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Coherent Photoproduction of proton anti-proton pair on Deuterum with

clas

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2014

Outline

- Introduction
- CEBAF/CLAS
- Experiment description
- Data analysis
- Event selection
- Results
- Conclusion and Future work


Introduction

First publications for experimental evidences

[1] A.S. Carroll et al., Phys. Rev. Lett. **32**, 247 (1974).

[2] P. Benkheiri et al., Phys. Lett. **B68**, 484 (1977).

[3] B.G. Gibbard et al., Phys. Rev. Lett. **42**, 1593 (1979).

[4] D. Aston et al., Phys. Lett. **93B**, 517 (1980).

[5] J. Bodenkamp et a., Phys. Lett. **B133**, 275 (1983).

[6] A. Ferrer, A.A. Grigoryan, V.F. Perepelitsa, P. Sonderegger, Eur. Phys. J **C10** 249 (1999).

[7] K. Abe et al., hep-ex/0202017 (2002)

[8] J.Z. Bai et al., hep-ex/0303006 (2003)

[9] V. Koubarovski, M. Battaglieri and M. Ripani, CLAS-ANALYSIS Note 2003-106

[10] FSU analysis

[11] Wiki page of eg3 run group, *http : //clasweb.jlab.org/rungroups/eg3/wiki/index.php/Mainpage*

[12] I.D. Overman, SLAC-140 (1971).

Y. Eisenberg et al., Nucl. Phys. **B42**, 349 (1972).

[13] P. Benz et al., Nucl. Phys. **B79**, 10 (1974).

[15] CLAS analysis notes, published for each physics analysis, *http : //www1.jlab.org/ul/Physics/Hall − B/clas/analysisIndex.cfm*

[15] D.I. Sober et al., The bremstrahlung tagged photon beam in hall B at jlab. Nucl. Intrum. Mehonds A, 440(2):263-284, 2000.

First experimental evidences for baryonium states

Volume 68B, number 5 PHYSICS LETTERS 4 July 1977

EVIDENCE FOR TWO NARROW $p\bar{p}$ RESONANCES AT 2020 MeV AND 2200 MeV

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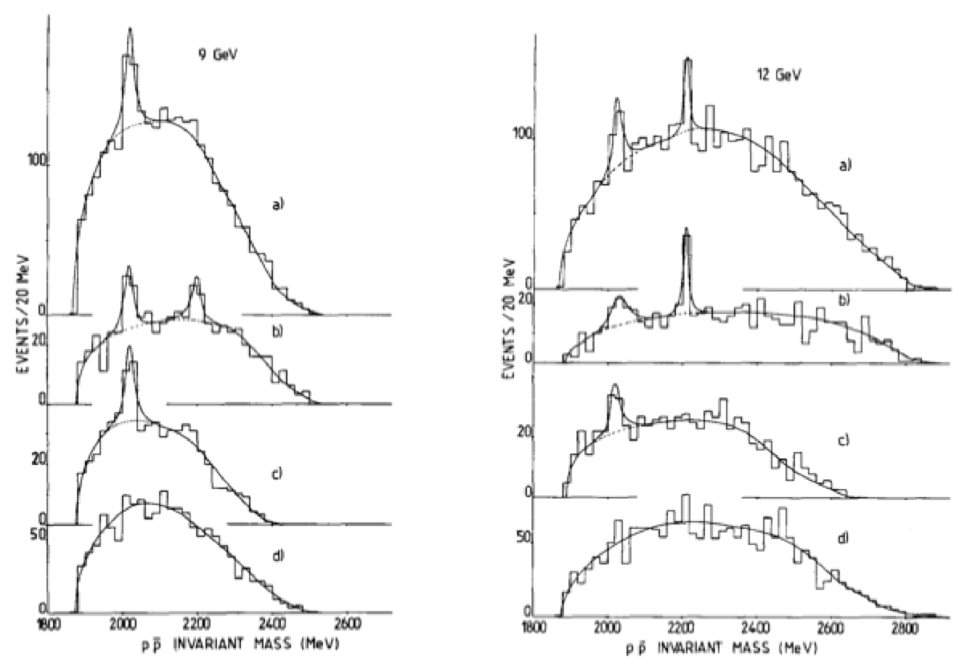
CERN, Collège de France, Ecole Polytechnique, Orsay Collaboration

Received 4 May 1977

Fig. 1. The distribution of the $p\bar{p}$ invariant mass at 9 GeV/*c*. (a) All the events. (b) Events with invariant mass $p_F\pi^-$ in $\Delta^0(1232)$ region $1175 < M(p_F\pi^-) < 1300$ MeV. (c) Events with invariant mass $p_F\pi^-$ in the $N^0(1520)$ region $1450 < M(p_F\pi^-) < 1600$ MeV. (d) Events with invariant mass $p_F\pi^-$ outside the regions of b and c. The full curves represent the fit of the data with a smooth background and one or two Breit Wigner resonances. The dotted curve under the peak represent the contribution of the background.

Volume 68B, number 5 PHYSICS LETTERS 4 July 1977

Many experiments have reported meson resonances in the 1900-2500 MeV region. The experimental situation is confusing but many indications exist for structures possibly connected to NN states. In 1700's BENKHEIRI and other scientists published results which are part of a general experiment made with the CERN Omega spectrometer. This experiment was done with a π⁻ beam at 9 and 12 GeV/c interacting on a hydrogen target.

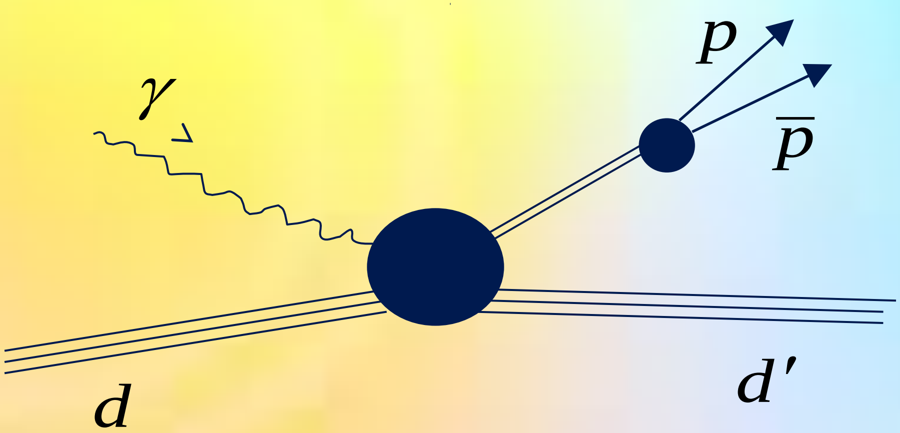


Introduction

- In this project coherent production of proton anti-proton pair on deuterium with a high energy bremsstrahlung photon beam is studied.
- The target reaction for this analysis is:

$$\gamma d \rightarrow p\bar{p}d'$$

- The main objective is to study claims of several groups on existence of exotic states, one below the $p\bar{p}$ threshold and two above, at ~2.02 GeV and ~2.2 GeV.
- The goal of the project is to examine invariant mass distribution of the $p\bar{p}$
- Coherent photo-production on deuteron has an advantage compared to the production on hydrogen. It will eliminate ambiguities in the production mechanism, since only t–channel production of $(p\bar{p})$ is allowed.




CLAS

The CLAS detector

CEBAF Large Acceptance Spectrometer

Superconducting torus magnets (Torus) generating magnetic field around the beam line

