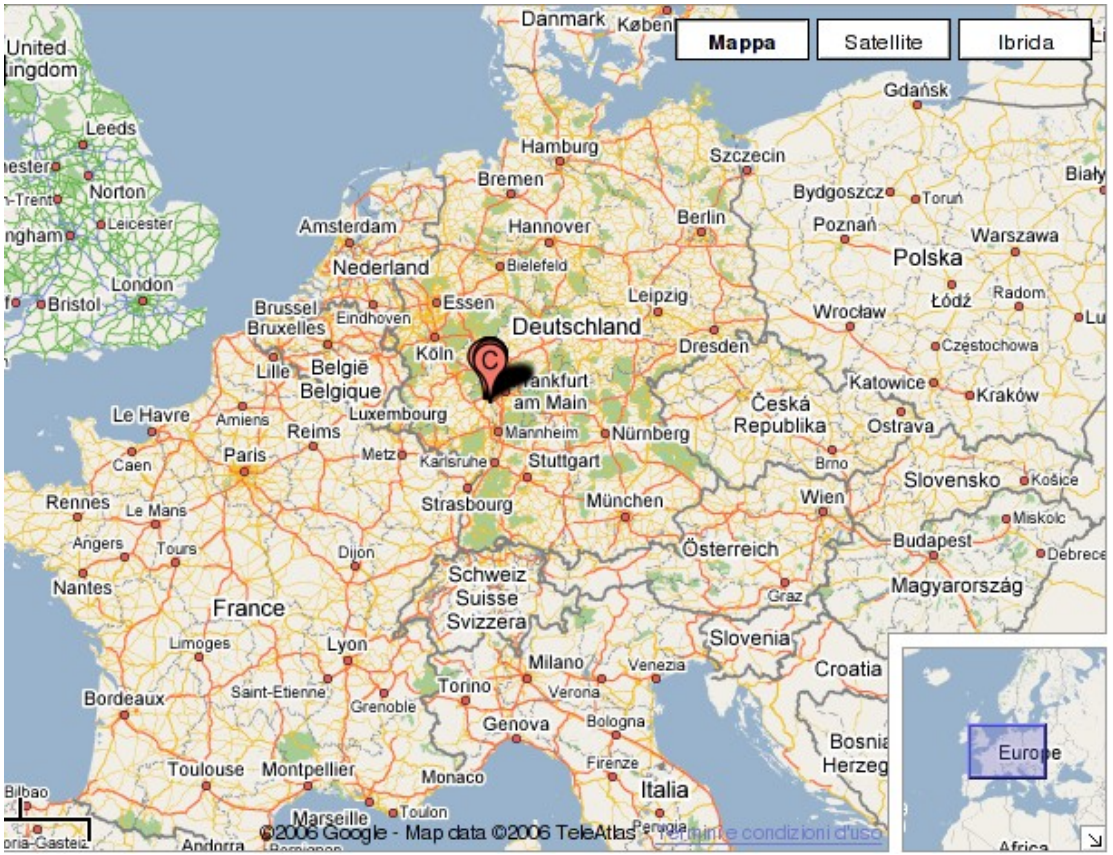
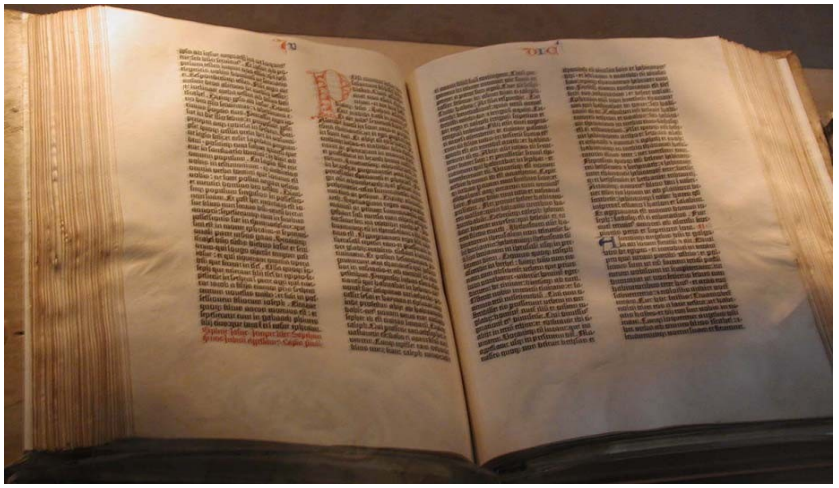
Report from the η network meeting in Mainz



B. Di Micco



Outline

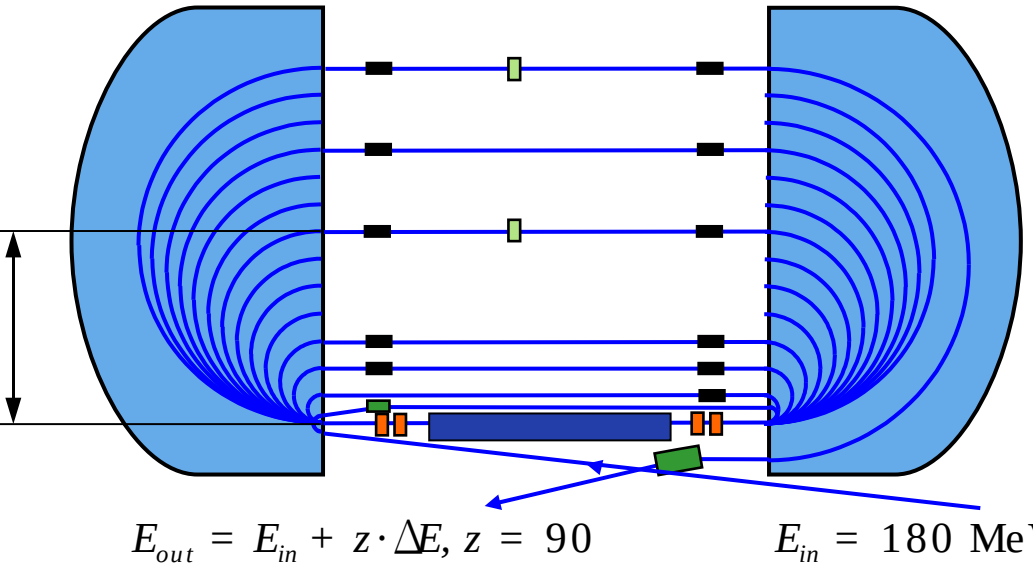
- η mass measurement @ MAMI-Crystal Ball
- $\eta \to 3\pi^0$ slope new measurement from CB@BNL, CB@MAMI, and WASA@CELSIUS;
- $\eta \to \pi^0 \gamma\gamma$ measurement in progress @ MAMI-Crystal Ball;
- $\eta \to e^+e^- \pi^+ \pi^-$ from WASA@CELSIUS

η mass measurement CB@MAMI

- η production threshold measurement from $\gamma p \rightarrow p\eta$.
- The mass of η is calculated from relation:

$$m_\eta = -m_p + \sqrt{m_p^2 + 2 \cdot m_p \frac{E_\gamma^{thr}}{c^2}}$$

where m_p is the proton mass, E_γ^{thr} – production threshold (the measurement)



