Search for $B_s \to \mu^+\mu^-$ Decays

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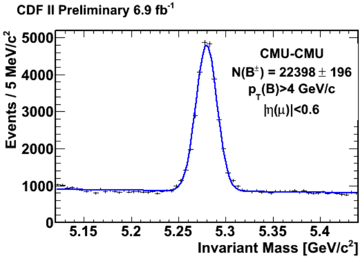
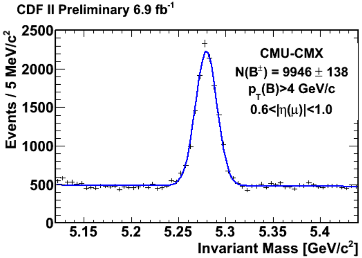
Analysis Method

- Measure rate of $B_s \to \mu^+\mu^-$ relative to $B^+ \to J/\Psi K^+$, $J/\Psi \to \mu^+\mu^-$
- Apply same selection to find $B^+ \to J/\Psi K^+$
- Systematic uncertainties will cancel in ratio $\Rightarrow$ e.g. dimuon trigger efficiency is the same for both modes





$$\mathcal{BR}(B_s \to \mu^+\mu^-) = \boxed{\frac{N_{B_s}}{N_{B^+}} \frac{\epsilon^{trig}_{B^+}}{\epsilon^{trig}_{B_s}}} \boxed{\frac{\epsilon^{reco}_{B^+}}{\epsilon^{reco}_{B_s}} \frac{\alpha_{B^+}}{\alpha_{B_s}} \frac{1}{\epsilon^{NN}_{B_s}}} \boxed{\frac{f_u}{f_s} \cdot \mathcal{BR}(B^+ \to J/\Psi K^+ \to \mu^+\mu^- K^+)}$$

Analysis Method

- Estimate acceptances and efficiencies
- Identify variables that discriminate signal and background
- Make multivariate discriminant, for background rejection
  - Optimized with Pythia signal MC and data mass sideband
  - Validate in B^+ sample
- Estimate Background
  - Combinatoric background
  - Peaking background: B$\to$hh

Trigger and Data Samples

Primary trigger: Rare B dimuon trigger, SUMPT version

- 2 CMU muons or 1 CMU and 1 CMX muon with $\Sigma p_{T_\mu} > 5.0 GeV$
- **CMU**: p_T >1.5 GeV and $|\eta|$ <0.6 – **CMX**: p_T >2.0 GeV and 0.6< $|\eta|$ <1.0

Data Sets

- Previously 0-20: 3.7 fb^{-1}
- Extended to period 30: 6.9 fb^{-1}

Improvements

- CMX Miniskirts included
- New Neural Network with better signal efficiency
- New dE/dx calibration
- Improved background predictions

Control for background estimates

- Signal has two oppisite sign muons that pass our particle ID
- Signal also has B_s p vector aligned with vector going from primary to secondary vertex
- Used 4 control regions to test background predictions
  - OS-: events with opposite sign muons but where the B_s p_T and the primary to secondary vertex vector are anti-aligned
  - SS+: events with same sign muons
  - SS-: events with same sign muons but where the B_s p_T and the primary to secondary vertex vector are anti-aligned
  - FM+: events where one of the muons fails our muon id

Previous Status of Analysis

Status of Analysis

Previous Status

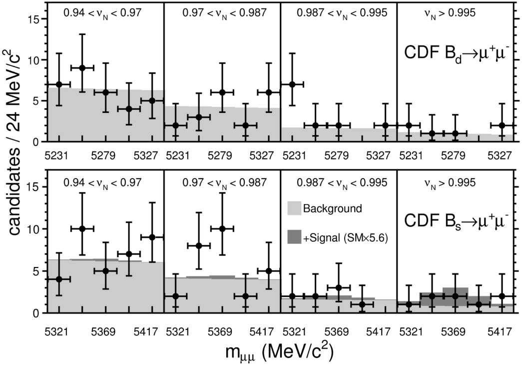
- Pre-blessed June 9th (http://www-cdf.fnal.gov/internal/WebTalks/Archive/1106/110609_b/02_110609_b_Walter_1.
- Revised background estimates: Dimuon mass >5GeV and fixed slope fit
- Revised OS+ and FM+ fake rates
- Background model tested in control regions
- Final CLs limits shown

Updates

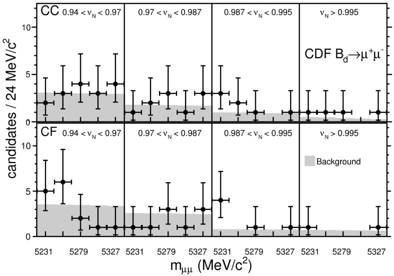
- Final PRL data plot
- p-values with signal floating.
- Background only and SM+background p-values
- p-values for highest 2 bins
- Point estimate and bounds from Bayesian technique
- Point estimate from likelihood fit (cross check)
- Additional cross check of bounds

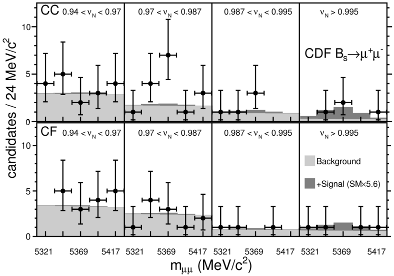
PRL Data Plot

- B_d: Consistent with background
- B_s: Significant signal like excess in top two NN bins
- Significant excess in 3rd NN bin
  - Does not appear signal like
  - More on this later
- Will calculate p-values, point estimate, and limits



