Prompt $\Lambda_c^+ \to p^+h^+h^-$ Update

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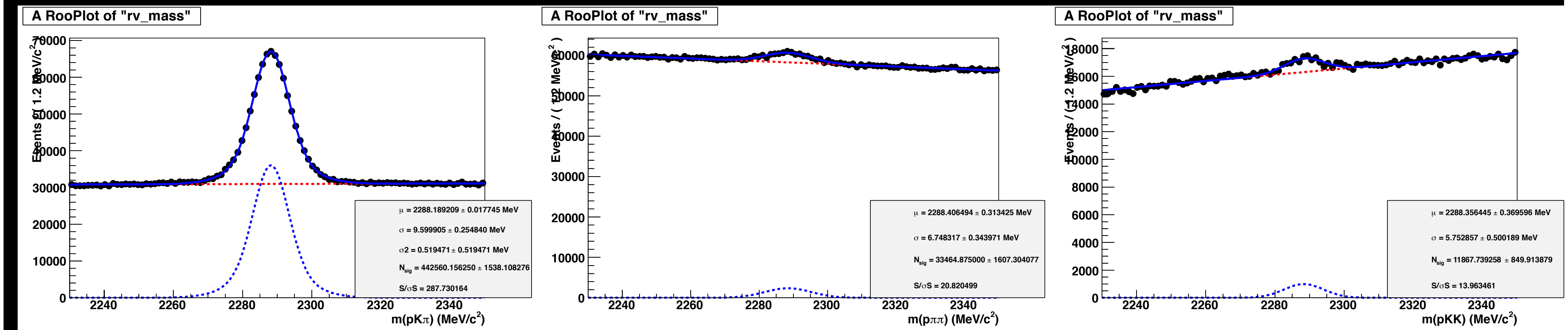
Recap

- It is our intention to make a relative BF measurement of the prompt $\Lambda_c^+ \to p^+h^+h^-$ decay modes.
- This incorporates a search for the DCS mode $\Lambda_c^+ \to p^+K^+\pi^-$, which is currently blinded.
- Have previously shown raw yields for the prompt and semileptonic CF and SCS modes in Stripping 17b.
- Below: raw prompt yields for (left to right) pkπ, pππ, pKK.



Trigger Chain – TIS vs TOS

- TIS – L0, HLT1, HLT2Phys TIS.
  - Highest raw yield
  - Smallest bias on Dalitz space
  - trigger conditions inconsistent over time
  - less pure signal
- TOS – L0 TIS, Hlt2CharmHadLambdaC2KPPi TOS
  - Cleaner but less yield.
  - Large Potential Biases in Dalitz space but consistent trigger conditions with time.
- Decide on chain using 2 quantitative metrics:
  - fraction of raw signal retained
  - Dalitz space flatness χ^2 of offline selection

