Measurement of $\Upsilon(2S)$ Hadronic Acceptance

Jim Pivarski

April 30, 2004

A quick reminder of what I'm doing:

$$\frac{\Gamma_{\mathrm{ee}}\Gamma_{\mathrm{had}}}{\Gamma_{\mathrm{total}}} = \frac{{M_\Upsilon}^2}{6\pi^2} \text{(area of hadronic lineshape)}$$

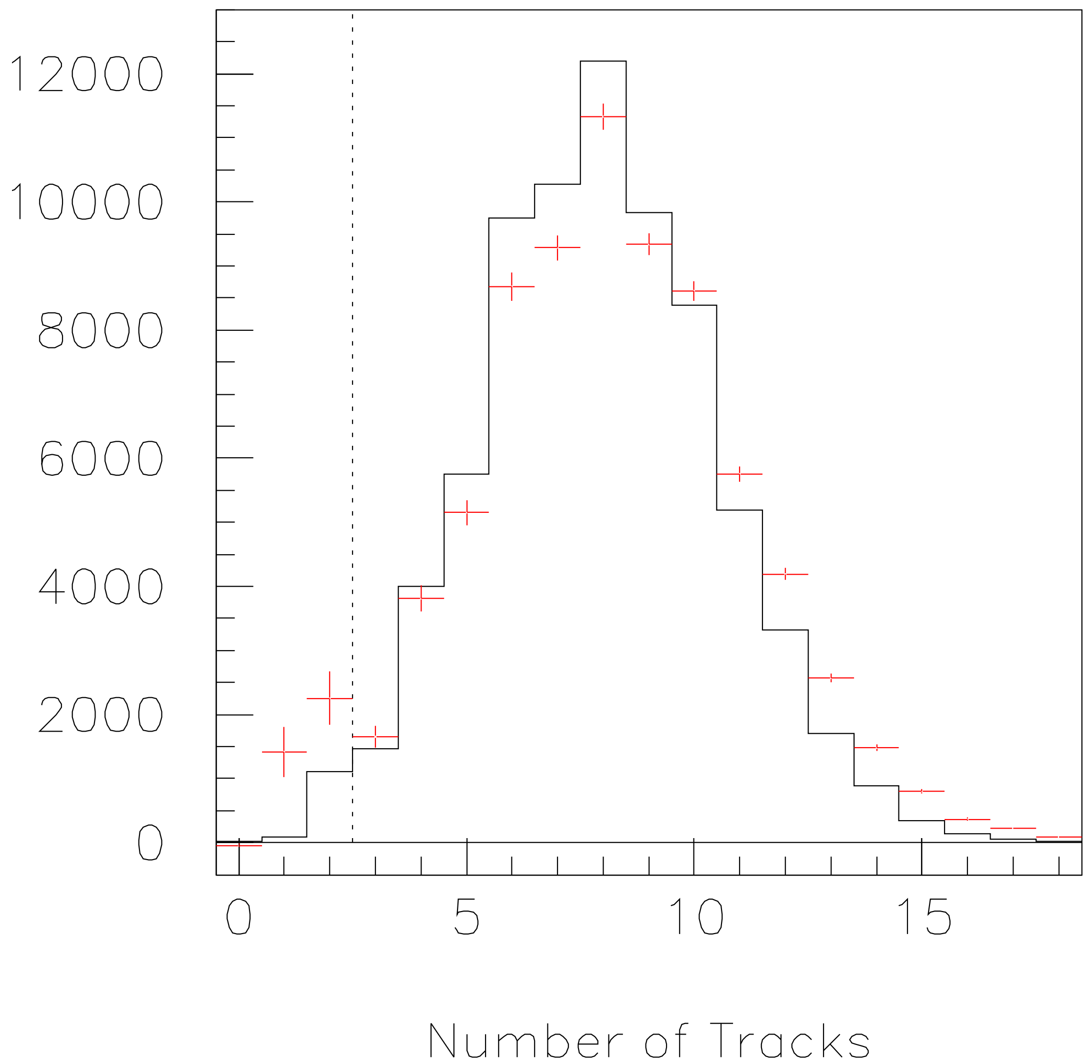
I have fitted lineshapes, but I need to calibrate them absolutely

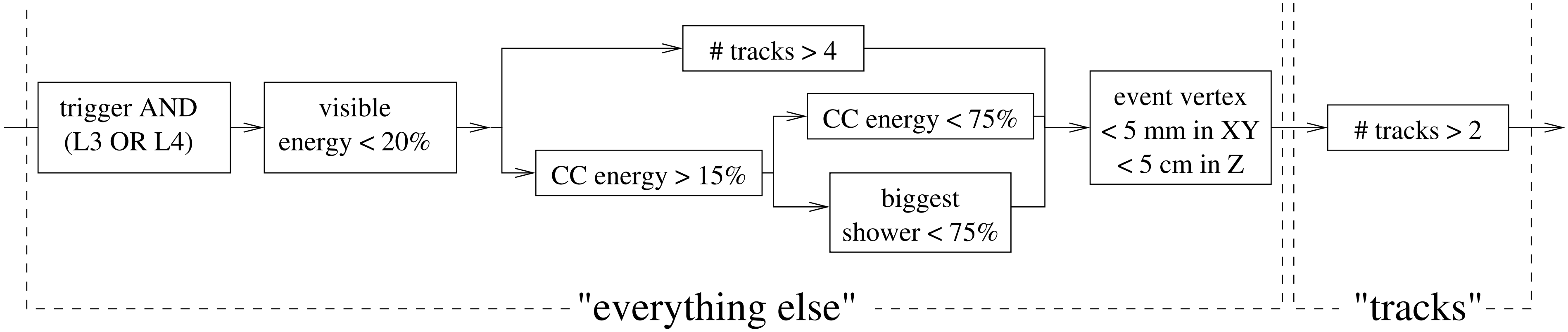
$$\text{real area} = \frac{\text{measured area}}{\text{acceptance}} \text{(possibly a luminosity correction)}$$

Today's talk: hadronic acceptance of $\Upsilon(2S)$.

Acceptance? Cut Monte Carlo and count survivors, right?

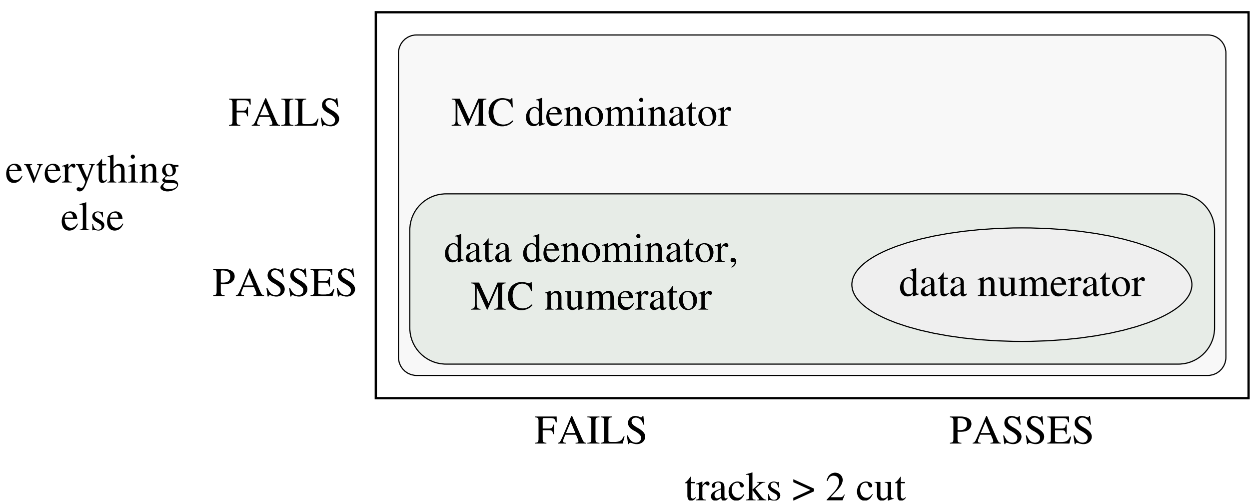
No: data (red) and Monte Carlo (black) disagree near a cut boundary

