FV and Systematics with Hybrid π^0s

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fiTQun! Workshop

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Overview

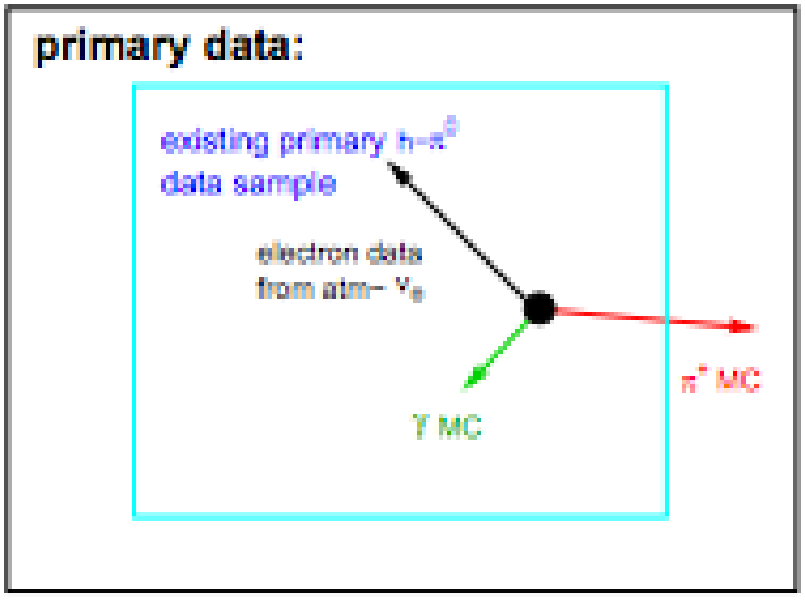
Hybrid π^0 samples are used to determine systematics in SK. In practice, this boils down to finding the data/MC efficiency difference for a given (π, θ_b) bin, and then treating this (and the statistical error) as an input to the global covariance matrices.

