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Title: Correlated Fission Simulations with MCNP6.2 and MCNPX-PoliMi

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Correlated Fission Simulations with MCNP6.2 and MCNPX-PoliMi

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Chicago, IL

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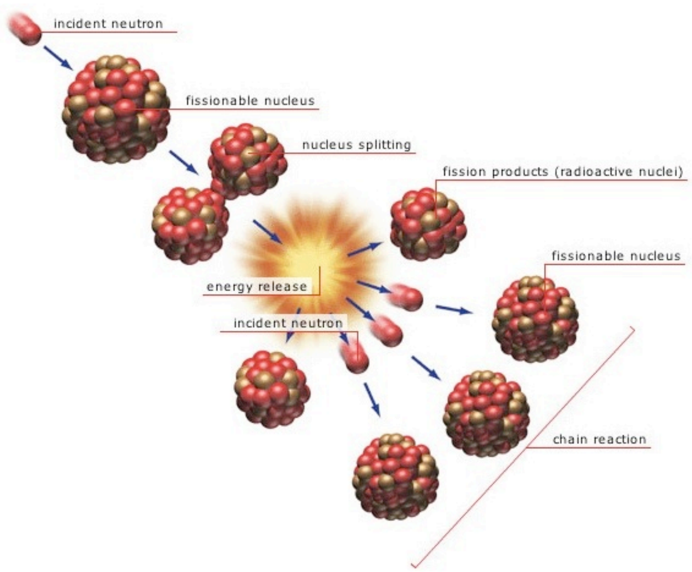
Outline

- **Introduction**
- **Background**
  - Nuclear Fission Physics
  - MCNP6.2
  - MCNPX-PoliMi
- **Preliminary numerical results**
- **Conclusions & future work**



Introduction

How do we solve the "what's in the box" kind of problem?

A predictive simulation tool would be nice to have…

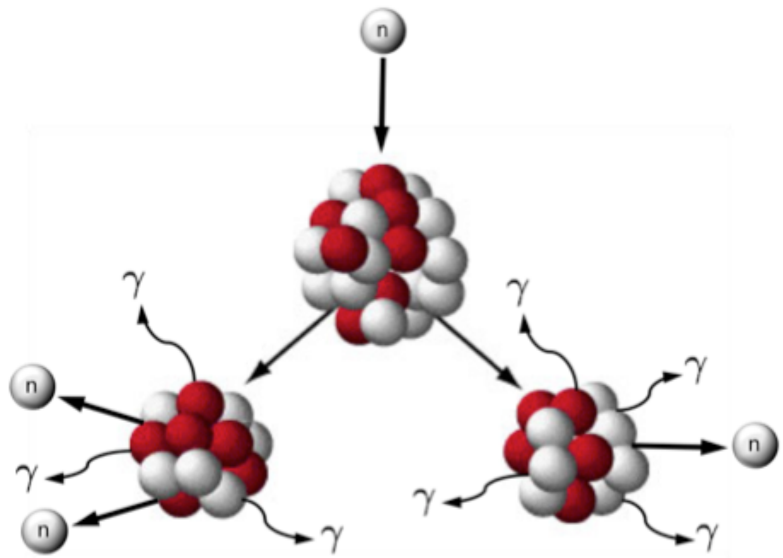
Background

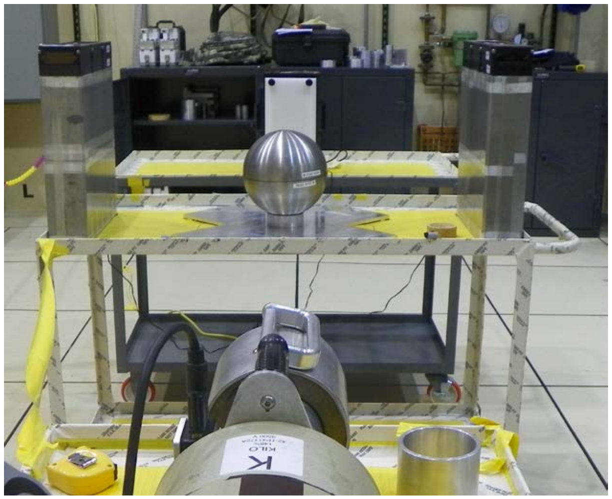
- **Warhead Measurement Campaign (WMC) meant to passively and actively measure nuclear warheads for treaty verification**
  - New measurements of neutron and photon coincidence data of shielded special nuclear materials (SNM)
  - At the time, the transport simulation tools available were limited in their ability to fully predict WMC-like measurements
  - This was due to the type of nuclear fission data available
  - To address these shortcomings, more detailed behavior of nuclear fission physics was needed
  - Making the transport simulations more predictive in SNM detection applications
- **Key Issues**
  - Average nuclear data quantities are insufficient (need fission event generator)
  - Need better ways to compare to experiment (need post-processing tools)
- **An ongoing NA-22 venture project was funded to address these problems in MCNP6**
  - Collaborators include LANL, LLNL, LBNL, & University of Michigan

Background
Nuclear Fission Physics

- **When fission occurs in nature there exists**
  - Multiplicity distribution of gamma rays
  - Multiplicity distribution of neutrons
  - Multiplicity dependent energy spectra (energy correlations)
  - Angular emission from fission fragments (angular correlations)

