Rare $B_d \to K^{*0}\mu^+\mu^-$ decays at LHCb

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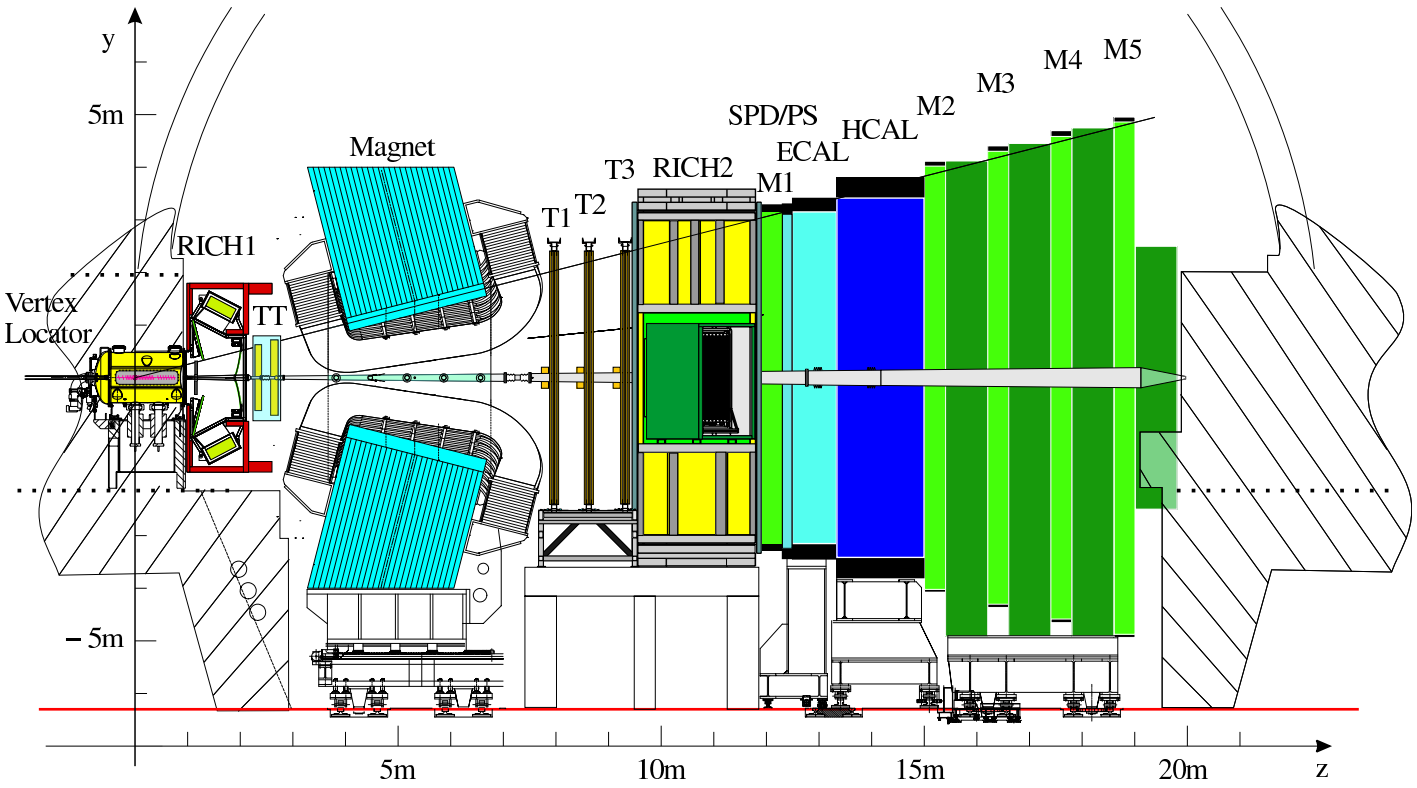
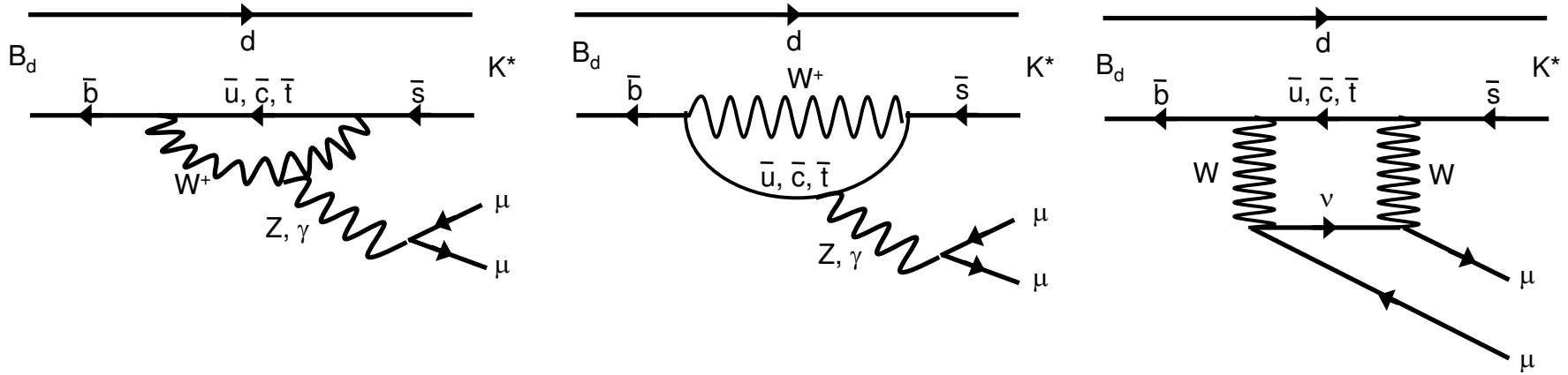
The LHCb experiment



