B^0 Mixing & A_{sl} in Run 2

M. Margoni, 27/3/2015

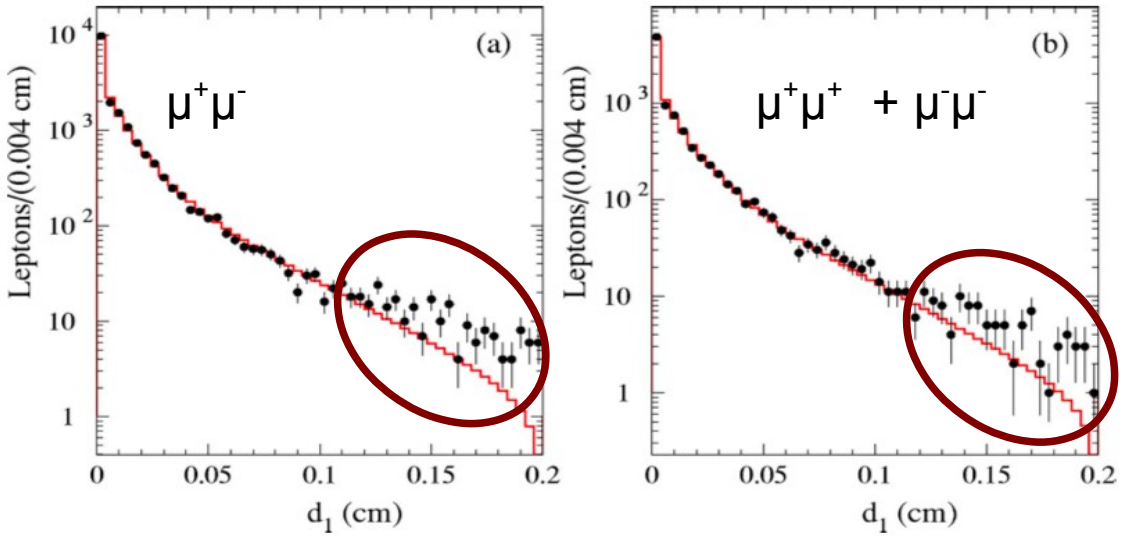
- Motivation
- Status & Perspectives
- Expressions of Interest from different Groups

B^0 Mixing

Motivations

- $\bar{\chi} = \frac{N(\mu^{++}) + N(\mu^{--})}{N(\mu\mu)} = f_d \chi_d + f_s \chi_s$
  - Useful to constrain production fractions of different B hadrons
  - Mixing in $t\bar{t}$ events: test of QCD factorization from comparison of $\chi(m_t)$ with $\chi(m_Z)$

- Test of the CDF excess ("ghost muons" issue) [Phys. Rev. D 69 012002 (2004)]



$$\bar{\chi} = 0.152 \pm 0.007 \pm 0.011$$

- From a fit to Impact Parameter distribution of Same Sign and Opposite Sign dimuons

