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Heavy Flavor Physics

DPF, Aug. 13, 2011

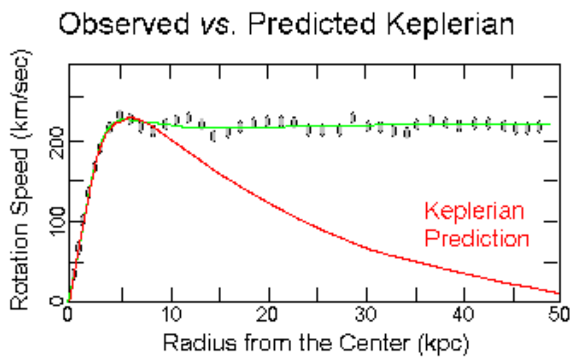
What is it?

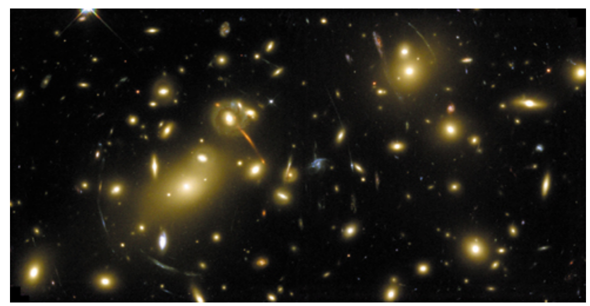
- Define Heavy Flavor Physics
  - Flavor Physics: Study of interactions that differ among flavors
  - Heavy: Not SM neutrino's or u or d quarks, maybe s quarks, concentrate here on c & b quarks, t too heavy

u, d, ν's	s, μ	c & b, τ; ν_M's ?	t
too light	maybe	just right	too heavy

Physics Beyond the Standard Model

- Baryogenesis: From current measurements can only generate $(n_B-n_{\bar{B}})/n_\gamma = \sim 10^{-20}$ but $\sim 6\times10^{-10}$ is needed. Thus New Physics must exist
- Dark Matter



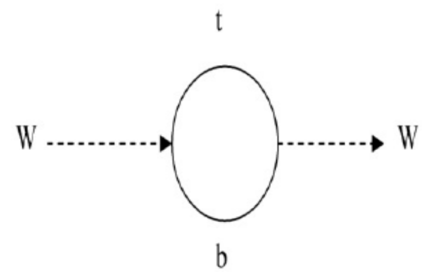


Gravitational lensing

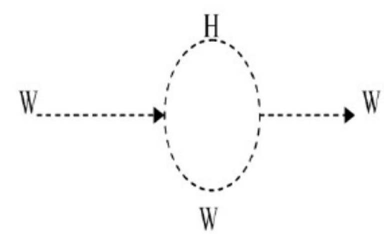
- Hierarchy Problem: We don’t understand how we get from the Planck scale of Energy $\sim 10^{19}$ GeV to the Electroweak Scale ~ 100 GeV without “fine tuning” quantum corrections

Seeking New Physics

- HFP as a tool for NP discovery
  - While measurements of fundamental constants are fun, the main purpose of HFP is to find and/or define the properties of physics beyond the SM
  - HFP probes large mass scales via virtual quantum loops. An example, of the importance of such loops is extracting the Higgs mass
  - M_w changes due to m_t $\quad \frac{dM_W}{dm_t} \alpha \frac{m_t}{M_w}$

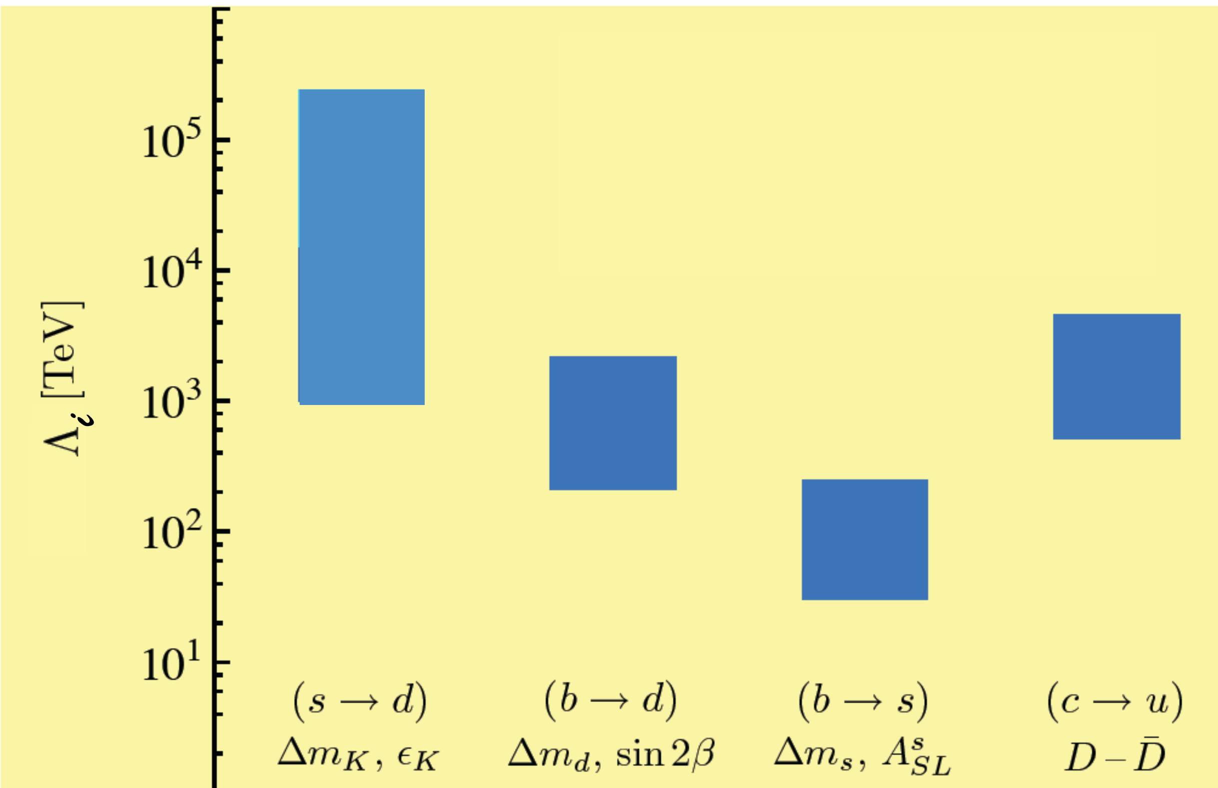


  - M_w changes due to m_H $\quad \frac{dM_W}{dm_H} \alpha - \frac{dm_H}{M_H}$



Flavor as a High Mass Probe

- Already excluded ranges
  - $\mathcal{L}_{\text{eff}} = \mathcal{L}_{\text{SM}} + \frac{c_i}{\Lambda_i} O_i$, take $c_i = 1$



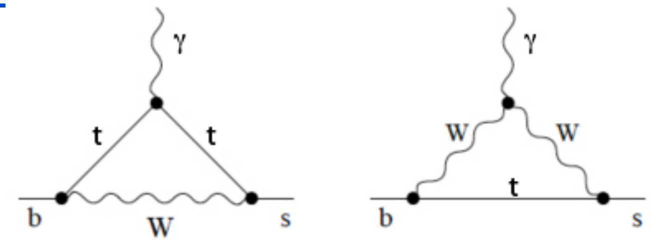
Ways out

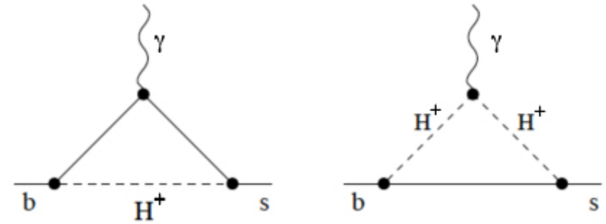
1. New particles have large masses >>1 TeV
2. New particles have degenerate masses
3. Mixing angles in new sector are small, same as in SM (MFV)
4. The above already implies strong constrains on NP

See: Isidori, Nir & Perez arXiv:1002.0900; Neubert EPS 2011 talk

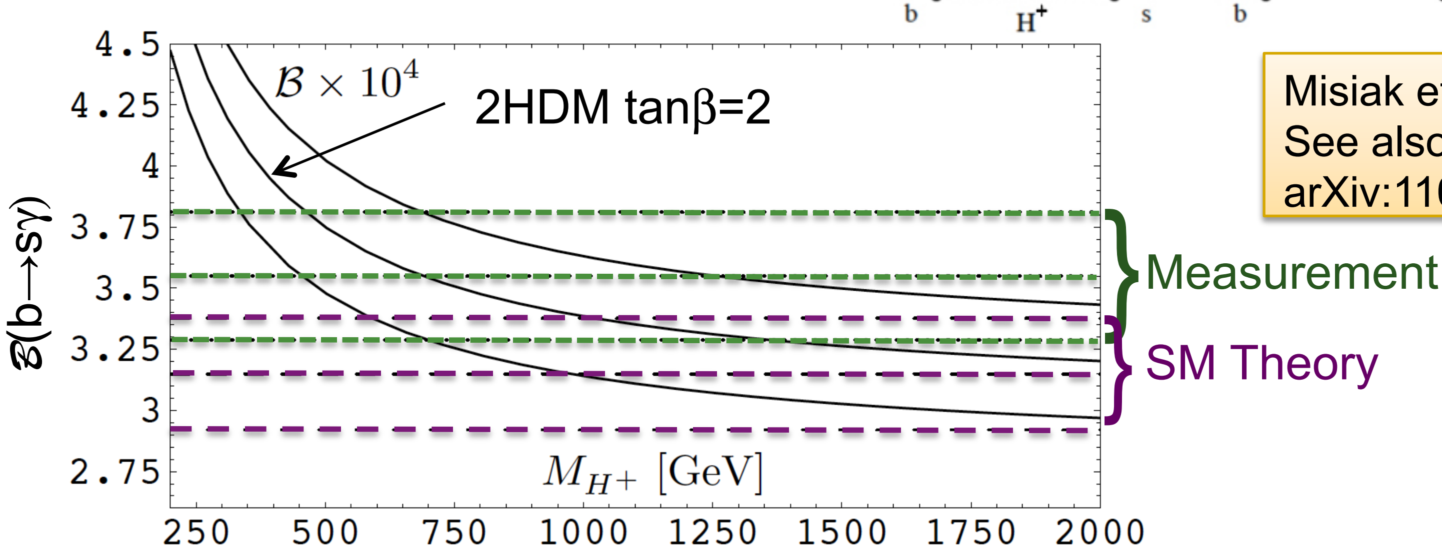
Ex. of Strong Constraints on NP

- Inclusive b→sγ, (Eγ > 1.6 GeV)
  - Measured (3.55±0.26)x10^{-4} (HFAG)
  - Theory (3.15±0.23)x10^{-4} (NNLL) Misiak arXiv:1010.4896
  - Ratio = 1.13±0.11, Limits most NP models
  - Example 2HDM
  - m(H$^+$) < 316 GeV



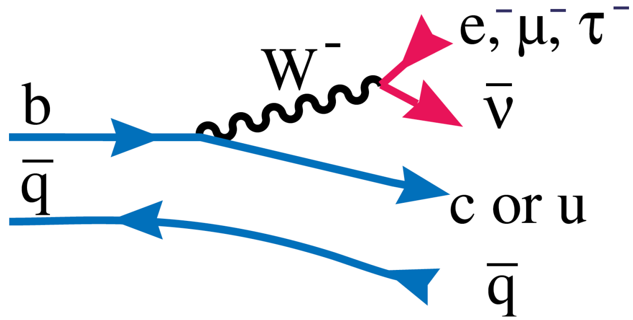


Misiak et. al hep-ph/0609232,
See also A. Buras et. al,
arXiv:1105.5146

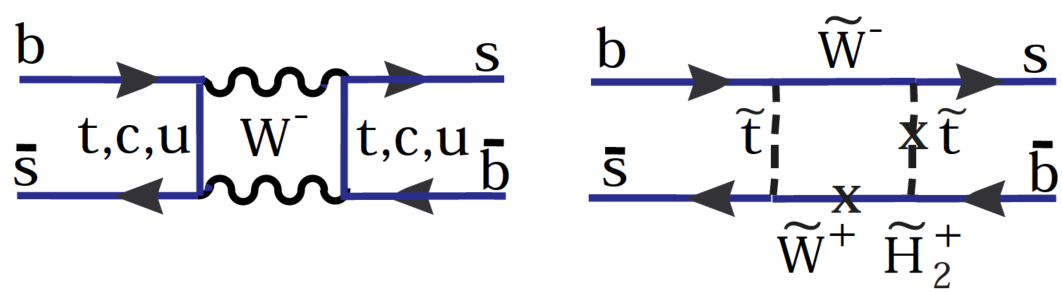


Limits on New Physics

- 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?
- One hypothesis: assume that tree level diagrams are dominated by SM and loop diagrams could contain NP



Tree diagram example

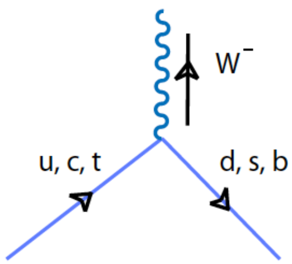


Loop diagram example

Quark Mixing & CKM Matrix

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

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

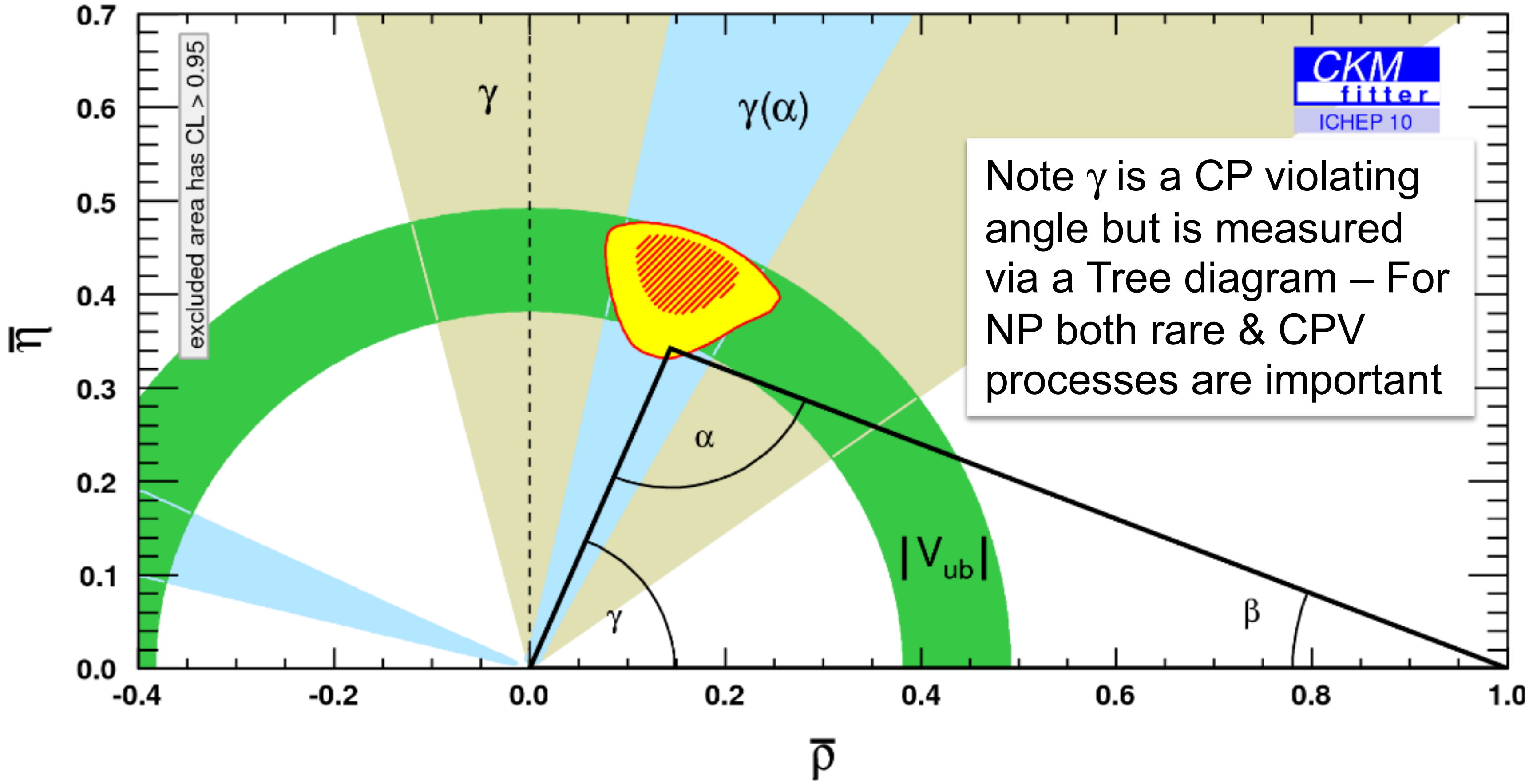


$$= \begin{pmatrix} 1-\lambda^2/2 & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\lambda^2/2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix} + O(\lambda^4)$$

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

What are limits on NP from quark decays?

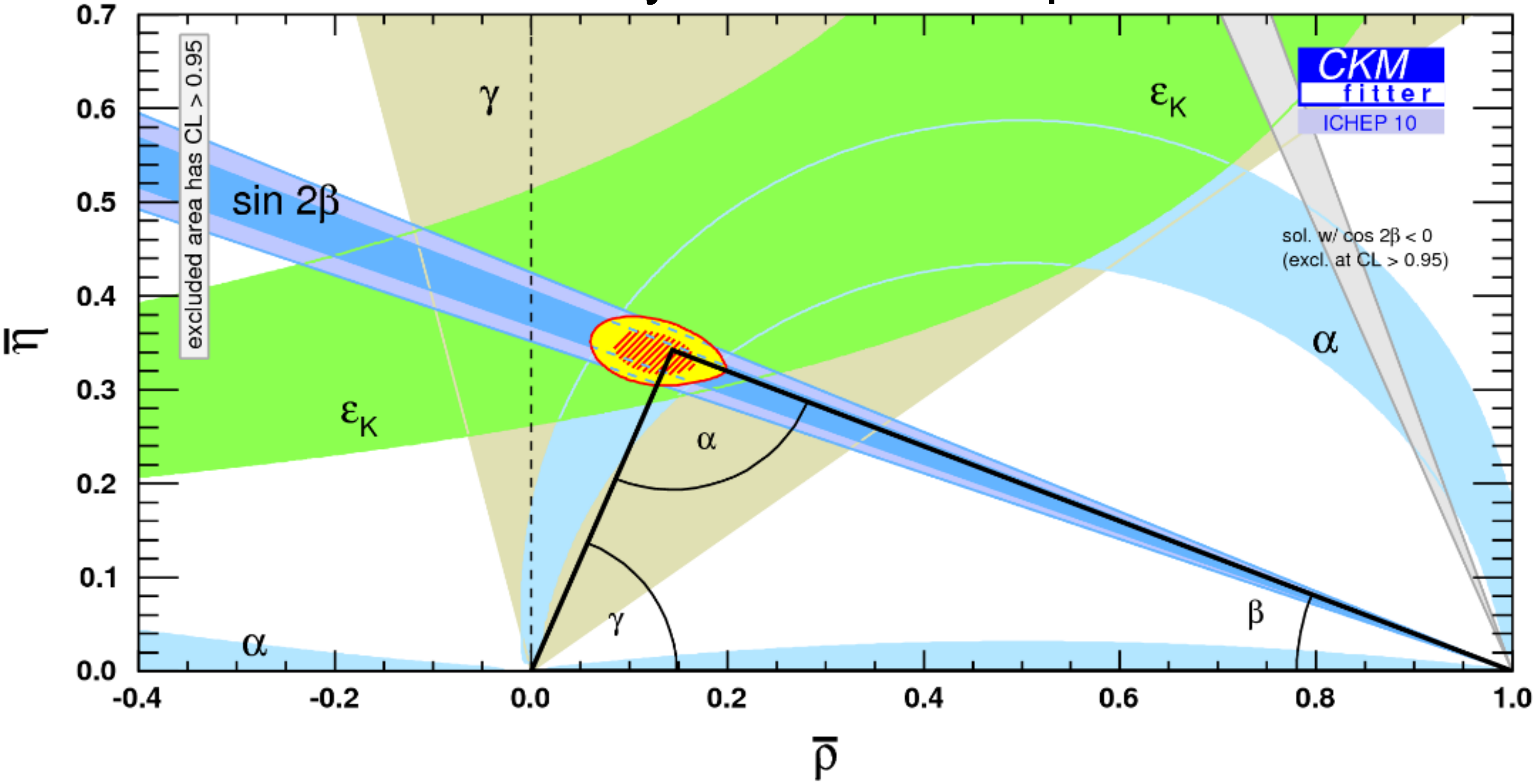
- Tree diagrams are unlikely to be affected by physics beyond the Standard Model



