

All the Propagation Plots and Tables

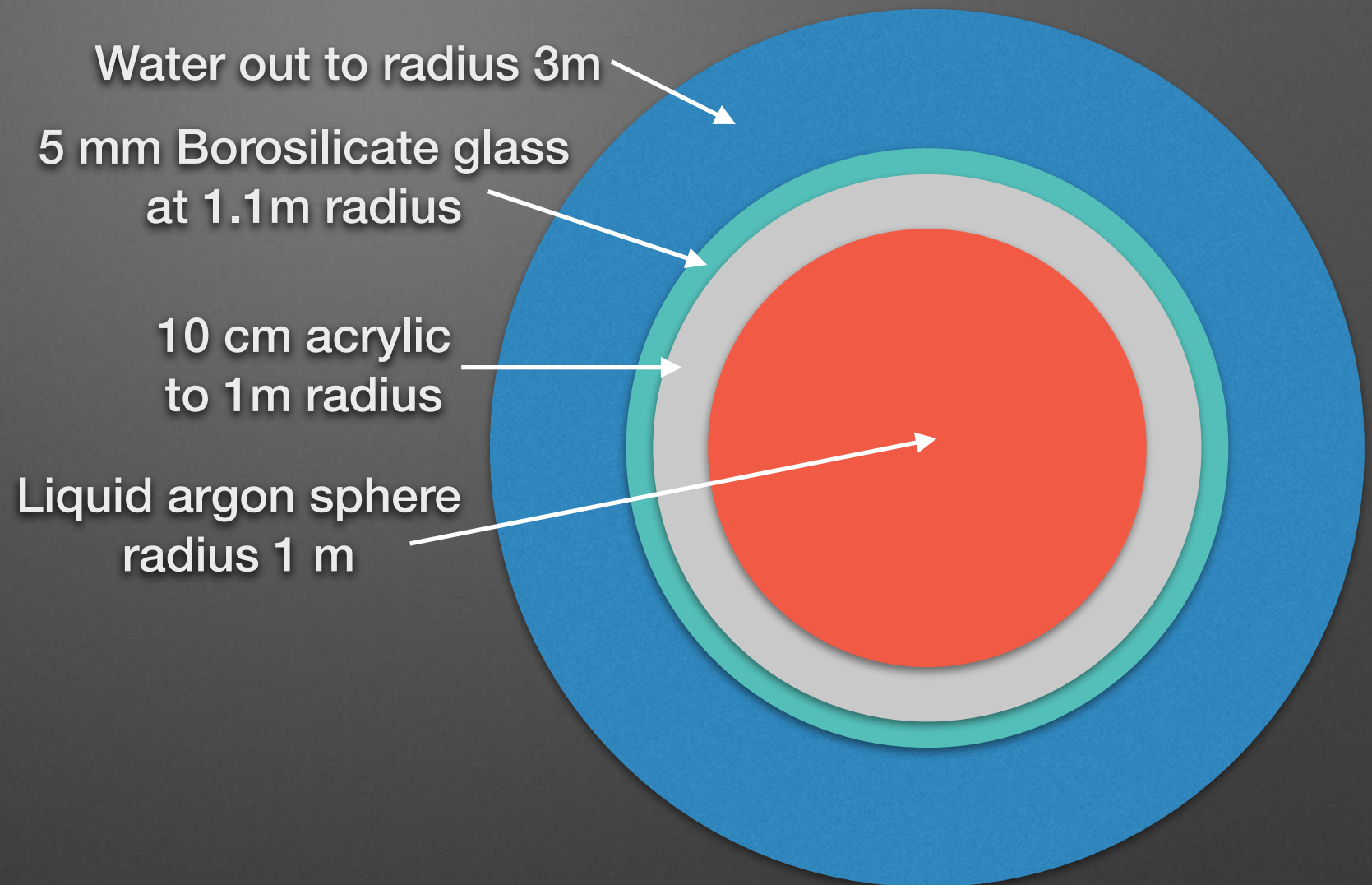
March 10, 2015
Kimberly Palladino

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- Ge: U238 in copper
- Ge:Th232 in copper

Argon detector simulations

- 250000 neutrons isotropic from borosilicate glass for each simulation
- Neutron recoil threshold of 20 keVnr used in analysis
- 1 keVee threshold for EM deposits to veto event in argon
- Neutron capture in water needed to externally veto event



Nested spheres geometry

- Apologies for cryptic columns on next pages
- No sophisticated shape comparisons done, just integrals of events

Argon (Borosilicate source U238)

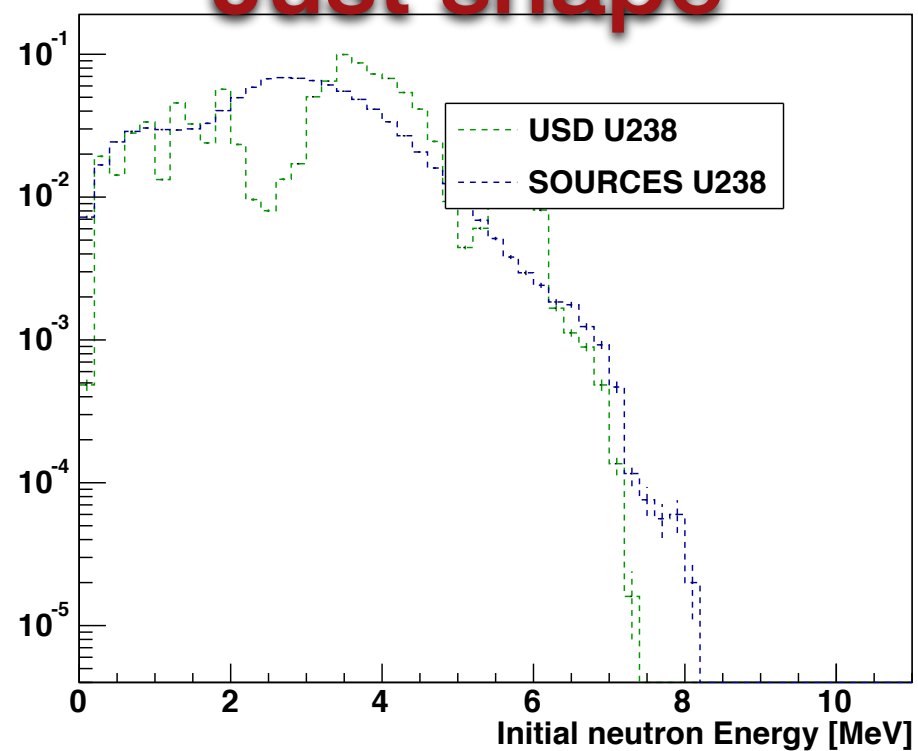
	Initial energy mean and sigma (MeV)	% total number recoils % recoil over 20 keV	%recoil %summerdnucle ar recoils over 20 keV	%single nuc %single nuc over 20 keV	%single no veto capture %over 20keV	%single no EM over 1 keV %over 20 keV	0 scatters% 1 scatter % 2 scatter % more scatters %
USD shape only	3.20 (sigma=1.43)	100.75+/-0.2% 39+/- 0.1%	44 +/- 0.1 % 5.2 +/- 0.05%	3.45 +/- 0.04% 0.71 +/-0.02%	3.3+/-0.04% 0.60 +/- 0.01%	2.4 +/-0.03% 0.30 +/- 0.01%	82.2+/-0.2% 3.4 +/-0.04% 2.7 +/-0.03% 11.7 +/- 0.08%
SOURCES shape only	2.73 (sigma=1.26)	92.1+/-0.2% 30.7+/-0.1%	44.1 +/- 0.1% 4.3 +/-0.04%	3.52+/-0.04% 0.66+/-0.02%	3.4+/-0.04% 0.55+/-0.01%	2.6+/-0.03% 0.28+/-0.01%	83.1 +/-0.2% 3.5 +/-0.04% 2.6 +/- 0.03% 10.8 +/- 0.08%
(all scaled by production)	neutron yield n/s/cm^3	recoils over 20keV	summed nuclear recoils over 20keV	single nuclear recoils over 20keV	singles no veto capture over 20 keV	singles no EM over 5 keV singles over 20 keV	0 scatters 1 scatter 2 scatters more
USD full	2.45E-10	2.47 +/-0.005 .88 +/- 0.003	1.08 +/-0.003 0.128 +/-0.001	0.084+/-0.0009 0.017 +/- 0.0004	0.0815 +/- 0.0009 0.0147 +/- 0.0004	0.061 +/- 0.0008 0.007 +/- 0.0003	2.01 +/- 0.004 0.084 +/- 0.0009 0.065 +/- 0.0008 0.28 +/- 0.002
SOURCES full	3.63E-10	3.34+/- 0.007 1.11 +/- 0.004	1.60+/- 0.005 0.157 +/- 0.0015	0.128+/-0.0013 0.024+/- 0.0006	0.124 +/- 0.0013 0.02 +/- 0.0005	0.093 +/- 0.0011 0.010 +/- 0.0004	3.02 +/- 0.07 0.128 +/- 0.0014 0.095 +/- 0.0012 0.39 +/- 0.008

More numbers

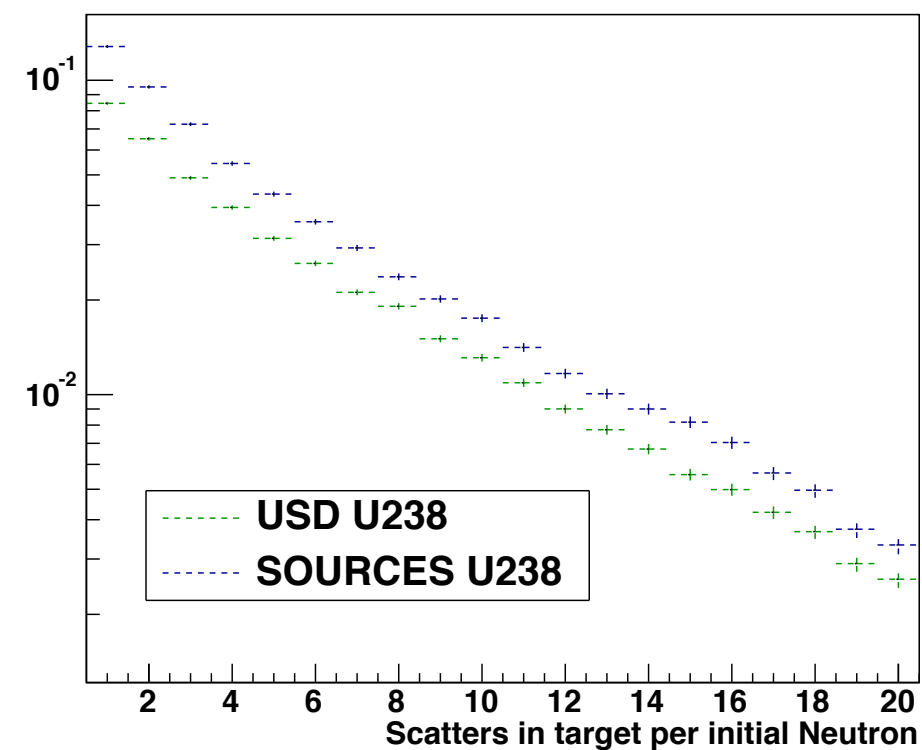
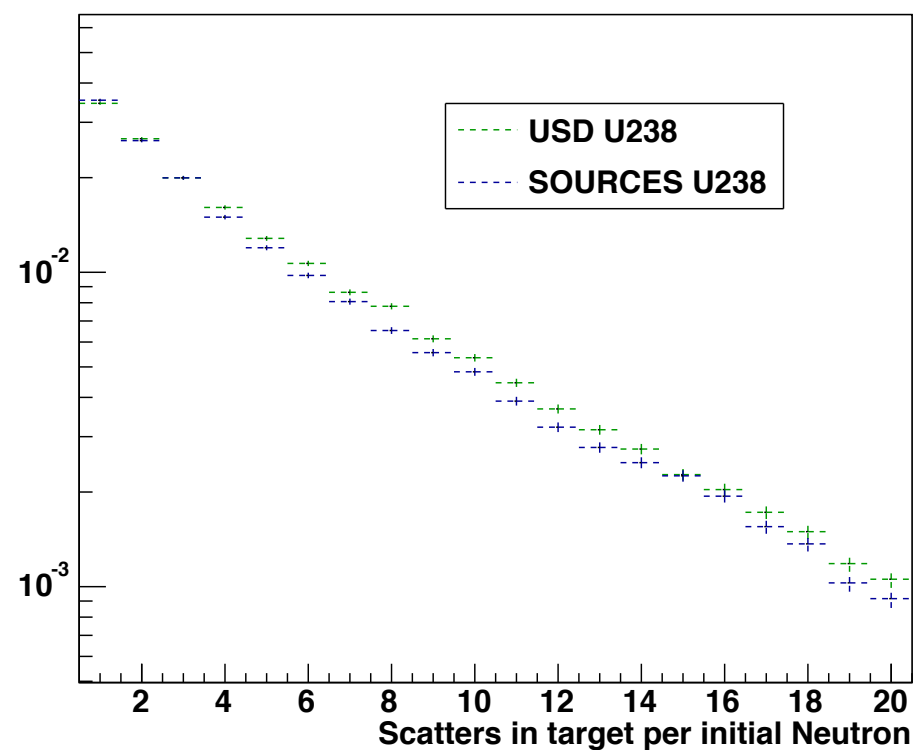
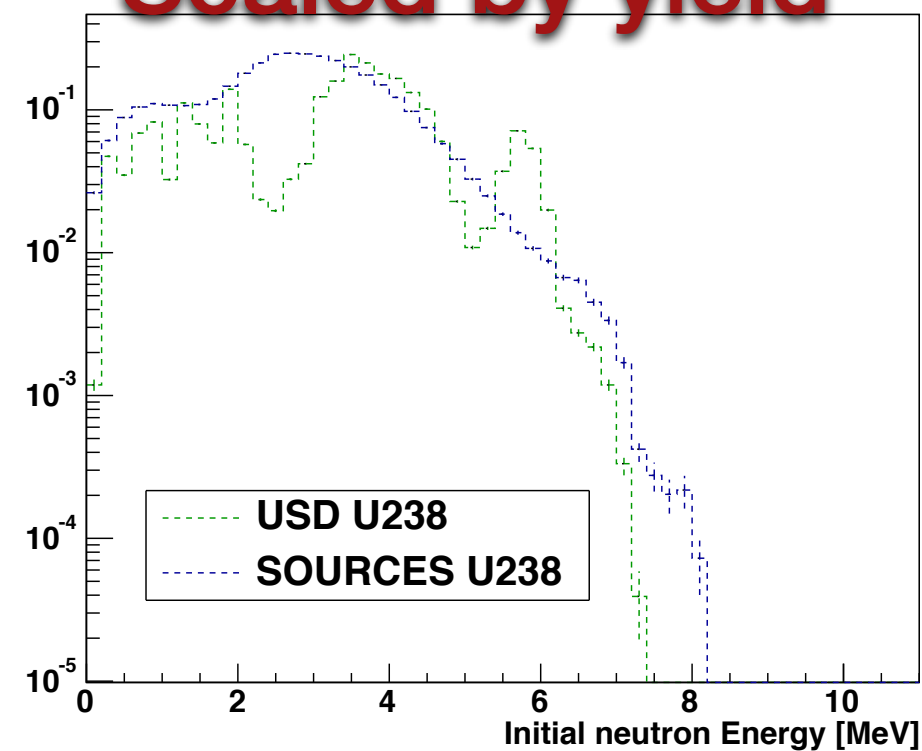
Simulation	%/# simulated scatters < 90 cm	%/# simulated single scatters <90 cm	ratio scatters more :2 more:1 2:1 2+:1	ratio single scatters total to those inside radius	ratio energy
USD shape only	7.5 +/-0.05%	0.082 +/- 0.006%	4.3 3.4 0.79 4.2	42	
SOURCES shape only	6.7 +/-0.05%	0.092 +/- 0.006%	4.15 3.09 0.74 3.8	38	
USD full	0.185 +/- 0.0013	0.002 +/- 0.0001			
SOURCES full	0.24 +/- 0.002	0.0033 +/- 0.0002			

Argon (Borosilicate U238)

Just shape

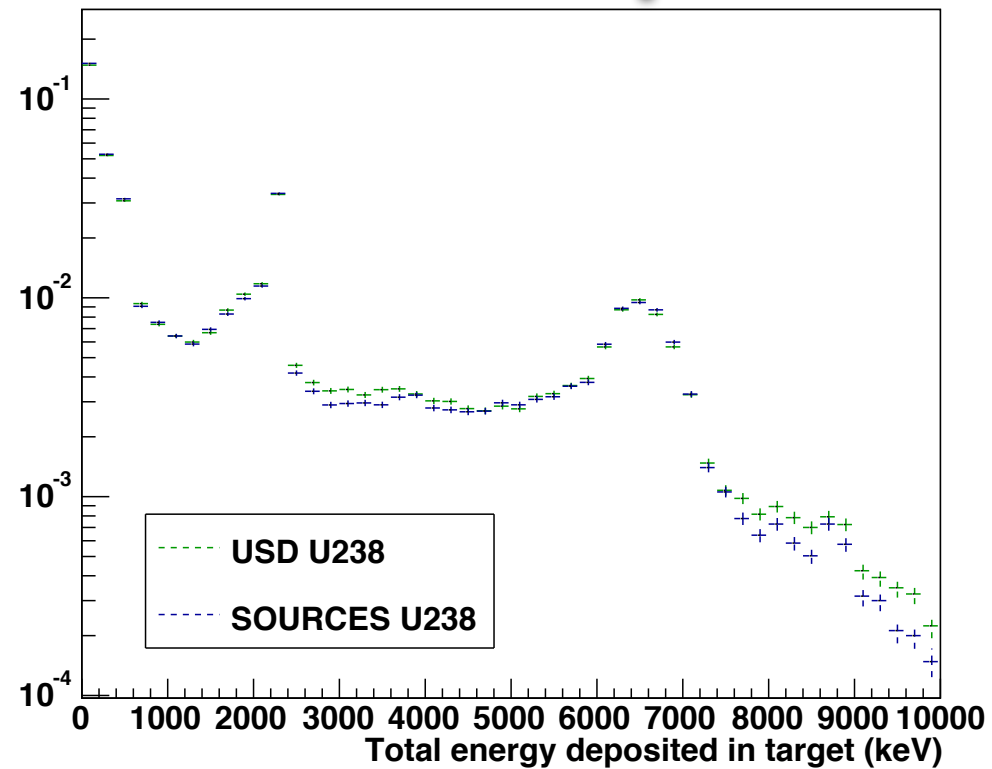


Scaled by yield

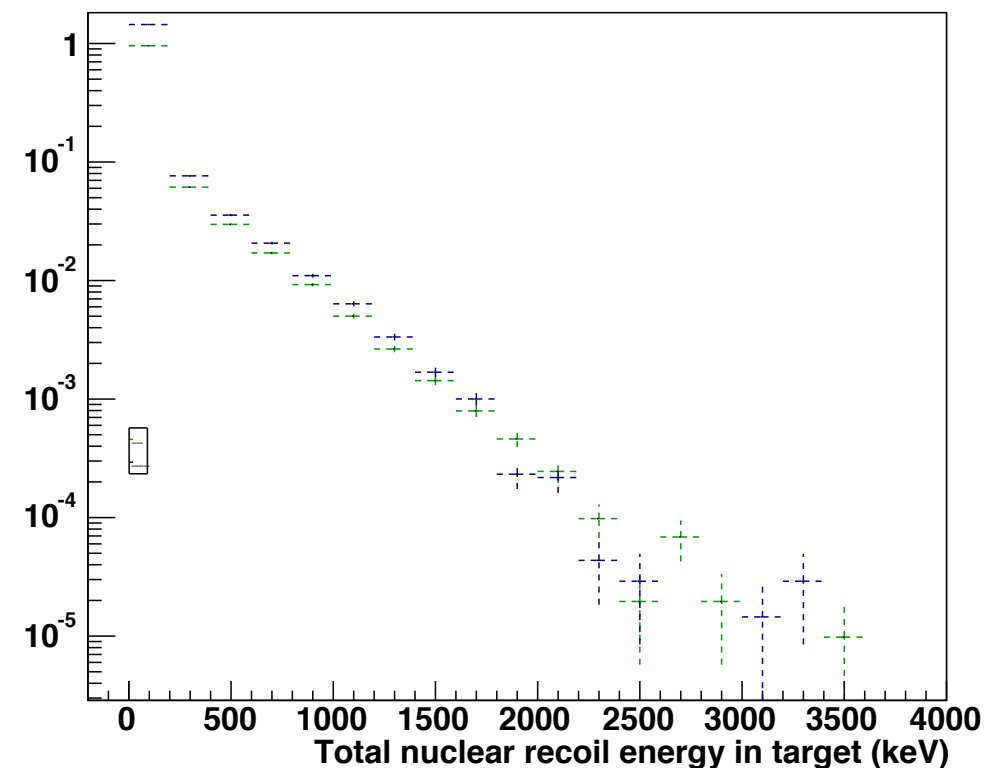
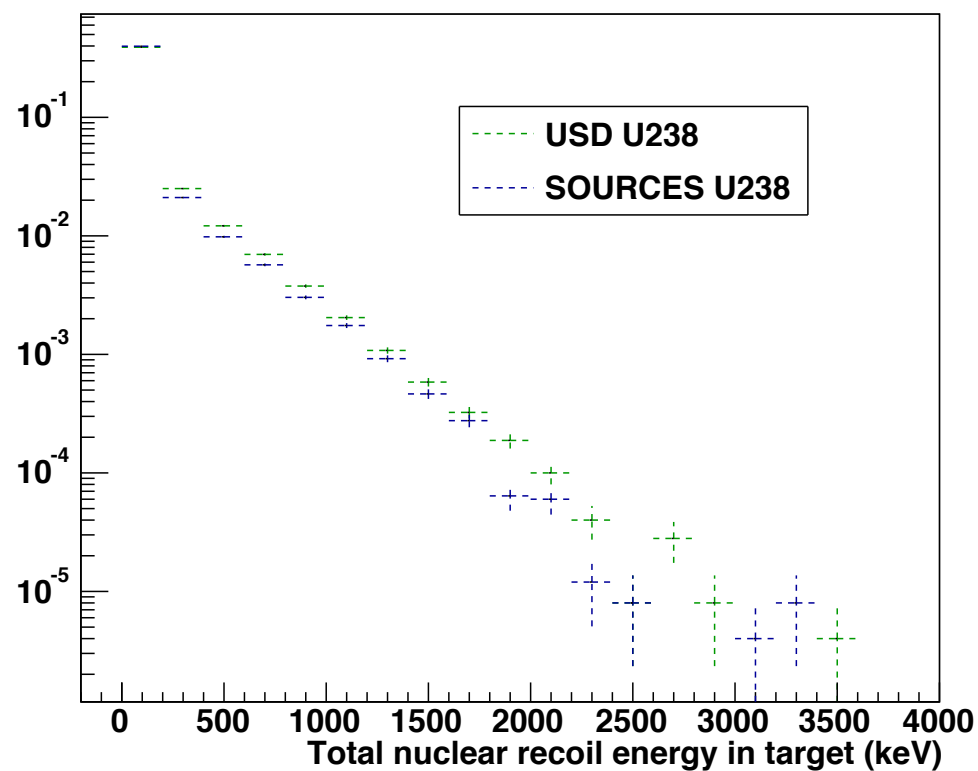
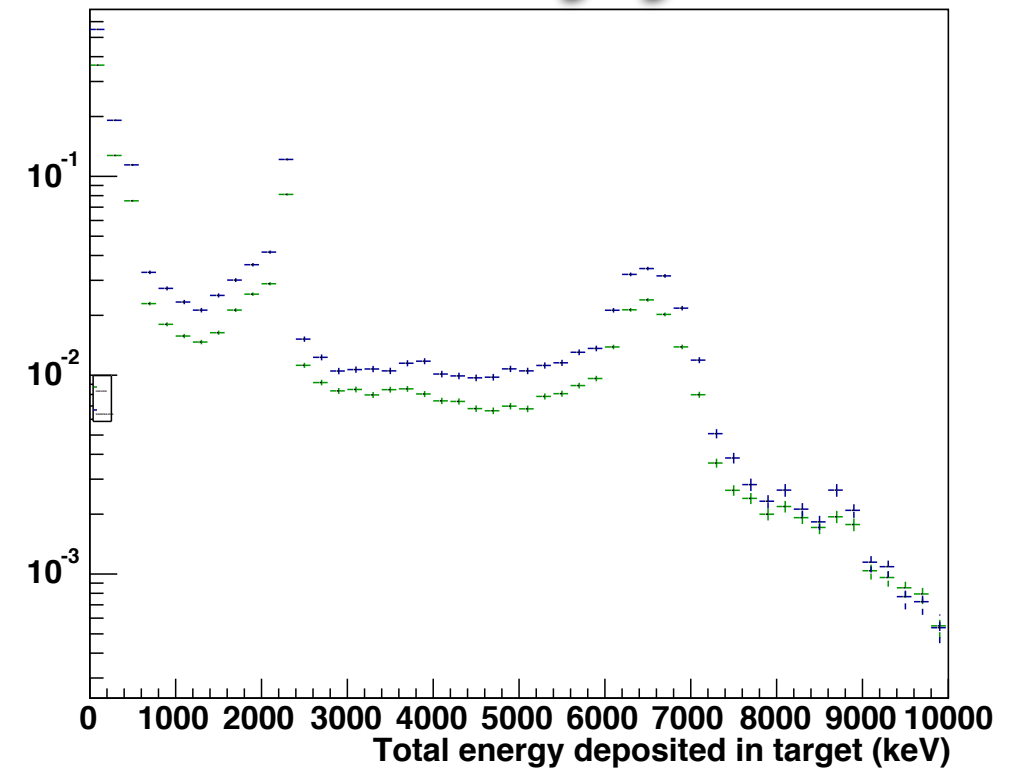


Ar (Borosilicate U238): Energy Deposited

Just shape

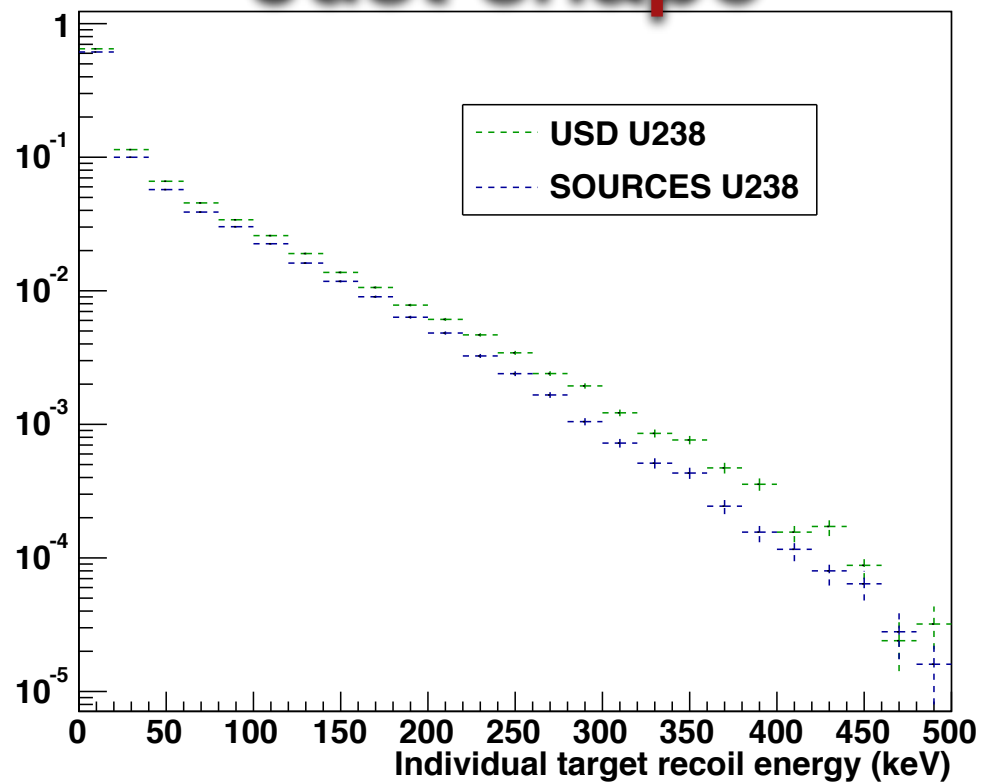


Scaled by yield

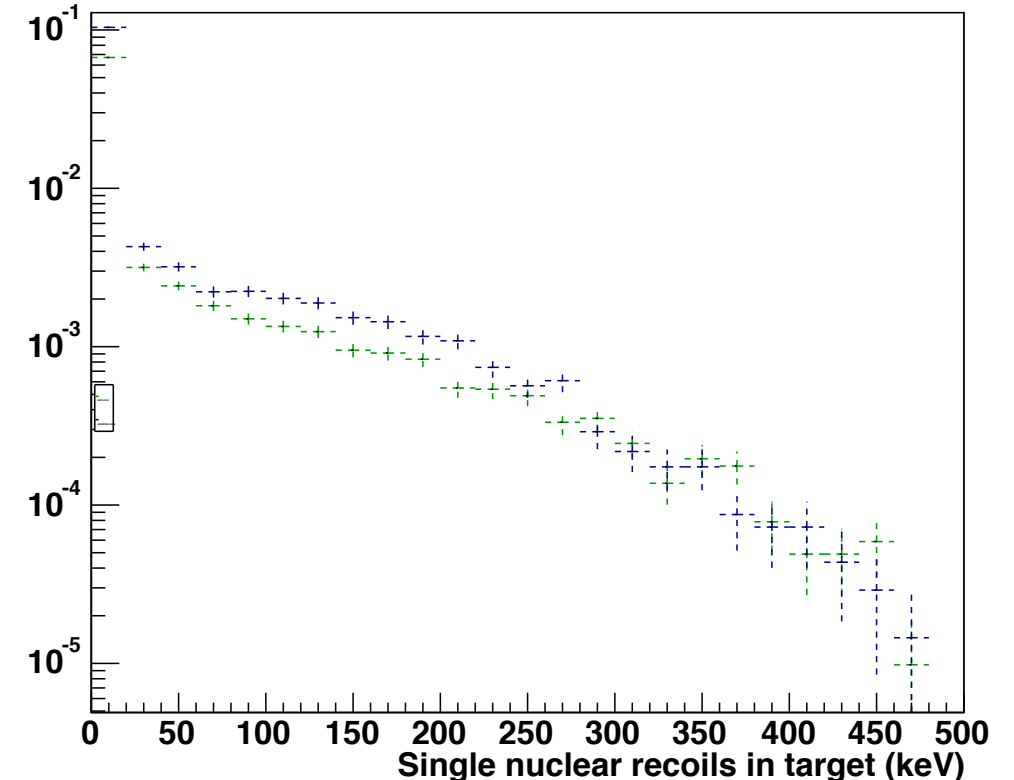
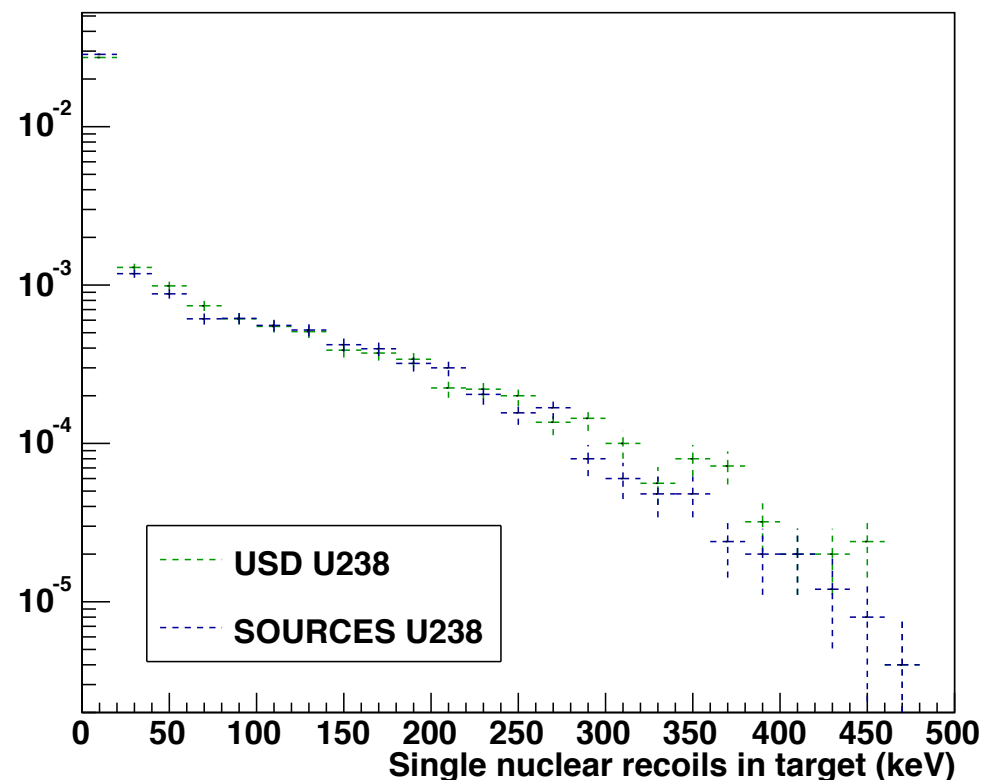
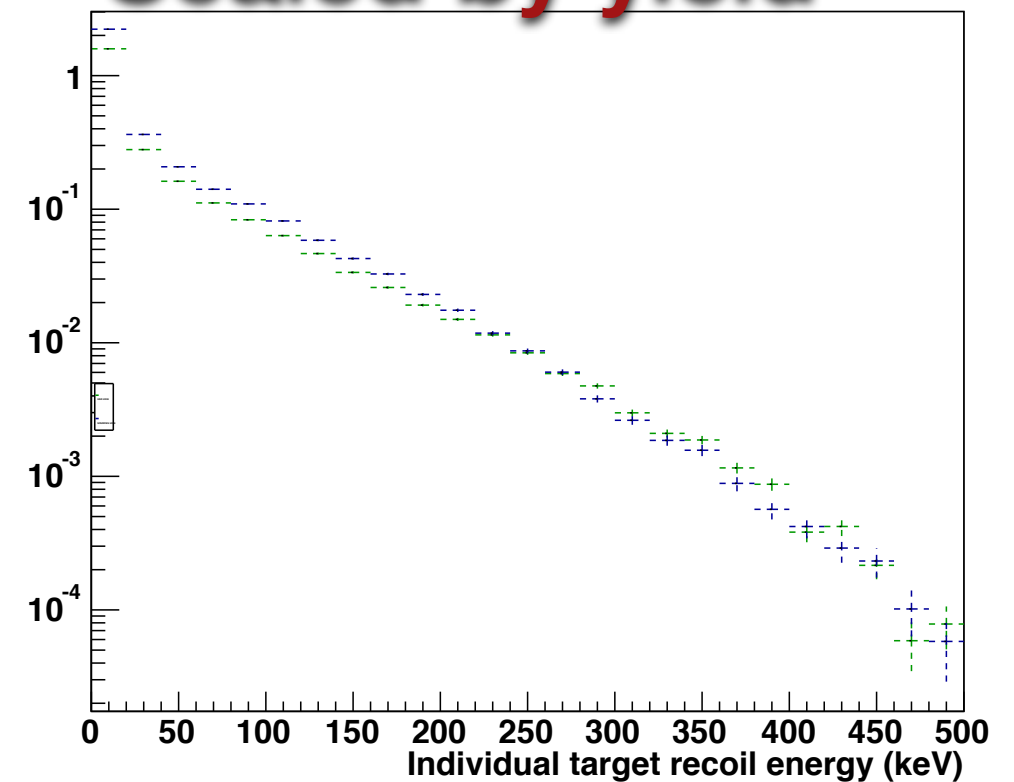


Ar (Borosilicate U238): Nuclear Recoils

Just shape

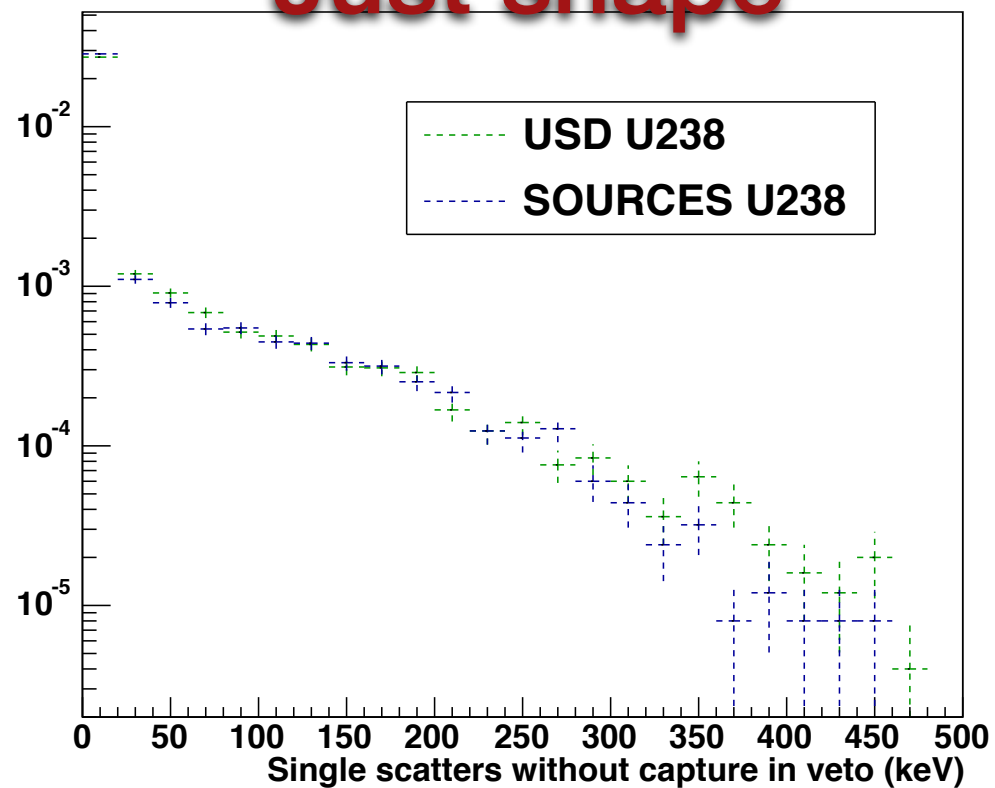


Scaled by yield

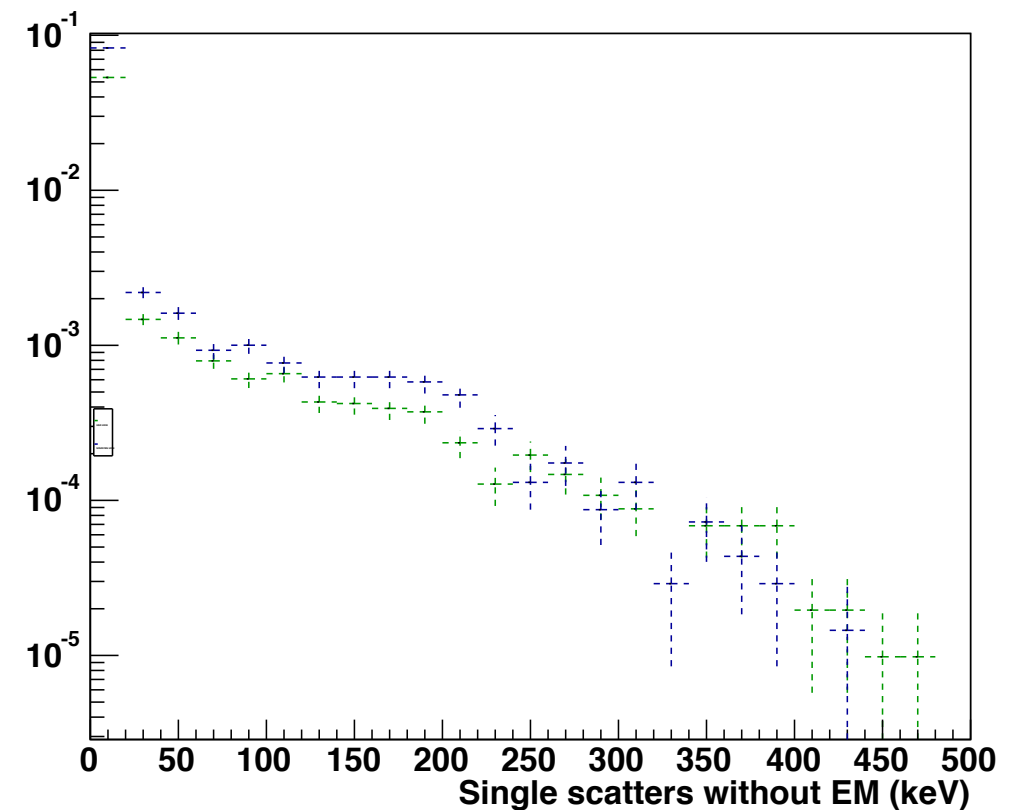
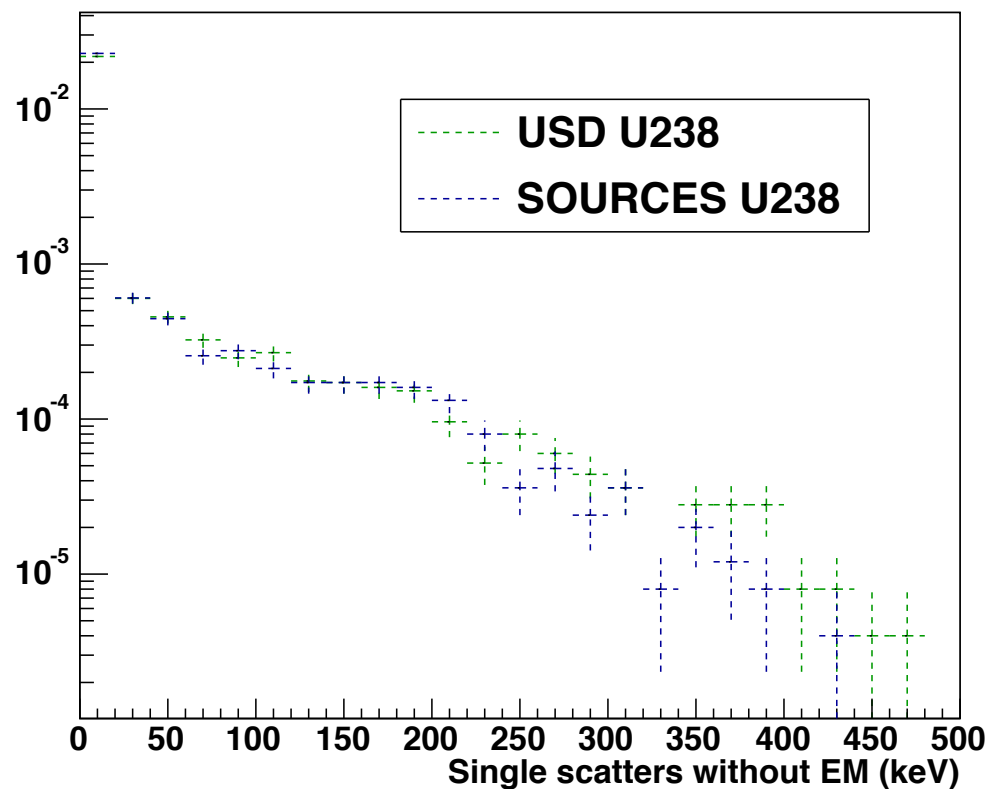
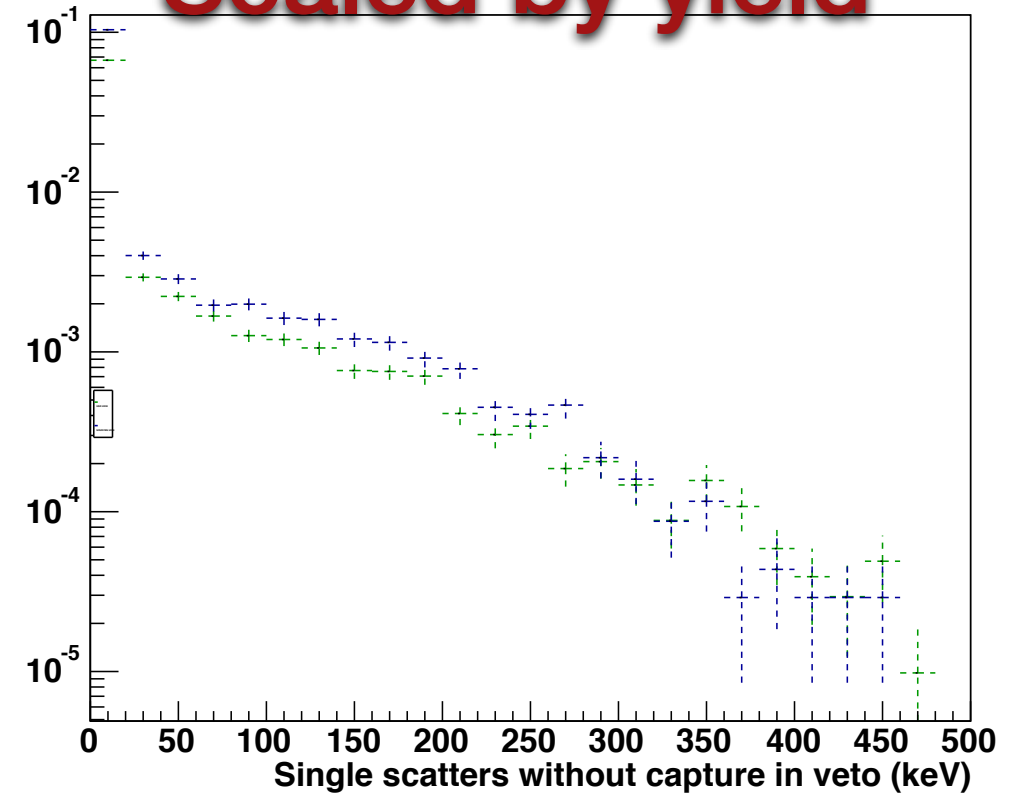


Ar (Borosilicate U238): Vetoed Recoils

Just shape

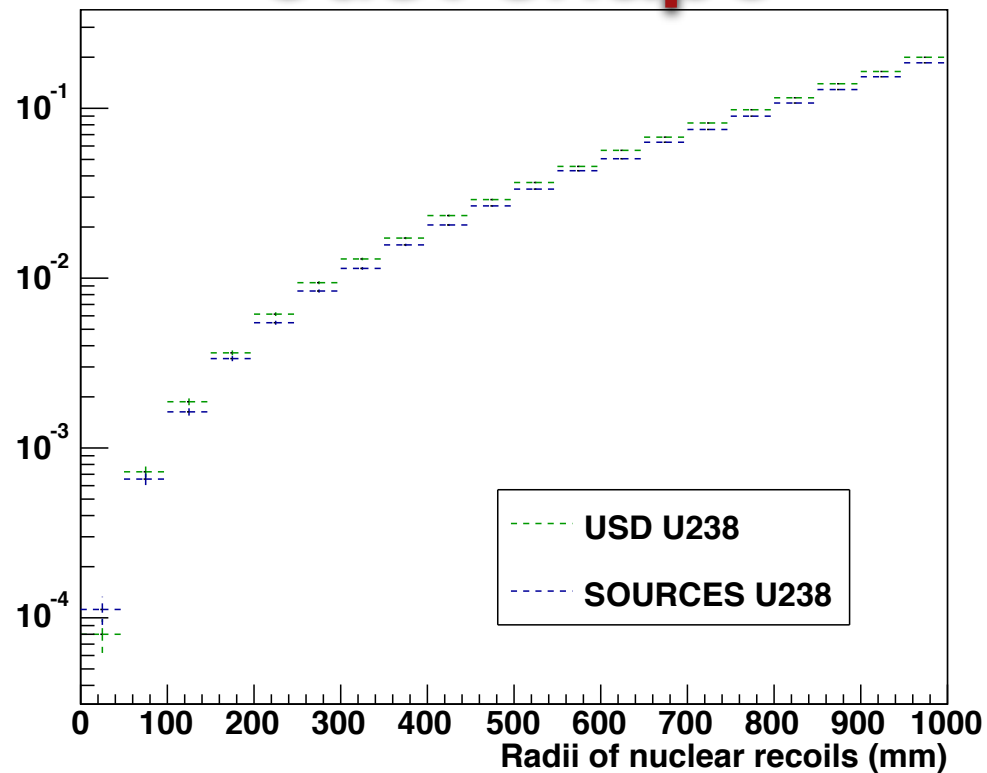


Scaled by yield

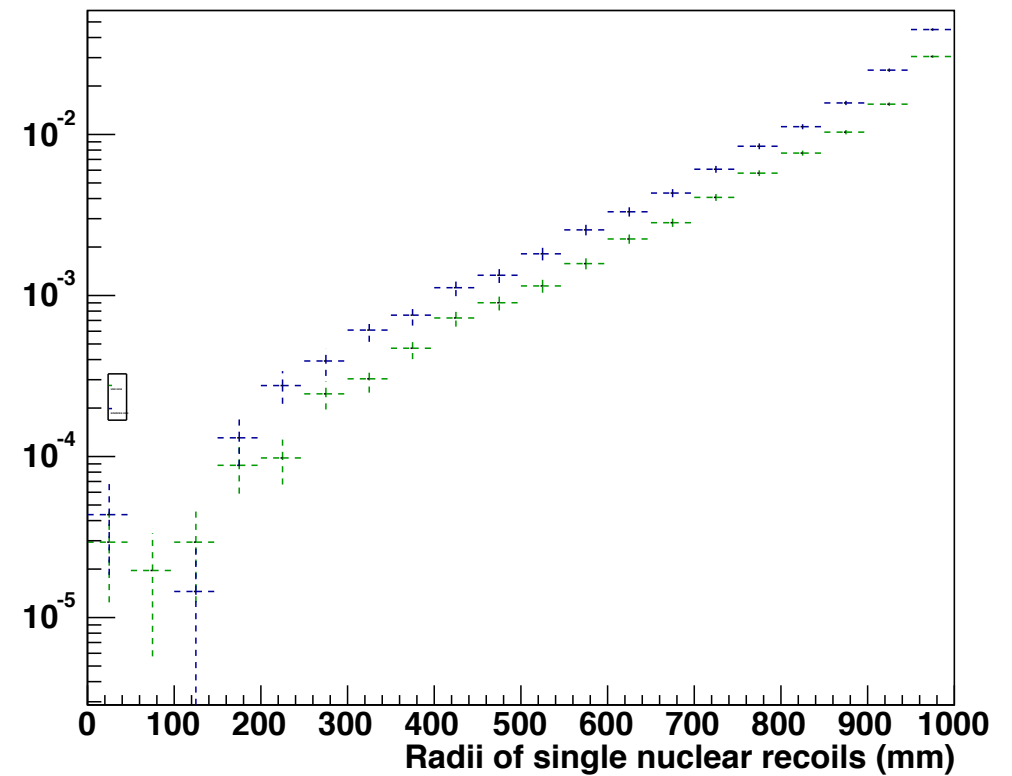
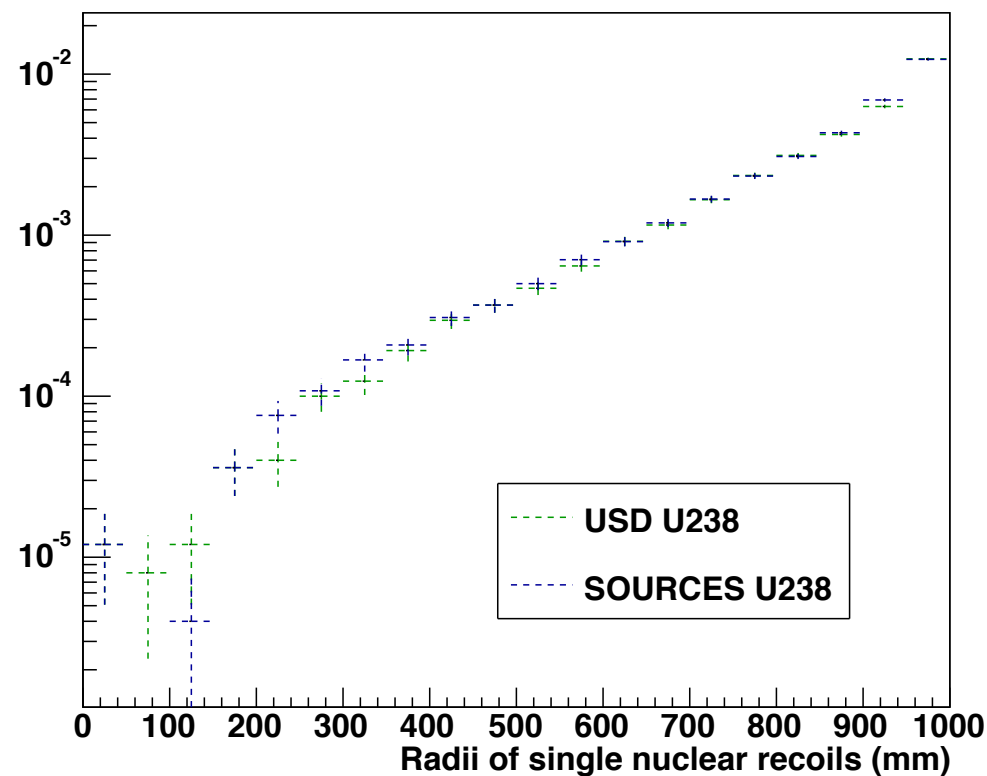
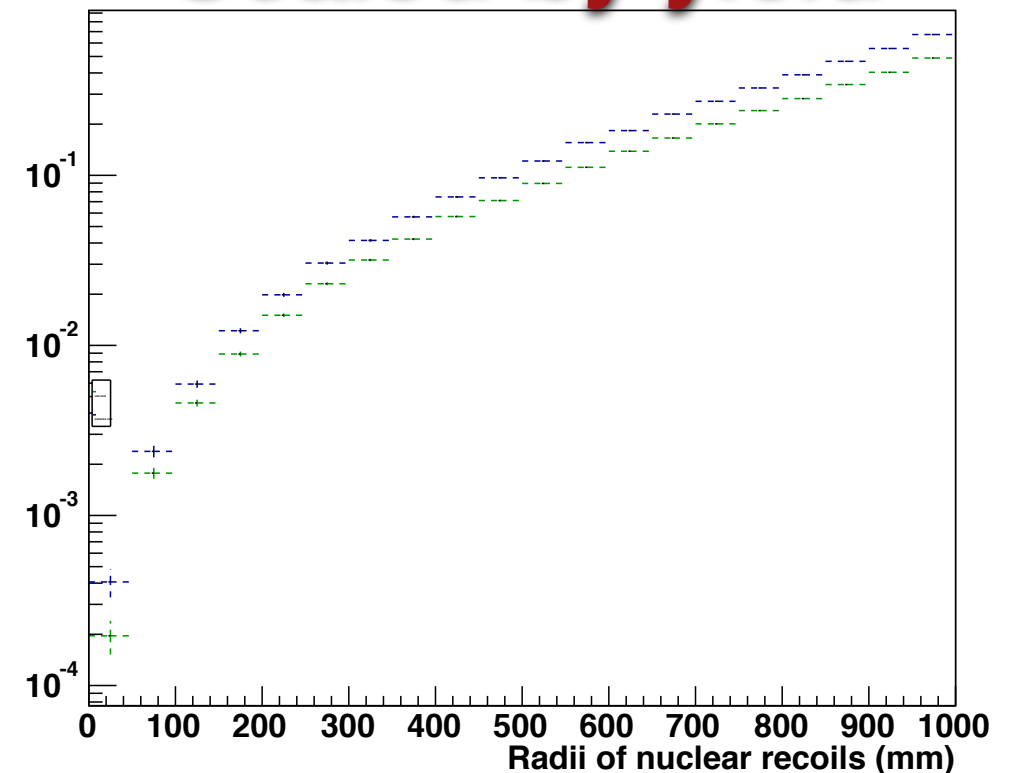