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

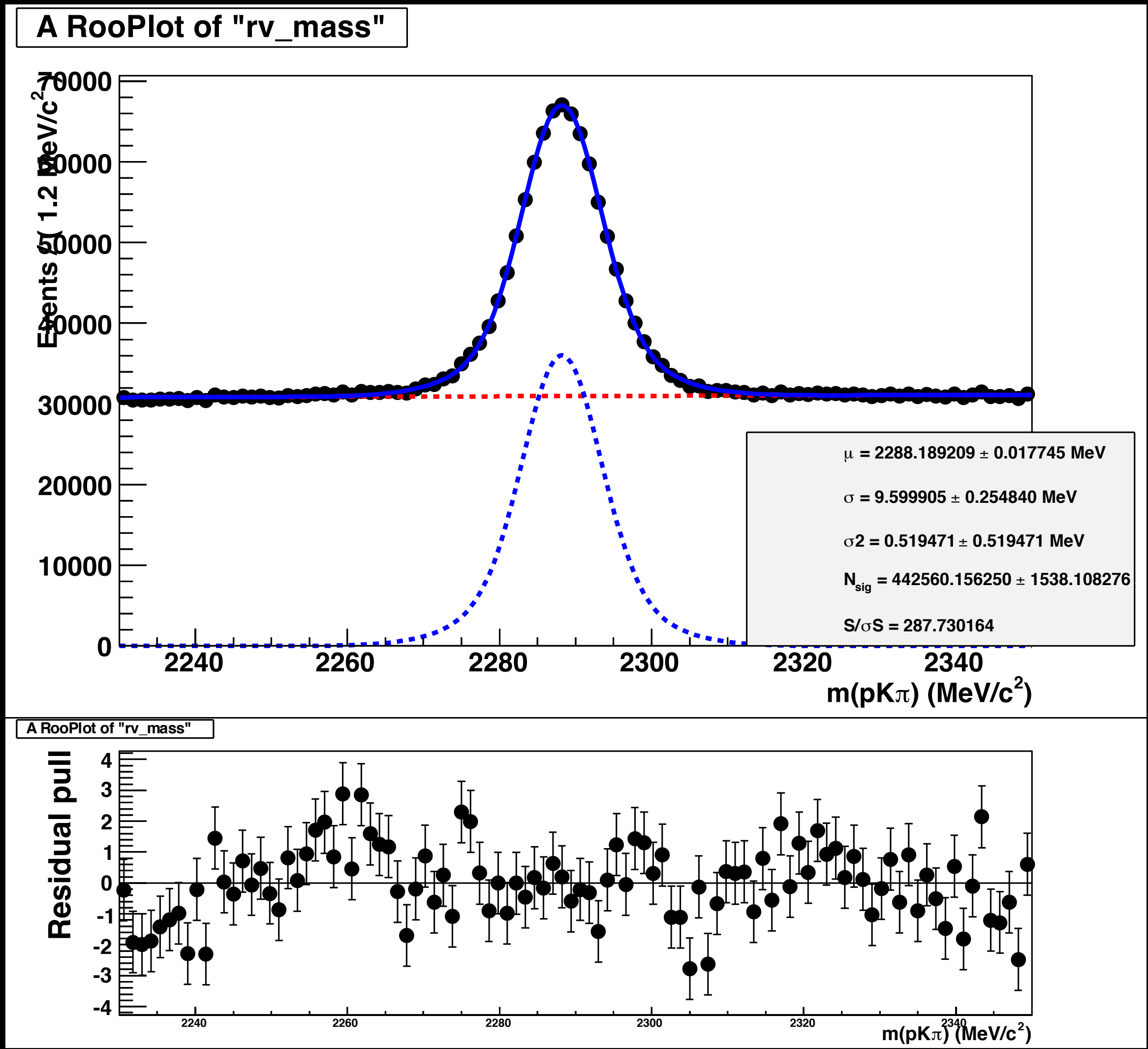
Pre Dedicated Line

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

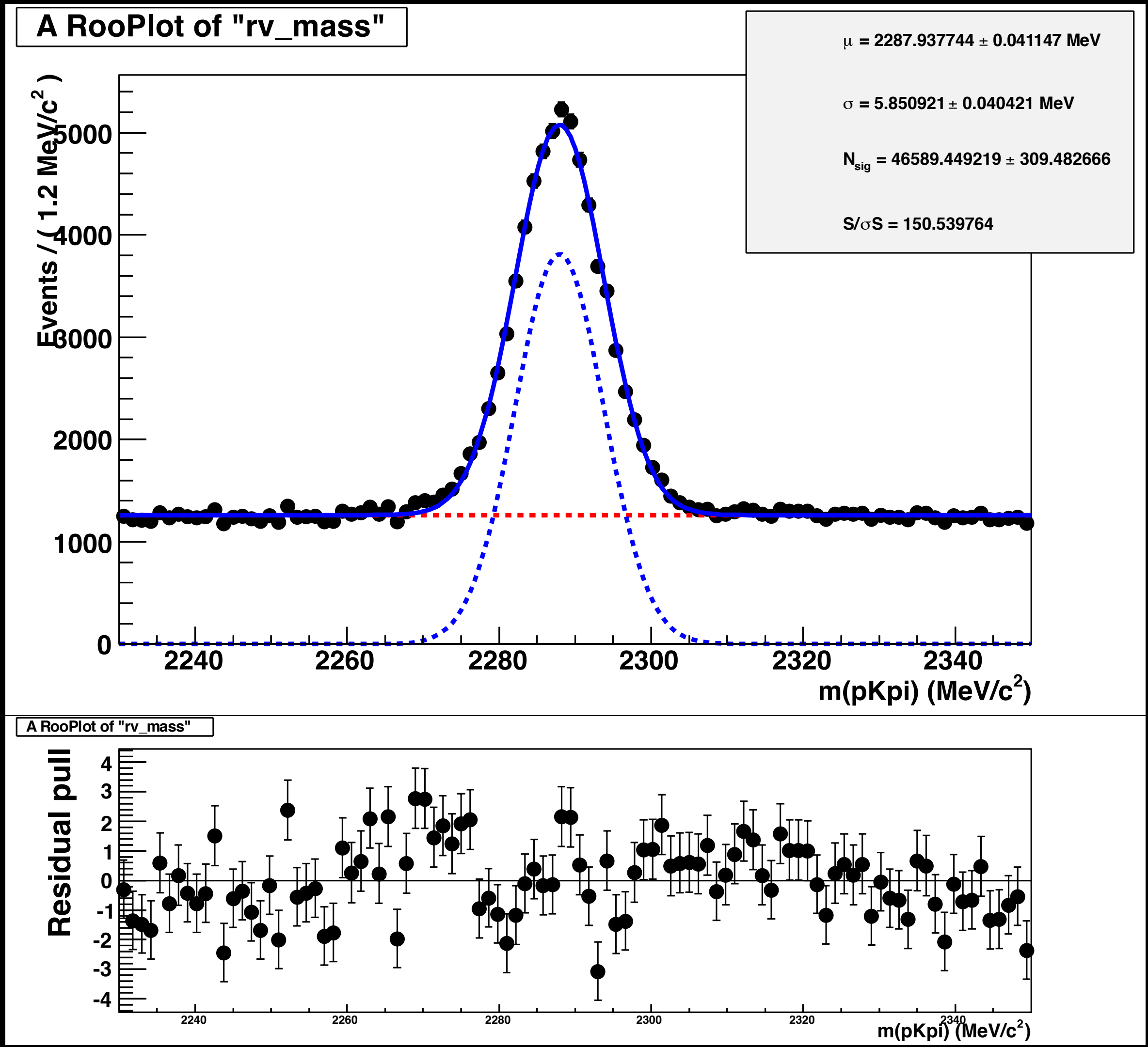
Line	TIS Decision	TOS Decision
Hlt2CharmHadLambdaC2KPPi	0.08331	0.08101
Hlt2Topo2BodyBBDT	0.1386	0.00475
Hlt2Topo3BodyBBDT	0.1889	0.004049
Hlt2CharmHadD2HHH	0.108	0.04804
Hlt2Phys	0.9774	0.118
Hlt1TrackAllL0	0.791	0.255
L0Hadron	0.5159	0.2295