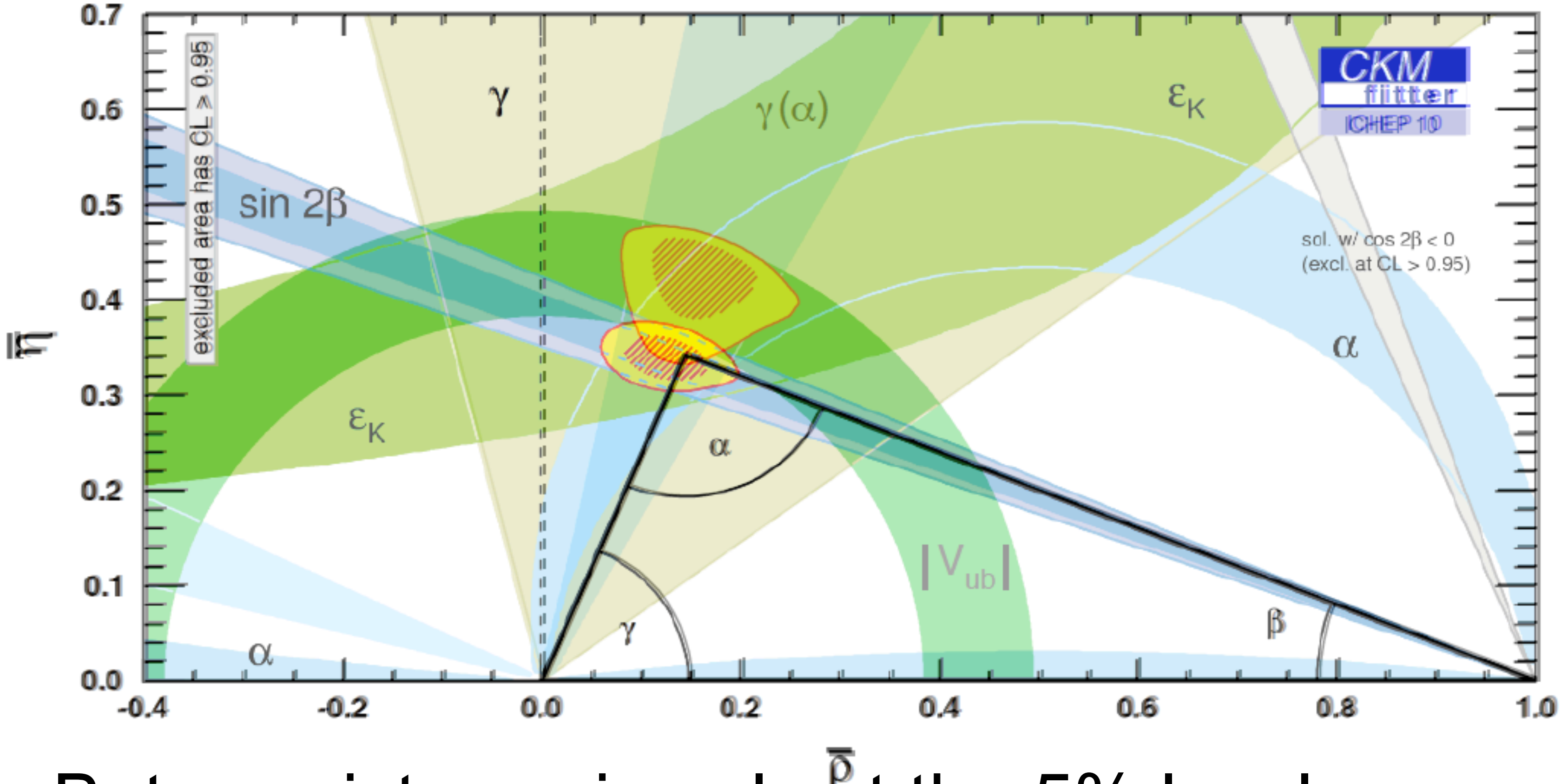
Note γ is a CP violating angle but is measured via a Tree diagram – For NP both rare & CPV processes are important

CP Violation in B° & K° Only

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



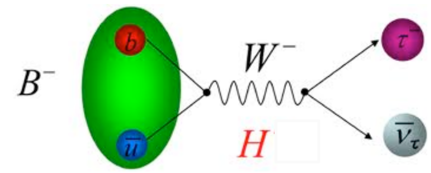
They are Consistent



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

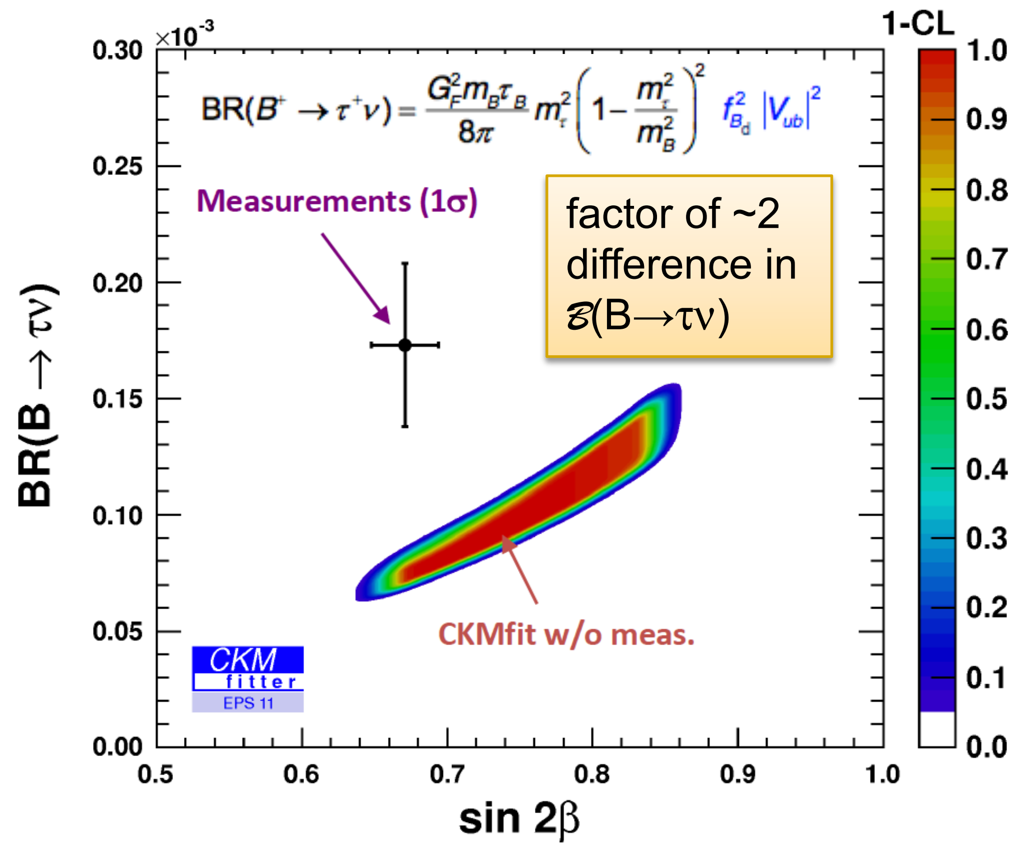
One Clear Problem

- $B^- \to \tau^- \nu$, tree process:



Can be new particles instead of W^- but why not also in $D^+_{(s)} \to \ell^+ \nu$?

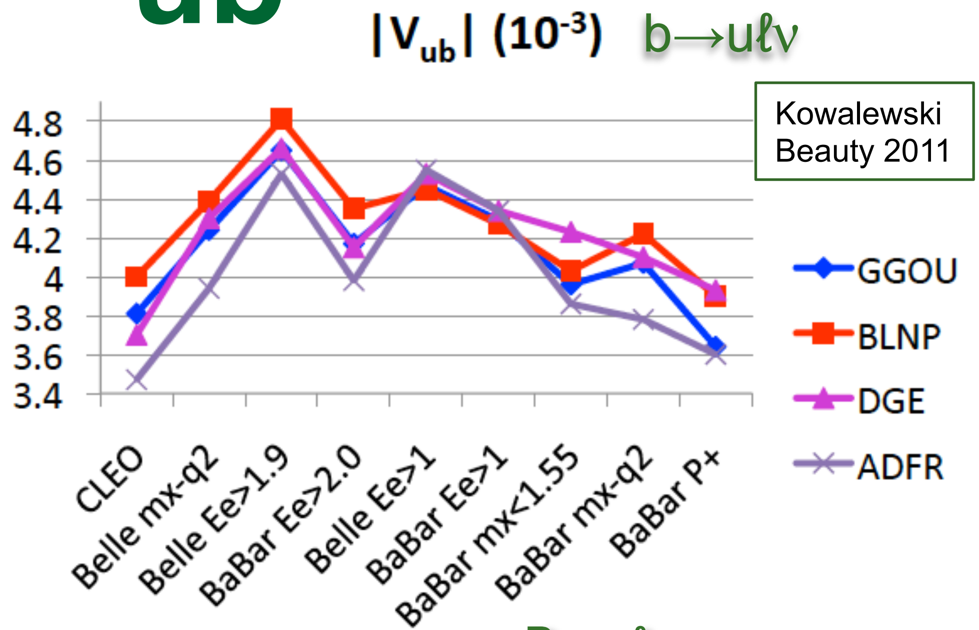
- sin2β, CPV in e.g. $B^o \to J/\psi\ K_s$: Box diagram
- Source of most of the CKM discrepancy
  - See: E. Lunghi & A. Soni, "Demise of CKM & its aftermath," [arXiv:1104.2117], they advocate a 4th generation

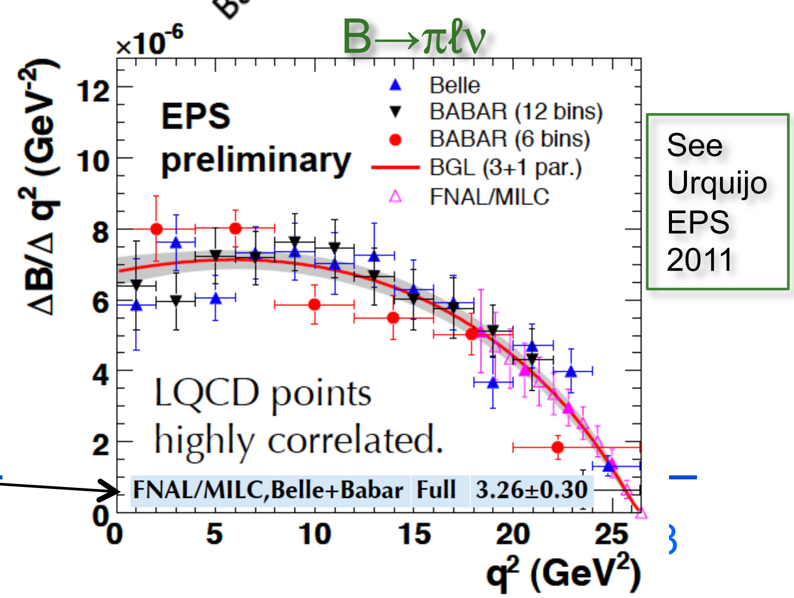


V_{ub}

- An irritating problem: Lingering difference between inclusive $b\rightarrow u\ell\nu$, & exclusive $B\rightarrow\pi\ell\nu$,
- Values $|V_{ub}|\times10^{-3}$
  - Inclusive: 4.25±0.15±0.20
  - Exclusive: 3.25±0.12±0.28

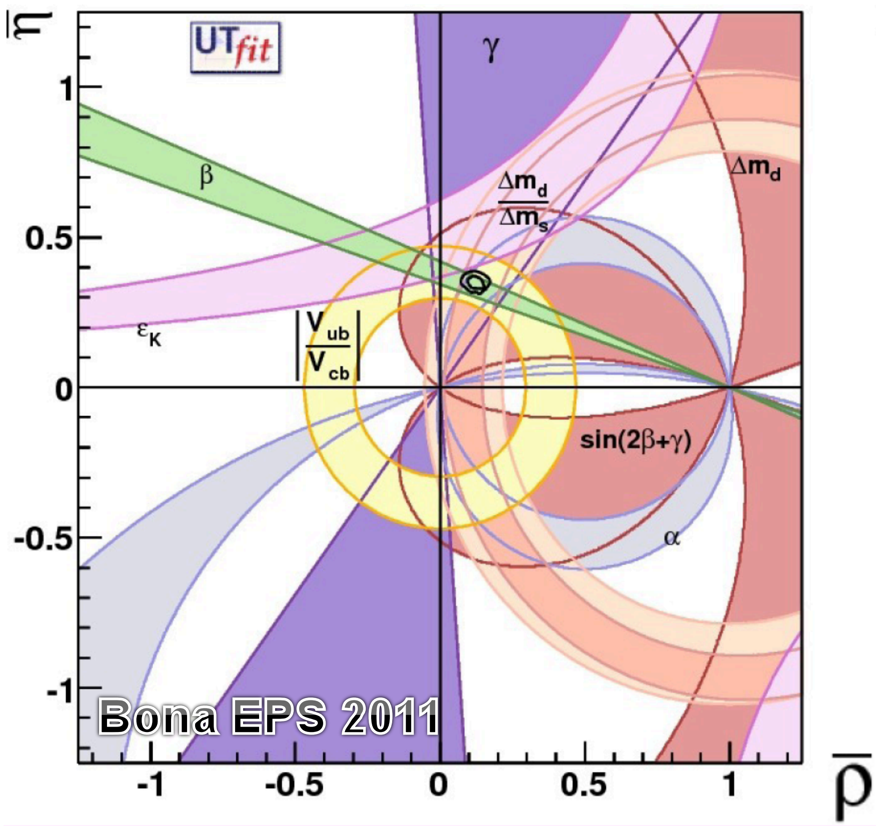
  New



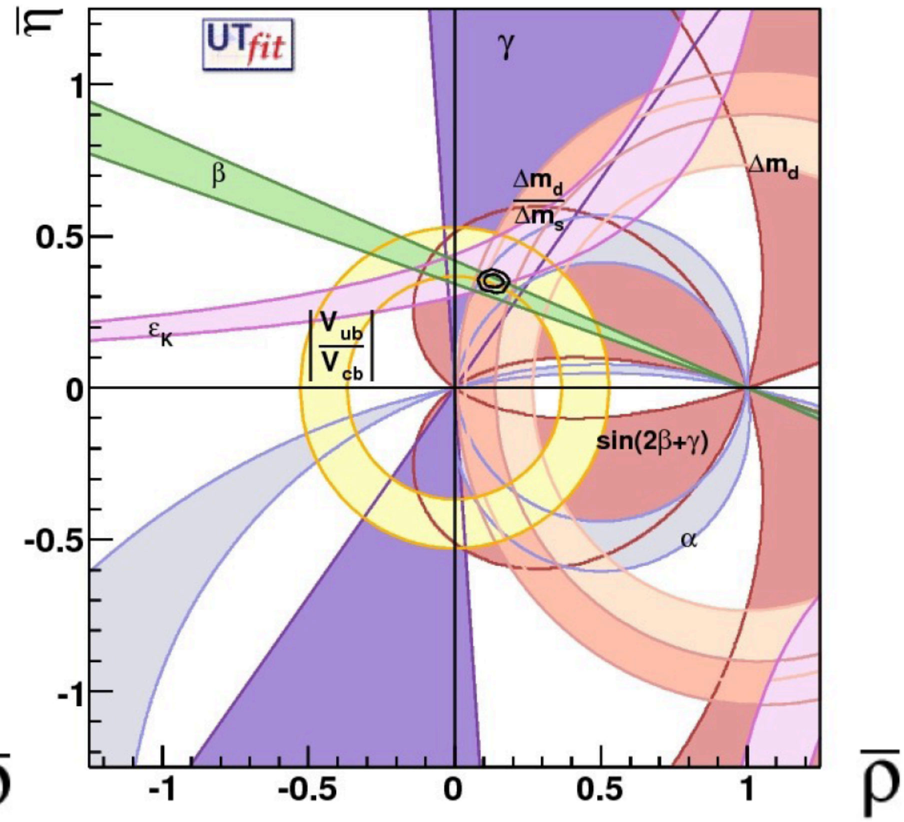


V_{ub} Consequences

Exclusive



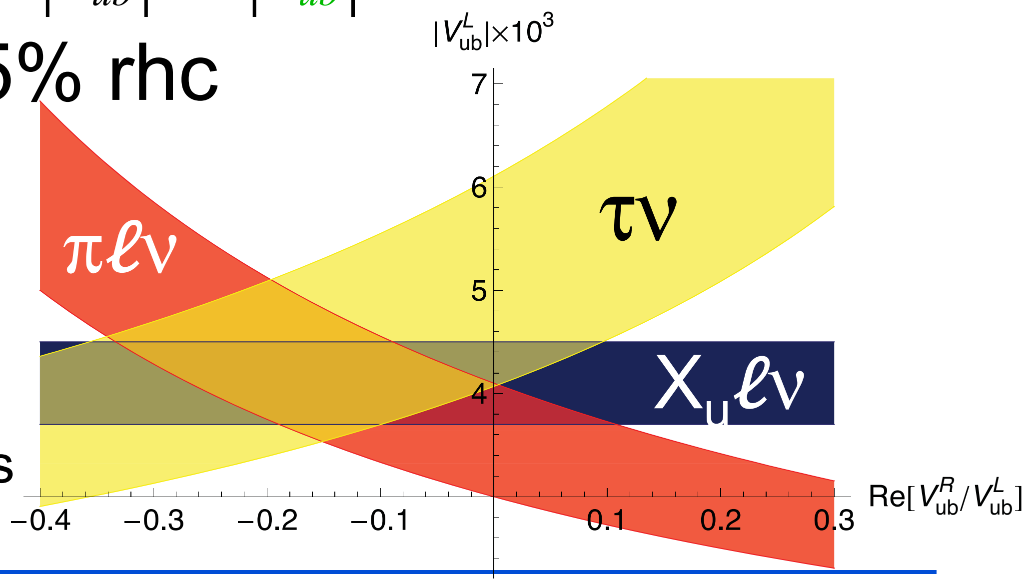
Inclusive



Use of Exclusive would increase τν sin2β discrepancy, use of Inclusive would not solve the problem

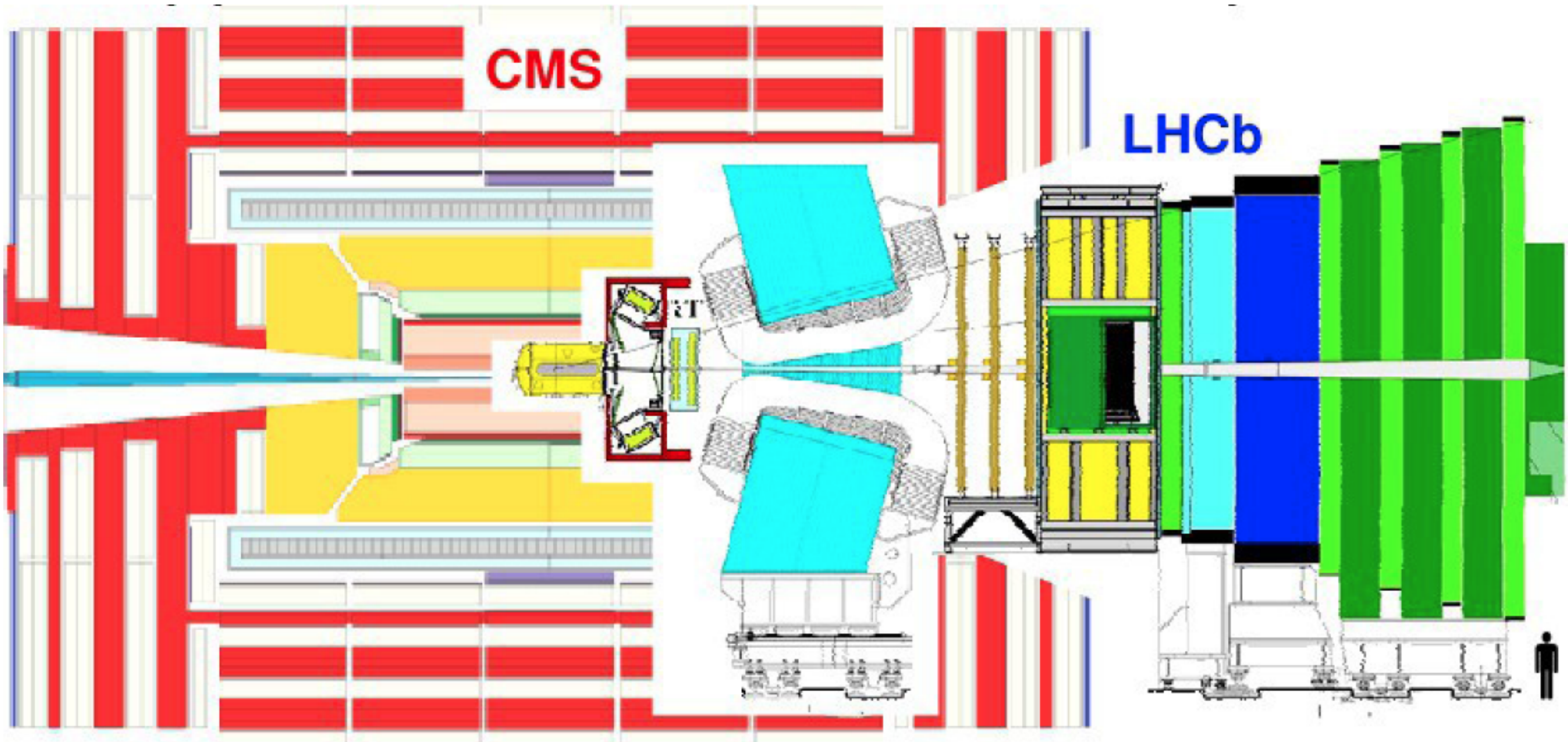
A V_{ub} fix?

