RC - $\Lambda_c^+ \to phh'$ secondary fractions

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Analysis overview

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

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

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

Current results

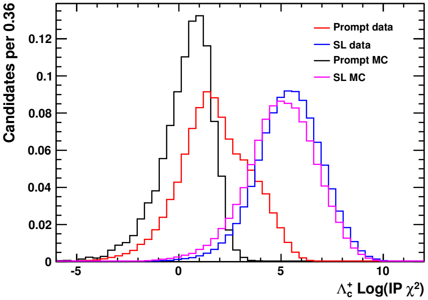
- At present:

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

- Efforts with efficiencies have improved agreement significantly.
- $\mathcal{B}(\Lambda_c^+ \to p\pi^-\pi^+)/\mathcal{B}(\Lambda_c^+ \to pK^-\pi^+)$ agree within error - 0.9 σ.
- But $\mathcal{B}(\Lambda_c^+ \to pK^-K^+)/\mathcal{B}(\Lambda_c^+ \to pK^-\pi^+)$ disagree at 2.6 σ 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 - $\Lambda_c^+ \to pK^-\pi^+$ $\log(IP\chi^2)$ 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.

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

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

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

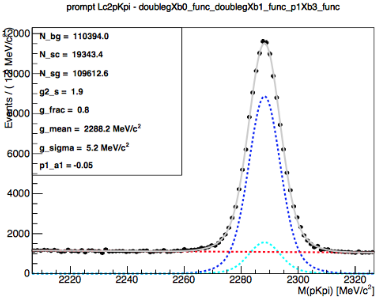
$$x_2 \equiv \mu + \sigma\sqrt{2\log 2}\left(\frac{\xi}{\sqrt{\xi^2+1}} + 1\right)$$

Strategy for Bukin fits to data

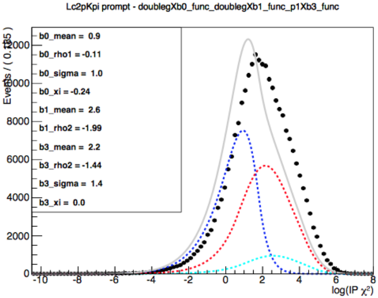
- Described in detail in our last WG talk.
- Semileptonic data/MC comparison shows that secondaries are likely modelled better than prompt.
- So allow prompt $\log(IP\chi^2)$ distribution as much freedom as possible.
- Prompt ρ_2 parameter has high errors in fits - region is dominated by secondaries. 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 $\Lambda_c^+ \to pK^-\pi^+$- initial conditions

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



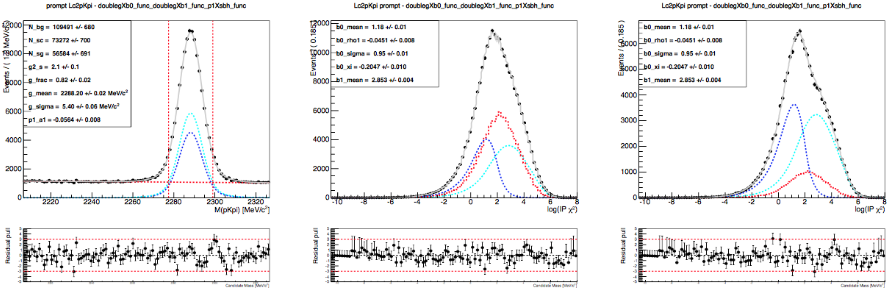
(a)



(b)

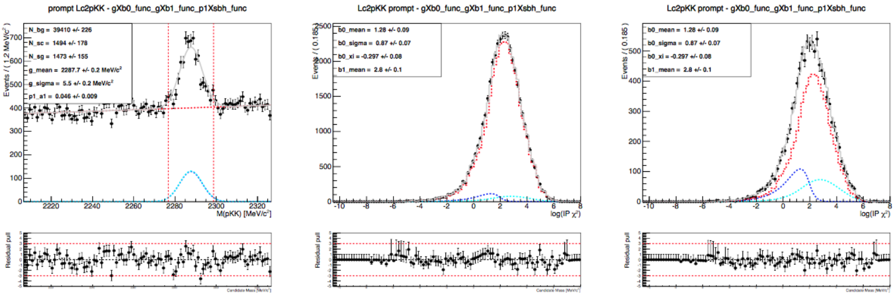
3-component fit for $\Lambda_c^+ \to pK^-\pi^+$

- 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.