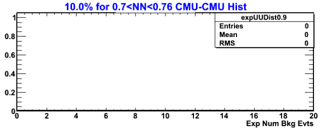
PRL Data Plot: UU and UX separation

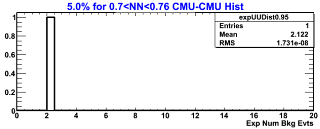


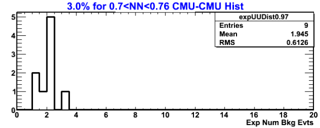


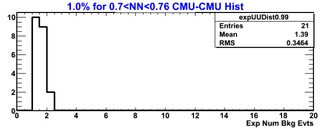
2 USB Evts: Estimate Bkg and Error on Estimate

Background Estimate

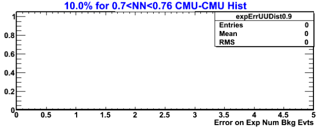


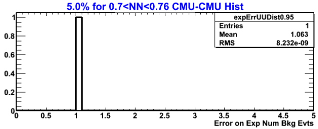


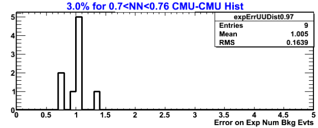


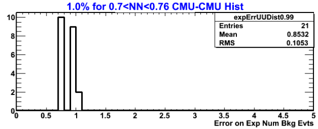


Error on Estimate









Toy MC Tables: Estimate Bkg and Error on Estimate

- Started with 118 bkg evts predicted in signal region for 0.7<NN<0.76 CMU-CMU mass hitogram
- Randomly removed 90%, 95%, 97%, and 99% of events
- Estimate bkg evts should be consistent with fraction of evts discarded from original histogram
- Mean of error should be consistent with error on prediction

Comparisons

Fraction of Evts Kept	Exp Mean	Obs Mean	RMS of Estimates	Mean of Error
10%	11.8	11.99	2.10	2.54
5%	5.90	6.07	1.75	1.79
3%	3.54	3.67	1.5	1.37
1%	1.18	1.12	0.67	0.72

Testing bkg shape with tail (Landau) for highest NN bins

Limits, point estimates and bounds

MCLimit Inputs

MC Limit expected inputs for each of the 80 bins:

- Yields
  - Expected Combinatoric Background
  - Expected B→hh Background
  - Expected Signal Yield
- Uncorrelated uncertainty associated with yields and bins (e.g. stat uncert)
- Correlated uncertainty associated with yields and bins
- What those correlations are

- All systematics modeled as truncated Gaussian
- Sampled between $\pm 20\sigma$
- Truncated Gaussians to avoid negative yields (both for signal as well as background)

Limit Inputs: Combinatoric Inputs

Yield

- Given in backup slides

Uncorrelated Errors

- There are no sources of uncert. that are completely uncorrelated across all bins

Correlated Errors

- Total given in backup slides
- Across all bins in each channel (CMU-CMU and CMU-CMX)
  - Slope uncertainty (3%)
- Across all mass bins in the same NN bin
  - Normalization uncertainty (7%-50%)

Limit Inputs: B→hh inputs

Yield

- See backup slides

Uncorrelated errors

- MC statistics: $\sim 2\%$
- Mass efficiency error: $\sim 1\%$

Correlated errors

- Correlated across all bins
    - Fake rate systematic (see cross check) (∼34%)
    - f_u/f_s ($\sim 5\%$)
    - Also included uncertainties on remaining eff and acceptance ($\sim 1\%$)
- Correlated across all NN bins for the same mass bin
    - Error on B→hh BR (3-45%)

Limit Inputs: Signal

Yield

- Estimated with relative normalization
- Assume MC Limit
- MC limit scales this yield

Uncorrelated errors

- MC statistics: $\sim 2\%$

Correlated errors

- Correlated across all bins
  - f_u/f_s ($\sim 13\%$)
  - $\mathrm{BR}(B^+ \to J/\Psi K^+)$ ($\sim 3\%$)
  - SES (acceptance, reco eff, trigger eff, NN eff) ($\sim 10\%$)
- Correlated across all NN bins for the same mass bin
  - Mass shape error, dominated by uncertainty on radiative tail (0.1%-9%)

MC Limit

- All systematics are nuissance parameters with Gaussian shapes
- Vary systematics between $\pm 20\sigma$
- Use -2ln(Q) as test statistic
- $\mathrm{Q} = P(s+b|data)/P(b|data)$
- Use CLs method for limits but cross check with Bayesian limits
- Use Bayesian posterior to get central value for B_s, max likelihood as cross check

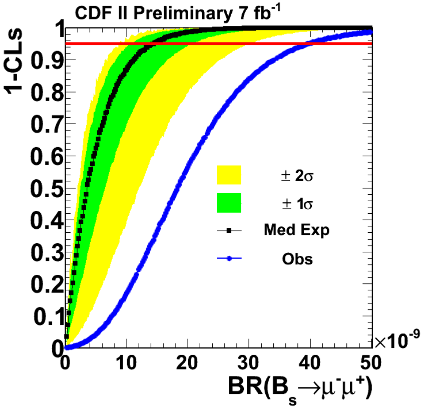
B_s and B_d Limits

B_s Limits

- Expected Limits at 95% (90%) CL: $1.5\ (1.1) \times 10^{-8}$
- Observed Limits at 95% (90%) CL: $4.0\ (3.5) \times 10^{-8}$

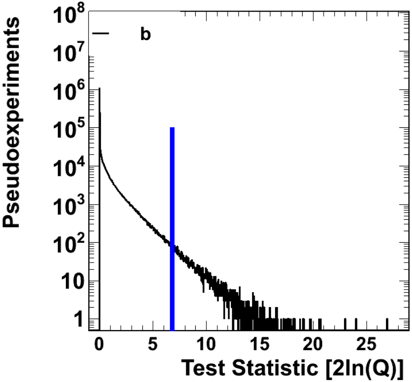
B_d Limits

- Expected Limits at 95% (90%) CL: $4.6\ (3.6) \times 10^{-9}$
- Observed Limits at 95% (90%) CL: $6.0\ (5.0) \times 10^{-9}$



