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Status of the Charmonium Analyses $J/\psi\omega$, $J/\psi\eta$, $J/\psi\pi^+\pi^-$ and $\psi_g\eta$

July 04, 2007
Panda Collaboration Meeting
Dubna

- $\bar{p}p \to J/\psi\omega$
  - only Y(3940) $\to J/\psi\omega$ decay mode observed (Belle)
  - interpretations:
    - exotic state (charmonium hybrid), conventional charmonium χ_{cJ}' state
  - spin probably J=0,1,2 $\to$study for different J

- $\bar{p}p \to J/\psi\eta$
  - E_{CMS}=3686, 3872, 4260 MeV
  - if exotic X(3870) and Y(4260): some models expect enhanced $J/\psi\eta$ decay
  - use ψ(2S) as reference signal

- Charmonium hybrid production in $\bar{p}p \to \psi_g\eta$, $\psi_g \to \chi_{c1}\pi^0\pi^0$, $\chi_{c1} \to J/\psi\gamma$ @ 15GeV
  - hypothetical J^{PC}=1^{-+} state at 4260 MeV
  - investigation of different production models / angular distributions in ψ_g decay

- $\bar{p}p \to J/\psi\pi^+\pi^-$
  - E_{CMS}=3526, 3686, 3872, 4260, 4600, 5000 MeV   E. Fioravanti
 - study different decay models, i.e. dipion S-wave system   Ferrarra

- same J/ψ→e⁺e⁻ selection criteria applied for all channels

- likelihood based e$^\pm$ identification
  – exploit DIRC+EMC information
  – probabilities: P(e$^\pm$)>0.2, P(e$^\mp$)>0.85

- kinematic fit
  – common vertex (vertex constraint)
  – confidence level: CL>0.1%

- mass window [2.98;3.16]GeV

- fit accepted J/ψ candidates w/ additional mass constraint
  – m(e⁺e⁻)=m$_{PDG}$(J/ψ), CL>0.1%
 – improvement of J/ψ+X signal resolution
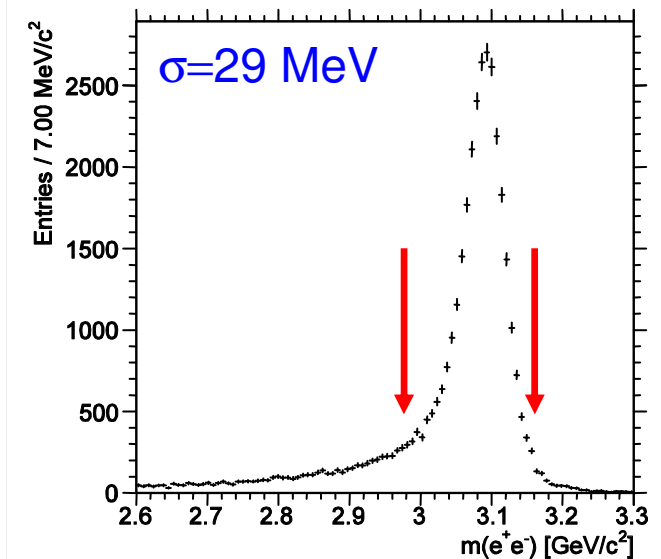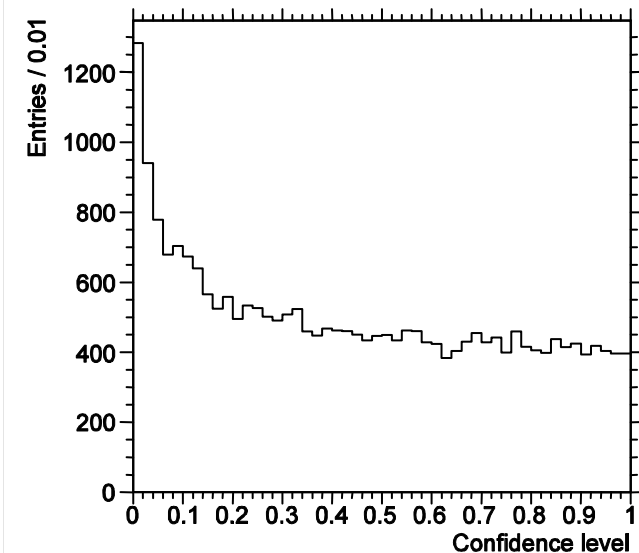
- **MC data sets at 3940 MeV**
  - 50k signal events: $\bar{p}p \rightarrow J/\psi\omega,\ \omega \rightarrow \pi^0\gamma,\ \pi^0 \rightarrow \gamma\gamma$

  - considered background (so far)
    - 494k evetns for $\bar{p}p \rightarrow \pi^+\pi^-\omega$
    - 569k events for $\bar{p}p \rightarrow \pi^0\pi^0\pi^0 \rightarrow (e^+e^-\gamma)\ (e^+e^-\gamma)(\gamma\gamma)$ [2π^0 Dalitz]

  - only phase space distribution considered in decays (so far)

