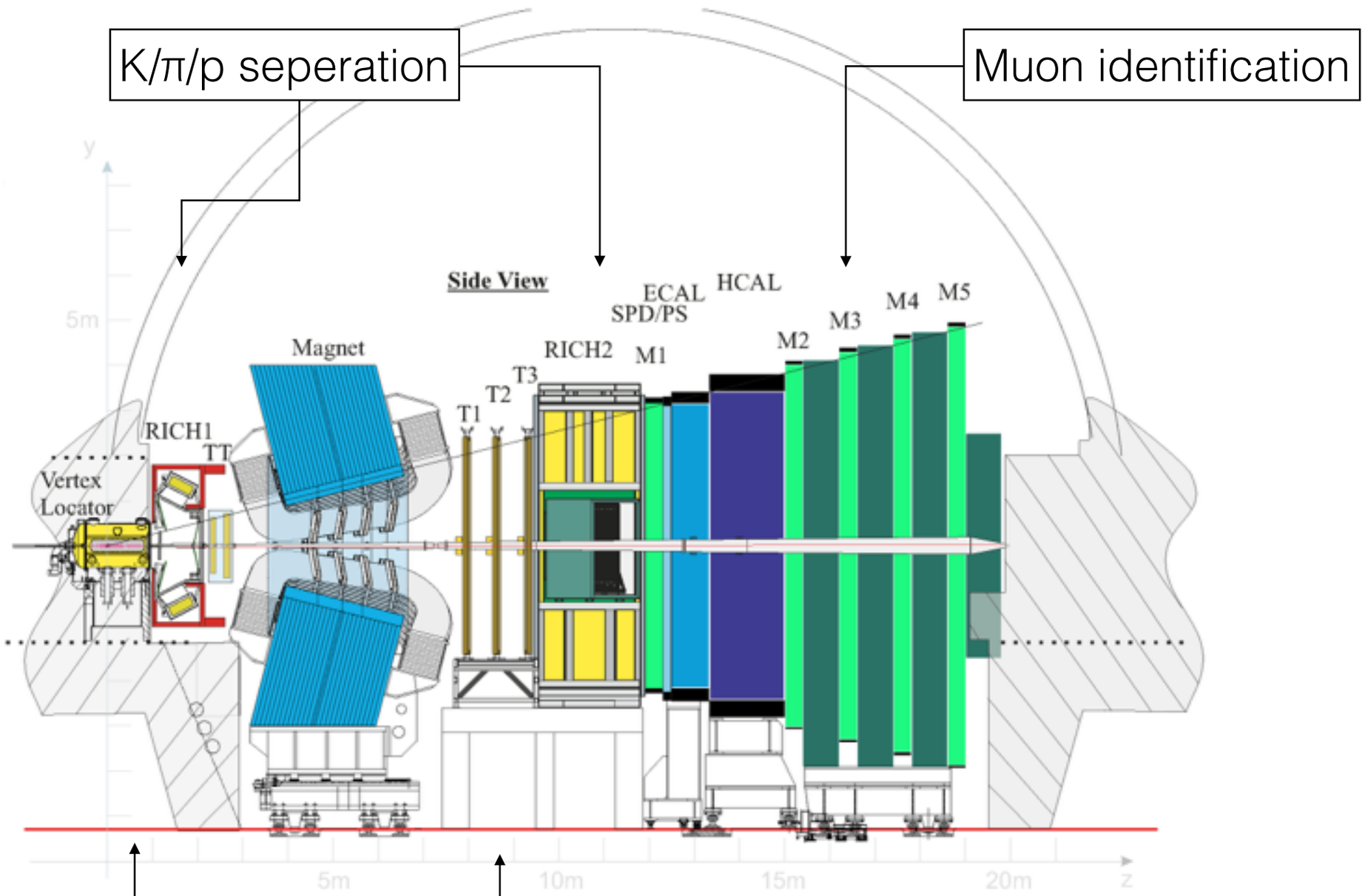
New results in semileptonic beauty decays with LHCb

LHCP 2016

June 16th 2016

Laurent Dufour, on behalf of the LHCb collaboration

The LHCb detector



$\Delta p/p = 0.4 - 0.8\%$
(5-100 GeV/c)

What

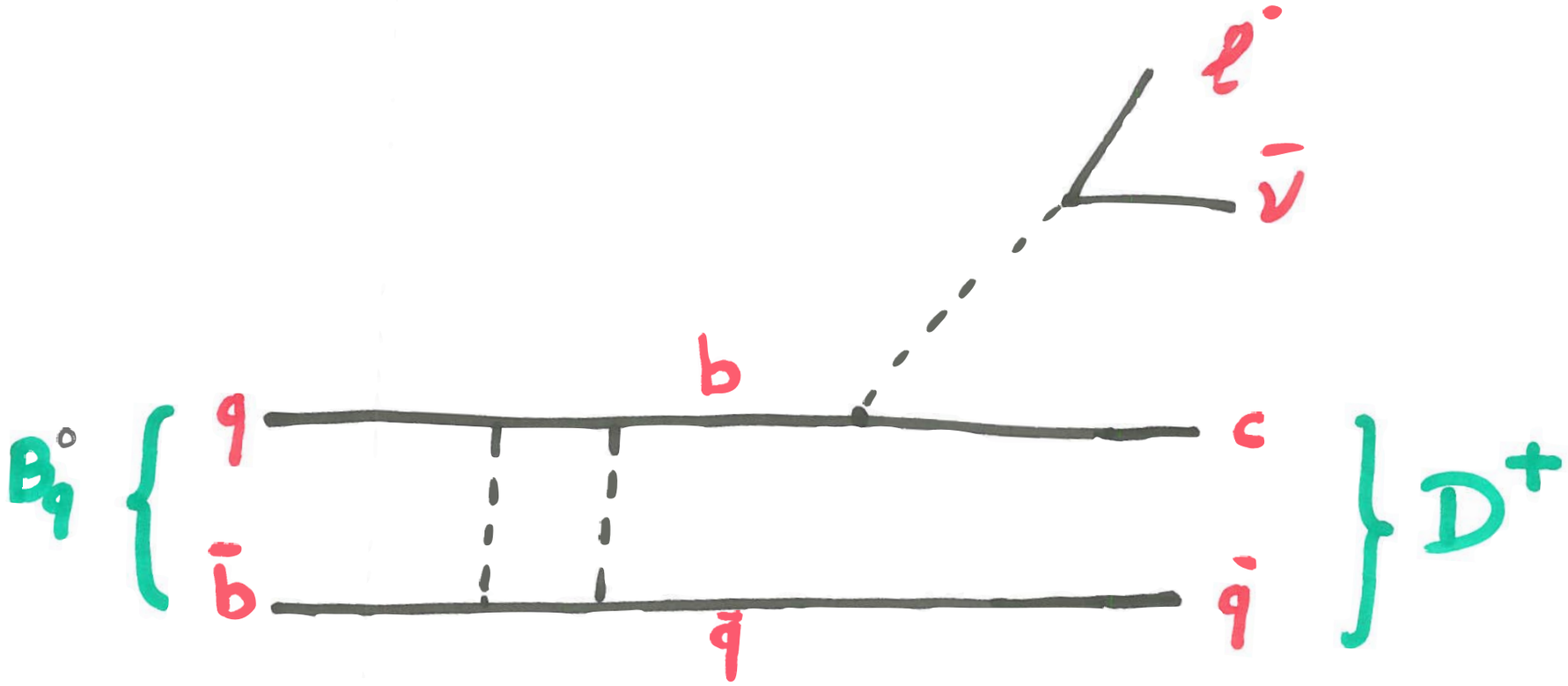
b decays with a missing daughter (e.g. neutrino)

