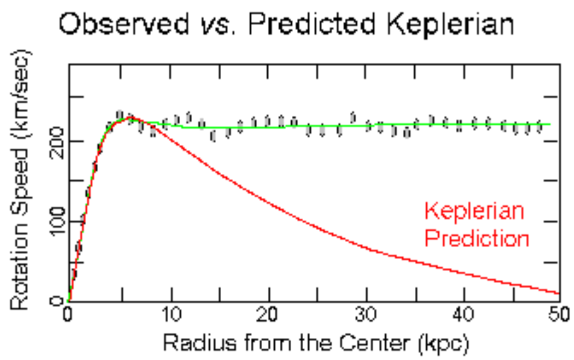
S. Stone

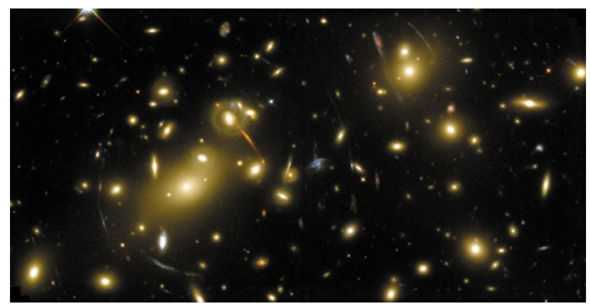
B Physics in the LHC Era

Madison, May 9, 2011

Physics Beyond the Standard Model

- Baryogensis: From current measurements can only generate $(n_B - n_{\bar{B}})/n_\gamma = \sim 10^{-20}$ but $\sim 6 \times 10^{-10}$ is needed. Thus New Physics must exist
- Dark Matter





Gravitational lensing

- Hierarchy Problem: We don't understand how we get from the Planck scale of Energy $\sim 10^{19}$ GeV to the Electroweak Scale ~ 100 GeV without "fine tuning" quantum corrections

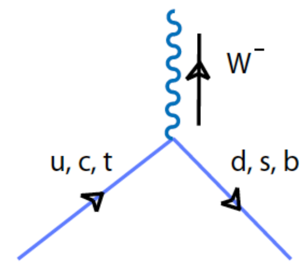
General Justification for Flavor Physics

- Expect New Physics will be seen at LHC
- However, it will be difficult to characterize this physics. How the new particles interfere virtually in the decays of b's (& c's) with the SM W's & Z's can tell us a great deal about their nature
- NP models must conform with severe constraints from flavor such as $\mathcal{B}(b\to s\gamma)$

Quark Mixing & CKM Matrix

- In SM charge -1/3 quarks (d, s, b) are mixed
- Described by CKM matrix (also ν are mixed)

$$V_{\left(\frac{2}{3},-\frac{1}{3}\right)} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

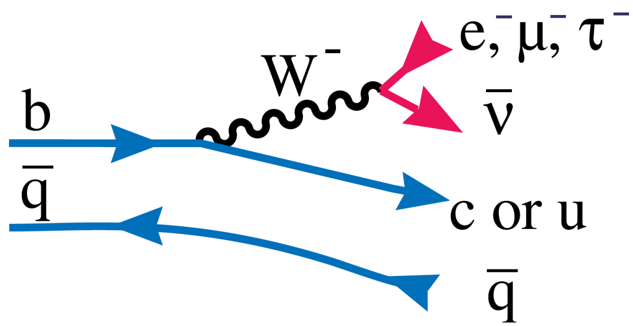


$$= \begin{pmatrix} 1-\lambda^2/2 & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\lambda^2/2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix} + O(\lambda^4)$$

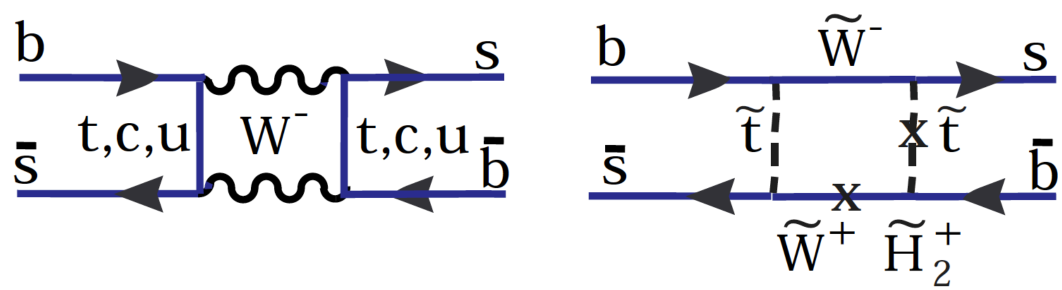
- λ=0.225, A=0.8, constraints on ρ & η
- These are fundamental constants in SM

Limits on New Physics

- It is oft said that we have not seen New Physics, yet what we observe is the sum of Standard Model + New Physics. How to set limits on NP?
- Assume that tree level diagrams are dominated by SM and loop diagrams could contain NP



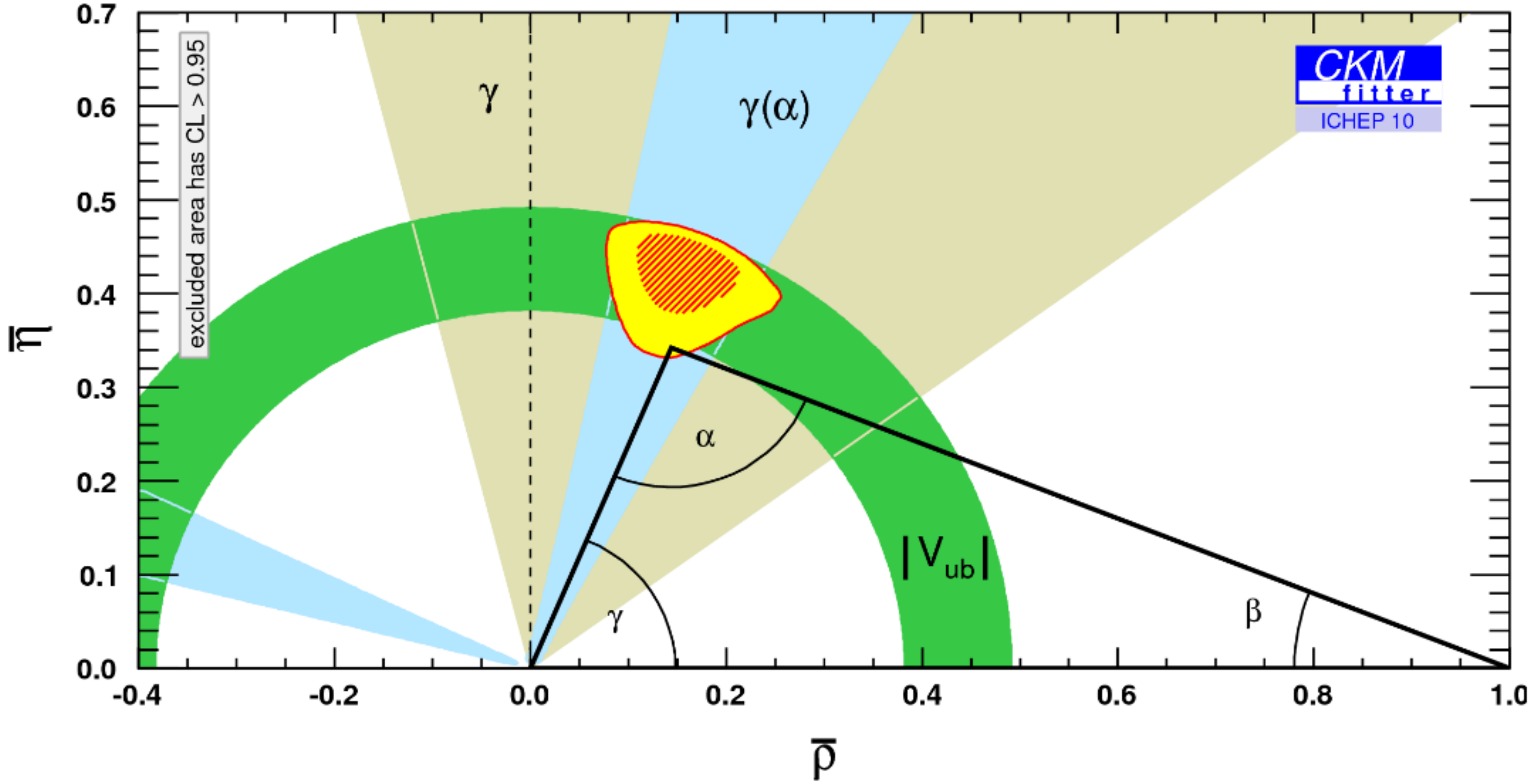
Tree diagram example



Loop diagram example

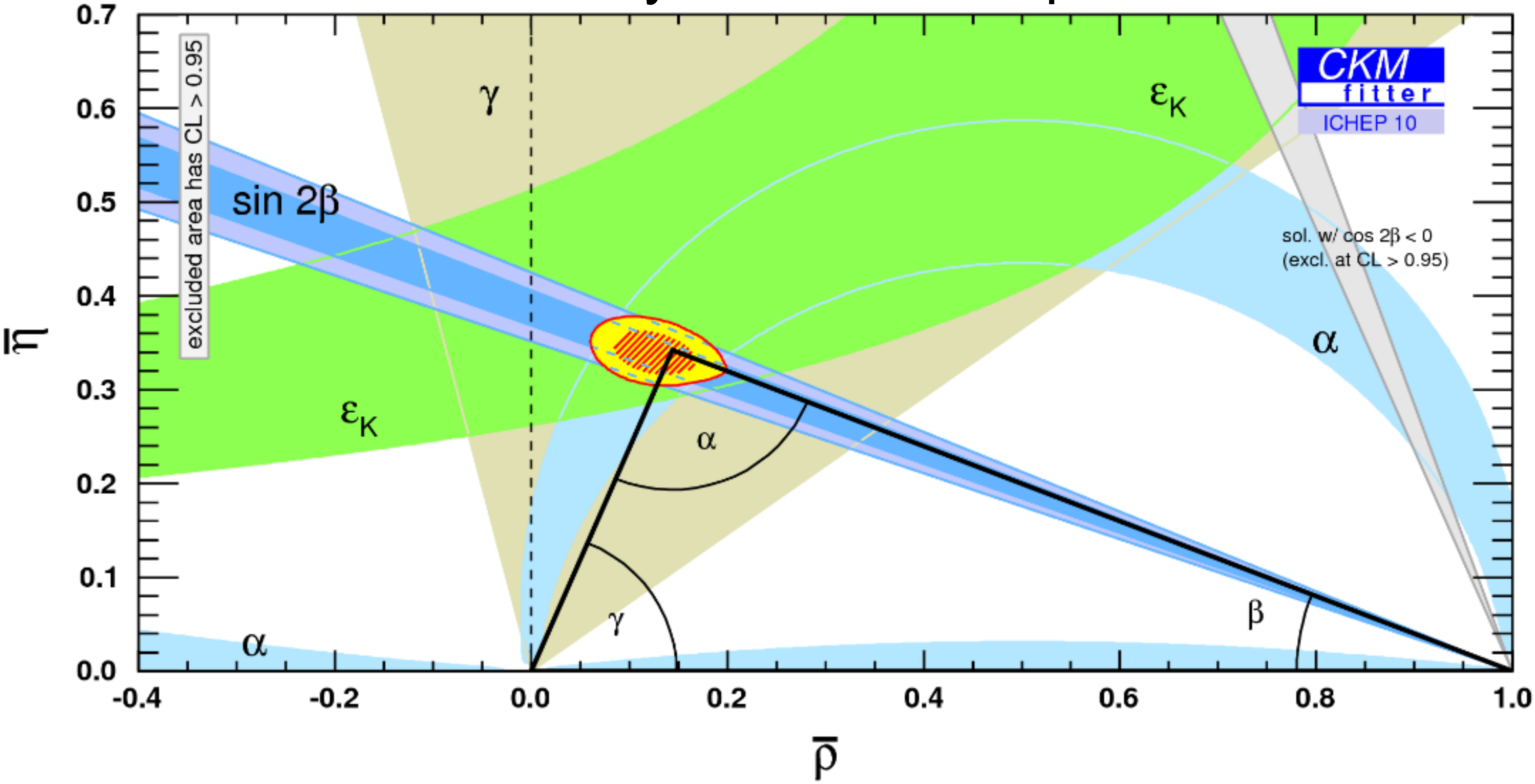
What are limits on NP from quark decays?

- Tree diagrams are unlikely to be affected by physics beyond the Standard Model

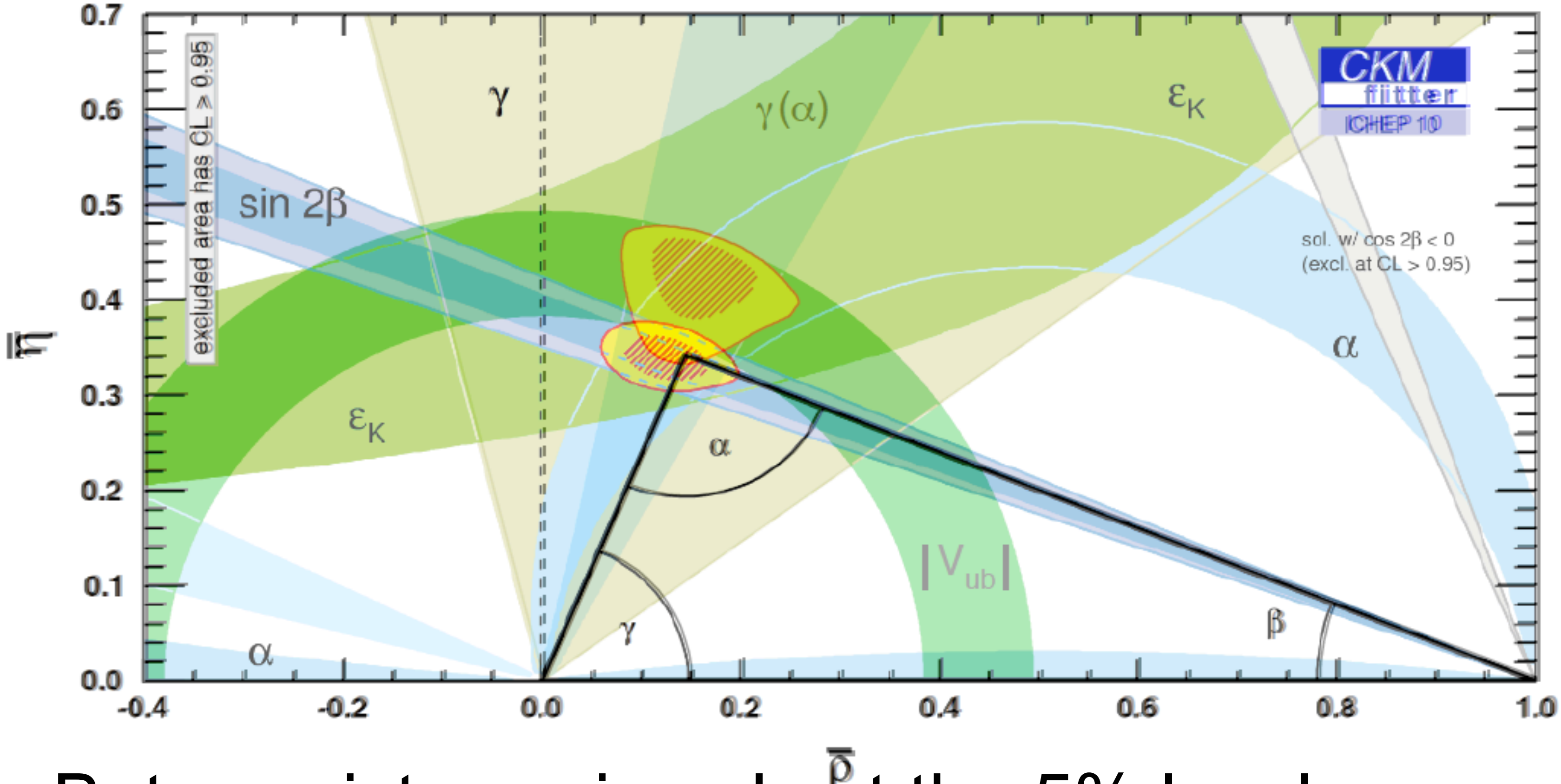


CP Violation in B° & K° Only

- Absorptive (Imaginary) of mixing diagram should be sensitive to New Physics. Lets compare



They are Consistent

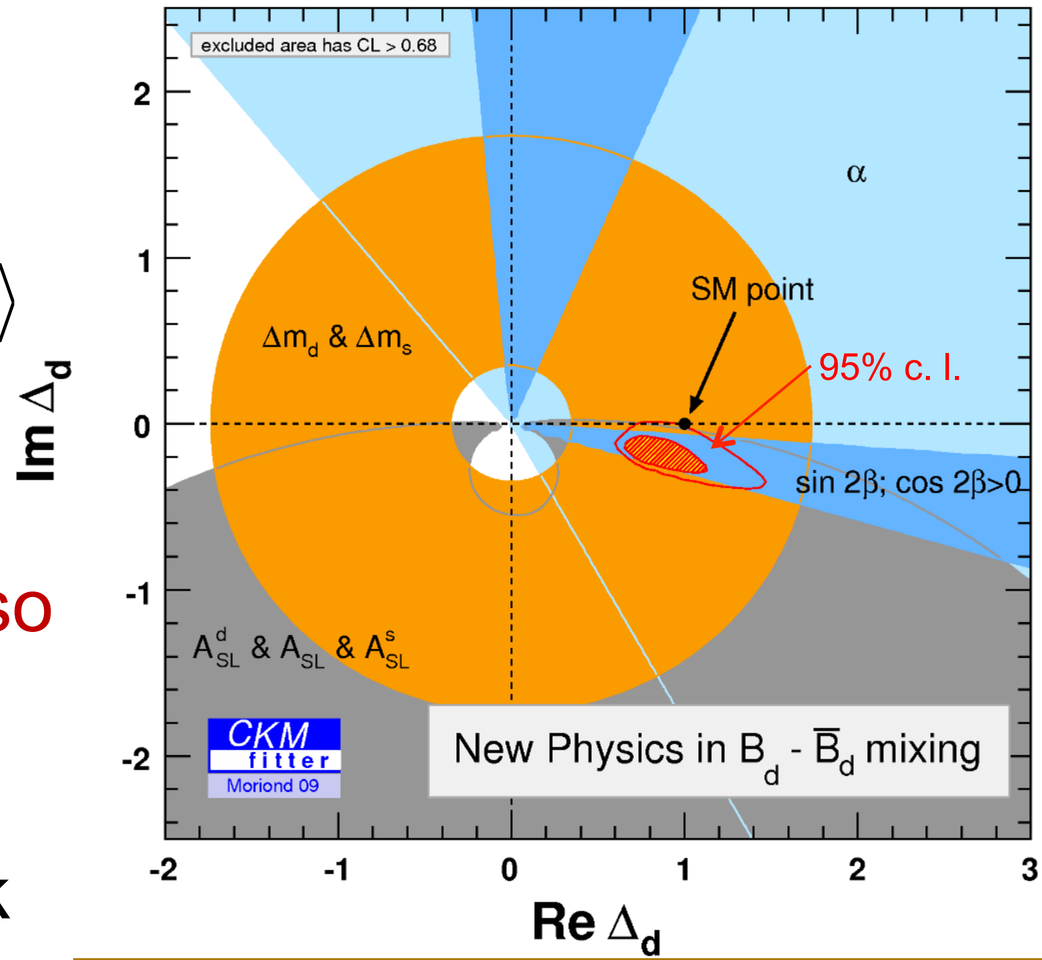


- But consistency is only at the 5% level
- Same for B_s – CP violation in J/ψ ϕ (not including D0 A_{sl}) ⇒limits on NP are not so strong

Limits on New Physics From B^o Mixing

- Is there NP in B^o-$\bar{B}^o$ mixing?
- $\langle B^o | H^{SM+NP}_{\Delta B=2} | \bar{B}^o \rangle = \Delta_d^{NP} \langle B^o | H^{SM}_{\Delta B=2} | \bar{B}^o \rangle$

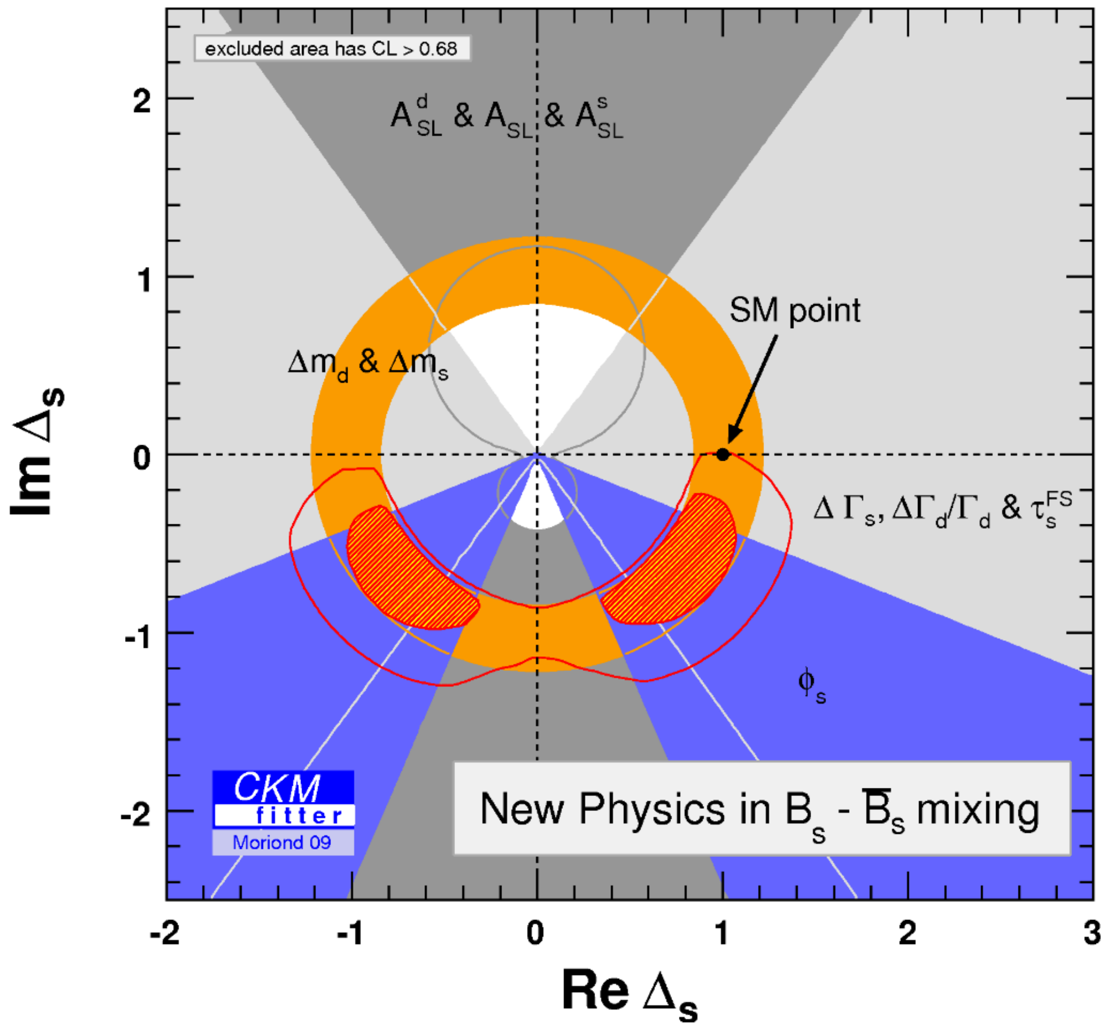
  $\Delta_d^{NP} = \mathrm{Re}\,\Delta_d + i\,\mathrm{Im}\Delta_d$
- Assume NP in tree decays is negligible, so no NP in $|V_{ij}|$, γ from $B^- \to D^o K^-$.
- Allow NP in Δm, weak phases, A_{SL}, & $\Delta\Gamma$.



- Room for new physics, in fact SM is only at 5% c.l.

