Monte Carlo studies of $\eta \rightarrow 4\pi^\circ$ CP symmetry violating decay with WASA-at-COSY detector

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In the Standard Model CP symmetry violation is described by the phase in the Cabibbo-Kobayashi-Maskawa quark-mixing matrix. Six quark flavours are grouped into three families. CP violation is related to family-changing interactions, while in family-conserving cases CP violation is not included in the SM. Detailed studies of CP violation may lead us to New Physics that goes beyond the Standard Model. Test of flavour-conserving CP symmetry violation may be carried out with η meson decays into even number of pions. The aim of presented investigation is to estimate the time of measurement for which the current branching ratio limit of $\eta \rightarrow 4\pi^\circ$ decay can be improved.

Investigated reaction:
$pp \rightarrow pp\eta \rightarrow pp4\pi^\circ \rightarrow pp8\gamma$

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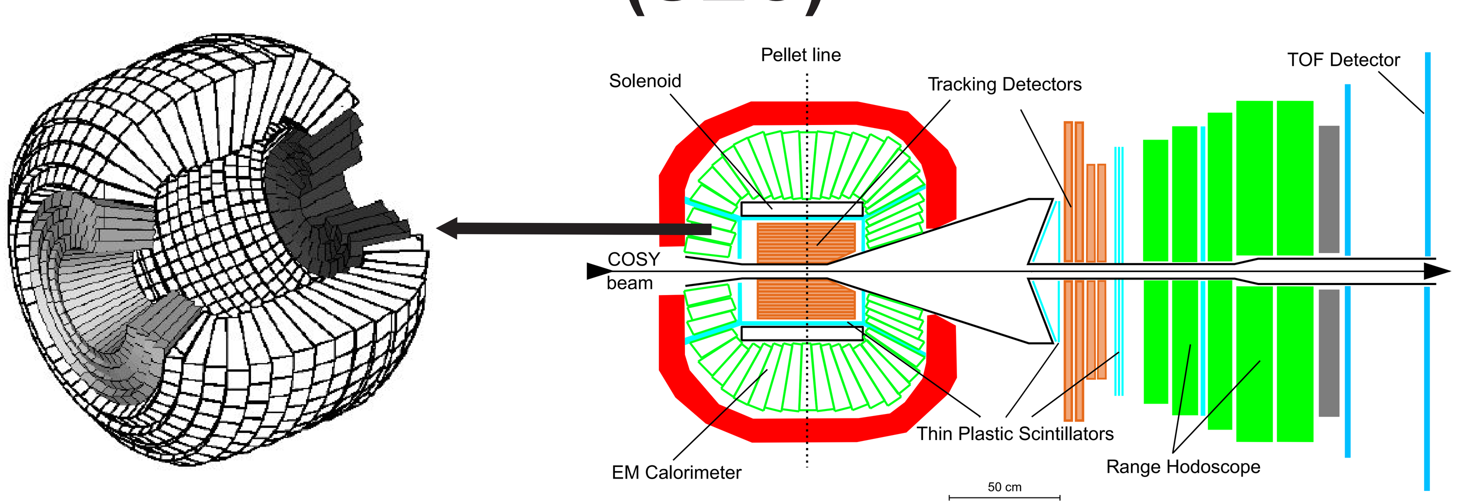
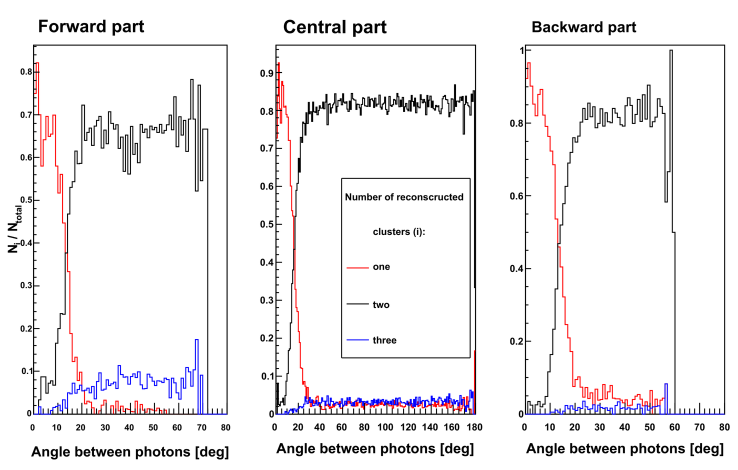
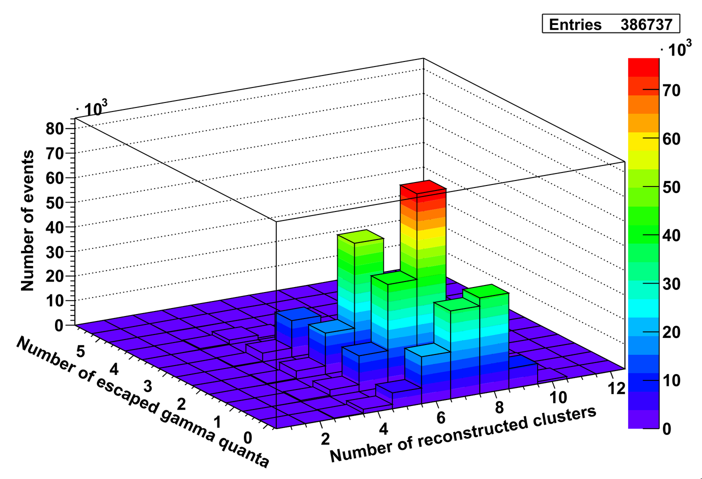
WASA-at-COSY detector with Scintillating Electromagnetic Calorimeter (SEC)



