CP violation in B^0-$\overline{B}^0$ mixing with dilepton events in *BABAR*

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BABAR

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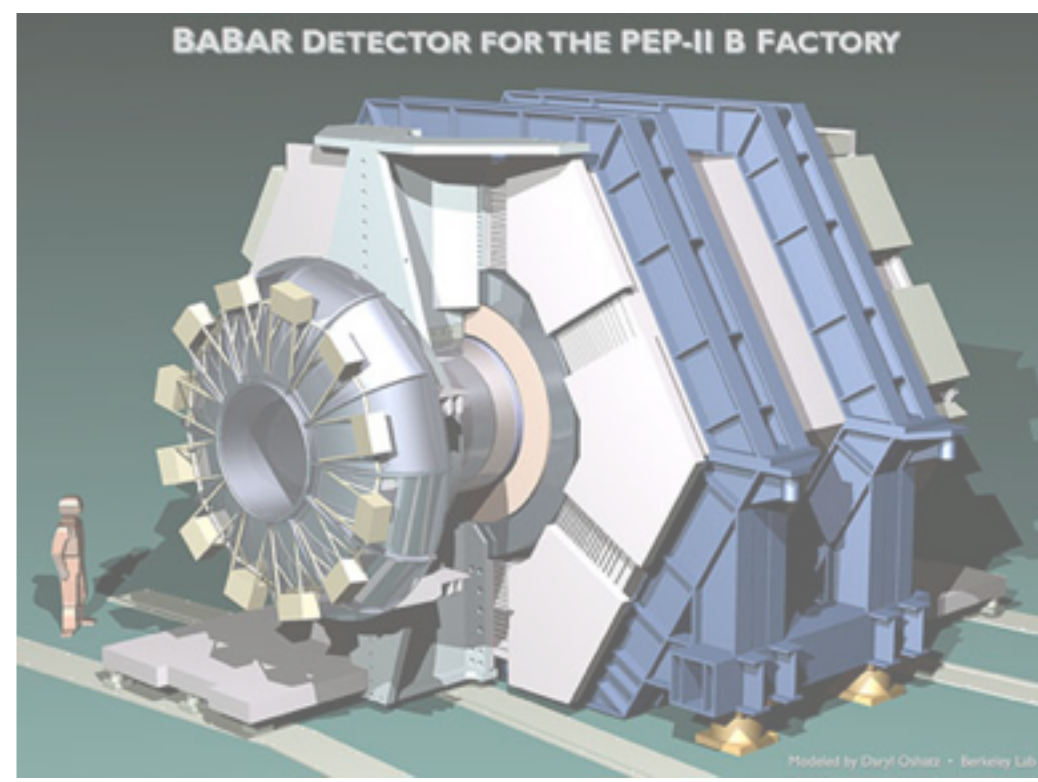
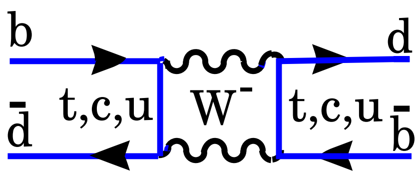
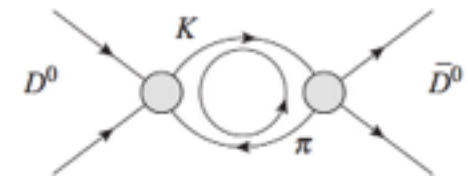
CKM2014



Neutral meson mixing

- Neutral mesons couple to their anti-particle through weak interaction.
  - $B^0_{d,s} \leftrightarrow \overline{B}^0_{d,s}$; $D^0 \leftrightarrow \overline{D}^0$; $K^0 \leftrightarrow \overline{K}^0$

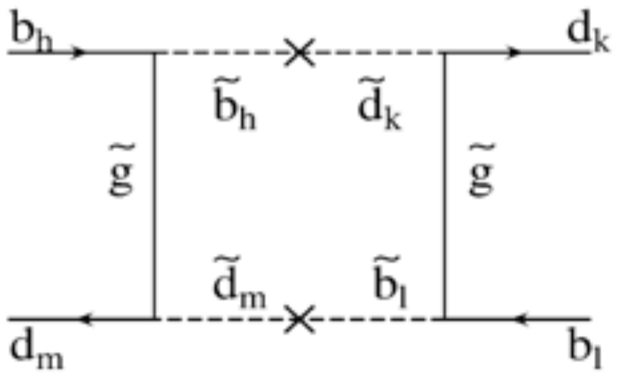




- Schrödinger equation with effective Hamiltonian:

$$i\frac{d}{dt}\begin{pmatrix} |B(t)\rangle \\ |\overline{B}(t)\rangle \end{pmatrix} = \left(\hat{M} - \frac{i}{2}\hat{\Gamma}\right)\begin{pmatrix} |B(t)\rangle \\ |\overline{B}(t)\rangle \end{pmatrix}$$

- Measurements of various aspects of mixing test the theory of weak interaction.
  - Mixing rate, decay rate difference, CP violation



- New physics in the loops could alter these observables.

CP violation in mixing

- The eigenstates

$$|B_{L/H}\rangle = \frac{1}{\sqrt{p^2+q^2}}(p|B^0\rangle \pm q|\overline{B}^0\rangle)$$

- Mixing probability (and decay to a flavor-specific state $|f\rangle$)

$$\begin{aligned}\mathcal{P}(B^0 \to \overline{B}^0 \to \bar{f})(t) &\propto |q/p|^2[\cosh(\Delta\Gamma t/2) - \cos(\Delta m t)]\\ \mathcal{P}(\overline{B}^0 \to B^0 \to f)(t) &\propto |p/q|^2[\cosh(\Delta\Gamma t/2) - \cos(\Delta m t)]\end{aligned}$$

- CP (or T) asymmetry

$$A_{CP} = \frac{\mathcal{P}(\overline{B}^0 \to B^0)(t) - \mathcal{P}(B^0 \to \overline{B}^0)(t)}{\mathcal{P}(\overline{B}^0 \to B^0)(t) + \mathcal{P}(B^0 \to \overline{B}^0)(t)} = \frac{1-|q/p|^4}{1+|q/p|^4} \simeq 2(1-|q/p|)$$

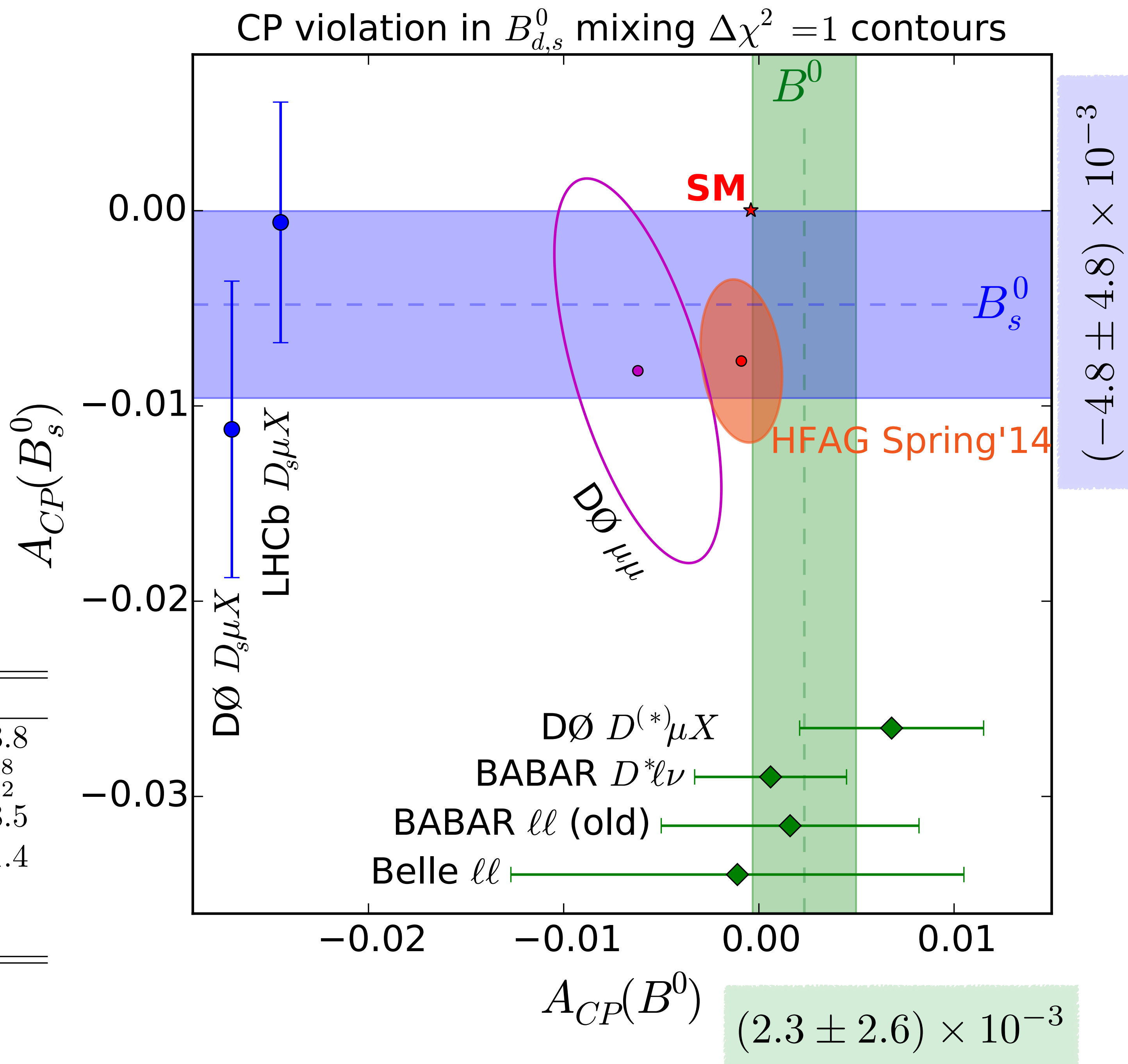
$$|q/p|^2 \simeq 1 - \mathrm{Im}\left(\frac{\Gamma_{12}}{M_{12}}\right);\ A_{CP} \simeq 2\mathrm{Im}\left(\frac{\Gamma_{12}}{M_{12}}\right) \simeq -\frac{\Delta\Gamma}{\Delta m}\tan\phi_{12}$$

Current experimental results

HFAG 2014 2-dim. fit (including DØ$\mu\mu$)

$$A_{CP}(B^0) = (-0.9 \pm 2.1) \times 10^{-3}$$
$$A_{CP}(B^0_s) = (-7.7 \pm 4.2) \times 10^{-3}$$

Experiment	Method	Data	$A^d_{\rm sl}$ (10^{-3})
BABAR	dilepton	232×10^6 $B\overline{B}$	$+1.6 \pm 5.4 \pm 3.8$
BABAR	$D^*\ell\nu$	470×10^6 $B\overline{B}$	$+0.6 \pm 1.7^{+3.8}_{-3.2}$
Belle	dilepton	78 fb^{-1}	$-1.1 \pm 7.9 \pm 8.5$
DØ	$D^{(*)-}\mu X$	10.4 fb^{-1}	$+6.8 \pm 4.5 \pm 1.4$
DØ	dimuon	10.4 fb^{-1}	-6.2 ± 4.3
DØ	combined fit	10.4 fb^{-1}	-0.9 ± 2.9

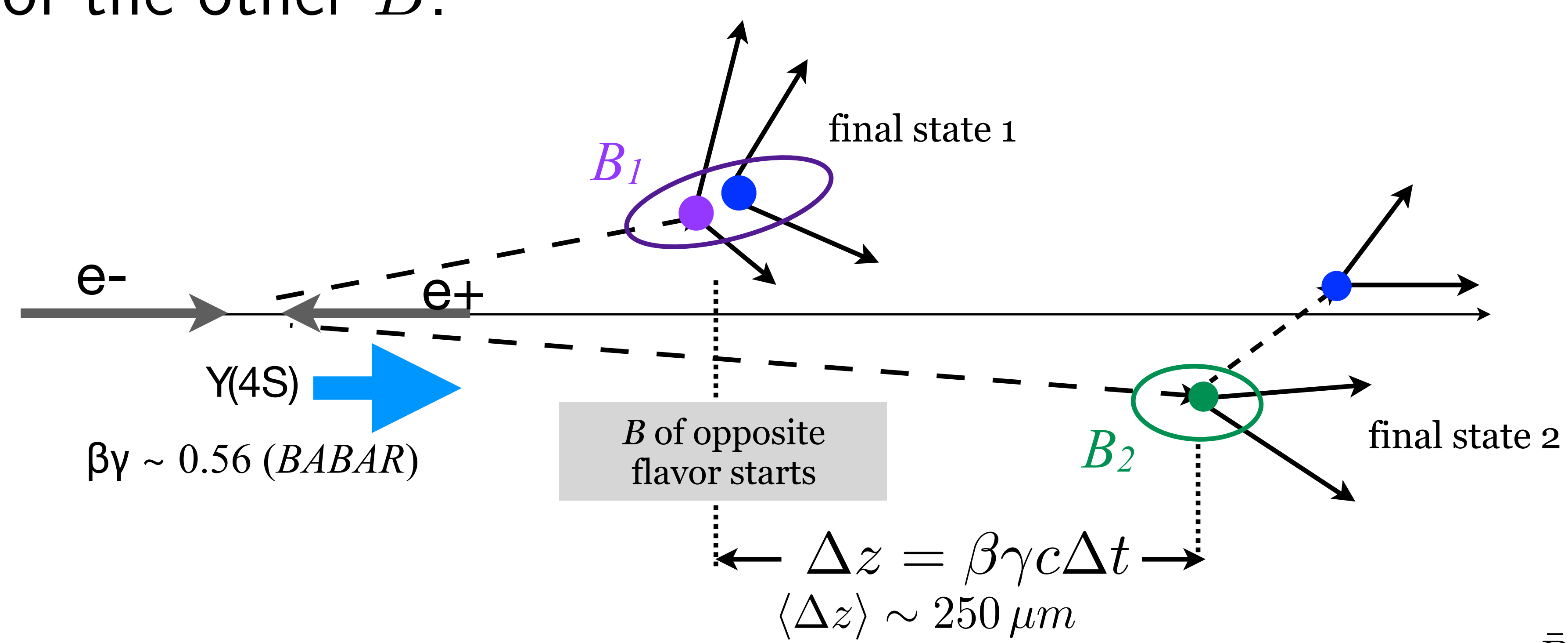


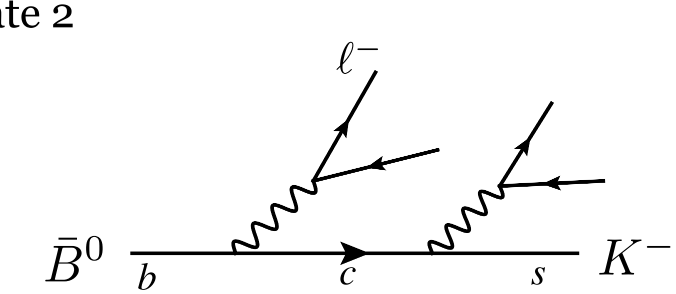
Experiment

- In B factories, $\Upsilon(4S)$ are produced and decay to a pair of B mesons in a coherent $L = 1$ anti-symmetric state