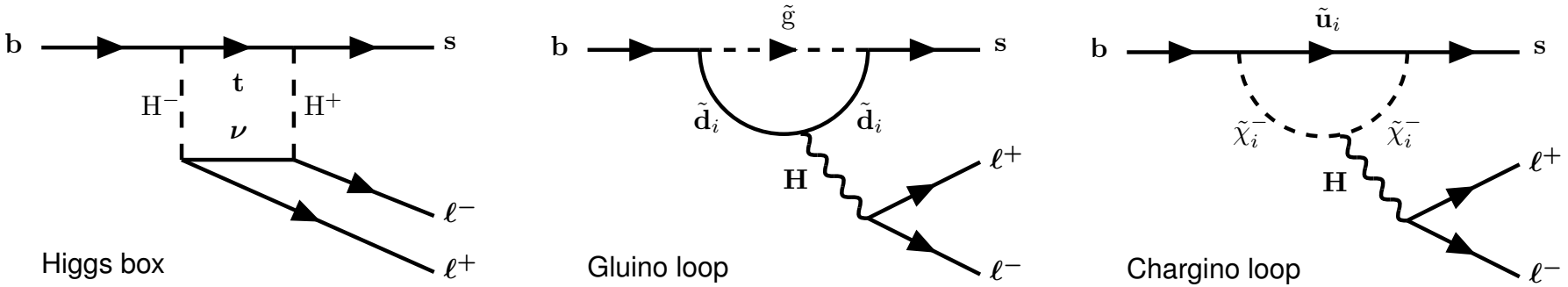
- LHC experiment to study CP violation & rare B meson decays to high precision
- Single forward arm spectrometer with good particle identification, tracking and high trigger efficiency

The decay $B_d \to K^* \mu\mu$

Decay rare (Branching ratio: $\mathcal{O}(10^{-6})$) in standard model, e.g.:



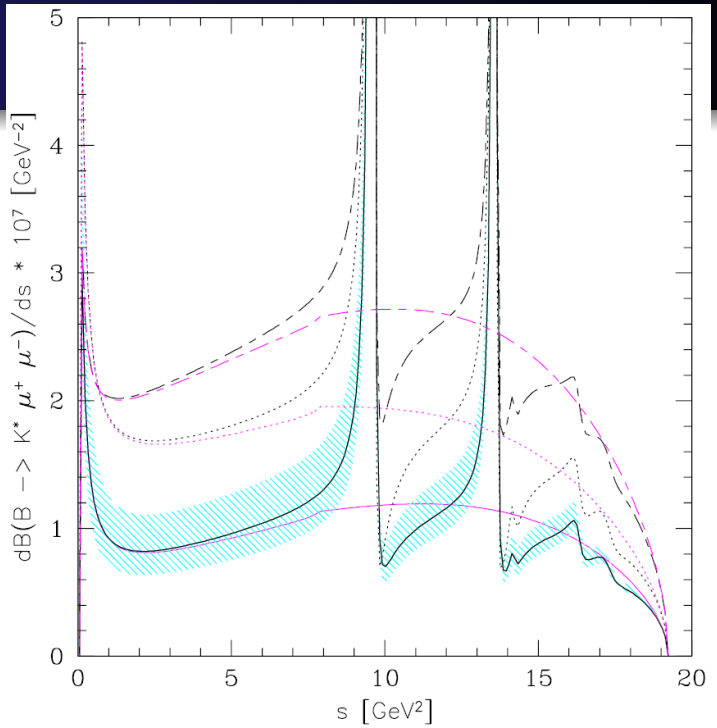
but sensitive to new physics inside loops, e.g.:

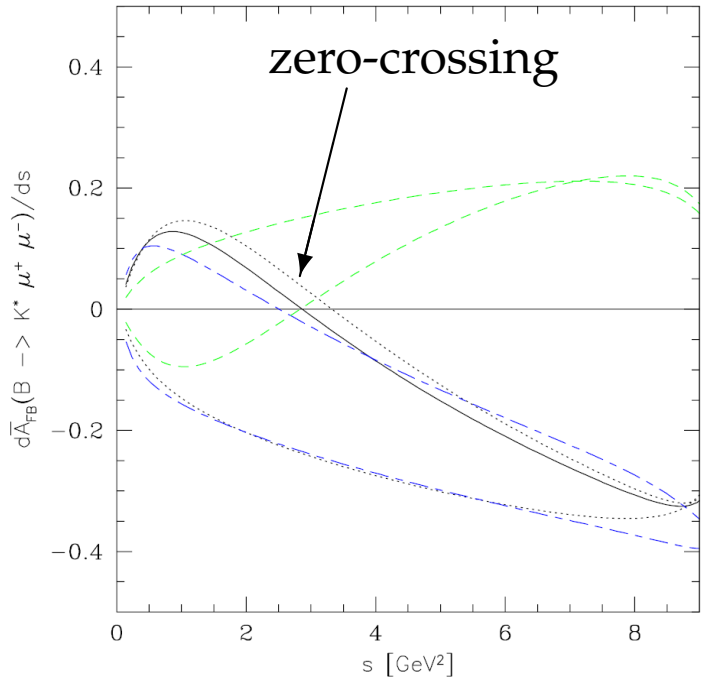


The decay $B_d \to K^* \mu\mu$ *cont.*

Decay acts as an indirect probe of new physics

- Branching ratio and dimuon mass spectrum may be modified
- Forward-backward asymmetry of the muons also sensitive to new physics and will be one of the early key measurements of LHCb
- Measurements of other angular correlations will be possible in the future with more data (LHCB/2007-057)

