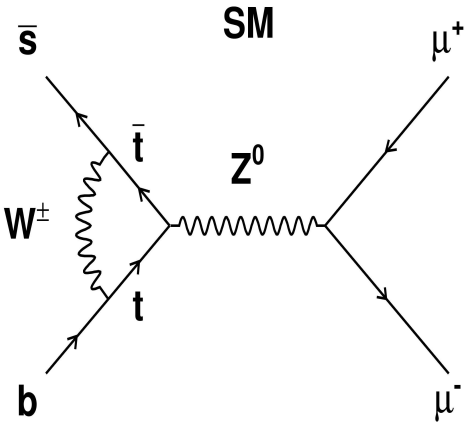
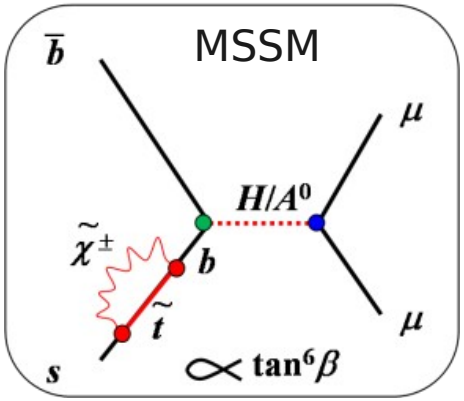
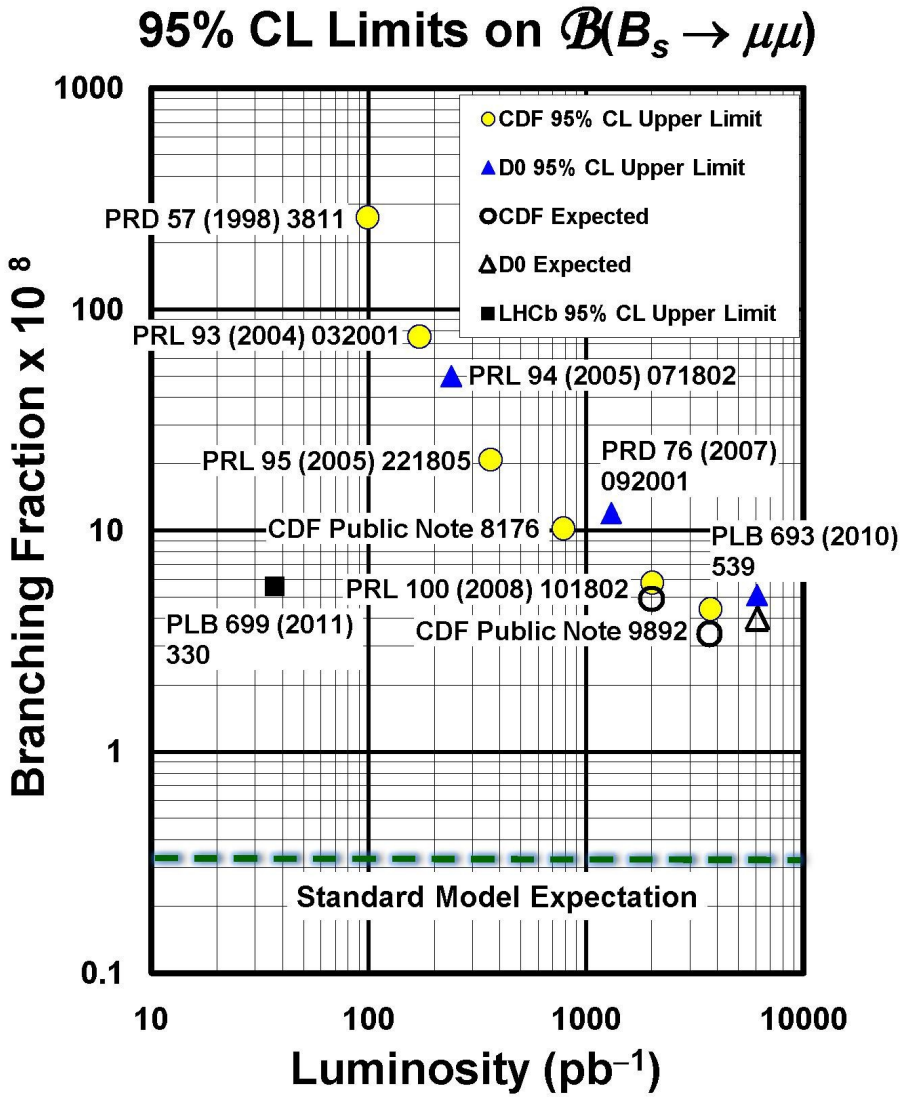
Updated Search for $B_s/B_d \to \mu^+\mu^-$ at CDF







Thomas Kuhr

EPS 2011 22.07.2011

Analysis Overview

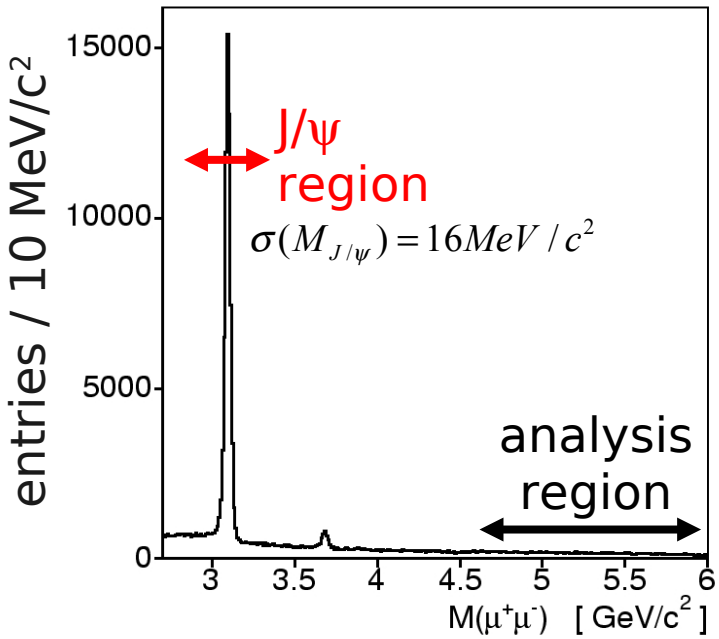
$$\mathcal{B}(B_s^0 \to \mu^+\mu^-) = \frac{N_{B_s^0}}{N_{B^+}} \frac{\alpha_{B^+}}{\alpha_{B_s^0}} \frac{\epsilon_{B^+}^{trig}}{\epsilon_{B_s^0}^{trig}} \frac{\epsilon_{B^+}^{reco}}{\epsilon_{B_s^0}^{reco}} \frac{1}{\epsilon_{B_s^0}^{NN}} \frac{f_u}{f_s} \mathcal{B}(B^+)$$

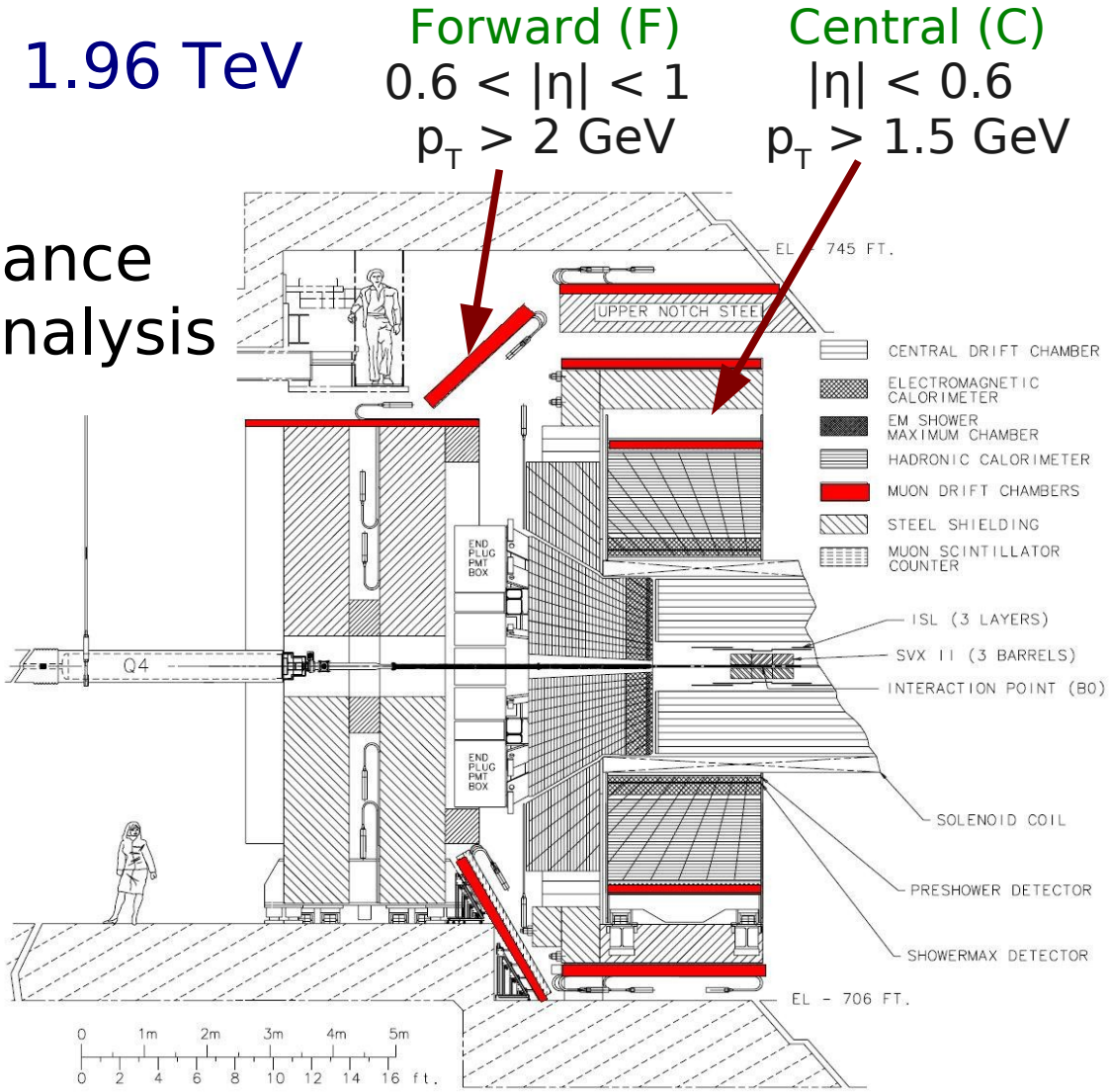
- Pre-selection of $B^0_{(s)} \to \mu^+\mu^-$ candidates
- NN discriminant to enhance signal purity
- Background estimate

- Normalization mode $B^+ \to J/\psi\, K^+$, $J/\psi \to \mu^+\mu^-$
- Relative trigger acceptance and efficiency
- NN efficiency
- Known relative production fractions and B^+ branching ratio

Data Sample

- 7 fb^{-1} of $p\bar{p}$ data at $\sqrt{s}$ = 1.96 TeV
  - Dimuon trigger: CC, CF
- ~20% increased acceptance compared to previous analysis

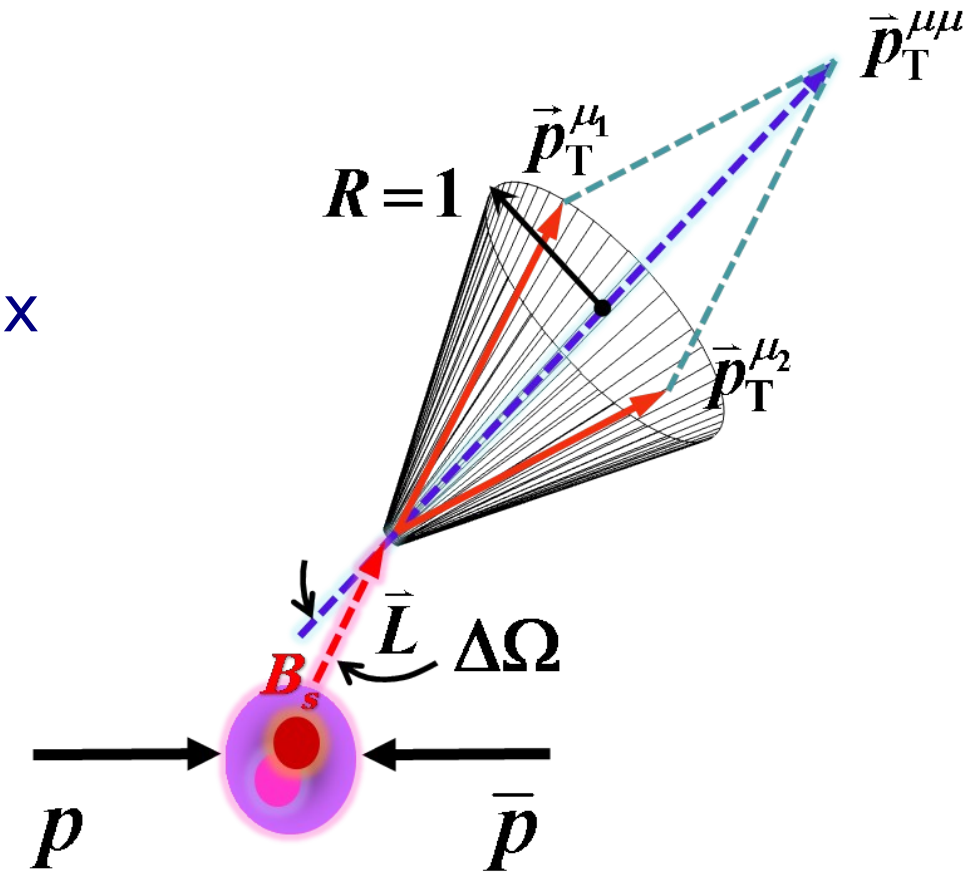




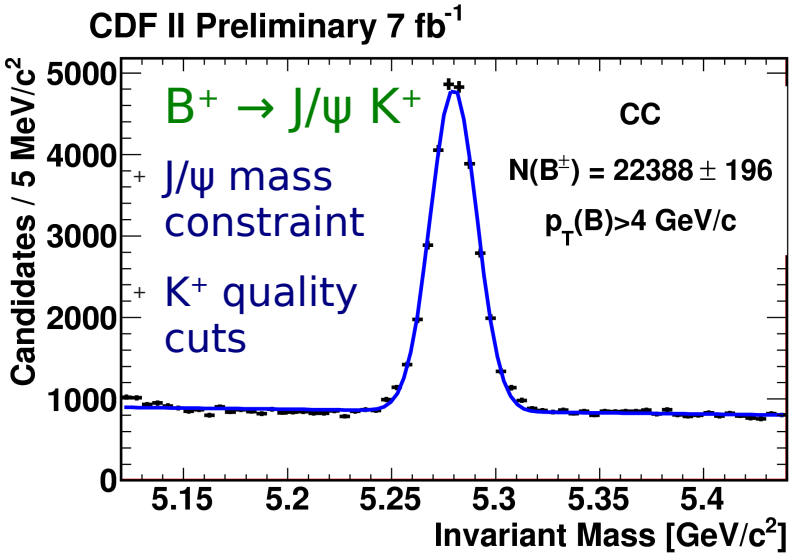
Pre-Selection

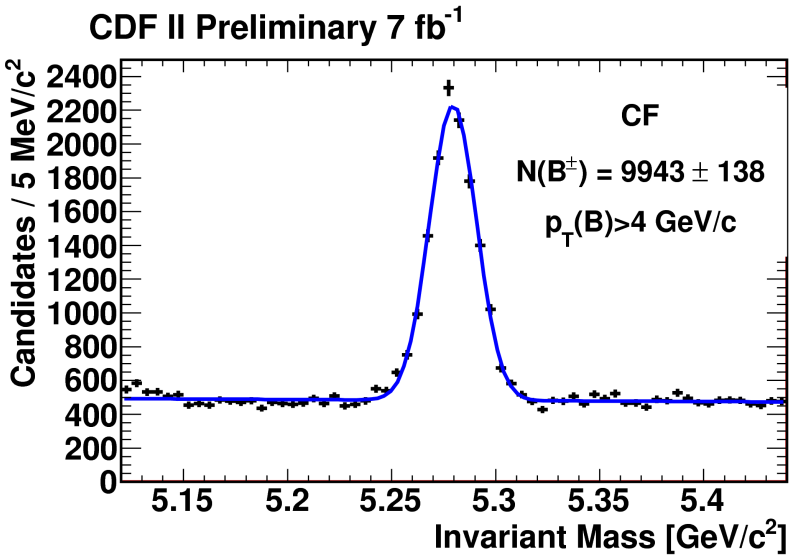
3D vertex fit and baseline cuts on

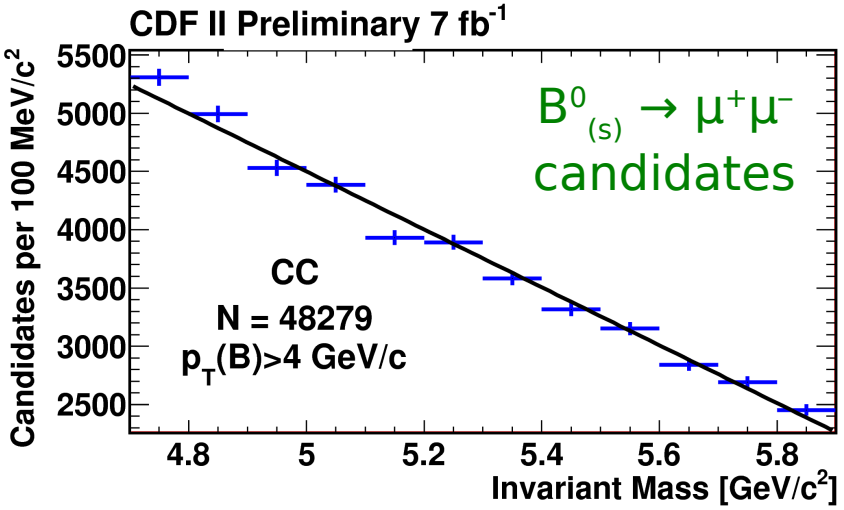
- Track quality
- Muon likelihood, dE/dx
- $p_T(\mu\mu)$
- $p_T(\mu)$
- Proper decay time significance
- Pointing angle
- Isolation: $p_T(\mu\mu) / [\sum_{R<1} p_T(\text{track}) + p_T(\mu\mu)]$

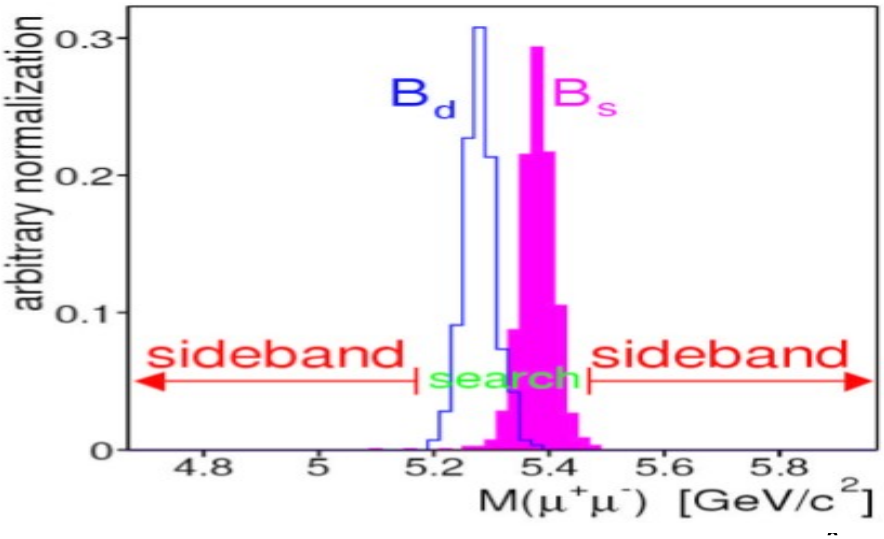


Pre-Selected Samples





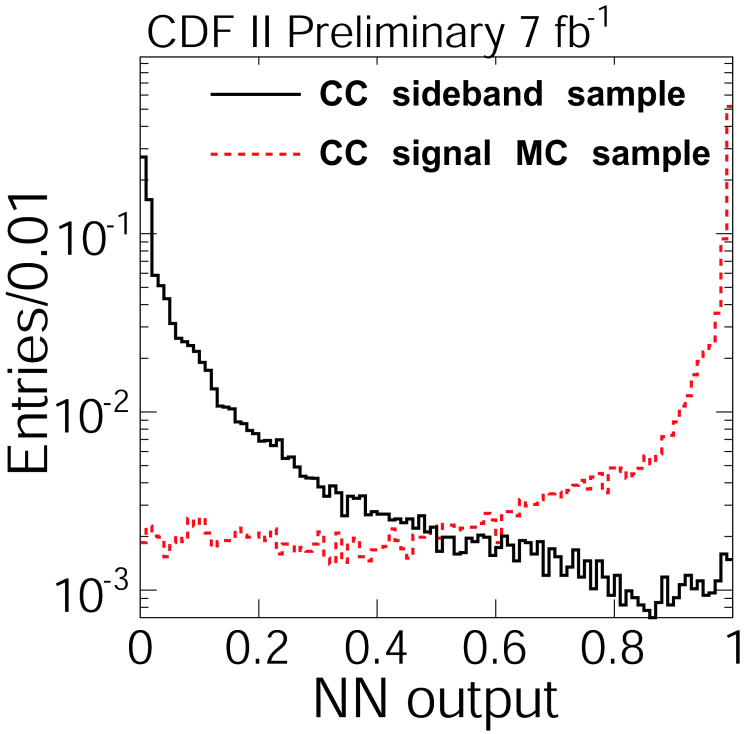


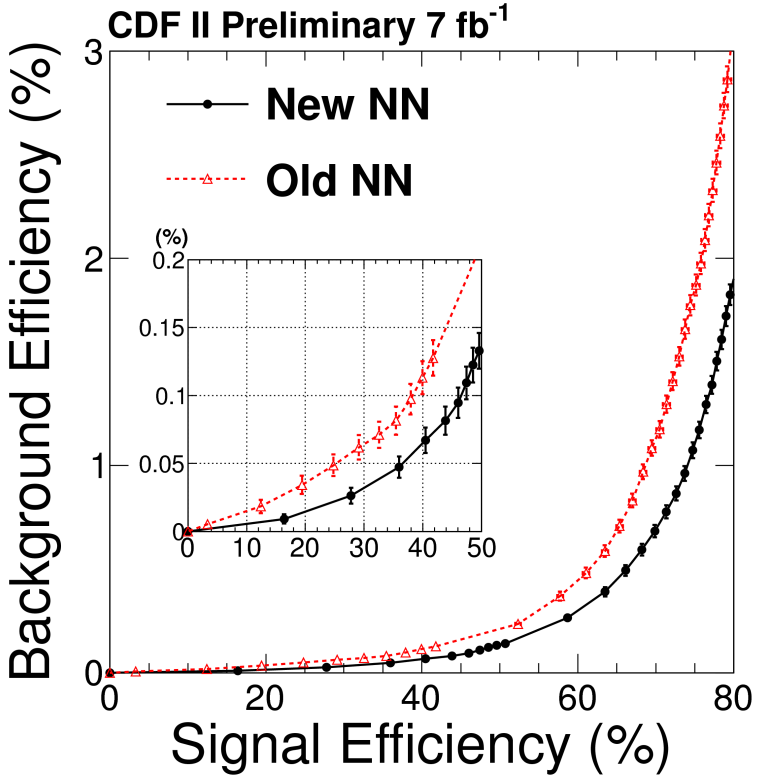


Blinded search region: 5.169 – 5.469 GeV

NN Discriminant

- 14 input variables
- → Signal: MC, p_T and isolation reweigthed to data
- → Background: mass sidebands





