Recent results from VES detector

VES experiment

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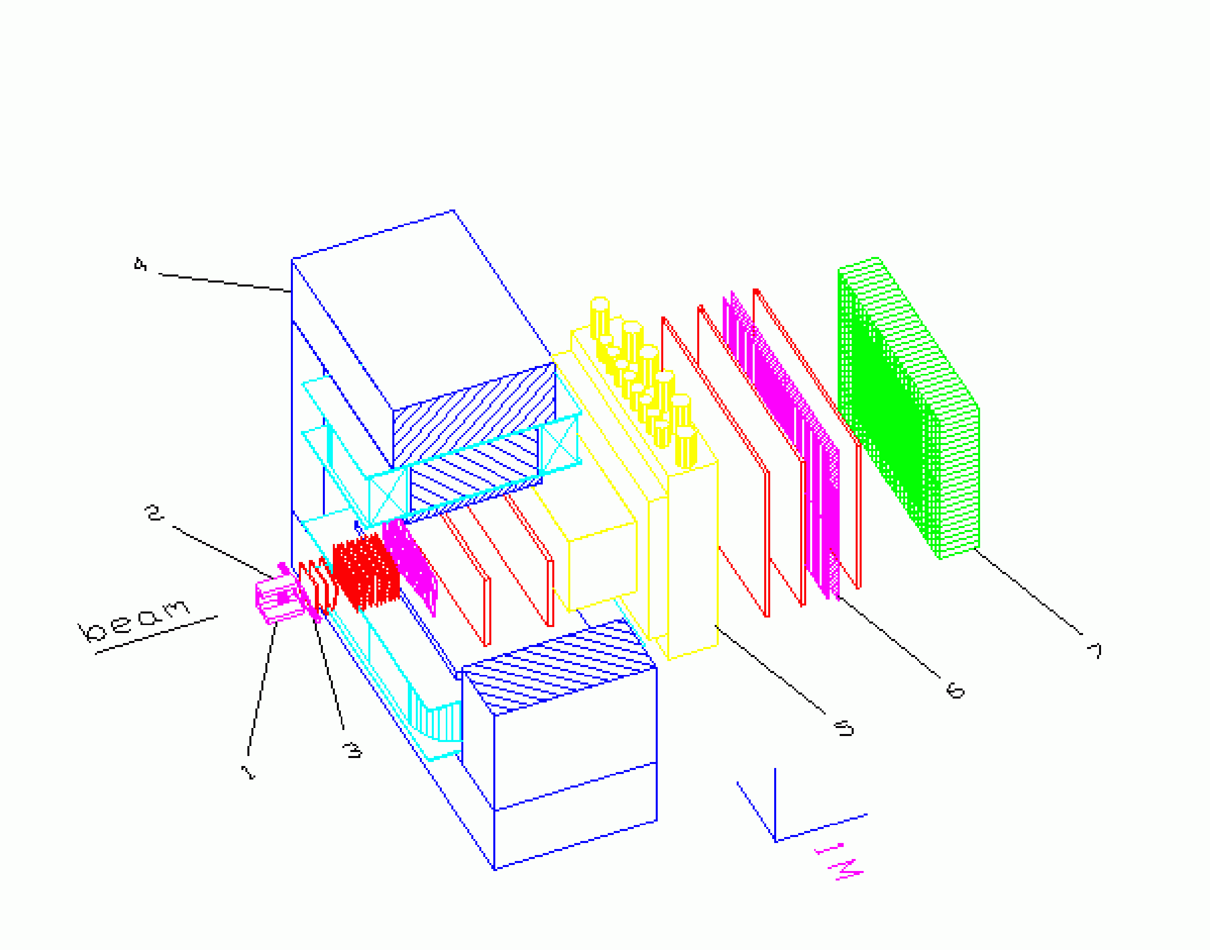
Introduction

- About detector
- Scalar wave in ($\omega\varphi$) **system**
- **Isospin symmetry violation in f_0 (980)–a_0(980) mixing**
- **Detector upgrade**

VES detector

- **The VES detector is a wide aperture forward spectrometer, which is installed in unseparated beam of negative particles from Serpukhov accelerator (mainly π^-).**
- **It is equipped with EM calorimeter and Cherenkov detectors for identification of beam and charged secondary particles.**
- **It has a forward multiplicity trigger.**
- **It has fast data acquisition system (up to 10000 triggers per spill).**

VES detector



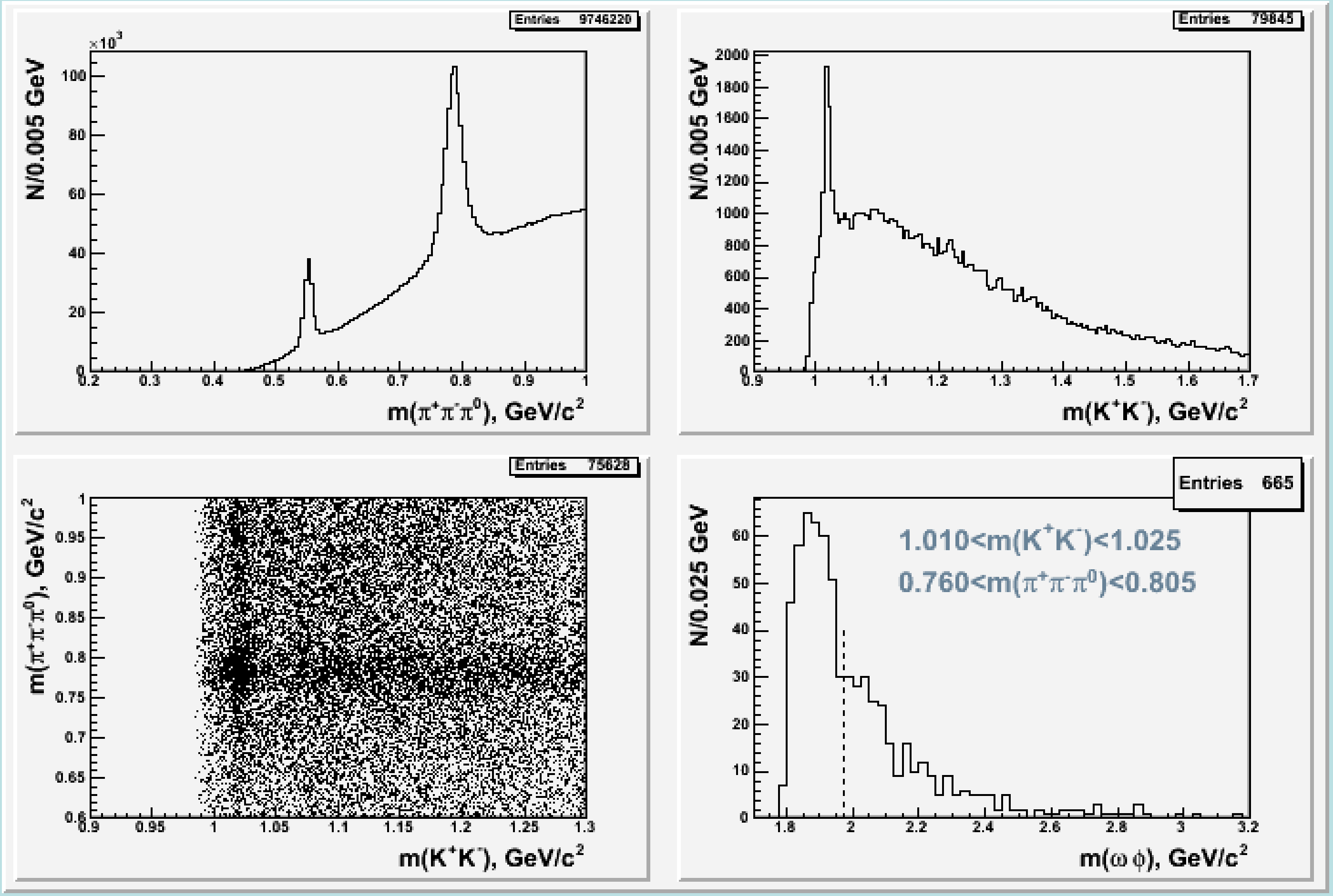
($\omega\varphi$) system

- Used data acquired at 27 and 37 GeV/c
- Selected events with 2 positive, 2 negative tracks and two showers in ECAL
- Cuts for ($\gamma\gamma$) mass and total energy of event were applied forming a π^0 , in “elastic peak”:

  $|m(\gamma\gamma)-m(\pi0)| < 30$ MeV;

  E tot > 25 GeV (27 GeV beam), E tot > 34 GeV (37 GeV beam;
- Requested K^+ and K^- identified in Cherenkov detector - seen φ
- Two remaining charged tracks taken with pion mass and $\pi0$ - seen ω
- Seen accumulation of events at intersection of φ and ω bands

