Flavour specific asymmetry from muon asymmetry in LHCb

a_{fs}
LHCb
LHCb and a_{fs}

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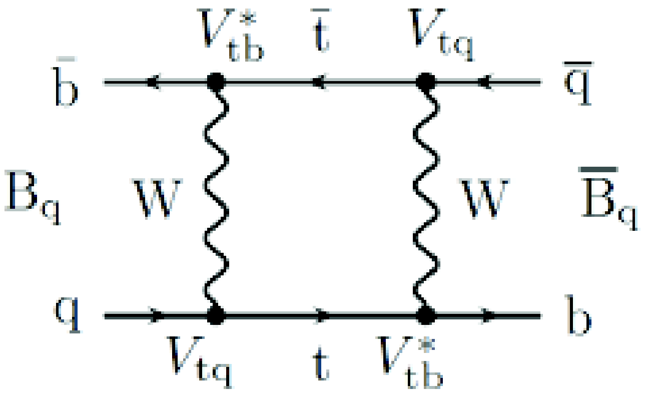
Introduction

- Keep in mind that
  - I am neither a SUSY expert
  - Nor a a_{fs} analysis expert
- I tried to understand from LHCb notes and presentations what LHCb can say about flavour specific asymmetries
- The a_{fs} measurements are studied in LHCb by
  - The flavour physics working group
  - And most specifically the semi-leptonic group
- These slides are mostly built from presentations by
  - Rob Lambert
  - Kim Vervink

B mixing and a_{fs}

- Neutral B mesons may oscillate
- Their evolution depends on

$$i\frac{\partial}{\partial t}\begin{pmatrix}|B_q^0(t)\rangle \\ |\bar{B}_q^0(t)\rangle\end{pmatrix}=\begin{pmatrix}M-\frac{i}{2}\Gamma & M_{12}-\frac{i}{2}\Gamma_{12} \\ M_{21}-\frac{i}{2}\Gamma_{21} & M-\frac{i}{2}\Gamma\end{pmatrix}\begin{pmatrix}|B_q^0(t)\rangle \\ |\bar{B}_q^0(t)\rangle\end{pmatrix}$$



- 3 observables can be extracted

$$|\Gamma_{12}|, M_{12}, \arg\left(\frac{-M_{12}}{\Gamma_{12}}\right)=\phi_q$$

- Where the mass eigenstates are :

$$|B_L^q\rangle = p|B_q^0(t)\rangle + q|\bar{B}_q^0(t)\rangle$$
$$|B_H^q\rangle = p|B_q^0(t)\rangle - q|\bar{B}_q^0(t)\rangle$$

- Defining $a^q \approx 2-2\left|\frac{p}{q}\right|$
- CPV in the mixing appears when $a^q \neq 0$

$$a^q = \left|\frac{\Gamma_{12}^q}{M_{12}^q}\right|\sin\phi_q = \frac{\Delta\Gamma_q}{\Delta M_q}\tan\phi_q$$

- NB : to a new physics phase in ϕ^{NP}_s would correspond the same NP phase in the measured angle $\phi^{J/\psi\phi}_s$ from the decay $B_s \rightarrow J/\psi\phi$

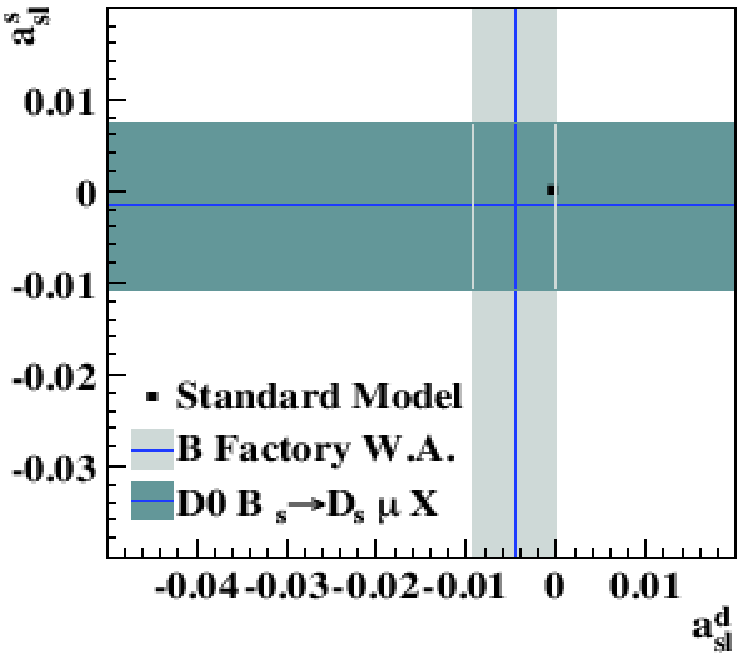
B mixing and a_{fs}

- a_{fs}
  - Measure of a_q in flavour specific decays
    - a^d_{fs}, a^s_{fs}
    - Measure of a_{fs} in the B_d and B_s sectors is supposed to be small

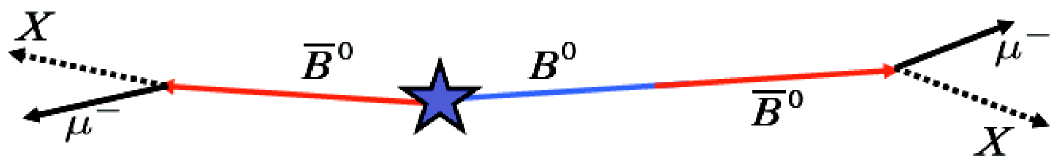
$$a^d_{fs}(SM) = (-4.8^{+1.0}_{-1.2}) \times 10^{-4}$$
$$a^s_{fs}(SM) = (2.1 \pm 0.6) \times 10^{-5}$$

A. Lenz and U. Nierste Hep-ph/0612167 for leptonic decays

- A large value of a_{fs} in the B sector → new physics
- B factories measured a^d_{fs} for the B_d meson
- D0 measured a^s_{fs} with $B_s \rightarrow D_s \mu X$ and 5 fb^{-1}
  - LHCb plan to use the same method



Di-muon charge asymmetry

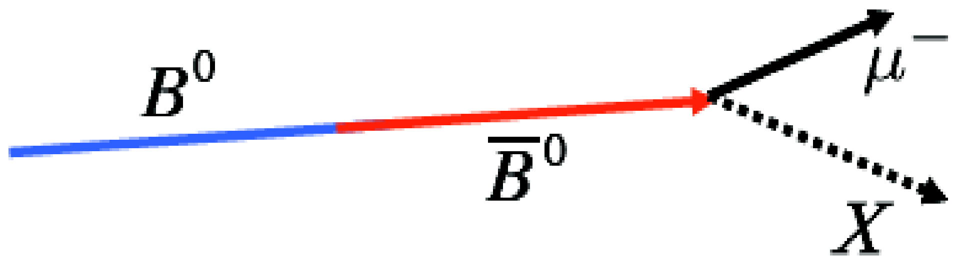


- Measure CP violation in B semi-leptonic decays from the di-muon charge asymmetry : A^b_{sl}

$$A^b_{sl} \equiv \frac{N_b^{++} - N_b^{--}}{N_b^{++} + N_b^{--}}$$

- Count the number of events with two B hadrons decaying semi-leptonically in two muons with the same charge.
  - One muon comes from direct semi-leptonic decay
  - One muon comes from direct semi-leptonic decay after neutral B meson mixing

