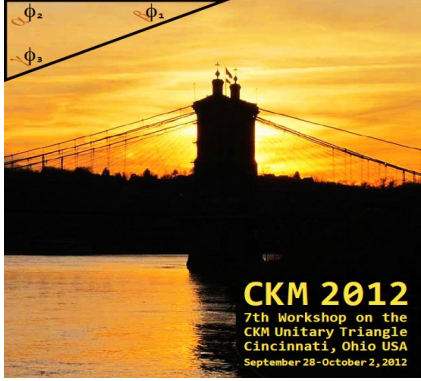

|g/p| Measurement from $B^0 \to D^* l\nu$ Partial Reconstruction

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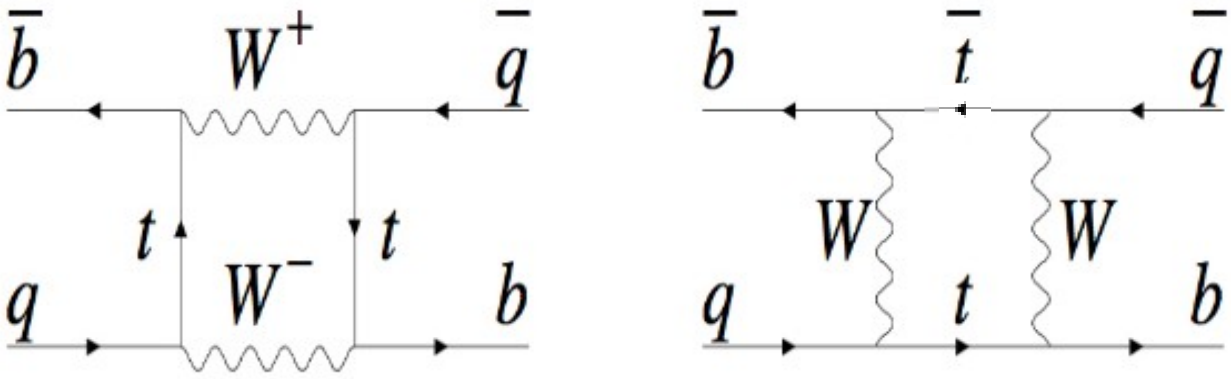
(on behalf of the BaBar Collaboration)

- Motivation
- Analysis Method
- Validation on MC
- Real Data Results
- Systematic Uncertainties
- Conclusions

Motivation

CPV in B^0 mixing



- New Particles in the boxes could modify SM expectations

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

$$i\frac{d}{dt}\begin{pmatrix} B_q \\ \overline{B}_q \end{pmatrix} = \left[\begin{pmatrix} M^q_{11} & M^{q\,*}_{21} \\ M^q_{21} & M^q_{11} \end{pmatrix} - \frac{i}{2}\begin{pmatrix} \Gamma^q_{11} & \Gamma^{q\,*}_{21} \\ \Gamma^q_{21} & \Gamma^q_{11} \end{pmatrix}\right]\begin{pmatrix} B_q \\ \overline{B}_q \end{pmatrix}$$

$[M_{ij}]$ = mass matrix

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

- Physical Eigenstates with defined masses and widths:

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

→ If $|(q/p)_q| \neq 1$ they would be also CP Eigenstates

- Neglecting $o(m^2_b/M^2_W)$:

$$\Delta m_q = m_H - m_L = 2\left|M^q_{12}\right|;\ \Delta\Gamma_q = \Gamma_L - \Gamma_H = 2\left|\Gamma^q_{12}\right|\cos\phi$$

$$\phi = arg\left(-M^q_{12}/\Gamma^q_{12}\right)$$ CP violating phase

CPV in B^0 mixing

- $\Upsilon(4S)$ machines & Hadron Colliders: b quarks produced mainly in $b\bar{b}$ pairs
  - → CP Asymmetry (time-independent):

$$A_{CP}=\frac{Prob(\bar{B}^0\to B^0,t)-Prob(B^0\to\bar{B}^0,t)}{Prob(\bar{B}^0\to B^0,t)+Prob(B^0\to\bar{B}^0,t)}=\frac{N(B^0B^0)-N(\bar{B}^0\bar{B}^0)}{N(B^0B^0)+N(\bar{B}^0\bar{B}^0)}$$

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

$$A_{SL}=\frac{N(\ell^+\ell^+)-N(\ell^-\ell^-)}{N(\ell^+\ell^+)+N(\ell^-\ell^-)}=\frac{1-|q/p|^4}{1+|q/p|^4}=\frac{|\Gamma_{12}^q|}{|M_{12}^q|}\sin\phi$$

→CPV in mixing if:
$A_{SL}\neq 0 \leftrightarrow |q/p|\neq 1 \leftrightarrow \Phi\neq 0$

Standard Model predicts

(Lenz, Nierste, arXiv:1102.4274 (2011)):

- B_d: $A^d_{SL}=(-4.1\pm0.6)10^{-4}$
  $\Phi_d=-4.3^\circ\pm1.4^\circ$
- B_s: $A^s_{SL}=(1.9\pm0.3)10^{-5}$
  $\Phi_s=0.22^\circ\pm0.06^\circ$

Beyond Standard Model

- New Physics could modify M_{12}^q and A_{SL} leaving Γ_{12}^q unchanged:

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

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

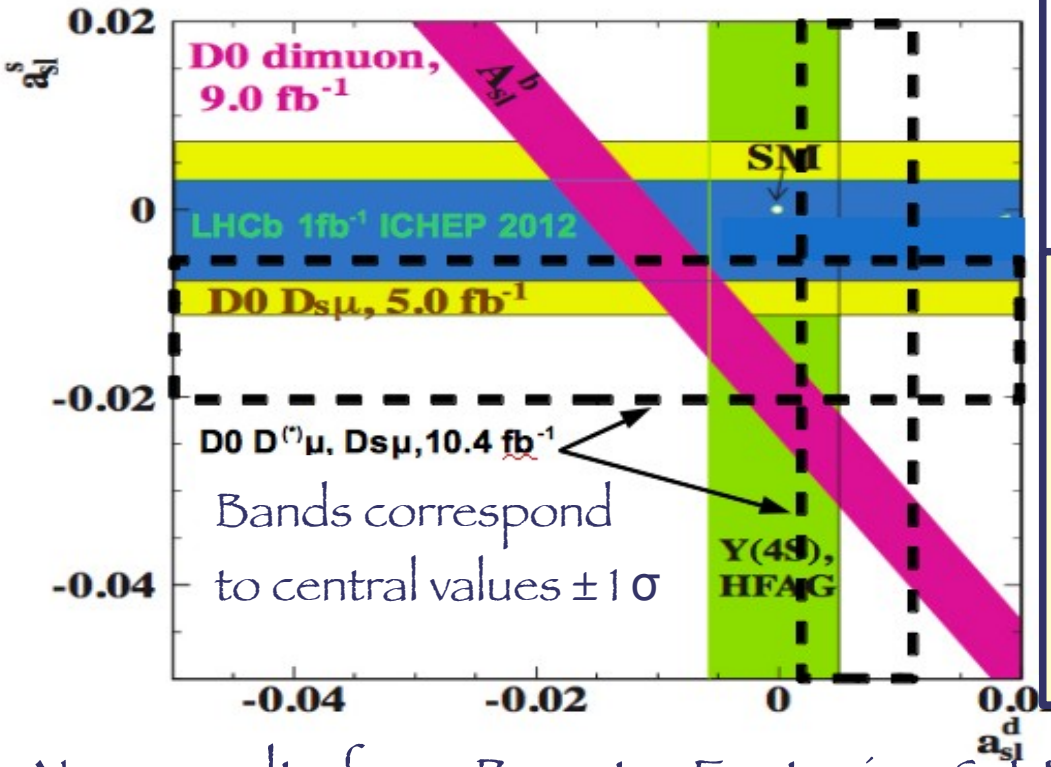
CPV in B^0 mixing

- HFAG average of $\Upsilon(4S)$ results (arXiv:1207.1158v1 (2011)):

$|q/p|_d = 1.0002 \pm 0.0028$

$A^d_{SL} = (-0.05 \pm 0.56)\%$

In agreement with SM



- 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:

$A^b_{SL} = (-0.028\ ^{+0.005}_{-0.006})\%$

- D0 result on charge Asymmetry of like-sign dimuons differs by 3.9 σ from SM expectation (Phys. Rev. D 84, 052007 (2011)):

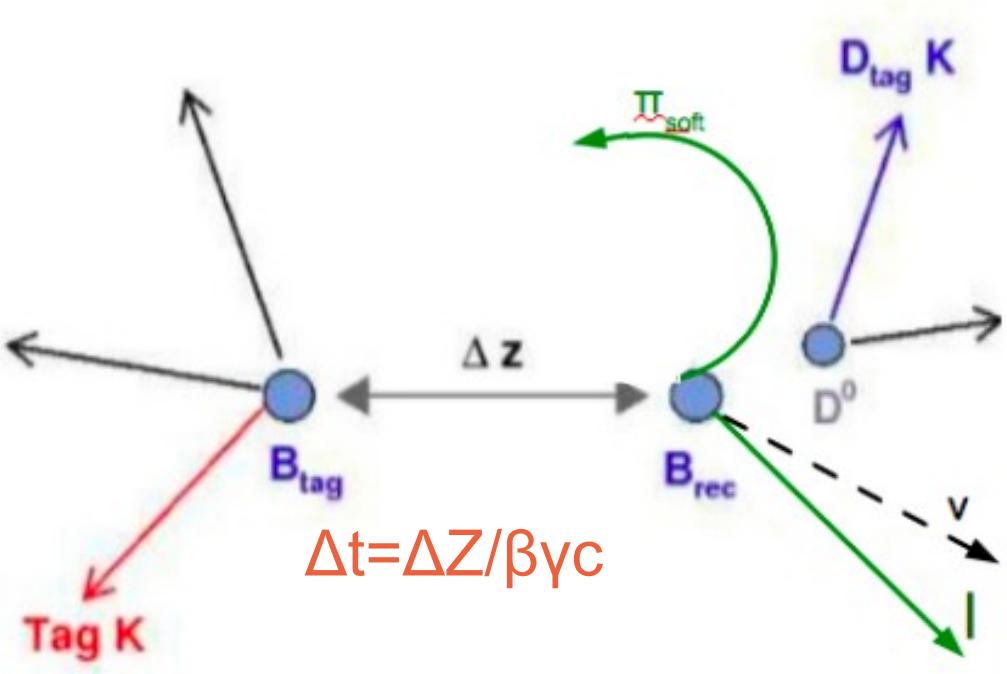
$A^b_{SL} = (-0.787 \pm 0.172 \pm 0.093)\%$

- New results from Beauty-Factories & LHCb will help to understand the tension

Analysis Method

Analysis Method

- Semileptonic Asymmetry measured from Partially Reconstructed $B^0 \to D^* l \nu$ 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

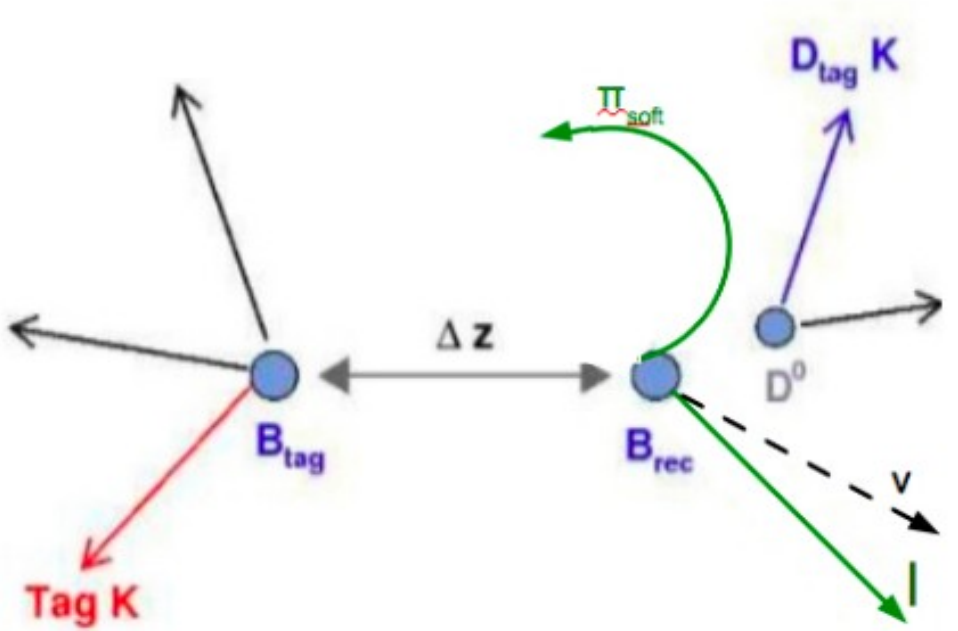
$$A_{SL} \approx \frac{N(\ell^+ K_T^+) - N(\ell^- K_T^-)}{N(\ell^+ K_T^+) + N(\ell^- K_T^-)}$$

- $|q/p|$ obtained using 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^-) using a BLIND Approach

Partial Reconstruction

- P. R. of $B^0 \to D^* l \nu$ already exploited in several measurements (τB^0, Δm,...)
- Reconstruct only lepton & π_{soft} with opposite charge
- Signal selection using missing squared neutrino mass with the approximation of B at rest in the Y(4s) frame
- D* 4-momentum estimated from π_{soft} kinematics
- Sample composition from a fit to $M^2\nu$ by floating D*, D** and Combinatorial using MC shapes and Continuum shape from Off-Peak events
- Residual Peaking ($D^*\tau\nu$, D^*DsX, D^*h) fixed to simulation