$E_{out} = E_{in} + z \cdot \Delta E,\ z = 90$ $\qquad$ $E_{in} = 180$ MeV

RTM 3

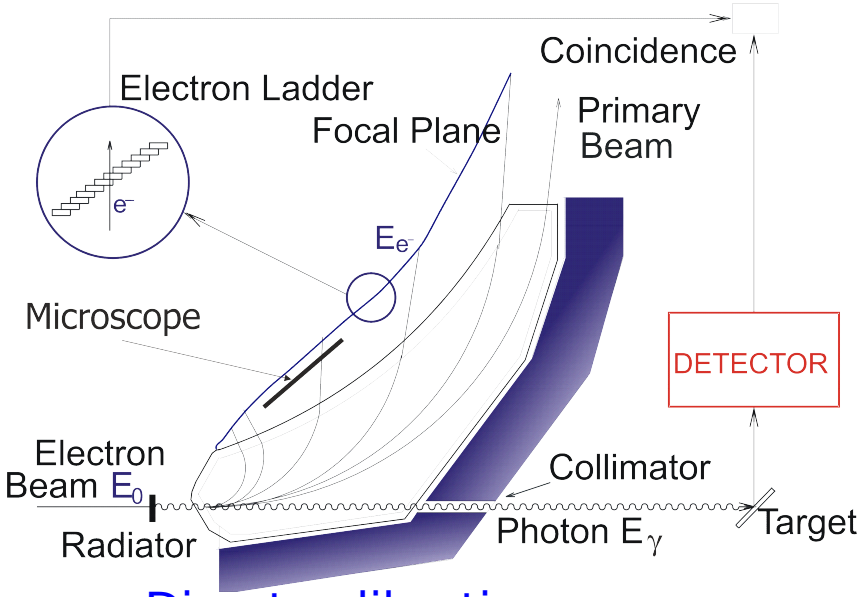
$B = 1.3260$ T $\pm$ 0.13 mT
$\Delta E = \sim 7.81 \pm 0.02$ MeV
$D_{73} = 3768.45 \pm 0.4$ mm

$E_{73} =$ 751.649 $\pm$ 0.107 MeV

Extrapolate to end energy:
$E_{out} = 883.X \pm 0.16$ MeV (FWHM)
$\sigma_{Eout} = 68$ keV

γ energy determination

The photons are produced by the bremsstrhalung of bent electrons.



- The energy E_γ of the photon is determined by: $E_\gamma = E_0 - E_{e-}$

$$\sigma^2_{E_\gamma} = \sigma^2_{E_0} + \sigma^2_{E_{e-}}$$

$\sigma_{Ee-} = 0.27\ \mu ch = 78\ \text{keV}$ $\sigma_{Eout} = 68\ \text{keV}$

$$\sigma(threshold) = 103\ \text{keV}$$
$$\sigma(m_\eta) = 65\ \text{keV}$$

-- Direct calibration:

– position of the MAMI electron beam for the energies E_{e^-} = 180.1 MeV, 195.2 MeV and 210.2 MeV using ($B_{cal} = B_{exp}$ = 1.049 T).

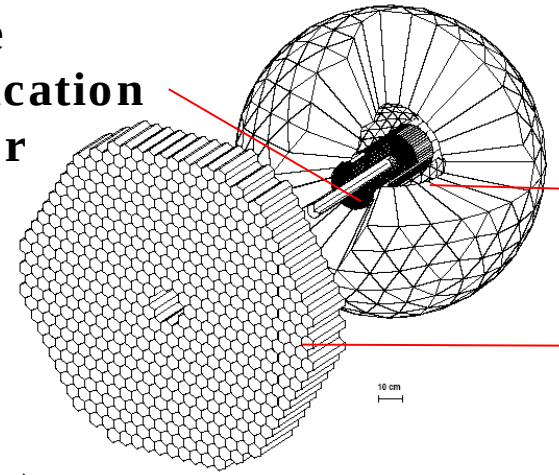
– Scan beam through microscope varying the dipole field:

– Increase tagger dipole magnetic field B_{cal} in small steps.

$$E_{e^-} = E_0 \times \frac{B_{exp}}{B_{cal}}$$

– Measure new electron beam position supposing equivalen electron beam energy for a given field setting B_{cal} :

Crystal Ball/TAPS detector

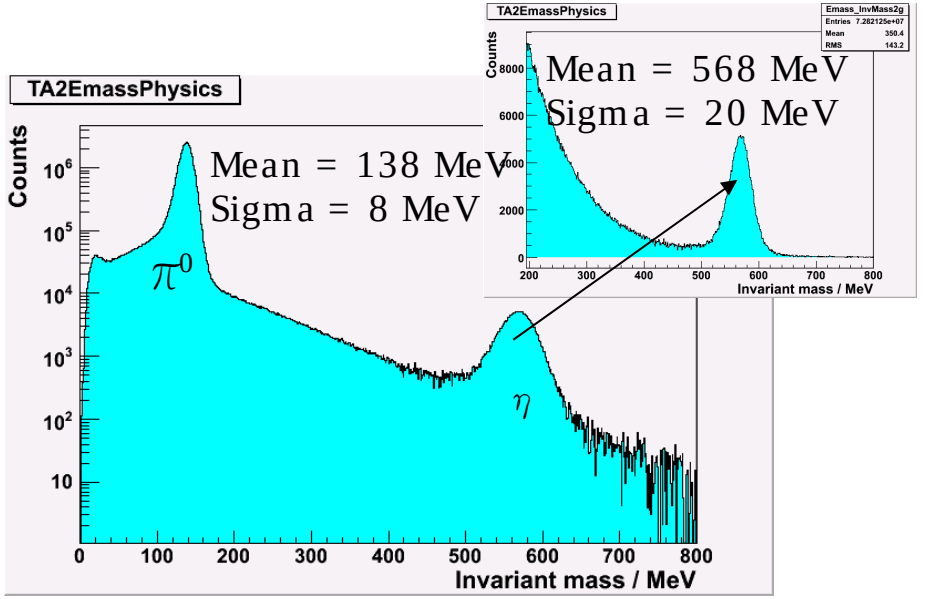


Crystal Ball detector:

- 672 NaI crystals
- measures E_γ and Θ_γ

$$\begin{cases} \eta \to 2\gamma & (39.43 \pm 0.26)\% \\ \eta \to 3\pi^0 & (32.51 \pm 0.29)\% \end{cases}$$

- η mesons are identified via their uncharged decay modes.
- Events with 2 photons and 6 photons (with or without proton) are investigated.

