|q/p| Measurement with P.R. $B^0 \rightarrow D^* \ell \nu$

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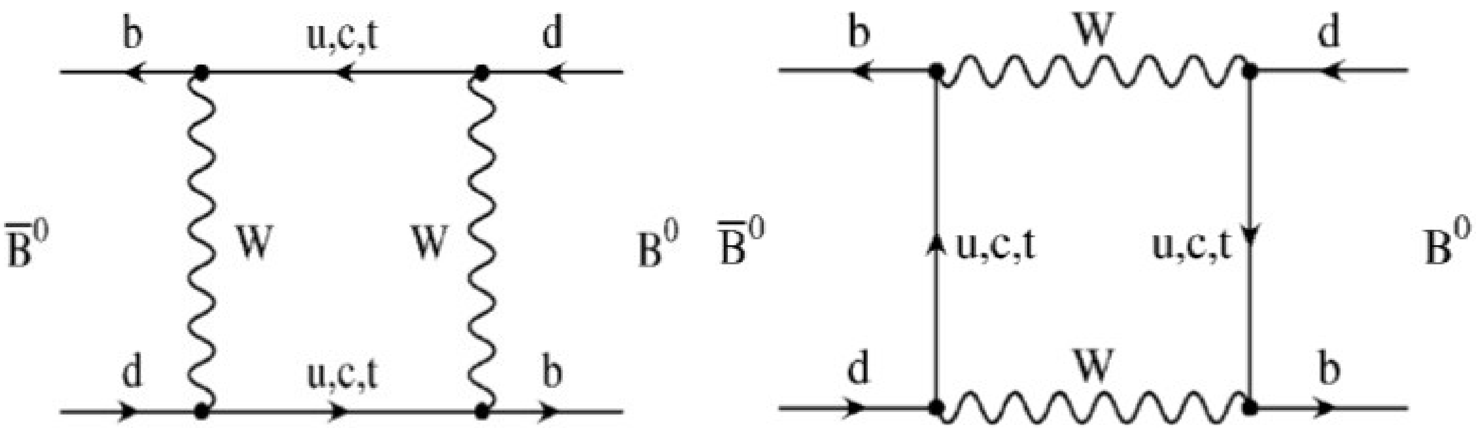
- Motivations
- Analysis Method
- Validation on MC Run1-Run6, Release 24-Analysis 5
- Very Preliminary Real Data BLIND Results
- Conclusion/Next Steps

Motivations

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 $|(q/p)_q|$=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 events:

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

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

Standard Model predicts
(Lenz, Nierste, J. High Energy Phys. 0706, 072):

- B_d: $A^d_{SL}=(-4.8^{+1.0}_{-1.2})10^{-4}$

  $\Phi_d=-5.2^{o}{}^{+1.5^o}_{-2.1^o}$

- B_s: $A^s_{SL}=(2.06\pm0.57)10^{-5}$

  $\Phi_s=0.24^o\pm0.08^o$

Beyond Standard Model

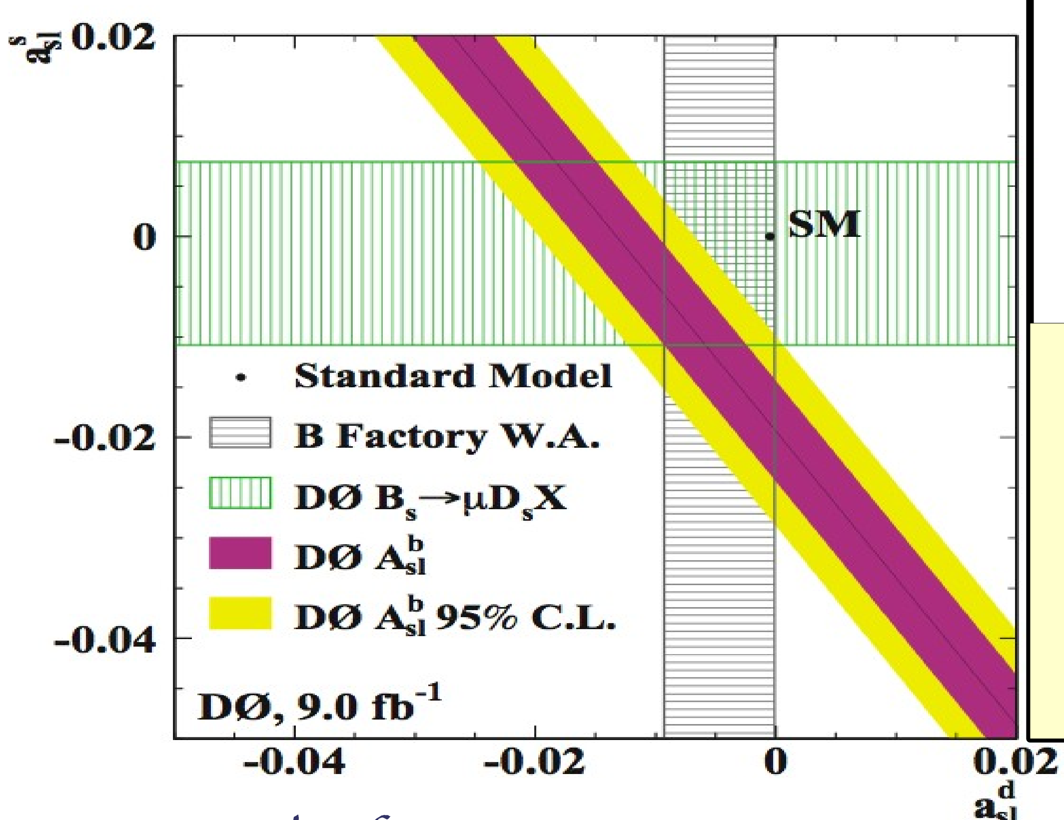
- New Physics could modify M_{12}^q and A_{SL} leaving Γ_{12}^q unchanged:

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

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

CPV in B^0 mixing

- HFAG average of Υ(4S) measurements gives (arXiv:1010.1589v3):
  $|q/p|_d = 1.0024 \pm 0.0023$
  $A^d_{SL} = -0.0047 \pm 0.0046$
  In agreement with SM



- Hadronic Colliders 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 & mean mixing probability
- SM predicts:
  $A^b_{SL} = (-0.028 ^{+0.005}_{-0.006})\%$

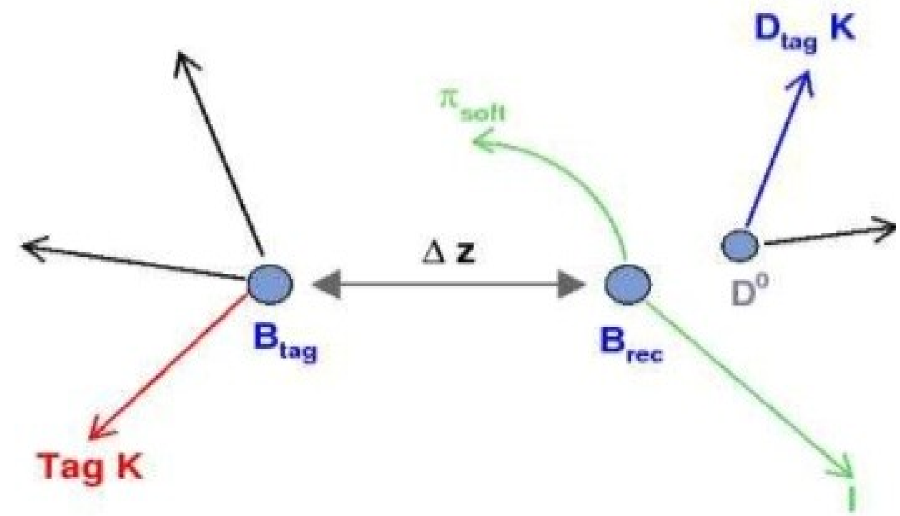
- New D0 result on charge Asymmetry of like-sign dimuons differs by 3.9 σ from SM expectation (Phys. Rev. D 84, 052007):
  $A^b_{SL} = (-0.787 \pm 0.172 \pm 0.093)\%$

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

Analysis Method

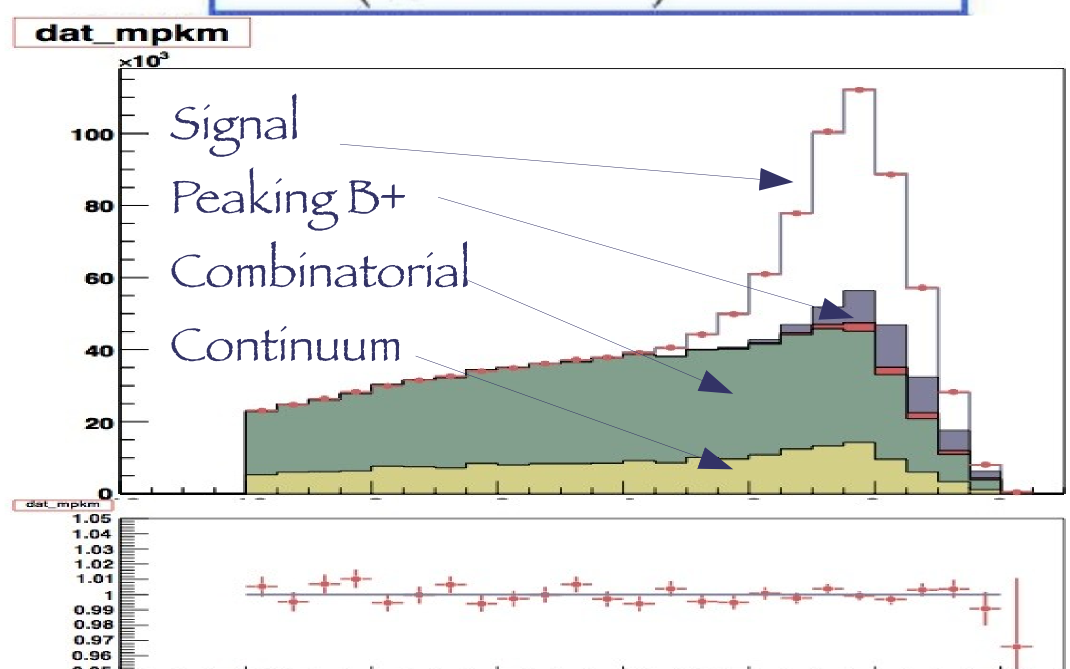
Partial Reconstruction

- Partial Reconstruction of $B^0 \rightarrow D^* l \nu$ already exploited in several measurements (Lifetime, Δm, $|q/p|$ with Lepton Tag)
- Reconstruct only Lepton & π_{soft}
- Signal selection by means of missing neutrino mass with the approximation of B at rest
- D^* energy from π_{soft} kinematics



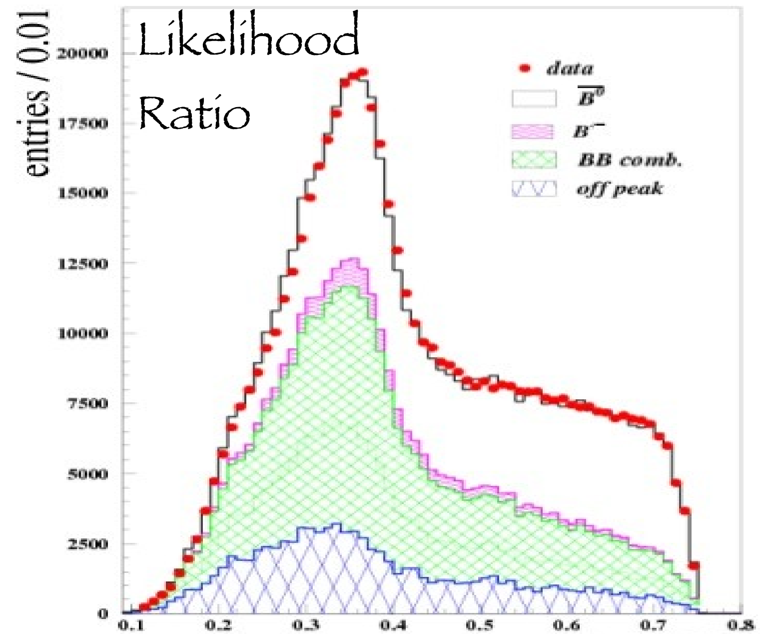
$$M_\nu^2 = \left(\frac{\sqrt{s}}{2} - \tilde{E}_{D^*} - E_\ell\right)^2 - (\tilde{\mathbf{p}}_{D^*} + \mathbf{p}_\ell)^2$$

- Fractions of the various subsamples $F_i(M^2\nu)$ from external fit

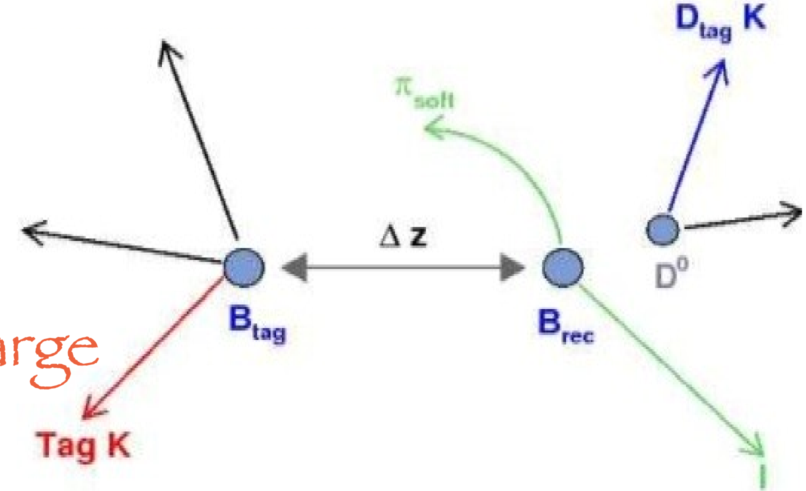


Selection and Tagging

- $0.06 < P\pi_{soft} < 0.20$ GeV; $1.40 < P_{e/\mu} < 2.30$ GeV
- Selectors: e: PIDLHElectrons,
  μ: muNNLoose, K: LooseKaonMicro
- Best lepton π_{soft} pair per event choosen exploiting Likelihood Ratio (P_l/π_{soft}, vertex probability)
- Continuum and Combinatorial BKG suppressed by means of Event Shape variables & vertex probability



- Flavor of the “other B” from tagging K charge
- Tag Vertex from Tagging-K & Beam Spot

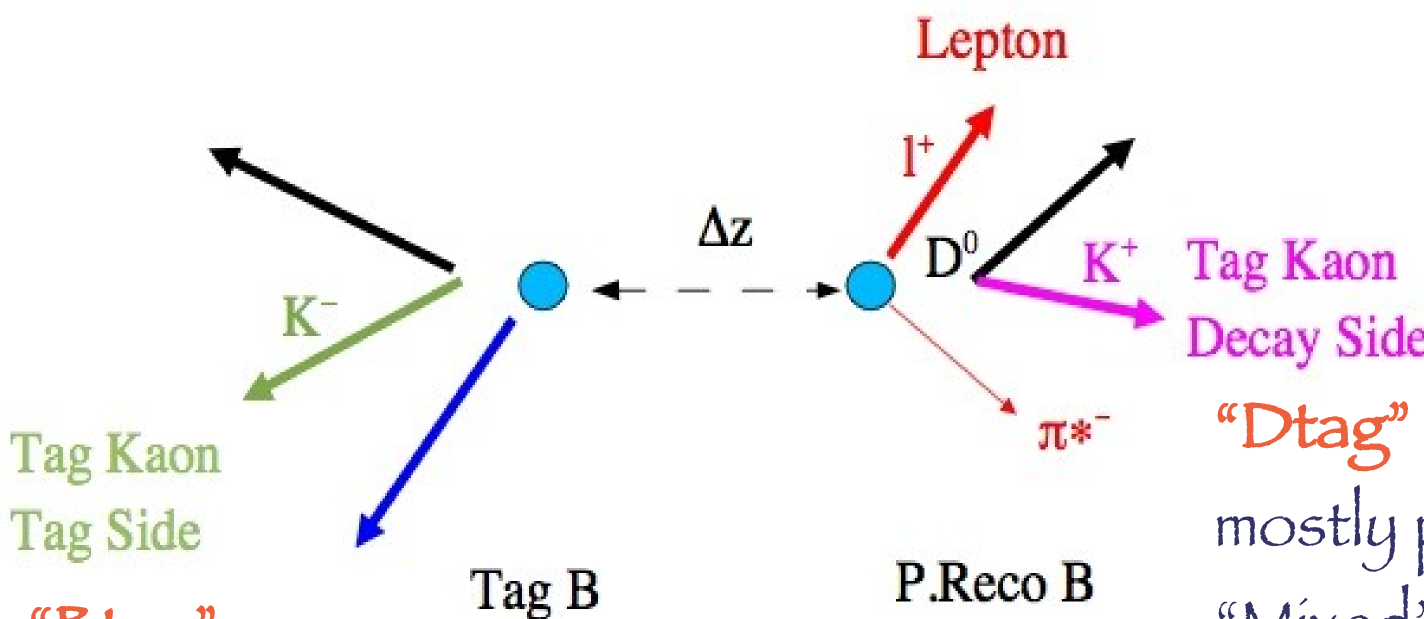


K-Tagging Categories

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

From tag B "Btag"

From decay B "Dtag"



"Btag"

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

PDF (Δt) Description

- |q/p| obtained by a Binned Likelihood simultaneous Δt Fit to 4 subsamples: Unmixed (l^-K^+, l^+K^-); Mixed (l^+K^+, l^-K^-)
- Signal B^0 Btag PDF for Positive Mixed (l^+K^+) sample, (similar expressions apply for the other ones):

$$\mathcal{F}_{signal}(\Delta t, s_t, s_m) = \frac{\Gamma}{2(1+r'^2)} e^{-\Gamma|\Delta t|} \left|\frac{p}{q}\right|^2 \left[\left(1+\left|\frac{q}{p}\right|^2 r'^2\right)\cosh(\Delta\Gamma\Delta t/2) - \right.$$

$$\left. -\left(1-\left|\frac{q}{p}\right|^2 r'^2\right)\cos(\Delta m_d \Delta t) + \left|\frac{q}{p}\right|(b+c)\sin(\Delta m_d \Delta t)\right]$$

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

Our analysis assumption:

- $\Delta\Gamma=0$
- Double Cabibbo Suppressed parameters b, c are treated as effective parameters due to strong correlation with resolution function
- Only |q/p| will be measured in this approach

PDF(Δt) Description

- In Real Life some Physics & Detector effects have to be taken into account:
- Physics
  - Mistag :
    ω^+ =Prob($B^0 \rightarrow K^-$), ω^- =Prob($\overline{B^0} \rightarrow K^+$), $\Delta\omega=\omega^+ - \omega^-$, $\omega=(\omega^+ + \omega^-)/2$
- Detector
  - Reconstruction Asymmetry:
    $\rho=\varepsilon(l^+,\pi^-)$, $\bar{\rho}=\varepsilon(l^-,\pi^+)$ $$A_{rec} = (\rho - \bar{\rho})/(\rho + \bar{\rho})$$
  - Tagging Asymmetry:
    $\tau=\varepsilon(K^+)$, $\bar{\tau}=\varepsilon(K^-)$ $$A_{tag} = (\tau - \bar{\tau})/(\tau + \bar{\tau})$$
  - Δt Resolution

PDF(Δt) Description

• Modified PDF for Positive Mixed (l^+K^+) sample, (similar expressions apply for the other ones):

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

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

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

Analysis Strategy

- 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 the same Detector Asymmetries in different combinations.