- **preselection requirements**
  - 2 charged tracks per event
  - 3 photon candidates per event
- $\pi^0 \rightarrow \gamma\gamma$ **selection**
  - form all $\gamma\gamma$ combinations in the event
  - mass window [125;145]MeV
- $\omega \rightarrow \pi^0\gamma$ **selection**
  - combine π^0 cands. w/ additional photon cand. in event
  - mass window [740;815]MeV
- **J/ψω selection**
  - combine all accepted J/ψ and ω cands. in the event
  - improve signal resolution using mass difference m(J/ψω)-m(ω)

σ=4.15 MeV

σ=13.6 MeV
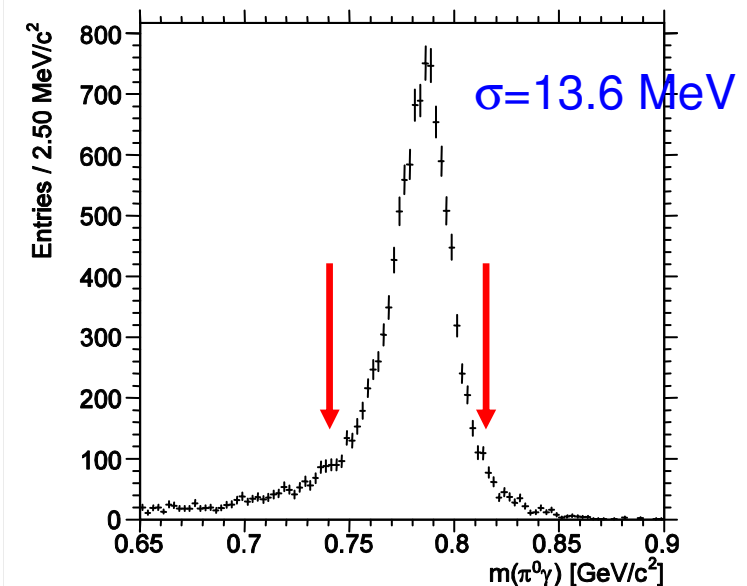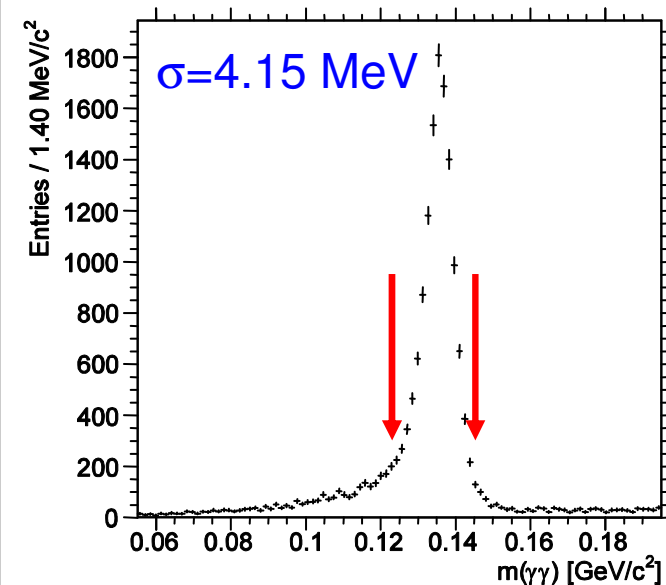
- **mass difference technique**
  - errors on J/ψω and ω invariant masses are correlated
  - signal resolution improves for projection m(J/ψω)-m(ω) along diagonal
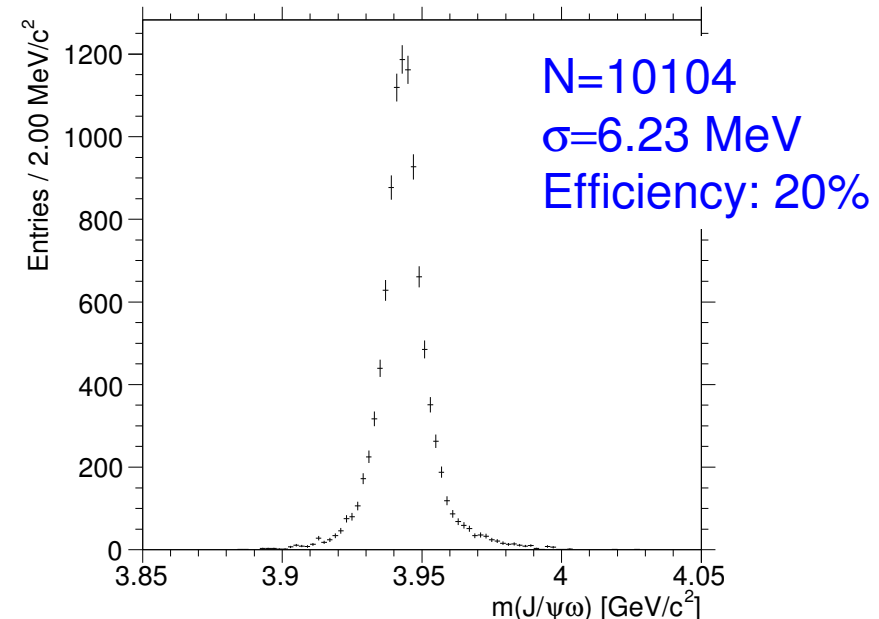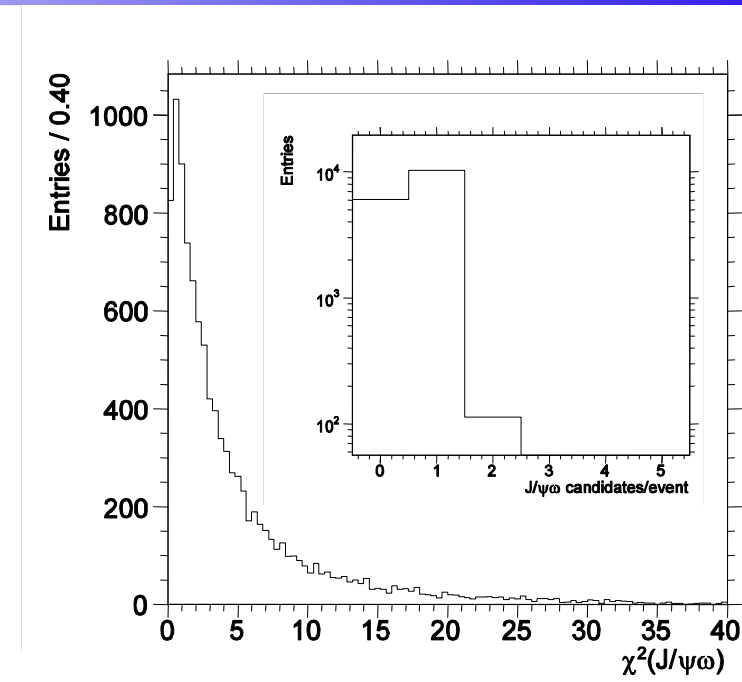