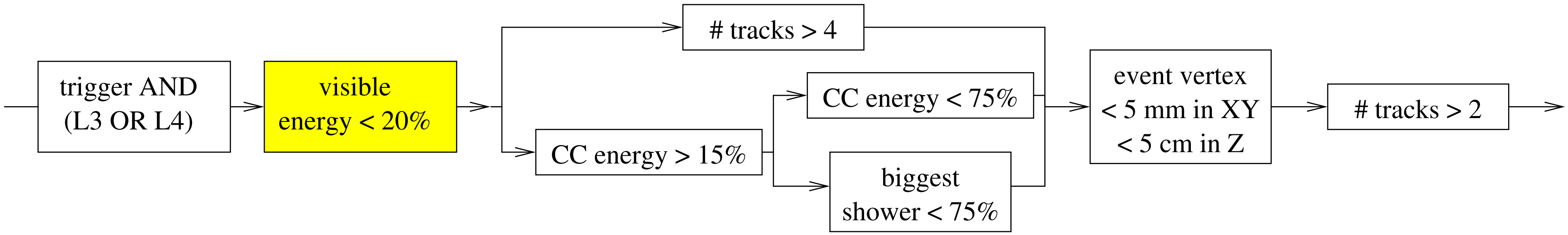


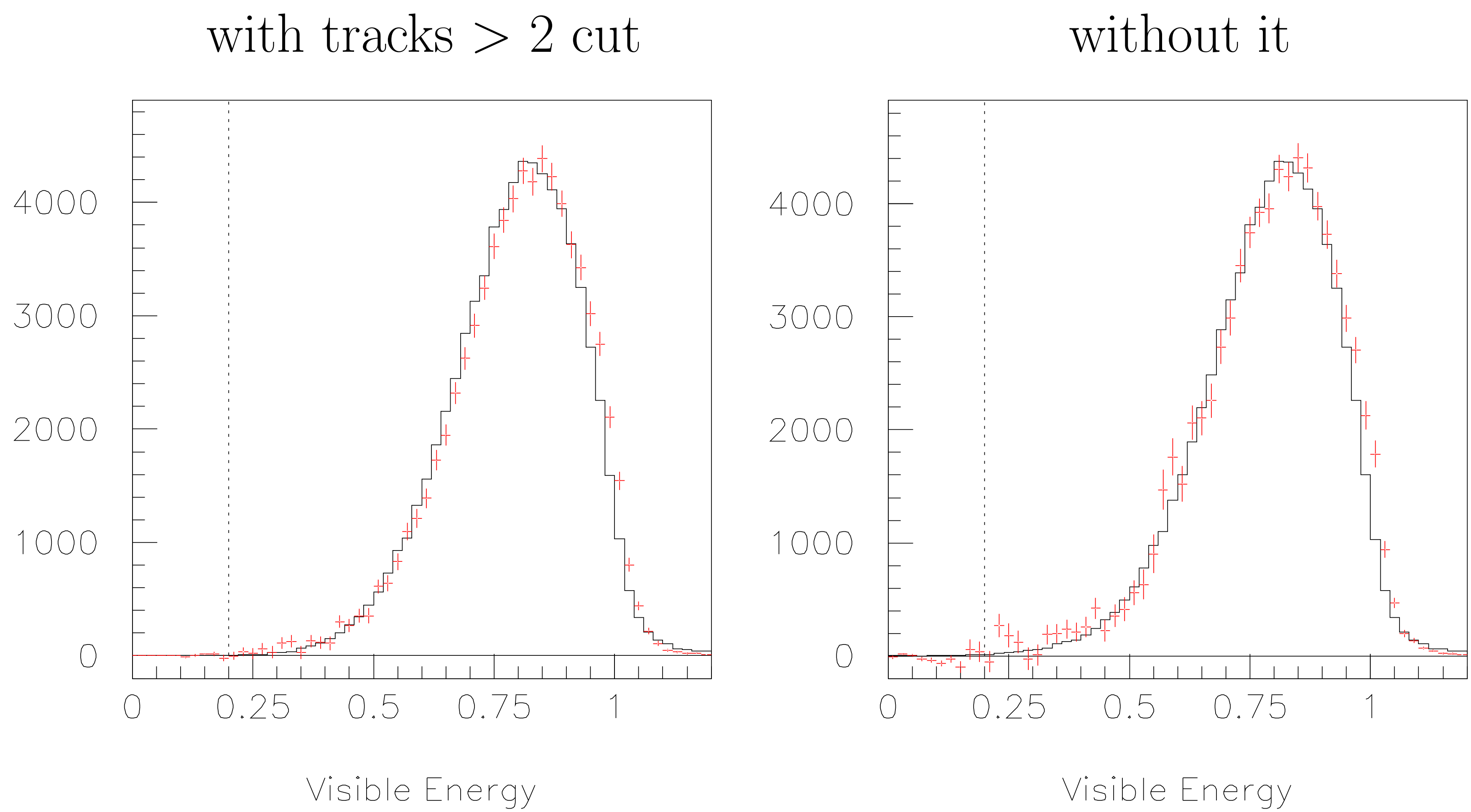


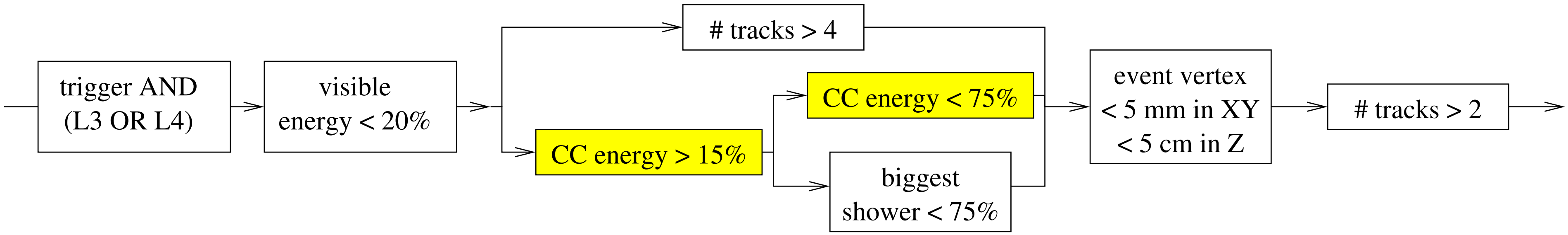
$$P\left(\begin{array}{c}\text{passes tracks AND}\\ \text{everything else}\end{array}\right) = \underbrace{P\left(\begin{array}{c|c}\text{passes} & \text{everything}\\ \text{tracks} & \text{else}\end{array}\right)}_{\text{from data}} \underbrace{P\left(\begin{array}{c}\text{passes}\\ \text{everything else}\end{array}\right)}_{\text{from Monte Carlo}}$$

$$= \frac{\text{data numerator}}{\text{data denominator}} \quad \frac{\alpha \text{ Monte Carlo numerator}}{\alpha \text{ Monte Carlo denominator}}$$



