Utilising the CLAS Start Counter as a Neutron Polarimeter

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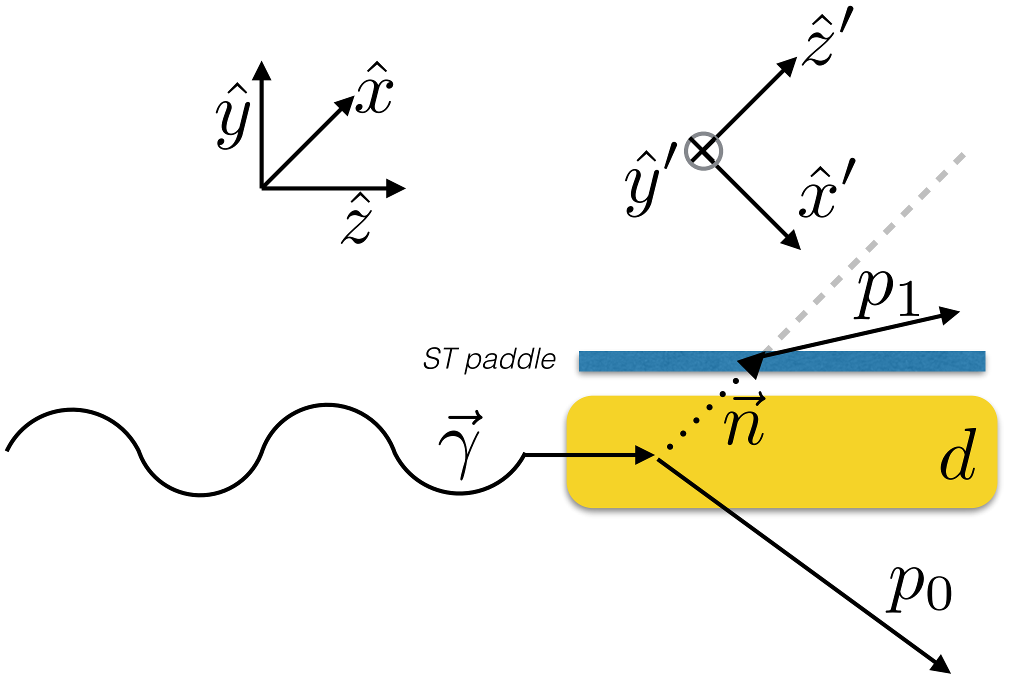
Motivation

- Provide first measurement of the final-state neutron spin polarisation from $\gamma d \rightarrow pn$
- Unexpected results of proton polarisation indicated a new dibaryonic resonance state
  - supported by numerous recent experiments
- Allow investigation of the recently discovered resonant state d*(2380)
- A key expectation from this dibaryonic state is that both proton and neutron would show a high degree of polarization

Analysis Approach

$$\gamma d \to pn$$

$$\hookrightarrow np \to pn$$



$$\vec{p}_n = \vec{p}_\gamma + \vec{p}_d - \vec{p}_{p0}$$

$$\hat{z}' = \frac{\vec{p}_n}{|\vec{p}_n|}$$

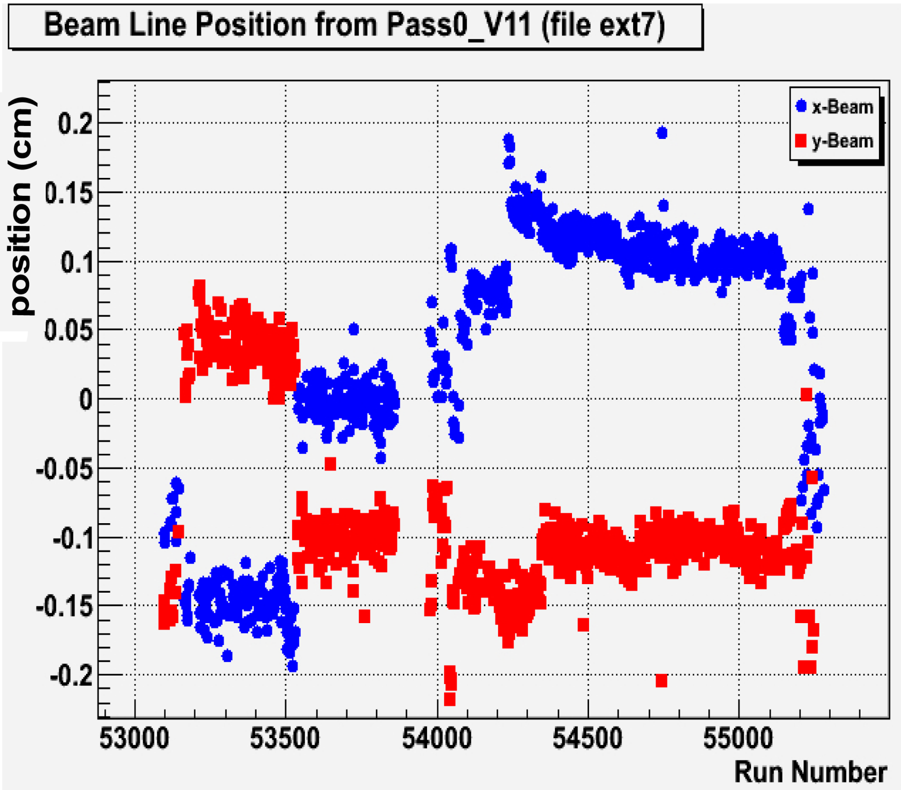
$$\hat{y}' = \frac{\vec{p}_\gamma \times \vec{p}_{p0}}{|\vec{p}_\gamma \times \vec{p}_{p0}|}$$

$$\hat{x}' = \hat{y}' \times \hat{z}'$$

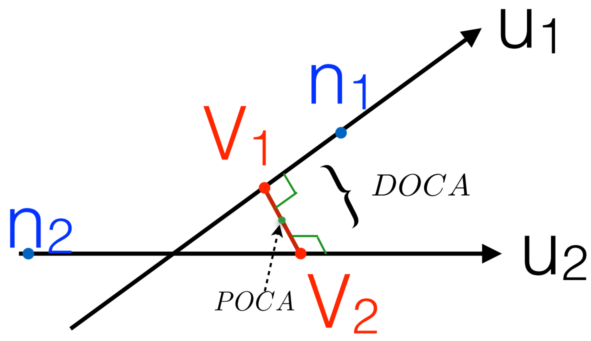
Reaction Reconstruction

Vertex Position

Beam line position



DOCA Vertex Position



Initial Vertex Positions n_1, n_2

Track vectors u_1, u_2

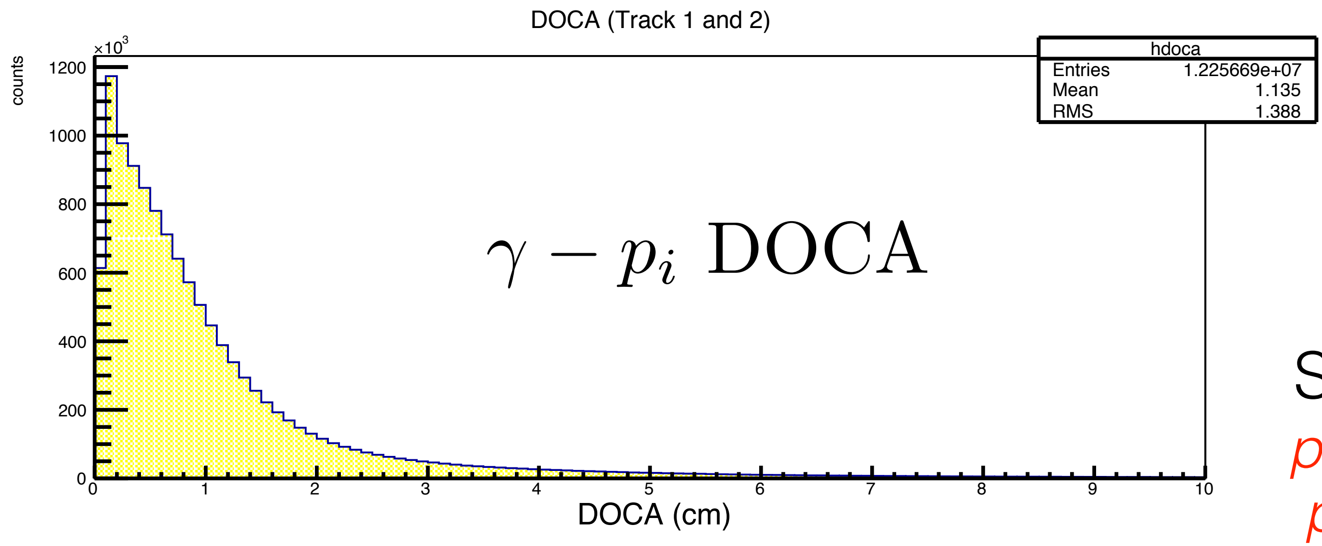
New Vertex Positions $\mathbf{V_i}=\mathbf{n_i}+t_i\,\mathbf{u_i}$

