

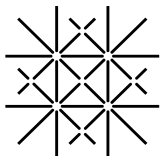
Coherent $\pi^0\pi^0$ and $\pi^0\pi^0\pi^0$ photoproduction on deuteron at MAMI

SPS Meeting 2017 - Genève, Switzerland

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August 24th 2017



Universität
Basel



Outline

① Motivation

- Strong hadronic interaction

- Known data

- Motivation

② Experimental settings

- Data information

③ Event selection

- Preselection and reconstruction

- Pion identification

- Deuteron identification

- Checking the selection process


④ Preliminary results

- Coherent Cross Sections

⑤ Outlook and Conclusion

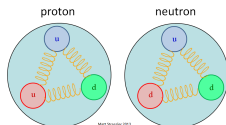
Fundamental forces

- ▶ Fundamental theories: Standard model and general relativity

- ▶ 4 fundamental interactions 
 - gravity
 - electronic
 - weak
 - strong

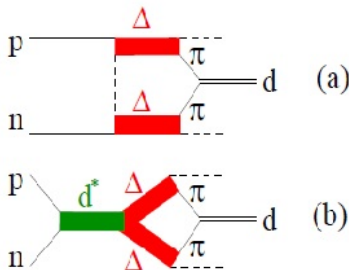
Strong Hadronic Interaction

- ▶ Quarks in Nuclei bound by strong interaction
- ▶ Hadrons are formed either with $q\bar{q}$ -pairs (meson) or with qqq -triplets (baryon)
 - ▷ What about more complicated bound states?
 - ▷ Exotic particles?



Access to exotic particles

- ▶ Exotic particles are still not completely verified
- ▶ $d^*(2380)$ is a much discussed candidate
 - ▷ Reported observation by CELSIUS/WASA and WASA@COSY
- ▶ Coherent photoproduction of π^0 -pairs is a possible production channel



- ▷ M. Bashkanov et al. (CELSIUS/WASA Collaboration)
Phys. Rev. Lett. 102, 052301
- ▷ P. Adlarson et al. (WASA-at-COSY Collaboration)
Phys. Rev. Lett. 106, 242302

Known quasifree $\pi^0\pi^0$ channel

- $\gamma + d \rightarrow \begin{matrix} p(n) \\ n(p) \end{matrix} + \pi^0\pi^0$ is rather well explored

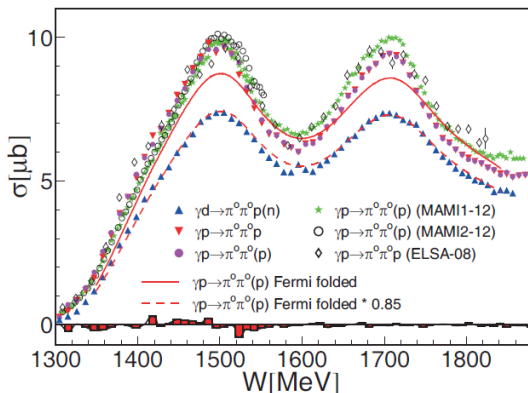


Figure: taken from M. Dieterle et al (Eur. Phys. J. A (2015) 51: 142)

Quasifree $\pi^0\pi^0\pi^0$ channel

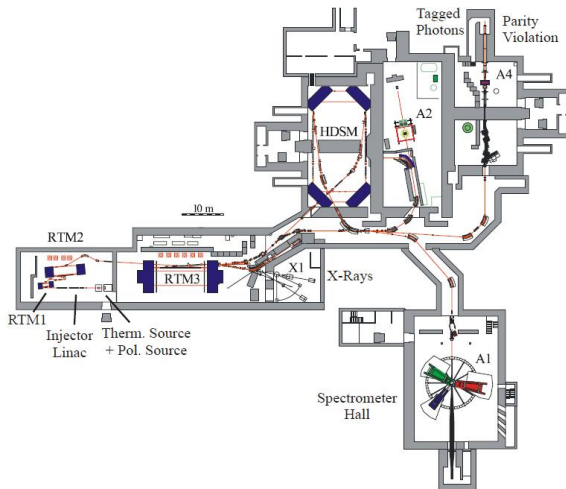
- ▶ $\gamma + d \rightarrow \begin{matrix} p(n) \\ n(p) \end{matrix} + \pi^0\pi^0\pi^0$ is mostly unknown
- ▶ Highly dominated by the $\eta \rightarrow \pi^0\pi^0\pi^0$ reaction
- ▶ No data has been published on isolated $\pi^0\pi^0\pi^0$ photoproduction off deuterium

Motivation

- ▶ $\pi^0\pi^0$ channel:
 - ▷ Possible access to $d^*(2380)$ di-baryon resonance
- ▶ $\pi^0\pi^0\pi^0$ channel:
 - ▷ First time analysis of this channel
- ▶ Help test and improve models for the strong hadronic interaction

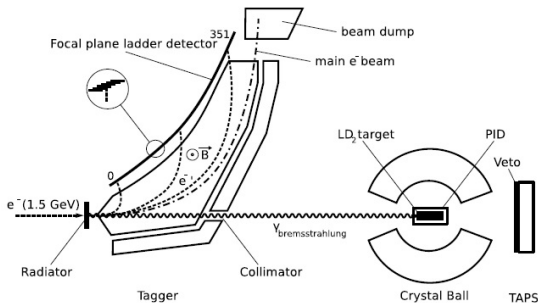
MAMI

- ▶ MAMI electron accelerator
- ▶ Cascade of racetrack Microtrons
- ▶ Final stage: Harmonic Double Sided Microtron
- ▶ Electron beam energy up to 1508 MeV



