

PD Simulation Refactoring for new LArG4

MU Wei

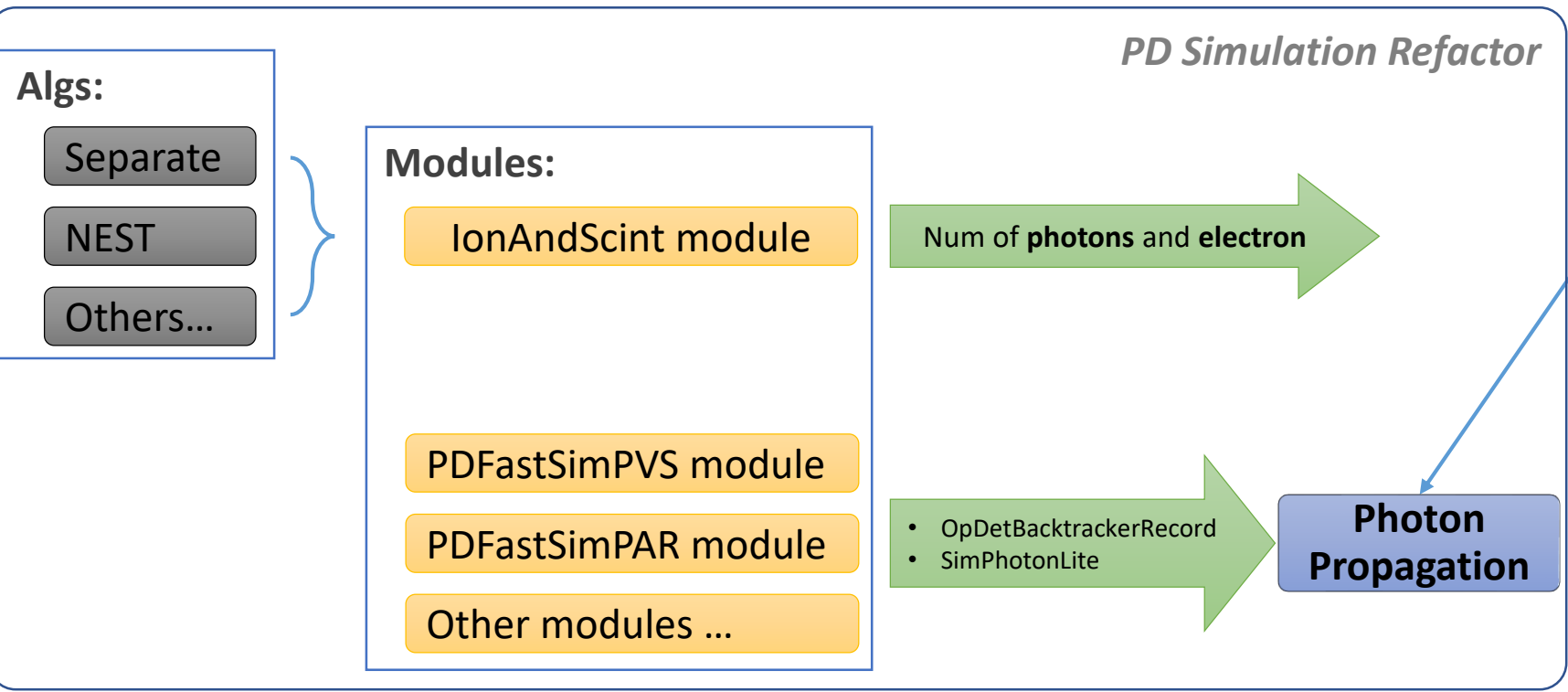
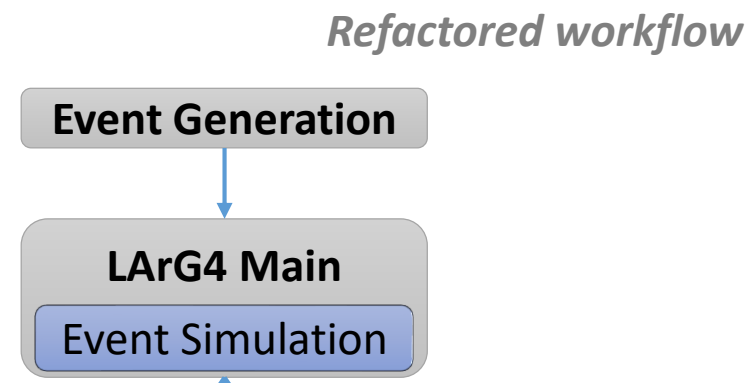
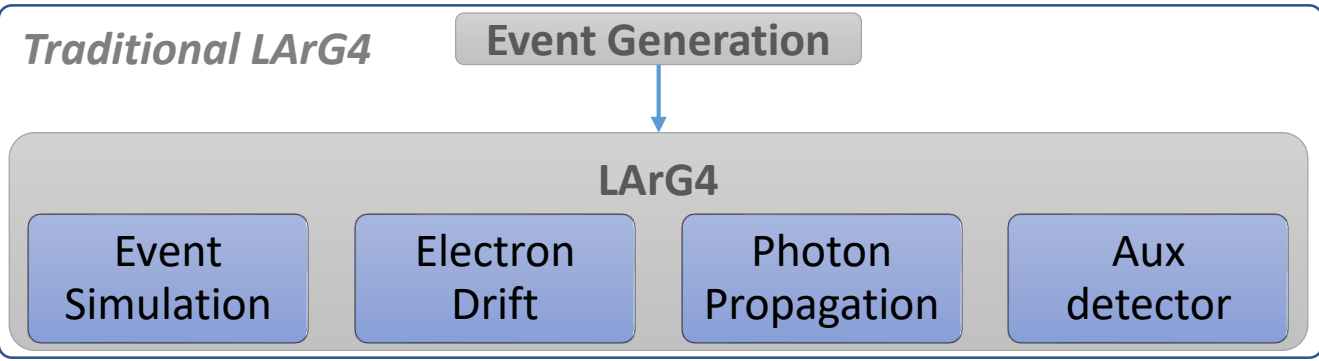
Oct. 08 2019

