Semileptonic Mixing Asymmetry Measurements of A^d_{SL} and A^s_{SL}

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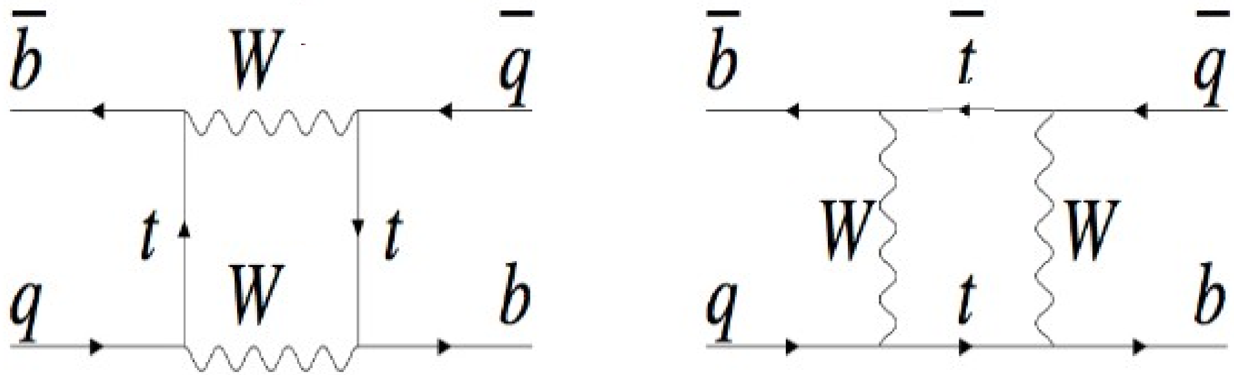
- Motivation
- D0 Inclusive dilepton Analysis
- D0, LHCb, BaBar Flavor Specific Analyses
- Conclusions

Motivation

CPV in B⁰ mixing



- New Particles in the boxes could modify SM expectations

- $B^0_q - \overline{B^0_q}$ oscillations & decay governed by an Effective Hamiltonian:

$$i\frac{d}{dt}\begin{pmatrix} B_q \\ \bar{B}_q \end{pmatrix} = \left[\begin{pmatrix} M_{11}^q & M_{21}^{q\,*} \\ M_{21}^q & M_{11}^q \end{pmatrix} - \frac{i}{2}\begin{pmatrix} \Gamma_{11}^q & \Gamma_{21}^{q\,*} \\ \Gamma_{21}^q & \Gamma_{11}^q \end{pmatrix}\right]\begin{pmatrix} B_q \\ \bar{B}_q \end{pmatrix}$$

$[M_{ij}]$ = mass matrix

$[\Gamma_{ij}]$ = decay matrix

- Physical Eigenstates with defined masses and widths:

$$|B_q^{L,H}\rangle = \frac{1}{\sqrt{1+|(q/p)_q|^2}}\left(|B_q\rangle \pm (q/p)_q |\bar{B}_q\rangle\right)$$

- If $|(q/p)_q|=1$ they would be also CP Eigenstates

- Neglecting $o(m_b^2/M_W^2)$:

$$\Delta m_q = m_H - m_L \simeq 2|M_{12}^q|;\ \Delta\Gamma_q = \Gamma_L - \Gamma_H \simeq 2|\Gamma_{12}^q|\cos\phi_q$$

$$\phi_q = arg(-M_{12}^q/\Gamma_{12}^q)$$ CP violating phase

CPV in B^0 mixing

- CP Asymmetry in $B^0_{(s)}$ mixing (time independent):

$$A^q_{CP} = \frac{Prob(\bar{B}^0_q \to B^0_q, t) - Prob(B^0_q \to \bar{B}^0_q, t)}{Prob(\bar{B}^0_q \to B^0_q, t) + Prob(B^0_q \to \bar{B}^0_q, t)} = \frac{1-|q/p|^4_q}{1+|q/p|^4_q} = \frac{|\Gamma^q_{12}|}{|M^q_{12}|}\sin\phi_q$$

- Experimentally: measure charge asymmetry in mixed semileptonic B^0_q decays:

$$A^q_{CP} = A^q_{SL} = \frac{\Gamma(\bar{B}^0_q \to B^0_q \to l^+ \nu X) - \Gamma(B^0_q \to \bar{B}^0_q \to l^- \nu X)}{\Gamma(\bar{B}^0_q \to B^0_q \to l^+ \nu X) + \Gamma(B^0_q \to \bar{B}^0_q \to l^- \nu X)}$$

- CPV in mixing if:

$A^q_{SL} \neq 0 \leftrightarrow |q/p|_q \neq 1 \leftrightarrow \phi_q \neq 0$

Standard Model predicts

(Nierste, arXiv:1212.5805 (2012)):

- B^0_d: $A^d_{SL} = (-4.0 \pm 0.6)10^{-4}$

  $\Phi_d = -4.9° \pm 1.4°$

- B^0_s: $A^s_{SL} = (1.8 \pm 0.3)10^{-5}$

  $\Phi_s = 0.24° \pm 0.06°$

Beyond Standard Model

(Lenz, Nierste, JHEP 0706, 072 (2007))

- New Physics could modify M^q_{12} and A^q_{SL} leaving Γ^q_{12} unchanged:

$$M^{NP,q}_{12} = M^{SM,q}_{12}\Delta_q ; \Delta_q = |\Delta_q| e^{i\phi^\Delta_q}$$

$$A^{NP}_{SL} = \frac{|\Gamma^q_{12}|}{|M^{SM,q}_{12}|}\frac{\sin(\phi^{SM}_q + \phi^\Delta_q)}{|\Delta_q|}$$

CPV in B^0 mixing

Two classes of measurements available:

- Inclusive dilepton asymmetry analyses:

$$A^b_{SL} = \frac{N_b(l^+l^+) - N_b(l^-l^-)}{N_b(l^+l^+) + N_b(l^-l^-)}$$

BaBar, Phys. Rev. Lett. 96 251802 (2006)
Belle, Phys. Rev. D 73 112002 (2006)
D0, Phys. Rev. D 84,052007 (2011)

- Hadron Colliders Experiments measure a combination of B^0_d & B^0_s CP parameters: $A^b_{SL} = C_d A^d_{SL} + C_s A^s_{SL}$
  - $C_{d,s}$ depend on $B^0_{d,s}$ production rates & mixing probability
  - SM predicts: $A^b_{SL} = (-0.028^{+0.005}_{-0.006})\%$

- Flavor specific B^0, B^0_s analyses:
  - Reconstruction of $B^0 \to D^{(*)} l X$, $B^0_s \to D_s l X$
  - With or without flavor-tagging at production

D0, Phys. Rev. D 86 072009 (2012)
D0, Phys. Rev. Lett. 110, 011801 (2013)
LHCb, LHCb-CONF-2012-022 (2012)
BaBar, arXiv:1305.1575 (2013)

Detector-related Asymmetries

- Current statistical precision of the experiments <0.5% requires very good control of spurious charge asymmetries from:
  - Charge-asymmetric BKG: hadrons misidentified as leptons & leptons from light hadron decays (e.g. positive kaons have smaller interaction cross-section than negative kaons in matter)
  - Track reconstruction and lepton identification (detector anisotropy could affect efficiencies)
- Most crucial point of the analyses and biggest systematic uncertainty

- Effect reduced by inverting magnets polarities (D0, LHCb)
- Estimated on control samples (D0, LHCb) or determined directly in the fit to A_{SL} (BaBar)

Inclusive dilepton Analyses

- D0: "Measurement of the anomalous like-sign dimuon charge asymmetry with 9 fb^{-1} of $p\bar{p}$ collisions", (9 fb^{-1})

  Phys. Rev. D 84, 052007, 2011

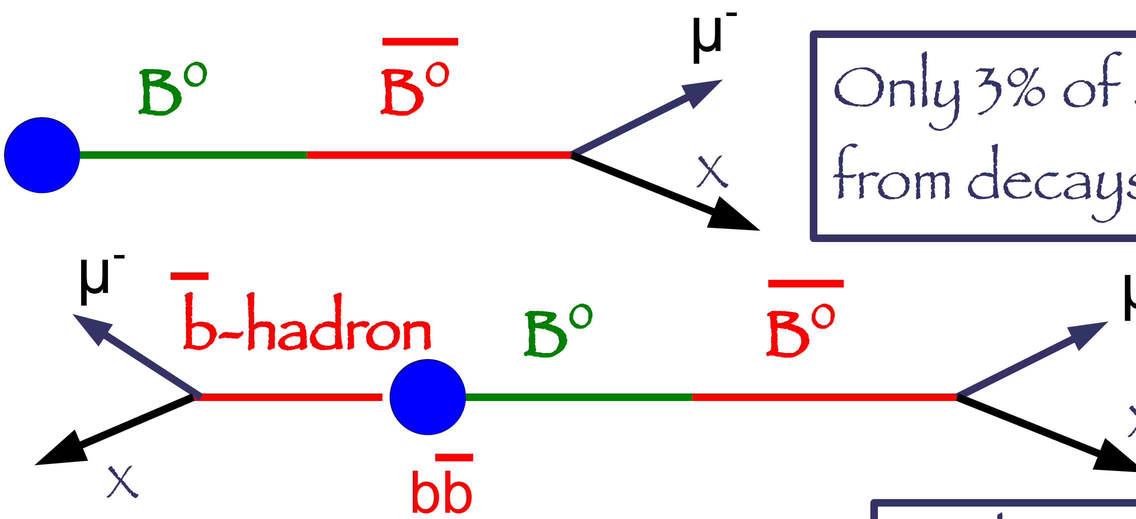
D0 like-sign dimuons charge Asymmetry

Phys. Rev. D 84,052007 (2011)

- Semileptonic asymmetry A^b_{SL} measured from inclusive single muon & like-sign dimuon charge asymmetries:

$$a = \frac{n(\mu^+) - n(\mu^-)}{n(\mu^+) + n(\mu^-)}$$

$$A = \frac{N(\mu^+\mu^+) - N(\mu^-\mu^-)}{N(\mu^+\mu^+) + N(\mu^-\mu^-)}$$



Only 3% of single muons from decays of mixed B^0_q

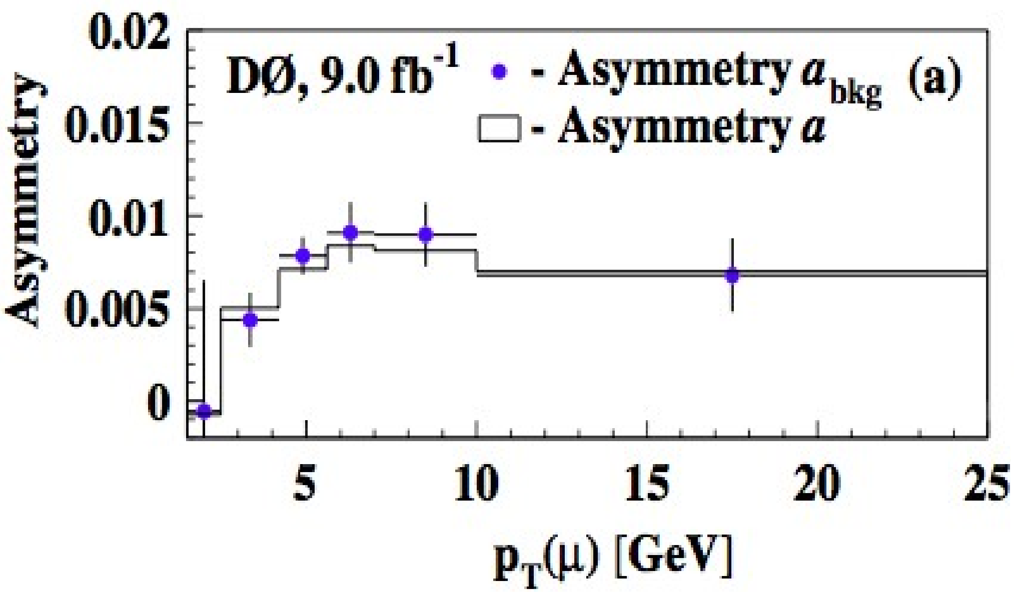
Only 30% of equal-charge muons from decays of mixed B^0_q