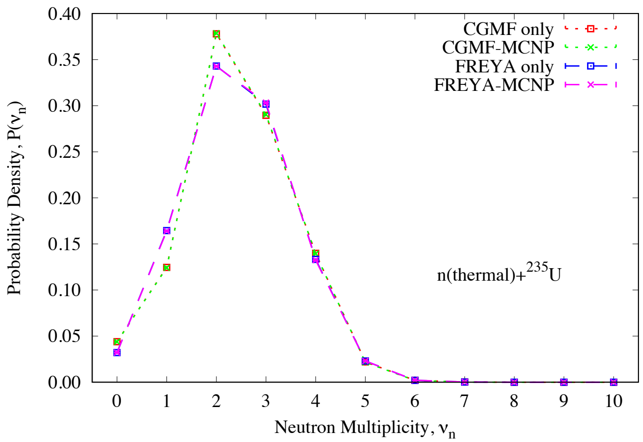
- **In general, this is not how fission is modelled in radiation transport codes**
  - Average or expected values are used in place of distributions (i.e. $\bar{\nu}$ vs. $P(\nu)$)
  - Each secondary particle is sampled independently (no correlations)

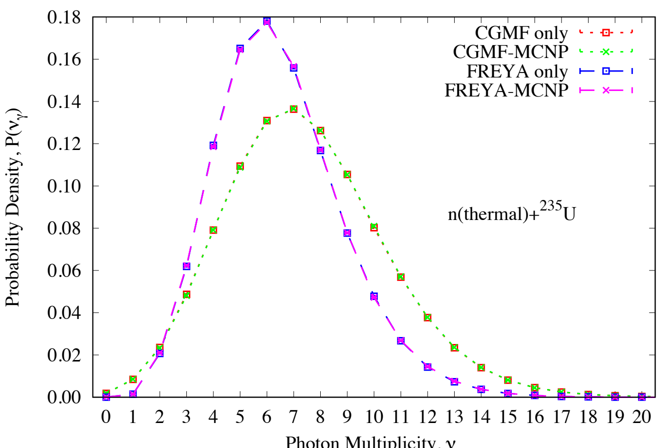


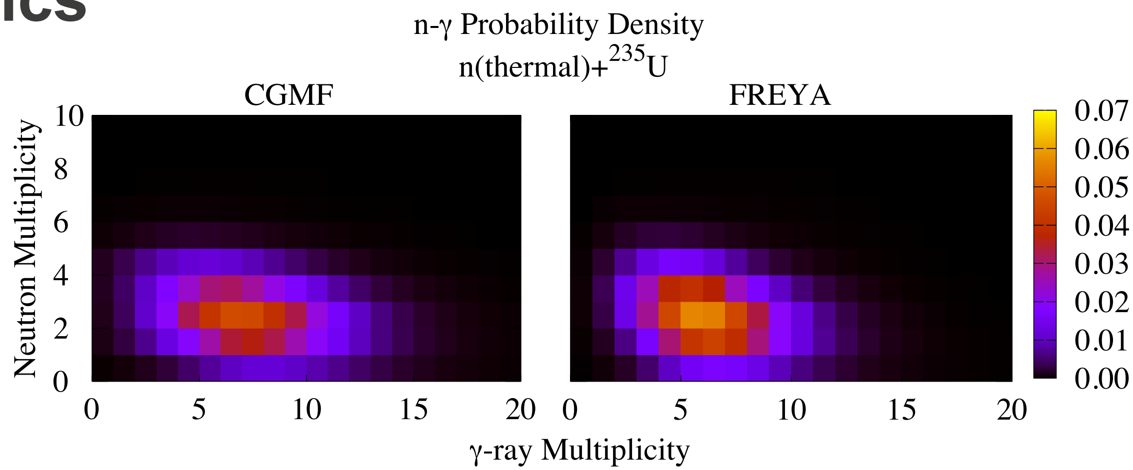


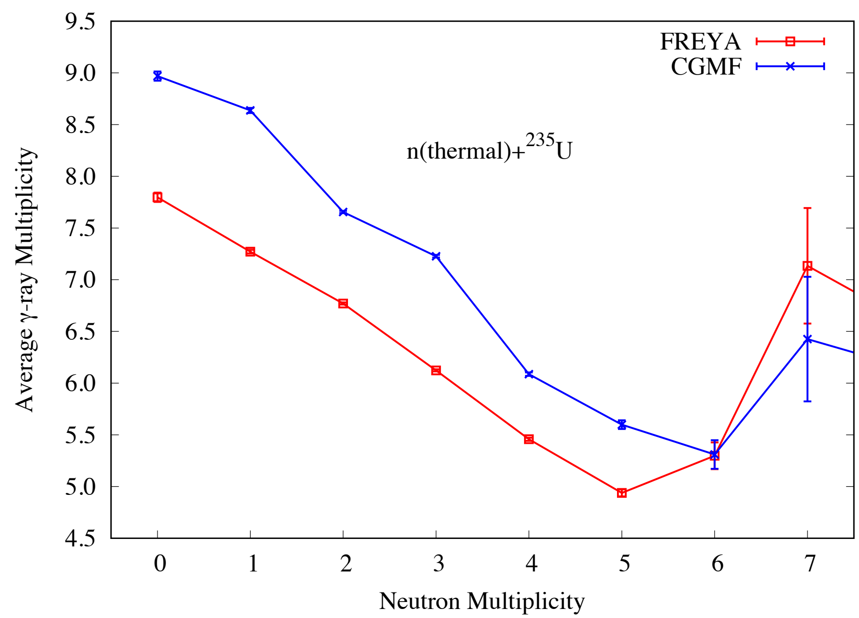
Background
Nuclear Fission Physics

- **Neutron & gamma-ray multiplicity**



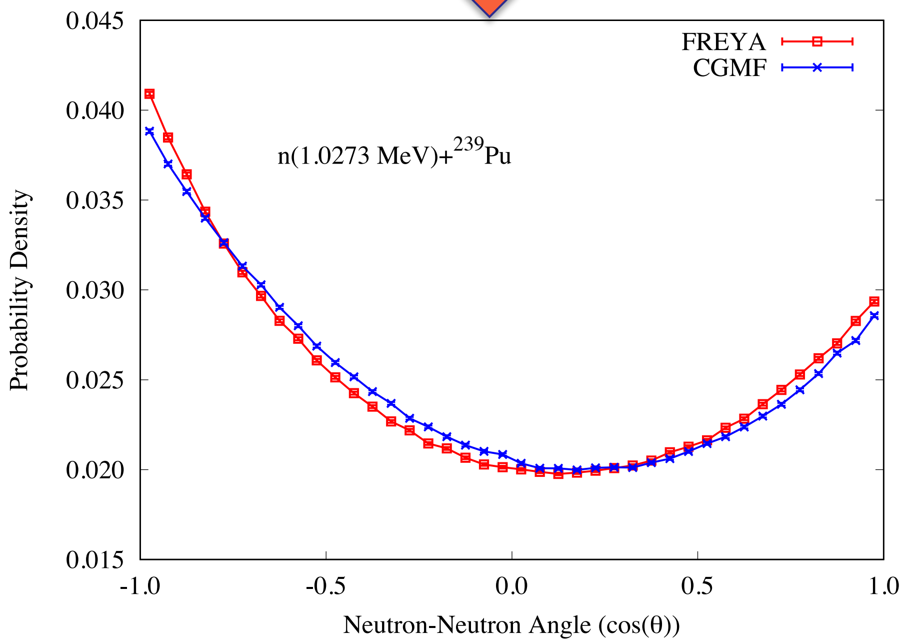


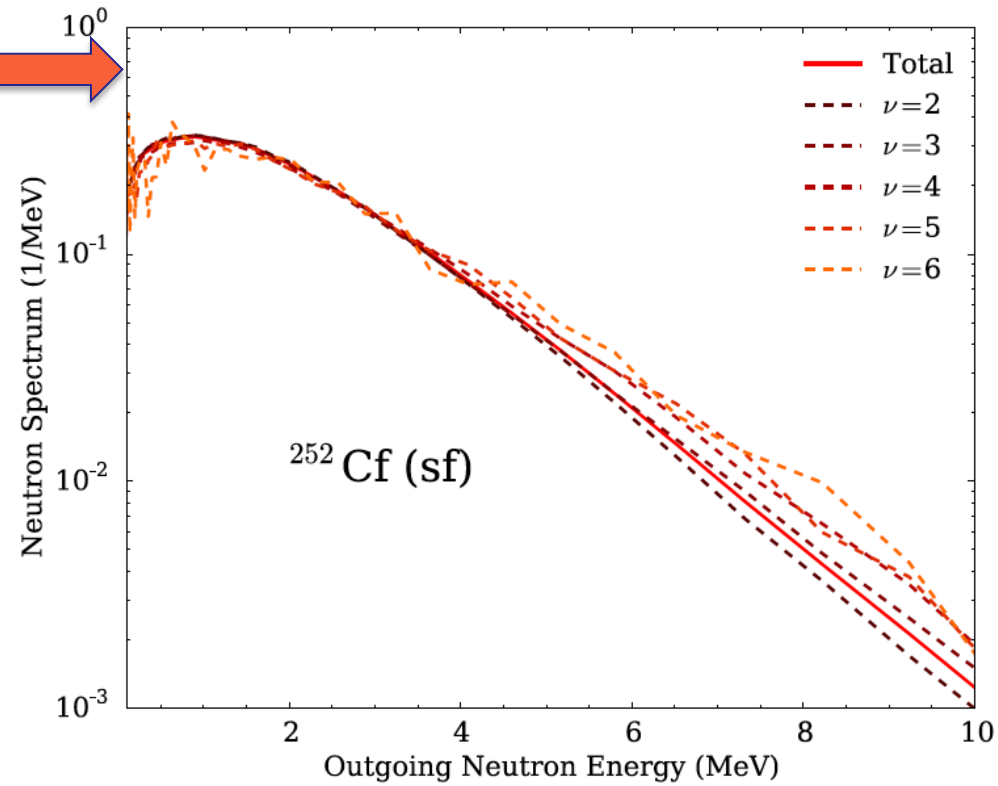




Background
Nuclear Fission Physics

- **Multiplicity-dependent spectra**
- **Neutron emission angular correlations**





Background
MCNP6.2

- **In the release:**
  - CGMF and FREYA fission event generators
  - (M)ISC : MCNP / general intrinsic source constructor
  - MCNPTools : MCNP outputs

- **To be released at a future date:**
  - DRiFT : Detector Response Function Toolkit

- **Presented at workshop at 2016 ANS ANNTP Conference in Santa Fe, NM (look on website under technical references and workshops)**
  - LA-UR-16-27559 : MCNP6 basics
  - LA-UR-16-27301 : fission multiplicity models
  - LA-UR-16-27265 : ISC and MCNPTools info
  - LA-UR-16-27166 : DRiFT

Background
MCNPX-PoliMi

- **MCNPX-PoliMi was developed to simulate correlation measurements with neutrons and gamma rays**

