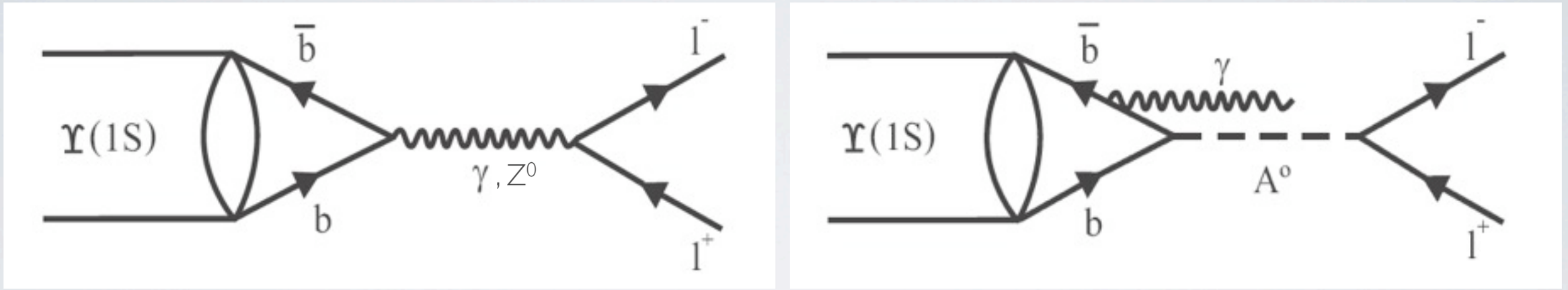
THE SEARCH FOR A CP-ODD LIGHT HIGGS IN $\Upsilon(1S)$ DECAYS AT BELLE

Jamal Rorie
University of Hawaii at Manoa
EPS-HEP Summer 2011 Grenoble, France
22/07/2011

PHYSICS MOTIVATION

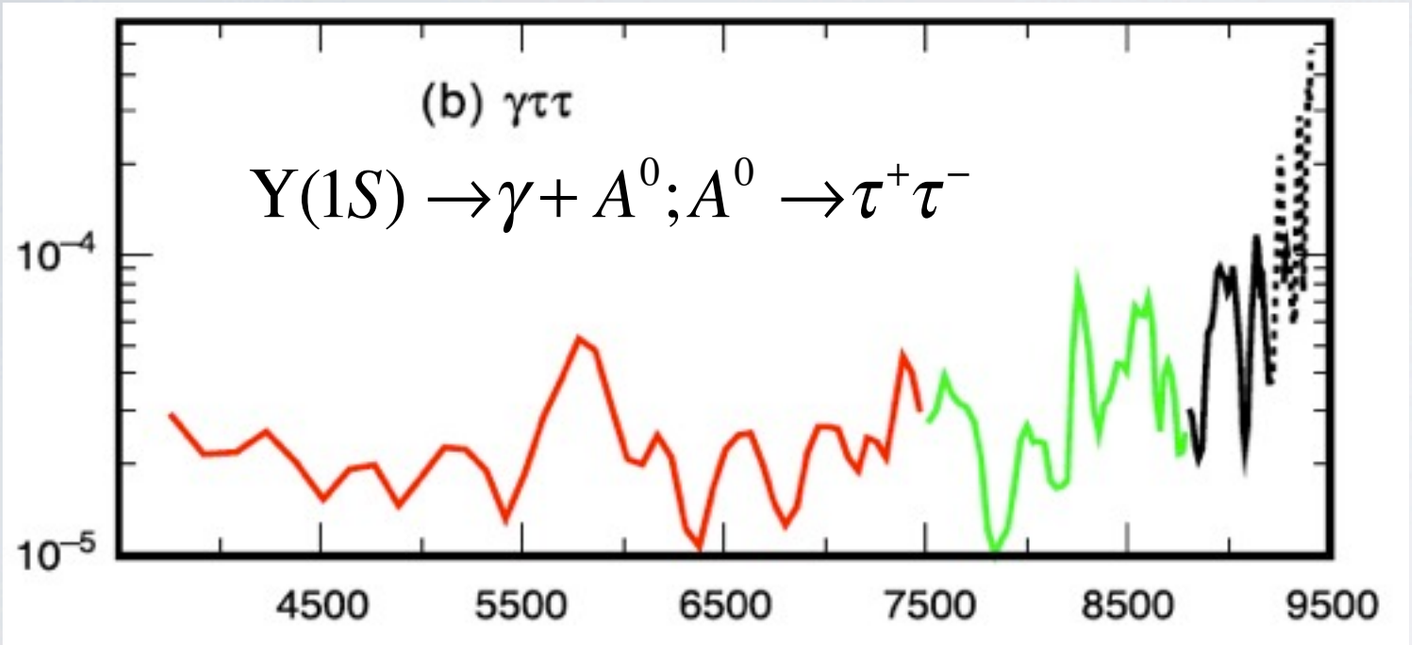
- $\Upsilon(1S)$ to $\tau\tau$ via annihilation interaction proposed in Dermíšek, Gunion, & McElrath in PhysRevD.**76**.051105



Figures From M.A. Sanchis-Lozano J.Phys.Soc.Jap. 76 (2007) 044101-044200

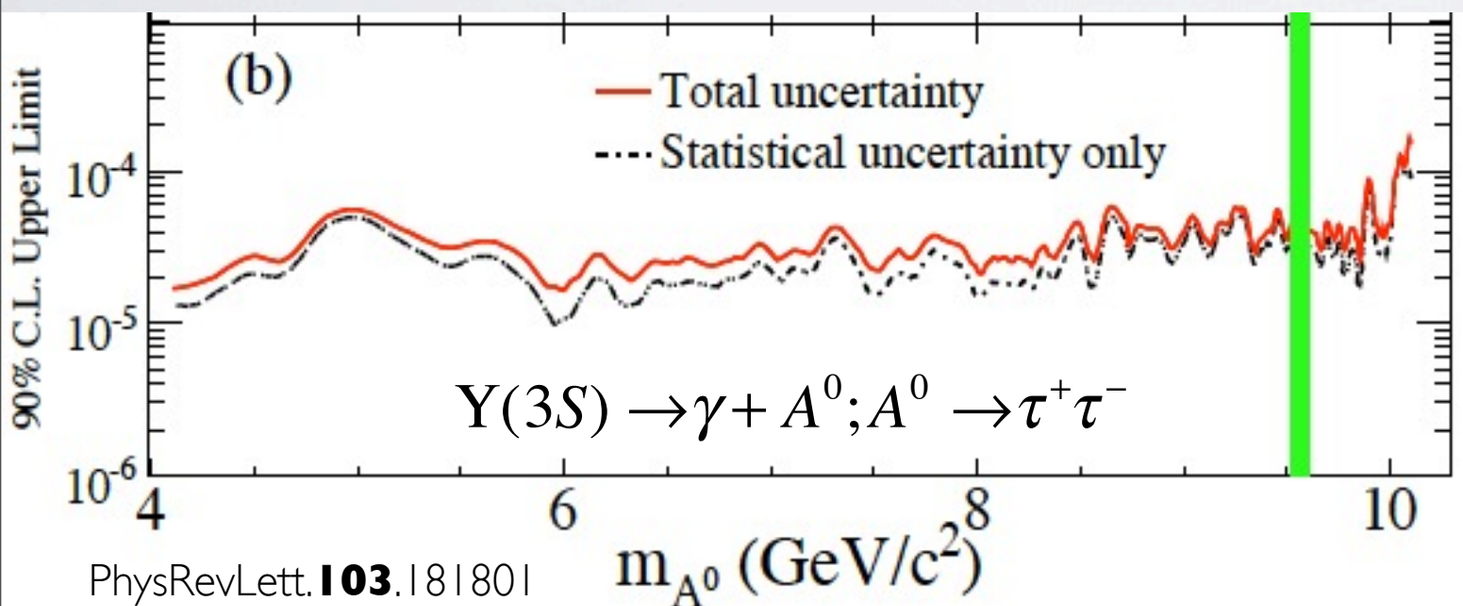
- For $M_{A^0} > 2M_\tau$ it is expected that τ pair decays will dominate.
- It follows that
  - -We should see a single photon peak with $E_\gamma = \frac{M^2_{\Upsilon 1S} - M^2_{A_0}}{2M_{\Upsilon 1S}}$
  - Looking for a set of events that have
    - -Monochromatic photon peak
    - -Evidence of τ pair decay in the final state