A2 - CB/TAPS

- ▶ Liquid deuterium target @A2 real photon experiment
- ▶ Glasgow Photon Tagger to identify photon energy
- ▶ Crystal Ball + TAPS - nearly 2π detector system
- ▶ Roughly 470 hours of data taking



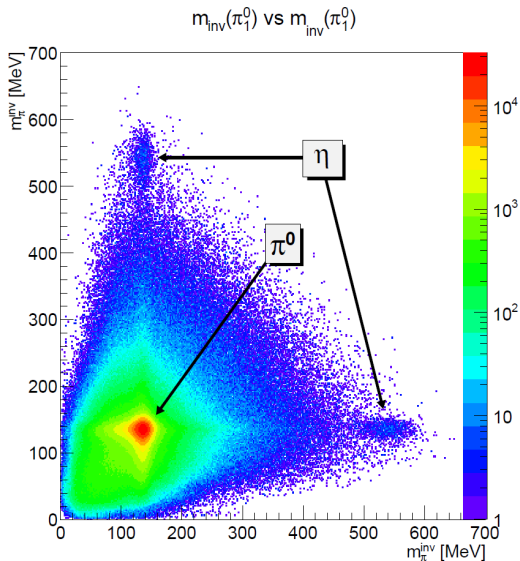
Presort and Reconstruction of π^0

- ▶ Final state*: $d + \pi^0\pi^0(\pi^0) \rightarrow d + \gamma\gamma + \gamma\gamma(+\gamma\gamma)$
- ▶ First step: Require 1 charged and 4 (6) uncharged particles
- ▶ Reconstruction of the π^0 s via χ^2 -method from the 4(6) neutral particles

* π^0 -decay probability into $\gamma\gamma = 98,823 \pm 0,034\%$

π^0 identification

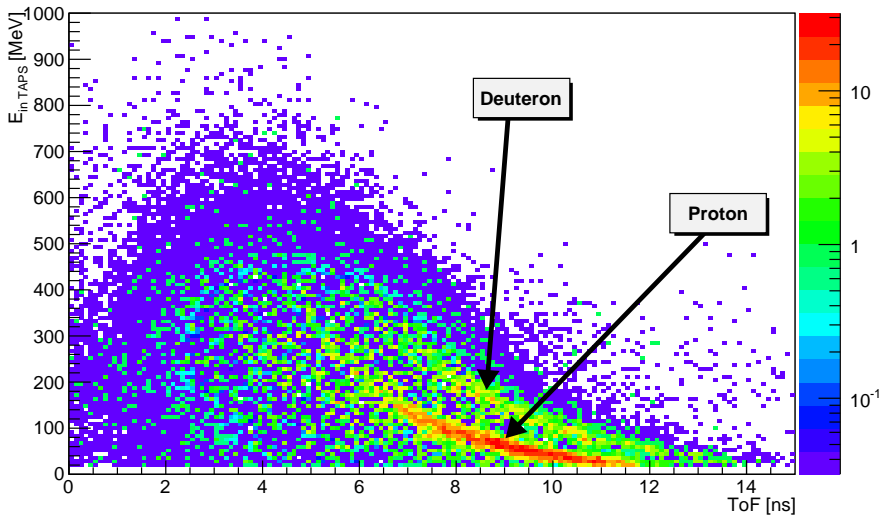
- ▶ Kinematic cuts on coplanarity and invariant mass of π^0
- ▷ Identify η background



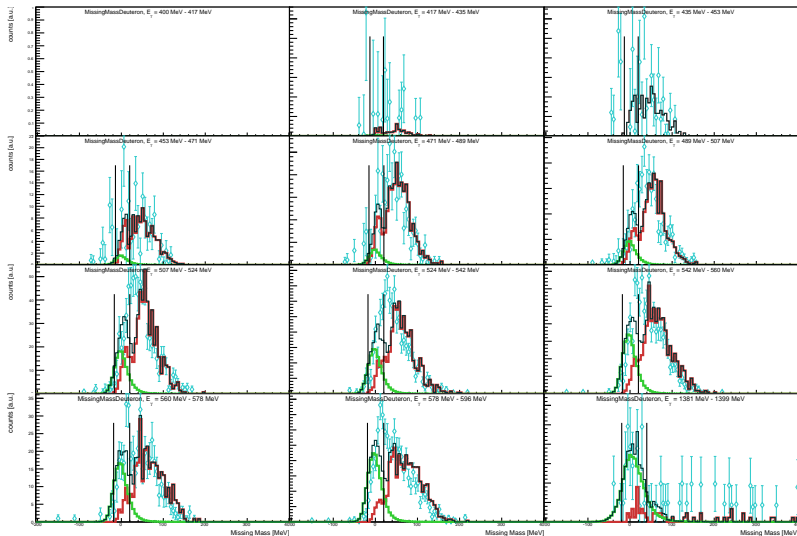
Deuteron identification

- ▶ Identification of deuterons is much more complicated
 - ▷ Highly dominated by quasi-free protons
 - ▷ Deuterons tend to get stuck in VETO/PID
- ▶ Kinematic cuts on Θ , missing mass, dE_E , ToF

