
Unfolding Systematics for GSI2021 analysis

— FOOT physics meeting 11/06/2024 —

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Summary & next steps of the previous meeting (21/05/2024)

- Standard sanity check on the unfolding machinery has been presented
- No unexpected behavior of the machinery has been found
- Performing checks on the dependence of different figures of merit on the number of iterations, 3 iterations could be chosen as the optimal value for **iterative bayesian unfolding**

...About systematics of the unfolding method

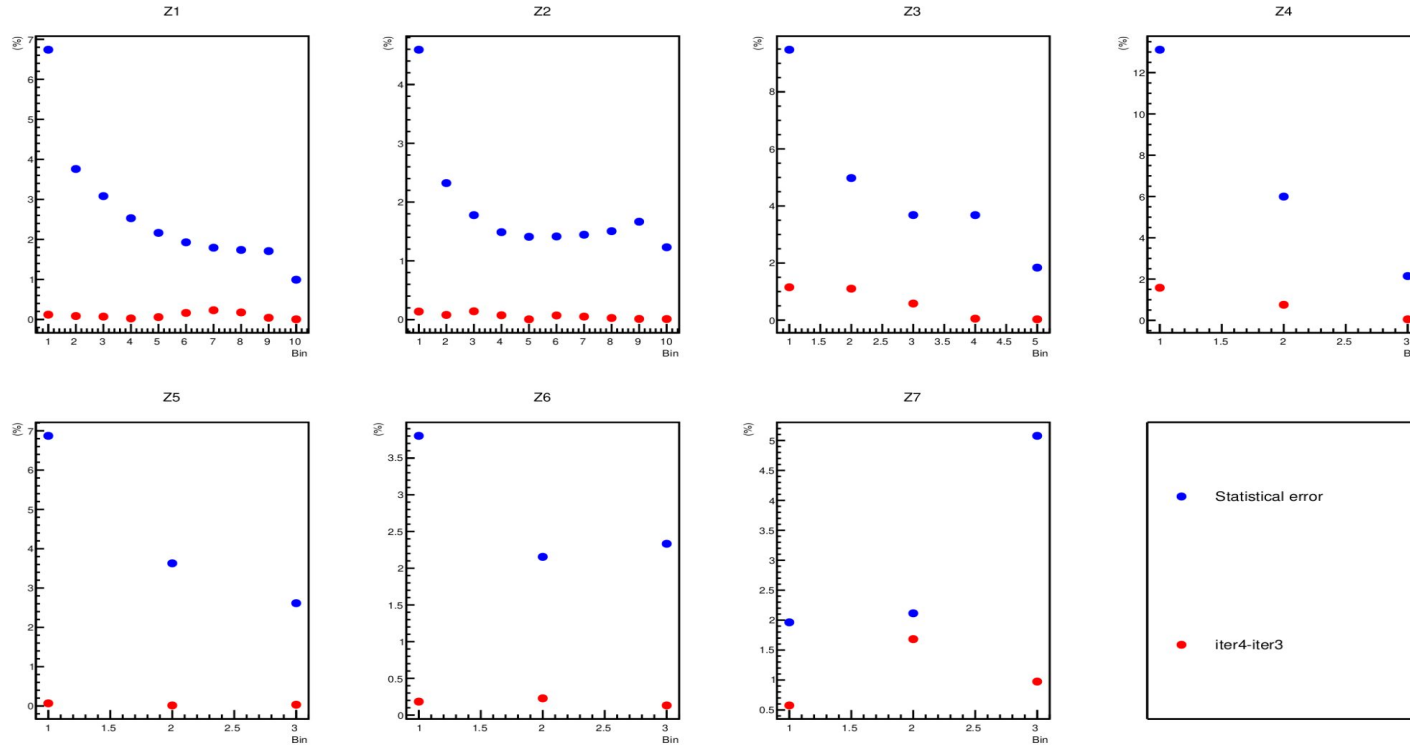
- “External”: difference compared to an alternative method
- “Internal”: difference between using 3 iteration and 4

expected to be at subpercent level

Table 1. Data tests performed on various unfolding methods.

	Y_{unf}	$\chi_A^2/N_{\text{d.f.}}$	$\text{Prob}(\chi_A^2, N_{\text{d.f.}})$
expectation	4584	$N_{\text{d.f.}} / N_{\text{d.f.}}$	0.5
bin-by-bin	4521	34.7 / 0	n.a.
matrix inversion	4584	0 / 0	n.a.
template fit	4572	12.0 / 16	0.74
constrained template fit	4584	12.0 / 16	0.74
Tikhonov $\tau = 0.0068$	4584	13.4 / 16	0.64
Tikhonov $\tau = 0.012$	4584	15.0 / 16	0.52
EM method $n = 0$	4537	5069 / 0	n.a.
EM method $n = 20$	4585	5.9 / 0	n.a.
EM method $n = 100$	4584	4.2 / 0	n.a.
EM method $n = 1000$	4584	3.9 / 0	n.a.
IDS $n = 1$	4584	76.8 / 0	n.a.
IDS $n = 3$	4584	26.1 / 0	n.a.
IDS $n = 10$	4584	8.0 / 0	n.a.
IDS $n = 30$	4584	4.9 / 0	n.a.