Ar (Borosilicate U238): Recoil Radii

Just shape



Scaled by yield



Ar U238 Conclusions

- USD has 7.5% more singles by shape only
- 10% error in # events from multi-scatter, and radial distribution comparisons possible
- Veto importance: USD has 10% more after capture, 7% more after EM
- 48% difference in neutron yield leads to a 40% difference in single scatters
- USD > Sources by shape; Sources > USD by yield

Argon (Borosilicate source Th232)

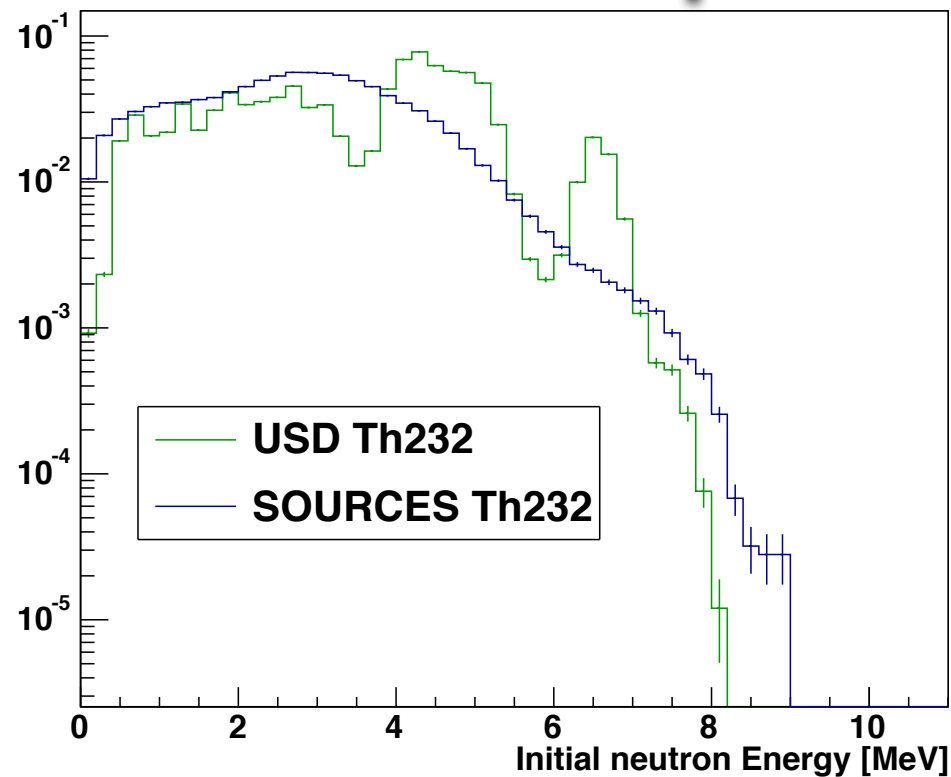
	Initial energy mean and sigma (MeV)	% total number recoils % recoil over 20 keV	%recoil %summed nuclear recoils over 20 keV	%single nuc %single nuc over 20 keV	%single no veto capture %over 20keV	%single no EM over 5 keV %over 20 keV	0 scatters% 1 scatter % 2 scatter % more scatters %
USD shape only	3.46 (sigma=1.58)	108.5 +/- 0.2% 40.27 +/- 0.13%	44.7 +/-0.13% 5.92 +/-0.04%	3.5 +/- 0.04% 0.78 +/- 0.017%	3.38 +/-0.037% 0.635 +/- 0.016%	2.53 +/- 0.032%	81.3+/- 0.18% 3.53 +/- 0.038% 2.62 +/- 0.033% 12.5 +/- 0.11%
SOURCES shape only	2.77 (sigma=1.41)	91.3 +/- 0.2% 30.94 +/- 0.11%	43.7 +/- 0.13% 4.44 +/-0.04%	3.44 +/- 0.037% 0.63 +/- 0.016%	3.33 +/- 0.036% 0.54 +/- 0.014%	2.54 +/- 0.032% 0.29 +/- 0.011%	83.3 +/- 0.18% 3.44 +/- 0.037% 2.51 +/- 0.032% 10.7
(all scaled by production)	neutron yield n/s/cm^3	recoils over 20keV	summed nuclear recoils over 20keV	single nuclear recoils over 20keV over 200 keV	singles no veto capture over 20 keV	singles no EM over 5 keV “ over 20 keV	0 scatters 1 scatter 2 scatters more
USD full	6.92 e-11	0.7506+/- 0.0014 0.2787 +/- 0.0009	0.3094 +/-0.0009 0.0410 +/-0.0003	0.0244 +/- 3e-4 0.0053 +/- 1e-4 0.0013 +/- 6e-5	0.0234 +/- 3e-4 0.0044 +/- 1e-4	0.0176 +/- 2e-4 0.0023 +/- 8e-5	0.56 +/- 0.0012 0.024 +/- 0.00026 0.018 +/- 0.00022 0.086 +/- 0.0008
SOURCES full	1.27E-10	1.159 +/- 0.002 0.393 +/- 0.001	0.5545 +/- 0.0017 0.0564 +/- 0.0005	0.0437 +/- 6.7e-4 8.0e-3 +/- 2.0e-4 1.88e-3 +/-9.8e-5	0.0423 +/- 4.6e-4 6.8e-3 +/-1.7e-4	0.0323 +/- 4e-4 0.00365 +/- 1.4e-4	1.05 +/-0.0023 0.0436 +/- 4.7e-4 0.0319 +/- 4e-4 0.136 +/- 7.9e-5

More numbers (Th232)

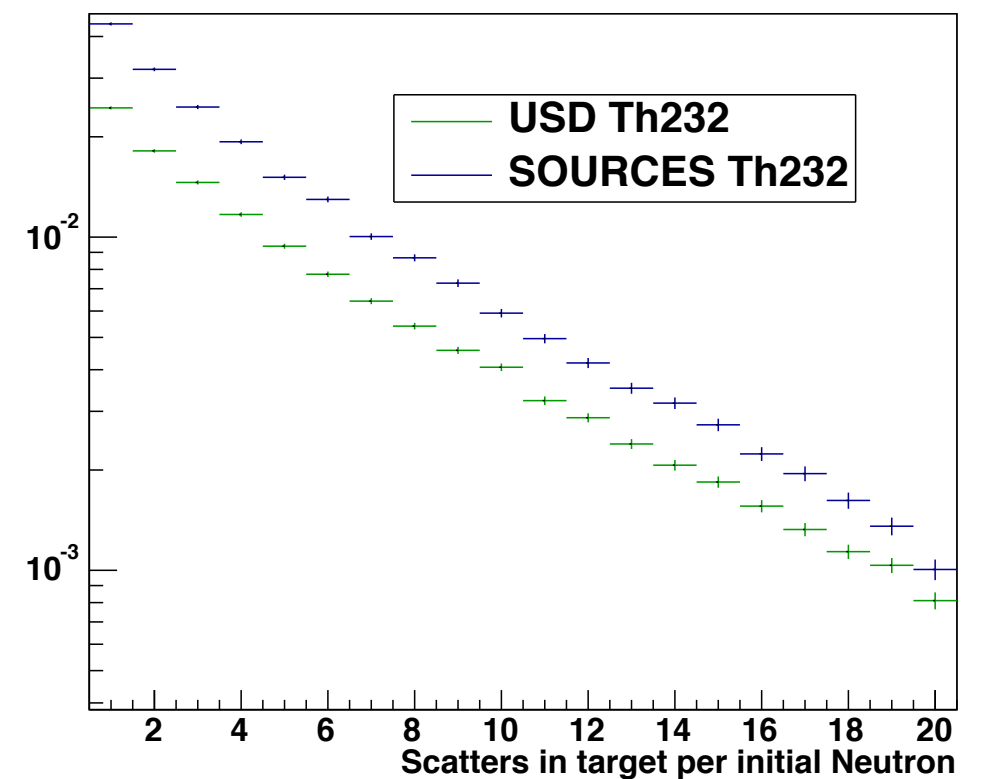
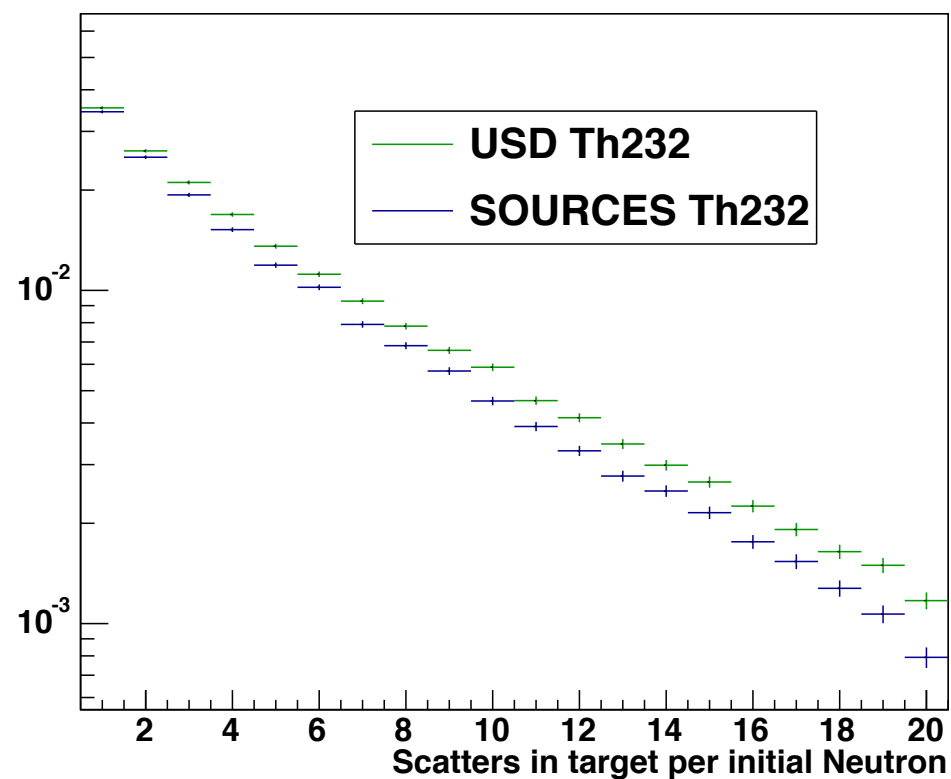
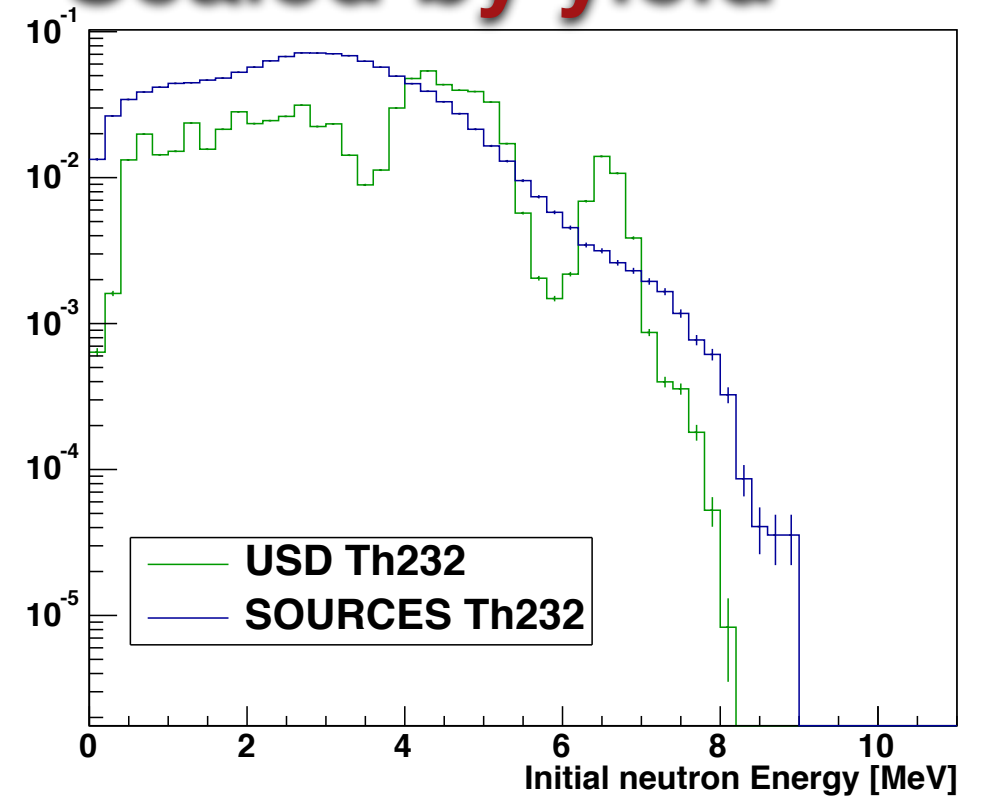
Simulation	%/# simulated scatters < 90 cm	%/# simulated single scatters <90 cm	ratio scatters more :2 more:1 2:1 2+:1	ratio single scatters total to those inside radius	ratio energy 20-200keV: >200keV
USD shape only	8.04+/- 0.06%	0.087 +/- 0.0006%	4.77 3.54 0.74 4.28	40.2	3.08
SOURCES shape only	6.8 +/- 0.05%	0.077 +/- 0.0006%	4.26 3.11 0.73 3.8	44.6	3.25
USD full	0.0554 +/- 4e-4	6e-4 +/- 4e-5			
SOURCES full	0.0870 +/- 73-4	9.8e-4 +/- 7e-5			

Argon (Borosilicate Th232)

Just shape

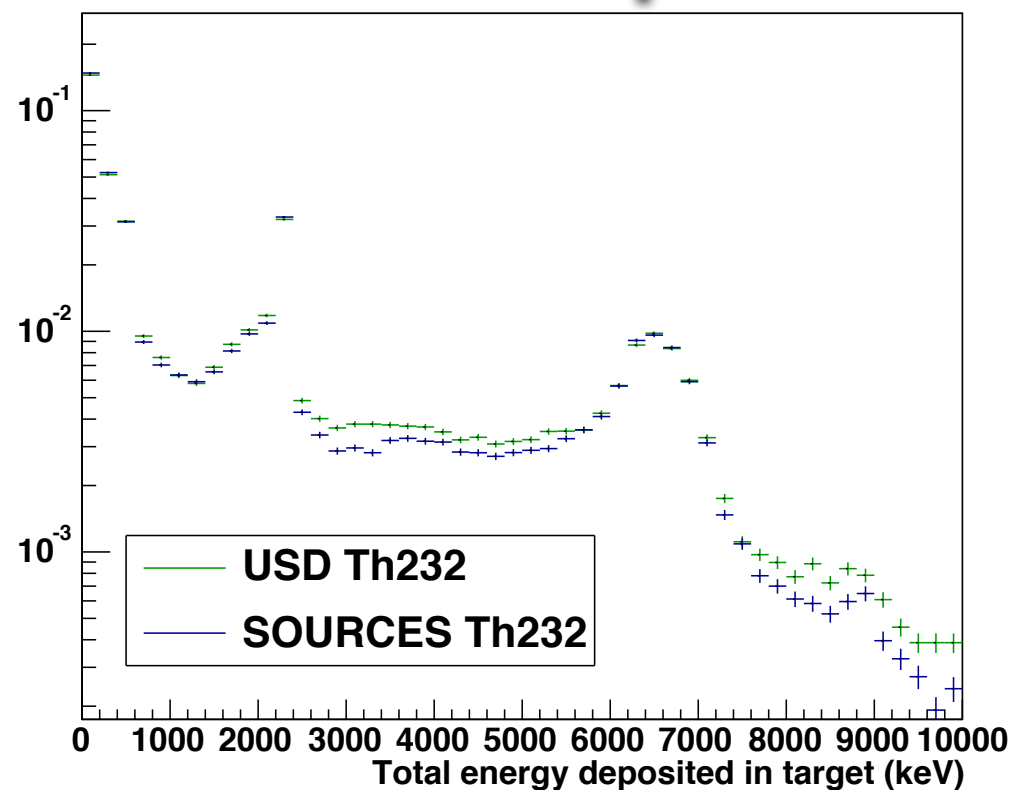


Scaled by yield

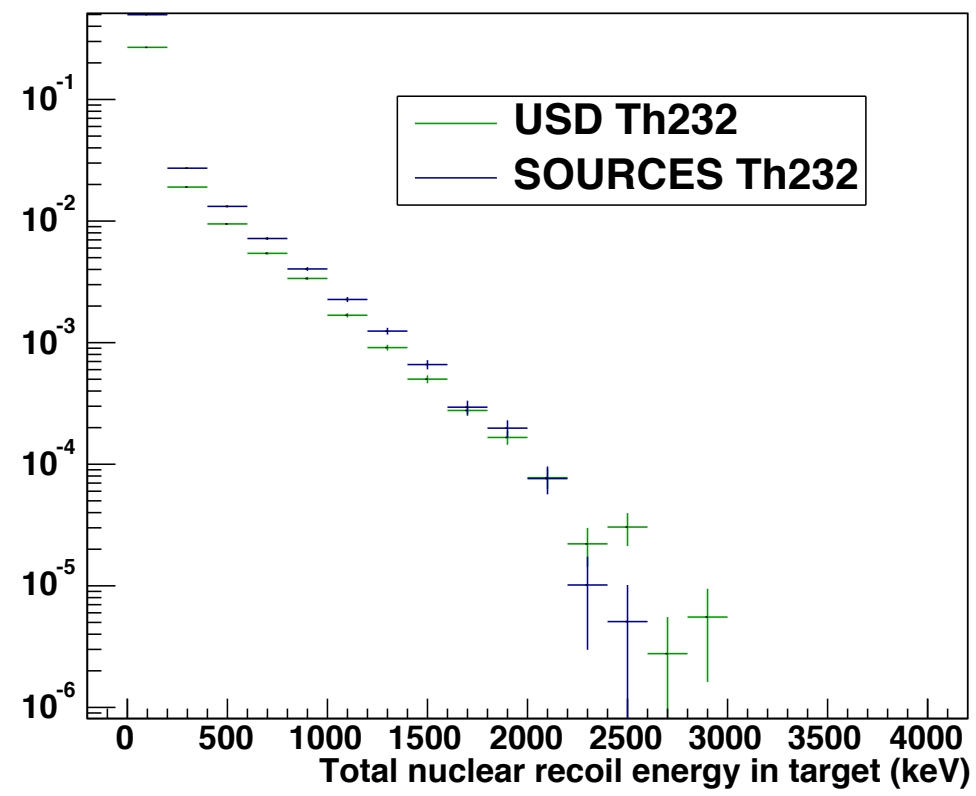
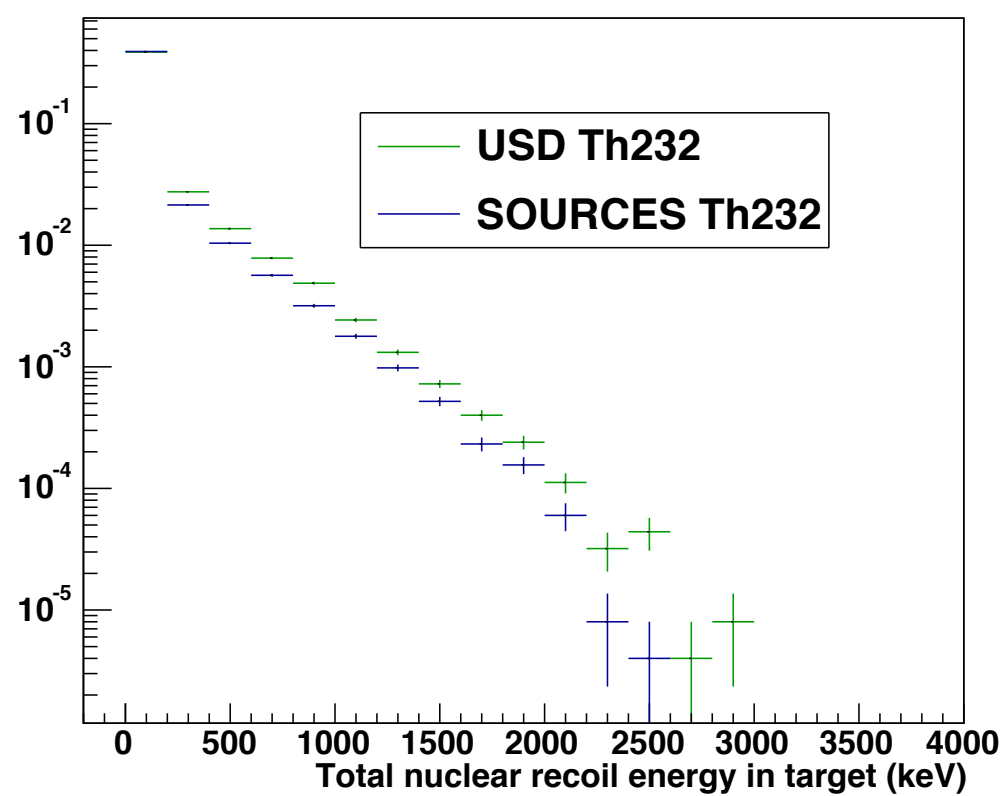
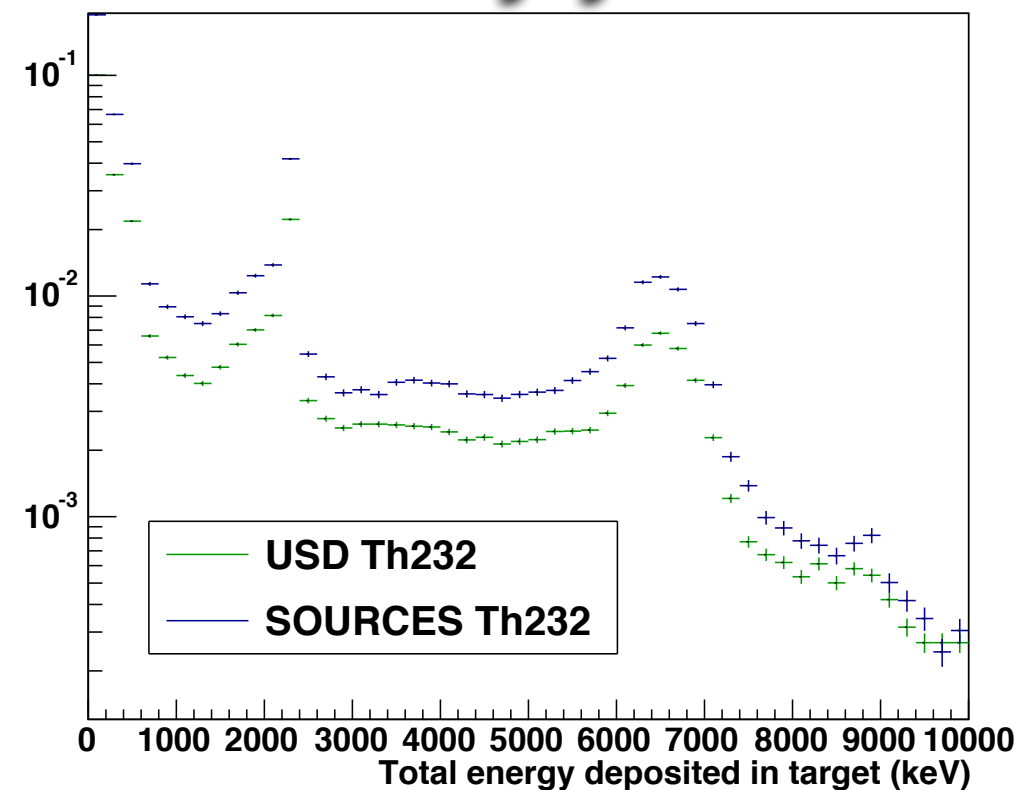


Ar (Borosilicate Th232): Energy Deposited

Just shape

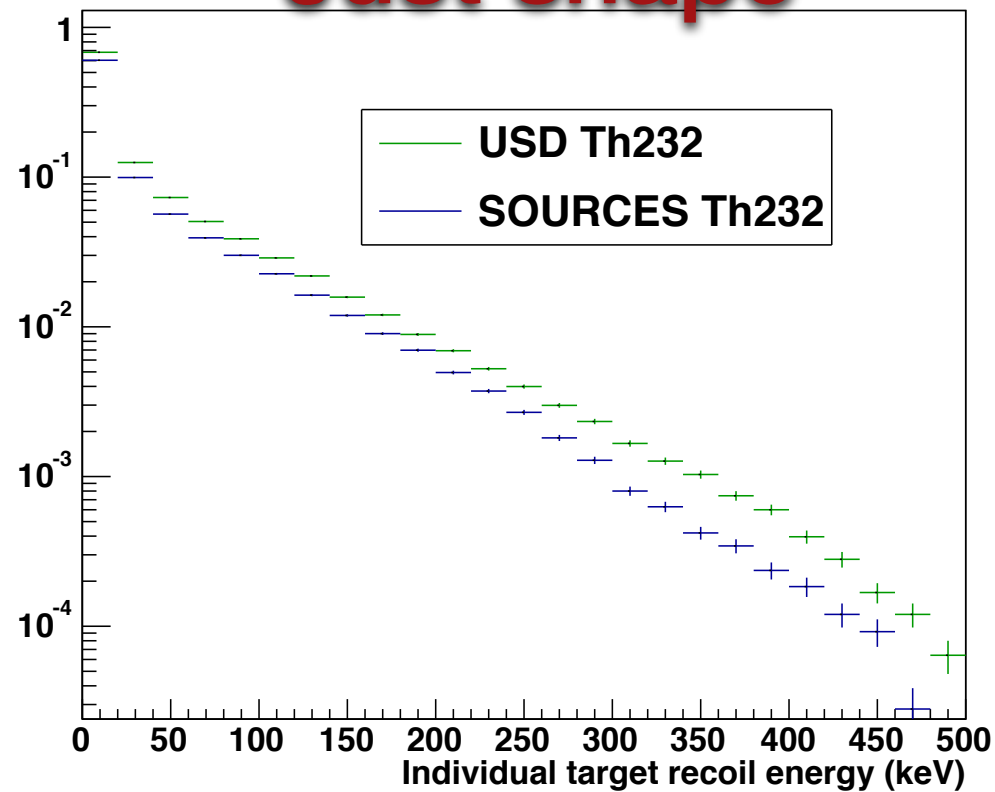


Scaled by yield

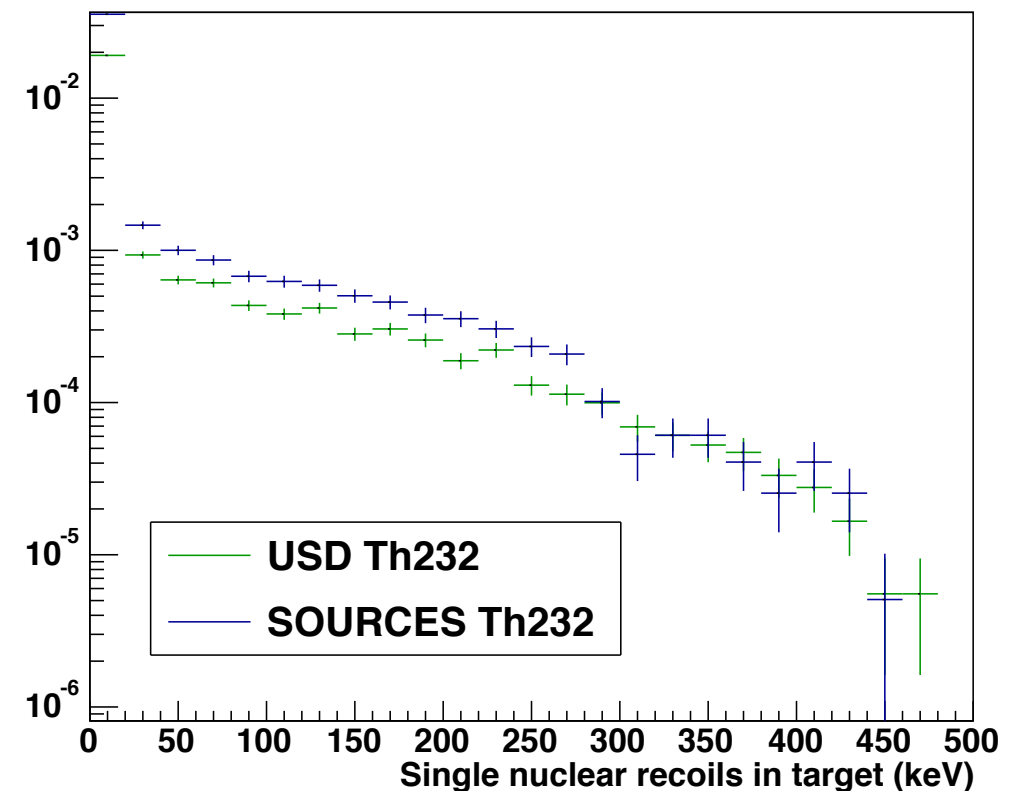
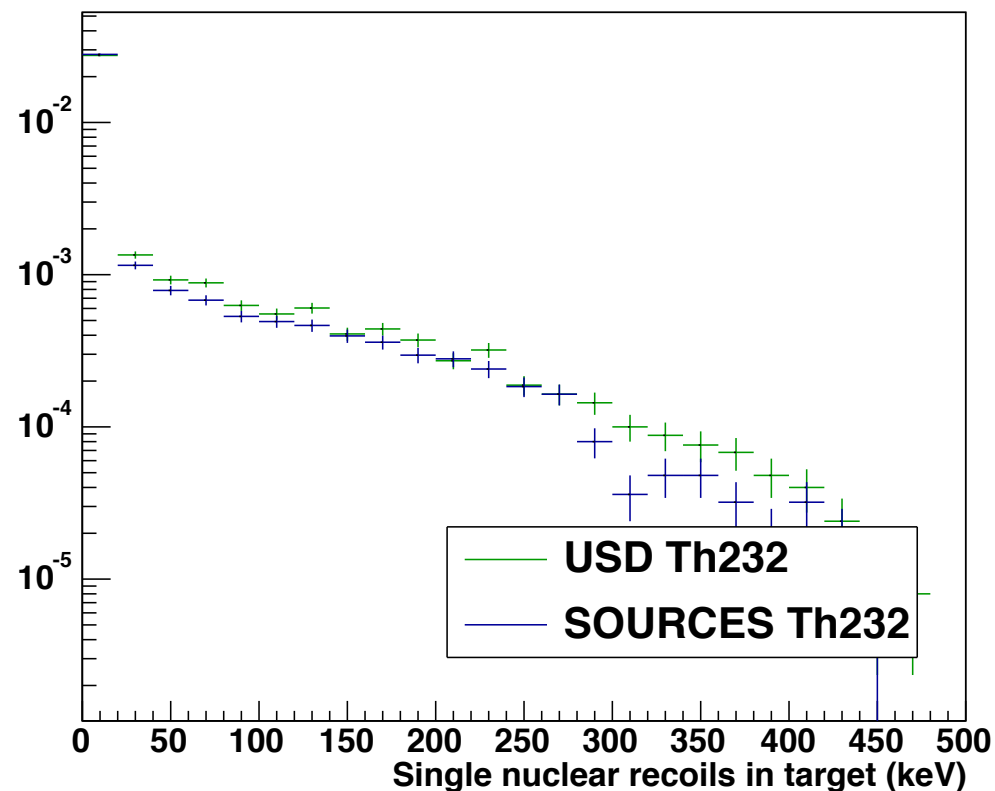
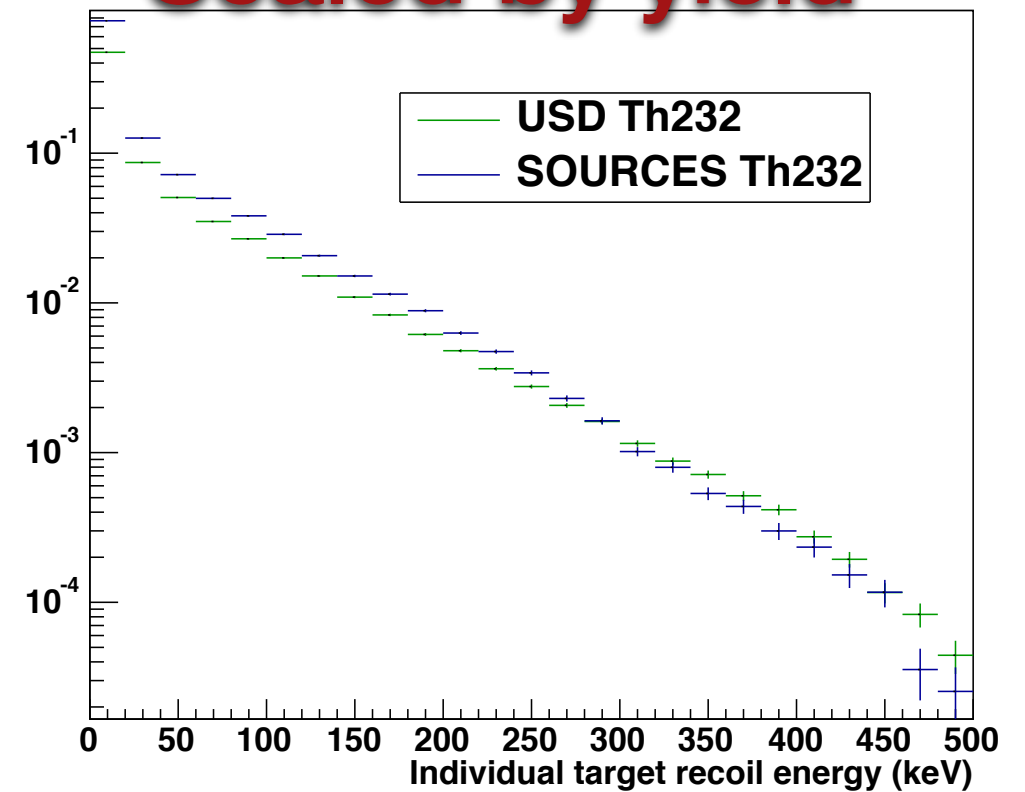


Ar (BorosilicateTh232): Nuclear Recoils

Just shape

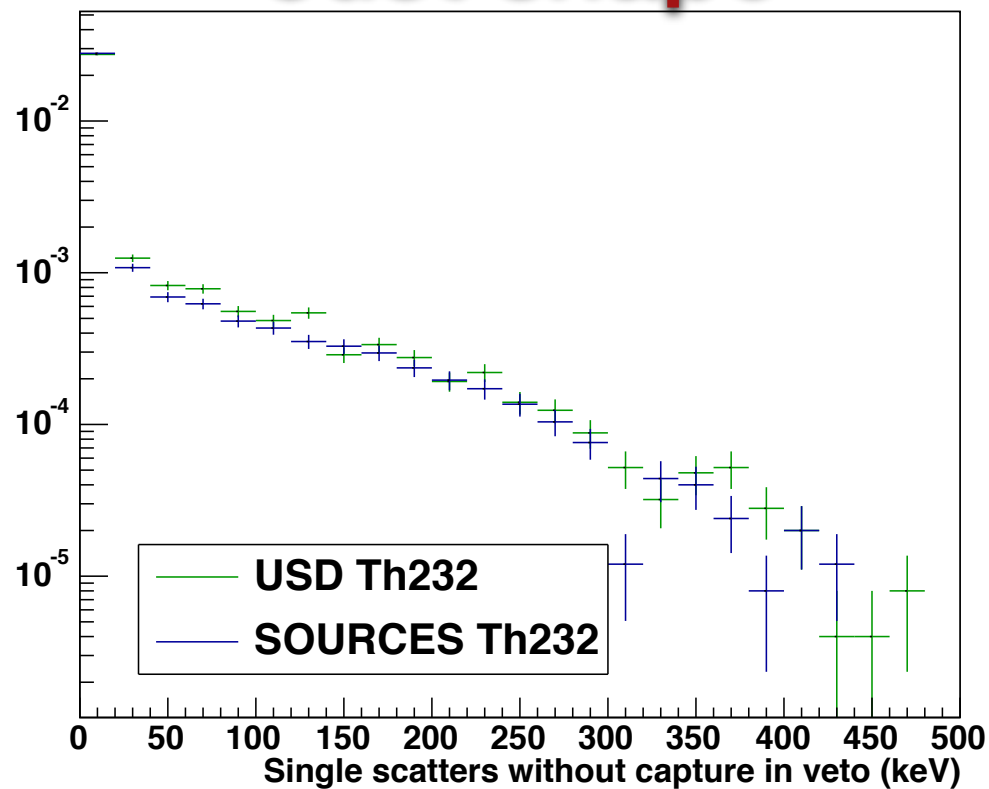


Scaled by yield

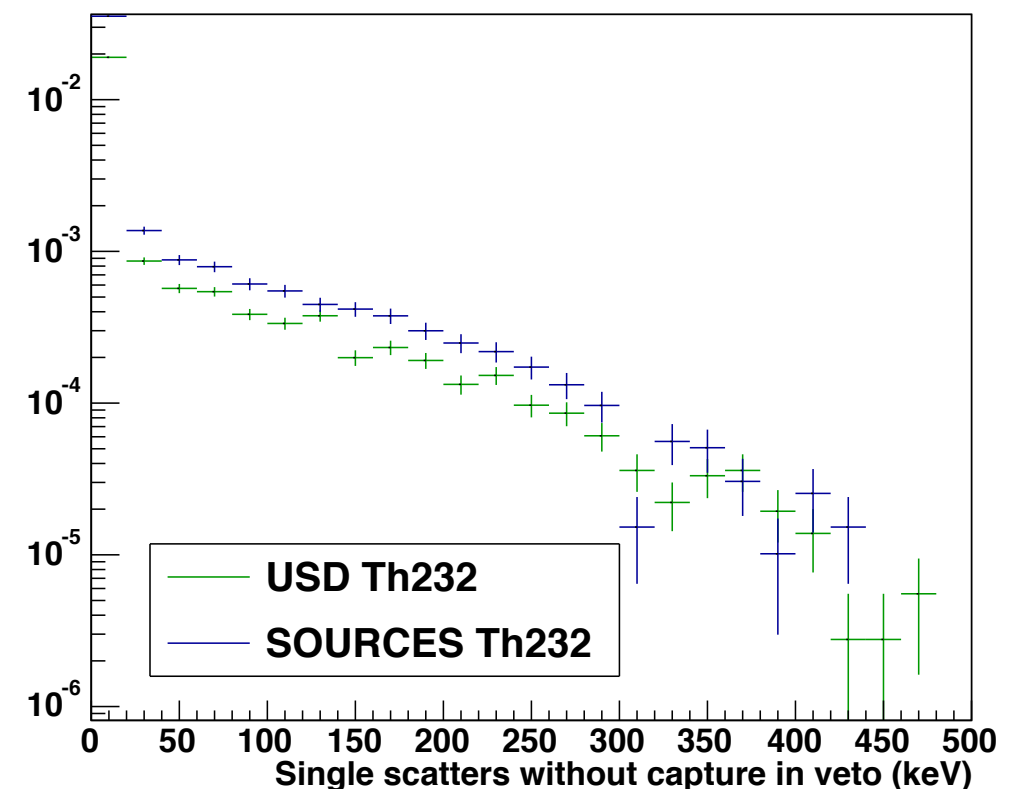
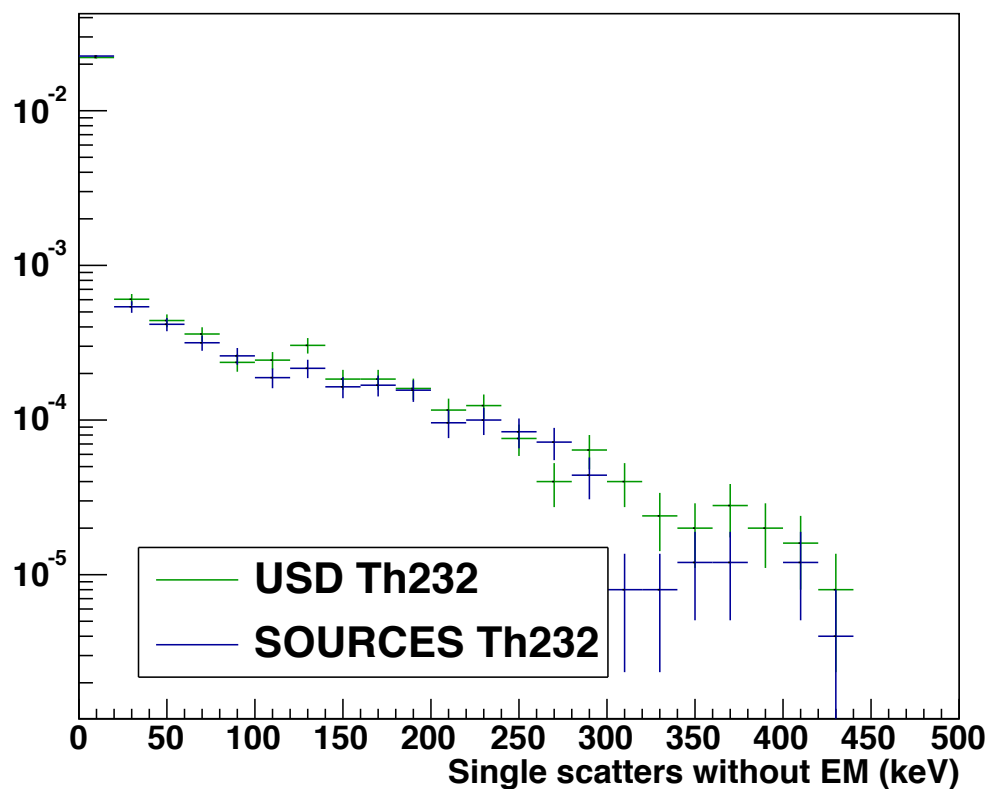
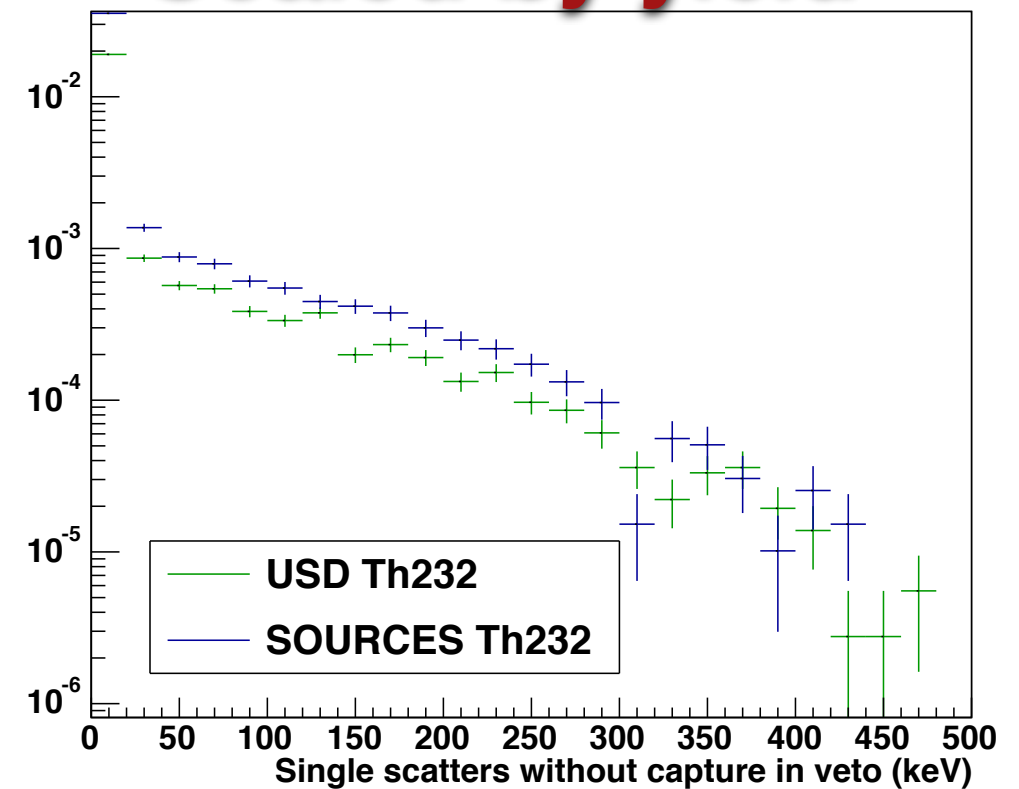


