

# RC - $\Lambda_c^+ \rightarrow phh'$ secondary fractions



Stephen Ogilvy

University of Glasgow



Proponents: Stephen Ogilvy, Paul Soler, Patrick Spradlin

- Glasgow analysis which attained WG sign off in early December:
  - Measuring the following quantities:

$$\mathcal{B}(\Lambda_c^+ \rightarrow pK^- K^+)/\mathcal{B}(\Lambda_c^+ \rightarrow pK^- \pi^+)$$

$$\mathcal{B}(\Lambda_c^+ \rightarrow p\pi^- \pi^+)/\mathcal{B}(\Lambda_c^+ \rightarrow pK^- \pi^+)$$

$$\mathcal{B}(\Lambda_c^+ \rightarrow p\pi^- K^+)/\mathcal{B}(\Lambda_c^+ \rightarrow pK^- \pi^+)$$

- Analysis makes independent measurements with two sources of  $\Lambda_c$ :
  - those promptly produced
  - from semileptonic  $\Lambda_b^0 \rightarrow \Lambda_c^+(pK^- \pi^+)\mu^- \bar{\nu}_\mu$ .
- DCS mode blind in both channels in this analysis.
- Using full 2011 dataset at  $\sqrt{s} = 7$  TeV
- Stripping17b, Reco14.
- Most recent ANA version [here](#).

# Current results

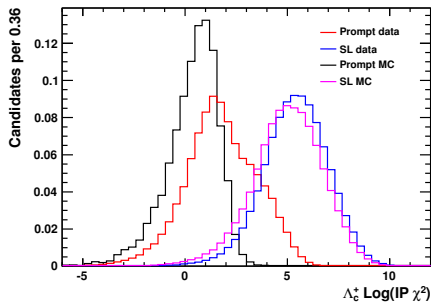
- At present:

Measurement	Prompt [%]	Semileptonic TOS [%]
$\frac{\mathcal{B}(\Lambda_c^+ \rightarrow pK^- K^+)}{\mathcal{B}(\Lambda_c^+ \rightarrow pK^- \pi^+)}$	$2.03 \pm 0.07 \pm 0.10$	$1.68 \pm 0.03 \pm 0.07$
$\frac{\mathcal{B}(\Lambda_c^+ \rightarrow p\pi^- \pi^+)}{\mathcal{B}(\Lambda_c^+ \rightarrow pK^- \pi^+)}$	$7.04 \pm 0.19 \pm 0.34$	$7.45 \pm 0.06 \pm 0.24$
$\frac{\mathcal{B}(\Lambda_c^+ \rightarrow pK^- K^+)}{\mathcal{B}(\Lambda_c^+ \rightarrow p\pi^- \pi^+)}$	$28.81 \pm 1.29 \pm 1.73$	$22.59 \pm 0.40 \pm 0.90$

- Efforts with efficiencies have improved agreement significantly.
- $\mathcal{B}(\Lambda_c^+ \rightarrow p\pi^- \pi^+)/\mathcal{B}(\Lambda_c^+ \rightarrow pK^- \pi^+)$  agree within error -  $0.9 \sigma$ .
- But  $\mathcal{B}(\Lambda_c^+ \rightarrow pK^- K^+)/\mathcal{B}(\Lambda_c^+ \rightarrow pK^- \pi^+)$  disagree at  $2.6 \sigma$  level.

# Secondary contamination

- Our selections very similar to 2011 x-sec analysis.
- Secondary contamination in that analysis was investigated and ruled out.
  - *Is the 2011 x-sec also affected?*
- Shown -  $\Lambda_c^+ \rightarrow pK^-\pi^+$   $\log(IP\chi^2)$  distributions for prompt and SL data/MC.
- Distributions of real data acquired with  $s\mathcal{P}lots$ .
- Clear and significant secondary contamination in the prompt sample.



# $IP\chi^2$ modelling

- Bukin function: a Novosibirsk function with extended tail functions.

$$B(x; \mu; \sigma; \xi; \rho_1; \rho_2) = \begin{cases} \exp \left[ \rho_1 \frac{(x-x_1)^2}{(x-x_1)^2} + \frac{(\mu-x_1)\xi\sqrt{\xi^2+1}\cdot\sqrt{2\log 2}}{\sigma(\sqrt{\xi^2+1}-\xi)^2 \log(\sqrt{\xi^2+1}+\xi)} - \log 2 \right] & x < x_1 \\ \exp \left[ -\log 2 \cdot \left[ \frac{\log \left( 1+2\xi\sqrt{\xi^2+1}\cdot\frac{x-\mu}{\sigma\sqrt{2\log 2}} \right)}{\log \left( 1+2\xi(\xi-\sqrt{\xi^2+1}) \right)} \right]^2 \right] & x_1 < x < x_2 \\ \exp \left[ \rho_2 \frac{(x_2-x)^2}{(x_2-\mu)^2} + \frac{(x_2-x)\xi\sqrt{\xi^2+1}\cdot\sqrt{2\log 2}}{\sigma(\sqrt{\xi^2+1}-\xi)^2 \log(\sqrt{\xi^2+1}+\xi)} - \log 2 \right] & x > x_2 \end{cases}$$

