Measuring $\gamma$

- $\gamma$ is the phase of $V_{ub}$. Can be determined using $B^\pm$ decays. These diagrams result in the same final state for $D^0 \rightarrow K^+K^-$, $K_S\pi^+\pi^-$.

- $A \propto V_{cb}V_{us}A_T$  
  $A \propto V_{ub}V_{cs}A_{CT}$

- Phase differs by $\gamma$, Amp by $A_{CT}/A_T$
  - different A’s for different final states
  - Can also use doubly Cabbibo suppressed decays
Results

- Analysis is very complicated & sums over many final states (including $D^0\pi^-$)
- Results for $\gamma$
  - BaBar $(69^{+17}_{-16})^\circ$
  - Belle $(68^{+15}_{-14})^\circ$
  - LHCb $(67\pm12)^\circ$

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The $B^0 \rightarrow \pi^+\pi^- \& \rho^+\rho^-$ decays can occur via

(a) 
\[
\begin{array}{c}
\bar{d} \rightarrow \bar{d} \rightarrow \\
\bar{u} \rightarrow \bar{u} \\
\end{array}
\]

(b) 
\[
\begin{array}{c}
\bar{b} \rightarrow \bar{t} \rightarrow \\
\bar{d} \rightarrow \bar{u} \\
\end{array}
\]

If (a) is dominant, then by measuring $a_{fcp}$, we measure 
\[\sin(2(\beta + \gamma)) = \sin(2(180 - \alpha)) = -\sin(2\alpha)\]

- Can tell by seeing the size of $\pi^0\pi^0 \& \rho^0\rho^0$.
- (a) not dominant for $\pi^+\pi^-$, but OK for $\rho^+\rho^-$. However its not a CP eigenstate, but this can be dealt with

- **BaBar**: $\alpha = (92.4 \pm 6.0 - 6.5)°$, **Belle**: $(84.9 \pm 12.9)°$
CP Violation in charm is not expected at a level $\sim 10^{-3}$, so is an excellent place to look for New Physics.
Are these measurements consistent?

- CKM fitter group
- Does a “frequentist” analysis
- Also UT fit group does a “Bayesian analysis

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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 the Lamb shift in atomic hydrogen
- A small difference in energy between $2S_{1/2}$ & $2P_{1/2}$ that should be of equal energy at lowest order
Another example of the importance of such loops are changes in the W mass

- $M_w$ changes due to $m_t$
  \[
  \frac{dM_w}{dm_t} \propto \frac{m_t}{M_w}
  \]

- $M_w$ changes due to $m_H$
  \[
  \frac{dM_w}{dm_H} \propto -\frac{dm_H}{M_H}
  \]
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
What are limits on NP from quark decays?

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

Note $\gamma$ is a CP violating angle but is measured via Tree diagrams here –
Absorptive (Imaginary) part of mixing diagram should be sensitive to New Physics. Let's compare.
They are Consistent

- But consistency is only at the 5% level
- Limits on NP are not so strong

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- Compare measurements
  - look for discrepancies
- $B^0$ mixing and CP. Parameterize NP as $h$ & $\sigma$
- $M_{12} = M_{12}^{SM} \times (1 + h e^{2i\sigma})$
Limits on New Physics

New Physics amplitudes could be $\sim 20\%$ of Standard Model

J. Charles et al
arXiv:1309.2293

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Ex. of Strong Constraints on NP

- Inclusive $b \rightarrow s \gamma$, $(E_\gamma > 1.6 \text{ GeV})$
  - Measured $(3.55 \pm 0.26) \times 10^{-4}$ (HFAG)
  - Theory $(3.15 \pm 0.23) \times 10^{-4}$ (NNLL) Misiak arXiv:1010.4896
  - Ratio = $1.13 \pm 0.11$, Limits most NP models
- Example 2HDM
  - $m(H^+) < 316$ GeV

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Theorists task

- A given theoretical model must explain all the data

Model must thread through all experimental constraints (12 axe handles). One measurement can, in principle, defeat the theorist, but we seek a consistent pattern.
Top Down Analyses

- Here we pick models and work out their consequences in many modes. Ex. (circa 2010):
$B_s \rightarrow \mu^+ \mu^-$

- SM branching ratio is $(3.5 \pm 0.2) \times 10^{-9}$ [Buras arXiv:1012.1447], NP can make large contributions.