PREVIOUS EXPERIMENTAL RESULTS



PhysRevLett.**101**.151802

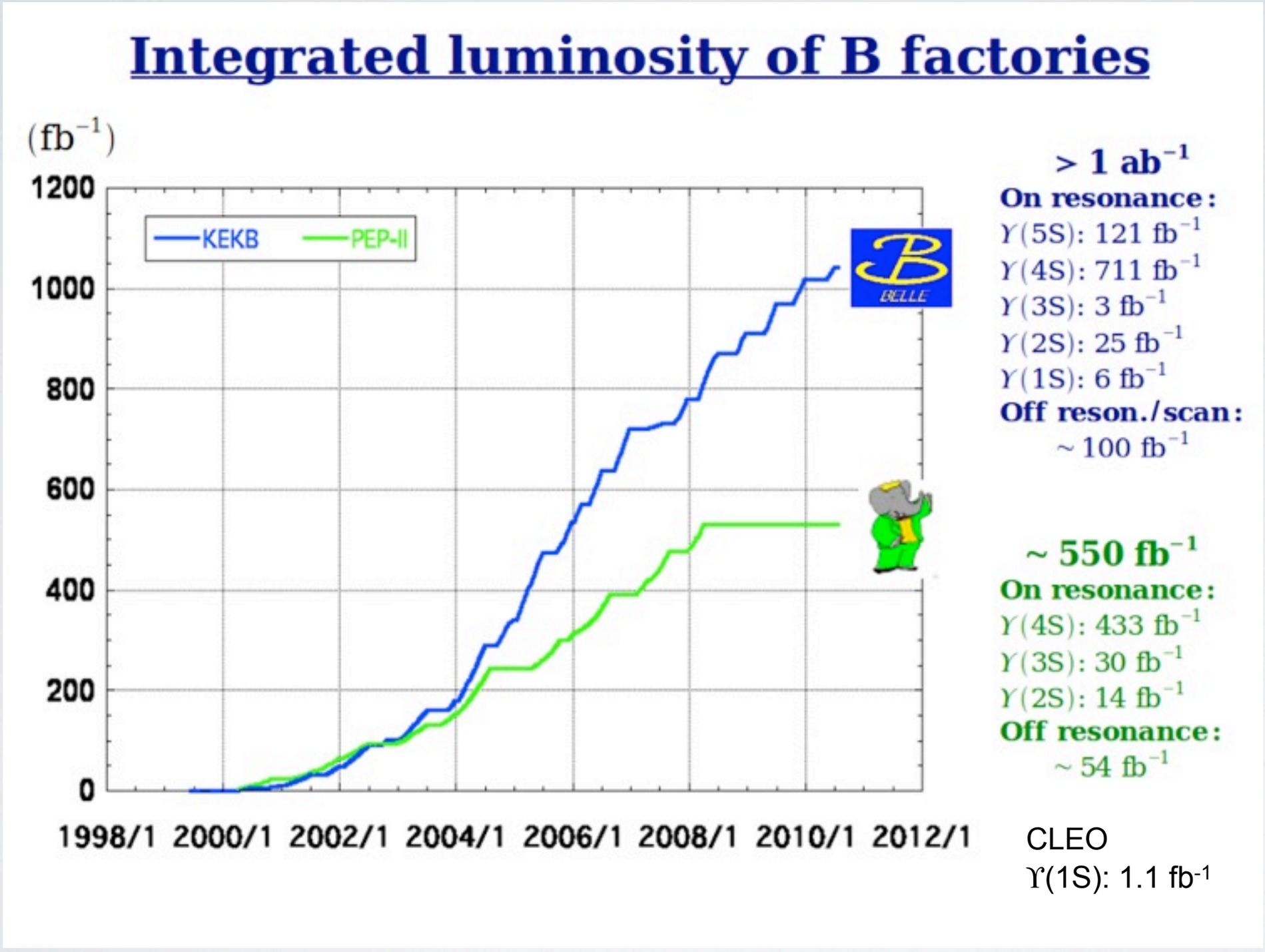
CLEO (top) sought a CP-odd light Higgs using an $\Upsilon(1S)$ sample. Their 90% C.L. upper limit for the branching fraction is shown.



PhysRevLett.**103**.181801

BaBar (bottom) searched for decays of $\Upsilon(3S)$ to CP-odd light Higgs coupled to a τ pair; their 90% Confidence Level upper limit for the branching fraction is shown.

DATA SAMPLES



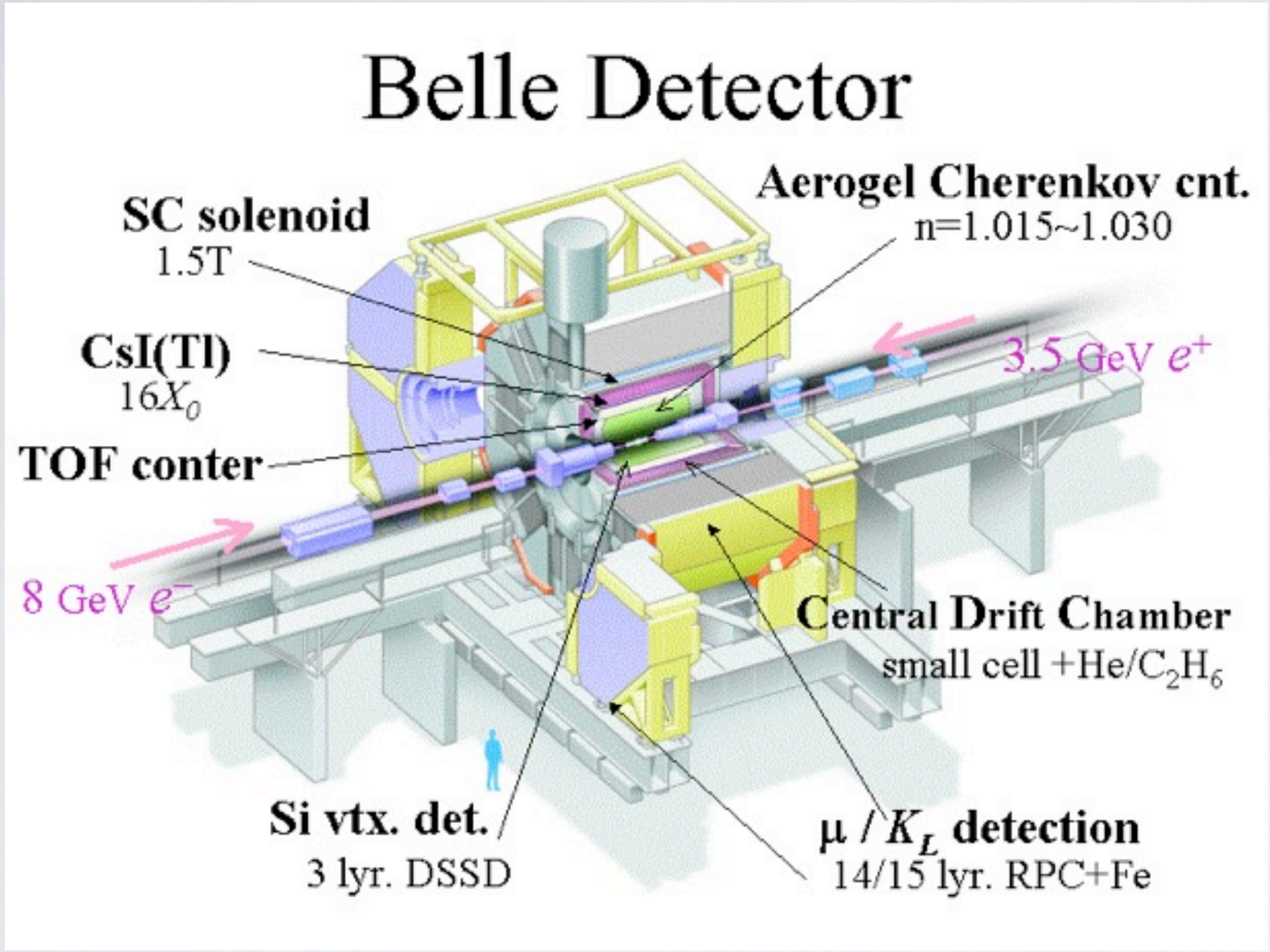
Largest Υ(1S) sample in the world!