Limits on New Physics From B_S Mixing

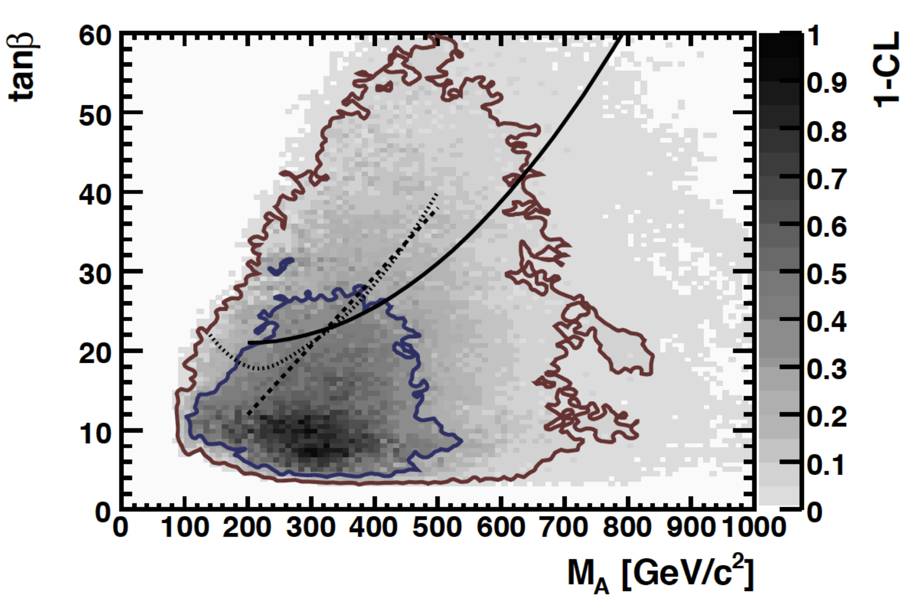
- Similarly for B_S
  - One CP Violation measurement using $B_S \rightarrow J/\psi\ \phi$
- Here again SM is only at 5% c.l.
- Much more room for NP due to less precise measurements

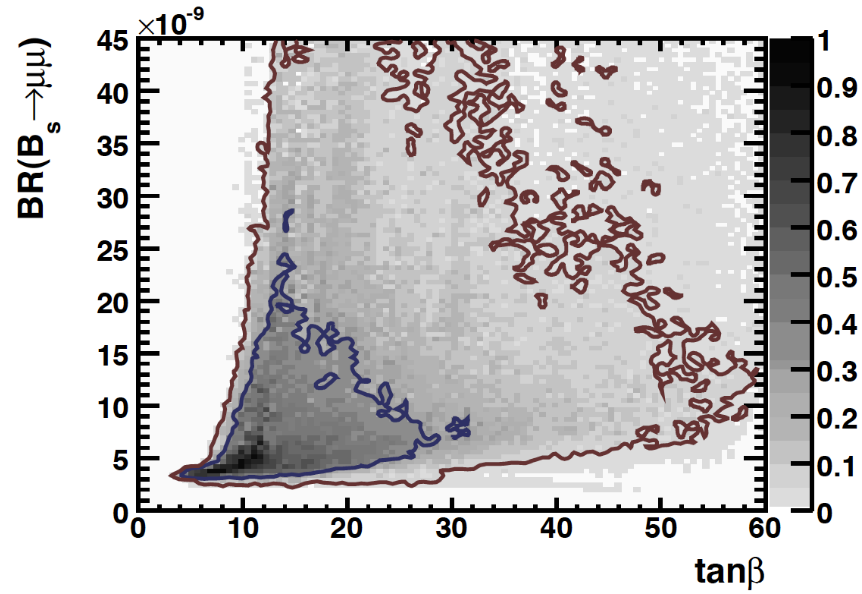


New Physics Models

- There is, in fact, still lots of room for "generic" NP
- What do specific models predict?
  - Supersymmetry: many, many different models
  - Extra Dimensions: "
  - Little Higgs: "
  - Left-Right symmetric models "
  - 4th Generation models "
- NP **must** affect every process; the amount tells us what the NP is ("DNA footprint")
- Many interesting cases exist

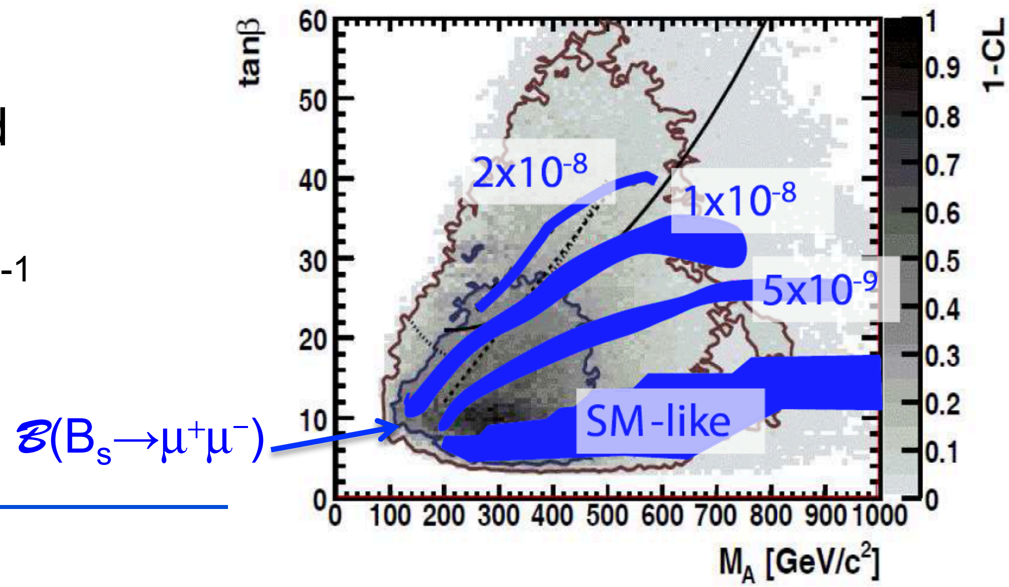
Exp: $\mathcal{B}(B_s \to \mu^+\mu^-)$ in NUHM1





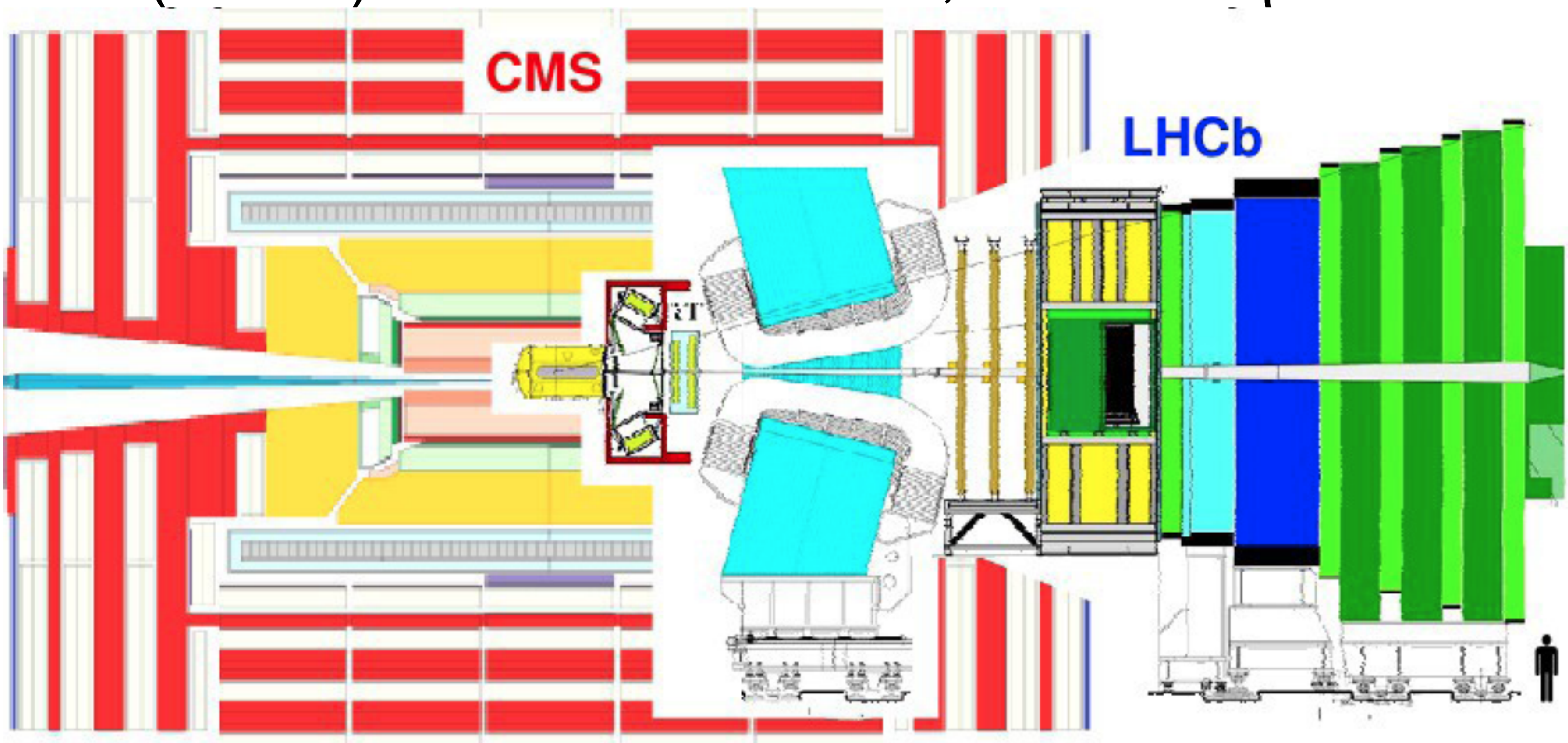
- CMS discovery contours for H, A $\to \tau^+\tau^- \to$jets (solid line), jet + μ (dashed), jet + e (dotted) using 30-60 fb^{-1}

- (From O. Buchmueller et al., arXiv:0907.5568)



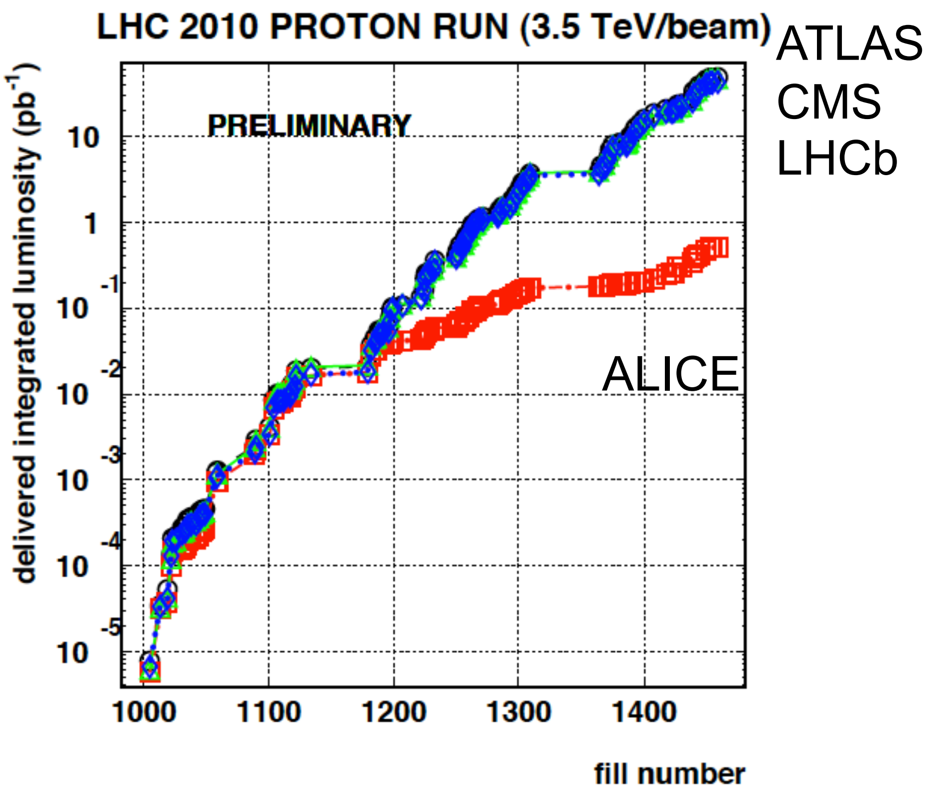
Experiments

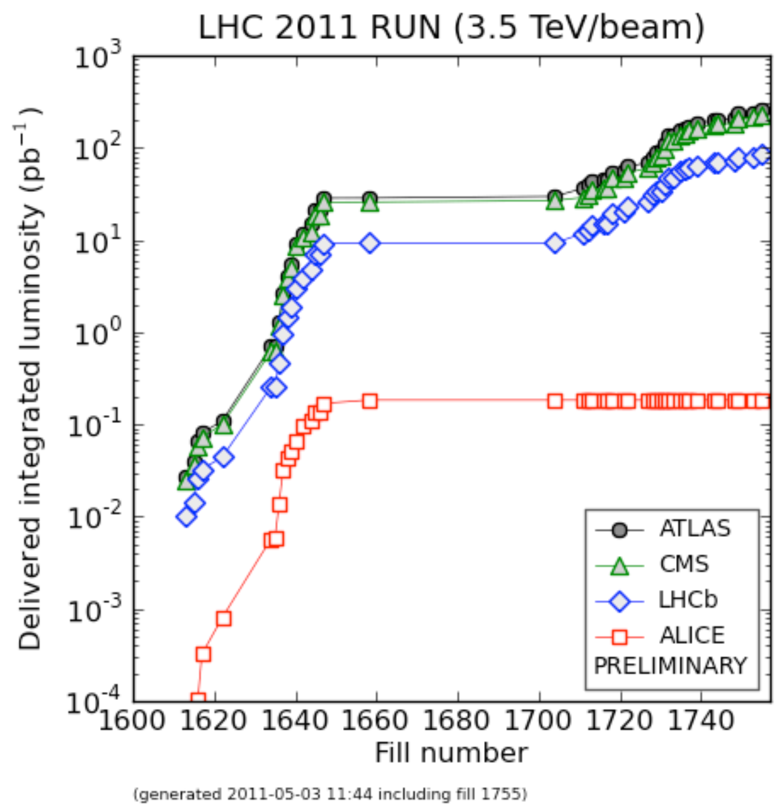
- CMS & ATLAS largely in central region, $\eta = -\ln(\tan\theta/2)$ between -2.4 & 2.4, LHCb $2<\eta<5$



Luminosities

- Luminosities – LHCb limited to ~$3x10^{32}/cm^2$-s
- LHCb luminosity is now being "Leveled"



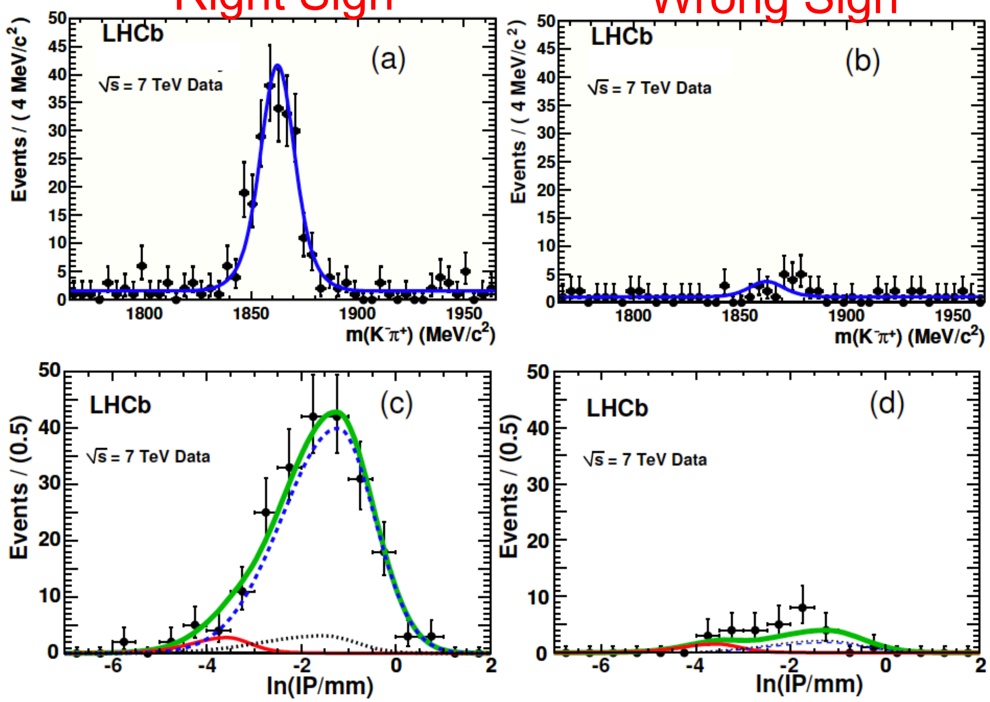


$\sigma(pp\rightarrow b\bar{b}X)$ using 15 nb^{-1}

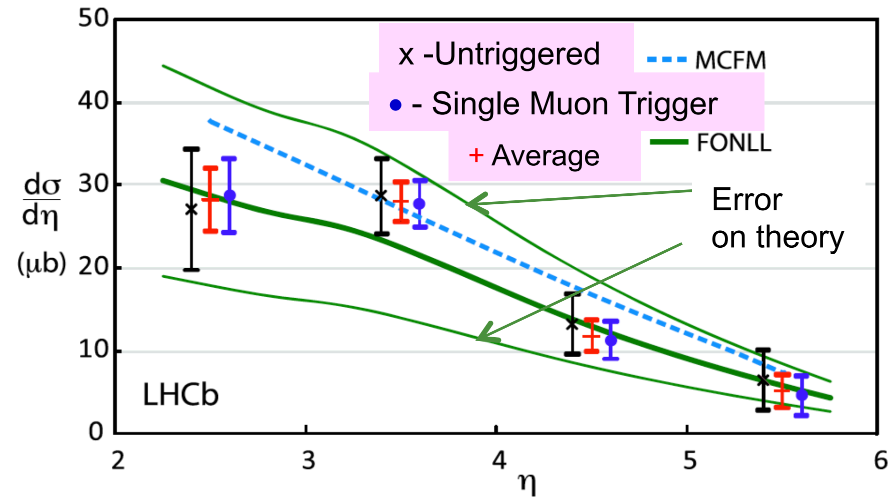
- $b\rightarrow D^0X\mu^-\nu$, $D^o\rightarrow K^-\pi^+$, ~280 events

Infancy

Right Sign Wrong Sign



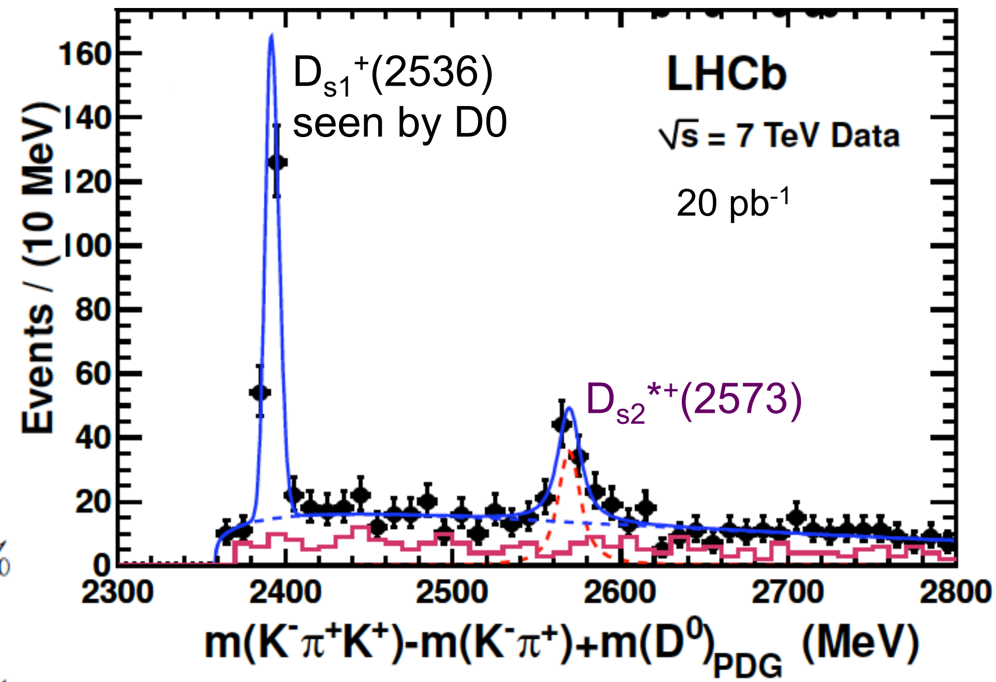
$$\sigma = \frac{\#\text{ of detected } D^0\mu^- \ \&\ \bar{D}^0\mu^+}{L \text{ x efficiency x } 2}$$



- In 2<η<6, (75.3±5.4±13.0) μb LEP frag ⇒ 284±20±49 μb
- In 2<η<6, 89.6 μb Tevatron frag ⇒ 338±24±58 μb
- Also measured charm cross-section, ~20x b

B_s Semileptonic Decays

- First Observation of $\overline{B}_s \rightarrow D_{s2}^{*+} X\mu^-\nu$ Decays
- Look at D^oK^+ mass in μ^- events



$$\frac{\mathcal{B}(\overline{B}_s^0 \rightarrow D_{s2}^{*+} X\mu^-\overline{\nu})}{\mathcal{B}(\overline{B}_s^0 \rightarrow X\mu^-\overline{\nu})} = (3.3 \pm 1.0 \pm 0.4)\%$$

$$\frac{\mathcal{B}(\overline{B}_s^0 \rightarrow D_{s1}^{+} X\mu^-\overline{\nu})}{\mathcal{B}(\overline{B}_s^0 \rightarrow X\mu^-\overline{\nu})} = (5.4 \pm 1.2 \pm 0.5)\%$$

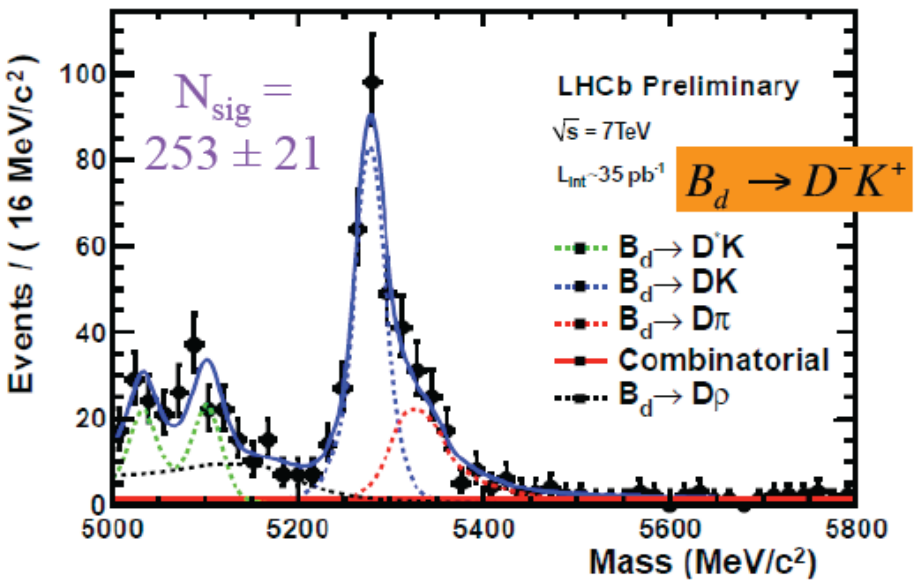
- First step in measuring structure of B_s semileptonic decays, fractions to D_s, D_s*, D_{sJ}, etc..