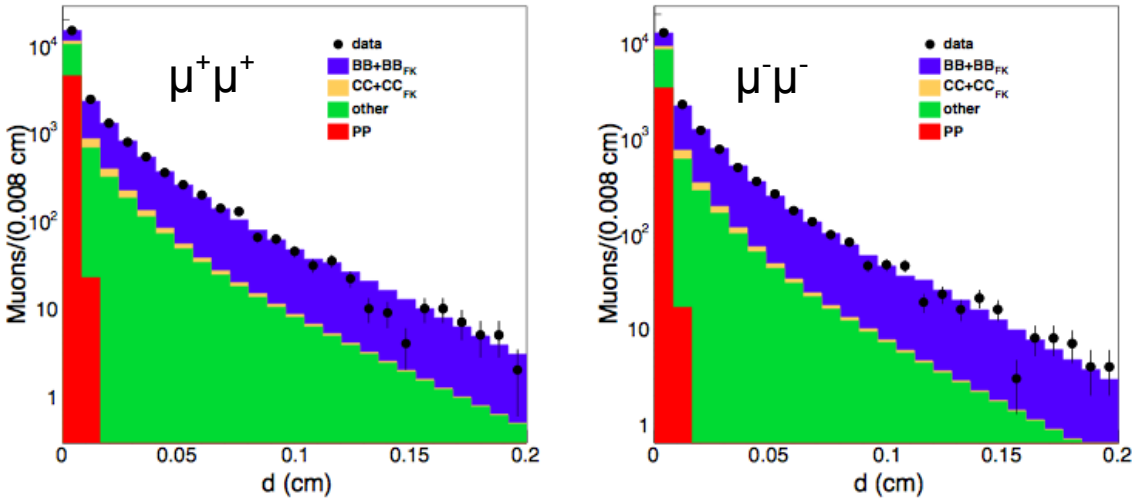
B^0 Mixing

Motivations

- $\bar{\chi} = \frac{N(\mu^{++}) + N(\mu^{--})}{N(\mu\mu)} = f_d \chi_d + f_s \chi_s$
  - Useful to constrain production fractions of different B hadrons
  - Mixing in $t\bar{t}$ events: test of QCD factorization from comparison of $\chi(m_t)$ with $\chi(m_Z)$

- Preliminary result from a fit to dimuons IP using much tighter selection and requiring muon hit in internal Layer 00 [CDF note 10335 (2011)]

$$\bar{\chi} = 0.126 \pm 0.008$$



B^0 Mixing

Motivations

- $\bar{\chi} = \frac{N(\mu^{++}) + N(\mu^{--})}{N(\mu\mu)} = f_d \chi_d + f_s \chi_s$
  - Useful to constrain production fractions of different B hadrons
  - Mixing in $t\bar{t}$ events: test of QCD factorization from comparison of $\chi(m_t)$ with $\chi(m_Z)$

- Fill a LHC column in the PDG table from [arXiv:1207.1158 (2013)] using preliminary results [CDF note 10335 (2011)]

	in Z decays [8]	at Tevatron [8]	at LHCb [74]
$\bar{\chi}$	0.1259 ± 0.0042	0.127 ± 0.008	
$f_u = f_d$	0.404 ± 0.009	0.330 ± 0.030	
f_s	0.103 ± 0.009	0.103 ± 0.012	
f_{baryon}	0.089 ± 0.015	0.237 ± 0.067	
f_s/f_d	0.254 ± 0.025	0.311 ± 0.037	0.256 ± 0.020

PDG 2014

CPV in B^0_q Mixing

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

- M_{12} and Γ_{12} off-diagonal elements of the B^0 mixing Hamiltonian

$$\mathcal{H}_{\text{eff}} = \mathbf{M} - \frac{i\mathbf{\Gamma}}{2}$$

- CPV can be observed through the Semileptonic Asymmetry:

$$A^q_{CP} = A^q_{sl} = \frac{N_{B^0_q}(\mu^+\mu^+) - N_{B^0_q}(\mu^-\mu^-)}{N_{B^0_q}(\mu^-\mu^-) + N_{B^0_q}(\mu^-\mu^-)}$$

- Predicted to be very small in the SM [Nierste, arXiv:1212.5805 (2012)]

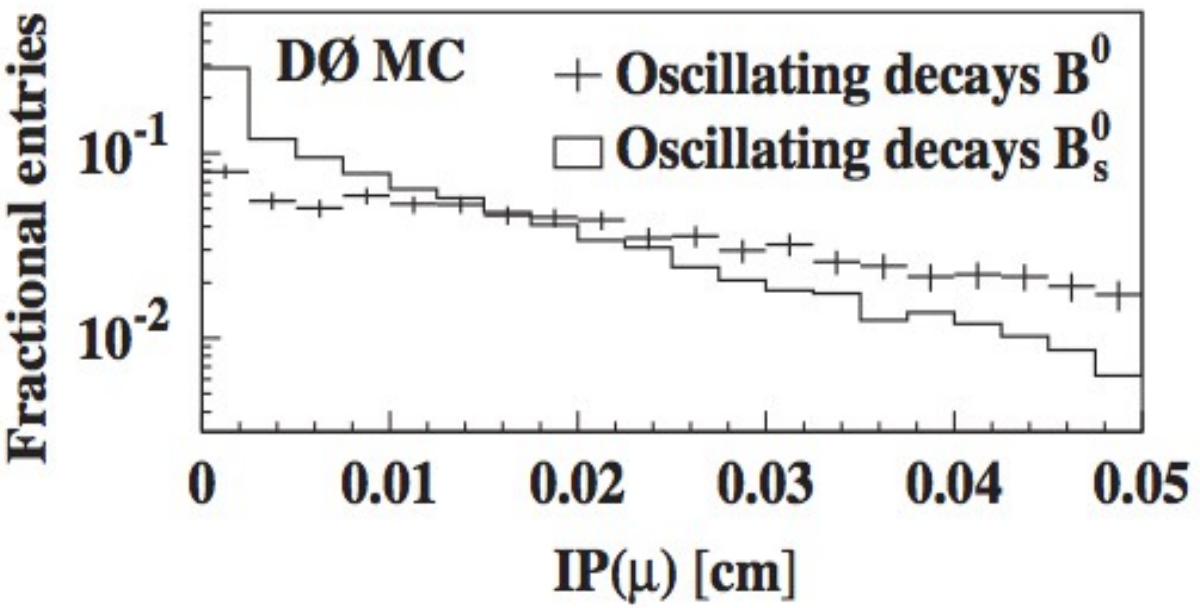
$$A^d_{CP} = (-4.0 \pm 0.6) \times 10^{-4}; \quad \Phi_d = -4.9^o \pm 1.4^o$$
$$A^s_{CP} = (1.8 \pm 0.3) \times 10^{-5}; \quad \Phi_s = 0.24^o \pm 0.06^o$$

