

Probing the physics of the elusive neutrino using electron scattering data with two nucleons at the final state in the CLAS12 experiment

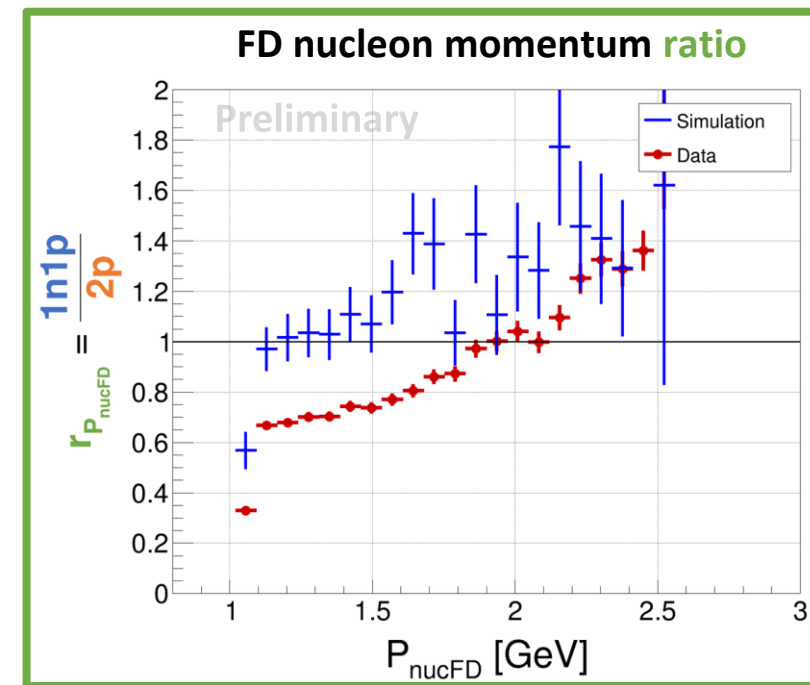
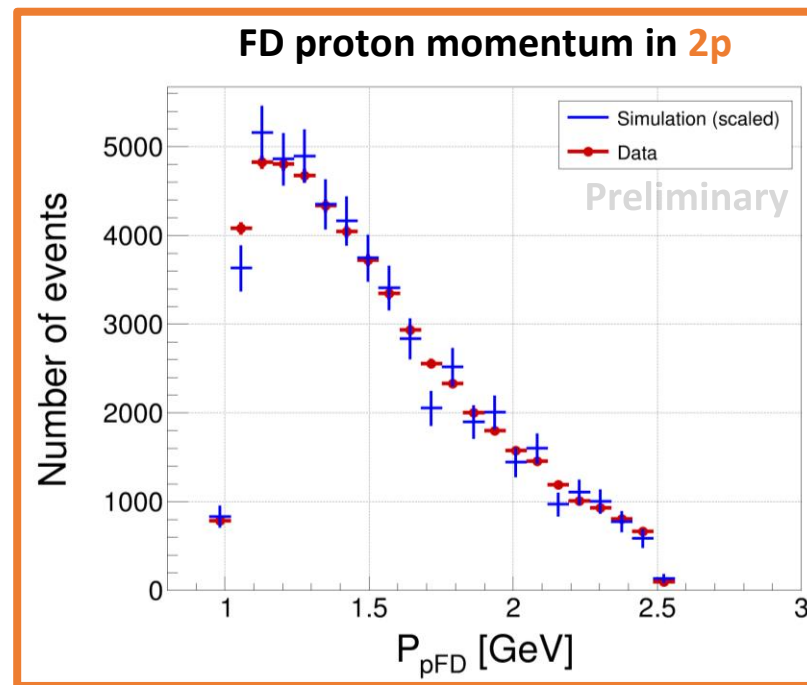
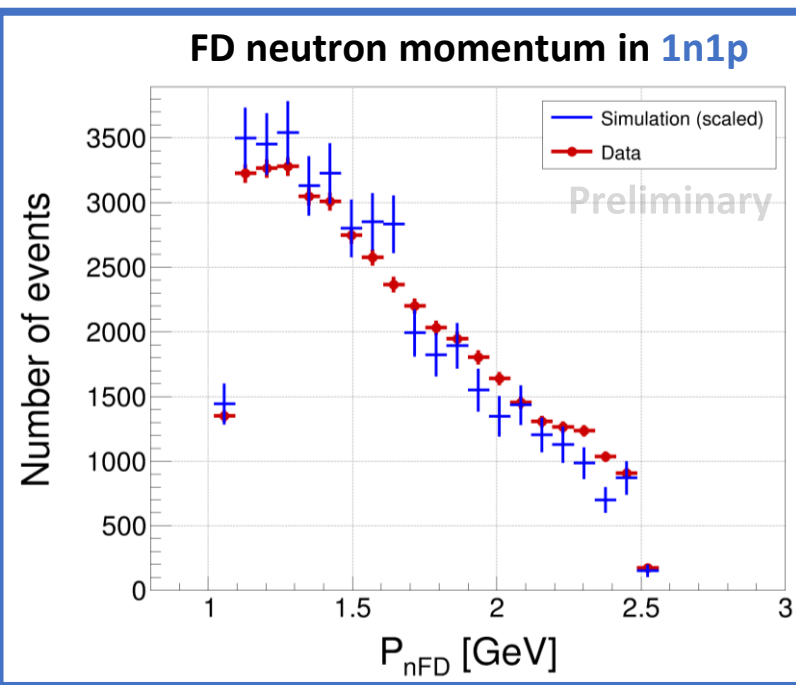
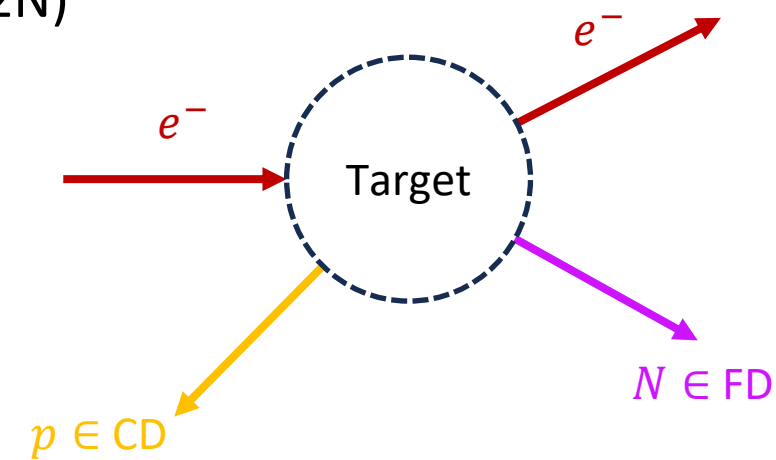
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The 2N analysis – overview

