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Title: DRiFT: An MCNP Post-Processing Tool for High-Fidelity Modeling of Gas-Filled Detectors

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DRiFT: An MCNP Post-Processing Tool for High-Fidelity Modeling of Gas-Filled Detectors

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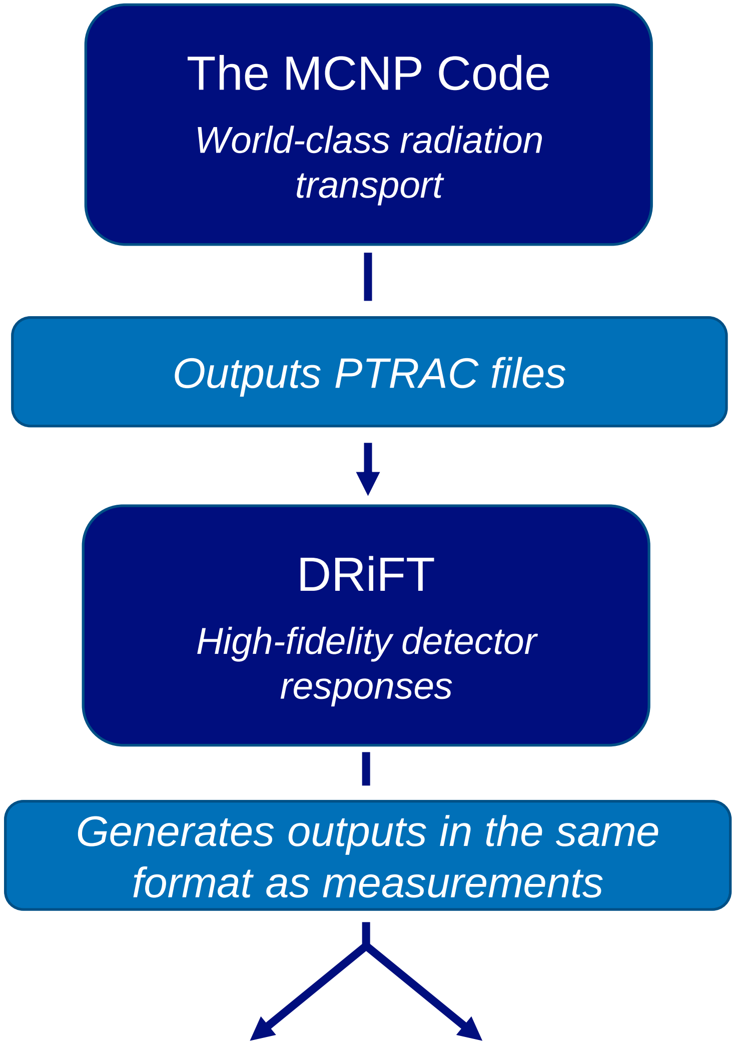
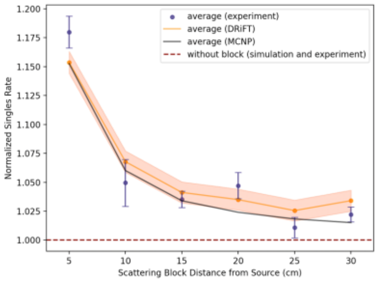
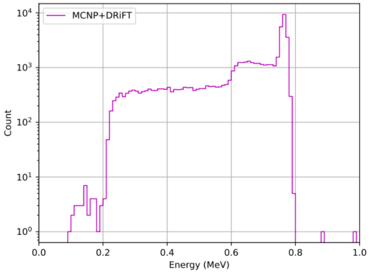
Background and Overview

- DRiFT, a Detector Response Function Toolkit, post-processes MCNP output to model detector response [1]
- Capability to model scintillator detectors has previously been demonstrated [2,3,4]
- Ability to model realistic nuclear instrumentation response for He-3 and other gas-filled neutron detectors has been developed and benchmarked
- Gas-filled neutron detectors are heavily used in nuclear safeguards, and a focus of this release has been to expand software usability by practitioner end-users



