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

HADRON Conference 2017 - Salamanca, Spain

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on behalf of the A2 Collaboration
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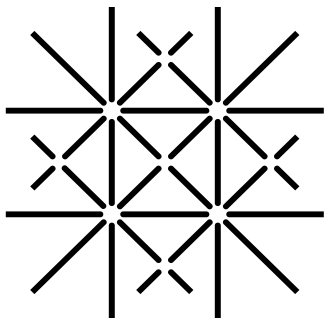


Universität Basel

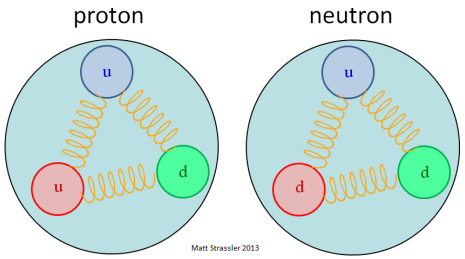
Outline

Fundamental forces

- Fundamental theories: Standard model and general relativity
- 4 fundamental interactions
  - gravity
  - electronic
  - weak
  - strong

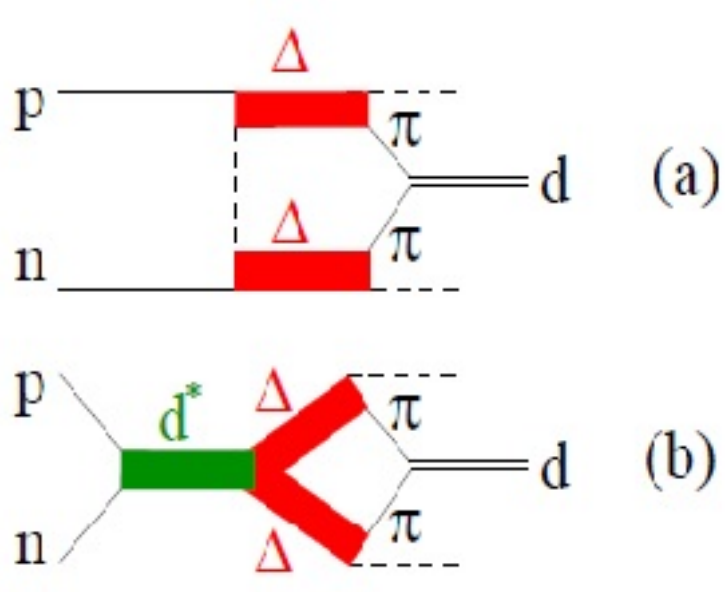
Strong Hadronic Interaction

- 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

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

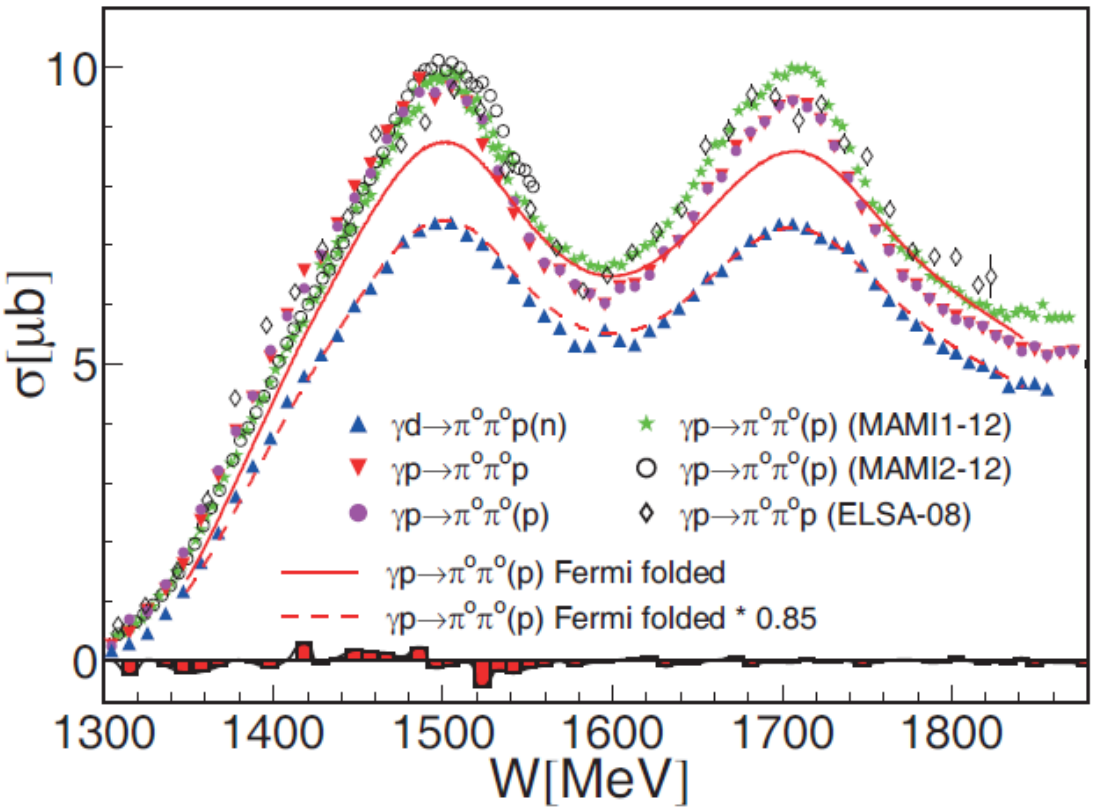


Figure: taken from M. Dieterle et all (Eur. Phys. J. A (2015) 51: 142)

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

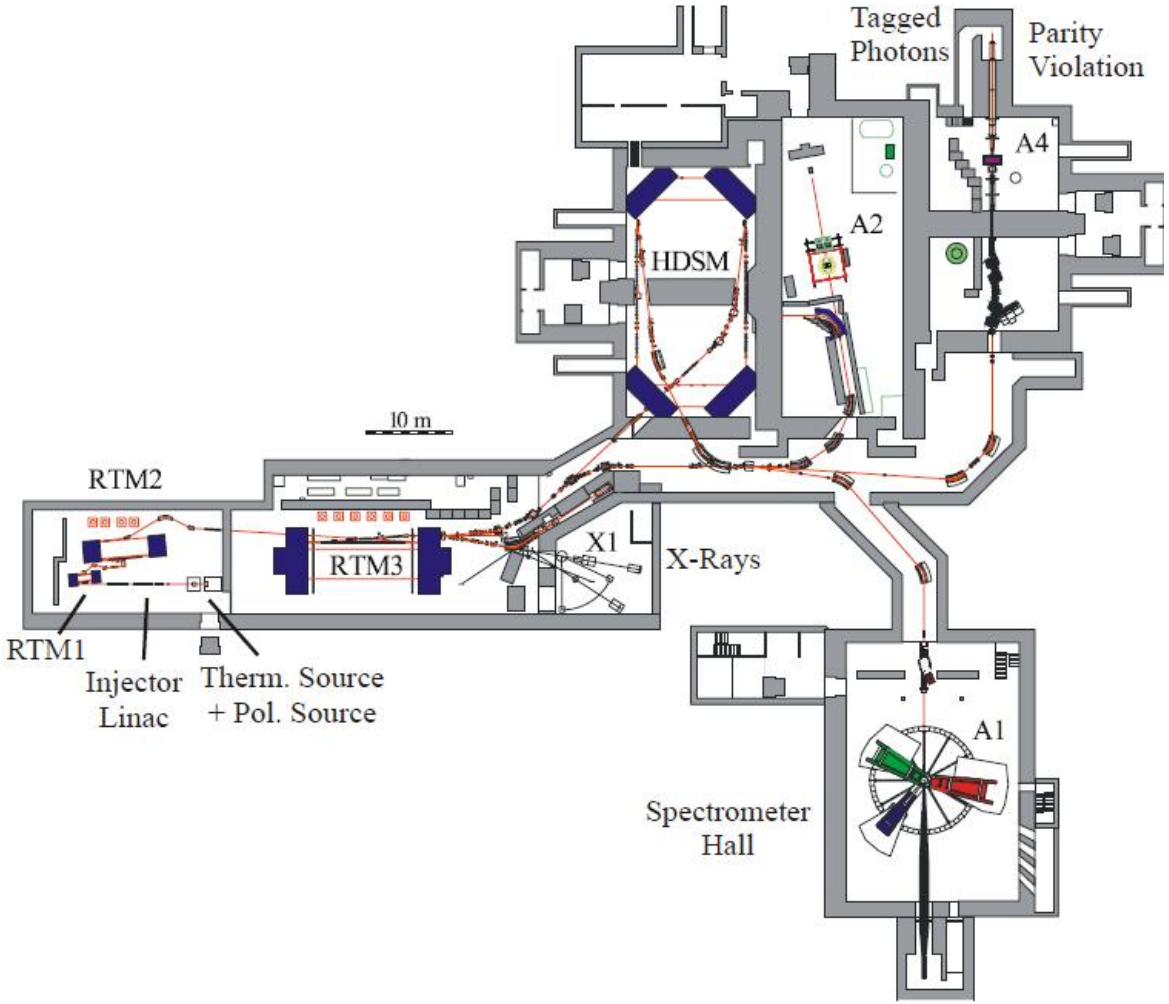
- $\gamma + d \rightarrow \begin{matrix} p(n) \\ n(p) \end{matrix} + \pi^0\pi^0\pi^0$ is mostly unknown
- Highly dominated by the $\eta \rightarrow \pi^0\pi^0\pi^0$ reaction
- No data has been published on isolated $\pi^0\pi^0\pi^0$ photoproduction off deuterium

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

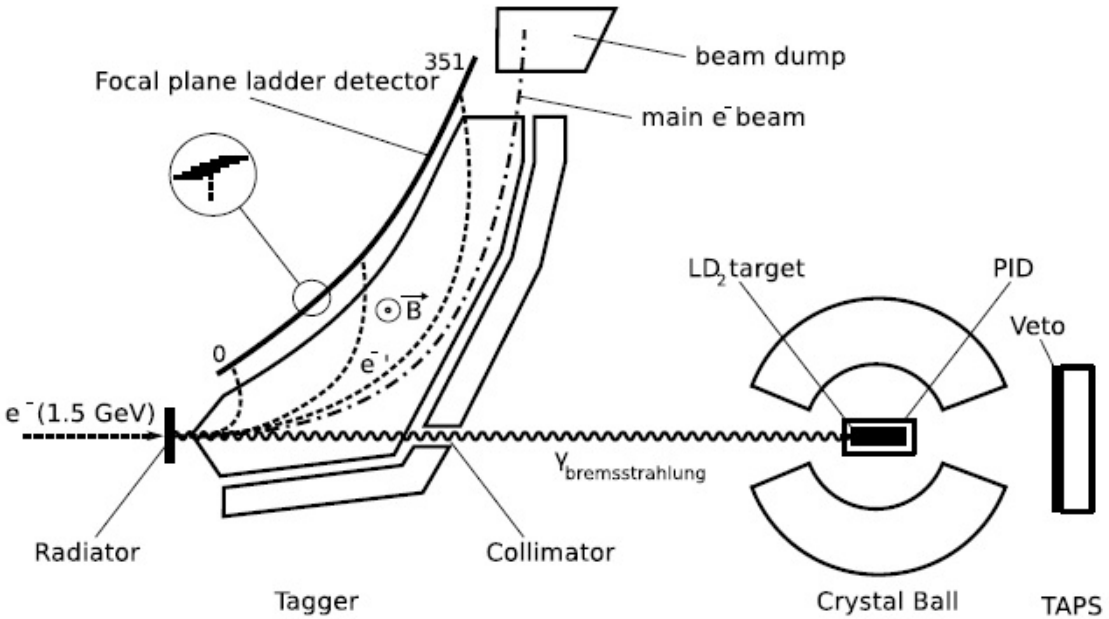
MAMI

- 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



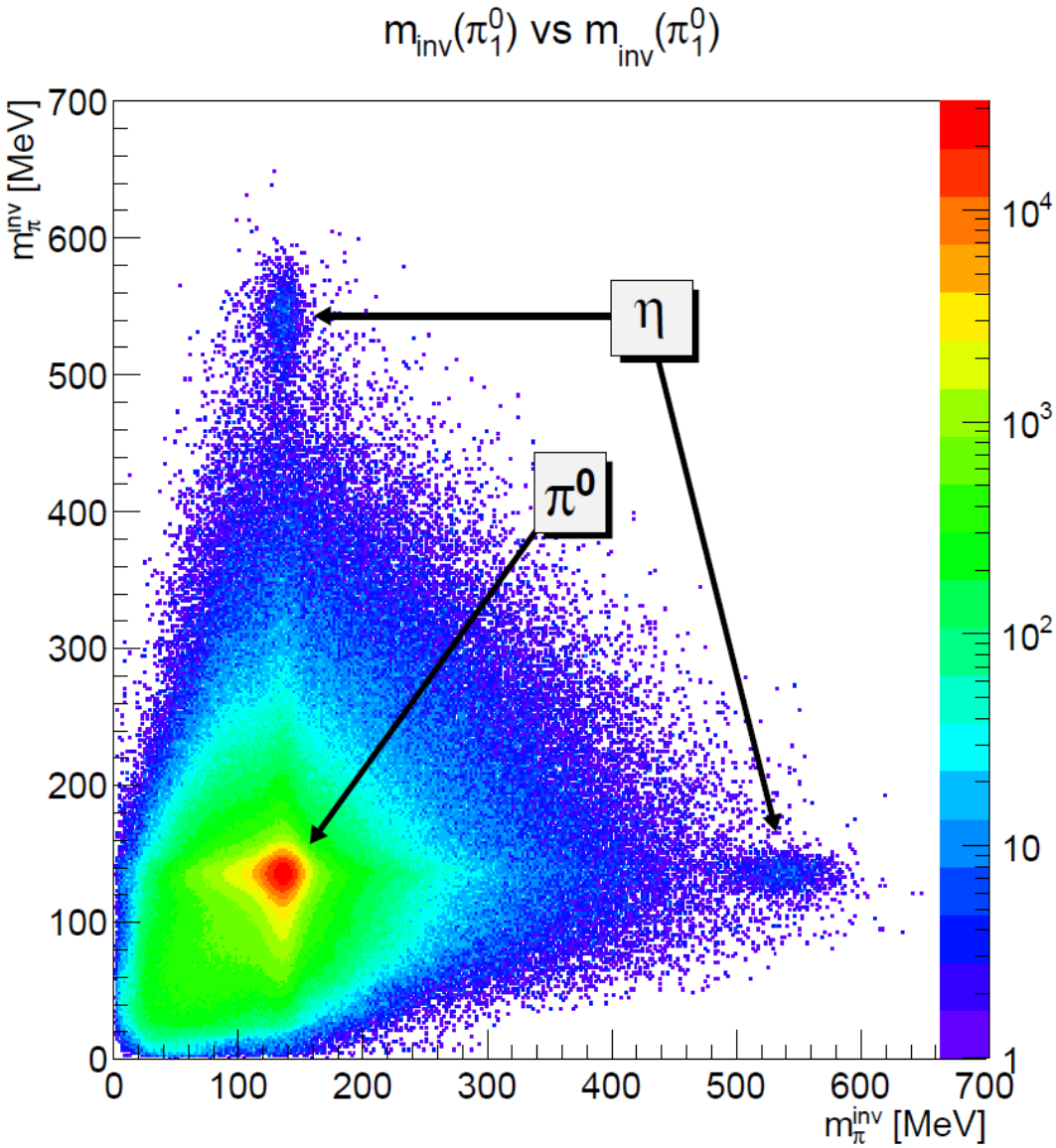
Presort and Reconstruction of π^0

- 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^0s 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