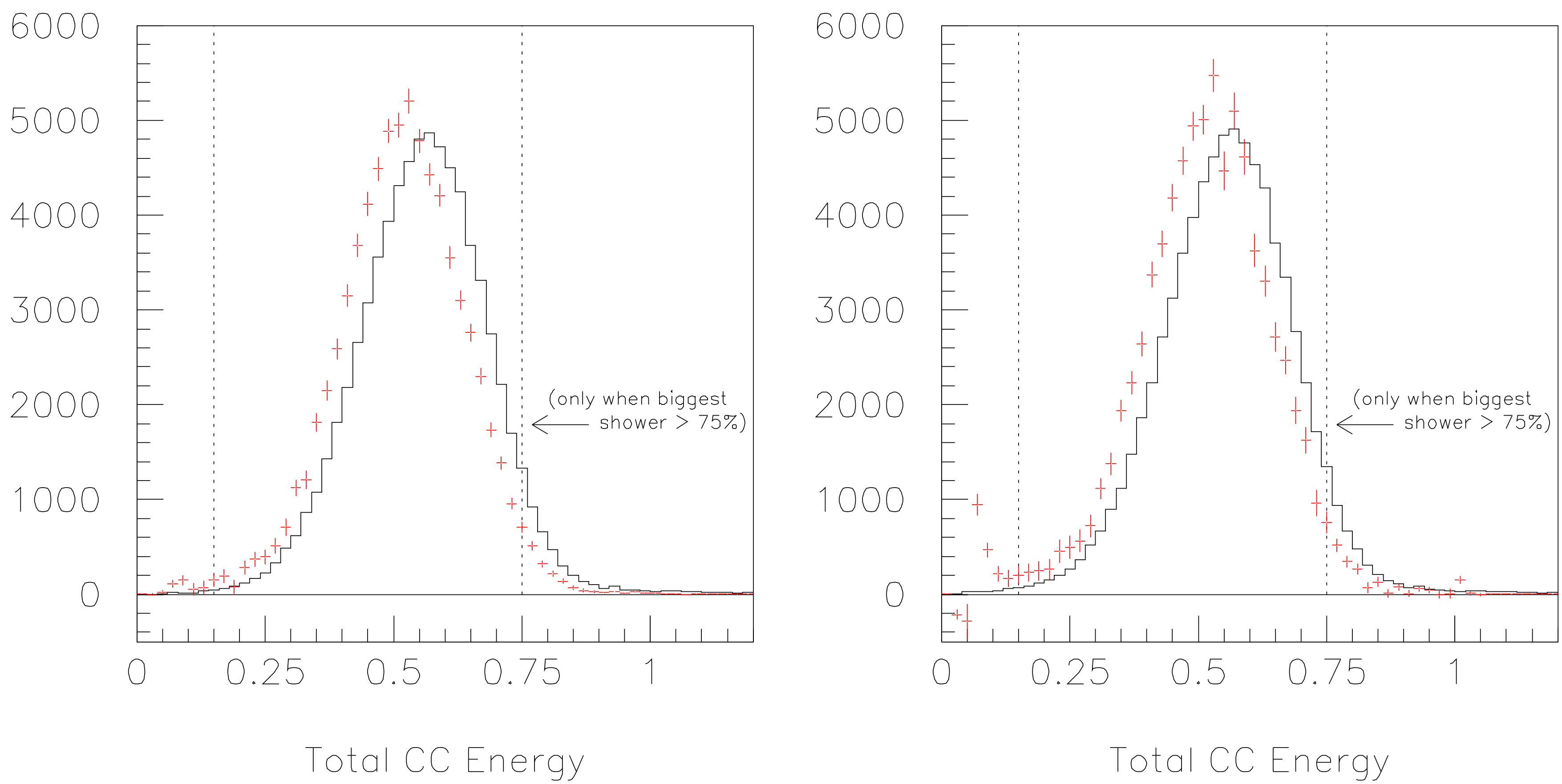

trigger AND
(L3 OR L4)
visible
energy < 20%
tracks > 4
CC energy > 15%
CC energy < 75%
biggest
shower < 75%
event vertex
< 5 mm in XY
< 5 cm in Z
tracks > 2

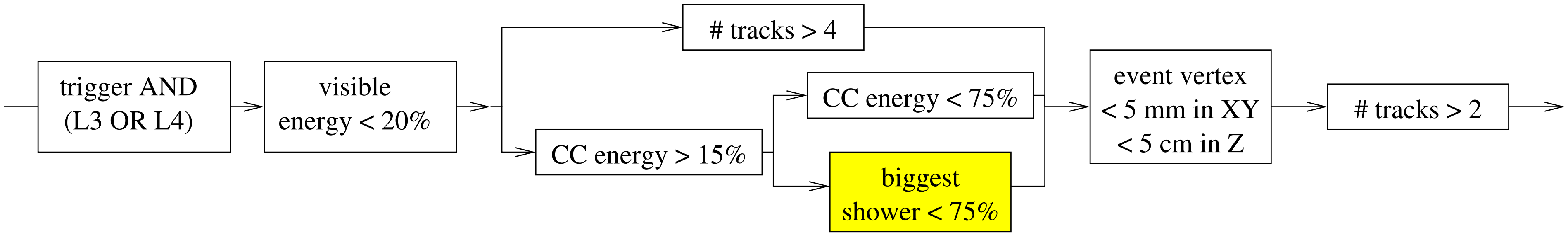

with tracks > 2 cut
without it
4000
3000
2000
1000
0
0
0.25
0.5
0.75
1
Visible Energy
Visible Energy



