Simulation Updates on PVDIS EC

Jin Huang
Los Alamos National Lab
EC performance w/o background

- Cited from March collaboration Meeting

π⁻ rejection

\[ \frac{1}{\text{Rejection}} \]

- PVDIS \( <\theta> = 28.5 \)
- SIDIS-Forward \( <\theta> = 12.0 \)
- SIDIS-Large \( <\theta> = 20.5 \)

Momentum (GeV)

e⁻ efficiency

\[ \text{Eff.} \]

- \( x \) in this bin

Jin Huang <jinhuang@jlab.org>  
EC group Internal Communication

2
Sixth update of CLEO background

- A.K.A. Babar More1 Block in Zhiwen’s notes
- Significant improvement observed
Updated radiation dose VS layers

Lead baffle

~ 11 layers per radiation length

High radiation $\phi$ slice

Low radiation $\phi$ slice
Readout occupancy per shower channel for \(~75\text{MeV}\) zero suppression

- High radiation phi slice
- Low radiation phi slice

Krypton baffle, 5th bgd update
Zhiwen’s Babar More 1 baffle

Lead baffle, 6th bgd update
Zhiwen’s Babar More 1 Block baffle
Composition of background
inner radius region within the high-radiation azimuthal sectors

→ Photon dominated

- Photon (3.5GHz @ R=120 cm): EM and \(\pi^0 \rightarrow \gamma\) origin
- Electron
- Pion- Pion+ Proton

lead baffle
PID performance – low radiation phi slice

Lead baffle

![Graphs showing efficiency after PID cut for electrons and pions with different radii at various momenta.](image)
PID performance – high radiation phi slice

Lead baffle
Trigger curve
– low radiation phi slice

Lead baffle

Electron

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<th>Trigger Efficiency</th>
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Pion

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Legend:
- R=230 cm, Trig = 1.5 GeV
- R=180 cm, Trig = 2.0 GeV
- R=150 cm, Trig = 2.5 GeV
- R=120 cm, Trig = 3.5 GeV
- R=113 cm, Trig = 3.8 GeV
Trigger curve – high radiation phi slice

Lead baffle

Electron

Pion

Trigger Efficiency

Momentum (GeV/c)

Momentum (GeV/c)
New trigger strategy

- Embedding bgd stochastically according to its 3D distribution
- Look for percentage of 30ns trigger window that pass trigger threshold
- Good for low energy background pile ups
- Can not handle rare events due to stat. limit
- Handle p<1GeV background particle trigger

- Embedding bgd stochastically according to its 3D distribution
- Produce trigger turn on curve for high energy particle
- Good for rare events, e.g. DIS
- Can not handle low energy particle dominated trigger, which is non-linear
- Handle p>1GeV particle dominated trigger

From background embedding

From trigger turn on curve
Low energy (P<1GeV) particle trigger

- Place a calorimeter 6+1 cluster at given reference radius location
- Assume a 30ns trigger integration window, stochastically simulate which bgd particle would fly into calorimeter
  - including e/gamma/pi+/-/0/proton, 1keV – 1GeV
  - Particle with P>1GeV is ignored in this case, since their trigger rate should be counted in high energy trigger curve x rate study
- Simulate scintillator energy deposition in the shower part for all these particle and sum to give a trigger signal
- Repeat for 60k times, check the probability to produce a trigger. Trigger threshold set according to the radius
- Multiply by number of trigger channels and get the total low energy trigger rate
Inspect on few triggered case

- For low radiation slice at R=230 cm, trigger threshold is
  - scintillator energy > 283 MeV
  - targeted high trigger efficiency for electron with E>1.5 GeV
- 9 out of 60k simulations produced a trigger

\[
\begin{array}{cccccccccccc}
\text{n}_*: & \text{number of that particle for 30ns window} \\
\text{sh}_*: & \text{shower scintillator energy deposition for that particle species} \\
\end{array}
\]

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\]
Total rate from $P<1\text{GeV}$ particle

- Sum = $0.10 \pm 0.2 \text{ MHz per sector}$
  - Statistical precision can be improved with more simulation
  - Ignored correlation between neighboring trigger channels -> over estimate
- Dominated by radius region $R \sim 230\text{cm}$, where trigger threshold is low ($E_{\text{target}} = 1.5\text{GeV}$)

- High radiation phi slice
- Low radiation phi slice
Fifth update of CLEO background

