Charm Baryon Spectroscopy

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Charm Spectroscopy

Several analyses on charmed baryons are currently underway in Charm WG. Will cover three today.

- Branching fractions of $\Lambda_c^+ \to p^+ h^+ h^-$, $h = K, \pi$.
- Search for the doubly charmed baryons $\Xi_{cc}^{+(++)}$.
- Spectroscopy of $D^0 p$ final states.

Lc Overview

- Physics Motivation
- Λ_c^+ Dataset.
- Mass Fits and Signal Yields
- Selections (cut based and MVA).
- Efficiencies
- Future Work

Physics Motivation

- $\Lambda_c^+ \rightarrow$ p h h modes still poorly understood in terms of Branching Fractions (BFs), decay amplitudes and resonance structure.
- Current PDG BFs shown below, the doubly-Cabibbo Suppressed decay $\Lambda_c^+ \rightarrow p^+ K^+ \pi^+$ has not been observed.

Decay Mode	PDG Branching Fraction
$\Lambda_c^+ \rightarrow p^+ K^- \pi^+$ (CF)	0.05 ± 0.013
$\Lambda_c^+ \rightarrow p^+ K^- K^+$ (SCS)	$(7.7 \pm 3.5) \times 10^{-4}$
$\Lambda_c^+ \rightarrow p^+ \pi^- \pi^+$ (SCS)	$(3.5 \pm 2.0) \times 10^{-3}$
$\Lambda_c^+ \rightarrow p^+ K^+ \pi^-$ (DCS)	$< 2.3 \times 10^{-4}$ @ 90% CL

The $\Lambda_c^+ \rightarrow$ p h h decay modes and their branching fractions.

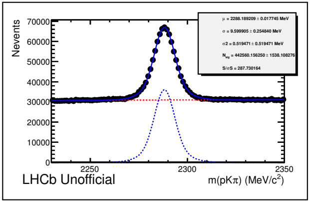
- Work is ongoing with Rio to perform multi-dimensional resonance analysis with the CF and DCS modes. CPV in SCS Λ_c^+ decays by Sajan et al.

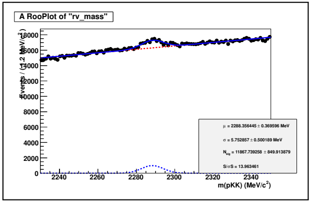
Λ_c^+ Stripping 17b 2011 Dataset

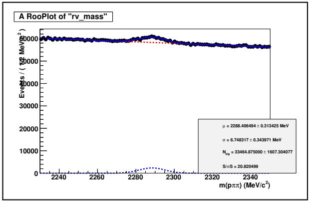
- Two sources of Λ_c^+ production: prompt and from semileptonic $\Lambda_b^0 \to \Lambda_c^+ \mu^- \nu_\mu$ decays.
- Expect more prompt production but prompt charm baryon triggers are inefficient. Dedicated $\Lambda_c^+ \to p^+ \pi^+ K^-$ TOS is 8.1% efficient. Partly due to the shorter time of flight for baryons than mesons: $\tau_{\Lambda_c} = 0.2$ps. $\tau_D = 0.4 - 1$ps.
- Compared to topological muon semileptonic lines, typically 80% TOS efficient.
- Both are important due to the lack of a suitable control mode for the decays. Treating both samples independently.
- Have chosen a TIS trigger chain for prompt as we have only had a prompt Cabibbo-Favoured dedicated trigger for half of 2011.
- In 2012 have prompt dedicated triggers in place for all four modes.

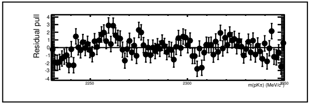
Mass Fits and Signal Yields I - Prompt

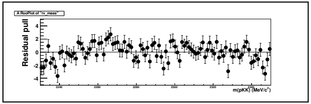
- Double (Single) Gaussian signal and linear background describe CF mode (SCS modes) well.

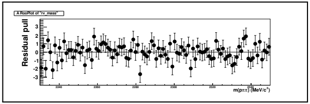












$\Lambda_c^+ \to p^+ K^- \pi^+$ $\Lambda_c^+ \to p^+ K^- K^+$ $\Lambda_c^+ \to p^+ \pi^- \pi^+$

Mass Fits and Signal Yields II - Prompt

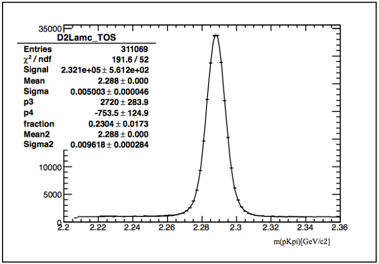
- The DCS mode is being kept blind in prompt. Peaking backgrounds likely to be more important for DCS mode due to much lower expected yield.
- Main sources likely to be from D reflections and double mis-ID from CF. Currently under investigation.

