Partial Wave Analysis of $\pi^-\pi^0$ system in VES experiment

Mikhail Mikhasenko

Institute for High Energy Physics,
the VES group, Protvino, Russia

November 8, 2013

Contents

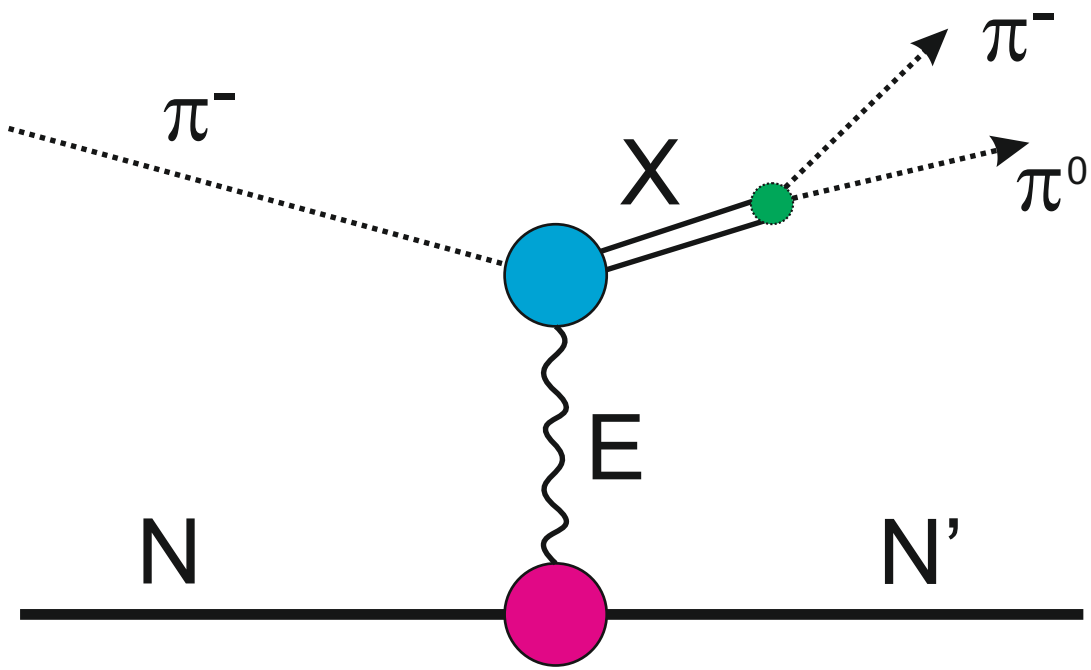
Proposals and motivation

The reaction $\pi^- + N \to \pi^-\pi^0 + N'$

- High statistics. ($> 10^6$)
- $I = 1,\ G = +1 \to$ A few resonances (Odd wave only).
  $\pi^+\pi^-$: S, P, D, F, G, H
  $\pi^-\pi^0$: $..., P, ..., F, ..., H$
- High mass ($> 2\,\mathrm{GeV/c^2}$) region has never been studied.
- Low mass ($[0.5 - 1.3]\,\mathrm{GeV/c^2}$): ρ-meson shape, production mechanism were studied at low energy only (till $5\,\mathrm{GeV/c^2}$)

Motivation-II. A resonance production

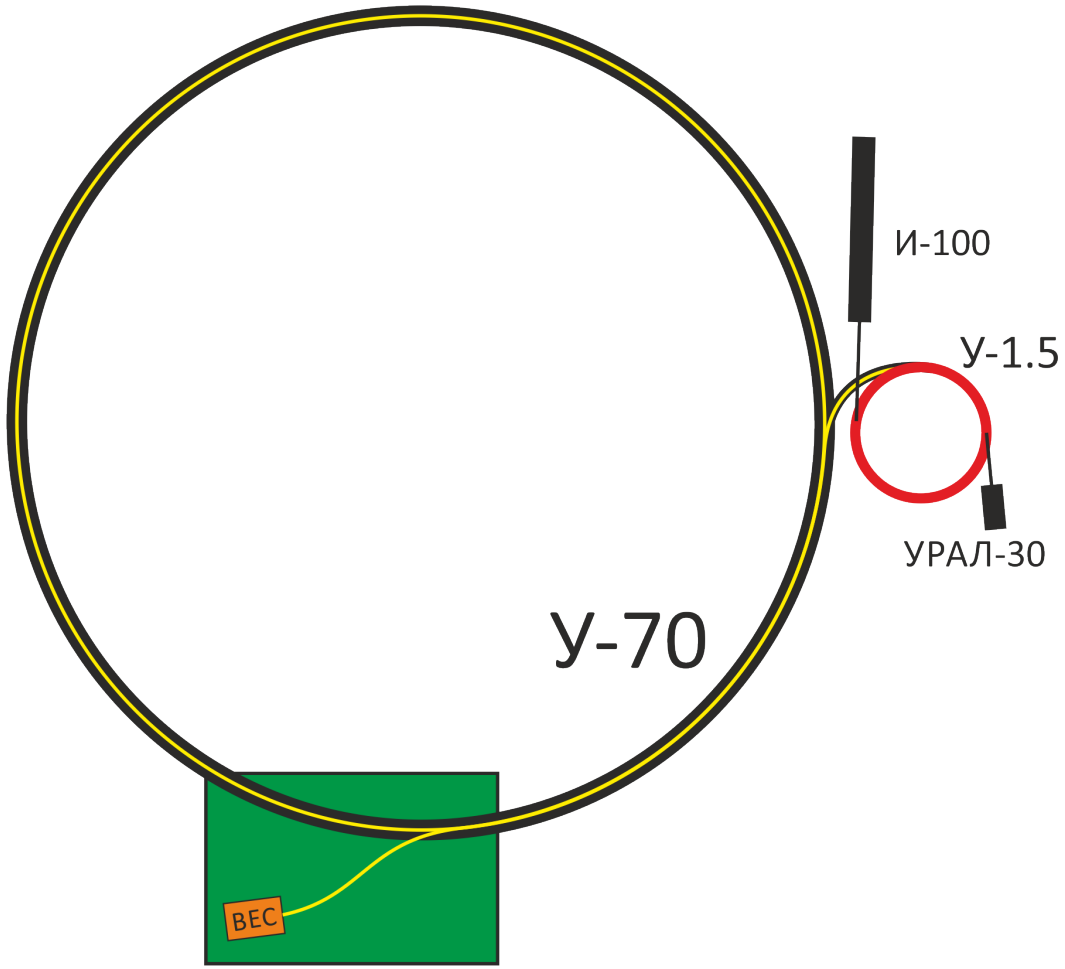
In the figure: **X** is ρ-meson in our case. **E** is exchange trajectory.



