B Hadronic Decays
Status of Analyses

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B Mixing Workshop, October 1, 2004

Proudly presenting...

- Fully reconstructed B's in various decay channels:
  - B^0: $D^- \pi^+$, $D^- 3\pi$, $D^{*-} \pi$, $D^{*-} 3\pi$, $J/\psi K^{*0}$
  - B^-: $D^0 \pi^-$, $J/\psi K^-$
  - $B_s \to D_s^- \pi^+$
    - $D_s \to \phi\pi, 3\pi, K^* K$
  - $B_s \to D_s^- 3\pi, D_s^- \to \phi \pi^-$
- Selection cuts, after $\frac{S}{\sqrt{S+B}}$ optimization
- Mass distributions, Yields

Thanks to all the contributors!

Contributors

+ $B^0 \to D^- \pi^+$: Jonatan, Nuno
+ $B^0 \to D^- 3\pi$: Arkadiy, Boris
+ $B^0 \to D^{*-} \pi$: Guillelmo
+ $B^0 \to D^{*-} 3\pi$: Guillelmo
+ $B^0 \to J/\psi K^{*0}$: Nuno, Jonatan
+ $B^- \to D^0 \pi^-$: Jonatan, Nuno
+ $B^- \to J/\psi K^-$: Nuno, Jonatan

+ $B_s \to D_s^- (\phi \pi^-) \pi^+$: Alberto
+ $B_s \to D_s^- (K^{*0} K^-) \pi^+$: Massimo, Alberto
+ $B_s \to D_s^- (3\pi) \pi^+$: Boris, Donatella, Paola
+ $B_s \to D_s^- (\phi \pi^-) 3\pi$: Arkadiy, Boris

Motivation

- Measure B Mixing
  - Use largest available sample
  - Optimize $S/\sqrt{S+B}$
  - Understand backgrounds in signal region

    need for a good MC description of data

- Measure Branching Ratios
  - Reliably estimate efficiencies: trigger, analysis
  - Select best understood cuts
  - Optimize number of candidates with those cuts

Data samples and analysis strategy

- Production 5.1.0; `xbhd0c`;$\mathcal{L} \simeq 240$ pb^{-1}
- Production 5.3.1; `xbhd0d`;$\mathcal{L} \simeq 24$ pb^{-1}
- Production 5.3.1; `jpmm0c`;$\mathcal{L} \simeq 264$ pb^{-1}
- Track quality selection:
  - # COT Axial Hits ≥ 10
  - # COT Stereo Hits ≥ 10
  - # SI $r\phi$ Hits ≥ 3
  - $p_T > 350$ MeV/c
- Strategy:
  - Few cuts, uncorrelated quantities
  - Cut optimized with MC
  - Templated fitting, MC used to model partially reconstructed B decays

News

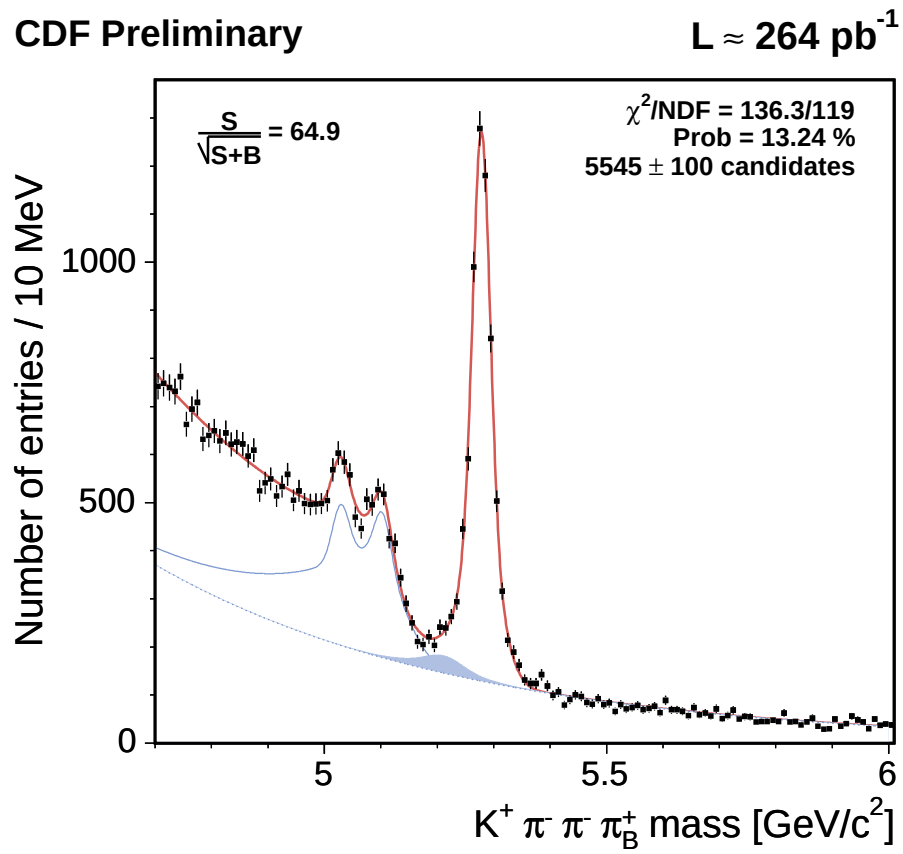
- Detailed MC study for $B_s \to D_s^- 3\pi$ (5.3.1 MC)
  - Analysis of 3π mass resonances provides new $m_{3\pi}$ cut
  - New templates improve mass fit
- Update of $B_s \to D_s^-(3\pi)\pi^+$ mode with new production data
- Lots of work done on unbinned max likelihood fits (Nuno, this afternoon)