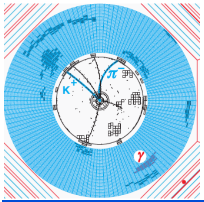
- Add new physics: right handed currents with coupling V_{ub}^R
  - B→πℓν rate goes as $\left|V_{ub}^L + V_{ub}^R\right|^2$
  - B→τν rate goes as $\left|V_{ub}^L - V_{ub}^R\right|^2$
  - B→X_uℓν rate goes as $\left|V_{ub}^L\right|^2 + \left|V_{ub}^R\right|^2$
- Agreement with ~15% rhc
  - Can arise in SUSY
  - Not in loops
  - See Crivellian [arXiv:0907.2461], also Buras et.al, [arXiv: 1007.1993]



New Results

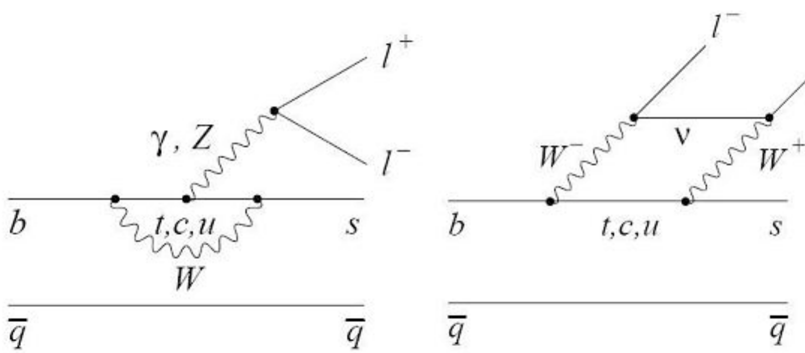
- NP **must** affect every process; the amount tells us what the NP is ("DNA footprint")
- New data from CDF, D0, BaBar BES, BELLE, ATLAS, CMS & LHCb – Not nearly enough time to cover





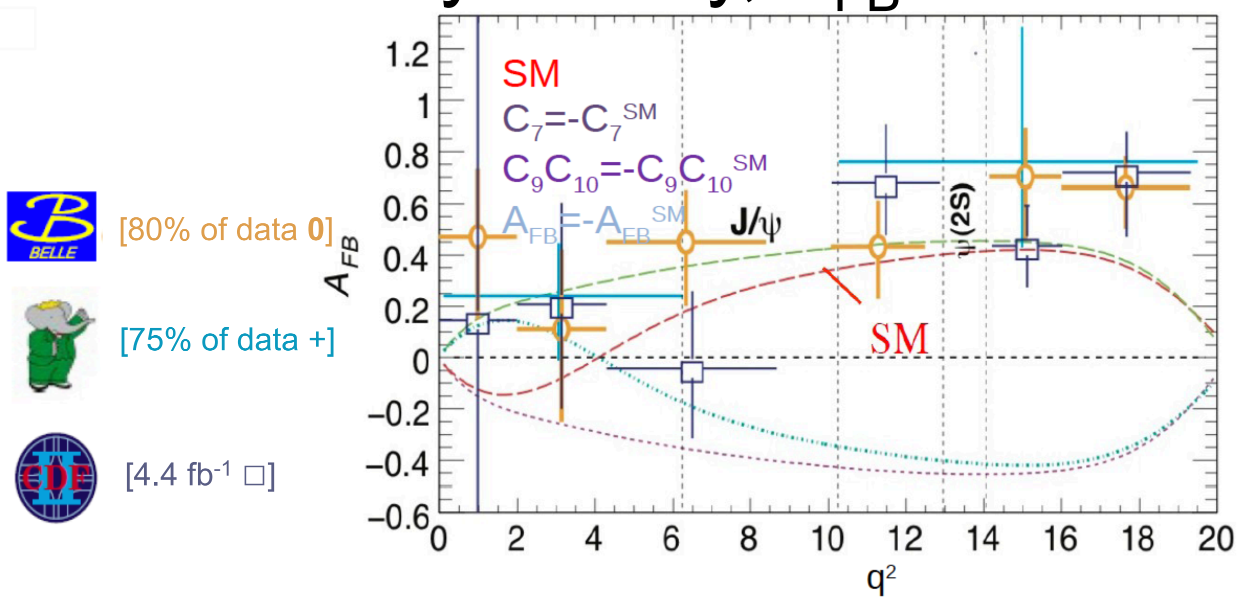
B°→K*°μ⁺μ⁻

- Similar to K*γ, but more decay paths



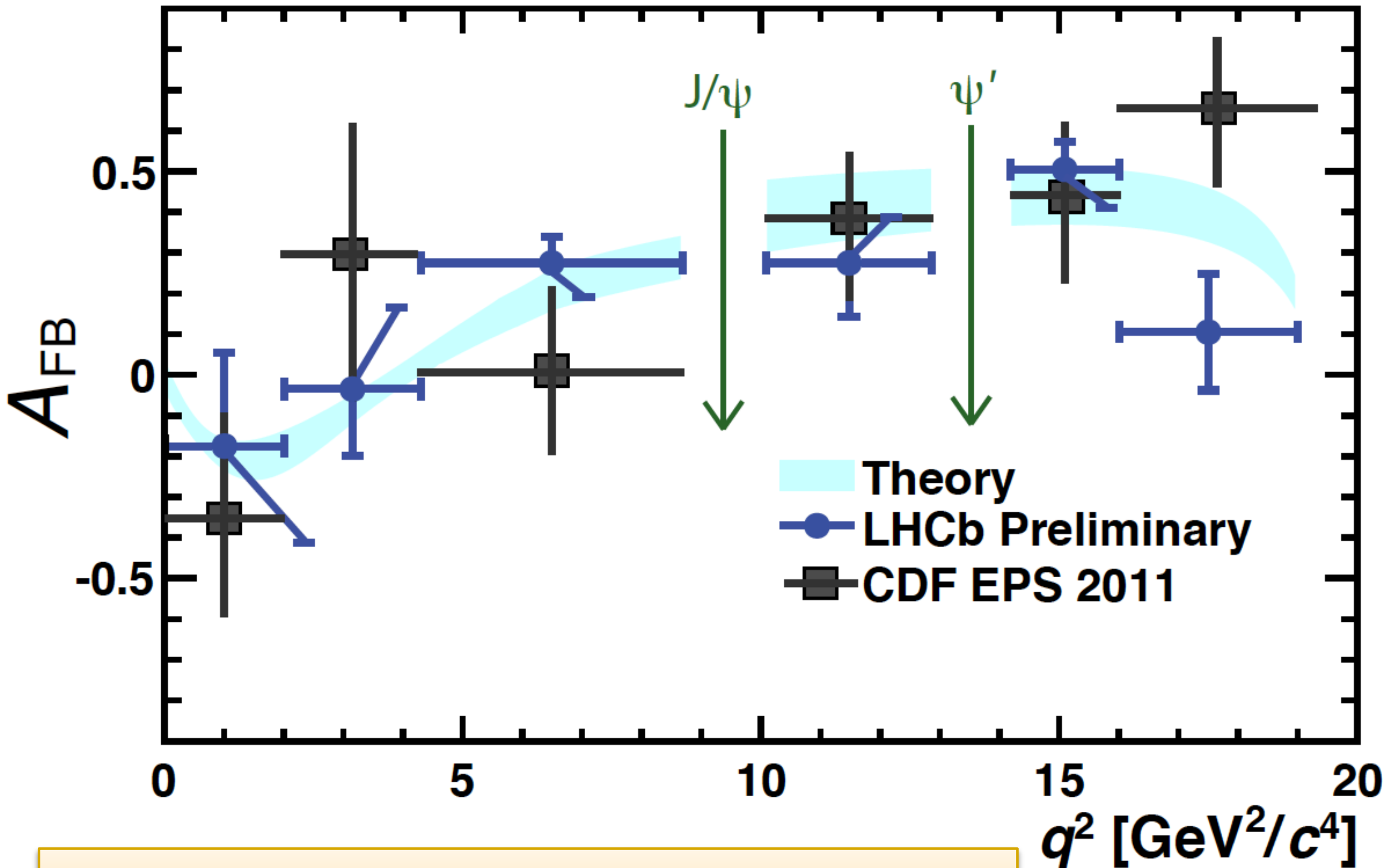
+ new particles in loops

- Several variables can be examined, e.g. muon forward-backward asymmetry, A_{FB} is well predicted
- Situation as of July 26



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

- New results from CDF 6.8 fb^{-1} & LHCb 0.3 fb^{-1}

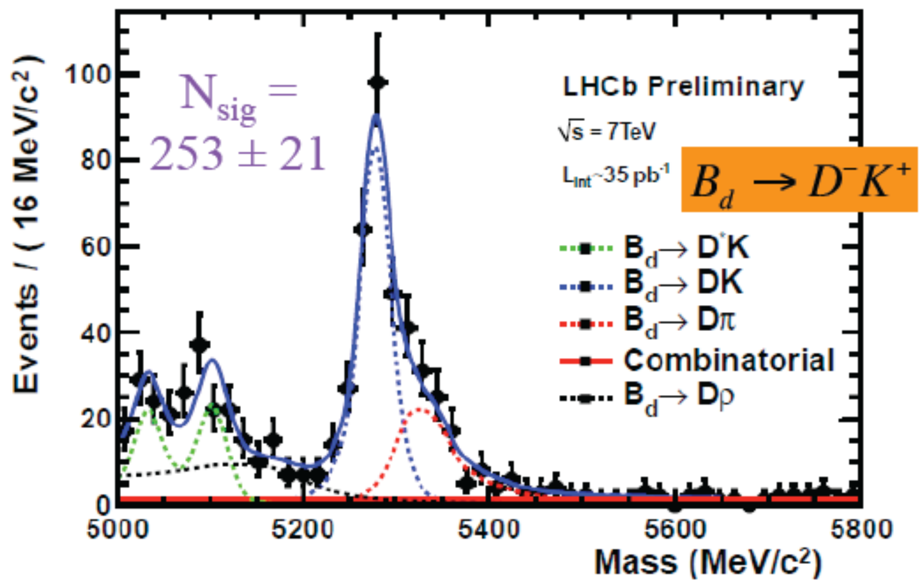


No evidence of deviation from SM so far

b Fractions (LHCb)

- Important to set normalization scale for B_s
- f_s/f_d using hadronic decays

$B_d \rightarrow D^- K^+ / B_s \rightarrow D_s^- \pi^+$, & $B_d \rightarrow D^- \pi^+ / B_s \rightarrow D_s^- \pi^+$

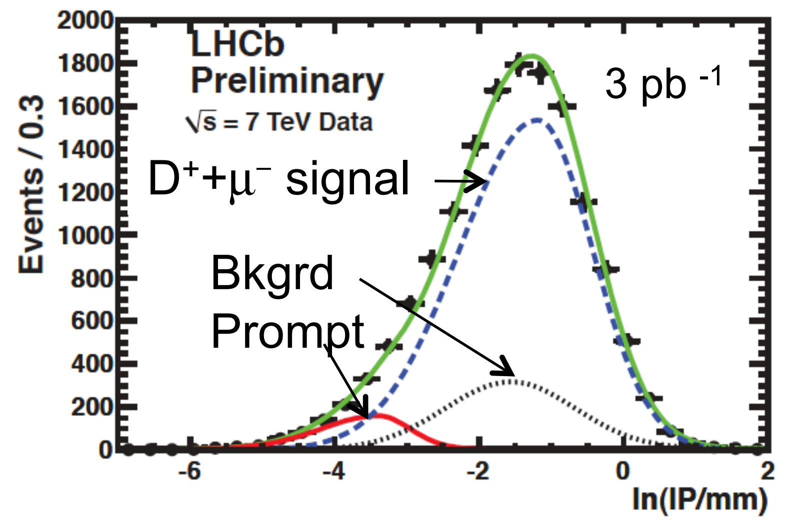


$$f_s / f_d = 0.253 \pm 0.017 \pm 0.017 \pm 0.020$$

Theory error

- Using Semileptonics:

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

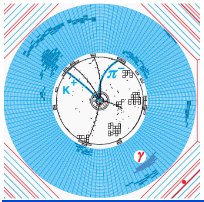


$$f_s / f_d = 0.268 \pm 0.008^{+0.022}_{-0.020}$$

- independent of η & p_t

$$f_s / f_d = 0.267^{+0.021}_{-0.020}$$

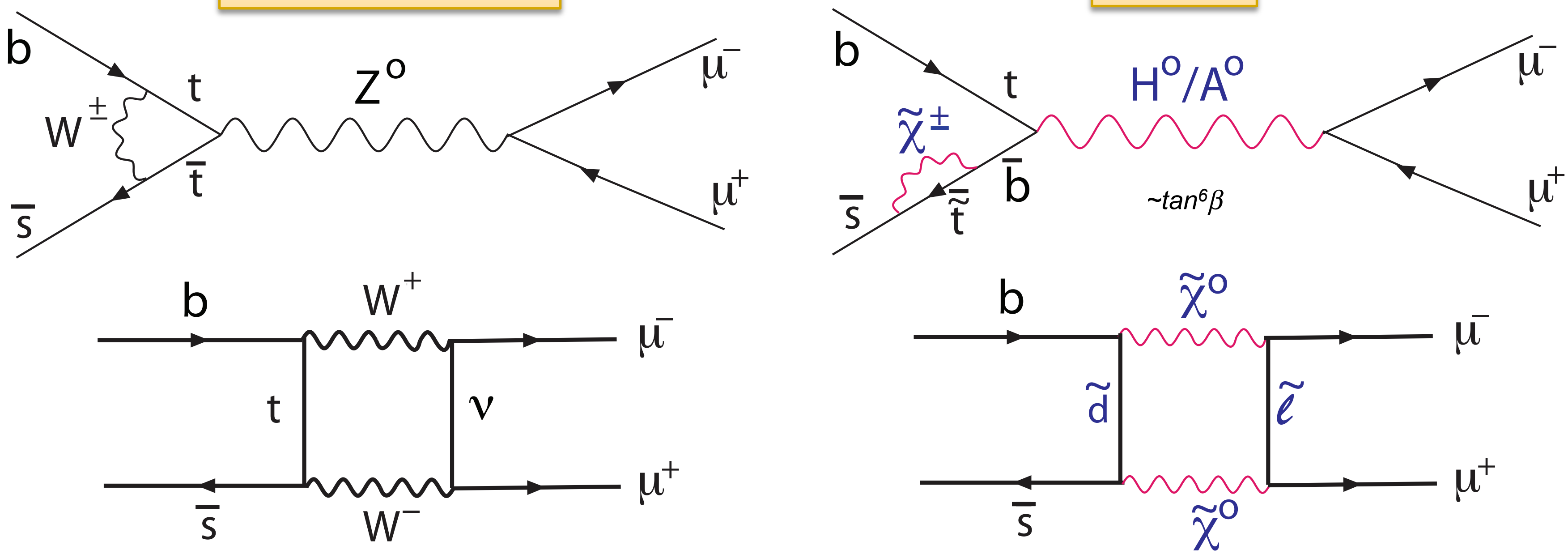
LHCb-CONF-2011-028



$B_s \to \mu^+\mu^-$

- SM branching ratio is $(3.2\pm0.2)\times10^{-9}$ [Buras arXiv: 1012.1447], NP can make large contributions.

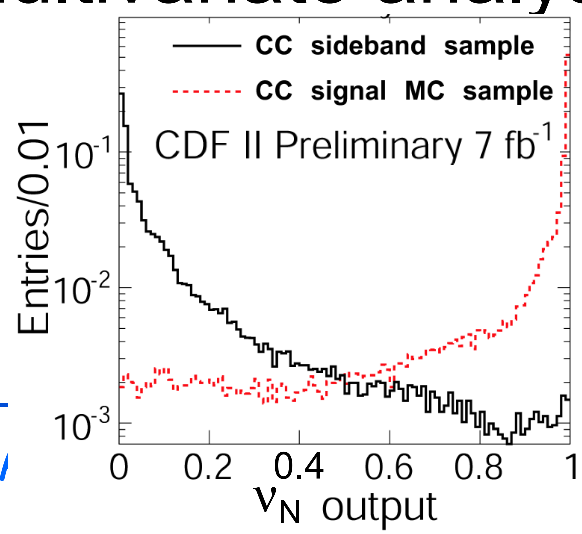
Standard Model | MSSM

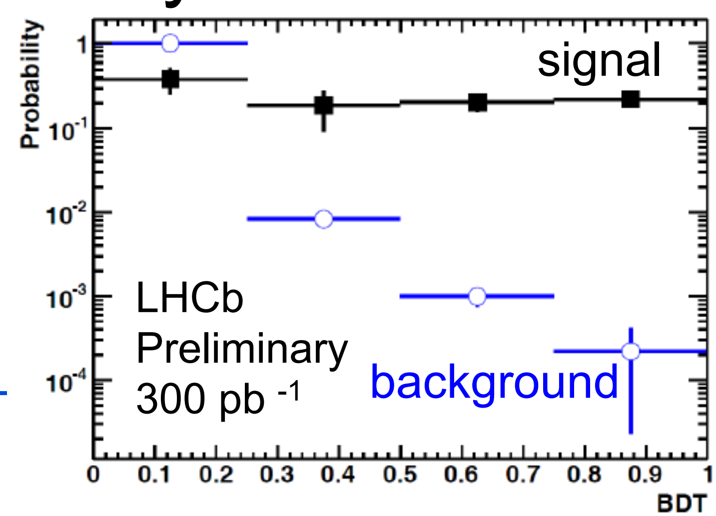


- Many NP models possible, not just Super-Sym

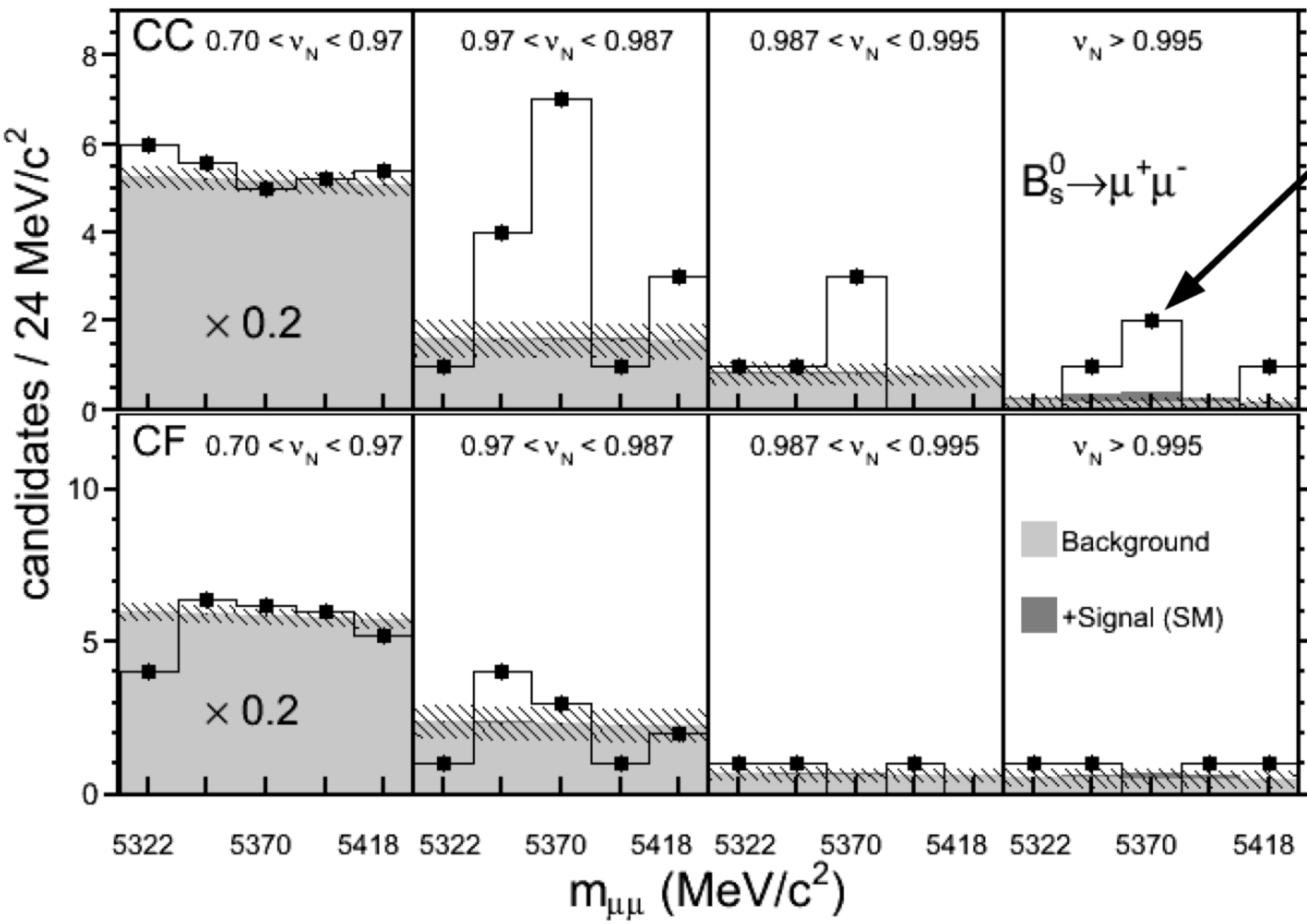
Discrimination

- Select same topology as $B \to h^+h^-$, add μ ID
- Lots of other variables to discriminate against bkgrd : B impact parameter, B lifetime, B p_t, B isolation, muon isolation, minimum impact parameter of muons, muon polarization…
- Can use $B \to h^+h^-$ to tune cuts or form a multivariate analysis, used by CDF & LHCb





CDF Result



Example:
Obs: 2
Bkg. exp:
0.16±0.12

$B(B_s \to \mu^+\mu^-)$

$= (1.8^{+1.1}_{-0.9})x10^{-8}$

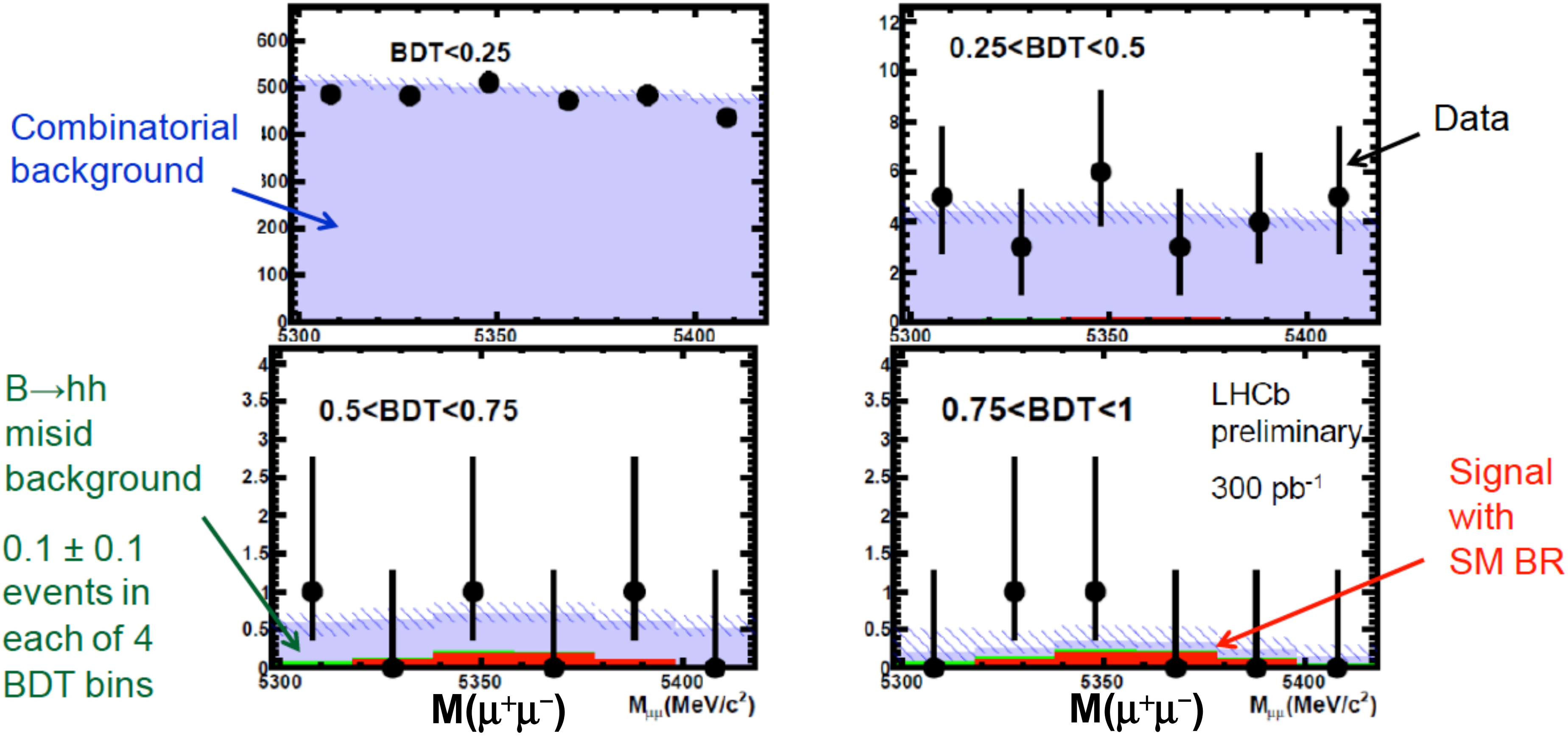
5.6 x SM expectation

p value for bkgrnd + SM is 2.9%

Set a “two sided limit @ 90% CL” $4.6 \times 10^{-9} < \mathcal{B}(B_s^0 \to \mu^+\mu^-) < 3.9 \times 10^{-8}$