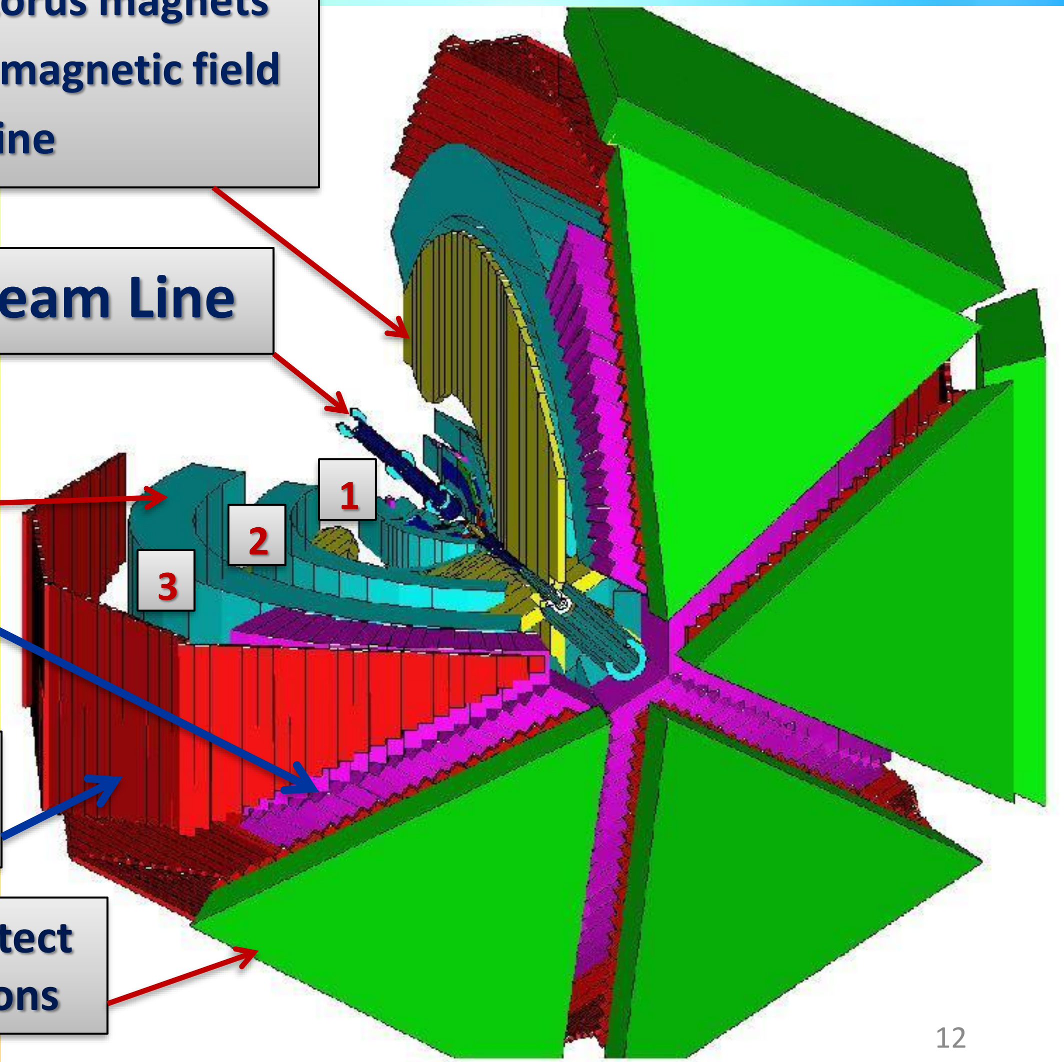
Beam Line

Drift chambers (DC) (Regions 1,2,3) to determine the trajectories of charged particles ($\pi^{\pm}, k^{\pm}, p, \overline{p}$)

Gas Cherenkov Counters (CC) for electron identification and separating from pions

Time-of-flight Scintillators (TOF or SC), record the time and Energy deposition

Electromagnetic Calorimeters(EC) to detect showering particles(e and p) and neutrons




Experiment Description

Running Conditions

- The CLAS/eg3 experiment was carried out from December 6th 2004 to February 1st 2005

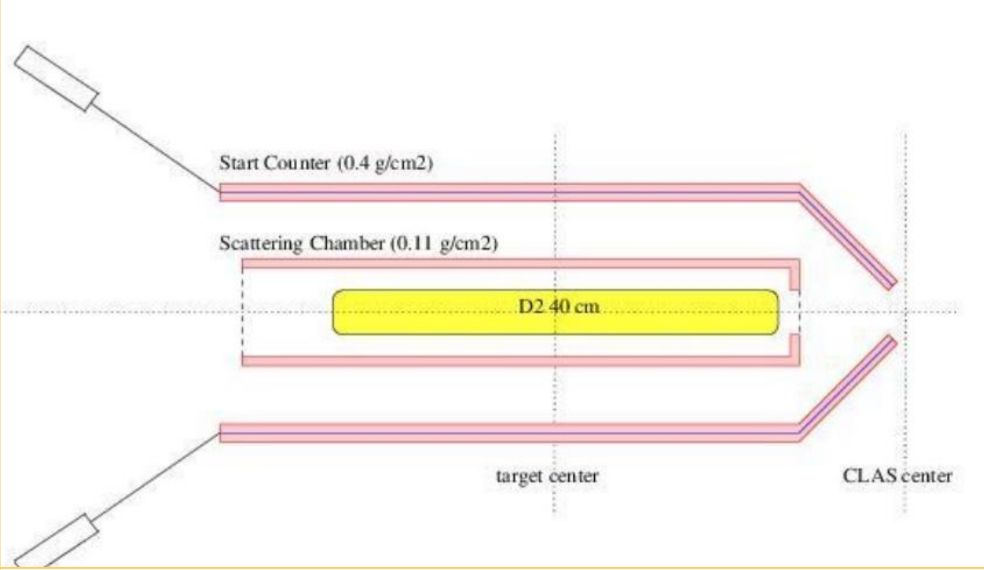
- About 4.2 billion events are collected, total of 32 TB of raw data with an average 2.7 tracks per event

- Bremsstrahlung Tagged Photon Beam was generated on a 3×10^{-4} r.l. radiator from 5.77 GeV electron beam at 30 nA,

- DAQ was triggered for events in photon energy range 4.5 GeV < E < 5.5 GeV

The Target

For the eg3 experiment a conical liquid deuterium target was chosen with **4 cm** diameter and **40 cm** length. It was positioned **40 cm** upstream of the nominal CLAS center. The upstream end located at the beginning of the start counter, allowing for a large event rate while maintaining an acceptable tagger rate.



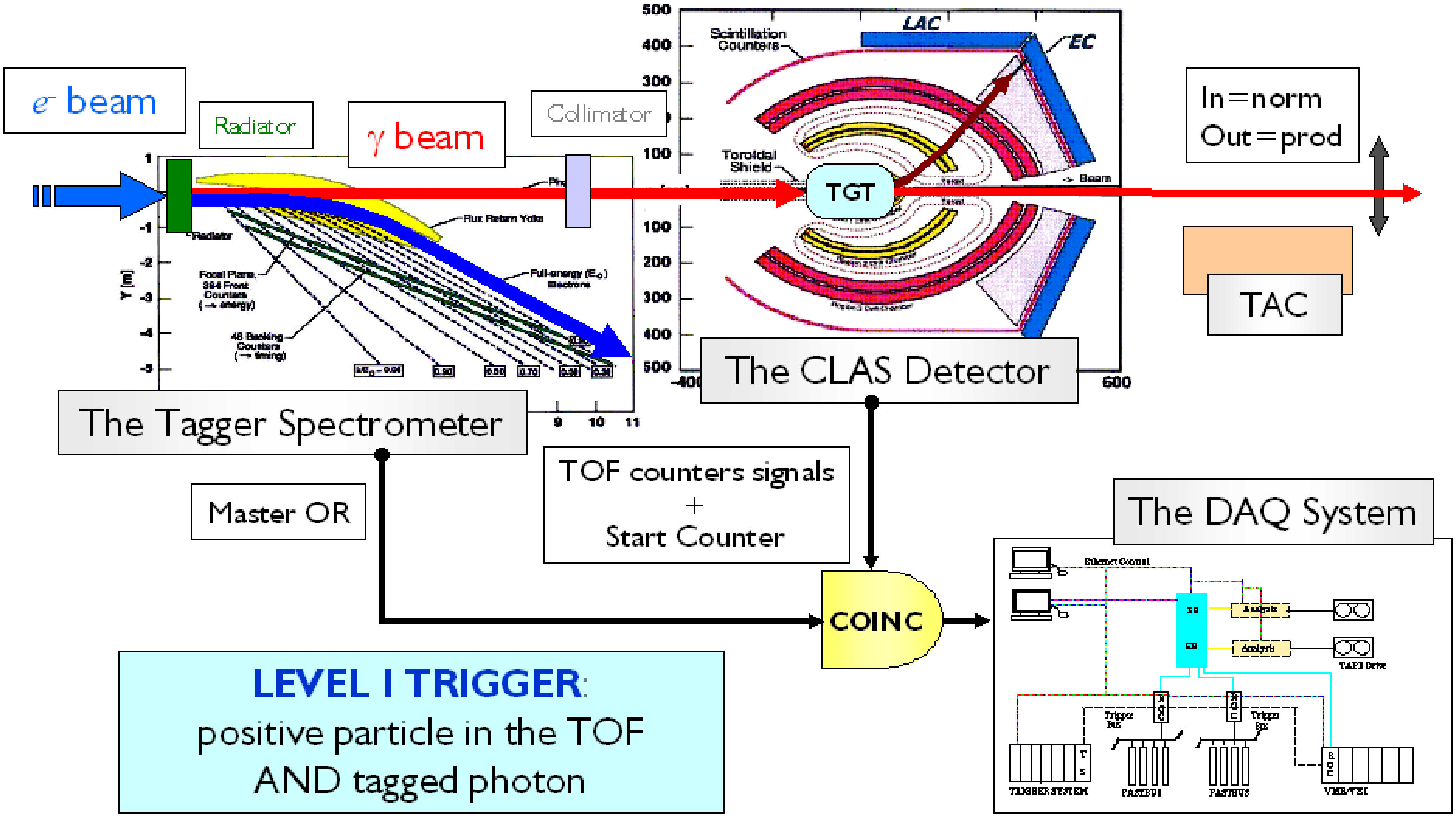
Trigger Setup

To filter out electronic noise and pick only events of interest, a trigger system is necessary. CLAS has a two level trigger system.

