

Study of the $\eta \rightarrow 3\pi^0$ decay with the Crystal Ball at MAMI-C

Sergey Prakhov, UCLA

PrimeNet meeting

Frascati, April 8, 2009

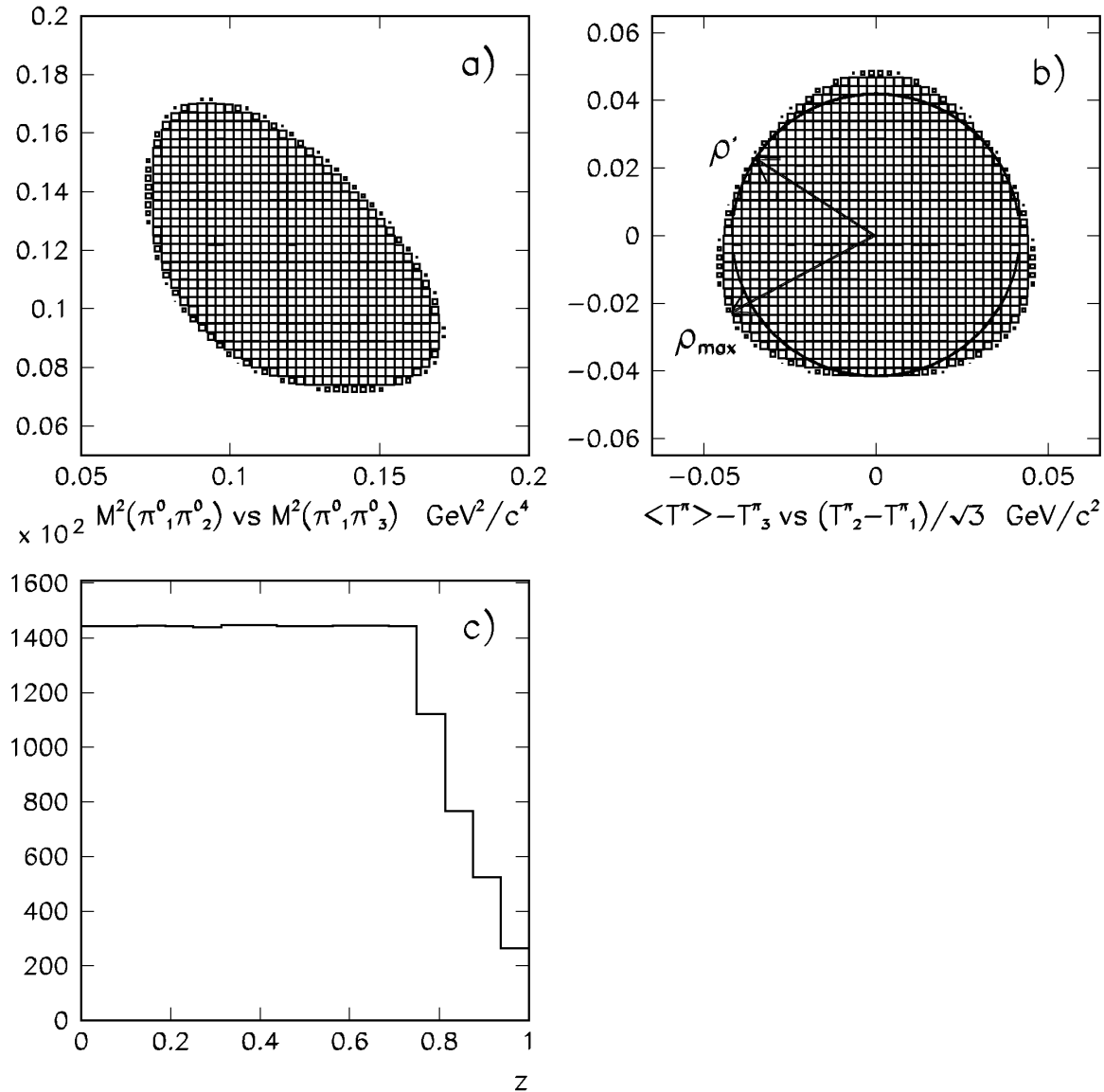
Talk outline

- Physical motivation for study of $\eta \rightarrow 3\pi^0$
- Current status on the experimental and theoretical study of the $\eta \rightarrow 3\pi^0$ decay
- Reproduction of the experimental conditions with the Monte Carlo simulation
- Result for the $\eta \rightarrow 3\pi^0$ slope parameter from the MAMI-C data
- A cusp-like structure in the $\pi^0\pi^0$ invariant mass of the $\eta \rightarrow 3\pi^0$ decay
- Final remarks

Physical motivation for study of $\eta \rightarrow 3\pi^0$: tests of χ PTh calculations

- $A(\eta \rightarrow 3\pi^0) \sim (m_d - m_u)(1 + \alpha z)$,
 $\Gamma(\eta \rightarrow 3\pi^0) \sim (m_d - m_u)^2(1 + 2\alpha z)$,
 $z = 6/(m_\eta - 3m_{\pi^0})^2 \sum_i (E_{\pi^0}^i - m_\eta/3)^2 = \rho^2 / \rho_{\max}^2$;
 precise measurement of α is required for a better
 calculation of $\Gamma(\eta \rightarrow 3\pi^0)$, needed for the $m_u - m_d$
 difference
- Search for a cusp in $m(\pi^0\pi^0)$ in the vicinity of the
 $\pi^+\pi^-$ threshold in the light of the recent $K^+ \rightarrow \pi^+\pi^0\pi^0$
 results providing a test of the χ PTh prediction for
 the S-wave scattering length combination $a_0 - a_2$

Variable $z = \rho^2 / \rho_{\max}^2$ reflects the density distribution along the radius of the $\eta \rightarrow 3\pi^0$ Dalitz plot