- Many NP models possible, not just Super-Sym
Discrimination

- LHCb uses $B \to h^+ h^-$ to tune cuts for a multivariate analysis.
- Other variables to discriminate against background: B impact parameter, B lifetime, B $p_t$, B isolation, muon isolation, minimum impact parameter of muons, ...
- $B_s$ production is measured by using the LHCb measured ratio $f_s/f_d$. New value of $0.259 \pm 0.015$.
Production fractions: $B \rightarrow DX_{\mu\nu}$
use equality of $\Gamma_{sl}$ & known $\tau$'s

$LHCb$

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

$D^+$

$LHCb$

$D_{s} \rightarrow K^-K^+\pi^+$

$D_{s}$

$D^0$, $\Lambda_b$
$P_T \& \eta$ dependence

$$\frac{f_s}{f_u + f_d} = \frac{n_{\text{corr}}(B_s \rightarrow D \mu)}{n_{\text{corr}}(B \rightarrow D^0 \mu) + n_{\text{corr}}(B \rightarrow D^+ \mu)} \frac{\tau_{B^-} + \tau_{B^0}}{2 \tau_{B^0}}$$

- $N_{\text{corr}}(B_s \rightarrow D \mu)$ is $D_s \mu + DK \mu$
- Also using hadronic $B_s$ & $B^0$ decays find

![Graphs showing $f_s/f_d$ vs $p_T(B)$ and $\eta(B)$]
Evidence for $B_S \rightarrow \mu^+\mu^-$

- Avg: $B(B_S \rightarrow \mu^+\mu^-) = (2.9 \pm 0.7) \times 10^{-9}$
- Avg: $B(B^0 \rightarrow \mu^+\mu^-) = (3.6^{+1.6}_{-1.4}) \times 10^{-10}$ (not significant)


Implications

Only this range allowed

$10^9 \times \text{BR}(B_d \rightarrow \mu^+\mu^-)$

$10^9 \times \text{BR}(B_s \rightarrow \mu^+\mu^-)$

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Flavor as a High Mass Probe

- Already excluded ranges from box diagrams
  \[ \mathcal{L}_{\text{eff}} = \mathcal{L}_{\text{SM}} + \frac{c_i}{\Lambda_i^2} \mathcal{O}_i, \text{ take } c_i \sim 1 \]

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

Some hints of discrepancies with SM
Similar to $K^{\ast}_{\gamma}$, but more decay paths

Several variables can be examined, e.g. muon forward-backward asymmetry, $A_{FB}$ is well predicted in SM

$B \rightarrow K^{(*)} l^+ l^-$

+ new particles in loops
Theory $K^{(*)}l^+l^-$

- Decay described by 3 angles & dimuon invariant mass ($q^2$)
- For each bin in $q^2$
  \[
\frac{1}{\Gamma} \frac{d^3(\Gamma + \tilde{\Gamma})}{d \cos \theta_\ell \, d \cos \theta_K \, d \phi} = \frac{9}{16\pi} \left[ \frac{3}{4} (1 - F_L) \sin^2 \theta_K + F_L \cos^2 \theta_K + \frac{1}{4} (1 - F_L) \sin^2 \theta_K \cos 2\theta_\ell \\
- F_L \cos^2 \theta_K \cos 2\theta_\ell + \frac{1}{2} (1 - F_L) A_T^{(2)} \sin^2 \theta_K \sin^2 \theta_\ell \cos 2\phi + \frac{1}{2} (1 - F_L) A_T^{Re} \sin^2 \theta_K \cos \theta_\ell + (S/A)_9 \sin^2 \theta_K \sin^2 \theta_\ell \sin 2\phi \right] \]
- $F_L$ is fraction of longitudinally polarized $K^{*0}$
- $A_{FB}$, forward-backward asymmetry \[= \frac{3}{4} (1 - F_L) A_T^{Re} \]
- SM prediction of $q^2$ for $A_{FB}$ crossing 0 is \[q_0^2 = 4.36^{+0.33}_{-0.31} \text{GeV}^2 \] (Beneke)
\[ \text{Conforms to SM predictions by} \]