Eight gamma quanta in exit channel of investigated reaction cause that electromagnetic calorimeter is the most important detector for measurement of that decay. Test of merging and splitting of clusters in the calorimeter was performed (left) and distribution of number of gamma quanta which can be observed in the SEC was determined based on the 1 000 000 simulated reactions (right).

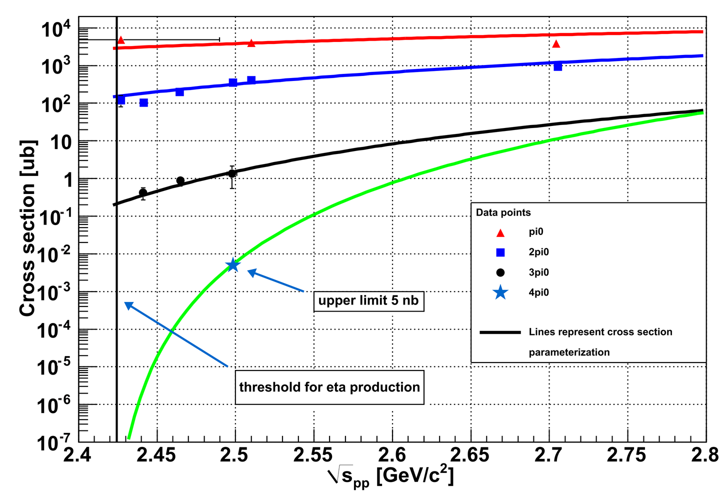


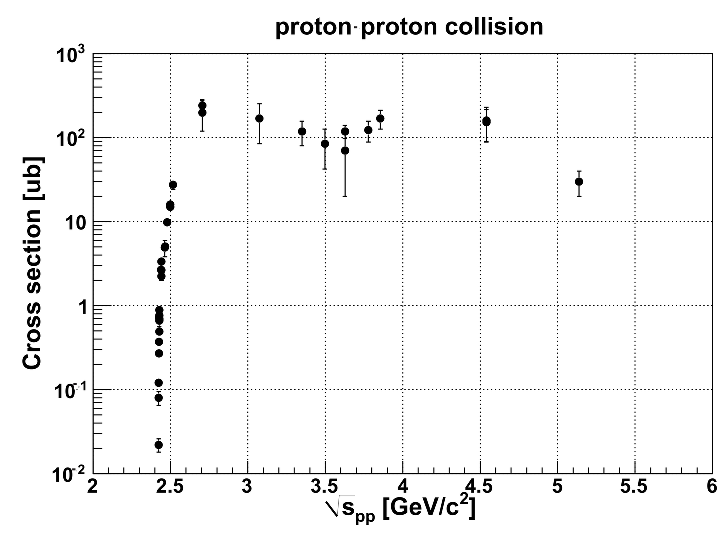


Main physical background reaction
$pp \rightarrow pp4\pi^\circ \rightarrow pp8\gamma$

The studied reaction is identified using missing mass and invariant mass methods. Anyhow in spite of using both techniques the $\eta \rightarrow 4\pi^\circ$ decay can be misidentified due to the unavoidable physical background. The main physical background of $\eta \rightarrow 4\pi^\circ$ is prompt $4\pi^\circ$ production in proton-proton collision.

