D meson and resonances fragmentation study at Belle

Work in progress

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Motivation: Weak and strong decay feeddown in fragmentation functions

- Hadrons from Weak decays technically not part of FF definition, but often included
- Strong decays part of total sum over hadronic final state
- Both can affect the z (and transverse momentum) dependence of the detected hadrons:
 - naturally included in unpolarized MC,
 - in part added to polarized generators
 - How does PHENO handle this (additional parameters?)

Decaying hadron fractions in light hadrons at \sqrt{s} = 10.58 GeV (PYTHIA6):



Bands: various Pythia tunes, including PARJ(11 VM to PS ratio) range from 0.3-0.55 Dashed lines: default, but PARJ(11) =0.6

Ongoing: Decaying particle FFs

- Study the explicit differential cross sections for VMs, D mesons as a function of x_p
- Also of interest for ultra highenergetic cosmic ray air shower research (muon problem)
- Mostly mass distributions and fits well-behaved, except for $\rho-\omega$ (interference) and more exotic resonances

 Example from MC at Belle energies (for 4π acceptance):





Analysis

- Use two/three-particle decays into charged pions, kaons and/or neutral pions
- Look for: $\rho^0 \rightarrow \pi\pi, \rho^+ \rightarrow \pi\pi, K^* \rightarrow K\pi, \phi \rightarrow KK, D^0 \rightarrow K\pi, \pi\pi, KK, \eta \rightarrow \pi\pi\pi, \omega \rightarrow \pi\pi\pi, D^+ \rightarrow K^-\pi^+\pi^+, D^0 \rightarrow K^-\pi^+\pi^0, D^{*+} \rightarrow (K^-\pi^+), \pi^+, D^{*0} \rightarrow (K^-\pi^+), \pi^0, D_s^+ \rightarrow (K^-K^+), \pi^+, D_s^+ \rightarrow (\pi^-\pi^+), K^+; recent PDGLive values for BR$
- Additional Mass constraints for D^0s from D^* decays and for ϕ , K_s from D_s decays
- Use x_p=p/p_{max} instead of z as fractional momentum due to mass constraints (runs truly from 0 to 1)
- Analsysis process and sources of uncertainties:
 - Calculate yields in 40 x_p and 100 inv. mass bins \rightarrow Stat uncertainties
 - PID correction → Unfolding method, random sampling of matrix uncertainties
 - Fit resonances, extract signal yields \rightarrow BG functional form, comparison to BG subtracted yields
 - Acceptance/efficiency correction within barrel, then to $4\pi \rightarrow MC$ stat uncertainties, MC tune variations
 - ISR correction → MC Tune Variations
- Some improvements for systematics still ongoing



Cuts, etc

- Belle data of second SVD detector period (558/74 fb⁻¹ on/off 4S resonance), separately analyzed, Evisible >7GeV,
- Tracks:
 - N_{SVD}>=3, Δz <4cm, Δr <2cm
 - Barrel+PID acceptance (-0.511 < costh_{lab} < 0.842, 0.5 GeV/c < p_{lab} <8 GeV/c), for D* one particle outside of range allowed and assumed as pion
 - PID cuts as in previous Fragmentation analysis to use M.Leitgab's 5x5 PID Matrices in 17x9 costhlab, plab binning
- π^0 : 0.12 GeV/c2 < m_{$\gamma\gamma$} < 150 GeV/c2, barrel cuts except for D* slow pion



Mass fits (ρ^0 , including interference terms)



Mass fits (ρ^0 , including interference terms)

Both $\rho - \omega$ and $\rho - \pi\pi$ interference clearly visible, two BW functions for ρ and ω do not describe mass distribution well



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K* fits

 $K^{*0}-K\pi$ interference not as strongly needed but improve fits slightly, similarly for charged ρ and K*





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φ fits

Threshold function required for background







$\omega \rightarrow \pi \pi \pi$ fit at high xp



$D^0 \rightarrow K\pi$ fits



R.Seidl: VM+D Fragmentation

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$D^+ \rightarrow K^- \pi^+ \pi^+ (BW + Pol2-4)$

$2000 = 0.500 < x_{p} < 0.525 + Data cont$	0.525 < x < 0.550	0.550 < x < 0.575	0.575 < x _n < 0.600	0.600 < x _p < 0.625
2285.3 ± 22.5 MC BG udsc	2649.6 ± 23.4 🛕	2966.5 ± 24.3 🗛	3245.0 ± 24.8 🍂	3365.4 ± 25.0 🍂
fit status 4000 MC BG Fit	fit status 4000	fit status 4000	fit status 4000	fit status 4000
1000 covmatr stat 3	covmatr stat 3	covmatr stat 3	covmatr stat 3	covmatr stat 3
Fit $D^+ \rightarrow K \pi^+ \pi^+$	fi Ok			fi Ok
Fit BG				
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2000 3542.8 ± 25.2 🐴	3618.1 ± 25.1 🥂	_ 3555.8 ± 24.7 🥂	⊨ 3490.0 ± 24.2 🕂	- 3351.0 ± 23.4 🎢
fit status 4000	fit status 4000	fit status 4000	fit status 4000	fit status 4000
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ch2/NDF 3.30	ch2/NDF 3.04	ch2/NDE 3 78	ch2/NDF 4 23	ch2/NDF 4 98
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$= 0.750 < x_p < 0.775$	__ 0.775 < x _p < 0.800 _⊥	E_0.800 < x _p < 0.825 _±	-0.825 < x _p < 0.850 _♯	E 0.850 < x _p < 0.875
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0.875 < x	0.900 < x _p < 0.925	0.925 < x _p < 0.950 ⊥	-0.950 < x _p < 0.975」	_0.975 < x _p < 1.000
800 1374.8 ± 14.4 ₩	940.3 ± 11.9	591.5 ± 9.4 🙀	304.5 ± 6.8	[104.1 ± 4.1 ↓]
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 $m \cdot m_{PDG}$ [GeV]