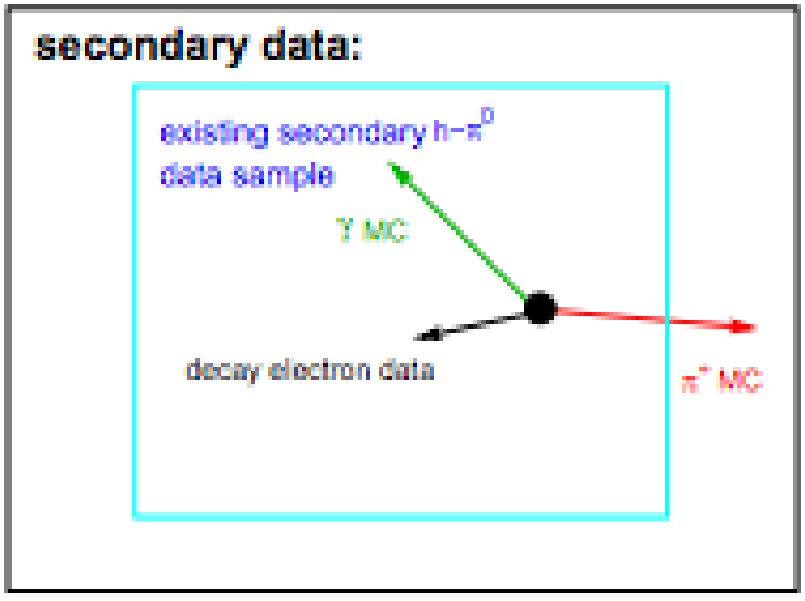
Hybrid Samples

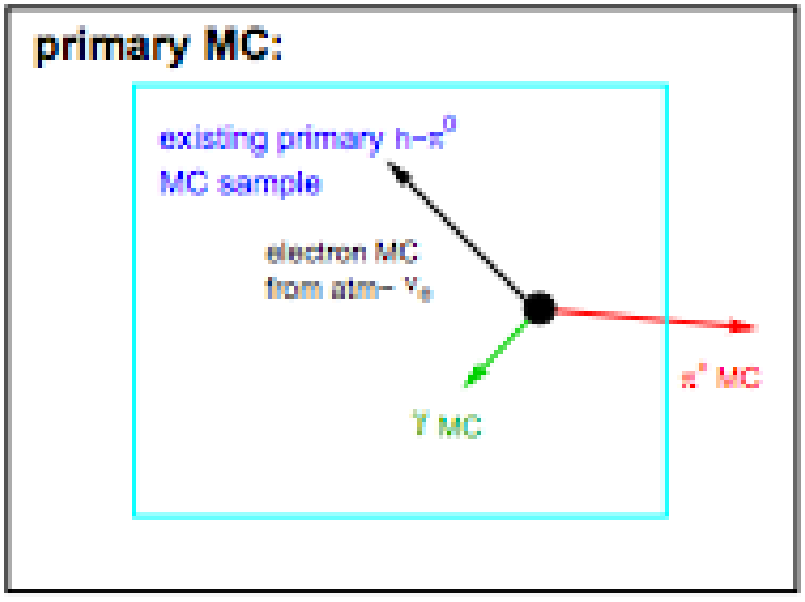
To date, we have been discussing the 'basic' hybrid MC samples (NC single π^0). Other samples have been constructed to match final state topologies in the T2K beam MC, including:

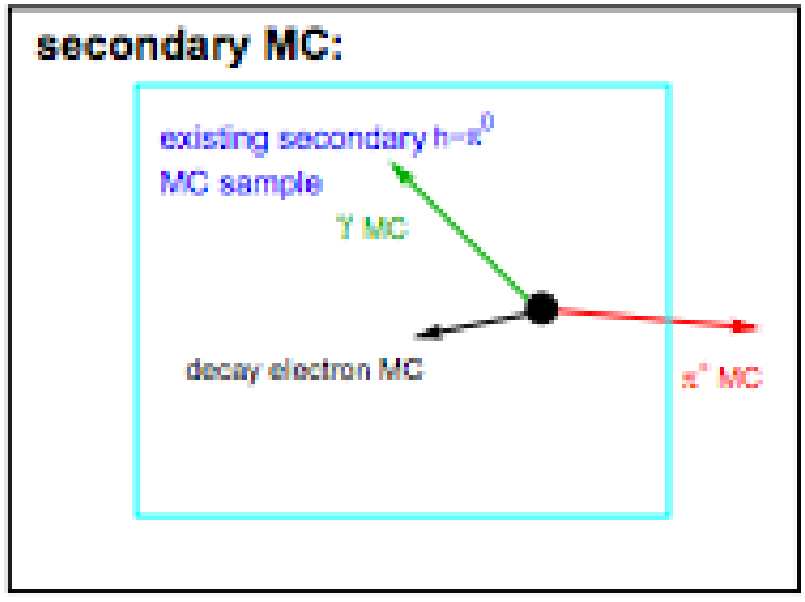
- NC h-π^0 + other (e.g., $\pi^0 + \pi^{\pm}$)
- CC h-π^0 + other (e.g., $\pi^0 + \mu + \pi^{\pm}$)

Sample Construction









Hybrid Use in Systematics

This usage should be applicable to other analyses done with fiTQun - it seems reasonable that if there are other final-state topologies present, they could also be included and used in a similar process to estimate systematic backgrounds for our fits.

NC h-π^0 Beam MC Topologies

Final state	Number of events	Fraction
$\pi^0 + \pi^\pm$	55/128	43%
$\pi^0 + p$	43/128	34%
$\pi^0 + 2\pi^\pm$	7/128	5%
$\pi^0 + p + \pi^\pm$	5/128	4%
$\pi^0 + \pi^\pm + 2\gamma$	3/128	2%
$\pi^0 + 2\pi^\pm + e$	2/128	2%
$2\pi^0$	1/128	1%
$2\pi^0 + p$	1/128	1%
$\pi^0 + e + \pi^\pm$	1/128	1%
$\pi^0 + e + p + \pi^\pm$	1/128	1%
$\pi^0 + \gamma + p$	1/128	1%
$\pi^0 + \gamma + \pi^\pm$	1/128	1%
$\pi^0 + \gamma + p + \pi^\pm$	1/128	1%
$\pi^0 + \gamma + 2\pi^\pm$	1/128	1%
$\pi^0 + \gamma + \pi^\pm + e$	1/128	1%
$\pi^0 + 2\gamma + \pi^\pm$	1/128	1%
$\pi^0 + 2\gamma + p + \pi^\pm$	1/128	1%
$\pi^0 + 3\gamma + 3\pi^\pm$	1/128	1%
$\pi^0 + 5\gamma + 2\pi^\pm$	1/128	1%

Figure: NC-hπ^0 + other topologies in the T2K beam MC.