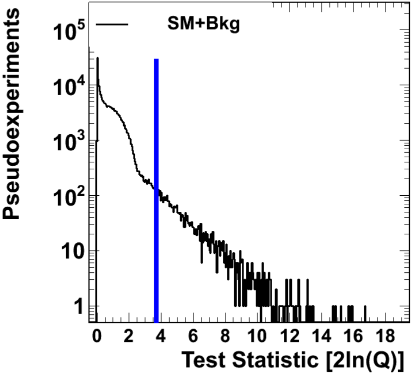
B_s p-value: Background Hypothesis Only

- Q $= P(s+b|data)/P(b|data)$
  - Black points: data in Q are background only p.e.
  - Blue line: Observed data
  - Includes all systematics
  - Now leave signal in S+B hypothesis floating in likelhood fit
- 0.0027 p-value.
- For reference, B_d background only p-value is 0.235



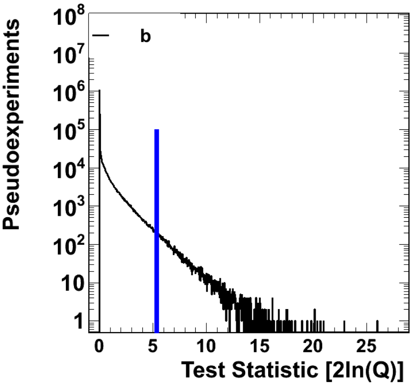
B_s p-value: SM-Signal+Background Hypothesis

- $Q = P(s+b|data)/P(b|data)$
  - Black points: data in Q are SM-Signal+background p.e.
  - Blue line: Observed data
  - Includes all systematics
  - Now leave signal in S+B hypothesis floating in likelhood fit
- 0.019 p-value.
- (SM+1σ)+background p-value: 0.021



B_s p-value for Two Highest NN Bins

- P-values using highest 2 NN bins
  - Observe non signal like fluctuation in 3rd NN bin
  - Adds to significance of p-values
  - Calculate p-values with larger signal contribution
- Background only: 0.0066 p-value.
- SM-Signal+Background: 0.043 p-value.
- (SM+1σ)+background p-value: 0.047
- Still incompatible with SM at 95% CL.



B_s Poisson Probabilities for Background Fluctuation

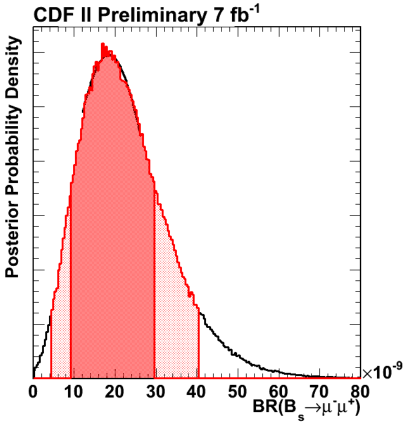
sample	NN cut	CMU-CMU pred	CMU-CMU obsv	CMU-CMU prob(%)	CMU-CMX pred	CMU-CMX obsv	CMU-CMX prob(%)
	$0.700<NN<0.760$	$39.3\pm(3.0)$	28	96.2	$41.4\pm(3.1)$	48	19.5
OSP	$0.760<NN<0.850$	$41.3\pm(3.1)$	43	42.3	$46.1\pm(3.4)$	37	90.1
	$0.850<NN<0.900$	$17.4\pm(1.9)$	22	18.2	$23.9\pm(2.3)$	20	79.0
	$0.900<NN<0.940$	$17.2\pm(1.9)$	25	6.0	$18.9\pm(2.0)$	17	67.5
	$0.940<NN<0.970$	$14.0\pm(1.7)$	18	19.4	$16.0\pm(1.9)$	17	43.5
	$0.970<NN<0.987$	$7.9\pm(1.3)$	16	1.5	$11.6\pm(1.6)$	11	59.0
	$0.987<NN<0.995$	$4.0\pm(0.9)$	5	36.7	$3.3\pm(0.8)$	3	60.8
	$0.995<NN<1.000$	$0.9\pm(0.4)$	4	2.0	$2.7\pm(0.7)$	4	28.6

Table: Bs Observed and expected events.

p-value for highest two NN bins: 0.66%
Investigating how 3rd NN bin contributes to p-value

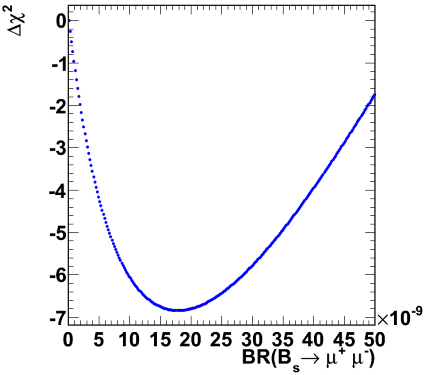
B_s Central Value: Bayesian Posterior

- Bayesian Posterior Probability Distribution
- Central value of $(1.8^{+1.1}_{-0.9}(\text{stat+syst})) \times 10^{-8}$
  - Central value from median
  - 68% CL from shortest interval
- 90% CL: $5.4{\times}10^{-9}$ – 3.9×10^{-8}
  - CLs 95% Limit: 4.0×10^{-8}