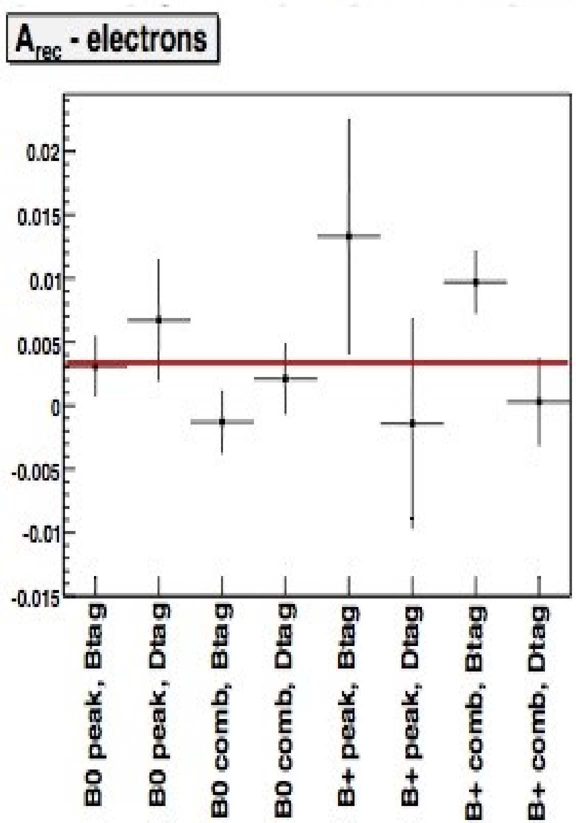
- **Strategy: disentangle the physical vs detector Asymmetries by exploiting all the available informations from different sub-samples.**

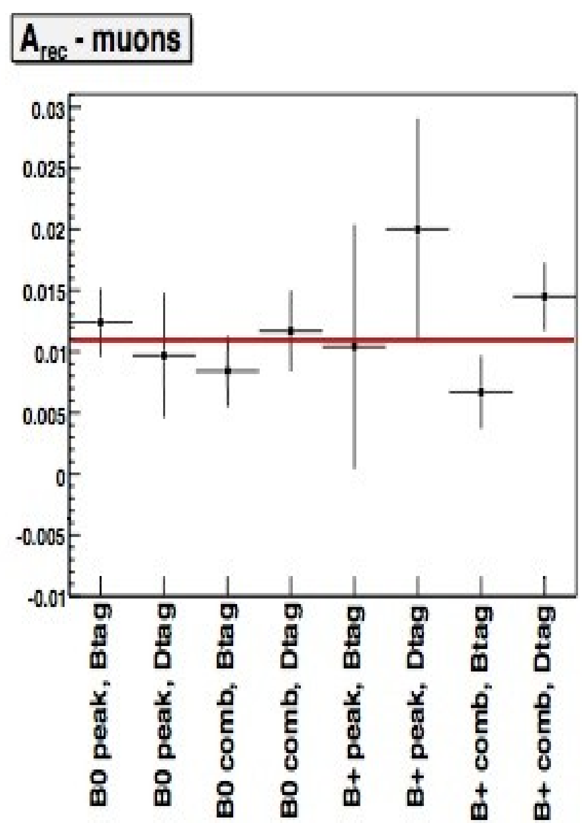
Analysis Strategy

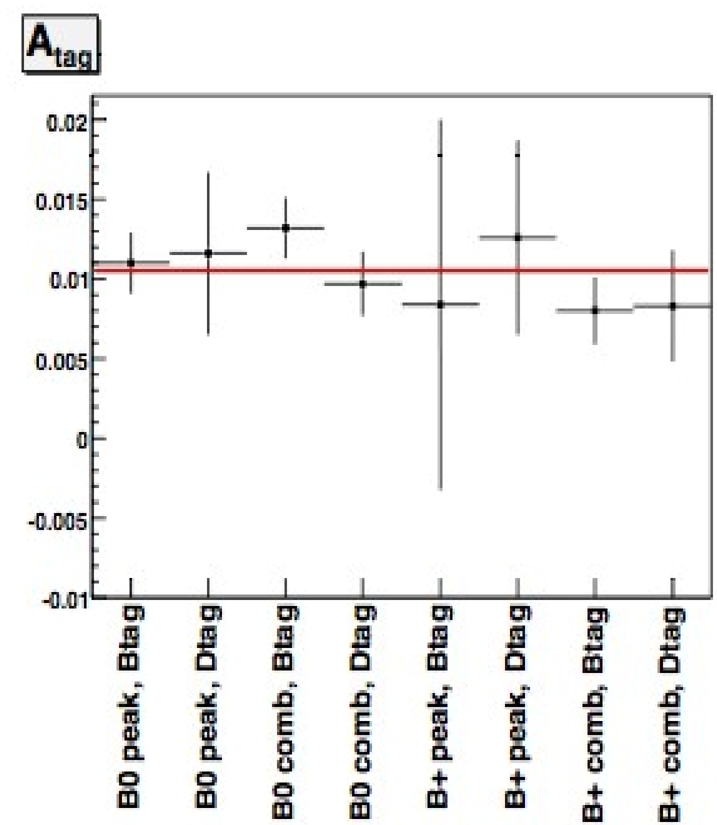
- Hypothesis: same Detector Asymmetries shared by different samples
- Verified on simulation:

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

	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







- Last version of the Fit uses different Arec for Peaking / BKG

Likelihood Constraints

- Best statistical accuracy on Physical/Detector Asymmetries and mistag obtained by applying to the Likelihood some multiplicative Binomial Constraints, defined in terms of the lepton and kaon charges
  - → Arec & Asl*x_d constrained using the total sample of reconstructed (tagged + not tagged) events which show single tag Asl
  - → Arec & Atag(P_K) constrained using all the tagged B^+ subsample (Peaking, BKG)X(Btag, Dtag) in P_K bins
  - → Asl, Arec & Atag(P_K) constrained using all the tagged B^0 subsample (Peaking, BKG)X(Btag, Dtag) in P_K bins
  - → B^0 Dtag samples show single tag Asl therefore constrain Asl*x_d
- Double counting problem due to the statistical correlation of the total reconstructed sample and the tagged subsamples to be managed (see later)

Likelihood 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

MC Validation

Mistag Determination

- Dilution $D(P_K)=1-2\omega$ floated
- ω lower at higher P_K
- $\Delta\omega(P_K)=\omega(K^+)-\omega(K^-)$ floated

Fit results in agreement with counting

B^0 PEAKING

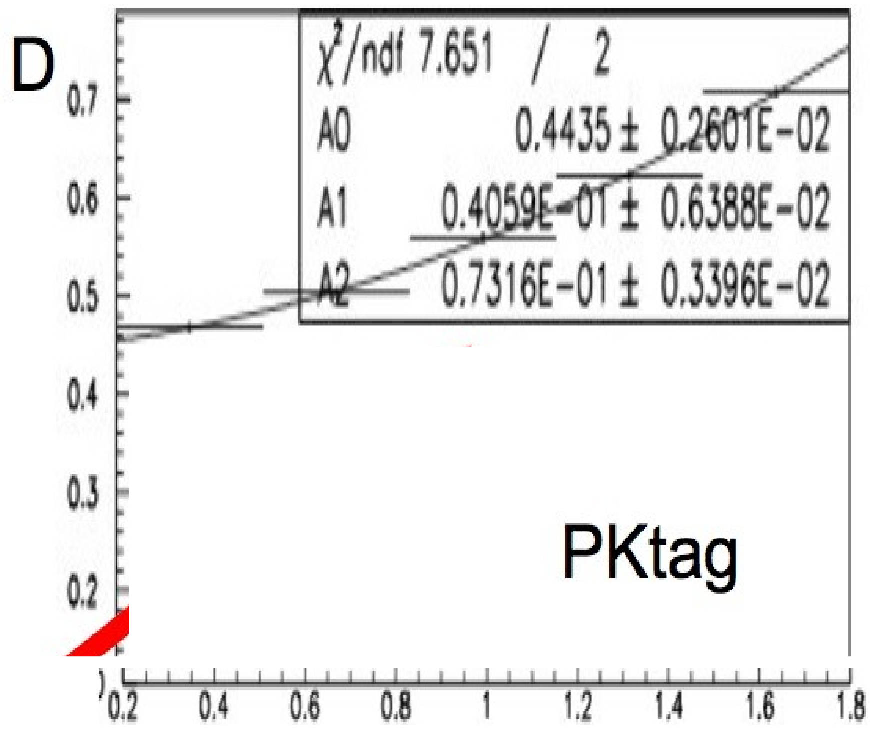
ω(Mixed)=ω(Unmixed)

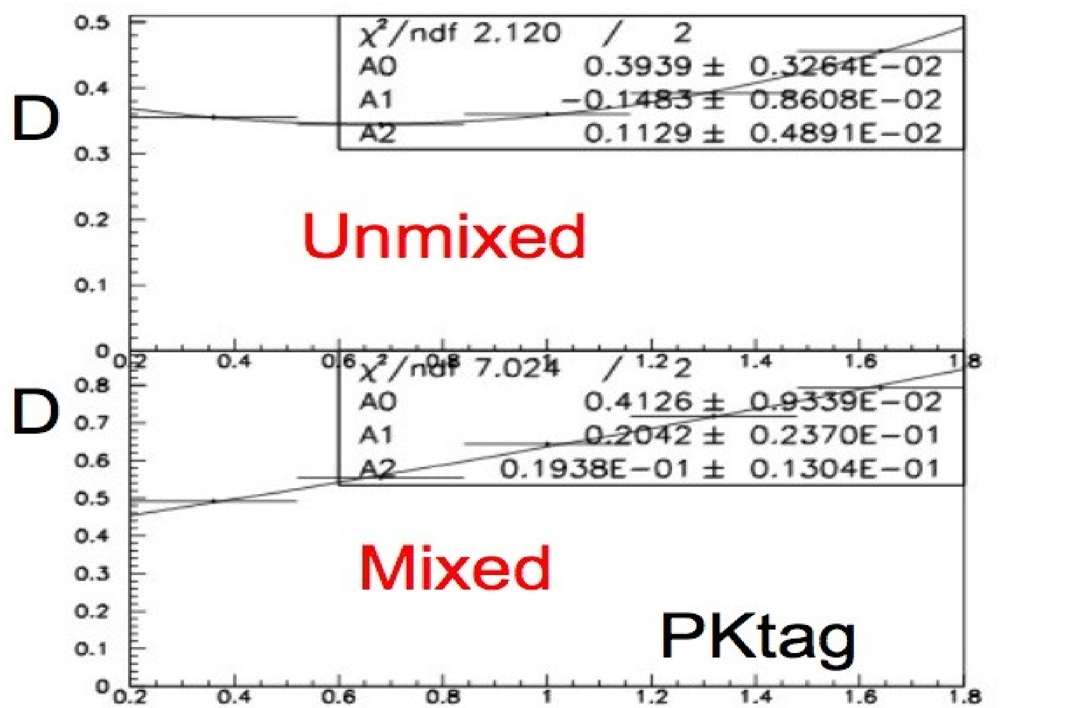
Mixed = True_Mixed*(1-ω)+True_Unmixed*ω
Unmixed=True_Unmixed*(1-ω)+True_Mixed*ω

B^0 Combinatorial BKG

ω(Mixed)<ω(Unmixed) !

Mixed = True_Mixed*(1-ω_M)+True_Unmixed*ω_U
Unmixed=True_Unmixed*(1-ω_U)+True_Mixed*ω_M

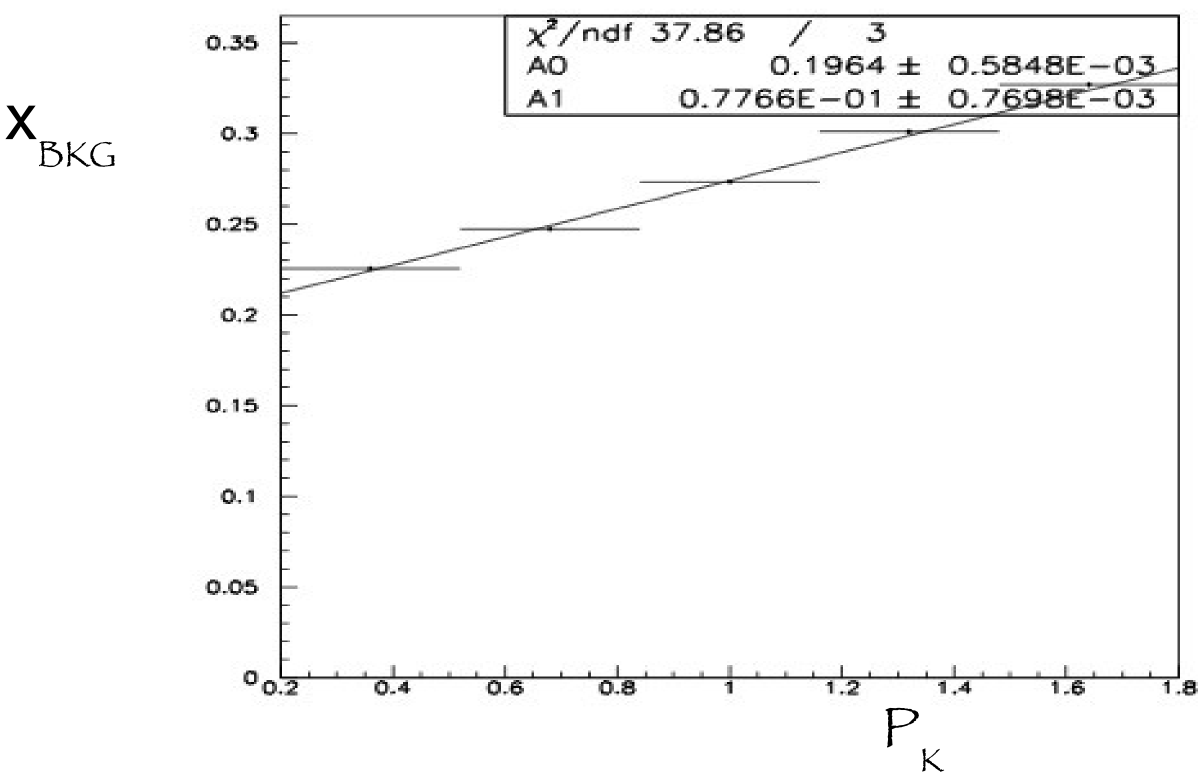




B^0 Combinatorial: Effective x_d

- 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).

$<x_d(BKG)>$~$1.4\, x_d(SIG)$ depending on P_K

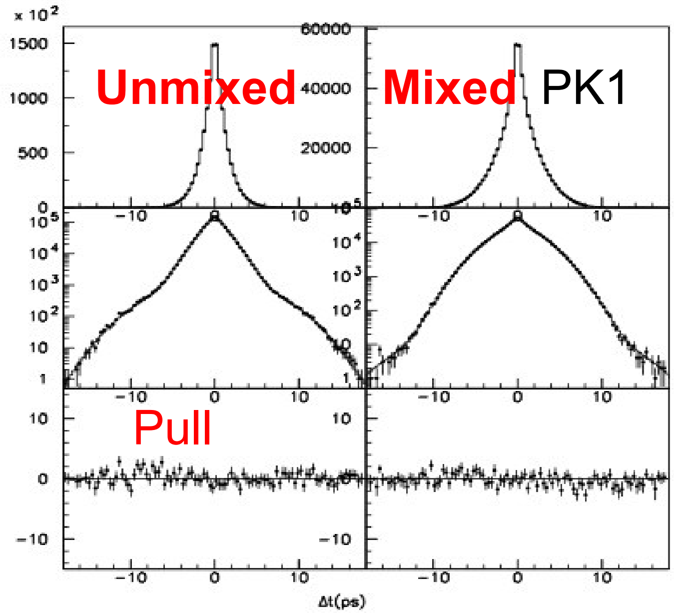


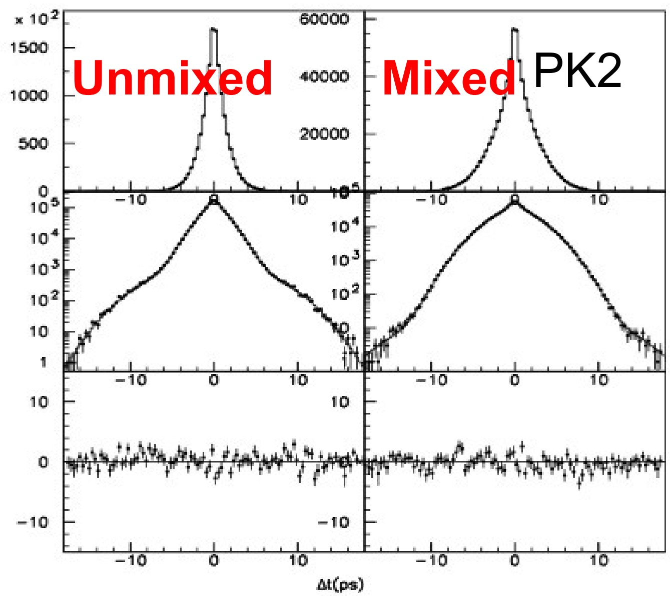
- B^0 BKG Observed PDF defined in order to disentangle this effect from the mistag

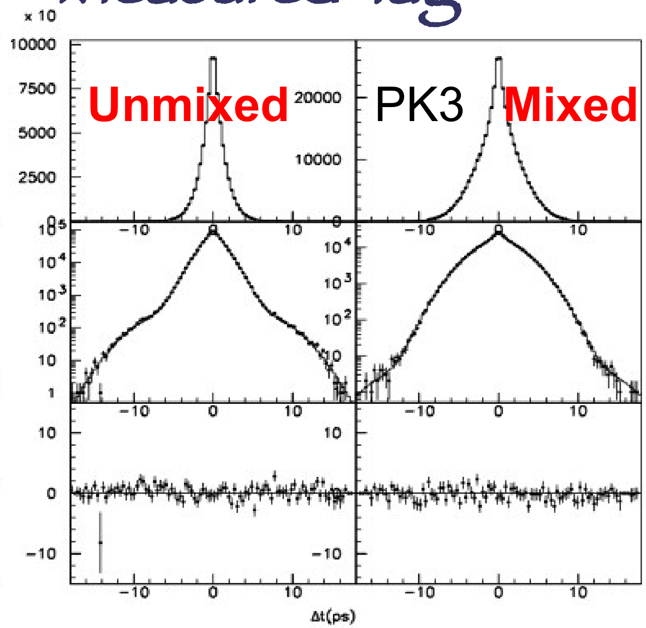
- 27 mistag parameters floated

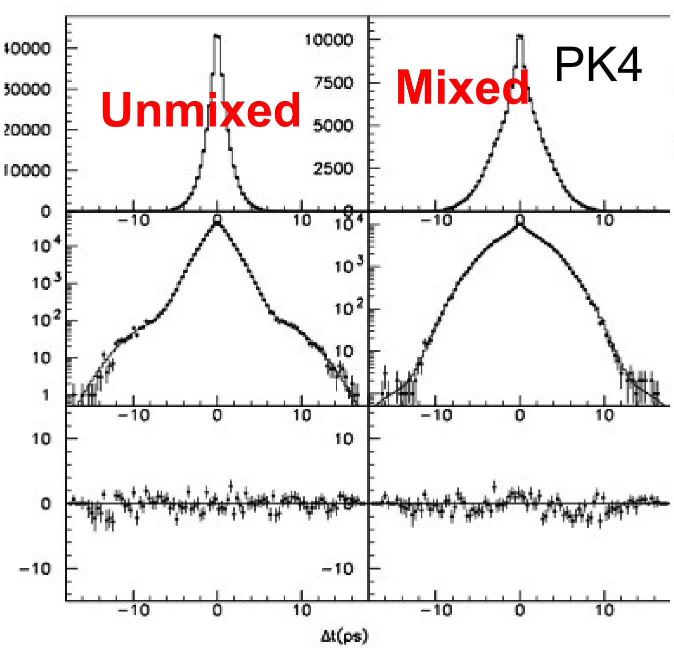
B^0 Peaking with Experimental Mistag

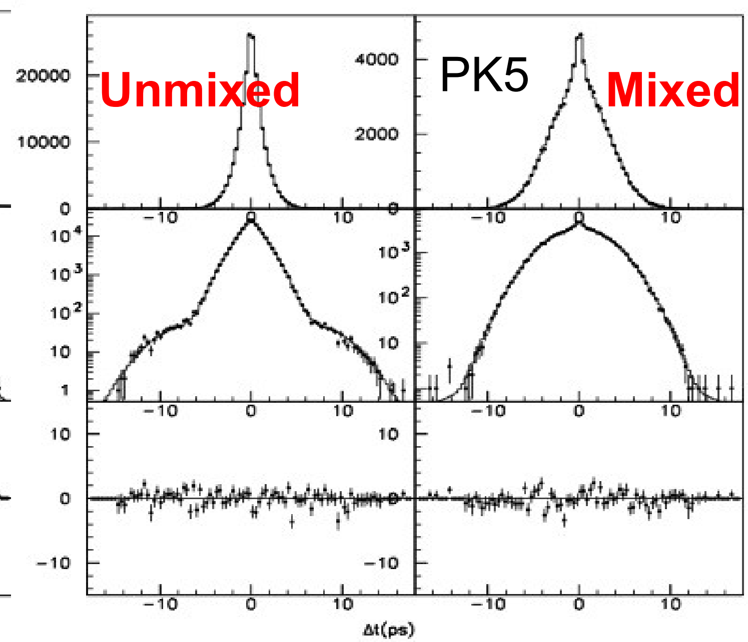
True Δt
Measured Tag











Fit of mistag in different PKtag Bins:

PK1=(0.2-0.52) GeV

PK2=(0.52-0.84) GeV

PK3=(0.84-1.16) GeV

PK4=(1.16-1.48) GeV

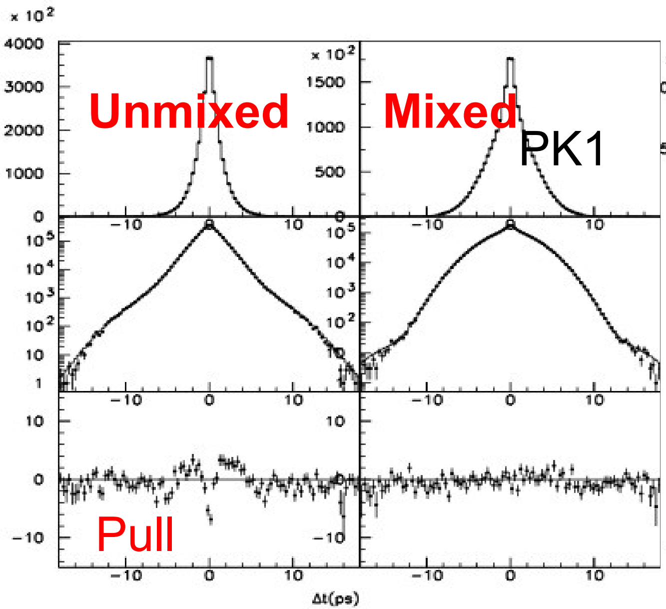
PK5>1.48 GeV

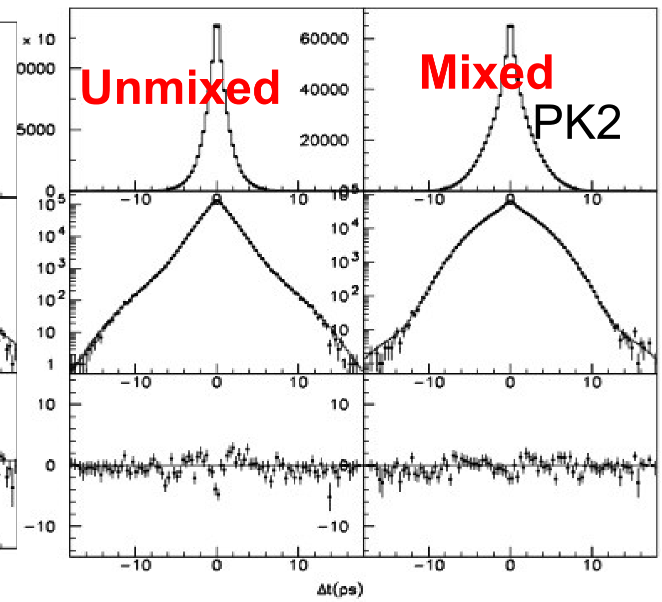
B^0 Comb. BKG with Experimental Mistag

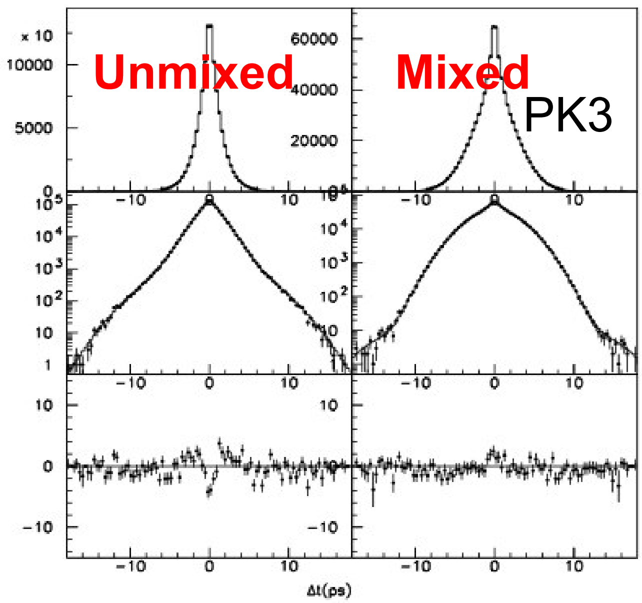
Effective x_{BKG} (P_K) taken into account in the PDF

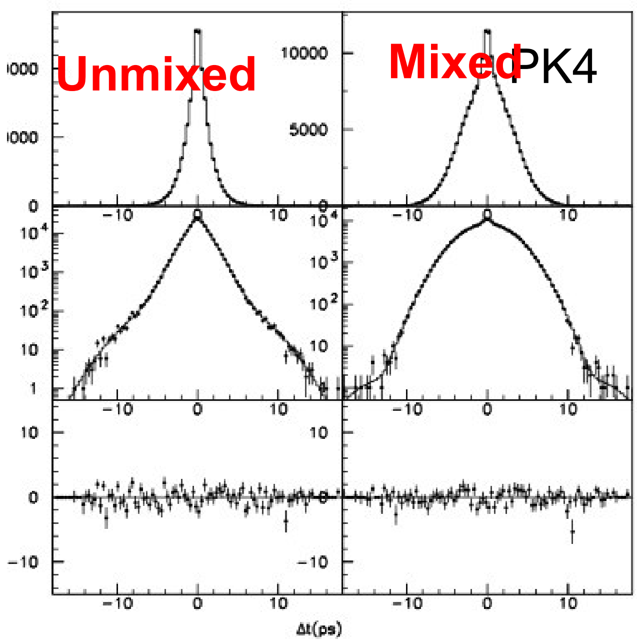
True Δt

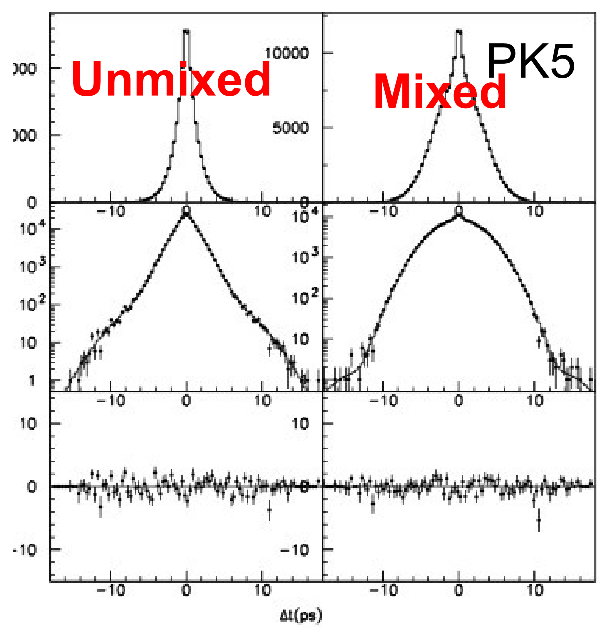
Measured Tag











Fit of mistag in different PKtag Bins:

PK1=(0.2-0.52) GeV

PK2=(0.52-0.84) GeV

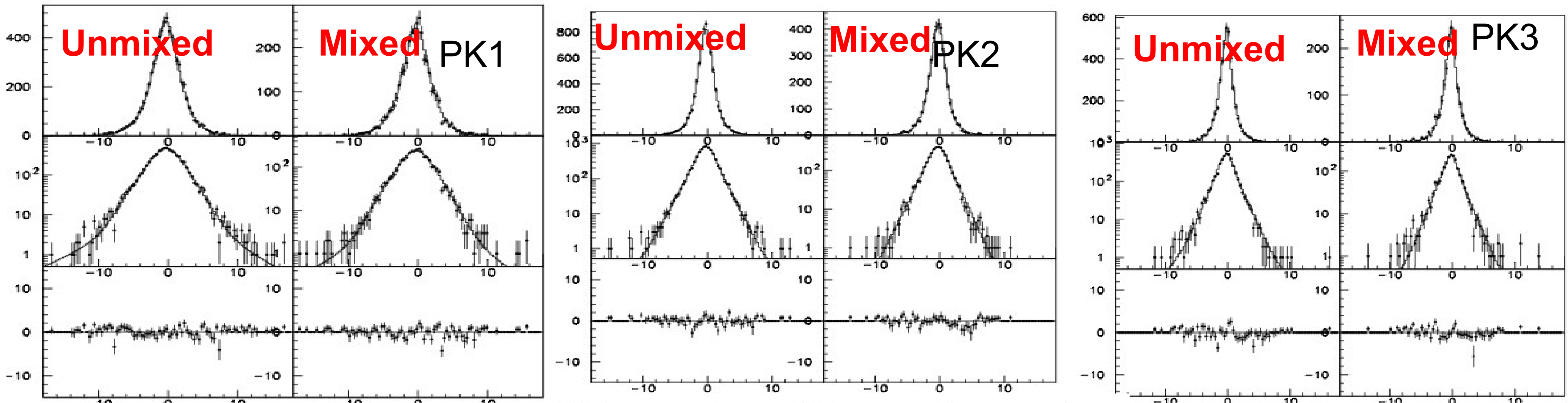
PK3=(0.84-1.16) GeV

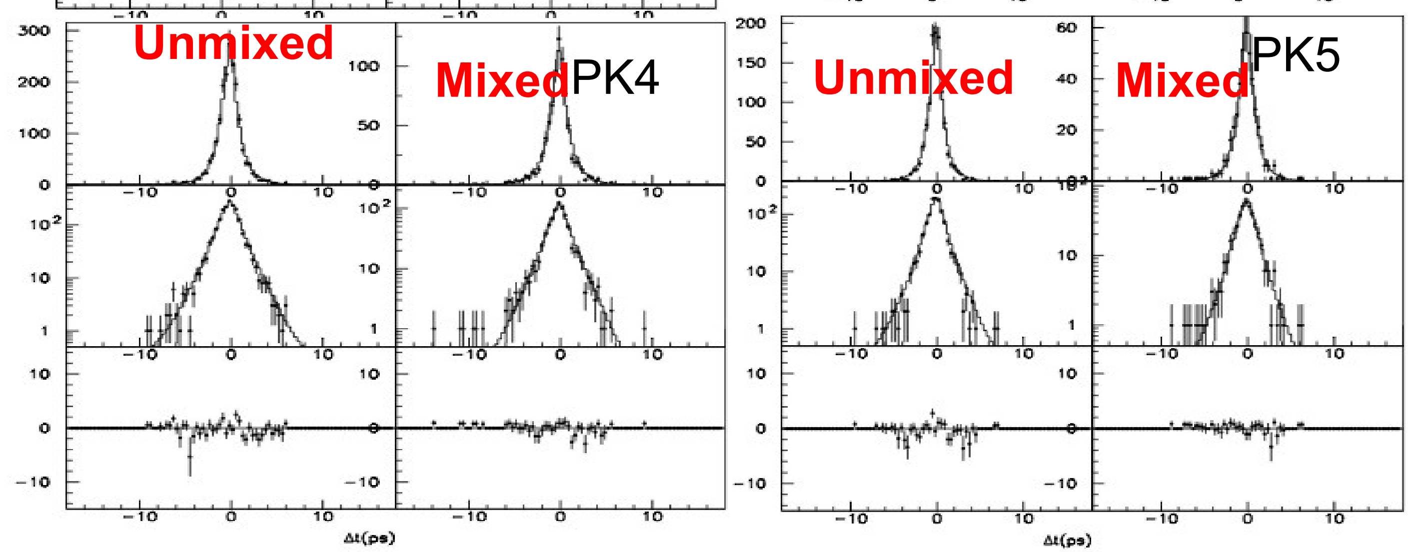
PK4=(1.16-1.48) GeV

PK5>1.48 GeV

Δt Resolution

- Resolution Model optimized by fitting $\delta t = \Delta t$ measured $- \Delta t$ true (Physics & mistag effects removed)
- Resolution parameters shared between B^0 & B^+ (different par. sets for Peaking & BKG): 51 Resolution Parameters floated





Different PK Bins:

PK1=(0.2-0.52) GeV

PK2=(0.52-0.84) GeV

PK3=(0.84-1.16) GeV

PK4=(1.16-1.48) GeV

PK5>1.48 GeV

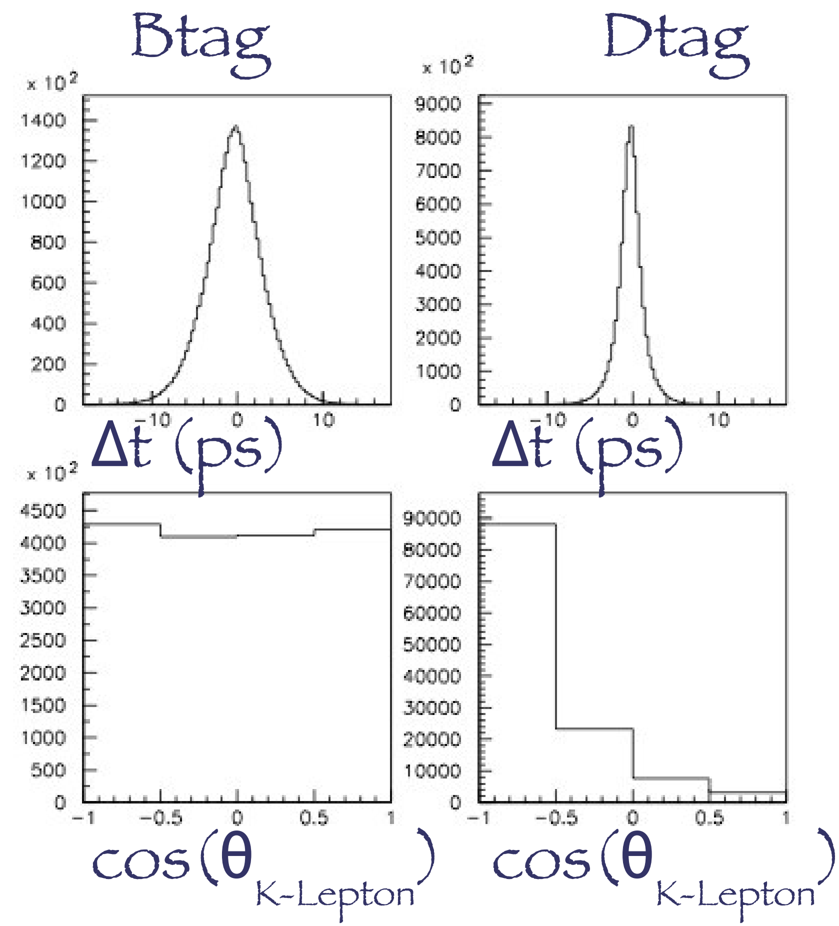
Dtag Description

- Dominant “BKG” in Mixed events: show single tag semileptonic asymmetry therefore Dtag Fraction depends on |q/p|:

$F^{B0}_{Dtag}(|q/p|) = F^{B0}_{Dtag}(|q/p|=1) * f(|q/p|)$

→ f(|q/p|) from integrals of the relevant Observed PDF

- F_{Dtag} floated by exploiting the different Δt & θ(K-Lepton) distributions wrt Btag events in every P_K bin of the subsamples $(B^0/B^+)\times(\mathrm{Peak}/\mathrm{BKG})\times(\mathrm{Mixed}/\mathrm{Unmixed})\times(K^+/K^-)$
- F^{B+}_{Dtag} constrained to $F^{B0}_{Dtag}(|q/p|=1)$ from MC in every sample and P_K bin
- 40 parameters floated



- $\cos(\theta_{K\text{-}Lepton})$ PDF from MC
- Δt PDF from a High Purity selection on Real Data

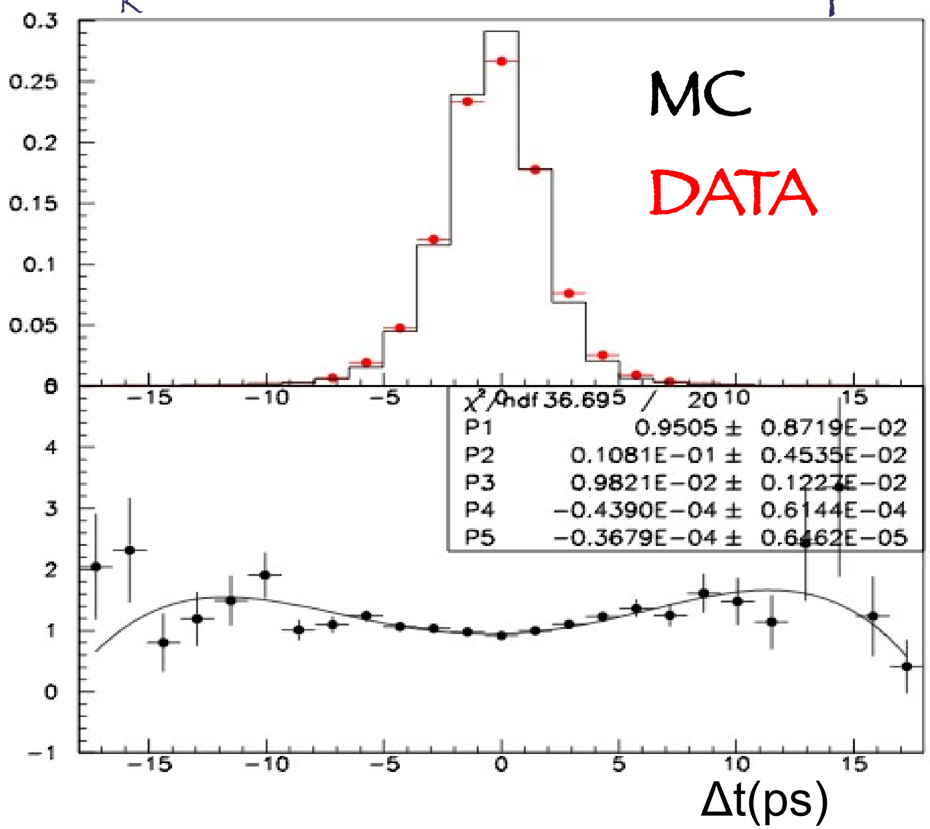
Dtag Description

Dtag Δt shape from a High Purity selection:

