

External Backgrounds (γs) in partial-fill and the Rope Analysis

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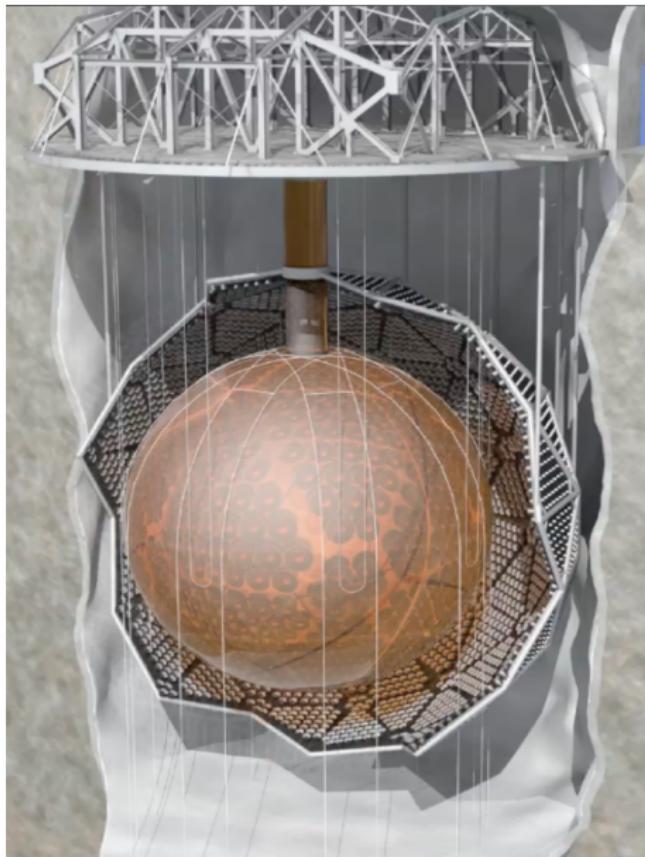
August 13, 2021



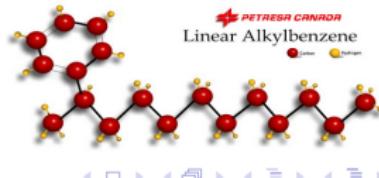
- PhD candidate,
Laurentian University/
SNO+
- Weekend line cook,
Motley Kitchen.



The SNO+ Experiment



- 2km Underground at SNOLAB in Vale's Creighton Mine (~ 70 cosmic muons/day)
- Acrylic vessel (AV): 6m radius, 5cm thickness
- 9400 Photo Multiplier Tubes (PMTs), ~ 8 m radius PSUP
- 905 tonnes of ultra-pure water/ 780 tonnes of liquid scintillator based cocktail
- 7000 tonnes external water shielding.

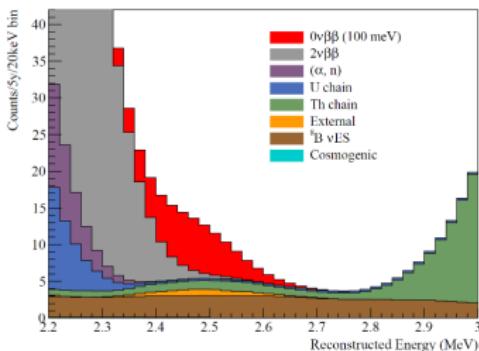
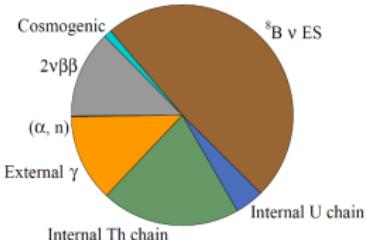


What is SNO+ searching for?

Physics Goals

- Water Phase: ^8B Solar Neutrinos and Invisible nucleon decay¹.
- Pure Scintillator Phase: Solar neutrinos, Geo/Reactor anti-neutrinos, and study internal backgrounds.
- Tellurium-loaded Scintillator: **Neutrino-less double beta decay with ^{130}Te**
- All phases:
 - Supernova Neutrinos
 - Reactor- and Geo- antineutrinos

ROI: 2.42 - 2.56 MeV [-0.5 σ - 1.5 σ]
Counts/Year: 9.47



¹see Physical Review D 99 (1), 012012 & Physical Review D 99 (3), 032008).