B_s Central Value: Max Likelihood

- Plotted -2ln(Q)
  - Equivalent to $\Delta\chi^2$
- No systematics included
- Central value of $(1.8^{+1.1}_{-0.9}(\text{stat+syst})) \times 10^{-8}$
  - Central value from minimum
  - 68% CL $+1\Delta\chi^2$ from minimum $\Delta\chi^2$
  - MINOS errors ± 1.0
- Agrees with Bayesian



Cross check of bounds

- Determine BR excluded at 95% CL by observed data
- Scan BRs and compute distribution of -2ln(Q)
- Find BR for which observed -2ln(Q) exclueds 95%
- Determine both upper and lower bounds to find 90% CL
- Bounds: 5.1×10^{-9} – 3.8×10^{-8}
- Consistent with Bayesian method and CLs upper limit

Conclusion

- Significant excess observed in Bs data
- Calculated p-values, point estimates, and bounds
- Cross checked all values using alternate statistical methods
- Worlds best limits:
    - Bd: 6.0×10^{-9}
    - Bs: 4.0×10^{-8}, even with possible signal
- $BR(Bs \rightarrow \mu^+\mu^-) = (1.8^{+1.1}_{-0.9}) \times 10^{-8}$
- $5.4 \times 10^{-9} < BR(Bs \rightarrow \mu^+\mu^-) < 3.9 \times 10^{-8}$ at 90%
- SM expectation $BR(Bs \rightarrow \mu^+\mu^-) = (3.2 \pm 0.2) \times 10^{-9}$
- p-value for SM-Signal+Background: 1.9%
- Blessing and paper seminar next week.

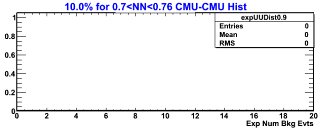
Backup Slides

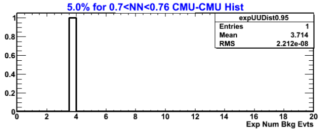
Backup Slides: Full Control Sample Table

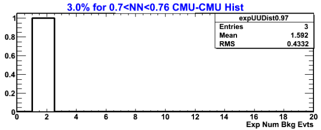
sample	NN cut	CMU-CMU pred	CMU-CMU obsv	CMU-CMU prob(%)	CMU-CMX pred	CMU-CMX obsv	CMU-CMX prob(%)
OS-	0.700<NN<0.760	217.4±(12.5)	203	77.7	209.3±(12.0)	187	88.8
	0.760<NN<0.850	262.0±(14.1)	213	99.1	332.3±(16.3)	325	62.0
	0.850<NN<0.900	117.9±(8.6)	120	44.7	146.7±(9.7)	144	57.7
	0.900<NN<0.940	112.1±(8.4)	116	39.4	144.2±(9.6)	139	63.9
	0.940<NN<0.970	112.7±(8.4)	108	64.2	128.6±(8.9)	112	88.4
	0.970<NN<0.987	80.2±(6.9)	75	68.3	92.8±(7.4)	89	63.0
	0.987<NN<0.995	67.6±(6.3)	41	99.8	45.4±(5.0)	55	14.0
	0.995<NN<1.000	32.5±(4.2)	35	37.5	38.3±(4.5)	37	58.2
SS+	0.700<NN<0.760	3.0±(0.9)	3	55.0	0.3±(0.3)	1	30.0
	0.760<NN<0.850	3.3±(1.0)	5	25.4	4.2±(1.1)	4	57.8
	0.850<NN<0.900	1.5±(0.7)	2	43.2	0.3±(0.3)	3	1.3
	0.900<NN<0.940	0.9±(0.5)	1	56.8	0.6±(0.4)	1	45.4
	0.940<NN<0.970	1.2±(0.6)	1	65.9	0.9±(0.5)	1	56.8
	0.970<NN<0.987	1.5±(0.7)	2	43.2	0.6±(0.4)	0	54.9
	0.987<NN<0.995	0.3±(0.3)	0	74.1	0.5±(0.4)	0	60.1
	0.995<NN<1.000	0.3±(0.3)	0	74.1	0.3±(0.3)	1	30.0
SS-	0.700<NN<0.760	5.7±(1.3)	8	23.7	4.2±(1.1)	4	57.8
	0.760<NN<0.850	8.4±(1.6)	7	69.8	5.1±(1.2)	7	27.1
	0.850<NN<0.900	3.3±(1.0)	6	14.3	2.7±(0.9)	2	71.0
	0.900<NN<0.940	2.4±(0.8)	4	24.0	0.9±(0.5)	4	2.8
	0.940<NN<0.970	2.4±(0.8)	4	24.0	3.0±(0.9)	1	92.3
	0.970<NN<0.987	2.1±(0.8)	0	12.2	2.4±(0.8)	5	12.2
	0.987<NN<0.995	1.5±(0.7)	0	22.3	0.6±(0.4)	0	54.9
	0.995<NN<1.000	0.3±(0.3)	1	30.0	1.8±(0.7)	0	16.5
FM+	0.700<NN<0.760	118.3±(8.6)	136	11.1	54.8±(5.6)	66	12.7
	0.760<NN<0.850	110.5±(8.3)	121	22.3	66.3±(6.2)	57	83.1
	0.850<NN<0.900	52.0±(5.4)	37	96.3	33.7±(4.3)	25	90.3
	0.900<NN<0.940	37.3±(4.5)	37	53.0	17.4±(3.1)	26	6.6
	0.940<NN<0.970	20.1±(3.3)	20	52.3	9.5±(2.2)	15	10.2
	0.970<NN<0.987	8.3±(2.0)	6	77.1	5.3±(1.7)	9	13.4
	0.987<NN<0.995	8.7±(2.0)	3	97.5	2.7±(1.2)	3	49.3
	0.995<NN<1.000	20.8±(3.5)	24	30.7	2.1±(1.0)	8	0.7