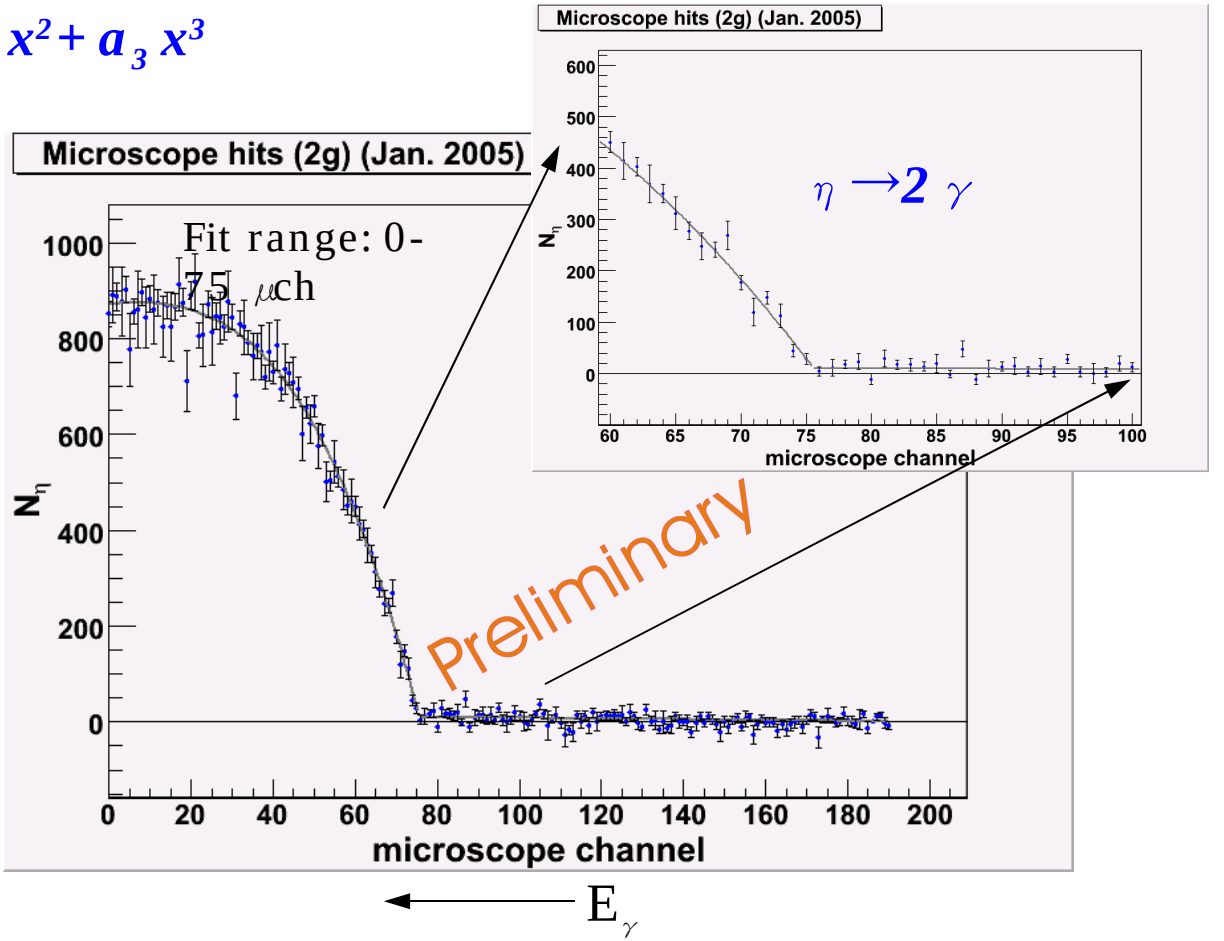


Estimated error and informal expectation

Fit function: $f(x)= a_0 + a_1 x + a_2 x^2 + a_3 x^3$

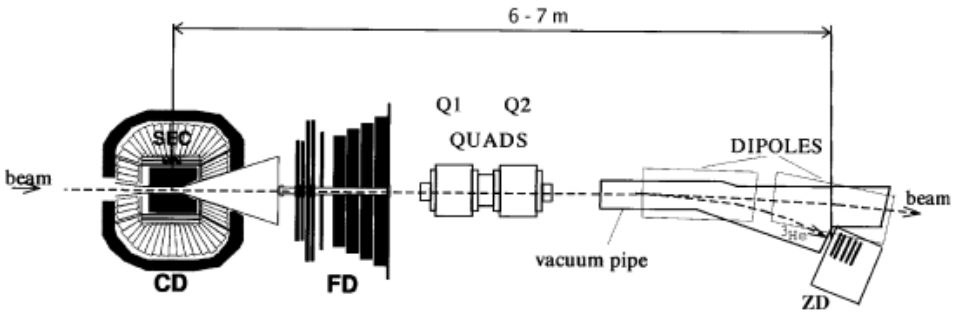
13 keV uncertainty from fit range variation.
65 keV from MAMI and tagger calibration.
Selection systematic to be computed. Informal

(they find an high value of the mass).



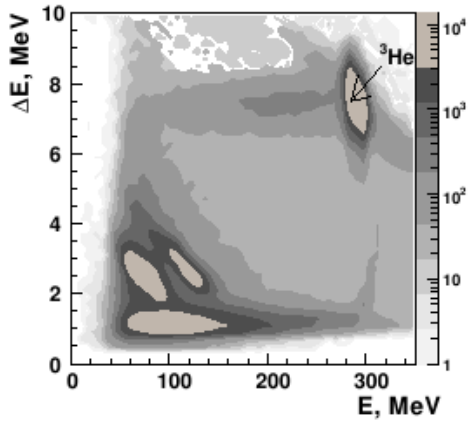
$\eta \to 3\pi^0$ @ WASA@CELSIUS ($dp \to \eta\, {}^3He$)

WASA detector with Zero Degree spectrometer

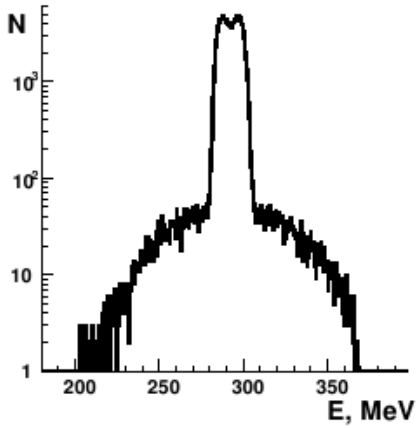


ZD spectrometer

2 Si (1.3mm) layers
2 Ge (29.4mm) layers
Operated at LN_2 temp.
^3He stopped up till 400 MeV
$\frac{\Delta E}{E}$(FWHM) = 1.5 MeV @300MeV



ΔE – deposition in Si layers
E – deposition in Ge layers



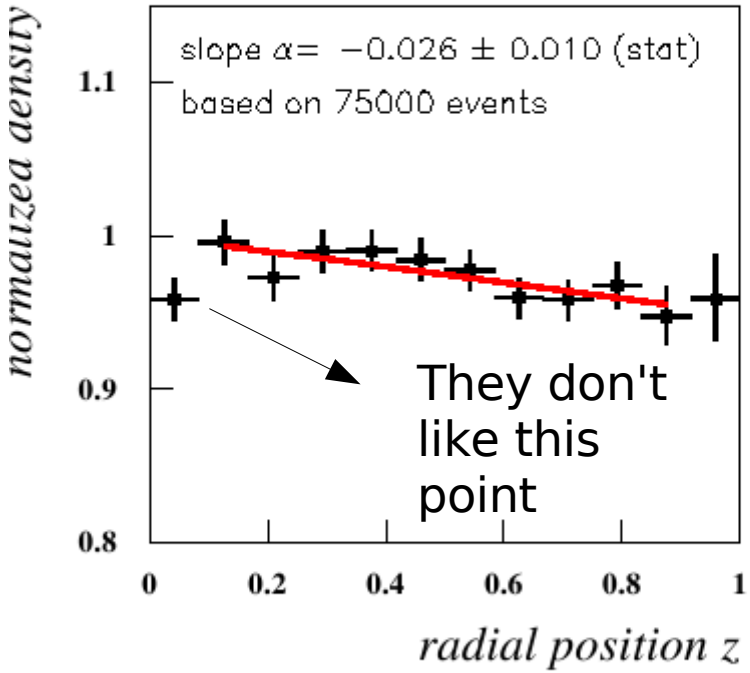
Energy spectrum of ^3He nuclei

Peak from η production
Less than 2% background, mainly due to direct 2π production

$\eta \to 3\pi^0$ @ WASA@CELSIUS (no hope to compete)

- $|A|^2 \sim 1 + 2\,\alpha\, z$

$$z = \frac{2}{3}\sum_{i=1}^{3}\left(\frac{3E_i - m_\eta}{m_\eta - 3m_{\pi^0}}\right)^2 = \frac{\rho^2}{\rho^2_{max}}$$



(based on combined data set, T=1360 MeV and T=1450 MeV)

$\alpha = -0.026 \quad \pm 0.010$ (stat)
± 0.010 (syst)

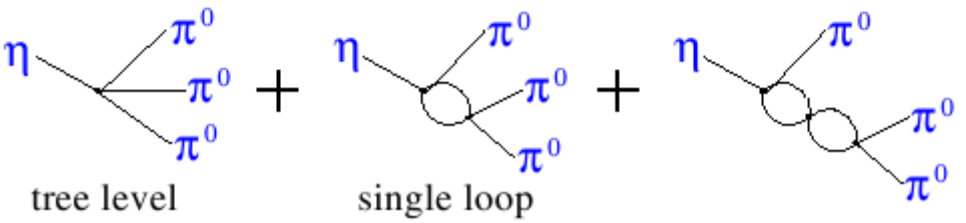
for comparison:

experimental results:

Crystal Ball (2001)	$\alpha = -0.031 \pm 0.004$
KLOE (2005)	$\alpha = -0.013 \pm 0.006$

theoretical predictions:

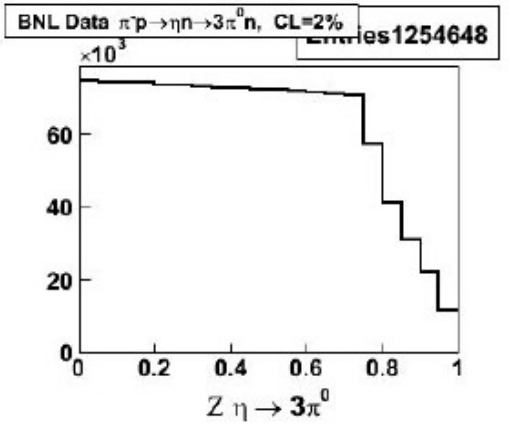
Borasoy et al. (2005)	$\alpha = -0.031 \pm 0.003$
Beisert et al. (2003)	$\alpha = -0.007$
Kambor et al. (1996)	$\alpha = -0.007/-0.014$
ChPT tree level	$\alpha = 0.000$

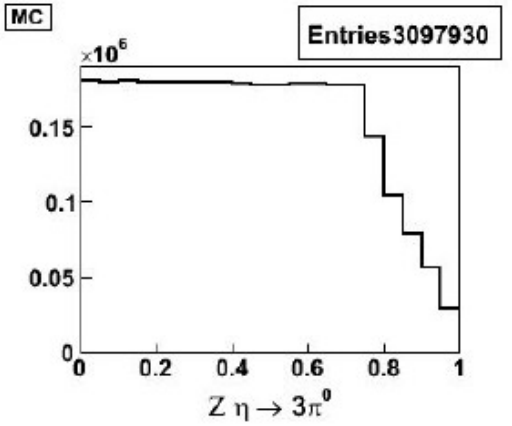


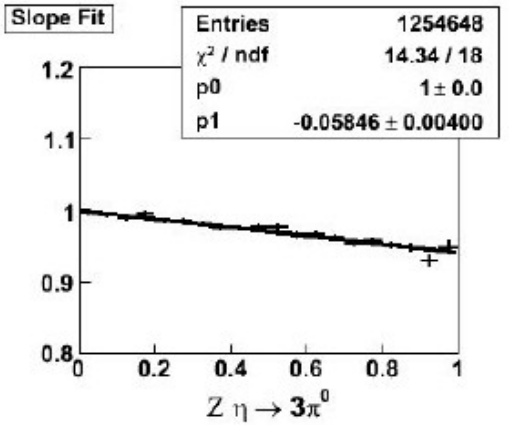
$\eta \to 3\pi^0$ from Prakhov @ BNL new measurement

PDG $\alpha = -0.031 \pm 0.004$ is based on analysis of 0.9M $\eta \to 3\pi^0$ events. More recent (unpublished) result from the CB@BNL data $\alpha = -0.029 \pm 0.002_{stat}$ is based on 1.25M events (from 27M η's produced)

New measurement with CB@BNL data

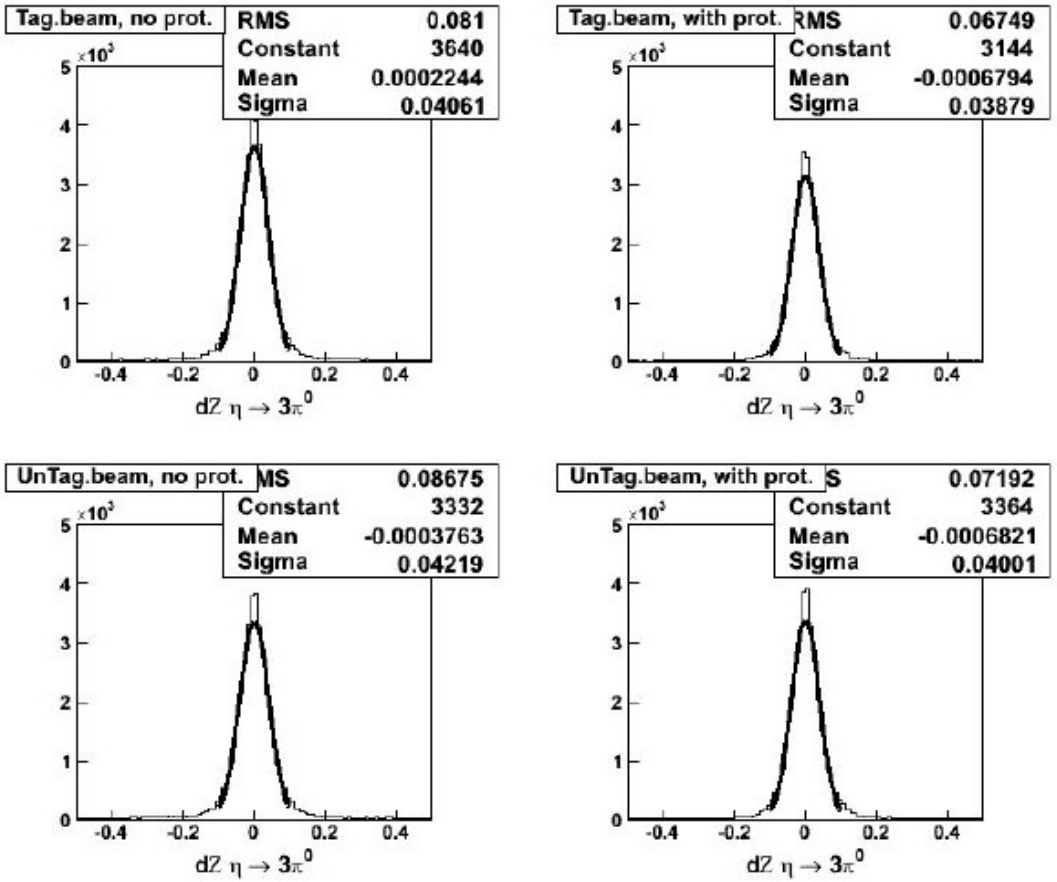






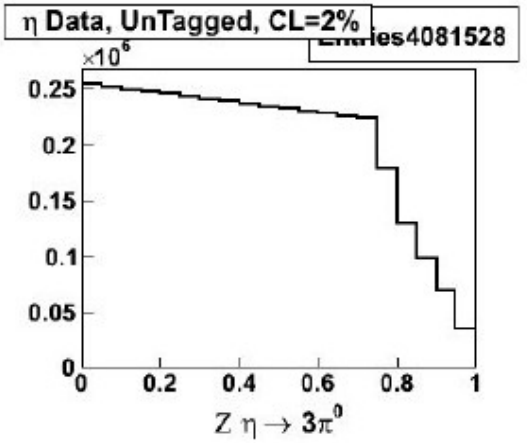
$\eta \to 3\pi^0$ from Prakhov @ MAMI
Z resolution

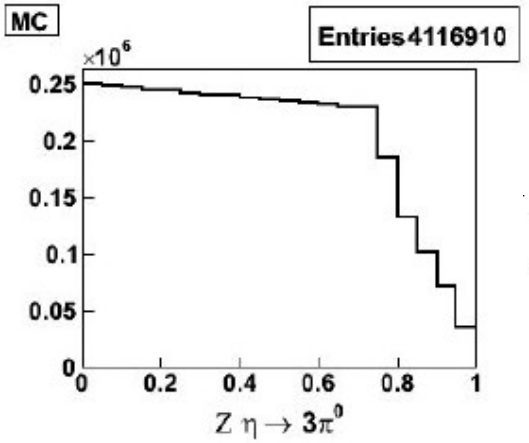
Resolution in the variable Z for different reconstruction conditions varies from 0.039 to 0.042 that allows to divide 0<Z<1 interval in 20 bins