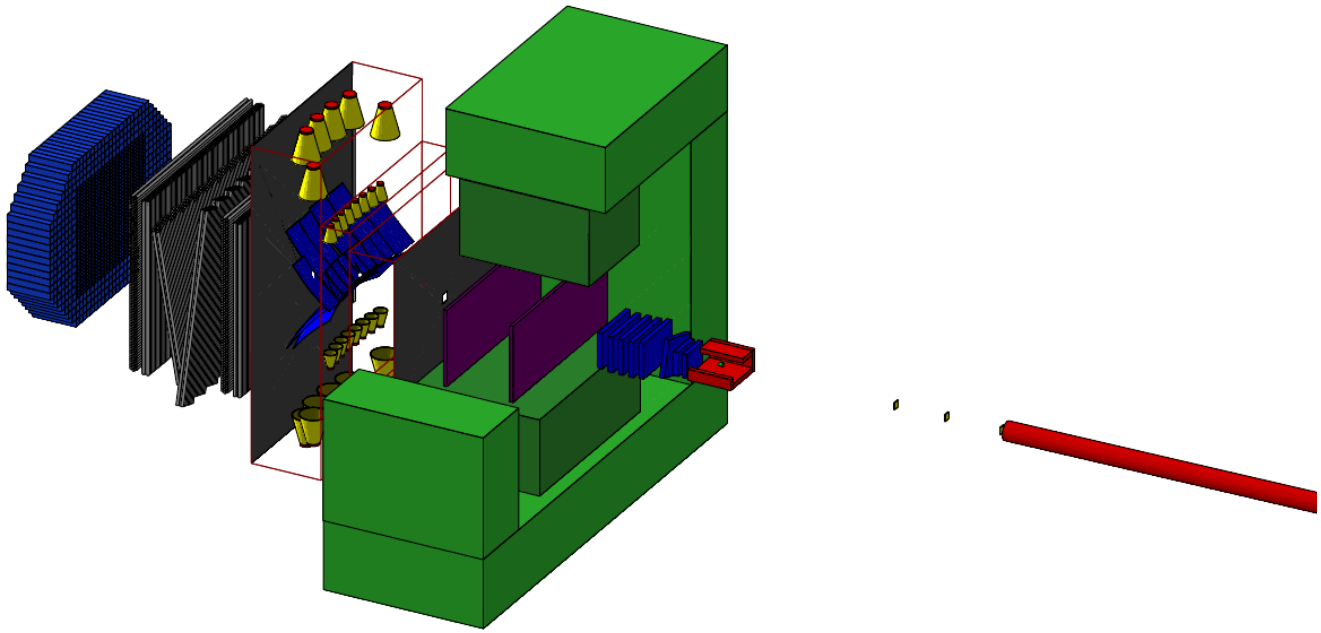
E can be π ($I^G J^P = 1^- 0^-$), a_2 ($I^G J^P = 1^- 2^+$), a_1 ($I^G J^P = 1^- 1^+$), ω ($I^G J^P = 0^- 1^-$)

The experimental facility

- U70 beam - proton 50...70 GeV
- VES beam (27 GeV) - secondary particles
- 99% pions and and 1% kaons, 0.1% antiprotons



VES experiment



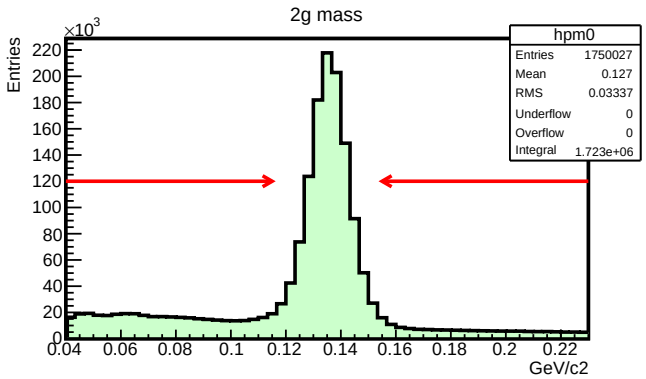
- Beam (π^-, 27 GeV)
- Target(Be 10%λ_I)
- Detectors $\rightarrow$
- Trigger $\underbrace{S1 \cdot S2 \cdot S3}_{beam} \cdot \underbrace{\bar{K}1 \cdot \bar{K}2}_{interaction} \cdot \underbrace{\bar{A1}0 \cdot \bar{A1}1}_{!halo} \cdot \underbrace{\bar{G}}_{!veto}$

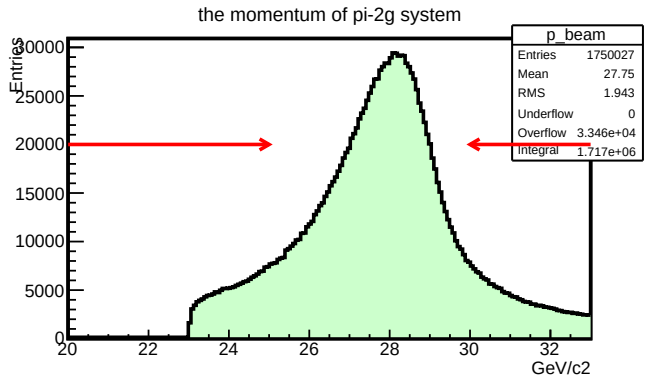
- Three beam Cerenkov counter
- Wire chambers
- Spectrometer 1 T
- Large Cerenkov counter
- Three station of drift tubes
- Calorimeter

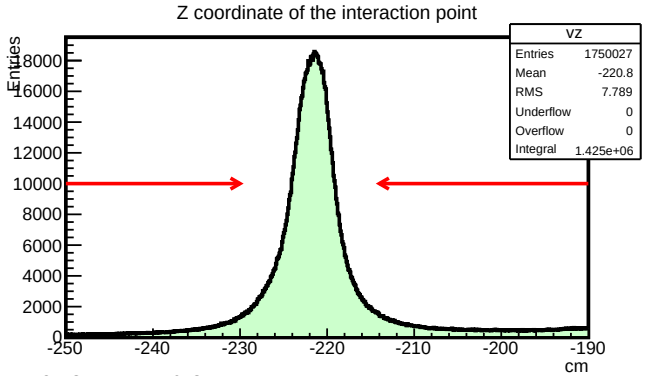
Data-sample

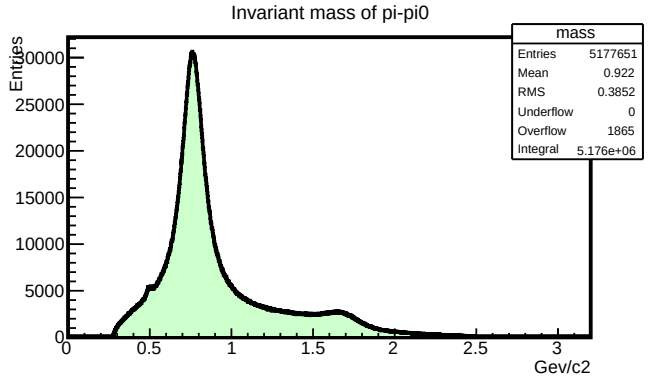
- The topology $(1n + 0p + 2z)$.
- The gamma's energy more 0.5 GeV
- π_0 mass cut $(m_\pi \pm 20\,\mathrm{MeV})$
- "Exclusivity" cut $25 - 30\,\mathrm{GeV}/c^2$.
- Vertex Z cut 16 cm, while target length is 4 cm

The analysis of the highest statistics run will be shown. Selection cuts:



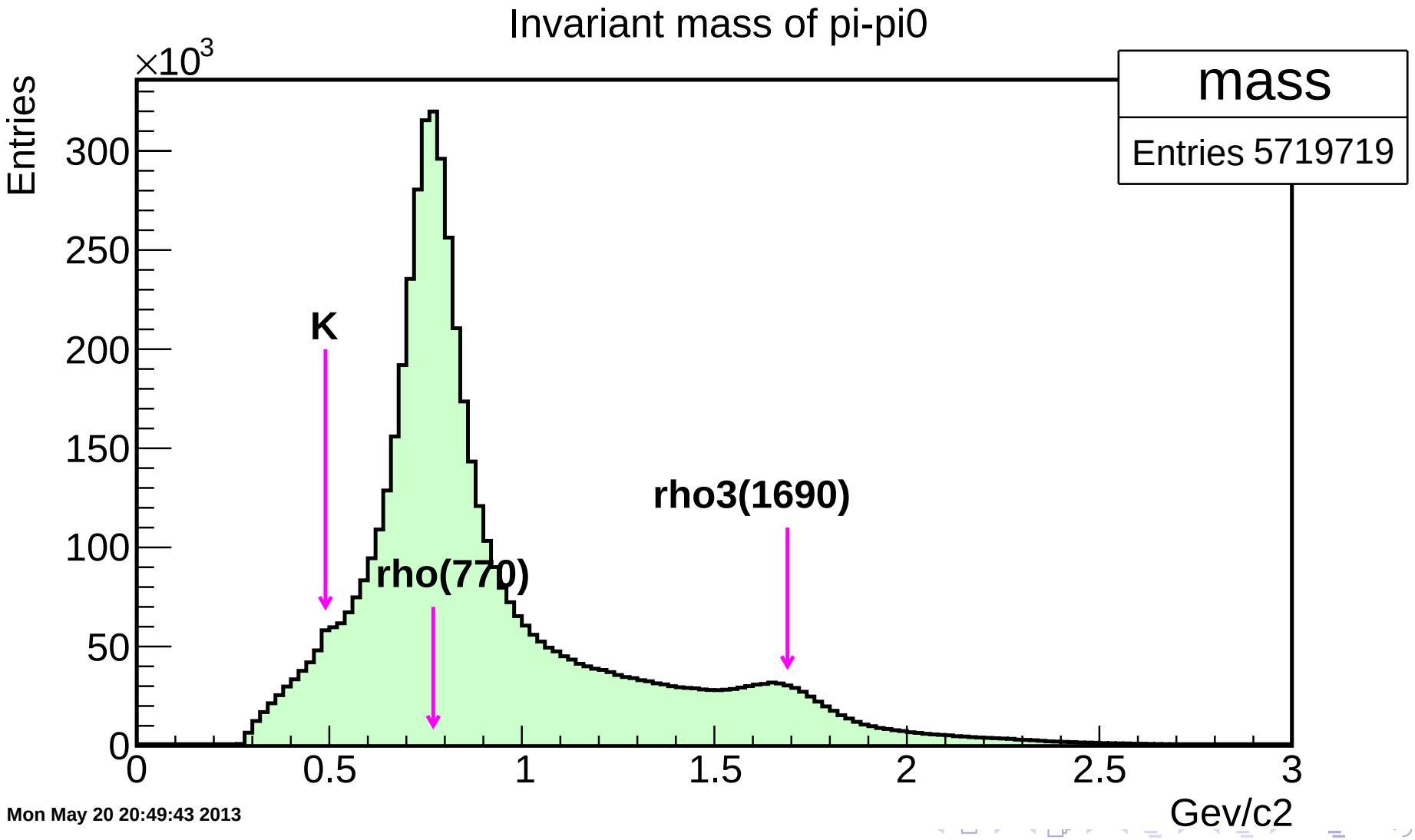






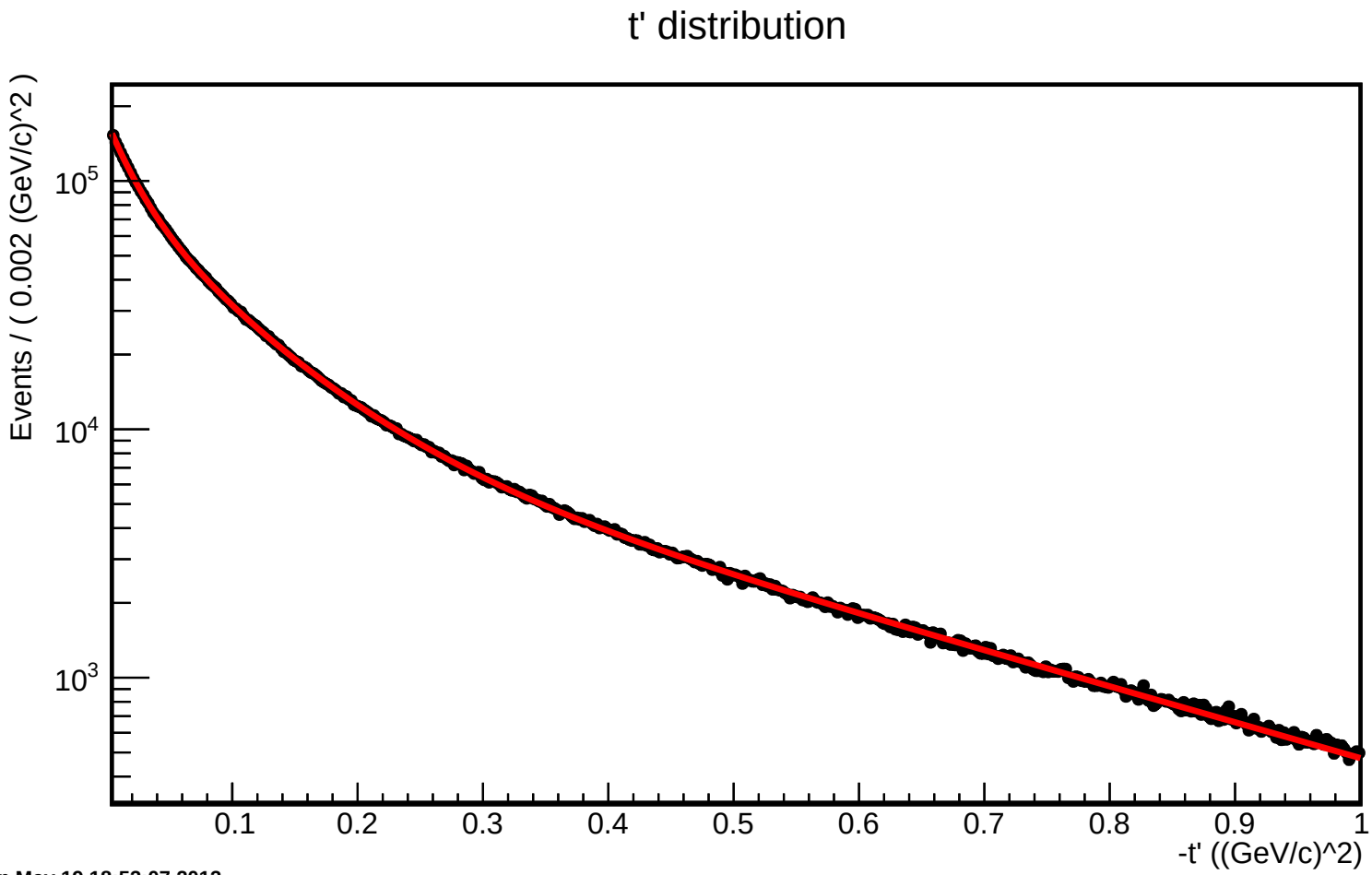
Data-sample-II

Mass spectrum in details:



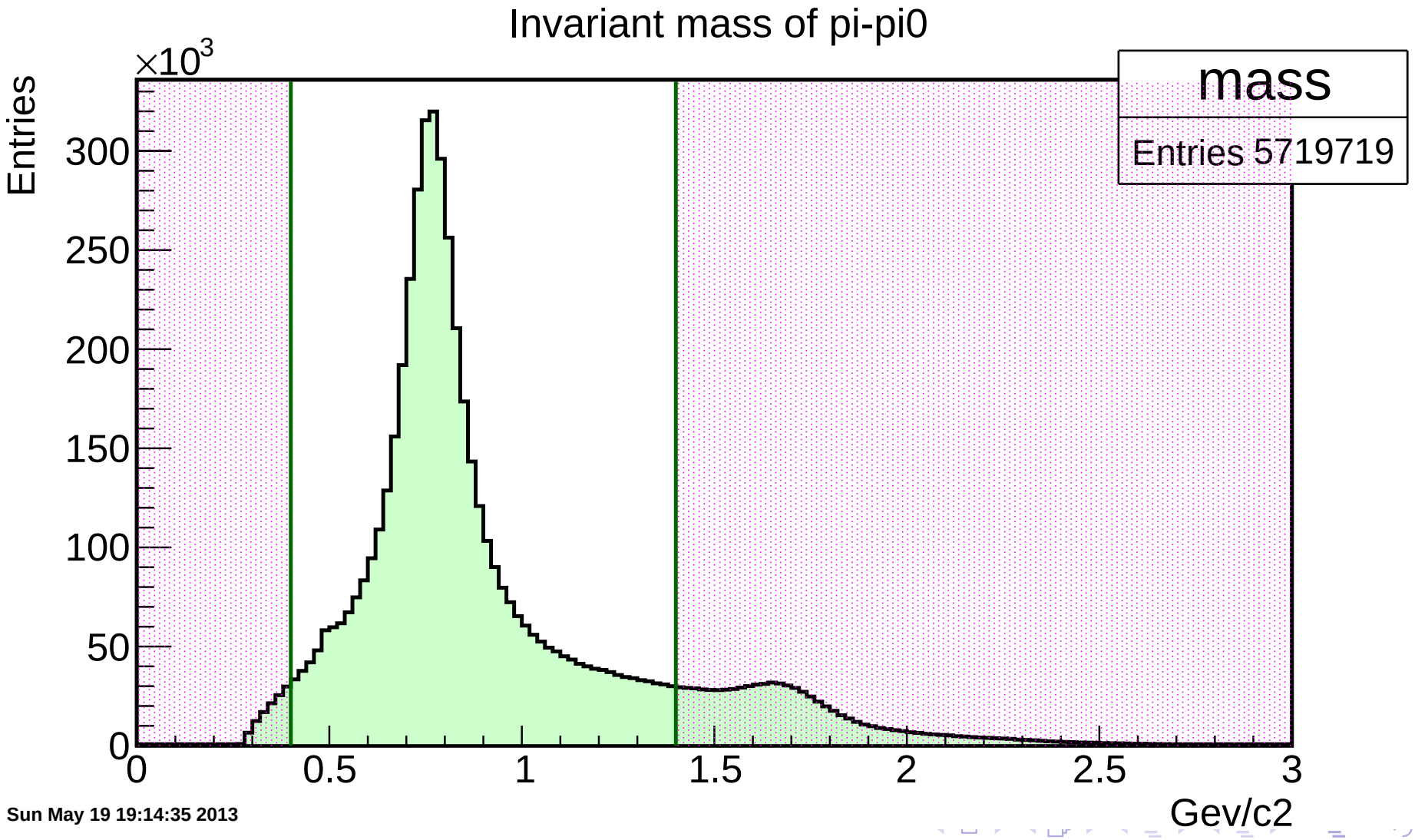
Data-sample-III

The distribution of $-t' = -(t - t_{\min}(m))$ is shown. The data ($t' > 0.004$) is fitted by sum of three exponents. The resulting slopes -45.4, -13.0, -3.3 with respective fractions: 13.6%, 52.2%, 34.2%. $\chi^2/\mathrm{Ndf} = 1.3$

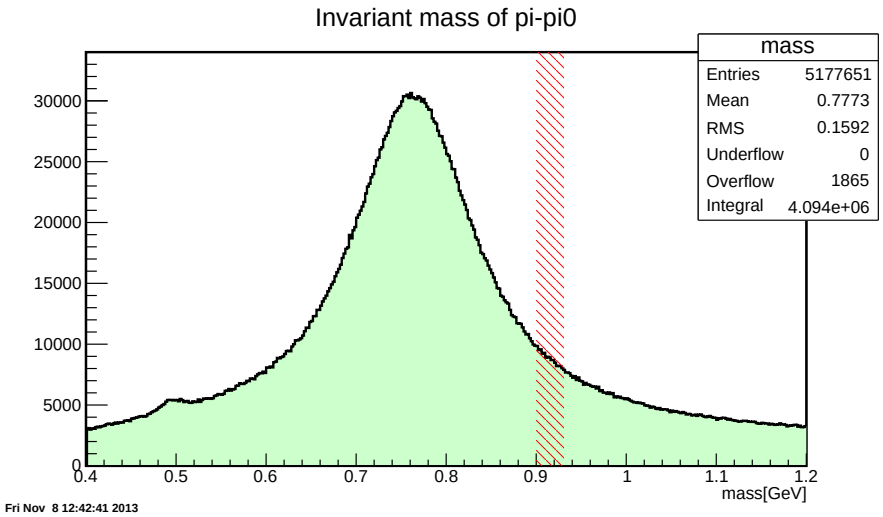


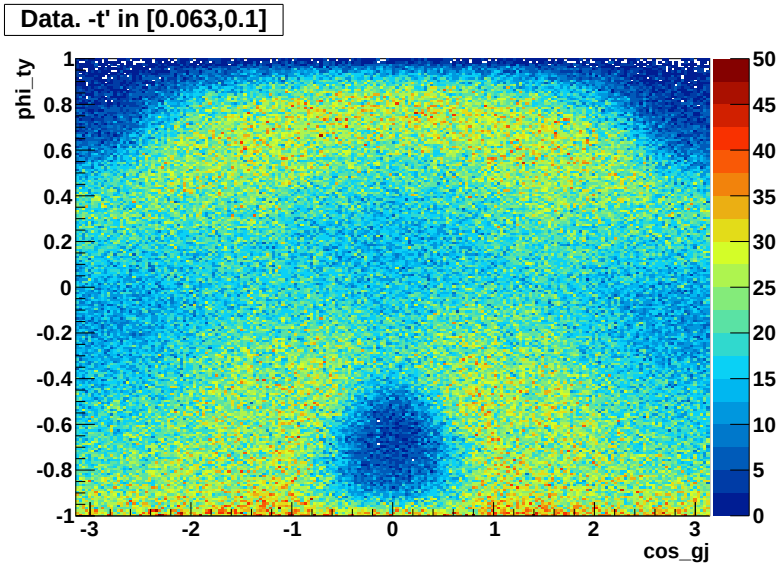
Analyzed mass interval

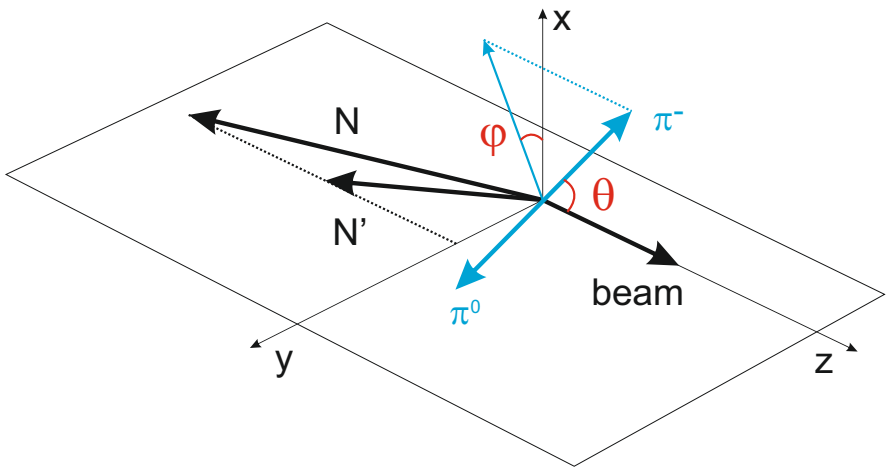
Region for analysis.