Ar (Borosilicate Th232): Vetoes Recoils

Just shape

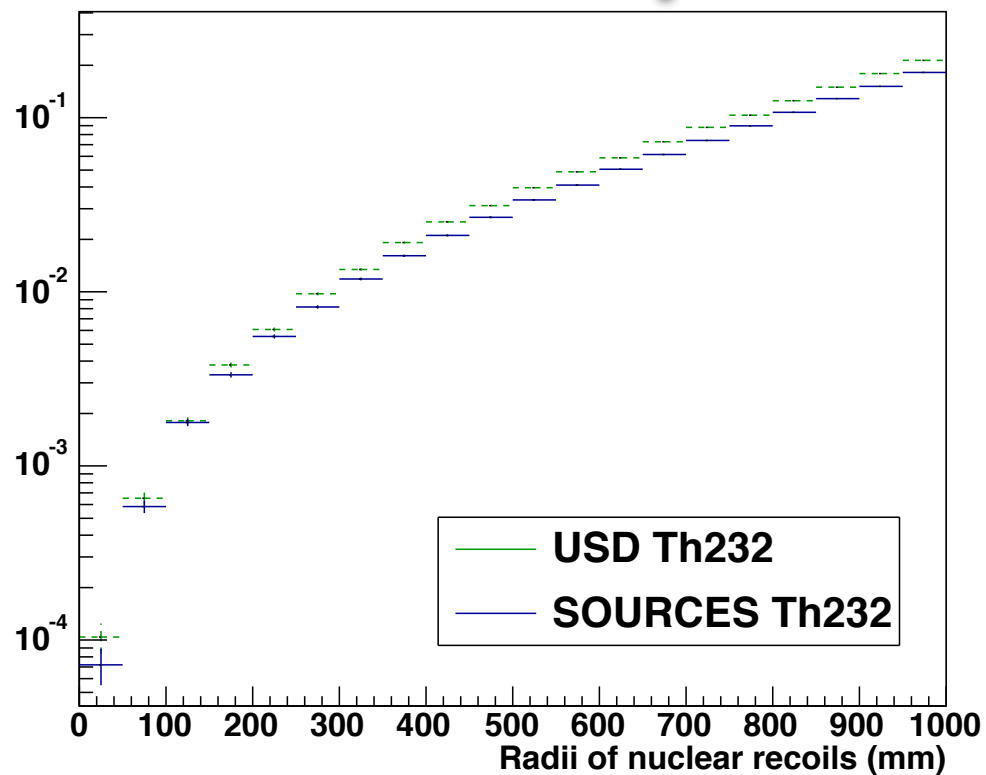


Scaled by yield

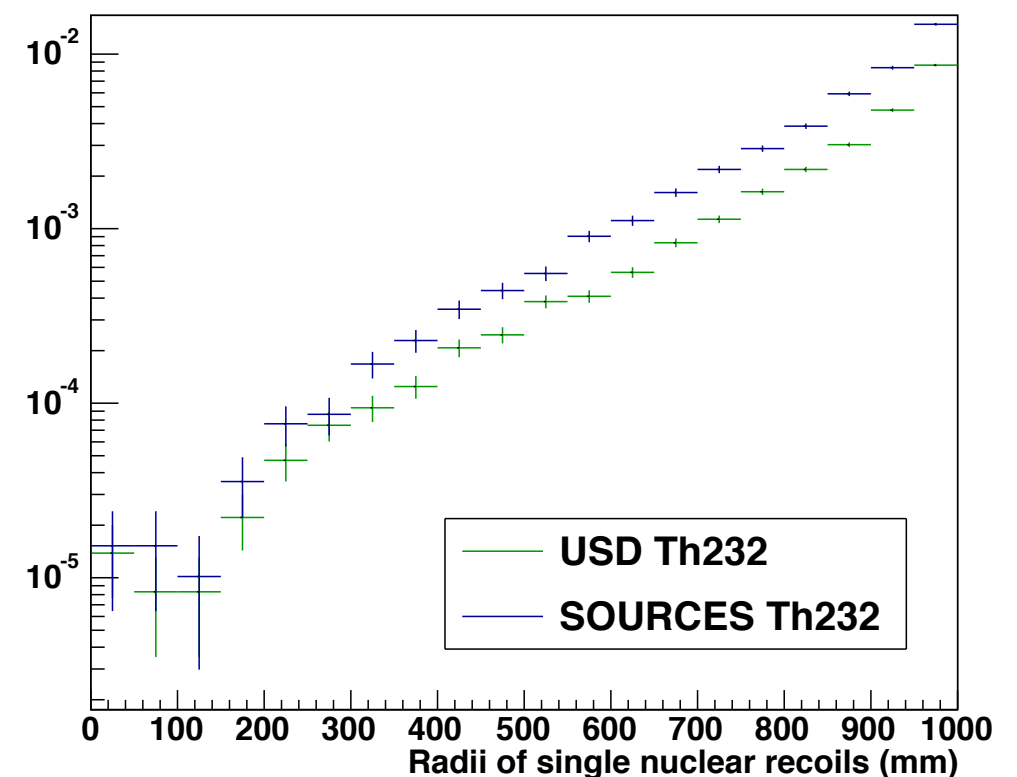
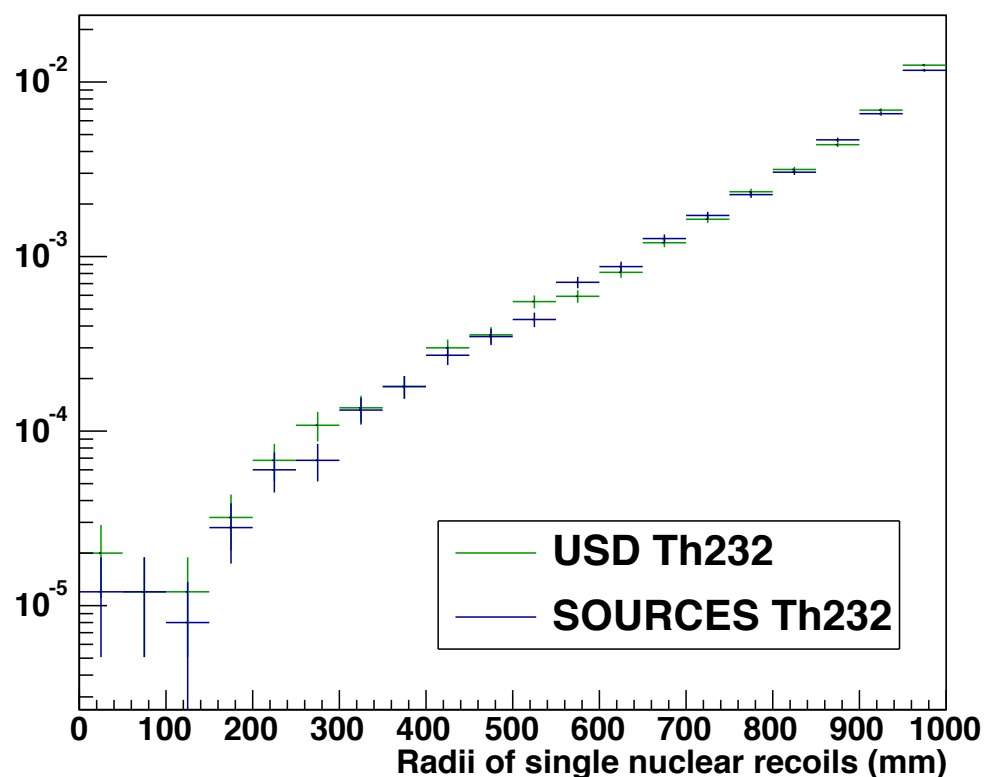
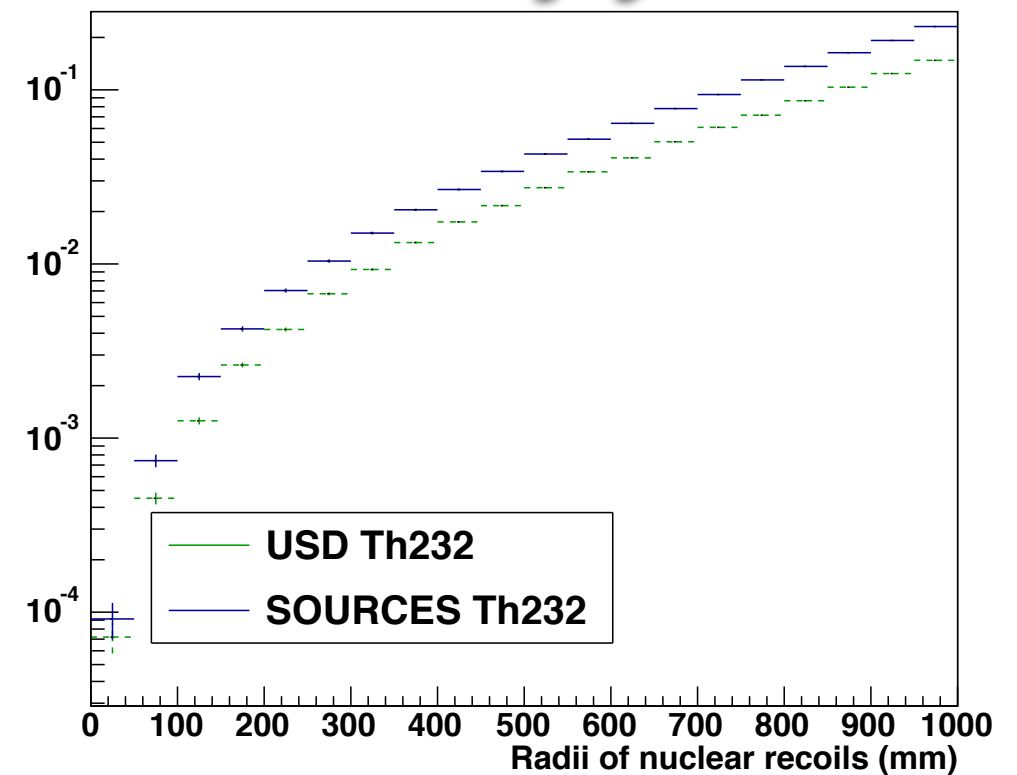


Ar (Borosilicate Th232): Recoil Radii

Just shape



Scaled by yield



Ar Th232 Conclusions

- By shape USD gives 24% more events; shapes are more affected over threshold energy
- 5% error in # events from energy comparisons, 10% error in # events from radial distribution, and 12% error in multiplicity comparisons possible
- Veto importance: 17% more events left in USD after captures,
- 83% difference in neutron yield leads to a 51% difference in single scatters
- USD > Sources by shape; Sources > USD by yield

Xe Detector Simulations

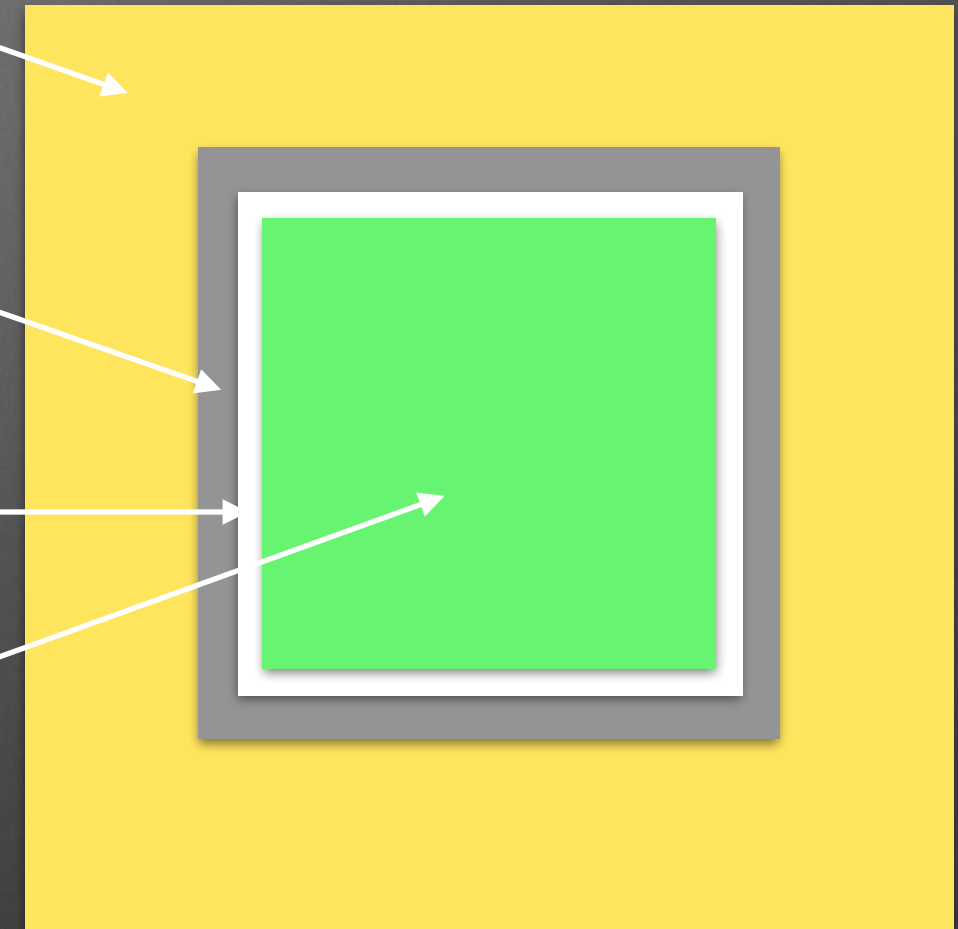
- 250000 neutrons isotropic from titanium or teflon for each simulation
- Neutron recoil threshold of 5 keVnr used in analysis
- 1 keVee threshold for EM deposits to veto event in xenon
- Neutron capture in oil-based scintillator needed to externally veto event

Liquid scintillator cylinder
3 m tall, 3 m wide

2 cm titanium
at 0.55m radius

3 cm PTFE
to 0.5m radius

Liquid xenon
1 m tall, 1m wide



Nested cylinders geometry

- Apologies for cryptic columns on next pages, dropped percentages and everything is straight fractions, some text values are wrong on my code output
- Should look at distance from wall and not radius in final work

Xenon (Titanium source U238)

	Initial energy mean and sigma (MeV)	% total number recoils % recoil over 5 keV	%recoil %summed nuclear recoils over 5 keV	%single nuc %single nuc over 5 keV	%single no veto capture %over 5keV	%single no EM over 1 keV %over 5 keV	0 scatters% 1 scatter % 2 scatter % more scatters %
USD shape only	2.00972 Sigma: 1.20324	4.70095 +/- 0.00433633 0.949584 +/- 0.00194893	0.424792 +/- 0.00130352 0.08876 +/- 0.000595852	0.040984 +/- 0.00040489 0.013396 +/- 0.000231482 0 +/- 0	0.02388 +/- 0.000309063 0.004384 +/- 0.000132424	0.014492 +/- 0.000240765 0.002804 +/- 0.000105906	0.605756 +/- 0.0015566 0.040984+/-0.00040489 0.035612+/-0.000377423 0.317592+/-0
SOURCES shape only	1.60417 Sigma: 1.02751	4.60908 +/- 0.00429375 0.852476 +/- 0.00184659	0.421944 +/- 0.00129914 0.076108 +/- 0.000551754	0.042648 +/- 0.000413028 0.012796 +/- 0.000226239 0 +/- 0	0.025476 +/- 0.000319224 0.004116 +/- 0.000128312	0.015296 +/- 0.000247354 0.002556 +/- 0.000101114	0.60898+/-0.00156074 0.042648+/-0.000413028 0.035468+/-0.000376659 0.312848+/-0.000105906
(all scaled by production)	neutron yield n/s/cm^3	recoils over 5keV	summed nuclear recoils over 5keV	single nuclear recoils over 5keV over 200 keV	singles no veto capture over 5 keV	singles no EM over 1 keV “ over 5 keV	0 scatters 1 scatter 2 scatters more
USD full	1.98E-10	9.30788 +/- 0.00858594 1.88018 +/- 0.00385889	0.841088 +/- 0.00258097 0.175745 +/- 0.00117979	0.0811483 +/- 0.000801682 0.0265241 +/- 0.000458335 0 +/- 0	0.0472824 +/- 0.000611945 0.00868032 +/- 0.000262199	0.0286942 +/- 0.000476716 0.00555192 +/- 0.000209693	1.1994 +/- 0.00308208 0.0811483+/-0.000801682 0.0705118+/-0.000747297 0.628832+/-0
SOURCES full	1.65E-10	7.60498 +/- 0.00708469 1.40659 +/- 0.00304688	0.696208 +/- 0.00214359 0.125578 +/- 0.000910393	0.0703692 +/- 0.000681496 0.0211134 +/- 0.000373294 0 +/- 0	0.0420354 +/- 0.00052672 0.0067914 +/- 0.000211715	0.0252384 +/- 0.000408134 0.0042174 +/- 0.000166838	1.00482+/-0.00257523 0.0703692+/-0.000681496 0.0585222+/-0.000621487 0.516199+/-0.000209693

More numbers (U238)

Simulation	%/# simulated scatters < 90 cm	%/# simulated single scatters <90 cm	ratio scatters more :2 more:1 2:1 2+:1	ratio single scatters total to those inside radius	ratio energy 20-200keV: >200keV
USD shape only	1.07616 +/- 0.00207477	0.000716 +/- 5.35164e-05	8.9 7.75 0.87 8.62	18.7	inf
SOURCES shape only	1.03551 +/- 0.0020352	0.000732 +/- 5.4111e-05	8.85 7.34 0.83 8.17	17.48	inf
USD full	2.1308 +/- 0.00410804	0.00141768 +/ 0.000105962			
SOURCES full	1.70859 +/- 0.00335808	0.0012078 +/- 8.92831e-05			

Raw output for chart

Just shape

USD Numbers:

Start energy mean: 2.00972 Sigma: 1.20324

0: 0.605756 +/- 0.00155661 1: 0.040984 +/- 0.00040489 2: 0.035612 +/- 0.000377423 More: 0.317592 +/- 0

Individual recoils, all: 4.70095 +/- 0.00433633 over threshold keV: 0.949584 +/- 0.00194893

Total nuclear recoils all: 0.424792 +/- 0.00130352 over threshold keV: 0.08876 +/- 0.000595852

Total nuclear + EM recoils all: 0.418128 +/- 0.00129326 over threshold keV: 0.339288 +/- 0.00116497

Single recoils, all: 0.040984 +/- 0.00040489 over threshold keV: 0.013396 +/- 0.000231482 over upper keV: 0 +/- 0

All neutron radii, within 90 cm: 1.07616 +/- 0.00207477

Single neutron radii, within 90 cm: 0.000716 +/- 5.35164e-05

Single recoils no veto, all: 0.02388 +/- 0.000309063 over threshold keV: 0.004384 +/- 0.000132424

Single recoils no EM, all: 0.014492 +/- 0.000240765 over threshold keV: 0.002804 +/- 0.000105906

Sources numbers:

Start energy mean: 1.60417 Sigma: 1.02751

0: 0.60898 +/- 0.00156074 1: 0.042648 +/- 0.000413028 2: 0.035468 +/- 0.000376659 More: 0.312848 +/- 0.000105906

Individual recoils, all: 4.60908 +/- 0.00429375 over threshold keV: 0.852476 +/- 0.00184659

Total nuclear recoils all: 0.421944 +/- 0.00129914 over threshold keV: 0.076108 +/- 0.000551754

Total nuclear and EM recoils all: 0.417008 +/- 0.00129152 over threshold keV: 0.33004 +/- 0.00114898

Single recoils, all: 0.042648 +/- 0.000413028 over threshold keV: 0.012796 +/- 0.000226239 over upper keV: 0 +/- 0

All neutron radii, within 90 cm: 1.03551 +/- 0.0020352

Single neutron radii, within 90 cm: 0.000732 +/- 5.4111e-05

Single recoils no veto, all: 0.025476 +/- 0.000319224 over 5 keV: 0.004116 +/- 0.000128312

Single recoils no EM, all: 0.015296 +/- 0.000247354 over threshold keV: 0.002556 +/- 0.000101114

Scaled by yield

USD Numbers:

Start energy mean: 2.00972 Sigma: 1.20324

0: 1.1994 +/- 0.00308208 1: 0.0811483 +/- 0.000801682 2: 0.0705118 +/- 0.000747297 More: 0.628832 +/- 0

Individual recoils, all: 9.30788 +/- 0.00858594 over threshold keV: 1.88018 +/- 0.00385889

Total nuclear recoils all: 0.841088 +/- 0.00258097 over threshold keV: 0.175745 +/- 0.00117979

Total nuclear + EM recoils all: 0.827893 +/- 0.00256065 over threshold keV: 0.67179 +/- 0.00230664

Single recoils, all: 0.0811483 +/- 0.000801682 over threshold keV: 0.0265241 +/- 0.000458335 over upper keV: 0 +/- 0

All neutron radii, within 90 cm: 2.1308 +/- 0.00410804

Single neutron radii, within 90 cm: 0.00141768 +/- 0.000105962

Single recoils no veto, all: 0.0472824 +/- 0.000611945 over threshold keV: 0.00868032 +/- 0.000262199

Single recoils no EM, all: 0.0286942 +/- 0.000476716 over threshold keV: 0.00555192 +/- 0.000209693

Sources numbers:

Start energy mean: 1.60417 Sigma: 1.02751

0: 1.00482 +/- 0.00257523 1: 0.0703692 +/- 0.000681496 2: 0.0585222 +/- 0.000621487 More: 0.516199 +/- 0.000209693

Individual recoils, all: 7.60498 +/- 0.00708469 over threshold keV: 1.40659 +/- 0.00304688

Total nuclear recoils all: 0.696208 +/- 0.00214359 over threshold keV: 0.125578 +/- 0.000910393

Total nuclear and EM recoils all: 0.688063 +/- 0.00213101 over threshold keV: 0.544566 +/- 0.00189582

Single recoils, all: 0.0703692 +/- 0.000681496 over threshold keV: 0.0211134 +/- 0.000373294 over upper keV: 0 +/- 0

All neutron radii, within 90 cm: 1.70859 +/- 0.00335808

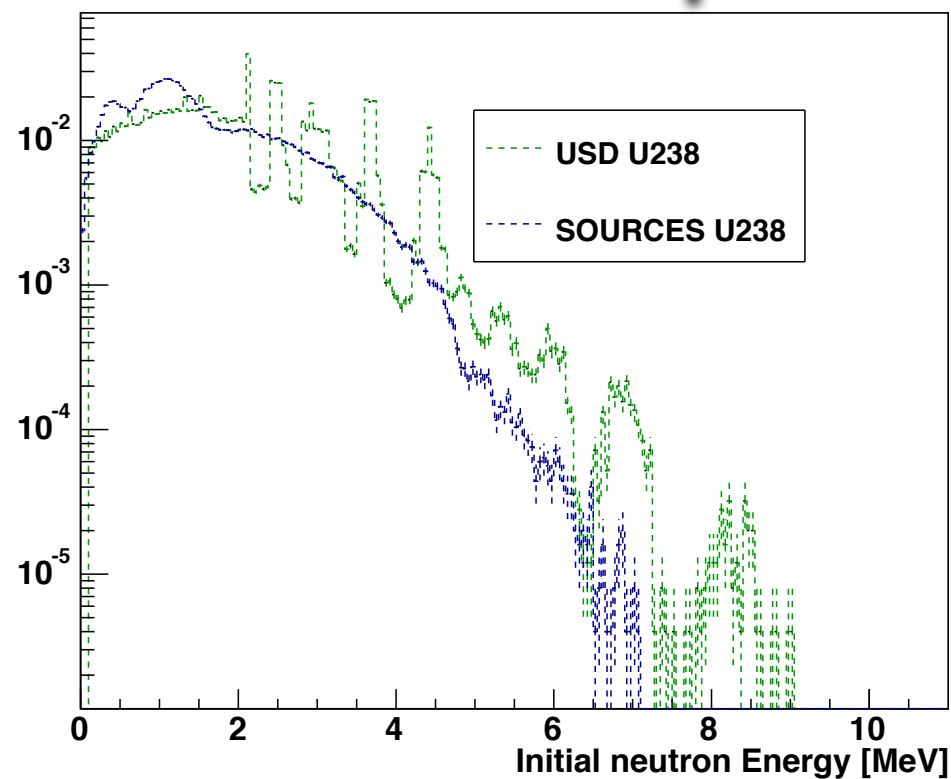
Single neutron radii, within 90 cm: 0.0012078 +/- 8.92831e-05

Single recoils no veto, all: 0.0420354 +/- 0.00052672 over 5 keV: 0.0067914 +/- 0.000211715

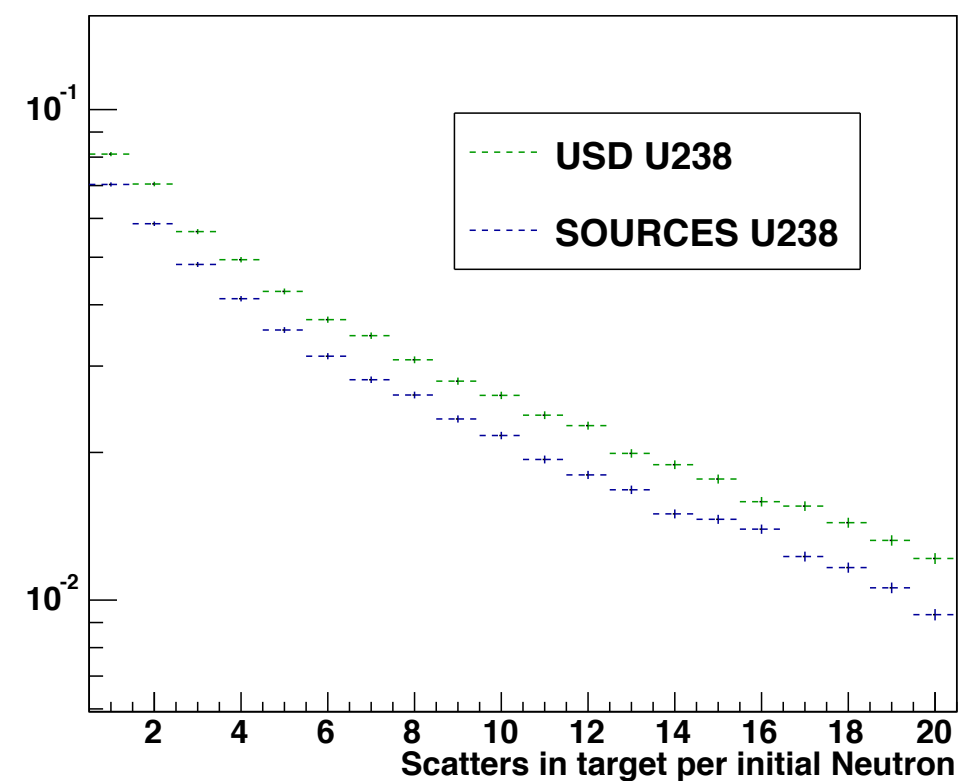
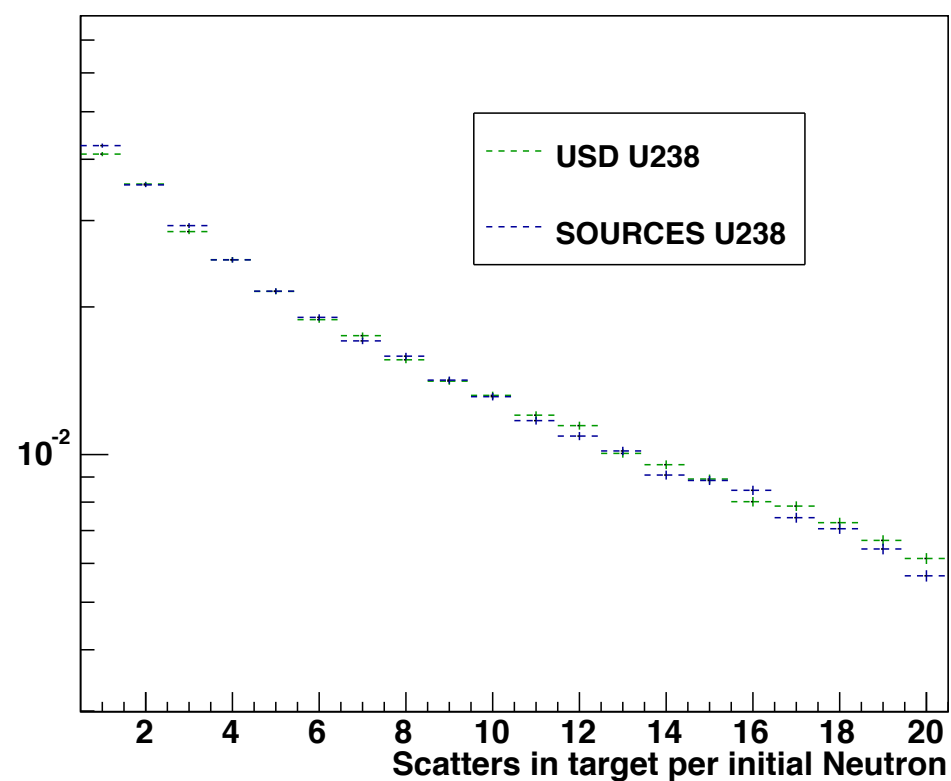
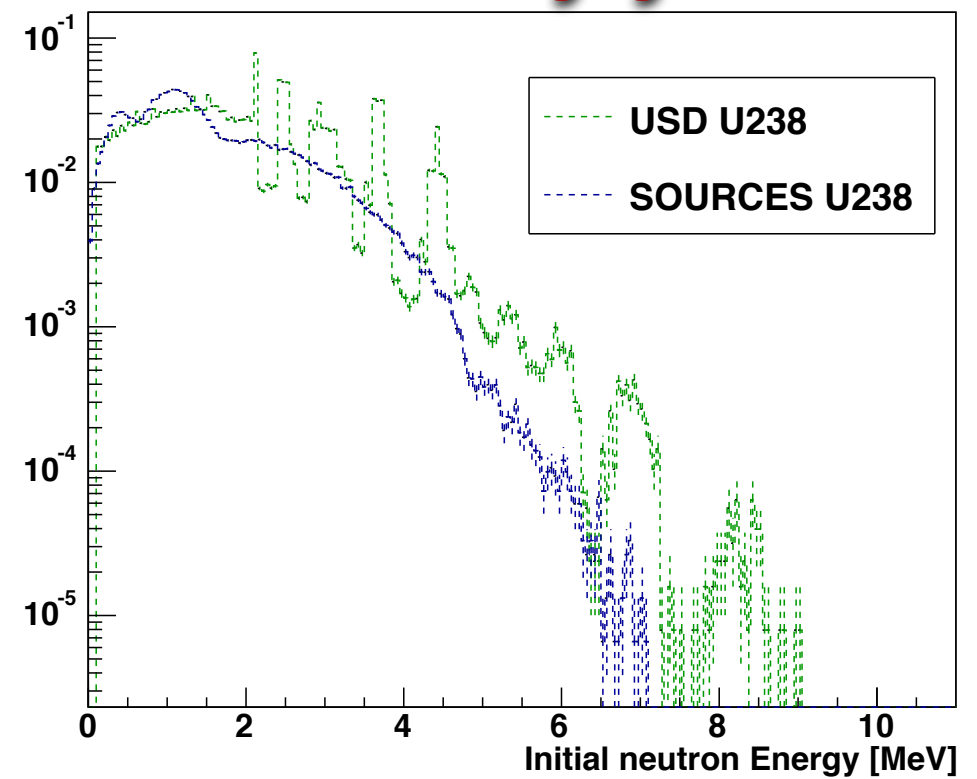
Single recoils no EM, all: 0.0252384 +/- 0.000408134 over threshold keV: 0.0042174 +/- 0.000166838

Xenon (Titanium U238)

Just shape

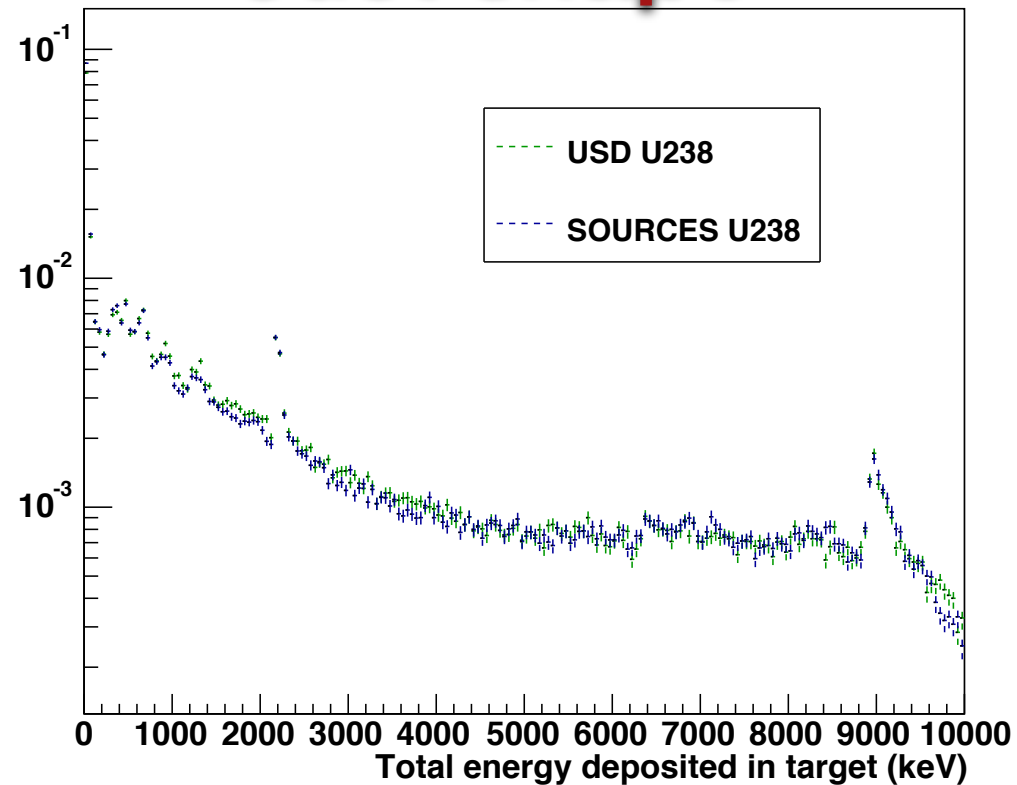


Scaled by yield

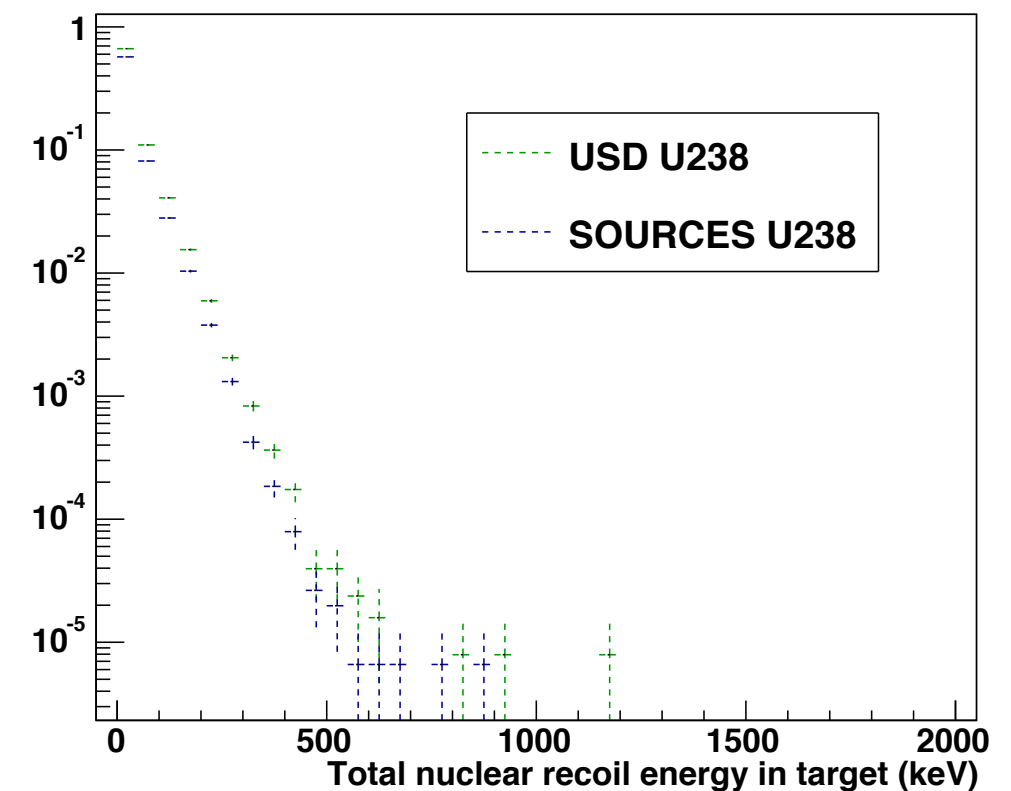
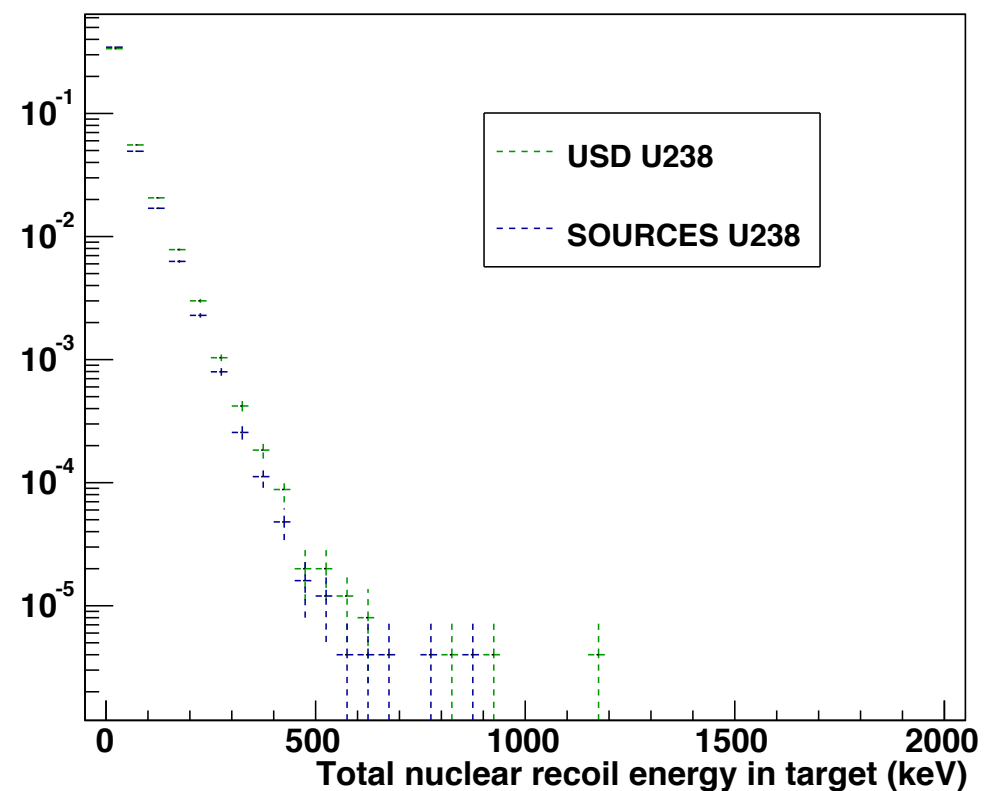
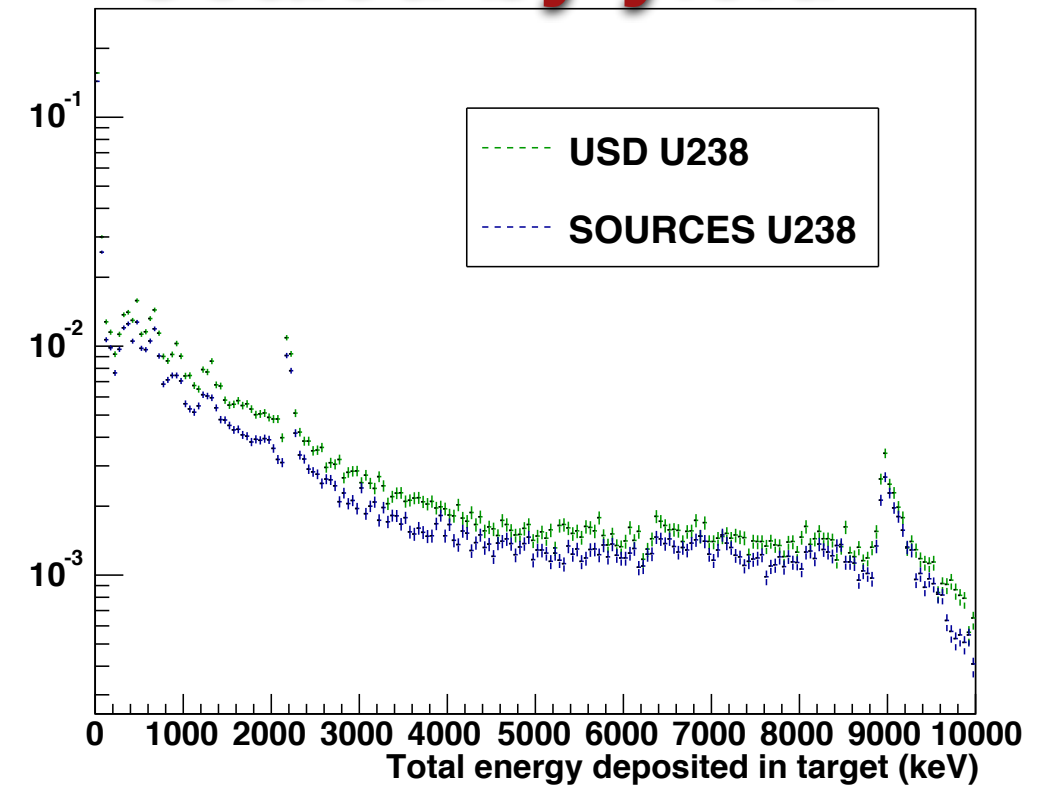


Xenon (Titanium U238): Energy Deposited

Just shape

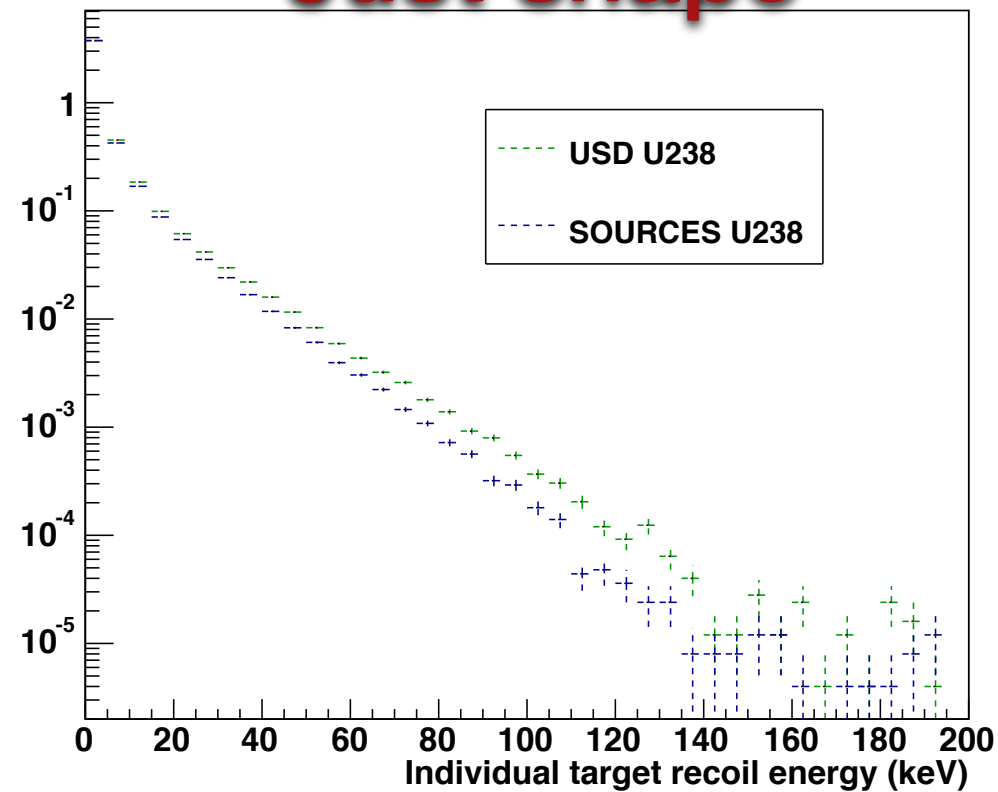


Scaled by yield

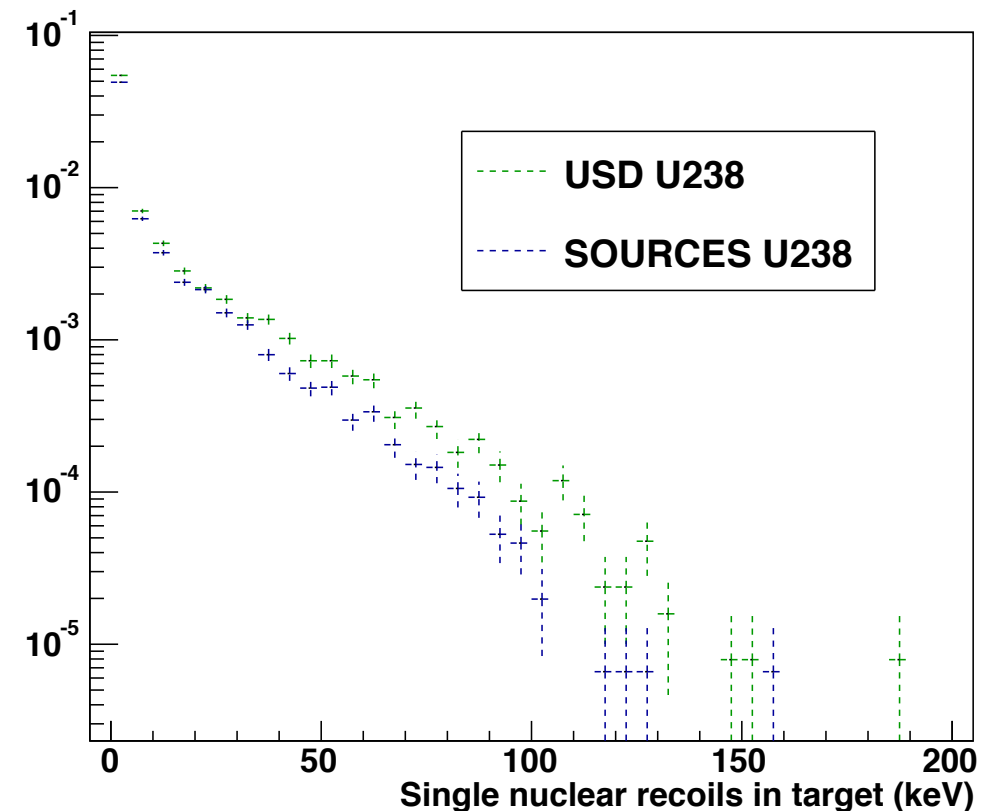
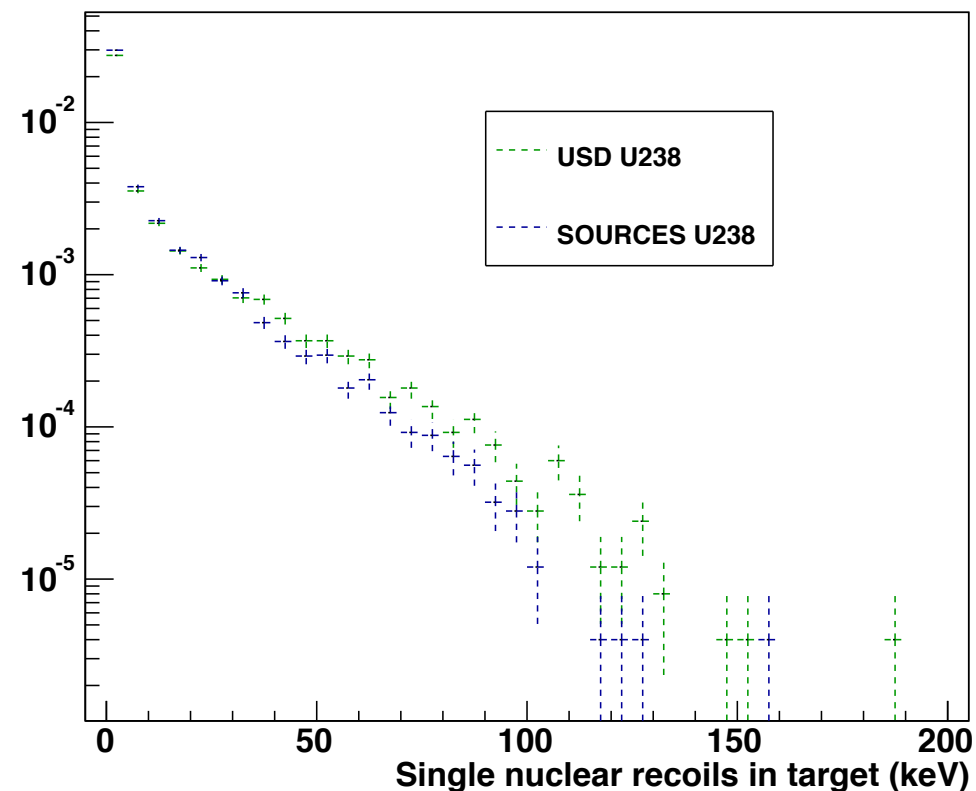
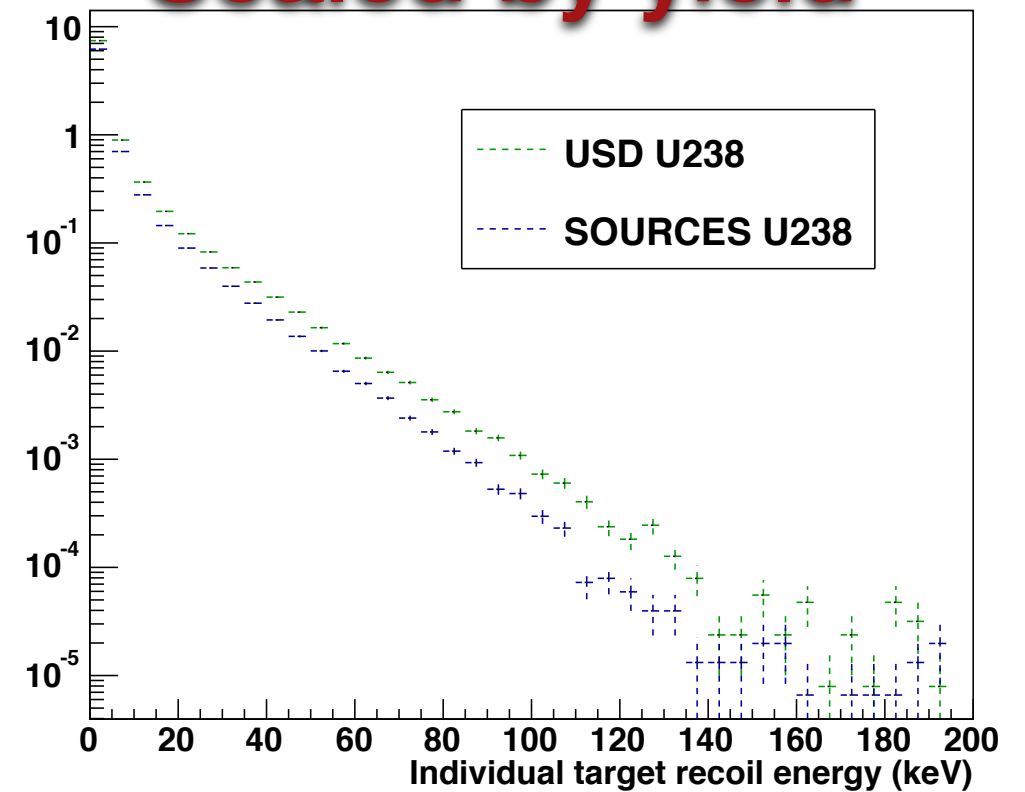


