HPS MC Status

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Outline

- Review of MC production chains
- Software updates
    - Updates for rebuilding mother-daughter relations in EGS5 output for truth
    - Updates for stdhep tools
    - Updates for readout system
    - Development of a package for checking MC production
- MC production
    - Discussion of configuration
    - MC samples:
        - Update of 2016 MC
        - 2019 MC
        - Future experiment with 2.3 GeV beam
        - Future experiment with 3.7 GeV beam
    - Confluence pages for information of MC samples
- Summary and next step

Chains for Signal-Beam Samples

Signal (ap, rad, tritrig, wab)	**Beam**	**Software**
event generation		→ MadGraph
passing through target	event generation	→ EGS5
adding mother particles	target offsetting, beam rotation and diffusion	} → stdhep tools
target offsetting, beam rotation and diffusion	beam bunch building	}
detector simulation	detector simulation	→ SLIC
filtering and spacing, and file bundling	file bundling	} → LCIO hps-java
signal and beam merging		}
readout		}
recon		}

Software Updates: rebuilding mother-daughter relation in EGS5 output for truth

- In EGS5 output, only final-state particles are saved, while information for mother particles are lost. For analysis, we need fully truth information in final MC samples for ap and rad so as to distinguish between recoiled e^- and e^- from pair. Therefore, we need to add mother particles with true vertex and Lorentz vector information and rebuild mother-daughter relations between mother particles and final-state particles in EGS5 output.

- EGS5 programs and a stdhep tool need to be updated for this purpose.

Software Updates: Update of EGS5 Programs for truth

- The EGS5 program lhe_v1.f is updated by Takashi to construct vertex of displaced ap and to set flags for mothers of final-state particles
  - lhe_prompt.f for ap prompt
  - lhe_exponential.f for ap displaced with vertex constructed by a decay model (ctau = 10 mm), applied by 2016 MC
  - lhe_uniform.f for ap displaced with vertex constructed by a uniform model (range: 0 - 150 mm), applied starting from 2019 MC
  - lhe_rad.f for rad
- lhe_v1.f is still used for tritrig and wab

Software Updates: Update of A stdhep Tool for truth

- The stdhep tool add_mother is updated with a new tool name "add_mother_update2". Mother particles are constructed based on information of MadGraph output and mother-daughter relations are built based on flags in EGS5 output. The event structure satisfies the HEPEVT standard https://home.fnal.gov/~mrenna/lutp0613man2/node49.html

- Add two mother particles:

  - PDG 623; mother for recoiled electron and its secondary particle(s); a virtual particle

  - PDG 622; mother for e^+e^- from pair and their secondary particle(s); A' for ap or γ^* for rad with true vertex and Lorentz vector

- After updates, truth information is propagated to final samples, and mother particles can be found and then true masses of e^+e^- pairs can be obtained from ap-beam or rad-beam final samples.

Software Updates: stdhep tools

- Update for the source code stdhep_util.cpp: avoid memory leak by releasing memory allocated by “new”. Decreasing memory request is critical to enhance JLab farm running efficiency.

- Update for random_sample.cc: this tool is used to randomly pick up input events to build beam bunches, but there are two issues: 1) huge memory usage since all events from input file are saved into a vector; 2) Built beam bunches are not completely independent

    - Solution 1: We have produced enough electrons by EGS5 to build beam bunches, so it is not necessary to randomly pick up events from input sample. In the new tool random_sample_usingInputEventsInOrder.cc, input events are orderly picked up to build beam bunches

    - Solution 2 - optimization of the tool random_sample (backup): Input events are cached into multi-vectors, where size of vectors is set by an option; then use std::shuffle to rearrange indices of elements in vector and pick up events in order of rearranged indices to build bunches. This code can control memory usage by the option. Additionally, it provides us a way to build multi beam-bunch samples using the same input sample by EGS5 if required, and beam bunches among output samples are quasi-independent.