The PWA scheme







$$I_S = |a_S|^2 = \ldots$$
$$I_{P_-} = |a_{P_-}|^2 = \ldots$$
$$I_{P_+} = |a_{P_+}|^2 = \ldots$$
$$I_{P_0} = |a_{P_0}|^2 = \ldots$$

The model

The PDF is the sum of two non-interfering blocks.

$$W(\Omega) = \left|a_{P_+} P_+\right|^2 + \left|a_{P_0} P_0 + a_{P_-} e^{i\phi_P} P_- + a_S e^{i\phi_S} S_0\right|^2$$

P, S are spherical functions:

"Natural" exchange

$$P_+ = -\sqrt{\frac{3}{8\pi}} \sin\theta \sin\phi$$

"Unnatural" exchange

$$P_0 = \sqrt{\frac{3}{4\pi}} \cos\theta$$

$$P_- = \sqrt{\frac{3}{8\pi}} \sin\theta \cos\phi$$

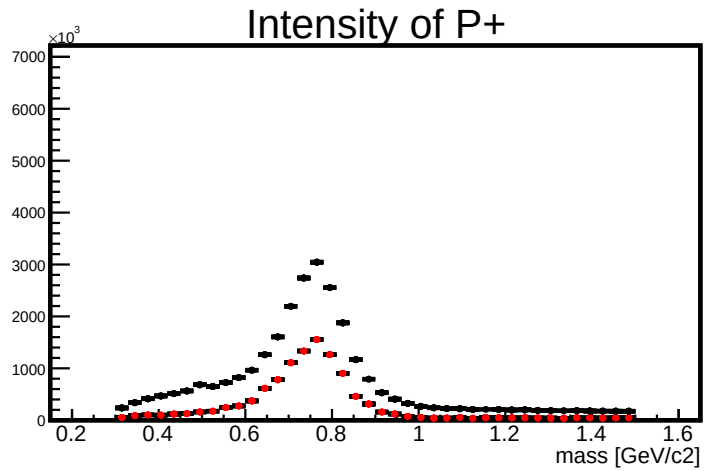
$$S_0 = \sqrt{\frac{1}{4\pi}}$$

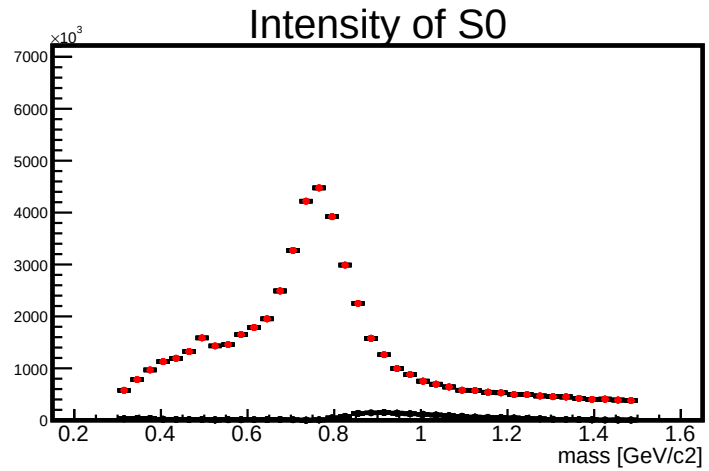
Minuit was used to minimize the functional L:

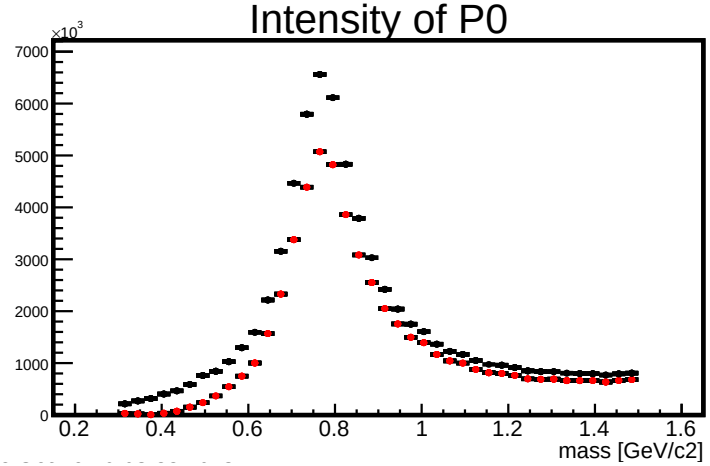
$$L = -\log W(\Omega, p) + N \int_{\Omega_{tot}} W(\Omega, p) A(\Omega) d\Omega, \quad p = (a_i, \phi_P, \phi_S)$$

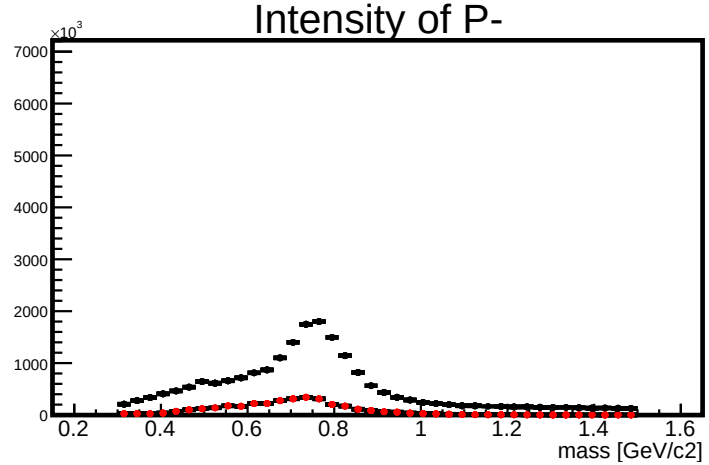
The partial wave intensities

Minimization result (10 attempts - different start values are shown). Two ambiguities: black and red points are well separated.