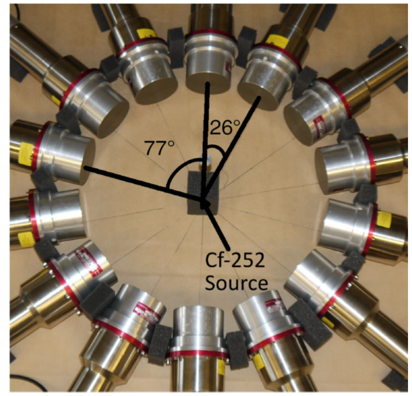
- **MCNPX-PoliMi contains several detailed fission models**
  - Complete neutron and gamma-ray multiplicity distributions
  - Neutron-multiplicity dependent energy distributions
  - Anisotropic neutron emission

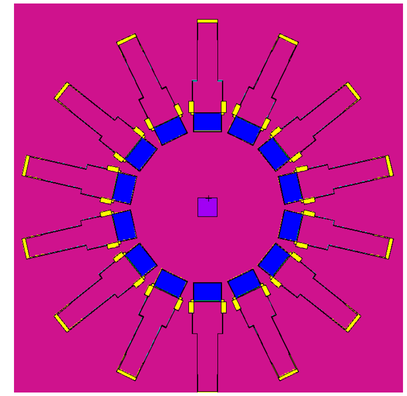
- **The number of neutrons and gamma rays from each fission event is currently sampled independently**

- **Recent research efforts included using CGMF and FREYA in spontaneous fission simulations**

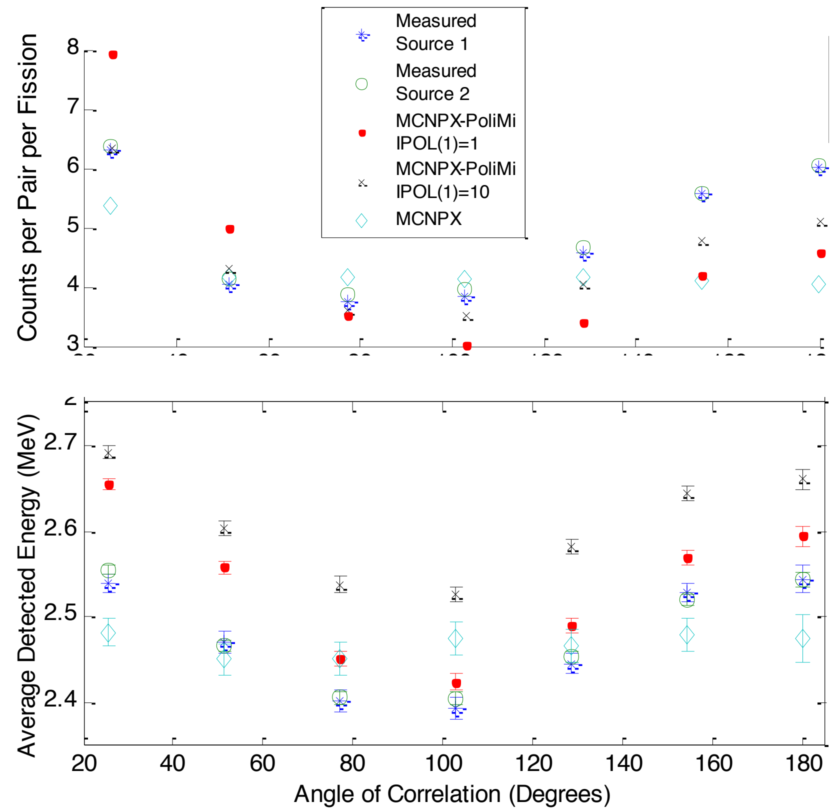
- **Detector response is emulated in post-processing using the code MPPost**

Preliminary Numerical Results



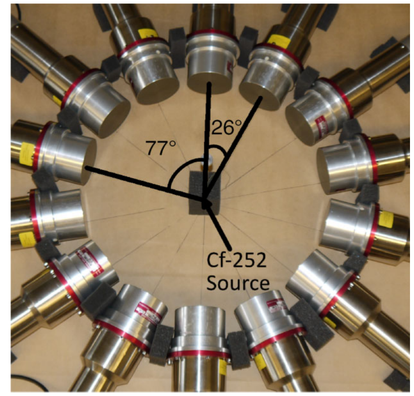


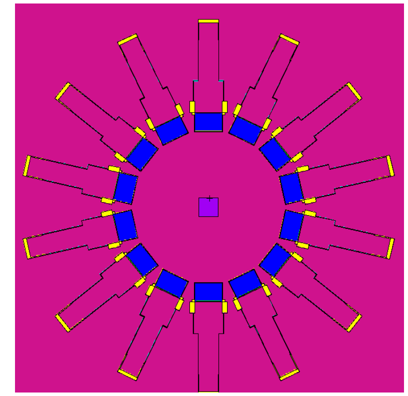
- **University of Michigan measurements of angular correlations**
- **Priority is to compare against experimental measurements**
- **Follow-up of 2014 NSE paper by S.A. Pozzi *et al*.**
- **Transport and post-processing code comparisons**
  - MCNP6 / DRiFT
  - MCNP6 / MPPost
  - MCNPX-PoliMi / MPPost
  - MCNPX-PoliMi / DRiFT



All results shown are very preliminary!