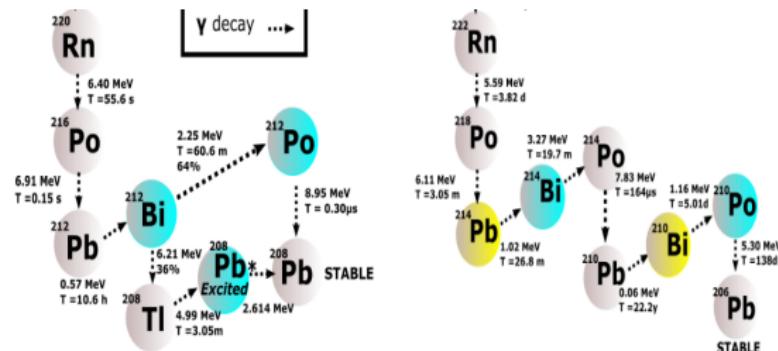
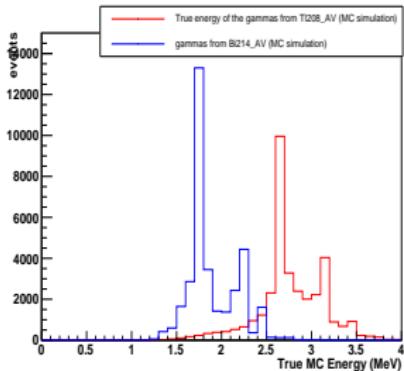
Current Status

- **Water phase data taking 2017-2019** - In addition to Physics and calibration, SNO+ made a measurement of external backgrounds (γ s).
- **Partial-fill 2020 APR-NOV**: Filling process stopped due to COVID-19 for 7 months while the detector was half-full.
- SNO+ used the partial-fill data to study internal/external backgrounds in scintillator.
- Detector is full and SNO+ is about to start the scintillator phase.



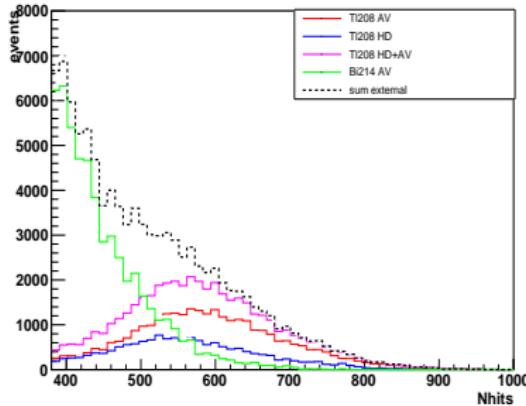
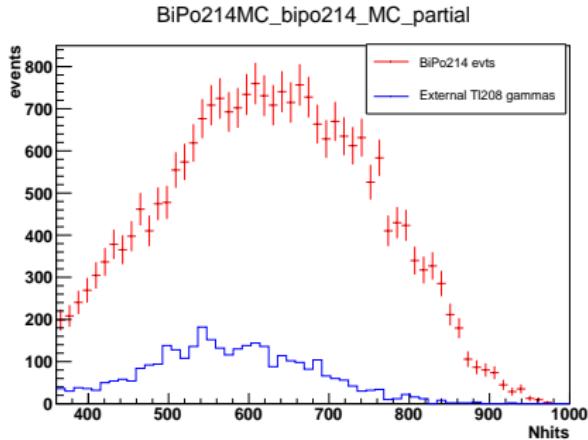
External γ s from ^{208}Tl and ^{214}Bi and ^{40}K

- External Backgrounds: High energy γ s from Tl208, Bi214 and K40 which are generated outside of the scintillator volume (AV) but can propagate and reconstructed inside.
- They come from the AV. external water, HU/HD ropes, PMTs, ...
- **Tl208** generate γ s up to 2.6 MeV which can be background for $0\nu\beta\beta$ and solar signals.