B^0 and B^- decays

$B^0 \to D^- \pi^+$

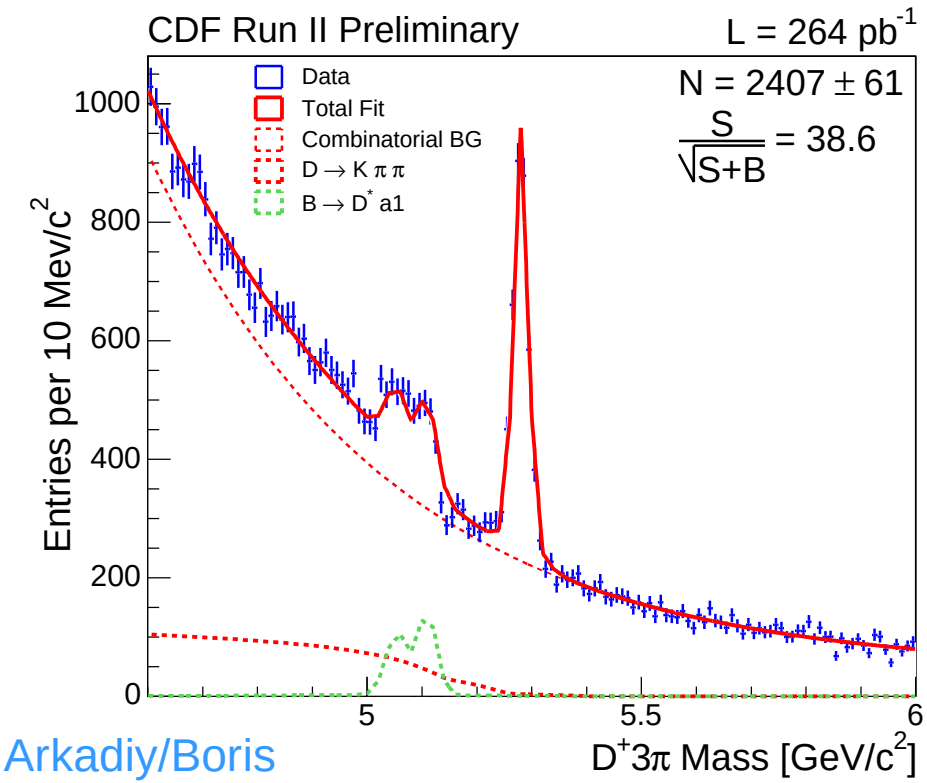
Selection cuts	
$\chi^2_{r,\phi}(B) <$	15
$\chi^2_{r,\phi}(D) <$	15
$L_{xy}/\sigma_{L_{xy}}(B) >$	11
$L_{xy}(B \leftarrow D) >$	$-300\ \mu$m
$\lvert d_0(B)\rvert <$	$110\ \mu$m
$p_T(\pi_B) >$	1.2 GeV/c
$\Delta R(D, \pi_B) <$	1.5

Cuts from CDF Note 7145



Jonatan/Nuno

$B^0 \to D^- 3\pi$



Arkadiy/Boris

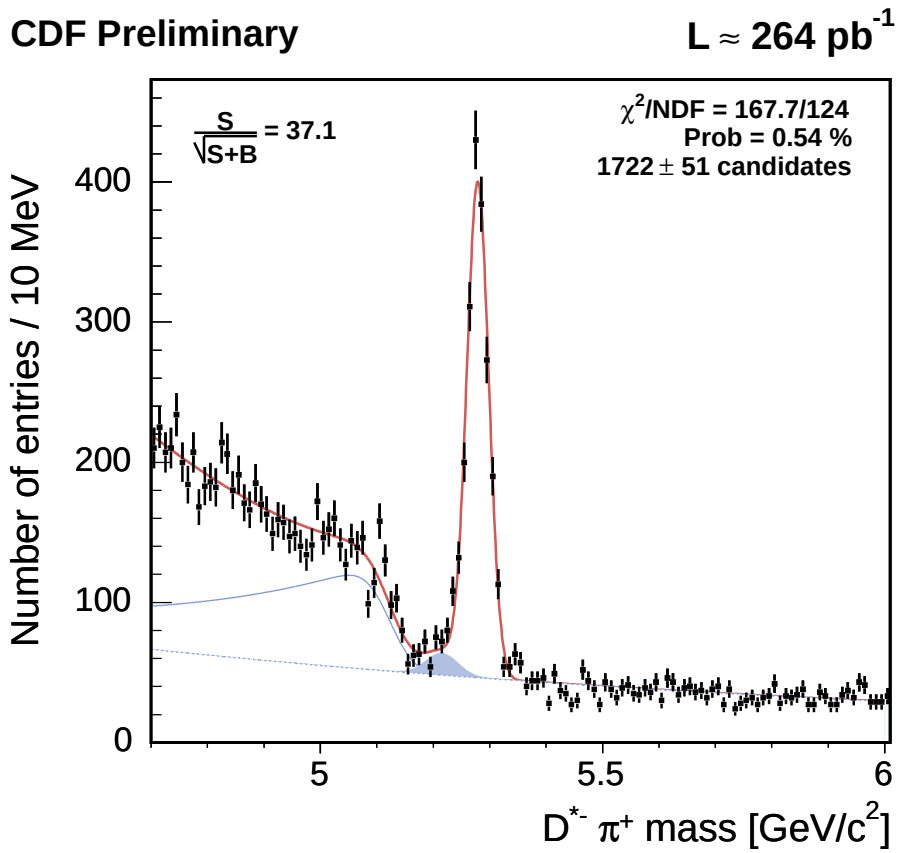
Selection cuts	
$\chi^2_{r,\phi}(B) <$	15
$\chi^2_{r,\phi}(D) <$	15
$L_{xy}/\sigma_{L_{xy}}(B) >$	12
$L_{xy}(B \leftarrow D) >$	$-200\ \mu$m
$\lvert d_0(B)\rvert <$	$65\ \mu$m
$p_T(B) >$	8.0 GeV/c
$p_T(\pi_B) >$	0.4 GeV/c
+ $m_{3\pi} <$	2.2 GeV/c^2