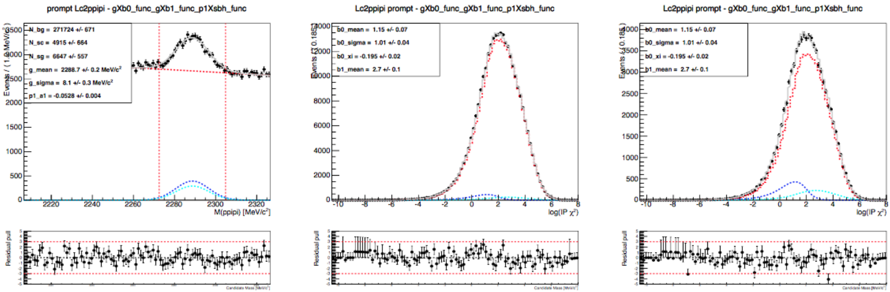
(a) (b) (c)

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



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

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

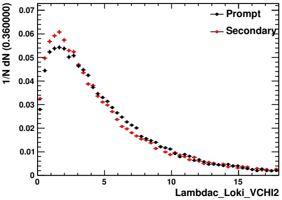


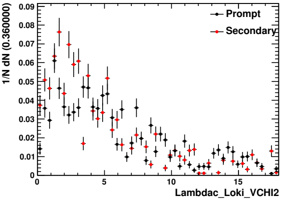
Cross checks on 17b fits

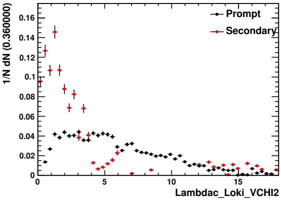
- Attempts to lower statistical uncertainties by reducing backgrounds not successful.
- So, with these fits, does the analysis work?
- Used the weights from ${}_s\mathcal{P}lots$ to acquire distributions of variables uncorrelated with either Λ_c mass or $\log(IP\chi^2)$, and the forms of the distributions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

Cross checks on 17b fits - Λ_c vertex χ^2

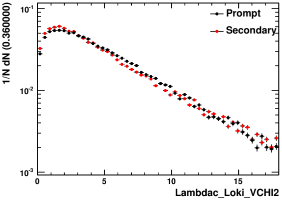
- Linear scale top, log bottom.
- Distributions in CF look sensible, others are clearly incorrect.
- $\Lambda_c^+ \to p\pi^-\pi^+$ is clearly wrong.

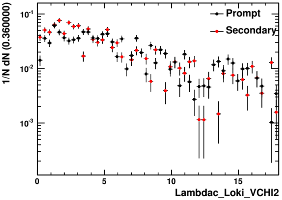


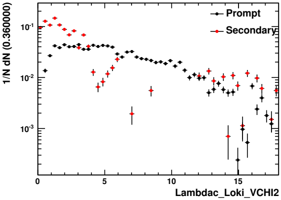




$\Lambda_c^+ \to pK^-\pi^+$ $\Lambda_c^+ \to pK^-K^+$ $\Lambda_c^+ \to p\pi^-\pi^+$

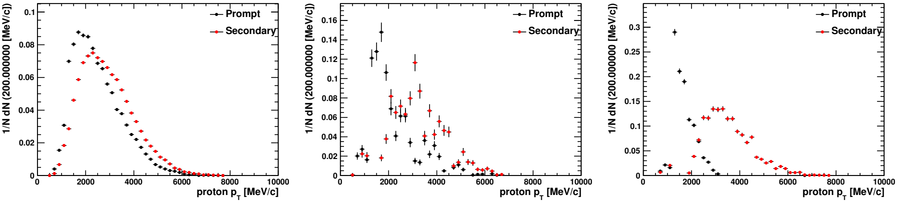




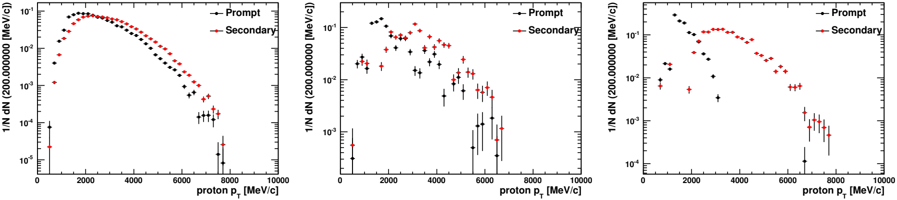


Cross checks on 17b fits - proton p_{T}

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



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



What causes the fits to fail?