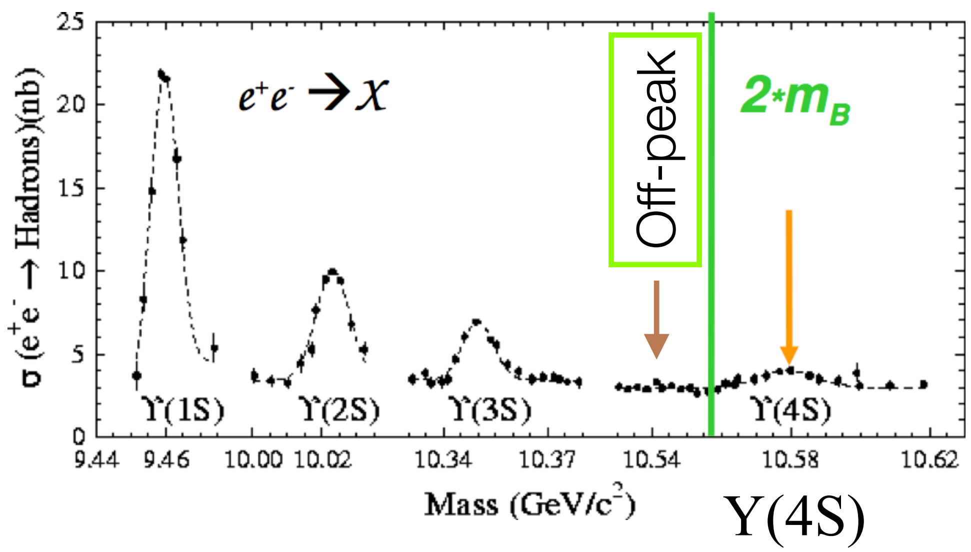
$$|i\rangle = \frac{1}{\sqrt{2}}[B^0(t_1)\overline{B}^0(t_2) - \overline{B}^0(t_1)B^0(t_2)]$$

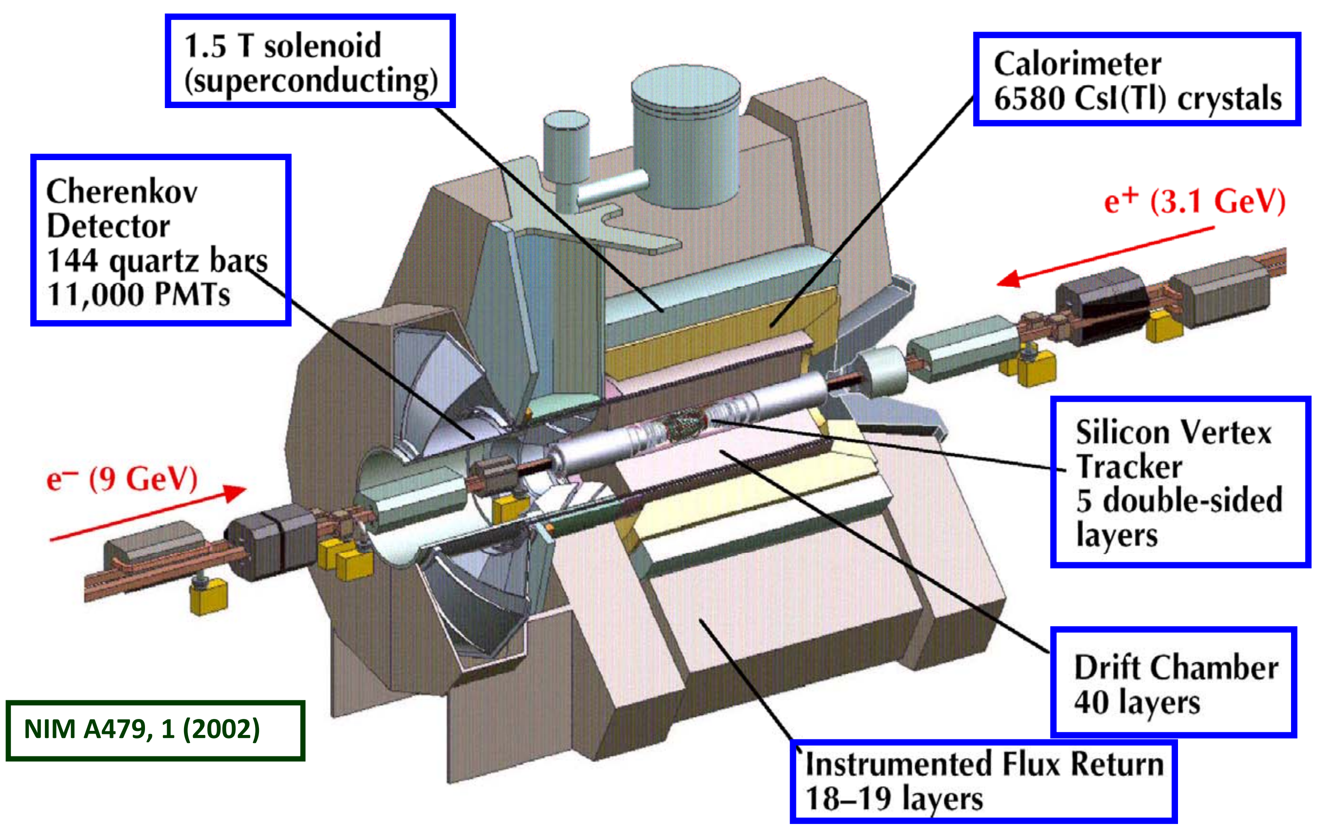
- Look for two flavor-specific final states; one would tag the initial state of the other B.

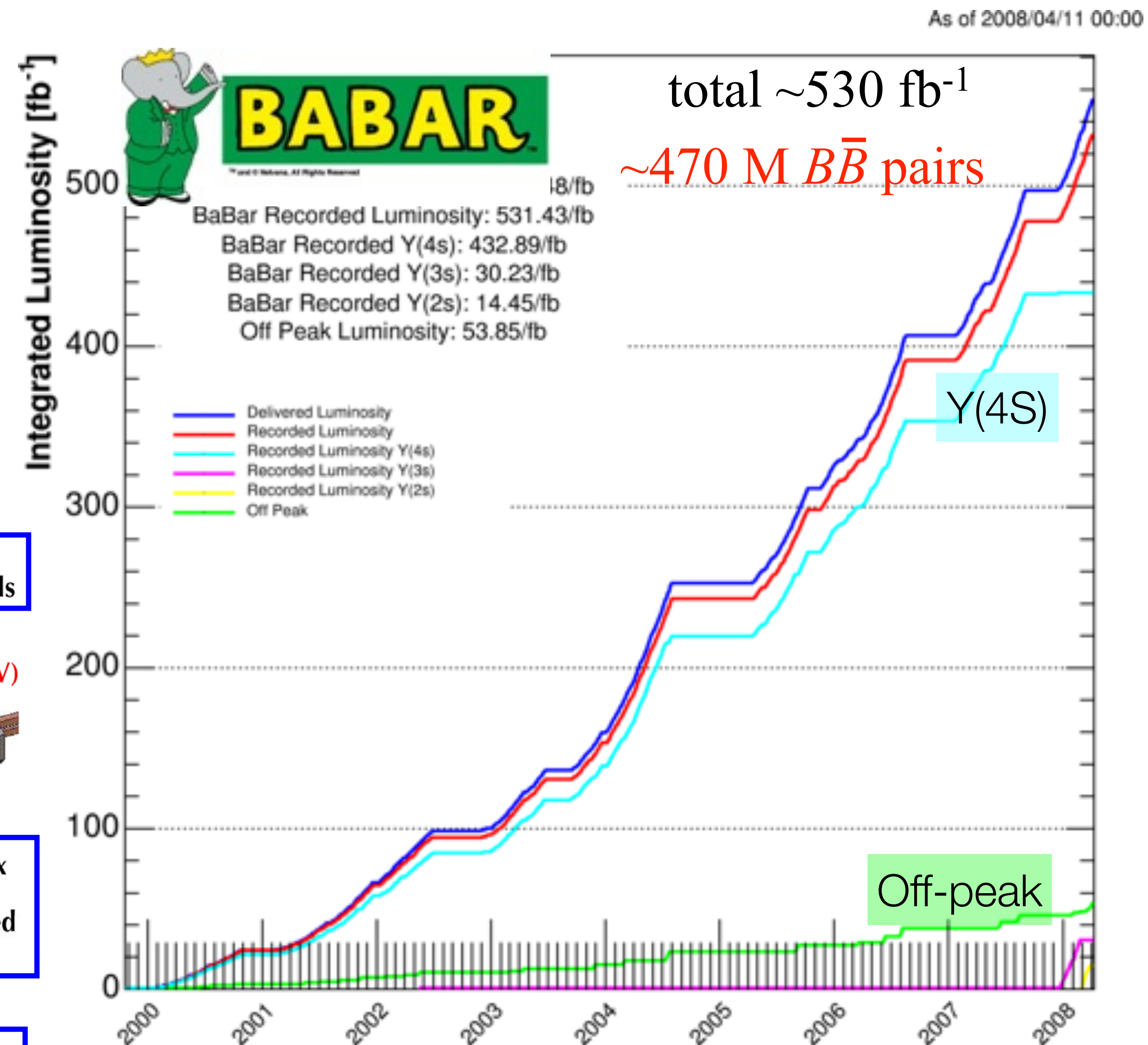




BABAR data set and detector

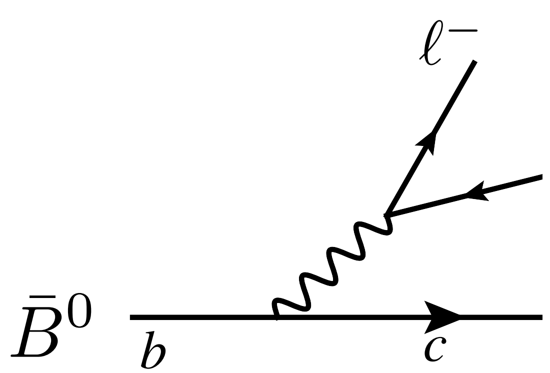






Inclusive dilepton

- Use the charge of the lepton from B semileptonic decays to identify the flavor of the B meson at the time of its decay.
- If both lepton have the same charge, mixing occurs:
  - $\ell^+\ell^+$: $\overline{B}^0 \rightarrow B^0$ occurs
  - $\ell^-\ell^-$: $B^0 \rightarrow \overline{B}^0$ occurs
  - $\ell^+\ell^-$: no mixing



Mixing probability

$$\mathcal{P}^{\pm\pm}(\Delta t) \propto e^{-\Gamma|\Delta t|}|q/p|^{\mp 2}[\cosh(\Delta\Gamma\Delta t/2) - \cos(\Delta m\Delta t)]$$
$$\mathcal{P}^{\pm\mp}(\Delta t) \propto e^{-\Gamma|\Delta t|}[\cosh(\Delta\Gamma\Delta t/2) + \cos(\Delta m\Delta t)].$$

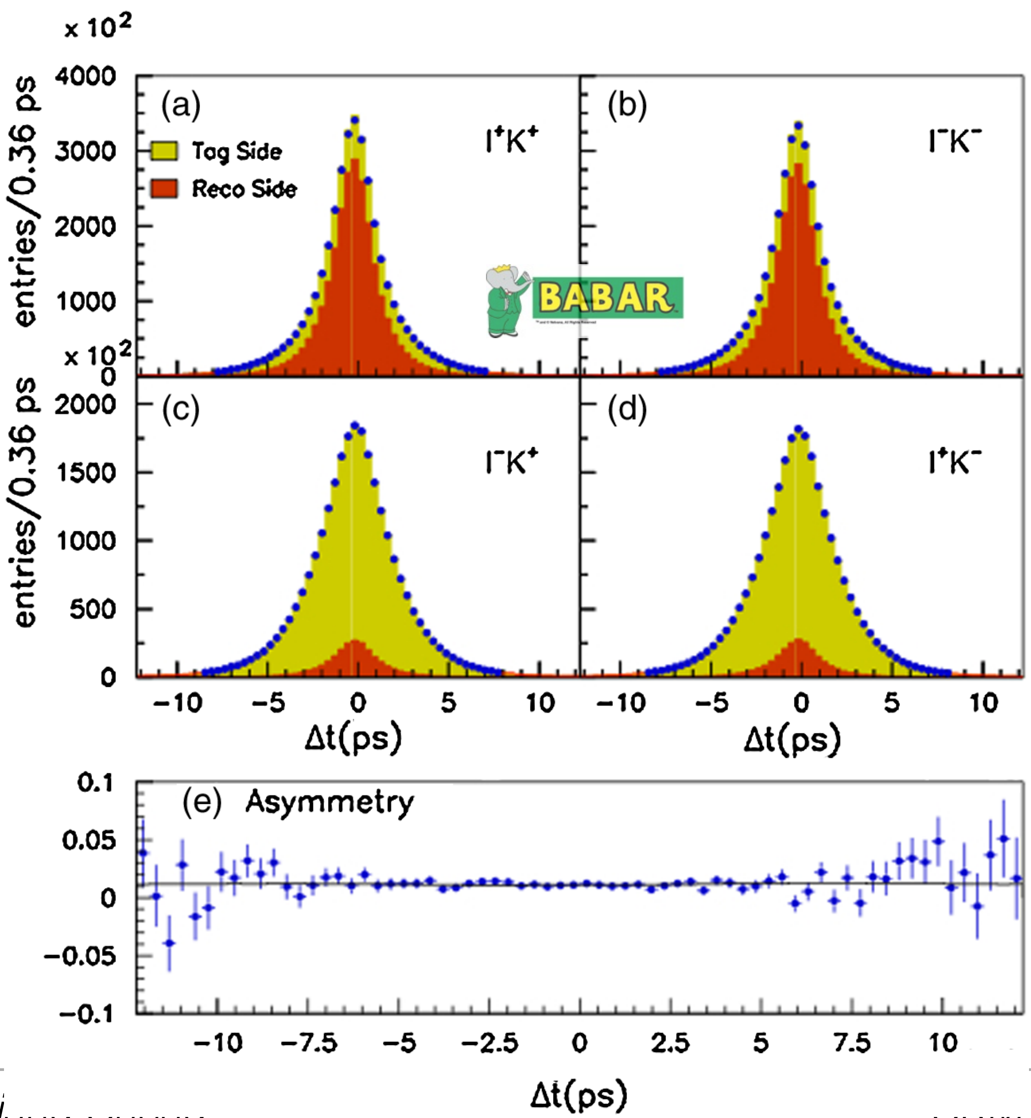
Time-integrated probability

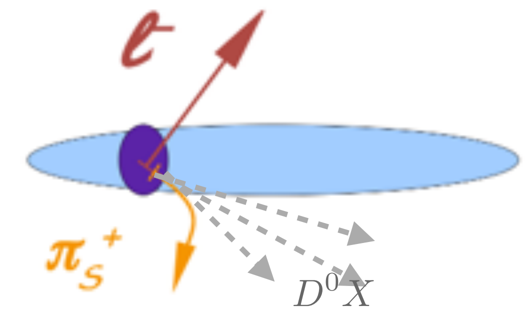
$$\mathcal{P}^{\pm\pm} \propto (1 \pm A_{CP})\chi_d$$
$$\mathcal{P}^{\pm\mp} \propto (1 - \chi_d)$$

