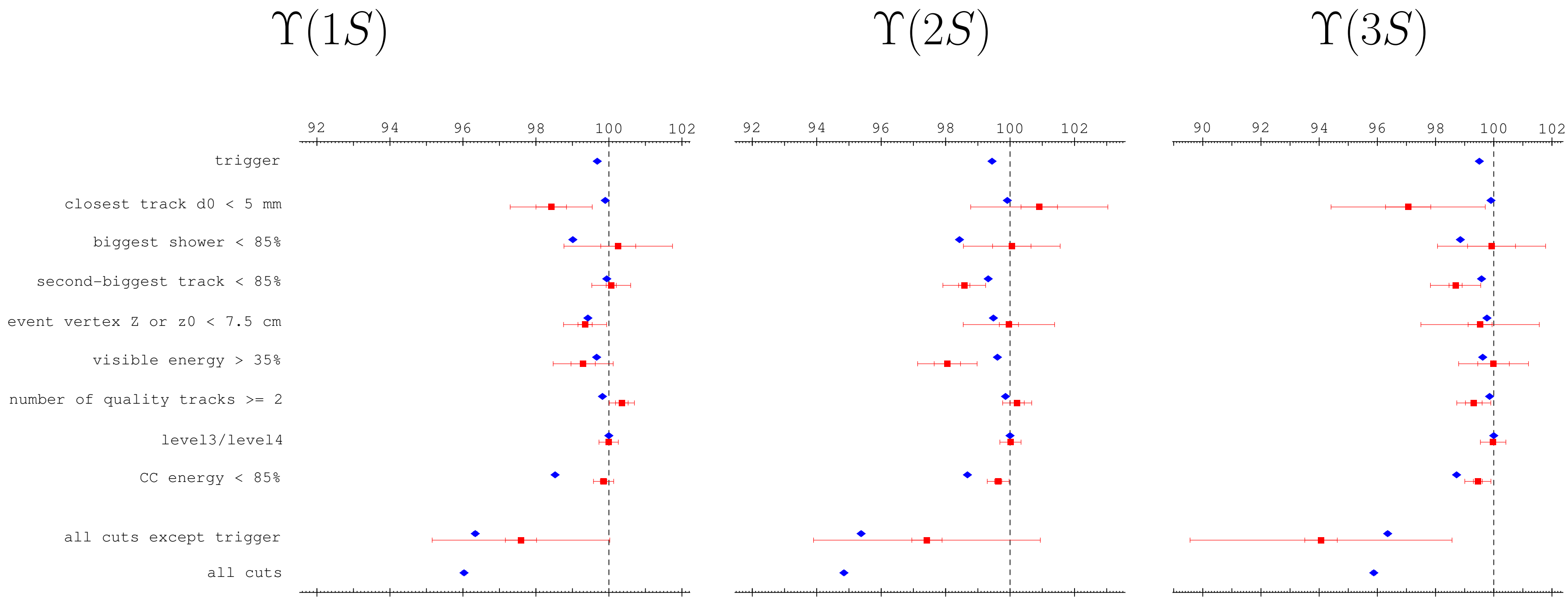


Monte Carlo is hadronic (no prompt leptons, but everything else (including *cascades* to leptons)).

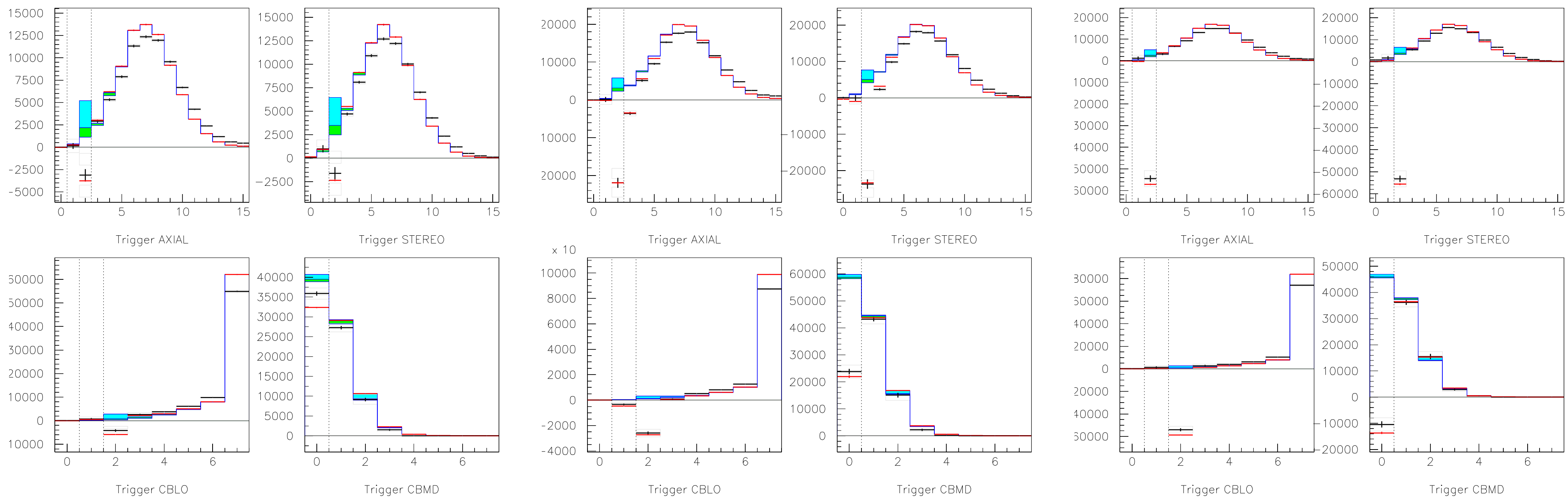
Data is hadronic (on-res minus off-res minus beamgas (from single-beam) minus cosmic rays (from no-beam) minus prompt decays to e^+e^-, $\mu^+\mu^-$, $\tau^+\tau^-$ (from Monte Carlo)).