This means to me that there isn’t a statistically significant result

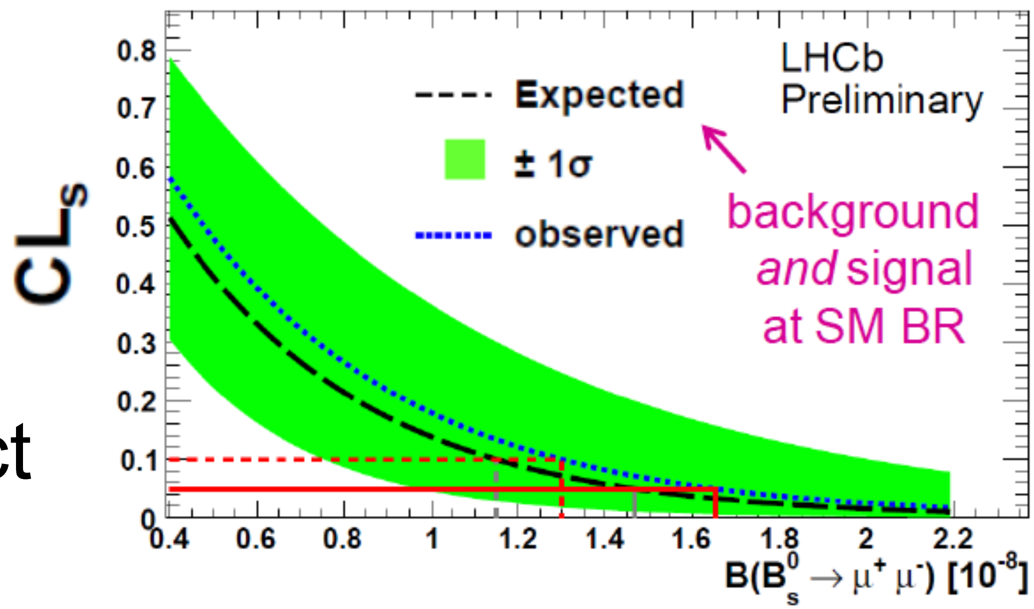
LHCb



	BDT<1/4	1/4<BDT<1/2	½<BDT<3/4	¾<BDT<1
# expected bkgrd	2968±69	25.0±2.5	2.99±0.89	0.66±0.40
# expected signal	1.26±0.13	0.61±0.06	0.67±0.07	0.72±0.07
Sum expected	2969±69	25.6±2.5	3.66±0.89	1.38±0.41
Observed	2872	26	3	2

LHCb

- LHCb does not observe any excess
- In the two BDT signal bins expect 5.1 events if $\mathcal{B}$ is at SM level, see 5



LHCb-CONF-2011-037

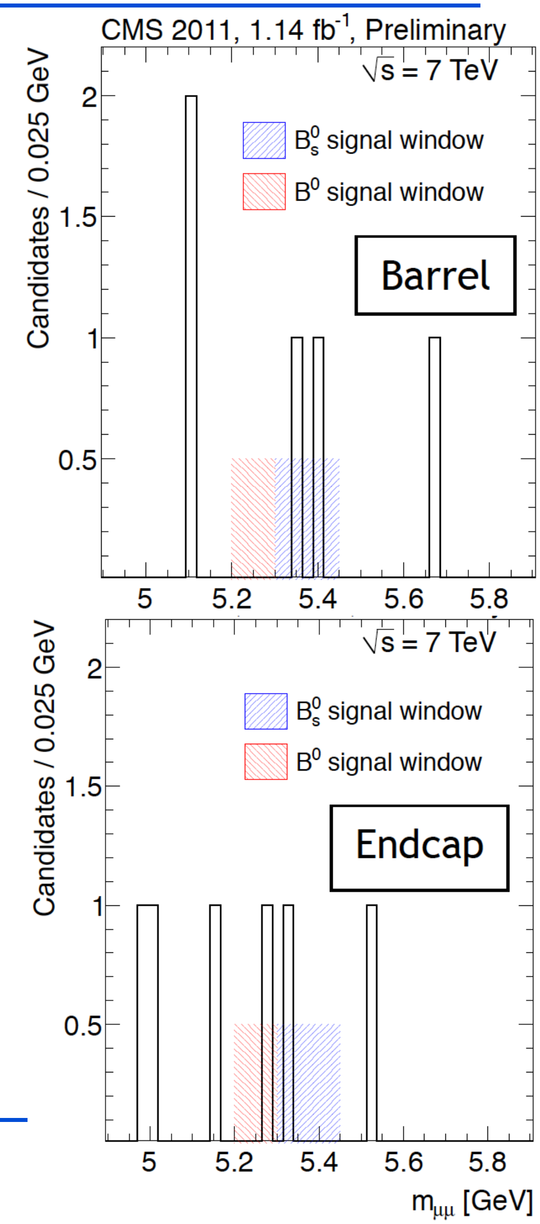
- Expected limit @95% (90%) $1.5(1.2)\times10^{-8}$
- Observed limit @95% (90%) $1.6(1.3)\times10^{-8}$
- p-value of bkgrnd only hypothesis 14%
- Observed limit with 2010 data $1.5(1.2)\times10^{-8}$

CMS

- Cut based analysis

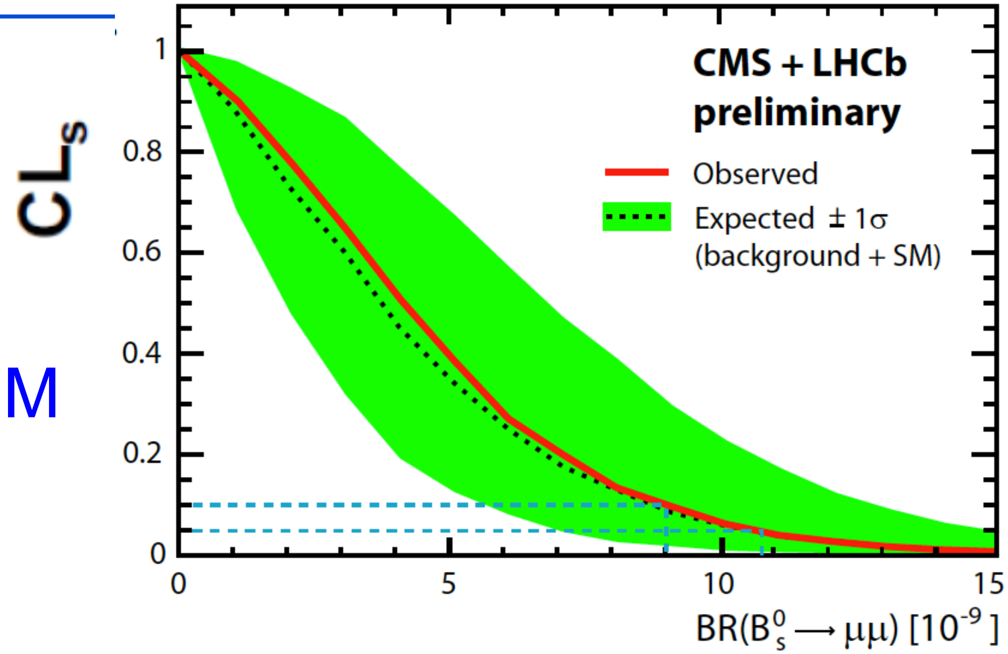
	Barrel	Endcap
# expected bkgrd	0.60±0.35	0.80±0.40
# bkgrd $B \to h^+h^-$	0.07±0.02	0.04±0.01
# expected signal	0.80±0.16	0.36±0.07
Sum expected	1.47±0.39	1.20±0.41
Observed	2	1

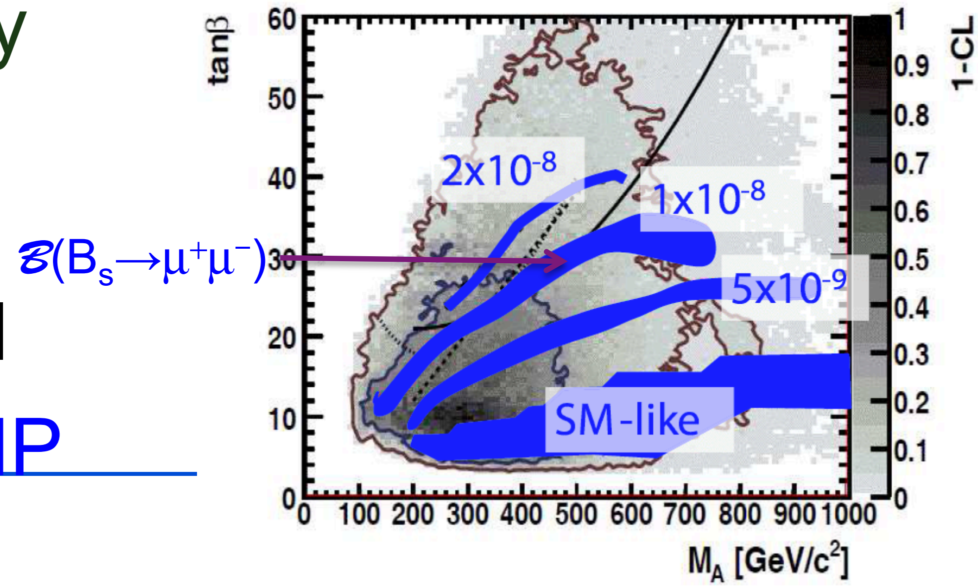
- Upper limits:
  - 1.9×10^{-8} @95% CL
  - 1.6×10^{-8} @90% CL



LHC Combined

- Observed limits
  - 1.1×10^{-8} @95% CL
  - 0.9×10^{-8} @90% CL,
  - This is 3.4(2.8) times SM value
- LHC consistent with CDF with a probability of 0.3%
- Set serious limits in NUHM1 SUSY model
- Still lots of room for NP

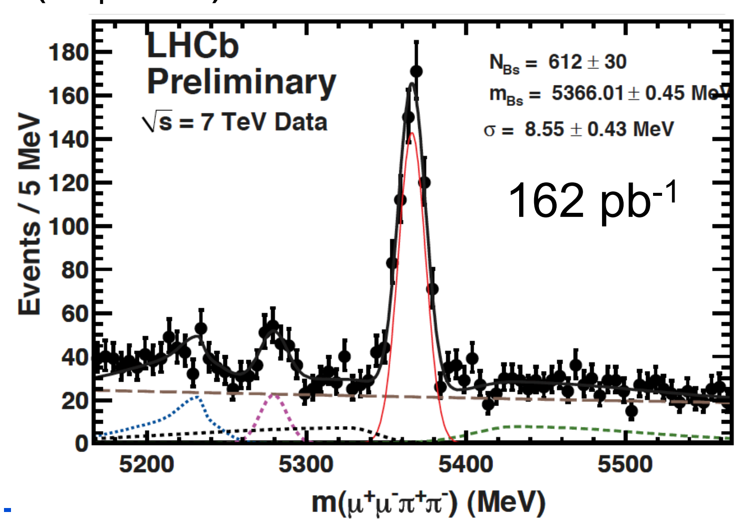




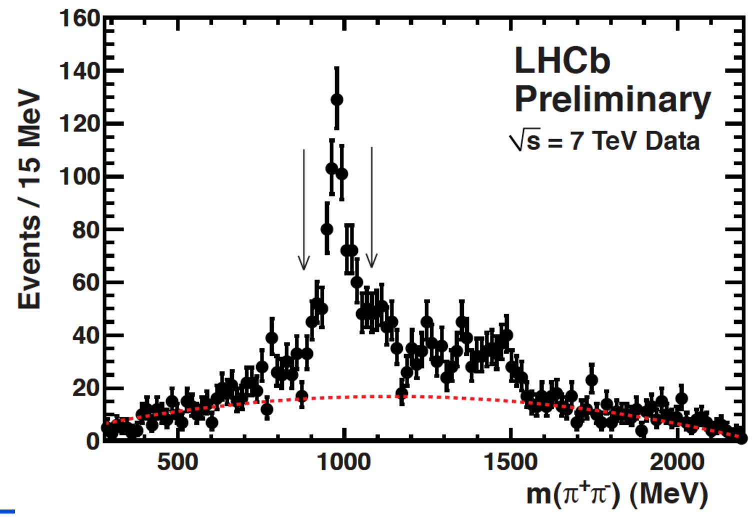
1^{st} Observation of $B_s \rightarrow J/\psi\ f_0(980)$

- 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

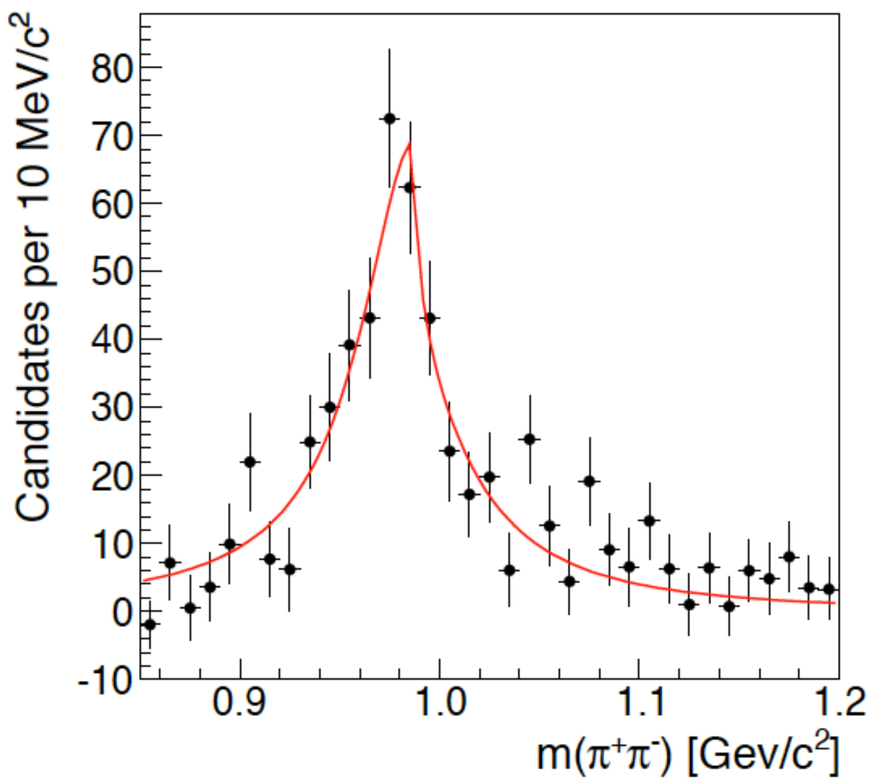


$m(\pi^+\pi^-)$ within 30 MeV of B_s mass

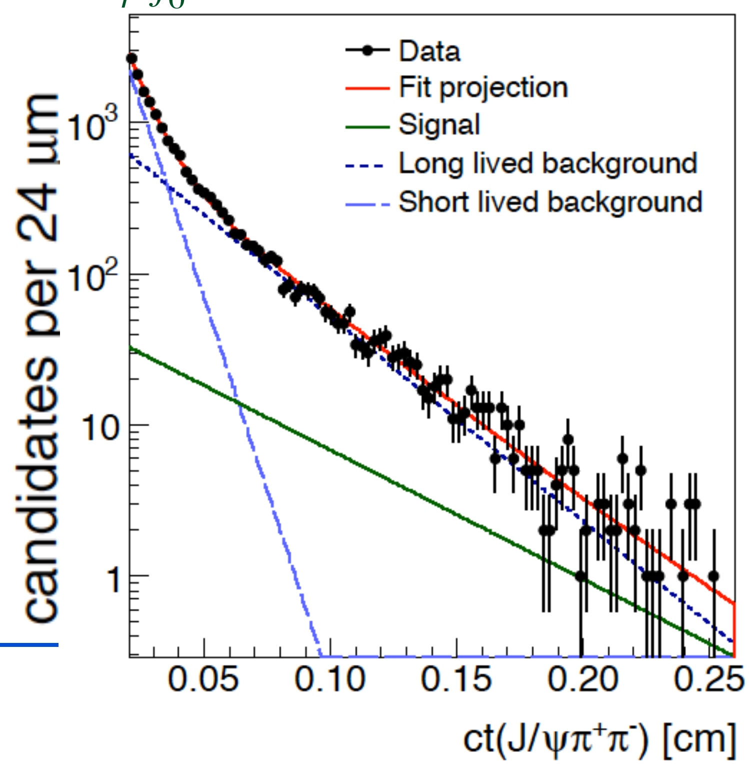


Confirmations

- Belle, CDF & D0
- CDF measures τ also, ignoring CP violation, in this CP odd eigenstate. $\langle\tau_{Bs}\rangle$=1.43±0.04 ps (PDG)

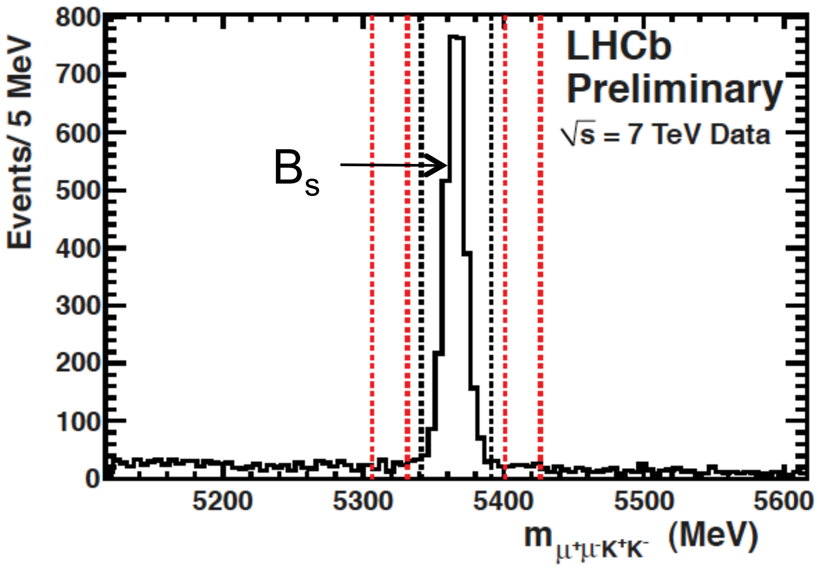


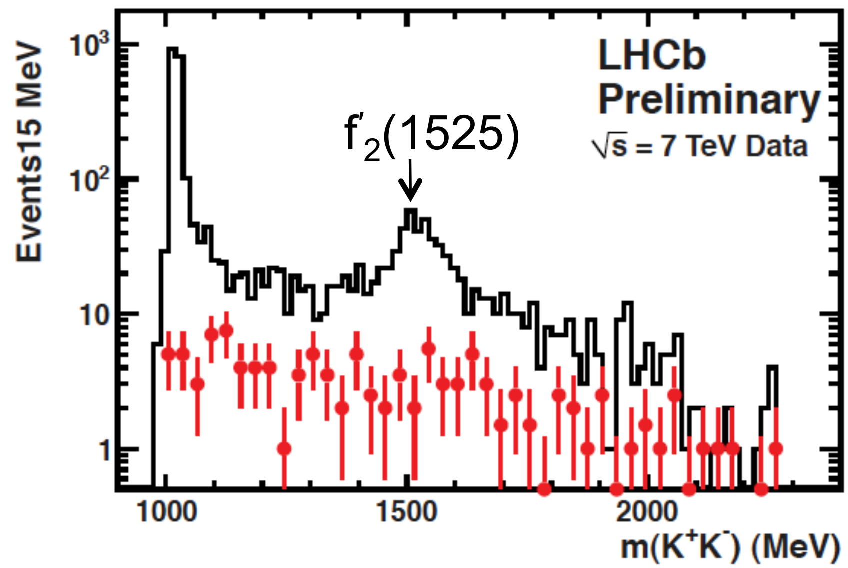
$$\tau_{J/\psi f_0} = 1.70^{+0.12}_{-0.11} \pm 0.03\,\mathrm{ps}$$