Software updates: a filter for singles trigger in hps-java

- Once a sample is produced for signal (ap, rad, tritrig, wab) by SLIC, we do filtering and spacing for the sample, and then the spaced sample is merged with beam background.
- Since singles trigger is applied in the new readout system, a proper filter specified for the singles trigger is necessary.
- A tool ExtractEventsWithHitAtHodoEcal is developed in hps-java to extract events with programmable # of hits at hodoscope and Ecal from MC samples at SLIC level, where hit at Ecal must have contribution from positron, as well as programmable lower energy thresholds for Ecal hits.

Software updates: the readout system overview of the readout system

- The old readout system was developed by Kyle for 2016 MC, and was updated later for digitization and raw conversion for hodoscope hits. Overall, the system includes digitization of detector's response and simulation of the trigger system.
    - Digitization: digitize hits from detector simulation to ADC samples
    - Simulation of the trigger system: simulate GTP (VTP for 2019) processing to generate triggers for readout of ADC samples.
- Drivers in the system are closely correlated:
    - Drivers for Ecal and hodoscope work as a chain, separately.
        - Ecal chain: truth hits -> digitization -> raw conversion -> GTP cluster
        - Hodoscope chain (new readout system): truth hits -> hit processing -> digitization -> raw conversion -> hodoscope hit patterns
    - GTP/VTP clusters from the Ecal chain and hodoscope hit patterns from the hodoscope chain are input of trigger drivers.
    - A readout data manager manages all drivers:
        - Control time line of the system
        - Take care of time displacement among drivers, including time displacement due to NSA (# of samples after threshold-crossing sample) in digitization drivers, time displacement due to clustering temporal window in GTP/VTP cluster driver, and trigger displacement in trigger drivers.
        - Cache data from output of drivers so that the cached data could be used for the next drivers and be output after triggered.
        - Triggered signal are sent to the manager, and the manager determines what data are finally output.
- Besides ADC samples for hits of Ecal, hodoscope and SVT, other useful information can be collected in output of the readout system, like truth information (MC particles, truth hits), relation between truth hits and ADC samples, etc.

Software updates: the readout system issue fixing in the old system

- Issue 1: Ecal and hodoscope share the same digitization driver: DigitizationReadoutDriver. The driver processes truth hits to transform pulses into FADC hits, where pulse amplitude is proportional to hit energy. By default, unit of hit energy is MeV, like energy of Ecal hits. However, unit of hodoscope gain in the database is self-defined (pulse * gain = 1000 ADC), instead of MeV. To let the digitization driver can process hodoscope hits like Ecal hits, a conversion factor is applied to do conversion for hodoscope gains from self-defined-unit/ADC to MeV/ADC. Note: the conversion factor depends on energy deposit at hodoscope, so the factor changes as beam energy changes

- Issue 2: In the old readout system, the threshold-crossing sample is regarded as a part of NSB, but actually it is a part of NSA. Comparison between two cases, length of integration range for pulse is the same, but the range shifts one clock-cycle.

- Issue 3: Deadtime for pulse integration is 32 ns for hardware. But in the old system, deadtime is set as 32 clock-cycles.

- The above issues have been fixed. According to evaluation, effects of the issues on 2016 MC is slight.

- Details for update of the readout system are in https://confluence.slac.stanford.edu/display/hpsg/2020.03.25+--+Software+Meeting?preview=/275089973/275089925/Updates%20of%20the%20Readout%20System%20for%202019%20MC.pdf

Software updates: the readout system new readout drivers

- HodoscopePatternReadoutDriver: For each event, four hit patterns are built corresponding to four layers of hodoscope. The hit patterns are built according to the logic of hardware. The built hit patterns are then applied for geometry matching in singles trigger.

- SinglesTrigger2019ReadoutDriver: Comparing to the 2016 singles trigger, there are more limits for the 2019 singles trigger

  - Cluster position-dependent cuts

$$x_{cluster} \geq x_{min}$$

$$E_{cluster} \geq C_0 + C_1 x + C_2 x^2 + C_3 x^3$$

  - Geometry matching for hodoscope and Ecal

- TriggerModule2019: developed based on TriggerModule for 2016; the class handles cuts for 2019 triggers and its logic is consistent with 2019 VTP hardware

- Besides, SVT readout driver is updated by Omar.