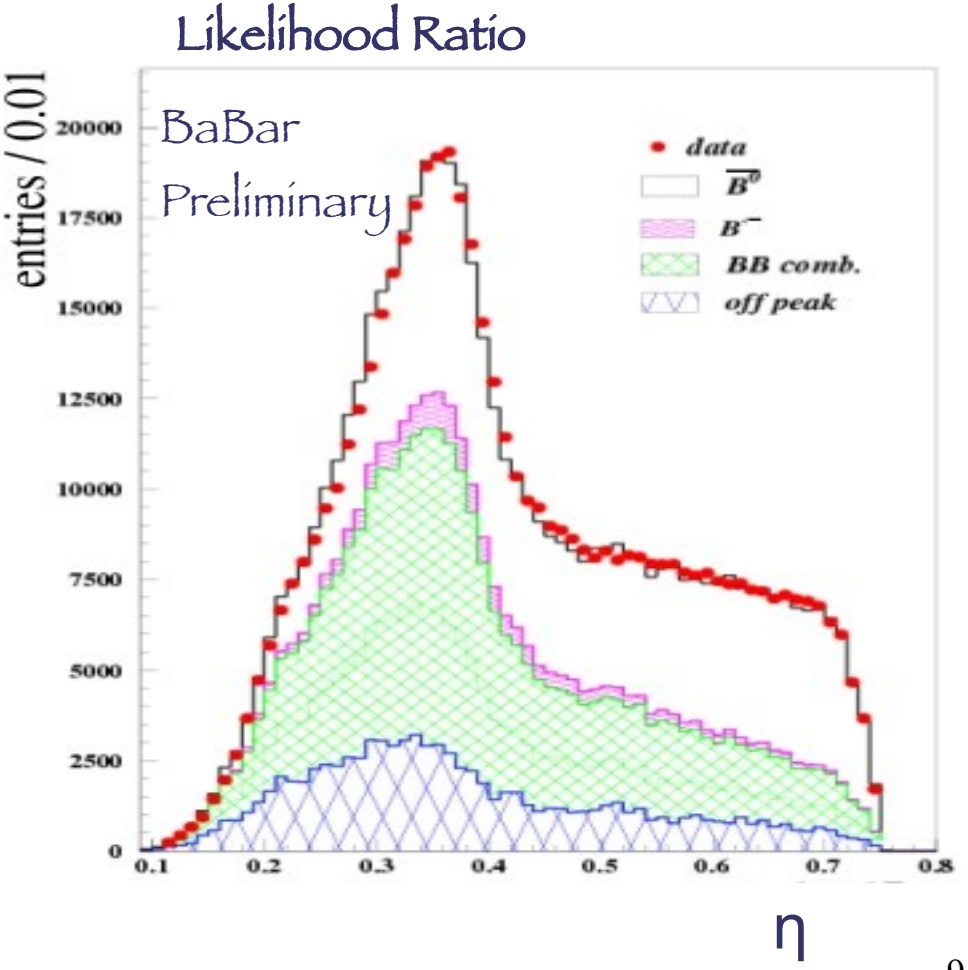


$$M_\nu^2 \equiv (E_{\rm beam} - E_{D^*} - E_\ell)^2 - (\vec{p}_{D^*} + \vec{p}_\ell)^2$$

Selection and Tagging

- Full BaBar statistics of 425.7 fb^{-1} analyzed
- 0.06 GeV/c<$P\pi_{soft}$<0.19 GeV/c; 1.40 GeV/c<$P_{e/\mu}$<2.30 GeV/c

- Best lepton π_{soft} pair per event choosen exploiting Likelihood Ratio η (P_l,$P\pi_{soft}$, Vertex Probability)

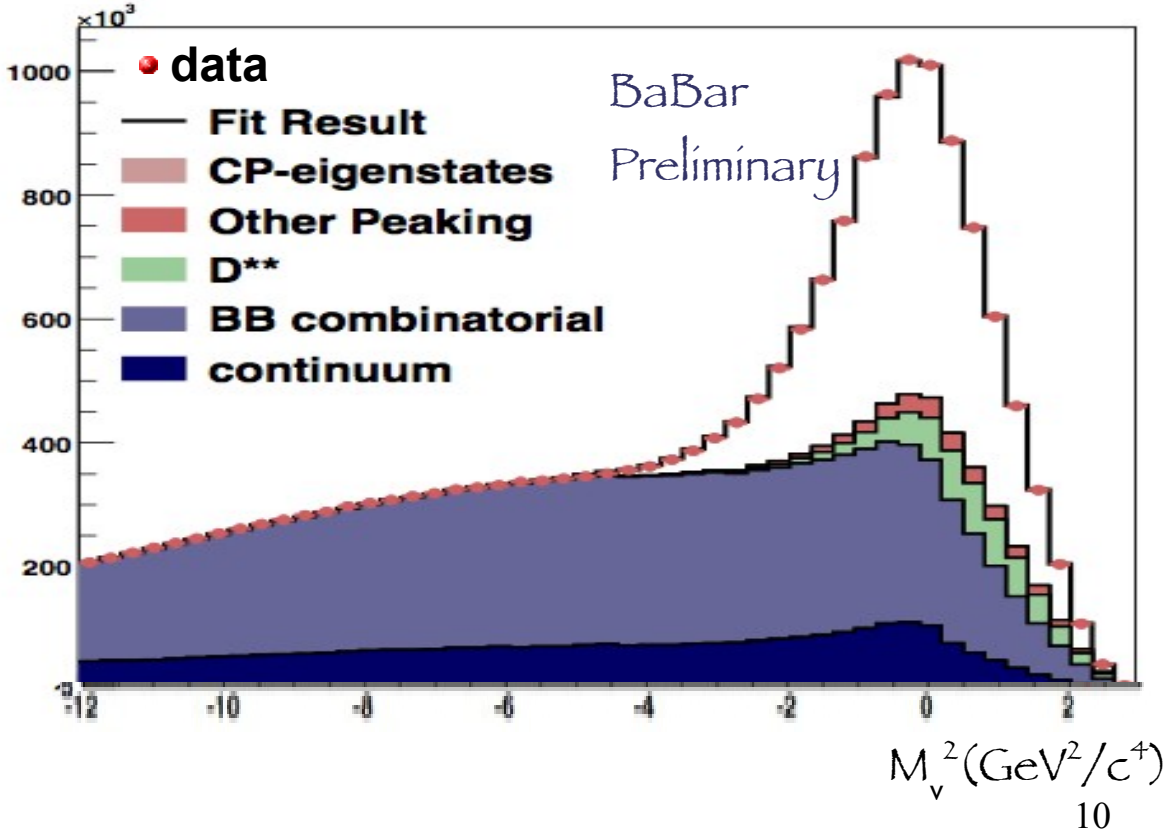


Selection and Tagging

- K selection by means of energy loss & Cherenkov detector information; P_K>0.2 GeV/c
- Continuum and Combinatorial BKG suppressed by means of Event Shape variables & Vertex Probability

→14 x 10^6 events selected with Signal Purity ~30% in the range:

-10 GeV^2/c^4<M^{2}ν<2.5 GeV^2/c^4

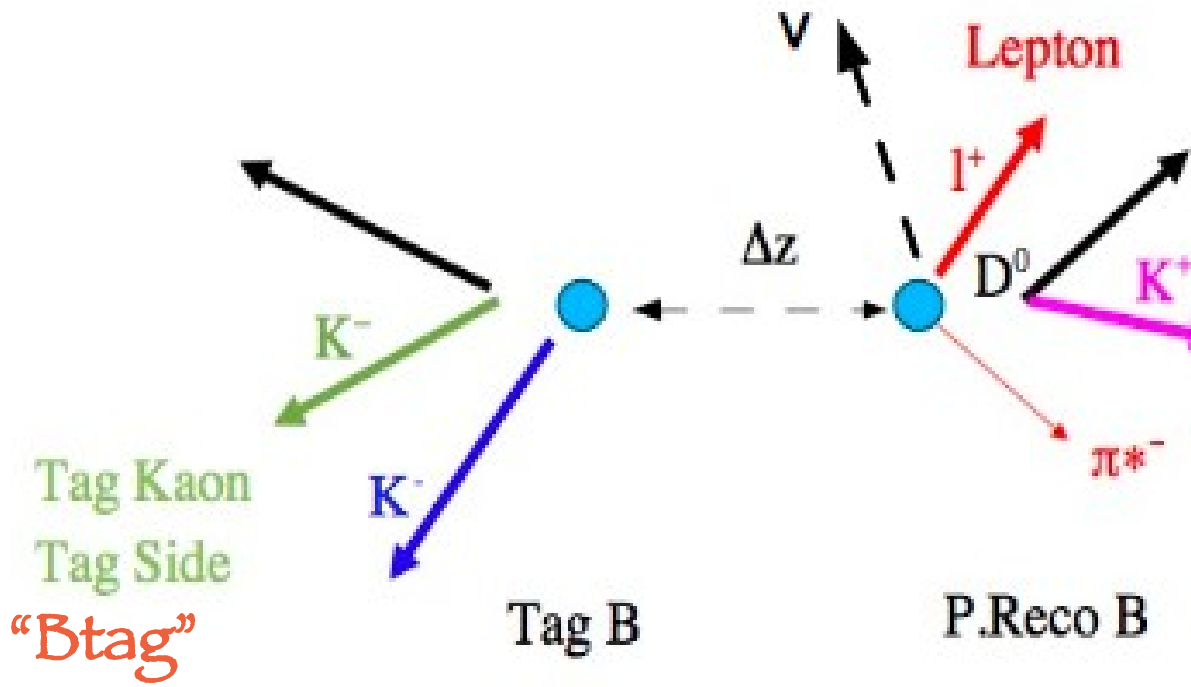


K-Tagging Categories

Tagging Kaon Sample: { b–> K + b–>c–>K
D^0 –> K

From tag B "Btag"

From decay B "Dtag"



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

PDF Description: Btag

- Signal B^0 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

Assumptions:

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

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

PDF Description: Btag

- In Real Life Physics & Detector effects have to be taken into account:
- Physics
  - Mistag, depending on P_K:
    $\omega^+ = \text{Prob}(B^0 \to K^-)$, $\omega^- = \text{Prob}(\overline{B^0} \to K^+)$, $\Delta\omega = \omega^+ - \omega^-$, $\omega = (\omega^+ + \omega^-)/2$

- Detector
  - 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:
    $\tau = \varepsilon(K^+)$, $\bar{\tau} = \varepsilon(K^-)$
    $$A_{tag} = (\tau - \bar{\tau})/(\tau + \bar{\tau})$$
  - **Δt** Resolution

PDF Description: Btag

- Modified PDF for Positive Mixed (l^+K^+) sample including Mistag & Detector Asymmetries, (similar expressions apply for the other ones):

$$\mathcal{F}_\chi^{meas}(\Delta t, s_t = 1, s_m = -1) = \rho\tau\left[(1-\omega_\chi^+)\mathcal{F}_\chi(\Delta t, 1, -1) + \omega_\chi^-\mathcal{F}_\chi(\Delta t, -1, 1)\right] =$$

$$= RT(1+A_{rec})(1+A_{tag})\left[(1-\omega_\chi^+)\mathcal{F}_\chi(\Delta t, 1, -1) + \omega_\chi^-\mathcal{F}_\chi(\Delta t, -1, 1)\right]$$

$$R = (\rho + \bar{\rho})/2$$

$$T = (\tau + \bar{\tau})/2$$

B_{rec} is a	B_{tag} is a	s_t	s_m
B^0	B^0	1	-1
$\overline{B}^0$	B^0	1	1
B^0	$\overline{B}^0$	-1	1
$\overline{B}^0$	$\overline{B}^0$	-1	-1

- Observed PDFs are obtained from the convolution of the modified PDFs with a resolution function (sum of Gaussians convolved with exponentials)

PDF Description: Dtag

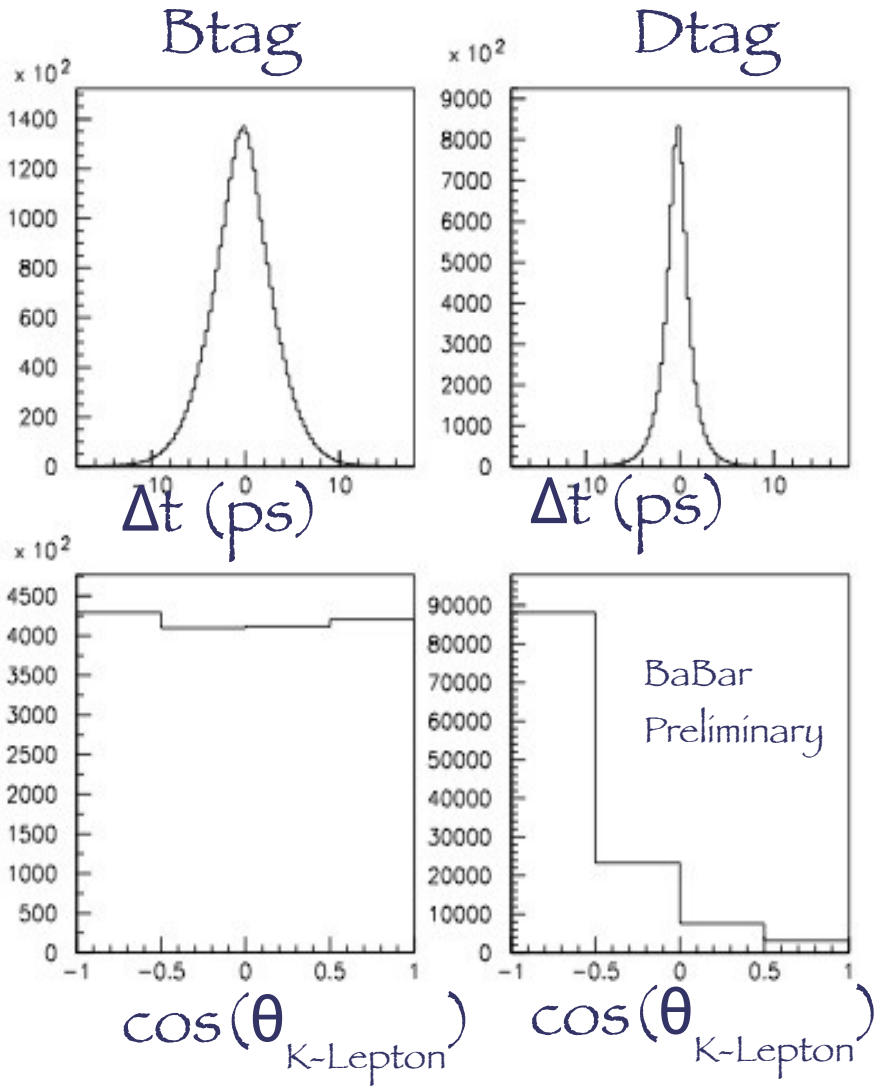
- Dominant BKG in Mixed events: shows single-tag semileptonic asymmetry

- 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%)

