Bounding the Trigger Inefficiency for $\Upsilon(1,2,3S)$

Jim Pivarski

First cut in any analysis: the trigger

Problem: only events which *pass* the trigger can be compared with data

My trigger lines: “Hadron” OR “RadTau” OR “ElTrack”

MC efficiency for these lines is 99.5% (nicely bounded above)

Is the MC generating *too few* untriggered events?

My trigger lines: “Hadron” OR “RadTau” OR “ElTrack”

Trigger depends on four variables: $\underbrace{\text{\#CBLO, \#CBMD,}}_{\text{CC cluster counting}}$ $\underbrace{\text{\#AXIAL, \#STEREO}}_{\text{DR track counting}}$

STEP 1: Check CC cluster counting with “TwoTrack” trigger line

STEP 2: Quantify systematic error from uncertainty in trigger track-finding efficiency

STEP 3.1: Check MC reconstructed track distribution with $\Upsilon(2S) \to \Upsilon(1S)$ cascade

STEP 3.2: Quantify systematic error from uncertainty in number of 0-, 1-track events

STEP 3.3: Quantify systematic error from differences in reconstructed track efficiency between data and MC

STEP 1: Check CC cluster counting with "TwoTrack" trigger

P(Υ passes trigger | TwoTrack) = P(event passes trigger | TwoTrack and event is Υ)

These cuts guarantee negligible backgrounds and no lower bounds on CC quantities:

data: TwoTrack trigger AND analysis cuts AND charged energy > 35% COM
AND continuum-subtraction

MC: TwoTrack trigger AND analysis cuts AND charged energy > 35% COM

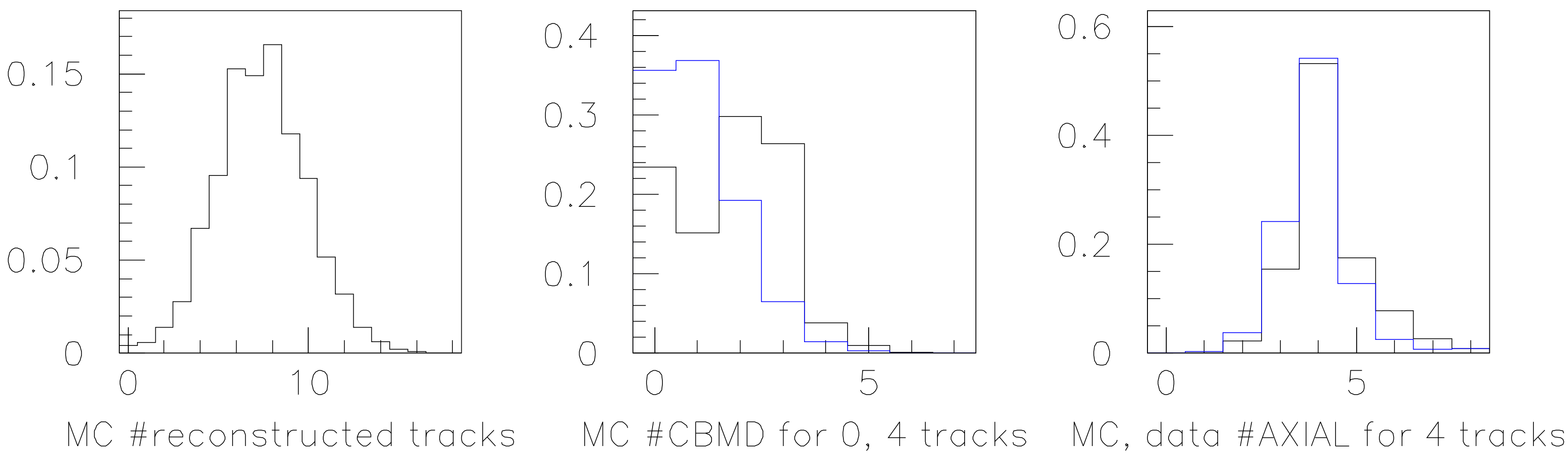
P(passes "Hadron" OR "RadTau" OR "ElTrack" | all those cuts):

