The CP violating semileptonic asymmetry in B_s decays

Christos Hadjivasiliou
Syracuse University

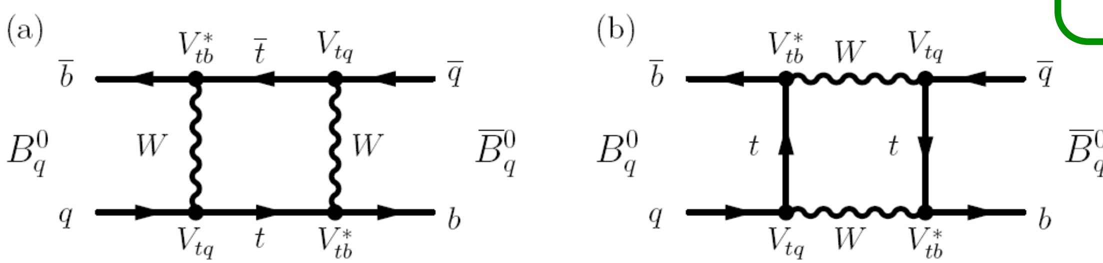
Young Physicist Lightning Round
US LHC Users Organization

A little bit of theory

- Neutral B mesons (B_s, B_d) can transform into their anti – particles before they decay. The time dependent mixing of the flavor eigenstates is governed by the Schrodinger equation:

$$i\frac{d}{dt}\begin{pmatrix} |B_q^0(t)\rangle \\ |\overline{B}_q^0(t)\rangle \end{pmatrix} = \left(M^q - \frac{i}{2}\Gamma^q\right)\begin{pmatrix} |B_q^0(t)\rangle \\ |\overline{B}_q^0(t)\rangle \end{pmatrix}$$

with mass eigenstates: $|B_{L,H}^q\rangle = p|B_q^0(t)\rangle \pm q|\overline{B}_q^0(t)\rangle$ and $a_s = 1 - \left|\frac{q}{p}\right|^2$



- Observable quantities are masses and differences in decay widths. We can access a_s by measuring asymmetries in flavor specific final states (for example semileptonic decays):

$$a_{sl}^s = \frac{\Gamma\left(\overline{B}_s^0 \to D_s^-\mu^+\nu\right) - \Gamma\left(B_s^0 \to D_s^+\mu^-\overline{\nu}\right)}{\Gamma\left(\overline{B}_s^0 \to D_s^-\mu^+\nu\right) + \Gamma\left(B_s^0 \to D_s^+\mu^-\overline{\nu}\right)} = \frac{1-(1-a_s)^2}{1+(1-a_s)^2} \sim a_s$$

What we measure

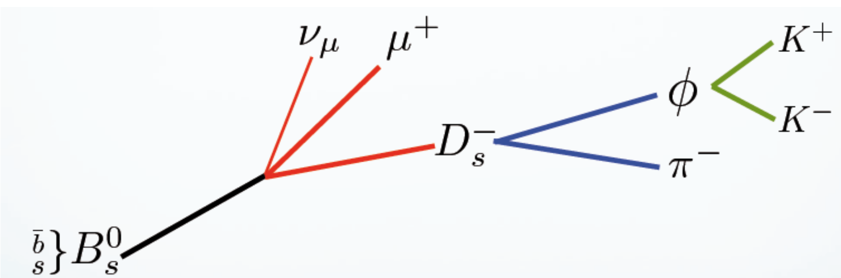
Untagged SL asymmetry

$B_s^0 / \bar{B}_s^0$ production asymmetry ≈1%

decay time acceptance function (from MC)

$$A_{meas} = A_\mu^c - A_{track} - A_{bkg} = \frac{\Gamma(D_s^- \mu^+) - \Gamma(D_s^+ \mu^-)}{\Gamma(D_s^- \mu^+) + \Gamma(D_s^+ \mu^-)} = \frac{a_{sl}^s}{2} + \left(a_p - \frac{a_{sl}^s}{2} \right) \frac{\int_{t=0}^{\infty} e^{-\Gamma_s t} \cos(\Delta M_s t) \varepsilon(t) dt}{\int_{t=0}^{\infty} e^{-\Gamma_s t} \cosh\left(\frac{\Delta \Gamma_s t}{2}\right) \varepsilon(t) dt}$$