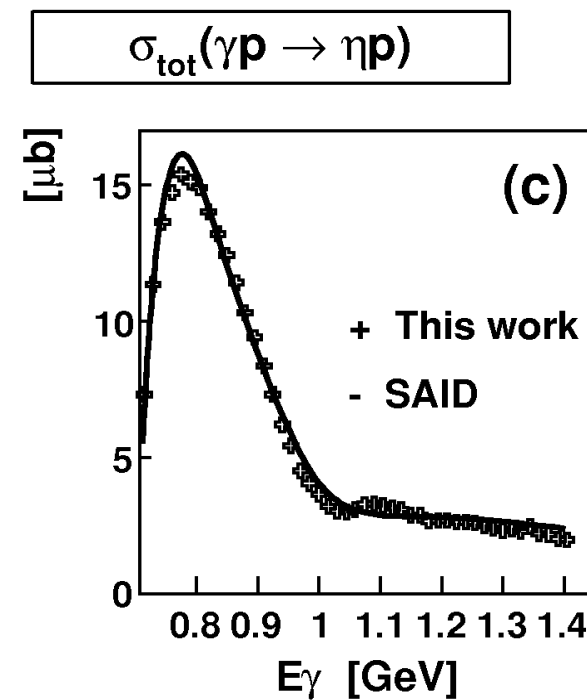
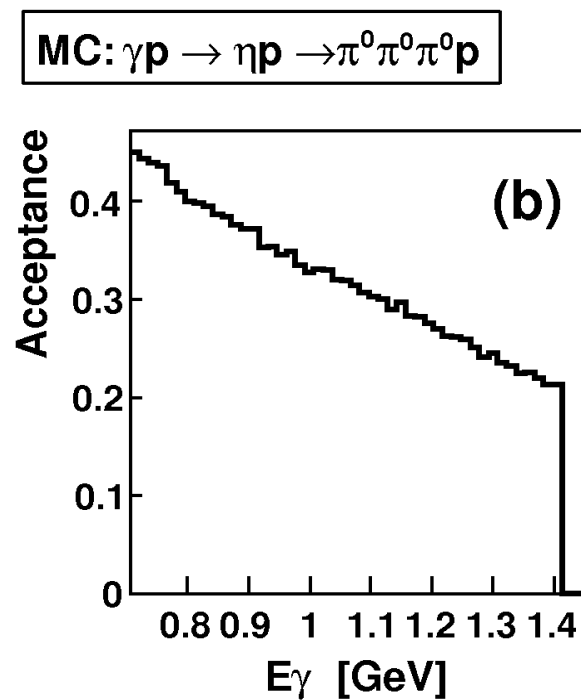
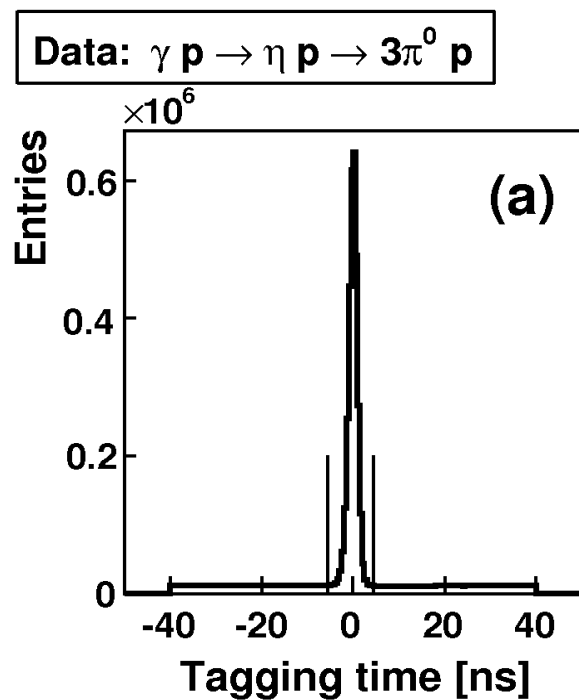
Experimental results and theoretical calculations for α

- Experimental results for α :
 - GAMS2000 (1984): -0.022 ± 0.023
 - CBarrel at LEAR (1998): $-0.052 \pm 0.017 \pm 0.010$
 - CBall at AGS (2001): -0.031 ± 0.004
 - KLOE (prelim.2005): $-0.013 \pm 0.004 \pm 0.005$
 - CELSIUS-WASA (2007): $-0.026 \pm 0.010 \pm 0.010$
 - KLOE (prelim.2007): $-0.027 \pm 0.004 \pm 0.005$
 - CBall at MAMI-B (2009): $-0.032 \pm 0.002 \pm 0.002$
 - CBall at MAMI-C (2009): -0.032 ± 0.003
- Calculations for α :
 - J.Kambor et al. (1996): -0.007 or -0.0014
 - B.Borasoy et al. (2005): -0.031 ± 0.003
 - J.Bijnens et al. (2007): 0.013 ± 0.032
- cusp in $m(\pi^0 \pi^0)$ appears to be very small

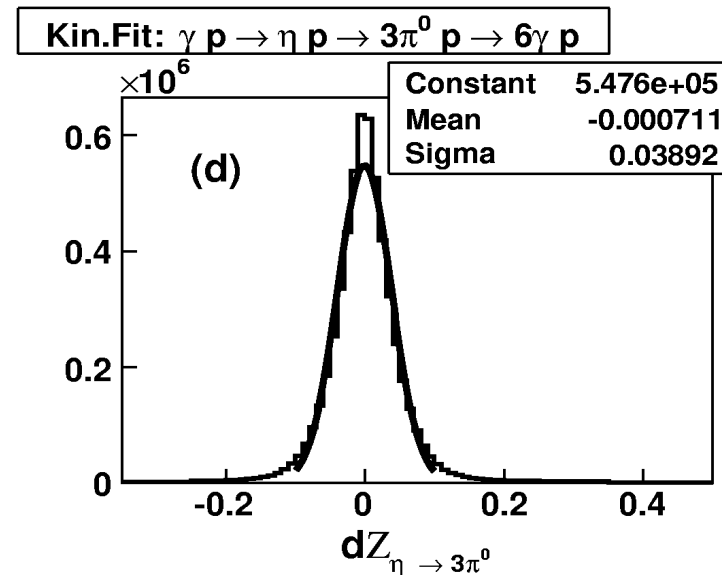
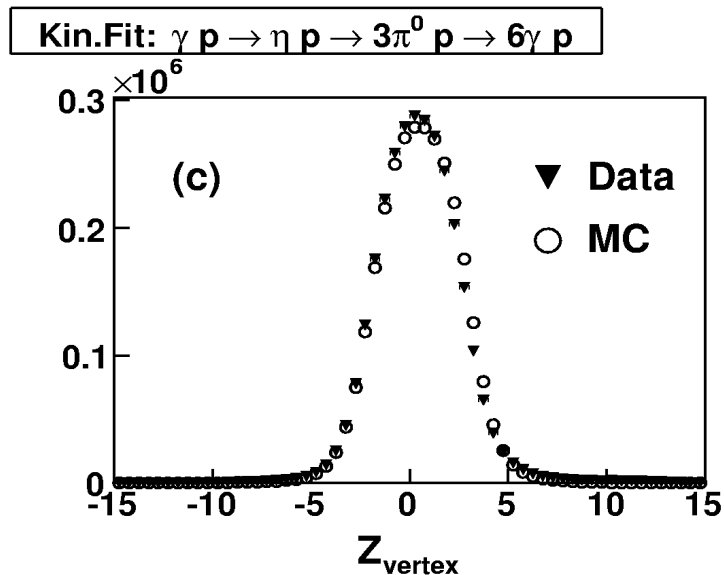
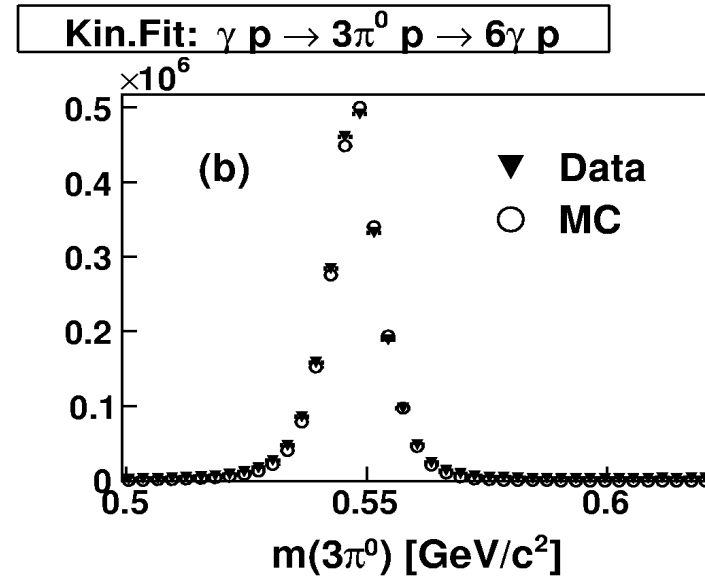
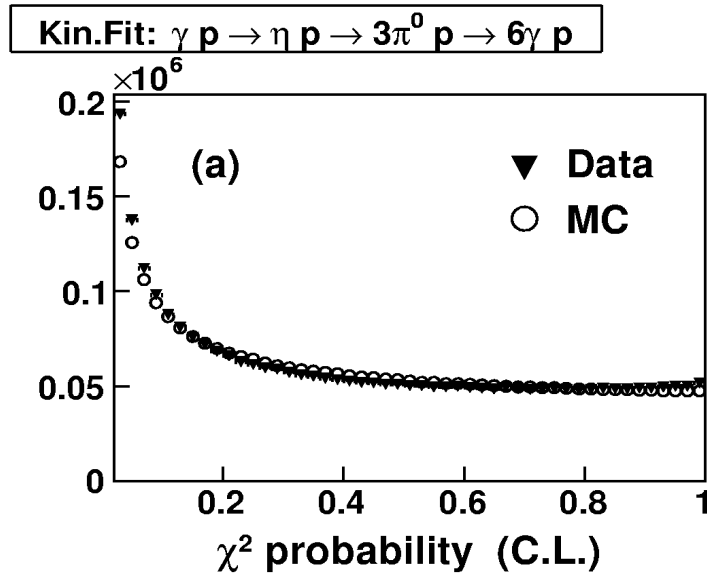
Selection of $\eta \rightarrow 3\pi^0$ events at CB@MAMI-C