$m(J/\psi\omega)-m(\omega)+m_{\omega PDG}$

$m(J/\psi\omega)$
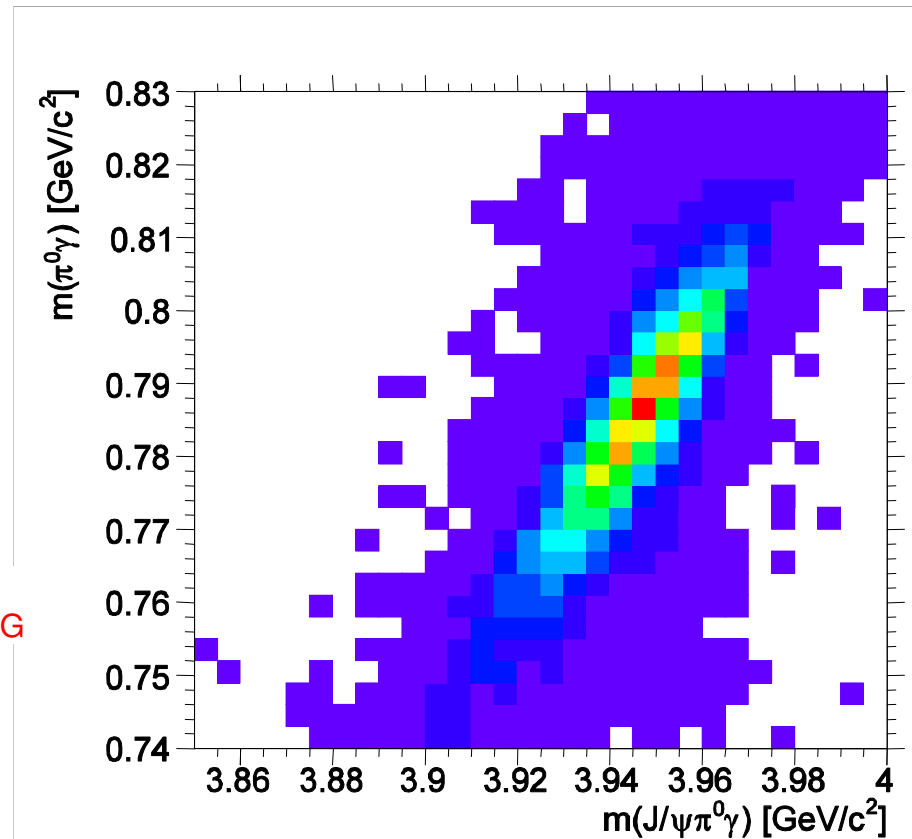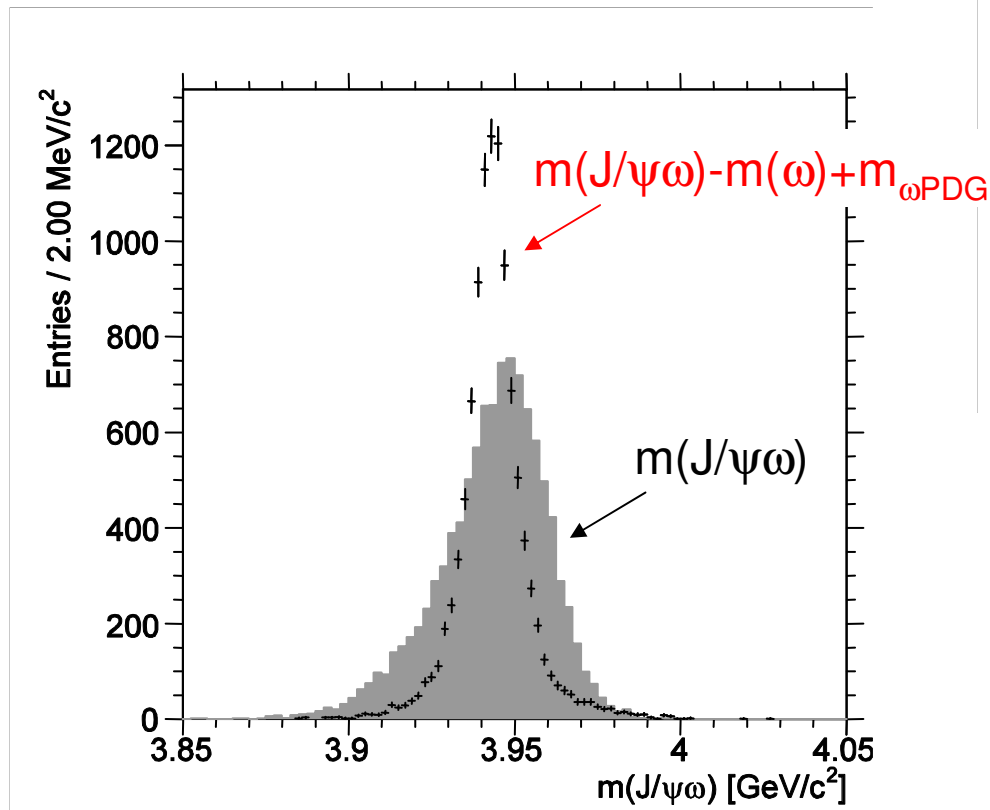
- more than one J/ψω cand. can be found in one event

