Γ_{ee} Measurement from Beginning to End

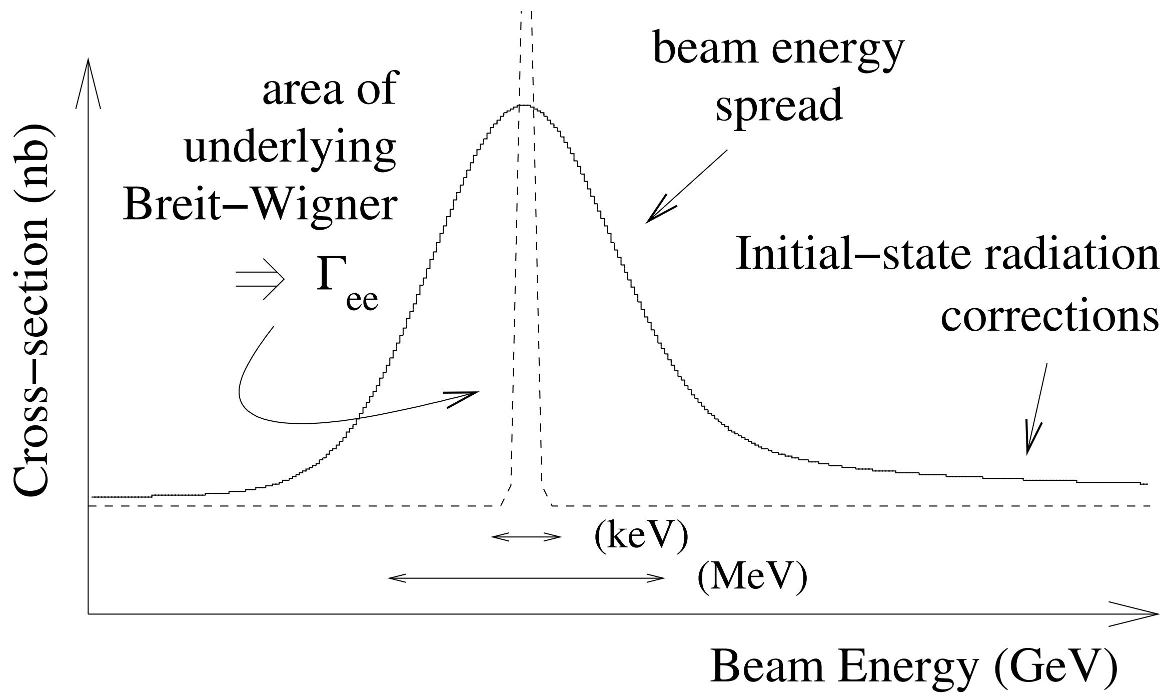
Jim Pivarski

Method

Use production process $e^+e^- \to \Upsilon$, integrated over e^+e^- energy

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

Integral will be replaced by a fit to production lineshape, excluding ISR tail



Lineshape scans were acquired in November 2001 – September 2002

Method

Measure cross-section by counting hadrons, correct for leptons with $(1 - 3\mathcal{B}_{\mu\mu})$

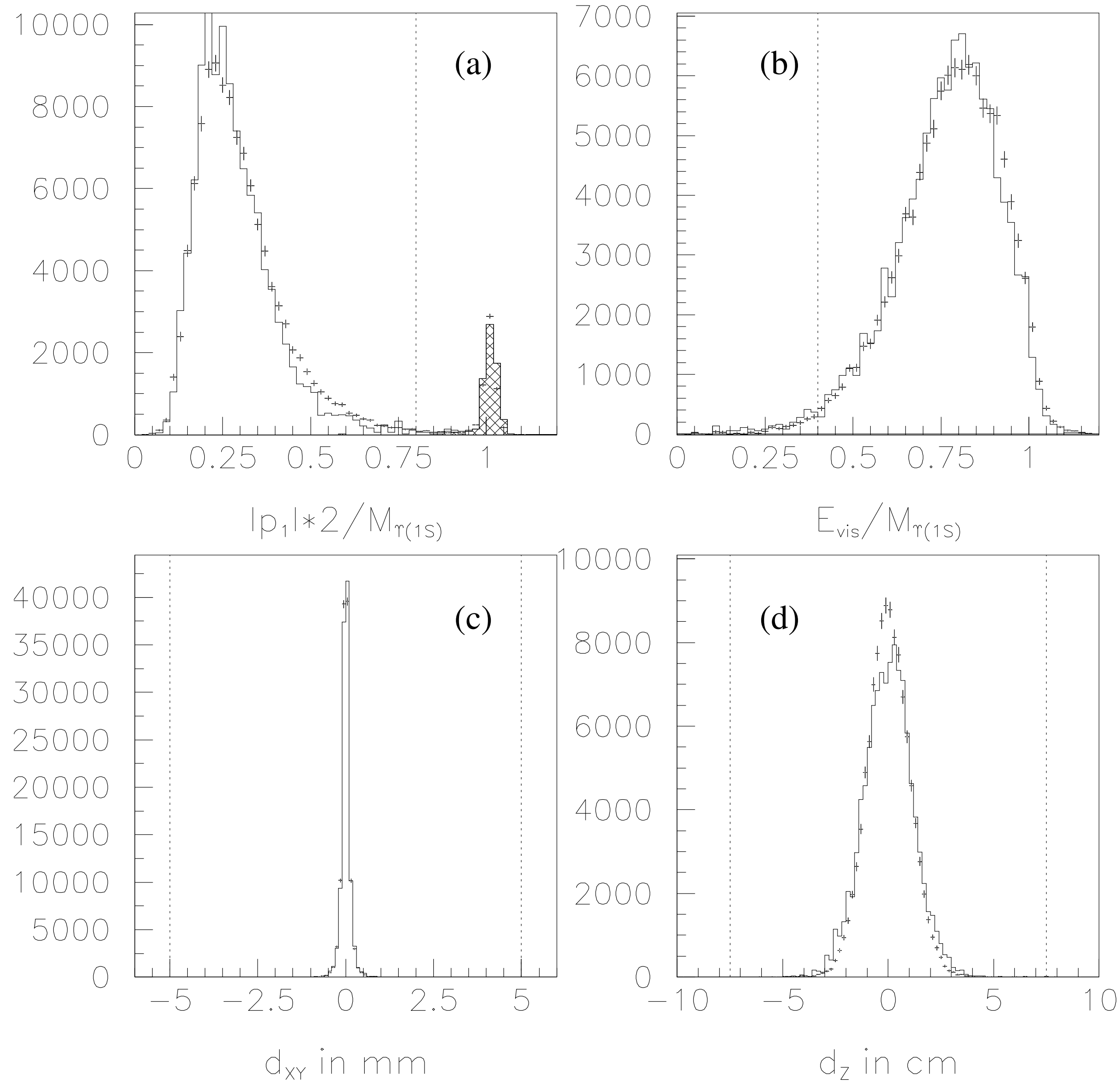
Hadron cuts:

(a) largest track momentum $< 70\%$ beam energy

(b) visible energy $> 40\%$ of center-of-mass energy

(c) event vertex XY within 5 mm of beamspot

(d) event vertex Z within 7.5 cm of beamspot



Issues (Table of Contents):

- **Hadronic efficiency**
- **Backgrounds**
- **Luminosity**
- **Cross-section stability**
- **Beam-energy measurement stability**
- **Fitting**

And then

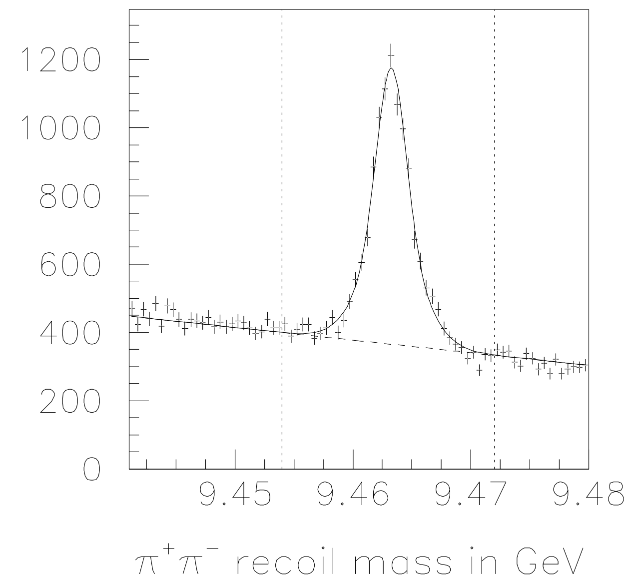
- **Preliminary results**

Hadronic Efficiency

$\Upsilon(1S)$ measured directly in $\Upsilon(2S) \to \pi^+\pi^-\Upsilon(1S)$

- $\pi^+\pi^-$ chosen to satisfy trigger
- Corrected for boost, track/shower confusion

