SFB 1044
THE LOW-ENERGY FRONTIER
OF THE STANDARD MODEL

JG|U

Produce a 1^{++} charmonium - χ_{c1} in e^+e^- machine

Achim Denig, Benedikt Kloss and **Zhiqing Liu**

JGU Mainz

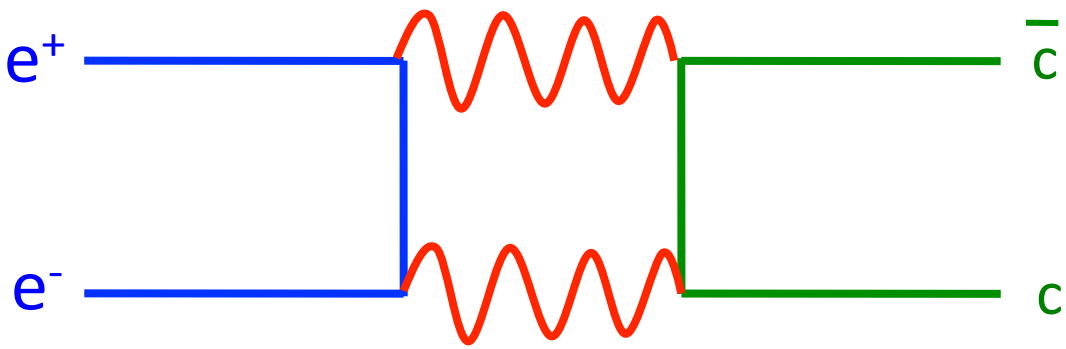
liuz@uni-mainz.de

Motivation

J. Kaplan, H.Kühn, PLB78 (1978) 252

- So far in e+e- annihilation only vector resonances with quantum numbers $J^{PC}=1^{--}$ have been produced
- Excellent performace of BEPC II and BESIII detector offer the opportunity to measure process $e^+e^- \to \chi_{c1}$ (1^{++}) through a two-photon production for the first time.

$$e^+e^- \to 1^{++}$$



Note: Landau-Yang theorem does not hold for virtual photons !

Relation to XYZ Spectroscopy

- Two-photon coupling to ($c\,\bar{c}$) provide unique input to theoretical understanding of charmonium(-like) resonances.

- Strategy:

  I) Establish method with a well-known charmonium state
  e+e- → X_{c1}

  II) Embark on a search e+e- → X(3872) – also 1^{++}

- Production cross section given by electronic width Γ_{ee}
  So far a few info. on Γ_{ee} existing!

→ Sensitive parameter to understand nature of X(3872) …. and eventually other exotics ?!

→ Talk Martin Ripka

Cross Section Estimates

- χ_{c1} Parameters: Mass χ_{c1} = 3510.66±0.07 MeV
  Width χ_{c1} = 0.86±0.05 MeV
  Dominant decay channel (34.4%):
  $\chi_{c1} \rightarrow \gamma\, J/\psi$

- Electronic width unknown (from H. Kühn @ Phipsi13, Rome)
  → ~1 order of magnitude uncertainty: unitarity limit: Γ_{ee}^{min} = 0.044 eV
  →Cross section > 10 pb taking into account ISR and beam energy spread
  (....not so small .... !)

- BABAR measured e+e- → $\rho^0\rho^0$, possible via two-photon process!
  Process can be well described by VMD model (Davier, Peskin, Snyder)