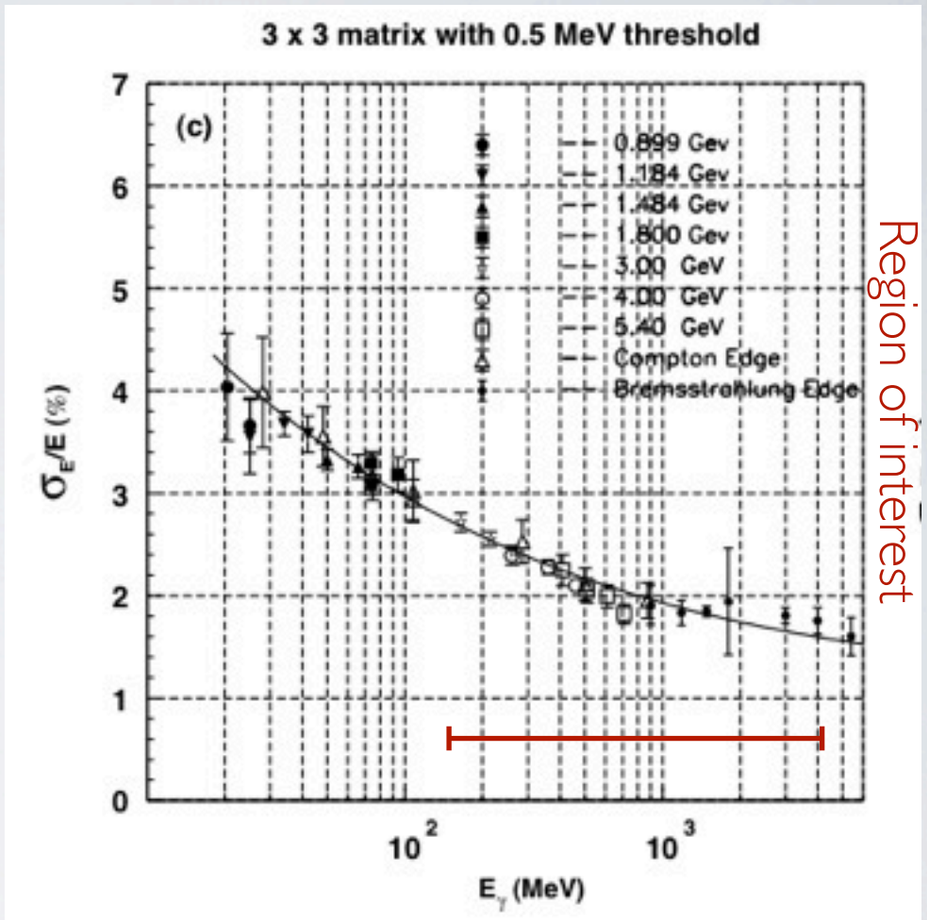
- With 5x the number of Υ(1S) events, we hope to improve upon the limits set by CLEO and BaBar.

KEK & THE BELLE DETECTOR

- TOP: KEK campus in Tsukuba, Japan. Tsukuba hall, the location of the Belle detector, is highlighted.
- BOTTOM: The Belle detector