Preliminary Numerical Results



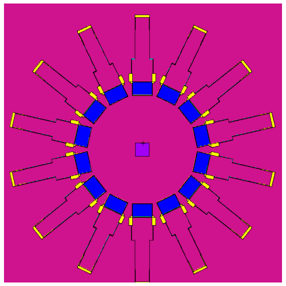


- **MCNP6.2 Simulations**
  - Default FMULT, FREYA and CGMF
  - Binary PTRAC file written and processed by DRiFT using MCNPtools
  - Script to convert PTRAC to PoliMi collision file format using MCNPtools for MPPost code detector response processing

- **MCNPX-PoliMi Simulations**
  - Default FMULT, IPOL(1)=1 and IPOL(1)=10
  - Collision file used for MPPost code detector response processing
  - ASCII PTRAC file written and processed by DRiFT using MCNPtools

- **Each simulation includes 2E7 ^{252}Cf spontaneous fission histories**
  - Note that the FMULT sources do not include spontaneous fission gamma rays
  - For count rates and pulse height spectra, 53 keVee light output threshold is used
  - For correlated counts, 100 keVee light output threshold is used

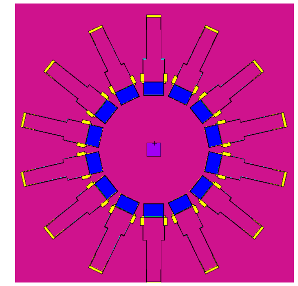
Preliminary Numerical Results



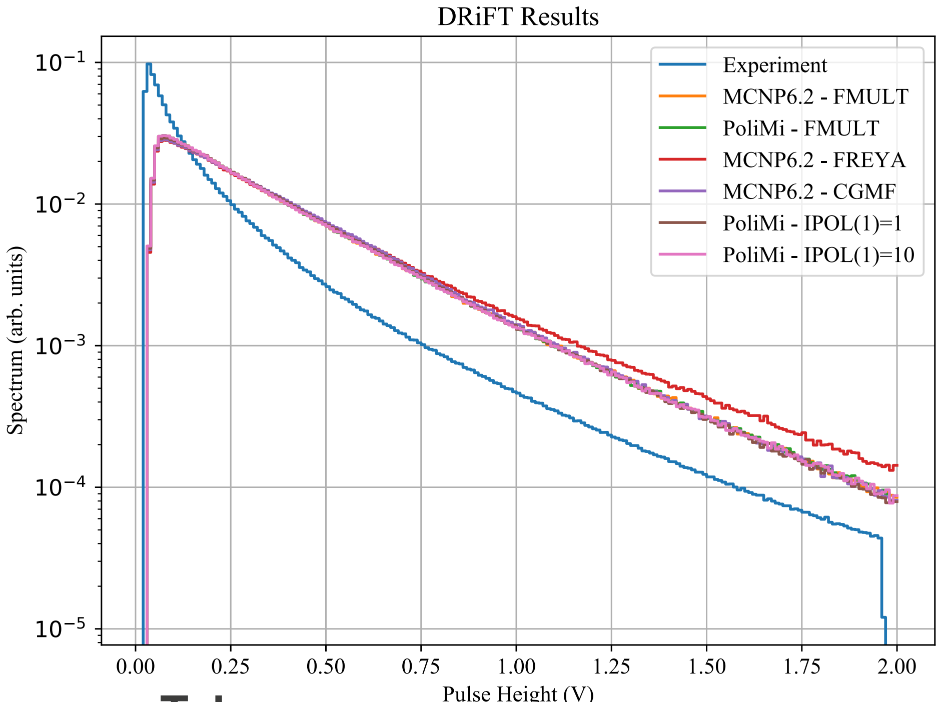
- **Current comparisons**
  - Transport code-to-code
  - Fission multiplicity models
  - Detector response post-processing tools
  - Only considering neutrons for now
- **Overall count rates**
  - DRiFT rates higher than experiment
  - MPPost rates consistent with experiment
- **Count rates between transport codes and multiplicity models appear consistent**

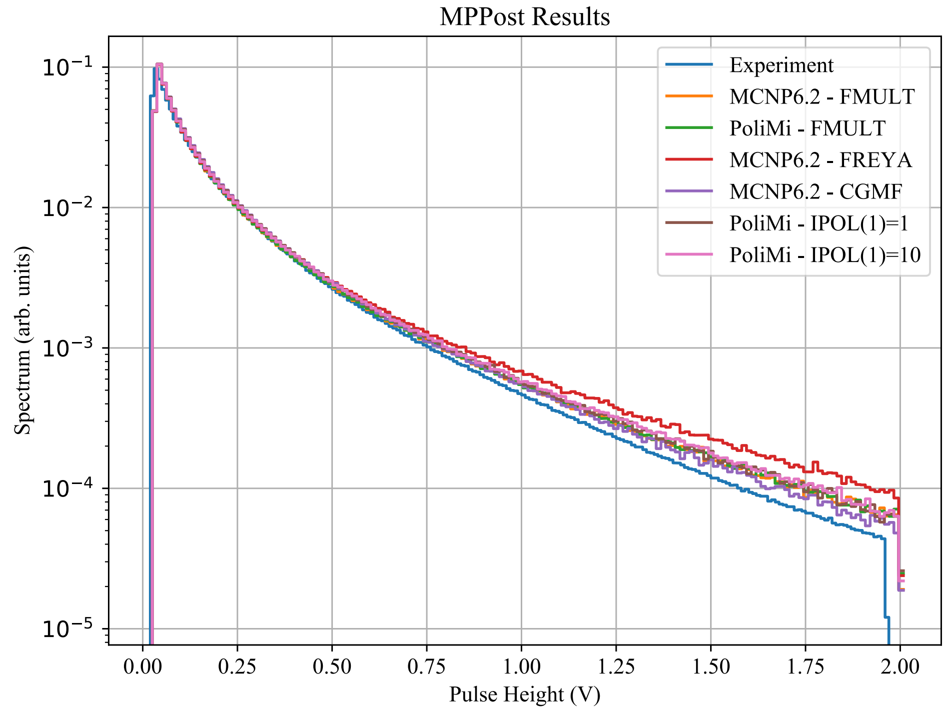
	Total Counts (#/fission)	Correlated Counts (#/fission)
Experimental rate	0.142	0.00439
Exp. light output threshold	64 keVee	100 keVee
DRiFT rates		
MCNP6.2, FMULT	0.211	0.0116
PoliMi, FMULT	0.212	0.0116
MCNP6.2, FREYA	0.209	0.0119
MCNP6.2, CGMF	0.212	0.0122
PoliMi, IPOL(1)=1	0.211	0.0121
PoliMi, IPOL(1)=10	0.211	0.0119
MPPost rates		
MCNP6.2, FMULT	0.138	0.00398
PoliMi, FMULT	0.138	0.00398
MCNP6.2, FREYA	0.141	0.00468
MCNP6.2, CGMF	0.143	0.00490
PoliMi, IPOL(1)=1	0.143	0.00461
PoliMi, IPOL(1)=10	0.141	0.00452
Sim. light output threshold	53 keVee	100 keVee