Strategy for determining efficiency

trigger closest d0 < 5 mm biggest shower $<$ 85% beam energy second-biggest track $<$ 85% beam energy	Background subtraction dominates uncertainties Data/MC agreement looks good Cut boundaries are far from signal Measure from Monte Carlo
Event vertex Z < 7.5 cm	Only $\Upsilon(1S)$ has sub-percent errors Measure from $\Upsilon(1S)$, apply to all three
visible energy $<$ 35% of center-of-mass energy quality tracks ≥ 2 level 3/level 4 CC energy $<$ 85% of center-of-mass energy	No more backgrounds Measure from data

Trigger variables

$\Upsilon(1S)$ $\Upsilon(2S)$ $\Upsilon(3S)$

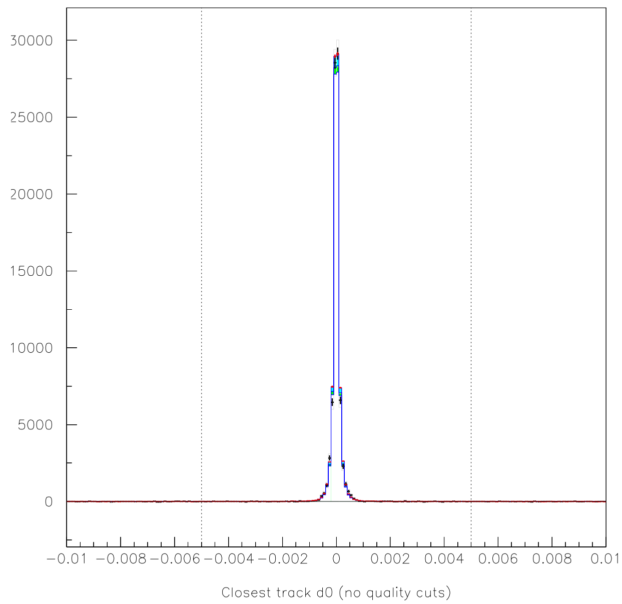


- Blue histogram is Monte Carlo
- Bluish bins are prompt decays to e^+e^- and $\mu^+\mu^-$
- Greenish bins are prompt decays to $\tau^+\tau^-$
- Red data points are the sum of these + beam-gas and cosmic rays
- Black points are on-res minus off-res data
- Black points should agree with red points

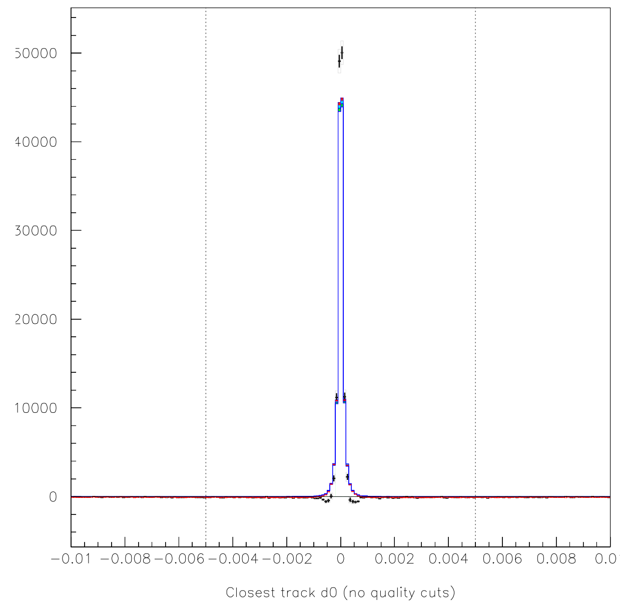
Suppose we take the error on trigger to be 100% of itself: 0.5% efficiency systematic.

d0 of closest track < 5 mm (trigger already implied existence of one track)

