Towards Background Model 2

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Background Model 2

Position	Isotope	Activity/Unit	Reference
LAr	^{39}Ar	0.00141 Bq/cc	MCC11
LAr	^{42}Ar	0.0001283768 Bq/cc	MCC11
LAr	^{85}Kr	0.00016 Bq/cc	MCC11
LAr	^{222}Rn	0.0000014 Bq/cc	New Goal
APA frame steel	^{60}Co	0.000082 Bq/cc	MCC11, MPIK
APA frame steel	^{238}U	0.0216 Bq/cc	Requirement
APA frame steel	^{232}Th	0.00018 Bq/cc	ProtoDUNE I Beam
APA CuBe wires	U early	0.000000258 Bq/cc	Measurement
APA CuBe wires	U late	$\leq$0.00000000034 Bq/cc	Measurement
APA CuBe wires	Th early	0.0000000086 Bq/cc	Measurement
APA CuBe wires	Th late	0.00000001 Bq/cc	Measurement
APA CuBe wires	^{40}K	0.0000039 Bq/cc	Measurement
APA electronic boards	^{40}K	0.0000037 Bq/cc	Majorana
APA electronic boards	^{238}U	0.0000058 Bq/cc	Majorana
APA electronic boards	^{232}Th	0.0000036 Bq/cc	Majorana
CPA	^{40}K	0.0027195 Bq/cc	MCC11
CPA	^{238}U	0.06105 Bq/cc	Requirement
PDs	^{222}Rn	0.000005 Bq/cc	MCC11
PDs	^{210}Po	0.0000001 Bq/cc	Estimation
Field Cage	^{40}K	0.000348 Bq/cc	EDELWEISS
Field Cage	^{226}Ra	0.000216 Bq/cc	EDELWEISS
Field Cage	^{228}Th	0.000427 Bq/cc	EDELWEISS

Table 1: Background Model 2

- Same as BG Model 1.0
- New radiopurity goal
- Measurements of materials
- Estimation based on others' experiments.

Full table available here: https://www.overleaf.com/6175337632brpsxjfxmryc

New Radiological fcl File

- Materials: more materials are now included, such as APA wires, Field Cage, etc.

- Isotopes: more radioactive isotopes in detector components and materials, especially those from ^{232}Th Chain and ^{208}Tl.

- Activities: up-to-date activity.

Isotopes in U and Th Chains

Checked the whole decay chain to make sure we have all "dangerous" alpha and beta emitter considered.

isotope	decay mode	energy (MeV)	in decay0	note
^{238}U	alpha	4.270	yes	
^{234}Th	beta	0.273	yes	
^{234m}Pa	beta	2.195	yes	
^{234}U	alpha	4.859	yes	
^{230}Th	alpha	4.770	yes	
^{226}Ra	alpha	4.871	yes	
^{222}Rn	alpha	5.590	yes	
^{218}Po	alpha	6.114	yes	beta (0.02%) Q=0.265
^{214}Pb	beta	1.024	yes	
^{214}Bi	beta (99.979%)	3.272	yes	to ^{214}Po
	alpha (0.021%)	5.617	yes	to ^{210}Tl
^{214}Po	alpha	7.833	yes	BiPo event
^{210}Tl	beta	5.489	no	
^{210}Pb	beta	0.063	yes	alpha(1.9E-6%)
^{210}Bi	beta	1.162	yes	alpha(1.32E-4%) Q=5.036
^{210}Po	alpha	5.407	yes	

Table 1: Alpha and beta emitters in ^{238}U Chain.

isotope	decay mode	energy (MeV)	in decay0	note
^{232}Th	alpha	4.083	no	
^{228}Ra	beta	0.046	yes	
^{228}Ac	beta	2.127	yes	
^{228}Th	alpha	5.520	no	
^{224}Ra	alpha	5.789	no	
^{220}Rn	alpha	6.405	no	
^{216}Po	alpha	6.907	no	
^{212}Pb	beta	0.574	yes	
^{212}Bi	beta (64.06%)	2.254	yes	to ^{212}Po
	alpha (35.94%)	6.207	yes	to ^{208}Tl
^{212}Po	alpha	8.954	yes	BiPo event
^{208}Tl	beta	5.001	yes	

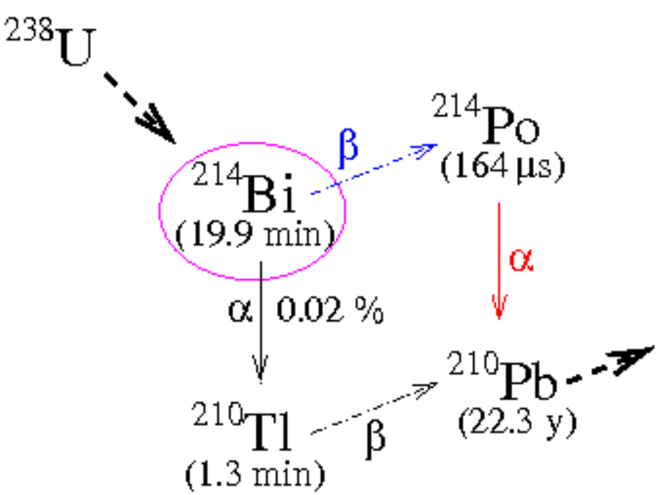
Table 2: Alpha and beta emitters in ^{232}Th Chain.

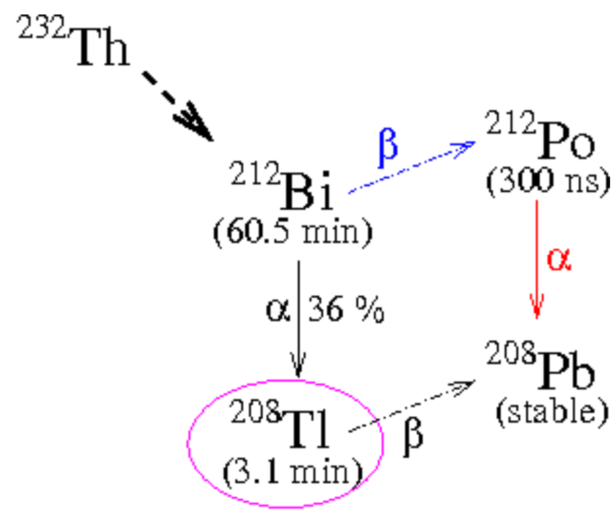
Full table available here: https://www.overleaf.com/6175337632brpsxjfxmryc

Adding Tl208 & Tl210

Added some decays that were not considered in MCC11, such as: Tl208, Tl210. BiPo event was generated automatically, but the Tl was ignored in the past. And unfortunately can not be simply added to the chain.