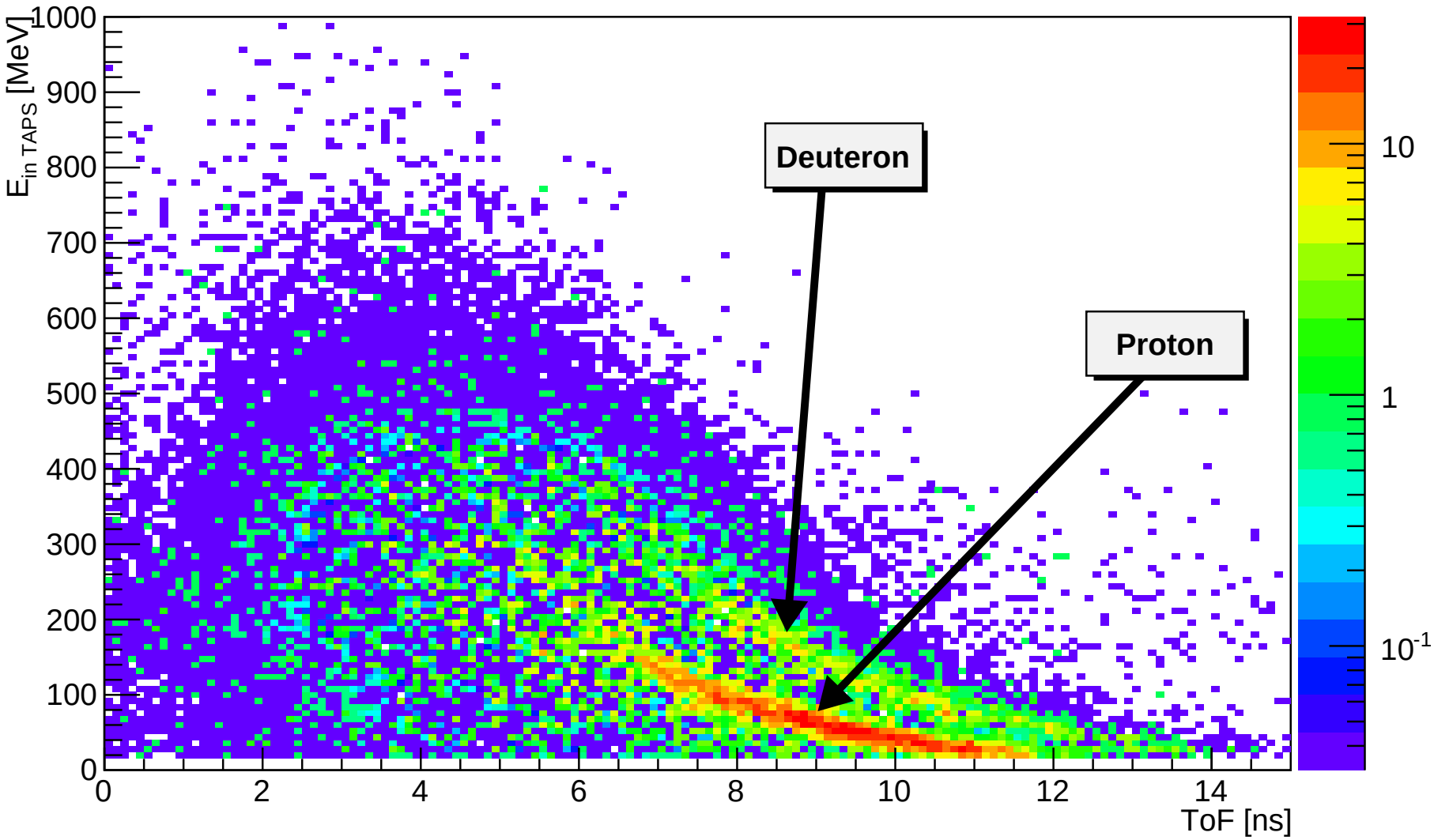
- Kinematic cuts on coplanarity and invariant mass of π^0
  - Identify η background



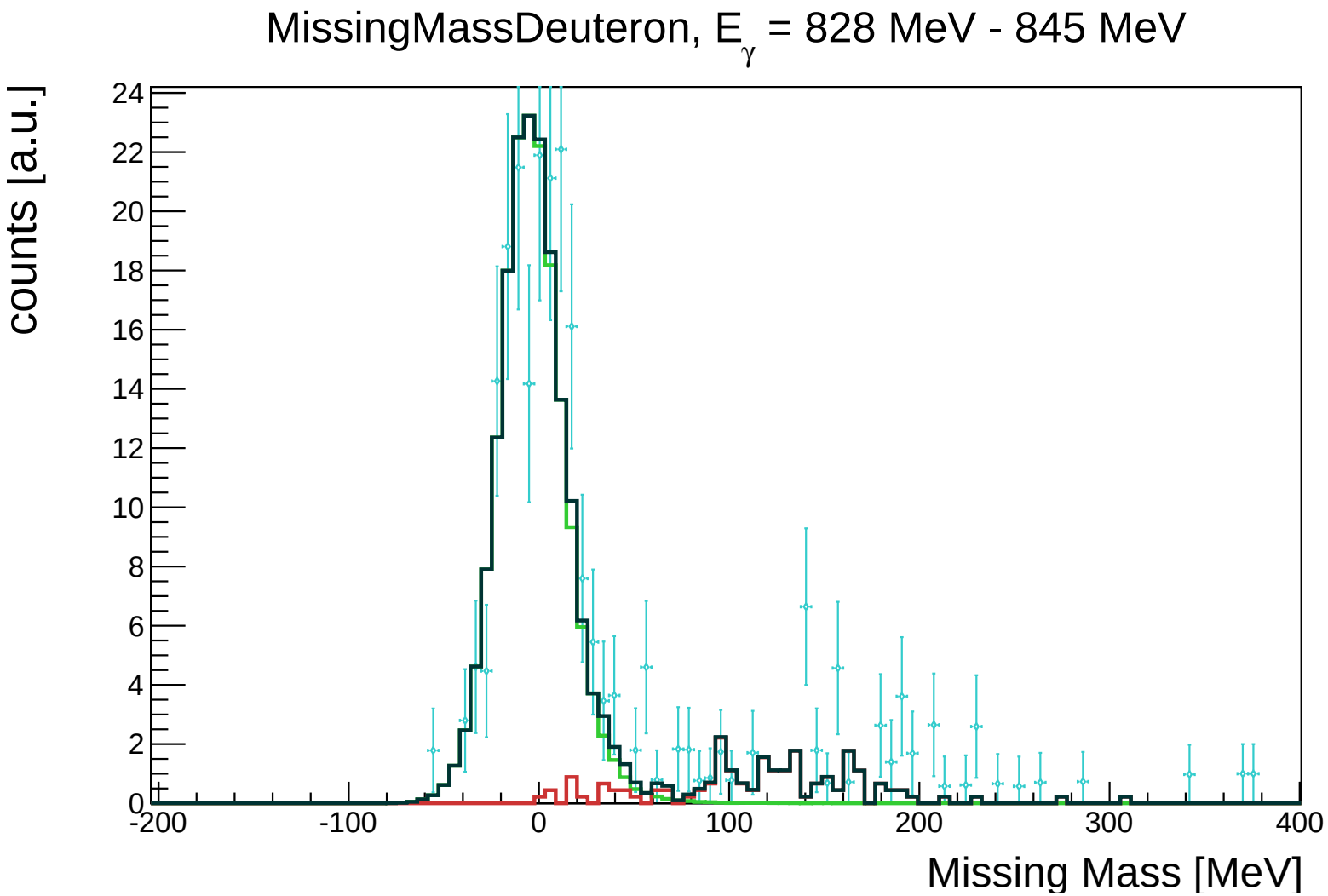
Deuteron identification

- 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



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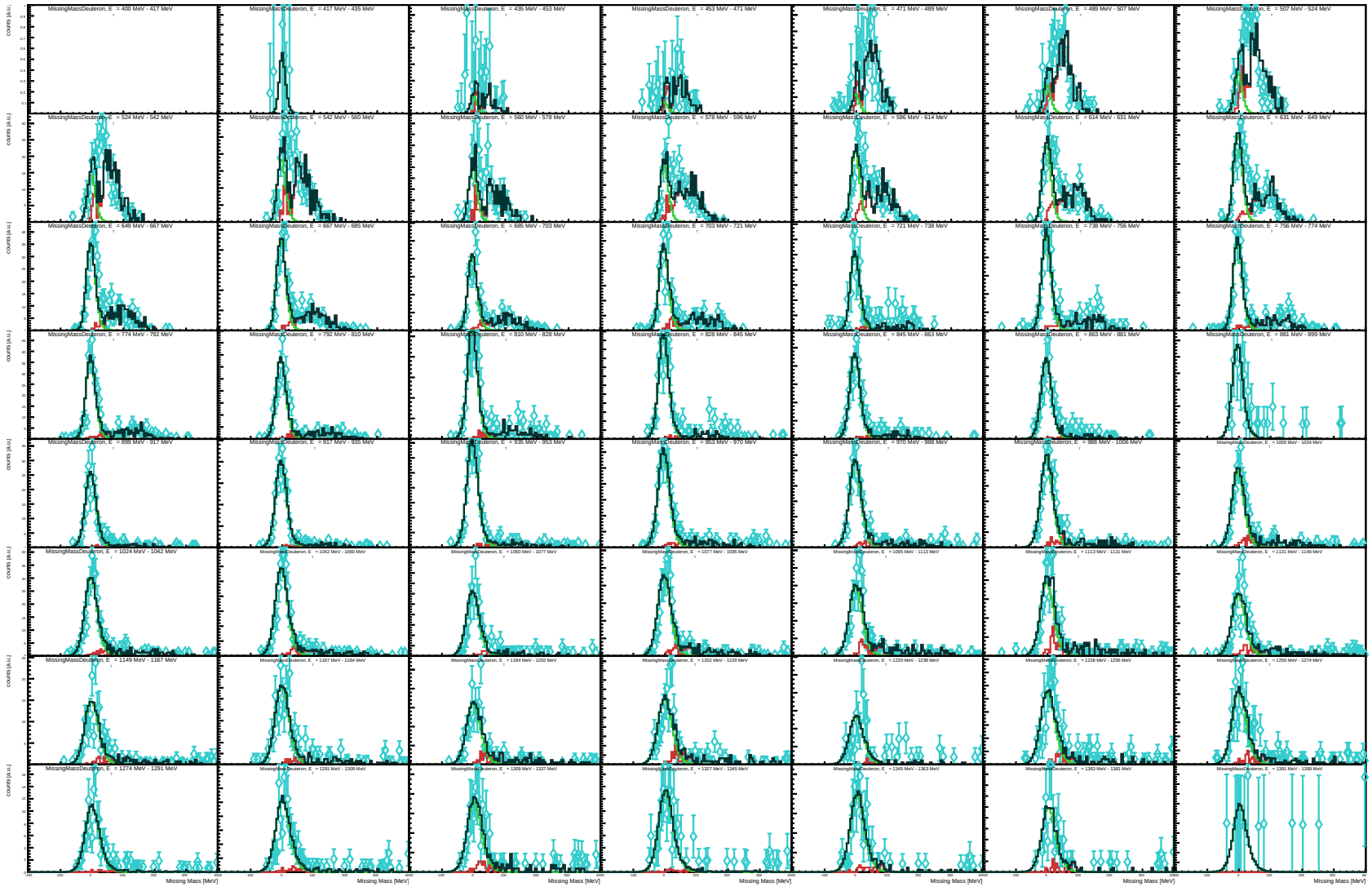