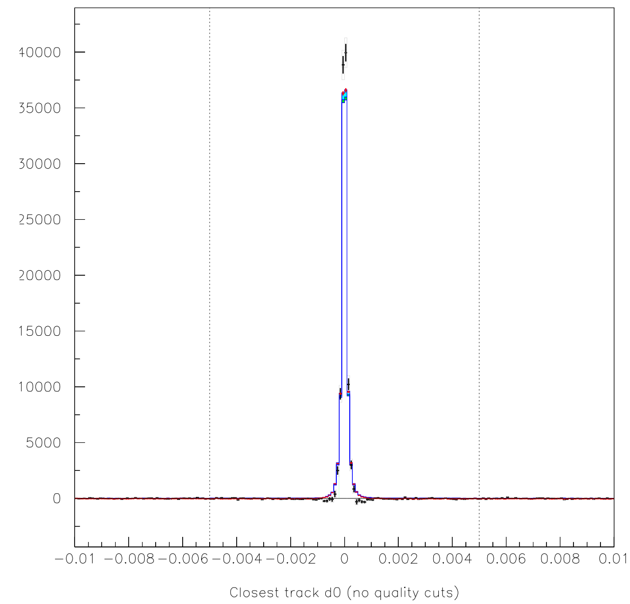
$\Upsilon(1S)$



$\Upsilon(2S)$



$\Upsilon(3S)$



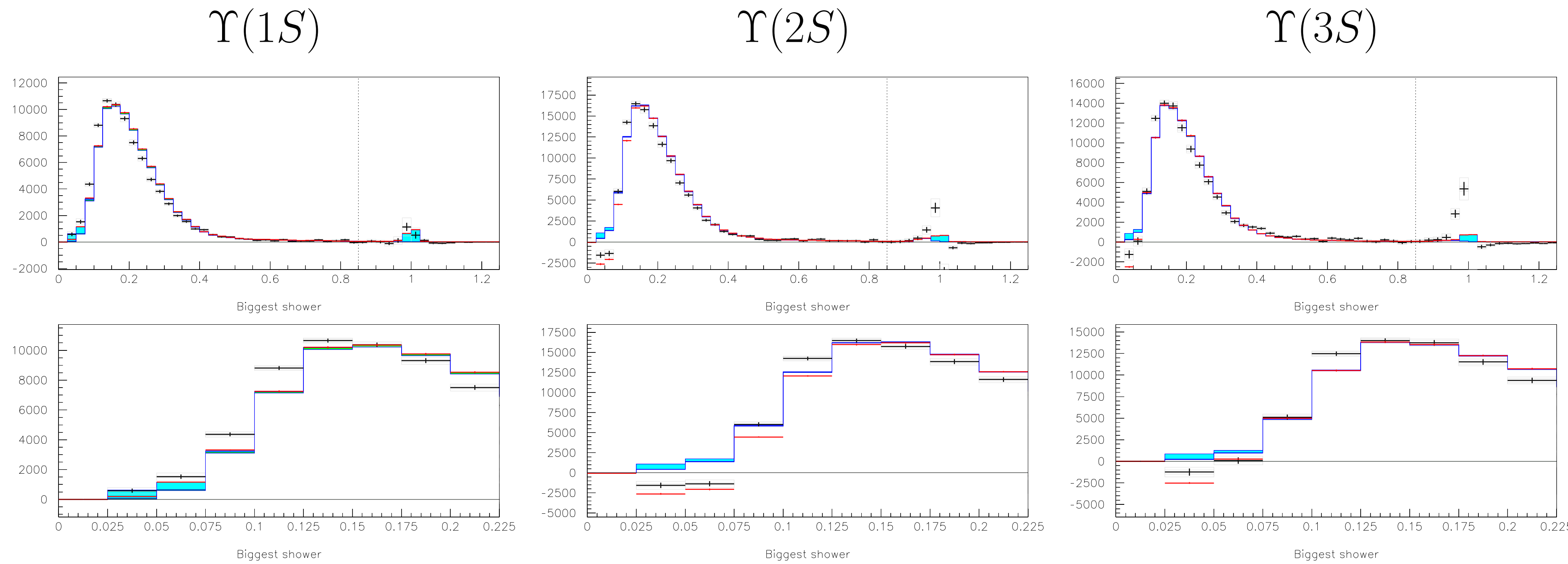
(Fixed beamspot problem!)

Taking error to be 100% of cut region would yield a 0.1% efficiency systematic

Suppose we're wrong the other way: shift cut from 5 mm down to 2 mm changes the result by 0.25%

Take efficiency systematic to be 0.25%.

Biggest shower < 0.85% of beam energy

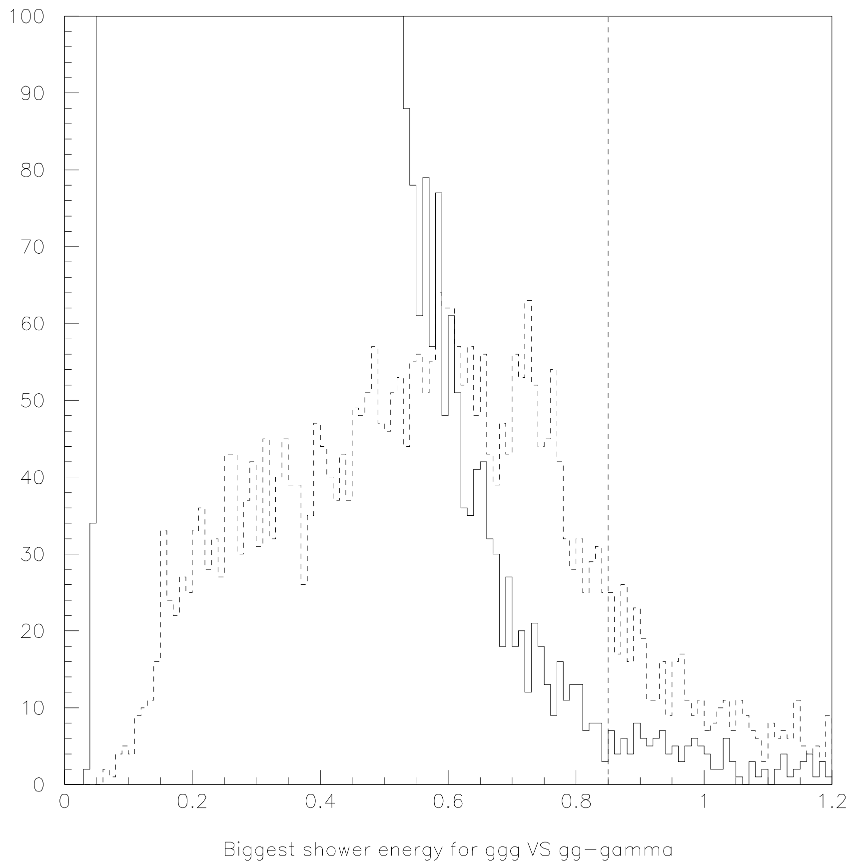


ggg events are all easily below the cut-off

$gg\gamma$ span the boundary

cascade decays to e^+e^- are all to the right of the boundary

Biggest shower uncertainty from $\Gamma_{gg\gamma}/\Gamma_{ggg}$



Solid is ggg, dashed is $gg\gamma$ (boundary is also dashed)

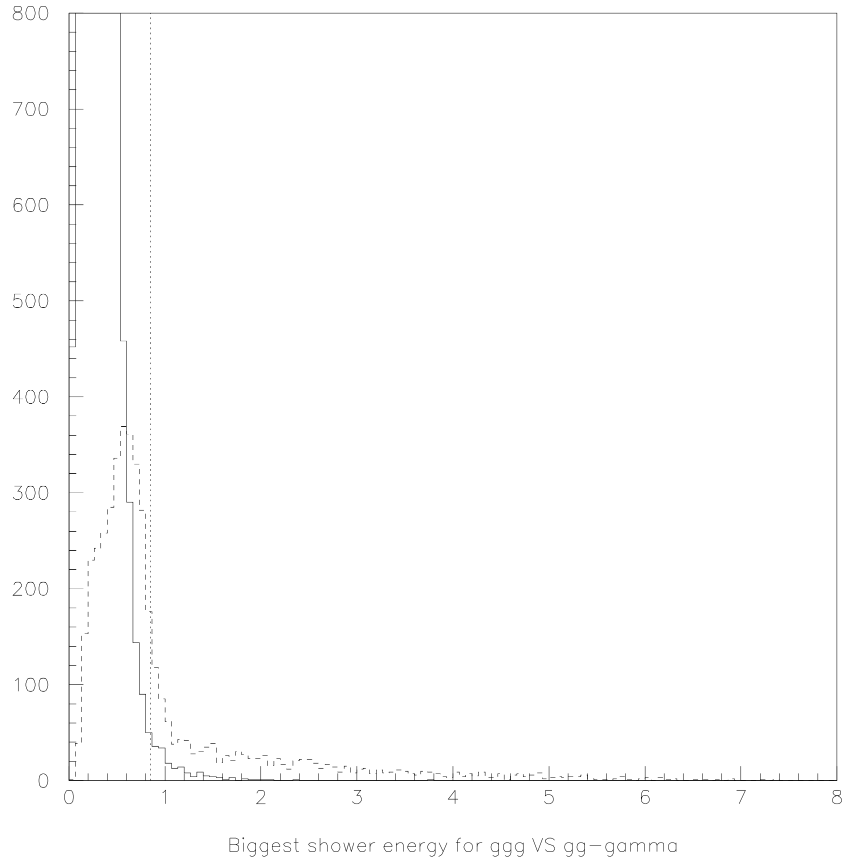
$\Gamma_{gg\gamma}/\Gamma_{ggg}$ is precise