Recap: Prompt Raw $\Lambda_c^+ \to p^+ k^- \pi^+$ Yields



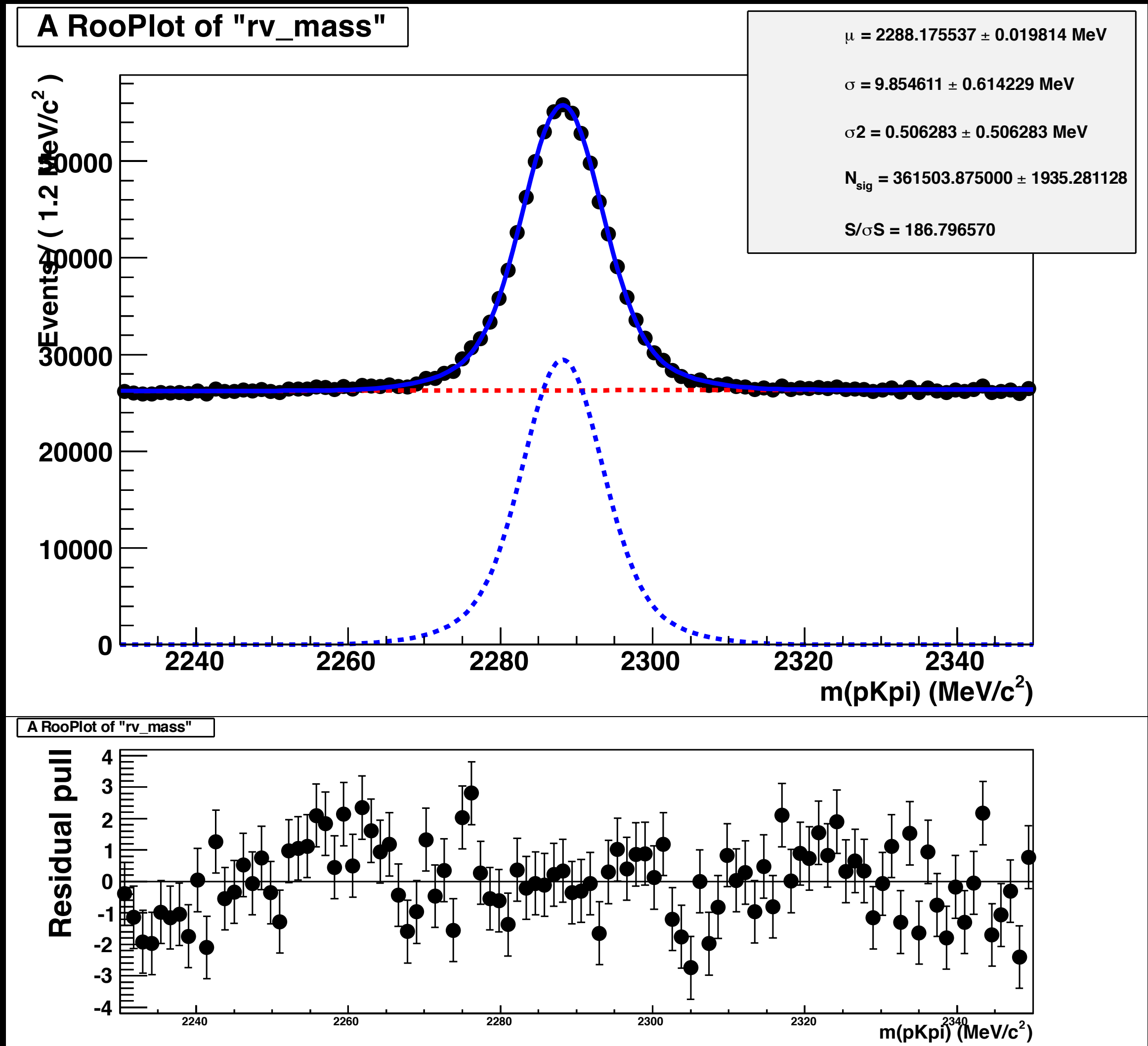
- Without trigger requirements: Nsig = 442560 ± 1538