PDF Description: Dtag

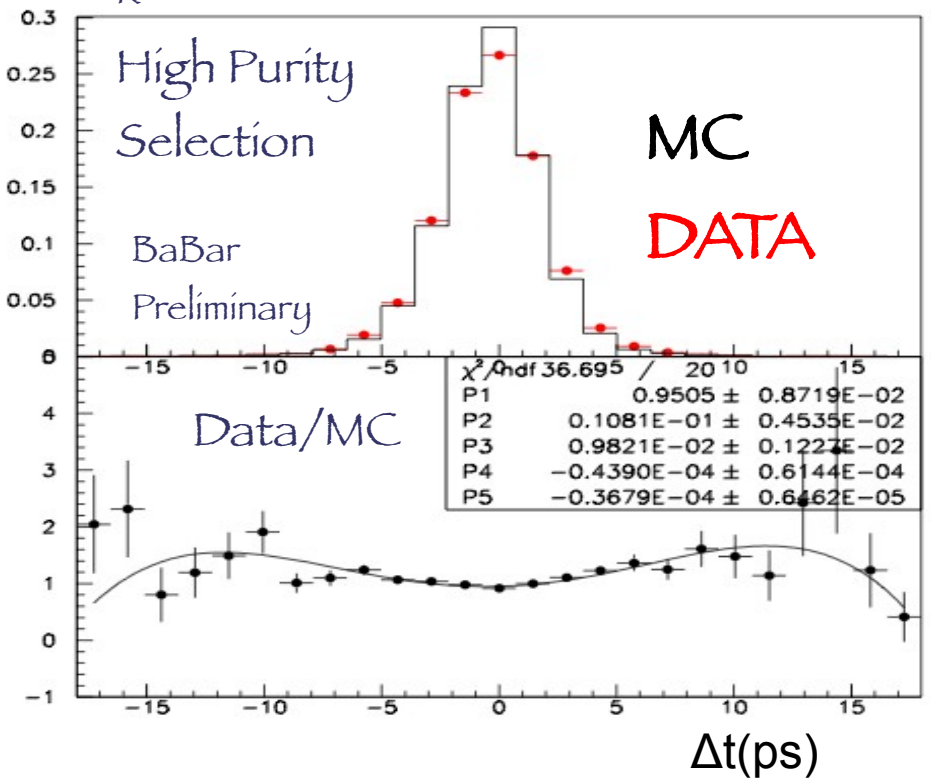
Dtag Δt shape from a High Purity selection, two alternative strategies:

1) $PDF^{DATA} = PDF^{DATA}_{\text{High Purity Selection}}$

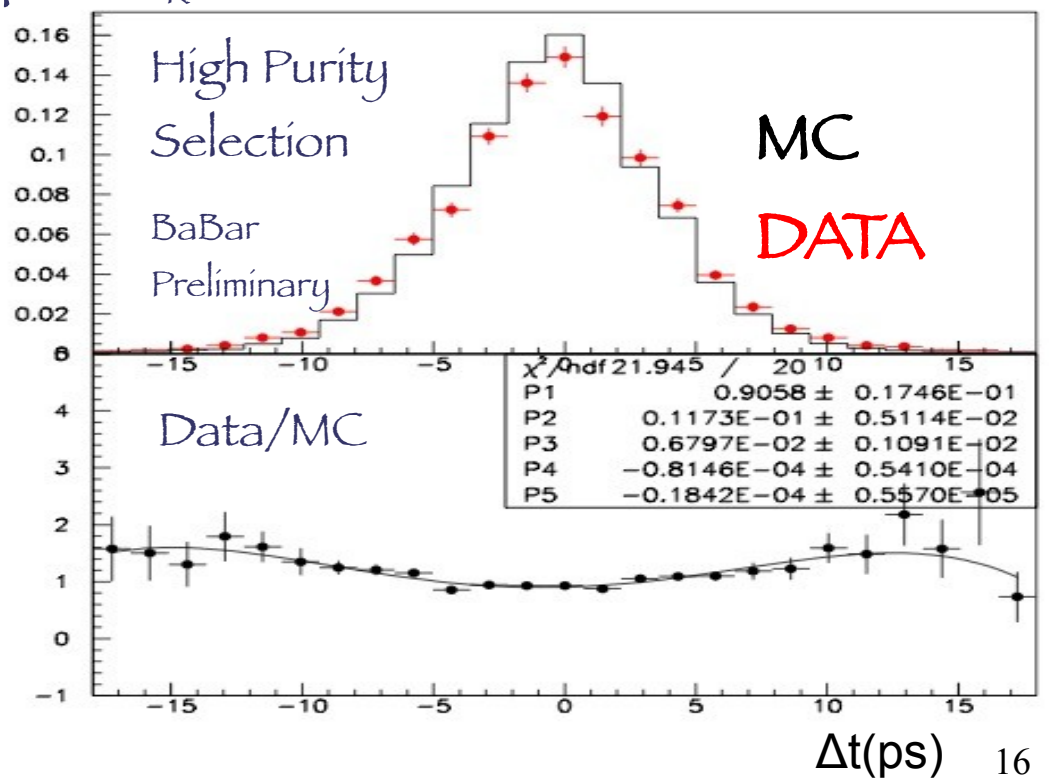
2) $PDF^{DATA} = PDF^{MC} \times (PDF^{DATA}/PDF^{MC})_{\text{High Purity Selection}}$

- Data/MC Corrections computed in bin of (P_K, σΔt)

P_K=[0.2,0.52] GeV/c, σΔt=[1.2,1.8] ps



P_K=[0.2,0.52] GeV/c, σΔt=[2.4,3.0] ps



PDF Description: BKG Samples

- B^0 Combinatorial PDF similar to Signal one with effective τB^0, Δm, same Asl and Atag, different Arec, mistag and resolution parameters.
- B^+ decays parameterized by exponential functions and same resolution model as for B^0 decays.
- Continuum modeled with an exponential with effective lifetime obtained by a simultaneous fit to Off-peak data.
- About 1% of selected events originate from B^0 decays to CP-eigenstates (mostly $D^* D^{(*)}$)
  - Described by:

$$\mathcal{F}_{CP-eigen} = \frac{\Gamma}{4} e^{-\Gamma|\Delta t|} \left[1 \pm S_{eff} \sin(\Delta m_d \Delta t) \pm C_{eff} \cos(\Delta m_d \Delta t)\right]$$

+: P.R. B^0
-: P.R. $\overline{B}^0$

  - Seff & Ceff obtained from the simulation

Detector Asymmetry determination

- Crucial Issue: discriminate between Physical & Detector charge asymmetry **without relying on control samples**

- 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 information from different sub-samples.**

Detector Asymmetry determination

- Observed Asymmetry in the different subsamples:

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

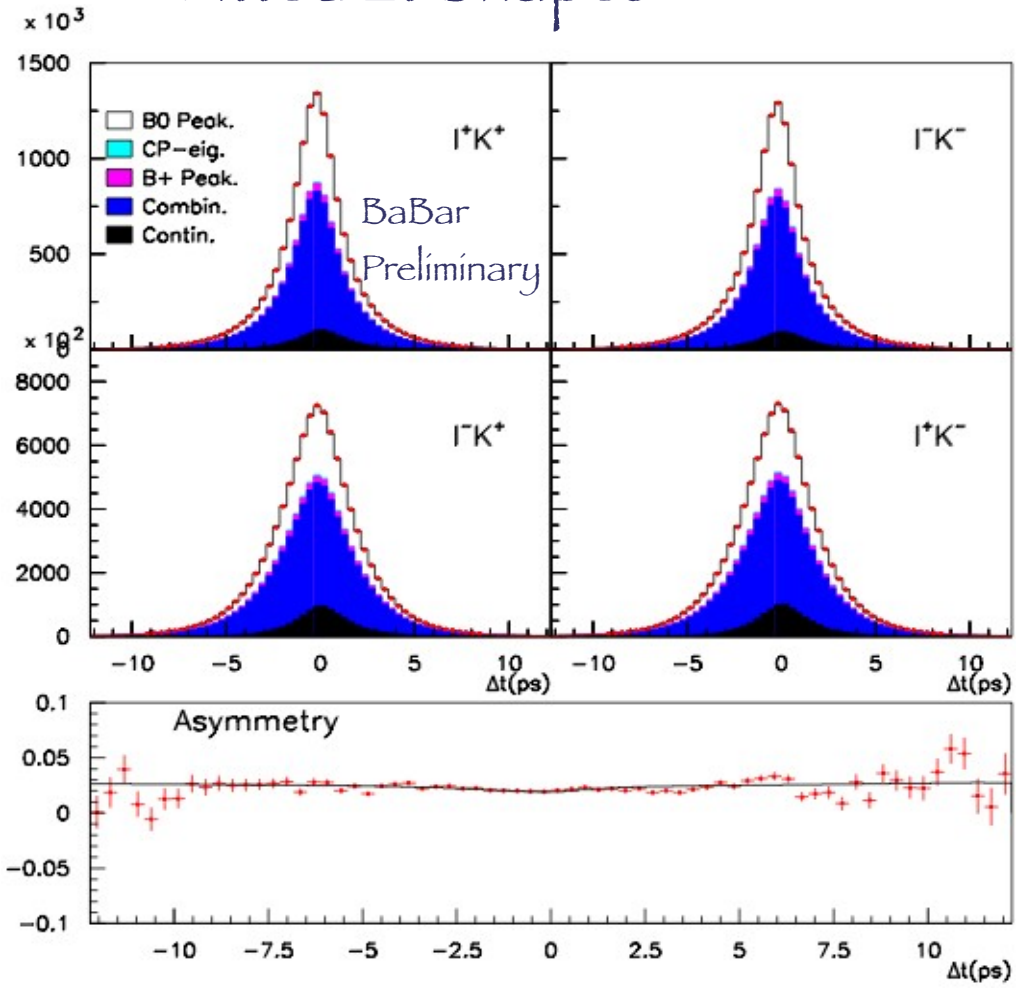
B^+ e Dtag BKG samples are useful in the |q/p| measurement!

MC Validation

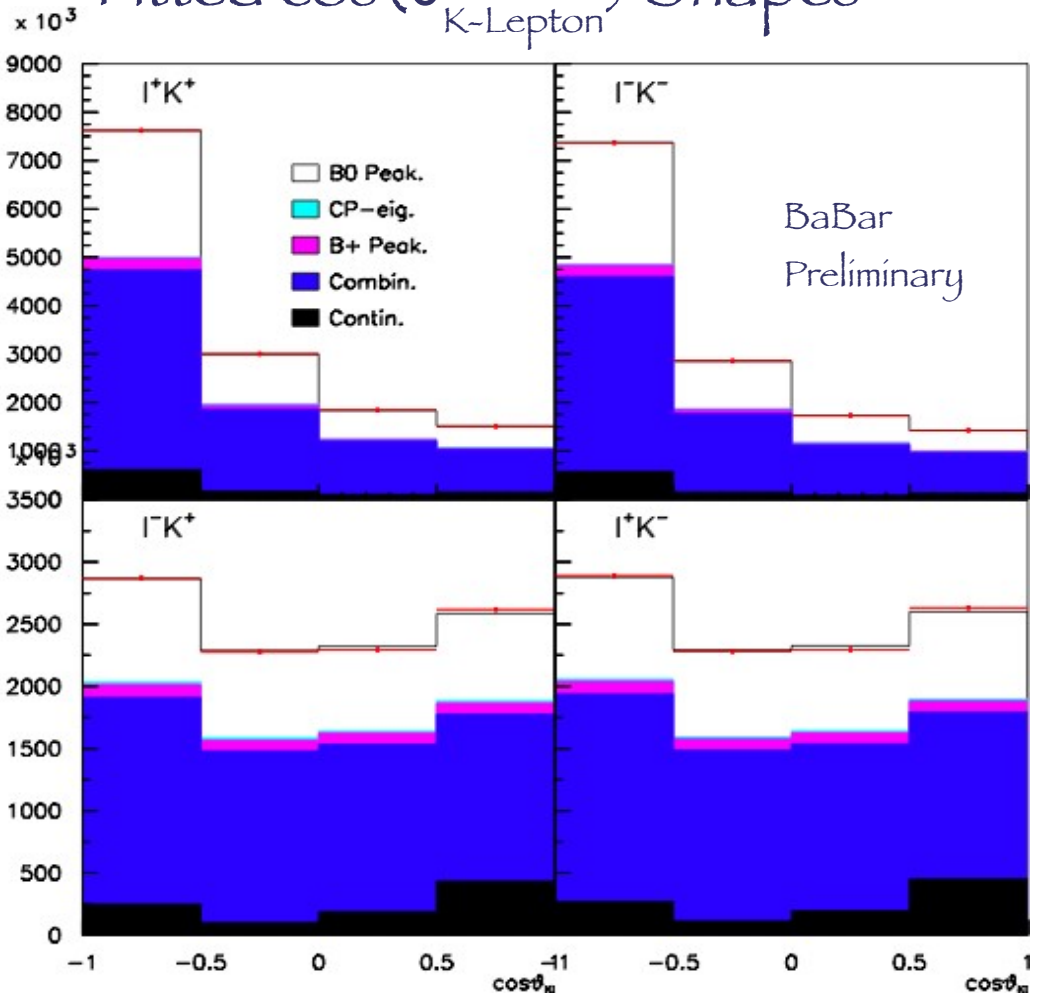
Monte Carlo Results

B^0+B+Continuum MC Fit

Fitted Δt Shapes



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



Raw $N(l^+K^+)/N(l^-K^-)$ Asymmetry

Monte Carlo Results

- Continuum generated with a Parameterized MC using as input the Off-Peak data sample relevant distributions and normalized to the MC statistics.
- Resolution parameters obtained using an iterative procedure and fixed in the final step.
- Total of 171 Fitted Parameters.

