The Beginnings of a Proper Statistical Analysis to Ensure a High-Quality Fitter

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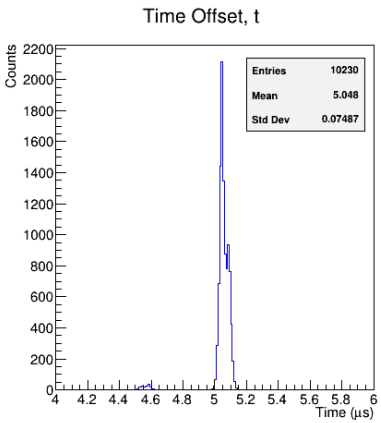
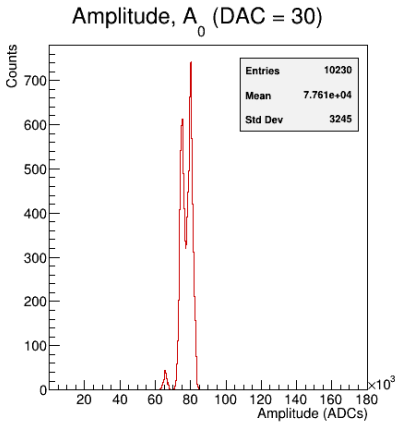
09/30/2024

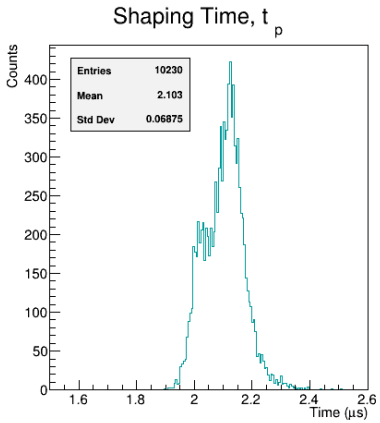
Dataset

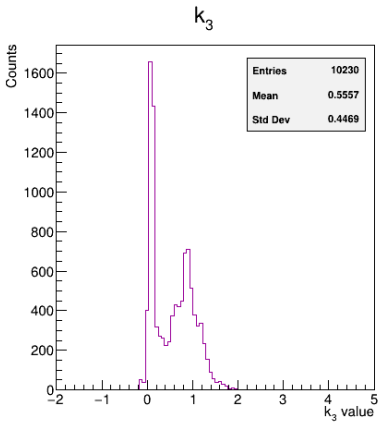
- NP04 TPC Electronics Studies Runs.
- Pulser Calibration **Run 28286** from last 07/29 and 07/30.
- **DAC = 30**.
- **7.8 mV/fC** LArASIC gain.
- 2 μs CE Shaping Time.
- LArASIC Output Mode: Single-ended.

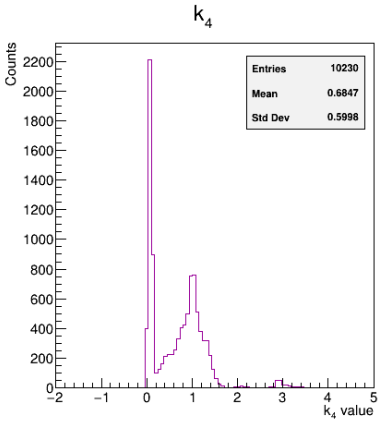
Current Status of the Fit Parameters

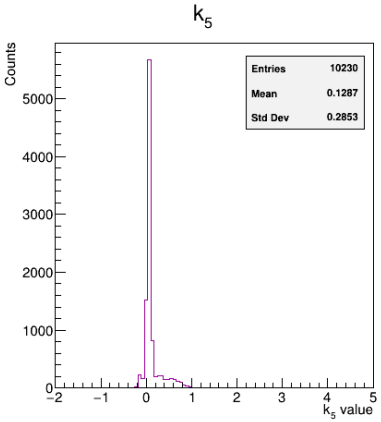


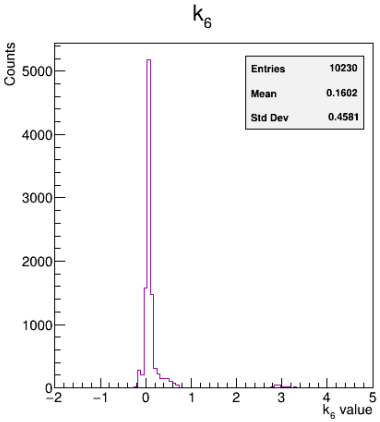


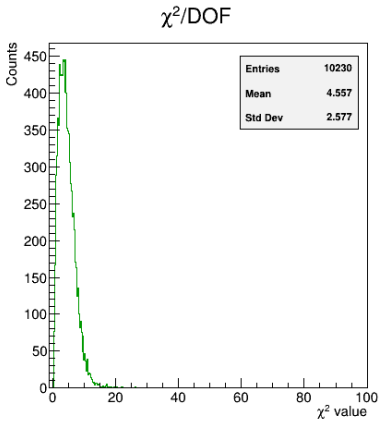












A change of Direction

Fit Status

- 0: Successful Fit -> 9,256 channels.
- 1: WARNING -> 946 channels.
- 2: WARNING -> 0 channels
- 3: FAILURE -> 28 channels
- 4: FAILURE -> 0 channels
- 5: FAILURE -> 0 channels

Fitter found a set of parameters that minimizes Chi2.

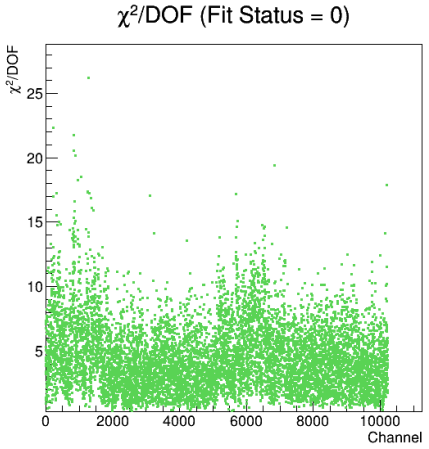
Covariance matrix was made positive definite.

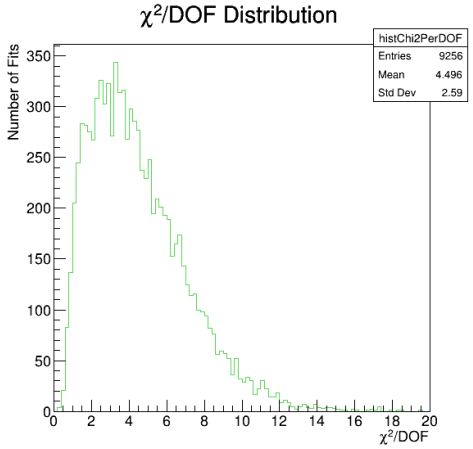
Hesse matrix could not be computed properly.