Semileptonic b-decays

✔ Large statistics: high precision measurements

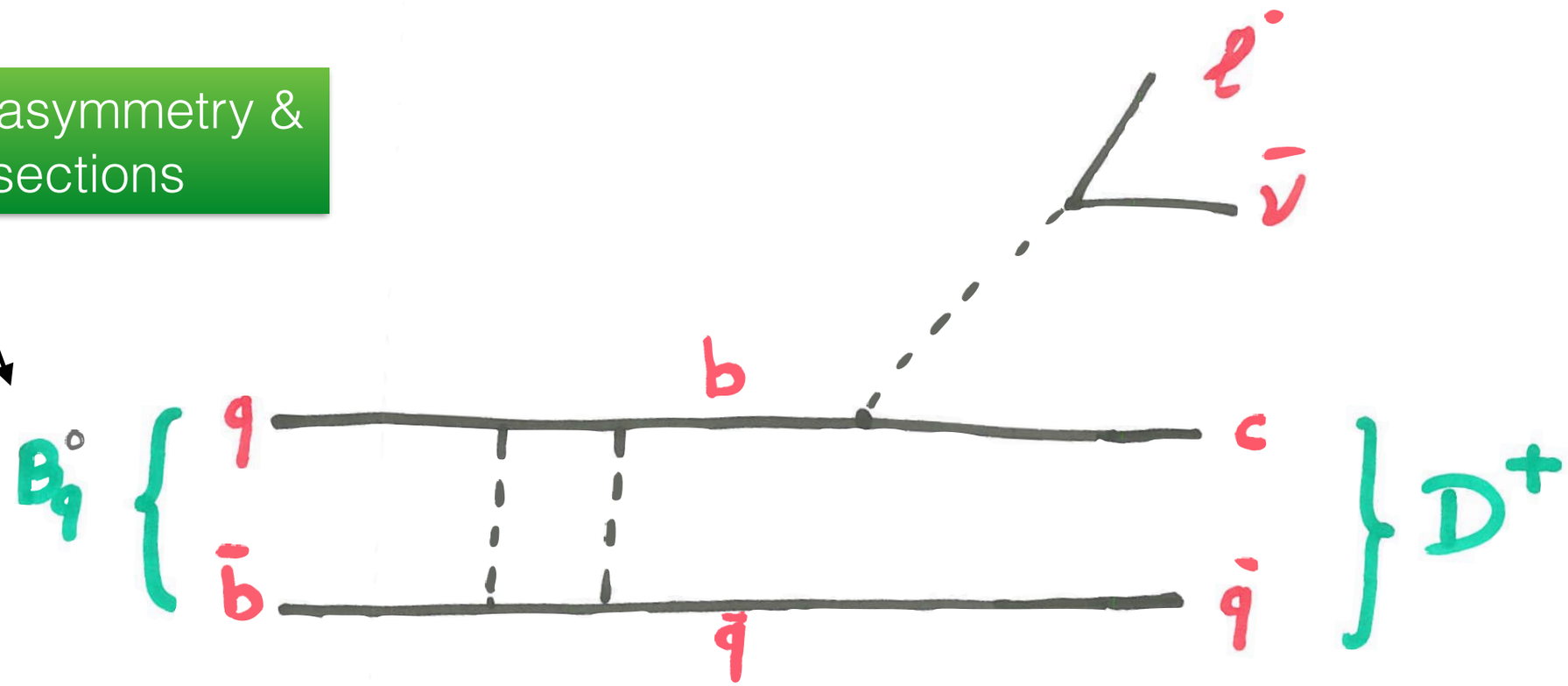
✘ Technical: always partially reconstructed decays