Inclusive semi-leptonic charge asymmetry



- a^b_{sl} is equal to the charge asymmetry of "wrong sign" semi-leptonic B decays
  - Due to the B meson oscillation or background processes (ex : charm decays)

$$a^b_{sl} \equiv \frac{\Gamma(\overline{B} \to \mu^+ X) - \Gamma(B \to \mu^- X)}{\Gamma(\overline{B} \to \mu^+ X) + \Gamma(B \to \mu^- X)} = A^b_{sl}$$

- Using both the B_d and the B_s :
  - A^b_{sl} is a combination of a^d_{sl} and a^s_{sl}
  - Introducing the fraction of B_d and B_s produced at D0 and measured by CDF

$$A^b_{sl} = (0.506 \pm 0.043) a^d_{sl} + (0.494 \pm 0.043) a^s_{sl}$$

  - Theoretical prediction is (A. Lenz, U. Nierste)

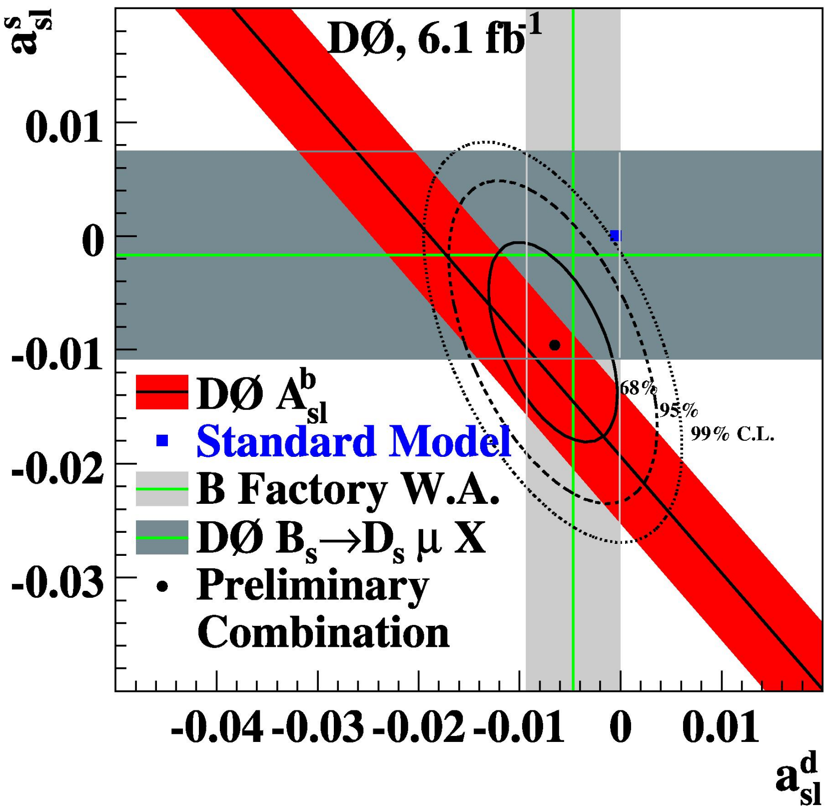
$$A^b_{sl} = (-2.3^{+0.5}_{-0.6}) \times 10^{-4}$$

Final measurement

$$A \equiv \frac{N^{++} - N^{--}}{N^{++} + N^{--}} \rightarrow A^b_{sl} \equiv \frac{N_b^{++} - N_b^{--}}{N_b^{++} + N_b^{--}}$$

$$a \equiv \frac{n^{+} - n^{-}}{n^{+} + n^{-}} \rightarrow a^b_{sl} \equiv \frac{\Gamma(\overline{B} \rightarrow \mu^{+}X) - \Gamma(B \rightarrow \mu^{-}X)}{\Gamma(\overline{B} \rightarrow \mu^{+}X) + \Gamma(B \rightarrow \mu^{-}X)}$$

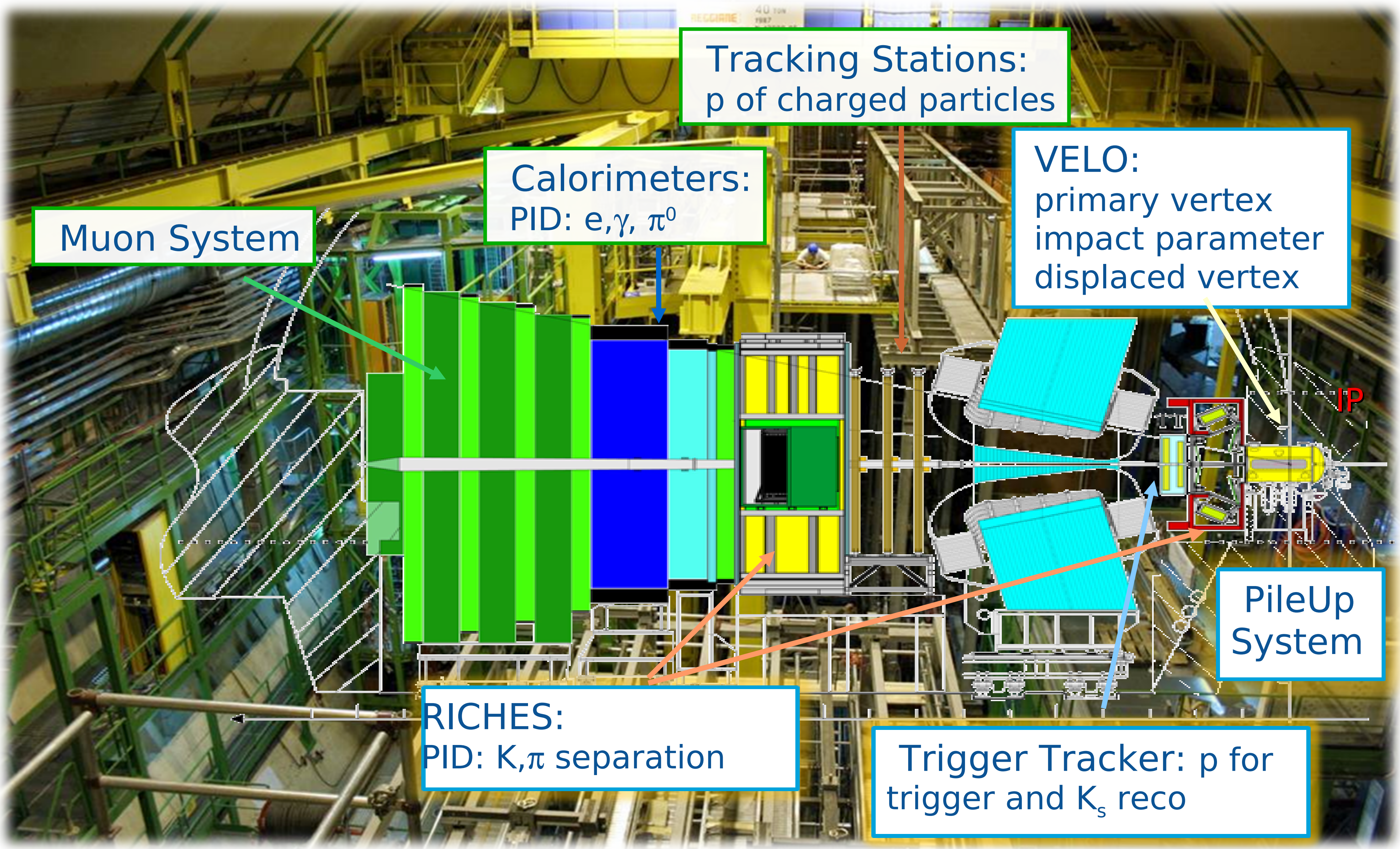
- The final measurement is a linear combination of those asymmetries
  - Reduce the correlated uncertainties in these asymmetries
    - $A_{final} = A - \alpha a$
- The measurement is affected by
  - Effects that enhance the asymmetry
    - Muon reconstruction asymmetry
    - False muon associations
    - Proton punch through
    - Kaons/Pions decays into muons
  - Dilution factors