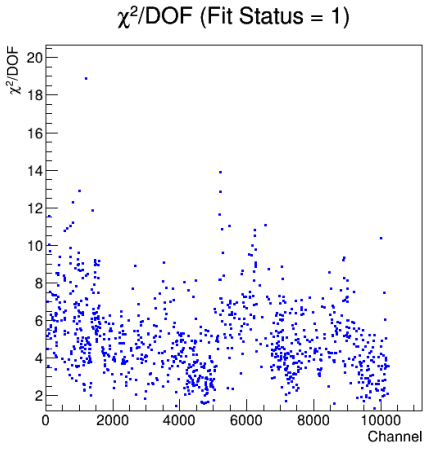
Estimated Distance to Minimum is above the max value, so algorithm did not converge.

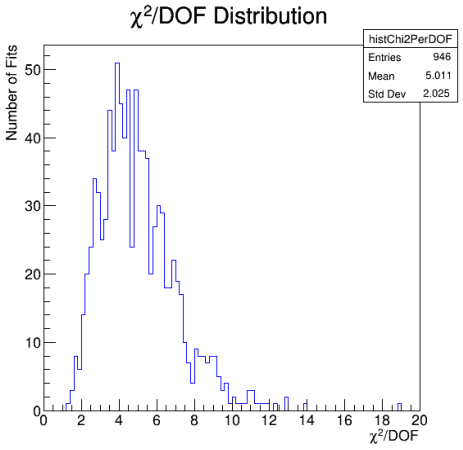
Fitter hit the limit on the number of function evaluations, it stopped before convergence.

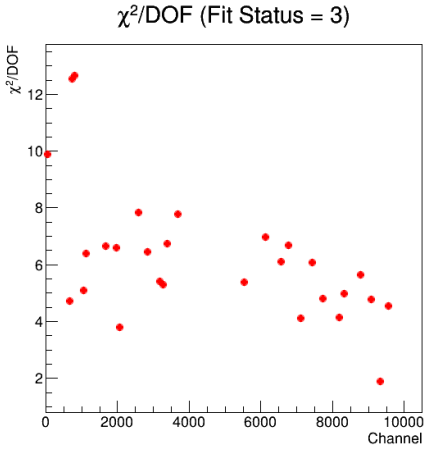
Fit process completely failed

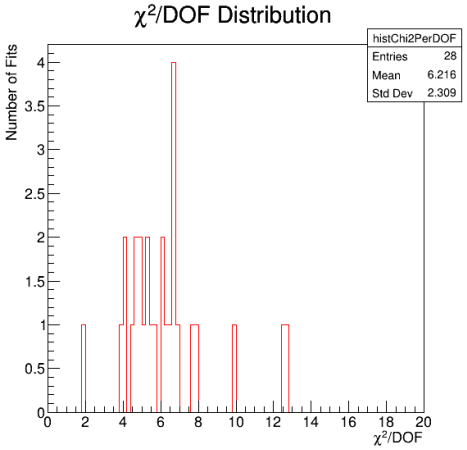












χ^2/DOF as a metric for good quality fits

- We want a high-quality fitter.

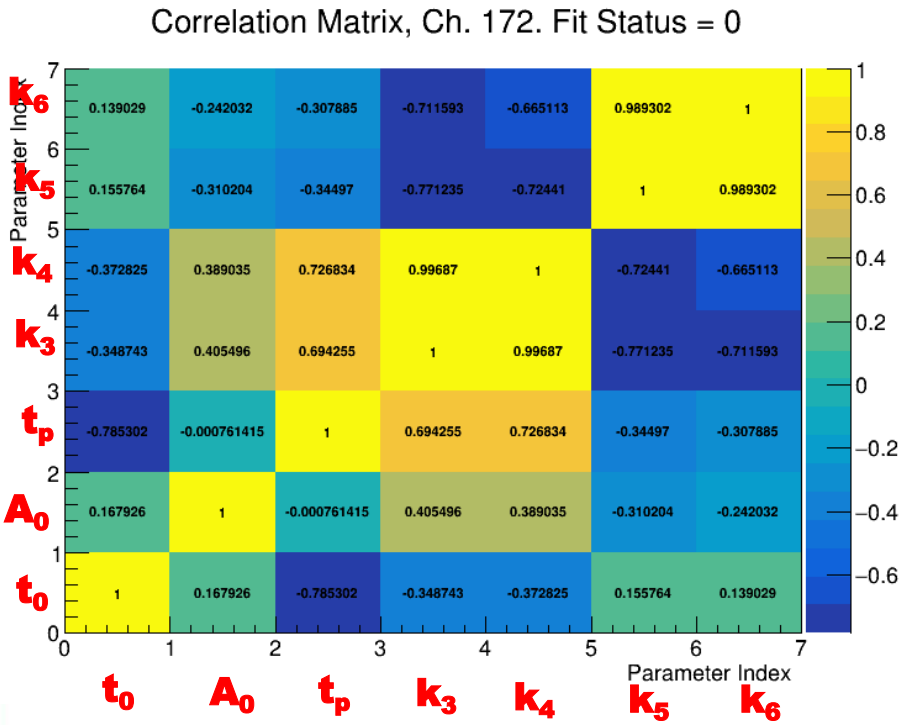
  $\chi^2/DOF \simeq 1$

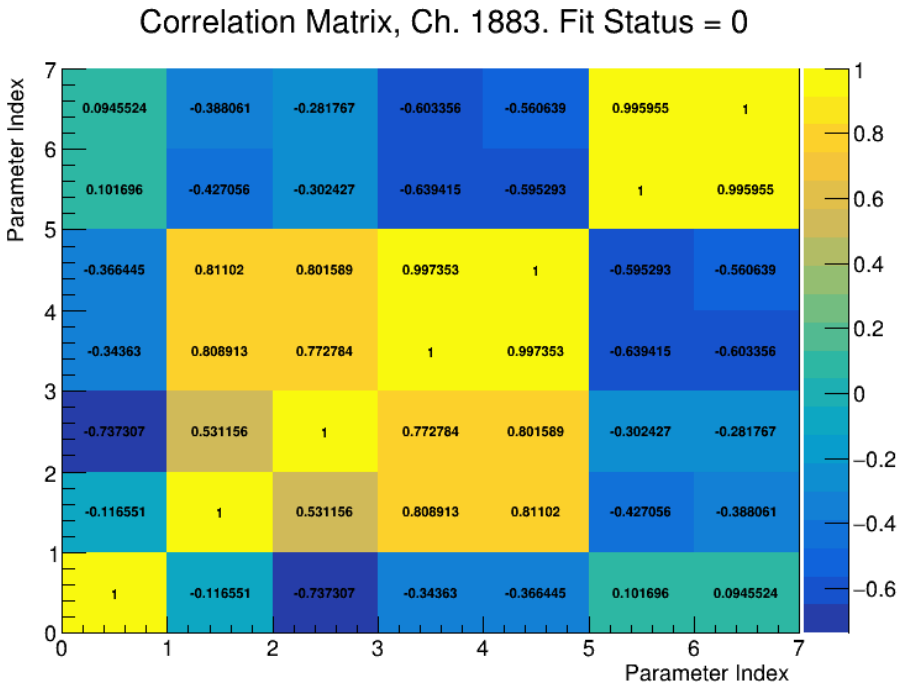
- Even for *successful* fits (Status = 0), χ^2/DOF can be bad.