Outline

Following Hans' work, the PD simulation has been refactored

- Refactored simulation workflow
- Modification to code
- Preliminary test for the refactored PD simulation modules

Simulation workflow – Refactored model



Status for the refactored PD simulation

feature/muve_pdsim_refector (v08_27_00)

Updated:

- lardataobj/Simulation/**SimEnergyDeposit.h**
- lardataobj/Simulation/classes_def.xml

Modified:

- larsim/ElectronDrift/**ShiftEdepSCE_module.cc**
- larsim/ElectronDrift/**SimDriftElectrons_module.cc**
- larsim/LArG4/OpDetPhotonTable.cxx
- larsim/LArG4/OpDetPhotonTable.h
- larsim/LArG4/OpFastScintillation.cxx
- larsim/PhotonPropagation/**PhotonLibraryPropagation_module.cc**
- larg4 Services/**SimEnergyDepositSD.cc**
- larwirecell/Modules/**BlipMaker_module.cc**

New

- larsim/IonizationScintillation/**IonAndScint_module.cc**
- larsim/IonizationScintillation/**ISCalcAna_module.cc**
- larsim/PhotonPropagation/**PDFastSimPAR_module.cc**
- larsim/PhotonPropagation/**PDFastSimPVS_module.cc**

- larsim/IonizationScintillation/ISCalc.cxx
- larsim/IonizationScintillation/ISCalc.h
- larsim/IonizationScintillation/ISCalcNESTLAr.cxx
- larsim/IonizationScintillation/ISCalcNESTLAr.h
- larsim/IonizationScintillation/ISCalcSeparate.cxx
- larsim/IonizationScintillation/ISCalcSeparate.h

- larsim/IonizationScintillation/*ISCalc_ana.fcl*
- larsim/PhotonPropagation/*PD_Sim_Chain_Ref.fcl*
- larsim/PhotonPropagation/*PD_Sim_Chain_Tra.fcl*