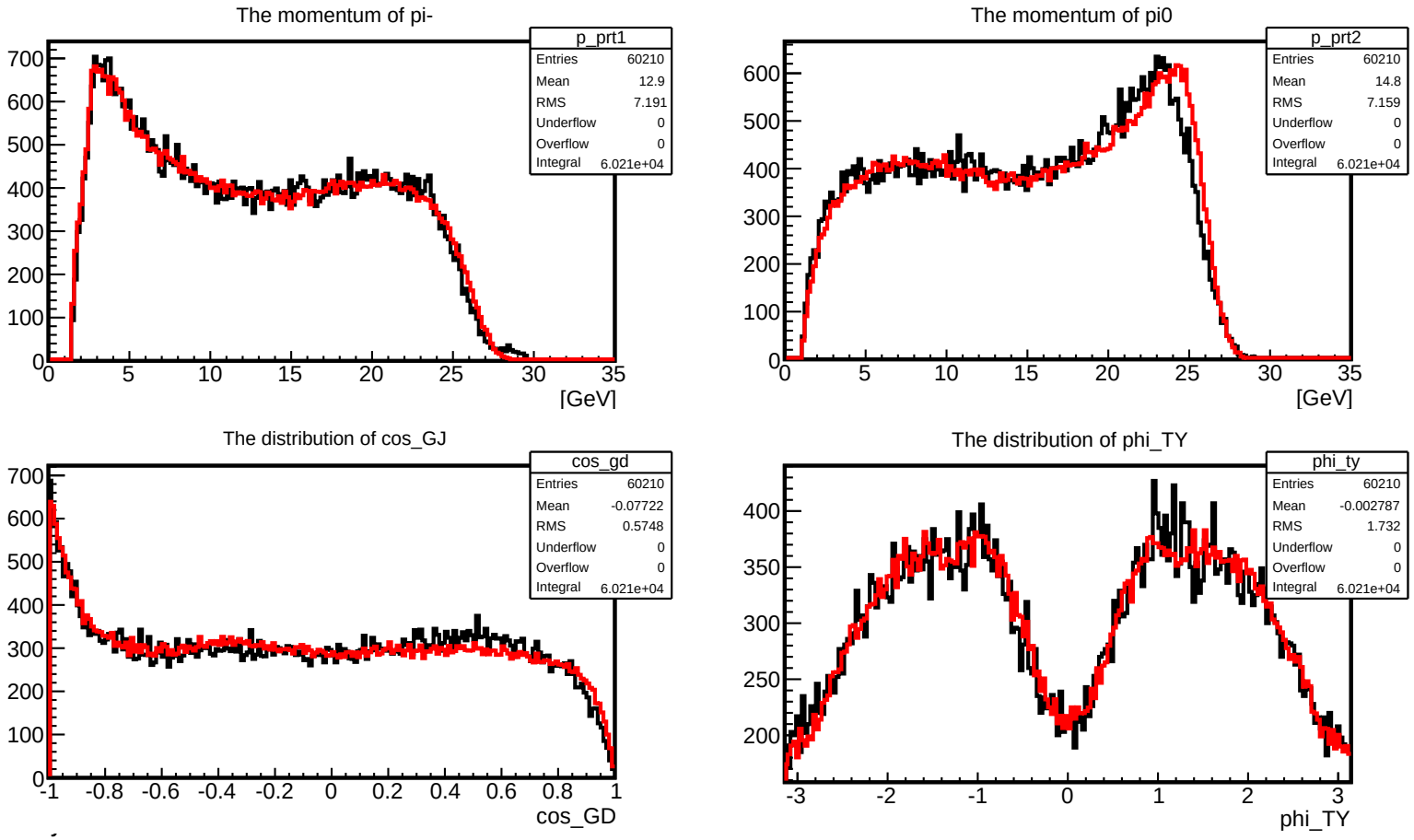






Results and predictions.

The comparison 'MC prediction' (events generated according to a model obtained as a result of the fit) (red) and Data (black). For $m_{\pi^-\pi^0} \sim m_\rho$.



Main background: Reaction $\pi^- N \to \pi^- 2\pi^0 N'$

$\pi^- 2\pi^0$: 1 track + 4 gamma $\to$ 1 track + 2 gamma : $\pi^- \pi^0$

$$\frac{\sigma(\pi^- N \to \pi^- 2\pi^0 N')}{\sigma(\pi^- N \to \pi^- \pi^0 N')} \sim 20...50, \quad \text{for our energy}$$

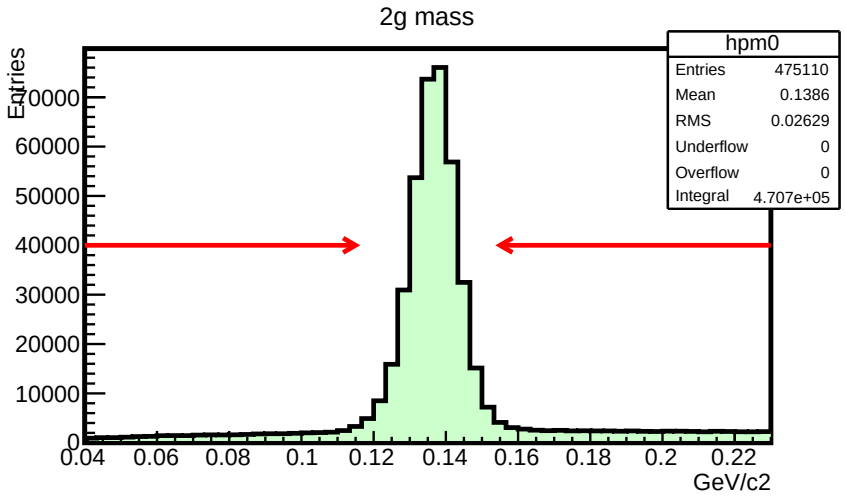
The leakage study:

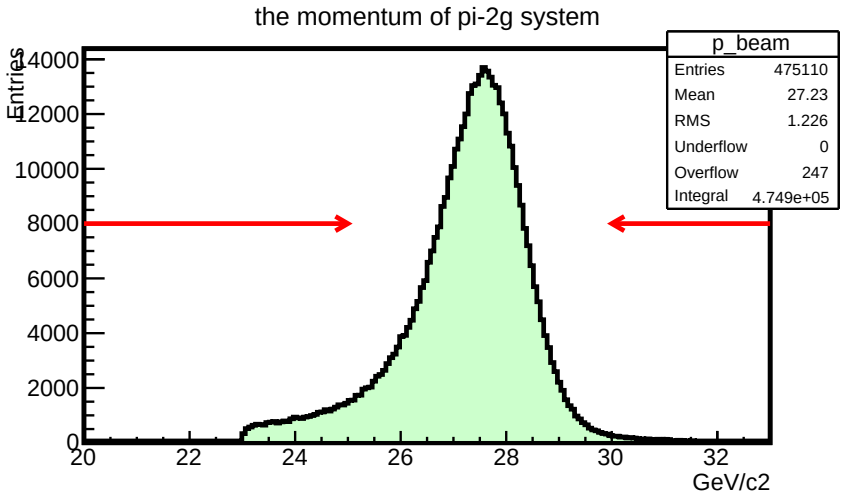
- The $\pi^- 2\pi^0$ PWA result (from Dmitry Riabchikov) is used as physical generator.
- Geant4 (or factMC) - for event simulation.

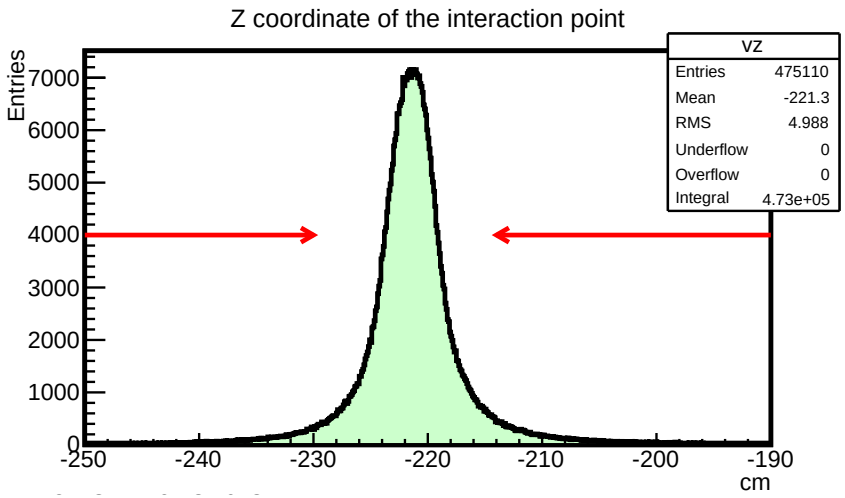
The $\pi^- 2\pi^0$ PWA model: (see report from VES at Hadron-2013)

