Method of moments for $\mathbf{B^0} \rightarrow \mathbf{K}^{*}\mu\mu$

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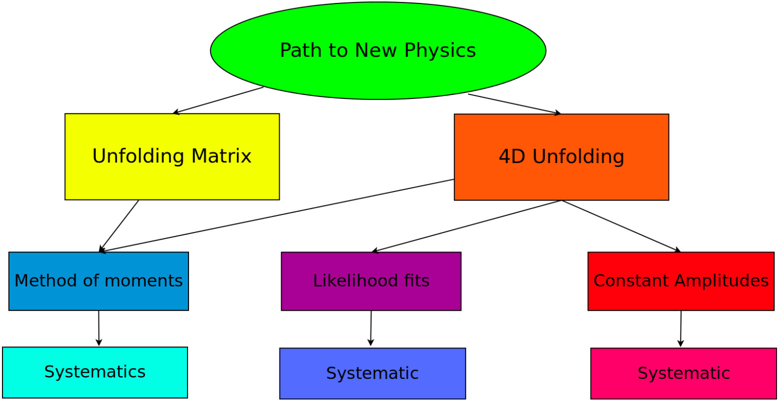
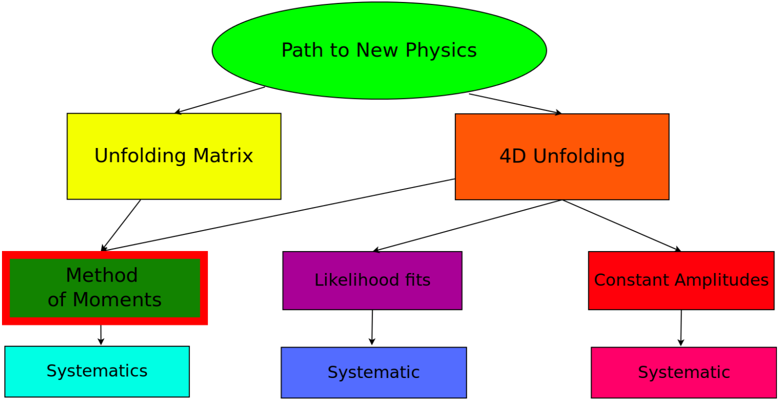
May 23, 2014

Quo vadis $B^0 \to K^* \mu\mu$?



Quo vadis $B^0 \to K^* \mu\mu$?



Introduction

Why method of moments:

1. Complementary approach to LL fits.
2. Allows to extract info measuring quantities in event basis depending on the angular distribution.
3. Used in $B \to \rho \ell \nu$(SLAC-386 UC-414), $J/\psi \to KK\gamma$(PRD 71, 032005 (2005)), etc.

Method of moments

Let's assume we have our pdf with k unknown parameters: $PDF(x_i, \alpha)$, $dim(\alpha) = k$. One can calculate k moments, which are the functions of α_i:

$$\mu_i = f(\alpha_1, ..., \alpha_k) = E[W_i] \tag{1}$$

For n events, we can estimate:

$$\widehat{\mu}_i = \frac{1}{n} \sum_{j=0}^{j=n-1} w_j \tag{2}$$

, where $w_j = g(x_i)$

Trivial example

Lets see how this works in practice:

$$f(x) = \frac{x^{a-1} e^{-x/b}}{b^a \Gamma(a)} \tag{3}$$

we measure the moments:

$$m_1 = \frac{X_1 + X_2 + ... + X_n}{n},$$
$$m_2 = \frac{X_1^2 + X_2^2 + ... + X_n^2}{n}.$$

and calculate them analytically:

$$m_1 = ab,\ m_2 = b^2 a(a+1)$$

So one just needs to solve this and get the answer:

$$a = \frac{m_1^2}{m_2 - m_1^2},\ b = \frac{m_2 - m_1^2}{m_1}$$

Our PDF

The angular terms:

$$PDF(\cos\theta_k, \cos\theta_l, \phi) = \frac{9}{32\pi}(\frac{3}{4}(1-F_l)\sin^2\theta_k + F_l\cos^2\theta_k + (\frac{1}{4}(1-F_l)\sin^2\theta_k - F_l\cos^2)\cos 2\theta_l + S_3\sin^2\theta_k\sin^2\theta_l cos2\phi + S_4\sin 2\theta_k\sin\theta_l\cos\phi + S_5\sin 2\theta_k\sin\theta_l\cos\phi + (S_{6s}\sin^2\theta_k + S_{6c}\cos^2\theta_k)\cos\theta_l + S_7\sin 2\theta_k\sin\theta_l\sin\phi + S_8\sin 2\theta_k\sin 2\theta_l\sin\phi + S_9\sin^2\theta_k\sin^2\theta_l\sin 2\phi) \quad (4)$$

Since we are fitting a PDF we need to ensure it is normalized:

$$\int_{-\pi}^{\pi} d\phi \int_{-1}^{1} dcos\theta_l \int_{-1}^{1} dcos\theta_k \frac{d^4\Gamma}{dq^2 dcos\theta_k dcos\theta_l d\phi} = 1 \quad (5)$$

Our PDF

The angular terms:

$$PDF(\cos\theta_k, \cos\theta_l, \phi) = \frac{9}{32\pi}(\frac{3}{4}(1-F_l)\sin^2\theta_k + F_l\cos^2\theta_k + (\frac{1}{4}(1-F_l)\sin^2\theta_k$$
$$- F_l\cos^2)\cos 2\theta_l + S_3\sin^2\theta_k\sin^2\theta_l cos2\phi + S_4\sin 2\theta_k\sin\theta_l\cos\phi +$$
$$S_5\sin 2\theta_k\sin\theta_l\cos\phi + (S_{6s}\sin^2\theta_k + S_{6c}\cos^2\theta_k)\cos\theta_l +$$
$$S_7\sin 2\theta_k\sin\theta_l\sin\phi + S_8\sin 2\theta_k\sin 2\theta_l\sin\phi + S_9\sin^2\theta_k\sin^2\theta_l\sin 2\phi) \tag{4}$$