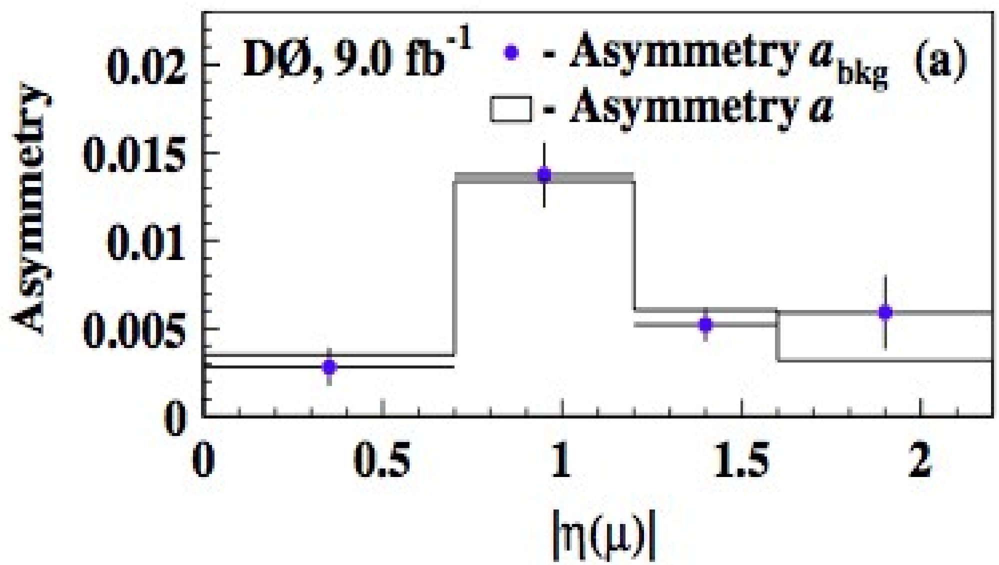
- Challenge: understand contributions from:
  - Muons from other b decays, charm and short-lived hadrons
  - Detector-related charge asymmetries

D0 like-sign dimuons charge Asymmetry

Phys. Rev. D 84,052007 (2011)

- BKG fractions and asymmetries from K, p, π → μ determined using $K^{*0} \to K^+\pi^-$, $\Phi \to K^+K^-$, $K_S \to \pi^+\pi^-$, $\Lambda \to p\pi^-$ control samples
- Observed single muon asymmetry agrees with BKG expectations:





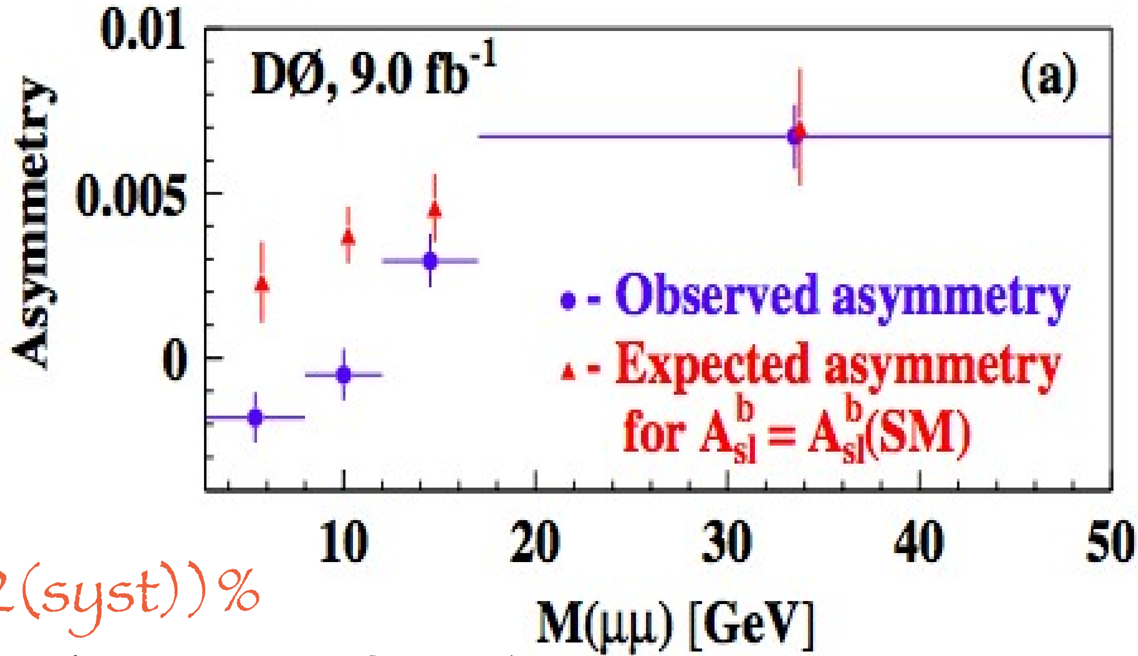
- From the inclusive muon sample alone:

A^b_{SL}=(-1.04±1.30(stat)±2.31(syst))%

Agrees with SM

D0 like-sign dimuons charge Asymmetry

Phys. Rev. D 84,052007 (2011)



- Observed like-sign dimuon asymmetry differs significantly from expectations
- From the dimuon sample alone:

A^b_{SL}=(-0.808±0.202(stat)±0.222(syst))%

- Result obtained using a linear combination of single lepton and dilepton asymmetries to reduce uncertainty:

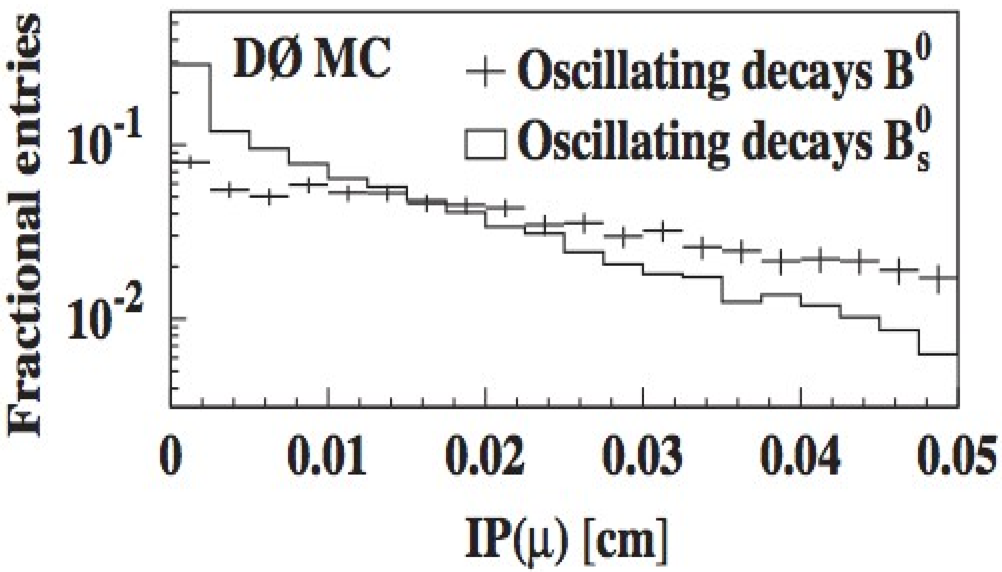
A^b_{SL}=(-0.787±0.172(stat)±0.093(syst))%

3.9 σ from SM prediction:

- Systematics dominated by BKG fraction determination

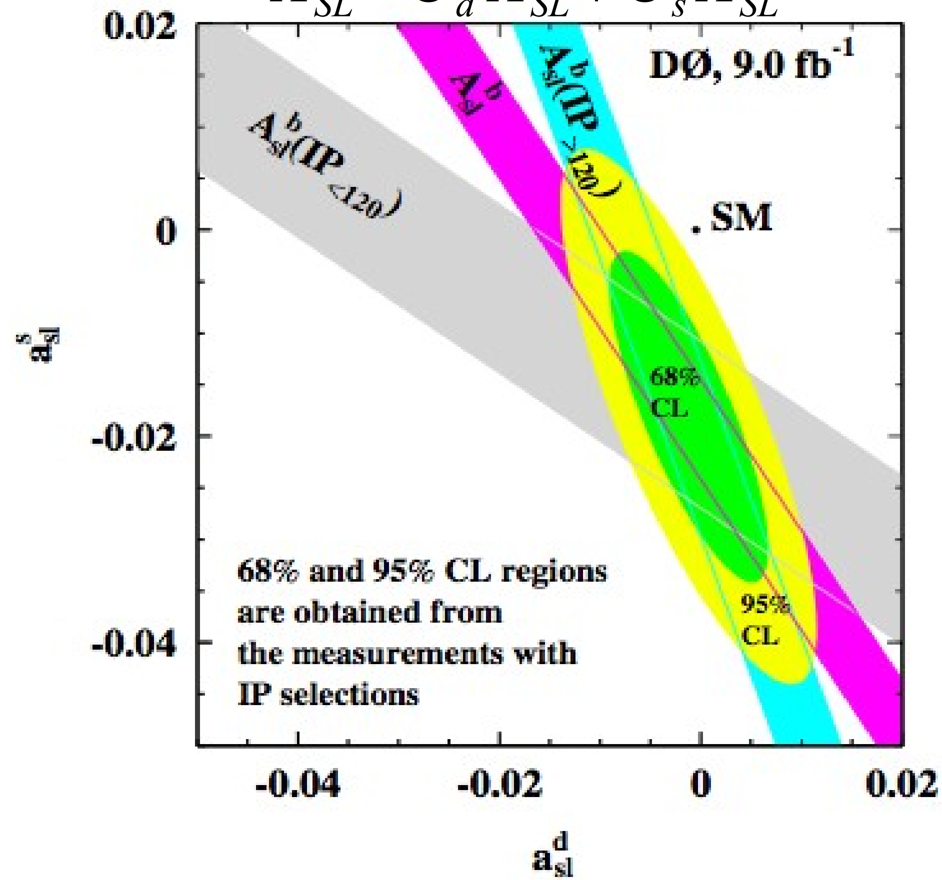
D0 like-sign dimuons charge Asymmetry

Phys. Rev. D 84,052007 (2011)



- Mixed $B^0_{(s)}$ fractions depend on muon Impact Parameter

$$A^b_{SL} = C_d A^d_{SL} + C_s A^s_{SL}$$



- A^b_{SL} computed in the two regions: IP>120 μm, IP<120 μm
- Allows separate determination of
  - $A^d_{SL} = (-0.12 \pm 0.52)\,\%$
  - $A^s_{SL} = (-1.81 \pm 1.06)\,\%$

D0 like-sign Asymmetry: Interpretation

Borissov, Hoeneisen, Phys. Rev. D 87, 074020 (2013)

- Results do not agree with SM only in dimuon charge asymmetry
  - Search for any neglected source of CP violation which could affect the dimuon asymmetry leaving the single muon one uninfluenced
- $B^0(\overline{B^0}) \rightarrow c\bar{c}d\bar{d}$ final states (e.g. D^+D^-) accessible from both B^0 and $\overline{B^0}$
  - Interference of decays with and without mixing results in CP violation which affects only the dilepton charge asymmetry:

$$A(c\bar{c}d\bar{d}) = -\sin(2\beta)\frac{x_d}{1+x_d^2}\,\omega(c\bar{c}d\bar{d}) = (-0.045 \pm 0.016)\,\%, \quad x_d = \frac{\Delta m_d}{\Gamma_d}$$

Contribution of the $c\bar{c}d\bar{d}$ channels in the inclusive dimuon sample

- Discrepancy with SM in like-sign asymmetry lowered from 2.8 σ to 2.3 σ
- Mandatory to perform measurements of flavor specific asymmetries

Flavor Specific Analyses

- D0: "Measurement of the semileptonic charge asymmetry in B^0 meson mixing with the D0 detector" (10.4 fb^{-1})

  Phys. Rev. D 86 072009 (2012)

- D0: "Measurement of the Semileptonic Charge Asymmetry using $B^0_s \to D_s \mu X$" (10.4 fb^{-1})

  Phys. Rev. Lett. 110, 011801 (2013)

- LHCb: "Measurement of the flavour-specific CP violating asymmetry A^s_{SL} in B^0_s decays" (1.0 fb^{-1})

  LHCb-CONF-2012-022 (2012), Preliminary

- BaBar: "Search for CP Violation in $B^0\bar{B}^0$ Mixing using Partial Reconstruction of $B^0 \to D^*Xl\nu$ and a Kaon Tag" (425.7 fb^{-1})

  ArXiv: 1305.1575 (2013), Submitted to Phys. Rev. Lett.