Unfolding Method Systematic (internal)



Difference between 4 and 3 iterations one order of magnitude smaller than the statistical error —> **the idea is to neglect it!**

Unfolding Method Systematic (external)

Singular Value Decomposition (SVD)

A. Hoecker and V. Kartvelishvili,
“SVD Approach to Data Unfolding,”
Nucl. Instrum. Meth. A 372
(1996) 469 [[arXiv:hep-ph/9509307](https://arxiv.org/abs/hep-ph/9509307)].

Iterative, Dynamically Stabilized (IDS)

Malaescu Bogdan
“An Iterative, Dynamically Stabilized
(IDS) Method of Data Unfolding”
(2011) [[arXiv:1106.3107](https://arxiv.org/abs/1106.3107)]

Unfolding Method Systematic (SVD kreg default)

SVD init 10 x 10 bins, kreg=5
 Preunfold integral = 127449
 Specunfold integral = 127419
 end loop for 2

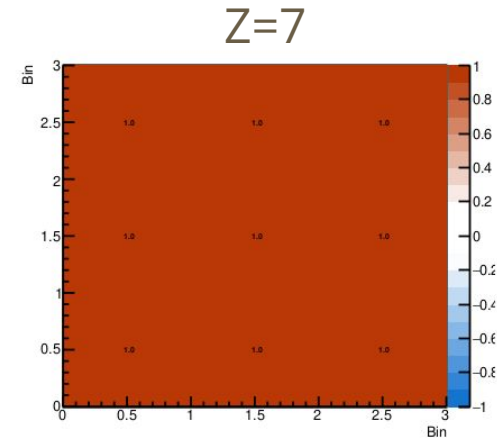
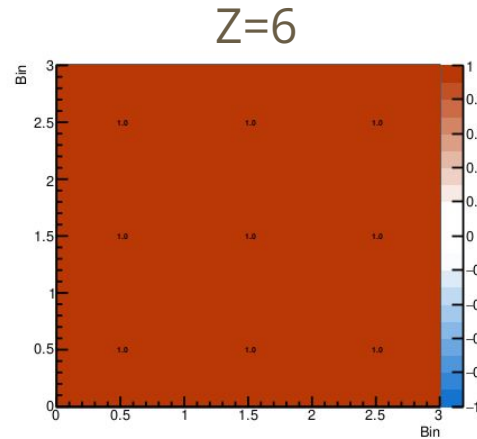
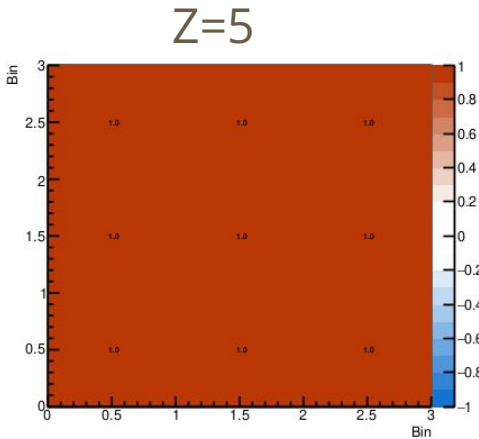
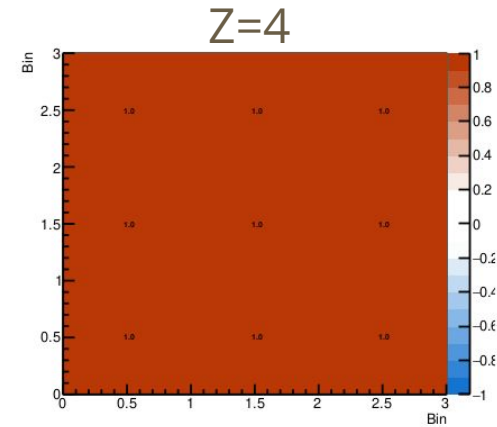
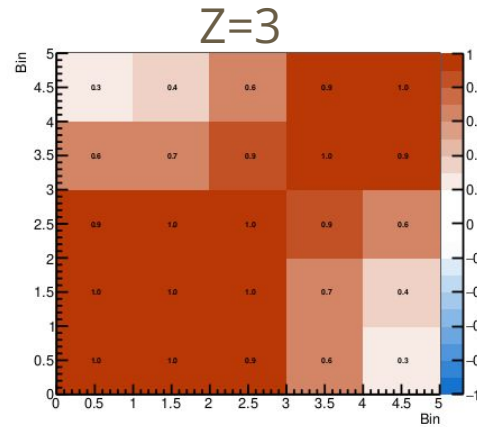
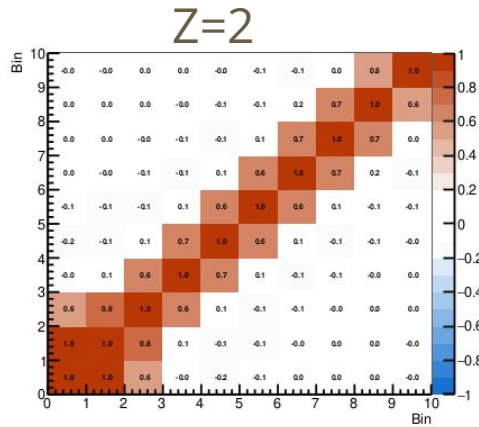
SVD init 5 x 5 bins, kreg=2
 Preunfold integral = 13687.6
 Specunfold integral = 13672.5
 end loop for 3