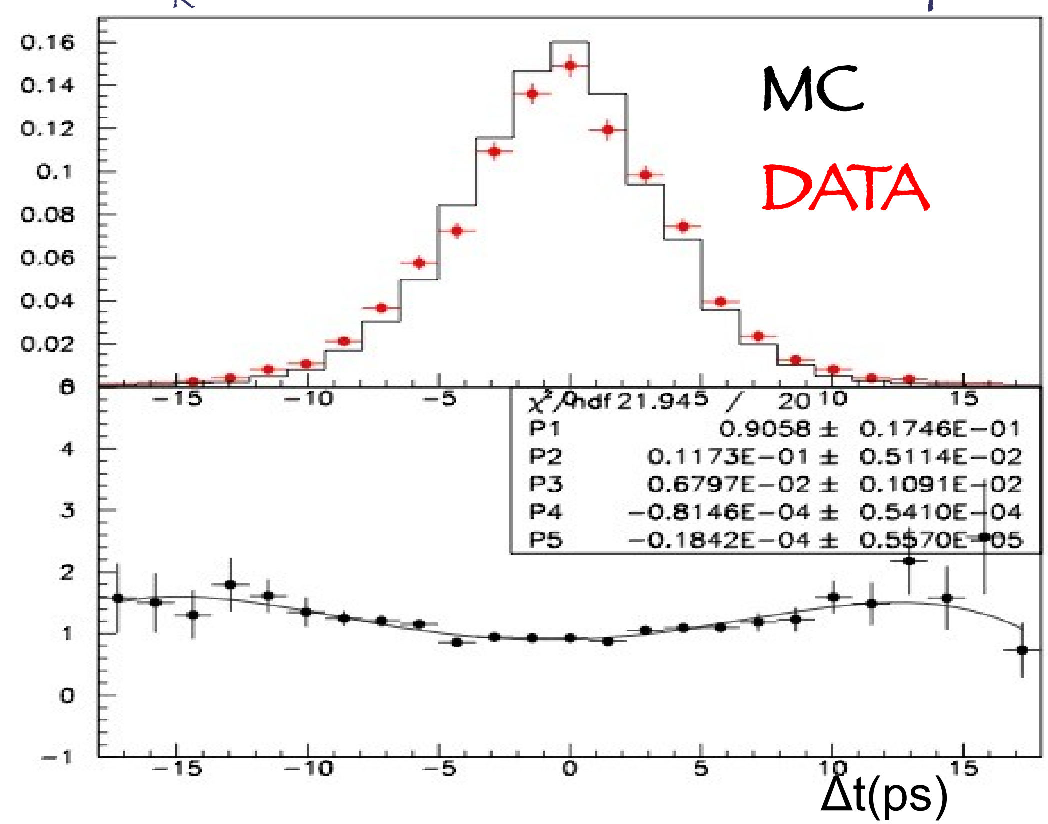
$PDF^{DATA}_{Class\ i} = PDF^{MC}_{Class\ i} * (PDF^{DATA}/PDF^{MC})_{High\ Purity\ Selection}$

- 4 Dtag Classes: $(B^0/B^+) X (Peaking/BKG)$
- Data/MC Corrections computed in bin of $(P_K, \sigma\Delta t)$

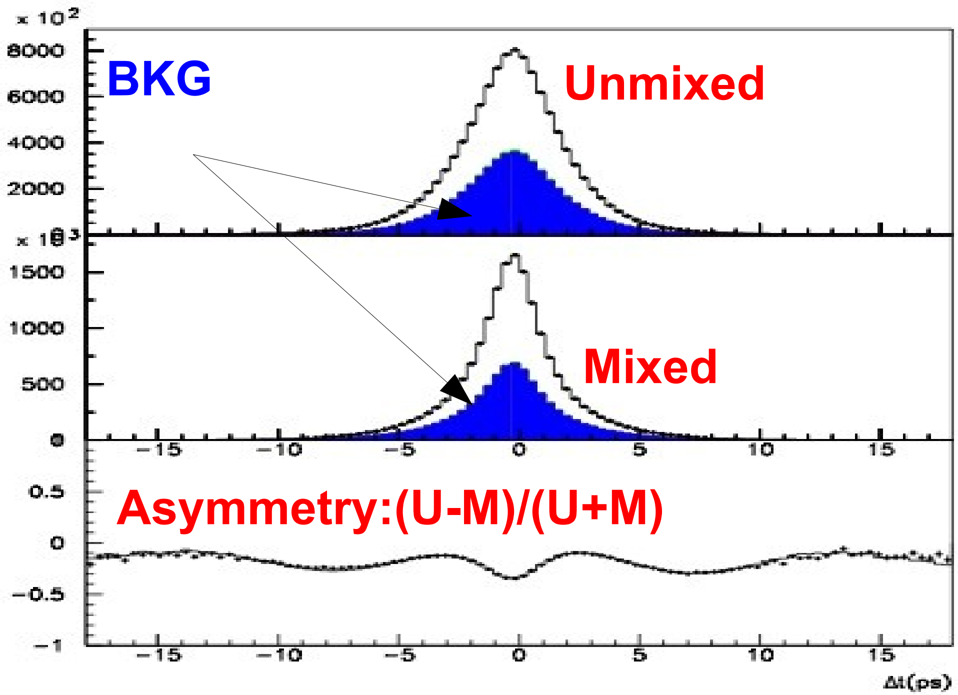
P_K=0.2/0.52 GeV, σΔt=1.2/1.8 ps

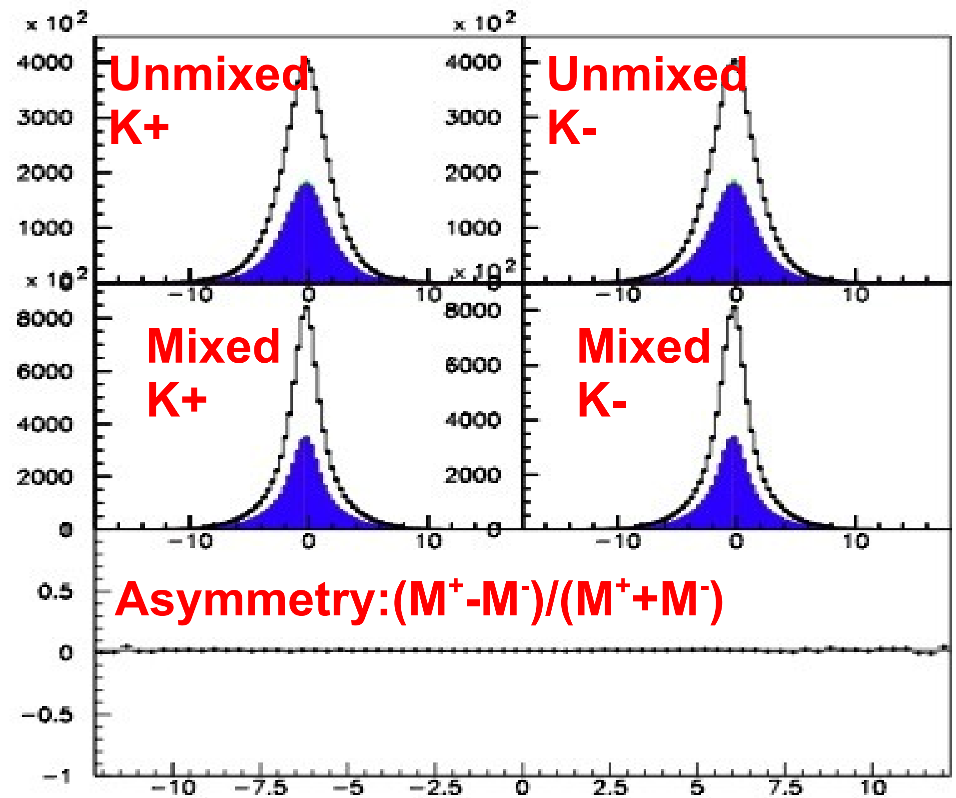


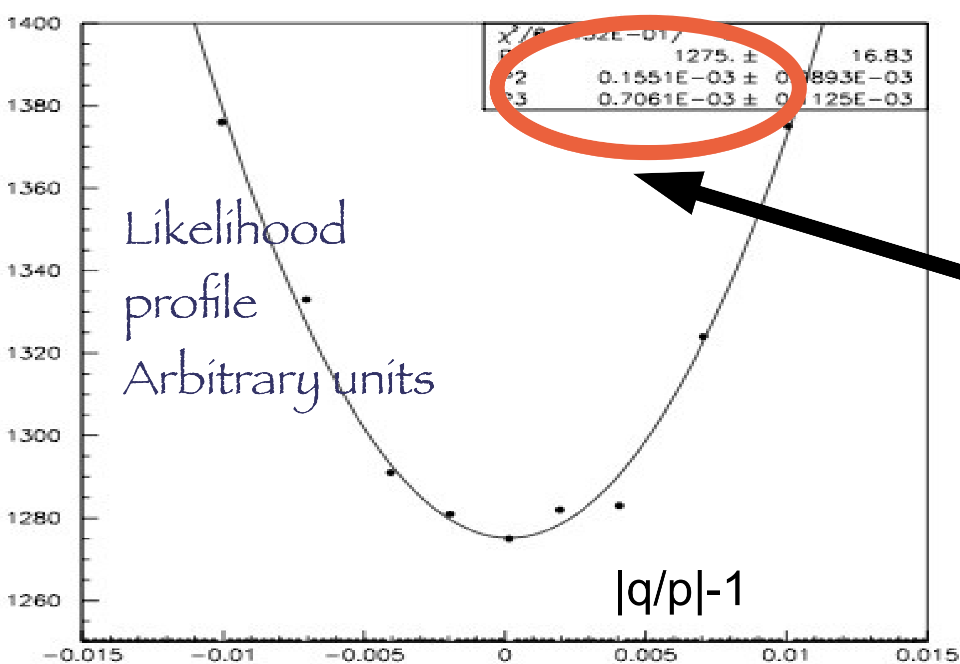
P_K=0.2/0.52 GeV, σΔt=2.4/3.0 ps



Results on B^0 Peaking+BKG





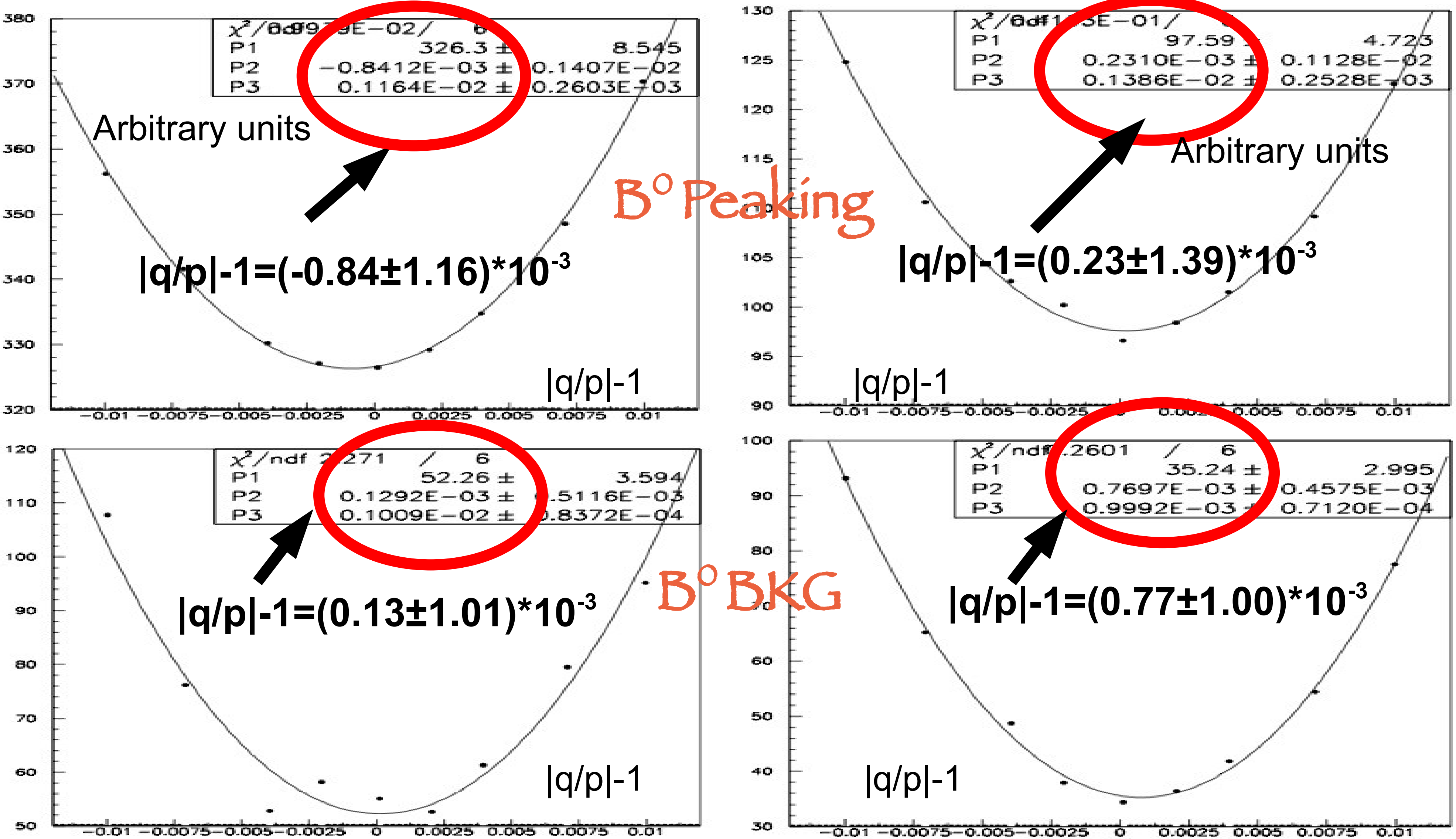


$|q/p|-1=(0.16\pm0.71)*10^{-3}$

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

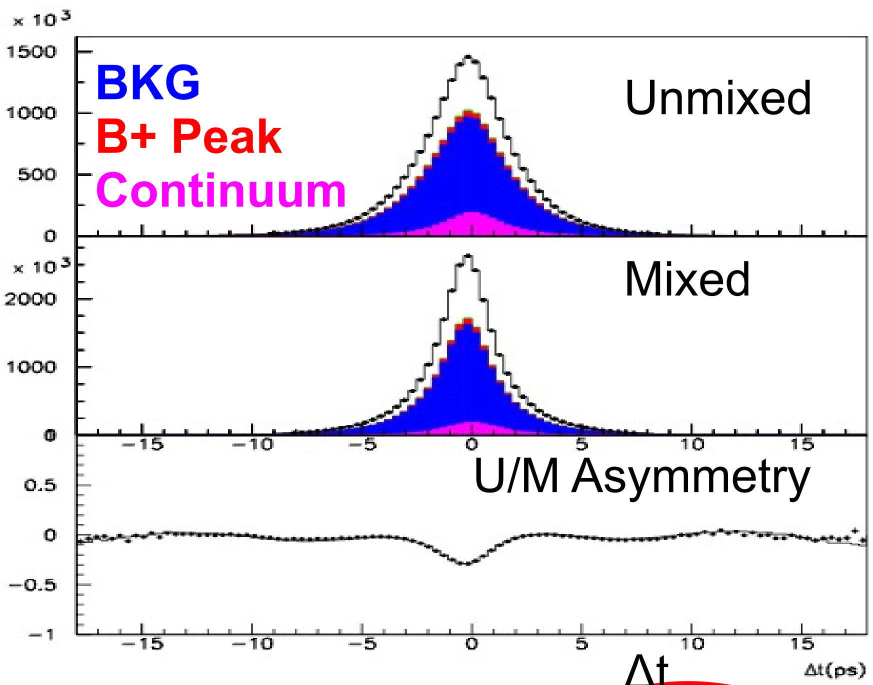
Results on B^0 Peaking vs BKG

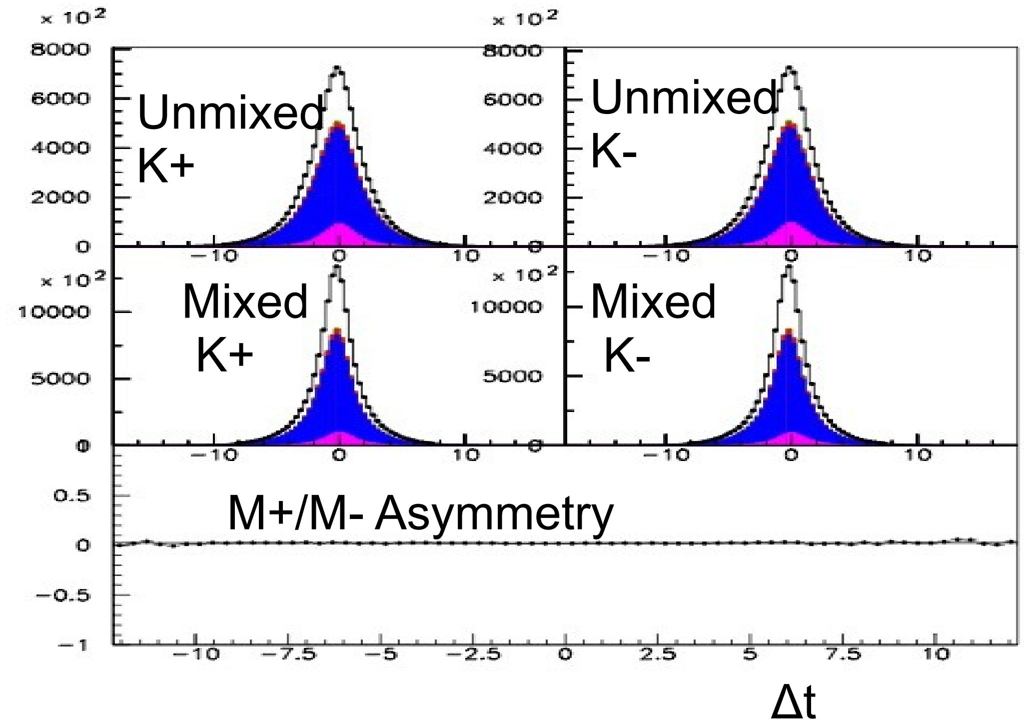
Only Btag | Btag + Dtag

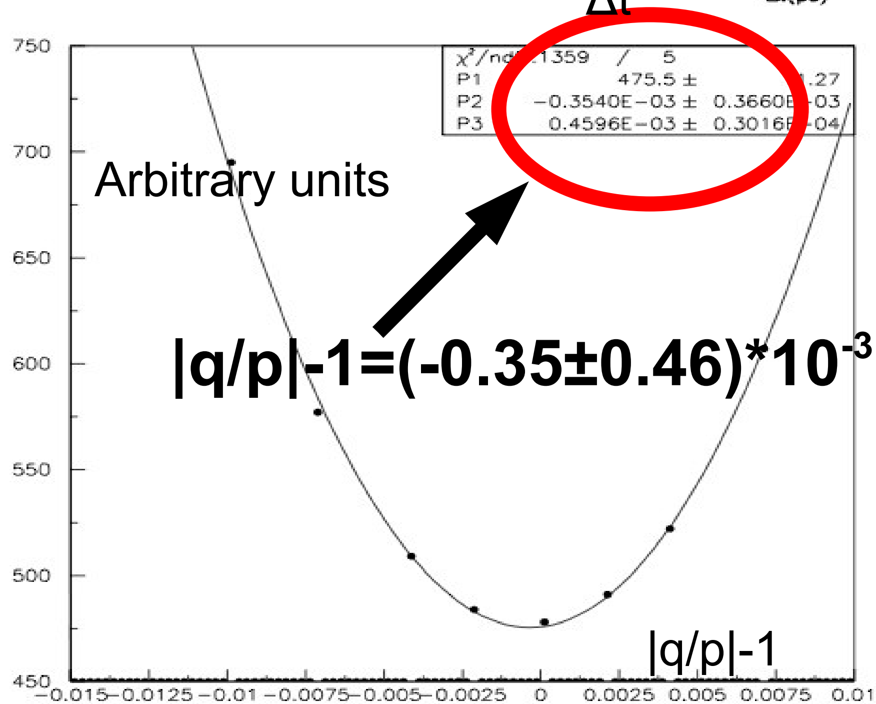


No Bias found in both the samples on MC with |q/p|=1

Results on B^0+B^++Continuum Full Fit







- Continuum generated with a Toy using as input the OffPeak data sample relevant distributions and normalized to the MC statistics.