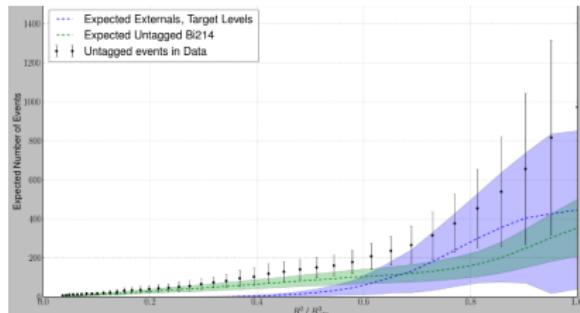
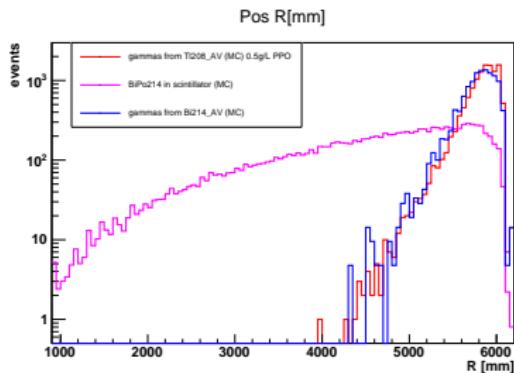
Identification of the 2.6 MeV γ s from external ^{208}TI in partial-fill

- The major background for this signal are the ^{214}Bi and ^{212}Bi β decays inside the detector.
- Bi-Po events are tagged using the delayed coincidence tagging technique.
- A set of MC was generated including the external signals as well as ^{214}Bi -Po in partial fill with the interface at 0.8 m and 0.5 g/L PPO.

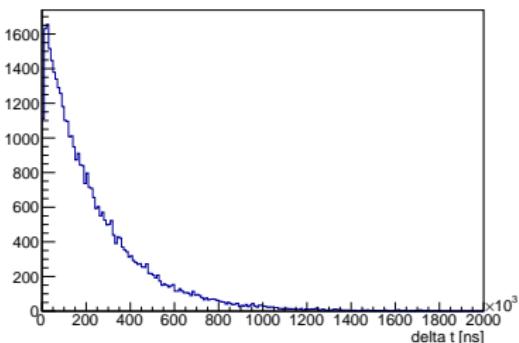
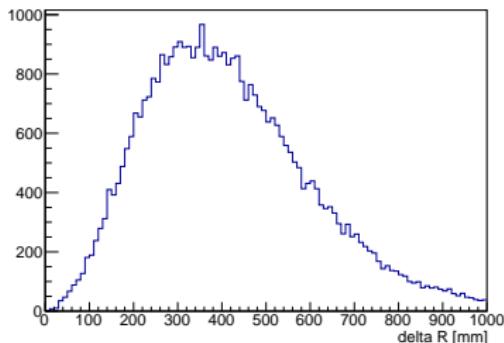
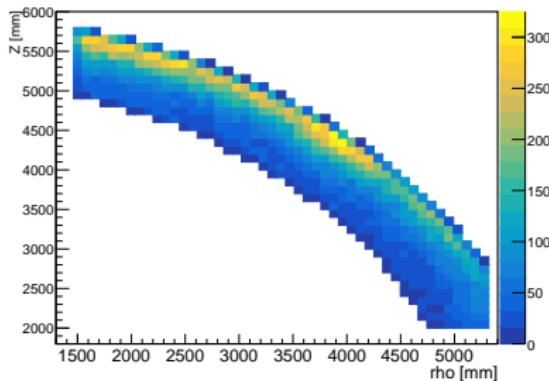
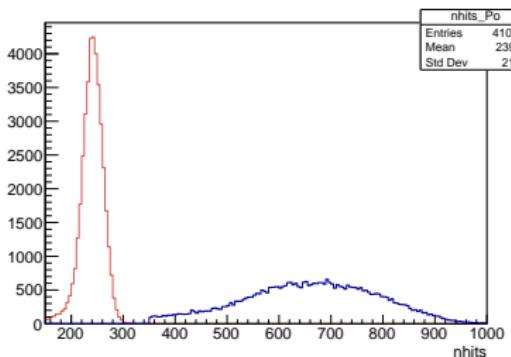