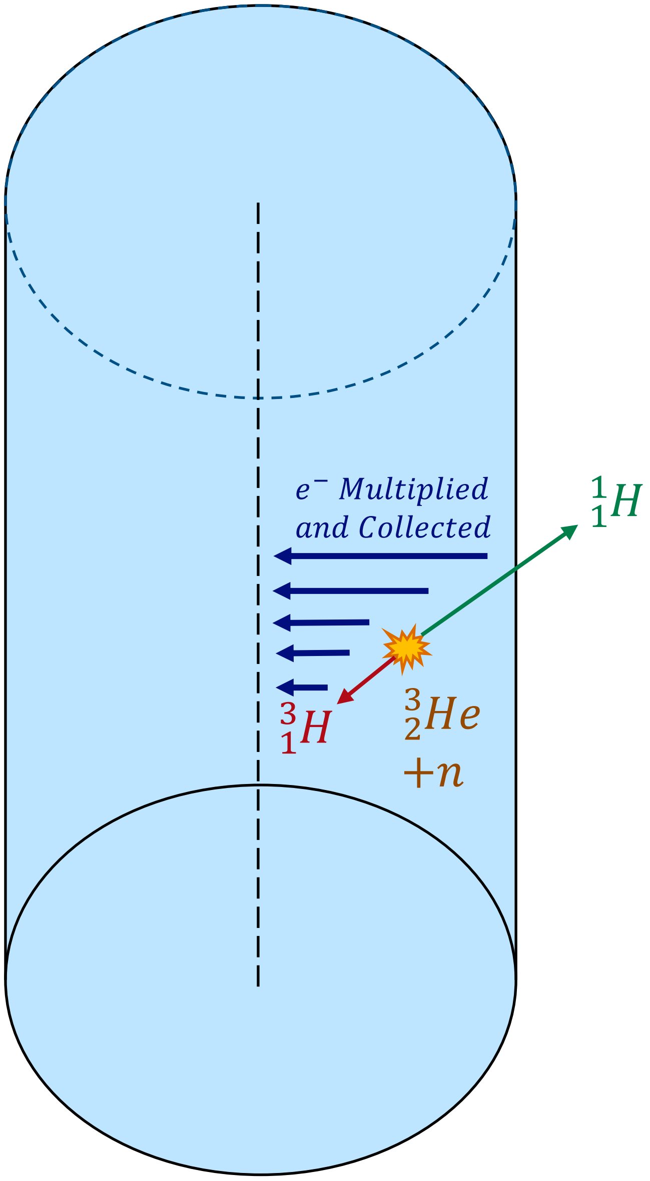




Gas-Filled Detectors

- Widely used in neutron detection due to their high reliability, high sensitivity to thermal neutrons, and relative insensitivity to gamma rays
- Converts thermal neutrons into charged particles via capture on He-3 (or B-10 for BF_3 detectors)
- Electrons generated by the charged particles are multiplied in the gas and collected to give an electronic signal
- Potential Effects:
  - Inactive end-tube effects
  - Wall effects
  - Downstream electronic effects
  - Spurious afterpulsing

He-3 Tube (Pictorial Representation)



Motivation for DRiFT Gas-Filled Detector Modeling

MCNP

- Excellent radiation transport capabilities
- Simulates neutron transport to, and interaction in, a gas-filled detector
- Can model some detector effects, such as the effects of pressure on detection efficiency and wall effects

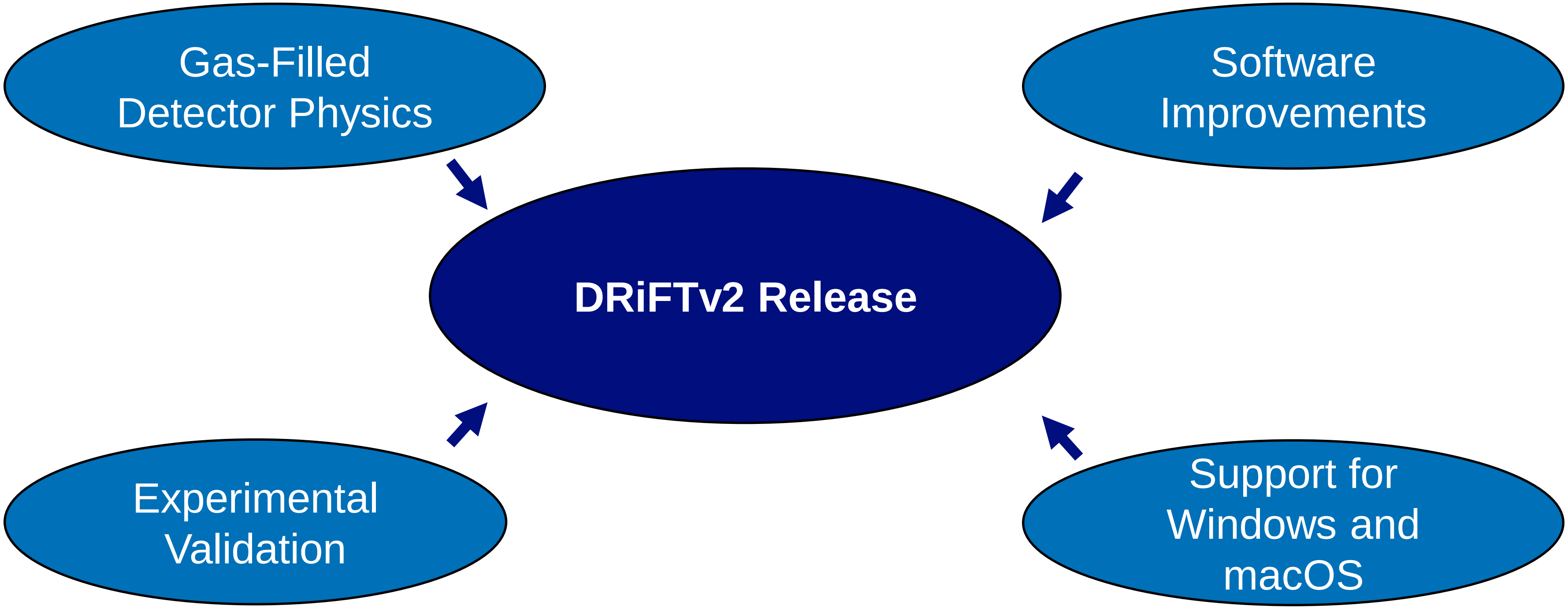
but

- Has limited capability to model other, more nuanced effects on gas-tube response