SVD init 3 x 3 bins, kreg=1
 Preunfold integral = **7266.69**
 Specunfold integral = **3647.41**
 end loop for 4

SVD init 3 x 3 bins, kreg=1
 Preunfold integral = **7661.97**
 Specunfold integral = **3817.45**
 end loop for 5

SVD init 3 x 3 bins, kreg= 1
 Preunfold integral = **17037.1**
 Specunfold integral = **8513.49**
 end loop for 6

SVD init 3 x 3 bins, kreg=1
 Preunfold integral = **21141**
 Specunfold integral = **10771.6**



Unfolding Method Systematic (SVD kreg default)

SVD init 10 x 10 bins, kreg=5
Preunfold integral = 127449
Specunfold integral = 127419
end loop for 2

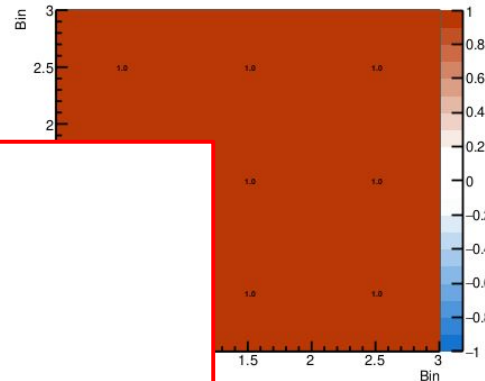
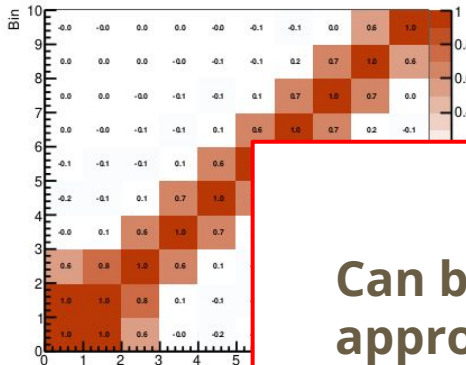
SVD init 5 x 5 bins, kreg=2
Preunfold integral = 13687.6
Specunfold integral = 13672.5
end loop for 3

SVD init 3 x 3 bins, kreg=1
Preunfold integral = 7266.69
Specunfold integral = 3647.41
end loop for 4

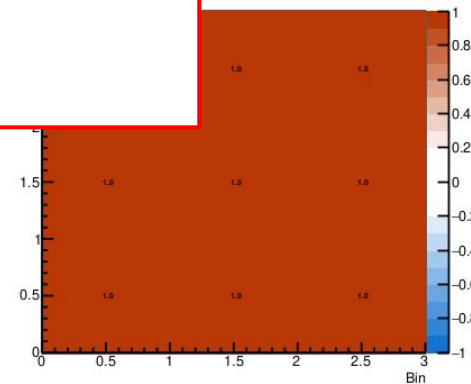
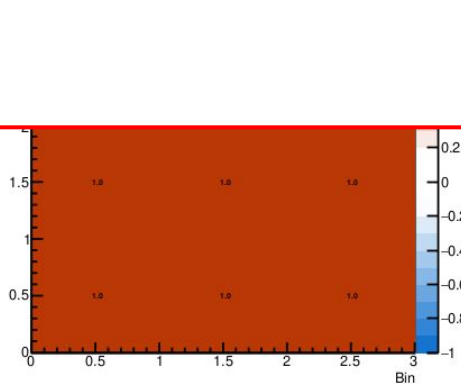
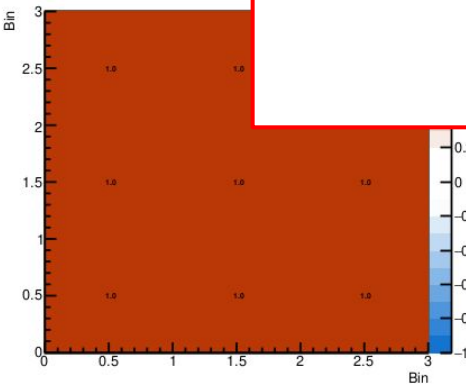
SVD init 3 x 3 bins, kreg=1
Preunfold integral = 7661.97
Specunfold integral = 3817.45
end loop for 5