Checked for selection bias in $M_{\mu\mu}$ (see backup)

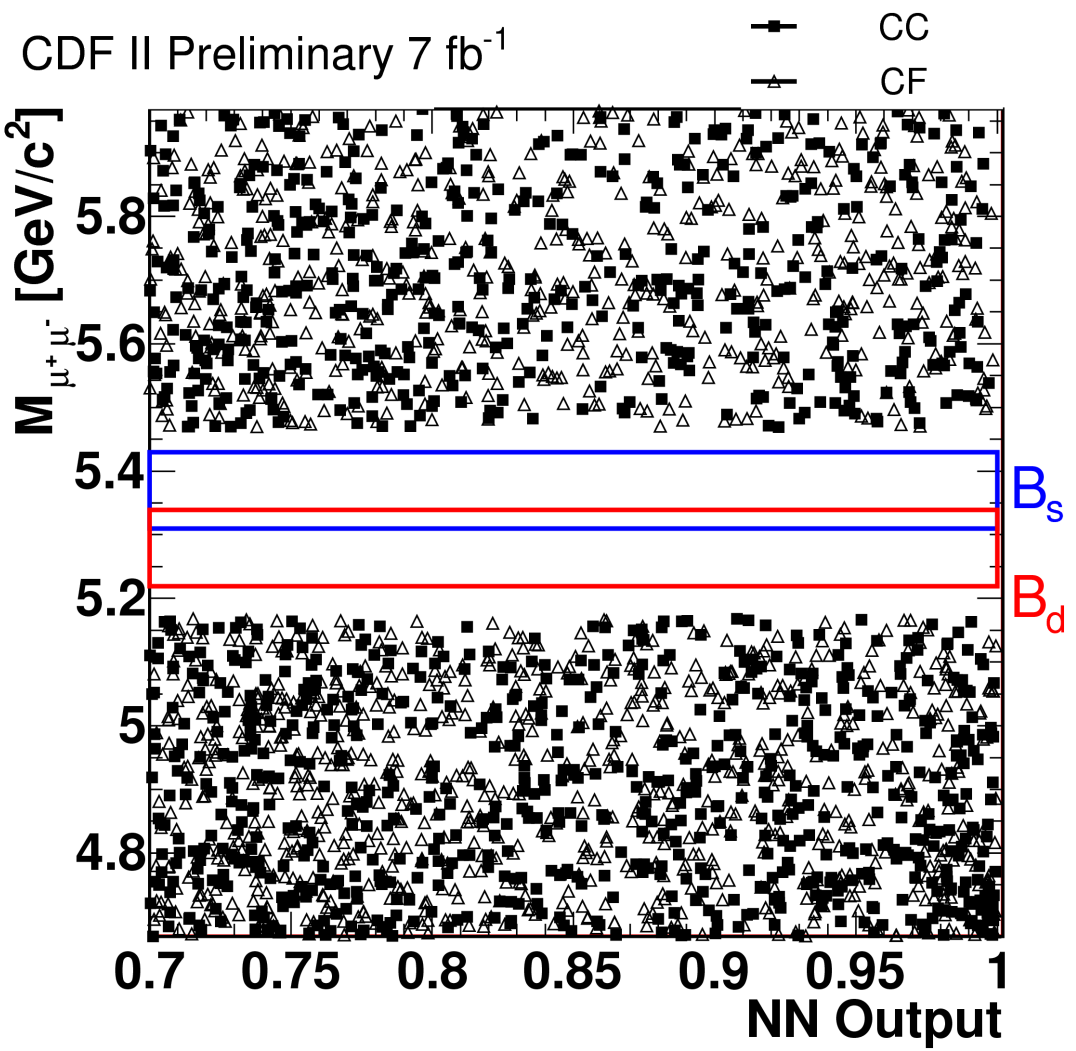
Performance checked on $B^+ \rightarrow J/\psi\, K^+$ data (see backup)

Optimization

Optimization on expected limit

- 8 bins in NN output from 0.7 to 1, highest bins: 0.97 - 0.987 - 0.995 – 1
- 5 bins in mass
- CC and CF

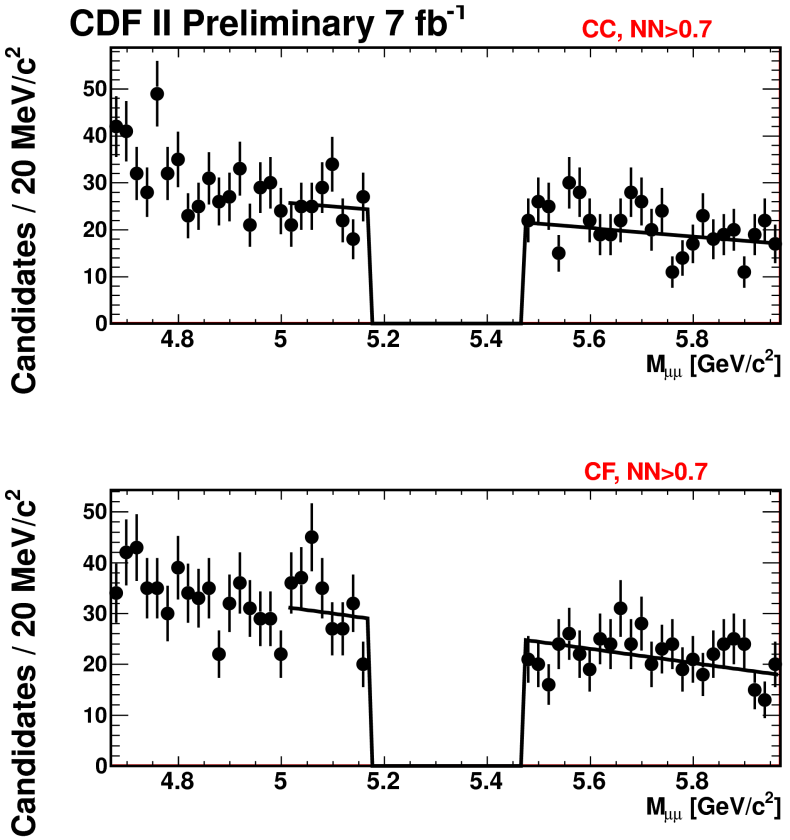
→ Backgrounds and efficiencies determined for each bin



Background Estimation

Combinatorial background:

- ➔ Smooth $M_{\mu\mu}$ distribution
- Fit linear function to sidebands for $M_{\mu\mu} > 5$ GeV to suppress $B \to \mu\mu X$
- Systematic uncertainty from different fit functions and ranges



$B \to h^+h'^-$ with mis-identified K,π:

- ➔ Peaking in signal region
- Kinematic distributions from MC
- Normalization from known branching ratios
- Fake rates from D^{*+} tagged $D^0 \to K^-\pi^+$ data

Background Estimates

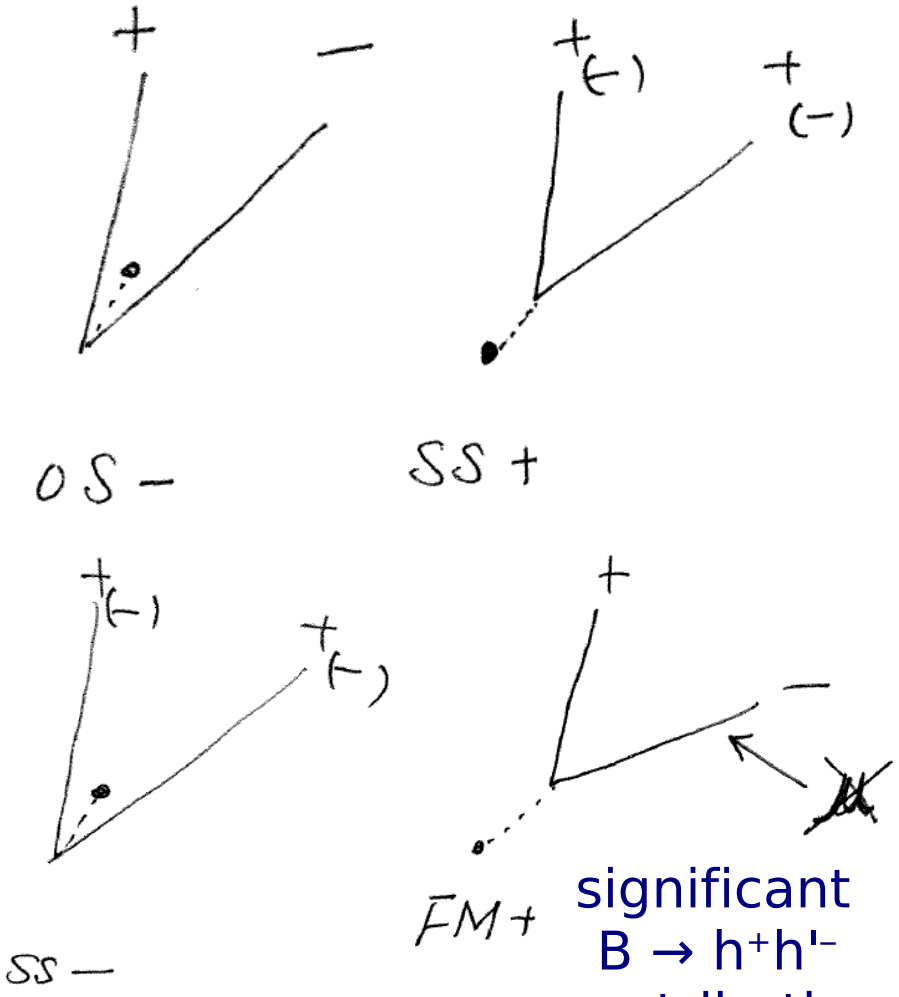
B^0_s signal window

NN Bin	combinatorial background CC	combinatorial background CF	$B \to h^+h'^-$ background CC	$B \to h^+h'^-$ background CF
$0.700 < NN < 0.970$	129.2±6.5	146.3±7.0	0.03±0.01	0.01± <0.01
$0.970 < NN < 0.987$	7.9±1.9	11.6±1.8	0.01± <0.01	0.01± <0.01
$0.987 < NN < 0.995$	4.0±1.1	3.3±1.0	0.02± <0.01	0.01± <0.01
$0.995 < NN < 1.000$	0.79±0.52	2.6±1.5	0.08±0.02	0.03±0.01

B^0 signal window

NN Bin	combinatorial background CC	combinatorial background CF	$B \to h^+h'^-$ background CC	$B \to h^+h'^-$ background CF
$0.700 < NN < 0.970$	134.0±6.6	153.4±7.3	0.31±0.08	0.09±0.02
$0.970 < NN < 0.987$	8.2±2.0	12.1±1.9	0.13±0.03	0.05±0.01
$0.987 < NN < 0.995$	4.1±1.2	3.4±1.1	0.19±0.05	0.04±0.01
$0.995 < NN < 1.000$	0.8±0.5	2.8±1.6	0.72±0.20	0.20±0.05

Control Samples



significant $B \to h^+h'^-$ contribution

sample	*NN* cut	CC pred	CC obsv	CC prob(%)
OS-	0.700<NN<0.760	217.4±(12.5)	203	77.7
	0.760<NN<0.850	262.0±(14.1)	213	99.1
	0.850<NN<0.900	117.9±(8.6)	120	44.7
	0.900<NN<0.940	112.1±(8.4)	116	39.4
	0.940<NN<0.970	112.7±(8.4)	108	64.2
	0.970<NN<0.987	80.2±(6.9)	75	68.3
	0.987<NN<0.995	67.6±(6.3)	41	99.8
	0.995<NN<1.000	32.5±(4.2)	35	37.5
SS+	0.700<NN<0.760	3.0±(0.9)	3	55.0
	0.760<NN<0.850	3.3±(1.0)	5	25.4
	0.850<NN<0.900	1.5±(0.7)	2	43.2
	0.900<NN<0.940	0.9±(0.5)	1	56.8
	0.940<NN<0.970	1.2±(0.6)	1	65.9
	0.970<NN<0.987	1.5±(0.7)	2	43.2
	0.987<NN<0.995	0.3±(0.3)	0	74.1
	0.995<NN<1.000	0.3±(0.3)	0	74.1
SS-	0.700<NN<0.760	5.7±(1.3)	8	23.7
	0.760<NN<0.850	8.4±(1.6)	7	69.8
	0.850<NN<0.900	3.3±(1.0)	6	14.3
	0.900<NN<0.940	2.4±(0.8)	4	24.0
	0.940<NN<0.970	2.4±(0.8)	4	24.0
	0.970<NN<0.987	2.1±(0.8)	0	12.2
	0.987<NN<0.995	1.5±(0.7)	0	22.3
	0.995<NN<1.000	0.3±(0.3)	1	30.0
FM+	0.700<NN<0.760	118.3±(8.6)	136	11.1
	0.760<NN<0.850	110.5±(8.3)	121	22.3
	0.850<NN<0.900	52.0±(5.4)	37	96.3
	0.900<NN<0.940	37.3±(4.5)	37	53.0
	0.940<NN<0.970	20.1±(3.3)	20	52.3
	0.970<NN<0.987	8.3±(2.0)	6	77.1
	0.987<NN<0.995	8.7±(2.0)	3	97.5
	0.995<NN<1.000	20.8±(3.5)	24	30.7

→ Observed number of events agrees with prediction

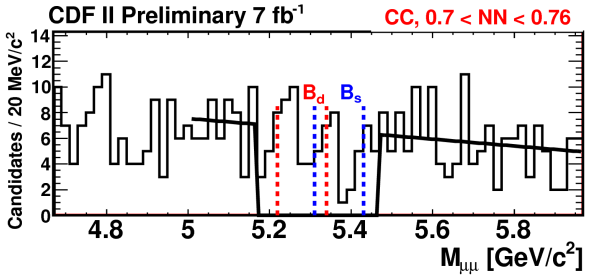
Signal Efficiency

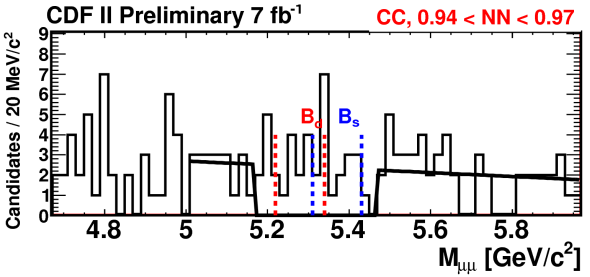
$$\mathcal{B}(B_s^0 \to \mu^+\mu^-) = \frac{N_{B_s^0}}{N_{B^+}} \frac{\alpha_{B^+}}{\alpha_{B_s^0}} \frac{\epsilon_{B^+}^{trig}}{\epsilon_{B_s^0}^{trig}} \frac{\epsilon_{B^+}^{reco}}{\epsilon_{B_s^0}^{reco}} \frac{1}{\epsilon_{B_s^0}^{NN}} \frac{f_u}{f_s} \mathcal{B}(B^+)$$

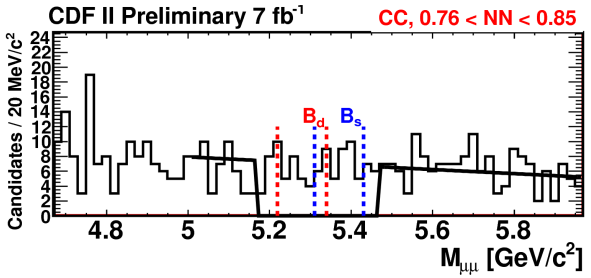
	CC		CF	
$(\alpha_{B^+}/\alpha_{B_s})$	0.307 ± 0.018	$(\pm 6\%)$	0.197 ± 0.014	$(\pm 7\%)$
$(\epsilon_{B^+}^{trig}/\epsilon_{B_s}^{trig})$	0.99935 ± 0.00012	$(< 1\%)$	0.97974 ± 0.00016	$(< 1\%)$
$(\epsilon_{B^+}^{reco}/\epsilon_{B_s}^{reco})$	0.85 ± 0.06	$(\pm 8\%)$	0.84 ± 0.06	$(\pm 9\%)$
$\epsilon_{B_s}^{NN}(NN > 0.70)$	0.915 ± 0.042	$(\pm 4\%)$	0.864 ± 0.040	$(\pm 4\%)$
$\epsilon_{B_s}^{NN}(NN > 0.995)$	0.461 ± 0.021	$(\pm 5\%)$	0.468 ± 0.022	$(\pm 5\%)$
N_{B^+}	22388 ± 196	$(\pm 1\%)$	9943 ± 138	$(\pm 1\%)$
f_u/f_s	3.59 ± 0.37	$(\pm 13\%)$	3.59 ± 0.37	$(\pm 13\%)$
$BR(B^+ \to J/\psi K^+ \to \mu^+\mu^- K^+)$	$(6.01 \pm 0.21) \times 10^{-5}$	$(\pm 4\%)$	$(6.01 \pm 0.21) \times 10^{-5}$	$(\pm 4\%)$
SES (All bins)	$(2.9 \pm 0.5) \times 10^{-9}$	$(\pm 18\%)$	$(4.0 \pm 0.7) \times 10^{-9}$	$(\pm 18\%)$

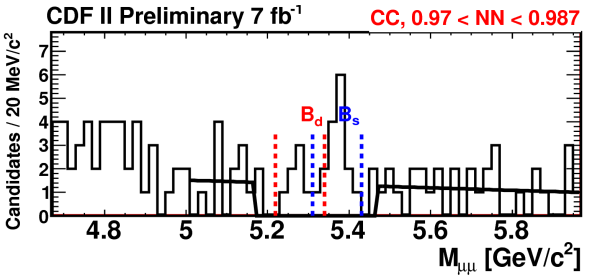
Single event sensitivity: expect to see 1.9 SM $B^0_s \to \mu^+\mu^-$ events