Hadronic efficiency is $(97.8 \pm 0.5)\%$



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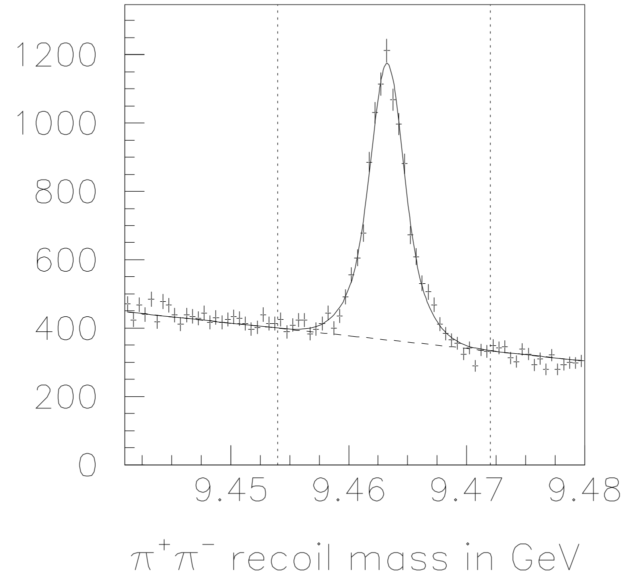
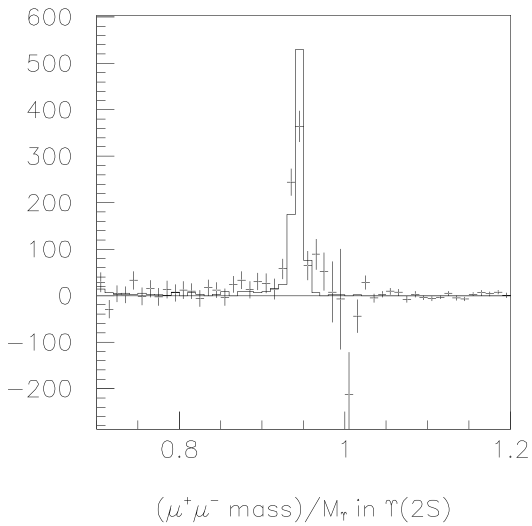
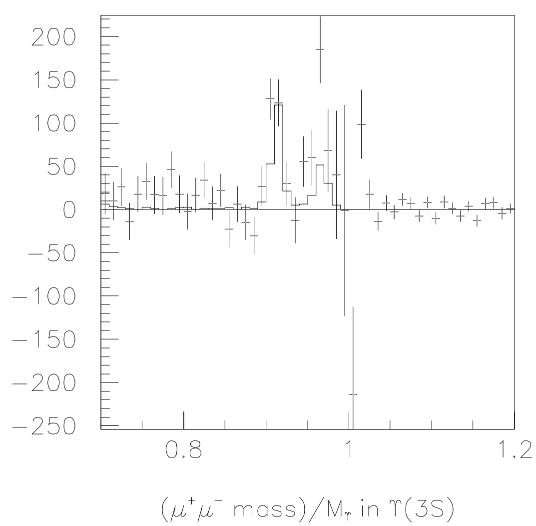


Correct $\Upsilon(2,3S)$ for cascades to leptons

$\mathcal{B}_{X\ell^+\ell^-} = (1.5 \pm 0.4)\%$



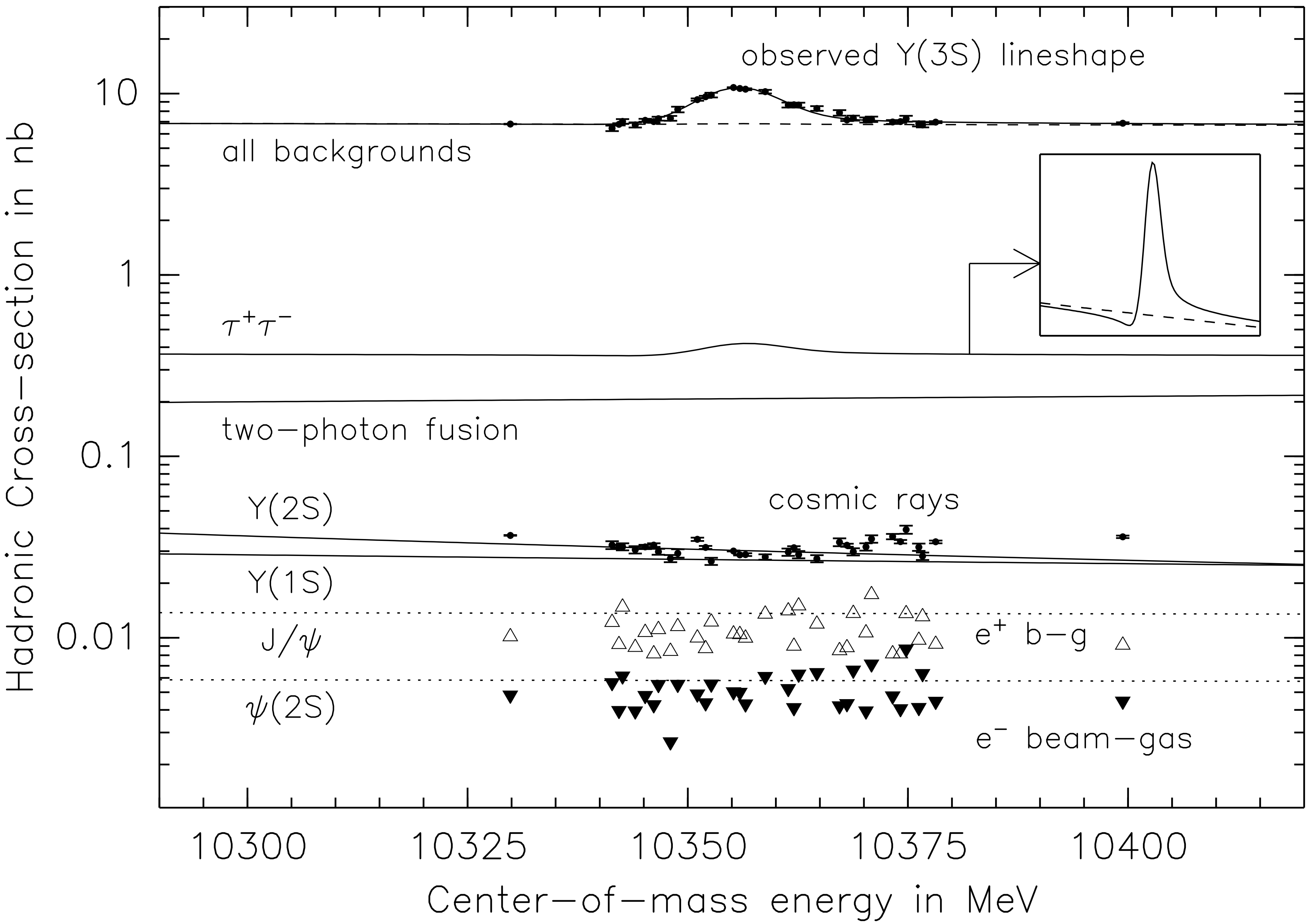
$\mathcal{B}_{X\ell^+\ell^-} = (1.4 \pm 0.5)\%$



Hadronic efficiency is $(96.1 \pm 0.6)\%$ (2S) and $(96.2 \pm 0.7)\%$ (3S)