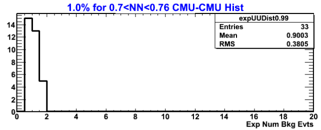
1 USB Evts: Estimate Bkg and Error on Estimate

Background Estimate

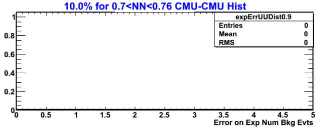


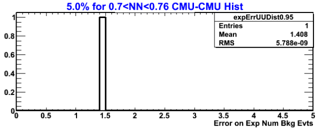


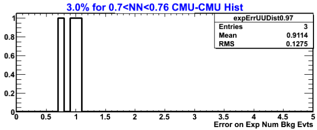


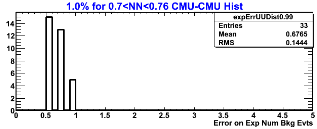


Error on Estimate









Combinatoric Background in OS+ Sample (B_s)

- Use >5 GeV fit with fixed slope and offset (but floating normalization)
- No Change

	CMU-CMU	CMU-CMX	CMU-CMU	CMU-CMX	CMU-CMU	CMU-CMX
	0.700<NN<0.760		0.760<NN<0.850		0.850<NN<0.900	
5.31-5.334	8.02±0.62	8.49±0.65	8.42±0.64	9.45±0.69	3.55±0.39	4.91±0.48
5.334-5.358	7.94±0.61	8.38±0.64	8.34±0.63	9.33±0.68	3.51±0.39	4.85±0.47
5.358-5.382	7.87±0.61	8.28±0.63	8.26±0.62	9.21±0.67	3.48±0.39	4.79±0.46
5.382-5.406	7.79±0.6	8.17±0.62	8.18±0.62	9.09±0.66	3.44±0.38	4.73±0.46
5.406-5.43	7.71±0.59	8.07±0.61	8.1±0.61	8.98±0.65	3.41±0.38	4.67±0.45
Total	39.33±3.03	41.39±3.15	41.3±3.11	46.06±3.35	17.39±1.93	23.94±2.32

	CMU-CMU	CMU-CMX	CMU-CMU	CMU-CMX	CMU-CMU	CMU-CMX
	0.900<NN<0.940		0.940<NN<0.970		0.970<NN<0.987	
5.31-5.334	3.51±0.39	3.87±0.42	2.86±0.35	3.29±0.38	1.61±0.26	2.37±0.32
5.334-5.358	3.47±0.39	3.82±0.41	2.83±0.35	3.25±0.38	1.6±0.26	2.34±0.32
5.358-5.382	3.44±0.38	3.77±0.41	2.81±0.34	3.21±0.37	1.58±0.25	2.31±0.31
5.382-5.406	3.41±0.38	3.73±0.4	2.78±0.34	3.17±0.37	1.57±0.25	2.28±0.31
5.406-5.43	3.37±0.38	3.68±0.4	2.75±0.34	3.12±0.36	1.55±0.25	2.25±0.31
Total	17.19±1.91	18.87±2.04	14.03±1.72	16.03±1.87	7.91±1.27	11.57±1.57

	CMU-CMU	CMU-CMX	CMU-CMU	CMU-CMX
	0.987<NN<0.995		0.995<NN<1.000	
5.31-5.334	0.81±0.18	0.67±0.17	0.16±0.08	0.54±0.15
5.334-5.358	0.8±0.18	0.66±0.17	0.16±0.08	0.53±0.15
5.358-5.382	0.79±0.18	0.65±0.16	0.16±0.08	0.53±0.15
5.382-5.406	0.78±0.18	0.64±0.16	0.16±0.08	0.52±0.15
5.406-5.43	0.78±0.17	0.63±0.16	0.16±0.08	0.51±0.14
Total	3.95±0.89	3.25±0.82	0.79±0.4	2.64±0.74

New B→hh in OS+ Sample (B_s)

CMU-CMU

Mass/NN bin	0.7-0.76	0.76-0.85	0.85-0.9	0.9-0.94	0.94-0.97	0.97-0.987	0.987-0.995	0.995-1.0
5.31 — 5.334	0.0024	0.0044	0.0035	0.0048	0.0077	0.0095	0.013	0.052
5.334 — 5.358	0.00084	0.0017	0.0012	0.0018	0.0025	0.0033	0.0052	0.019
5.358 — 5.382	0.00031	0.00056	0.0004	0.00064	0.0009	0.0012	0.0018	0.0064
5.382 — 5.406	0.00012	0.00022	0.00016	0.00025	0.00032	0.00045	0.00064	0.0024
5.406 — 5.43	0.00003	0.00006	0.00003	0.00005	0.00006	0.00011	0.00014	0.00061
Total	0.0037	0.0069	0.0052	0.0076	0.011	0.015	0.021	0.08

CMU-CMX

Mass/NN bin	0.7-0.76	0.76-0.85	0.85-0.9	0.9-0.94	0.94-0.97	0.97-0.987	0.987-0.995	0.995-1.0
5.31 — 5.334	0.00079	0.0013	0.0012	0.0016	0.0021	0.0032	0.0028	0.015
5.334 — 5.358	0.00033	0.00065	0.00048	0.00065	0.00084	0.0014	0.0012	0.0064
5.358 — 5.382	0.00012	0.00023	0.00019	0.00026	0.00033	0.00056	0.00045	0.0025
5.382 — 5.406	0.00006	0.00011	0.00008	0.00012	0.00016	0.00024	0.00022	0.0011
5.406 — 5.43	0.00002	0.00003	0.00002	0.00002	0.00005	0.00008	0.00006	0.00036
Total	0.0013	0.0024	0.0019	0.0026	0.0035	0.0055	0.0047	0.026

