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Title: DRiFT - Detector Response Function Toolkit

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DRiFT – Detector Response Function Toolkit

Organic Scintillator and Gas Detector Capability Overview

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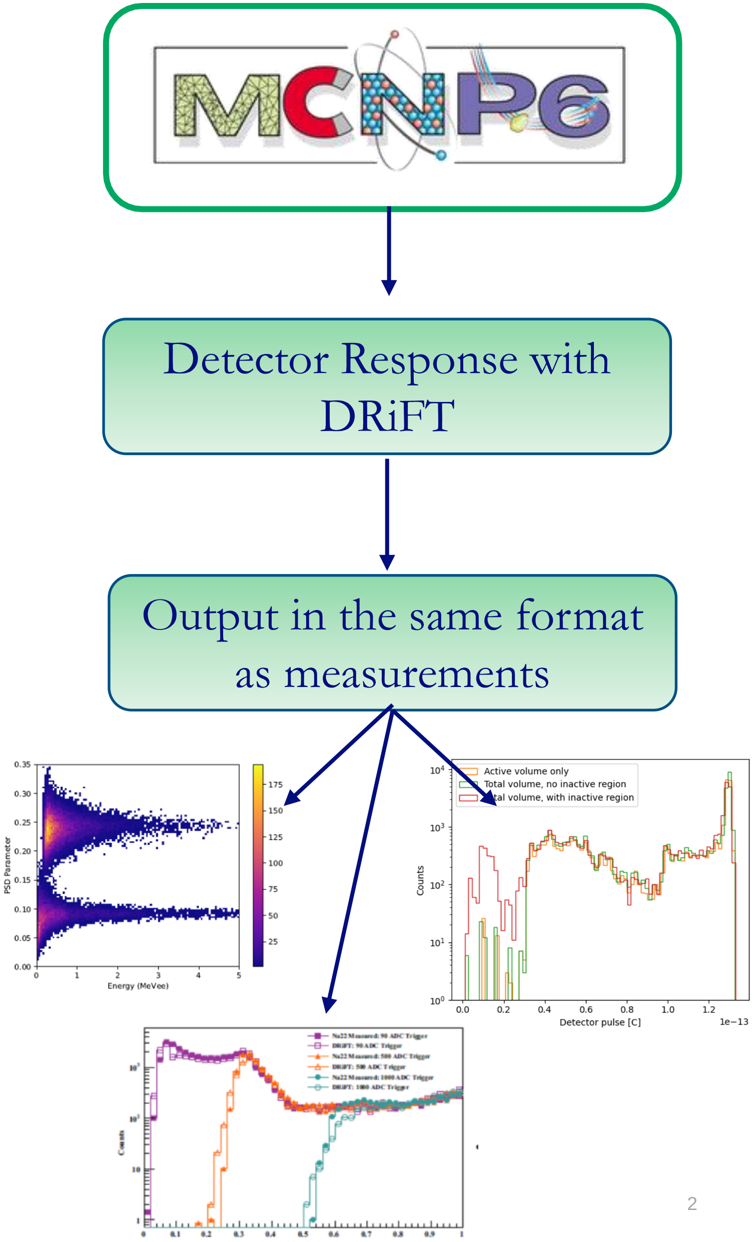
DRiFT – A Brief Overview

- DRiFT post-processes MCNP output and ***simulates realistic nuclear instrumentation response***.
  - DRiFT can be used to assess the performance of instrumentation (and their settings) under a wide variety of deployment scenarios.
  - Dead-time, pile-up, and damage in simulations can determine when a detection system is unreliable.
- ***Modular*** – easily accommodates new instrumentation and physics models
- **Easy to use** – simple keyword input and one line execution, flexible ASCII write-out that can be post-processed.
- **Capabilities:** Organic Scintillators and Gas Detectors (primarily He-3).



Part I: DRiFT Overview

- In this talk, features will not be described in detail, rather highlighted so you can get a feel for DRiFT capabilities.

- Split into four short sections: Overview, Scintillators, Gas Detectors, and Other Features.

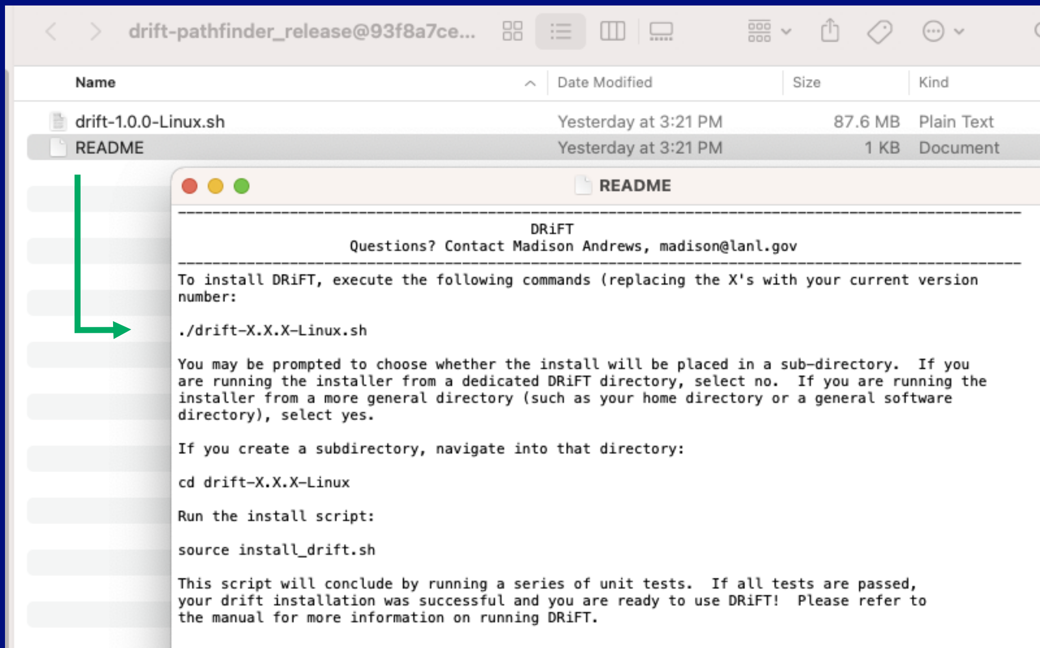
DRiFT Use and Input

- Required: MCNP output (PTRAC)
- Distribution
  - Executable for scintillators (new!)
  - HPC build for gas detectors
- Input file
  - Simple keywords for each module
- Output
  - Text file output
  - ROOT trees

```
[global]
modeltype=event
datasource=mcnp
ptrac_type=bin
#Name of the PTRAC file you want to process
datafile=omcnp_p
#datafile is the file name of the mcnp ptrac output
det_cells=1

[SourceInformation]
call=SourceInformation
multi_src=yes

[Scintillation]
call=Scintillation
detector=EJ301
optical_transport=0.6
pmt_type=9821B
voltage=1500
divider_option=B

[Digitizer]
call=Digitizer
voltage_range =2.0
digitizer_samples=256
resolution=16384
ter_res = 50
DC_offset = 0.1
start_point = 0.1
digitizer_rate=500.e6
```

source_e (MeV)	NPS	det_pulse (MeVee)	det_cell	corr_count	time (s)	PSD	cells_history	
1.63259	71	0.133547	1	no	7.39562e-09	0.212628	2	1
1.814	354	0.255438	1	no	3.94077e-09	0.216505	2	1
3.29549	640	0.484216	1	no	3.26886e-09	0.234059	2	1
1.66616	763	0.105647	1	no	4.30608e-09	0.169014	2	1
0.879835	774	0.0920073	1	no	9.41205e-09	0.218329	2	1
2.02652	1001	0.440321	1	no	4.41343e-09	0.255421	2	1
2.76593	1016	0.606231	1	no	3.3331e-09	0.234813	2	1

Release – Creating a DRiFT Installer



- A DRiFT executable installer is now available to approved requesters.
- It contains the installer (drift-1.0.0-Linux.sh) and a README file with simple installation instructions for the user.