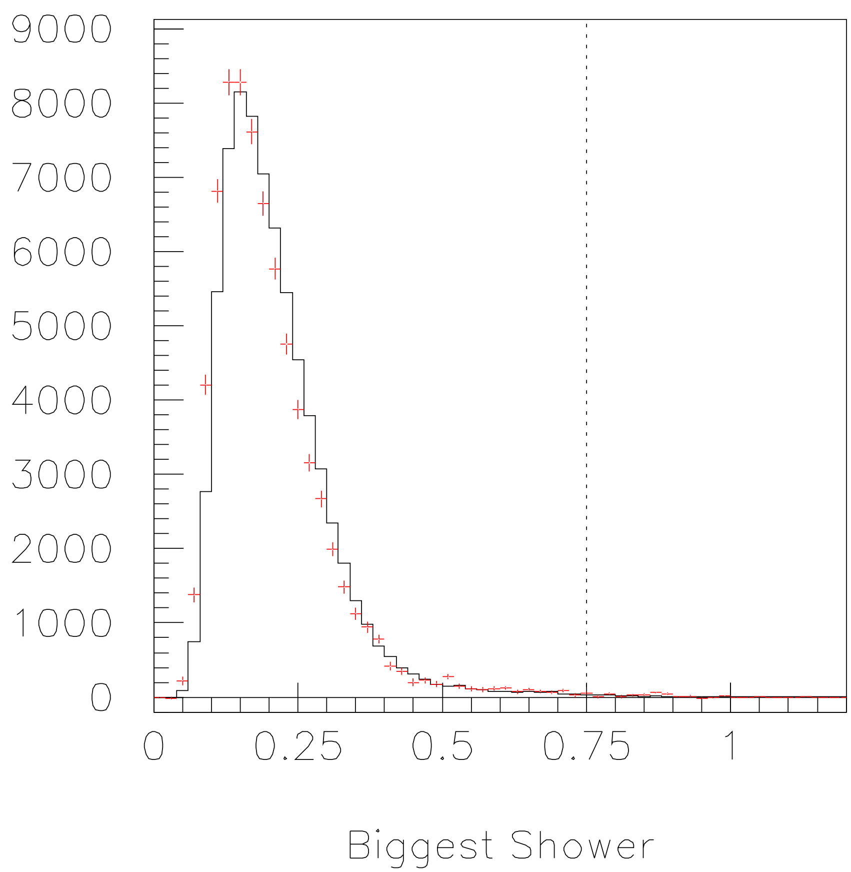
with tracks > 2 cut

without it

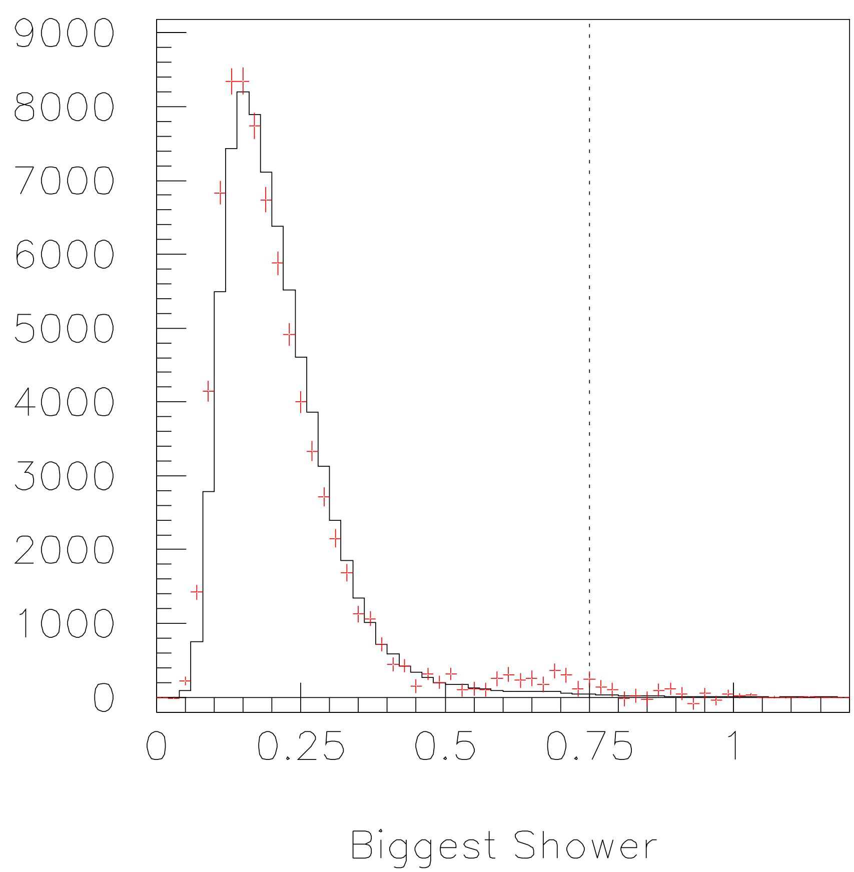


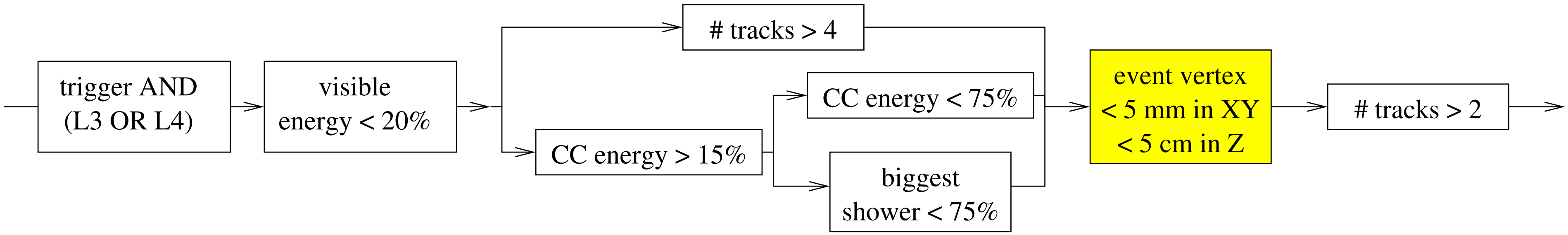


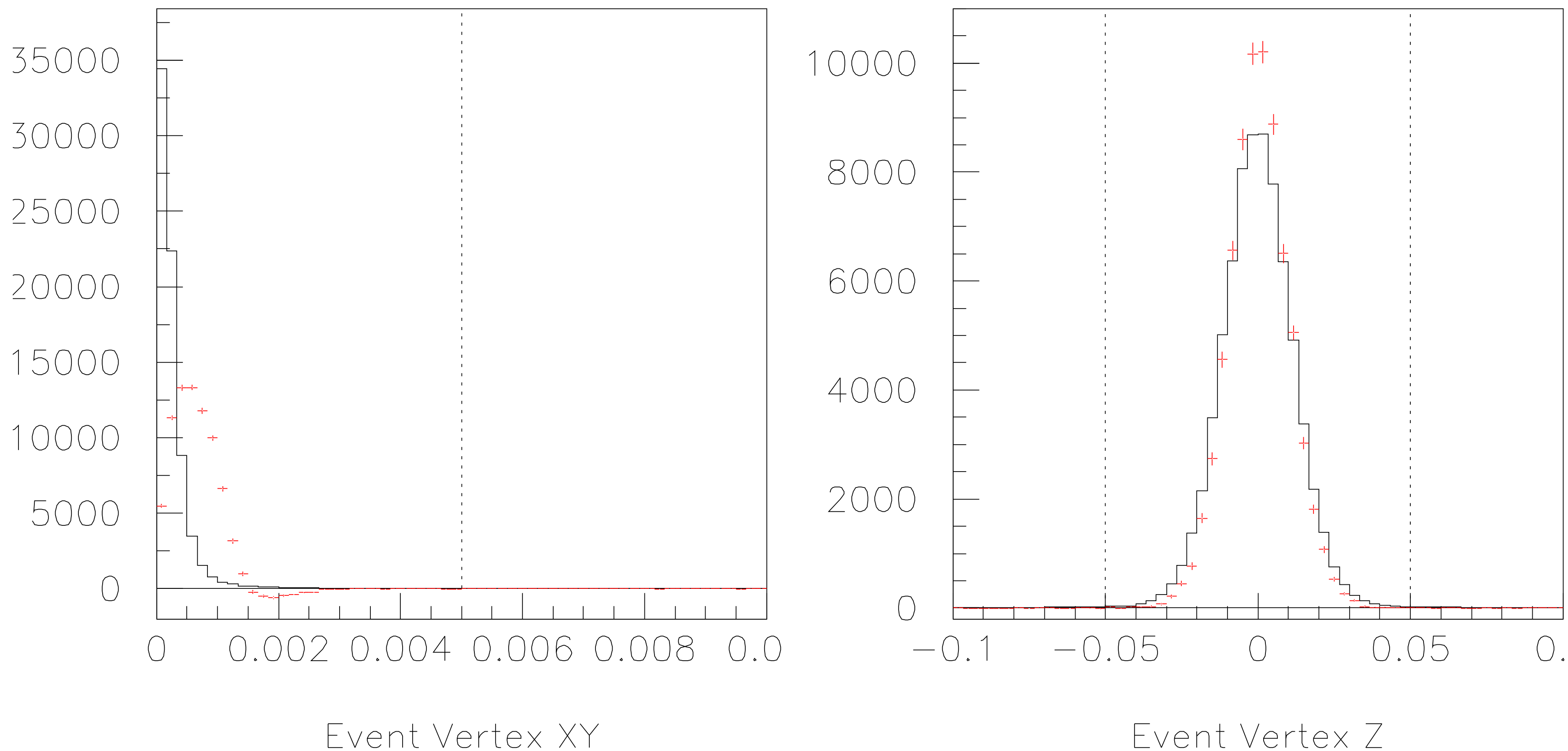
with tracks $>$ 2 cut

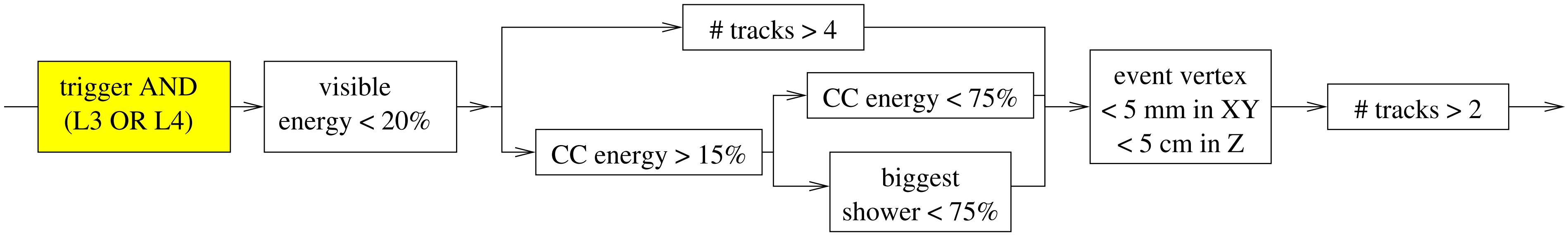


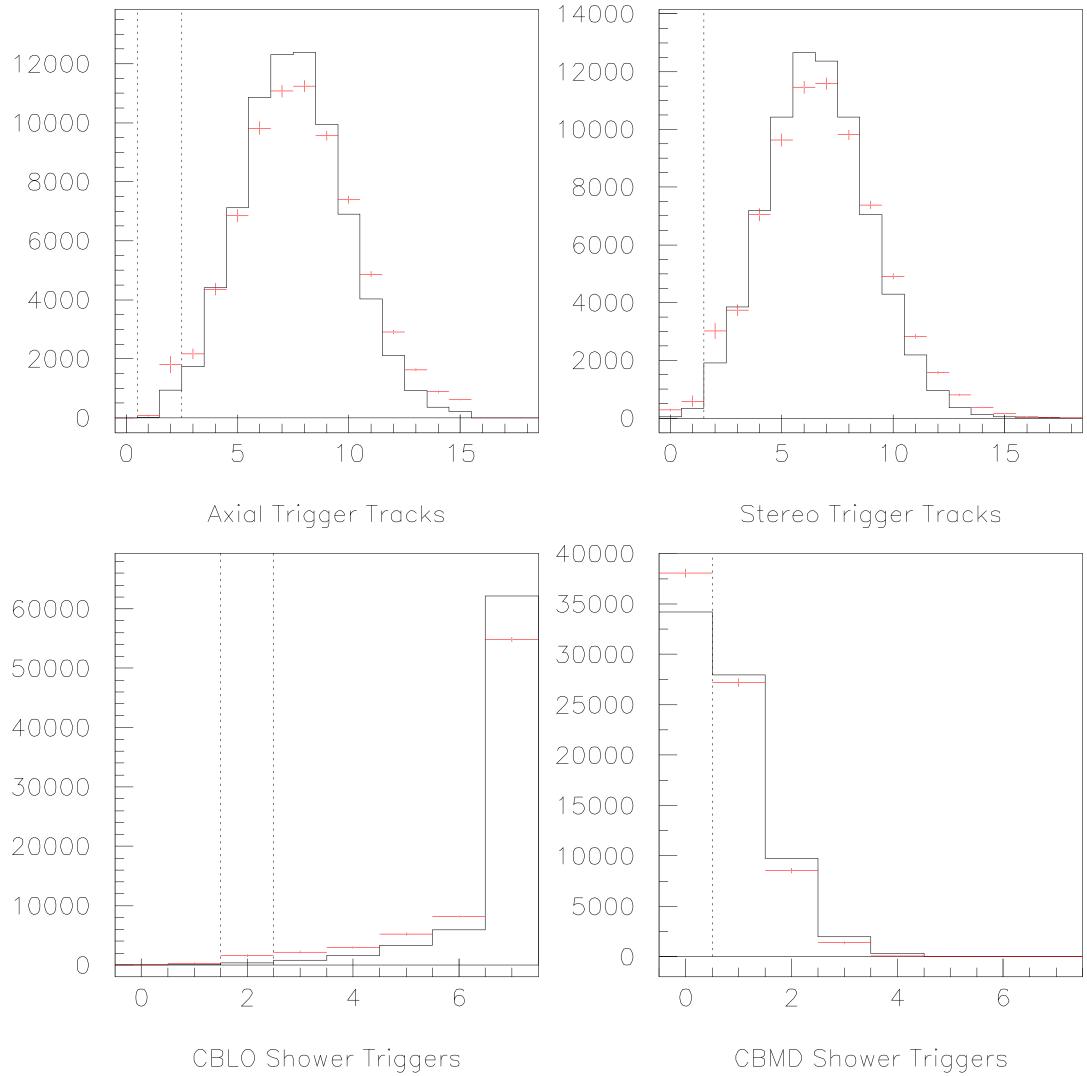
without it




trigger AND (L3 OR L4)
visible energy < 20%
tracks > 4
CC energy > 15%
CC energy < 75%
biggest shower < 75%
event vertex < 5 mm in XY < 5 cm in Z
tracks > 2


35000
30000
25000
20000
15000
10000
5000
0
0
0.002
0.004
0.006
0.008
0.0
Event Vertex XY
10000
8000
6000
4000
2000
0
−0.1
−0.05
0
0.05
Event Vertex Z





Though the modelling isn't perfect, the trigger is extremely efficient

$> 99.6\%$ pass

(99.8% with other cuts)

I will neglect trigger uncertainties

	MC $\Upsilon \to X\ell^+\ell^-$	MC $\Upsilon \to$ other
pass "everything else"	3.1%	97.35%

Systematic errors		MC $\Upsilon \to$ other
shift visible energy $+0.015$		$+0.007\%$
shift CC energy -0.037		$+0.132\%$
shift biggest shower -0.01		$+0.013\%$
$\boxed{\text{tracks} > 4} \to \boxed{\text{tracks} > 5}$		-0.12%
$\boxed{\text{tracks} > 4} \to \boxed{\text{tracks} > 3}$		$+0.23\%$

Tail Fractions	Data	MC $\Upsilon \to$ other
Event vertex XY	0.177%	0.24%
Event vertex Z	-0.097%	0.52%
CC energy	0.0014%	0.029%
Biggest shower	0.00082%	0.0077%