Physics



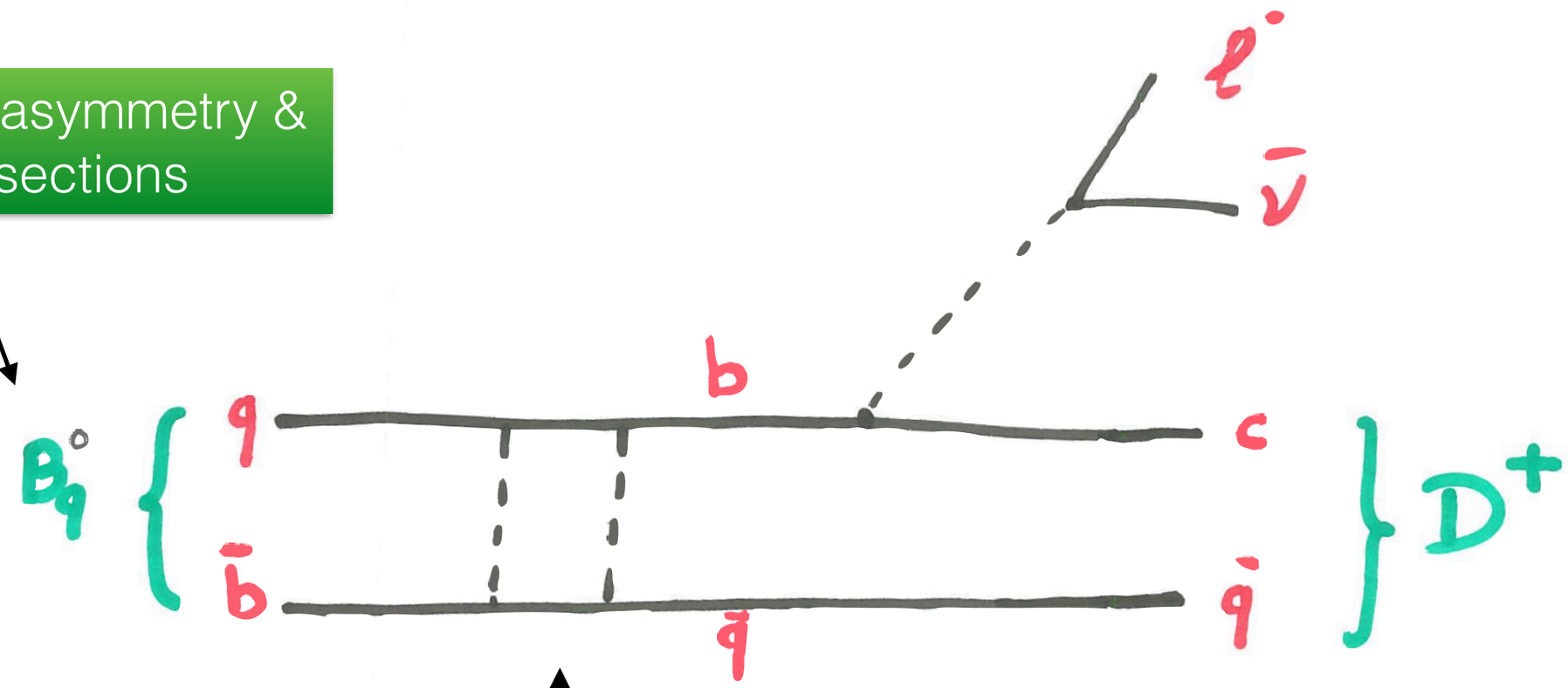
Physics

Production asymmetry & cross-sections



Physics

Production asymmetry & cross-sections

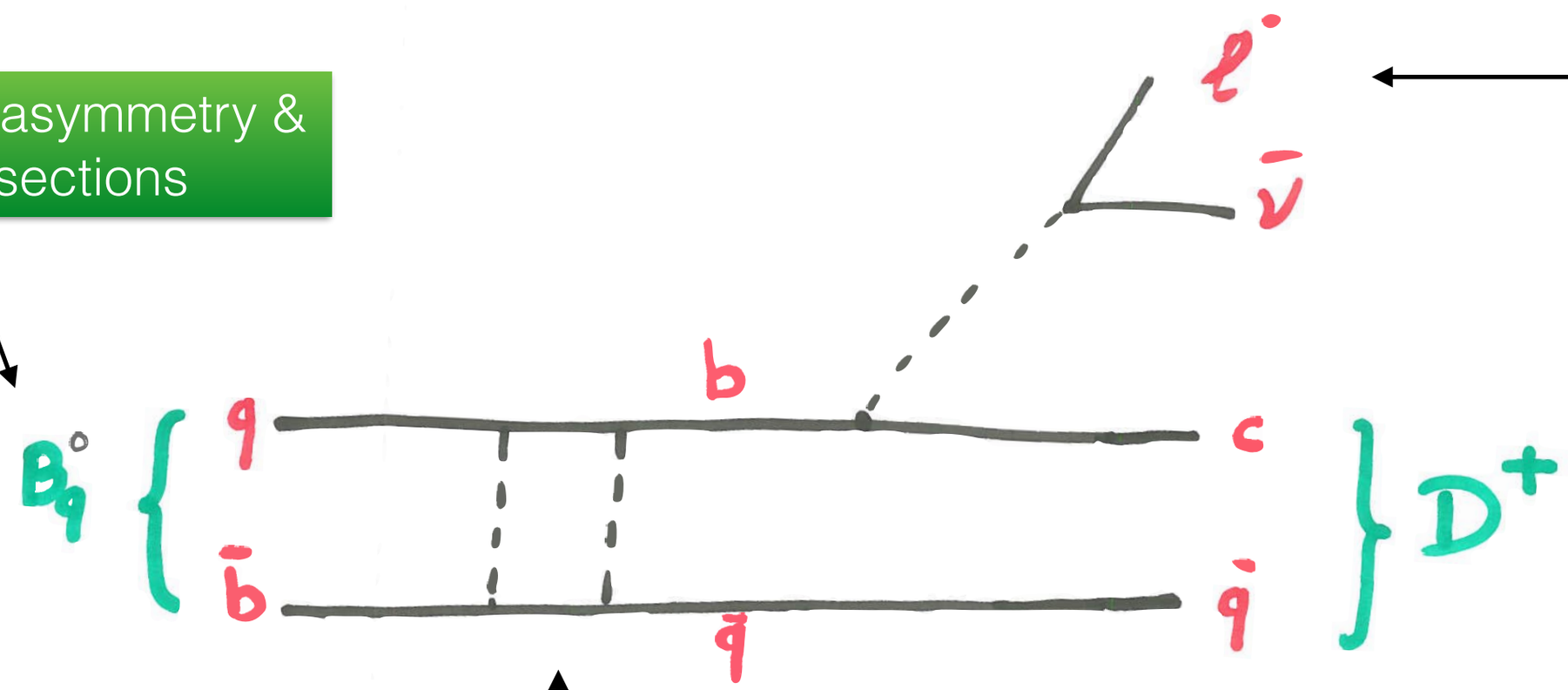


Mixing process: Δm, CP violation in mixing

Physics

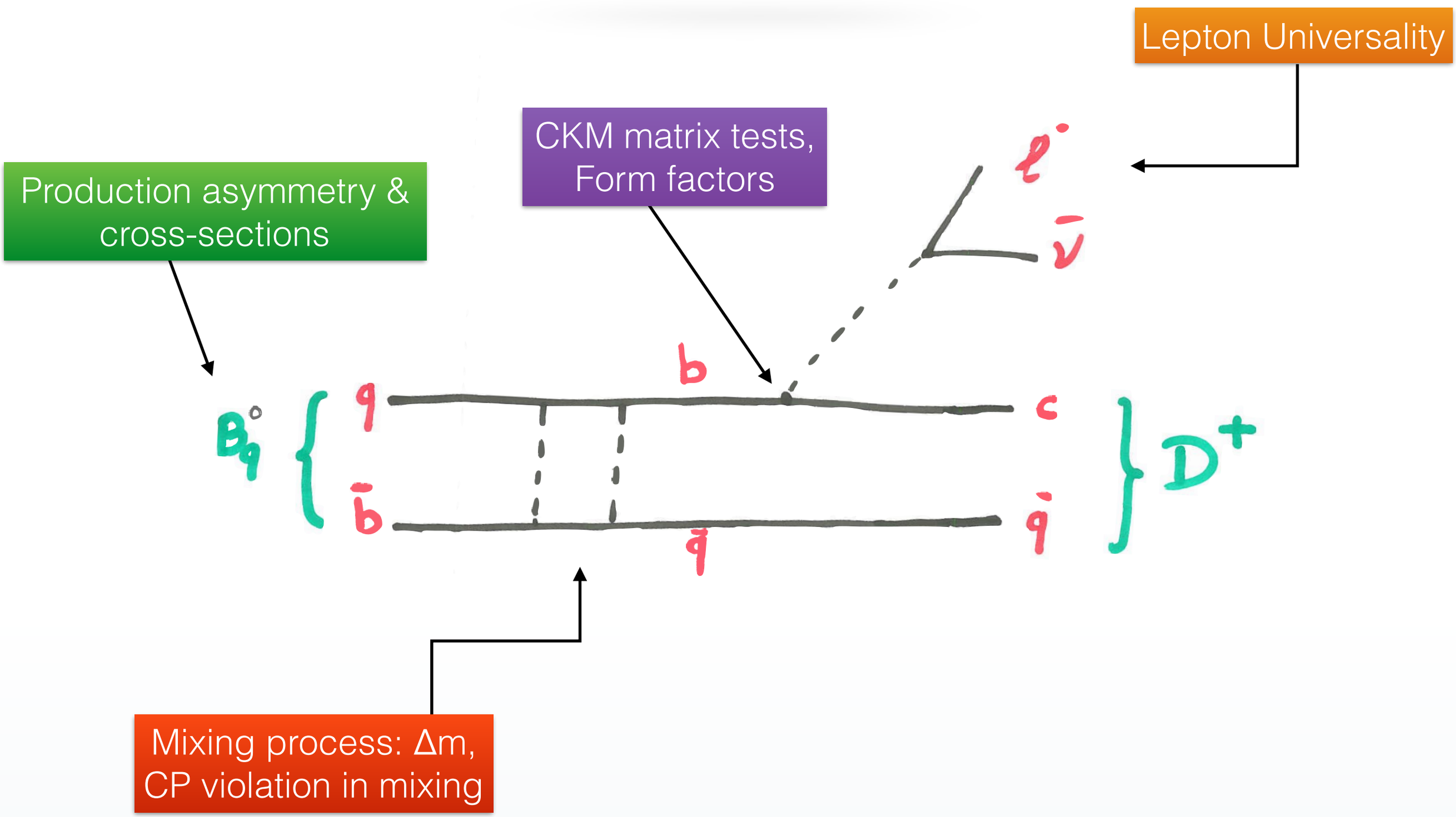
Lepton Universality

Production asymmetry & cross-sections



Mixing process: Δm, CP violation in mixing

Physics

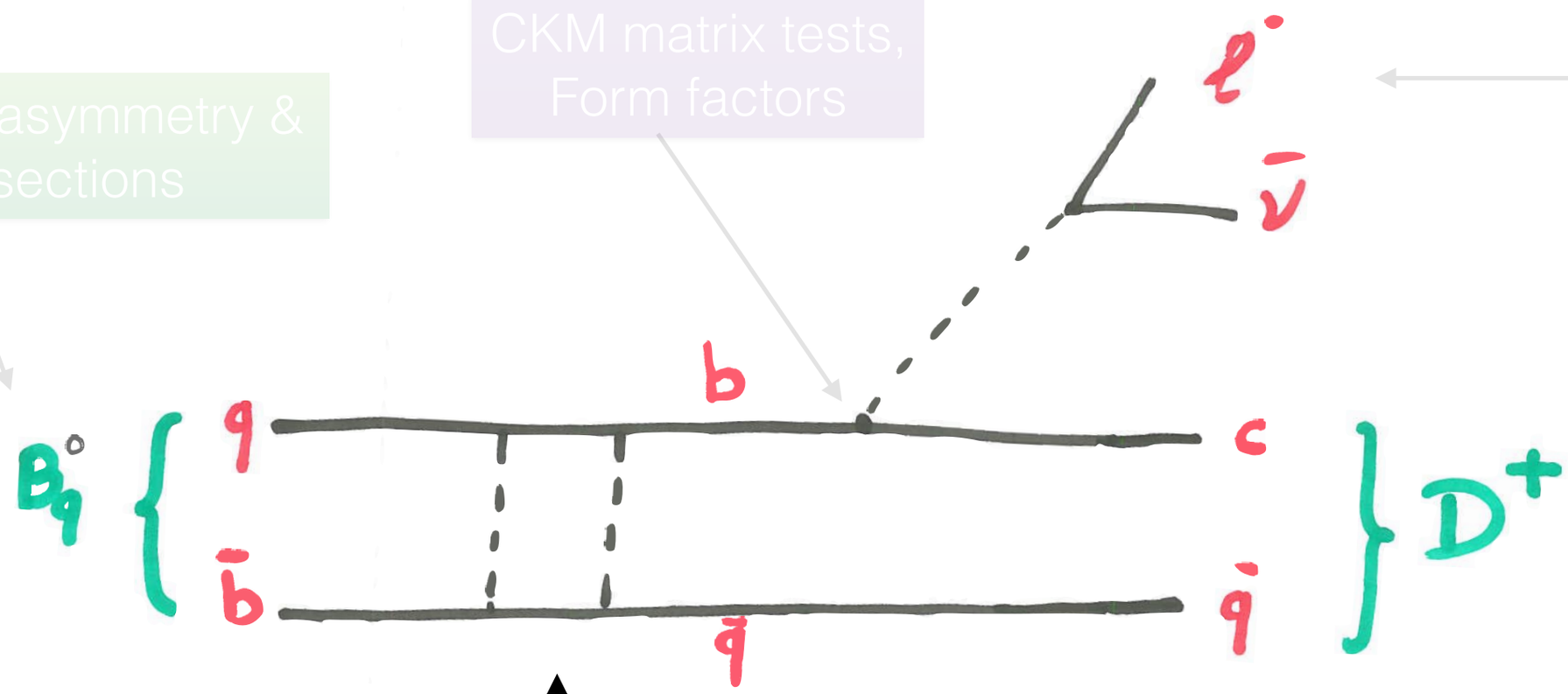

Lepton Universality
CKM matrix tests, Form factors
Production asymmetry & cross-sections
Mixing process: Δm, CP violation in mixing
ℓ^-
$\bar{\nu}$
b
q
c
B_q^0
$\bar{b}$
$\bar{q}$
$\bar{q}$
D^+

Physics

Lepton Universality

CKM matrix tests, Form factors

Production asymmetry & cross-sections

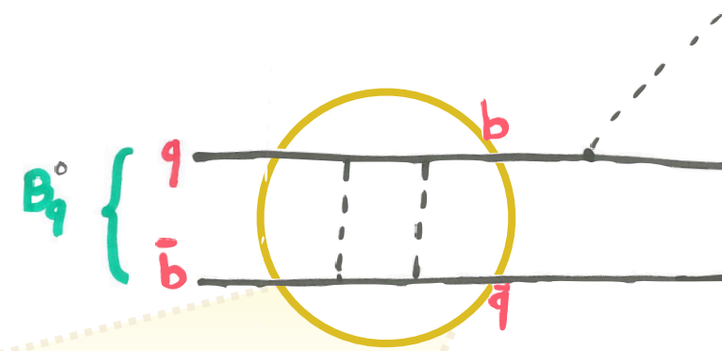


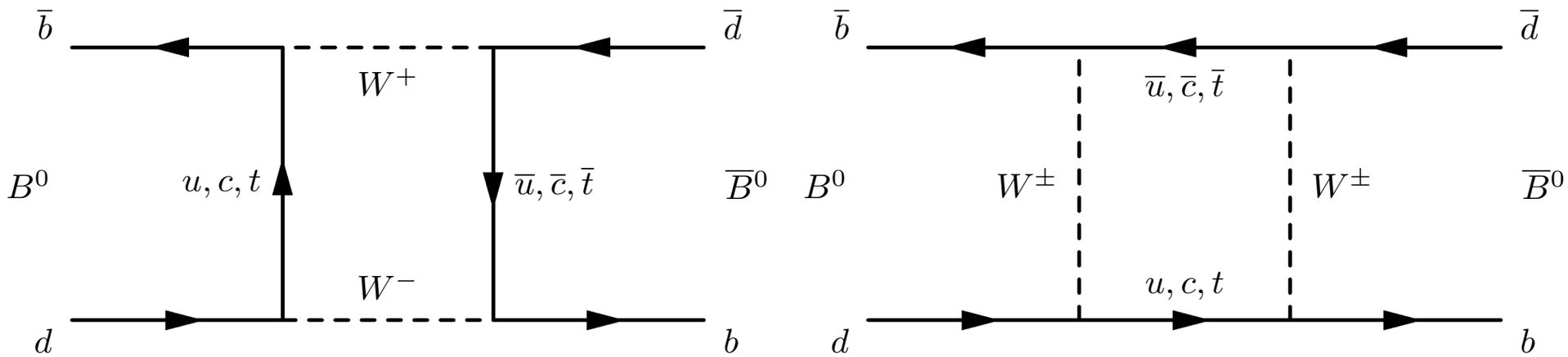
Mixing process: Δm, CP violation in mixing