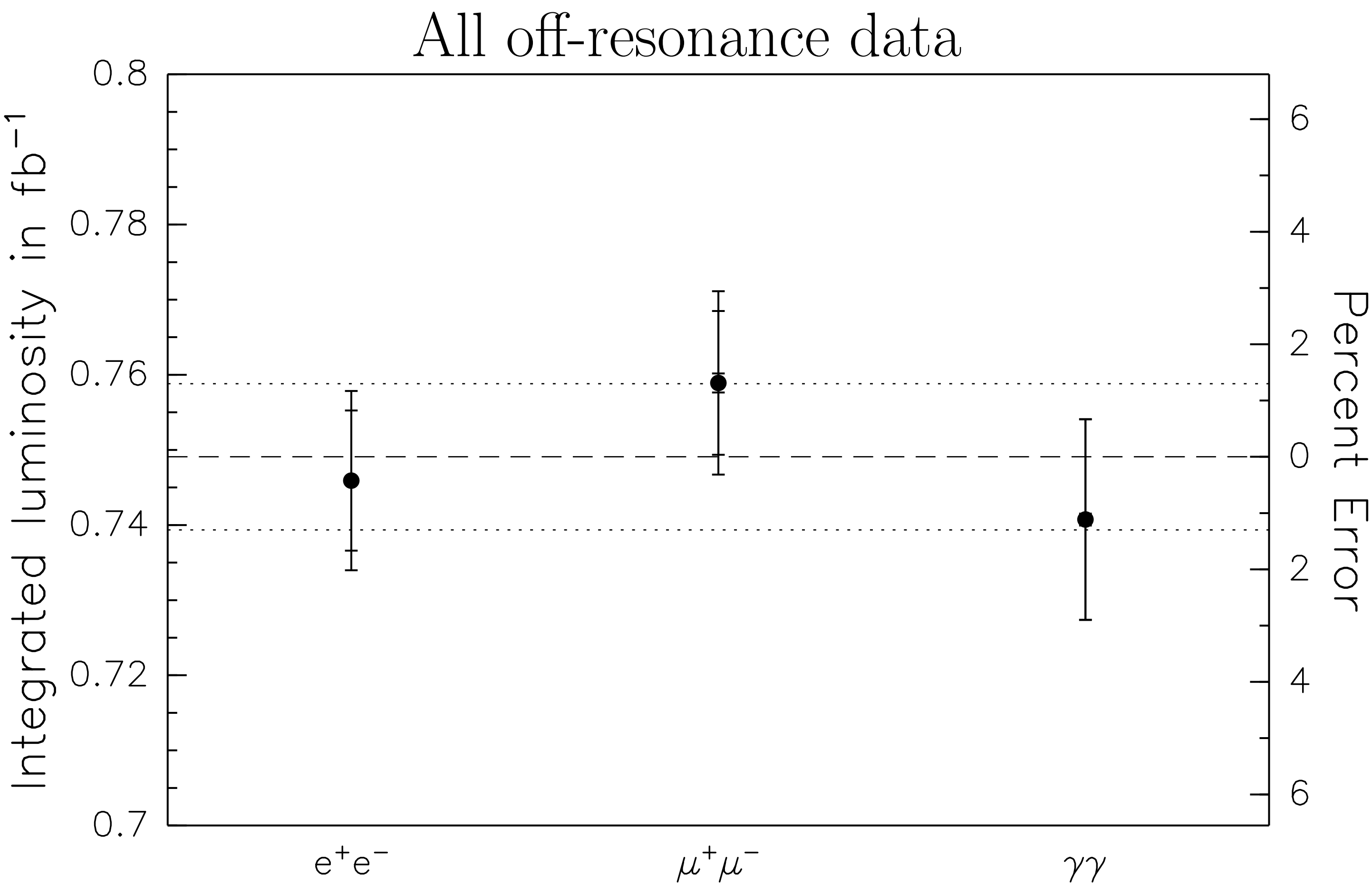
Backgrounds

Explicitly subtract cosmic rays and beam-gas, effectively subtract the rest in the fit



Luminosity

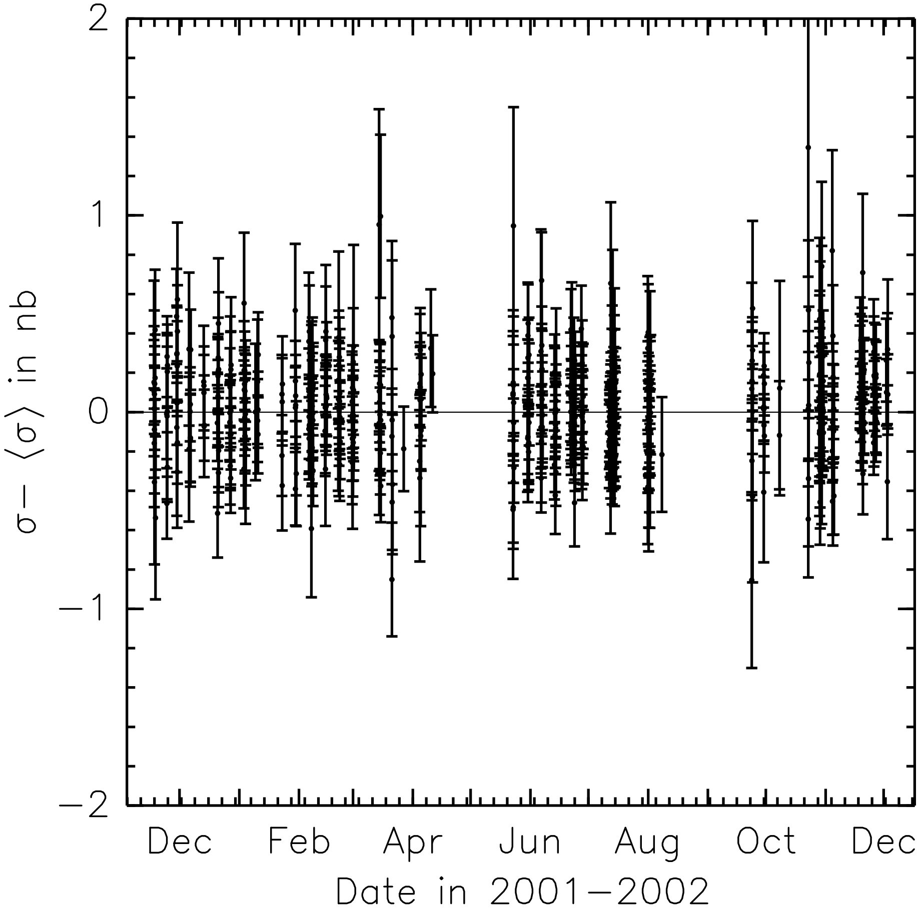
Surik and Brian determined luminosity calibration to 1.3% (CBX 05-17)