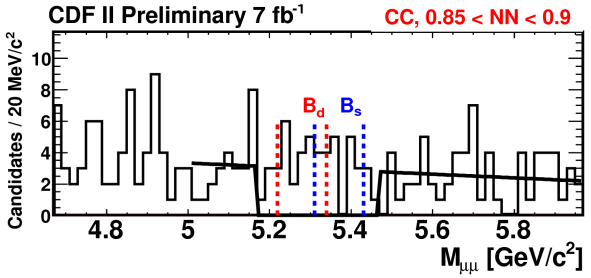
Unblinded Data

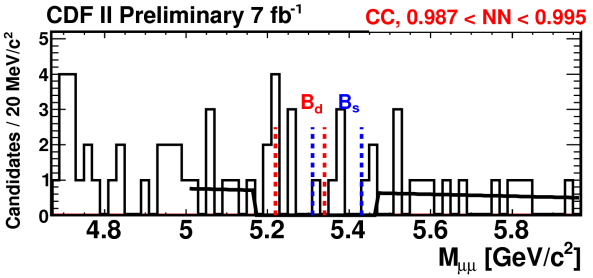


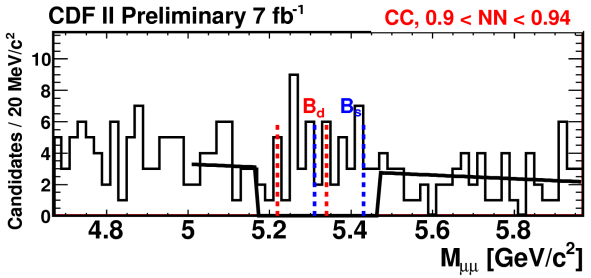


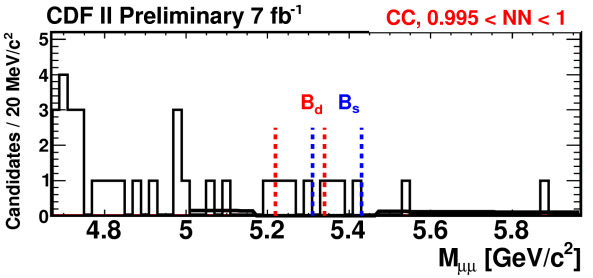






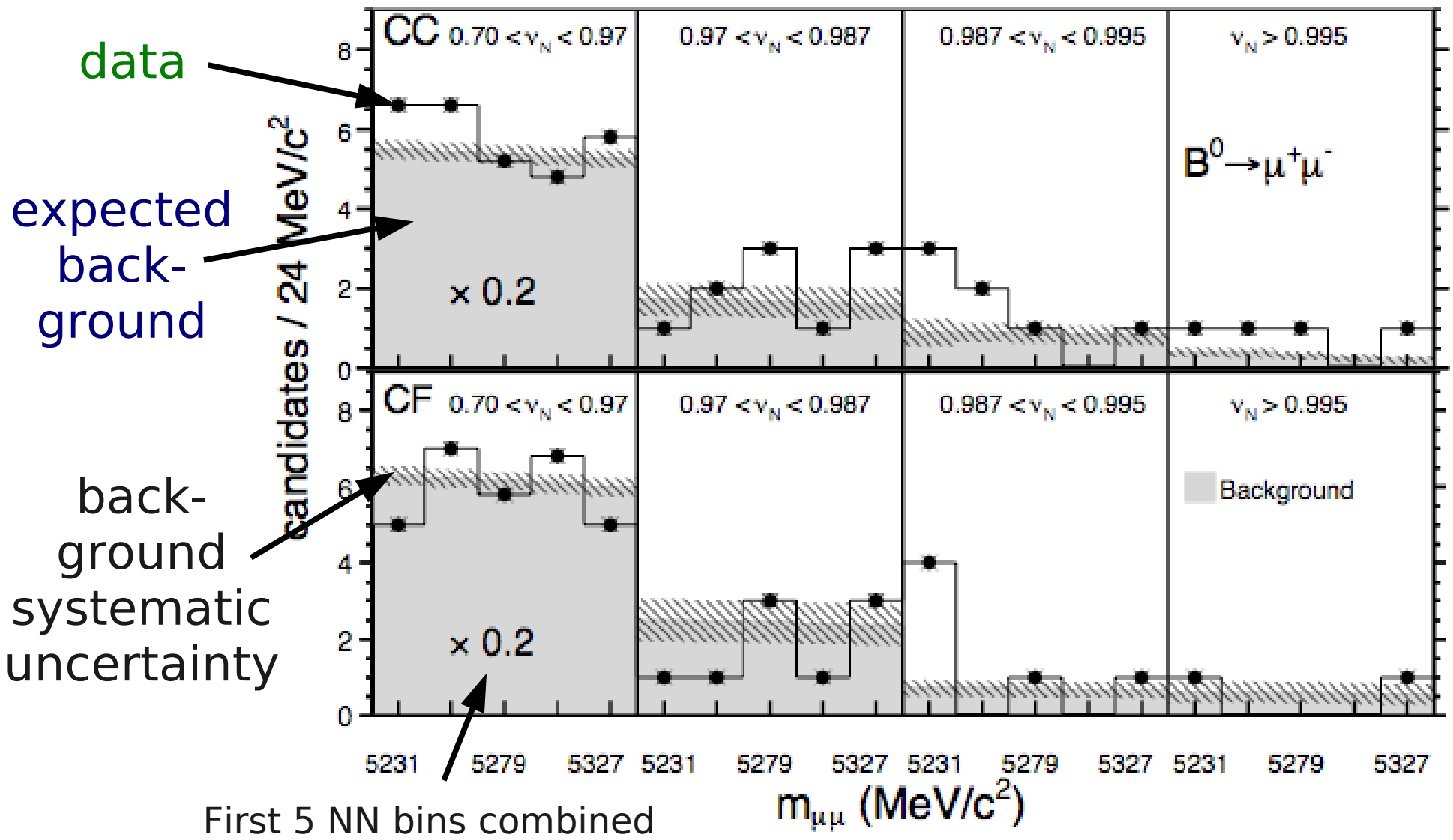






8 NN bins of CC sample

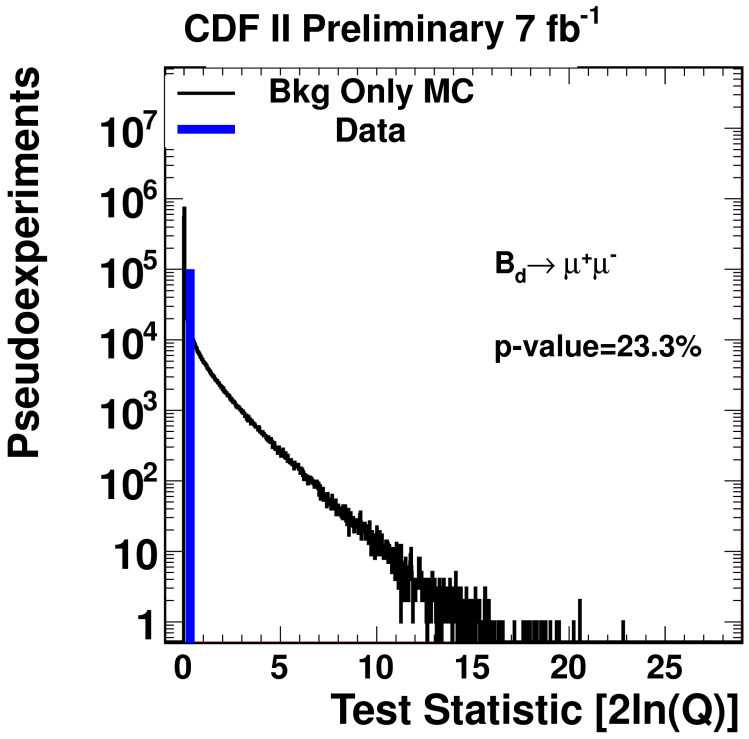
B^0 Search Window

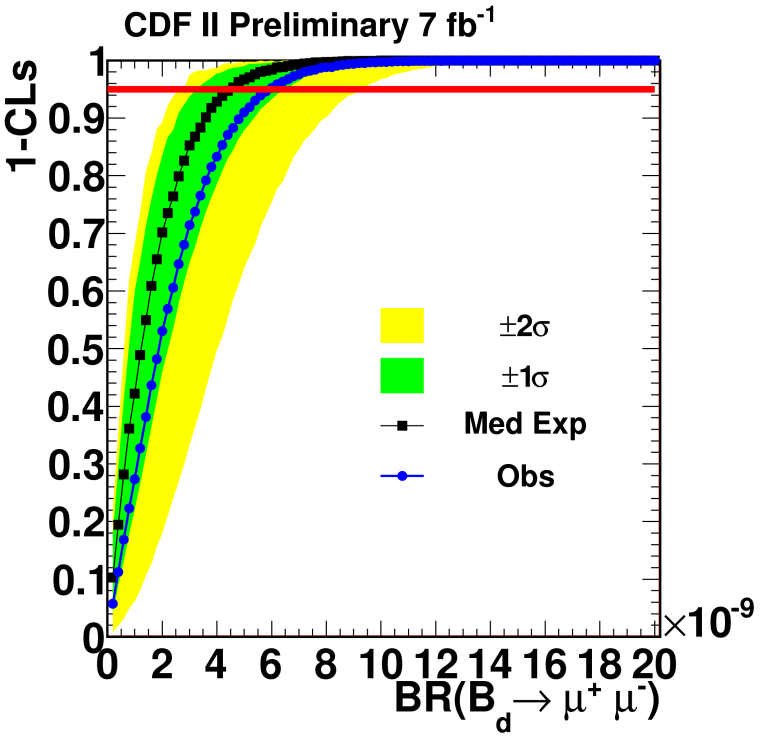


B^0 Result

- Agreement with background-only hypothesis evaluated with pseudo experiments using LH ratio Q = L(s+b)/L(b)

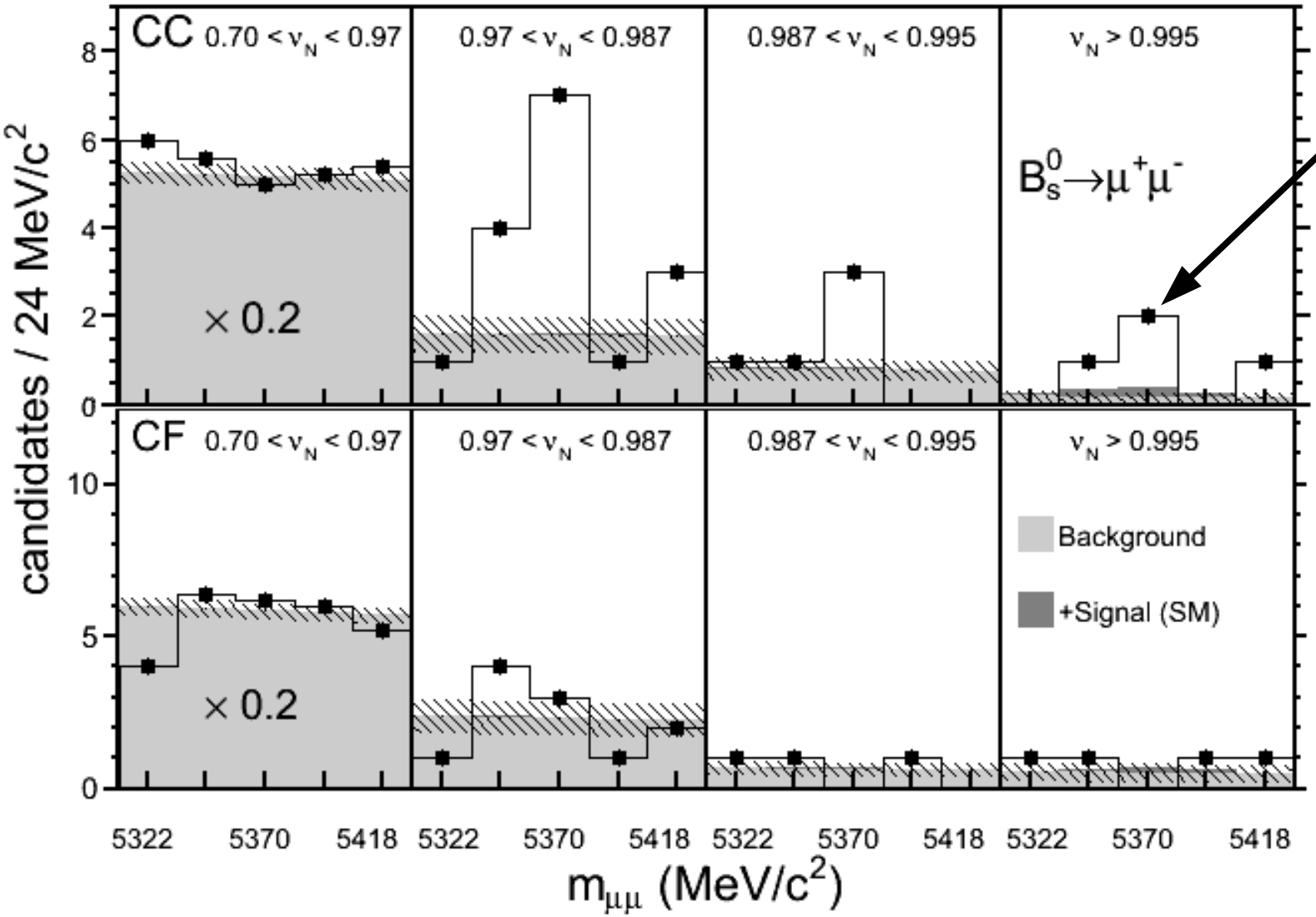
→ p-value = 23.3%





➤ 95% CL Limit:
$BR(B^0 \rightarrow \mu^+\mu^-) < 6.0 \times 10^{-9}$

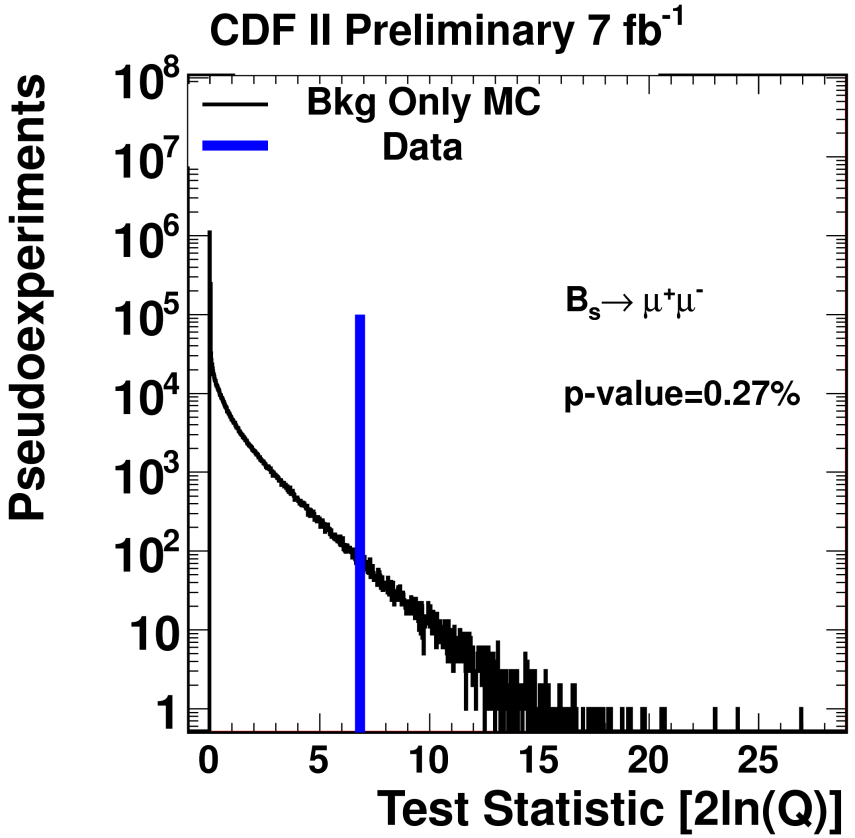
B^0_s Search Window

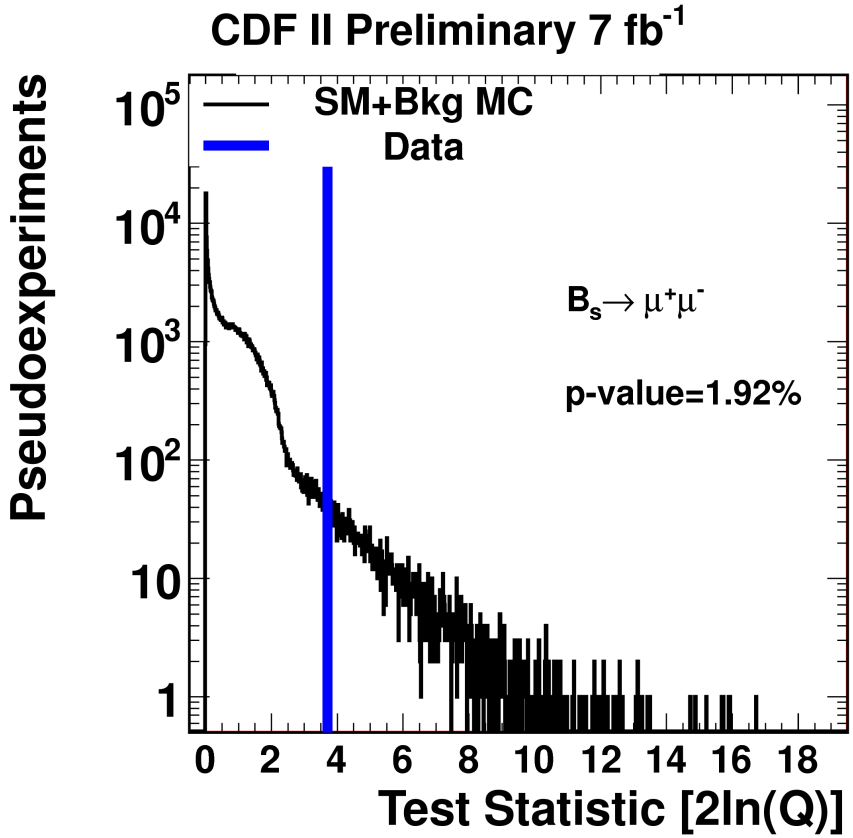


Example:
Obs: 2
Bkg. exp:
0.16±0.12

Consistency with Background and SM

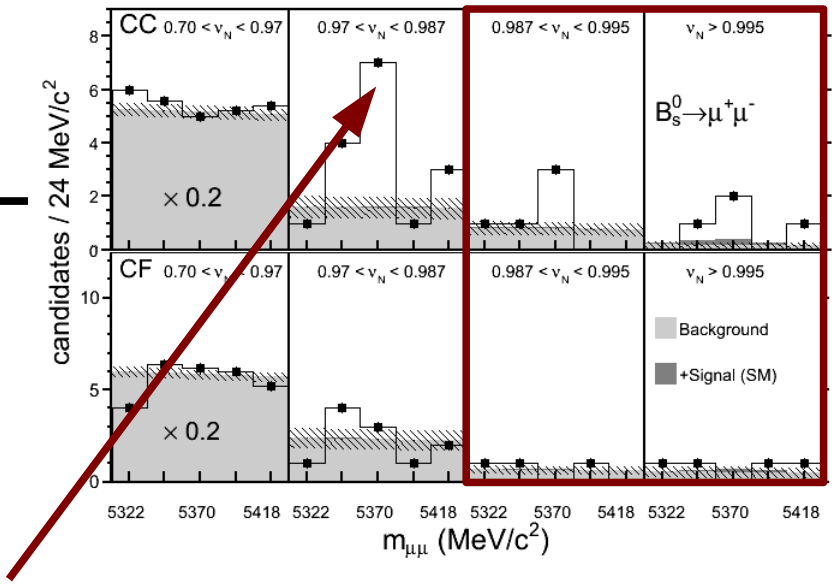
- p-value for background-only hypothesis: 0.27%
- p-value for background+SM hypothesis: 1.9%





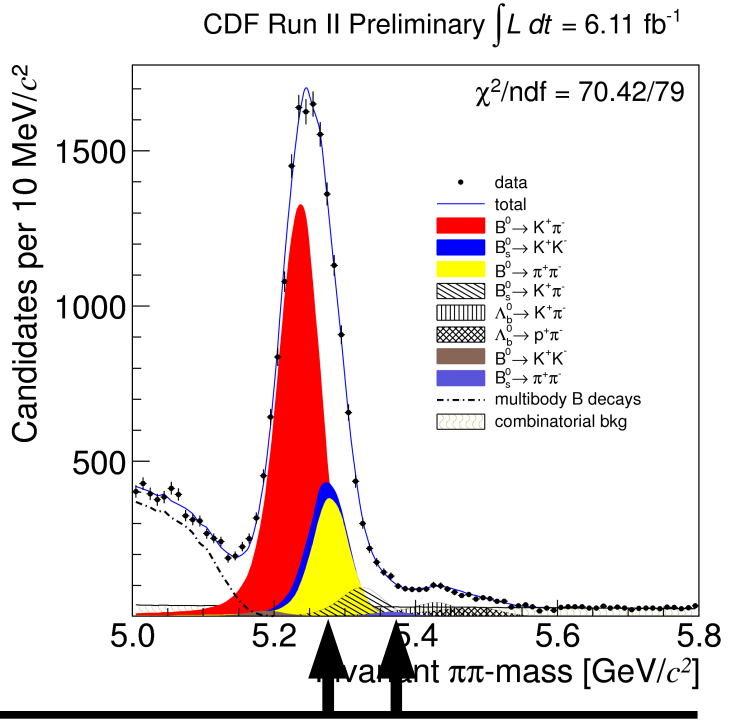
Cross Checks

- p-values for highest two NN bins:
- ✔ Background-only: 0.66%
- ✔ Background+SM: 4.1%



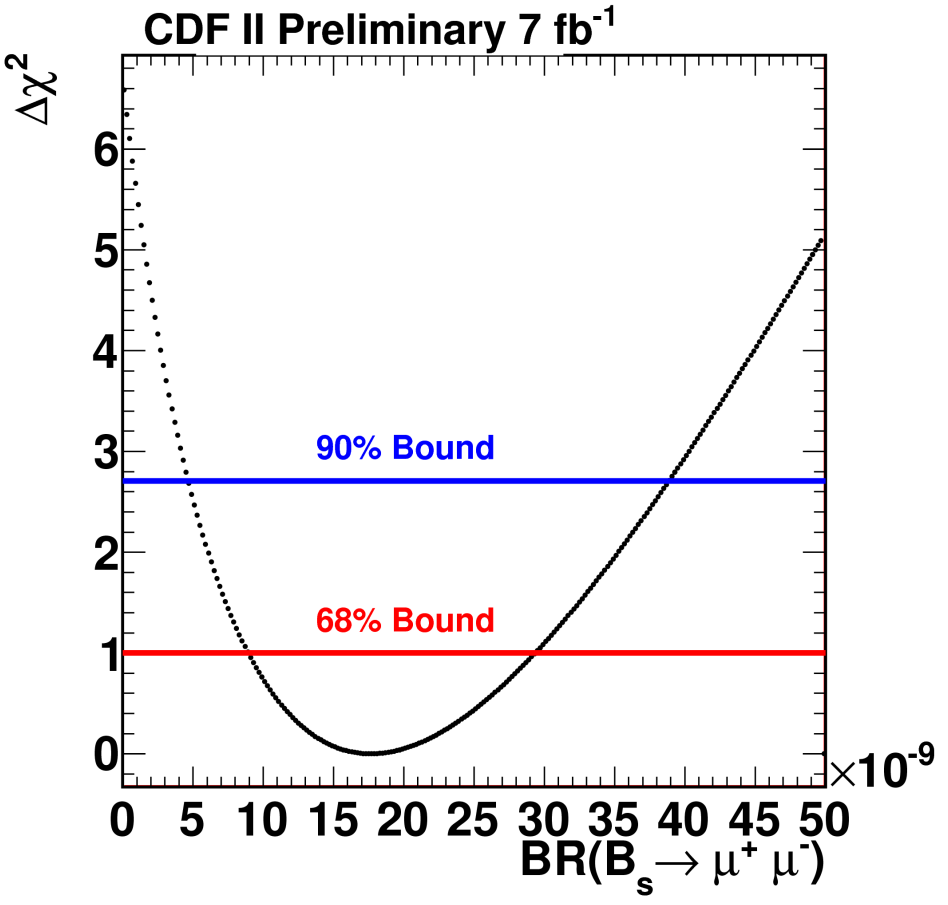
Reason for excess in 3rd highest NN bin of CC sample?

- Peaking background ($B \to h^+h'^-$)?
  ⇨ Unlikely, not seen in B^0
- $B^0_{(s)} \to \mu^+\mu^-$ signal?
  ⇨ Unlikely, NN well described for B^+
- Combinatorial background?
  ⇨ Unlikely, no NN bias observed
- Statistical fluctuation?
  ⇨ Can happen in one out of 80 bins



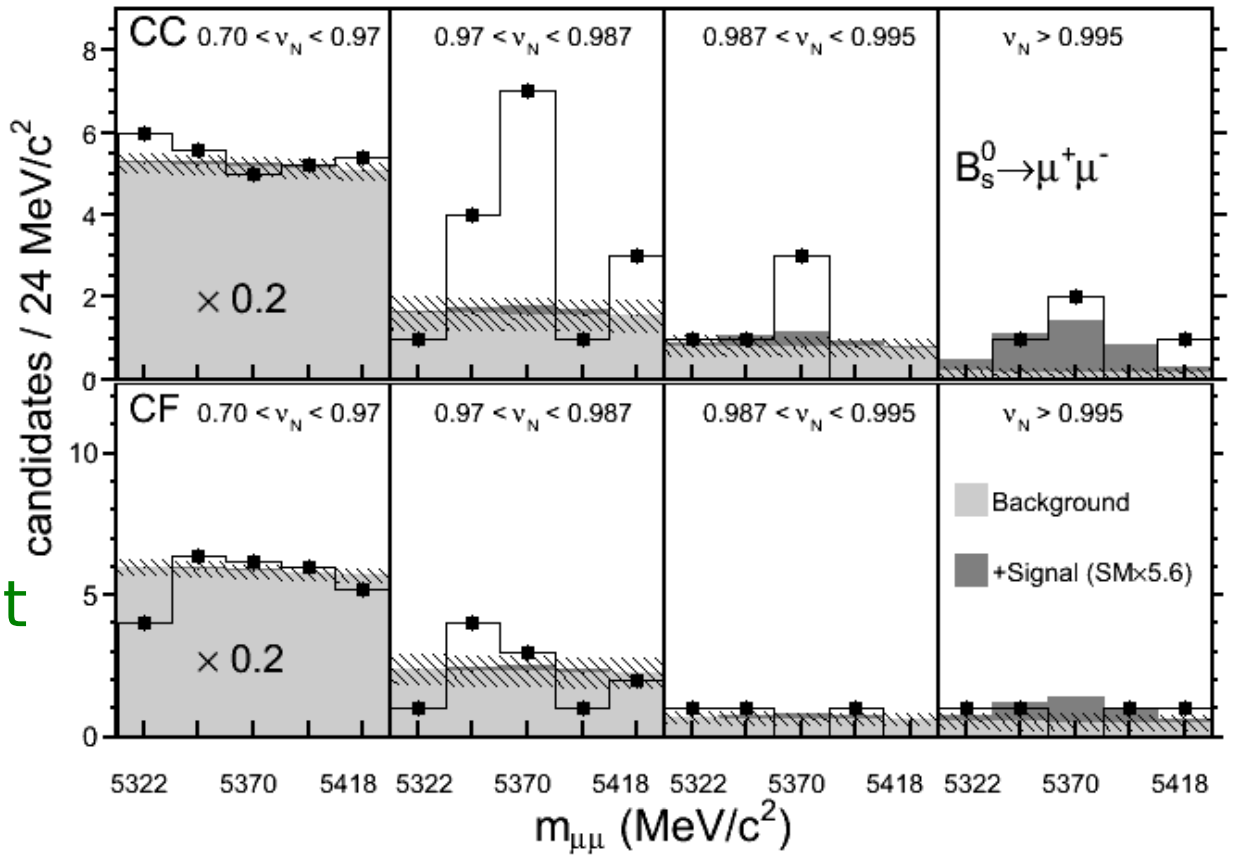
B^0_s Result

- 90% CL region: $4.6 \times 10^{-9} < BR(B^0_s \to \mu^+\mu^-) < 3.9 \times 10^{-8}$
- Central value:
  - $BR(B^0_s \to \mu^+\mu^-) = 1.8\ ^{+1.1}_{-0.9} \times 10^{-8}$
- Central value using only the highest two NN bins:
  - $BR(B^0_s \to \mu^+\mu^-) = 1.4\ ^{+1.0}_{-0.8} \times 10^{-8}$



Conclusions

- Significantly improved sensitivity
- B^0: consistent with background
- ➔ World's best BR limit (until today?)
- Excess in B^0_s search window



- ➔ First double sided confidence region on BR($B^0_s \to \mu^+\mu^-$)

- Submitted to PRL, arXiv 1107.2304:
- ➔ "Although of moderate statistical significance, this is the first indication of a $B^0_s \to \mu^+\mu^-$ signal."