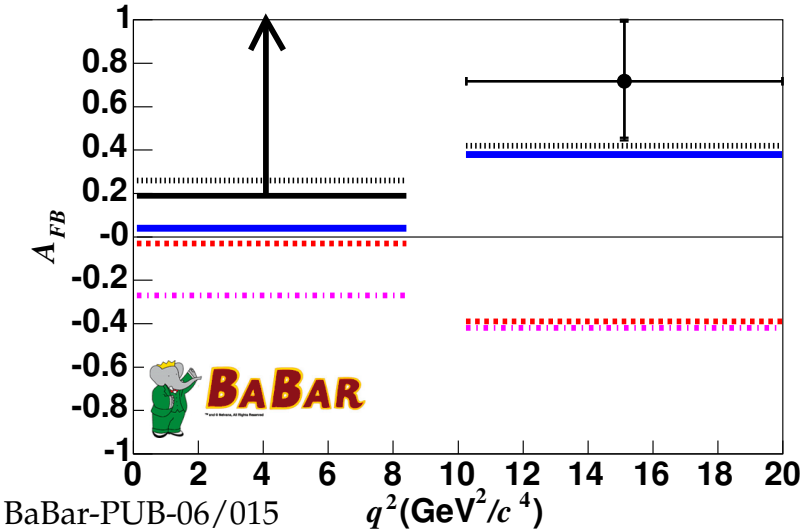




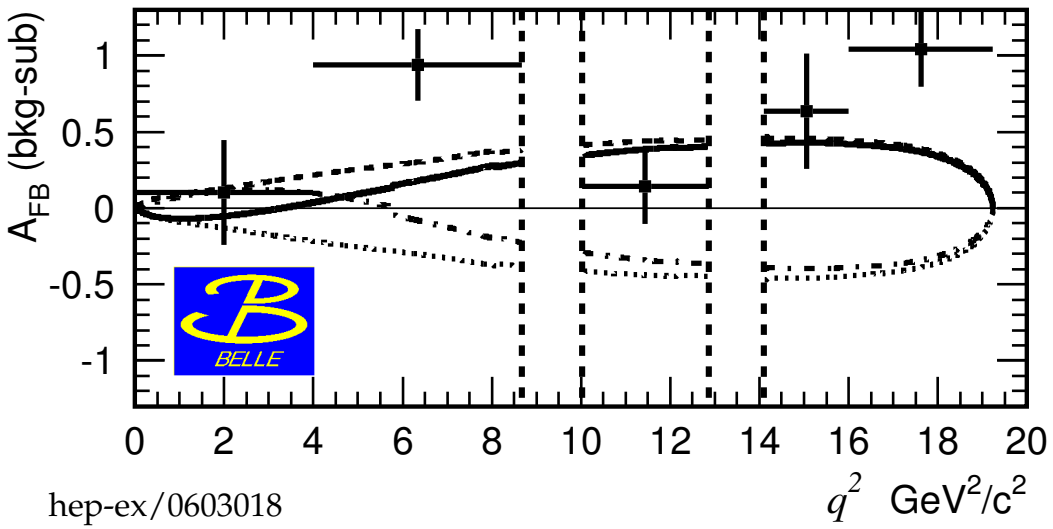
Phys. Rev. D61 (2000) 074024 or hep-ph/9910221v2

Results from other experiments

- BaBar, Belle, CDF have all recorded data ($\mathcal{O}(10^2)$ events each) and made measurements of branching ratios and forward-backward asymmetry