This talk:

Δm_d, a^s_{sl}

Zooming in





- Neutral B mesons: $|B^0_{H,L}\rangle = p|B^0_q\rangle \pm q|\overline{B}^0_q\rangle$
  - Hamiltonian eigenstates ≠ flavour eigenstates
- Mass difference determines the **oscillation frequency**, Δm
- **CP violation** in mixing as measured in flavour specific decays? |p/q| ≠ 1.

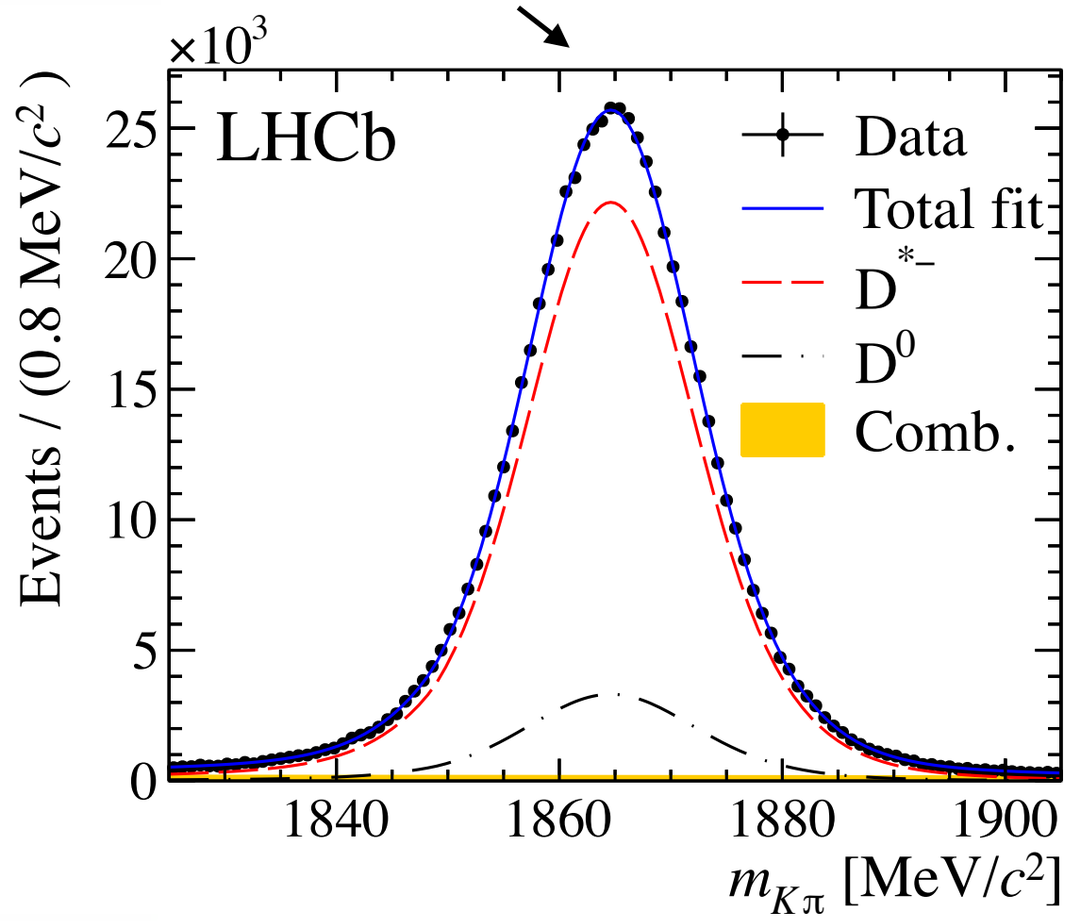
CERN-EP-2016-084

B_d OSCILLATIONS: ΔM_d

$$B_d^0 \to D^{(*)-}\mu^+ X$$

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

- Tag initial flavour of the B. Track flavour at decay, as function of **decay time**
- Correct for missing momentum to estimate the decay time of the B
- Flavour at production: deduce from *opposite* B **(flavour tagging)**
- Flavour at decay: determined by the charge of the muon (flavour specific)
- Make sure charm was from B: use track isolation & minimal IP requirement.



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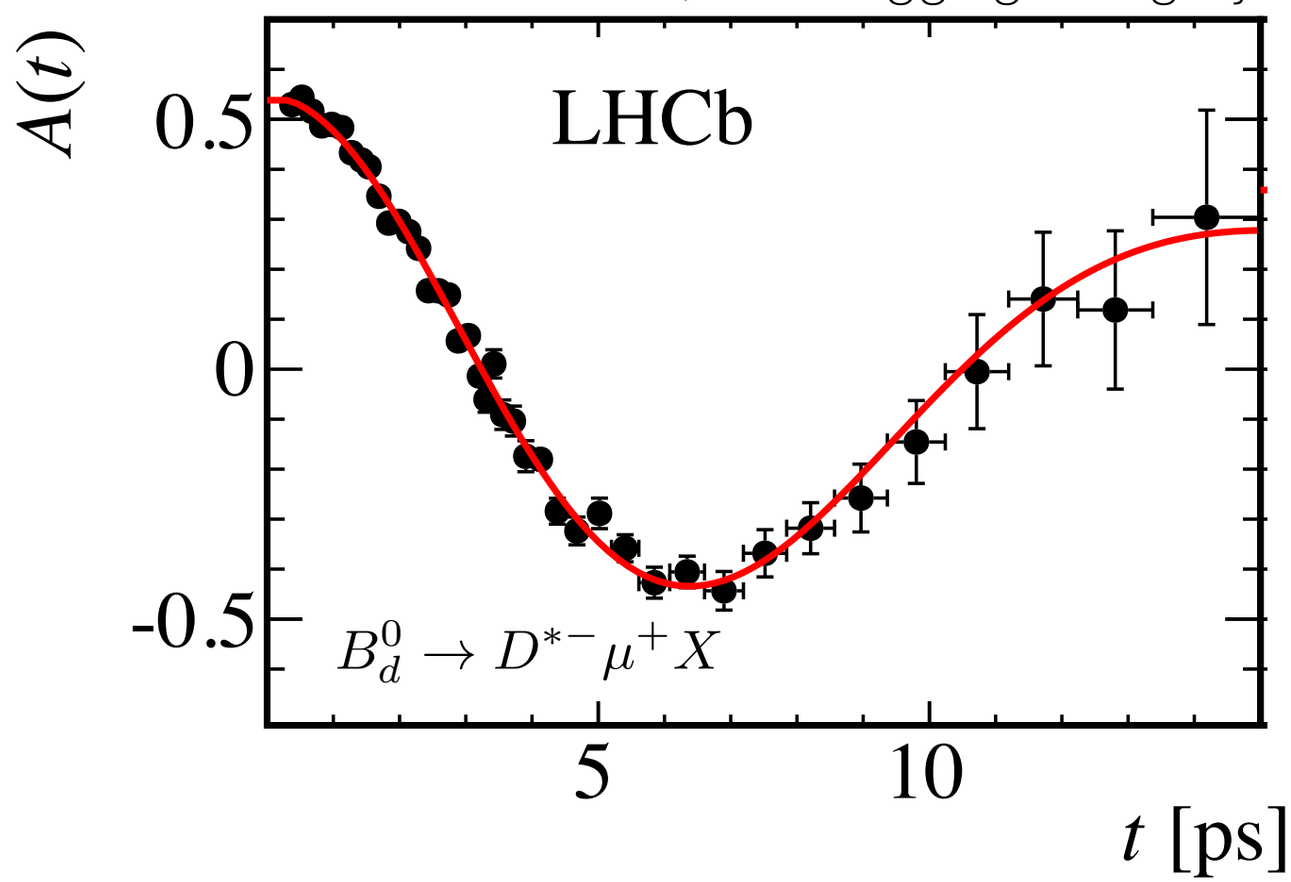
B_d OSCILLATIONS: ΔM_d

$$A(t) = \frac{N^{\text{unmix}}(t) - N^{\text{mix}}(t)}{N^{\text{unmix}}(t) + N^{\text{mix}}(t)} \propto \cos(\Delta m_d t)$$

