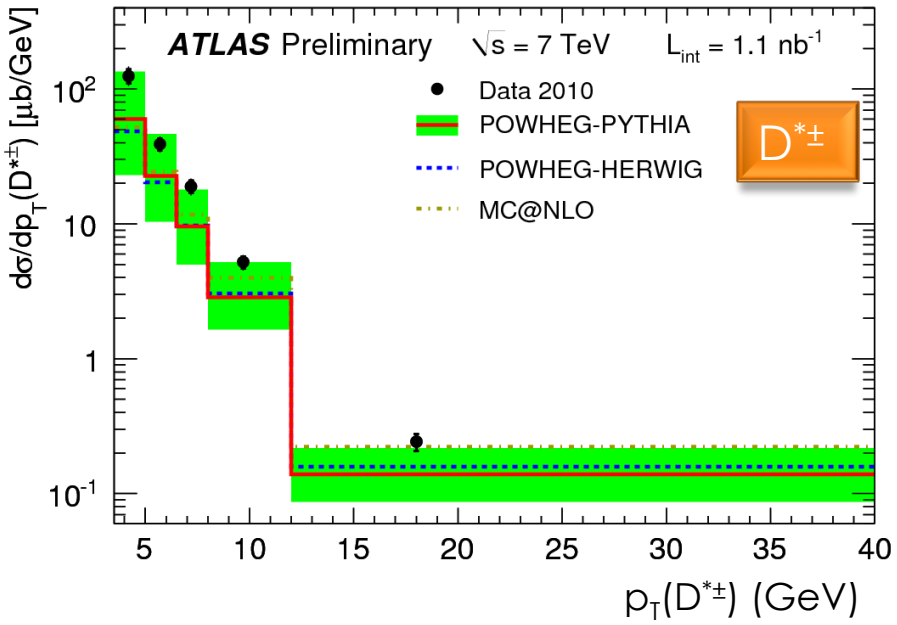


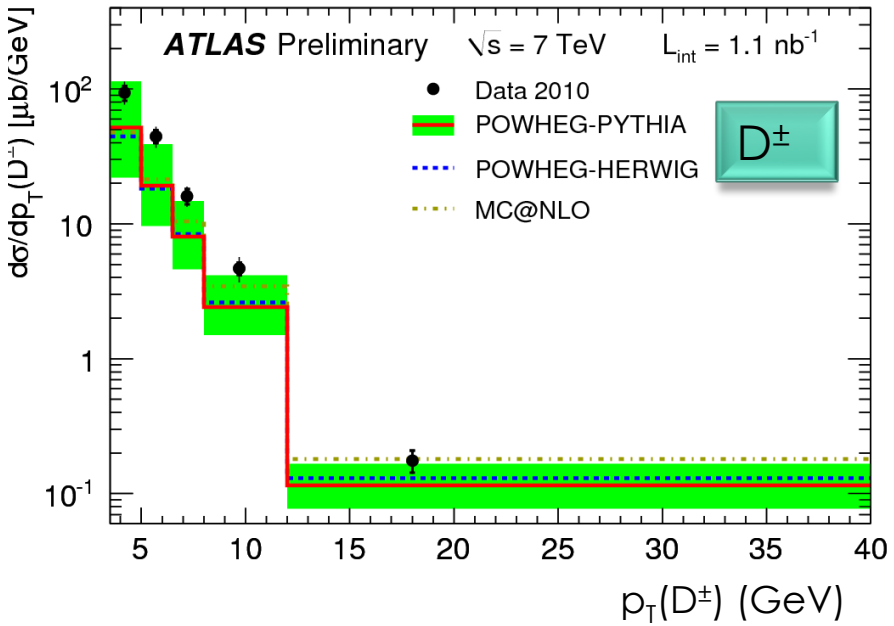
$C\,\tau\,(D+) \approx 312\mu m$



Mesons	PDG Mass (MeV)	ATLAS Mass (MeV)
$D^\pm$	1869.60 ± 0.16	1871.8 ± 1.1
$D_s^\pm$	1968.47 ±0.33	1971.5 ± 4.6