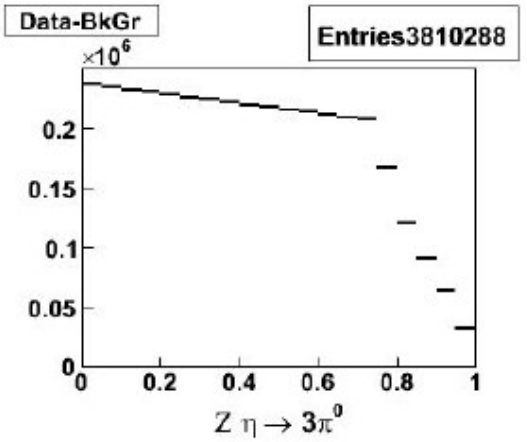


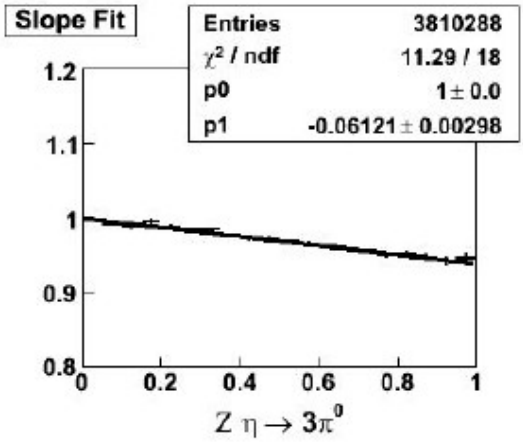
$\eta \to 3\pi^0$ from Prakhov @ MAMI first results

Slope fit for the highest statistics data sample of 3.8M $\eta \to 3\pi^0$ events collected at CB@MAMI (from 30M η's produced)



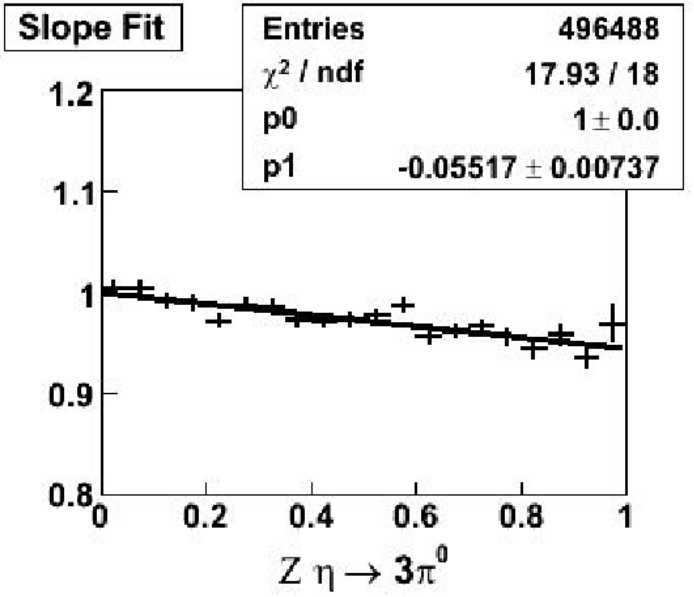






$\alpha = -0.0306 \pm 0.0015_{stat}$

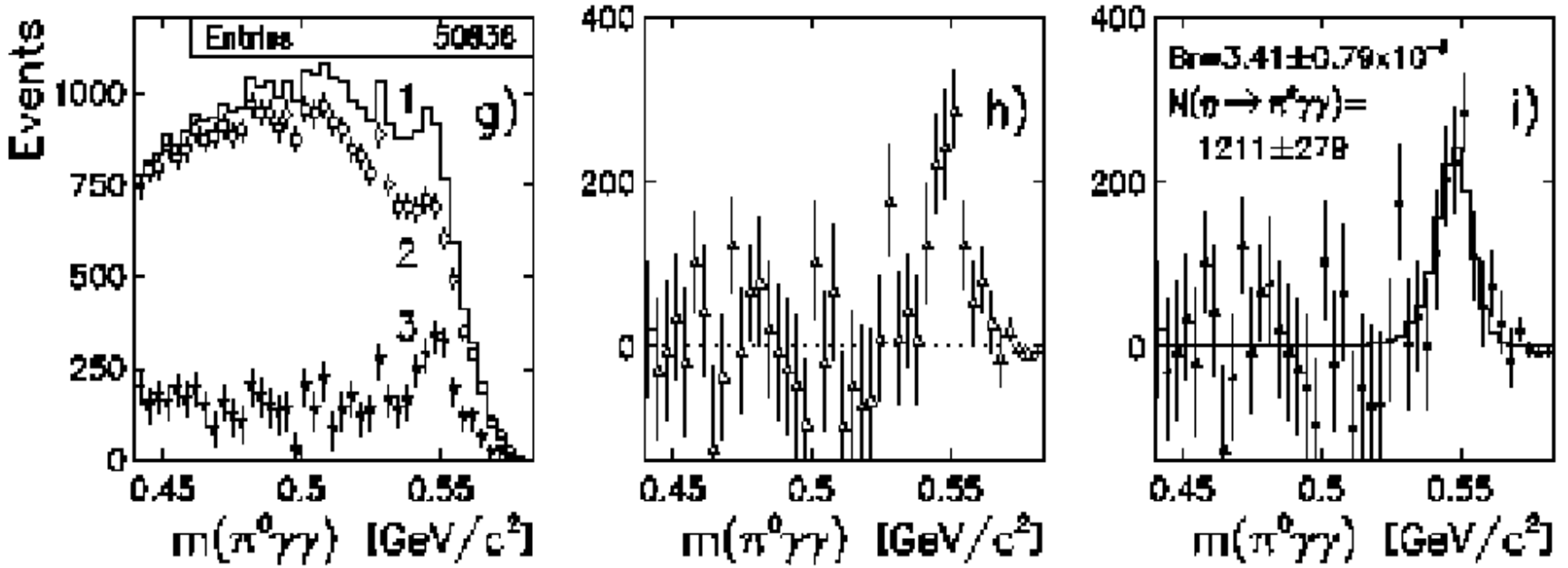
Require proton for signal selection



$\alpha = -0.028 \pm 0.004_{stat}$

$\eta \to \pi^0\gamma\gamma$ from CB@BNL

CB old analysis, huge background subtraction.