- Why bad fits?
  1. Correlated Parameters.
  2. Local Minima.
  3. *Wrong Parameter Limits (the use of `SetParLimits()`)*

DEEP UNDERGROUND NEUTRINO EXPERIMENT

Correlation Matrices for Good Fits (χ^2/DOF ≃1)

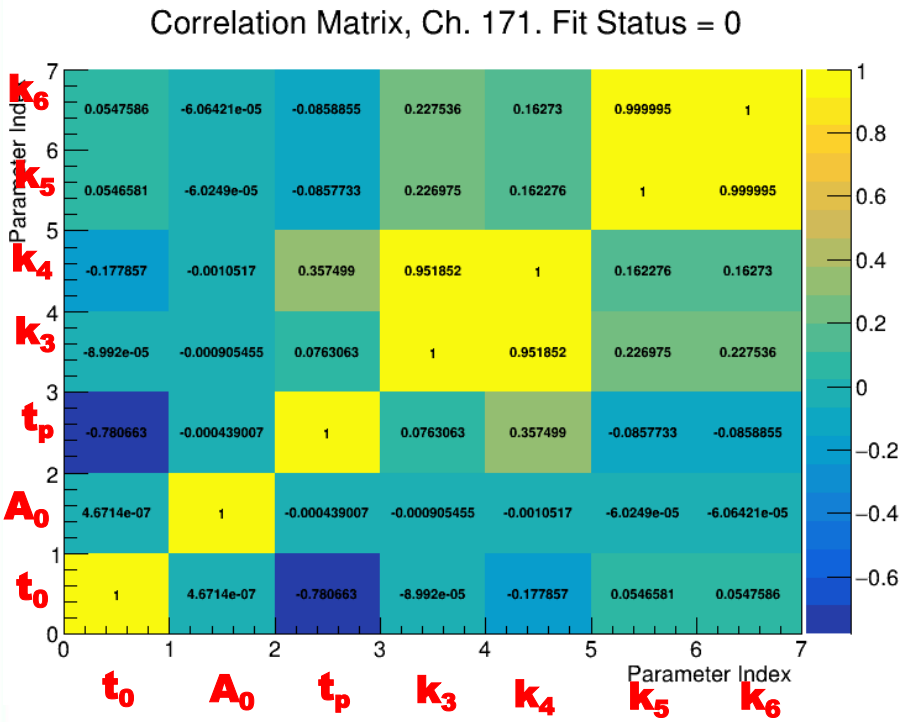


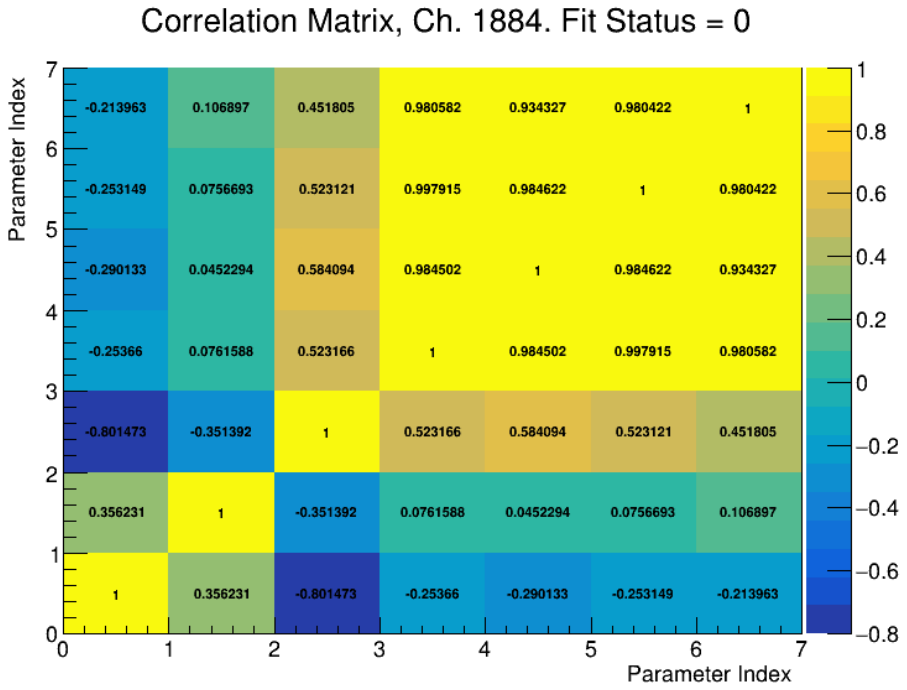


χ^2/DOF = 1.009

χ^2/DOF = 1.002

Correlation Matrices for Bad Fits (χ^2/DOF >> 1)





χ^2/DOF = 9.784

χ^2/DOF = 5.308

What's next?