- In order to generate a Linux executable:
  - DRiFT dependencies on LANL's HPC cluster, ROOT, Garfield++ and MCNPTools builds were removed.
  - CPACK was used to generate a STGZ self-extracting installer
  - Remaining dependencies (HDF5 and GCC libraries) were statically linked
- The release contains 7 test suites / examples in addition to 3 unit tests.
  - The unit tests are automatically executed at the end of the install process, and compare the output of various internal DRiFT functions against archived values.

Documentation – Manual

DRiFT - RELEASE 1.0.0
ORGANIC SCINTILLATORS

DRiFT CONTRIBUTORS:

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MATTHEW MARCATH[1], AND AVNEET SOOD[1]

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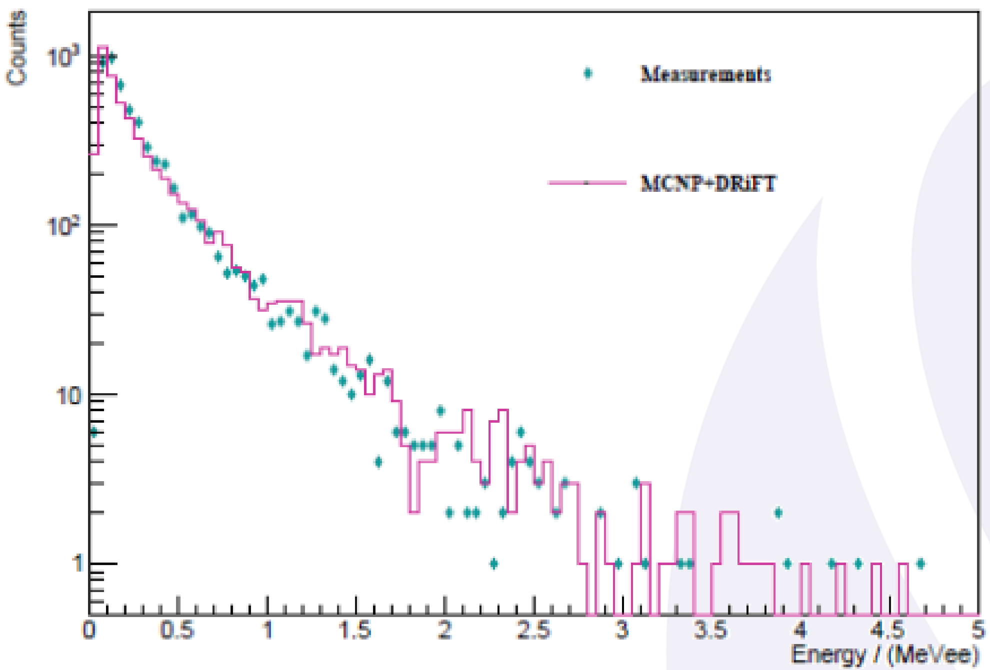
- Detailed 65 page manual was created with TED funds to accompany the DRiFT executable.

- The manual contains 12 chapters split into 4 parts:
  - DRiFT Overview
  - Detector Physics – Scintillators
  - Additional DRiFT Features
  - Test Suites and Examples

- DRiFT executable and manual have undergone some external (to XCP-7) testing.

Generating Test Suites, Examples, and Unit Tests



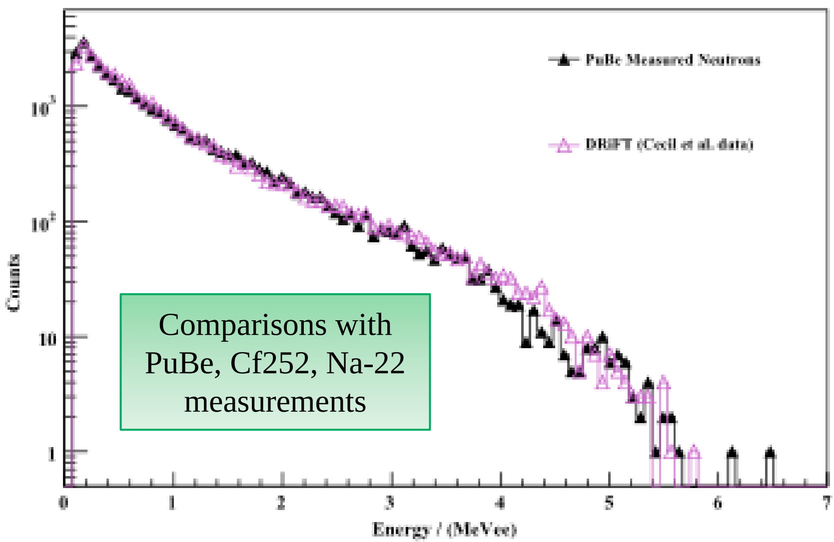
- DRiFT executable contains 7 test suites and examples.
- **Nuclear safeguards relevant examples** include: correlated fission measurements, pile-up, cross talk, source activities, and comparisons of DRiFT with measurements (shown on left)

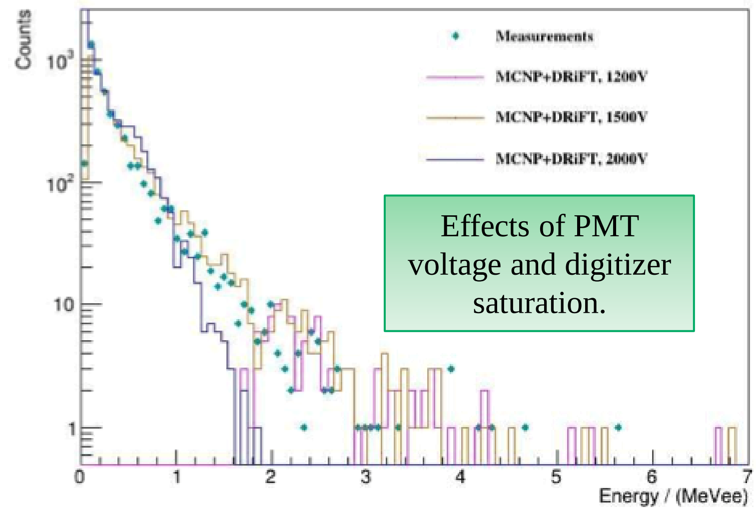
- **Unit tests were developed to test code functionality** upon installation.
- The 3 unit tests are automatically executed at the end of the installation process, and compare the output of various internal DRiFT functions against archived "truth" values generated using pre-determined inputs.

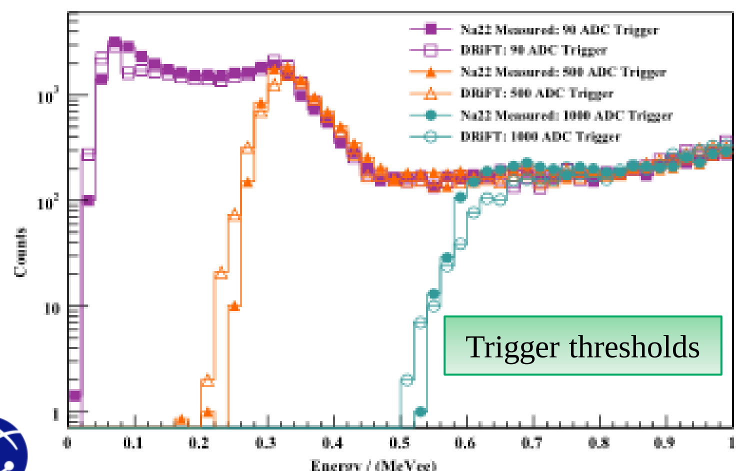
Part II: Organic Scintillators

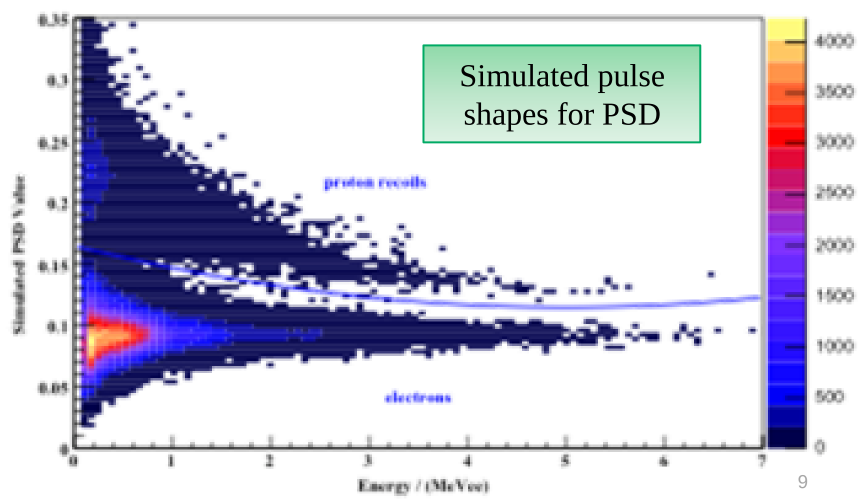
Organic Scintillators in DRiFT

- There are two large components to organic scintillator simulations in DRiFT: scintillator (and PMT) response, and digitizer effects (i.e. the conversion of electrons to a digitized signal).