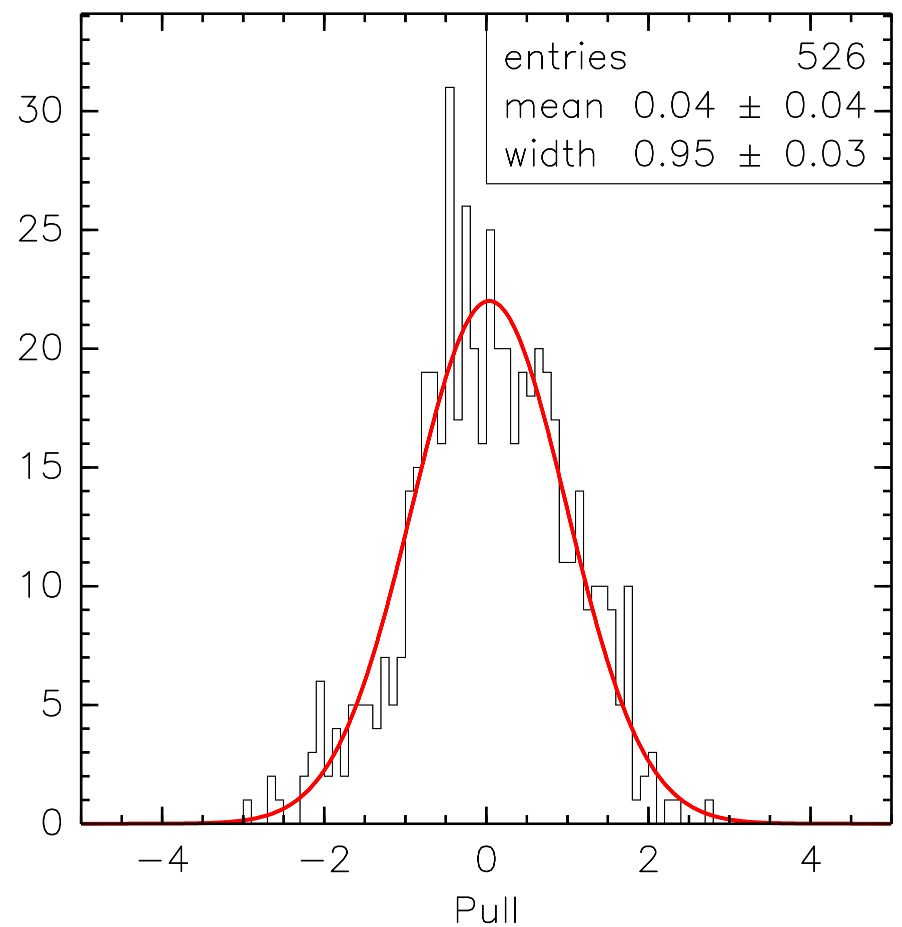


We use $\gamma\gamma$ for point-by-point luminosity (no backgrounds from Υ), and the above average to normalize all luminosities

Cross-section Stability

All off-resonance runs at a given energy reproduce the same cross-section, within statistics

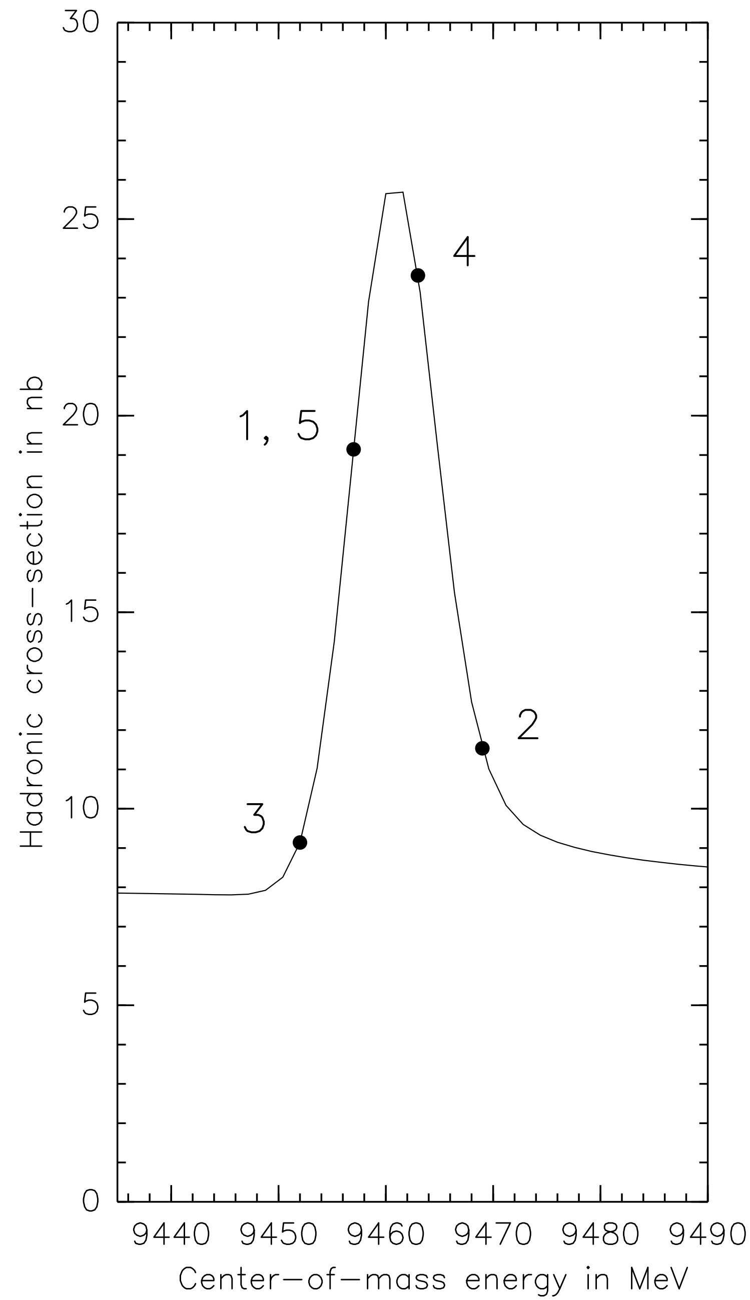




Cross-section **in**stability $\lesssim 0.03$ nb

Beam-energy Measurement Stability

- weekly scans were short and independent
- measurements alternated above and below resonance peak
- a point of high slope was repeated in the scan



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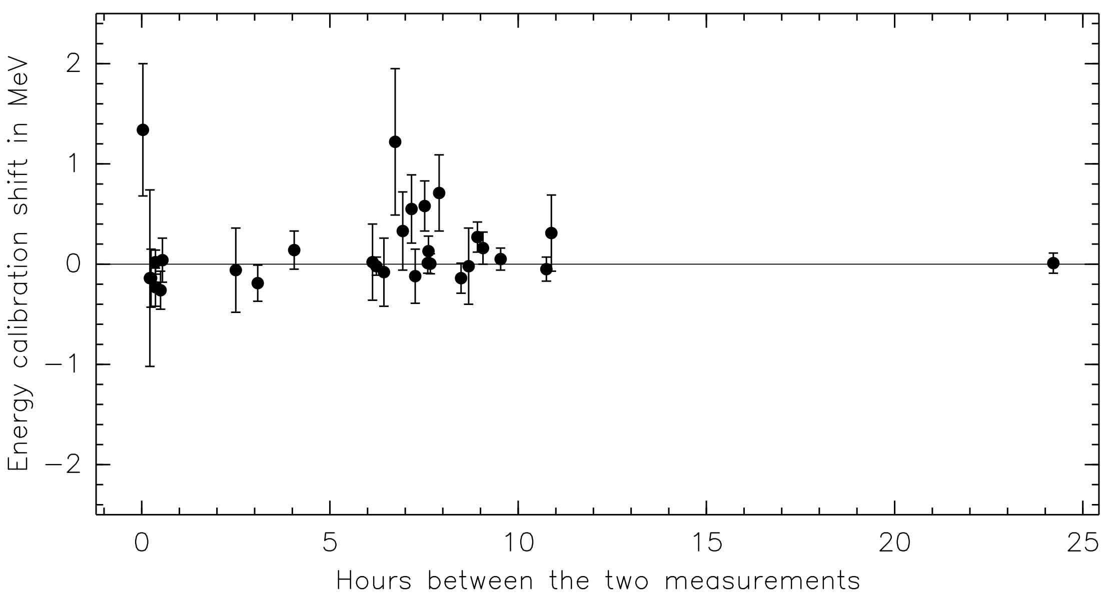
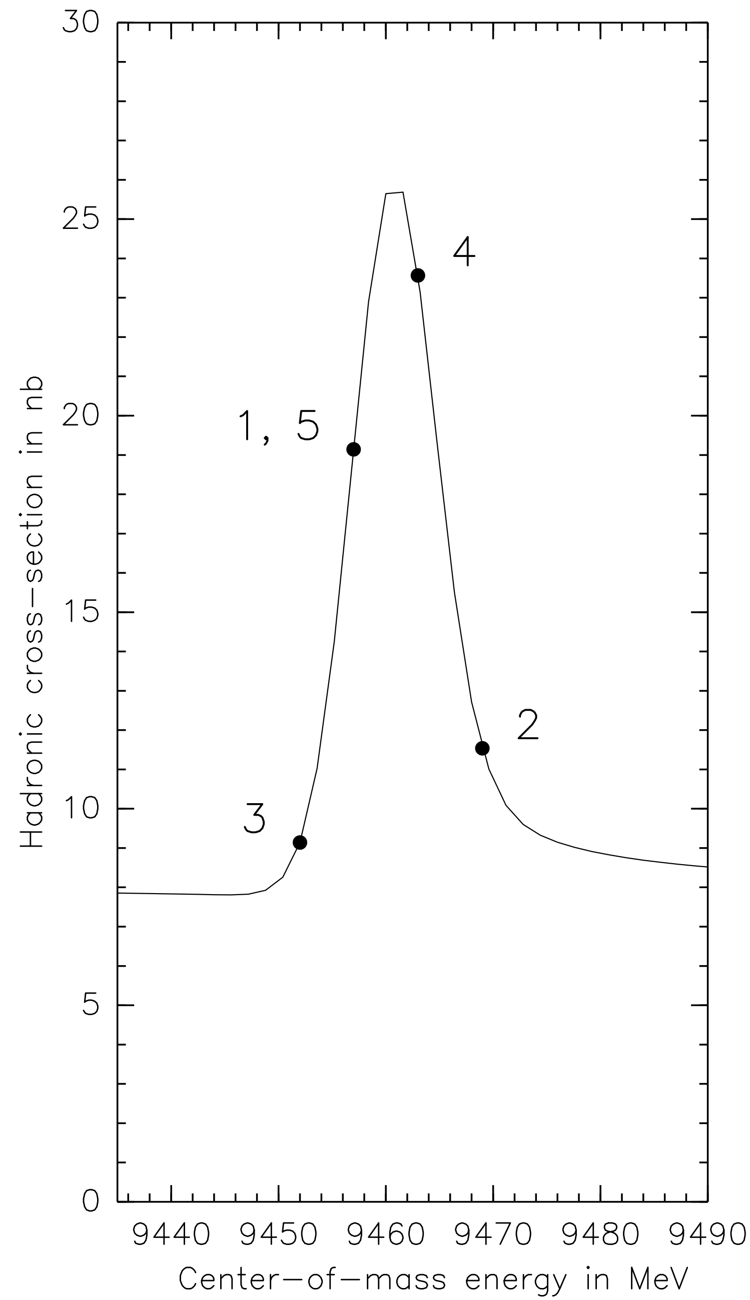