$$A^b_{sl} = (-0.957 \pm 0.251\,(\text{stat}) \pm 0.146\,(\text{syst}))\%$$

3.2σ deviation

The LHCb Detector

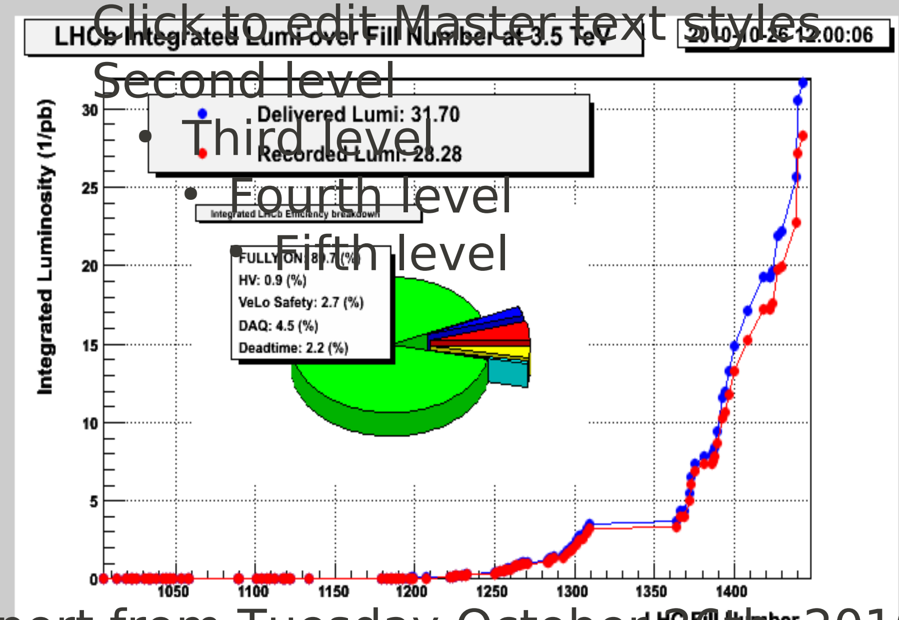


What LHCb can do on a_{fs}

- Theoretically a_{fs} is simple for LHCb
  - It is a ratio of event counts
  - Efficiencies, triggering, acceptances, branching fractions, luminosity normalization, do not have to be considered
  - It can be done with the highest rate B-channels
  - LHCb will have a huge B statistics
  - LHCb has an excellent proper time resolution
- But in fact, this is a very difficult measurement
  - The measurement requires first the precise determination of several parameters
  - Detector asymmetries have to be extracted
  - Production asymmetries (proton-proton and not proton anti-proton) have to be corrected ($0(10^{-2})$?)
    - Prevents from using di-muon charge asymmetry
- For the first data sample, the priority is on
  - ϕ_s from $B_s \rightarrow J/\psi\phi$ (related to a_{fs} !)
  - $B_s \rightarrow \mu\mu$

LHC conditions at LHCb interaction point

- LHC/LHCb are performing well
  - Luminosity regularly increased :
    - 42 pb^{-1} delivered, ~ 37pb^{-1} recorded, ~ 35pb^{-1} data flagged “ok”
  - LHCb efficiency is good
  - No major problem with the detector
- Beam conditions “unexpected”
- Priorities for 2010 (2011) lead to
  - Have a high statistics for muons
  - Muons not so penalized by pile up
    - High pile up ~ 2 – 3 (!)
  - Original plan : <1
- The other physics channels suffer
- A simple solution would consist to
  - Increase β^*
    - We have the same as Atlas and CMS !
  - Even simpler and has been tested
    - Have not head-on beam crossings
- The pile-up effect on a_{fs} seems limited. High statistics should be soon avail.



Report from Tuesday October 26th, 2010

The method : time-dependent, un-tagged

$$A_{fs}^{q}(t) = \frac{\Gamma(f) - \Gamma(\bar{f})}{\Gamma(f) + \Gamma(\bar{f})}$$

$$A_{fs}^{q}(t) = \frac{a_{fs}^{q}}{2} - \left(\frac{a_{fs}^{q}}{2}\right)\frac{\cos(\Delta m_q t)}{\cosh(\Delta\Gamma_q t/2)}$$

10^{-3} -> 10^{-5}

The method

$$A_{fs}^{q}(t) = \frac{\Gamma(f) - \Gamma(\bar{f})}{\Gamma(f) + \Gamma(\bar{f})}$$

$$A_{fs}^{q}(t) = \frac{a_{fs}^{q}}{2} - \frac{\delta_c^q}{2} - \left(\frac{a_{fs}^{q}}{2} + \frac{\delta_p^q}{2}\right)\frac{\cos(\Delta m_q t)}{\cosh(\Delta\Gamma_q t/2)} + \frac{\delta_b^q}{2}\left(\frac{B}{S}\right)^q$$