TOS chain Massfit



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

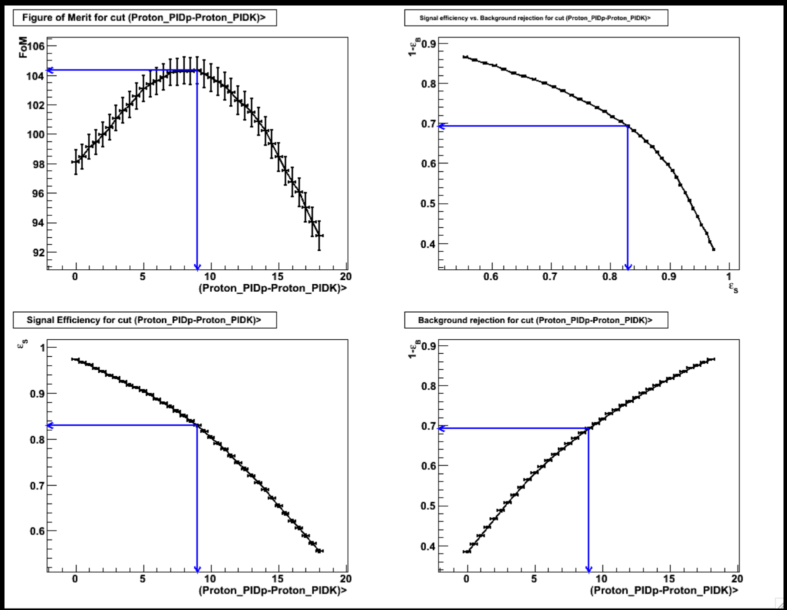
TIS Chain Massfit



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

Offline Selection 1

- Have been preparing and have almost finalised both a BDT and MLP MVA selection.
- However, nasty bug appeared in latest training on sweighted data.
- In the meantime have utilised Conor Fitzpatrick's Cut Recursive OPtimiser (CROP) to attain a placeholder selection.
- CROP is a rectangular cut optimisation tool that recursively re-optimises an ensemble of cuts until a stable maxima in the signal significance S/sqrt(S+B) is achieved.
- Have trained this on sweighted Cabibbo favoured data.



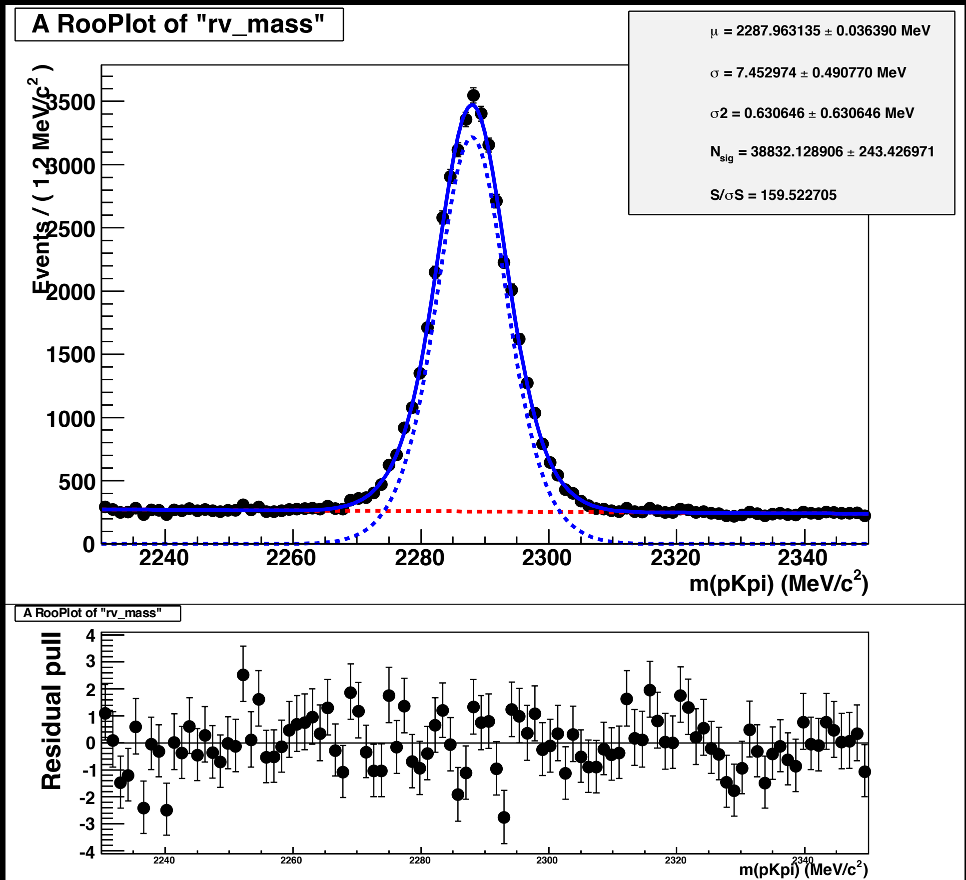
Sample CROP optimisation of (Proton_PIDp-Proton_PIDK) > X cut for the TIS sample.