($\omega\varphi$) system

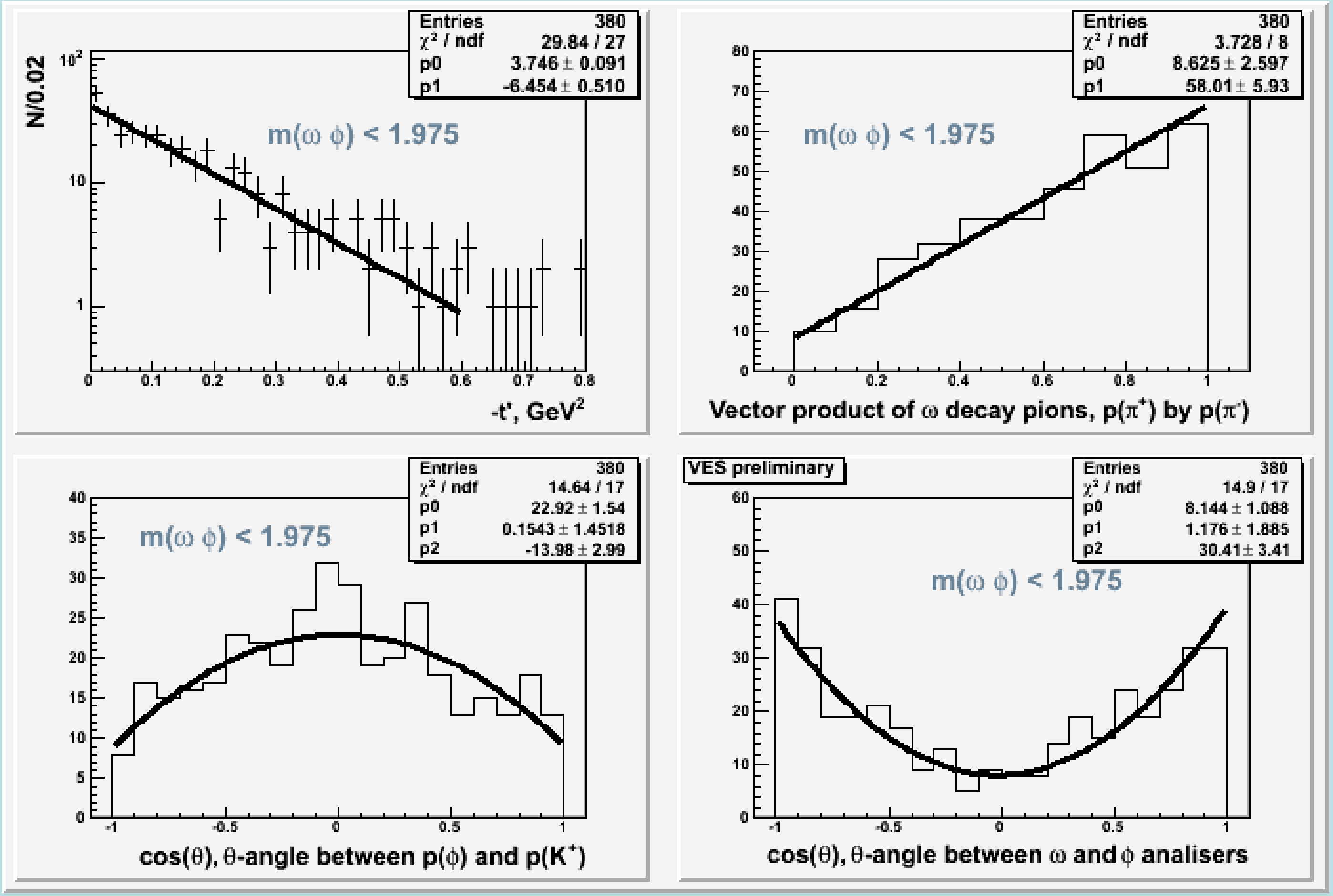


($\omega\varphi$) system

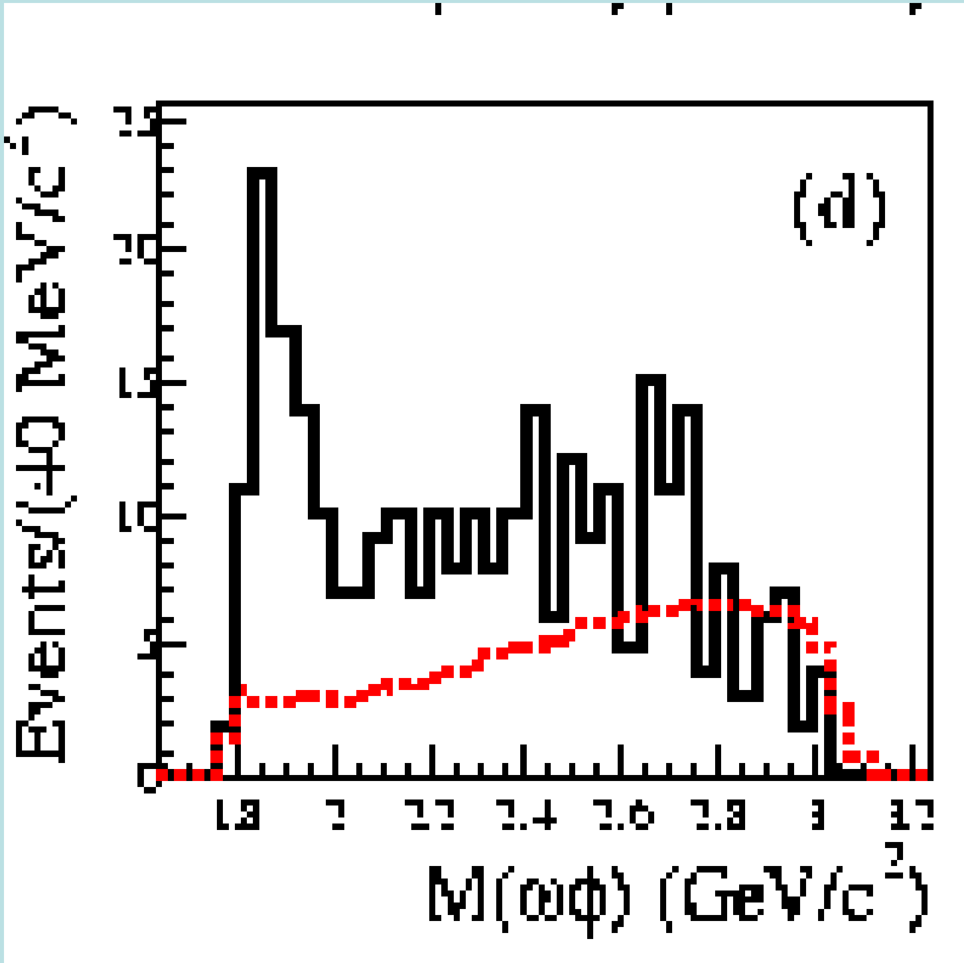
- Taken events at the intersection of ω and φ bands
- Clear bump near threshold is observed
- t- slope is consistent with pion exchange
- Angular distributions: the ω- and φ-analyzers are shown
- - Cosine of polar angle for one of K mesons from φ decay in the rest frame of φ. Distribution is consistent with spin 1 of φ.

  - Normalized absolute value of vector product of 3-momenta o two π -mesons from ω-decay in the rest frame of ω
- Cosine of the angle between two analyzers is shown, it is consistent with cos ^{2} (expected for the scalar decaying into two vectors in S-wave) plus background
- We have 380 ($\omega\varphi$) events – and 99 $\varphi\varphi$ events

($\omega\varphi$) system



Observed in J/ψ→(γ ω φ)