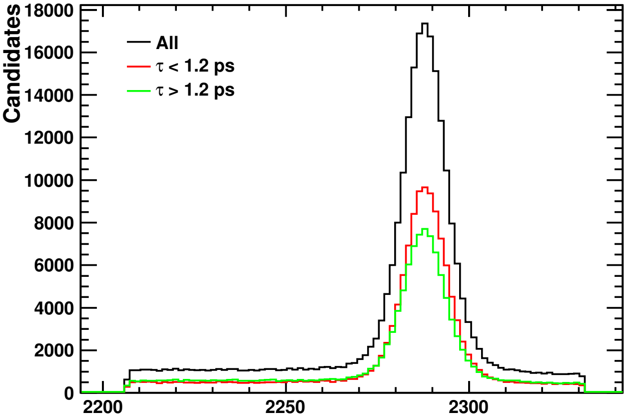
- That the fits appear to work in the CF channel but not the CS - issue with low signal on top of high combinatoric.
- Analysis procedure relies on reliable extraction of data distributions:
  - Λ_c daughter kinematics for `PIDCalib`.
  - Λ_c helicity variables for efficiency re-weighting.
- Without 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 Λ_c proton PID calibration data - no need for vetoes.
- In checking newer lines discovered something even more interesting in 21r1.
- 17b and 20 selections emply a maximum lifetime cut on the Λ_c candidate of 1.2 ps (about $6\tau(\Lambda_c)$).
- *But no max lifetime cut in 21r1.*

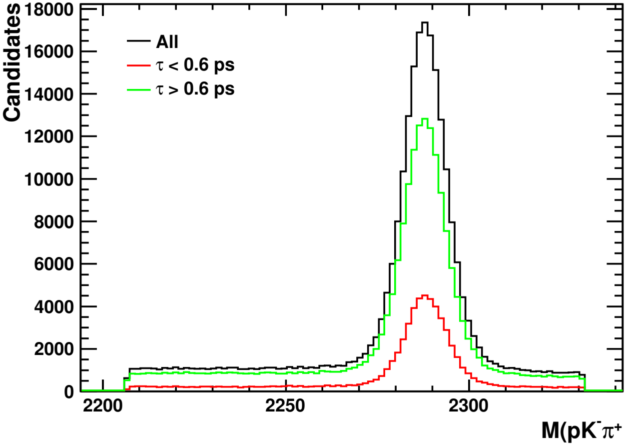
Stripping 21r1 prompt $\Lambda_c^+ \to pK^-\pi^+$

- Reapplied the prompt selection on the 21r1 data with no proton vetoes for `PIDCalib`.
- Shown - all Λ_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.



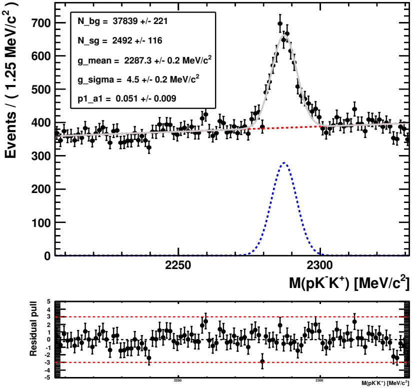
Stripping 21r1 prompt $\Lambda_c^+ \to pK^-\pi^+$- II

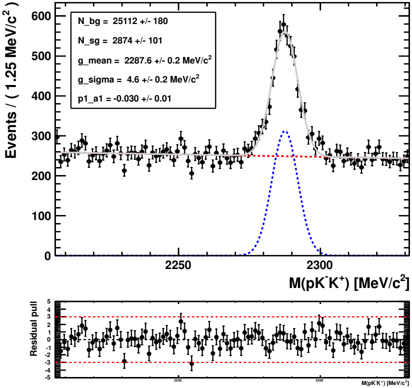
- Shown - distributions below and above 0.6 ps.
- Expect 99.9 % of prompt candidates to fall below this threshold.
- So effectively all signal under the green curve is secondary!



17b vs 21r1 - $\Lambda_c^+ \to pK^-K^+$ Λ_c mass distributions

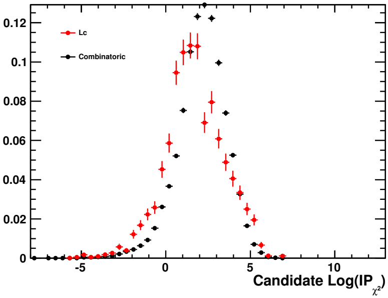
- Reoptimised PID selection - 21r1 favours tighter values because more overall signal.
    - Only concern is we cut away at the prompt, so prompt yield will be lower.
    - But what yield is there is useless if we can't fit it!
- 21r1 (right) selection is much more pure and higher signal, but should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



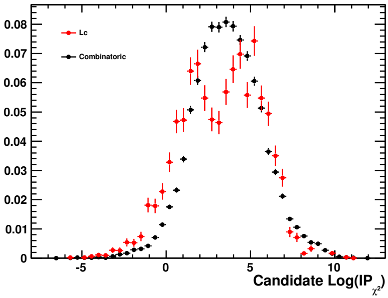


17b vs 21r1 - $\Lambda_c^+ \to pK^-K^+$ log($IP\chi^2$) distributions

- Fit the Λ_c mass and use $_s\mathcal{P}lots$ to get the Λ_c log($IP\chi^2$) distributions for $\Lambda_c^+ \to pK^-K^+$.
- Shows us the union of prompt an 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