Study of Λ_c^+ polar angle distribution

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Polar angle distribution study: Methodology

- Data and efficiency-determining MC are divided into 10 $cos\theta$ bins.
- ST signal yield, i.e., $N_{\rm ST}^{\pm,k}$, is extracted by fitting the $M_{\rm BC}$ spectrum of data.
- ST detection efficiency, i.e., $\varepsilon_{\rm ST}^{\pm,k}$, is determined by fitting the $M_{\rm BC}$ spectrum of MC.
- The yields are corrected with the detection efficiencies bin-by-bin: $N_{\rm crt}^{\pm,k} = N_{\rm ST}^{\pm,k}/\varepsilon_{\rm ST}^{\pm,k}$.
- Average corrected yields are calculated by averaging: $\bar{N}_{\rm crt}^{k} = (N_{\rm crt}^{+,k} + N_{\rm crt}^{-,k})/2$.
- $\bar{N}_{\rm crt}^{k}$ is actually proportional to $\mathrm{d}\sigma/\mathrm{d}\cos\theta$, since $\mathcal{L}_{\rm int}$, $f_{\rm ISR}$, $f_{\rm VP}$, and $\mathcal{BR}_{\pm}$ are independent on $\cos\theta_{\Lambda_c}$.
- $\mathrm{d}\sigma/\mathrm{d}\cos\theta$ is parameterized by G_E and G_M [Phys. Rev. **124**, 1577 (1961)]:

$$\frac{\mathrm{d}\sigma}{\mathrm{d}\cos\theta} \propto \left[|G_M|^2(1+\cos^2\theta) + \frac{4m^2_{\Lambda_c^+}}{s}|G_E|^2\sin^2\theta\right],$$

A χ^2 fit is performed on the $\bar{N}_{\rm crt}^{k}$ distributions with the parameterization function:

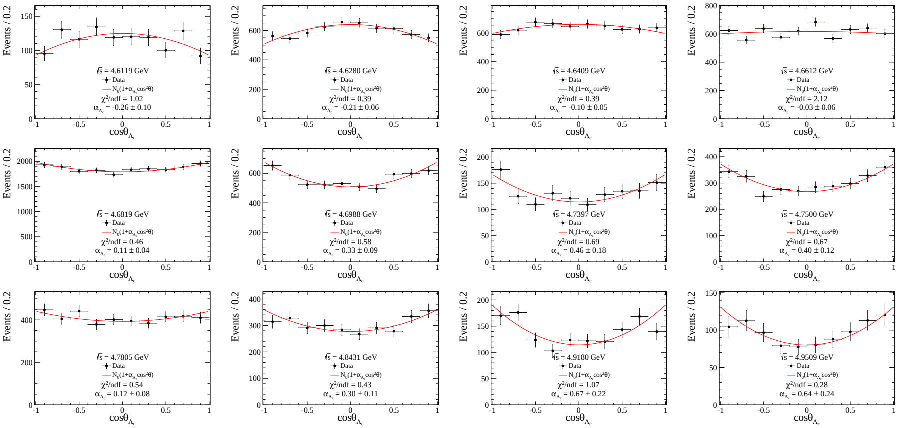
$$f(x) = N_0(1+\alpha_{\Lambda_c}x^2), \qquad x = \cos\theta,$$

in which the nominal (in this analysis) and conventional estimators χ^2 are defined as:

$$\chi^2 = \sum_{i=1}^{N_{\rm bin}} \frac{\left(f(x_i) - N_i\right)^2}{(\Delta N_i)^2 + (f'(x)\Delta x/2)^2} \qquad \text{v.s.} \qquad \chi^2 = \sum_{i=1}^{N_{\rm bin}} \frac{\left(f(x_i) - N_i\right)^2}{(\Delta N_i)^2}$$