New more consistent cut selection

$B^0 \to D^{*-}\pi^+$

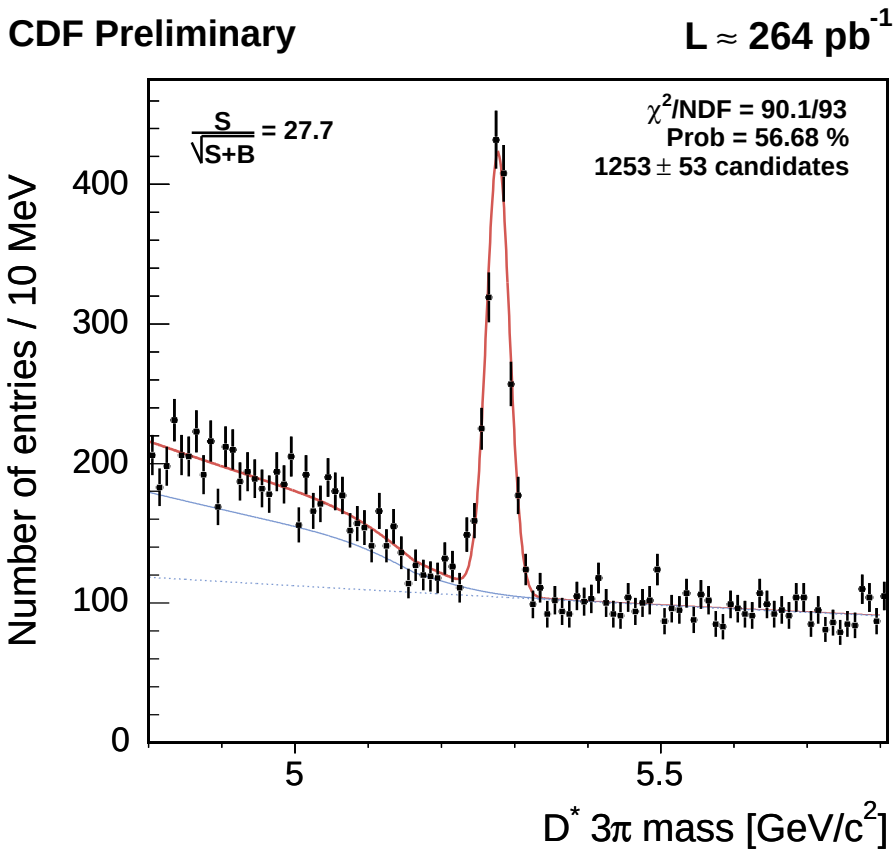
Selection cuts	
$\chi^2_{r,\phi}(B) <$	20
$L_{xy}/\sigma_{L_{xy}}(B) >$	4
$\lvert d_0(B)\rvert <$	$120\ \mu$m
$\lvert d_0(D)\rvert >$	$80\ \mu$m
$p_T(\pi_s) >$	0.4 GeV/c

Cuts from CDF Note 7145



Guillelmo

$B^0 \to D^{*-} 3\pi$



Guillelmo

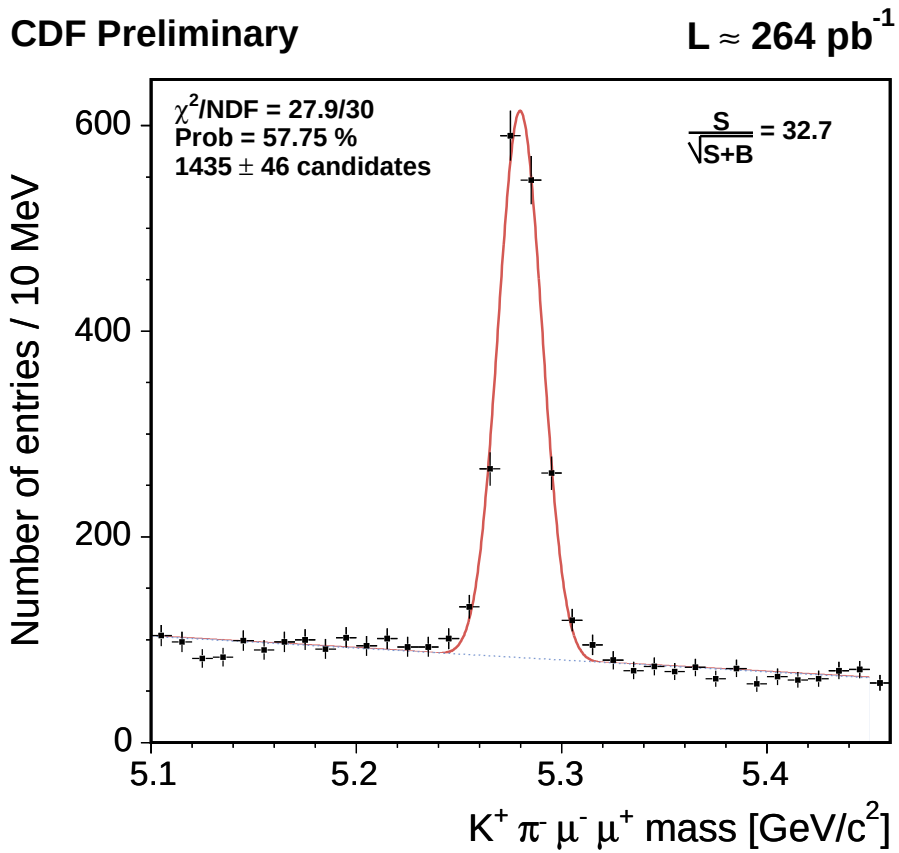
Selection cuts	
$\chi^2_{r,\phi}(B) <$	20
$L_{xy}/\sigma_{L_{xy}}(B) >$	4
$\lvert d_0(B)\rvert <$	$120\ \mu$m
$\lvert d_0(D)\rvert >$	$80\ \mu$m
$p_T(B) >$	9.0 GeV/c
$p_T(\pi_B) >$	0.4 GeV/c
$p_T(\pi_s) >$	0.4 GeV/c