D0 Flavor Specific $A^{d,s}_{SL}$

Phys. Rev. D 86 072009 (2012), Phys. Rev. Lett. 110, 011801 (2013)

- Flavor specific asymmetries $A^{d,s}_{SL}$ measured using exclusive decay channels of $B^0_{(s)}$ mesons:
  - $B^0 \rightarrow D^- X \mu^+ \nu$ ($D^- \rightarrow K^+\pi^-\pi^-$),
  - $B^0 \rightarrow D^{*-} X \mu^+ \nu$ ($D^{*-} \rightarrow \overline{D}^0\pi^-$, $\overline{D}^0 \rightarrow K^+\pi^-$)
  - $B^0_s \rightarrow D^-_s X \mu^+ \nu$ ($D^-_s \rightarrow \Phi\pi^-$, $\Phi \rightarrow K^+ K^-$)

$$A^{d,s}_{SL} = \frac{A - A_{BKG}}{F^{osc}_{B^0(s)}}, \quad A = \frac{N_{\mu^+ D^-} - N_{\mu^- D^+}}{N_{\mu^+ D^-} + N_{\mu^- D^+}}$$

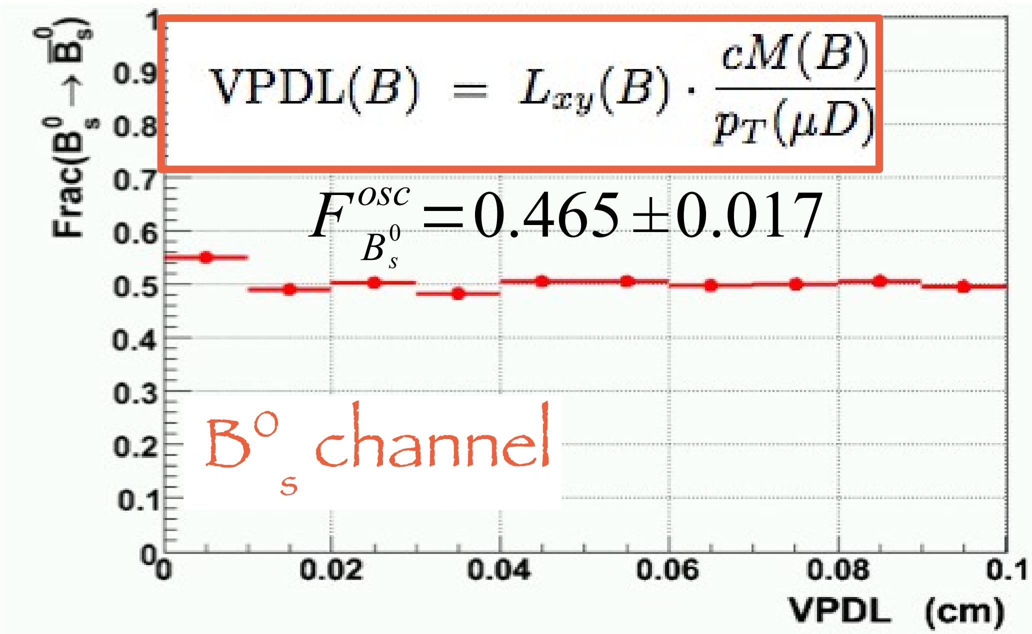
No flavor-tagging at production

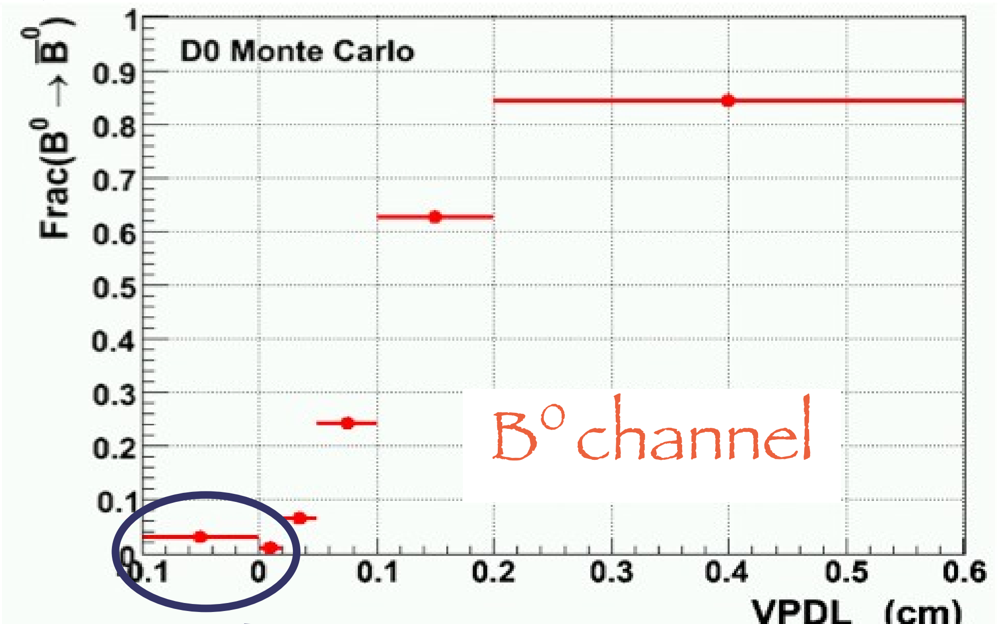
- A: Measured raw asymmetry
- A_{BKG}: Detector-related asymmetry
- $F^{osc}_{B^0(s)}$: Fraction of signal events originating from oscillated $B^0_{(s)}$
- Assumption: no production asymmetry & no direct CPV in charged D-mesons or in B semileptonic decays

D0 Flavor Specific $A^{d,s}_{SL}$

Phys. Rev. D 86 072009 (2012), Phys. Rev. Lett. 110, 011801 (2013)

- Fraction of signal from oscillated $B^0_{(s)}$ computed on MC
- B^0 and B^0_s have different oscillation frequencies
  - Different $F^{osc}_{B^0(s)}$ dependence on $B^0_{(s)}$ Visible Proper Decay Length





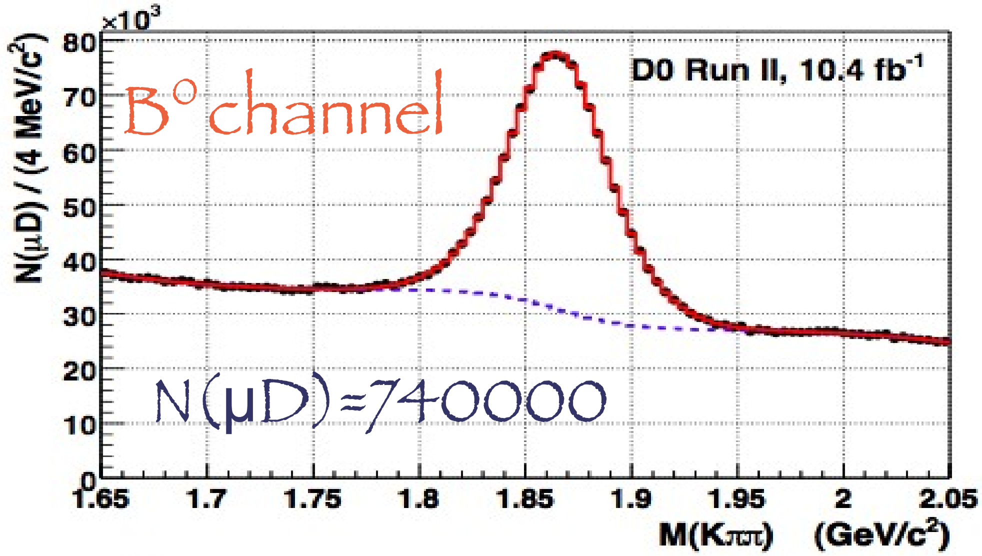
- Analysis optimized in the different VPDL bins for B^0 decays
- Time integrated analysis used for B^0_s

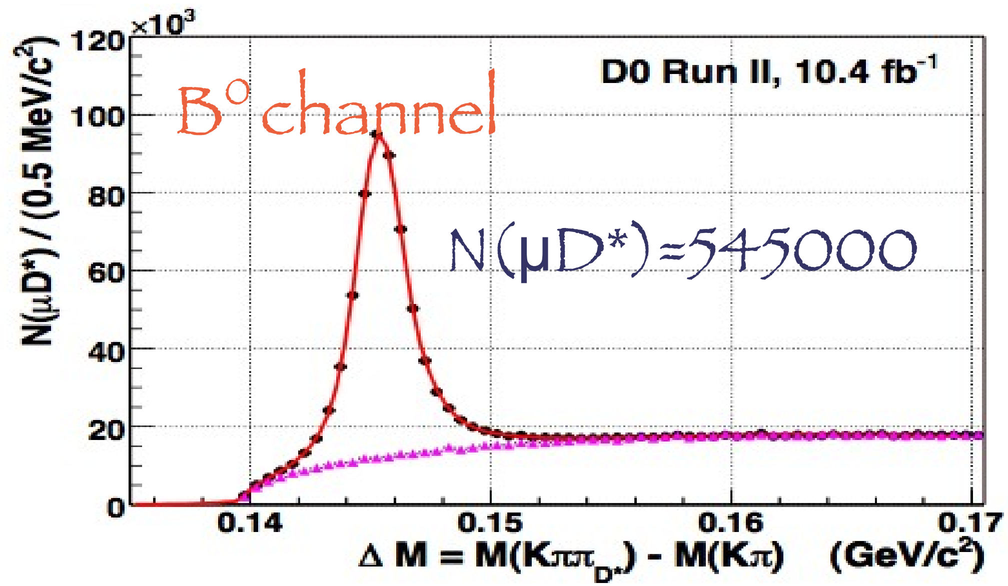
- Control sample:
  - Expect $A - A_{BKG} = 0$

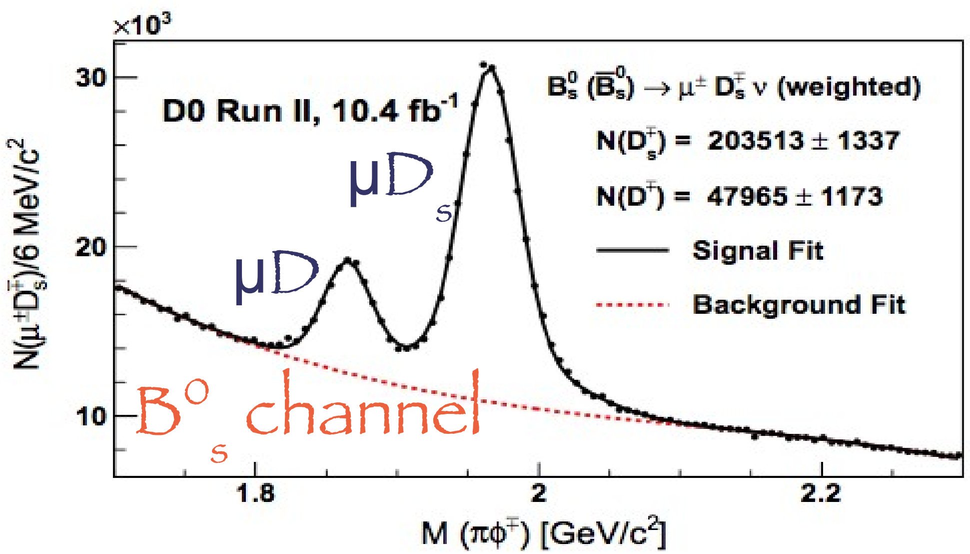
D0 Flavor Specific $A^{d,s}_{SL}$

Phys. Rev. D 86 072009 (2012), Phys. Rev. Lett. 110, 011801 (2013)