Software Updates:

a package for checking MC production

- Three tools:
  - whatFailed: check what files are failed to be produced so that corresponding failed jobs can be identified and resubmitted
  - integratedCS: extract cross section from each lhe file of rad, tritrig, or wab sample, and then plot distribution
  - eventEvolution: extract key information from each log file of a MC sample, and then take analysis to find bad files, to study event evolution along MC chain for information of efficiency and statistics, and to obtain information for normalization; besides, the tool help us to determine strategy of signal-beam merging
- Application: The package is friendly. Each tool is run by a command, and then text files with information of interest and/or a root file with histograms are produced.
  - Location for the package at JLab farm: /u/group/hps/users/caot/tools/mcProductionTools
  - All tools in the package are comprised of scripts, no need installation; ROOT and python need to be installed
  - How to run tools:
    - run under tcsh
    - Env. setup: source path-of-package/setup.csh
    - Command: path-of-package/tool-name/run.csh arguments
- See more details in https://confluence.slac.stanford.edu/display/hpsg/April+21%2C+2020+Meeting?preview=/276211151/276211403/System%20%20for%20MC%20Production.pdf

MC Production: discussion of configuration

- Configuration needs to be taken care when application of software at each level of MC production chain, especially when beam energy changes for new experiments

- General setup for experiments: parameters for beam, target, and ap mass points of interest

- MadGraph: setup in run_card.dat, including beam energy and kinematic limits

- EGS5 program for beam generation: setup of kinematic limits

- stdhep tools: parameters for beam size, beam rotation, and target shift

- SLIC: detector with specified field map

- hps-java: parameters for filtering and spacing signal samples, detector with specified field map, run number, setup in steering files for readout and reconstruction

MC Production: kinematic limits in event generators

Kinematic limits in run cards of MadGraph and EGS5 programs are set with consideration of MC efficiency, acceptance, cuts in trigger, cuts in event selection and divergence of MadGraph

- ap: no limits
- rad:

Limits	2016	2019
Minimum for energy of e^+ or e^- from pair	50 MeV	100 MeV
Minimum for y direction (p_y/p) of e^+ or e^- from pair	0.005	0.005
Minimum for total energy of e^+e^- pair	500 MeV	1000 MeV
Minimum for invariant mass of e^+e^- pair	10 MeV/c^2	10 MeV/c^2

- tritrig:

Limits	2016	2019
Minimum for energy of e^+	100 MeV	200 MeV
Minimum for y direction (p_y/p) of e^+ or e^- from pair	0.005	0.005
Minimum for total energy for at least one pair	1000 MeV	2000 MeV
Minimum for invariant mass for at least one pair	10 MeV/c^2	10 MeV/c^2

- wab:

Limits	2016	2019
Minimum for energy of photon	400 MeV	800 MeV
Minimum for y direction (p_y/p) of photon	0.005	0.005

- beam:

Limits	2016	2019
Minimum for energy of e^-	$0.005*E_{beam}$	$0.005*E_{beam}$
Minimum for transverse (2016) / y (2019) direction if energy is larger than $0.6*E_{beam}$ for e^-	0.005	0.005
Minimum for y direction of photon	0.004	0.004
Maximum for y direction if energy is larger than 400 MeV (800 MeV for 2019) for photon	0.005	0.005