Cuts from CDF Note 7145

$B^0 \to J/\psi K^{*0}$

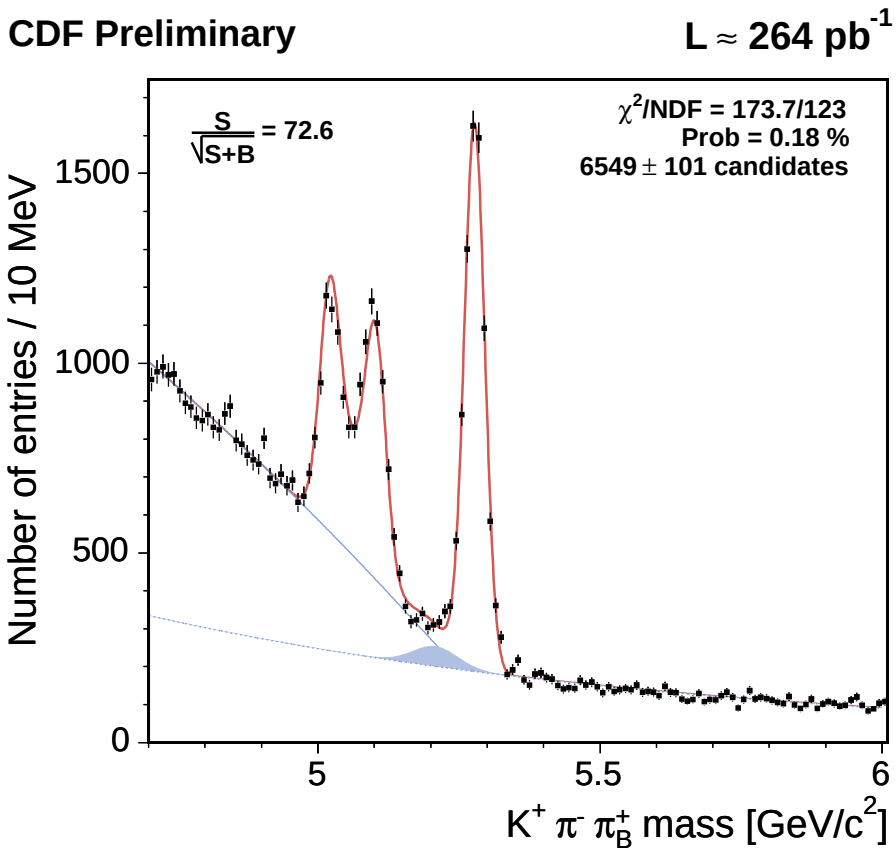
Selection cuts	
$\chi^2_{r,\phi}(B) <$	20
$L_{xy}/\sigma_{L_{xy}}(B) >$	4.0
$p_T(B) >$	5.0 GeV/c
$p_T(K^{*0}) >$	1.6 GeV/c
$p_T(\mu^{\pm}) >$	1.5 GeV/c
$\lvert m_{\mu\mu} - m_{J/\psi}\rvert <$	80 MeV/c^2
$\lvert m_{K\pi} - m_{K^{*0}}\rvert <$	50 MeV/c^2

Cuts from CDF Note 7145



Nuno/Jonatan

$B^- \to D^0 \pi^-$



Jonatan/Nuno

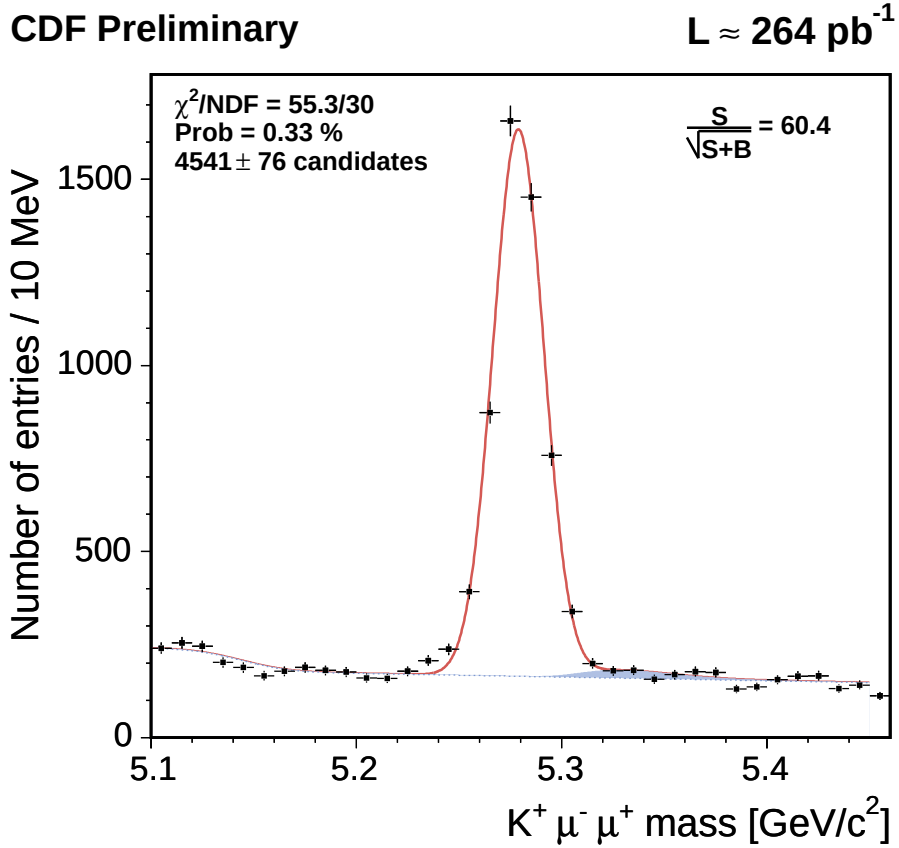
Selection cuts	
$\chi^2_{r,\phi}(B) <$	15
$\chi^2_{r,\phi}(D) <$	15
$L_{xy}/\sigma_{L_{xy}}(B) >$	8
$L_{xy}(B \leftarrow D) >$	$-150\ \mu$m
$\lvert d_0(B)\rvert <$	$80\ \mu$m
$p_T(\pi_B) >$	1.0 GeV/c
$\Delta R(D, \pi_B) <$	2.0