$^{214}\text{BiPo}$ rejection efficiency and the external sacrifice

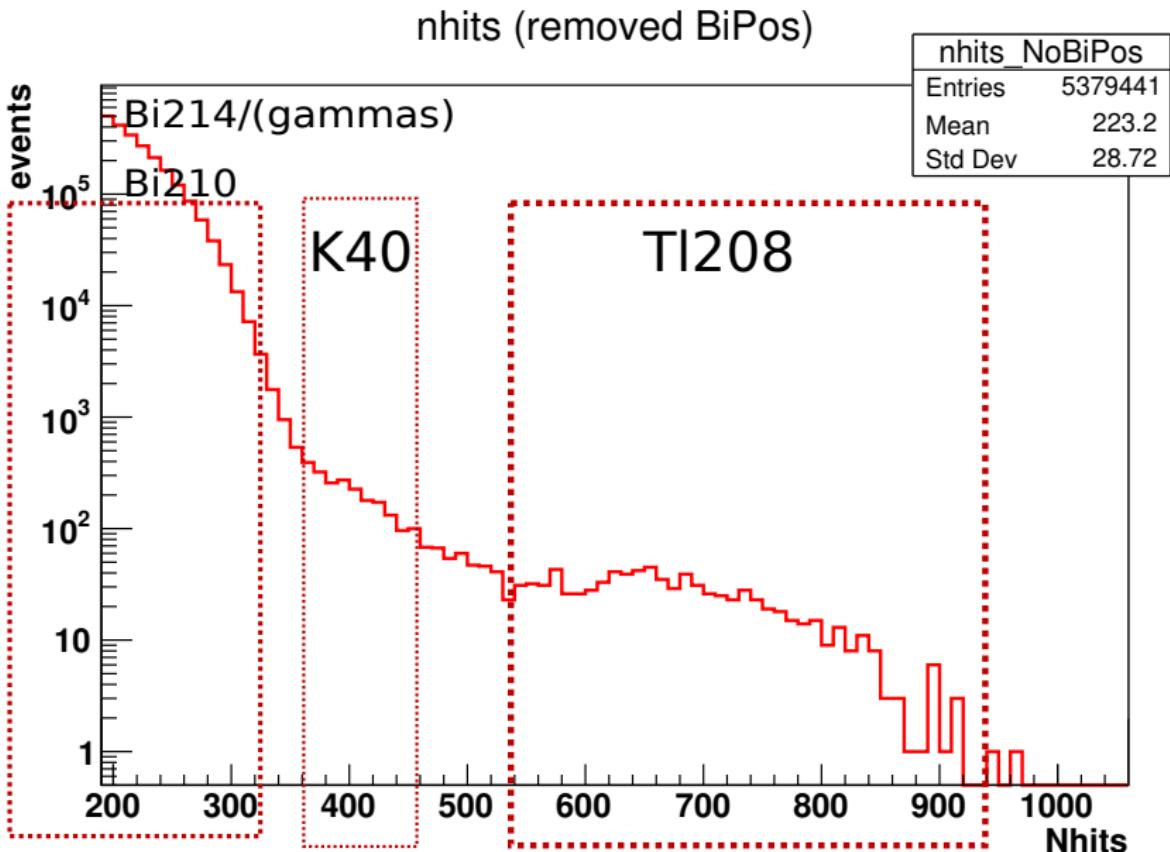
- 99% of the externals are being reconstructed beyond $R > 5.2\text{m}$ according to MC.
- ROI: $5.2\text{m} < R & 2\text{m} < \rho$ (to avoid PFA tubing) & $1.5 < z < 5.3\text{m}$
- For rope studies the same cuts were used plus $1.5 < z < 3\text{m}$



Tagging and rejecting $^{214}\text{BiPo}$ events for $4.2m < R$ between 20200401 and 20200808 (70 days, most of June/July data are not included!)

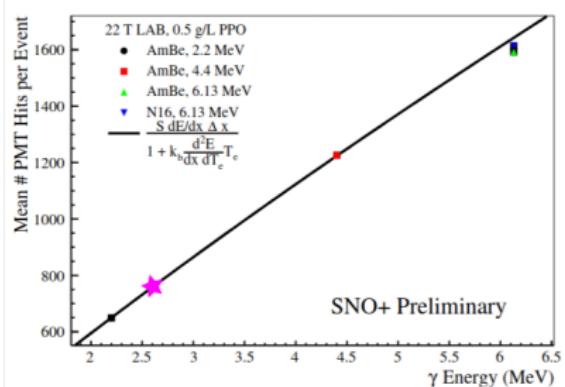
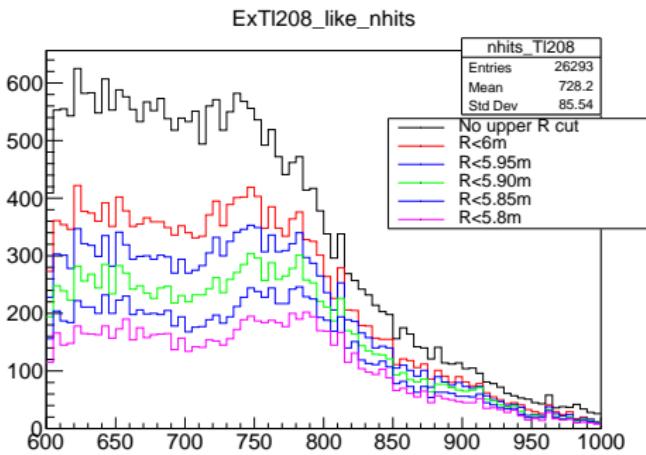