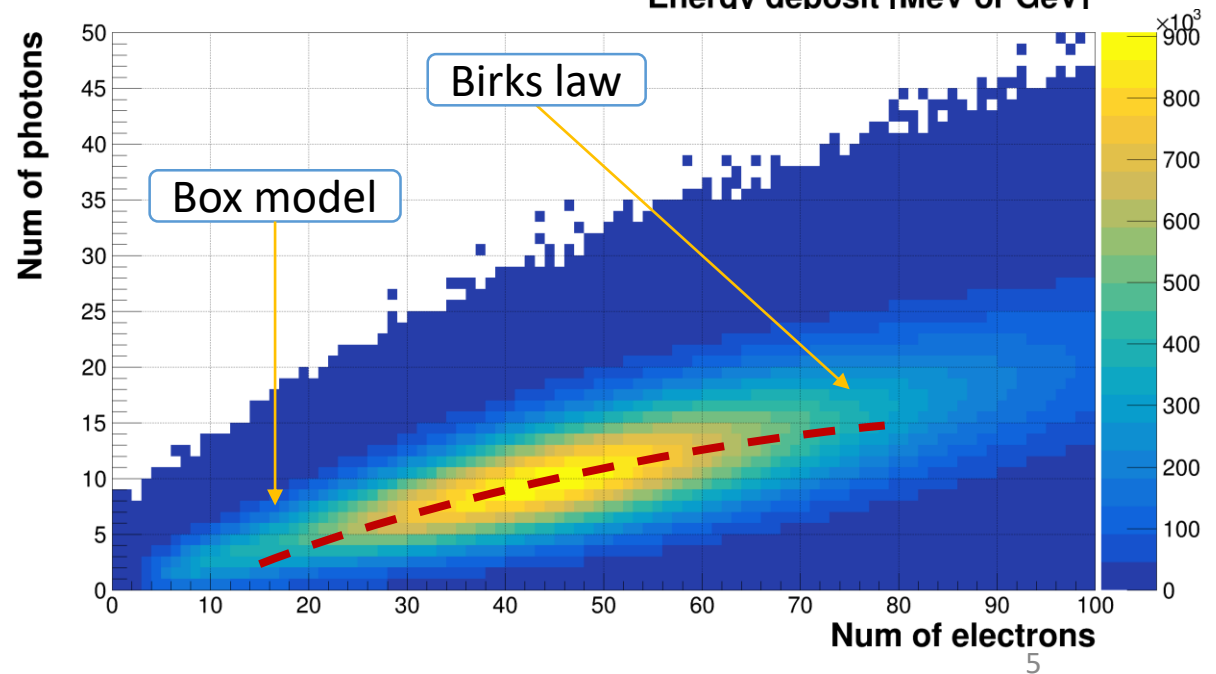
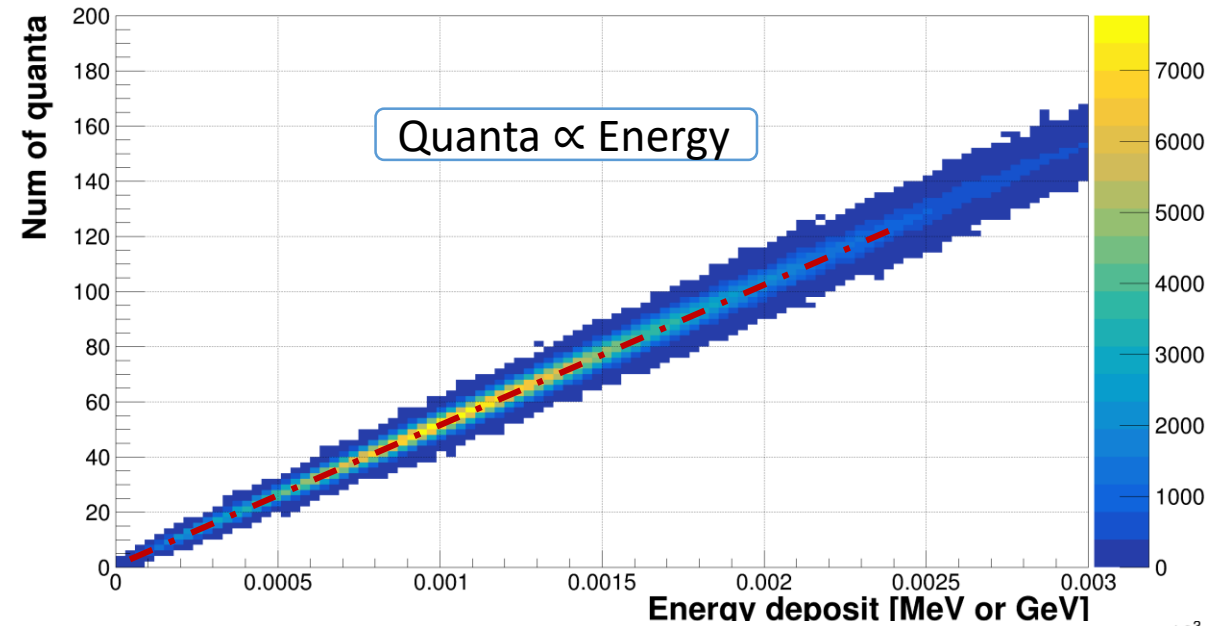
Verification of customized IS calculation

Function verification ← done

- Num of quanta proportional to energy deposit
- Correlation between electrons and photons

Accuracy verification ← to be measured

- Work function
- Quenching factor
- Anticorrelation between electrons and photons
- ...