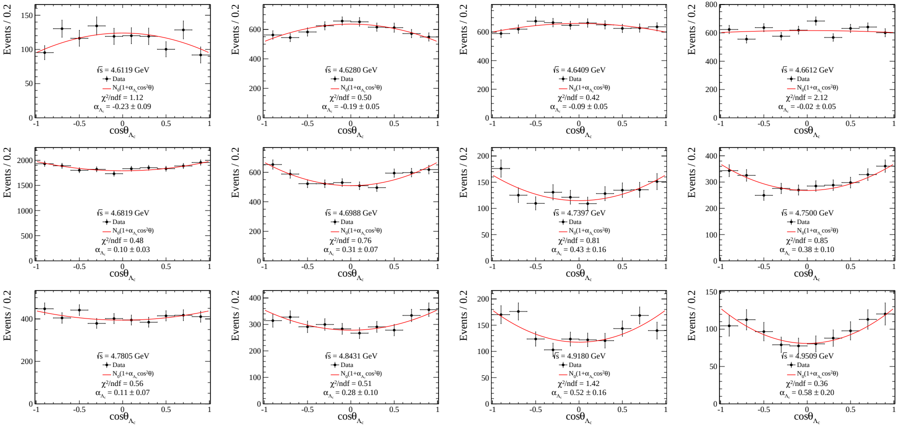
with $\quad N_{\rm bin} = 10, \quad \Delta x = 0.2 \;\text{ and }\; x_i = -1.0 + (i-0.5)\Delta x$

Fit the data with the nominal estimator



- Dots with error bar stand for the averaged corrected yield in each $\cos\theta$ bin.
- Red curves illustrate the fit with $\chi^2 = \sum_{i=1}^{N_{\rm bin}} \frac{\left(f(x_i)-N_i\right)^2}{(\Delta N_i)^2+(N_0\alpha_{\Lambda_c}x_i\Delta x)^2}$.

Fit the data with the conventional estimator



- Dots with error bar stand for the averaged corrected yield in each $\cos\theta$ bin.
- Red curves illustrate the fit with $\chi^2 = \sum_{i=1}^{N_{\rm bin}} \frac{\left(f(x_i)-N_i\right)^2}{(\Delta N_i)^2}$.

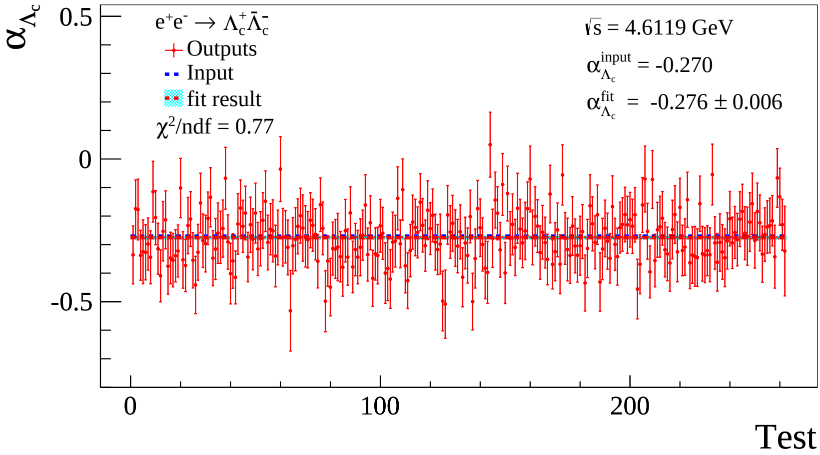
Comparisons

Comparisons of α_{Λ_c} between the nominal and conventional estimators:

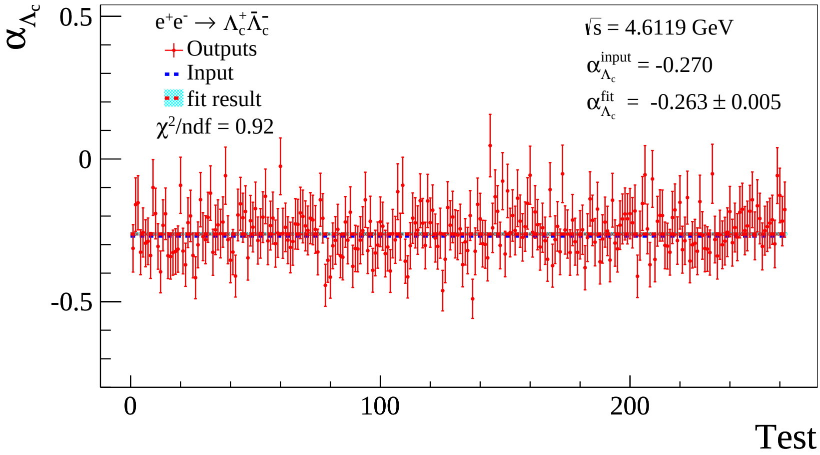
$\sqrt{s}$(GeV)	Nominal α_{Λ_c}	Conventional α_{Λ_c}	Δ_{rel} (%)
4.5995	-0.2048 ± 0.0512	-0.1969 ± 0.0396	3.86
4.6119	-0.2556 ± 0.1001	-0.2331 ± 0.0929	8.80
4.6280	-0.2080 ± 0.0607	-0.1863 ± 0.0458	10.43
4.6409	-0.0973 ± 0.0495	-0.0914 ± 0.0461	6.06
4.6612	-0.0270 ± 0.0561	-0.0221 ± 0.0504	18.15
4.6819	0.1057 ± 0.0357	0.1042 ± 0.0318	1.42
4.6988	0.3335 ± 0.0864	0.3112 ± 0.0670	6.69
4.7397	0.4626 ± 0.1754	0.4272 ± 0.1575	7.65
4.7500	0.3961 ± 0.1151	0.3757 ± 0.0989	5.15
4.7805	0.1208 ± 0.0792	0.1112 ± 0.0725	7.95
4.8431	0.2982 ± 0.1136	0.2755 ± 0.0989	7.61
4.9180	0.6656 ± 0.2234	0.5207 ± 0.1630	21.77
4.9509	0.6378 ± 0.2429	0.5810 ± 0.1999	8.91