Inclusive dilepton A_{SL}

D0 Measurement (L=10.4 fb^{-1}) [D0, Phys. Rev. D 89 012002 (2014)]

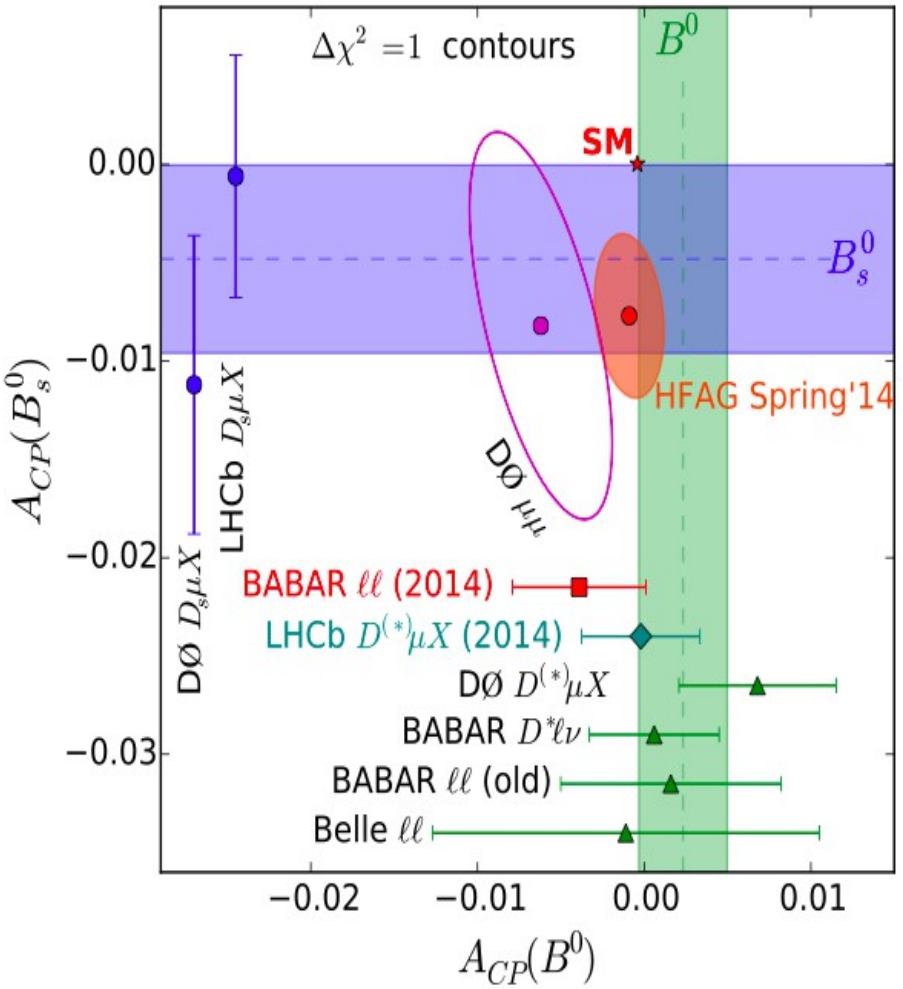
- A_{SL} measured from inclusive single muon and like-sign dimuon charge asymmetries:
  A_{SL}=(-0.496 ± 0.153 ± 0.072)%
  differs from SM expectation by 2.8 σ

- Measurement performed in three different muon Impact Parameter regions to separate B_s vs B^0