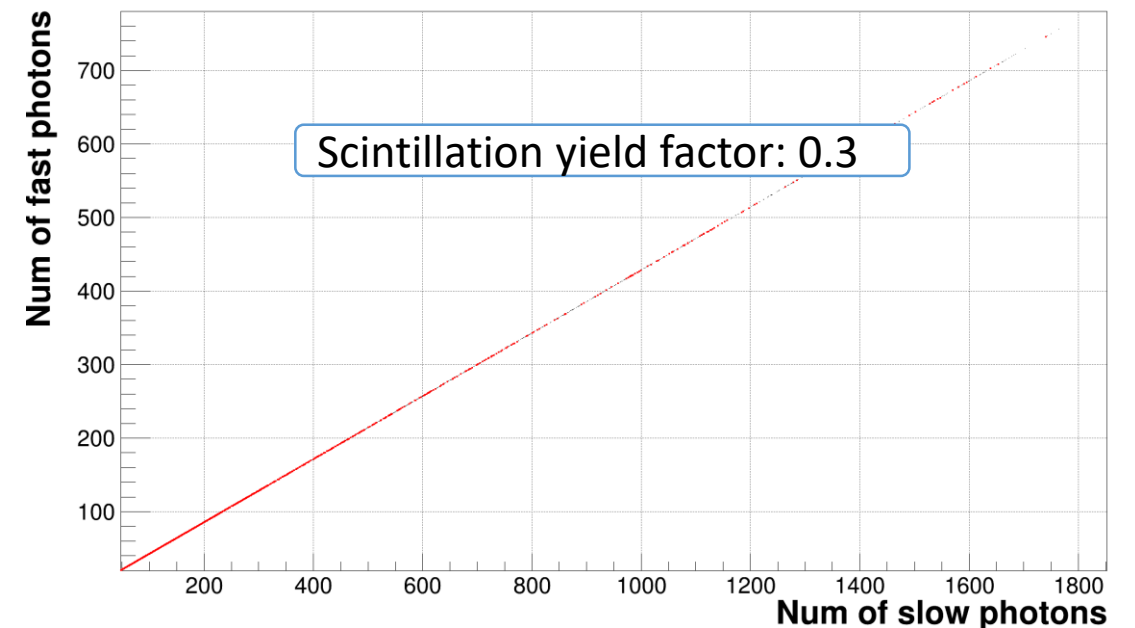
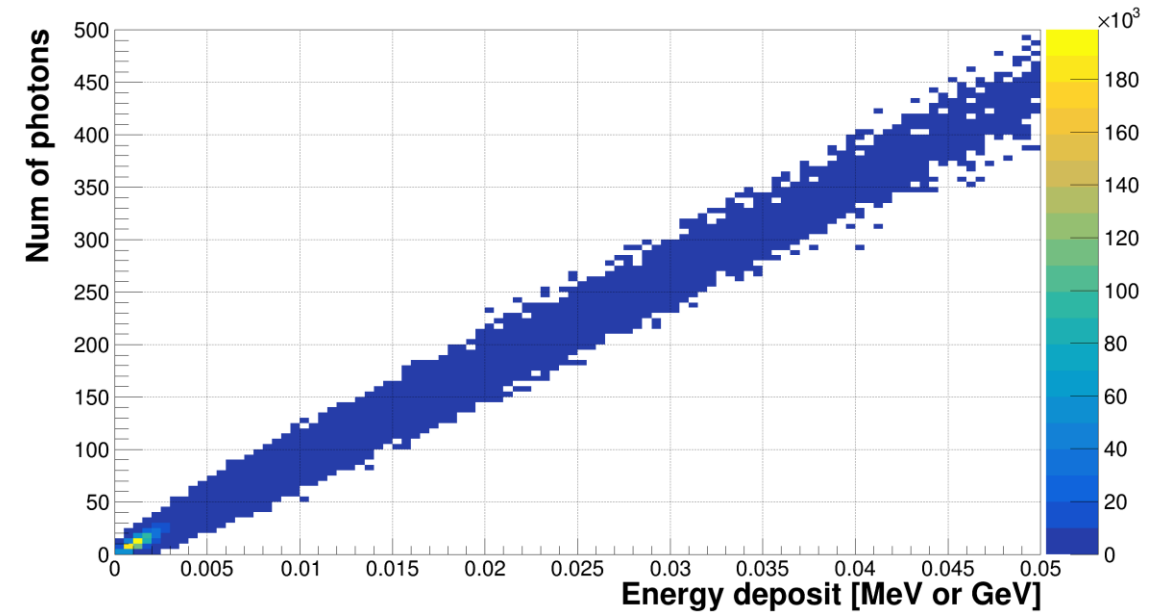
Verification of customized IS calculation

Function verification ← done

- Num of photons proportional to energy deposit
- Scintillation yield factor

To make it more accurate

- Scintillation yield factor based on LAr purity?
- ...



Test of the PD simulation

Event generation: 6 GeV muons x 500 (/dune/data/users/wmu/output/protodune_muon.fcl)

Simulation

Refactored

- /fcl/PD_Sim_Chain_REF.fcl
- Geometry: protodune_v5_refactored_nowires
- Service: protodunev4_photonvisibilityservice

Event simulation: LArG4Main

IS calc: IonAndScint (*NEST – customized scint/ion process*)

PD simulation: PDFastSimPVS

Traditional

- /fcl/PD_Sim_Chain_TRA.fcl
- Geometry: protodune_v5_refactored_nowires
- Service: protodunev4_photonvisibilityservice
- IS calculation: *NEST algorithm*
- PD simulation: photon visibility service

Data analysis:

- SimPhotonCounter module: **SimPhotonCounter**
- DumpOpDetBacktrackerRecords: **DumpOpDetBacktrackerRecords**

Refactored PD simulation workflow

```
services.PhotonVisibilityService: @local::protodunev4_photonvisibilityservice
services.LArG4Parameters.UseLitePhotons: true
services.LArG4Parameters.IonAndScintCalculator: "NEST"
//services.LArG4Parameters.IonAndScintCalculator: "Separate"
physics:
{
  producers:
  {
    //retain largeant name for compatibility
    largeant:
    {
      module_type: "larg4Main"
      enableVisualization: false
      macroPath: "../macros"
      visMacro: "vis.mac"
    }
  }

  IonAndScint:
  {
    module_type: "IonAndScint"
    SimulationLabel: "largeant:LArG4DetectorServicevolTPCActive"
  }

  PDFastSim:
  {
    module_type: "PDFastSimPVS"
    module_type: "PDFastSimPAR"
    SimulationLabel: "IonAndScint:NEST"
    SimulationLabel: "IonAndScint:Seperate"
    DoSlowComponent: "true"
    RiseTimeFast: 0.0
    RiseTimeSlow: 0.0
  }
}

rns:
{
  module_type: "RandomNumberSaver"
}
```

IS calc algorithms

Event simulation

IS calculation

PD simulation

Refactored

```
services.PhotonVisibilityService: @local::protodunev4_photonvisibilityservice
services.LArG4Parameters.FillSimEnergyDeposits: true
services.LArG4Parameters.UseLitePhotons: true
services.LArG4Parameters.IonAndScintCalculator: "NEST"
physics:
{
  producers:
  {
    largeant: @local::standard_largeant
    rns: { module_type: "RandomNumberSaver" }
  }
}
```

Traditional

Event simulation
IS calculation
Photon simulation
Electron simulation
...