- Keep working on finding correlations and how to fix any issues due to these.
- Try the fitter with new parameters whose values are solely based on observations from the statistical analysis.
- Characterize Waveforms: Different types of waveforms require different types of starting parameters for the fit to work.
- Build a robust dataset that can later be used to identify patterns and/or possible issues with our electronics.
- We need the waveform correction, independently of whether the fitter is good-quality or not. We can always make changes to the fitter in the repository!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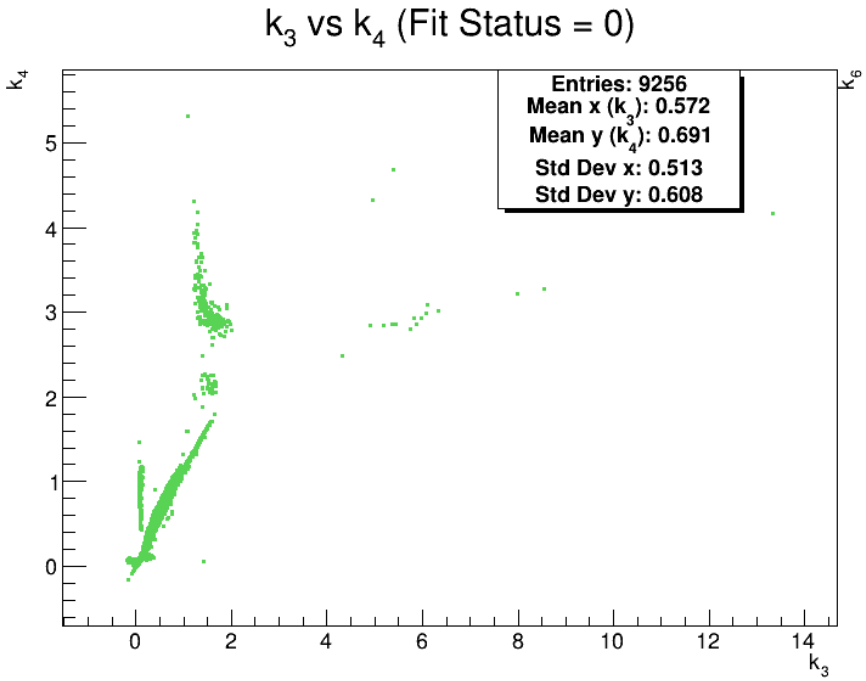
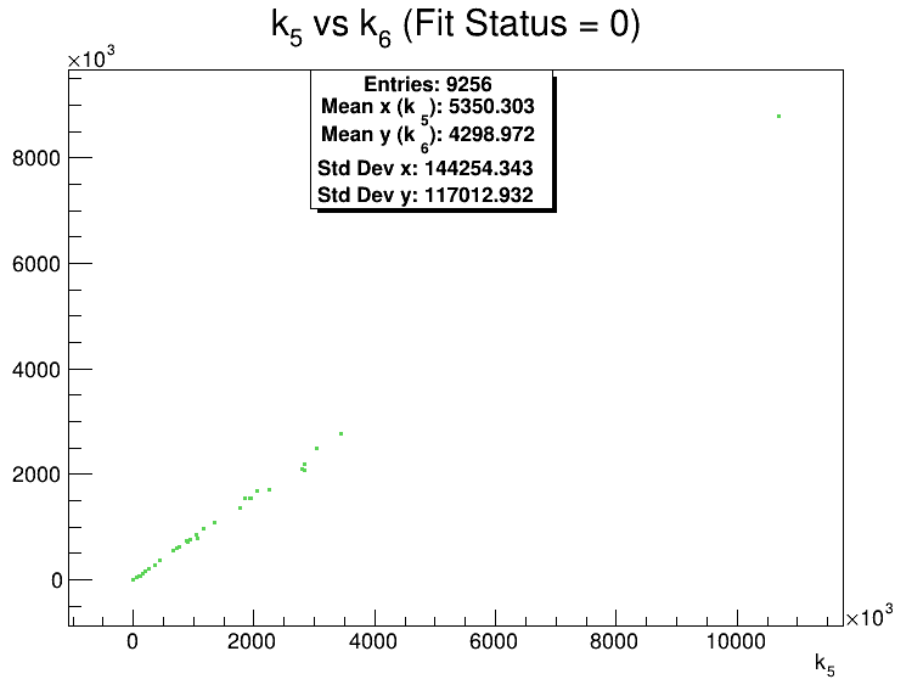
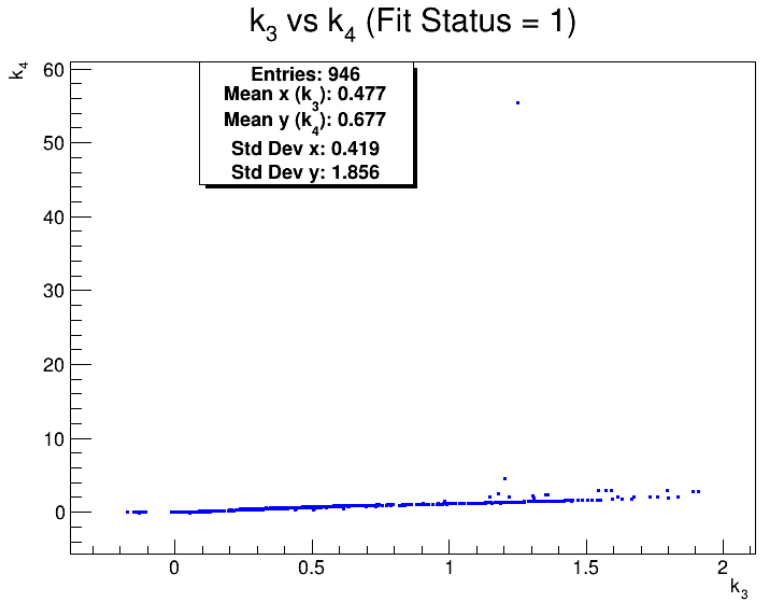
How correlated are the k parameters?