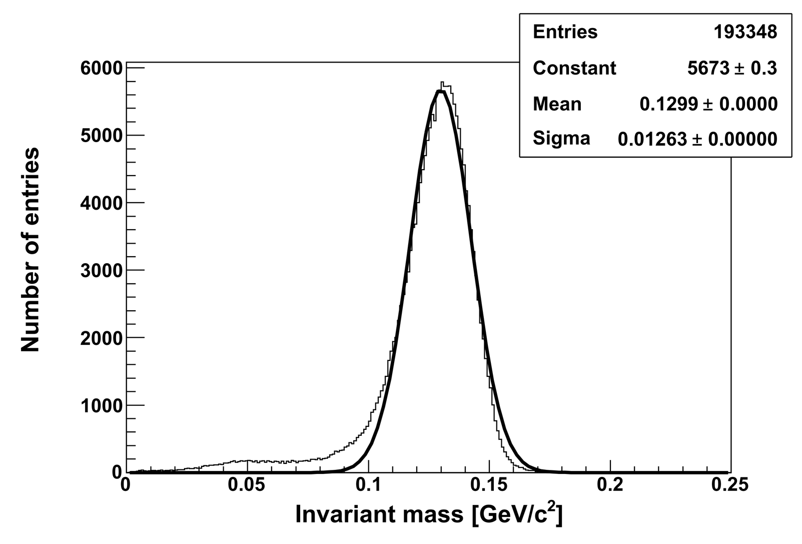
The cross section for $4\pi^\circ$ production in proton-proton collisions is not established and so far only an upper limit for a single energy point was determined. In order to estimate the background from direct pions production, an energy dependence of the upper limit of the total cross section was derived under assumption of the homogeneous phase-space population. The result is shown below (left). For comparision, cross sections of η meson production are presented in right-side figure.