Backup

Experimental Status (95% CL Limits)

D0: 6.1 fb^{-1}, *PLB 693 539 (2010)*

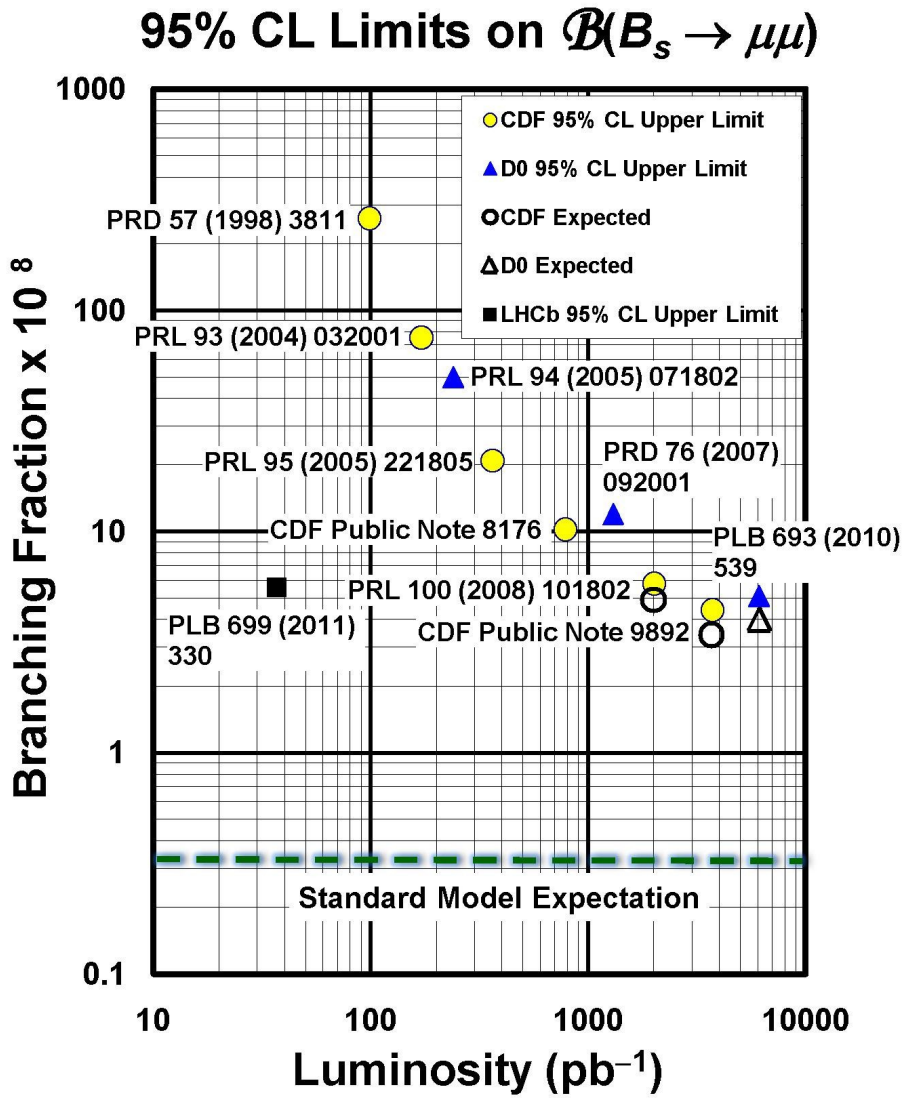
- BR($B_s \to \mu^+\mu^-$)< 5.1 x 10^{-8}

CDF: 3.7 fb^{-1}, *public note 9892*

- BR($B_s \to \mu^+\mu^-$) < 4.3 x 10^{-8}
- BR($B^0 \to \mu^+\mu^-$) < 7.6 x 10^{-9}

LHCb: 37 pb^{-1}, *PLB 699, 330 (2011)*

- BR($B_s \to \mu^+\mu^-$) < 5.6 x 10^{-8}
- BR($B^0 \to \mu^+\mu^-$) < 15 x 10^{-9}



Predictions

Standard Model, *A.J.Buras et al. JHEP 1010:009, 2010:*

- $BR(B_s \to \mu^+\mu^-) = (3.2 \pm 0.2) \times 10^{-9}$
- $BR(B^0 \to \mu^+\mu^-) = (1.0 \pm 0.1) \times 10^{-10}$

➔ Small theoretical uncertainty

Plenary talk A.Buras, Beauty 2011:

Maximal Enhancements of $S_{\psi\varphi}$, $Br(B_s \to \mu^+\mu^-)$ and $K^+ \to \pi^+\nu\bar{\nu}$

(without taking correlation between them)

Model	Upper Bound on ($S_{\psi\varphi}$)	Enhancement of $Br(B_s \to \mu^+\mu^-)$	Enhancement of $Br(K^+ \to \pi^+\nu\bar{\nu})$
CMFV	0.04	20%	20%
MFV	0.04	1000%	30%
LHT	0.30	30%	150%
RS	0.75	10%	60%
4G	0.80	400%	300%
AC	0.75	1000%	2%
RVV	0.50	1000%	10%

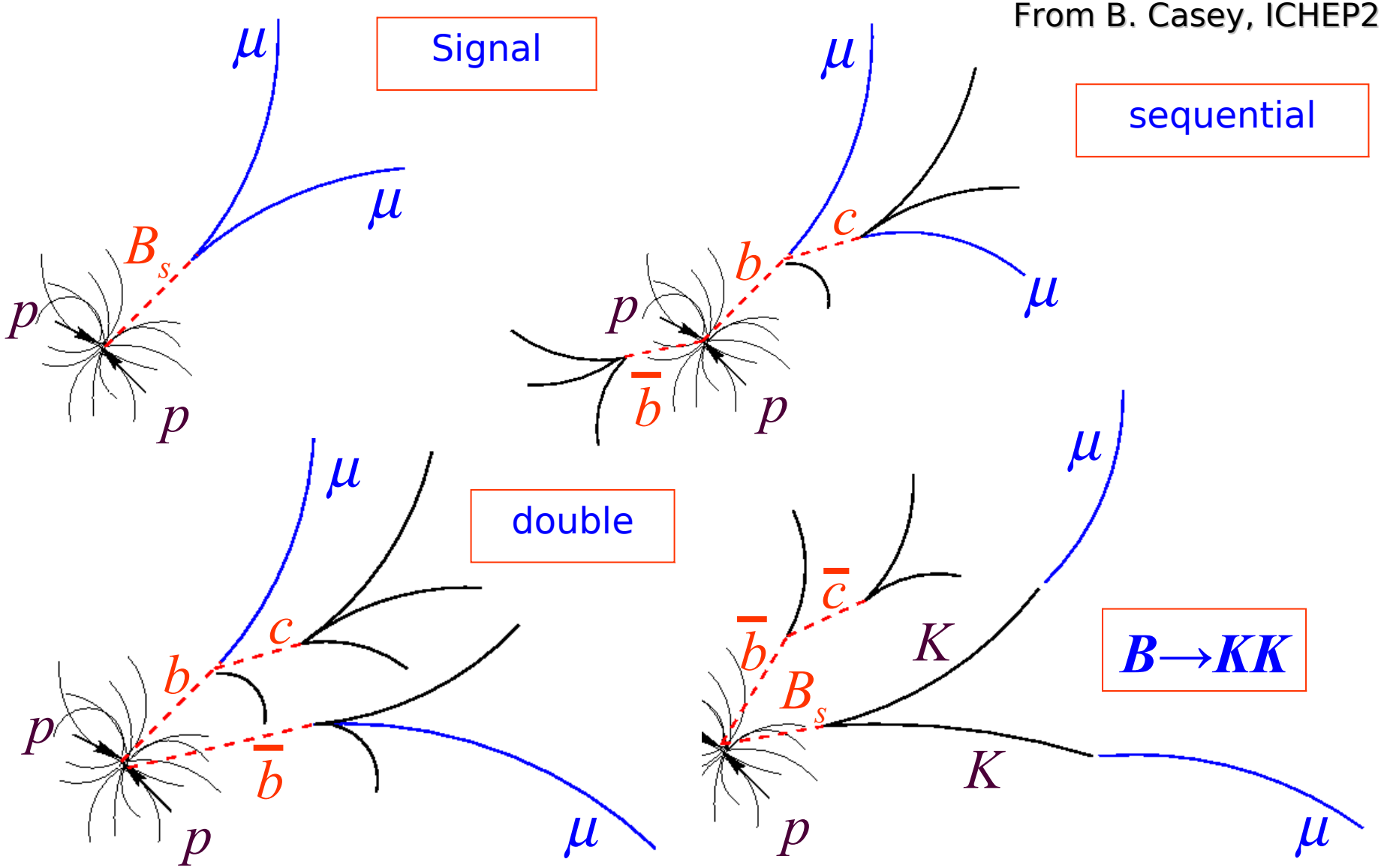
Large RH Currents

RS = RS with custodial protections
AC = Agashe, Carone
RVV = Ross, Velaso-Sevilla, Vives (04)

$U(1)_F$
$SU(3)_F$

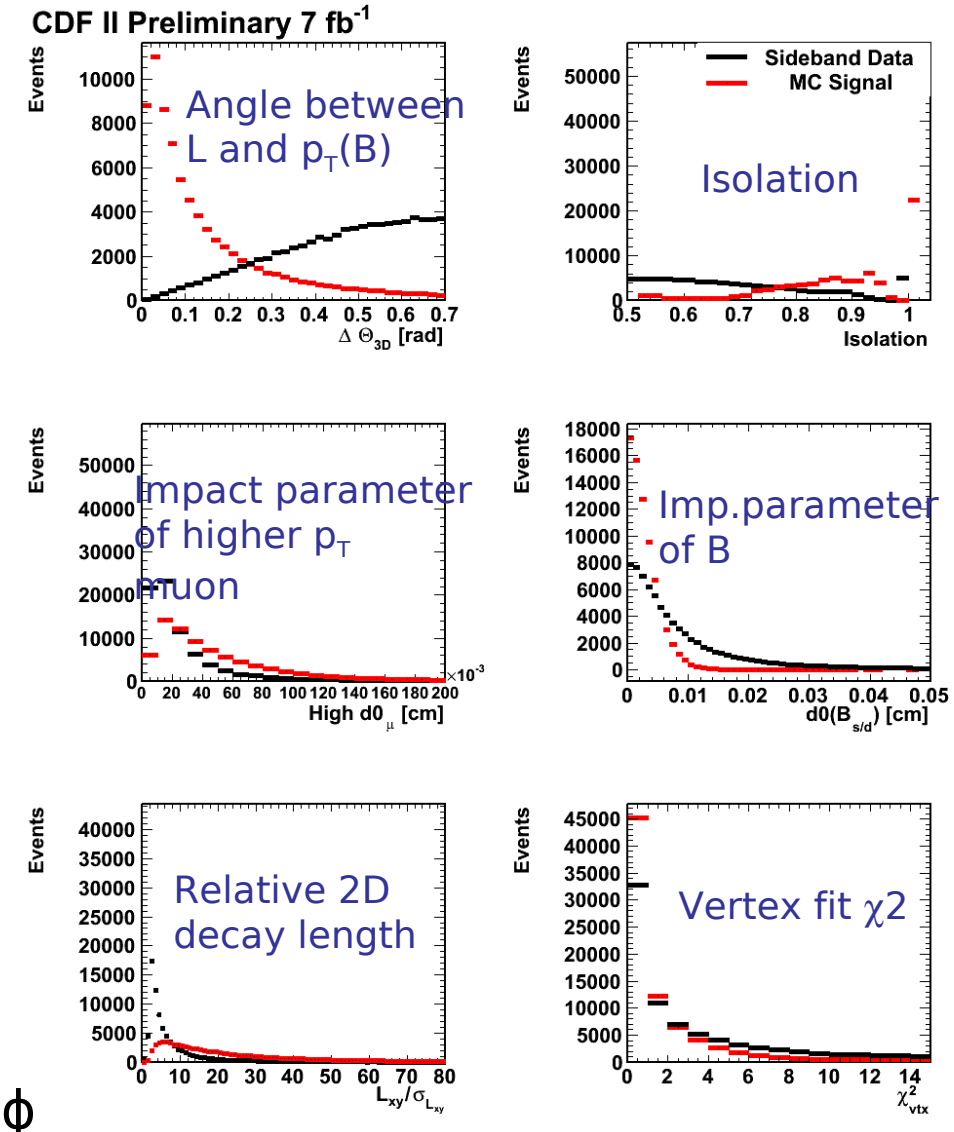
Signal and Background Components

From B. Casey, ICHEP2010



NN Variables

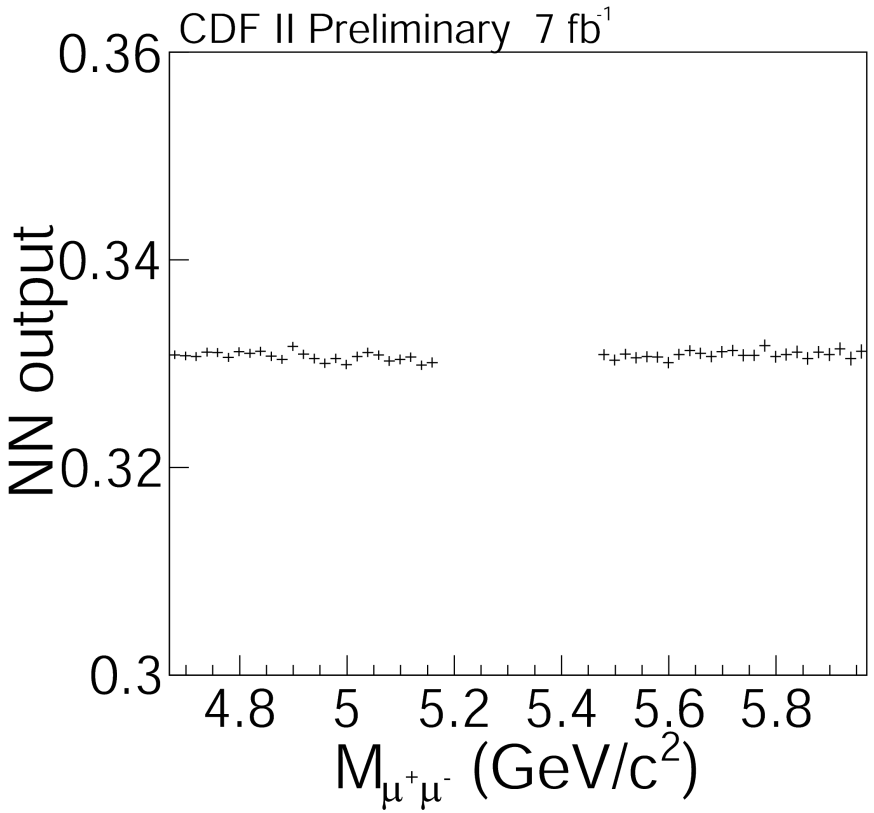
Rank	Variable
1	$\Delta\alpha_{3d}$
2	Isolation
3	Larger $\lvert d_0(\mu)\rvert$
4	$\lvert d_0(B_s^0)\rvert$
5	$L_{2d}/\sigma_{L_{2d}}$
6	χ^2_{vtx}
7	L_{3d}
8	Lower $p_T(\mu)$
9	Significance of smaller $\lvert d_0(\mu)\rvert$
10	$\lambda_{3d}/\sigma_{\lambda 3d}$
11	λ_{3d}
12	Smaller $\lvert d_0(\mu)\rvert$
13	$\Delta\alpha_{2d}$
14	Significance of larger $\lvert d_0(\mu)\rvert$

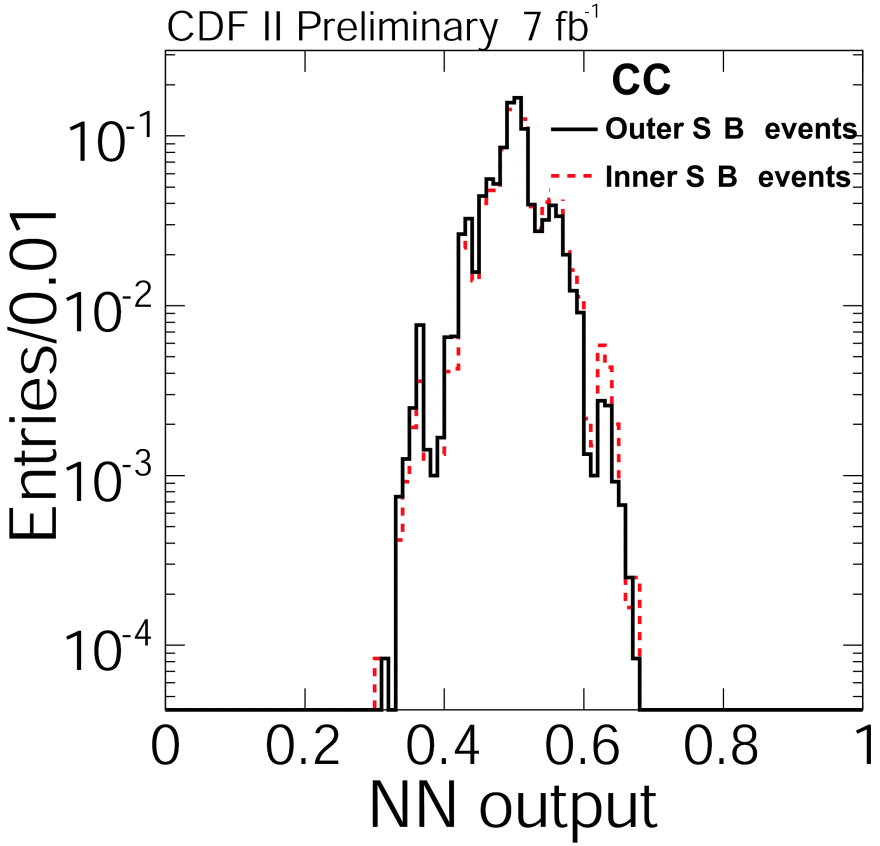


- p_T reweighted to $B^+ \rightarrow J/\psi\, K$
- Isolation reweighted to $B_s \rightarrow J/\psi\, \phi$

Selection Cross Checks

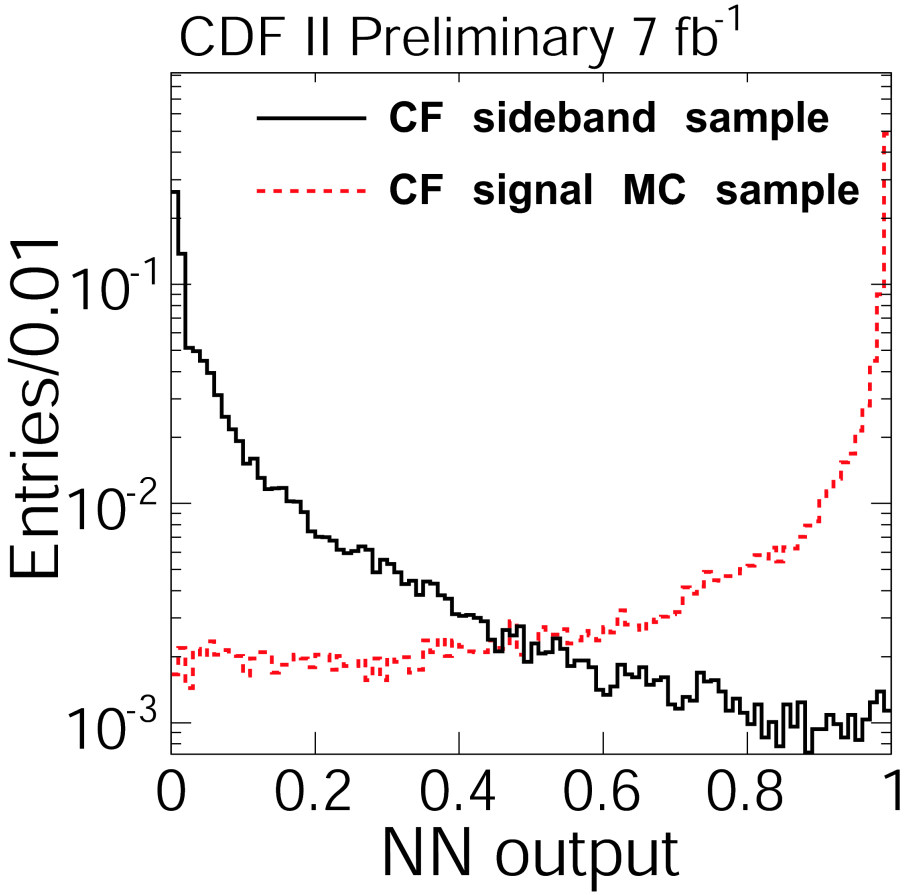
- ✔ No NN output dependency on $M_{\mu\mu}$
- ✔ NN cannot learn difference between inner and outer mass sidebands events



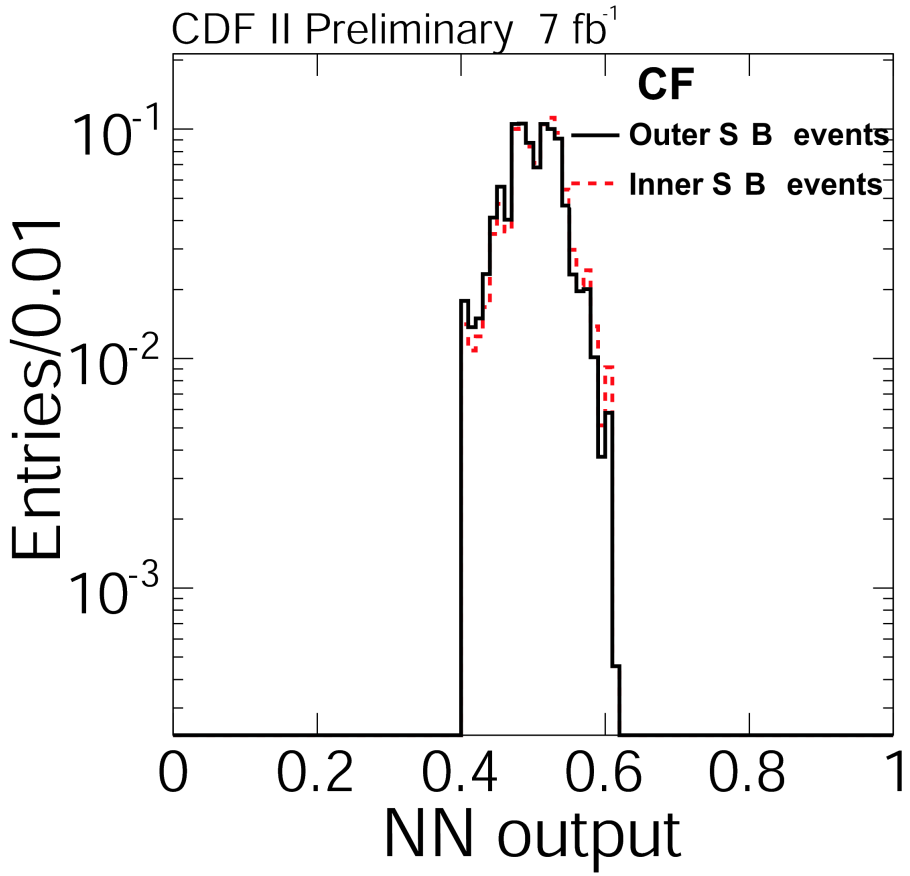


CF NN

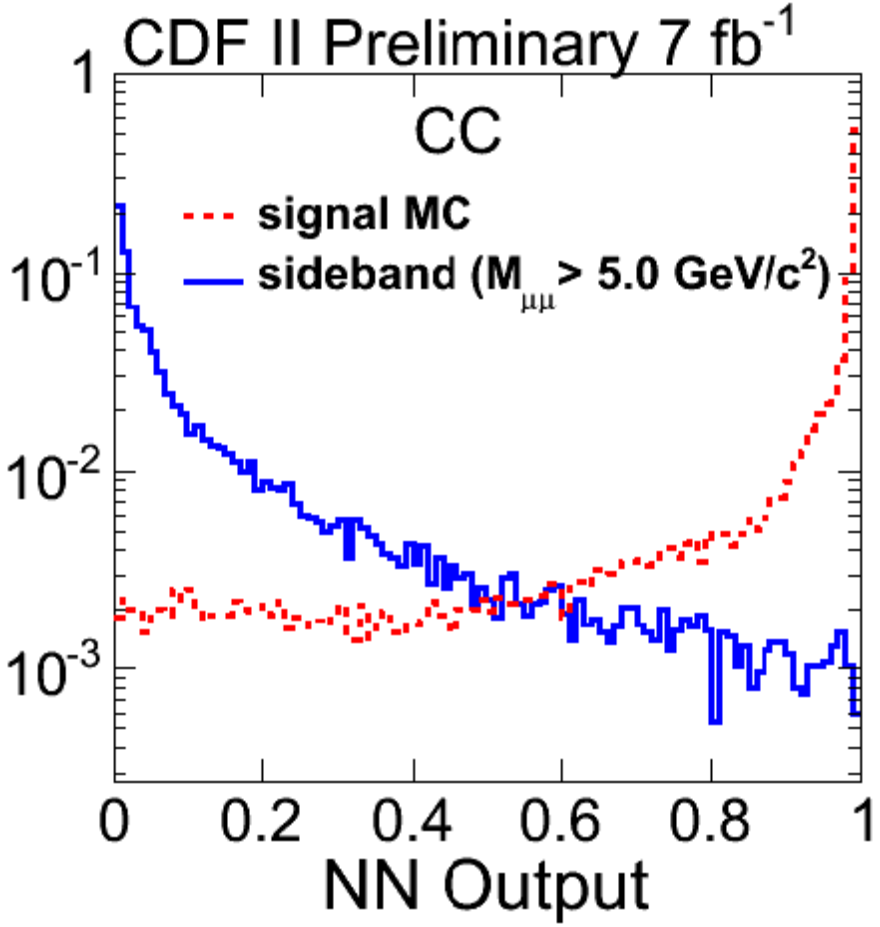
- Signal MC vs. background from data sidebands

