Identified particle production in inelastic pp scattering with ATLAS

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On behalf of the ATLAS Collaboration

Physics at the LHC 2010

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Identified particles and resonances with tracking

- These particles are produced in low-p_T minimum-bias events
  - Observation possible in early data in ATLAS with minimum-bias trigger
  - Related to the underlying-event background in high-p_T collisions

  →Important for tuning MC generators
- Broadly identified through peaking behavior in invariant-mass spectra of combinations of tracks
  - Here we present distributions reconstructed with the ATLAS Inner Detector
  - Not yet corrected for efficiency or other detector effects
- Useful for evaluating and calibrating tracking performance
  - Tracking reconstruction and efficiency, momentum scale
  - Secondary vertexing and tracking for long-lived particles
  - dE/dx

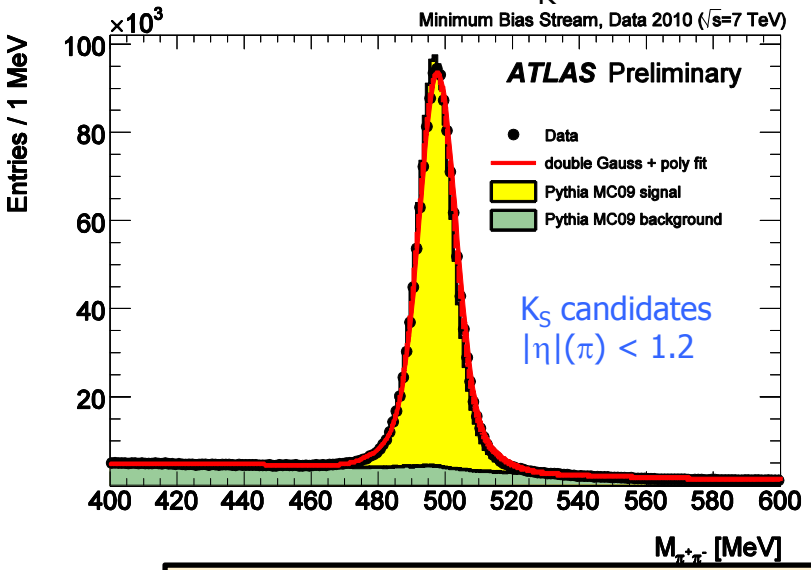
K_S and Λ Reconstruction

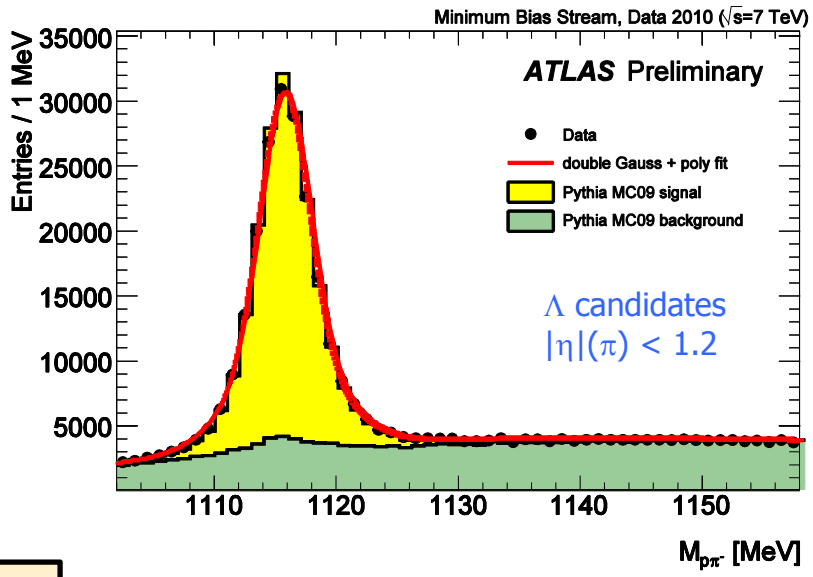
~190 μb^{-1} of 7 TeV minimum-bias collision data
Non-diffractive minimum bias simulation
(Pythia ATLAS MC09 tune)

- $K_S \rightarrow \pi^+\pi^-$ (BF≈69%, $c\tau$=2.7 cm) $\Lambda \rightarrow p^+\pi^-$ (BF≈63%, $c\tau$=7.9 cm)

→ Identified as V^0 decays with a secondary vertex displaced from the primary vertex

- Use pairs of oppositely charged tracks with loose quality criteria and p_T > 100 MeV
  - K_S selection
    - flight length > 4 mm
    - angle between flight and momentum direction: cos θ_K > 0.999
  - $\Lambda/\bar{\Lambda}$ selection
    - flight length > 30 mm
    - cos θ_K > 0.9998

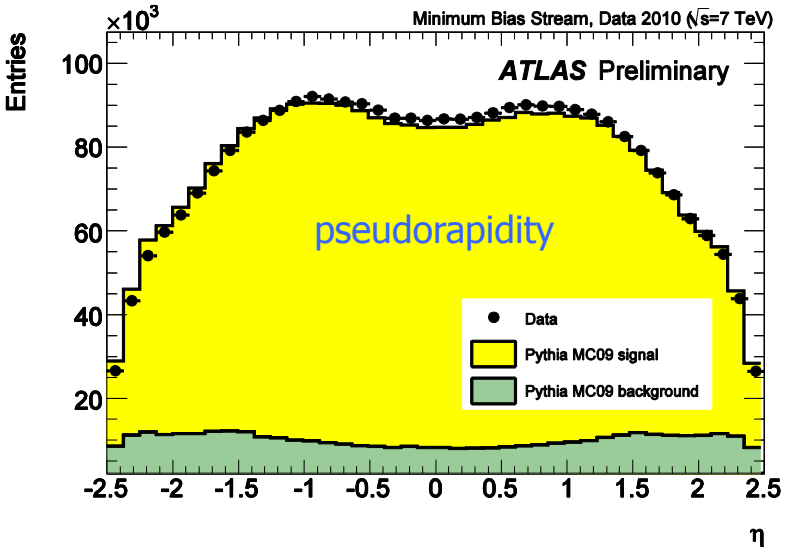


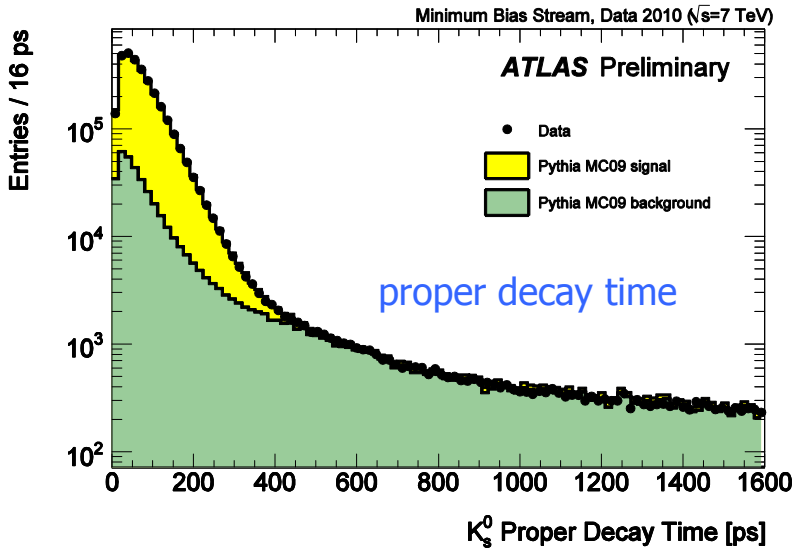


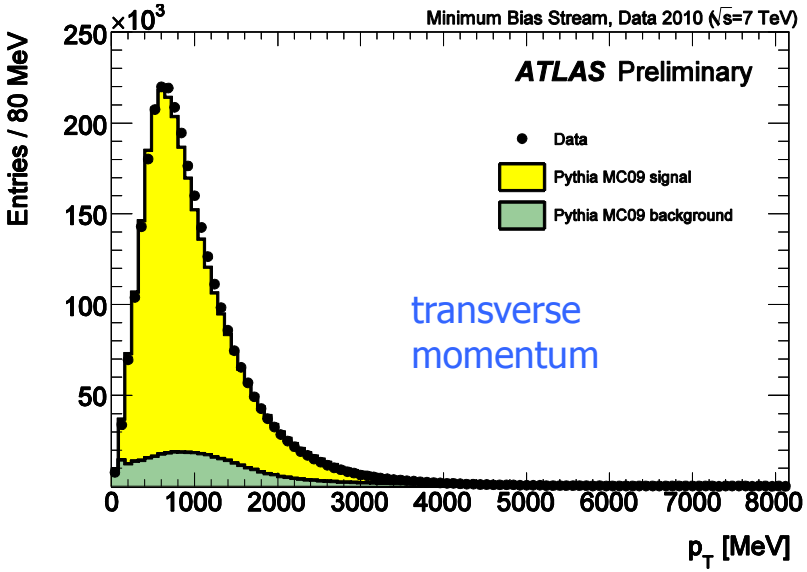
Signal and background adjusted separately in MC to match signal-to-background ratio in data