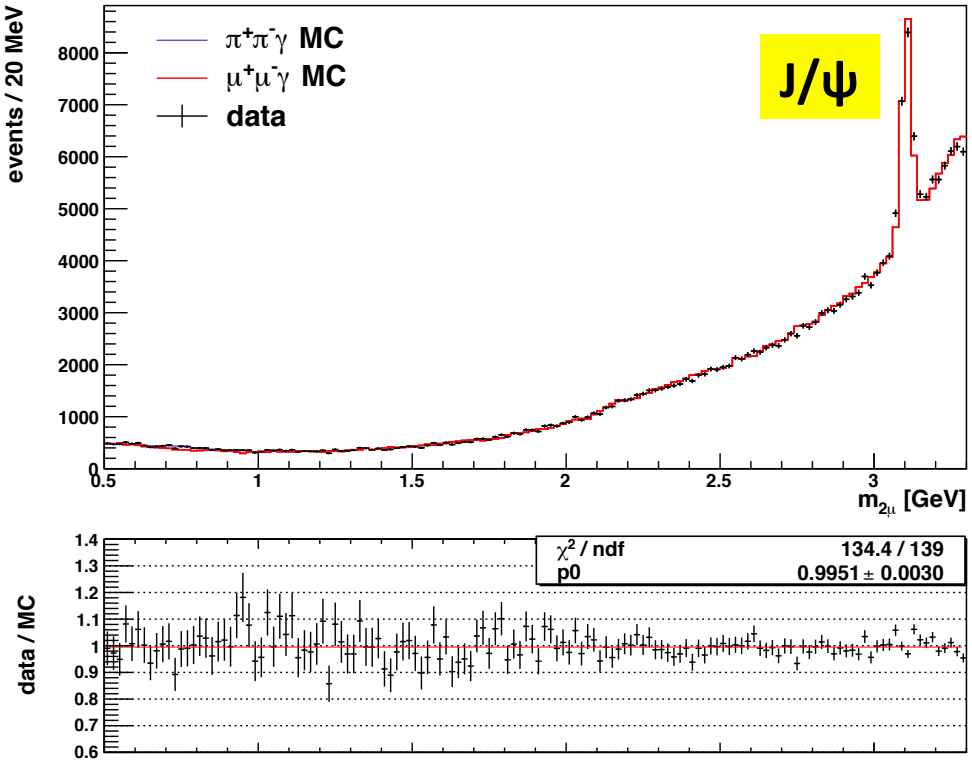
  → Use same model also for cross section estimate: Γ_{ee}^{VMD} = 0.46 eV

ISR production

Channel $e^+e^- \rightarrow \gamma\mu^+\mu^-$ extremely well known in BESIII !