Offline Selection 2

- 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 selections for each channel. One for the CF mode and one for the DCS mode.
- For DCS mode use a rough global weighting on signal of $\frac{|V_{ud}|^2 |V_{cs}|^2}{|V_{cd}|^2 |V_{us}|^2} \approx 0.003$
- Variables examined:
  - Λ_c^+:
    - P_t , MAXDOCA, Vertex χ^2 , IP χ^2, FD χ^2, DIRA
  - PID:
    - Proton_PIDp, Kaon_PIDK, Kaon_PIDp, (Proton_PIDp-Proton_PIDK)
    - Aware that discrimination achieved here may be in effect daughter Pt cuts which makes the selection less agnostic to daughters – under investigation.

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



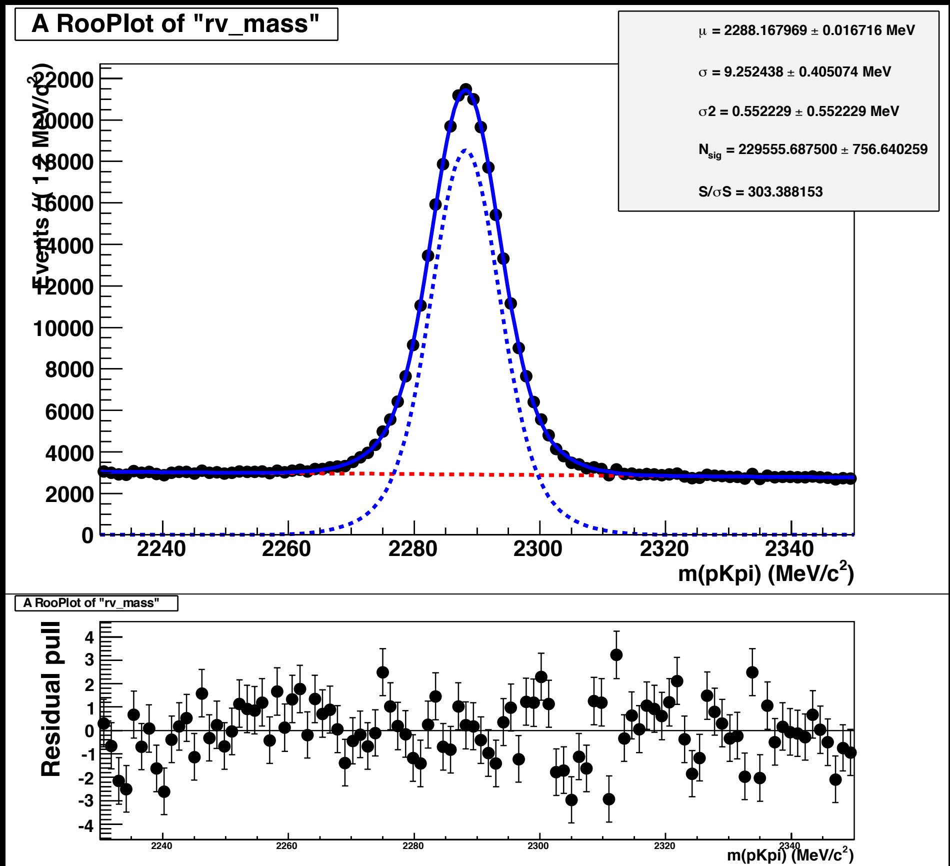
- CF Final Nsig = 38832 ± 243
- CF Final Fraction of Raw yield = (8.77 ± 0.7)%