10^{-3} -> 10^{-5} 10^{-2} 10^{-2} 10^{-3}

$$\delta_c = \frac{\varepsilon(\bar{f}_i)}{\varepsilon(f_i)} - 1$$

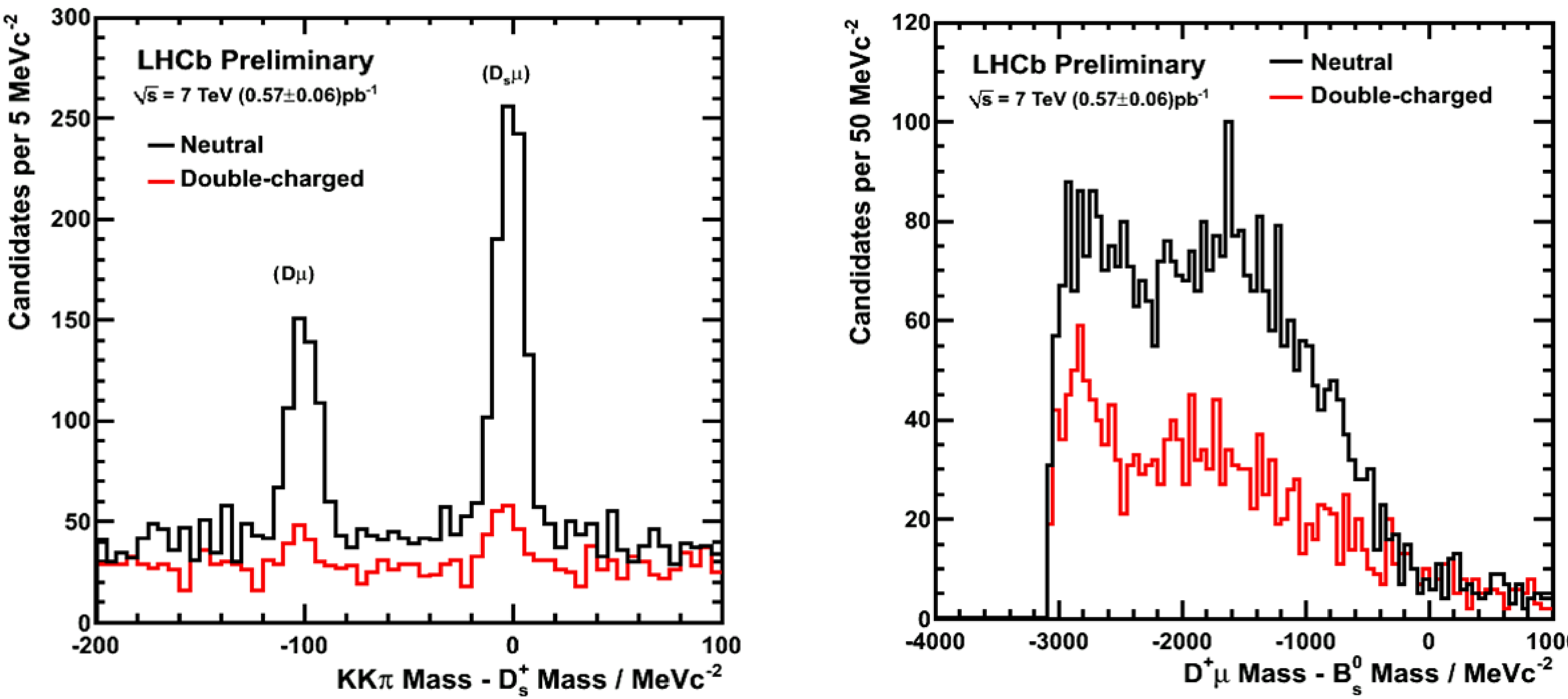
$$\delta_p = \frac{N(\bar{I}_0)}{N(I_0)} - 1$$

$$\delta_b = \frac{\bar{B}/\bar{S}}{B/S} - 1$$

- Polluting asymmetries are much larger than a_{fs}
  - Detector asymmetry δ_c ~(10^{-2})
  - Production asymmetry δ_p ~(10^{-2})
  - Background asymmetry δ_b ~(10^{-3})

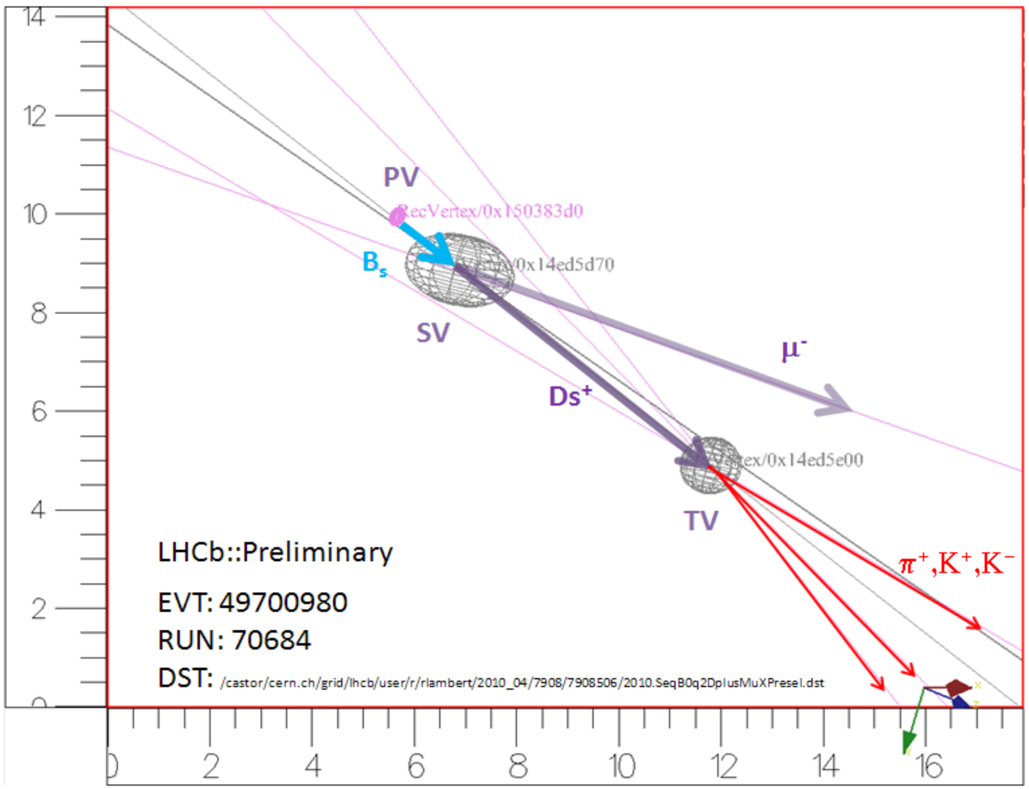
The signals : $B^0_{(s)} \rightarrow D^{+/-}_{(s)}\mu^{+/-}\nu$, $D^{+/-}_{(s)} \rightarrow KK\pi$