Bobeth et al. & Matias et al

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Forward-Backward asymmetry

No evidence of deviation from SM so far

$LHCb$

$A_{FB}$

$q_0^2 = 4.9 \pm 0.9 \text{ GeV}^2/c^4$
Resonances found in high $q^2$ region

One would think they would be in $K^{*0}\pi^+\pi^-$ also

Should affect theory predictions
More $\angle$variables

- Back to $K^{(*)}l^+l^-$, new observables in formalism designed to less sensitive to hadronic form-factors

$$\frac{1}{\Gamma} \frac{d^3(\Gamma + \bar{\Gamma})}{d \cos \theta_\ell d \cos \theta_K d \phi} = \frac{g}{32\pi} \left[ \frac{3}{4} (1 - F_L) \sin^2 \theta_K + F_L \cos^2 \theta_K + \frac{1}{4} (1 - F_L) \sin^2 \theta_K \cos 2\theta_\ell ight]$$

$$- F_L \cos^2 \theta_K \cos 2\theta_\ell + \frac{1}{2} (1 - F_L) A_T^{(2)} \sin^2 \theta_K \sin^2 \theta_\ell \cos 2\phi +$$

$$\sqrt{F_L(1 - F_L)} P_4' \sin 2\theta_K \sin 2\theta_\ell \cos \phi + \sqrt{F_L(1 - F_L)} P_5' \sin 2\theta_K \sin \theta_\ell \cos \phi +$$

$$(1 - F_L) A_{Re}^T \sin^2 \theta_K \cos \theta_\ell + \sqrt{F_L(1 - F_L)} P_6' \sin 2\theta_K \sin \theta_\ell \sin \phi +$$

$$(1 - F_L) P_8' \sin 2\theta_K \sin 2\theta_\ell \sin \phi + (S/A)_9 \sin^2 \theta_K \sin^2 \theta_\ell \sin 2\phi$$

Descotes-Genon et al. arXiv:1303.5794

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Possible deviation

- Could be something, but significance depends on theoretical model, & deviation is only in one place.

![Graph showing LHCb data with 3.7σ local deviation and 1 fb⁻¹ significance.](image-url)

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\[ \mathcal{H}_{\text{eff}} = -\frac{4 G_F}{\sqrt{2}} V_{tb} V_{ts}^* \frac{e^2}{16 \pi^2} \sum_i (C_i O_i + C'_i O'_i) + \text{h.c.} \]

- \( C_i O_i \) for SM, \( C_i' O_i' \) are for NP. Operators are for \( P_{R,L} = (1\pm\gamma_5)/2 \)

\[
O_7 = \frac{m_b}{e} (\bar{s} \sigma_{\mu\nu} P_R b) F^{\mu\nu}, \quad O_8 = \frac{g m_b}{e^2} (\bar{s} \sigma_{\mu\nu} T^a P_R b) G^{\mu\nu a},
\]

\[
O_9 = (\bar{s} \gamma_\mu P_L b)(\bar{\ell} \gamma^\mu \ell), \quad O_{10} = (\bar{s} \gamma_\mu P_L b)(\bar{\ell} \gamma^\mu \gamma_5 \ell),
\]

\[
O_S = m_b (\bar{s} P_R b)(\bar{\ell} \ell), \quad O_P = m_b (\bar{s} P_R b)(\bar{\ell} \gamma_5 \ell),
\]