- Exactly same $\bar{N}^k_{\text{crt}}$ distribution is fitted at each c.m. energy.
- The nominal fit method suffers from slightly larger statistical uncertainty.
- There is systematic difference between these two fit methods.

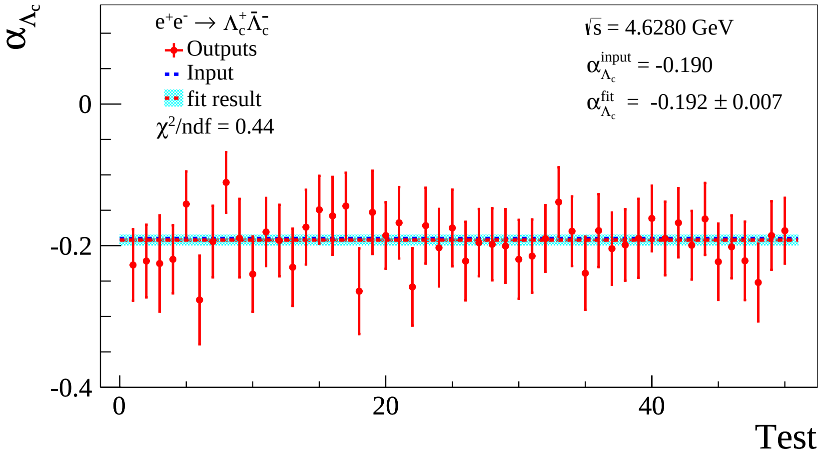
IO check with nominal estimator: 4.6119 GeV



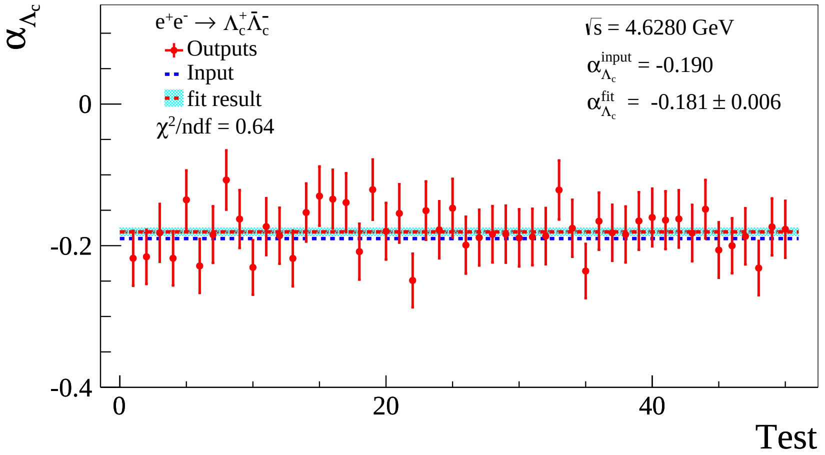
IO check with conventional estimator: 4.6119 GeV