Final state	Events	Fraction	Final state	Events	Fraction
		$p < 300$ MeV/c			
$\pi^0 + \pi^\pm$	8/9	88.9%	$\pi^0 + p$	1/9	11.1%
		$300 < p < 700$ MeV/c			
$\pi^0 + p$	9/21	42.9%	$\pi^0 + \pi^\pm$	7/21	33.3%
$\pi^0 + 2\,\pi^\pm$	3/21	14.3%	$\pi^0 + 2\,\pi^\pm + p$	1/21	4.8%
$\pi^0 + \pi^\pm + p$	1/21	4.8%			
		$700 < p < 1250$ MeV/c			
$\pi^0 + p$	14/21	66.7%	$\pi^0 + \pi^\pm$	5/21	23.8%
$\pi^0 + 2\,\pi^\pm$	1/21	4.8%	$\pi^0 + \pi^\pm + p$	1/21	4.8%
		$1250 < p < 2000$ MeV/c			
$\pi^0 + p$	55/245	22.4%	$\pi^0 + \pi^\pm$	49/245	20.0%
$2\,\pi^0$	27/245	11.0%	$\pi^0 + \pi^\pm + p$	16/245	6.5%
$2\,\pi^0 + \pi^\pm$	15/245	6.1%	$3\,\pi^0$	13/245	5.3%
$2\,\pi^0 + p$	12/245	4.9%	$\pi^0 + 2\,\pi^\pm$	9/245	3.7%
$2\,\pi^0 + 2\,\pi^\pm$	7/245	2.9%	$2\,\pi^0 + \pi^\pm + p$	6/245	2.4%
$2\,\pi^0 + 2\,\pi^\pm + p$	5/245	2.0%	$\pi^0 + 2\,\pi^\pm + p$	5/245	2.0%
$3\,\pi^0 + \pi^\pm + p$	3/245	1.2%	$3\,\pi^0 + \pi^\pm$	3/245	1.2%
$3\,\pi^0 + p$	3/245	1.2%	$5\,\pi^0$	2/245	0.8%
$4\,\pi^0 + \pi^\pm + p$	2/245	0.8%	$4\,\pi^0 + \pi^\pm$	2/245	0.8%
$3\,\pi^0 + 3\,\pi^\pm$	2/245	0.8%	$3\,\pi^0 + 2\,\pi^\pm$	2/245	0.8%
$\pi^0 + 3\,\pi^\pm$	2/245	0.8%	$6\,\pi^0 + 2\,\pi^\pm$	1/245	0.4%
$5\,\pi^0 + 3\,\pi^\pm$	1/245	0.4%	$5\,\pi^0 + \pi^\pm$	1/245	0.4%
$4\,\pi^0$	1/245	0.4%	$2\,\pi^0 + 3\,\pi^\pm$	1/245	0.4%

Figure: Partial list of nc-hπ^0 + other topologies.

See TN-156 for the full list of samples considered.

CC-hπ^0 + other beam MC Topologies.

Final state	Number of events	Fraction
$\pi^0 + \mu$	12/46	26%
π^0	8/46	17%
$\pi^0 + \mu + \gamma$	5/46	11%
$\pi^0 + \mu + e$	5/46	11%
$\pi^0 + \mu + \pi^\pm$	4/46	9%
$\pi^0 + e$	2/46	4%
$\pi^0 + \mu + p$	2/46	4%
$\pi^0 + \mu + p + \gamma$	2/46	4%
$\pi^0 + \mu + 2e$	1/46	2%
$\pi^0 + \mu + p + e$	1/46	2%
$\pi^0 + \mu + \pi^\pm + e$	1/46	2%
$\pi^0 + \mu + \pi^\pm + 2e$	1/46	2%
$\pi^0 + \mu + 2\pi^\pm + e$	1/46	2%
$\pi^0 + \mu + \pi^\pm + e + \gamma$	1/46	2%

Figure: CC-hπ^0 + other topologies in the T2K beam MC.