Xenon (Titanium U238): Nuclear Recoils

Just shape

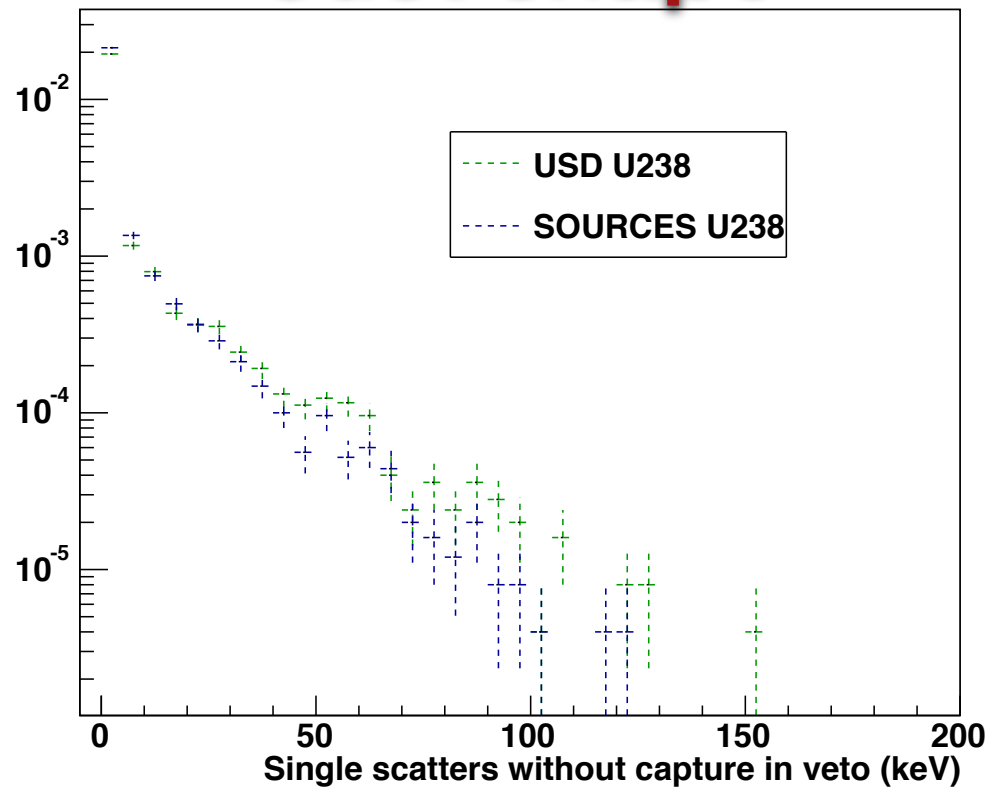


Scaled by yield

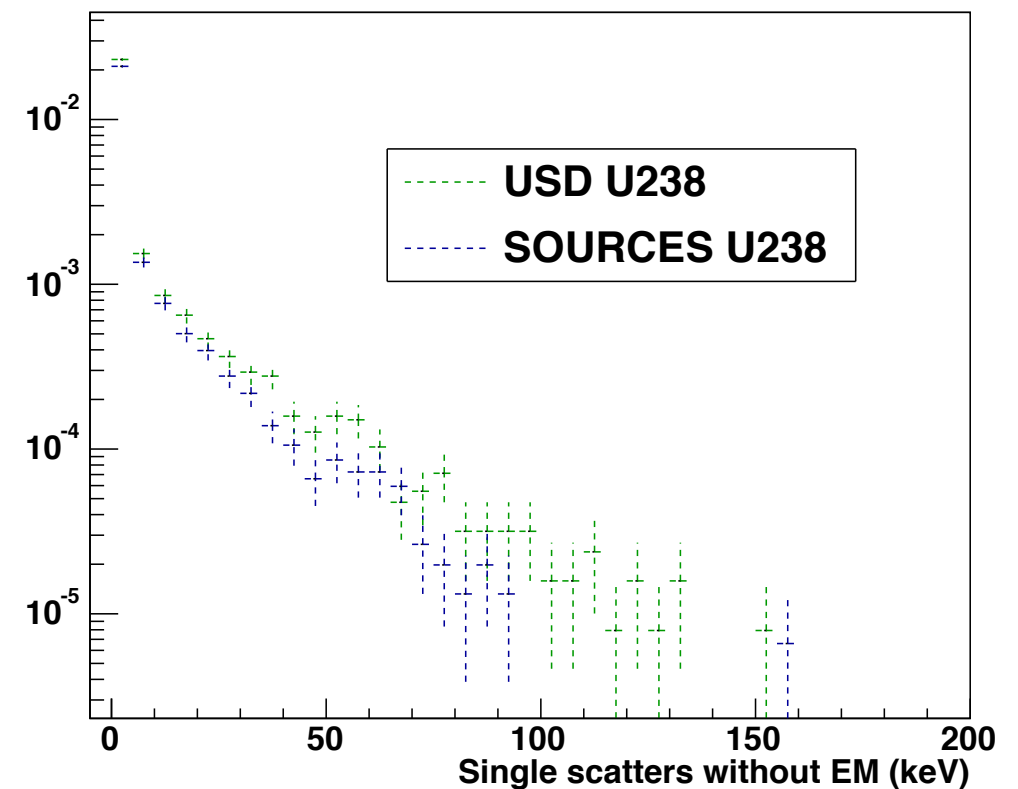
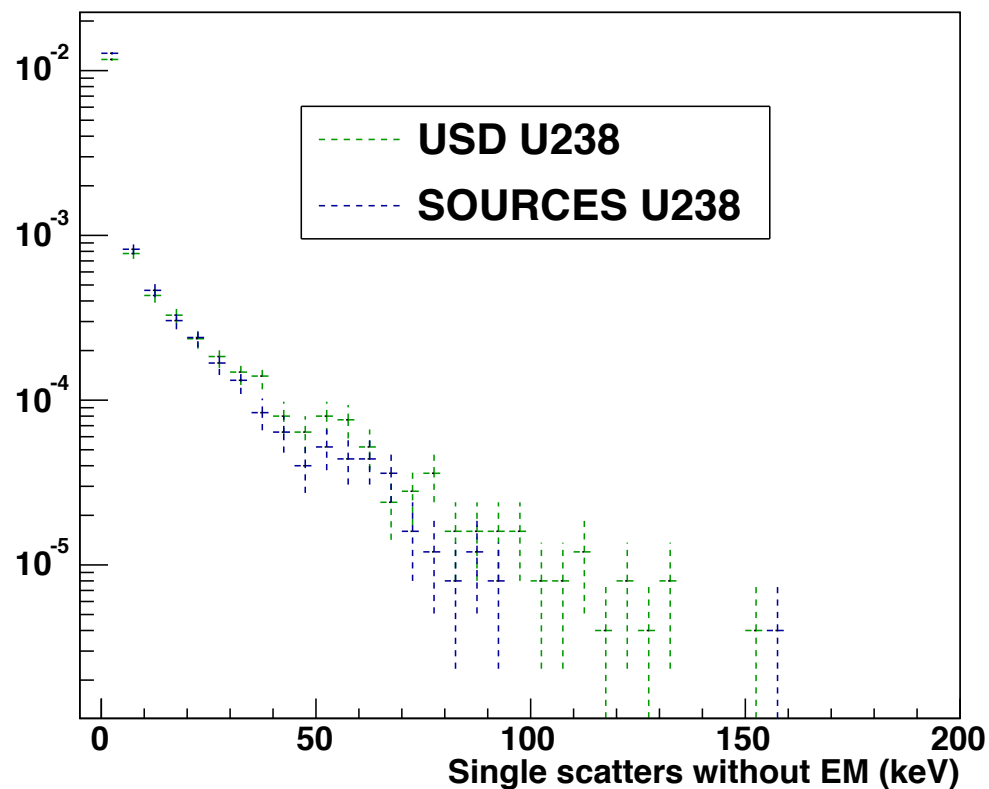
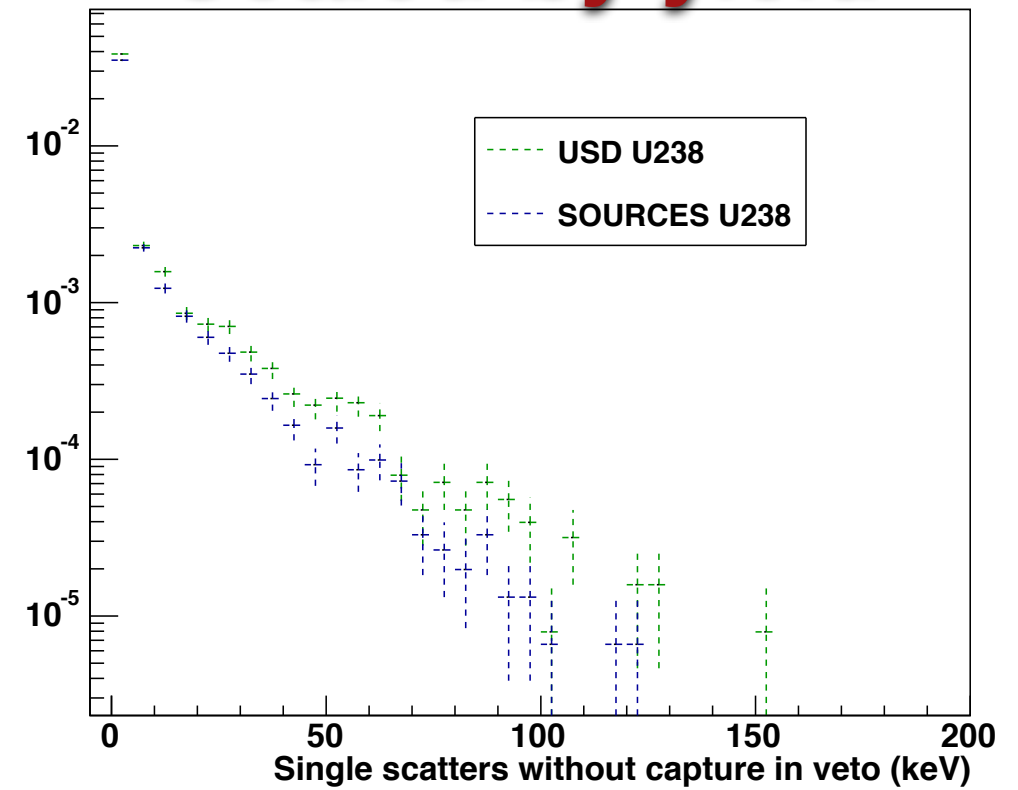


Xenon (Titanium U238): Vetoed Recoils

Just shape

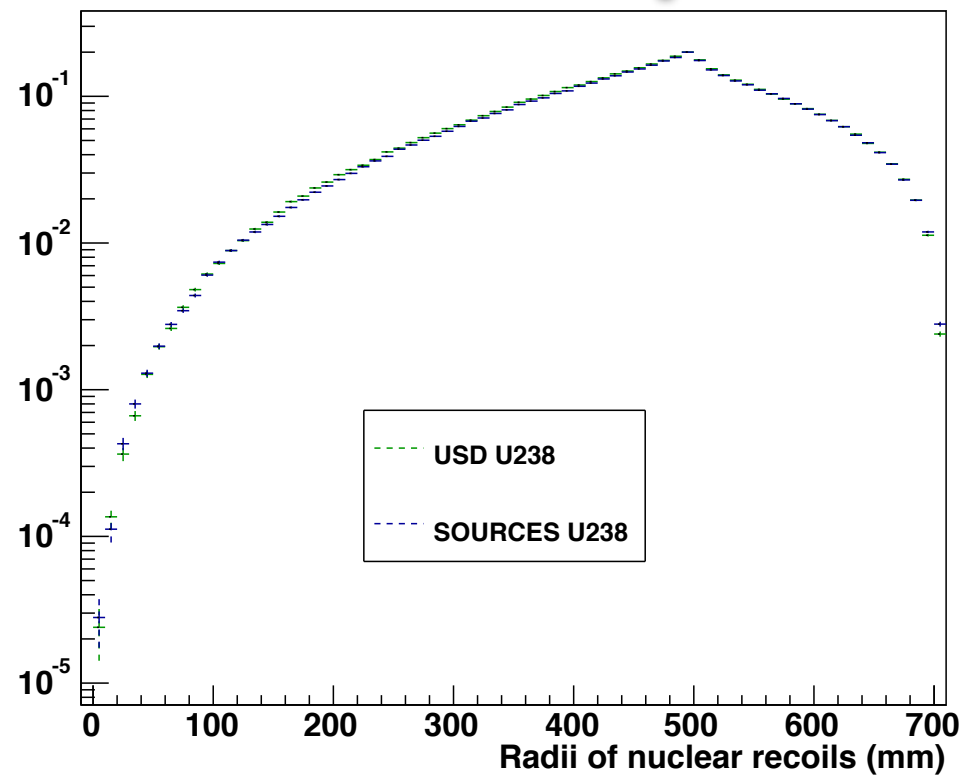


Scaled by yield

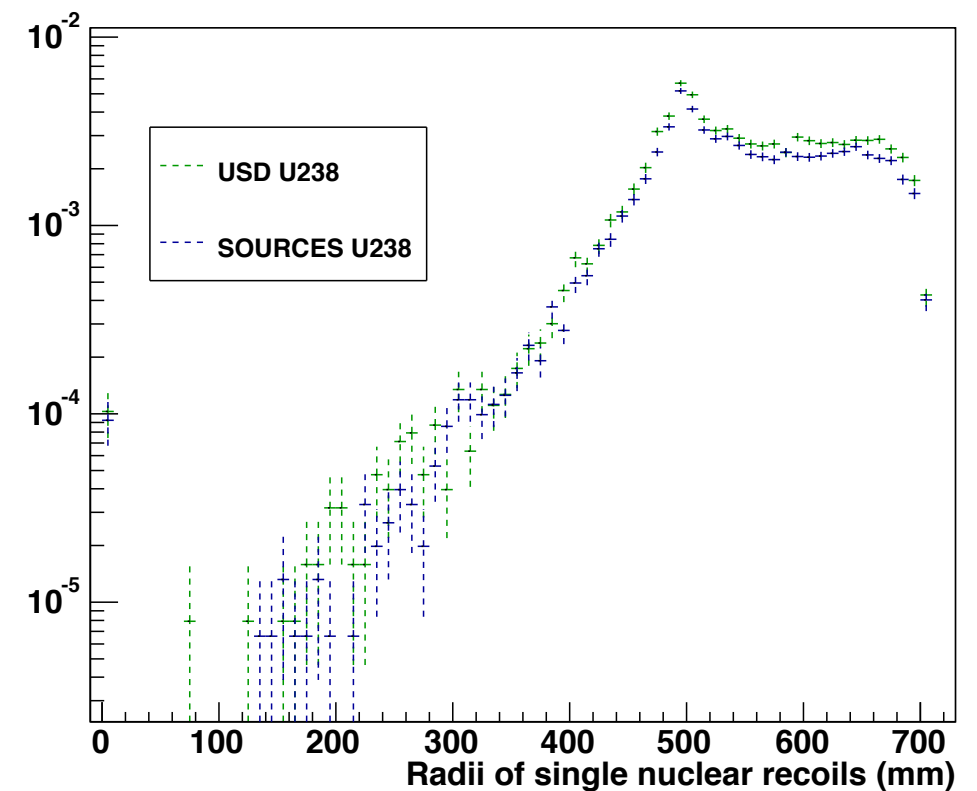
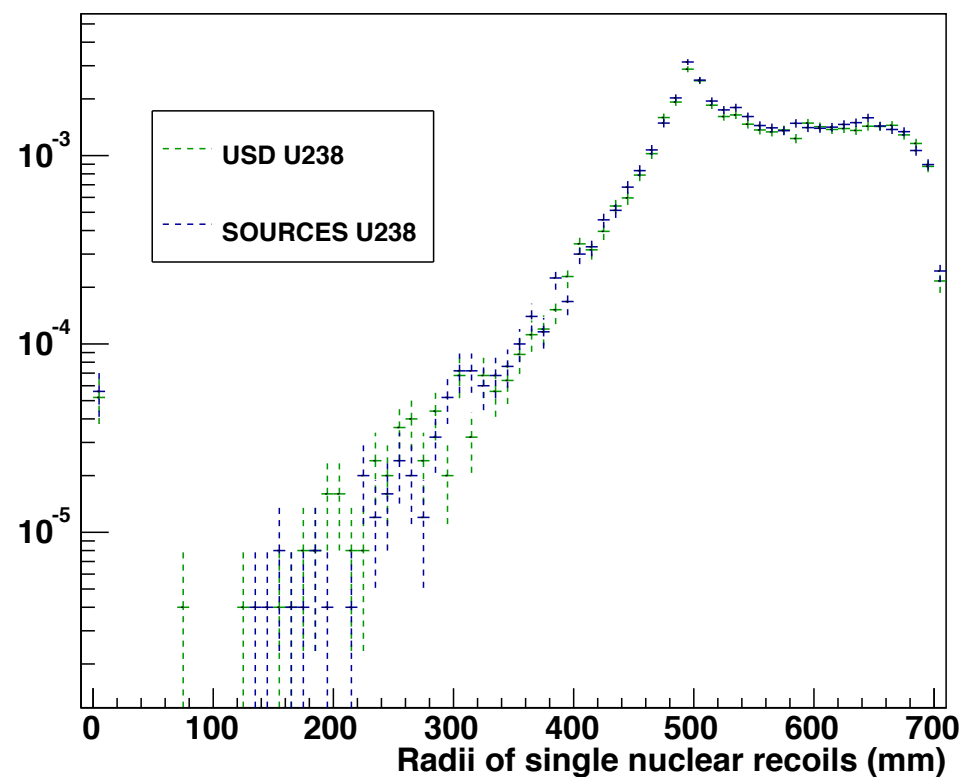
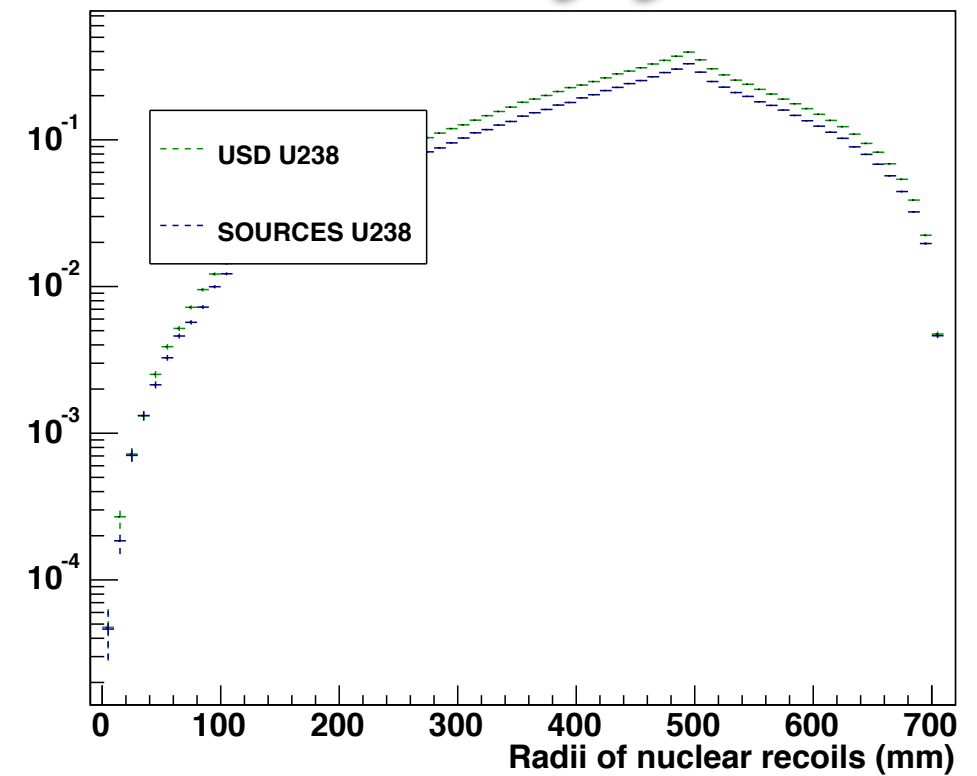


Xenon (Titanium U238): Recoil Radii

Just shape



Scaled by yield



Xe Ti U238 Conclusions

- 7% error in # events from radial distribution, and 5.5% error in multiplicity comparisons possible, 5% difference in shape
- Veto importance: 6.5% difference by capture, 9.7% by EM
- 20% difference in neutron yield leads to a 24% difference in single scatters
- USD $\geq$ Sources by shape; USD > Sources by yield

Xenon (Titanium source Th232)

	Initial energy mean and sigma (MeV)	% total number recoils % recoil over 5 keV	%recoil %summed nuclear recoils over 5 keV	%single nuc %single nuc over 5 keV	%single no veto capture %over 5keV	%single no EM over 1 keV %over 5 keV	0 scatters% 1 scatter % 2 scatter % more scatters %
USD shape only	2.09762 Sigma: 1.33437	4.69336 +/- 0.00433283 0.949304 +/- 0.00194864	0.425064 +/- 0.00130394 0.089536 +/- 0.000598451	0.04066 +/- 0.000403286 0.013724 +/- 0.000234299 0 +/- 0	0.023808 +/- 0.000308597 0.004504 +/- 0.000134224	0.015732 +/- 0.000250855 0.002916 +/- 0.000108	0.60666 +/- 0.00155777 0.04066+/-0.000403286 0.03526+/-0.000375553 0.317368+/-0
SOURCES shape only	1.68092 Sigma: 1.08699	4.63402 +/- 0.00430535 0.86788 +/- 0.0018632	0.421724 +/- 0.00129881 0.077232 +/- 0.000555813	0.04268 +/- 0.000413183 0.013464 +/- 0.000232069 0 +/- 0	0.025136 +/- 0.000317087 0.004476 +/- 0.000133806	0.015732 +/- 0.000250855 0.002916 +/- 0.000108	0.61056+/-0.00156277 0.04268+/-0.000413183 0.034768+/-0.000372924 0.311936+/-0.000105981
(all scaled by production)	neutron yield n/s/cm^3	recoils over 5keV	summed nuclear recoils over 5keV	single nuclear recoils over 5keV over 200 keV	singles no veto capture over 5 keV	singles no EM over 1 keV “ over 5 keV	0 scatters 1 scatter 2 scatters more
USD full	1.24 e-10	5.81977 +/- 0.00537271 1.17714 +/- 0.00241632	0.527079 +/- 0.00161688 0.111025 +/- 0.00074208	0.0504184 +/- 0.000500075 0.0170178 +/- 0.000290531 0 +/- 0	0.0295219 +/- 0.00038266 0.00558496 +/- 0.000166437	0.0179502 +/- 0.000298384 0.00348192 +/- 0.000131417	0.752258 +/- 0.00193163 0.0504184+/-0.000500075 0.0437224+/-0.000465686 0.393536+/-0
SOURCES full	9.96 e-11	4.61548 +/- 0.00428813 0.864408 +/- 0.00185575	0.420037 +/- 0.00129361 0.0769231 +/- 0.00055359	0.0425093 +/- 0.00041153 0.0134101 +/- 0.000231141 0 +/- 0	0.0250355 +/- 0.000315818 0.0044581 +/- 0.000133271	0.0156691 +/- 0.000249851 0.00290434 +/- 0.000107568	0.608118+/-0.00155652 0.0425093+/-0.00041153 0.0346289+/-0.000371432 0.310688+/-0.000131417

More numbers (Th232)

Simulation	%/# simulated scatters < 90%Rad	%/# simulated single scatters <90 %Rad	ratio scatters more :2 more:1 2:1 2+:1	ratio single scatters total to those inside radius	ratio energy 20-200keV: >200keV
USD shape only	1.07257 +/- 0.0020713	0.000696 +/- 5.27636e-05	9 7.8 0.87 8.7	19.71	inf
SOURCES shape only	1.04291 +/- 0.00204246	0.000788 +/- 5.61427e-05	8.97 7.31 0.81 8.12	17.09	inf
USD full	1.32998 +/- 0.00256841	0.00086304 +/ 6.54269e-05			
SOURCES full	1.03874 +/- 0.00203429	0.000784848 +/- 5.59181e-05			

Raw output for chart

Just shape

USD Numbers:

Start energy mean: 2.09762 Sigma: 1.33437

0: 0.60666 +/- 0.001557771: 0.04066 +/- 0.0004032862: 0.03526 +/- 0.000375553 More: 0.317368 +/- 0

Individual recoils, all: 4.69336 +/- 0.00433283 over threshold keV: 0.949304 +/- 0.00194864

Total nuclear recoils all: 0.425064 +/- 0.00130394 over threshold keV: 0.089536 +/- 0.000598451

Total nuclear + EM recoils all: 0.418628 +/- 0.00129403 over threshold keV: 0.340936 +/- 0.00116779

Single recoils, all: 0.04066 +/- 0.000403286 over threshold keV: 0.013724 +/- 0.000234299 over upper keV: 0 +/- 0

All neutron radii, within 90 cm: 1.07257 +/- 0.0020713

Single neutron radii, within 90 cm: 0.000696 +/- 5.27636e-05

Single recoils no veto, all: 0.023808 +/- 0.000308597 over threshold keV: 0.004504 +/- 0.000134224

Single recoils no EM, all: 0.014476 +/- 0.000240632 over threshold keV: 0.002808 +/- 0.000105981

Sources numbers:

Start energy mean: 1.68092 Sigma: 1.08699

0: 0.61056 +/- 0.001562771: 0.04268 +/- 0.0004131832: 0.034768 +/- 0.000372924 More: 0.311936 +/- 0.000105981

Individual recoils, all: 4.63402 +/- 0.00430535 over threshold keV: 0.86788 +/- 0.0018632

Total nuclear recoils all: 0.421724 +/- 0.00129881 over threshold keV: 0.077232 +/- 0.000555813

Total nuclear and EM recoils all: 0.416892 +/- 0.00129134 over threshold keV: 0.332652 +/- 0.00115352

Single recoils, all: 0.04268 +/- 0.000413183 over threshold keV: 0.013464 +/- 0.000232069 over upper keV: 0 +/- 0

All neutron radii, within 90 cm: 1.04291 +/- 0.00204246

Single neutron radii, within 90 cm: 0.000788 +/- 5.61427e-05

Single recoils no veto, all: 0.025136 +/- 0.000317087 over 5 keV: 0.004476 +/- 0.000133806

Single recoils no EM, all: 0.015732 +/- 0.000250855 over threshold keV: 0.002916 +/- 0.000108

Scaled by yield

USD Numbers:

Start energy mean: 2.09762 Sigma: 1.33437

0: 0.752258 +/- 0.001931631: 0.0504184 +/- 0.0005000752: 0.0437224 +/- 0.000465686 More: 0.393536 +/- 0

Individual recoils, all: 5.81977 +/- 0.00537271 over threshold keV: 1.17714 +/- 0.00241632

Total nuclear recoils all: 0.527079 +/- 0.00161688 over threshold keV: 0.111025 +/- 0.00074208

Total nuclear + EM recoils all: 0.519099 +/- 0.0016046 over threshold keV: 0.422761 +/- 0.00144807

Single recoils, all: 0.0504184 +/- 0.000500075 over threshold keV: 0.0170178 +/- 0.000290531 over upper keV: 0 +/- 0

All neutron radii, within 90 cm: 1.32998 +/- 0.00256841

Single neutron radii, within 90 cm: 0.00086304 +/- 6.54269e-05

Single recoils no veto, all: 0.0295219 +/- 0.00038266 over threshold keV: 0.00558496 +/- 0.000166437

Single recoils no EM, all: 0.0179502 +/- 0.000298384 over threshold keV: 0.00348192 +/- 0.000131417

Sources numbers:

Start energy mean: 1.68092 Sigma: 1.08699

0: 0.608118 +/- 0.001556521: 0.0425093 +/- 0.000411532: 0.0346289 +/- 0.000371432 More: 0.310688 +/- 0.000131417

Individual recoils, all: 4.61548 +/- 0.00428813 over threshold keV: 0.864408 +/- 0.00185575

Total nuclear recoils all: 0.420037 +/- 0.00129361 over threshold keV: 0.0769231 +/- 0.00055359

Total nuclear and EM recoils all: 0.415224 +/- 0.00128618 over threshold keV: 0.331321 +/- 0.00114891

Single recoils, all: 0.0425093 +/- 0.00041153 over threshold keV: 0.0134101 +/- 0.000231141 over upper keV: 0 +/- 0

All neutron radii, within 90 cm: 1.03874 +/- 0.00203429

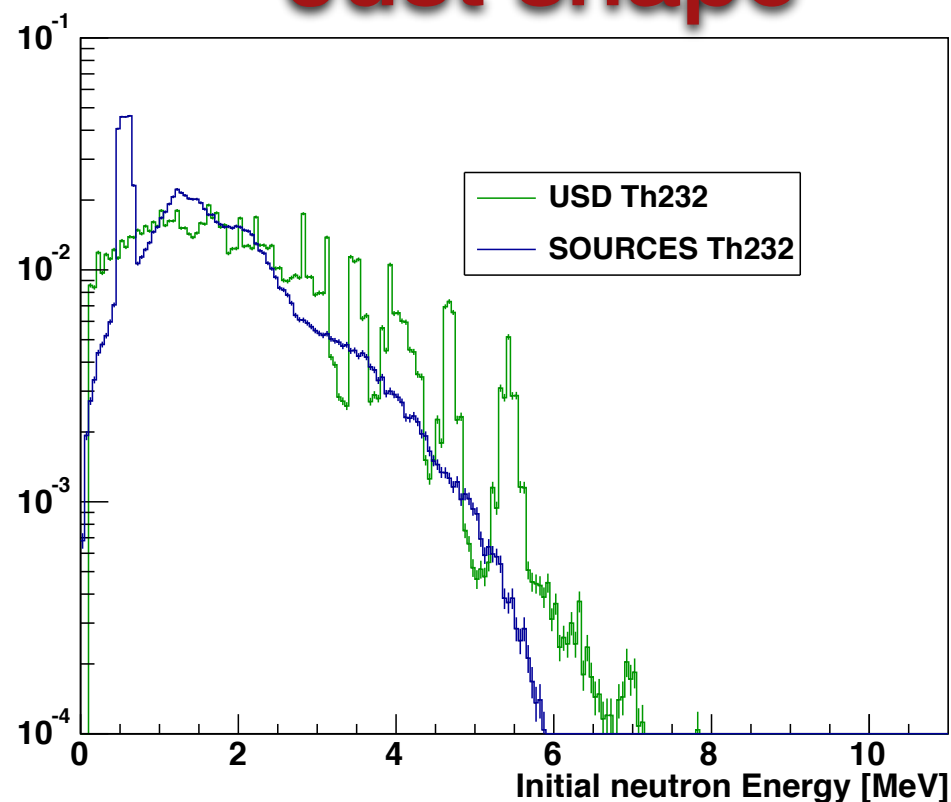
Single neutron radii, within 90 cm: 0.000784848 +/- 5.59181e-05

Single recoils no veto, all: 0.0250355 +/- 0.000315818 over 5 keV: 0.0044581 +/- 0.000133271

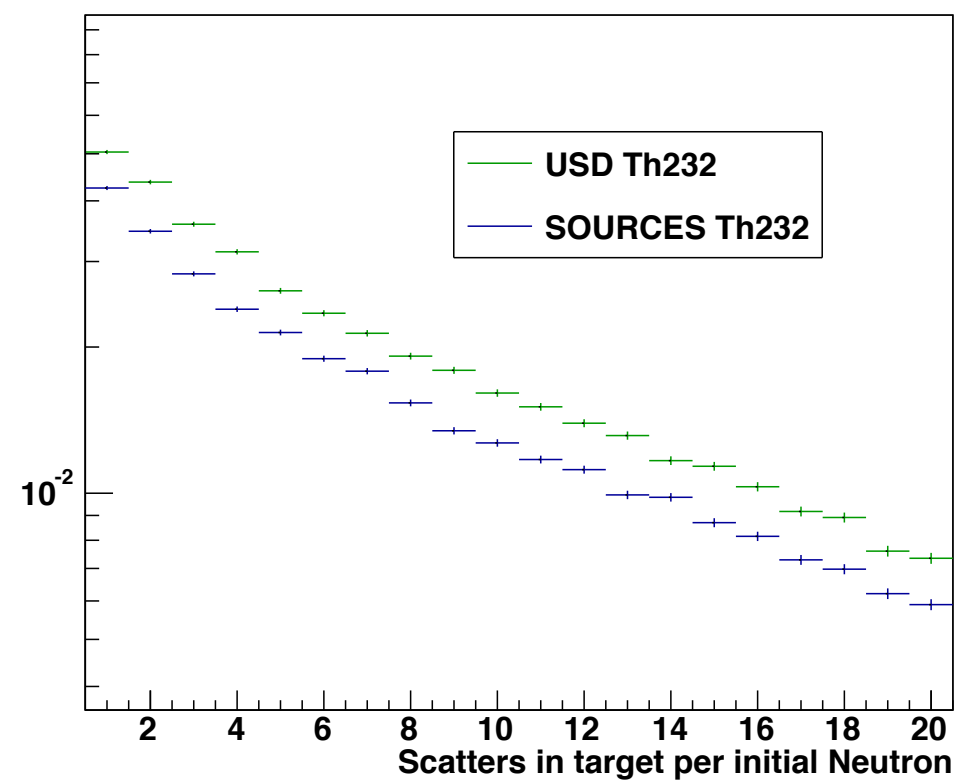
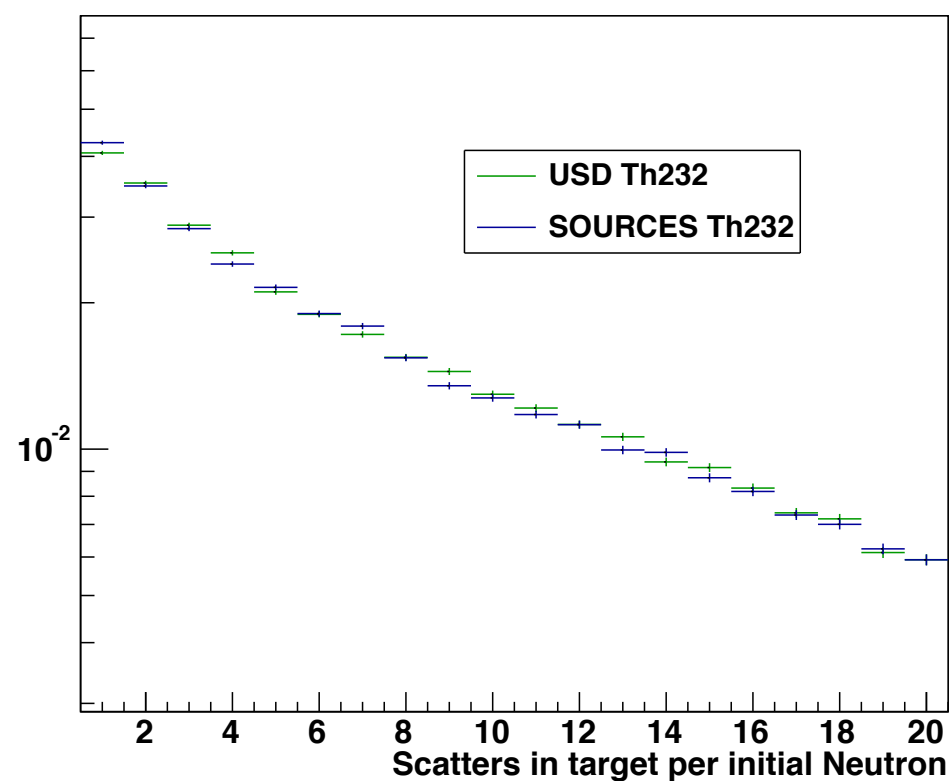
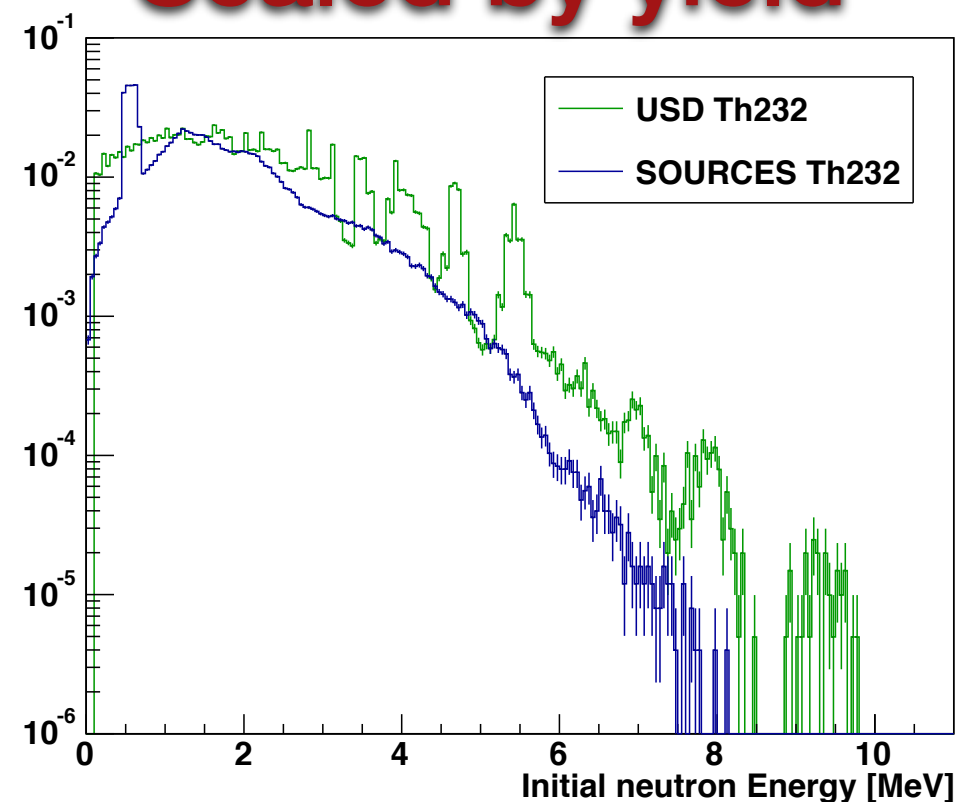
Single recoils no EM, all: 0.0156691 +/- 0.000249851 over threshold keV: 0.00290434 +/- 0.000107568

Xenon (Titanium Th232)

Just shape

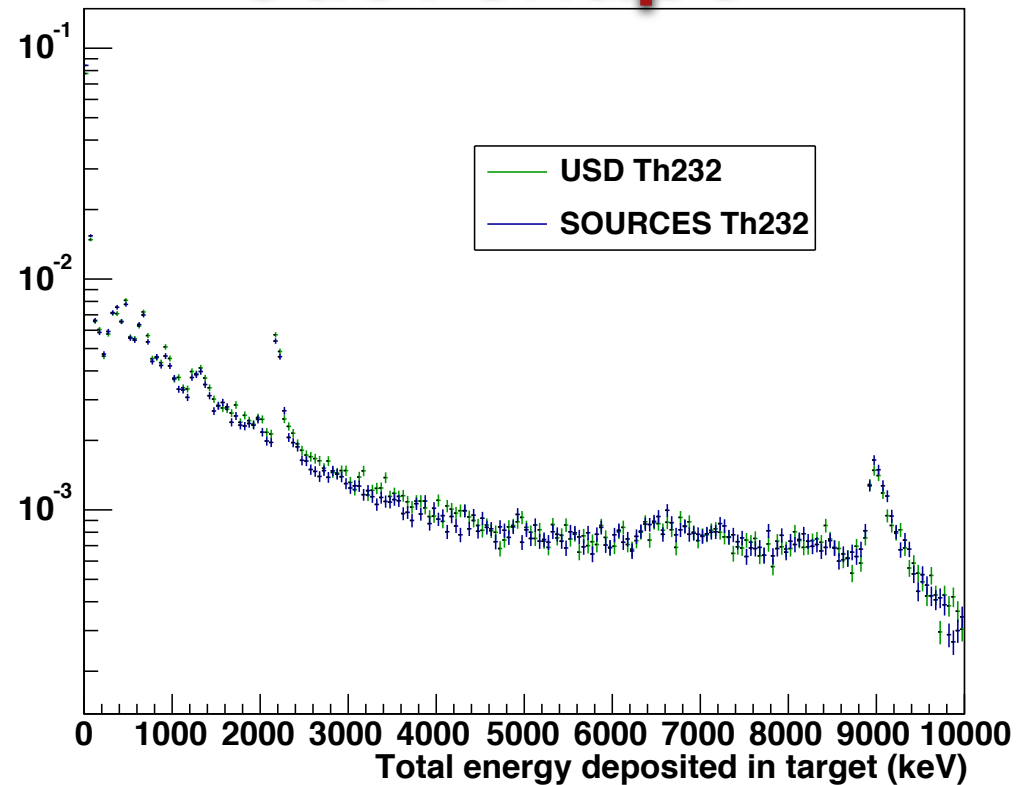


Scaled by yield

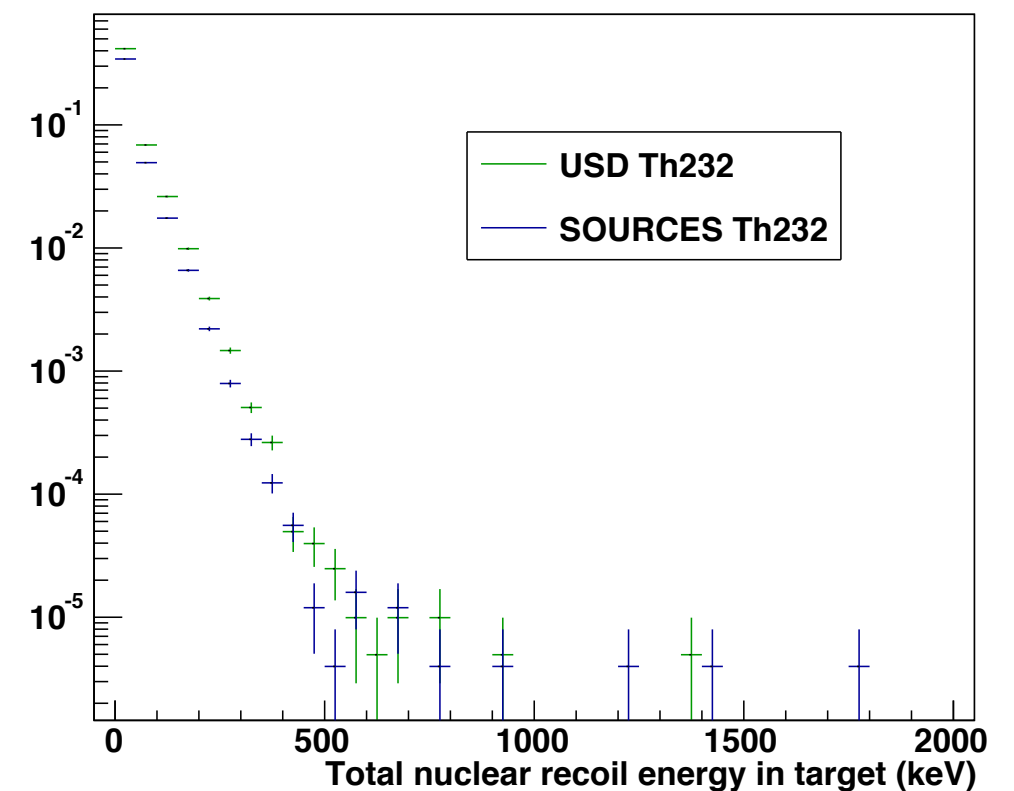
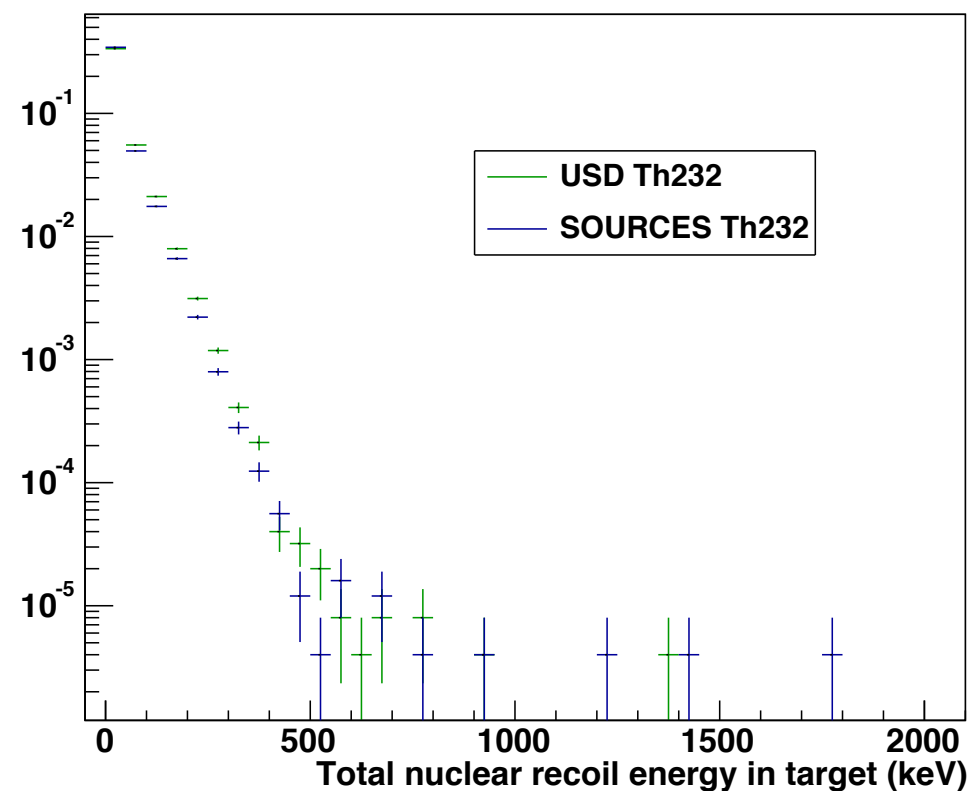
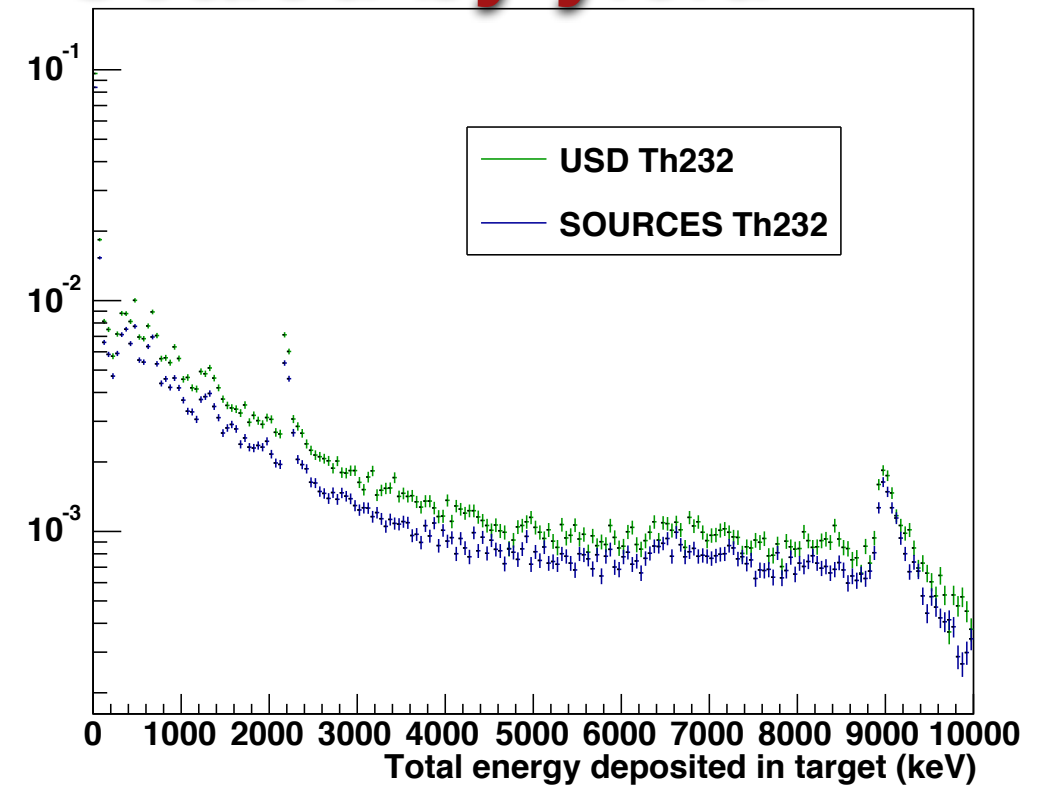


Xenon (Titanium Th232): Energy Deposited

Just shape

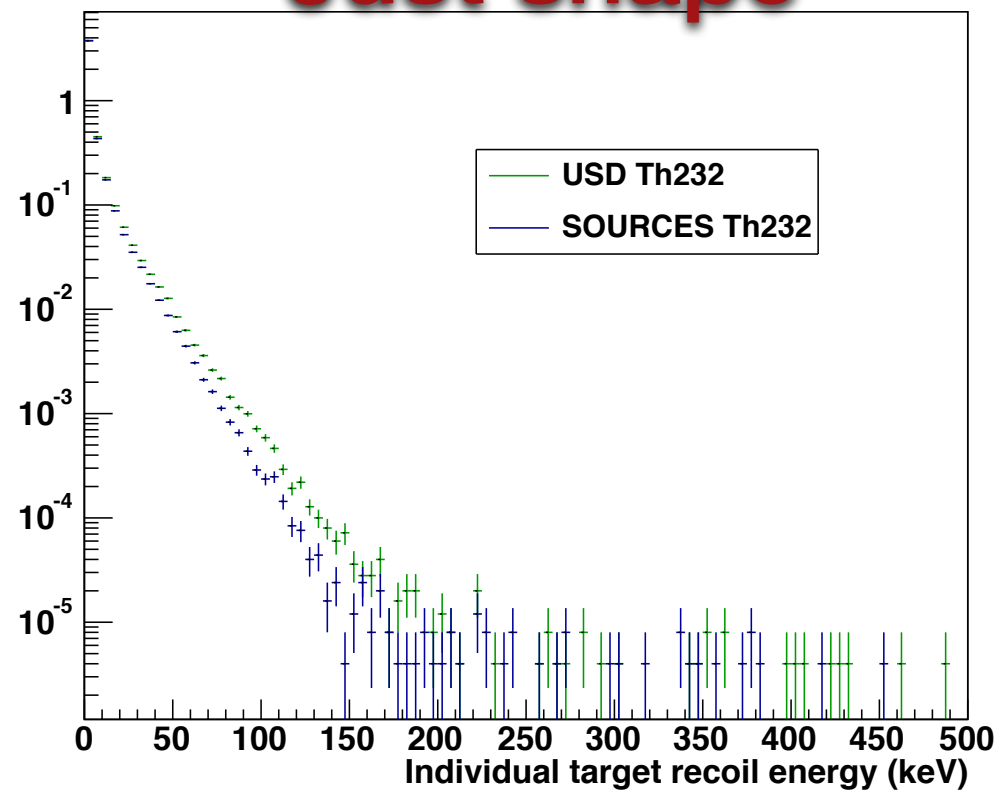


Scaled by yield

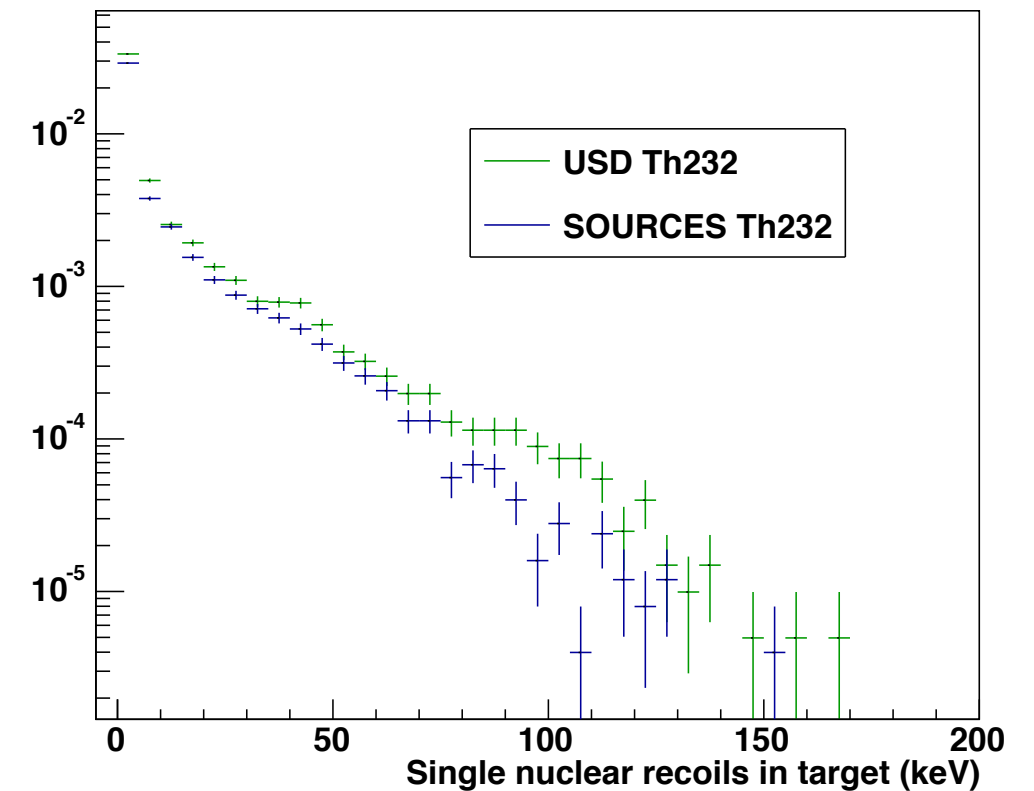
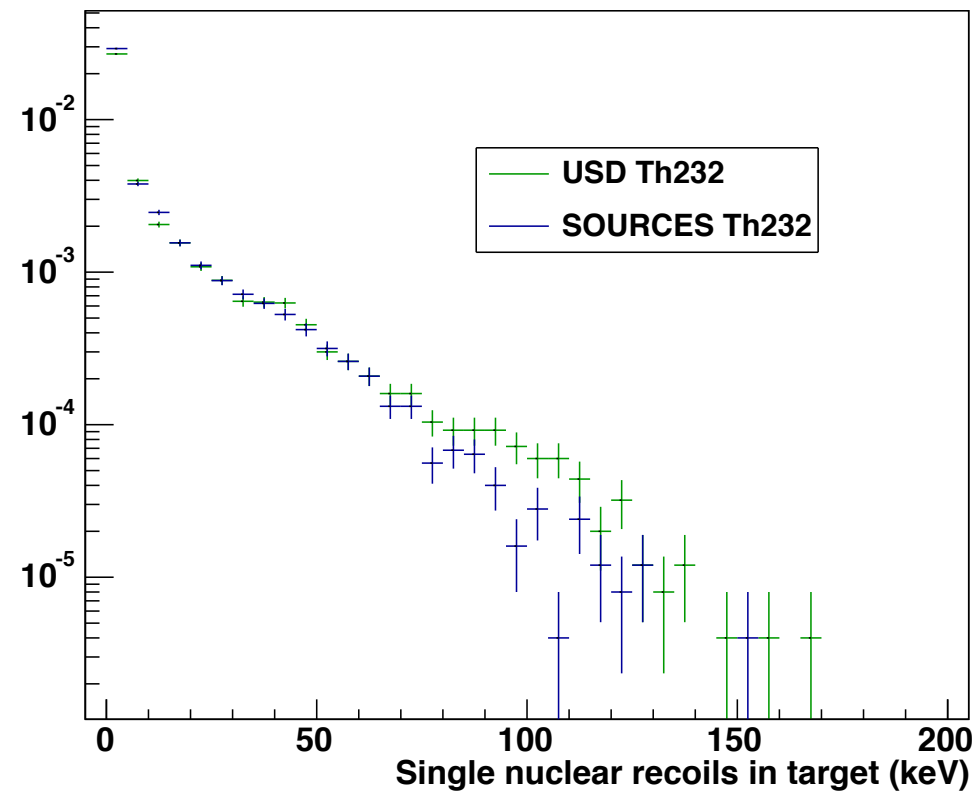
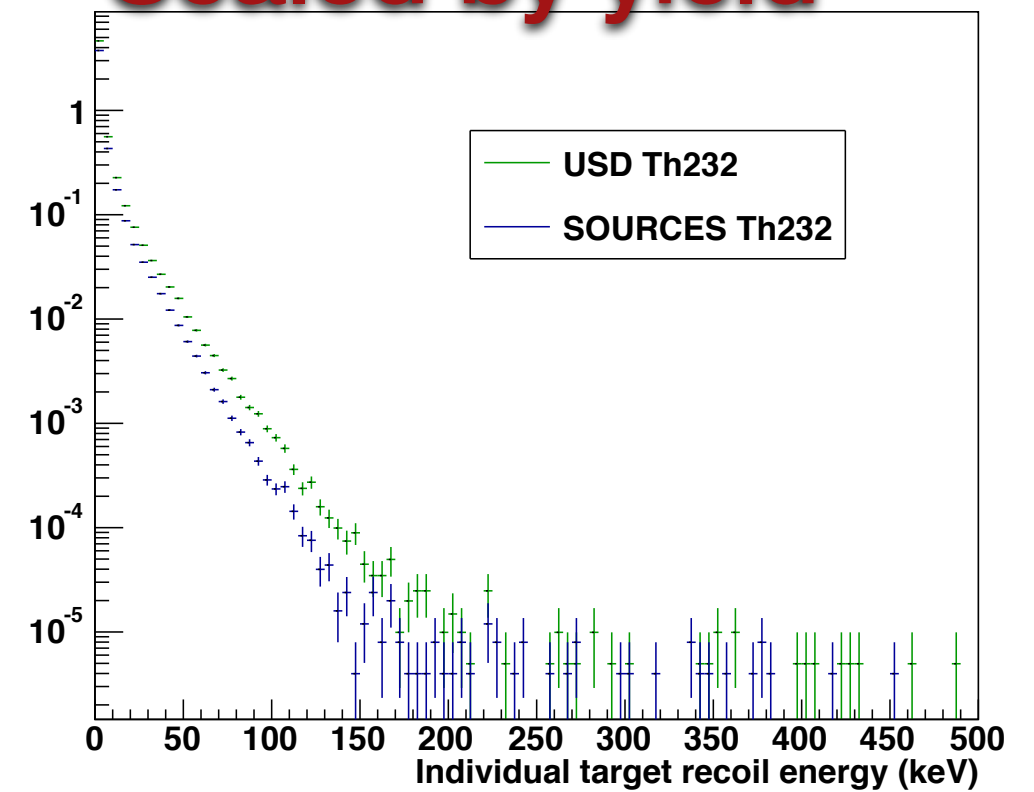