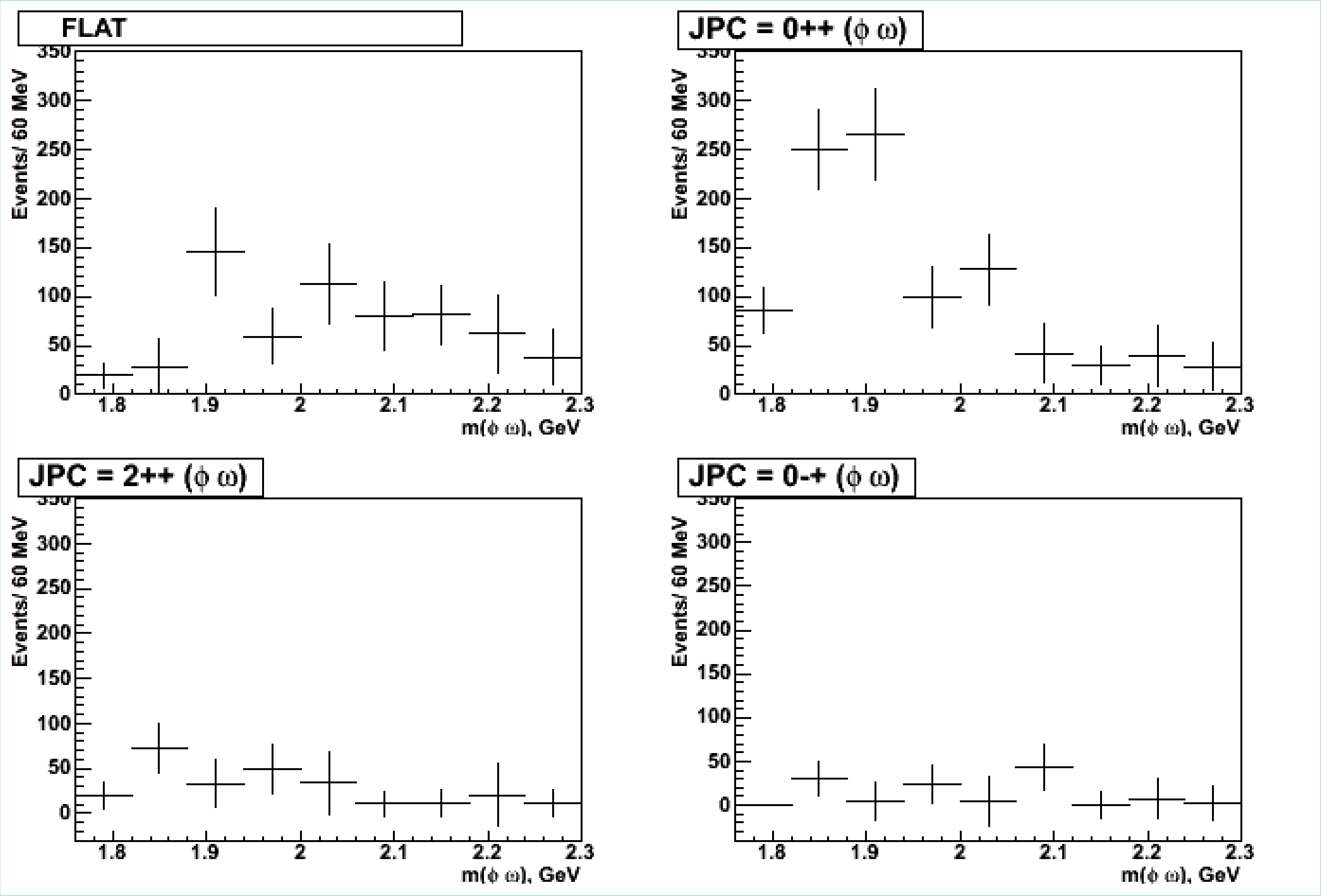


By BES Collaboration. (Ablikim et al.), Phys. Rev.Lett.96:162002,2006, hep-ex/ 0602031

PWA of $\omega\varphi$ system

- Available statistics permits to make a PWA with few waves:
  - FLAT
  - *JP = 0+, 2+, 0−*
- The scalar wave dominates near the $\omega\varphi$ threshold

PWA of ($\omega\varphi$) system



PWA of $\omega\varphi$ system

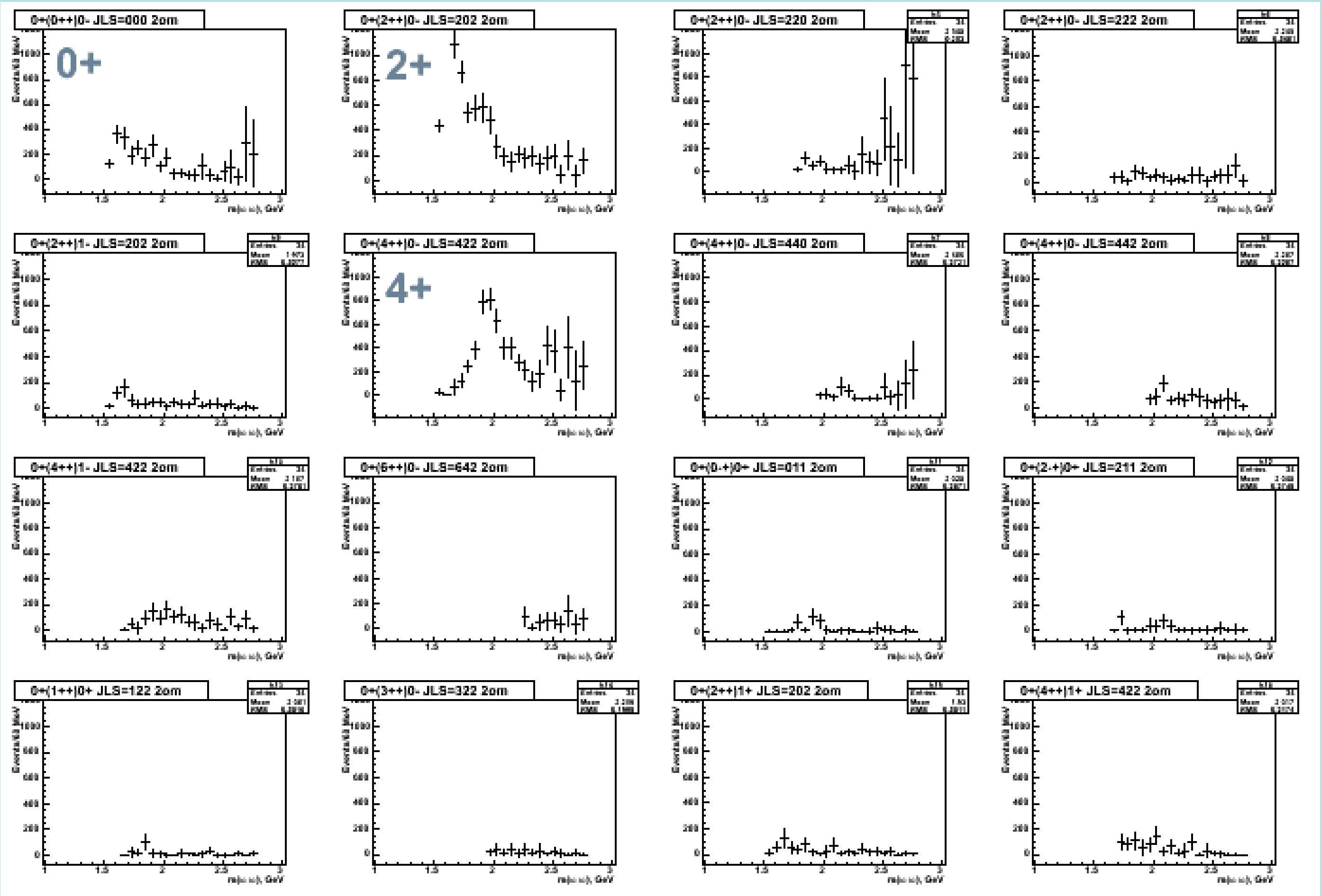
- With higher statistics and in another production process we confirm the resonance-like bump near $\boldsymbol{\omega\varphi}$ threshold. The PWA demonstrate the scalar quantum numbers of this object.
- Having the PWA results for the $\boldsymbol{\omega\omega}$ system at the same beam momentum, we can compare the intensities of scalar waves in $\boldsymbol{\omega\varphi}$ and $\boldsymbol{\omega\omega}$ channels.