OVERVIEW OF THE BELLE DETECTOR



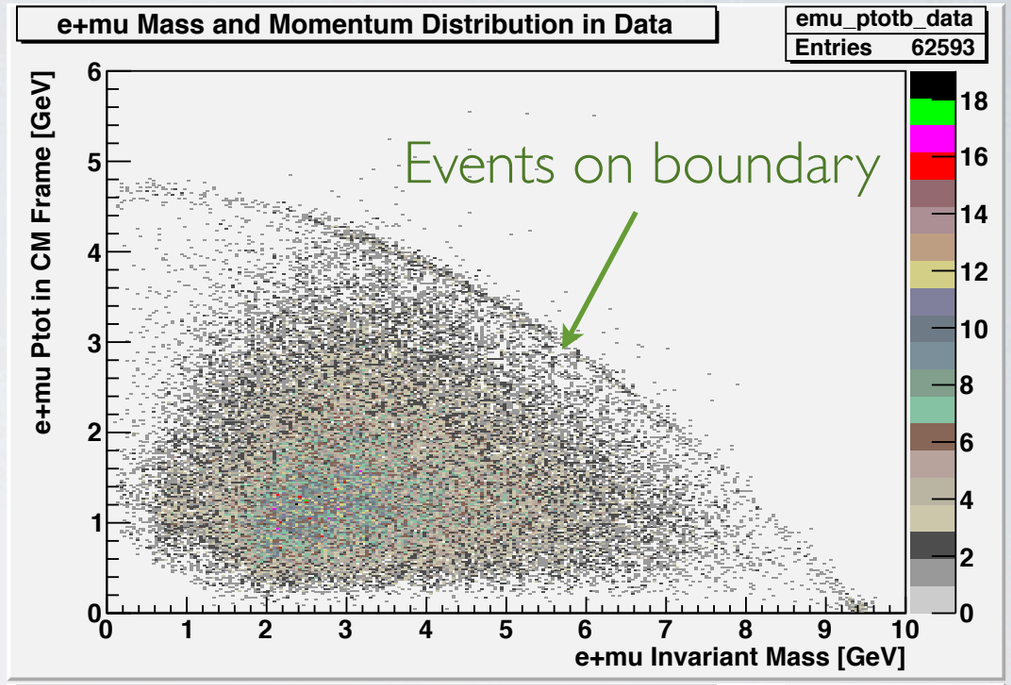


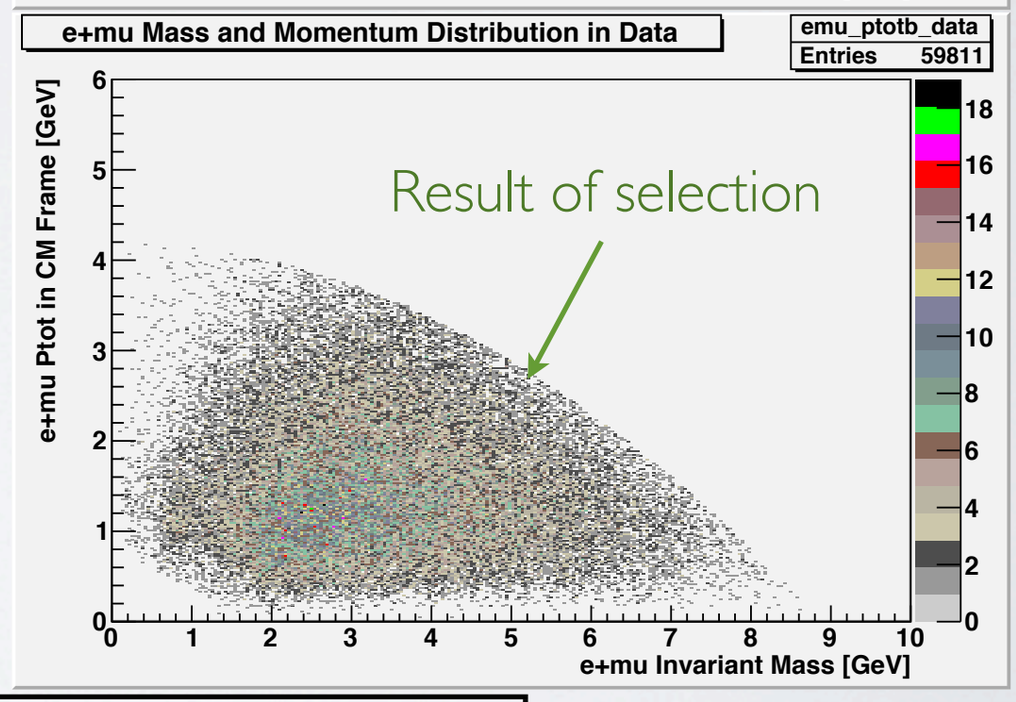
σ_E/E~2% in our region of interest

- If E_μ> 1 GeV then detection efficiency >95%
- If E_e > 1.5 GeV then detection efficiency >95%

SAMPLE SELECTION

Selection	Criteria
Charge	2 charged tracks Charge sum is zero
Lepton	1)No e- e+ events allowed 2) Require one electron **AND** one muon in the final state.
Missing Mass	1.0GeV < M(miss,CM) < 7.0GeV
Missing Angle	30 deg < theta(miss,CM) < 150deg
Location	Candidate γ must be detected in barrel region
Bremsstrahlung	Photons rejected if their tracks lie in a cone of 0.2 radians around an e^+ or μ^-
Pi0 Cut	Photon can't combine with other photons to form Pi0 mass, 3σ
Kinematic Boundary	$s - M^2_{e+mu} - 2E_{e+mu}P_{e+mu} < 10GeV^2$