1st Observation of $B_s \rightarrow J/\psi\ f'_2(1525)$

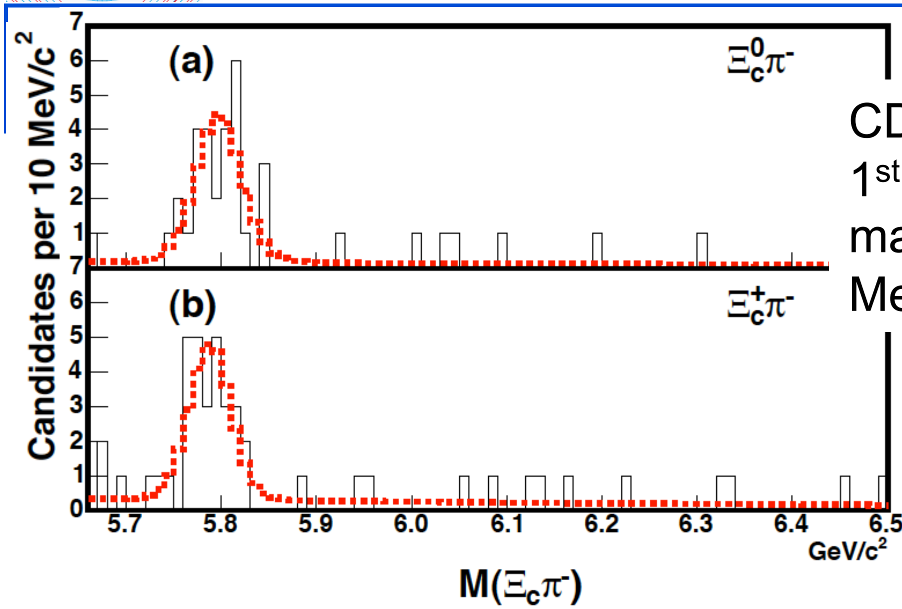
- $B_s \rightarrow J/\psi\ K+K-$



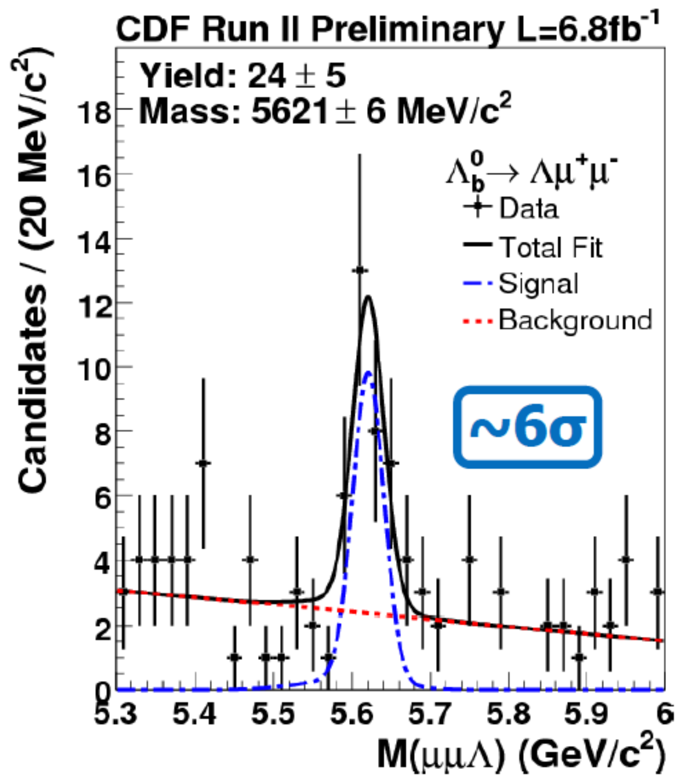


- $$R^{f'_2}_{\text{effective}} \equiv \frac{\mathcal{B}(B^0_s \to J/\psi f'_2(1525),\ f'_2(1525) \to K^+K^-)}{\mathcal{B}(B^0_s \to J/\psi\phi,\ \phi \to K^+K^-)} = (19.4 \pm 1.8 \pm 1.1)\%$$
$$\text{for } \left|m(K^+K^-) - 1525 \text{ MeV}\right| < 125 \text{ MeV}.$$

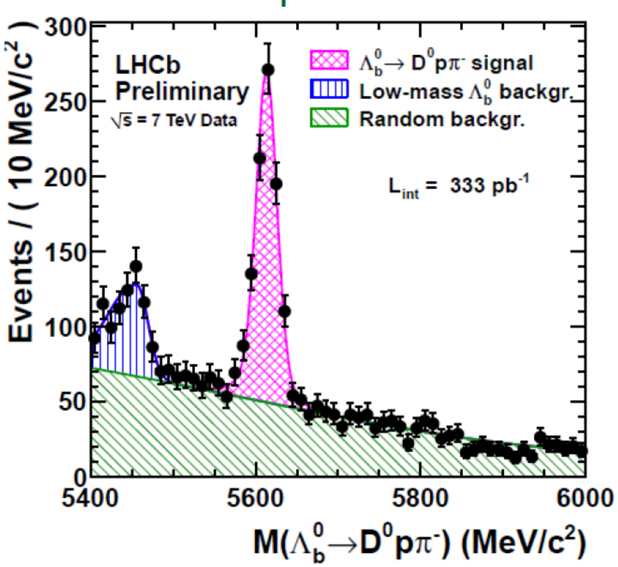
New b-Baryon Decays



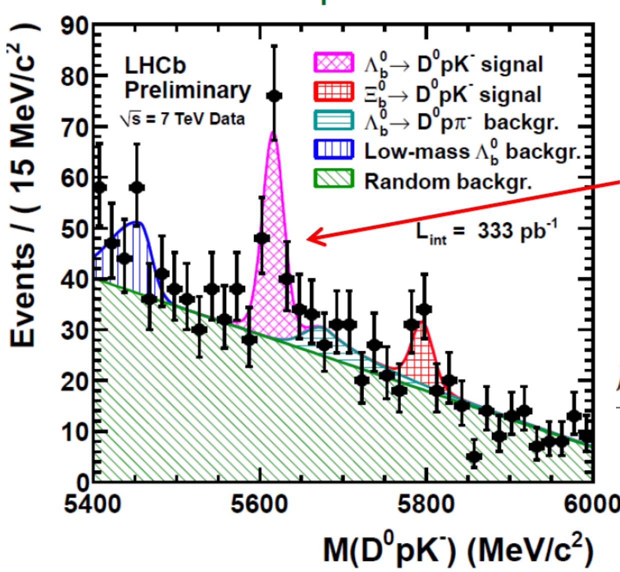
CDF Ξ_b^o
1st observation
mass 5787.8±5.0 MeV



$D^0p\pi^-$



D^0pK^-



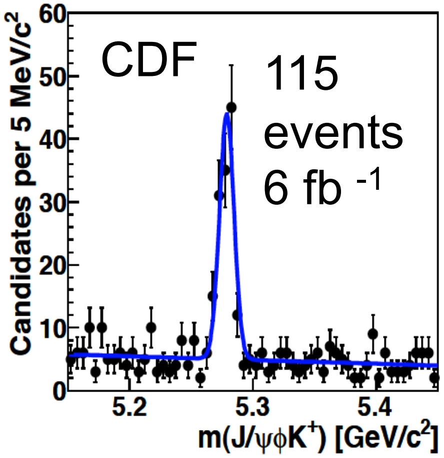
$\Lambda_b \to D^0pK$

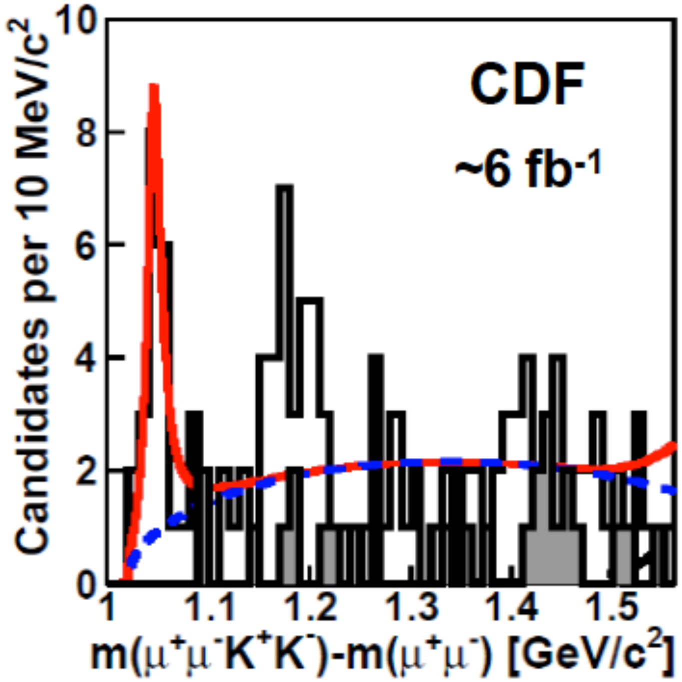
$\Lambda_b \to D^0pK$ observed for first time with significance of 6.3σ

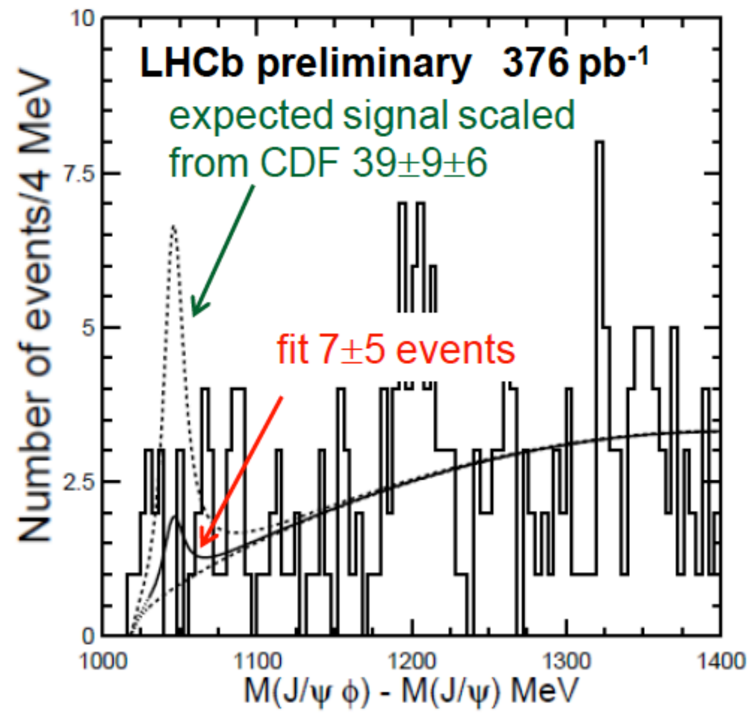
$$\frac{\mathcal{B}(\Lambda_b^0 \to D^0 p K^-)}{\mathcal{B}(\Lambda_b^0 \to D^0 p \pi^-)} = 0.112 \pm 0.019^{+0.011}_{-0.014}$$

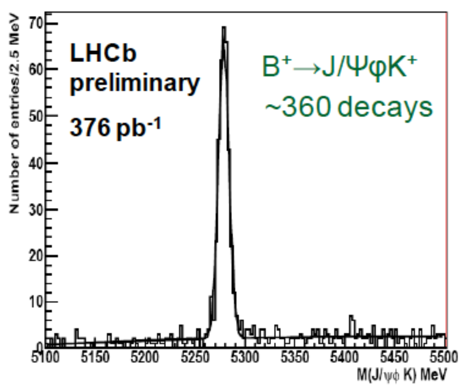
X(4140)?

- In $B^- \to J/\psi\phi K^-$ decays, CDF reported a narrow structure in $m(J/\psi\phi)$ mass [arXiv:1101.6058]

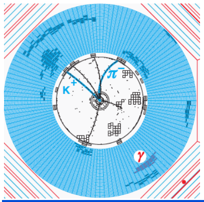






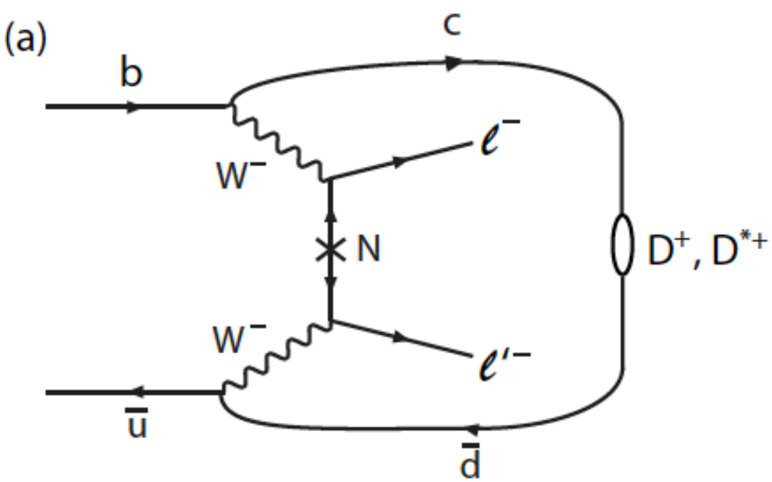


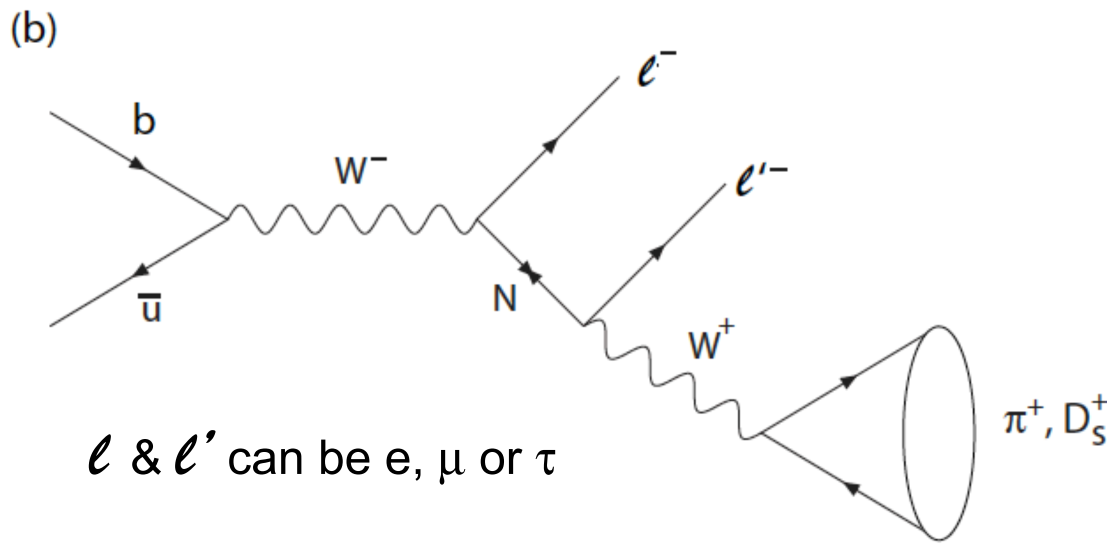
No signal evident in LHCb data



Majorana ν's

- Several ways of looking for presence of heavy ν's (N) in heavy quark decays if they are Majorana (their own anti-particles) and couple to "ordinary" ν's





ℓ & ℓ' can be e, μ or τ

Analogous to ν-less nuclear β decay

Current Searches

- Belle $B^- \to D^- \ell\ell'$
- Found upper limits,

ee mode not competitive with nuclear β decay, others unique

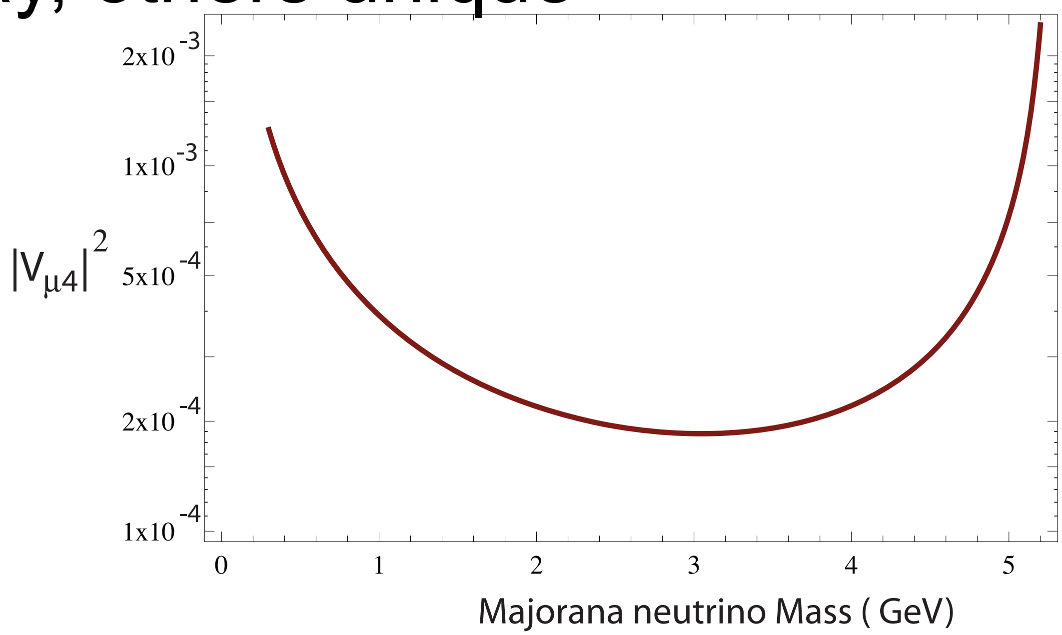
Mode	U.L. $[10^{-6}]$
$B^+ \to D^- e^+ e^+$	< 2.6
$B^+ \to D^- e^+ \mu^+$	< 1.8
$B^+ \to D^- \mu^+ \mu^+$	< 1.0

[arXiv:1107.064]

LHCb $B^- \to \pi^+ \mu^- \mu^-$,

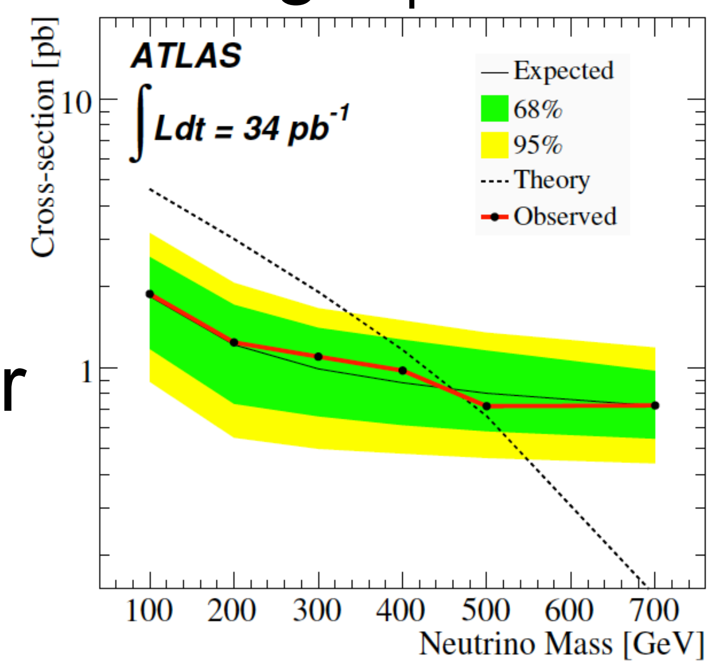
u.l < 4.5×10^{-8}

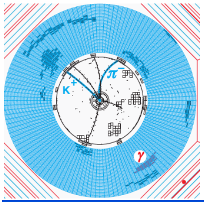
See A. Atre, T. Han, S. Pascoli, & B. Zhang [arXiv:0901.3589]



Searches at higher masses

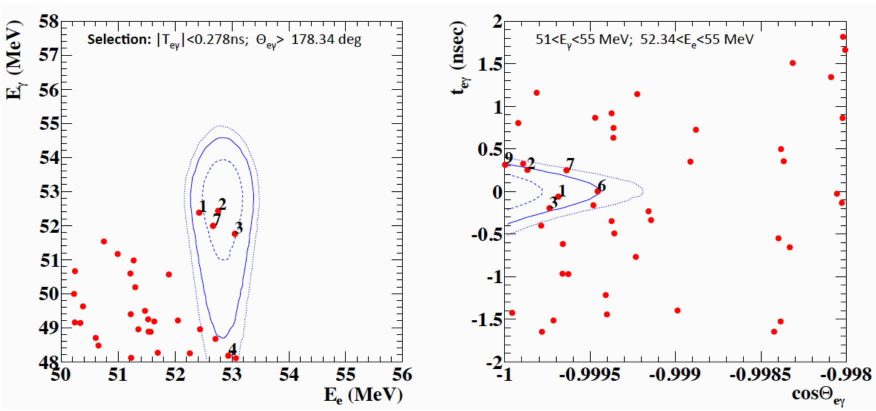
- CDF general search for like-sign dileptons [A. Abulencia et. al, Phys. Rev. Lett. 98, 221803 (2007)]
- CMS search for events with two isolated like-sign leptons, hadronic jets & missing E_T [arXiv:1104.3168]
- ATLAS [arXiv:1108.0366]
- If seen could also be interpreted in terms of other NP, ie. supersymmetery….