-	Decay Mode	Signal Yield
Prompt	$\Lambda_c^+ \to p^+ K^- \pi^+$	442 k
	$\Lambda_c^+ \to p^+ K^- K^+$	11.8 k
	$\Lambda_c^+ \to p^+ \pi^- \pi^+$	33.4 k

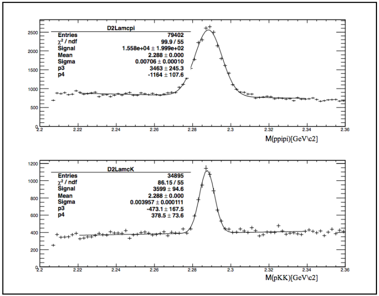
The signal yields of the Λ_c^+ unblinded prompt modes.

Mass Fits and Signal Yields III - Semileptonic

- Much higher raw yields from stripping than in prompt for CF and SCS modes.
- Both datasets are being analysed in parallel.
- Mass distributions and fits for the semileptonic shown below with additional offline cuts (detailed in backup).



$\Lambda_c^+ \to p^+ K^- \pi^+$



$\Lambda_c^+ \to p^+ \pi^- \pi^+$
$\Lambda_c^+ \to p^+ K^- K^+$

Mass Fits and Signal Yields IV - Semileptonic

- Using a TOS trigger chain:
  - TOS = L0MuonDecision, Hlt1TrackAllL0Decision or Hlt1TrackMuonDecision, Hlt2TopoMu(n)BodyBBDTDecision or Hlt2SingleMuonDecision.
- The DCS mode has been unblinded in the semileptonic stream.
- A clear peak is observed that is unlikely to be caused by reflections or mis-ID. Matches expected centre and width.
- Work underway to fully understand background sources before presenting the mode.
- From here on in will only discuss prompt sample.

Offline Selections I - Outline

- Main strategy: make the selection as agnostic to the daughter properties as possible. This will make the application to a relative BF measurement much more amenable.
- Have trained 2 cut-based and are training 2 MLP selections. One for the CF mode and one for the DCS mode using sWeighted CF data.
- For DCS mode also use a global weighting on signal events of $\frac{|V_{ud}|^2|V_{cs}|^2}{|V_{cd}|^2|V_{us}|^2} = 0.003$.
- Variables utlised:
    - Λ_c^+:
        - Pt , MAXDOCA, Vertex χ^2 , IPχ^2, FD χ^2, DIRA
    - PID:
        - $p_{PIDp}, K_{PIDK}, K_{PIDp}, (p_{PIDp} - p_{PIDK})$
- Aware that discrimination achieved with PID may be in effect daughter Pt cuts which makes the selection less agnostic to daughters, under investigation.

Offline Selections II - Cut Based

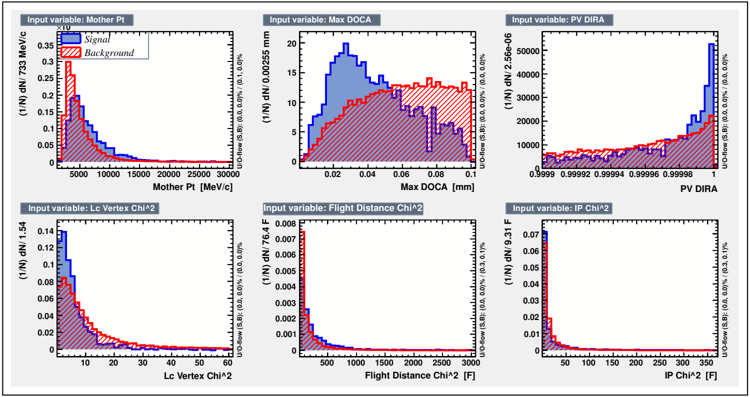
- Implement TIS trigger chain: L0, HLT1, HLT2Phys TIS.
- Conor Fitzpatrick's Cut Recursive OPtimiser (CROP) used to acquire optimum $\frac{S}{\sqrt{S+B}}$ with rectangular cuts.
- Final yields for the CF mode shown below.

Post...	N_{sig}	% of raw
Raw	$442k \pm 1538$	-
TIS	$361k \pm 1935$	81.6 ± 0.9
Offline	$229k \pm 756$	51.86 ± 0.35

- With this selection expect for the DCS mode in the signal region ($\pm 15 MeV$) a significance of $\frac{S}{\sqrt{S+B}} = 3.27$.