CC h-π^0 Topologies

Final state	Events	Fraction	Final state	Events	Fraction
		$p < 1250$ MeV/c			
$\pi^0 + \mu$	7/12	58.3%	π^0	3/12	25.0%
$\pi^0 + \mu + \pi^\pm$	1/12	8.3%	$\pi^0 + \pi^\pm$	1/12	8.3%
		$1250 < p < 2000$ MeV/c			
$\pi^0 + \mu$	22/59	37.3%	$\pi^0 + \mu + p$	6/59	10.2%
$\pi^0 + \mu + \pi^\pm$	5/59	8.5%	$2\,\pi^0 + \mu + \pi^\pm$	4/59	6.8%
$2\,\pi^0 + \mu$	4/59	6.8%	$3\,\pi^0 + \mu$	3/59	5.1%
$2\,\pi^0 + \mu + 2\,\pi^\pm$	3/59	5.1%	π^0	2/59	3.4%
$4\,\pi^0 + \mu + 4\,\pi^\pm$	1/59	1.7%	$3\,\pi^0 + \mu + 2\,\pi^\pm + p$	1/59	1.7%
$3\,\pi^0 + \mu + \pi^\pm + p$	1/59	1.7%	$3\,\pi^0 + \mu + \pi^\pm$	1/59	1.7%
$3\,\pi^0 + \mu + p$	1/59	1.7%	$3\,\pi^0$	1/59	1.7%
$2\,\pi^0 + \mu + 2\,\pi^\pm + p$	1/59	1.7%	$2\,\pi^0 + \pi^\pm$	1/59	1.7%
$\pi^0 + \mu + 2\,\pi^\pm + p$	1/59	1.7%	$\pi^0 + \mu + \pi^\pm + p$	1/59	1.7%
		$2000 < p < 5000$ MeV/c			
$\pi^0 + \mu$	32/102	31.4%	$2\,\pi^0 + \mu$	11/102	10.8%
$3\,\pi^0 + \mu$	9/102	8.8%	$2\,\pi^0 + \mu + \pi^\pm$	7/102	6.9%
$3\,\pi^0 + \mu + \pi^\pm$	5/102	4.9%	$\pi^0 + \mu + 2\,\pi^\pm$	5/102	4.9%
$\pi^0 + \mu + \pi^\pm$	5/102	4.9%	$2\,\pi^0 + \mu + p$	4/102	3.9%
$\pi^0 + \mu + p$	3/102	2.9%	$3\,\pi^0 + \mu + p$	2/102	2.0%
$2\,\pi^0 + \mu + 2\,\pi^\pm$	2/102	2.0%	$\pi^0 + \mu + 3\,\pi^\pm$	2/102	2.0%
$5\,\pi^0 + \mu + 2\,\pi^\pm$	1/102	1.0%	$5\,\pi^0 + \mu + \pi^\pm$	1/102	1.0%
$4\,\pi^0 + \mu + 2\,\pi^\pm$	1/102	1.0%	$4\,\pi^0 + \mu + \pi^\pm$	1/102	1.0%
$3\,\pi^0 + 2\,\mu + \pi^\pm + p$	1/102	1.0%	$3\,\pi^0 + \mu + 4\,\pi^\pm + 2\,p$	1/102	1.0%
$3\,\pi^0 + \mu + 3\,\pi^\pm + p$	1/102	1.0%	$3\,\pi^0 + \mu + 2\,\pi^\pm$	1/102	1.0%
$3\,\pi^0 + 2\,\pi^\pm$	1/102	1.0%	$2\,\pi^0 + \mu + 3\,\pi^\pm + p$	1/102	1.0%
$2\,\pi^0 + \mu + \pi^\pm + p$	1/102	1.0%	$\pi^0 + \mu + 2\,\pi^\pm + p$	1/102	1.0%
$\pi^0 + \mu + \pi^\pm + p$	1/102	1.0%	$\pi^0 + \pi^\pm$	1/102	1.0%
π^0	1/102	1.0%			

Figure: List of cc-hπ^0 + other topologies.