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

Results on Modified MC with |q/p|≠1

- |q/p| measured from Semileptonic Asymmetry:

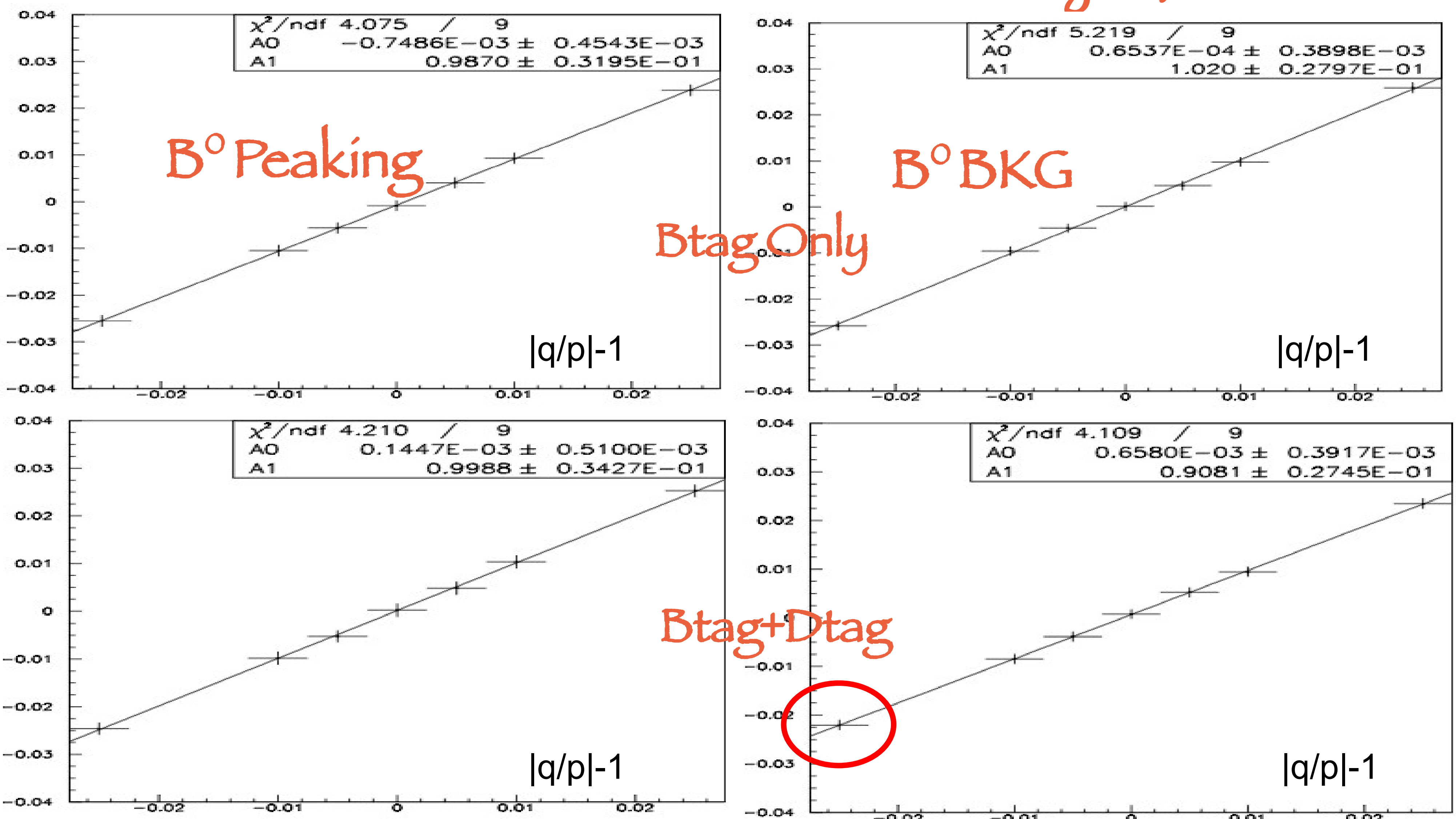
$$\mathcal{A}_{SL} = \frac{N(B^0B^0) - N(\overline{B}^0\overline{B}^0)}{N(B^0B^0) + N(\overline{B}^0\overline{B}^0)}$$

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

- 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 $\overline{B^0B^0}$ (K>0) events
- Fraction F/2 of Unmixed events ($B^0\overline{B^0}$) rejected to preserve the correct x_d=M/(U+M)
- Rejection performed by exploiting the MC truth on B^0 flavor

- This exercise checks correctness of algorithm, mistag, detector asymmetries and Dtag fraction determination

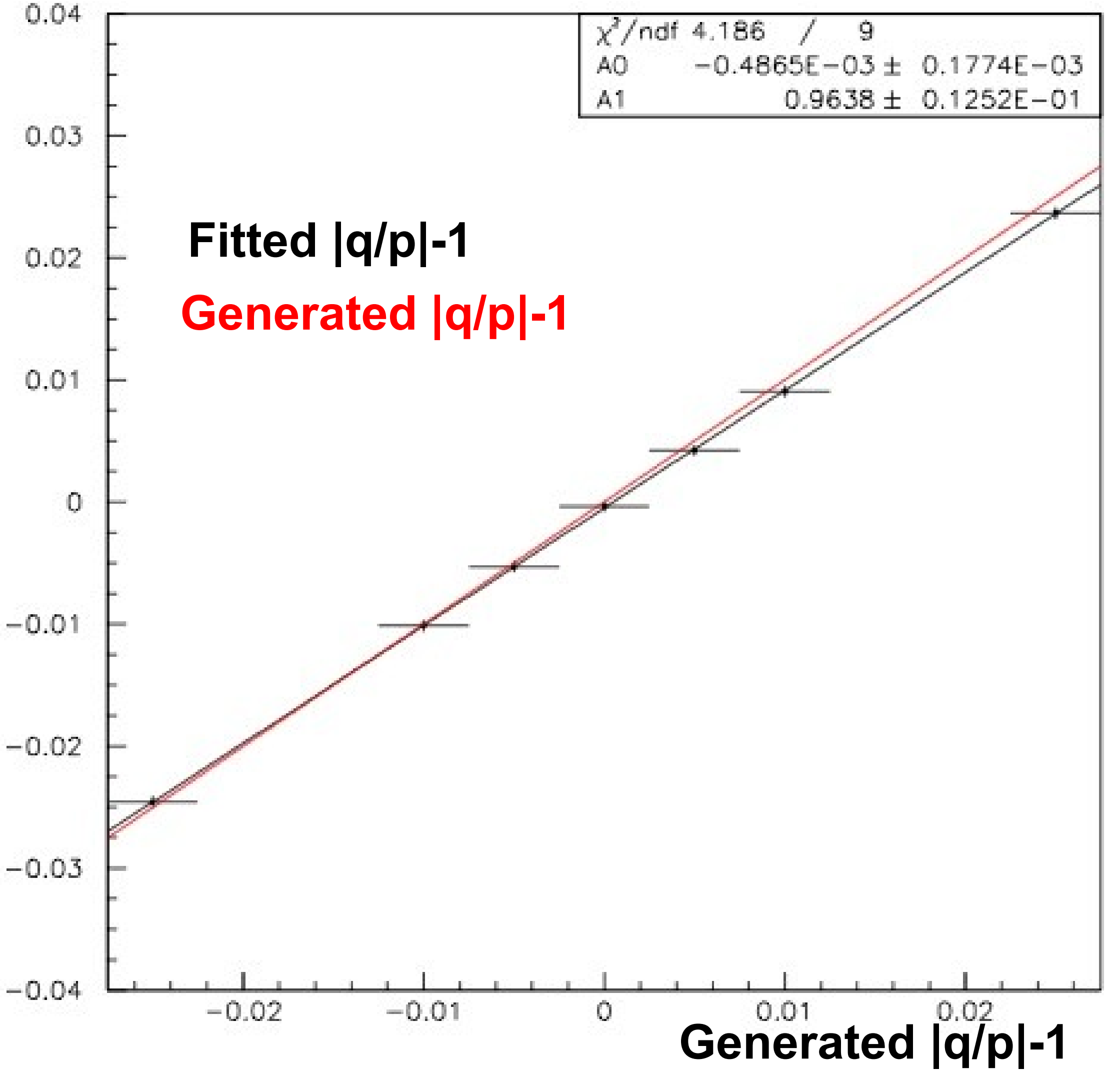
Fitted vs Generated |q/p|-1



- Statistical errors correlated between different bins
- B^0 Peaking: no bias found
- B^0 BKG only (Btag+Dtag) :10% bias (2.7 σ) on |q/p|-1 for |q/p|-1= -0.025

Fitted vs Generated |q/p|-1

Full MC Fit



- Caveat: Only parameters correlated with |q/p| floated
- Resolution parameters fixed to reduce time consuming
- Statistical errors correlated between different bins

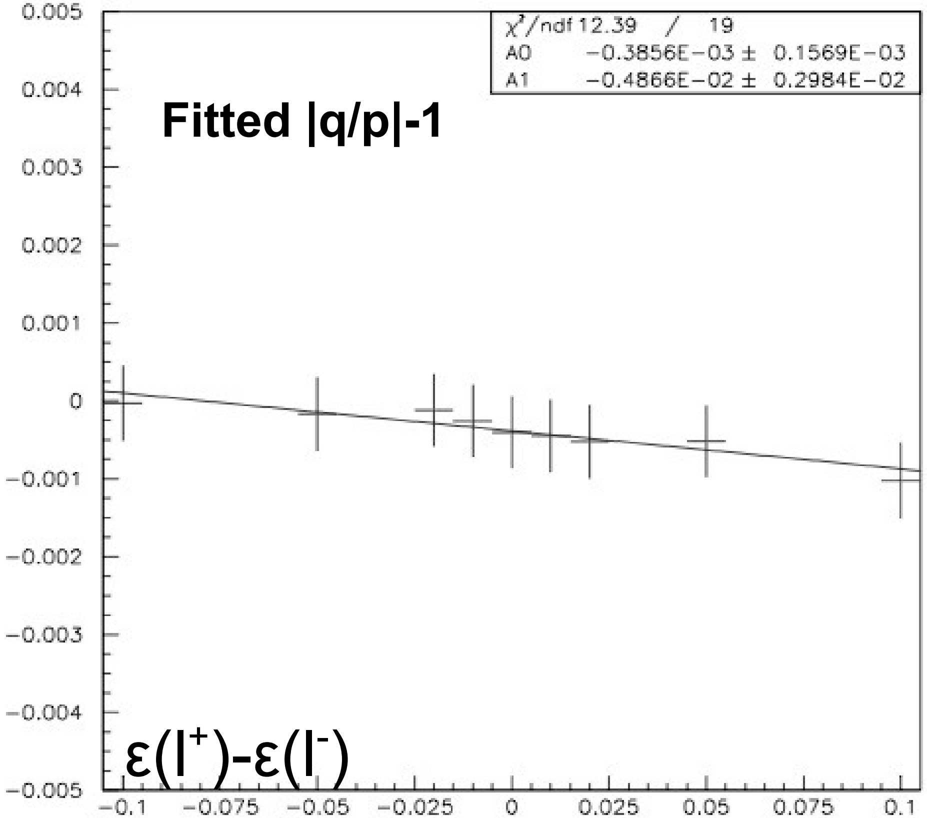
- Slope=0.96: ~4% relative bias on |q/p|-1 found
- Effect negligible compared with the expected statistical error

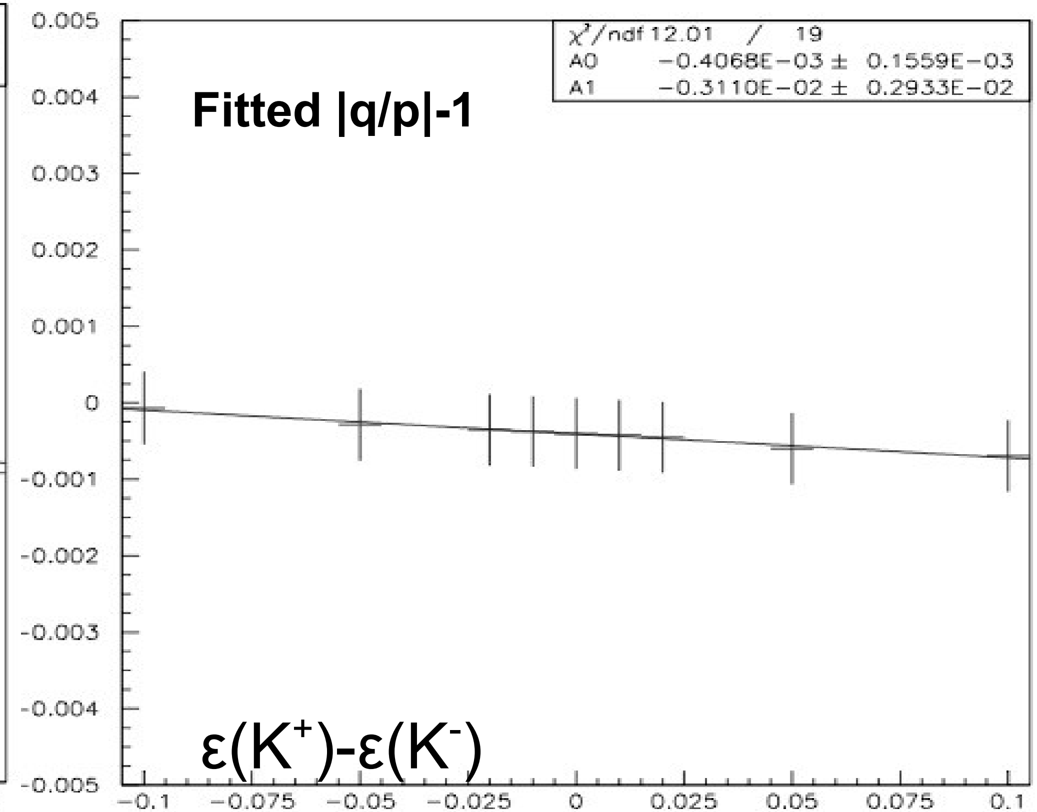
|q/p| vs detector Asymmetries

- Strategy of the measurement: disentangle the Physical vs Detector Asymmetries by exploiting all the available informations from different subsamples
- **|q/p| and detector Asymmetries are strongly related in the PDF**
- Test performed to look for possible bias on the |q/p| determination produced by a not correct description of the Physical vs Detector Asymmetries interconnection in the Fit constraints:
  - Modify the MC in order to produce an artificial efficiency asymmetry by random rejecting positive or negative leptons/kaons from the selected sample
  - Artificial $|\Delta\varepsilon|=|\varepsilon^{+}-\varepsilon^{-}|$ = 1%, 2%, 5%, 10% produced
- **To be compared with:**

Reco Asymm(l^{+}, l^{-}) ~0.5%; Tag Asymm(K^{+},K^{-})~1% (fitted on MC)

|q/p|-1 vs Δε: Full MC Fit





- Statistical errors are correlated
- Observed bias < 0.001 in all the $\Delta\varepsilon$ range of variation
- $\Delta\varepsilon$ varied in a huge range wrt reasonable values

→ The Fit correctly disentangles physical vs detector asymmetries

→ Negligible systematic uncertainty estimated on Real Data (see later)