B→hh in OS+ Sample (B_d)

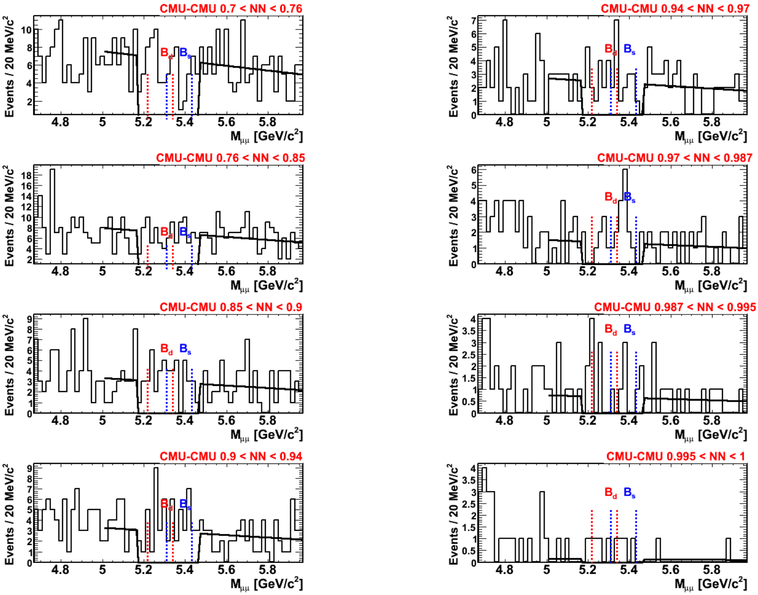
CMU-CMU

Mass/NN bin	0.7-0.76	0.76-0.85	0.85-0.9	0.9-0.94	0.94-0.97	0.97-0.987	0.987-0.995	0.995-1.0
5.219 — 5.243	0.011	0.019	0.016	0.022	0.034	0.042	0.06	0.23
5.243 — 5.267	0.0096	0.019	0.013	0.021	0.028	0.037	0.059	0.21
5.267 — 5.291	0.0076	0.014	0.0097	0.016	0.022	0.029	0.043	0.16
5.291 — 5.315	0.0043	0.0081	0.0059	0.0092	0.012	0.016	0.024	0.09
5.315 — 5.339	0.0016	0.0031	0.0019	0.0028	0.0036	0.0063	0.0081	0.035
Total	0.034	0.064	0.046	0.07	0.099	0.13	0.19	0.72

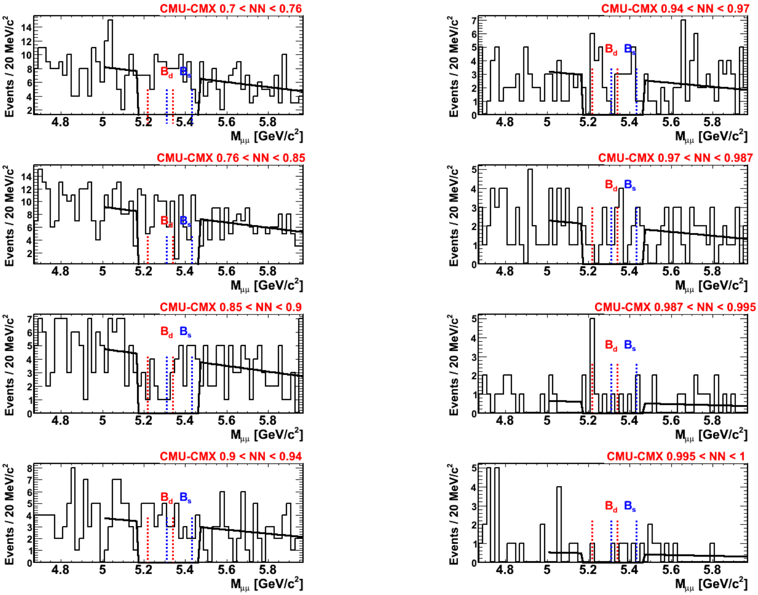
CMU-CMX

Mass/NN bin	0.7-0.76	0.76-0.85	0.85-0.9	0.9-0.94	0.94-0.97	0.97-0.987	0.987-0.995	0.995-1.0
5.219 — 5.243	0.003	0.005	0.0044	0.0058	0.0081	0.012	0.01	0.057
5.243 — 5.267	0.0031	0.0061	0.0045	0.0062	0.0078	0.013	0.011	0.061
5.267 — 5.291	0.0023	0.0044	0.0037	0.0051	0.0064	0.011	0.0087	0.048
5.291 — 5.315	0.0014	0.0028	0.0019	0.0028	0.004	0.0059	0.0053	0.028
5.315 — 5.339	0.00047	0.00087	0.00065	0.00093	0.0013	0.0022	0.0018	0.011
Total	0.01	0.019	0.015	0.021	0.028	0.045	0.037	0.2