- **The Level-1 trigger uses the information from the TOF, CC, EC, ST, and the Tagger.**
- **The Level-2 trigger requires additional tracking information in DC.**

Only after trigger conditions are satisfied, the data acquisition system (DAQ) will collect the digitized data and send the information to storage media for later off-line analysis.

DAQ system



The CLAS tagging system tags bremsstrahlung photons with energies ranging from 20% to 95% of the incoming electron energy. eg3 had 4.5 GeV to 5.5 GeV region of tagged photons in the trigger".


Event Selection

Particle identification

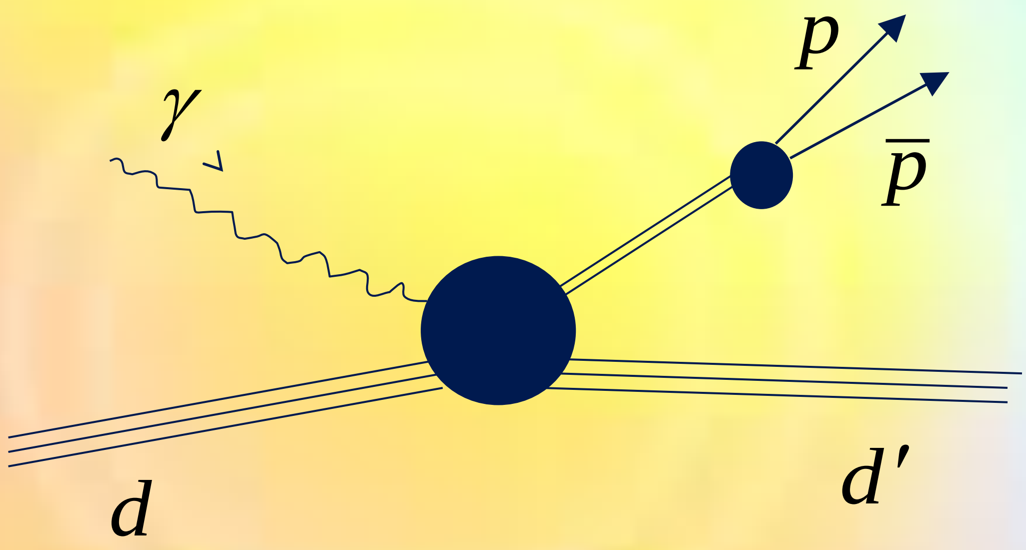
PID in CLAS relies heavily on the combination of the measured charged particle momentum(P) and the time-of-flight(TOF) of the particle from the target to the respective plastic scintillation counters.

Other charged particle identification capabilities are due to the gas Cherenkov Counters which separate electrons from pions for momenta up to about 3 GeV/c, and the energy loss of the charged particles in the TOF counters versus particle momentum.

Event Selection (by charge)

The first pass of the analysis selects events with this characteristics:

The final state of interest contains three particles:



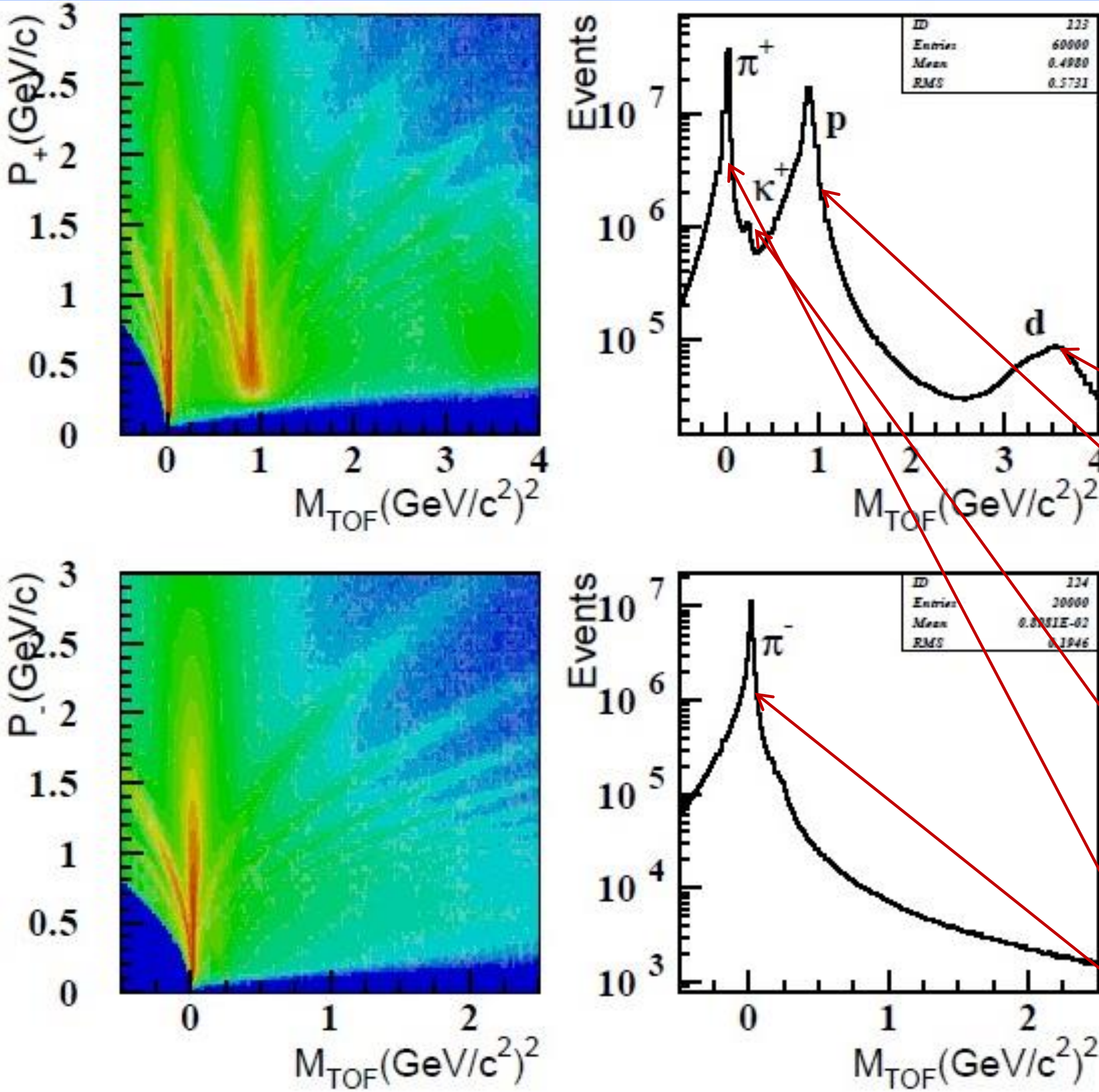
$$n_{(q^{\pm})} = 3$$

$$n_{(q^{+})} = 2$$

$$n_{(q^{-})} = 1$$

$$n_{(q^{0})} = 0$$

Event Selection (by TOF mass)



Distribution of mass squared for positively (top) and negatively (bottom) charged particles measured using time-of-flight and momentum of particles are shown as a function of momentum. Projections s squared ax .

$$m_d^2 = 3.515\left(\frac{GeV}{c^2}\right)^2$$

$$m_{p\bar{p}}^2 = 0.88\left(\frac{GeV}{c^2}\right)^2$$

$$m_{k^\pm}^2 = 0.247\left(\frac{GeV}{c^2}\right)^2$$

$$m_{\pi\pm}^2 = 0.0194\left(\frac{GeV}{c^2}\right)^2$$

Event Selection (by vertex time)

2. All three particles should come from the same beam bunch. For that reason the vertex times of particles have been calculated by assuming one positive particle is deuteron and another one proton and negative particle is antiproton.

$$\Delta t_v = t_{SC} - t_{st} - \frac{R_{SC}}{c\beta_c}$$, where $$\beta_c = \frac{P}{\sqrt{P^2 + m_d^2}}$$

t_{SC} - time measured by SC

R_{SC} - distance from the production vertex to SC

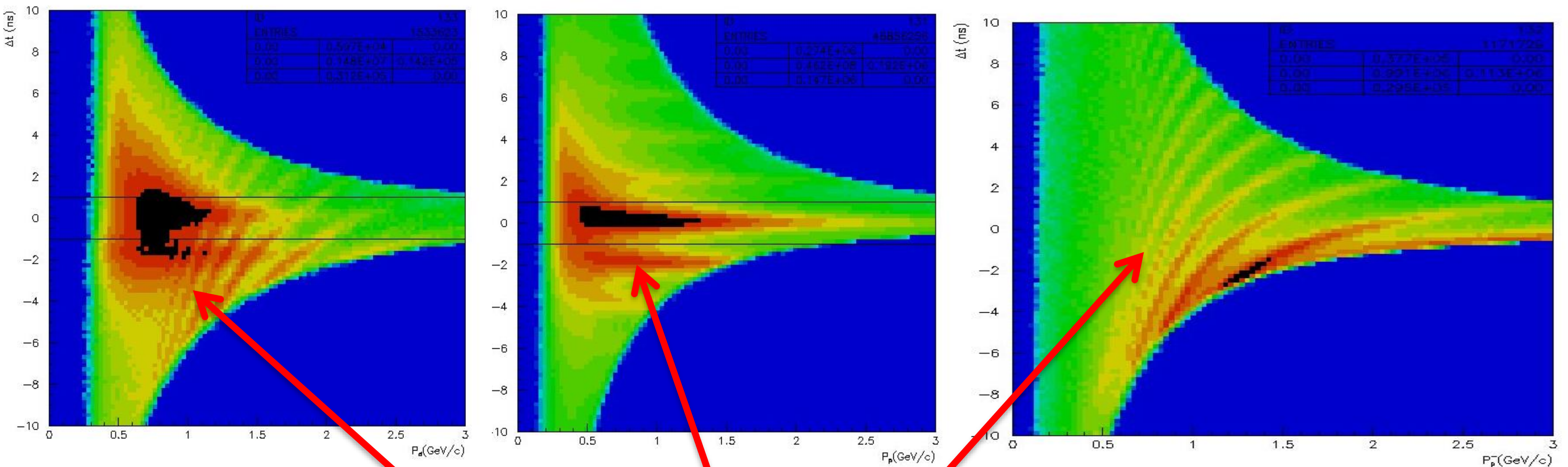
t_{st} - event start time determined by the tagged photon