Beam-energy **in**stability $\lesssim 0.07$ MeV

Fitting

Parameters:

1. Area without tail (MeV nb) $\longrightarrow \Gamma_{ee}$ (keV)
2. Beam energy spread (MeV)
3. Background level (nb)

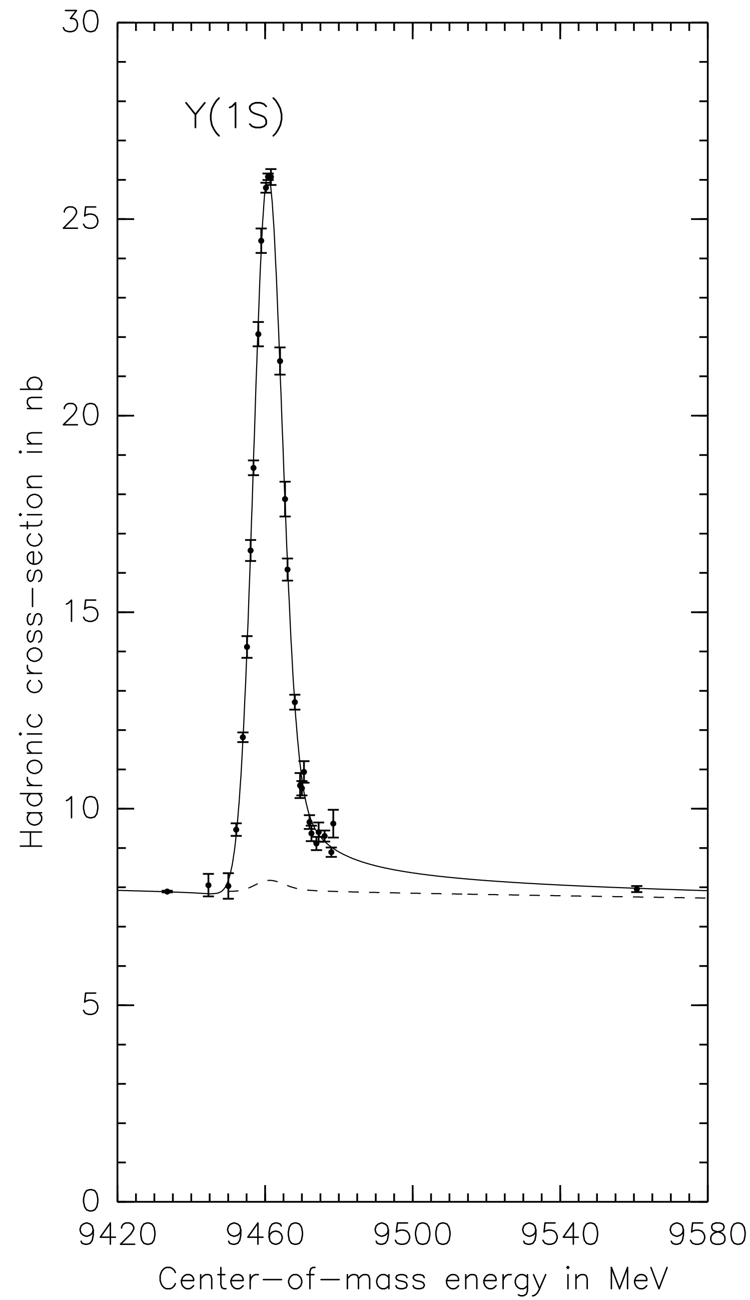
4–15. Upsilon mass for each weekly scan (MeV)

Fit function:

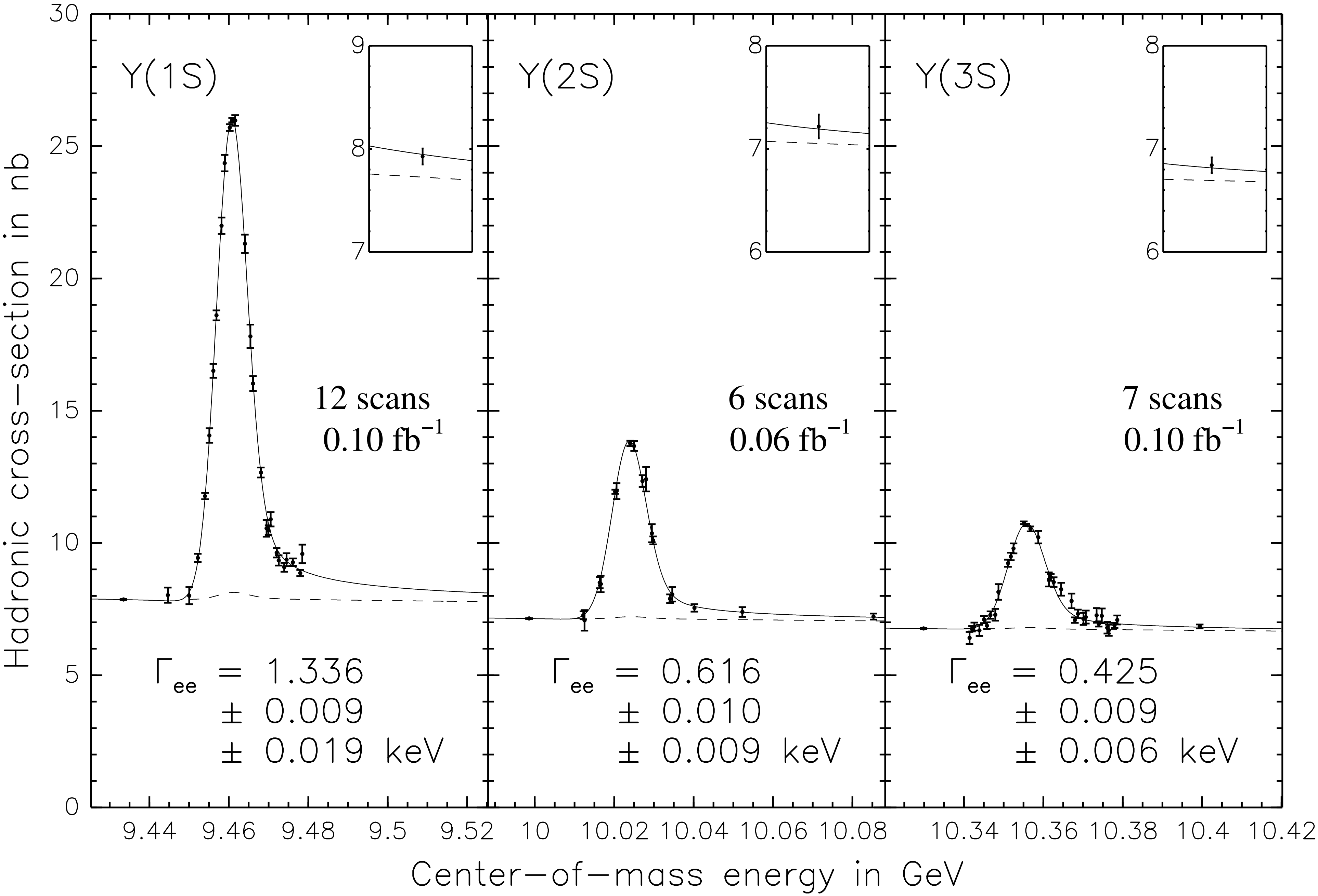
1. Breit-Wigner $\otimes$ Gaussian $\otimes$ ISR tail
   (Kuraev and Fadin 0.1% calculation)
   Includes interference term (small effect)