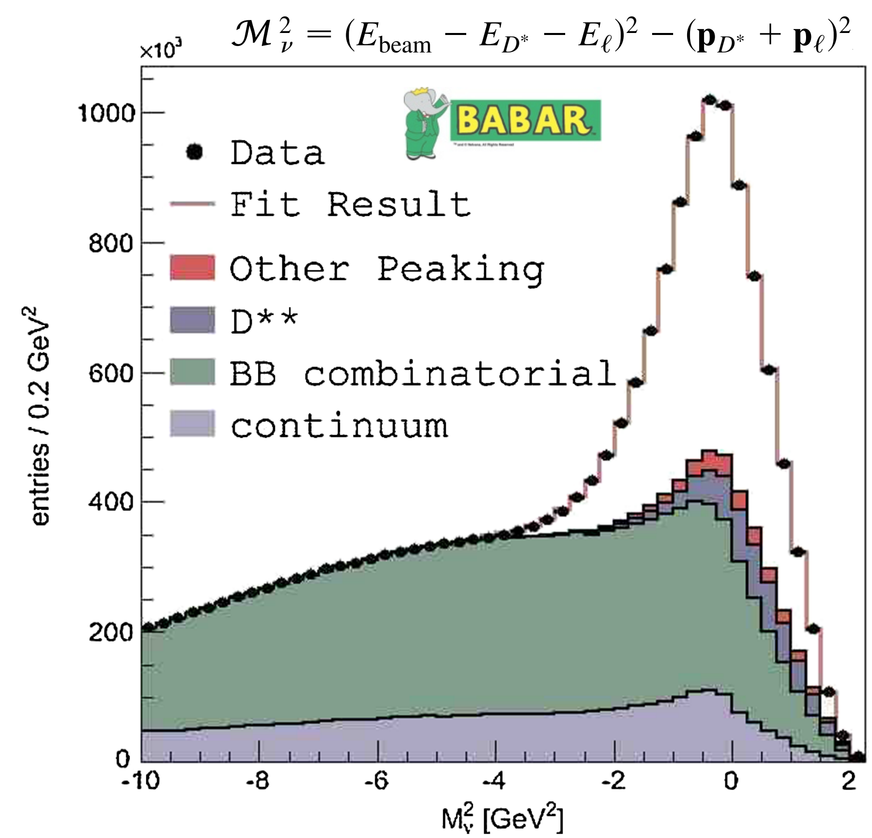
$$A_{CP} = \frac{\mathcal{P}(\Delta t)^{++} - \mathcal{P}(\Delta t)^{--}}{\mathcal{P}(\Delta t)^{++} + \mathcal{P}(\Delta t)^{--}} = \frac{|p/q|^2 - |q/p|^2}{|p/q|^2 + |q/p|^2}.$$

Earlier *BABAR* result using $B^0 \to D^*\ell\nu$

- Partial reconstruction
  - ℓ and π_s from D^*
- Kaon tag
- Time-dependent fit







$$A_{CP} = (0.6 \pm 1.7^{+3.8}_{-3.2}) \times 10^{-3}$$

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Dilepton analysis strategy

- Consider detector efficiency charge asymmetry a_{ℓ_j} for lepton ℓ_j, and B^+B^- contribution $r_B = N_{B^+B^-}/N_{B^0\overline{B}^0}$:

$$\mathcal{P}^{\pm\pm} \propto (1 \pm a_{\ell_1} \pm a_{\ell_2} \pm A_{CP})\chi_d,$$
$$\mathcal{P}^{\pm\mp} \propto (1 \pm a_{\ell_1} \mp a_{\ell_2})(1 - \chi_d + r_B)$$

- Sum of all events, separating $\ell_1\ell_2 \in \{ee, e\mu, \mu e, \mu\mu\}$, ordered by p^*

$$N^{\pm\pm}_{\ell_1\ell_2} = \frac{1}{2}N^0_{\ell_1\ell_2}(1 \pm a_{\ell_1} \pm a_{\ell_2} \pm A_{CP})\chi_d^{\ell_1\ell_2},$$
$$N^{\pm\mp}_{\ell_1\ell_2} = \frac{1}{2}N^0_{\ell_1\ell_2}(1 \pm a_{\ell_1} \mp a_{\ell_2})(1 - \chi_d^{\ell_1\ell_2} + r_B),$$

  - ⋄ 16 observables, 13 unknowns.

- High correlations among a_{ℓ_j} and A_{CP}.
- $\Rightarrow$ Use events with *single electrons* (much purer than muons) to constrain a_e.
  - ⋄ $a_{\text{single}} = f(A_{CP}, a_e)$ (17th observable).
- Use 16+1 observables in a χ^2 fit to extract A_{CP}, 4 B^0 yields $N^0_{\ell_1\ell_2}$, 4 efficiency asymmetries a_{ℓ_j}, and 4 effective mixing probabilities $\chi_d^{\ell_1\ell_2}$.

Background in dilepton sample

- Continuum $e^+e^- \to f\bar{f}(\gamma)$ ($f \in \{u, d, s, c, e, \mu, \tau\}$): off-peak data.
- Cascade: one or two leptons from $B \to X \to \ell Y$.
- Misidentified lepton.
- Observed events: $M^{\pm\pm}_{\ell_1\ell_2} = N^{\pm\pm}_{\ell_1\ell_2}/f^{\pm\pm}_{\ell_1\ell_2}$, where $f = N_S/(N_S + N_B)$ is the signal fraction.
- N_S and N_B are also functions of A_{CP}
  - $N^{\pm\pm}_{S;\ell_1\ell_2} \to N^{\pm\pm}_{S;\ell_1\ell_2}(1 \pm A_{CP})$; $N^{\pm\pm}_{B;\ell_1\ell_2} \to N^{\pm\pm}_{B;\ell_1\ell_2}(1 \pm \delta_{\ell_1\ell_2} A_{CP})$.
- $f = \frac{1 \pm A_{CP}}{(1 \pm A_{CP}) + R^{\pm\pm}_{\ell_1\ell_2}(1 \pm \delta_{\ell_1\ell_2} A_{CP})}$

$R^{\pm\pm}_{\ell_1\ell_2} \equiv \frac{N^{\pm\pm}_{B;\ell_1\ell_2}}{N^{\pm\pm}_{S;\ell_1\ell_2}}$
background-to-signal ratio under $A_{CP} = 0$

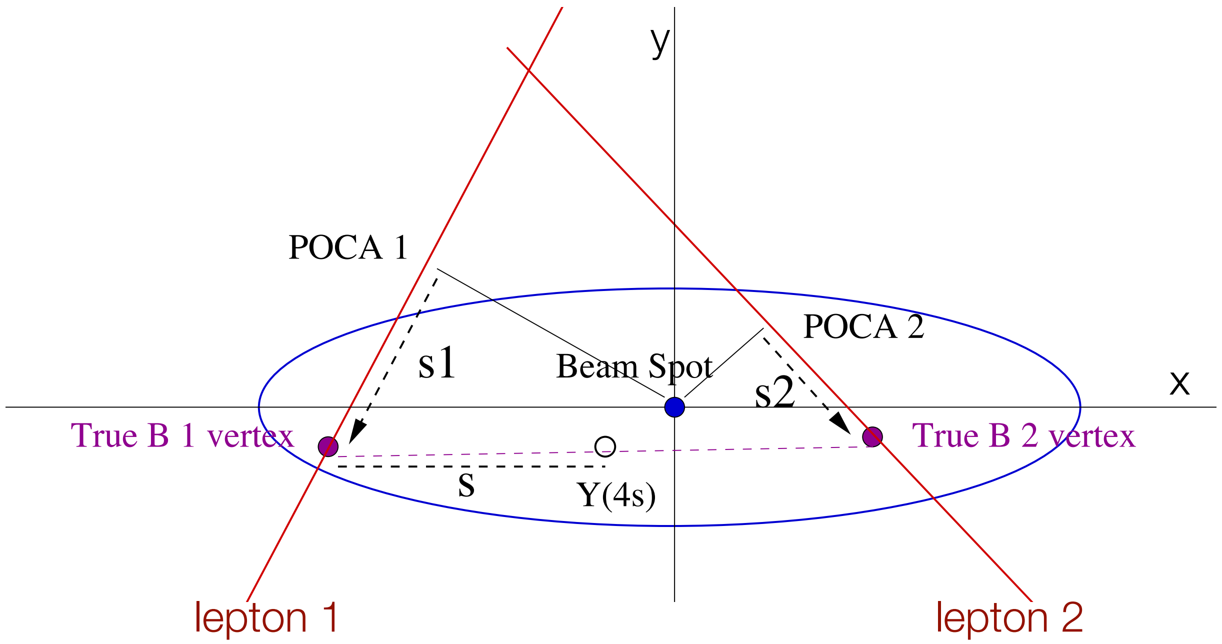
$\delta_{\ell_1\ell_2} = (n_c - n_w)/N_B$: a dilution factor. Some same-sign background (n_c) have a right sign for a true mixed event; some (n_w) have a wrong sign.

Single electron event charge asymmetry

- The only sources of charge asymmetry in real primary electrons from B semileptonic decay are CP violation in mixing and detector efficiency charge asymmetry.
- Observed charge asymmetry in on-peak data:
  - $a_{\mathrm{on}} = f(A_{CP}, a_e) = \alpha + \beta\chi_d A_{CP} + \gamma a_e$
  - Coefficients α, β, and γ are obtained from off-peak data, data control samples (for probabilities of hadrons faking leptons), and simulation (for various component fractions).

Event selection

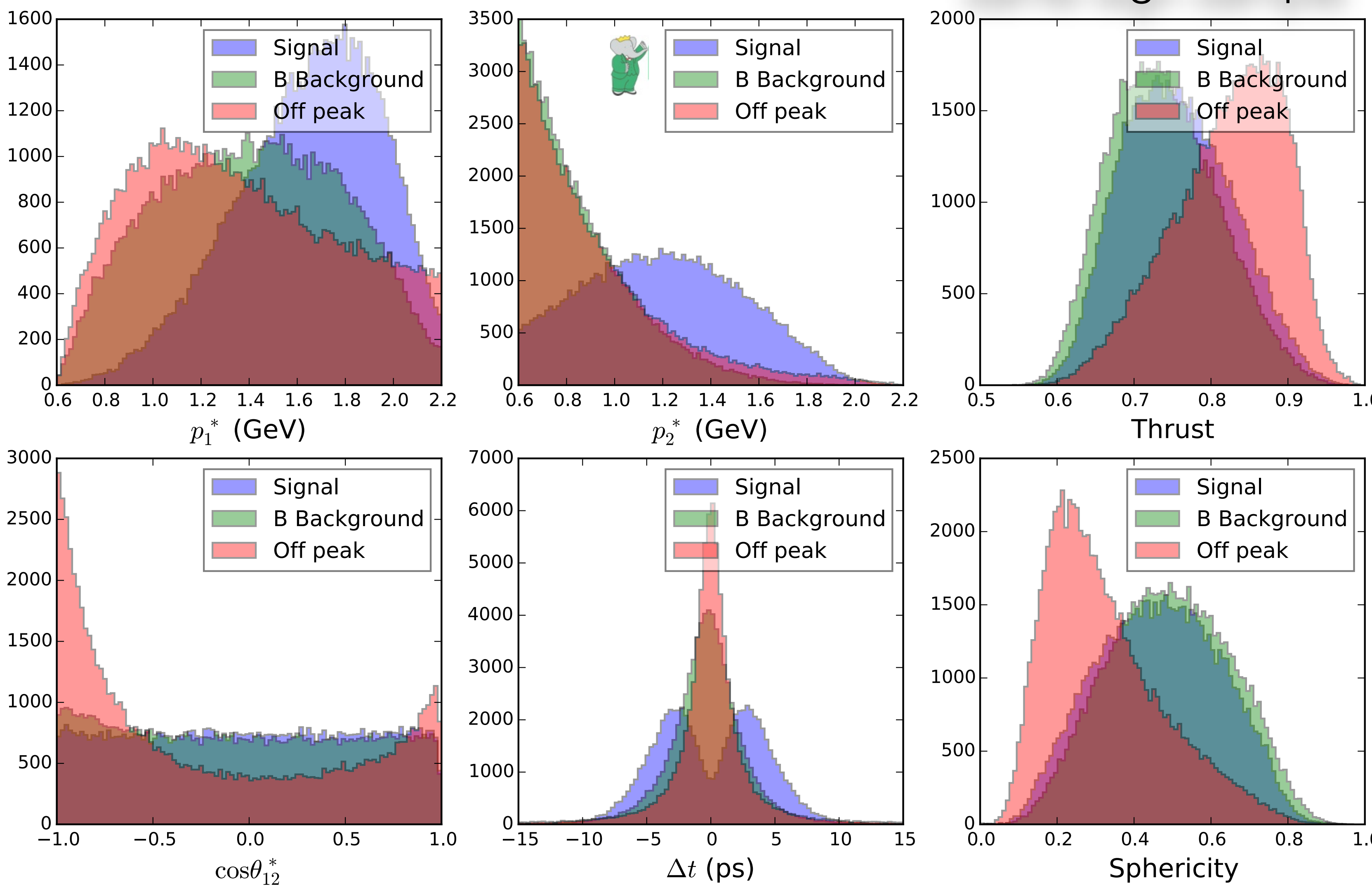
- Event shape consistent with a $B\bar{B}$ decay ($\sim$ isotropic, ≥ 4 tracks).
- Two tracks with $p^* > 0.6\,\mathrm{GeV}$ (or one for single electron sample).
- Consistent with e or μ hypothesis in particle id algorithms.
  - Algorithms select $\varepsilon_e \sim 93\%$ and $\varepsilon_\mu \sim 40\%$–$80\%$. Probability of a hadron faking lepton: $\mathcal{P}(h \to e) < 0.1\%$, $\mathcal{P}(h \to \mu) \sim 1\%$.
- Veto tracks consistent with from J/ψ, $\psi(2S)$, and photon conversion.
- Other quality and fiducial cuts.
- Δt is calculated from the separation of the two POCAs along the beam direction and the c.m. boost factor ~ 0.56.
- Require $|\Delta t| < 15$ ps, $\sigma_{\Delta t} < 3$ ps.