PWA of $\omega\omega$ system

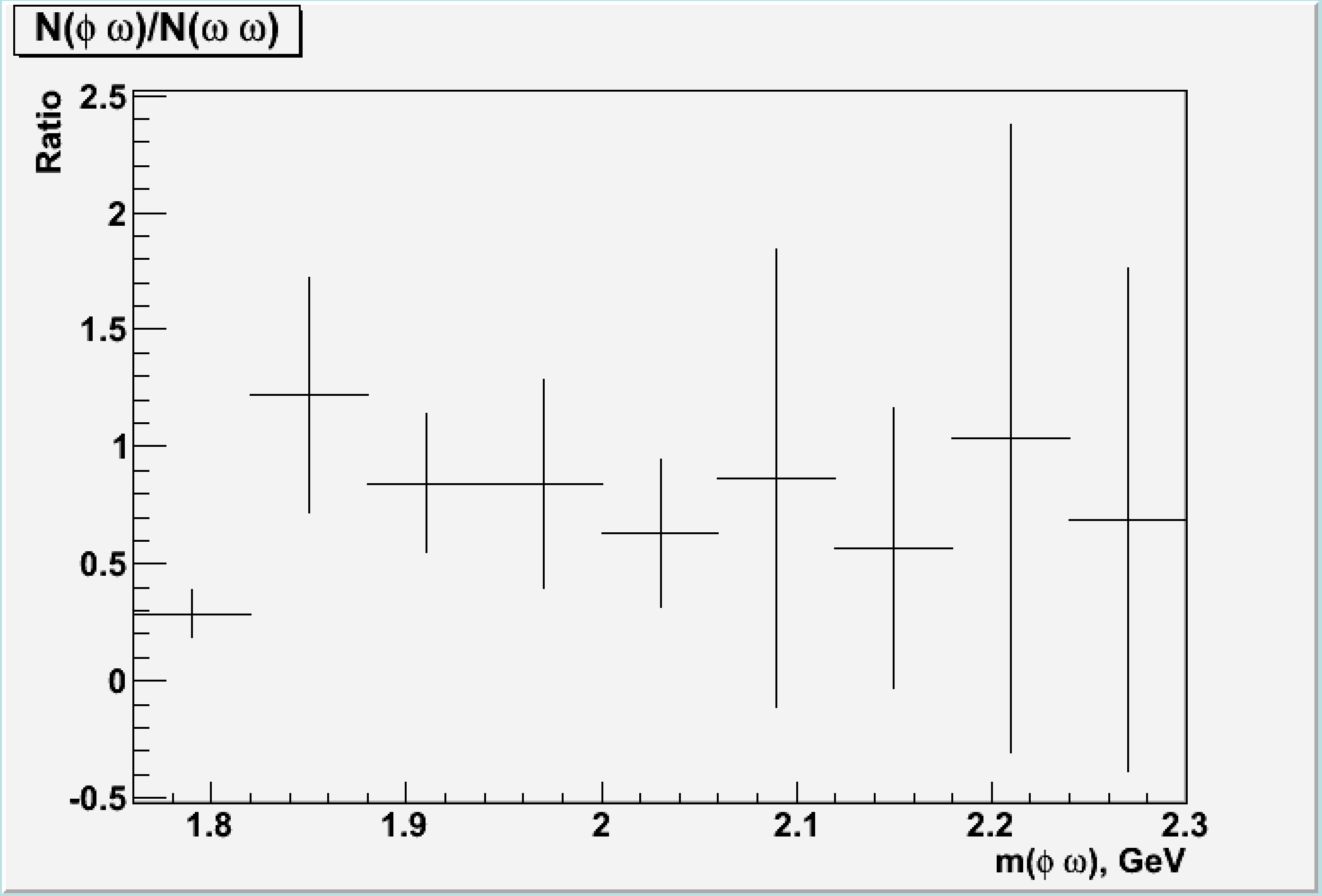
- **Included waves (η is reflectivity):**
- $(J^{PC})M^{\eta}JLS$ $(J^{PC})M^{\eta}\ JLS$
- **1. (0++)0− 000**
- **2. (2++)0− 202**
- **3. (2++)0− 220**
- **4. (2++)0− 222**
- **5. (2++)1− 202**
- **6. (4++)0− 422**
- **7. (4++)0− 440**
- **8. (4++)0− 442**
- **9. (4++)0− 422**
- **10. (6++)0− 642**

11. (0−+)0+ 011
12. (2−+)0+ 211
13. (1++)0+ 122
14. (3++)0− 322
15. (2++)1+ 202
16. (4++)1+ 422
17. FLAT

PWA of (ωω) system



N(ωφ) scalar wave/N(ωω) scalar wave ratio



Acceptance and BR(φ)/BR(ω) are taken into account

N(ωφ) scalar wave/N(ωω) scalar wave ratio

- ***Ratio of scalar wave intensities in 1.82< M <2.0 GeV mass range is:***
  N(ωφ)/N(ωω) = 0.65 ± 0.1
- ***This is large value. For example***

:   - similar ratio for J = 2 waves is 0.045 ± 0.01

- σ(π⁻p → φn)/ σ(π⁻p → ωn) ≈ 0.01 at our beam energies (see hep-ph/0204259

- ***So we see strong OZI violation in production of ωφ scalar wave***
- ***Violation of OZI rule for scalars has been predicted theoretically***

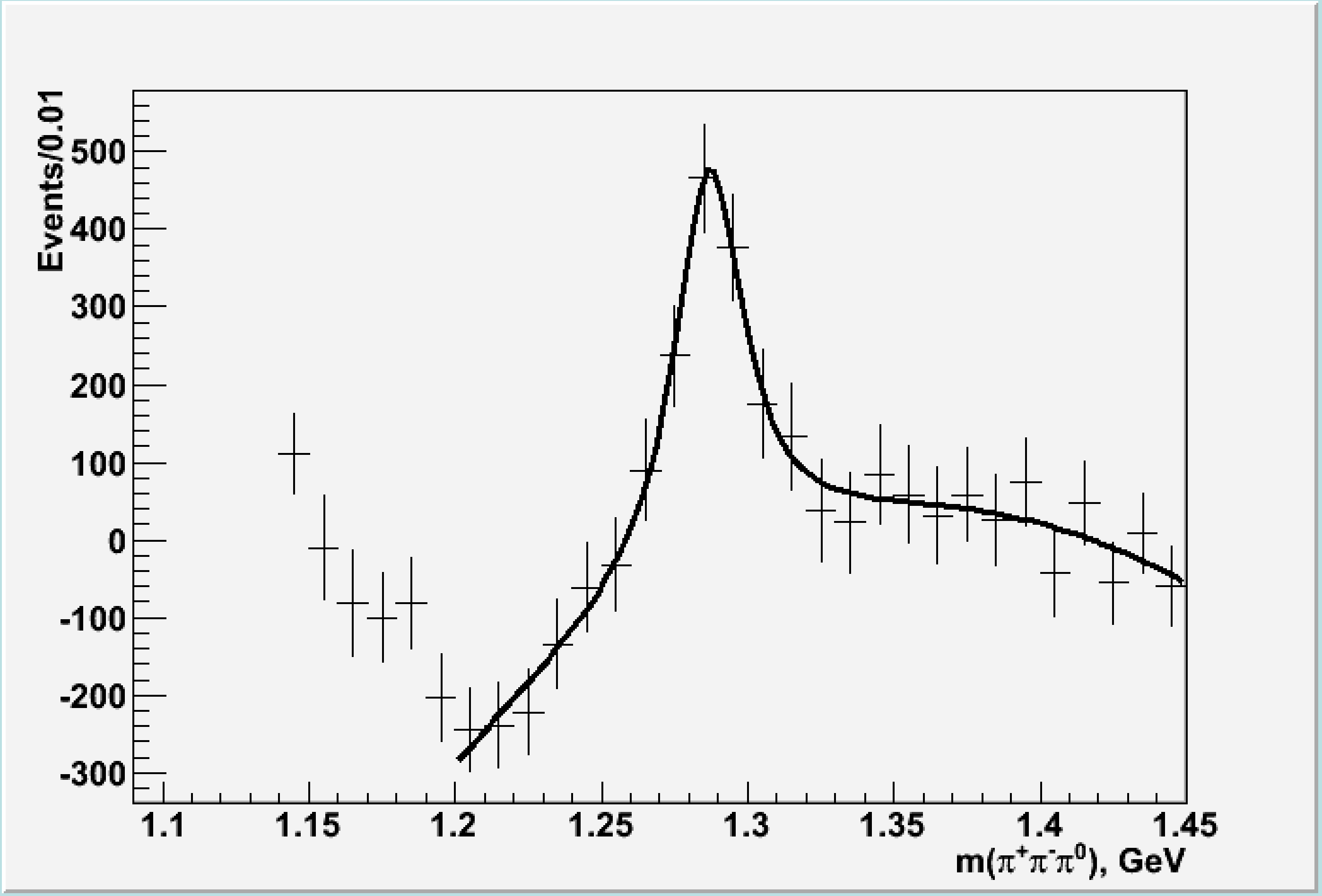
Observation

- It worth mentioning an observation concerning decays of heavy scalar mesons:
- $BR(\eta'\eta') > BR(\eta\eta')$ and $BR(\eta\eta') > BR(\eta\eta)$ (see Berdnikov et al. Z.Phys.C57:13-16,1993 and D. Aide et al.: Phys. Lett. B276 (1992) 375)
- This observation points to SU(3) singlet dominance in this mass region (for scalars).

Isospin symmetry violation

- VES experiment has observed decays $f_1(1285)\to\pi^+\pi^-\pi^0$ via $a_0(980)\to f_0(980)$ transition,
- $BR(a_0(980)\to\pi^+\pi^-) = (1.9\pm0.5\pm0.6)\%$
- Now we search similar effect in opposite direction, $f_0(980)\to a_0(980)$ transition
- Decays $\pi(1800)\to f_0(980)\,\pi$ with relative branching $\Gamma(f_0(980))/\Gamma(f_0(600))$ ~40% are used as a source of $f_0(980)$.

$a_0(980)\to f_0(980)$ transition



Isospin symmetry violation

- It worth mentioning that π(1800) is produced in diffractive reaction. Background processes, leading to the ($\eta\pi^0\pi^-$) system in final state, are not diffractive and therefore should be suppressed.