2012, best tagging category



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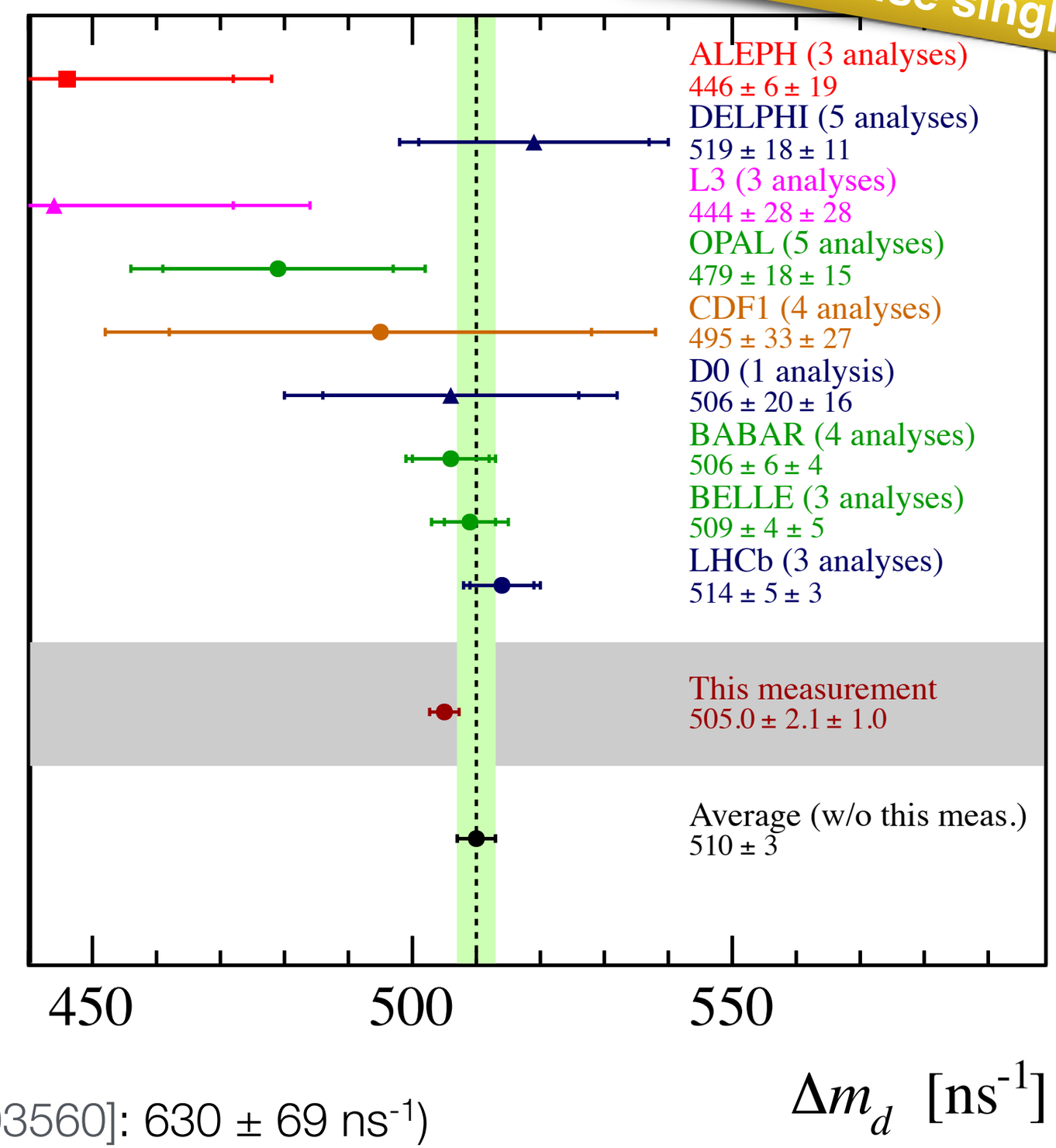
B_d OSCILLATIONS: ΔM_d

Most precise single measurement



(**Theory** [arXiv:1602.03560]: 630 ± 69 ns^{-1})

CERN-EP-2016-133 & CERN-PH-EP-2014-237

CP violation in B-$\bar{B}$ mixing

$$P(B \to \bar{B}) \neq P(\bar{B} \to B)$$

- Observed (only) in the neutral Kaon system.
- Use a flavour specific final state: semileptonics.

$$a_{\rm sl} = \frac{N(\bar{B} \to B \to f) - N(B \to \bar{B} \to \bar{f})}{N(\bar{B} \to B \to f) + N(B \to \bar{B} \to \bar{f})} = \frac{1 - |q/p|^4}{1 + |q/p|^4}$$

- Standard Model values: effectively 0.

$$a_{sl}^d = (-4.7 \pm 0.6) \times 10^{-4}$$
$$a_{sl}^s = (2.22 \pm 0.27) \times 10^{-5}$$

Artuso, Borissov, Lenz [arXiv:1511.09466]

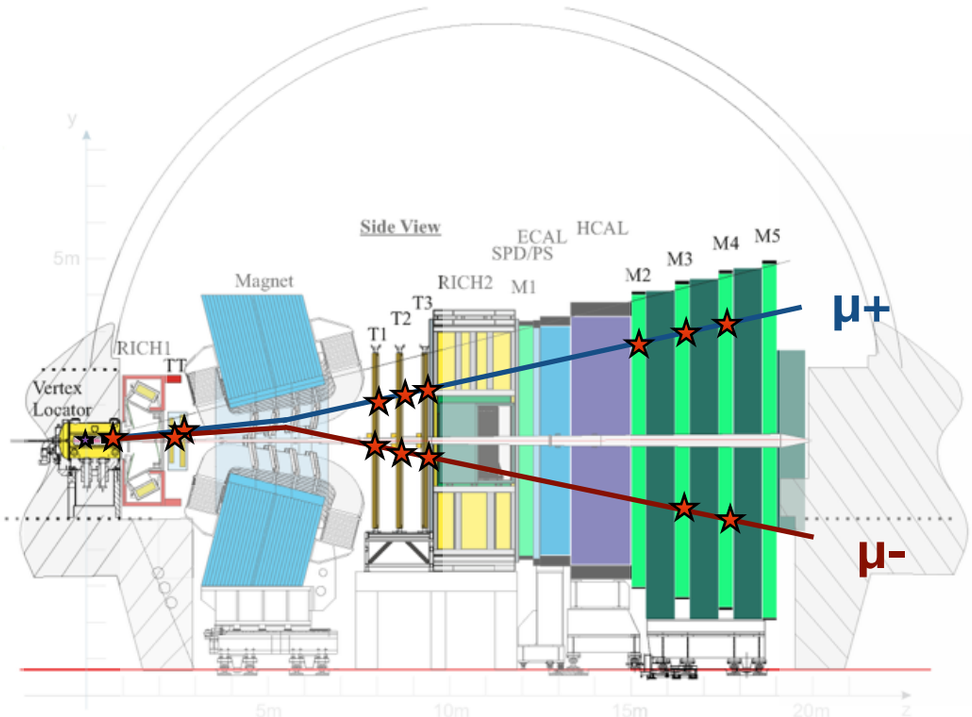
CERN-EP-2016-133 & CERN-PH-EP-2014-237

S.L. MIXING ASYMMETRY: a_{SL}

METHOD

The knowledge of the flavour of the B at production is not needed, but the raw asymmetry becomes dependent on the **production asymmetry**.

$$A_{raw} = \frac{N(f,t) - N(\bar{f},t)}{N(f,t) + N(\bar{f},t)} = \frac{a_{sl}}{2} + (A_P - \frac{a_{sl}}{2})\cos(\Delta m\, t)$$



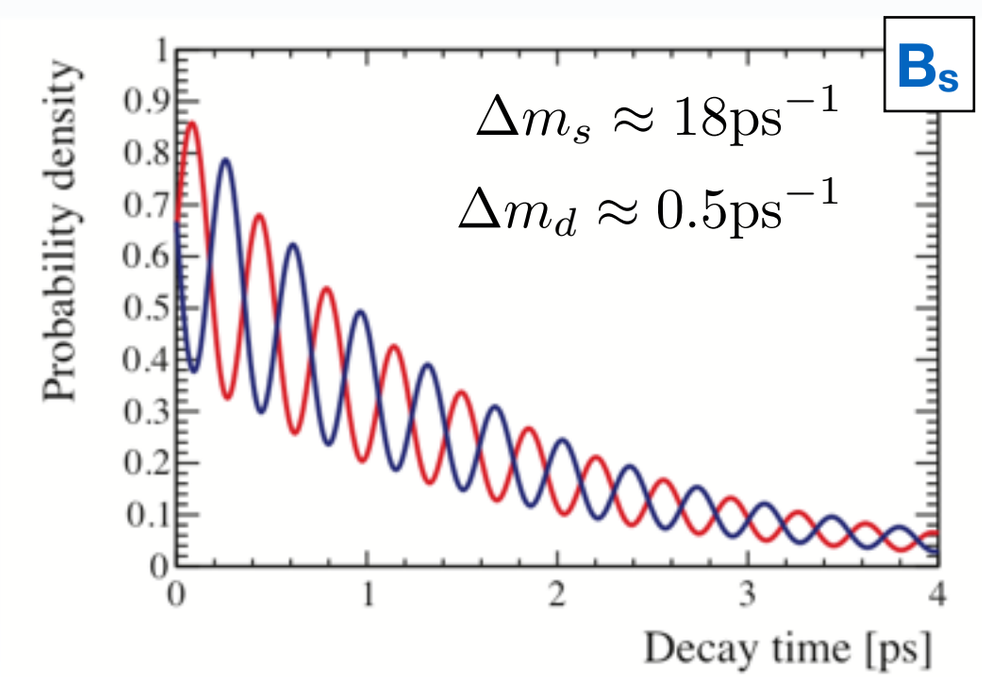
Asymmetries and yields for the final state are extracted from data. This quantity by itself must be corrected: what is the **detector response** for *f* relative to *f* ?