Preliminary Numerical Results



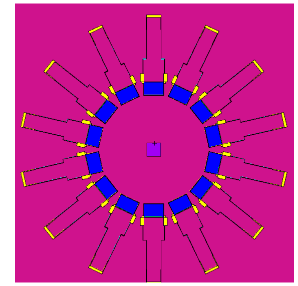
- **Because count rates are discrepant between experiments and simulations, all subsequent comparisons are arbitrarily normalized**
- **Pulse Height Spectra (53 keVee light output threshold for simulations):**



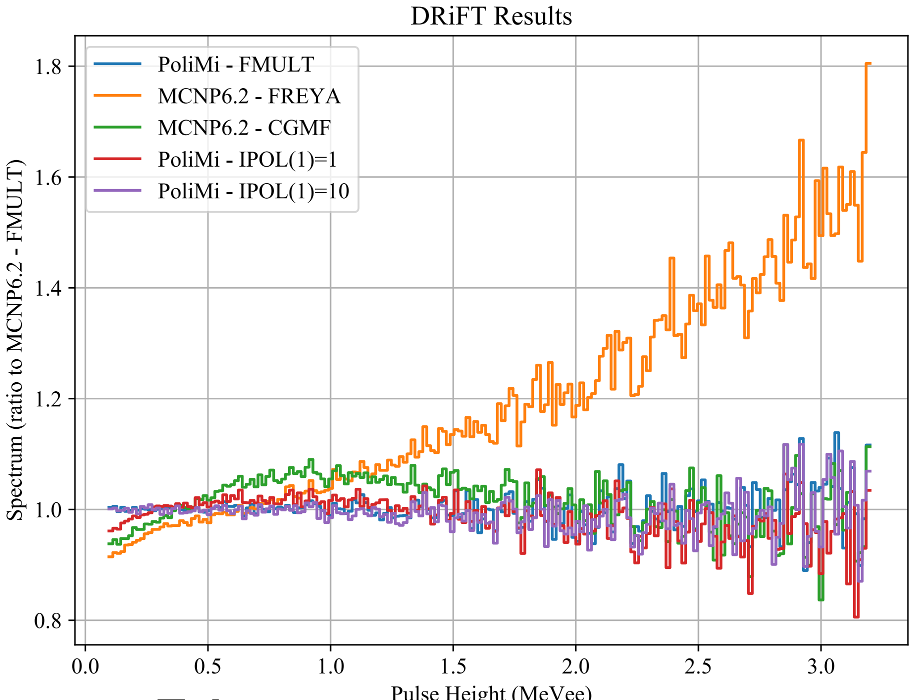


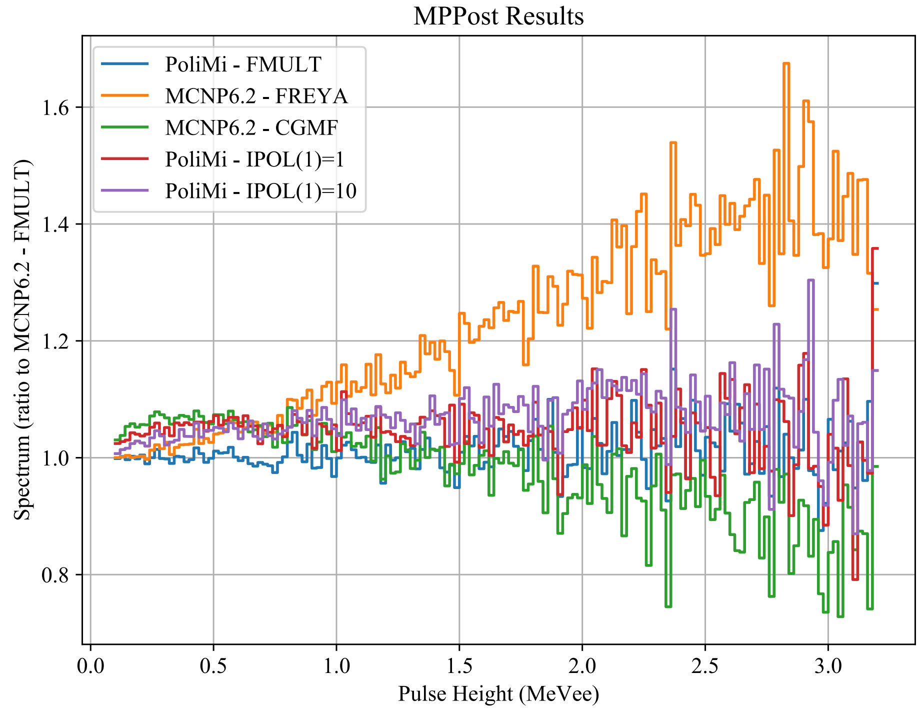
- **Take away**
  - Definite shape differences between DRiFT and MPPost results