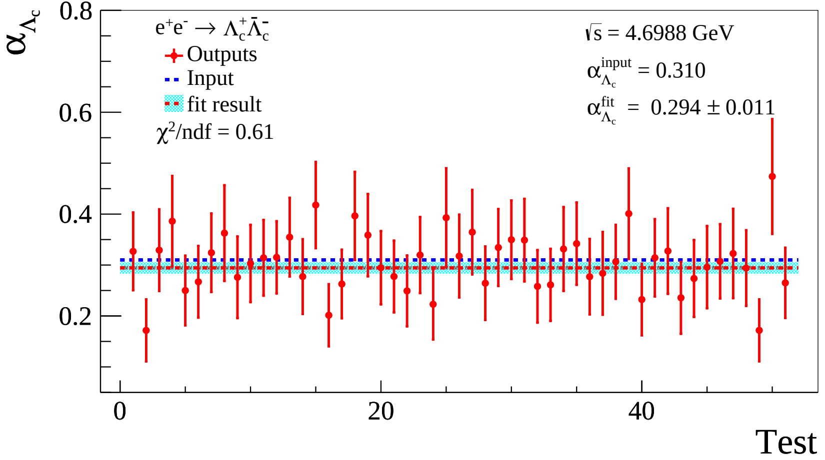
IO check with nominal estimator: 4.6280 GeV



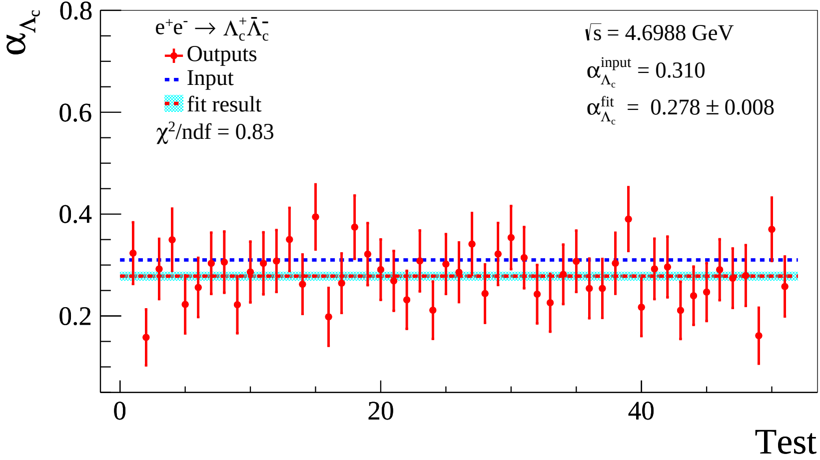
IO check with conventional estimator: 4.6280 GeV



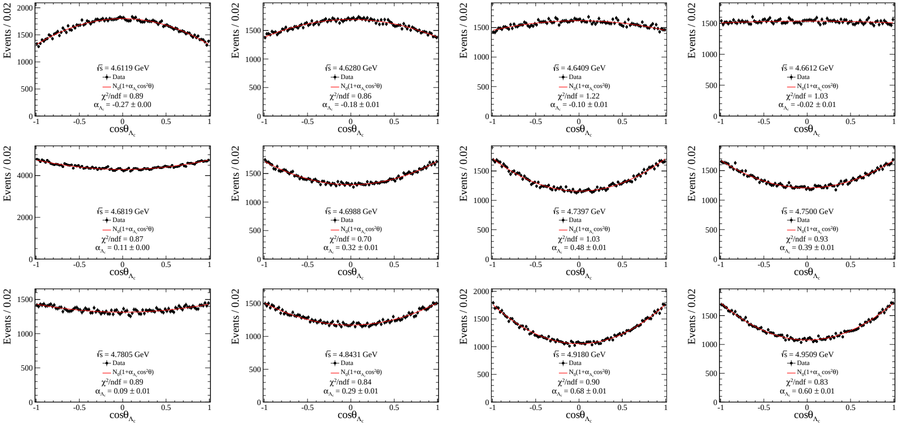
IO check with nominal estimator: 4.6988 GeV