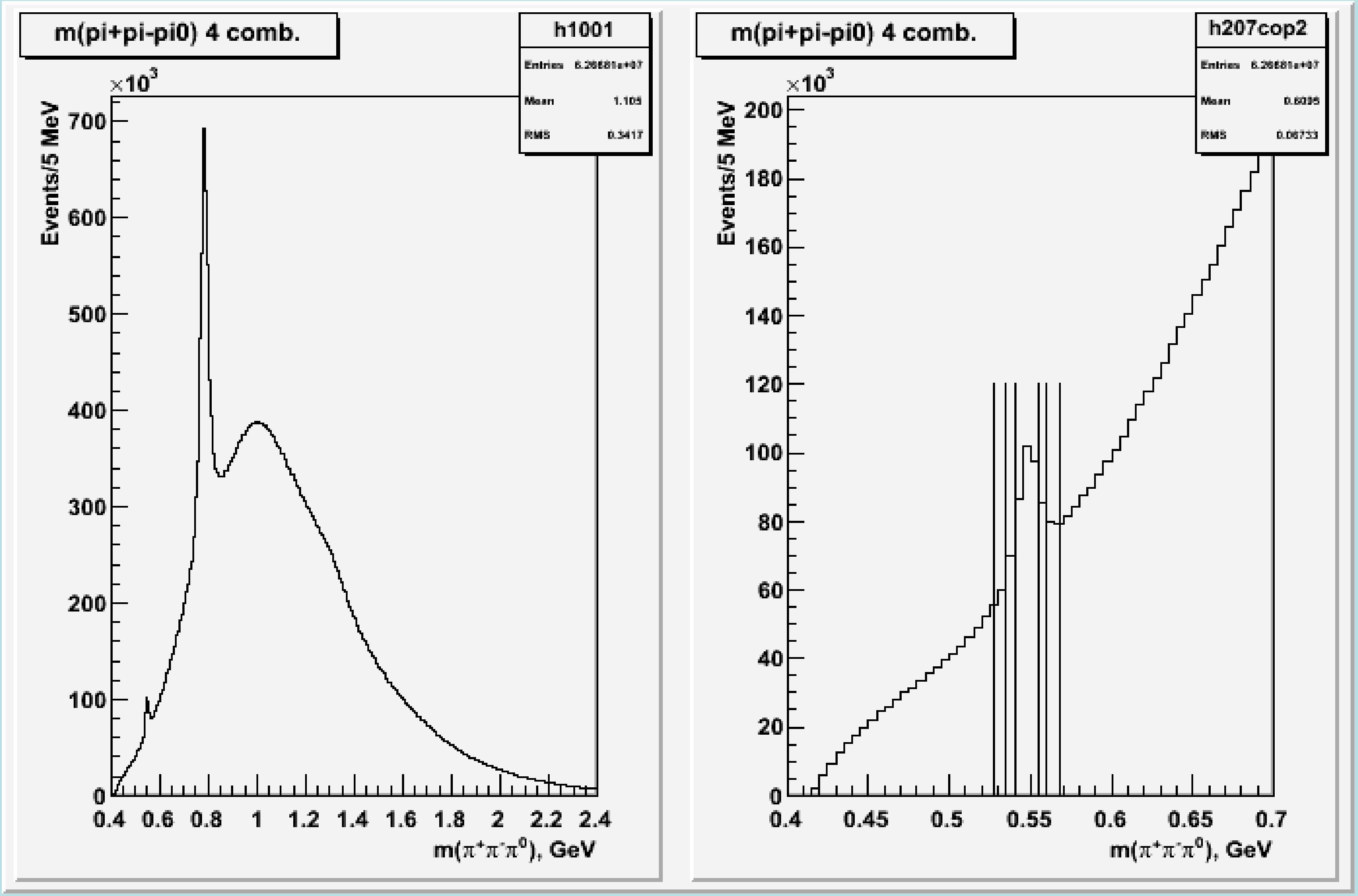
Selection requirements

- Data aquired in π^- beam at 27, 37 and 41 GeV/c used, two negative and one positive secondary track and four EM-clusters in ECAL requested;
- Total energies of secondary particles should be in "Elastic peak", E_{tot} >25, E_{tot} > >34 and E_{tot} > >37 GeV, respectively;
- Four gamma-clusters should form two π^0 within tolerances $| m(\gamma\gamma) - m(\pi^0) | < 30$ MeV

Selection requirements

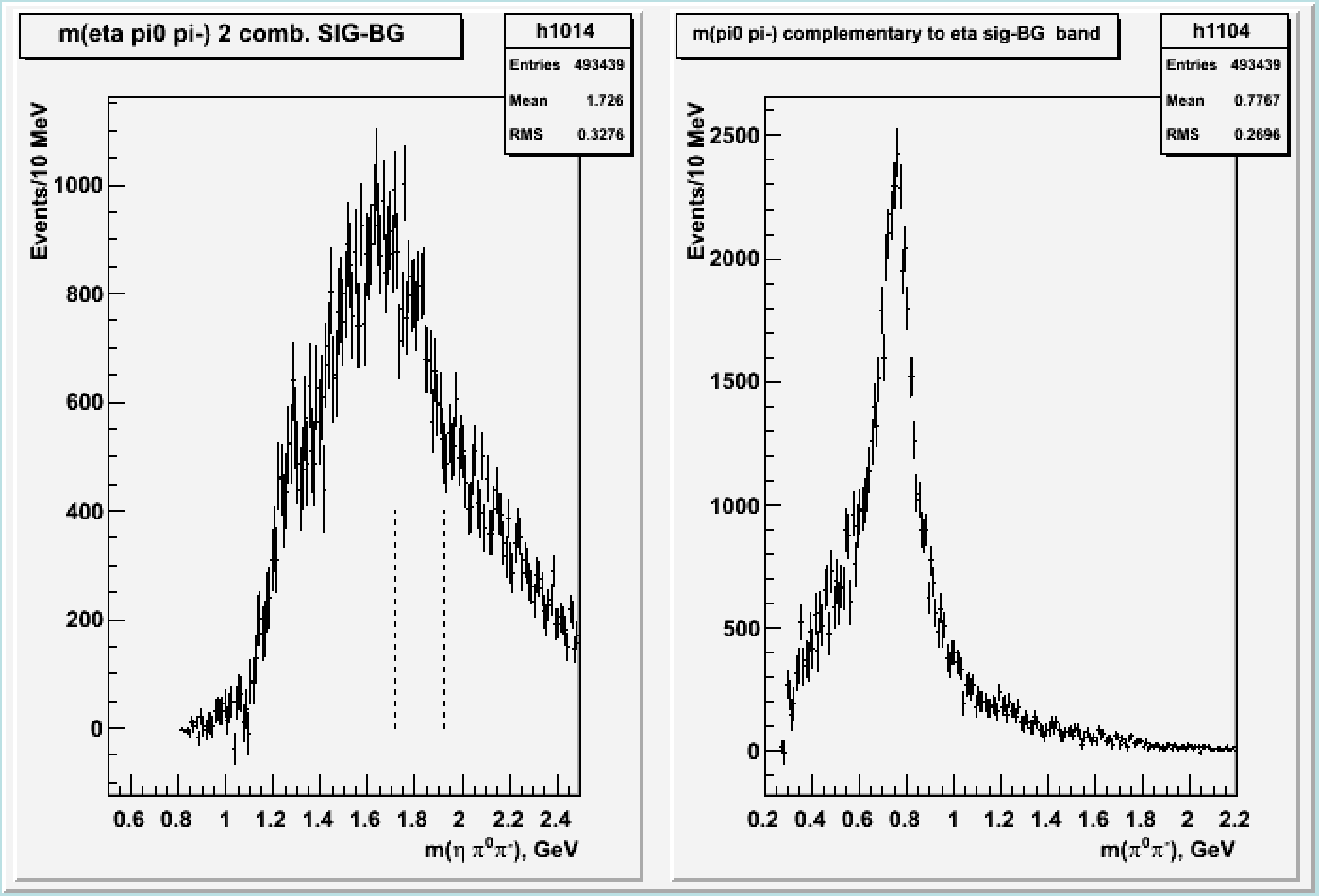
- **Signal events selected in η-signal mass region, $0.540<m(\pi^+\pi^-\pi^0)<0.555$ GeV**
- **Background events selected in regions $0.5275<m(\pi^+\pi^-\pi^0)<0.535$ or $0.560<m(\pi^+\pi^-\pi^0)<0.5675$ GeV**
- **Mass spectra were accumulated for signal and background events separately, and then subtracted;**
- **Events with total mass in π(1800) region, $1.72<m(\eta\pi^0\pi^-)<1.92$ GeV selected.**