- reaction $\gamma p \rightarrow \eta p \rightarrow 3\pi^0 p$ at MAMI-C:
 $E_\gamma = 707\text{-}1402$ MeV is tagged,
CB+TAPS \rightarrow 30% average acceptance,
80% of the protons are detected
- kinematic fit of $\gamma p \rightarrow \eta p \rightarrow 3\pi^0 p \rightarrow 6\gamma p$
at the 2%CL is used to identify $\eta \rightarrow 3\pi^0$
events
- Background contributions:
random coincidences in the tagger $\sim 8\%$,
 $\gamma p \rightarrow 3\pi^0 p$ from 0.4% to 4%,
empty target from 1% to 4%

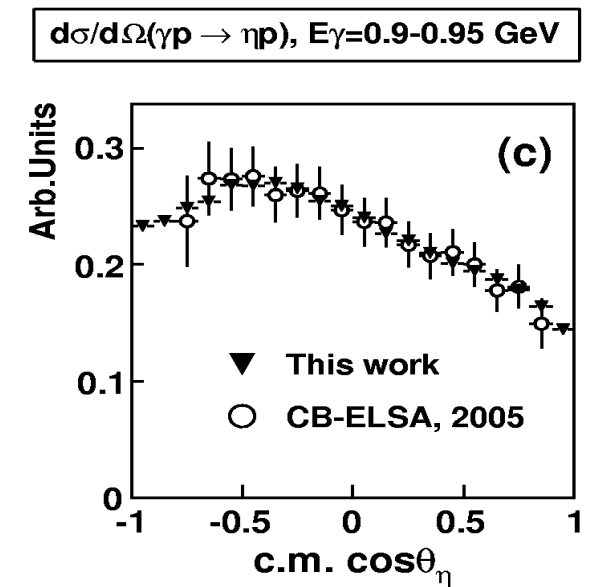
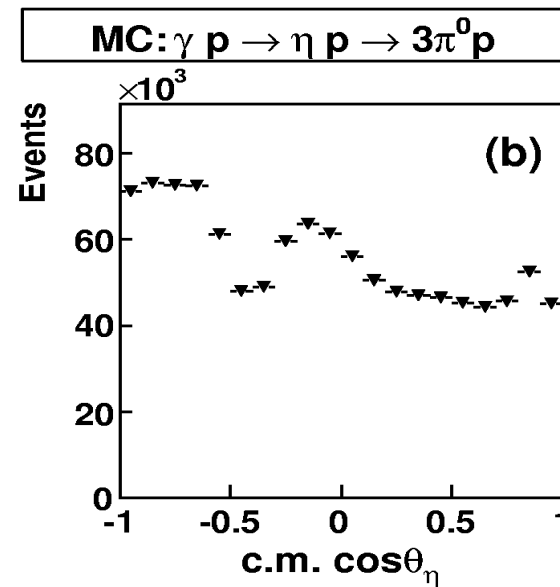
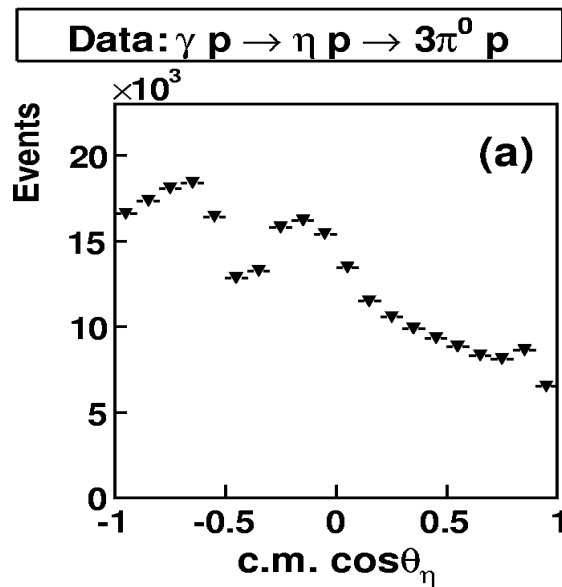
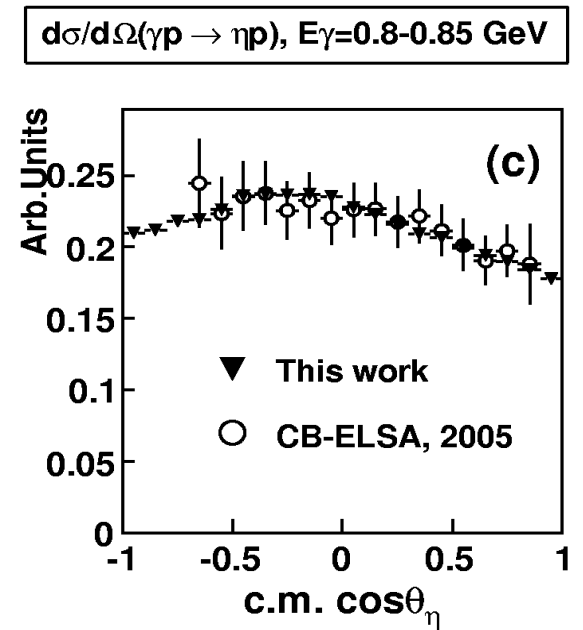
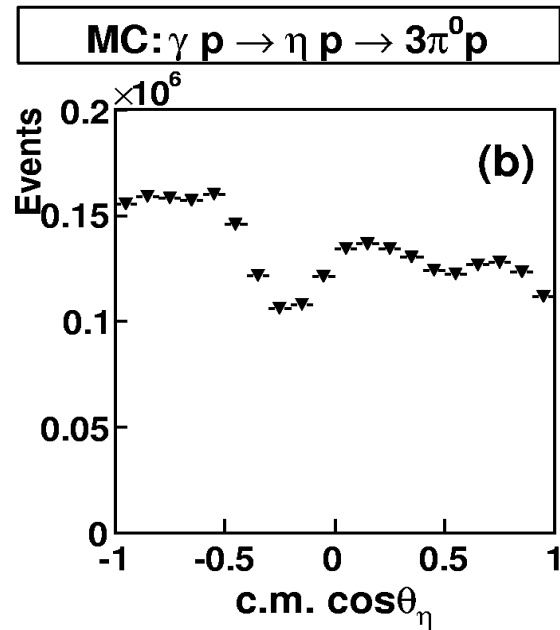
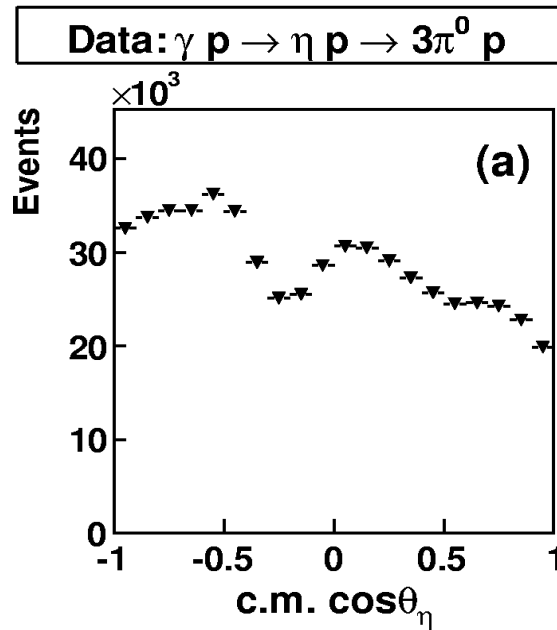
Production of $\eta \rightarrow 3\pi^0$ events