- 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

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,

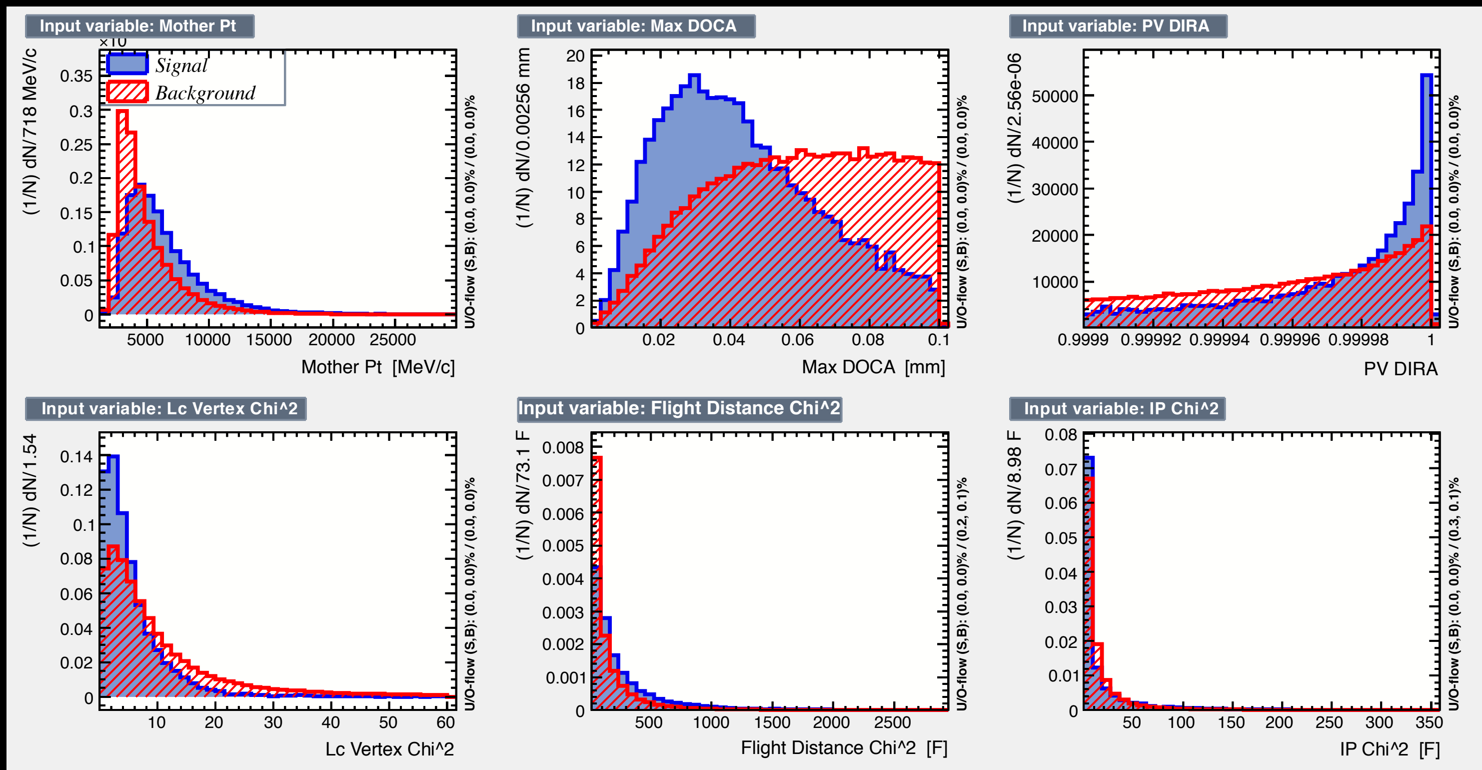
TIS vs TOS – After CROP Selection

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.

For the (very near) future – Full MVA

- Why use MVA?
  - Would obviously expect better discrimination and significance.
  - As can be seen below some variables with potential MVA discrimination offer none with rectangular cuts alone.
  - If I don't Mike will shout at me.



- sWeighted TIS Λ_c^+ variables of interest for TMVA.

Relative Phase Space Flatness χ^2 Study 1

- The "Dalitz" (not quite) space of decay modes are of key interest in this analysis.
  - Very strong resonance structure in $\Lambda_c^+ \rightarrow p^+h^+h^-$ decay modes.
    - pKπ: almost half the mode decays resonantly with Δ(1232)++K, p K*(892)0 and Λ(1520)π+ in the mix.
    - pππ: current measurements put intermediate p f0(980) at around 80% of the decay.
  - Decay amplitudes poorly understood for these modes.
  - Work will be imminent on model independent CPV (similar to 4 body Miranda charm work) and on decay amplitudes with the Λ_c^+ SCS modes.

Relative Phase Space Flatness χ^2 Study 2

- Define a quantitative χ^2 of the relative flatness of two phase spaces.
- Datasets D, $C \subset D$. Partition into 2D bins d_i, c_i.
  Eliminate kinematically forbidden region
- Our χ^2 is:

$$\chi^2 = \sum_i \frac{(c_i - \epsilon d_i)^2}{\sigma_i^2}$$

- Our datasets are subsets of one another, therefore correlated. Need to take this into account in our variance.
- Introduce complement set $d_i = b_i + c_i$