FV Efficiencies

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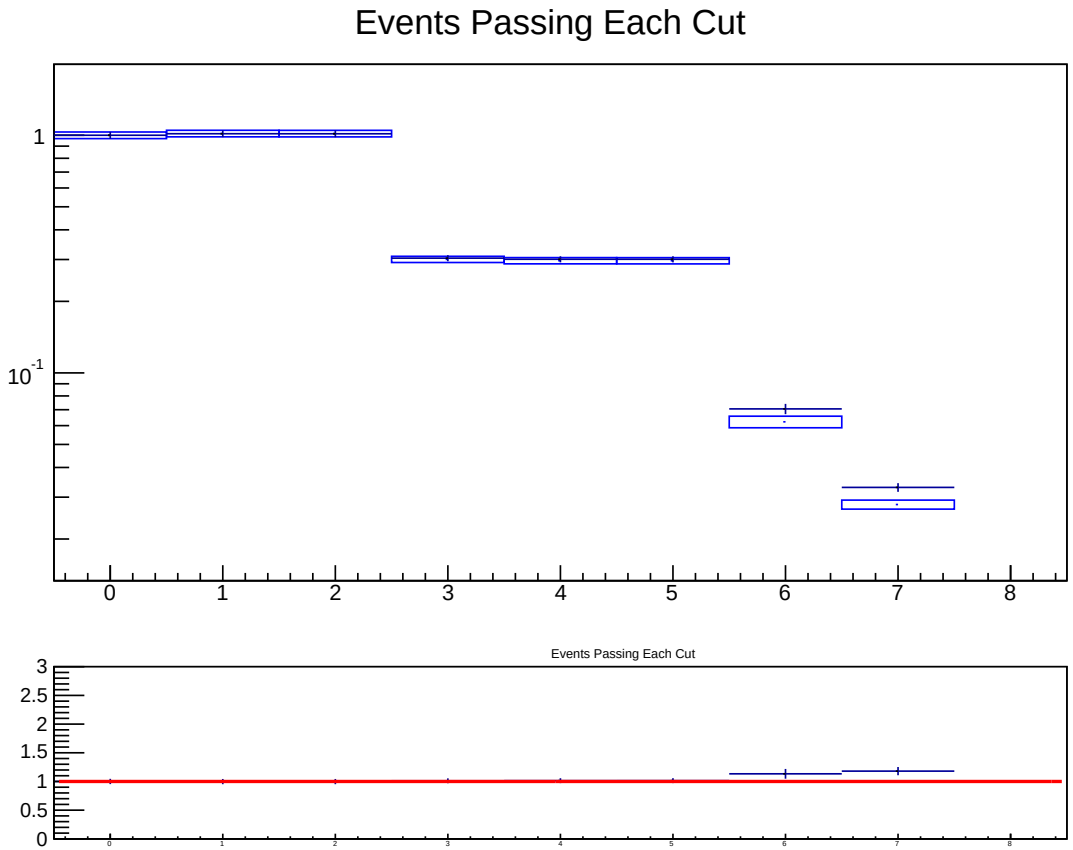

Figure: π^0 sample efficiency for the current FV.