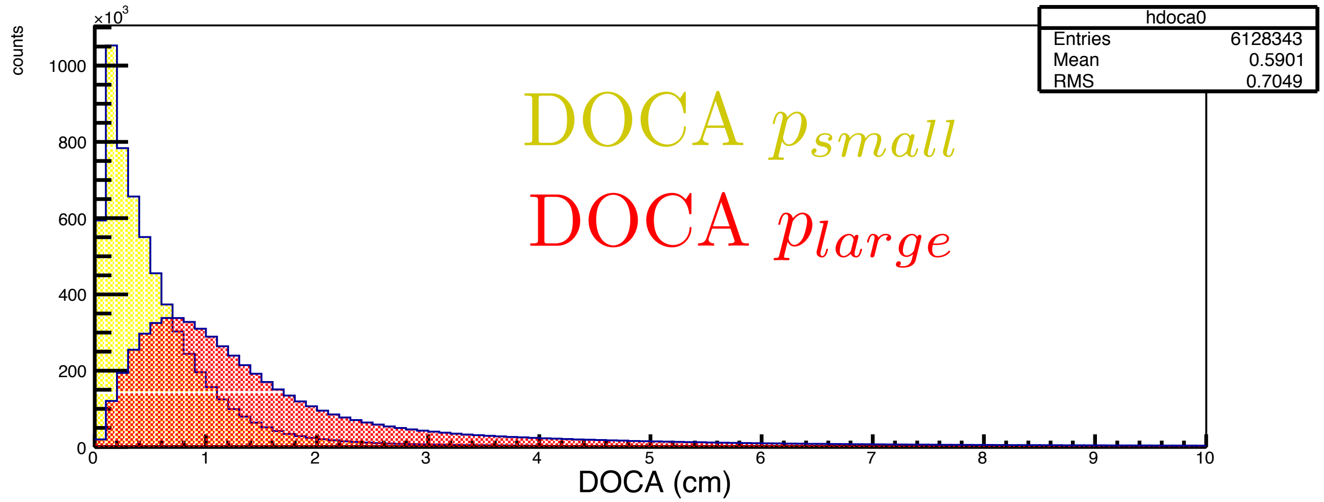
$$\mathbf{u_i} \cdot \mathbf{\Delta V_i} = 0$$

$$\gamma - p_0 \qquad n - p_1$$
$$\gamma - p_1$$

Reaction Reconstruction

DOCA





Select p based on DOCA

p_1 proton with smallest DOCA

p_2 proton with largest DOCA

Event Vertex DOCA of p_1

$\Delta\beta$ cut

g13 experiment

Experiment run in 2006-2007

LD$_2$ Target 40 cm long

Two photon polarisation settings

Circular (g13a)

Linear (g13b)

50 billion physics events

g13a

- Current: ~40 nA
- Two e-beam energies
  - 1.990 GeV
  - 2.655 GeV
- 20 billion events

g13b

- Current: ~10 nA
- Eight e-beam energies between 3.3 and 5.16 GeV
- Collected events for 6 photon-energy bins between 1.1 and 2.3 GeV
- 30 billion events

Reaction Reconstruction

Particle ID

Skim

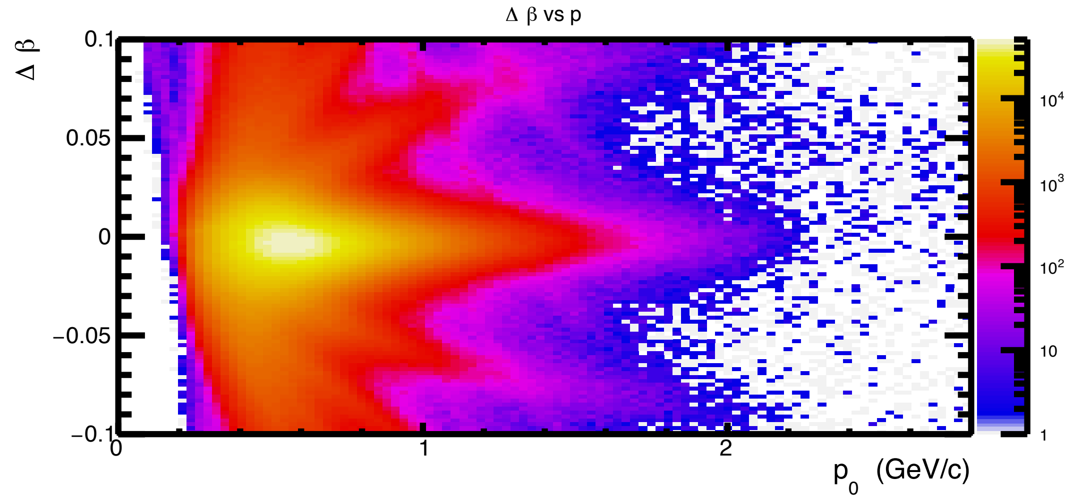
2-positively charged tracks only
loose cut on proton mass +…

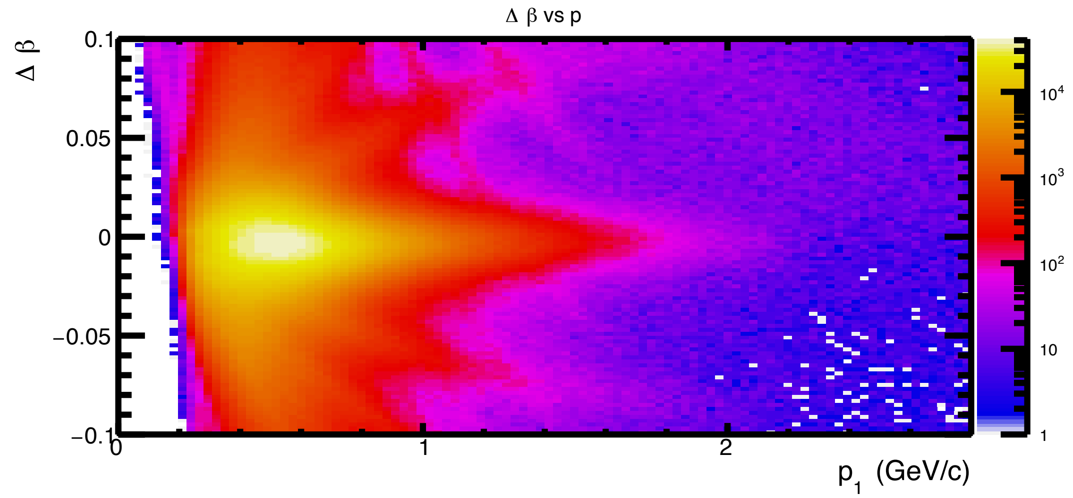
$$\Delta\beta = \beta_{meas} - \beta_{calc}$$