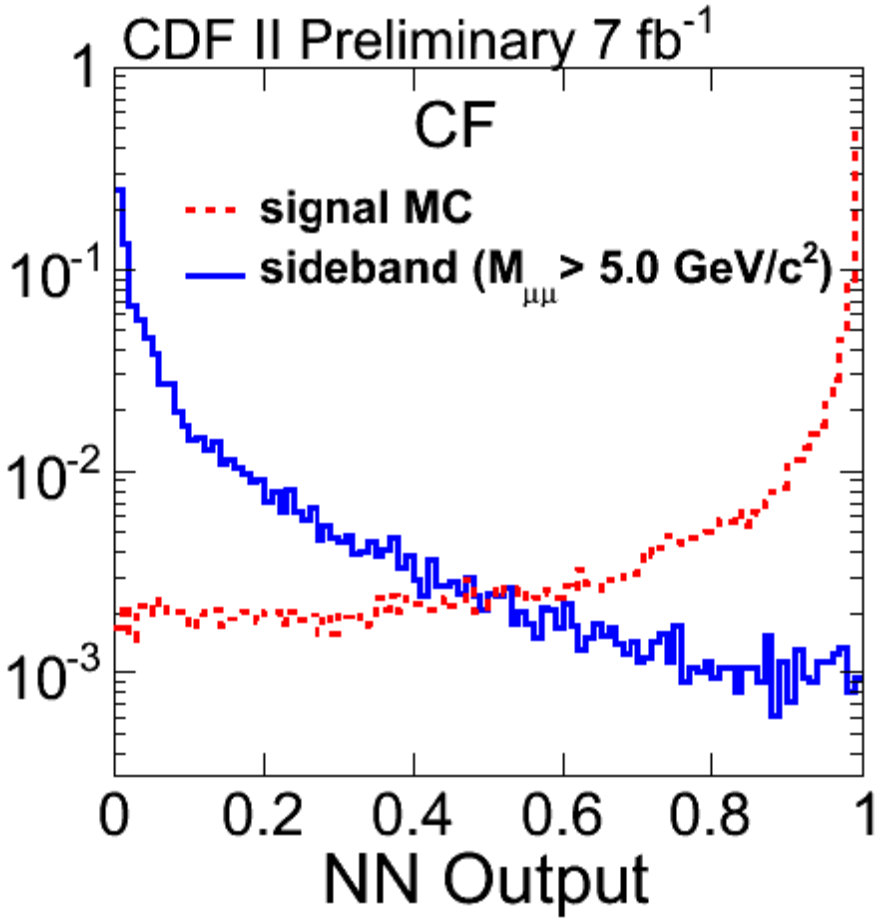


- Inner vs. outer data sidebands



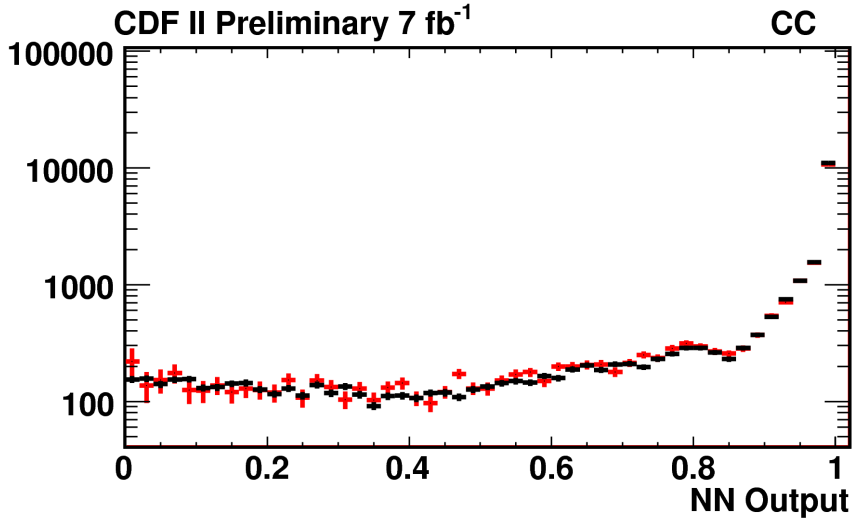
NN for $M_{\mu\mu}$ > 5 GeV

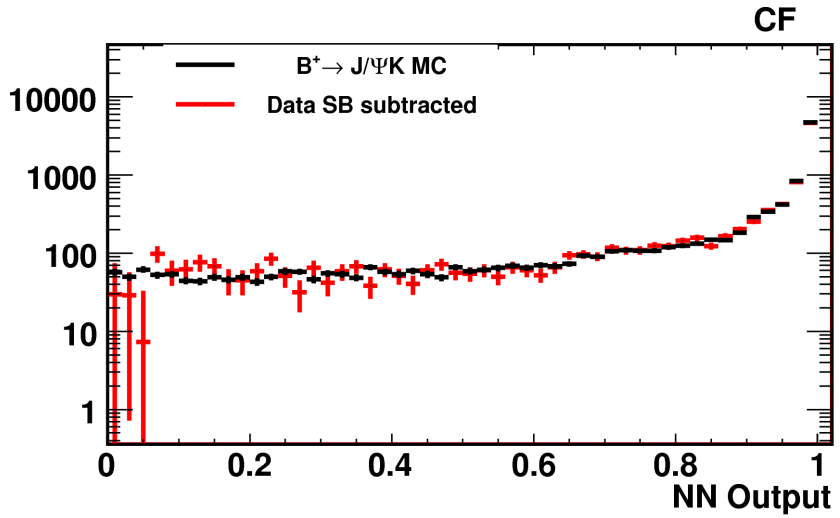




NN Validation

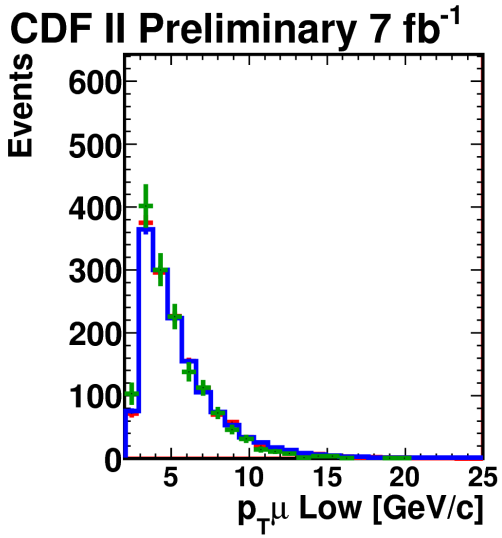
- Comparison of NN output for $B^+ \rightarrow J/\psi\, K^+$ data and MC

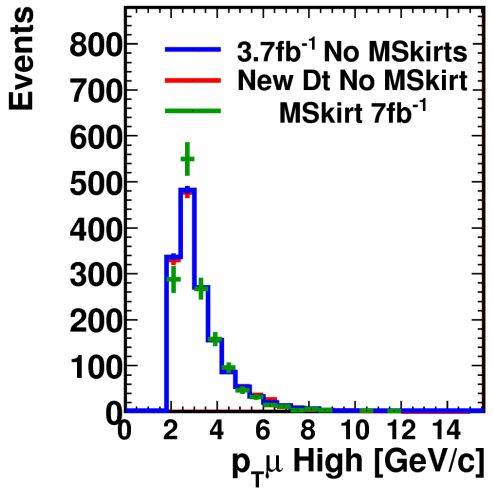


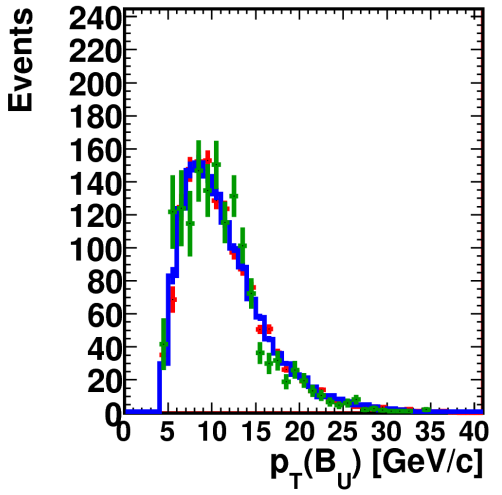


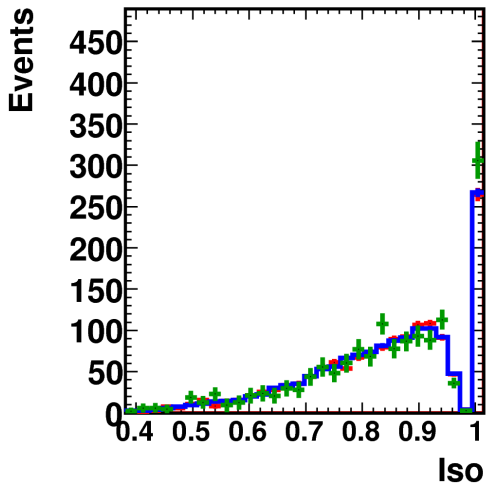
NN cut	CC Data	CC MC	CC Diff	CF Data	CF MC	CF Diff
NN>0.90	0.648±0.003	0.666±0.004	0.022	0.654±0.005	0.667±0.005	0.013
NN>0.95	0.571±0.003	0.588±0.004	0.017	0.574±0.005	0.583±0.005	0.007
NN>0.96	0.544±0.003	0.561±0.004	0.015	0.550±0.005	0.562±0.005	0.012
NN>0.97	0.514±0.003	0.530±0.004	0.016	0.515±0.005	0.530±0.005	0.015
NN>0.98	0.476±0.003	0.489±0.004	0.013	0.469±0.005	0.476±0.005	0.007
NN>0.99	0.392±0.003	0.406±0.004	0.014	0.356±0.005	0.380±0.005	0.024
NN>0.992	0.360±0.003	0.374±0.004	0.014	0.338±0.005	0.362±0.005	0.024
NN>0.995	0.304±0.003	0.312±0.004	0.008	0.299±0.005	0.319±0.005	0.020