S.L. MIXING ASYMMETRY: a_{SL}

METHOD

The knowledge of the flavour of the B at production is not needed, but the raw asymmetry becomes dependent on the **production asymmetry** and the **detection asymmetry.**

$$A_{raw} = \frac{N(f,t) - N(\bar{f},t)}{N(f,t) + N(\bar{f},t)} = A_{det} + \frac{a_{sl}}{2} + (A_P - \frac{a_{sl}}{2})\cos(\Delta m\, t)$$



For **B_s** mesons: high frequency, time-integrated analysis.

For **B_d** mesons: low frequency, time-dependent analysis. Add A_P in data fit.

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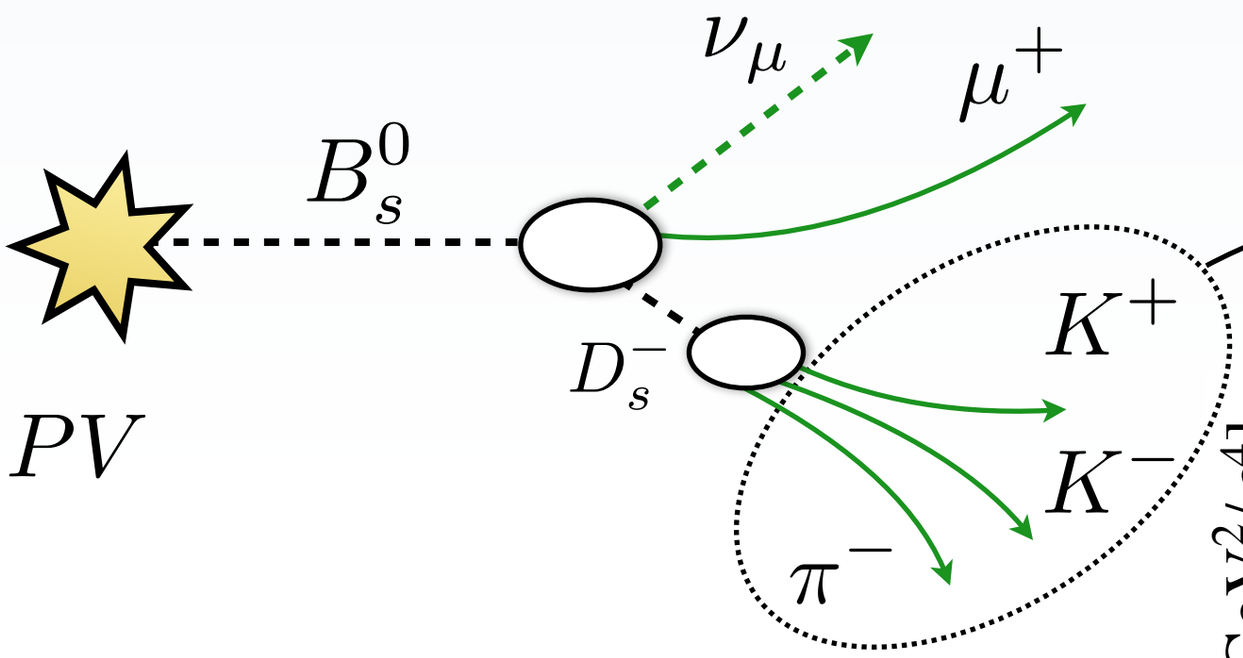
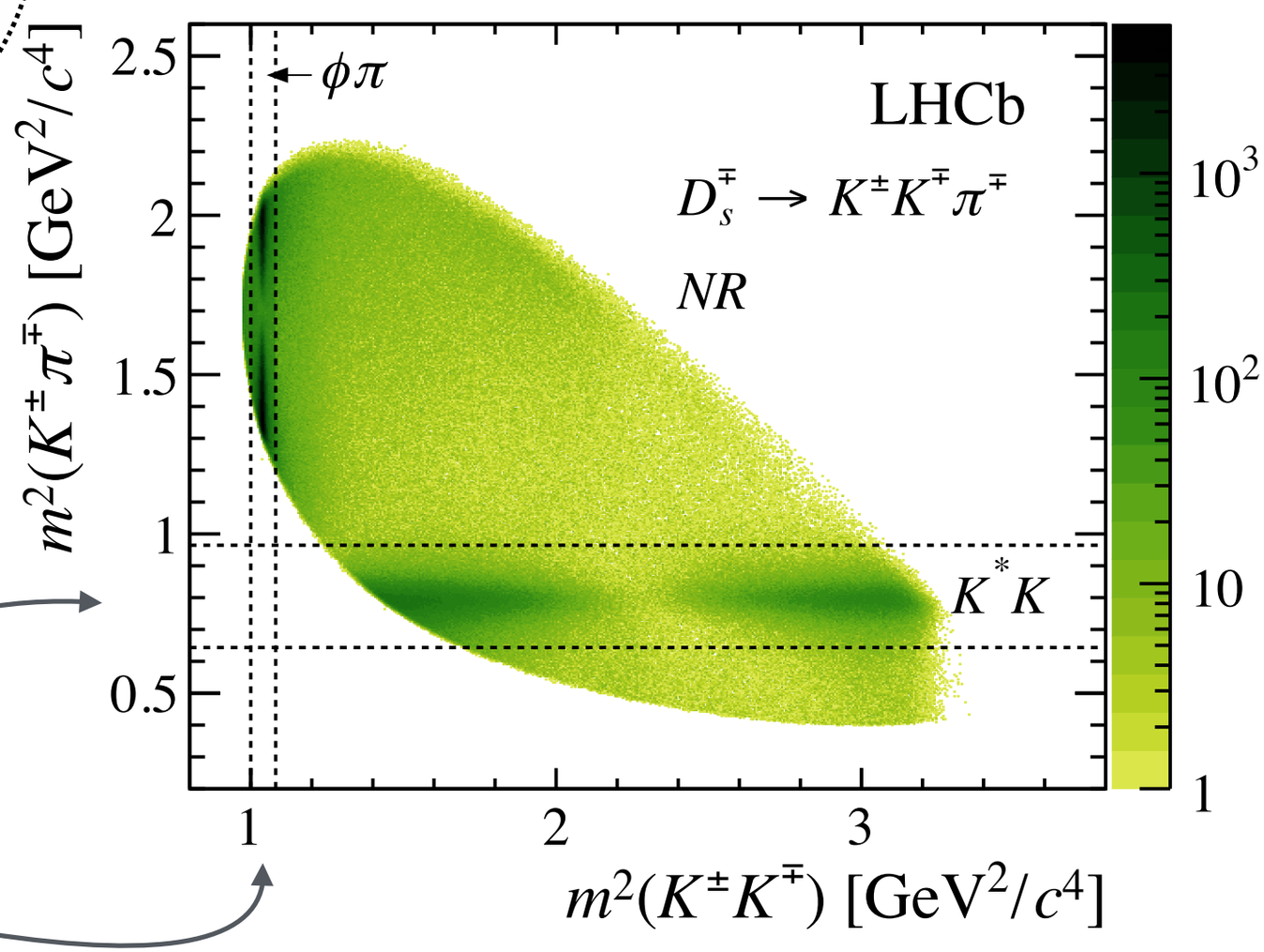
LATEST MEASUREMENT: a^{S}_{SL}





Analysis split up in Dalitz plot regions. Levels of backgrounds vary between these regions and thus call for different selection strategies.