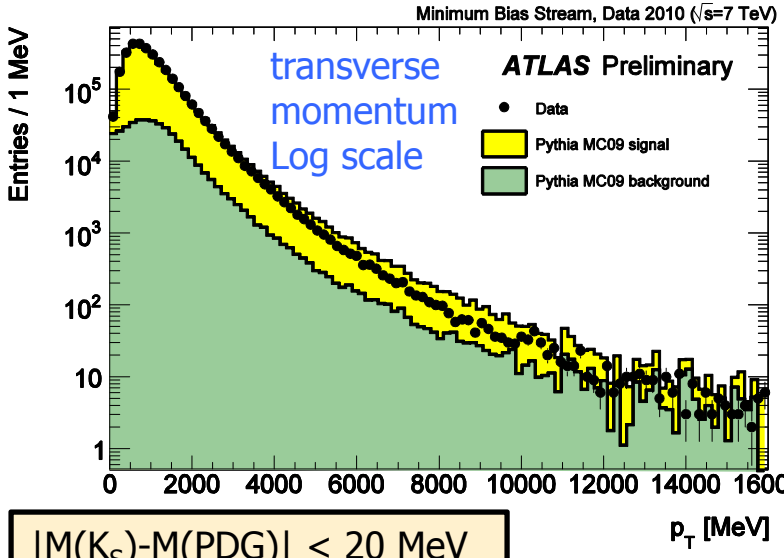
K_S kinematic distributions

Signal and background adjusted separately in MC to match signal-to-background ratio in data (no bin-by-bin correction for background)





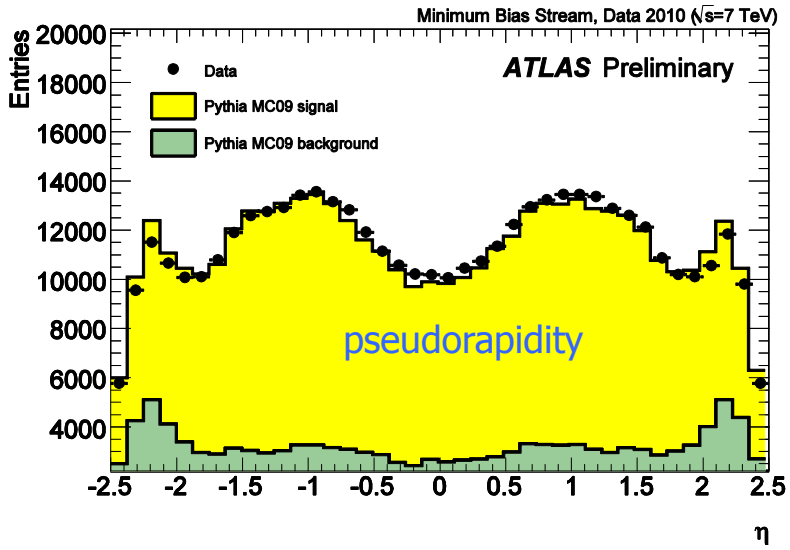


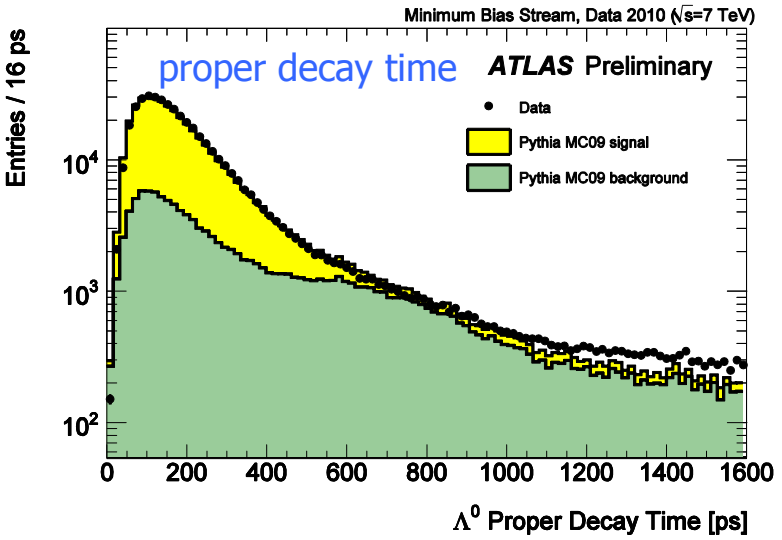


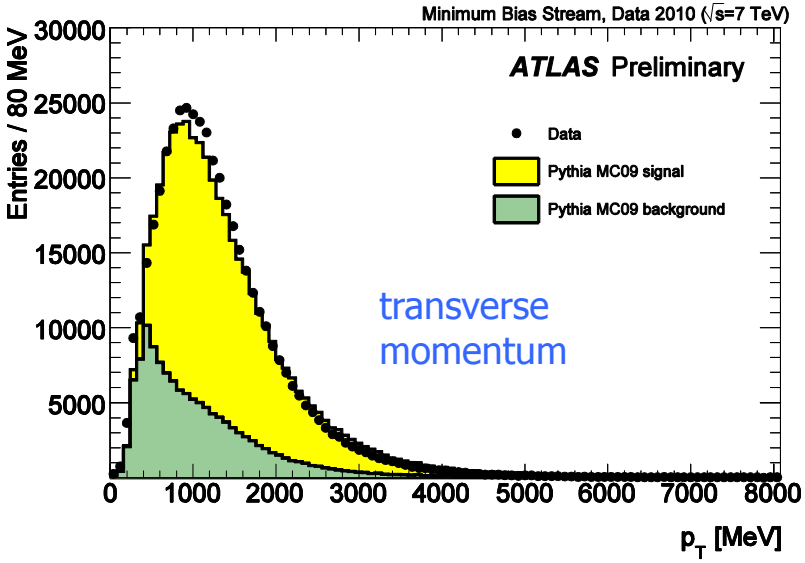
$|M(K_S)-M(PDG)| < 20$ MeV

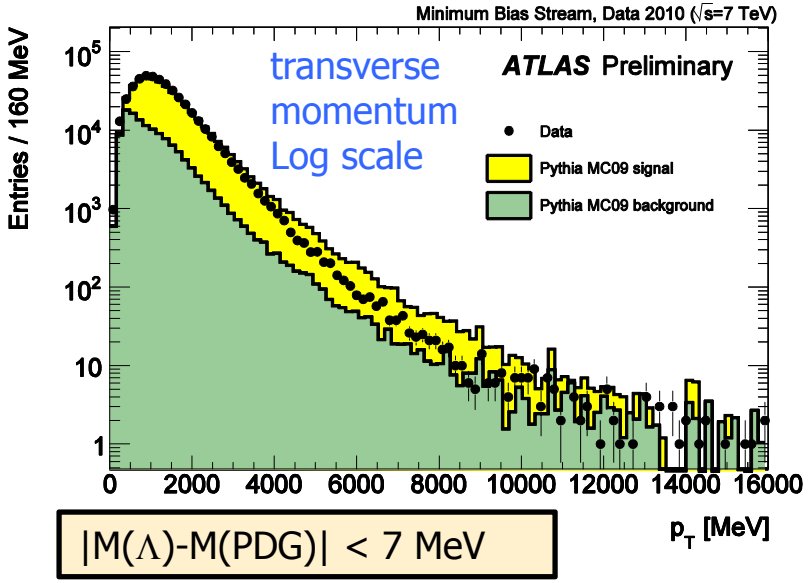
Λ Kinematic distributions

Signal and background adjusted separately in MC to match signal-to-background ratio in data (no bin-by-bin correction for background)