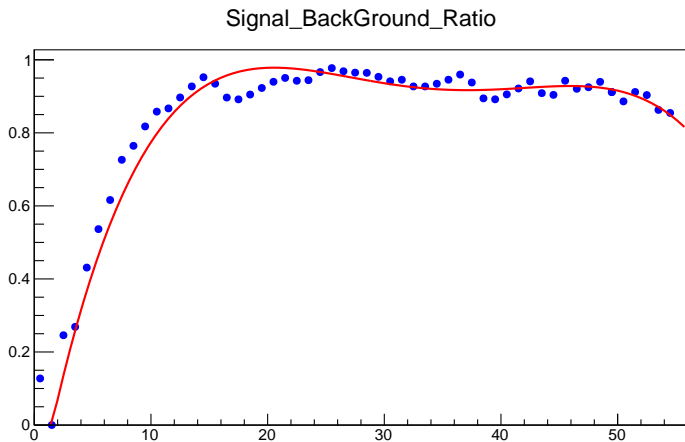
Deuteron time of flight



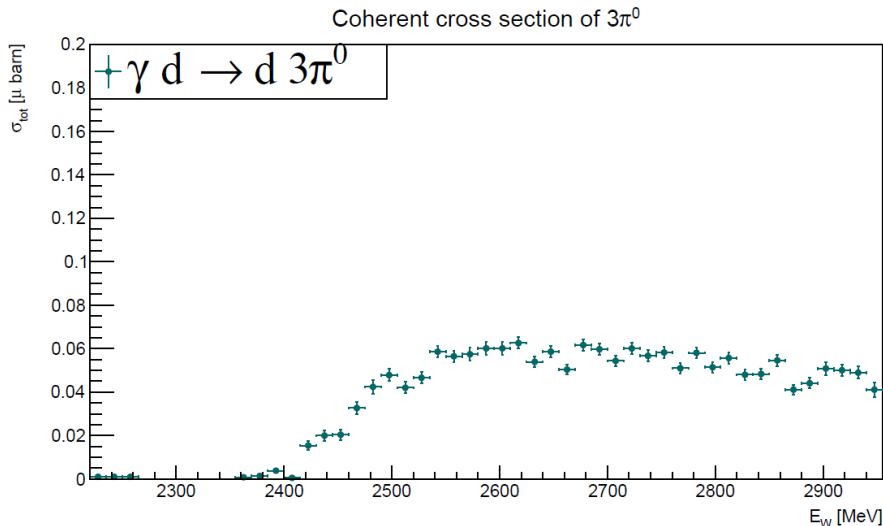
Check with Missing Mass



Check with Missing Mass

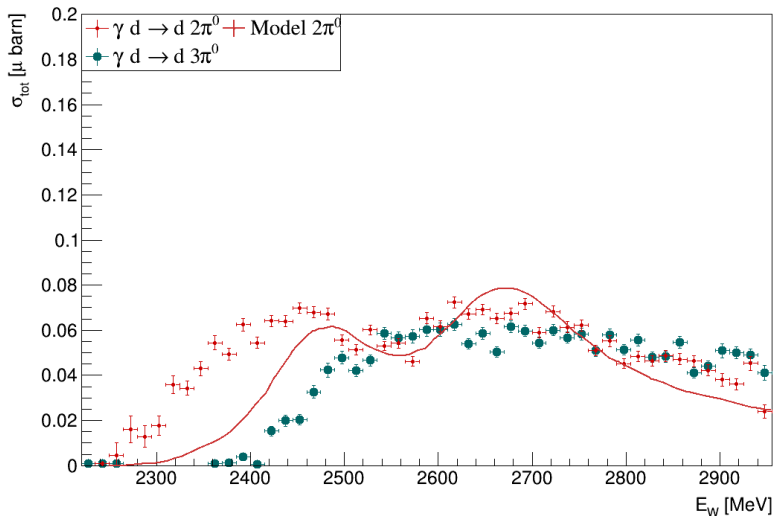


Total coherent cross section - Preliminary



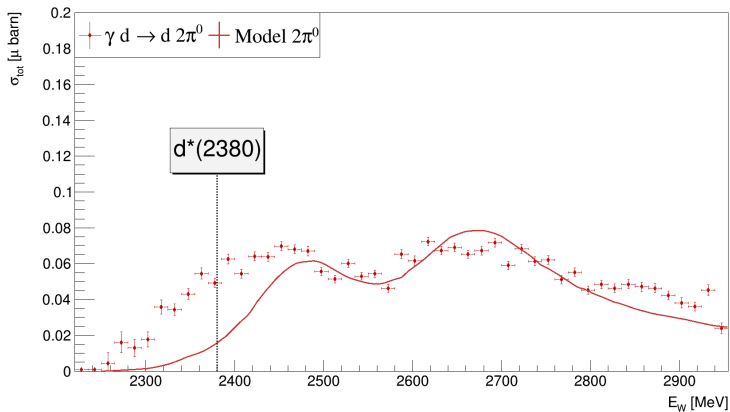
Total coherent cross section - Preliminary