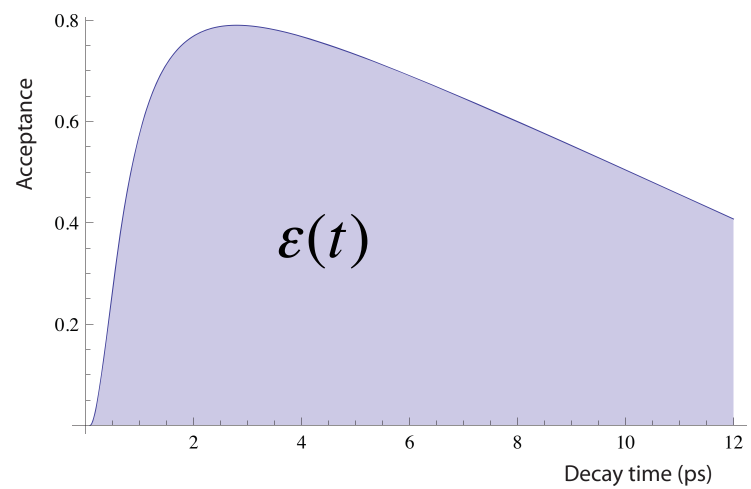
0.2% in our case



Effects of production asymmetry diluted by the fast B_s oscillations

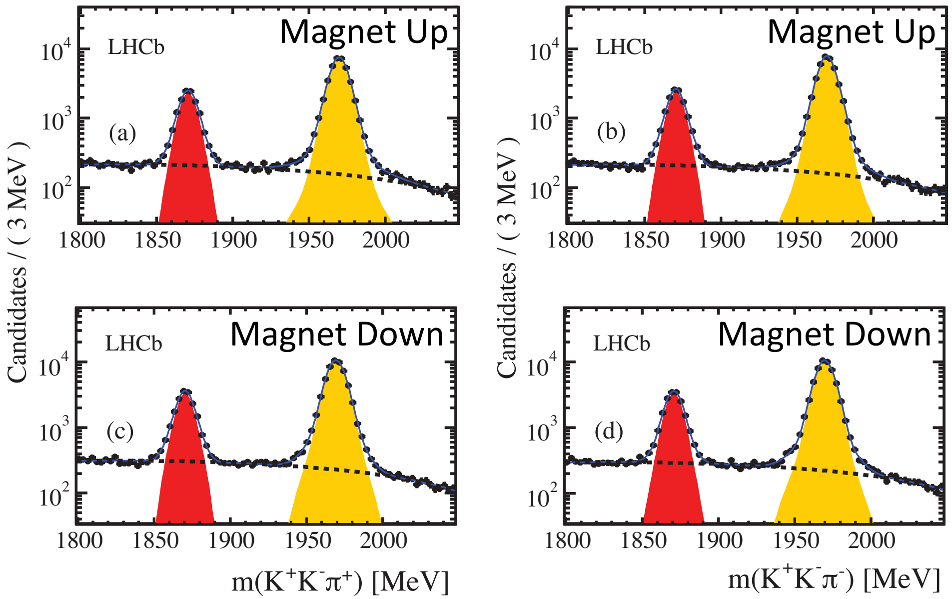
$$A_{meas} \cong \frac{a_{sl}^s}{2}$$

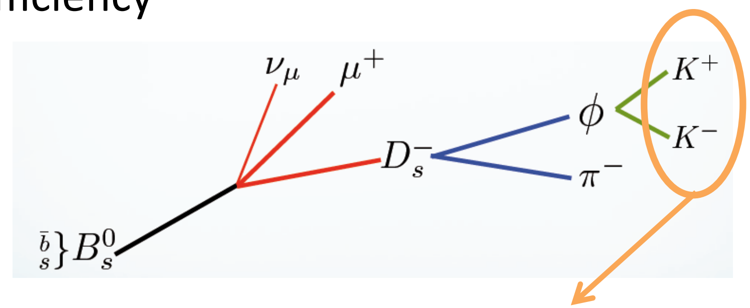
and
$$A_\mu^c = \frac{N(D_s^- \mu^+) - N(D_s^+ \mu^-) \times \frac{\varepsilon(\mu^+)}{\varepsilon(\mu^-)}}{N(D_s^- \mu^+) + N(D_s^+ \mu^-) \times \frac{\varepsilon(\mu^+)}{\varepsilon(\mu^-)}}$$



Key elements of the analysis

- Determination of the signal yields using *Magnet Up* (447pb^{-1}) and *Magnet Down* (595pb^{-1}) data samples of almost equal size, which allows us to average out residual charge asymmetries in detection efficiency