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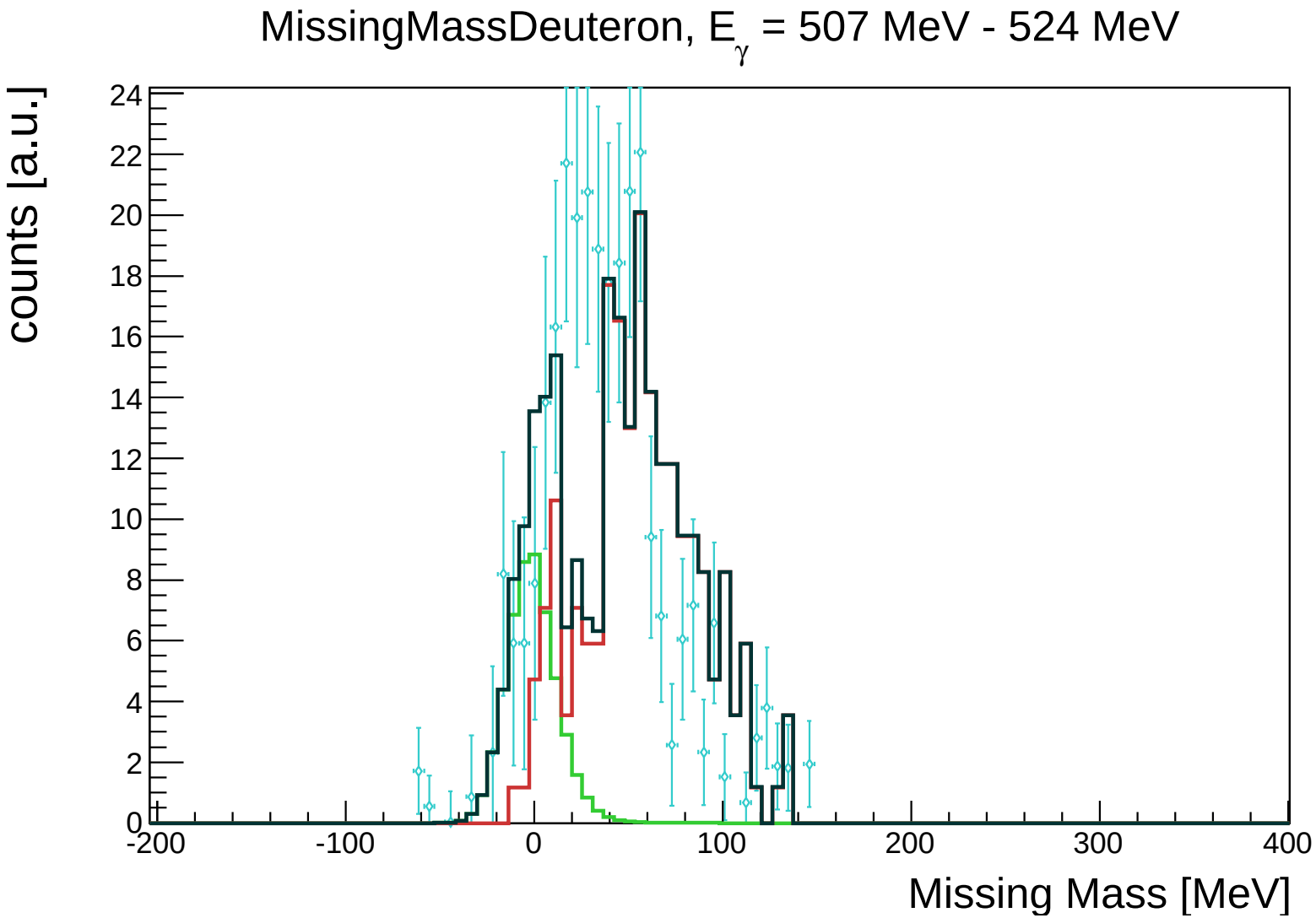
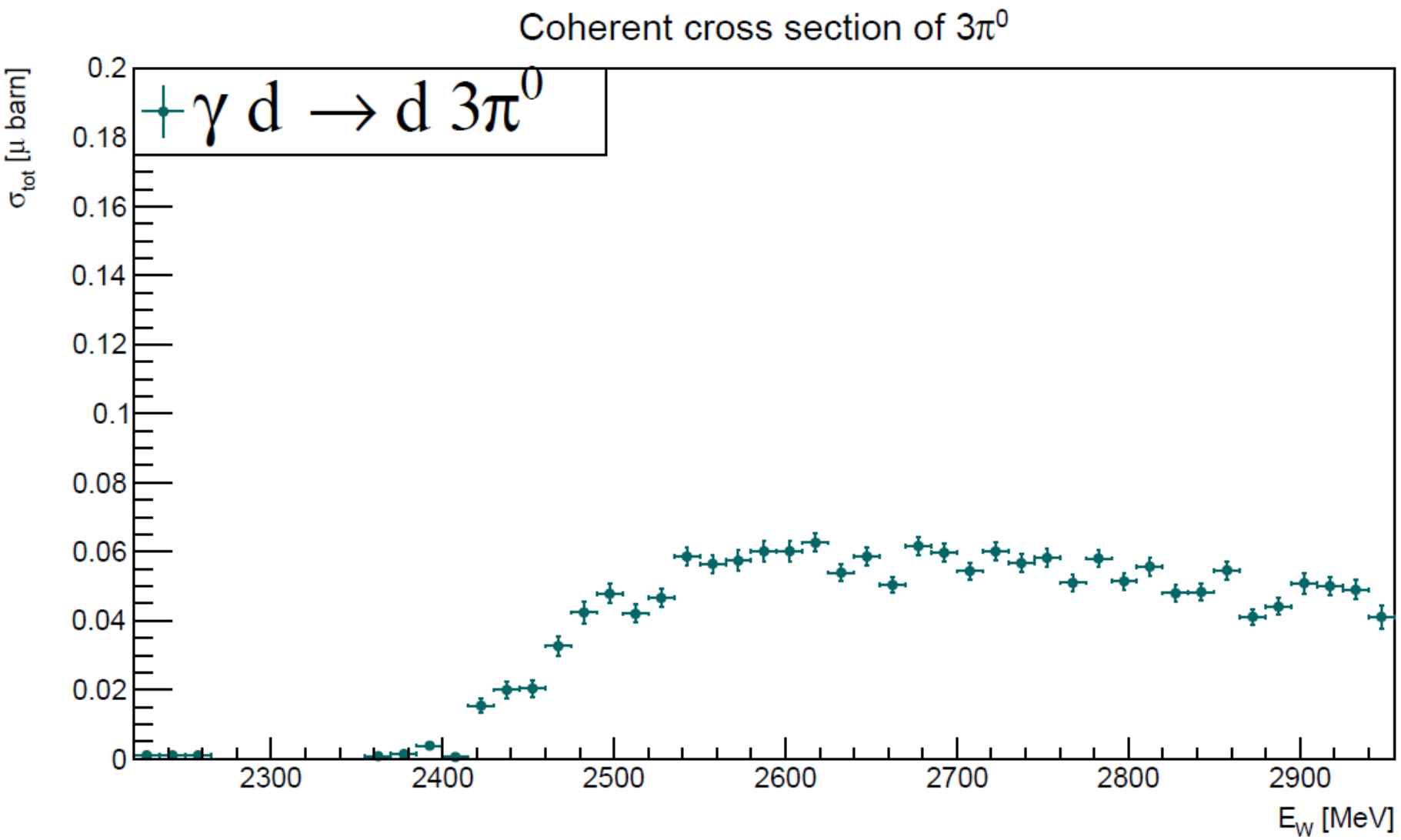


Total coherent cross section - Preliminary



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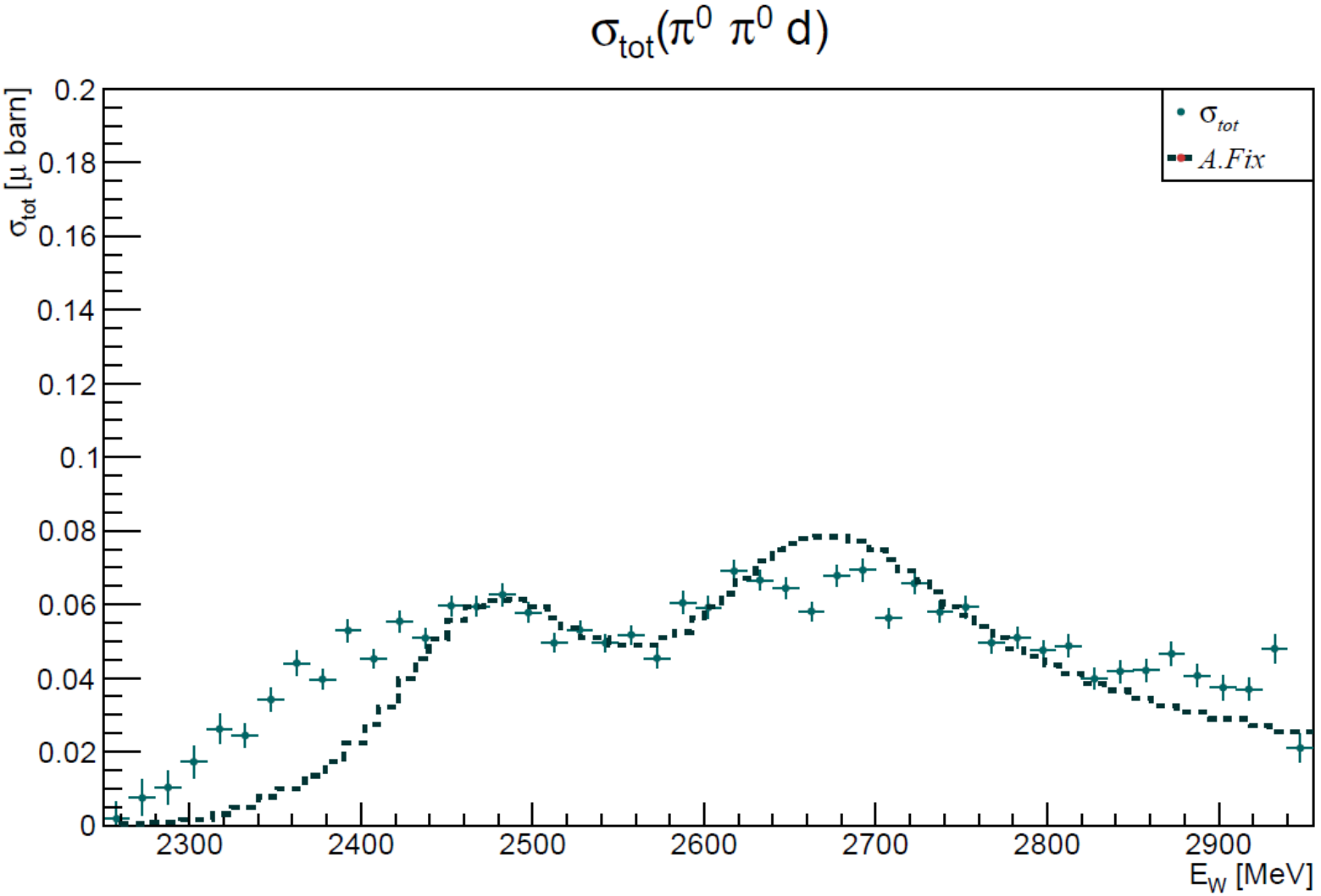


Outlook

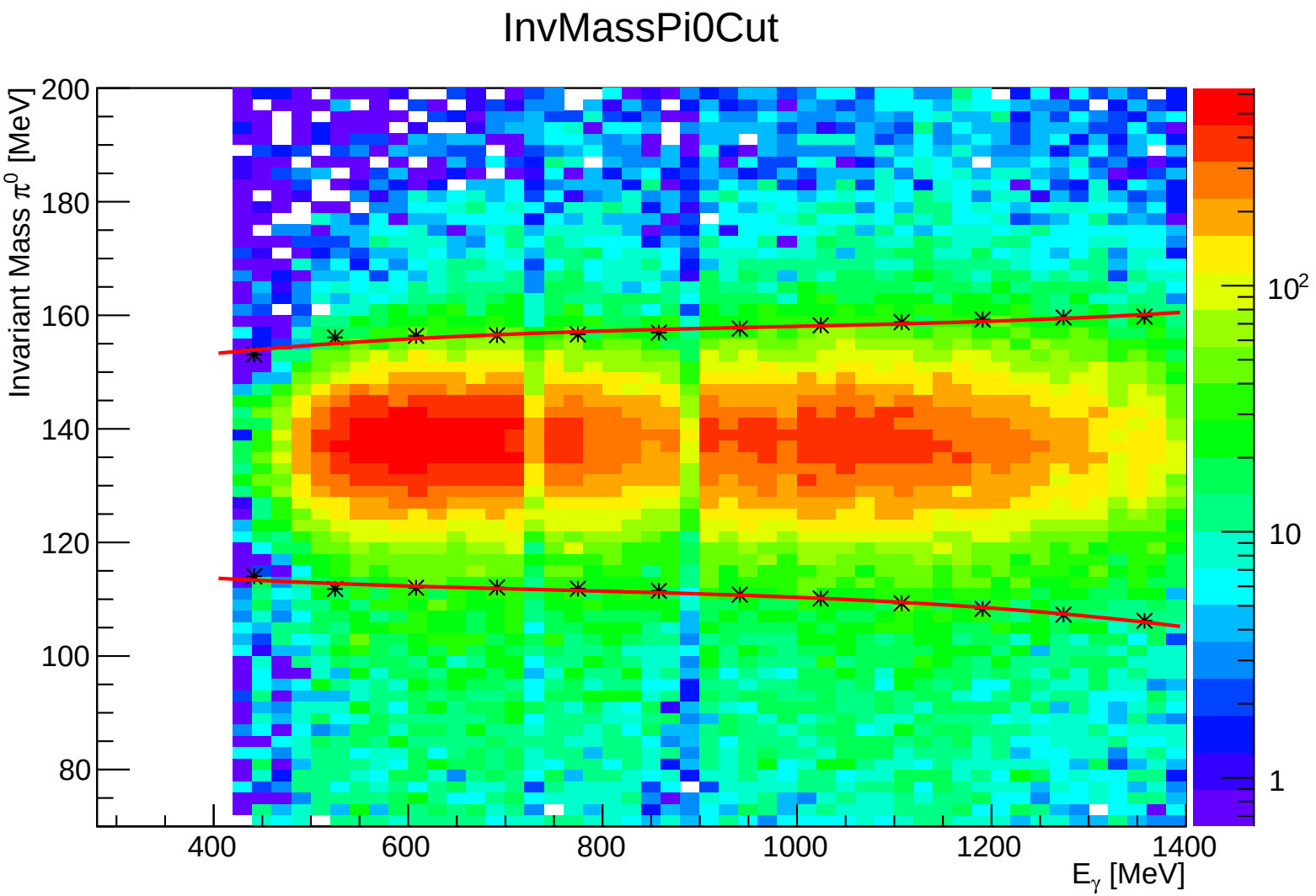
π^0-pairs:

- 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



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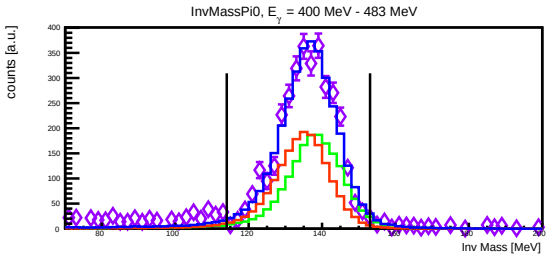
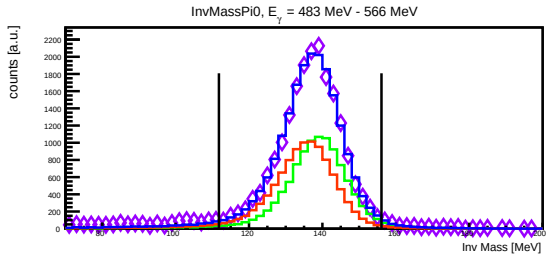
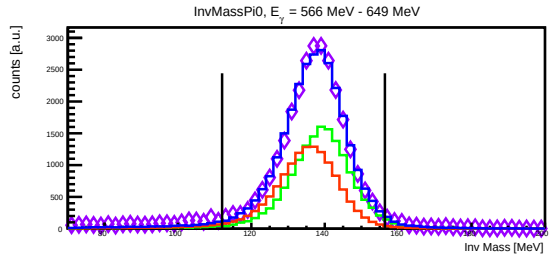
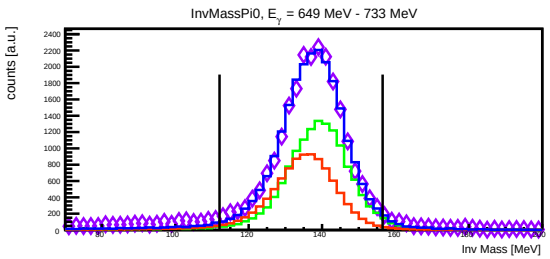
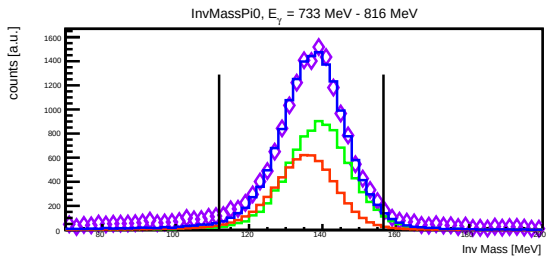
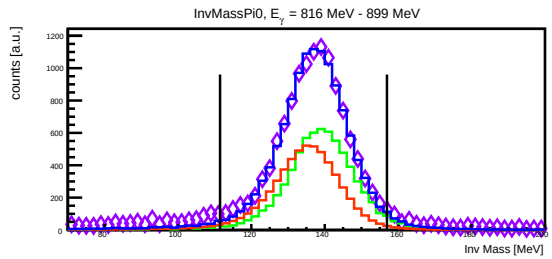