Coherent cross section of $2\pi^0$ and $3\pi^0$



Total coherent cross section - Preliminary

Coherent cross section of $2\pi^0$



Outlook

π^0 -pairs:

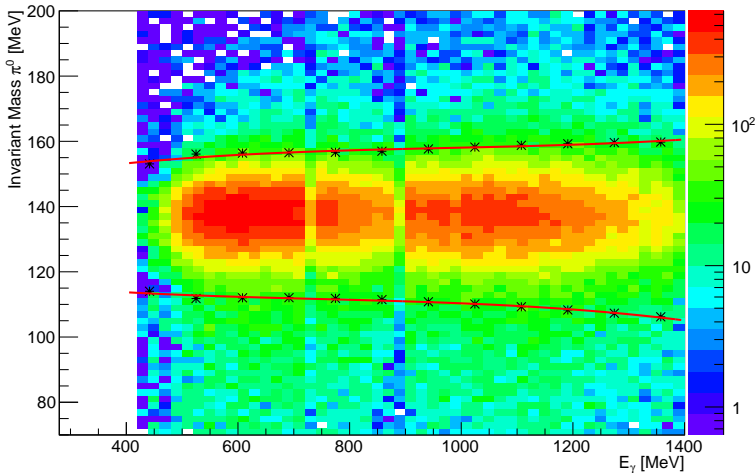
- ▶ Achieved a somewhat precise measurement of the $\pi^0\pi^0$ -coherent channel on deuteron
- ▶ Found signs of an enhancement at the predicted $d^*(2380)$ resonance
- ▶ Need of further statistical/analytically investigations
- ▶ Take a look at other deuteron beamtimes from A2

π^0 -triplets:

- ▶ First measurement of isolated $\pi^0\pi^0\pi^0$ photoproduction off deuterons
- ▶ Results look quite promising
- ▶ Still early level of analysis

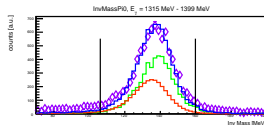
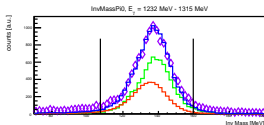
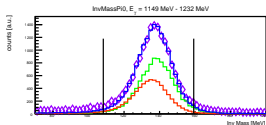
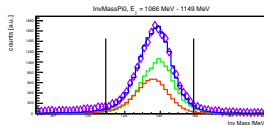
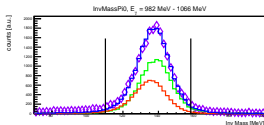
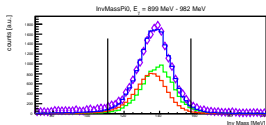
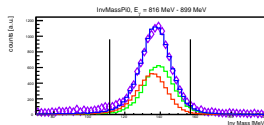
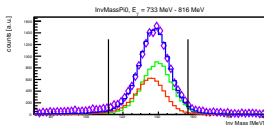
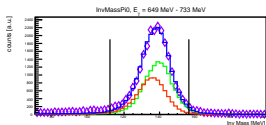
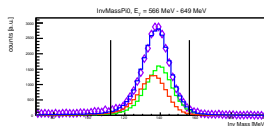
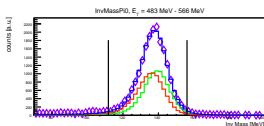
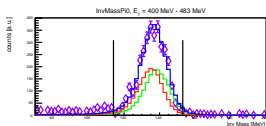
Event selection - Invariant mass cut