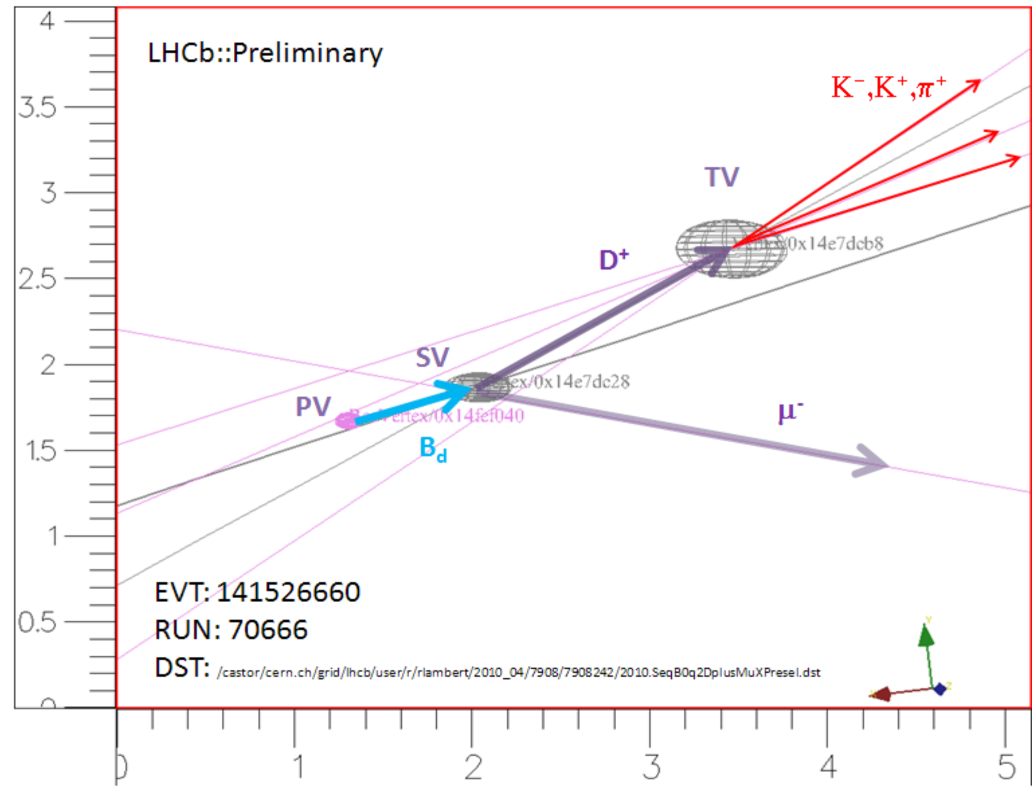
- The selection on the first data samples
  - Mass resolution leads to a clean separation of
    - B_d and B_s states



- Hadronic decay
  - $B^0_{(s)} \rightarrow D^{+/-}_{(s)}\pi$, $D^{+/-}_{(s)} \rightarrow KK\pi$
  - Alternative method (precision 2-3x lower) / Control sample
  - Production asymmetries are smaller than in the semi-leptonic decay