$$\beta_{calc} = \frac{p}{\sqrt{p^2 + m^2_{PDG}}}$$

$$\beta_{meas} = \frac{1}{c}\frac{L_{TOF}}{t_{TOF}}$$

$$\boxed{|\Delta\beta| < 0.035}$$





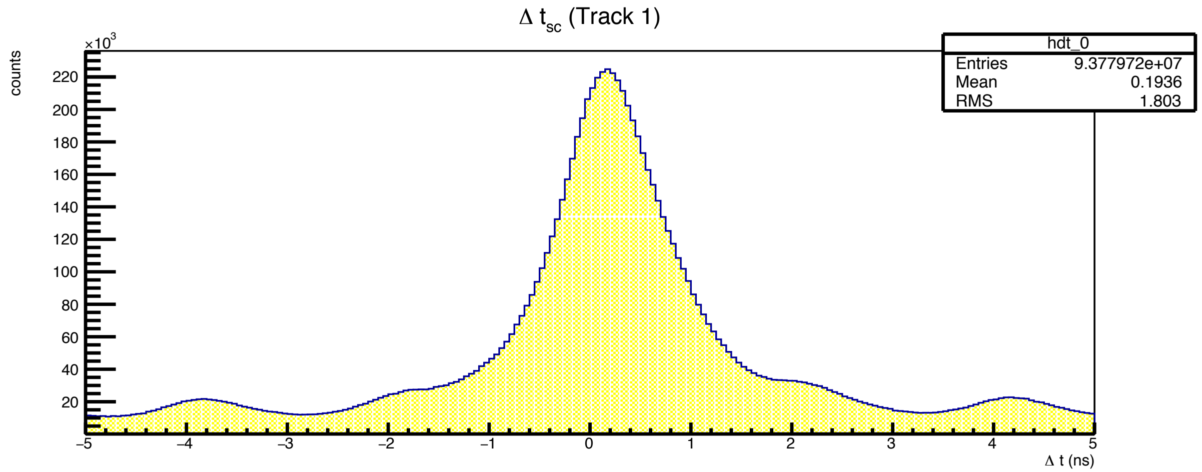
Reaction Reconstruction

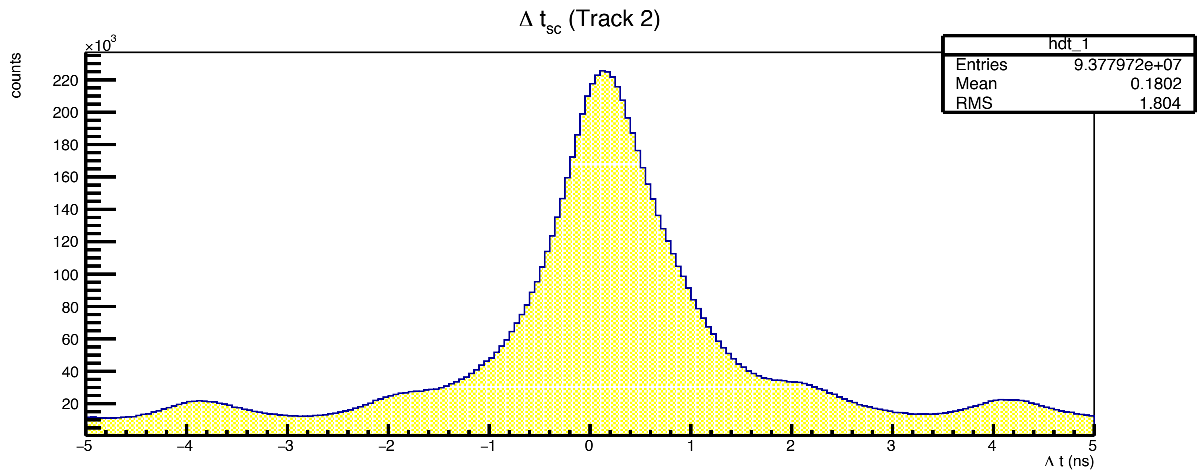
Photon Selection

$$\Delta t = t_p - t_\gamma$$

$$t_p = T_{tof} - \frac{L_{TOF}}{c \cdot \beta_{calc}}$$

$$t_\gamma = t_{pho} + t_{prop}$$





$\Delta\beta$ cut

Reaction Reconstruction

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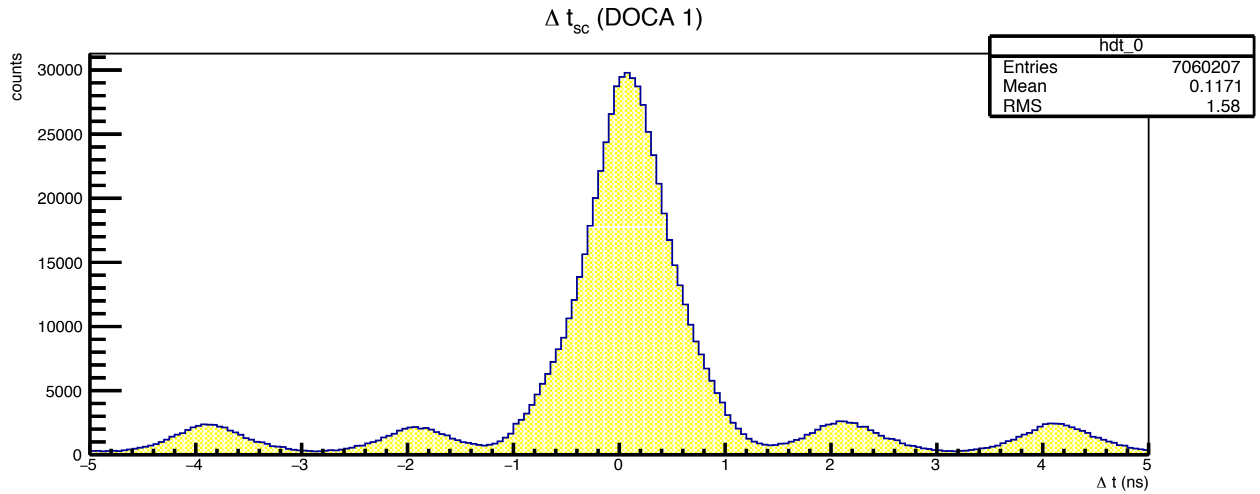
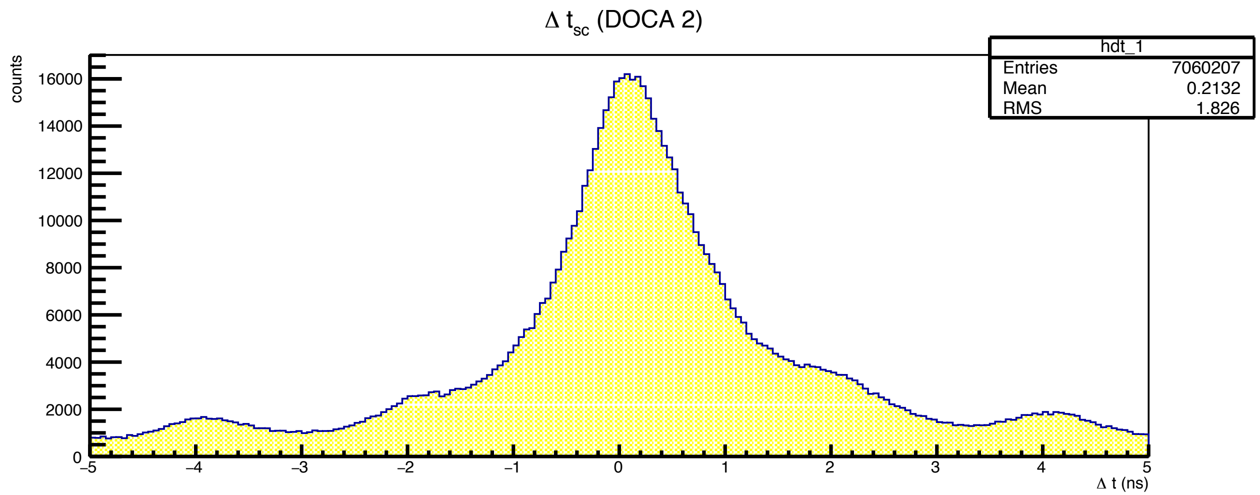