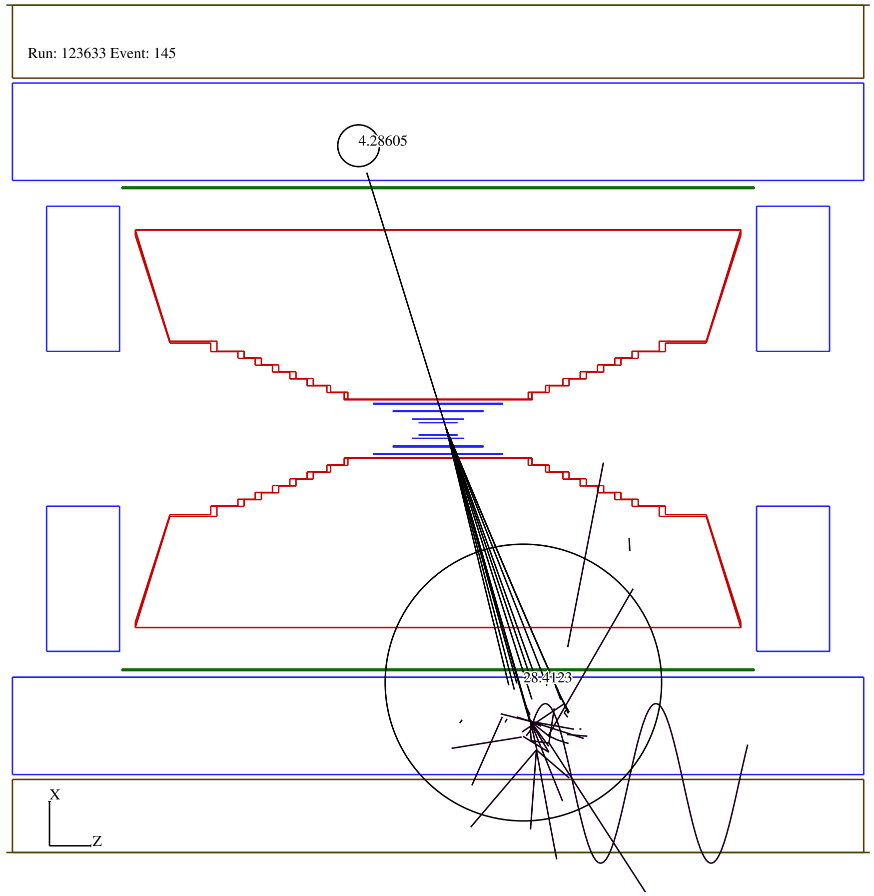
- $2.75 \pm 0.15\%$ from CLEO PRD 55, 5273 direct measurement
- $3.646 \pm 0.054\%$ from PDG world-average and running to M_Υ

Even if we straddle both, efficiency gets a systematic of 0.15% error

But wait! There's a disaster!

Disasterous uncertainty in $gg\gamma$ Monte Carlo





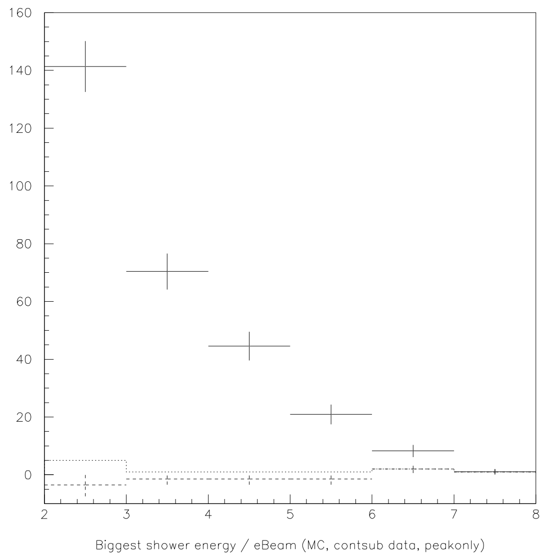
(Yes, that says 28.4 GeV in the bottom shower)

The big showers don't come from the prompt photon, they come from a massively overlapped jet from the gg. This tail extends way beyond the full center-of-mass energy.

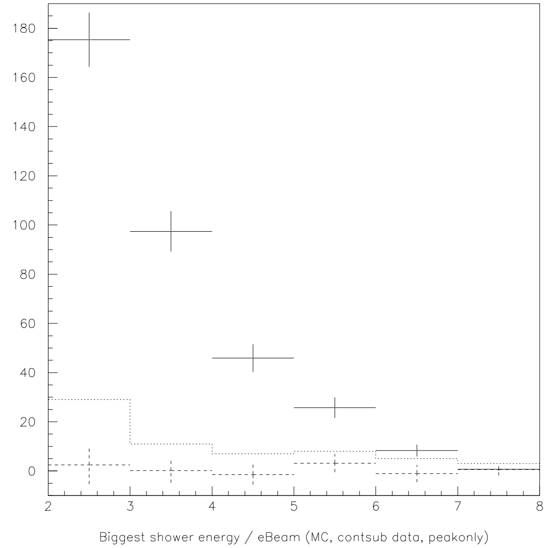
$\boxed{\text{Is this feature in the data?}}$

No. Not even a little bit.