Cuts from CDF Note 7145

$B^- \to J/\psi K^-$

Selection cuts	
$\chi^2_{r,\phi}(B) <$	20
$L_{xy}/\sigma_{L_{xy}}(B) >$	4.5
$p_T(B) >$	4.0 GeV/c
$p_T(K^+) >$	1.0 GeV/c
$p_T(\mu^\pm) >$	1.5 GeV/c
$\lvert m_{\mu\mu} - m_{J/\psi}\rvert <$	80 MeV/c^2

Cuts from CDF Note 7145



Nuno/Jonatan

Summary of cuts for B selections

	$D^- \pi^+$	$D^- 3\pi$	$D^{*-}\pi^-$	$D^{*-}3\pi$	$D^0\pi^-$
$\chi^2_{r,\phi}(B) <$	15	15	20	20	15
$\chi^2_{r,\phi}(D) <$	15	15			15
$L_{xy}/\sigma_{L_{xy}}(B) >$	11	12	4	4	8
$L_{xy}(B \leftarrow D) >$	-300 μm	-200 μm			-150 μm
$\lvert d_0(B)\rvert <$	110 μm	65 μm	120 μm	120 μm	80 μm
$\lvert d_0(D)\rvert >$			80 μm	80 μm	
$p_T(B) >$		8.0 GeV/c		9.0 GeV/c	
$p_T(\pi_B) >$	1.2 GeV/c	0.4 GeV/c$^{(\dagger)}$		0.4 GeV/c$^{(\dagger)}$	1.0GeV/c
$p_T(\pi_s) >$			0.4 GeV/c	0.4 GeV/c	
$m_{3\pi} <$		2.2 GeV/c^2			
$\Delta R(D, \pi_B) <$	1.5				2.0

\+ *D mass constrained to PDG value in B candidate fit.*

$(\dagger)$ $\min p_T$ of the 3π

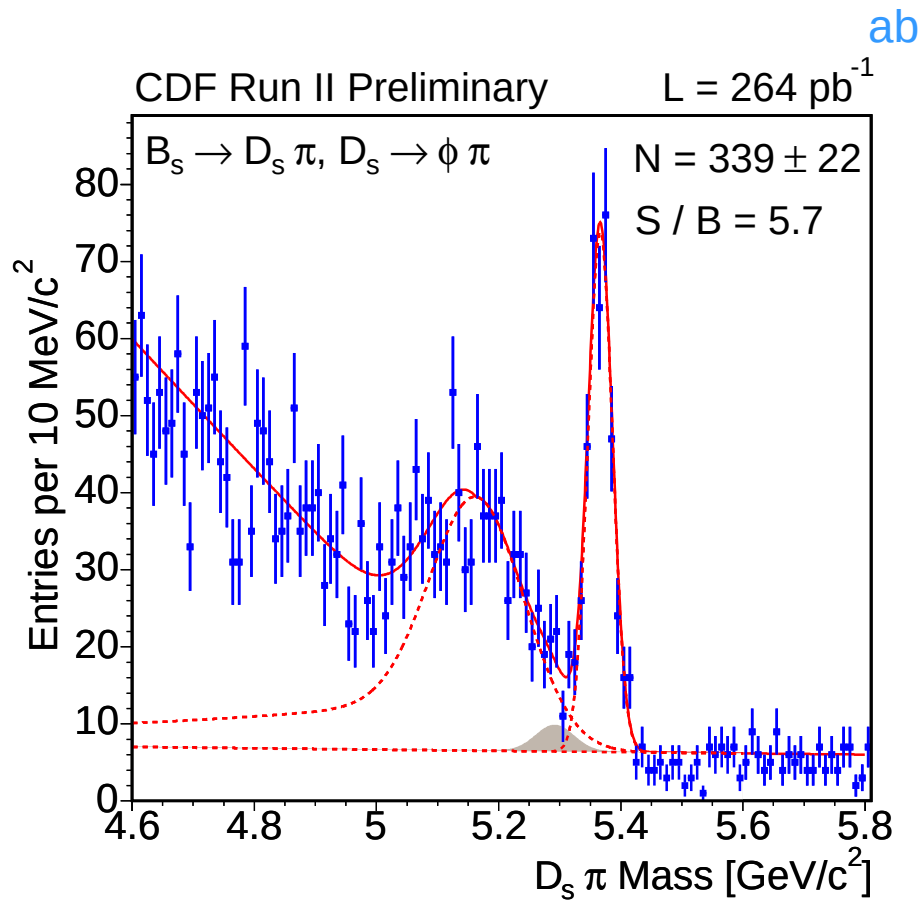
Summary of cuts for B selections

	$J/\psi K^{*0}$	$J/\psi K^{-}$
$\chi^2_{r,\phi}(B) <$	20	20
$L_{xy}/\sigma_{L_{xy}}(B) >$	4	4.5
$p_T(B) >$	5.0 GeV/c	4.0 GeV/c
$p_T(K) >$	1.6 GeV/c	1.0 GeV/c
$p_T(\mu^{\pm}) >$	1.5 GeV/c	1.5GeV/c
$\lvert m_{\mu\mu} - m_{J/\psi}\rvert <$	80 MeV/c^2	80 MeV/c^2
$\lvert m_{K\pi} - m_{K^{*0}}\rvert <$	50 MeV/c^2	