Preliminary Numerical Results



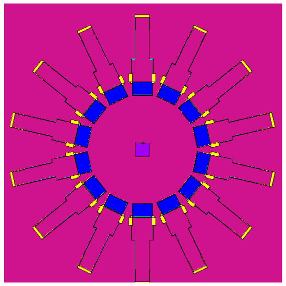
- **Ratio of Pulse Height Spectra to MCNP6.2 – FMULT option:**



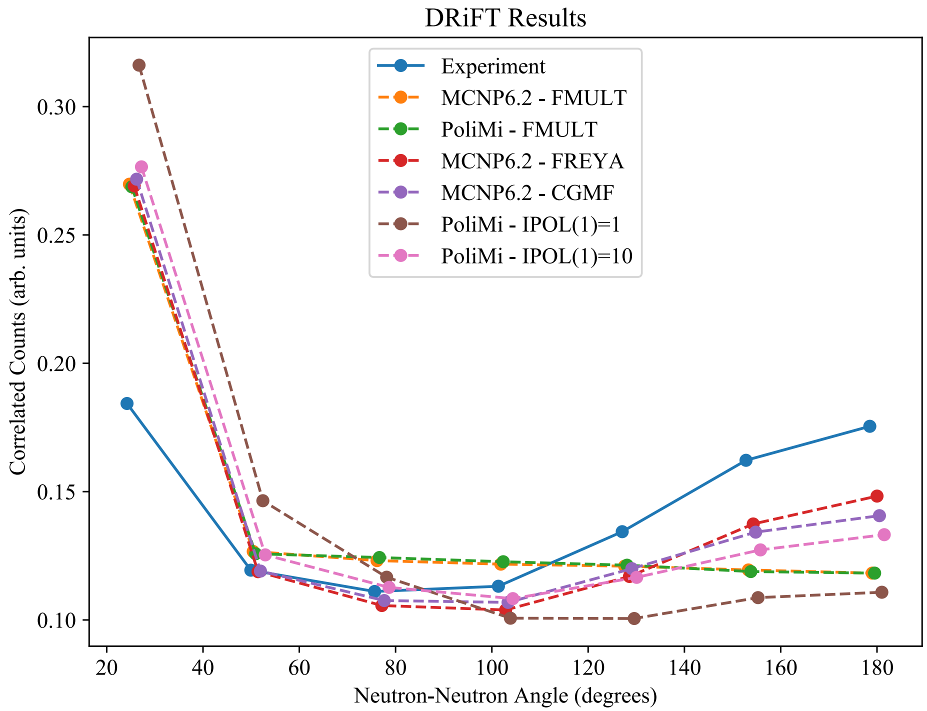


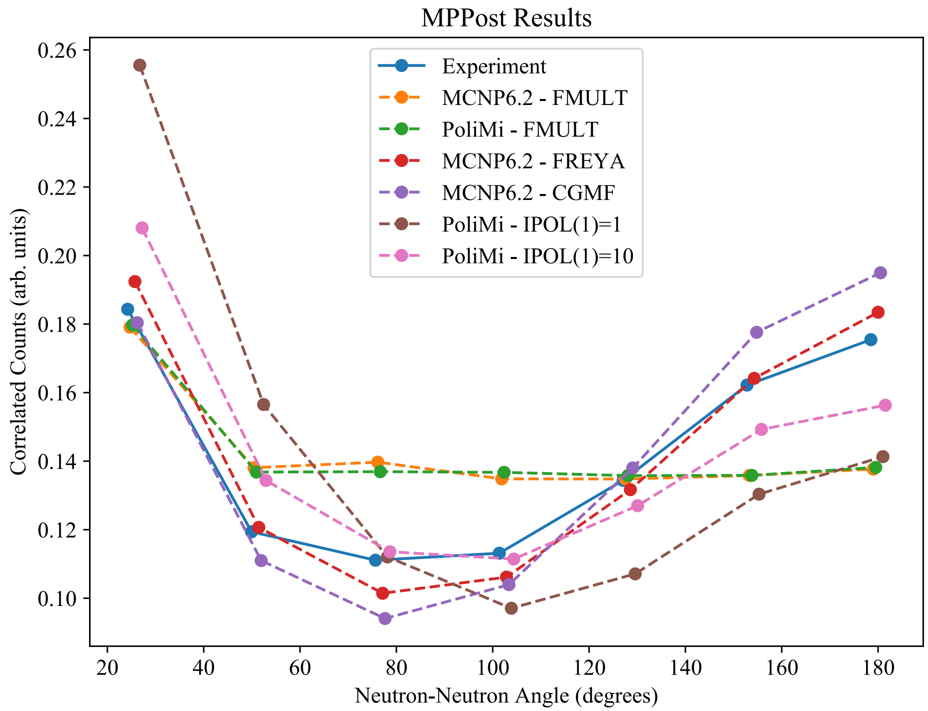
- **Take away**
  - MPPost has sharper peak in low energy region of pulse height spectrum
  - Small trends below 1 MeVee for FREYA, CGMF and IPOL(1)=1
  - FREYA trends high for larger pulse heights above 1 MeVee