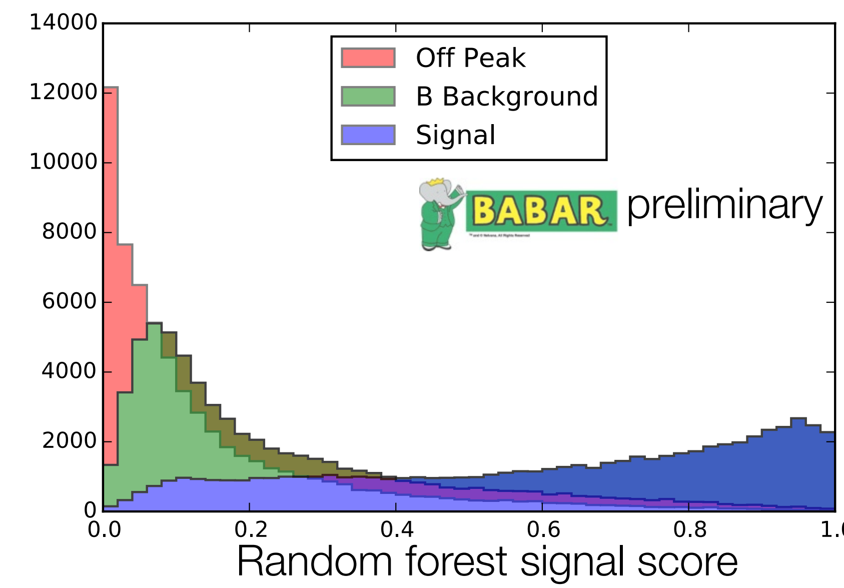


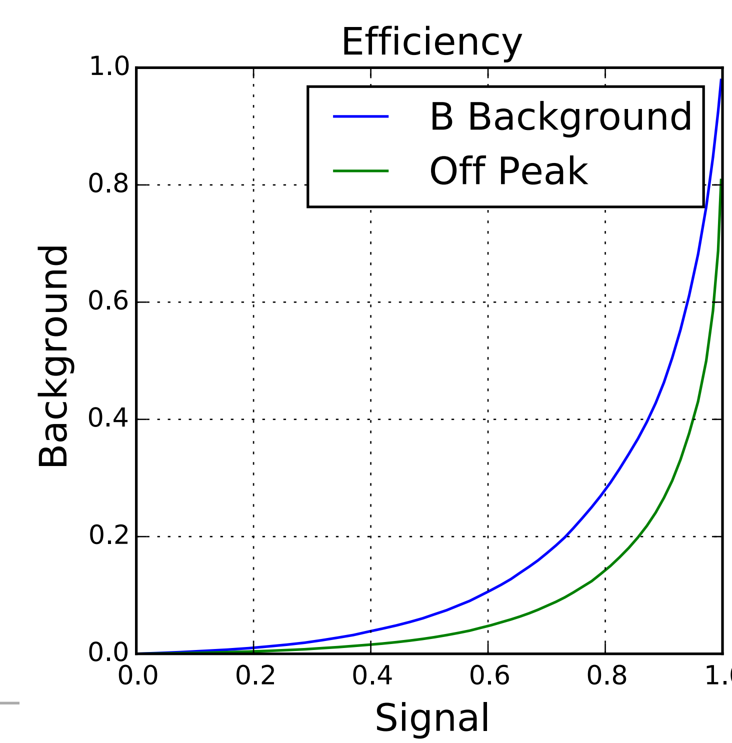
Background suppression

- Dilepton: 6 variables; random forest learning; to classify signal, $B\overline{B}$ background, and continuum.
- Same-sign and opposite-sign samples are trained separately.

same-sign sample



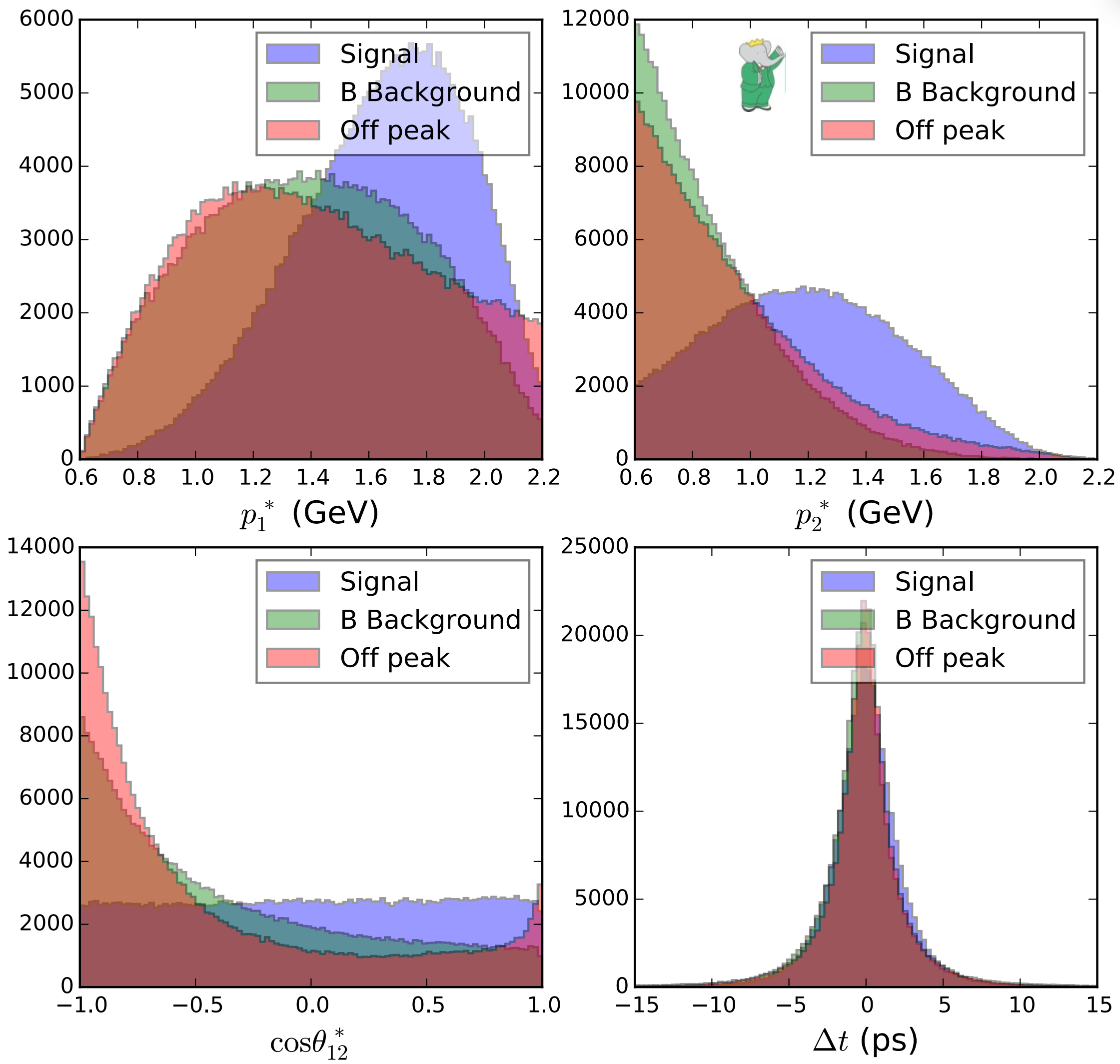


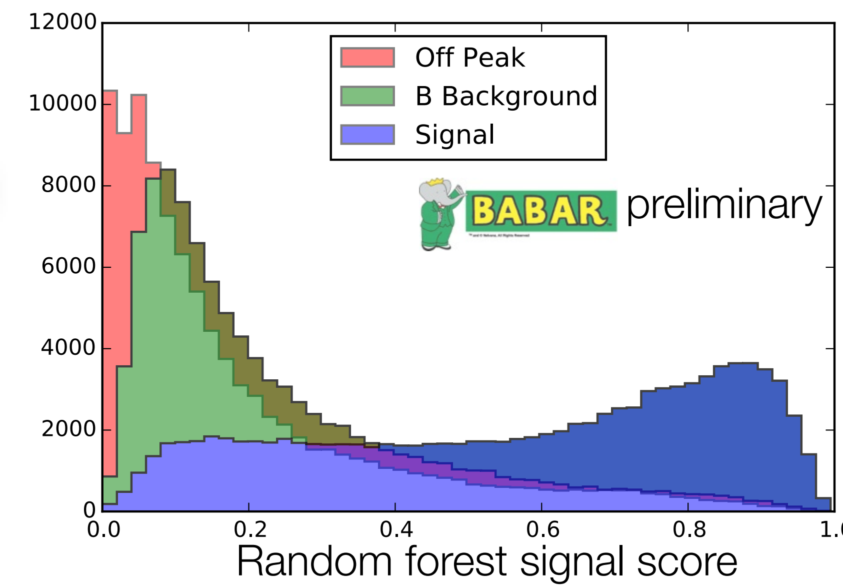


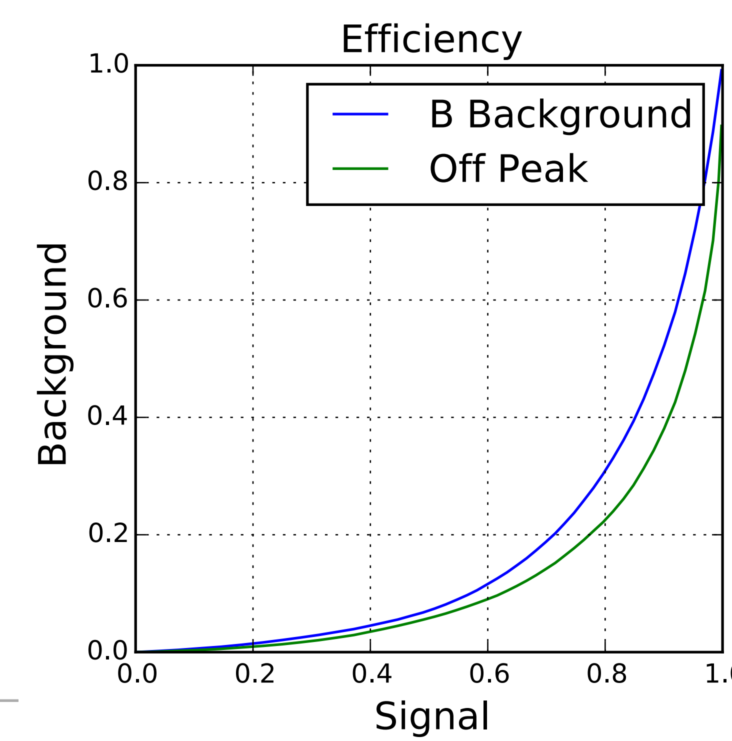
Background suppression

- Dilepton: 6 variables; random forest learning; to classify signal, $B\overline{B}$ background, and continuum.
- Same-sign and opposite-sign samples are trained separately.