Xenon (Titanium Th232): Nuclear Recoils

Just shape

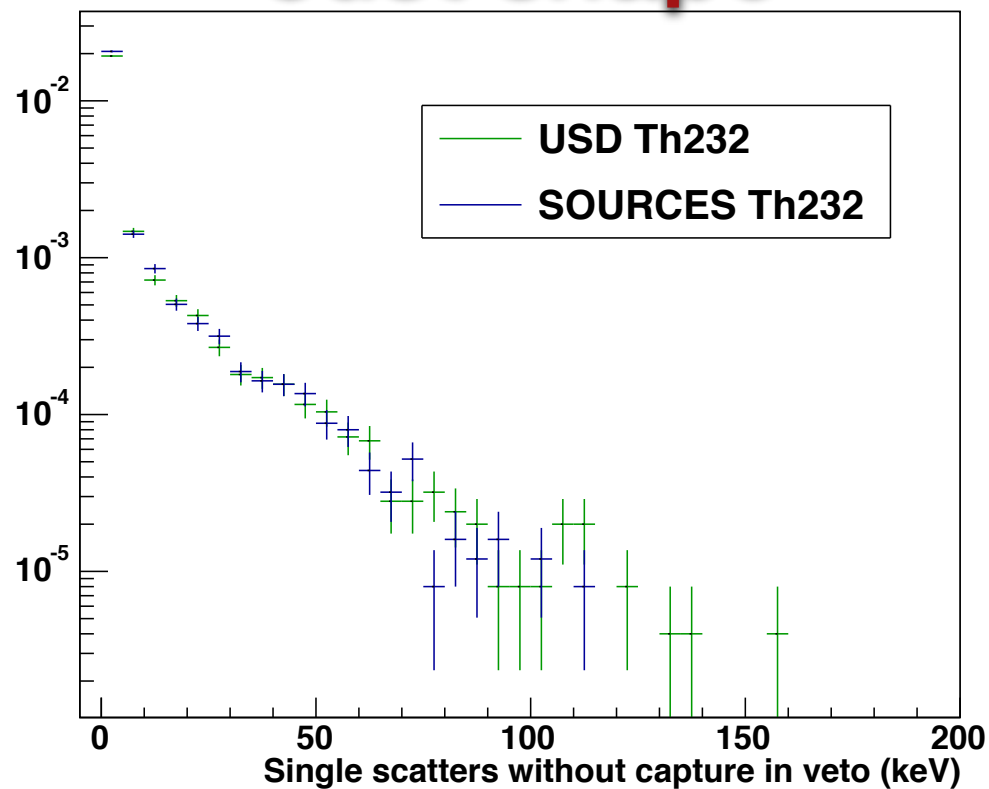


Scaled by yield

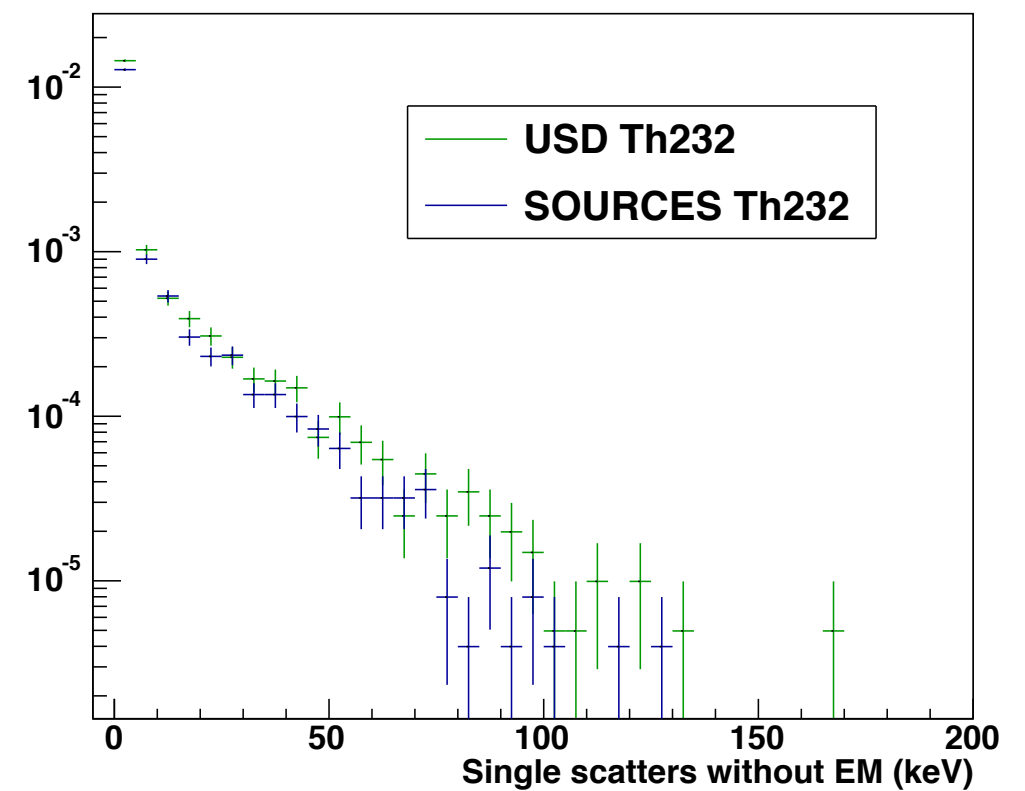
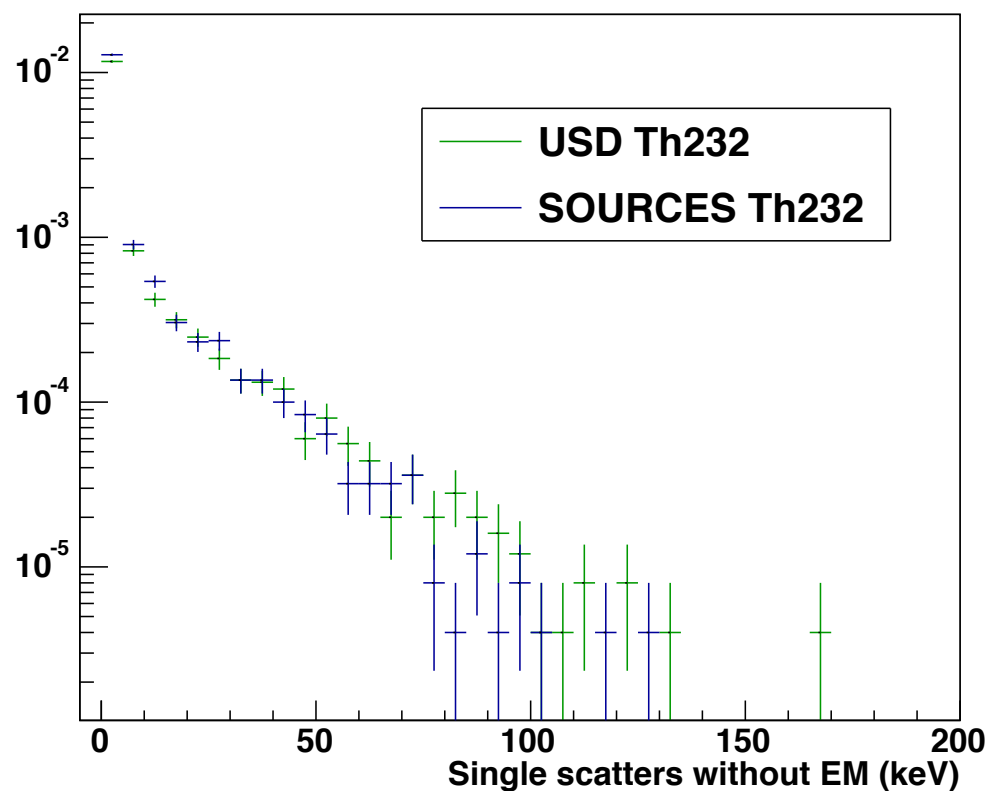
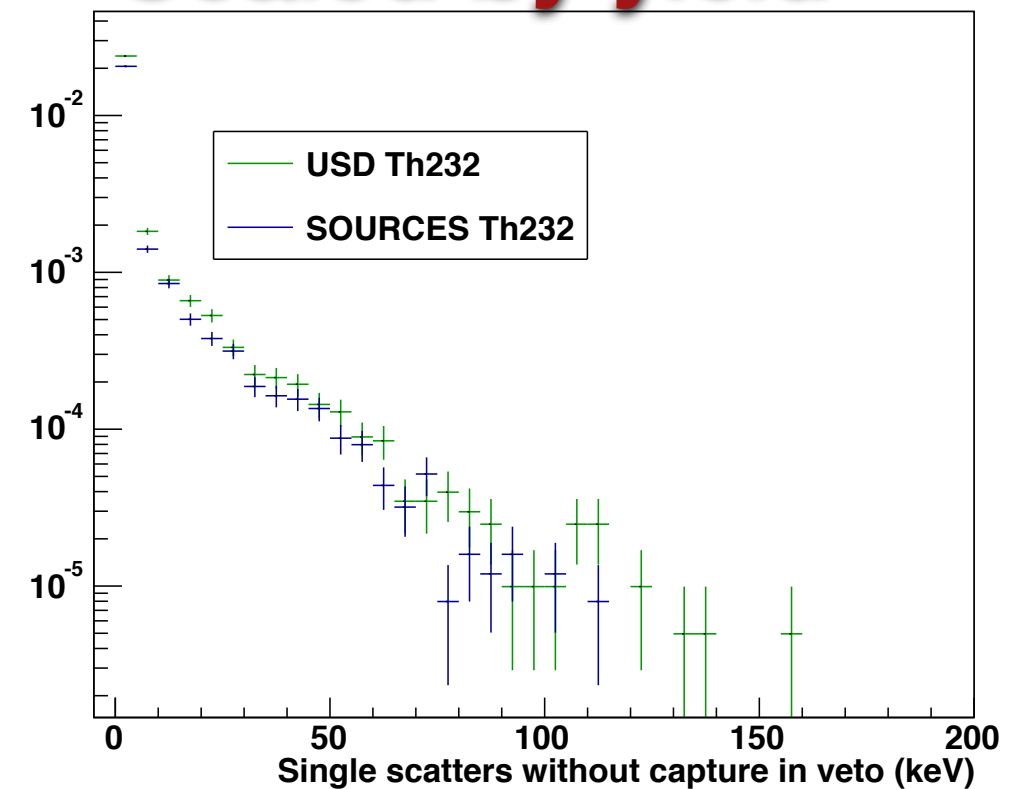


Xenon (Titanium Th232): Vetoed Recoils

Just shape

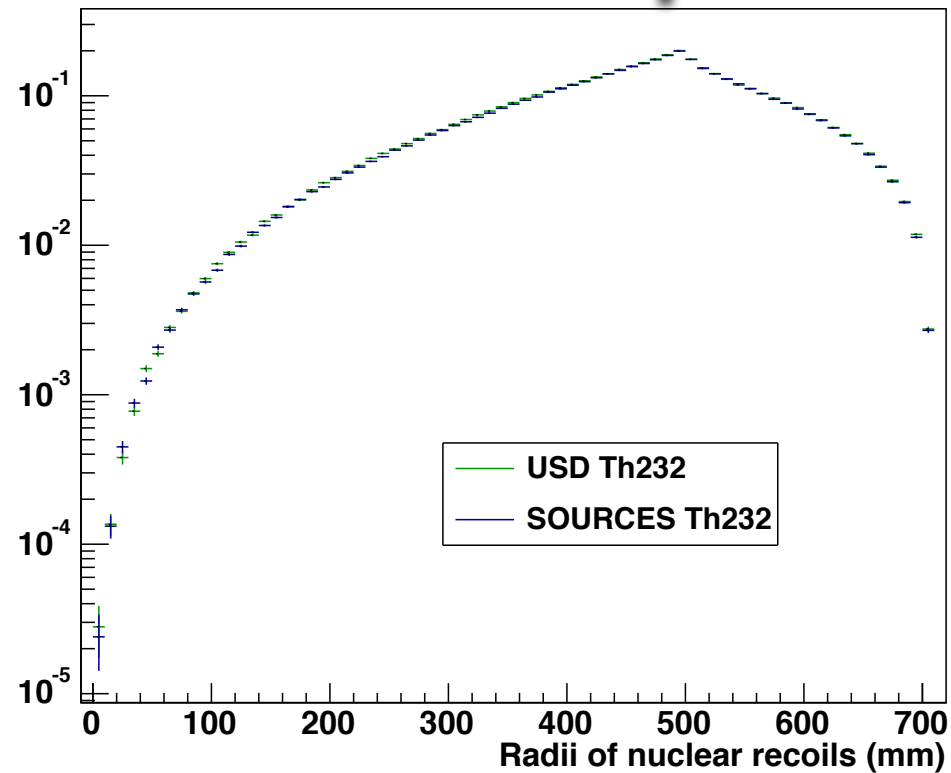


Scaled by yield

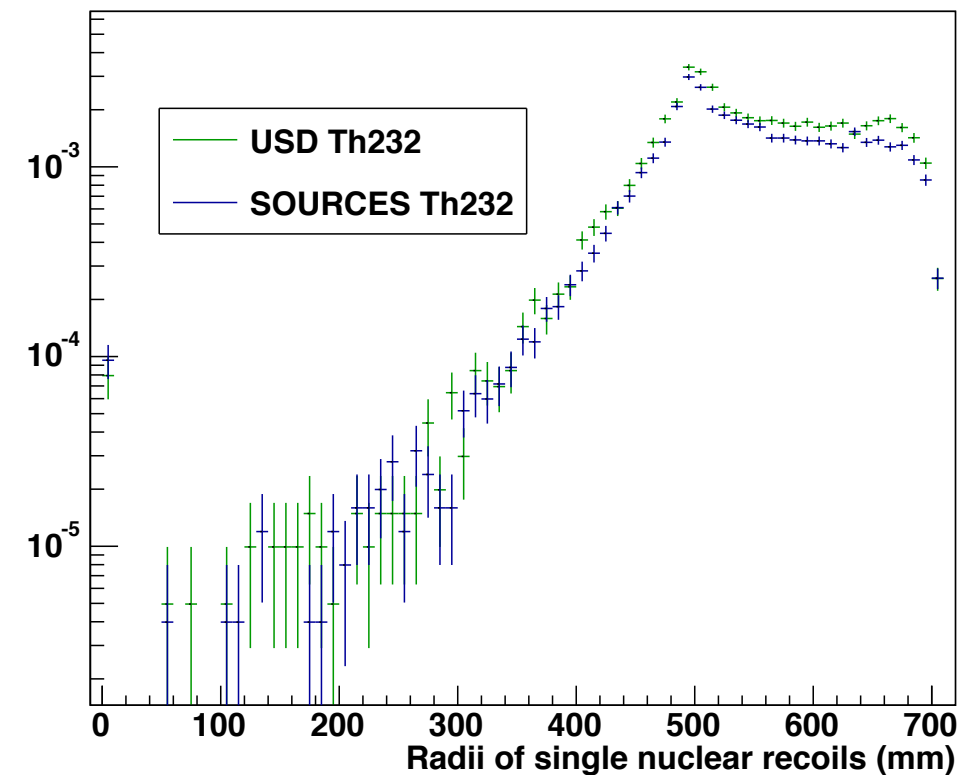
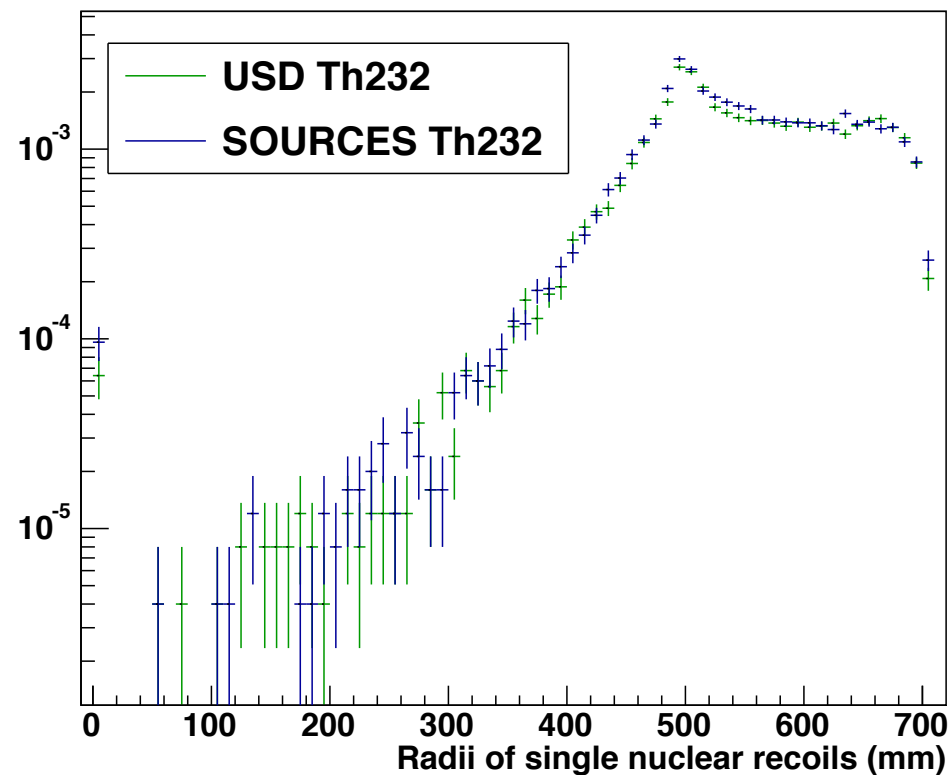
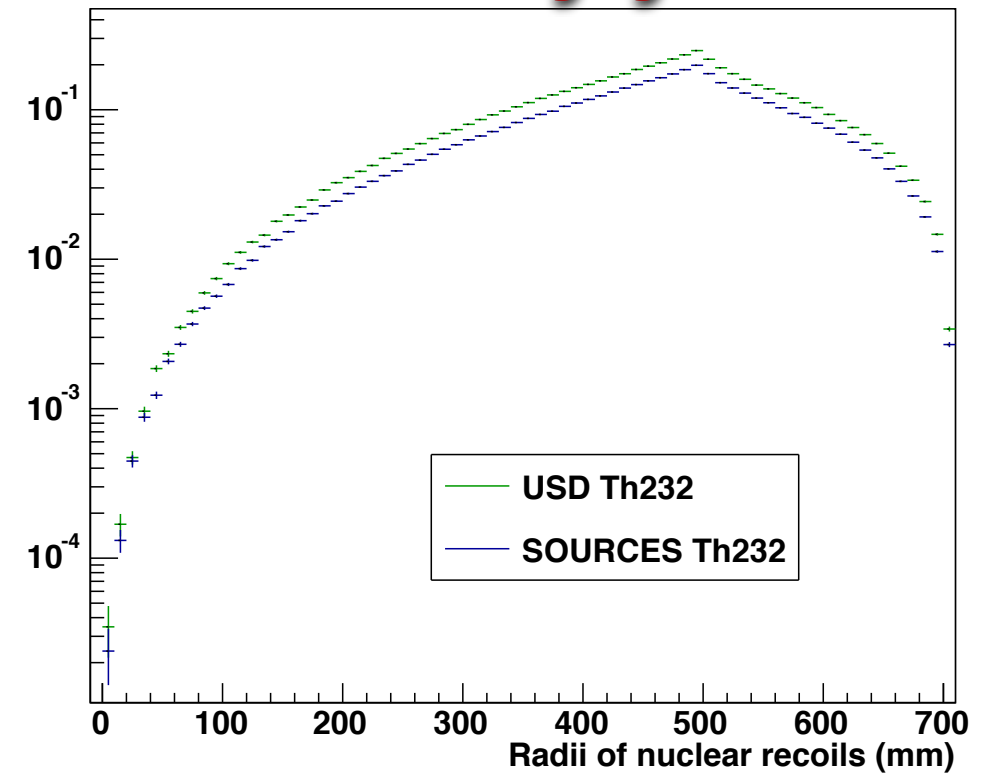


Xenon (Titanium Th232): Recoil Radii

Just shape



Scaled by yield



Xe Ti Th232 Conclusions

- Despite odd Ti cross section induced spectrum shape, by shape singles are only 2% different
- 15% error in # events from radial distribution, and 7% error in multiplicity comparisons possible
- Veto importance: same by capture, same by EM
- 24% difference in neutron yield leads to a 27% difference in single scatters
- USD= Sources by shape; USD > Source by yield

Xenon (PTFE source U238)

	Initial energy mean and sigma (MeV)	% total number recoils % recoil over 5 keV	%recoil %summed nuclear recoils over 5 keV	%single nuc %single nuc over 5 keV	%single no veto capture %over 5keV	%single no EM over 1 keV %over 5 keV	0 scatters% 1 scatter % 2 scatter % more scatters %
USD shape only	1.89763 Sigma: 0.992563	0.217368 +/- 0.000932455 0.041492 +/- 0.000407392	0.019168 +/- 0.000276897 0.003436 +/- 0.000117235	0.002004 +/- 8.95321e-05 0.00062 +/- 4.97996e-05 0 +/- 0	0.0012 +/- 6.9282e-05 0.000192 +/- 2.77128e-05	0.00052 +/- 4.5607e-05 8e-05 +/- 1.78885e-05	0.98216 +/- 0.00198208 0.002004+/-8.95321e-05 0.001436+/-7.57892e-05 0.0144+/-0
SOURCES shape only	1.60746 Sigma: 0.961817	0.205616 +/- 0.000906898 0.03618 +/- 0.000380421	0.018564 +/- 0.0002725 0.003012 +/- 0.000109763	0.002076 +/- 9.11263e-05 0.000612 +/- 4.94773e-05 0 +/- 0	0.001224 +/- 6.99714e-05 0.000164 +/- 2.56125e-05	0.000616 +/- 4.96387e-05 8.8e-05 +/- 1.87617e-05	0.982184+/-0.0019821 0.002076+/-9.11263e-05 0.00174+/-8.34266e-05 0.014+/-1.78885e-05
(all scaled by production)	neutron yield n/s/cm^3	recoils over 5keV	summed nuclear recoils over 5keV	single nuclear recoils over 5keV over 200 keV	singles no veto capture over 5 keV	singles no EM over 1 keV “ over 5 keV	0 scatters 1 scatter 2 scatters more
USD full	1.60488E-08	0.347789 +/- 0.00149193 0.0663872 +/- 0.000651827	0.0306688 +/- 0.000443035 0.0054976 +/- 0.000187576	0.0032064 +/- 0.000143251 0.000992 +/- 7.96794e-05 0 +/- 0	0.00192 +/- 0.000110851 0.0003072 +/- 4.43405e-05	0.000832 +/- 7.29712e-05 0.000128 +/- 2.86217e-05	1.57146 +/- 0.00317133 0.0032064+/-0.000143251 0.0022976+/-0.000121263 0.02304+/-0
SOURCES full	9.033E-08	1.85054 +/- 0.00816208 0.32562 +/- 0.00342379	0.167076 +/- 0.0024525 0.027108 +/- 0.00098787	0.018684 +/- 0.000820137 0.005508 +/- 0.000445295 0 +/- 0	0.011016 +/- 0.000629743 0.001476 +/- 0.000230512	0.005544 +/- 0.000446748 0.000792 +/- 0.000168855	8.83966+/-0.0178389 0.018684+/-0.000820137 0.01566+/-0.00075084 0.126+/-2.86217e-05

More numbers (U238)

Simulation	%/# simulated scatters < 90 cm	%/# simulated single scatters <90 cm	ratio scatters more :2 more:1 2:1 2+:1	ratio single scatters total to those inside radius	ratio energy 20-200keV: >200keV
USD shape only	0.0453 +/- 0.000425676	4e-05 +/- 1.26491e-05	10.03 7.19 0.72 7.90	15.5	inf
SOURCES shape only	0.043188 +/- 0.000415634	3.2e-05 +/- 1.13137e-05	8.05 6.74 0.84 7.58	19.125	inf
USD full	0.07248 +/- 0.000681081	6.4e-05 +/- 2.02386e-05			
SOURCES full	0.388692 +/- 0.00374071	0.000288 +/- 0.000101823			

Raw output for chart

Just shape

USD Numbers:

Start energy mean: 1.89763 Sigma: 0.992563

0: 0.98216 +/- 0.00198208 1: 0.002004+/-8.95321e-05 2: 0.001436+/-7.57892e-05 More: 0.0144+/-0

Individual recoils, all: 0.217368 +/- 0.000932455 over threshold keV: 0.041492 +/- 0.000407392

Total nuclear recoils all: 0.019168 +/- 0.000276897 over threshold keV: 0.003436 +/- 0.000117235

Total nuclear + EM recoils all: 0.018916 +/- 0.000275071 over threshold keV: 0.015208 +/- 0.000246641

Single recoils, all: 0.002004 +/- 8.95321e-05 over threshold keV: 0.00062 +/- 4.97996e-05 over upper keV: 0 +/- 0

All neutron radii, within 90 cm: 0.0453 +/- 0.000425676

Single neutron radii, within 90 cm: 4e-05 +/- 1.26491e-05

Single recoils no veto, all: 0.0012 +/- 6.9282e-05 over threshold keV: 0.000192 +/- 2.77128e-05

Single recoils no EM, all: 0.00052 +/- 4.5607e-05 over threshold keV: 8e-05 +/- 1.78885e-05

Sources numbers:

Start energy mean: 1.60746 Sigma: 0.961817

0: 0.982184+/-0.0019821 1: 0.002076+/-9.11263e-05 2: 0.00174+/-8.34266e-05 More: 0.014+/-1.78885e-05

Individual recoils, all: 0.205616 +/- 0.000906898 over threshold keV: 0.03618 +/- 0.000380421

Total nuclear recoils all: 0.018564 +/- 0.0002725 over threshold keV: 0.003012 +/- 0.000109763

Total nuclear and EM recoils all: 0.018424 +/- 0.00027147 over threshold keV: 0.014612 +/- 0.00024176

Single recoils, all: 0.002076 +/- 9.11263e-05 over threshold keV: 0.000612 +/- 4.94773e-05 over upper keV: 0 +/- 0

All neutron radii, within 90 cm: 0.043188 +/- 0.000415634

Single neutron radii, within 90 cm: 3.2e-05 +/- 1.13137e-05

Single recoils no veto, all: 0.001224 +/- 6.99714e-05 over 5 keV: 0.000164 +/- 2.56125e-05

Single recoils no EM, all: 0.000616 +/- 4.96387e-05 over threshold keV: 8.8e-05 +/- 1.87617e-05

Scaled by yield

USD Numbers:

Start energy mean: 1.89763 Sigma: 0.992563

0: 1.57146 +/- 0.00317133 1: 0.0032064+/-0.000143251 2: 0.0022976+/-0.000121263 More: 0.02304+/-0

Individual recoils, all: 0.347789 +/- 0.00149193 over threshold keV: 0.0663872 +/- 0.000651827

Total nuclear recoils all: 0.0306688 +/- 0.000443035 over threshold keV: 0.0054976 +/- 0.000187576

Total nuclear + EM recoils all: 0.0302656 +/- 0.000440113 over threshold keV: 0.0243328 +/- 0.000394626

Single recoils, all: 0.0032064 +/- 0.000143251 over threshold keV: 0.000992 +/- 7.96794e-05 over upper keV: 0 +/- 0

All neutron radii, within 90 cm: 0.07248 +/- 0.000681081

Single neutron radii, within 90 cm: 6.4e-05 +/- 2.02386e-05

Single recoils no veto, all: 0.00192 +/- 0.000110851 over threshold keV: 0.0003072 +/- 4.43405e-05

Single recoils no EM, all: 0.000832 +/- 7.29712e-05 over threshold keV: 0.000128 +/- 2.86217e-05

Sources numbers:

Start energy mean: 1.60746 Sigma: 0.961817

0: 8.83966+/-0.0178389 1: 0.018684+/-0.000820137 2: 0.01566+/-0.00075084 More: 0.126+/-2.86217e-05

Individual recoils, all: 1.85054 +/- 0.00816208 over threshold keV: 0.32562 +/- 0.00342379

Total nuclear recoils all: 0.167076 +/- 0.0024525 over threshold keV: 0.027108 +/- 0.00098787

Total nuclear and EM recoils all: 0.165816 +/- 0.00244323 over threshold keV: 0.131508 +/- 0.00217584

Single recoils, all: 0.018684 +/- 0.000820137 over threshold keV: 0.005508 +/- 0.000445295 over upper keV: 0 +/- 0

All neutron radii, within 90 cm: 0.388692 +/- 0.00374071

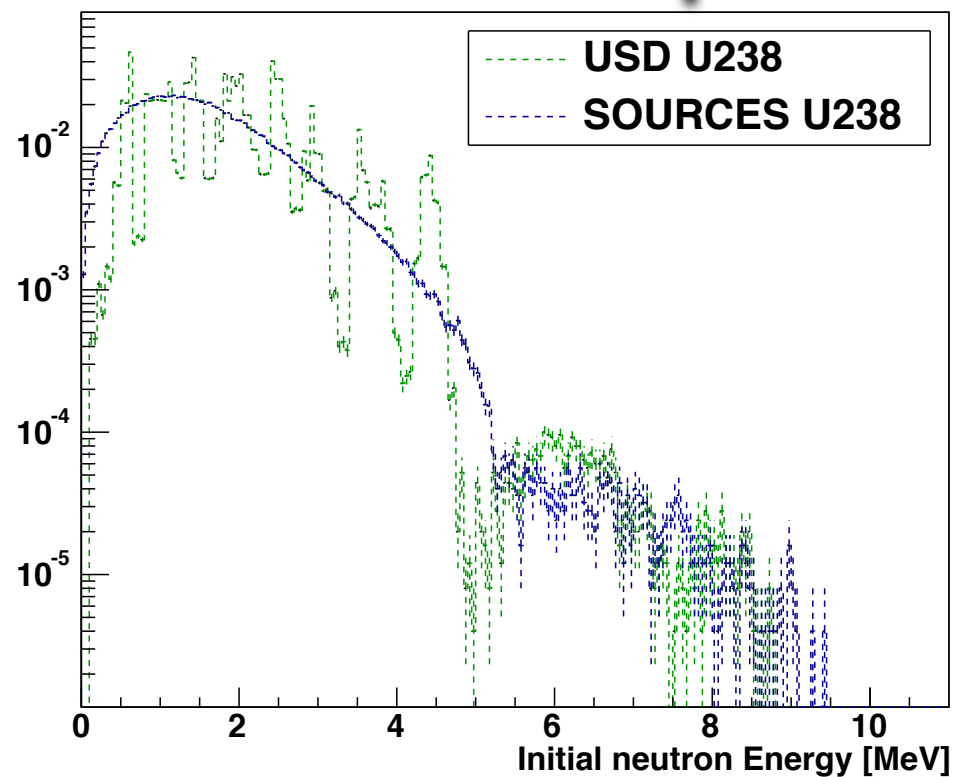
Single neutron radii, within 90 cm: 0.000288 +/- 0.000101823

Single recoils no veto, all: 0.011016 +/- 0.000629743 over 5 keV: 0.001476 +/- 0.000230512

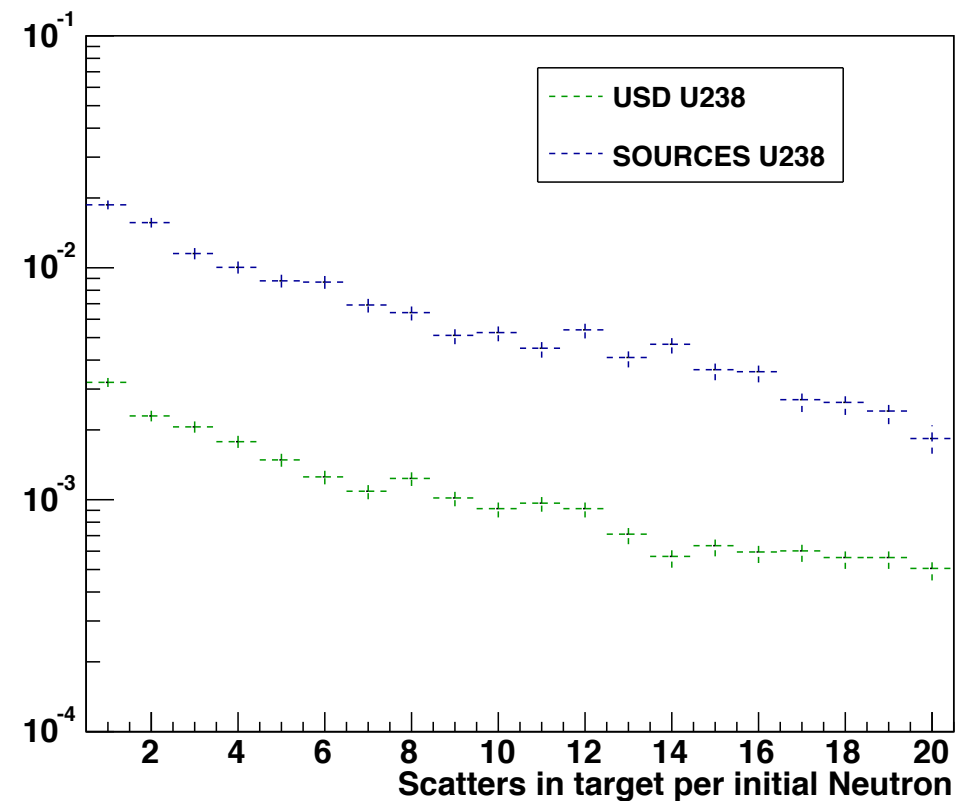
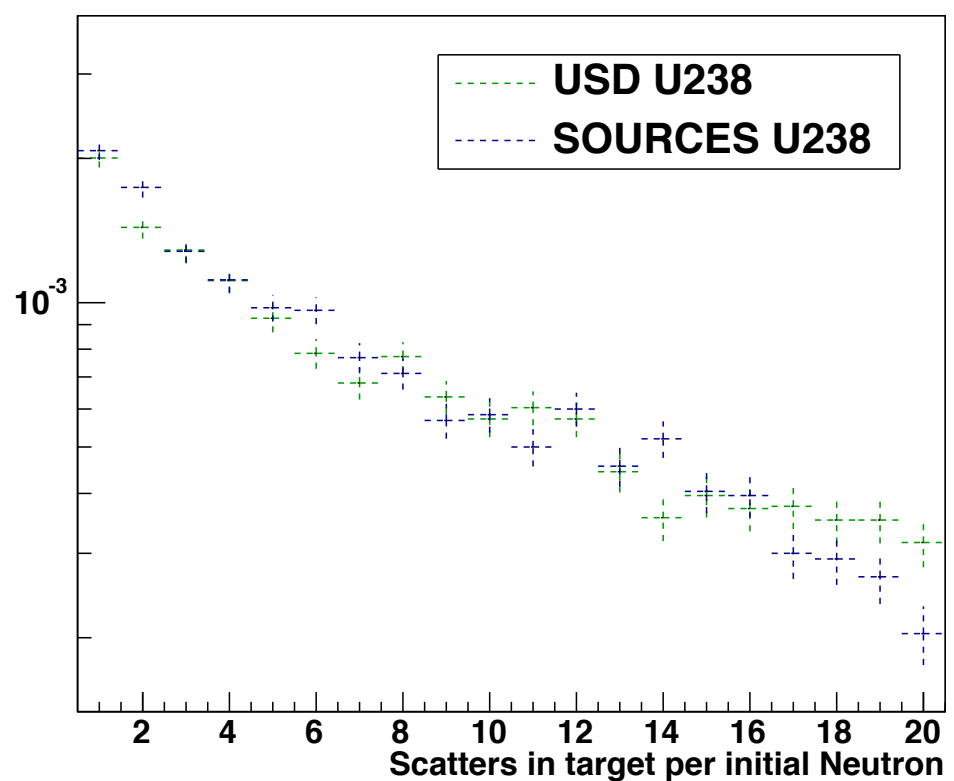
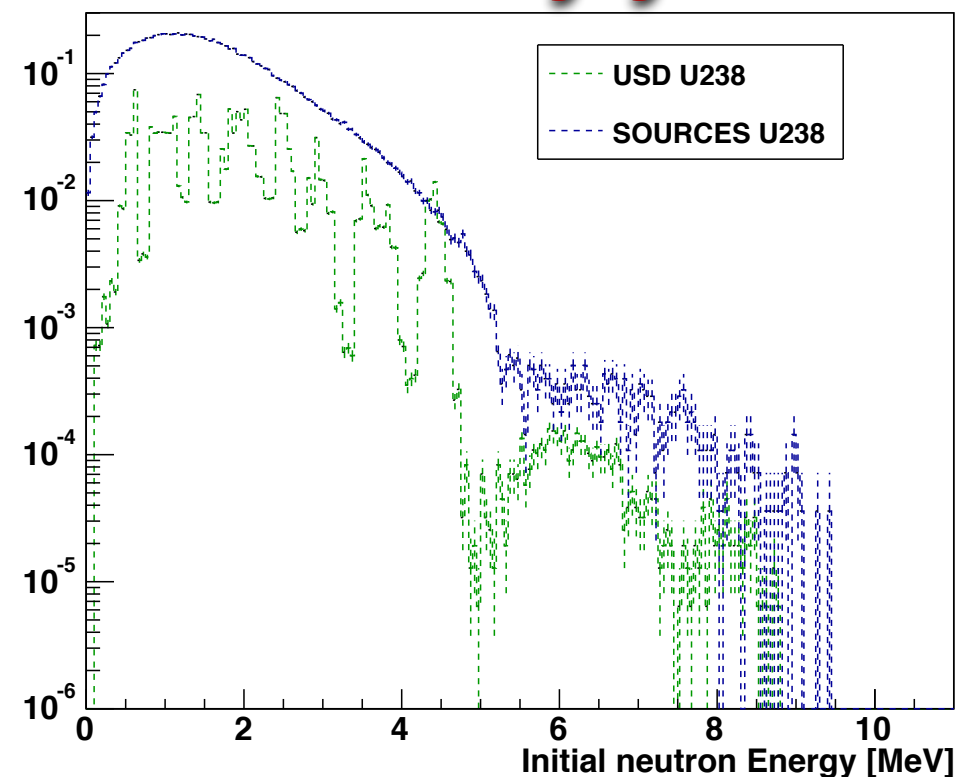
Single recoils no EM, all: 0.005544 +/- 0.000446748 over threshold keV: 0.000792 +/- 0.000168855

Xenon (PTFE U238)

Just shape

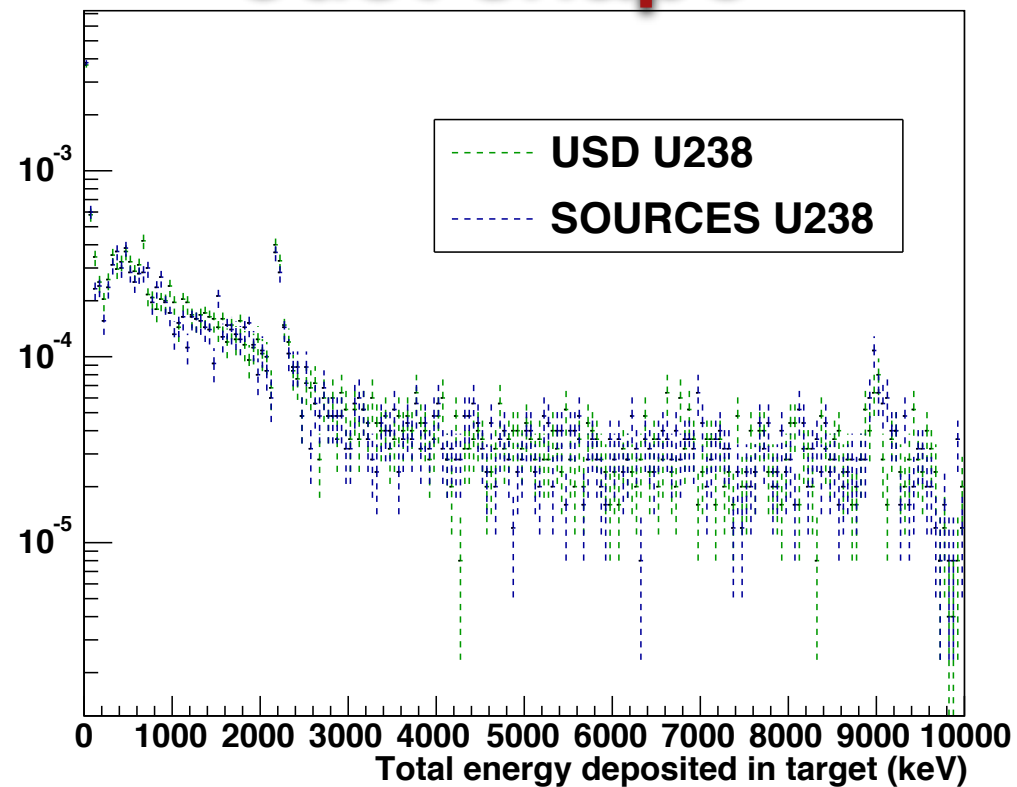


Scaled by yield

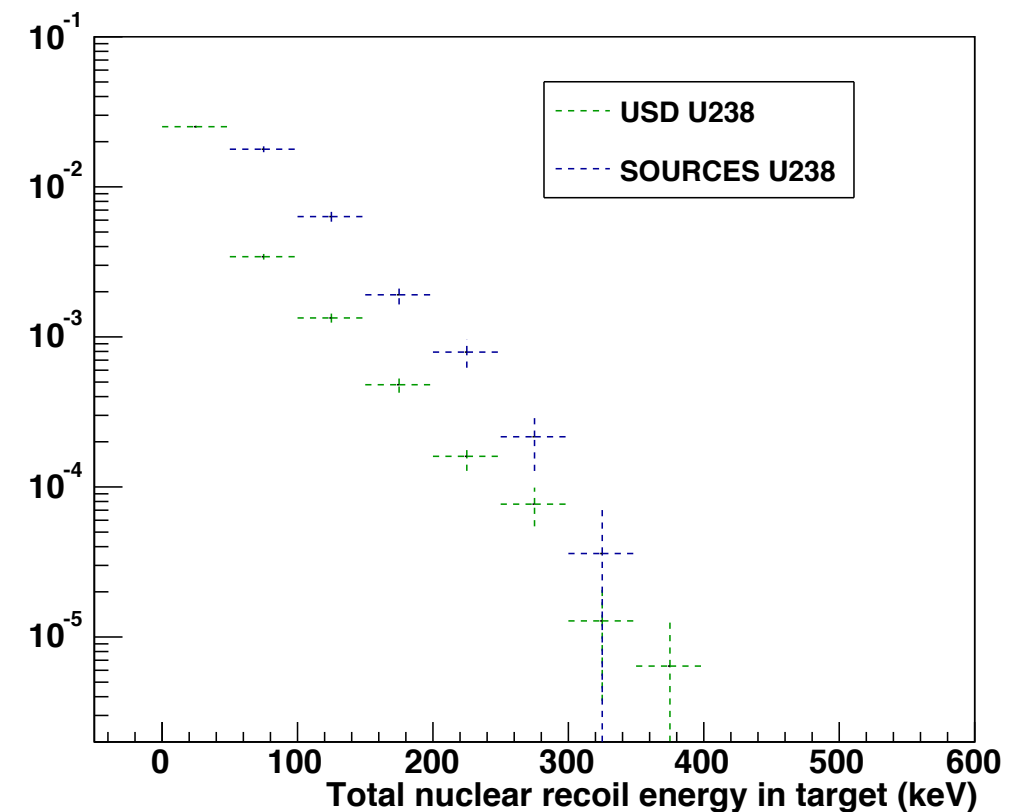
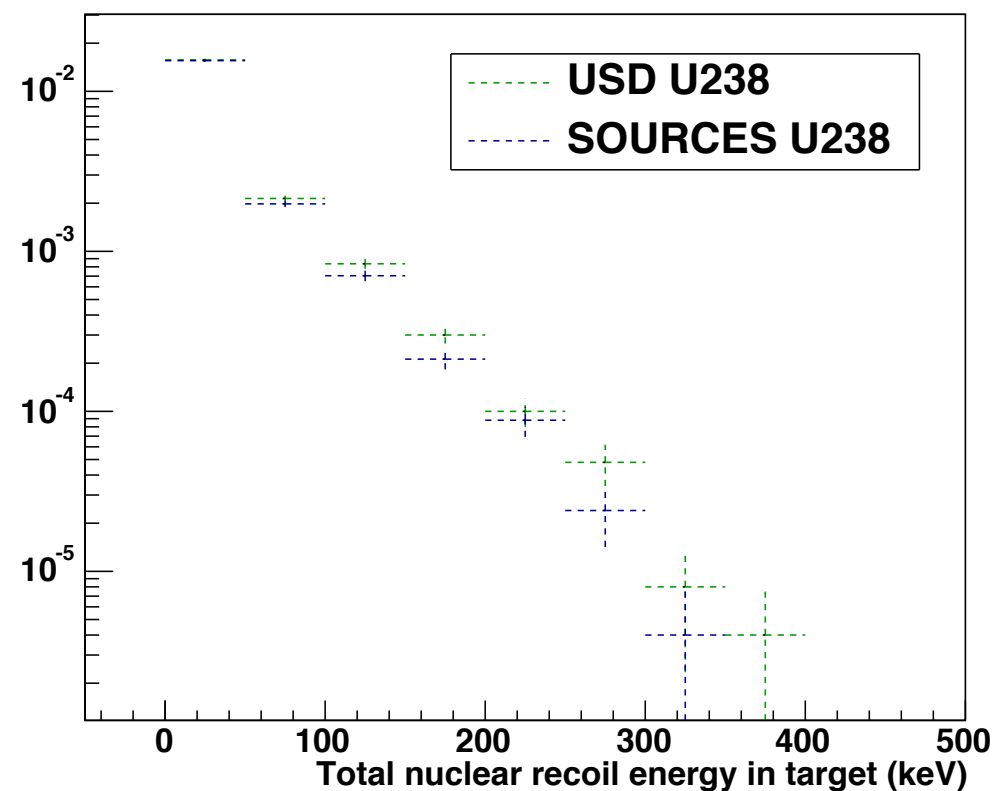
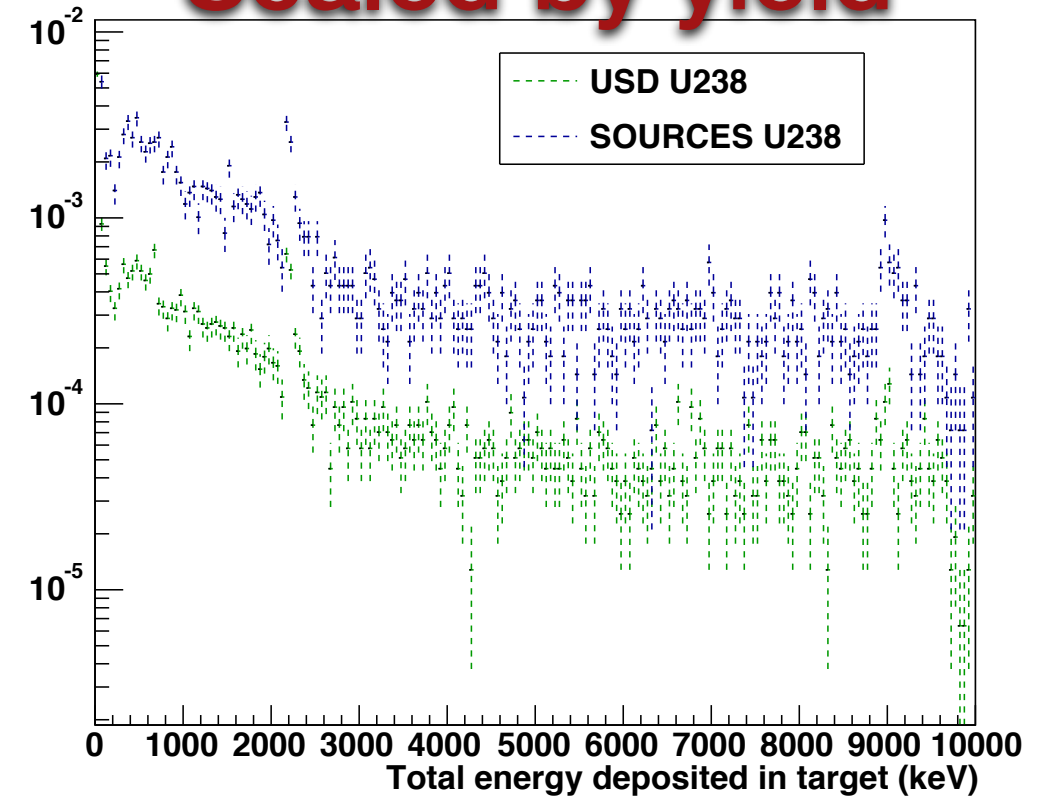


