Precise Measurement of $\Upsilon(1S, 2S, 3S)$ Γ_{ee} in CLEO-III

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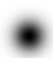
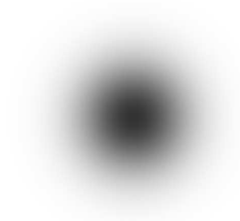
What is $\Upsilon(1S, 2S, 3S)$ Γ_{ee}?

e^+e^- contribution to Υ decay width: $\Gamma_{ee} = \mathcal{B}_{ee} \times \Gamma$

Related to the shape of the $b\bar{b}$ wavefunction: $\Gamma_{ee} = \left(\frac{16\pi{\alpha_{QED}}^2}{3{M_\Upsilon}^2}\right)|\psi(0)|^2$

 decays to e^+e^- more readily than 

Therefore, it characterizes the strength of $b\bar{b}$ binding:

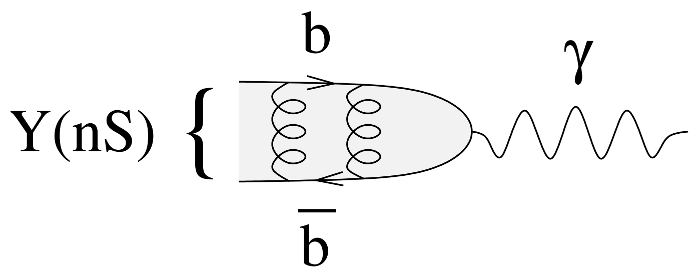
how big an Υ the QCD potential permits

Why measure Γ_{ee} to high precision ($\sim 2\%$)?

It can be calculated on the lattice without "quenching":
this is a test of precision lattice gauge theory

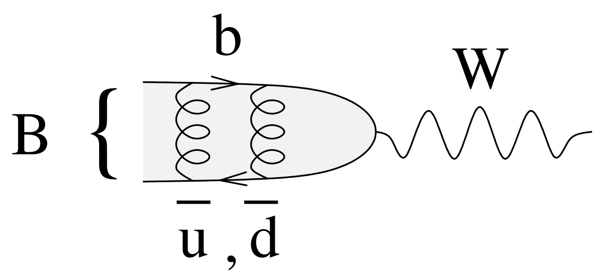
Also notice the similarity between

Γ_{ee}:



and

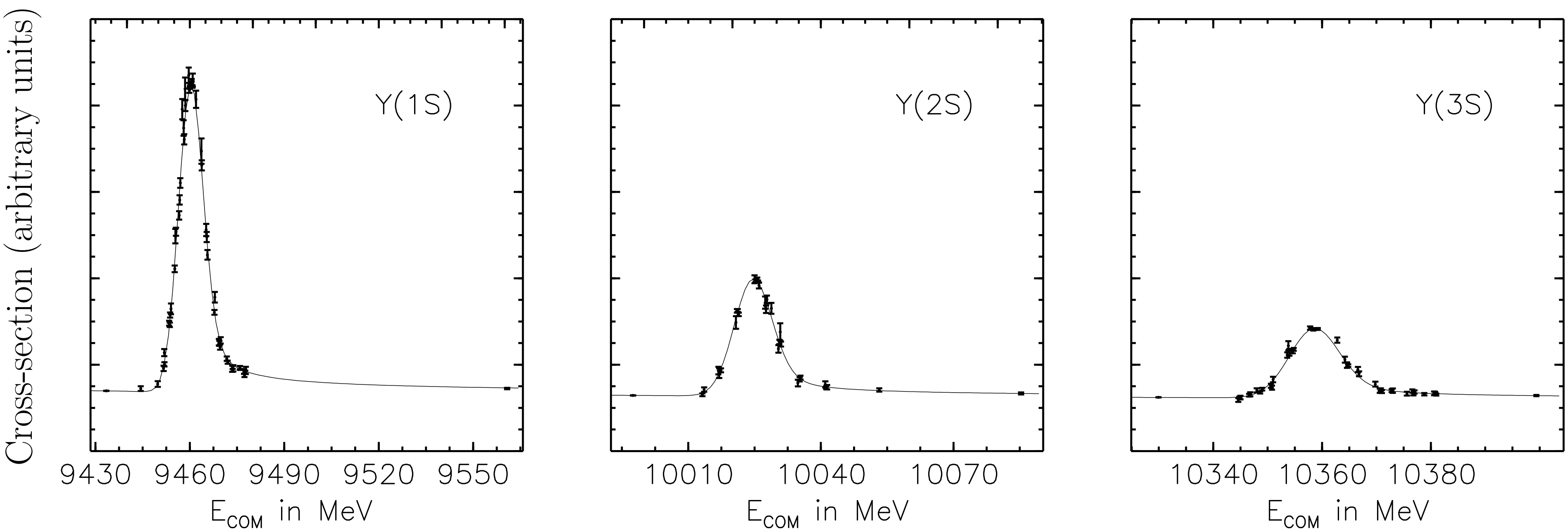
f_B:



Experimental verification of Γ_{ee} lends credence to calculation of f_B.

Best-kept secret about Γ_{ee} measurement: uses $e^+e^- \to \Upsilon$, not $\Upsilon \to e^+e^-$!

$$\Gamma_{ee} = \left(\frac{{M_\Upsilon}^2}{6\pi^2}\right) \int \sigma(e^+e^- \to \Upsilon)\, dE$$

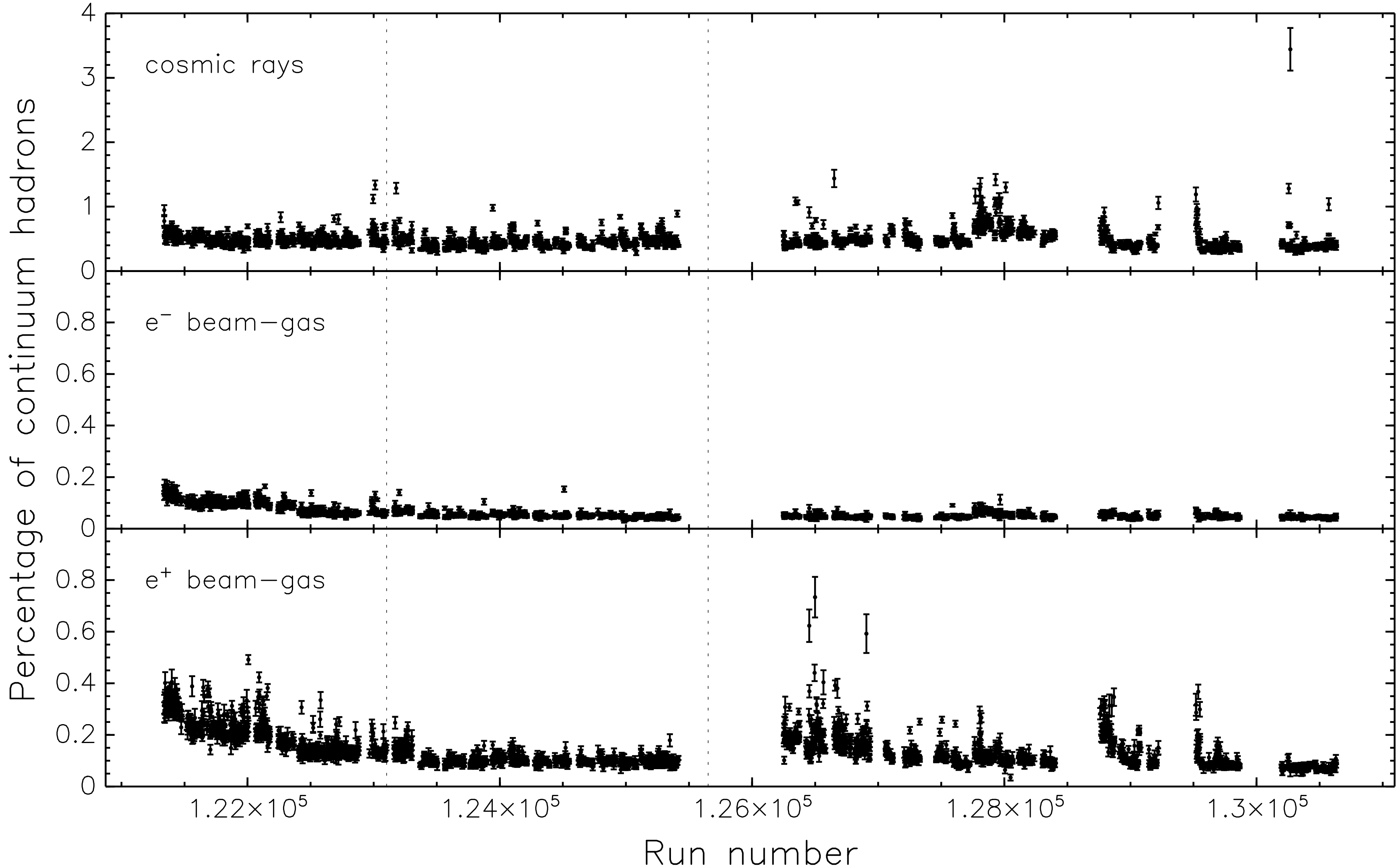


So it's mostly a hadron count: the e^+e^- final state is treated as a background

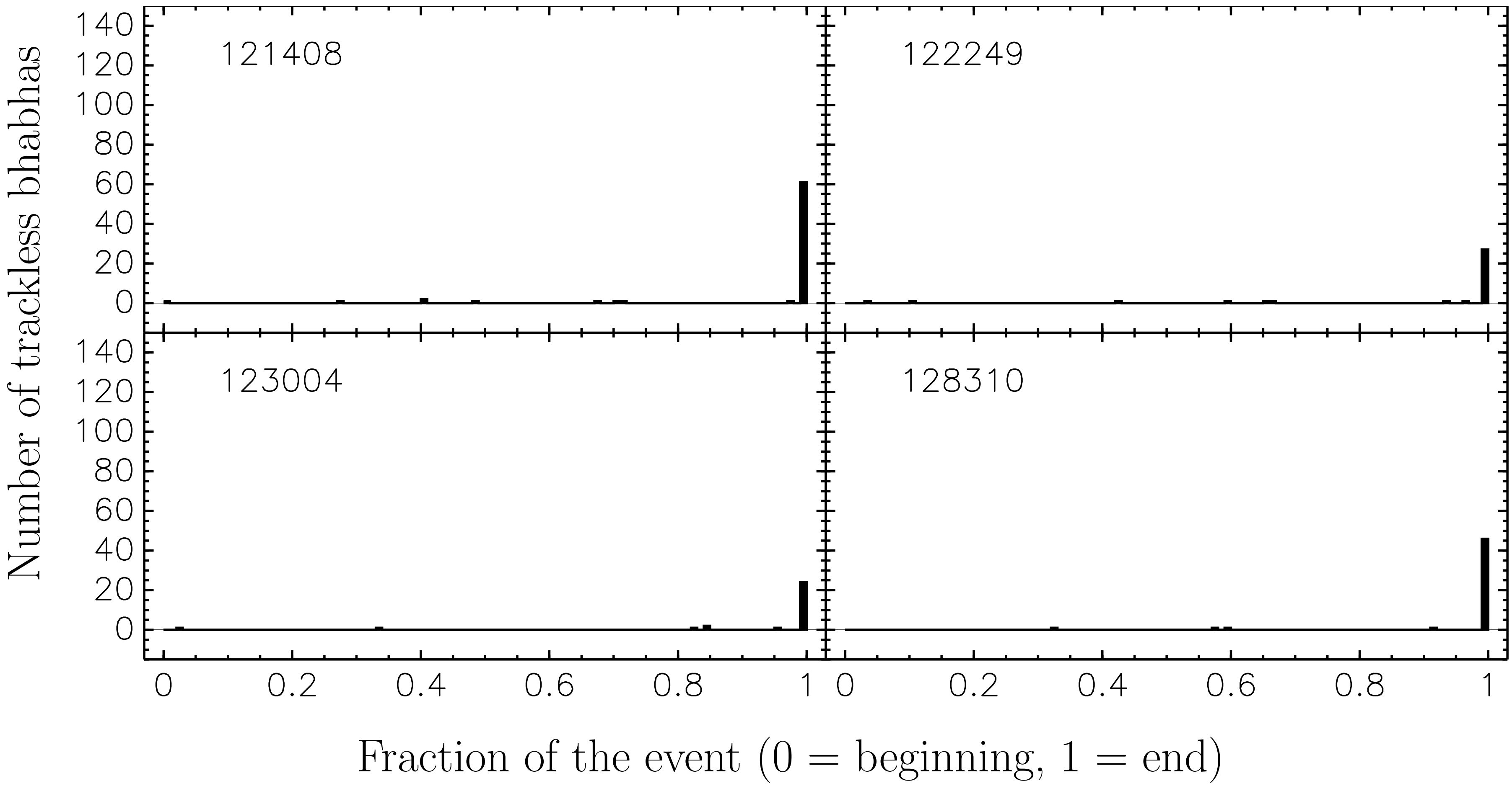
Things that need to be very precise:

			$\Upsilon(1S)$	$\Upsilon(2S)$	$\Upsilon(3S)$
	1.	Statistical uncertainty (dominated by $e^+e^- \to \gamma\gamma$ counting)	0.4 – 0.7%	1.0 – 1.6%	1.0 – 2.4%
$\surd$	2.	Background subtraction	$\longleftarrow$	0.3%	$\longrightarrow$
$\surd$	3.	Search for bad runs			
$\surd$	4.	Radiative corrections and continuum interference (Karl Berkelman)	0.2%	0.2%	0.2%
	5.	Beam energy-calibration jitter?	$\longleftarrow$	1% ?	$\longrightarrow$
$\surd$	6.	Hadronic efficiency	1.1%	1.4%	1.3%
$\surd$	7.	$(1 - 3\mathcal{B}_{\mu\mu})$ for total σ (Istvan Danko)	$\longleftarrow$	0.1%	$\longrightarrow$
	8.	Luminosity (Surik Mehrabyan, Brian Heltsley, and sometimes me)	$\longleftarrow$	2% ?	$\longrightarrow$

Backgrounds: all continuum processes are subtracted in the fit, non-beam-beam backgrounds are subtracted run-by-run



Search for bad runs: lots of methods, most useful are trackless bhabha fraction and events versus time



Search for bad runs: found 64 beyond those in Dave Kreinick's `badruns3S`

Cosmic ray backgrounds > 5% or beam-gas backgrounds > 2%	122353 126341 129522
Other large backgrounds	121595 122093 122330 126510
BarrelBhabha trigger inefficiency	121710 121928 121929 121930 121944 121953 121954 123884 127951 127955 130278
Noisy (high-energy) showers in barrel	122331 122335 122336 122339 122341 122342 122344 122345 122349 122350 122352
DR lost sensitivity before end of run (trackless bhabhas)	121476 121748 121822 121847 122685 123436 123847 123873 124816 124860 124862 125367 126273 126329 127280
Bhabha track momentum distribution is abruptly wide	124452 124454 124456 124458 124462 124464 124465 124466 124467 124469 124472 124473 124474 124475 124477 124478 124479 124480
Hadronic cross-section plummets in the last few minutes	123281 123411

Hadronic efficiency:

I define "Hadronic decay" to be "anything but $\Upsilon \to e^+e^-$, $\mu^+\mu^-$, or $\tau^+\tau^-$."