EFFICIENCY

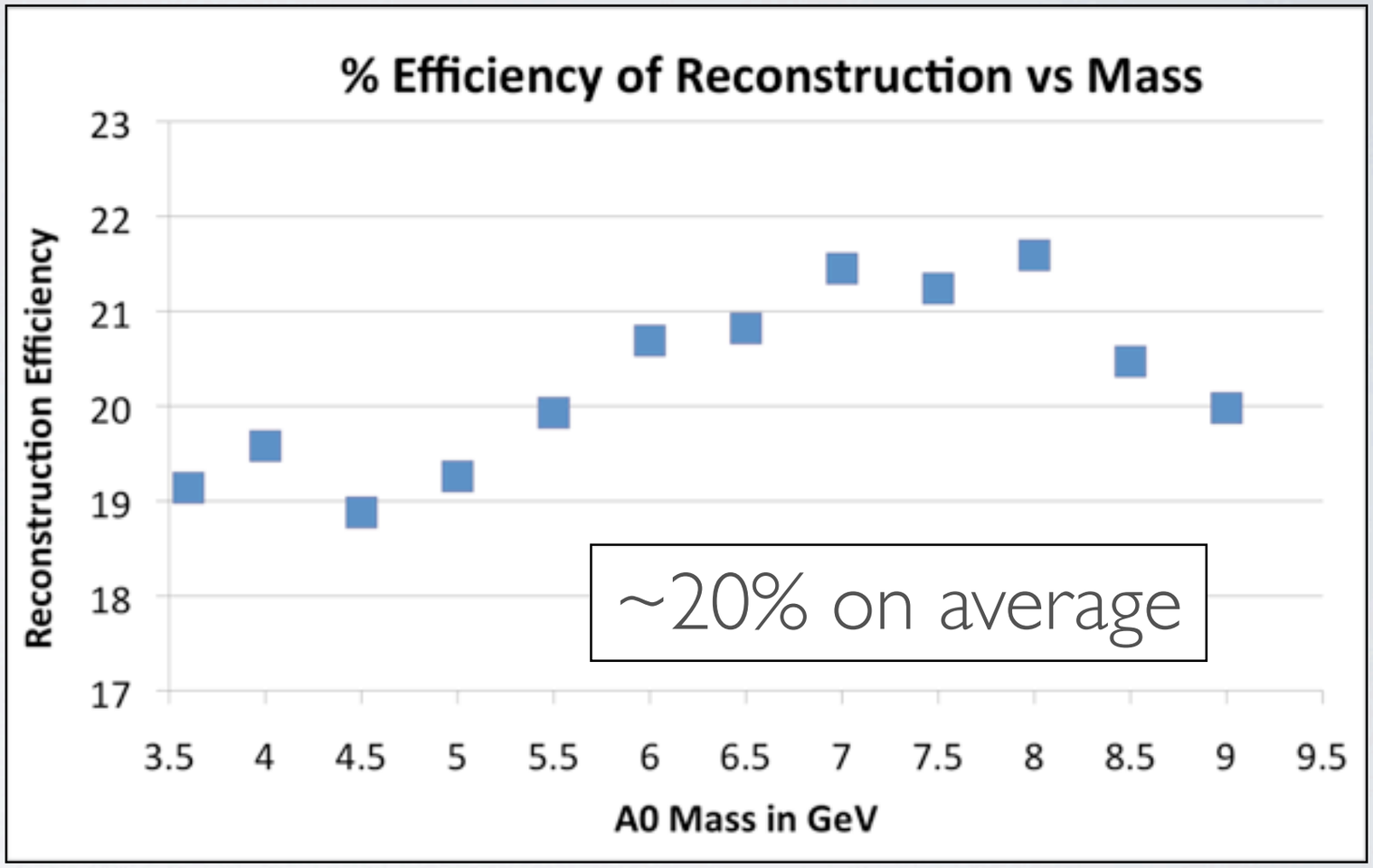
<u>EvtGen MC</u>

$\Upsilon(1S) \rightarrow \gamma A^0$

$A^0 \rightarrow \tau^+\tau^-$

$\tau^+ \rightarrow (\mu^+, e^+)\nu_{(\mu,\, e)}\nu_\tau$

$\tau^- \rightarrow (e^-, \mu^-)\nu_{(e,\mu)}\,\nu_\tau$



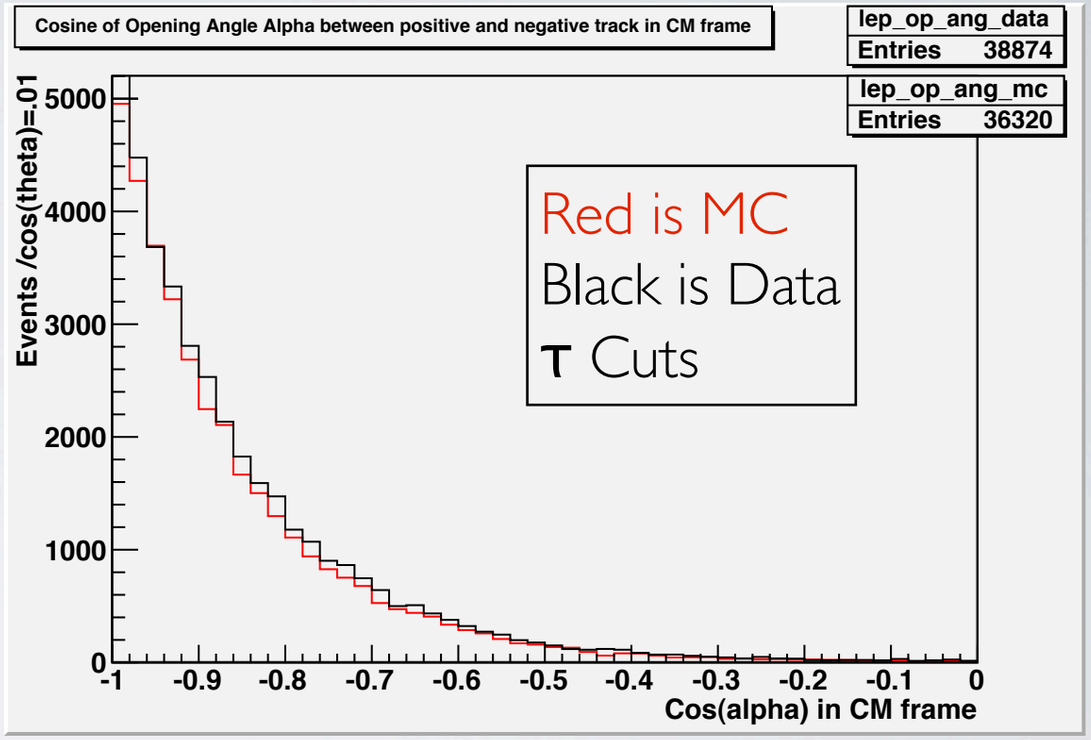
- (left) Signal decay mode detailed
- (right) Reconstruction efficiency after all selection criteria applied

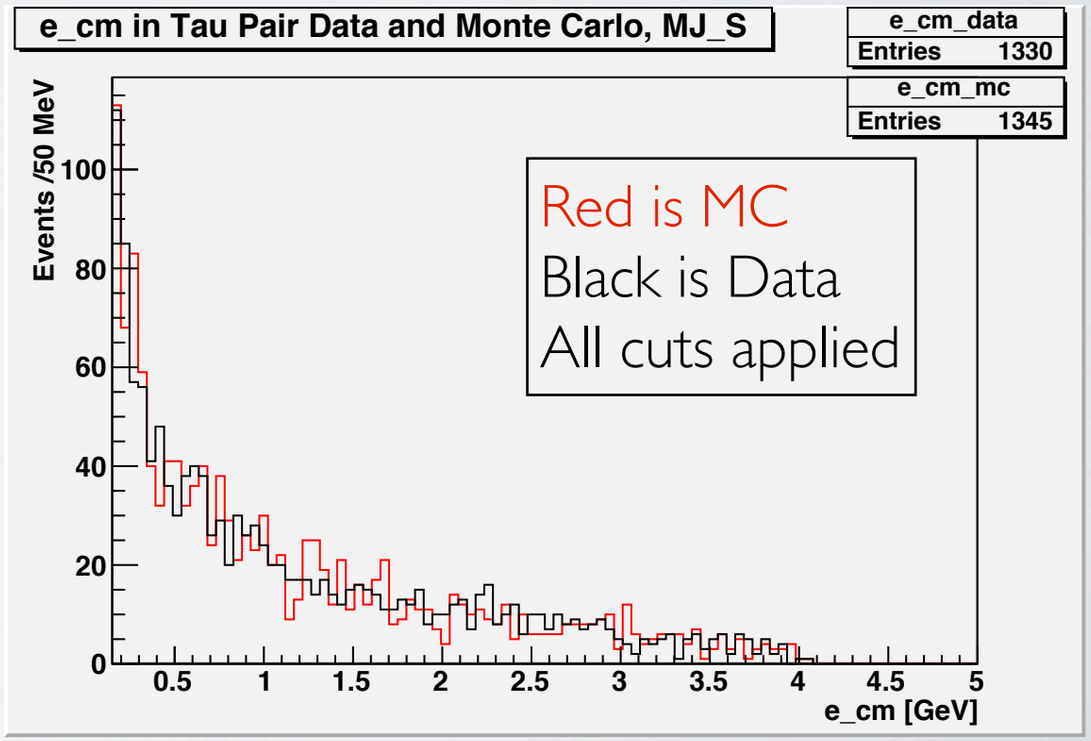
DATA SAMPLE

- Off-resonance integrated luminosity ($\int$Ldt)is 1.802fb^{-1}
  - $\sigma_{\tau\tau}$ =0.919 nb at Υ(4S) resonance, well understood
  - cross section scaling = $\left(\frac{10.58\ GeV}{9.43\ GeV}\right)^2$
  - Total #τ pair: 2.085M events, $N_{\tau\tau}$→final state e, μ~129K
- On-resonance integrated luminosity ($\int$Ldt)is 5.712fb^{-1}
  - Continuum $\tau\tau$ contribution:
    #τ pair: 6.566M events, $N_{\tau\tau}$→final state e,μ ~ 406K
  - Υ(1S)→ $\tau\tau$ contribution w/ 100M Υ(1S):
    #τ pair: 2.574M, $N_{\tau\tau}$→final state e,μ~160K

MONTE CARLO MODELING

- Off-resonance τ sample was simulated in MC using KKMC
- On-resonance τ sample was recreated using EvtGen for the peak production and KKMC for the continuum.
- Photon spectrum studied after τ sample was modeled
- ISR & FSR photons modeled in continuum sample.
- Only FSR modeled in peak sample.