- **accept only cand. w/ least χ² per event**
  - calculated from intital CMS 4-vector p_i and reconstructed J/ψω system p_r

$$-\chi^2 = \sum_{j=1}^{3} (p_{r,j} - p_{i,j})^2 / \sigma_{r,j}^2 + (m_r - m_i)^2 / \sigma_m^2$$

  - **require χ²<25**

N=10104
σ=6.23 MeV
Efficiency: 20%

- apply same selection to background events

- no reco'ed event from 498k events $\bar{p}p \rightarrow 3\pi^0$ ($2\pi^0$ Dalitz sample)

  - no problem up to 2.8×10^{12} events

- 1 reco'ed event in signal region from 569k $\bar{p}p \rightarrow \pi^+\pi^-\omega$ events

  - S/N=20

  - further investigation w/ more data required to draw final conclusion
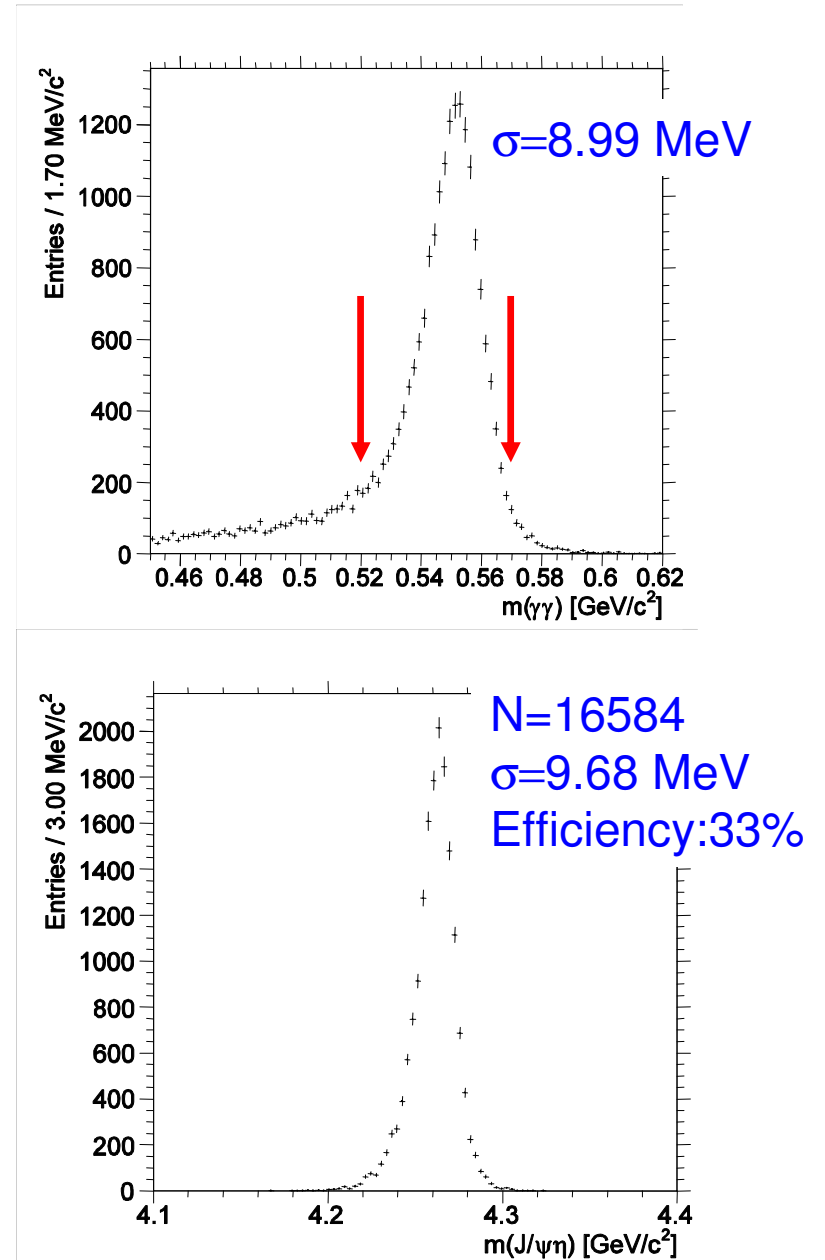
  - better suppression w/ tighter $e^\pm$ PID, χ^2 possible