Overall systematic error of 0.60% on MC $\Upsilon \to$ other

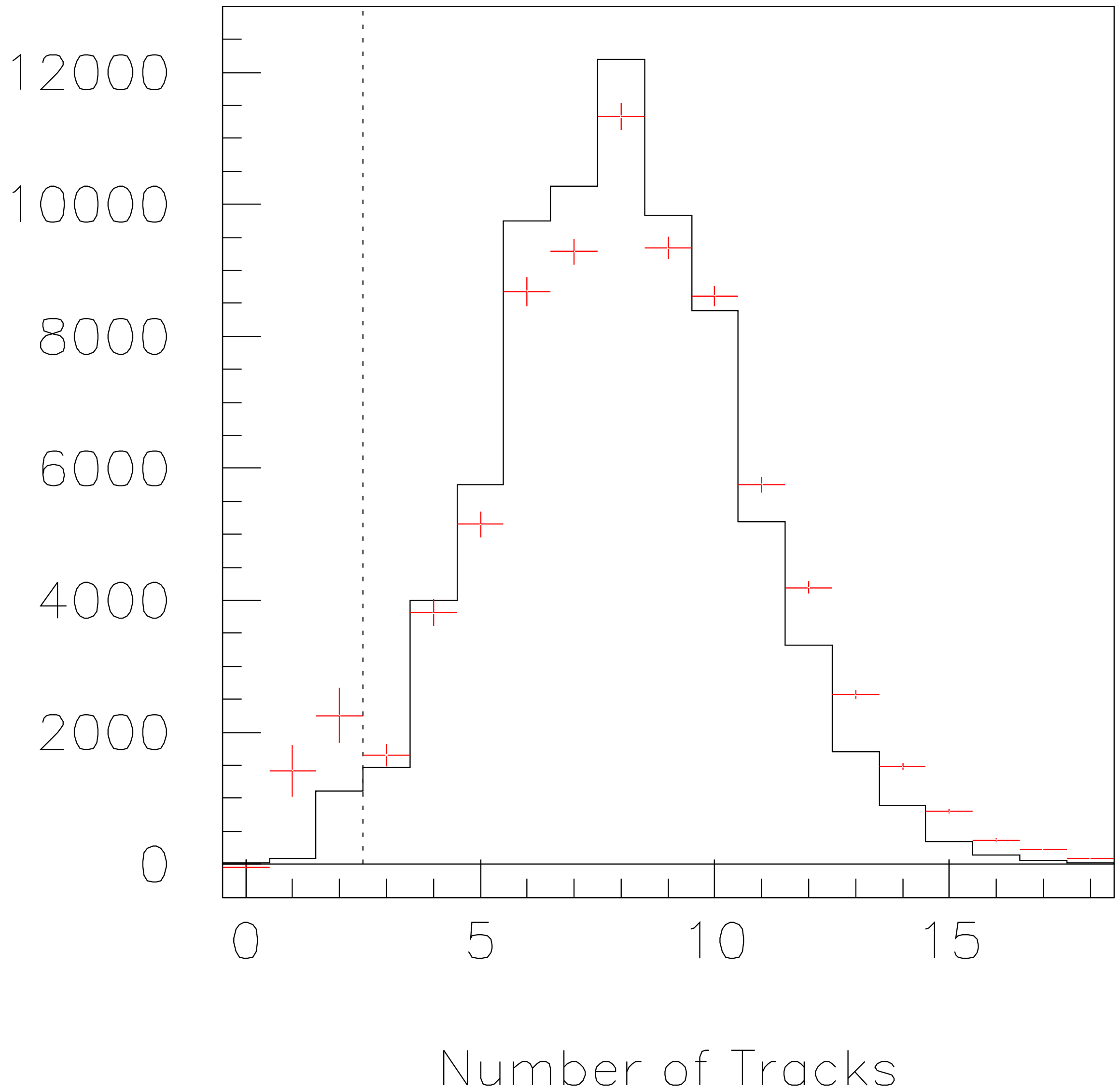
$$\text{PDG} \quad \mathcal{B}_{\mu\mu} = 4.10\% \pm 0.30\%$$

$$\text{Istvan's} \quad \mathcal{B}_{\mu\mu} = 5.82\% \pm 0.13\%$$

$$P\left(\begin{array}{c}\text{passes}\\ \text{everything else}\end{array}\right) = 3.1\%\,\mathcal{B}_{\mu\mu} + 97.35\%\,(1-\mathcal{B}_{\mu\mu})$$

$$= \begin{cases} 93.48\% \pm \underbrace{0.28\%}_{stat} \pm \underbrace{0.58\%}_{syst} & \text{PDG} \\ \\ 91.86\% \pm \underbrace{0.12\%}_{stat} \pm \underbrace{0.58\%}_{syst} & \text{Istvan} \end{cases}$$

Now for $P(\text{tracks} > 2 \mid \text{everything else})$:



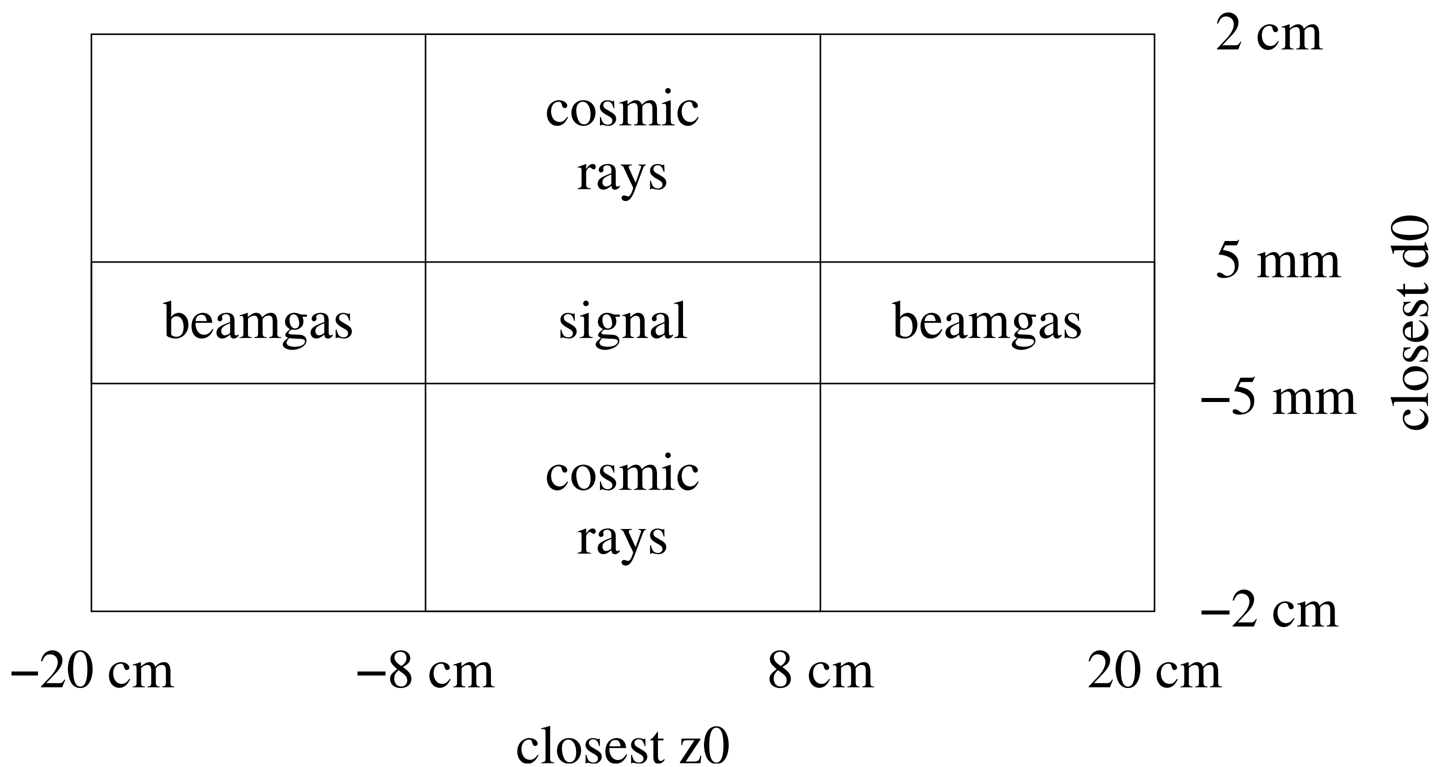
All cuts except $\boxed{\text{tracks} > 2}$ have been applied.