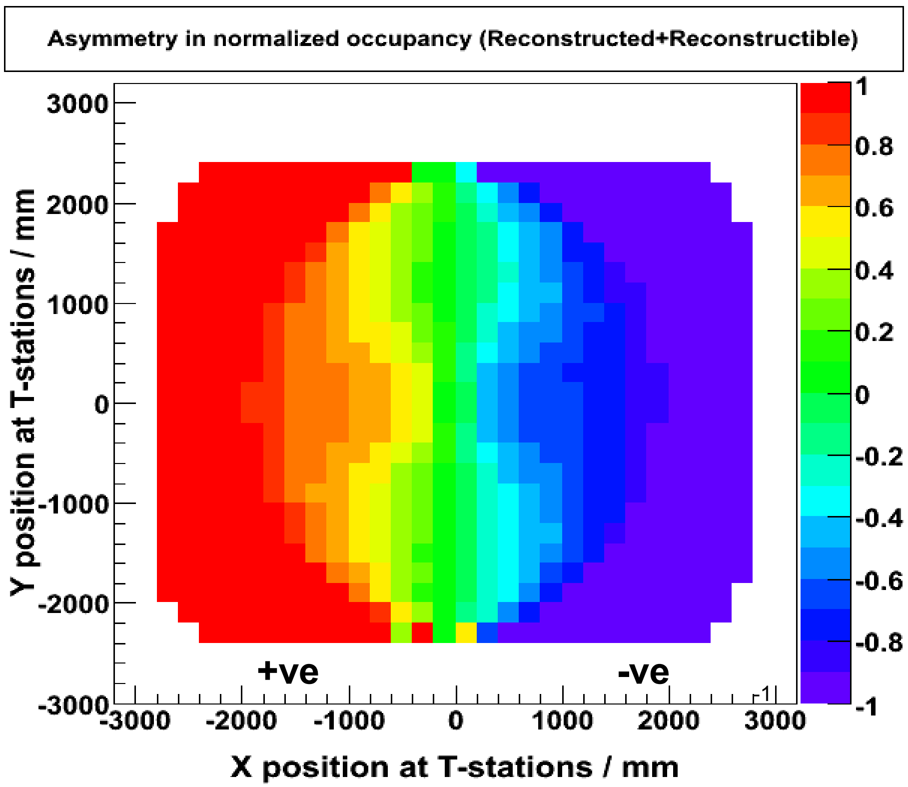
Some B_d/B_s events

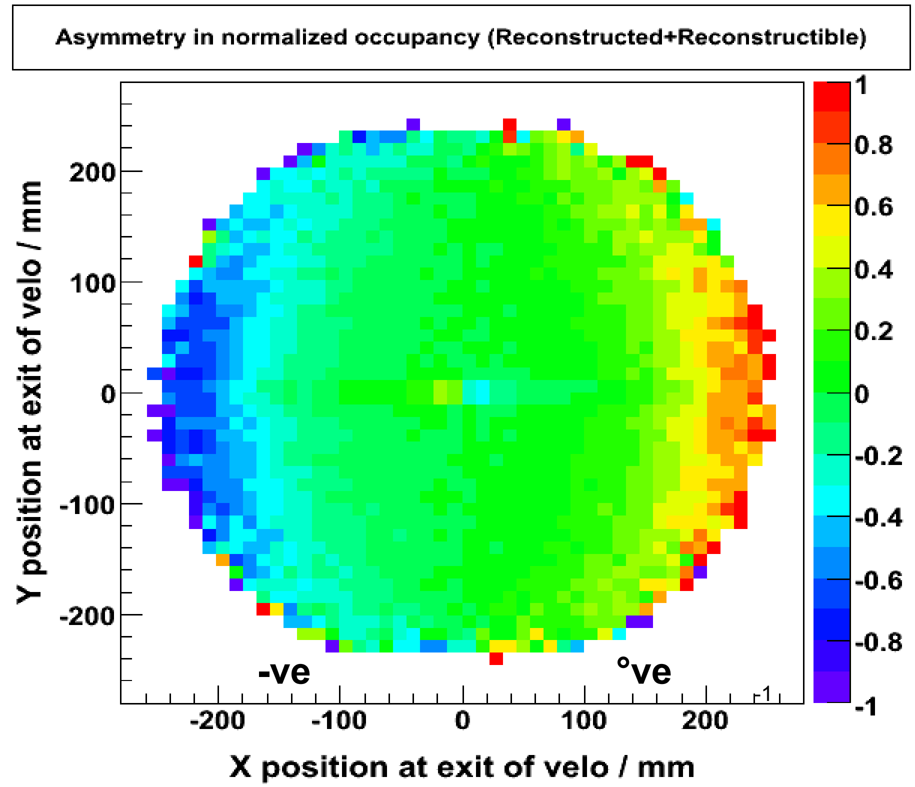




Detector asymmetries

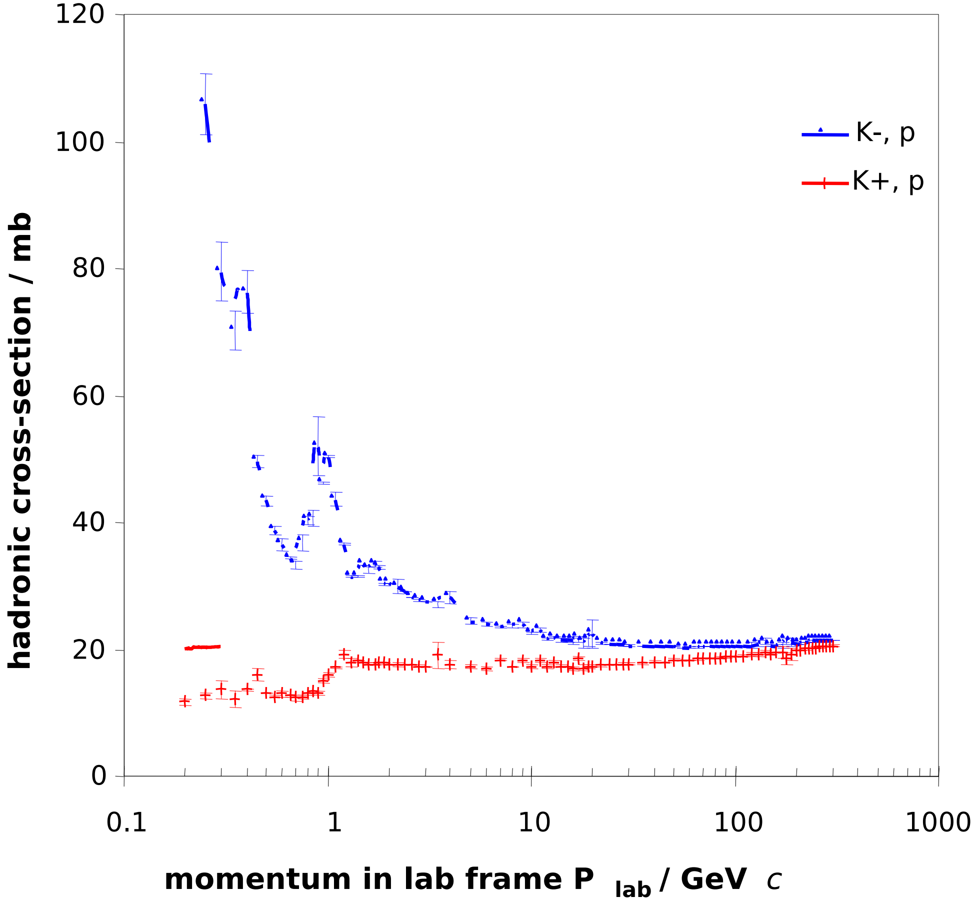
- Asymmetries from long muon tracks reconstructed

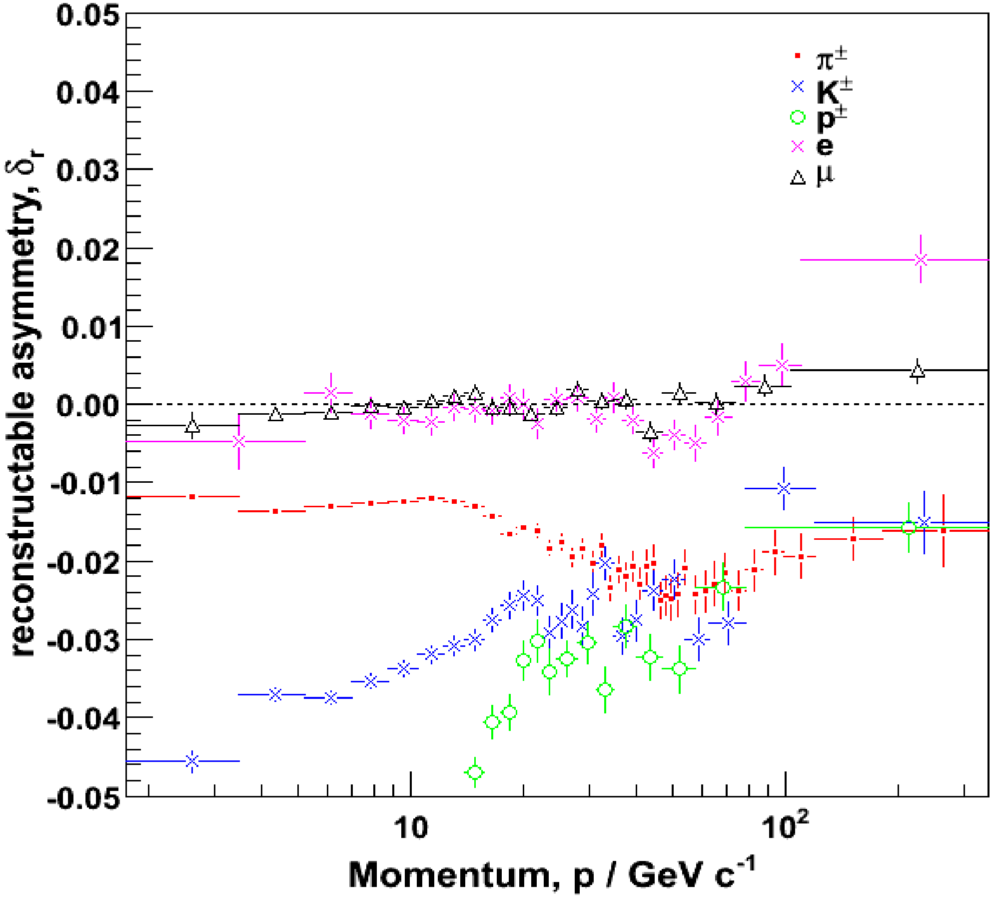




- Magnet separates +/- tracks → +/- asymmetry
- As for D0, magnet field inversion should reduce the systematics
  - 3% → 0.1% ?