- X^2 of the different results vs IP reflects in a 3.6 σ discrepancy from SM expectations

Summary on A^q_{SL}



- World Average from HFAG Fall 2014 using a 2D fit (ρ = - 0.158)
- A^d_{SL}:
  - Υ(4S): -0.0019 ± 0.0027
  - World Average: -0.0015 ± 0.0017
- A^s_{SL}:
  - World Average: -0.0075 ± 0.0041
- WA of flavor specific measurements agree with SM
- Global WA agrees with SM at ~ 1.5 σ
- Tension wrt expectations only in the inclusive D0 measurement

Projection on A^{q}_{SL}

Back of envelope Run 2 projection & comparison assuming

- CMS:
  σ(Run 2) = 2 σ(Run 1)
  L(Run 2) = 100 / 120 fb^{-1} = 5 L(Run 1)
  - Increase in statistics = 10 times
  - Total sample = 11 x Run 1

- LHCb:
  σ(Run 2) = 2 σ(Run 1)
  L(Run 2) = 5 / 6 fb^{-1} = 1.5 / 2 L(Run 1)
  - Increase in statistics = 3 / 4 times
  - Total sample = 5 x Run 1

Projection on A^q_{SL}

Most precise Flavor Specific A^q_{SL} measurement from LHCb

- Using exclusive reconstruction of $B^0 \rightarrow D^{(*)}\mu$, $D \rightarrow K\pi\pi$, $D^* \rightarrow D^0(K\pi)\pi$ (L= 3 fb^{-1}) [LHCb, Phys. Rev. Lett. 114, 041601 (2015)]

$$A^d_{SL} = (-0.02 \pm 0.10 \pm 0.30) \times 10^{-2}$$

  - Limited by systematics on detection asymmetry (0.26 x 10^{-2}) from the statistics of the calibration samples (reducible with statistics)
  - Projection for Run 2:

$$\delta A^d_{SL} \sim 0.20 \times 10^{-2}$$

- Using exclusive reconstruction of $B^0_s \rightarrow D^-_s X\, \mu^+ \nu$ ($D^-_s \rightarrow \Phi\pi^-$, $\Phi \rightarrow KK$) (L= 1 fb^{-1}) [LHCb, Phys. Lett. B 728 607-615 (2014)]

$$A^s_{SL} = (-0.06 \pm 0.50 \pm 0.36) \times 10^{-2}$$

  - Statistically limited
  - Systematics dominated by tracking asymmetry (0.26 x 10^{-2} reducible with statistics)
  - Projection for Run 2:

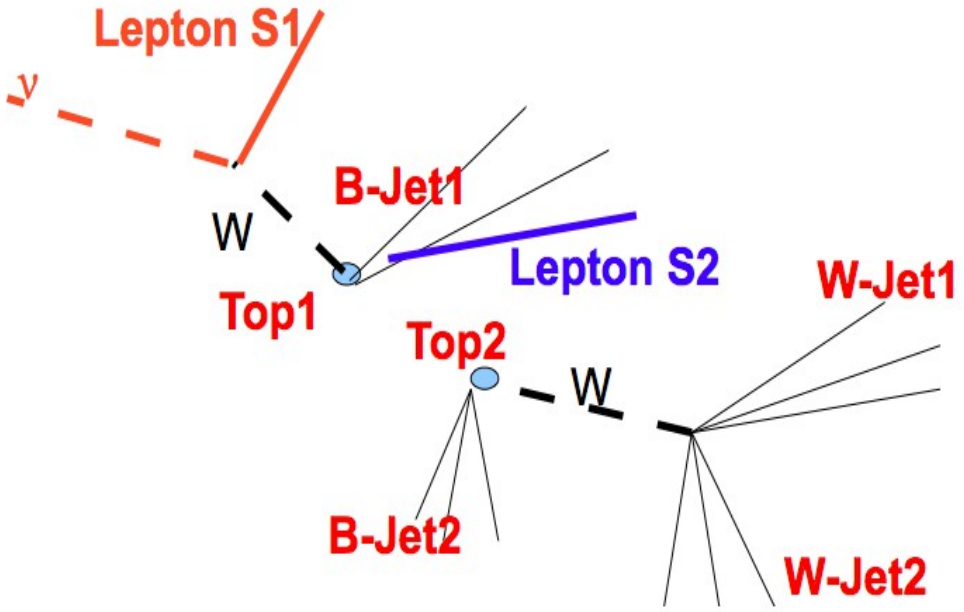
$$\delta A^s_{SL} \sim 0.30 \times 10^{-2}$$