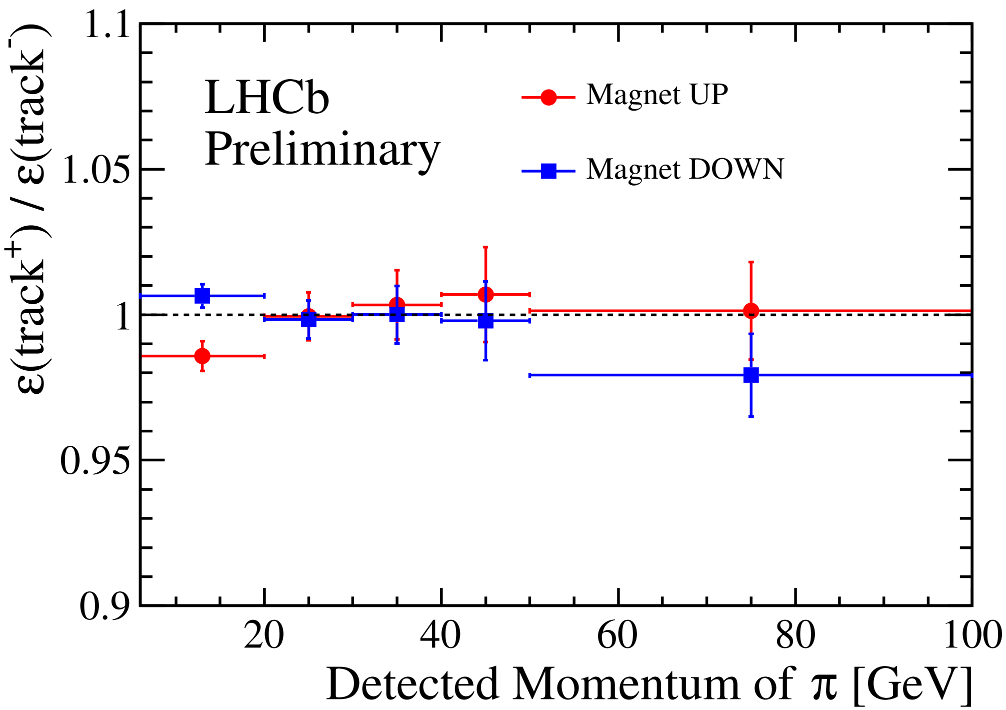
Almost equal kaon momentum spectra

Data driven analysis
All corrections are derived from data

- Analysis relies on muon system in several ways, thus we study the asymmetry in the fine kinematic binning in muon phase space with two different schemes: (p_x, p_y) and also using (p_T, ϕ)
- *Detailed analysis of background sources*: Prompt charm production, fake muons associated with real D_s particles produced in b-hadron decays, and B→DD_s decays where the D hadron decays semileptonically.

Data driven corrections (I)

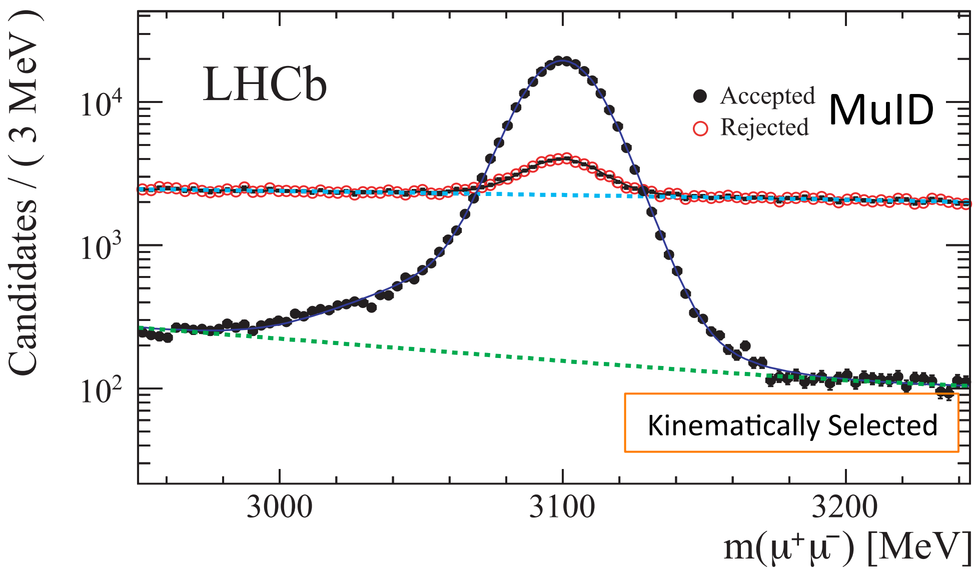
- *The μ and π charge tracks have very similar reconstruction efficiencies.* Partially reconstructed $D^{*+} \rightarrow D^0\pi^+$, $D^0 \rightarrow K^-\pi^-\pi^+(\pi^+)$ demonstrated that tracking efficiency ratio $\varepsilon(\pi^+)/\varepsilon(\pi^-)$ does not depend upon particle momentum and p_T. Since π and μ have opposite charges in $D_s\mu$, the tracking asymmetries almost cancel out.