Offline Selections III - MVA Setup

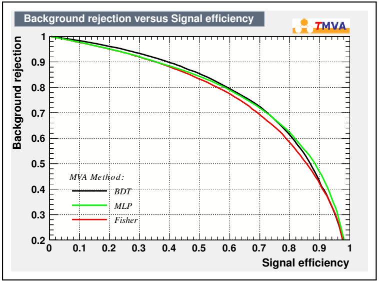
- To gain sensitivity we approached a full MVA selection using our non-PID discriminating variables.
- Variable input distributions for training below.



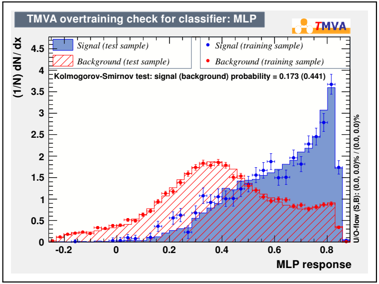
Input variables for MVA training.

Offline Selections IV - MVA Training

- Investigated the use of a BDT, MLP and Fisher discriminant.
- BDT and MLP display the expected superior discrimination to the Fisher.
- However, MLP displays more robustness against overtraining. Currently optimising MVA construction within TMVA to reduce overtraining and maximise separation.



ROC curve for $\Lambda_c^+ \to p^+ K^- \pi^+$.



Overtraining check for the MLP.

Efficiencies I

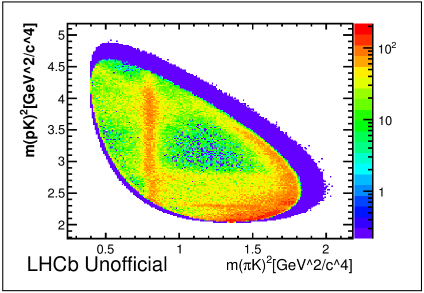
- Efficiencies composed of reconstruction and the full selection, incorporating the efficiencies of the trigger, stripping and offline.
- As usual, separate the PID efficiencies from our selection efficiencies to utilise Andrew Powell's PID reweighting. This prohibits the use of PID variables in MVA training.
- Relative BF between CF and other phh mode given by:

$$\frac{\mathcal{B}_{\Lambda_c^+ \to p^+ K^- \pi^-}}{\mathcal{B}_{\Lambda_c^+ \to p^+ h^- h^-}} = r \times \epsilon_{acc} \times \epsilon_{reco} \times \epsilon_{trigger} \times \epsilon_{sel}$$

  where r is the measured signal yield ratio.
- All decay modes of interest have a rich resonance structure. It therefore becomes necessary to consider the Dalitz space when calculating our efficiencies.
- In mesons invariant mass of daughter pairs is sufficient to parameterise the resonance structure, with baryons spin becomes a concern.

Efficiencies II

- The extension of the 2D Dalitz space in the meson sector to particles with spin incorporates an additional 3 angular parameters to make a 5D phase space.
- Strong resonance structures demonstrated in the sWeighted CF charge-opposite daughter pair invariant masses, below. Strong $K^*(892)$ and $\Lambda(1520)$ contributions can be seen.



CF prompt resonance structure for the TIS dataset.

- Take the reconstruction efficiency from MC with a binning in the 5D phase space such that there should be no strong variation of the resonance structure within each bin.
- Then calculate a bin by bin efficiency to apply to the data.
- Work ongoing in this area.

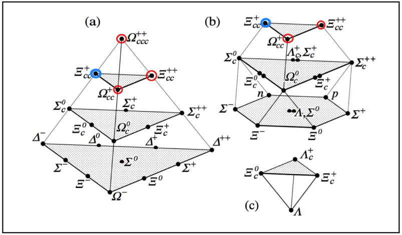
Future Work

- Are finalising an MVA selection for use in searching for the DCS mode.
- BF analysis progressing, moving onto efficiency techniques and calculations.
- Still requires a thorough consideration of physics backgrounds for the DCS mode and systematics for all modes.
- Analysis note currently under construction.
- When finished much of the groundwork for further analyses with Λ_c^+ will already be there.

Double Charm Baryon Searches - Motivation

- Baryons containing u,d,c,s form an SU(4) group, below.

- LHCb expected to produce Ξ_{cc}^{+} copiously:
  $\sigma(pp \to \Xi_{cc}^{+} X) = 300\text{nb}$.



SU(4) generated multiplets of charm baryons. Circled in blue, observed only by SELEX. Red not observed. From PDG [1].