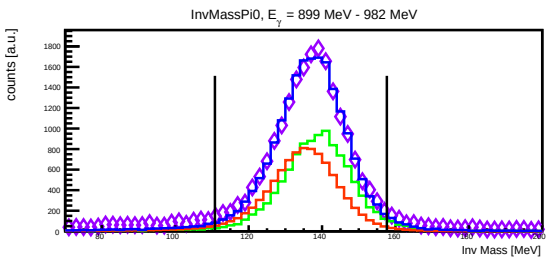


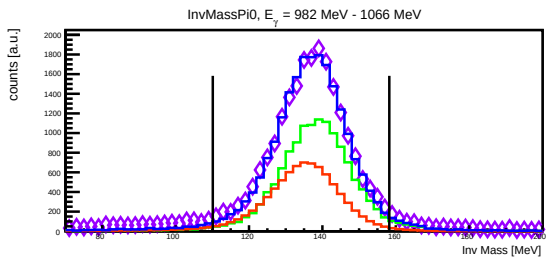


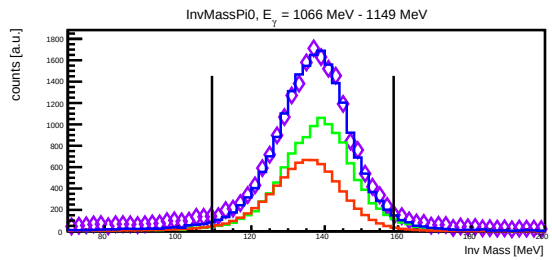


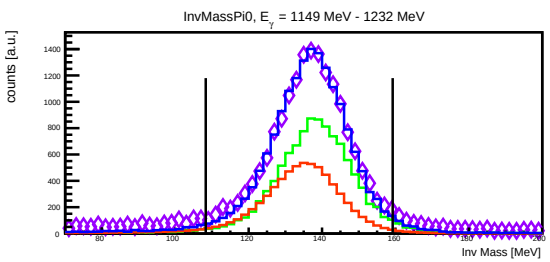


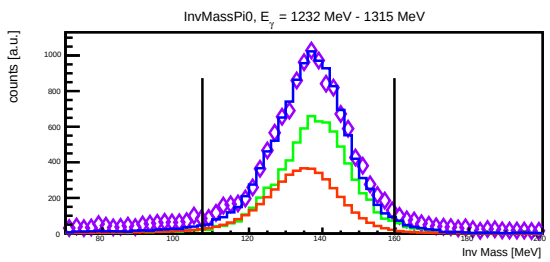


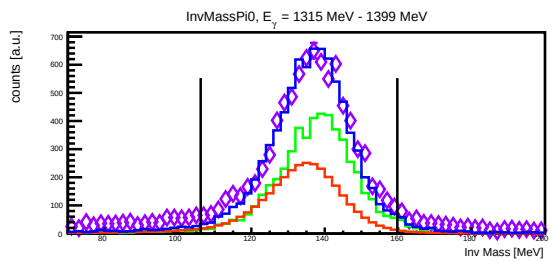












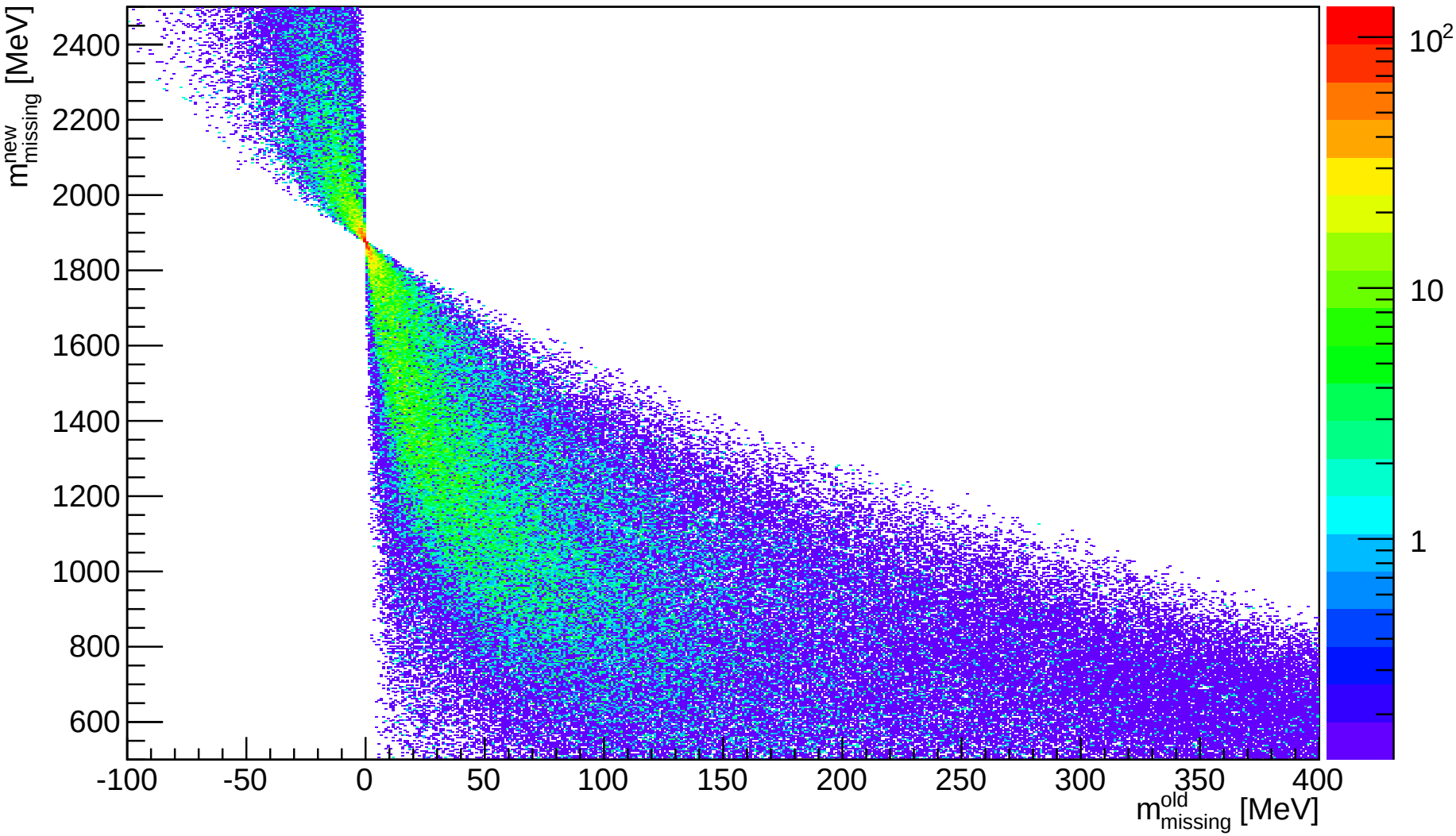
Check with Missing Mass

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

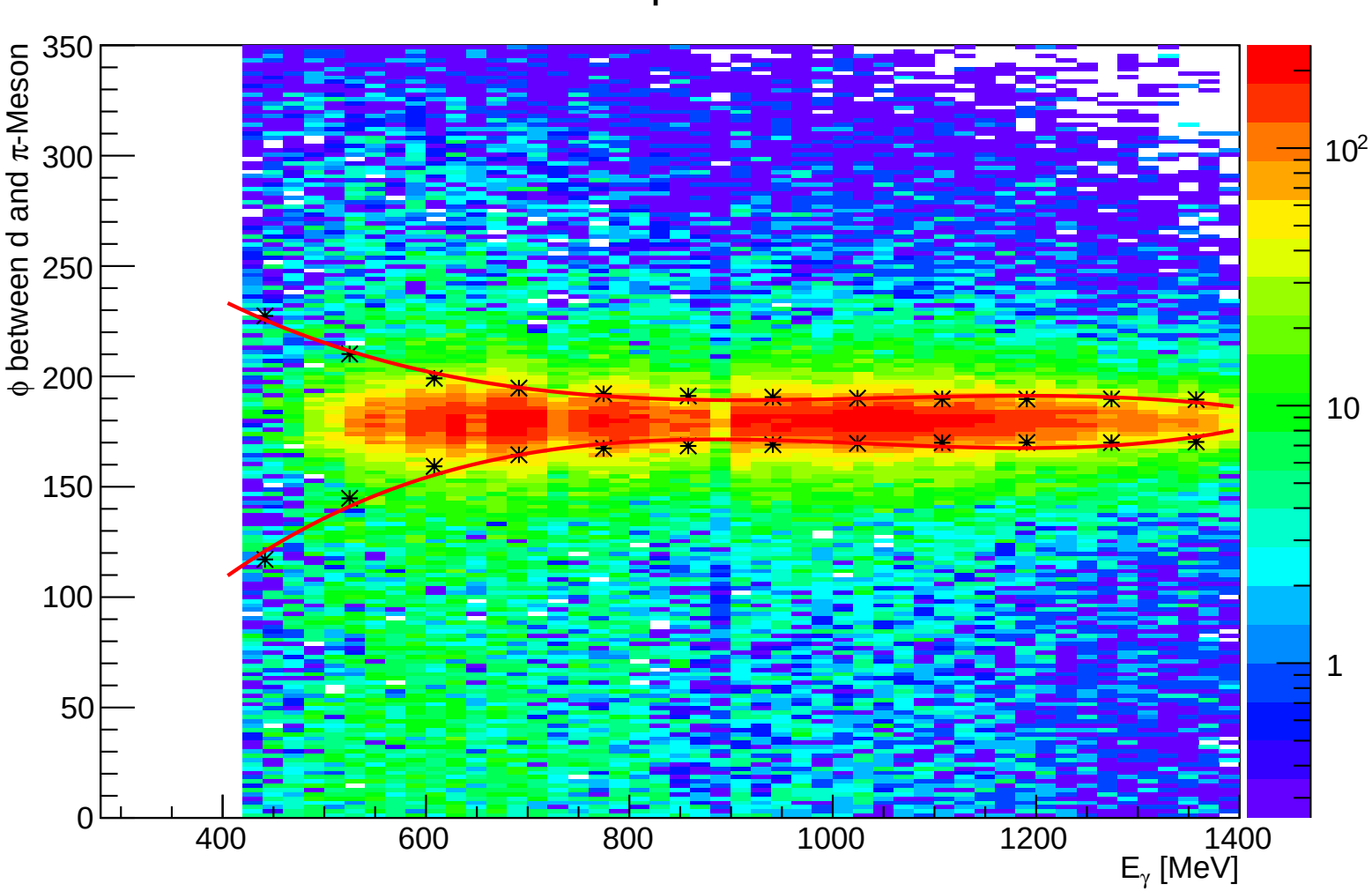
$$m^{\text{old}}_{\text{missing}} = \sqrt{E^2 - (\vec{p}_{\text{missing}})^2}$$

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

Check with Missing Mass



Event selection - Coplanarity cut



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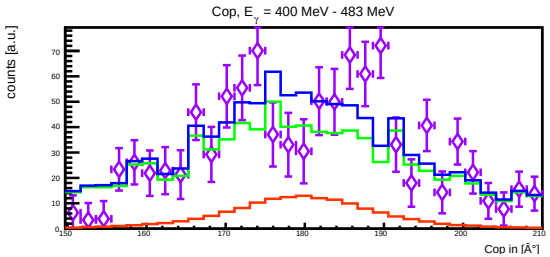
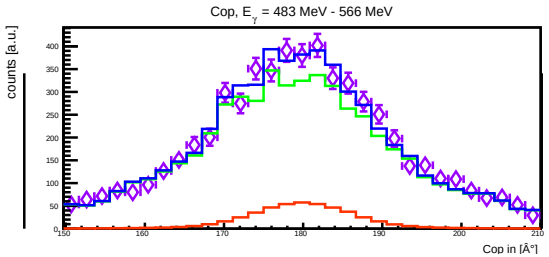
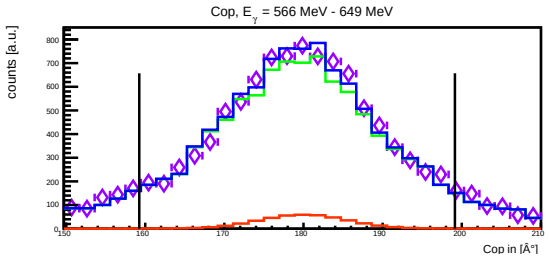
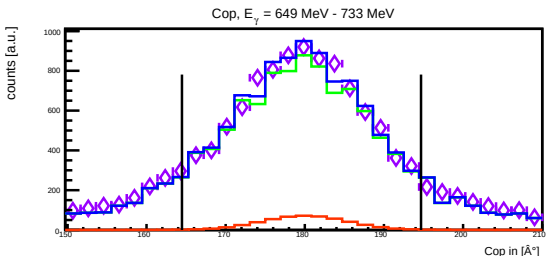
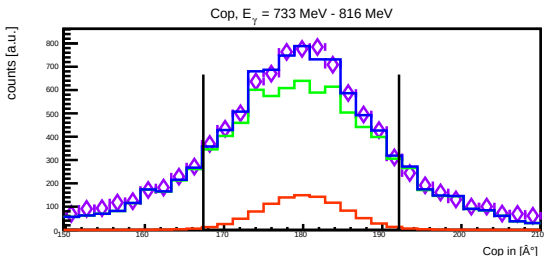
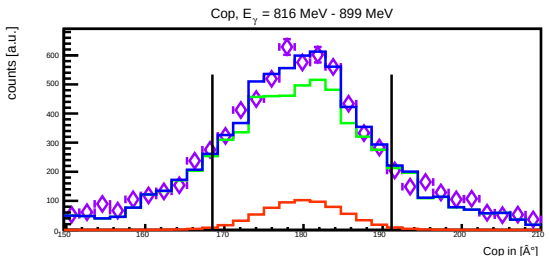