- \( O' = O \) with \( P_{R,L} \rightarrow P_{L,R} \)

- Each process depends on a unique combination
Other Processes

- Other processes probe different operators
- Let $\delta C_i = C_i(\text{NP}) - C_i(\text{SM})$
- Examples:

\[
\mathcal{B}(B \to X_s \mu^+\mu^-) = 10^{-7} \times \left[ \sum_{i,j=0,7,7',9,9',10,10'} b_{(i,j)} \delta C_i \delta C_j \pm \delta_b \right]
\]

\[
\mathcal{B}(B \to X_s \gamma)_{E_{\gamma} > 1.6 \text{ GeV}} = \left[ a_{(0,0)} \pm \delta_a + a_{(7,7)} [(\delta C_7)^2 + (\delta C_{7'})^2] + a_{(0,7)} \delta C_7 + a_{(0,7')} \delta C_{7'} \right] \cdot 10^{-4}
\]
Maximizing deviations

- Filled bands:
  $B \rightarrow K^* \mu^+ \mu^-$, $K^* \gamma$ & $B_s \rightarrow \mu^+ \mu^-$

- Dashed: all $q^2$ for $K^* \mu^+ \mu^-$

- Orange: only $1 < q^2 < 6$ GeV$^2$ for $K^* \mu^+ \mu^-$

- Some suggest a 7 TeV $Z'$

Descotes-Genon et al
arXiv:1307.5683

Gauld et al
arXiv:1308.1959!

Buras, Girrbach
arXiv:1309.2466

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B\(^-\)\(\rightarrow\)\(\tau^-\bar{\nu}\) problem?

- B\(^-\)\(\rightarrow\)\(\tau^-\bar{\nu}\), tree process:
- \(\sin 2\beta\), CPV in e.g. B\(^0\)\(\rightarrow\)J/\(\psi\) K\(_s\): Box diagram
- Measurement not in good agreement with SM prediction based on CKM fit

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

New Belle measurement in using 1 method. Discrepancy may be resolved, but 3 other determinations need to be checked

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Also, tree level – BaBar result

Similar to $B^\to \tau^\nu$ analysis

Fully reconstruct one $B$, keep events with an additional $D^{(*)}$ plus an $e^-$ or $\mu^-$. 

Signal is wide, background, especially $D^{**} \nu$, needs careful estimation
Results given in terms of ratio to $\text{B} \to \text{D}^{(*)} \tau \nu$

<table>
<thead>
<tr>
<th></th>
<th>SM Theory</th>
<th>BaBar value</th>
<th>Diff.</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R(D)$</td>
<td>0.297±0.017</td>
<td>0.440±0.058±0.042</td>
<td>+2.0$\sigma$</td>
</tr>
<tr>
<td>$R(D^*)$</td>
<td>0.252±0.003</td>
<td>0.332±0.024±0.018</td>
<td>+2.7$\sigma$</td>
</tr>
</tbody>
</table>

- Sum is 3.4$\sigma$ above SM
- Also inconsistent with type II 2HDM
Other searches
Several ways of looking for presence of heavy $\nu$’s (N) in heavy quark decays if they are Majorana (their own anti-particles) and couple to “ordinary” $\nu$’s.

- Modes analogous to $\nu$–less nuclear $\beta$ decay

Simplest Channels:

- $B^- \rightarrow D^+ l^- l'^- \& B^- \rightarrow D^{*-} l^- l'^-$
- $l^- \& l'^-$ can be $e^-$, $\mu^-$ or $\tau^-$. 

