Monte Carlo Status

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MC Status Summary

• MadGraph5 is now used for all tridents

• A more efficient background ("tritrig-wab-beam") is available for acceptance/reach studies, made by artificially raising the trident rate

• Tuples for FEE, Mollers, and tridents are now being generated at recon, along with the output slcio/DST files

• The most recent Monte Carlo (all detectors) is in “production/rotationFix”, named for a tweak in the event processing before SLIC

• Scripts and software needed to run Monte Carlo are now in a git repository
MC Generator types
Monte Carlo events come from several different generators:

- **Egs5 (scattered beam, Mollers)**
  - Events are generated only using egs5
  - HPS target parameters are set (thickness, current)

- **MadGraph (tri, tritrig, wab, ap, TM)**
  - Events are generated with MadGraph
  - Scattering within the HPS target is then handled using egs5
  - MadGraph cross sections used to mix events with egs5 beam events

- **Geant4 (hadrons)**
  - A macro is set up and run using an xml script:
    /u/group/hps/production/mc/EngRun2015Scripts/stdhep/hadrons.xml
MC Components from egs5
(egs5 generation -> .stdhep output)

• Scattered Beam (egs5, beam_v5)
  • Saves all events passing the following cuts:
    • Photon theta_y > 4 mrad
    • Electron energy > Ebeam*0.005
    • Electron energy < Ebeam*0.6 and Electron theta > 15 mrad

• Mollers (egs5, moller_v3)
  • Saves after-target events from Moller subroutine if:
    • Electron energy > 10 MeV
    • Electron theta > 5 mrad
    • May also save photons/positrons from the event
2 versions of MadGraph

- MadGraph5 (all tridents)
  - Tritrig (full diagram. Unbiased tridents without sum cut is unstable)
    - ESum cut > ~Ebeam/2
  - RAD (radiative only, no exchange term)
  - BH (Bethe-Heitler only, no exchange term)

- MadGraph4
  - wab (wide-angle bremsstrahlung)
  - A’ signal (and anything else made using this generator)
MC Production Chain

• After generation and any further processing with egs5, the remaining simulation steps are:

  • SLIC
    • The background mixing using MadGraph cross sections, and the 30.5 mrad beam offset happens **BEFORE** this step
    • This is also when most .lhe events get converted to .stdhep (via egs5)
    • Scattering of the events is simulated within a target volume by egs5 before offsets are applied
      • Scripts that perform the things in this step are in hps-mc/mc_scripts/slic/

  • Readout
    • Non-XS-mixed pure signals (tritrig, A’) are spaced out by 250 blank events to avoid pileup before this step (org.hps.users.meeg.FilterMCBunches)
    • Standard Clustering + Triggering procedures are then applied via HPS-java
      • Scripts that perform this step are in hps-mc/mc_scripts/readout/

  • Recon
    • Standard track Finding + Fitting + Vertexing in HPS-java
      • Scripts that perform this step are in hps-mc/mc_scripts/recon/
Mixing Procedure before SLIC (wab-beam-tri)

- All .lhe (MadGraph) events are
  - Processed through egs5 (.lhe -> .stdhep)
  - Target thickness and beam current are set, as it is for scattered beam generation
  - After this, any tridents without a parent are given a 622 (`stdhep/add_mother’)

- “Rotated” about y, and moved in z by -5mm (stdhep/beam_coords)

\[
vtx_x' = vtx_x \times \cos(\theta) + vtx_z \times \sin(\theta) \quad px' = px \times \cos(\theta) + pz \times \sin(\theta) \\
vtx_z' = vtx_z \times \cos(\theta) - vtx_x \times \sin(\theta) \quad pz' = pz \times \cos(\theta) - px \times \sin(\theta)
\]

- Vertex positions are then sampled within a beamspot of user-defined Gaussian widths: \( \sigma_x = 0.3 \, mm \) \( \sigma_y = 0.03 \, mm \)