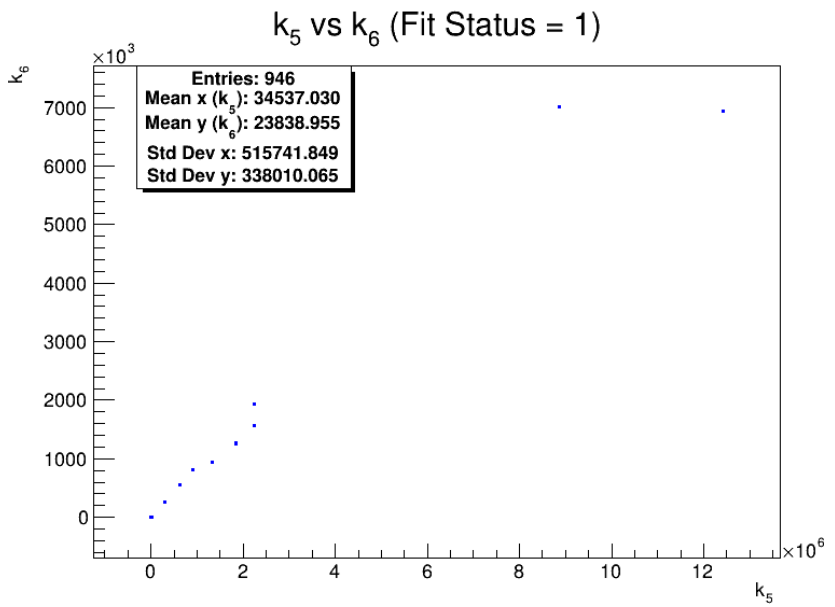


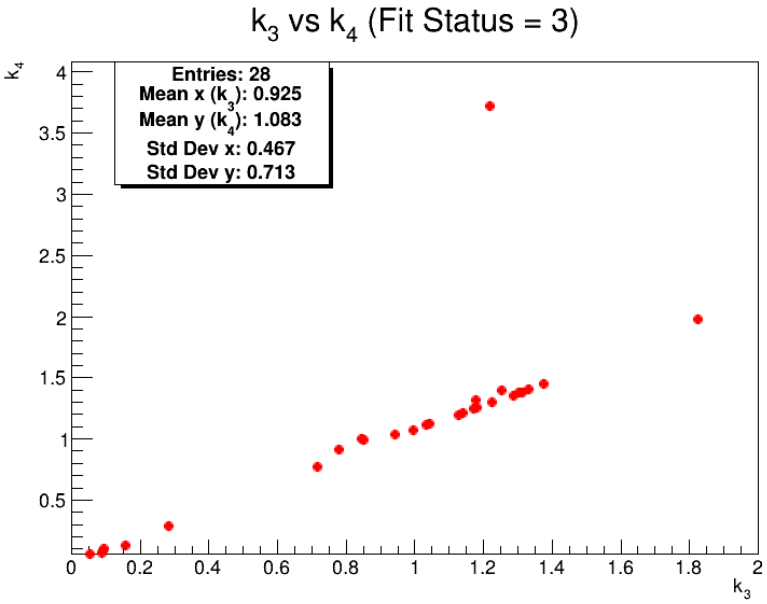


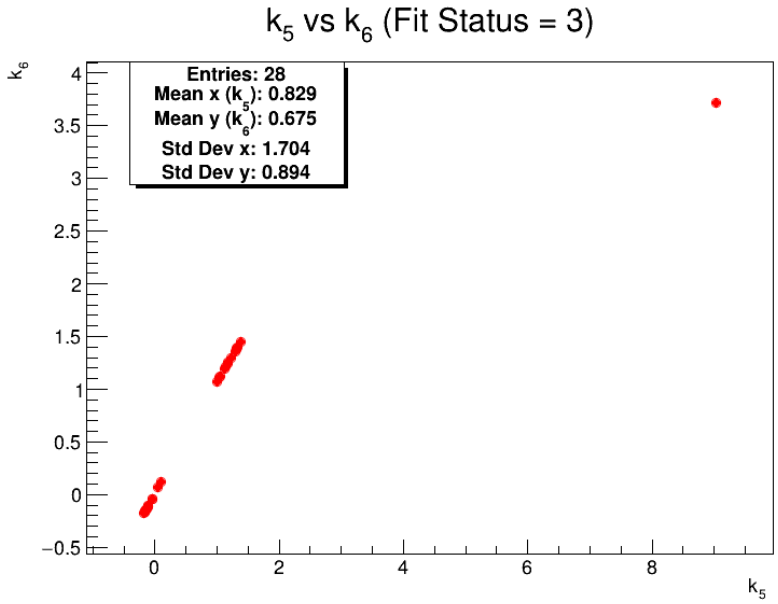
... very correlated.

How correlated are the k parameters?