Xenon (PTFE U238): Energy Deposited

Just shape

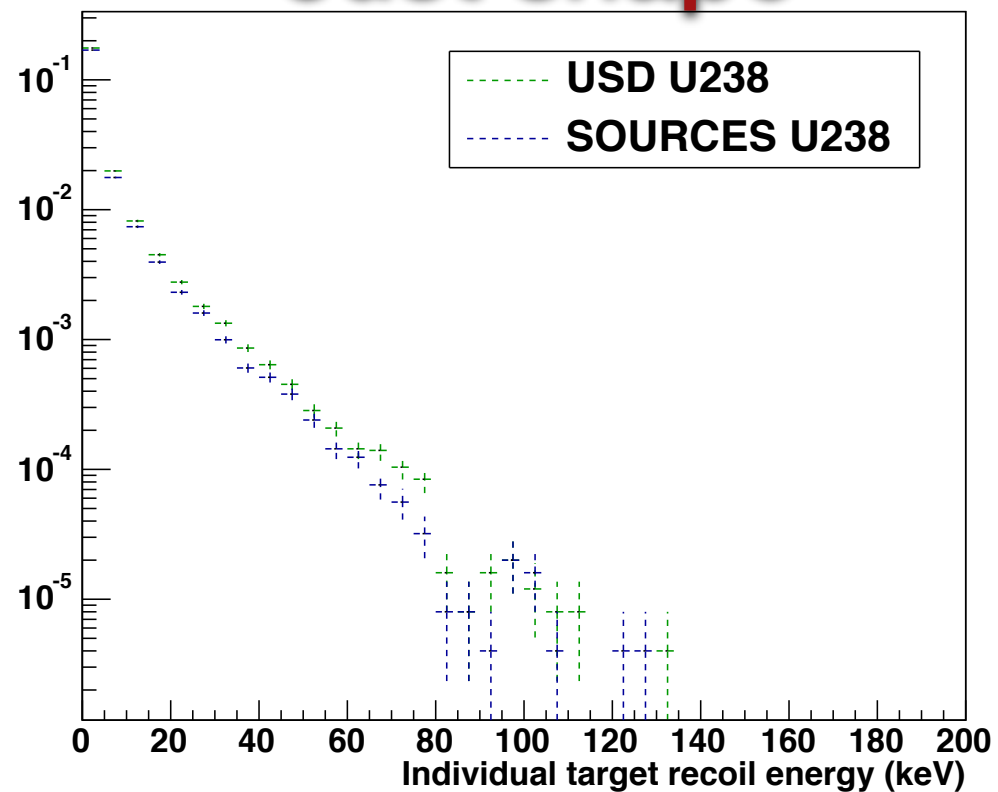


Scaled by yield

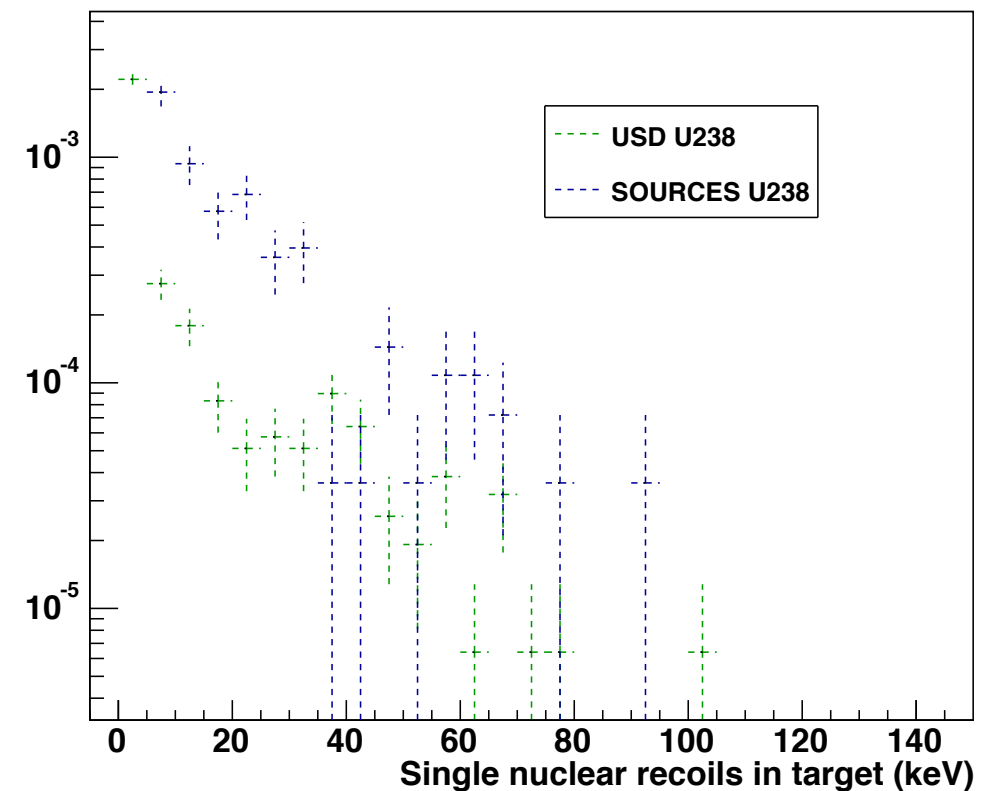
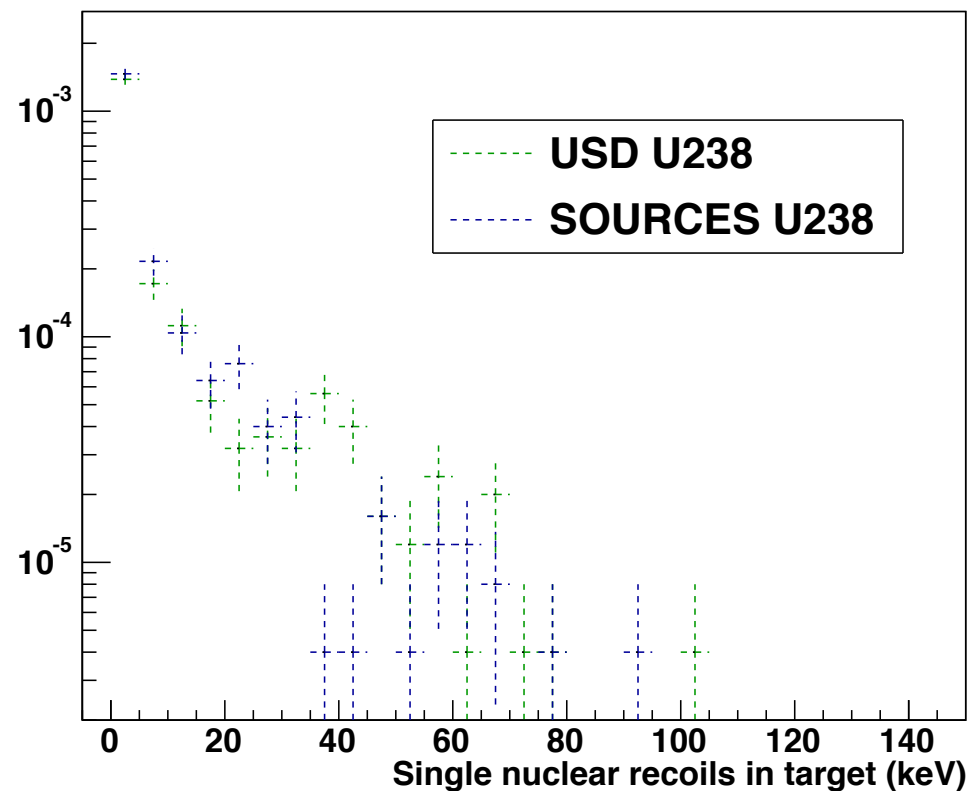
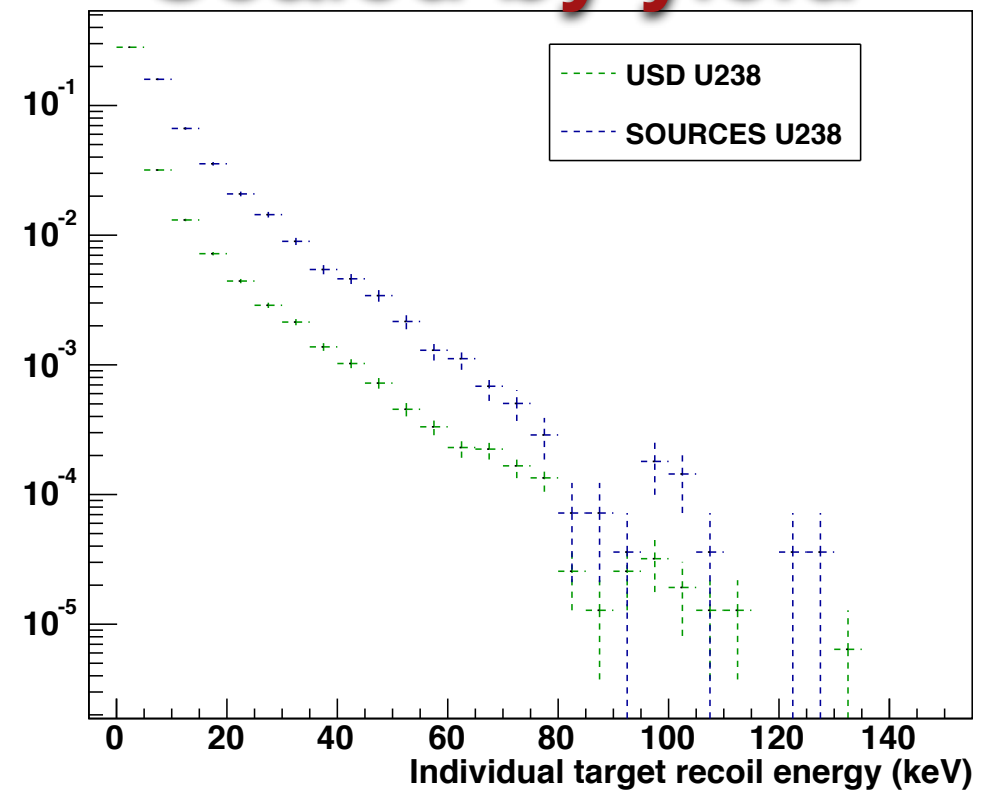


Xenon (PTFE U238): Nuclear Recoils

Just shape

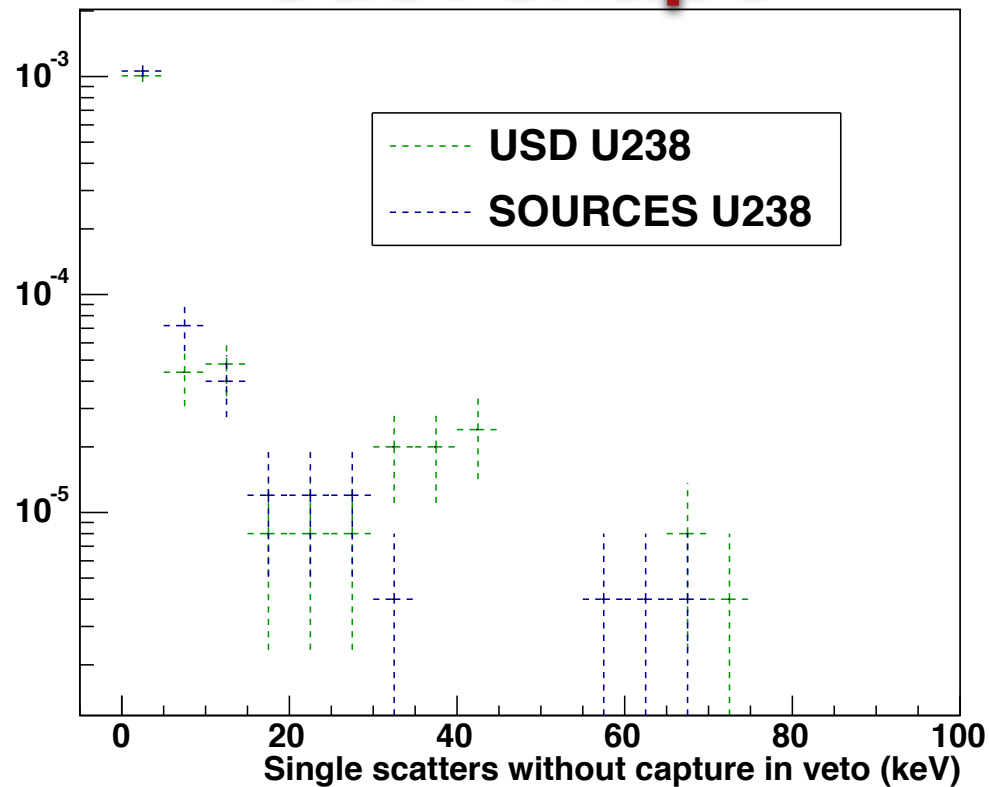


Scaled by yield

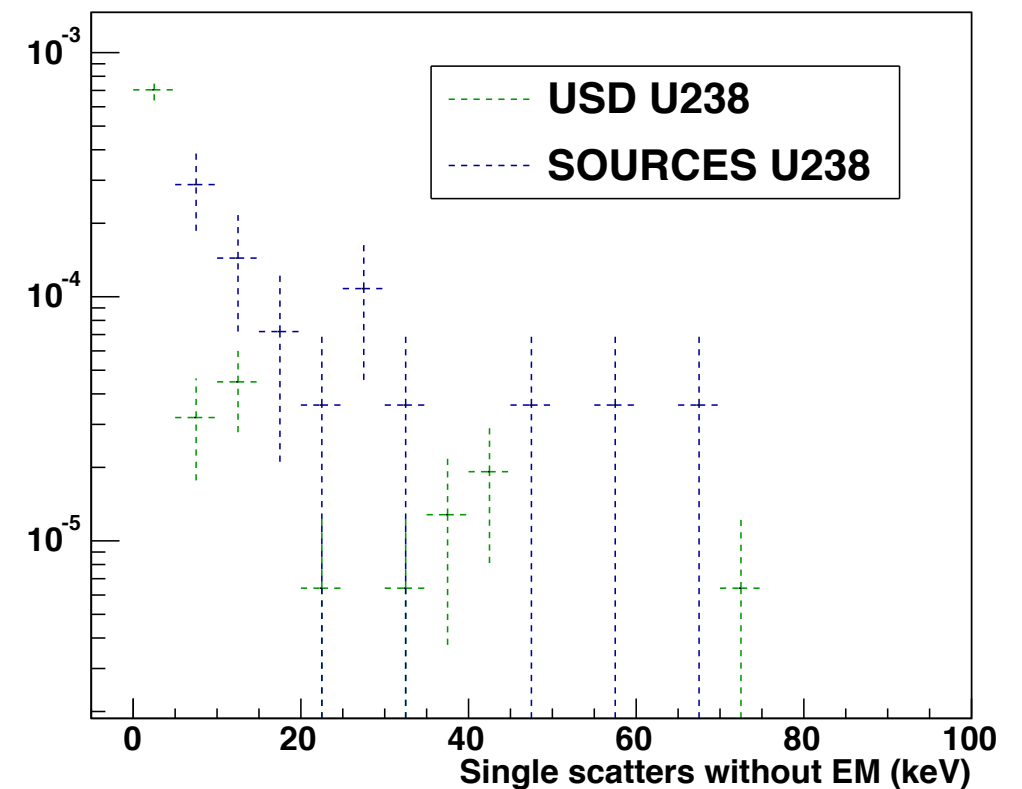
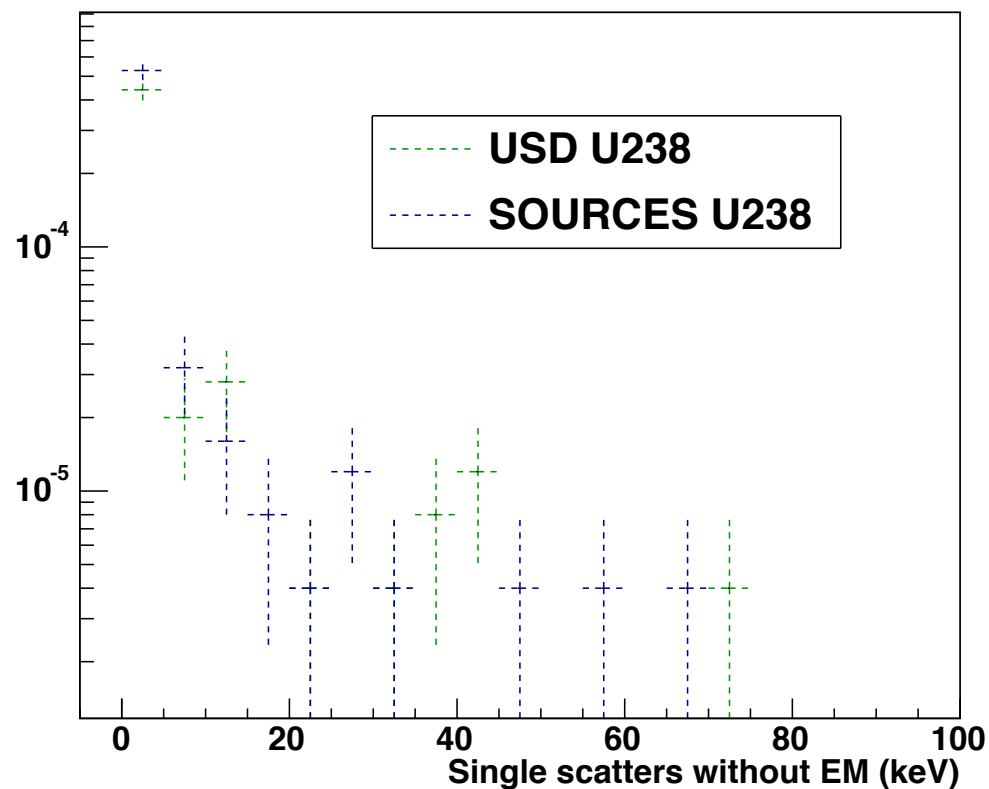
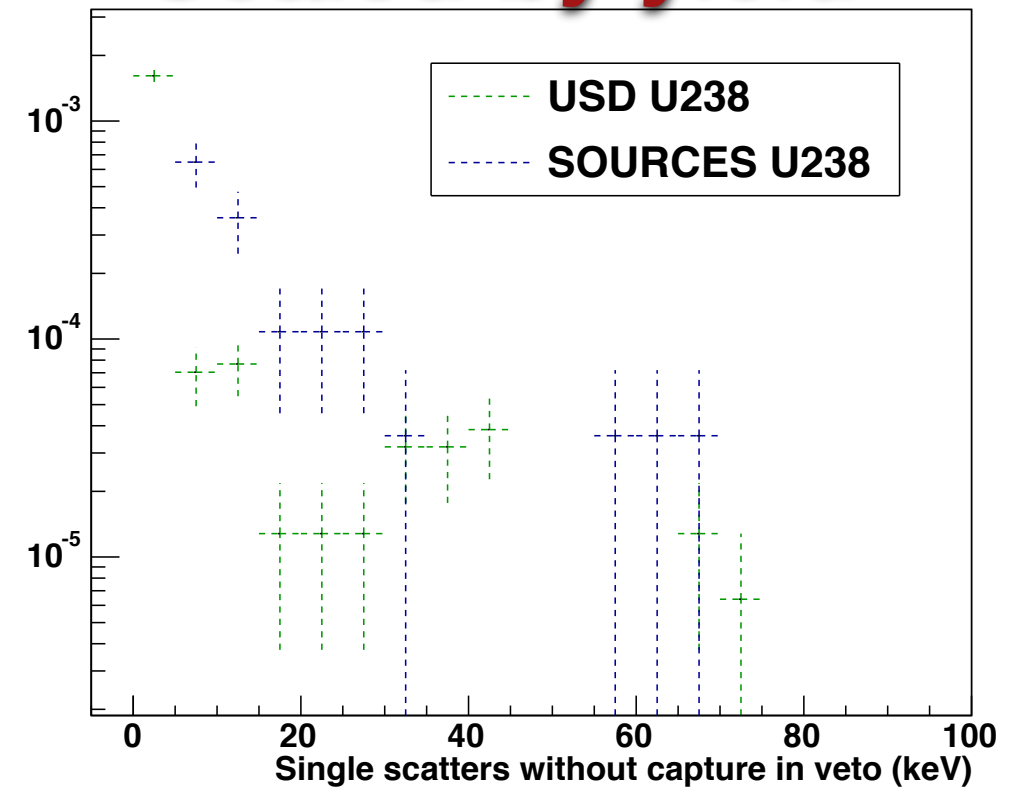


Xenon (PTFE U238): Vetoes Recoils

Just shape

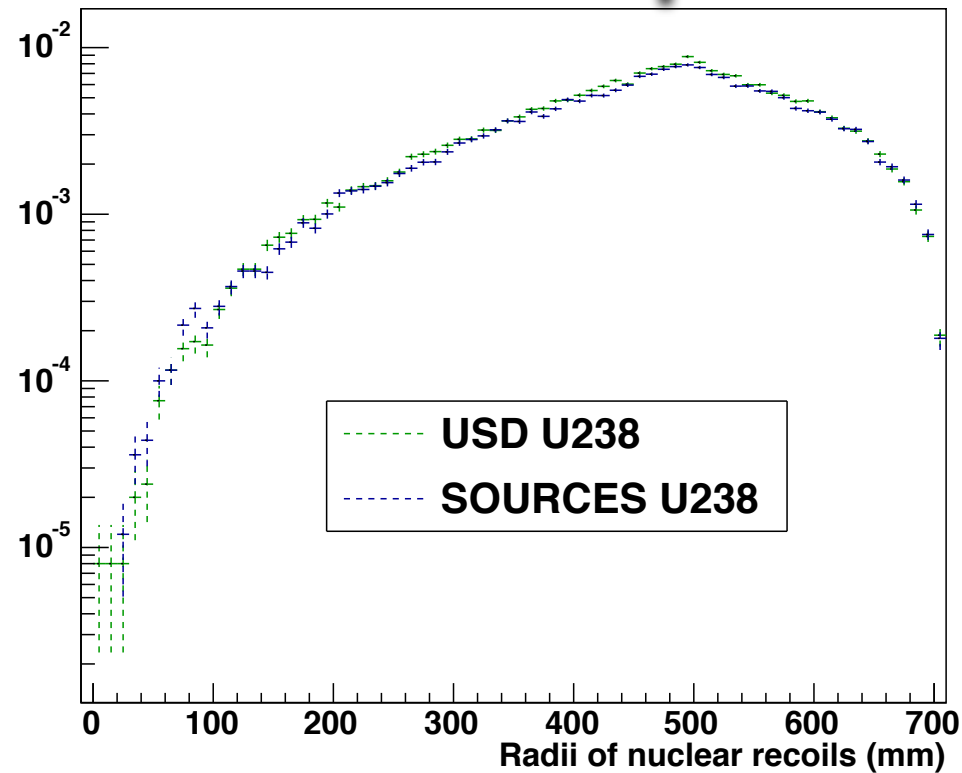


Scaled by yield

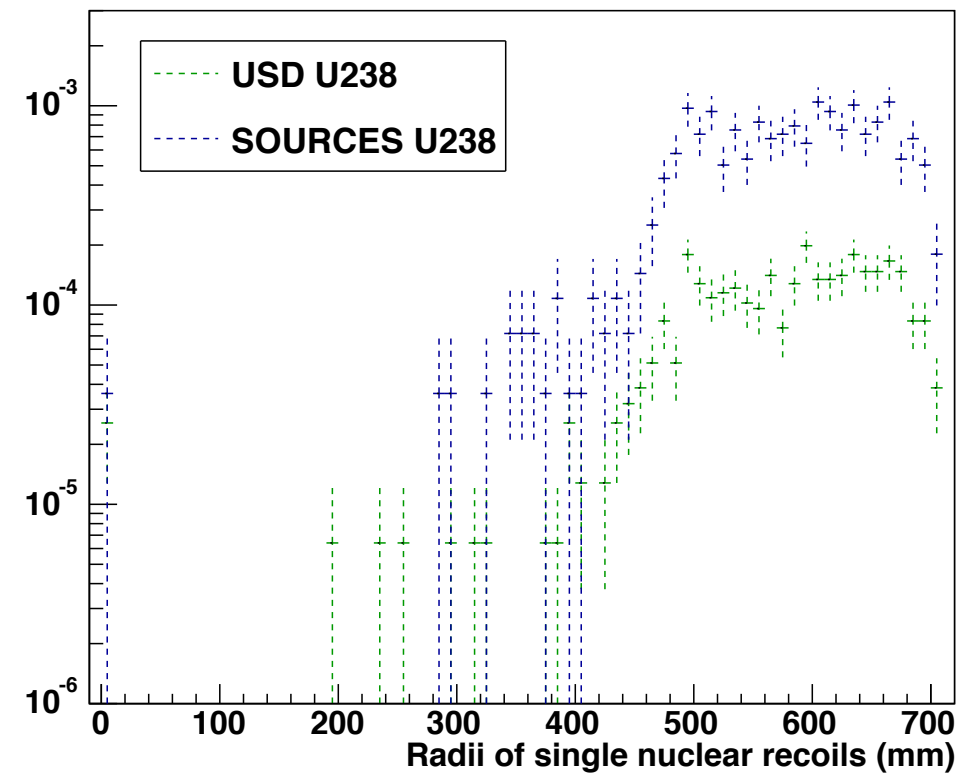
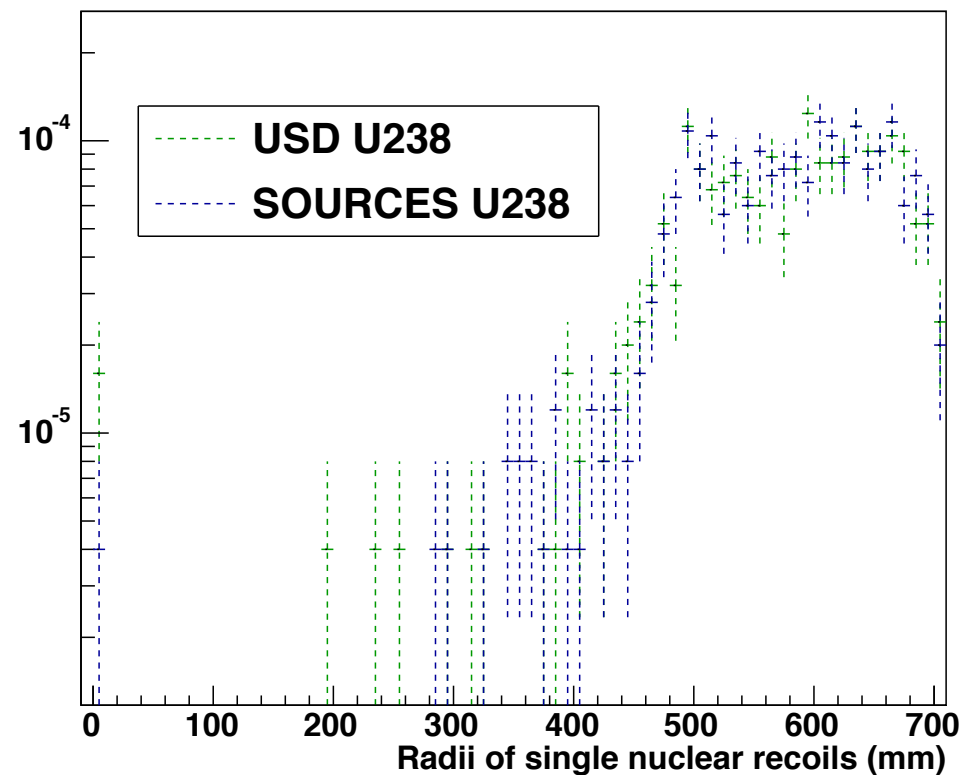
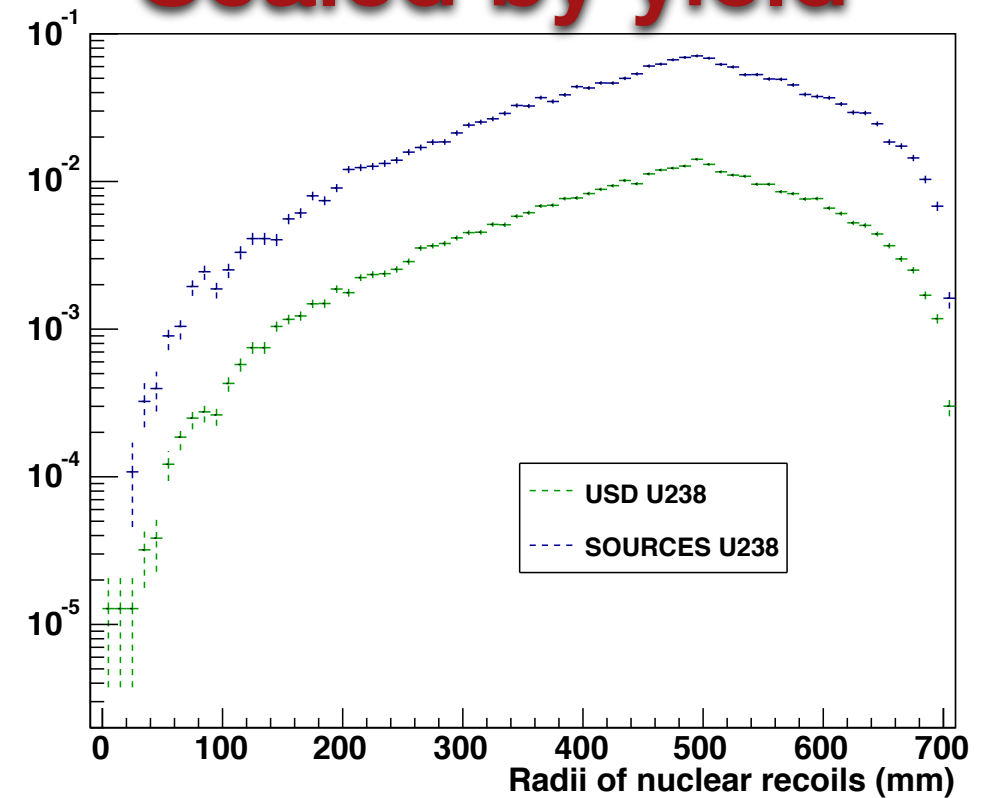


Xenon (PTFE U238): Recoil Radii

Just shape



Scaled by yield



Xe PTFE U238 Conclusions

- 1% difference in numbers by shape
- 23% error in # events from radial distribution, and 4% error in multiplicity comparisons possible
- 463% difference in neutron yield leads to a 455% difference in single scatters
- Veto importance: USD higher by 17% no capture, Sources 10% more no EM
- USD=Sources by shape; Sources >> USD by yield

Xenon (PTFE source Th232)

	Initial energy mean and sigma (MeV)	% total number recoils % recoil over 5 keV	%recoil %summed nuclear recoils over 5 keV	%single nuc %single nuc over 5 keV over 200 keV	%single no veto capture %over 5keV	%single no EM over 1 keV %over 5 keV	0 scatters% 1 scatter % 2 scatter % more scatters %
USD shape only	2.12744 Sigma: 1.14341	0.217048 +/- 0.000931768 0.043596 +/- 0.000417593	0.019116 +/- 0.000276521 0.003824 +/- 0.000123677	0.002056 +/- 9.06863e-05 0.000556 +/- 4.71593e-05 0 +/- 0	0.001328 +/- 7.28835e-05 0.00016 +/- 2.52982e-05	0.000668 +/- 5.16914e-05 0.0001 +/- 2e-05	0.98198 +/- 0.0019819 0.002056+/-9.06863e-05 0.001436+/-7.57892e-05 0.014528+/-
SOURCES shape only	1.77022 Sigma: 1.08517	0.2126 +/- 0.000922171 0.038512 +/- 0.000392489	0.018888 +/- 0.000274867 0.003148 +/- 0.000112214	0.00212 +/- 9.20869e-05 0.000504 +/- 4.48999e-05 0 +/- 0	0.001332 +/- 7.29932e-05 0.000156 +/- 2.498e-05	0.000656 +/- 5.1225e-05 8.8e-05 +/- 1.87617e-05	0.981884+/-0.0019818 0.00212+/-9.20869e-05 0.00166+/-8.14862e-05 0.014336+/-2e-05
(all scaled by production)	neutron yield n/s/cm^3	recoils over 5keV	summed nuclear recoils over 5keV	single nuclear recoils over 5keV over 200 keV	singles no veto capture over 5 keV	singles no EM over 1 keV “ over 5 keV	0 scatters 1 scatter 2 scatters more
USD full	5.41563E-09	0.117206 +/- 0.000503155 0.0235418 +/- 0.0002255	0.0103226 +/- 0.000149321 0.00206496 +/- 6.67856e-05	0.00111024 +/- 4.89706e-05 0.00030024 +/- 2.5466e-05 0 +/- 0	0.00071712 +/- 3.93571e-05 8.64e-05 +/- 1.3661e-05	0.00036072 +/- 2.79134e-05 5.4e-05 +/- 1.08e-05	0.530269 +/- 0.00107022 0.00111024+/-4.89706e-05 0.00077544+/-4.09262e-05 0.00784512+/-
SOURCES full	3.8811E-08	0.824888 +/- 0.00357802 0.149427 +/- 0.00152286	0.0732854 +/- 0.00106648 0.0122142 +/- 0.000435391	0.0082256 +/- 0.000357297 0.00195552 +/- 0.000174212 0 +/- 0	0.00516816 +/- 0.000283213 0.00060528 +/- 9.69224e-05	0.00254528 +/- 0.000198753 0.00034144 +/- 7.27953e-05	3.80971+/-0.00768939 0.0082256+/-0.000357297 0.0064408+/-0.000316166 0.0556237+/-1.08e-05

More numbers (Th232)

Simulation	Frac/# simulated scatters < 90%Rad	Frac/# simulated single scatters <90%Rad	ratio scatters more :2 more:1 2:1 2+:1	ratio single scatters total to those inside radius	ratio energy 20-200keV: >200keV
USD shape only	0.047312 +/- 0.000435026	5.6e-05 +/- 1.49666e-05	10.11 7.07 0.70 7.76	9.93	Inf
SOURCES shape only	0.044076 +/- 0.000419886	2.8e-05 +/- 1.0583e-05	8.64 6.76 0.78 7.51	18	Inf
USD full	0.0255485 +/- 0.000234914	3.024e-05 +/- 8.08198e-06			
SOURCES full	0.171015 +/- 0.00162916	0.00010864 +/- 4.10621e-05			

Raw output for chart

Just shape

USD Numbers:

Start energy mean: 2.12744 Sigma: 1.14341

0: 0.98198 +/- 0.00198191: 0.002056+/-9.06863e-052: 0.001436+/-7.57892e-05More: 0.014528+/-0

Individual recoils, all: 0.217048 +/- 0.000931768 over threshold keV: 0.043596 +/- 0.000417593

Total nuclear recoils all: 0.019116 +/- 0.000276521 over threshold keV: 0.003824 +/- 0.000123677

Total nuclear + EM recoils all: 0.018832 +/- 0.000274459 over threshold keV: 0.0154 +/- 0.000248193

Single recoils, all: 0.002056 +/- 9.06863e-05 over threshold keV: 0.000556 +/- 4.71593e-05 over upper keV: 0 +/- 0

All neutron radii, within 90 cm: 0.047312 +/- 0.000435026

Single neutron radii, within 90 cm: 5.6e-05 +/- 1.49666e-05

Single recoils no veto, all: 0.001328 +/- 7.28835e-05 over threshold keV: 0.00016 +/- 2.52982e-05

Single recoils no EM, all: 0.000668 +/- 5.16914e-05 over threshold keV: 0.0001 +/- 2e-05

Sources numbers:

Start energy mean: 1.77022 Sigma: 1.08517

0: 0.981884+/-0.00198181: 0.00212+/-9.20869e-052: 0.00166+/-8.14862e-05More: 0.014336+/-2e-05

Individual recoils, all: 0.2126 +/- 0.000922171 over threshold keV: 0.038512 +/- 0.000392489

Total nuclear recoils all: 0.018888 +/- 0.000274867 over threshold keV: 0.003148 +/- 0.000112214

Total nuclear and EM recoils all: 0.018676 +/- 0.00027332 over threshold keV: 0.014784 +/- 0.000243179

Single recoils, all: 0.00212 +/- 9.20869e-05 over threshold keV: 0.000504 +/- 4.48999e-05 over upper keV: 0 +/- 0

All neutron radii, within 90 cm: 0.044076 +/- 0.000419886

Single neutron radii, within 90 cm: 2.8e-05 +/- 1.0583e-05

Single recoils no veto, all: 0.001332 +/- 7.29932e-05 over 5 keV: 0.000156 +/- 2.498e-05

Single recoils no EM, all: 0.000656 +/- 5.1225e-05 over threshold keV: 8.8e-05 +/- 1.87617e-05

Scaled by yield

USD Numbers:

Start energy mean: 2.12744 Sigma: 1.14341

0: 0.530269 +/- 0.001070221: 0.00111024+/-4.89706e-052: 0.00077544+/-4.09262e-05More: 0.00784512+/-0

Individual recoils, all: 0.117206 +/- 0.000503155 over threshold keV: 0.0235418 +/- 0.0002255

Total nuclear recoils all: 0.0103226 +/- 0.000149321 over threshold keV: 0.00206496 +/- 6.67856e-05

Total nuclear + EM recoils all: 0.0101693 +/- 0.000148208 over threshold keV: 0.008316 +/- 0.000134024

Single recoils, all: 0.00111024 +/- 4.89706e-05 over threshold keV: 0.00030024 +/- 2.5466e-05 over upper keV: 0 +/- 0

All neutron radii, within 90 cm: 0.0255485 +/- 0.000234914

Single neutron radii, within 90 cm: 3.024e-05 +/- 8.08198e-06

Single recoils no veto, all: 0.00071712 +/- 3.93571e-05 over threshold keV: 8.64e-05 +/- 1.3661e-05

Single recoils no EM, all: 0.00036072 +/- 2.79134e-05 over threshold keV: 5.4e-05 +/- 1.08e-05

Sources numbers:

Start energy mean: 1.77022 Sigma: 1.08517

0: 3.80971+/-0.007689391: 0.0082256+/-0.0003572972: 0.0064408+/-0.000316166More: 0.0556237+/-1.08e-05

Individual recoils, all: 0.824888 +/- 0.00357802 over threshold keV: 0.149427 +/- 0.00152286

Total nuclear recoils all: 0.0732854 +/- 0.00106648 over threshold keV: 0.0122142 +/- 0.000435391

Total nuclear and EM recoils all: 0.0724629 +/- 0.00106048 over threshold keV: 0.0573619 +/- 0.000943534

Single recoils, all: 0.0082256 +/- 0.000357297 over threshold keV: 0.00195552 +/- 0.000174212 over upper keV: 0 +/- 0

All neutron radii, within 90 cm: 0.171015 +/- 0.00162916

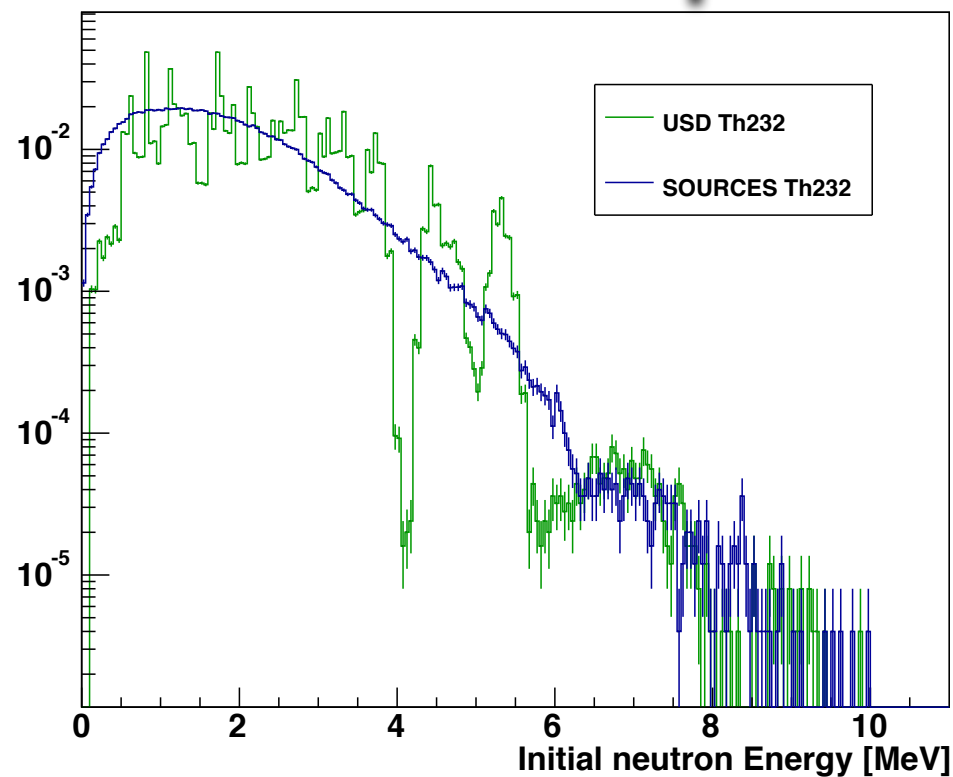
Single neutron radii, within 90 cm: 0.00010864 +/- 4.10621e-05

Single recoils no veto, all: 0.00516816 +/- 0.000283213 over 5 keV: 0.00060528 +/- 9.69224e-05

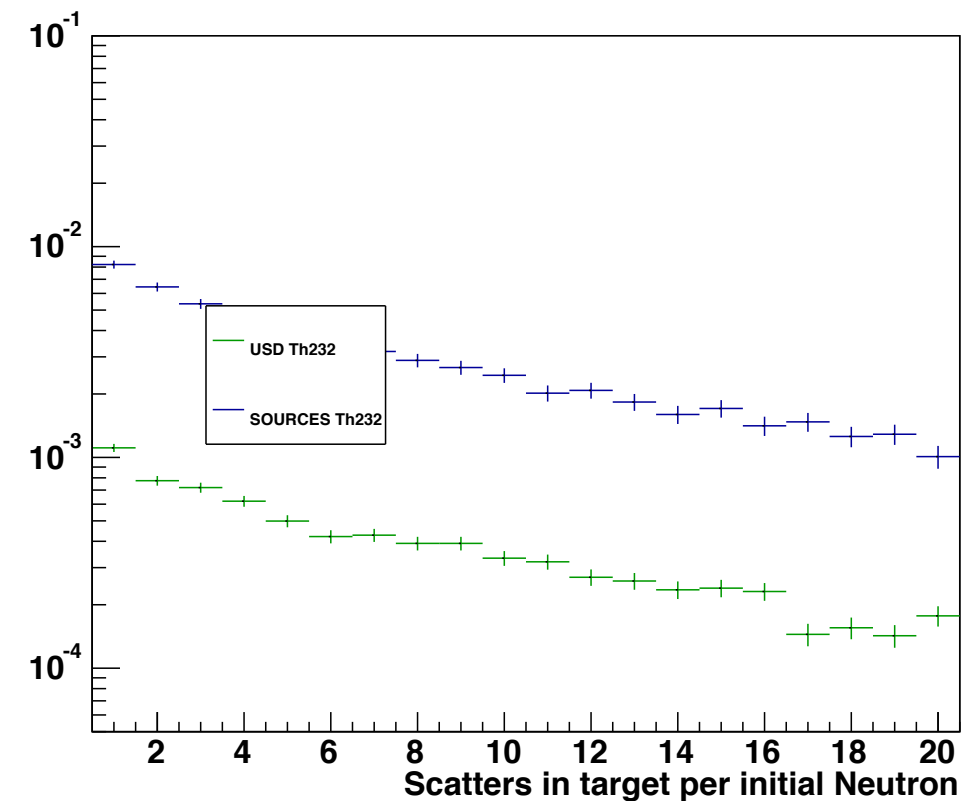
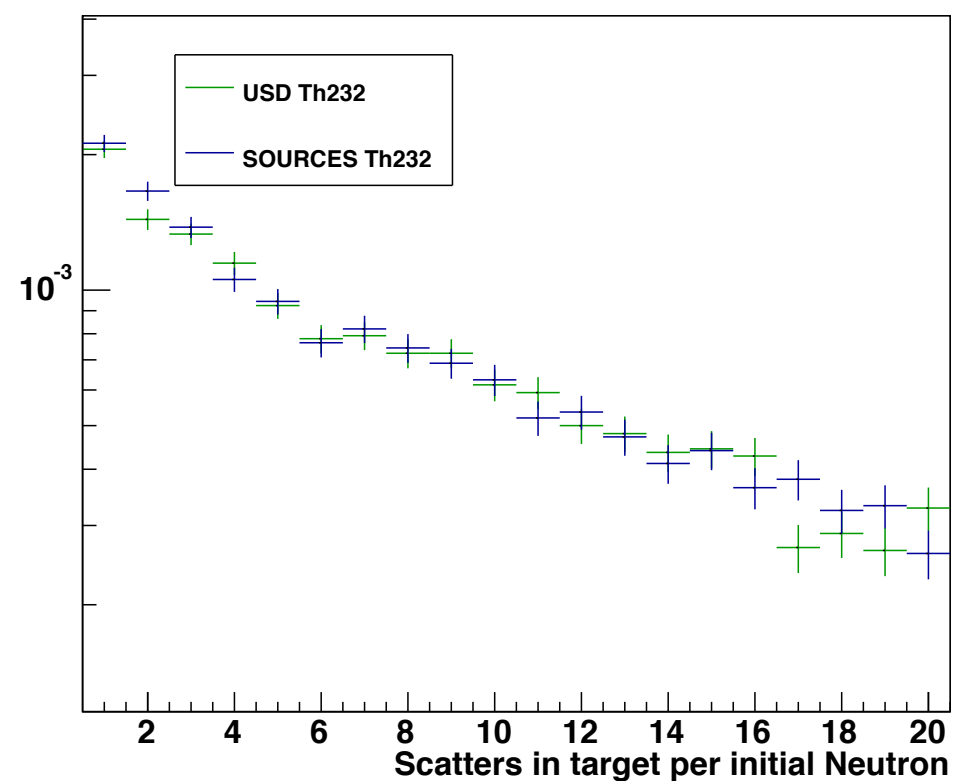
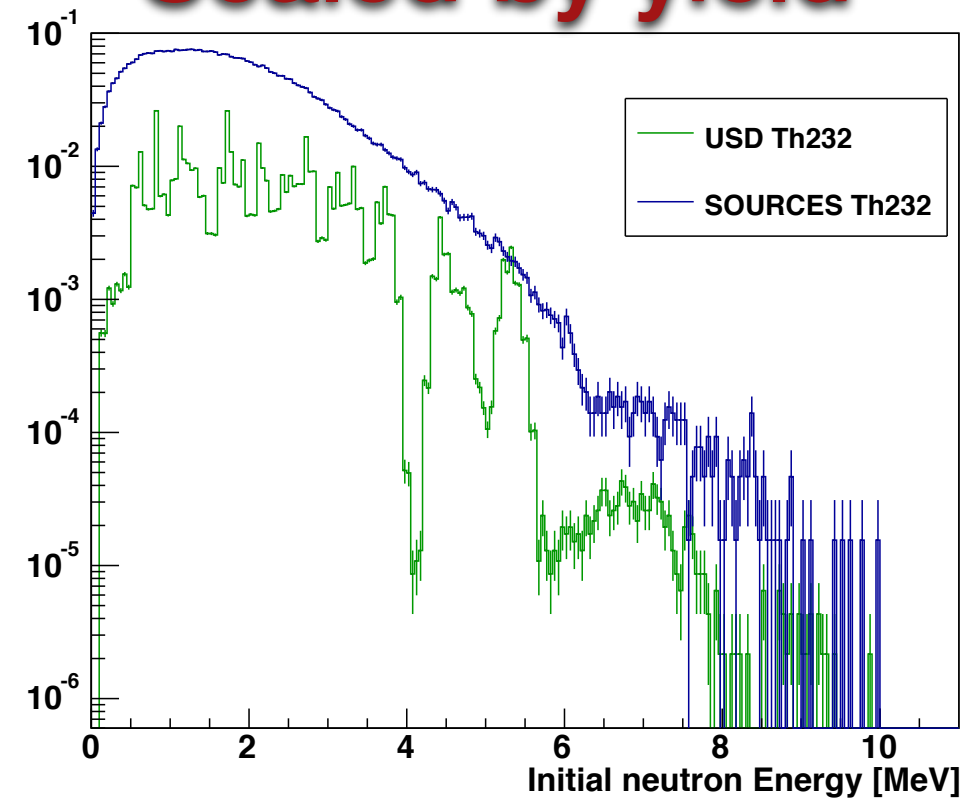
Single recoils no EM, all: 0.00254528 +/- 0.000198753 over threshold keV: 0.00034144 +/- 7.27953e-05

Xenon (PTFE Th232)