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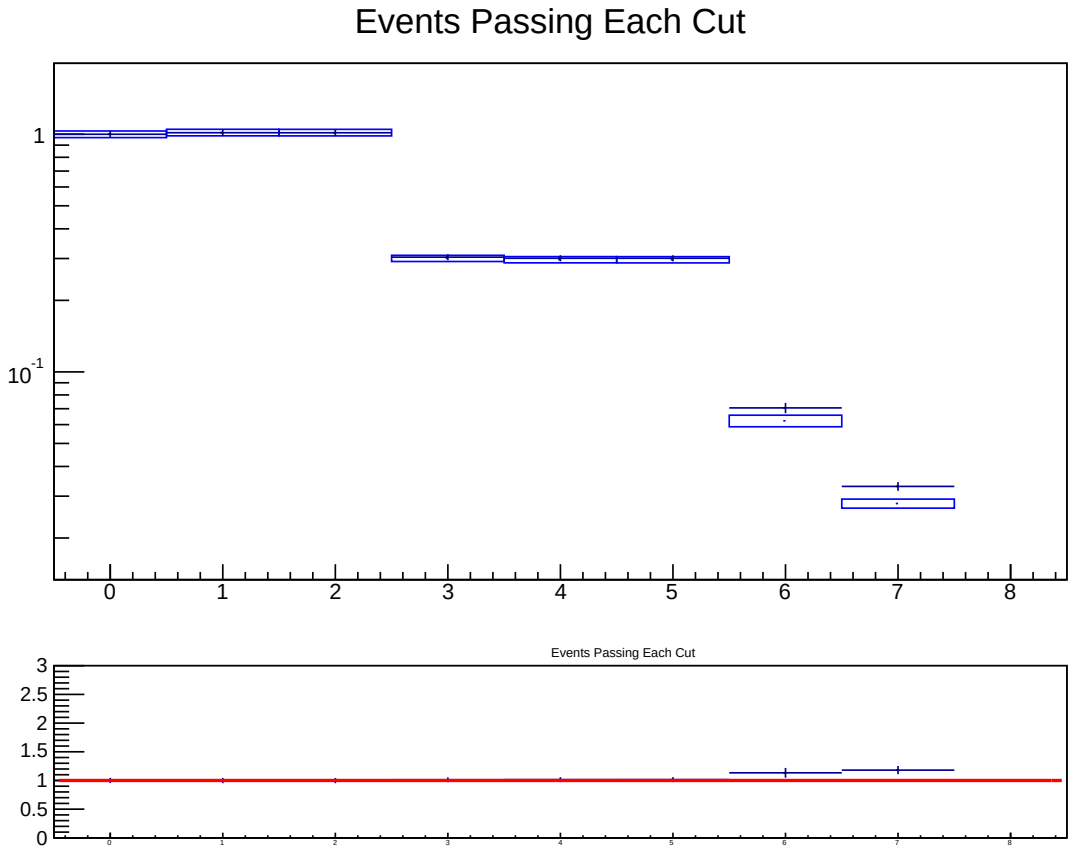
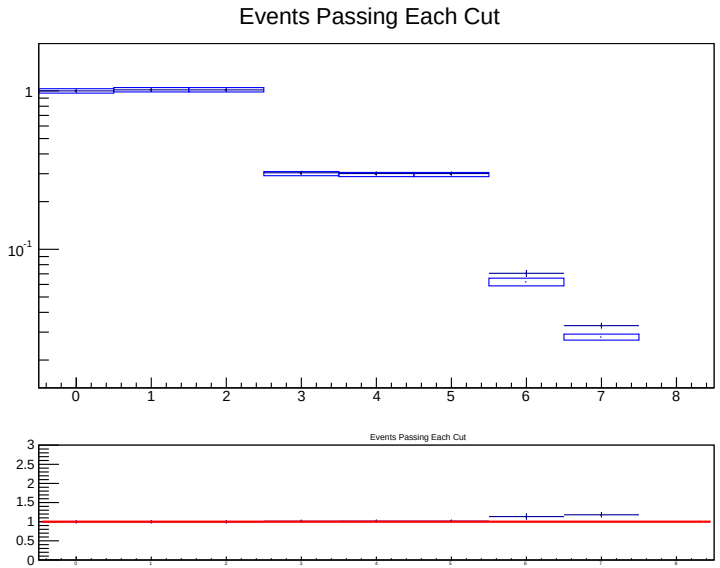
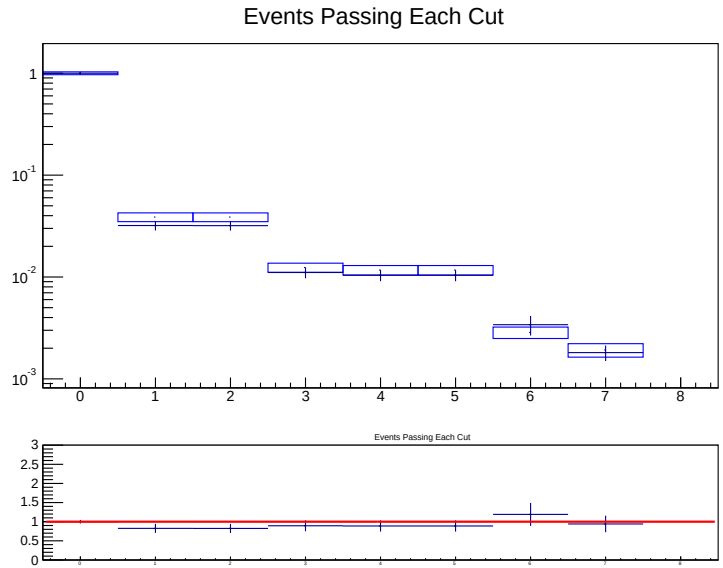