  Then our variance becomes:
  Where ε is the"average efficiency

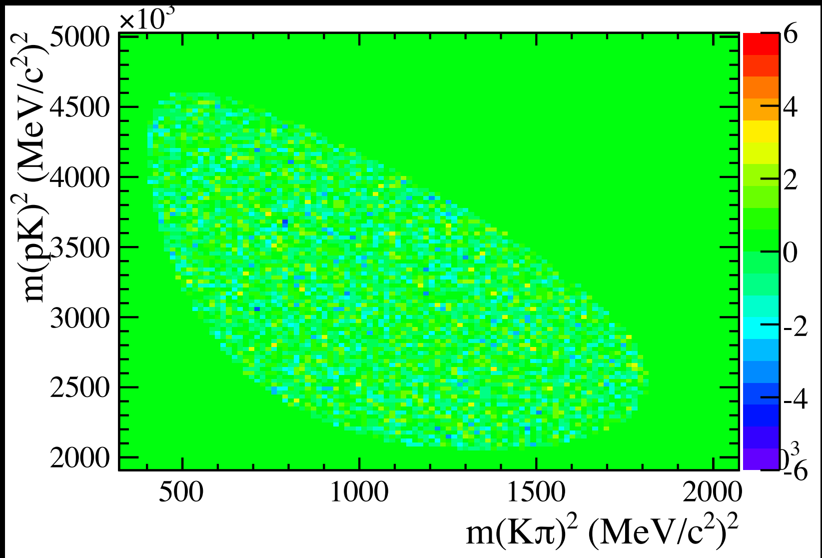
$$\sigma_i^2 = (1-\epsilon)^2 \sigma_{c,i}^2 + \epsilon^2 \sigma_{b,i}^2, \\ = (1-2\epsilon)\sigma_{c,i}^2 + \epsilon^2 \sigma_{d,i}^2.$$

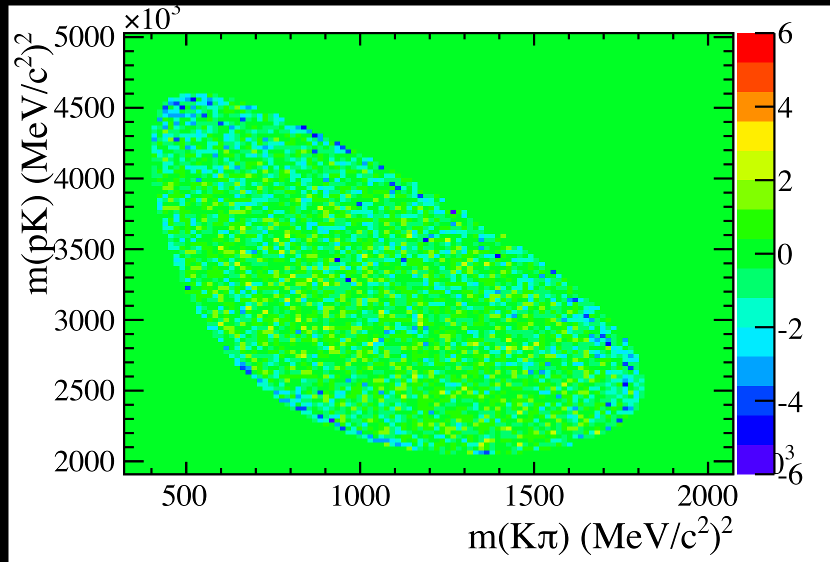
- Minimise the χ^2 with respect to ε using TMinuit.

Relative Phase Space Flatness χ^2 Study 3

- Validation on a priori relatively flat sets.
- In this case random 30% subset of the TIS sample.
- Pulls shown below.
- p-value for flatness = 0.1858

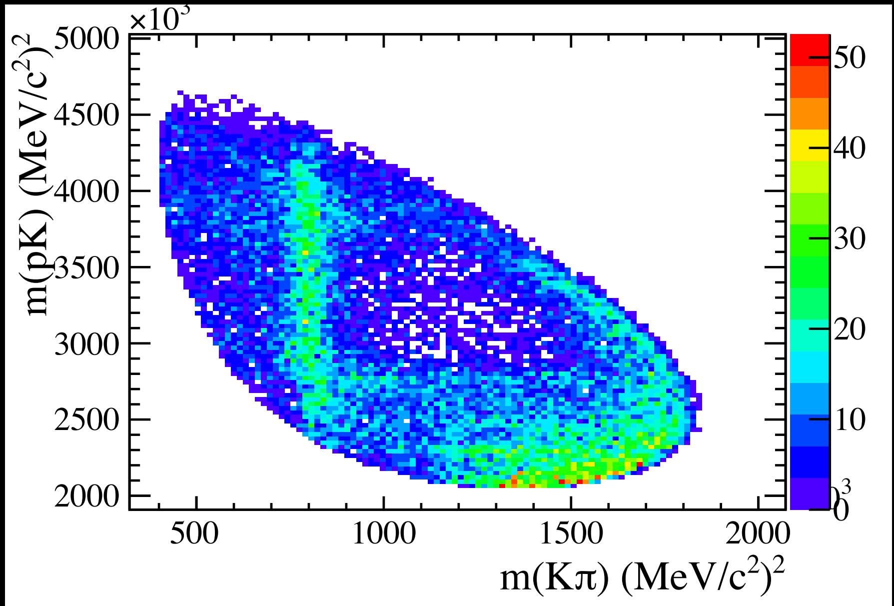
- Validation on a priori not relatively flat sets.
- In this case TOS sample with respect to raw stripping output.
- Pulls shown below.
- p-value for flatness consistent with zero.