BaBar-PUB-06/015

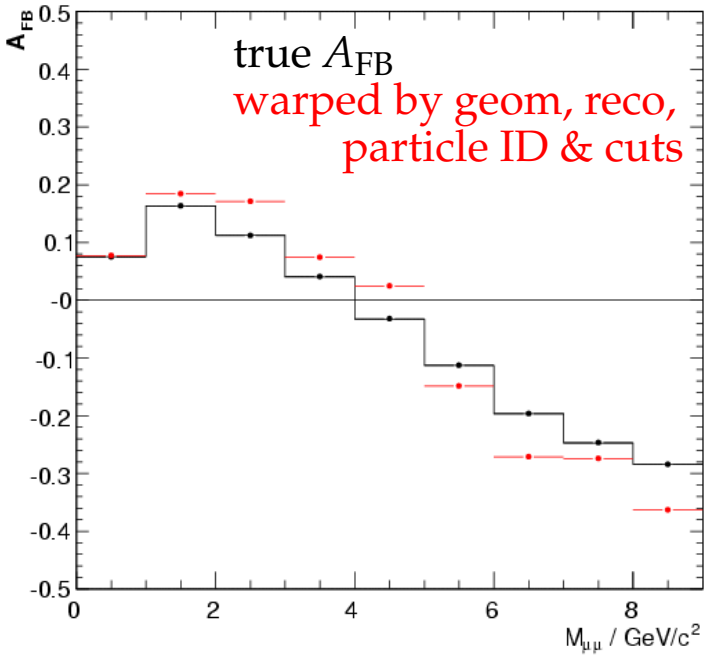


hep-ex/0603018

- LHCb will record the same statistics as the B-factories in < 1 week of running at nominal $\mathcal{L} = 2 \times 10^{32}\text{cm}^{-2}\text{s}^{-1}$

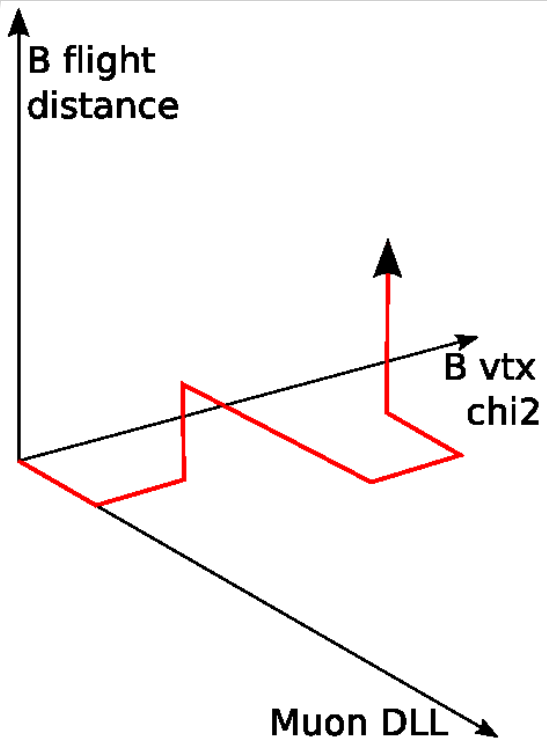
$B_d \to K^* \mu\mu$ in LHCb

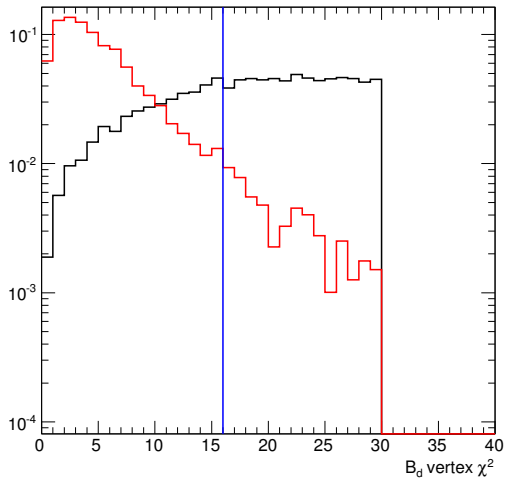
- Previous work developed a simple cut based selection that should result in LHCb recording 7200 signal events per year and 1770 background (LHCB/2007-038)
- Now working with more realistic simulations, giving $\sim 5\times$ higher background yield
  - Need to re-consider our event selection
- Studies of how angular acceptance (and forward-backward asymmetry) is warped by geometry, reconstruction, PID and selection cuts (→ F. Marinho, later this session)