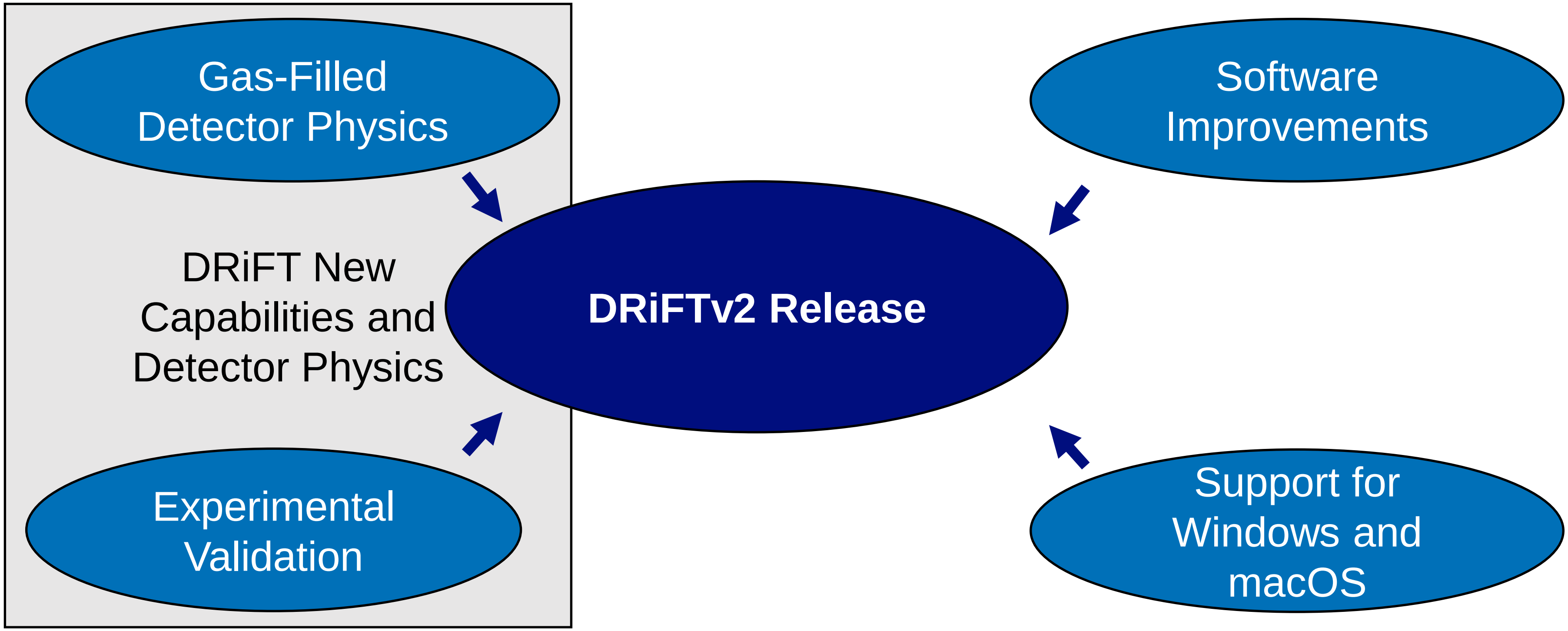
DRiFT

- Models the effects of detector geometry, pressure, and temperature on electron generation in the gas and collection at the anode
- Models charge collection in inactive end-tube regions
- Can model afterpulsing on request
- Converts collected charge into a pulse via a simulated charge-integrating preamp
- Models electronic effects like dead time and pileup

DRiFTv2 Release Summary



DRiFTv2 Release Summary



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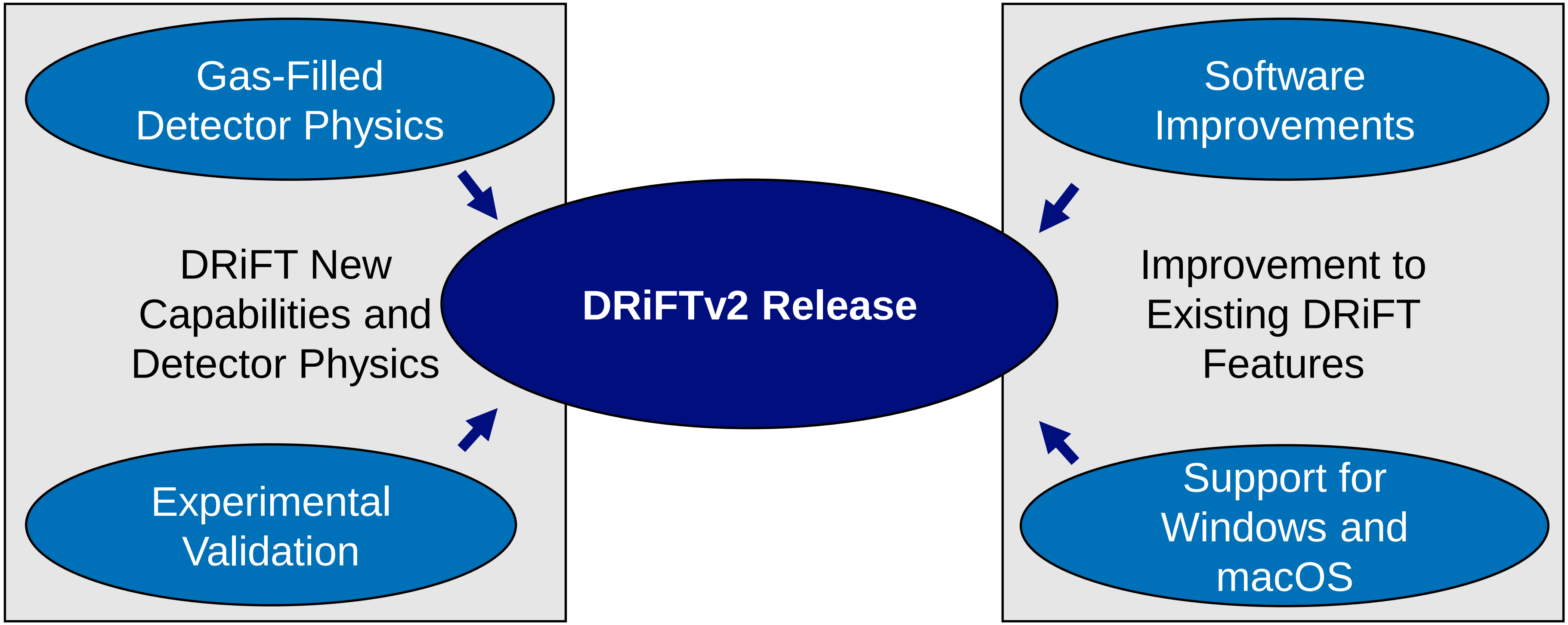
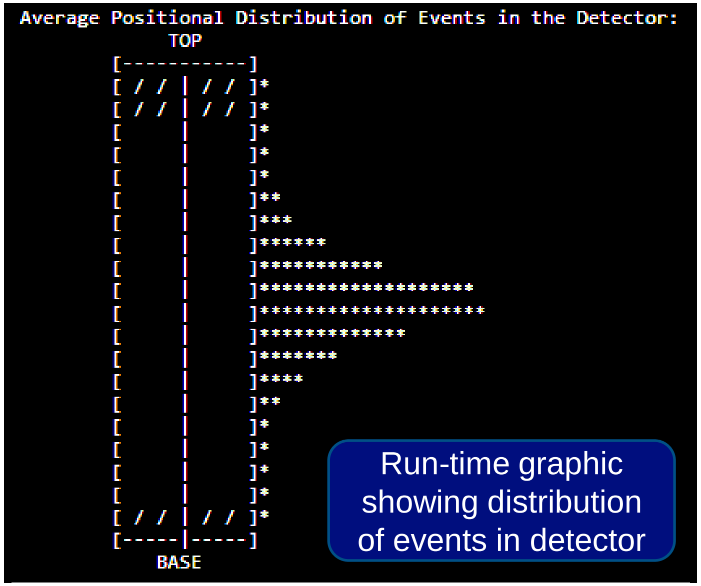
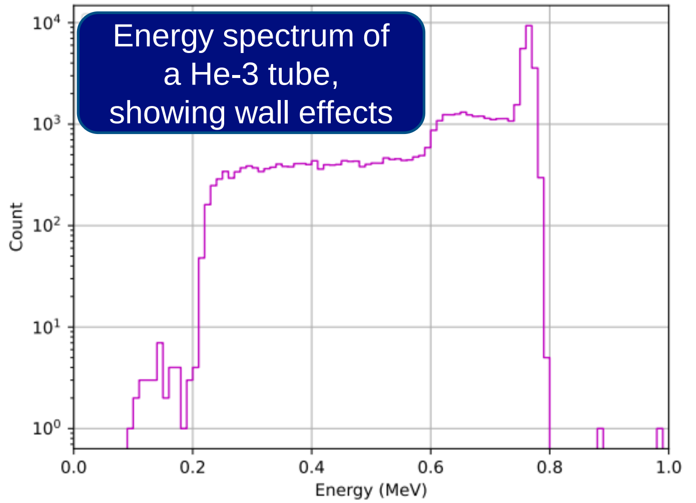