|M(Λ)-M(PDG)| < 7 MeV

$\bar{\Lambda}$ Kinematic distributions

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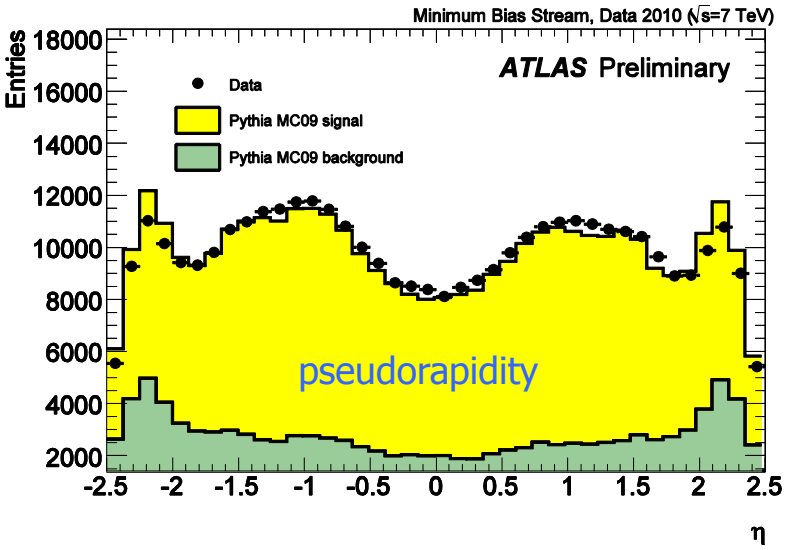
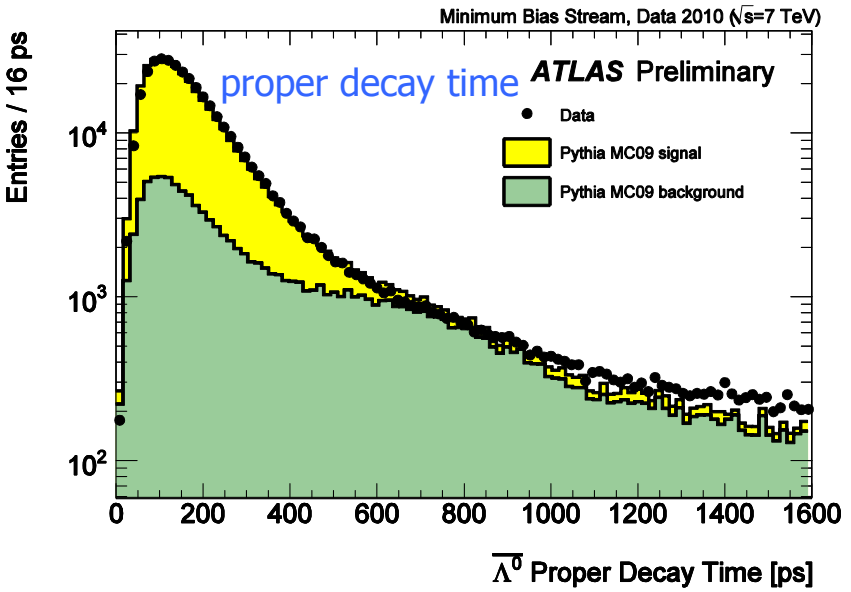
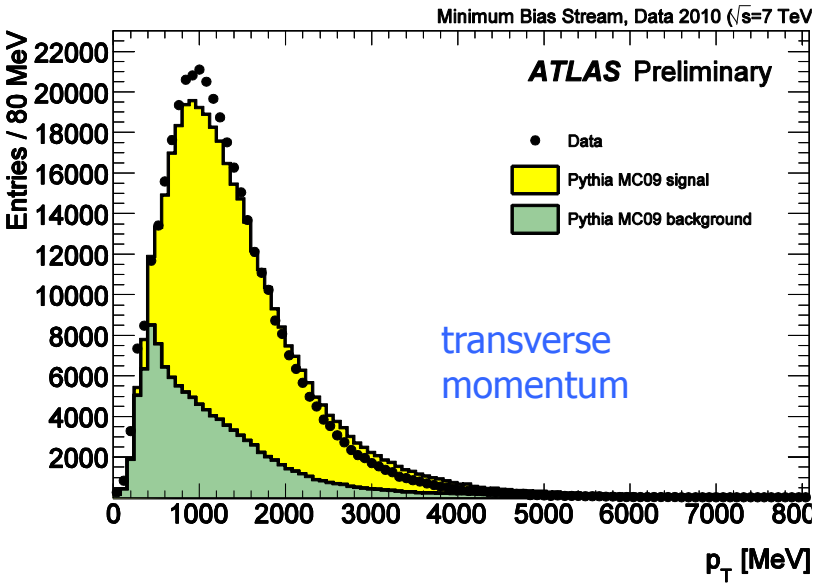
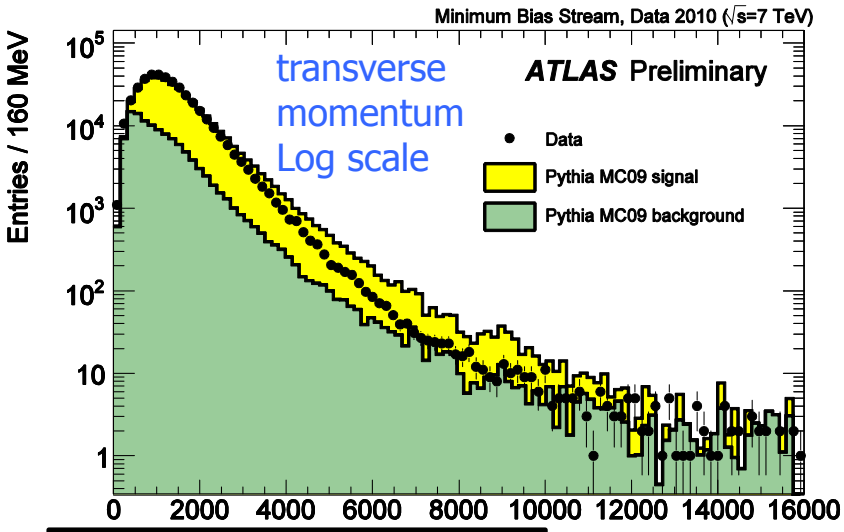