- Analyzes and compares events with two nucleons at the final state (= 2N) using CLAS12 simulation and data
- Specifically:**
 - 2p** & **1n1p** final states
 - Due to efficiency – no constraint on FD neutron multiplicity
 - Look at the **ratio** of kinematical variables of these states
 - Previous work used ^{12}C sim. (GENIE) and data (run 015188) at 6 GeV



nFD = FD neutron

pFD = FD proton

$nucFD$ = FD nucleon

Full results

The next gen 2N analysis

Overarching goal – work on next generation 2N analysis with:

- **More beam energies:** 2, 4, 6 GeV
- **More targets:** ^2D , ^{12}C , ^{40}Ar
- **More GENIE tunes:** G18_10a_00_000 (= G18) and GEM21_11a_00_000 (= SuSa)

Current focus:

- New sample production
- Acceptance maps generation

New sample production

Statistics in previous analysis:

- **In simulation (using G18_02a_00_000):** only ~ 3200 2p and ~ 2800 1n1p events remained (after all analysis cuts) from ~ 24 M events at truth-level
- **In the data (run 015188):** 2p:1n1p \simeq 50K:31K out of ≈ 101 M events (after all analysis cuts)

Current status of new sample production:

- Large samples are to be generated. To be composed of skimmed samples of 250M events for each target, GENIE tune, and beam energy
- First batch of 250M samples has been completed – except for ^{40}Ar , SuSa, at 2 GeV
- No passes through GEMC, waiting for ^{40}Ar implementation

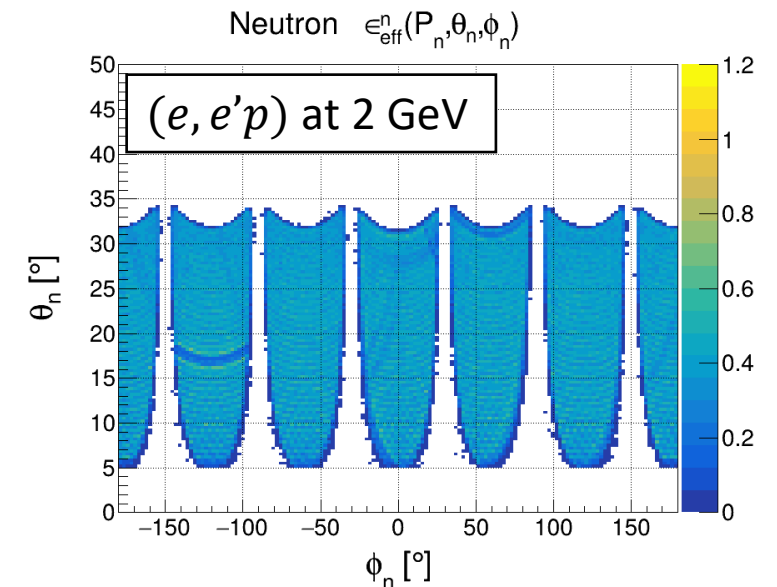
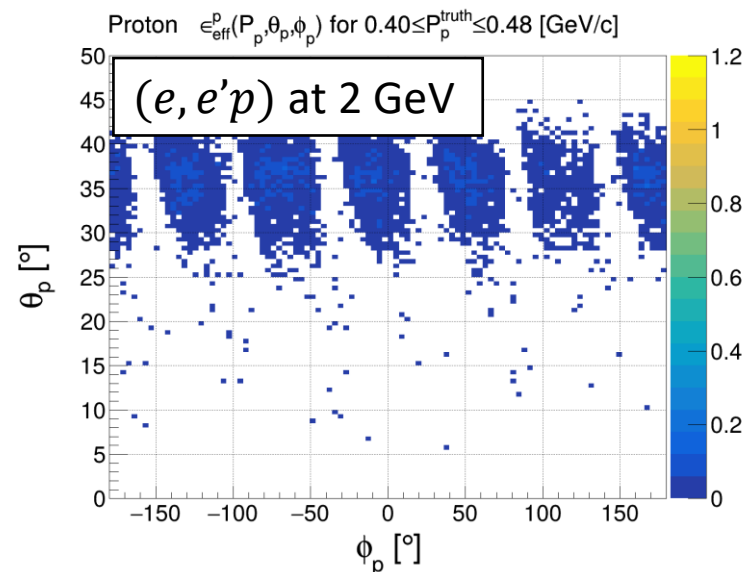
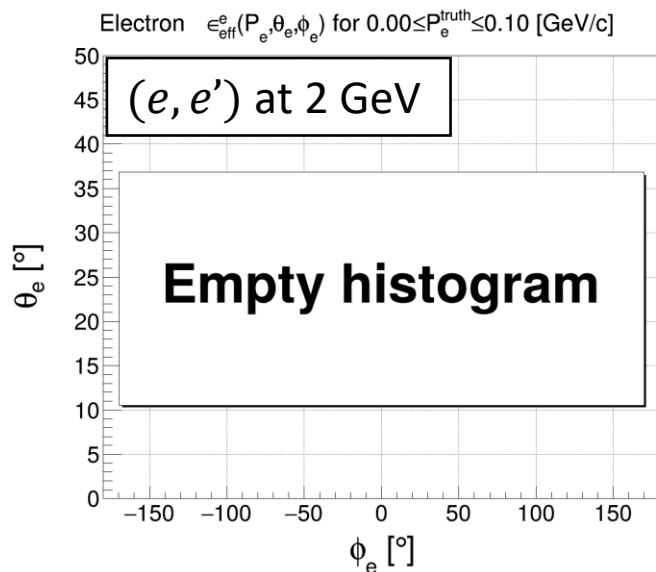
More about ^{40}Ar
implementation