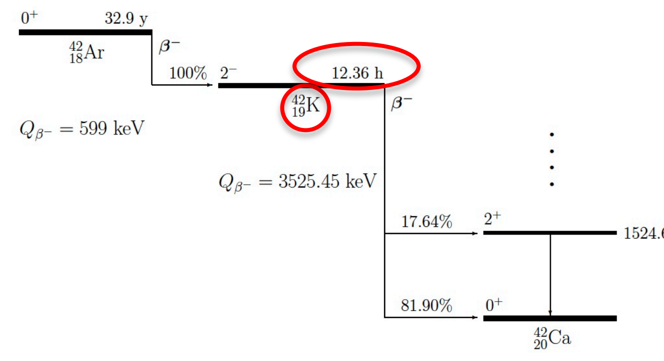
My solution: treat them as separate isotopes, and use the modified activity = branching ratio * activity of the Th232/U238 chain respectively.





Positive ^{42}K ions

- GERDA observed positive ^{42}K ion collection on the surface by E-field.



Simplified decay scheme of ^{42}Ar.

- Exo-200 reported that, in LXe (76.4±5.7)% of ^{214}Bi ions from ^{214}Pb β-decay are positive.

- I would suggest that we use ~80% for ^{42}K as positive ions in LAr from ^{42}Ar β-decay

- 80% on CPA, 20% (neutral) uniform in LAr.

Simulation of Radon in LAr

- Start with ^{222}Rn Chain in LAr. This is a very preliminary study.

- Full BG simulation is coming soon.

- Larsoft and dunetpc version:

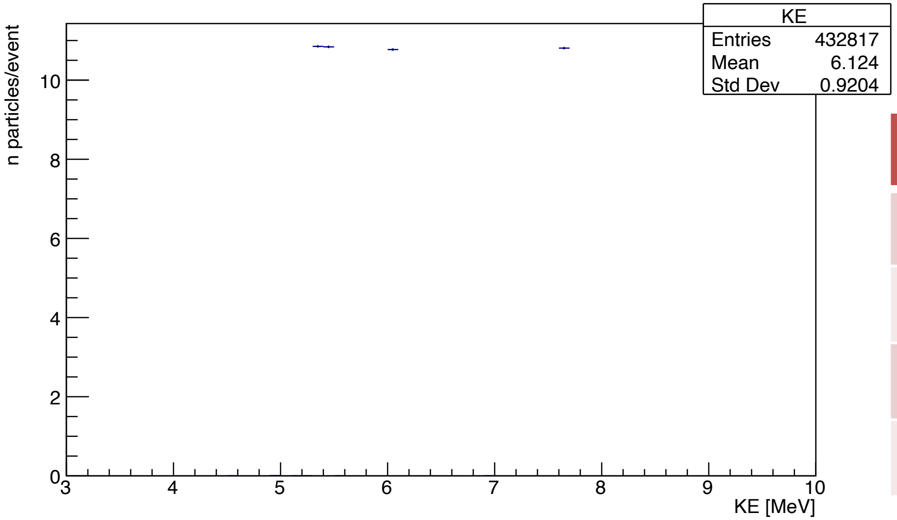
  larsoft_v09_10_02_e19_prof

  dunetpc develop branch (v09_10_02)

- Generator: RadioGen vs DECAY0

α Energy of ^{222}Rn Chain

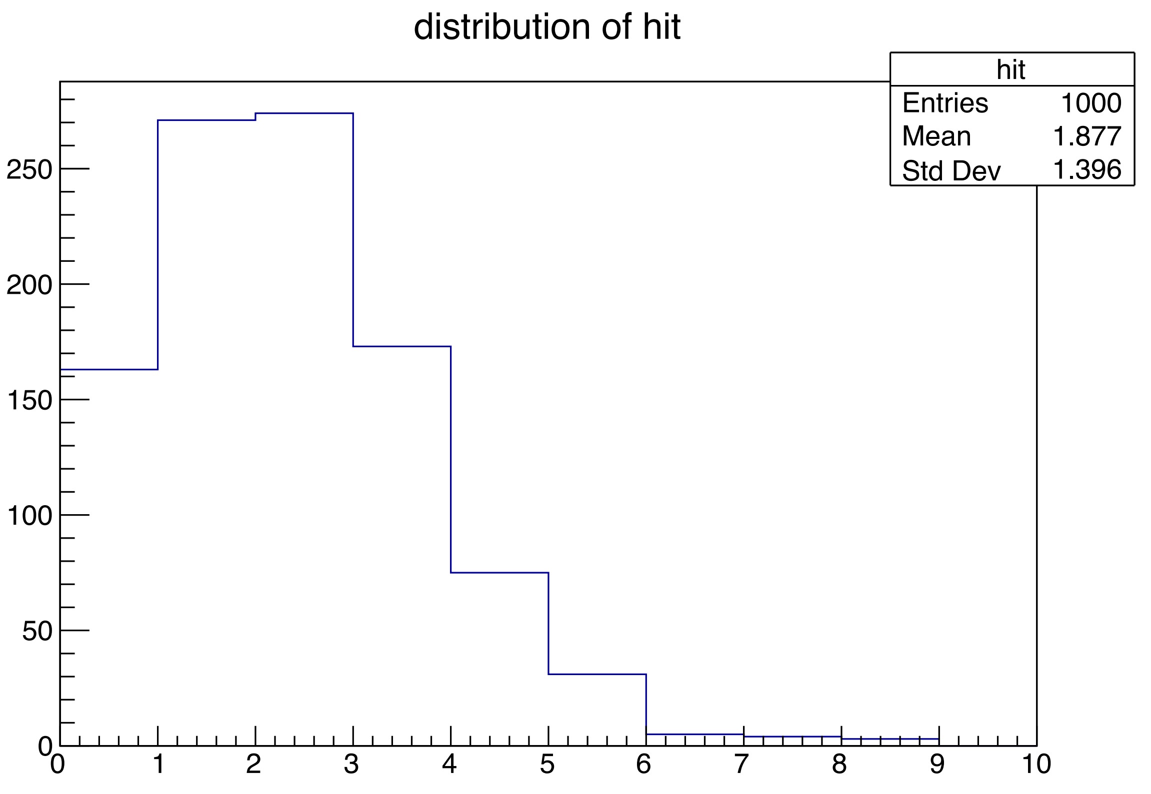
α energy generated by decay0 generator is 5.48948 MeV (99.922%) and 4.986 MeV (0.078%), and it was 5.5903 MeV from in RadioGen module used for MCC11.