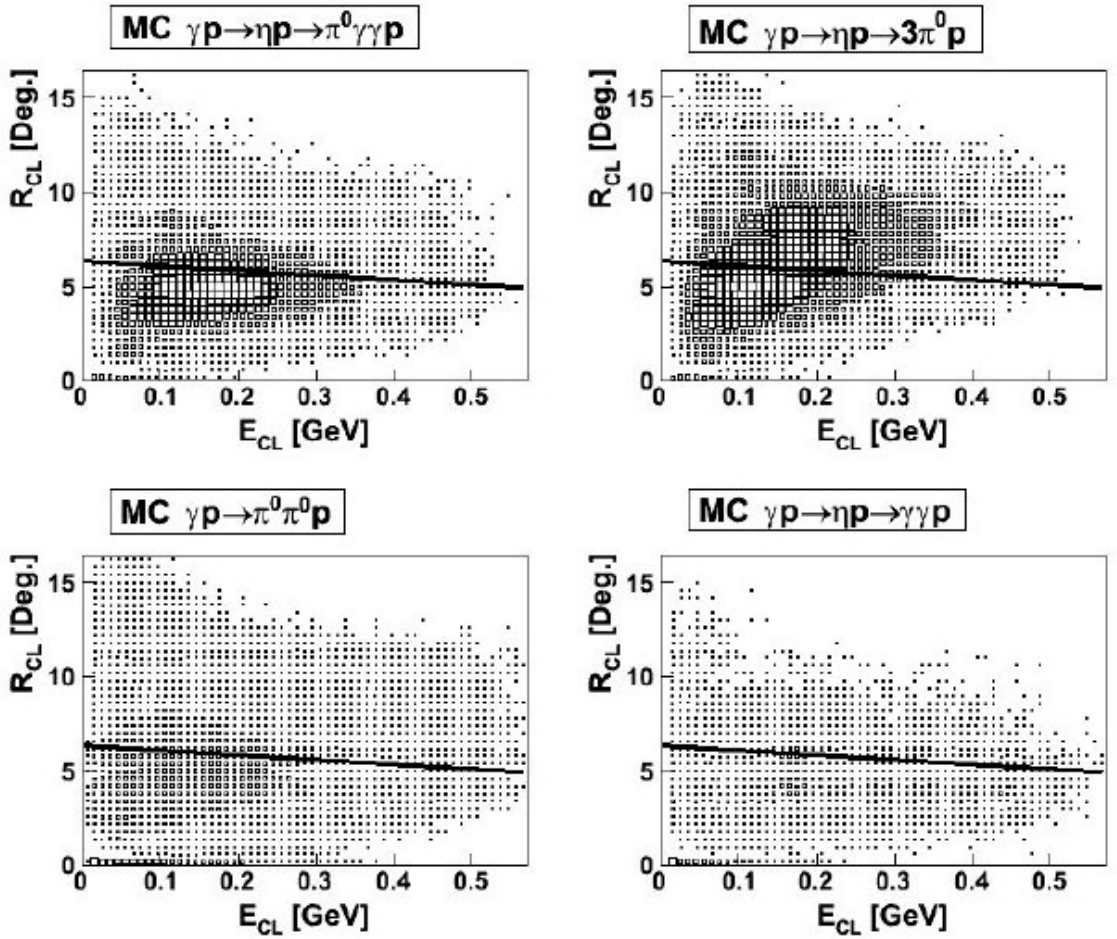


$\eta \to 3\pi^0$ subtracted

$\eta \to \gamma\gamma$ subtracted

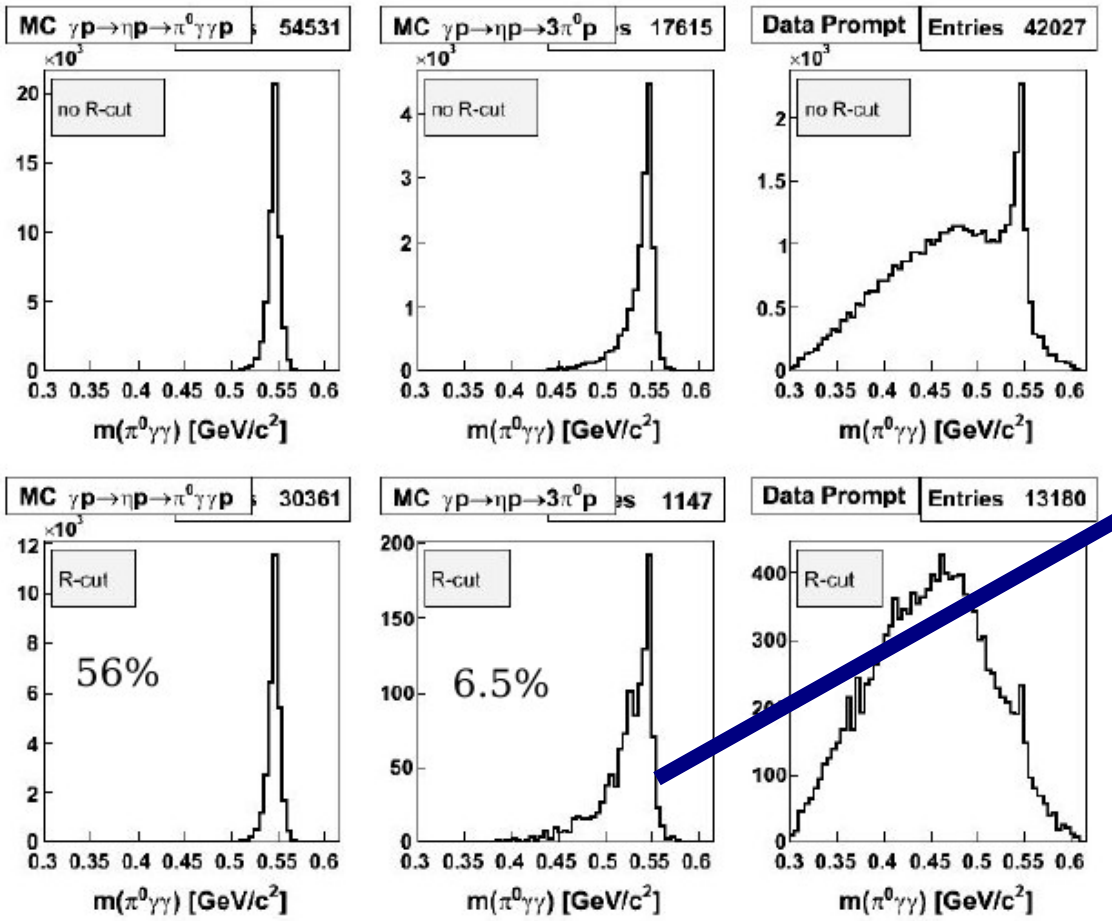
$\eta \to \pi^0\gamma\gamma$ from CB@MAMI, merging rejection

Plot of cluster radius R in the CB vs cluster energy E for MC of different reactions. Cut discards events which have entries above the line.



Rejection power of the cut

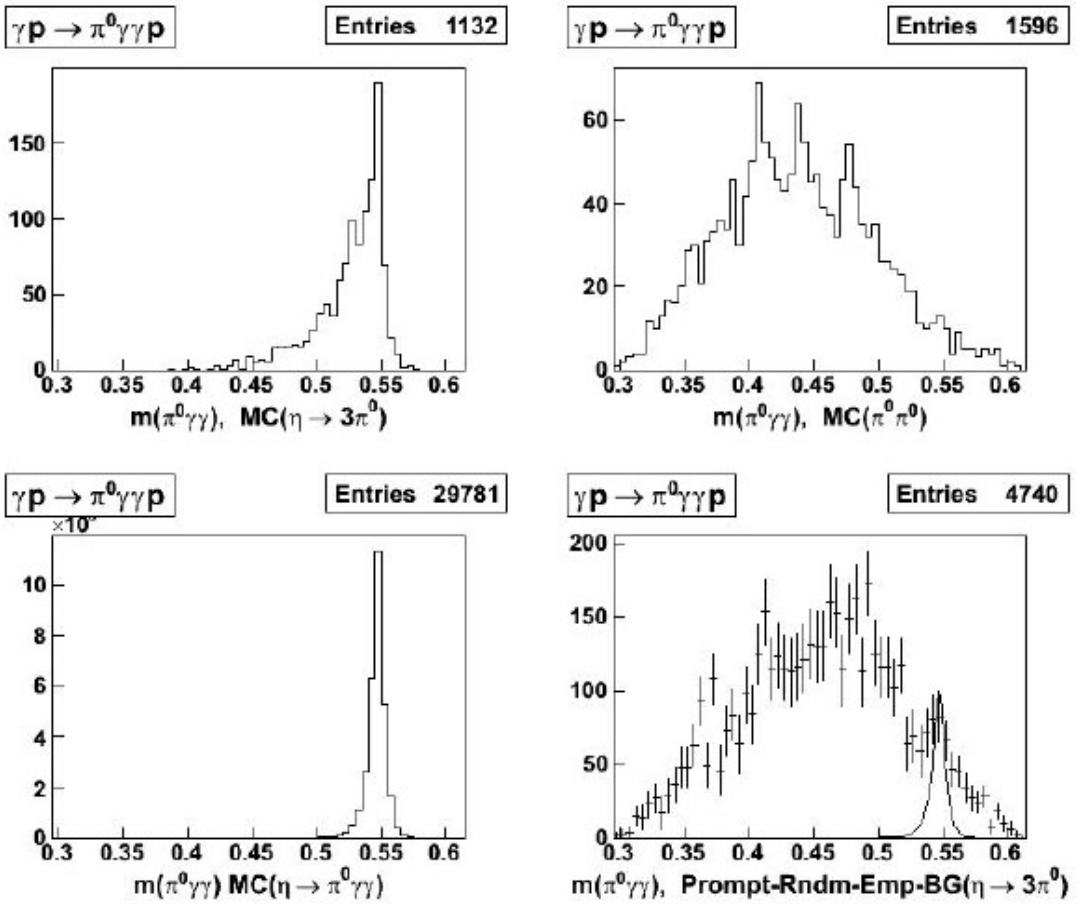
Result of applying R-cut for MC of $\eta \to \pi^0 \gamma\gamma$ and $\eta \to 3\pi^0$ and experimental events