- "Poissonized" (stdhep/merge_poisson)
  - Events sampled from a Poisson distribution, based on MadGraph integrated cross section (must be correct!)
Recent MC Change: “rotationFix”

- Recent change in Pre-SLIC rotation/translation order

![Diagram showing rotation and translation order]

- Will avoid a slight beamspot shift in $-x$
Mixing Procedure before SLIC (wab-beam-tri)

- Poisson Sampling procedure
  - Takes an input stdhep file, and writes a random # of events into a new stdhep file, sampled from a Poisson distribution. These events get merged with beam events
  - This Poisson distribution is weighted according to the MadGraph integrated cross section and calculated luminosity

\[
\text{# of sampled events} = \text{gsl\_ran\_poisson}(r, \mu) = \frac{\mu^r e^{-\mu}}{r!}
\]

- \( \mu = \text{mean # events per sampled event} = \text{luminosity} \times \sigma = \text{density} \times \text{thickness} \times \text{bunchsize} \times \sigma \)
- 1 bunch = 2ns of beamtime
- 500k bunches per background file => 1ms per file
- Typical wab-beam-tri sample (10k SLIC files): **5 Billion bunches = 10 sec.**
Mixing Procedure before SLIC (wab-beam-tri)

• Each beam file is randomly sampled into 100 files using 100 different seeds
  .../hps_soft/stdhep/src/random_sample.cc
  • For the beam’s Poisson distribution, \( \mu = \frac{\text{# of generated events}}{500k} \sim 1.4 \)
  • After sampling, each beam file contains 500k events

• Each signal file is also sampled into 100 files (according to cross section), and each of these 100 files are merged with sampled beam files 1-to-1
  • hps-mc/stdhep/src/merge_files.cc
  • Each mixed file contains 500k events to be run through SLIC

• After SLIC, each of these 100 files are readout at the same time
  • where the “100to1” tag comes from
Mixing Procedure before SLIC (wab-beam-tri)

beam
500k events

tri
σ~1.31 mbarns

wab
σ~590 mbarns

wab-beam-tri

sampled
After SLIC

• Files are readout, either 10-to-1 or 100-to-1 (explicitly labelled)
  • /org/hps/steering/readout/EngineeringRun2015TrigPairs1_Pass2.lcsim
  • /org/hps/steering/readout/EngineeringRun2015TrigSingles1_Pass2.lcsim

• Then reconstructed
  • /org/hps/steering/recon/EngineeringRun2015FullReconMC.lcsim

• The latest MC (output from every step + DSTs + tuples) is in
  /mss/hallb/hps/production/rotationFix
MC chain for wab-beam-tri (flowchart)

- Beam background (one record per bunch)
  - EGS5 → (stdhep)→(rotate)
- Trident
  - MG5 → (lhe) → EGS5 → (stdhep)→(rotate)
- WAB
  - MG4 → (lhe) → EGS5 → (stdhep)→(rotate)
- Hadrons
  - Geant 4 → (stdhep)→(rotate)

Saved permanently

CPU Time: 10%

~few days / 10 sec long beam time (5 billion bunches) + overhead for job failures

Disk space: ~5 TB / (10sec beam time) dominated in the SLIC-Readout step

500K bunches/job

~5×10⁻⁵ bunches trigger

100 SLIC→ 1 Readout

Generated events sampled 100 times

3% 84% 3%

10× more statistics is doable, but 100× is the “effective limit” (months of production).