opposite-sign sample

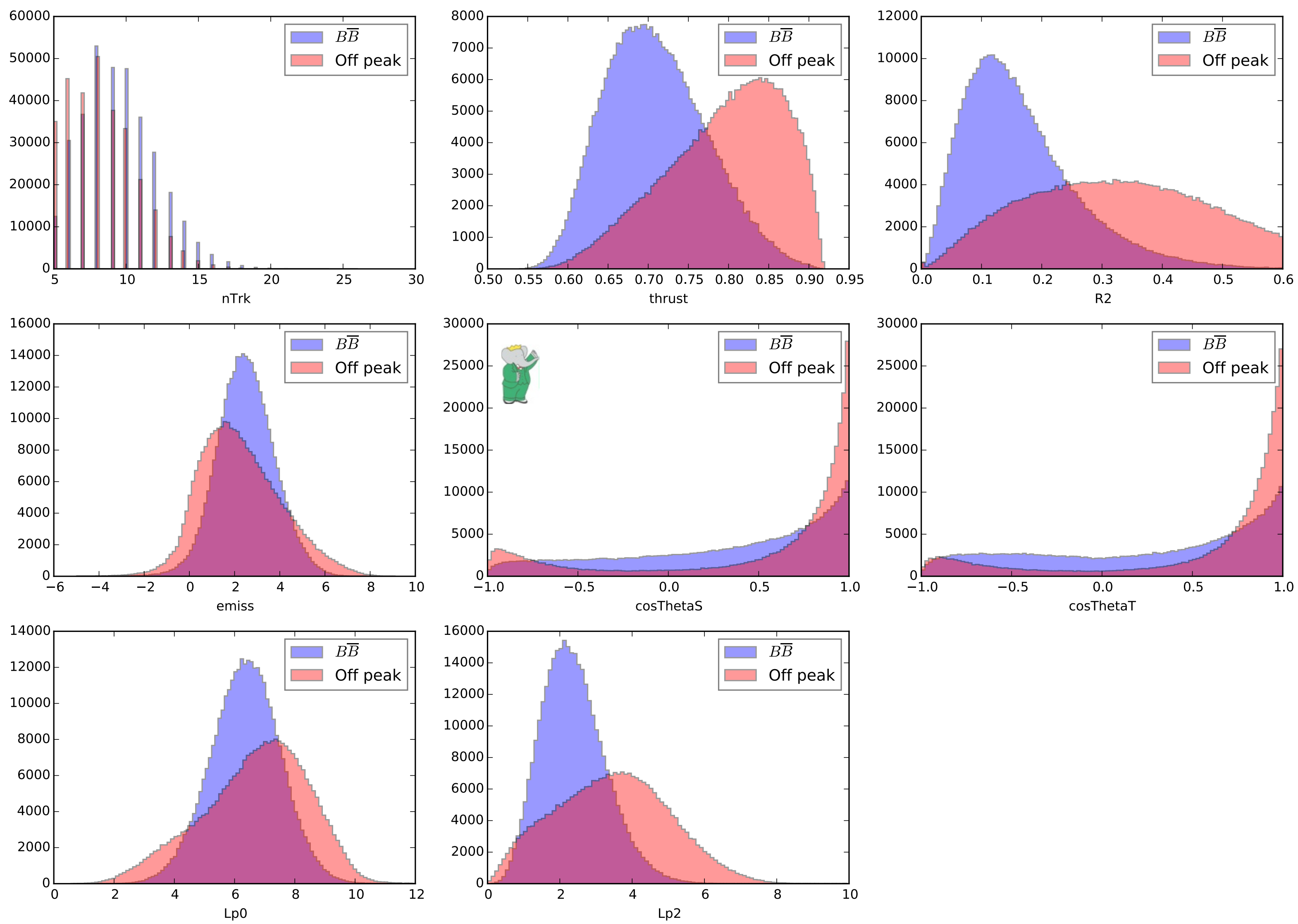


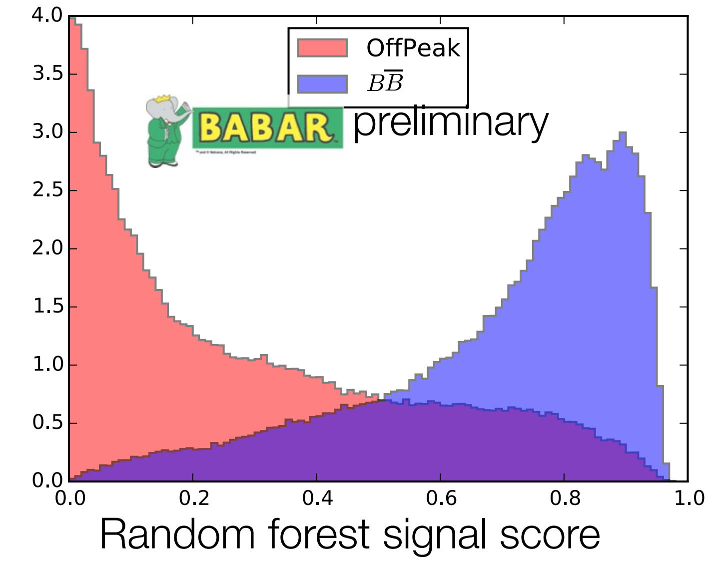


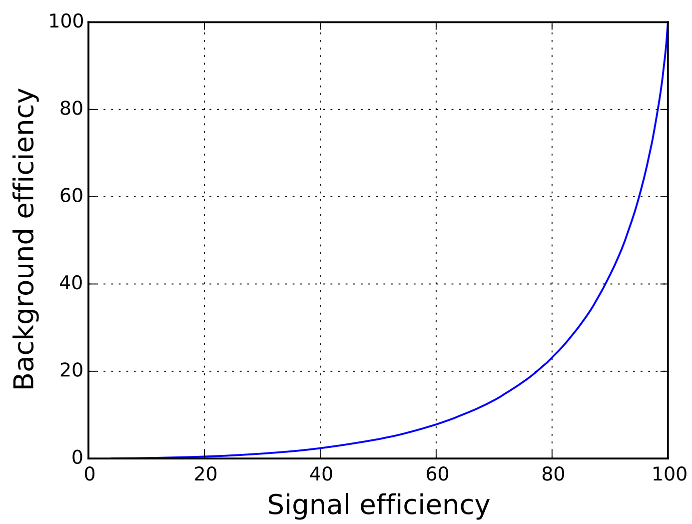


Background suppression

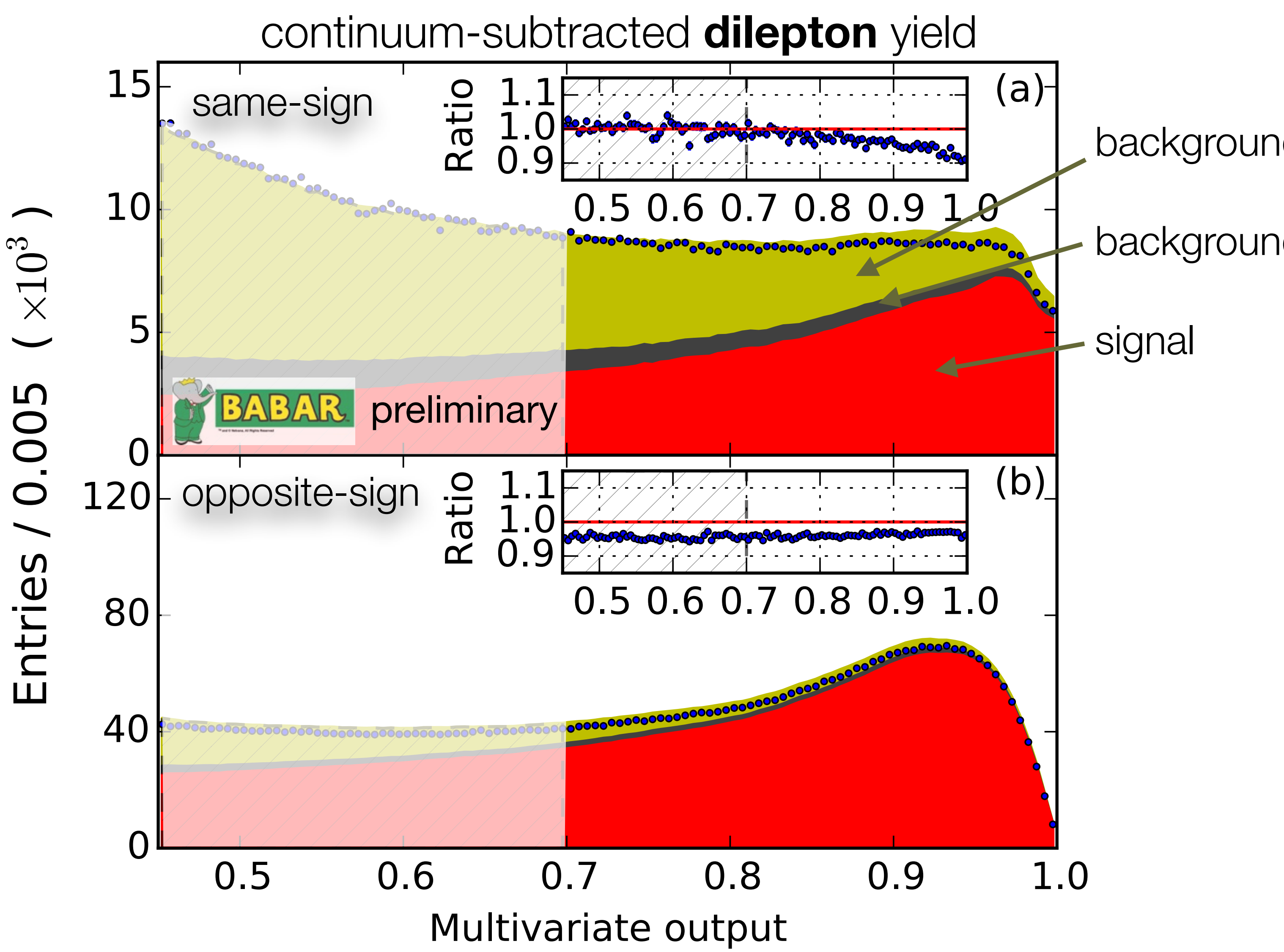
- Single lepton: 8 variables; random forest learning; classify $B\overline{B}$ and continuum.

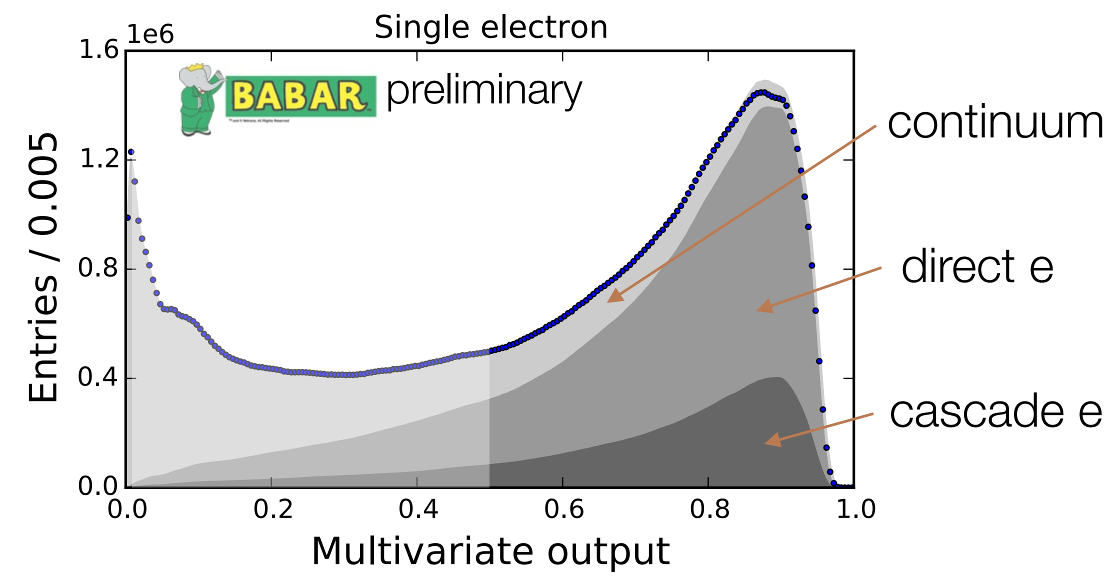






Final samples

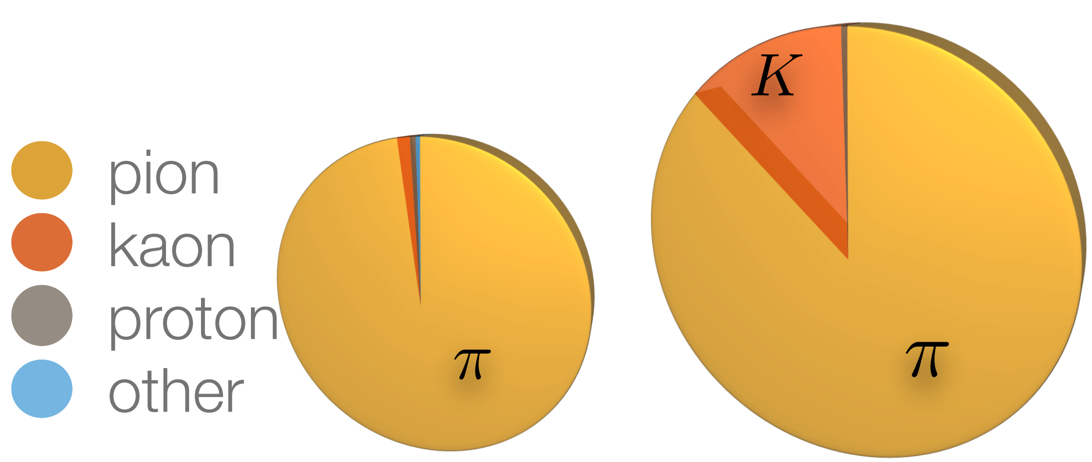




- Selection optimized to minimize stat. uncertainty.
- 517 k same-sign events; 3196 k opposite-sign events.
- 2.5% continuum background;
  35% (8%) $B\overline{B}$ background in same(opposite)-sign sample.
- 85 M single electrons

Fake lepton correction

- $\sim$0.1% of electrons and $\sim$3% of muons in the dilepton sample are misidentified hadrons.
- 98% of fake electrons are from pions.
- 87% of fake muons are from pions; 12% from kaons.
- Correct the fake lepton contribution in MC using clean kaon and pion control samples from $D^{*-} \to \overline{D}^0\pi^-$ with $\overline{D}^0 \to K^+\pi^-$, and pion samples from $K_S^0 \to \pi^+\pi^-$.
- Fit for D^0 yield before and after muon id is applied to kaon or pion.
- Fit for K_S^0 yield before and after electron is is applied to pion.



fake e source

fake μ source

correction factors

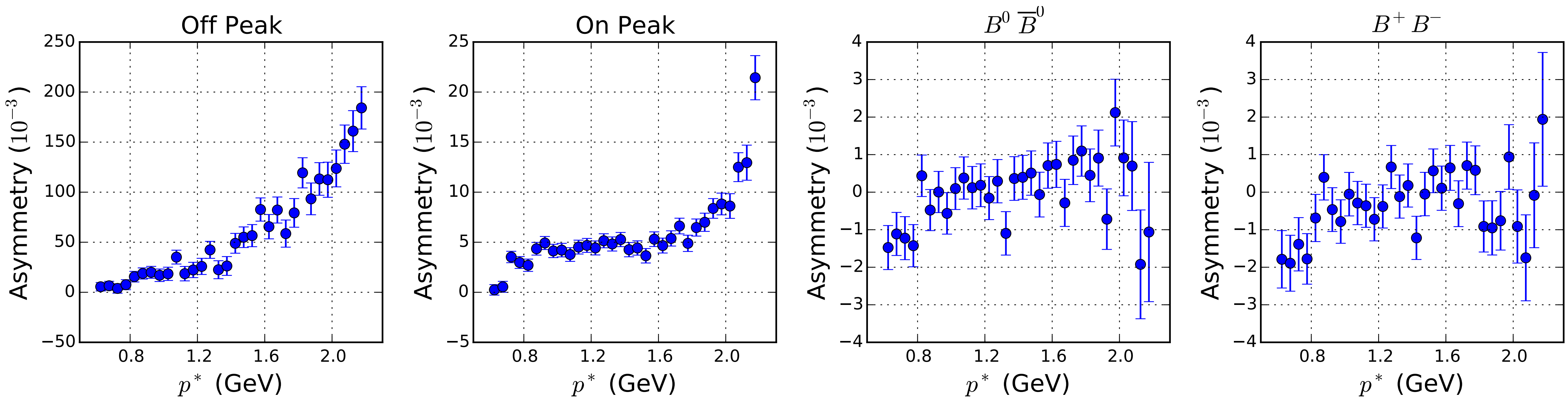
$$w^{\mathrm{fake}}_{\ell^\pm} = \sum_{h=K,\pi,p} f_{h\to\ell^\pm}\frac{\epsilon^{\mathrm{data}}_{h\to\ell^\pm}}{\epsilon^{\mathrm{MC}}_{h\to\ell^\pm}},$$

$$w^{\mathrm{fake}}_{\mu^+} = 0.792 \pm 0.012 \qquad w^{\mathrm{fake}}_{e^+} = 1.00 \pm 0.10$$

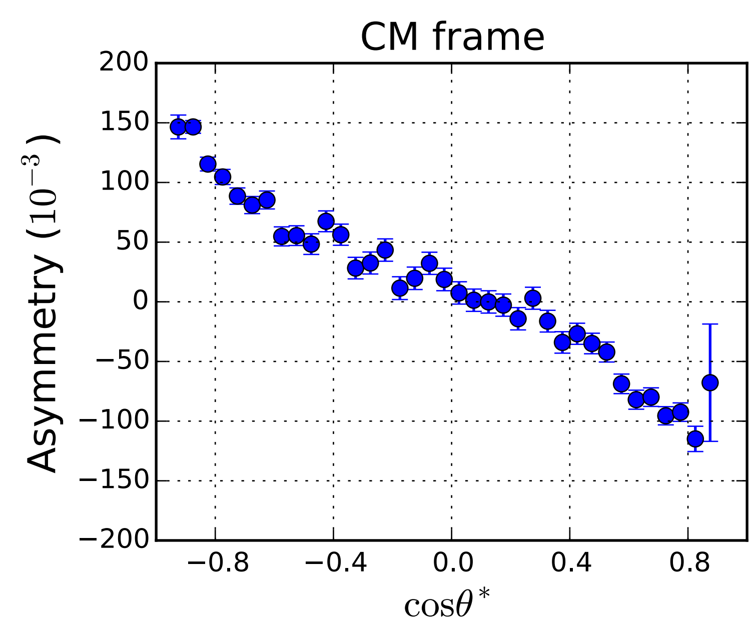
$$w^{\mathrm{fake}}_{\mu^-} = 0.797 \pm 0.013 \qquad w^{\mathrm{fake}}_{e^-} = 0.56 \pm 0.10$$

Single electron study

- Raw asymmetries



- Large asymmetry in continuum is due to forward-backward asymmetry in radiative Bhabha, and asymmetric detector acceptance (larger hole in the e^- direction in the c.m. frame).



Single electron summary

- Data asymmetry: $a_{\mathrm{on}} = (4.16 \pm 0.14) \times 10^{-3}$; $a_{\mathrm{cont}} = (11.1 \pm 1.4) \times 10^{-3}$.
- Continuum fraction: $f_{\mathrm{cont}} = (10.315 \pm 0.016)\%$.
- $B^0\overline{B}^0$ fraction in $B\overline{B}$ component: $f_{B^0} = (48.5 \pm 0.6)\%$.
- Cascade fractions: $f_{B^0}^{\mathrm{casc}} = (19.778 \pm 0.006)\%$; $f_{B^\pm}^{\mathrm{casc}} = (15.347 \pm 0.006)\%$.
- Fake electron in $B\overline{B}$ component: $f_B^{\mathrm{fake}} = (1.913 \pm 0.005) \times 10^{-3}$,
- Fake electron asymmetry: $a_B^{\mathrm{fake}} = 35\%$.
- Direct-/cascade-electron asymmetry difference:
  $\delta_e^{\mathrm{casc}} \equiv a_e^{\mathrm{casc}} - a_e^{\mathrm{dir}} = (-1.16 \pm 0.25) \times 10^{-3}$.
- Cascade lepton mistag: $w^{\mathrm{casc}} = (73.77 \pm 0.10)\%$.