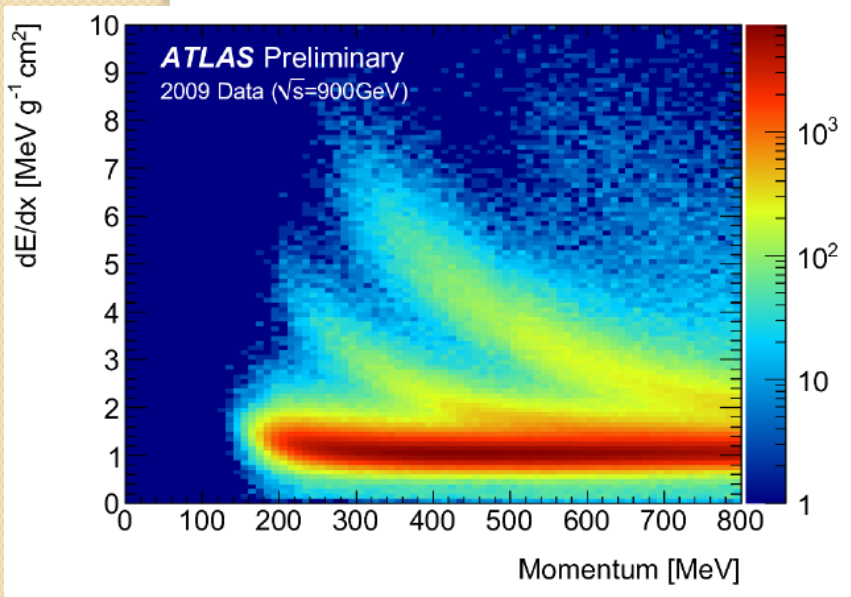


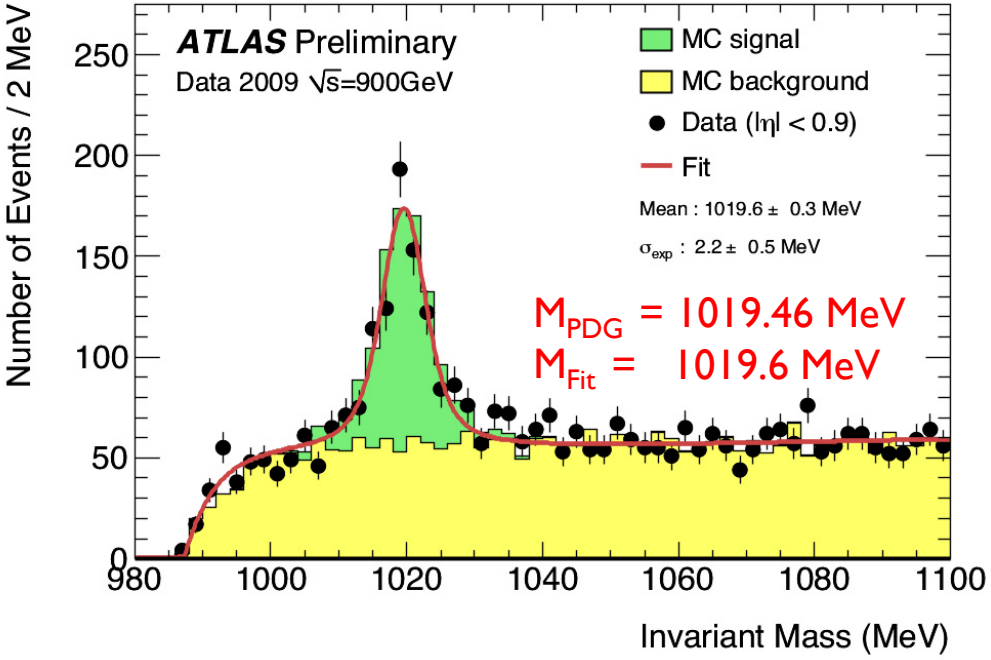
|M(Λ)-M(PDG)| < 7 MeV

Φ Reconstruction

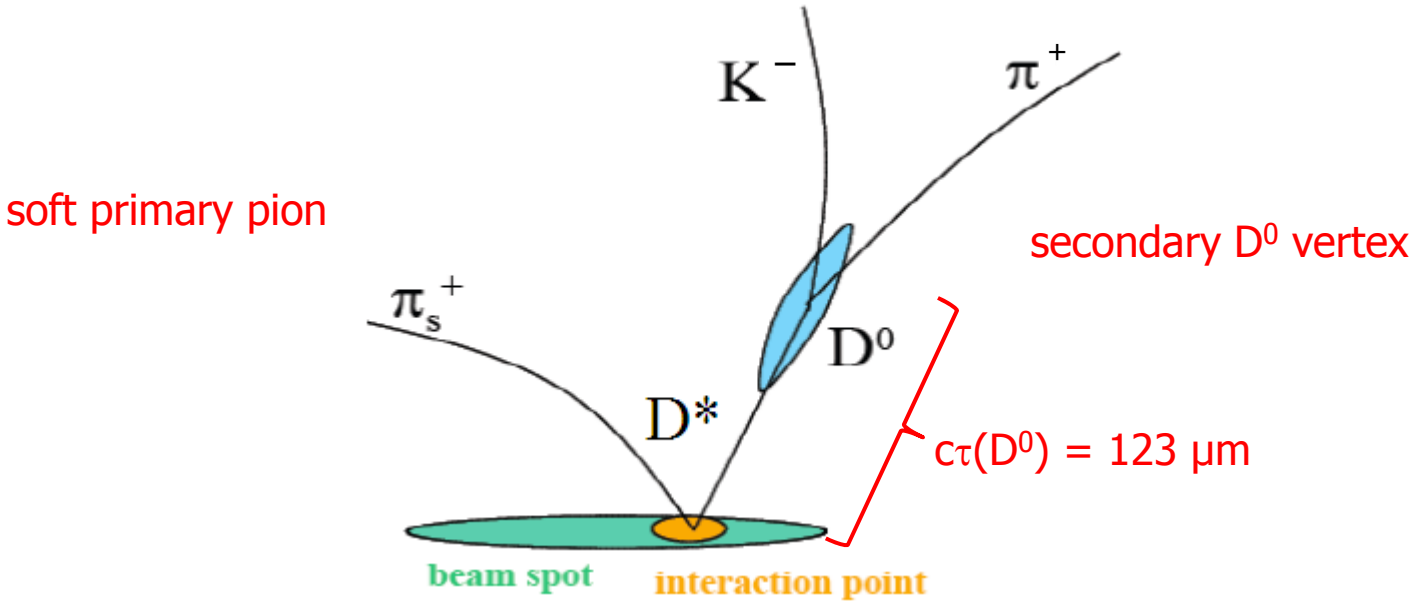
900 GeV collision data
Non-diffractive minimum bias simulation
(Pythia ATLAS MC09 tune)

- $\Phi \rightarrow K^+K^-$
- Using time-over-threshold measurements from the Pixel detector for kaon identification through dE/dx up to momenta of around 800 MeV
- Mass of the signal peak is consistent with simulation and the PDG value





D^* Reconstruction on 7 TeV data

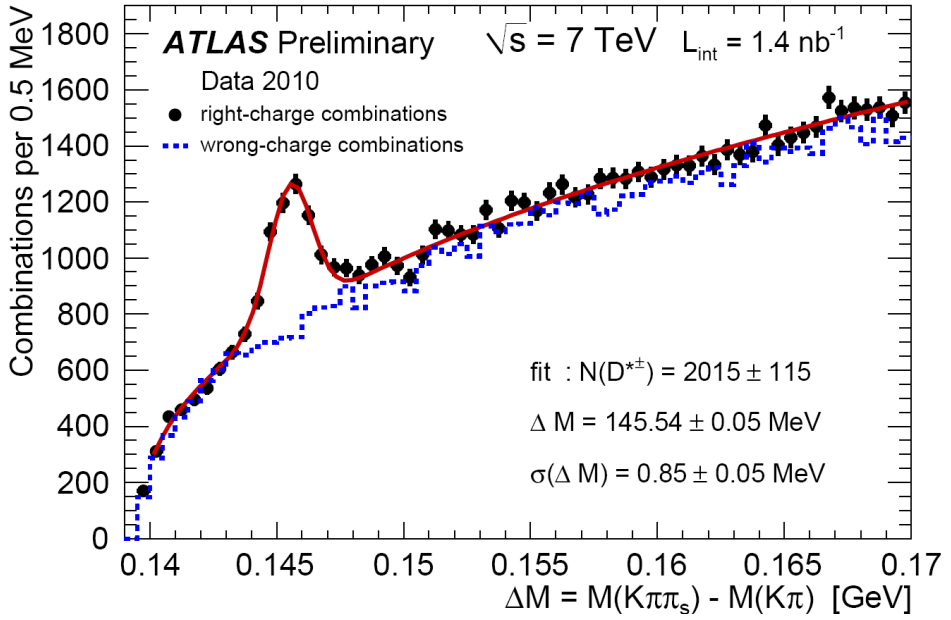


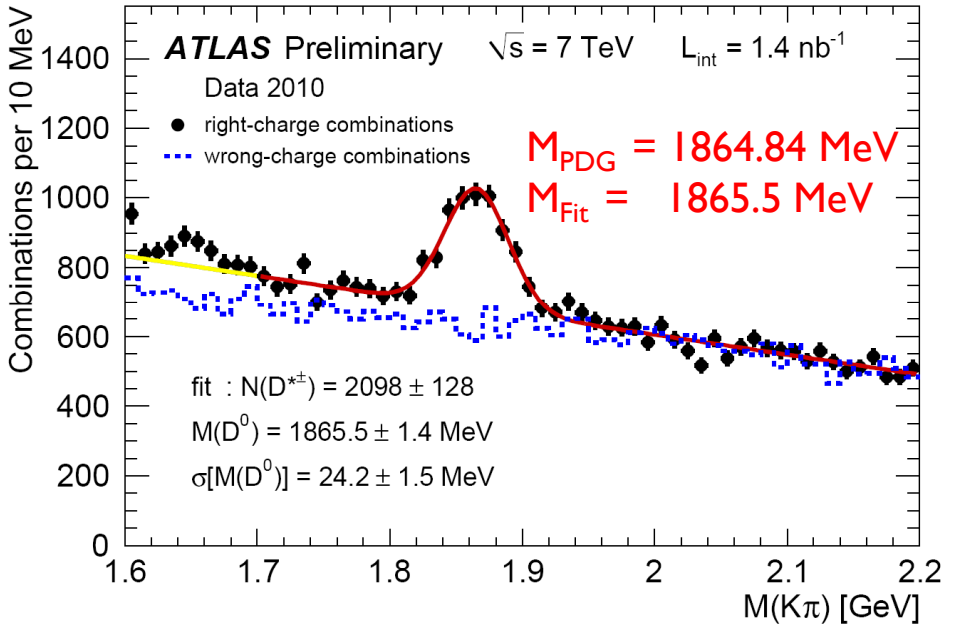
- $D^{*+} \rightarrow D^0\pi^+_S$, using vertexing of $D^0 \rightarrow K^-\pi^+$
- Reconstruction strategy:
  - Exploit the displacement of the D^0 vertex: require positive transverse decay length
  - D^0 momentum points to primary vertex
  - Exploit hard production: $p_T(D^*) > 3.5$ GeV $p_T(K,\pi) > 1.0$ GeV
  - Exploit hard nature of charm fragmentation: $p_T(D^*) / \Sigma E_T > 0.02$
- Use $\Delta m = M(K\pi\pi) - M(K\pi)$ as discriminating variable
  - $M(D^*)-M(D^0)-M(\pi) = 6$ MeV, so most tracking resolutions affect the D^0 decay and cancel out in the correlated difference → signal 40 times narrower than the D^* mass peak