InvMassPi0Cut





Event selection - Invariant mass cut



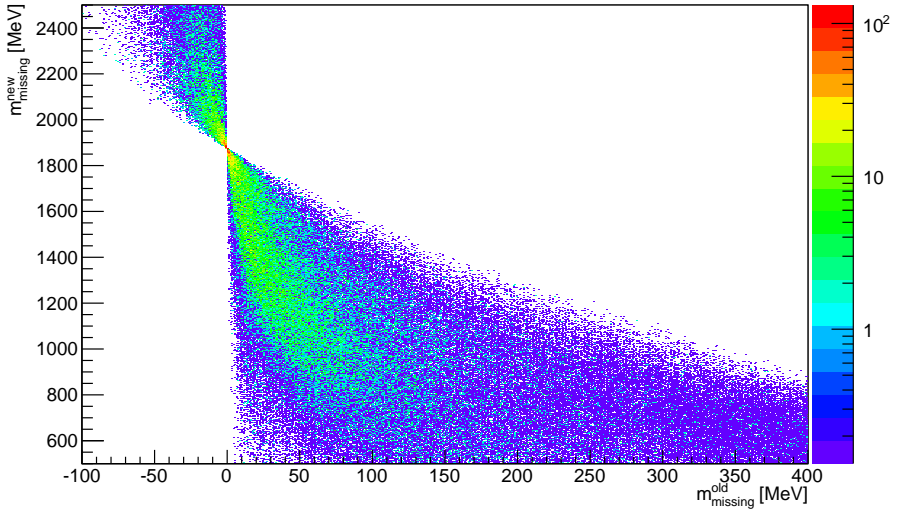
Check with Missing Mass

$$p_{\text{missing}} = p_{\text{beam}} + p_{\text{target}} - p_{\pi^0}$$

$$m_{\text{missing}}^{\text{old}} = \sqrt{E^2 - (\vec{p}_{\text{missing}})^2}$$

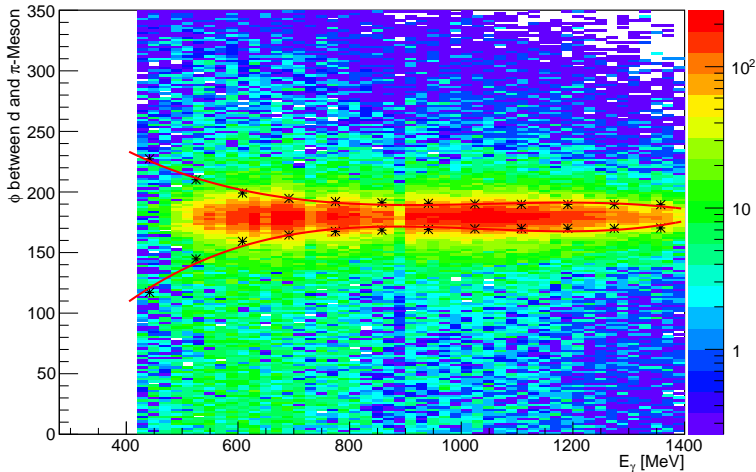
$$m_{\text{missing}}^{\text{new}} = \frac{(p_{\text{beam}} - p_{\pi^0})^2}{2(E_{\pi^0} - E_{\text{beam}})}$$