- Selection optimized by means of multivariate discriminants



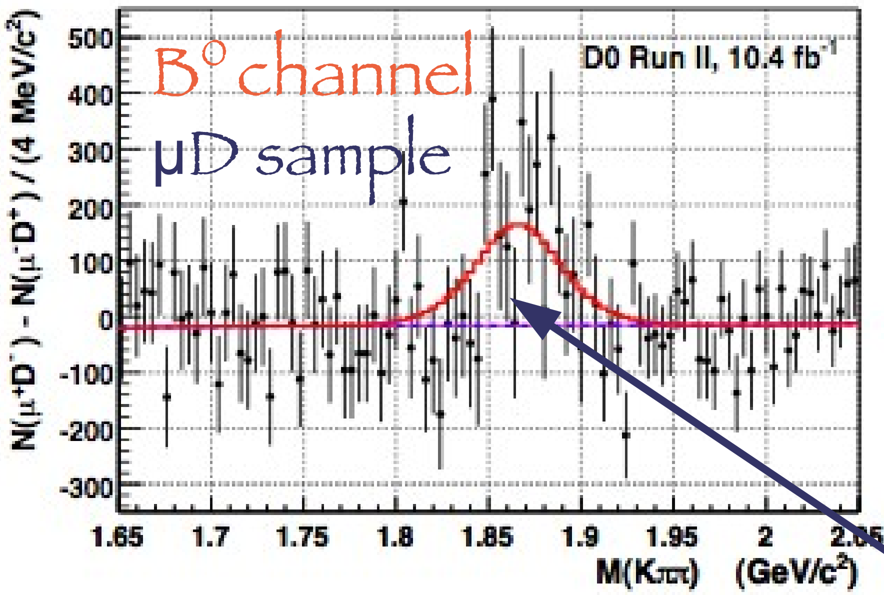


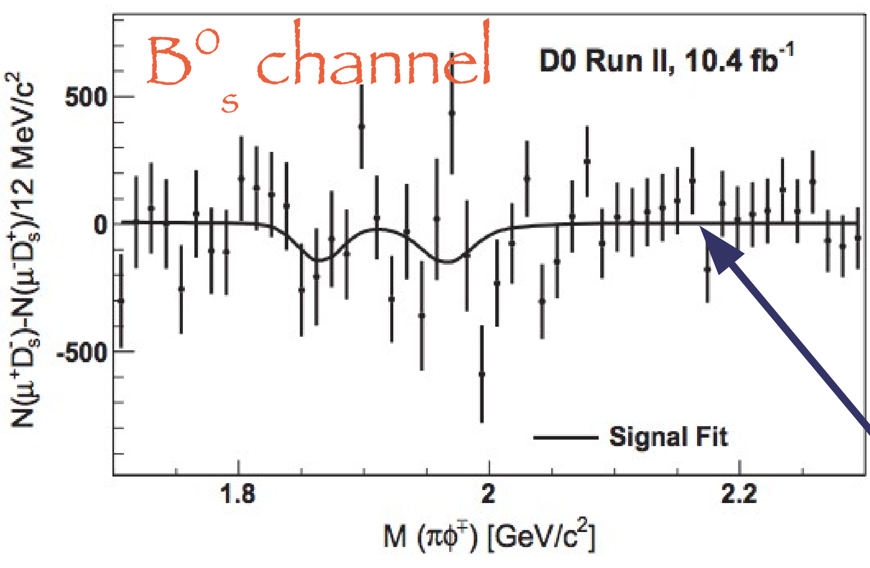


- Several variables used: D transverse decay length, track isolation, B candidate mass,...
- Final cuts chosen to maximize signal significance

D0 Flavor Specific $A^{d,s}_{SL}$

Phys. Rev. D 86 072009 (2012), Phys. Rev. Lett. 110, 011801 (2013)





- Raw asymmetry obtained from simultaneous fits to the sum and difference of signal μ^+D^- and μ^-D^+ distributions:

$$F_{sum} = F^{BKG}_{sum} + N_{sum} F_{sig}$$

$$F_{dif} = F^{BKG}_{dif} + A N_{sum} F_{sig}$$

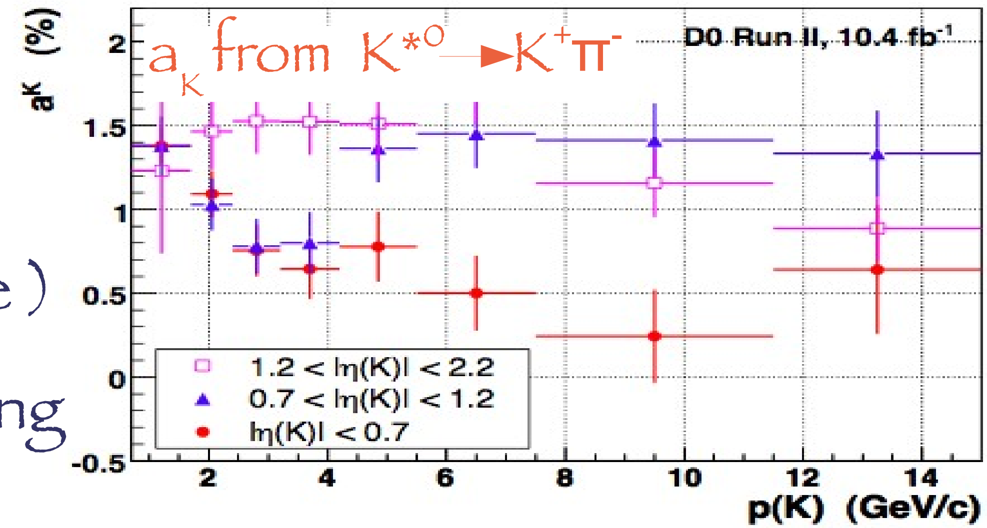
- B^0: $A=(1.48\pm0.41)\%$
  - Significant asymmetry due to kaon identification

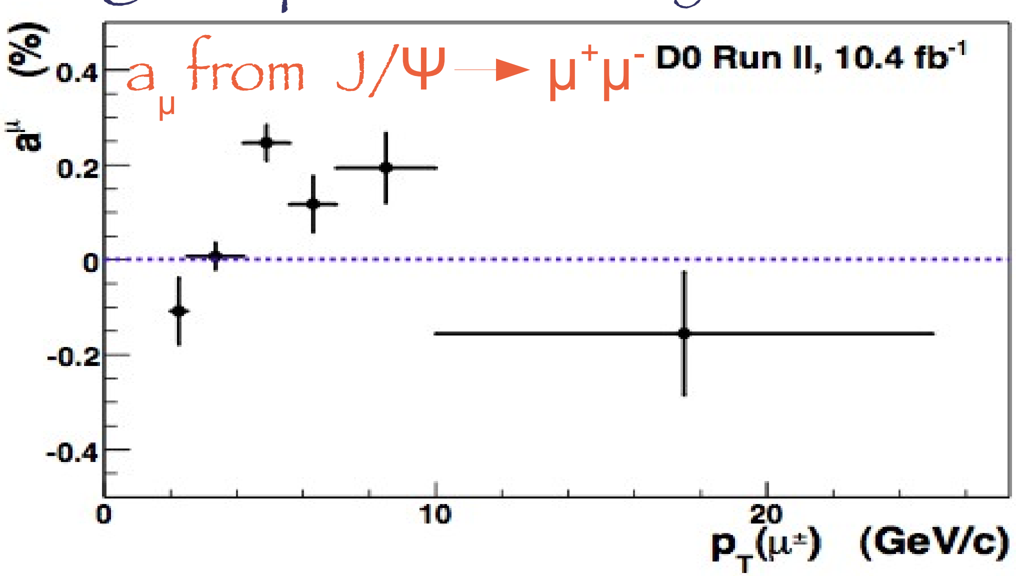
- B^0_s: $A=(-0.40\pm0.33)\%$
  - Negligible asymmetry in Side Bands: Small track reconstruction effect

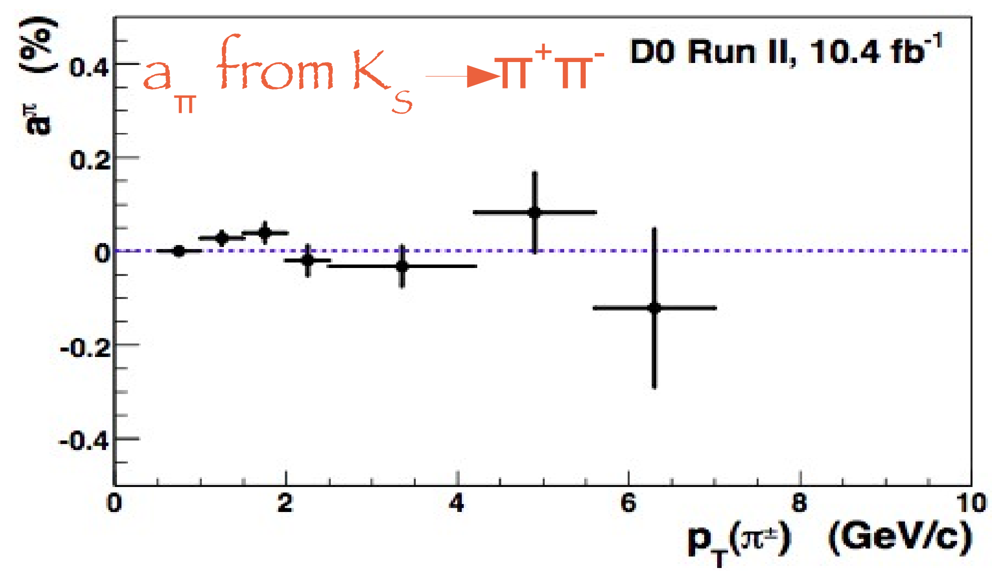
D0 Flavor Specific $A^{d,s}_{SL}$

Phys. Rev. D 86 072009 (2012), Phys. Rev. Lett. 110, 011801 (2013)

- BKG asymmetries computed on control samples
- Dominated by kaon reconstruction (B^0_s unaffected due to K^+K^- final state)
- Detector effects reduced by reversing magnets polarities every two weeks





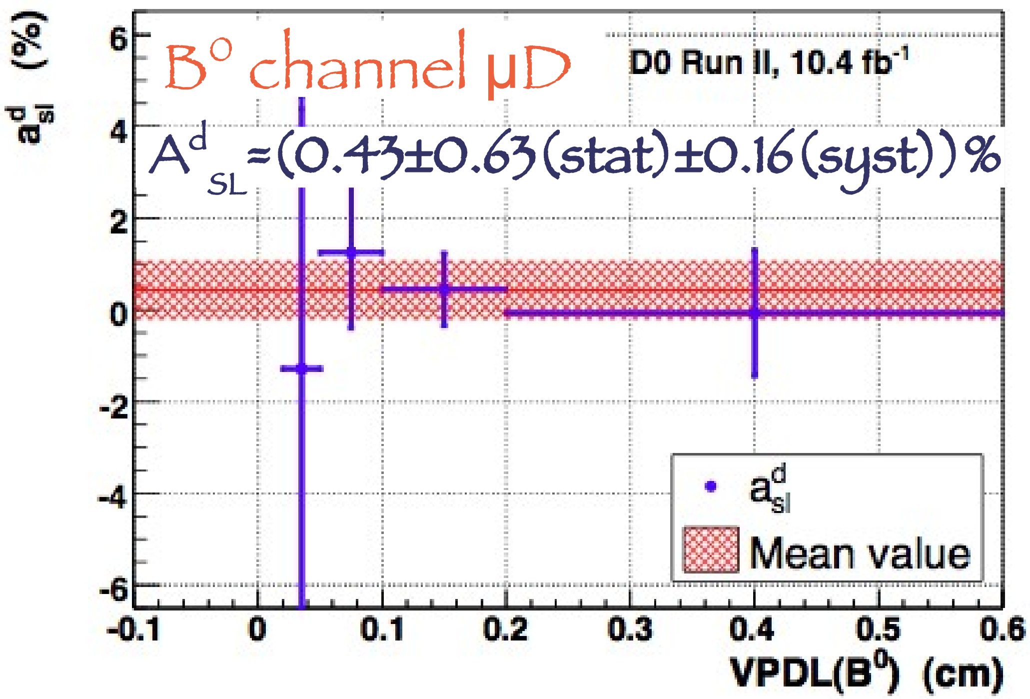


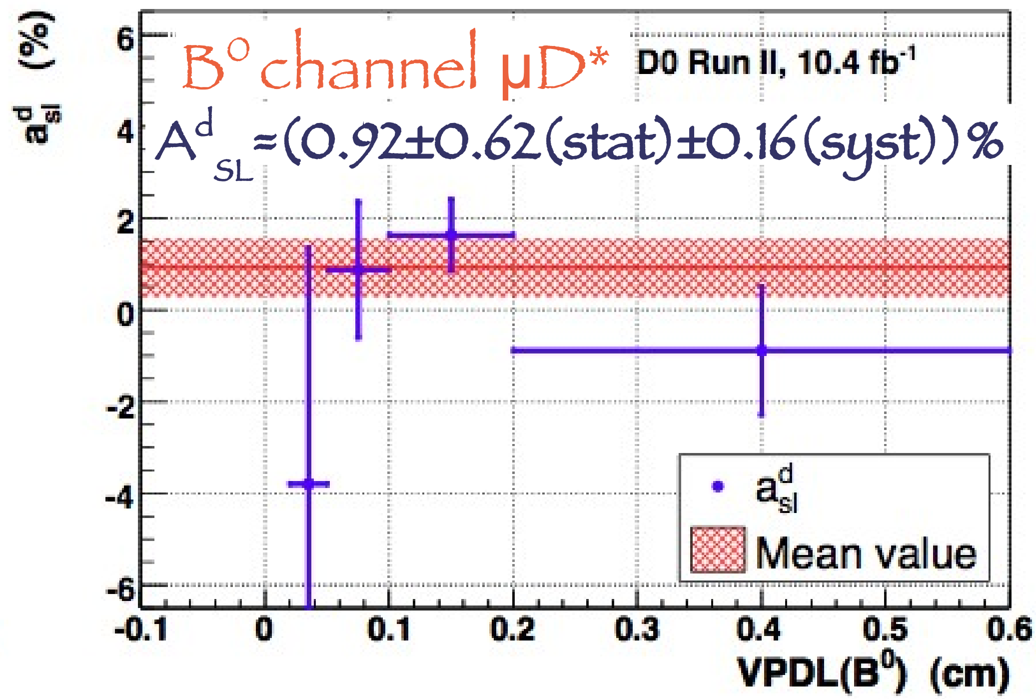
➔ $A_{BKG}(B^0)=(1.18\text{-}1.27)\%$ depending on VPDL bin, $A_{BKG}(B^0_s)=(0.13\pm0.06)\%$