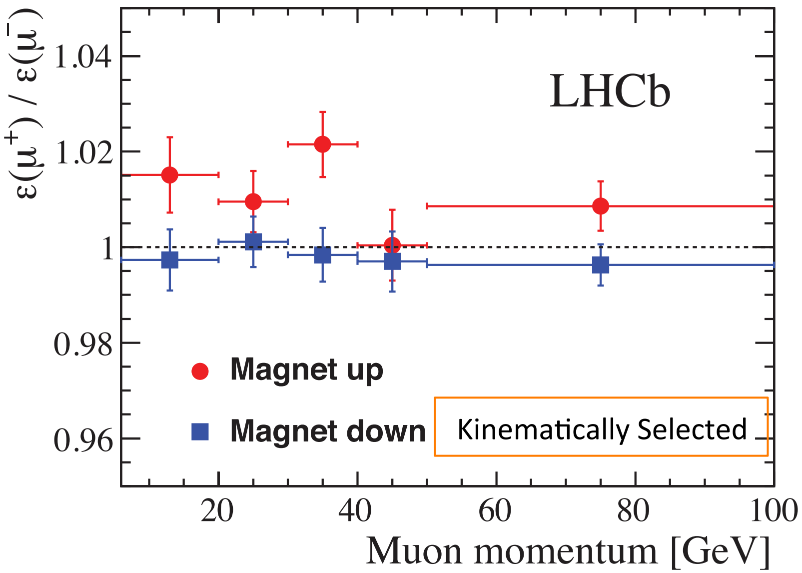


Using $\varepsilon(\pi^+)/\varepsilon(\pi^-)$, we determine A_{track} by adding the contributions from KK and μπ pairs.

Data driven corrections (II)