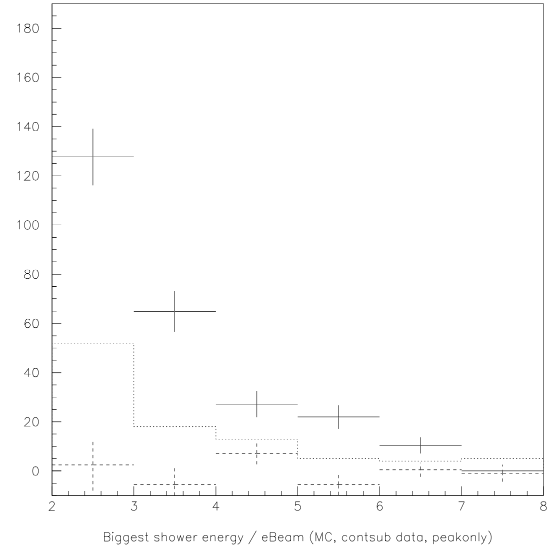
$\Upsilon(1S)$



$\Upsilon(2S)$



$\Upsilon(3S)$

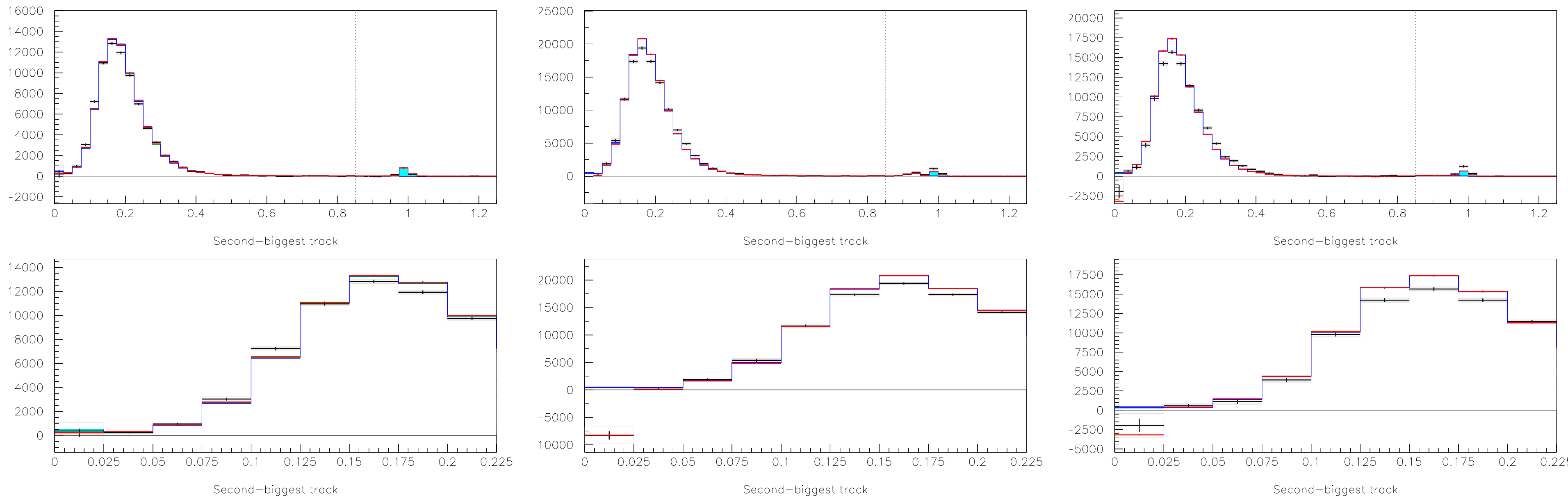


- Horizontal axis is in units of center-of-mass energy
- Solid is Monte Carlo
- Dashed is on-res minus off-res
- Histogram is just on-res

If Monte Carlo didn't make this mistake, would $gg\gamma$ events be below the cut boundary? I can't tell, so I'll take uncertainty in $\Gamma_{gg\gamma}/\Gamma_{ggg}$ to be all of itself, incurring a 1.1% systematic in efficiency.

Second-biggest track $< 0.85\%$ of beam energy

$\Upsilon(1S)$ $\Upsilon(2S)$ $\Upsilon(3S)$



No such problems here. All ggg and $gg\gamma$ pass this cut.

I haven't forgotten the cascade to leptons systematic.

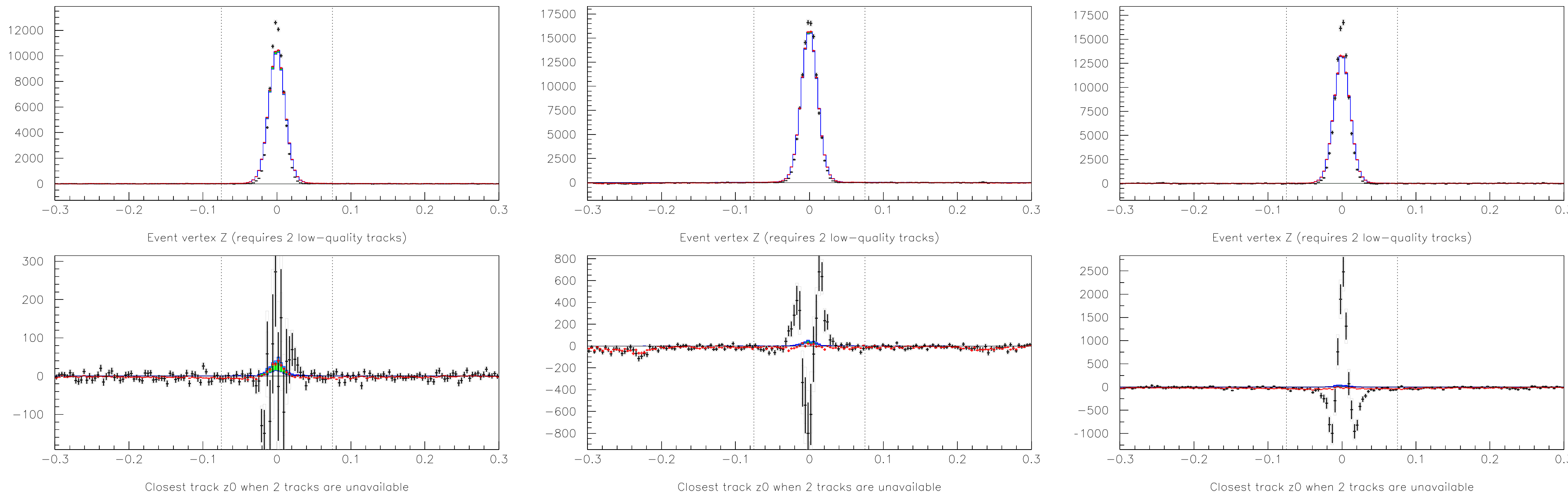
With Istvan's new $\mathcal{B}_{\mu\mu}$, $\Upsilon(nS) \to X\ell^+\ell^-$ (where X cannot be nothing) is 0 for $\Upsilon(1S)$, $0.795 \pm 0.036\%$ for $\Upsilon(2S)$ and $0.480 \pm 0.028\%$ for $\Upsilon(3S)$.