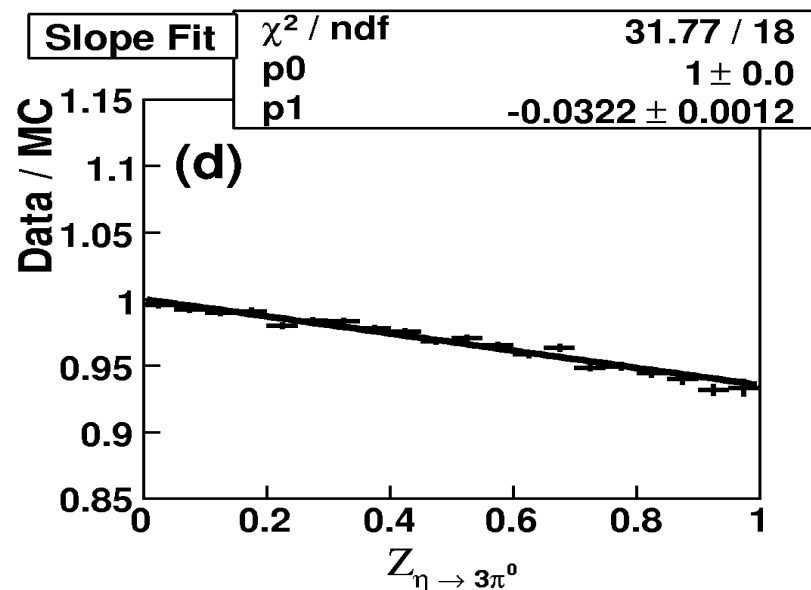
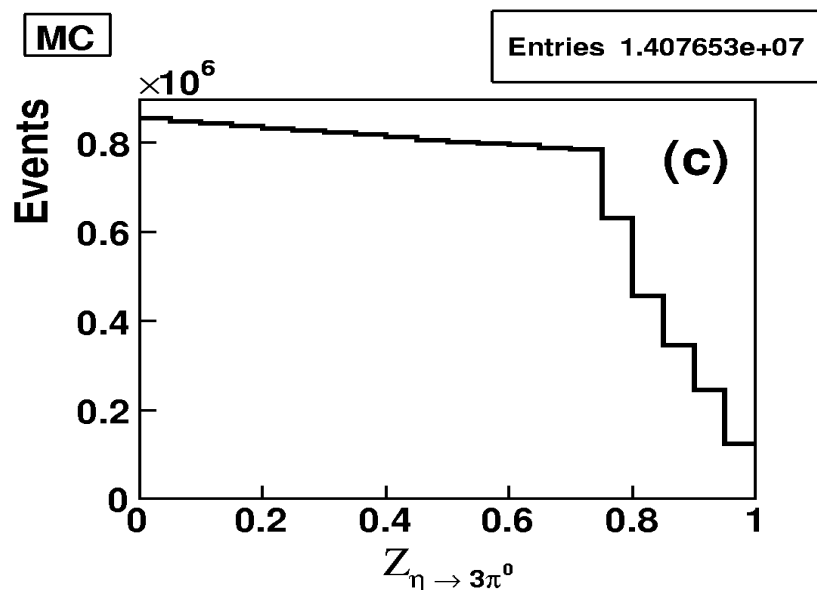
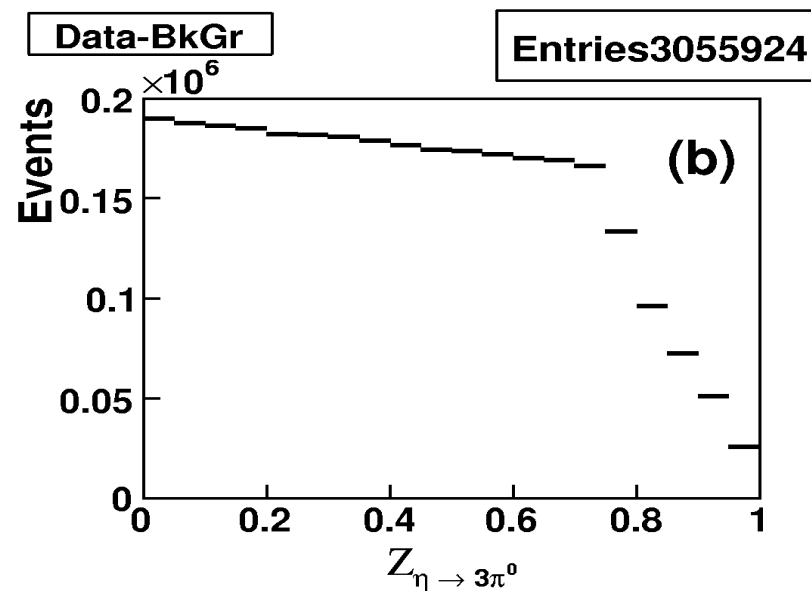
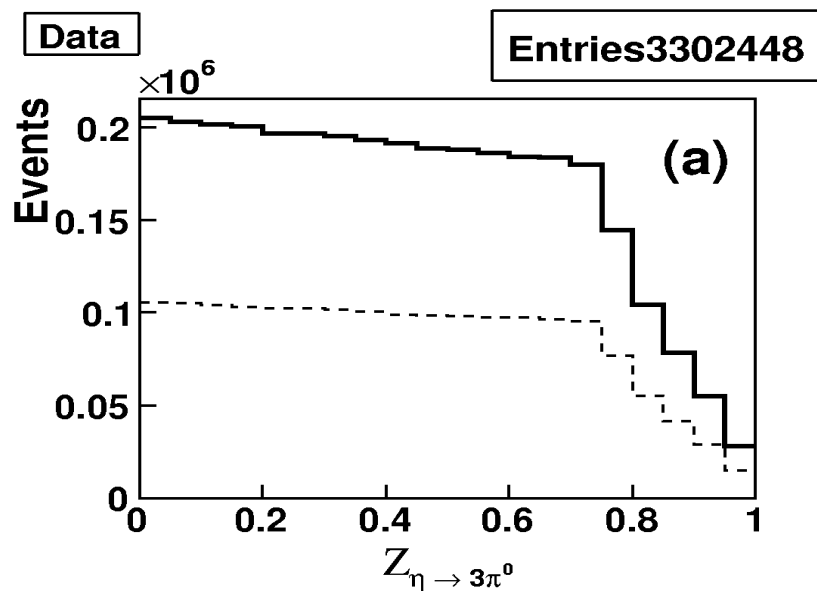
Agreement between the data and MC for $\eta \rightarrow 3\pi^0$ events;
Resolution in the invariant mass (6 MeV) and in parameter z