IO check with conventional estimator: 4.6988 GeV

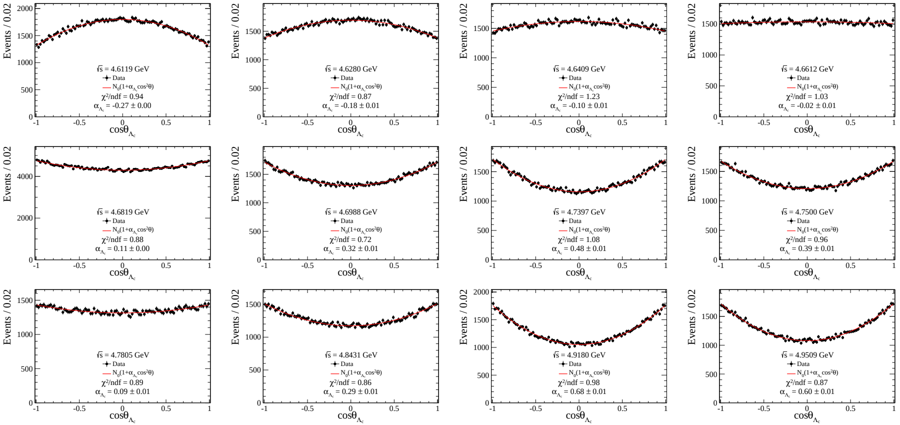


Fit the MC truth with the nominal estimator



- Dots with error bar stand for the MC truth yields in each $\cos\theta$ bin.
- Red curves illustrate the fit with $\chi^2 = \sum_{i=1}^{N_{\rm bin}} \frac{\left(f(x_i)-N_i\right)^2}{(\Delta N_i)^2+(N_0\alpha_{\Lambda_c}x_i\Delta x)^2}$, with $N_{\rm bin} = 100$.

Fit the MC truth with the conventional estimator



- Dots with error bar stand for the MC truth yields in each $\cos\theta$ bin.
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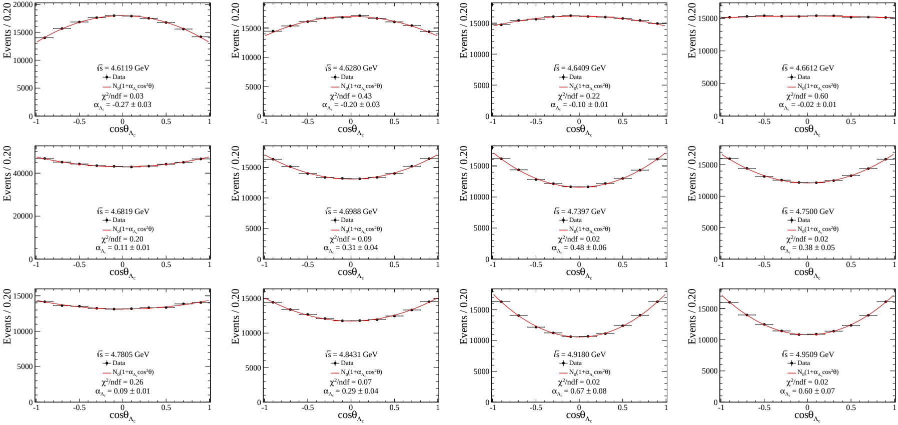
Comparisons

Comparisons of α_{Λ_c} between the nominal and conventional fits on the MC truth:

$\sqrt{s}$ (GeV)	Nominal estimator α_{Λ_c}	Nominal estimator $\Delta^{\text{io}}_{\text{rel}}$ (%)	Conventional estimator α_{Λ_c}	Conventional estimator $\Delta^{\text{io}}_{\text{rel}}$ (%)	Δ_{rel} (%)
4.6119	-0.2679 ± 0.0049	0.78 ± 1.81	-0.2675 ± 0.0047	0.93 ± 1.74	0.15
4.6280	-0.1847 ± 0.0052	2.79 ± 2.74	-0.1844 ± 0.0051	2.95 ± 2.68	0.16
4.6409	-0.1012 ± 0.0056	-1.20 ± 5.60	-0.1011 ± 0.0055	-1.10 ± 5.50	0.10
4.6612	-0.0190 ± 0.0060	-90.0 ± 60.0	-0.0189 ± 0.0060	-89.0 ± 60.0	0.53
4.6819	0.1062 ± 0.0039	3.45 ± 3.55	0.1061 ± 0.0038	3.55 ± 3.45	0.09
4.6988	0.3166 ± 0.0080	-2.13 ± 2.58	0.3164 ± 0.0078	-2.06 ± 2.52	0.06
4.7397	0.4823 ± 0.0093	-0.48 ± 1.94	0.4815 ± 0.0089	-0.31 ± 1.85	0.17
4.7500	0.3893 ± 0.0086	2.68 ± 2.15	0.3888 ± 0.0084	2.80 ± 2.10	0.13
4.7805	0.0903 ± 0.0069	9.70 ± 6.90	0.0902 ± 0.0069	9.80 ± 6.90	0.11
4.8431	0.2883 ± 0.0082	0.59 ± 2.83	0.2879 ± 0.0081	0.72 ± 2.79	0.14
4.9180	0.6770 ± 0.0108	-2.58 ± 1.64	0.6765 ± 0.0102	-2.50 ± 1.55	0.07
4.9509	0.6000 ± 0.0102	1.64 ± 1.67	0.5995 ± 0.0098	1.72 ± 1.61	0.08

- Exactly same $\bar{N}^k_{\text{crt}}$ distribution is fitted at each c.m. energy.
- $\Delta^{\text{io}}_{\text{rel}} = (\alpha_{\text{input}} - \alpha_{\text{ouput}})/\alpha_{\text{input}}$ stands for the deviation from the input value.
- There is no systematic deviations from the input α_{Λ_c} at different c.m. energies.
- There is no significant difference between these two fit methods.