- SELEX [2] measurements of the Ξ_{cc}^{+} properties disagree strongly with theory.
  - SELEX
    - $\tau < 0.33\text{ps}$ at $90\% CL$
    - $0.2\ \Lambda_c^+$ from Ξ_{cc}^{+} decays
  - Theory
    - $\tau < 0.07 - 0.20\text{ps}$
    - $10^{-5}\Lambda_c^+$ from Ξ_{cc}^{+} decays
- Belle, BaBar and FOCUS have searched for and not observed doubly charmed baryon production.

Double Charm Baryon Searches at LHCb

- Multiple decay modes bing stripped, including:
  - $\Xi_{cc}^{+} \rightarrow D^{+}(K^{-}\pi^{+}\pi^{+})p^{+}K^{-}$
  - $\Xi_{cc}^{+} \rightarrow D^{0}(K^{-}\pi^{+})p^{+}K^{-}\pi^{+}$
  - $\Xi_{cc}^{+} \rightarrow \Lambda_{c}^{+}\pi^{+}K^{-}$
  - And the corresponding Ξ_{cc}^{++} modes.
- The Ξ_{cc}^{+} mass window is blinded in the range $3.3 - 3.8$GeV.
- MC created with GenXicc2.0, a dedicated double heavy baryon generator.
- Simulated particle properties:
  - $m_{\Xi_{cc}^{+}} = 3.5$GeV
  - $\tau_{\Xi_{cc}^{+}} = 330$fs
  - $\Gamma_{\Xi_{cc}^{+}} = 7$MeV

Double Charm Baryon Searches at LHCb

- Initial search with 2011 data will use the $\Xi_{cc}^{+} \to \Lambda_c^+ \pi^+ K^-$ mode.
- If found intend to measure the production ratio relative to the Λ_c^+:

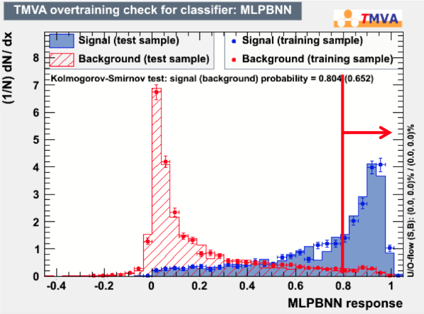
$$\frac{\sigma(\Xi_{cc}^{+}\to\Lambda_c^+ K^- \pi^+)\times\mathcal{B}(\Xi_{cc}^{+}\to\Lambda_c^+ K^- \pi^+)}{\sigma(\Lambda_c^+\to p^+ K^- \pi^+)}$$

- If not found will produce an upper limit for production.
- After this will produce a second paper using the full suite of modes in place and use the 2011 and 2012 data.

Double Charm Baryon Searches - MVA Selection

- Before MVA additional cut applied:
  - Ξ_{cc}^{+} PVFit $\chi^2 < 50$, PVFit χ^2 is the DecayTreeFitter χ^2 with a PV constraint, no mass constraint.
  - Multilayer Perceptron with BFGS training method and bayesian regulator trained on MC for offline selection.

- Variables used in training:
  - Ξ_{cc}^{+} MAXDOCA
  - Ξ_{cc}^{+} IP χ^2
  - Ξ_{cc}^{+} Vertex χ^2
  - Ξ_{cc}^{+} daughter P_t
  - Λ_c^{+} MAXDOCA
  - Λ_c^{+} IP χ^2
  - Λ_c^{+} Vertex χ^2
  - Λ_c^{+} Flight Distance χ^2
  - Ξ_{cc}^{+} PVFit χ^2



MLP response and overtraining plot.

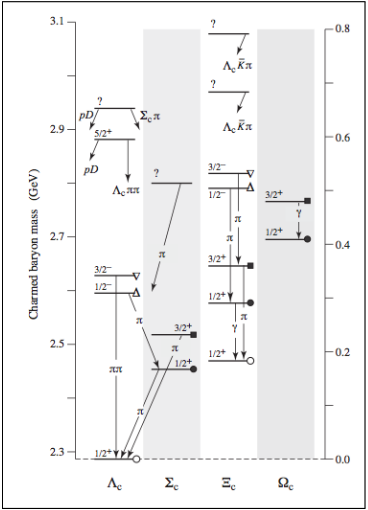
Efficiencies and Preliminary Projections

- Derive all acceptance, reconstruction, trigger and selection efficiencies for signal from the MC.
- Use the cross section with the combined efficiency to predict N_{sig} in the signal region, use sidebands to estimate our N_{bkg}.
- Provisional expected $N_{sig} = 2.5, N_{bkg} = 36$ for data where our efficiency is well defined across a ± 20 mass window (expected signal width between 4-5MeV) - very dependent on assumed cross section.
- We have additional subsamples which are less suitable for a cross section measurement but can be used in an existence search.
- By measuring the ratio of the production of Ξ_{cc} and Λ_c^+ we cancel some systematics.