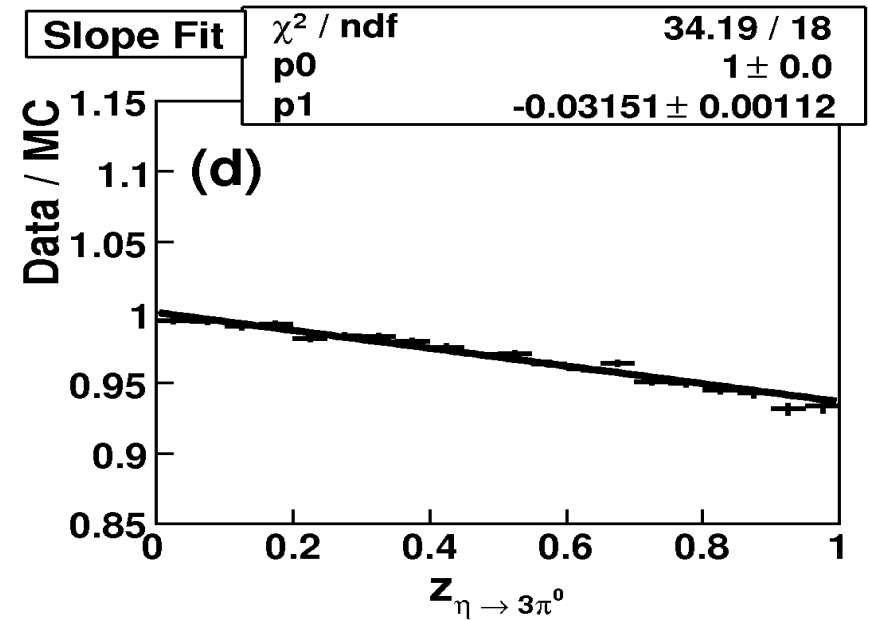
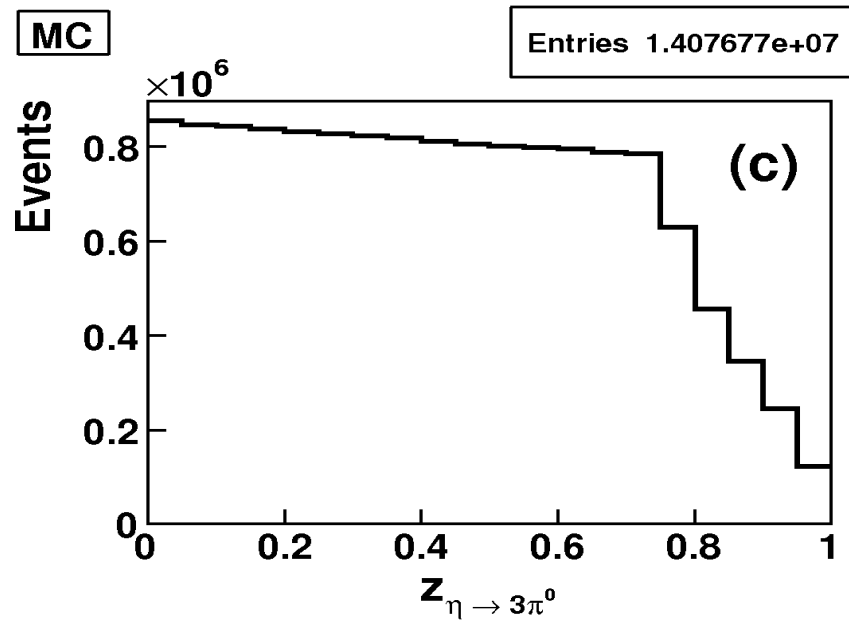
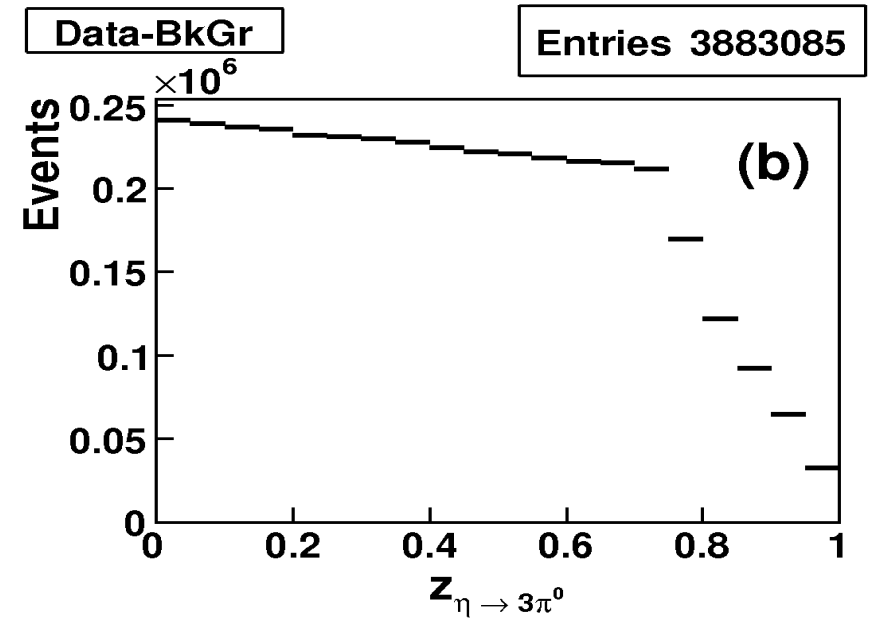
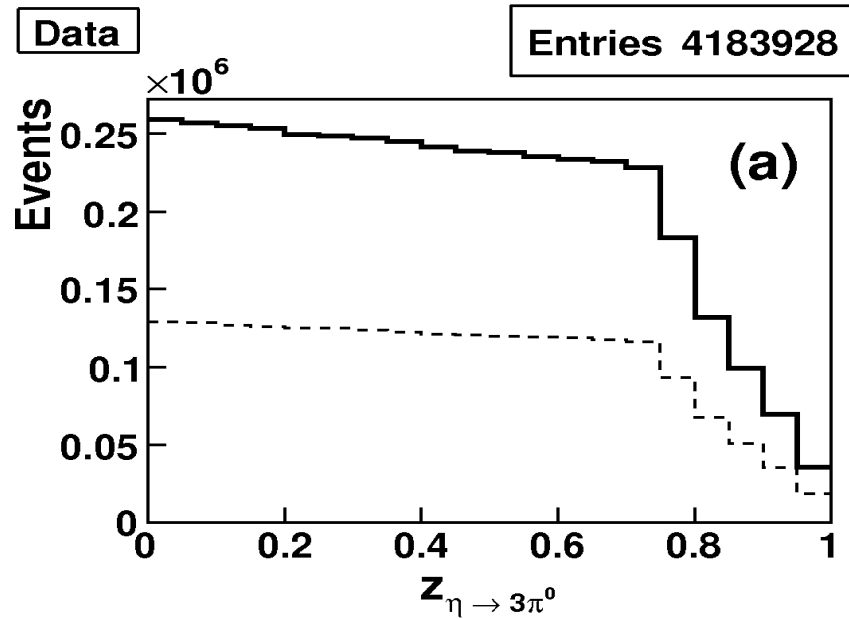
Angular distribution for $\gamma p \rightarrow \eta p$ and its acceptance