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**Limits on \(D(*)+l^- l'^-\)**

- Upper limits in \(e^-e^-\) mode not competitive with nuclear \(\beta\) decay
- Others unique since measure coupling of Majorana \(\nu\) to \(\mu^-\)

<table>
<thead>
<tr>
<th>Mode</th>
<th>Exp.</th>
<th>(u.\ l. \times 10^{-6})</th>
</tr>
</thead>
<tbody>
<tr>
<td>(B^- \rightarrow D^+ e^- e^-)</td>
<td>Belle</td>
<td>&lt; 2.6</td>
</tr>
<tr>
<td>(B^- \rightarrow D^+ e^- \mu^-)</td>
<td>Belle</td>
<td>&lt; 1.8</td>
</tr>
<tr>
<td>(B^- \rightarrow D^+ \mu^- \mu^-)</td>
<td>Belle</td>
<td>&lt; 1.0</td>
</tr>
<tr>
<td>(B^- \rightarrow D^* \mu^- \mu^-)</td>
<td>LHCb</td>
<td>&lt; 0.69</td>
</tr>
<tr>
<td>(B^- \rightarrow D^{*+} \mu^- \mu^-)</td>
<td>LHCb</td>
<td>&lt; 3.6</td>
</tr>
</tbody>
</table>

Belle [arXiv:1107.064]
On-Shell $\nu$

- Can also look for Majorana $\nu$ (N), where $N \rightarrow W^+ \mu^-$
- A. Atre, T. Han, S. Pascoli, & B. Zhang [arXiv:0901.3589]
- Many other ways of searching:
  - $K^- $π$^- $N
  - $\mu^- $e$^- $γ
  - $\tau^- $μ$^+ $π$^- $π$^- $
  - ...
LHCb search as a function of Majorana neutrino mass and lifetime
Could it be that there are 3 classes of matter?
- SM particles with charges $[SU(3) \times SU(2) \times U(1)]$
- Dark matter particles with “dark” charges
- Some matter having both (“mediators”)

Searches for “dark photons”
- A mediator, couples to b-quarks (see arXiv:056151 hep/ph)
- BaBar $\varepsilon(Y(1S)\rightarrow\text{invisible}) < 3 \times 10^{-4}$ @ 90% cl
- Other experiments
Parameterize by mixing $\varepsilon$

- Dark photon mass $m_{A'}$

Needed to explain $g-2$

From B. Echenard arXiv:1205.3505
Tetraquarks, both heavy & light
Belle 2008: $B^0 \rightarrow J/\psi \pi^- K^+$. Claimed resonant signal decaying into $J/\psi \pi^-$ at 4430 MeV ⇒ a charged "charmonium" state, not possible with only $c\bar{c}$

Tetraquark candidate
But not BaBar

- BaBar shows that moments of $K^+\pi^-$ resonances can reflect in mass peak
- Data are compatible with Belle
- Difference is in interpretation
Belle does 4D amplitude fit

- New fit confirms observation, but questions remain
LHCb full fit for $1^+ Z$

- p value of 12%  
  
  arXiv:1404.1903

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Argand diagram

- Replace the Breit-Wigner amplitude for $Z(4430)^-$ by 6 independent amplitudes in $m_{\psi'\pi^-}^{2}$ bins in its peak region.

Rapid phase transition at the peak of the amplitude $\rightarrow$ resonance!

First time ever the resonant character of the four-quark candidate has been demonstrated this way!

arXiv:1404.1903
Scalar octet problem

- 0\(^+\) vs 1\(^-\) meson masses (charge = 0)

\[
\begin{align*}
I = 0 : m[f_0(600)] & \approx 500 \text{ MeV} \\
I = 1 : m[\rho(776)] & \approx 776 \text{ MeV} \\
I = 1/2 : m[\kappa] & \approx 800 \text{ MeV} \\
I = 0 : m[\omega(783)] & \approx 783 \text{ MeV} \\
I = 0 : m[f_0(980)] & \approx 980 \text{ MeV} \\
I = 1/2 : m[K^*(892)] & \approx 892 \text{ MeV} \\
I = 1 : m[a_0(980)] & \approx 980 \text{ MeV} \\
I = 0 : m[\phi(1020)] & \approx 1020 \text{ MeV}
\end{align*}
\]