For further use let's introduce a notation:

$$PDF(\cos\theta_k, \cos\theta_l, \phi) = \frac{9}{32\pi}(\frac{3}{4}(1-F_l)\sin^2\theta_k + F_l\cos^2\theta_k +$$
$$(\frac{1}{4}(1-F_l)\sin^2\theta_k - F_l\cos^2)\cos 2\theta_l + \sum_{x=3}^{9} S_x f_x(\cos\theta_k, \cos\theta_l, \phi) \tag{5}$$

Moments for $\mathbf{B} \to \mathbf{K}^{*}\mu\mu$ 1/2

Let's calculate the moments(means of the given distribution):

$$\int_{-1}^{1} d\cos\theta_l \int_{-1}^{1} d\cos\theta_k \int_{-\pi}^{\pi} d\phi PDF(\cos\theta_k, \cos\theta_l, \phi) \sin^2\theta_k = \frac{2}{5}(2 - F_l) \quad (6)$$

$$\int_{-1}^{1} d\cos\theta_l \int_{-1}^{1} d\cos\theta_k \int_{-\pi}^{\pi} d\phi PDF(\cos\theta_k, \cos\theta_l, \phi) \cos^2\theta_k = \frac{1}{5}(2F_l + 1) \quad (7)$$

$$\int_{-1}^{1} d\cos\theta_l \int_{-1}^{1} d\cos\theta_k \int_{-\pi}^{\pi} d\phi PDF(\cos\theta_k, \cos\theta_l, \phi) \cos^2\theta_k = -\frac{2}{25}(2 + F_l) \quad (8)$$

$$\int_{-1}^{1} d\cos\theta_l \int_{-1}^{1} d\cos\theta_k \int_{-\pi}^{\pi} d\phi PDF(\cos\theta_k, \cos\theta_l, \phi) \sin^2\theta_k = -\frac{1}{25}(1 + 8F_l) \quad (9)$$

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Moments for $\mathbf{B} \to \mathbf{K}^{*}\mu\mu$ 2/2

Let's calculate the moments(means of the given distribution):

$$\int_{-1}^{1} d\cos\theta_l \int_{-1}^{1} d\cos\theta_k \int_{-\pi}^{\pi} d\phi PDF(\cos\theta_k, \cos\theta_l, \phi) f_{S_x} = \frac{8}{25} S_x, \quad (10)$$

for $x = 3, 4, 8, 9$, and:

$$\int_{-1}^{1} d\cos\theta_l \int_{-1}^{1} d\cos\theta_k \int_{-\pi}^{\pi} d\phi PDF(\cos\theta_k, \cos\theta_l, \phi) f_{S_x} = \frac{2}{5} S_x, \quad (11)$$

for $x = 5, 6, 7$.
New physics apparently as we like orthogonal world:

$$\int_{-1}^{1} d\cos\theta_l \int_{-1}^{1} d\cos\theta_k \int_{-\pi}^{\pi} d\phi \left(f_{S_x} \times f_{S_y}\right) = \alpha_{xy}\delta_{x\ y} \quad (12)$$

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Moments for $\mathbf{B} \to \mathbf{K}^{*}\mu\mu$

- We are abusing the fact that the basis is orthogonal and moments do not mix.
- Makes live easier and reduces the systematics.
- Each of the S does not know about other.
- In case of full PDF, S_{1s}, S_{2s}, S_{1c}, S_{2c} S_{6s}, S_{6c} are not orthogonal.
- Still we can get them solving equation system:

$$\frac{d^3\Gamma}{\Gamma dcos\theta_k dcos\theta_l d\phi} sin^2\theta_k cos\theta_l = 0.1(S_6 c + 4S_6 s) \tag{13}$$

$$\frac{d^3\Gamma}{\Gamma dcos\theta_k dcos\theta_l d\phi} cos\theta_l = 0.25(S_6 c + 2S_{6s}) \tag{14}$$

solution: $S_{6c} = 2(4M_{S_{6c}} - 5M_{S_{6s}})$, $S_{6s} = -2M_{S_{6c}} + 5M_{S_{6s}}$

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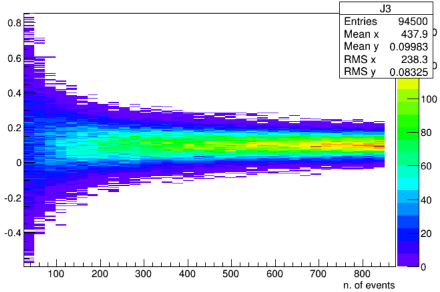
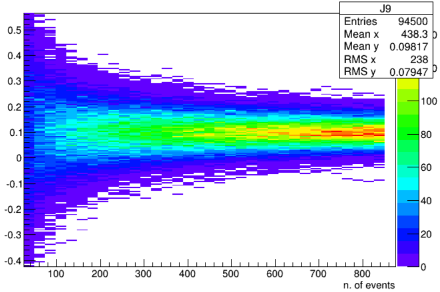
Moments for $B \to K^* \mu\mu$

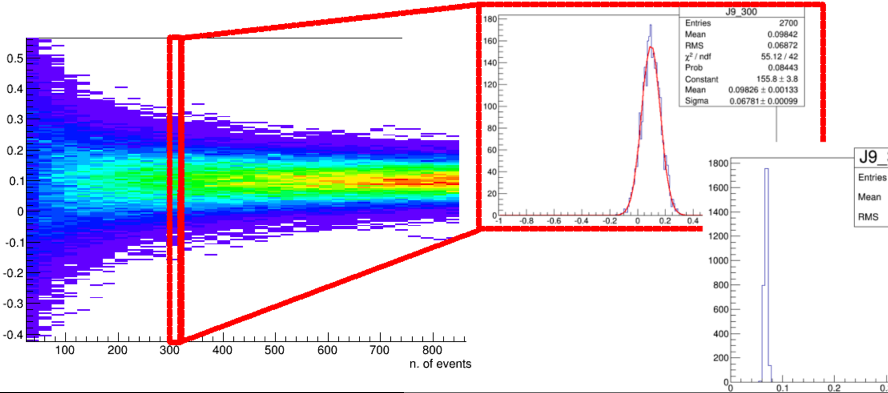
Lets see if this method actually works. Let's take some random parameters for the PDF and make a toy.