However, in an effort to help increase statistics...
New MC type: tritrig-wab-beam

• A MG5 updated version of “tritrig-beam-tri”

• Mixing tridents by cross section before SLIC (WBT) is very inefficient
  • ~270,000 triggered events per 5,000,000,000 bunches

• Instead, mix tridents into “wab-beam” after SLIC, but before readout
  • Space tridents by 250 bunches (~4 trigger windows) and insert into beam
  • Each readout event is approximately a trident event
  • ~8.7 million triggered events per 5,000,000,000 bunches (32x increase!)
  • A much more efficient way to increase statistics
  • However, the trigger rate is artificially increased to ~2 MHz
    • Please be aware of this when normalizing

• “wabtrig-beam-tri” can be made the same way to study wab backgrounds
New MC type: tritrig-wab-beam

• Full MadGraph5 tridents are only “tritrig” (tridents with an ESum cut)

• Unbiased (uncut) MG5 tridents below ESum~Ebeam/2 give an unstable cross section across files

• Since there is a trident event inserted in each trigger window, unbiased ones are left out from pre-SLIC mixing for now. MG4 “tri” would need to be used for this (but probably shouldn’t).

• Tridents are inserted at 2 MHz (20k events per 10 ms of beam), so this may be difficult to normalize. More of a hack to get events with background.
New MC repository to house framework

- https://github.com/JeffersonLab/hps-mc.git

- Contains everything needed to run the MC chain:
  - EGS5 + HPS-specific configs
  - Madraph4 + Madgraph5 generators
  - Stdhep programs needed for pre-SLIC processing
  - Scripts to submit MC jobs to a batch farm

- Jeremy has been tweaking the layout and creating wrappers to build everything more easily
For more information on how to run MC or what the files contain,

- [https://confluence.slac.stanford.edu/display/hpsg/MC+Production](https://confluence.slac.stanford.edu/display/hpsg/MC+Production)

How to run:

- [2015 MC Production using a Command Line](https://confluence.slac.stanford.edu/display/hpsg/MC+Production)
- [2015 MC Production Using Scripts](https://confluence.slac.stanford.edu/display/hpsg/MC+Production)

Normalizations:

- [https://confluence.slac.stanford.edu/display/hpsg/MC+Generated+Cros+Sections](https://confluence.slac.stanford.edu/display/hpsg/MC+Generated+Cros+Sections)

- If you need something, or run into issues, please email Takashi and me
MC Tasklist (discussion)

- At least 100 sec. of Nominal/L0 tritrig-wab-beam (all energies)
- 2.3 GeV everything
- “Wabtrig-beam-tri”
- More 1.056 GeV A’
- 1.5mm
- Rough Priority? (Publications/upgrade -> who’s graduating next?)
Backup
Les Houches Events (.lhe->.stdhep)  
MadGraph generation + Egs5 Scattering

- **Unbiased Tridents** ("tri", e- N+ > e- N+ e+ e-)
  - MadGraph cuts:
    - 50 MeV < e+ energy < 100 GeV
    - 10 mrad < e+ theta_y < 100 rad
    - No additional cuts in egs5 (lhe_v1)

- **Preselected Tridents** ("tritrig", same diagram)
  - MadGraph cuts:
    - 50 MeV < e+, e- energy < 100 GeV
    - 10 mrad < e+, e- theta_y < 100 rad
    - 10 MeV < invariant mass < 100 GeV
    - ESum > 500 MeV (for 1.056 GeV beam)
    - No additional cuts in egs5 (lhe_v1)
Les Houches Events (.lhe->.stdhep) MadGraph generation + Egs5 Scattering

• Unbiased Tridents ("tri", e- N+ > e- N+ e+ e-)
  • MadGraph cuts:
    • 50 MeV< e+ energy < 100 GeV
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• Preselected Tridents ("tritrig", same diagram)
  • MadGraph cuts:
    • 50 MeV < e+, e- energy < 100 GeV
    • 10 mrad < e+, e- theta_y < 100 rad
    • 10 MeV < invariant mass < 100 GeV
    • ESum > 500 MeV (for 1.056 GeV beam)
    • No additional cuts in egs5 (lhe_v1)
    • e- N+ > e- N+ f+ f- @3 (RAD)
    • e- N+ > e- N+ f+ f- @2 (BH)

“RAD” and “BH” can also be generated separately, and have distinguishable electrons
Les Houches Events (.lhe->.stdhep)
MadGraph generation + Egs5 Scattering