Preliminary Numerical Results



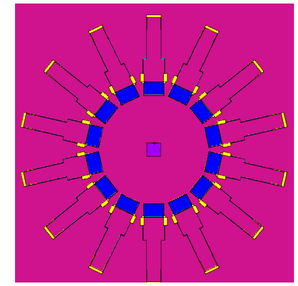
- **Neutron-neutron angular correlations (100 keVee light output threshold):**



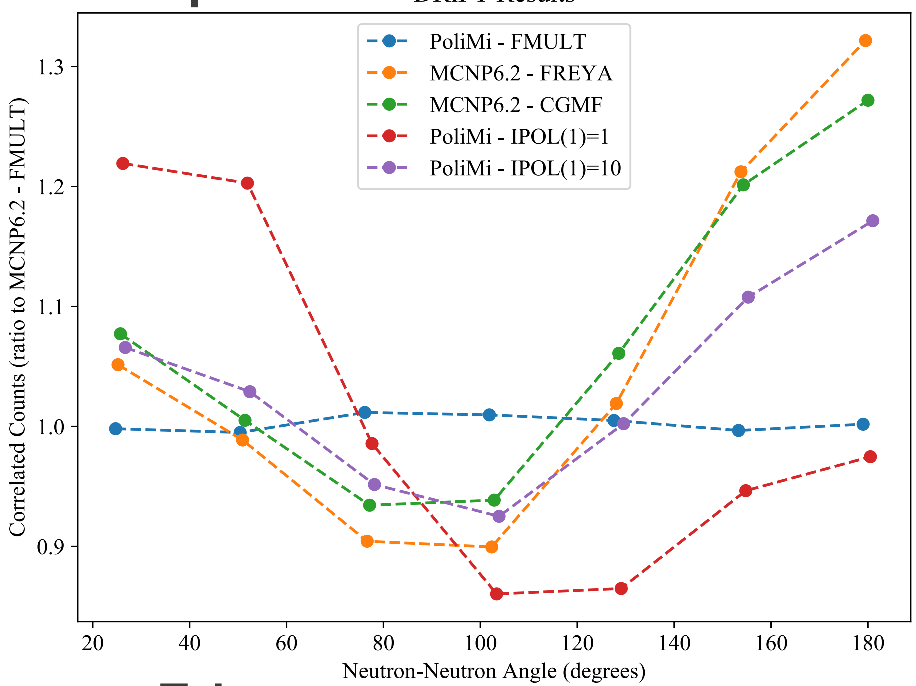


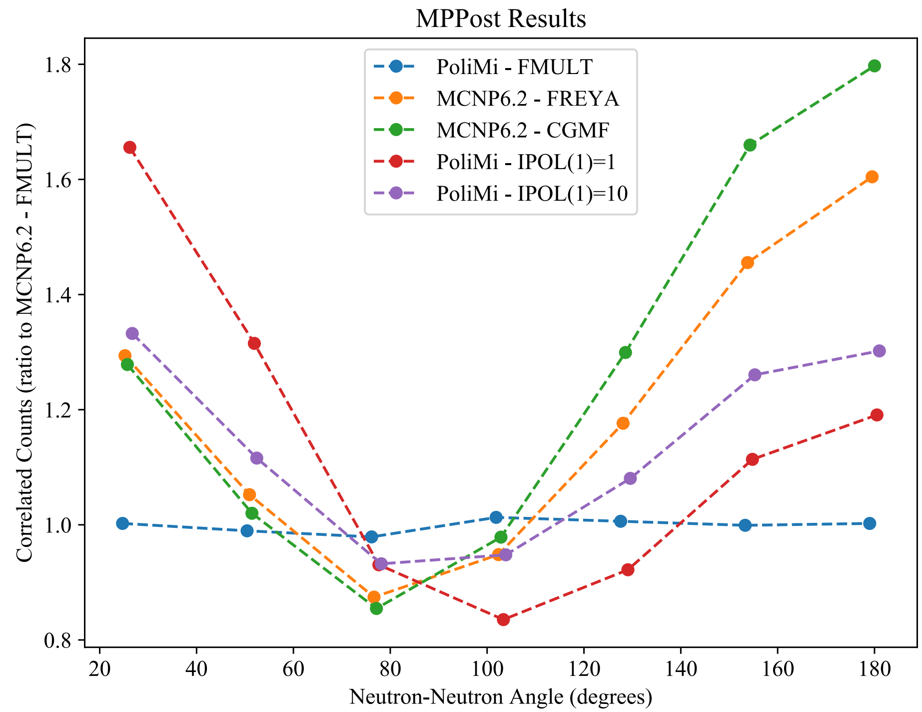
- **Take away**
  - All DRiFT results over predict at low angles, under predict at high angles
  - FREYA and CGMF seem to best match experimental shape

Preliminary Numerical Results



- **Ratio of neutron-neutron angular correlations to MCNP6.2 – FMULT option:**





- **Take away**
  - All models include higher low angle counts compared to FMULT because of anisotropic emission of neutrons from fission
  - IPOL(1)=1 seems to deviate the most from other models

Conclusions & Future Work

Impact

- **Excellent collaboration with LANL/LBNL/LLNL researchers and University of Michigan professors and students under NA-22 venture project**
- **More nuclear fission options available to compare to experiment for some complex coincident/multiplicity measurements**
- **New capabilities in MCNP6.2 and post-processing tools available now to users in many application areas**

Future Work

- **Determine differences between DRiFT and MPPost because this seems to be source of largest discrepancy in preliminary results**
- **Continue MCNP6.2 and MCNPX-PoliMi comparisons**
- **Validation – more simulation vs. experiment**
- **Improve MCNP and CGMF/FREYA codes**
  - Better algorithms and parallel processing support
  - Tune models to better predict nature

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Thank you!

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