	$\Upsilon(1S)$	$\Upsilon(2S)$	$\Upsilon(3S)$
data	99.97%	99.48%	99.51%
MC	99.83%	99.86%	99.86%
difference	0.14%	0.38%	0.35%
	±0.20%	±0.31%	±1.00%

STEP 2: Quantify systematic error from uncertainty in trigger track-finding efficiency

Toy MC:

1. pick a random #reconstructed tracks from the full MC's distribution
2. for this #tracks, pick a random #CBLO, #CBMD (2-d distributions from full MC)
3. for this #tracks, pick a random #AXIAL (from full MC or from data)
4. for this #AXIAL, pick a random #STEREO (from full MC or from data)
5. calculate ("Hadron" OR "RadTau" OR "ElTrack") and repeat many times



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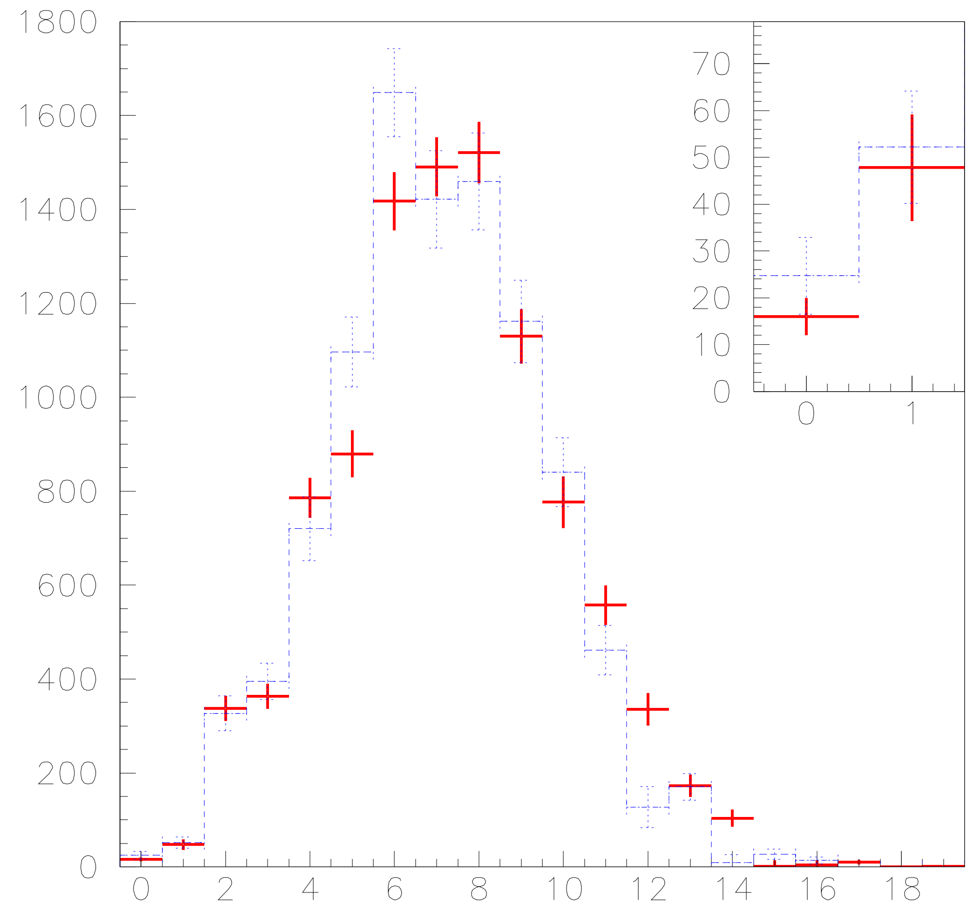
	$\Upsilon(1S)$	$\Upsilon(2S)$	$\Upsilon(3S)$
Full MC	99.7%	99.4%	99.5%
Toy MC	99.7%	99.5%	99.6%
Get #AXIAL, #STEREO from data	99.6%	99.4%	99.5%
Throw out every 12^{th} AXIAL track in MC	99.5%	99.4%	99.5%