→by B. Kloss

Agreement: Δ(Data-MC)=(0.5±0.3)%

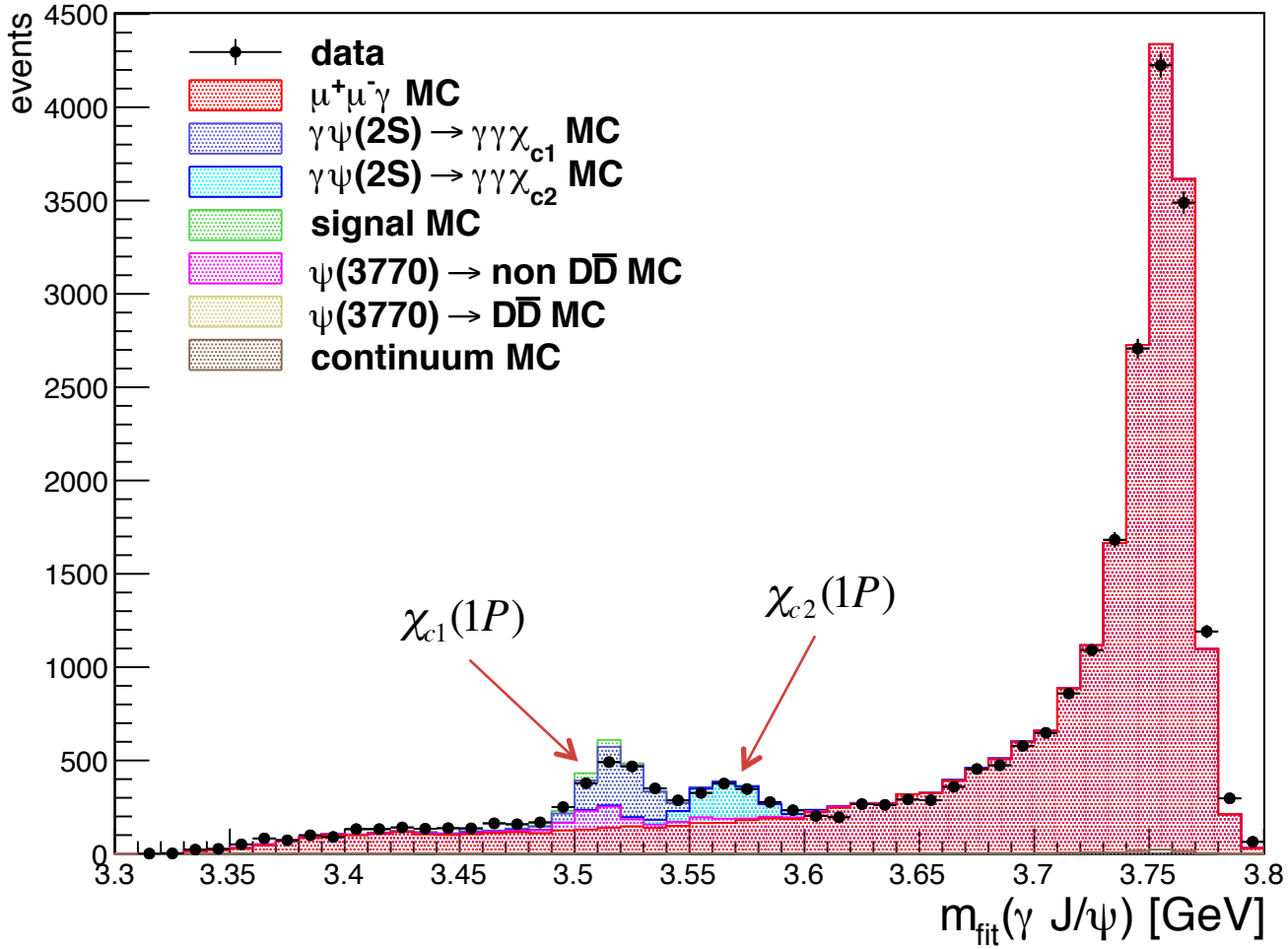


Selection:

- at least 1 photon
- 2 tracks with Muon PID
- 4C kinematic fit, $\chi^2<30$
- 3.05 GeV < $m_{\mu\mu}$ < 3.15 GeV

Intermediate Result: $e^+e^- \rightarrow \chi_{c1}\,\gamma_{ISR}$

- No cut on angle of ISR photon
- Suffer from $\psi(3770) \rightarrow \gamma\chi_{c1}$ background



Direct production

Determination of the signal cross section:

- Bare peak cross section 637 pb

↓

- Taking into account ISR corrections and beam energy spread (1.47 MeV, estimated by tau mass scan data).
  → cross section 115pb

↓

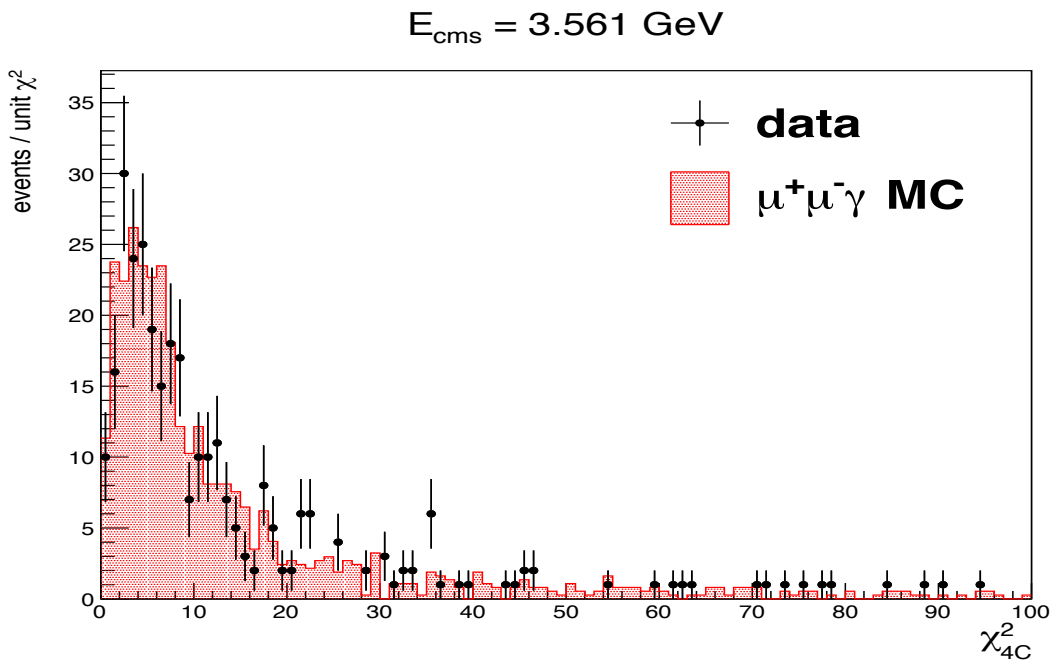
- Taking into account the BRs for the final state μμγ
  → cross section 2.42 pb

- Finally taking into account the efficiency (~65%)
  Final effective signal cross section σ^{eff} = 1.57 pb