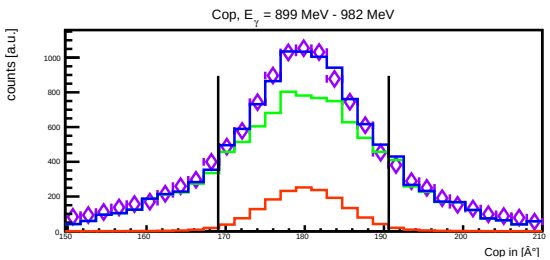


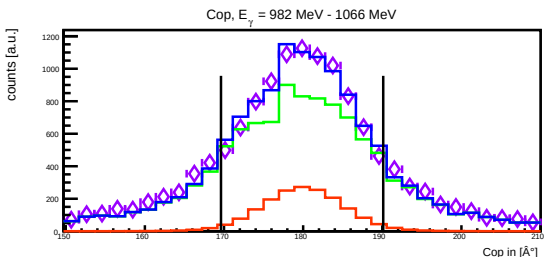


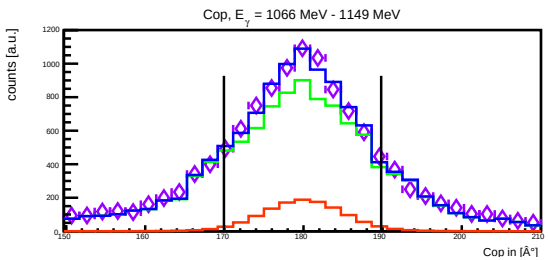


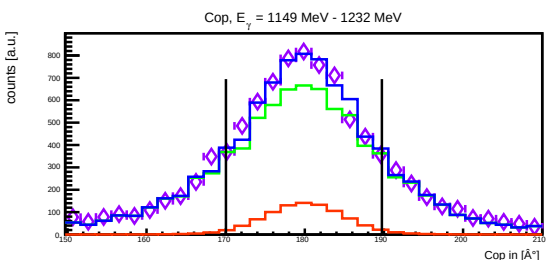


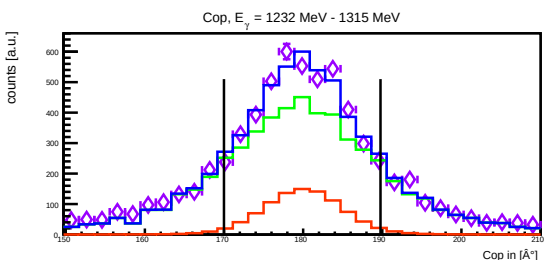


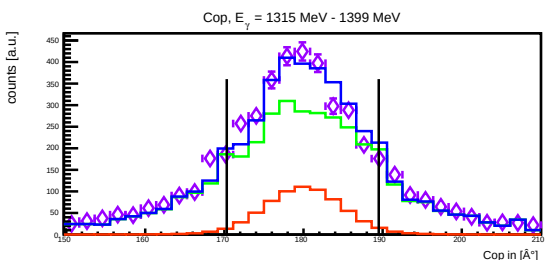




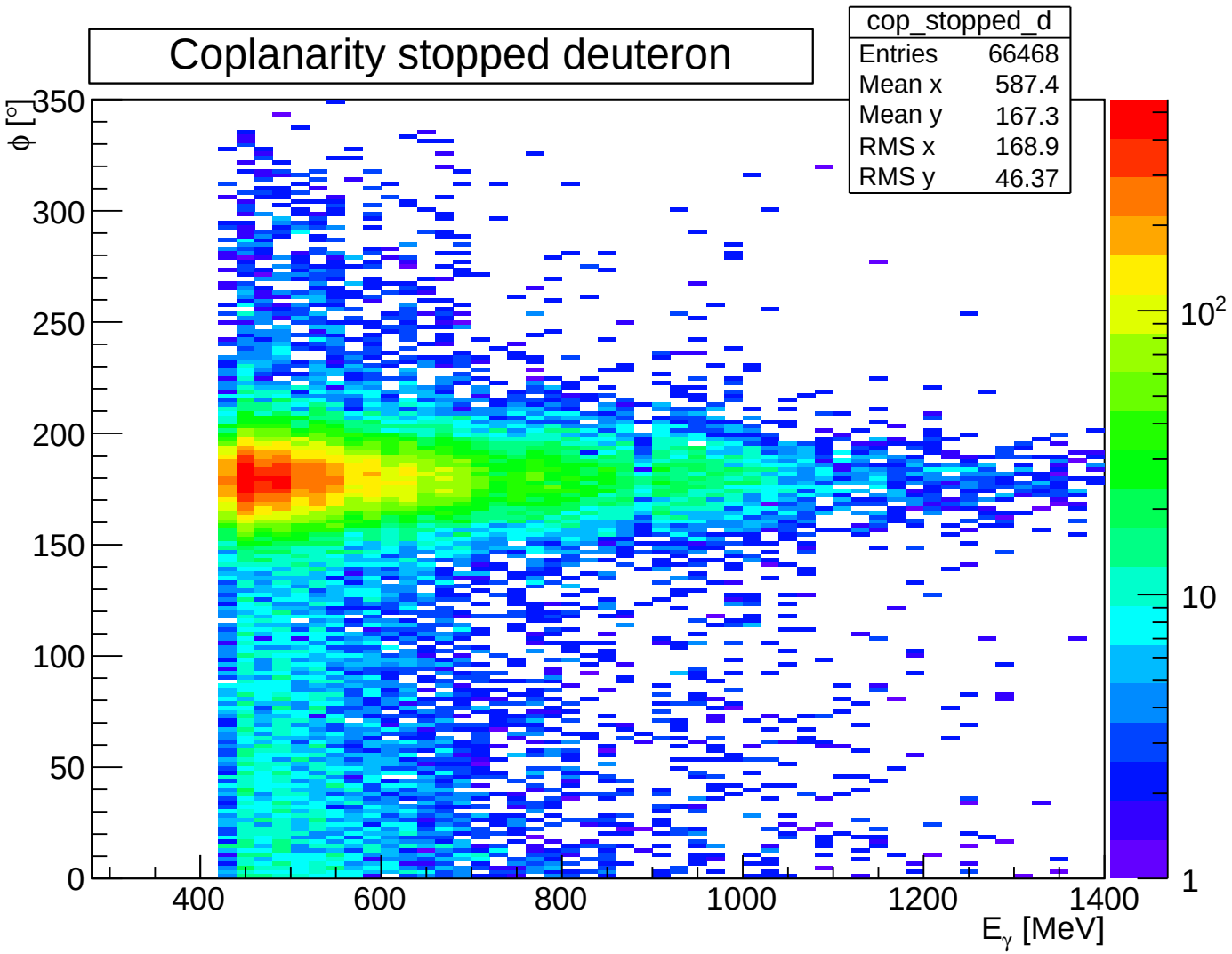




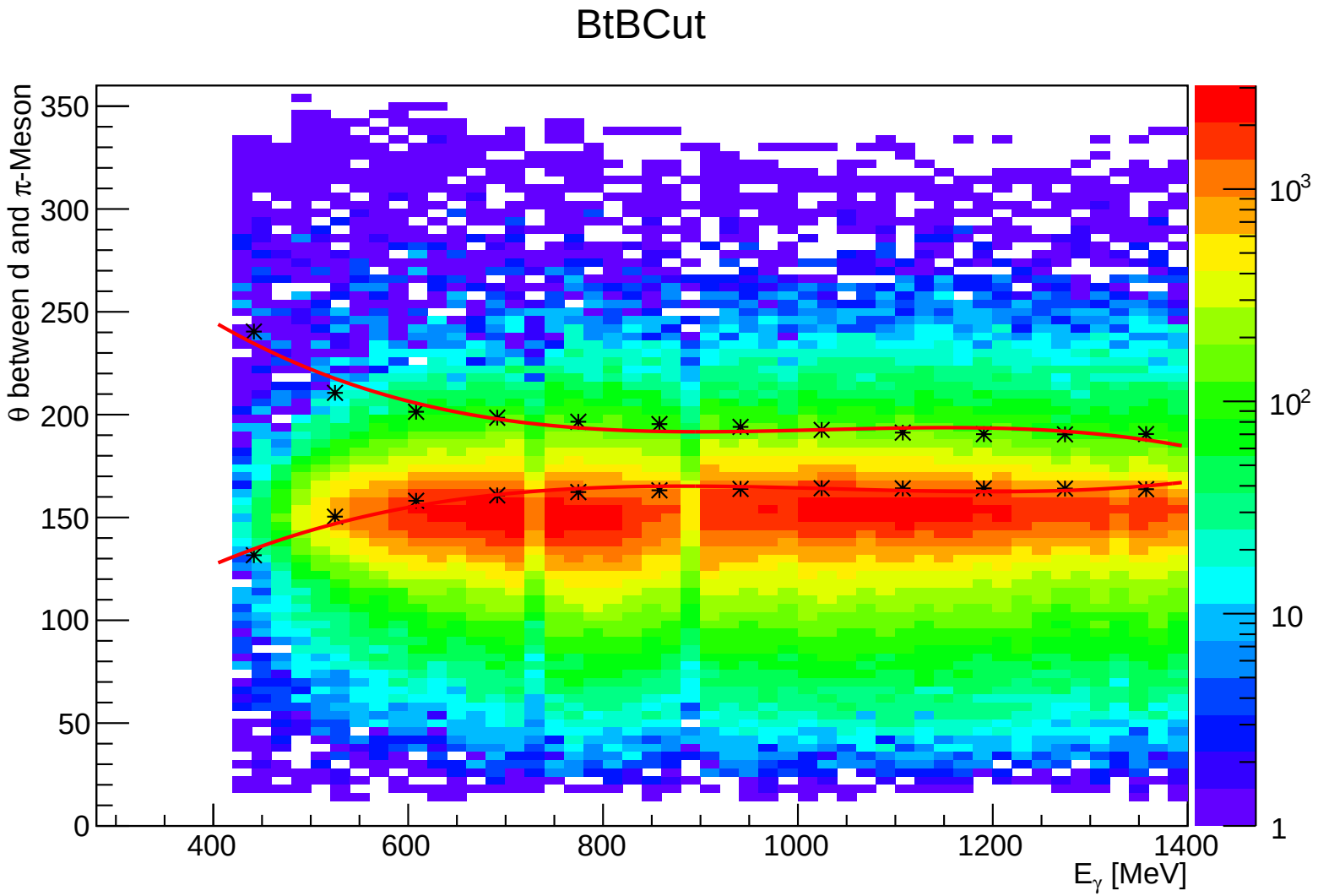




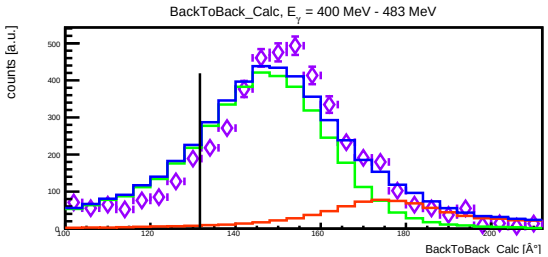
Event selection - Coplanarity cut

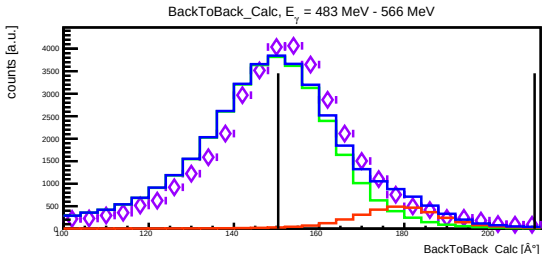


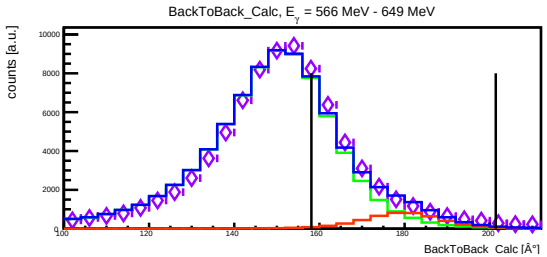
Event selection - Theta information cut

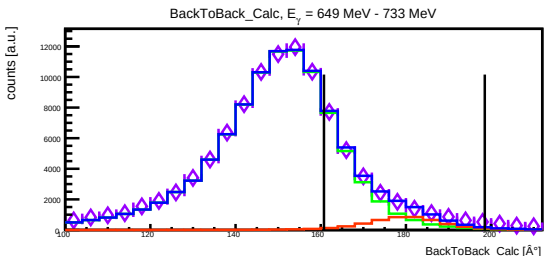


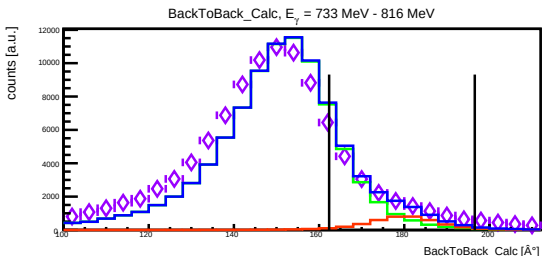
Event selection - Theta cut

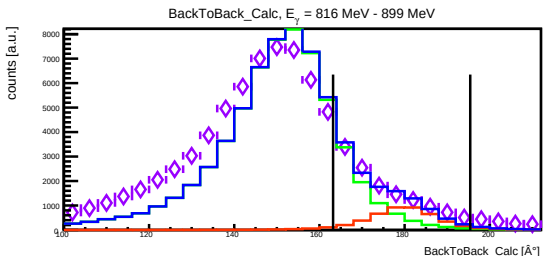


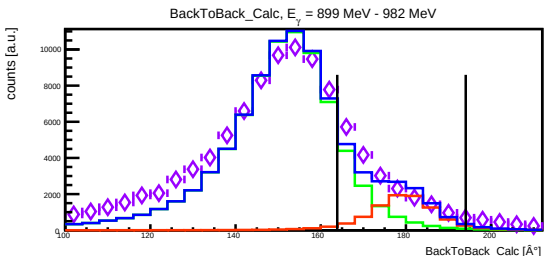