See Carson's parallel session talk

b Fractions (LHCb)

- Important to set normalization scale for $\mathcal{B}$'s
- f_s/f_d using hadronic decays

$B_d \to D^- K^+$, $B_s \to D_s^- \pi^+$, $B_s \to D_s^- \pi^+$



$$f_s / f_d = 0.245 \pm 0.017 \pm 0.018 \pm 0.018$$

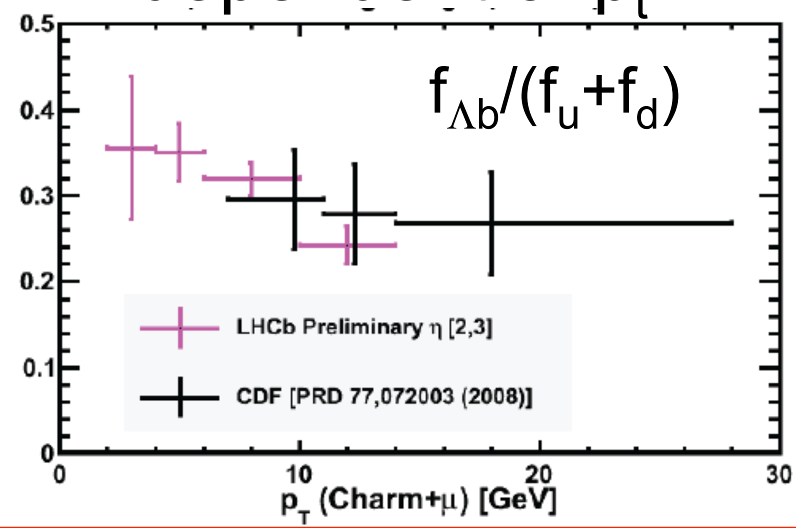
Theory error

- Using Semileptonics:

$b \to (D^o, D^+, D_s, \Lambda_b) X\mu\upsilon$

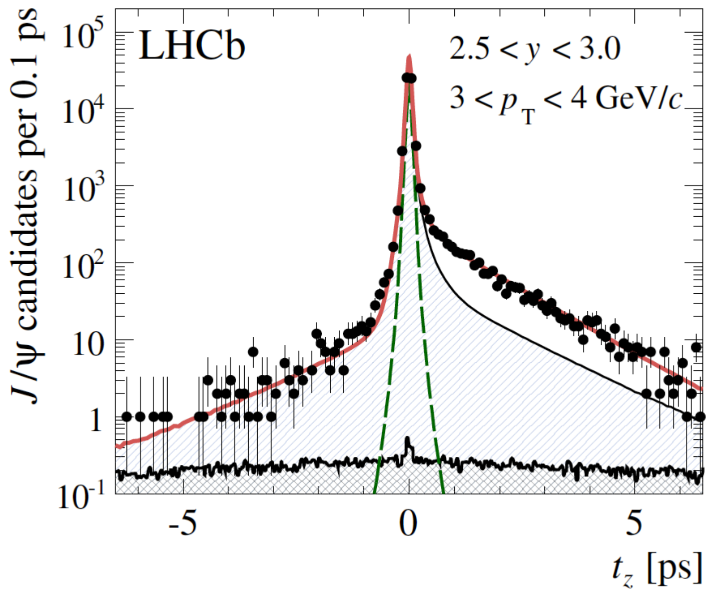
$$f_s / f_d = 0.272 \pm 0.008^{+0.024}_{-0.022}$$

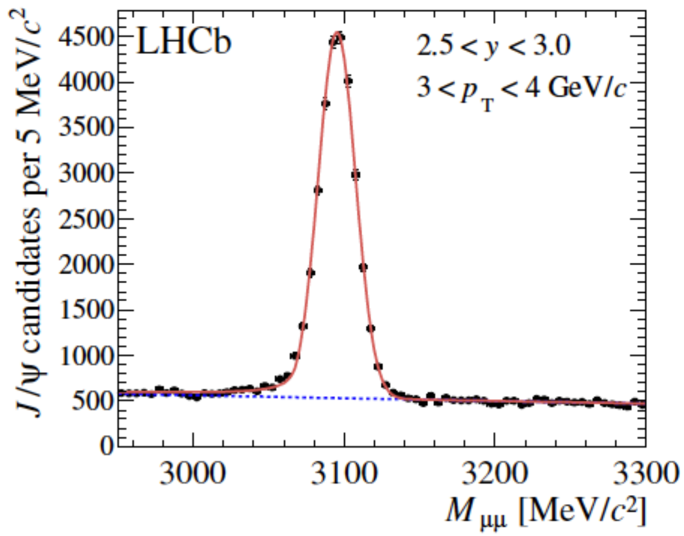
- independent of p_t



$$f_{\Lambda_b} / \left(f_d + f_u\right) = 0.401 \pm 0.019 \pm 0.106$$
$$-\left(12.0 \pm 2.5 \pm 1.2\right) \times 10^{-3} \times p_t\,(GeV)$$

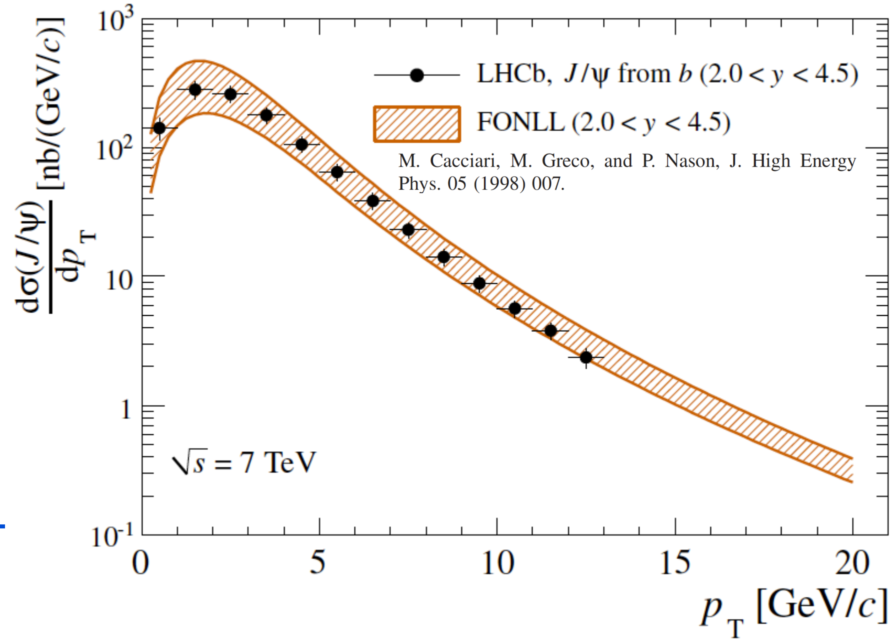
b xsect from b→J/ψX



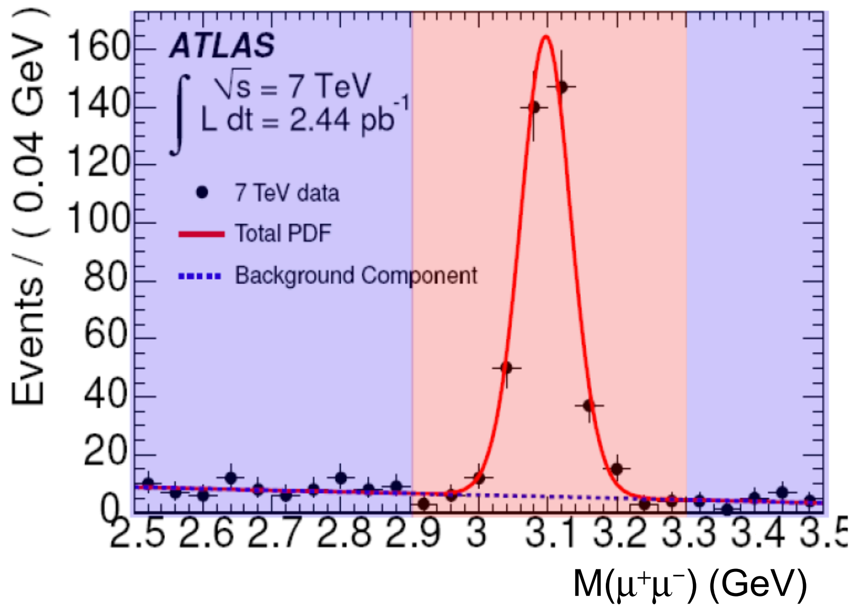


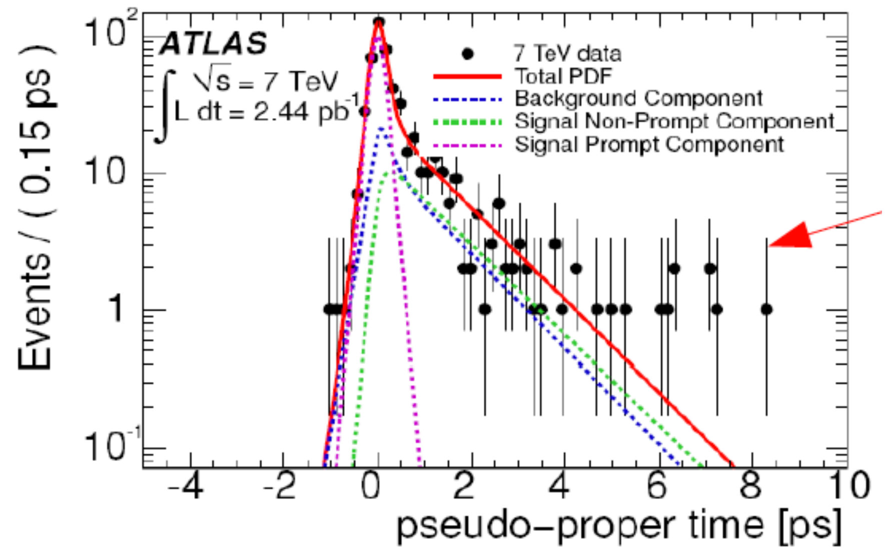
$$t_z = \frac{(z_{J/\psi} - z_{PV}) \times M_{J/\psi}}{p_z}$$

- Here use 5.2 pb^{-1}
- σ= 288±4±48 μb

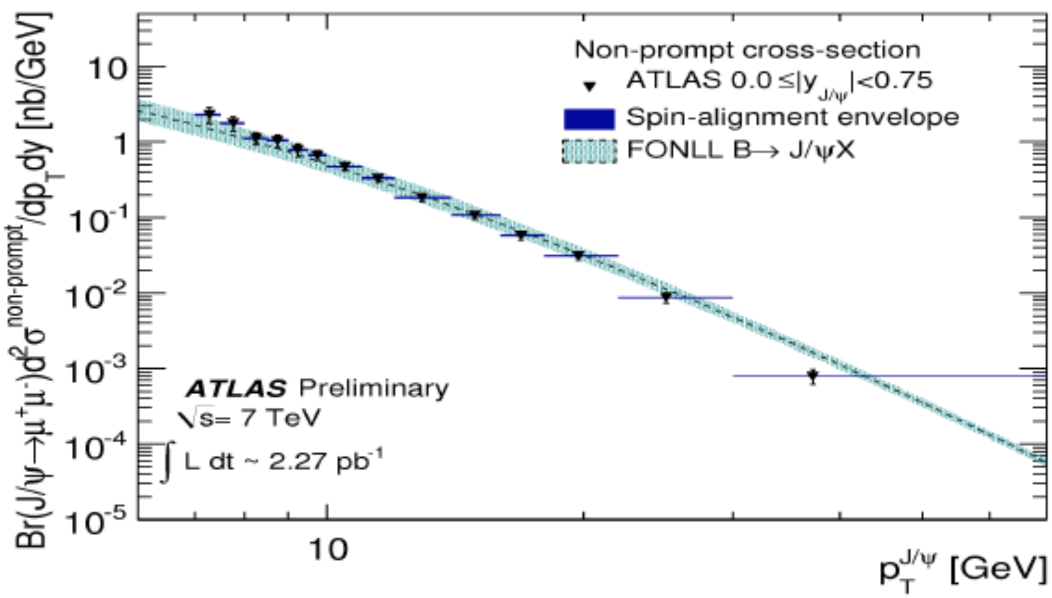


ATLAS σ from b→J/ψX

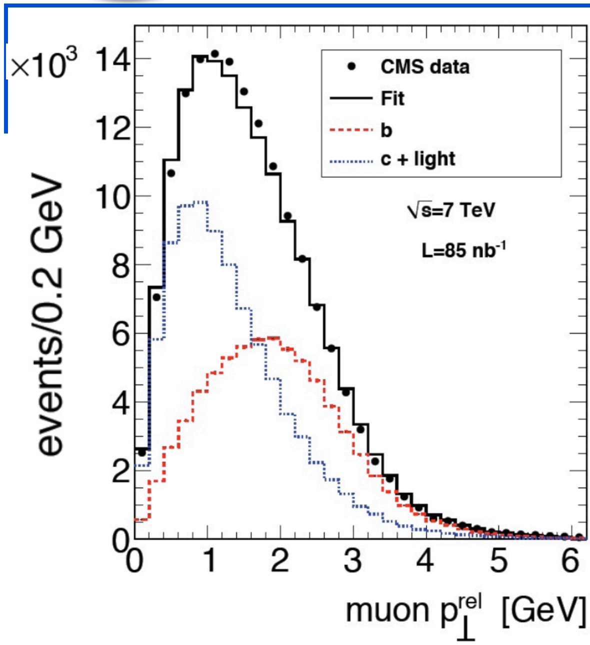




- ATLAS also in agreement with FONLL for p_t>5 GeV/c

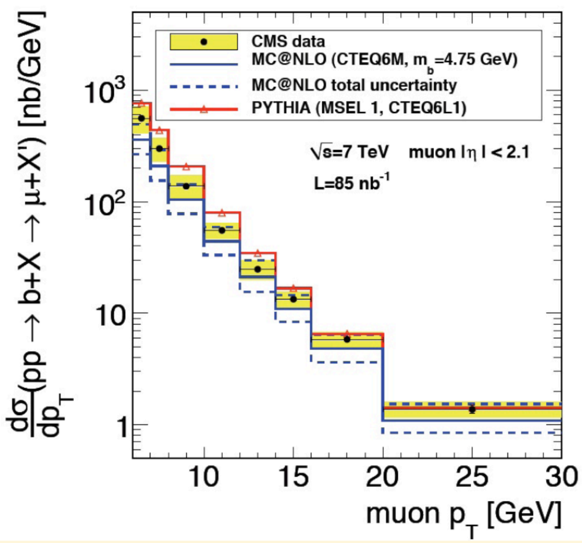


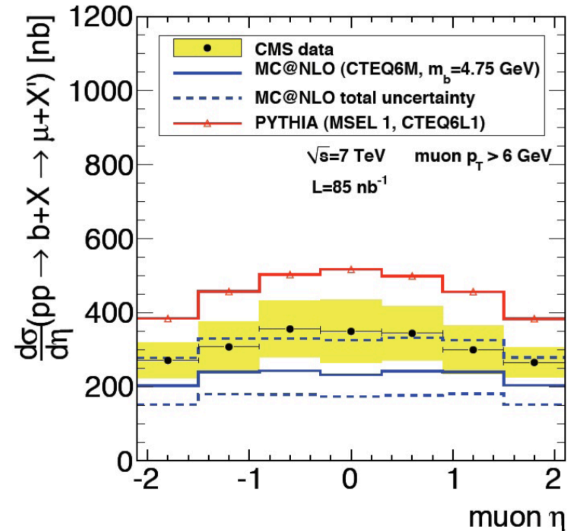
CMS σ from b→Xμν



$$\sigma = 1.32 \pm 0.01(\mathrm{stat}) \pm 0.30(\mathrm{syst}) \pm 0.15(\mathrm{lumi})\ \mu\mathrm{b}$$

$$\sigma_{MC@NLO} = 0.84^{+0.36}_{-0.19}(\mathrm{scale}) \pm 0.08(\mathrm{m_b}) \pm 0.04(\mathrm{pdf})\mu\mathrm{b} \qquad \sigma_{PYTHIA} = 1.8\mu\mathrm{b}$$





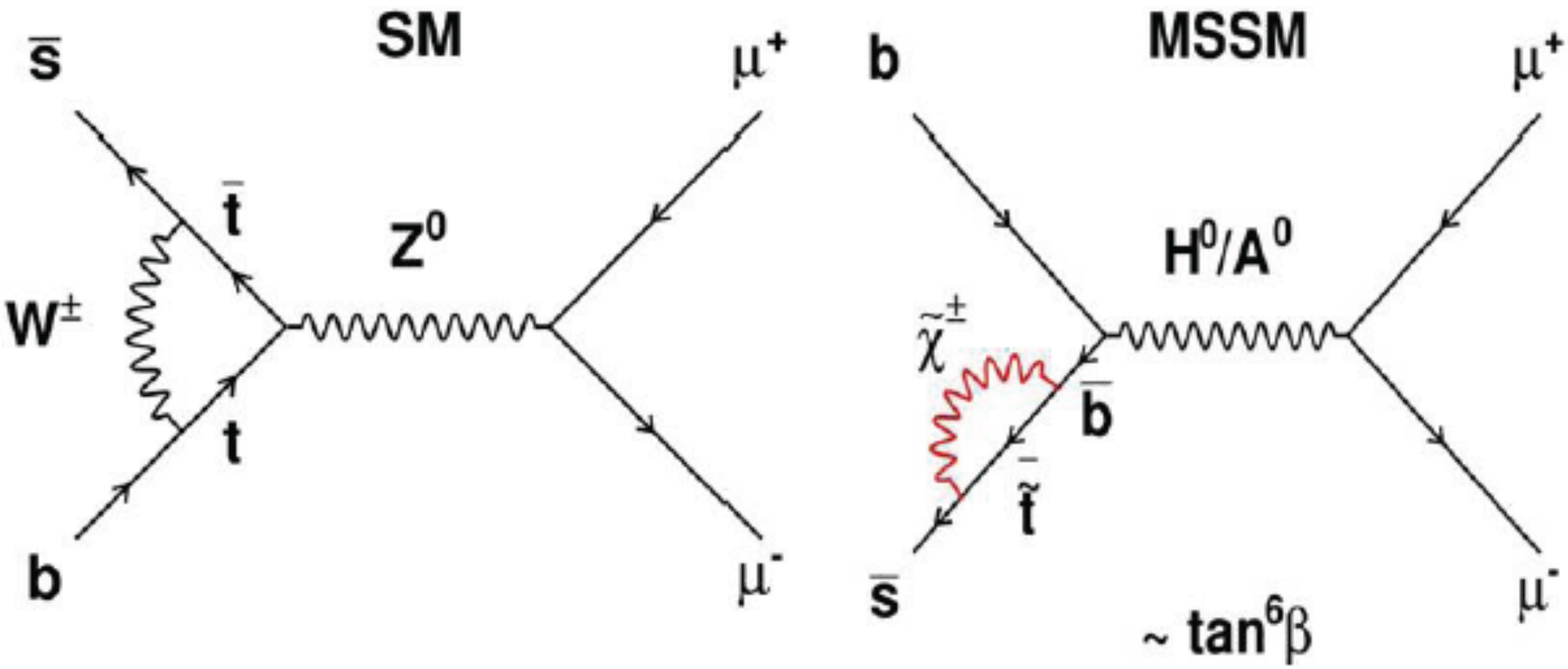
- In all cases generally good agreement with NLO calculations, within large errors

See parallel session talk of S. De Visscher

Progress on “Key” Measurements

$B_s \rightarrow \mu^+\mu^-$

- SM branching ratio is small, NP can make large contributions.

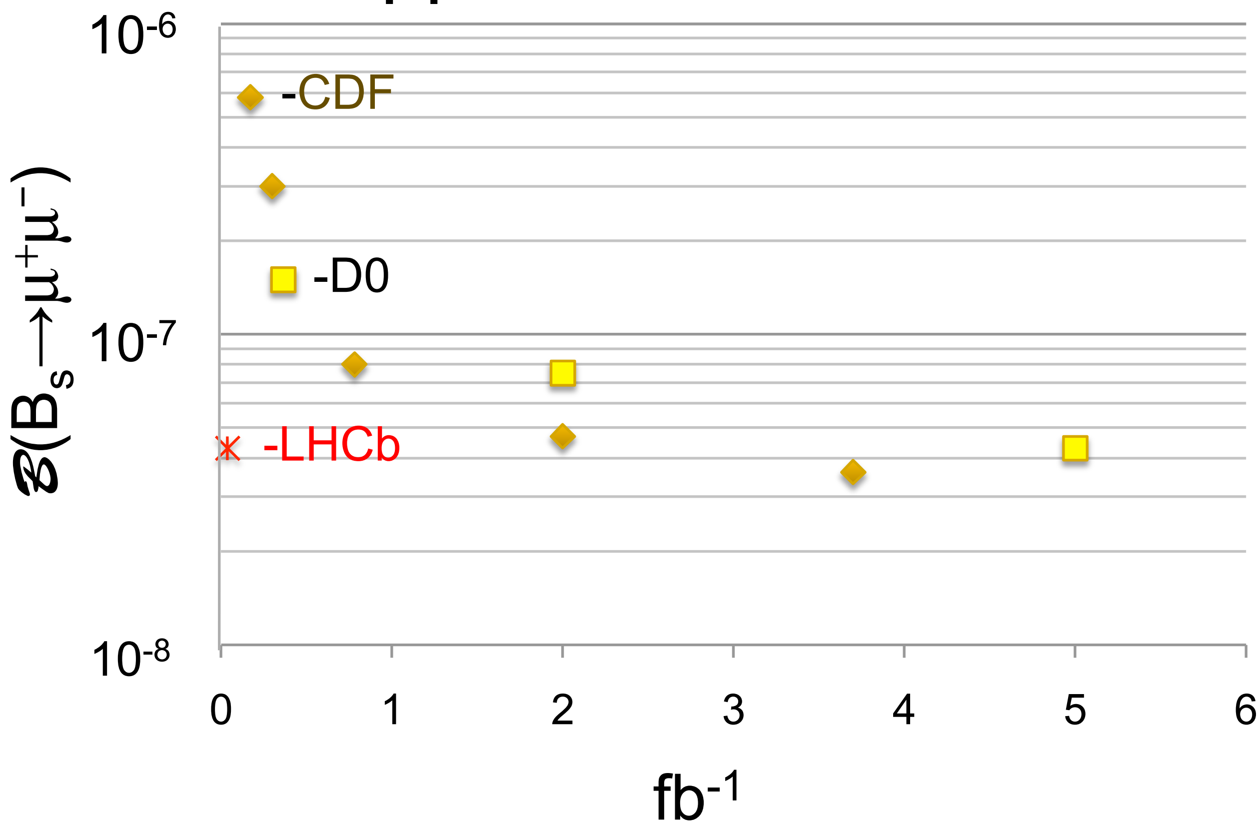


- Many NP models possible, not just Super-Sym

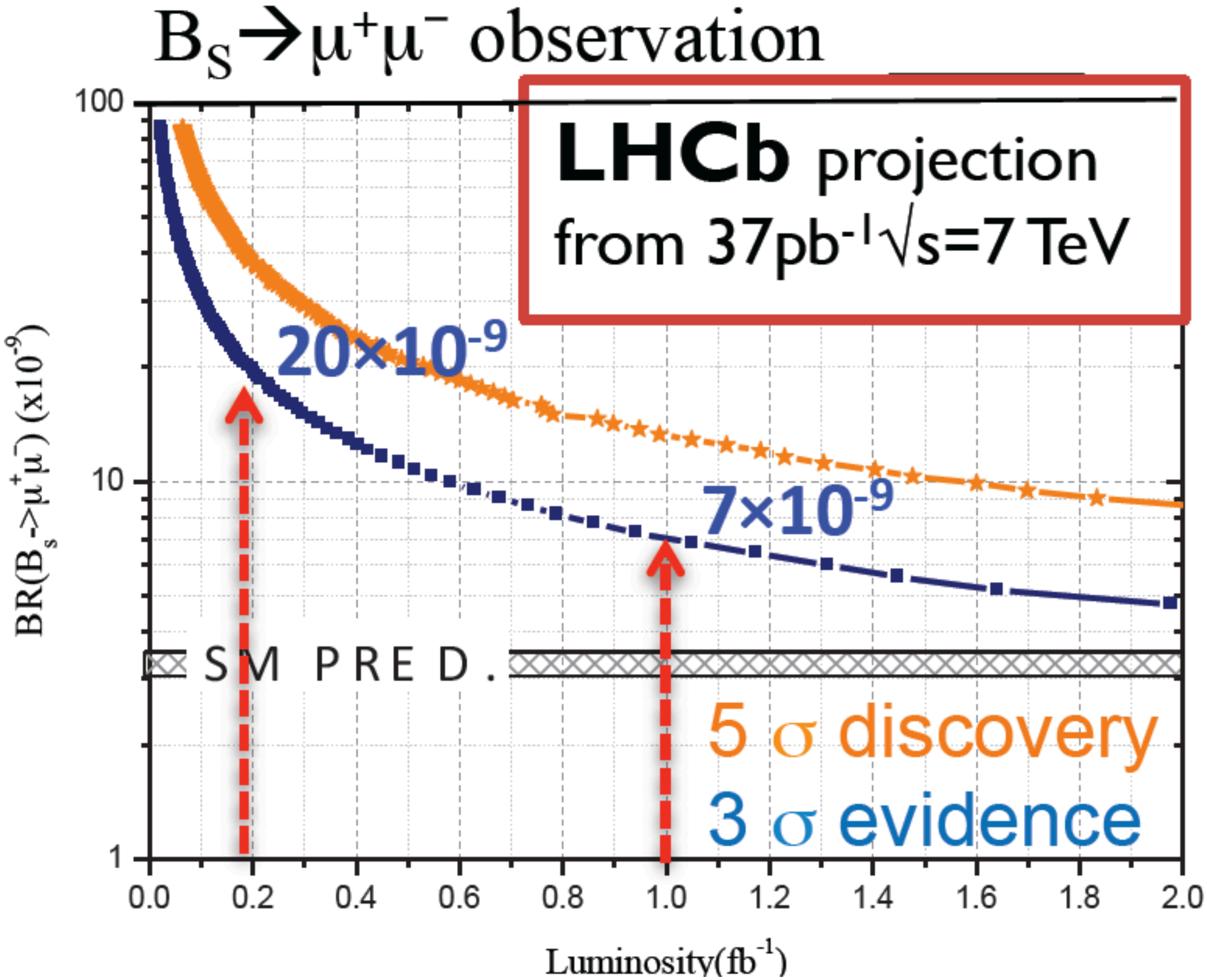
$B_s \rightarrow \mu^+\mu^-$ Current Status

LHCb 1 year old, 37 pb^{-1}

Upper limits at 90% c.l.