$m(\pi^+\pi^-\pi^0)$, 4 combinations



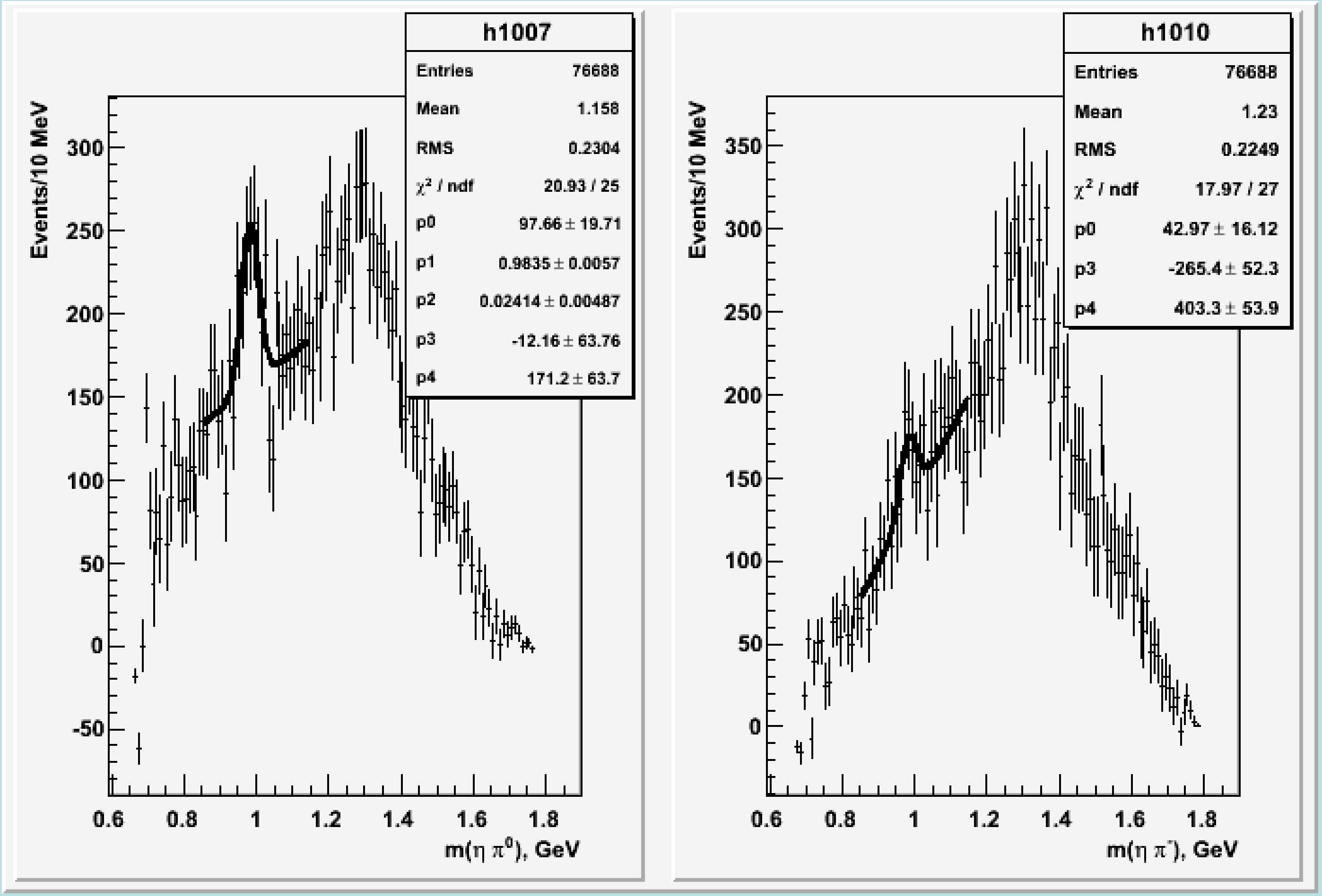
All masses and η-region

$m(\eta\pi^0\pi^-)$ and $m(\pi^0\pi^-)$, background subtracted



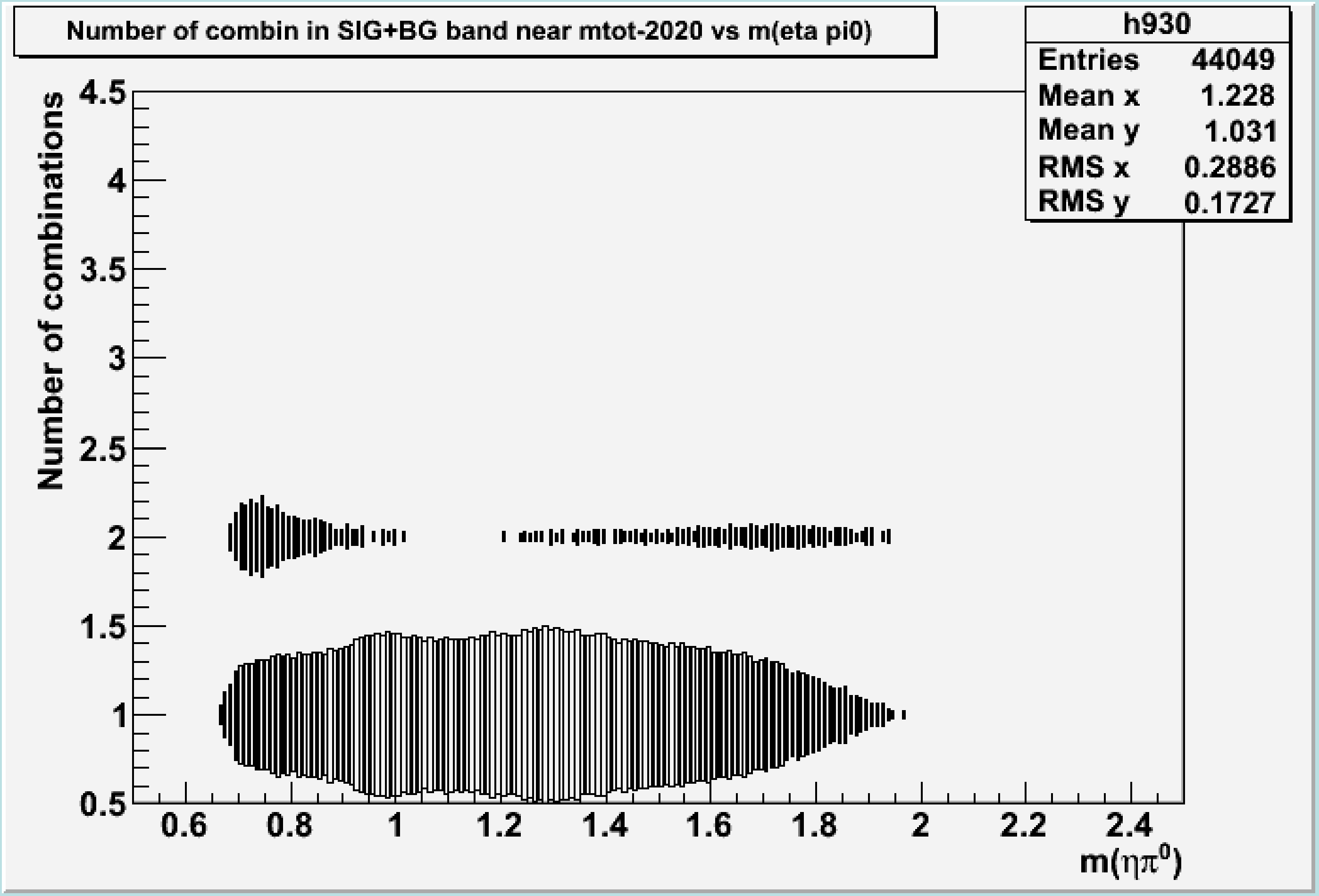
$m(\pi^0\pi^-)$ in $\pi(1800)$ region

m($\eta\pi^0$) (left) and m($\eta\pi^-$), background subtracted



Selected events in $\pi(1800)$ region

N combinations in η-bands vs m($\eta\pi^0$)



Fraction of events with 2 comb. near a_0 is small

$(\eta\pi^0\pi^-)$ system

- Slide 24 left: $m(\eta\pi^0\pi^{--})$ spectrum, lines show selected $\pi(1800)$ region
- Slide 24 right: $m(\pi^0\pi^{--})$ spectrum in $\pi(1800)$ region
- Slide 25 left : $m(\eta\pi^0)$ spectrum in $\pi(1800)$ region and fit by Gaussian+linear BG
- Slide 25 right: $m(\eta\pi^{--})$ spectrum in $\pi(1800)$ region and similar fit with gaussian mass and width fixed

$(\eta\pi^0\pi^-)$ sample

- After BG subtraction, here are 14734 events in total, including 7092 events at 27 GeV/c. Total number of events in the signal mass band is 45711.
- Fit of t-distribution by sum of two EXP yields the slopes $b_1 = -55\pm12$ GeV^{-2} (corresponding to diffraction or ω-exchange) and $b_2 = -6.8\pm1.0$ (corresponding to π-exchange).