Removing BiPo214/212 events



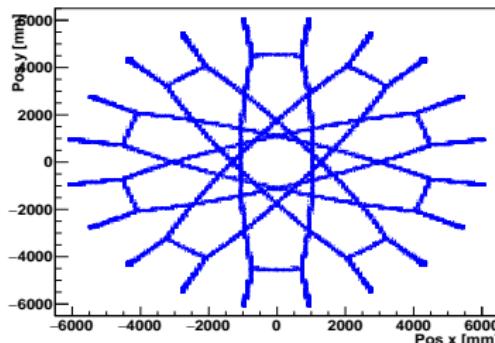
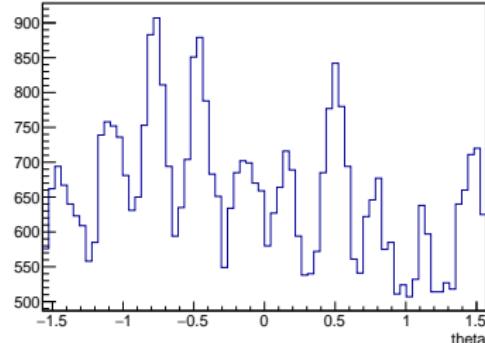
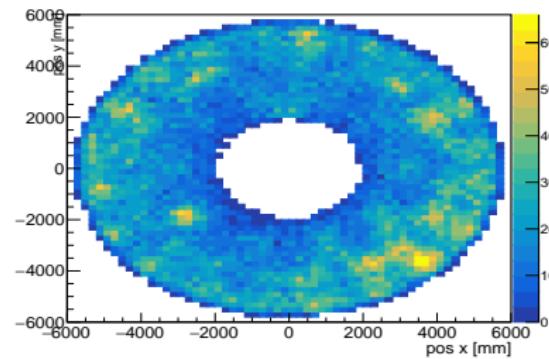
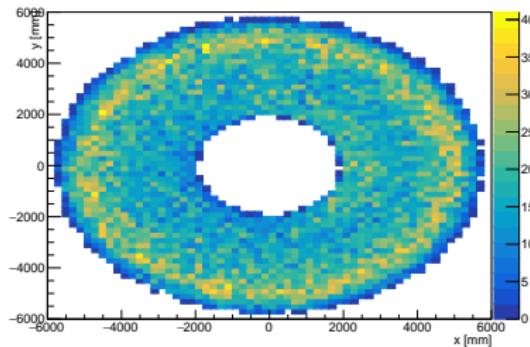
Removing BiPo214/212 events and identifying ^{208}TI signal

- The fit values: $\mu = 762 \pm 86$ consistent with the calibration light curve.
- Light yield has a significant radial dependency.