Alpha KE generated by decay0 generator

Isotope	KE
Rn-222	5.48948 MeV
Po-218	6.002 MeV
Po-214	7.687 MeV
Po-210	5.306 MeV

Distribution of Hits – RadioGen



Rn: 5.584E-6 Bq/cc

(1.4E-6Bq/cc * 4 alphas

0.1 mBq/kg)

Simulated 1000 events

0 hit 16.3%

1 hit 27.3%

2 hits 27.4%

3 hits 17.3%

4 hits 7.5%

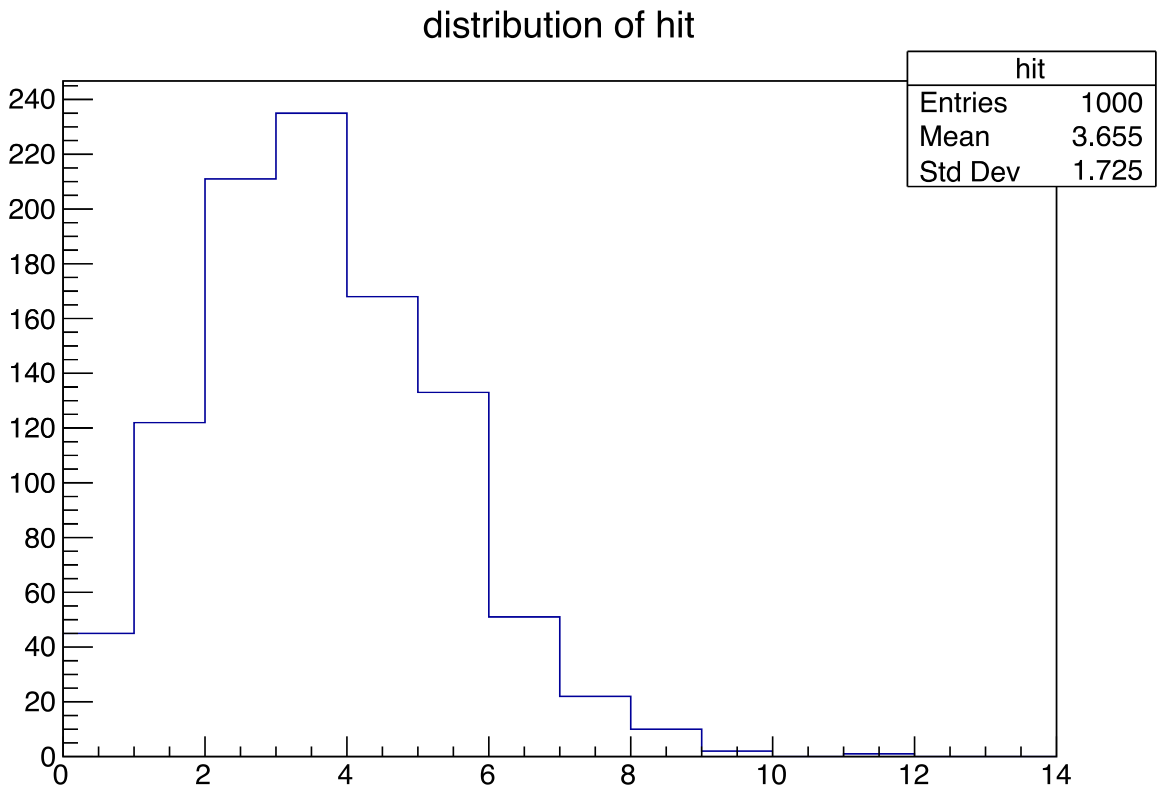
5 hits 3.1%

6 hits 0.6%

7 hits 0.4%

8 hits 0.3%

Distribution of Hits – Decay0



Possible reason: pile-up events

Rn: 1.4E-6 Bq/cc

Simulated 1000 events

0 hit 4.5%

1 hit 12.3%