Fit the MC truth with the nominal estimator



- Dots with error bar stand for the MC truth yields in each $\cos\theta$ bin.
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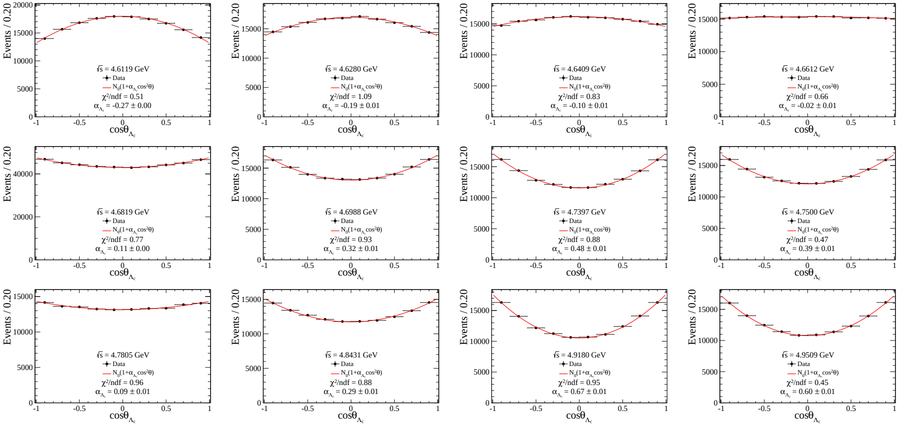
Fit the MC truth with the conventional estimator



- Dots with error bar stand for the MC truth yields in each $\cos\theta$ bin.
- Red curves illustrate the fit with $\chi^2 = \sum_{i=1}^{N_{\text{bin}}} \frac{\left(f(x_i)-N_i\right)^2}{(\Delta N_i)^2}$, with $N_{\text{bin}} = 10$.

Comparisons

Comparisons of α_{Λ_c} between the nominal and conventional fits on the MC truth:

$\sqrt{s}$ (GeV)	Nominal estimator		Conventional estimator		
	α_{Λ_c}	$\Delta^{\text{io}}_{\text{rel}}$ (%)	α_{Λ_c}	$\Delta^{\text{io}}_{\text{rel}}$ (%)	Δ_{rel} (%)
4.6119	-0.2674 ± 0.0323	0.96 ± 12.0	-0.2671 ± 0.0048	1.07 ± 1.78	0.11
4.6280	-0.1973 ± 0.0256	-3.84 ± 13.5	-0.1853 ± 0.0053	2.47 ± 2.79	6.08
4.6409	-0.1004 ± 0.0144	-0.40 ± 14.4	-0.0985 ± 0.0057	1.50 ± 5.70	1.89
4.6612	-0.0182 ± 0.0069	-82.0 ± 69.0	-0.0173 ± 0.0061	-73.0 ± 61.0	4.95
4.6819	0.1070 ± 0.0141	2.73 ± 12.8	0.1059 ± 0.0039	3.73 ± 3.55	1.03
4.6988	0.3054 ± 0.0381	1.48 ± 12.3	0.3170 ± 0.0080	-2.26 ± 2.58	-3.80
4.7397	0.4840 ± 0.0600	-0.83 ± 12.5	0.4836 ± 0.0091	-0.75 ± 1.90	0.08
4.7500	0.3837 ± 0.0477	4.08 ± 11.9	0.3911 ± 0.0086	2.23 ± 2.15	-1.93
4.7805	0.0937 ± 0.0147	6.30 ± 14.7	0.0899 ± 0.0071	10.1 ± 7.10	4.06
4.8431	0.2868 ± 0.0364	1.10 ± 12.6	0.2892 ± 0.0083	0.28 ± 2.86	-0.84
4.9180	0.6671 ± 0.0825	-1.08 ± 12.5	0.6747 ± 0.0104	-2.23 ± 1.58	-1.14
4.9509	0.5989 ± 0.0741	1.82 ± 12.1	0.6007 ± 0.0100	1.52 ± 1.64	-0.30

- Exactly same $\bar{N}^k_{\text{crt}}$ distribution is fitted at each c.m. energy.
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