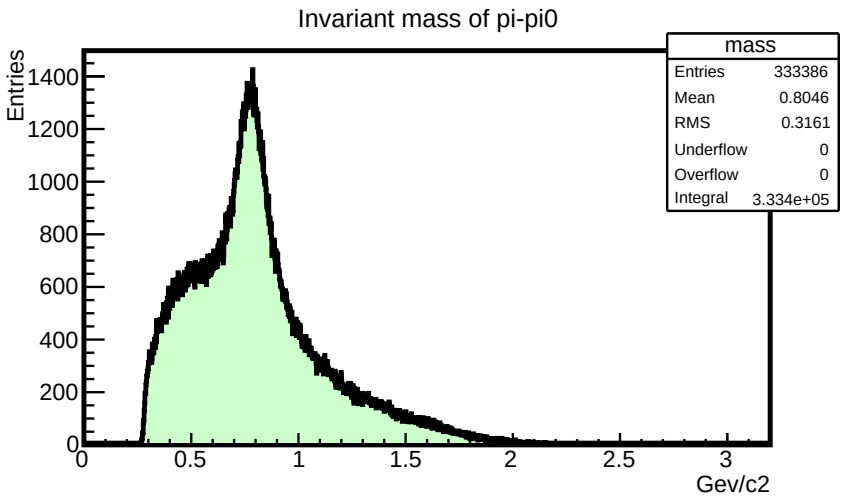
- The isobar model
- m- and t- independent analysis
- Matrix Rank-1 with partial coherency.

The selected background spectra



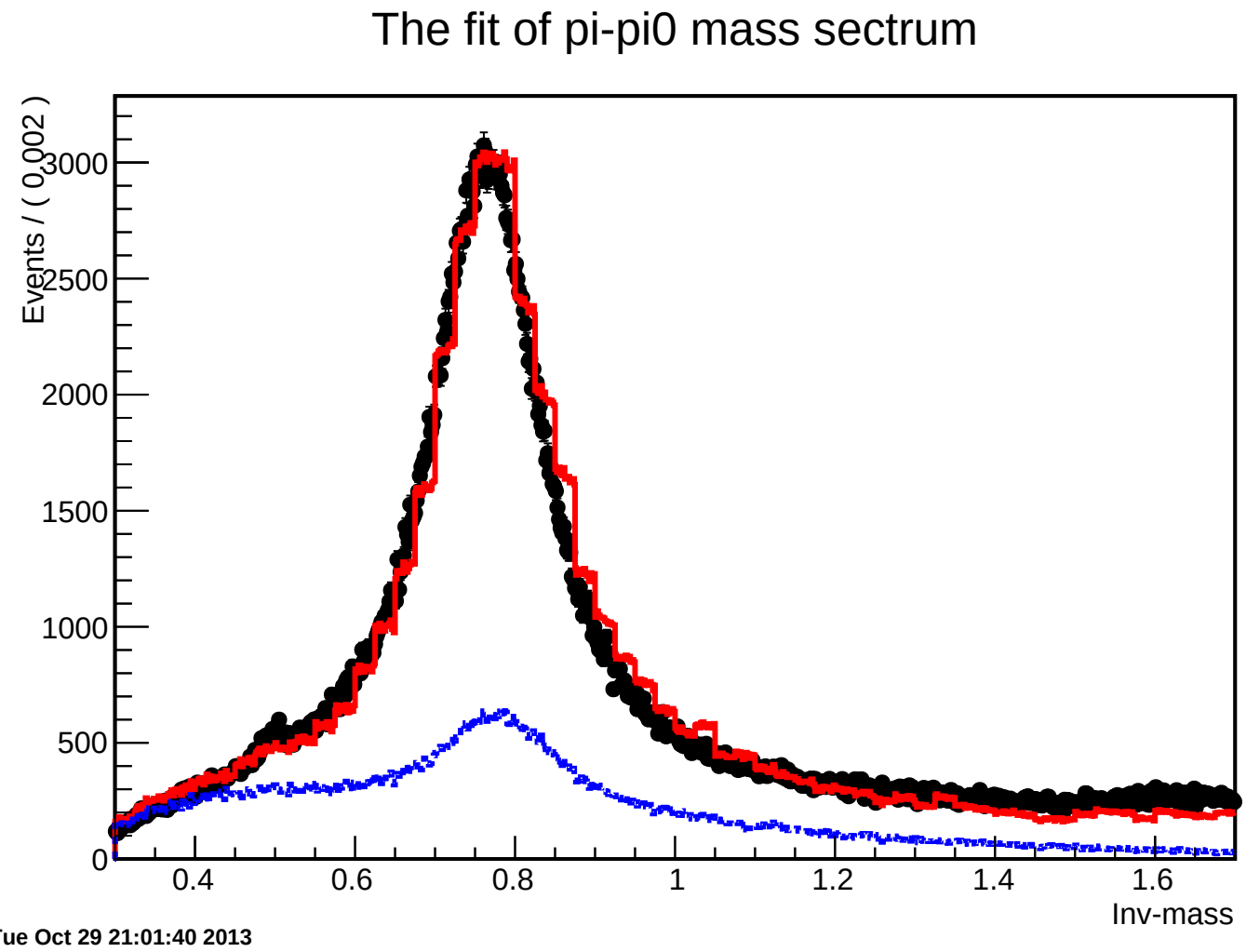






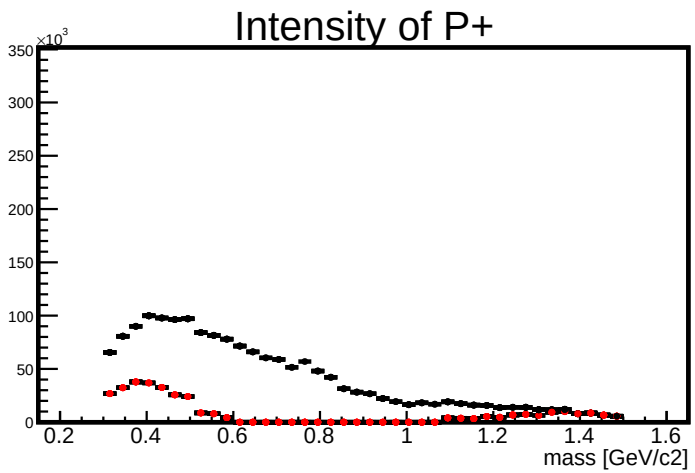
The background contribution

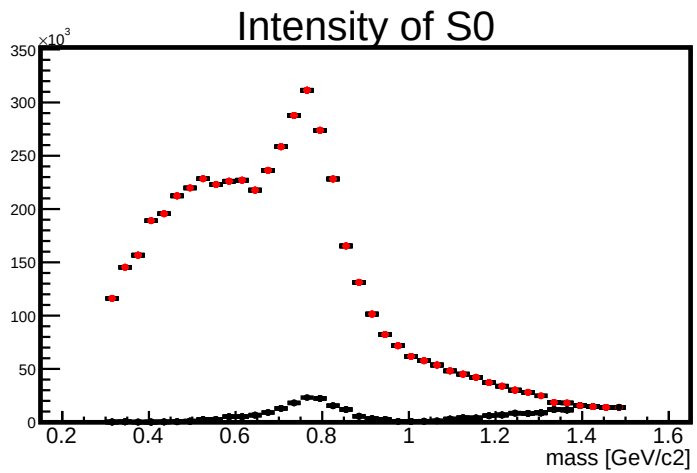
The data (black) were fitted by leakage background(blue) and clean ρ-meson shape. Evaluated background contribution is $40^{+30}_{-10}\%$.