Check with Missing Mass



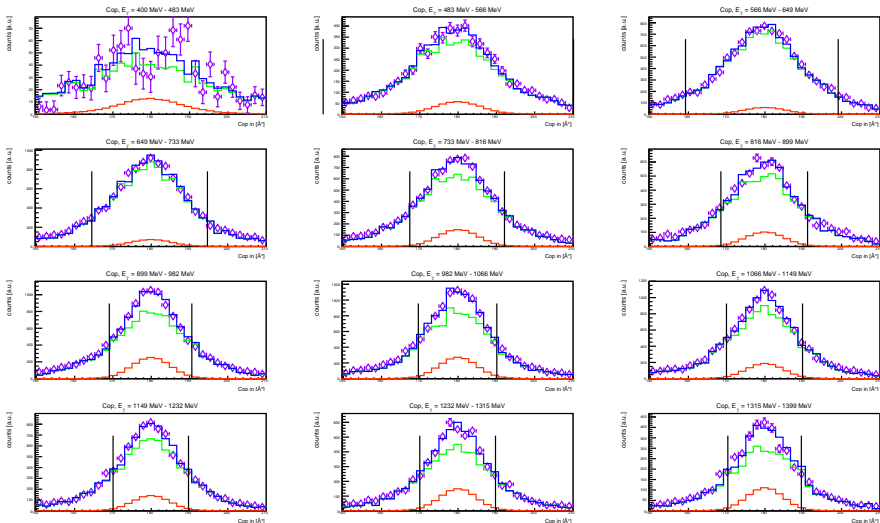
Event selection - Coplanarity cut

CopCut

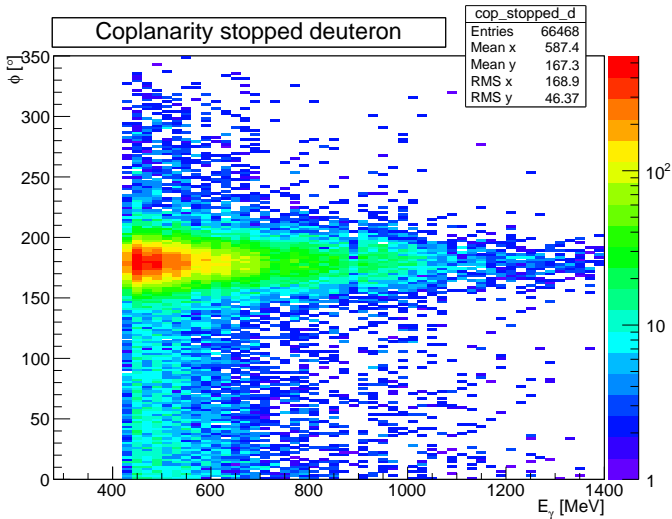




Event selection - Coplanarity cut

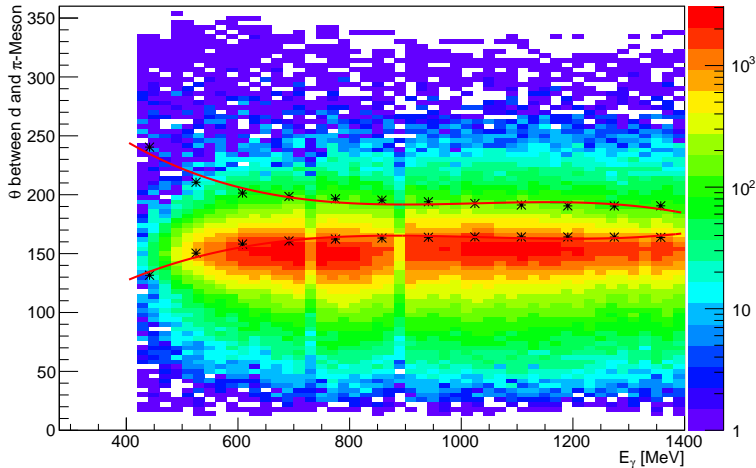


Event selection - Coplanarity cut

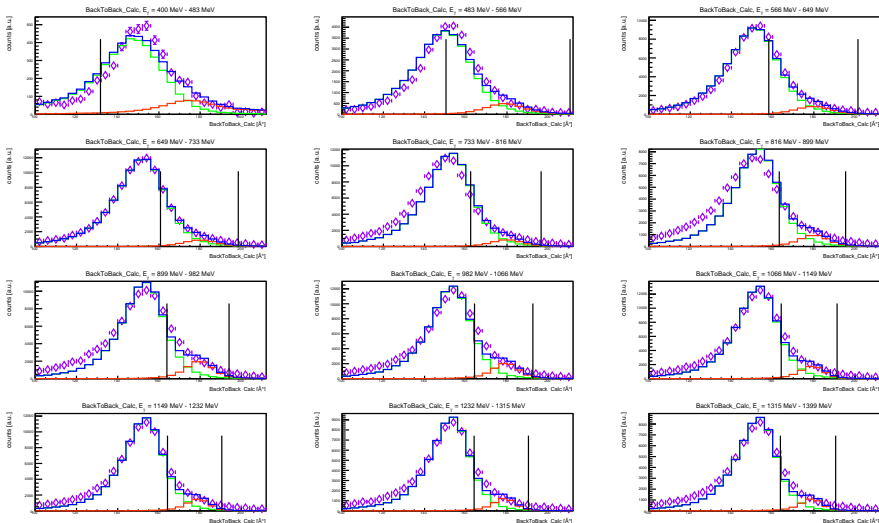


Event selection - Theta information cut

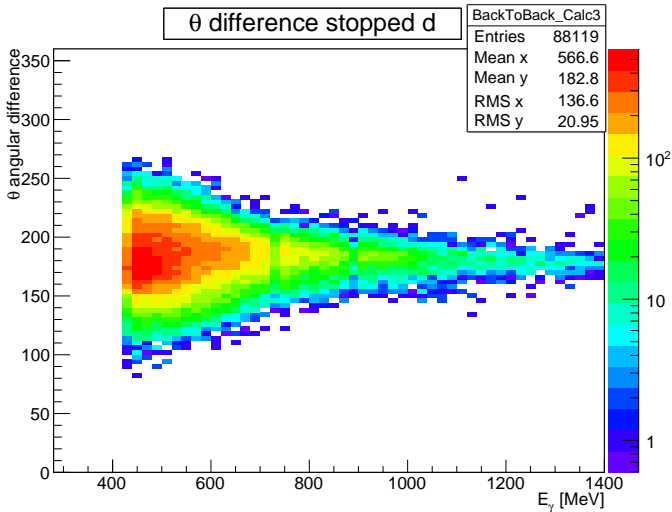
BtBCut



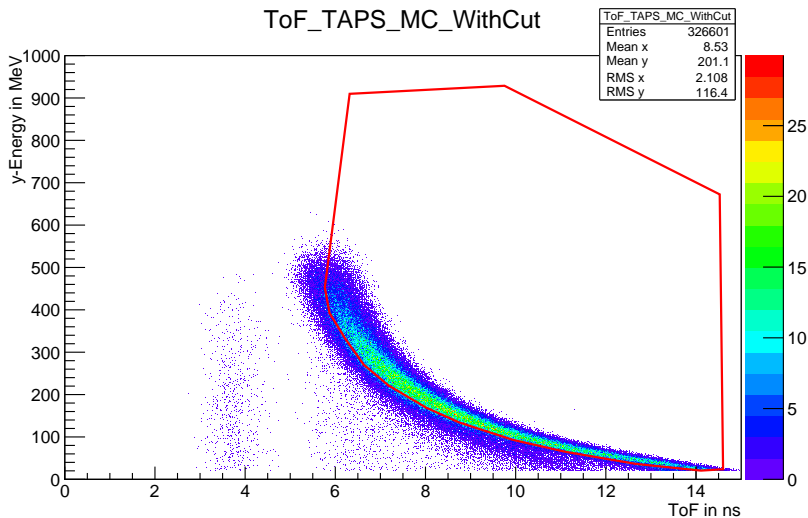
Event selection - Theta cut



Event selection - Theta cut

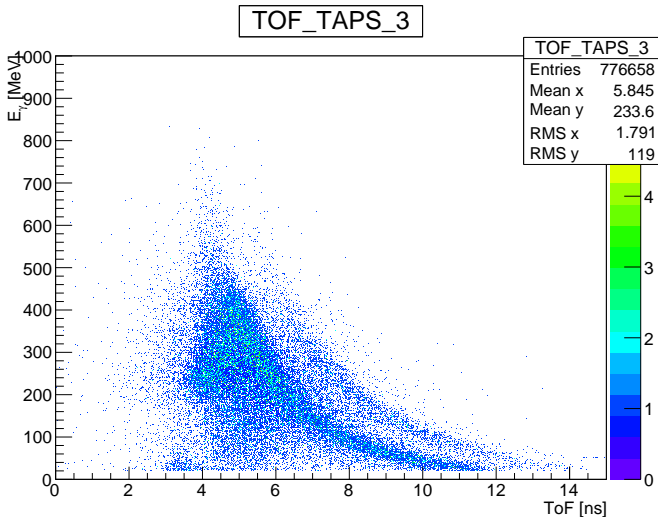