- For 1\(^-\), adding an s quark increases meson mass

- Suggestions that 0\(^+\) mesons are tetraquarks

- For q\(\bar{q}\), \(\sigma \equiv f_0(500) \& f_0(980)\) are mixed with \(f_0(980)\) mostly s\(\bar{s}\)

- As tetraquarks

\[
[f_0] = \frac{1}{\sqrt{2}} \left( [su][\bar{s}u] + [sd][\bar{s}d] \right), \quad [\sigma] = [ud][\bar{u}d]
\]

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Here $f_0 \equiv f_0(980)$, $\sigma = f_0(500)$

Large $f_0$ expected in $q\bar{q}$, no $\sigma$ rate for tetraquark

Suggested $B^0$ test

- Here $f_0 \equiv f_0 (980)$, $\sigma = f_0 (500)$

  - $q\bar{q}$ model

  - Small $f_0$ expected in $q\bar{q}$, half of $\sigma$ rate in tetraquark

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$B_s$ & $B^0$ signals

arXiv:1404.5673
**B_s results**

Huge $f_0$, no $\sigma$

arXiv:1402.6248
B^0 results

Nice $\sigma$

no $f_0$

arXiv:1404.5673
Not tetraquarks

\[ \tan^2 \varphi_m \equiv r^f_\sigma = \frac{\mathcal{B} \left( \overline{B}^0 \to J/\psi f_0(980) \right) \phi(500)}{\mathcal{B} \left( \overline{B}^0 \to J/\psi f_0(500) \right) \phi(980)} \]

\[ \frac{\mathcal{B} \left( \overline{B}^0 \to J/\psi f_0(980), \ f_0(980) \to \pi^+\pi^- \right)}{\mathcal{B} \left( \overline{B}^0 \to J/\psi f_0(500), \ f_0(500) \to \pi^+\pi^- \right)} = (0.6^{+0.7+3.3}_{-0.4-2.6})\% \]

\[ \tan^2 \varphi_m \equiv r^f_\sigma = (1.1^{+1.2+6.0}_{-0.7-0.7}) \times 10^{-2} < 0.098 \text{ at } 90\% \text{ C.L.} \]

- In qq model mixing \[ \angle \varphi_m < 17^\circ \] at 90\% CL
- Tetraquark prediction of 0.5 ruled out at 8\sigma

Future Acts

- LHCb Upgrade: run at $10^{33}$ cm$^{-2}$/s (x5), & double trigger efficiency on purely hadronic final states. Much improved sensitivities to New Physics at higher mass
  - Implemented by having a purely software trigger
  - Requires entire detector to be read-out at 40 MHz

- $e^+e^-$ Super Belle

- Time scales are on the order of 5 years
Conclusions

- Heavy Flavor physics is very sensitive to potential New Physics effects at high mass scales.
- LHCb has started to make world class measurements of flavor physics.
- We hope to find physics beyond the Standard Model or derive limits that strongly constrains theories of New Physics.
- The LHCb upgrade is necessary to improve sensitivities.
- Many other interesting results have not been mentioned.

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Theory conquers
The End
Common Analysis


- Many more such generic constraints

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Also $B \rightarrow Dh^-$

- Take ratios, use theory
- $P_t$ dependence now evident, implications for ATLAS, CMS analyses
- **B_s** lifetime results here use only fully reconstructed decays.
- **K^+K^-** is taken as CP even \( (A_{\Delta\Gamma} = -1) \)
- Ovals show 39% cl, while bands 68% cl
- \( \tau_s = 1.509 \pm 0.010 \) ps, \( \Delta\Gamma_s = 0.092 \pm 0.011 \) ps\(^{-1} \), \( y_s = \Delta\Gamma_s / 2\Gamma_s = 0.07 \pm 0.01 \) (from Anna Phan)