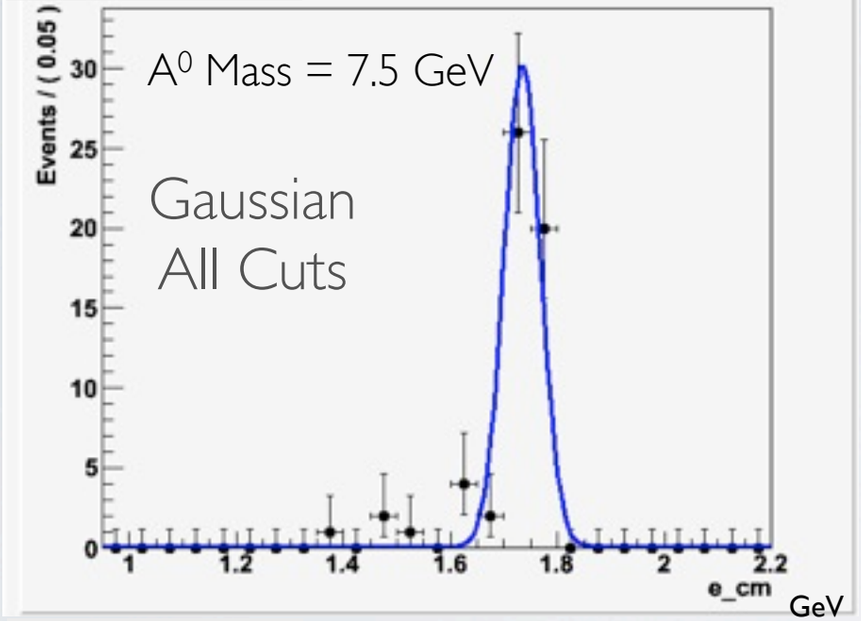




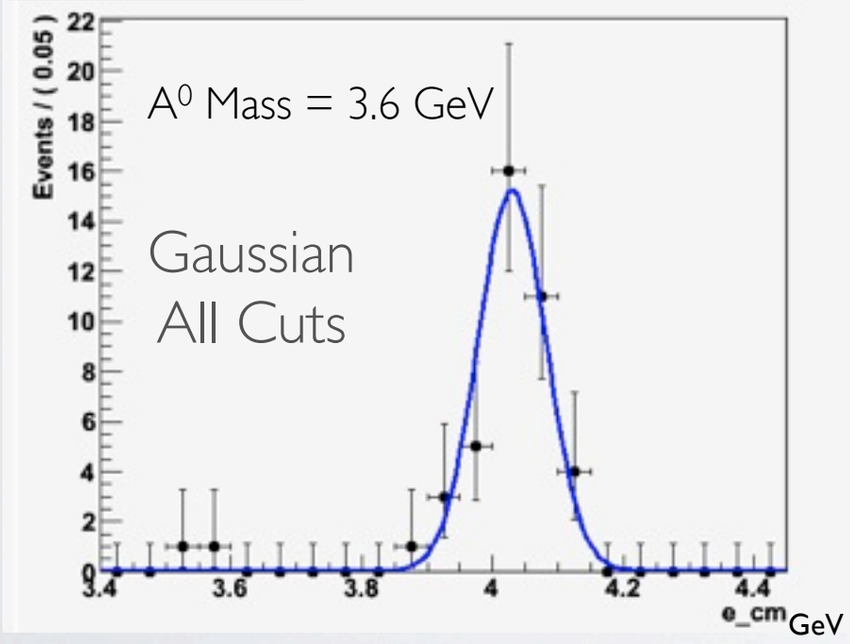
(bottom) Photon spectrum in CM frame
(top) Charged track opening angle

FITTING: SIGNAL

Signal Monte Carlo



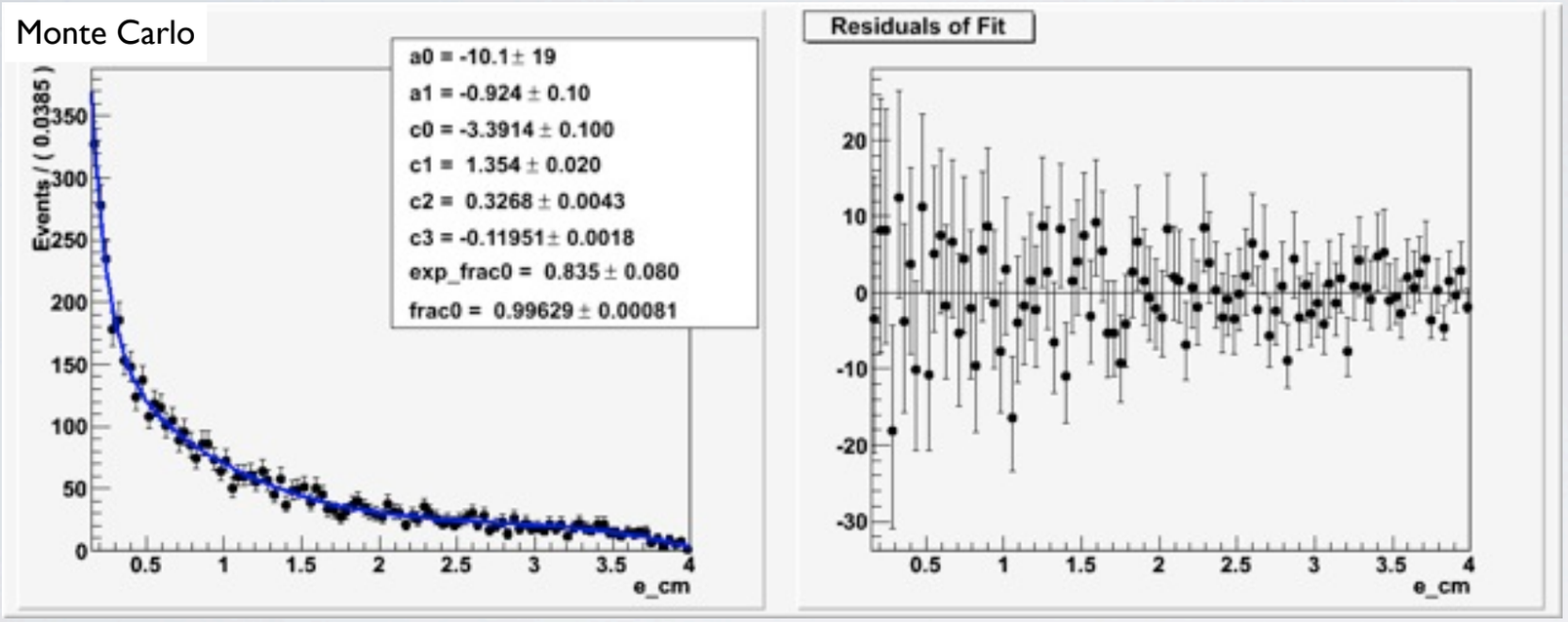
Signal Monte Carlo

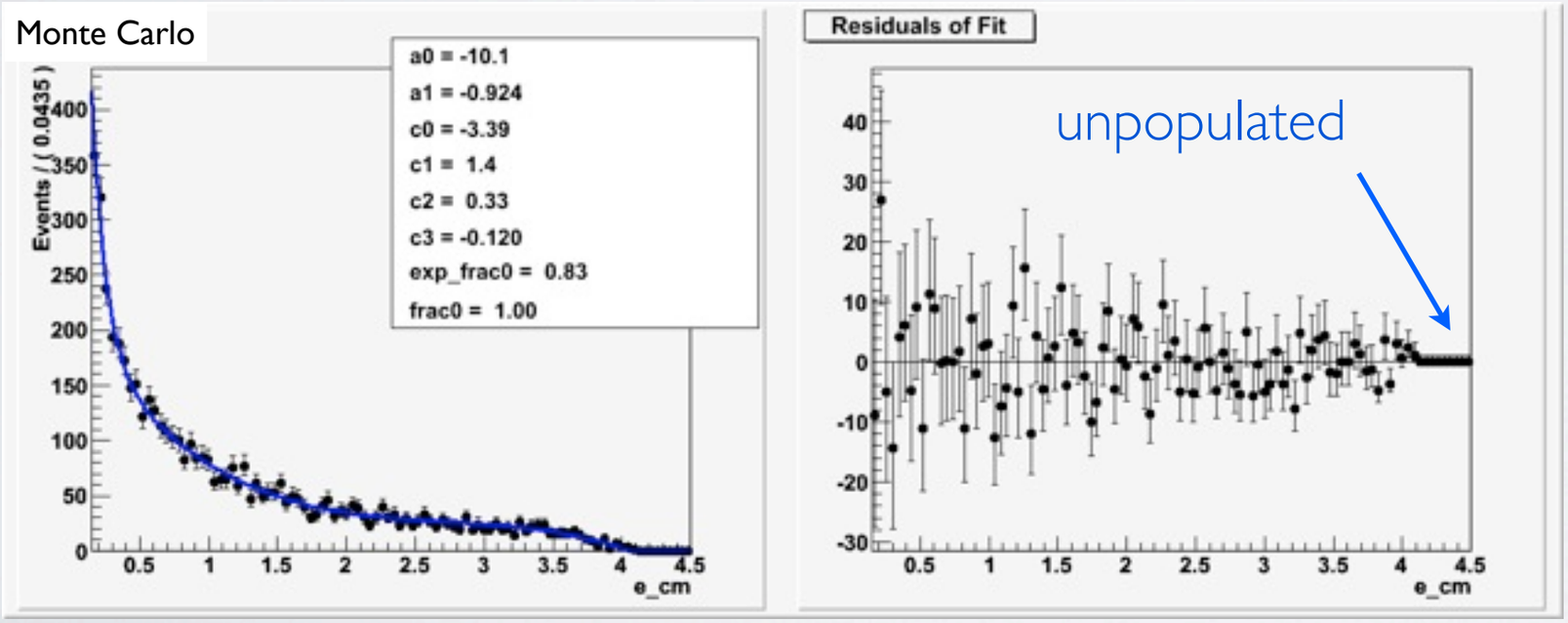


- A fit to $\sigma_{Gaussian}$ in terms of $E\gamma$ returned $\sigma_{Gaussian} \sim 0.02 \times E\gamma$
- $\sigma_{Gaussian}$ is what was expected for peak width dominated by ECL resolution
- Reconstruction efficiency with Gaussian very similar to Crystal Ball
- Gaussian gives better convergence during background+signal fitting