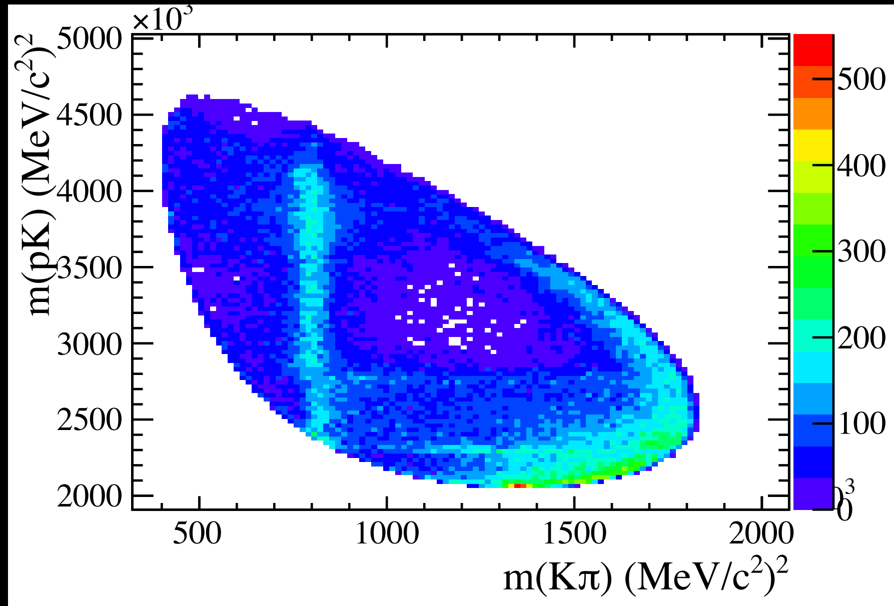


TIS and TOS Dalitz plots

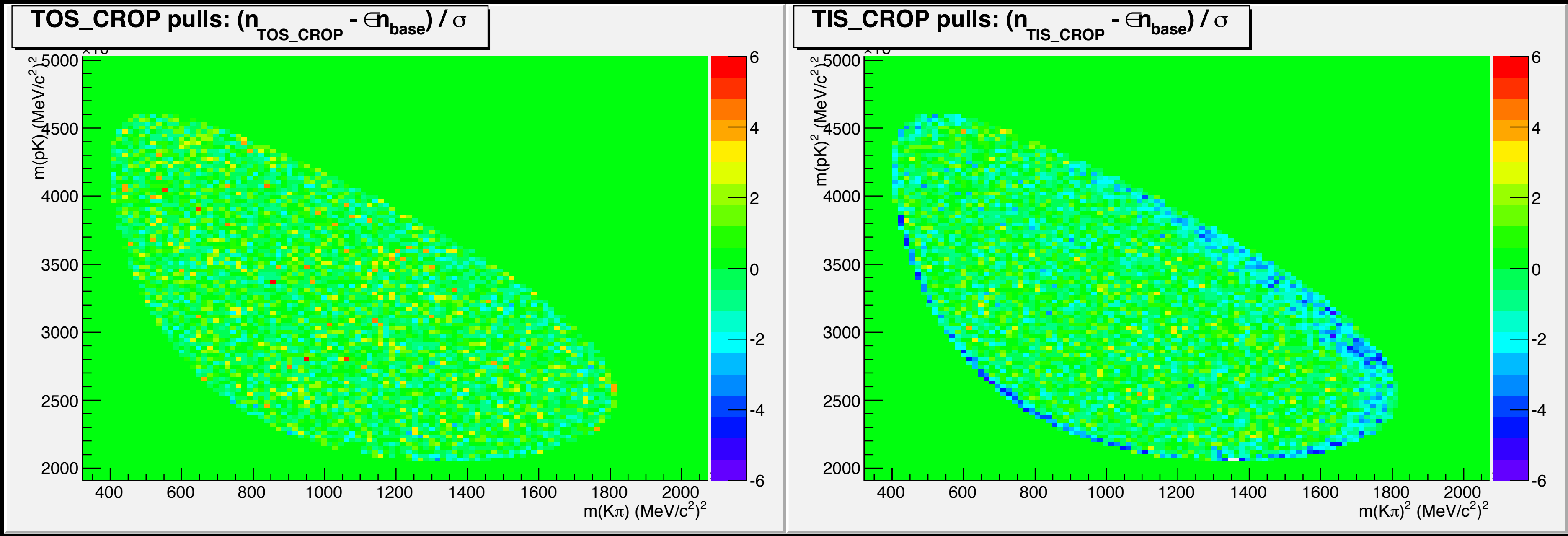
TOS



TIS



Crop Selection Relative Flatness - Pulls



- Both distributions give a p-value for flatness consistent with zero.
- TIS sample's edge effects at the kinematic boundary not surprising given the TOS trigger cuts already remove these events before applying the selection.
- With this selection, all things considered, it's fairly easy to vouch for the TIS chain.

What next for prompt

- Finalise our MVA selections and check what gains in significance we can get, especially from the DCS mode.
- Decide on best selection and proceed with reco and PID efficiencies.
- Then move onto our physics backgrounds, likely from D reflections, then systematics.

- This work will also be carried out on the semileptonic channels.