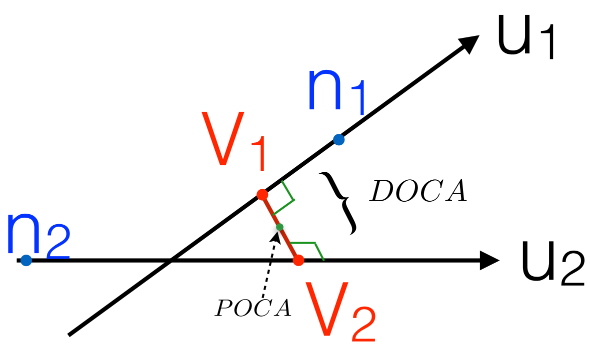


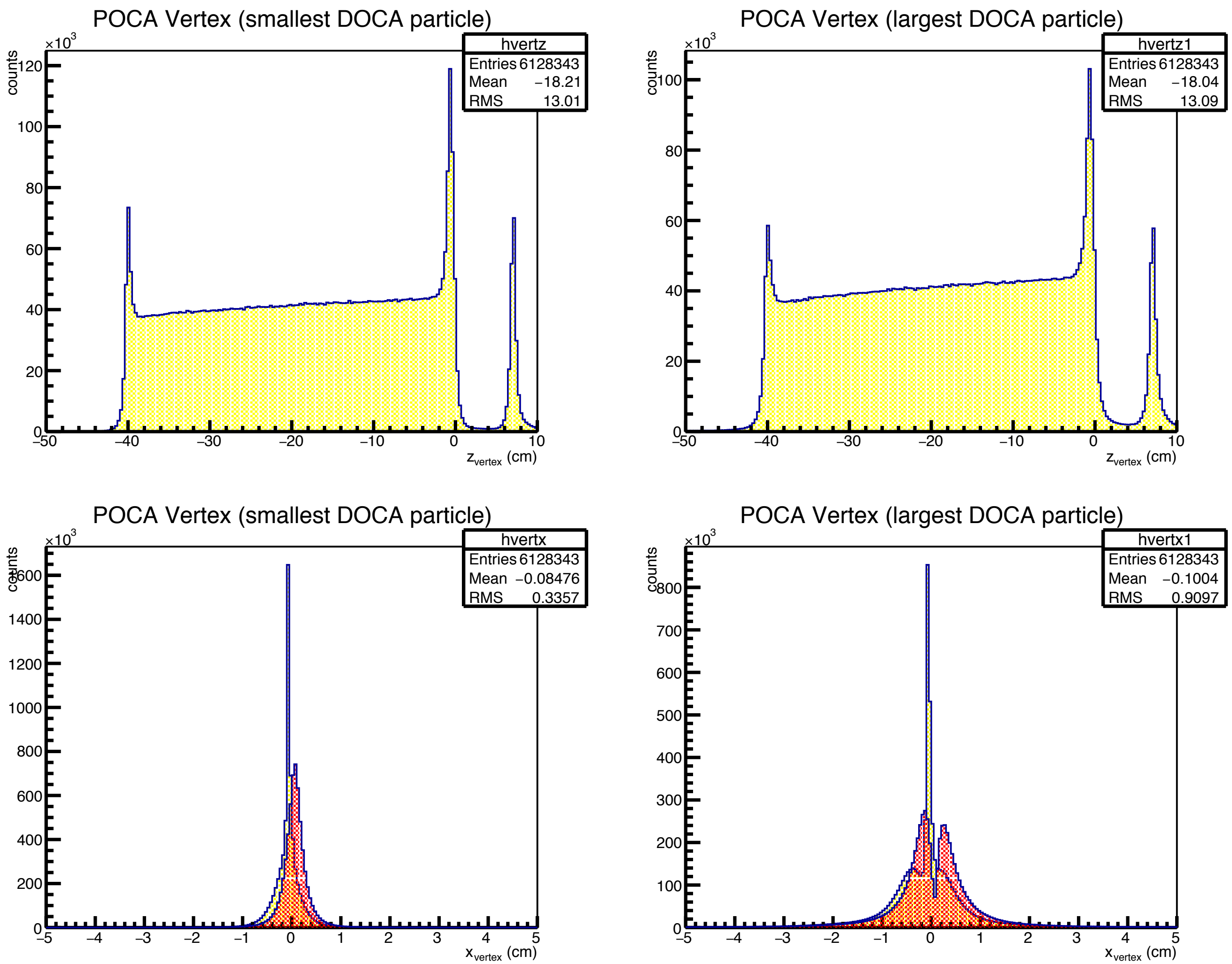
$\Delta\beta$ cut

MM cut

Reaction Reconstruction

Vertex Position





$\Delta\beta$ cut

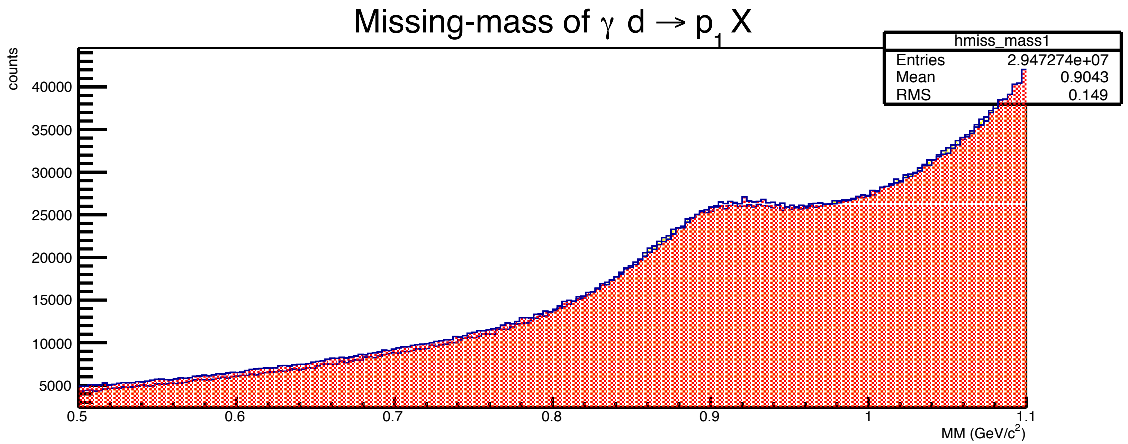
Reaction Reconstruction

Missing Mass

$$\gamma d \to pX$$

$$\gamma d \to p_1 X$$

$$\gamma d \to p_2 X$$

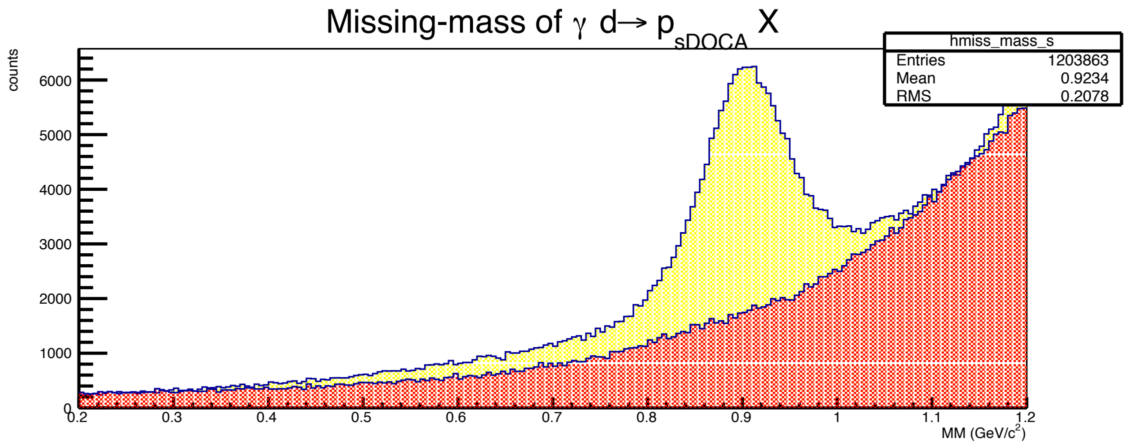


p_s smallest DOCA Proton

p_l largest DOCA Proton

$$\gamma d \to p_s X$$

$$\gamma d \to p_l X$$



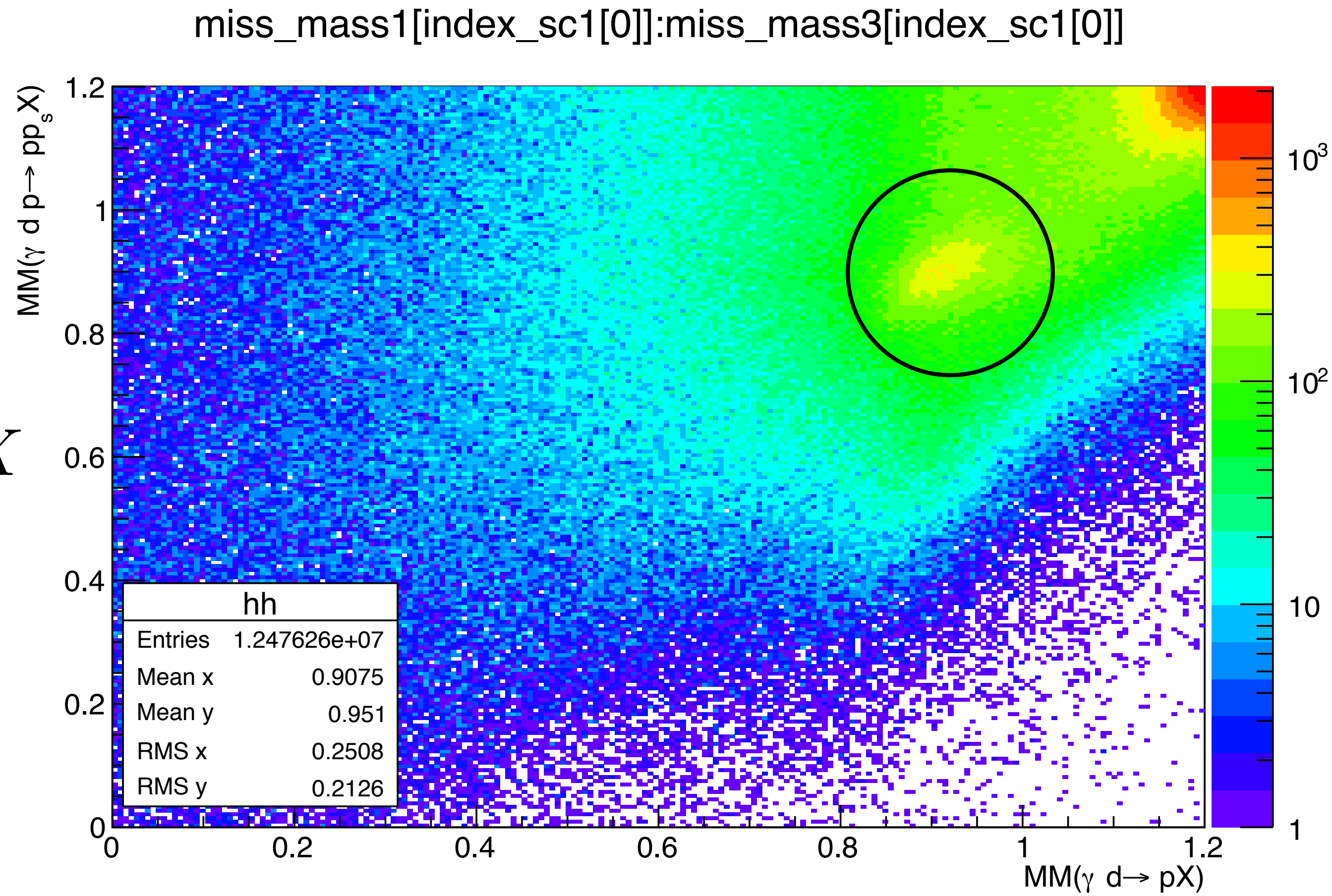
$\Delta\beta$ cut