D0 Flavor Specific $A^{d,s}_{SL}$

Phys. Rev. D 86 072009 (2012), Phys. Rev. Lett. 110, 011801 (2013)

- Results:





- A^d_{SL}=(0.68±0.45(stat)±0.14(syst))%
- A^s_{SL}=(-1.12±0.74(stat)±0.17(syst))%

In agreement with SM

- Systematics dominated by BKG asymmetries and $F^{osc}_{B^0(s)}$

LHCb Flavor Specific A^s_{SL}

LHCb-CONF-2012-022 (2012)

- Flavor specific asymmetry A^s_{SL} measured from exclusive decay:
  - $B^0_s \to D^-_s X \mu^+ \nu$ ($D^-_s \to \Phi\pi^-$, $\Phi \to K^+K^-$)

$$A_{\rm meas} = \frac{\Gamma[D_s^-\mu^+] - \Gamma[D_s^+\mu^-]}{\Gamma[D_s^-\mu^+] + \Gamma[D_s^+\mu^-]} = \frac{A^s_{SL}}{2} + \left[a_{\rm p} - \frac{A^s_{SL}}{2}\right] \frac{\int_{t=0}^{\infty} e^{-\Gamma_s t}\cos(\Delta M_s t)\epsilon(t)dt}{\int_{t=0}^{\infty} e^{-\Gamma_s t}\cosh\frac{\Delta\Gamma_s t}{2}\epsilon(t)dt}$$

- A_{meas}: Measured asymmetry corrected for detector effects
- $a_p = \frac{N-\overline{N}}{N+\overline{N}}$: Production asymmetry (o(1%))
- $\epsilon(t)$: Decay time acceptance

Acceptance integral ratio o(0.2%)

- Production asymmetry effect negligible due to fast B^0_s oscillation

LHCb Flavor Specific A^s_{SL}

LHCb-CONF-2012-022 (2012)

- Time integrated raw asymmetry corrected for detector effects:

$$A_{\rm meas} = \frac{N(D_s^-\mu^+) - N(D_s^+\mu^-) \times \frac{\epsilon(D_s^-\mu^+)}{\epsilon(D_s^+\mu^-)}}{N(D_s^-\mu^+) + N(D_s^+\mu^-) \times \frac{\epsilon(D_s^-\mu^+)}{\epsilon(D_s^+\mu^-)}}$$

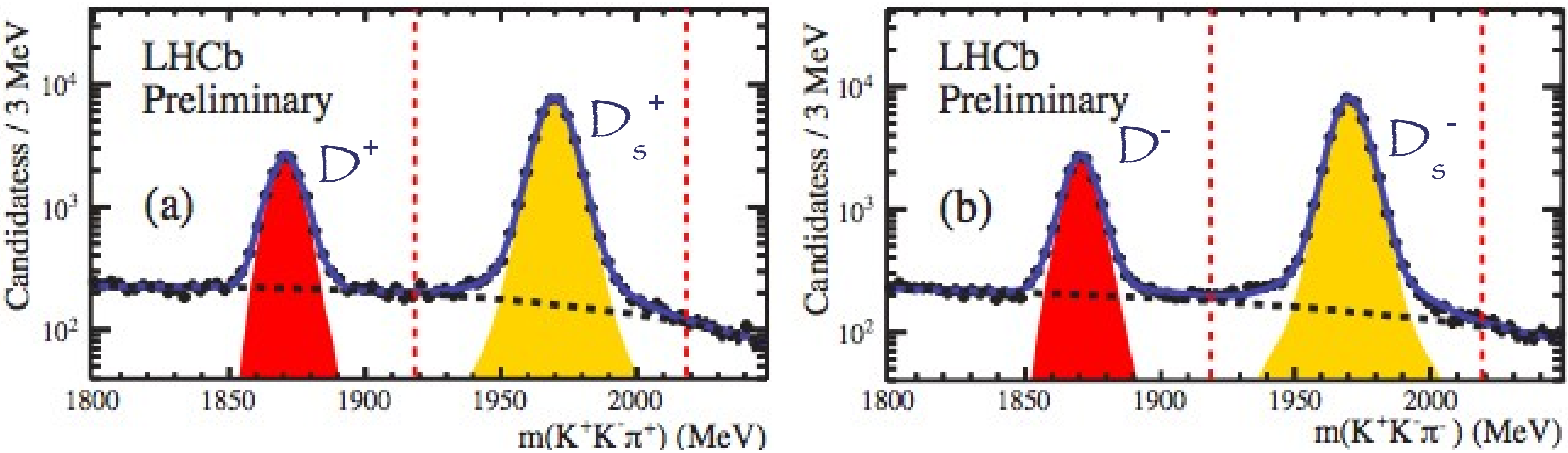
- Detector effects reduced by periodically reversing magnets polarities
- Tracking asymmetry mostly cancels between π & μ in the $\Phi\pi^-\mu^+$ sample
- Relative efficiencies computed on calibration samples:
  - Track efficiency ratio $\varepsilon(\pi^+)/\varepsilon(\pi^-)$ from ratio of fully reconstructed and partially reconstructed $D^{*+} \to D^0\pi^+$, $D^0 \to K^-\pi^+\pi^-(\pi^+)$
  - Muon efficiency ratio $\varepsilon(\mu^+)/\varepsilon(\mu^-)$ from $J/\Psi \to \mu^+\mu^-$ using a tag and probe method

LHCb Flavor Specific A^s_{SL}

LHCb-CONF-2012-022 (2012)

- Signal yields extracted from $KK\pi$ invariant mass distributions

$K^+K^-\pi^+$ $K^+K^-\pi^-$

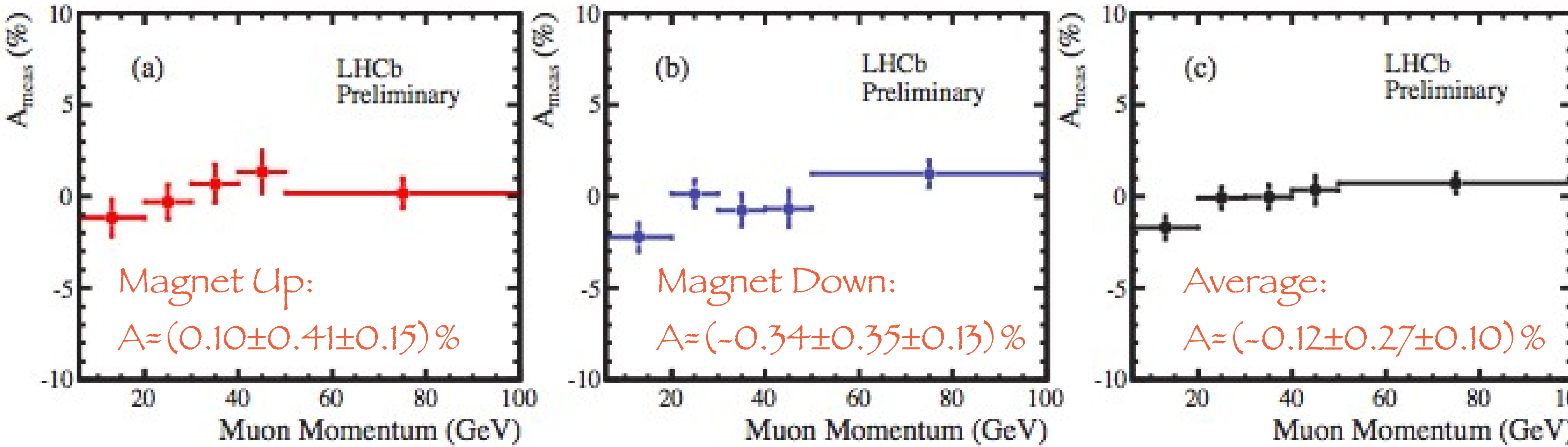


- Background asymmetries due to $K, \pi \rightarrow \mu$ misidentification, prompt D_s, $B \rightarrow D_s X_c$, $D_s K\mu\nu X$ ~o(10^{-4})
  - Negligible effect on the result
  - BKG not subtracted from the selected events
  - Taken into account in the systematic error evaluations

LHCb Flavor Specific A^s_{SL}

LHCb-CONF-2012-022 (2012)

- Corrected asymmetries vs P_μ:



➔ A^s_{SL}=(-0.24±0.54(stat)±0.33(syst))%

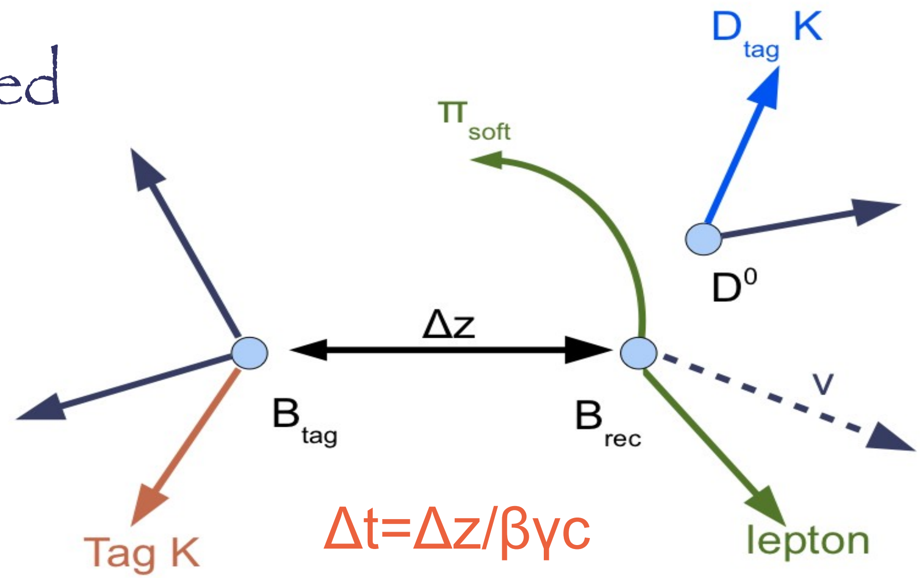
In agreement with SM

- Systematics dominated by statistical error on the muon efficiency ratio $\varepsilon(\mu^+)/\varepsilon(\mu^-)$

BaBar Flavor Specific A^d_{SL}

arXiv:1305.1575 (2013)

- B^0 Semileptonic Asymmetry measured from Partially Reconstructed $B^0 \to D^* l \nu$, $D^* \to \pi_{soft} D^0$ and K Tag



- P.R. B^0 flavor from lepton charge
- Tag B^0 flavor from K charge
- Tag B vertex from K track estrapolation to the e^+e^- Interaction Region

$$A^d_{SL} \approx \frac{N(\ell^+ K_T^+) - N(\ell^- K_T^-)}{N(\ell^+ K_T^+) + N(\ell^- K_T^-)}$$