Gas-Filled Detector Physics

- Gas-filled detector responses and the response of a charge-integrating preamplifier are now modeled in DRiFT
- Uses data generated by SRIM and Garfield++ to calculate electric fields and ionization [5,6]
- Two detector fill gases and two quench gases are available to mix and match at any concentration from 95% to 100% fill gas
- Continuous voltage support between 1000 and 1900 V, continuous temperature support between 253 and 293 K, and continuous pressure support between 1 and 10 atm
- Both cylindrical and spherical detector geometries are supported at any arbitrary size

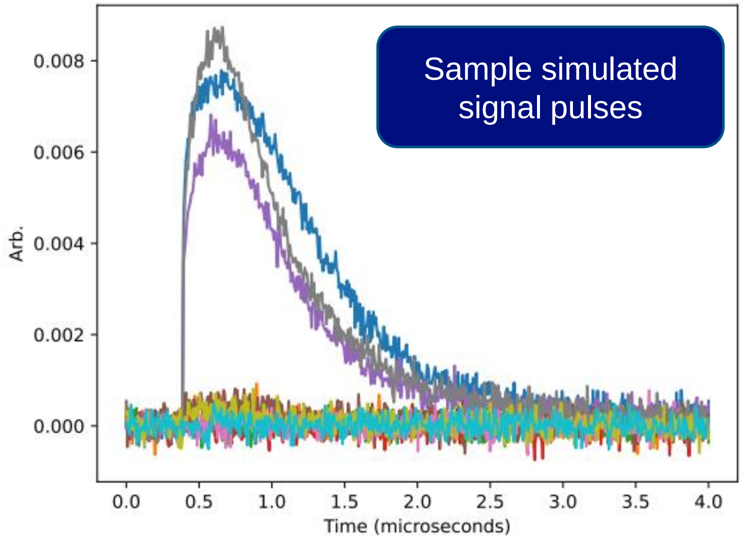




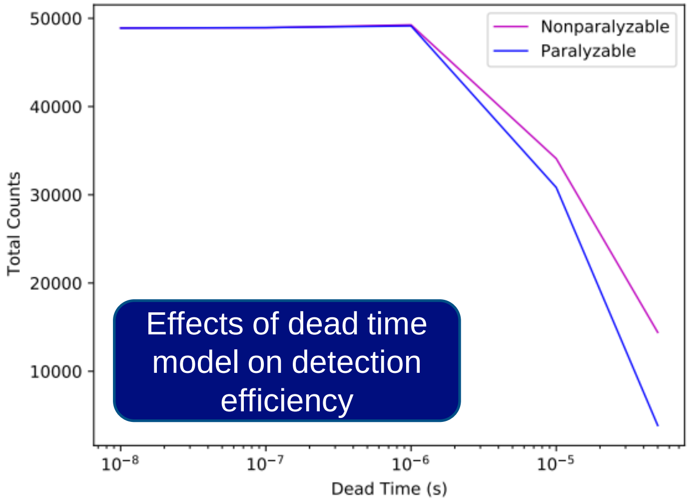
Gas-Filled Detector Physics

- Ability to perform automatic Rossi-Alpha calculation is included
- Individual simulated signal pulses from detector events are generated and can be output by DRiFT
- Pulse pileup, dead time, inactive end-tube regions, and spurious after-pulsing are all modeled