Double Charm Baryon Searches - Future Work

- MVA selection trained on MC in place.
- Next converge on a fit procedure and limit calculation.
- If we find the particle we can publish the observation and refine our trigger and stripping to reduce our mass window and increase our efficiencies and acquired dataset. If the particle is not found we will produce an upper limit for its production relative to the Λ_c^+.
- Regardless of the outcome we will perform the same analysis on the full set of decay modes of the Ξ_{cc}^+ and Ξ_{cc}^{++} using the full 2011 and 2012 dataset using what we have learned.
- This will use the existing triggers for the D^+ and D^0 modes from 2011 and 2012. Will also use the $\Xi_c^0 -> \Xi^- \pi^+ (\pi^+)$ mode through additional 2012 hyperon triggers. Should make for a more powerful search and analysis.

$D^0 p$ Final State Spectroscopy - Motivation



The spectra of the singly charmed baryons.

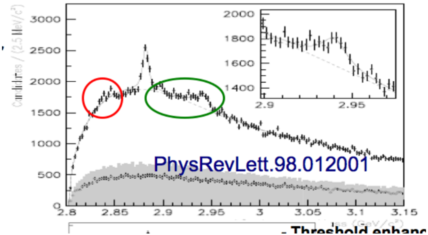
- Spectroscopy of excited charm baryons offers tests of HQET - approximate the heavy baryon as a stationary heavy quark interacting with a light quark dipole.
- $\Lambda_c(2880, 2940) \rightarrow D^0 p$ first observed by BaBar.
- LHCb can make a significant contribution in this area of research.

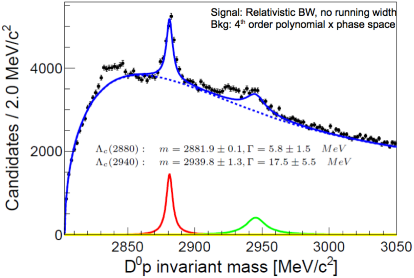
$D^0 p$ Final State Spectroscopy - Cuts and Selection

- Using Stripping 17b prompt $D^0 p$ production.
- Standard set of offline cuts using variables with negligible correlations.
  - $\cos\theta > 0, \theta =$ angle between p momentum in $D^0 p$ frame and boost of $D^0 p$ frame in lab frame. Reduces combinatoric background by more than 95%.
  - All tracks associated to same PV.
  - PID $\mathrm{DLL}_{p-K} < 8$. Soft PID requirements on D^0 daughters.
  - $P_t(D^0 p) > 4.5\mathrm{GeV}$.
- All cuts are going to be optimised in the future using the signal significance of the $\Lambda_c(2880)$.
- Vital to eliminate mis-ID crossfeed, eg. $D_{s2}^{+}(2573) \rightarrow D^0 K$

D^0p Final State Spectroscopy - Mass Spectrum I

- Use same fit model as Babar: relativistic Breit-Wigner distribution for signals and $4th$ order polynomial background.
- Distributions from Babar (left) and LHCb shown below.

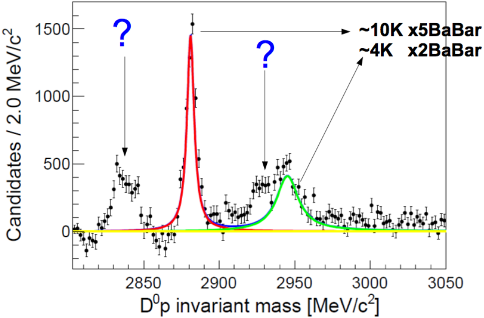




- $\Lambda_c(2880, 2940)$ resonances can be clearly seen in our data, but more structure emerges.

D^0p Final State Spectroscopy - Mass Spectrum II

- Background subtracted mass distribution shown below.



- The nature of this structure is at present unclear.
- Possible explanations include reflections (particularly $D_{s2}^{+}(2573) \rightarrow D^0K$ cross-feed), missing π^0/γ, distortion from pPID cut, clones, threshold enhancement...
- If we can eliminate these possibilities the new peaks may be down to genuine new structures.

D^0p Final State Spectroscopy - Future Work

- Selection Optimisation is underway.
- The auxiliary D*p decay mode requires further study to establish the possibility of crossfeed.
- This will enable us to find out the source of the new structure in the D^0p mass spectra.
- Note is being written, plans to release it to the Charm WG by the end of September.