B^0 Mixing & A_{SL} in $t\bar{t}$ events

- Semileptonic top decays: $t\,\bar{t}$, $t \rightarrow b\,l\,\nu$, $\bar{t} \rightarrow bX$
  - Lepton from top decay tags the flavor of both the B hadrons at the production time
  - Dilepton Trigger (2012): HLT_L17_L8 (L=MUO, ELE)

- Analysis of 2012 dataset:
  - N(S1) = 230 k (e, μ)
  - N(S2) = 10 k (μ only), same and opposite top

  - $\delta(\chi) = 0.003$, $\delta(A_{SL}) = 0.03$ (μ only)
  - $\delta(\chi) = 0.002$, $\delta(A_{SL}) = 0.02$ (e + μ)



- Run 2 Top-Dileptons Trigger paths
  [S. Beauceron, Padova Trigger workshop 9-12 March 2015]:

  HLT paths: HLT_Mu17_TkIsoVVL_Ele12_WPMedium/
  HLT_Mu8_TkIsoVVL_Ele17_WPMedium/HLT_Ele17_Ele12_Iso/
  HLT_Mu17_TrkIsoVVL_Mu8_TrkIsoVVL

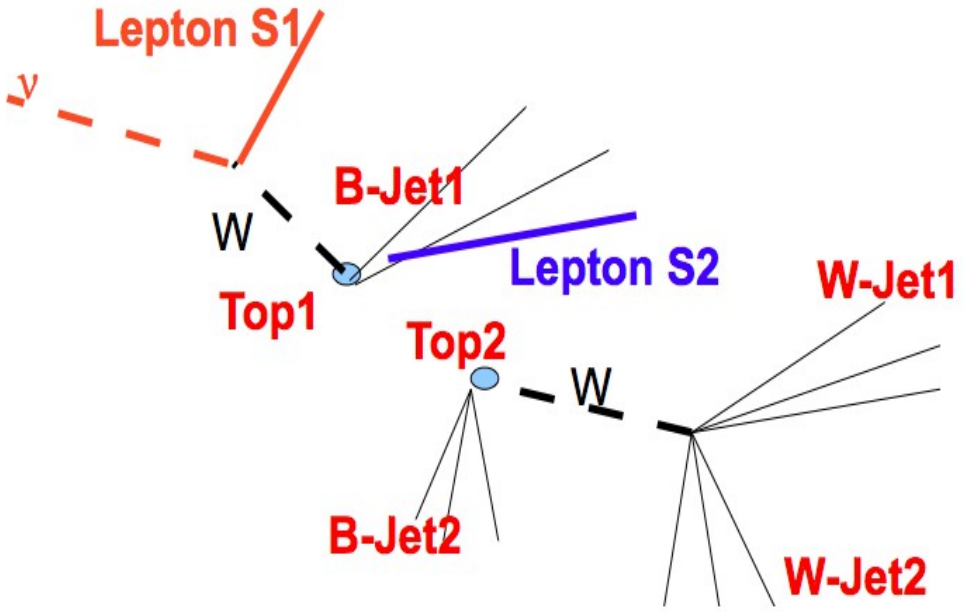
- Electron S2 threshold increased from 8 GeV to 12 GeV: 40% loss in efficiency

B^0 Mixing & A_{SL} in $t\bar{t}$ events

- Semileptonic top decays: $t\bar{t}$, $t \rightarrow b\, l\, \nu$, $\bar{t} \rightarrow bX$
  - Lepton from top decay tags the flavor of both the B hadrons at the production time
  - Dilepton Trigger (2012): HLT_L17_L8 (L=MUO, ELE)

- Analysis of 2012 dataset:
  - N(S1) = 230 k (e, μ)
  - N(S2) = 10 k (μ only), same and opposite top

  - $\delta(\chi) = 0.003$, $\delta(A_{SL}) = 0.03$ (μ only)
  - $\delta(\chi) = 0.002$, $\delta(A_{SL}) = 0.02$ (e + μ)



- Projection for 100 fb^{-1}:

$$\delta_{stat}(\chi) \sim 0.77 \times 10^{-3}$$

$$\delta_{stat}(A_{SL}) \sim 0.68 \times 10^{-2}$$

- Not competitive with LHCb flavor-specific measurements... but first inclusive A_{SL} measurement from LHC esperiments using an innovative technique