- $a_{\mathrm{on}} - \alpha = \beta\chi_d A_{CP} + \gamma a_e$:
  - $a_{\mathrm{on}} - \alpha = (2.60 \pm 0.20) \times 10^{-3}$
  - $\beta\chi_d = 0.0573 \pm 0.0011$
  - $\gamma = 0.89513 \pm 0.00016$

Event yields

16 dilepton sample continuum-subtracted yields

	$\ell^+\ell^+$	$\ell^+\ell^-$	$\ell^-\ell^+$	$\ell^-\ell^-$
ee	82303 ± 320	426296 ± 783	425309 ± 782	81586 ± 323
$e\mu$	55277 ± 263	384552 ± 684	378261 ± 660	55878 ± 264
μe	67399 ± 290	467591 ± 737	475363 ± 744	67152 ± 290
$\mu\mu$	47384 ± 243	277936 ± 619	278691 ± 618	48145 ± 247

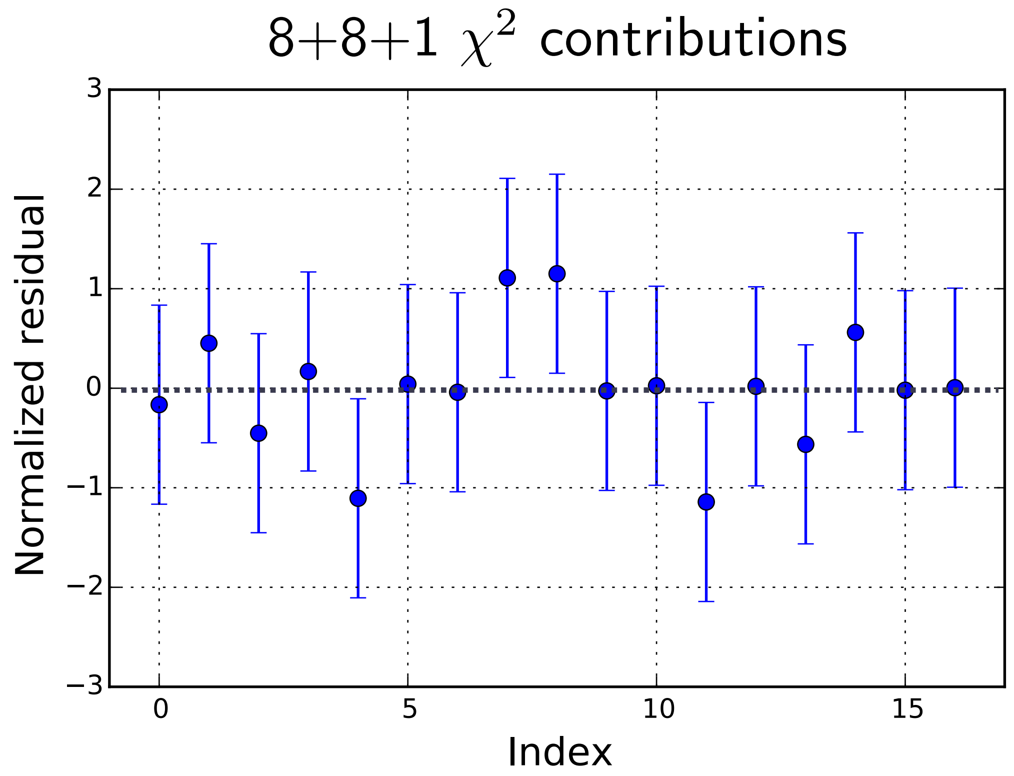
35% $B\overline{B}$ background in same-sign sample;
8% $B\overline{B}$ background in opposite-sign sample

Preliminary fit result

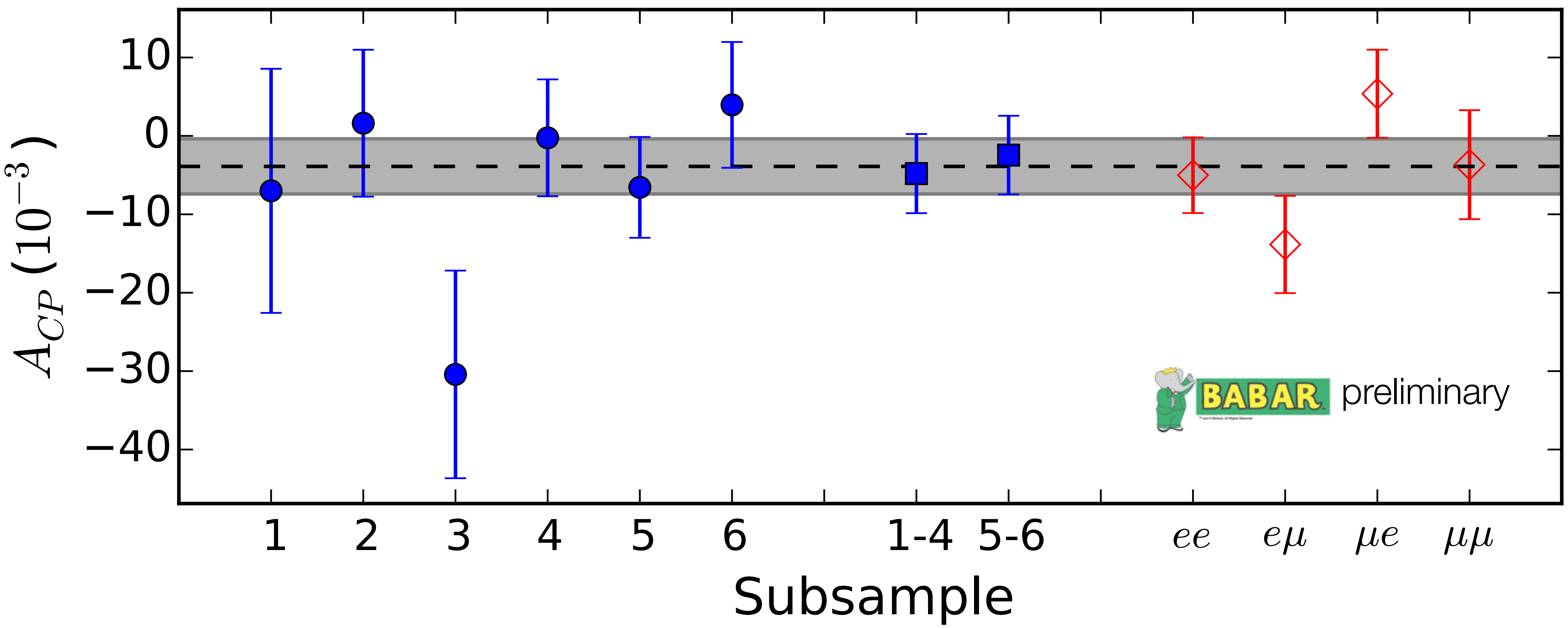
$A_{CP} = (-3.9 \pm 3.5) \times 10^{-3}$ BABAR preliminary			
N^0_{ee}	$N^0_{e\mu}$	$N^0_{\mu e}$	$N^0_{\mu\mu}$
430875 ± 515	365343 ± 429	458200 ± 480	268077 ± 391
χ_d^{ee}	$\chi_d^{e\mu}$	$\chi_d^{\mu e}$	$\chi_d^{\mu\mu}$
0.2248 ± 0.0006	0.1769 ± 0.0006	0.1754 ± 0.0005	0.2032 ± 0.0007
a_{e1}	a_{e2}	$a_{\mu 1}$	$a_{\mu 2}$
0.0034 ± 0.0006	0.0030 ± 0.0006	-0.0056 ± 0.0011	-0.0065 ± 0.0011

correlations

	a_{e_1}	a_{e_2}	a_{μ_1}	a_{μ_2}
A_{CP}	-0.41	-0.47	-0.54	-0.51
a_{e_1}		-0.38	$+0.09$	$+0.39$
a_{e_2}			$+0.46$	$+0.15$
a_{μ_1}				$+0.43$



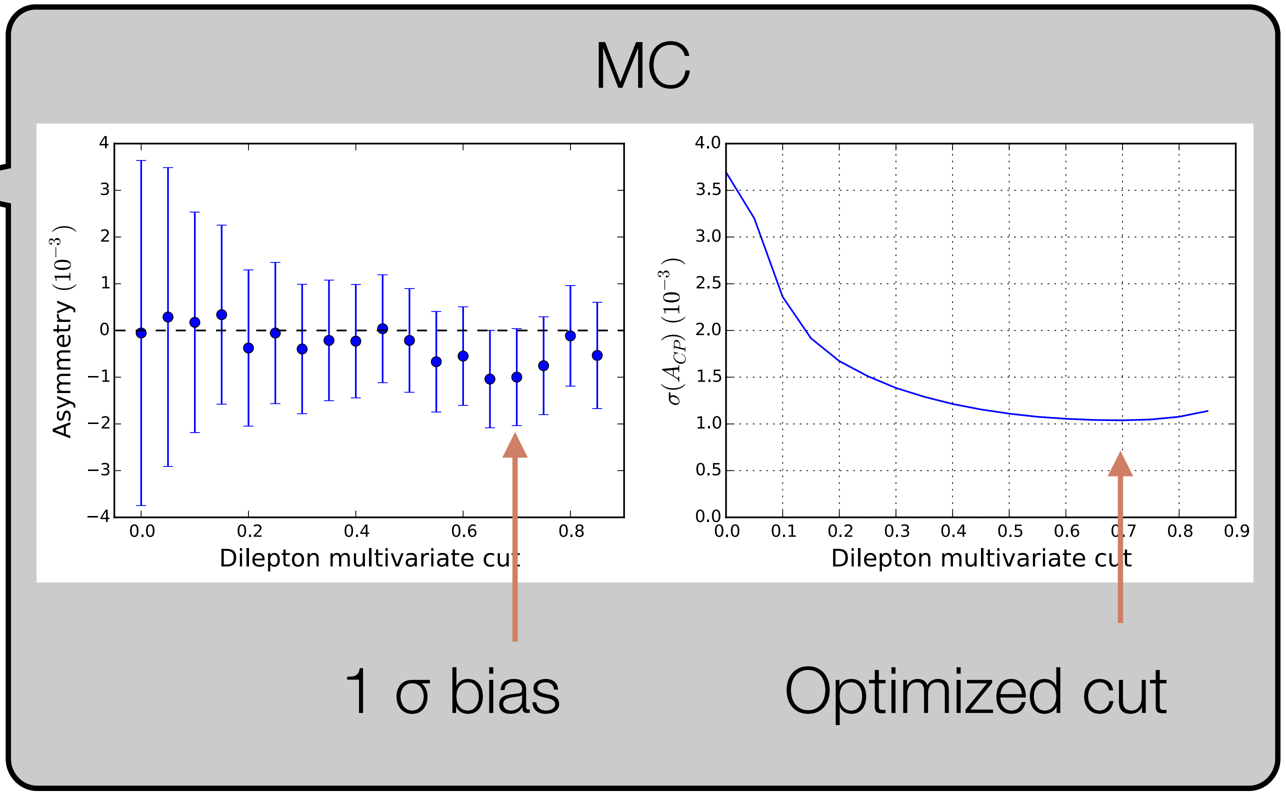
Consistency among sub-samples



Systematic uncertainties

Source	(10^{-3})
Generic MC bias correction	1.04
MC branching fractions	0.43
Fake lepton corrections in dilepton	0.77
Fake e correction in single electron	0.65
Neutral/charged B difference	0.74
Direct-/cascade e asymmetry difference	0.44
Direct-/cascade μ asymmetry difference	0.34
Background-to-signal ratios	0.68
Random forest cut efficiency	0.08
Total	1.90

BABAR preliminary



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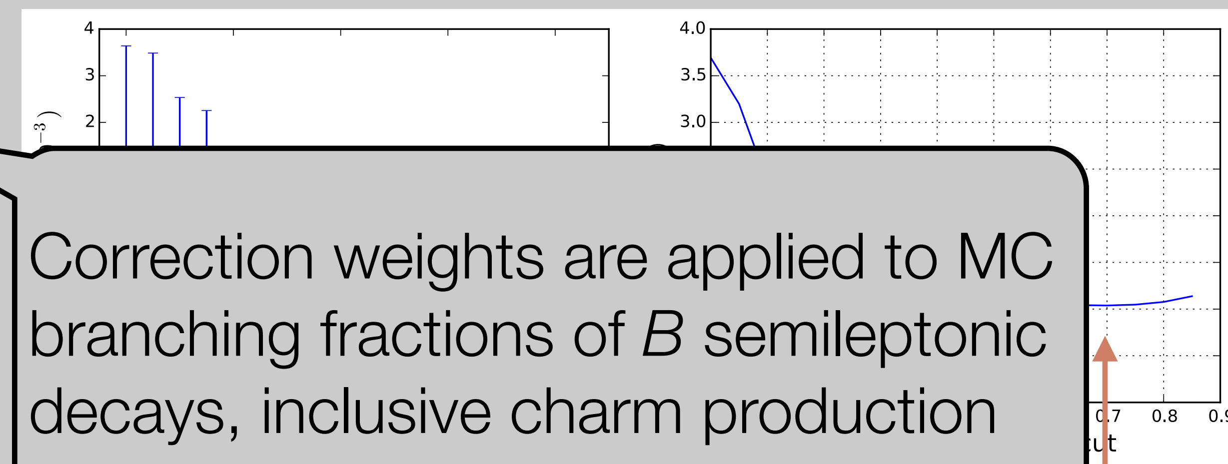
BABAR preliminary

MC



Correction weights are applied to MC branching fractions of B semileptonic decays, inclusive charm production from B decay, and charm semileptonic decays, to match PDG. Weights vary 0.57—1.32; uncertainties dominated by BF uncertainties.

Systematic uncertainties

Source	(10^{-3})
Generic MC bias correction	1.04
MC branching fractions	0.43
Fake lepton corrections in dilepton	0.77
Fake e correction in single electron	0.65
Neutral/charged B difference	0.74
Direct-/cascade e asymmetry difference	0.44
Direct-/cascade μ asymmetry difference	0.34
Background-to-signal ratios	0.68
Random forest cut efficiency	0.08
Total	1.90

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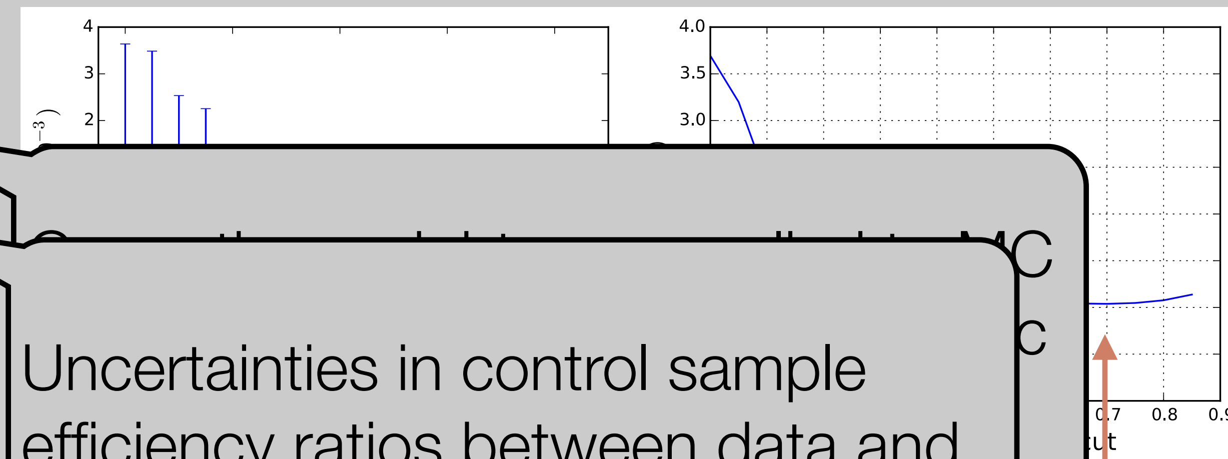

Uncertainties in control sample efficiency ratios between data and MC.

uncertainties dominated by BF uncertainties.