SVD init 3 x 3 bins, kreg= 1
Preunfold integral = 17037.1
Specunfold integral = 8513.49
end loop for 6

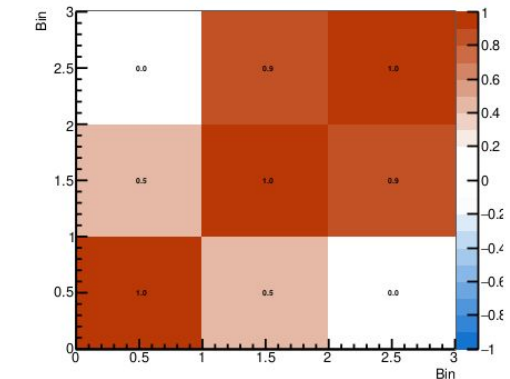
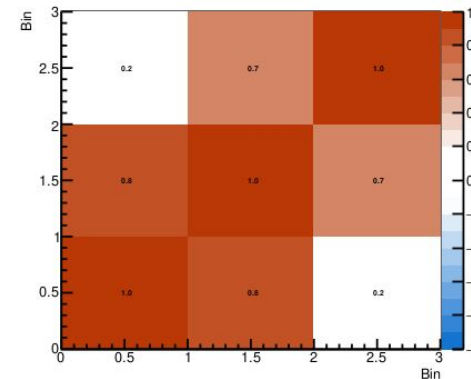
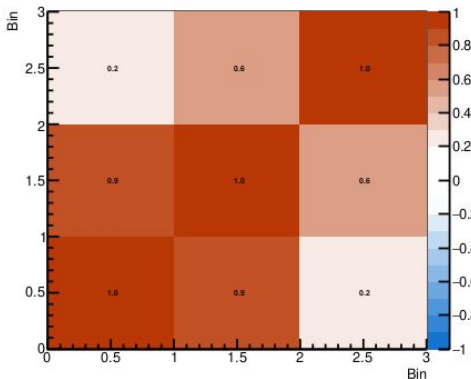
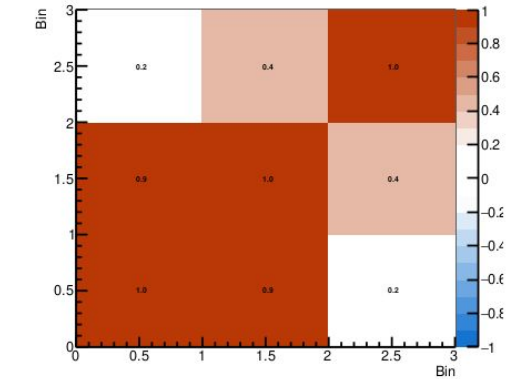
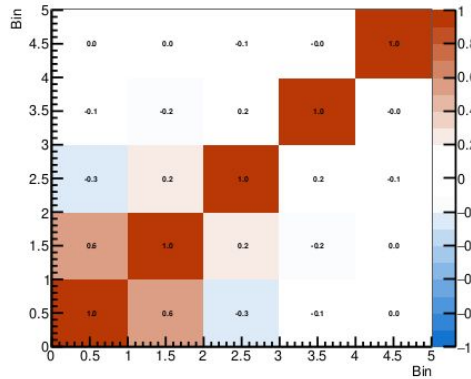
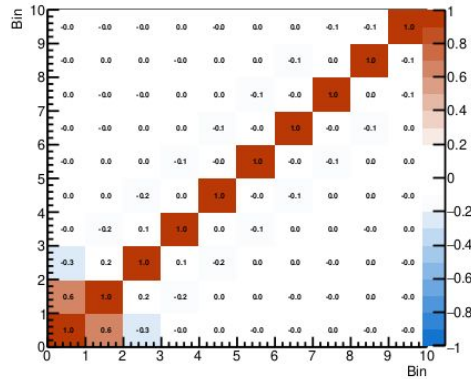
SVD init 3 x 3 bins, kreg=1
Preunfold integral = 21141
Specunfold integral = 10771.6