B^0+B+Continuum MC Fit Result:

$|q/p|-1=(-0.35\pm0.46) \times 10^{-3}$

No Bias found on MC with $|q/p|=1$

Results on Modified MC with |q/p|≠1

- |q/p| related to Semileptonic Asymmetry:

$$\mathcal{A}_{SL} = \frac{N(B^0B^0) - N(\overline{B}^0\overline{B}^0)}{N(B^0B^0) + N(\overline{B}^0\overline{B}^0)}$$

$$\mathcal{A}_{SL} = \frac{1 - |q/p|^4}{1 + |q/p|^4} \simeq 2\left(1 - \left|\frac{q}{p}\right|\right)$$

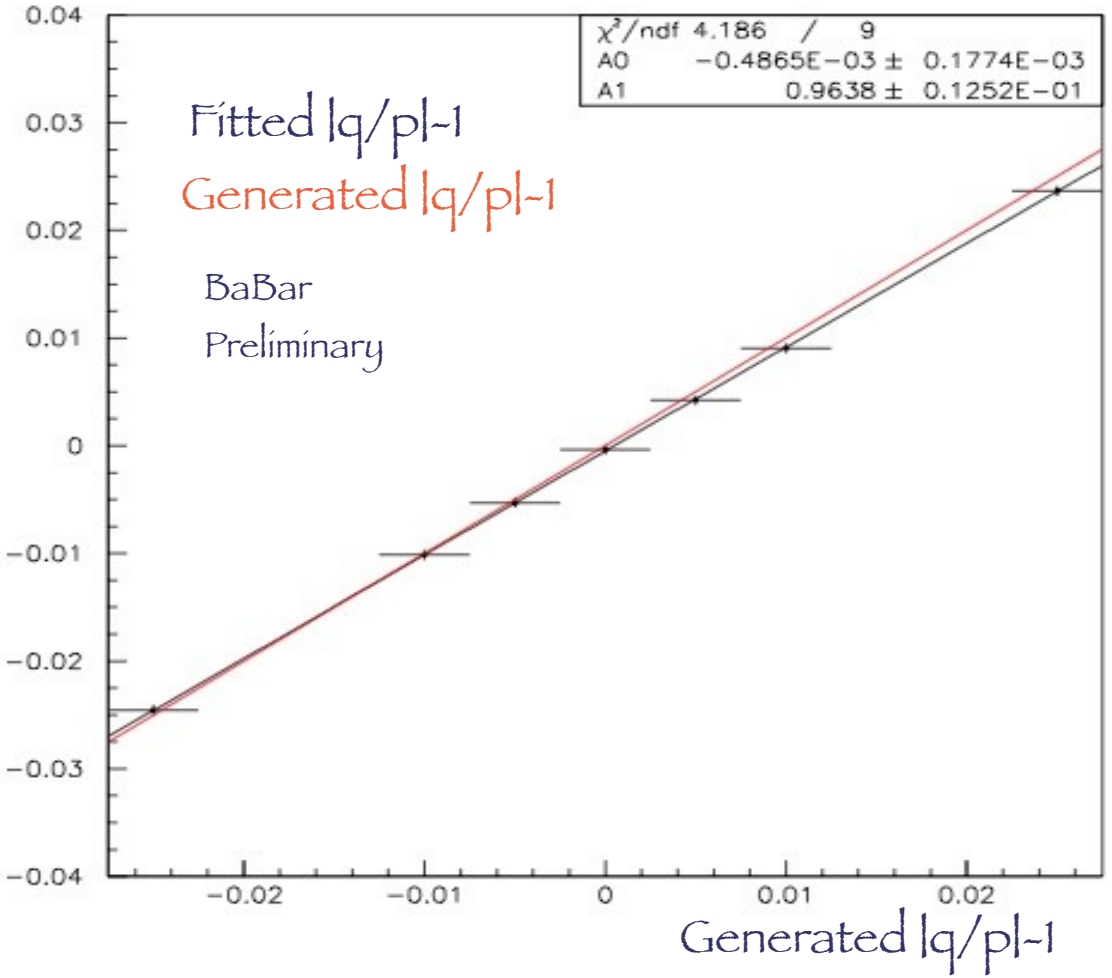
- MC with K=|q/p|-1≠0 obtained by random rejecting a fraction F=4K/(2K+1) of mixed B^0B^0 (K<0) or $\overline{B}^0\overline{B}^0$ (K>0) events
- Fraction F/2 of Unmixed events ($B^0\overline{B}^0$) rejected to preserve the correct value of x_d
- Rejection performed by exploiting the MC truth on B^0 flavor

- Checks: correctness of algorithm, mistag, detector asymmetries and Dtag fraction determination

Fitted vs Generated lq/pl-1

Result obtained on B°+B+Continuum

Full MC Fit



- Slope=0.96: ~4% relative bias on lq/pl-1 found

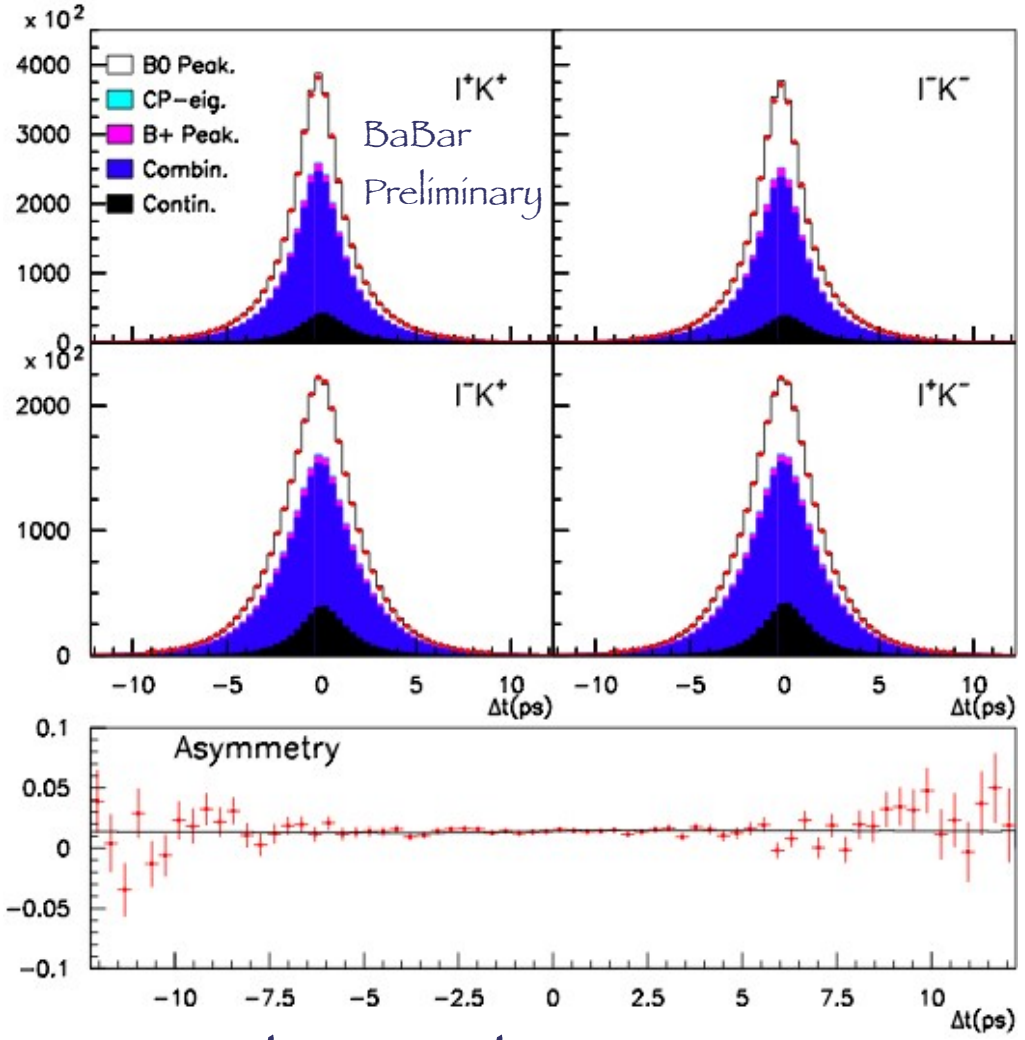
- Effect lower than Data statistical error in a very wide lq/pl range.

- Correction applied to the lq/pl unblinded result.

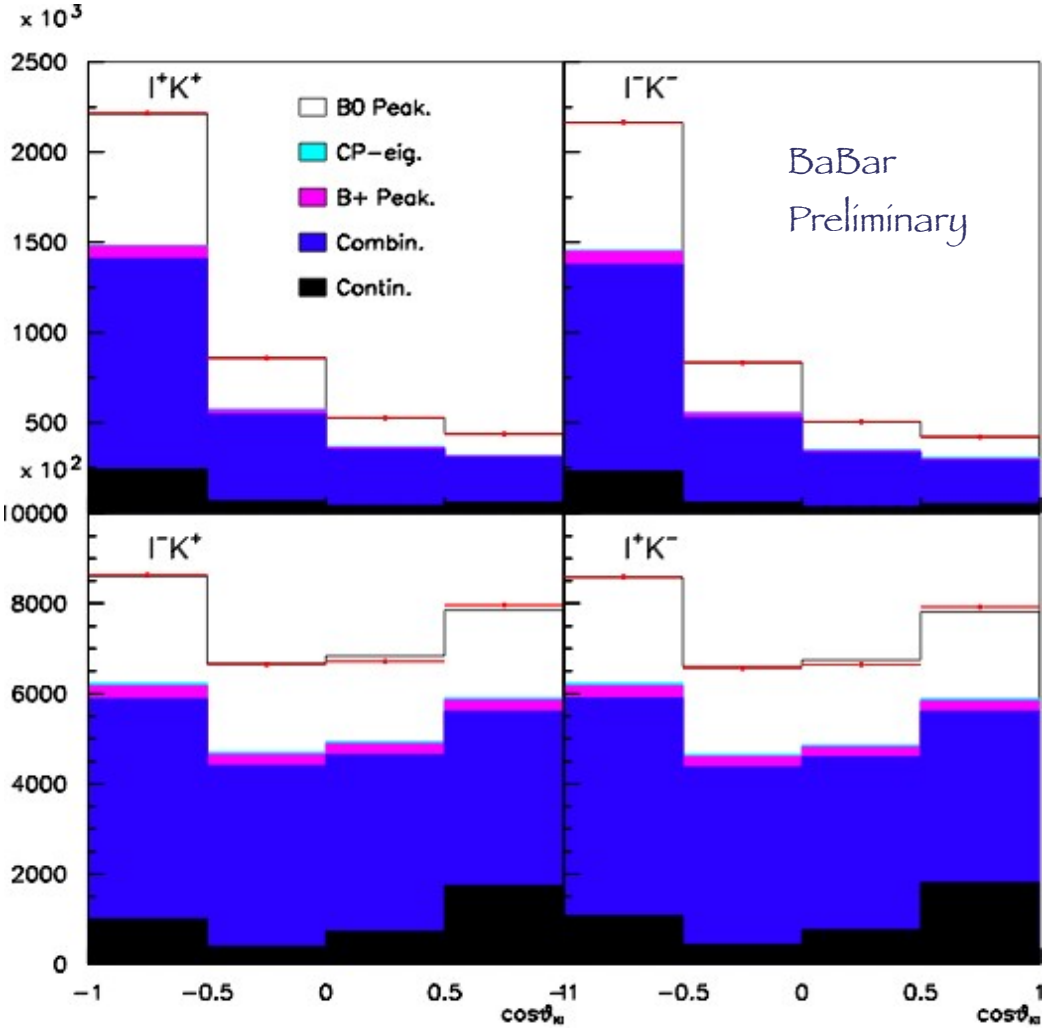
Real Data Results

Real Data Results

Fitted Δt Shapes



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



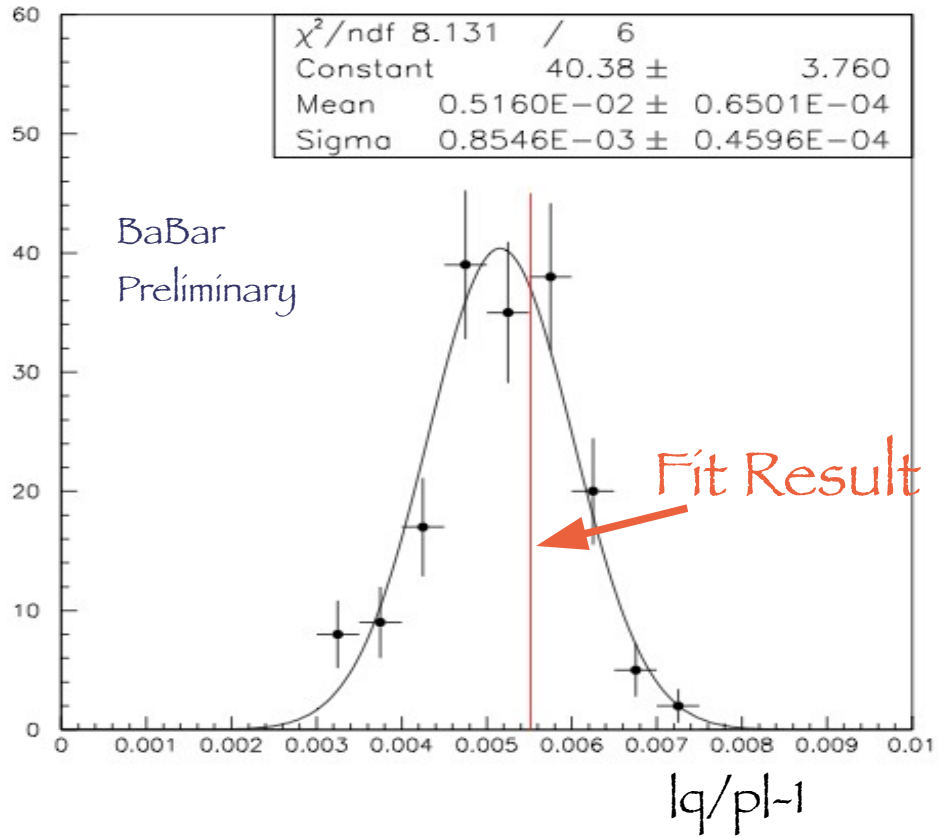
Raw $N(l^+K^+)/N(l^-K^-)$ Asymmetry

Real Data Results

Blind Result

$|q/p|-1=(5.56\pm0.84) \times 10^{-3}$

Pseudo Experiments results



- Result checked using a parameterized simulation by generating several pseudo-experiments (Toy MC)

→ Toy MC Spread in very good agreement with statistical error of the result

→ Bias of $-3.6 \times 10^{-4} < 0.5\ \sigma$ wrt Nominal Fit quoted as systematic error related to analysis bias