Refactored PD simulation workflow

```
services.PhotonVisibilityService:
services.LArG4Parameters.UseLitePhotons:
services.LArG4Parameters.IonAndScintCalculator:
//services.LArG4Parameters.IonAndScintCalculator:
physics:
{
  producers:
  {
    //retain largeant name for compatibility
    largeant:
    {
      module_type: "larg4Main"
      enableVisualization: false
      macroPath: "../macros"
      visMacro: "vis.mac"
    }

    IonAndScint:
    {
      module_type: "IonAndScint"
      SimulationLabel: "largeant:LArG4DetectorServicevolTPCActive"
    }

    PDFastSim:
    {
      module_type: "PDFastSimPVS"
      module_type: "PDFastSimPAR"
      SimulationLabel: "IonAndScint:NEST"
      SimulationLabel: "IonAndScint:Seperate"
      DoSlowComponent: "true"
      RiseTimeFast: 0.0
      RiseTimeSlow: 0.0
    }

    rns:
    {
      module_type: "RandomNumberSaver"
    }
  }
}

@local::protodunev4_photonvisibilityservice
true
"NEST"
"Seperate" }
```

IS calc algorithms

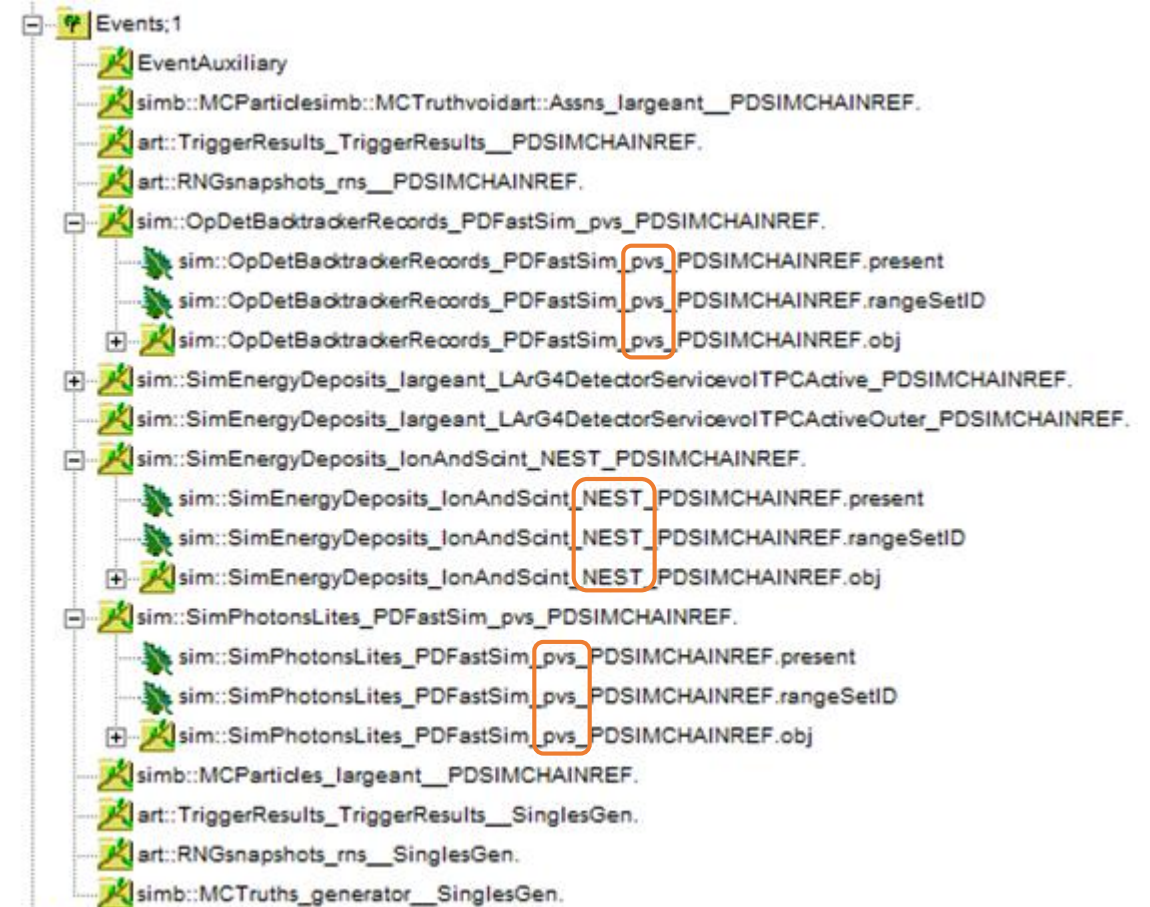
Event simulation

IS calculation

PD simulation

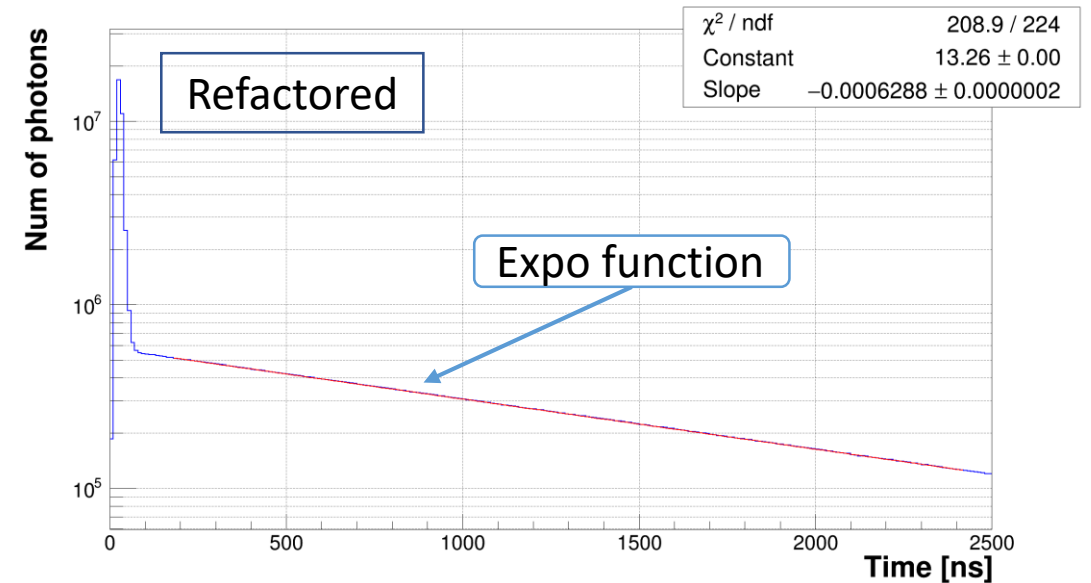
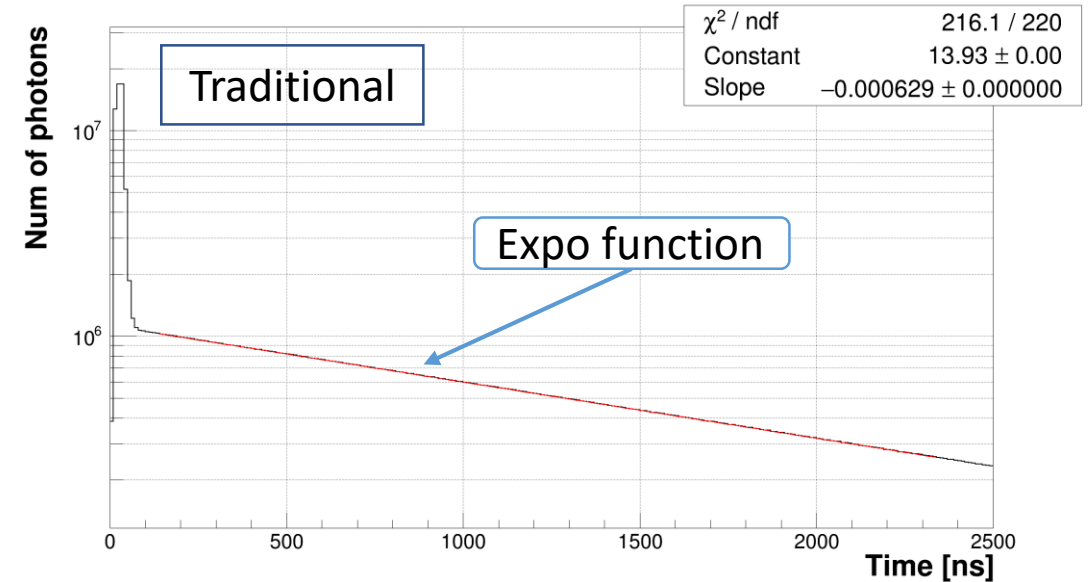
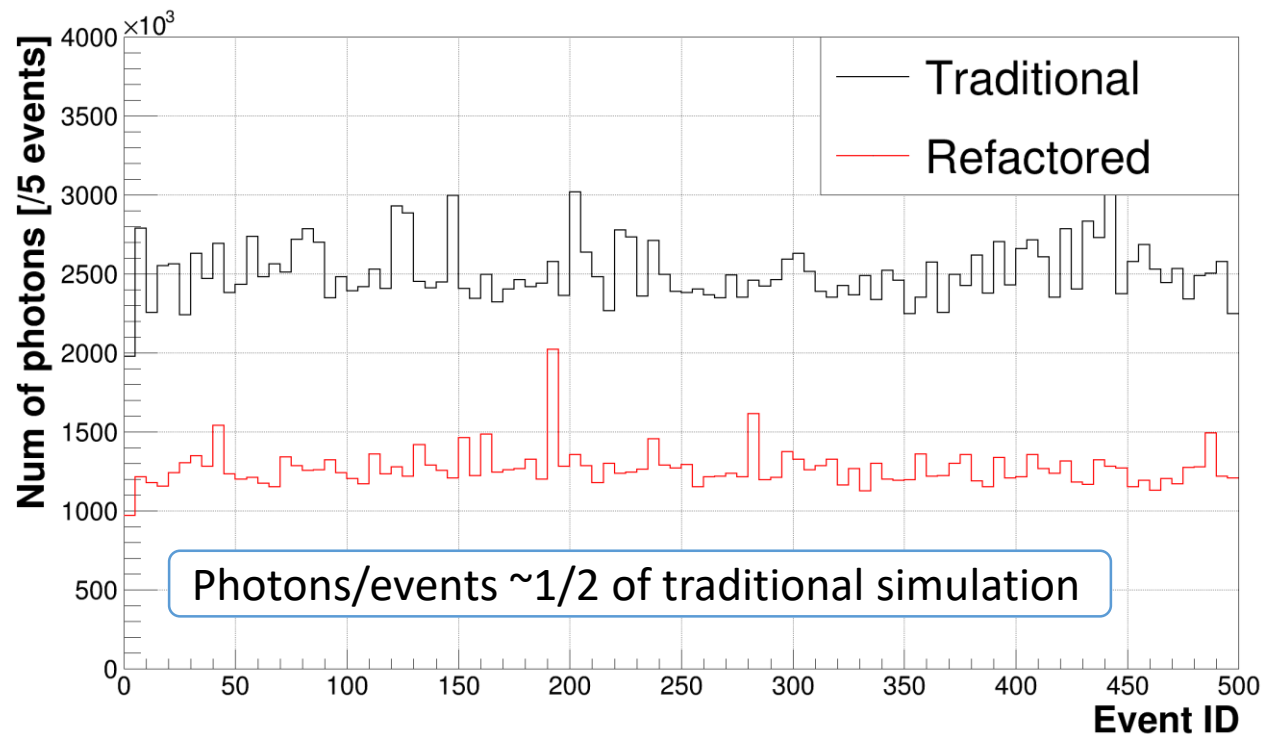
Refactored