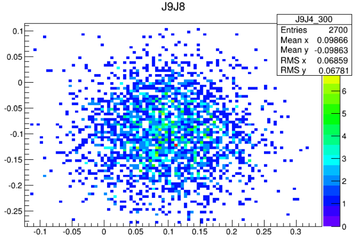
Error Estimation

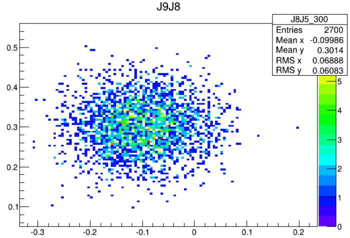
- Since moment is the mean of a given distribution the error can be estimated as *mean*/*RMS*
- use TOY MC to check this assumption
- Do not worry, detail description an numbers will come in other presentation.



Correlation check

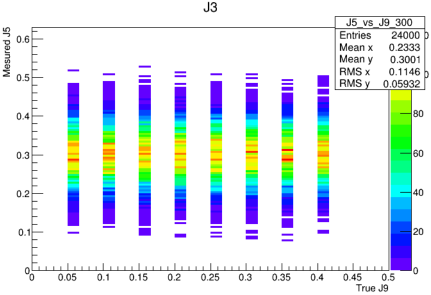
- In theory S_i shouldn't be correlated to S_j in the moment calculation.
- Lets put this to a test.

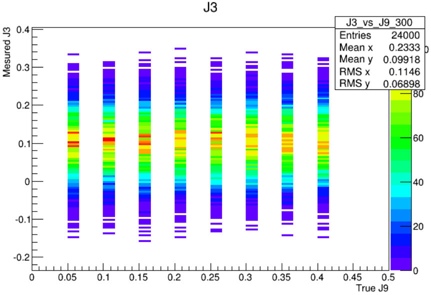




Correlation check 2

- Let's now FIX J_x and simulate different J_y
- Again theory would suggest that one J shouldn't know about the other, so J_x shouldn't change with scanning J_y parameter





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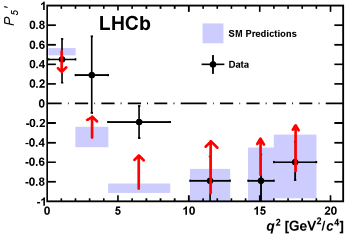
S-wave pollution

- Unfortunately in our perfect orthogonal world lives an imposter.
- This imposter is $B^0 \longrightarrow (K\pi)_{S-wave}\ \mu\mu$
- This "ghost" dilutes our NP! Like dark matter the universe.
- We need something to bust this ghost away



S-wave hunting

Our PDF with the S-wave will look as follows:

$$PDF_{full}(\cos\theta_k, \cos\theta_l, \phi) = \frac{9}{32\pi}((1 - F_s)(\frac{3}{4}(1 - F_l)\sin^2\theta_k + F_l\cos^2\theta_k +$$
$$(\frac{1}{4}(1 - F_l)\sin^2\theta_k - F_l\cos^2)\cos 2\theta_l + S_3\sin^2\theta_k\sin^2\theta_l cos2\phi +$$
$$S_4\sin 2\theta_k\sin\theta_l\cos\phi + S_5\sin 2\theta_k\sin\theta_l\cos\phi +$$
$$(S_{6s}\sin^2\theta_k + S_{6c}\cos^2\theta_k)\cos\theta_l + S_7\sin 2\theta_k\sin\theta_l\sin\phi +$$
$$S_8\sin 2\theta_k\sin 2\theta_l\sin\phi + S_9\sin^2\theta_k\sin^2\theta_l\sin 2\phi) +$$
$$\frac{2}{3}F_s\sin^2\theta_l + \frac{4}{3}A_s\sin^2\theta_l\cos\theta_k + I_4\sin\theta_k\sin 2\theta_l\cos\phi$$
$$+ I_5\sin\theta_k\sin\theta_l\cos\phi + I_7\sin\theta_k\sin\theta_l + \sin\phi + I_8\sin\theta_k\sin 2\theta_l\sin\phi) \quad (15)$$

In this form we ensure normalization.

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How does the dilution work? 1/2

$$\int_{-1}^{1} d\cos\theta_l \int_{-1}^{1} d\cos\theta_k \int_{-\pi}^{\pi} d\phi PDF_{full}(\cos\theta_k, \cos\theta_l, \phi) f_{S_x} = \frac{8}{25} S_x(1 - F_s), \quad (16)$$

for $x = 3, 4, 8, 9$, and:

$$\int_{-1}^{1} d\cos\theta_l \int_{-1}^{1} d\cos\theta_k \int_{-\pi}^{\pi} d\phi PDF_{full}(\cos\theta_k, \cos\theta_l, \phi) f_{S_x} = \frac{2}{5} S_x(1 - F_s), \quad (17)$$

for $x = 5, 6, 7$.

Not much harm and easy to control.