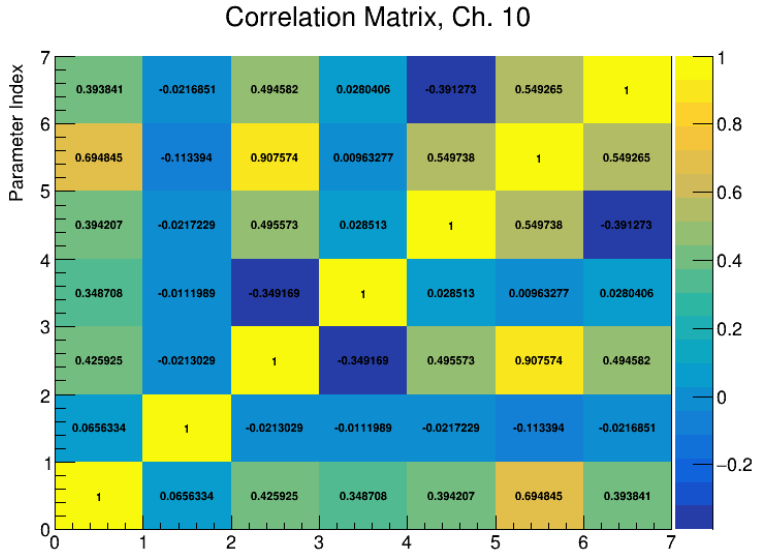


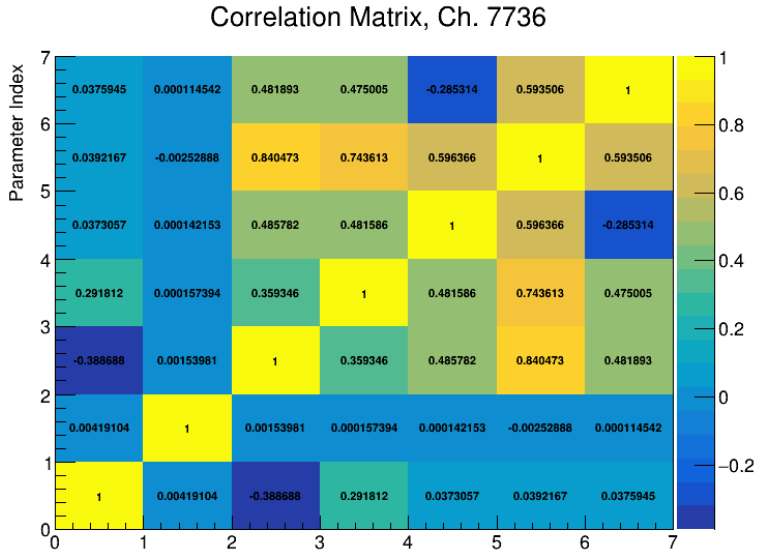


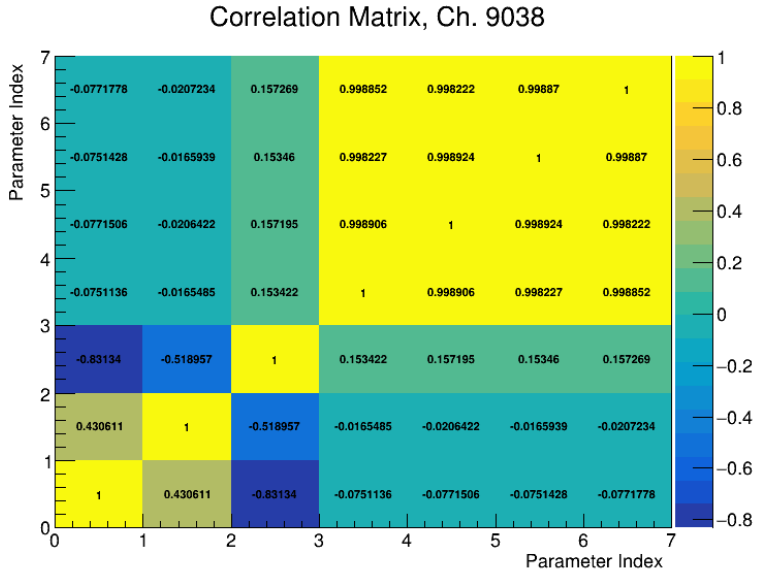


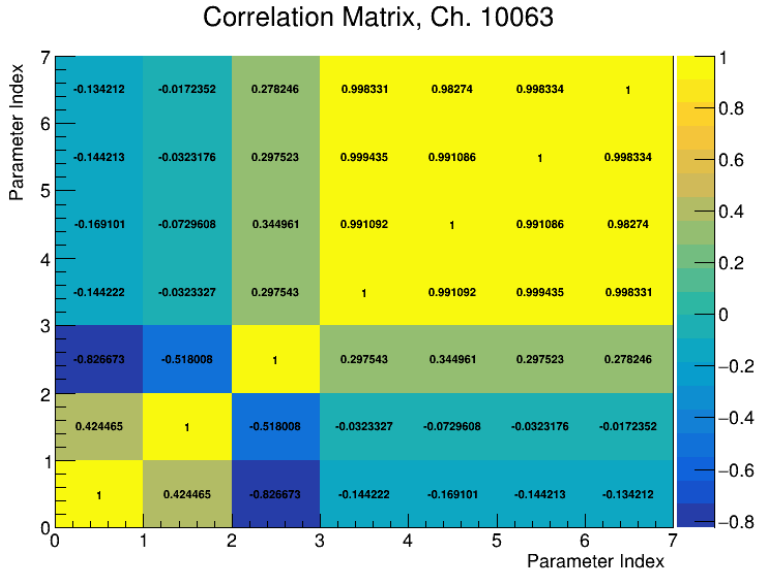


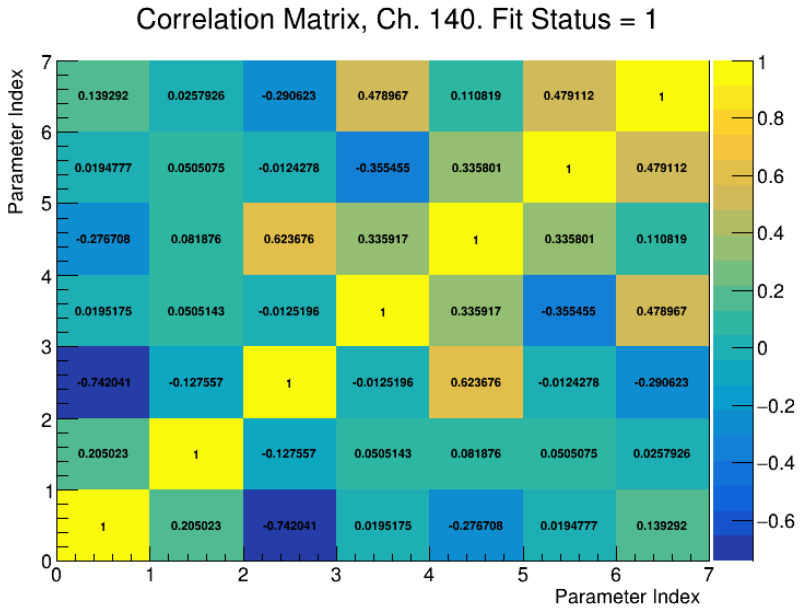
(Fit Status = 0)

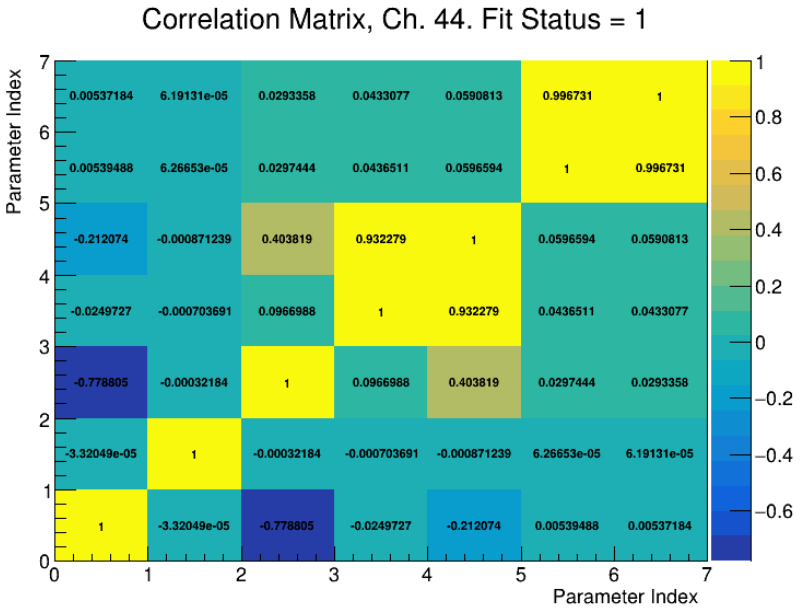

Correlation Matrix, Ch. 10
Parameter Index
0.393841 -0.0216851 0.494582 0.0280406 -0.391273 0.549265 1
0.694845 -0.113394 0.907574 0.00963277 0.549738 1 0.549265
0.394207 -0.0217229 0.495573 0.028513 1 0.549738 -0.391273
0.348708 -0.0111989 -0.349169 1 0.028513 0.00963277 0.0280406
0.425925 -0.0213029 1 -0.349169 0.495573 0.907574 0.494582
0.0656334 1 -0.0213029 -0.0111989 -0.0217229 -0.113394 -0.0216851
1 0.0656334 0.425925 0.348708 0.394207 0.694845 0.393841

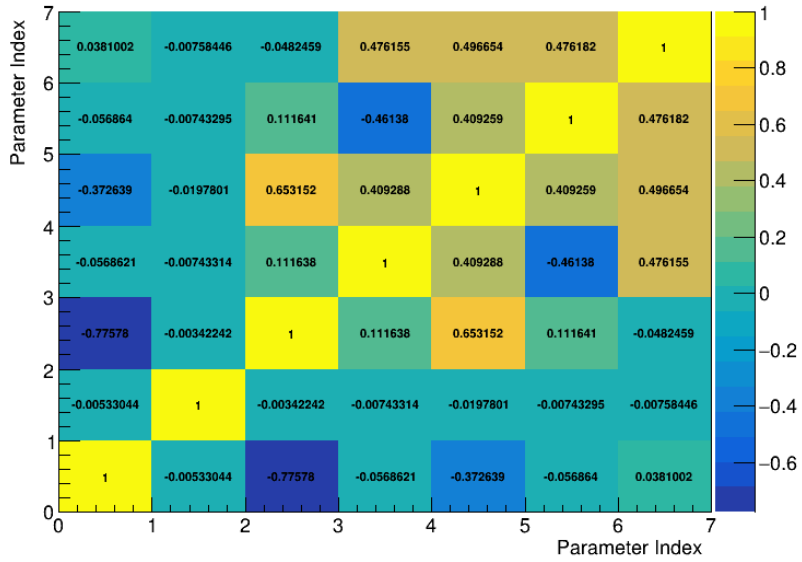

Correlation Matrix, Ch. 7736
Parameter Index
0.0375945 0.000114542 0.481893 0.475005 -0.285314 0.593506 1
0.0392167 -0.00252888 0.840473 0.743613 0.596366 1 0.593506
0.0373057 0.000142153 0.485782 0.481586 1 0.596366 -0.285314
0.291812 0.000157394 0.359346 1 0.481586 0.743613 0.475005
-0.388688 0.00153981 1 0.359346 0.485782 0.840473 0.481893
0.00419104 1 0.00153981 0.000157394 0.000142153 -0.00252888 0.000114542
1 0.00419104 -0.388688 0.291812 0.0373057 0.0392167 0.0375945