* A.K.A. Babar More1 in Zhiwen’s notes
* Inputs received on Friday Sept 6

Data points saved to ROOT format and uploaded to SVN:
https://solid.physics.umass.edu/svn/solid/solidtech/calorimeter/figs
Comments on this update

- Use Babar More1 baffle in Zhiwen’s notes
- Two version background are generated:
  - With krypton baffle for hadron background and that with lead baffle
- Now only one region show significant radiation effect: inner radius in the higher-radiation phi slice
- The updated dominate background is photons, which can be attenuated by x10 with 4 radiation length of absorbing material (~2cm lead)
- Updated to use 30 ns-equivalent ADC integration window instead of 50 ns
  - Suggested in previous meetings
  - Confirmed again with Alex
- Simulated assuming NO supporting structure between preshower and shower
  - Supporting structure could be before the Pb absorber or between Pb and the preshower scintillator
- Updated plots and data points uploaded to SVN
  https://solid.physics.umass.edu/svn/solid/solidtech/calorimeter/figs
Updated: Per-event pion rate for 1+6 hexagon cluster at Mid radius, high radiation $\phi$-slice

4th Update

Krypton baffle

New 5th Update
Significant improvement in charged particle

Electron
Pion-
Pion+
Updated radiation dose VS layers (High radiation $\phi$ slice)

- Photon (EM) $\leftarrow$ dominant!
- Photon ($\pi^0$)
- Electron
- Pion- Pion+ Proton

Krypton baffle

Improved Krypton baffle

Soft EM $\gamma$

4th Update

New: 5th Update
Updated radiation dose VS layers

Krypton baffle

~ 11 layers per radiation length

High radiation $\phi$ slice

Low radiation $\phi$ slice
Updated radiation dose VS layers

Lead baffle

~ 11 layers per radiation length

High radiation $\phi$ slice

Low radiation $\phi$ slice
Readout occupancy per shower channel for ~75MeV zero suppression

Krypton baffle
- High radiation phi slice
- Low radiation phi slice
**Composition of background**

inner radius region within the high-radiation azimuthal sectors

→ Photon dominated

- **Photon (3.5GHz @ R=120 cm):** EM and $\pi^0 \rightarrow \gamma$ origin
- **Electron**
- **Pion- Pion+ Proton**

Krypton baffle
PID performance – low radiation phi slice

Krypton baffle

Significantly improved
PID performance – high radiation phi slice

Lower radius remains high

4th update, last curve as reference
Trigger curve – low radiation phi slice

Electron

Pion

Krypton baffle
Trigger curve
– high radiation phi slice

Improved now

Krypton baffle

4th update as reference
PID performance – low radiation phi slice

Lead baffle

[Graph showing efficiency after PID cut for electrons and pions with different R values.]
PID performance – high radiation phi slice

Lead baffle
Trigger curve – low radiation phi slice

Lead baffle

Electron and Pion trigger efficiency graphs showing momentum vs. trigger efficiency for different radii and trigger energies.
Trigger curve – high radiation phi slice

Lead baffle

Electron

Pion

Momentum (GeV/c)
New trigger strategy

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From background embedding

- Embedding bgd stochastically according to its 3D distribution
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- Handle p>1GeV particle dominated trigger

From trigger turn on curve
Forth update of CLEO background

Cutting 2cm away on 1st baffle inner radius
Received background simulation from Zhiwen on May 24
Updated: Per-event pion rate for 1+6 hexagon cluster at Mid radius, high radiation φ-slice

- Electron (mostly absorbed in Pb)
- Pion-
- Pion+

New 4th Update
Updated radiation dose VS layers (High radiation $\phi$ slice)

- Photon (EM) < dominant!
- Photon ($\pi^0$)
- Electron
- Pion- Pion+ Proton

3rd Update

New: 4th Update

Improve by two-fold
Update on PID
Mid radius, higher γ ϕ-band shown
Other configuration also simulated

Improvement

Pion Efficiency

Electron Efficiency
Trigger turn on curve for 2 GeV electron
Shower Hex 1+6 trigger > 1.6 GeV

Outer radius, higher $\gamma$ $\phi$-band, full bgd

100% pass for ~250 events/bin

Middle radius, higher $\gamma$ $\phi$-band, full bgd

Physics

Pion Efficiency

Electron Efficiency
Trigger turn on curve for 2.5 GeV electron
Shower Hex 1+6 trigger > 2.1 GeV