How does the dilution work? 2/2

Unfortunately F_l and F_s will mix with each other:

$$\int_{-1}^{1} d\cos\theta_l \int_{-1}^{1} d\cos\theta_k \int_{-\pi}^{\pi} d\phi PDF_{full}(\cos\theta_k, \cos\theta_l, \phi)\sin^2\theta_k = \frac{2}{15}(6 + 3F_l(F_s - 1) - F_s) = M_{F_l} \quad (18)$$

$$\int_{-1}^{1} d\cos\theta_l \int_{-1}^{1} d\cos\theta_k \int_{-\pi}^{\pi} d\phi PDF_{full}(\cos\theta_k, \cos\theta_l, \phi)\sin^2\theta_l = \frac{1}{5}(3 + F_l + F_s - F_l F_s) = M_{F_s} \quad (19)$$

They can solve this system:

$$\begin{cases} F_s = \frac{15}{4}(M_{F_l} + 2M_{F_s}) \\ F_l = \frac{(15M_{F_l} + 10M_{F_s} - 18)}{(15M_{F_l} + 30M_{F_s} - 34)} \end{cases}$$

S-wave moments

We can even measure directly the S-wave:

$$\frac{d^3\Gamma}{\Gamma dcos\theta_k dcos\theta_l d\phi} sin^2\theta_l cos\theta_k = \frac{32 I_{1b}}{45} \quad (20)$$

$$\frac{d^3\Gamma}{\Gamma dcos\theta_k dcos\theta_l d\phi} sin\theta_k sin2\theta_l cos\phi = \frac{16 I_4}{45} \quad (21)$$

$$\frac{d^3\Gamma}{\Gamma dcos\theta_k dcos\theta_l d\phi} sin\theta_k sin\theta_l cos\phi = \frac{4 I_5}{9} \quad (22)$$

$$\frac{d^3\Gamma}{\Gamma dcos\theta_k dcos\theta_l d\phi} sin\theta_k sin2\theta_l sin\phi = \frac{4 I_7}{9} \quad (23)$$

$$\frac{d^3\Gamma}{\Gamma dcos\theta_k dcos\theta_l d\phi} sin\theta_k sin2\theta_l sin\phi = \frac{16 S_8}{45} \quad (24)$$

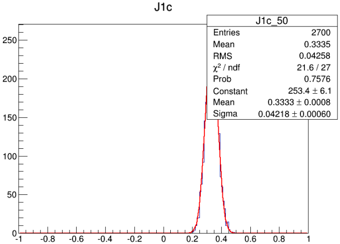
Conclusions

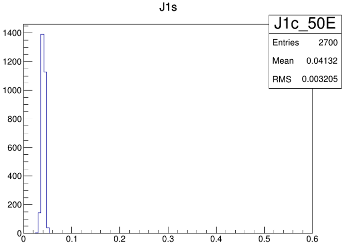
- Method of moments very suitable for $B^0 \to K^* \mu\mu$.
- The method converge fast and works for the "simple case", i.e. signal only.
- Method very insensitive to S-wave component, thanks to orthogonality.
- Complementary one can measure in-depended S-wave component.
- No problem with boundary problems.

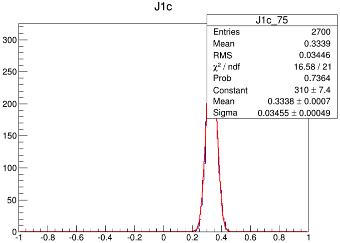
What comes in the next talks(stay tuned):

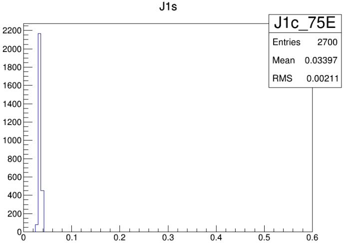
- This method reduces the error on unfolding.
- No problem with convergence.
- Systematics easy accessible.

BACKUPS









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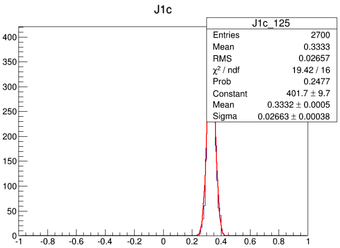
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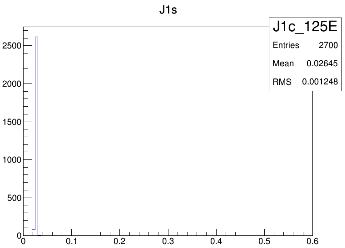
RMS 0.02657
χ² / ndf 19.42 / 16
Prob 0.2477
Constant 401.7 ± 9.7
Mean 0.3332 ± 0.0005
Sigma 0.02663 ± 0.00038
400
350
300
250
200
150
100
50
0
-1 -0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8 1


J1s
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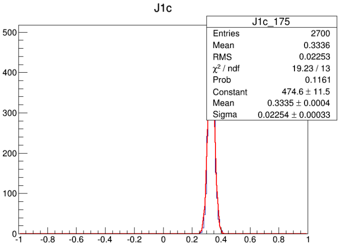
2000
1500
1000
500
0
0 0.1 0.2 0.3 0.4 0.5 0.6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J1c_175
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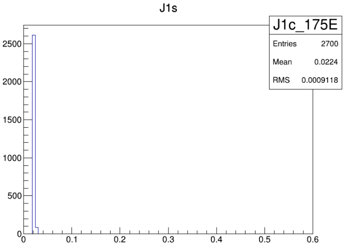
Mean 0.3336
RMS 0.02253
χ² / ndf 19.23 / 13
Prob 0.1161
Constant 474.6 ± 11.5
Mean 0.3335 ± 0.0004
Sigma 0.02254 ± 0.00033
500
400
300
200
100
0
-1 -0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8 1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500
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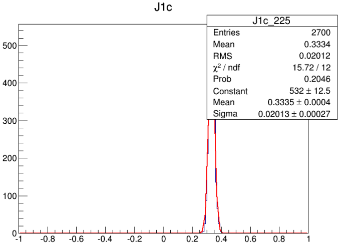
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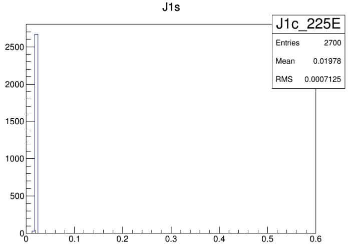
Mean 0.3335 ± 0.0004
Sigma 0.02013 ± 0.00027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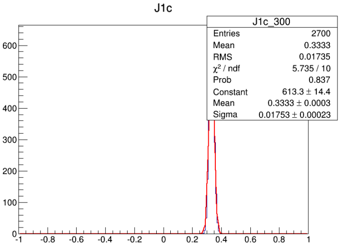
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Entries 2700
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RMS 0.01735
χ² / ndf 5.735 / 10
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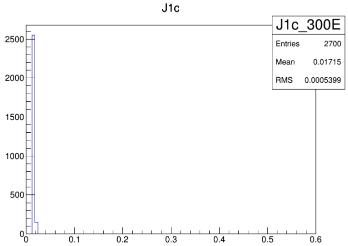
Mean 0.3333 ± 0.0003
Sigma 0.01753 ± 0.00023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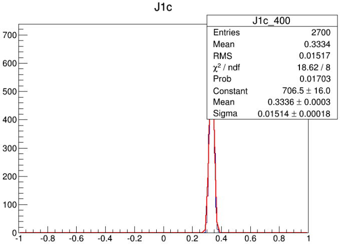