$B_s \to \mu^+\mu^-$ Short Term Projection



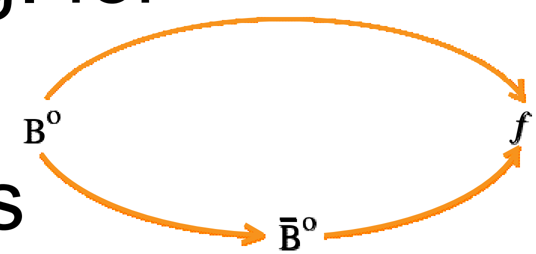
- CMS is also interested in this measurement

CP Violation

- CPV in appears in the difference between $B \rightarrow f$ & $\overline{B} \rightarrow \overline{f}$; for CP eigenstates $f=\overline{f}$
- CP asymmetry, e.g. B^o decays is given by

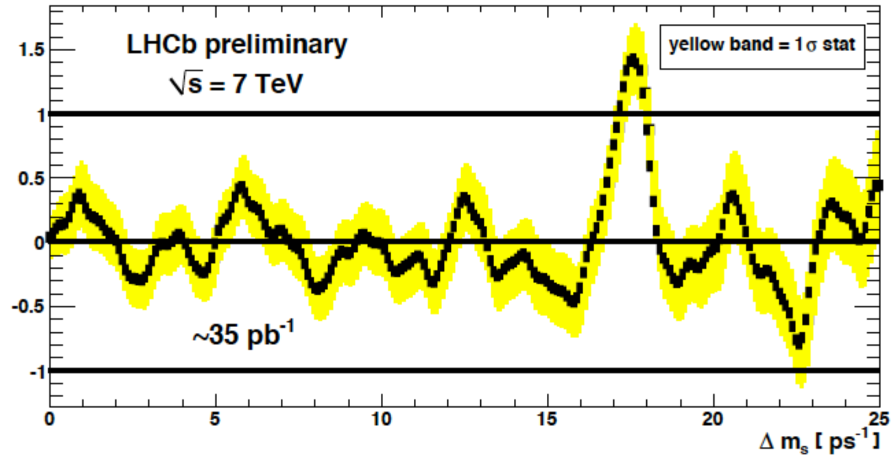
$$A_{CP} = \frac{\Gamma\left(\overline{B}^0 \rightarrow f\right) - \Gamma\left(B^0 \rightarrow f\right)}{\Gamma\left(\overline{B}^0 \rightarrow f\right) + \Gamma\left(B^0 \rightarrow f\right)} = \sin\left(2\Psi\right)\sin\left(\Delta m t\right)$$

- Ψ depends on decay mode, e.g. for $B^o \rightarrow J/\psi\ K_s$, $\Psi = \beta$.
- Need two interfering amplitudes one can be provided by mixing

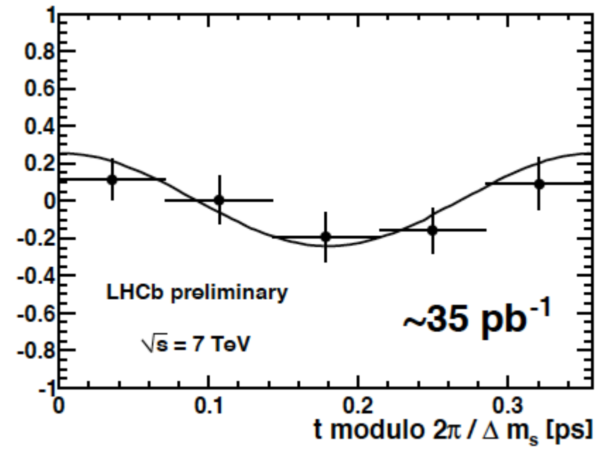


Measurement of Δm_s

- Amplitude Scan



A_{mix} vs time



- Use ~1400 fully hadronic B_s decays

See parallel session talk of Furcas

- LHCb: Δm_s = 17.63 ± 0.11 ± 0.04 ps^{-1}
- CDF: Δm_s = 17.77 ± 0.10 ± 0.07 ps^{-1} (PRL 97, 242003)
- Now ready for time-dependent CPV in B_s

CPV in $B_s \to J/\psi\phi$

- B_s is complicated because $\Delta\Gamma \neq 0$

$$\Gamma_{\bar{B}_s \to f}(t) = \frac{\mathcal{N}_f e^{-t/\tau(B_s)}}{4\tau(B_s)} \Big[\cosh\left(\frac{\Delta\Gamma_s t}{2}\right) + S_f \sin(\Delta m_s t) - C_f \cos(\Delta m_s t) + \mathcal{A}_f^{\Delta\Gamma} \sinh\left(\frac{\Delta\Gamma_s t}{2}\right) \Big],$$

$$\Gamma_{B_s \to f}(t) = \frac{\mathcal{N}_f e^{-t/\tau(B_s)}}{4\tau(B_s)} \Big[\cosh\left(\frac{\Delta\Gamma_s t}{2}\right) - S_f \sin(\Delta m_s t) + C_f \cos(\Delta m_s t) + \mathcal{A}_f^{\Delta\Gamma} \sinh\left(\frac{\Delta\Gamma_s t}{2}\right) \Big],$$

- Here $S_f=\sin(2\beta_s)$, $C_f=0$, $A_f^{\Delta\Gamma}=-\cos(2\beta_s)$,
- $\beta_s = \arg\left(-V_{ts}V_{tb}^*/V_{cs}V_{cb}^*\right)$ in SM $\beta_s=-0.018$, thus a good place for NP to appear
- $J/\psi\phi$ is not a CP eigenstate, so do ∠ analysis

Decay Angles

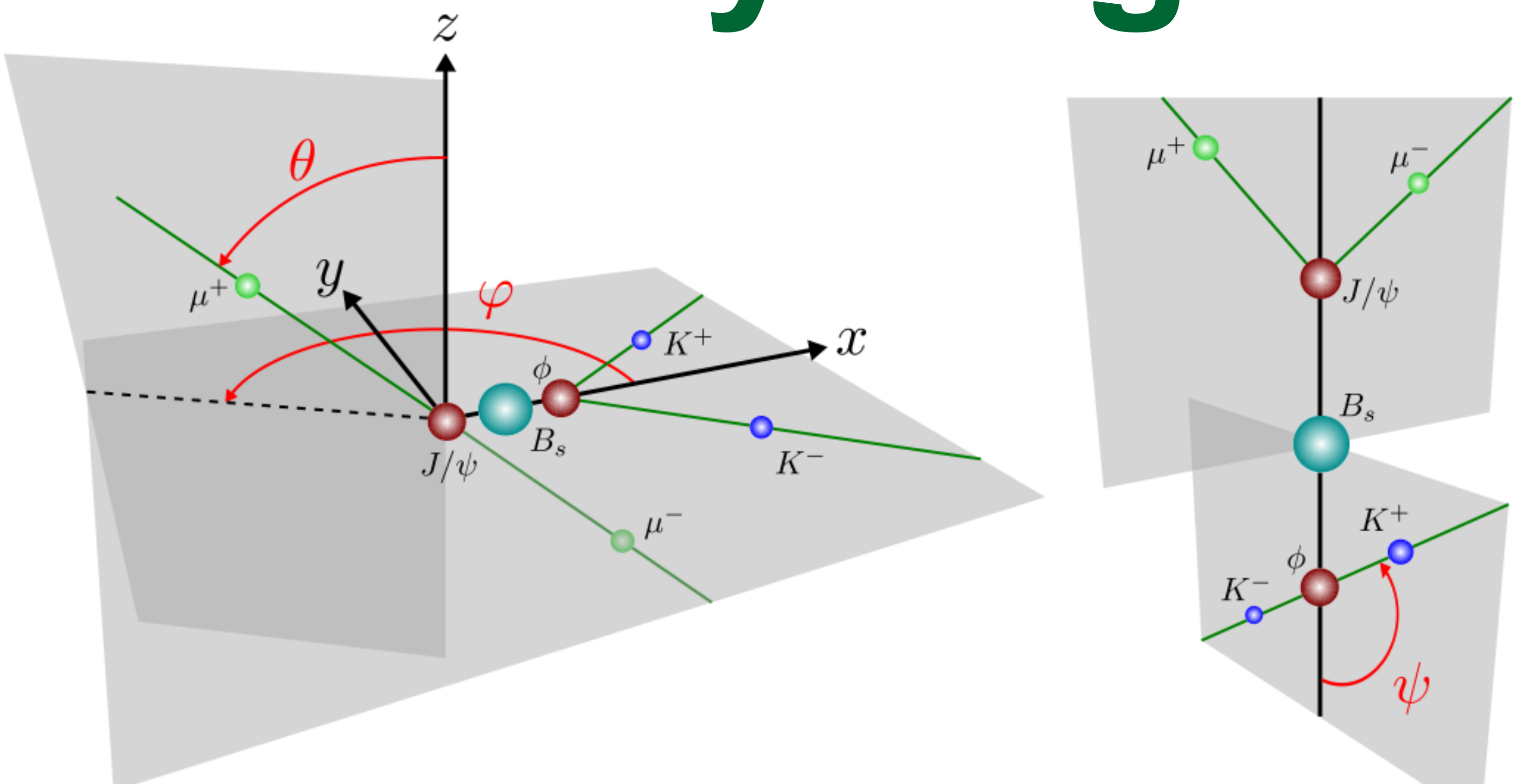
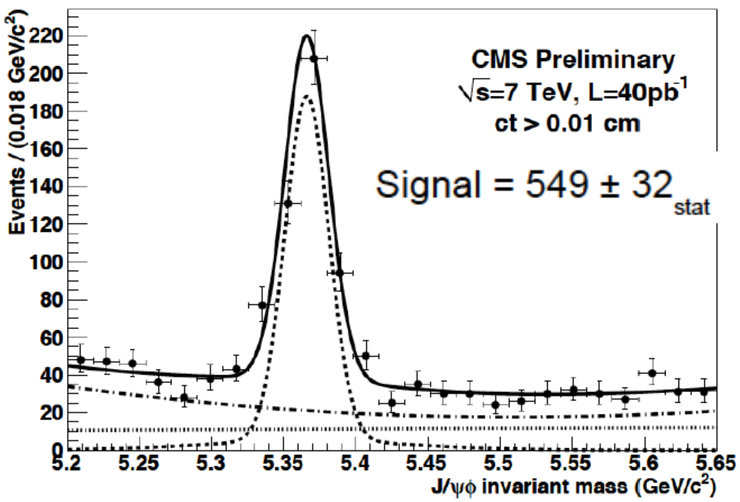
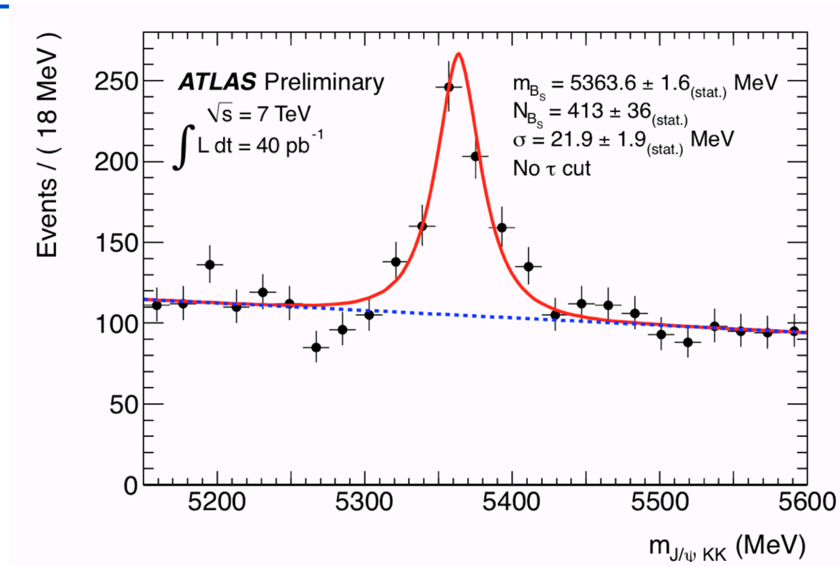
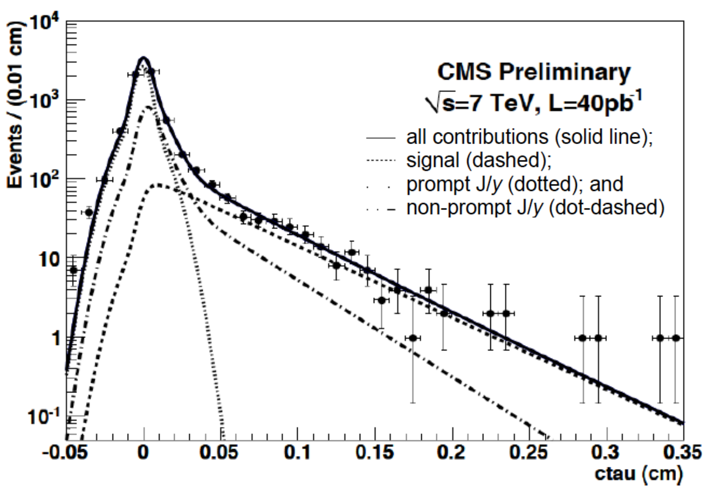


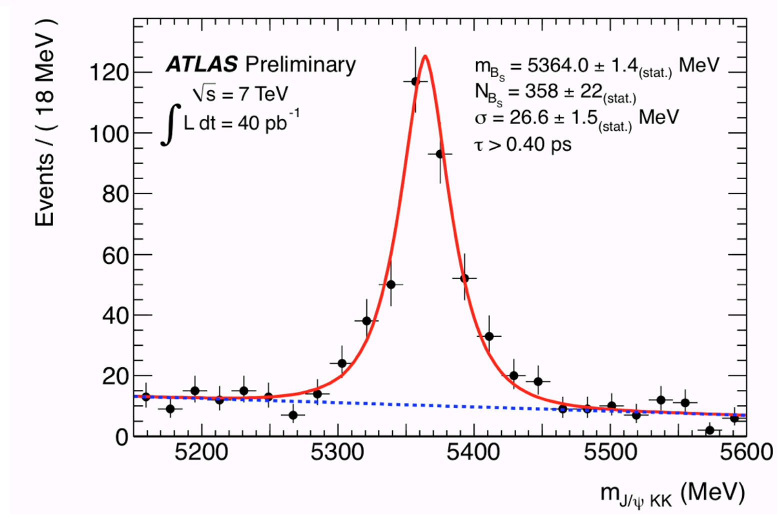
Figure 6: Angle definition: θ is the angle formed by the positive lepton (ℓ^+) and the z axis, in the J/ψ rest frame. The angle φ is the azimuthal angle of ℓ^+ in the same frame. In the ϕ meson rest frame, ψ is the angle between $\vec{p}(K^+)$ and $-\vec{p}(J/\psi)$. The definition is the same whether a B_s^0 or a $\overline{B}_s^0$ decays.

Signals: ATLAS & CMS



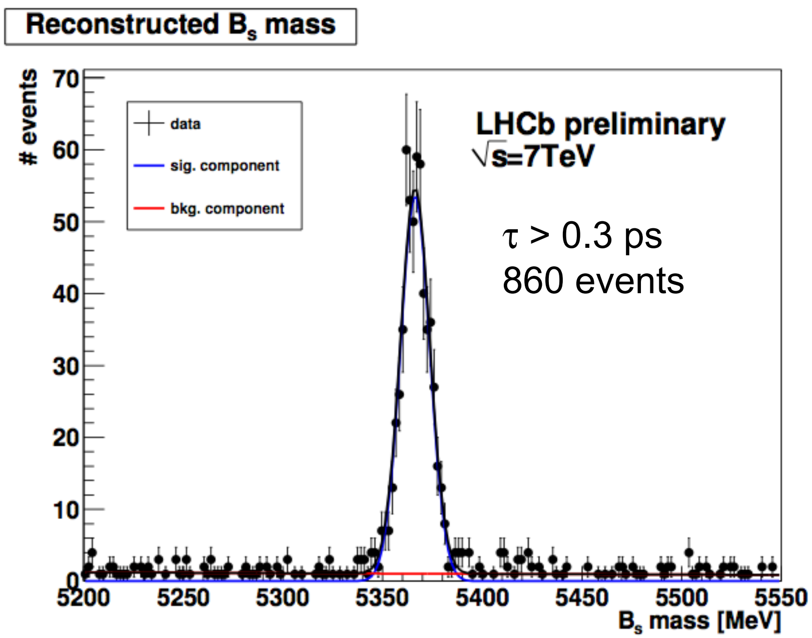


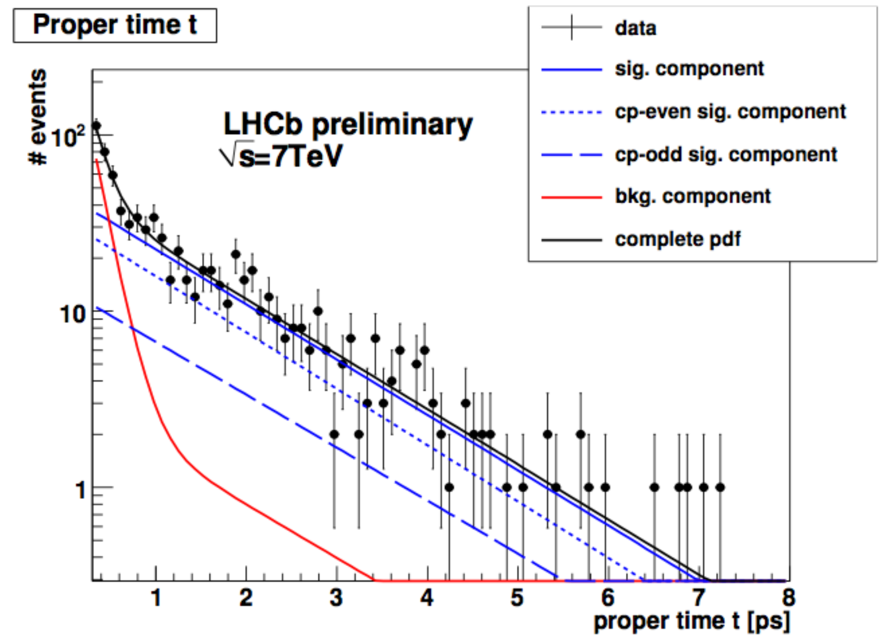


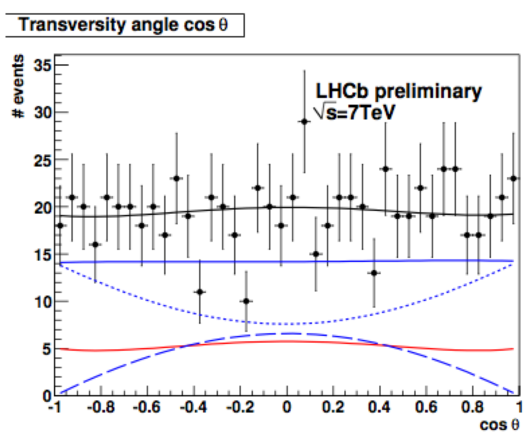


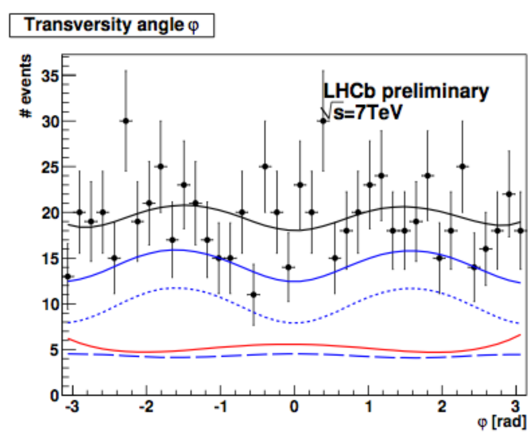

If you can read this THANK A TEACHER

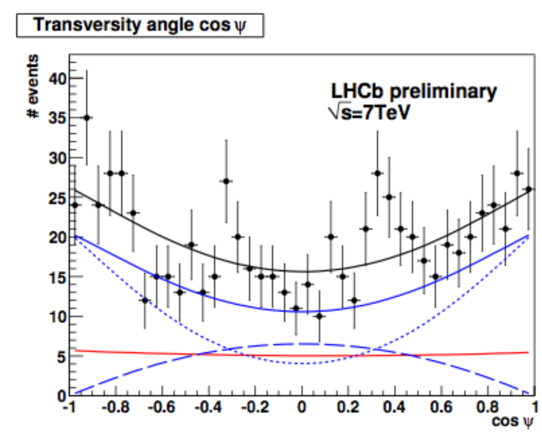
LHCb data


Reconstructed B_s mass
events
data
sig. component
bkg. component
LHCb preliminary
√s=7TeV
τ > 0.3 ps
860 events
B_s mass [MeV]


Proper time t
events
LHCb preliminary
√s=7TeV
data
sig. component
cp-even sig. component
cp-odd sig. component
bkg. component
complete pdf
proper time t [ps]

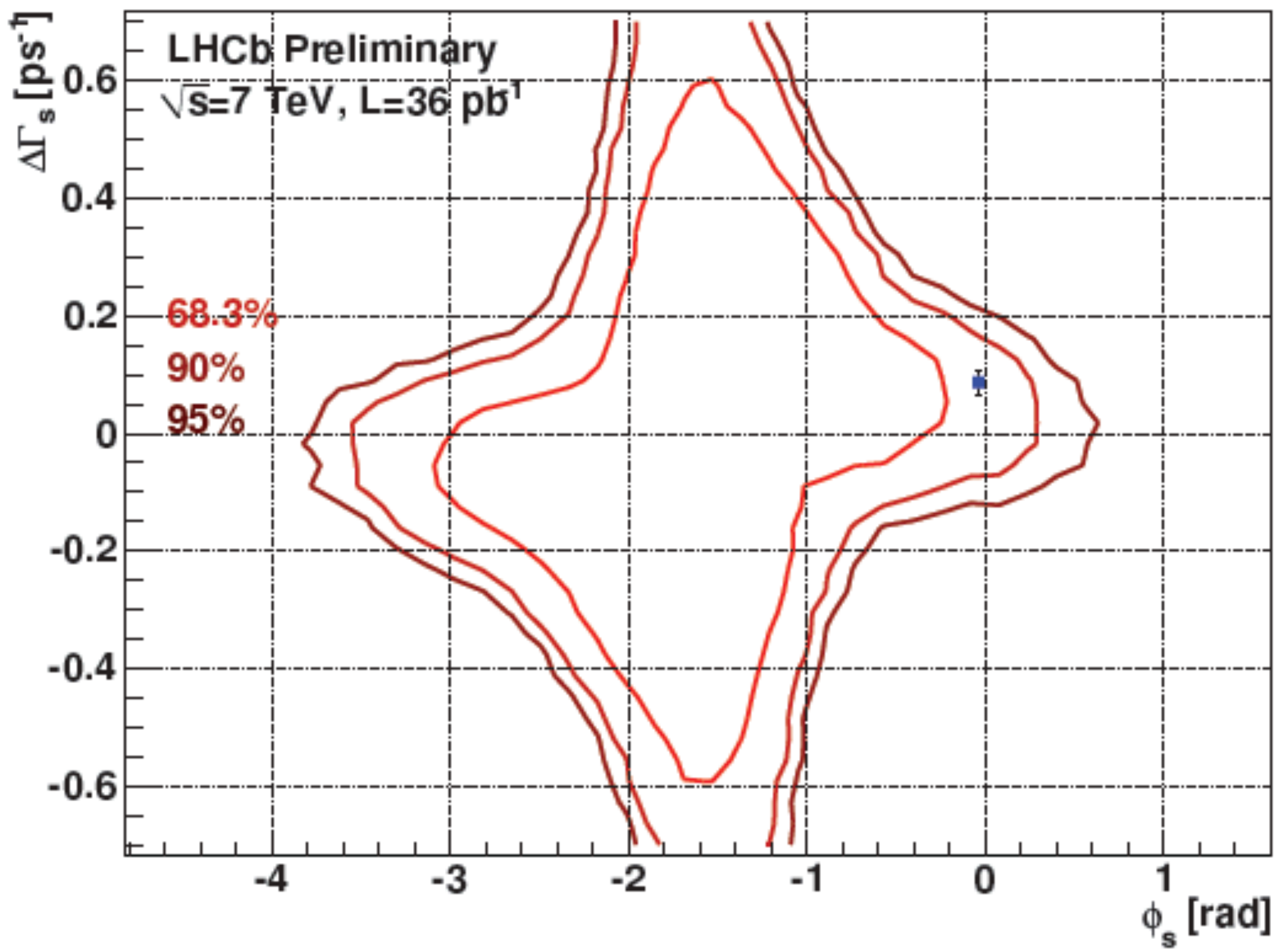

Transversity angle cos θ
events
LHCb preliminary
√s=7TeV
cos θ


Transversity angle φ
events
LHCb preliminary
√s=7TeV
φ [rad]

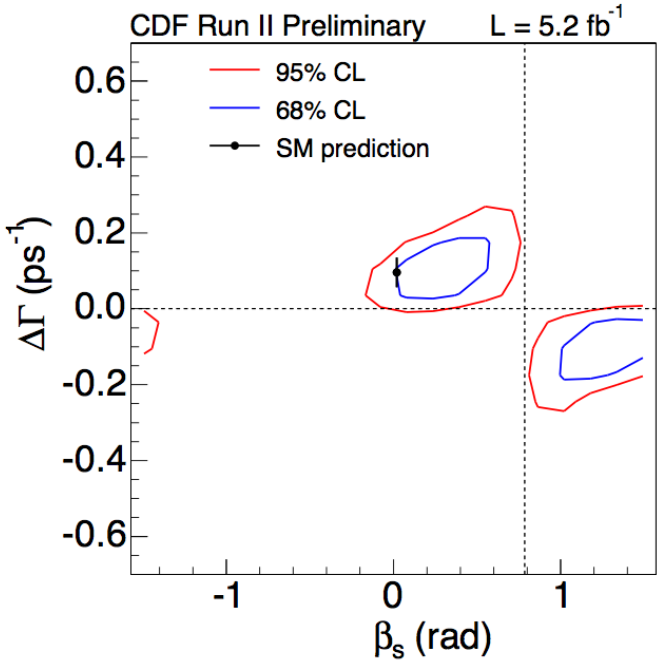

Transversity angle cos ψ
events
LHCb preliminary
√s=7TeV
cos ψ

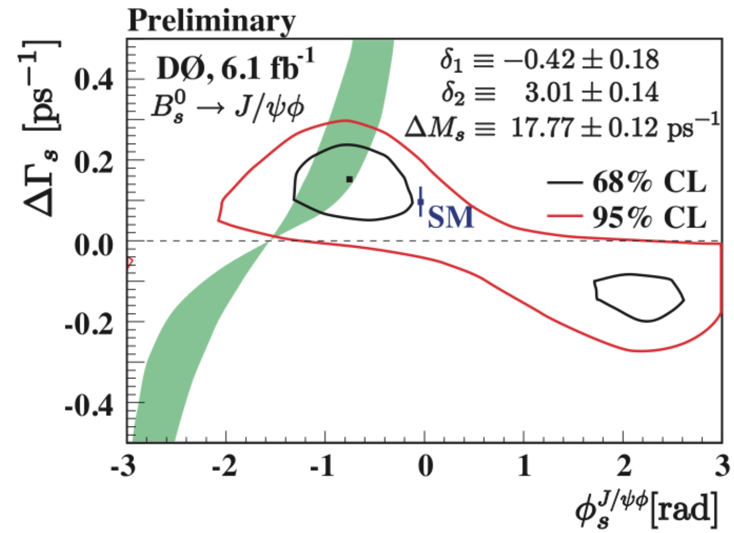
LHCb ϕ_s Measurement

- Confidence Level scan
- 1.2 σ from SM
- Using opposite side flavor tagging only



Comparison with CDF/D0





$\beta_s = -\phi_s$

	Signal yield (lumi)	$\phi_s^{J/\psi\phi}$ (rad)	Ref.
CDF	6 500 (5.2 pb^{-1})	$-0.54 \pm 0.50^{(*)}$	CDF Note 10206
DØ	3 400 (6.1 fb^{-1})	$-0.76^{+0.38}_{-0.36}$(stat) $\pm$ 0.02(syst)	DØ 6098-CONF

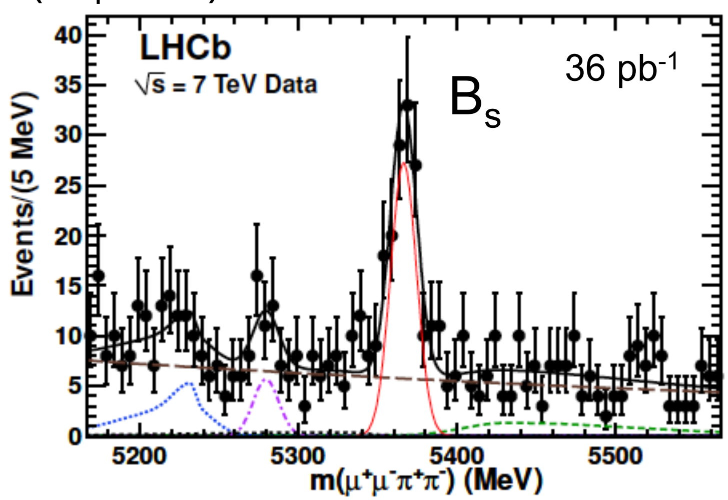
LHCb 860 (37 pb^{-1}) $-2.7 < \phi_s < -0.5$ @ 68% c.l.