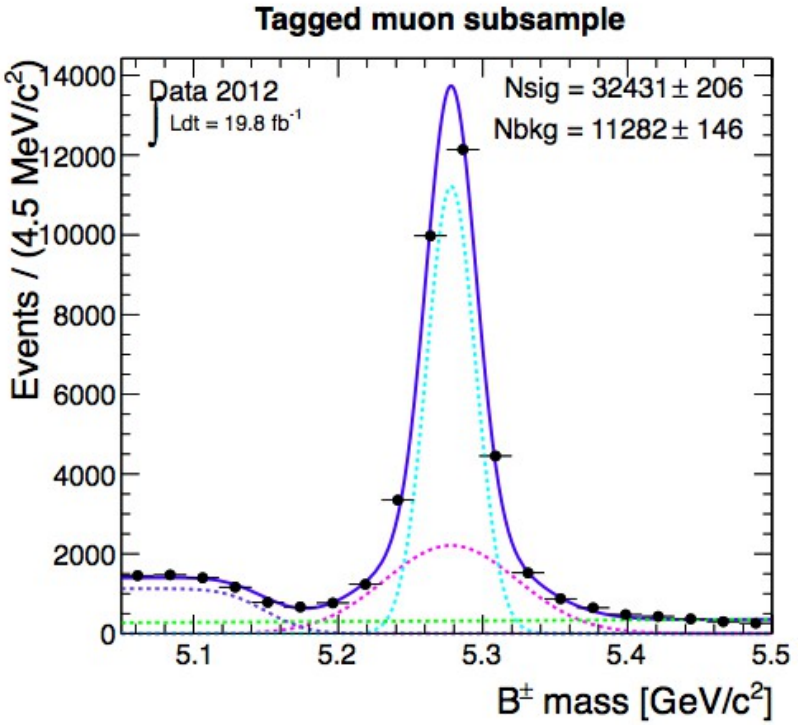
Tagged sample $B^+ \rightarrow J/\psi\, K^+$

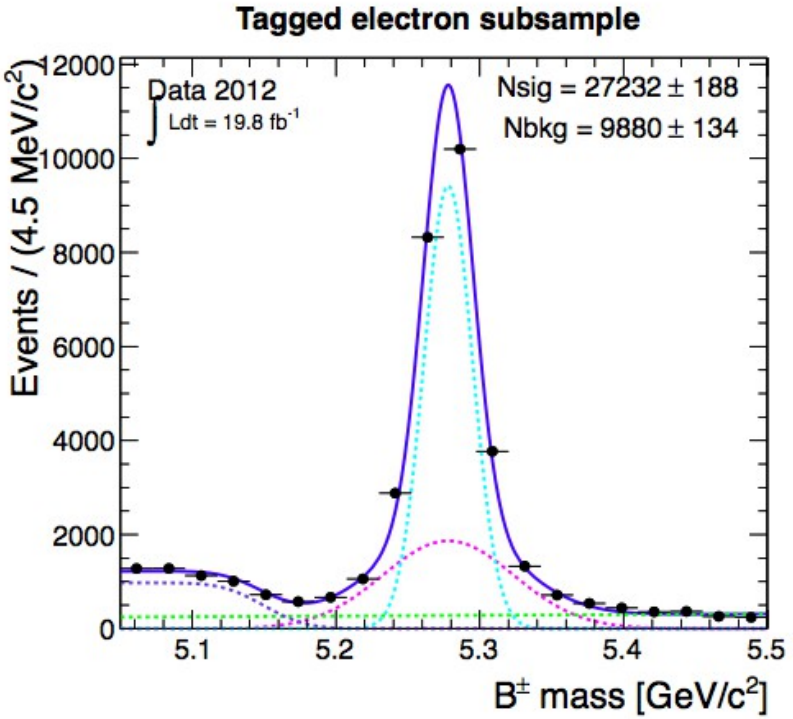
- 2012: DISPLACED_J/Ψ Trigger:
  60 k events with a lepton tag (e, μ):
- Right flavor information fraction: 60% μ (45% e)
  - $\delta(\chi) = 0.0018$, $\delta(A_{SL}) = 0.016$ (e + μ)

