Trident Cross-section Measurement for the 2015 Engineering Run @ 1.05 GeV

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Abstract

We describe the reconstruction, selection, and cross-section determination of $e^-\ W \rightarrow e^-e^-e^+\ W$, i.e. "tridents". This analysis reconstructs e^-e^+ pairs from data taken during the 1.05 GeV running in spring 2015. We compare the measured cross-sections and kinematic distributions between data and MC.

I. Introduction

At the amplitude level, there are two diagrams (at the lowest order) which contribute to "trident" (i.e. 3-prong) final states when scattering an electron beam off a nuclear target: Bethe-Heitler (BH) and radiative diagrams**??**. Both of these amplitudes (and their interference) contribute to the background in the dark photon (A') search.

The BH background has a huge amplitude but very different kinematics than the A' reaction and can be significantly, but not completely, suppressed by making appropriate phase space cuts.

The radiative reaction, however, has identical kinematics to the A' reaction $e^-\ W \rightarrow e^-A'(\rightarrow e^-e^+)\ W$ and the rate of A' production is related to the radiative production via:

$$\sigma(A') = X\sigma(rad). \tag{1}$$

Verifying the radiative cross-section that is observed by HPS is an important confirmation that the experiment is working as designed and is also a key input to setting mass-coupling limits for A' detection.

This note describes the reconstruction, selection, and methods used to extract the trident cross-section as well as a number of cross-checks performed.

II. Datasets

Below we summarize the datasets used in this study.

- Data
  - reconstruction pass-2.1, DST v0.8.1 unblind sample
- Monte Carlo: using HPS-EngineeringRun2015-v3 with pass-2 reconstruction
  - pure samples
    - **Full amplitude tridents**: MadGraph generation includes BH+radiative interference. Generator-level cuts: blahblah;
    - **Radiative tridents**: MadGraph generation. Generator-level cuts: blahblah;
    - **Bethe-Heitler tridents**: MadGraph generation. Generator-level cuts: blahblah;

Summarize some stuff about the MC generations, readout and recon.

Table 1: *default*

Sample	Generated Cross-Section	Number Generated	Pair1 Acceptance
Full Tridents	1.76mb	16560k	0.126
Radiative Tridents	0.12mb	3000k	0.129
BH Tridents	8.28mb	5000k***	0.022
Full w/pileup	1.76mb	87.7k	0.141

III. Reconstruction

The data and MC both use the pass-2 reconstruction (release???) but with the correction (bug) that was effecting the momenta and invariant mass of fitted e^+e^- pairs. We will update this to an official pass as soon as it is available. The reconstruction chain is described briefly below.

The tracking reconstruction follows this chain:

- for each strip hit recorded, the six ADC samples from the APV25 chip are fit to extract the time and amplitude
- on each sensor, neighboring strip hits are clustered together, defining a strip cluster
- hits on stereo pair sensors are combined to make a hit in 3D space
- a seed of a track is created by fitting a helix to hits in 3 layers iterating, over all hits in those layers
- hits in subsequent layers are added to the seed and either added to the track or rejected depending on goodness of fit and whether it pulls the track too far from the beamspot at the target
- multiple combinations of seeding layers are used to ensure good efficiency

The tracking efficiency has been shown to be $> 95\%$ (I hope!), using a combination of Moller events and full-energy electrons [**?**]. More detail on the tracking reconstruction can be found in Reference [**?**].

Similar for ECal recon and SVT-ecal matching.

IV. Event Selection & Efficiency

At this stage of analysis, we've chose to keep cuts simple and fairly loose. Below, we list the criteria used for selecting trident candidates:

- pass the pairs-1 trigger; the fraction of events passing this trigger is listed in Table 1.
- N(e^+)=1
- 0<N(e^-)<5
- the event must have at least 1 e^+e^- pair (a "V0") satisfying the following cuts:
  - unconstrained vertex fit $\chi^2 < 10$

- unconstrained fitted Z-momentum: $0.6 < p_z < 1.3\ GeV$
- unconstrained fitted vertex position: $|V_x| < 2\ mm$; $|V_y| < 2\ mm$; $|V_z| < 25\ mm$
- $50 < p < 900\ MeV$ for both tracks
- $p(e^+) \times p(e^-) < 0$ (top-bottom pairs)

- the number of V0 candidates cuts = 1

Nice table with cut-by-cut efficiency for different samples.

V. Cross-Section Calculation

I. Integrated Luminosity & Live Time

Discussion on how lumi and livetime is calculated...

II. Cross-Section Results

Discussion on how XS is calculated...
Nice table of results comparing MC and data
Run-by-run XS plot

VI. Kinematic Distribution Comparisons

Some plot and discussion of plots

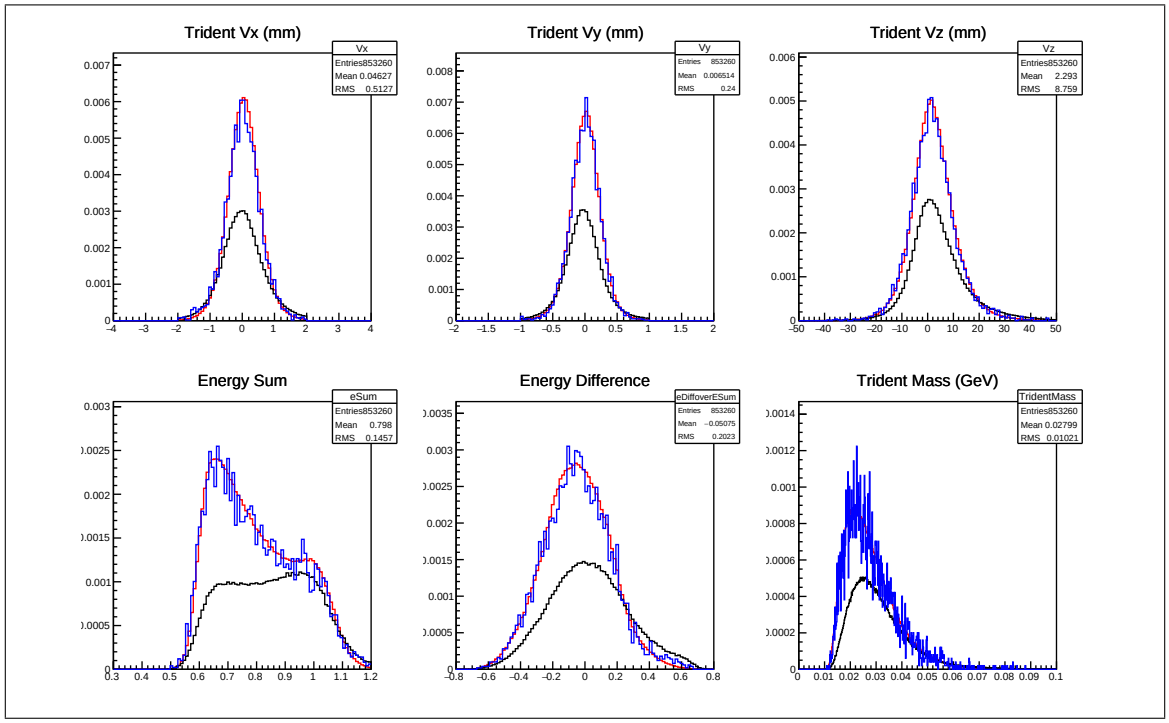

Figure 1: *Make nicer plots!!!*

VII. Conclusion

Wrap it up

References