Selecting events

- In order to find the most discriminating variables for use in a selection method (e.g. likelihood), use system for automatically choosing cuts
- Produces a simple cut-based selection or explores cut space and takes account of variable correlations, in a simple & transparent way
- Iterative program that attempts to maximize $S/\sqrt{S+B}$ by incrementally tightening or loosening cuts on path through available cut space
- Monitors fluctuations in chosen cuts with lower statistics





Results

- Tool obtains much higher metric than manually chosen cuts used previously in this channel
- A selection created by the automatic tool is now in use for tuning the trigger for this decay

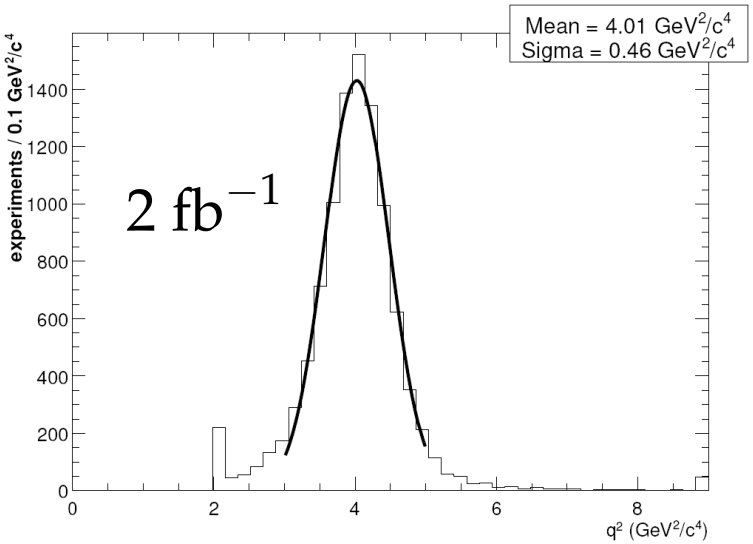
	Tool's cuts	*New manual cuts*	*Published cuts*[1]
Annual signal yield	4800	5700	7200
Annual background yield	120	1700	1770
$S/\sqrt{S+B}$	69	66	76

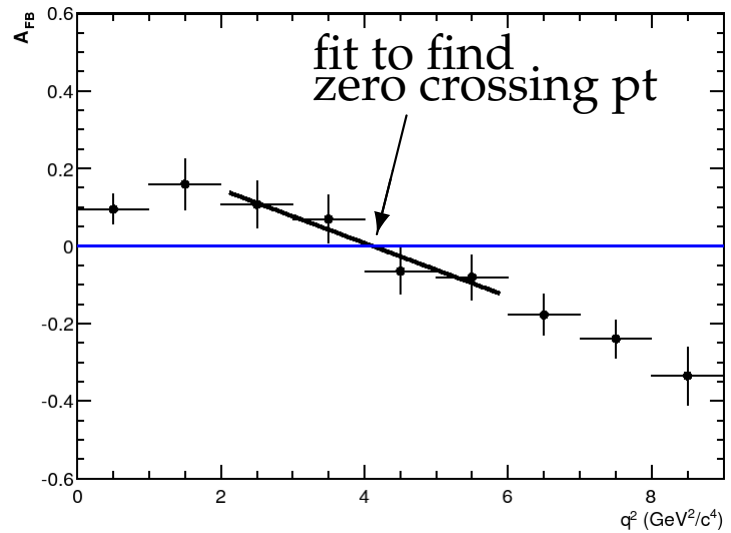
- The same iterative cut-finding code has been used successfully in $B^{\pm} \to D^0(K\pi)K^{\pm}$
- Robustness tests in that study give expected results, with sets of cuts mostly being stable, apart from some minor changes between highly correlated cuts