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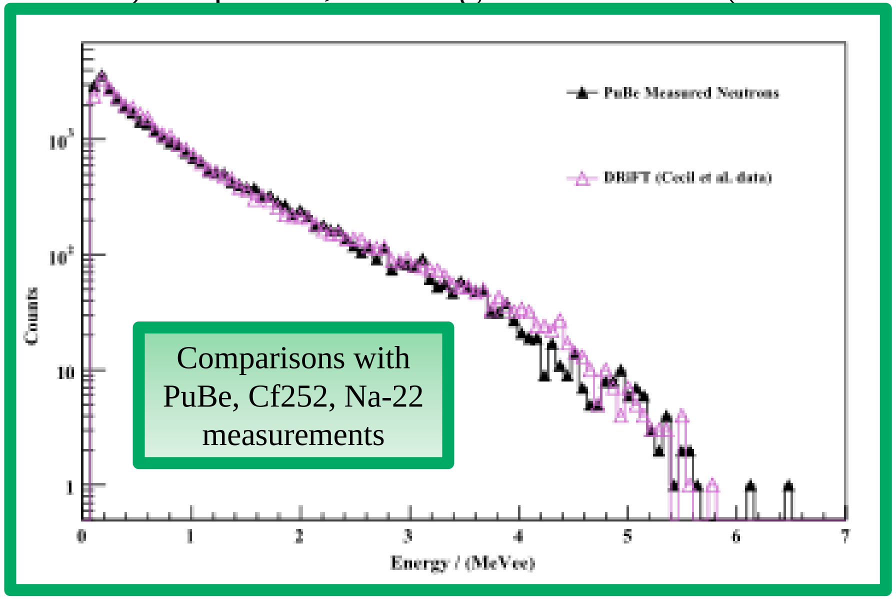

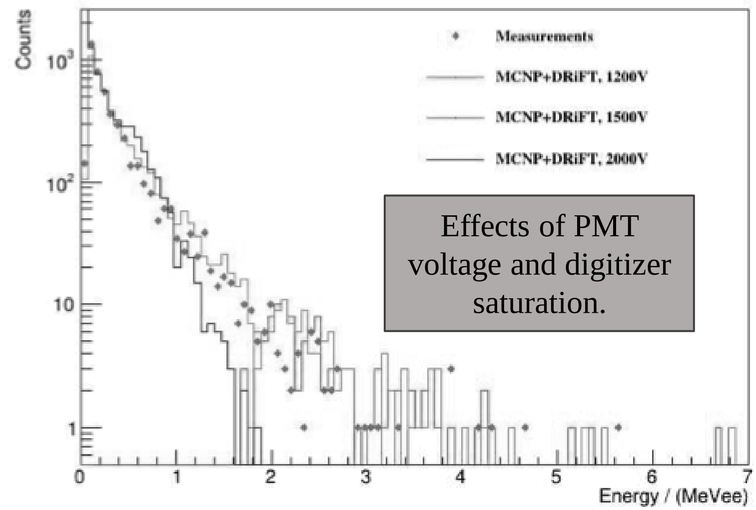

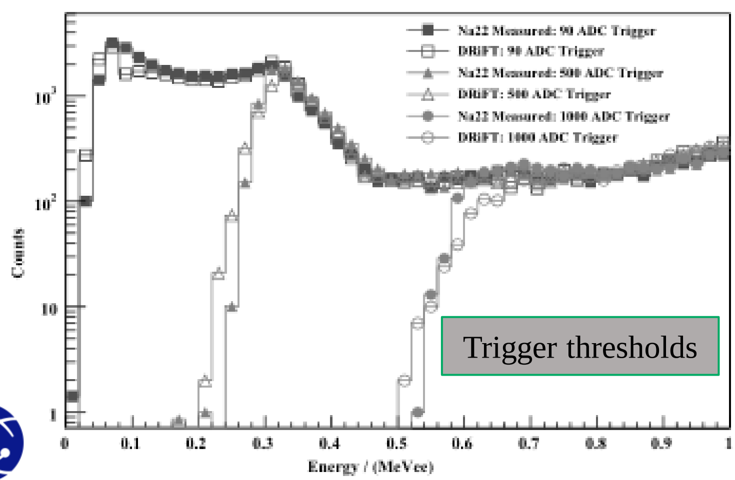

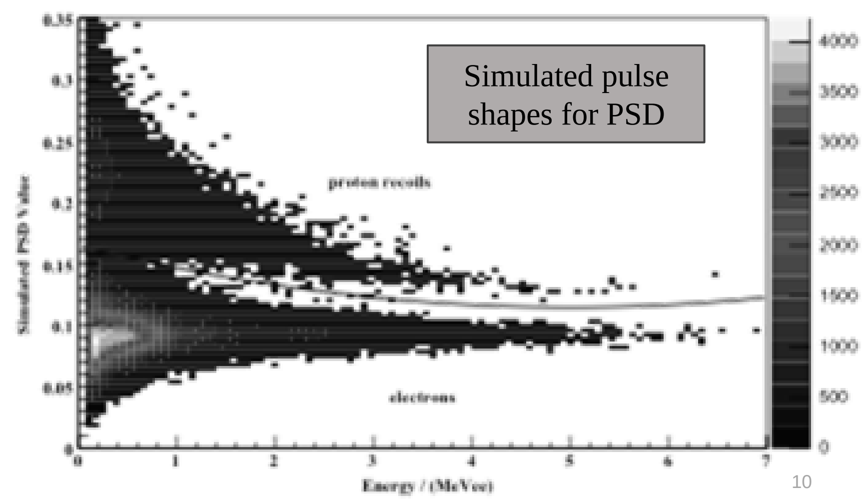

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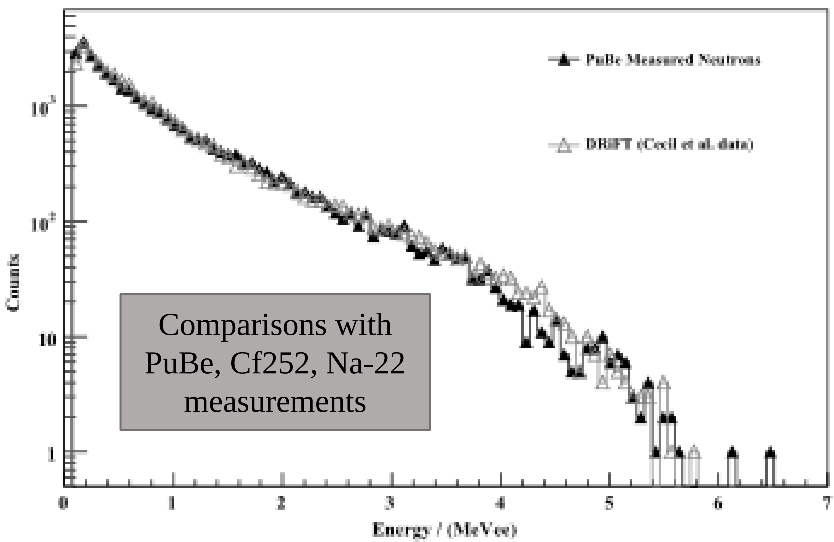