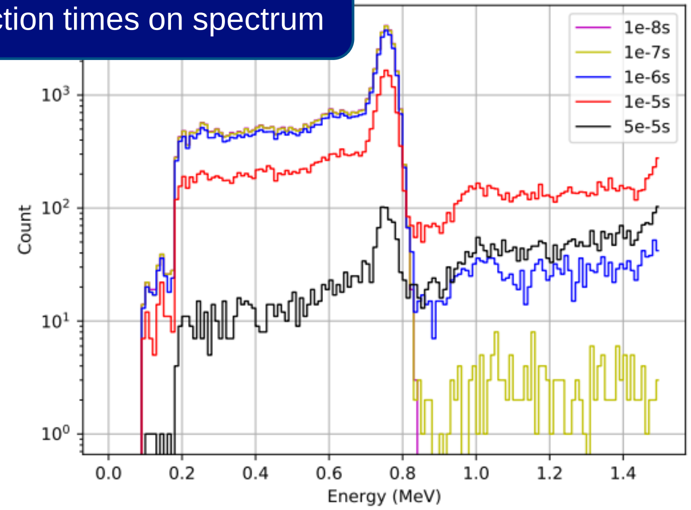
Sample simulated signal pulses



Effects of dead time model on detection efficiency



Effects of different pre-amp collection times on spectrum



Usage

- Three new modules added to support gas detector functionality

```
[global]
modeltype=event
datasource=mcnp
datafile=omcnp_p.h5
ptrac_type=hdf5
det_cells=4 7 10 ... <Omitted for brevity>

[SourceInformation]
call=SourceInformation
multi_src=no
source_particles_list=1

[TimeDistribution]
call=TimeDistribution
activity=1e3

[Gas]
call=Gas
gas1=He3
gas2=CO2
voltage=1900
comp1=98
comp2=2
tube_base_x= 12.302 ... <Omitted for brevity>
tube_base_y= 0      ... <Omitted for brevity>
tube_base_z=-38.02  ... <Omitted for brevity>
temperature=293
pressure=10
tube_length=79.85
tube_radius=1.190
inactive_area=yes
inactive_bottom=2.46
inactive_top=6.27

[Gas_Preamp]
call=Gas_Preamp
pileup=yes
shaping_time_constant = 1e-7
dead_time_enabled=no
dead_time = 1e-8
paralyzable = no
LLD_units = pC
LLD = 0.05

[SafeguardsCalculator]
call=SafeguardsCalculator
rossi_alpha=yes
rossi_alpha_time_window= 1e-4
rossi_alpha_bin_size= 1e-6

[WriteOutput]
call=WriteOutput
output=output_30.txt
outputs=count source_e det_e det_c det_cell corr_count reals accidentals time pileup cells_history
```

Usage

- Three new modules added to support gas detector functionality
- The Gas module simulates detector physics, include charge generation and collection in the tube

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Usage

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- The Gas module simulates detector physics, include charge generation and collection in the tube
- The Gas_Preamp module models electronic effects, like pileup, deadtime, and a lower-level discriminator

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Usage

- Three new modules added to support gas detector functionality
- The Gas module simulates detector physics, include charge generation and collection in the tube
- The Gas_Preamp module models electronic effects, like pileup, deadtime, and a lower-level discriminator
- The SafeguardsCalculator module performs Rossi-Alpha and coincidence calculations