B_s decays

$B_s \to D_s^- \pi^+, D_s^- \to \phi \pi^-$, *golden mode*

Selection cuts	
$\chi^2_{r,\phi}(B) <$	15
$\chi^2_{r,\phi}(D) <$	14
$L_{xy}/\sigma_{L_{xy}}(B) >$	7
$L_{xy}(B \leftarrow D) >$	$-200\ \mu$m
$\lvert d_0(B)\rvert <$	$60\ \mu$m
$p_T(\pi_B) >$	1.2 GeV/c
+ $m_{KK} \in$	$[1.013, 1.028]$ GeV/c^2

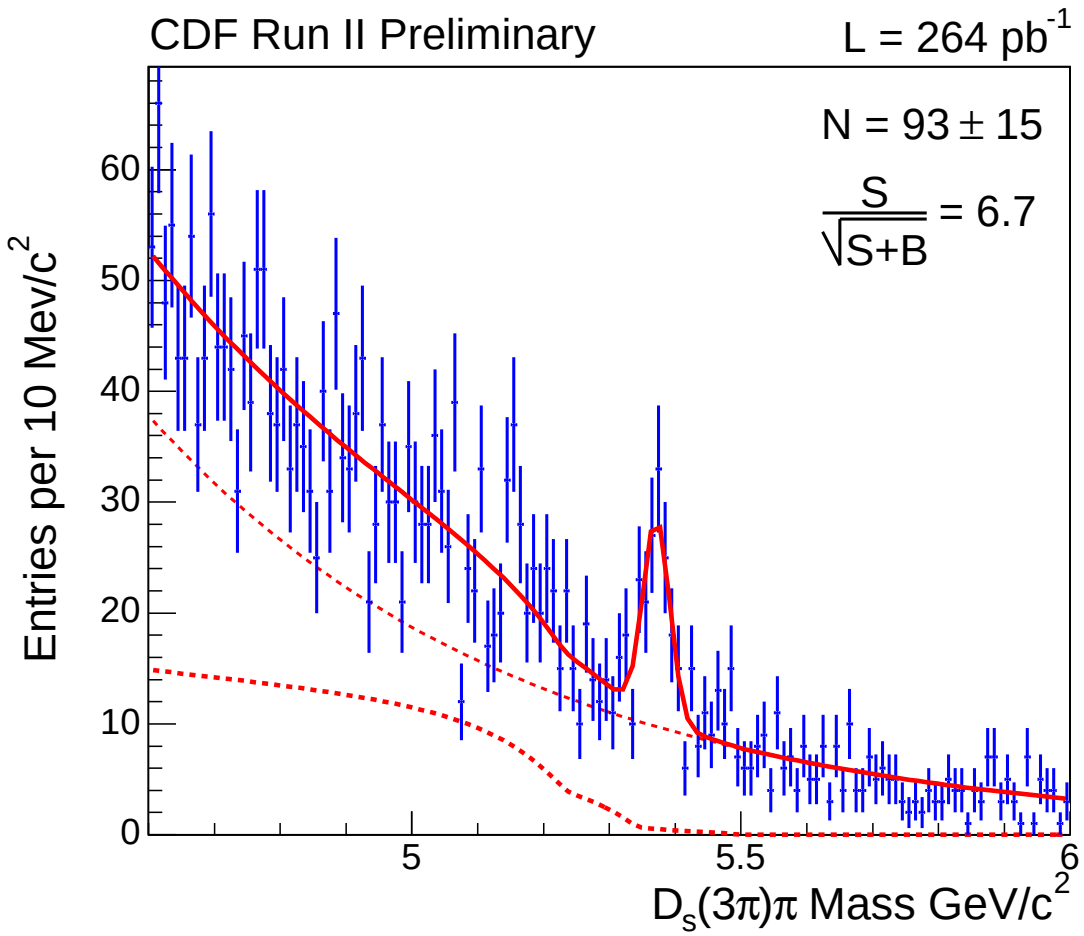


$S/\sqrt{S+B} \simeq 17$!

m_{KK} cut removes contamination

$B_s \to D_s^- \pi^+, D_s \to 3\pi$

Boris/Donatella/Paola



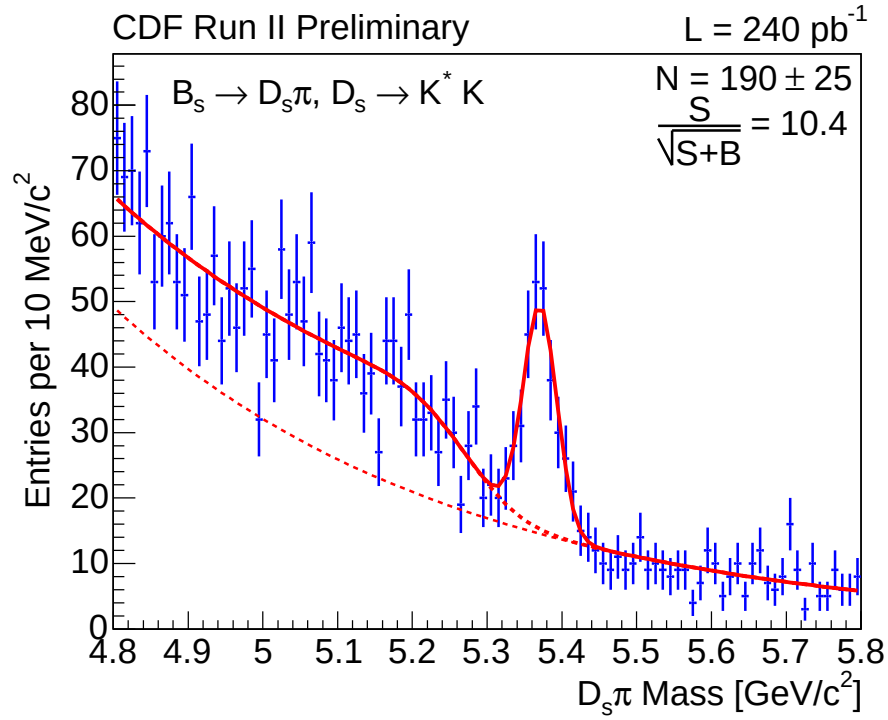
Selection cuts	
$\chi^2_{r,\phi}(B) <$	6
$\chi^2_{r,\phi}(D) <$	15
$L_{xy}/\sigma_{L_{xy}}(B) >$	11
$L_{xy}(B \leftarrow D) >$	$-100\ \mu$m
$\lvert d_0(B)\rvert <$	$60\ \mu$m
$p_T(\pi_B) >$	1.5 GeV/c
p_T(all tracks) $>$	0.4 GeV/c