$\sigma(Y(3940))$	100nb	charmonium formation in $\bar{p}p$
BR(Y(3940)$\rightarrow$J/ψω)	>17%	if conventional χ_{cJ}' state
$\sigma(\pi^0\pi^0\pi^0)$	10μb	from DPM generator
$\sigma(\pi^+\pi^-\omega^0)$	10μb	from DPM generator
Signal efficiency	20%	
BR(J/ψ$\rightarrow$e$^+$e$^-$)	5.94%	
BR(ω$\rightarrow$π^{0}γ)	8.90%	
BR(π$^0 \rightarrow$γ γ)	98.9%	
BR(π$^0 \rightarrow$e$^+$e$^-$ γ)	1.20%	

model dependent assumptions for 4 free parameters

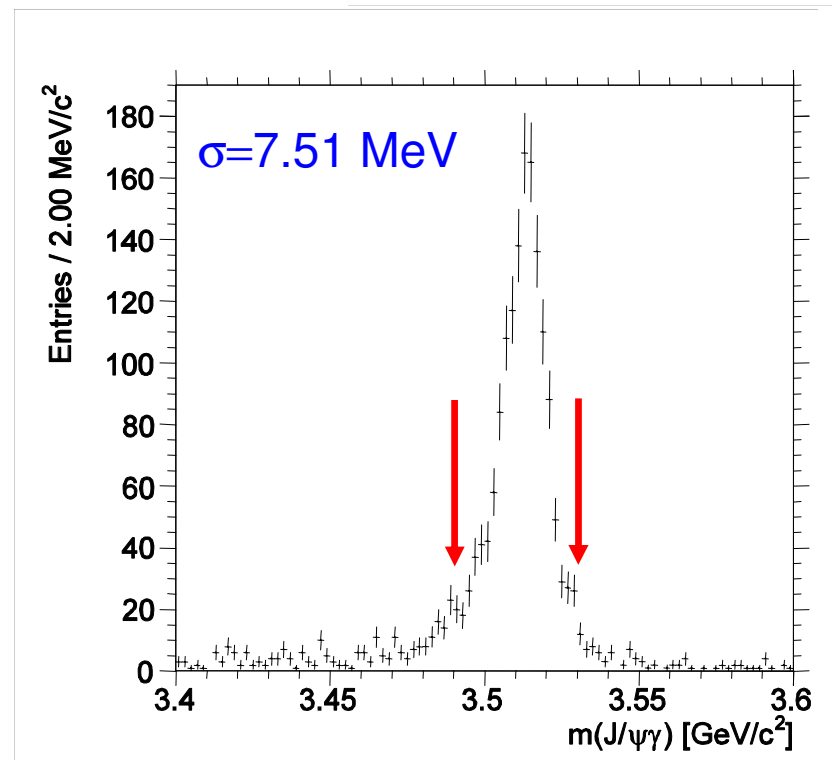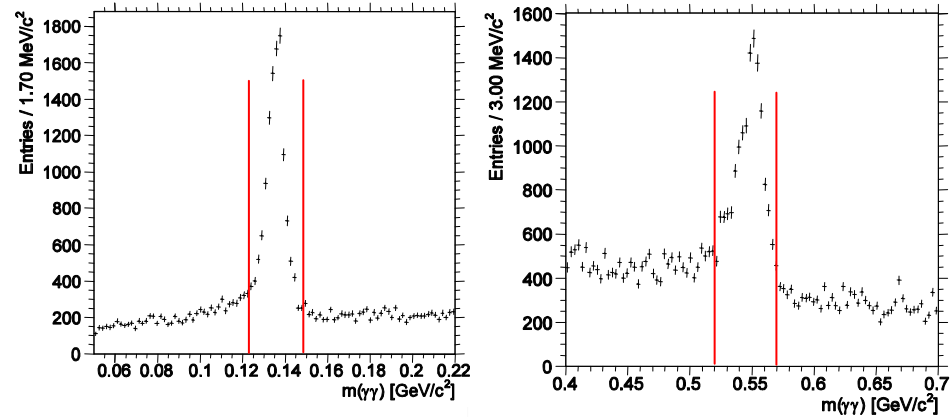with 8pb^{-1}/day expect 10k reconstructed signal events within 70 days