1st Observation of $B_s \rightarrow J/\psi\, f_0(980)$

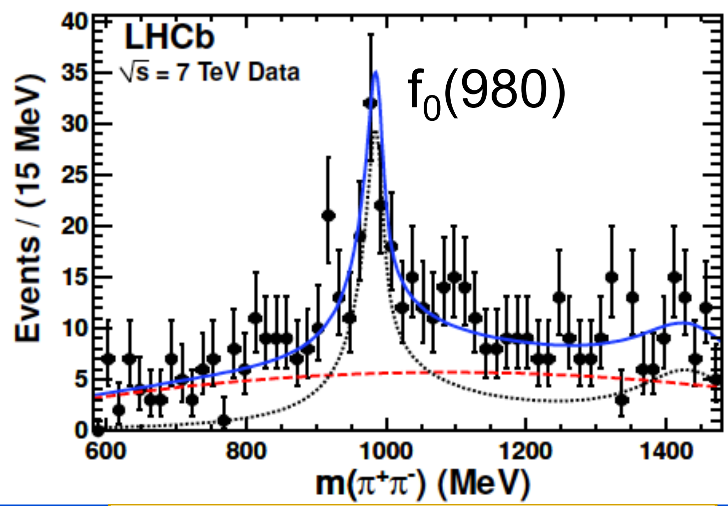
- In $B_s \rightarrow J/\psi\,\phi$ there is the possibility of an S-wave contamination under the ϕ. If this existed it could manifest itself as a 0^+ $\pi^+\pi^-$ system. [Stone & Zhang PRD 79, 074024 (2009)]. As a CP eigenstate could be used to measure ϕ_s without angular analysis
- Found by LHCb.

$$\frac{\Gamma\left(J/\psi f_0;\, f_0 \rightarrow \pi^+\pi^-\right)}{\Gamma\left(J/\psi\phi;\, \phi \rightarrow K^+K^-\right)} \approx 0.25$$

$m(J/\psi\,\pi^+\pi^-)$ within 90 MeV of 980 MeV



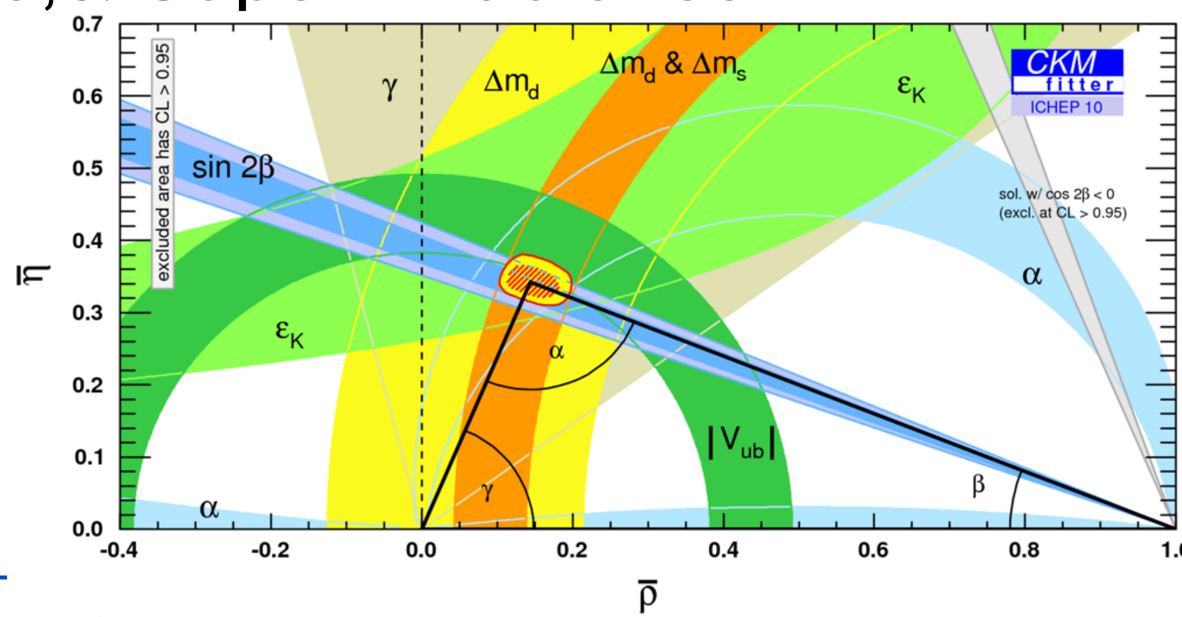
$m(\pi^+\pi^-)$ within 30 MeV of B_s mass



Confirmed by Belle & CDF

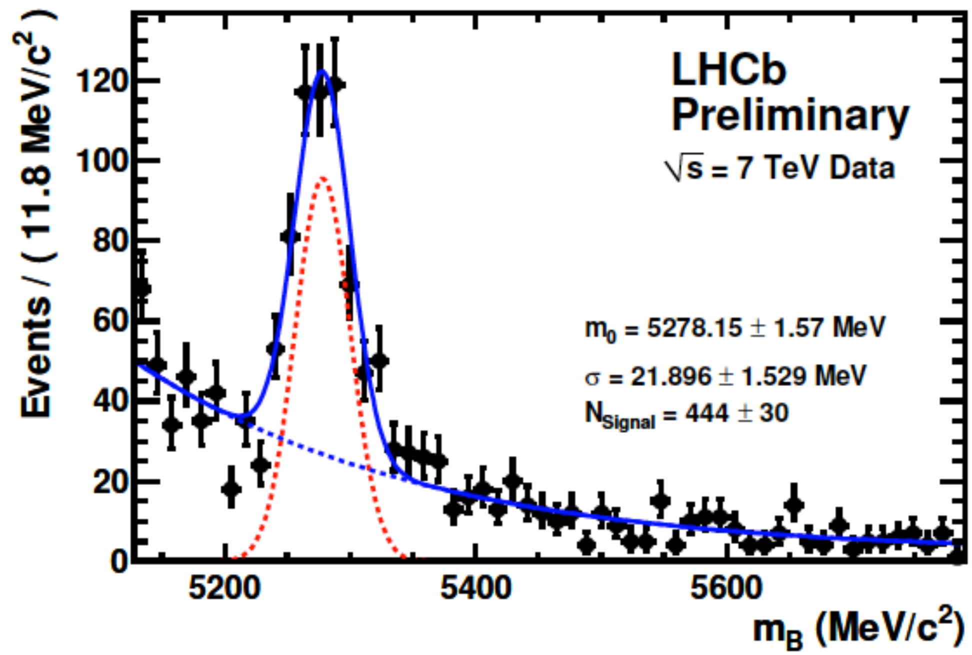
γ Projections

- Important goal.
- Expect error on γ of 3-4 using a combination of DK and D_sK modes in current LHCb
- Desire error of 1^o, to be pursued by LHCb Upgrade,& Super B factories



Measurement of γ using $B^- \rightarrow D^o K^-$

- One of several ways to determine γ
- Uses several modes with different D^o decays into $K^-\pi^+$, $K^+\pi^-$ (doubly Cabibbo suppressed), K^+K^-, $\pi^+\pi^-$
- Here $D^o \rightarrow K^-\pi^+$



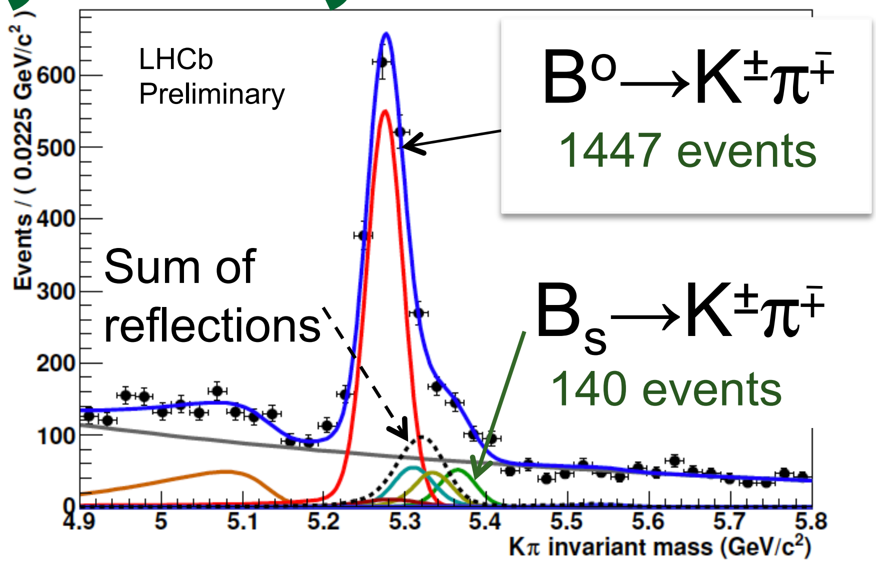
See parallel session talk of Whithead

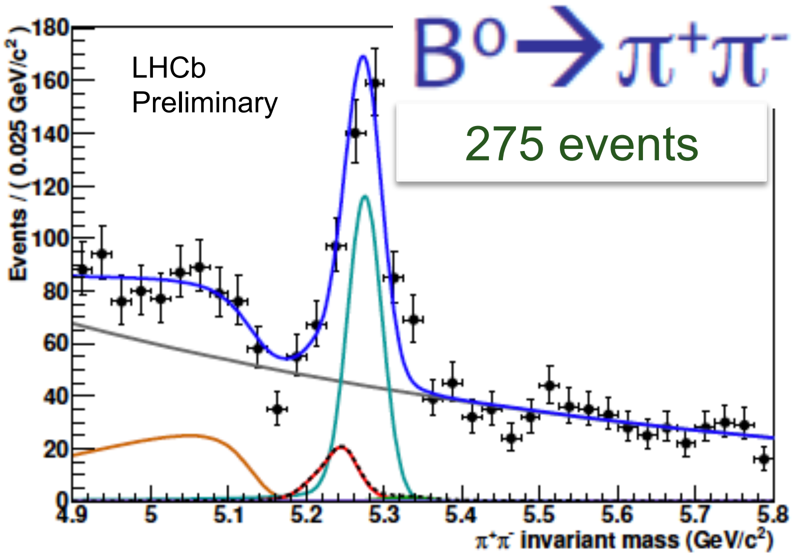
- Can also use $B \rightarrow hh$ coupled with SU(3)

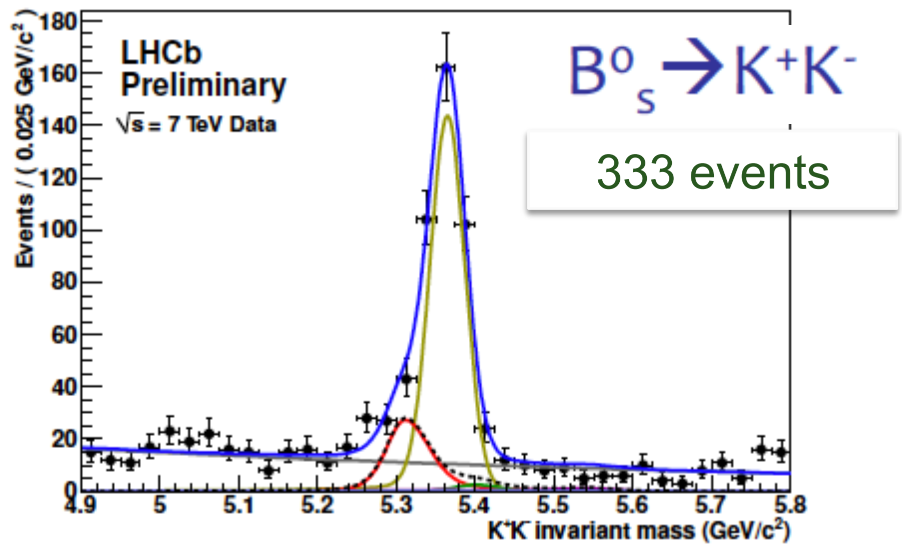
B→πK, ππ, KK

- 35 pb^{-1}, "loose cuts"
- LHCb will get as many Kπ in 0.5-0.7 fb^{-1} as Belle in 1000 fb^{-1}

$B(B\rightarrow\pi^+\pi^-)=5\times10^{-6}$

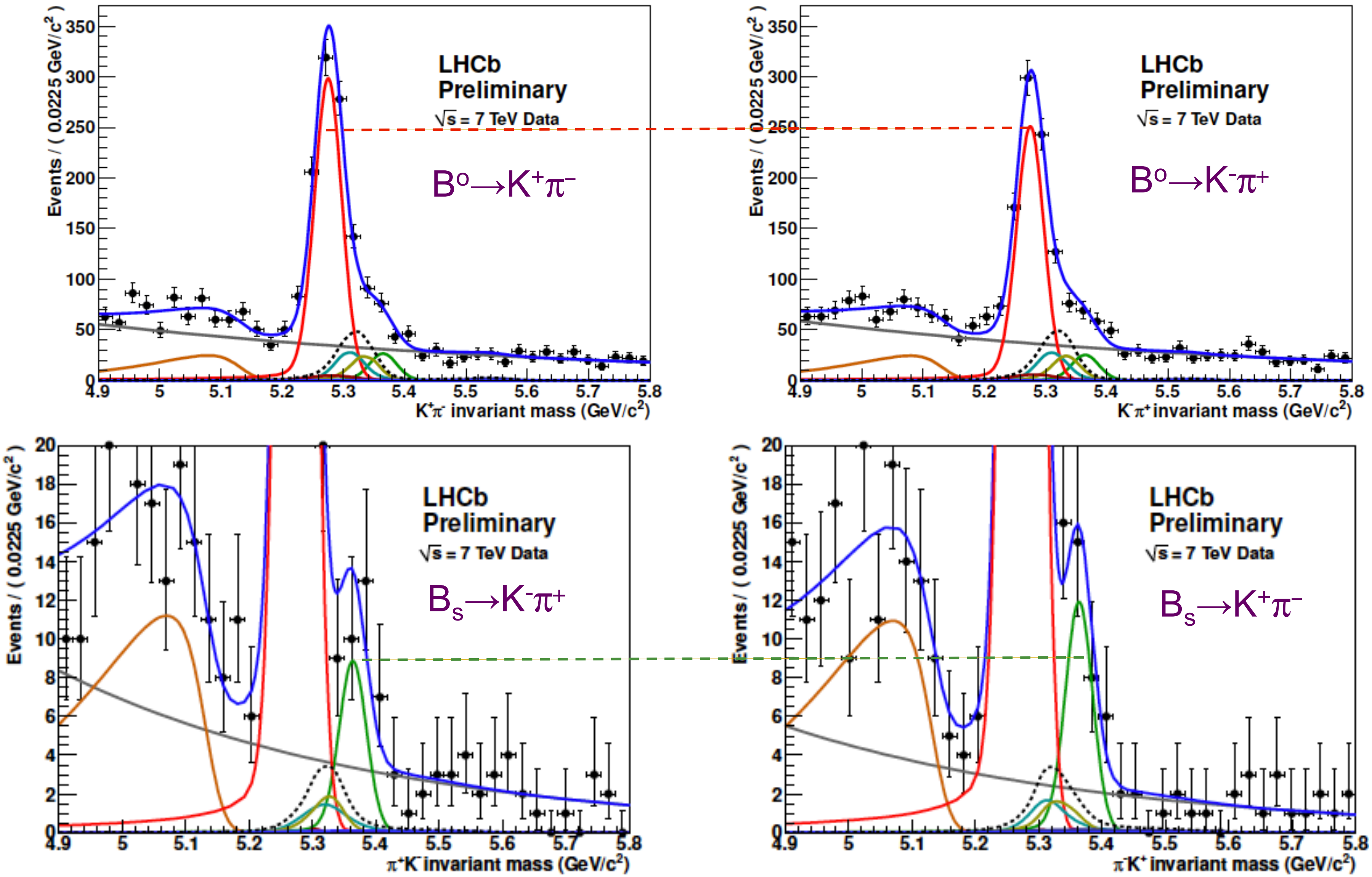







If you can read this
THANK A TEACHER

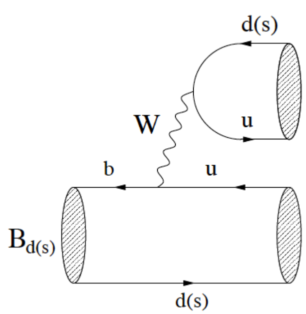
B→πK: CPV

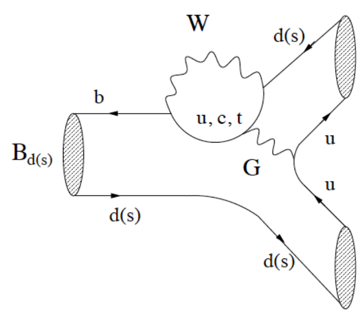

LHCb
Preliminary
√s = 7 TeV Data
B⁰→K⁺π⁻
B⁰→K⁻π⁺
Bs→K⁻π⁺
Bs→K⁺π⁻
Events / (0.0225 GeV/c²)
K⁺π⁻ invariant mass (GeV/c²)
K⁻π⁺ invariant mass (GeV/c²)
π⁺K⁻ invariant mass (GeV/c²)
π⁻K⁺ invariant mass (GeV/c²)

CP Asymmetries

- Obvious CPV in both B_s & B^o
- Using loose cuts $A_{CP}(B^o)$=-0.074±0.033±0.008
- (HFAG: -0.098±0.012)
- Using tight cuts $A_{CP}(B_s)$=0.15±0.19±0.02

  (CDF: 0.39±0.15±0.08 in 1 fb^{-1})
- These asymmetries are sensitive to new particles in loops

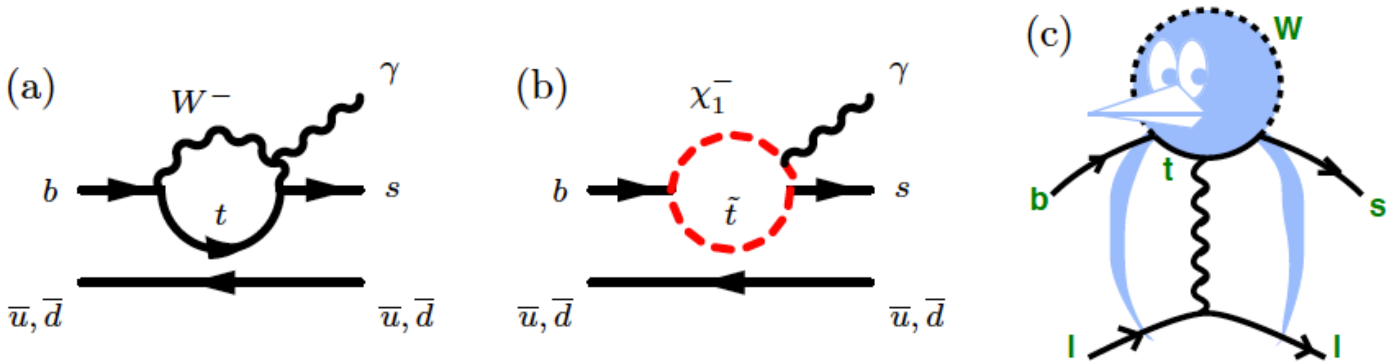




See parallel session talk of H Cliff

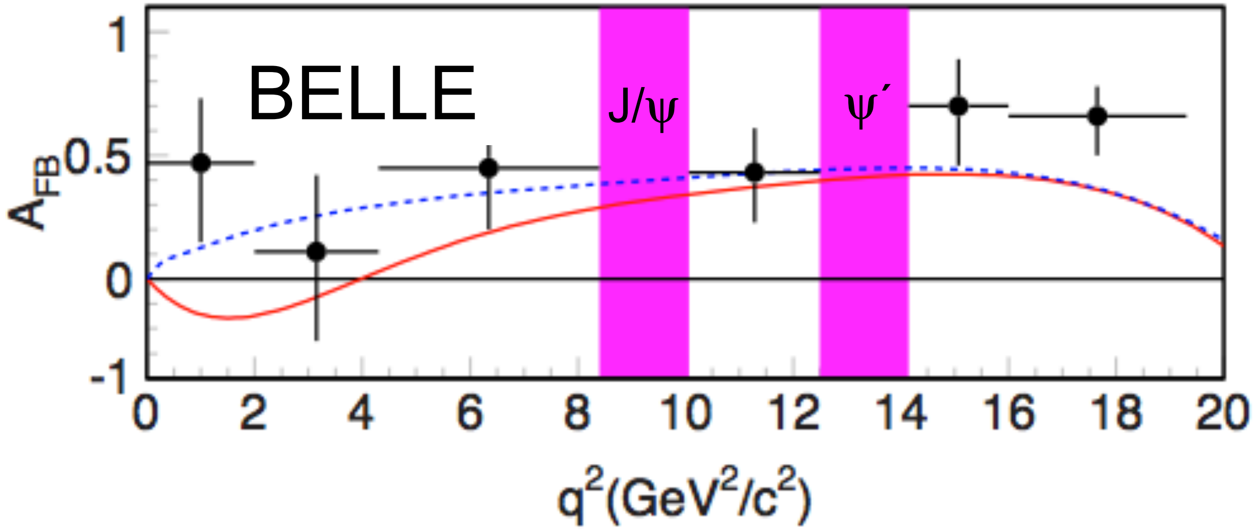
$B^o \rightarrow K^{*o} \mu^+\mu^-$

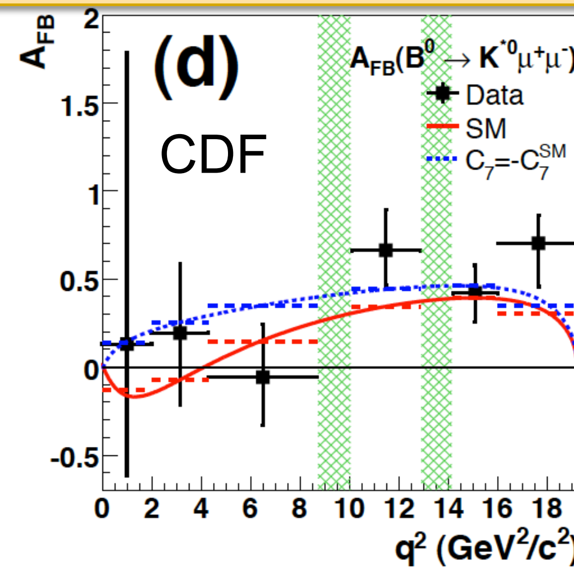
- Measuring the angular asymmetries in $B^o \rightarrow K^{*o} \mu^+\mu^-$. Sensitive to the presence of new particles