Results: Unblinded Mass Plots for CMU-CMU



Results: Unblinded Mass Plots for CMU-CMX



Results: B_s

	Mass Bin (GeV)	5.31-5.334	5.334-5.358	5.358-5.382	5.382-5.406	5.406-5.43	Total
UU NN bin	Exp Bkg	8.02±0.62	7.94±0.61	7.87±0.61	7.79±0.6	7.71±0.59	39.34
0.7-0.76	Obs	9	6	6	2	5	28
UU NN bin	Exp Bkg	8.43±0.64	8.34±0.63	8.26±0.62	8.18±0.62	8.1±0.61	41.32
0.76-0.85	Obs	8	6	11	11	7	43
UU NN bin	Exp Bkg	3.55±0.39	3.51±0.39	3.48±0.39	3.44±0.38	3.41±0.38	17.4
0.85-0.9	Obs	5	6	2	5	4	22
UU NN bin	Exp Bkg	3.51±0.39	3.47±0.39	3.44±0.38	3.41±0.38	3.37±0.38	17.2
0.9-0.94	Obs	4	5	4	5	7	25
UU NN bin	Exp Bkg	2.87±0.35	2.84±0.35	2.81±0.34	2.78±0.34	2.75±0.34	14.04
0.94-0.97	Obs	4	5	2	3	4	18
UU NN bin	Exp Bkg	1.62±0.26	1.6±0.26	1.58±0.25	1.57±0.25	1.55±0.25	7.92
0.97-0.987	Obs	1	4	7	1	3	16
UU NN bin	Exp Bkg	0.82±0.18	0.8±0.18	0.79±0.18	0.78±0.18	0.78±0.17	3.97
0.987-0.995	Obs	1	1	3	0	0	5
UU NN bin	Exp Bkg	0.21±0.08	0.18±0.08	0.16±0.08	0.16±0.08	0.16±0.08	0.87
0.995-1	Obs	0	1	2	0	1	4
UX NN bin	Exp Bkg	8.49±0.65	8.39±0.64	8.28±0.63	8.17±0.62	8.07±0.61	41.4
0.7-0.76	Obs	8	13	9	9	9	48
UX NN bin	Exp Bkg	9.45±0.69	9.33±0.68	9.21±0.67	9.1±0.66	8.98±0.65	46.07
0.76-0.85	Obs	7	8	7	11	4	37
UX NN bin	Exp Bkg	4.91±0.48	4.85±0.47	4.79±0.46	4.73±0.46	4.67±0.45	23.95
0.85-0.9	Obs	1	5	6	3	5	20
UX NN bin	Exp Bkg	3.87±0.42	3.82±0.41	3.77±0.41	3.73±0.4	3.68±0.4	18.88
0.9-0.94	Obs	4	1	6	3	3	17
UX NN bin	Exp Bkg	3.29±0.38	3.25±0.38	3.21±0.37	3.17±0.37	3.12±0.36	16.04
0.94-0.97	Obs	0	5	3	4	5	17
UX NN bin	Exp Bkg	2.38±0.32	2.34±0.32	2.31±0.31	2.28±0.31	2.25±0.31	11.57
0.97-0.987	Obs	1	4	3	1	2	11
UX NN bin	Exp Bkg	0.67±0.17	0.66±0.17	0.65±0.16	0.64±0.16	0.63±0.16	3.25
0.987-0.995	Obs	1	1	0	1	0	3
UX NN bin	Exp Bkg	0.56±0.15	0.54±0.15	0.53±0.15	0.52±0.15	0.51±0.14	2.66
0.995-1	Obs	1	1	0	1	1	4

Results: B_d

	Mass Bin (GeV)	5.219-5.243	5.243-5.267	5.267-5.291	5.291-5.315	5.315-5.339	Total
UU NN bin	Exp Bkg	8.32±0.64	8.25±0.63	8.17±0.63	8.09±0.62	8.01±0.62	40.83
0.7-0.76	Obs	11	10	6	5	7	39
UU NN bin	Exp Bkg	8.75±0.66	8.67±0.65	8.58±0.65	8.5±0.64	8.41±0.63	42.91
0.76-0.85	Obs	8	10	5	6	9	38
UU NN bin	Exp Bkg	3.69±0.41	3.66±0.4	3.62±0.4	3.58±0.4	3.54±0.39	18.09
0.85-0.9	Obs	7	2	6	5	4	24
UU NN bin	Exp Bkg	3.66±0.4	3.62±0.4	3.58±0.4	3.54±0.39	3.5±0.39	17.9
0.9-0.94	Obs	5	8	5	5	5	28
UU NN bin	Exp Bkg	3.0±0.36	2.97±0.36	2.93±0.36	2.9±0.35	2.86±0.35	14.65
0.94-0.97	Obs	2	3	4	3	4	16
UU NN bin	Exp Bkg	1.71±0.27	1.69±0.27	1.67±0.26	1.64±0.26	1.62±0.26	8.33
0.97-0.987	Obs	1	2	3	1	3	10
UU NN bin	Exp Bkg	0.9±0.19	0.89±0.19	0.86±0.19	0.84±0.18	0.81±0.18	4.29
0.987-0.995	Obs	3	2	1	0	1	7
UU NN bin	Exp Bkg	0.4±0.11	0.38±0.1	0.32±0.09	0.25±0.08	0.2±0.08	1.54
0.995-1	Obs	1	1	1	0	1	4
UX NN bin	Exp Bkg	8.89±0.68	8.79±0.67	8.68±0.66	8.58±0.65	8.47±0.65	43.41
0.7-0.76	Obs	7	10	10	12	9	48
UX NN bin	Exp Bkg	9.9±0.72	9.78±0.71	9.66±0.7	9.54±0.69	9.42±0.69	48.31
0.76-0.85	Obs	7	10	11	13	10	51
UX NN bin	Exp Bkg	5.15±0.5	5.09±0.49	5.02±0.49	4.96±0.48	4.9±0.47	25.12
0.85-0.9	Obs	3	4	1	2	1	11
UX NN bin	Exp Bkg	4.06±0.44	4.01±0.43	3.96±0.43	3.91±0.42	3.86±0.42	19.8
0.9-0.94	Obs	3	5	5	6	4	23
UX NN bin	Exp Bkg	3.45±0.4	3.41±0.4	3.37±0.39	3.32±0.39	3.28±0.38	16.83
0.94-0.97	Obs	5	6	2	1	1	15
UX NN bin	Exp Bkg	2.5±0.34	2.47±0.33	2.44±0.33	2.4±0.33	2.37±0.32	12.17
0.97-0.987	Obs	1	1	3	1	3	9
UX NN bin	Exp Bkg	0.71±0.18	0.7±0.17	0.69±0.17	0.68±0.17	0.67±0.17	3.44
0.987-0.995	Obs	4	0	1	0	1	6
UX NN bin	Exp Bkg	0.62±0.16	0.62±0.16	0.6±0.15	0.57±0.15	0.55±0.15	2.97
0.995-1	Obs	1	0	0	0	1	2