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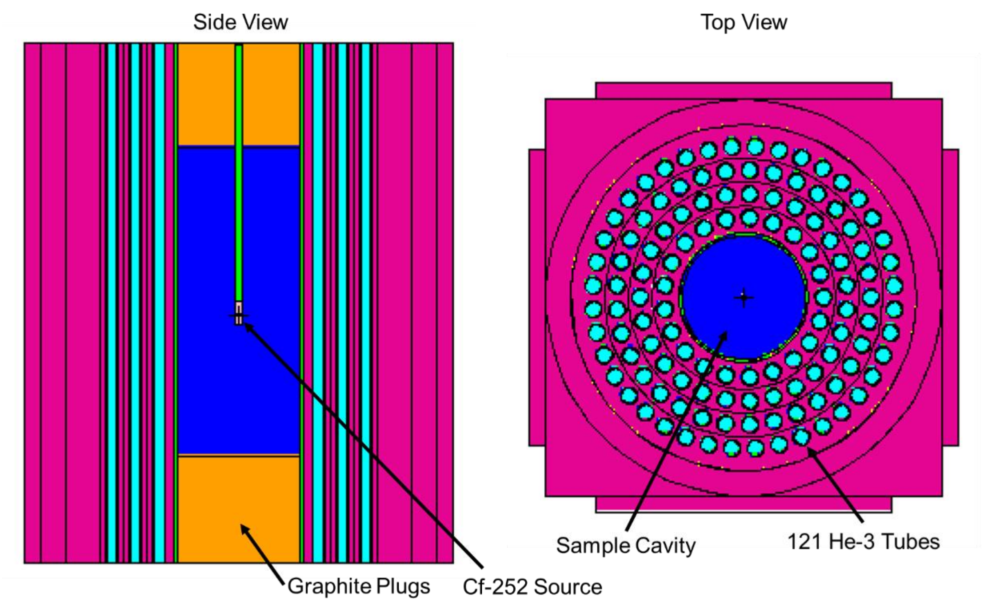
```

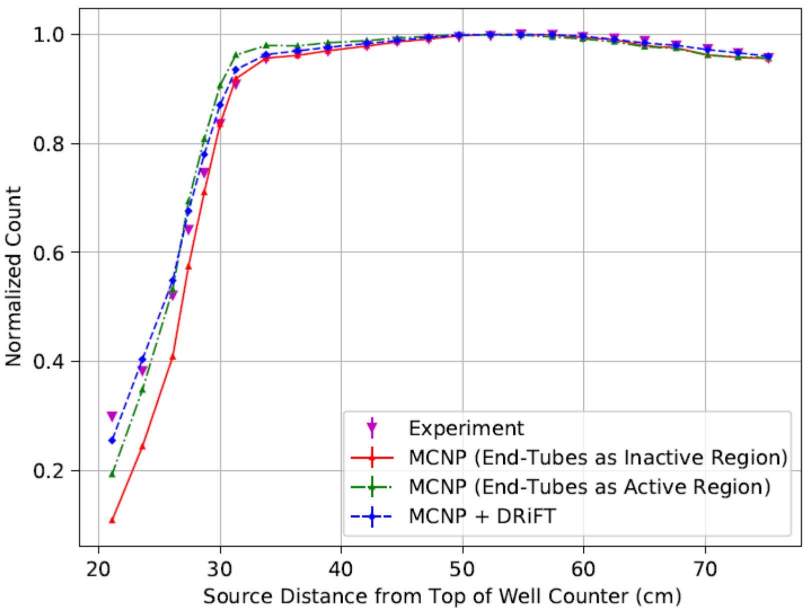
Documentation Updated with New Features

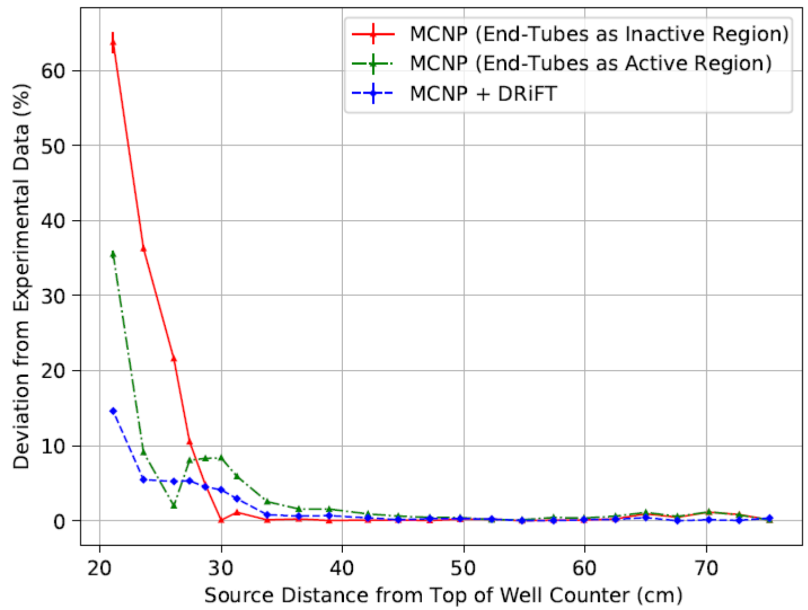
- Users are referred to the new section of the manual (released alongside the DRiFT executable) for a more complete description of the new modules, along with a list of all parameters [7]

Experimental Validation

- DRiFT results validated against experimental measurements using the Epithermal Neutron Multiplicity Counter (ENMC) [8]

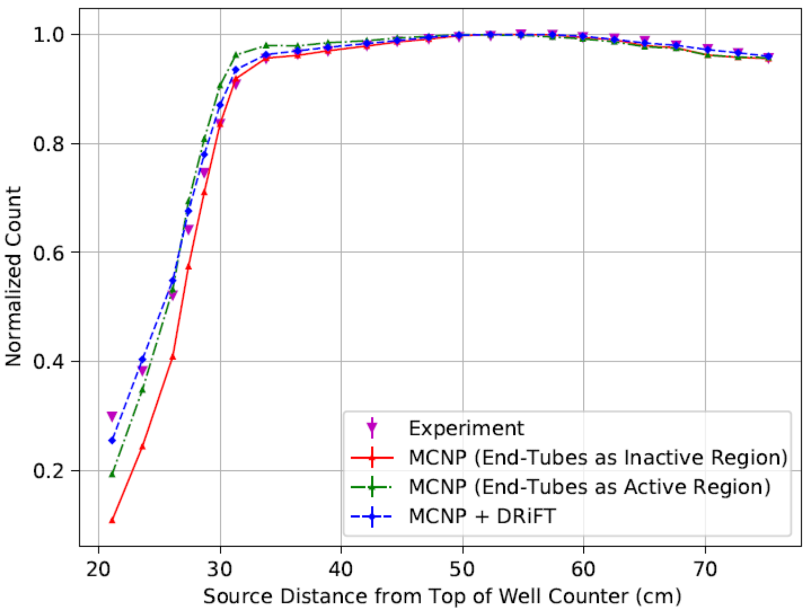


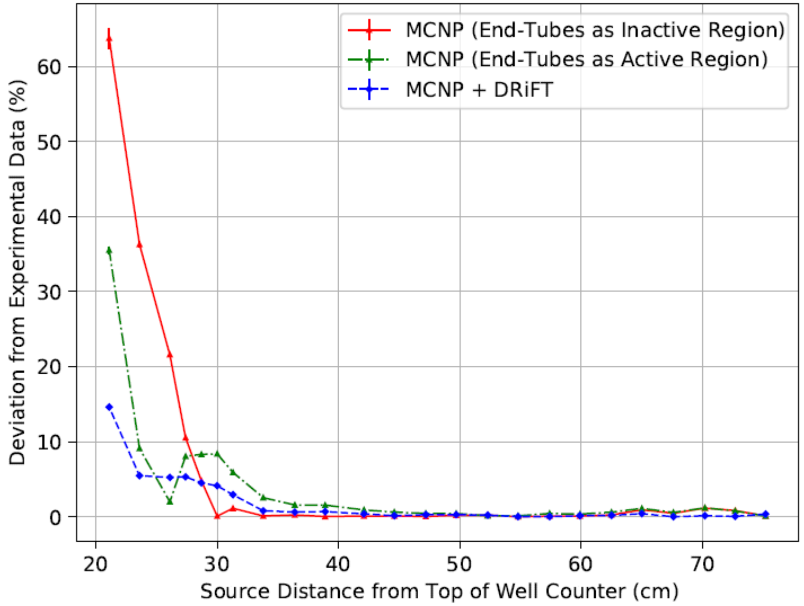




Experimental Validation

- DRiFT results validated against experimental measurements using the Epithermal Neutron Multiplicity Counter (ENMC) [8]
- DRiFT outputs compare favorably to experimental results when compared to outputs generated using the MCNP code alone
- DRiFT better matches with experimental data at the extremes of the detector, where end-tube effects have the greatest importance





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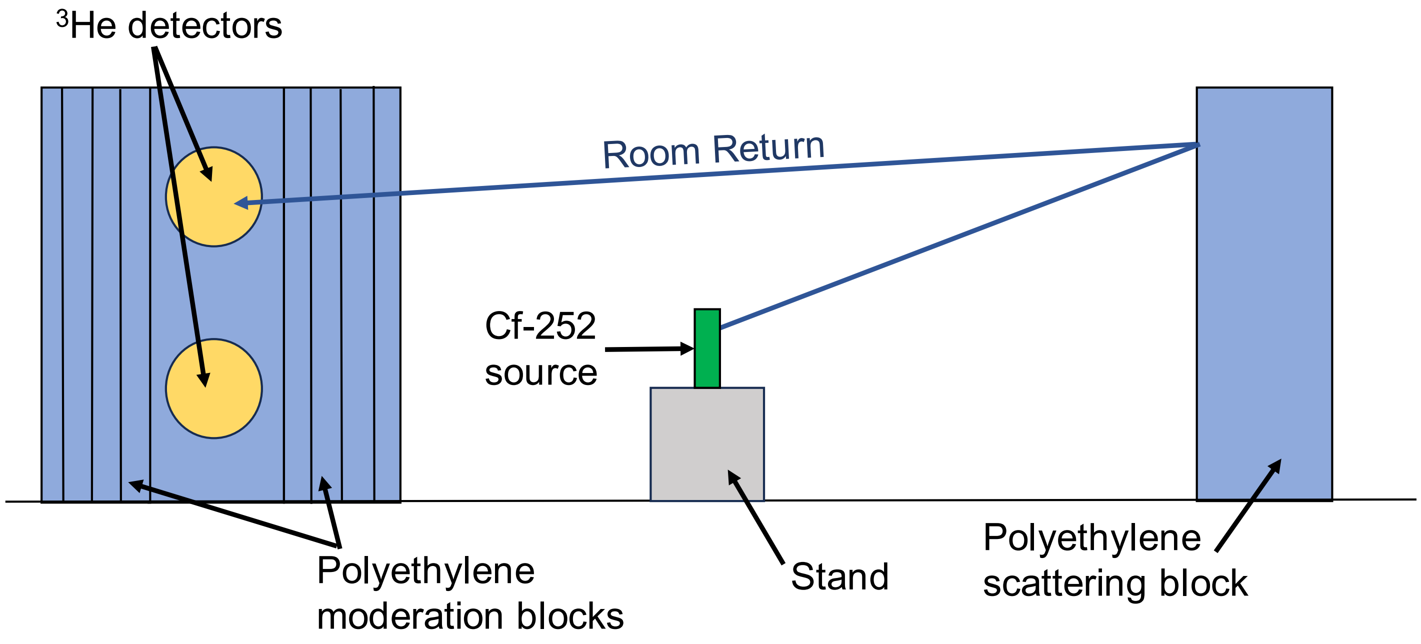
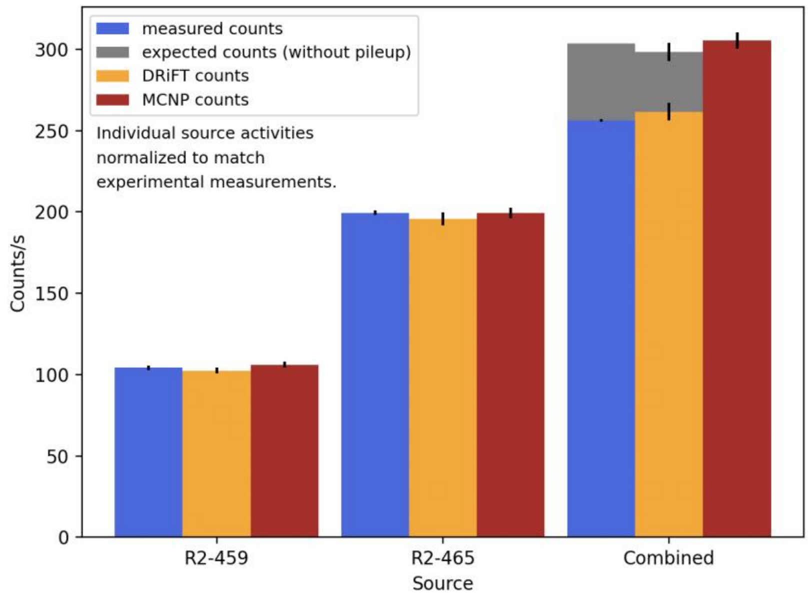
Experimental Validation

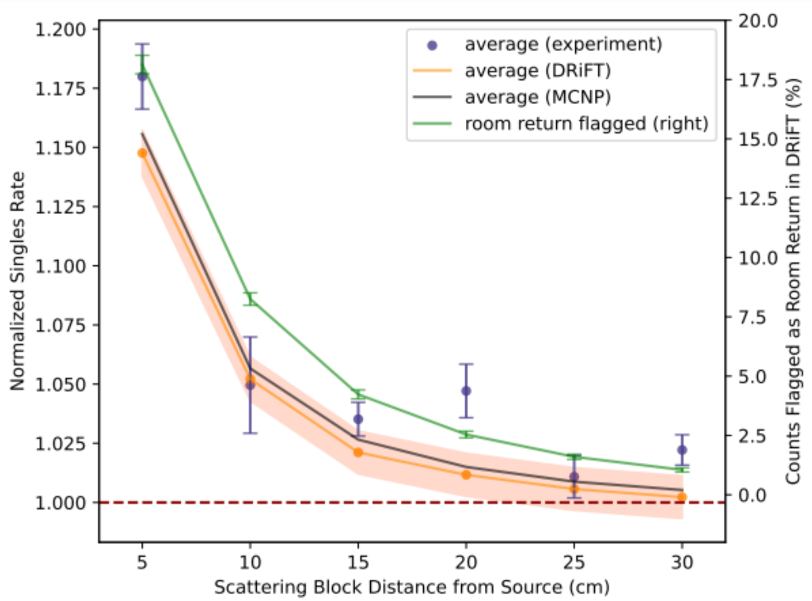
- Capability of DRiFT to model pileup was demonstrated using two Cf-252 sources on a detector system with two He-3 tubes