List of completed
samples

Acceptance maps generation

- **Goal:** generate fiducial cuts for FD particles that are P , θ , and ϕ dependent using dedicated isotropic samples
- **The samples:**
 - **Split into 3 samples:** (e, e') – for electrons; $(e, e'p)$ – for protons; $(e, e'n)$ – for neutrons
 - Made with dedicated code; based on previous RGM work
 - The samples are *unphysical* – no momentum conservation is upheld
- **In $(e, e'p)$, $(e, e'n)$:** the electron is added as the trigger and constant in $P_e = E_{beam}$, θ_e and ϕ_e is “opposite” to the nucleon’s ϕ

Other acceptance maps results

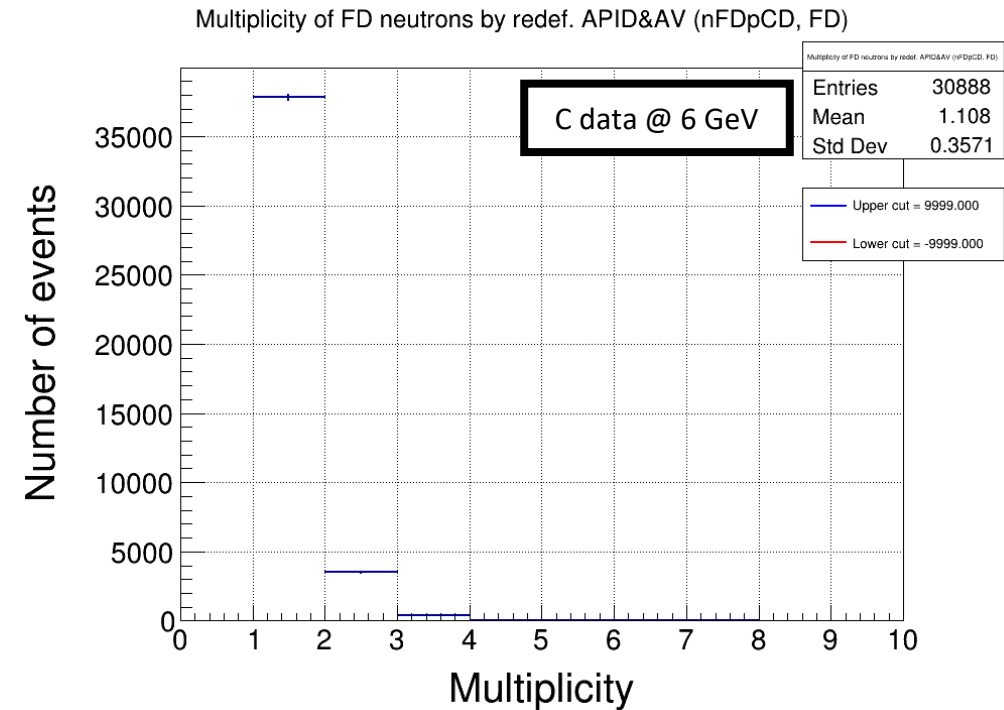
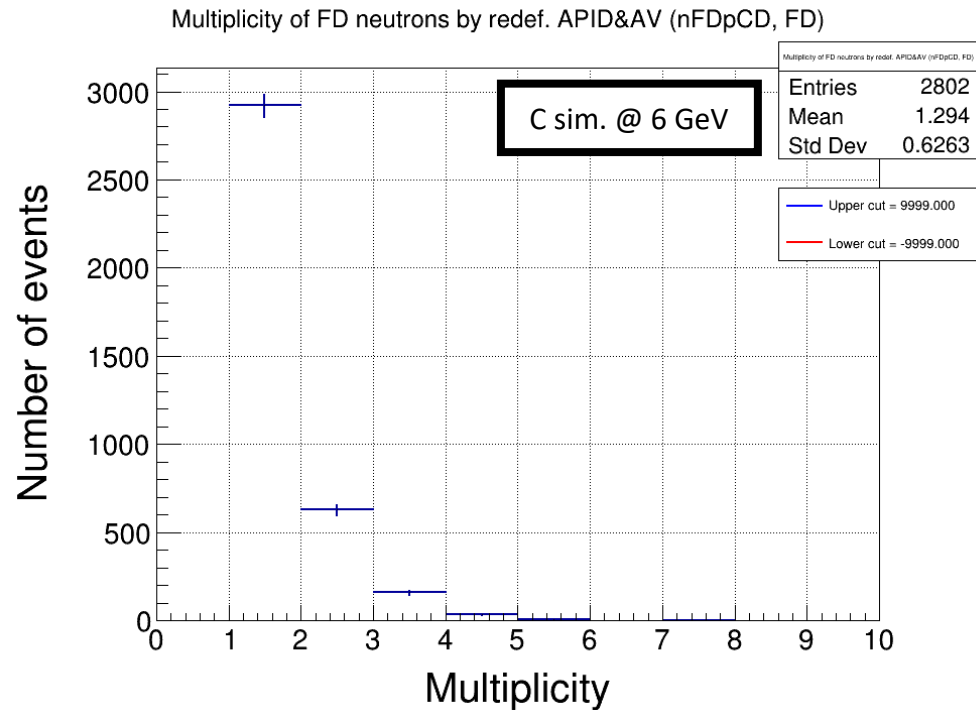