MC Production: MC samples — update of 2016 MC

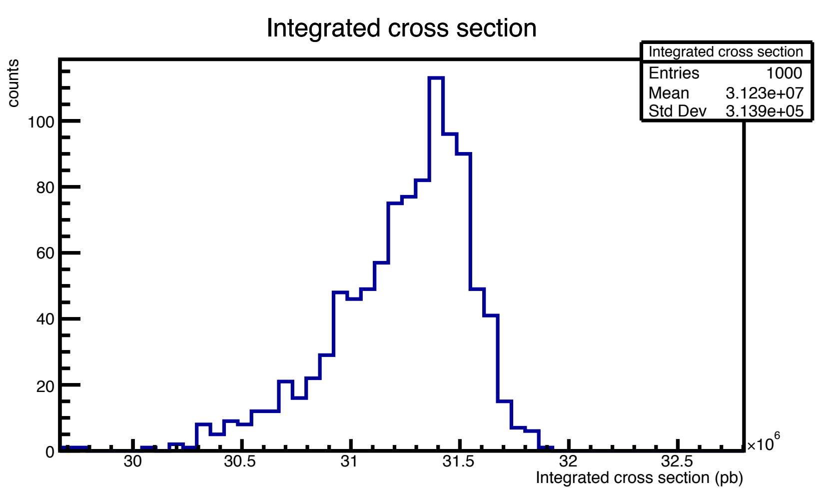
- Since last collaboration meeting, more 2016 MC samples have been produced with requirements of 2016 analysis, including:
  - Ap-beam and rad-beam samples with truth information for analysis of radiative fraction and others
  - Ap-beam samples for more ap mass points at low mass and high mass
  - Ap-beam samples with +/- 0.5 mm target shift for analysis of systematic uncertainty.
  - Moeller-beam sample for analysis of mass resolution

MC Production: MC samples — 2019 MC

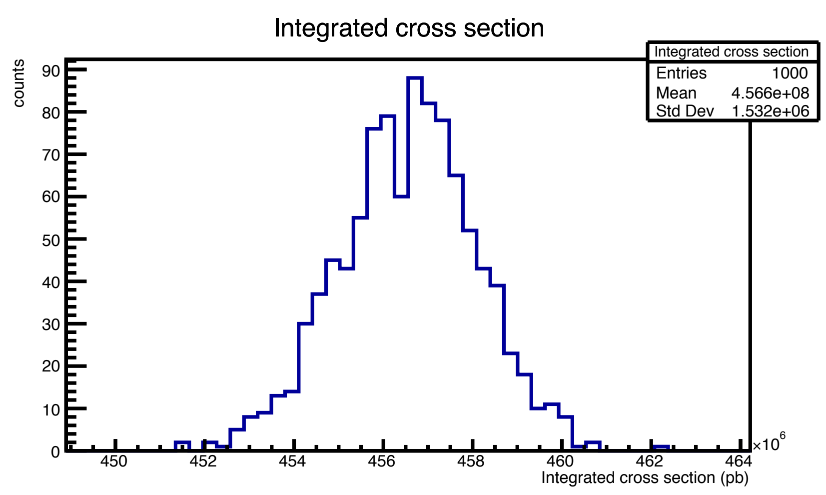
- Configuration:
  - General setup is referring to production runs during Sep.1st to 9th of 2019
    - beam: 4.55 GeV; 120 nA
    - target: 20 um tungsten
    - ap mass points: 75 100 105 110 115 120 125 130 135 140 145 150 160 170 180 190 200 MeV/c^2
  - Setup for kinematic limits in MadGraph and EGS5 is referring to 2016 MC
  - Parameters for stdhep tools: beam size (0); beam rotation (30.5 mrad around y); target offset (-7.5 mm along z)
  - SLIC: detector (HPS-PhysicsRun2019-v2-4pt5) and field map developed by Omar and Maurik
  - hps-java: detector is consistent with SLIC, run (10666), parameters in the readout steering file are setup referring to the trigger configuration hps_v12_1.cnf (https://userweb.jlab.org/~vpk/HPS/Trigger/Run2019/hps_v12_1.cnf)
- Large-scale samples with singles trigger for the first pass of 2019 MC have been produced for reach study, including ap-beam, rad-beam, tritrig-beam, and wab-beam