2. $\tau^+\tau^-$ background peaks under signal,
   precisely subtracted with Jean's $\mathcal{B}_{\tau\tau}$

3. Smooth backgrounds: $1/s$ and $\log s$

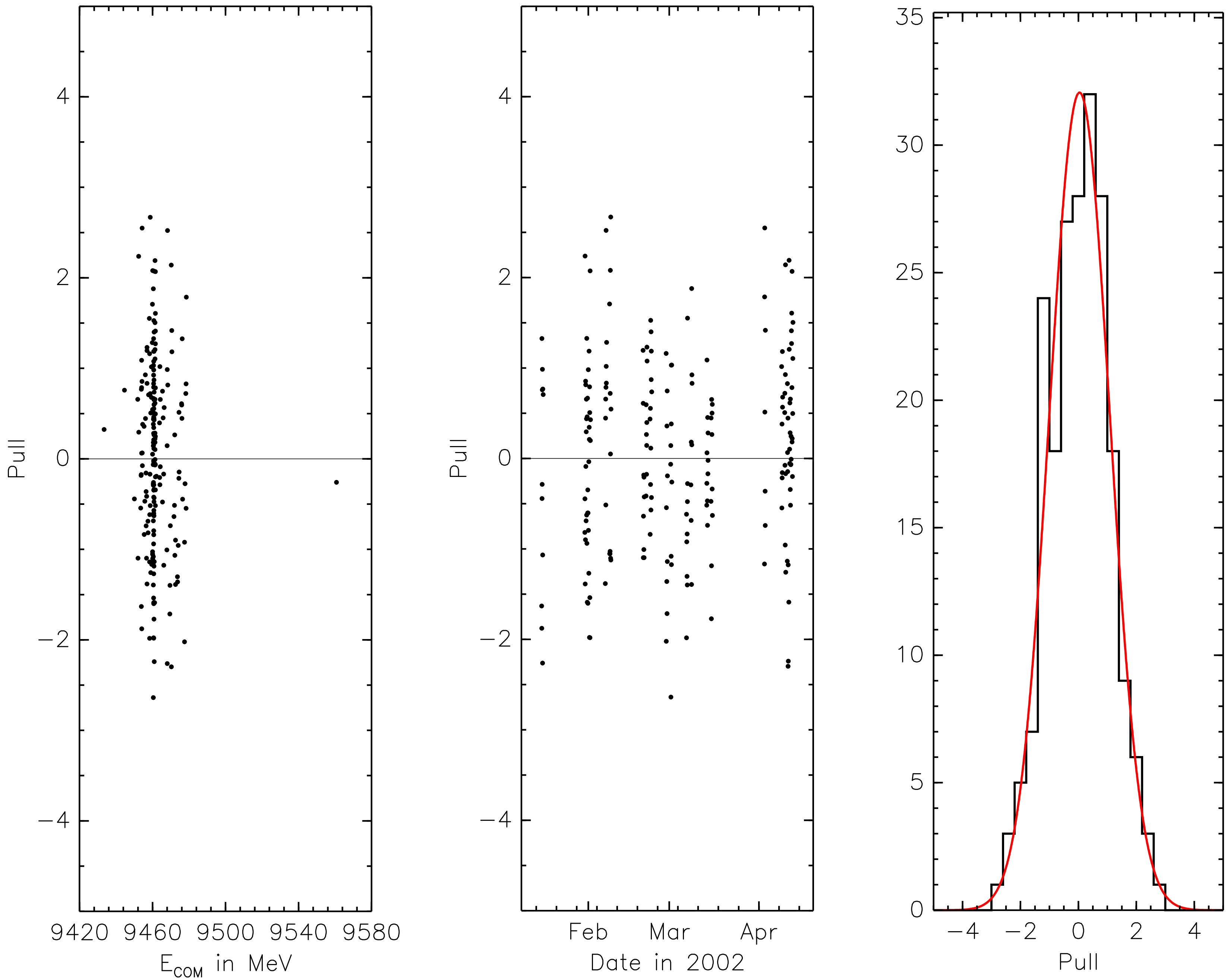


Fit Results

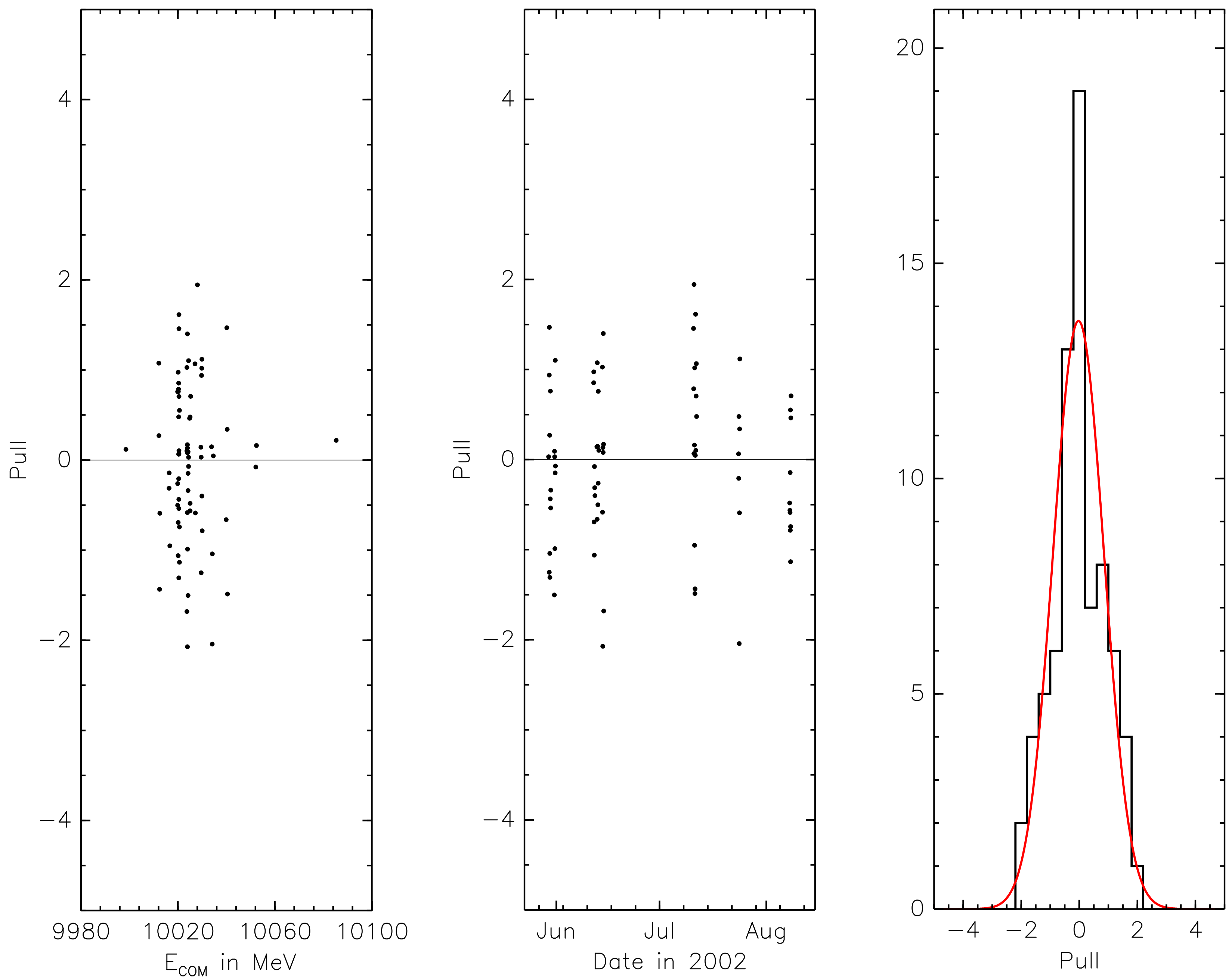


Υ(1S)
Υ(2S)
Υ(3S)
12 scans
0.10 fb^{-1}
6 scans
0.06 fb^{-1}
7 scans
0.10 fb^{-1}
Γ_{ee} = 1.336 ± 0.009 ± 0.019 keV
Γ_{ee} = 0.616 ± 0.010 ± 0.009 keV
Γ_{ee} = 0.425 ± 0.009 ± 0.006 keV
Hadronic cross-section in nb
Center-of-mass energy in GeV