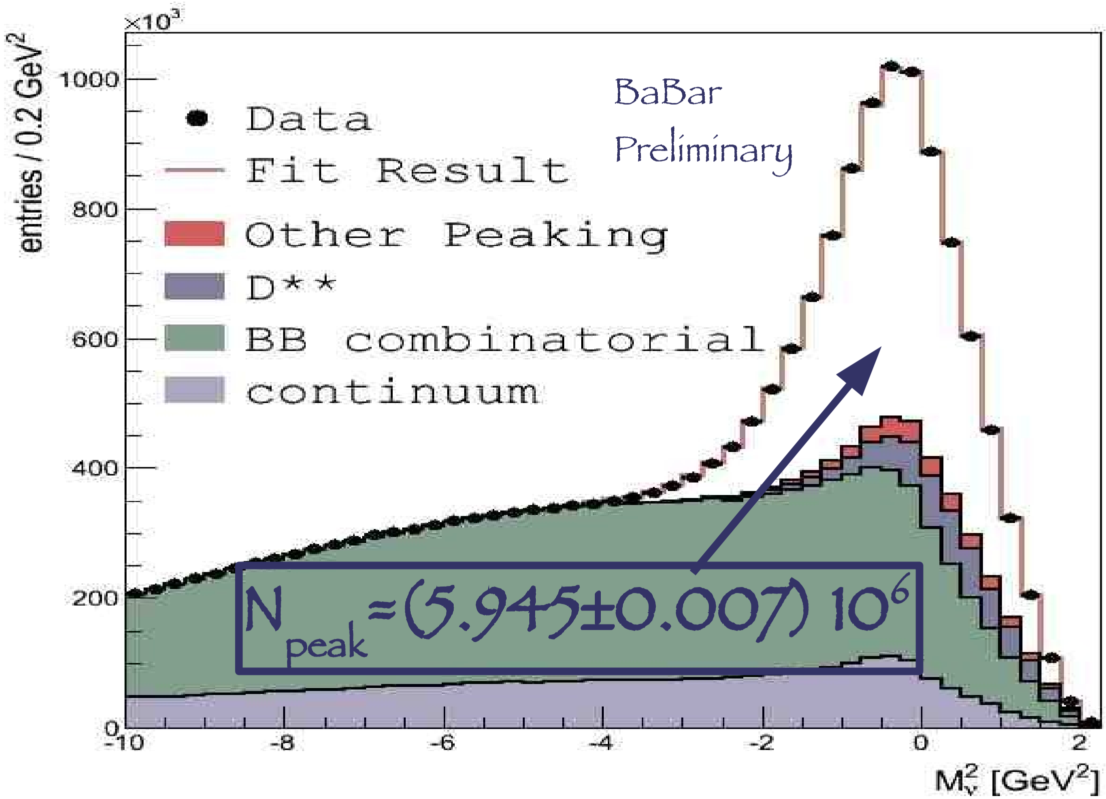
- A^d_{SL} from an Extended Maximum Likelihood binned fit to the Δt & $\cos(\theta_{K\text{-}Lepton})$ distributions of the 4 subsamples:

Unmixed (l^-K^+, l^+K^-); Mixed (l^+K^+, l^-K^-)

BaBar Flavor Specific A^d_{SL}

arXiv:1305.1575 (2013)

- Reconstruct only lepton & π_{soft} with opposite charge
- Signal selection using missing squared neutrino mass with the approximation of B^0 at rest in the $\Upsilon(4s)$ frame
- D* 4-momentum estimated from π_{soft} kinematics



$$\mathcal{M}_\nu{}^2 \equiv (E_{\rm beam} - E_{D^*} - E_\ell)^2 - (\vec{p}_{D^*} + \vec{p}_\ell)^2$$

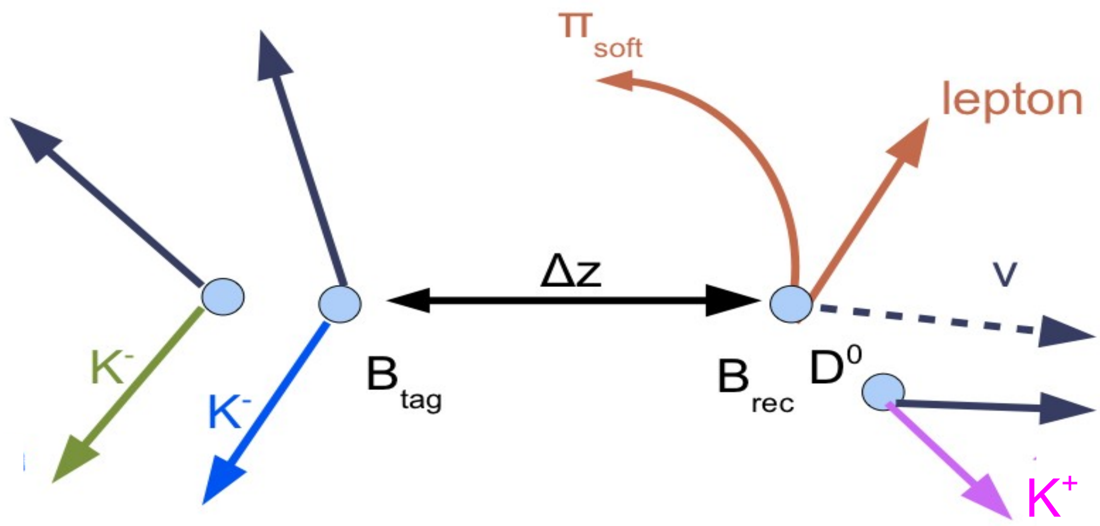
- Sample composition from a fit to M^2_ν by floating D*, D** and Combinatorial using MC shapes and Continuum shape from Off-Peak events

BaBar Flavor Specific A^{d}_{SL}

arXiv:1305.1575 (2013)

- Tagging Kaon Sample: $\left\{ \begin{array}{l} b \rightarrow K + b \rightarrow c \rightarrow K \\ D^0 \rightarrow K \end{array} \right.$

From Tag B	"Btag"
From Reco B	"Dtag"



Tag Kaon
Decay Side

Tag Kaon
Tag Side
"Btag"

"Dtag"
mostly populate the "Mixed" event sample (K-lepton charge correlation)

BaBar Flavor Specific A^d_{SL}

arXiv:1305.1575 (2013)

- Crucial Issue: discriminate between Physical & Detector charge asymmetry without relying on control samples
  - Reconstruction Asymmetry: $\rho=\varepsilon(l^+,\pi^-)$, $\bar{\rho}=\varepsilon(l^-,\pi^+)$

    $$A_{rec} = (\rho - \bar{\rho})/(\rho + \bar{\rho})$$

  - Tagging Asymmetry, depending on P_K: $\tau = \varepsilon(K^+)$, $\bar{\tau} = \varepsilon(K^-)$

    $$A_{tag} = (\tau - \bar{\tau})/(\tau + \bar{\tau})$$

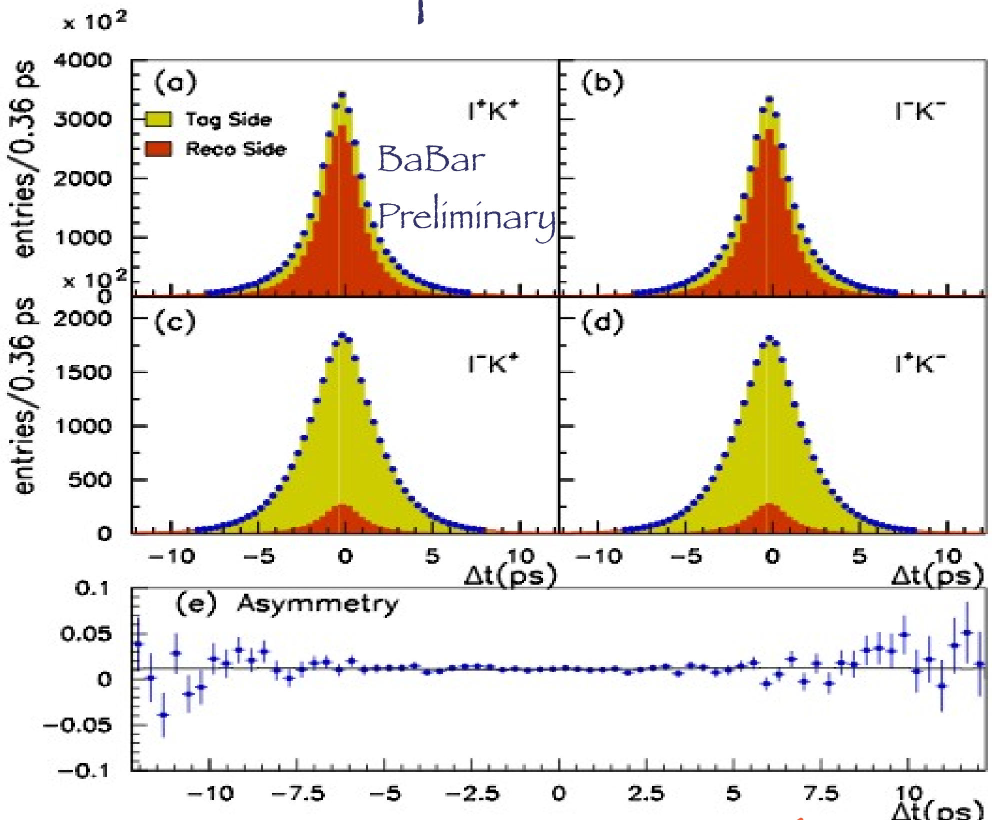
- Different sub-samples (B^0, B^+)X(Peaking, BKG)X(Btag, Dtag) share Physical and/or Detector asymmetries in different combinations.

- **Strategy: disentangle the Physical and Detector asymmetries by exploiting all the available informations from different sub-samples.**

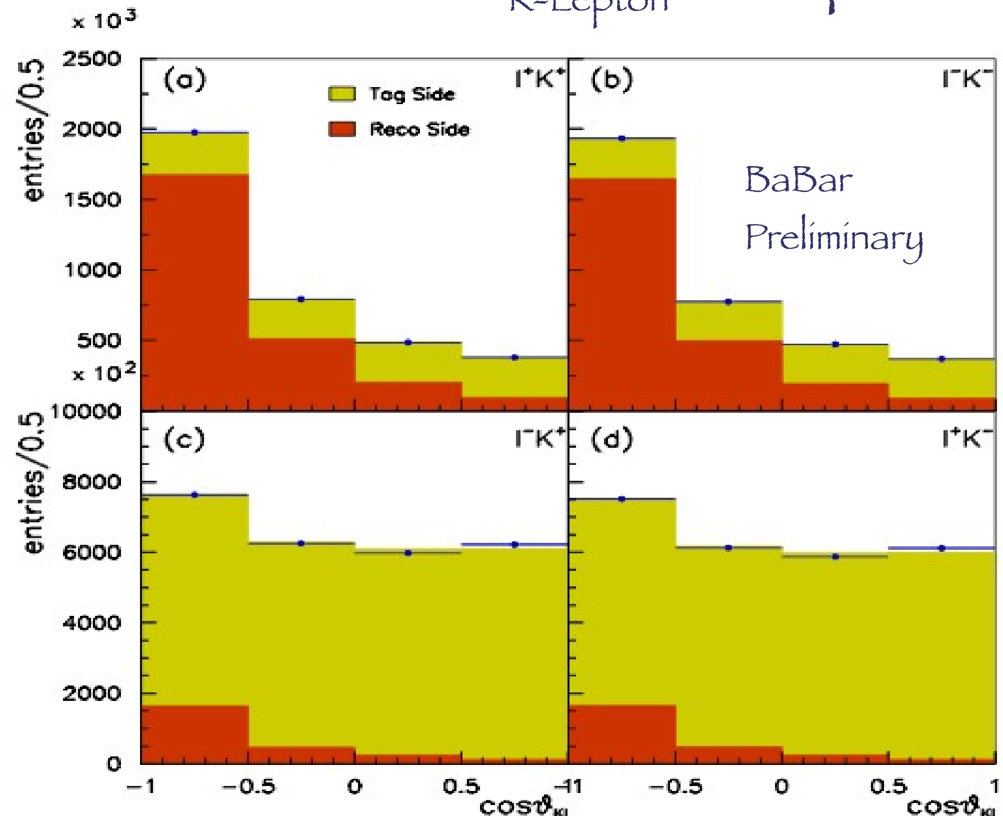
BaBar Flavor Specific A^{d}_{SL}

arXiv:1305.1575 (2013)

Fitted Δt Shapes



Fitted cos($\theta_{K\text{-}Lepton}$) Shapes



$$|q/p|-1=(-0.29\pm0.84^{+1.61}_{-1.78})\times10^{-3} \rightarrow A^{d}_{SL}=(0.06\pm0.17^{+0.38}_{-0.32})\%$$