- Projection for 100 fb^{-1}:

$$\delta_{stat}(\chi) \sim 0.56 \times 10^{-3}$$

$$\delta_{stat}(A_{SL}) \sim 0.49 \times 10^{-2}$$





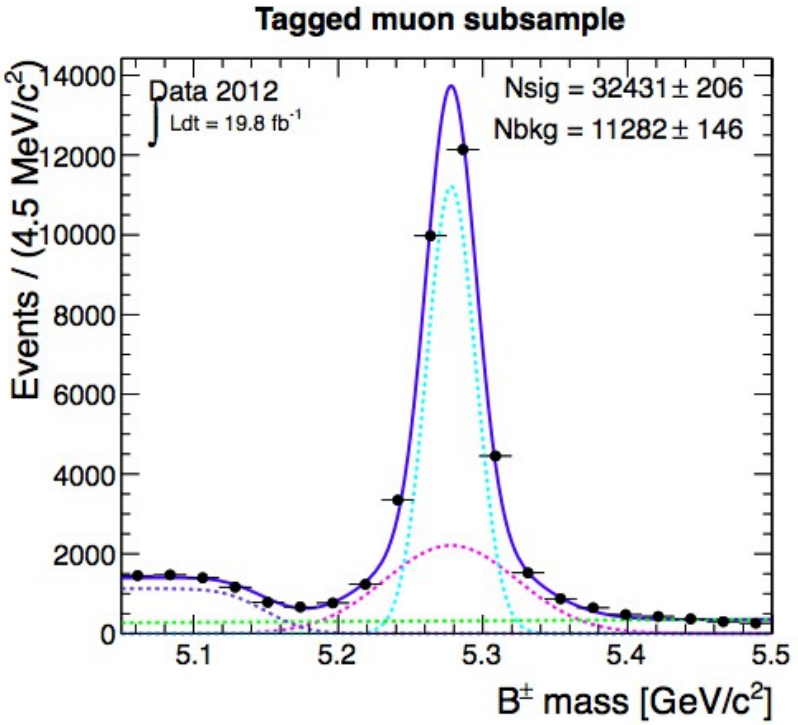
Tagged sample $B^+ \rightarrow J/\psi\, K^+$

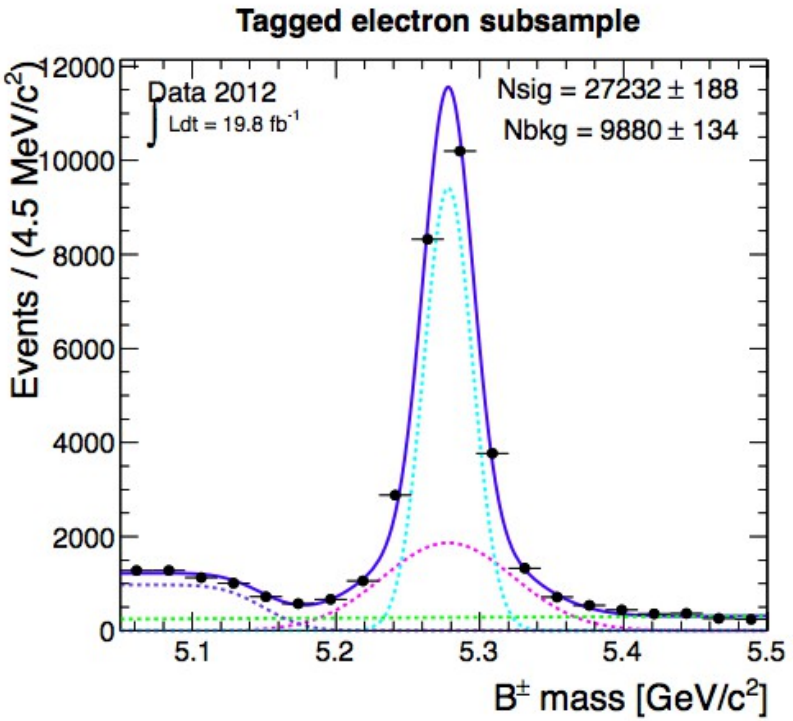
- 2012: DISPLACED_J/Ψ Trigger:
  60 k events with a lepton tag (e, μ):
- Right flavor information fraction: 60% μ (45% e)
  - $\delta(\chi) = 0.0018$, $\delta(A_{SL}) = 0.016$ (e + μ)