Background

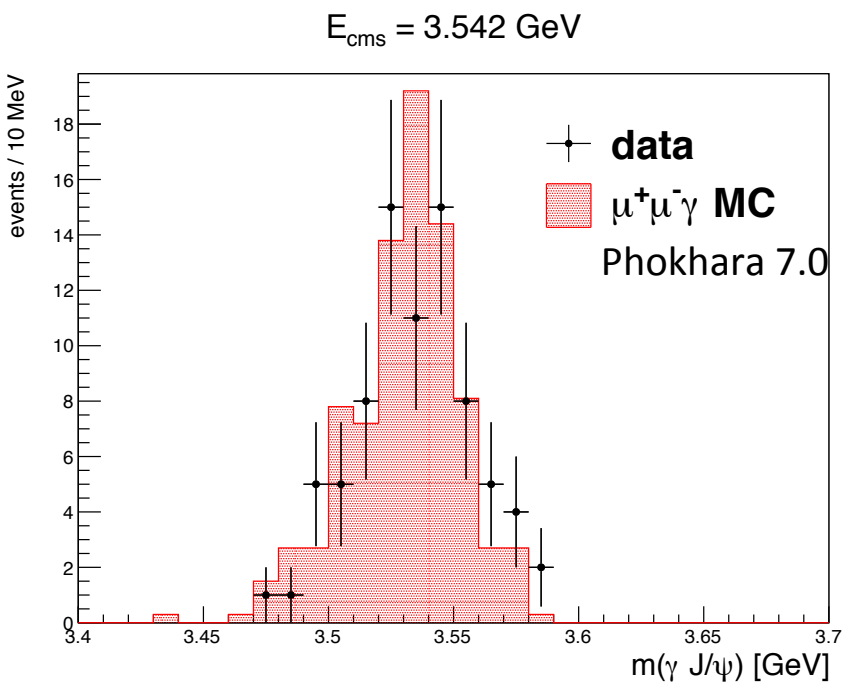
- Irreducible background: ISR production of J/ψ:
  (different polar angle distribution of photon)
  → existing MC generator PHOKHARA7.0

- Additional background $e^+e^- \rightarrow \gamma_{ISR}\ \mu^+\mu^-$? → look into data distributions from existing tau-mass scan data √s=3.542 GeV and √s=3.561 GeV in vicinity to mass of χ_{c1}

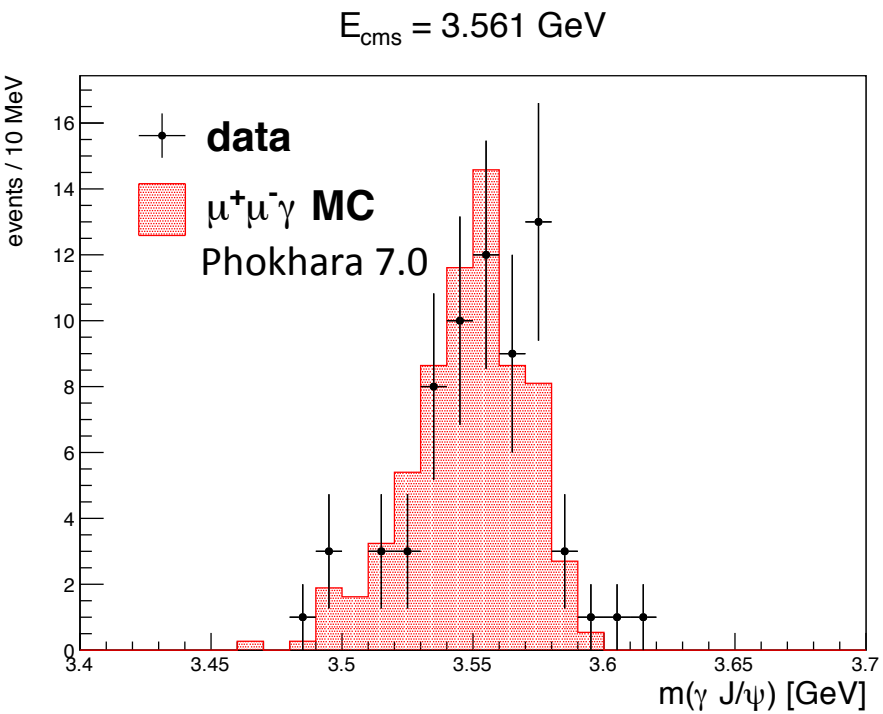


ISR Background

31 MeV below signal



50 MeV above signal



- **excellent agreement, no indication of additional background**
- **effective background cross section 19 pb**