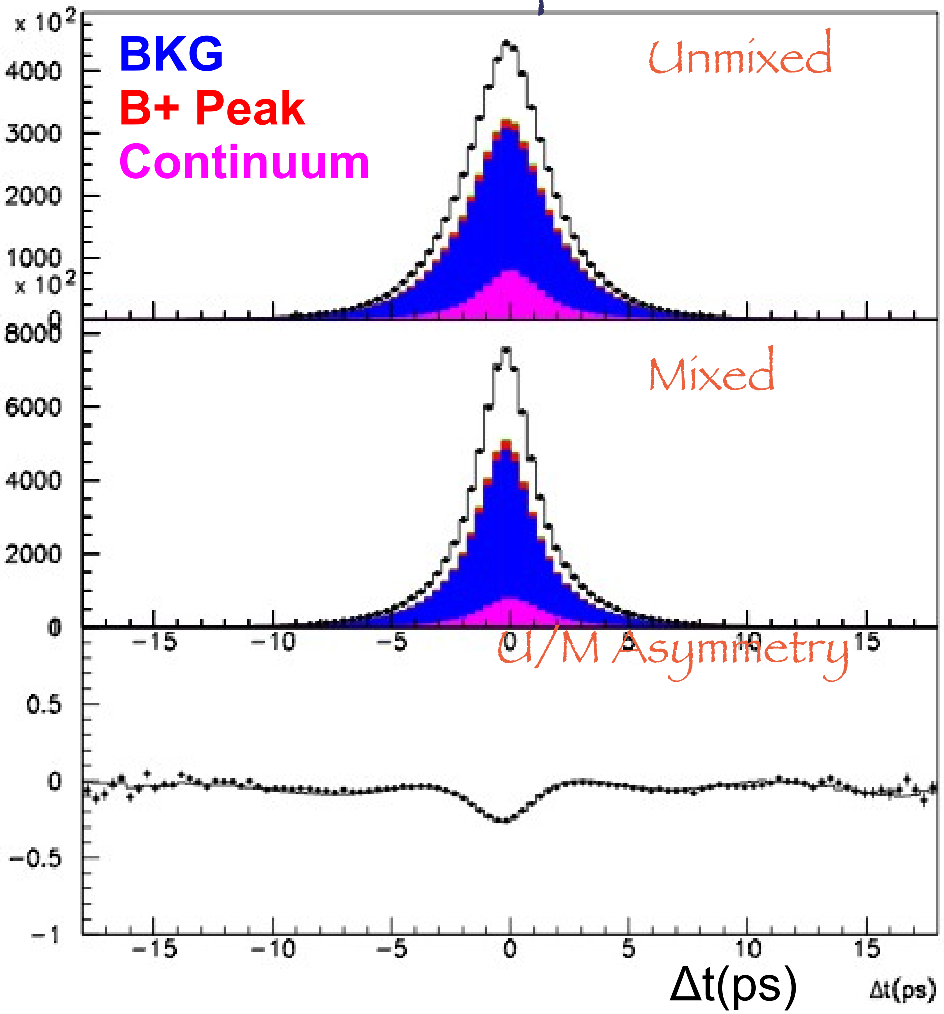
Real Data

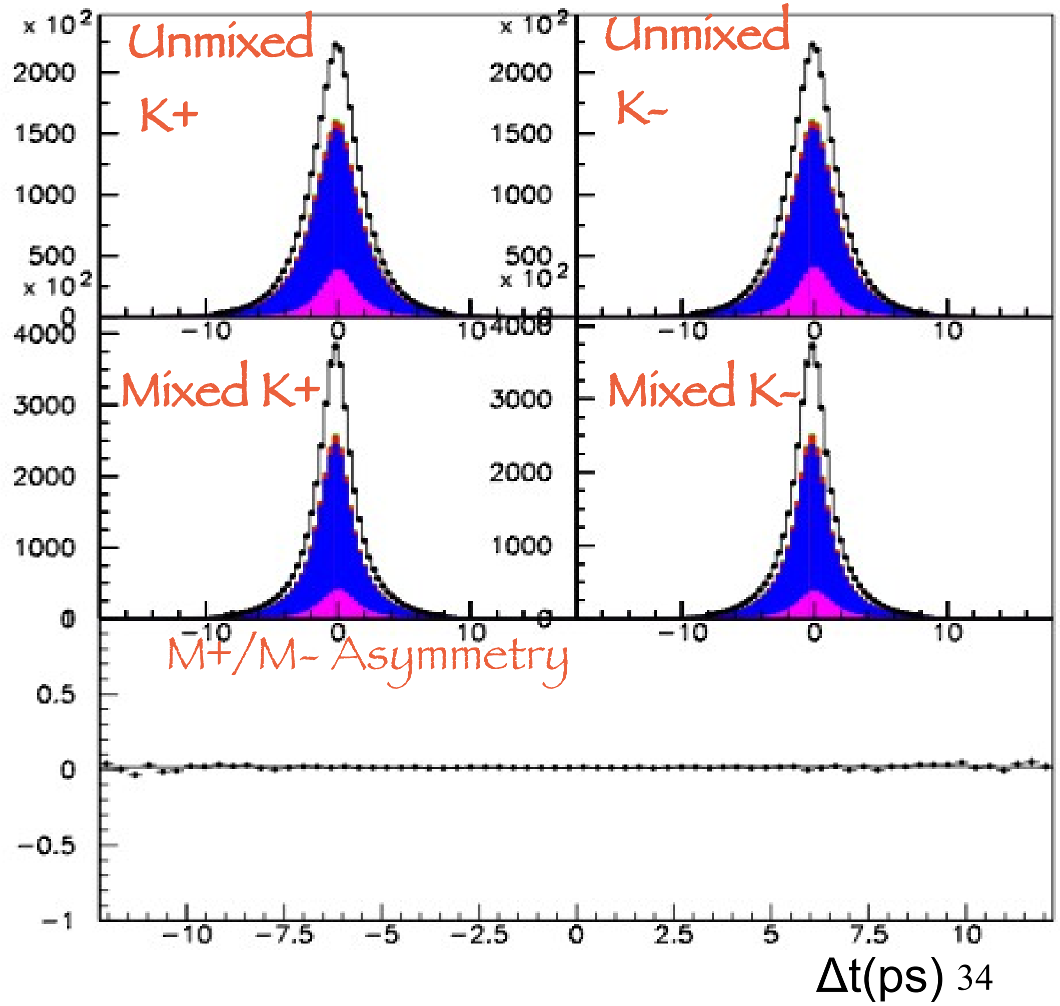
BLIND Studies

Preliminary BLIND Results

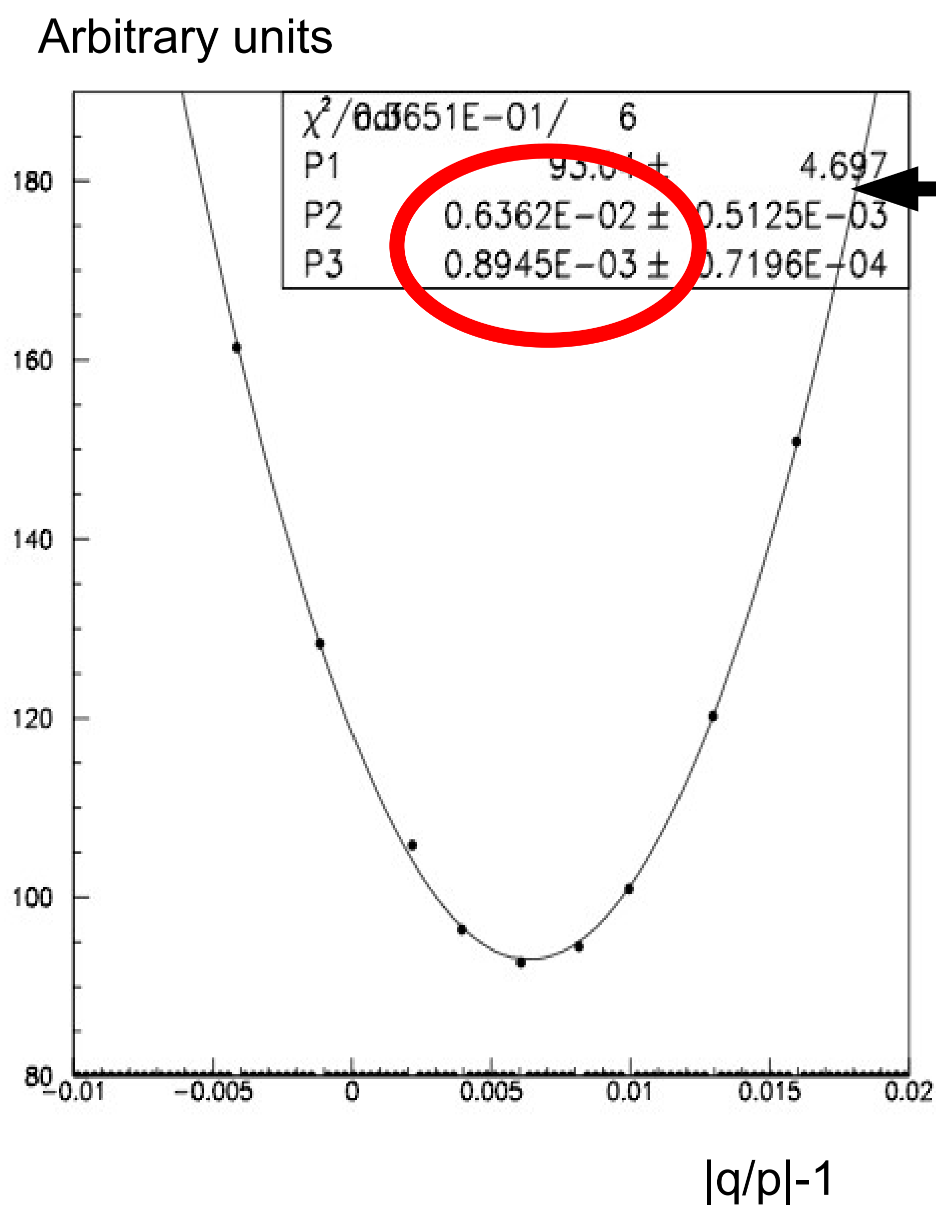
Fitted Δt Shapes

- Floated only parameters correlated with |q/p|
- Fixed resolution parameters





Preliminary BLIND Results



Blind Result:

$|q/p|-1=(6.36\pm0.89)*10^{-3}$

- Only parameters correlated with |q/p| floated, resolution fixed
- Nice convergence reached
- Statistical error scales correctly wrt Real Data/MC statistics

Preliminary Systematics:
Dtag description

Dtag description is one of the few elements of the analysis not completely data-driven: source of systematic errors:

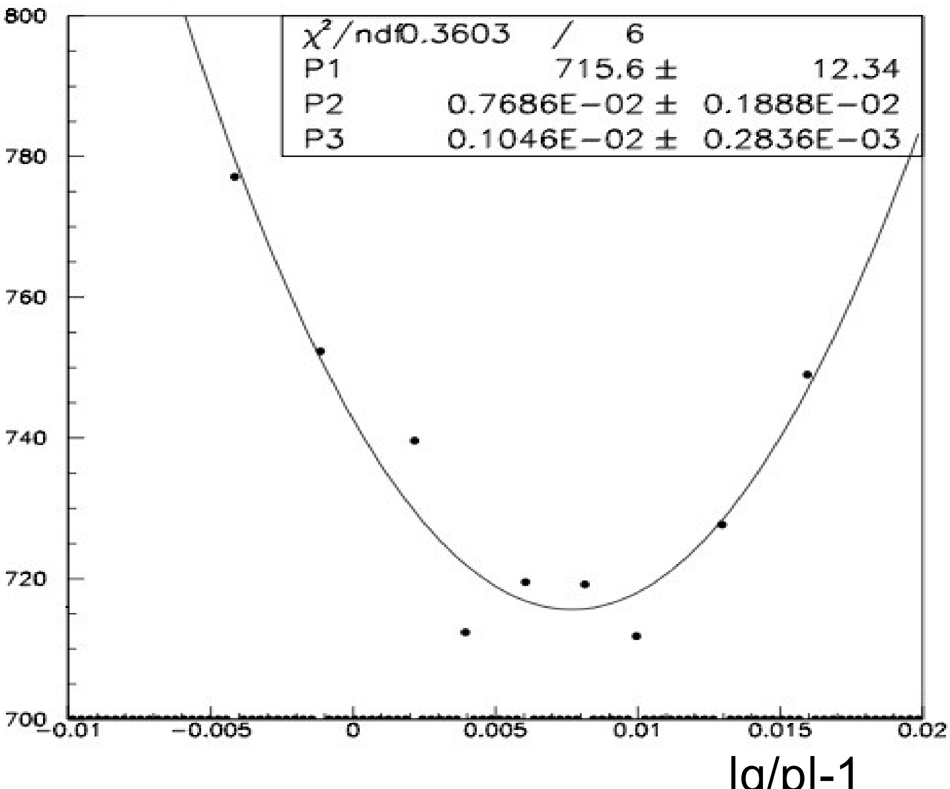
- Dtag Δt shape from Data/MC correction
  - ➔ Use alternatively Δt shape from High Purity selection on Real Data or from "inclusive" Dtag from MC

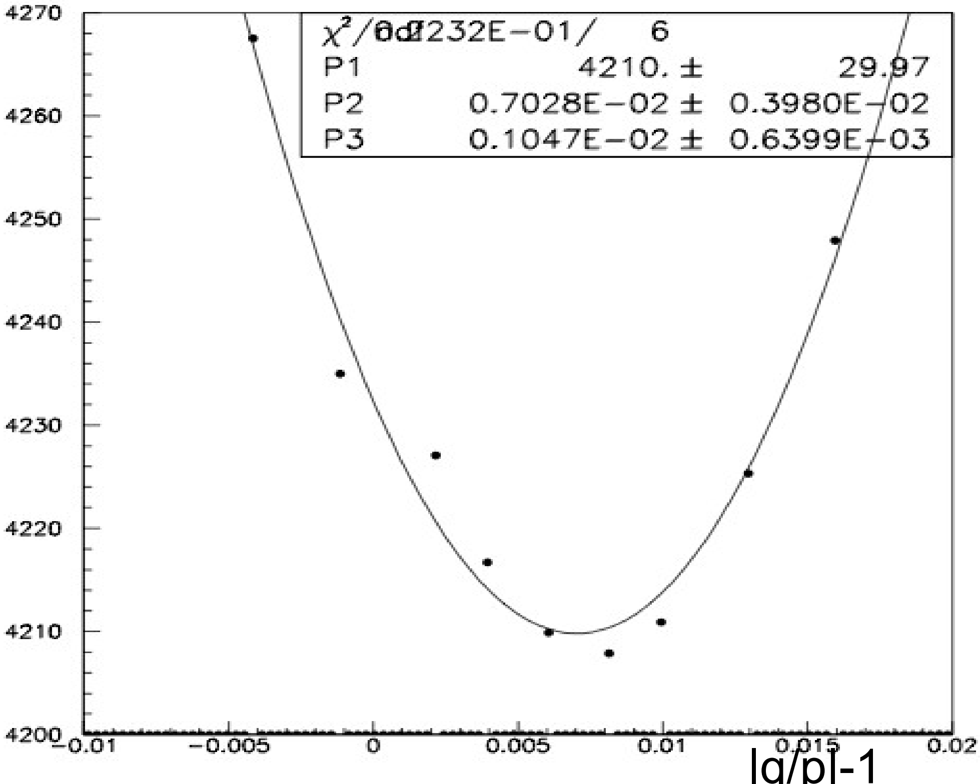
- Dtag Fraction in the B^+ sample (Peaking & BKG) constrained to B^0 one using ratios $R_{MC}(P_K)=F^{B+}_{Dtag}/F^{B0}_{Dtag}$ from MC
- R_{MC} depend on $BR(B^{0/+} \to DX \to KY)$
  - ➔ Conservatively vary R_{MC} by 20%, to be optimized

Dtag Systematics: Δt shape

Dtag Δt shape from:

- High Purity selection on Real Data
- Inclusive Dtag from MC





- Difference wrt Standard Procedure (scans to be optimized):

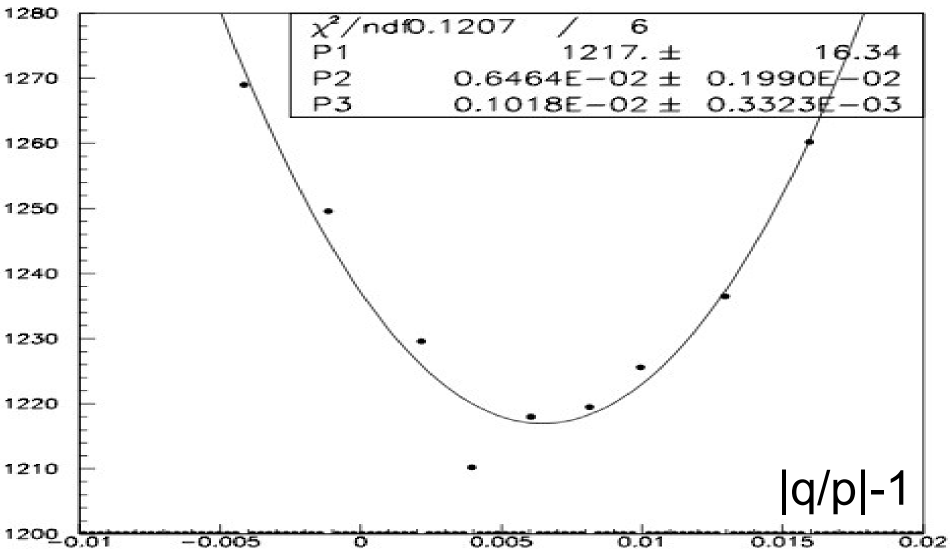
→ $\Delta|q/p|=+1.3\ 10^{-3}$ $\Delta|q/p|=+7\ 10^{-4}$

Dtag Systematics: B^+ sample fraction

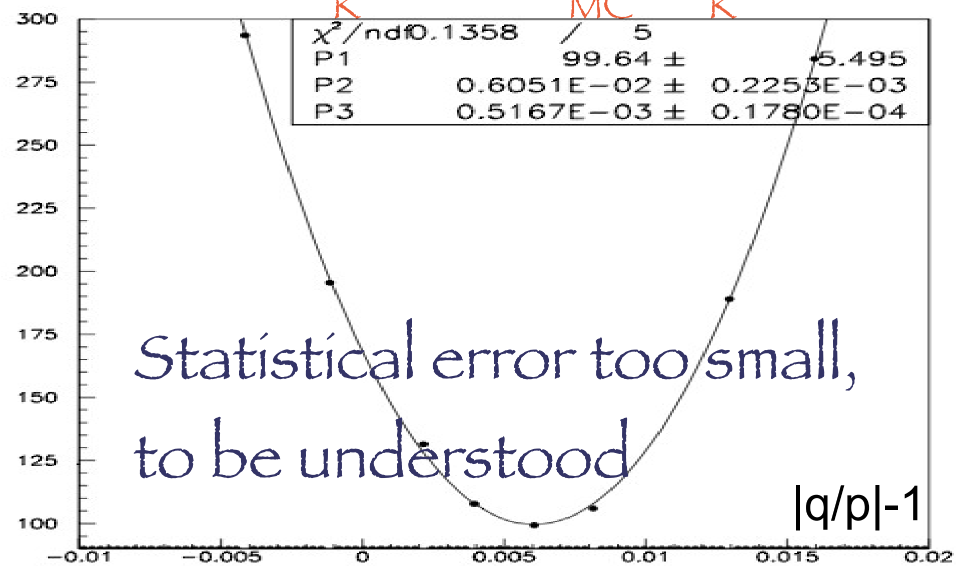
Dtag Fraction in the B^+ sample:

- $R_{MC}(P_K) = F^{B+}_{Dtag} / F^{B0}_{Dtag}$ varied by ±20%

$R(P_K)=0.8*R_{MC}(P_K)$



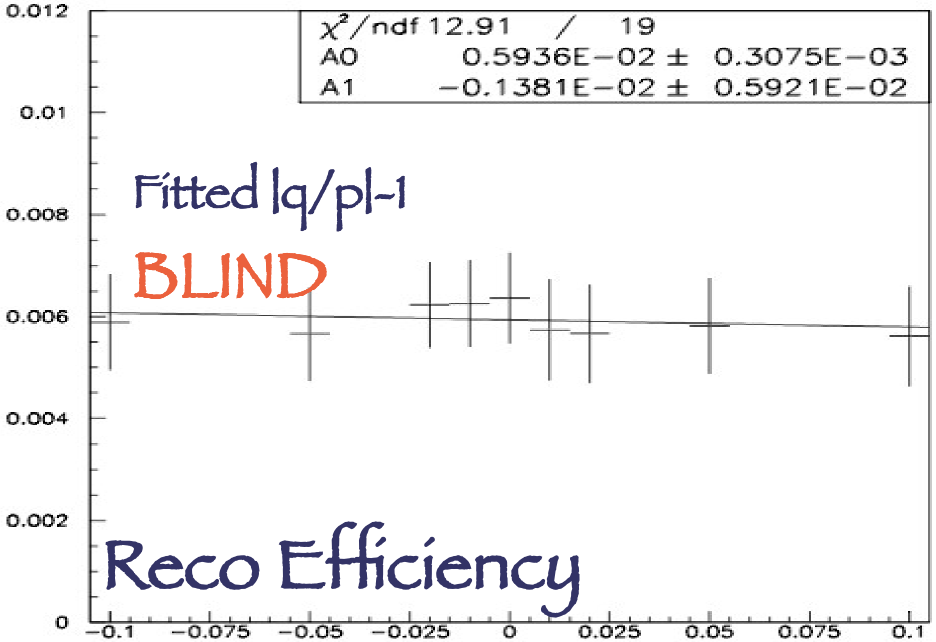
$R(P_K)=1.2*R_{MC}(P_K)$



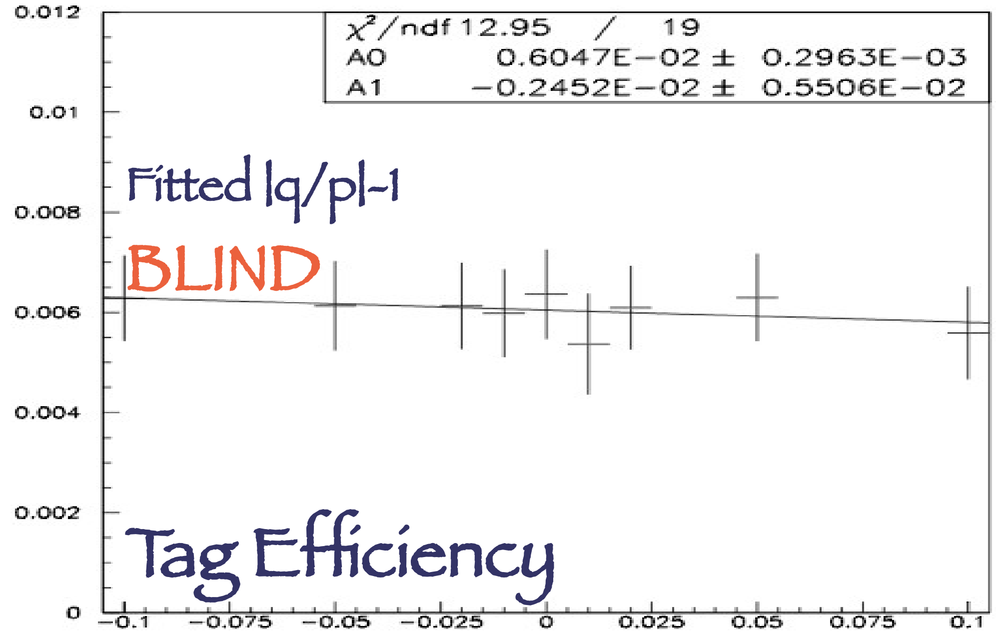
Statistical error too small, to be understood

- Difference wrt Standard Procedure (to be optimized):
  - → $\Delta|q/p| = +1.0\ 10^{-4}$ $\Delta|q/p| = -3.1\ 10^{-4}$
  - → Total preliminary systematic error from Dtag $\Delta|q/p| = {}^{+1.3\ 10^{-3}}_{-0.3\ 10^{-3}}$

|q/p|-1 vs Δε



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



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

- Same approach as for MC
- Observed |q/p| variation < 0.001 in all the Δε range
- The Fit correctly disentangles physical vs detector asymmetries
- Fitted Areco(e+μ) ~6.5 10^{-3}, Atag~1.5%
  - → Δε(Reco)<1.3%, Δε(Tag)<3% (PID tables <1%, ~1.5%)
  - → Δ|q/p|(Reco)<2 10^{-5}, Δ|q/p|(Tag)<6 10^{-5} (to be optimized)

Double Counting Problem

|q/p| and Detector Asymmetries are simultaneously obtained by applying Binomial-Constraints on:

a) Reconstructed Tagged+Untagged Events:

Constrains Reconstruction Asymmetry

b) Tagged Events divided in different categories

(B^0, B^+)X(Btag, Dtag)X(Peaking, BKG)X(Mixed, Unmixed):

Constrains Physical and/or Detector Asymmetries

- Underestimation of statistical error due to double counting of events in the two different Binomial-Constraints has to be avoided

- Possible Solutions already investigated:
  1) Remove Constraint a): introduce a |q/p| bias ~0.0015
  2) Modify the Likelihood using a Multinomial Approach: needs heavy debugging, not in time for ICHEP
  3) Proposal: estimate a statistical error correction using a Toy MC

Expected Final Errors

Statistical Error:

- From fit with fixed resolution parameters $\pm 0.9\ 10^{-3}$
- Preliminary results obtained by floating all the parameters show a relative increase of ~10%
- Double counting studies show an increase of ~25% by removing the constraint on total number of reconstructed events

→ Estimated $\delta(|q/p|) \pm 1.25\ 10^{-3}$ (δA_{SL} ~$2.5\ 10^{-3}$)

Systematic Uncertainties:

- Dtag description $\pm 1.3\ 10^{-3}$
- Detector Asymmetries ~$0.1\ 10^{-3}$
- Sample Composition from external fit to M_{ν}^{2}
- Resolution (SVT alignment); Fixed Parameters (?)