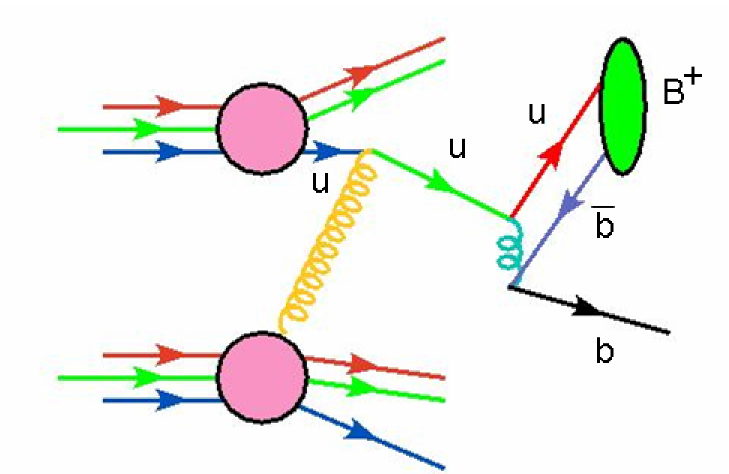
Detector asymmetries

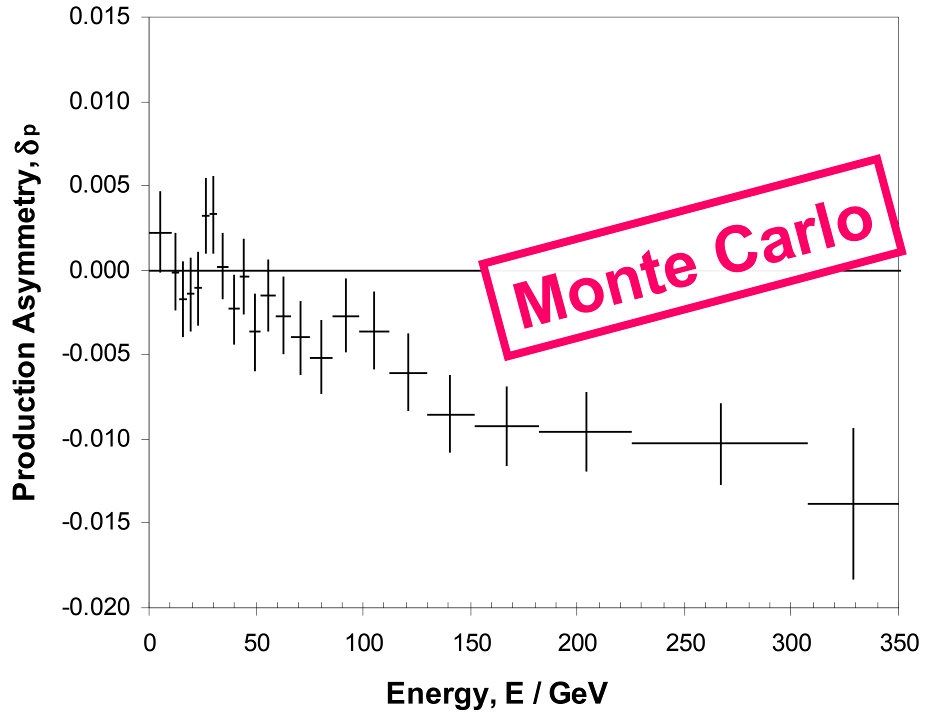




- Matter detector → hadronic interactions are asymmetric
- Dominant systematics at the level of 1%

B meson production asymmetries



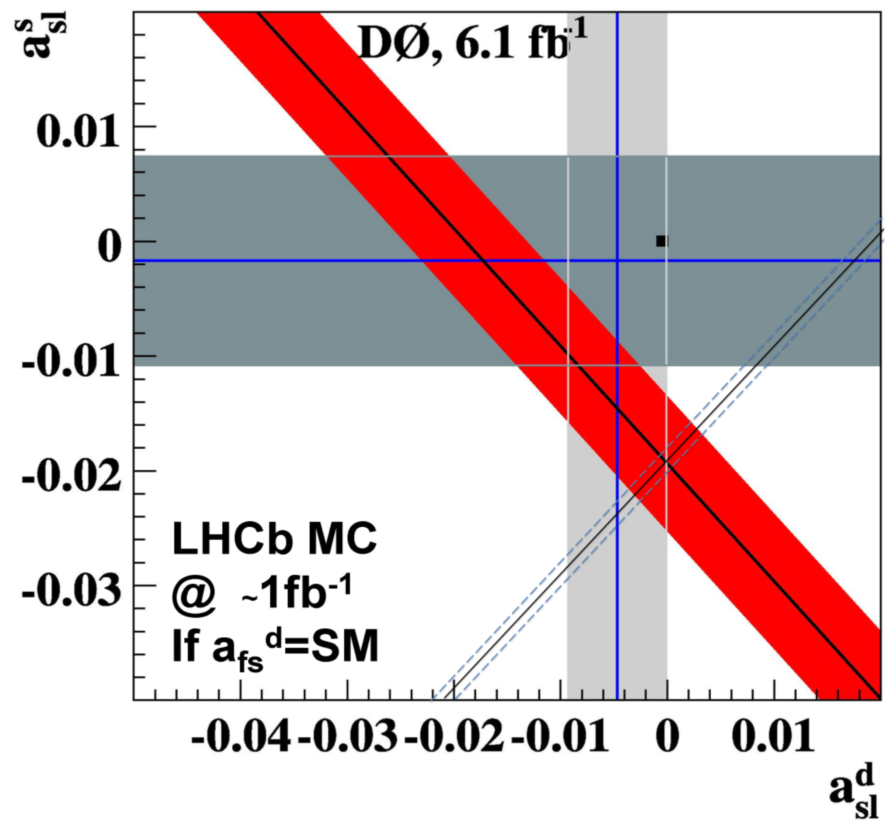


- There is an explicit production asymmetry at LHC (proton-proton)
- LHCb is at high rapidity : the asymmetries are the largest
- Control samples have to be analysed to measure this asymmetry
- MC estimations tend to give an overall effect < 10^{-2}

- This effects cannot be removed by from a di-muon inclusive charge asymmetry
- Time-dependent exclusive muon asymmetry permits to extract either the production or the detector asymmetry on top of the asymmetry itself :
  - The plan is to extract production asym. → useful for other analysis

The measurements

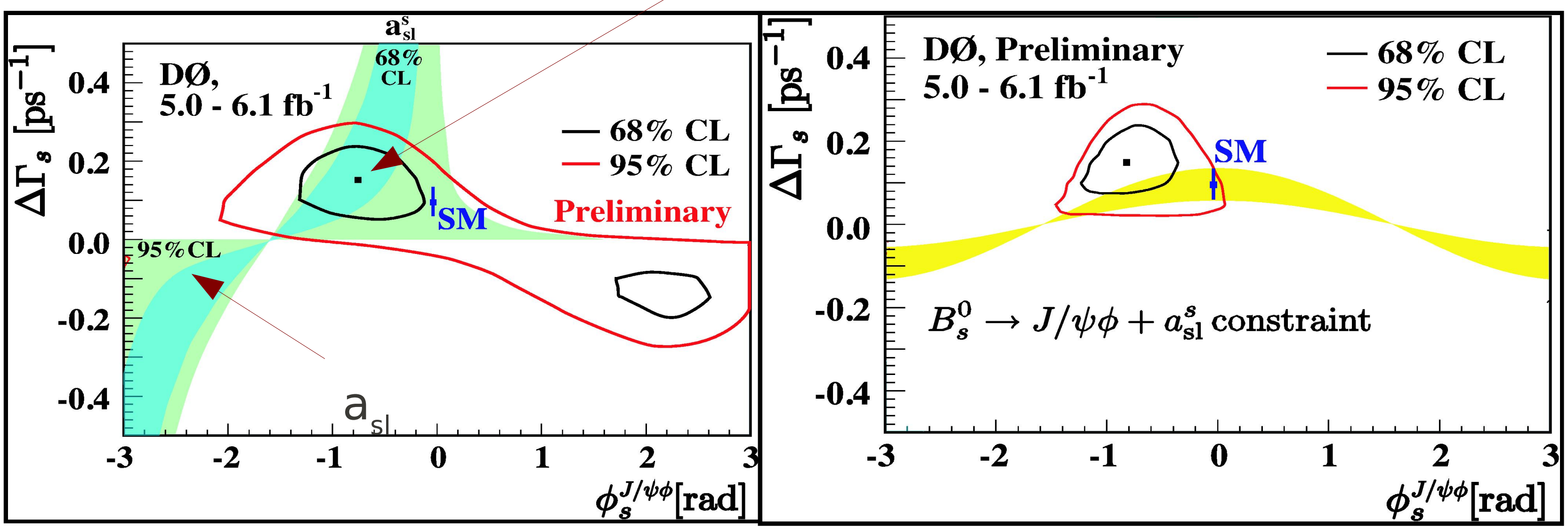
- Extract a^s_{fs} and a^d_{fs}
  - Time-dependent un-tagged analysis
  - semi-leptonic/hadronic decay
    - $B_{(s)} \rightarrow D_{(s)}\mu\nu$
    - $B_{(s)} \rightarrow D_{(s)}\mu\pi$
  - Requires detector asymmetry input
  - Semi-leptonic → σ_a~0.2% (2fb^{-1}, stat. Only)
    - ~1M signal events
  - Hadronic → σ_a~0.5% (2fb^{-1}, stat. Only)