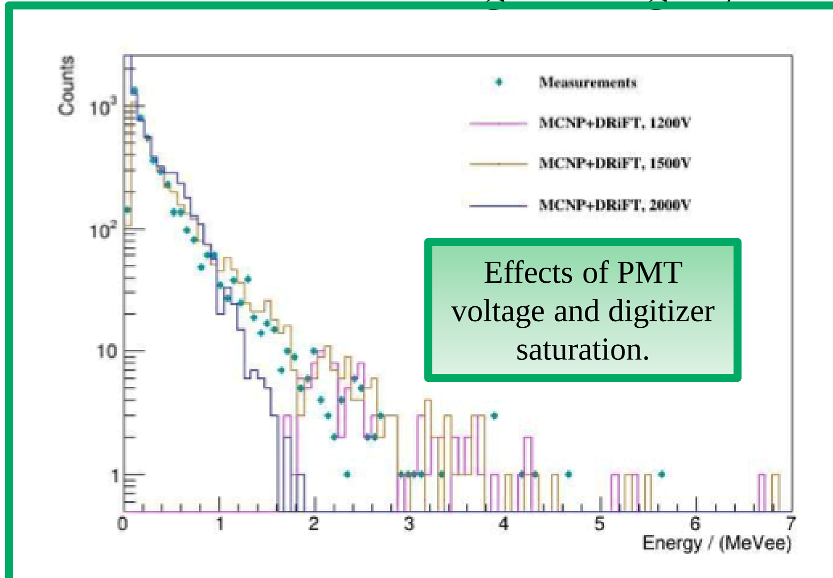

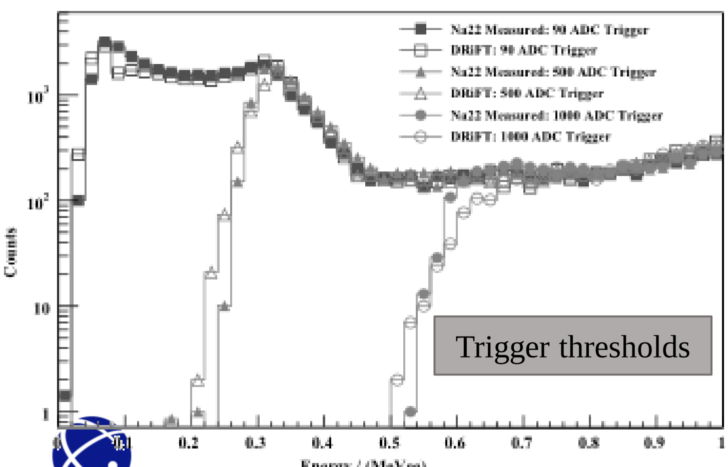

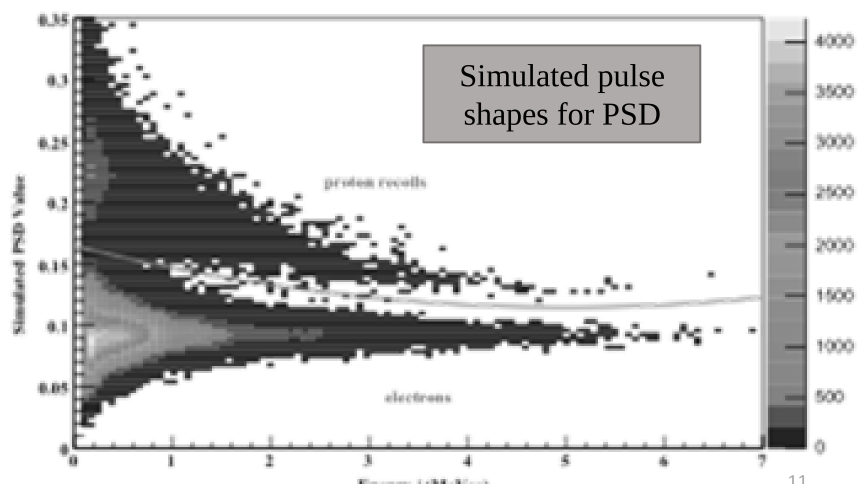

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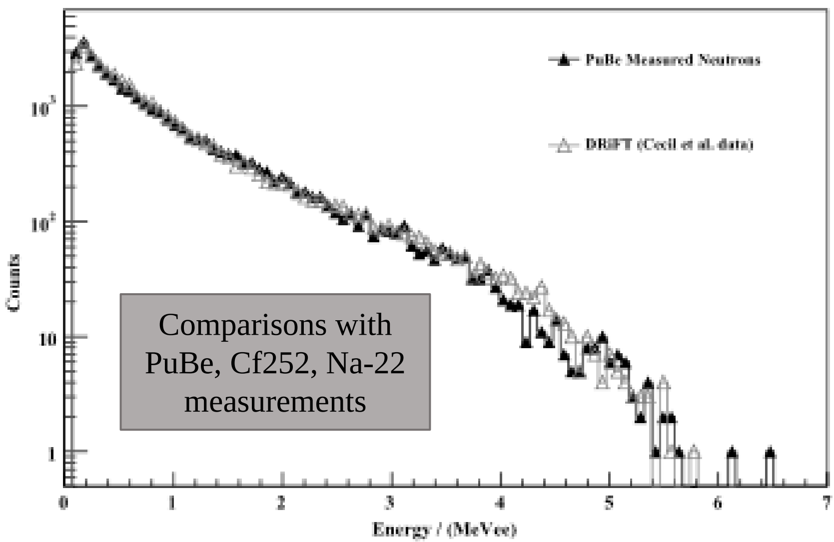