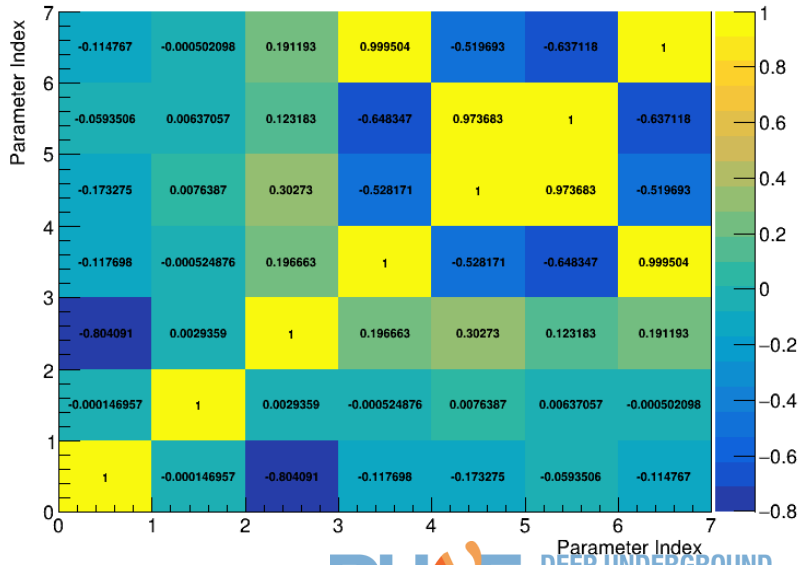

Correlation Matrix, Ch. 9038
Parameter Index
-0.0771778 -0.0207234 0.157269 0.998852 0.998222 0.99887 1
-0.0751428 -0.0165939 0.15346 0.998227 0.998924 1 0.99887
-0.0771506 -0.0206422 0.157195 0.998906 1 0.998924 0.998222
-0.0751136 -0.0165485 0.153422 1 0.998906 0.998227 0.998852
-0.83134 -0.518957 1 0.153422 0.157195 0.15346 0.157269
0.430611 1 -0.518957 -0.0165485 -0.0206422 -0.0165939 -0.0207234
1 0.430611 -0.83134 -0.0751136 -0.0771506 -0.0751428 -0.0771778
Parameter Index

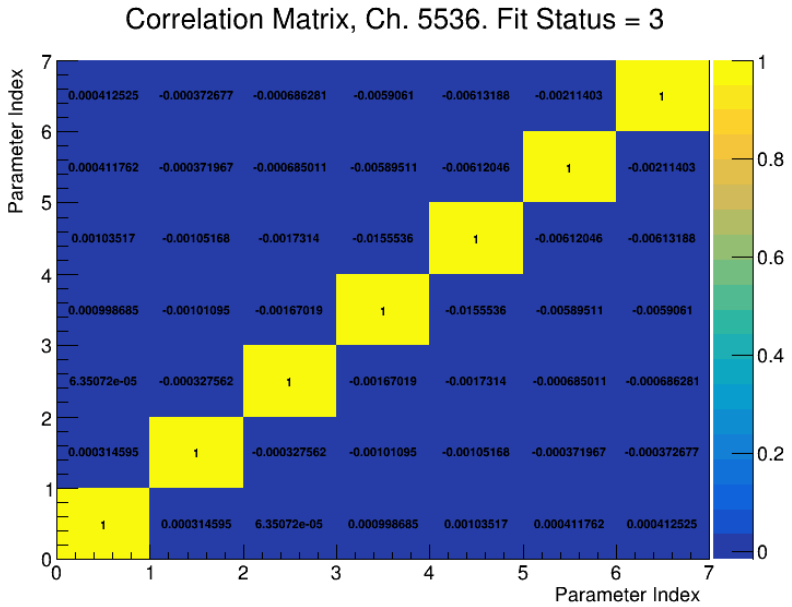

Correlation Matrix, Ch. 10063
Parameter Index
-0.134212 -0.0172352 0.278246 0.998331 0.98274 0.998334 1
-0.144213 -0.0323176 0.297523 0.999435 0.991086 1 0.998334
-0.169101 -0.0729608 0.344961 0.991092 1 0.991086 0.98274
-0.144222 -0.0323327 0.297543 1 0.991092 0.999435 0.998331
-0.826673 -0.518008 1 0.297543 0.344961 0.297523 0.278246
0.424465 1 -0.518008 -0.0323327 -0.0729608 -0.0323176 -0.0172352
1 0.424465 -0.826673 -0.144222 -0.169101 -0.144213 -0.134212
Parameter Index

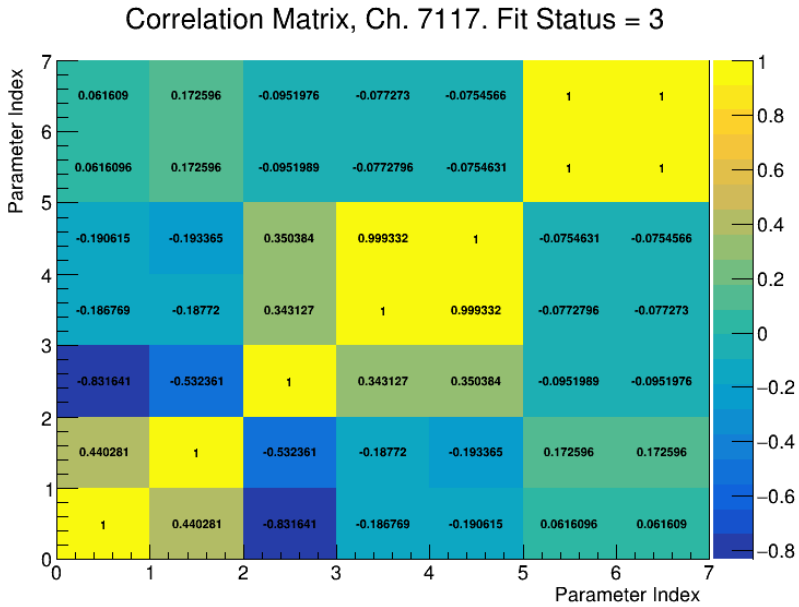

Correlation Matrix, Ch. 140. Fit Status = 1
Parameter Index
Parameter Index
0.139292 0.0257926 -0.290623 0.478967 0.110819 0.479112 1
0.0194777 0.0505075 -0.0124278 -0.355455 0.335801 1 0.479112
-0.276708 0.081876 0.623676 0.335917 1 0.335801 0.110819
0.0195175 0.0505143 -0.0125196 1 0.335917 -0.355455 0.478967
-0.742041 -0.127557 1 -0.0125196 0.623676 -0.0124278 -0.290623
0.205023 1 -0.127557 0.0505143 0.081876 0.0505075 0.0257926
1 0.205023 -0.742041 0.0195175 -0.276708 0.0194777 0.139292

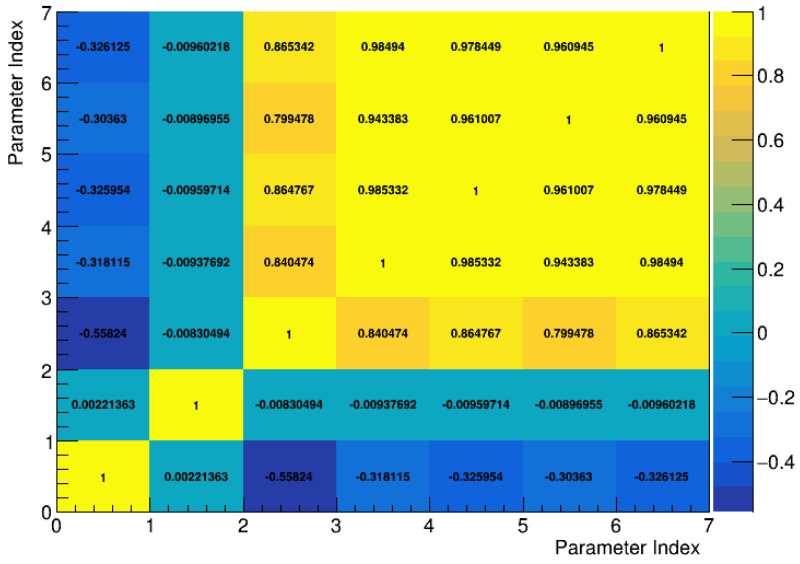

Correlation Matrix, Ch. 44. Fit Status = 1
Parameter Index
Parameter Index
0.00537184 6.19131e-05 0.0293358 0.0433077 0.0590813 0.996731 1
0.00539488 6.26653e-05 0.0297444 0.0436511 0.0596594 1 0.996731
-0.212074 -0.000871239 0.403819 0.932279 1 0.0596594 0.0590813
-0.0249727 -0.000703691 0.0966988 1 0.932279 0.0436511 0.0433077
-0.778805 -0.00032184 1 0.0966988 0.403819 0.0297444 0.0293358
-3.32049e-05 1 -0.00032184 -0.000703691 -0.000871239 6.26653e-05 6.19131e-05
1 -3.32049e-05 -0.778805 -0.0249727 -0.212074 0.00539488 0.00537184