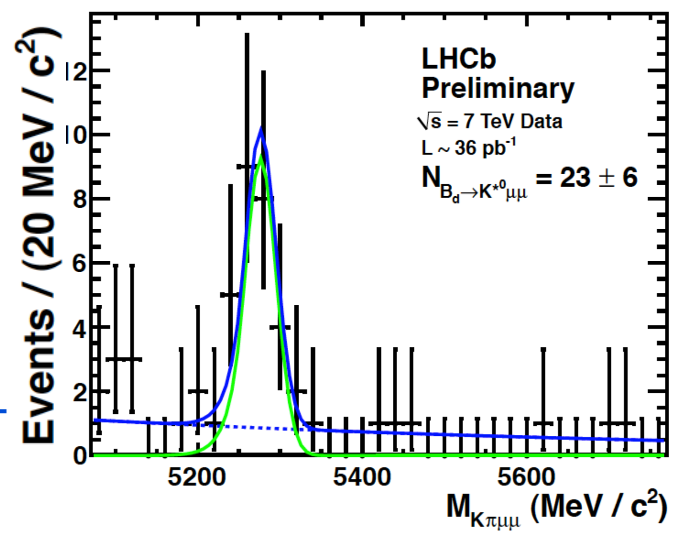
$B^o \to K^{*o}\mu^+\mu^-$ Results

Belle has 250 events in 605 fb^{-1}, CDF 101 in 4.4 fb^{-1}



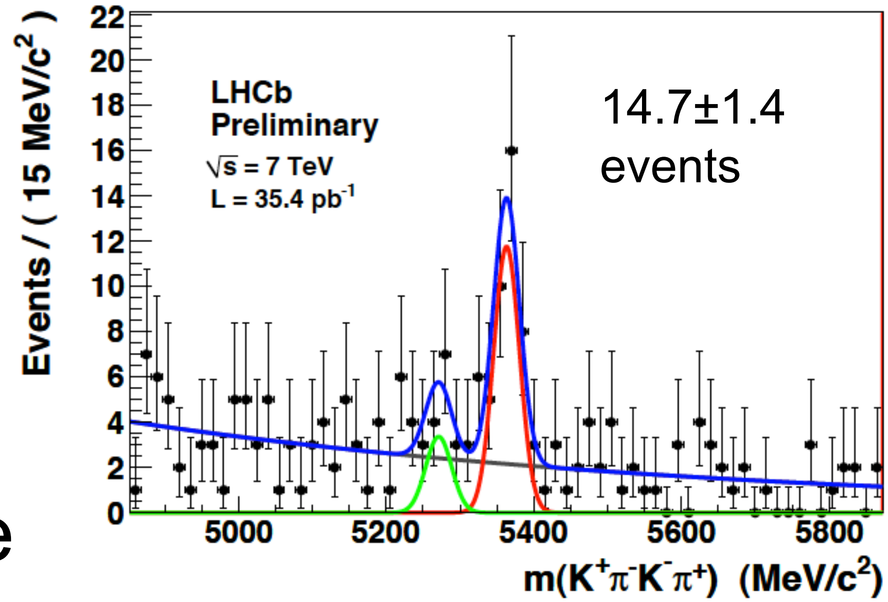


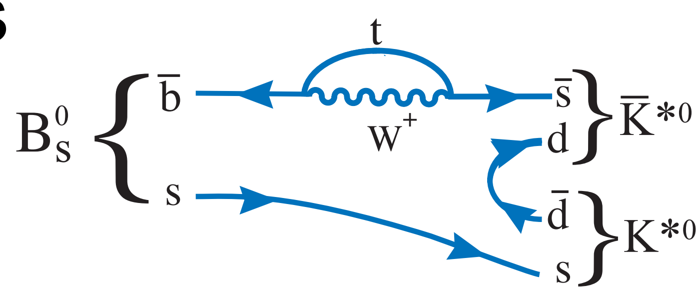
- Hint of NP, but lots more luminosity needed
- LHCb: First signal seen 23±6 events, S/B = 5



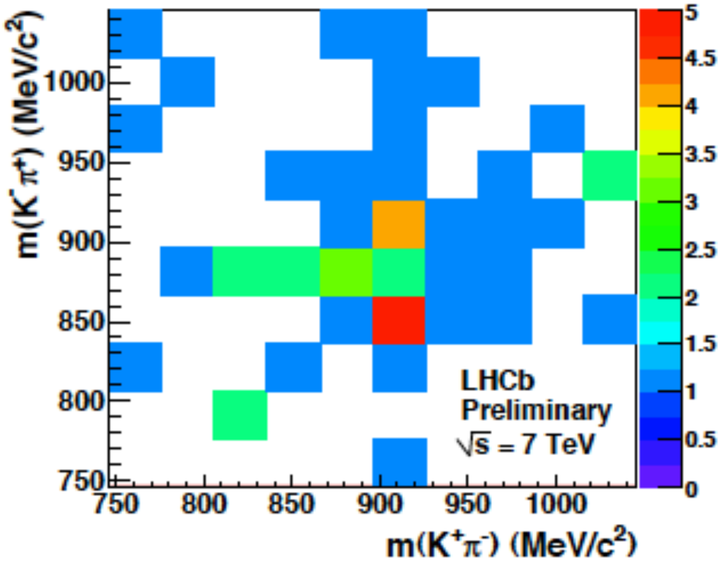
Signals Seen in Other Key Modes

- Two examples
- 1st Observation of $B_s \to \overline{K}^{*o} K^{*o}$
- Branching ratio ≈2×10^{-5}
- Will be used to measure CP violation in B_s gluonic Penguin modes

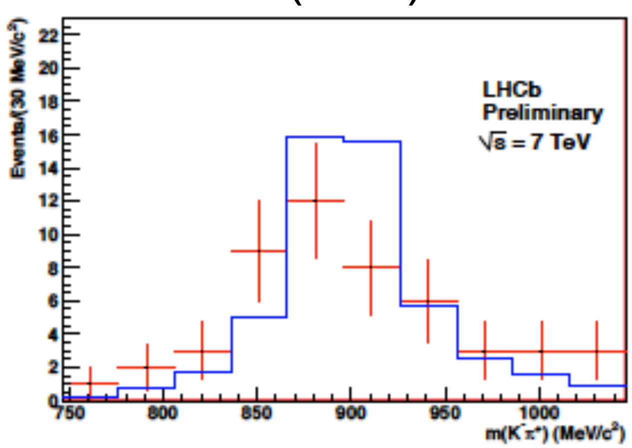




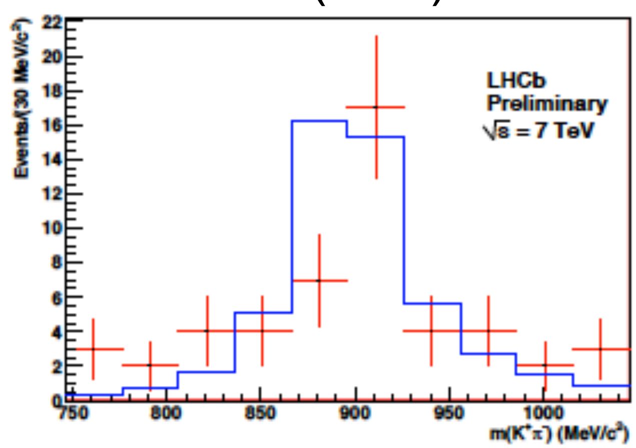
$B_s \rightarrow \bar{K}^{*o} K^{*o}$



m($K^-\pi^+$)

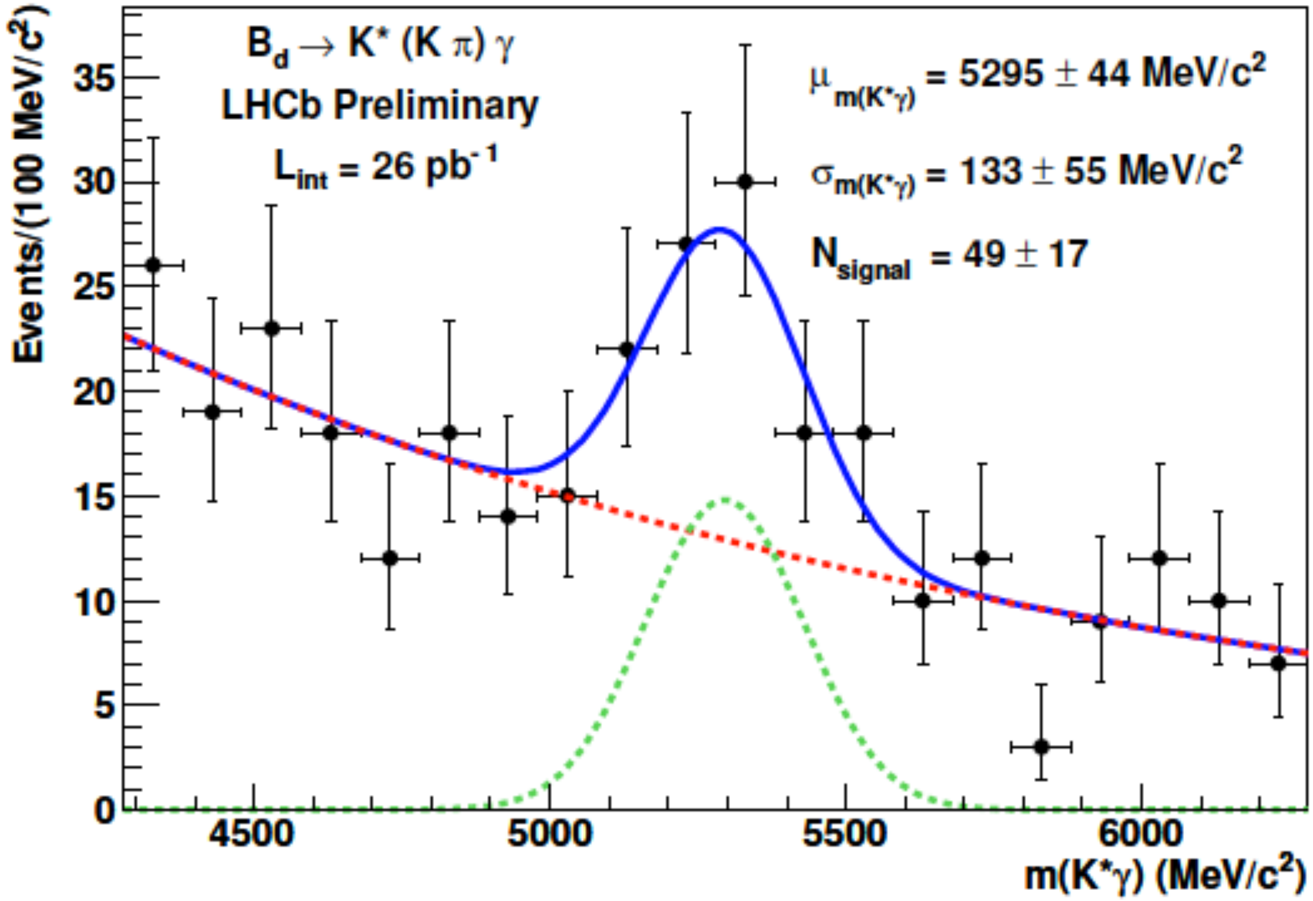


m($K^+\pi^-$)



$B^o \rightarrow K^{*o}\gamma$

- Looking forward to $B_s \rightarrow \phi\gamma$



Future Acts

- LHCb Upgrade: run at 10^{33} cm^{-2}/s (x5), double trigger efficiency on purely hadronic final states
- Super B factories
- Time scales are on the order of 6 years

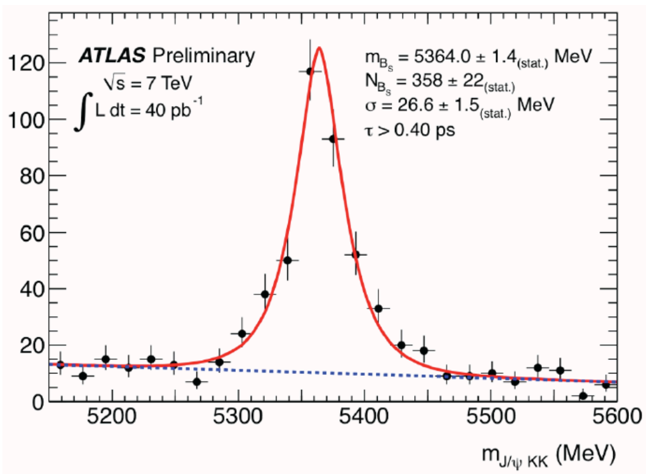
Conclusions

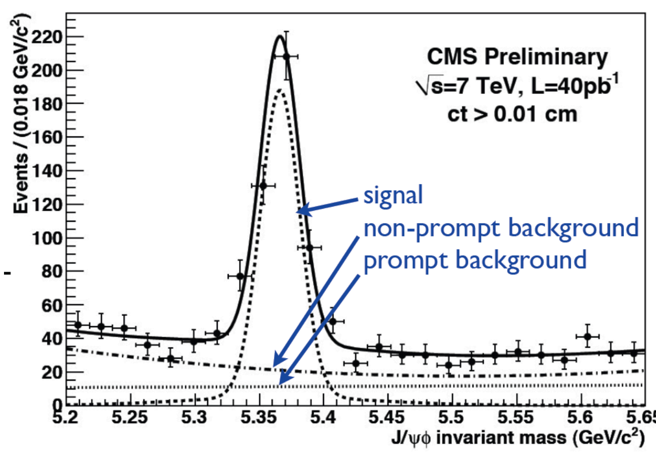
- B physics at the LHC is still a baby, perhaps we will reach adolescence this year
  - b cross-section has been measured & agree with expectations (with large errors)
  - fractions of b hadron species have been determined
- Well known decays have been seen, & LHCb has already observed new B_s decay modes
  - $B_s \to D_{s2}^{*+}(2573)\ X\ \mu\nu$, $J/\psi\ f_o(980)$, $K^{*o}K^{*o}$, D^oK^{*o}, $\psi'\phi$
- We are ready to search for and limit New Physics with the 2011 data

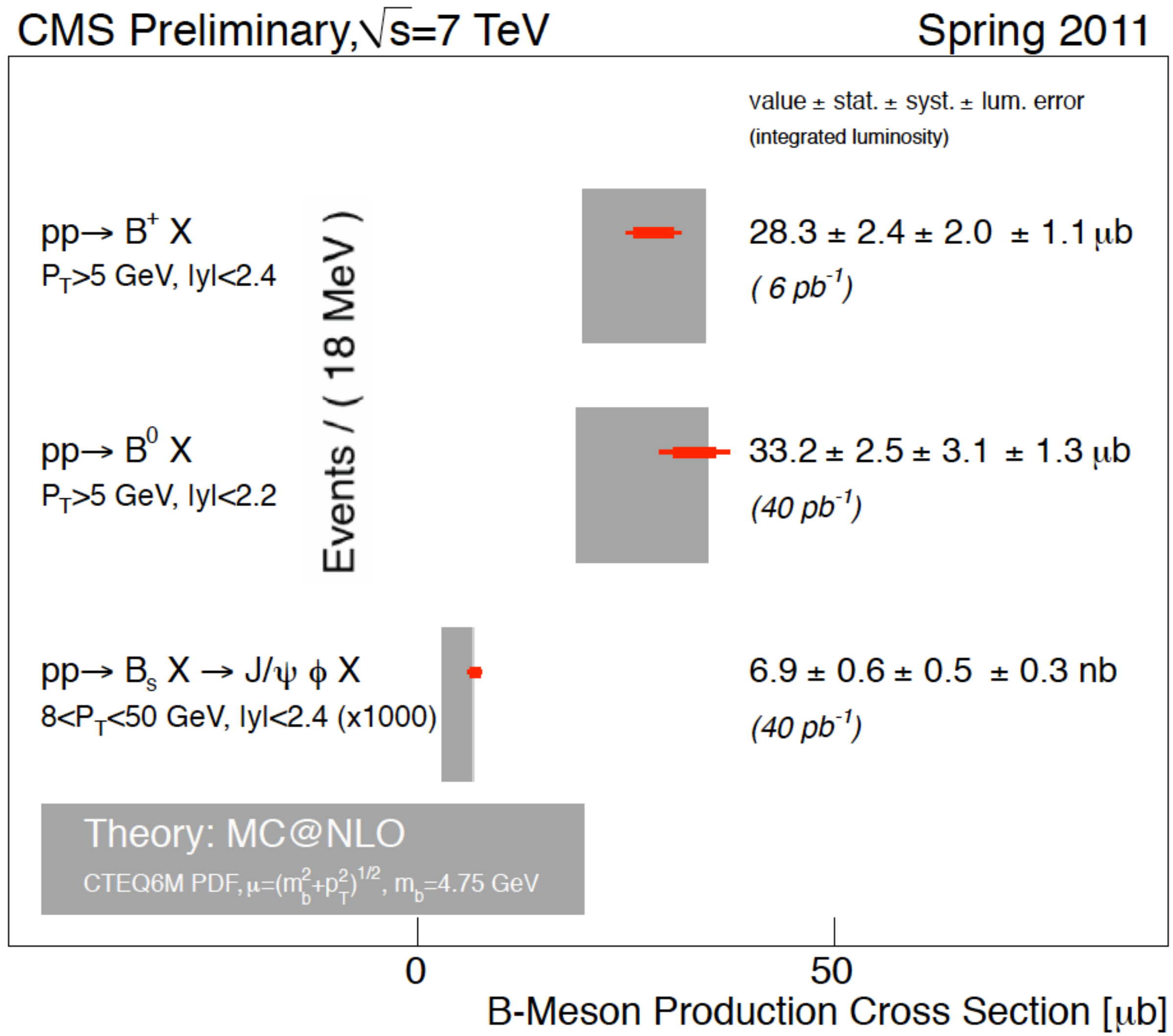
The End


If you can read this THANK A TEACHER

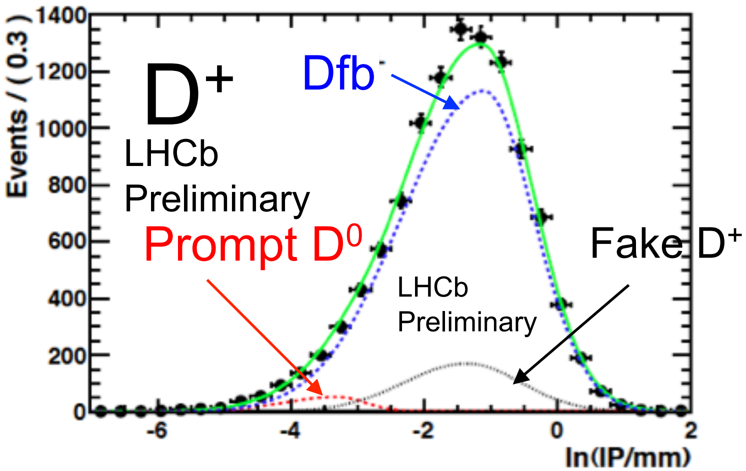
ATLAS B σ's

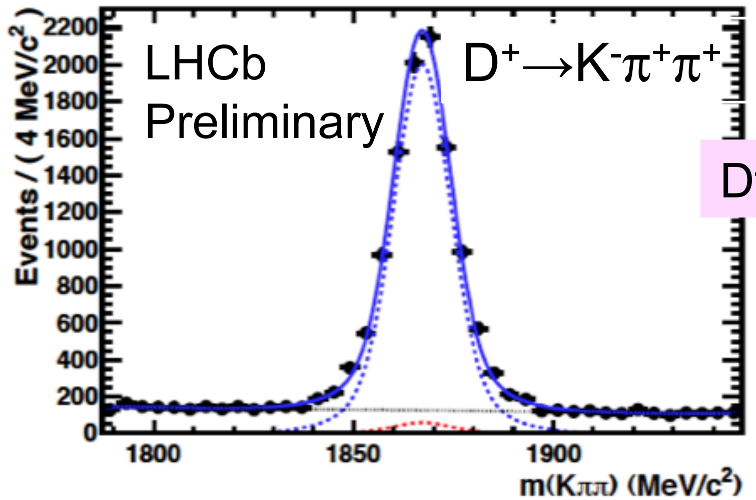

ATLAS Preliminary
√s = 7 TeV
∫L dt = 40 pb-1
m_Bs = 5364.0 ± 1.4(stat.) MeV
N_Bs = 358 ± 22(stat.)
σ = 26.6 ± 1.5(stat.) MeV
τ > 0.40 ps
0
20
40
60
80
100
120
5200
5300
5400
5500
5600
m_J/ψ KK (MeV)


CMS Preliminary
√s=7 TeV, L=40pb-1
ct > 0.01 cm
signal
non-prompt background
prompt background
Events / (0.018 GeV/c²)
0
20
40
60
80
100
120
140
160
180
200
220
5.2
5.25
5.3
5.35
5.4
5.45
5.5
5.55
5.6
5.65
J/ψφ invariant mass (GeV/c²)

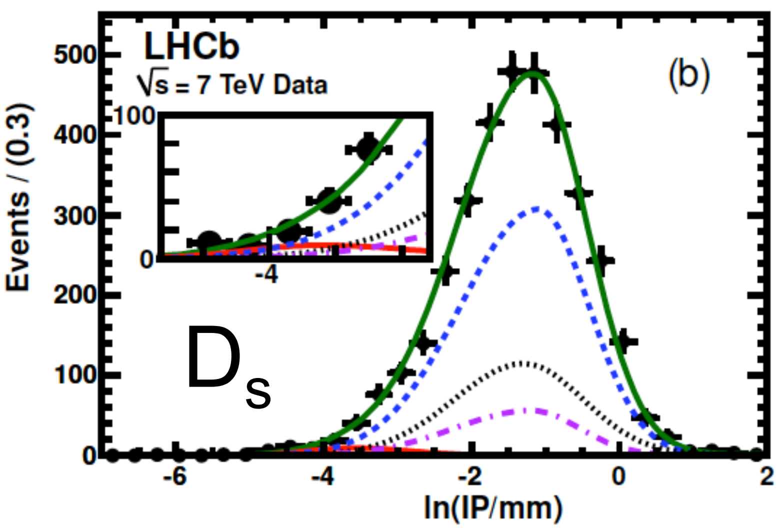

CMS Preliminary,√s=7 TeV
Spring 2011
value ± stat. ± syst. ± lum. error
(integrated luminosity)
pp→ B+ X
PT>5 GeV, lyl<2.4
28.3 ± 2.4 ± 2.0 ± 1.1 μb
(6 pb-1)
pp→ B0 X
PT>5 GeV, lyl<2.2
33.2 ± 2.5 ± 3.1 ± 1.3 μb
(40 pb-1)
pp→ Bs X → J/ψ φ X
8<PT<50 GeV, lyl<2.4 (x1000)
6.9 ± 0.6 ± 0.5 ± 0.3 nb
(40 pb-1)
Events / (18 MeV)
Theory: MC@NLO
CTEQ6M PDF, μ=(mb²+pT²)^1/2, mb=4.75 GeV
0
50
B-Meson Production Cross Section [μb]