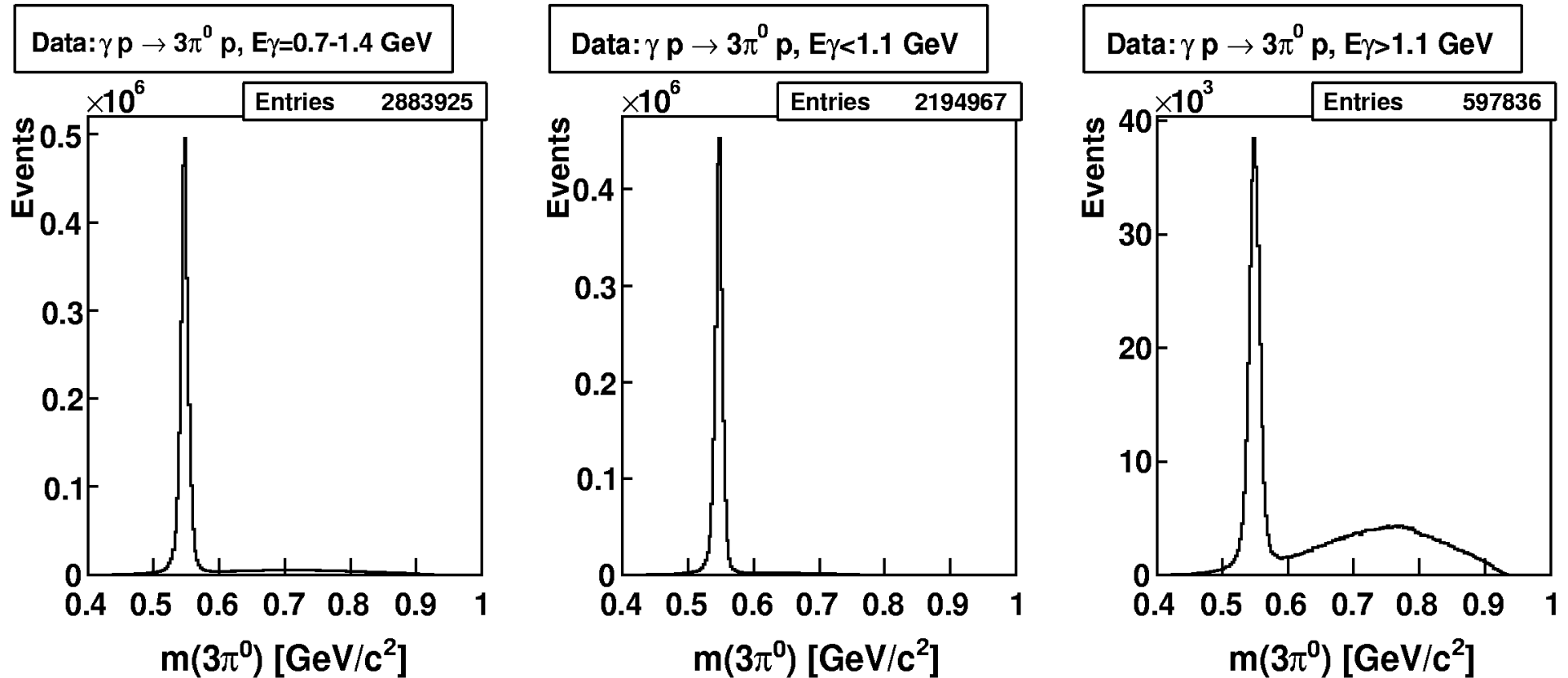
Statistics used for the result published in PRC79(2009)
 (3 runs: 04.07, 06.07, 07.07 ; 26.6M η 's produced)



Full statistics collected with the CB at MAMI-C in 2007



The $3\pi^0$ invariant mass depending on the beam-energy range for $\gamma p \rightarrow 3\pi^0 p$ events



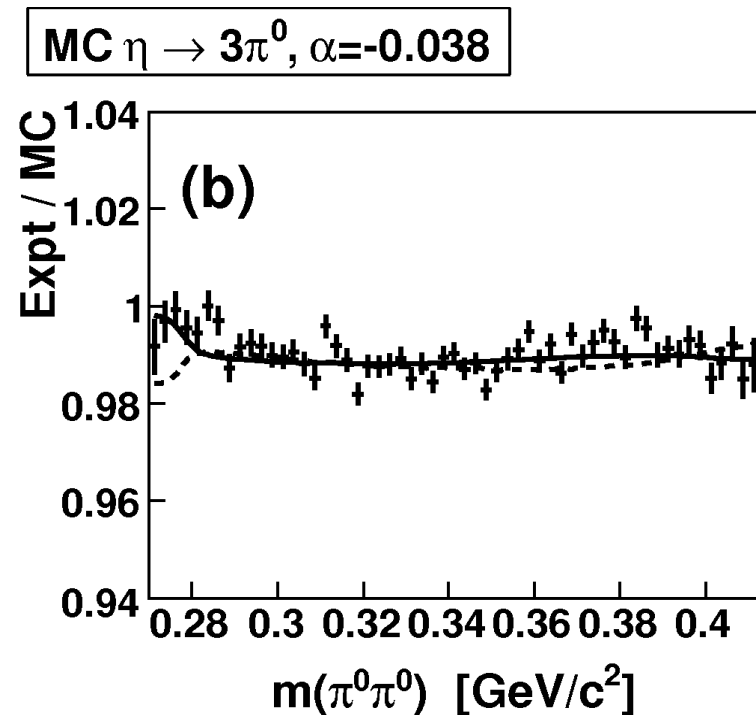
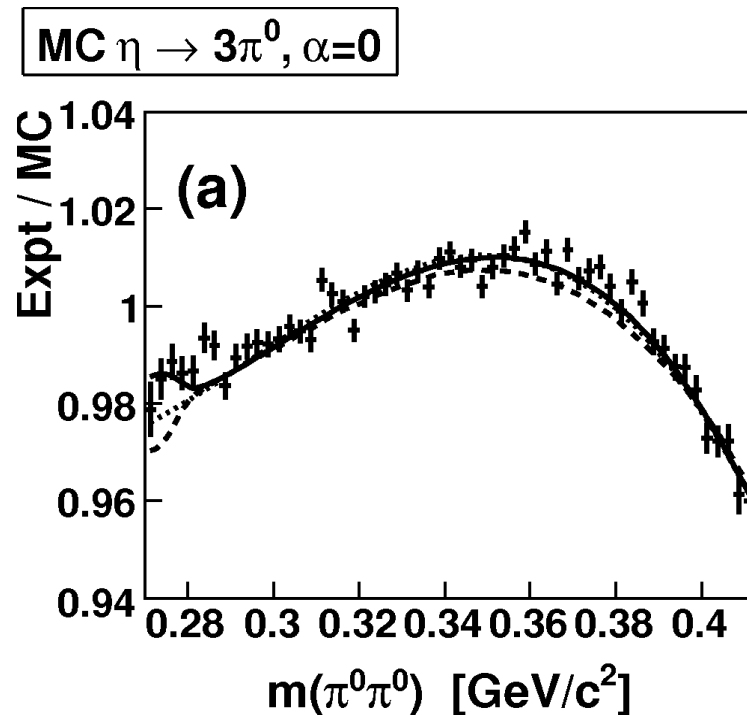
Stability of results for the $\eta \rightarrow 3\pi^0$ slope parameter
depending on experimental conditions and
selection cuts $\rightarrow \alpha = -0.032 \pm 0.003$