C - speed of light

P - track momentum

m_d =1.877(Gev/c2) - deuteron mass

Event Selection (vertex time)



From left to righ… time distribution versus mo… respectively for deut… antiproton candidates.

Lines are correspond to out-of-time protons and pions (RF=±2 ns bunches)

Event Selection (3 momentum conservation)

One of the kinematic constraint of a fully exclusive final state that holds even before final state particle identification is the 3-momentum conservation;

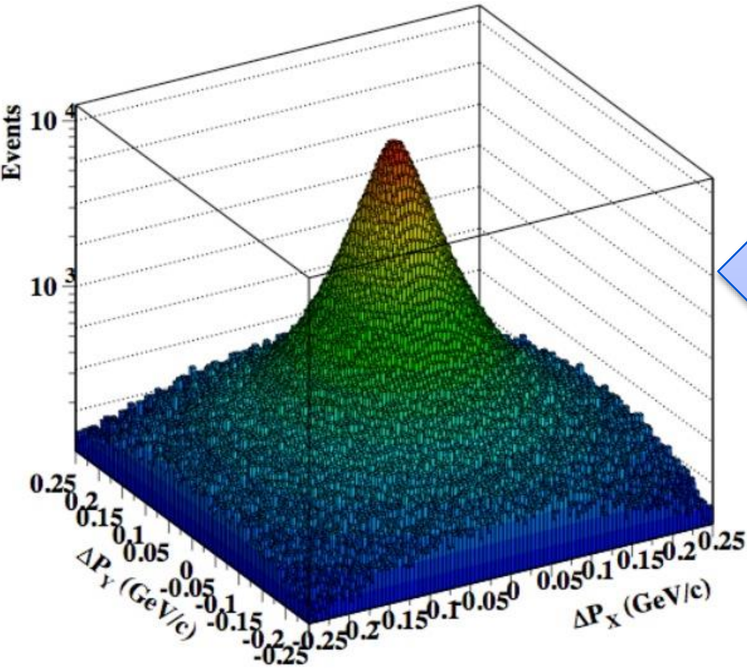
$$\sum P^{i}_{X\,(Y)} = 0 \qquad \sum P^{i}_{Z} = E_{\gamma}$$

i - is the final state track number

Since the incoming photon or target deuteron do not have transverse momentum component, and the target deuteron is in rest

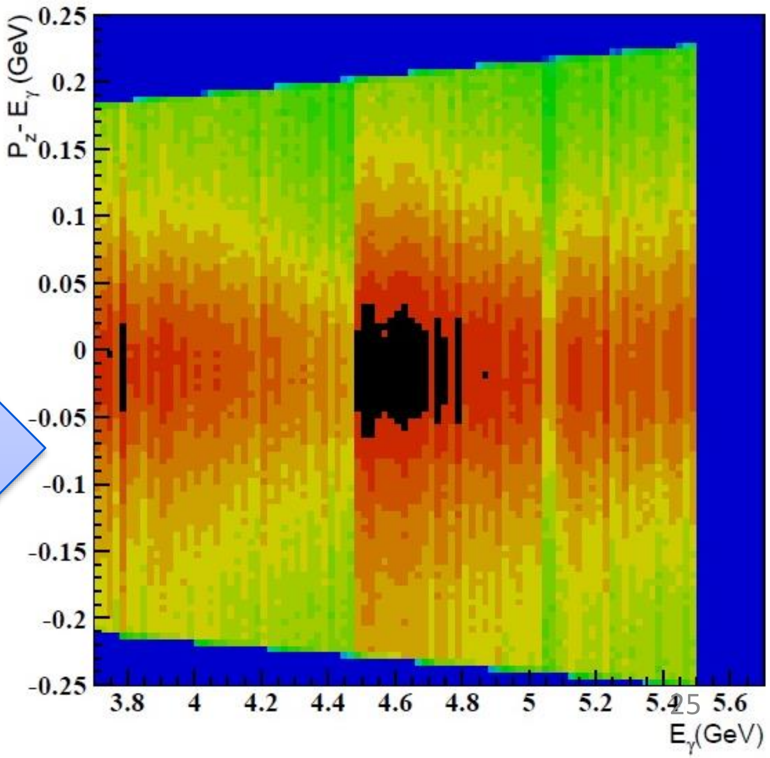
Event Selection (3 momentum conservation)

Transverse momentum distribution of 3-prong events.

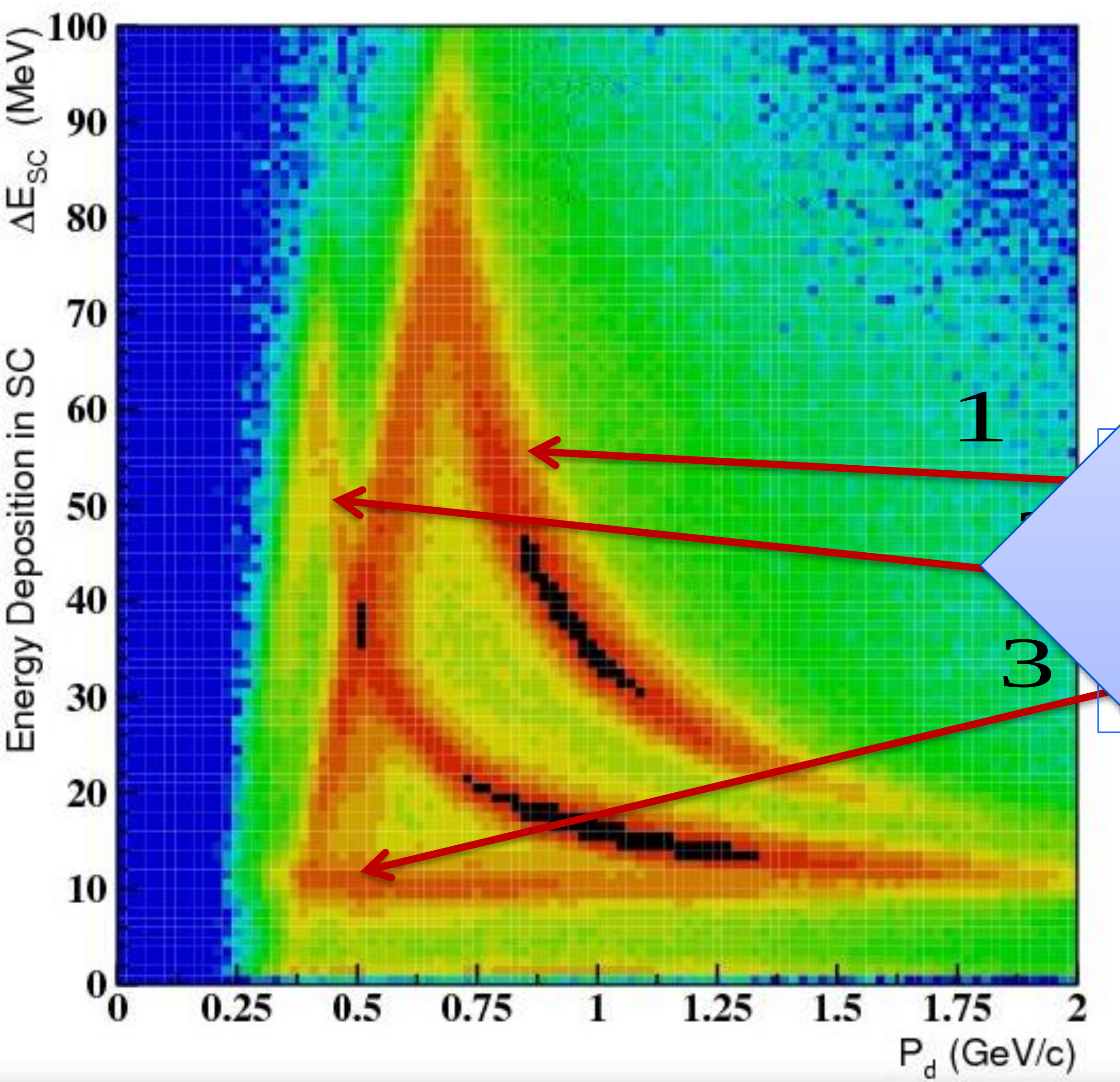


Since this is a fully exclusive reaction, 3-momentums should conserve and that will be used to select correct tagged photon and calculate proper start time of the CLAS event