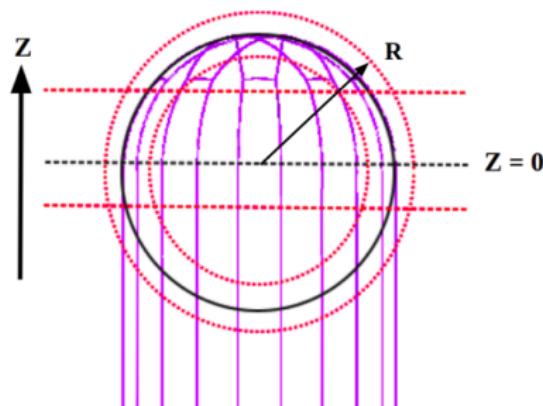
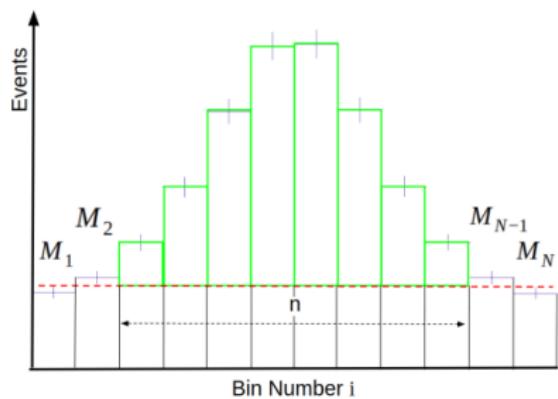
Reconstructed position and angular distribution

- Total events with a valid fitter:
- after tagging and rejecting BiPo214/212s:

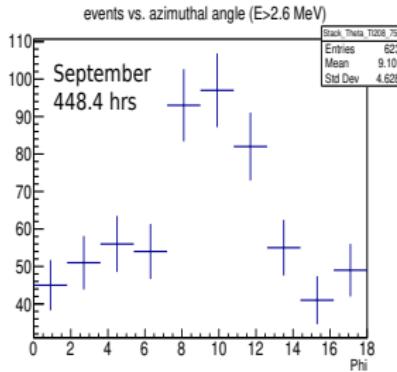
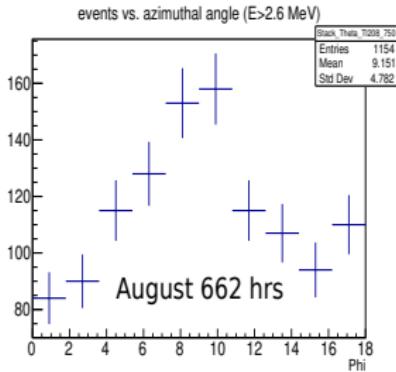
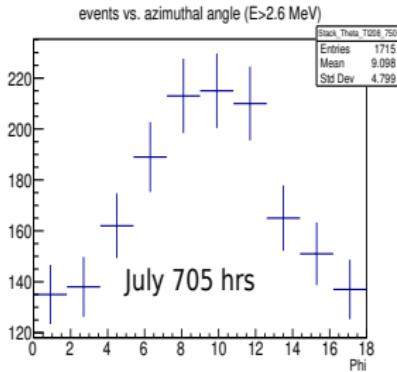
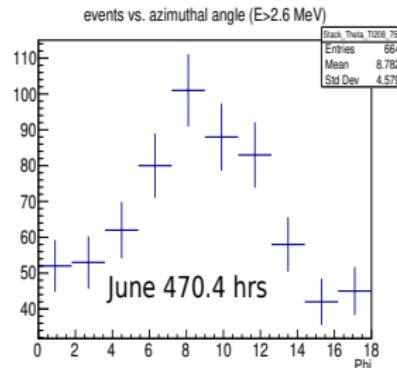
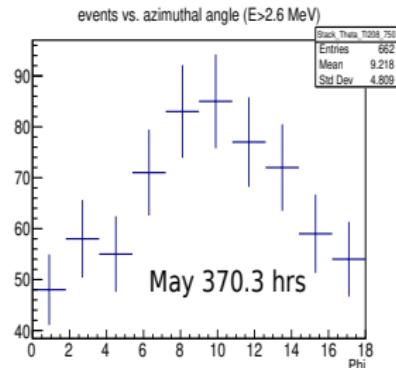
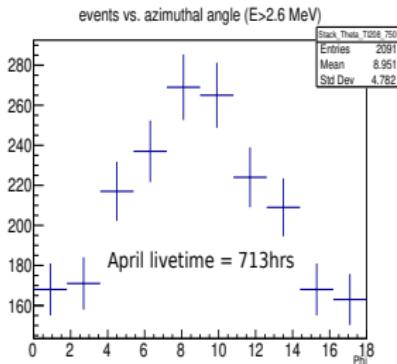


Azimuthal analysis of the ropes through stacking method

- Rope Analysis cuts: $1.5 < Z < 3\text{m}$ & $5.2\text{m} < R <$ energy $> 2.6\text{MeV}$.
- Stacking method done is used to measure the level of background from the HD ropes. (see SNO+-doc-5169-v1).