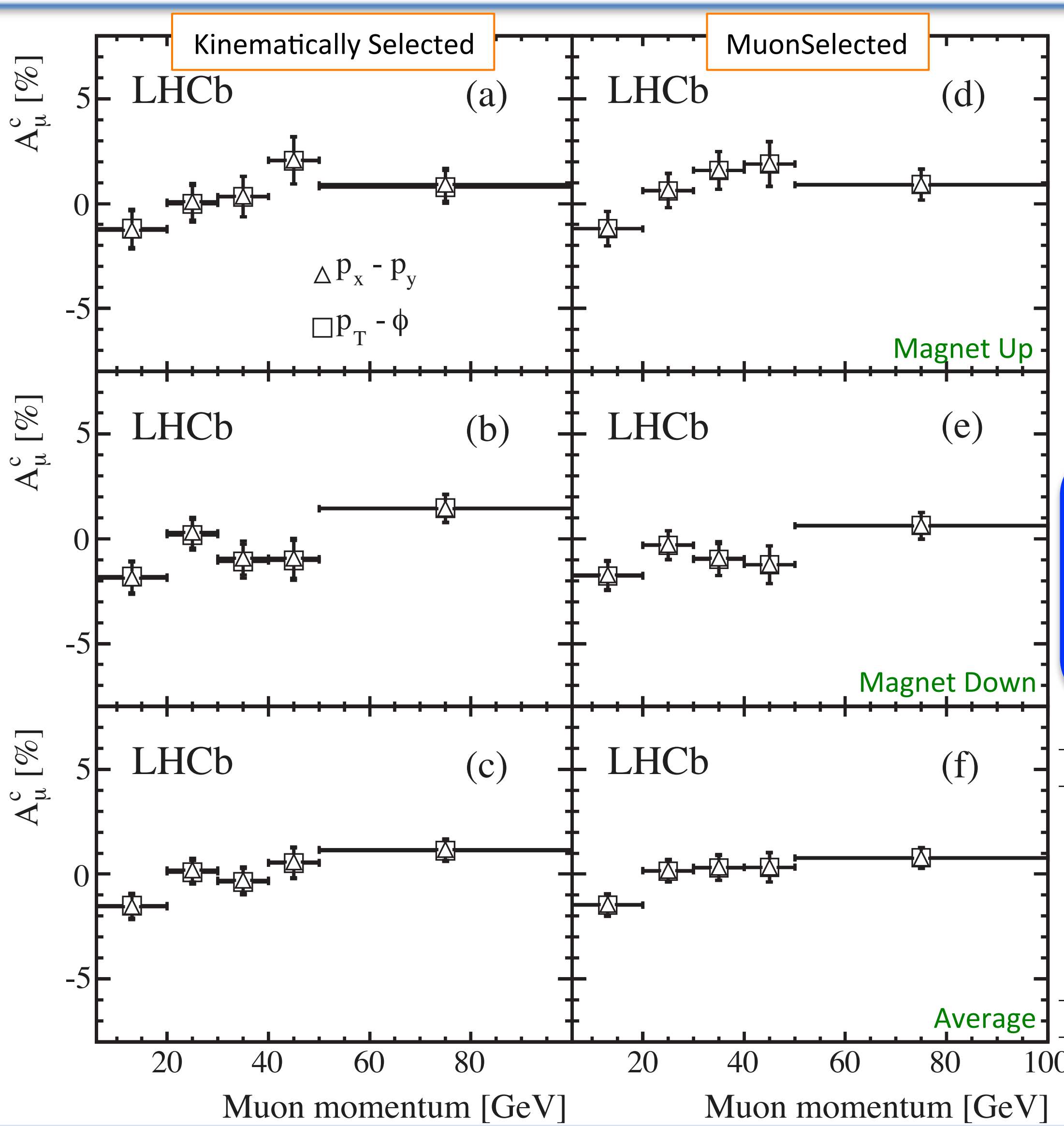
- Determination of $\varepsilon(\mu^+)/\varepsilon(\mu^-)$ – measure relative MuID and trigger efficiencies
  - Kinematically Selected $J/\psi \rightarrow \mu^+\mu^-$ decays in samples triggered (TOS) by hadronic B decays not including J/ψ in the final state
  - Muon Selected $J/\psi \rightarrow \mu^+\mu^-$ where a detached J/ψ is found by combining one track (probe) with an opposite sign track that is well identified as a muon (tag)





- $B \rightarrow D^+\mu^- X$ with $D^+ \rightarrow K^-\pi^+\pi^+$ for software trigger checks