no B^0 contamination; few % bkg from other B_s decays

$B_s \to D_s^- \pi^+, D_s^- \to K^{*0} K^-$

Selection cuts	
$\chi^2_{r,\phi}(B) <$	4
$\chi^2_{r,\phi}(D) <$	4
$L_{xy}/\sigma_{L_{xy}}(B) >$	8
$L_{xy}(B \leftarrow D) >$	$-100\ \mu$m
$\lvert d_0(B)\rvert <$	$50\ \mu$m
$p_T(B) >$	5.0 GeV/c
$p_T(\pi_B) >$	1.2 GeV/c
$p_T(D) >$	4.0 GeV/c
p_T(all tracks) $>$	0.4 GeV/c
$\lvert m_{KK\pi} - m_{D_s}\rvert <$	25 MeV/c^2
$\lvert m_{K\pi} - m_{K^{*0}}\rvert <$	0.1 GeV/c^2
+ $\lvert m_{K\pi\pi} - m_{D^-}\rvert >$	24 MeV/c^2

Massimo/ab



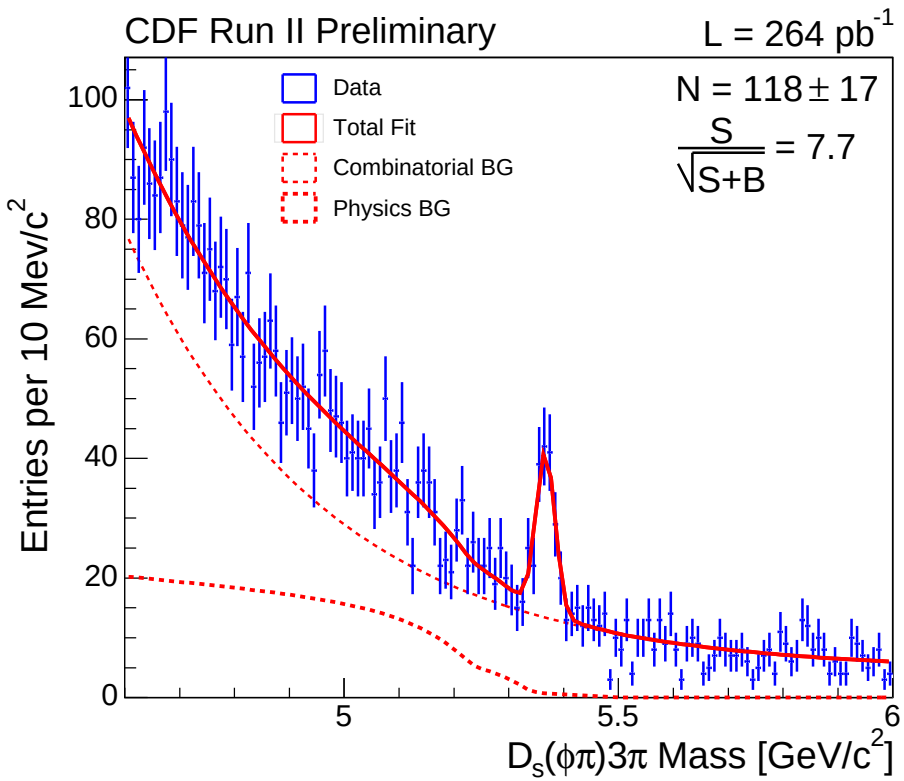
$m_{K\pi\pi}$ is $m_{KK\pi}$ after $K \leftrightarrow \pi$;

high rejection power for B^0: 9 events expected

(see backup slides)

$B_s \to D_s^- 3\pi, D_s^- \to \phi\pi^-$

Arkadiy/Boris



Selection cuts	
$\chi^2_{r,\phi}(B) <$	13
$\chi^2_{r,\phi}(D) <$	10
$\chi^2_{r,\phi}(KK) <$	15
$\chi^2_{r,\phi}(3\pi) <$	10
$L_{xy}/\sigma_{L_{xy}}(B) >$	11
$L_{xy}(B \leftarrow D) >$	$-100\ \mu$m
$\lvert d_0(B)\rvert <$	$55\ \mu$m
$p_T(B) >$	9.0 GeV/c
p_T(all tracks) $>$	0.45 GeV/c
$m_{KK} \in$	$[1.011, 1.028]$ GeV/c^2
+ $m_{3\pi} <$	2.2 GeV/c^2