D meson differential cross sections w.r.t. p_T



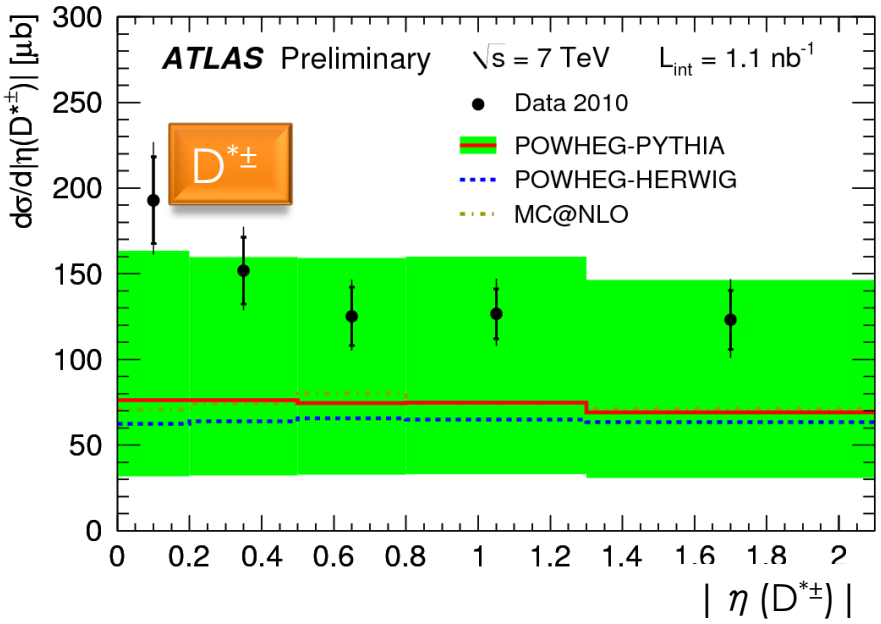


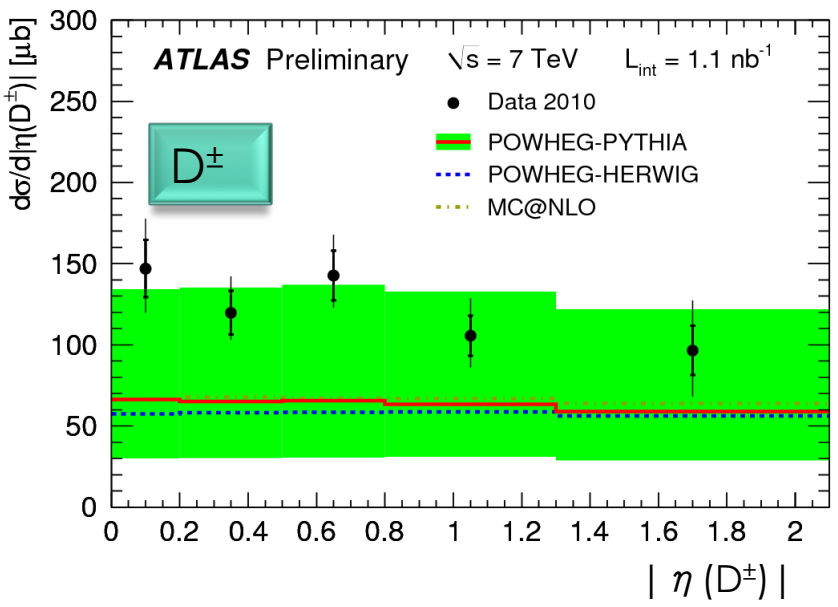
Cross-section uncertainties from:

- Track reconstruction and selection
- D meson selection
- Model dependence of acceptance
- Signal fits
- Luminosity and branching ratios

Data higher than NLO predictions, but within large theoretical (scale) uncertainties

D meson differential cross sections w.r.t. η





Integral cross sections in the kinematic range $p_T(D^{(*)})>3.5$ GeV and $|\eta(D^{(*)})|<2.1$

ATLAS measurement with 1.1 nb^{-1}

$$\sigma^{vis}(D^{*\pm}) = 285 \pm 16(\text{stat.})^{+32}_{-27}(\text{syst.}) \pm 31(\text{lum.}) \pm 4(\text{br.})\,\mu\text{b}$$

$$\sigma^{vis}(D^{\pm}) = 238 \pm 13(\text{stat.})^{+35}_{-23}(\text{syst.}) \pm 26(\text{lum.}) \pm 10(\text{br.})\,\mu\text{b}$$

$$\sigma^{vis}(D_s^{\pm}) = 168 \pm 34(\text{stat.})^{+27}_{-25}(\text{syst.}) \pm 18(\text{lum.}) \pm 10(\text{br.})\,\mu\text{b}$$

POWHEG predictions

$$\sigma(D^{*\pm}) = 153^{+169}_{-80}(\text{scale})^{+13}_{-15}(m_Q)^{+24}_{-21}(\text{PDF})^{+20}_{-16}(\text{hadr.})\,\mu\text{b}$$

$$\sigma(D^{\pm}) = 132^{+137}_{-65}(\text{scale})^{+11}_{-10}(m_Q)^{+20}_{-18}(\text{PDF})^{+21}_{-11}(\text{hadr.})\,\mu\text{b}$$

$$\sigma(D_s^{\pm}) = 59^{+57}_{-28}(\text{scale})^{+4}_{-6}(m_Q)^{+9}_{-8}(\text{PDF})^{+7}_{-8}(\text{hadr.})\,\mu\text{b}$$

Summary and Outlook

Many interesting results from the first year of data in ATLAS:

- D meson states observed and cross section measured.
  ATLAS-CONF-2011-017
- Observation of $B^{\pm} \rightarrow J/\psi(\mu\,\mu)K^{\pm}$
  ATLAS-CONF-2010-098
- Observation of $B_d \rightarrow J/\psi(\mu\,\mu)K^{0*}$ and $B_s \rightarrow J/\psi(\mu\,\mu)\phi$ and measurement of their lifetime.
  ATLAS-CONF-2011-050, ATLAS-CONF-2011-092

Short and longer term plans include

- Exclusive decays $B_C \rightarrow J/\psi(\mu\,\mu)\pi$
- Continue preparations for searches on rare decays such as $B_s \rightarrow \mu\,\mu$ and studies into CP violation.
- Updates of current results using full dataset and many more measurements in progress.