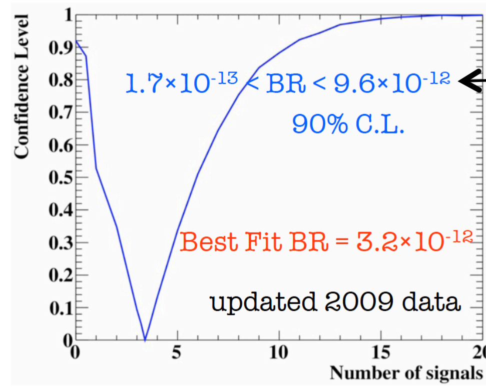




Lepton Flavor Violation

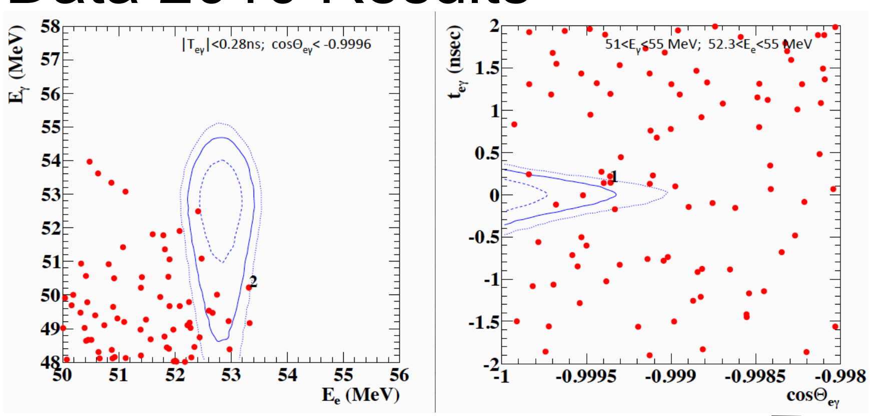
- $\mu\to e\gamma$ MEG data 2009 results (Mori EPS2011)

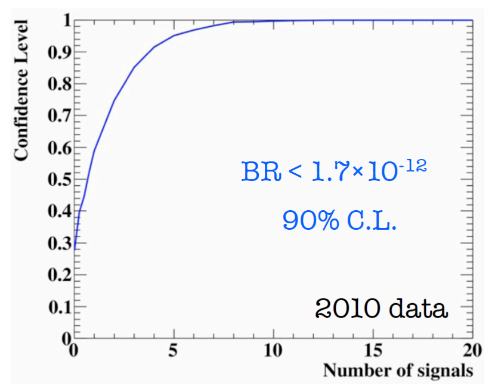




Note 2-sided limit

- Data 2010 Results



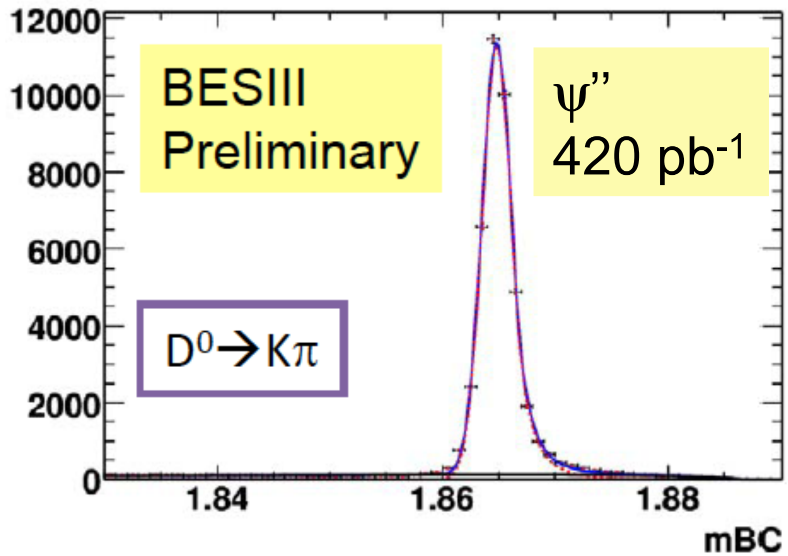


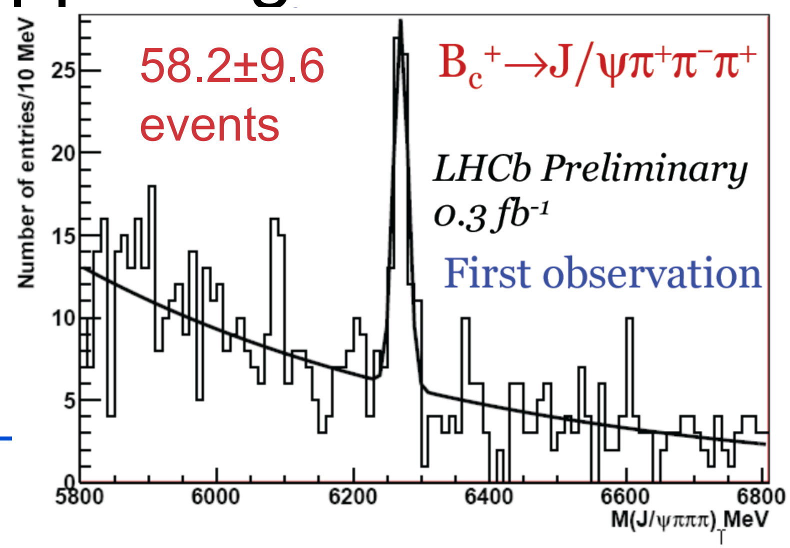
Combined $\mathcal{B}<2.4\times10^{-12}$

- Many limits on $\tau\to\ell hh$, Λh, $\bar{\Lambda}h$, $\mu\gamma$, μh, 3μ, best limits near 10^{-8} (Belle, BaBar)

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
- BES III, LHCb are happening now





Conclusions

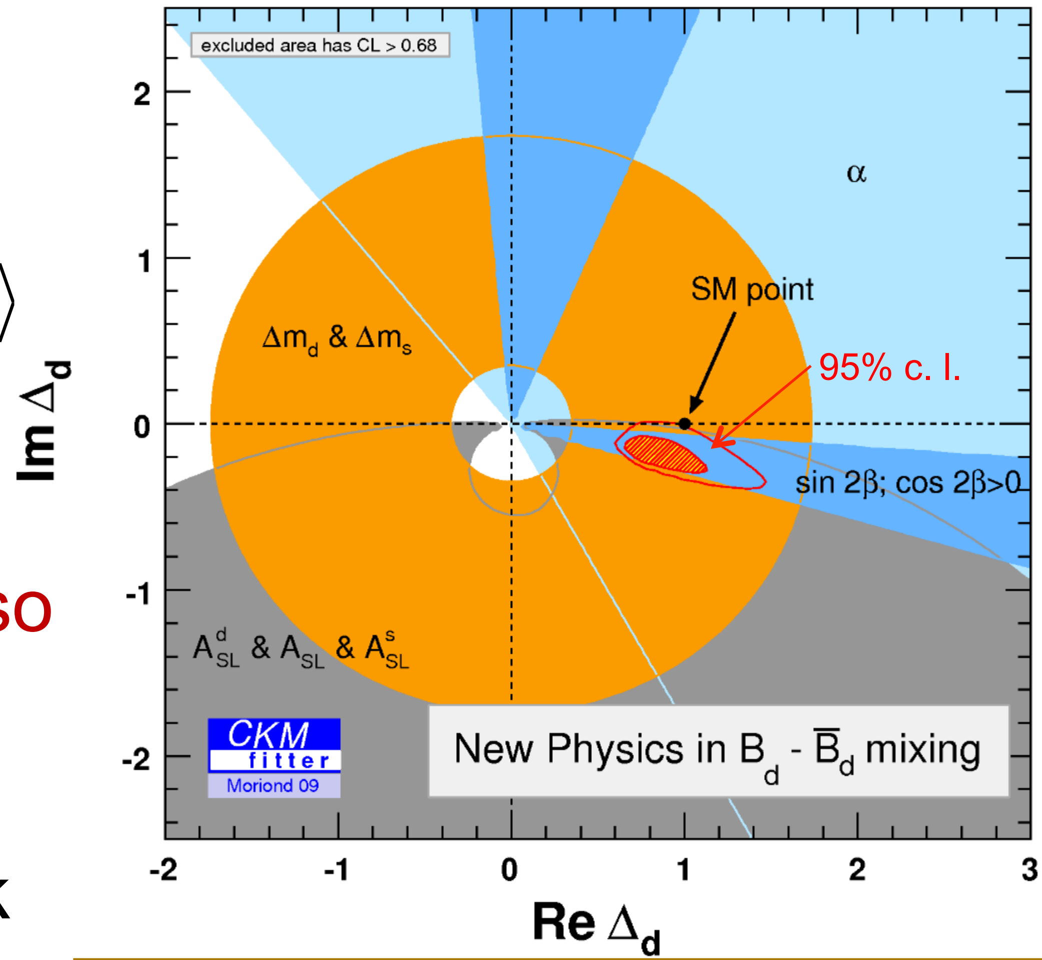
- Heavy Flavor physics is now very sensitive to potential New Physics effects at high mass scales
- LHC experiments have shown their ability by already making world class 1st measurements of flavor physics. They are ready!
- Heavy Flavor experiments are ready to search for and limit New Physics, especially in b & c decays at the LHC with the 2011 data and beyond
- Many other interesting flavor results have not been mentioned – apologies

The End

Limits on New Physics From B^o Mixing

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

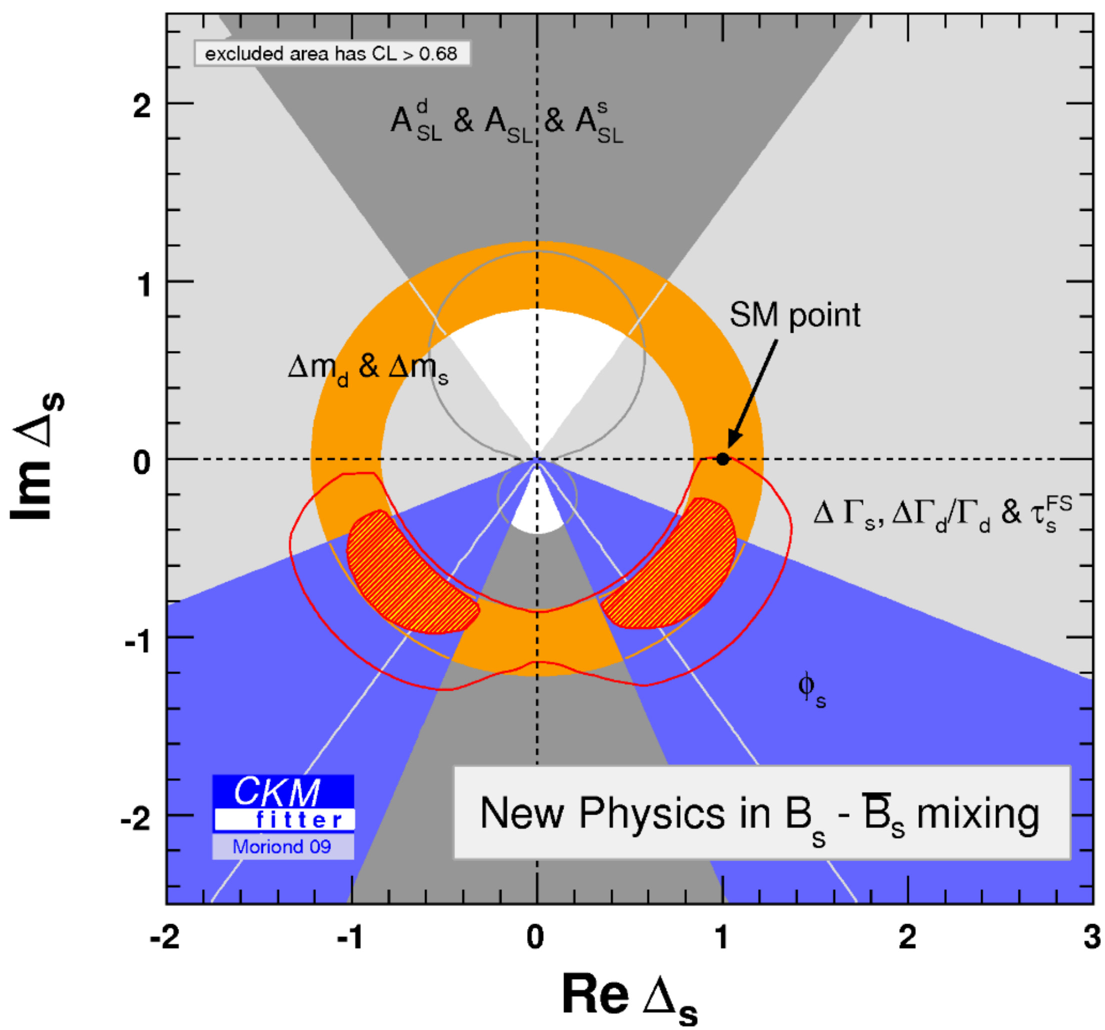
  $\Delta^{NP}_d = \mathrm{Re}\,\Delta_d + i\,\mathrm{Im}\Delta_d$
- Assume NP in tree decays is negligible, so no NP in $|V_{ij}|$, γ from $B^- \rightarrow D^o K^-$.
- Allow NP in Δm, weak phases, A_{SL}, & $\Delta\Gamma$.



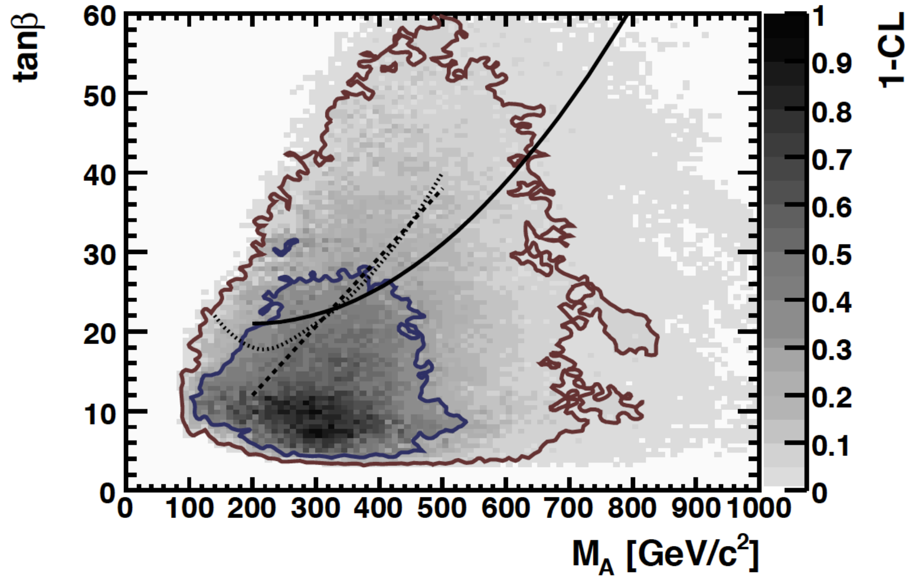
- Room for new physics, in fact SM is only at 5% c.l.

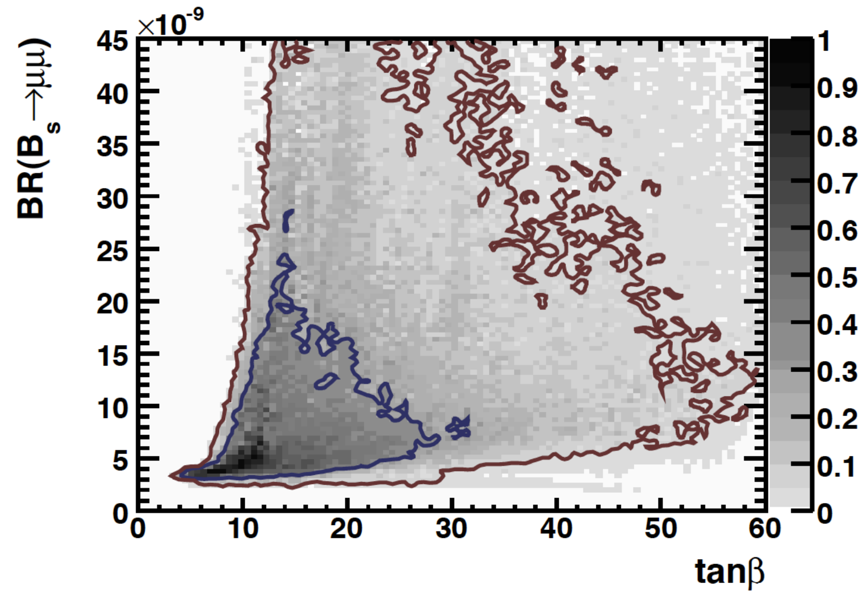
Limits on New Physics From B_S Mixing

- 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



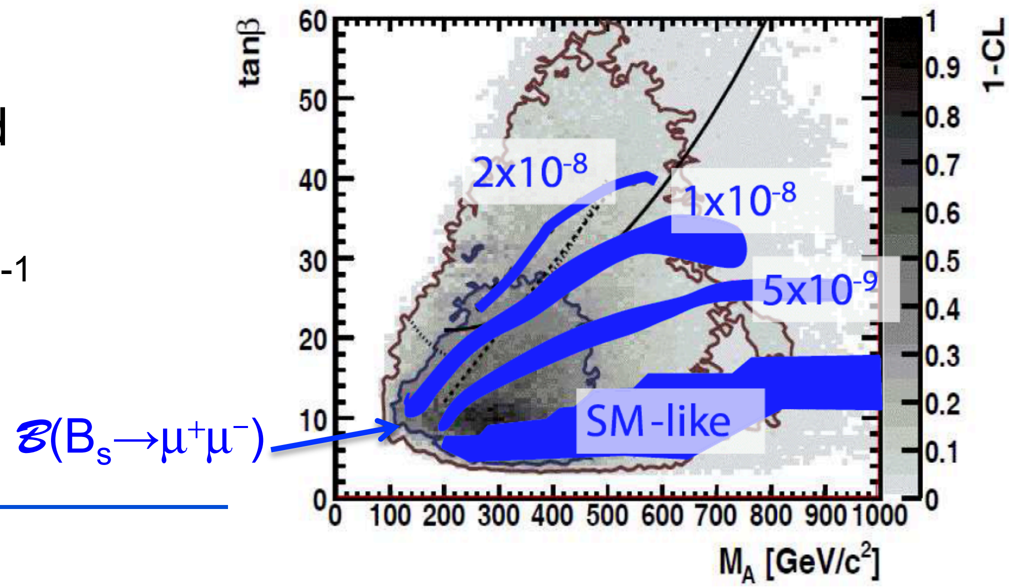
Exp: $\mathcal{B}(B_s \to \mu^+\mu^-)$ in NUHM1





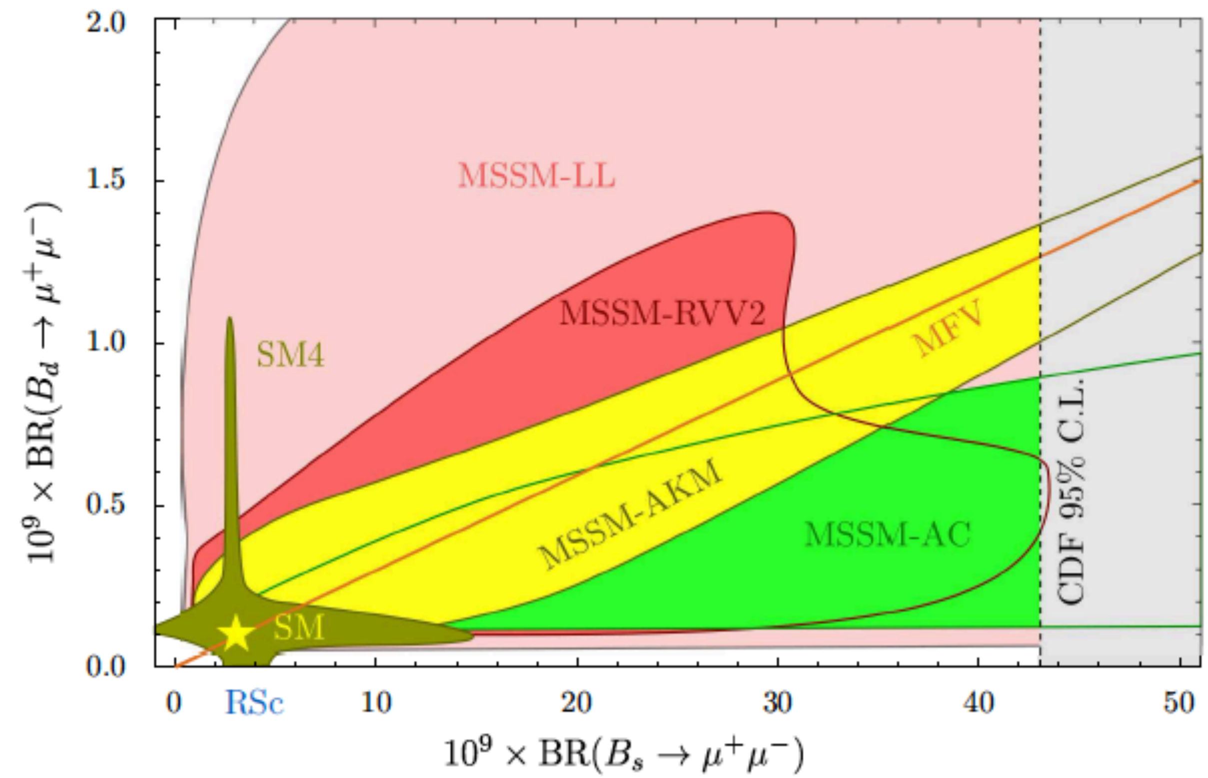
- CMS discovery contours for H, A $\to \tau^+\tau^- \to$jets (solid line), jet + μ (dashed), jet + e (dotted) using 30-60 fb^{-1}