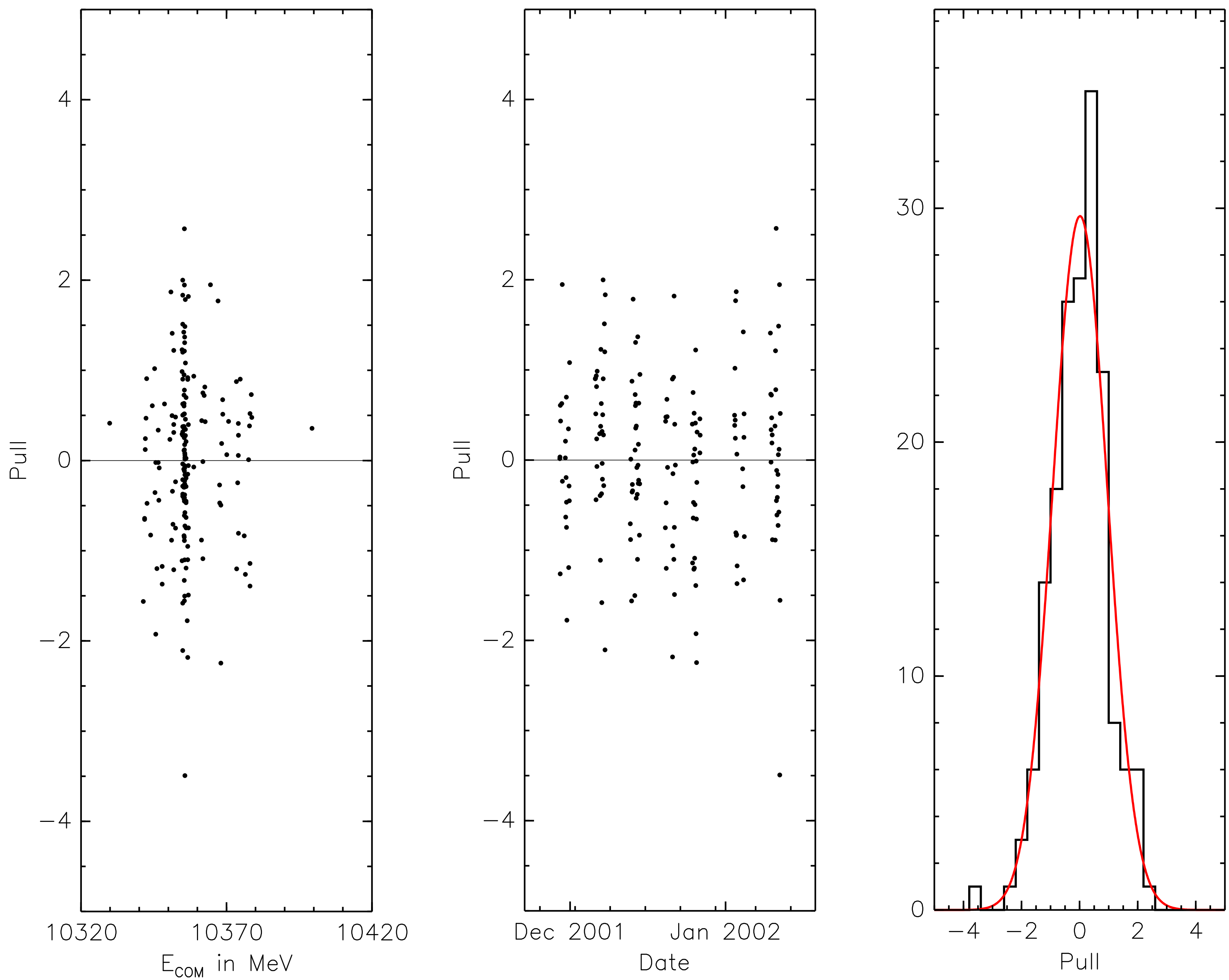
$\Upsilon(1S)$ Pull Distributions: $\chi^2/\mathrm{ndf} = 230/195 = 1.2$, C.L. = 4%



$\Upsilon(2S)$ Pull Distributions: $\chi^2/\mathrm{ndf} = 58/66 = 0.87$, C.L. = 76%



$\Upsilon(3S)$ Pull Distributions: $\chi^2/\mathrm{ndf} = 155/165 = 0.94$, C.L. = 70%



Summary of Uncertainties

Contribution to Γ_{ee}	$\Upsilon(1S)$	$\Upsilon(2S)$	$\Upsilon(3S)$
Statistical*	**0.7%**	**1.6%**	**2.2%**
$(1 - 3\mathcal{B}_{\mu\mu})$	0.2%	0.2%	0.3%
Hadronic efficiency	0.5%	0.6%	0.7%
Luminosity calibration	**1.3%**	**1.3%**	**1.3%**
Cross-section stability	0.1%	0.1%	0.1%
Beam-energy stability	0.2%	0.2%	0.2%
Shape of the fit function	0.05%	0.06%	0.05%
Total	**1.6%**	**2.2%**	**2.7%**

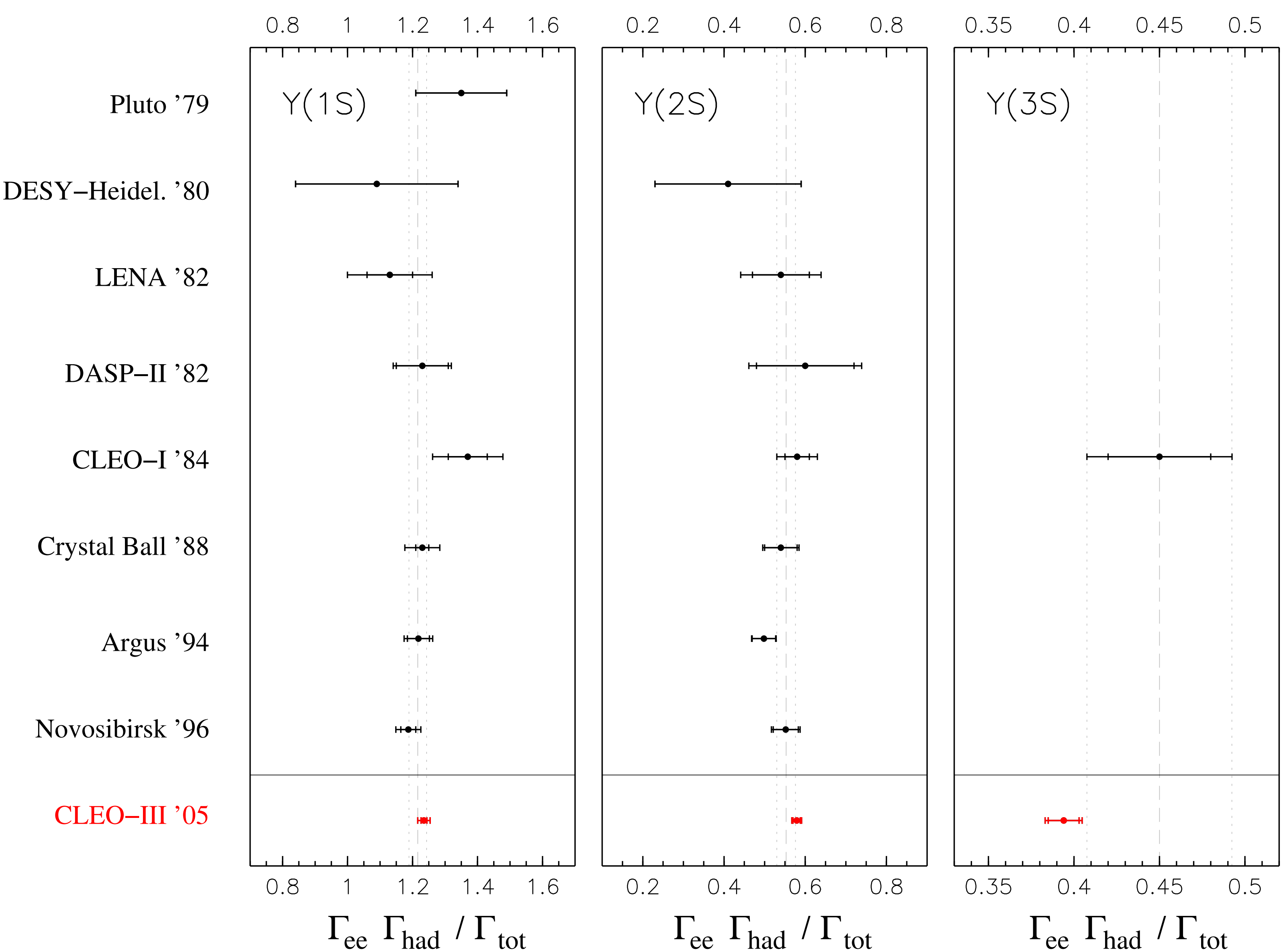
*Statistical uncertainty is dominated by run-by-run luminosity measurement ($e^+e^- \to \gamma\gamma$ counting) and contains background subtractions.