Just shape

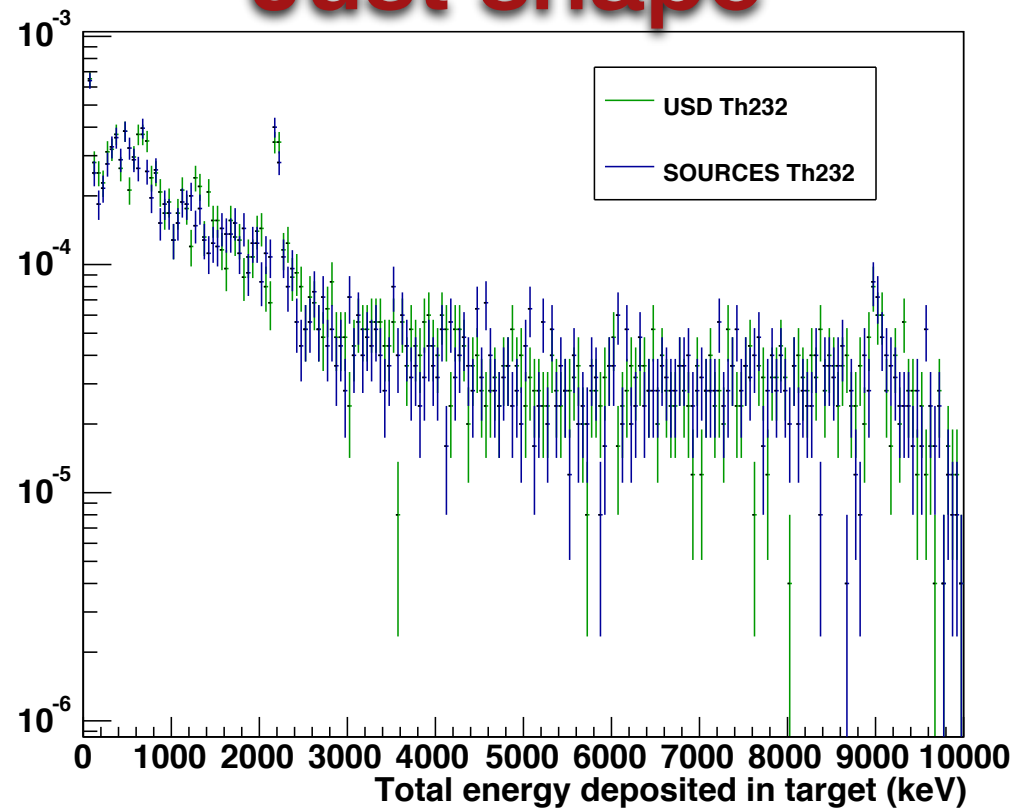


Scaled by yield

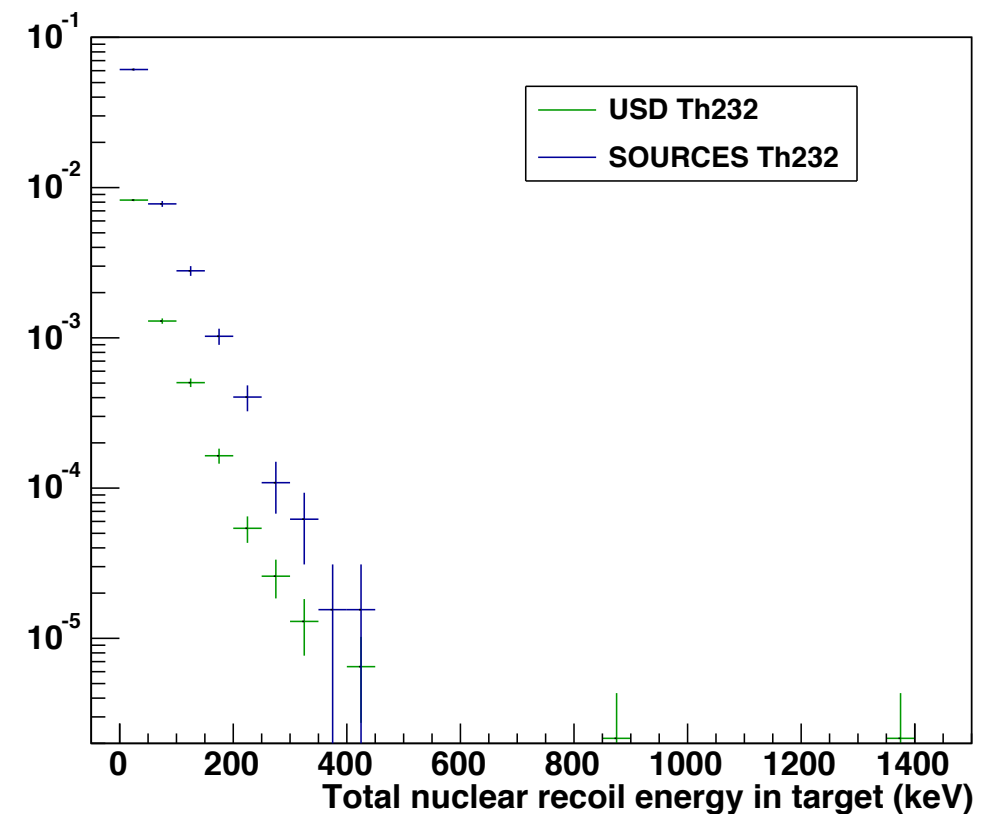
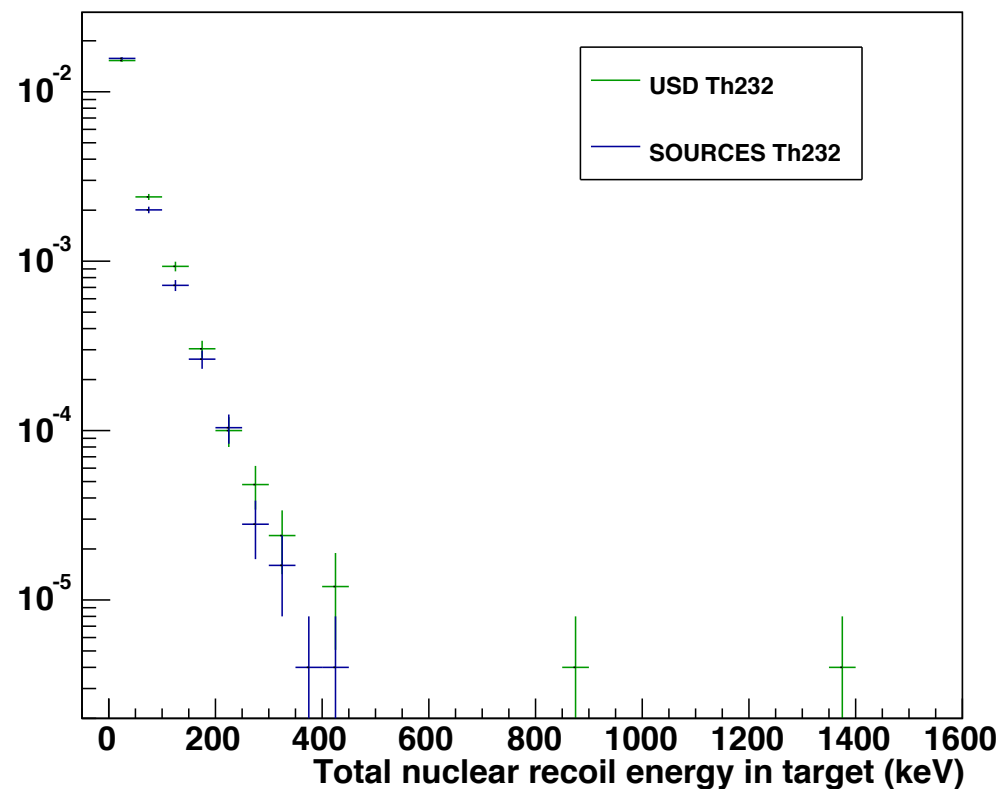
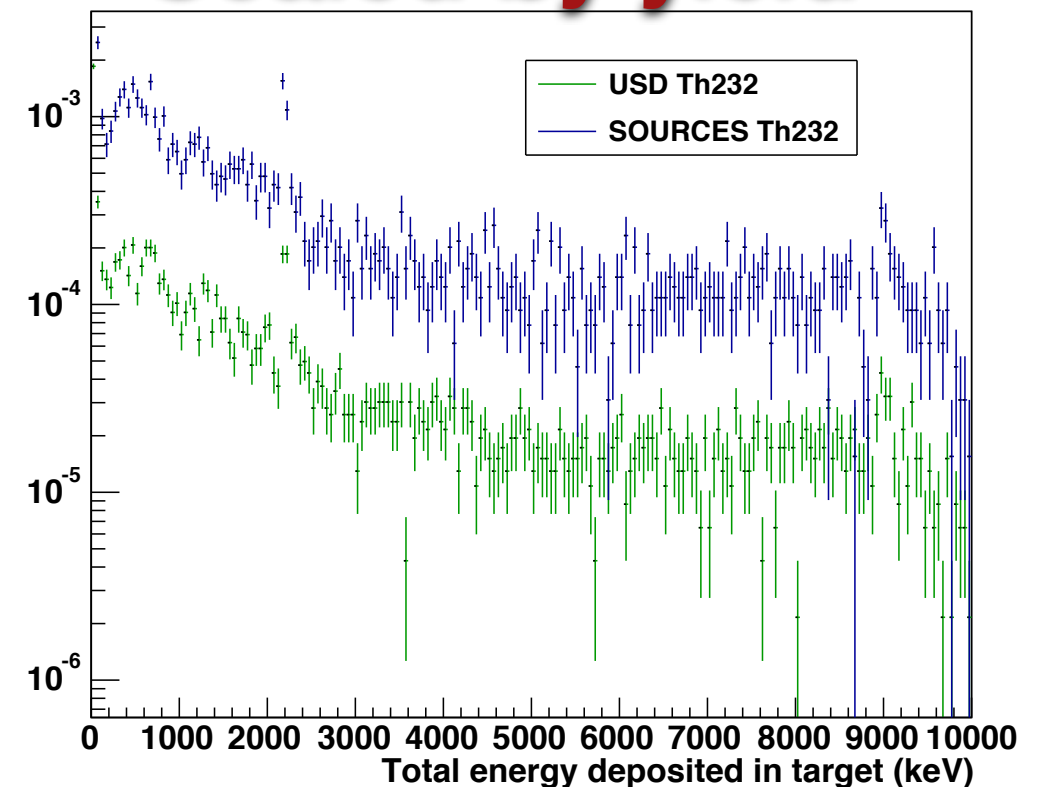


Xenon (PTFE Th232): Energy Deposited

Just shape

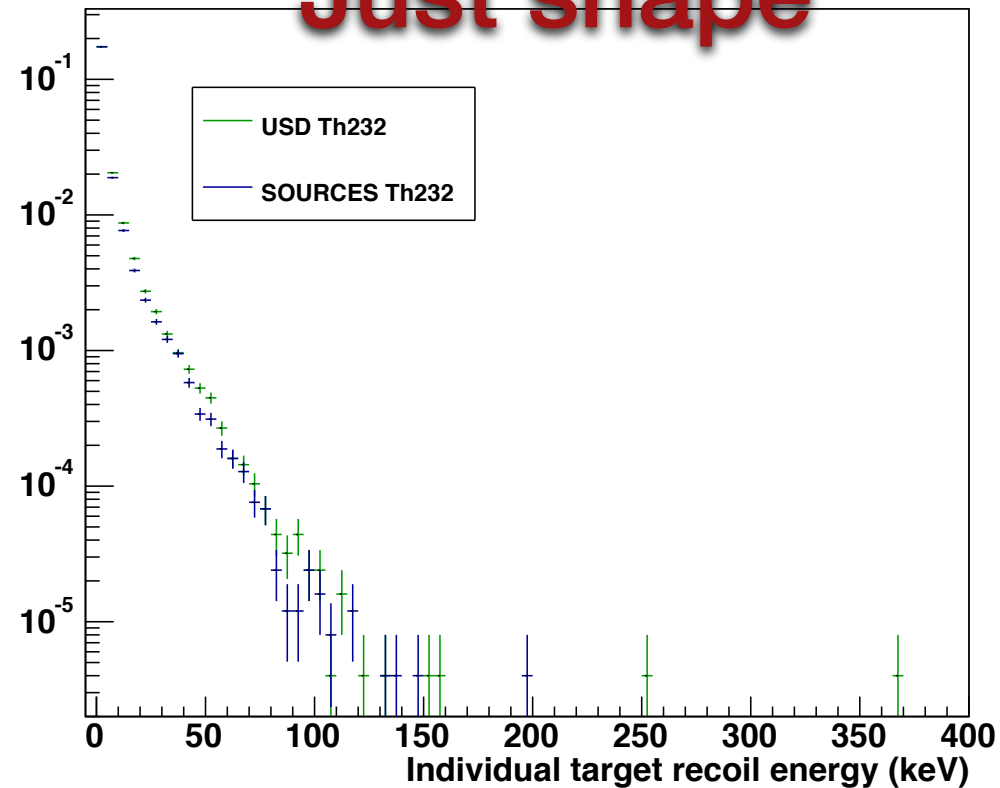


Scaled by yield

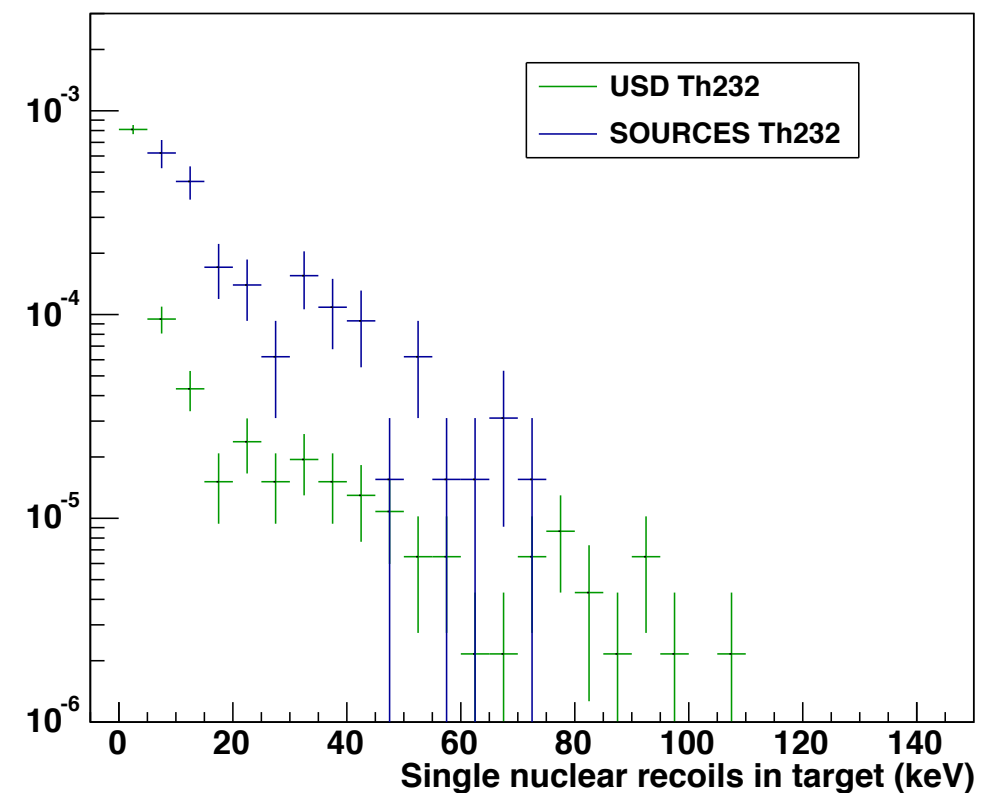
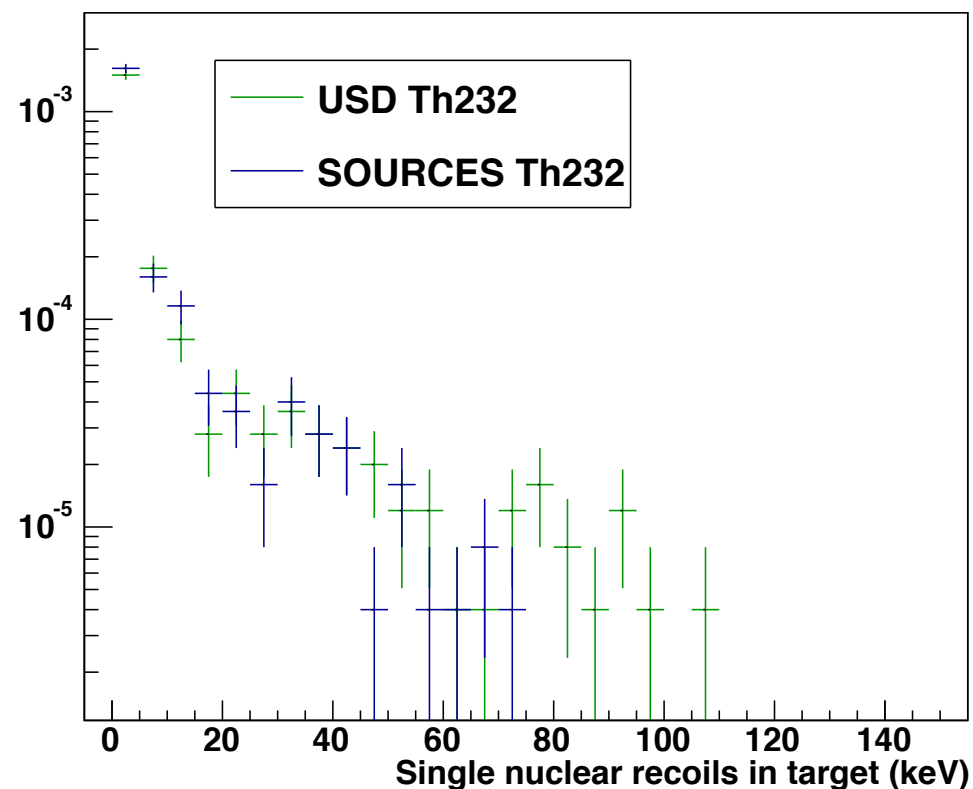
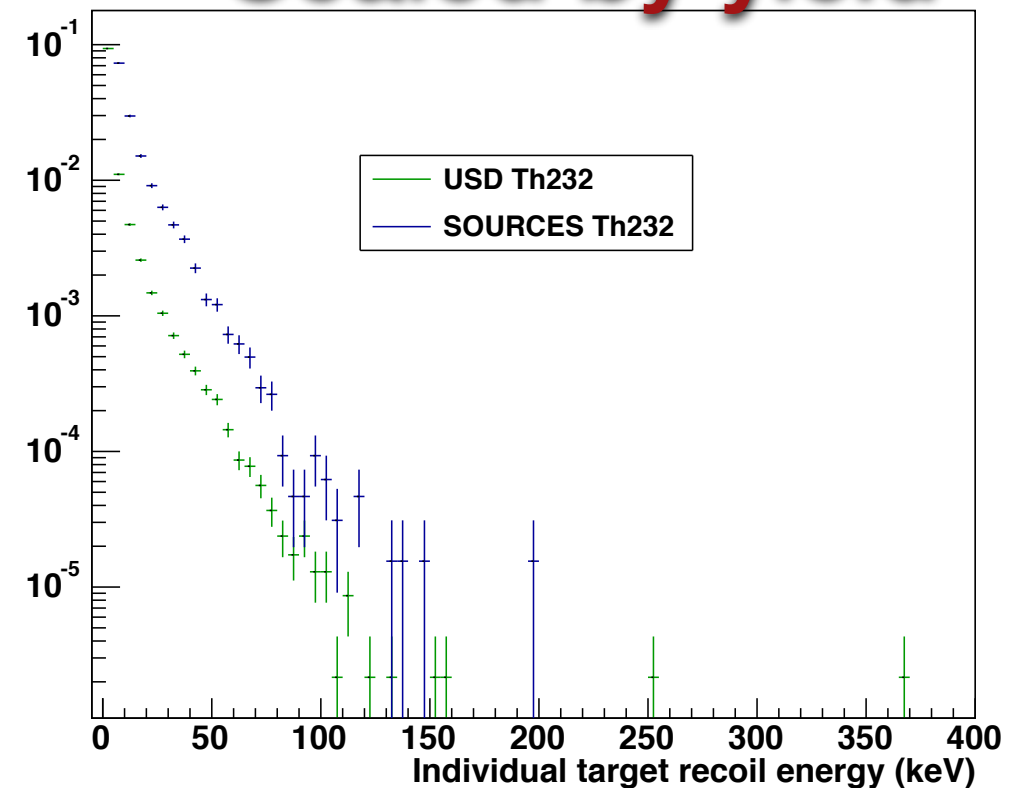


Xenon (PTFE Th232): Nuclear Recoils

Just shape

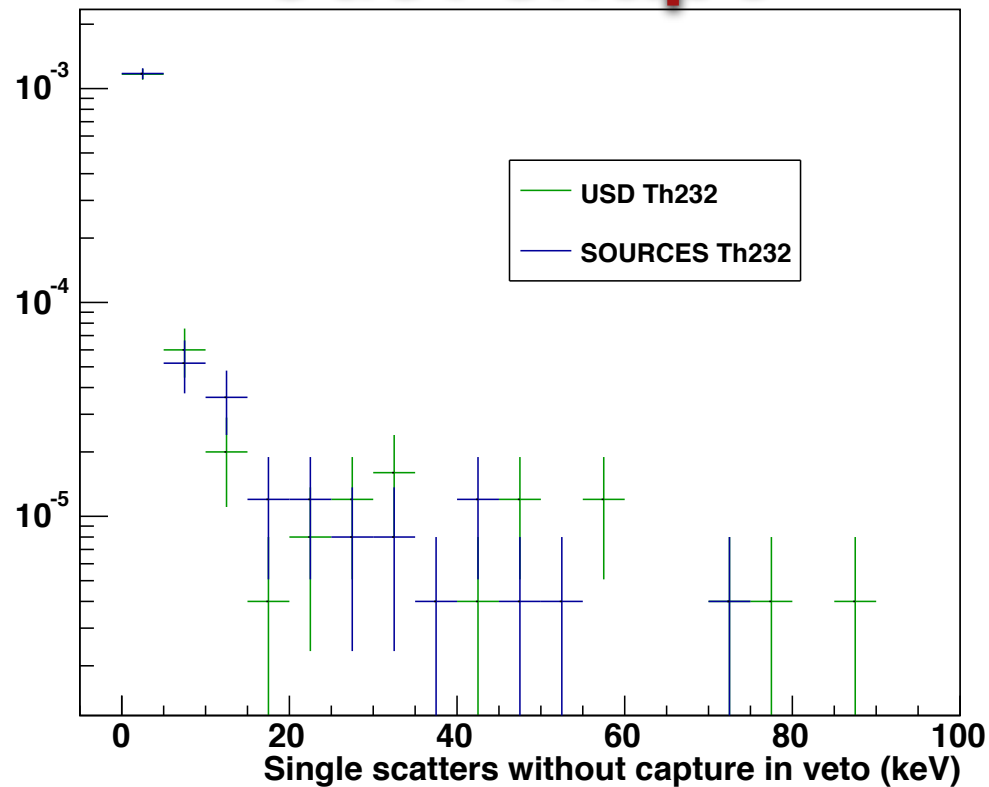


Scaled by yield

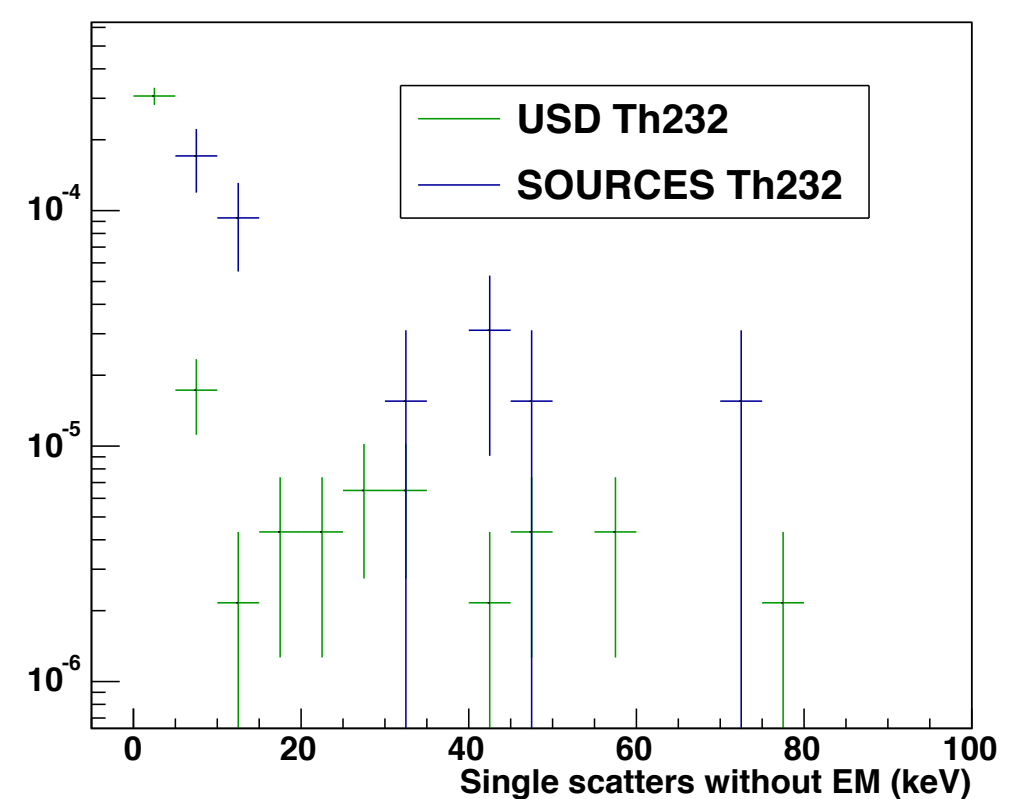
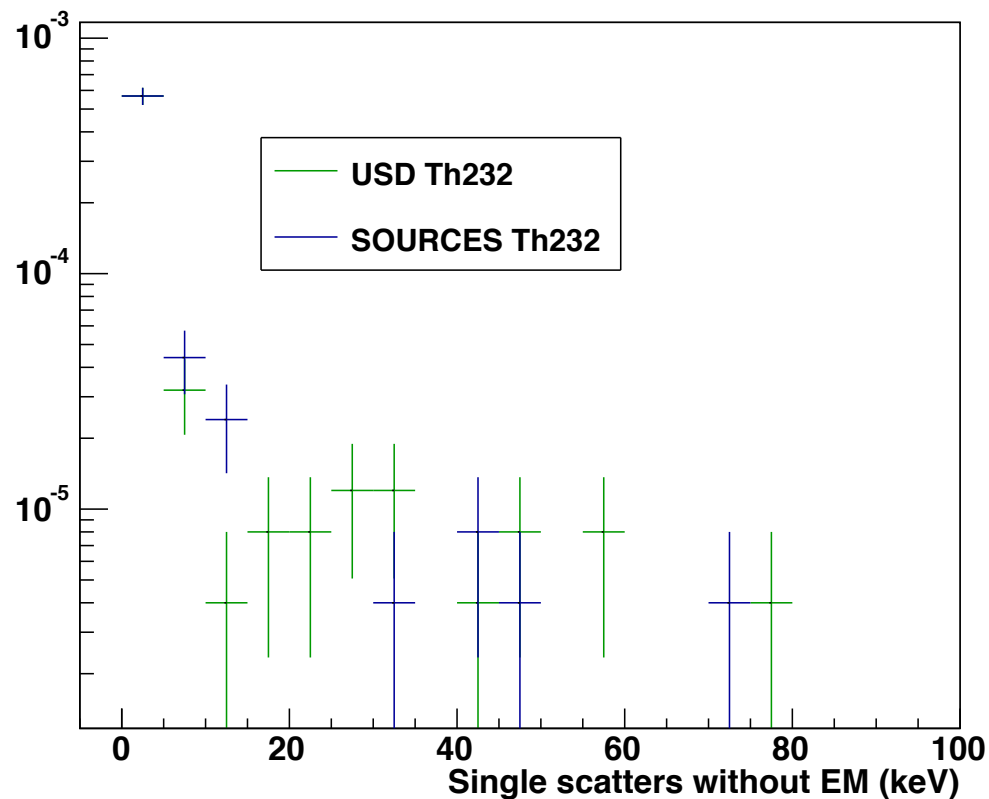
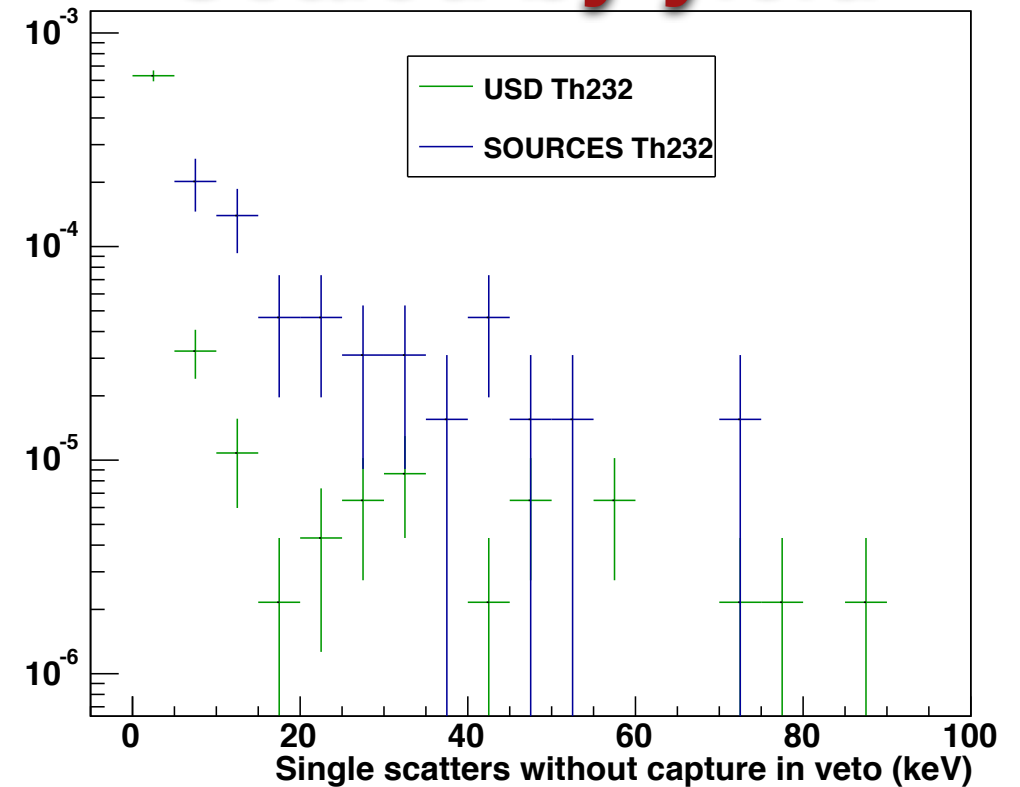


Xenon (PTFE Th232): Vetoes Recoils

Just shape

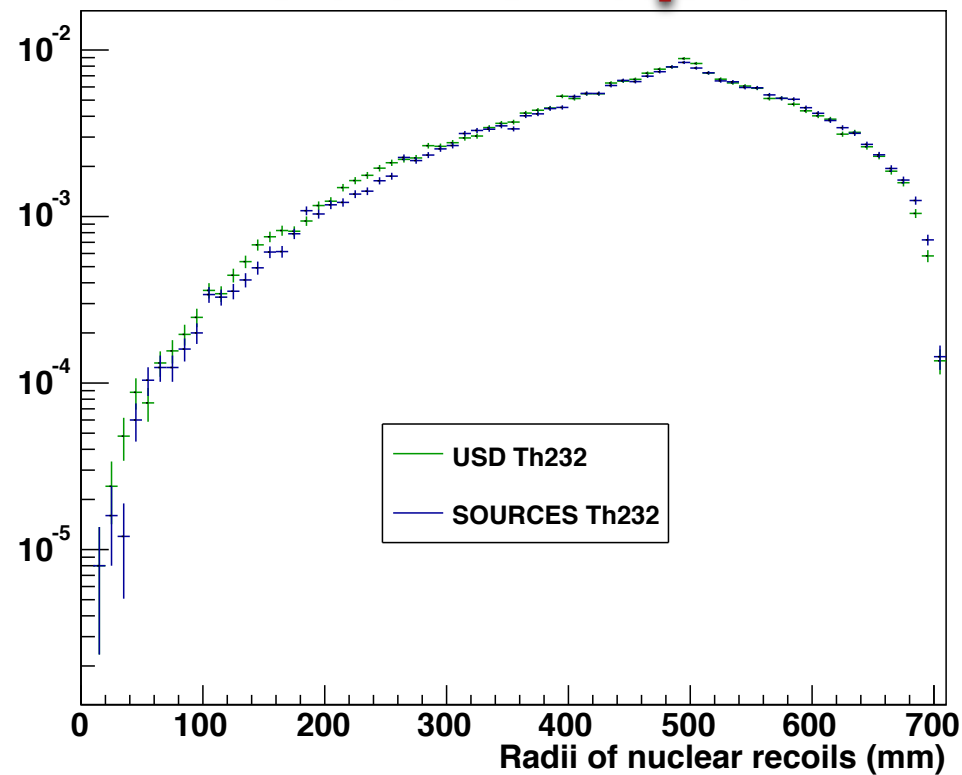


Scaled by yield

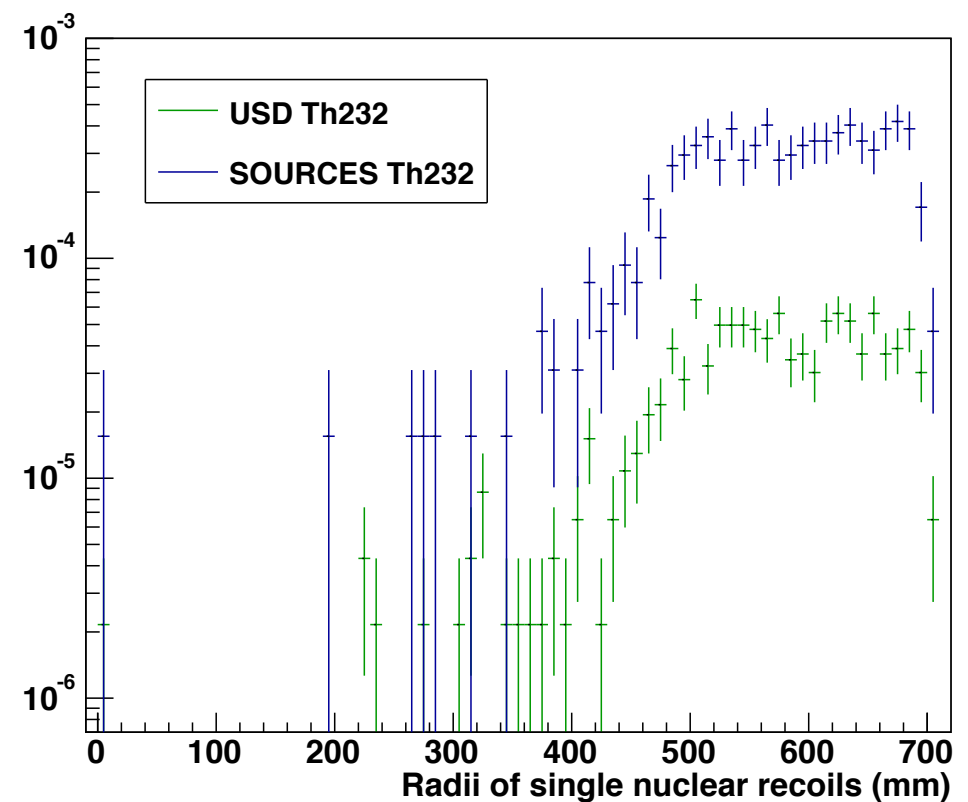
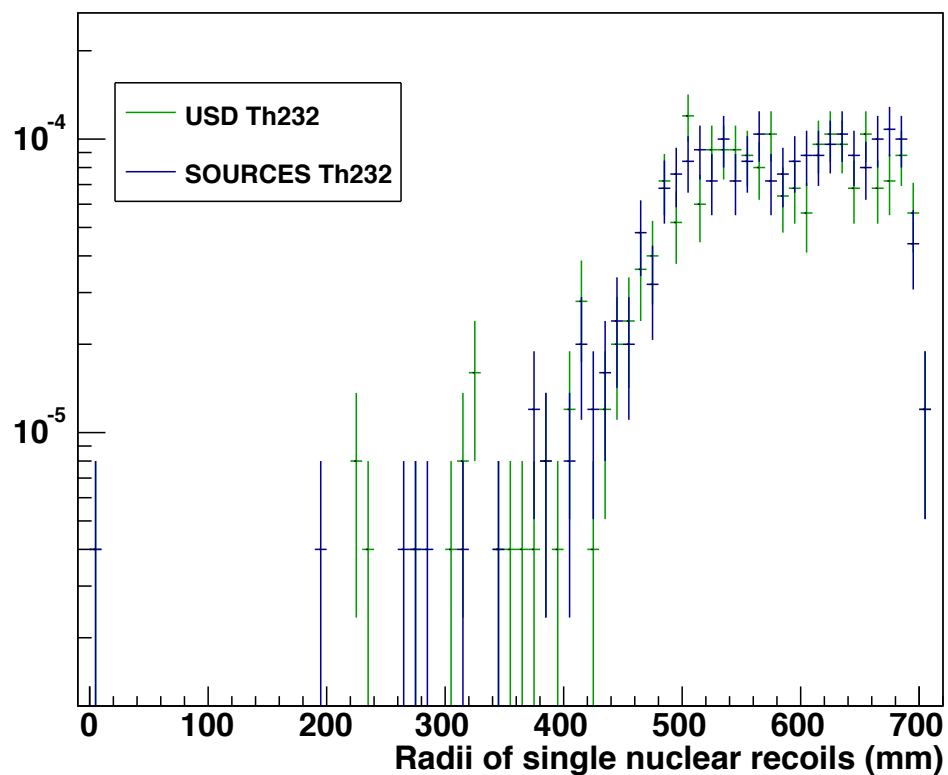
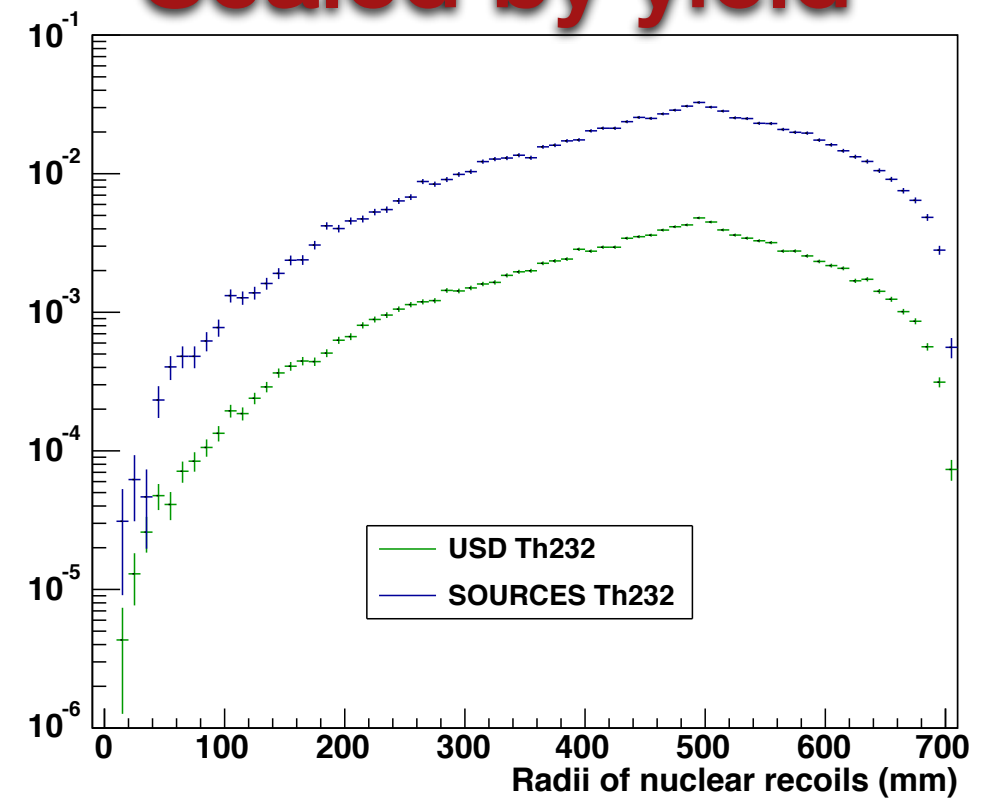


Xenon (PTFE Th232): Recoil Radii

Just shape



Scaled by yield



Xe PTFE Th232 Conclusions

- By shape, they are incredibly close for production (10% effect, but stats limited -> should run more)
- 81% error in # events from radial distribution (not believable at all), and 13% error in multiplicity comparisons possible
- Veto importance: 2.5% more unvetoes by capture in USD, 14% more without EM in USD by shape
- 617% difference in neutron yield leads to a 550% difference in single scatters
- USD > Sources by shape, Sources >> USD by yield

Ge Detector Simulations

- 250000 neutrons isotropic from copper for each simulation
- Neutron recoil threshold of 5 keVnr used in analysis
- 1 keVee threshold for EM deposits to veto event in argon
- Neutron capture in plastic scintillator needed to externally veto event

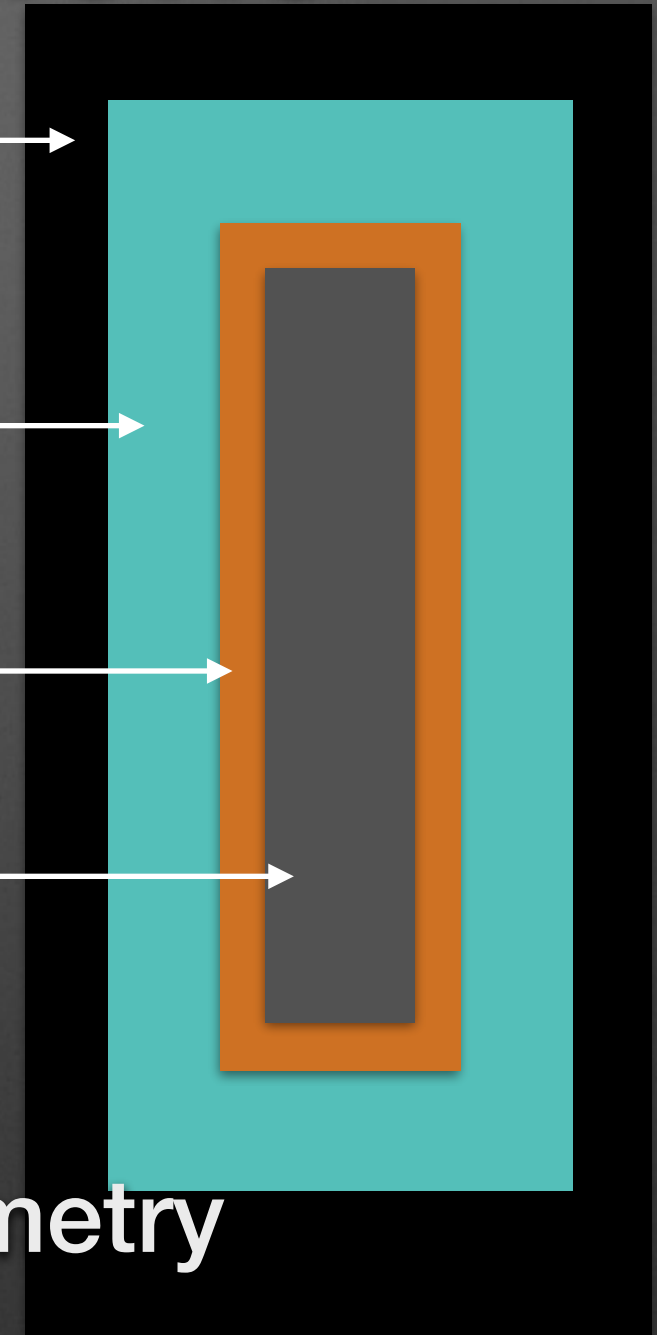
10 cm Lead shield cylinder
31 cm radius, 1.75m tall

15 cm polyethylene
down to 6 cm radius,
1.5 m tall

1 cm copper
to 5 cm radius

Germanium
10 cm diameter,
1.2m tall

Nested cylinders geometry



- Apologies for cryptic columns on next pages, dropped percentages and everything is straight fractions, some text values are wrong on my code output
- Should look at distance from wall and not radius in final work
- USD Th232 sims seg fault currently

Germanium (Copper source U238)

	Initial energy mean and sigma (MeV)	% total number recoils % recoil over 5 keV	%recoil %summed nuclear recoils over 5 keV	%single nuc %single nuc over 5 keV	%single no veto capture %over 5keV	%single no EM over 1 keV %over 5 keV	0 scatters% 1 scatter % 2 scatter % more scatters %
USD shape only	0.467108 Sigma: 0.176935	3.7478 +/- 0.00387185 1.47977 +/- 0.00243292	0.968096 +/- 0.00196784 0.142196 +/- 0.000754178	0.17294 +/- 0.000831721 0.10206 +/- 0.000638937	0.047188 +/- 0.000434456 0.024056 +/- 0.0003102	0.152092 +/- 0.000779979 0.08872 +/- 0.000595718	0.235472 +/- 0.000970509 0.17294+/-0.000831721 0.129444+/-0.000719567 0.462144+/-0
SOURCES shape only	0.611618 Sigma: 0.310856	2.59043 +/- 0.00321896 0.74866 +/- 0.0017305	0.93546 +/- 0.00193438 0.083004 +/- 0.000576208	0.12658 +/- 0.000711562 0.06708 +/- 0.000517996	0.042892 +/- 0.000414208 0.015708 +/- 0.000250663	0.112348 +/- 0.000670367 0.058192 +/- 0.00048246	0.470072+/-0.00137124 0.12658+/-0.000711562 0.089388+/-0.000597957 0.31396+/-0.000595718
(all scaled by production)	neutron yield n/s/cm^3	recoils over 5keV	summed nuclear recoils over 5keV	single nuclear recoils over 5keV over 50 keV	singles no veto capture over 5 keV	singles no EM over 1 keV “ over 5 keV	0 scatters 1 scatter 2 scatters more
USD full	3.46 E-12	12.9674 +/- 0.0133966 5.12001 +/- 0.00841789	3.34961 +/- 0.00680872 0.491998 +/- 0.00260945	0.598372 +/- 0.00287776 0.353128 +/- 0.00221072 0 +/- 0	0.16327 +/- 0.00150322 0.0832338 +/- 0.00107329	0.526238 +/- 0.00269873 0.306971 +/- 0.00206118	0.814733 +/- 0.00335796 0.598372+/-0.00287776 0.447876+/-0.0024897 1.59902+/-0
SOURCES full	2.90 E-12	7.51225 +/- 0.009335 2.17111 +/- 0.00501846	2.71283 +/- 0.00560971 0.240712 +/- 0.001671	0.367082 +/- 0.00206353 0.194532 +/- 0.00150219 0.0073544 +/- 0.000292081	0.124387 +/- 0.0012012 0.0455532 +/- 0.000726923	0.325809 +/- 0.00194406 0.168757 +/- 0.00139914	1.36321+/-0.00397658 0.367082+/-0.00206353 0.259225+/-0.00173407 0.910484+/-0.00206118

More numbers (U238)

Simulation	%/# simulated scatters < 90%Rad	%/# simulated single scatters < 90%Rad	ratio scatters more :2 more:1 2:1 2+:1	ratio single scatters total to those inside radius	ratio energy 5-50keV:>5 0keV
USD shape only	2.28021 +/- 0.00302007	0.099516 +/- 0.000630923	3.57 2.67 0.75 3.42	1.74	Infinity
SOURCES shape only	1.56994 +/- 0.00250595	0.070832 +/- 0.000532286	3.51 2.48 0.71 3.17	1.79	25.45
USD full	7.88953 +/- 0.0104495	0.344325 +/- 0.00218299			
SOURCES full	4.55284 +/- 0.00726725	0.205413 +/- 0.00154363			

Raw output for chart

Just shape

USD Numbers:

Start energy mean: 0.467108 Sigma: 0.176935
0: 0.235472 +/- 0.000970509 1: 0.17294+/-0.000831721 2: 0.129444+/-0.000719567 More: 0.462144+/-0
Individual recoils, all: 3.7478 +/- 0.00387185 over threshold keV: 1.47977 +/- 0.00243292
Total nuclear recoils all: 0.968096 +/- 0.00196784 over threshold keV: 0.142196 +/- 0.000754178
Total nuclear + EM recoils all: 0.913612 +/- 0.00191166 over threshold keV: 0.85324 +/- 0.00184742
Single recoils, all: 0.17294 +/- 0.000831721 over threshold keV: 0.10206 +/- 0.000638937 over upper keV: 0 +/- 0
All neutron radii, within 90 cm: 2.28021 +/- 0.00302007
Single neutron radii, within 90 cm: 0.099516 +/- 0.000630923
Single recoils no veto, all: 0.047188 +/- 0.000434456 over threshold keV: 0.024056 +/- 0.0003102
Single recoils no EM, all: 0.152092 +/- 0.000779979 over threshold keV: 0.08872 +/- 0.000595718

Sources numbers:

Start energy mean: 0.611618 Sigma: 0.310856
0: 0.470072+/-0.00137124 1: 0.12658+/-0.000711562 2: 0.089388+/-0.000597957 More: 0.31396+/-0.000595718
Individual recoils, all: 2.59043 +/- 0.00321896 over threshold keV: 0.74866 +/- 0.0017305
Total nuclear recoils all: 0.93546 +/- 0.00193438 over threshold keV: 0.083004 +/- 0.000576208
Total nuclear and EM recoils all: 0.880868 +/- 0.00187709 over threshold keV: 0.843316 +/- 0.00183664
Single recoils, all: 0.12658 +/- 0.000711562 over threshold keV: 0.06708 +/- 0.000517996 over upper keV: 0 +/- 0
All neutron radii, within 90 cm: 1.56994 +/- 0.00250595
Single neutron radii, within 90 cm: 0.070832 +/- 0.000532286
Single recoils no veto, all: 0.042892 +/- 0.000414208 over 5 keV: 0.015708 +/- 0.000250663
Single recoils no EM, all: 0.112348 +/- 0.000670367 over threshold keV: 0.058192 +/- 0.00048246

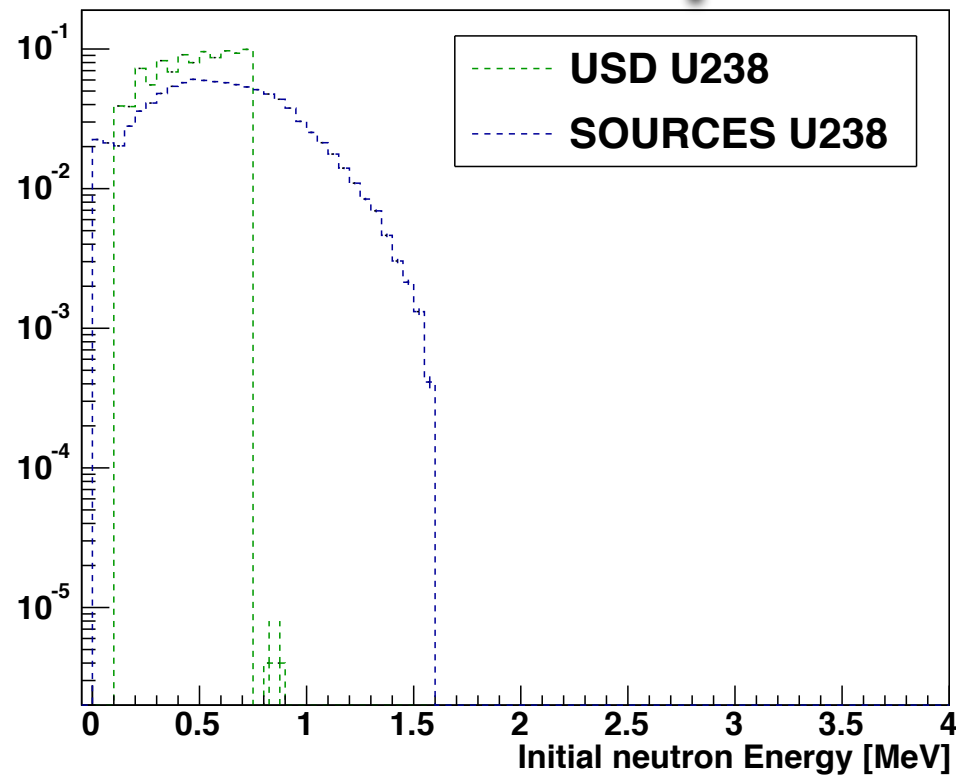
Scaled by yield

USD Numbers:

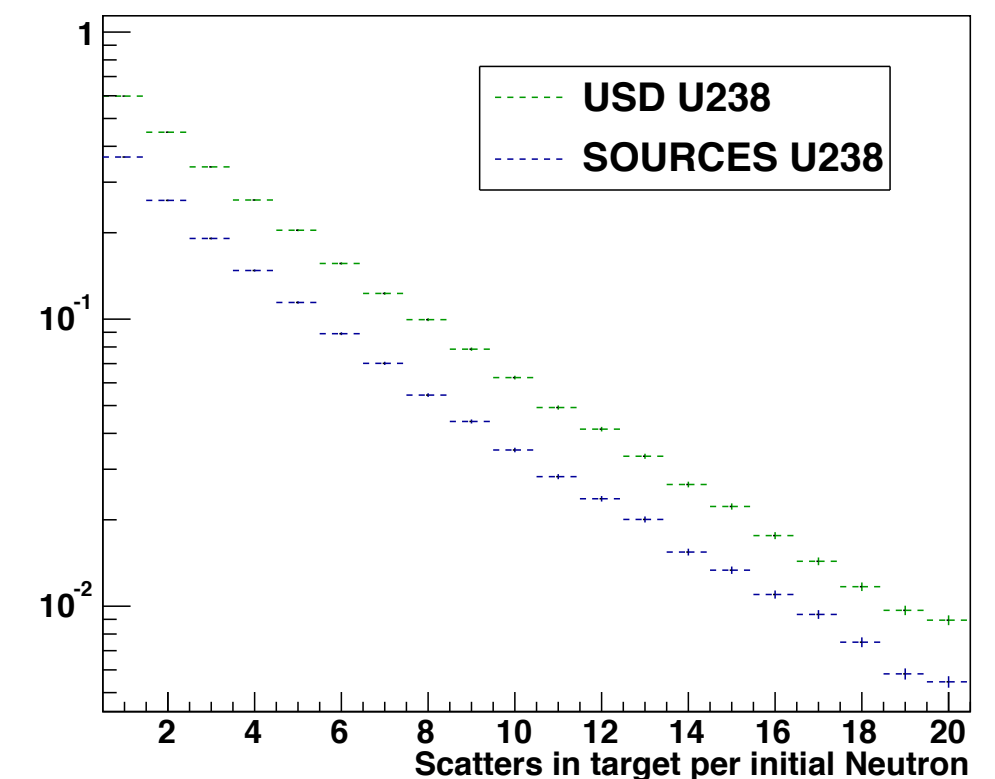
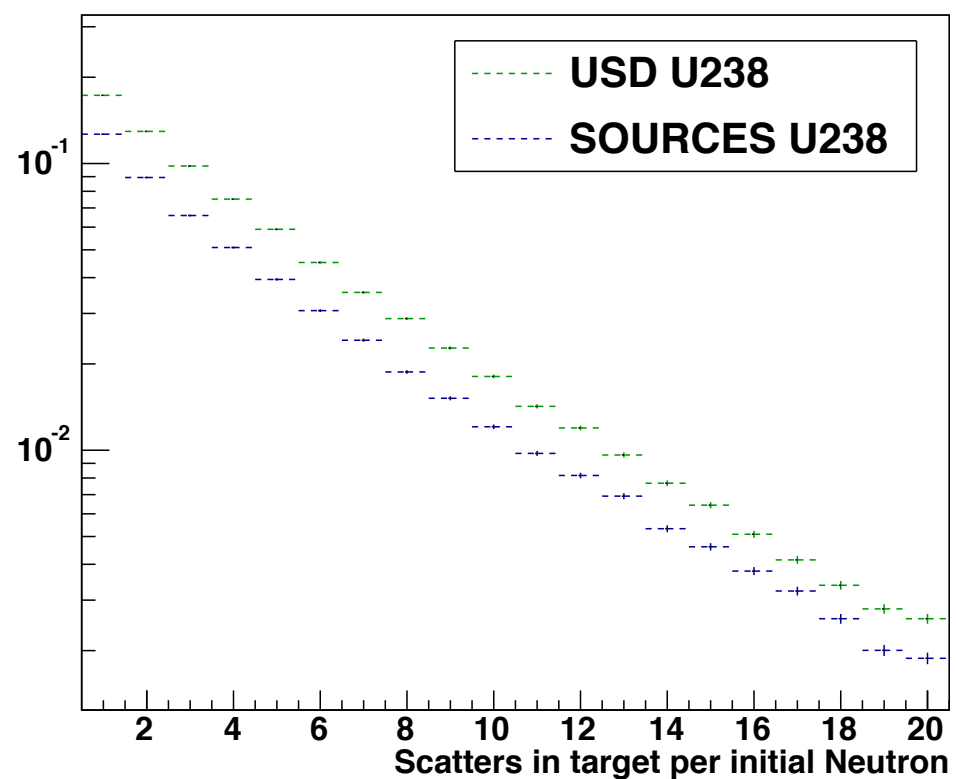
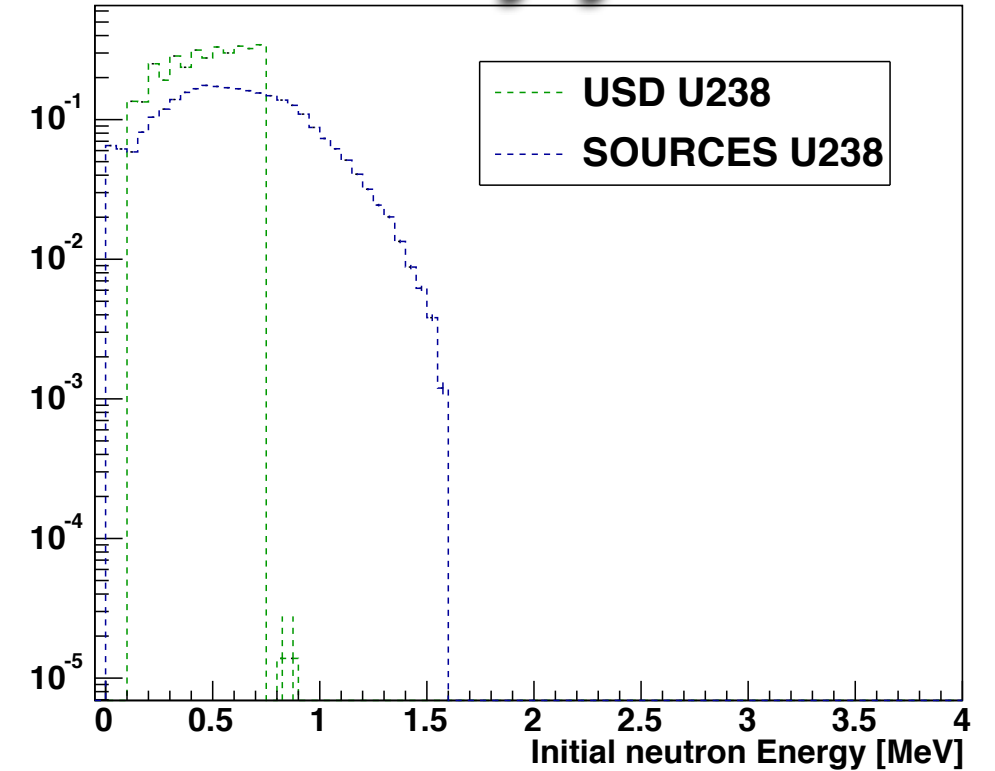
Start energy mean: 0.467108 Sigma: 0.176935
0: 0.814733 +/- 0.00335796 1: 0.598372+/-0.00287776 2: 0.447876+/-0.0024897 More: 1.59902+/-0
Individual recoils, all: 12.9674 +/- 0.0133966 over threshold keV: 5.12001 +/- 0.00841789
Total nuclear recoils all: 3.34961 +/- 0.00680872 over threshold keV: 0.491998 +/- 0.00260945
Total nuclear + EM recoils all: 3.1611 +/- 0.00661435 over threshold keV: 2.95221 +/- 0.00639207
Single recoils, all: 0.598372 +/- 0.00287776 over threshold keV: 0.353128 +/- 0.00221072 over upper keV: 0 +/- 0
All neutron radii, within 90 cm: 7.88953 +/- 0.0104495
Single neutron radii, within 90 cm: 0.344325 +/- 0.00218299
Single recoils no veto, all: 0.16327 +/- 0.00150322 over threshold keV: 0.0832338 +/- 0.00107329
Single recoils no EM, all: 0.526238 +/- 0.00269873 over threshold keV: 0.306971 +/- 0.00206118
Sources numbers:
Start energy mean: 0.611618 Sigma: 0.310856
0: 1.36321+/-0.00397658 1: 0.367082+/-0.00206353 2: 0.259225+/-0.00173407 More: 0.910484+/-0.00206118
Individual recoils, all: 7.51225 +/- 0.009335 over threshold keV: 2.17111 +/- 0.00501846
Total nuclear recoils all: 2.71283 +/- 0.00560971 over threshold keV: 0.240712 +/- 0.001671
Total nuclear and EM recoils all: 2.55452 +/- 0.00544356 over threshold keV: 2.44562 +/- 0.00532627
Single recoils, all: 0.367082 +/- 0.00206353 over threshold keV: 0.194532 +/- 0.00150219 over upper keV: 0.0073544 +/- 0.000292081
All neutron radii, within 90 cm: 4.55284 +/- 0.00726725
Single neutron radii, within 90 cm: 0.205413 +/- 0.00154363
Single recoils no veto, all: 0.124387 +/- 0.0012012 over 5 keV: 0.0455532 +/- 0.000726923
Single recoils no EM, all: 0.325809 +/- 0.00194406 over threshold keV: 0.168757 +/- 0.00139914

Germanium (Cu U238)

Just shape

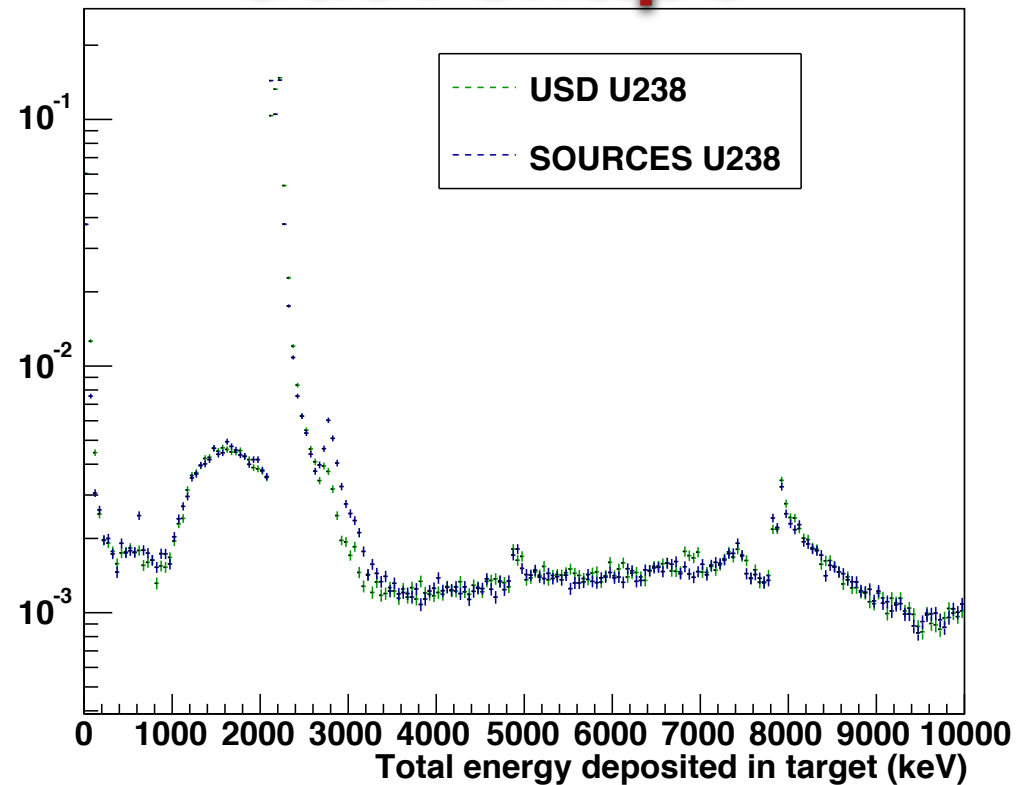


Scaled by yield

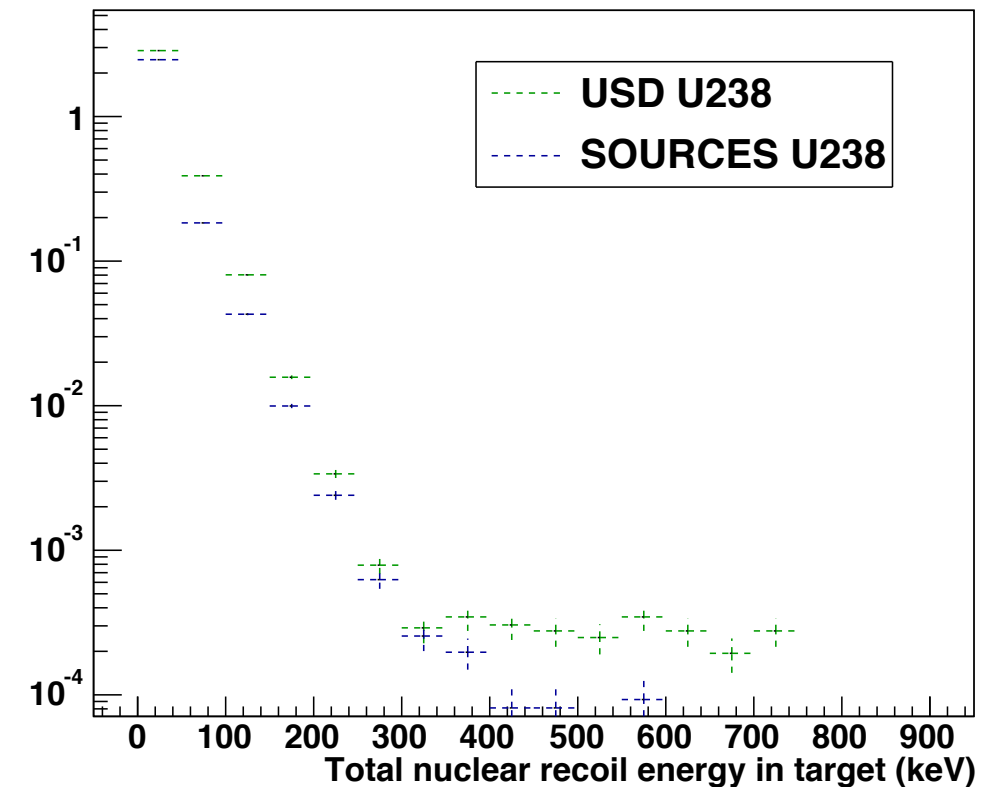
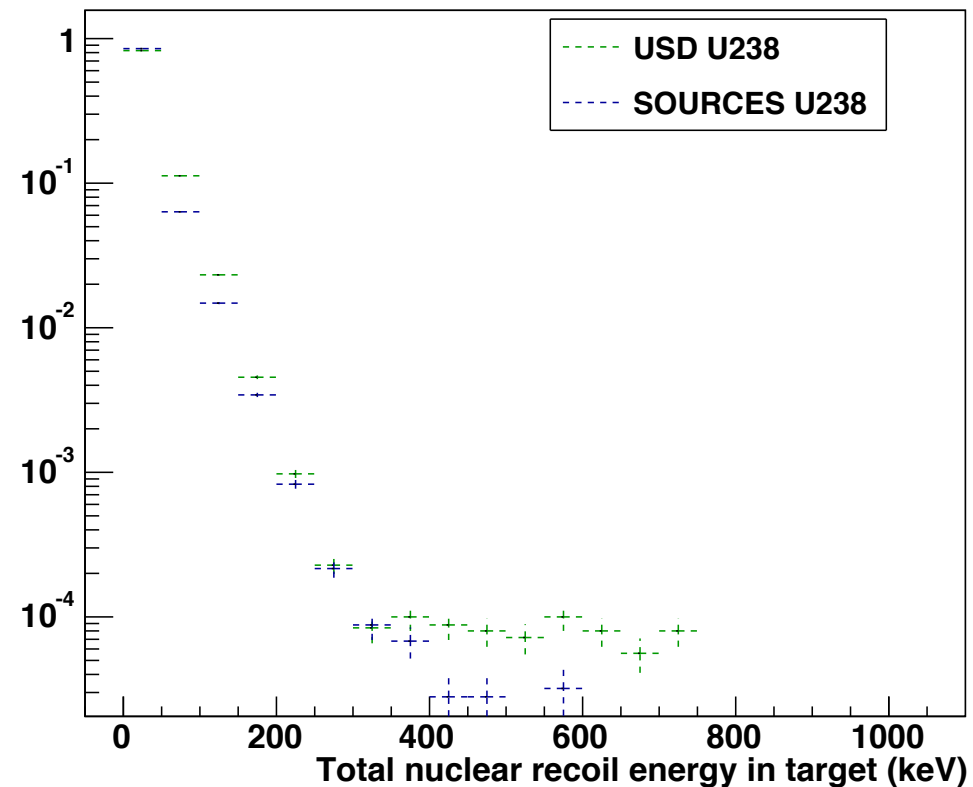
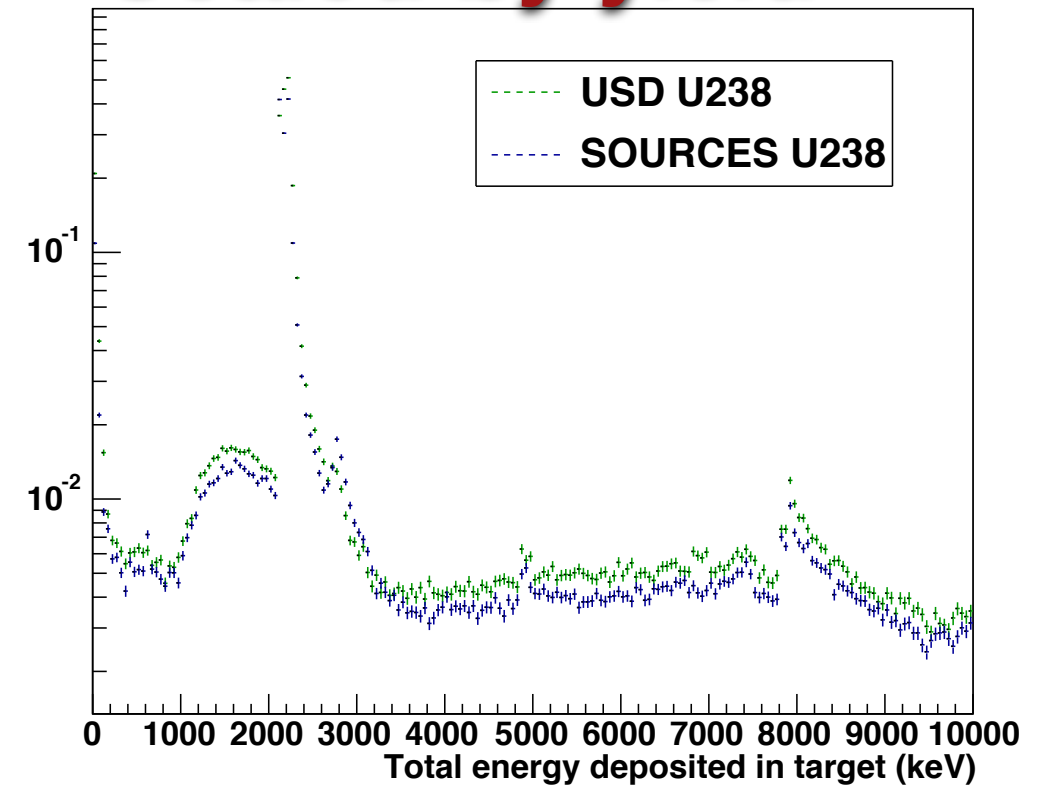


Germanium (Cu U238): Energy Deposited

Just shape

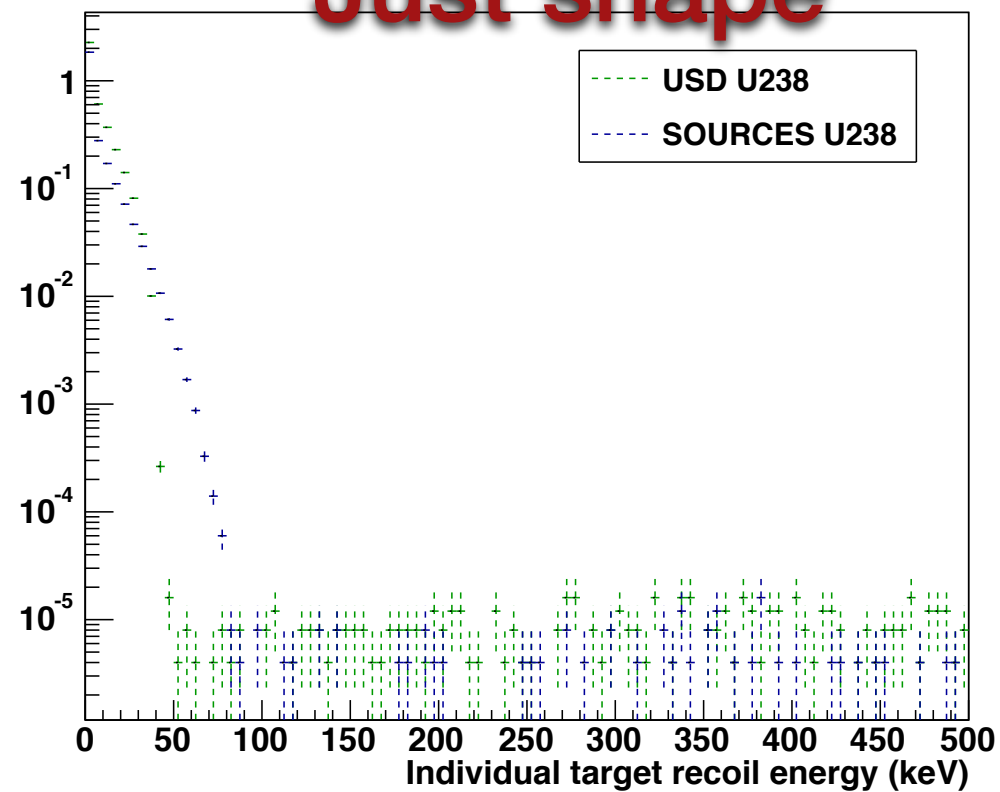


Scaled by yield

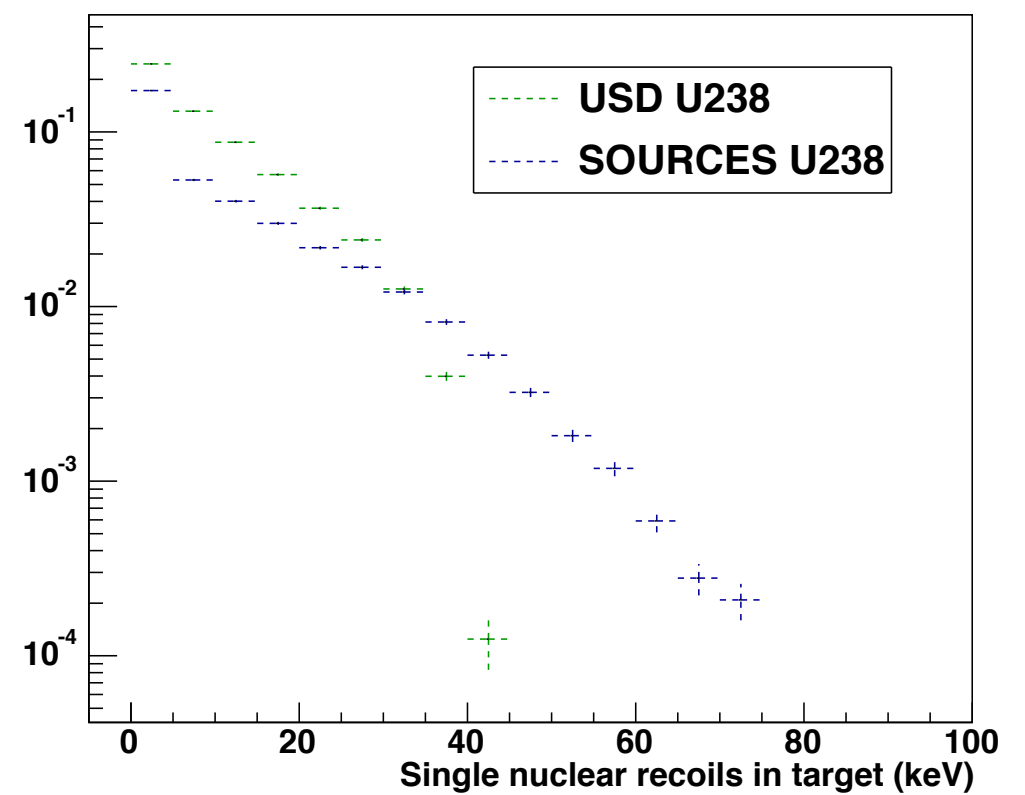
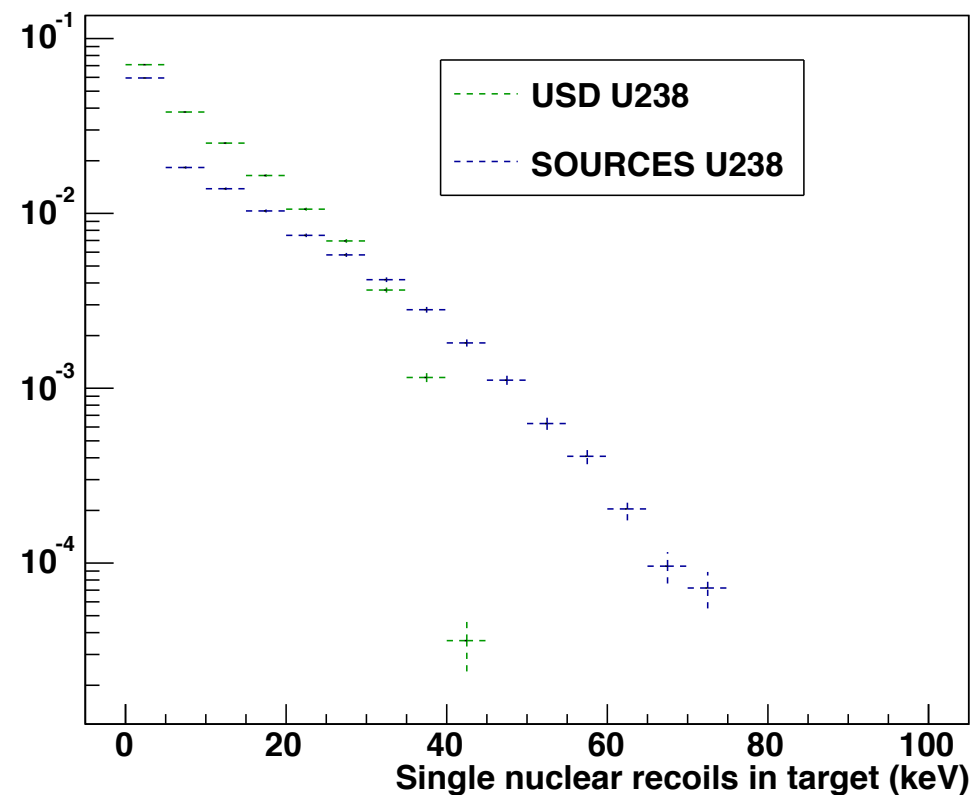
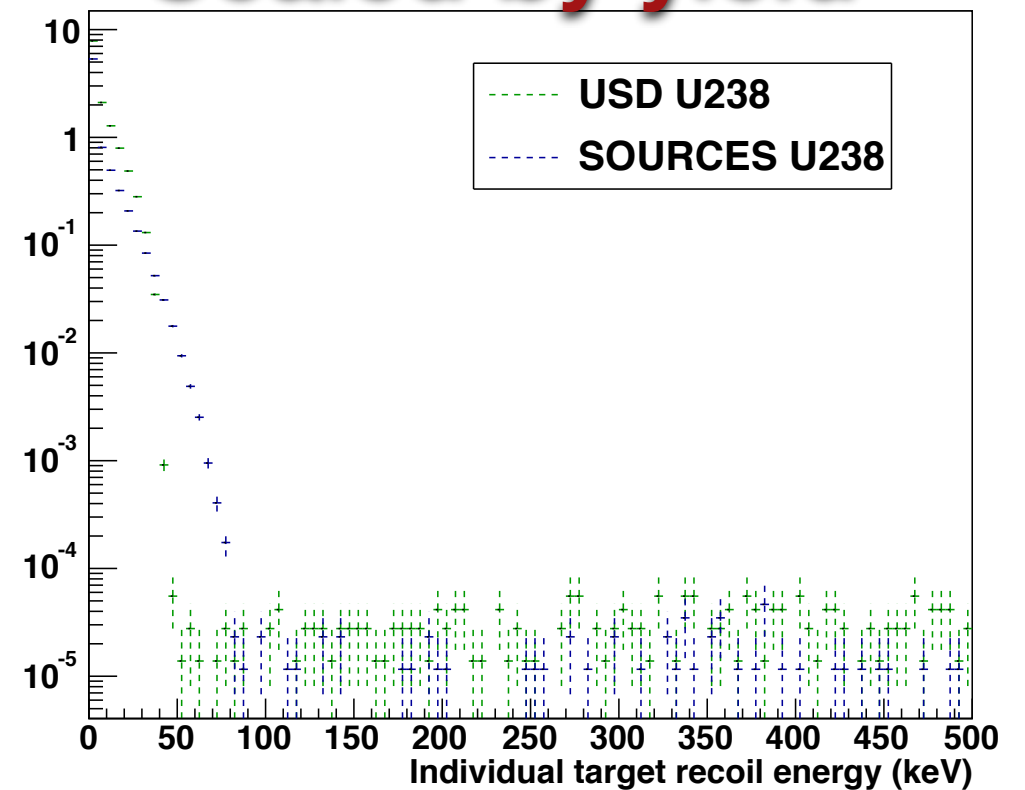


Germanium (Cu U238): Nuclear Recoils

Just shape

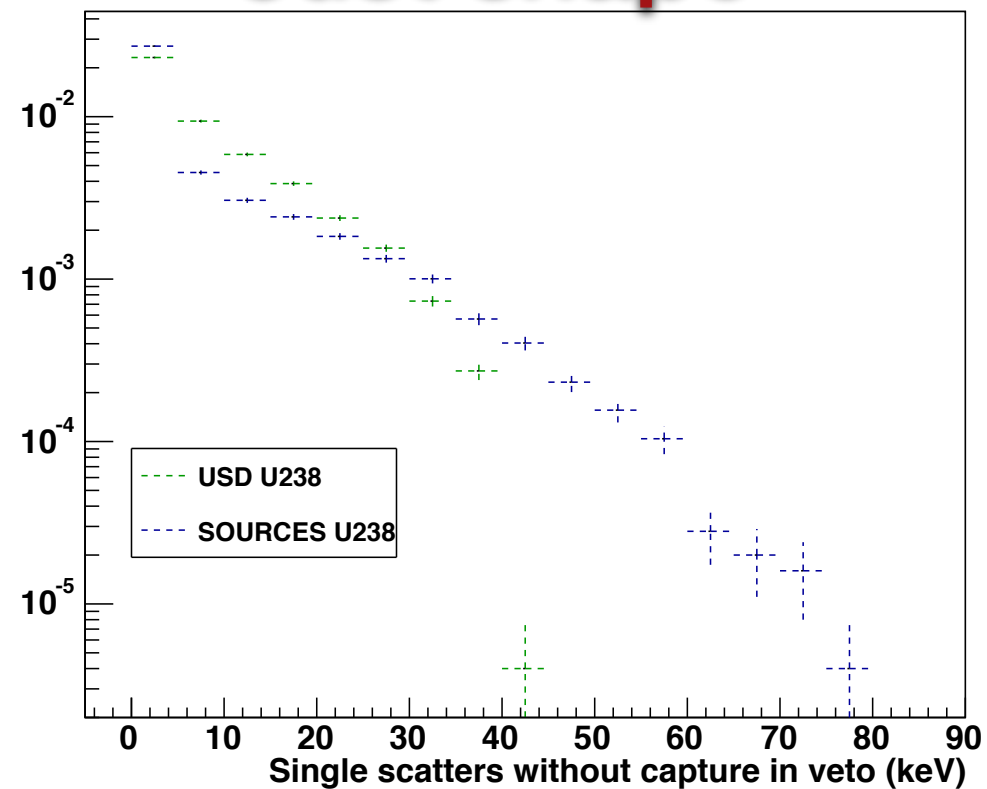


Scaled by yield

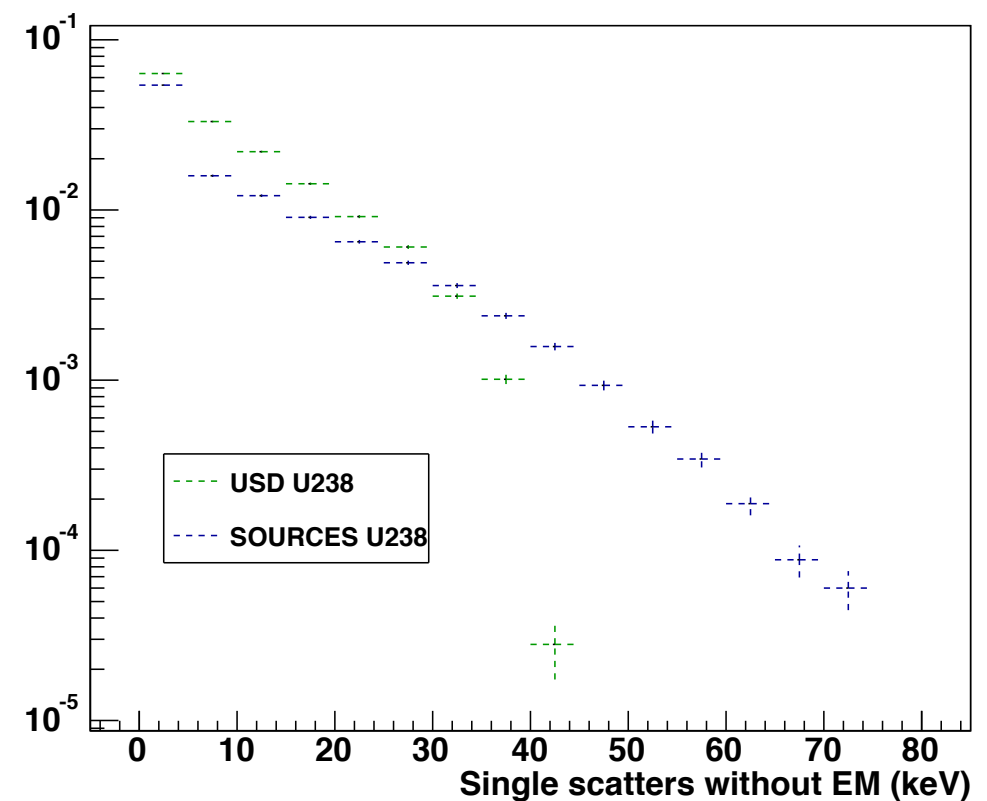
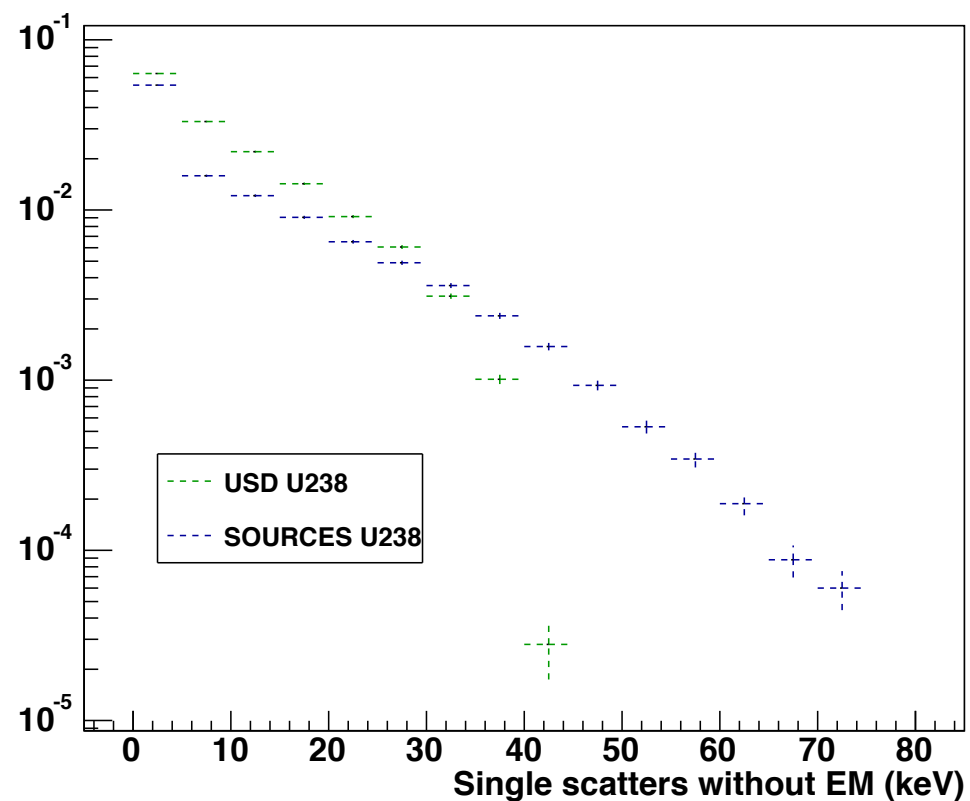
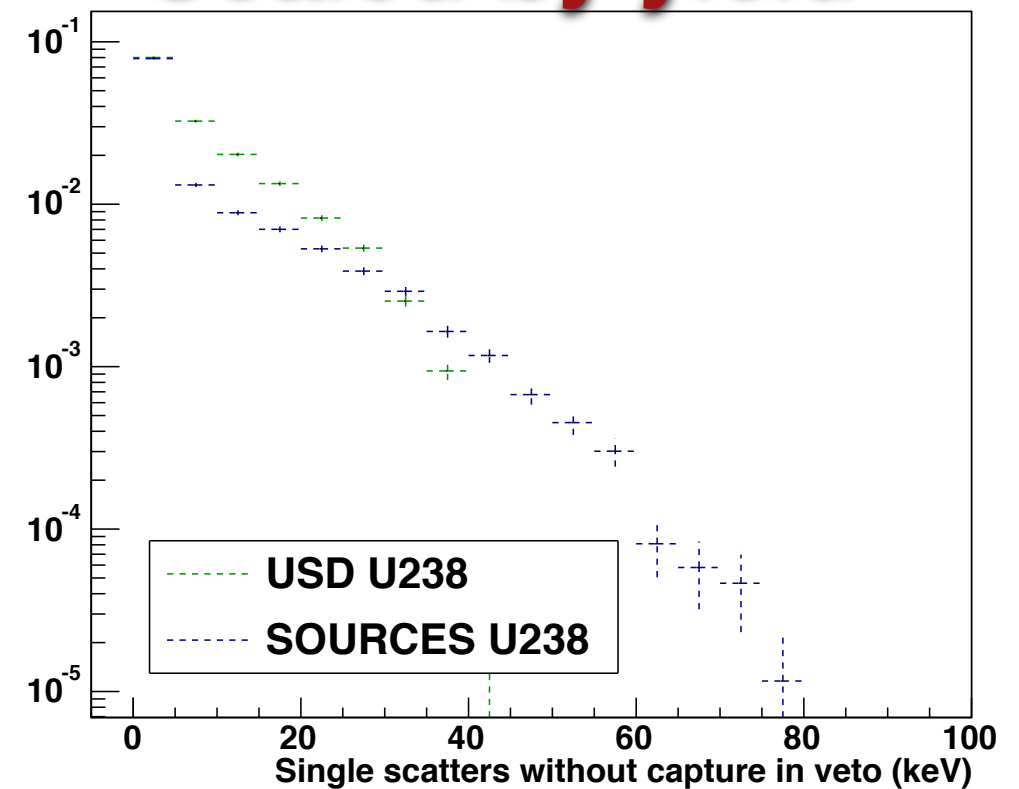


Germanium (Cu U238): Vetoed Recoils

Just shape

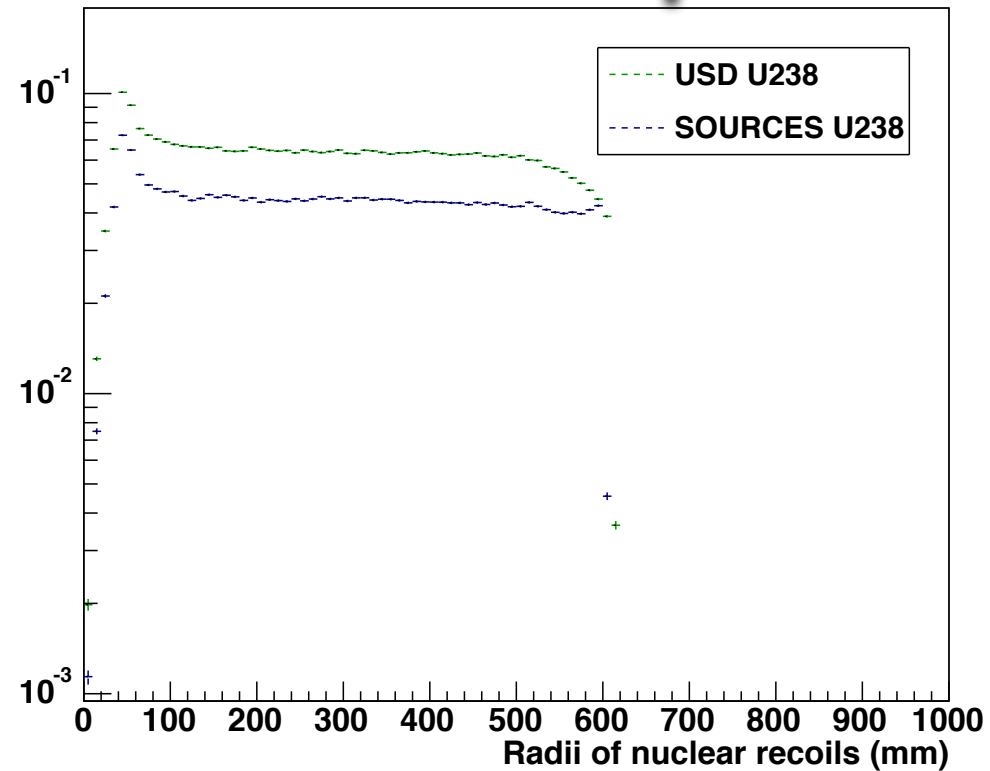


Scaled by yield

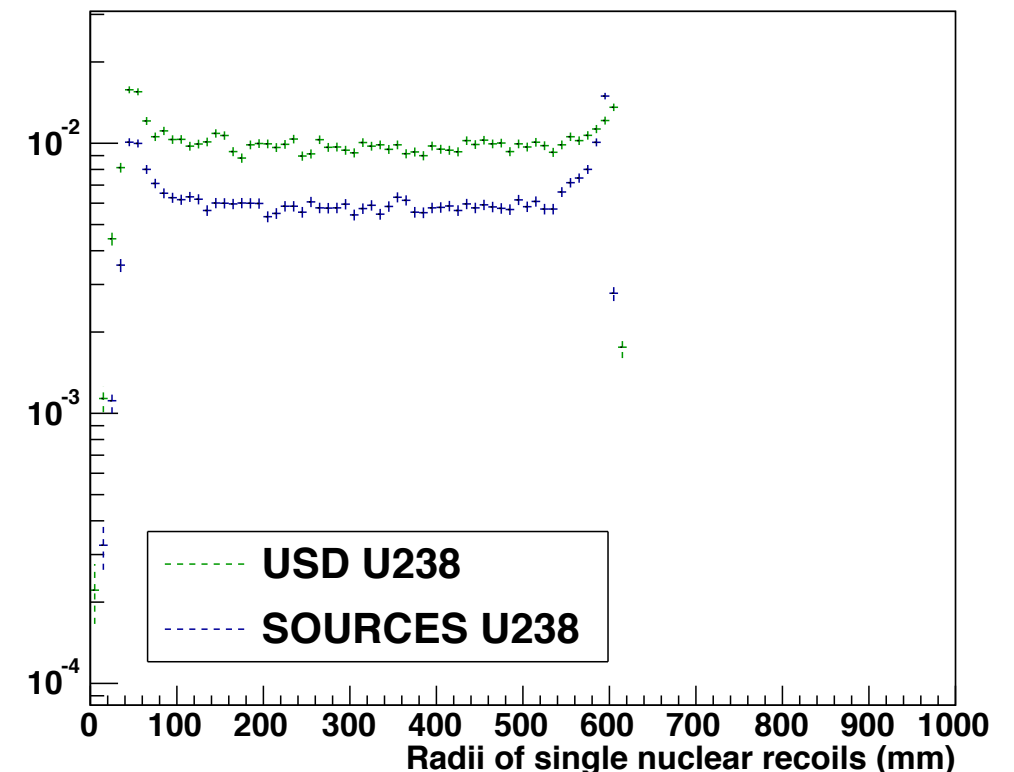
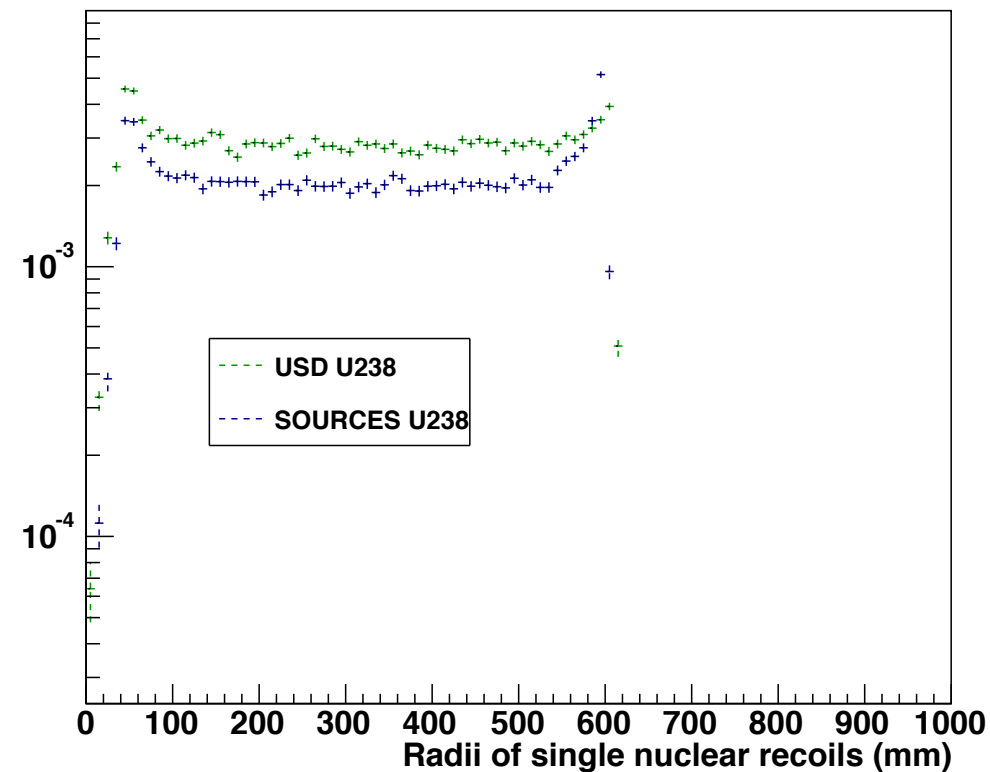
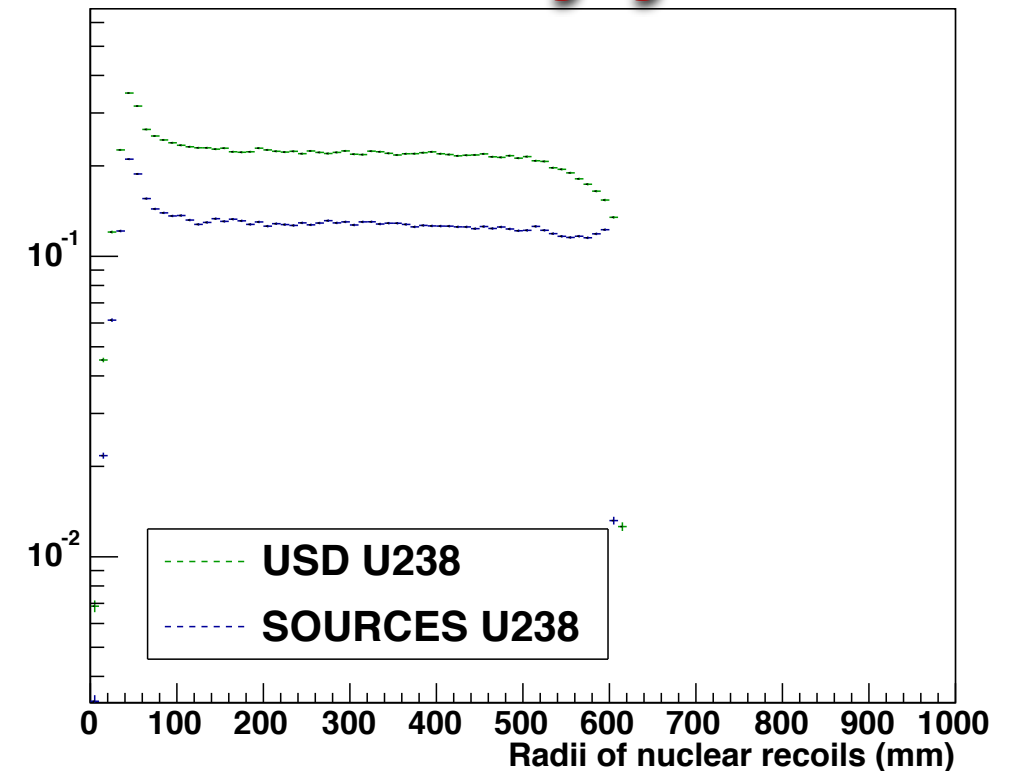


Germanium (Cu U238): Recoil Radii

Just shape



Scaled by yield



Ge Cu U238 Conclusions

- Vast difference in Spectra as USD cuts off at half the energy that Sources does
 - energy cutoffs for single/individual scatters
 - many more scatters in the USD case (somewhat counterintuitively), at all multiplicities
 - more events at higher summed nuclear recoil energy for USD
- Infinite error in # events from energy comparisons possible, 3% error in # events from radial distribution, and 8% error in multiplicity comparisons possible
- Veto importance: USD gives 53% more scatters unvetoed by captures shape, 52% without EM
- Shape is responsible for the USD spectrum to give 64% more single scatters than the Sources spectrum from 97% more individual scatters
- Adding a 19% difference in neutron yield leads to a total 80% difference in single scatters
- Germanium simulations only ones with noise of individual events out to higher energy after spectrum falls (see slide 62)
- USD > Sources by shape; USD > Sources by yield

Overall conclusions

- No systematic patterns seen to comparisons in scatter spectra shape or numbers of scatters
 - Sometimes there is good agreement in spectra shape, other times they differ by shape, and either USD or Sources could predict higher initial neutron yields
- Systematic error cannot be universally added to simulations of events easily
 - factors of 20%-50% most common, but factor of 500% also seen
 - once fitting spectral shapes ~10% errors are most likely except in odd cases such as that of copper
- Spectral shapes have not been so different as to make number of multiple scatters or veto captures differentiate between the models