Middle radius, higher γ φ-band, full bgd

Inner radius, higher γ φ-band, full bgd

Pion Efficiency

Electron Efficiency
Readout occupancy per shower channel for ~75MeV zero suppression

- High radiation phi slice
- Low radiation phi slice

Improvement
Third update of CLEO background

Received background simulation from Zhiwen on May 19
Running background imbedding
Updated radiation dose VS layers

- Photon (EM) <- dominant!
- Photon (Pi⁰)
- Electron
- Pion- Pion+ Proton

High radiation azimuthal region

Low radiation azimuthal region
Background imbedding and distribution
Mid-R, High Radiation phi slice

- Photon (6GHz/6+1 Hex cluster)
- Electron
- Pion- Pion+ Proton
Updated: Per-event pion rate
for 1+6 hexagon cluster at Mid radius, high radiation φ-slice

- Electron (mostly absorbed in Pb)
- Pion-
- Pion+

+ 6 GHz photon not shown (3GHz for lower φ-radiation)
Update on PID with DC component removal (PS > MIP + Bgd + (2-3) $\sigma$)

Outer radius, higher $\gamma \phi$-band

Outer radius, lower $\gamma \phi$-band

Due to Soft EM $\gamma$

Pion Efficiency

Electron Efficiency
Update on PID with DC component removal (PS > MIP + Bgd + (2-3) σ)

Outer radius, higher γ φ-band

Mid radius, higher γ φ-band

Due to Hadron rate

Pion Efficiency

Electron Efficiency
More detail in PID cut
Middle radius, lower $\gamma \phi$-band, full bgd
Update on PID with DC component removal (PS > MIP + Bgd + (2-3) σ)

Inner radius, higher $\gamma \phi$-band

Inner radius, lower $\gamma \phi$-band

Pion Efficiency

Electron Efficiency
Trigger turn on curve for 2 GeV electron
Shower Hex 1+6 trigger > 1.6 GeV

Inner radius, higher \( \gamma \phi \)-band, full bgd

Middle radius, higher \( \gamma \phi \)-band, full bgd

100% pass for \(~250 \) events/bin

Pion Efficiency

Electron Efficiency
Trigger turn on curve for 2.5 GeV electron
Shower Hex 1+6 trigger > 2.1 GeV

Middle radius, higher γ φ-band, full bgd

Outer radius, higher γ φ-band, full bgd

Pion Efficiency

Electron Efficiency
More detail in trigger cut

Middle radius, higher γ ϕ-band, full bgd
Shower Hex 1+6 trigger > 2.1 GeV

Pion Efficiency

Electron Efficiency
Readout occupancy per shower channel for \(~75\text{MeV}\) zero suppression

- High radiation phi slice
- Low radiation phi slice

Diagram showing probability as a function of radius (cm) with 
- Probability to for background \(\rightarrow 0.33\text{ MIP per block}\)
- Axes: Probability on the y-axis and Radius (cm) on the x-axis.

Data points indicating high and low radiation phi slices with error bars.
Trigger Study for Second update of CLEO background

 Reported May 7 Calorimeter Meeting
Update on PID with DC component removal (MIP + 2.5 \sigma)

Outer radius, higher \( \gamma \phi \)-band

Mid radius, higher \( \gamma \phi \)-band

Pion Efficiency

Electron Efficiency
Update on PID with DC component removal (MIP + 2.5 $\sigma$)

Inner radius, higher $\gamma$ $\phi$-band

Inner radius, lower $\gamma$ $\phi$-band

Pion Efficiency

Electron Efficiency
Pion Trigger Turn-On Curve (No background), Electron Eff. > 97%

Hex 1+6 Shower Trigger > 1.6GeV (for 2GeV electron)

+ Preshower Pad on top of central shower block > MIP + 1σ
Trident turn on curve with background

Middle radius, higher $\gamma\phi$-band

Inner radius, higher $\gamma\phi$-band

Pion Efficiency

Electron Efficiency
All background particle pile ups

- Look at single Hexagon shower blocks which passed 0.75 MIP cut.
  - Full background spectrum used
  - ADC integration window = 50ns
- ~10% blocks will produce a 0.75MIP signal for clock trigger
  - Data readout is least 10% of modules
  - A shower MIP trigger is likely just trigger on lower energy particles

- higher $\gamma \phi$-band
- lower $\gamma \phi$-band

![Graph showing probability to 0.75 MIP per block vs radius in cm.](image)
Quick estimation on impact of preshower radiation damage