Here is distributed $\sum P_Z^i - E_\gamma$ and E_γ for events selected after ±3σ cut on $\sum P_X^i$ and å P_y^i



Particle ID (Energy Deposition in SC)



For deuterons ID, energy loss in SC counters must be applied. This is the most reliable information for deuteron identification

Kinematic cuts (Tagger Energy)

Since this is a fully exclusive reaction, four momentum should converse if tagged photon is correctly identified. The longitudal momentum should be equal to the beam photon energy:

$$\sum P_Z^i = E_\gamma = \sum E_i - M_d$$

or

$$\Delta E = E_\gamma - \sum E_i + M_d$$

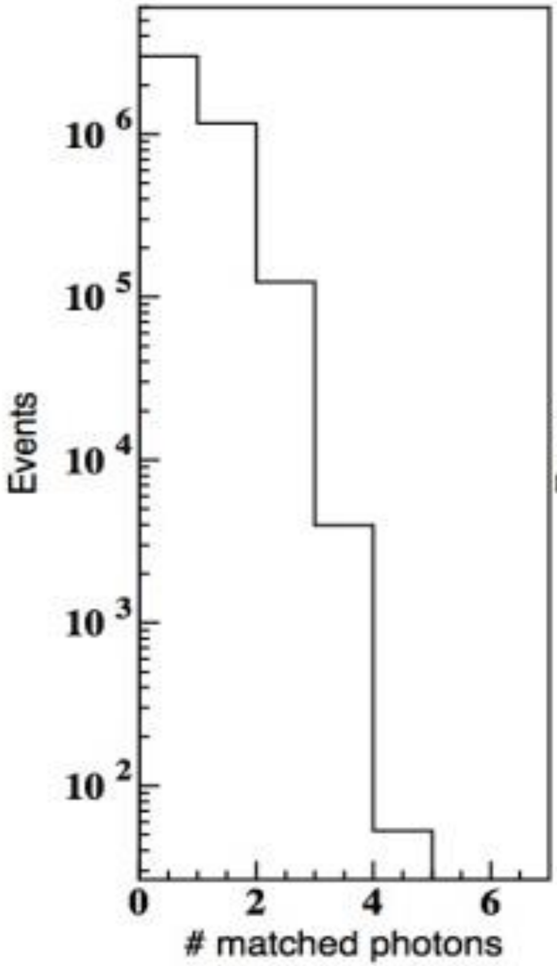
Where $$E_i = \sqrt{P_i^2 + M_i^2}$$

P – momentum measured in CLAS
M- correct masses of $p, \bar{p}, d$

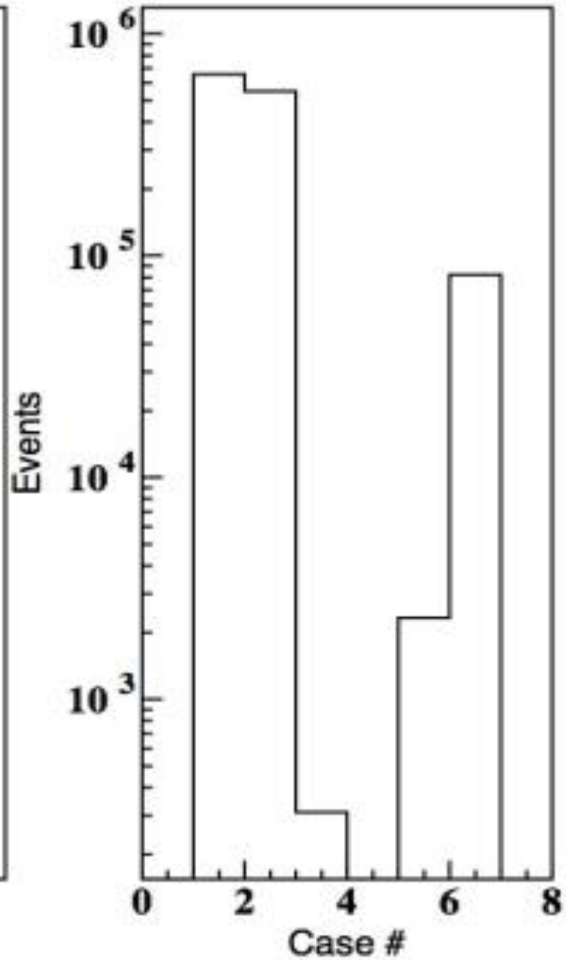
As for transverse components, ±3σ cut has been used to select exclusive 3-prong events with matched photons.

Kinematic cuts (Tagged photons)

Number of tagged photons satisfying ±3σ cut on $\sum P_Z^i - E_\gamma$



Number of different cases of 1 and 2 matched tagged photons



Case #1 → One matched photon and that photon is the one that was selected during the data processing.

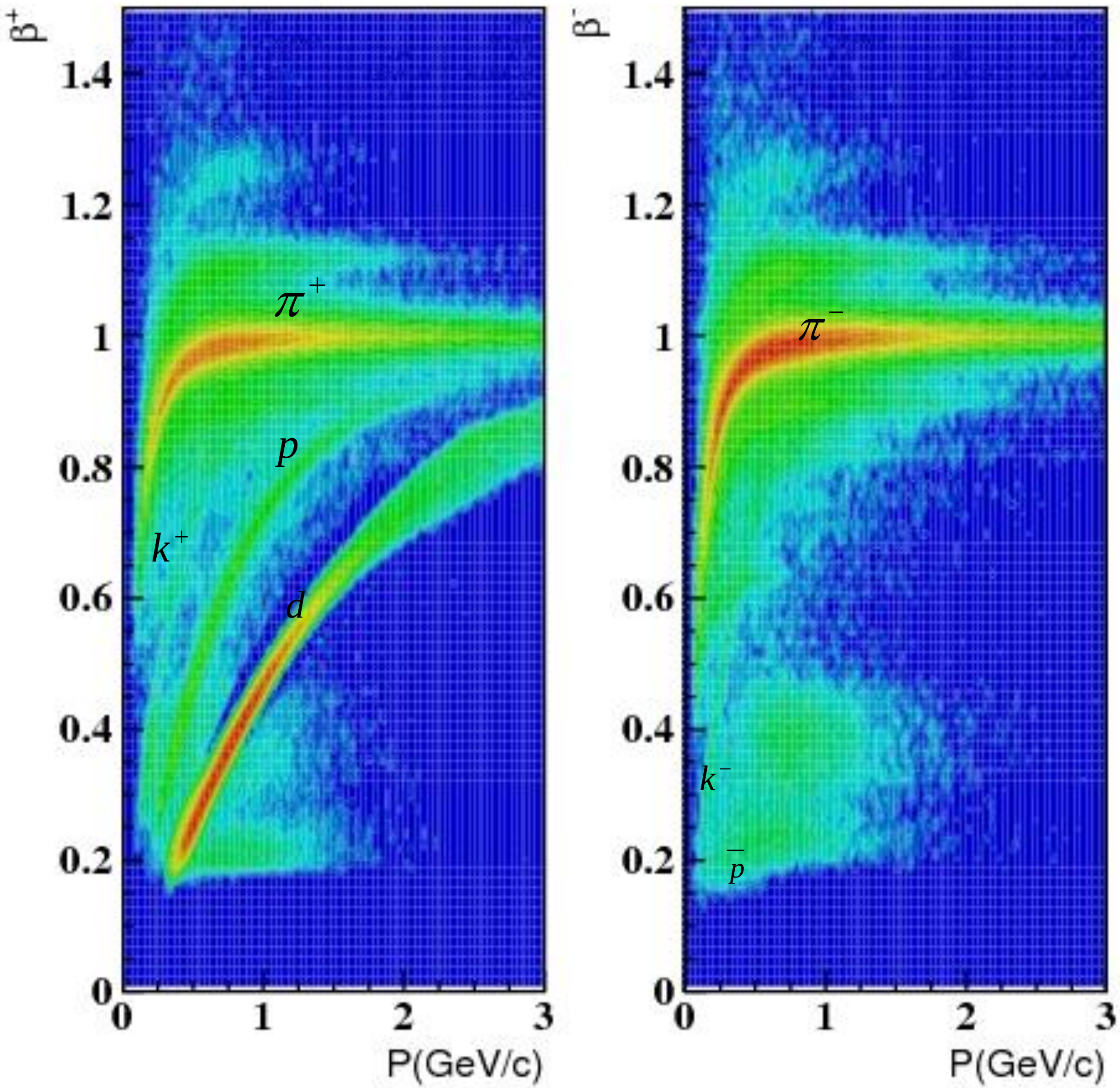
Case #2 → One matched photon but the photon is different from the one that was selected during the data processing.