Can be mitigated a bit by appropriately choosing the regularization parameter Kreg



Unfolding Method Systematic (SVD kreg tuned)



SVD init 10 x 10 bins, kreg=8
 Preunfoid integral = 127449
 Specunfoid integral = 127444
 end loop for 2

SVD init 5 x 5 bins, kreg=4
 Preunfoid integral = 13687.6
 Specunfoid integral = 13685.7
 end loop for 3

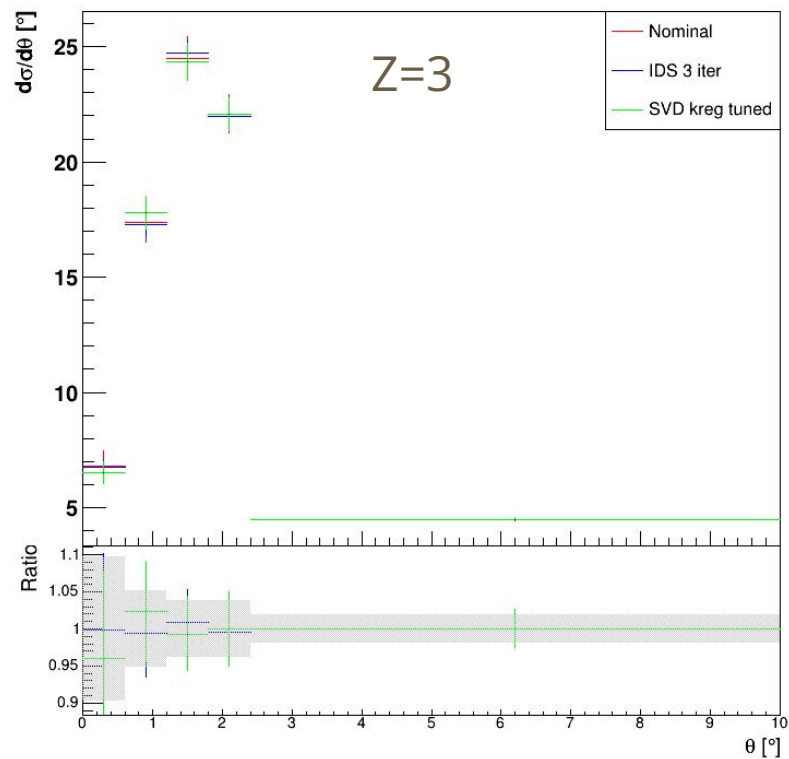
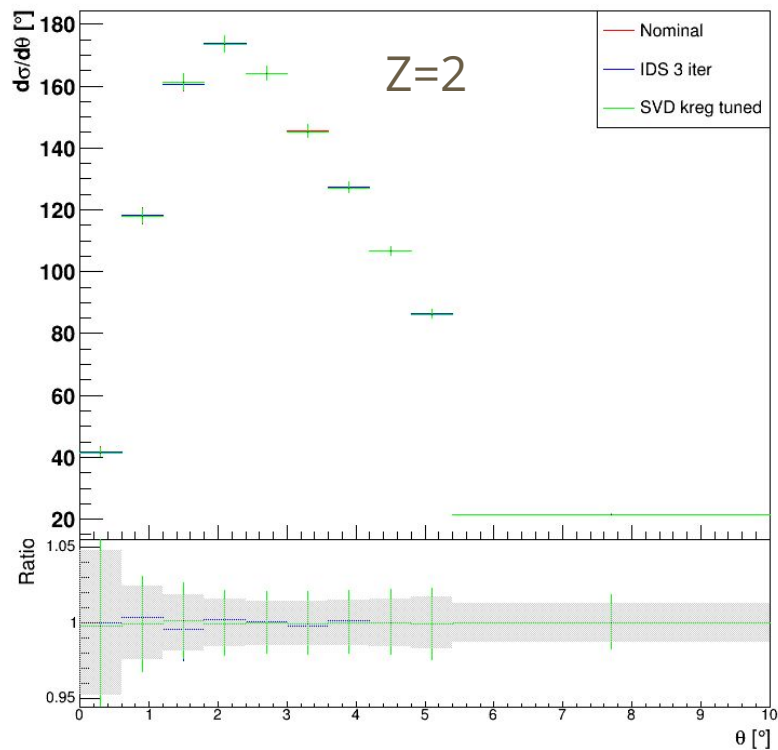
SVD init 3 x 3 bins, kreg=2
 Preunfoid integral = **7266.69**
 Specunfoid integral = **7282.13**
 end loop for 4