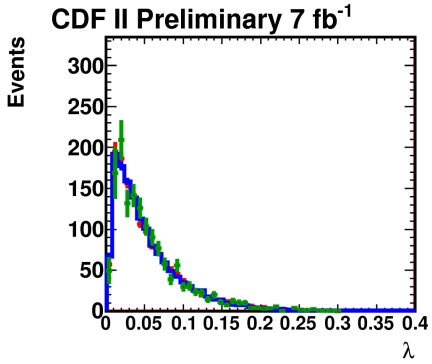
Validation of “miniskirt” data

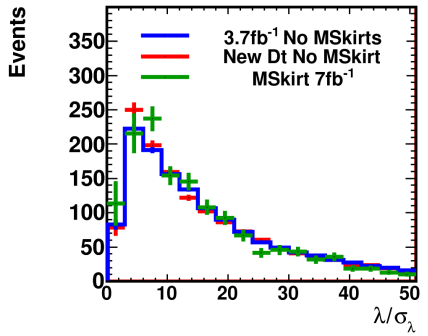


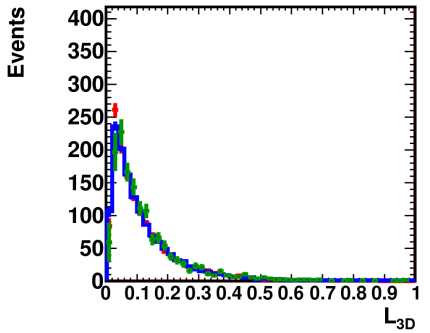


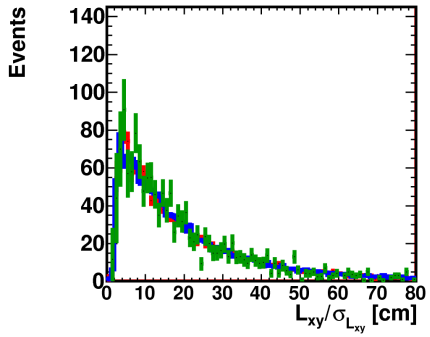


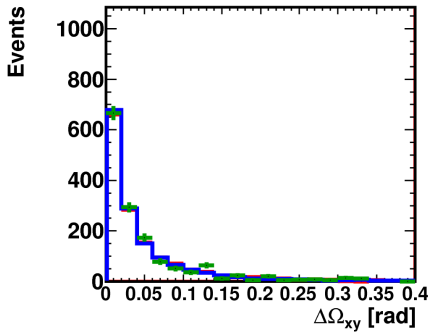


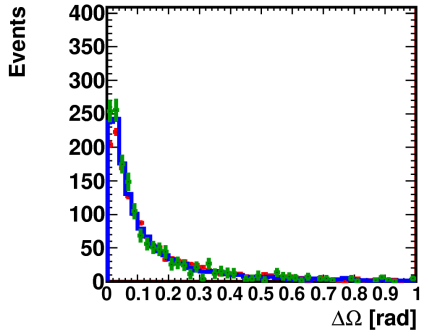




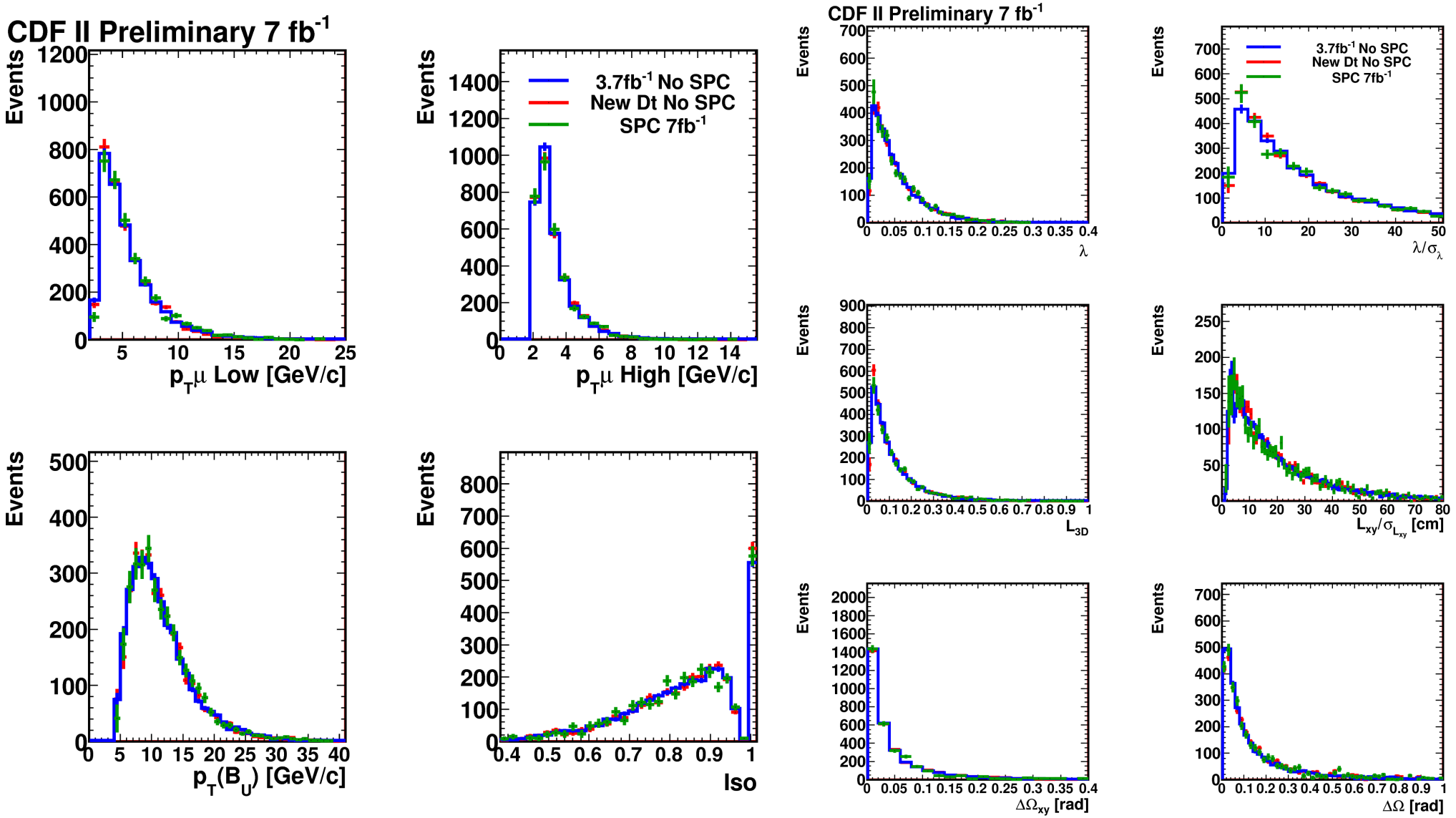




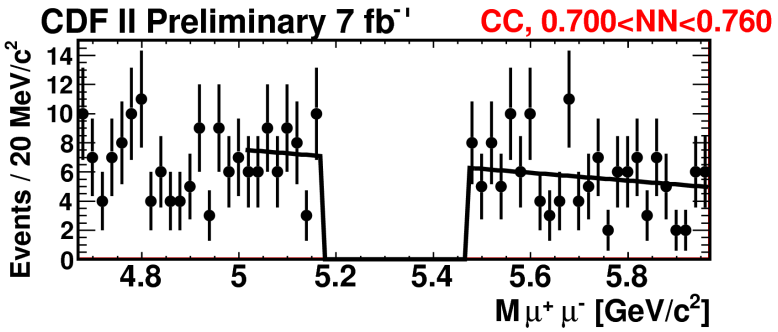


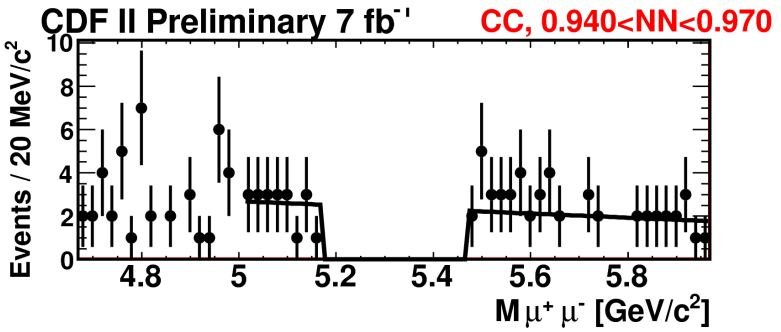


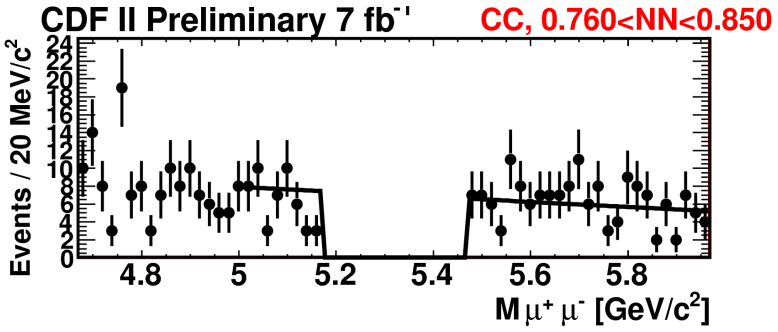
Validation of “COT spacer” data

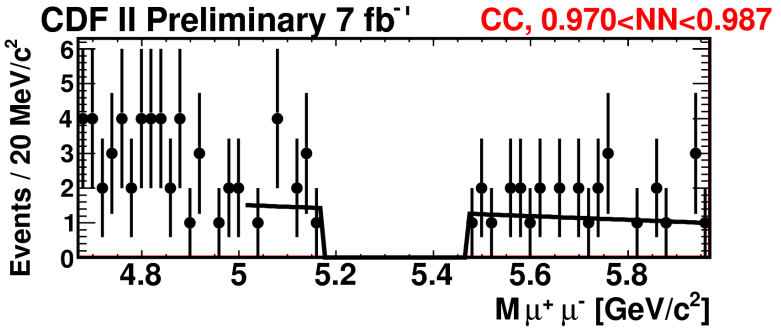


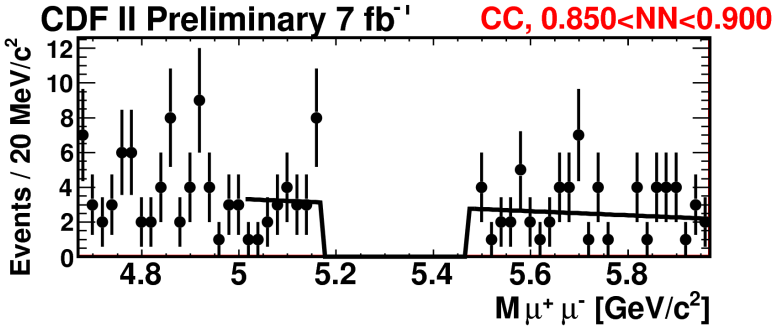
Blinded CC Mass Plots

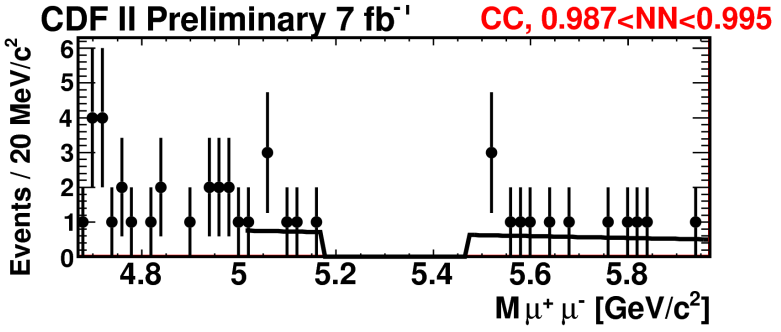


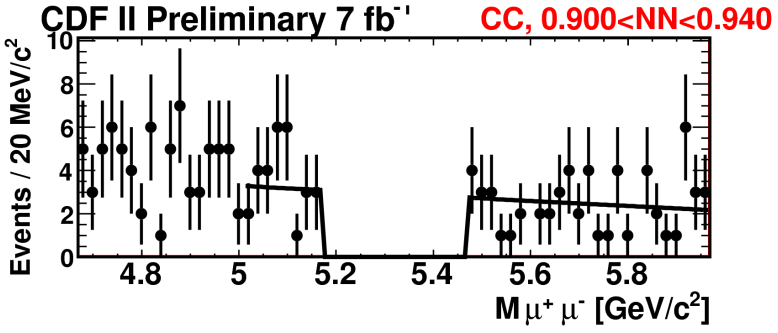


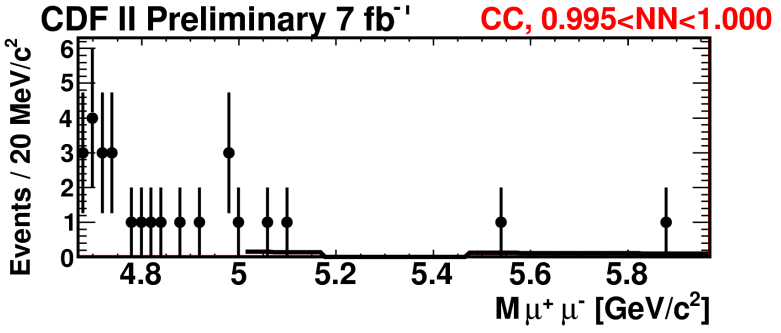




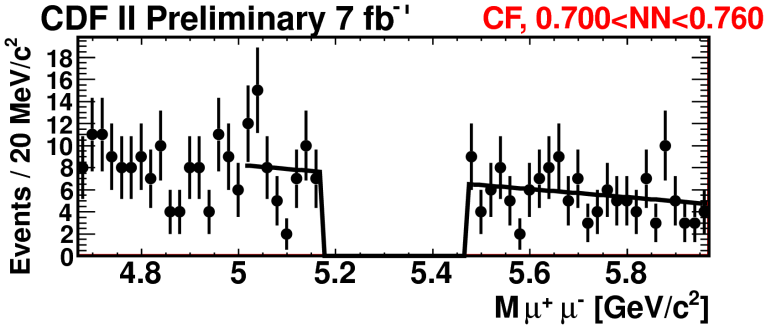


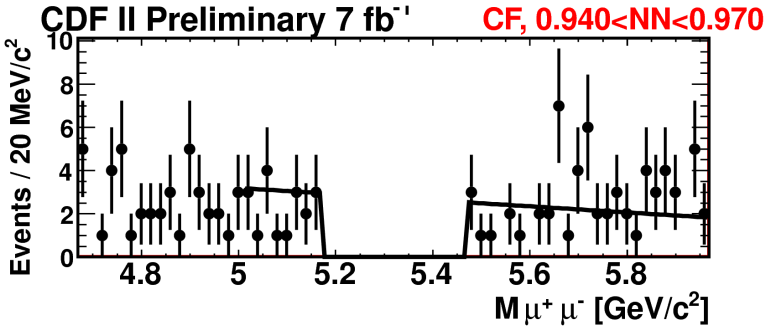


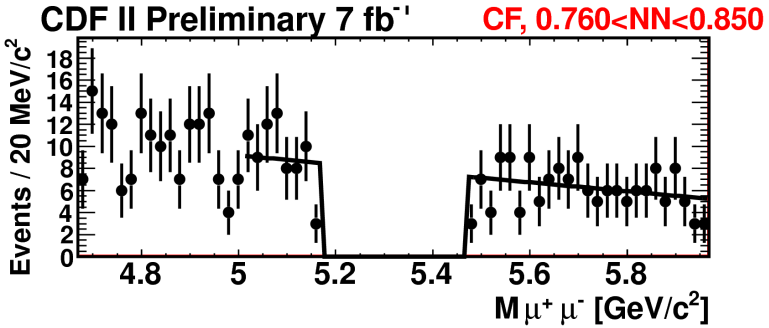


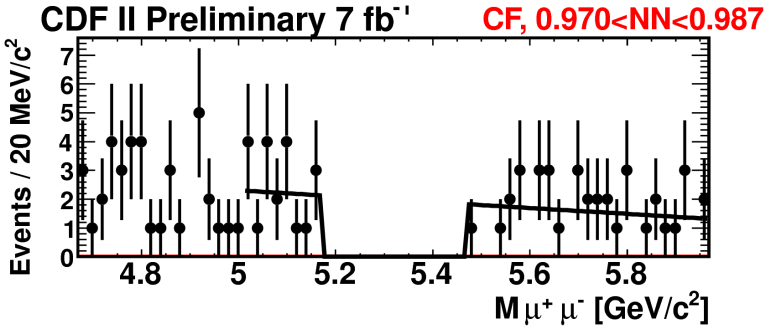


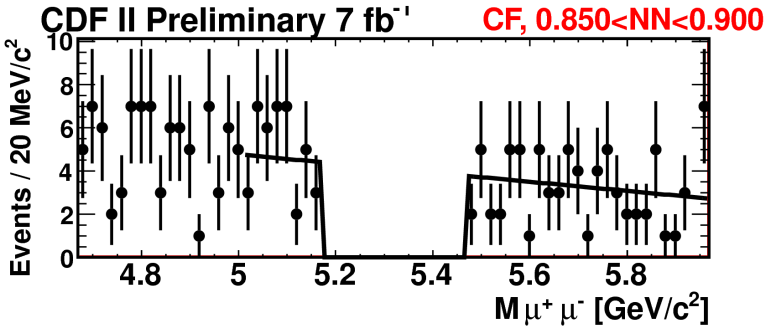
Blinded CF Mass Plots

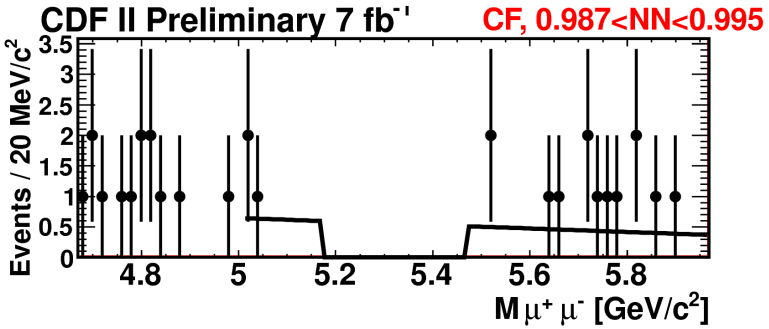


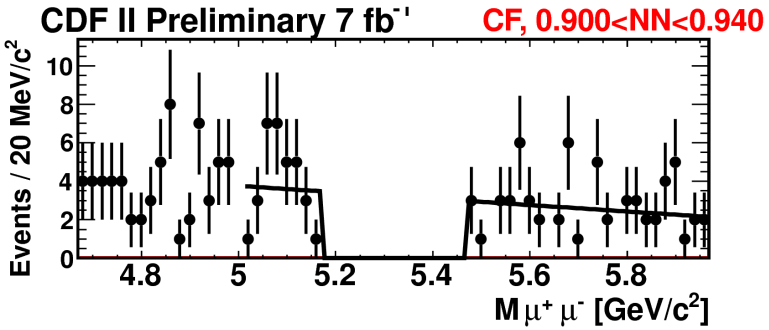


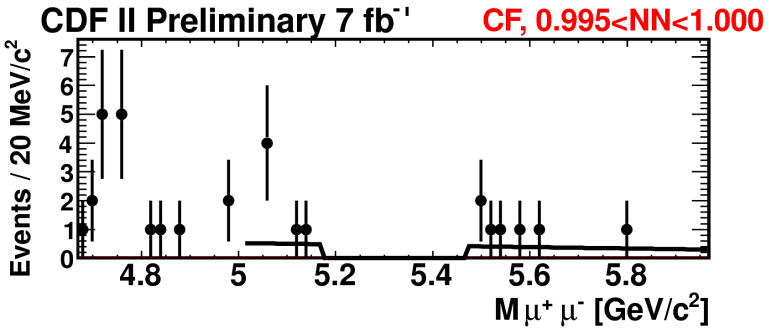




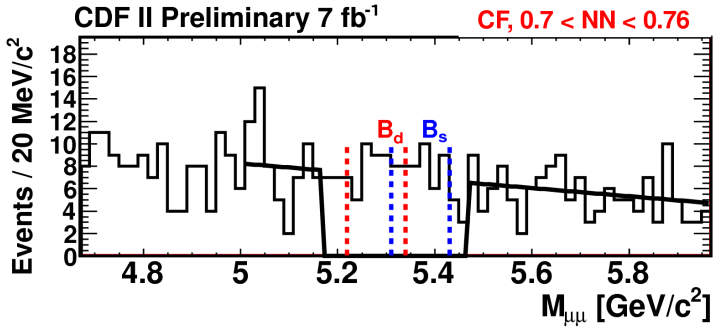


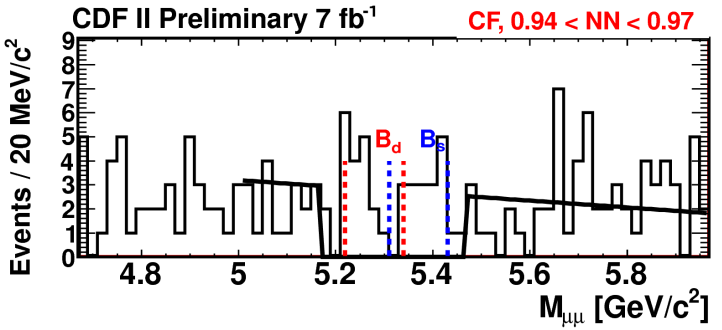


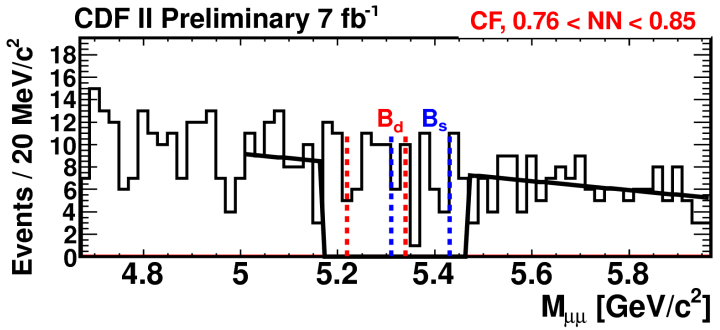


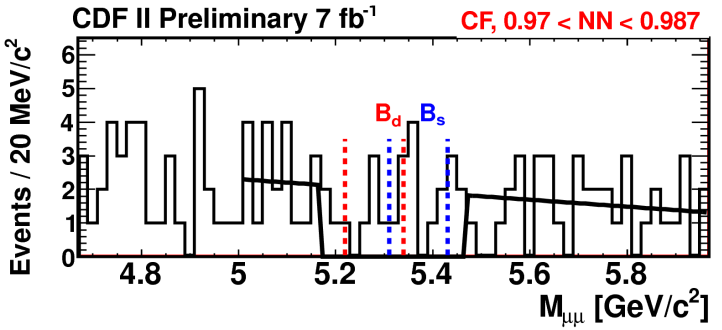


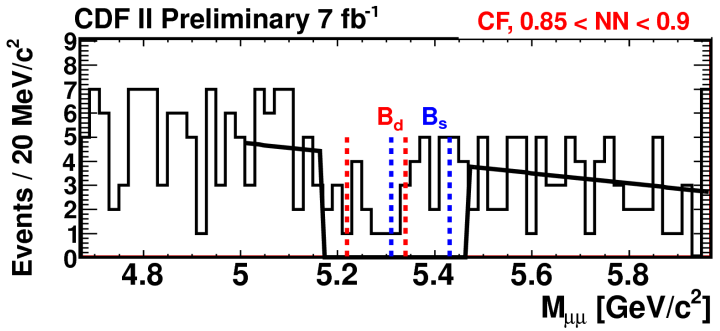
Unblinded CF Mass Plots

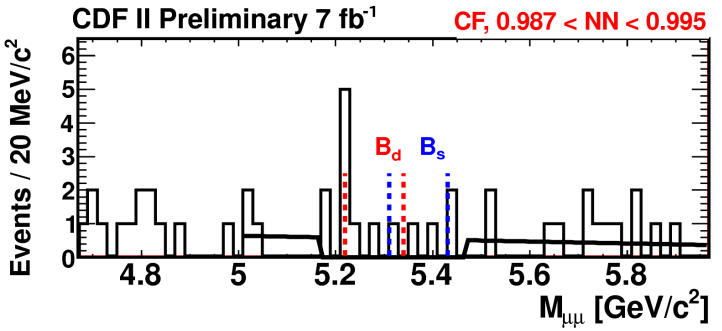


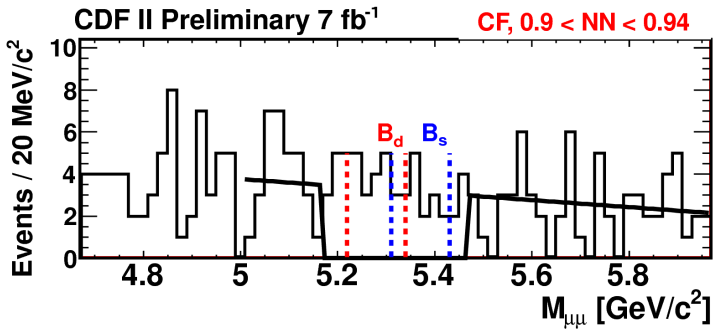


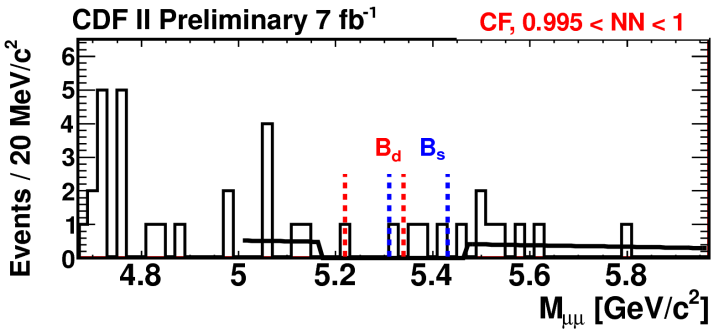




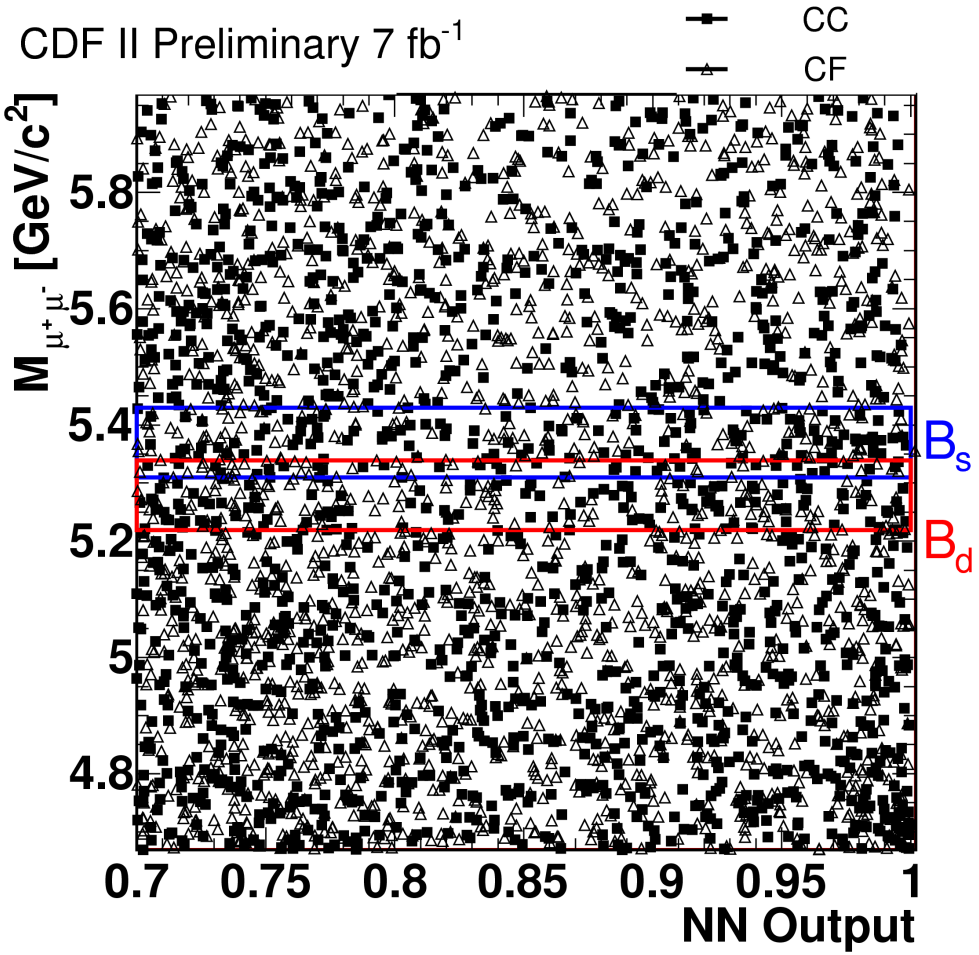


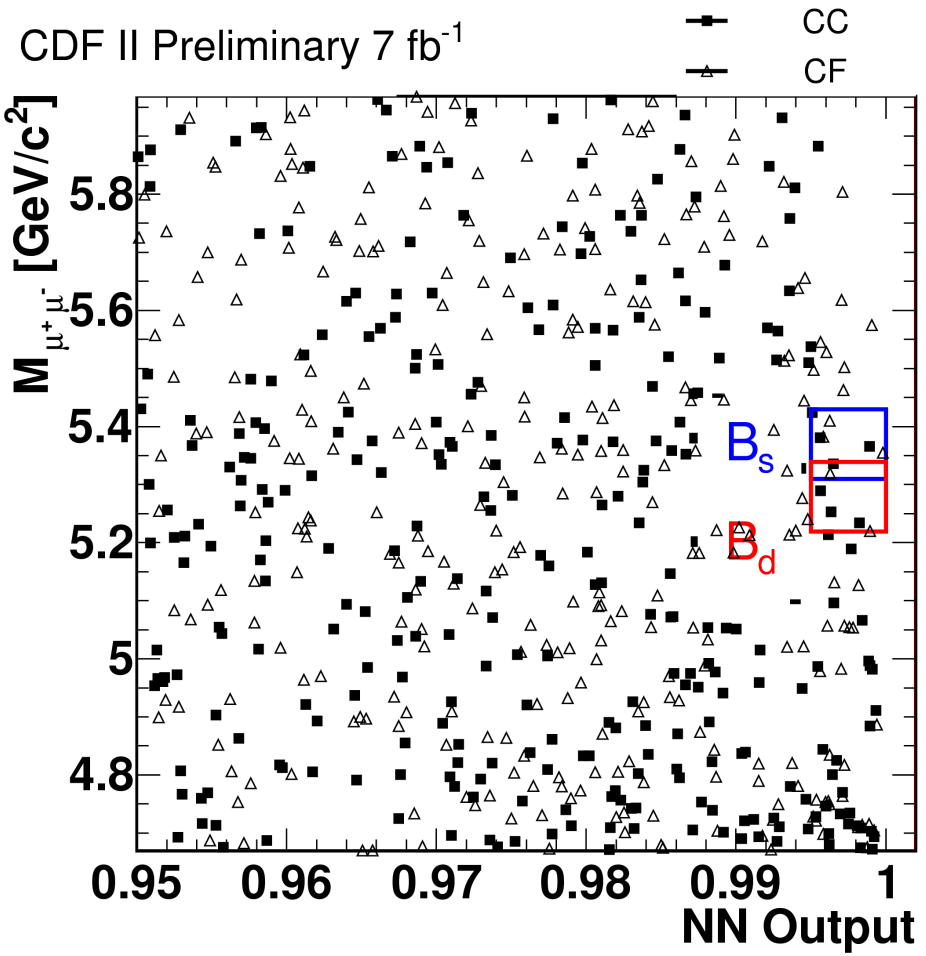




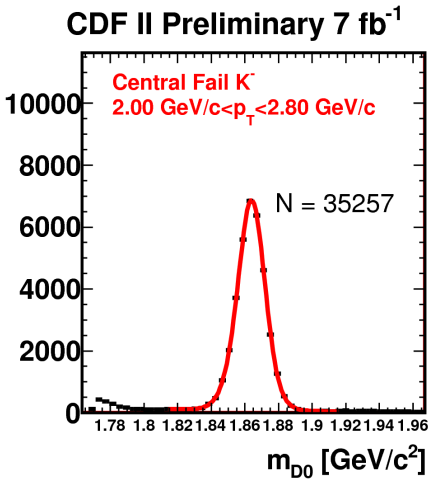


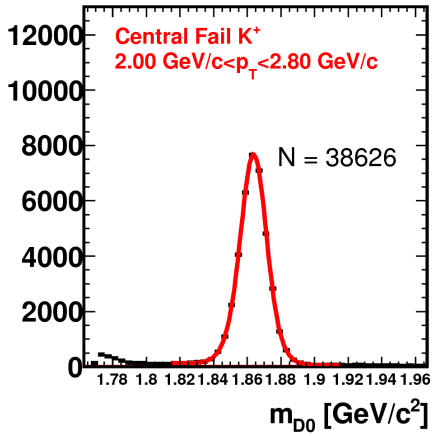
Unblinded Data





Fake Rates


CDF II Preliminary 7 fb-1
Central Fail K-
2.00 GeV/c<pT<2.80 GeV/c
N = 35257
mD0 [GeV/c2]