Correlation Matrix, Ch. 243. Fit Status = 1
Parameter Index
Parameter Index
0.0381002 -0.00758446 -0.0482459 0.476155 0.496654 0.476182 1
-0.056864 -0.00743295 0.111641 -0.46138 0.409259 1 0.476182
-0.372639 -0.0197801 0.653152 0.409288 1 0.409259 0.496654
-0.0568621 -0.00743314 0.111638 1 0.409288 -0.46138 0.476155
-0.77578 -0.00342242 1 0.111638 0.653152 0.111641 -0.0482459
-0.00533044 1 -0.00342242 -0.00743314 -0.0197801 -0.00743295 -0.00758446
1 -0.00533044 -0.77578 -0.0568621 -0.372639 -0.056864 0.0381002


Correlation Matrix, Ch. 9955. Fit Status = 0
Parameter Index
Parameter Index
-0.114767 -0.000502098 0.191193 0.999504 -0.519693 -0.637118 1
-0.0593506 0.00637057 0.123183 -0.648347 0.973683 1 -0.637118
-0.173275 0.0076387 0.30273 -0.528171 1 0.973683 -0.519693
-0.117698 -0.000524876 0.196663 1 -0.528171 -0.648347 0.999504
-0.804091 0.0029359 1 0.196663 0.30273 0.123183 0.191193
-0.000146957 1 0.0029359 -0.000524876 0.0076387 0.00637057 -0.000502098
1 -0.000146957 -0.804091 -0.117698 -0.173275 -0.0593506 -0.114767


Correlation Matrix, Ch. 5536. Fit Status = 3
Parameter Index
Parameter Index
0.000412525 -0.000372677 -0.000686281 -0.0059061 -0.00613188 -0.00211403 1
0.000411762 -0.000371967 -0.000685011 -0.00589511 -0.00612046 1 -0.00211403
0.00103517 -0.00105168 -0.0017314 -0.0155536 1 -0.00612046 -0.00613188
0.000998685 -0.00101095 -0.00167019 1 -0.0155536 -0.00589511 -0.0059061
6.35072e-05 -0.000327562 1 -0.00167019 -0.0017314 -0.000685011 -0.000686281
0.000314595 1 -0.000327562 -0.00101095 -0.00105168 -0.000371967 -0.000372677
1 0.000314595 6.35072e-05 0.000998685 0.00103517 0.000411762 0.000412525


Correlation Matrix, Ch. 7117. Fit Status = 3
Parameter Index
Parameter Index
0.061609 0.172596 -0.0951976 -0.077273 -0.0754566 1 1
0.0616096 0.172596 -0.0951989 -0.0772796 -0.0754631 1 1
-0.190615 -0.193365 0.350384 0.999332 1 -0.0754631 -0.0754566
-0.186769 -0.18772 0.343127 1 0.999332 -0.0772796 -0.077273
-0.831641 -0.532361 1 0.343127 0.350384 -0.0951989 -0.0951976
0.440281 1 -0.532361 -0.18772 -0.193365 0.172596 0.172596
1 0.440281 -0.831641 -0.186769 -0.190615 0.0616096 0.061609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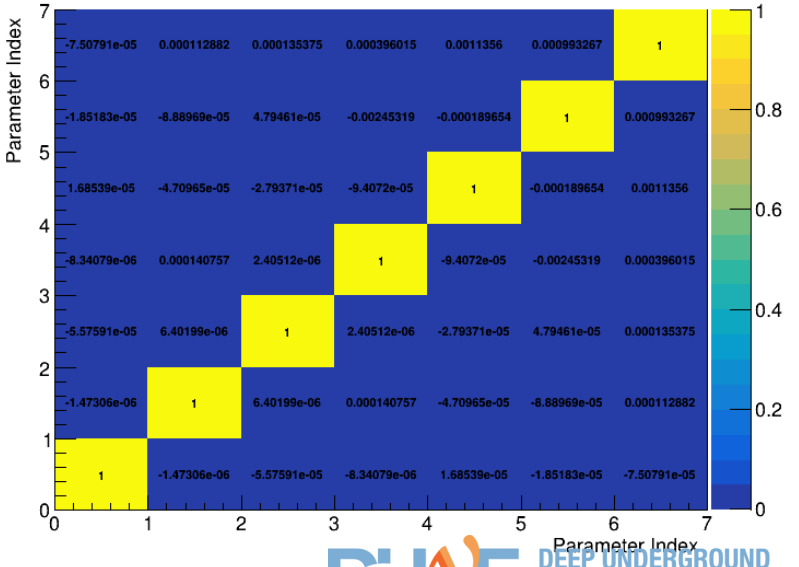
Parameter Index
Parameter Index
-0.326125 -0.00960218 0.865342 0.98494 0.978449 0.960945 1
-0.30363 -0.00896955 0.799478 0.943383 0.961007 1 0.960945
-0.325954 -0.00959714 0.864767 0.985332 1 0.961007 0.978449
-0.318115 -0.00937692 0.840474 1 0.985332 0.943383 0.98494
-0.55824 -0.00830494 1 0.840474 0.864767 0.799478 0.865342
0.00221363 1 -0.00830494 -0.00937692 -0.00959714 -0.00896955 -0.00960218
1 0.00221363 -0.55824 -0.318115 -0.325954 -0.30363 -0.326125


Correlation Matrix, Ch. 38. Fit Status = 3
Parameter Index
Parameter Index
-7.50791e-05 0.000112882 0.000135375 0.000396015 0.0011356 0.000993267 1
-1.85183e-05 -8.88969e-05 4.79461e-05 -0.00245319 -0.000189654 1 0.000993267
1.68539e-05 -4.70965e-05 -2.79371e-05 -9.4072e-05 1 -0.000189654 0.0011356
-8.34079e-06 0.000140757 2.40512e-06 1 -9.4072e-05 -0.00245319 0.000396015
-5.57591e-05 6.40199e-06 1 2.40512e-06 -2.79371e-05 4.79461e-05 0.000135375
-1.47306e-06 1 6.40199e-06 0.000140757 -4.70965e-05 -8.88969e-05 0.000112882
1 -1.47306e-06 -5.57591e-05 -8.34079e-06 1.68539e-05 -1.85183e-05 -7.50791e-05