[1] LHCB/2007-038; study used earlier version of LHCb simulation

Sensitivity to the $\mu\mu$ forward-backward asymmetry

- LHCb's sensitivity to the zero-crossing point of the forward-backward asymmetry with one nominal year of data found to be $0.46\,\mathrm{GeV}^2/c^4$ using old simulation (LHCB/2007-039)
- The current theoretical prediction for the zero-crossing point in the SM is $4.2 \pm 0.6\,\mathrm{GeV}^2/c^4$
- See F. Marinho's talk for an update of the sensitivity with a new method and using a newer simulation





Summary

- Automated tool used to find most discriminating variables to use in selecting events
- New selection methods and studies of detector effects under investigation
- LHCb will quickly overtake B-factories statistics, accumulating $\sim$ 5k events/year at $\mathcal{L} = 2 \times 10^{32} \mathrm{cm}^{-2} \mathrm{s}^{-1}$
- LHCb will be ready to search for new physics via $\mathrm{B_d} \to \mathrm{K}^* \mu\mu$ with very first data

SPARES

Selecting events: low statistics

- The limited statistics of our background sample leads to fluctuations in the cuts chosen
- Set a limit to how many background events can be removed by cuts to control this
- As this limit is varied, look for trends in the way cuts are applied

Results from automated cut selection runs

bkg evt limit	K: DLL K − p	μ: DLL $\mu - \pi$	B_d χ^2	B_d cos	B_d FS	B_d sIPS	K^* p_T	K^* cos	K^* FS	K^* FD	π sIPS	K sIPS	$\mu\mu$ χ^2	μ sIPS	μ trackχ^2
500		-5.0	16.0	0.99995	8.0	5.0					3.0	3.0		1.0	300.0
400		-5.0	16.0	0.99995	8.0	5.0				1.0	3.0	3.0		1.5	300.0
300		-5.0	20.25	0.99999		5.0				1.0	3.0	3.0		1.0	300.0
200		-5.0	25.0	0.99999		5.0				1.0	3.0	3.0		3.0	300.0
100		-5.0	20.25	0.99999	6.0	5.0		0.0	0.5		3.0	3.0	25.0	3.0	300.0
80		-5.0	16.0	0.99999	6.0	5.0			0.5		3.0	3.0	49.0	4.0	300.0
60		-5.0	20.25	0.99999	20.0	5.0			3.0		3.0	3.0		3.0	300.0
40		-5.0	16.0	0.99999	8.0	5.0			3.0		4.0	4.0		3.0	300.0
30		-5.0	20.25	0.99999	20.0	5.0			3.0		4.0	4.0	25.0	3.0	300.0
20		-5.0	16.0	0.99999	30.0	5.0			0.5		4.0	4.0	25.0	4.0	300.0
10	-1.0	-5.0	16.0	0.99995	30.0	3.0	500.0		0.5		4.0	4.0	25.0	4.0	300.0
0	-1.0	-5.0	16.0	0.99995	30.0	3.0	500.0		0.5		4.0	4.0	25.0	6.0	100.0

Results from automated cut selection runs *cont.*

evtLim	S/2fb^{-1}	B/2fb^{-1}	$S/\sqrt{S+B}$	% ghost	% From PV	% From diff PV	% $b\bar{b}$
500	9668	58725	35.927	37.2	17.5	4.7	36.8
400	9443	47853	38.9081	38.0	17.1	3.6	37.7
300	8427	36681	39.569	44.0	17.8	5.4	27.9
200	8146	24733	44.7556	44.4	16.7	5.1	29.3
100	7899	12307	54.5201	41.5	20.2	3.2	29.8
80	7621	10634	56.4066	45.0	16.3	7.5	27.5
60	7119	6930	59.5554	32.8	17.2	5.2	41.4
40	6748	4660	62.8521	41.0	7.7	5.1	46.2
30	6706	3584	66.1073	36.7	13.3	6.7	43.3
20	6380	2270	68.1317	47.4	10.5	5.3	36.8
10	6375	1195	73.2708	40.0		10.0	50.0
0	6024	358	75.4032	33.3			66.7