Systematic error on efficiency for these uncertainties is 0.06%.

Supposing PHOTOS is wrong by 50%, we get another systematic of 0.03%.

Event vertex Z $<$ 7.5 cm (or closest track z0 $<$ 7.5 cm, if only one track)

$\Upsilon(1S)$ $\Upsilon(2S)$ $\Upsilon(3S)$



(Bottom plot is closest z0 for those few events which didn't have two tracks to form a Z vertex. It doesn't cancel well because I forgot to move z0 to the beamspot— $\Upsilon(2S)$ and $\Upsilon(3S)$ samples contain many runs.)

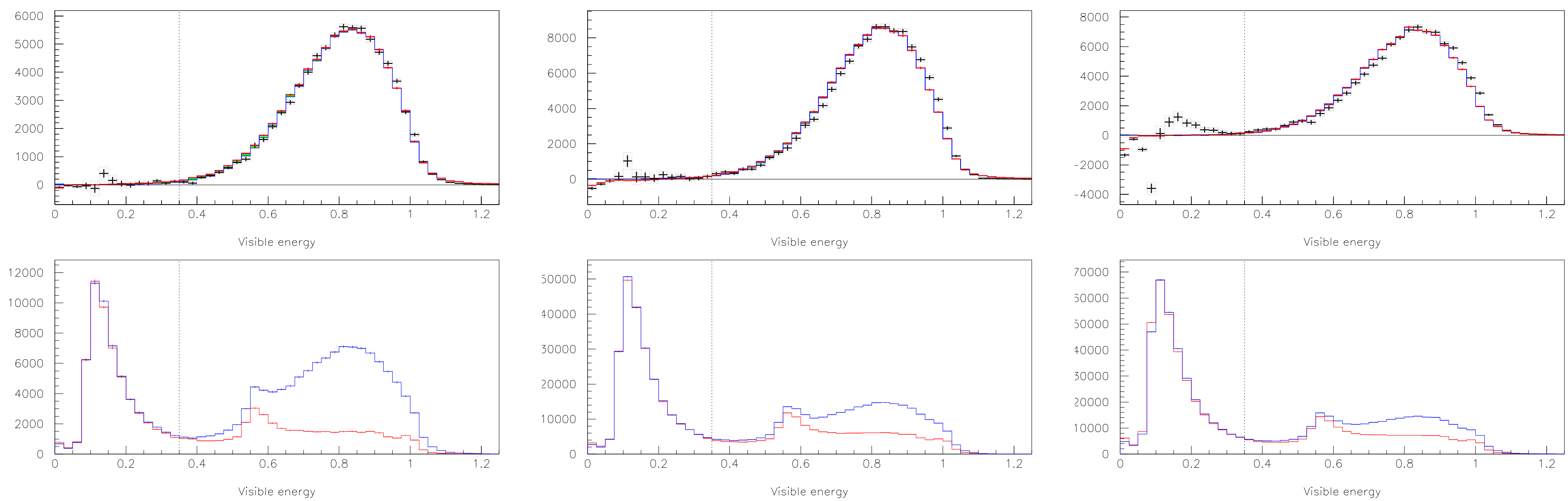
This cut is perhaps a little too close to trust Monte Carlo, backgrounds are now controlled for $\Upsilon(1S)$ (the tallest peak), and cut efficiency should be the same for all three resonances, so take $\Upsilon(1S)$ value for each.

$99.35 \pm 0.20 \pm 0.56\%$ $\quad$ $99.96 \pm 0.30 \pm 1.39\%$ $\quad$ $99.53 \pm 0.41 \pm 1.99\%$

First error is statistical (binomial fluctuations in samples that pass cuts) and second is systematic (fluctuations in control samples, scale factors).