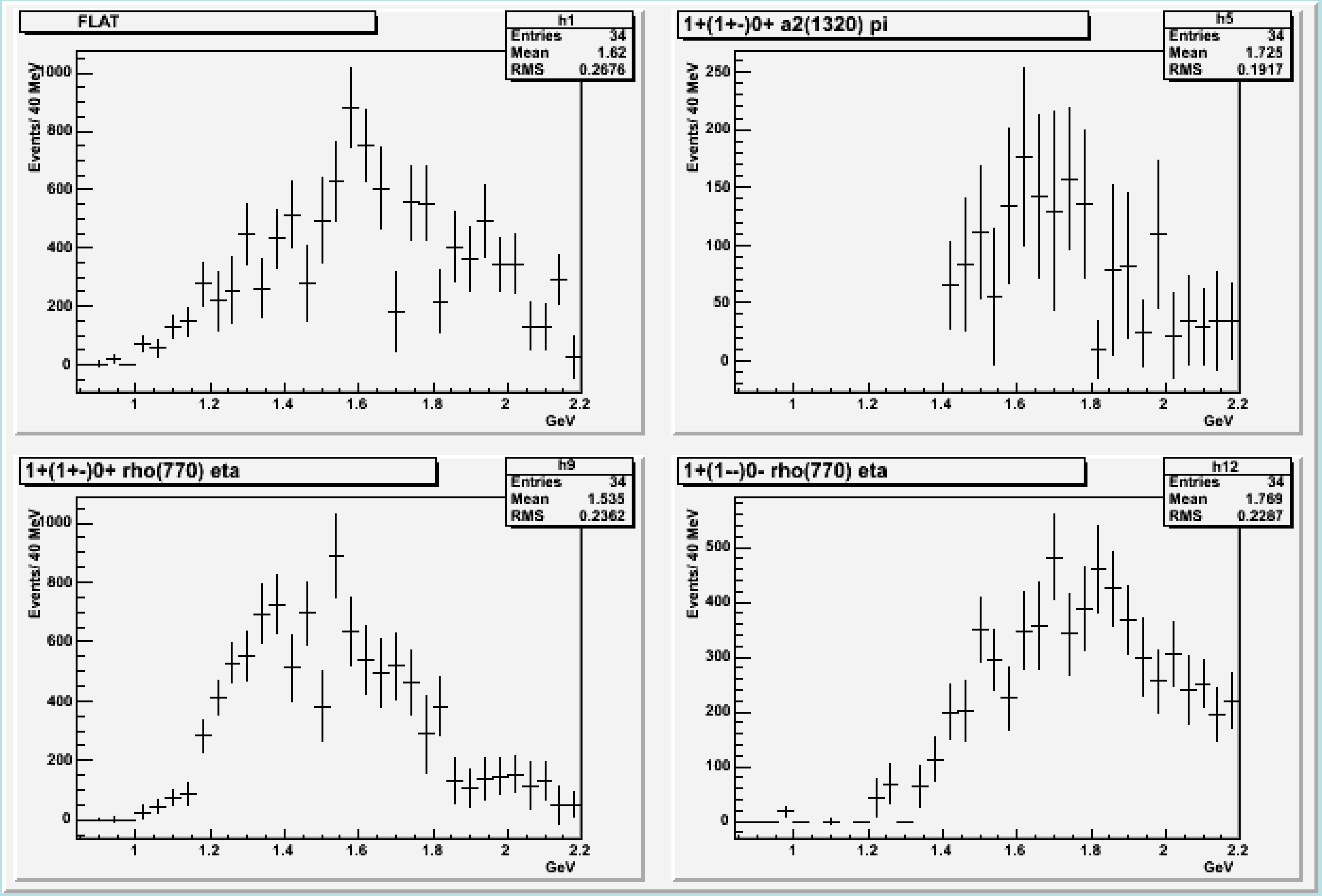
$N(\eta\pi^0)$ and $N(\eta\pi^-)$

- With signal band $0.950<m(\eta\pi)<1.030$ and BG bands $0.950<m(\eta\pi)<1.030$ and $0.950<m(\eta\pi)<1.030$, number of a_0 events
- $N(a_0$ neutral$) = 602\pm55$;
- $N(a_0$ negative$) = 130\pm50$;
- $N(a_0$ neutral$)$ - $N(a_0$ negative$) = 472\pm74$;
- Is this difference associated with $\pi(1800)$? Needed Partial Wave Analysis

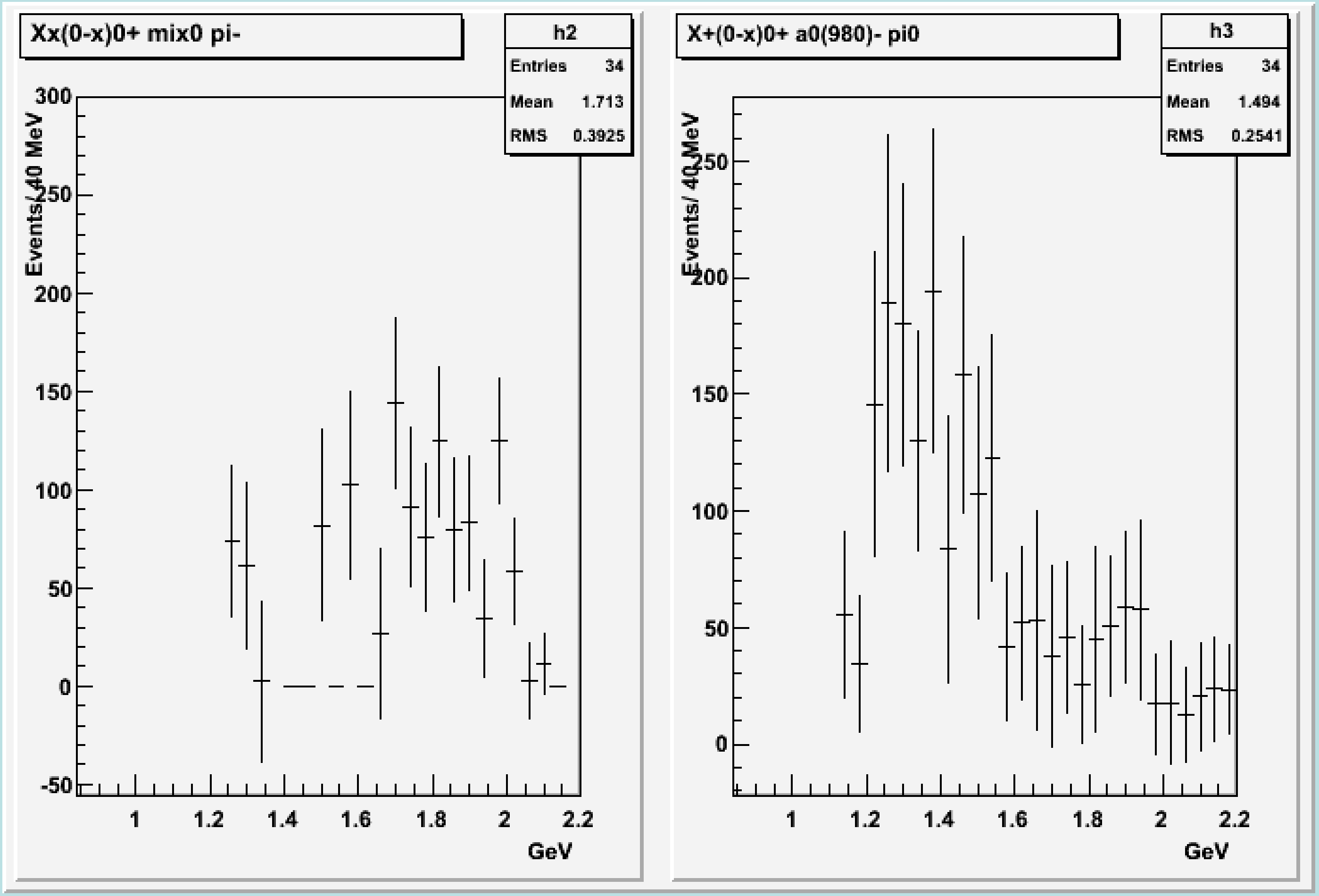
Partial Wave analysis

- PWA is performed presently for the data aquired at 27 GeV/c only. Zemach tensors used for decay amplitudes. Several sets of partial waves were tested, including waves with ω-resonance, which is posiible due to combinatorics, Some distributions for fit at $|t|<0.05$ GeV^2 shown below, for large waves, for $J^P=0^-$ with neutral and negative $a_0(980)$ and a comparison between Data and MC.