ToF With Cuts - MC



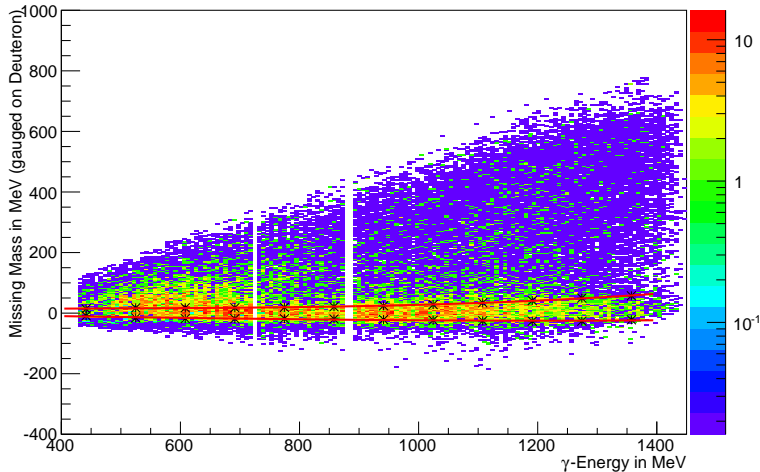
○○○○○○○○○○○●○○○

ToF with Cuts - Data

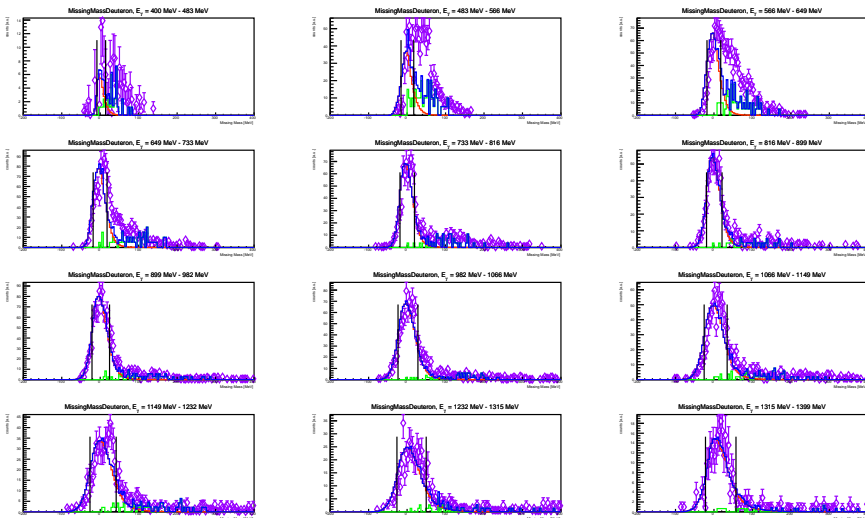


Event selection - Missing Mass cut

MMDeut_cut



Event selection - Missing Mass cut

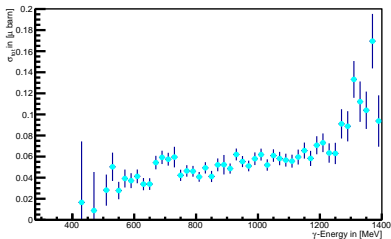


Conclusion and Outlook

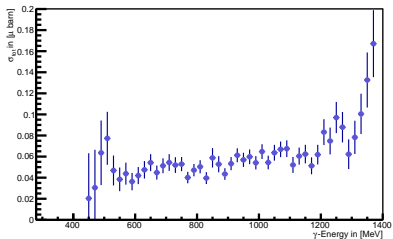
- ▶ A reasonable match with the coherent $\pi^0\pi^0$ model.
- ▶ Statistical and or analytically problems in regions below 2450 W or above 2800 W.
- ▶ For the $\pi^0\pi^0\pi^0$ channel, still more data available (Dec + Feb).