Preliminary Results

Quantity	Value	Uncertainty
$\Gamma_{ee}(1S)$	$1.336 \pm 0.009 \pm 0.019$ keV	1.6%
$\Gamma_{ee}(2S)$	$0.616 \pm 0.010 \pm 0.009$ keV	2.2%
$\Gamma_{ee}(3S)$	$0.425 \pm 0.009 \pm 0.006$ keV	2.7%
$\Gamma_{ee}(2S)/\Gamma_{ee}(1S)$	$0.461 \pm 0.008 \pm 0.003$	1.8%
$\Gamma_{ee}(3S)/\Gamma_{ee}(1S)$	$0.318 \pm 0.007 \pm 0.002$	2.4%
$\Gamma_{ee}(3S)/\Gamma_{ee}(2S)$	$0.690 \pm 0.019 \pm 0.006$	2.8%

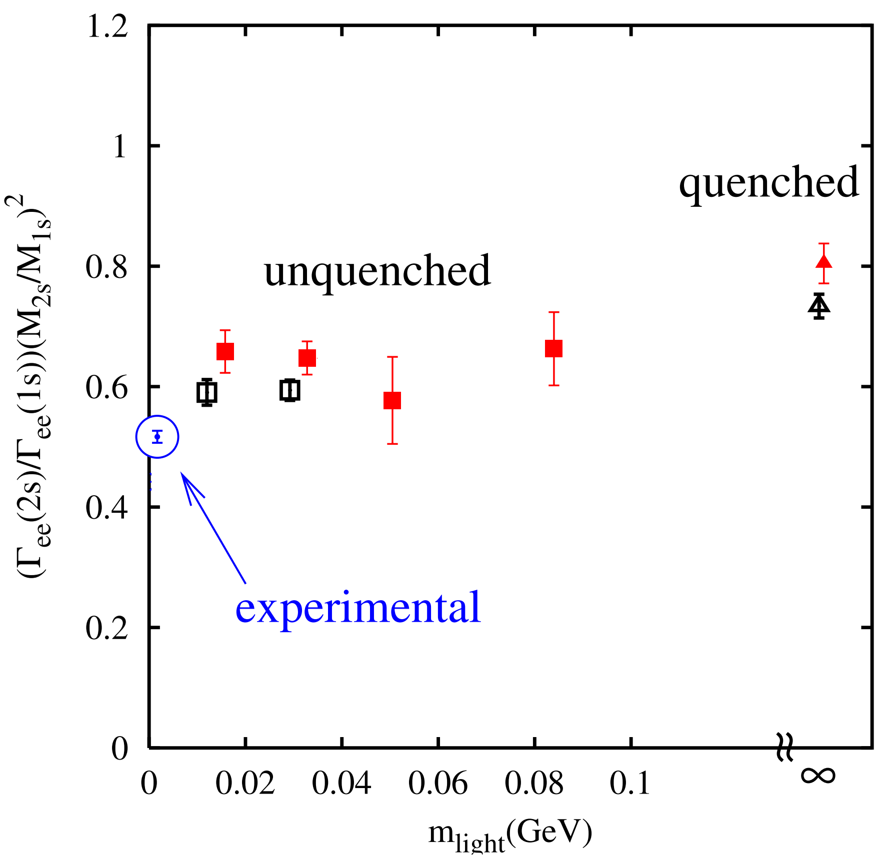
Will be presented at EPS, Lattice05

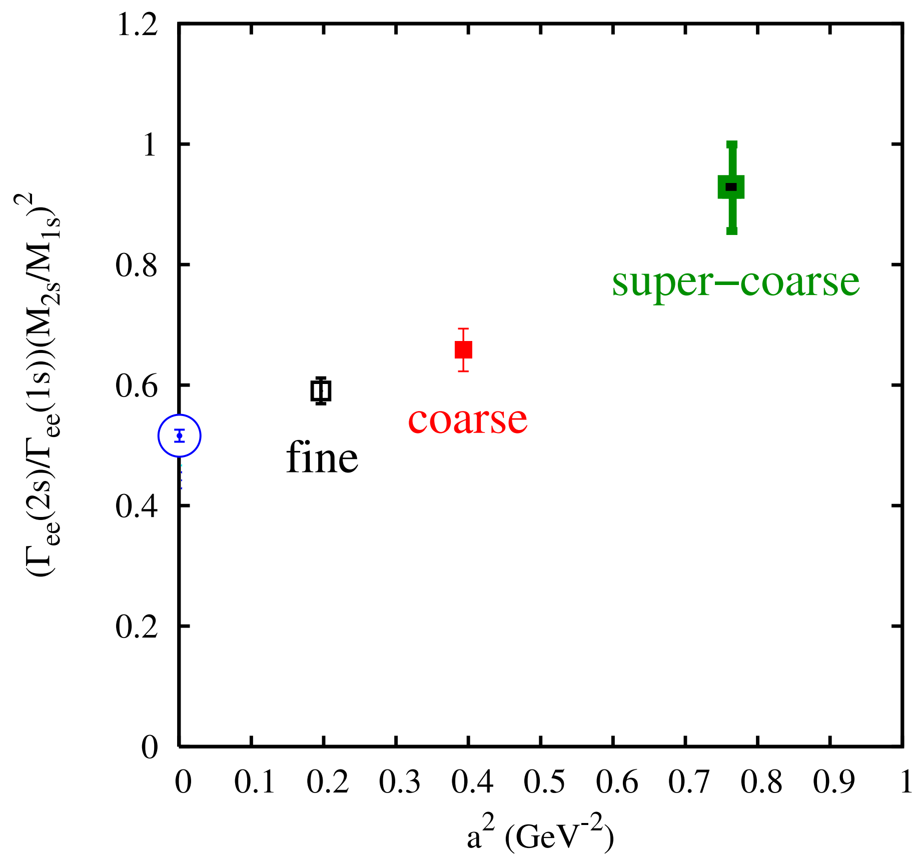
Preliminary Results



Comparison with Theory

Theoretical calculation of $\Gamma_{ee}(2S)/\Gamma_{ee}(1S)$ (hep-lat:0507013, 13 July 2005)





Strong dependence on lattice spacing ($\Gamma_{ee} \propto |\psi(0)|^2$, one point on the lattice)

"Fine" unquenched result: $(13 \pm 5)\%$ higher than experiment.