MC Production: 2019 MC: cross section

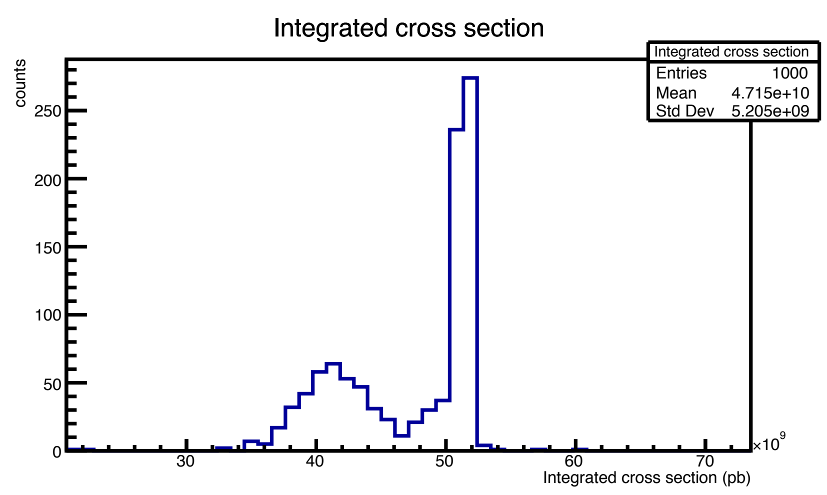
rad



tritrig



wab



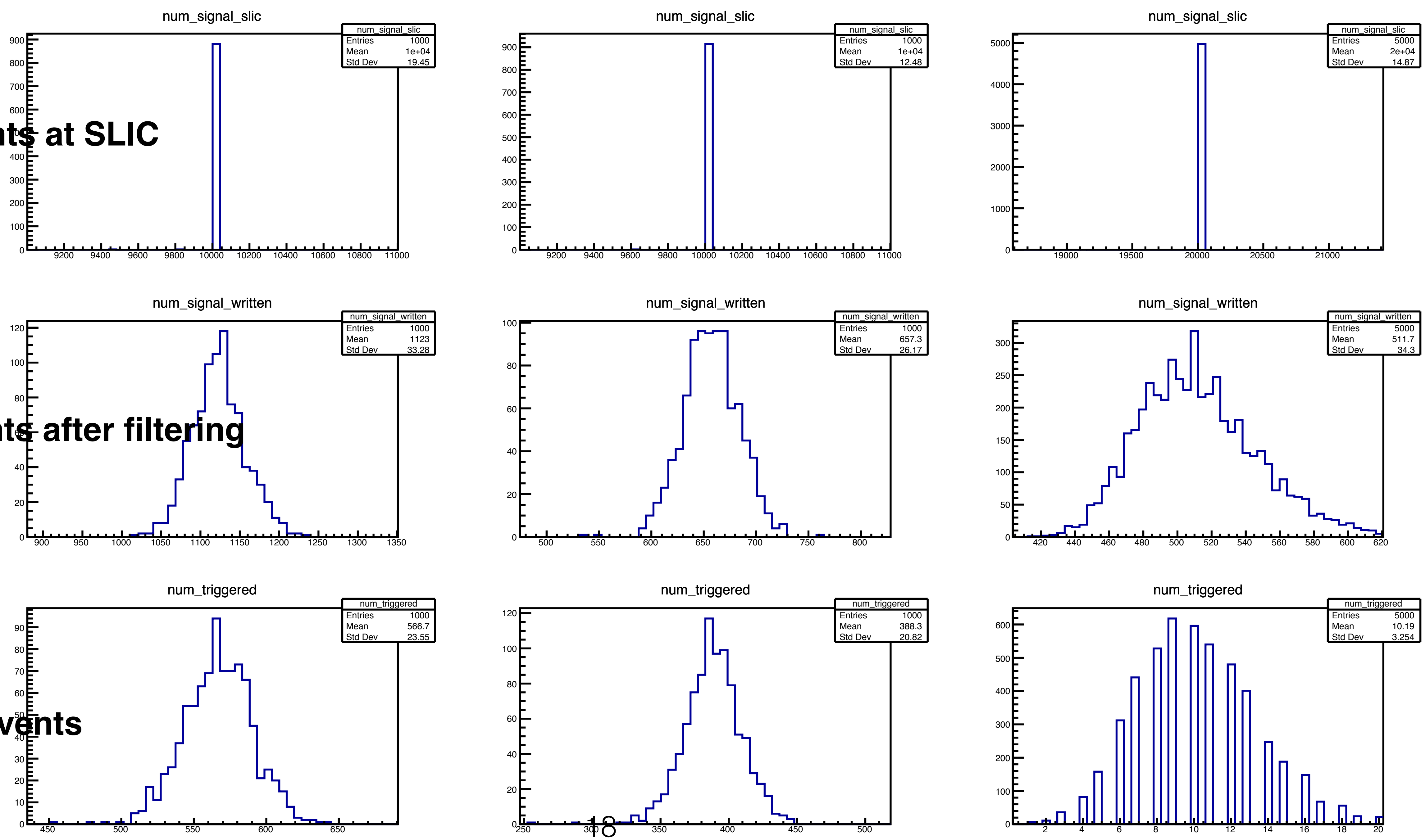
MC Production:
2019 MC: event evolution

rad-beam **tritrig-beam** **wab-beam**

# of signal events at SLIC

# of signal events after filtering

# of triggered events



MC Production: 2019 MC: statistics

of triggered events for samples with singles trigger:

- rad-beam: ~495k
- tritrig-beam: ~350k
- wab-beam: ~50k
- ap-beam for prompt or displaced of each mass point: a few million

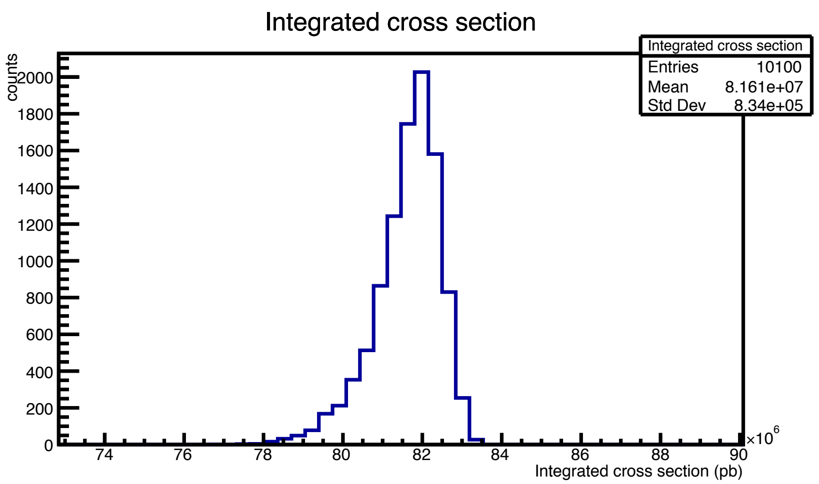
MC Production:
MC samples — future experiment with 2.3 GeV

- Configuration:
  - General setup: consistent with 2016 MC except target thickness
    - beam: 2.3 GeV; 200 nA
    - target: 8 um tungsten