• **WAB ("wab", f- N+ > f- N+ x)**
  • MadGraph cuts (similar for unbiased tridents)
    • 50 MeV< e+, e- energy < 100 GeV
    • 10 mrad < e+, e- theta_y < 100 rad
    • No additional cuts in egs5 (lhe_v1)

• **A’ ("ap", e- N+ > e- N+ ( x > f+ f- ))**
  • MadGraph cuts (virtually none)
    • e+, e- energy < 100 GeV
    • e+, e- theta_x,y < 100 rad
    • Invariant mass < 100 GeV
    • No additional cuts in egs5 (lhe_v1)
Les Houches Events (.lhe->.stdhep)
MadGraph generation + Egs5 Scattering

• WAB ("wab", f- N+ > f- N+ x)
  • MadGraph cuts (similar for unbiased tridents)
    • 50 MeV< e+, e- energy < 100 GeV
    • 10 mrad < e+, e- theta_y < 100 rad
    • No additional cuts in egs5 (lhe_v1)

• A' ("ap", e- N+ > e- N+ ( x > f+ f- ))
  • MadGraph cuts (virtually none)
    • e+, e- energy < 100 GeV
    • e+, e- theta_x,y < 100 rad
    • Invariant mass < 100 GeV
    • No additional cuts in egs5 (lhe_v1)

No egs5 scattering for A’s

Decay length is applied
during stdhep conversion
("stdhep/lhe_tridents")
MadGraph Generator Scripts

• Scripts that run MadGraph:
  /u/group/hps/production/mc/EngRun2015Scripts/lhe/

• The generators and run cards can be found here:
  /u/group/hps/production/mc/MadGraph/
To Calculate Expected Tridents in a WBT File

# of trident events per 500k bunches =
(0.14566 barns)*(6.306*^-2 nuclei/barn-cm)*(0.0004062 cm)
*(625 electrons/bunch)*(500000 bunches)
= 1166
MC directory naming
(/mss/hallb/hps/production/***/...)

postTriSummitFixes:
Incorporates the following fixes/improvements that took effect after the Trident Summit:

• WAB events are now unweighted (labelled 'wabv2')
• The WAB process is now suppressed in egs5, since it was not being handled correctly (the electron was not being scattered). This also prevents double-counting the MadGraph WABs. (files labelled ‘egsv5’)
• Updated target thickness (now 4.062 um from 4.375 um). Calculated from Clive's Note
• MC events are shifted 5mm along the z-axis to account for a discrepancy in target position
• New detector geometry that removes extraneous material (EngRun2015-Nominal-v5-0-fieldmap)
  • The carbon fiber volume in the L1-3 half-modules was previously too large, obstructing the beam.
  • 1.5mm SVT version is also available
• GEANT4/SLIC has been updated to 10.01.p03/REL, from 10.01.p02/HEAD.
• Additional 'wab-beam-tri' tags within the 'postTriSummitFixes' directory:
  • 500kBunches: Enough WABs were guaranteed to be generated in order to make 500k bunches (1ms) of mixed background per SLIC file, 10ms per recon file. Corrects the overall normalization of wab-beam-tri in analysis.
  • zipFix: 500kBunches + fixes another small error which potentially prevented photons from being handled correctly
  • T0Offset: Recon used the same steering file as for data recon, which sets 'correctT0Shift' and 'correctChanT0' flags to 'true' in RawTrackerHitFitterDriver (determined to not be the correct way to process MC)
• The "most correct" 2015 wab-beam-tri files are currently labelled 'zipFix' (NOT T0Offset!)
Other 2015 MC directories
(/mss/hallb/hps/production//***/...)

Pass #
• Uses a jar (also tagged in the file name) that matches an 'official' data pass of the same number

DBGainsPass
• Database runtime gains used for readout

LucaTri
• Luca’s various Vegas trident generator tests (labeled by date)

Layer0Studies (older L0 studies, “rotationFix” is updated)
• A pass using the new Layer-0 detectors will go here