D^* Reconstruction on 7 TeV data

~1.4 nb^{-1} of 7 TeV collision data

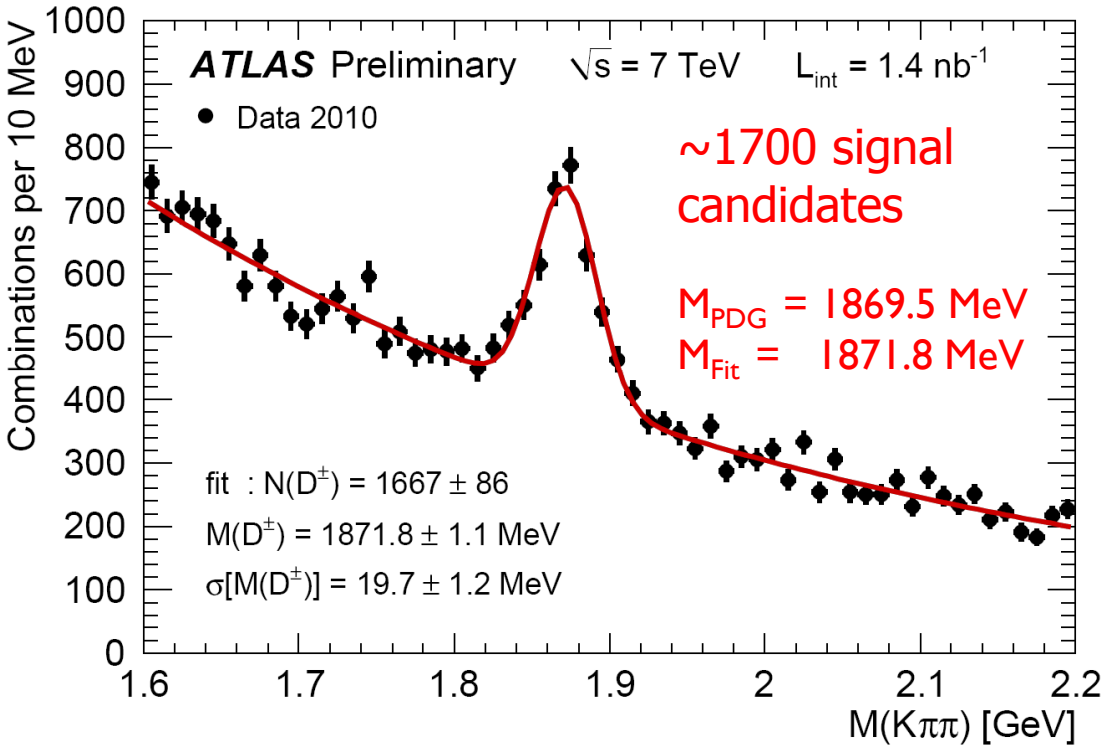
- ~2000 D^{*+} candidates in the Δm peak
- Wrong-charge combinations with $D^0 \rightarrow K^+\pi^+$, or $K^-\pi^-$ used to compare with right-charge combinatoric background
- Compatible number of D^0 candidates in the $M(K^-\pi^+)$ peak





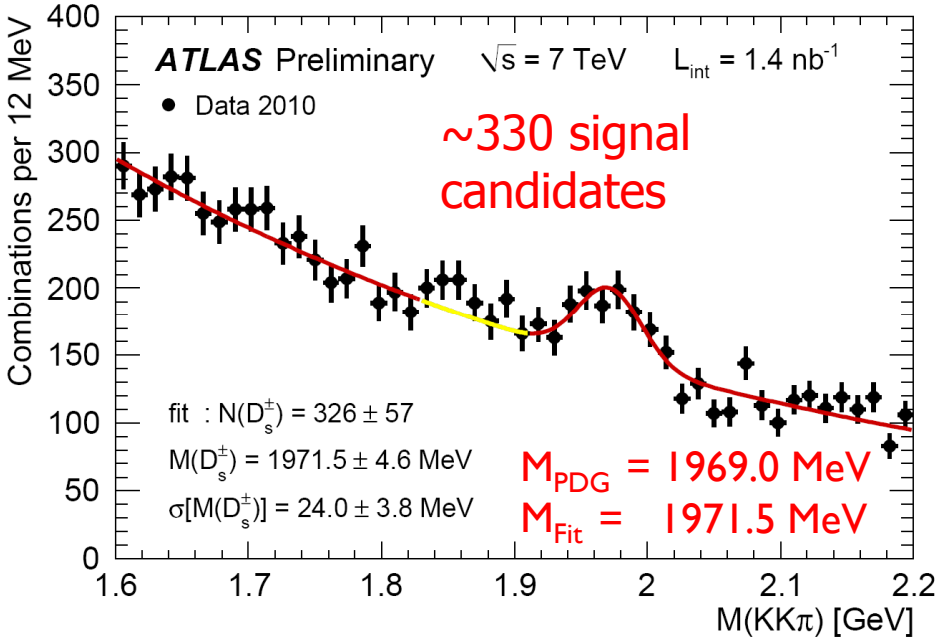
$D^+ \rightarrow K^-\pi^+\pi^+$ reconstruction on 7 TeV data

- Similar vertexing with D^+ mesons originating at the primary vertex
- But $c\tau(D^+) = 312\ \mu$
- → harder cut on transverse decay length > 1.3 mm
- $p_T(D^+) > 3.5$ GeV
- $p_T(D^+) / \Sigma E_T > 0.02$
- Veto D^* and $D_S \rightarrow \Phi(K^+K^-)\pi$ decays

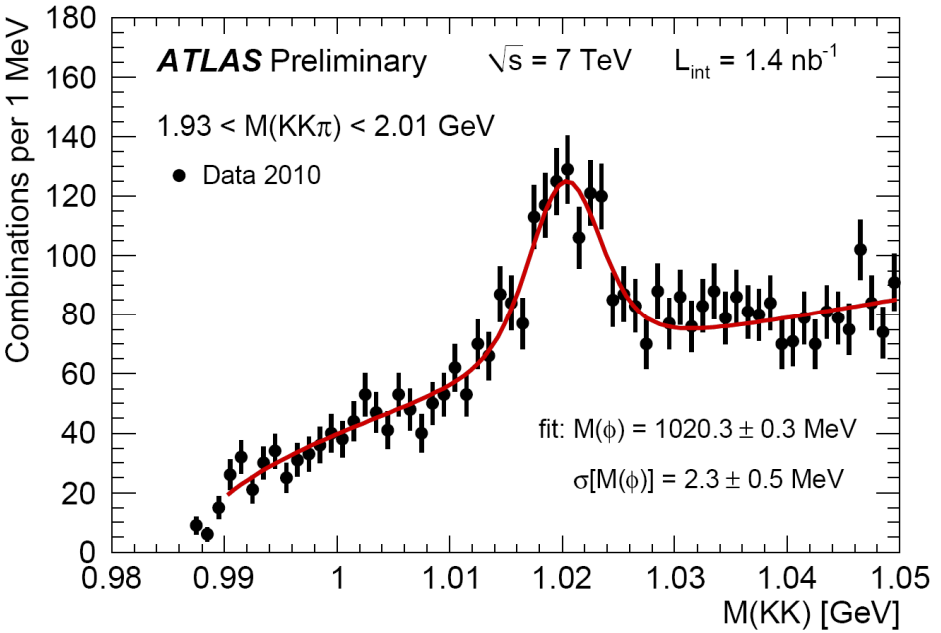


D_S Reconstruction on 7 TeV data

- $D_S \rightarrow \Phi\pi^+$, with $\Phi \rightarrow K^+K^-$
- Φ selection
  - decay angles (vector decay)
  - $|M(K^+K^-) - M(\Phi)_{PDG}| < 6$ MeV
- $p_T(D_S) > 3.5$ GeV
- $p_T(D_S) / \Sigma E_T > 0.04$