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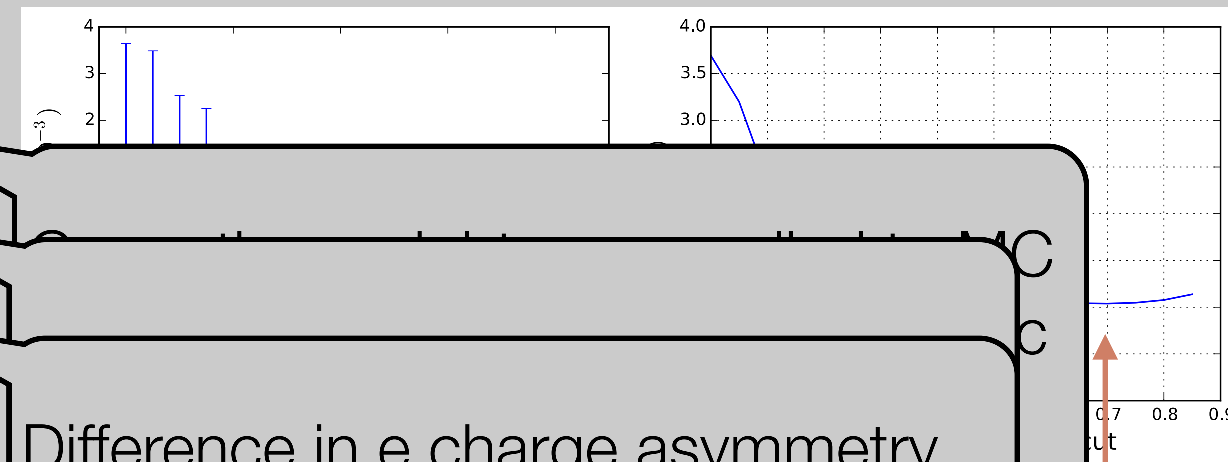

Difference in e charge asymmetry between neutral B MC and average of neutral and charged B.

uncertainties dominated by BF uncertainties.

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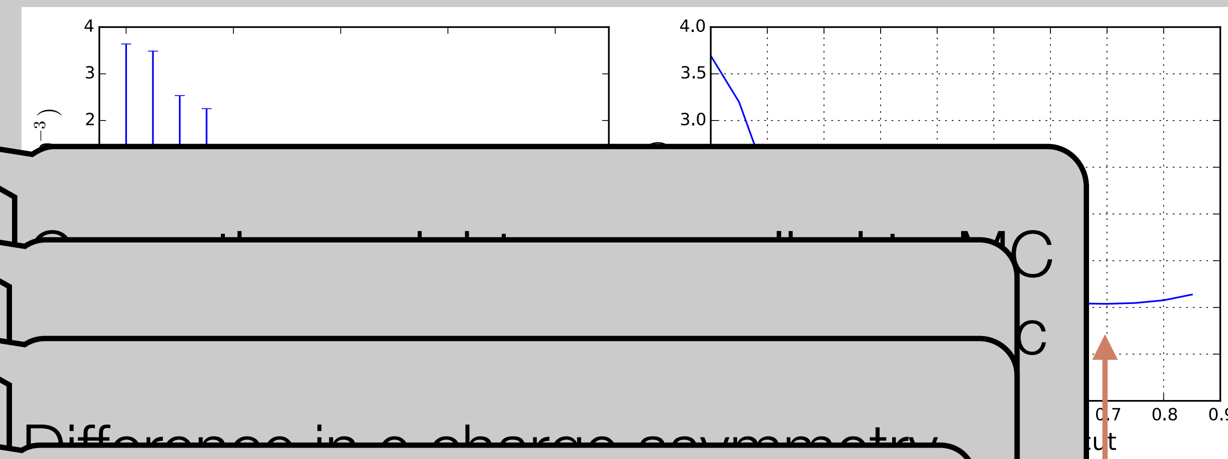

Lower momentum leptons have a lower charge asymmetry:

$$a_e^{\rm casc} - a_e^{\rm dir} = (-1.16 \pm 0.25) \times 10^{-3} \text{ (MC)}$$
$$a_{e_2} - a_{e_1} = (-0.4 \pm 0.7) \times 10^{-3} \text{ (Data)}$$
$$a_\mu^{\rm casc} - a_\mu^{\rm dir} = (-0.47 \pm 0.28) \times 10^{-3} \text{ (MC)}$$
$$a_{\mu_2} - a_{\mu_1} = (-0.9 \pm 1.2) \times 10^{-3} \text{ (Data)}$$

Check systematic by setting

$$a^{\rm casc} = a^{\rm dir}$$

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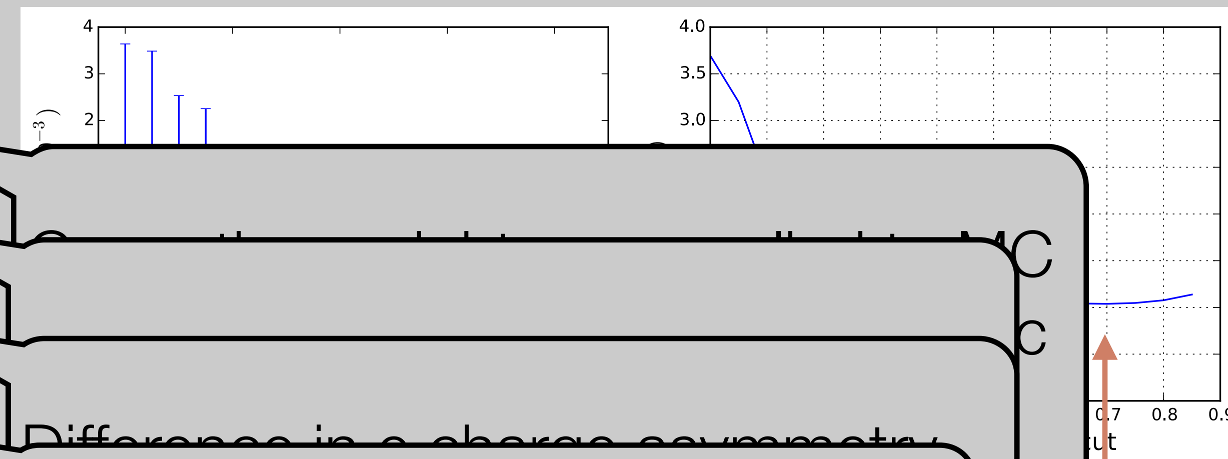

Lower momentum leptons have a lower charge asymmetry:

Real lepton portion of B/S ratios for $\ell^+\ell^+$ and $\ell^-\ell^-$ should be the same because efficiencies cancel. Systematics small. Relaxing this condition, allowing them to be different, vary them over MC statistics.

Systematic uncertainties

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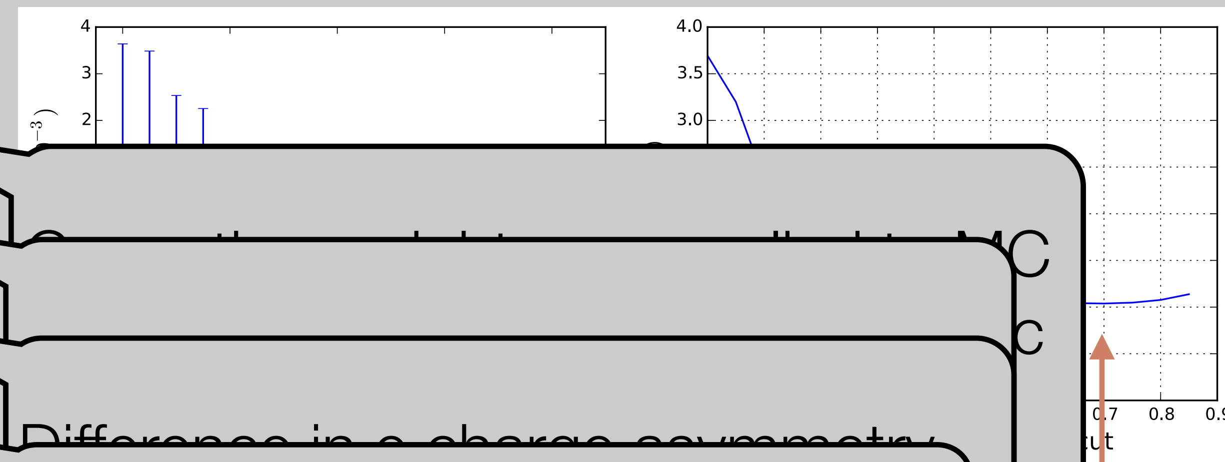


Lower momentum leptons have a lower charge asymmetry;

Real lepton portion of B/S ratios for $\ell^+\ell^+$ and $\ell^-\ell^-$ should be the same be-

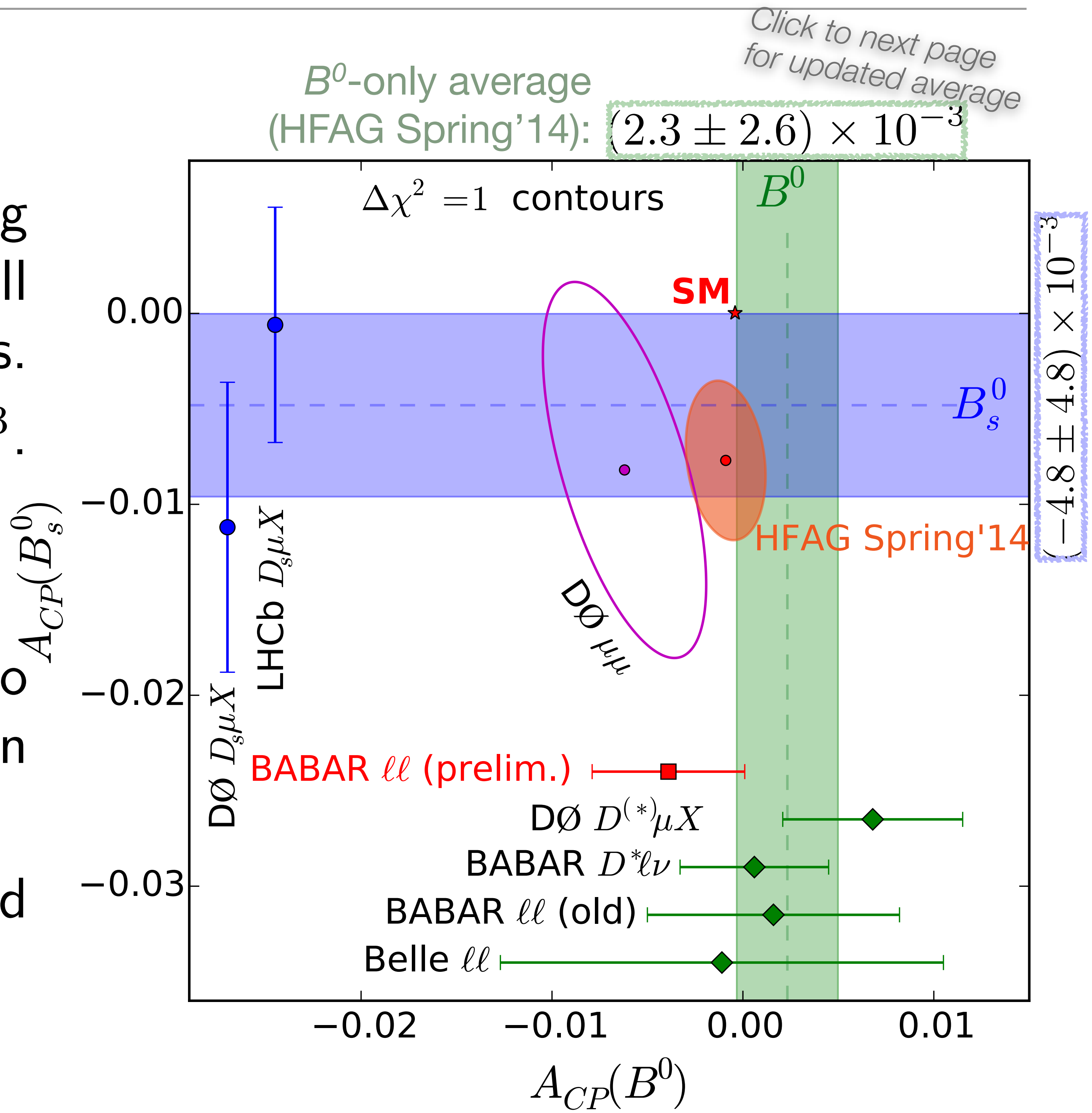
Vary cut in MC so the MC yields vary around data yields. Changing this cut affects *B/S* ratio calculation and in turn affects A_{CP}.

Summary

- We measure A_{CP} in B^0-$\overline{B}^0$ mixing using dilepton events from the full *BABAR* dataset 471×10^6 $B\overline{B}$ pairs.
- $A_{CP} = (-3.9 \pm 3.5 \pm 1.9) \times 10^{-3}$.

  BABAR preliminary

- Competitive and complementary to similar measurements at hadron colliders.
- Consistent with the Standard Model.