$m(K\pi)$ in $[806, 986]$ MeV/c^2

$m(KK)$ in $[1000, 1040]$ MeV/c^2

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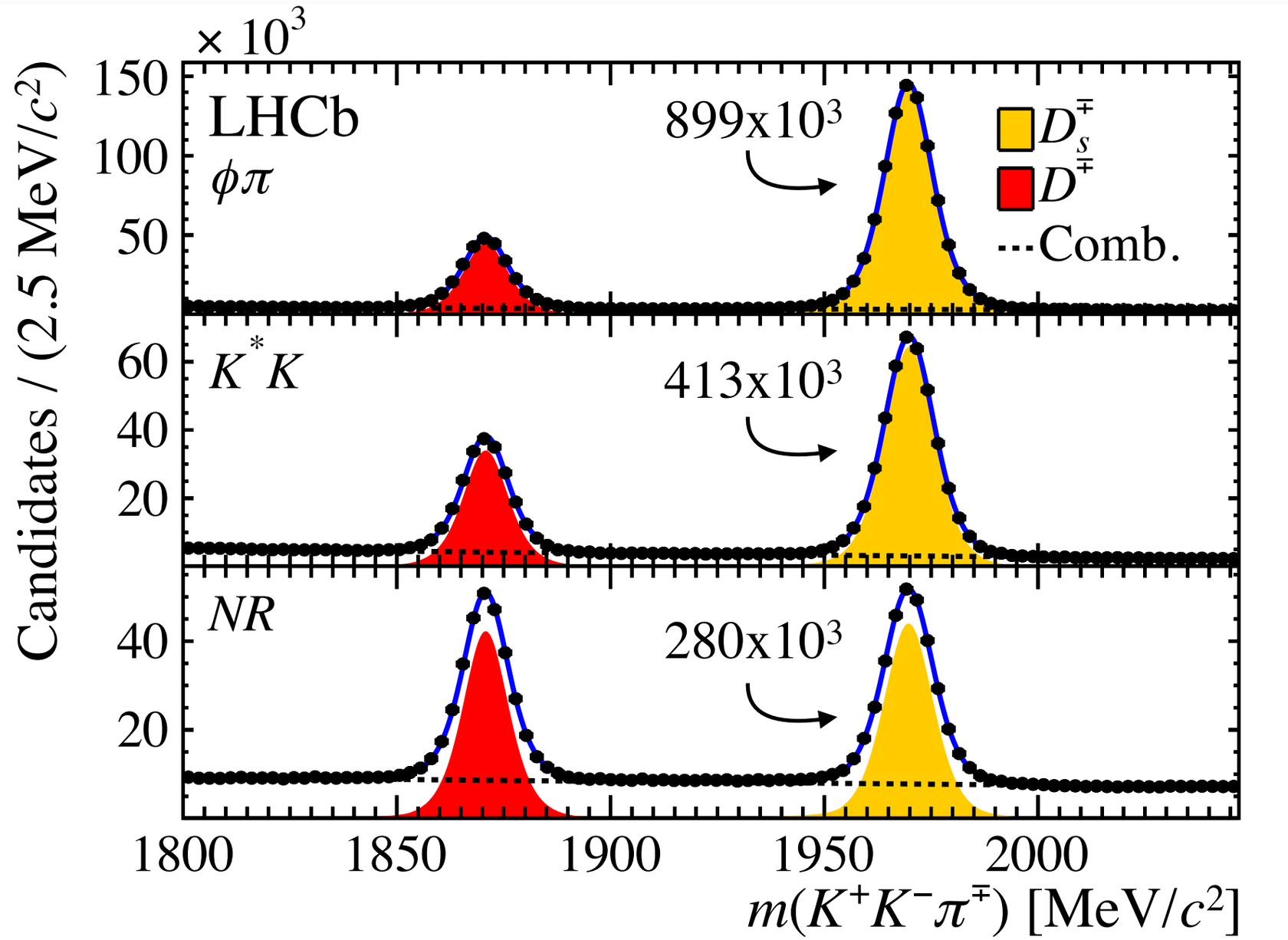
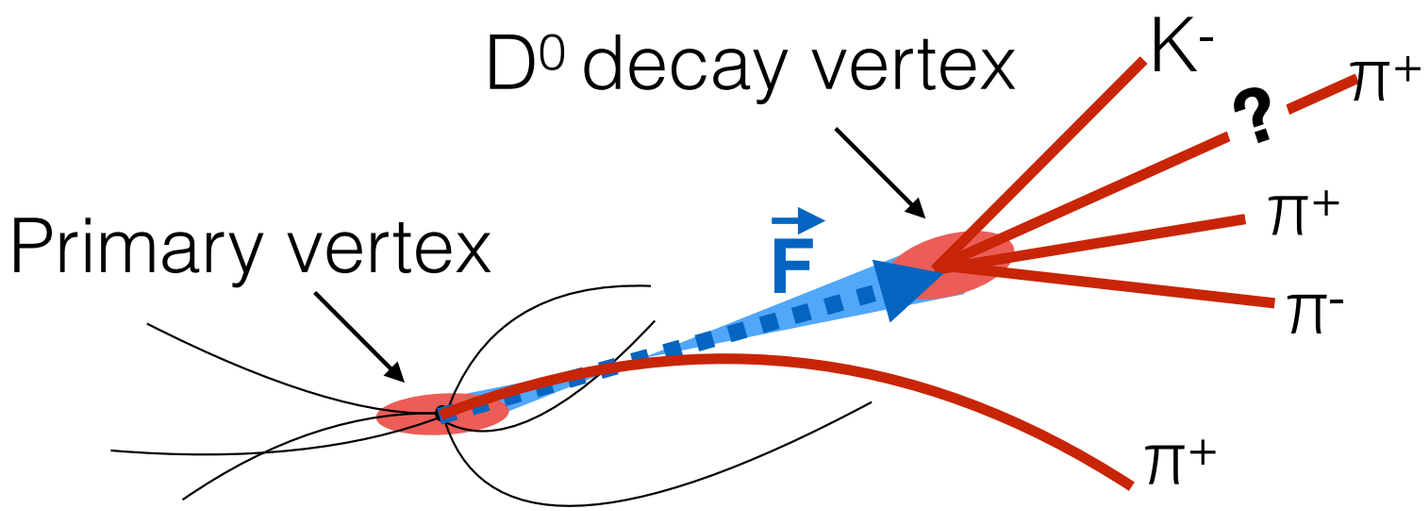
YIELDS a^{s}_{SL}



Detection asymmetries

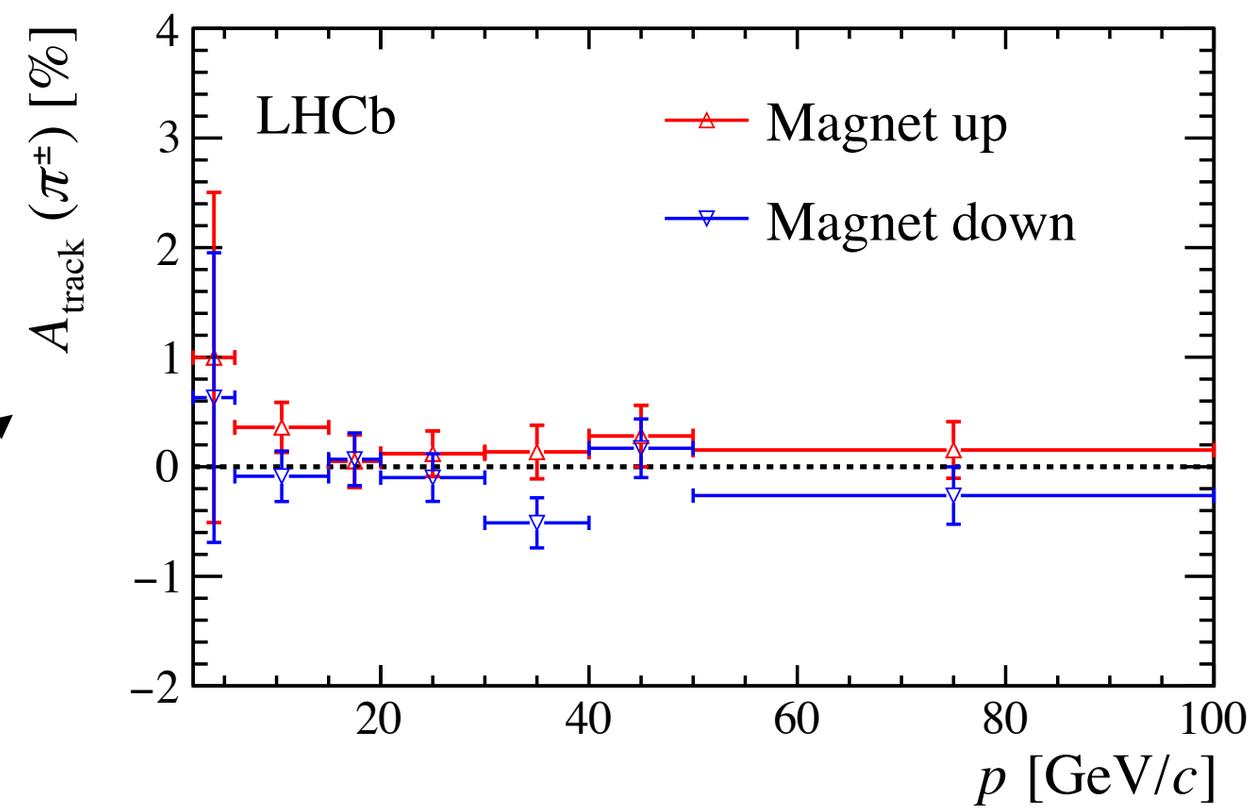


One of the ways of determining the detection asymmetry, is via a **tag & probe** method for (partially) reconstructed prompt charm decays.