(all table uncertainties $< 0.03\%$)

STEP 3.1: Check MC reconstructed track distribution with cascade

$$\Upsilon(2S) \to \Upsilon(1S)\,\underbrace{\pi^+\pi^-}$$
$\hookrightarrow$ satisfy TwoTrack requirement, L4, and "quality tracks ≥ 2"

1. Get **all** $\Upsilon(2S)$ events from tau subcollection with TwoTrack trigger
2. Plot $\pi^+\pi^-$ missing mass distribution for each number of tracks
3. Count number of $\Upsilon(1S)$ events in each peak
4. Do exactly the same for MC
5. Plot number of $\Upsilon(1S)$ events per number of non-$\pi^+\pi^-$ tracks $\longrightarrow \longrightarrow \longrightarrow \longrightarrow \longrightarrow \longrightarrow \longrightarrow$



Number of non$-\pi^+\pi^-$ tracks, compared with MC (dashed blue)

STEP 3.2: Quantify systematic error from uncertainty in number of 0-, 1-track events

Instead of replacing the #AXIAL and #STEREO distributions, replace the #tracks distribution

(For apples-to-apples, we must compare *boosted* data to *boosted* MC.)

	$\Upsilon(1S)$	$\Upsilon(2S)$	$\Upsilon(3S)$
Toy MC	99.7%		
with boosted MC tracks	99.6%		
with boosted data tracks	99.7%		
same with 0-, 1-tracks raised 1σ	99.6%		

(all table uncertainties $< 0.03\%$)

STEP 3.3: Quantify systematic error from differences in reconstructed track efficiency between data and MC

Everything has been tied to #reconstructed tracks, but what if MC generates too many charged particles and loses too many tracks?

Tracking efficiency is understood to about 2%

	$\Upsilon(1S)$	$\Upsilon(2S)$	$\Upsilon(3S)$
add 2% more tracks	99.7%	99.6%	99.7%
standard toy MC	99.7%	99.5%	99.6%
drop 2% of tracks	99.7%	99.5%	99.6%

(all table uncertainties $< 0.03\%$)

Summary of trigger efficiency systematic errors:

	$\Upsilon(1S)$	$\Upsilon(2S)$	$\Upsilon(3S)$
CC cluster counting (STEP 1)	0.20%	0.31%	0.31%
trigger track efficiency (STEP 2)	0.11%	0.12%	0.15%
reconstructed track distribution (STEP 3.2)	0.08%	0.08%	0.08%
reconstructed track efficiency (STEP 3.3)	0.03%	0.07%	0.03%
	0.24%	0.35%	0.35%

What could still go wrong?

Cascades study could miss events with:

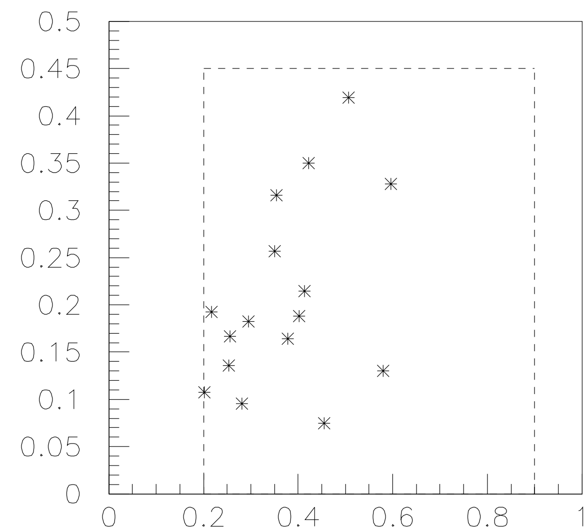
- visible energy $<$ 20% $\Upsilon(1S)$ mass,
- CC energy $>$ 90% $\Upsilon(1S)$ mass,

OR

- biggest shower $>$ 90% $\Upsilon(1S)$ mass / 2

If we missed 100 zero-track events, trigger efficiency would decrease by 0.2%.

Zero-track events ($\sim \frac{1}{2}$ signal)



Biggest shower/eCOM versus CC energy/eCOM