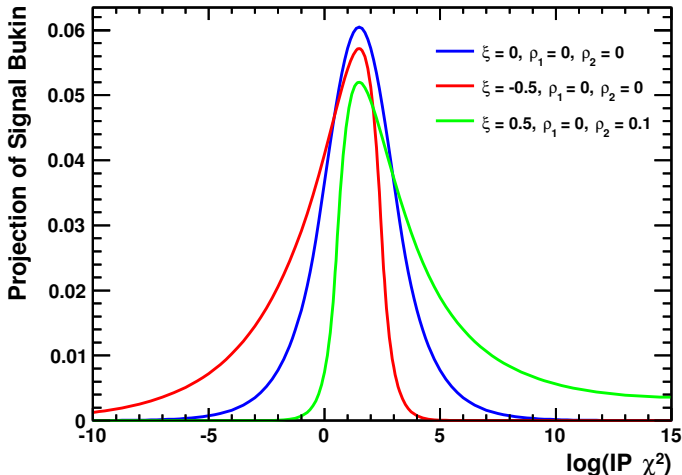
- $\sqrt{2\log 2}\sigma$  is FWHM,  $\xi$  is assymetry parameter,  $\rho$  are tail parameters.
- $x_1$  and  $x_2$  are turnover points where function has half max value.

$$x_1 \equiv \mu + \sigma\sqrt{2\log 2} \left( \frac{\xi}{\sqrt{\xi^2+1}} - 1 \right)$$

$$x_2 \equiv \mu + \sigma\sqrt{2\log 2} \left( \frac{\xi}{\sqrt{\xi^2+1}} + 1 \right)$$

# Example Bukin functions

- To aid in visualisation, some example Bukin functions.
- All have a mean and width of 1.5 but varying asymmetry and tail parameters.

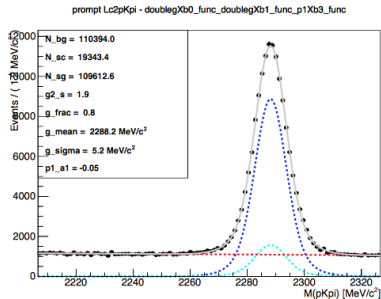


# Strategy for 2D prompt yield extractions

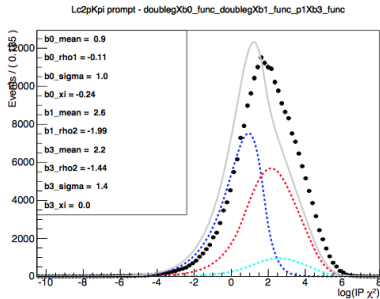
- Simultaneous fit to the  $\Lambda_c$  mass and  $\log(IP\chi^2)$ .
- Described in detail [in our last WG talk](#).
- Semileptonic data/MC comparison shows that secondaries are likely modelled better than prompt.
- So allow prompt  $\log(IP\chi^2)$  distribution as much freedom as possible.
- Prompt  $\rho_2$  parameter has high errors in fits - region is dominated by secondaries. Fixed to value from simulation.
- Secondary mean floated, all other parameters fixed to values from simulations.
- In CS modes, also constrain the lower prompt tail to aid fit convergence.
- 3-component fits under these conditions converge for all modes.

# 3-component fit for $\Lambda_c^+ \rightarrow pK^-\pi^+$ - initial conditions

- Initial conditions taken from simulation fits.
- Initial assumption of secondary fraction - 15 %.
- Shown - data with initial condition PDFs.