Beam Time Estimation

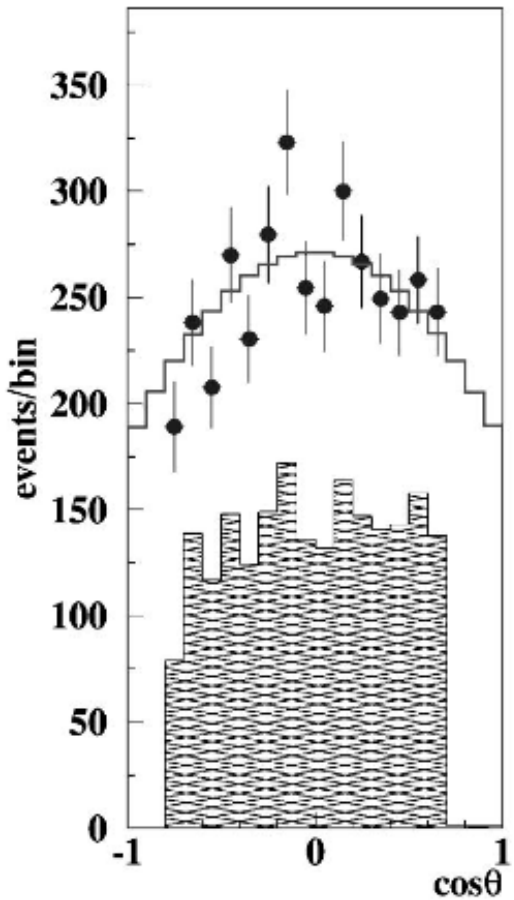
- Measure only on resonance –> background known!
- Signal to Background Ratio 1.57 : 19 = 8.3%
- Assuming BEPC II performance: 15 pb^{-1} / day

Significance	Luminosity	Data taking time
1 sigma	8.4 pb^{-1}	13.4 h
2 sigma	33.4 pb^{-1}	53.4 h
3 sigma	75.1 pb^{-1}	120.2 h
4 sigma	133.5 pb^{-1}	213.6 h
5 sigma	208.6 pb^{-1}	333.8 h

Proposal: 2 weeks of beam time!

What is lacking of now?

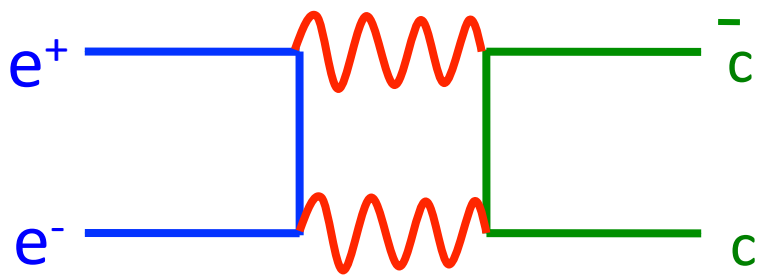
Radiative photon in $e^+e^- \rightarrow \chi_{c1} \rightarrow \gamma\, J/\psi$ goes predominantly via E1 transition



E835
PRD65, 052002 (2002)

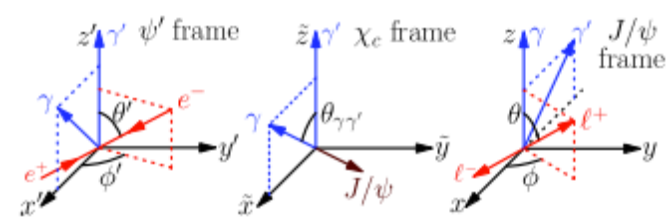
To measure the Γ_{ee}, understand acceptance and detection efficiency:

- Angular distribution of E1 photon and leptons?
- Good generator !
- In $\psi(2S) \rightarrow \gamma\chi_{c1} \rightarrow \gamma\gamma J/\psi$, we understood well (E1+M2) !



BESIII ?

CLEO-c
PRD80,112003 (2009)



Conclusions

- First search of e+e- → 1^{++} in reach at BESIII
  → Great potential .... Especially regarding X(3872)

- Background for this measurement: ISR production of J/ψ
  → Precision MC is available (Phokhara 7), well understood

- Search for the signal reaction via ISR limited by statistics
  → Proposed direct production

With 2 weeks of beam time at BESIII → New Discovery !