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



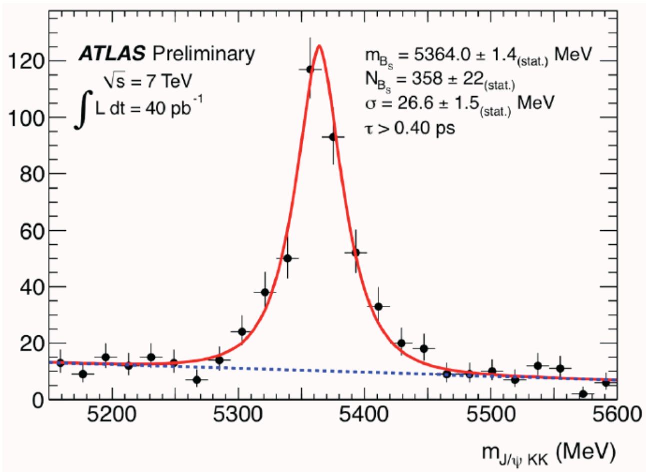
$B^o \rightarrow \mu^+\mu^-$

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

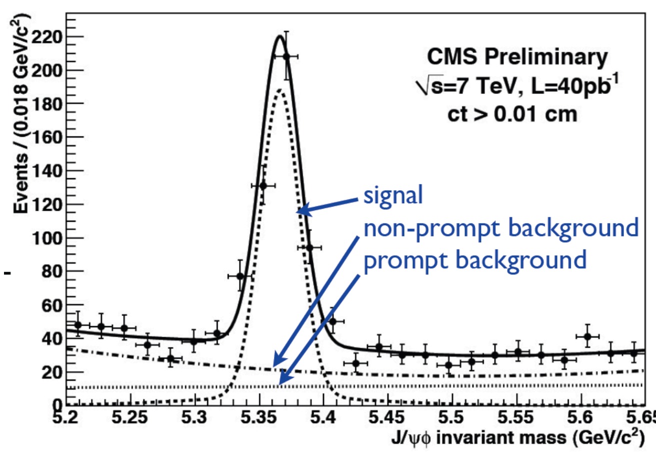


- This can only be done with the LHCb Upgrade

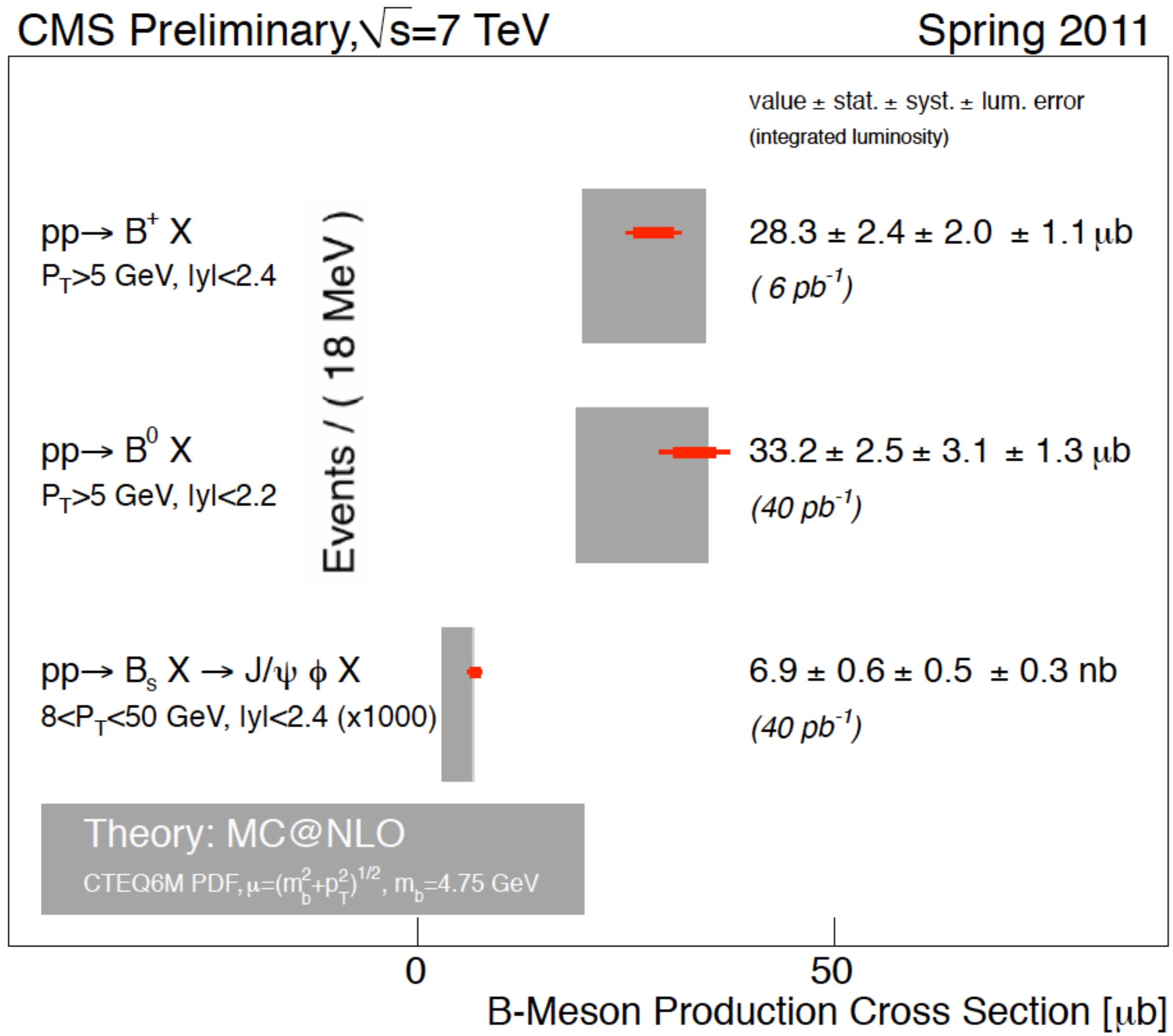
ATLAS B σ's



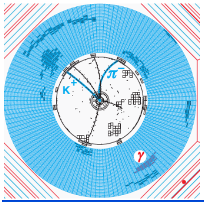
ATLAS Preliminary
√s = 7 TeV
∫L dt = 40 pb⁻¹
m_Bs = 5364.0 ± 1.4(stat.) MeV
N_Bs = 358 ± 22(stat.)
σ = 26.6 ± 1.5(stat.) MeV
τ > 0.40 ps
m_J/ψ KK (MeV)



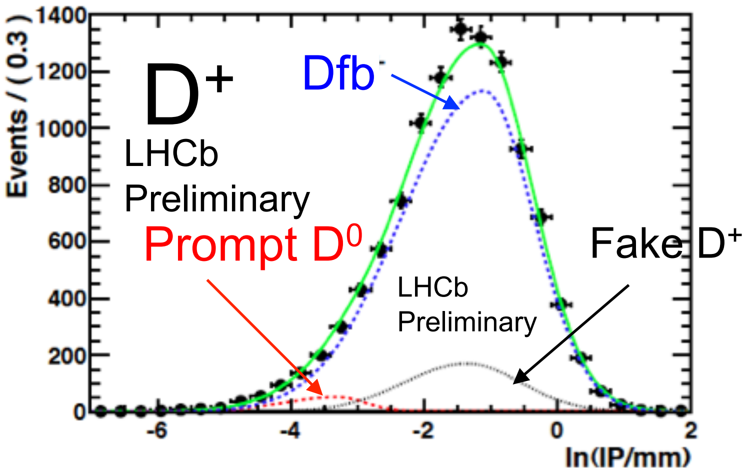
CMS Preliminary
√s=7 TeV, L=40pb⁻¹
ct > 0.01 cm
signal
non-prompt background
prompt background
Events / (0.018 GeV/c²)
J/ψφ invariant mass (GeV/c²)

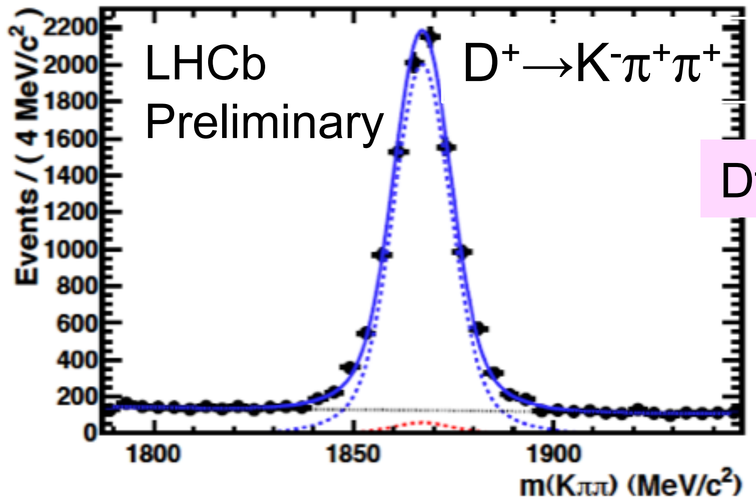


CMS Preliminary,√s=7 TeV
Spring 2011
value ± stat. ± syst. ± lum. error
(integrated luminosity)
pp→ B⁺ X
P_T>5 GeV, |y|<2.4
28.3 ± 2.4 ± 2.0 ± 1.1 μb
(6 pb⁻¹)
pp→ B⁰ X
P_T>5 GeV, |y|<2.2
33.2 ± 2.5 ± 3.1 ± 1.3 μb
(40 pb⁻¹)
pp→ B_s X → J/ψ φ X
8<P_T<50 GeV, |y|<2.4 (x1000)
6.9 ± 0.6 ± 0.5 ± 0.3 nb
(40 pb⁻¹)
Events / (18 MeV)
Theory: MC@NLO
CTEQ6M PDF, μ=(m_b²+p_T²)^1/2, m_b=4.75 GeV
0
50
B-Meson Production Cross Section [μb]

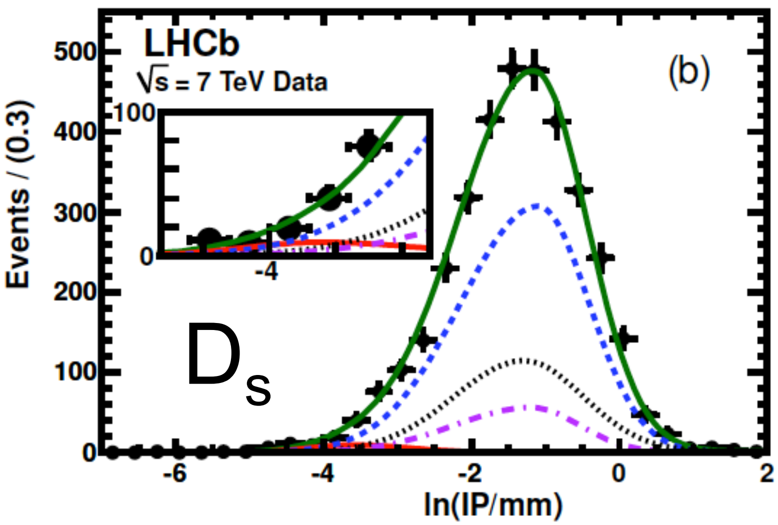


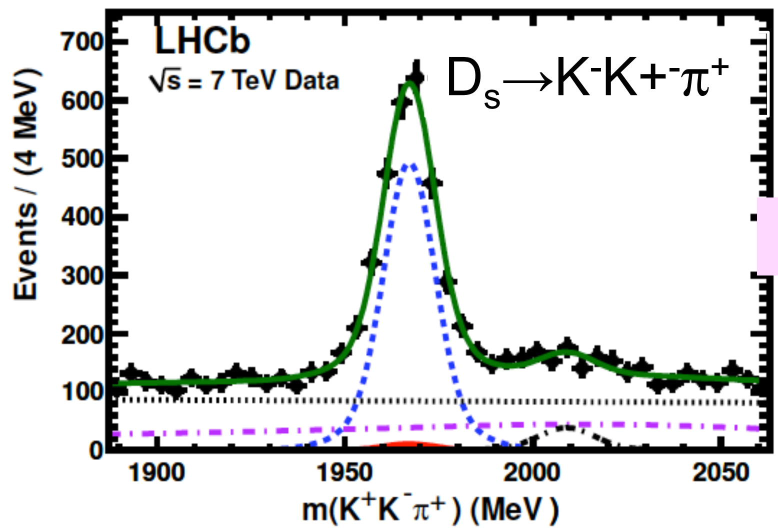
Also D^+, D_s, Λ_b





Dfb: 9406±110



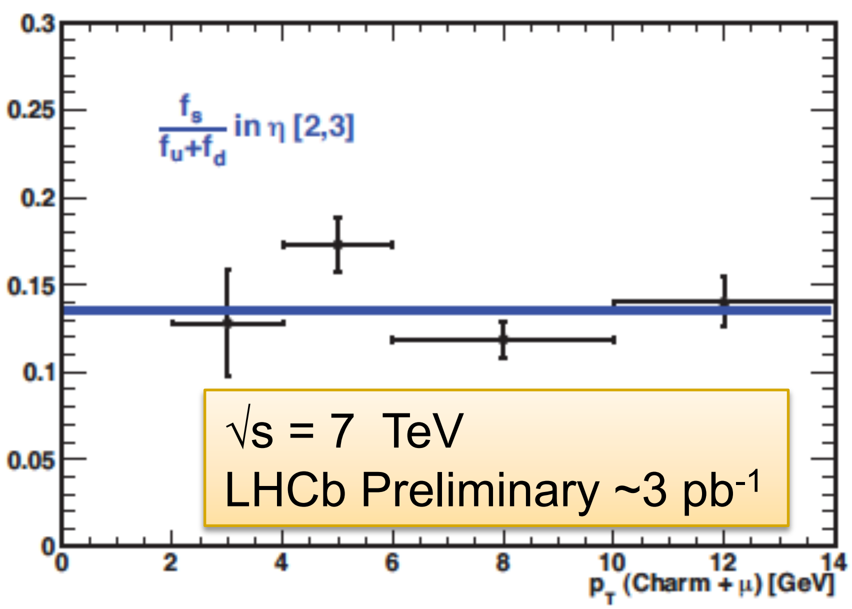


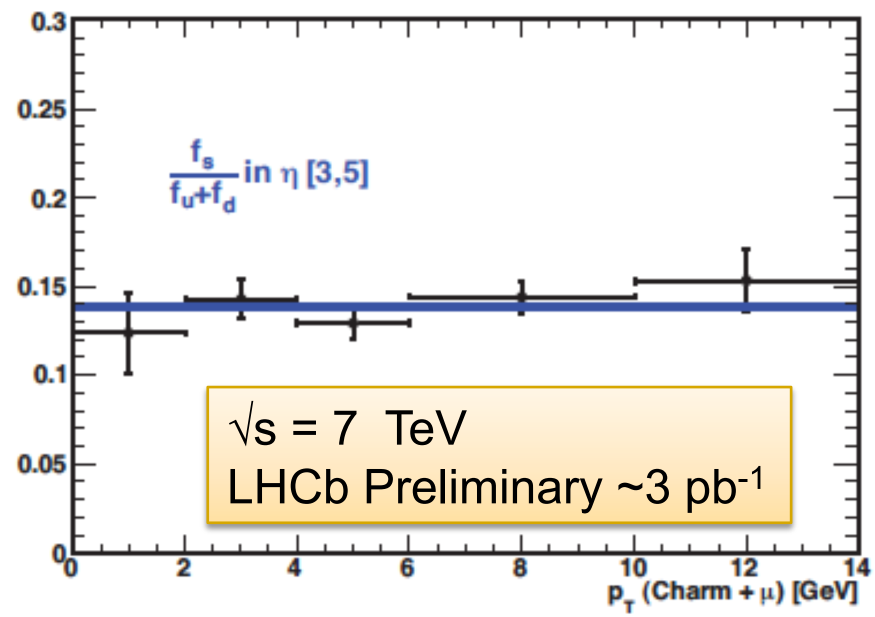
Dfb: 2446±60

Extract B_s fractions

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

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

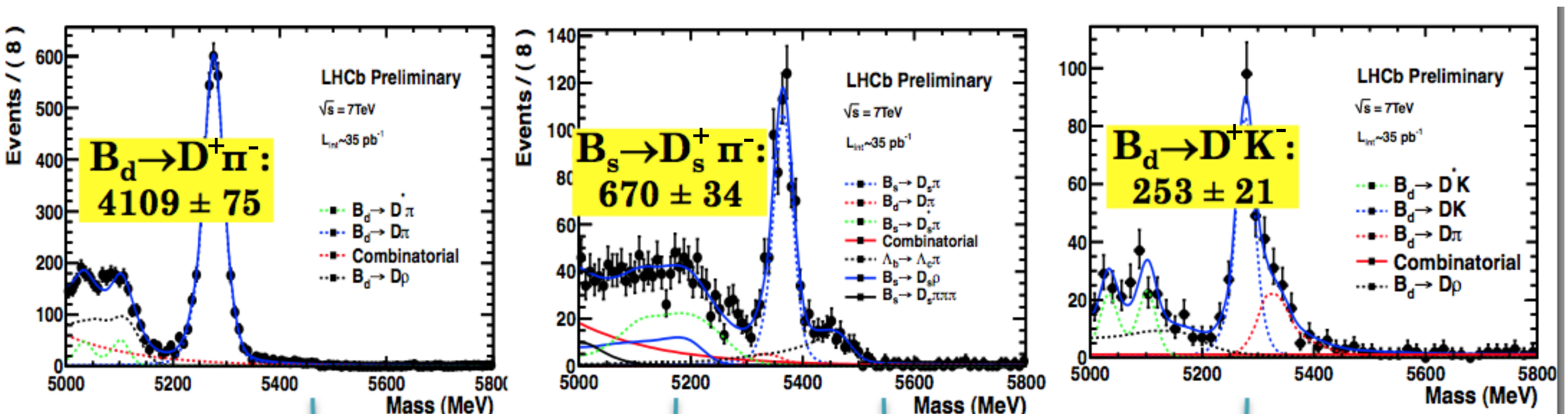




B_s fraction - hadronic

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

√s = 7 TeV
LHCb Preliminary



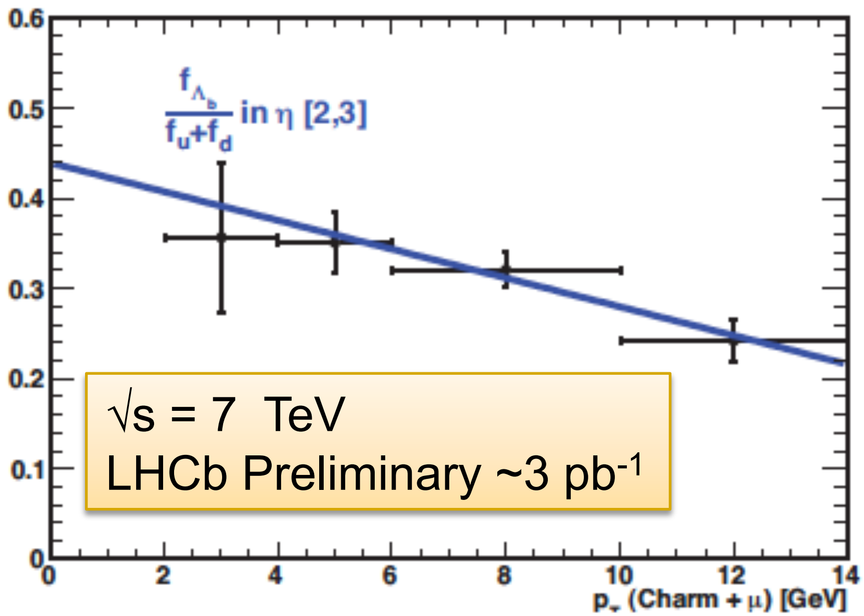
$$\frac{f_s}{f_d} = 0.249 \pm 0.013^{\text{stat}} \pm 0.020^{\text{syst}} \pm 0.025^{\text{theor}}$$

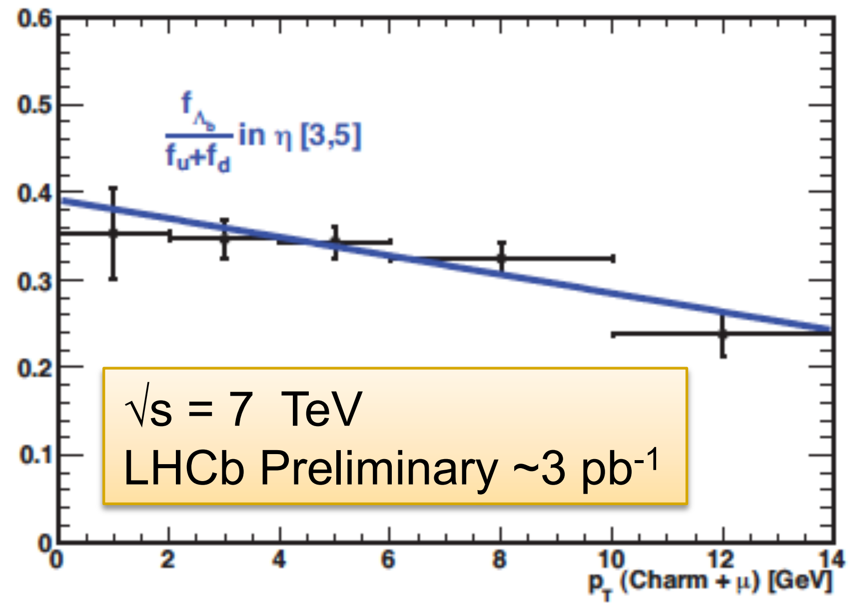
$$\frac{f_s}{f_d} = 0.242 \pm 0.024^{\text{stat}} \pm 0.018^{\text{syst}} \pm 0.016^{\text{theor}},$$

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

Λ_b Fraction

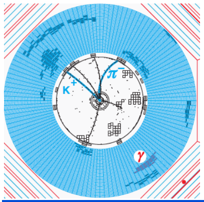
- Significant p_t dependence





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

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

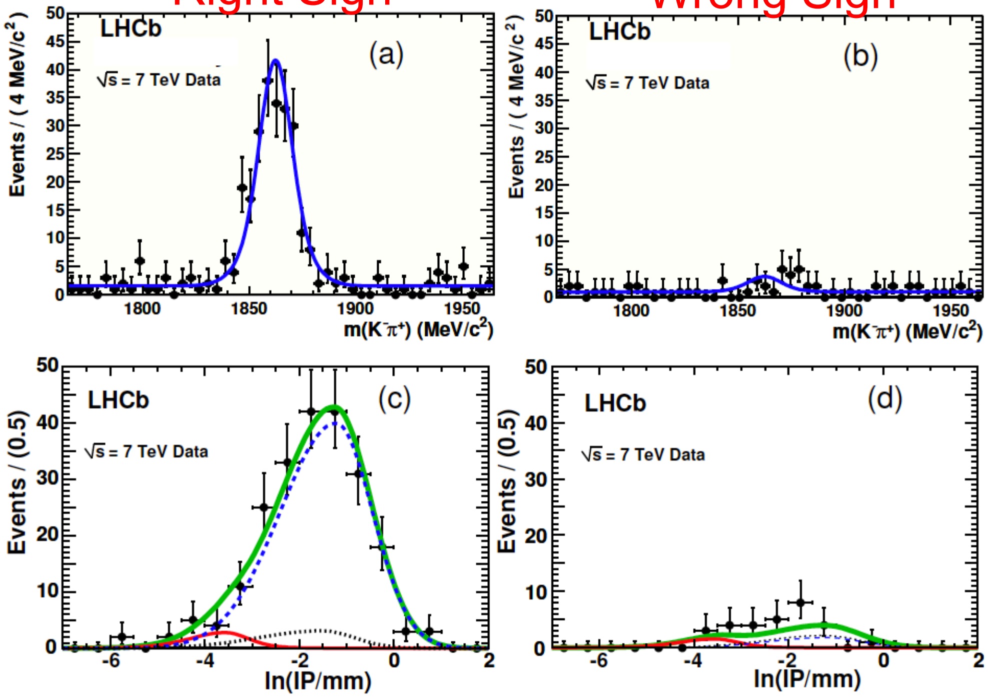


$\sigma(pp\to b\bar{b}X)$ using 15 nb^{-1}

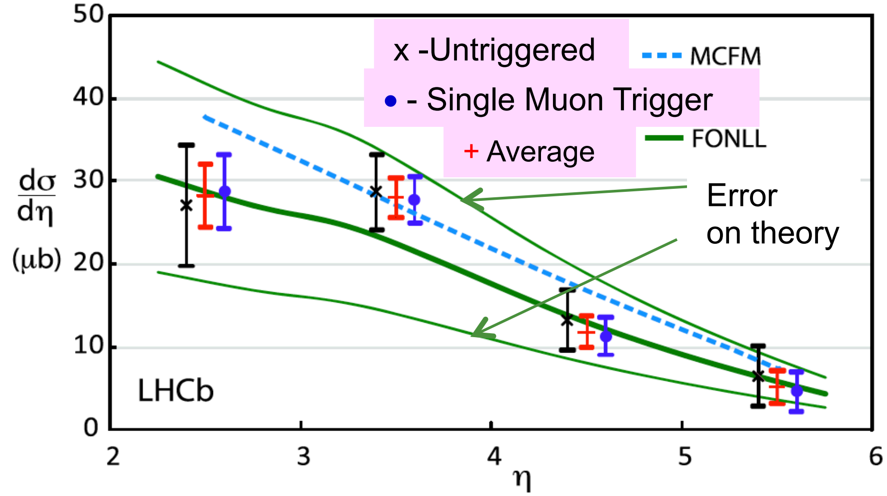
- $b\to D^0X\mu^-\nu$, $D^o\to K^-\pi^+$, ~280 events