CS Beamtime seperated

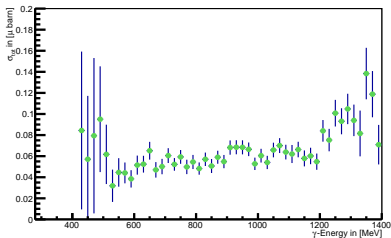
Total CS May_09



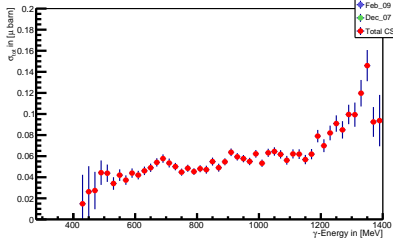
Total CS Feb_09



Total CS Dec_07

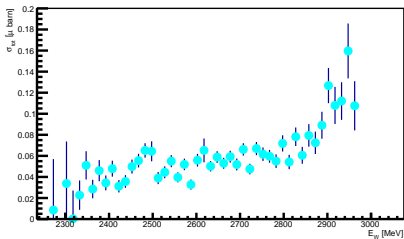


Total CS All

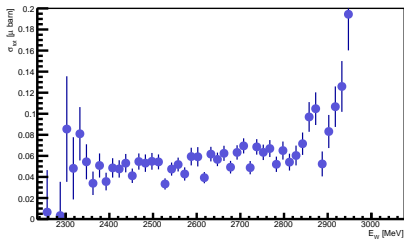


CS Beamtime seperated - W

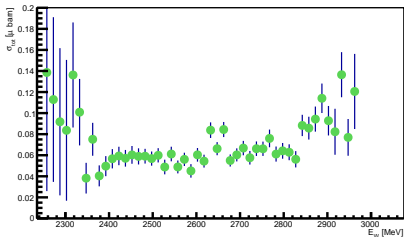
Total CS May_09



Total CS Feb_09

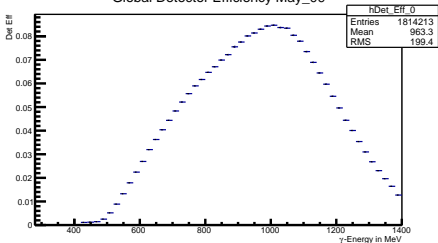


Total CS Dec_07

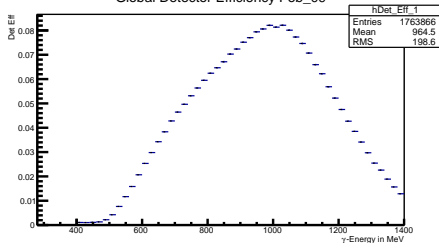


Total Efficiency

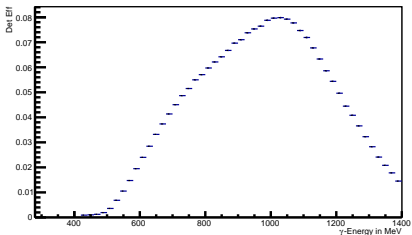
Global Detector Efficiency May_09



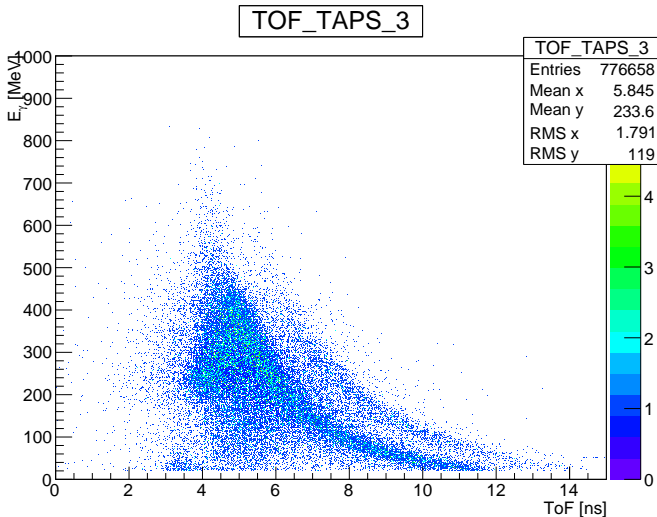
Global Detector Efficiency Feb_09



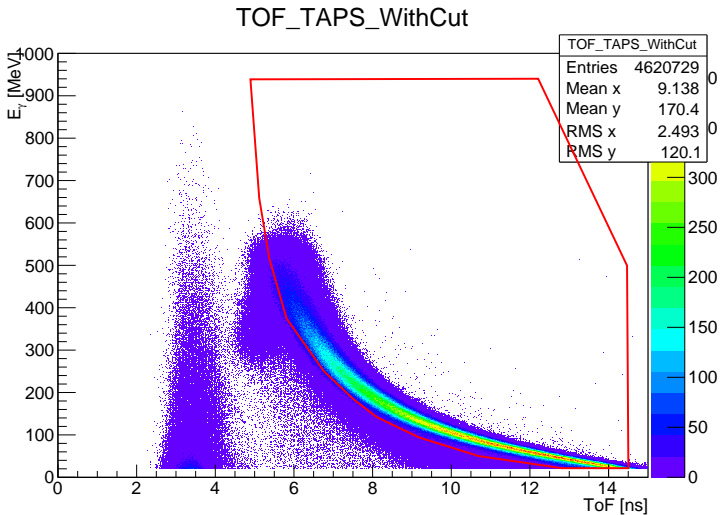
Global Detector Efficiency Dec_07



ToF With Cuts - Data



ToF With Cuts - Data



Beamtime overview

Parameter	Dec. 2007	Feb. 2009	May 2009
beam time hours	140	141	190
electron energy	1508.4 MeV	1508.4 MeV	1557.5 MeV
electron current	10 nA	5 nA	4.5 nA
tagged photon energy	410 - 1401 MeV	413 - 1401 MeV	423 - 1447 MeV
collimator	4 mm	4 mm	4 mm
radiator	10 μm Cu	10 μm Cu	Møller foil
target	<i>LD</i> ₂	<i>LD</i> ₂	<i>LD</i> ₂
target length [cm]	4.72	4.72	3.02
CB Energy Sum Trigger	> 300 MeV	> 300 MeV	> 300 MeV
multiplicity trigger	M2+	M3+	M2+