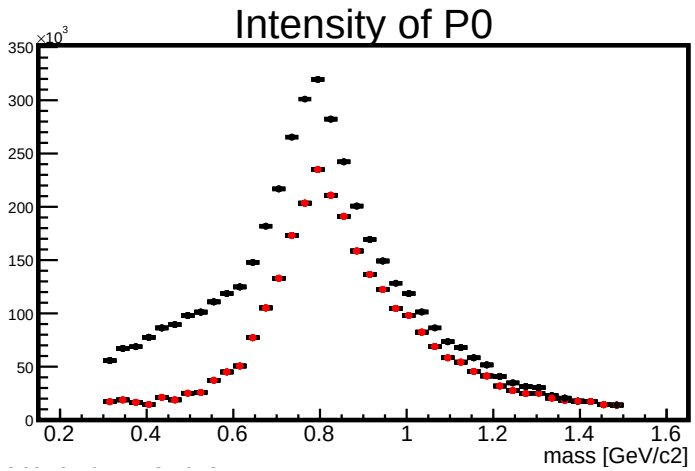


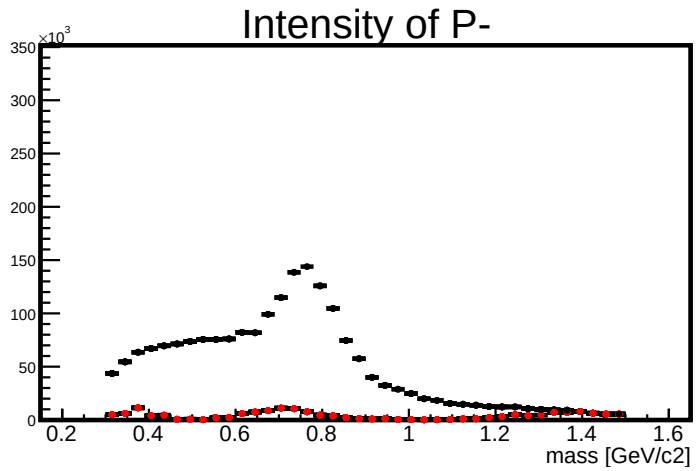
The PWA of leakage data sample

Minimization results.









Conclusion

- Two waves (S,P) are enough do describe data at $[0.4, 1.2]\,\mathrm{GeV}/c^2$
- The $\pi\pi$ scattering to I=2,J=0 is known to be small, so only the smallest S-wave solution is taken as physical - to resolve the ambiguity.
- The background ($\pi^- 2\pi^0$ leakage) contribution ($\sim 40 - 80\%$) was investigated and understood.
- The background suppression and subtraction can be next steps for the analysis.

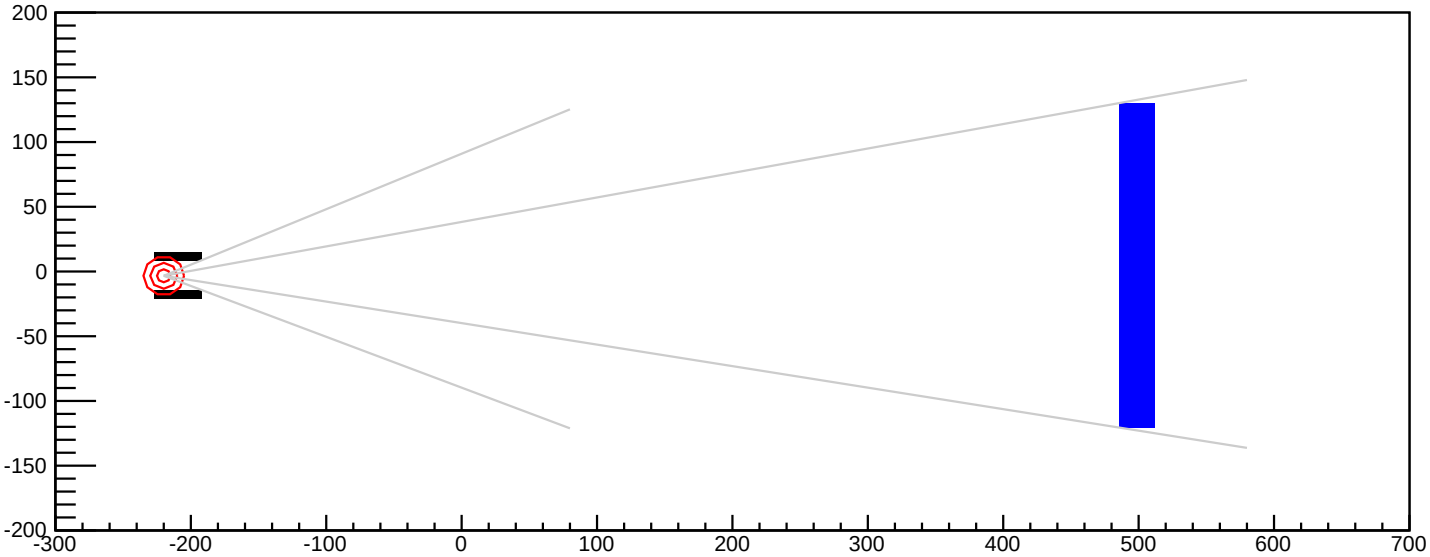
The end

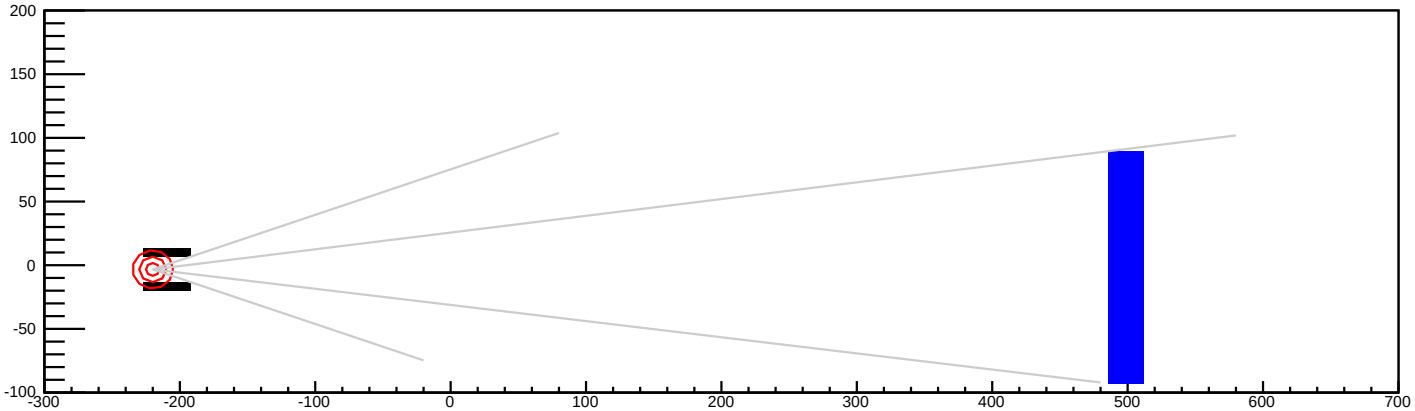
Thanks.

continue

More slides

BackSlide, Near-target Guard





BackSlide, the acceptance for gammas