SVD init 3 x 3 bins, kreg=2
 Preunfoid integral = **7661.97**
 Specunfoid integral = **7648.56**
 end loop for 5

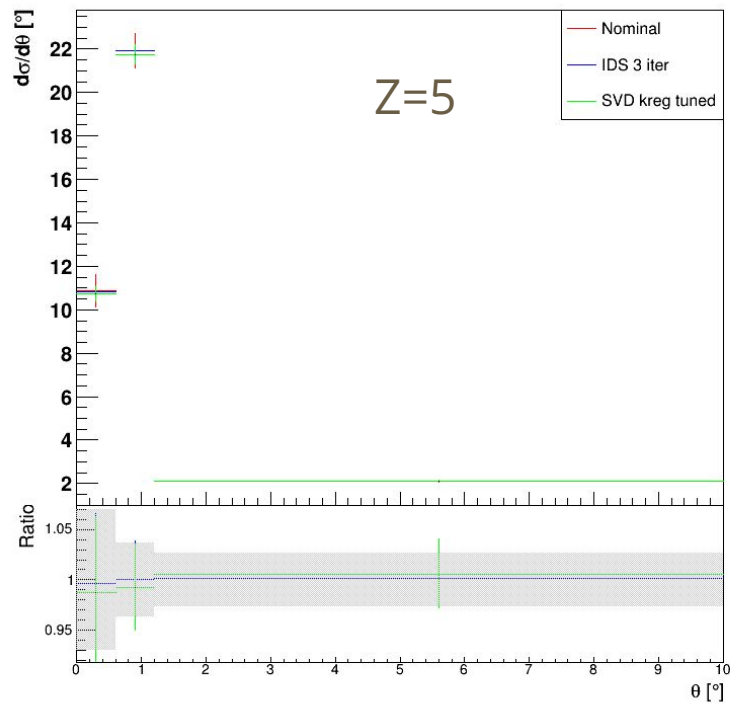
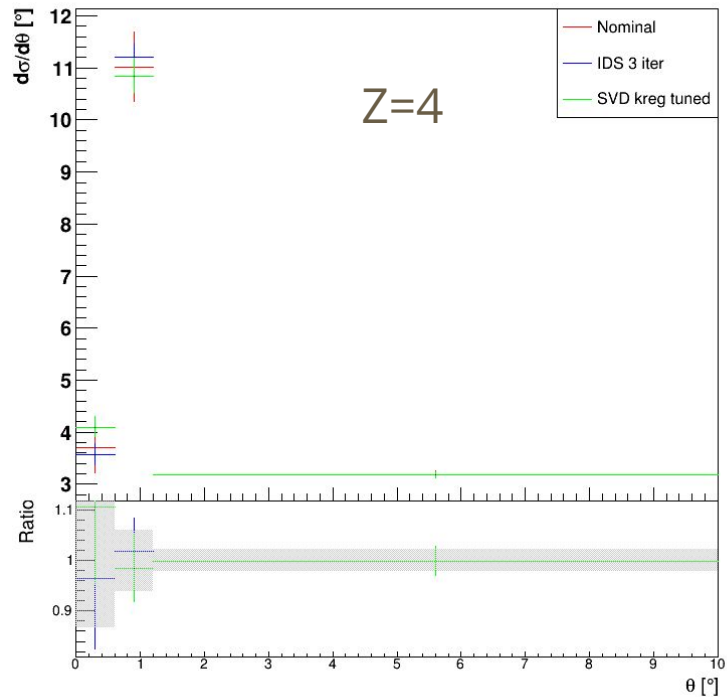
SVD init 3 x 3 bins, kreg=2
 Preunfoid integral = **17037.1**
 Specunfoid integral = **17046.6**
 end loop for 6

SVD init 3 x 3 bins, kreg=2
 Preunfoid integral = **21141**
 Specunfoid integral = **21434.4**