The dangerous guy

The new guess

Subtraction of the $\eta \to 3\pi^0$ background and comparison of the remaining spectrum with the expected signal from $\eta \to \pi^0 \gamma\gamma$ assuming BR=$3.5*10^{-4}$

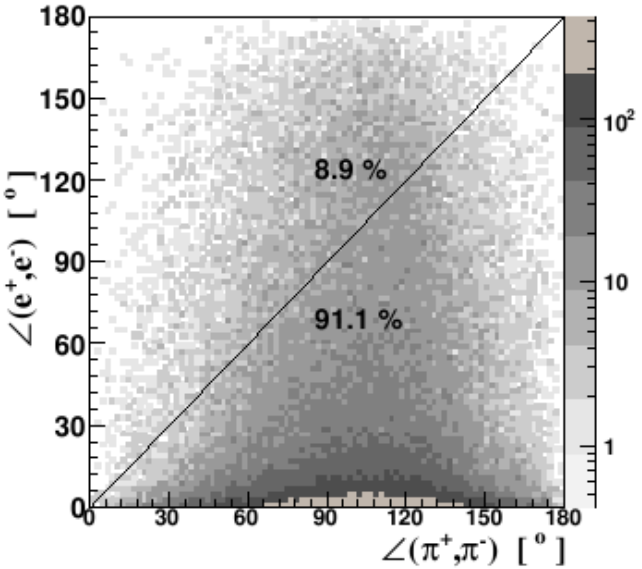


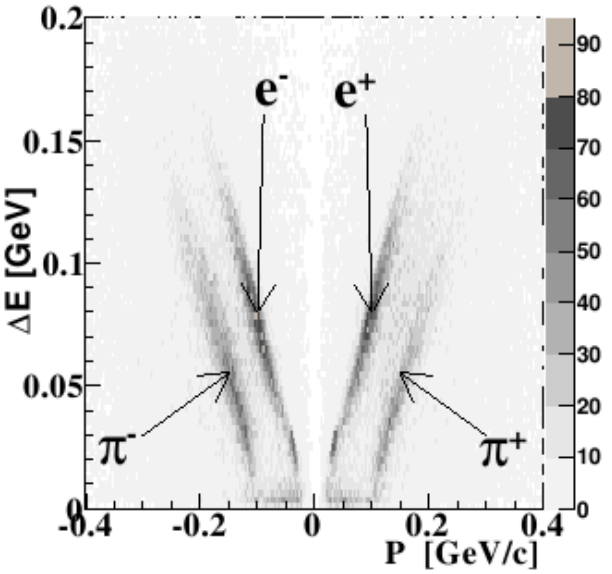
The signal yield is too high in case of CB@BNL measurement!! at least a factor 2

Particle identification - Monte Carlo

The two-lepton invariant mass is closely correlated to the opening angle between leptons leading to a sharp peak at small opening angles.
This feature is used for PID.

In addition ΔE(E)-P method is applied to all the track leaving MDC.



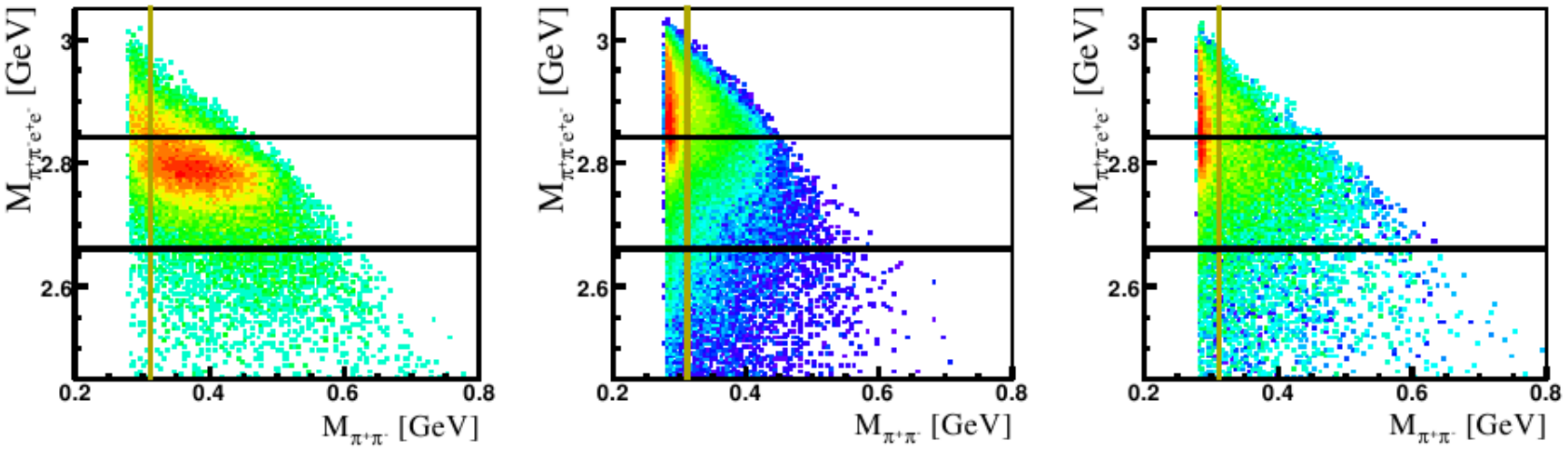


Overall identification is correct in 90% for MC.

$\eta \to \pi^+\pi^- e^+e^-$ Background rejection

Selection: $M_{\pi\pi}$ and $M_{\pi\pi ee}$

$\eta \to \pi^+\pi^- e^+e^-$ $\eta \to \pi^+\pi^-\pi^0$ $\eta \to \pi^+\pi^-\gamma$



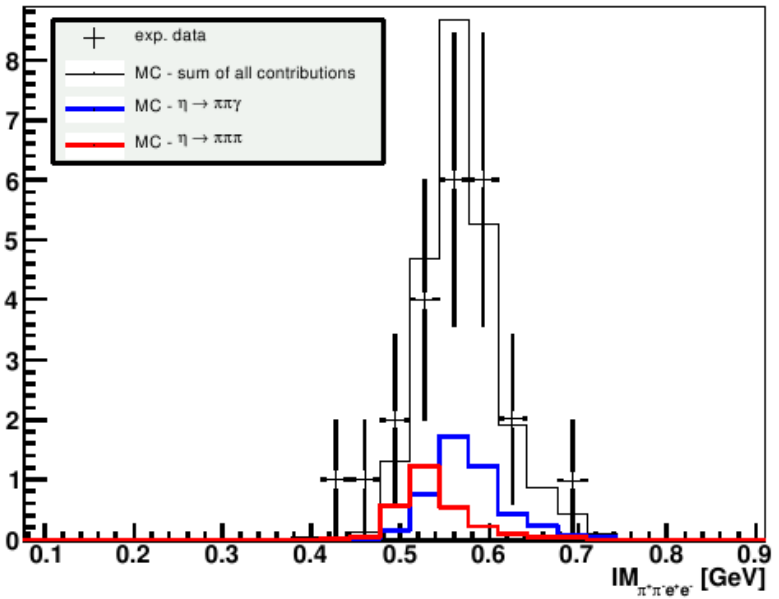
- $M_{\pi\pi} > 305$ MeV
- 2.65 GeV < $M_{\pi\pi ee}$ < 2.875 GeV