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only full reconstructed **B_s** decays used
By definition \( a_{sl} = \frac{\Gamma(\bar{M} \rightarrow f) - \Gamma(M \rightarrow \bar{f})}{\Gamma(\bar{M} \rightarrow f) + \Gamma(M \rightarrow \bar{f})} \)

at \( t=0 \) \( \bar{M} \rightarrow f \) is zero as is \( M \rightarrow \bar{f} \)

Here \( f \) is by construction flavor specific, \( f \neq \bar{f} \)

Can measure eg. \( \bar{B}_s \rightarrow D_s^+ \mu^- \nu \), versus \( B_s \rightarrow D_s^- \mu^+ \nu \),

Or can consider that muons from two B decays can be like-sign when one mixes and the other decays, so look at \( \mu^+ \mu^+ \) vs \( \mu^- \mu^- \)

\( a_{sl} \) is expected to be very small in the SM, \( a_{sl} = (\Delta\Gamma/\Delta M) \tan \phi_{12} \), where \( \tan \phi_{12} = \text{Arg}(-\Gamma_{12}/M_{12}) \)

In SM \( (B^o) a_{sl}^d = -4.1 \times 10^{-4} \), \( (B_s) a_{sl}^s = +1.9 \times 10^{-5} \)
D^0 a_{s,l}

- Using dimuons (3.9σ)
  \[ A_{s,l}^b = (-0.787 \pm 0.172 \pm 0.093)\% \]

- Indication from D0 that its B_s

- Separate dimuons into B_d and B_s samples using muon impact parameter

- Find
  \[ a_{s,l}^d = (-0.12 \pm 0.52)\% \]
  \[ a_{s,l}^s = (-1.81 \pm 1.06)\% \]
New D0 Analysis

- Measure $a_{sl}^s$ using $D_s \mu^- \nu$ events, $D_s \to \phi \pi^\pm$
- Detect a $\mu$ associated with a $D_s$ decay
- Find $a_{sl}^s=\left(-1.08\pm0.72\pm0.17\right)\%$
- Also measure $a_{sl}^d$ using $D^+ \mu^- \nu$, $D^+ \to K \pi^+ \pi^+$
- $a_{sl}^d=\left(0.93\pm0.45\pm0.14\right)\%$

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$a_{s_{l}}$ according to D0

- $a_{s_{l}}^{s}=(-1.81\pm0.56)\%$
- $a_{s_{l}}^{d}=(-0.22\pm0.30)\%$
- $3\sigma$ from SM
- arXiv:1208.5813
- Use $D_s \mu^- \nu$, $D_s \rightarrow \phi \pi^\pm$, magnet is periodically reversed. For magnet down:

- Effect of $B_s$ production asymmetry is reduced to a negligible level by rapid mixing oscillations.

- Calibration samples ($J/\psi$, $D^{*+}$) used to measure detector trigger, track & muon ID biases.
LHCb finds

\[ a^s_{sl} = \left( -0.24 \pm 0.54 \pm 0.33 \right)\%
\]

B-factory

\[ a^d_{sl} = \left( -0.05 \pm 0.56 \right)\%
\]

Results consistent with SM

Expect \( \phi_s \) to grow as

\[ \sin[2|\beta_s|+\text{arg}(M_{12})] \]

for finite \( a^s_{sl} \).

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$\Lambda_b$ Fraction

- Significant $p_t$ dependence

\[ \frac{f_{\Lambda_b}}{f_u + f_d} \text{ in } \eta [2,3] \]

\[ \frac{f_{\Lambda_b}}{f_u + f_d} \text{ in } \eta [3,5] \]

$\sqrt{s} = 7$ TeV
LHCb Preliminary $\sim 3$ pb$^{-1}$

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

- In general agreement with CDF measured at $<p_t> \sim 10$ GeV/c

$\sqrt{s} = 7$ TeV
LHCb Preliminary $\sim 3$ pb$^{-1}$

\[
f_{\Lambda_b}/(f_u + f_d) = 0.281 \pm 0.012^{+0.011+0.128}_{-0.056-0.086}
\]