Checks & Systematic Uncertainties

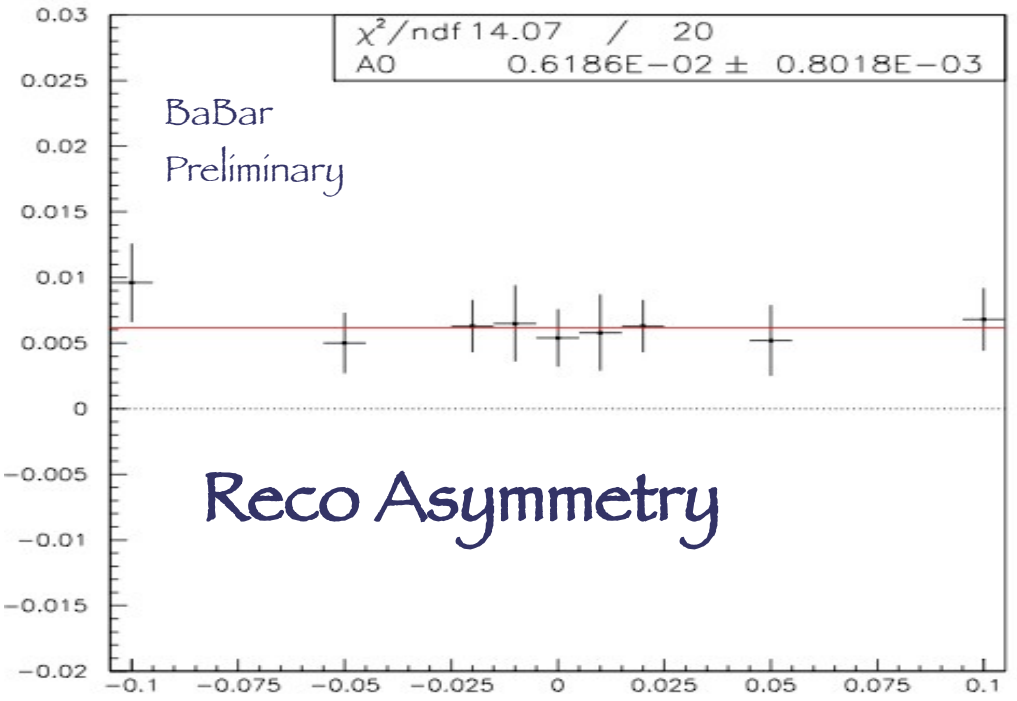
|q/p| vs Detector Asymmetries

- Physical and Detector Asymmetries are strongly correlated

- Test performed to look for possible bias on the |q/p| determination produced by a not correct description of the interconnection between Physical & Detector Asymmetries in the Fit:
  - Modify the data in order to produce an artificial efficiency asymmetry by random rejecting positive or negative leptons/kaons from the selected sample
  - Artificial $|\Delta\varepsilon| = |\varepsilon(l^+\pi^-) - \varepsilon(l^-\pi^+)|$ & $|\varepsilon(K^+) - \varepsilon(K^-)| = 1\%, 2\%, 5\%, 10\%$ produced
  - $|\Delta\varepsilon|$ range of variation very large as compared to PID studies

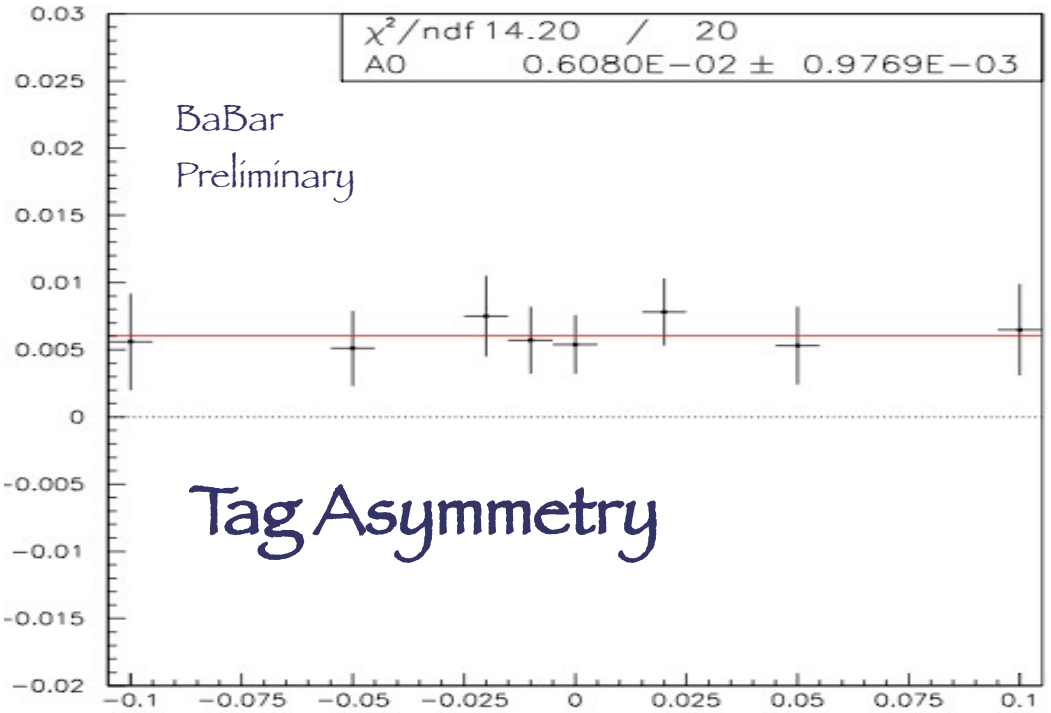
|q/p|-1 vs Δε

Fitted |q/p|-1 BLIND



$\varepsilon(l^+\pi^-) - \varepsilon(l^-\pi^+)$

Fitted |q/p|-1 BLIND



$\varepsilon(K^+) - \varepsilon(K^-)$

- Real Data Uncorrelated Subsamples
- Stable |q/p| behaviour observed in all the Δε range

→ The Fit correctly disentangles Physical vs Detector Asymmetries

Systematic Uncertainties

- Sample Composition determined by an external Fit on M^2_ν by floating D*, D** and Combinatorial using shapes from MC and Off-peak events
  - Statistical error of M^2_ν fit, Uncertainty on Fraction of other Peaking events, CP-eigenstates and B^+ events in the Combinatorial sample
  - $\Delta|q/p| = {}^{+1.23}_{-1.55} \times 10^{-3}$ **Dominant Uncertainty**
- Δt Resolution Model:
  - Fit repeated by leaving free all the Resolution Parameters
  - $\Delta|q/p| = +0.6 \times 10^{-3}$
- Analysis Bias:
  - MC Statistical error plus bias from Toy MC study
  - $\Delta|q/p| = {}^{+0.46}_{-0.58} \times 10^{-3}$

Systematic Uncertainties

- Dtag Δt shape:
  - Semi-difference of the two different strategies (High Purity Sel.)
    - $\Delta|q/p| = \pm 0.65 \times 10^{-3}$
- Dtag Fraction in the B^+ sample:
  - $F^{B+}_{Dtag} = R_{MC} * F^{B0}_{Dtag}$; $R_{MC} = BR(D^{*0} \to K^- X)/BR(D^{*+} \to K^- X)$, $\Delta R_{MC} = 6.8\%$
    - $\Delta|q/p| = \pm 0.11 \times 10^{-3}$
- Physical Parameters floated or fixed to the world averages
  - $\Delta\Gamma = 0/0.02\ ps^{-1}$; $\Delta m = 0.508\,(Fit)/0.507\,(PDG)$
  - $\tau B^0 = 1.553\,(Fit)/1.519\,(PDG)$; $\tau B^+ = 1.76\,(Fit)/1.4\,(PDG)$
    - $\Delta|q/p| = +0.28 \times 10^{-3}$

- **Total Systematics:** $\Delta|q/p| = {}^{+1.61}_{-1.78} \times 10^{-3}$

Conclusions

Unblinded Preliminary Result

Preliminary Systematic Uncertainties

Source	$\Delta\lvert q/p\rvert$
Peaking Sample Composition	$^{+1.17}_{-1.50} \times 10^{-3}$
Combinatoric Sample Composition	$\pm 0.39 \times 10^{-3}$
ΔT Resolution Model	$+0.60 \times 10^{-3}$
Dtag fraction	$\pm 0.11 \times 10^{-3}$
Dtag ΔT distribution	$\pm 0.65 \times 10^{-3}$
Fit Bias	$^{+0.46}_{-0.58} \times 10^{-3}$
CP-eigenstate description	—
Physical Parameters	$+0.28 \times 10^{-3}$
Total	$^{+1.61}_{-1.78} \times 10^{-3}$

After Unblinding:

$$|q/p|-1=(-0.76\pm0.84\ ^{+1.61}_{-1.78})\times10^{-3}$$

After Bias Correction:

$$|q/p|-1=(-0.29\pm0.84\ ^{+1.61}_{-1.78})\times10^{-3}$$

In agreement with SM

Conclusions

- We present a new precise measurement of the parameter governing CP violation in B^0 mixing based on the full BaBar statistics and using a technique exploiting a Partial Reconstruction of $B^0 \to D^* l \nu$ decays and K Tag.

We obtain the preliminary result:

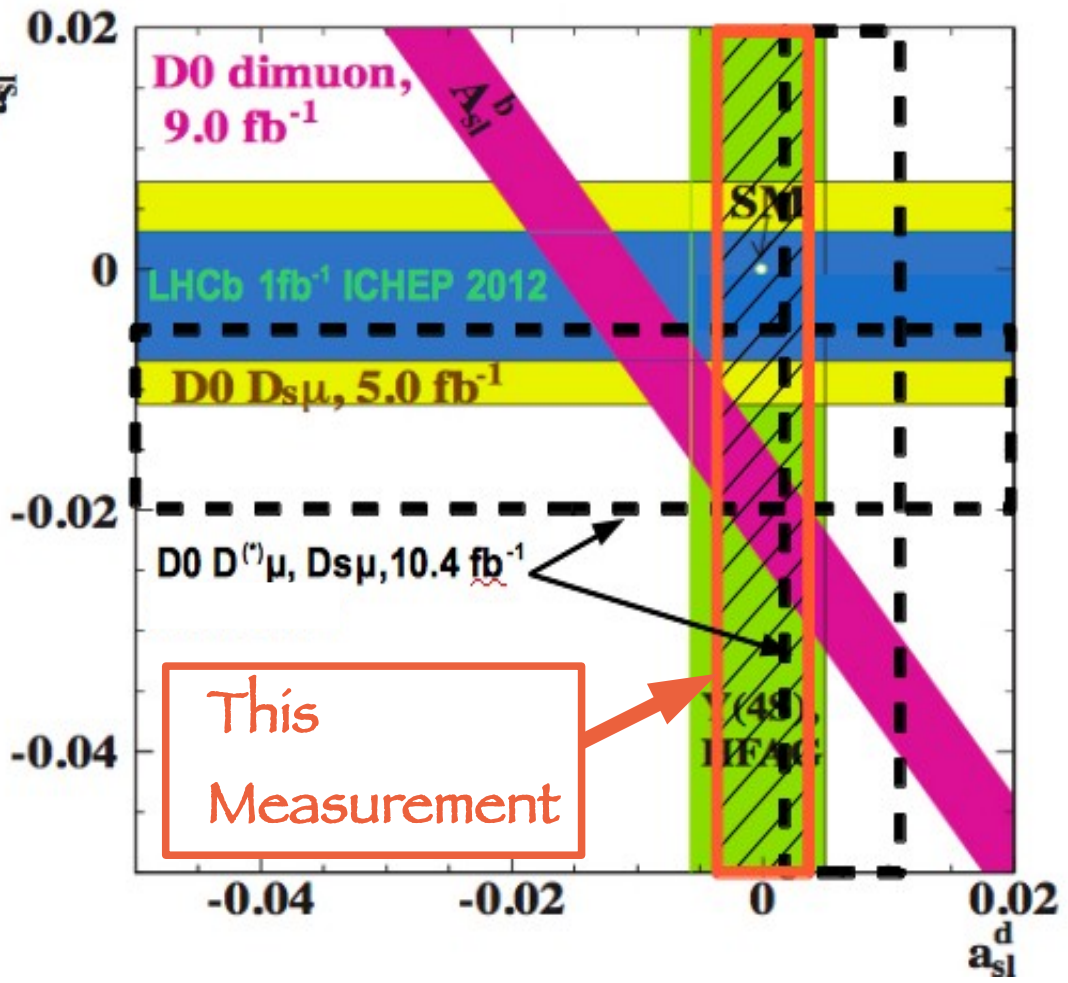
$$|q/p|-1=(-0.29^{+1.82}_{-1.97}) \times 10^{-3}$$

$$A_{sl}=(0.06^{+0.39}_{-0.36})\%$$

To be compared with the current average from B-factories:

$$|q/p|-1=(0.2\pm2.8) \times 10^{-3}$$

$$A_{sl}=(-0.05\pm0.56)\%$$



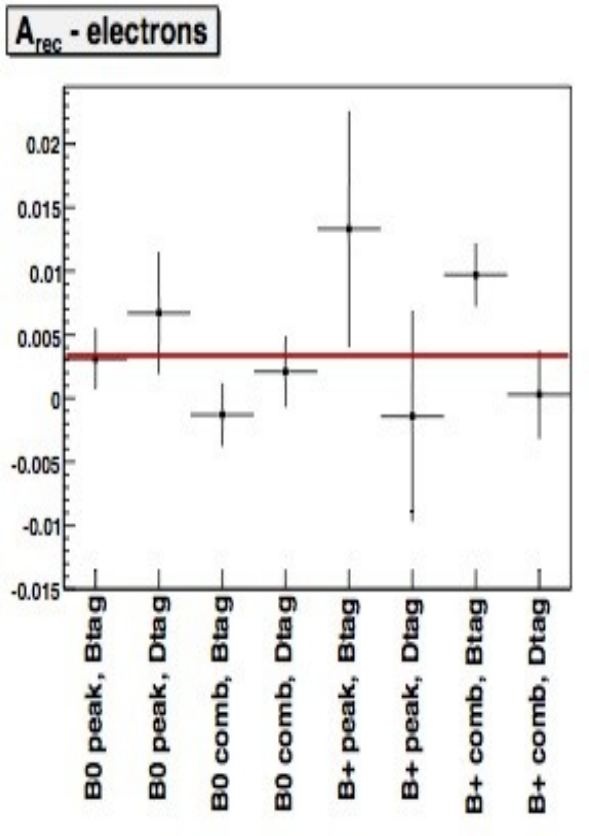
Backup

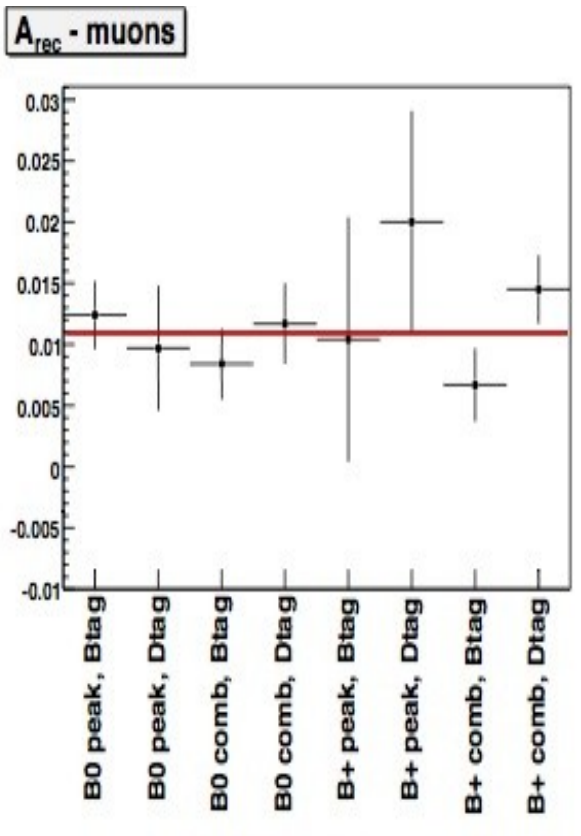
Analysis Strategy

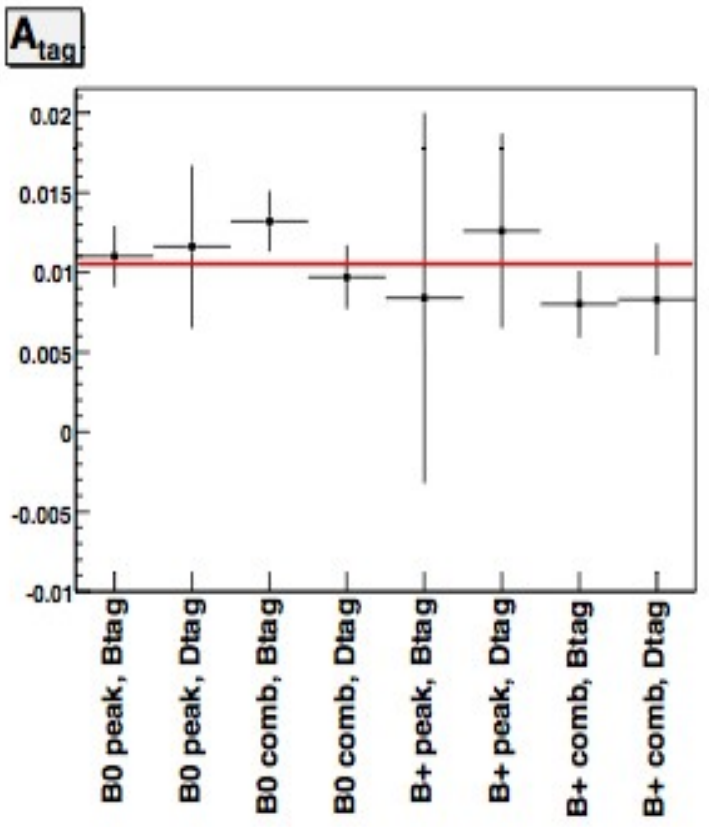
- Hypothesis: same Detector Asymmetries shared by different samples
- Verified on simulation:

$$A_{\ell K} = \frac{N(\ell^+ K^+) - N(\ell^- K^-)}{N(\ell^+ K^+) + N(\ell^- K^-)}$$