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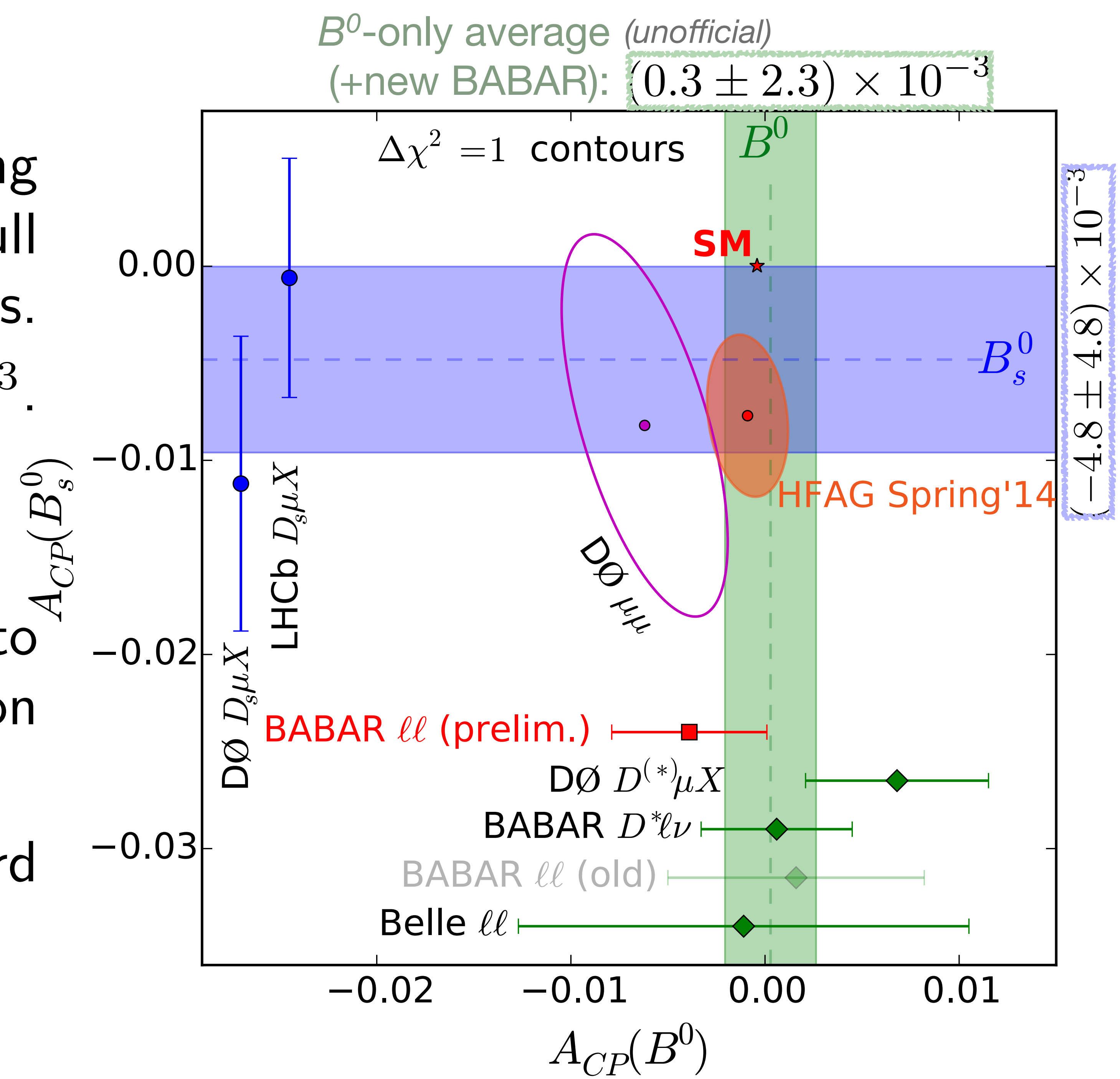


Thank you for your attention

Back up

Background in dilepton sample

- Continuum $e^+e^- \to f\bar{f}(\gamma)$ ($f \in \{u, d, s, c, e, \mu, \tau\}$): off-peak data.
- Cascade: one or two leptons from $B \to X \to \ell Y$.
- Misidentified lepton.
- Observed events: $M^{\pm\pm}_{\ell_1\ell_2} = N^{\pm\pm}_{\ell_1\ell_2}/f^{\pm\pm}_{\ell_1\ell_2}$, where $f = N_S/(N_S + N_B)$ is the signal fraction.
- If $A_{CP} \neq 0$, N_S and N_B from simulation are not correct.
  - $N^{\pm\pm}_{S;\ell_1\ell_2} \to N^{\pm\pm}_{S;\ell_1\ell_2}(1 \pm A_{CP})$; $N^{\pm\pm}_{B;\ell_1\ell_2} \to N^{\pm\pm}_{B;\ell_1\ell_2}(1 \pm \delta_{\ell_1\ell_2} A_{CP})$.

$$
\begin{aligned}
M^{\pm\pm}_{\ell_1\ell_2} &= \frac{1}{2}\left(N^0_{\ell_1\ell_2}(1 \pm a_{\ell_1} \pm a_{\ell_2} \pm A_{CP})\chi_d^{\ell_1\ell_2}\right)\frac{(1 \pm A_{CP}) + R^{\pm\pm}_{\ell_1\ell_2}(1 \pm \delta_{\ell_1\ell_2} A_{CP})}{1 \pm A_{CP}} \\
&= \frac{1}{2}N^0_{\ell_1\ell_2}(1 \pm a_{\ell_1} \pm a_{\ell_2})[1 \pm A_{CP} + R^{\pm\pm}_{\ell_1\ell_2}(1 \pm \delta_{\ell_1\ell_2} A_{CP})]\chi_d^{\ell_1\ell_2} \\
&= \frac{1}{2}N^0_{\ell_1\ell_2}(1 \pm a_{\ell_1} \pm a_{\ell_2})[1 + R^{\pm\pm}_{\ell_1\ell_2} \pm (1 + \delta_{\ell_1\ell_2} R^{\pm\pm}_{\ell_1\ell_2})A_{CP}]\chi_d^{\ell_1\ell_2} \\
&= \frac{1}{2}N^0_{\ell_1\ell_2}(1 + R^{\pm\pm}_{\ell_1\ell_2})\left[1 \pm a_{\ell_1} \pm a_{\ell_2} \pm \frac{1 + \delta_{\ell_1\ell_2} R^{\pm\pm}_{\ell_1\ell_2}}{1 + R^{\pm\pm}_{\ell_1\ell_2}} A_{CP}\right]\chi_d^{\ell_1\ell_2}.
\end{aligned}
$$

$R^{\pm\pm}_{\ell_1\ell_2} \equiv \frac{N^{\pm\pm}_{B;\ell_1\ell_2}}{N^{\pm\pm}_{S;\ell_1\ell_2}}$ under $A_{CP} = 0$

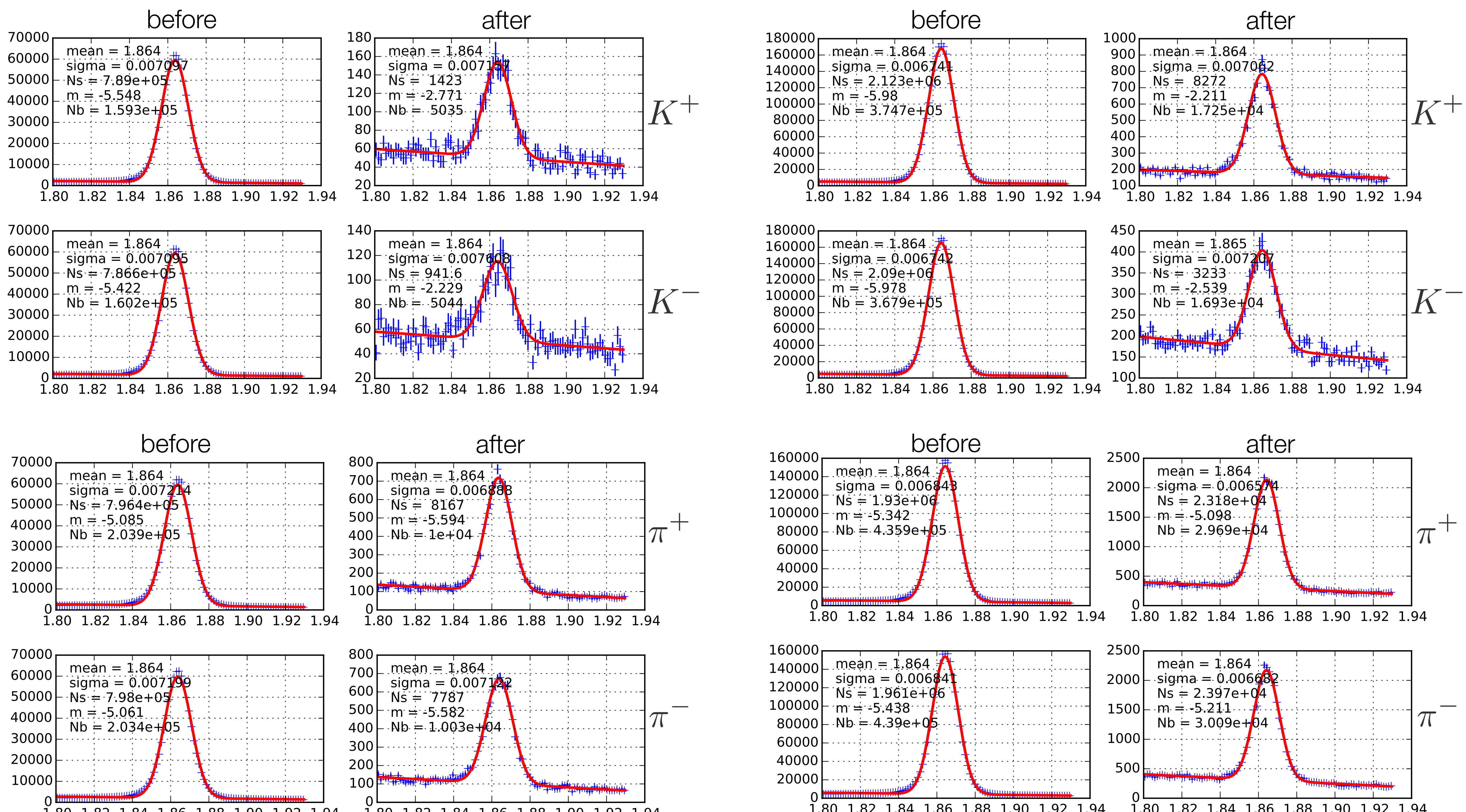
Selected events

Data	Sample	ee	$e\mu$	μe	$\mu\mu$	Sum
OnPeak	same sign	168 k	114 k	138 k	98 k	517 k
	opposite sign	886 k	776 k	957 k	576 k	3196 k
OffPeak (weighted)	same sign	4 k	3 k	3 k	2 k	12 k
	opposite sign	35 k	13 k	14 k	19 k	82 k
Signal MC (weighted)	same sign	98 k	66 k	83 k	56 k	303 k
	opposite sign	789 k	696 k	884 k	512 k	2882 k
$B\overline{B}$ bkg. no fake (weighted)	same sign	67 k	38 k	50 k	30 k	185 k
	opposite sign	75 k	62 k	79 k	42 k	258 k
$B\overline{B}$ bkg. ≥ 1 fake (weighted)	same sign	0.7 k	9.9 k	5.9 k	11.8 k	28.3 k
	opposite sign	1.2 k	27.0 k	18.6 k	28.3 k	75.1 k

single electron sample

OnPeak	85230 k
Continuum (weighted OffPeak)	11343 k
$B\overline{B}$ MC signal (weighted)	54088 k
$B\overline{B}$ MC bkg. (weighted)	20944 k

Fake muon correction: use D^* sample



$$w_{\mu^+}^{\text{fake}} = 0.792 \pm 0.012$$

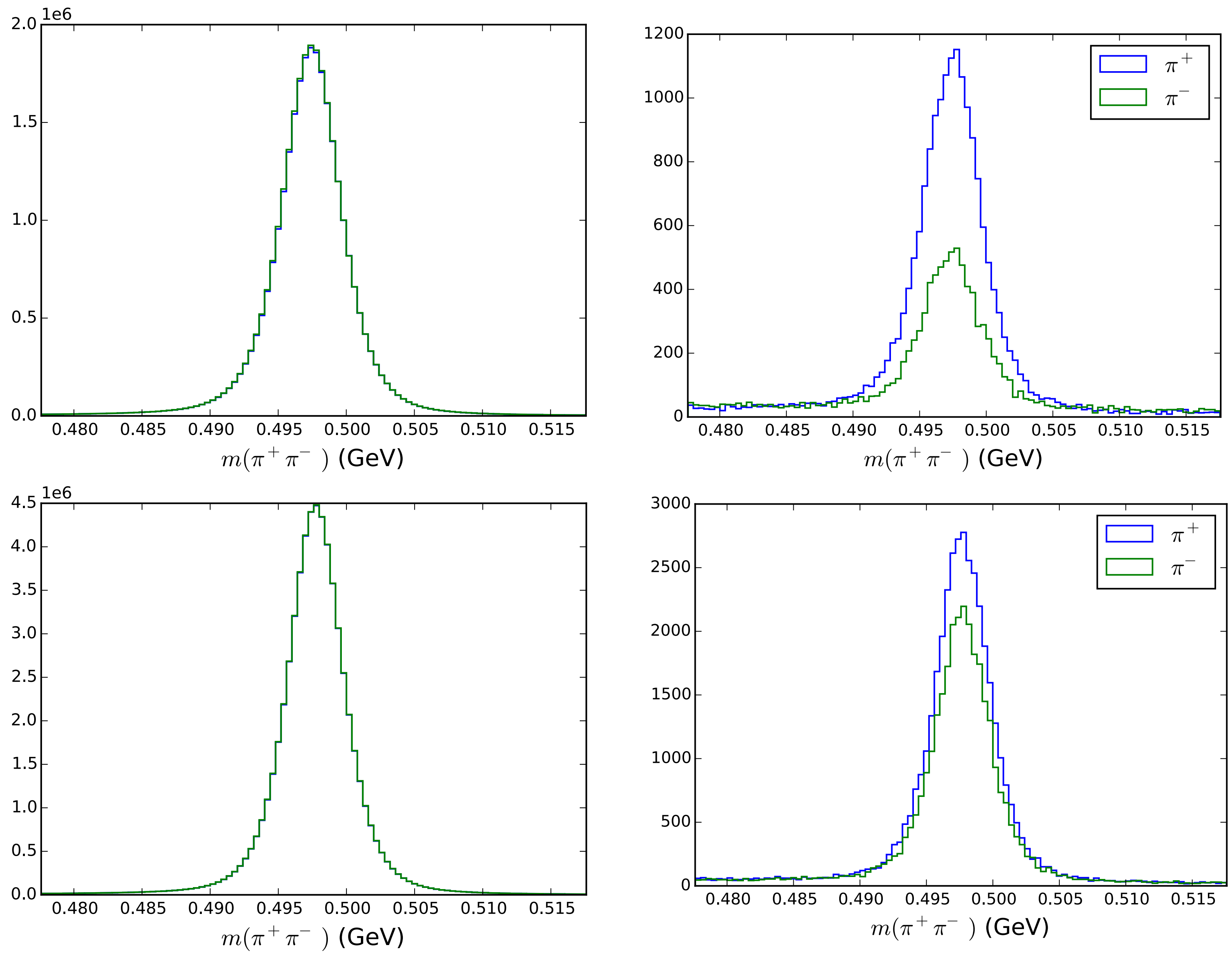
Data $\qquad$ MC

$$w_{\mu^-}^{\text{fake}} = 0.797 \pm 0.013$$

Fake electron correction: use K_S sample

Data

MC



before

after

K_S sample is larger then D* sample but does not cover the high end of the dilepton spectrum. So, larger systematic uncertainty on the correction factors.

$$w_{e^+}^{\mathrm{fake}} = 1.00 \pm 0.10$$
$$w_{e^-}^{\mathrm{fake}} = 0.56 \pm 0.10$$

Event yields

16 dilepton sample continuum-subtracted yields

	$\ell^+\ell^+$	$\ell^+\ell^-$	$\ell^-\ell^+$	$\ell^-\ell^-$
ee	82303 ± 320	426296 ± 783	425309 ± 782	81586 ± 323
$e\mu$	55277 ± 263	384552 ± 684	378261 ± 660	55878 ± 264
μe	67399 ± 290	467591 ± 737	475363 ± 744	67152 ± 290
$\mu\mu$	47384 ± 243	277936 ± 619	278691 ± 618	48145 ± 247

Background-to-signal ratios from MC

	$\ell^+\ell^+$	$\ell^+\ell^-$	$\ell^-\ell^+$	$\ell^-\ell^-$
ee	0.695 ± 0.003	0.096 ± 0.001	0.096 ± 0.001	0.689 ± 0.003
$e\mu$	0.730 ± 0.004	0.126 ± 0.001	0.130 ± 0.001	0.709 ± 0.004
μe	0.679 ± 0.003	0.111 ± 0.001	0.110 ± 0.001	0.670 ± 0.003
$\mu\mu$	0.766 ± 0.004	0.137 ± 0.001	0.139 ± 0.001	0.741 ± 0.004

- 2.5% continuum background;
  35% $B\overline{B}$ background in same-sign sample;
  8% $B\overline{B}$ background in opposite-sign sample