2 hits 21.1%

3 hits 23.5%

4 hits 16.8%

5 hits 13.3%

6 hits 5.1%

7 hits 2.2%

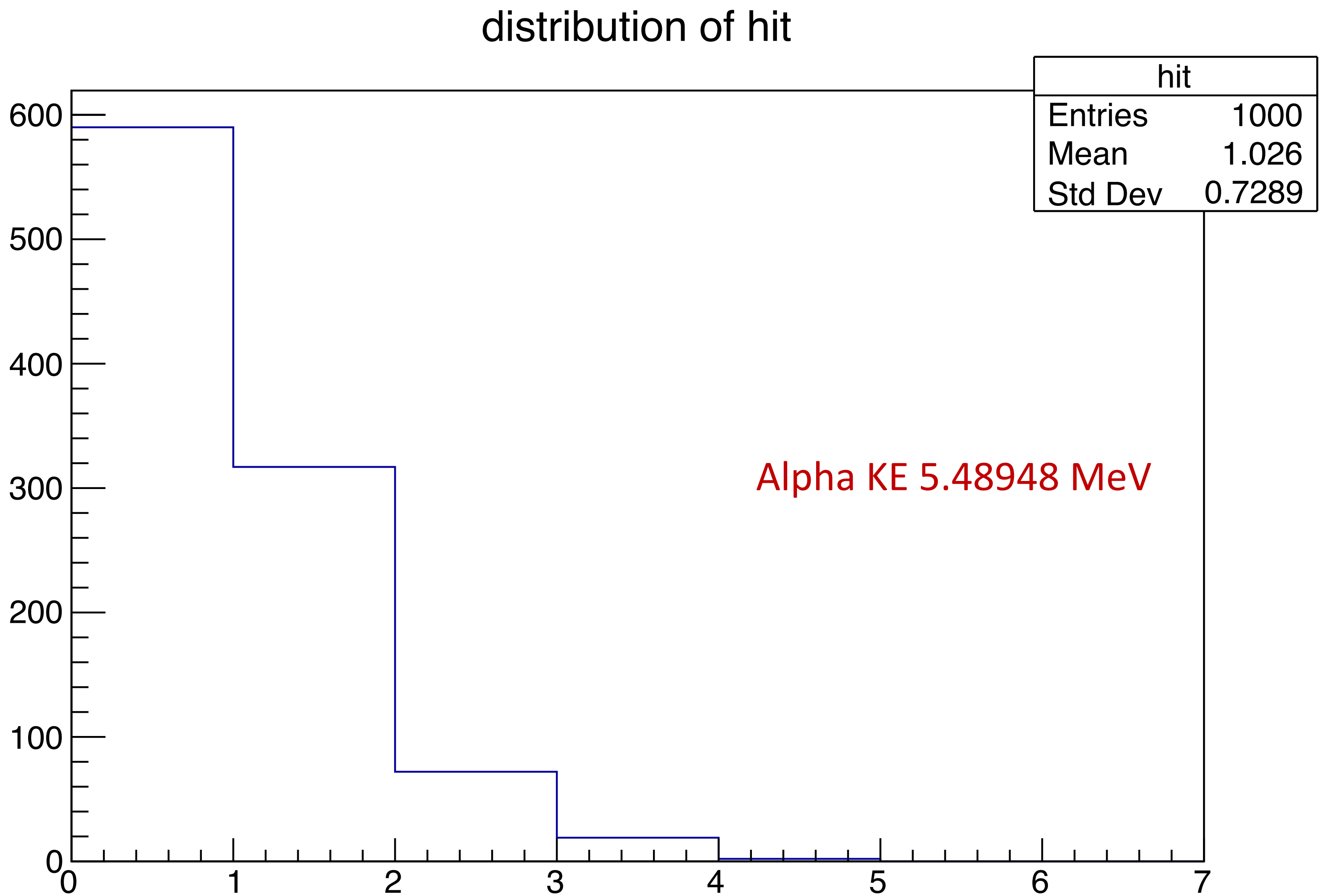
8 hits 1.0%

9 hits 0.2%

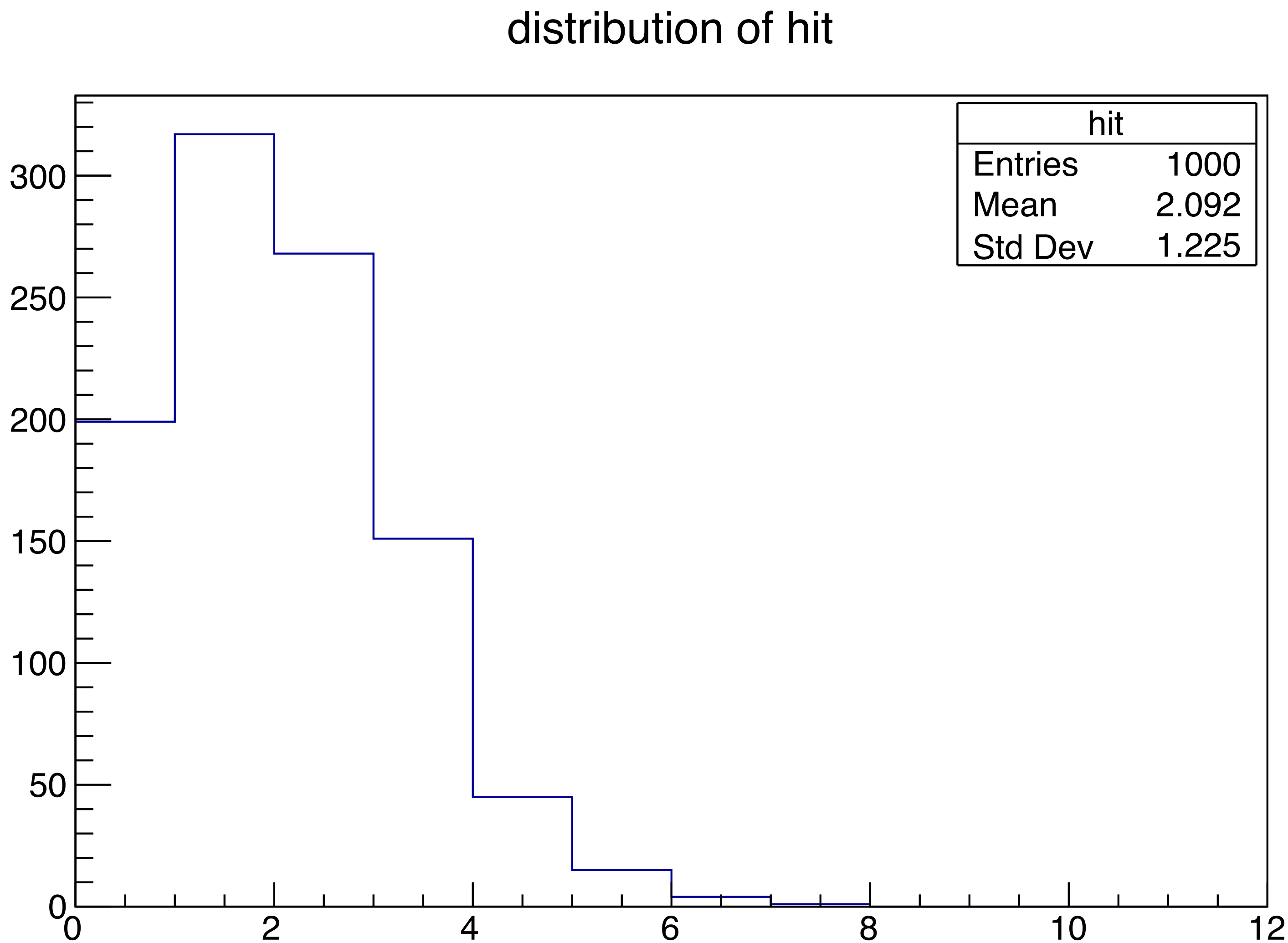
10 hits 0%

11 hits 0.1%

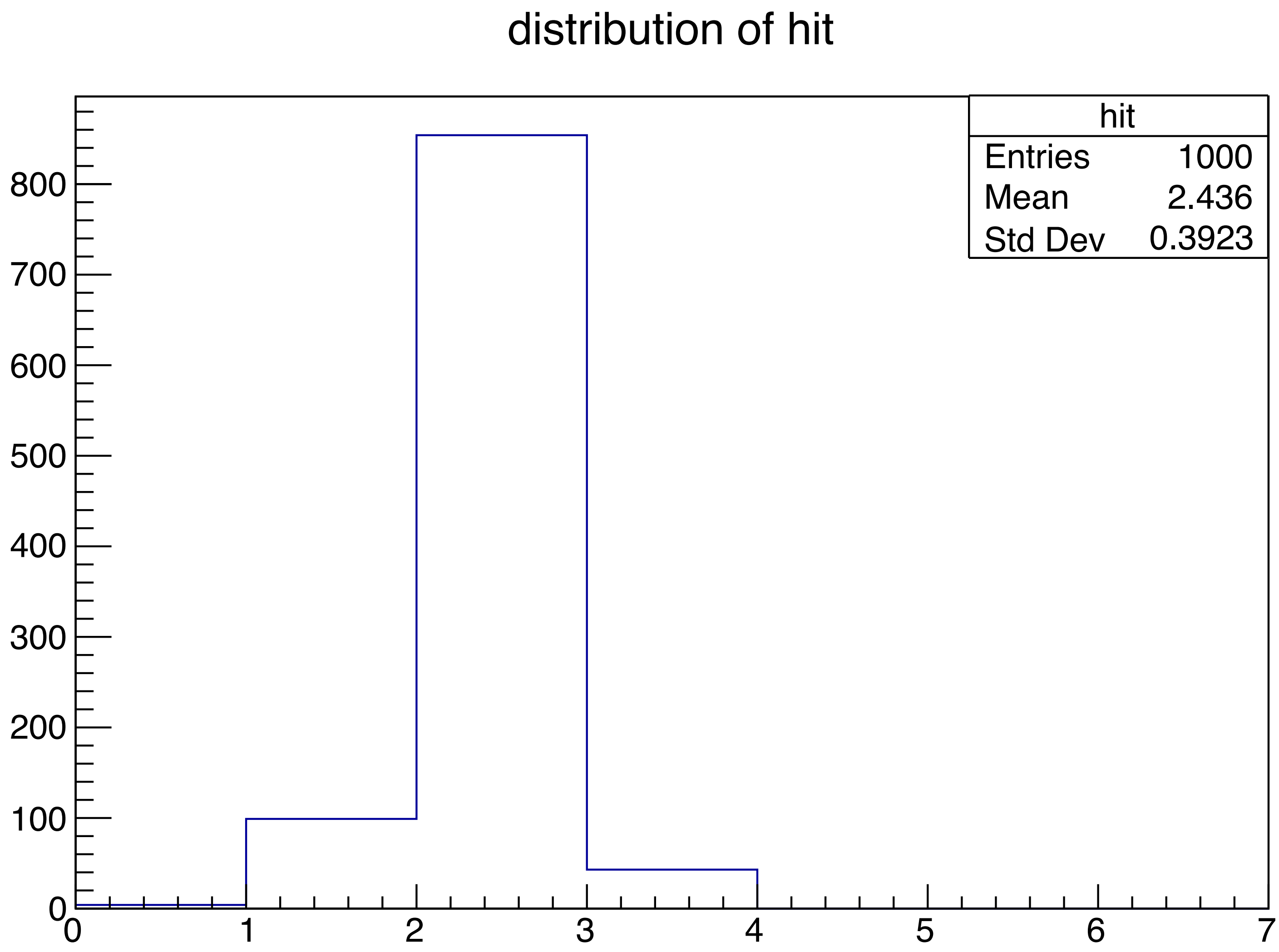