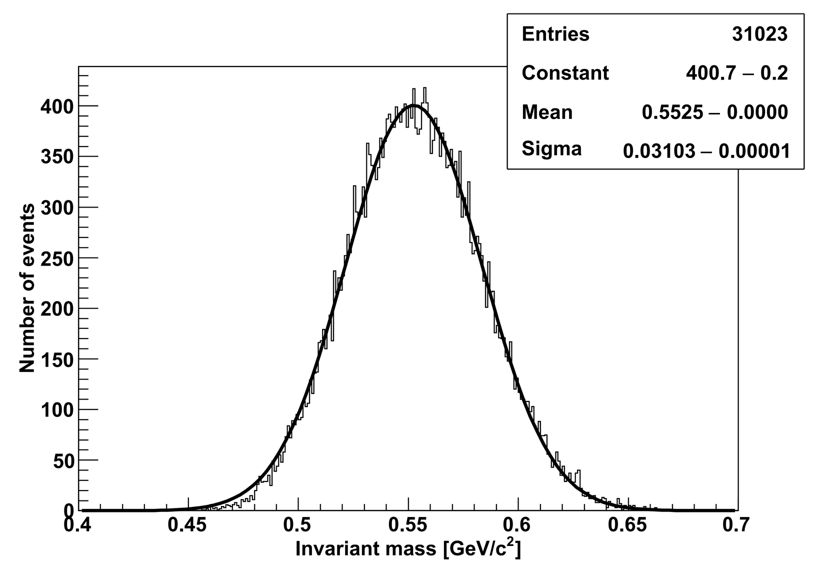


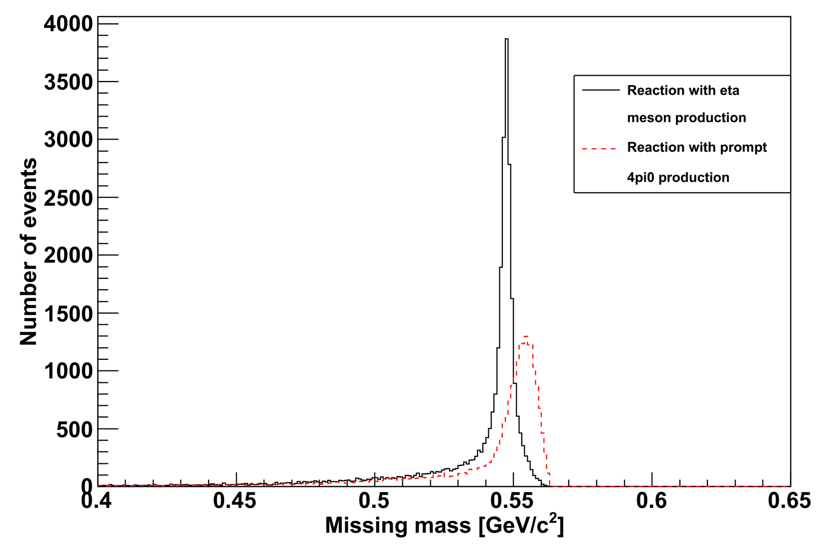


Reconstruction of $pp \rightarrow pp\eta \rightarrow pp4\pi^\circ \rightarrow pp8\gamma$ reaction using WASA-at-COSY detector via invariant and missing mass technique

Large number of gamma quanta in exit channel cause reconstruction difficulties. In order to identify which gamma quantum comes from decay of which neutral pion, matching routine was created. Invariant mass of pairs of gamma quanta coming from same π° meson are shown in the left-side figure. Central one presents invariant mass of eight gamma quanta originating from η meson decay. The η meson can be fully reconstructed only for 3% of all simulated reactions. Right-side histogram shows missing mass distribution for prompt $4\pi^\circ$ and η meson production. For obtaining those distributions the same number of $pp \rightarrow pp4\pi^\circ$ and $pp \rightarrow pp\eta \rightarrow pp4\pi^\circ$ reactions were simulated.







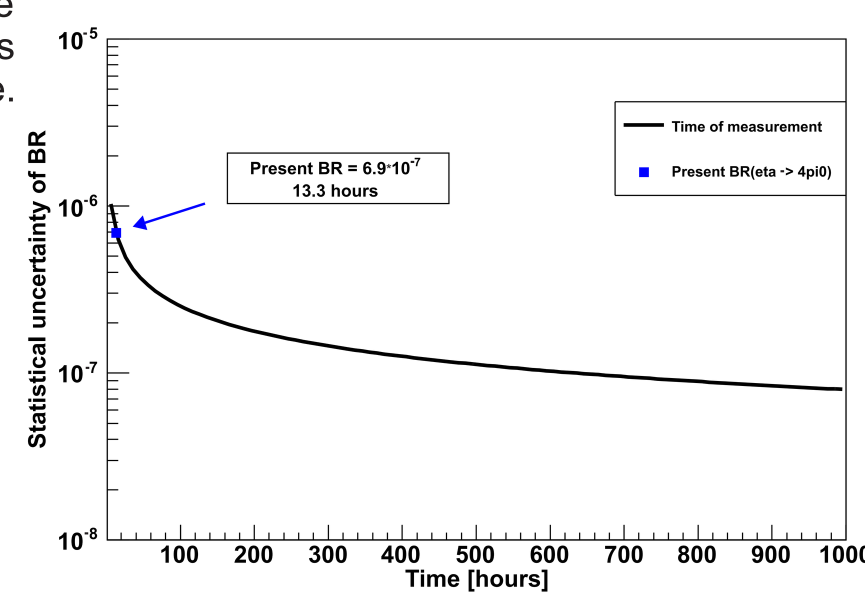
Time of measurement with WASA-at-COSY detector

Statistical error of branching ratio achievable with WASA-at-COSY at CL=95% detector as a function of time is shown in the right figure.

Statistical uncertainty of BR in the figure was calculated from:

$$\sigma(BR) = \left| \frac{\sigma(N_{\eta \rightarrow 4\pi^0})}{A_\eta \cdot \sigma_\eta \cdot L \cdot \Delta t} \right|,$$

where
$N_{\eta \rightarrow 4\pi^\circ}$ - number of observed events,
A_η - acceptance of detector,
L - luminosity,
BR - branching ratio,
σ_η - cross section for η production
Δt - time of measurement



Outlook

Established results show that the value of current upper limit of BR($\eta \rightarrow 4\pi^\circ$) can be improved with WASA-at-COSY detector.

References

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