	Electrons	Muons
$A_{\ell K}(B_{tag})$	0.0149 ± 0.0013	0.0196 ± 0.0016
$A_{\ell K}(D_{tag})$	0.0152 ± 0.0009	0.0205 ± 0.0010
$A_{\ell K}(B_{tag})$ - $A_{\ell K}(D_{tag})$	-0.0003 ± 0.0016	-0.0009 ± 0.0019







Likelihood Constraints

- Best statistical accuracy on Physical/Detector Asymmetries and mistag obtained by applying to the Likelihood some multiplicative Binomial Constraints

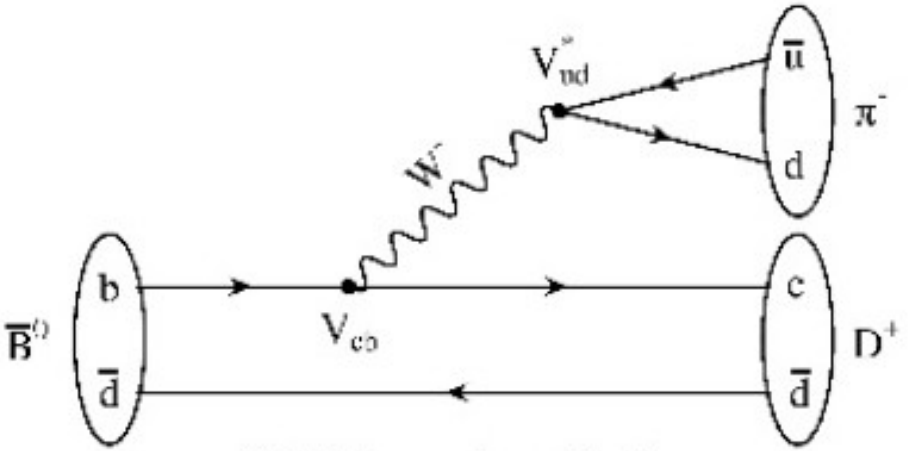
- For every P_K bin of Signal B^0 Btag events, (similar expressions apply for the other samples):

$$C(\omega, Arec, Atag, |q/p|) = \binom{N}{N_M} p_M^{N_M} (1-p_M)^{N_U} \times$$

$$\binom{N_M}{N_{MK+}} p_{MK+,M}^{N_{MK}+} (1-p_{MK+,M})^{N_{MK}-} \binom{N_U}{N_{UK+}} p_{UK^+,U}^{N_{UK}+} (1-p_{UK^+,U})^{N_{UK}-}$$

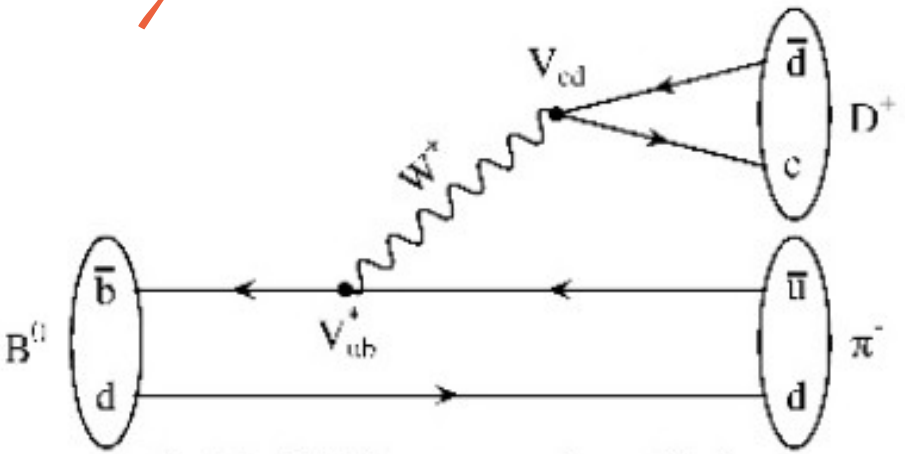
- $N = N_{Mixed} + N_{Unmixed}$; $N_{Mixed} = N_{Mixed\ K+} + N_{Mixed\ K-}$; $N_{Unmixed} = N_{Unmixed\ K+} + N_{Unmixed\ K-}$
- Probabilities p_{XY} obtained from integrals of the relevant observed PDF(Δt) in terms of mistag, Physical and Detector Asymmetries
- 8 Detector-Asymmetry parameters floated in the fit

DCS Decays



CKM-favored amplitude

$\overline{\mathcal{A}}_{CF}$



doubly-CKM suppressed amplitude

$\mathcal{A}_{DCS}$

$$r' = \left|\overline{\mathcal{A}}_{DCS}/\mathcal{A}_{CF}\right|$$

$$\mathcal{A}_{CF} = \overline{\mathcal{A}}_{CF} = |\mathcal{A}_{CF}|\, e^{i\delta_c}$$

$$\overline{\mathcal{A}}_{DCS} = r'\,|\mathcal{A}_{CF}|\, e^{i\delta_u} e^{i\gamma}$$

$$\mathcal{A}_{DCS} = r'\,|\mathcal{A}_{CF}|\, e^{i\delta_u} e^{-i\gamma}$$

δc,δu: strong phases of CF, DCS

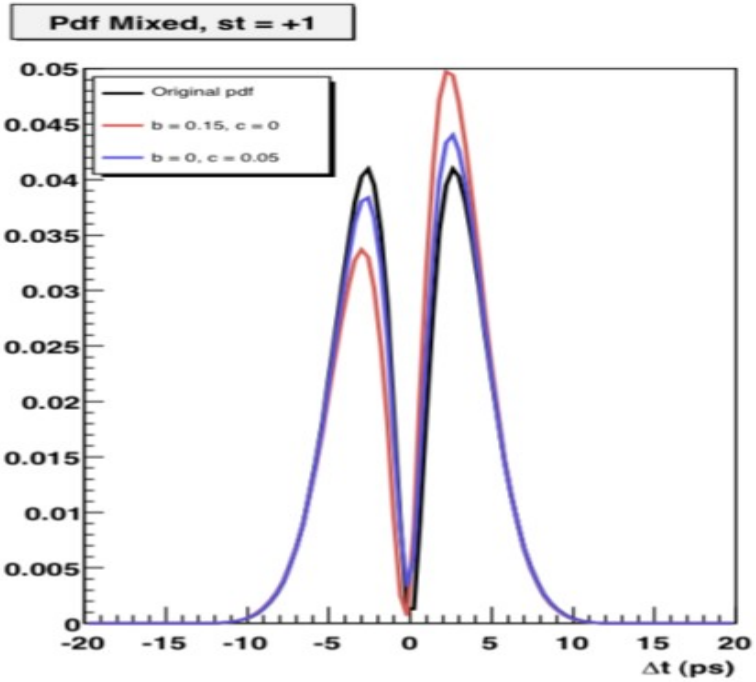
γ: relative weak phase between the two decays

$$\frac{q}{p} = \left|\frac{q}{p}\right| e^{-2i\beta}$$

$$b = 2r' \sin(2\beta+\gamma)\cos\delta'$$

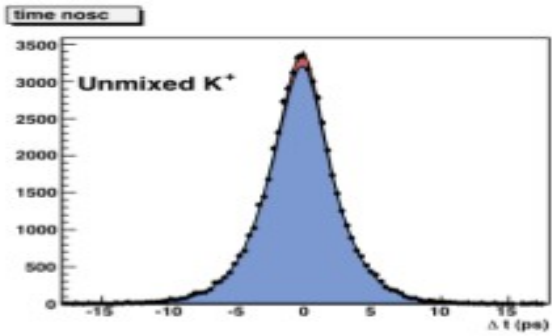
$$c = -2r' \cos(2\beta+\gamma)\sin\delta'$$

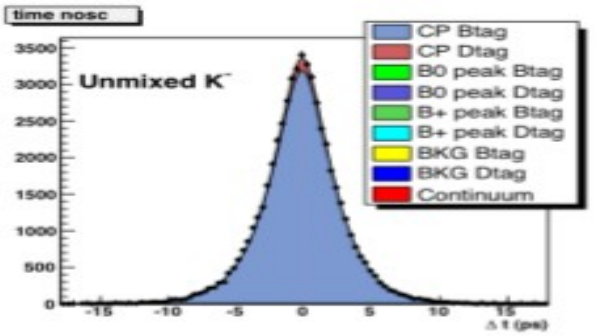
$$\delta' = \delta_u - \delta_c$$



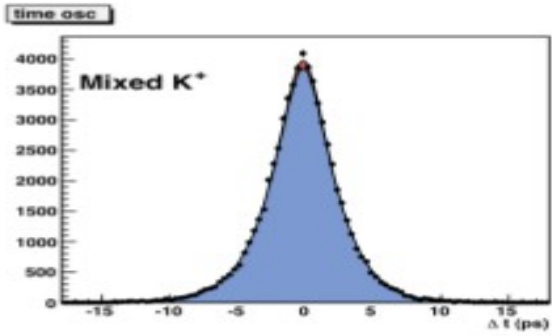
CP-eigenstates

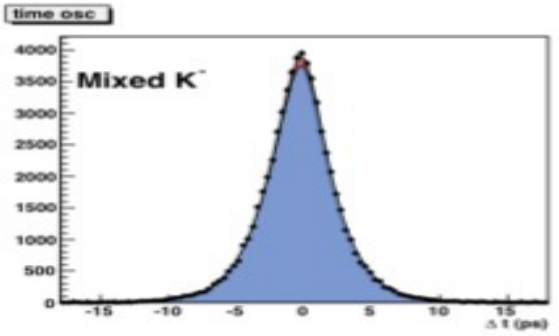
$$\mathcal{F}_{CP-eigen} = \frac{\Gamma}{4} e^{-\Gamma|\Delta t|}\left[1 \pm S_{eff}\sin(\Delta m_d \Delta t) \pm C_{eff}\cos(\Delta m_d \Delta t)\right]$$

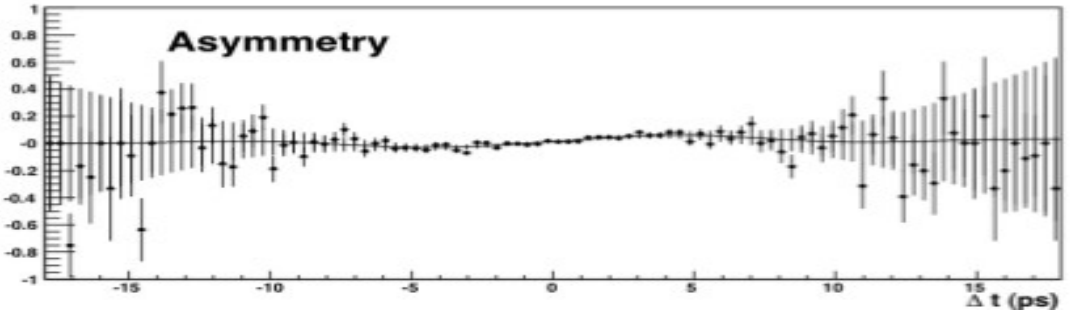




Parameter	Fit result
C_{eff}	-0.0110 ± 0.0066
S_{eff}	-0.0886 ± 0.0056



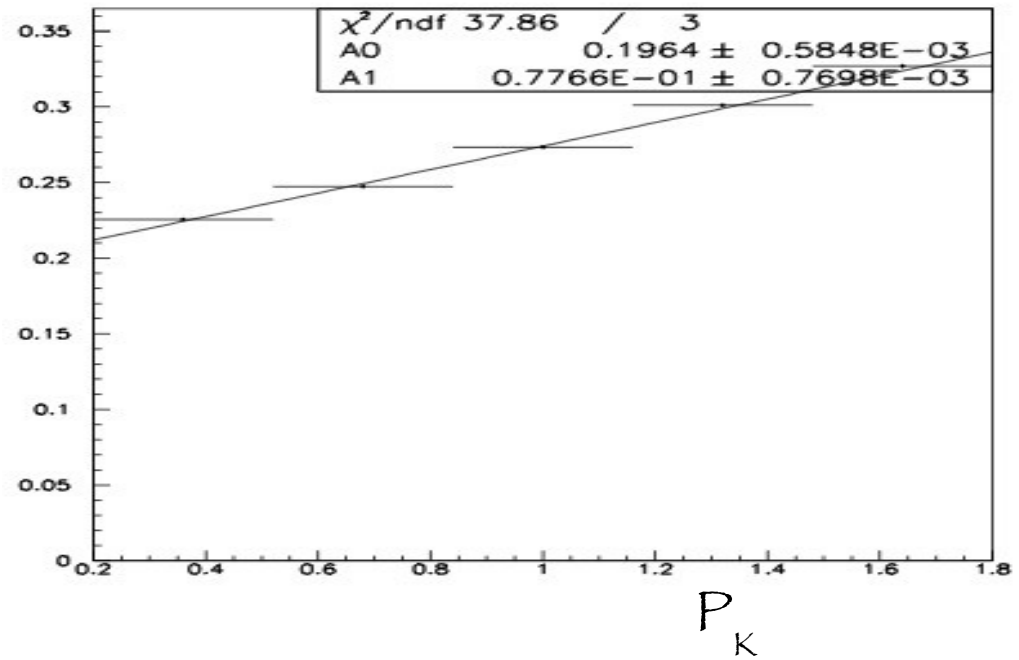




B^0 Combinatorial: Effective χ_d

- Due to charge correlation between Lepton & π_{soft}, B^0 Combinatorial Sample shows a higher fraction of mixed events wrt Signal
- In BKG events it's possible to pick up Lepton & π_{soft} from the two different B^0 decays (more probable in "Mixed" events).