- Radiation on preshower is high for PVDIS
  - Last meeting we showed that preshower will show radiation damage in a few months run in PVDIS configuration (assuming no cure for photon bgd)
  - Estimated light loss is a fraction depending on the choice of scintillator and fibers
- Our preshower was designed to produce high photon yield
  - Scint. thickness = 2cm with WLS imbedding
  - Expected photon / MIP = 140 eγ
  - After 50% radiation damage (70 eγ), MIP resolution from photon fluctuation = 12%
  - Intrinsic fluctuation on MIP sampling = 23%, PID cut on MIP + 2.5 σ
  - Therefore, effect on radiation damage to MIP resolution is expected to be minimal, as long as we calibrate the photon yield online

Beam test for LHCb pad (1.5cm thick)
From LHCb technical design report

1.5cm -> 105 eγ
Second update of CLEO background

Reported Apr 30 Calorimeter Meeting
For each sector, background rate were calculated in high and low regions in phi

- Photon (EM) <- dominant!
- Photon (\(\text{Pi}^0\))
- Electron
- Pion- Pion+

![Graph showing radiation in different regions](image)

**High radiation azimuthal region**

**Low radiation azimuthal region**
Background distribution
New: with photon and pi+, Mid R, High Rad phi slice

- Photon (7 GHz/6+1 Hex cluster!)
- Electron
- Pion- Pion+
PID Performance (pion eff. w/ 94% elec. eff) w/o photon and pi+, Mid R, High Rad phi slice

![Graphs showing Preshower VS E/p, PS-E/p cut efficiency, Preshower VS p, E/p VS p.](image-url)
PID Performance (pion eff. w/ 94% elec. eff)
w/o photon, w/ pi+, Mid R, High Rad phi slice
PID Performance (pion eff. w/ 94% elec. eff) w/ photon, w/ pi+, Mid R, High Rad phi slice
Look elsewhere, Outer/Inner R PID Performance (pion eff. w/ 94% elec. eff)

- w/ photon, w/ pi+, Outer R, High Rad phi slice
- w/ photon, w/ pi+, Outer R, Low Rad phi slice
- w/ o photon, w/ pi+, Inner R, High Rad phi slice
- w/ o photon, w/ pi+, Inner R, Low Rad phi slice
First update of CLEO background

Reported Apr 23 Calorimeter Meeting
Zhiwen Updated background contribution for all configurations. PVDIS shown here:

- Photon
- Electron
- Pion- Pion+
Updated: Per-event pion rate for 1+6 hexagon cluster at inner radius

Background particle per trigger

- Electron
- Pion-
- Pion+

Lower pion- rate in new simulation
Updated: electron efficiency
Only electron and pi- background used

- Preshower VS $E/p$
- PS $E/p$ cut efficiency
- Preshower VS $p$
- $E/p$ VS $p$

$p>2\text{GeV}$

Not much change in electron eff.
Updated: pion rejection
Only electron and pi- background used

- Preshower VS E/p
- PS-E/p cut efficiency
- Preshower VS p
- E/p VS p

$p>2\text{GeV}$
x2 improved from last version
PVDIS trigger turn on curve
2GeV electron cut based on shower Hex1+6 cluster only
Layer #1 is 2cm preshower scint.

\[\gamma \text{ dominate}
\]

But attenuated quickly

EM Background on Forward ECal in Layers (Red: e, Blue: \(\gamma\), Green: \(\pi^+\), Yellow: \(\pi\))

Radiation per PAC month (rad)
Layer #1 is 2cm preshower scint.

\[ \gamma \text{ get reduced by } \sim 5 \]

\[ \pi^+ \text{ become important here} \]
Last Version of Background Simulation (reported last week)
Why it is hard – lots of deep pions

- Photon
- Electron
- Pion- Pion+
Per-event pion rate for 1+6 hexagon cluster at inner radius

High pi+ rate?? Need to be checked
Electron efficiency w/ background at inner radius. Ignore gamma and pi+ bgd

Background pile ups

- Preshower VS E/p
- PS-E/p cut efficiency
- Preshower VS p
- E/p VS p
Pion efficiency w/ background at inner radius. Ignore gamma and pi+ bgd

Significant drop in rejection
What we can further try

- Position or kinematic dependent trigger threshold and cut threshold
- Use track multiplicity to assist calorimeter cuts