Muon corrected asymmetry and A_{meas}



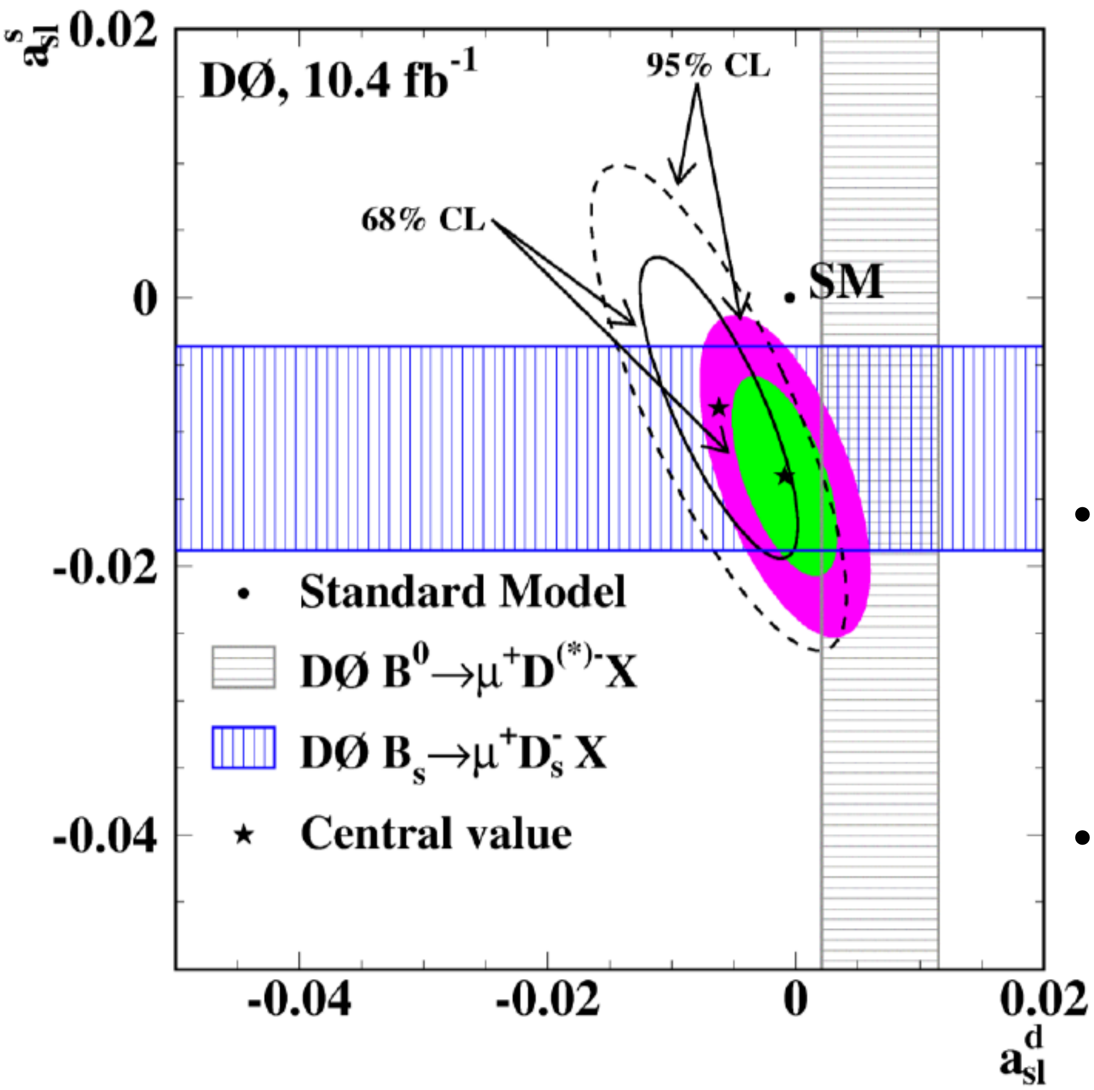
A^c_μ [%]	KS muon correction		MS muon correction		Average
Magnet	$p_x p_y$	$p_T \phi$	$p_x p_y$	$p_T \phi$	
Up	+0.38 ± 0.38	+0.30 ± 0.38	+0.64 ± 0.37	+0.63 ± 0.37	+0.49 ± 0.38
Down	−0.17 ± 0.32	−0.25 ± 0.32	−0.60 ± 0.32	−0.62 ± 0.32	−0.41 ± 0.32
Avg.	+0.11 ± 0.25	+0.02 ± 0.25	+0.02 ± 0.24	+0.01 ± 0.24	+0.04 ± 0.25

A_{track} = (+0.02 ± 0.13)%
A_{bkg} = (+0.05 ± 0.05)%
$A_\mu{}^c$ = (+0.04 ± 0.25)%

Applying corrections for tracking asymmetry & backgrounds:

$a_{sl}{}^s$ = (-0.06 ± 0.50 ± 0.36)%

Source	$\sigma(A_{meas})$[%]
Signal modelling and muon correction	0.07
Statistical uncertainty on the efficiency ratios	0.08
Background asymmetry	0.05
Asymmetry in track reconstruction	0.13
Field-up and field-down run conditions	0.01
Software trigger bias (topological trigger)	0.05
Total	0.18



a_{sl} according to D0

a_{sl}^{s} = (-1.33 ± 0.58)%
a_{sl}^{d} = (-0.09 ± 0.29)%

- 3.1σ from Standard Model prediction using also $\mu^{+}\mu^{+}$ versus $\mu^{-}\mu^{-}$
- *Source*: Borrisov talk, CERN Oct. 29 2013

LHCb a_{sl}^s results

- This is the most precise measurement of a_{sl}^s

$$a_{sl}^s = (-0.06 \pm 0.50 \pm 0.36)\%$$

- In good agreement with the Standard Model prediction (Lenz, arXiv:1205.1444)

$$a_{sl}^s = (0.0019 \pm 0.0003)\%$$
$$a_{sl}^d = (-0.0410 \pm 0.0006)\%$$

- We are including (in progress) the 2fb^{-1} of 2012 data sample to this analysis