Test	Cuts	Statistics	α	χ^2/ndf
1	CL=2%	3.06M	-0.0322 \pm 0.0012	31.4/18
2	CL=5%	2.78M	-0.0326 \pm 0.0013	32.2/18
3	CL=10%	2.50M	-0.0329 \pm 0.0014	30.0/18
4	CL=20%	2.11M	-0.0326 \pm 0.0015	25.9/18
5	CL=2%, $E_\gamma < 1.1\text{GeV}$	2.76M	-0.0320 \pm 0.0013	26.9/18
6	CL=2%, $E_\gamma < 0.9\text{GeV}$	2.18M	-0.0321 \pm 0.0015	20.2/18
7	CL=2%, $E_{cb} < 0.42\text{GeV}$	2.83M	-0.0316 \pm 0.0013	29.1/18
8	CL=2%, $E_{cb} < 0.47\text{GeV}$	2.60M	-0.0319 \pm 0.0013	30.7/18
9	CL=2%, $\cos \theta_\eta < 0$.	1.73M	-0.0334 \pm 0.0017	23.5/18
10	CL=2%, $\cos \theta_\eta > 0$.	1.32M	-0.0312 \pm 0.0019	14.5/18
11	CL=2%, 7cl	2.39M	-0.0323 \pm 0.0014	26.4/18
12	CL=2%, 6cl	0.663M	-0.0292 \pm 0.0027	22.0/18

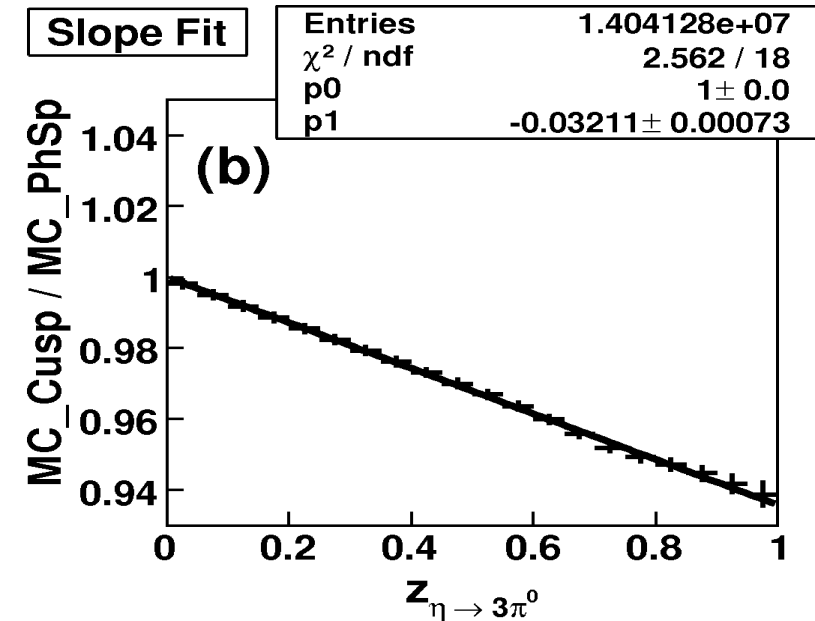
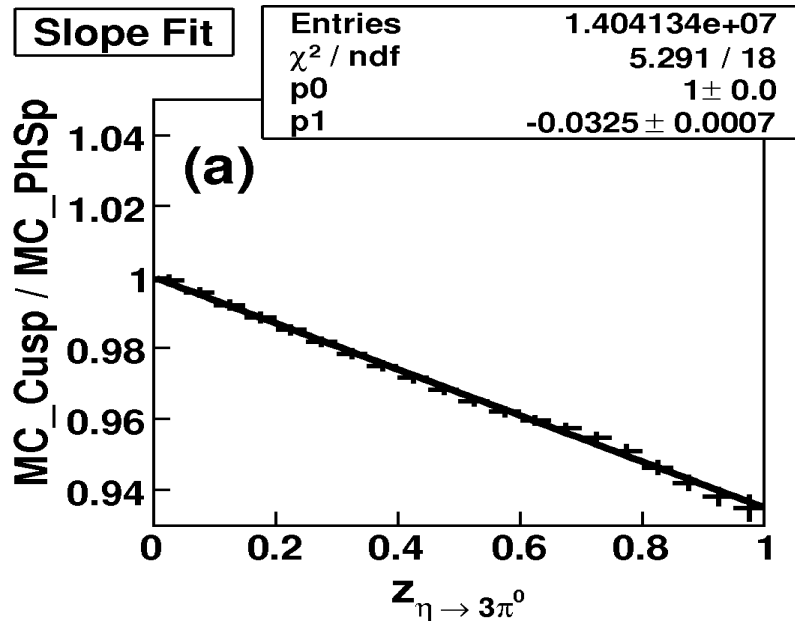
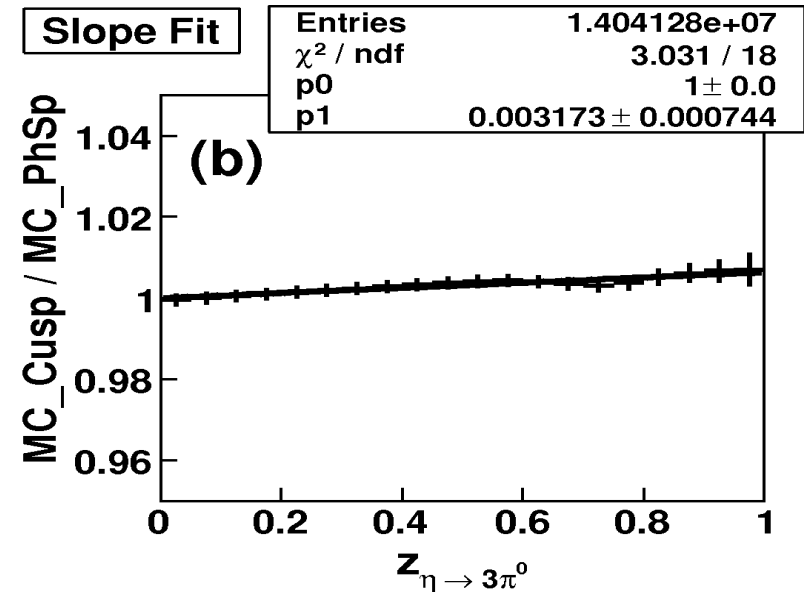
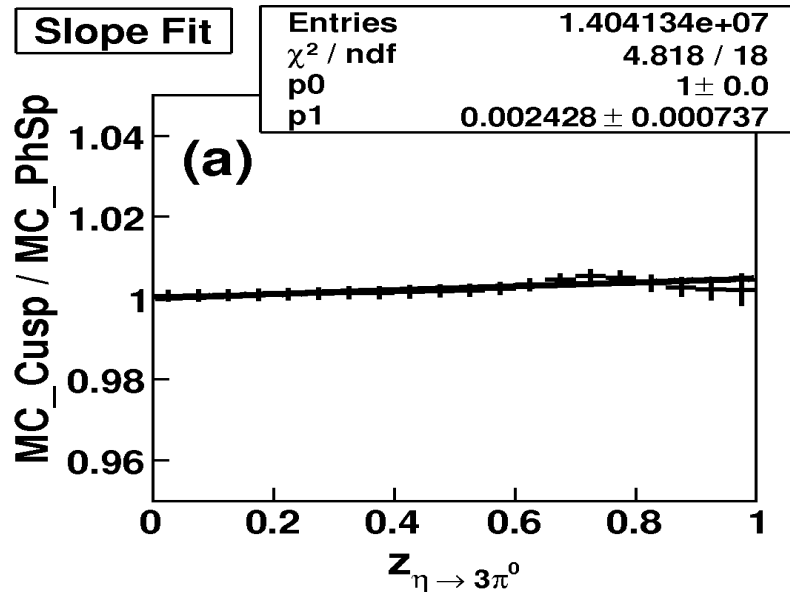
Looking for a cusp-like structure in $m(\pi^0\pi^0)$