Large waves at $|t|<0.05\ GeV^2$

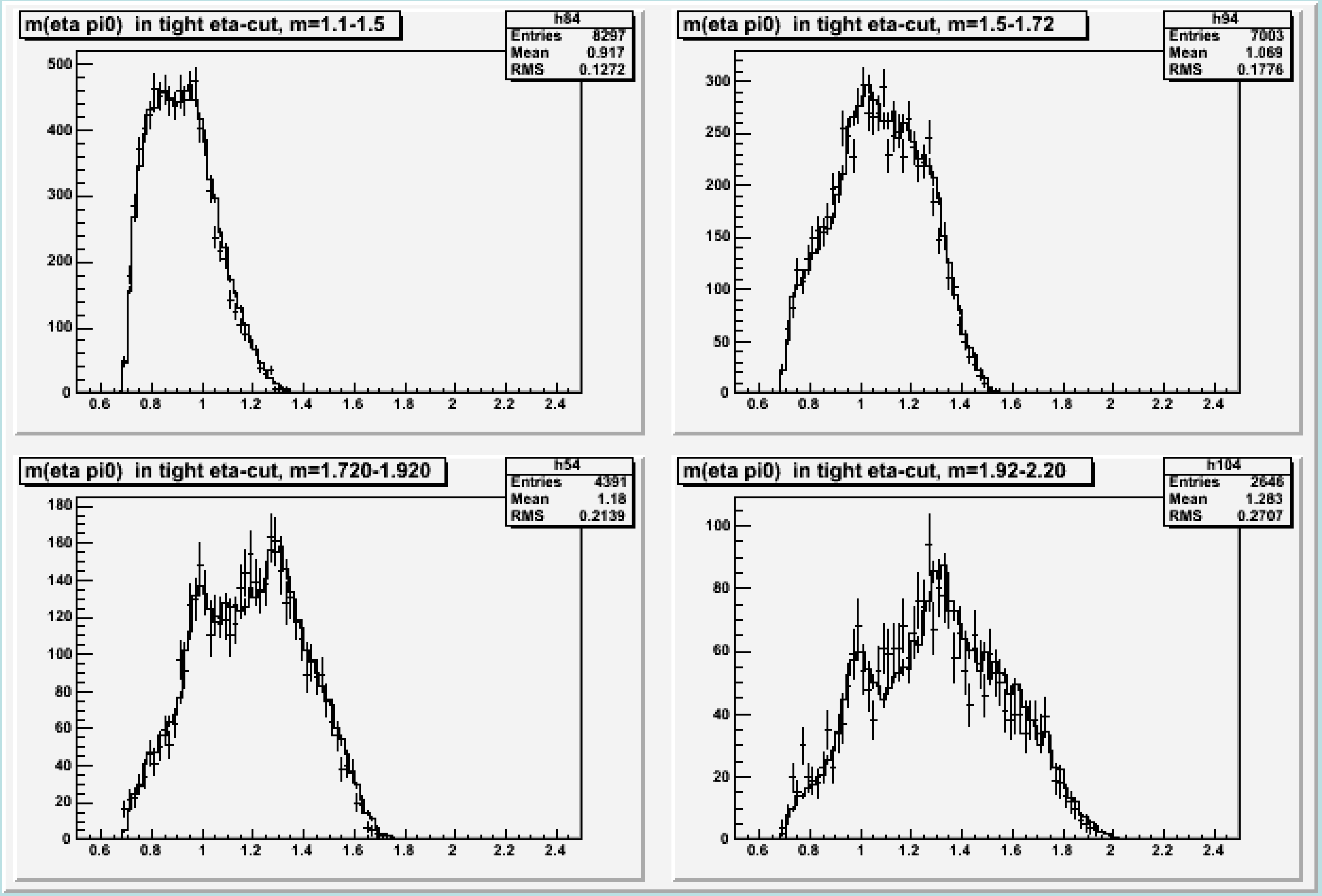


$J^P = 0^-$ waves with neutral and charged $a_0(980)$ at $|t|<0.05$ GeV^2



Left hist (neutral a_0) used for BR

Data/MC comparison for 0^- wave with a_0 in several intervals on m_{total}



Limit on BR(f_0(980))

- Taking number of events in 0^- wave with neutral a_0, known number of $\pi(1800) \to f_0(980)\pi \to (\pi^+\pi^-)\pi$ and efficiencies from MC, we estimated

$$\frac{BR(\pi(1800) \to a_0(980)\pi}{BR(\pi(1800) \to f_0(980)\pi \to (\pi^+\pi^-)\pi} = (1.0 \pm 0.7)\%$$

- This value van be transformed to upper limit:

$$\frac{BR(\pi(1800) \to a_0(980)\pi}{BR(\pi(1800) \to f_0(980)\pi \to (\pi^+\pi^-)\pi} < 1.9\%$$

at 90% conf.level

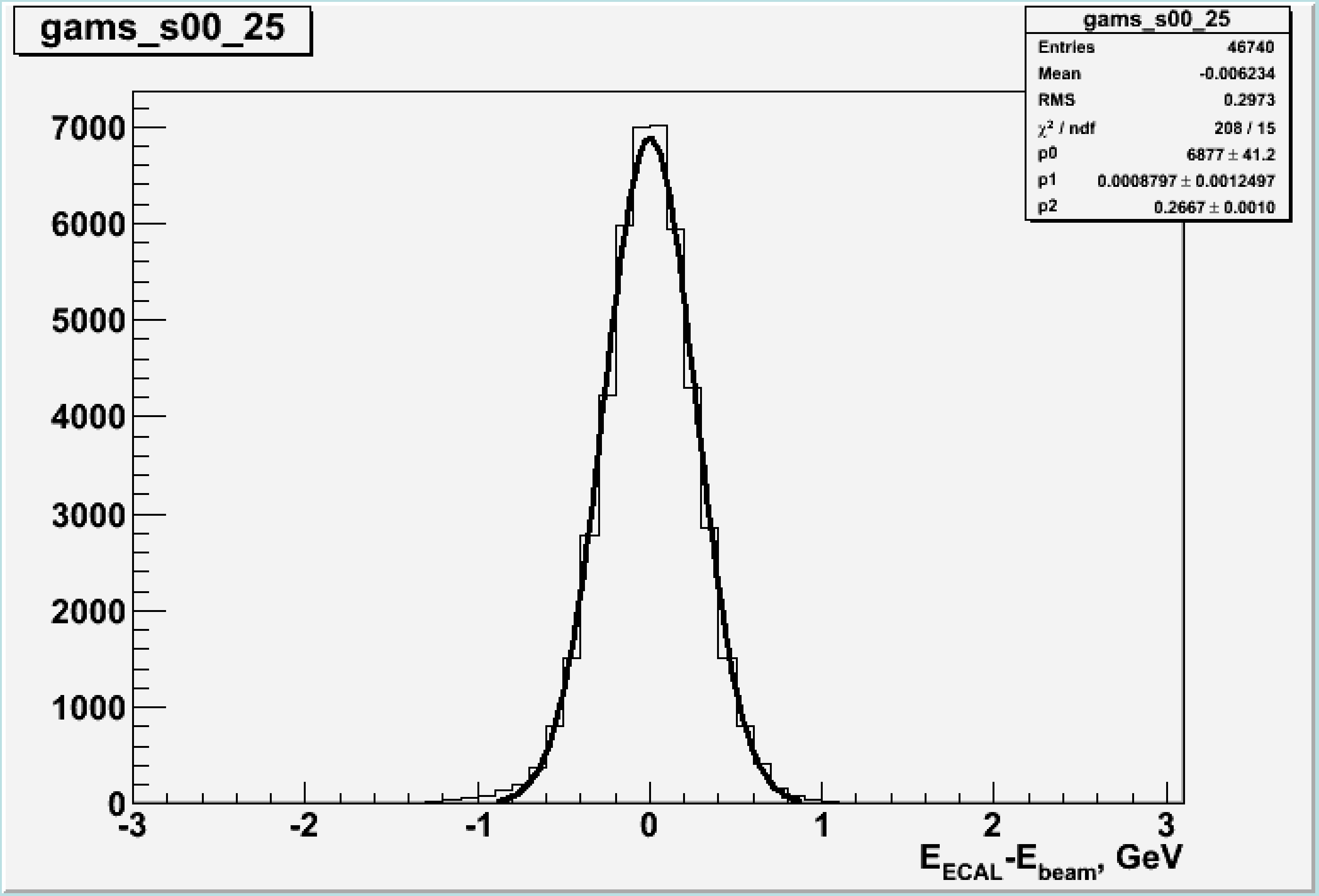
Detector upgrade

- New "shashlyk"- based ECAL is constructed, under commissioning. Energy resolution measured in electron beam: $\sigma(E)/E<4.1\%$ at 5 GeV; $\sigma(E)/E<2.7\%$ at 10 GeV; spatial resolution $\sigma(X)<4$ mm at 10 GeV.
- New USB-based DAQ controllers, stable running achieved with data flow rate of 40 Mb/sec.

Detector upgrade

- LabView- based detector control system (DCS) finalized.
- Designing of the large-aperture tracking detector is in progress to replace old drift chambers.

ECAL in e^- beam at 10 GeV/c



Conclusions

- Partial wave analysis of the resonance-like bump near (ωφ) threshold is performed. The PWA demonstrates the scalar quantum numbers of this object, $J^P=0^+$.
- Comparison with scalar wave in (ωω)-system at the same beam momentum shows that OZI-suppression is not observed. Violation of OZI rule for scalar mesons has been predicted theoretically.

Conclusions

- Preliminary results from study of $(\eta\pi^0\pi^-)$ system give upper limit for $f_0(980) \rightarrow a_0(980)$ transition.