Visible energy $< 0.35\%$ of center-of-mass energy

$\Upsilon(1S)$ $\Upsilon(2S)$ $\Upsilon(3S)$

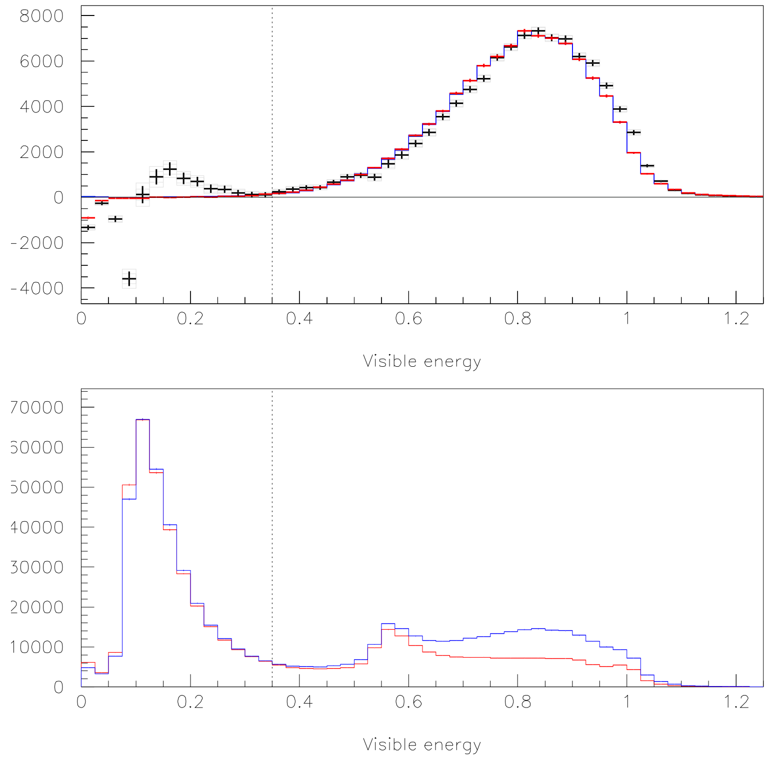


Bottom plot is the on-res (blue) and off-res (red) before subtraction.

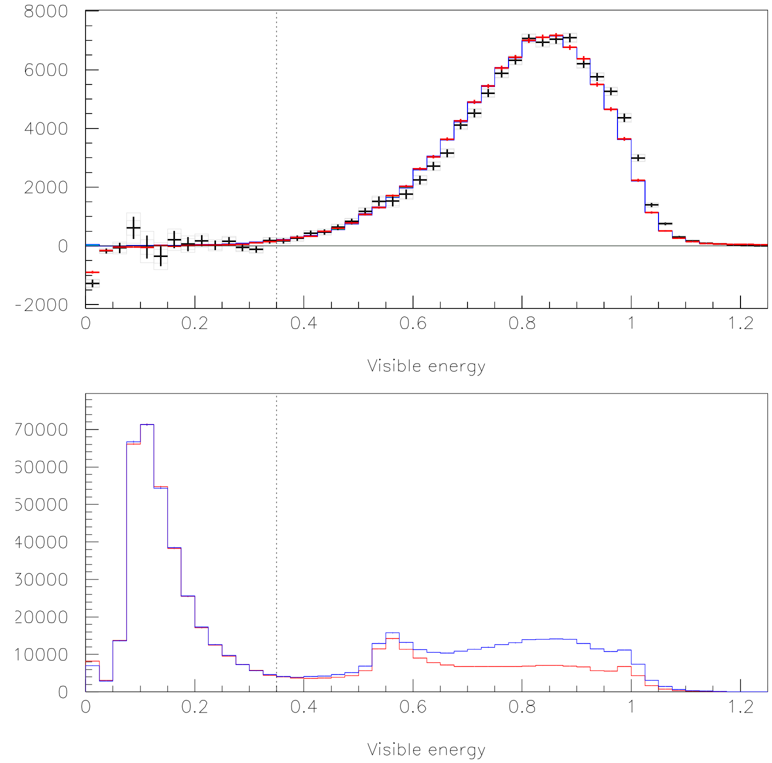
The low-energy bump seems to be mostly two-photon events.

The problem: $\Upsilon(3S)$ doesn't subtract perfectly— low-energy on-res events got about 50 MeV more neutral energy per event than off-res events.

The solution:



Normal visible energy



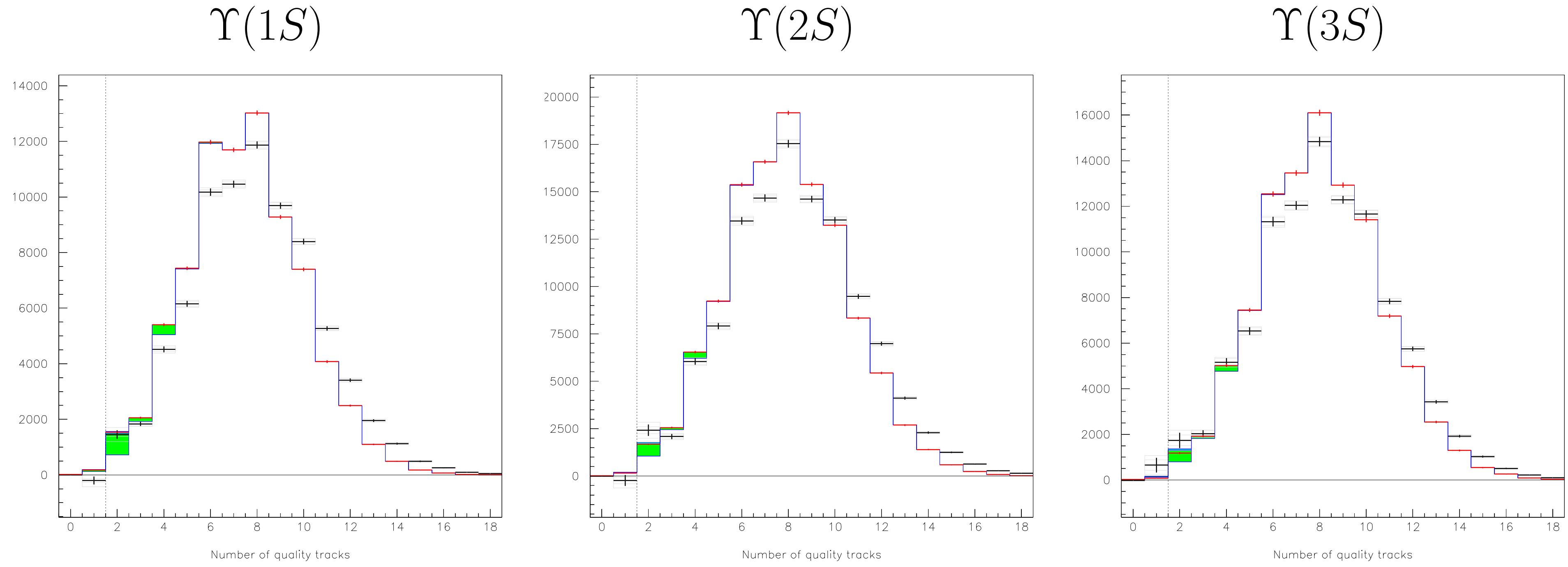
No hot showers

Calculate visible energy excluding hot showers and the mismatch is gone.