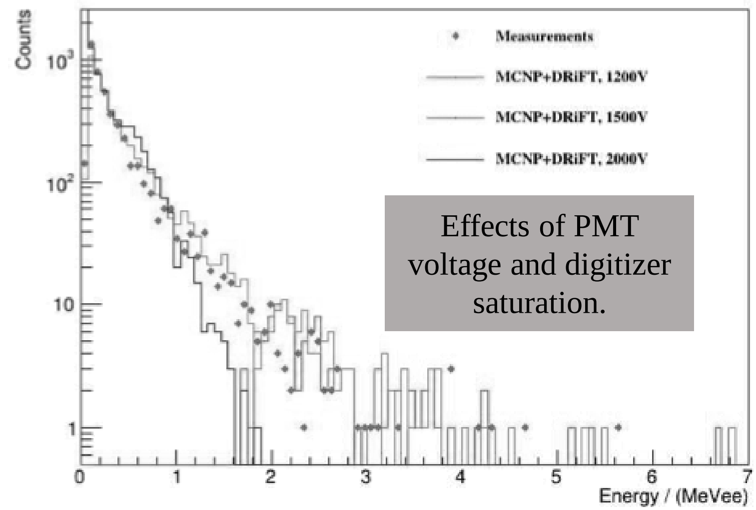

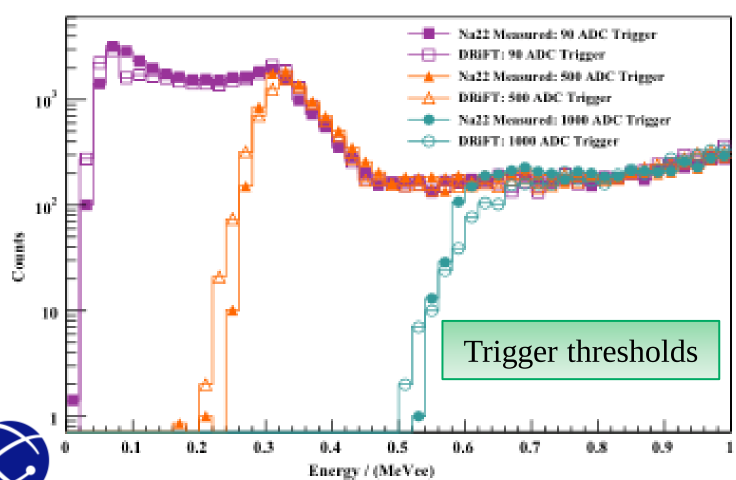

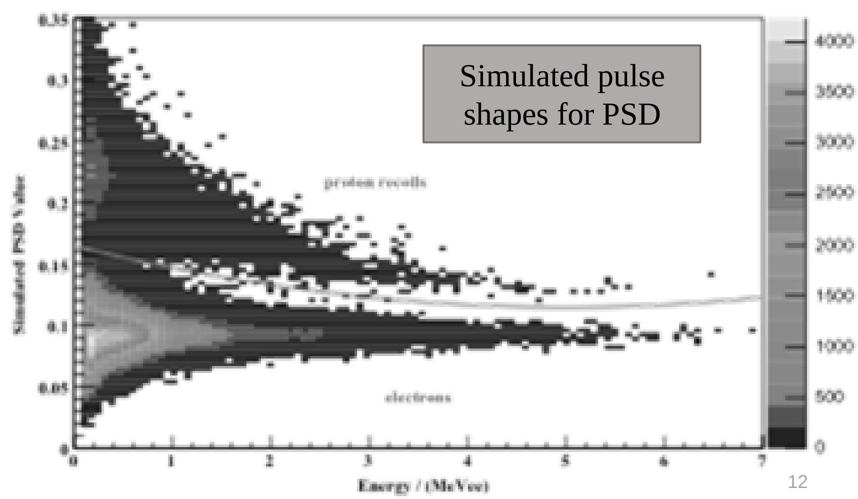

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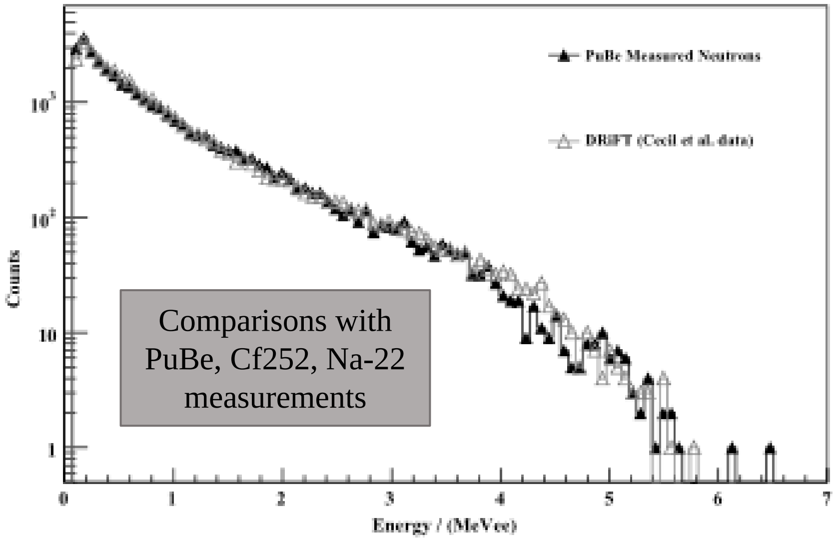
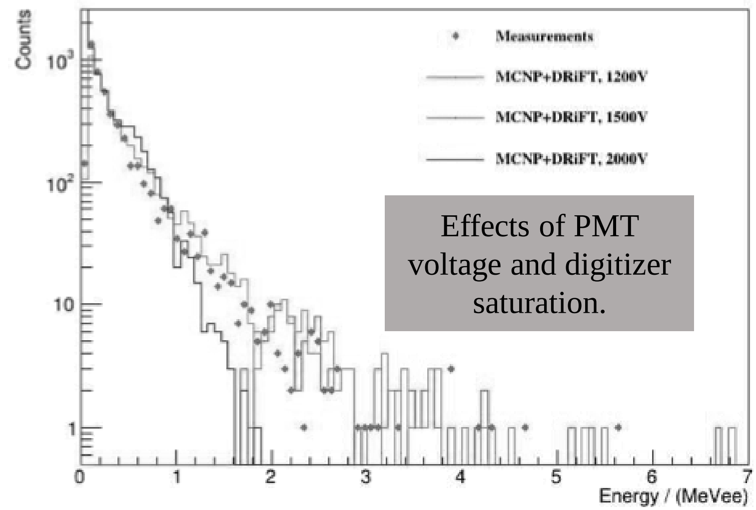
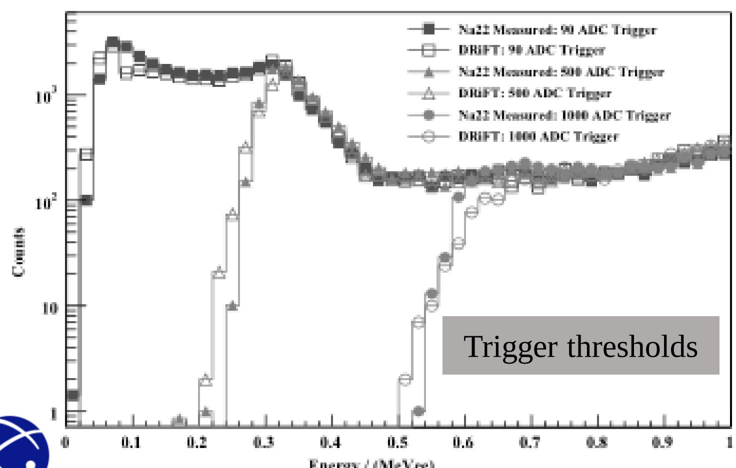
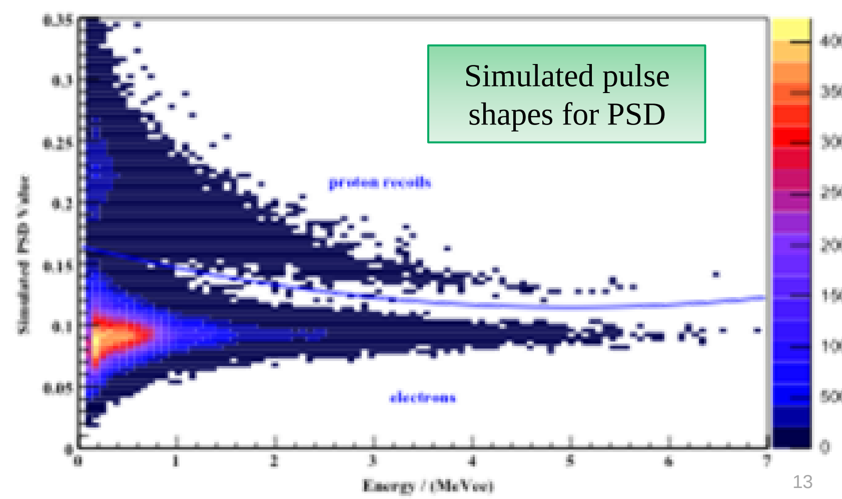








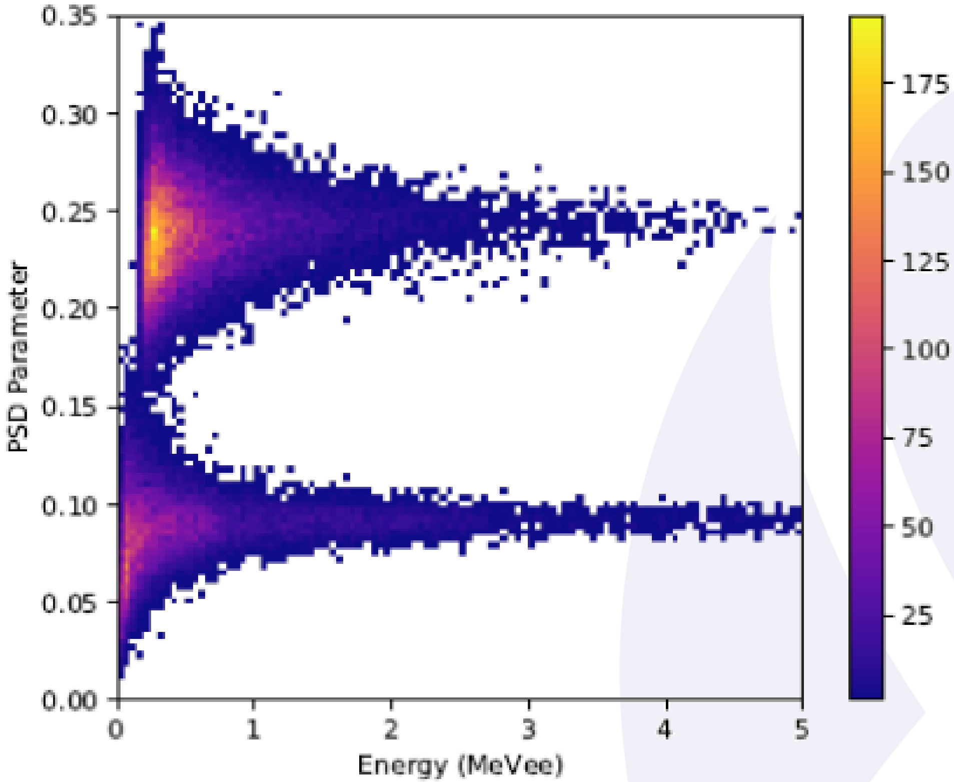
Expansion of Scintillator and PMT Physics Options