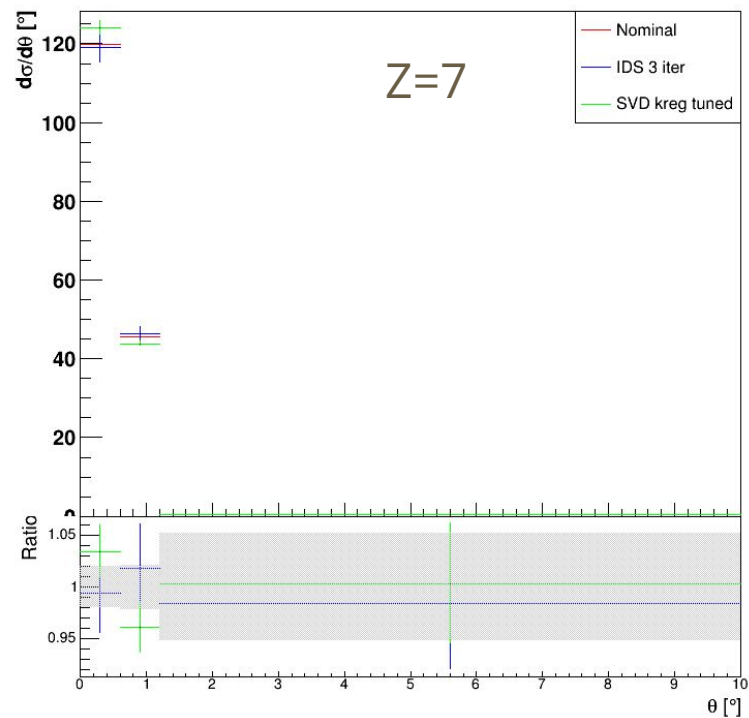
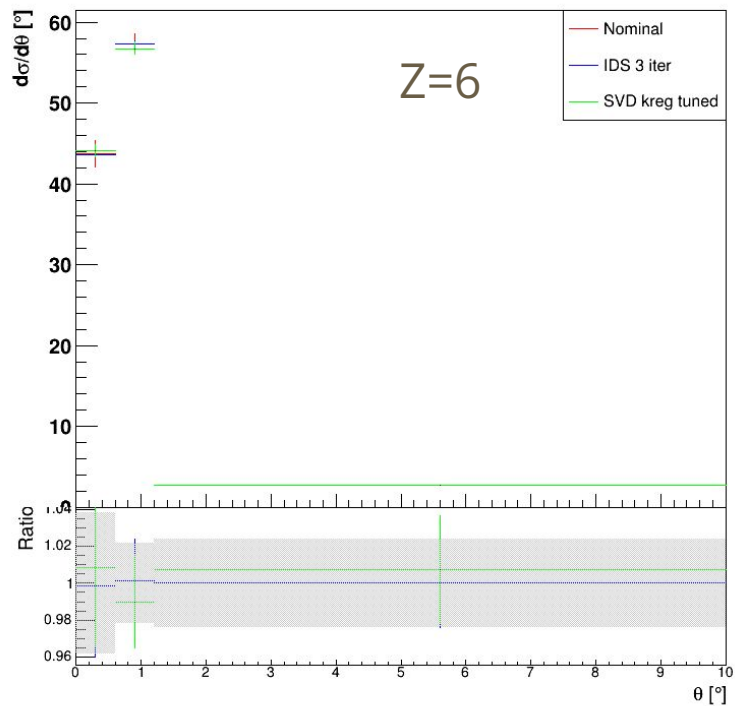
Systematics uncertainty: Unfolding method comparison