Case #3 → Two matched photon and only one has energy above 4.5 GeV.

Case #4 → Two matched photons and both photons have energy above 4.5 GeV.

Case #5 → Two matched photons but both photons have energy less than 4.5 GeV.

PID after photon is selected **(by β)**



β of positively(left) and negatively (right) charged particles.

$$\beta = \frac{R}{t_{SC} - t_{St}} \cdot \frac{1}{c}$$

Ideal case, when the photon is in δPz range and is the one was selected during the data processing

Background Reactions

- Target reaction is coherent photoproduction of $p\bar{p}$ pair on deuterium:

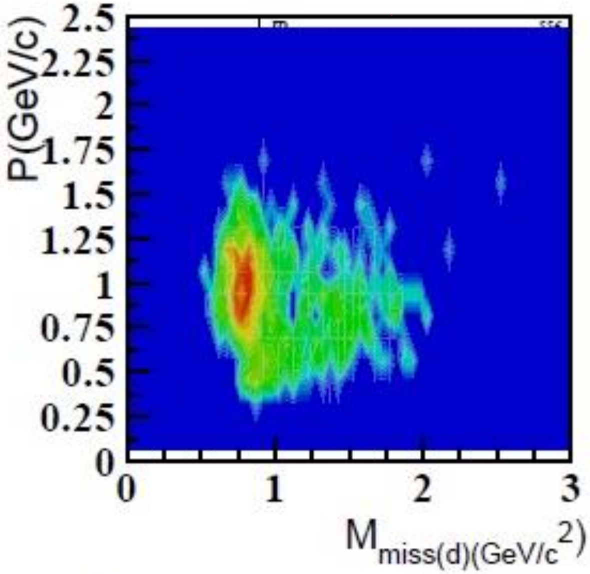
$$\boxed{\gamma d \rightarrow p\bar{p}d}$$

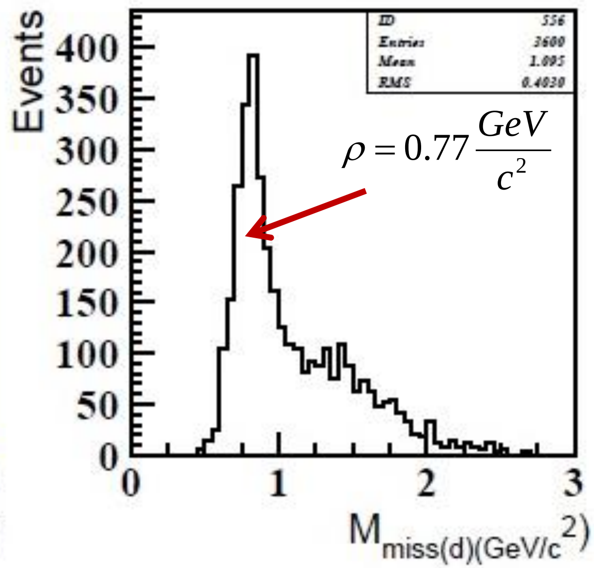
- Reactions that can mimic coherent photoproduction of $p\bar{p}$ are:

$$\boxed{\gamma d \rightarrow \pi^{+}\pi^{-}d}\ ,\ \boxed{\gamma d \rightarrow k^{+}k^{-}d}\ ,\ \boxed{\gamma d \rightarrow pp\pi^{-}}$$