    - ap mass points: 30 35 40 45 50 55 60 65 75 80 85 90 95 100 105 110 115 120 125 130 135 140 145 150 155 160 165 170 175 MeV/c^2
  - Setup for kinematic limits in MadGraph and EGS5 is consistent with 2016 MC
  - Parameters for stdhep tools: beam size (0); beam rotation (30.5 mrad around y); target offset (0)
  - SLIC: detector (HPS-v2019-2pt3GeV); detector is constructed referring to 2019 detector
  - hps-java: detector is consistent with SLIC, run (10666), the readout steering file is developed based on the 2019 readout steering file
- Large-scale samples with singles trigger for the first pass of future experiment of 2.3 GeV have been produced, including ap-beam, rad-beam, tritrig-beam, and wab-beam

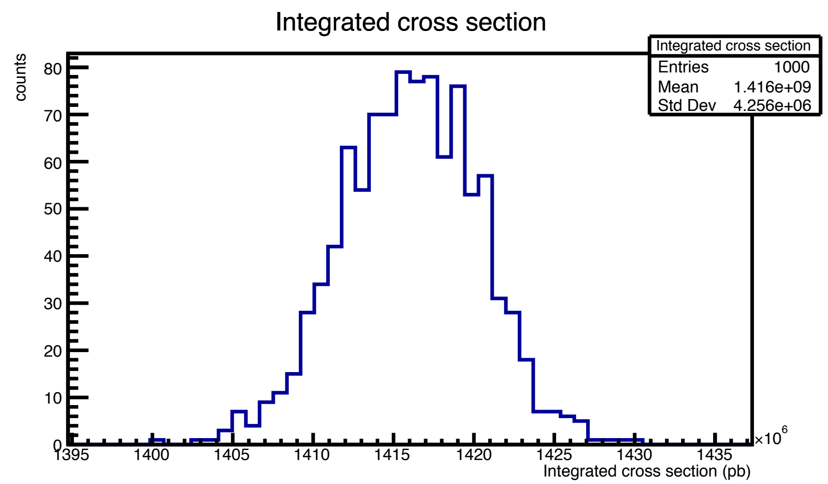
MC Production:

future experiment with 2.3 GeV: cross section

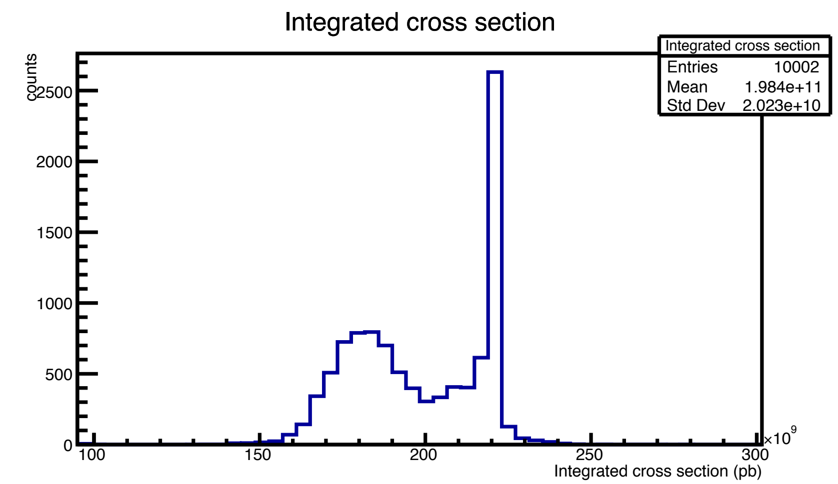
rad



tritrig



wab



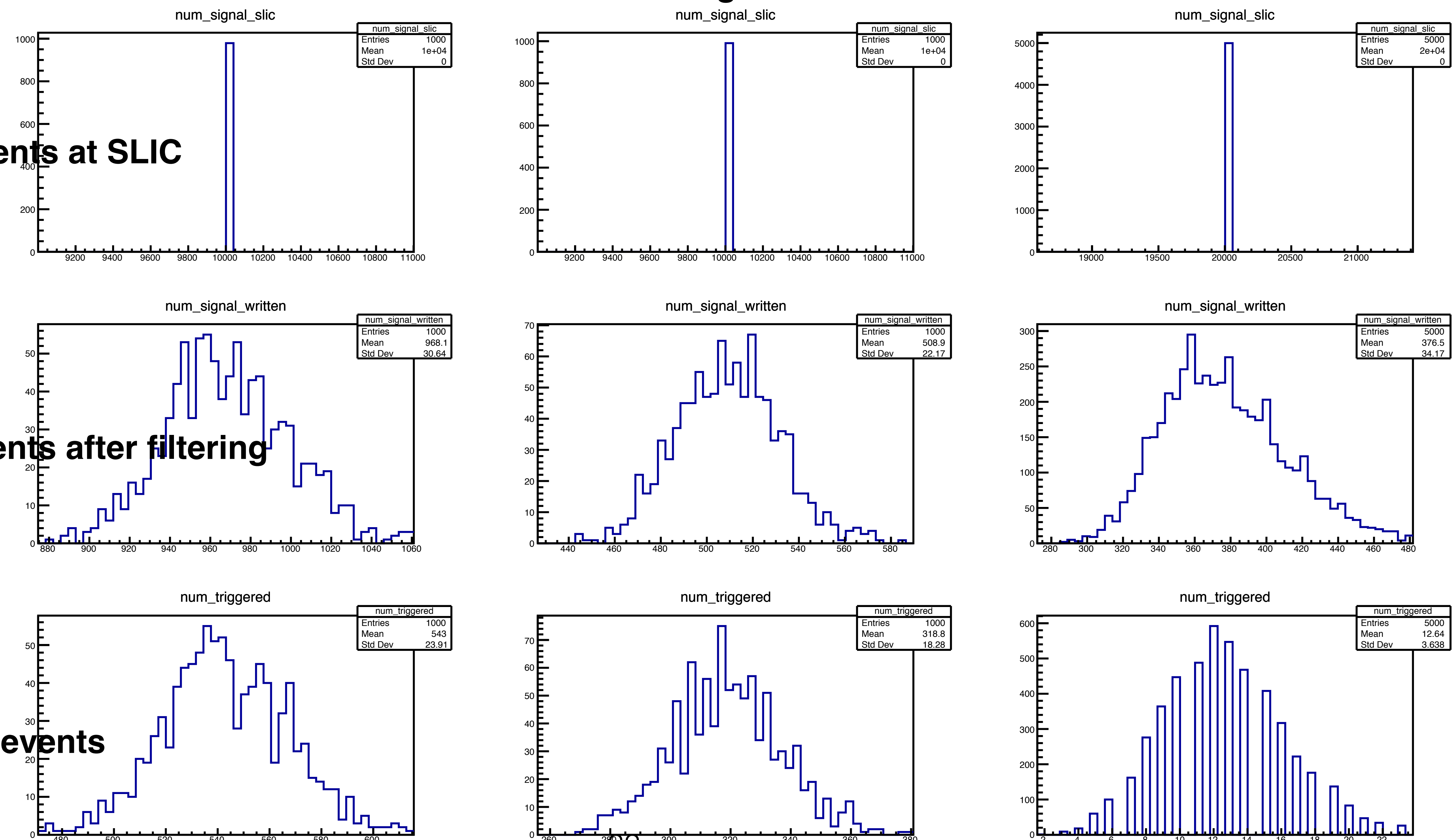
MC Production:
future experiment with 2.3 GeV: event evolution

rad-beam | **tritrig-beam** | **wab-beam**

# of signal events at SLIC

# of signal events after filtering

# of triggered events



MC Production: future experiment with 2.3 GeV: statistics

of triggered events for samples with singles trigger:

- rad-beam: ~530k
- tritrig-beam: ~320k
- wab-beam: ~63k
- ap-beam for prompt or displaced of each mass point: 100k to 1M

MC Production:
MC samples — future experiment with 3.7 GeV

- Configuration: in plan or under testing
  - General setup:
    - beam: 3.7 GeV; 120 nA
    - target: 20 um tungsten
    - ap mass points: 50 60 70 80 90 100 105 110 115 120 125 130 135 140 145 150 160 170 180 190 200 MeV/c^2
  - Setup for kinematic limits in MadGraph and EGS5 is referring to 2016 and 2019 MC
  - Parameters for stdhep tools: beam size (0); beam rotation (30.5 mrad around y); target offset (0)
  - SLIC: detector (HPS-v2019-3pt7GeV); detector is constructed referring to 2019 detector
  - hps-java: detector is consistent with SLIC, run (10666), the readout steering file is developed based on the 2019 readout steering file
- Development and test for configuration and job scripts are in progress, and then large-scale samples will be produced.

MC Production:
confluence pages for information of MC samples

- For each pass of experiments, a confluence page is edited. The confluence page includes details for configuration, commands of softwares, locations of samples, normalization information, etc

- Main page: https://confluence.slac.stanford.edu/display/hpsg/MC+Samples

- Child pages: 2016 MC Samples; 2019 MC Samples; Future experiments

Summary and Next Step

- MC softwares have been updated for requirement of analysis, bug fixing, and 2019/future experiment simulation. The MC system works well.

- More 2016 MC samples have been produced with requirement of 2016 analysis. The first pass samples of 2019/future experiment with 2.3 GeV have been produced for reach study. Production for future experiment with 3.7 GeV is in progress.

- Optimization of the job submission system is in progress.

- Study for 2019 trigger diagnostics is on the way.