Distribution of Hits – ^{222}Rn



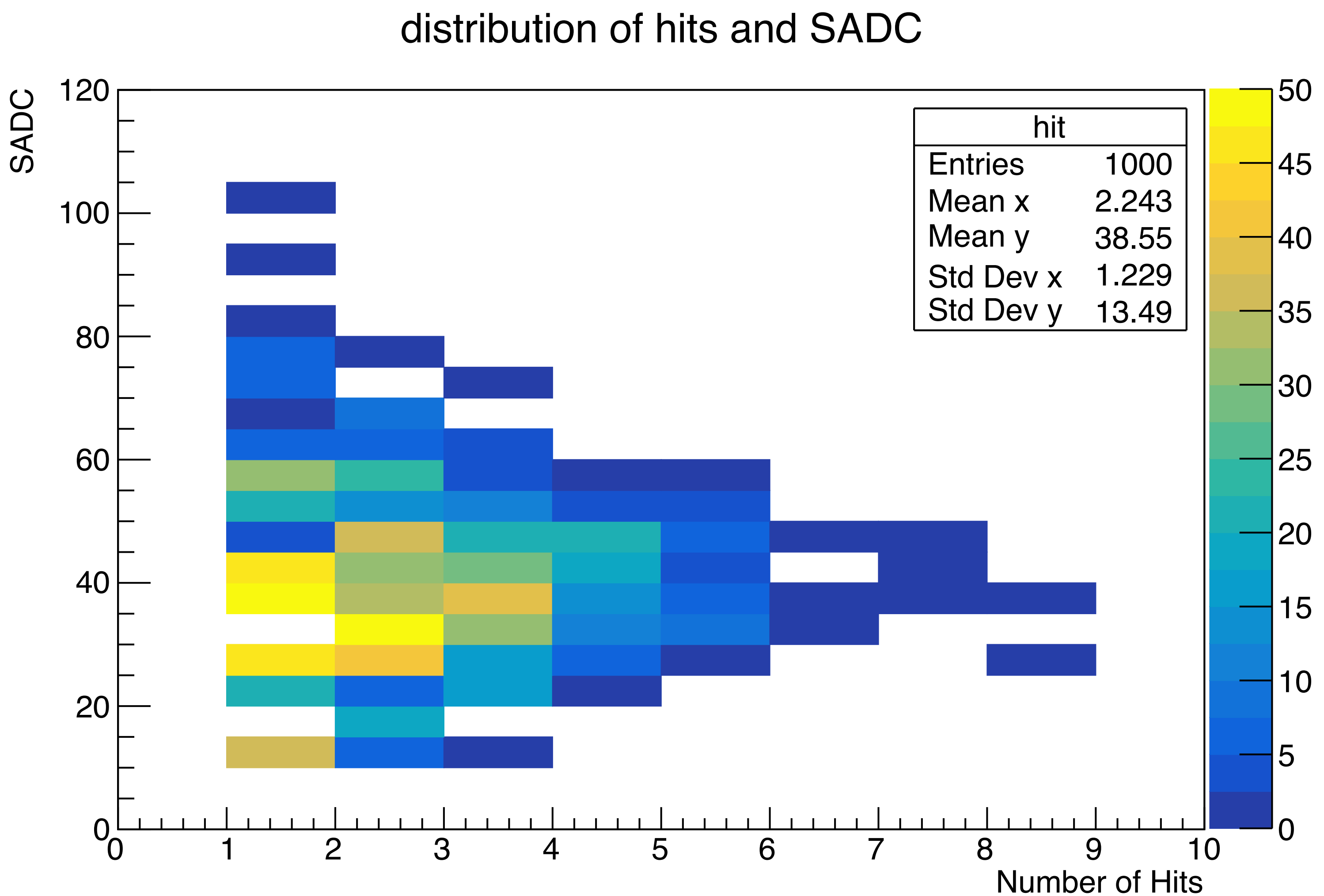
Distribution of Hits – ^{214}Po



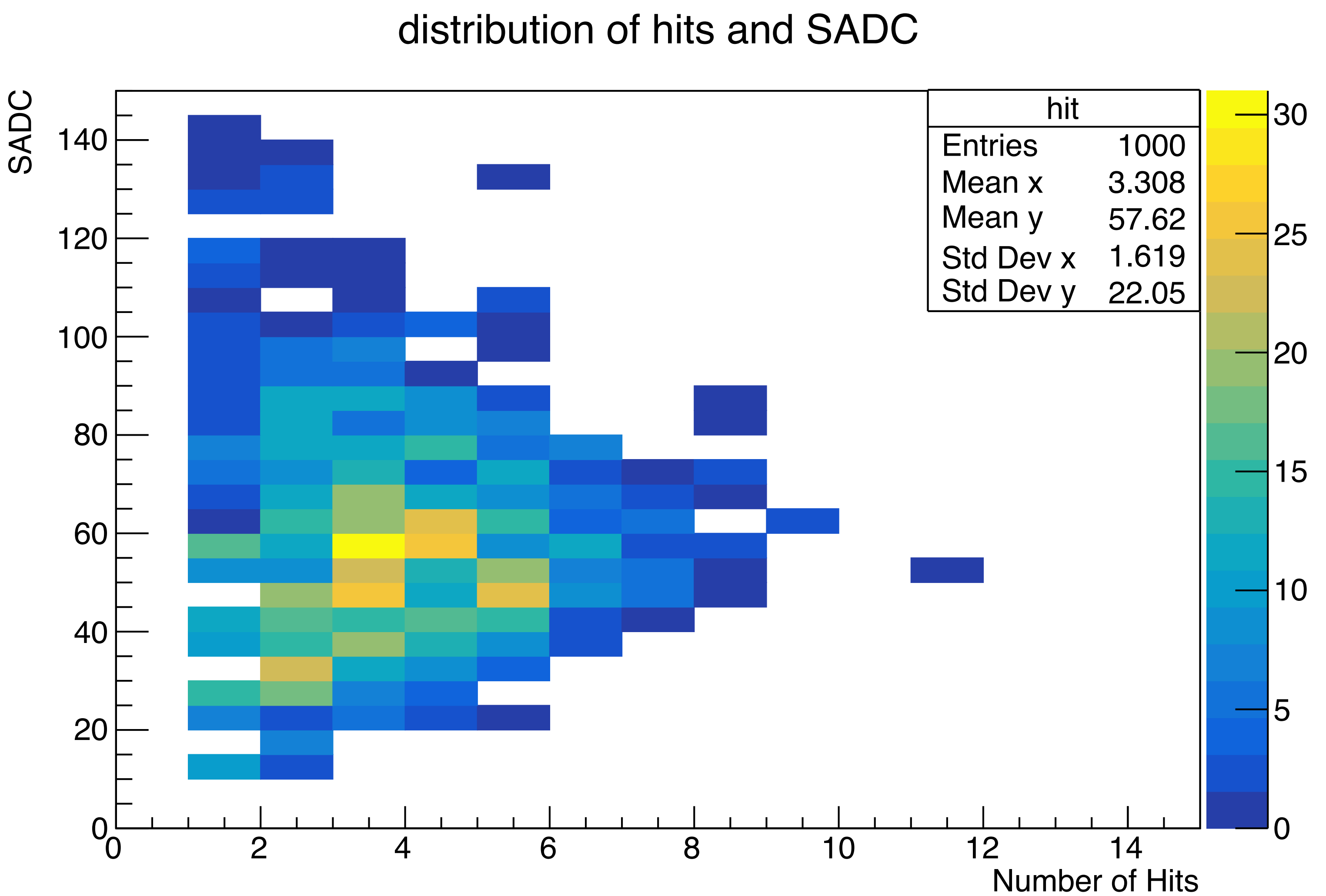
Distribution of Hits – Beta@2.18 MeV



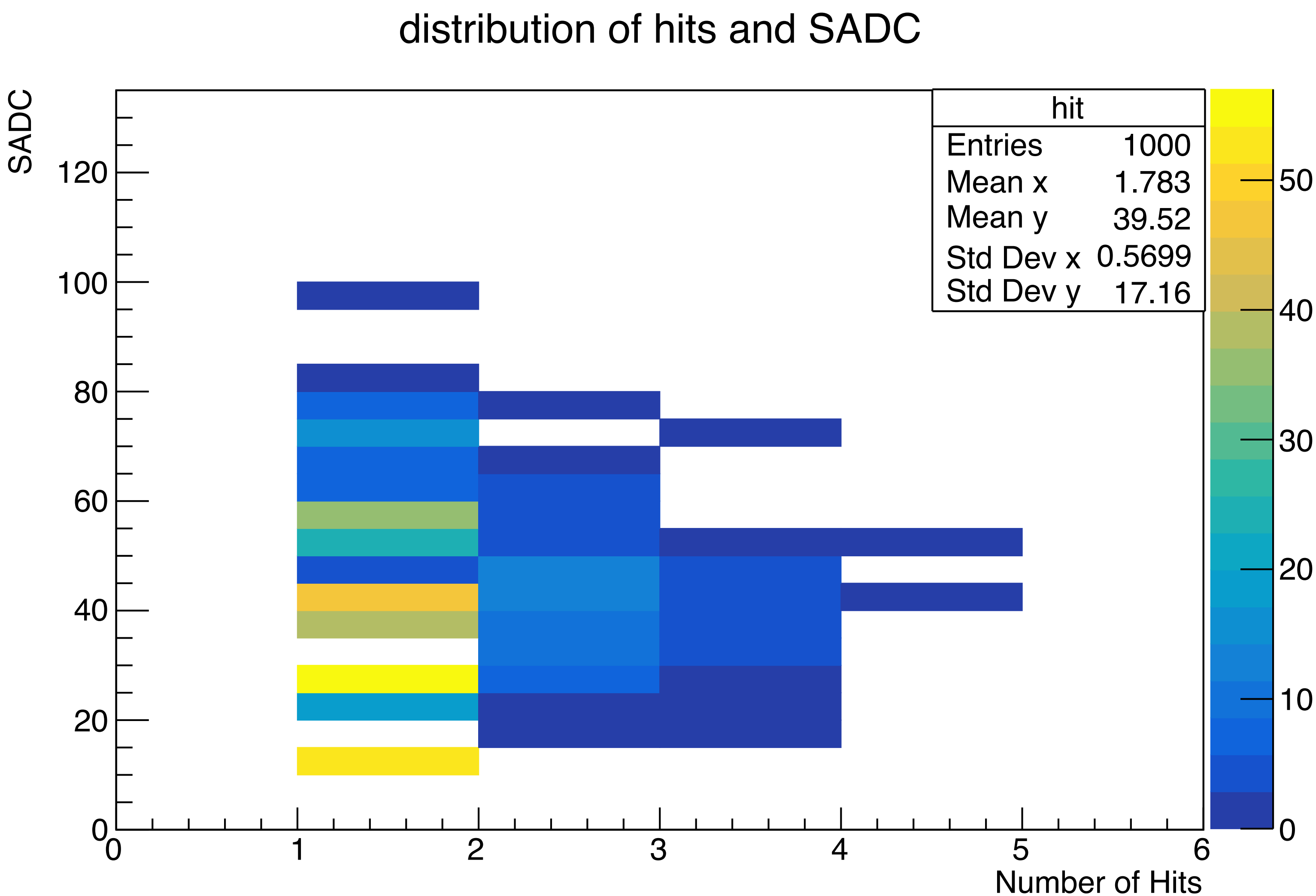
Hits & Summed ADC – MCC11