Concluding Remarks

- Variety of work in progress with charmed baryons at LHCb.
- $\Lambda_c^+ \to p^+ h^- h^+$ BF measurement is finalising an MVA selection. Now dealing with a thorough calculation of the relative efficiencies between the modes. Systematics and background studies for the DCS mode to follow.
- $\Xi_{cc}^{+(++)}$ search has an MVA selection in place for the $\Xi_{cc}^+ \to \Lambda_c^+ K^- \pi^+$ mode. Establishing a fit procedure and limit calculations. Aim to produce either an observation or an upper production limit with the 2011 $\Xi_{cc}^+ \to \Lambda_c^+ \pi^+ K^-$ data. Follow this up with full analysis of all decay modes with 2011 and 2012 data.
- $D^0 p$ final state spectroscopy is working with larger statistics than previous efforts at BaBar. Investigations into potential crossfeed from $D^* p$ decays are underway to establish the sources of the new structures in the spectra observed and whether or not it is some genuine new feature.

$\Lambda_c^+ \to p^+ h^+ h^-$ - Backup I

Prompt $\Lambda_c^+ \to p^+ k^- \pi^+$ TISTOS Info

Pre Dedicated Line

Line	TIS Decision	TOS Decision
Hlt2CharmHadLambdaC2KPPi	0	0
Hlt2Topo2BodyBBDT	0.118	0.004449
Hlt2Topo3BodyBBDT	0.1609	0.0036
Hlt2CharmHadD2HHH	0.09305	0.04902
Hlt2Phys	0.9784	0.09113
Hlt1TrackAllL0	0.6986	0.2601
L0Hadron	0.4626	0.2019

Post Dedicated Line

Line	TIS Decision	TOS Decision
Hlt2CharmHadLambdaC2KPPi	0.08331	0.08101
Hlt2Topo2BodyBBDT	0.1386	0.00475
Hlt2Topo3BodyBBDT	0.1889	0.004049
Hlt2CharmHadD2HHH	0.108	0.04804
Hlt2Phys	0.9774	0.118
Hlt1TrackAllL0	0.791	0.255
L0Hadron	0.5159	0.2295

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$\Lambda_c^+ \rightarrow p^+ h^+ h^-$ - Backup II

Prompt Stripping 17b Cuts

Particle	Cut
All daughter	PT > 400 MeV/c
	P > 3200 MeV/c
	TRCHI2DOF < 5
	BPVIPCHI2() > 4.0
Proton	(StdNoPIDsProtons)
	(PIDp-PIDpi) > 5.0
Kaon	(StdNoPIDsKaons)
	(PIDK-PIDpi) > 5.0
Pion	(StdNoPIDsPions)
	(PIDK-PIDpi) < 0.0
pKpi comb	ADAMASS('Lambda_c+') < 90.0 MeV/c^2
	ADOCAMAX('') < 0.1 mm
	AMAXCHILD(BPVIPCHI2()) > 8.0
	AMAXCHILD(PT) > 1200.0 MeV/c
Lambda_c	VFASPF(VCHI2/VDOF) < 20
	BPVVDCHI2 > 16
	BPVDIRA > 0.9999
	0.0 < BPVLTIME('PropertimeFitter/properTime:PUBLIC') < 1.2 * ps
Trigger:	Hlt2Global%TIS

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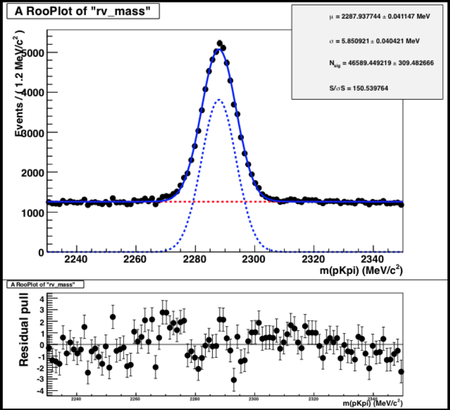
TOS chain Massfit



- Nsig = 46589 ± 309
- Fraction of signal retained = (10.5 ± 0.1)%

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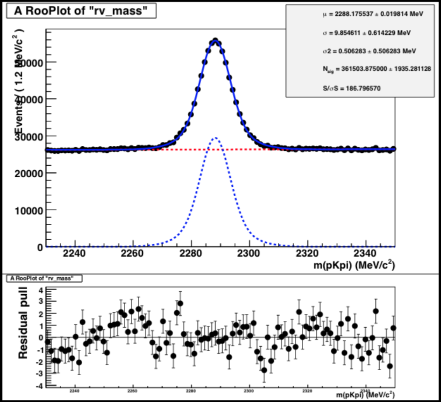
$\Lambda_c^+ \to p^+ h^+ h^-$ - Backup IV