Central Fail K+
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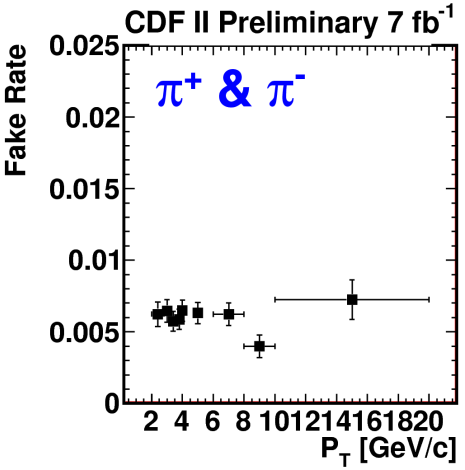
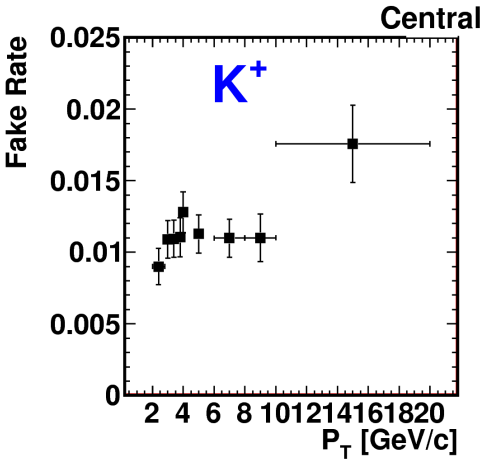
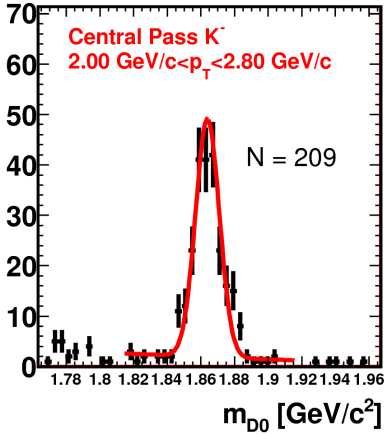
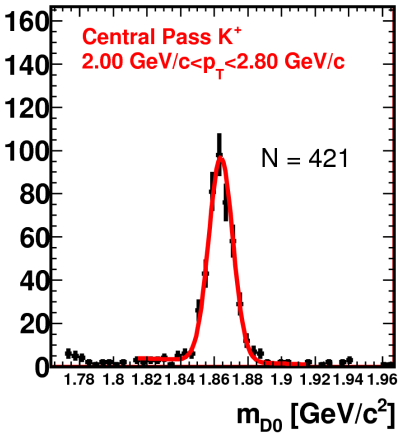
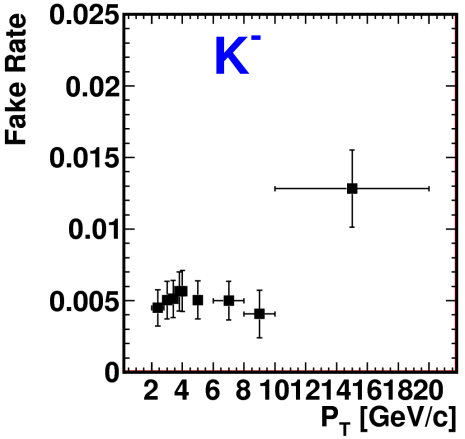
N = 38626
mD0 [GeV/c2]


CDF II Preliminary 7 fb-1
π+ & π-
Fake Rate
PT [GeV/c]

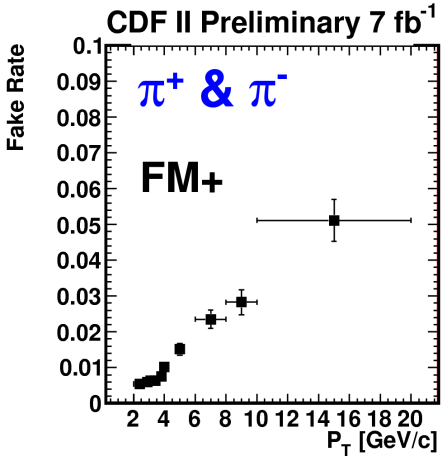

Central
K+
Fake Rate
PT [GeV/c]

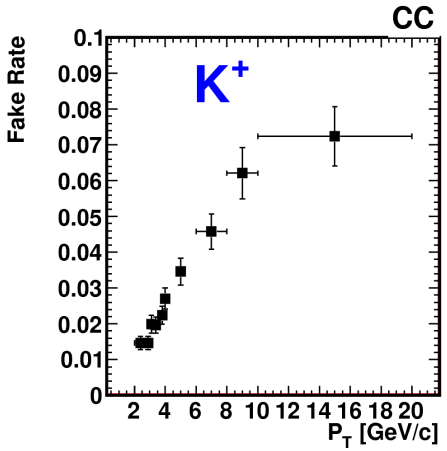

Central Pass K-
2.00 GeV/c<pT<2.80 GeV/c
N = 209
mD0 [GeV/c2]

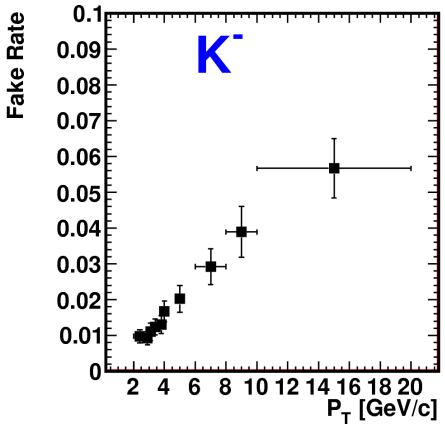

Central Pass K+
2.00 GeV/c<pT<2.80 GeV/c
N = 421
mD0 [GeV/c2]


K-
Fake Rate
PT [GeV/c]

Fake Rates for FM+ sample







NN Bin	CC	CF
0.700<NN<0.760	0.17±(0.02)	0.02±(0.01)
0.760<NN<0.850	0.18±(0.02)	0.03±(0.01)
0.850<NN<0.900	0.21±(0.02)	0.03±(0.01)
0.900<NN<0.940	0.22±(0.02)	0.04±(0.01)
0.940<NN<0.970	0.26±(0.03)	0.04±(0.01)
0.970<NN<0.987	0.42±(0.05)	0.06±(0.01)
0.987<NN<0.995	0.82±(0.09)	0.11±(0.02)
0.995<NN<1.000	8.65±(0.93)	1.16±(0.20)

Control Samples

- CF in NN bins →
- All NN bins and CC+CF combined:

Control Sample	Prediction	Nobs	Prob(N>=Nobs)
OS-	2140.0±53.9	1999	98%
SS+	19.7±3.4	25	19%
SS-	46.8±5.3	53	25%
FM+	567.8±25.4	593	24%
Sum	2774.3±59.9	2670	91%

sample	*NN* cut	CF pred	CF obsv	CF prob(%)
OS-	0.700<NN<0.760	209.3±(12.0)	187	88.8
	0.760<NN<0.850	332.3±(16.3)	325	62.0
	0.850<NN<0.900	146.7±(9.7)	144	57.7
	0.900<NN<0.940	144.2±(9.6)	139	63.9
	0.940<NN<0.970	128.6±(8.9)	112	88.4
	0.970<NN<0.987	92.8±(7.4)	89	63.0
	0.987<NN<0.995	45.4±(5.0)	55	14.0
	0.995<NN<1.000	38.3±(4.5)	37	58.2
SS+	0.700<NN<0.760	0.3±(0.3)	1	30.0
	0.760<NN<0.850	4.2±(1.1)	4	57.8
	0.850<NN<0.900	0.3±(0.3)	3	1.3
	0.900<NN<0.940	0.6±(0.4)	1	45.4
	0.940<NN<0.970	0.9±(0.5)	1	56.8
	0.970<NN<0.987	0.6±(0.4)	0	54.9
	0.987<NN<0.995	0.5±(0.4)	0	60.1
	0.995<NN<1.000	0.3±(0.3)	1	30.0
SS-	0.700<NN<0.760	4.2±(1.1)	4	57.8
	0.760<NN<0.850	5.1±(1.2)	7	27.1
	0.850<NN<0.900	2.7±(0.9)	2	71.0
	0.900<NN<0.940	0.9±(0.5)	4	2.8
	0.940<NN<0.970	3.0±(0.9)	1	92.3
	0.970<NN<0.987	2.4±(0.8)	5	12.2
	0.987<NN<0.995	0.6±(0.4)	0	54.9
	0.995<NN<1.000	1.8±(0.7)	0	16.5
FM+	0.700<NN<0.760	54.8±(5.6)	66	12.7
	0.760<NN<0.850	66.3±(6.2)	57	83.1
	0.850<NN<0.900	33.7±(4.3)	25	90.3
	0.900<NN<0.940	17.4±(3.1)	26	6.6
	0.940<NN<0.970	9.5±(2.2)	15	10.2
	0.970<NN<0.987	5.3±(1.7)	9	13.4
	0.987<NN<0.995	2.7±(1.2)	3	49.3
	0.995<NN<1.000	2.1±(1.0)	8	0.7

SM Expectation for B_s Signal Window

	5.310-5.334	5.334-5.358	5.358-5.382	5.382-5.406	5.406-5.430
0.700-0.760	0.002 ± 0.000	0.007 ± 0.001	0.011 ± 0.002	0.006 ± 0.001	0.001 ± 0.000
0.760-0.850	0.004 ± 0.001	0.015 ± 0.003	0.020 ± 0.004	0.011 ± 0.002	0.003 ± 0.001
0.850-0.900	0.004 ± 0.001	0.010 ± 0.002	0.014 ± 0.003	0.008 ± 0.001	0.002 ± 0.000
0.900-0.940	0.005 ± 0.001	0.016 ± 0.003	0.023 ± 0.004	0.012 ± 0.002	0.002 ± 0.000
0.940-0.970	0.008 ± 0.001	0.022 ± 0.004	0.032 ± 0.006	0.016 ± 0.003	0.003 ± 0.001
0.970-0.987	0.010 ± 0.002	0.029 ± 0.005	0.041 ± 0.007	0.022 ± 0.004	0.005 ± 0.001
0.987-0.995	0.013 ± 0.002	0.046 ± 0.008	0.062 ± 0.011	0.031 ± 0.006	0.007 ± 0.001
0.995-1.000	0.052 ± 0.009	0.167 ± 0.030	0.227 ± 0.040	0.119 ± 0.021	0.029 ± 0.005

Table: Expected number SM Signal events in CMU-CMU channel

	5.310-5.334	5.334-5.358	5.358-5.382	5.382-5.406	5.406-5.430
0.700-0.760	0.002 ± 0.000	0.006 ± 0.001	0.007 ± 0.001	0.005 ± 0.001	0.001 ± 0.000
0.760-0.850	0.003 ± 0.001	0.012 ± 0.002	0.015 ± 0.003	0.009 ± 0.002	0.002 ± 0.000
0.850-0.900	0.003 ± 0.001	0.009 ± 0.002	0.012 ± 0.002	0.006 ± 0.001	0.001 ± 0.000
0.900-0.940	0.004 ± 0.001	0.012 ± 0.002	0.017 ± 0.003	0.009 ± 0.002	0.002 ± 0.000
0.940-0.970	0.005 ± 0.001	0.015 ± 0.003	0.021 ± 0.004	0.013 ± 0.002	0.003 ± 0.001
0.970-0.987	0.008 ± 0.002	0.026 ± 0.005	0.036 ± 0.007	0.019 ± 0.003	0.005 ± 0.001
0.987-0.995	0.007 ± 0.001	0.021 ± 0.004	0.029 ± 0.005	0.017 ± 0.003	0.004 ± 0.001
0.995-1.000	0.039 ± 0.007	0.116 ± 0.021	0.159 ± 0.029	0.090 ± 0.016	0.023 ± 0.004

Table: Expected number SM Signal events in CMU-CMX channel

SM and Background Expectations for B_s

CC

NN Bin	ϵ_{NN}	B→hh Bkg	Total Bkg	Exp SM Signal
$0.700 < NN < 0.970$	20%	0.03	129.24±6.50	0.26±0.05
$0.970 < NN < 0.987$	8%	< 0.01	7.91±1.27	0.11±0.02
$0.987 < NN < 0.995$	12%	0.02	3.95±0.89	0.16±0.03
$0.995 < NN < 1.000$	46%	0.08	0.79±0.40	0.59±0.11

CF

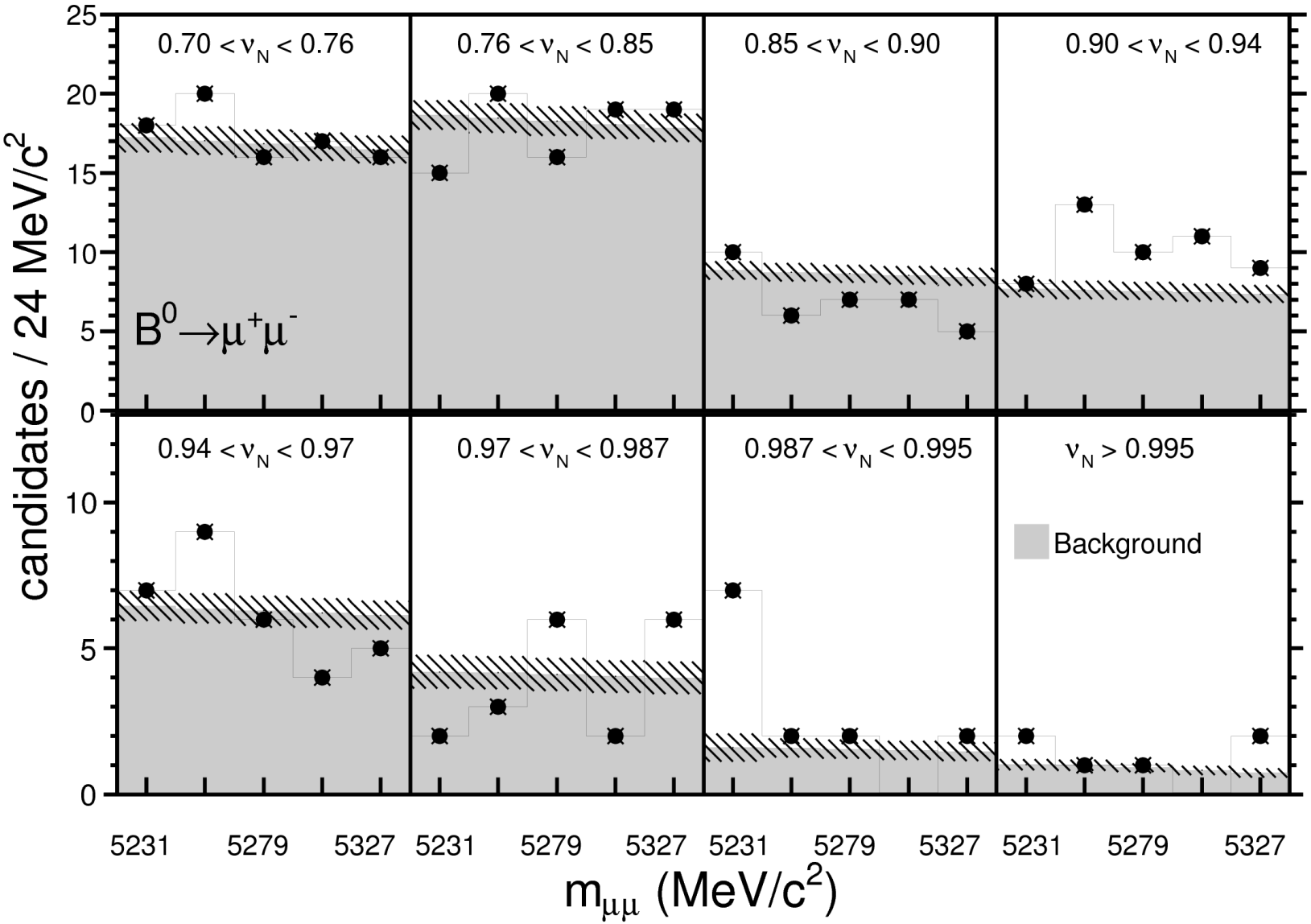
NN Bin	ϵ_{NN}	B→hh Bkg	Total Bkg	Exp SM Signal
$0.700 < NN < 0.970$	21%	0.01	146.29±7.00	0.19±0.04
$0.970 < NN < 0.987$	10%	0.01	11.57±1.57	0.09±0.02
$0.987 < NN < 0.995$	8%	0.01	3.25±0.82	0.08±0.01
$0.995 < NN < 1.000$	46%	0.03	2.64±0.74	0.43±0.08

B^0 Expected and Observed Events

	Mass Bin (GeV/c^2)	5.219-5.243	5.243-5.267	5.267-5.291	5.291-5.315	5.315-5.339	Total
CC 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
CC 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
CC 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
CC 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
CC 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
CC NN bin	Exp Bkg	1.71±0.50	1.69±0.50	1.67±0.50	1.64±0.49	1.62±0.49	8.33
0.97-0.987	Obs	1	2	3	1	3	10
CC NN bin	Exp Bkg	0.90±0.28	0.89±0.28	0.86±0.27	0.84±0.27	0.81±0.27	4.29
0.987-0.995	Obs	3	2	1	0	1	7
CC NN bin	Exp Bkg	0.40±0.21	0.38±0.20	0.32±0.17	0.25±0.15	0.20±0.14	1.54
0.995-1	Obs	1	1	1	0	1	4
CF 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
CF 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
CF 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
CF 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
CF 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
CF NN bin	Exp Bkg	2.50±0.59	2.47±0.58	2.44±0.58	2.40±0.57	2.37±0.56	12.17
0.97-0.987	Obs	1	1	3	1	3	9
CF NN bin	Exp Bkg	0.71±0.25	0.70±0.25	0.69±0.25	0.68±0.24	0.67±0.24	3.44
0.987-0.995	Obs	4	0	1	0	1	6
CF NN bin	Exp Bkg	0.62±0.42	0.62±0.42	0.60±0.41	0.57±0.40	0.55±0.39	2.97
0.995-1	Obs	1	0	0	0	1	2

Table: B_d signal window for CC(top) and CF(bottom): Expected backgrounds, including $B \to hh$, and number of observed events.

B^0 all NN bins, CC+CF Combined

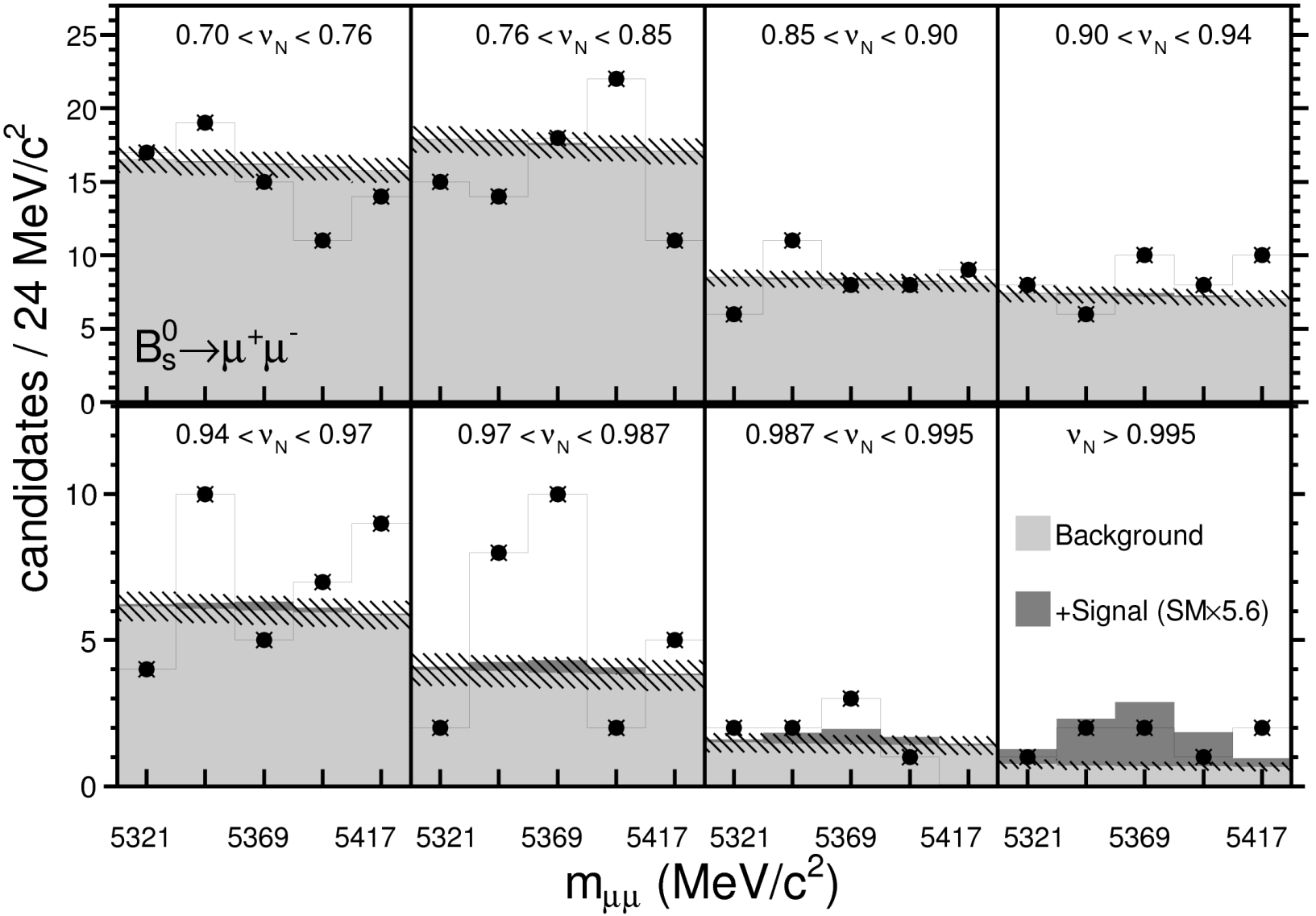


B^0_s Expected and Observed Events

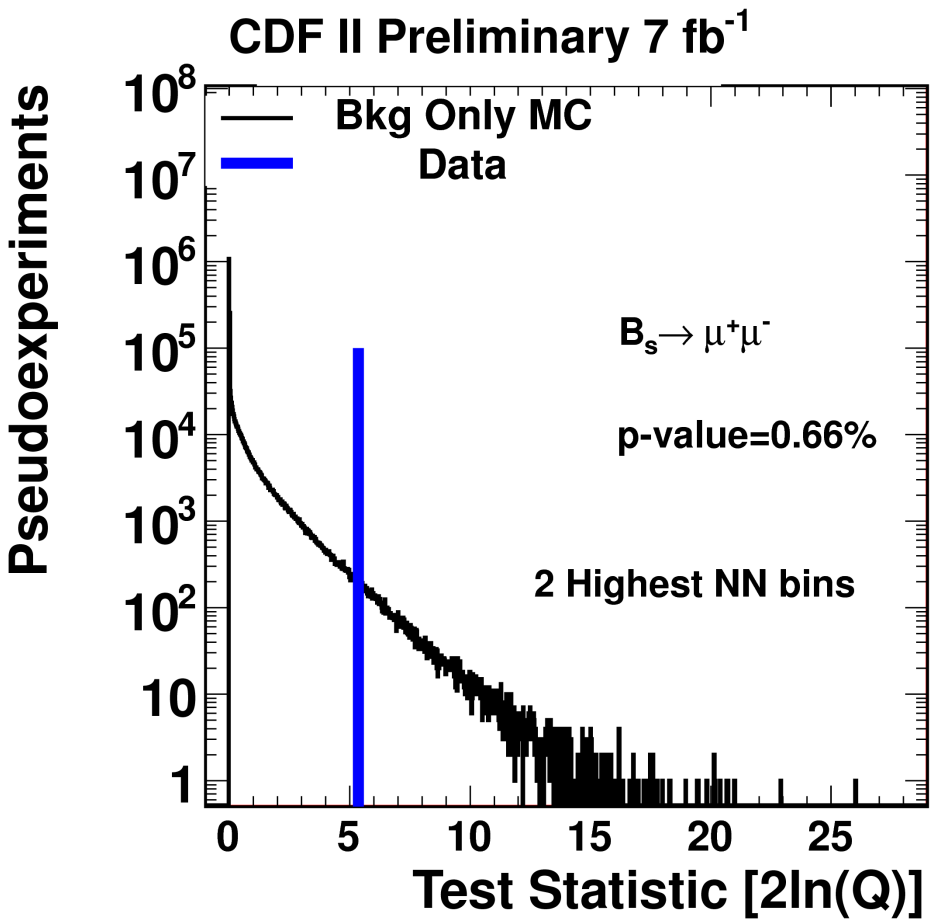
	Mass Bin (GeV/c^2)	5.31-5.334	5.334-5.358	5.358-5.382	5.382-5.406	5.406-5.43	Total
CC NN bin	Exp Bkg	8.02±0.62	7.94±0.61	7.87±0.61	7.79±0.6	7.71±0.59	39.34
0.7-0.76	Obs	9	6	6	2	5	28
CC NN bin	Exp Bkg	8.43±0.64	8.34±0.63	8.26±0.62	8.18±0.62	8.1±0.61	41.32
0.76-0.85	Obs	8	6	11	11	7	43
CC NN bin	Exp Bkg	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
CC 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
CC 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
CC NN bin	Exp Bkg	1.62±0.49	1.60±0.48	1.58±0.47	1.57±0.47	1.55±0.46	7.92
0.97-0.987	Obs	1	4	7	1	3	16
CC NN bin	Exp Bkg	0.82±0.27	0.80±0.27	0.79±0.26	0.78±0.26	0.78±0.26	3.97
0.987-0.995	Obs	1	1	3	0	0	5
CC NN bin	Exp Bkg	0.21±0.14	0.18±0.13	0.16±0.12	0.16±0.12	0.16±0.12	0.87
0.995-1	Obs	0	1	2	0	1	4
CF 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
CF 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
CF 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
CF 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
CF 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
CF NN bin	Exp Bkg	2.38±0.56	2.34±0.55	2.31±0.54	2.28±0.54	2.25±0.53	11.57
0.97-0.987	Obs	1	4	3	1	2	11
CF NN bin	Exp Bkg	0.67±0.24	0.66±0.24	0.65±0.24	0.64±0.23	0.63±0.22	3.25
0.987-0.995	Obs	1	1	0	1	0	3
CF NN bin	Exp Bkg	0.56±0.39	0.54±0.38	0.53±0.38	0.52±0.37	0.51±0.36	2.66
0.995-1	Obs	1	1	0	1	1	4