Just count how many are to the right of the line?

What about backgrounds?

Event vertices can't be constructed when you have fewer than 3 tracks

Instead, plot closest $|d_0|$ and $|z_0|$ to the beamspot



Project beamgas into signal region with single-beam

Project cosmics into signal region with no-beam

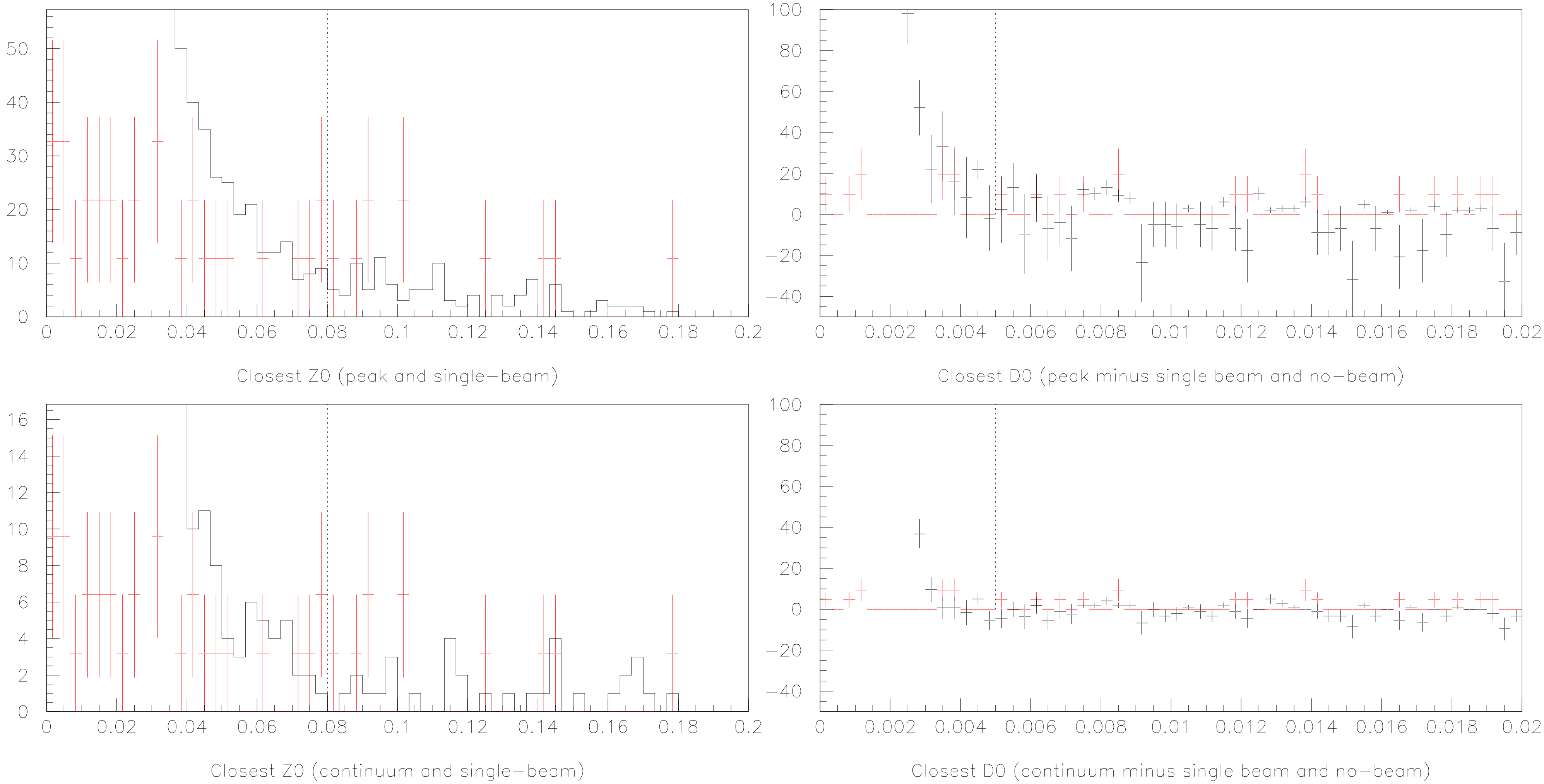
Do this independently for peak and continuum, then do a continuum subtraction to be background-free (1- and 2-track events)

All cuts applied except that tracks $\in \{1, 2\}$ and "event vertex" cuts are replaced with "closest d_0" and "closest z_0"

Data is black, single-beam and no-beam samples are red

Beamgas extrapolation

Cosmic ray extrapolation



Number that fail:

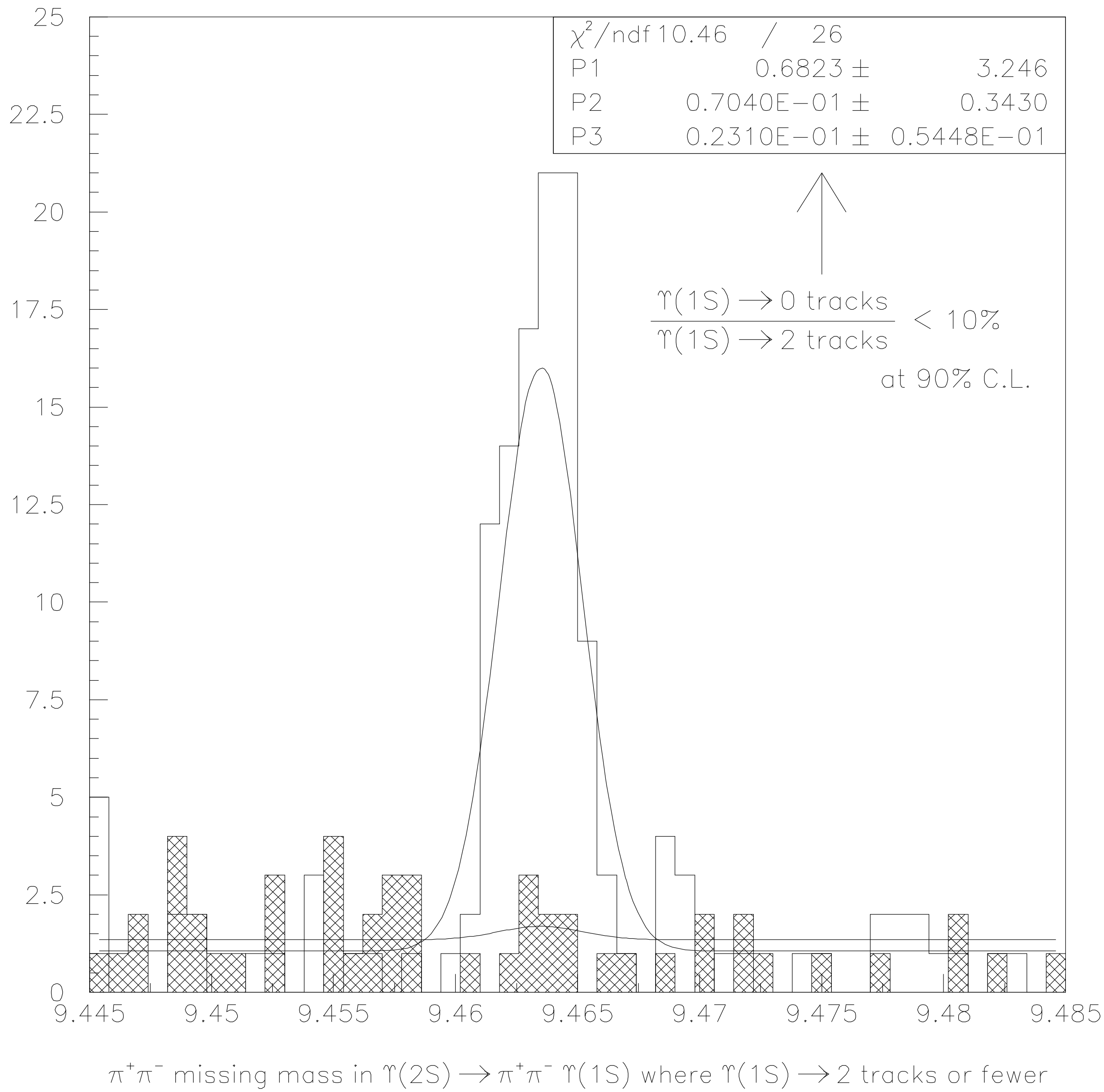
Number of 1, 2 track events	3656 ± 570	16% statistical error
Beamgas correction	160	4.4% difference
Cosmic ray correction	97	2.6% difference
Zero-track upper limit	267	7.3% of 1, 2 tracks
		19% error