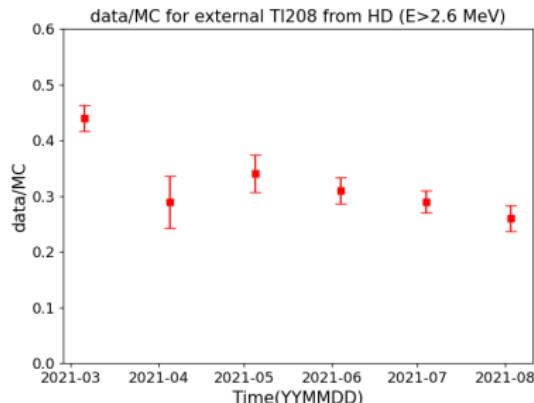
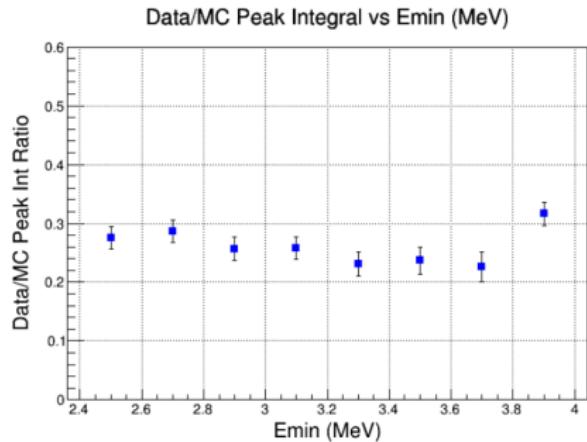


Month by month Azimuthal analysis of data (20200401-20200920)



Conclusions and the next steps

- The 2.6 MeV γ s is identified in partialfill, and used for calibration purposes.
- The γ s from the ropes is estimated in partialfill and (data/MC) is consistent with previous measurements. $\text{data}/\text{MC} \sim 0.31 \pm 0.04$ ([doc-6580-v1](#)).
- In order to reject the externals several classifiers are developed and optimized based on timing and geometry of the events.



MC production for partial-fill and expected rate of external backgrounds.

- RAT-6.18.7

source	Tl208 AV	Tl208 HD	K40 AV	K40 HD	K40 water	Bi214 AV	Bi214 HD	PMT gammas Tl208
Expected number of evts/year	1.5e+06	(2.32/1.55)e+6 (full/shell)	7.32e+7	1.89e+8	3.92e+06	2.67e+6	(4.06/2.72)e+6 (full/shell)	—
Simulated evts.	614248	580637	3044471	5442269	—	1130866	542112	500458
Scale factor (roughly 70 days)	0.5856	0.64021	—	0.2046	2.7923			
No. of evts with valid fit		165100						
No, events Rope cuts** with E>2.6 MeV Nhit>600 (MC)		2057						

Backup; BiPo214 tagging

BiPo214 Coincidence Tagging

- Inter-event cut:
 - Δt : (4000ns, 1ms)
 - Δr : [0, 1000mm]
- Delayed event (Po214):

- Nhit cut:

Before 30/06/21: (120, 320)

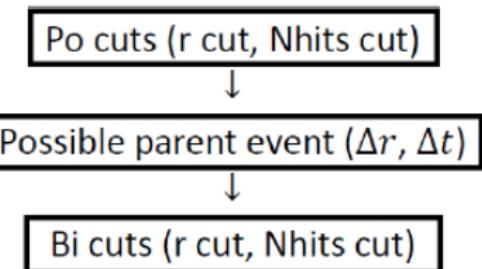
After 30/06/21: (120, 320) for $Z > 0$ and (150, 320) for $Z < 0$

- Prompt event (Bi214):

- Nhit cut:

Before 30/06/21: (300, 1050)

After 30/06/21: (300, 1050) for $Z > 0$ and (350, 1050) for $Z < 0$



BiPo212 Coincidence Tagging

- Inter-event cut:

- Δt : (400ns, 800ns)

- Δr : [0, 1000mm]

- Delayed event (Po212):

- Nhit cut:

Before 30/06/21: (230, 300)

After 30/06/21: (230, 300) for $Z > 0$ and (230, 380) for $Z < 0$

- Prompt event (Bi212):

- Nhit cut: (120, 750)