→ $\langle \chi_d(BKG) \rangle \sim 1.4\, \chi_d(SIG)$ depending on P_K



- B^0 BKG Observed PDF modified to include this effect

- 27 mistag & effective mixing parameters floated

B^0 Combinatorial: Mistag vs Effective χ_d

- Combinatorial BKG B^0 Btag PDF for Positive Mixed (l^+K^+) sample, (similar expressions apply for the other ones):

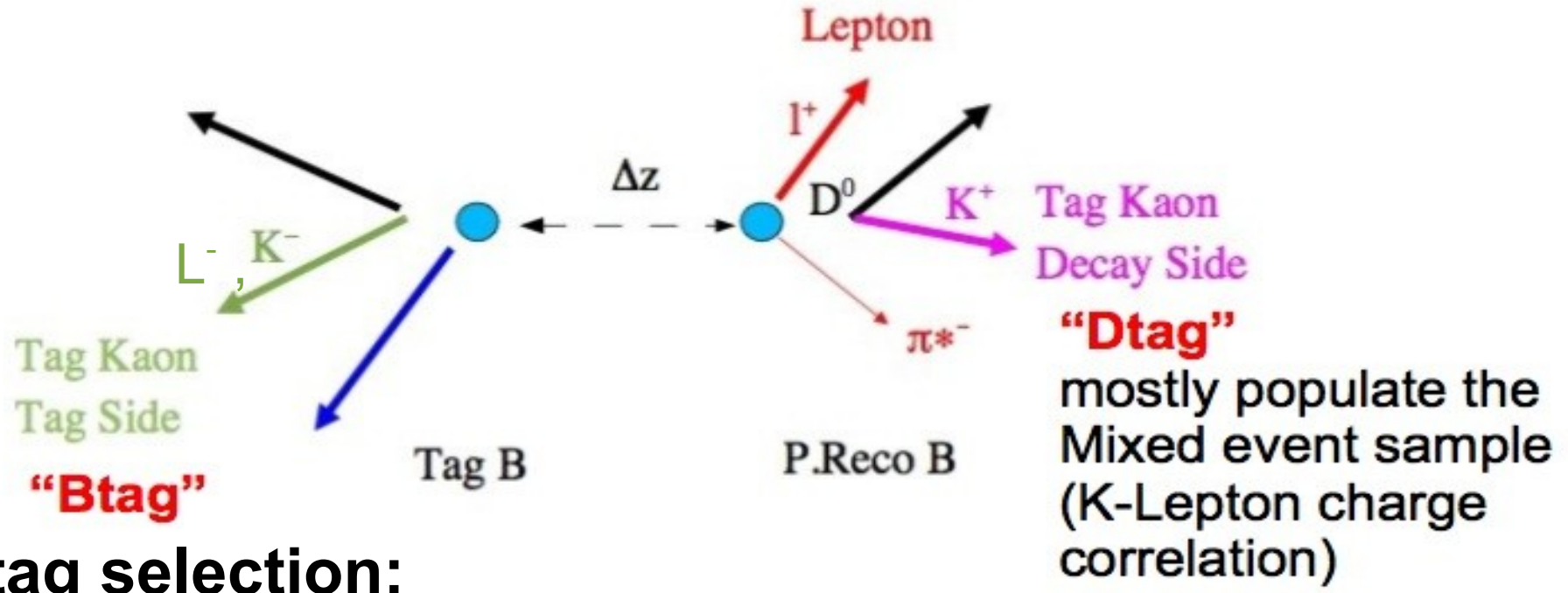
$$\mathcal{F}_\chi^{meas}(\Delta t, s_t = 1, s_m = -1) = \rho\tau \left[(1-\omega_\chi^+)\frac{\chi_d^{Bkg}}{\chi_0^{Bkg}}\mathcal{F}_\chi(\Delta t, 1, -1) + \omega_\chi^- \frac{1-\chi_d^{Bkg}}{1-\chi_0^{Bkg}}\mathcal{F}_\chi(\Delta t, -1, 1) \right] =$$

$$= RT(1+A_{rec})(1+A_{tag}) \left[(1-\omega_\chi^+)\frac{\chi_d^{Bkg}}{\chi_0^{Bkg}}\mathcal{F}_\chi(\Delta t, 1, -1) + \omega_\chi^- \frac{1-\chi_d^{Bkg}}{1-\chi_0^{Bkg}}\mathcal{F}_\chi(\Delta t, -1, 1) \right]$$

$$\chi_d^{Bkg}(P_K) = \chi_0^{Bkg} \times (a + bP_K)$$

$$\chi_0^{Bkg} = \frac{x_{Bkg}^2}{2(1+x_{Bkg}^2)}, \text{ where } x_{Bkg} = \tau_{B^0}^{Bkg}\Delta m_d^{Bkg}$$

High Purity Dtag Selection



Dtag selection:

- Look for same charge (L^+_{Reco}, K^+) pairs
- Opposite charge Tag Lepton L^- required to suppress Btag Mixed events B->K^+
- (L^+_{Reco}, L^-_{Tag}, K^+) sample has Dtag-Purity=87%
- 13% Residual Btag contamination from Tag Side B->D->K^+, Tag Side B->D->L^-, Reco Side B->D->L^-
- Purity can be increased from 87% to **94% (ε~5%)** by requiring K tracks to be assigned to Reco Side according to some angular variables included in a likelihood ratio

Δt Dtag PDF Determination on Real Data

Strategy:

- **High-Purity Dtag selection optimized with Purity =94%, ε~5%**

- Perform the same Dtag selection on MC & Real Data (OnPeak & OffPeak)

- Subtract residual Continuum BKG from OnPeak using Luminosity-rescaled selected OffPeak events

- Subtract residual Btag events (~6%) using MC predictions

- **Compute Real Data PDFs for the four different Dtag classes (B^0, B^+)X(Peaking, BKG):**

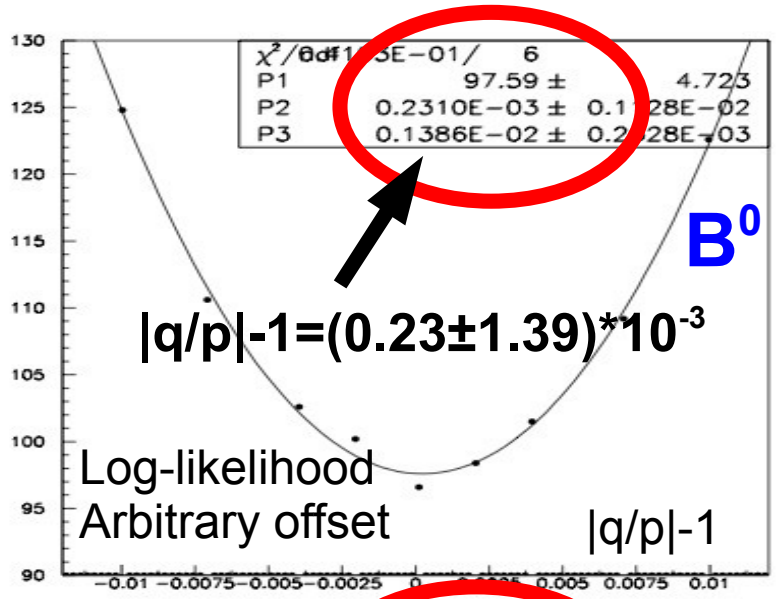
$$PDF^{DATA}_{Class\ i} = PDF^{MC}_{Class\ i} * (PDF^{DATA}/PDF^{MC})_{High\ Purity\ Selection}$$

- Method checked on MC using Standard vs High Purity Selection PDFs

MC Dtag Δt PDF: Standard vs High Purity Selection

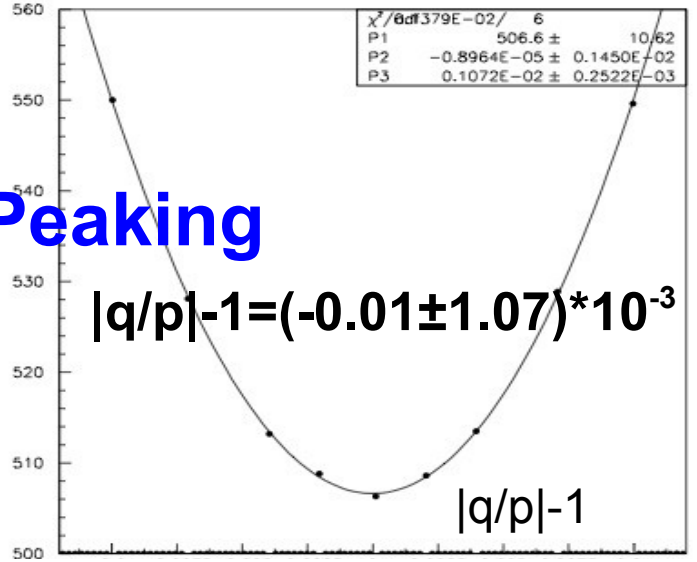
•Comparison of MC Fit results using the Standard or High Purity PDFs:

Standard PDF | **High Purity Selection** | **δ|q/p|**



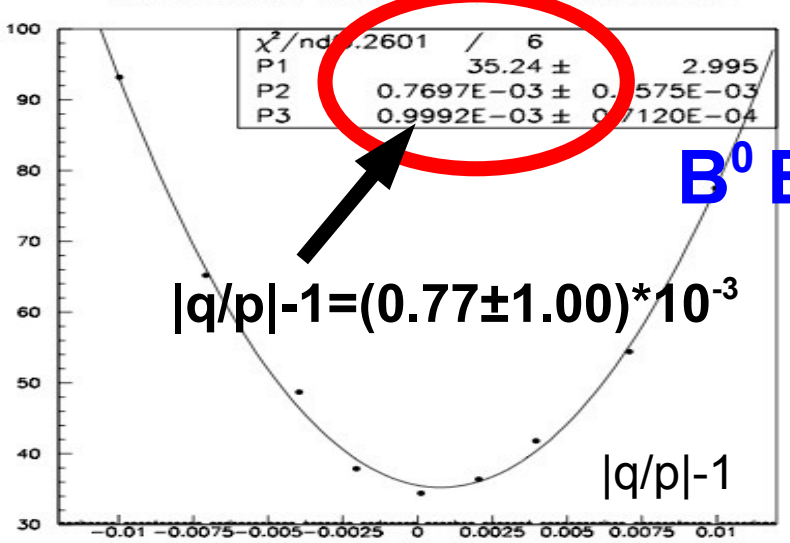
B^0 Peaking

|q/p|-1=(0.23±1.39)*10^{-3}



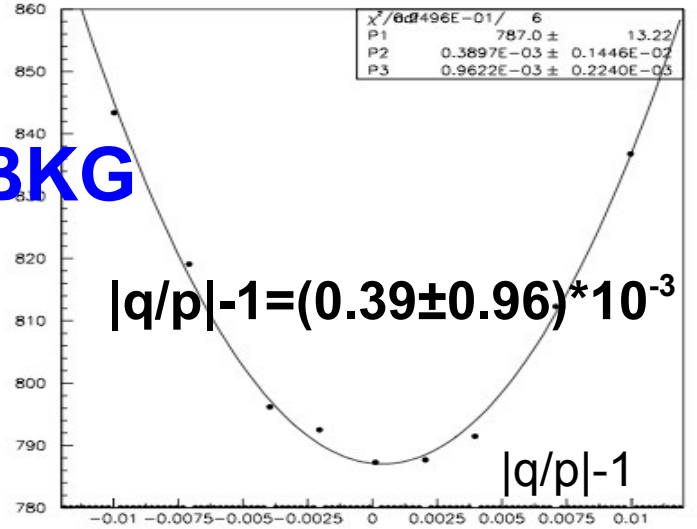
|q/p|-1=(-0.01±1.07)*10^{-3}

-0.24*10^{-3}



B^0 BKG

|q/p|-1=(0.77±1.00)*10^{-3}



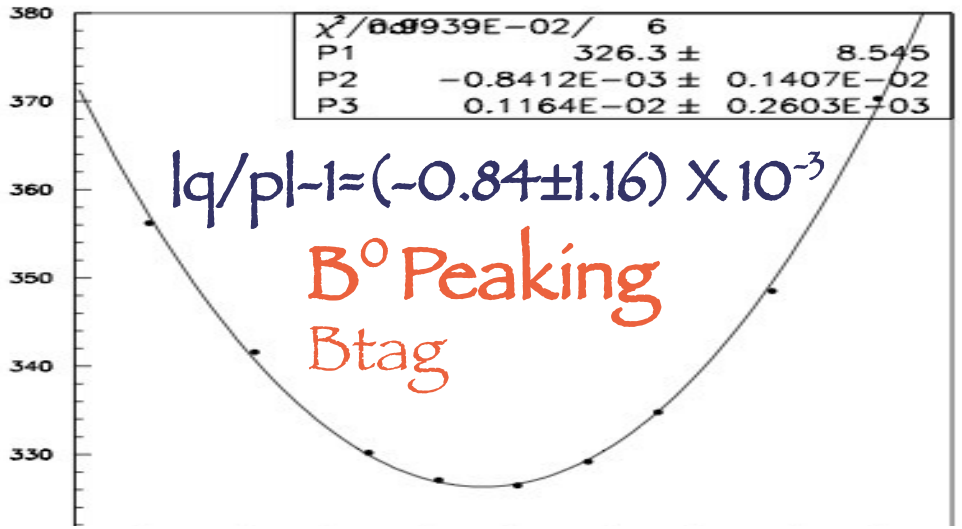
|q/p|-1=(0.39±0.96)*10^{-3}

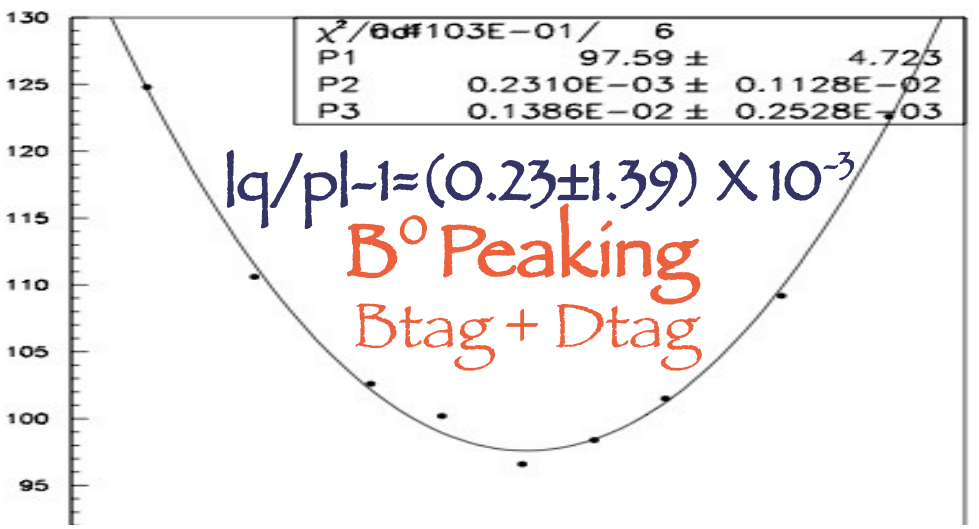
-0.38*10^{-3}

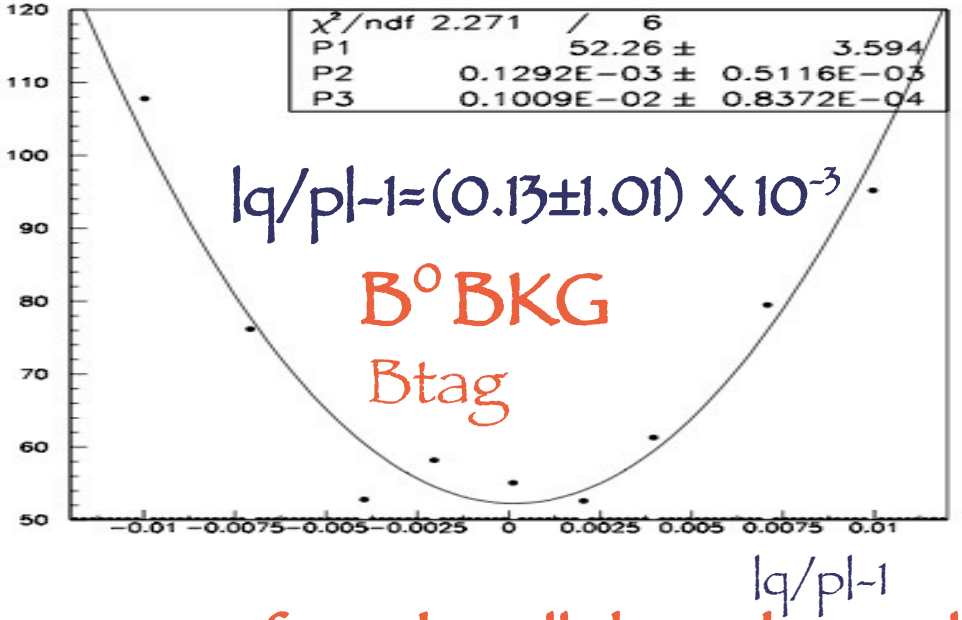
Effect~1/3 of MC Statistical σ

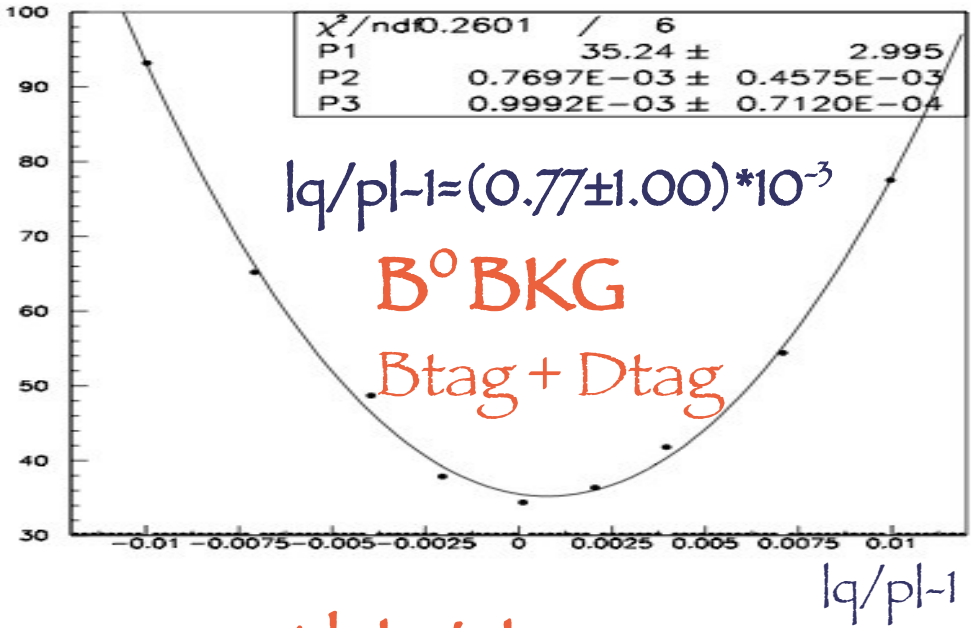
MC Results on different B^0 subsamples

Likelihood Profiles with Arbitrary Offsets



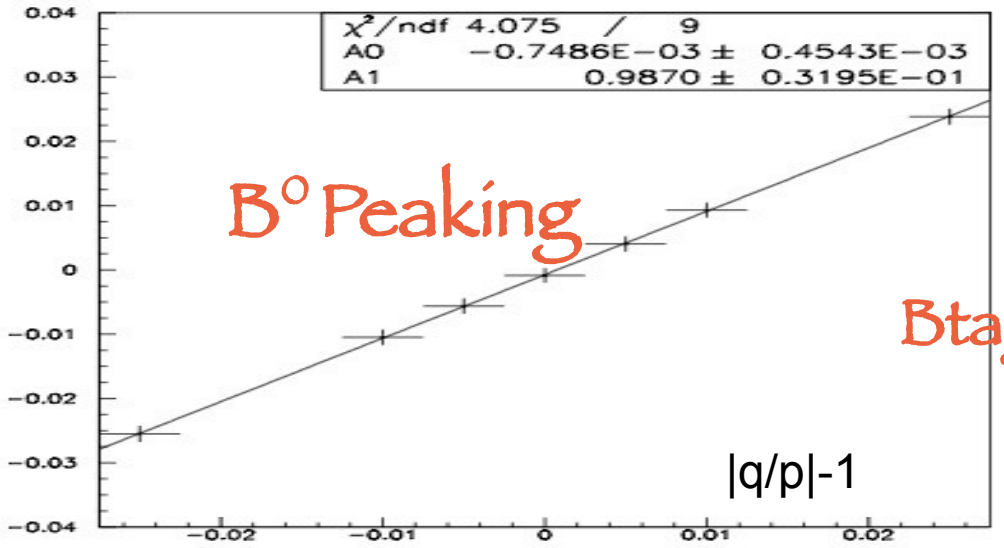


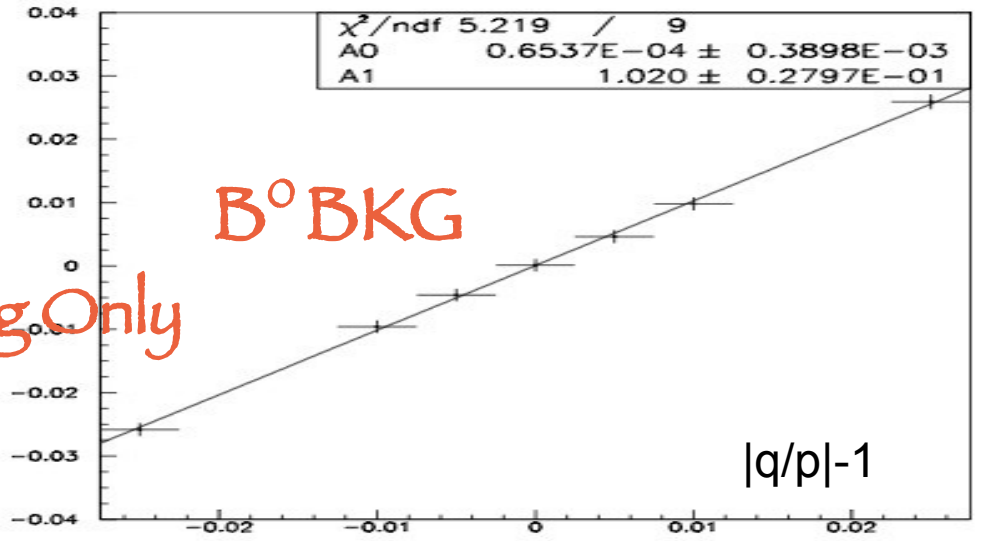




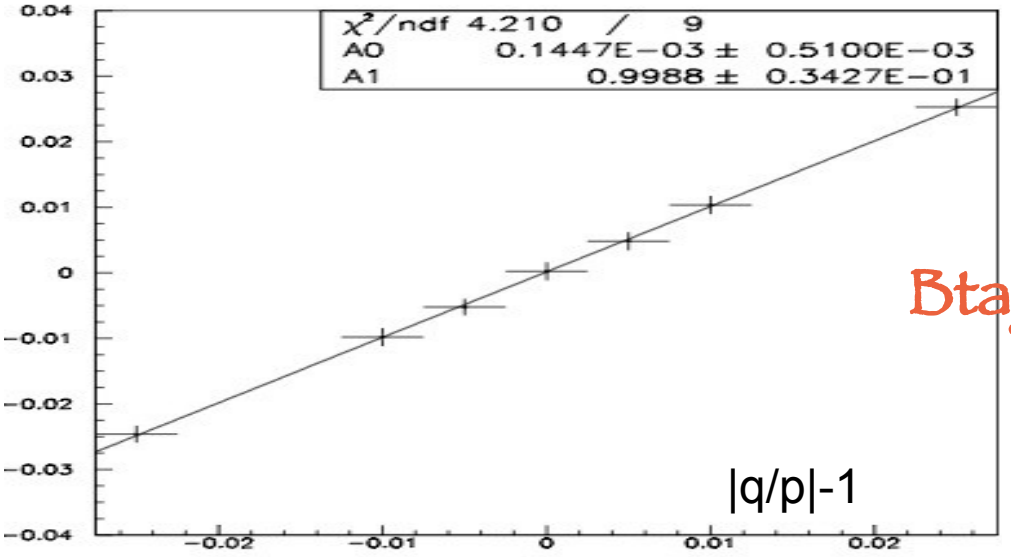
- No Bias found in all the subsamples on MC with |q/p|=1
- B^0 combinatorial BKG helps in |q/p| measurement

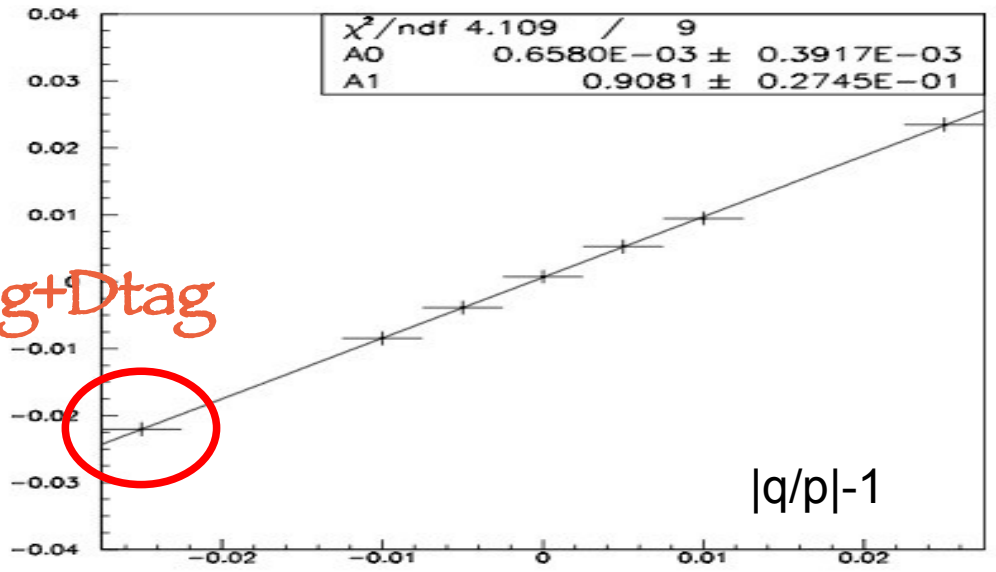
Fitted vs Generated |q/p|-1





Btag Only





Btag+Dtag

- B° Peaking: no bias found
- B° BKG only (Btag+Dtag):

10% bias (2.7 σ) on |q/p|-1 for |q/p|-1= -0.025

Sample Composition

Sample Composition determined by an external Fit on M^2 by floating D*, D** and Combinatorial using shapes from MC

- Dominant systematic uncertainty

- Peaking Sample Uncertainty
  - Statistical error of external fit $\pm 1.09\ 10^{-3}$
  - Isospin symmetry breaking: B^0/B^+ in the D^{**} = (50±25) % $\pm 0.20\ 10^{-3}$
  - CP-eigenstates yield varied by ±50% $\pm 0.31\ 10^{-3}$
  - Remnant Peaking yield (D* , D*DsX, D*h) varied by ±20% $+0.22/-0.96\ 10^{-3}$

$$|q/p| = {}^{+1.17}_{-1.50} \times 10^{-3}$$

Sample Composition

- Combinatorial Sample Uncertainty

- Fraction of B^+ and B^0 in the Combinatorial fixed to MC expectations
  - Difference between B^0 and B^+ is expected when mixing takes place and the lepton is coupled with a slow pion from the tag side: $B^0 \rightarrow D^*X$, $D^* \rightarrow {}^*D^0$
  - B^0 BKG has 40% more mixed events than B^0 Peaking
  - Other BKG events have same probability between B^0 and B^+
  - Fraction of B^+ conservatively varied by ±4.5% which corresponds to the error on inclusive BR($B^0 \rightarrow D^{*+}X$) (from PDG)

$\Delta|q/p| = \pm 0.39 \times 10^{-3}$