Number that pass:

Data events passing all cuts	73354 ± 568	0.77% statistical error
Beamgas correction		0.06% difference

$$P(\text{tracks} > 2 \mid \text{everything else}) = 95.25\% \pm 0.84\%$$

How did I bound the number of zero-track events?



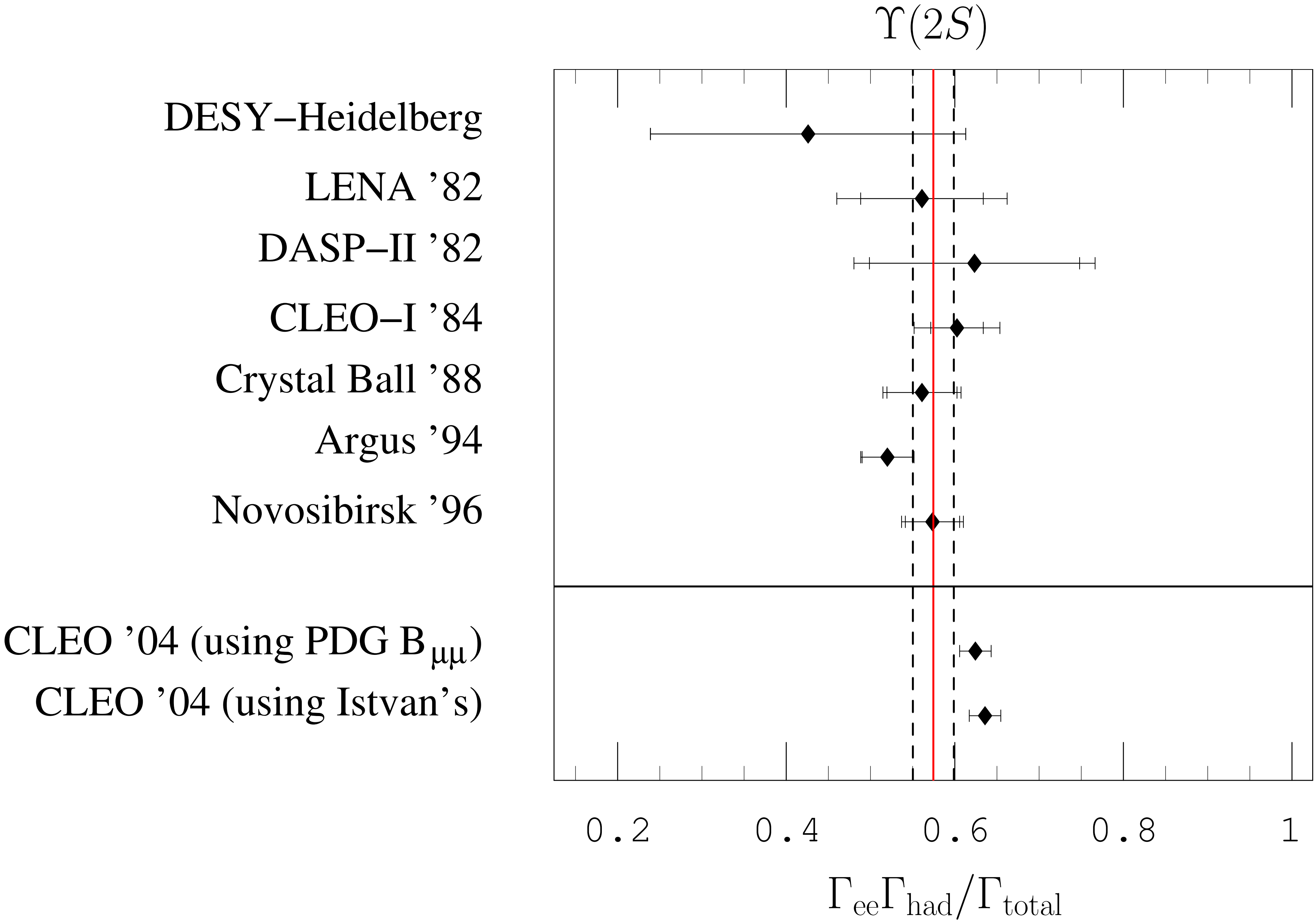
$$\text{So } P(\text{pass analysis cuts}) = \begin{cases} 89.04\% \pm 1.05\% & \mathcal{B}_{\mu\mu} \text{ from PDG} \\ 87.50\% \pm 0.95\% & \mathcal{B}_{\mu\mu} \text{ from Istvan} \end{cases}$$

$\Upsilon(2S)$ has a real area of

$$\begin{matrix} 138.0 \\ 140.4 \end{matrix} \text{ MeV nb } \underbrace{\pm \underbrace{0.47\%}_{stat} \pm \underbrace{0.2\%}_{back} \pm \underbrace{1.1\%}_{eff} \pm \underbrace{2.5\%}_{lumi} \pm \underbrace{1.0\%}_{energy}}_{2.9\%}$$

And the bottom line is

$$\frac{\Gamma_{\text{ee}}\Gamma_{\text{had}}}{\Gamma_{\text{total}}} = \begin{cases} 0.601 \pm 0.018 \text{ keV} & 1.7\,\sigma\text{'s high} & \mathcal{B}_{\mu\mu} \text{ from PDG} \\ 0.612 \pm 0.018 \text{ keV} & 2.0\,\sigma\text{'s high} & \mathcal{B}_{\mu\mu} \text{ from Istvan} \end{cases}$$



$\Upsilon(2S)$
DESY–Heidelberg
LENA '82
DASP–II '82
CLEO–I '84
Crystal Ball '88
Argus '94
Novosibirsk '96
CLEO '04 (using PDG $B_{\mu\mu}$)
CLEO '04 (using Istvan's)
0.2
0.4
0.6
0.8
1
$\Gamma_{ee}\Gamma_{had}/\Gamma_{total}$