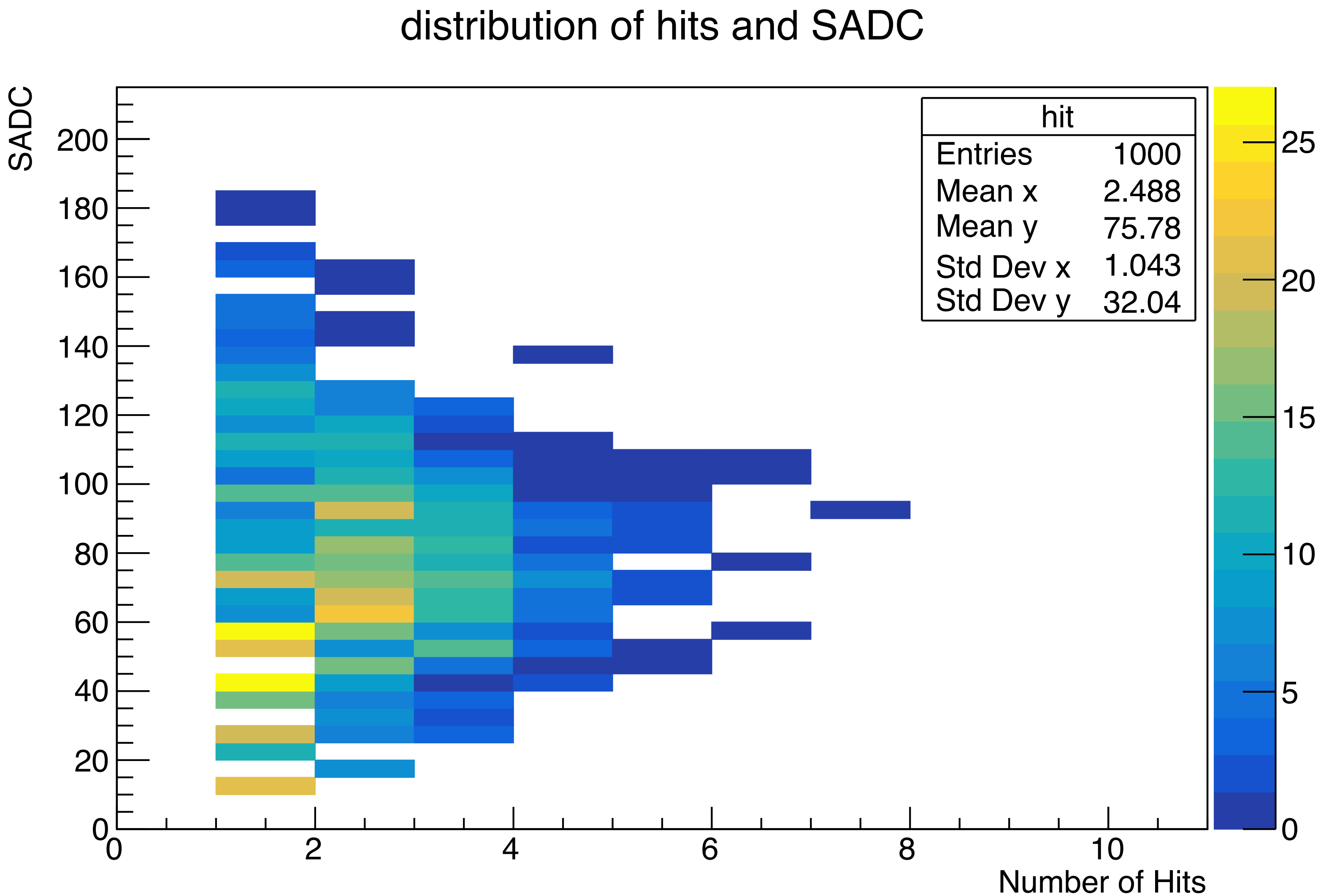
Hits & Summed ADC – Decay0



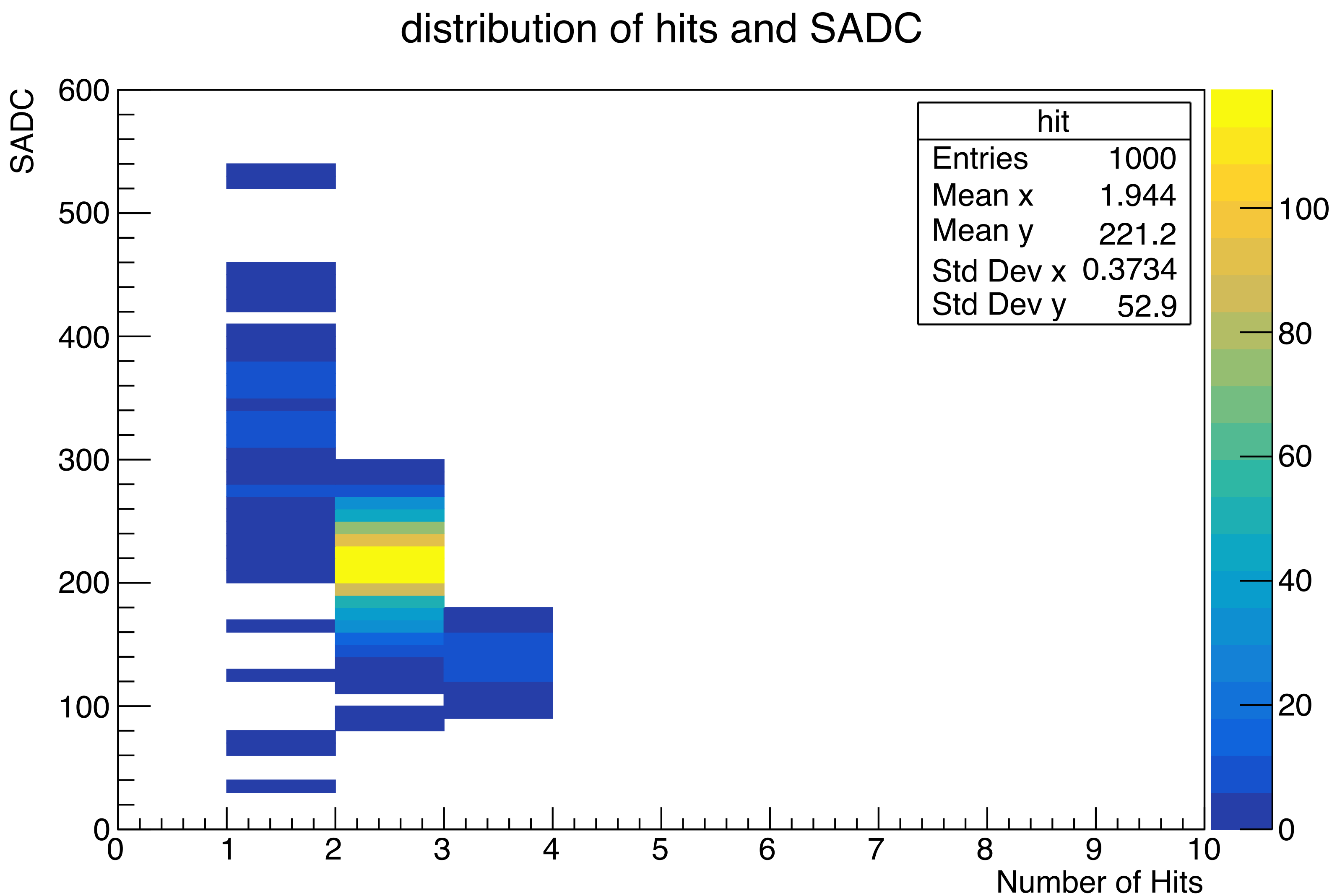
Hits & Summed ADC – ^{222}Rn



Hits & Summed ADC – ^{214}Po



Hits & Summed ADC – Beta@2.18 MeV



Looking forward

- Radon only -> full BG simulation
- Compare the difference of alpha and beta particles in terms of detector performance.
- Replace the generator for individual isotopes with full decay chains. Solve the particle track problem.
- Determine an approximate upper limit that the SN trigger can tolerate for each of the BGs.