- 50k $\bar{p}p{\to}J/\psi\eta$, $\eta{\to}\gamma\gamma$ events at E_{CMS}=4260 MeV

- preselection
  - 2 charged tracks per event
  - 2 photon candidates per event

- $\eta{\to}\gamma\gamma$ selection
  - mass window [520;570] MeV

- J/ψη selection
  - mass difference technique
  - χ^2<25
  - select cand. w/ least χ^2 in event

- 1000 reco'ed signal events in 6 days expected
  - assume: 8pb^{-1}/day, $\sigma(\bar{p}p{\to}Y(4260))$=100nb, BR(Y(4260)${\to}J/\psi\eta$)=3% (BR for ψ(2S))
  - BR($\eta{\to}\gamma\gamma$)=39% from PDG

σ=8.99 MeV

N=16584
σ=9.68 MeV
Efficiency:33%

- 42k pp→$\psi_g\eta$, $\eta\rightarrow\gamma\gamma$
  $\psi_g\rightarrow\chi_{c1}(\pi^0\pi^0)_S$, $\chi_{c1}\rightarrow J/\psi\gamma$

- preselection
  - 2 charged tracks per event
  - 7 photon candidates per event
- $\pi^0\rightarrow\gamma\gamma$, $\eta\rightarrow\gamma\gamma$ mass windows [125;145] and [520;570] MeV
- $\chi_c\rightarrow J/\psi\gamma$
  - window [3.49;3.53]GeV

- $\psi_g\rightarrow\chi_c\pi^0\pi^0$
  - $m(J/\psi\pi^0\pi^0)-m(\pi^0)-m(\pi^0)+2*m_{PDG}(\pi^0)$

- accept only $\psi_g\eta$ candidate w/ least χ^2 per event, $\chi^2<25$
  - mass window [5520;5450] MeV