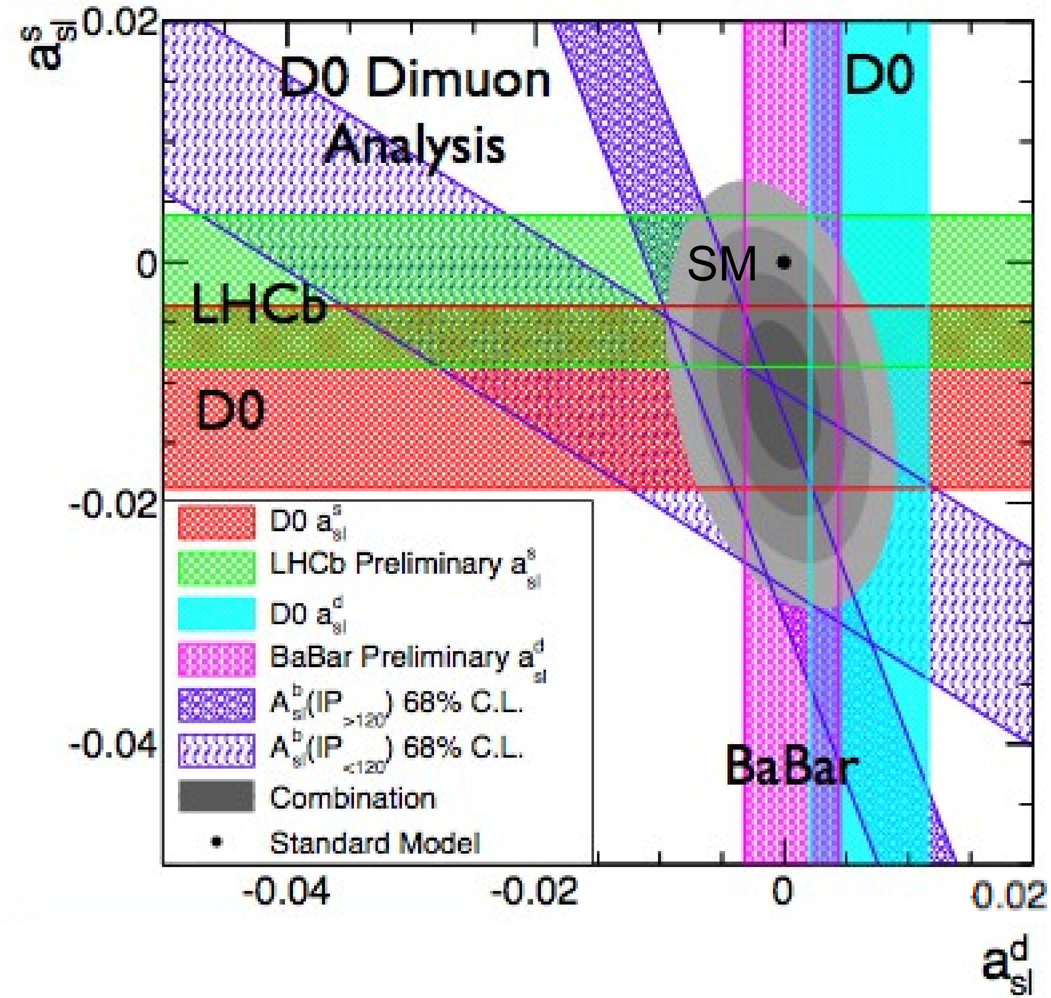
- Systematics dominated by uncertainty on sample composition

Best single Measurement, in agreement with SM

Conclusions

Combination of Results

Iain Bertram – DIS 2013

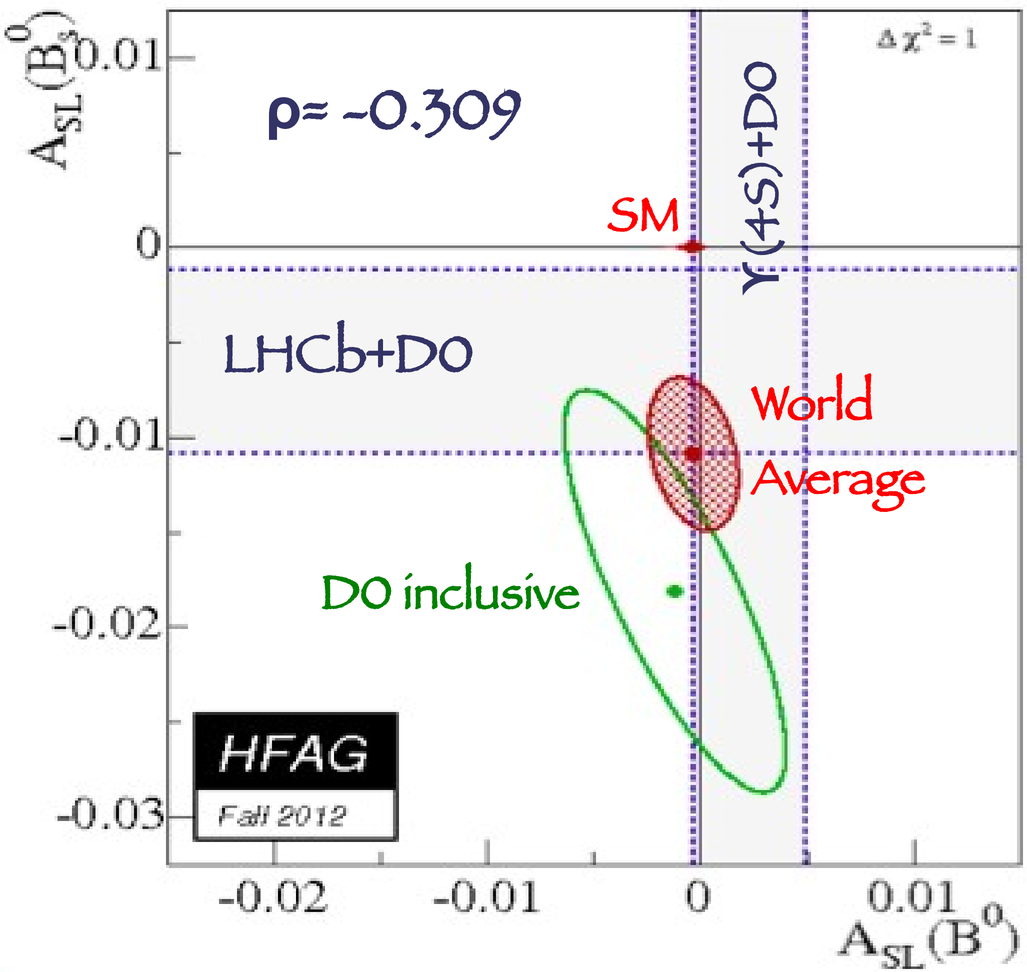


- Results from flavor specific measurements:
- A^d_{SL}:
  - $\Upsilon(4S) = (0.02 \pm 0.31)\%$
  - $\Upsilon(4S) + D0 = (0.23 \pm 0.26)\%$
- A^s_{SL}:
  - $D0 + LHCb = (-0.60 \pm 0.49)\%$

- World averages of flavor specific measurements agree with SM

World Average

- HFAG averages (after CKM2012) (http://www.slac.stanford.edu/xorg/hfag/osc/fall_2012/#CPV)



- From a 2-D fit to $A^{d,s}_{SL}$:
  - A^d_{SL} (world)=(-0.03±0.21)%
  - A^s_{SL} (world)=(-1.09±0.40)%

- World average of experimental results deviates 2.4 σ from SM prediction

Constraints on New Physics

- New Physics could modify M^q_{12} and A_{SL} leaving Γ^q_{12} unchanged

(Lenz et al., Phys, Rev. D 86, 033008 (2012), Nierste, arXiv:1212.5805 (2012))

$$M_{12}^{NP,q} = M_{12}^{SM,q}\Delta_q ; \Delta_q = |\Delta_q| e^{i\phi_q^\Delta}$$

$$\Delta_q^{SM} = 1$$

$$A_{SL}^{NP} = \frac{|\Gamma_{12}^q|}{|M_{12}^{SM,q}|} \frac{\sin(\phi_q^{SM} + \phi_q^\Delta)}{|\Delta_q|}$$

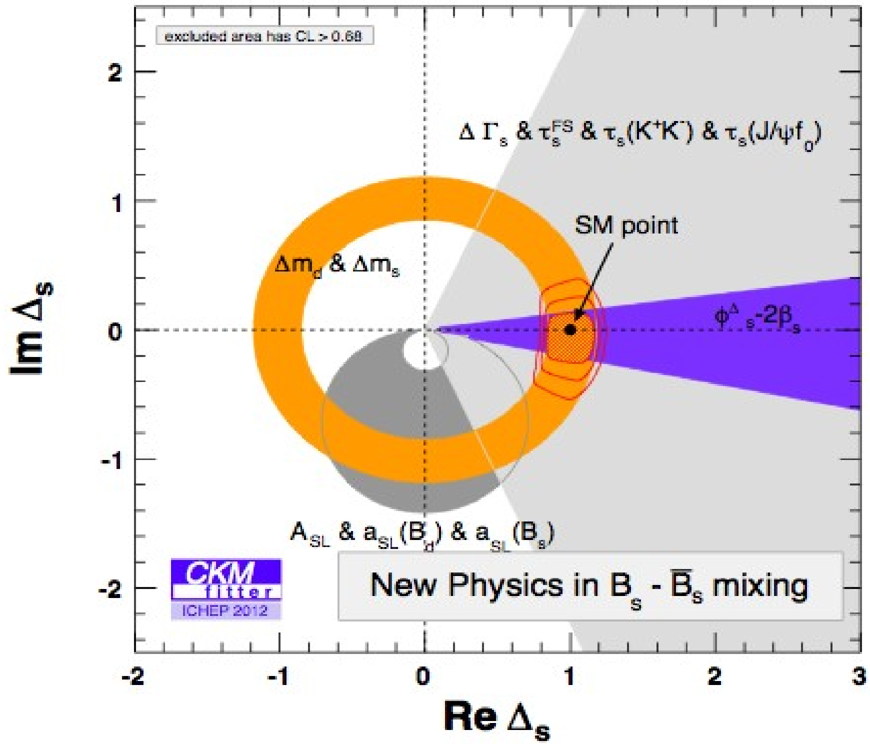
- New phases ϕ_q^Δ would shift also the CP phases from the mixing-induced CP asymmetries:
  - $B^0 \to J/\psi K_S$: $2\beta \to 2\beta + \phi_d^\Delta$
  - $B^0_s \to J/\psi\Phi$: $2\beta_s \to 2\beta_s - \phi_s^\Delta$
- Strong constraint from recent LHCb $B^0_s \to J/\psi\Phi$ measurement:
  - $2\beta_s - \phi_s^\Delta = (0.1 \pm 5.8 \pm 1.5)^o$ (LHCb-CONF-2012-002)

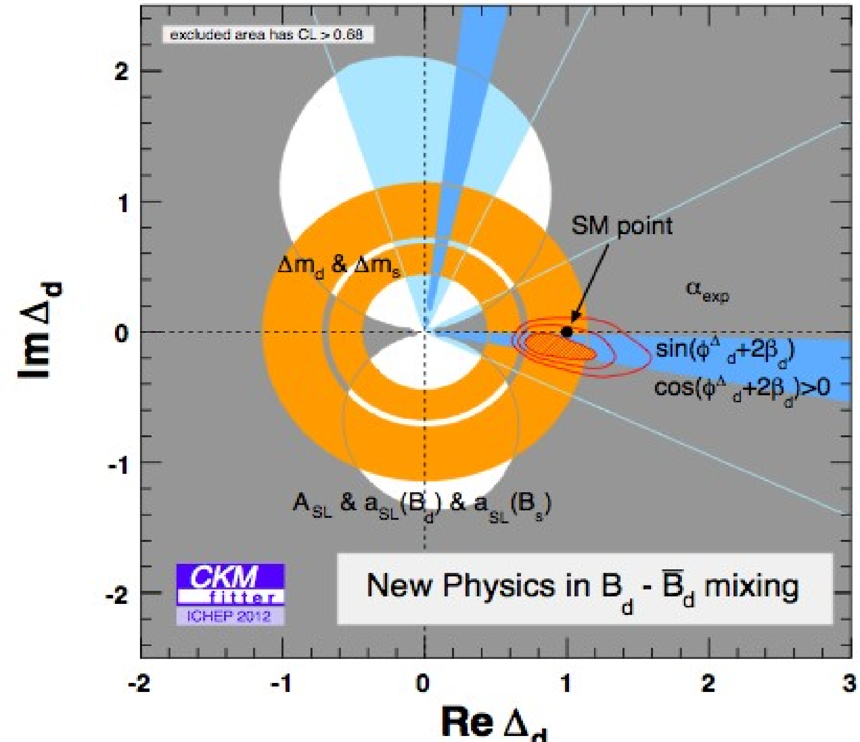
$(2\beta_s = 2\,arg(-V_{ts}V_{tb}^*/V_{cs}V_{cb}^*) \simeq 2.1^o)$

Constraints on New Physics

- Global fit of $\Delta_{d,s}$ and CKM elements performed to all relevant data

(Nierste, arXiv:1212.5805 (2012), CKMfitter Group (J. Charles et al.), http://ckmfitter.in2p3.fr):