MCLimit Systematics: Signal

- All systematics modeled as truncated Gaussian
- Sampled between $\pm 20\sigma$
- Truncated Gaussians to avoid negative yields (both for signal as well as background)

Syst	Value (CMU-CMU)	Value (CMU-CMX)
f_u/f_s	3.549 ± 0.461	3.549 ± 0.461
$\frac{\epsilon \cdot \alpha}{N_{B^+}}$	$(1.16 \pm 0.11) \times 10^{-5}$	$(1.63 \pm 0.16) \times 10^{-5}$
$BR(B^+ \to J/\Psi K^+ \to K^+\mu^+\mu^-)$	$(6.01 \pm 0.21) \times 10^{-5}$	$(6.01 \pm 0.21) \times 10^{-5}$
$\epsilon_{NN>0.995}$	0.461 ± 0.022	0.464 ± 0.021
$\epsilon_{NN>0.700}$	0.915 ± 0.0366	0.864 ± 0.039

MCLimit Systematics: Combinatoric Background

- All systematics modeled as Gaussian
- Sampled between $\pm 20\sigma$
- Truncated Gaussians to avoid negative yields (both for signal as well as background)
- See combinatoric background table for central values.

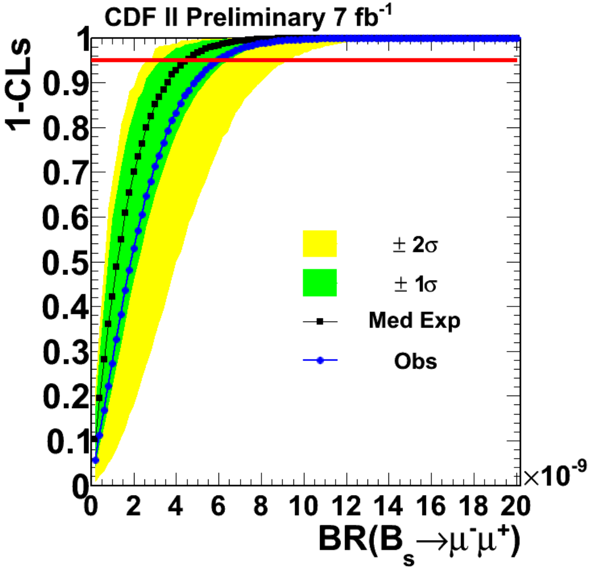
Syst	Rel. Err (CMU-CMU)	Rel. Err (CMU-CMX)
Bkg Shape Uncert. 0.995<NN<1	42%	50%
Bkg Shape Uncert. 0.987<NN<0.995	17%	19%
Bkg Shape Uncert. 0.970<NN<0.987	18%	7%
Slope Uncert.	3%	3%

MCLimit Systematics: B→hh Background

- All systematics modeled as Gaussian
- Sampled between $\pm 20\sigma$
- Truncated Gaussians to avoid negative yields (both for signal as well as background)
- See B→hh background table for central values.

Syst	Rel. Err (CMU-CMU)	Rel. Err (CMU-CMX)
Fake Rate	34%	34%
f_u/f_s (only for B_s modes)	3.549 ± 0.461	3.549 ± 0.461
$\frac{\epsilon \cdot \alpha}{N_{B^+}}$	$(1.16 \pm 0.11) \times 10^{-5}$	$(1.63 \pm 0.16) \times 10^{-5}$
$BR(B^+ \to J/\Psi K^+ \to K^+\mu^+\mu^-)$	$(6.01 \pm 0.21) \times 10^{-5}$	$(6.01 \pm 0.21) \times 10^{-5}$
$BR(B_d \to \pi^+\pi^-)$	$(5.16 \pm 0.22) \times 10^{-6}$	$(5.16 \pm 0.22) \times 10^{-6}$
$BR(B_d \to K\pi)$	$(19.4 \pm 0.6) \times 10^{-6}$	$(19.4 \pm 0.6) \times 10^{-6}$
$BR(B_d \to K^+K^-)$	$(1.5 \pm 1.1) \times 10^{-7}$	$(1.5 \pm 1.1) \times 10^{-7}$
$BR(B_s \to \pi^+\pi^-)$	$(1.2 \pm 1.2) \times 10^{-6}$	$(1.2 \pm 1.2) \times 10^{-6}$
$BR(B_s \to K\pi)$	$(5.0 \pm 1.1) \times 10^{-6}$	$(5.0 \pm 1.1) \times 10^{-6}$
$BR(B_s \to K^+K^-)$	$(26.5 \pm 4.4) \times 10^{-6}$	$(26.5 \pm 4.4) \times 10^{-6}$

B_d Limits



CDF II Preliminary 7 fb^{-1}
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0.6
0.5
0.4
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0.2
0.1
0
$\pm$ 2σ
$\pm$ 1σ
Med Exp
Obs
0 2 4 6 8 10 12 14 16 18 20
$\times 10^{-9}$
BR($B_s \to \mu^- \mu^+$)