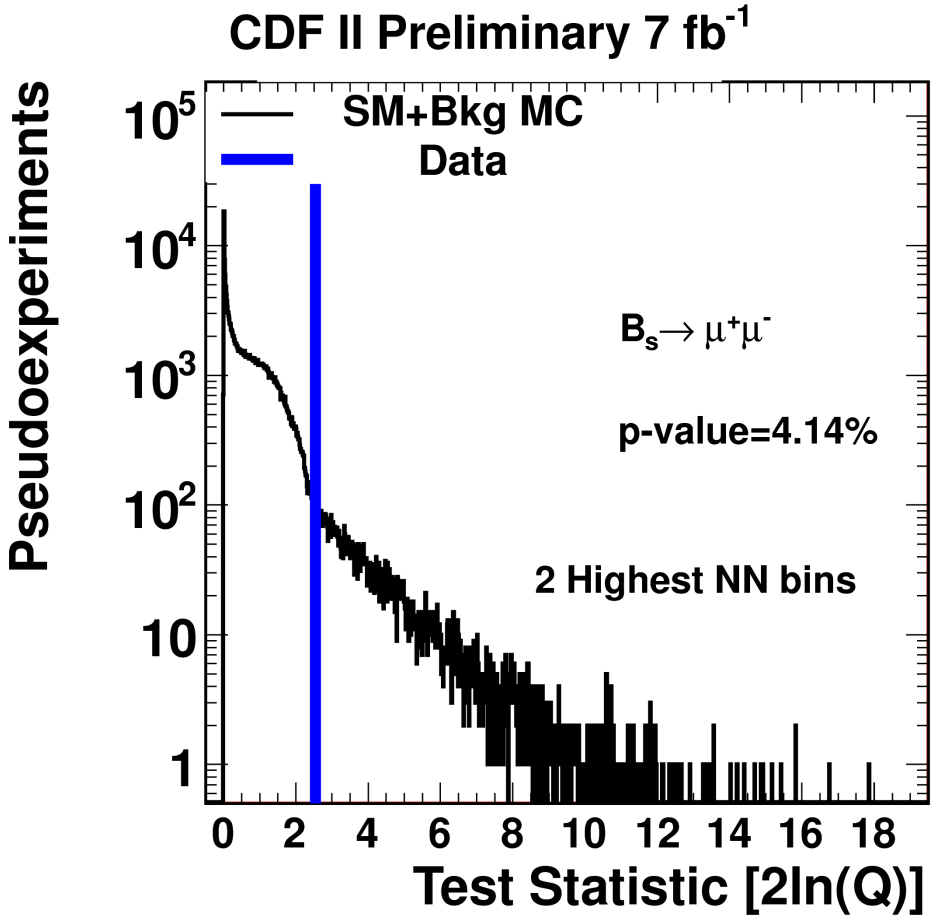
Table: B_s signal window for CC(top) and CF(bottom): Expected backgrounds, including $B \to hh$, and number of observed events.

B^0_s all NN bins, CC+CF Combined



LH Ratio Plots for Two Highest NN Bins





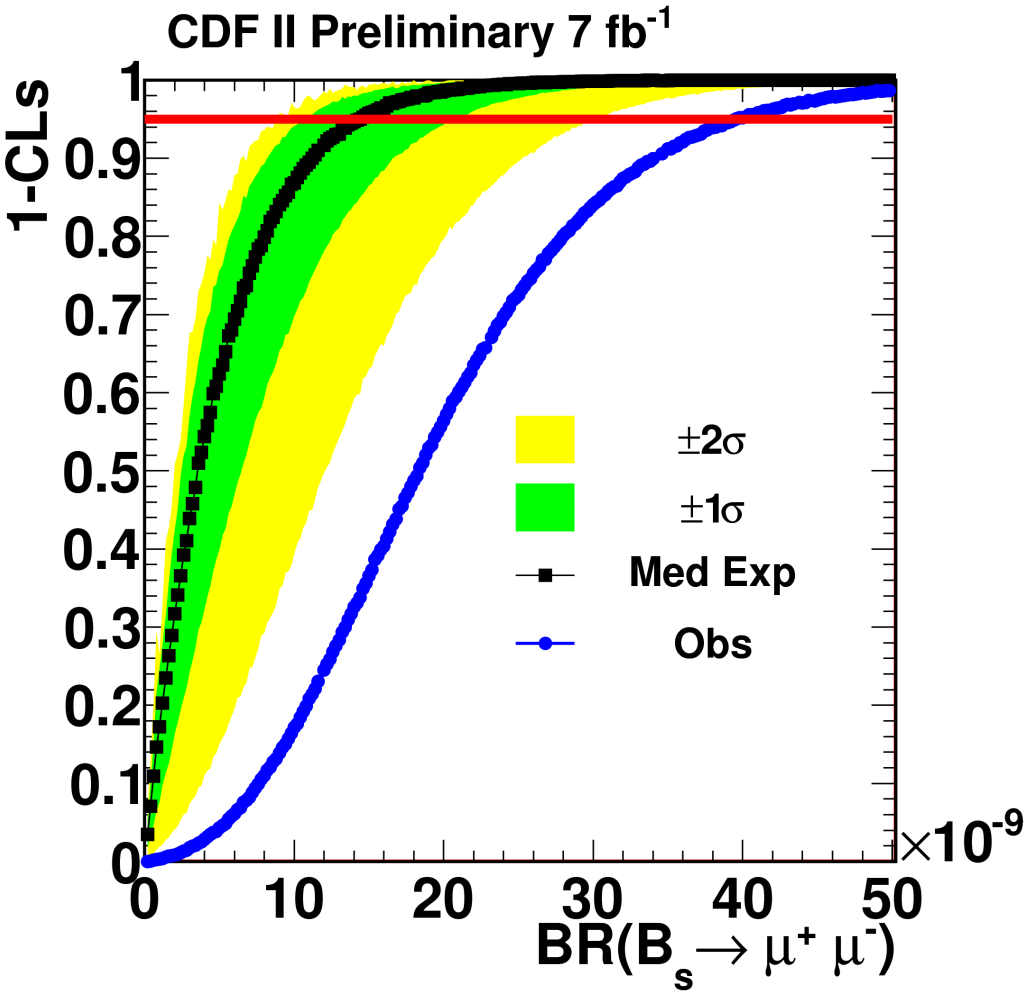
BR($B^0_s \to \mu^+\mu^-$) 95% CL Limit

Observed limit:

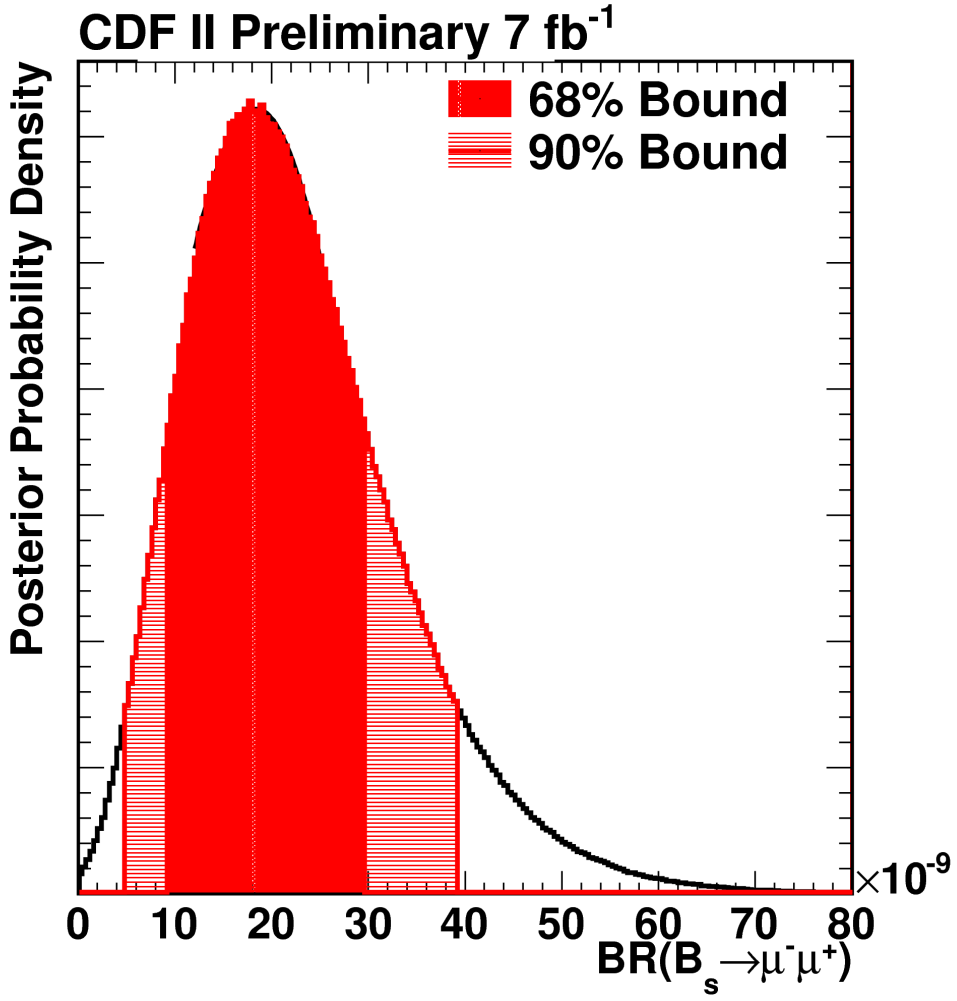
- 4.0×10^{-8}

Expected limit:

- 1.5×10^{-8}



Bayesian Method

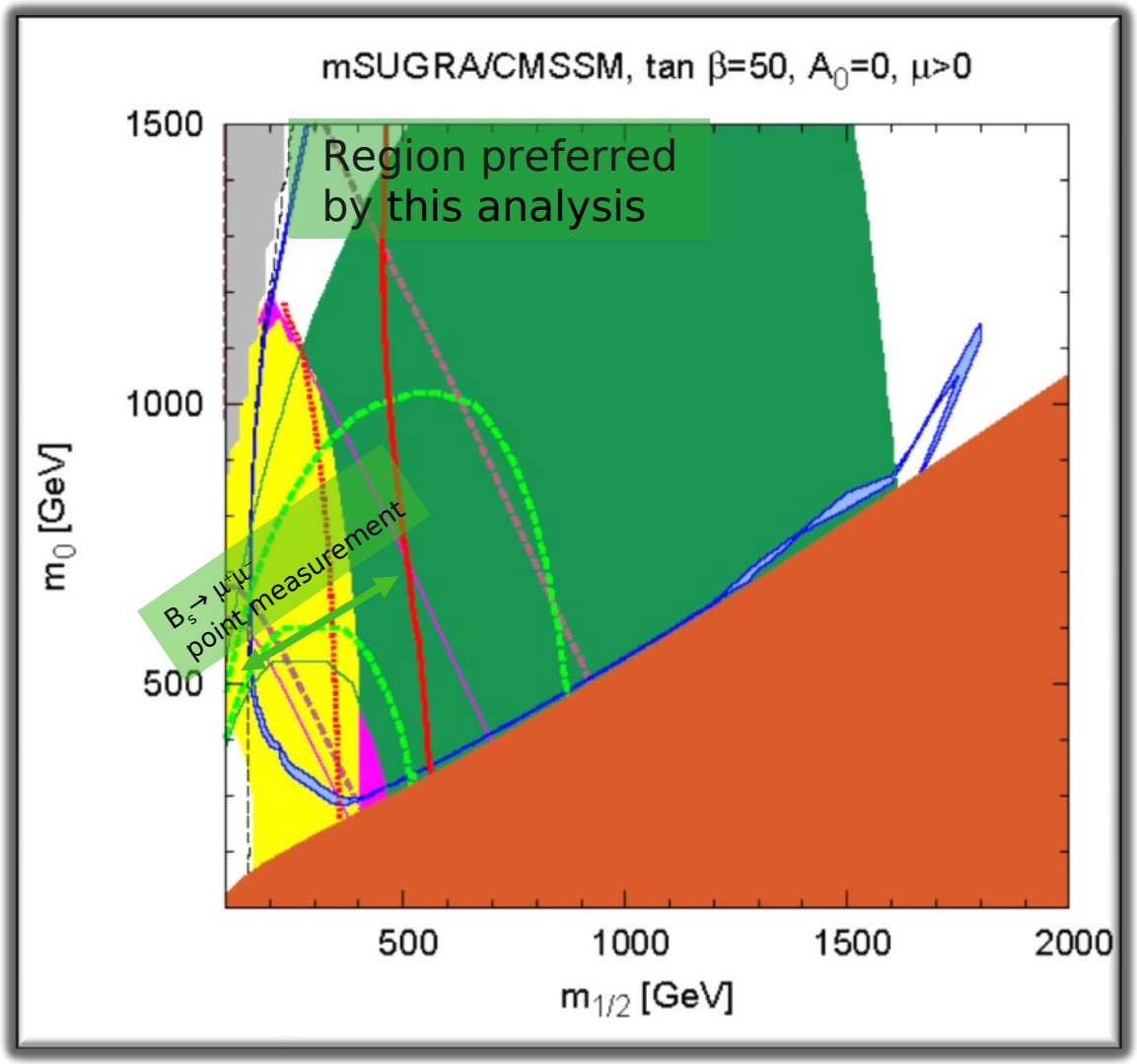


- 90% CL region:
  $5.4 \times 10^{-9} < BR(B^0_s \rightarrow \mu^+\mu^-) < 3.9 \times 10^{-8}$
- Central value:
  $BR(B^0_s \rightarrow \mu^+\mu^-) = 1.8\ ^{+1.1}_{-0.9} \times 10^{-8}$

Interpretations

$m_0/m_{1/2}$ plane in a mSUGRA interpretation with tanβ=50
B. Dutta, Y.Mimura, Y. Santoso

Green: Region preferred by $B_s \to \mu^+\mu^-$ 90% range
Dashed green: point measurement



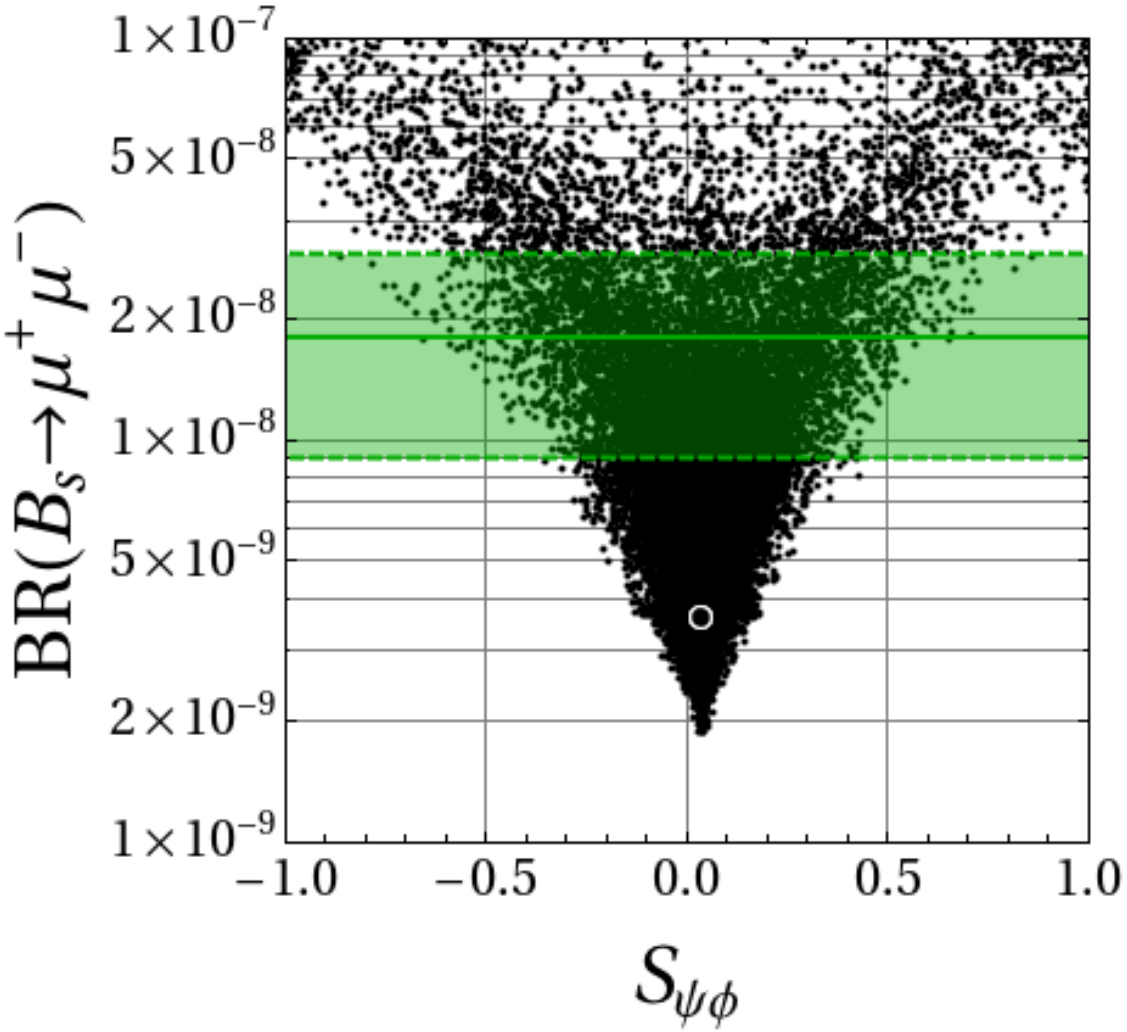
Excluded by

a Rare B decay $b \to s\gamma$
b No CDM candidate
c No EWSB

Interpretations

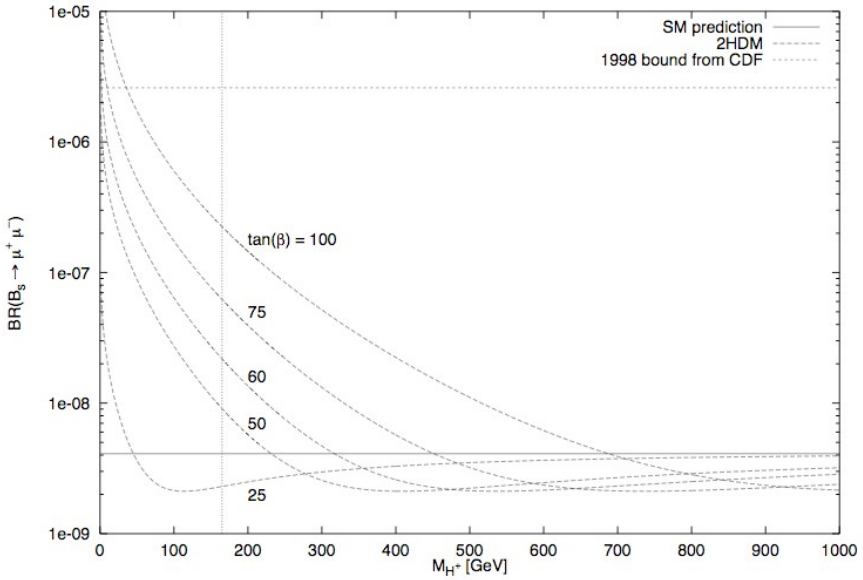
Updated plot from Altmannshofer, Buras, Gori, Paradisi, Straub, Nucl.Phys.B830:17-94,2010 (arXiv:0909.1333)

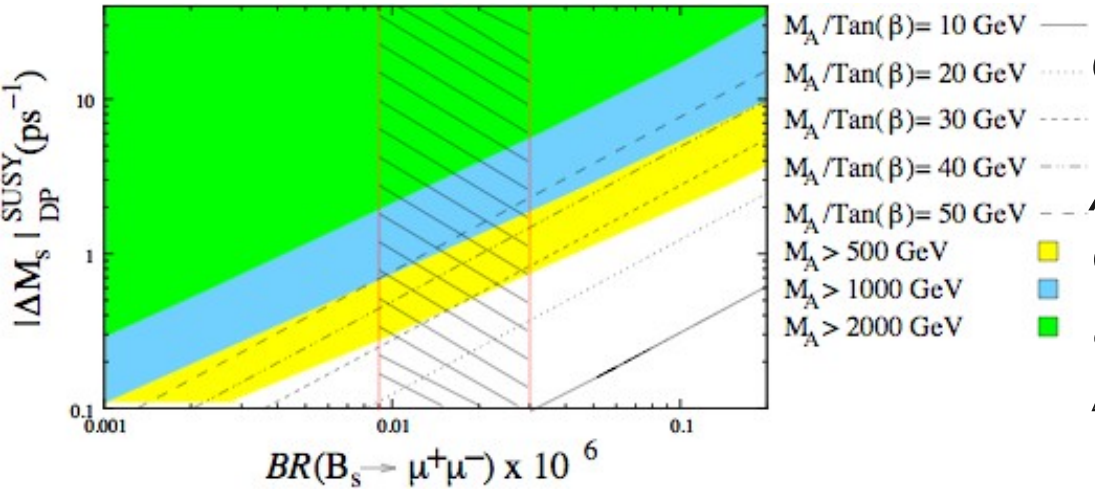
correlation between $BR(B_s \to \mu^+\mu^-)$ and the CP violating phase in Bs mixing in a SUSY model from *Agashe, Carone Phys.Rev. D68 (2003) 035017 (hep-ph/0304229).*



Interpretations

U.Nierste, H.Logan: New two-sided limit excludes a significant portion of the allowed parameter space for tanβ and M_{H+} in a two-Higgs Doublet model:





C.Wagner, M. Carena, A.Menon, A. Szynkman and R. Noriega: correlation between $B_s \to \mu^+\mu^-$ and the SUSY contributions to ΔM_s in the MSSM with minimal flavor violation