→ Rough Estimation $\delta(|q/p|) \pm 1.8\ 10^{-3}$ (δA_{SL} ~$3.6\ 10^{-3}$)

Conclusions

- Validation on MC Run1-Run6 Release 24, Analysis 51:
  - Full Fit on B^0+B^+ + Continuum finalized
  - Negligible Analysis Bias found using a Modified MC with $|q/p| \neq 1$
  - Fit is able to disentangle Physical vs Detector asymmetries

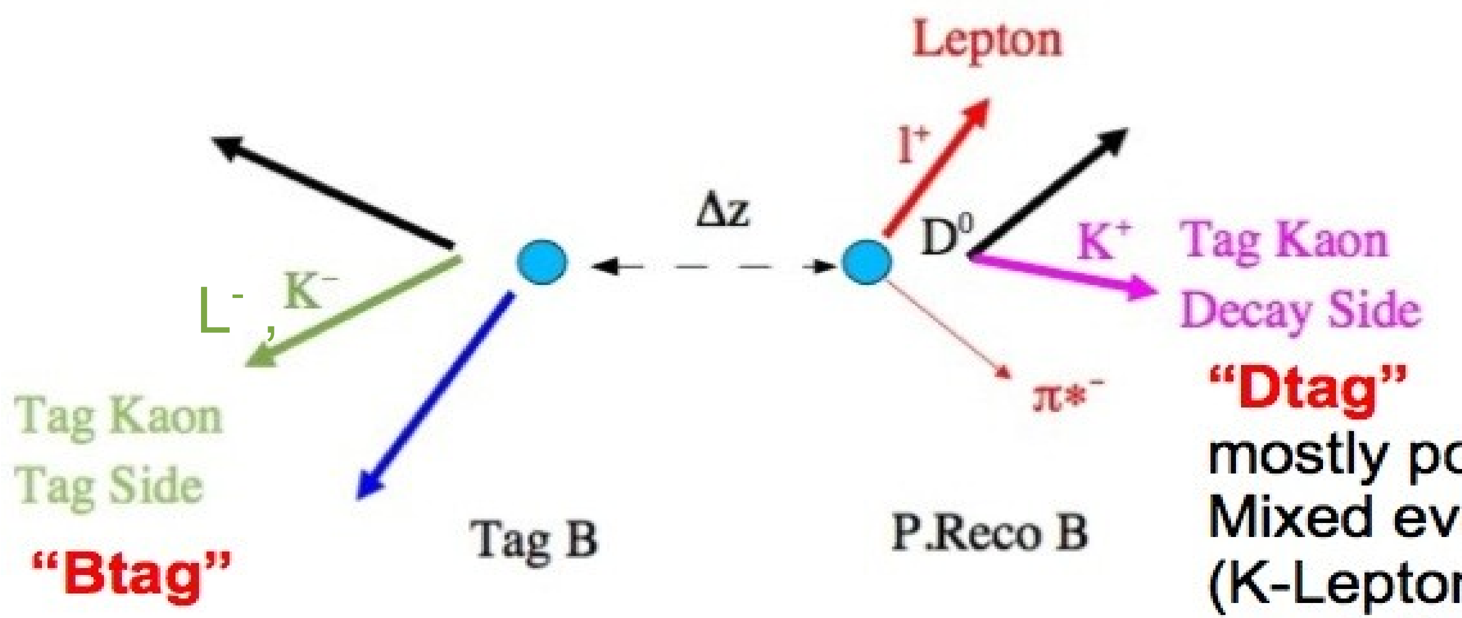
- Real Data:
  - Dtag Δt shape optimized for Real Data
  - Preliminary Blind Results obtained with statistical error in agreement with MC predictions
  - Preliminary Systematic errors evaluated

Next Steps

- Next Steps:
  - ➔ Update the Documentation & Restart the Review process
  - ➔ Reproduce MC/Real Data results by floating also resolution parameters
  - ➔ Develop a Toy MC for the evaluation of the statistical error (double counting problem)
  - ➔ Finalize systematic errors evaluation: sample composition from external fit, resolution parameterization, variation of (few) fixed parameters
  - ➔ Cross checks: e/μ, Mass Band/Side Band

Backup

High Purity Dtag Selection



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

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%, $\varepsilon \sim 5\%$**

•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):**

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

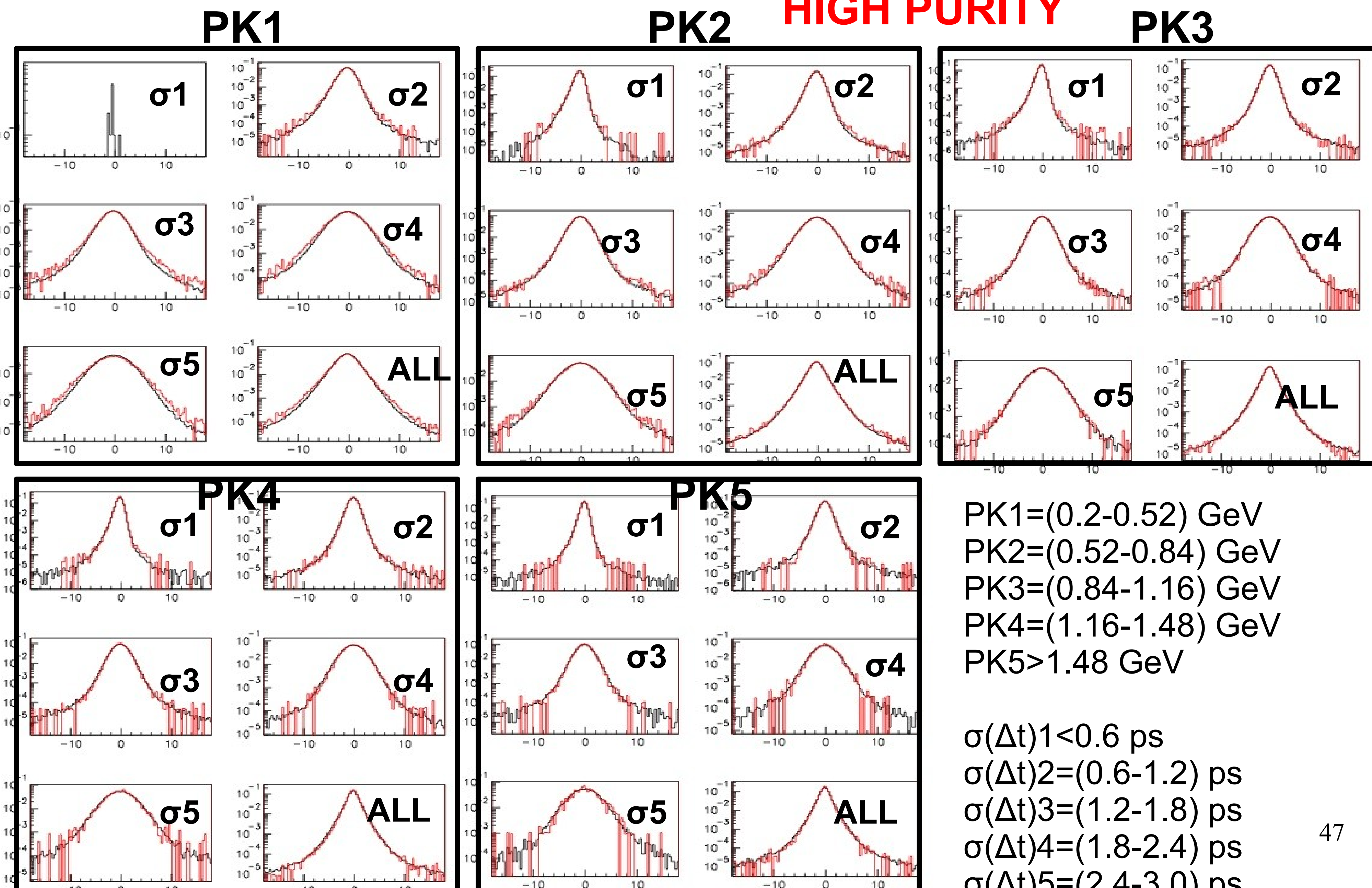
•Systematic error on Real Data from the comparison of the |q/p| results obtained using the calculated PDFs or the High Purity Selection PDFs

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

MC Dtag Δt PDF: Standard vs High Purity Selection

- Comparison in PK & σ(Δt) bins:

STANDARD
HIGH PURITY



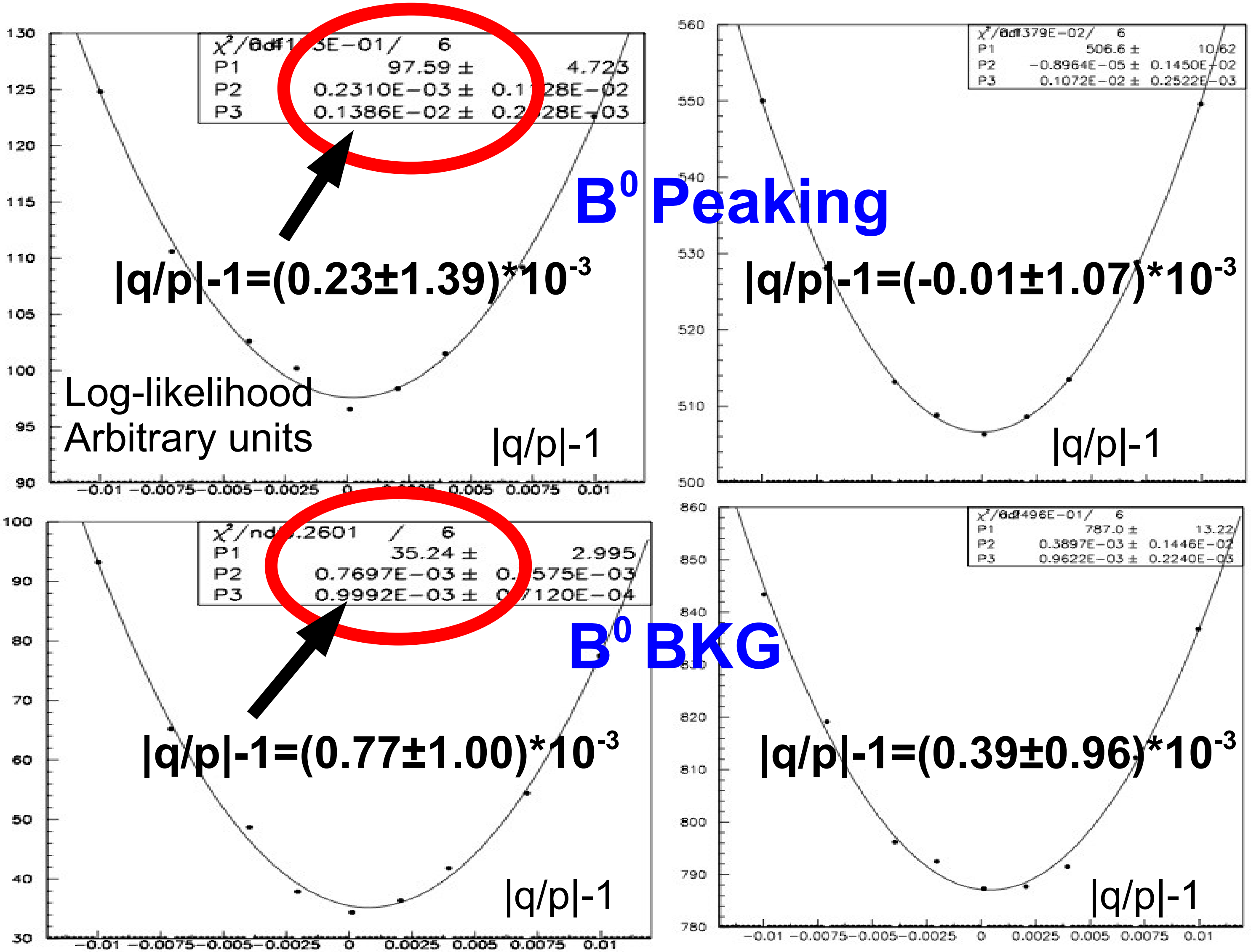
PK1=(0.2-0.52) GeV
PK2=(0.52-0.84) GeV
PK3=(0.84-1.16) GeV
PK4=(1.16-1.48) GeV
PK5>1.48 GeV

σ(Δt)1<0.6 ps
σ(Δt)2=(0.6-1.2) ps
σ(Δt)3=(1.2-1.8) ps
σ(Δt)4=(1.8-2.4) ps
σ(Δt)5=(2.4-3.0) ps

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|**



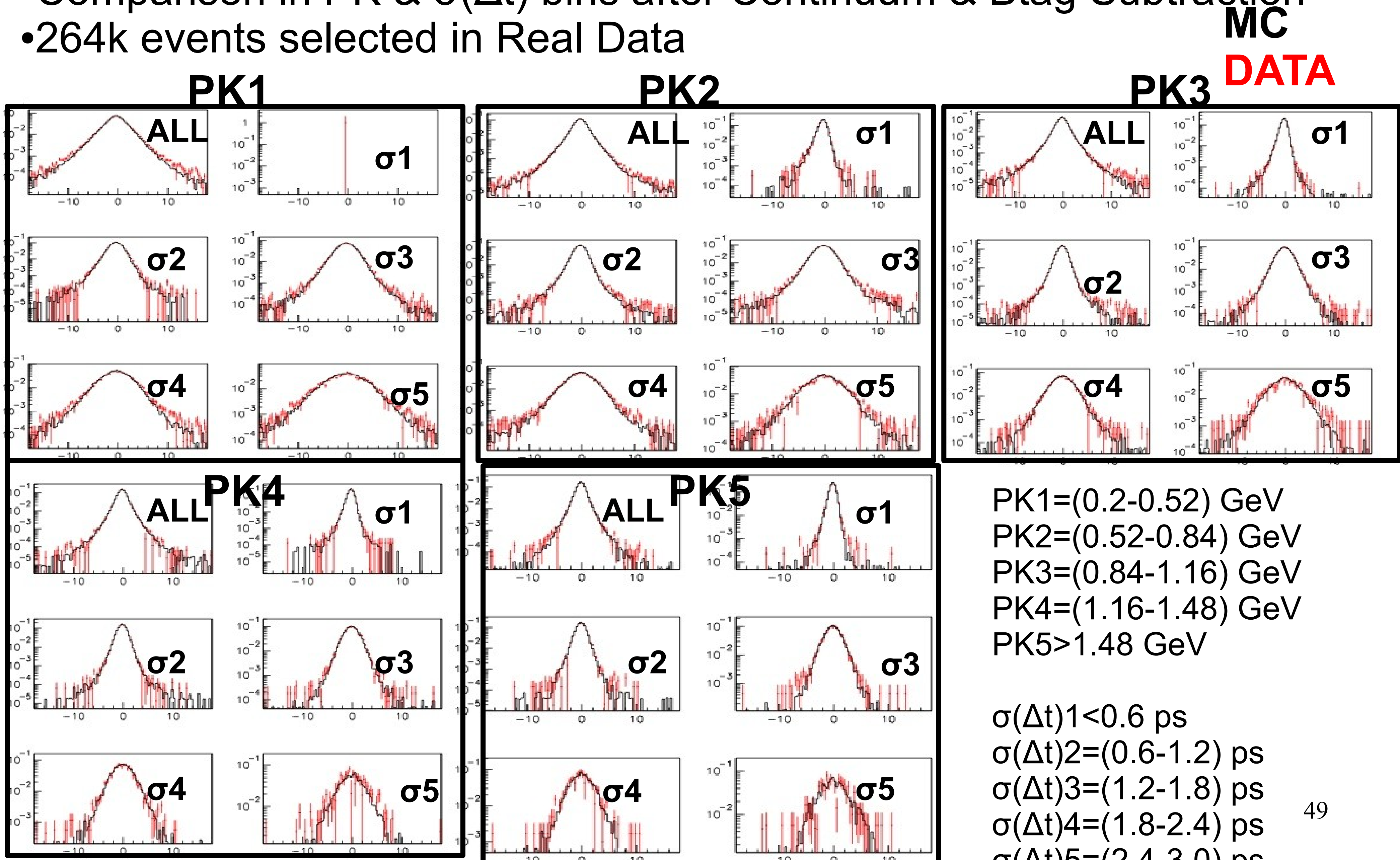
$-0.24*10^{-3}$

$-0.38*10^{-3}$

Effect~1/3 of MC Statistical σ

High Purity Dtag selection on Data & MC

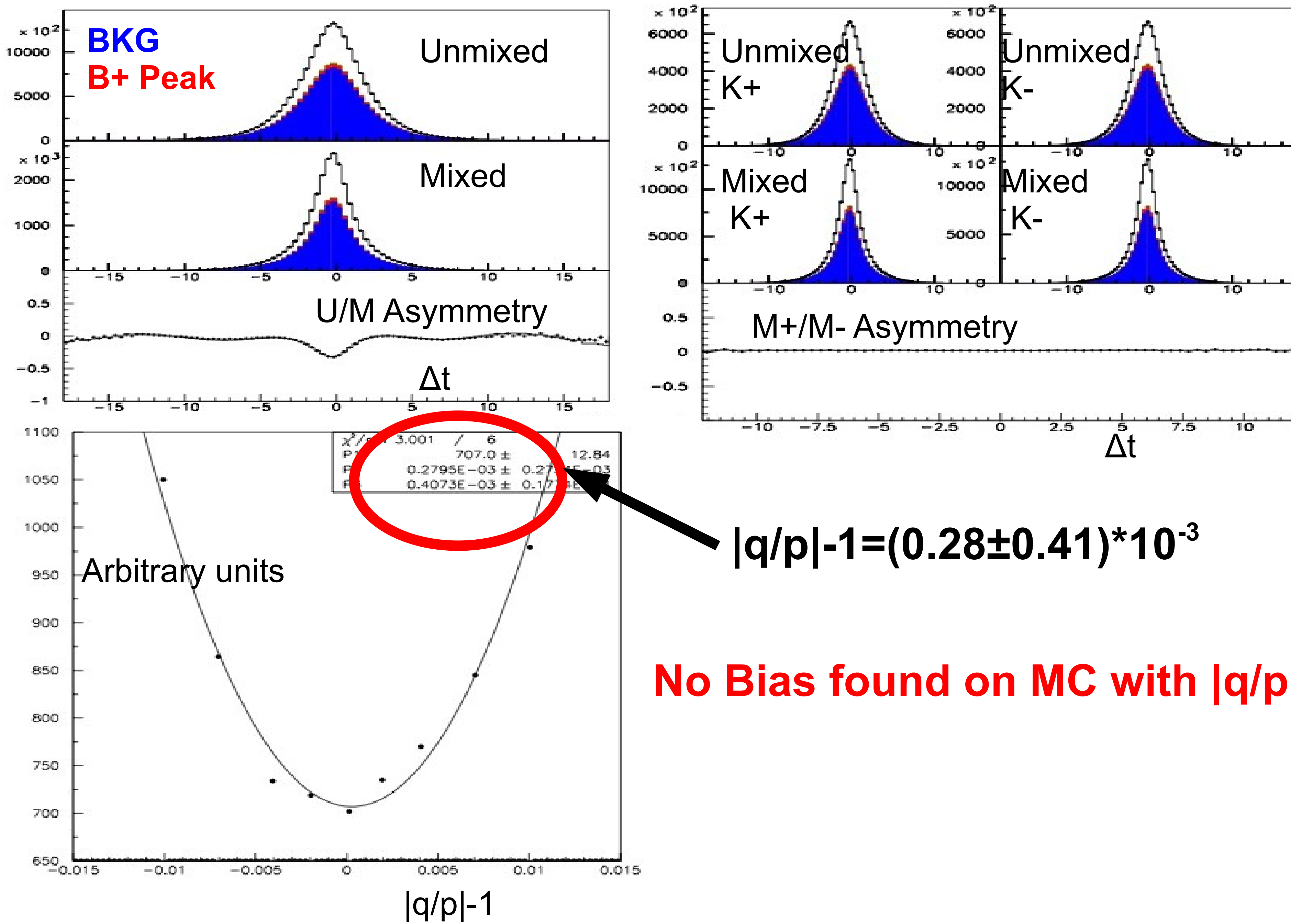
- Comparison in PK & σ(Δt) bins after Continuum & Btag Subtraction
- 264k events selected in Real Data