- Average still not includes recent D0 & BaBar flavor specific results
- Due to LHCb costraint on ϕ^Δ_s, SM prediction disfavored by only 1 σ
- Difficult to accomodate the D0 inclusive A_{SL} result in this framework

Conclusions

- CP violation in $B^0_{(s)}$ mixing is an excellent laboratory for the search for physics beyond the Standard Model
- In the last two years, five new measurements from B-Factories & Hadron Colliders released with experimental precision o(0.5%):
  - agreement with SM is improving
- In the Near Future:
  - BaBar is finalizing the inclusive B^0 dilepton asymmetry with the full statistics & a single tag measurement using $B^0 \rightarrow D^* l \nu$ P.R.
  - LHC experiments & Belle II will offer the Opportunity to:
    - provide very stringent SM tests
    - Hopefully discover/understand New Physics

Backup

D0 like-sign dimuons charge Asymmetry

Phys. Rev. D 84,052007 (2011)

$$a=\frac{n(\mu^+)-n(\mu^-)}{n(\mu^+)+n(\mu^-)}=F(a_S,\delta,a_{BKG}),\quad a_s=c_b A^b_{SL}$$

$$A=\frac{N(\mu^+\mu^+)-N(\mu^-\mu^-)}{N(\mu^+\mu^+)+N(\mu^-\mu^-)}=G(A_S,\delta,A_{BKG}),\quad A_S=C_b A^b_{SL}$$

- a_S, A_S: Asymmetries of muons from b, c, and short-lived hadrons
- c_b, C_b: Dilutions computed in terms of the various processes contributing to the BKG-subtracted muon samples:
  - c_b=0.061±0.007, C_b=0.474±0.032
- δ: Muon reconstruction asymmetry
- a_{BKG}, A_{BKG}: Background asymmetries from K, π decays determined using real data control samples

D0 like-sign dimuons charge Asymmetry

Phys. Rev. D 84,052007 (2011)

- Background asymmetry determined from real data control samples
  - $a_{BKG}=f_K a_K+f_\pi a_\pi+f_p a_p$
- Fractions f_X determined in PT_μ, η_μ bins from

$K^{*0}\to K\pi$, $K_S\pi$ ($K\to\mu$), $P(\pi\to\mu)/P(K\to\mu)$, $P(p\to\mu)/P(K\to\mu)$

- Asymmetries a_X determined from $K^{*0}\to K\pi$, $\Phi\to KK$, $K_S\to\pi\pi$ and

$\Lambda\to p\pi$ requiring an hadron to be identified as a muon

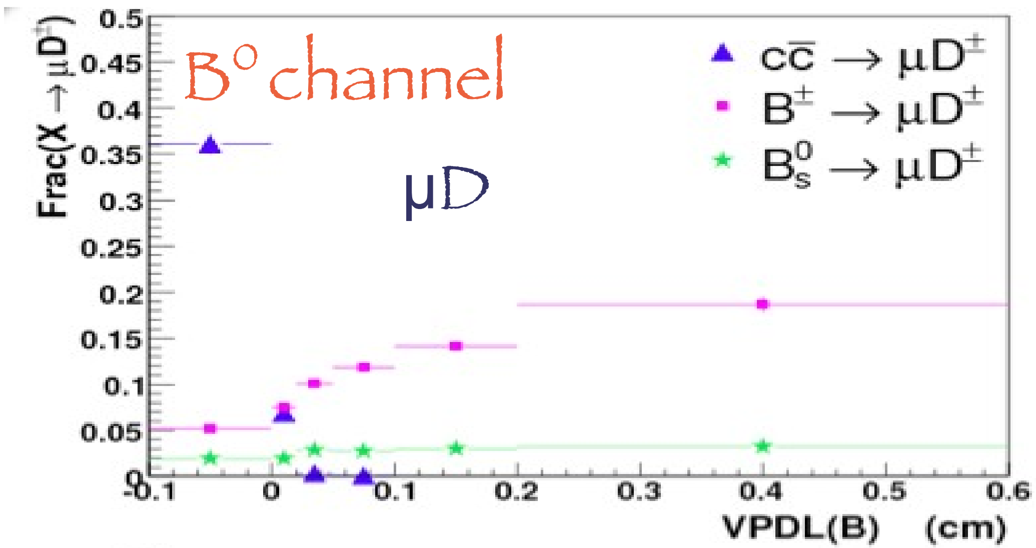
- Muon reconstruction asymmetry from $J/\Psi\to\mu\mu$ with one

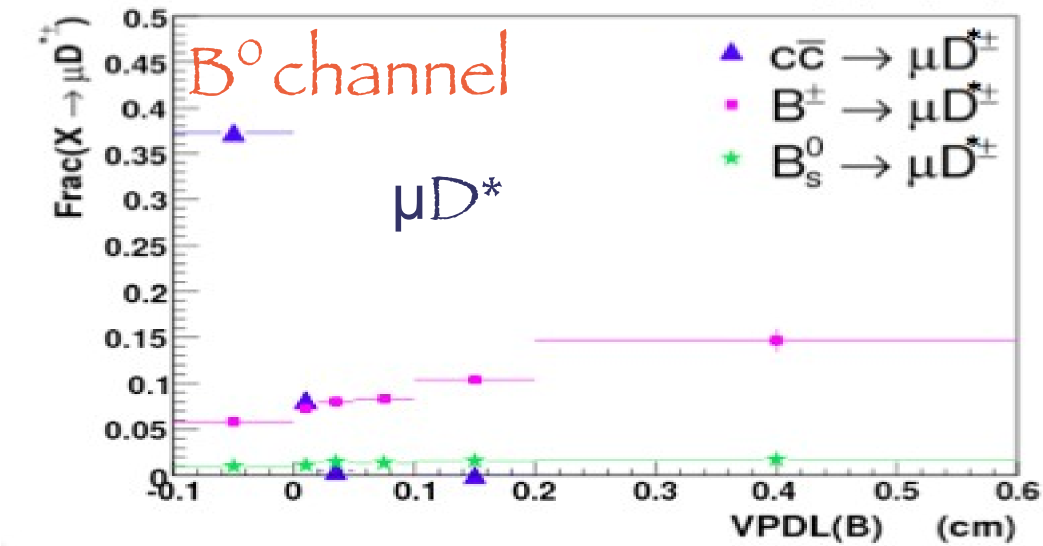
identified muon and an additional track with opposite charge

D0 Flavor Specific $A^{d,s}_{SL}$

Phys. Rev. D 86 072009 (2012), Phys. Rev. Lett. 110, 011801 (2013)

- Fraction $F^{osc}_{B^0(s)}$ of signal from oscillated $B^0_{(s)}$ computed on MC (EvtGen)





- Fraction of μD candidates from different sources depends on Visible Proper Decay Lenght

- >80% of signal events from $B^0_{(s)}$ decays

BaBar Flavor Specific A^d_{SL}

arXiv:1305.1575 (2013)

- Signal B⁰ Btag PDF for Positive Mixed (l^+K^+) sample, (similar expressions apply for the other ones):

$$\mathcal{F}_{signal}(\Delta t, s_t, s_m) = \frac{\Gamma}{2(1+r'^2)} e^{-\Gamma|\Delta t|} \left|\frac{p}{q}\right|^2 \left[\left(1 + \left|\frac{q}{p}\right|^2 r'^2\right) \cosh(\Delta\Gamma\Delta t/2) - \right.$$
$$\left. - \left(1 - \left|\frac{q}{p}\right|^2 r'^2\right) \cos(\Delta m_d \Delta t) + \left|\frac{q}{p}\right| (b+c) \sin(\Delta m_d \Delta t) \right]$$

- r', b, c: parameters resulting from interference between Cabibbo-Favoured and Doubly Cabibbo-Suppressed decays on the tag side

$$r' = \left|\overline{\mathcal{A}}_{DCS}/\mathcal{A}_{CF}\right|$$
$$b = 2r' \sin(2\beta+\gamma)\cos\delta'$$
$$c = -2r' \cos(2\beta+\gamma)\sin\delta'$$
$\delta' =$ Strong Phase

- Assumed $\Delta\Gamma = 0$
- b, c are treated as effective parameters due to strong correlation with resolution function
  - Only |q/p| is measured

PDF Description: Dtag

- Dominant BKG in Mixed events: shows single-tag semileptonic asymmetry

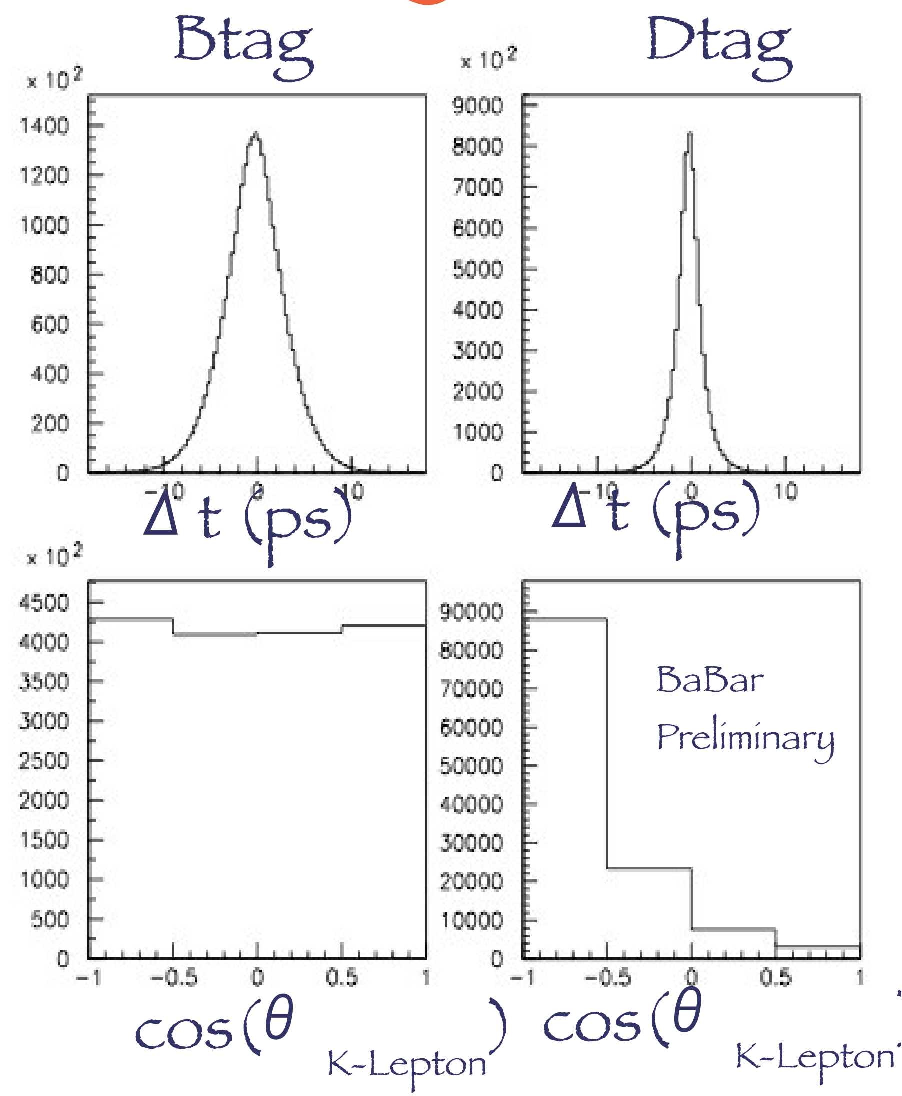
- F_{Dtag} floated by exploiting the different Δt & θ (K-Lepton) distributions wrt Btag events in different P_K bins

- Dtag fraction in B^+ events constrained to B^0 using simulation informations:

$F^{B+}_{Dtag} = R_{MC}(P_K) * F^{B0}_{Dtag}$

- $\cos(\theta_{K\text{-}Lepton})$ PDF from MC

- Δt PDF from **a High Purity selection on Real Data (Dtag Purity ~95%)**



Detector Asymmetry determination

- Observed asymmetry in the different subsamples: arXiv:1305.1575 (2013)

	B^0	B^+
P.R. evts (Tag+Untag)	$A_{rec} + A_{SL} {}^{*}\chi_d$	A_{rec}
Btag	$A_{rec} + A_{tag}(P_K) + A_{SL}$	$A_{rec} + A_{tag}(P_K)$
Dtag	$A_{rec} + A_{tag}(P_K) + A_{SL} {}^{*}\chi_d$	$A_{rec} + A_{tag}(P_K)$

χ_d : Time-Integrated Mixing Probability

B^+ e Dtag BKG samples are useful in the A^d_{SL} measurement!