Reaction Reconstruction

Missing Mass

$$\gamma d \rightarrow p_s n$$

$$n p_T \rightarrow p_l X$$



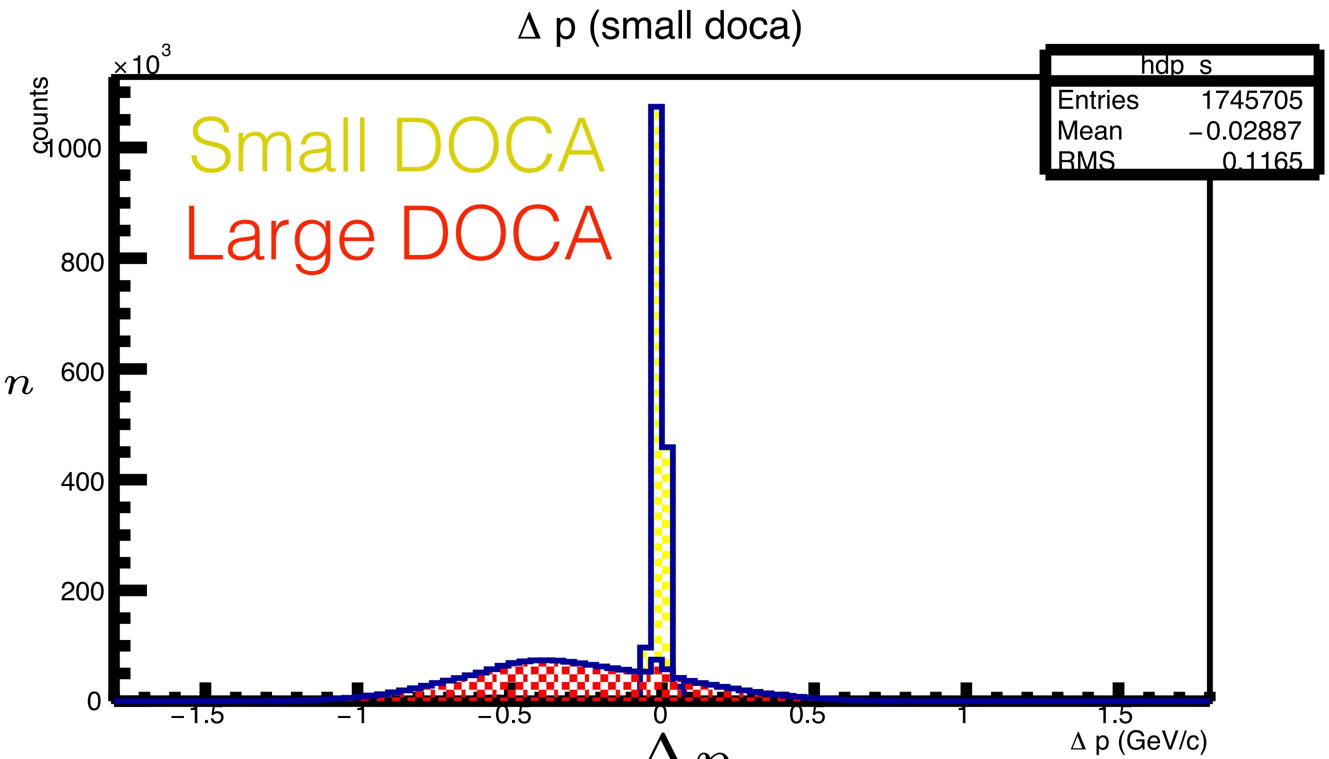
$$\gamma d \rightarrow p_s X$$

Simulations

$$\gamma d \to pn$$

$$\gamma d \to pn \quad np \to pn$$ within ST and target

$$\Delta p = p_{rec} - p_{gen_{\gamma d \to pn}}$$



$$\Delta p$$

$$\gamma d \to pn \quad pp \to pp$$

$$\gamma d \to pp\pi^-$$

Analysis

Angle definition

$$\gamma d \to pn$$

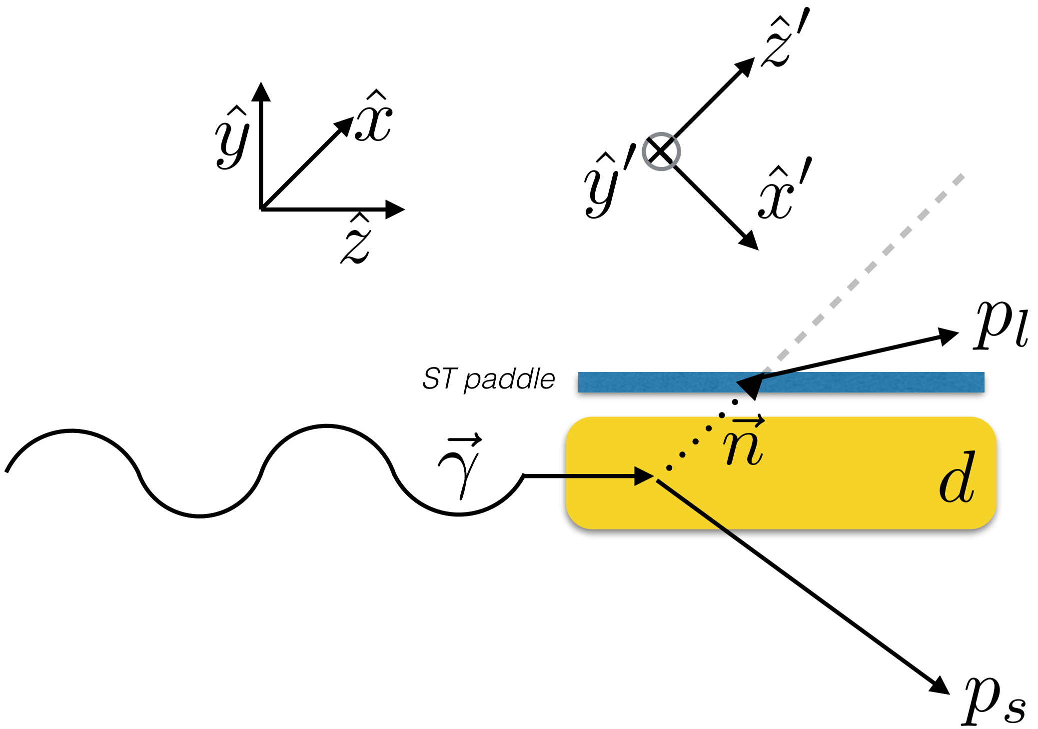
$$p_n^{rec} = p_\gamma + p_d - p_{p_s}$$