- $\Phi \rightarrow K^+K^-$ peak clearly visible in $M(K^+K^-)$ plot



Ξ, Ω, K* Decays – more complicated vertexing

Charged cascade decays:

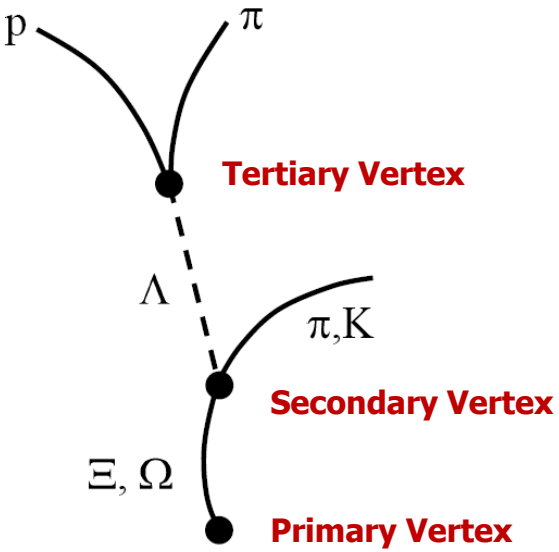
$\Xi^- \rightarrow \Lambda(p\pi^-)\pi^-$ $c\tau$=4.91cm (+ charged conjugate)

$\Omega^- \rightarrow \Lambda(p\pi^-)K^-$ $c\tau$=2.46cm (+ charged conjugate)

Use simultaneous vertexing of entire decay chain with pointing constraints

Λ is mass-constrained in the vertex fit

$|M_{p\pi} - M_{\Lambda}| < 8$ MeV pre-selection



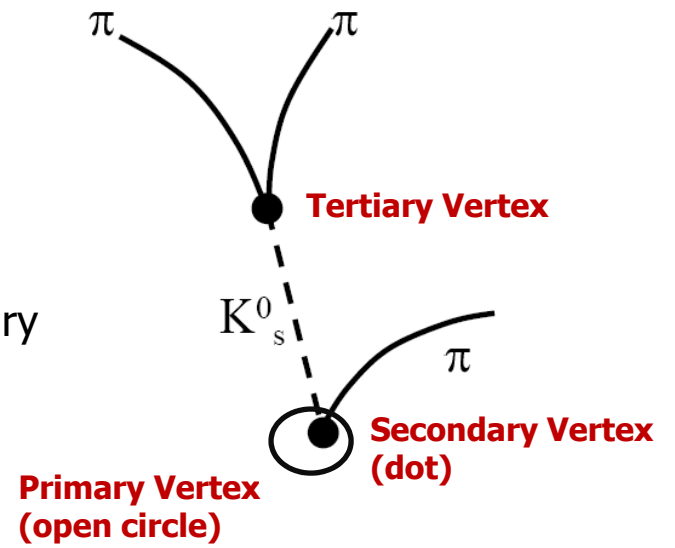
Prompt hadronic decay:

$K^{*+/-} \rightarrow K^0(\pi^+\pi^-)\pi^{+/-}$

Same vertexing but enforcing small distance between secondary and primary vertices to enhance the signal

K_S is mass-constrained in fit

$|M_{\pi\pi} - M_{Ks}| < 25$ MeV pre-selection



$\Xi^- \rightarrow \Lambda\pi^-$ Reconstruction

~250 μb^{-1} of 7 TeV collision data

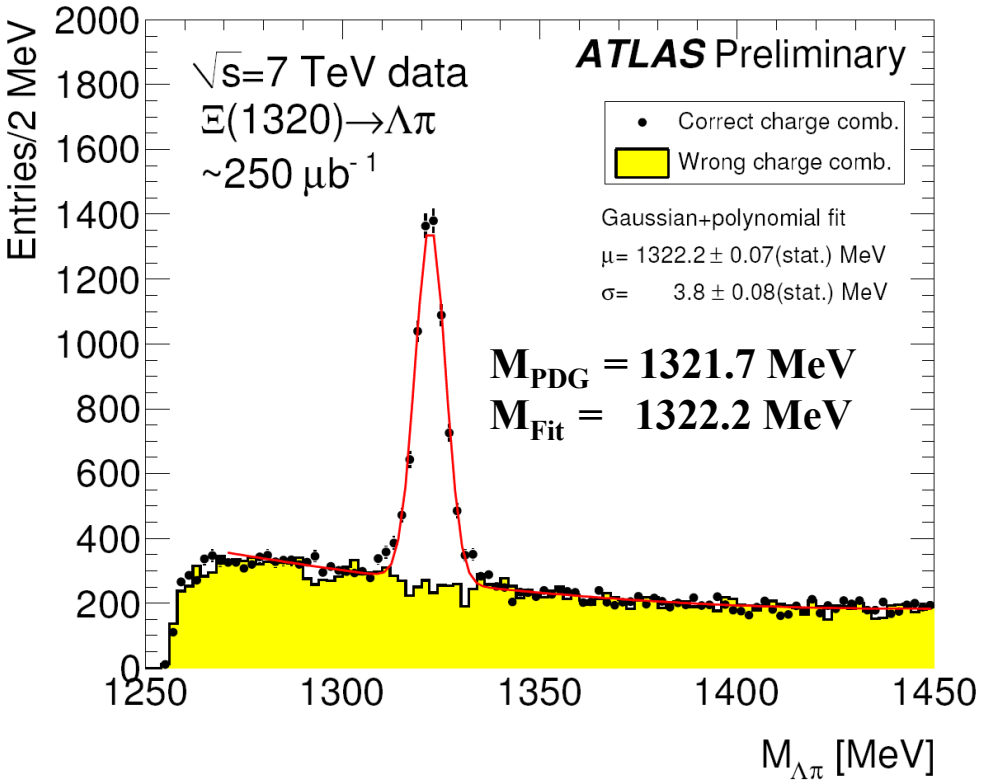
bachelor π track:

transverse IP > 0.5 mm

p_T > 150 MeV

χ^2 of cascade vertex < 7

Ξ flight distance > 4 mm



wrong-charge combinations $\Lambda\pi^+$ (+c.c.) used to compare with right-charge combinatoric background

$\Omega^- \rightarrow \Lambda K^-$ Reconstruction

~250 μb^{-1} of 7 TeV collision data

bachelor K track:

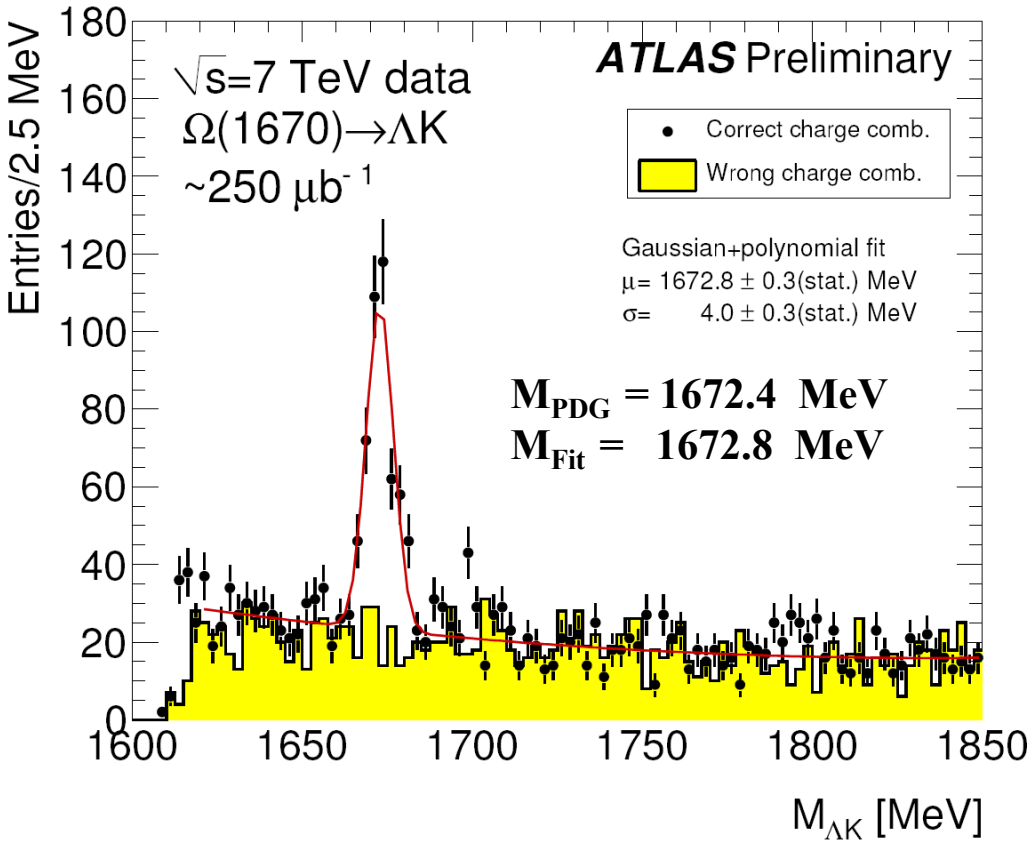
transverse IP > 1 mm

p_T > 400 MeV

χ^2 of cascade < 7

Ω flight distance > 6 mm

$p_T(\Omega)$ > 1500 MeV



$| M_{\Lambda\pi} - M_{\Xi} |$ > 8 MeV for the pion-mass hypothesis to reject Ξ reflection

wrong-charge combinations ΛK^+ (+c.c.) used to compare with right-charge combinatoric background

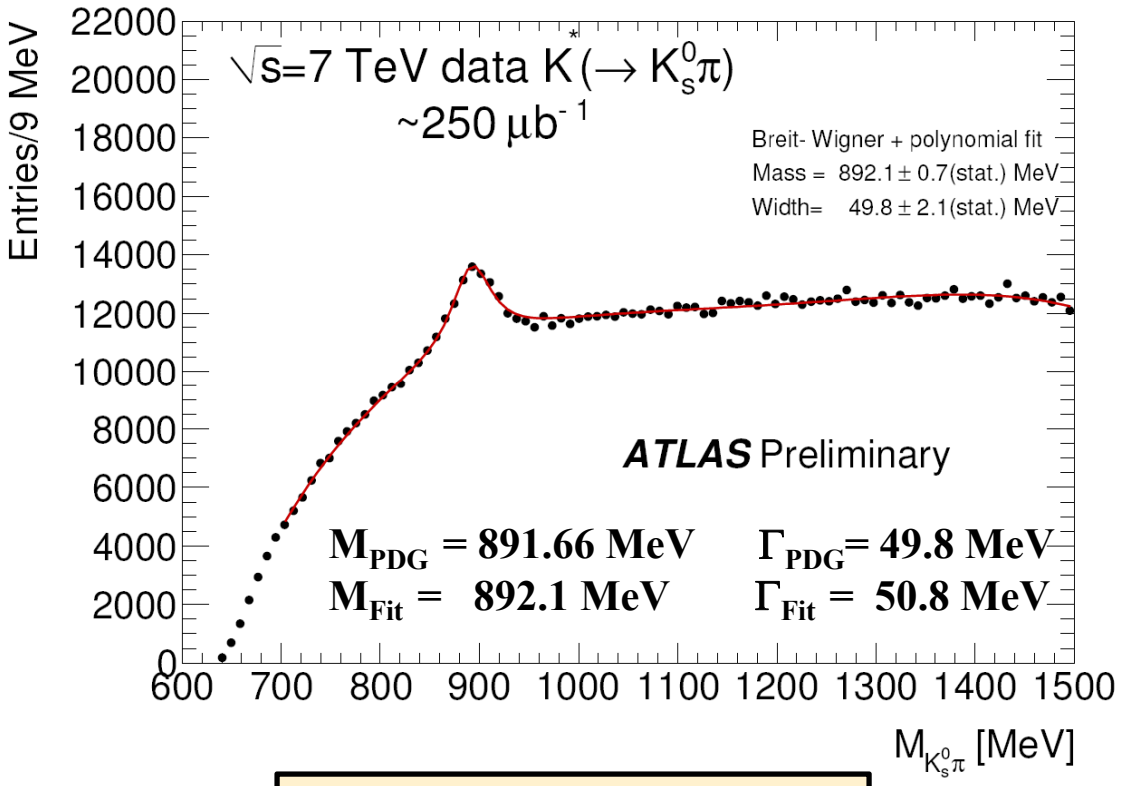
K^* Reconstruction

Reconstruct only charged $K^{*+} \rightarrow K_S \pi^+$ (+ c.c.)

χ^2 of K_S vertex < 4

K^* flight distance < 0.8 mm (prompt decay)

$p_T(K^*)$ > 1000 MeV



~250 μb^{-1} of 7 TeV collision data

Conclusions

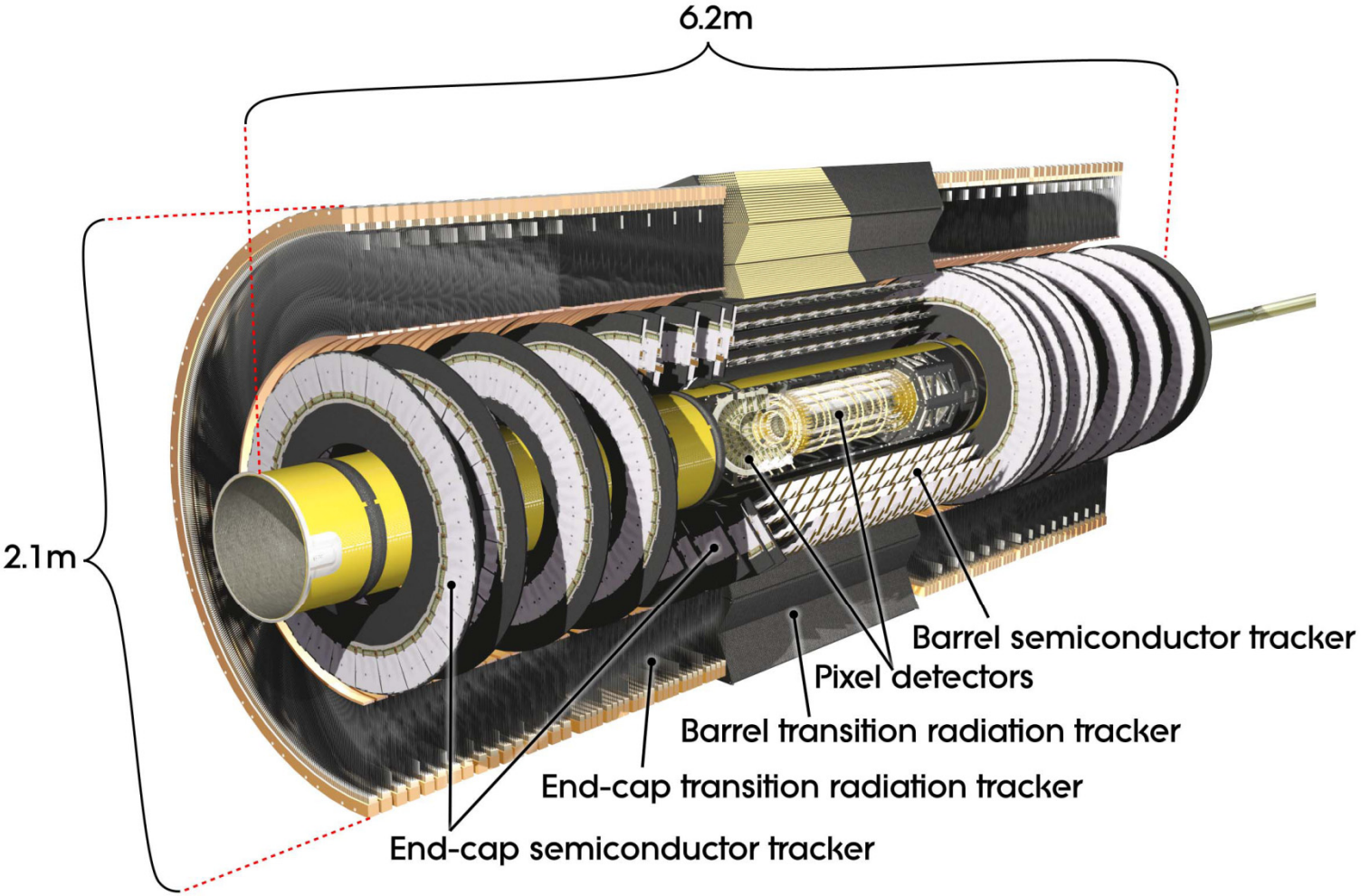
For more details see:
ATLAS-CONF-2010-023
ATLAS-CONF-2010-032
ATLAS-CONF-2010-033
ATLAS-CONF-2010-034