- Users can specify their own scintillator, PMT, and digitizer properties.
- Or, they can use models natively supported by DRiFT (17 scintillators, 13 PMTs, and 7 digitizer types).
- Additionally, the **user can now add their own response** without modifying source code.
  - The release contains instructions and examples.
  - Information required for users to "build their own" response is usually easily found on manufacturer's websites.

Name	Keywords	Options
[Scintillation]		
	call	Scintillation
	detector	*Scintillator name, ej. EJ301*
	optical_transport	*double, default 0.6*
	voltage	*double, 1500 V, PMT voltage*
	pmt_type	*PMT name, i.e. 9821B*
	max_energy	*double, 25.0 MeV default*
	gain	*double, default set by PMT voltage and model*
	scint_yield	*double, default set by scintillator type*
	PE_file	*filename of scintillator emission spectrum*
	QE_file	*filename of PMT quantum efficiency spectrum*
	light_file	*filename of scintillator light output table*
	pulse_shape_file	*filename of user-defined pulse shape*
	rise_time	*double, rise time of the scintillator (in ns) for pulse shape*
	decay_fast	*double, fast decay time constant (in ns) for pulse shape*
	decay_slow	*double, slow decay time constant (in ns) for pulse shape*
	fast_decay_weight	*double, relative weight of fast decay time constant*
	pulse_arrival_time	*double, default 15 ns*

Name	Keywords	Options
[Digitizer]		
	call	Digitizer
	digitizer_samples	*int, 512*
	resolution	*int, 16384 default*
	voltage_range	*double, 2.0 V default*
	ter_res	*double, 50.0 ohm default*
	DC_offset	*double, 0.1 % default*
	start_point	*double, 0.1 by default*
	trigger_ADC	*int, 100 by default*
	rate	*double, 500.e6 default (Hz)*
	s_gate	*double, 22 e-9 by default (22 ns)*
	l_gate	*double, 90e-9 by default (90 ns)*
	PSD	*string, no by default*
	pileup	*string, no by default*
	digitizer_type	*string, none specified by default*

Accommodating User Defined Pulse Shapes



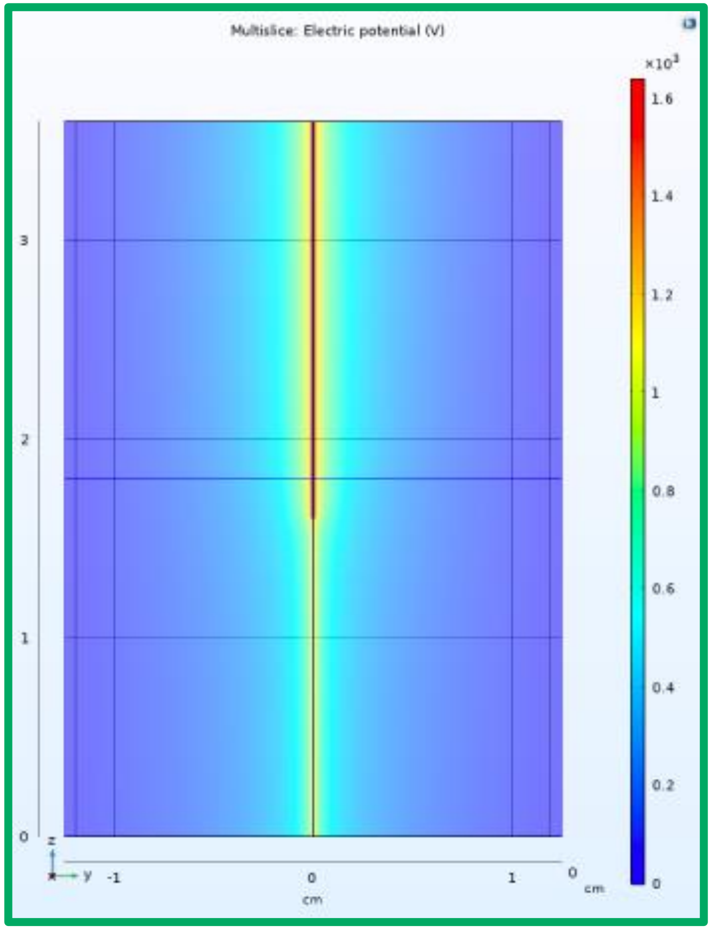
- One of the key useful and unique features of DRiFT is the ability to simulate digitizer electronic effects and pulses.
- Simulated pulse shapes have a wide variety of options from testing pulse shape discrimination (PSD) analysis to generating testing data for machine learning algorithms.

- ***The code was expanded to accommodate user-defined pulses***. An example of a PSD plot produced with this option is shown above.
- Users can define pulse shapes two ways: analytic equations or with an example measured pulse as drift input

Part III: Gas Detectors

Gas Detector – A new capability for DRiFT

- Substantial progress has been made on helium-3 gas detector simulation capabilities and the ***gas detector proof of concept as been demonstrated.***



- Gas detector physics simulations necessitated output from many codes to create a DRiFT gas detector database (*users do not need to interact with these external codes*).

- COMSOL was used to model the tube electric fields in detail, these fields were imported into Garfield++ successfully.
  - Incorporates ***field-tube (end-tube) effects***.

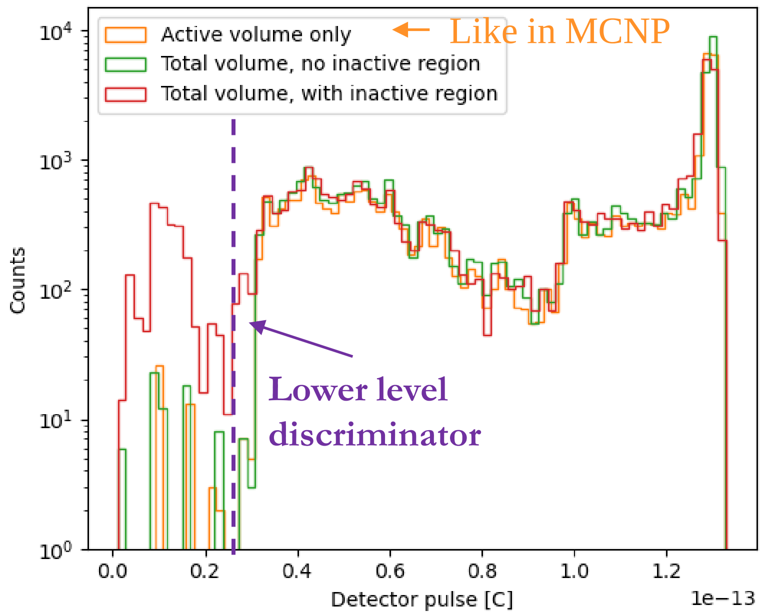
- An interface to Magboltz computes gas properties, SRIM generates proton and triton stopping and range tables.