Output from the simulation



Comparisons

To check whether or not the refactored PD simulation behaves the same as the traditional PD simulation.



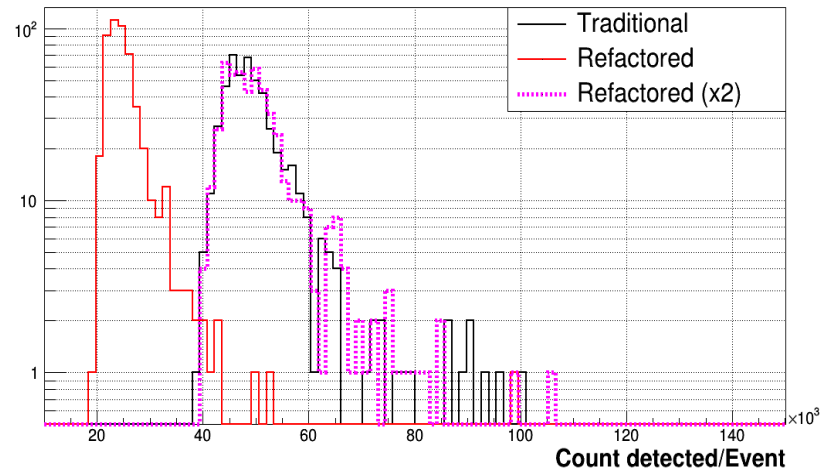
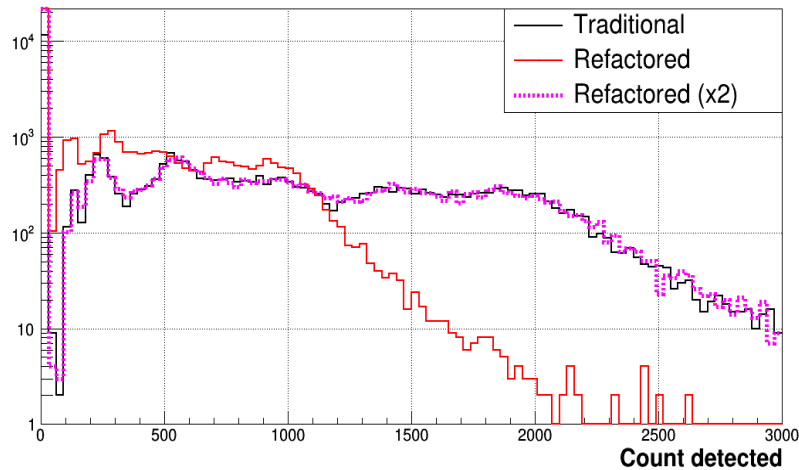
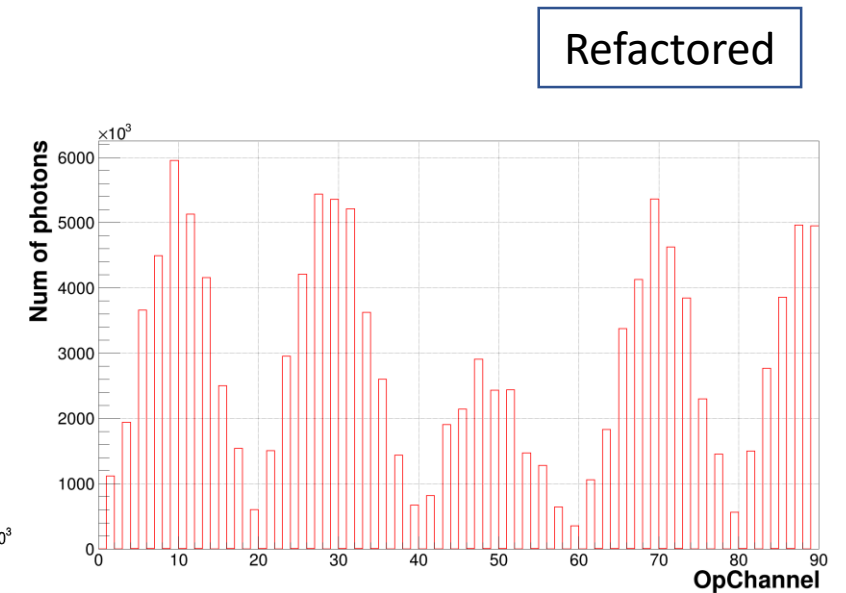
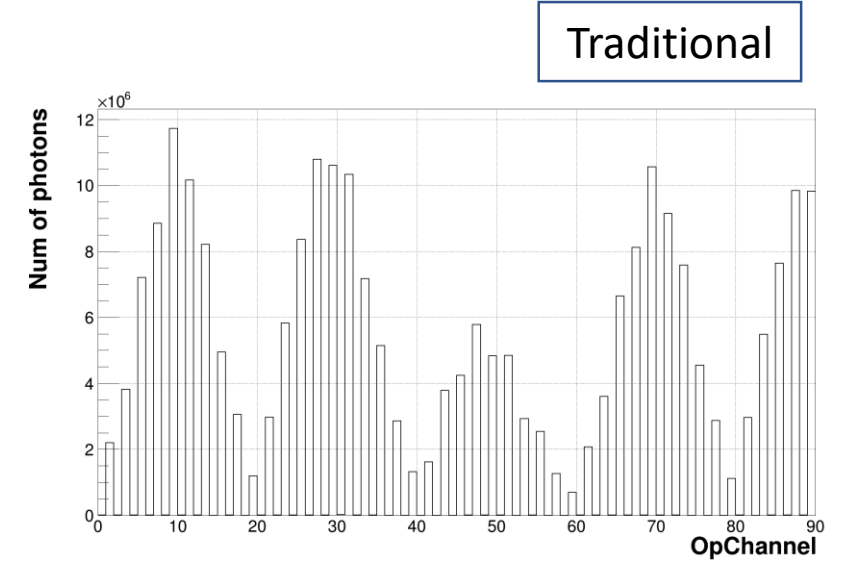
Comparisons