Background Reactions

The main background will come from

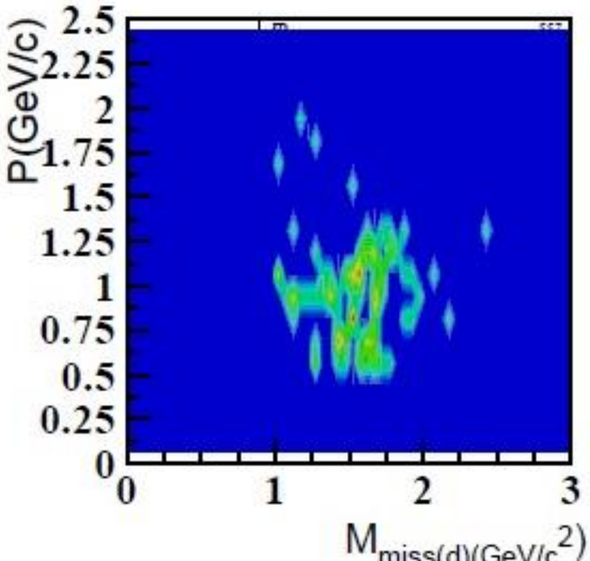


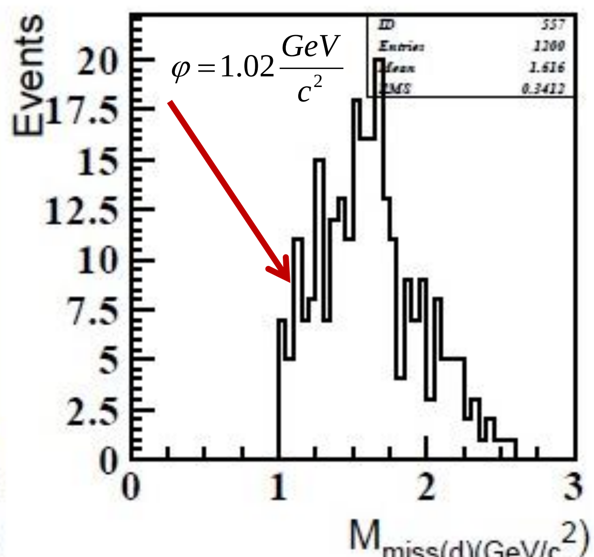


$$\gamma d \to d(\pi^+\pi^-)$$

$$\rho \to \pi^+\pi^-$$

and



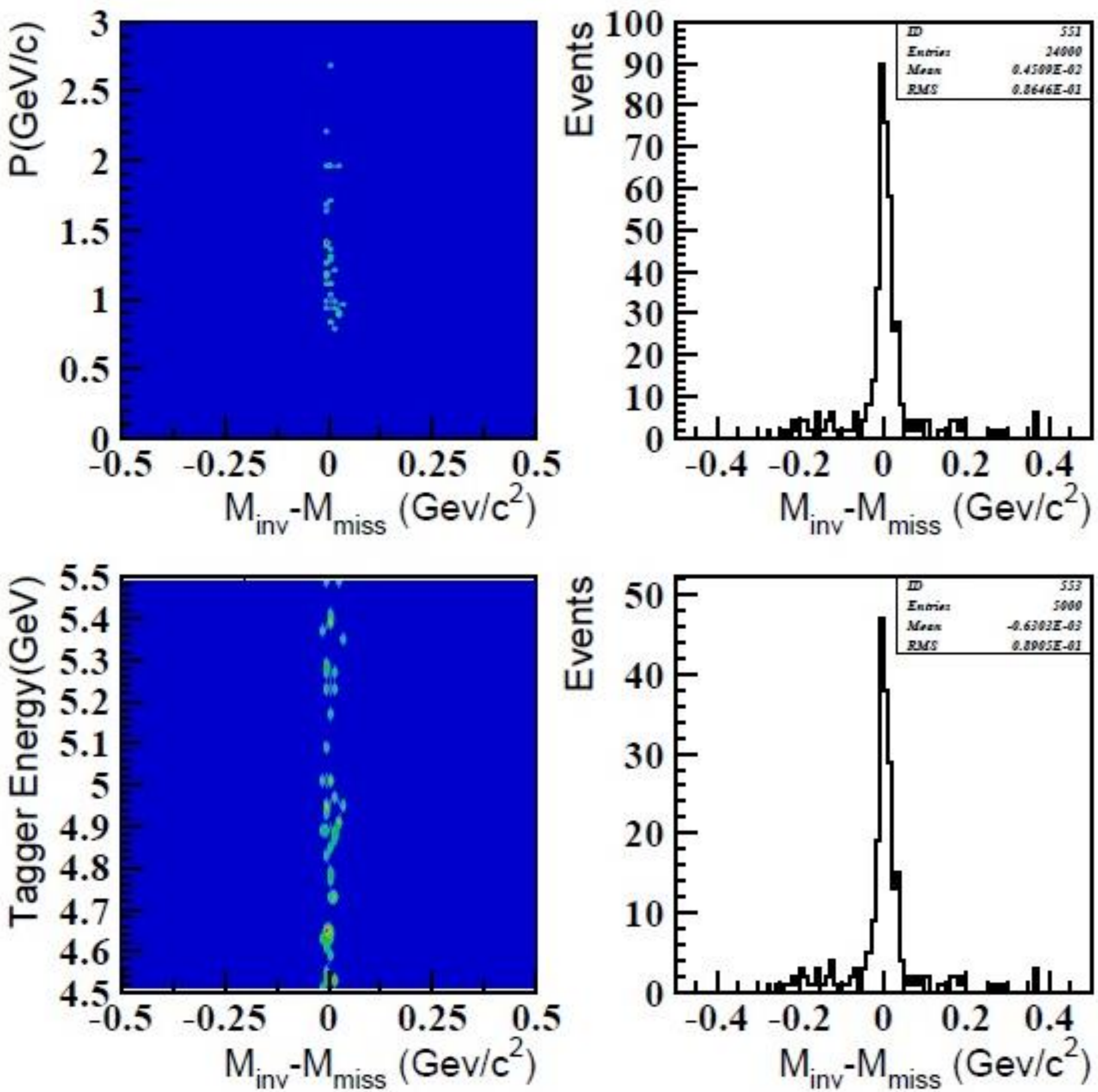


$$\gamma d \to d(k^+k^-)$$

$$\varphi \to k^+k^-$$


Results

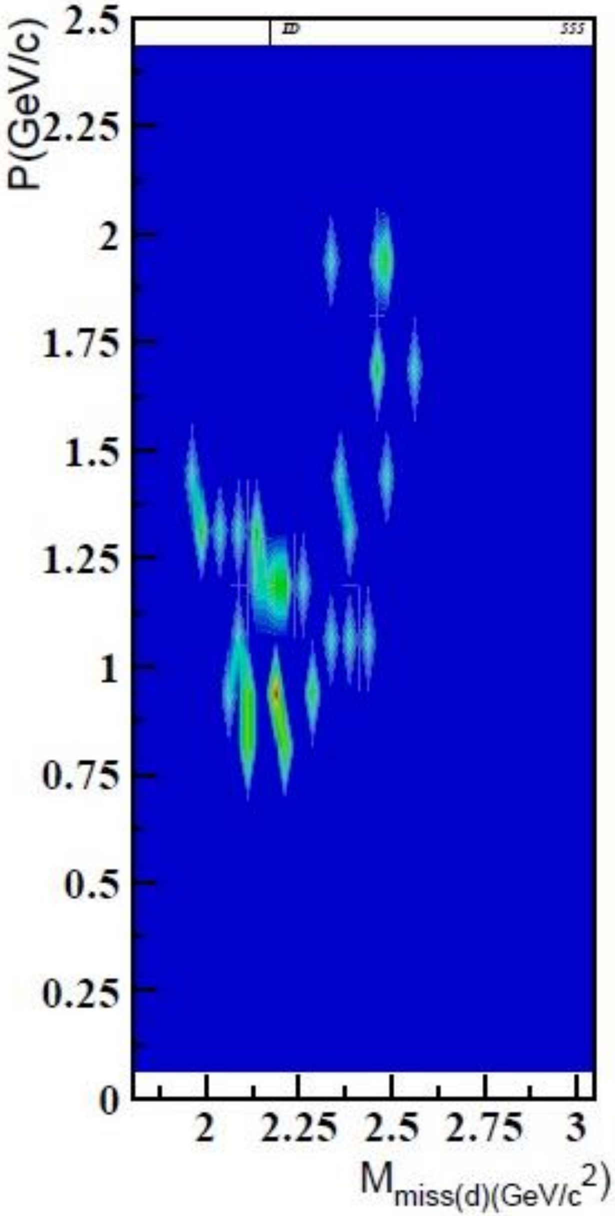
Results

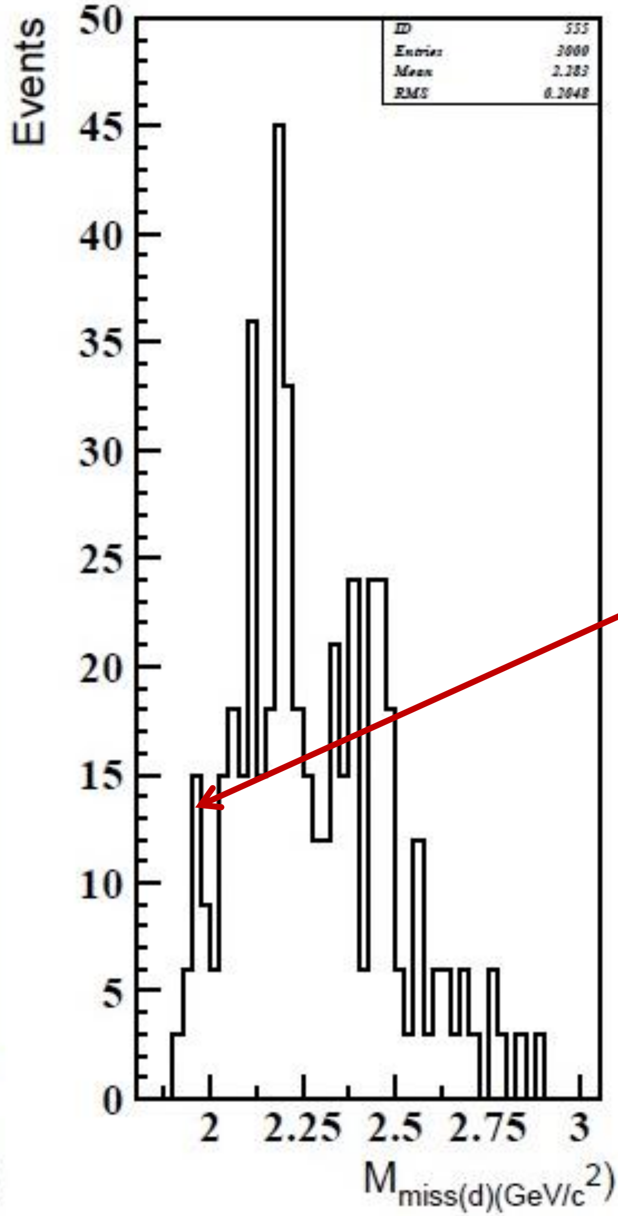


$$M_{inv}^2 = \left(\sum E\right)^2 - \left(\sum \left\|\vec{P}\right\|\right)^2$$

$$M_{miss}^2 = (E_{initial} - E_{final})^2 - (\vec{P}_{initial} - \vec{P}_{final})^2$$

Results





Missing mass of

$$\gamma d \to d(p\bar{p})$$

reaction is repre-sented.

$$M_{Miss} = 1.875 \frac{GeV}{c^2}$$


Summary/
Future work

Summary

- Fully exclusive $\gamma d \rightarrow p\bar{p}d$ reaction has been observed in the $4.5GeV < E_{\gamma} < 4.5GeV$ photon energy range
- Particle Identification was done with various cuts
- The photon which was in $\Delta\vec{P}_{z}$ range has been selected and future analysis was done based on that (the one was selected during the initial data processing)
- Missing mass of $\gamma d \rightarrow (p\bar{p})d$, $\gamma d \rightarrow (\pi^{+}\pi^{-})d$, $\gamma d \rightarrow (k^{+}k^{-})d$ reactions has been plotted.

Future Plans

- Angular distribution in CM(Center of Mass) system
- Invariant mass distribution of $(p\bar{p})$
- Studding of cross section of $\gamma d \rightarrow p\bar{p}d$ reaction
- Analyzing of $\gamma d \rightarrow \bar{p}dX$ semi-exclusive final state

Thank You

Back up slides

Bethe-Bloch formula for charged particle Energy Deposition in the Detector

$$-\frac{dE}{dx} = \frac{4\pi q_e^4}{m_0}\frac{z^2}{v^2}NZ\left[\ln\frac{2m_0v^2}{I} - \ln\left(1-\beta^2\right) - \beta^2\right]$$

z, v – atomic number and velocity of projectile

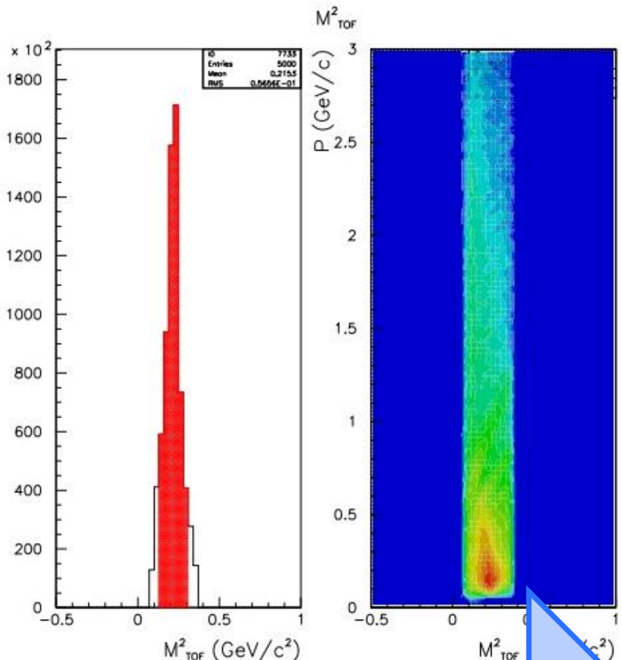
N, Z – particle density and atomic number of absorber