$$\hat{\eta} = \frac{\vec{p}_n \times \vec{p}_{p_l}}{|\vec{p}_n \times \vec{p}_{p_l}|}$$

$$\sin\theta_{sc} = \frac{\vec{p}_n \times \vec{p}_l}{|\vec{p}_n||\vec{p}_l|}$$

$$\cos\phi_{sc} = \hat{y}' \cdot \hat{\eta}$$

$$\sin\phi_{sc} = -\hat{x}' \cdot \hat{\eta}$$



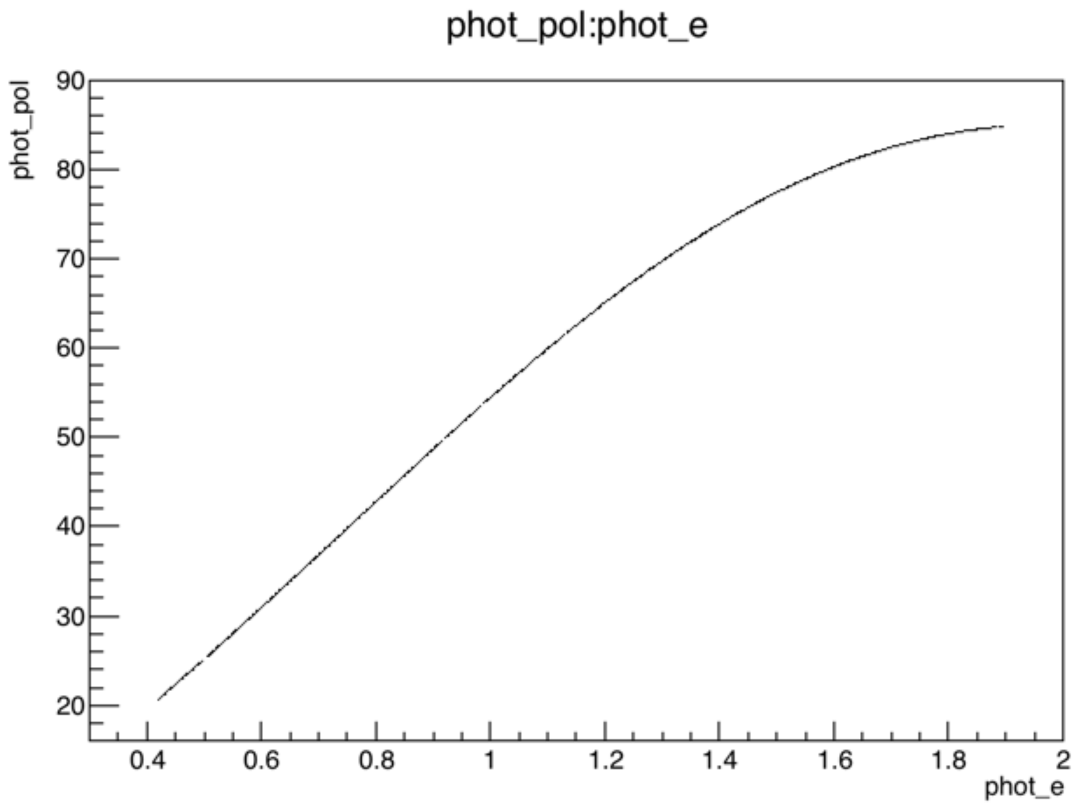
$$I(\theta_{sc}, \phi_{sc}) = I_0(\theta_{sc})[1 + A(\theta_{sc})(P_y \cos\phi_{sc} - C_{x'} P_\gamma^{\odot} \sin\phi_{sc})]$$

Analysis

Photon Polarisation

$$P_{cir} = \frac{E_\gamma (E + \frac{1}{3}E^{'})P_e}{E^2 + E'^2 - \frac{2}{3}EE'}$$