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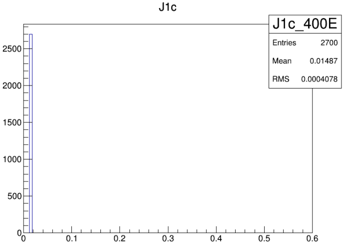
Sigma 0.01514 ± 0.00018



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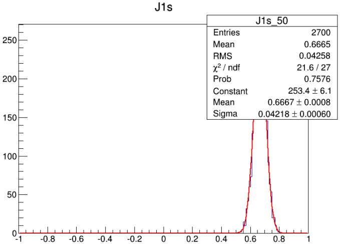
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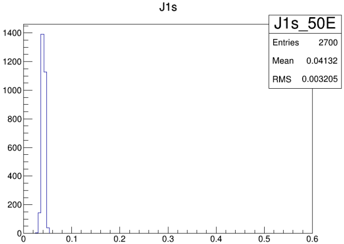
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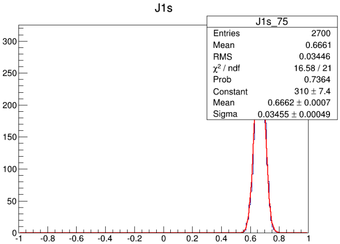
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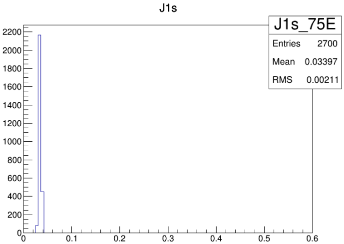
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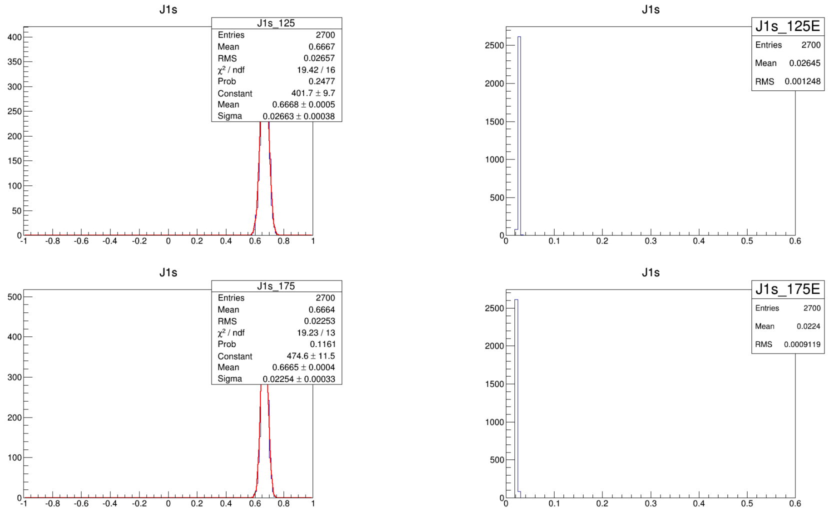
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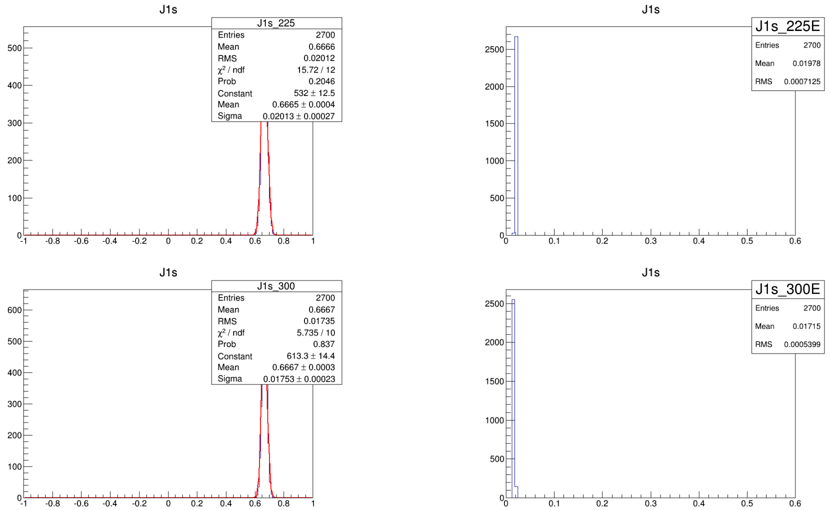
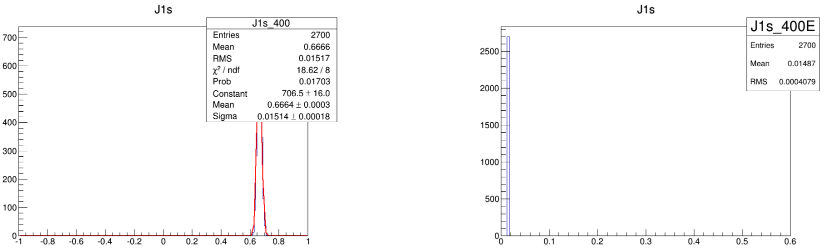
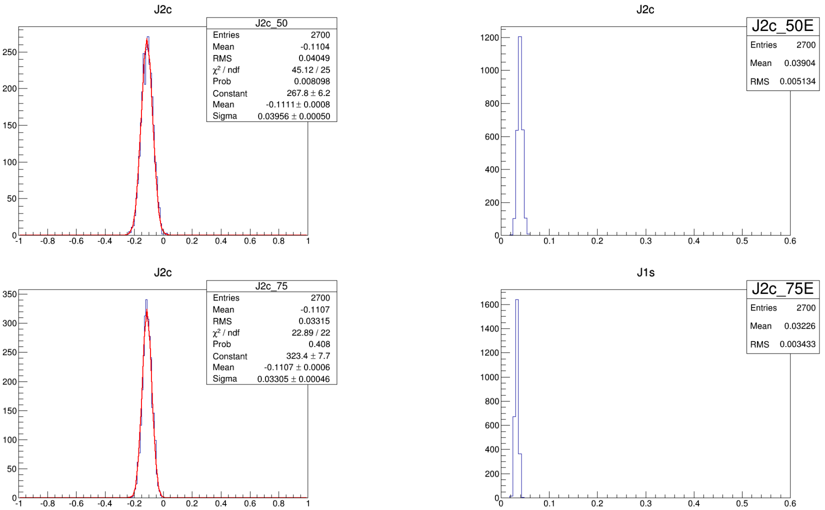
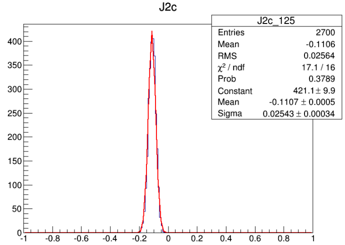
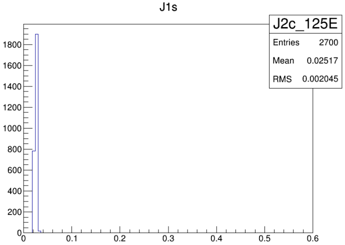
J1s_125
Entries 2700
Mean 0.6667
RMS 0.02657
χ² / ndf 19.42 / 16
Prob 0.2477
Constant 401.7 ± 9.7
Mean 0.6668 ± 0.0005
Sigma 0.02663 ± 0.00038
J1s
J1s_125E
Entries 2700
Mean 0.02645
RMS 0.001248
J1s
J1s_175
Entries 2700
Mean 0.6664
RMS 0.02253
χ² / ndf 19.23 / 13
Prob 0.1161
Constant 474.6 ± 11.5
Mean 0.6665 ± 0.0004
Sigma 0.02254 ± 0.00033
J1s
J1s_175E
Entries 2700
Mean 0.0224
RMS 0.0009119