TIS Chain Massfit



- Nsig = 361503 ± 1935
- Fraction of signal retained = (81.6 ± 0.9)%

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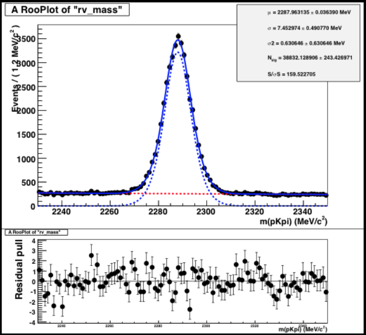
TOS Offline Selection

- Optimum CF cuts:
  - (Proton_PIDp-Proton_PIDK) > 7
  - Proton_PIDp > 12
  - Kaon_PIDK > 6
  - Lambdac_ENDVERTEX_CHI2 < 22
  - Lambdac_FDCHI2_OWNPV > 42
  - Lambdac_PT > 2200MeV
- CF Final Nsig = 38832 ± 243
- CF Final Fraction of Raw yield = (8.77 ± 0.7)%



- Optimum DCS cuts:
  - (Proton_PIDp-Proton_PIDK)> 12
  - Proton_PIDp > 17.5
  - Kaon_PIDK > 11
  - Lambdac_ENDVERTEX_CHI2 < 14
  - Lambdac_FDCHI2_OWNPV > 44
  - Lambdac_PT > 1000MeV
- DCS weighted Nsig = 79.8 ± 0.529
- DCS weighted Nbkg = 1.02e+04 ± 121
- S/sqrt(S+B) in mass region = 1.55

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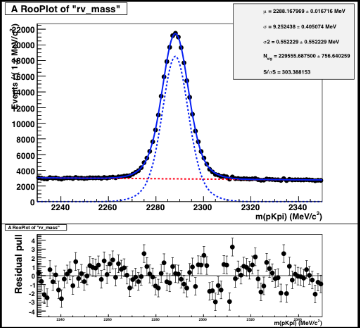
TIS Offline Selection

- Optimum CF cuts:
  - (Proton_PIDp-Proton_PIDK) > 9
  - Proton_PIDp > 14
  - Kaon_PIDK > 9
  - Lambdac_ENDVERTEX_CHI2 < 17
  - Lambdac_FDCHI2_OWNPV > 30
  - Lambdac_PT > 3000MeV



- CF Final Nsig = 229555± 756
- CF Final Fraction of Raw yield = (51.86 ± 0.35)%

- Trained on 10% of data
- Optimum DCS cuts:
  - (Proton_PIDp-Proton_PIDK)> 14
  - Proton_PIDp > 20
  - Kaon_PIDK > 13.5
  - Lambdac_ENDVERTEX_CHI2 < 9
  - Lambdac_FDCHI2_OWNPV > 34
  - Lambdac_PT > 3400MeV
- DCS weighted Nsig = 31.8 ± 0.349
- DCS weighted Nbkg = 3.64e+03 ± 81.1
- S/sqrt(S+B) in mass region = 1.03
- S/sqrt(S+B) scaled up to full TIS sample = 3.27

CAVEAT! All DCS significances are calculated using sWeights,

9/4/12 Prompt Lc Update - Stephen Ogilvy 13

$\Lambda_c^+ \to p^+ h^+ h^-$ - Backup VII

TIS vs TOS – After CROP Selection

Trigger Chain	CF Fraction of Raw Preserved	CF Significance	DCS Significance
TOS	(8.77 ± 0.7)%	159.5	1.55
TIS	(51.86 ± 0.35)%	303.3	3.27

- Obvious advantage in all areas to using the TIS chain.
- Will reexamine these numbers when we have our MVA finalised.

Stripping and selection cuts
SEMILEPTONIC stream

Tracks
- TRCHI2DOF<4
- p_T >0.3GeV/c
- P >2.0GeV/c
- MIPCHI2DV >4

Muon
- p_T >0.8GeV/c
- P >3.0GeV/c
- TRCHI2DOF <5
- MIPCHI2DV >9
- PIDmu >0

Pion:
- dllK <10

Kaon:
- dllK >4

Proton:
- dllP >4
- dllP-dllK>0

Combination
- SumPt >1.8GeV/c
- ADOCACHI2CUT = 20
- VFASPF(VCHI2/VDOF) < 6
- BPVVDCHI2 >100
- SUMTREE(PT, ISBASIC) >1.8GeV/c
- BPVDIRA >0.99

Stripping Line implemented for 17b by Mika

Offline selection
- 3.5 < Bmass/GeV < 5.3 *
- $p_T(\Lambda_c)$ > 1.5GeV/c
- dllK(K) > 10, dllK(π) <-5, dllP(p)-dllK(p)>10
- $p_T(\mu)$ > 1.8GeV/c
- lifetime(Λ_c) >0
- right sign DCS: charge(K)*charge(μ) <0 *
- right sign CF: charge(K)*charge(μ) >0