PK1=(0.2-0.52) GeV
PK2=(0.52-0.84) GeV
PK3=(0.84-1.16) GeV
PK4=(1.16-1.48) GeV
PK5>1.48 GeV

σ(Δt)1<0.6 ps
σ(Δt)2=(0.6-1.2) ps
σ(Δt)3=(1.2-1.8) ps
σ(Δt)4=(1.8-2.4) ps
σ(Δt)5=(2.4-3.0) ps

Results on B^0+B^+ Peaking+BKG

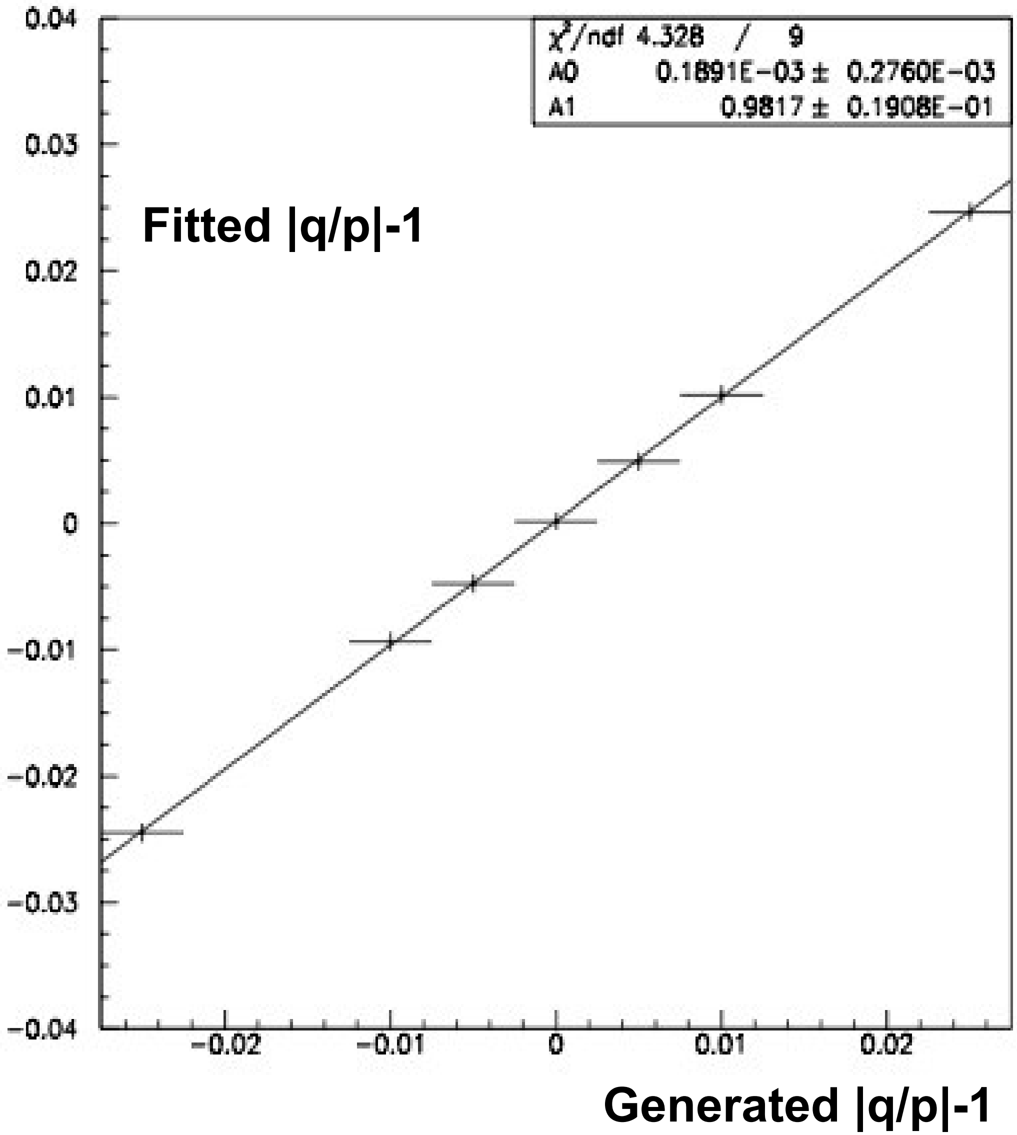


$|q/p|-1=(0.28\pm0.41)*10^{-3}$

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

Fitted vs Generated K=|q/p|-1

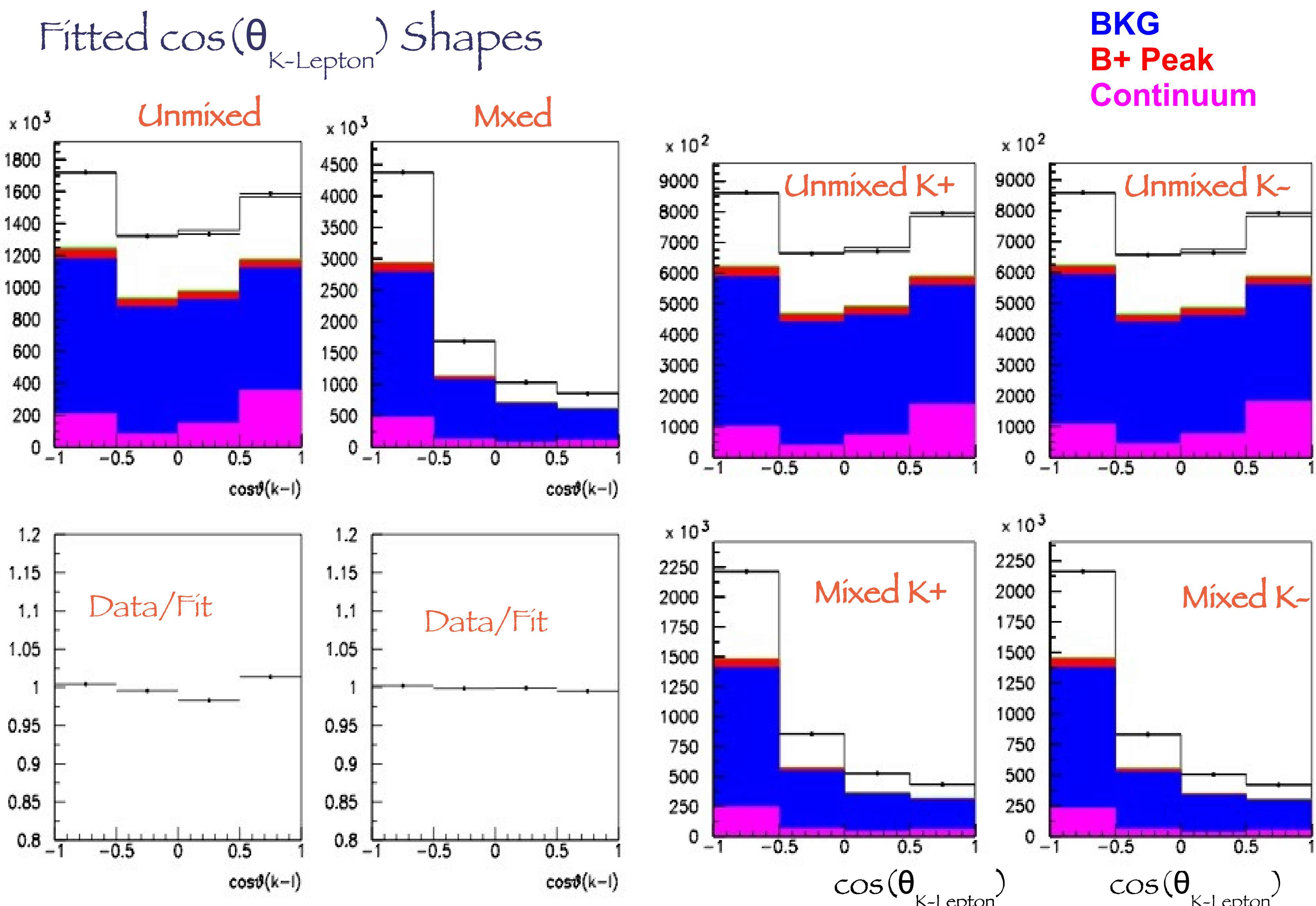
B^0 Peaking+BKG Btag+Dtag



- Statistical errors correlated between different bins
- **Slope=0.98:**
  ~no bias on |q/p|-1 found
- Very wide |q/p| range as compared with the expectations

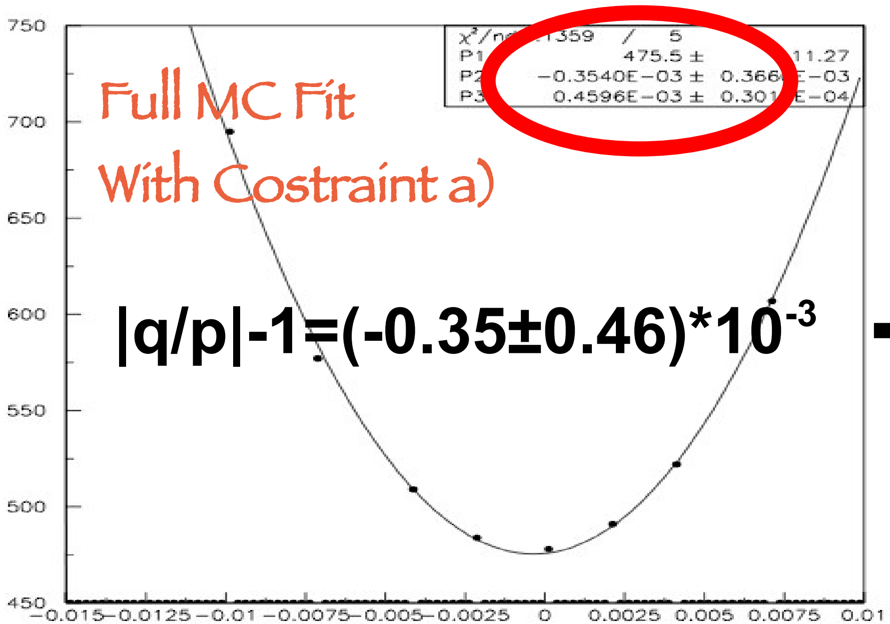
Preliminary BLIND Results

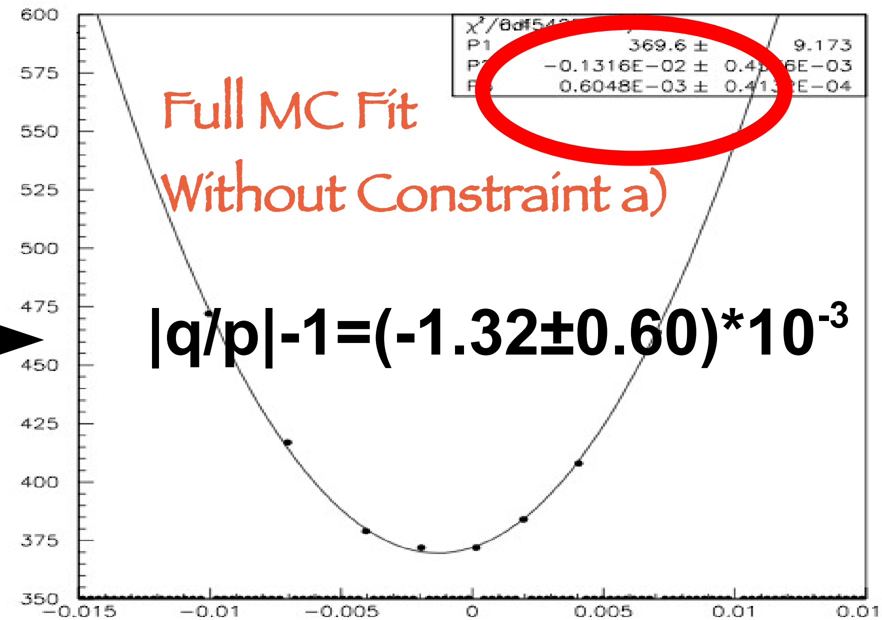
Fitted $\cos(\theta_{K\text{-}Lepton})$ Shapes

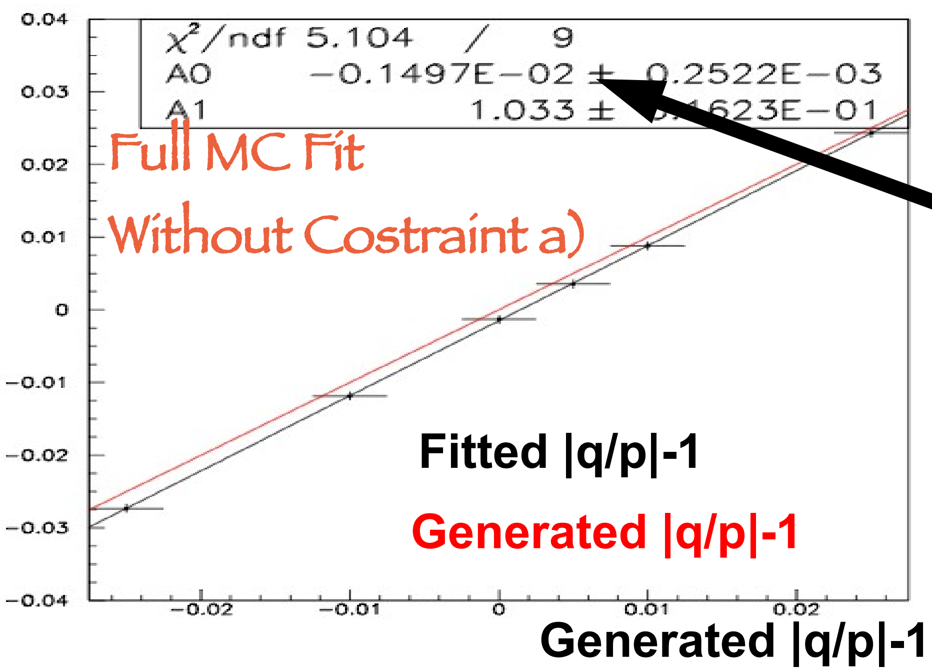


Double Counting Problem

Solution 1): MC Test removing Constraint a)



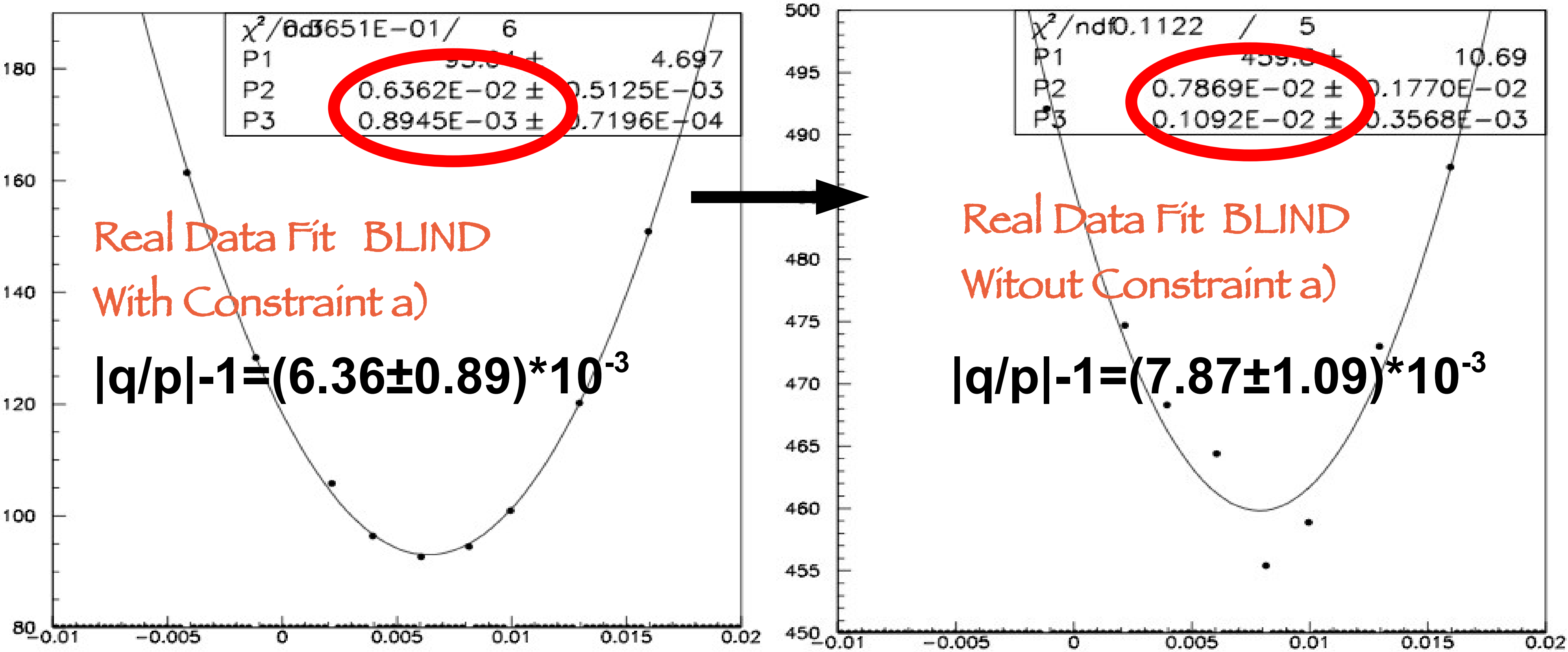




- Statistical error increases by 30%
- Bias ~0.0015 on |q/p| for |q/p|~1
  - → Constraint a) is very useful to disentangle Physical vs Detector Asymmetries

Double Counting Problem

Solution 1): Real Data Test removing Constraint a)



- Statistical error increases by 22%
- Central Value moves by -1.5 10^{-3} in the opposite direction wrt MC
  - → Do not remove Constraint a)

Double Counting Problem

Solution 2): Multinomial Constraint

- For every $(l^+,l^-)\times(B^0, B^+)\times$(Peaking, BKG) category:

$$L=\frac{\nu^N e^{-\nu}}{N!}\frac{N!}{NBt^{Mix}!\,NBt^{Unm}!\,NDt^{Mix}!\,NDt^{Unm}!\,NNt!}\times$$

$$P(Bt^{Mix})^{NBt^{Mix}}\,P(Bt^{Unm})^{NBt^{Unm}}\,P(Dt^{Mix})^{NDt^{Mix}}\,P(Dt^{Unm})^{NDt^{Unm}}\,P(Nt)^{NNt}$$

$$N=NBt^{Mix}+NBt^{Unm}+NDt^{Mix}+NDt^{Unm}+NNt$$

- Poissonian term constrains the Reconstruction Asymmetry
- Different probabilities are proportional to the corresponding tagging efficiencies:

$$P(Bt)\propto\epsilon(Bt);P(Dt)\propto\epsilon(Dt)\qquad P(Nt)=1-\epsilon(Bt)-\epsilon(Dt)$$

  - ➔ Fit in addition also the Tagging Efficiencies ε(Bt) and ε(Dt) for Btag and Dtag events

- Strategy not ready in time for summer conferences
- Proposal: use a Toy MC for the determination of the statistical error

Event Statistics

MC statistics: ~47 Mevents

B0 Btag Mixed Events

$\delta\lvert q/p\rvert_{stat}$		Limit	Meas.	Corrected (expected)
Signal	1519576			
Combinatorial	2002682			
Total	3522258	$2.7\ 10^{-4}$	$4.6\ 10^{-4}$	$6.6\ 10^{-4}$

Data statistics: ~14 Mevents

B0 Btag Mixed	~1174000	$4.6\ 10^{-4}$	$8.9\ 10^{-4}$	$1.25\ 10^{-3}$