$\eta \to \pi^+\pi^- e^+e^-$ The result

Final IM$_{\pi^+\pi^- e^+e^-}$

- 23 events left
- 7 belonging to background decays
- 16 $\eta \to \pi^+\pi^- e^+e^-$

Efficiency cross checked with $\eta \to e^+e^-\gamma$

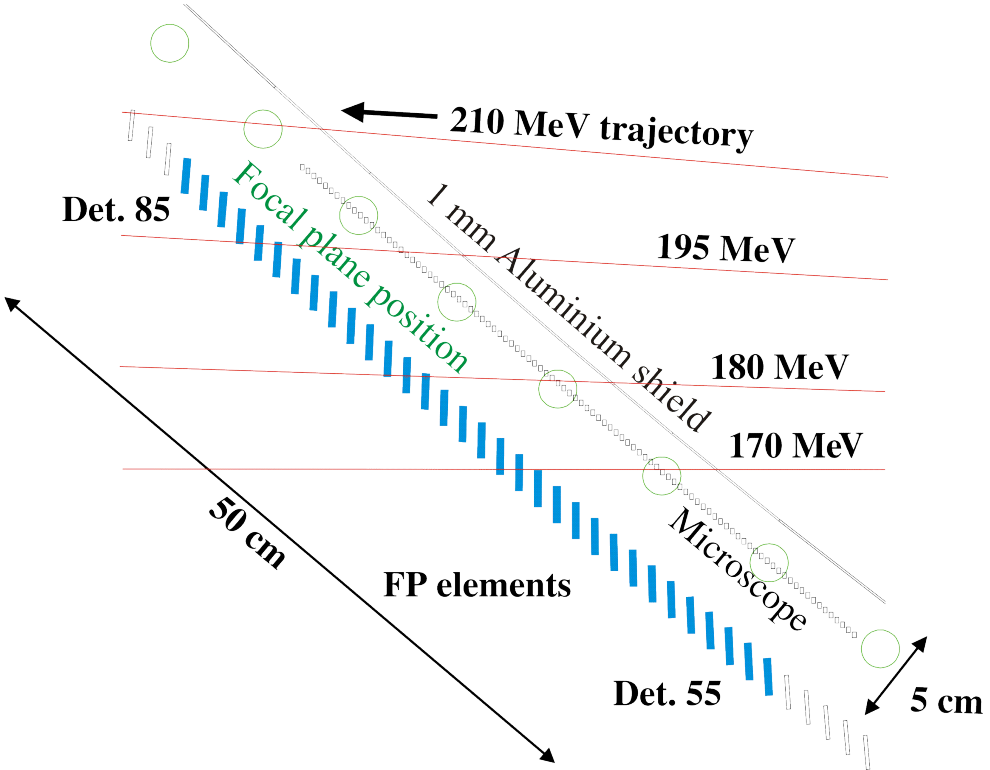


- 0.25 M ηs measured in reaction $pd \to {}^3\mathrm{He}\eta$ 1 MeV above thr.
- 16 $\eta \to \pi^+\pi^- e^+e^-$ events observed
- measurement gives BR = $(4.6 \pm 1.4 \pm 0.5) \times 10^{-4}$.
- Normalisation to $\eta \to \pi^+\pi^-\pi^0$ decay (33% acceptance)

Conclusions

- Several measurements are coming from new experiments;
  - η mass and $\eta \to \pi^0\gamma\gamma$ in our direction;
  - $\eta \to 3\pi^0$ in CB direction, but the only independent measurement cannot disentangle;
  - $\eta \to \pi\pi ee$, big room for improvements, both in Br and in CP violation study via asymmetries.

Tagger microscope detector



An array of **96 plastic scintillator fibres** (3 mm x 2 mm).

Each single fibre overlaps by 1/3 with its neighbor. The overlap region defines microscope detector channel μch **(191 channels in total)**.

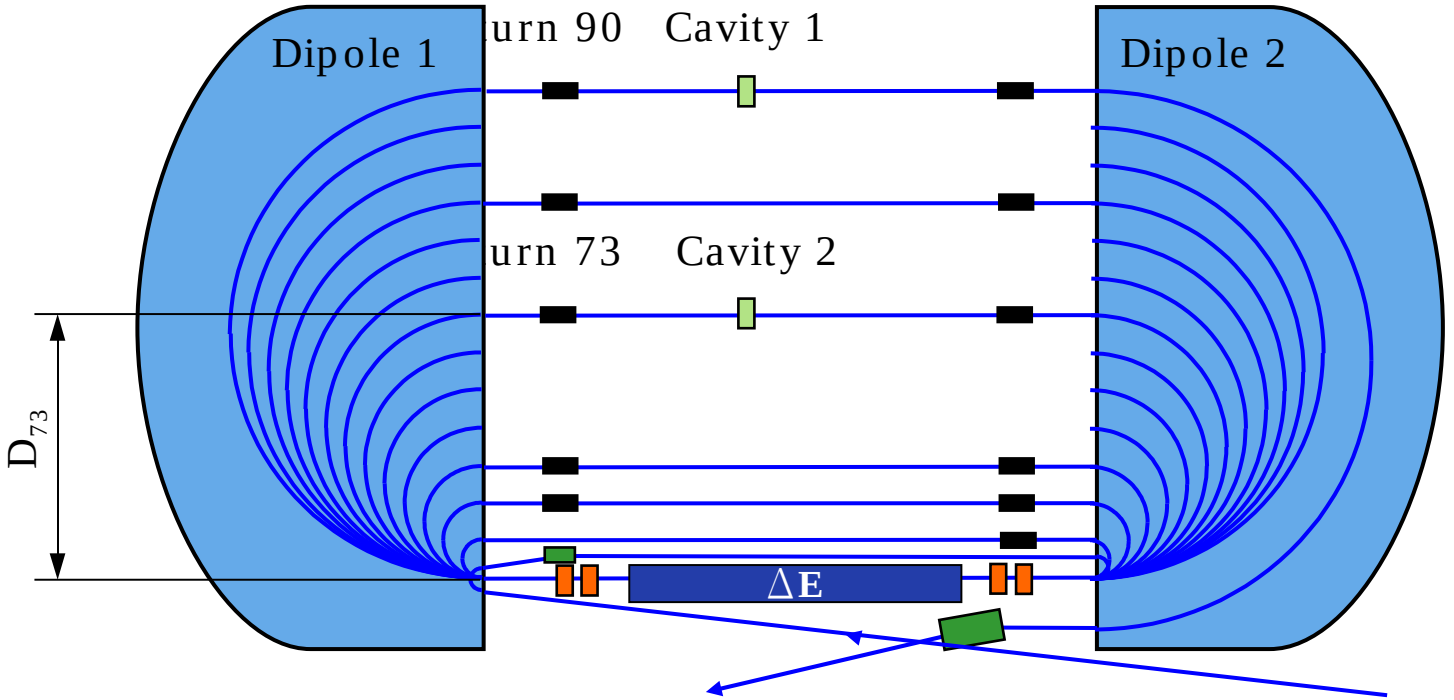
The energy resolution is **0.3 MeV per microscope channel** μch.

Tagger microscope is positioned to cover electron energies 153 to 209 MeV. At a beam energy of 883 MeV this corresponds to **tagged photons between 674 MeV and 730 MeV (** η **threshold ~707 MeV).**

MAMI energy determination uncertainty

$$E = e \cdot c \cdot B \cdot \frac{D}{2}$$

where e is electron charge, B is dipole magnetic field, D - electron track diameter.



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D_{73} = 3768.45 ± 0.4 mm

E_{73} = 751.649 ± 0.107 MeV

Extrapolate to end energy:
E_{out} = 883.X ± 0.16 MeV (FWHM)
σ_{Eout} = 68 keV

Slope fit for tagged $\eta \to 3\pi^0$ events with the proton required