SL B-decays especially efficient for Λ_c ,

Double Charm Baryons - Backup I

Theoretical predictions for Ξ_{cc}^{+} mass

- Steal from Matt's slide

arXiv:1001.4693

References	Ξ_{cc}	Ω_{cc}	Ξ_{bb}	Ω_{bb}
[5]	3.620	3.778	10.202	10.359
[7]	3.676	3.815	10.340	10.454
[8]	3.612	3.702	10.197	10.260
[11]	3.579	3.697	10.189	10.293
[12]	3.48	3.59	10.09	10.18
[13]	3.547	3.648	10.185	10.271
[14]	3.520	3.619	10.272	10.369
[15]	3.48		9.94	
[16]	4.26	4.25	9.78	9.85
[32]	3.5189	?	?	?
This work	3.57 ± 0.14	3.71 ± 0.14	10.17 ± 0.14	10.32 ± 0.14
[7]*	3.910	4.046	10.493	10.616

Double Charm Baryons - Backup II

StrippingXicc in S17

Selections in StrippingXicc.py								
Ξ_{cc}^{+}	APT > 2 GeV	VFASPF(VCHI2) < 30.	BPVVDCHI2 > 16	M < 4.5GeV	CHILD(1,VFASPF(VZ))-VFASPF(VZ) > 0.01mm	BPVDIRA > 0.999	74 (47)	5%
K^{-}	P > 2GeV	PIDK-PIDpi > 5.0	TRCHI2DOF < 4.0	Pt > 0.25GeV	MIPCHI2DV(PRIMARY) > 4.0		109 (65)	7%
π^{+}	P> 2GeV	PIDpi-PIDK > 0.0	TRCHI2DOF < 4.0	Pt > 0.25GeV	MIPCHI2DV(PRIMARY) > 4.0			
Λ_c^{+}			BPVVDCHI2 > 25	2.185GeV< M < 2.385GeV	NINGENERATION((MIPCHI2DV(PRIMARY)>30.),1) >= 1	BPVDIRA > 0.95	419 (217)	26%
p		PIDp-PIDpi > 5.0		TRCHI2DOF < 4.0 (MIPCHI2DV(PRIMARY) > 4.0)			1157 (303)	71%
K^{-}		PIDK-PIDpi > 5.0		TRCHI2DOF < 4.0 (MIPCHI2DV(PRIMARY) > 4.0)				
π^{+}		PIDpi-PIDK > 0.0		TRCHI2DOF < 4.0 (MIPCHI2DV(PRIMARY) > 4.0)				
							1623	100%

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Double Charm Baryons - Backup III

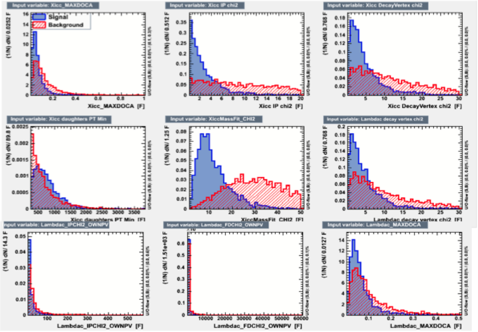
Offline cuts and MVA sample

- Offline cuts
  - Proton: PIDp > 10
  - Kaon: PIDK > 10
  - Pion: PIDK < -5
  - Ξ_{cc}^{+} IP $\chi^2 < 20$
  - Ξ_{cc}^{+} PV $\chi^2 < 50$
  - Λ_c^{+} mass window: $\pm$40MeV
- MVA Samples

	Signal	Background
Source	Ξ_{cc}^{+} MC	Sideband
Size	3690	5000

Double Charm Baryons - Backup IV

The Variables in MLP



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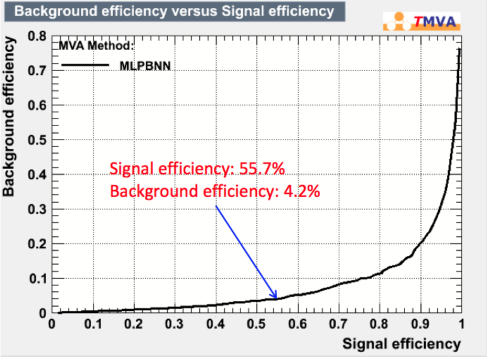
Double Charm Baryons - Backup V

The TMVA cut

- The TMVA cut is chosen to be 0.8(Without optimization)



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