Signal fit function found: Gaussian with width prescribed as a function of peak energy

FITTING: BACKGROUND



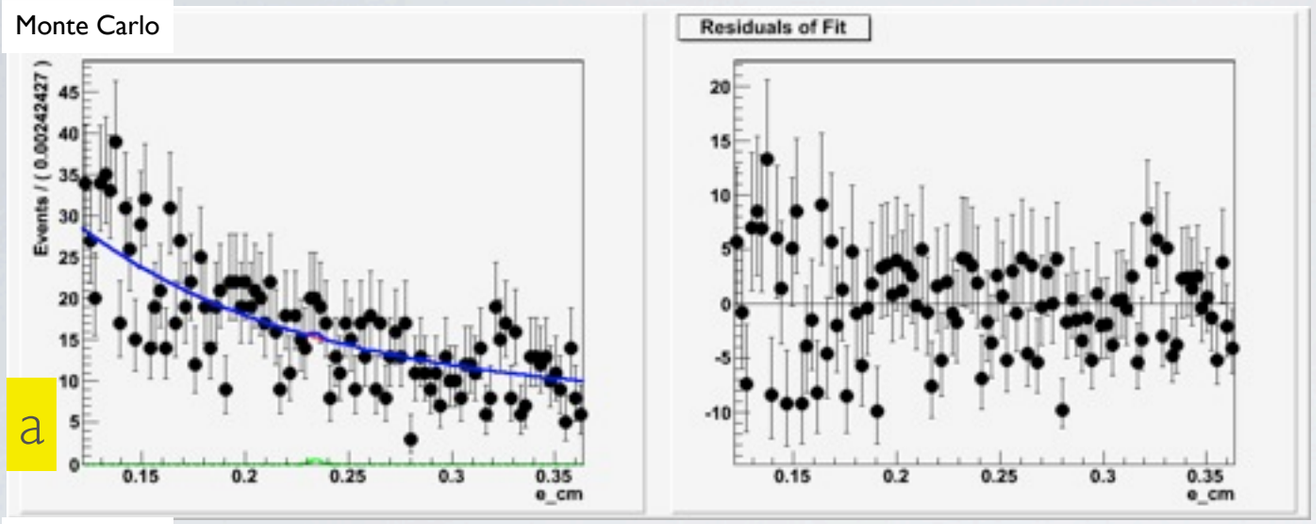


On-resonance MC, All Cuts

Background Fit: 2 exponentials and a polynomial.

- Exponentials fit well in low Eγ region
- Polynomials fit well in high Eγ region
- Fit with combination of both
- (top) Fit populated region with polynomial +exponentials
- (bottom) Make a user-defined function with PDF=0 after the populated region ends;.

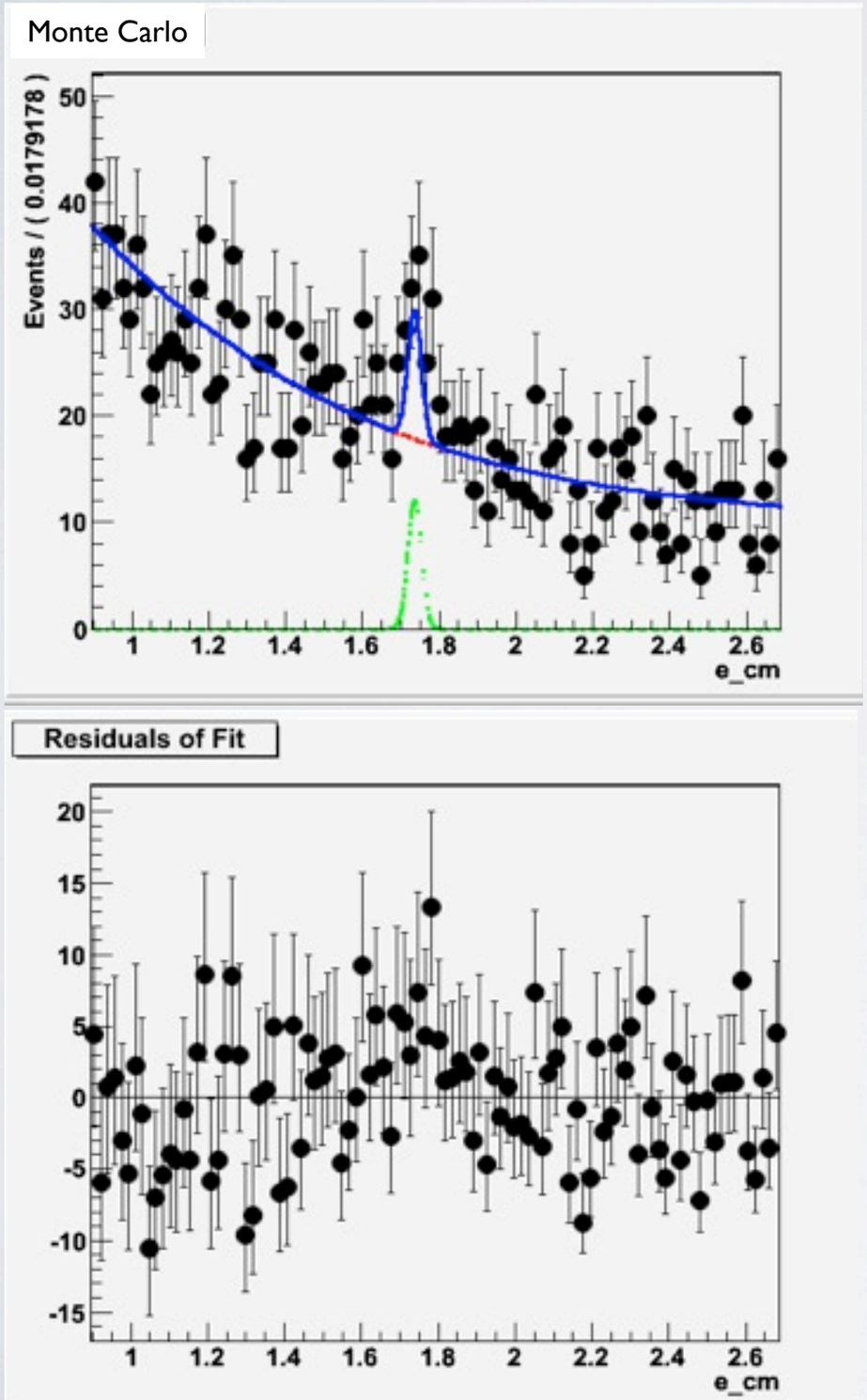
FITTING: BACKGROUND



- Fit in high A^0 mass (low Eγ) has unbiased residuals as expected (a)
- Similar result for the fit near transition region of 4 GeV (b)
- Fit including transition region also good (c)