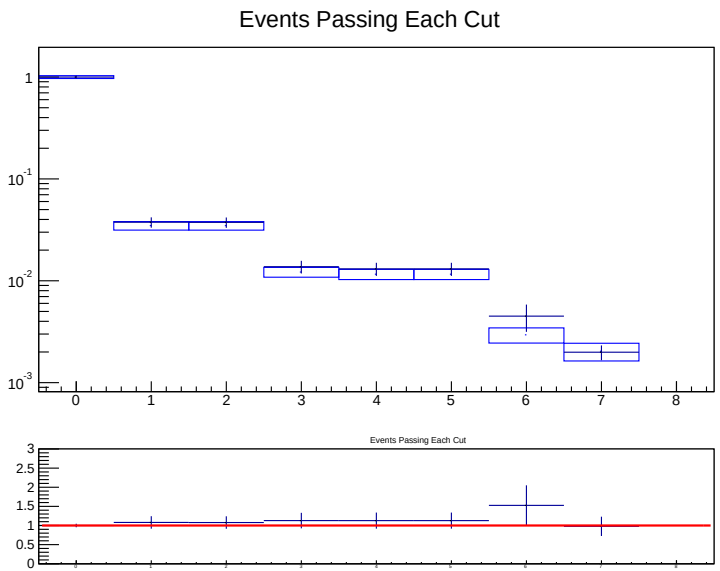
Figure: π^0 sample efficiency for the current FV.

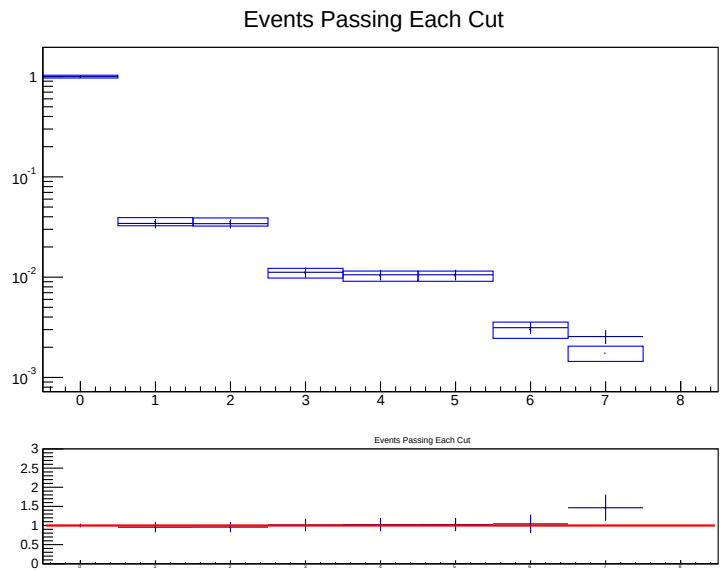
FV Efficiencies

Plots are shown moving outward from the current FV, in bins of 25 cm.