Tau subcollection cuts on visible energy including hot showers.

I will continue to cut on that variable, but raise the threshold above the dangerous bump.

Quality tracks ≥ 2

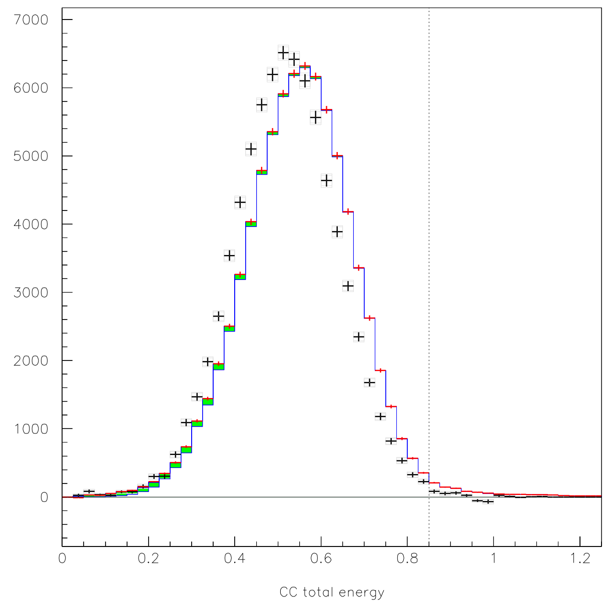


This was the reason I switched to the tau subcollection: data/MC mismatch doesn't matter when the cut is made so low.

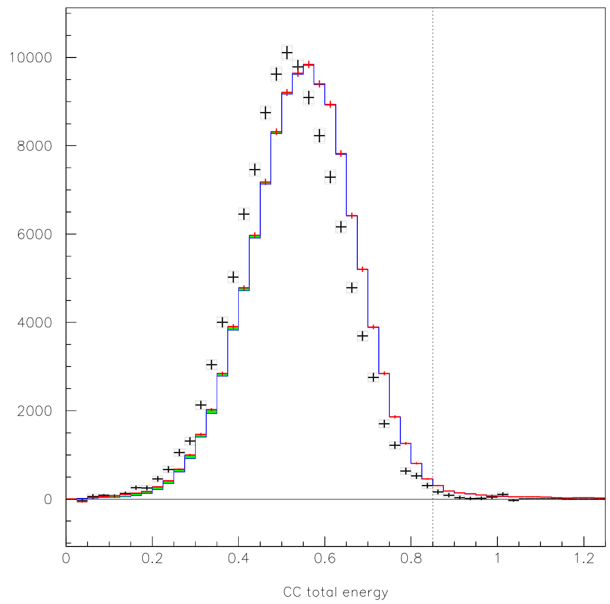
Nor does it matter now anyway, since I'm reading the efficiency from data for this variable.

CC energy < 0.85% of center-of-mass energy

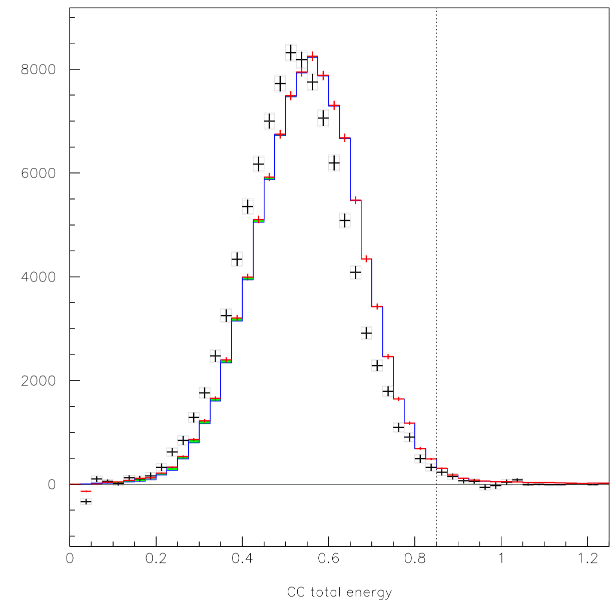
$\Upsilon(1S)$



$\Upsilon(2S)$



$\Upsilon(3S)$



This was the data/MC disagreement I introduced by the switch. I will remind you that I'm measuring the efficiency from the data.

The big table

	$\Upsilon(1S)$	$\Upsilon(2S)$	$\Upsilon(3S)$
Monte Carlo part	0.9852	0.9711	0.9773
statistical	$\pm$ 0.00032	$\pm$ 0.00040	$\pm$ 0.00048
trigger	$\pm$ 0.0050	$\pm$ 0.0050	$\pm$ 0.0050
closest d0	$\pm$ 0.0025	$\pm$ 0.0025	$\pm$ 0.0025
100% of $\Gamma_{gg\gamma}/\Gamma_{ggg}$	$\pm$ 0.0111	$\pm$ 0.0108	$\pm$ 0.0109
$\mathcal{B}$ of cascade-leptons (1σ)	$\pm$ 0	$\pm$ 0.0006	$\pm$ 0.0005
PHOTOS by 50%	$\pm$ 0	$\pm$ 0.0003	$\pm$ 0.0001
event Z	0.9935	0.9935	0.9935
statistical	$\pm$ 0.0020	$\pm$ 0.0020	$\pm$ 0.0020
systematic	$\pm$ 0.0056	$\pm$ 0.0056	$\pm$ 0.0056
data part	0.9949	0.9792	0.9874
statistical	$\pm$ 0.0034	$\pm$ 0.0039	$\pm$ 0.0055
systematic	$\pm$ 0.0081	$\pm$ 0.0088	$\pm$ 0.0110
	0.9738	0.9447	0.9587
total	$\pm$ 0.0040	$\pm$ 0.0044	$\pm$ 0.0059
	$\pm$ 0.0159	$\pm$ 0.0160	$\pm$ 0.0174