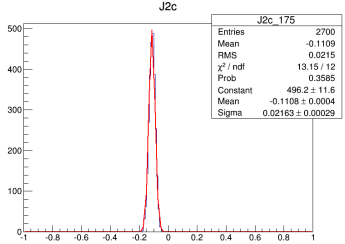

J1s
J1s_225
Entries 2700
Mean 0.6666
RMS 0.02012
χ² / ndf 15.72 / 12
Prob 0.2046
Constant 532 ± 12.5
Mean 0.6665 ± 0.0004
Sigma 0.02013 ± 0.00027
J1s
J1s_225E
Entries 2700
Mean 0.01978
RMS 0.0007125
J1s
J1s_300
Entries 2700
Mean 0.6667
RMS 0.01735
χ² / ndf 5.735 / 10
Prob 0.837
Constant 613.3 ± 14.4
Mean 0.6667 ± 0.0003
Sigma 0.01753 ± 0.00023
J1s
J1s_300E
Entries 2700
Mean 0.01715
RMS 0.0005399

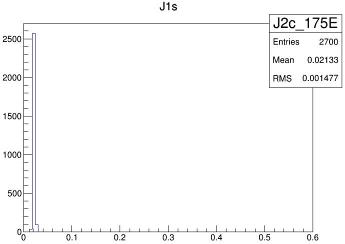

J1s
J1s_400
Entries 2700
Mean 0.6666
RMS 0.01517
χ^2 / ndf 18.62 / 8
Prob 0.01703
Constant 706.5 ± 16.0
Mean 0.6664 ± 0.0003
Sigma 0.01514 ± 0.00018
J1s
J1s_400E
Entries 2700
Mean 0.01487
RMS 0.0004079


J2c
J2c_50
Entries 2700
Mean -0.1104
RMS 0.04049
χ² / ndf 45.12 / 25
Prob 0.008098
Constant 267.8 ± 6.2
Mean -0.1111 ± 0.0008
Sigma 0.03956 ± 0.00050
J2c
J2c_50E
Entries 2700
Mean 0.03904
RMS 0.005134
J2c
J2c_75
Entries 2700
Mean -0.1107
RMS 0.03315
χ² / ndf 22.89 / 22
Prob 0.408
Constant 323.4 ± 7.7
Mean -0.1107 ± 0.0006
Sigma 0.03305 ± 0.00046
J1s
J2c_75E
Entries 2700
Mean 0.03226
RMS 0.003433









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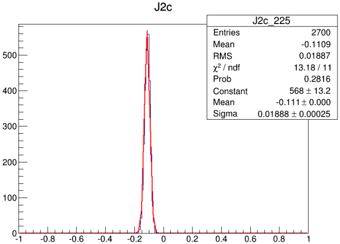
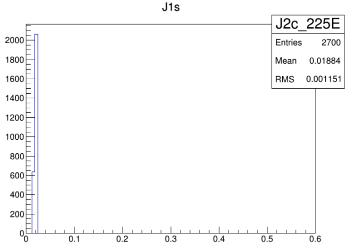
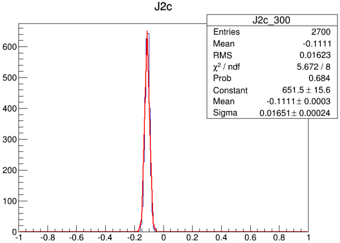
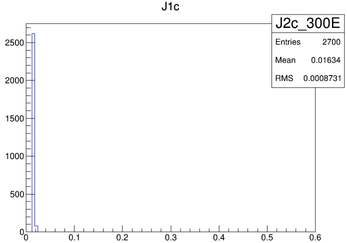
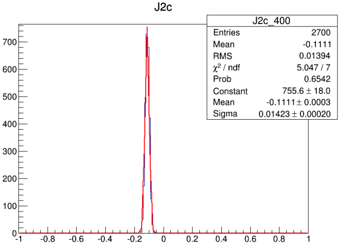
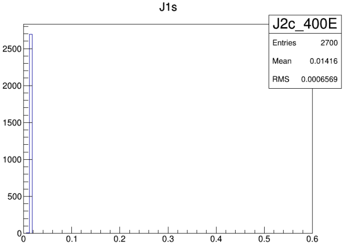