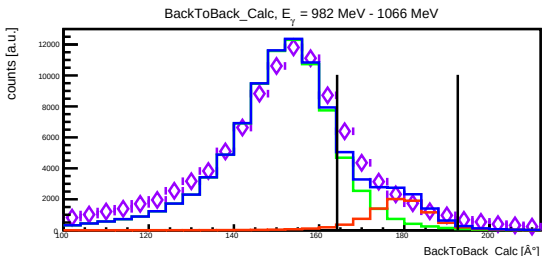


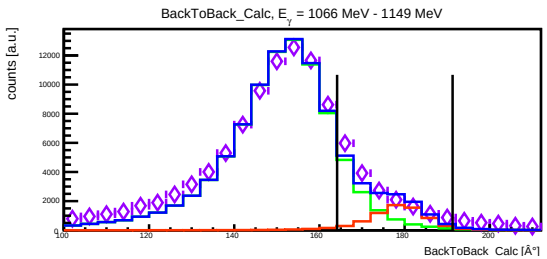


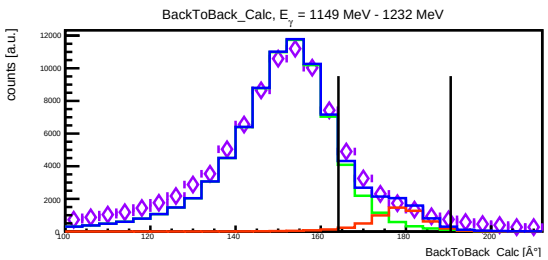


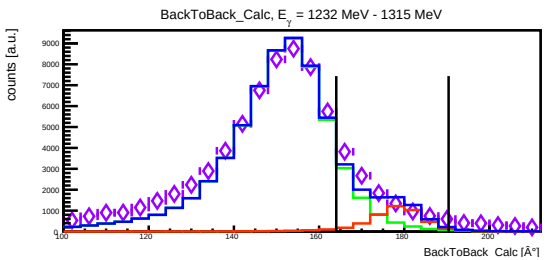


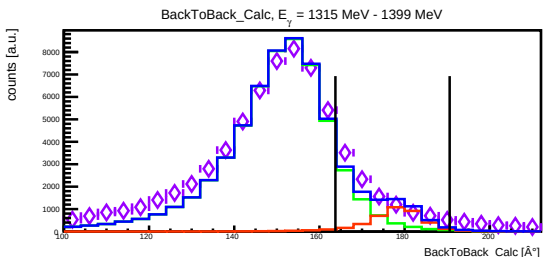




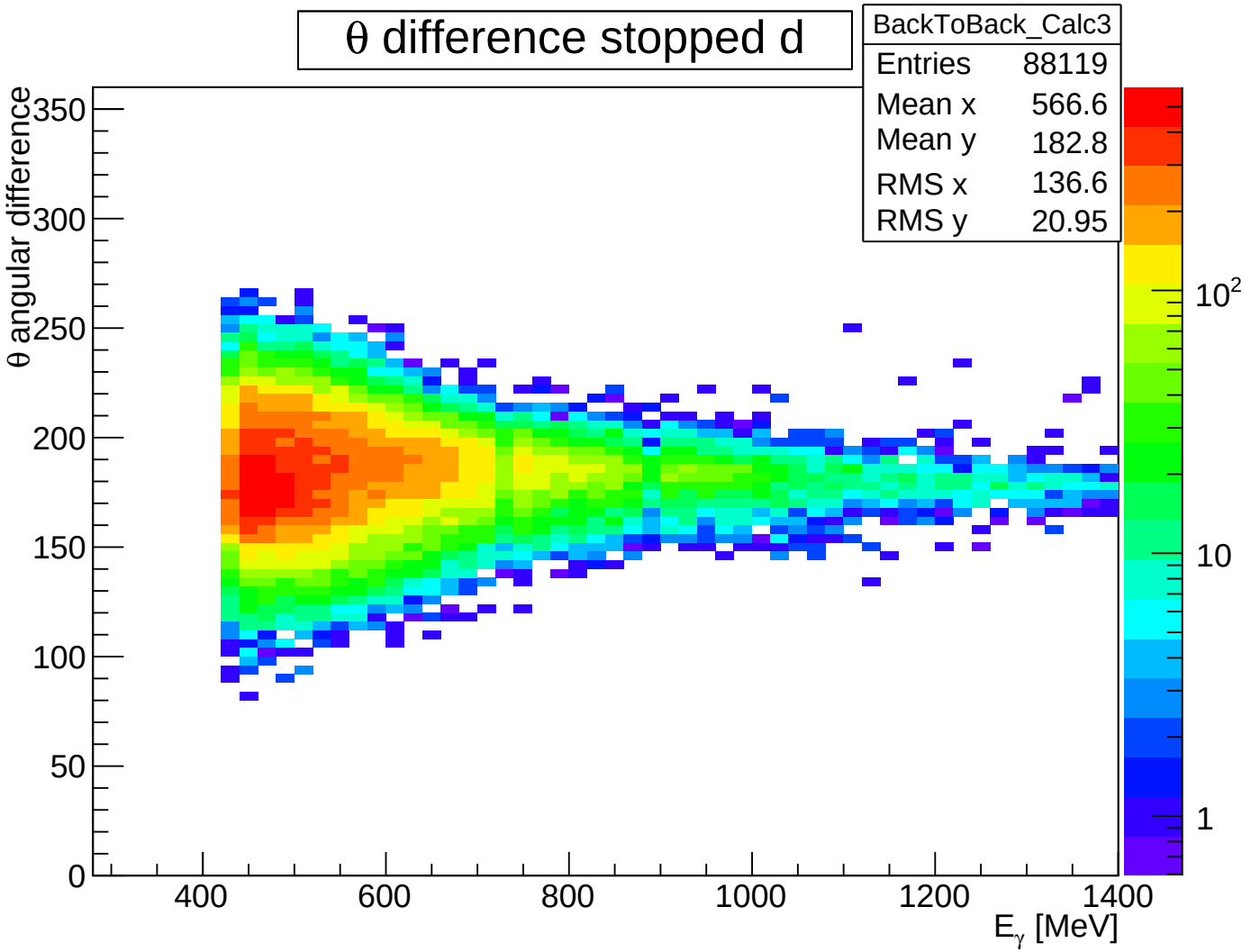




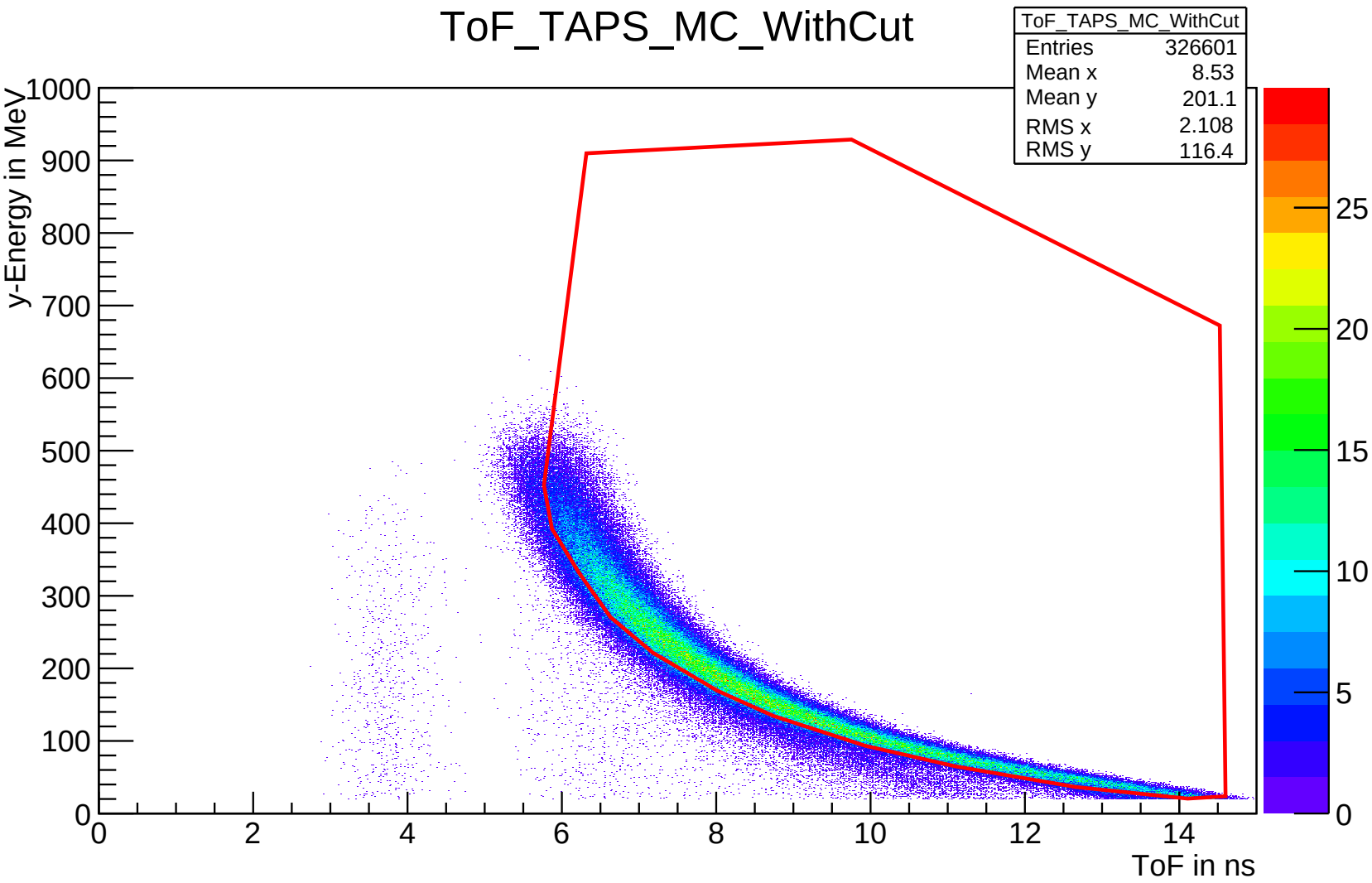




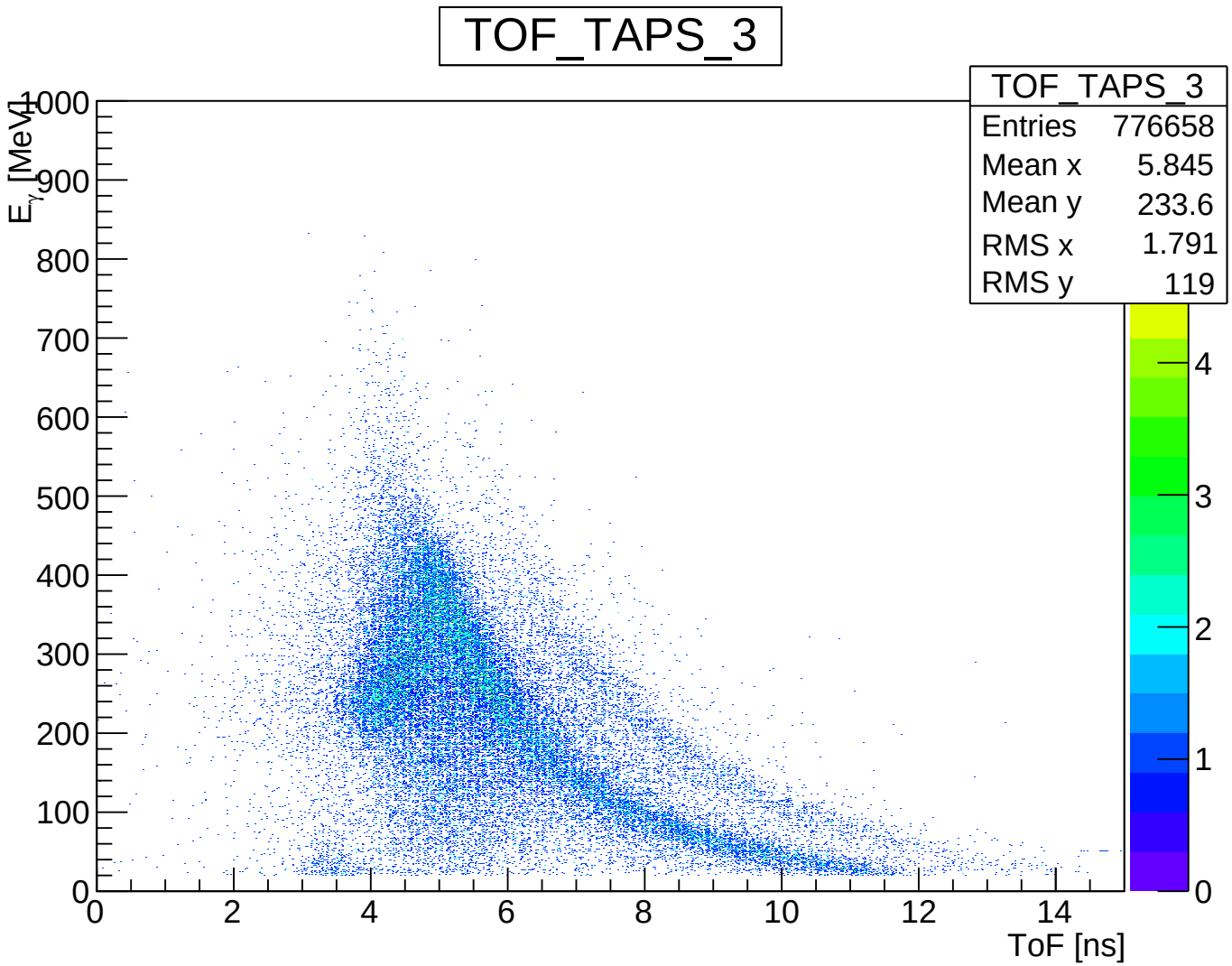
Event selection - Theta cut



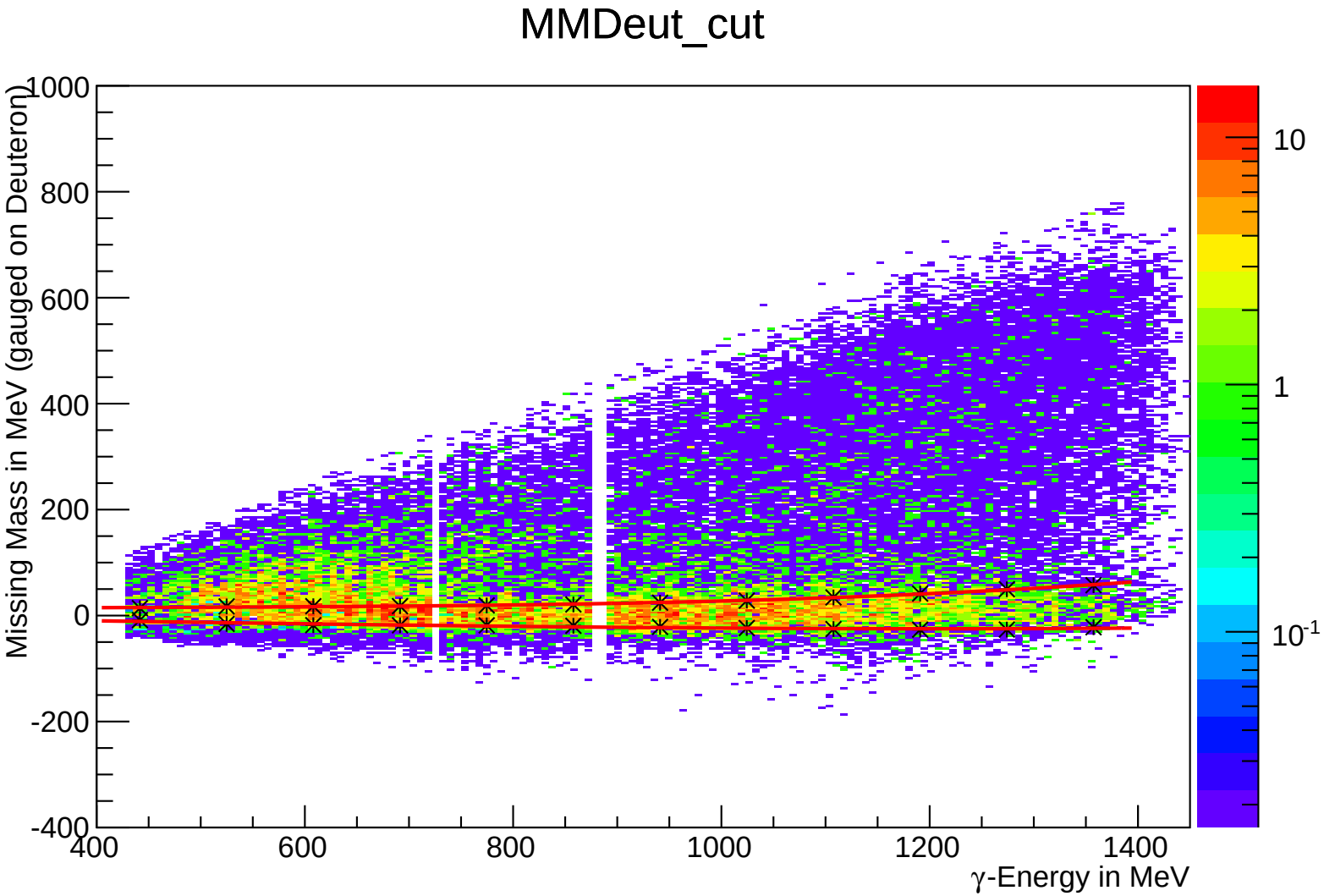
ToF With Cuts - MC



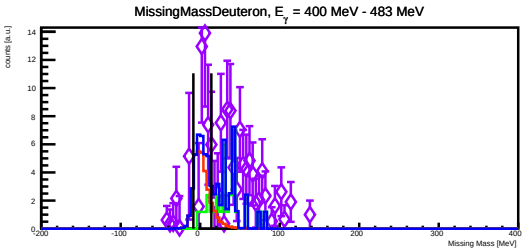
ToF with Cuts - Data

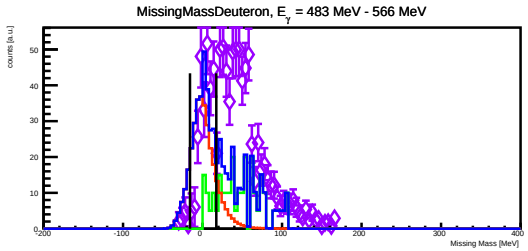


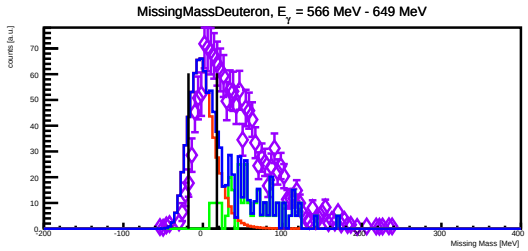
Event selection - Missing Mass cut

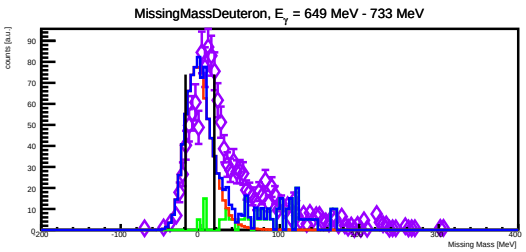


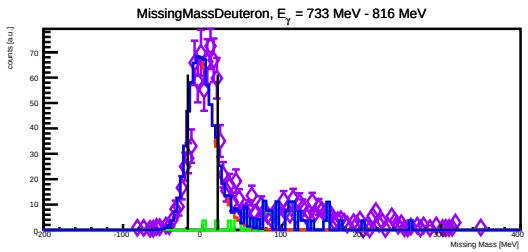