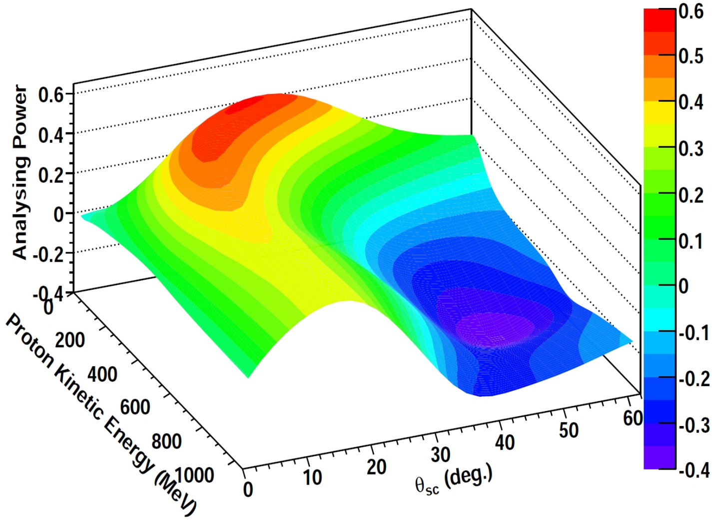
Olsen-Maximon 1959



Analysis

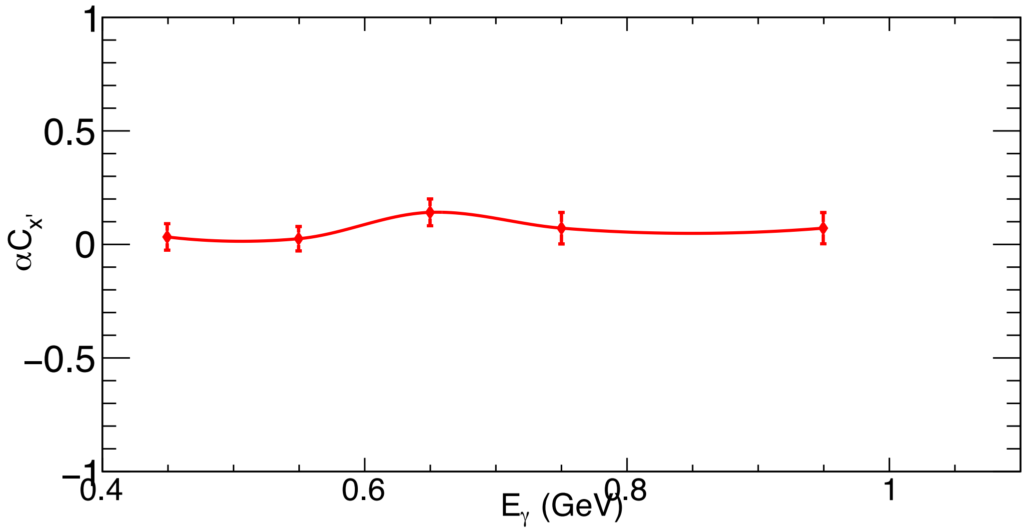
Analysing Power

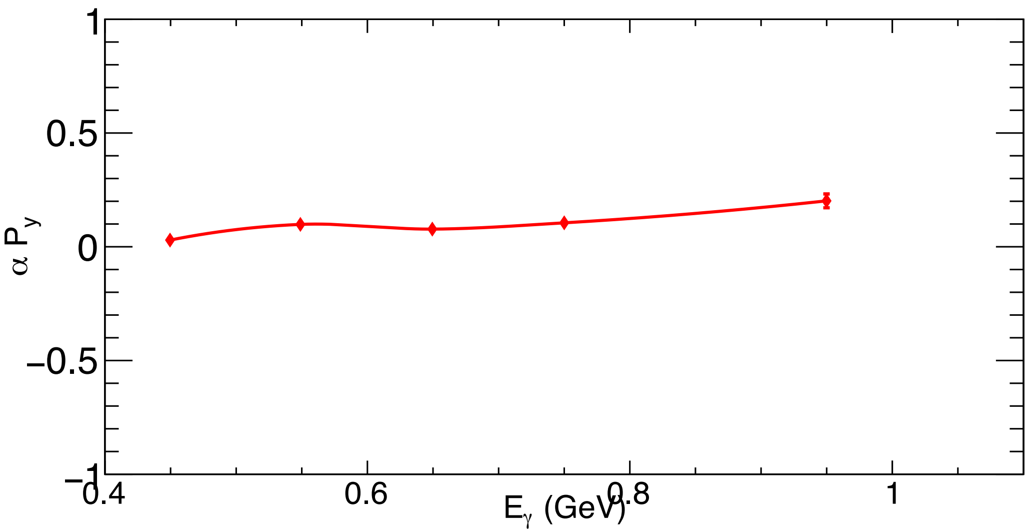
- Use results from SAID on α



- Develop GEANT4 simulation of g13 target and ST to establish an effective α
  - GEANT4 accurately calculates energy losses and θ_{sc} distributions it does not include effects of polarised scattering
  - We will provide proper algorithms to introduce the polarised distributions to obtain the analysing power from simulation

Preliminary Results





Summary

- Determination of the neutron polarisation from deuteron photodisintegration utilising CLAS data (g13) is underway $\gamma d \to pn$

  $np \to pn$
- Distance of closest approach between γ and each proton allows us to identify the proton from $\gamma d \to pn$ and thus reconstruct the neutron
- Angular distributions of second proton with respect to neutron are determined
- Monte Carlo simulations will be used to obtain the effective analysing power
- First results on neutron polarisation transfer weighted by the effective analysing power were determined

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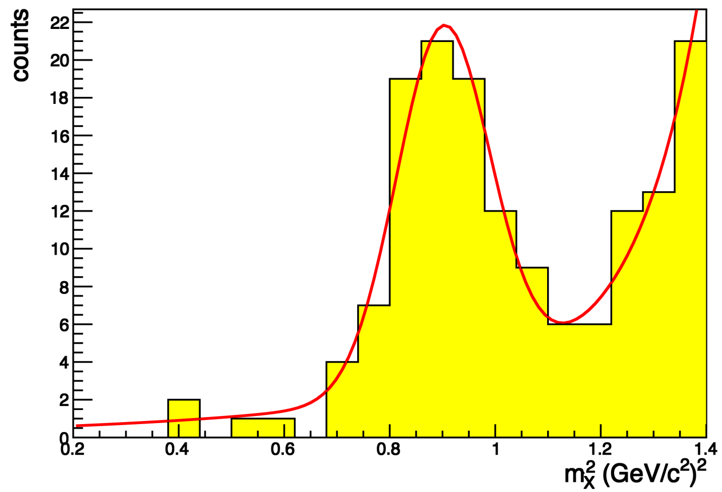
Extras

Analysis

Background Subtraction

M. Williams, CLAS Note 2007-013



Probabilistic event Weighting

$$d_{ij} = \sum_k \left[\frac{(\xi_k)_i - (\xi_k)_j}{r_k} \right]^2$$

Signal $\quad g(m_X^2, A, \mu, \sigma) = Ae^{-\frac{1}{2}\left(\frac{m_X^2-\mu}{\sigma}\right)^2}$

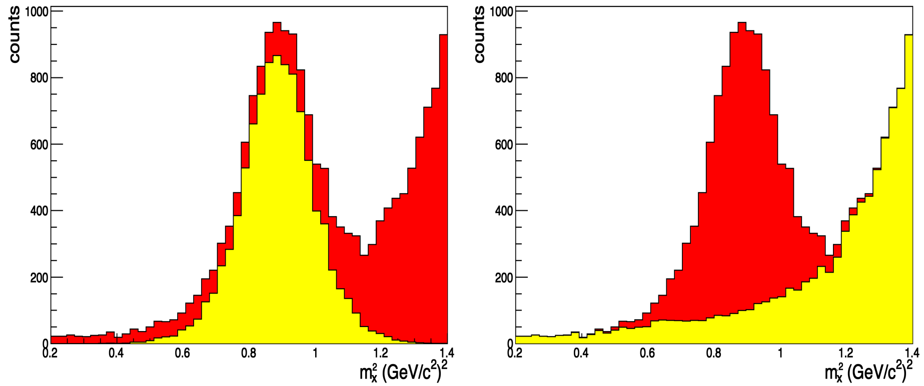
Background $\quad b(m_X^2, A_1, A_2, B_1, B_2) = A_1 e^{A_2 m_X^2} + B_1 e^{B_2 m_X^2}$

Calculate Q-value Q_i using m^2_X and determined parameters

$$Q_i = \frac{g(m_X^2[i], A, \mu, \sigma)}{g(m_X^2[i], A, \mu, \sigma) + b(m_X^2[i], A_1, A_2, B_1, B_2)}$$

$$\sigma_{Q_i} = \sum_{jk} \frac{\partial Q_i}{\partial p_j} Cov(i,j) \frac{\partial Q_i}{\partial p_k},$$