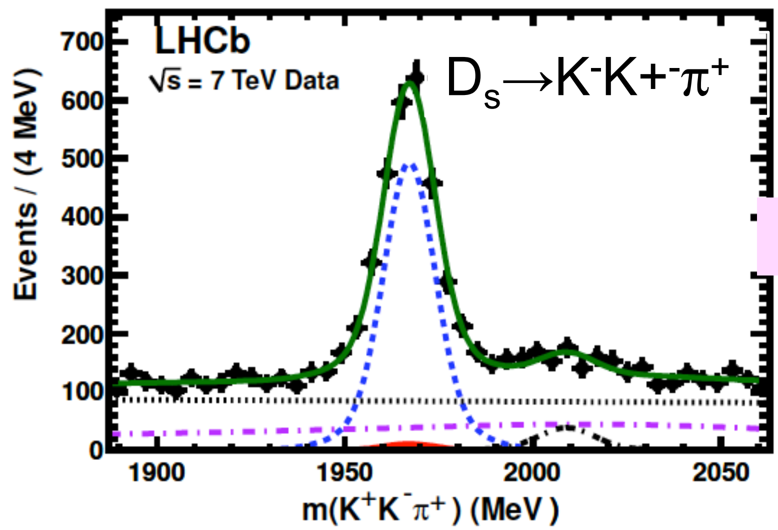
Also D^+, D_s, Λ_b





Dfb: 9406±110



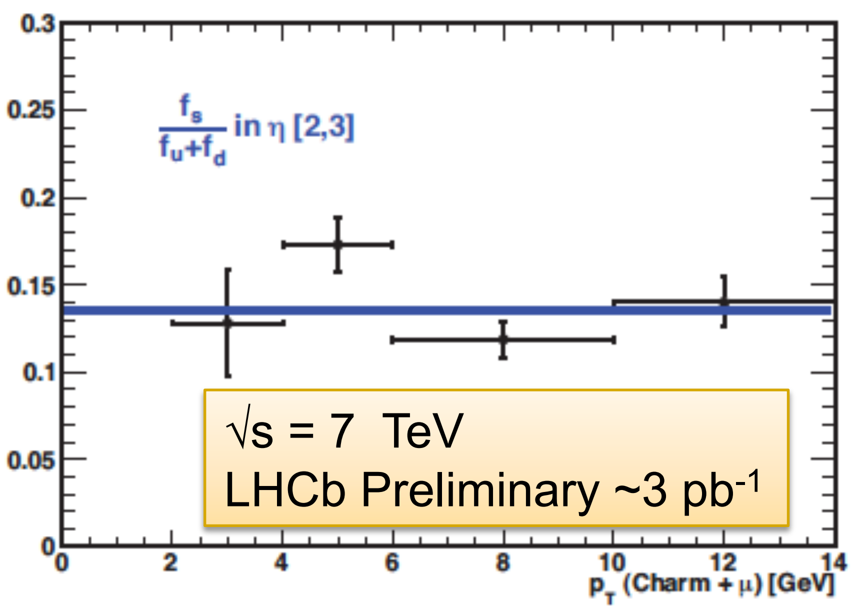


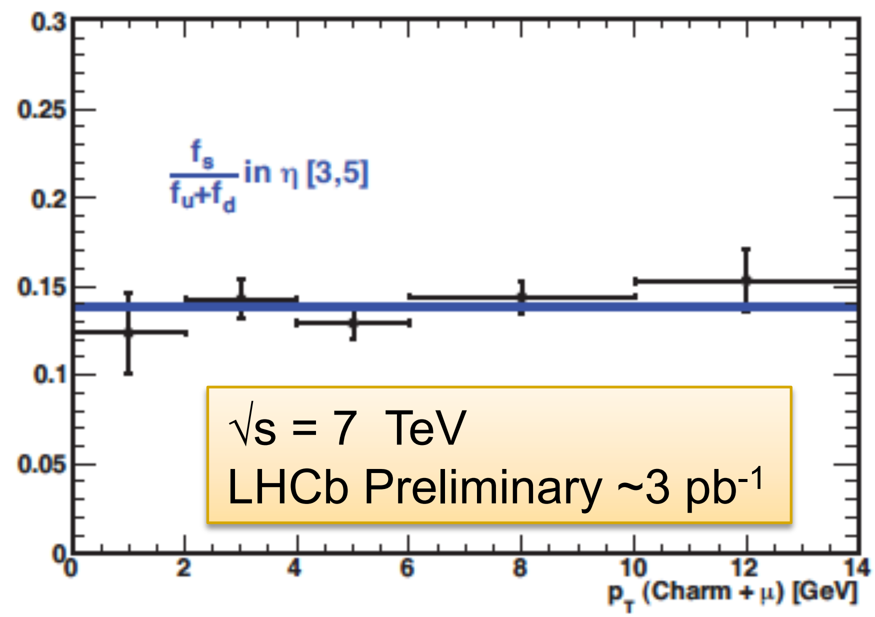
Dfb: 2446±60

Extract B_s fractions

- Crucial to set absolute scale for B_s rates, since not given by e^+e^- machines.
- Must correct for $B_s \to D^o K^+ X \mu\nu$, also $\Lambda_b \to D^o p X \mu\nu$

$$f_s/(f_u+f_d) = 0.136 \pm 0.004^{+0.012}_{-0.011}$$

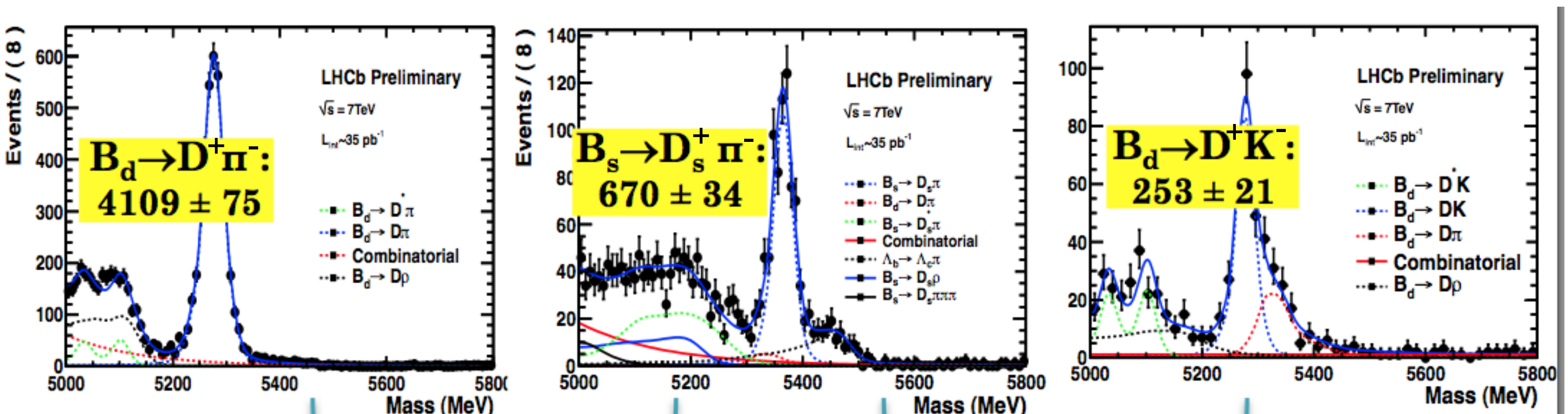




B_s fraction - hadronic

- Also can use hadronic decays + theory ~35 pb^{-1}

$\sqrt{s}$ = 7 TeV
LHCb Preliminary



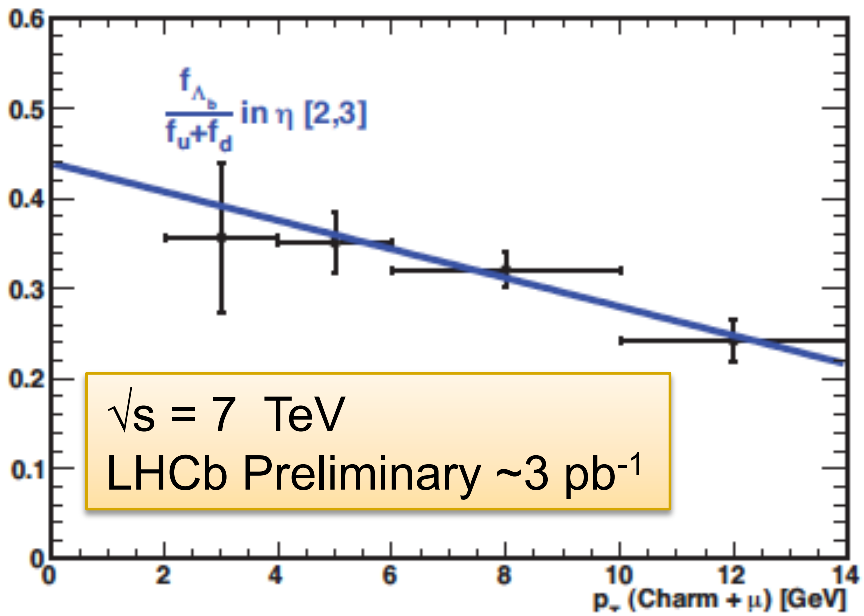
$$\frac{f_s}{f_d} = 0.249 \pm 0.013^{\text{stat}} \pm 0.020^{\text{syst}} \pm 0.025^{\text{theor}}$$

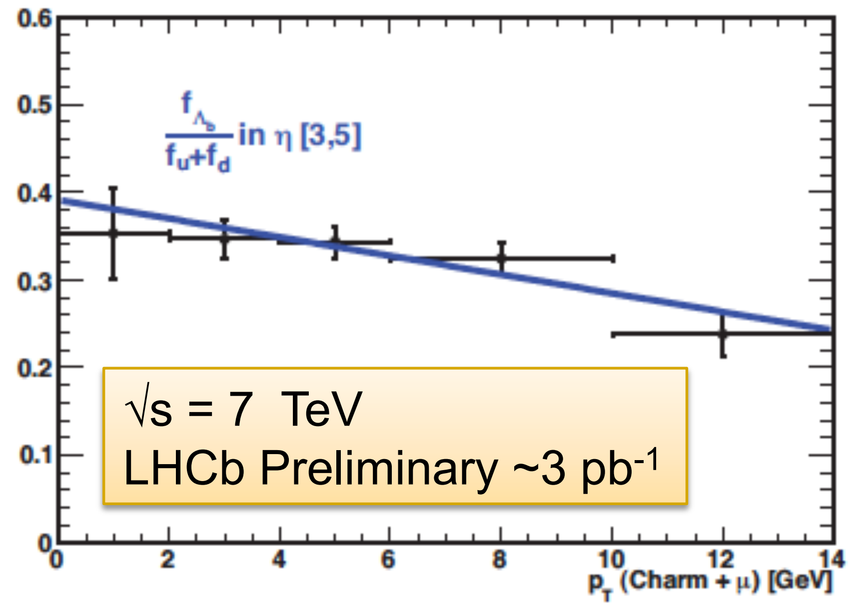
$$\frac{f_s}{f_d} = 0.242 \pm 0.024^{\text{stat}} \pm 0.018^{\text{syst}} \pm 0.016^{\text{theor}},$$

Semileptonics: $f_s / f_d = 0.272 \pm 0.008^{+0.024}_{-0.022}$

Λ_b Fraction

- Significant p_t dependence

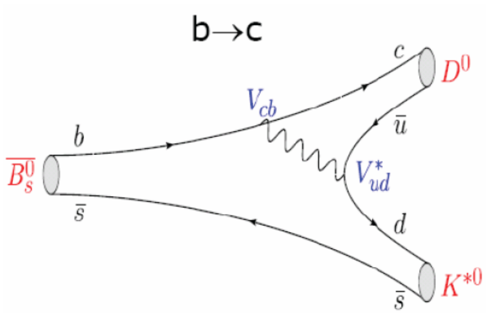




$$[f_{\Lambda_b}/(f_u+f_d)] = 0.401 \pm 0.019 \pm 0.106 - (0.012 \pm 0.0025 \pm 0.0012) \times p_t(\mathrm{GeV})$$

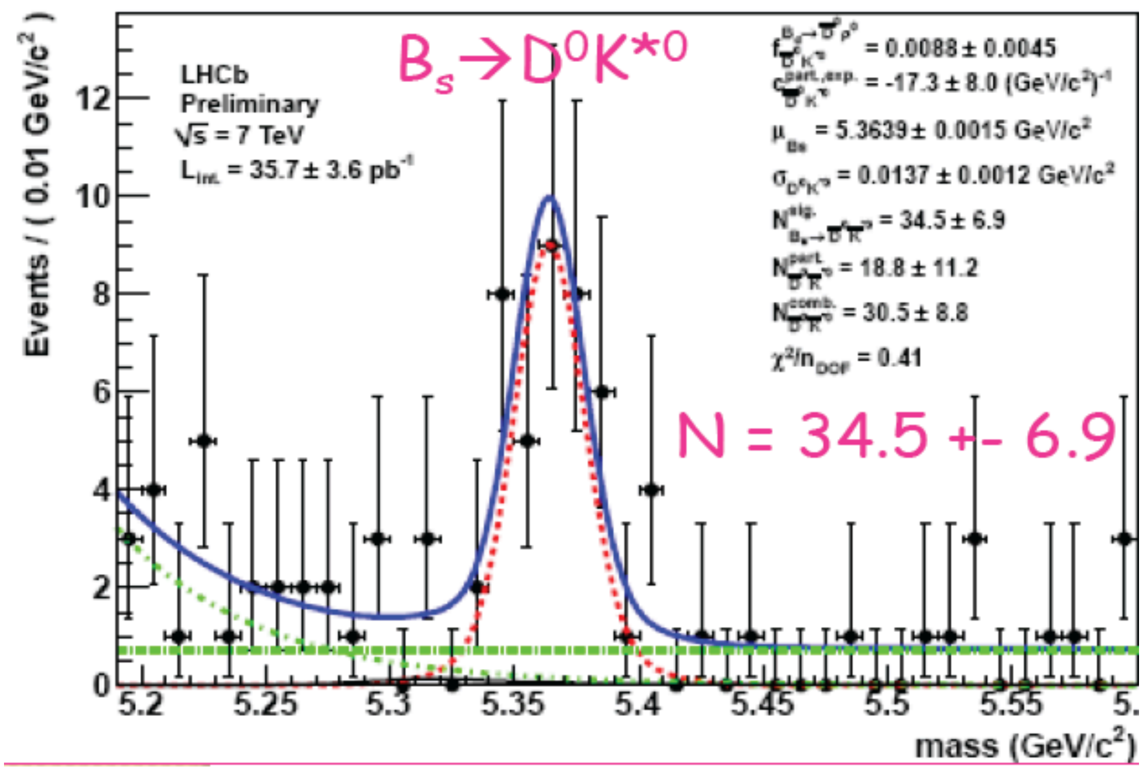
- In general agreement with CDF measured at $\langle p_t \rangle \sim 10$ GeV/c $f_{\Lambda_b}/(f_u+f_d) = 0.281 \pm 0.012^{+0.011+0.128}_{-0.056-0.086}$

1^{st} Observation of $\overline{B}_s \rightarrow D^o K^{*o}$

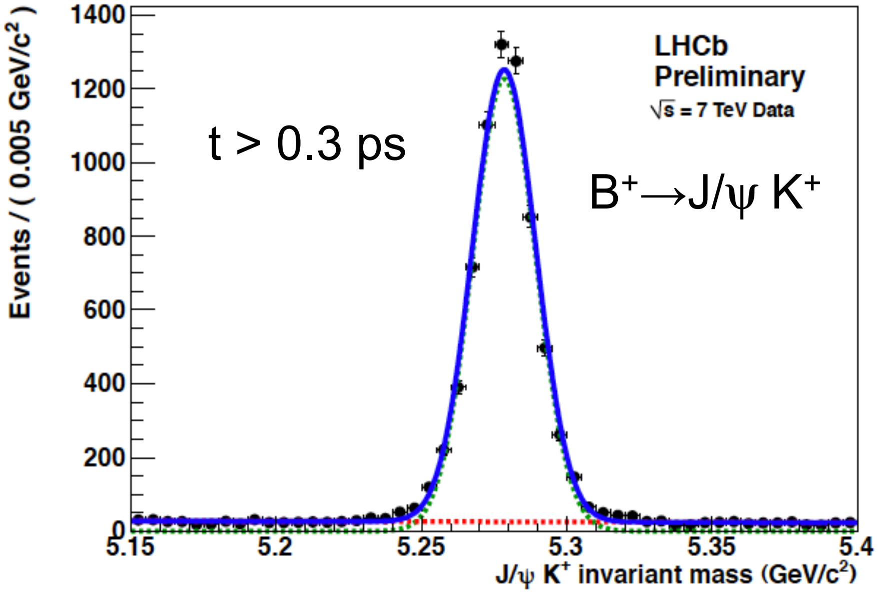


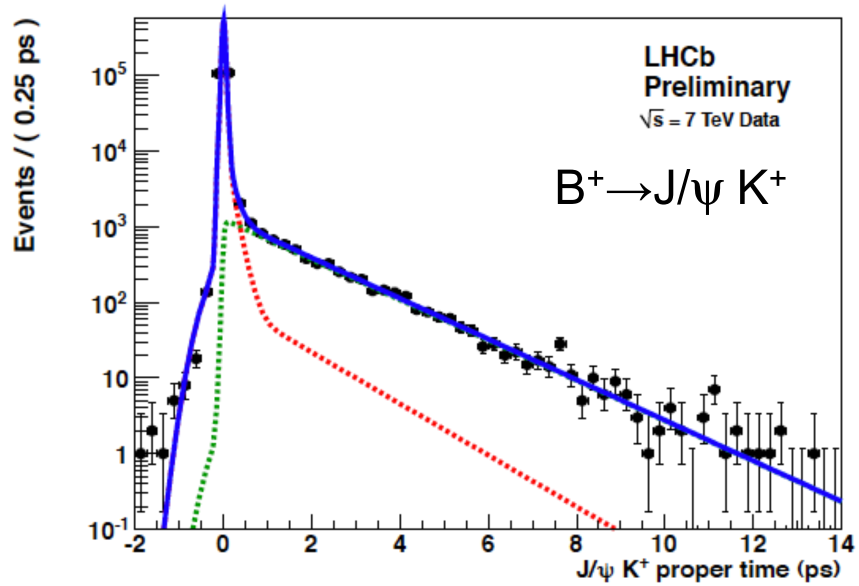
$$\frac{\mathcal{B}\left(\overline{B}{}^0_s \rightarrow D^0 K^{*0}\right)}{\mathcal{B}\left(\overline{B}{}^0 \rightarrow D^0 \rho^0\right)} = 1.39 \pm 0.31 \pm 0.25$$

$$\mathcal{B}\left(\overline{B}{}^0_s \rightarrow D^0 K^{*0}\right) = (4.44 \pm 1.00 \pm 0.79) \times 10^{-4}$$



Exclusive B→ J/ψ h

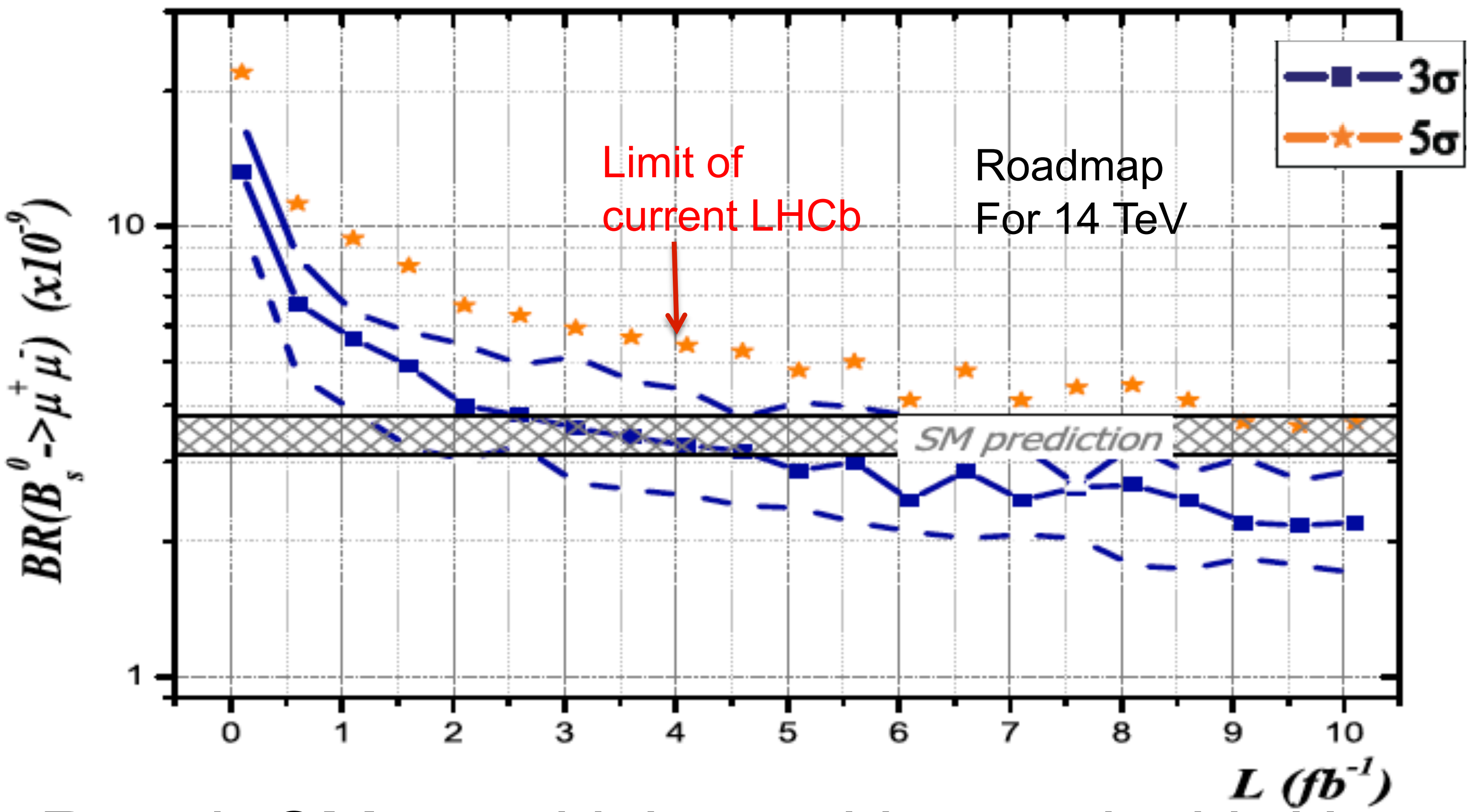




Channel	LHCb yield	LHCb "lifetime"(*) stat. and sys. (ps)	PDG (ps)
$B^+ \to J/\psi K^+$	$6\,741 \pm 85$	$1.689 \pm 0.022 \pm 0.047$	1.638 ± 0.011
$B^0 \to J/\psi K^{*0}$	$2\,668 \pm 58$	$1.512 \pm 0.032 \pm 0.042$	1.525 ± 0.009
$B^0 \to J/\psi K^0_S$	838 ± 31	$1.558 \pm 0.056 \pm 0.022$	1.525 ± 0.009
$B^0_s \to J/\psi \phi$	570 ± 24	$1.447 \pm 0.064 \pm 0.056$	1.477 ± 0.046
$\Lambda_b \to J/\psi \Lambda$	187 ± 16	$1.353 \pm 0.108 \pm 0.035$	$1.391^{+0.038}_{-0.037}$

$B_s \rightarrow \mu^+\mu^-$ longer term

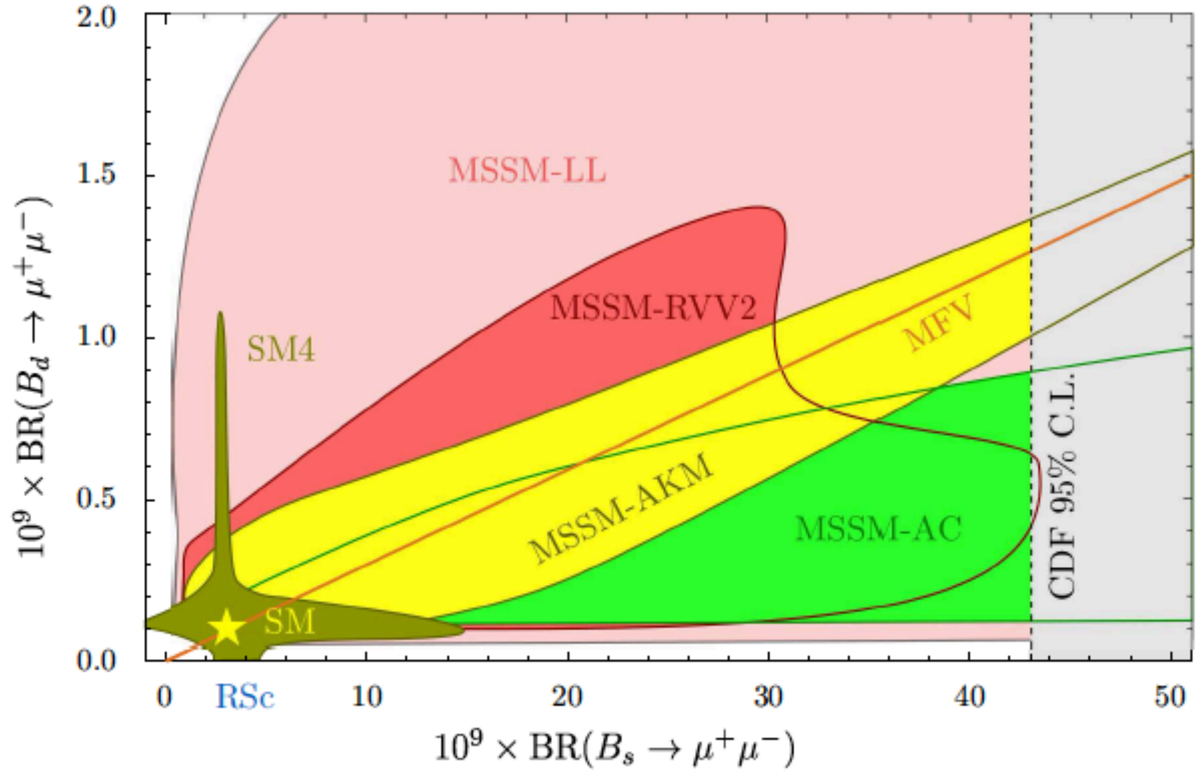
- Will take Upgrade to reach SM sensitivity