Current status of new acceptance maps

- The isotropic samples have already been generated, and so do the new maps
- The work is focused on new issues regarding FD neutron efficiency

Backup

nFD multiplicity in previous 2N analysis (1n1p events)



NOTE: these results are after all analysis cuts

New sample production

- **Expected statistics from truth-level (^{12}C):**
 - In table
 - Includes momentum and acceptance cuts!

GENIE tune	G18			SuSa		
Beam energy [GeV]	2	4	6	2	4	6
Fraction of 2p events (%)	0.04	0.04	0.03	0.06	0.13	0.05
Fraction of 1n1p events (%)	0.16	0.12	0.08	0.42	0.49	0.22

Fiducial cuts generation and application mechanism

Goals:

- Constrain the fiducial volume of electrons and FD nucleons based on acceptance efficiency:

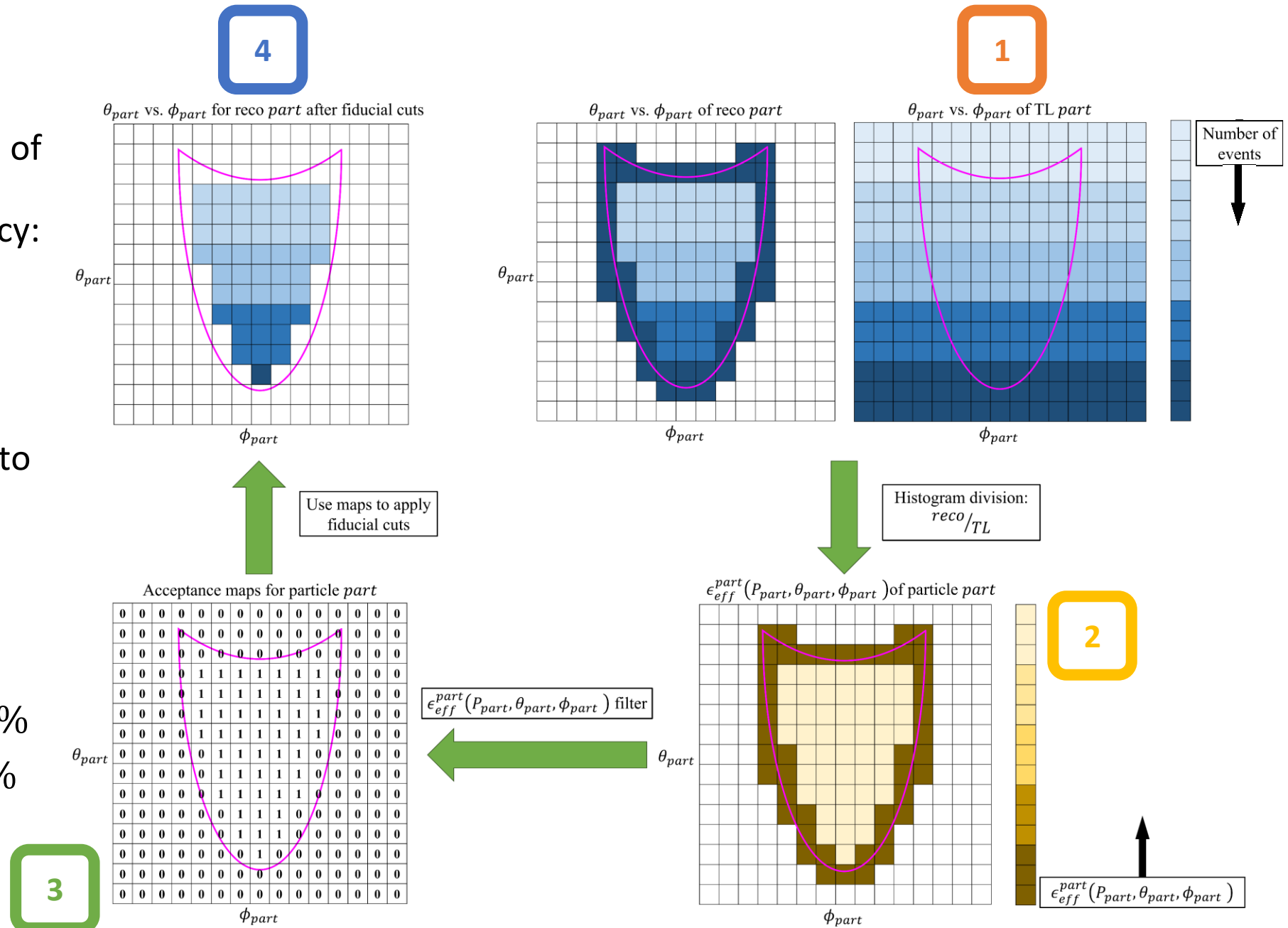
$$\epsilon_{eff}^{part}(P_{part}, \theta_{part}, \phi_{part})$$

where $part = e, p, n$

- FD nucleons, constrain them to the overlap of their “good” detection regions

ϵ_{eff} thresholds:

- Charged particles: $\epsilon_{eff} \geq 70\%$
- Neutral particles: $\epsilon_{eff} \geq 20\%$

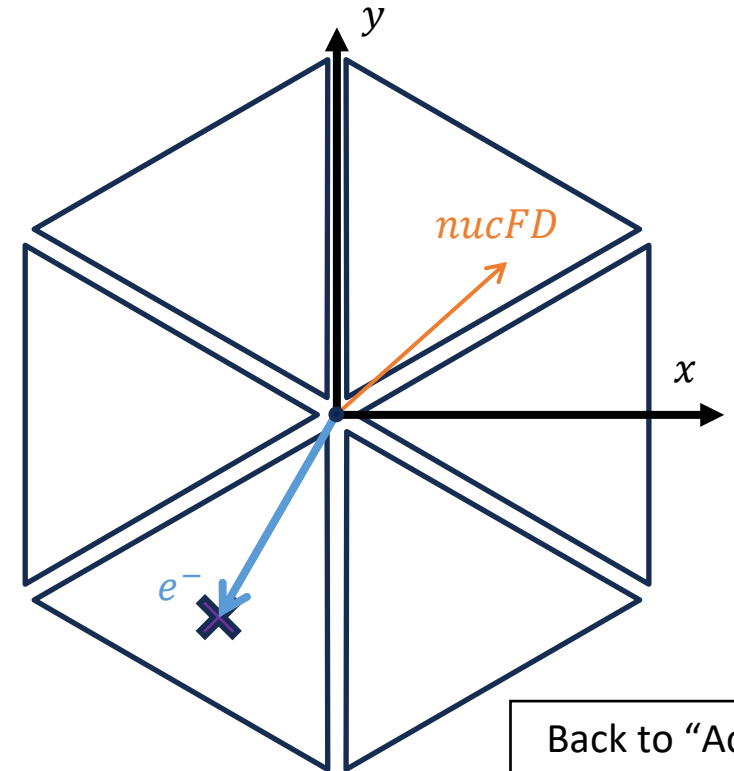


Generating uniform samples – phase space coverage

Sample	θ_e		ϕ_e		P_e		θ_{nuc}		ϕ_{nuc}		P_{nuc}	
	Min. θ_e [°]	Max. θ_e [°]	Min. ϕ_e [°]	Max. ϕ_e [°]	Min. P_e [GeV/c]	Max. P_e [GeV/c]	Min. θ_{nuc} [°]	Max. θ_{nuc} [°]	Min. ϕ_{nuc} [°]	Max. ϕ_{nuc} [°]	Min. P_{nuc} [GeV/c]	Max. P_{nuc} [GeV/c]
$(e, e'p)$	25 (constant)		$\phi_0 + \{-120, -60, 0, 60, 120, 180\}$ that is the closest to 180 away from ϕ_{nuc}		E_{beam} (constant)		5	45	-180	180	0.3	E_{beam}
$(e, e'n)$							5	35				

• ϕ_0 - varies with E_{beam} . Accounts for the solenoid field:

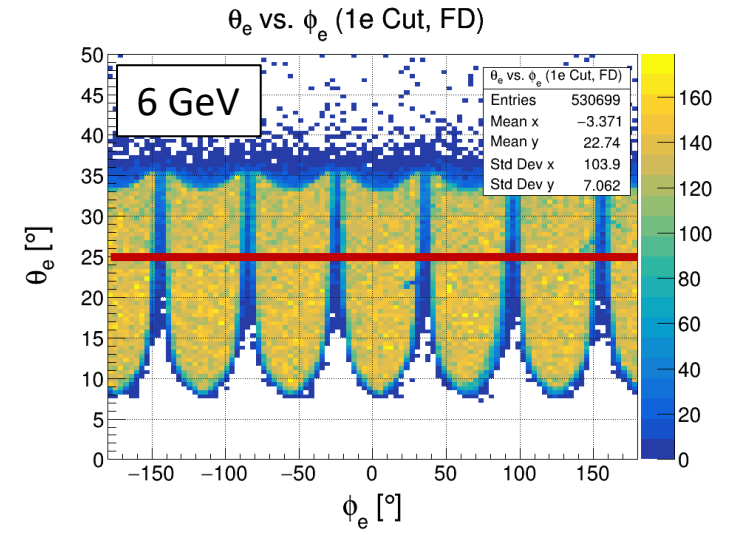
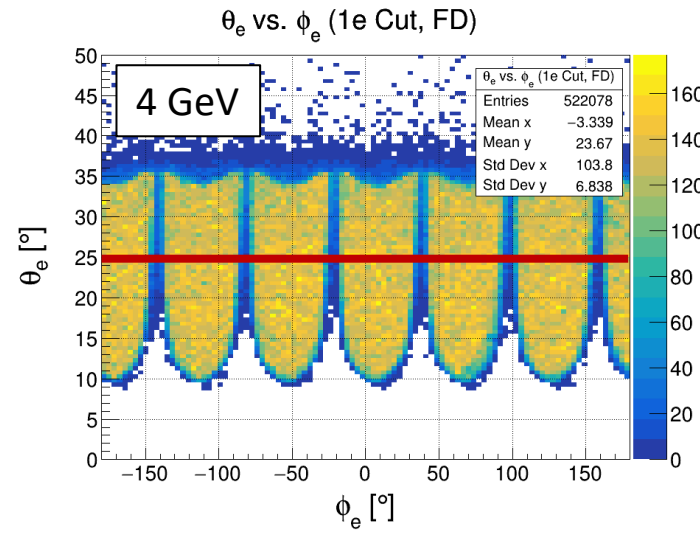
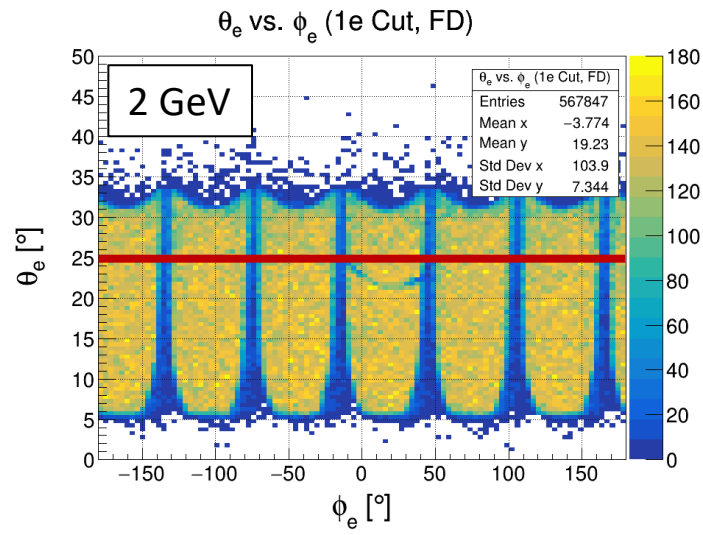
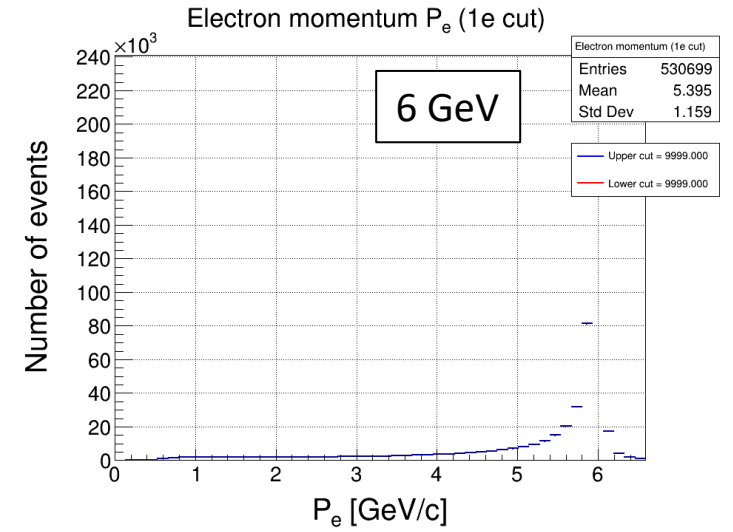
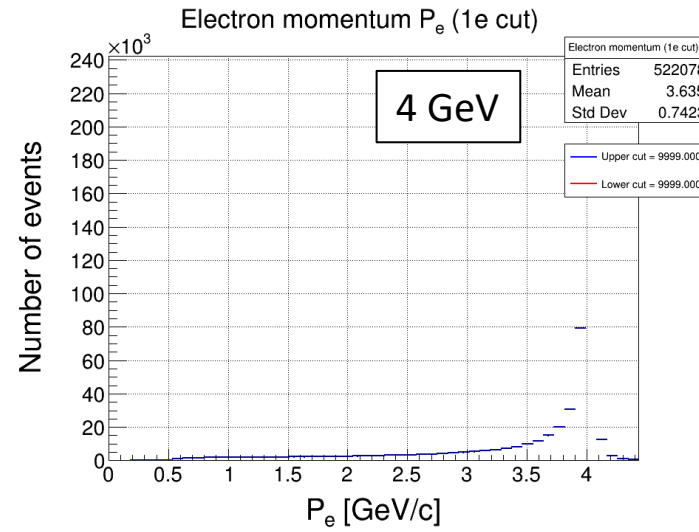
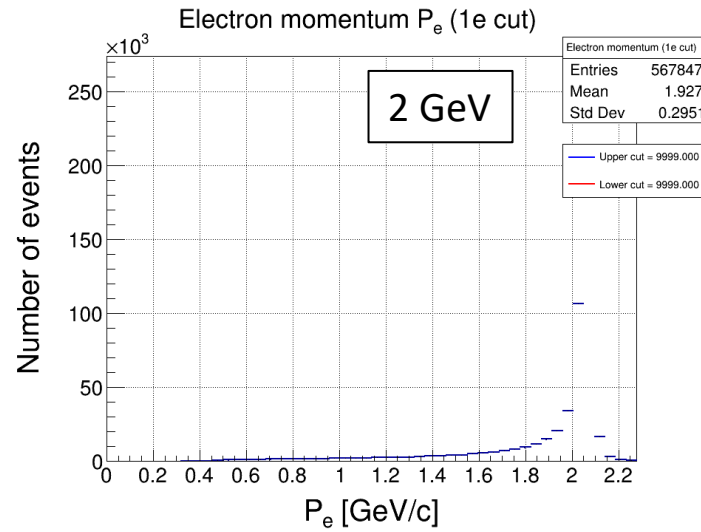
- $E_{beam} = 2 \text{ GeV}$: $\phi_0 = 16^\circ$
- $E_{beam} = 4 \text{ GeV}$: $\phi_0 = 7^\circ$
- $E_{beam} = 6 \text{ GeV}$: $\phi_0 = 5^\circ$



Back to “Acceptance maps generation”