Know with high certainty the track must have been there, then compute efficiency.

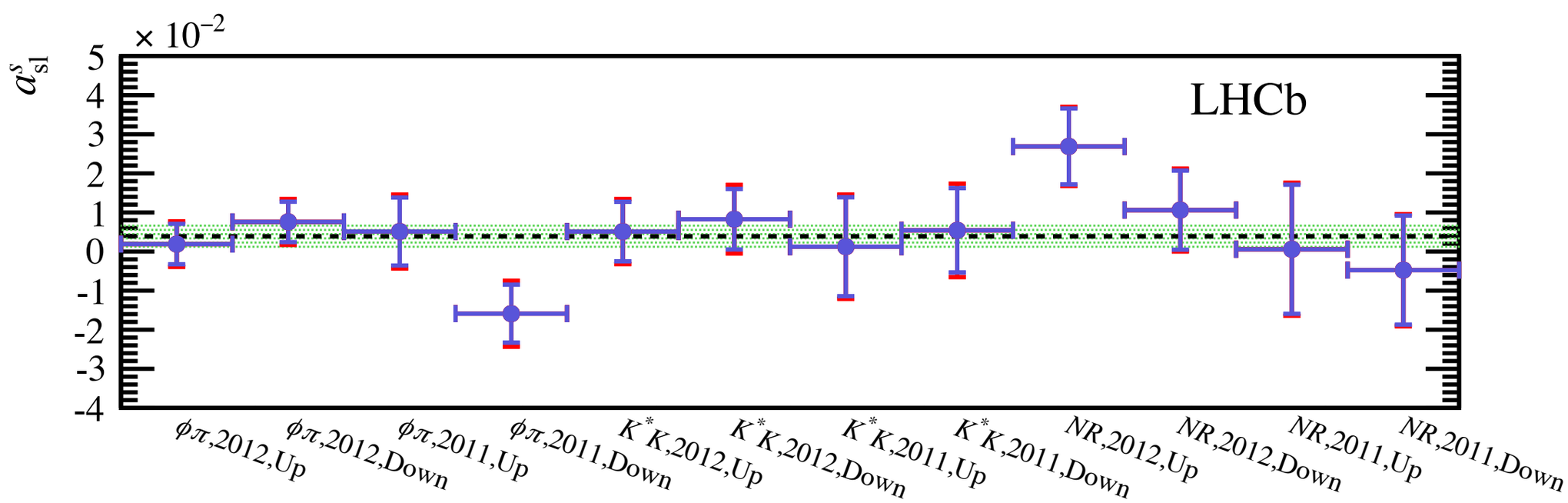
$$\epsilon = \frac{\text{found}}{\text{total}}$$

Relative difference



Results

Source	Value	Stat. uncert.	Syst. uncert.
A_{raw}	0.11	0.09	0.02
$A_{\text{track}}(K^+K^-)$	−0.01	0.00	0.03
$A_{\text{track}}(\pi^-\mu^+)$	−0.01	0.05	0.04
A_{PID}	0.01	0.02	0.03
$A_{\text{trig}}(\text{hardware})$	−0.03	0.02	0.02
$A_{\text{trig}}(\text{software})$	0.00	0.01	0.02
$f_{\text{bkg}}\ A_{\text{bkg}}$	−0.02	–	0.03
f_{bkg}	–	–	0.06
Total a^s_{sl}	0.39	0.26	0.20



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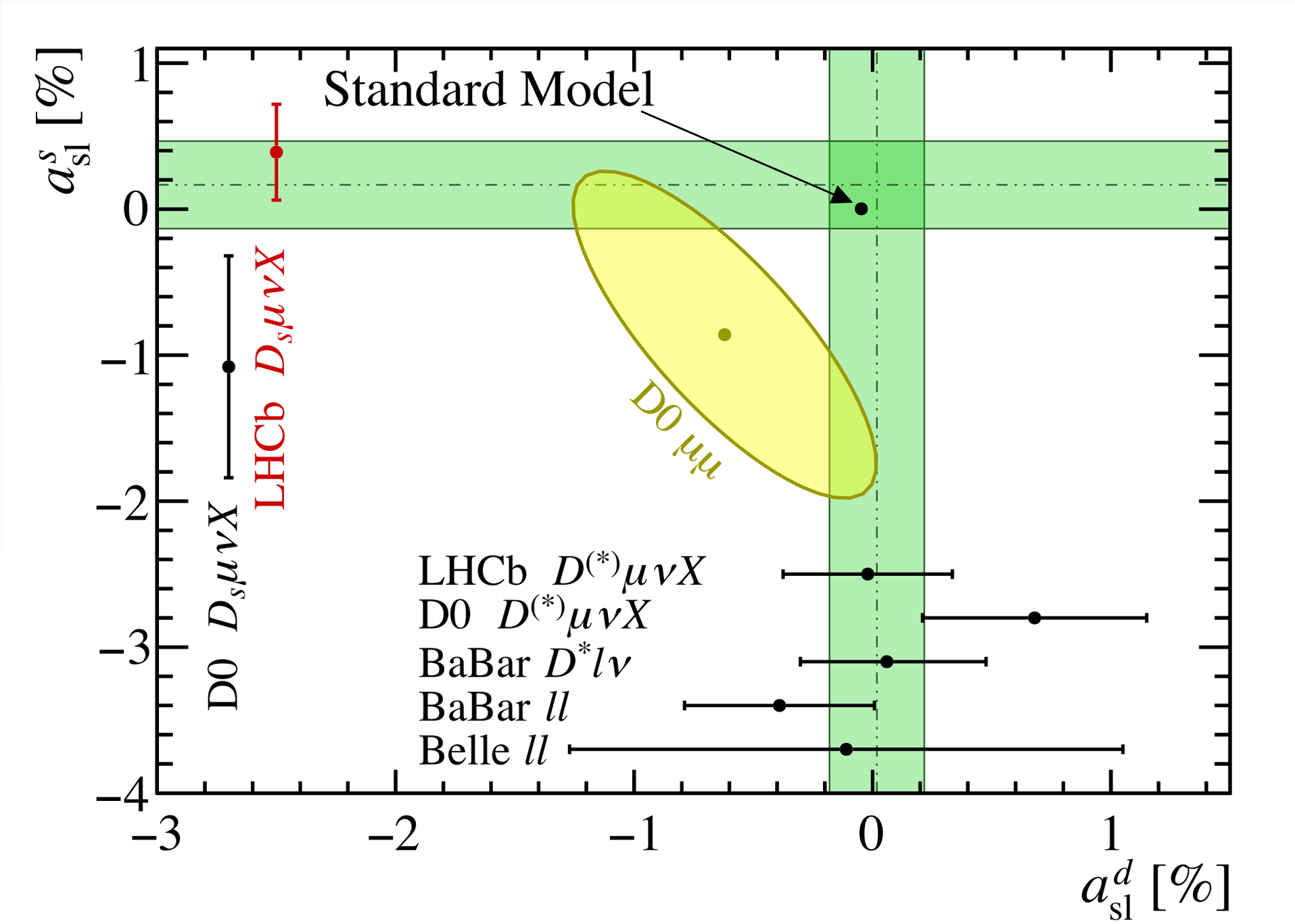
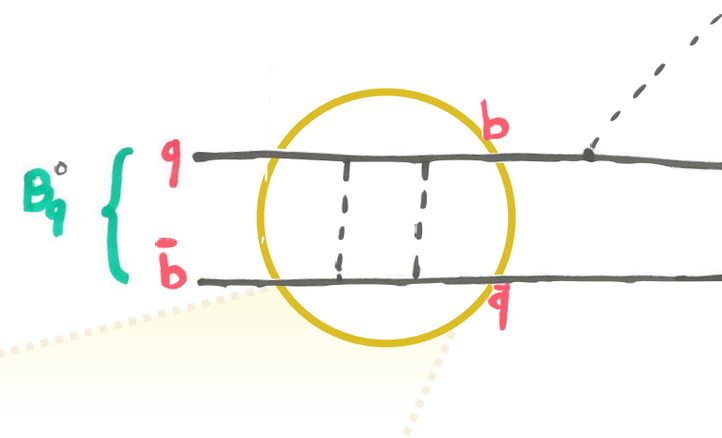
THE BIG PICTURE



Conclusion



Using **semileptonic** decays, LHCb has provided the most precise measurements of the mixing parameters for B_s & B_d mesons.

Very recent result of CP Violation in mixing compatible with the Standard Model. Long standing discrepancy reduced.

The prospects for Run-II are promising, as the results are limited by statistics.

New results in semileptonic beauty decays with LHCb

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June 16th 2016

Laurent Dufour, on behalf of the LHCb collaboration

arXiv:1605.09768

CP violation in B-B mixing

$$a_{\rm sl} = \frac{N(\bar{B}\to B \to f) - N(B\to \bar{B} \to \bar{f})}{N(\bar{B}\to B \to f) + N(B\to \bar{B} \to \bar{f})} = \frac{1-|q/p|^4}{1+|q/p|^4}$$

$$\frac{\Delta\Gamma}{\Delta m}\tan(\phi) = 2\left(1-\left|\frac{q}{p}\right|\right)$$

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B_d OSCILLATIONS: ΔM_d