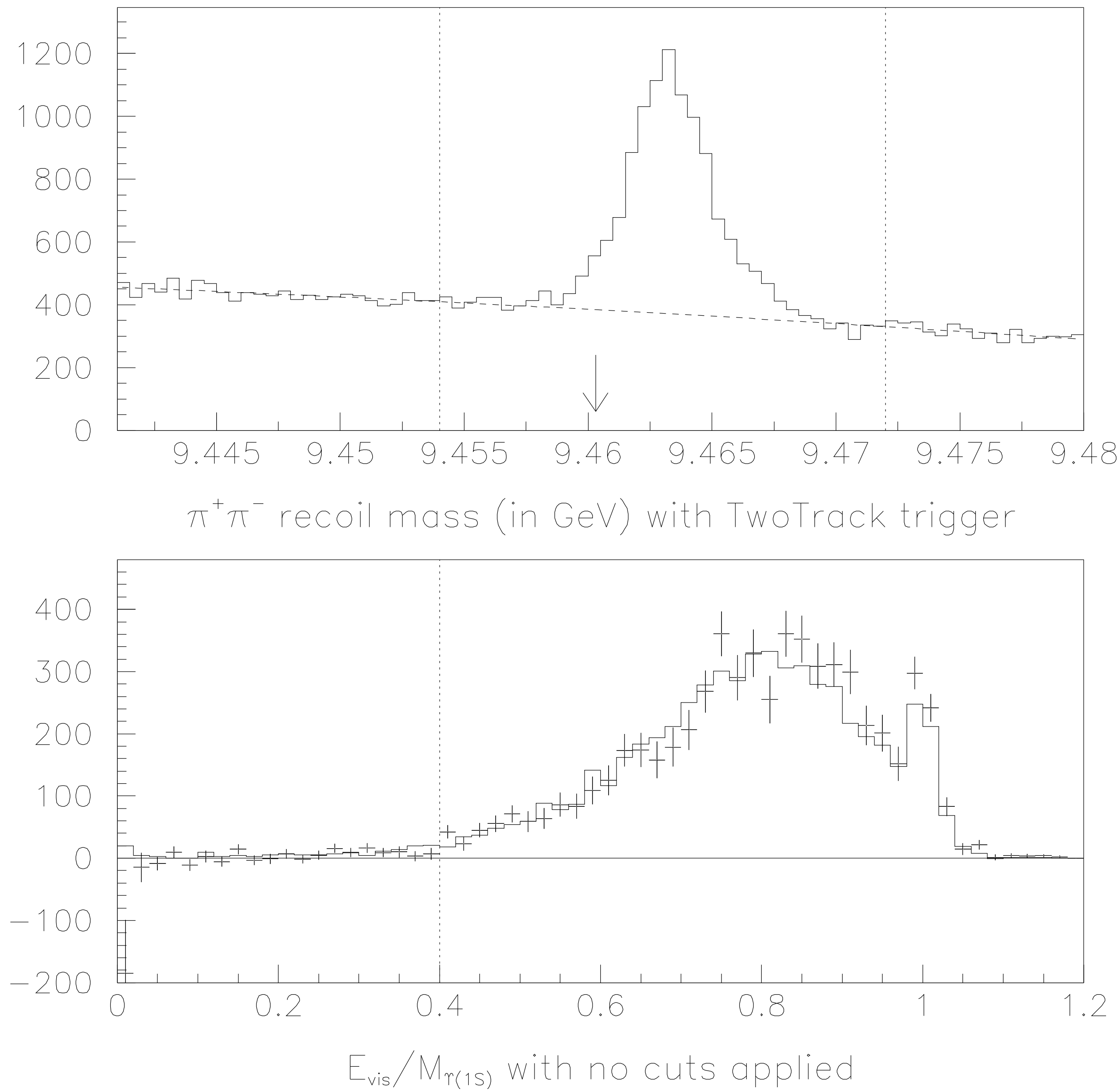
Can't be certain that the Monte Carlo simulates all decays