- Combination of the two analyses:

$$\delta_{stat}(\chi) \sim 0.45 \times 10^{-3}$$

$$\delta_{stat}(A_{SL}) \sim 0.40 \times 10^{-2}$$

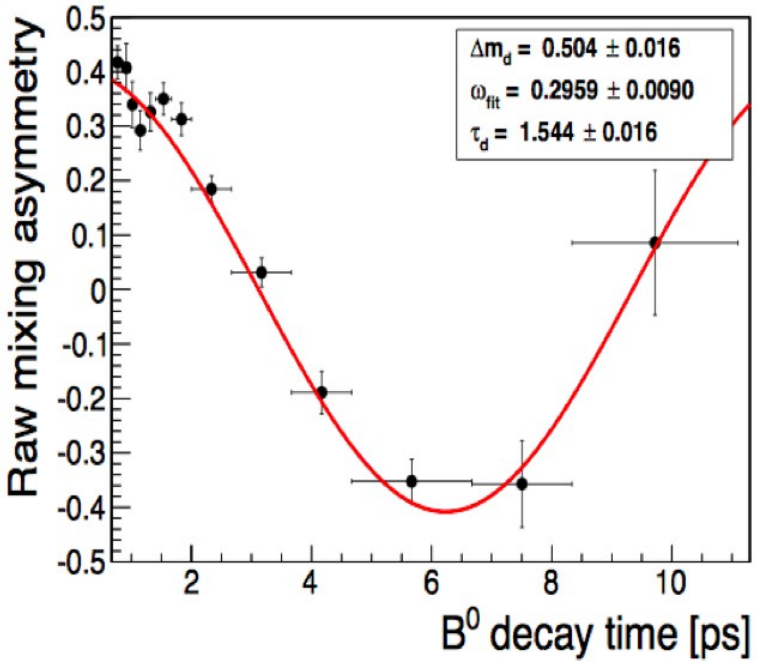




B^0 Mixing & A_{sl} in Run 2

Expression of Interests for Run 2

- Helsinki Group
  Terhi Jarvinen, Paula Eerola
  Time-dependent analysis of Δm_d, sinergy with Flavor-tagging validation
  - Goal: physics paper including Flavor-Tagging algorithm description (Reanalysis of $B_s \rightarrow J/\psi/\Phi$ with improved Flavor-Tagging,...?)



2012 Preliminary results

Fit results

$\tau_d = 1.544 \pm 0.016$ ps (PDG: 1.519 ± 0.005 ps)

$\Delta m_d = 0.504 \pm 0.016$ ps^{-1} (PDG: 0.510 ± 0.003 ps^{-1})

B^0 Mixing & A_{sl} in Run 2

Expression of Interests for Run 2

- Helsinki Group
  Terhi Jarvinen, Paula Eerola
  Time-dependent analysis of Δm_d, sinergy with Flavor-tagging validation
  - Goal: physics paper including Flavor-Tagging algorithm description (Reanalysis of $B_s \rightarrow J/\psi/\Phi$ with improved Flavor-Tagging,...?)

- Padova Group
  Alessio Boletti, Paolo Ronchese, Martino Margoni, Franco Simonetto
  Time-integrated measurement of χ & A_{SL} using $t\bar{t}$ events
  - Topic identified as one of the eight analyses we plan to deliver within a year (aiming at Moriond 2016), using (also) the 2015 dataset

Measurements with Run 1 dataset

- Mixing with dimuons (Ongoing)
  - Use 3 x 10^5 non-resonant dimuons (2010 dataset)
  - Fraction of events from B decays from a fit to $p_T(\mu)$ relative to jet direction for different charge correlation samples (SS, OS, SS^{++}, SS^{--})
  - $\delta(X)=0.002(stat) \pm 0.005(syst)$
  - Issues: fit convergence, fit/data agreement, BKG composition

- A_{SL} analysis using dimuons (Not started yet, lack of manpower)
  - Use 3 x 10^7 same-sign low p_T dimuons (2012 dataset)
  - No need for further data
  - Needs careful treatment of systematics uncertainties (BKG, charge-dependent muon efficiency, B^0 production asymmetry)

BACKUP

Expected Statistics

- CMS Analysis with semileptonic top, data 2012, i.e.
  CMS PAS TOP-13-008 (W helicity):

- 200 K evts after selection

- 50% with W->μ, the same withit W->e
- ε HLT(μ)=62%, ε HLT(e)=53%
- BR(b->l)=10%
- ε lepton from b ~40%

} 230 K top quarks
9 K events b->μ
with top tag

- To be considered also cascade decays b → c → l (… and b → e)

- δχ ~ 0.002 (without taking into accont BKG and dilution...)