Different

☐ Num of photons/channel ← *different IS calc algorithm*

Identical

☐ Hit Pattern ← *same photon visibility service*



Conclusion

- The basic functions of refactored PD simulation are ready;
- The framework for ion/scint calculation algorithm based on customized scintillation and ionization process is setup, more features can be introduced based on the experiment;
- The performance of the new LArG4 module need to be improved, specially to find the optimal step limit.

Performance

Traditional

TimeTracker printout (sec)	Min	Avg	Max	Median	RMS	nEvts
Full event	1.11353	1.42688	7.40342	1.35197	0.351473	500
source:RootInput(read)	0.000160229	0.000222149	0.00199898	0.000188864	0.000177647	500
simulate:rns:RandomNumberSaver	2.97E-05	4.27E-05	0.000255171	3.95E-05	1.24E-05	500
simulate:largeant:LArG4	0.960195	1.24694	7.22227	1.17688	0.334198	500
[art]:TriggerResults:TriggerResultInserter	1.55E-05	1.99E-05	8.99E-05	1.81E-05	7.08E-06	500
end_path:out1:RootOutput	4.02E-06	5.36E-06	3.25E-05	4.85E-06	2.00E-06	500
end_path:SimPh:SimPhotonCounter	0.0125384	0.0155078	0.0349295	0.0149767	0.00222159	500
end_path:out1:RootOutput(write)	0.129282	0.163927	0.311172	0.155701	0.027348	500

Refactored

TimeTracker printout (sec)	Min	Avg	Max	Median	RMS	nEvts
Full event	19.9151	23.5643	64.7467	22.654	3.41722	500
source:RootInput(read)	0.000353222	0.00103867	0.0117735	0.000931529	0.00072863	500
simulate:rns:RandomNumberSaver	3.34E-05	4.40E-05	0.000596761	3.90E-05	3.78E-05	500
simulate:largeant:larg4Main	4.99001	5.95891	12.2898	5.82788	0.601505	500
simulate:IonAndScint:IonAndScint	1.15368	1.4506	4.17135	1.38401	0.237032	500
simulate:PDFastSimPVS:PDFastSimPVS	5.22251	6.33678	18.8219	6.08039	1.00276	500
[art]:TriggerResults:TriggerResultInserter	1.72E-05	2.46E-05	0.000617209	2.05E-05	3.76E-05	500
end_path:out1:RootOutput	4.00E-06	5.64E-06	2.80E-05	5.13E-06	2.01E-06	500
end_path:ISCalcAna:ISCalcAna	2.00605	2.86237	7.88696	2.66712	0.532126	500
end_path:SimPh:SimPhotonCounter	0.109091	0.160912	0.5473	0.148256	0.0380358	500
end_path:out1:RootOutput(write)	5.51305	6.79283	21.028	6.45885	1.22719	500