- Trigger efficiency is studied three different ways: MC's 99.6% is given $\pm1.0\%$ error
- MC cut efficiencies are tested in $\Upsilon(2S) \to \underbrace{\pi^+\pi^-}\Upsilon(1S)$ decays

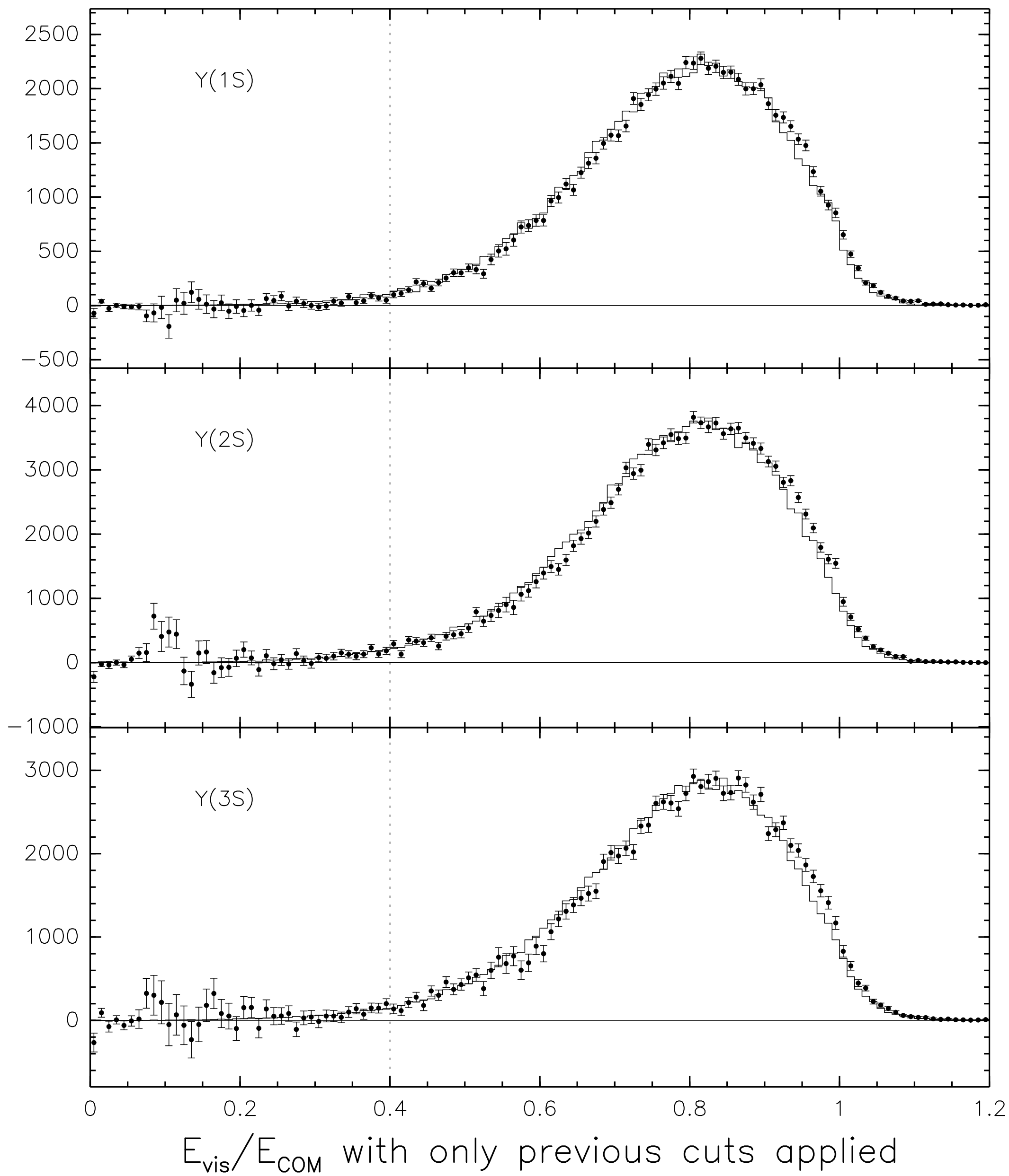
  chosen to satisfy trigger and L4
  satisfy event type filters
  miss the calorimeter barrel
  not "curl" in drift chamber
  (acceptance independent of $\Upsilon(1S)$)