Event selection - Missing Mass cut

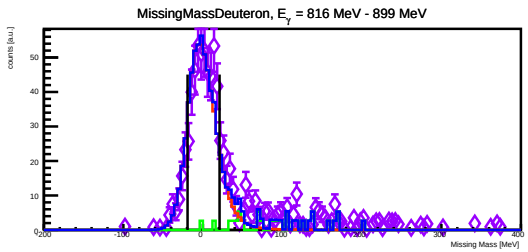


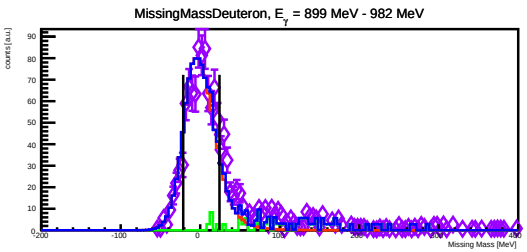


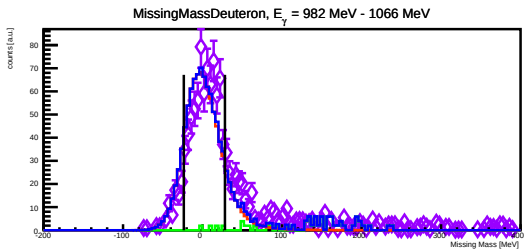


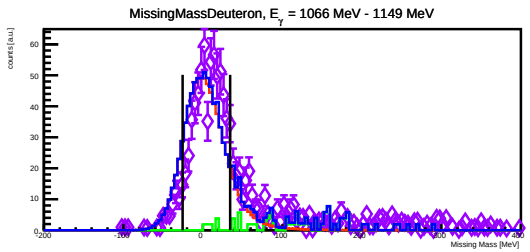


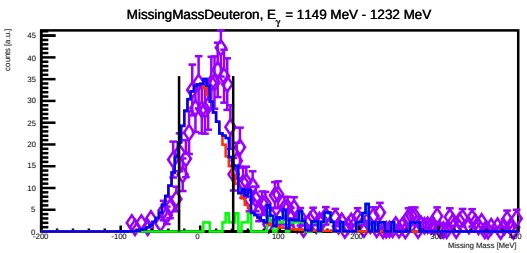


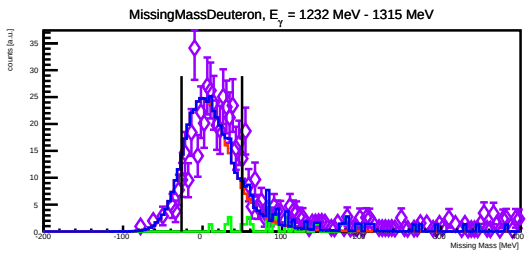


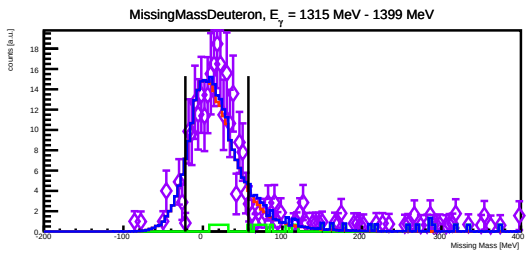








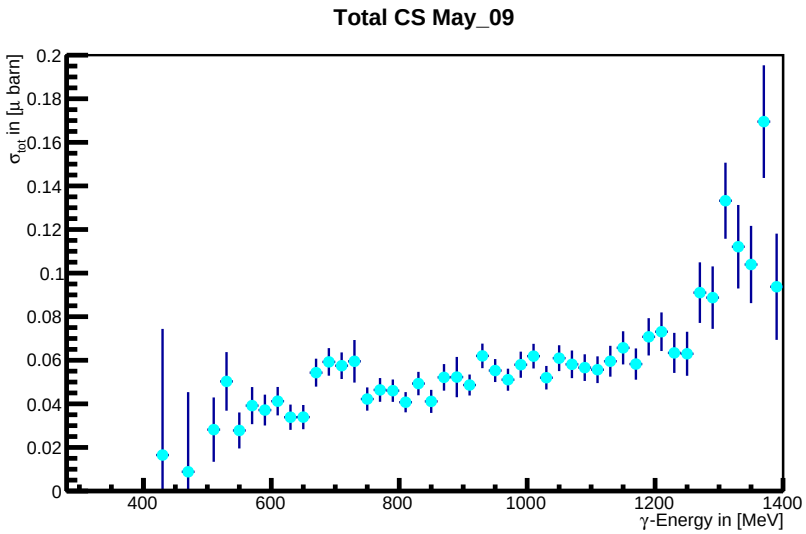


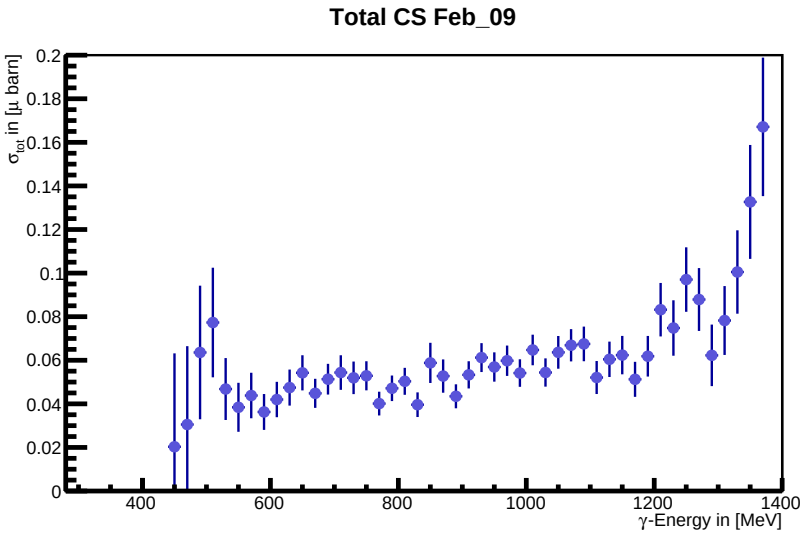


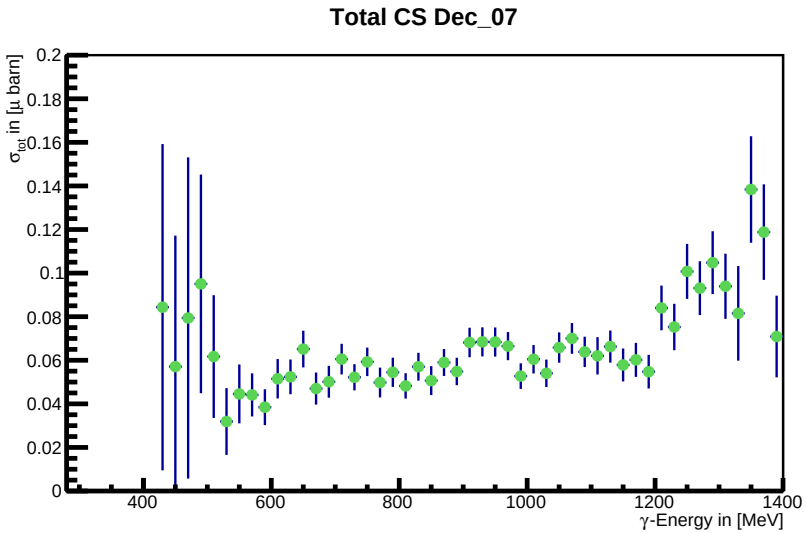
Conclusion and Outlook

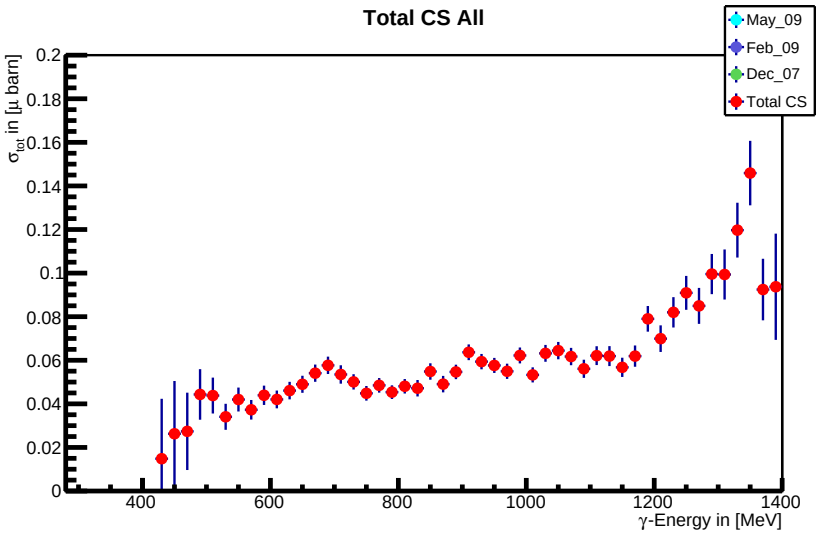
- A resonable match with the coherent $\pi^0\pi^0$ model.
- Statistical and or analytically problems in regions below 2450 W or above 2800 W.
- For the $\pi^0\pi^0\pi^0$ channel, still more data available (Dec + Feb).