m · m_{PDG} [GeV]

$D^{*+} \rightarrow (K^-\pi^+) \pi^+$, (BW +threshold function)

300	0.500 < x < 0.525 + Data on_res	0.525 < x < 0.550	0.550 < x < 0.575	0.575 < x < 0.600	0.600 < x < 0.625
250	9750 4 + 31 0 MC BG udsc	10745 3 + 31 5	11626 6 + 32 0	12489 9 + 32 7	12963 9 + 32 9
200			E 11020.0 ± 32.0	- 12403.3 ± 32.7	12303.3 1 32.3
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50	₀o⊑ ch2/NDF 36.85	ch2/NDF 48.47	ch2/NDF 54.27	ch2/NDF 57.22	ch2/NDF 64.88
	<u> </u>	<u> </u>	<u> </u>		
	0.625 < x _p < 0.650	0.650 < x _p < 0.675	0.675 < x _p < 0.700	0.700 < x _p < 0.725	0.725 < x _p < 0.750
400	13108.1 ± 32.6	12927.5 ± 32.1	12586.6 ± 31.4	11946.5 ± 29.2	11168.2 ± 28.2
300		<i>64 atatus</i> 4000	fit status 4000	<i>fit status</i> 4000	fit status 4000
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	E				
	0				
400	00 = 0.750 < X < 0.775	0.775 < x < 0.800	0.800 - x - 0.825	0.825 - x - 0.850	-0.850 - x - 0.875
350	$x_{p} = 0.730 < x_{p} < 0.773$	$x_p < 0.000$	$x_{p} < 0.023$	$0.020 < x_p < 0.000$	$x_p < 0.075$
300	me 10315.0 ± 27.1	9407.7 ± 25.8	8373.7 ± 24.3	7403.8 ± 22.9	- 6428.6 ± 21.3
250	fit status 4000	fit status 4000	fit status 4000	fit status 4000	fit status 4000
200	covmatr stat 3	covmatr stat 3	covmatr stat 3	covmatr stat 3	covmatr stat 3
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100	∭E ch2/NDF 101.03	ch2/NDF 88.19	ch2/NDF 92.56	ch2/NDF 76.37	ch2/NDF 77.67
50					
-50		<u> </u>	_ 		
200	0.875 < x _n < 0.900	0.900 < x _n < 0.925	0.925 < x _a < 0.950	0.950 < x _n < 0.975	0.975 < x _n < 1.000
	5237.6 ± 19.2	4112.6 ± 17.0	3117.2 ± 14.8	2048.0 ± 12.0	1040.5 ± 8.6
150	F fit status 4000	fit status 4000	fit status 4000	fit status 4000	fit status 4000
100	covmatr stat 3	covmatr stat 3	covmatr stat 3	covmatr stat 3	covmatr stat 3
	fit Ok	fit Ok	fit Ok	fit Ok	fit Ok
50	00 ch2/NDF 70.17	ch2/NDF 59.15	ch2/NDF 49.38	ch2/NDF 34.51	ch2/NDF 42.76
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	A 10 7 A 10 1398 V 1	A 11 7 A 10 13 307 V 1	(A 111 * /A 111 13-169 V 1	A 10 7 A 10	A 10 * A 10eee 1399 V



$D^{*0} \rightarrow (K^-\pi^+) \pi^0$, (BW + threshold function)



Some fit result summaries





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Acceptance/efficiency + smearing correction

Correction still within barrel acceptance



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Acceptance correction II

Correction from barrel to 4π (different Pythia tunes)





Acceptance correction (three hadrons)



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ISR correction: ratios no ISR / ISR



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ISR correction: ratios no ISR / ISR

Some deviation in Aleph Tune at low x_p , old Belle tune, general behavior as expected: low $x_p < 1$; high $x_p > 1$



Systematic uncertainties

Dominated by tune variations (Acceptance+ISR), and BG function variation and PID



Continuum – on resonance comparisons



D⁰ channel comparisons





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D meson Tune comparisons

LEP/Tevatron and old Belle tune
good



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D* meson tune comparisons

- LEP/Tevatron, Belle tune good
- Aleph sightly too hard



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All D mesons



VM summary



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Next steps

- Resonance + D meson differential cross sections extracted for 2 and 3-hadron decay modes
- Most of the corrections performed and currently trying to improve uncertainties (and find source of remaining discrepancies, esp D_s)
- Analysis note mostly written, plan to finalize the results soon