- One of DRiFT's diagnostic capabilities was also demonstrated by flagging room return events on the same detector system, by moving a polyethylene scattering block closer to and further away from the Cf-252 source



Experimental Validation

- DRiFT outputs are consistent with experimental results for the pileup experiment, accurately modelling the reduction in count rate
- The room-return experiment demonstrates the power of DRiFT's diagnostic capabilities; it can be seen from the plot that the increase in count rate as the scattering block is moved closer to the source is entirely due to room return events from that scattering block





Additional Software Improvements

- Improved DRiFT execution speed significantly in many cases
- Now handles HDF5 output to work with MCNP6.3 outputs
- Added compatibility with MCNP universes and lattices
- Additional diagnostic capabilities, like the ability to flag room return and reals/accidentals added

source_e (MeV)	NPS	det_pulse (MeVee)	det_cell	corr_count
2.46561	2	0.760884	1 [-1,0,0]	no
2.30261	3	0.308517	1 [-1,1,0]	no
0.443801	9	0.0429783	1 [-1,0,0]	no
1.71909	12	0.282561	1 [0,1,0]	double
1.44482	12	0.276578	1 [1,0,0]	double
3.87434	24	0.138036	1 [1,-1,0]	no
2.39633	39	0.724142	1 [-1,1,0]	double
0.847697	39	0.092614	1 [1,0,0]	double

DRiFT now distinguishes between events in different lattice elements and calculates coincidences appropriately