- Each cut is assigned a systematic error from this data/MC comparison
- Assume MC is equally good at describing $\Upsilon(2S)$, $\Upsilon(3S)$
  (verified by data in most of the parameter space)
- Propagate branching fraction uncertainties

Hadronic efficiency: $\Upsilon(1S)$ from $\Upsilon(2S) \to \pi^+\pi^-\Upsilon(1S)$



Hadronic efficiency: application of $\Upsilon(1S)$ MC validity to $\Upsilon(2S, 3S)$



Hadronic efficiency: bottom line

	$\Upsilon(1S)$	$\Upsilon(2S)$	$\Upsilon(3S)$
Trigger	0.7%	1.0%	1.0%
Verification with $\Upsilon(2S) \to \pi^+\pi^-\Upsilon(1S)$	0.6%	$\longrightarrow$	$\longrightarrow$
Further verification with continuum-subtracted data	0.3%	0.3%	0.3%
Branching fraction uncertainties	0.01%	0.05%	0.04%
Monte Carlo errors	0.5%	0.5%	0.4%
Total uncertainty	1.1%	1.3%	1.3%

Total hadronic efficiency	98.7%	96.7%	97.0%

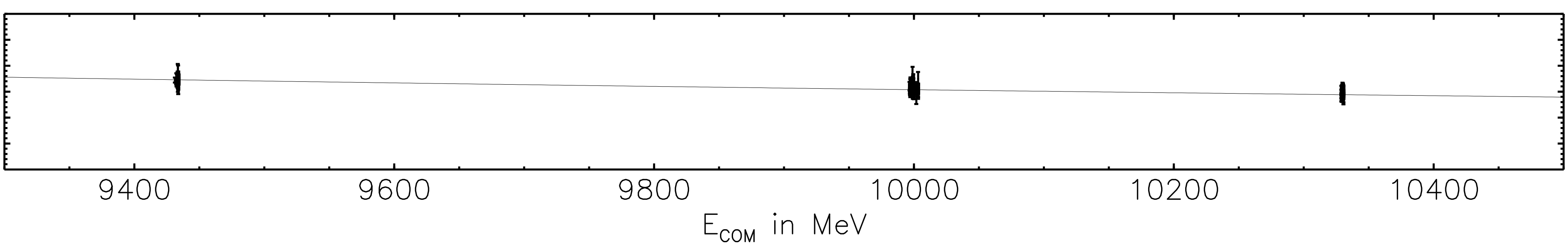
Hadronic cross-section stability:

Reduced χ^2 for fits to a constant cross-section

	$\Upsilon(1S)$	$\Upsilon(2S)$	$\Upsilon(3S)$
off-resonance runs	0.87	0.95	0.91
#degrees of freedom	(124)	(274)	(125)
on-resonance runs	1.08	1.02	0.91
#degrees of freedom	(651)	(262)	(601)

Reduced χ^2 for all-continuum fit to $1/s$ (+ tail corrections) 0.98

(525)



Checklist:

$\surd$ 1. Background subtraction

$\surd$ 2. Search for bad runs

$\surd$ 3. Hadronic efficiency (completely done)

$\sim$ 4. Fit all scans (minor improvement in method needed)

5. Quantify beam energy-calibration uncertainty (σ versus time)

6. Convert $e^+e^- \to \gamma\gamma$ count into luminosity

Barring disasters, you will see a 10-day CBX posting before next meeting