(a)

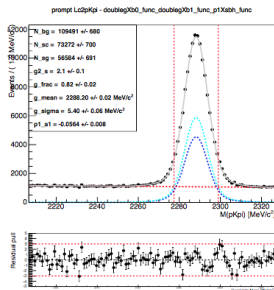


(b)

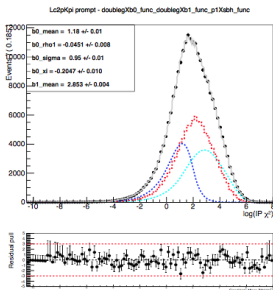


# 3-component fit for $\Lambda_c^+ \rightarrow pK^-\pi^+$

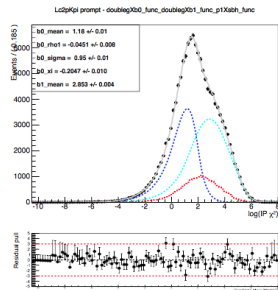
- Fit converges with accurate error matrix.
- Histogram PDF combinatoric and Bukin combinatoric compatible.
- (a) mass, (b)  $\log(IP\chi^2)$ , (c)  $\log(IP\chi^2)$  projections in signal region.
- Secondary fraction is fitted to large value.
- Large combinatoric component in Cabibbo-suppressed modes - fits do not converge.



(a)



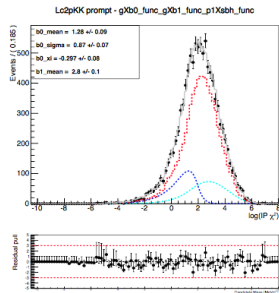
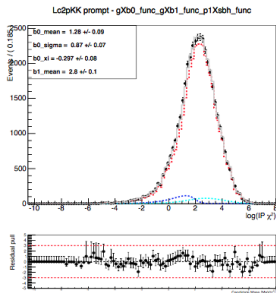
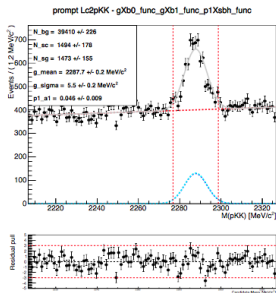
(b)



(c)

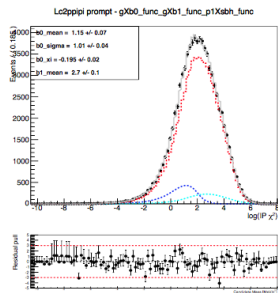
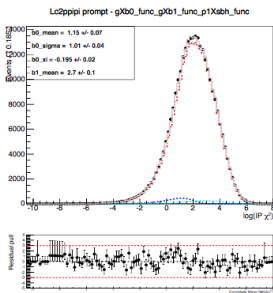
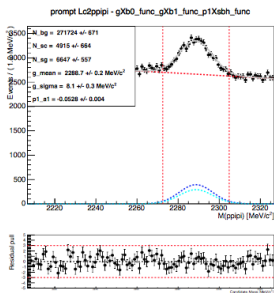
# 3-component fit for $\Lambda_c^+ \rightarrow pK^-K^+$

- Very high statistical errors on prompt yields - 10.5 %.
- Compare to  $\Lambda_c^+ \rightarrow pK^-K^+$  statistical error from fit to  $m(\Lambda_c^+)$  - 4 %.



# 3-component fit for $\Lambda_c^+ \rightarrow p\pi^-\pi^+$

- $\Lambda_c^+ \rightarrow p\pi^-\pi^+$  stat error rises from 3 % in 1D fit to 8.3 %.

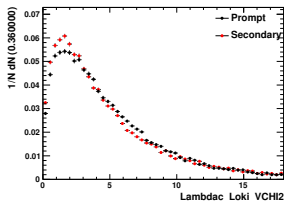


# Cross checks on 17b fits

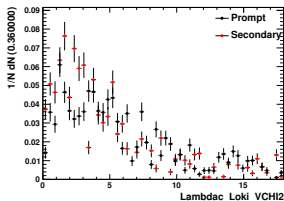
- Attempts to lower statistical uncertainties by reducing backgrounds not successful.
- So, with these fits, does the analysis work?
- Used the weights from  $s\mathcal{P}lots$  to acquire distributions of variables uncorrelated with either  $\Lambda_c$  mass or  $\log(IP\chi^2)$ , and the forms of the distributions are known to some degree.
- For example:
  - $\Lambda_c$  daughter kinematics -  $p$ ,  $p_T$ ,  $\eta$  etc.
  - $\Lambda_c$  vertex quality.
- If the weights don't reproduce the control distributions

# Cross checks on 17b fits - $\Lambda_c$ vertex $\chi^2$

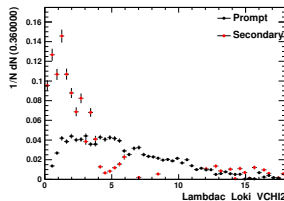
- Linear scale top, log bottom.
- Distributions in CF look sensible, others are clearly incorrect.
- $\Lambda_c^+ \rightarrow p\pi^-\pi^+$  is clearly wrong.