FV Efficiencies II

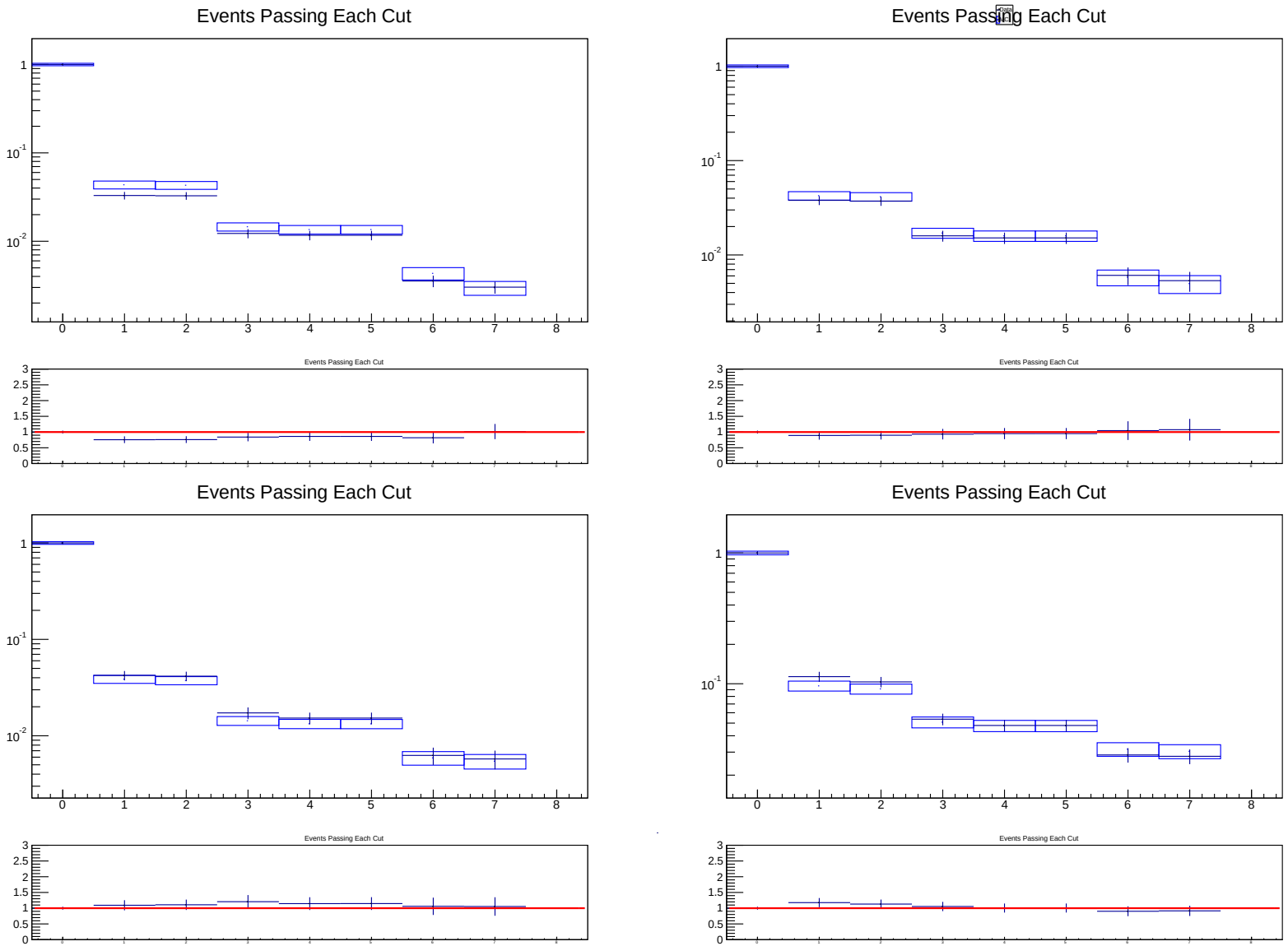


Figure: Cut-by-cut efficiencies for 25 cm bins in wall going to the ID wall. Note the last bin is for the final 50 cm.

Further Considerations

Beyond considering wall alone, we can also consider efficiency in terms of any other relevant parameter space, e.g. (wall, towall)... However, we should be mindful of the current state of data-MC disagreement above 1250 MeV...

Further Reading

For more information on the hybrid samples and calibration, see:

- TN-156 (most recent hybrid TechNote)
- TN-110 (more details about construction/modeling of h-π^0 samples)

Summary

- Hybrid samples have been constructed to estimate systematic errors for final state topologies in the T2K beam MC.
  - 'Standard' NC-π^0
  - NC-π^0 + other
  - CC-π^0 + other
- Likely possible to generate similar sets for backgrounds in more studies if necessary
- Hybrid samples can also be used in FV studies
  - Will likely be most useful to split into relevant parameter spaces [e.g., (wall,towall), &c.]