no bkg in signal region from Cabibbo-suppr. modes

Summary of cuts for B_s selections

	$D_s(\phi\pi)\pi$	$D_s(3\pi)\pi$	$D_s(K^{*0}K)\pi^{(\dagger)}$	$D_s(\phi\pi)3\pi$
$\chi^2_{r,\phi}(B_s) <$	15	6	4	13
$\chi^2_{r,\phi}(D_s) <$	14	15	4	10
$\chi^2_{r,\phi}(\phi) <$				15
$\chi^2_{r,\phi}(3\pi) <$				10
$L_{xy}/\sigma_{L_{xy}}(B_s) >$	7	11	8	11
$L_{xy}(B_s \leftarrow D_s) >$	$-200\ \mu$m	$-100\ \mu$m	$-100\ \mu$m	$-100\ \mu$m
$\lvert d_0(B_s)\rvert <$	$60\ \mu$m	$60\ \mu$m	$50\ \mu$m	$55\ \mu$m
$p_T(B_s) >$			5.0 GeV/c	9.0 GeV/c
$p_T(\pi_{B_s}) >$	1.2 GeV/c	1.5 GeV/c	1.2 GeV/c	
$p_T(D_s) >$			4.0 GeV/c	
p_T(all tracks) $>$		0.4 GeV/c	0.4 GeV/c	0.45 GeV/c
$m_{KK} \in$	$[1.013, 1.028]$			$[1.011, 1.028]$
$\lvert m_{K\pi} - m_{K^{*0}}\rvert <$			0.1 GeV/c^2	
$m_{K\pi\pi} - m_{D^-}\rvert >$			24 MeV/c^2	
$m_{3\pi} <$				2.2 GeV/c^2

\+ *D_s mass constrained to PDG value in B_s candidate fit, except in $(\dagger)$, where $|m_{KK\pi} - m_{D_s}| < 25$ MeV/c^2 holds*

Summary of yields and significances

$L = 264$ pb^{-1}	Yield	$S/\sqrt{S+B}$	S/B
$B^0 \to D^- \pi^+$	5545 ± 100	63.0	6.0
$B^0 \to D^- 3\pi$	2407 ± 61	39.1	1.7
$B^0 \to D^{*-} \pi$	1722 ± 51	37.0	4.6
$B^0 \to D^{*-} 3\pi$	1253 ± 53	27.9	1.8
$B^0 \to J/\psi K^{*0}$	1435 ± 46	32.7	2.9
$Total$	12362 ± 146		
$B^- \to D^0 \pi^-$	6549 ± 101	72.3	4.6
$B^- \to J/\psi K^-$	4541 ± 76	60.4	4.1
$Total$	11090 ± 126		
$B_s \to D_s^- (\phi \pi^-) \pi^+$	339 ± 22	16.9	5.7
$B_s \to D_s^- (3\pi) \pi^+$	93 ± 15	6.7	0.9
$B_s \to D_s^- (K^{*0} K^-) \pi^+ (L = 240$ pb$^{-1})$	190 ± 25	10.4	1.3
$B_s \to D_s^- (\phi \pi^-) 3\pi$	118 ± 17	7.7	1.0
$Total$	740 ± 40		

Status

+ 5.1.0 and 5.3.1 production data; $\mathcal{L} \simeq 264$ pb^{-1}
+ Large 5.3.1 realistic MonteCarlo in good agreement with data

$$\Downarrow$$

+ $\sim 25K$ non-strange B mesons available
+ ~ 750 fully reconstructed B_s's, mostly from the golden mode
+ Good description of background

Plans

+ Process first part of `xbhd0d` (~ 1 month)
+ Add `xbhd0e`; soon to be included in PR plots (~ 2 weeks)

+ Develop procedure to share samples with taggers

  list of run/event for each channel

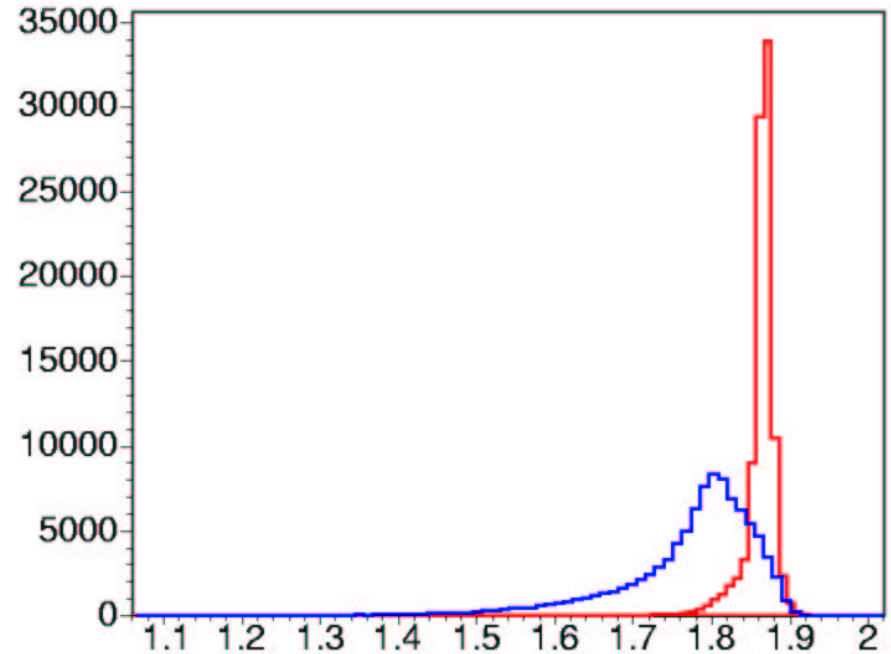
+ Looking forward to seeing also $D_s \to K\pi\pi$.

Backup slides

Active rejection of B^0 in $B_s \to D_s^- \pi^+$, $D_s^- \to K^{*0} K^-$

+ $B^0 \to D^- \pi^+$ source of dangerous background: D^- misreconstructed as D_s^- $\Rightarrow$ B^0's fall under the B_s signal peak
+ One possible workaround: with correct mass assignment, D^-'s peak at true D^- mass, D_s's lag behind, in low mass region

+ $m_{K\pi\pi}$ separates D_s's and D^-'s



— true D_s

— D^- from B^0 that passed the selection as B_s