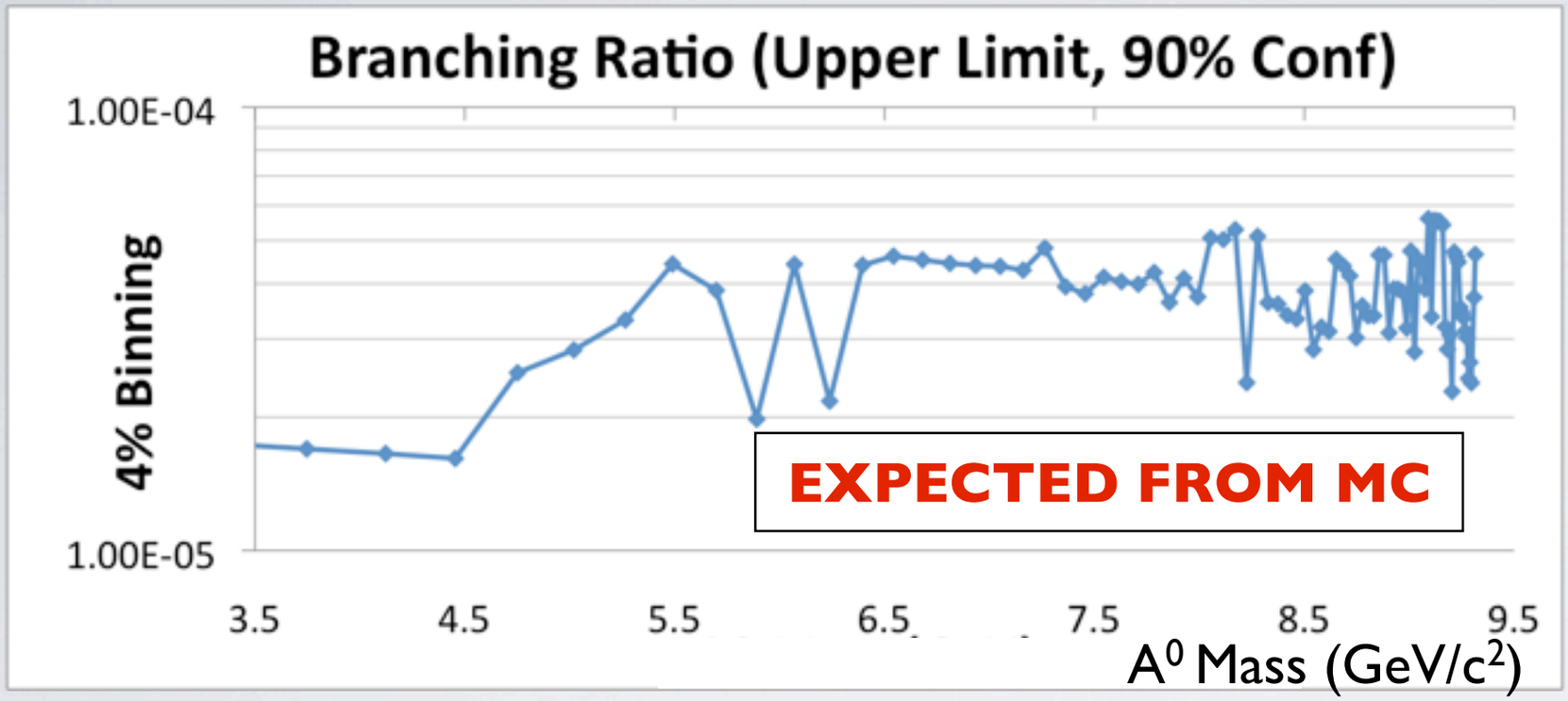
On-resonance MC, All Cuts

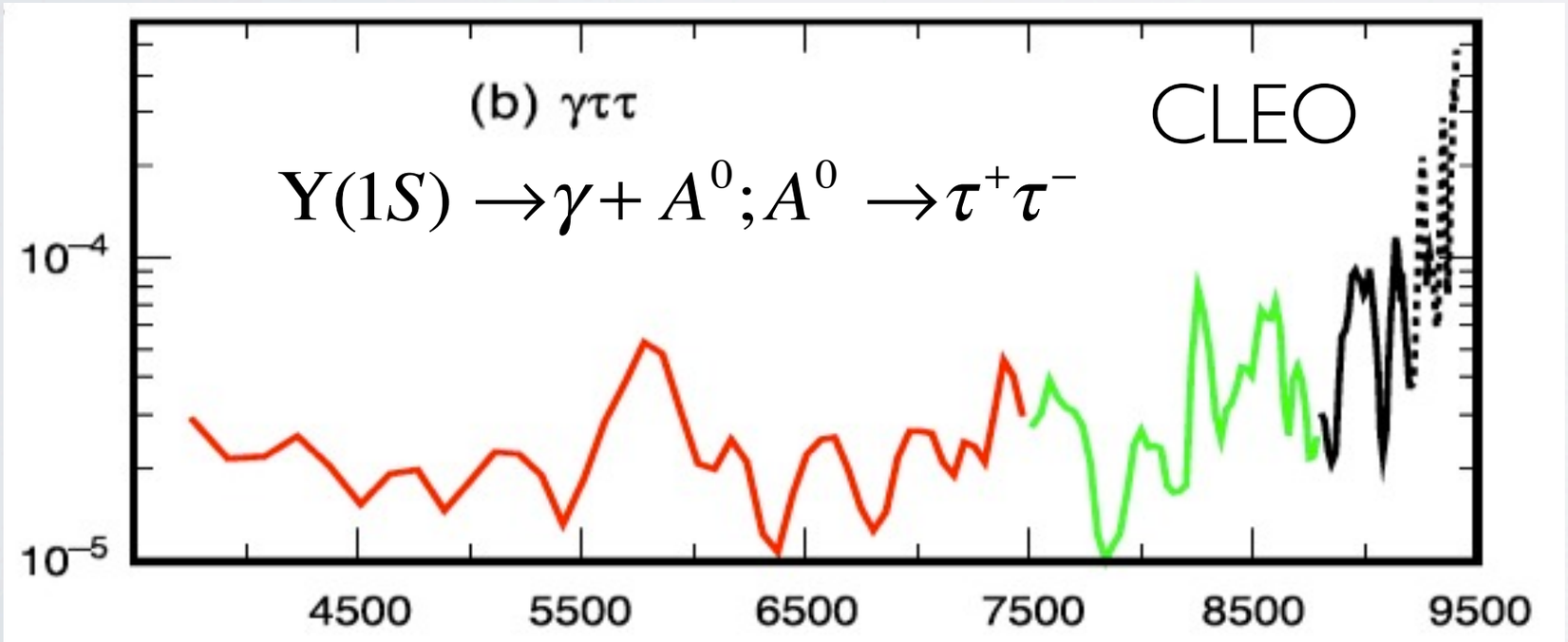
FITTING: SIGNAL+BACKGROUND FIT



- Signal+Background fit:
  - Fit window edges $\pm 50 \times \sigma_{Gaussian}$ about the Gaussian mean
  - Mean is allowed to float $\pm 10 \times \sigma_{Gaussian}$ about initial value
  - Floating signal normalization based on number of of events
  - Step size is consistent with detector resolution

SCAN





PhysRevLett.**101**.151802

-U.L. from likelihood integration
-CLEO has better sensitivity over most of the range
-Belle may have better sensitivity to A^0 with masses >8.5 GeV
-Expect to unblind soon

SUMMARY & WHAT'S NEXT

- Summary:
  - Using the world's largest $\Upsilon(1S)$ data in a search for evidence of an A^0 decay..
  - Succeeded in isolating an extremely pure sample of τ pairs.
    - We expect our search will be able to corroborate previous best limits utilizing a decay mode that hasn't been fully explored.
- What's Next
  - Improve detection sensitivity by allowing events with one e *or* one μ and the other charged track left unidentified.