σ=7.51 MeV
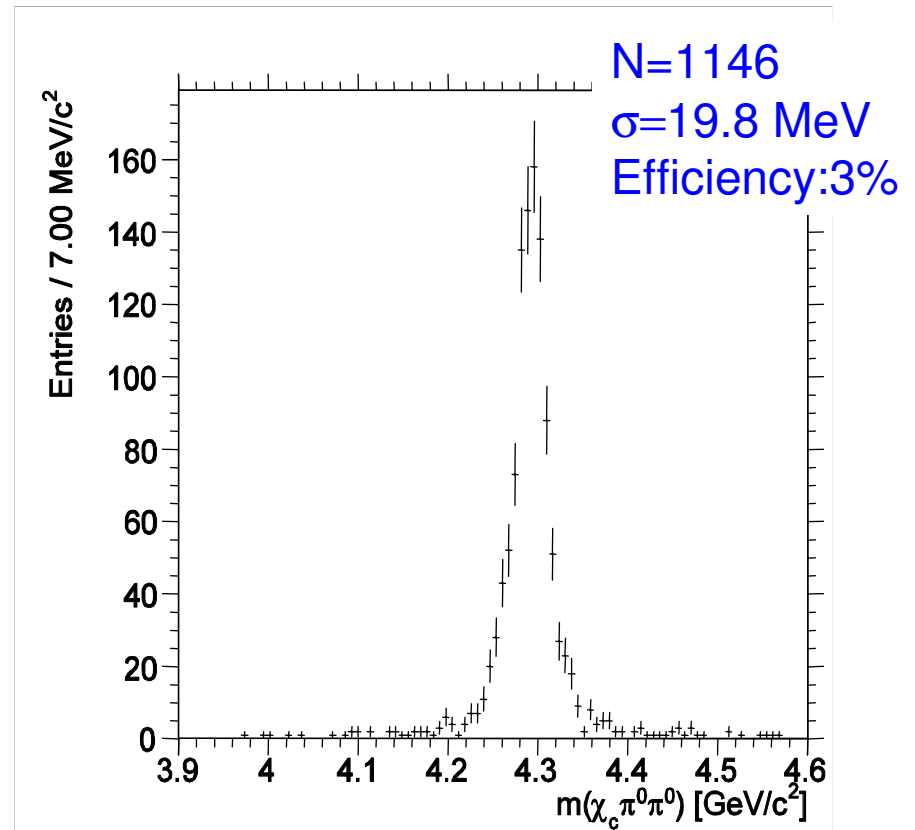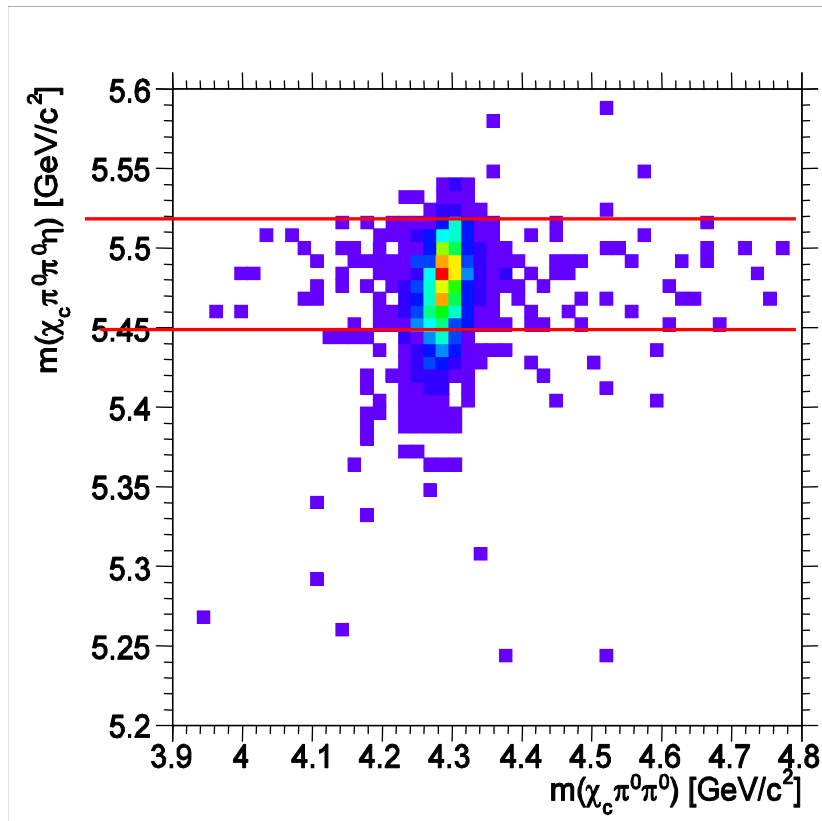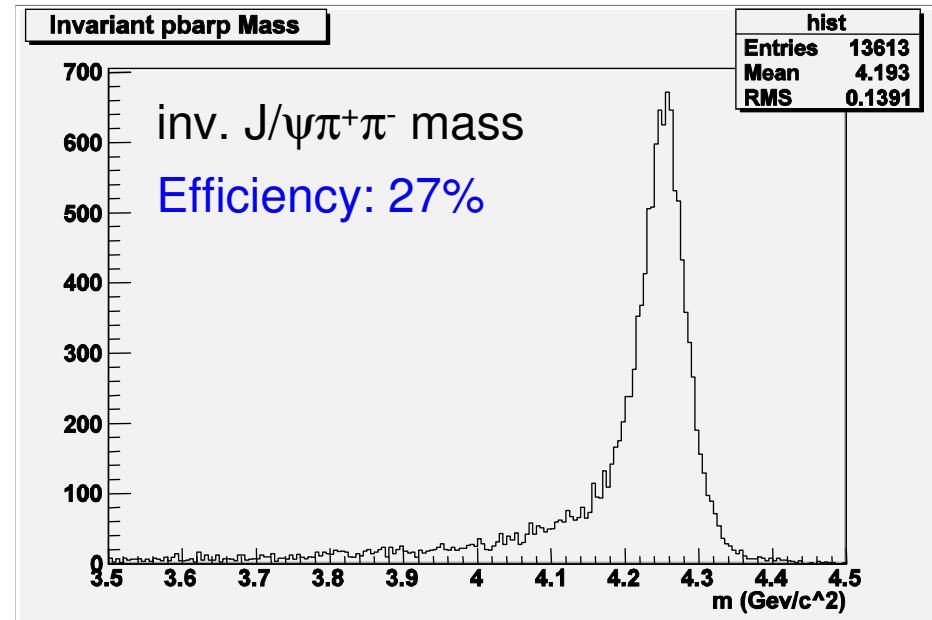
- $\psi_g\eta$ mass window [5520;5450] MeV
- 100 reconstructed signal events in 9 months expected
  - assumed cross section $\bar{p}p \to \psi_g\eta$: 0.2nb
  - 8pb^{-1}/day, BR($\psi_g \to \chi_{c1}\pi^0\pi^0$)=1, BRs of subsequal decays from PDG

J/ψπ⁺π⁻ selection

E. Fioravanti
Ferrarra

- 50k $\bar{p}p \to J/\psi\pi^+\pi^-$ signal events
  - non-phase space decay model used

- $J/\psi \to e^+e^-$ selection
  - $e^{\pm}$ PID probability $P(e^{\pm}) > 0.2$
  - kinematic fit w/ vertex/mass constraint CL>0.1
  - mass window [2.1;3.6] GeV

- $J/\psi\pi^+\pi^-$ selection
  - $\pi^{\pm}$ identification $P(\pi^{\pm}) > 0.2$
  - kinematic fit w/ $J/\psi\pi^+\pi^-$ vertex constraint, CL>0.1%