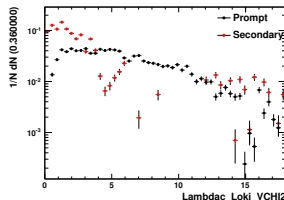
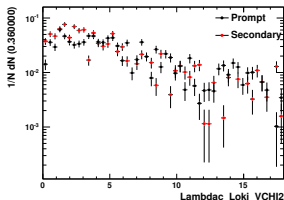
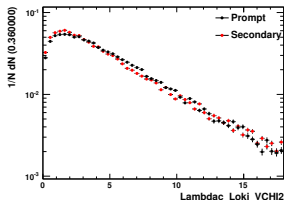
$$\Lambda_c^+ \rightarrow pK^-\pi^+$$



$$\Lambda_c^+ \rightarrow pK^-K^+$$

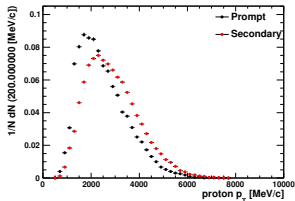


$$\Lambda_c^+ \rightarrow p\pi^-\pi^+$$

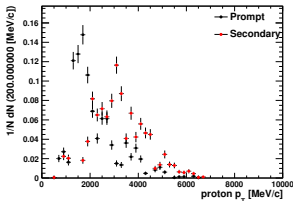


# Cross checks on 17b fits - proton $p_T$

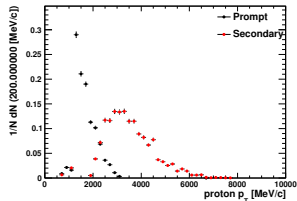
- Proton kinematics equally non-sensical in CS.
- Strong evidence that *these yield extractions do not work at present.*



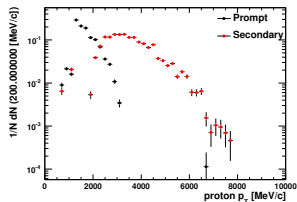
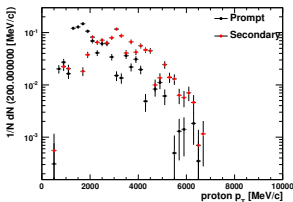
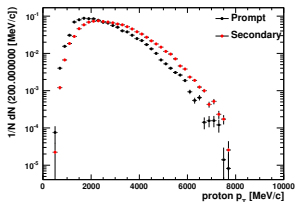
$$\Lambda_c^+ \rightarrow pK^- \pi^+$$



$$\Lambda_c^+ \rightarrow pK^- K^+$$



$$\Lambda_c^+ \rightarrow p\pi^- \pi^+$$



# What causes the fits to fail?

- That the fits appear to work in the CF channel but not the CS - issue with low signal on top of high combinatoric.
- Analysis procedure relies on reliable extraction of data distributions:
  - $\Lambda_c$  daughter kinematics for PIDCalib.
  - $\Lambda_c$  helicity variables for efficiency re-weighting.
- Without these the BF analysis is subject to potentially large and unquantifiable systematics.
- Higher signal statistics and lower backgrounds could remedy the fits.

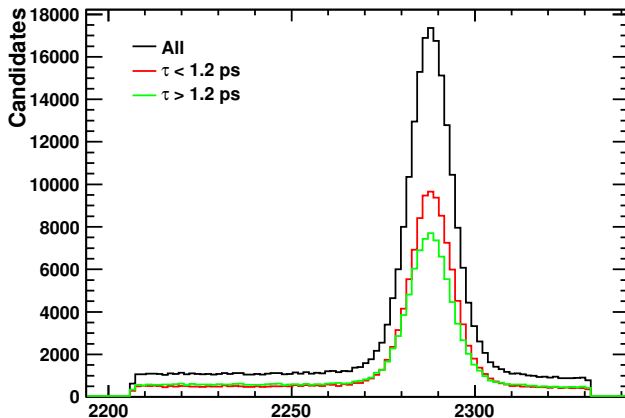
# Prompt Stripping 21r1 vs Stripping 17b

- Lack of high  $p_T$  proton PID calibration samples in 17b necessitates candidate vetoes which get rid of around 30 % signal.
  - Unavoidable in 17b, as PID cuts are in stripping lines.
- But in Stripping 20 onwards we have the  $\Lambda_c$  proton PID calibration data - no need for vetoes.
- In checking newer lines discovered something even more interesting in 21r1.
- 17b and 20 selections imply a maximum lifetime cut on the  $\Lambda_c$  candidate of 1.2 ps (about  $6\tau(\Lambda_c)$ ).
- *But no max lifetime cut in 21r1.*