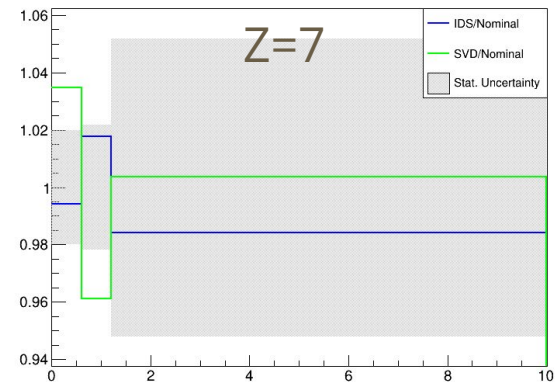
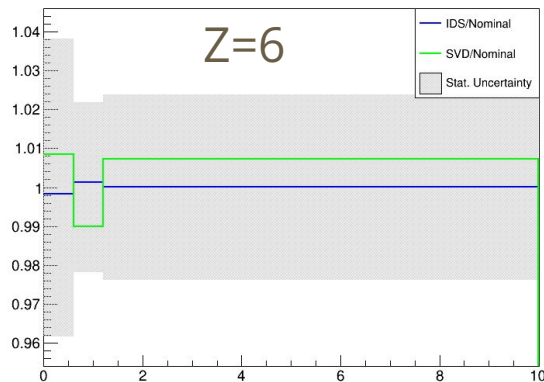
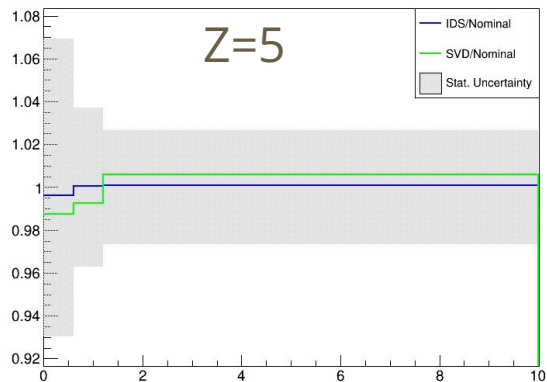
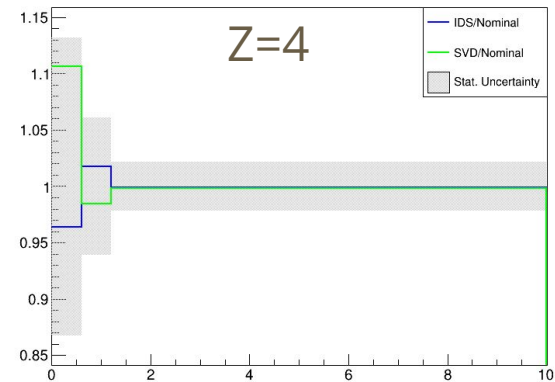
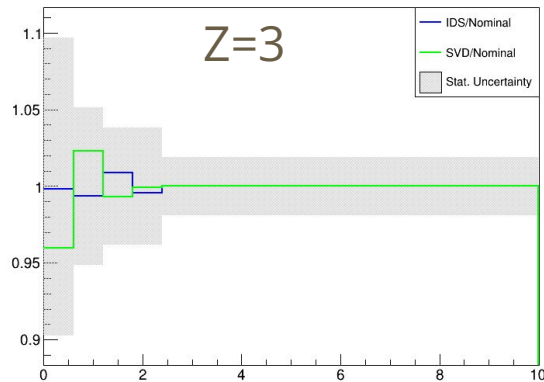
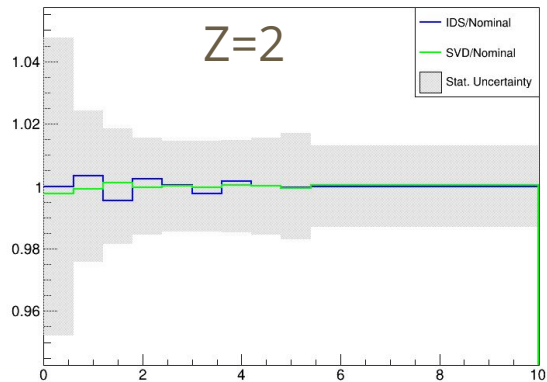
Systematics uncertainty: Unfolding method comparison



Systematics uncertainty: Unfolding method comparison



Systematics uncertainty: closer look to ratio plots



Systematics uncertainty: Values in a table

Z=2

Bin	Center	Width	$\Delta(\text{IDS}/\text{Nominal})$ [%]	$\Delta(\text{SVD}/\text{Nominal})$ [%]
1	0.30	0.30	-0.01	-0.23
2	0.90	0.30	0.34	-0.10
3	1.50	0.30	-0.45	0.12
4	2.10	0.30	0.24	-0.04
5	2.70	0.30	0.05	0.01
6	3.30	0.30	-0.23	-0.03
7	3.90	0.30	0.15	0.03
8	4.50	0.30	0.01	0.02
9	5.10	0.30	-0.03	-0.07
10	7.70	2.30	-0.01	0.03

Z=3

1	0.30	0.30	-0.19	-4.00
2	0.90	0.30	-0.62	2.32
3	1.50	0.30	0.87	-0.68
4	2.10	0.30	-0.42	-0.07
5	6.20	3.80	0.01	0.04

Z=4

1	0.30	0.30	-3.60	10.64
2	0.90	0.30	1.79	-1.56
3	5.60	4.40	-0.13	-0.17

Z=5

1	0.30	0.30	-0.38	-1.25
2	0.90	0.30	0.04	-0.75
3	5.60	4.40	0.10	0.58

Z=6

1	0.30	0.30	-0.16	0.85
2	0.90	0.30	0.12	-1.00
3	5.60	4.40	0.00	0.72

Z=7

1	0.30	0.30	-0.57	3.46
2	0.90	0.30	1.78	-3.87
3	5.60	4.40	-1.58	0.37

In general no big difference is observed apart from Be and N

Table 1: Percentage differences for each bin compared to nominal.

Summary and Conclusions

- Two different kind of the unfolding methods systematics has been investigated: (*internal, external*)
- The *internal method systematics* results at subpercent level almost everywhere in the unfolded distributions and one order of magnitude smaller wrt the statistical uncertainty → **can be safely neglected**
- *External method systematics* by looking at two alternative unfolding methods:
 - Singular Value Decomposition (SVD)
 - Iterative Dynamically Stabilized (IDS)
- SVD suffers of no conservation of the integral and strong dependance on the regularization parameter choice, while IDS shows a more stable behavior.

Reasonable proposal: *Assess ONE unfolding systematics by taking the relative difference between our nominal method (Bayes) and the IDS one.*

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