β=v/c , c – speed of light

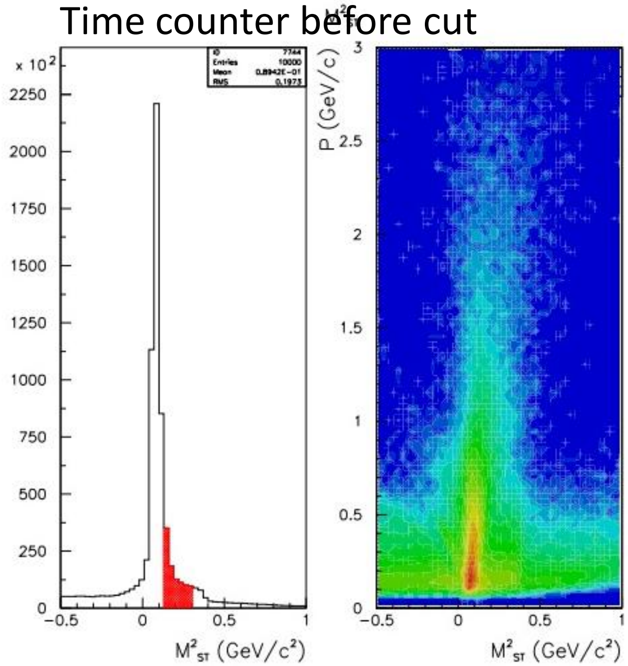
q, m – charge and a rest mass of the particle respectively

$I = 16 * Z^{0.9}(EV)$ **, when Z>1 - constant**

TOF mass spectrum for negatively charged particles before cut



TOF mass spectrum for negatively charged particles based on Start Time counter before cut

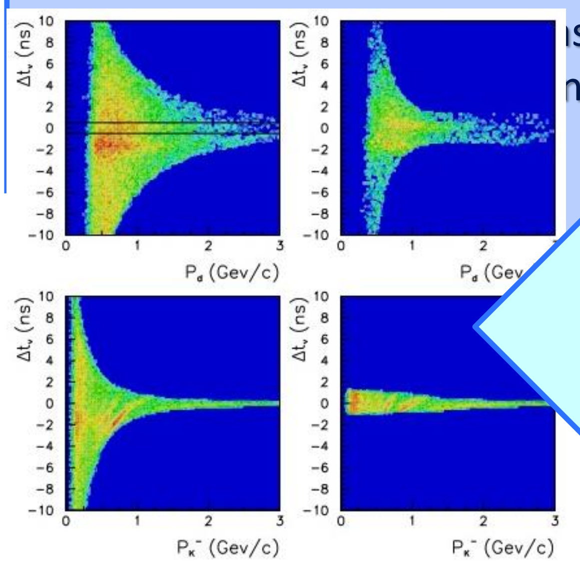


where

$$M_{ST}^2 = P^2 \cdot \left(\frac{1}{\beta_{ST}^2} - 1 \right)$$

and

$$\beta_{ST} = \frac{R_{SC} - R_{ST}}{(t_{SC} - t_{ST})} \cdot \frac{1}{c}$$



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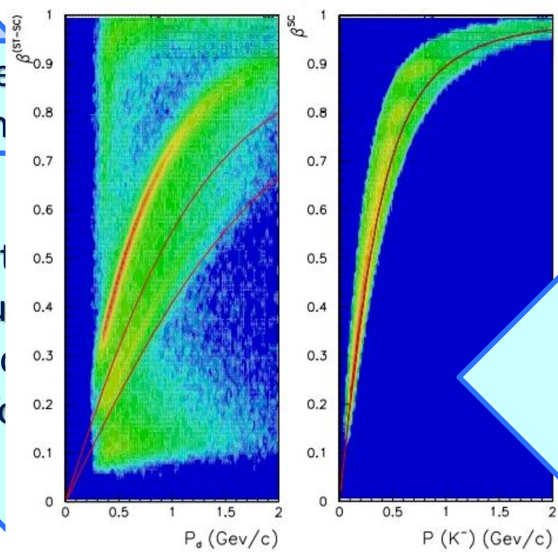

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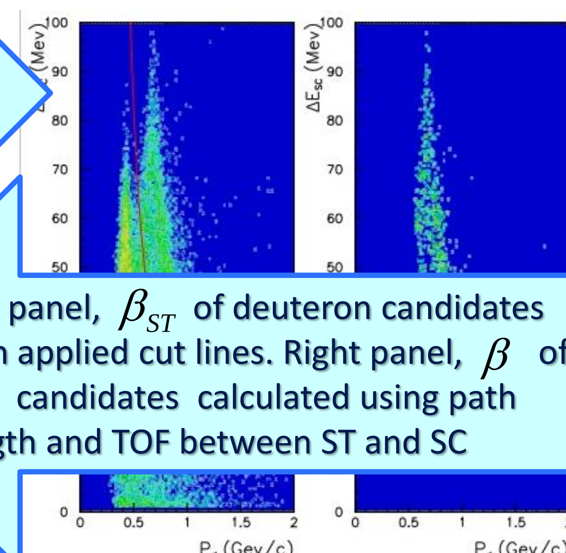
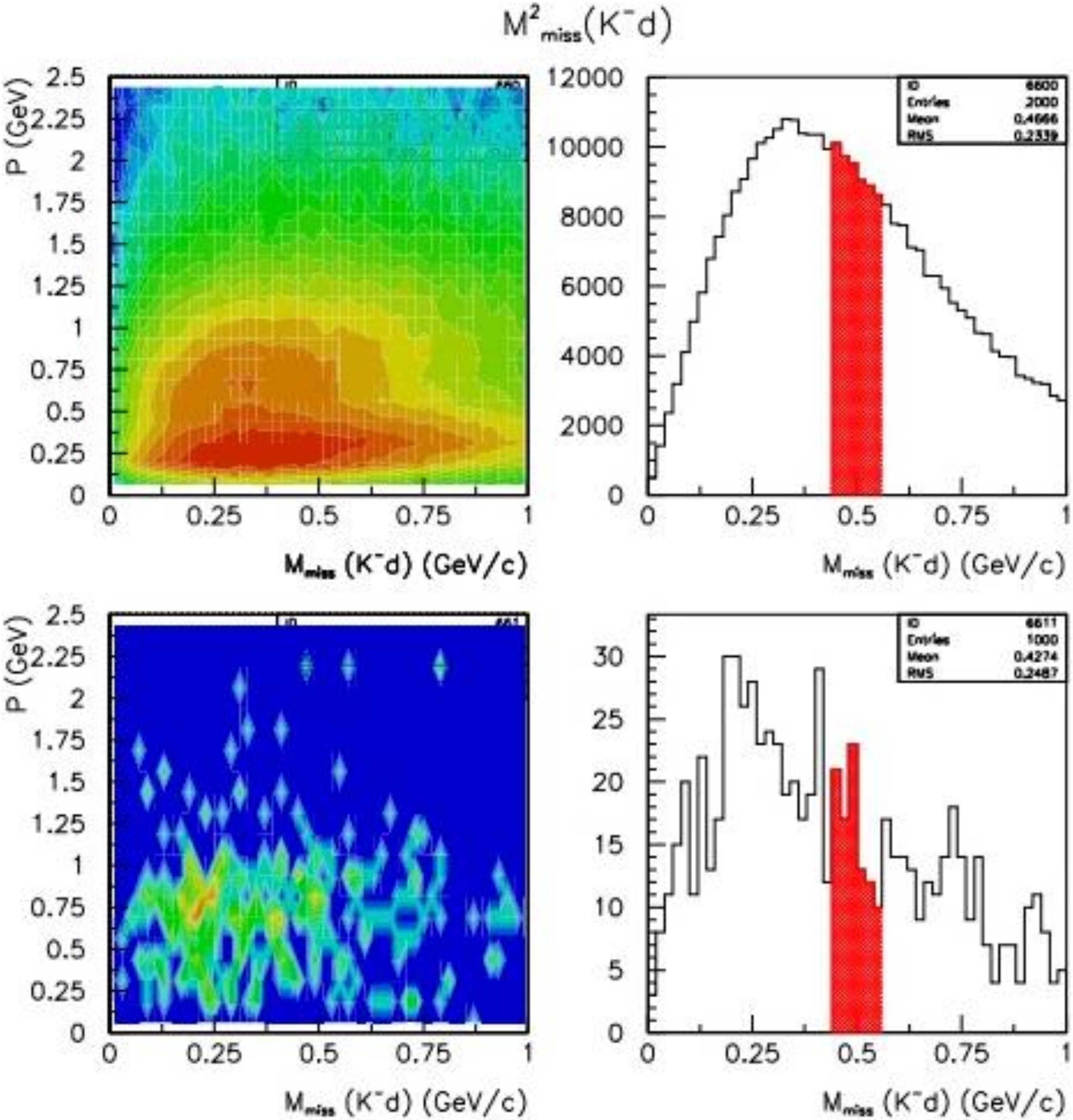


Left panel, β_{ST} of deuteron candidates with applied cut lines. Right panel, β of k^- candidates calculated using path length and TOF between ST and SC



$M_{miss}(k^- d)$ before cuts

The background mainly comes from the reaction $\gamma d \rightarrow \pi^+ \pi^- d'$

$M_{miss}(k^- d)$ after cuts