- Λ/K_S reconstructed kinematic distributions in data show good agreement with simulation
  - Excellent modeling of ATLAS tracking at low p_T
- $D^{(*)}_{(s)}$ mesons, Ξ and Ω cascade decays, and K^* resonance clearly observed in 7 TeV data
  - Masses very close to PDG values, excellent momentum scale in the multiple-scattering-dominated regime
  - Validates complex vertexing algorithms in ATLAS
- ATLAS Tracker has rediscovered many low-p_T particles
  - Foundation for measurement of corrected kinematic distributions and cross sections and tuning of MC models
  - Tracking also used for high p_T particles → see W/Z talk in this conference

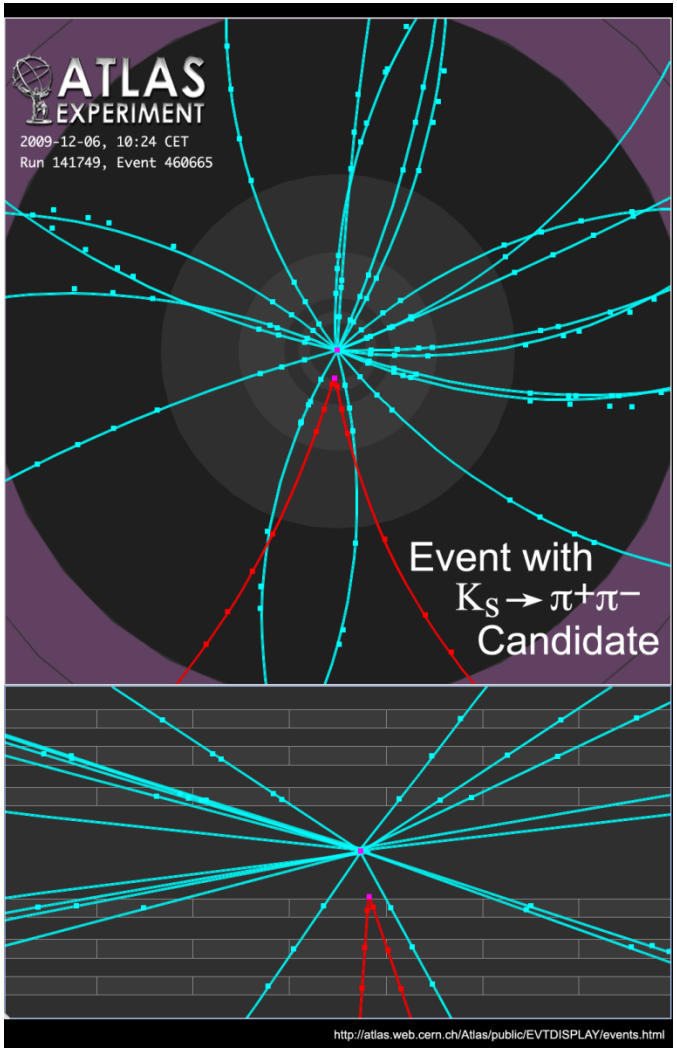
→ ready for discovery physics!

Backup Slides

The ATLAS Inner Detector



K_S candidate in ATLAS data



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- $K_S \rightarrow \pi^+\pi^-$ (BF≈69%, $c\tau$=2.7 cm) $\Lambda \rightarrow p^+\pi^-$ (BF≈63%, $c\tau$=7.9 cm)

→ Identified as V^0 decays with a vertex displaced from the primary vertex

- Vertexing of pairs of oppositely charged tracks with
  - p_T > 100 MeV
  - number of silicon hits > 2
  - vertex fit χ^2 / ndof < 15

~190 μb^{-1} of 7 TeV collision data
Non-diffractive minimum bias simulation
(Pythia ATLAS MC09 tune)

- K_S selection
  - flight length > 4 mm
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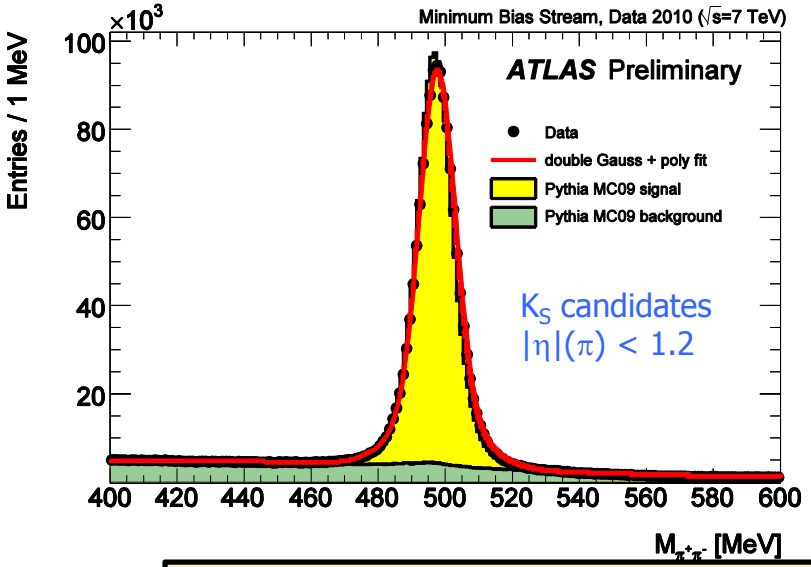

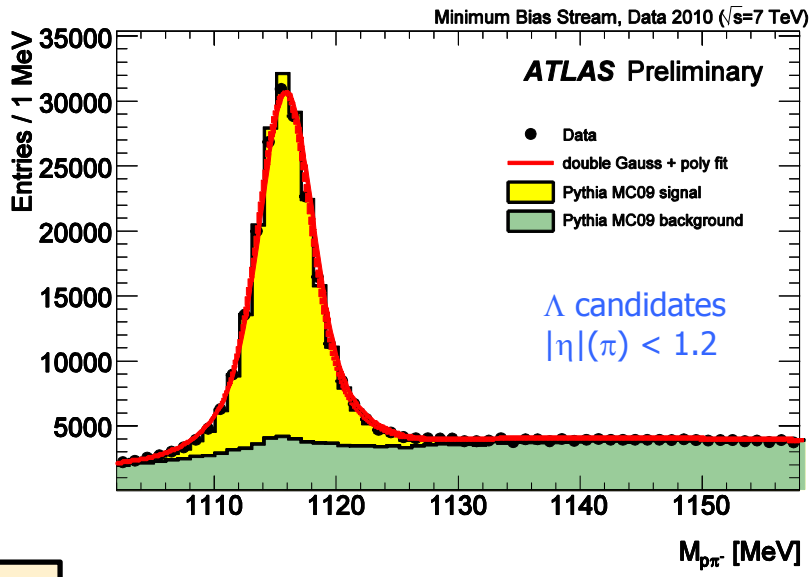

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D^+ Reconstruction on 7 TeV data

- Similar secondary vertexing strategy for $D^+ \rightarrow K^-\pi^+\pi^+$ decays with the D^+ originating at the primary vertex, but $c\tau(D^+) = 312\ \mu$
- → transverse decay length > 1.3 mm
- Also $p_T(D^+) > 3.5$ GeV, $p_T(D^+) / \Sigma E_T > 0.02$
- Veto D^* decays with $\Delta m > 150$ MeV
- Veto $D_S \rightarrow \Phi\pi$, $\Phi \rightarrow KK$ with $|M(K^\pm,K^\mp) - M(\Phi)_{PDG}| > 8$ MeV