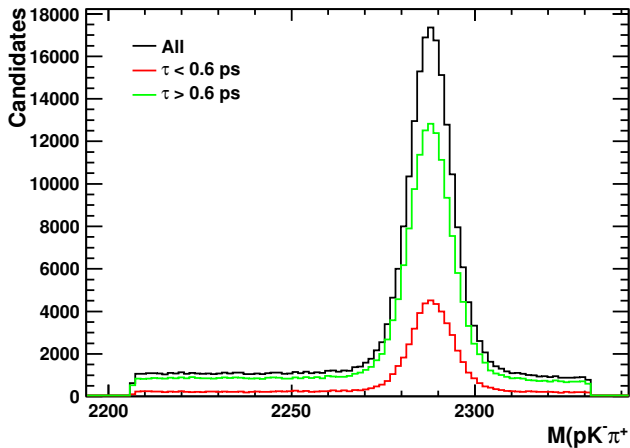
# Stripping 21r1 prompt $\Lambda_c^+ \rightarrow pK^-\pi^+$

- Reapplied the prompt selection on the 21r1 data with no proton vetoes for PIDCalib.
- Shown - all  $\Lambda_c$ , and below/above 1.2 ps.
- Almost as much signal above 1.2 ps as below.
- A clear mass dependence on lifetime can also be seen.



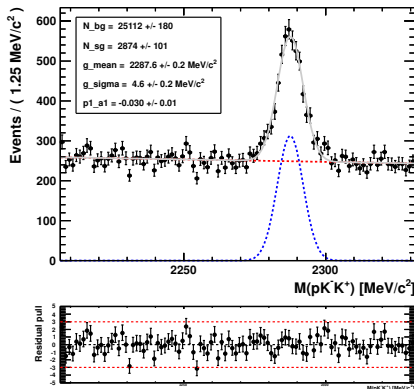
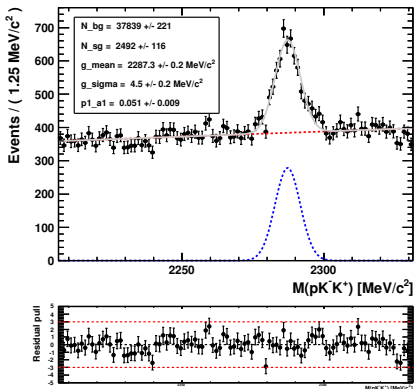
# Stripping 21r1 prompt $\Lambda_c^+ \rightarrow pK^-\pi^+$ - II

- Shown - distributions below and above 0.6 ps.
- Expect 99.9 % of prompt candidates to fall below this threshold.
- So effectively all signal under the green curve is secondary!



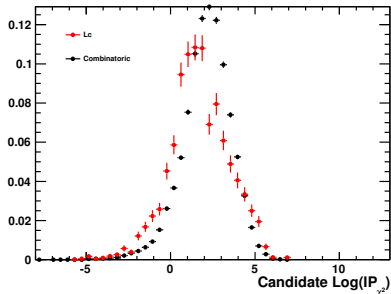
# 17b vs 21r1 - $\Lambda_c^+ \rightarrow pK^-K^+$ $\Lambda_c$ mass distributions

- Reoptimised PID selection - 21r1 favours tighter values because more overall signal.
  - Only concern is we cut away at the prompt, so prompt yield will be lower.
  - But what yield is there is useless if we can't fit it!
- 21r1 (right) selection is much more pure and higher signal, but should contain less prompt than 17b.

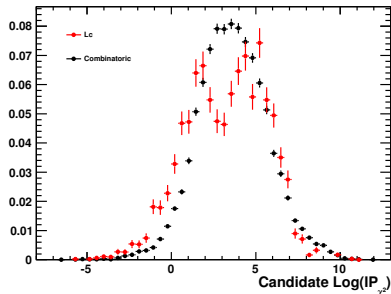


# 17b vs 21r1 - $\Lambda_c^+ \rightarrow pK^-K^+$ $\log(IP\chi^2)$ distributions

- Fit the  $\Lambda_c$  mass and use  $s\mathcal{P}lots$  to get the  $\Lambda_c \log(IP\chi^2)$  distributions for  $\Lambda_c^+ \rightarrow pK^-K^+$ .
- Shows us the union of prompt and secondary. Can we see features more easily?
- Structure much more clear in 21r1 - prompt and secondary peaks now visible.
- 2D fit to 21r1 should have much more power than for 17b.



17b



21r1