- **8k reco'ed signal events per day expected**
  - assumed cross section $\sigma(\bar{p}p \to Y(4260)) = 100$nb
  - 8pb⁻¹/day, BR(Y→J/ψπ⁺π⁻)=2/3, BR(J/ψ→e⁺e⁻)=5.94%

Invariant pbarp Mass

hist
Entries 13613
Mean 4.193
RMS 0.1391

inv. J/ψπ⁺π⁻ mass

Efficiency: 27%

m (Gev/c^2)
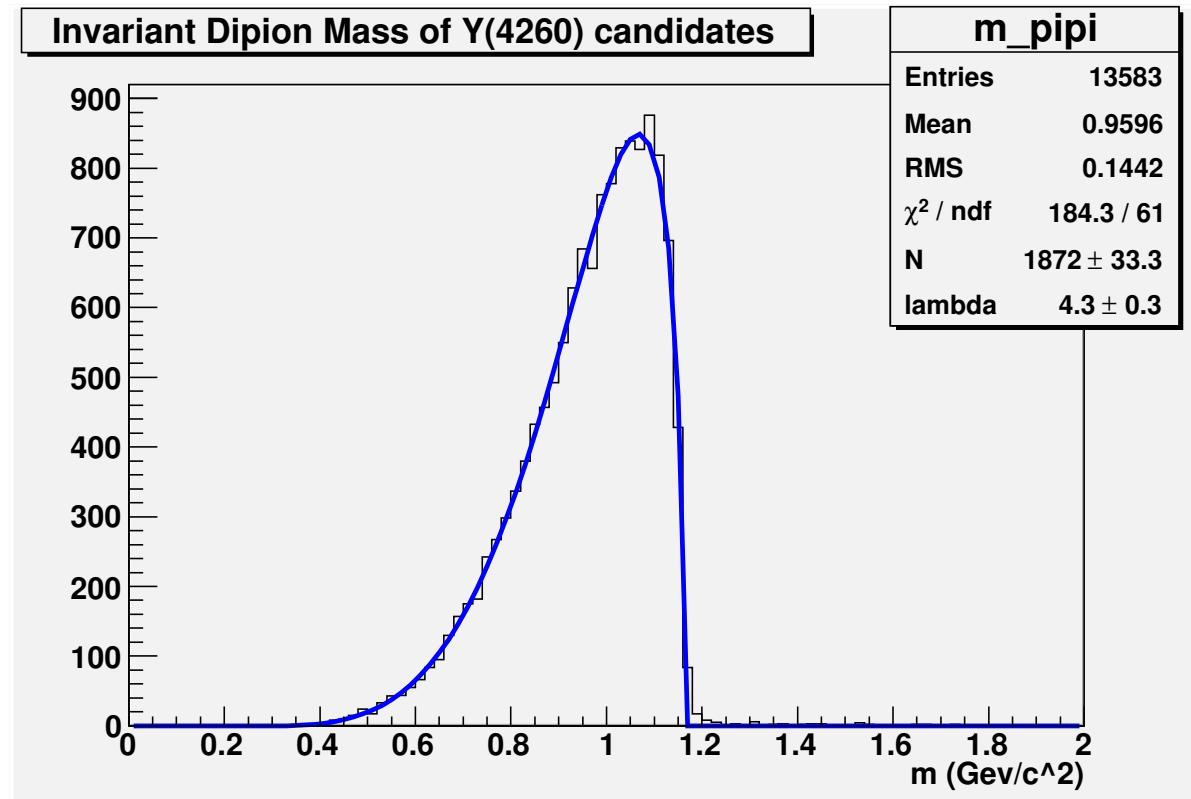
- parameterization of dipion mass in Y(4260)→J/ψπ⁺π⁻ E. Fioravanti Ferrarra

$$\frac{d\Gamma}{dm_{\pi\pi}} \propto (PS) \cdot (m_{\pi\pi}^2 - \lambda_{\pi\pi} m_\pi^2)^2 \qquad \text{(PS) phase space factor}$$

  – motivated by observations from ψ(2S)→J/ψπ⁺π⁻

Simulation: λ=4.0
Fit result: λ=4.3±0.3

Invariant Dipion Mass of Y(4260) candidates

m_pipi	
Entries	13583
Mean	0.9596
RMS	0.1442
χ^2 / ndf	184.3 / 61
N	1872 ± 33.3
lambda	4.3 ± 0.3

m (Gev/c^2)

- **investigated channels J/$\psi\omega$, J/$\psi\eta$, J/$\psi\pi^+\pi^-$, $\psi_g\eta$**
  - reasonable efficiency 3-33%
  - planned to add J/$\psi \rightarrow \mu^+\mu^-$ channel for all analyses

- **first studies with different decay models**
  - started for Y(4260)$\rightarrow$J/$\psi\pi^+\pi^-$
  - planned for other channles too

- **background studies**
  - started for Y(3940)$\rightarrow$J/$\psi\omega$
    (more data required to decide on $\pi^+\pi^-\omega$ background)
  - data production planned for other channels
    (need further input from conveners)