nps	det_cell	corr_count	reals	accidentals	time (s)
4	1	no	0	0	0.000201278
9	3	no	0	0	0.000774805
11	4	no	0	2	0.000914986
12	4	no	0	2	0.00101122
13	2	no	0	2	0.00101203
15	2	no	0	1	0.00107837
16	2	no	0	1	0.00109314
24	1	no	0	0	0.00197347
26	2	no	0	0	0.00212082
28	2	no	0	0	0.00233646
32	4	no	0	0	0.00261535
39	1	no	0	0	0.00311304
43	2	double	1	4	0.00327029
43	3	double	1	4	0.00327029
45	3	double	1	4	0.00330403
45	4	double	1	4	0.00330403
46	3	double	1	4	0.00330657
46	4	double	1	4	0.00330657
54	3	no	0	0	0.00450981
56	1	no	0	0	0.00468424
61	4	no	0	0	0.0051045
70	2	double	1	0	0.00608656
70	1	double	1	0	0.00608657
71	4	no	0	0	0.00631641
73	4	no	0	0	0.00659137

Reals and accidentals are calculated according to a user specified time window

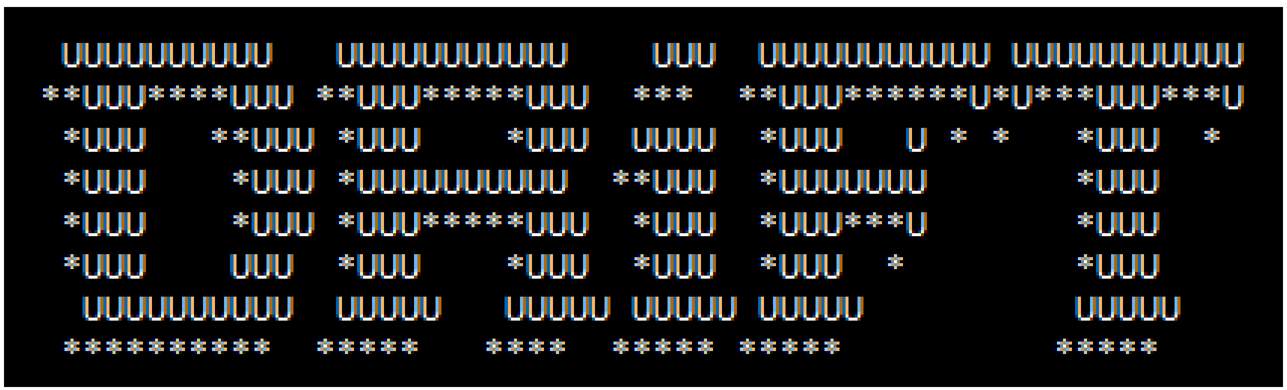
Support for Windows and macOS

- Installers for Windows, macOS, and Linux are available
- Installers require no prerequisites and only require two steps to install, meaning that the software can be installed and run with practically no system requirements in a short amount of time

Conclusions

DRiFTv2 release available now!

- Contact austin_mullen@lanl.gov or madison@lanl.gov if you are interested in receiving a copy
- Future work: Continued refinement of gas-filled detector capabilities, introduction of semiconductor detector capabilities [9]



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