- Reach SM sensitivity and beyond with Upgrade

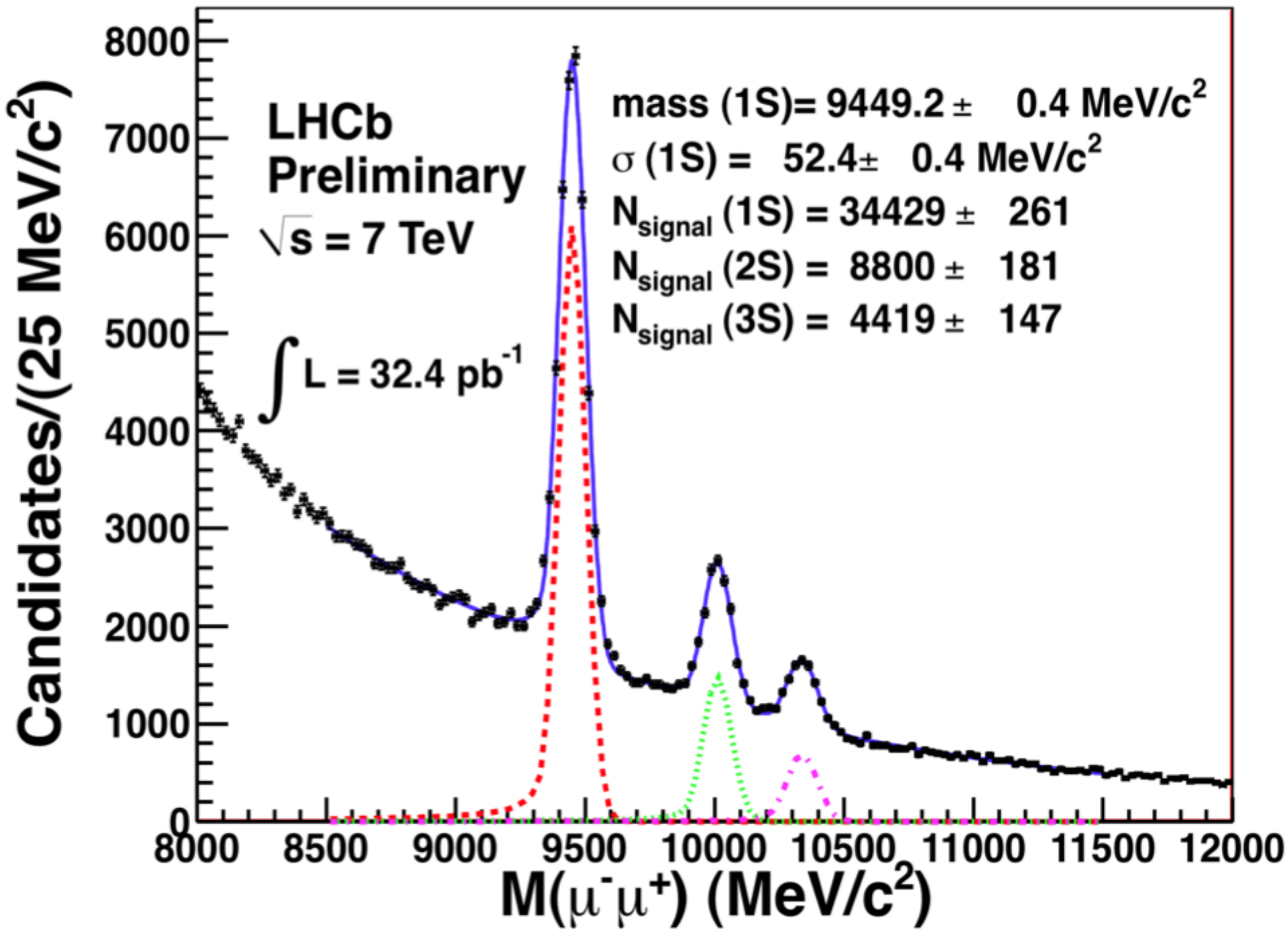
$B^o \rightarrow \mu^+\mu^-$

- In fact correlation between B_d & B_s $\mu^+\mu^-$ could be crucial



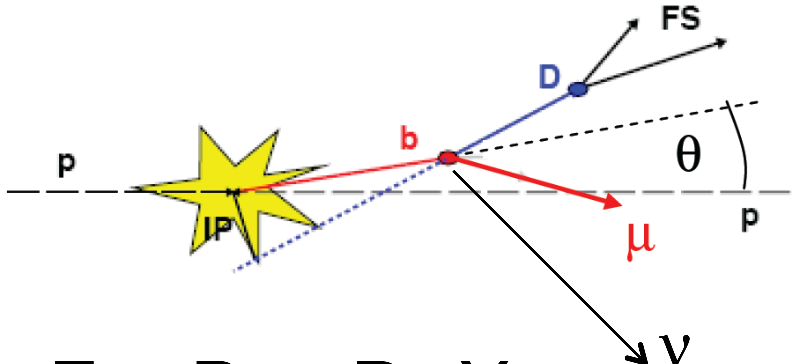
- This can only be done with the LHCb Upgrade

Upsilons too



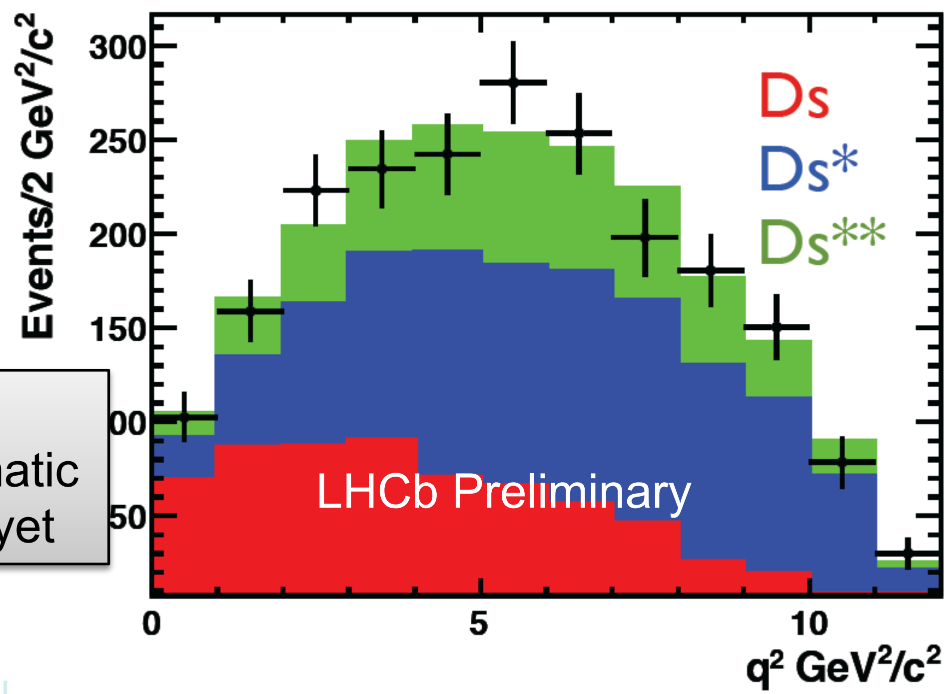
Exclusive semileptonic decays

- Accurate measurement of B-flight direction allows missing neutrino reconstruction



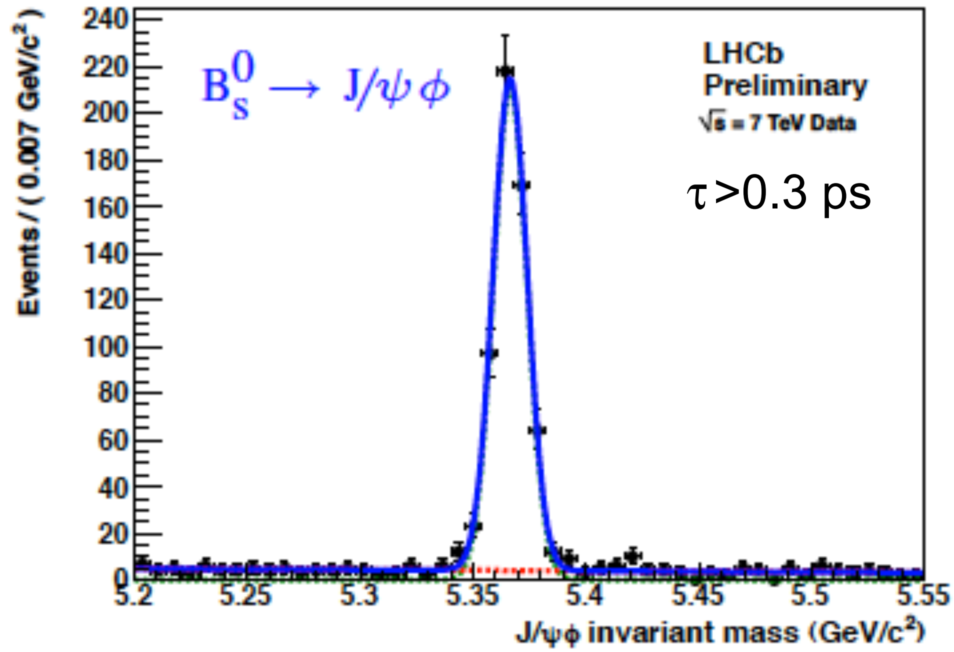
- For $B_s \to D_s\, X\, \mu\nu$
  - D_s: 0.26±0.06
  - D_s^*: 0.49±0.069
  - D_s^{**}: 0.25±0.12
  - LHCb preliminary

No systematic errors yet



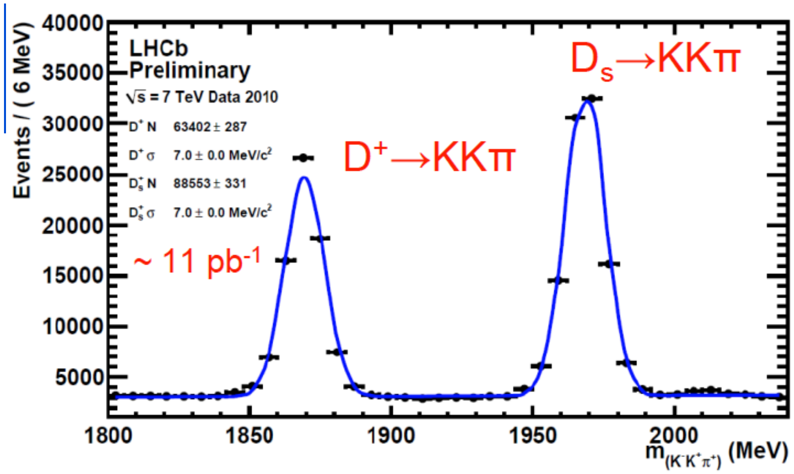
CP Violation in B_s

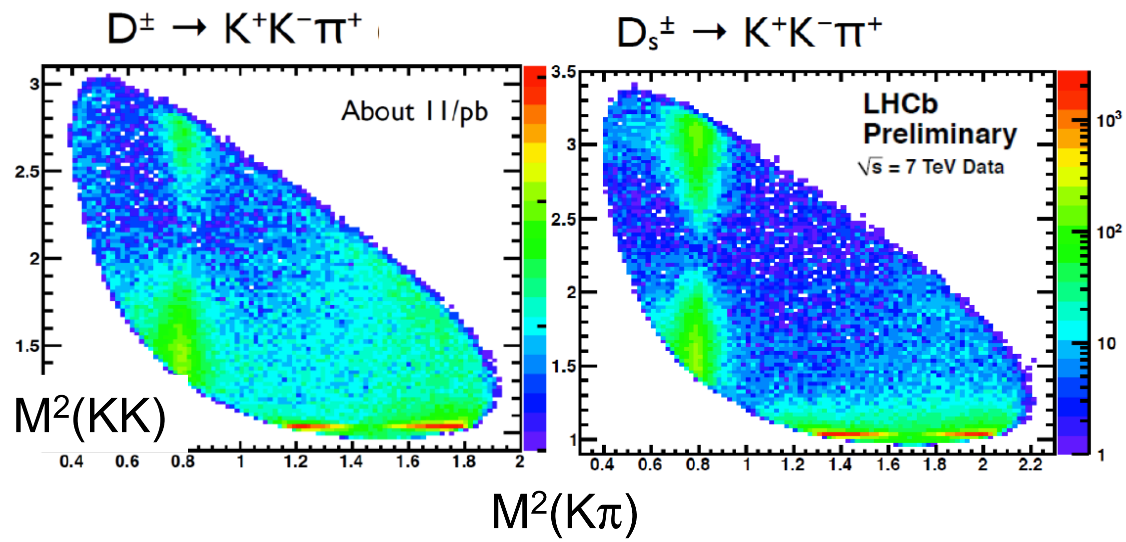
- Will try & measure $\phi_s = -\beta_s$ in SM without SS tags

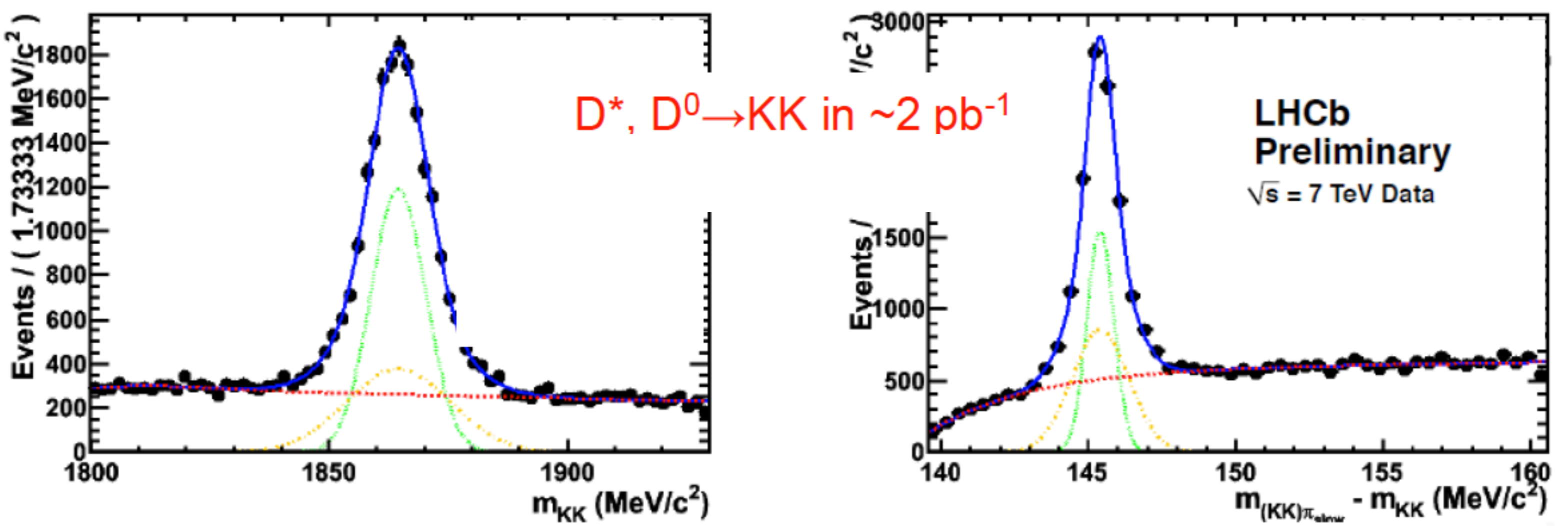


	Roadmap (36 pb^{-1})	LHCb (36 pb^{-1})	CDF 5.2 fb^{-1}
# $J/\psi\phi$	1050	836	6500
$\sigma(\tau)$ (fs)	38	50	100
OS tag power	6.2%	(2.2±0.8)%	(1.2±0.2)%
SS tag power		working on	(3.5±1.4)%

Great Prospects in Charm

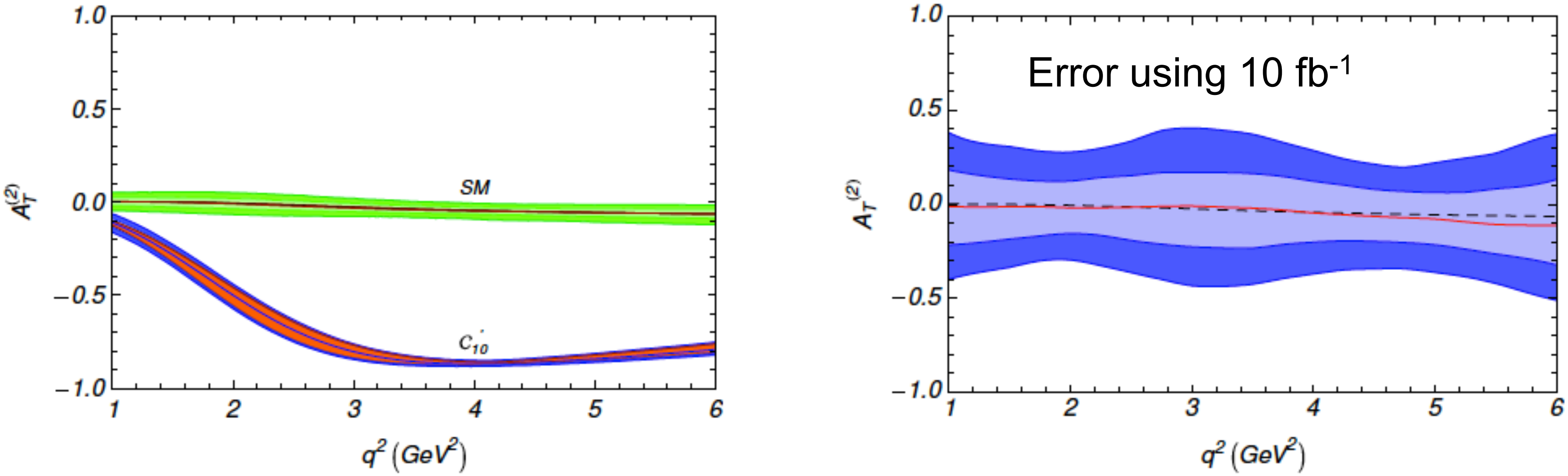






$B^o \rightarrow K^{*o} \mu^+\mu^-$ Upgrade

- Other better angular correlation variables

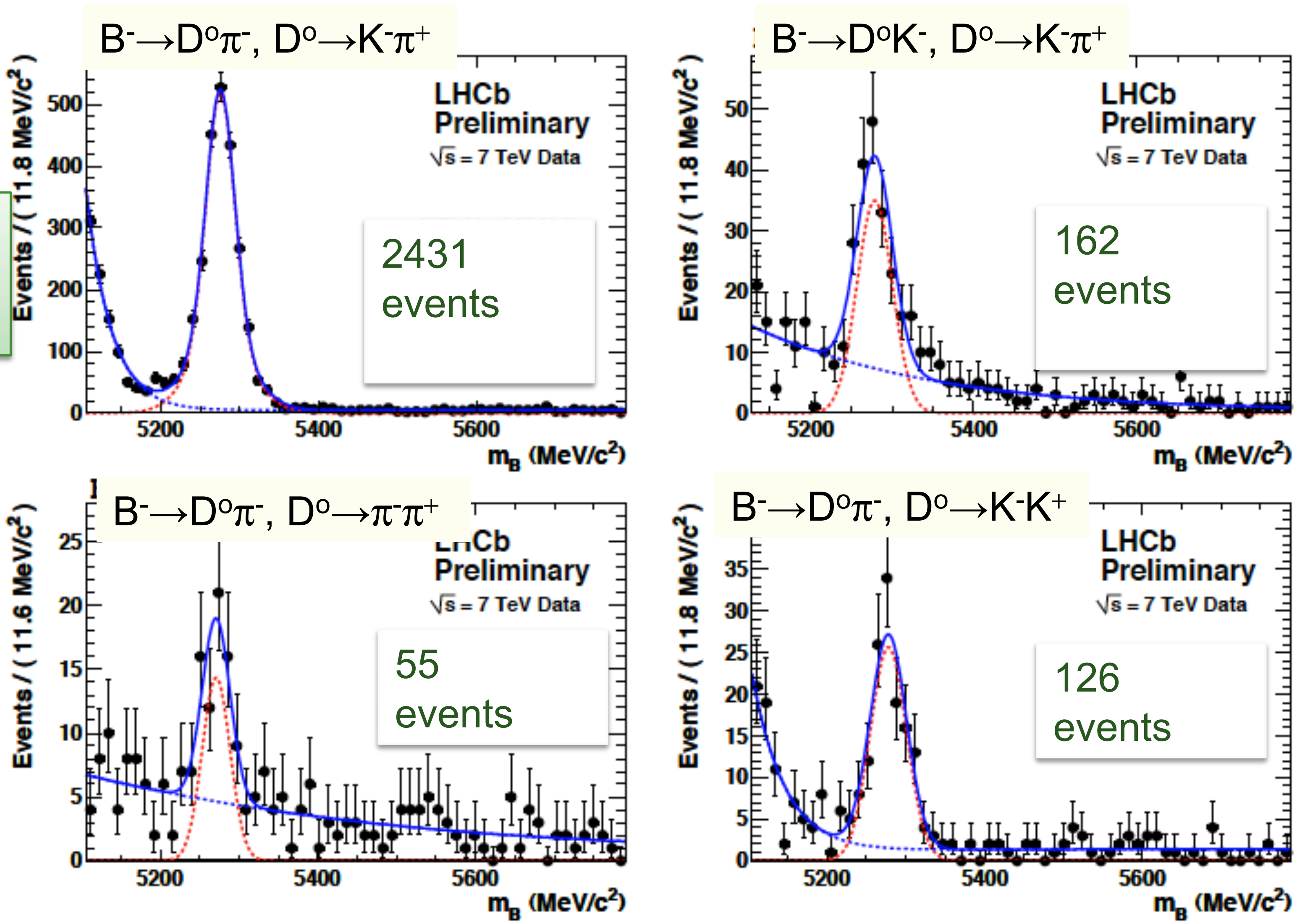


- Need 50 fb^{-1} to reduce errors below differences in SM - NP

$B^- \to D^o h^-$

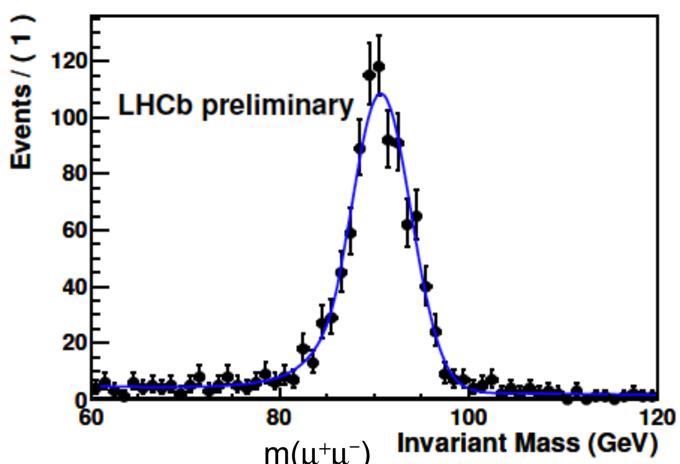
$\mathcal{B}(B \to D^o \pi^-) \bullet \mathcal{B}(D^o \to \pi^+ K^-) = 1.9 \times 10^{-4}$

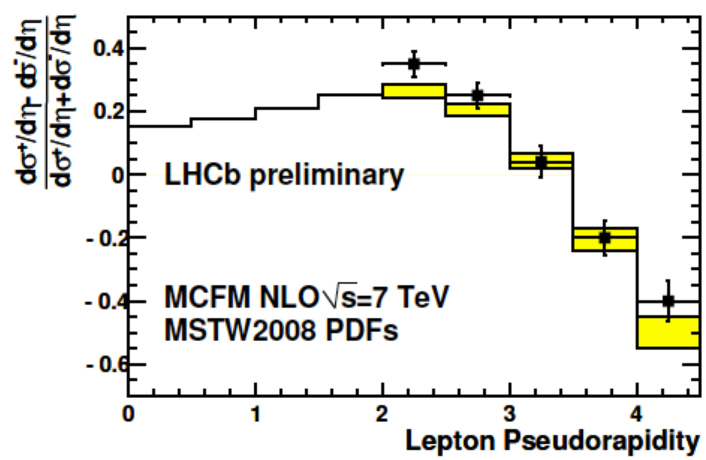
$\sim 12\ pb^{-1}$



Electroweak Physics

- LHCb can make unique measurements of many important quantities
  - $W^{\pm}$ & Z^{o} cross-sections at $\eta > 2$, allows access to precision PDF measurements necessary for precision W mass measurement. Data from 16 pb^{-1}





  - Measure A_{FB} in Z^{o} decays, determine $\sin^2\theta_{lept}$ to ±0.00010 in 50 fb^{-1}, -discrepancy between LEP & SLD

(0.23221±0.00029, 0.23098±0.00026)