CS Beamtime seperated

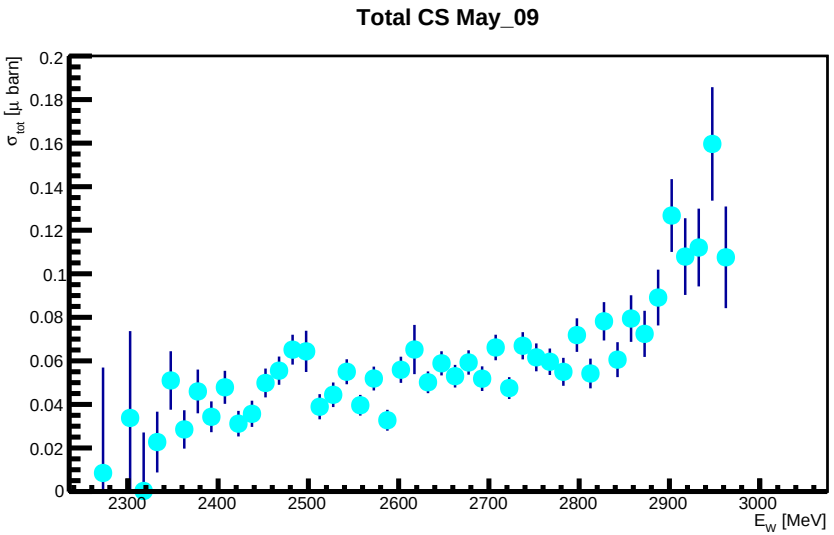


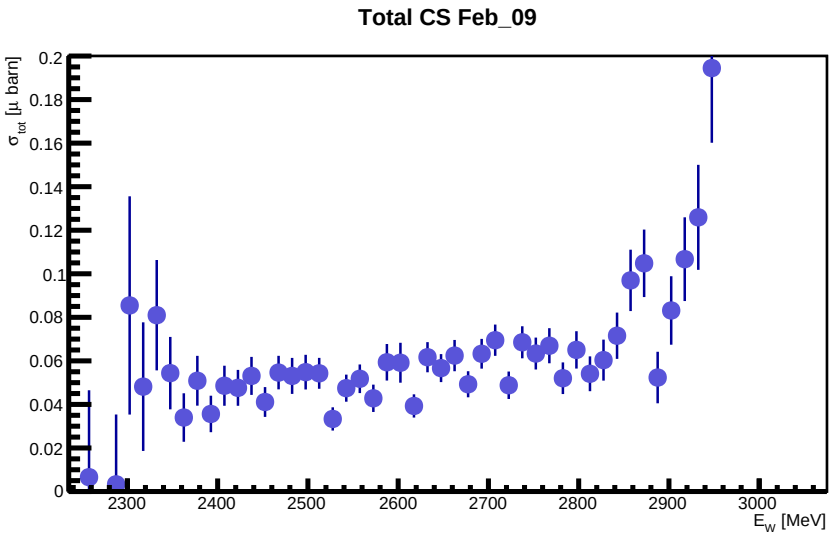


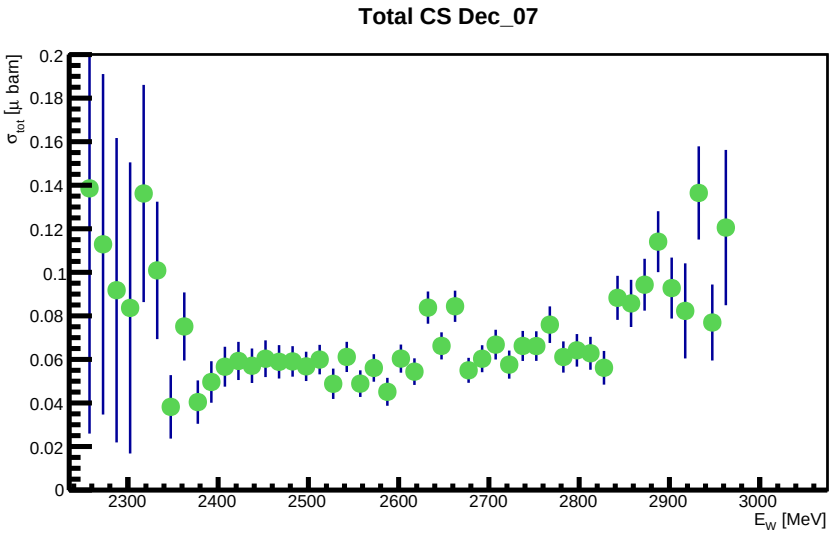




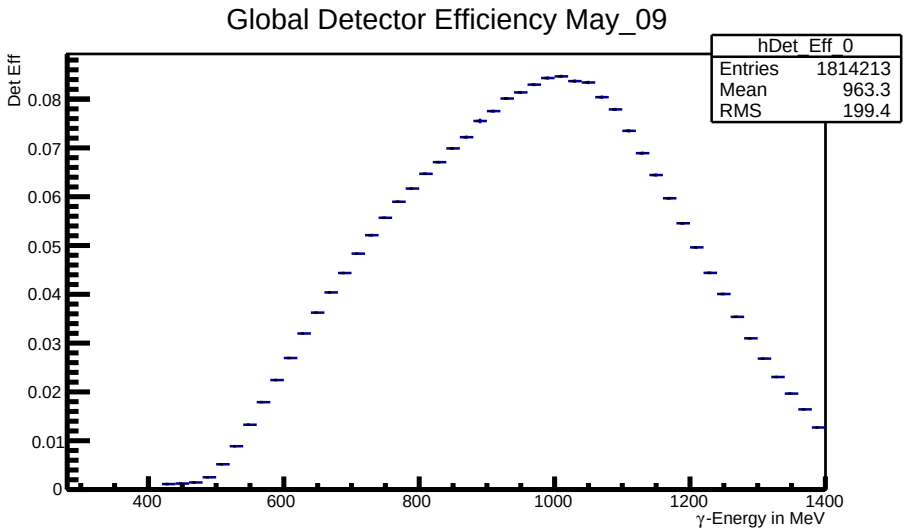
CS Beamtime seperated - W

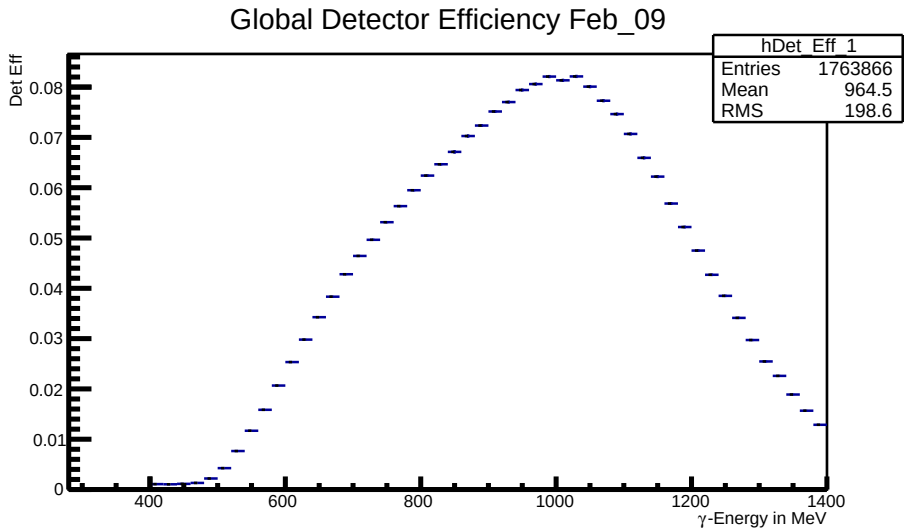


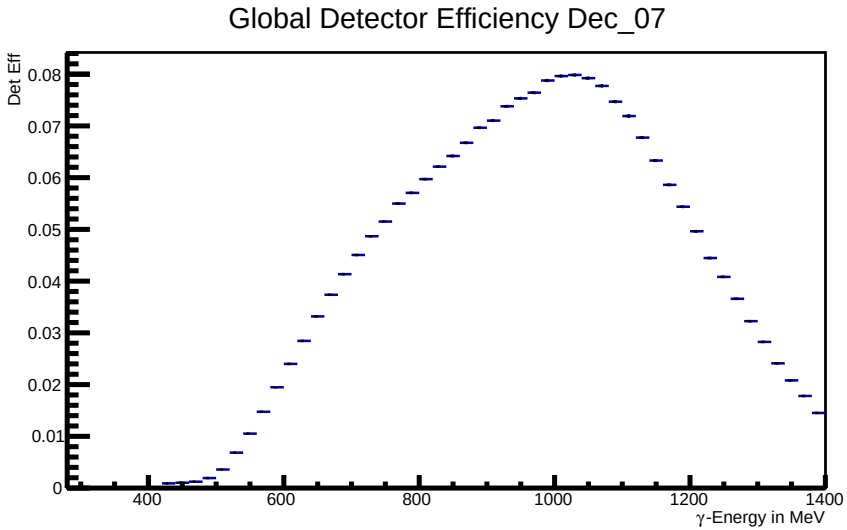




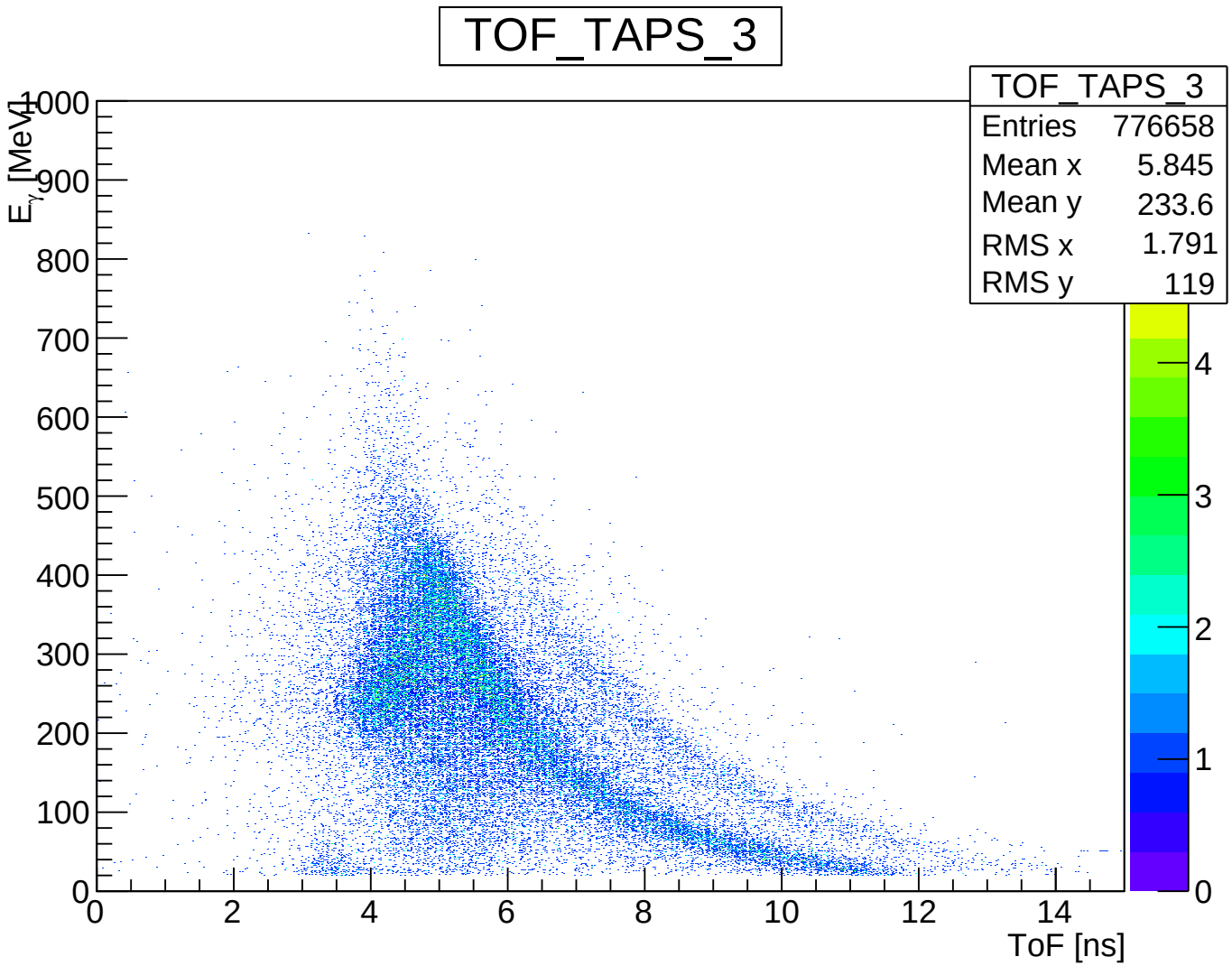
Total Efficiency



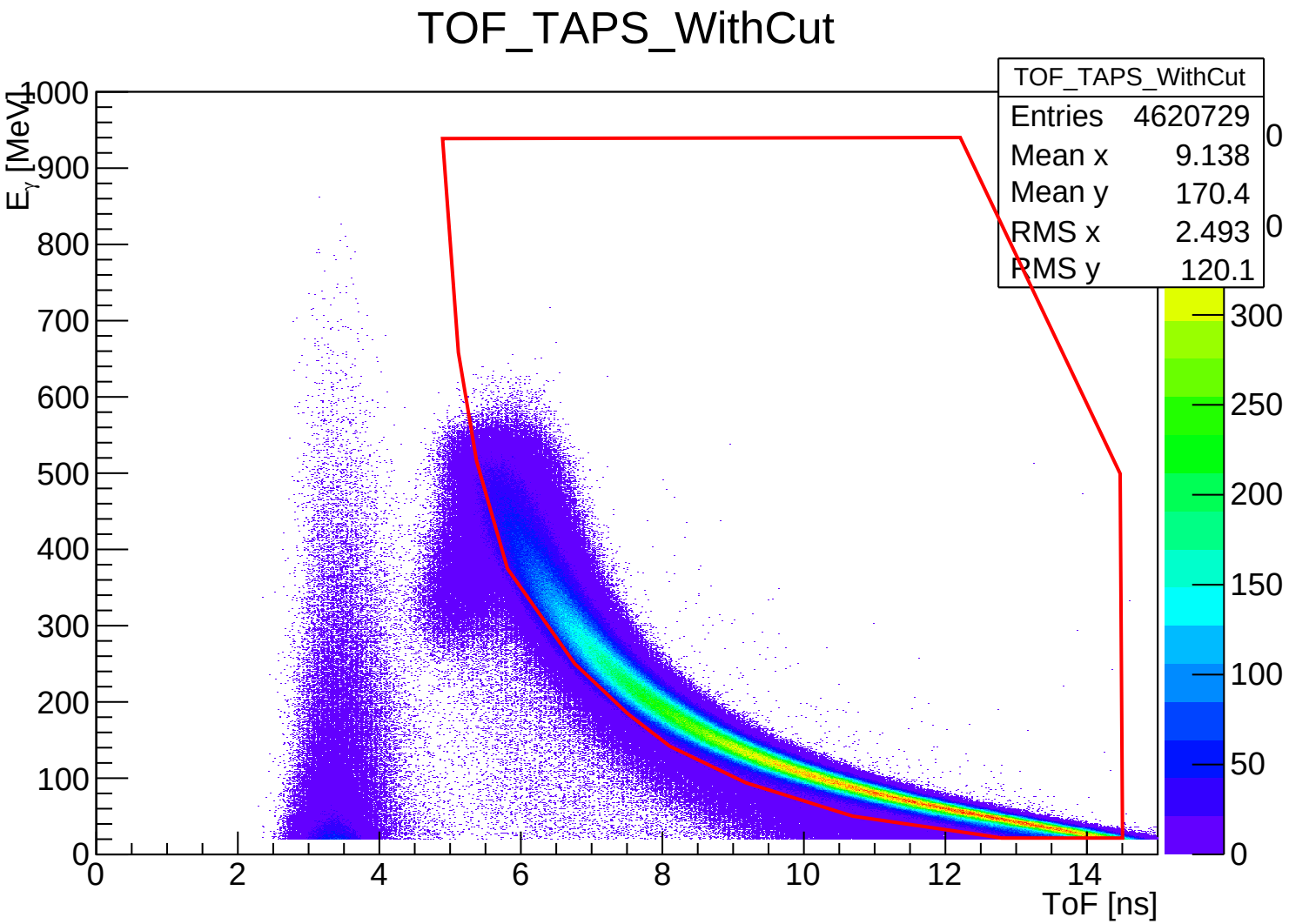




ToF With Cuts - Data



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	LD_2	LD_2	LD_2
target lenght [cm]	4.72	4.72	3.02
CB Energy Sum Trigger	$>$ 300 MeV	$>$ 300 MeV	$>$ 300 MeV
multiplicity trigger	M2+	M3+	M2+