J2c
J2c_225
Entries 2700
Mean -0.1109
RMS 0.01887
χ² / ndf 13.18 / 11
Prob 0.2816
Constant 568 ± 13.2
Mean -0.111 ± 0.000
Sigma 0.01888 ± 0.00025

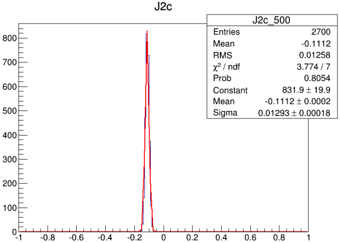

J1s
J2c_225E
Entries 2700
Mean 0.01884
RMS 0.001151

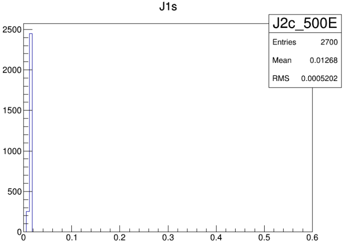

J2c
J2c_300
Entries 2700
Mean -0.1111
RMS 0.01623
χ² / ndf 5.672 / 8
Prob 0.684
Constant 651.5 ± 15.6
Mean -0.1111 ± 0.0003
Sigma 0.01651 ± 0.00024


J1c
J2c_300E
Entries 2700
Mean 0.01634
RMS 0.0008731









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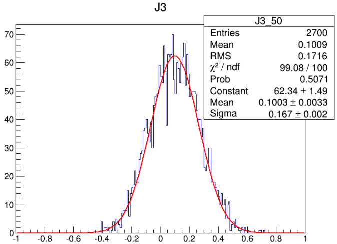
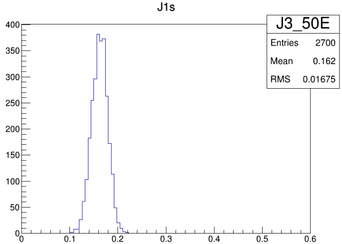
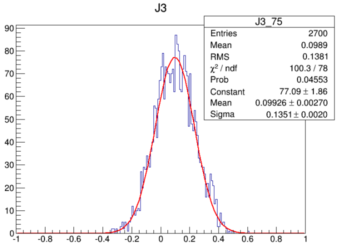
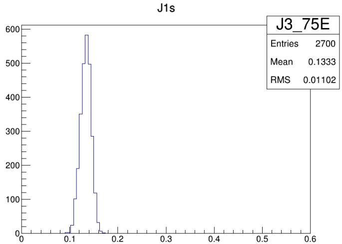
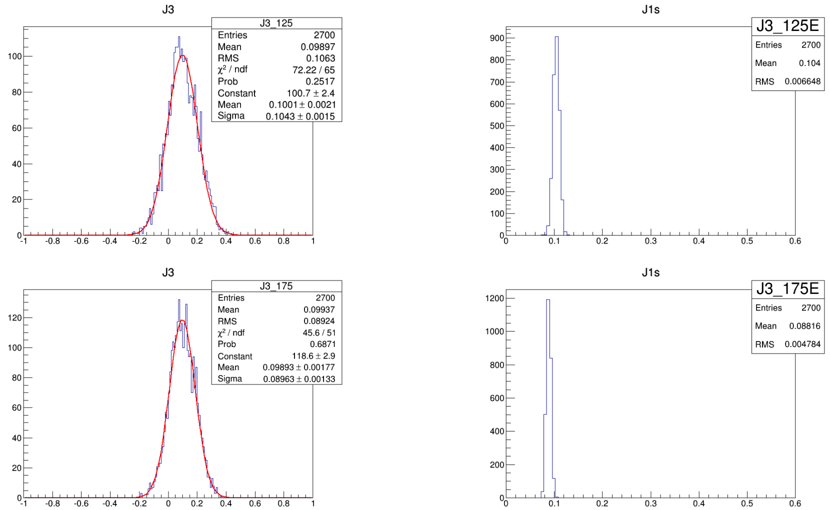

J3
J3_50
Entries 2700
Mean 0.1009
RMS 0.1716
χ2 / ndf 99.08 / 100
Prob 0.5071
Constant 62.34 ± 1.49
Mean 0.1003 ± 0.0033
Sigma 0.167 ± 0.002


J1s
J3_50E
Entries 2700
Mean 0.162
RMS 0.01675


J3
J3_75
Entries 2700
Mean 0.0989
RMS 0.1381
χ2 / ndf 100.3 / 78
Prob 0.04553
Constant 77.09 ± 1.86
Mean 0.09926 ± 0.00270
Sigma 0.1351 ± 0.0020