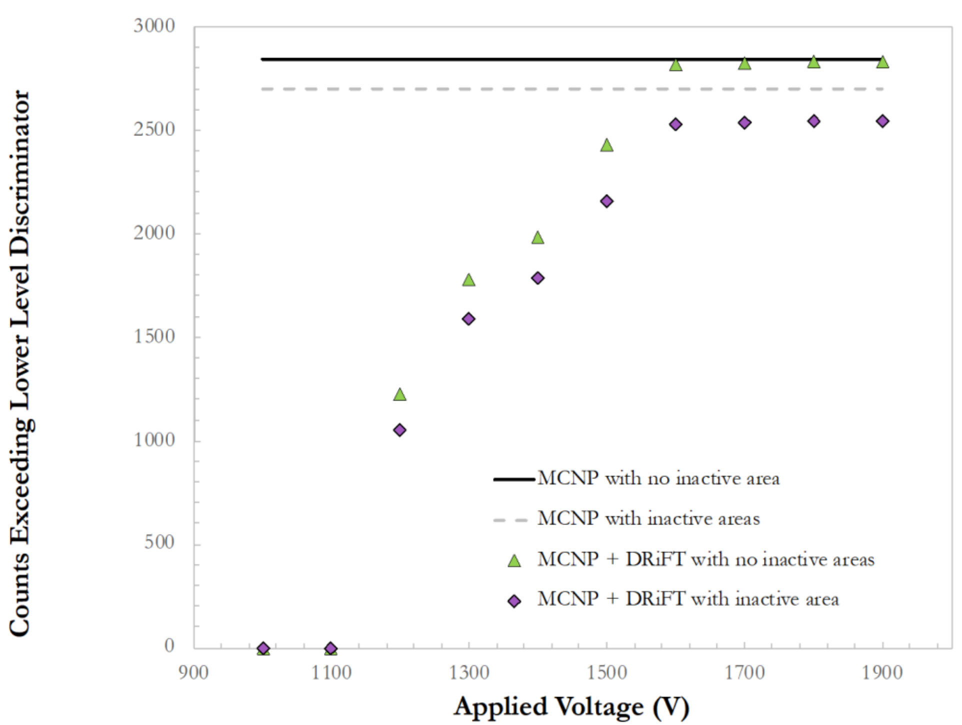
- Many combinations of tube pressures, sizes, quench gas, temperatures, and voltages to generate data tables that are read by DRiFT.

DRiFT Gas Detector Features

- DRiFT account for decreases in detection efficiencies due to
  - Operating at lower voltages
  - The inactive tube area.

- Also added a pre-amplifier module compatible with both gas and semiconductor output, can give an estimate of ***pile-up***, and photons mis-attributed as neutron events.





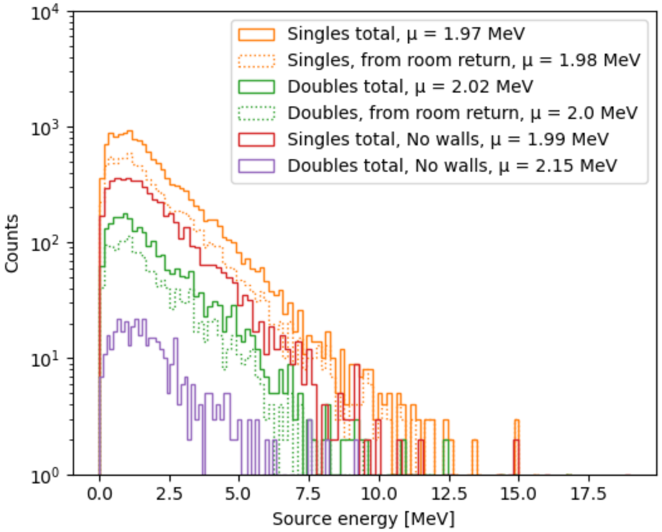
- DRiFT simulation options include:
  - No detector physics turned on, produces MCNP output equivalent (F8 tally)
  - ***End-tube effects*** (decrease in efficiency)
  - ***Applied voltage*** on detector
  - ***Lower level discriminator*** (MCNP option as well)
  - Pre-amplifier module coupled with photons in simulation for ***photon pile-up***
  - Provide an estimate of charge deposition.

Gas Options Implemented in DRiFT

Keyword	Description	Unit	Default	Options / Notes
Gas1/Gas2	Primary gas/quench gas		Helium-3/CO_2	He-3, BF3,CO_2 whatever gases are supported in Garfield++ (many),
Comp1/Comp 2	Composition of primary/secondary gas	Atom %	100	0 – 100
Voltage	Voltage applied to the tube	V	1600	1000 – 1900 V
Pressure	Gas tube pressure	Atm	10 atm	1, 2, 4, 10 atm
Aval	Model the electron transport in the tube		No	Yes, no
Inactive area	Include end tube effects		No	Yes, no in Phase I a COMSOL + GARIFLED++ generated file was required.
Inactive bottom/ top	Can describe the size of the inactive areas on the top and bottom	cm	0	With reserve funds we demonstrated that complex COMSOL models were not necessary, significantly increasing the flexibility of this feature.
LLD_c	Lower level discriminator -charge	C	0 C	$\geq$ 0, also added this to the pre-amplifier model
LLD_e	Lower level discriminator - energy	MeV	0 MeV	$\geq$ 0, also added this to the pre-amplifier model
Temperature	Temperature of the tube	K	293 K	Any
srim	Whether the tracks of the reaction products are modelled		Yes	Yes, No

Part IV: Other Features in DRiFT

Information of source particles leading to detection events



- ***DRiFT enables the tracking of particles from source point to final termination in detectors, allowing tabulation of source energy for each detection event.***
  - Uses MCNPTools to accomplish this
  - Potential input for unfolding and analysis codes

Defining Source Activity in DRiFT

- Users can define the source activity levels and DRiFT will automatically sort the PTRAC events in time accordingly.
- This allows an estimation of pile-up effects at a large number of detector settings.
- Options demonstrated include, ***pile-up, tube-end effects, collection time, energy thresholds and applied voltage***.
- Currently DRiFT assumes a non-paralyzable deadtime in the pre-amplifier module.

Flexible Output

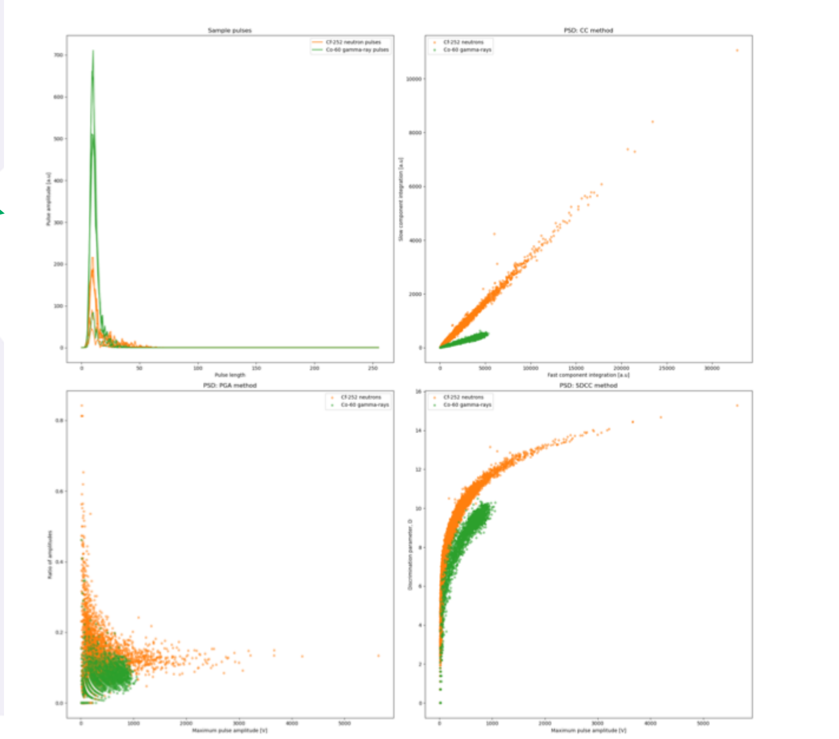
- The executable version can write out text files with columns corresponding to user-specified outputs and rows, each detector event.
  - Can also output history of the particle (i.e. which cells in the MCNP file it interacted with).