Bissegger et al. Phys.Lett.B 659 (2008) 576

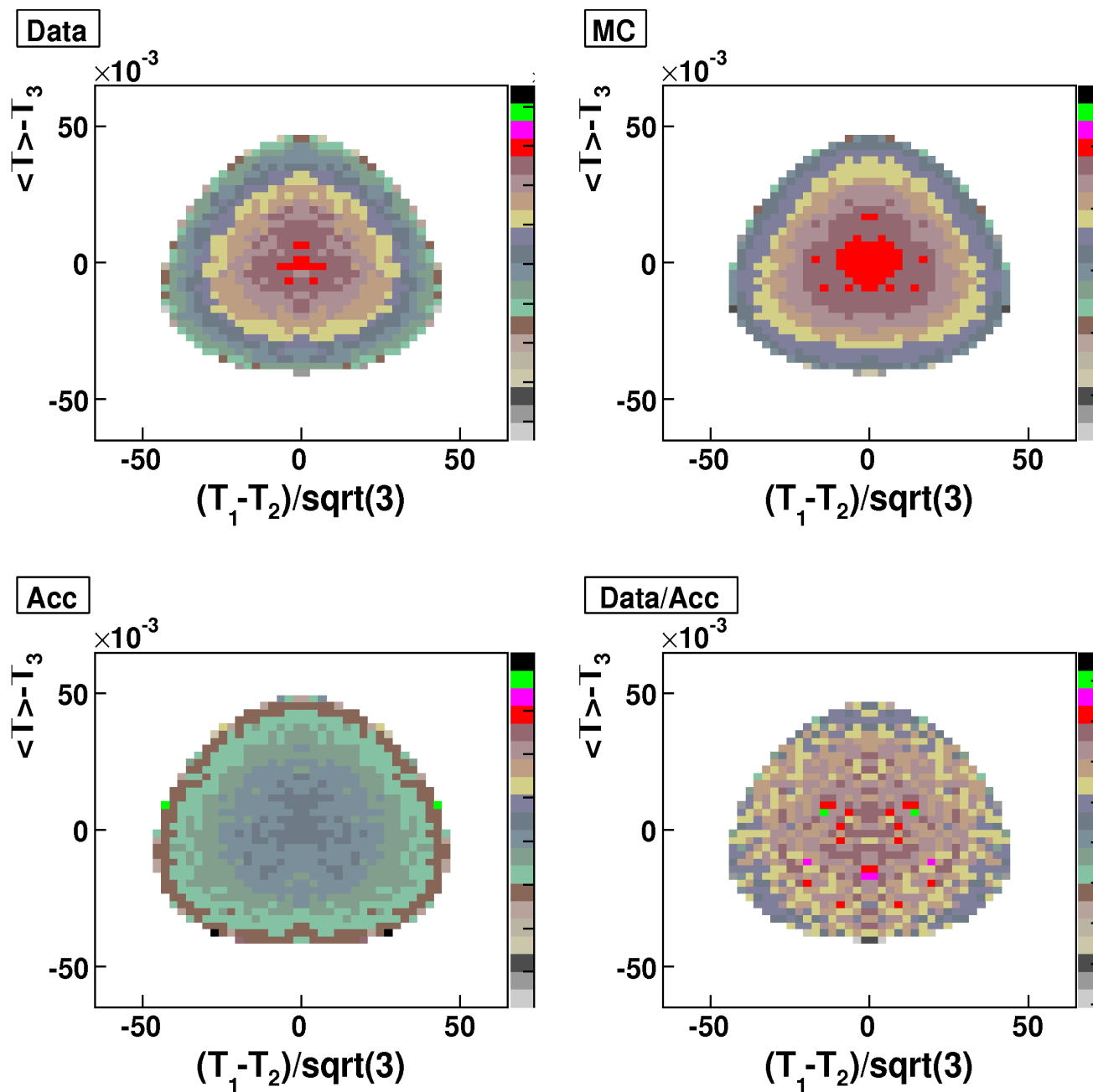
$A(\eta \rightarrow 3\pi^0) = u_0 + u_1 z$; $A(\eta \rightarrow \pi^+\pi^-\pi^0) = v_0 + v_1 y + v_2 y^2 + v_3 x^2$;
tried $v_0/u_0 = -1/3(+1/3)$ and $v_0=1$, $v_1=-0.52*1.25$, $v_2=-0.063$,
 $v_3=0.025$, $\alpha = -0.038$ from $\eta \rightarrow \pi^+\pi^-\pi^0$ of KLOE



Influence of the cusp structure on the z distribution



Experimental Dalitz plot for $\eta \rightarrow 3\pi^0$



Final remarks on the $\eta \rightarrow 3\pi^0$ analysis

- “Standard” analysis of $\eta \rightarrow 3\pi^0$ decays from the CB data at MAMI-C yields $\alpha = -0.032 \pm 0.003$, confirming the PDG value, $\alpha = -0.031 \pm 0.004$.
- A cusp-like structure in $m(\pi^0\pi^0)$ from $\eta \rightarrow 3\pi^0$ decays is seen on the level $\leq 1\%$. More statistics is needed to understand the structure better.
- Neglecting the $\eta \rightarrow \pi^+\pi^-\pi^0$ contribution in the $\eta \rightarrow 3\pi^0$ analysis can result in a biased value for α .
- Joint analysis of the $\eta \rightarrow 3\pi^0$ and $\eta \rightarrow \pi^+\pi^-\pi^0$ decays is needed for more reliable results on their parameters.