Tester_e for 2,4,6 GeV – one reco e^- and NO CUTS

Sample	Min. θ_e [°]	Max. θ_e [°]	Min. ϕ_e [°]	Max. ϕ_e [°]	Min. P_e [GeV/c]	Max. P_e [GeV/c]	Min. θ_{nuc} [°]	Max. θ_{nuc} [°]	Min. ϕ_{nuc} [°]	Max. ϕ_{nuc} [°]	Min. P_{nuc} [GeV/c]	Max. P_{nuc} [GeV/c]
e^- testing sample	5	40	-180	180	E_{beam} (constant)		-	-	-	-	-	-

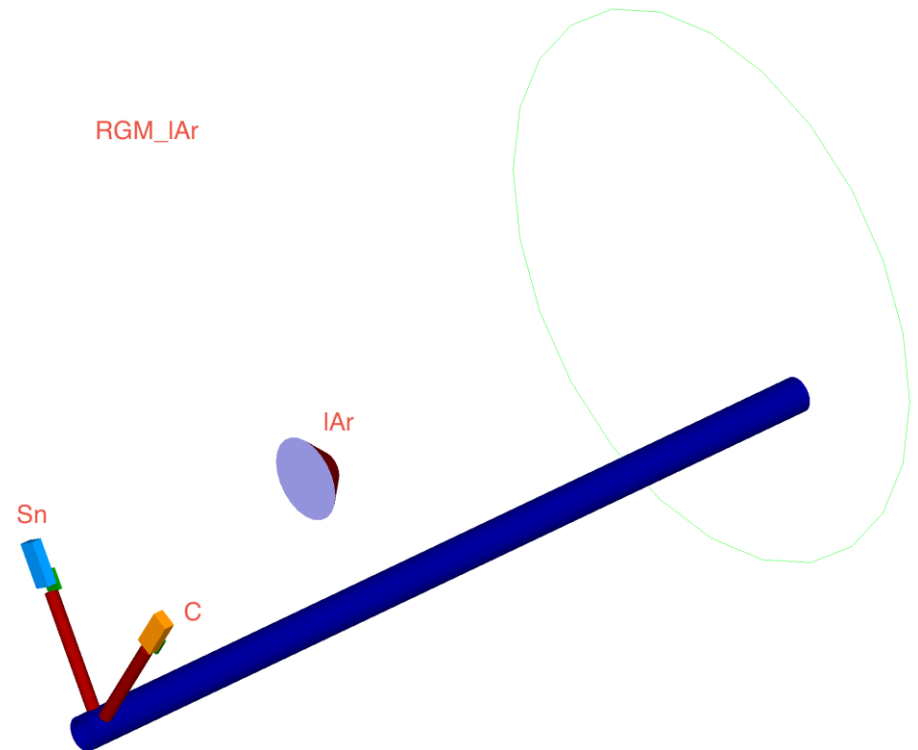
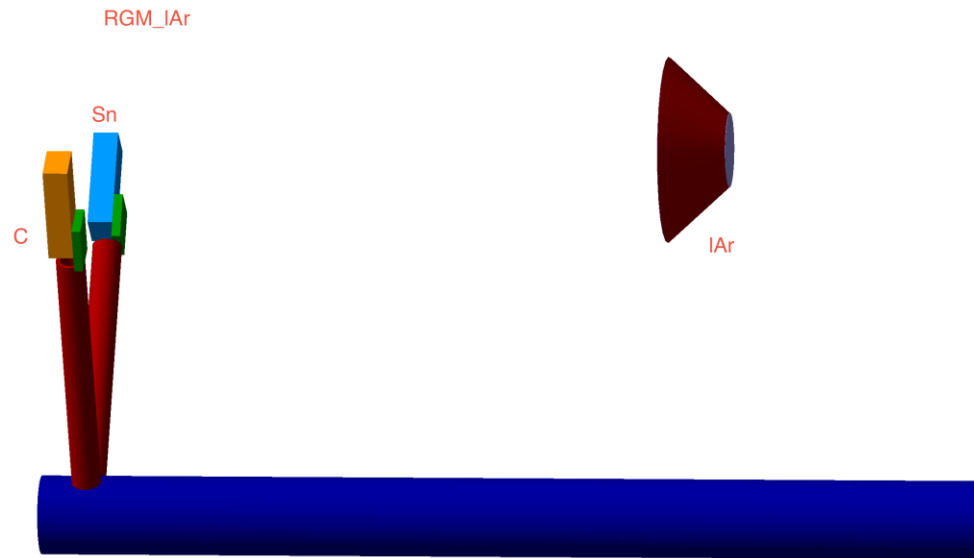


3 new variations added:

- **RGM_IAr**: Ar40 implementation. Includes 1-foil C and Sn targets, rotated to $\pm 30^\circ$
- **RGM_2_C_v2_S**: 1-foil C and Sn targets, rotated to C (small foils)
- **RGM_2_C_v2_L**: 1-foil C and Sn targets, rotated to C (large foils)

Current status – ^{40}Ar implementation:

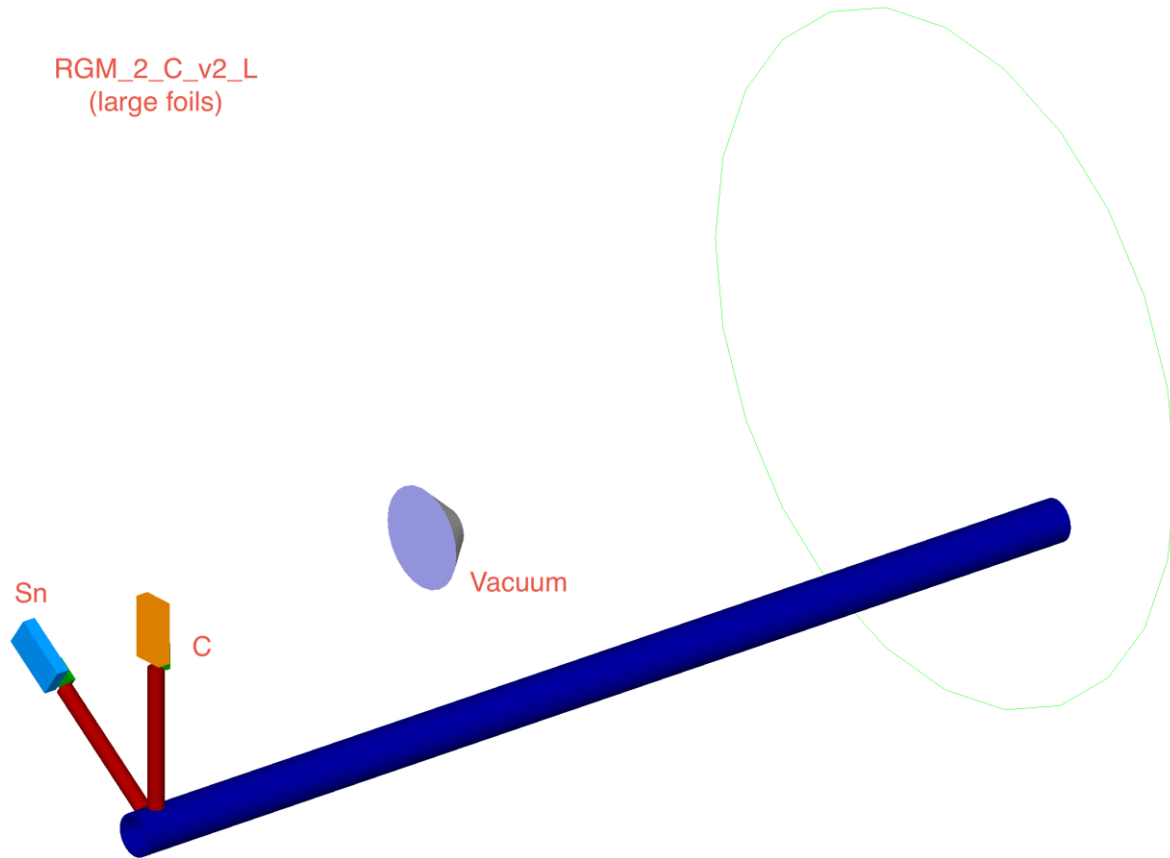
- Code for implementation – about finished
- Work waits for testing



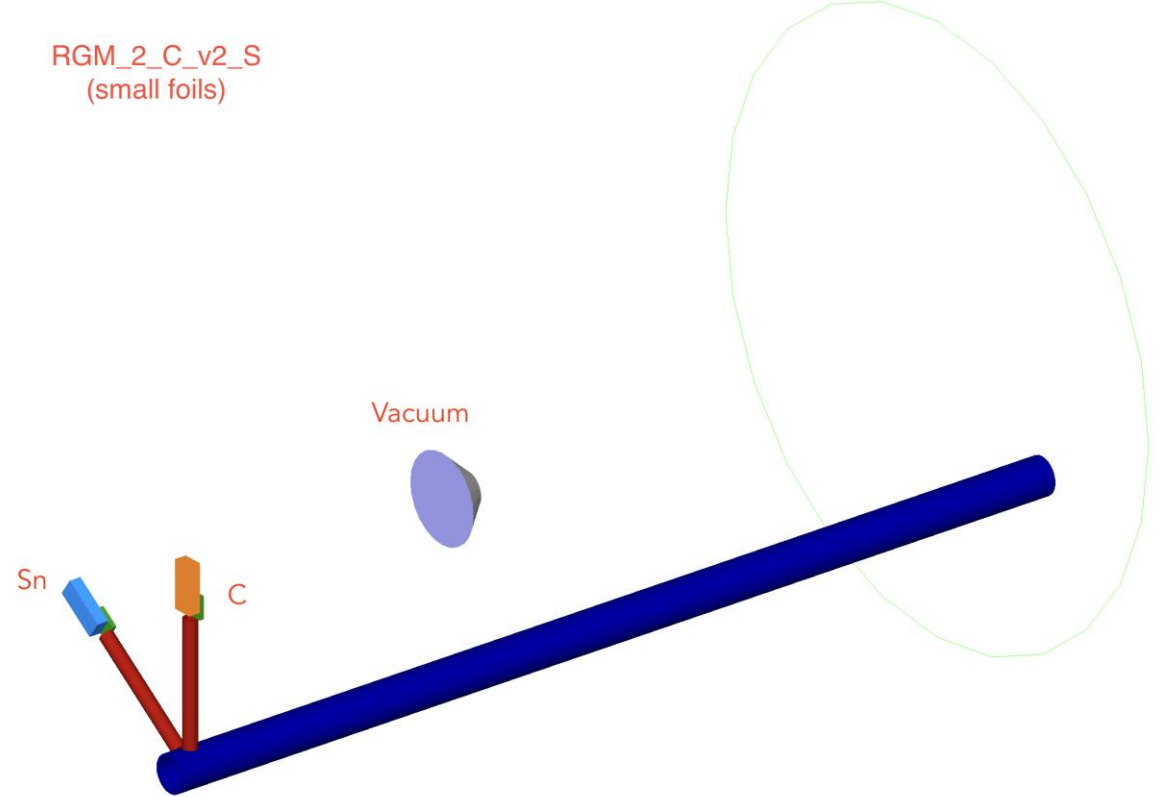
Back to “New sample production”

The ^{40}Ar implementation in GEMC

RGM_2_C_v2_L
(large foils)



RGM_2_C_v2_S
(small foils)



Back to "New sample production"