- Additionally, users can output digitizer waveforms for scintillator simulations to assess their analysis algorithms.

- The HPC version also have the option to output DRiFT results as root trees.

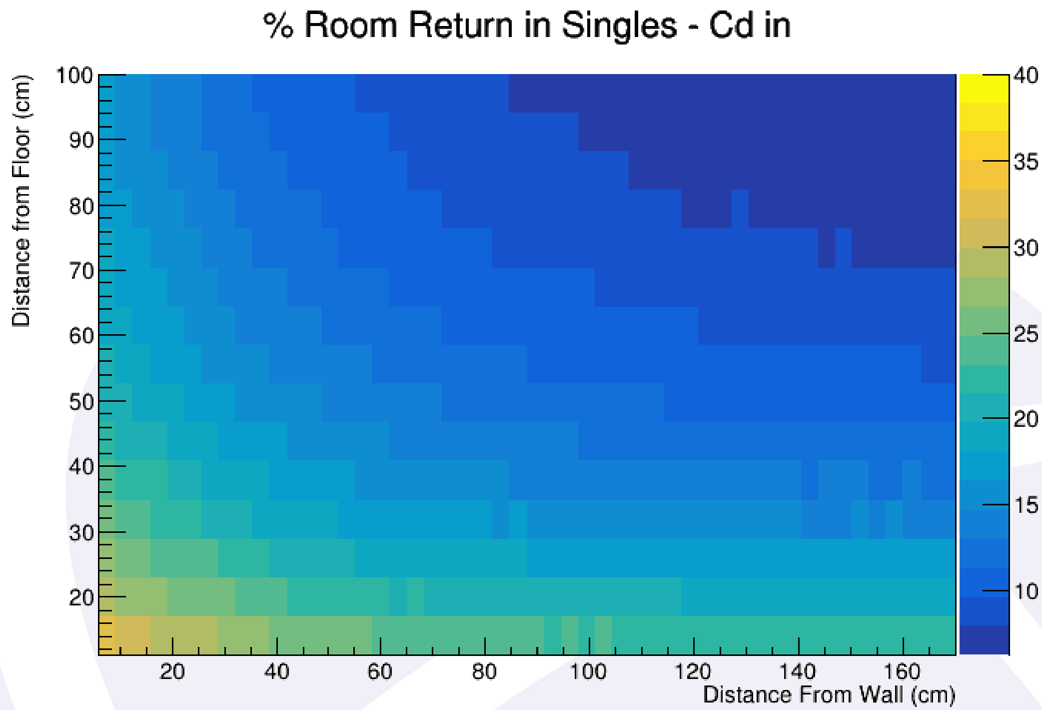
Table 3.6: DRiFT Sections Keyword Options - WriteOutput

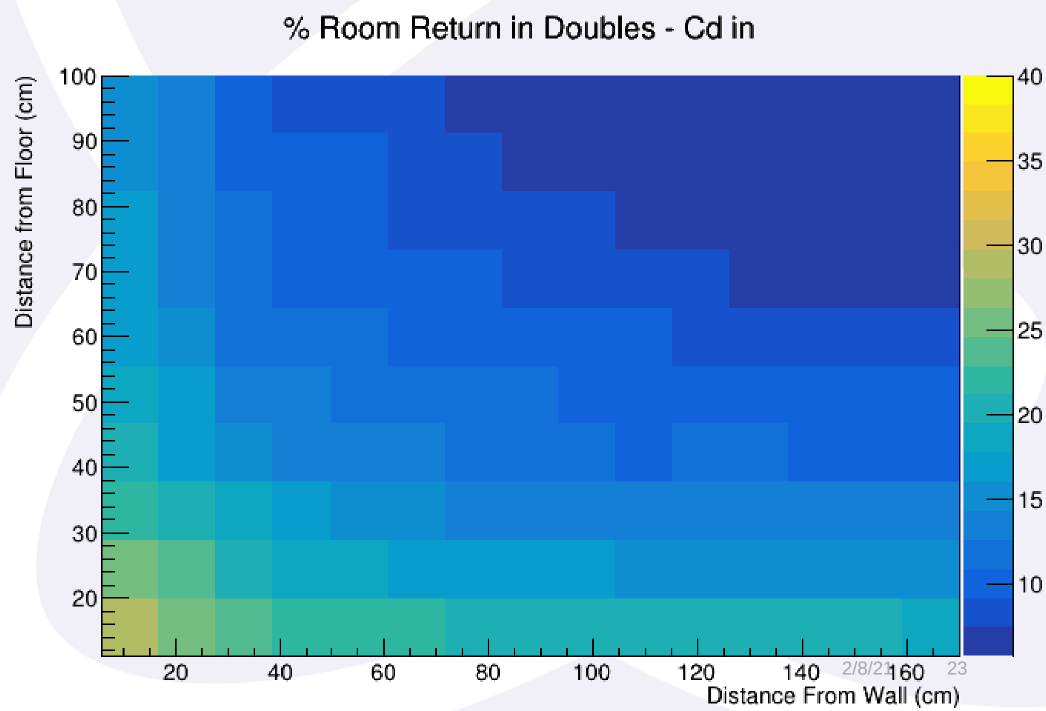
Name	Keywords	Options
[WriteOutput]		
	call	WriteOutput
	num_outputs	*integer less than 10*
	outputs	source_e *(default), MeV*
		source_t *seconds*
		source_cell
		source_type
		count
		det_pulse
		det_cell
		corr_count
		PSD



Diagnostic Capabilities

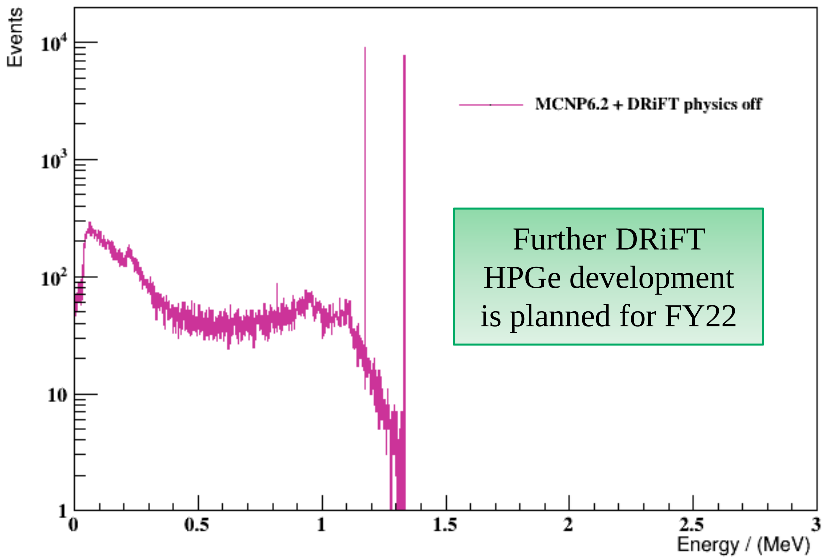
- DRiFT has many diagnostic capabilities including:
  - Flagging ***room return*** (in the example on the right the % of detected events with interacted with the wall and/or floor is displayed for singles and doubles).
  - Flags ***detector cross talk*** (when an event from the same particle registers in two or more detectors)
  - Flags ***pile-up*** (two separate particles recorded as one event)
  - Flags: ***doubles, triples, correlated events***





Conclusions and Future Work

- DRiFT simulates nuclear instrumentation in levels of detail not available in other codes.
- Allows users to assess tool performance and develop analysis algorithms (i.e. PSD).
- A DRiFT executable has been generated for Linux OS for organic scintillator capabilities.
- Gas detector proof of concept has been implemented.
- Future work:
  - Streamlining of gas detector simulation process
  - comparisons with He-3 measurements needed.
  - Implementation of pulse shapes in gas detectors



Acknowledgements

- LDRD MFR, TED Funds.
- We appreciate the contributions of measurements, information, feedback, testing, and MCNP decks from: K. Meierbachtol, J. Favorite, A. Madden, L. Misurek, M. Lombardi, K. Shults, M. James, T. Borgwardt, D. Broughton, S. Sarnoski, and M. Root.

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