Infancy

Right Sign　　Wrong Sign

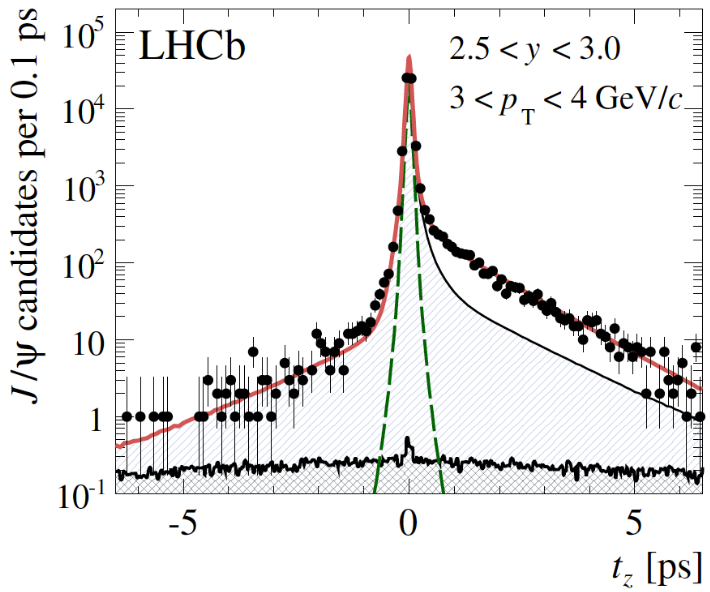


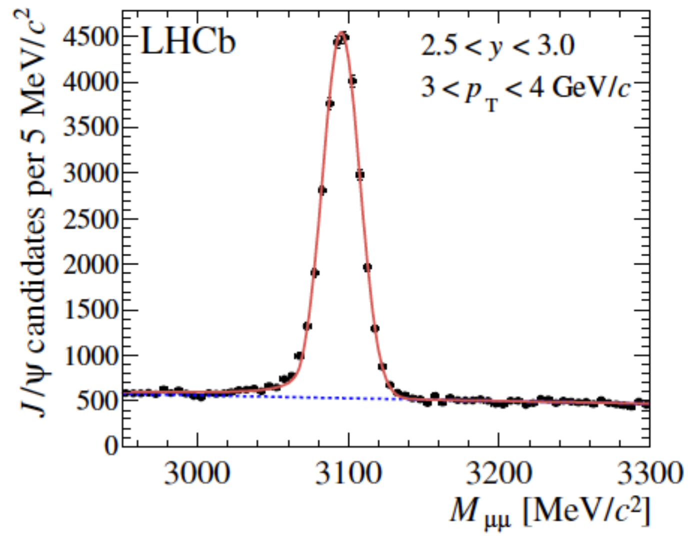
$$\sigma = \frac{\#\text{ of detected } D^0\mu^- \ \&\ \bar{D}^0\mu^+}{L \text{ x efficiency x } 2}$$



- 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

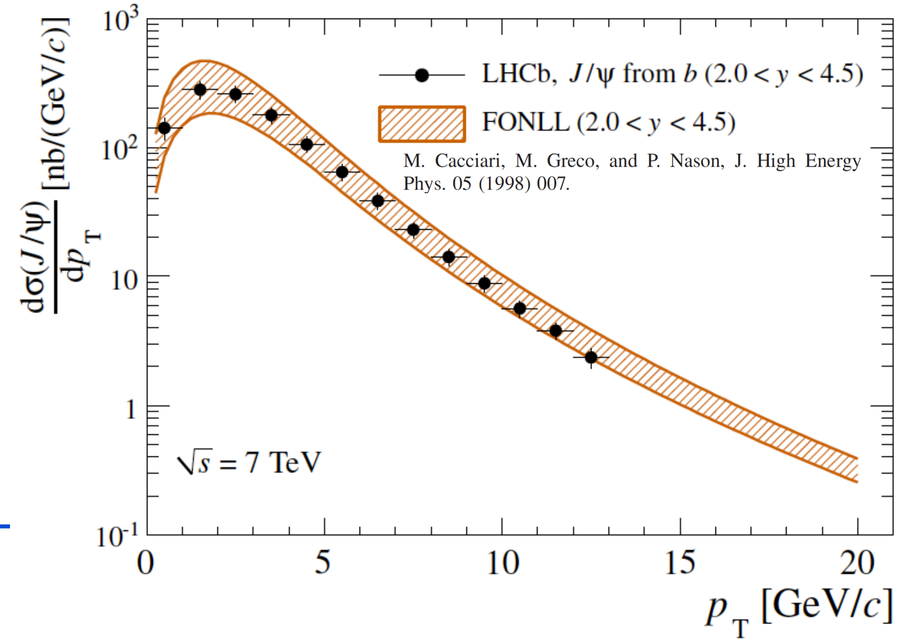
b xsect from b→J/ψX



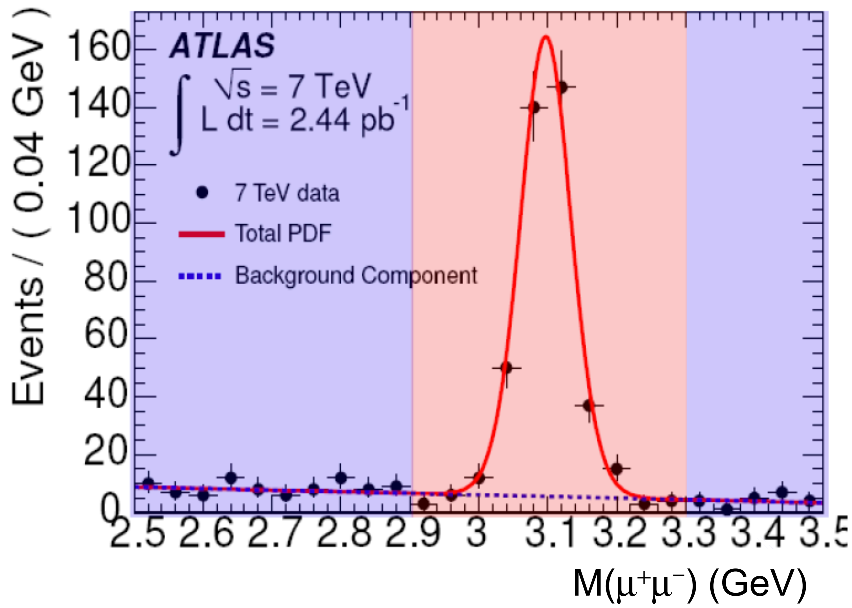


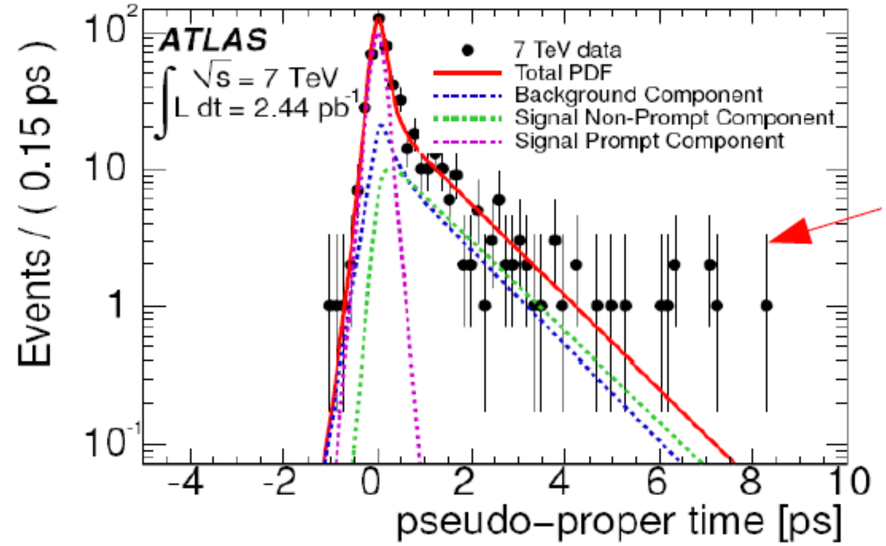
$$t_z = \frac{(z_{J/\psi} - z_{\rm PV}) \times M_{J/\psi}}{p_z}$$

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

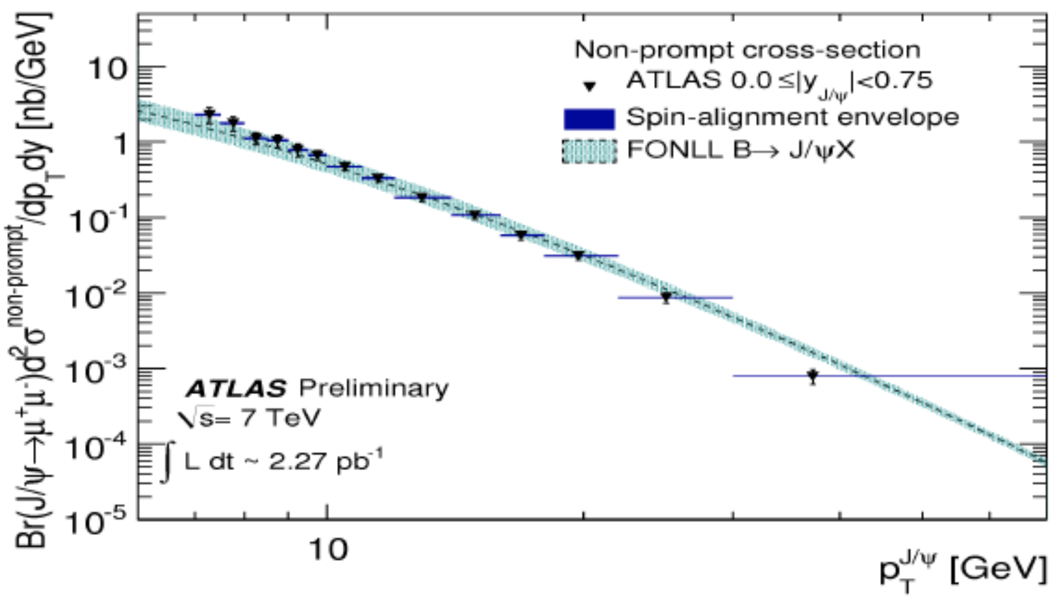


ATLAS σ from b→J/ψX

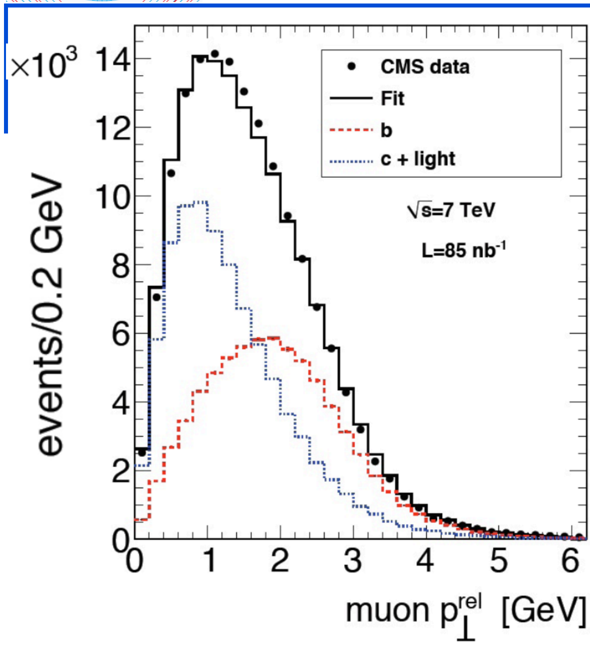




- ATLAS also in agreement with FONLL for p_t>5 GeV/c

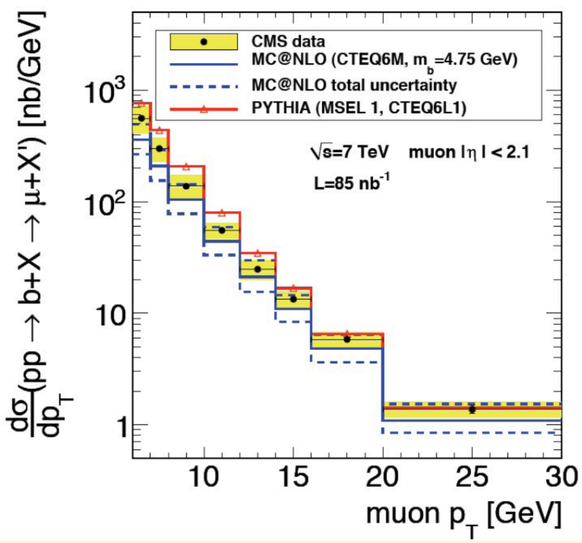


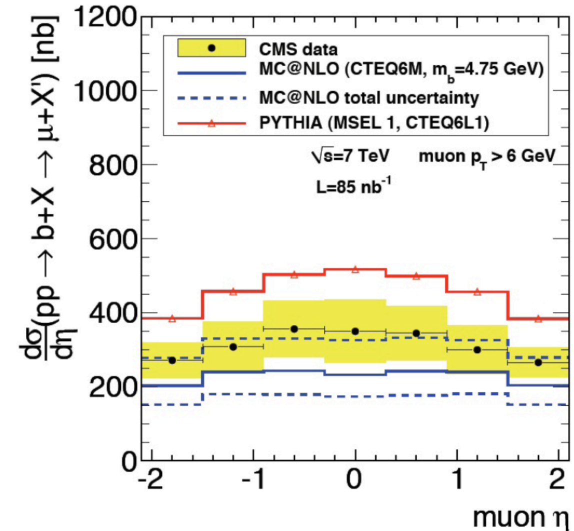
CMS σ from b→Xμν



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

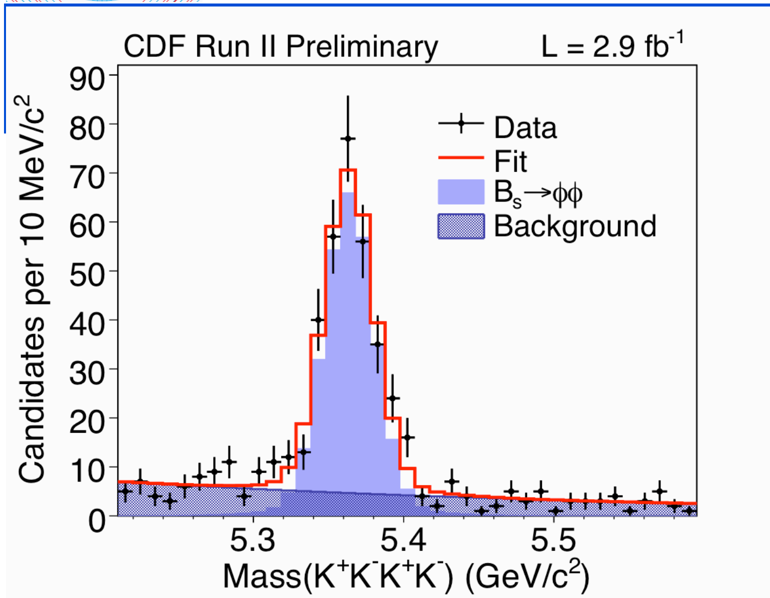
$$\sigma_{MC@NLO} = 0.84^{+0.36}_{-0.19}(\mathrm{scale}) \pm 0.08(\mathrm{m_b}) \pm 0.04(\mathrm{pdf})\mu\mathrm{b} \qquad \sigma_{PYTHIA} = 1.8\mu\mathrm{b}$$

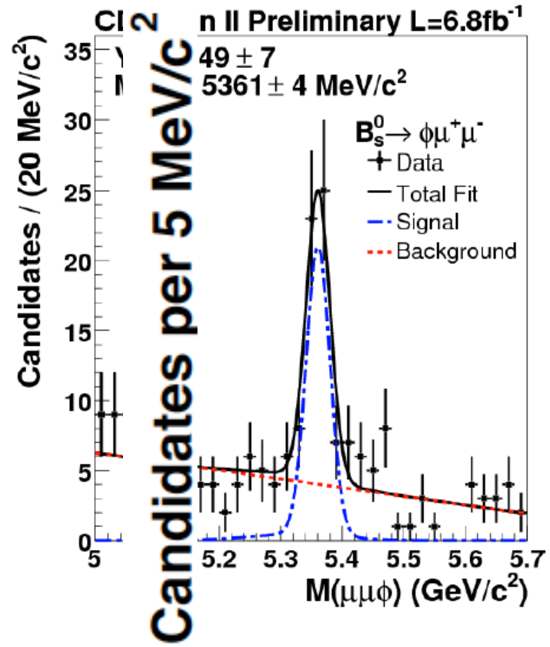




- In all cases generally good agreement with NLO calculations, within large errors

Other Bs Decays



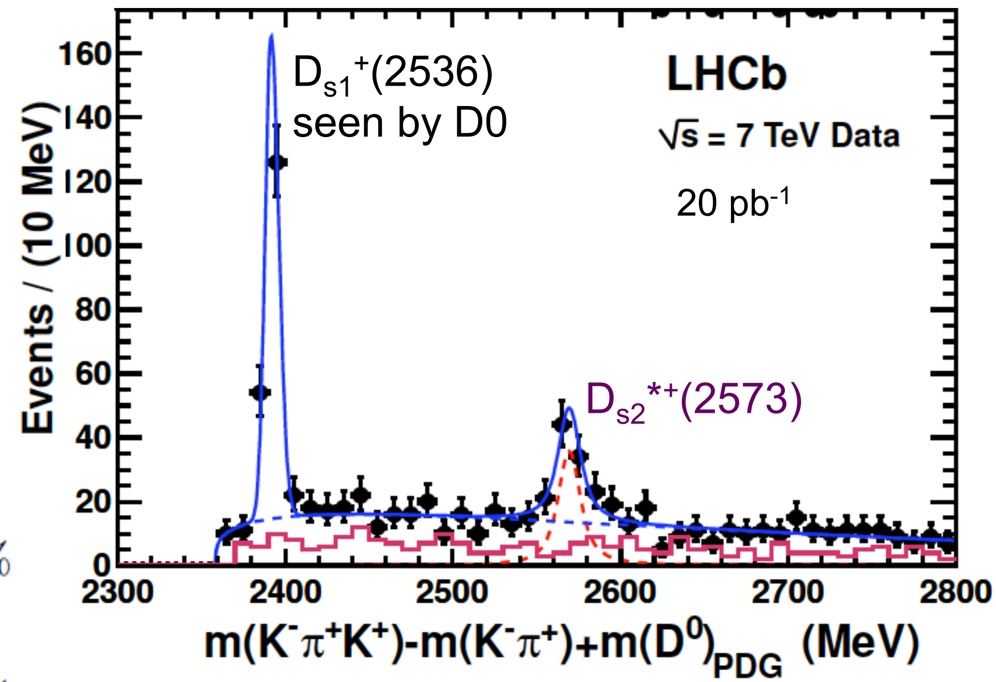


B_s Semileptonic Decays

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

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

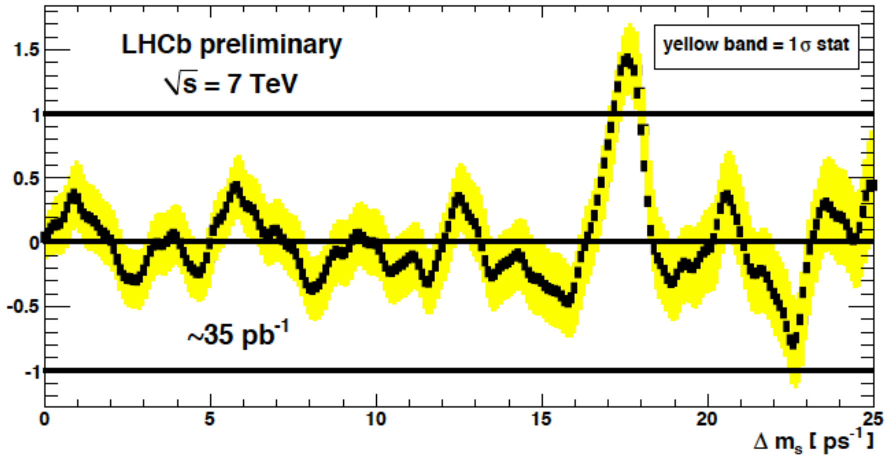
$$\frac{\mathcal{B}(\overline{B}_s^0 \to D_{s1}^{+} X \mu^- \overline{\nu})}{\mathcal{B}(\overline{B}_s^0 \to X \mu^- \overline{\nu})} = (5.4 \pm 1.2 \pm 0.5)\%$$



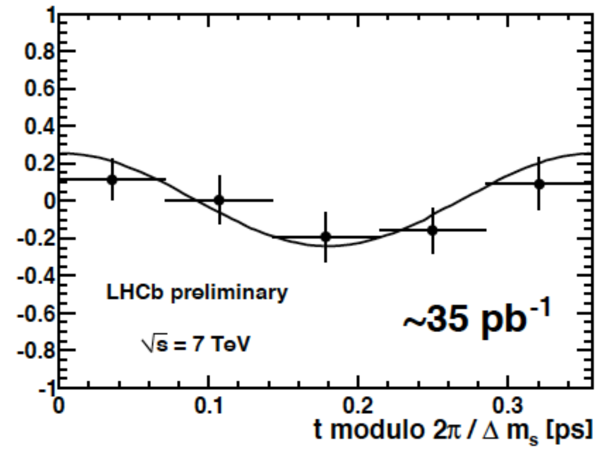
- First step in measuring structure of B_s semileptonic decays, fractions to D_s, D_s*, D_{sJ}, etc..

Measurement of Δm_s

- Amplitude Scan



A_{mix} vs time



- Use ~1400 fully hadronic B_s decays
- LHCb: $\Delta m_s = 17.63 \pm 0.11 \pm 0.04$ ps^{-1}
- CDF: $\Delta m_s = 17.77 \pm 0.10 \pm 0.07$ ps^{-1} (PRL 97, 242003)
- Now ready for time-dependent CPV in B_s