- Measure $\Delta A^{s,d}_{fs} = \frac{a^s_{fs} - a^d_{fs}}{2}$
  - Detector asymmetry are cancelled
  - Reduce the systematics
- 2 fb^{-1} is the "nominal" luminosity per year
  - We have ~40pb^{-1} in 2010
  - The official plan is 1.5fb^{-1} in 2011 (?)
  - The first LHCb measurement of $\Delta A^{s,d}_{fs}$ at LHCb is planned for 100 pb^{-1}

Conclusion

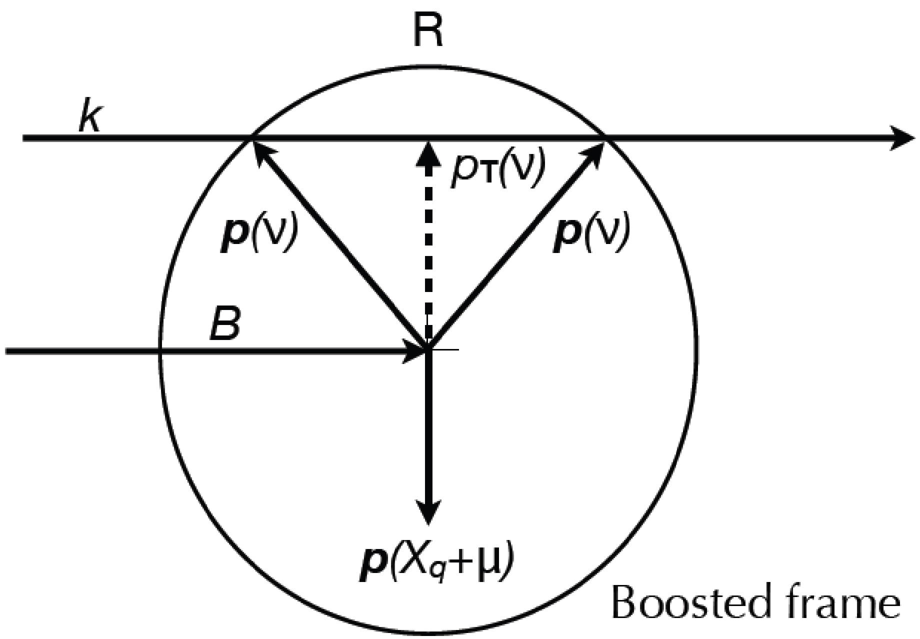
- LHCb plan to measure $a^{(s/d)}_{fs}$ in the mode $B_{s/d} \rightarrow D_{(s)}\mu\nu$
  - Di-muon asymmetry → impossible to remove the production asymmetry
  - The first measurement is planned for $100pb^{-1}$ (we have $40pb^{-1}$)
  - May hope for a precision of 0.2% ($2fb^{-1}$, stat.only) on a^{s}_{fs} BUT
    - Largest systematics from detector
  - Plan is to measure $$\Delta A^{s,d}_{fs} = \frac{a^{s}_{fs} - a^{d}_{fs}}{2}$$
  - This is the start up of the experiment → many effects have to be understood first
- The priority are mostly on $B_s \rightarrow \mu\mu$ and ϕ_s from $B_s \rightarrow J/\psi\phi$ (same NP contrib.)

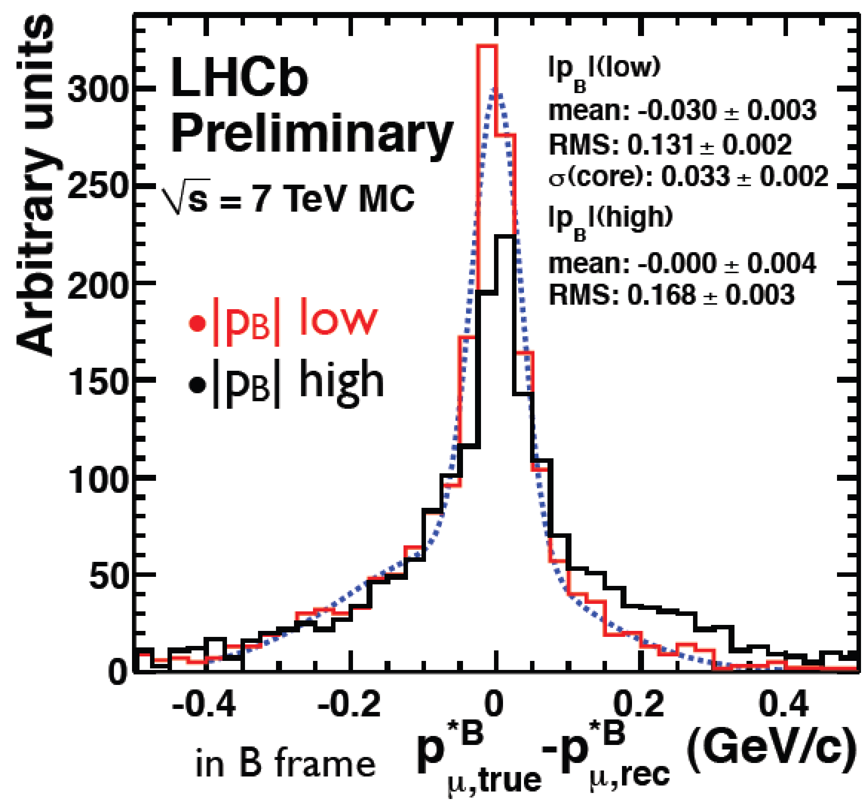


Backup

Neutrino reconstruction

- Use kinematics to reconstruct neutrino momentu
- Two ambiguous solutions
- The lower pt solution has the lower error





Pile up effects

- Problem related to proper time and pile up
  - How often do we get the correct PV
  - Is there a systematic effect with choosing the wrong PV