Q-factor is used as weight for each event



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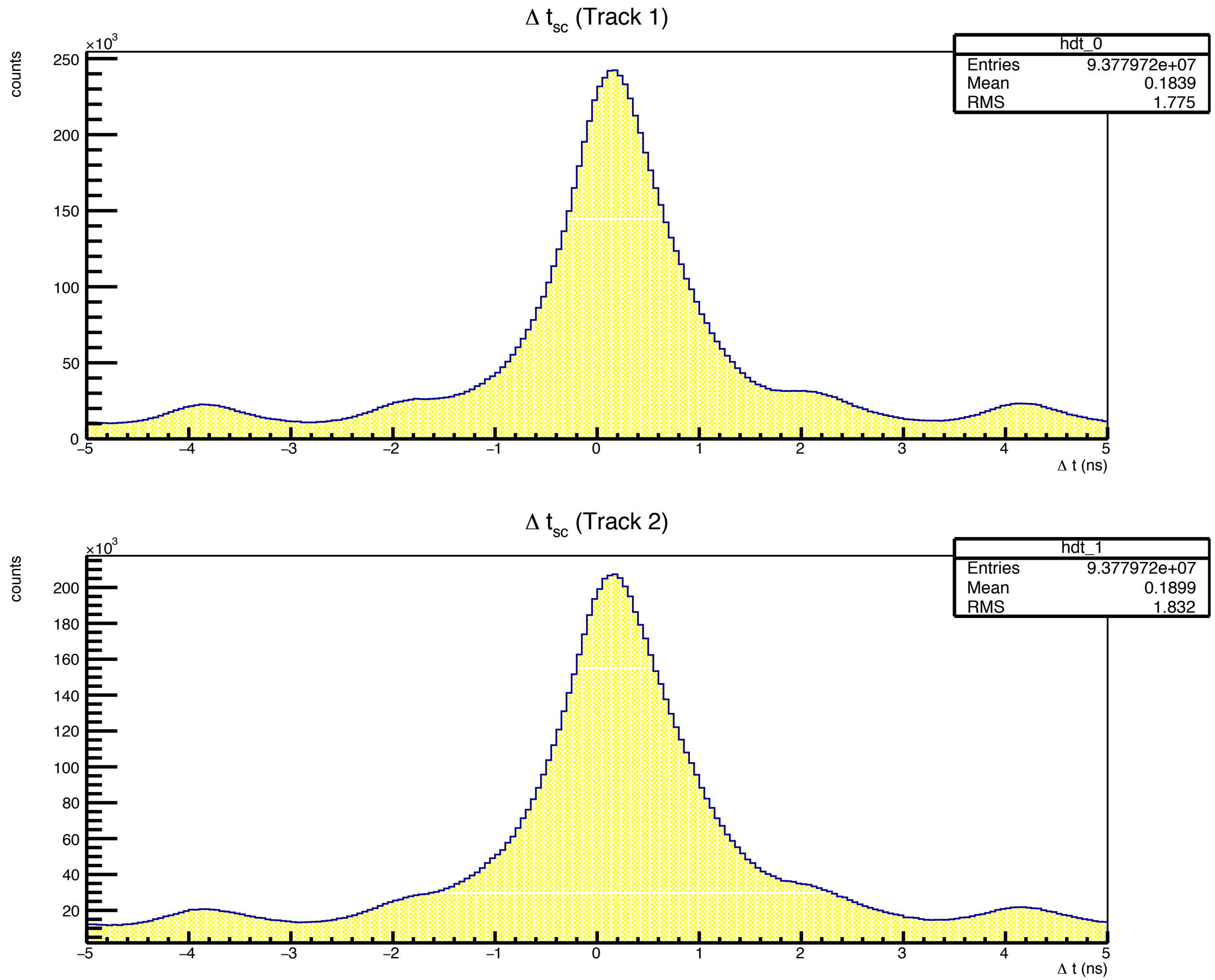

$\Delta\beta$ cut

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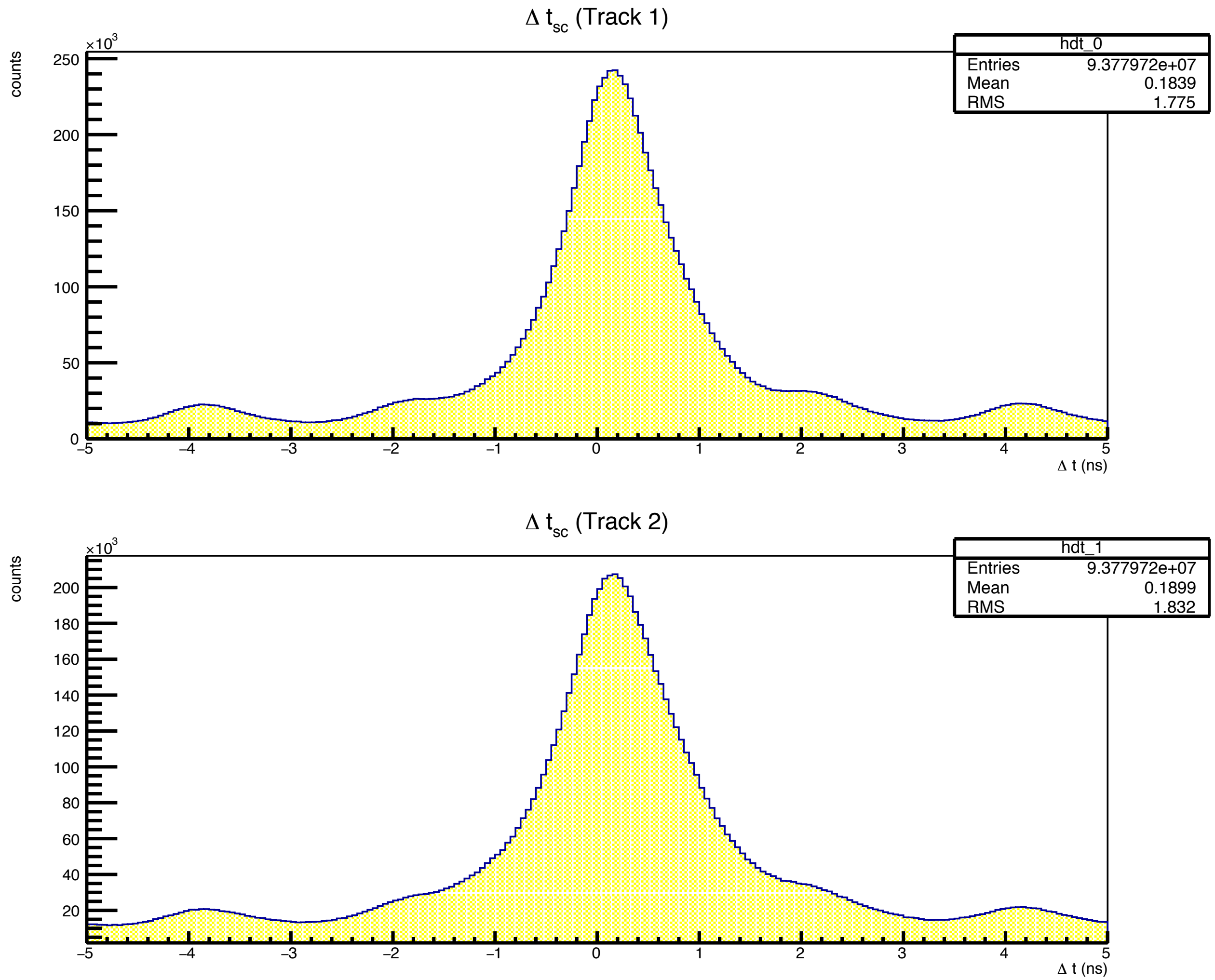

$\Delta\beta$ cut