J1s
J3_75E
Entries 2700
Mean 0.1333
RMS 0.01102



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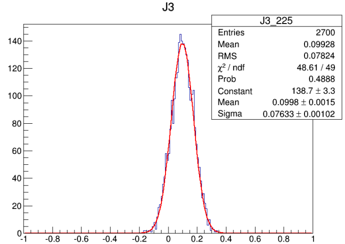
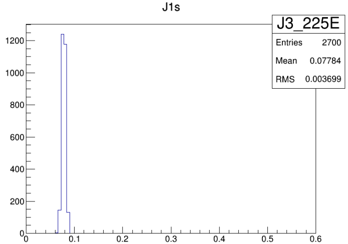
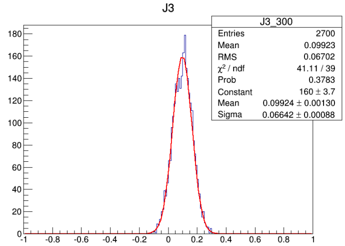
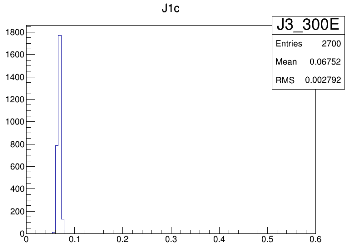
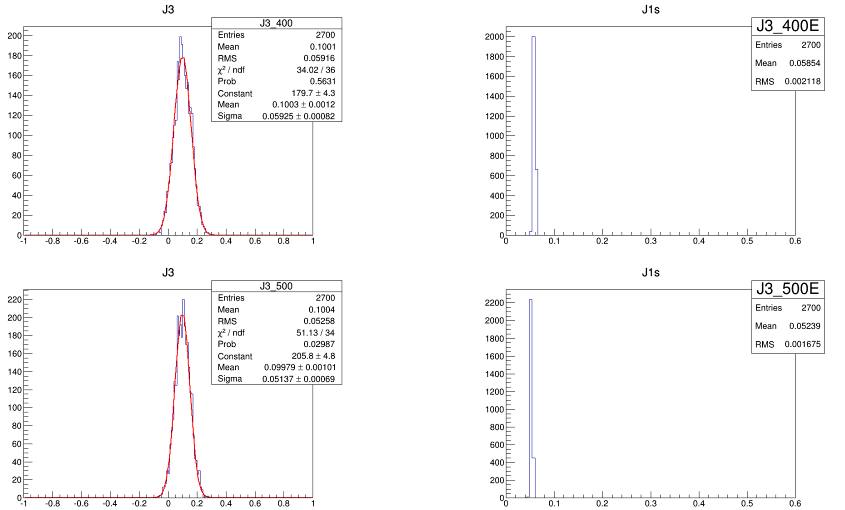

J3
J3_225
Entries 2700
Mean 0.09928
RMS 0.07824
χ2 / ndf 48.61 / 49
Prob 0.4888
Constant 138.7 ± 3.3
Mean 0.0998 ± 0.0015
Sigma 0.07633 ± 0.00102


J1s
J3_225E
Entries 2700
Mean 0.07784
RMS 0.003699


J3
J3_300
Entries 2700
Mean 0.09923
RMS 0.06702
χ2 / ndf 41.11 / 39
Prob 0.3783
Constant 160 ± 3.7
Mean 0.09924 ± 0.00130
Sigma 0.06642 ± 0.00088


J1c
J3_300E
Entries 2700
Mean 0.06752
RMS 0.002792



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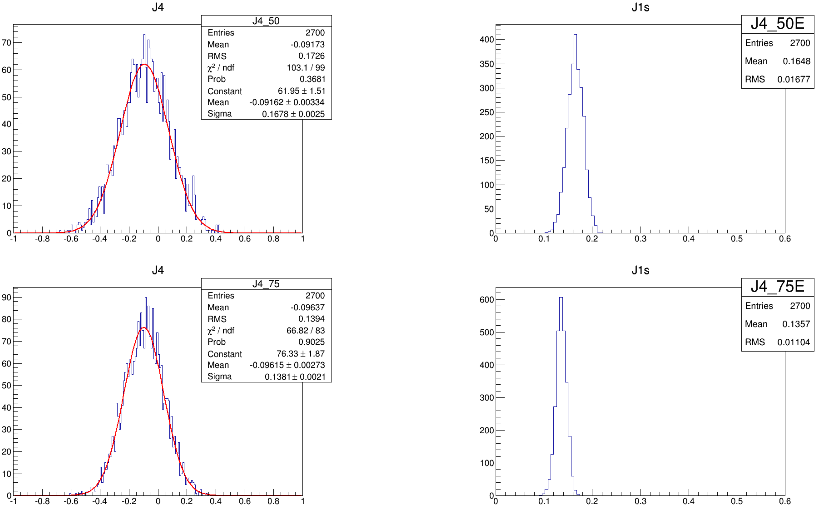
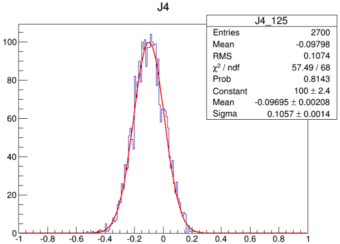
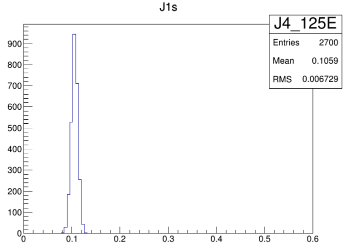
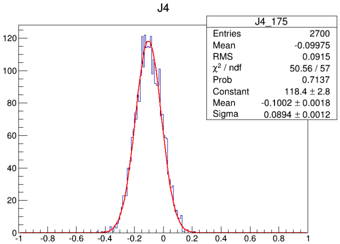
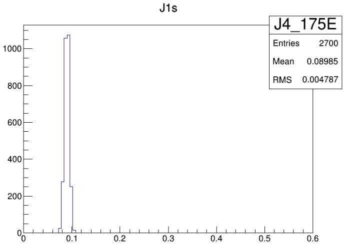
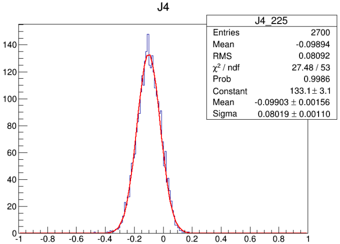

J4
J4_50
Entries 2700
Mean -0.09173
RMS 0.1726
χ² / ndf 103.1 / 99
Prob 0.3681
Constant 61.95 ± 1.51
Mean -0.09162 ± 0.00334
Sigma 0.1678 ± 0.0025
J1s
J4_50E
Entries 2700
Mean 0.1648
RMS 0.01677
J4
J4_75
Entries 2700
Mean -0.09637
RMS 0.1394
χ² / ndf 66.82 / 83
Prob 0.9025
Constant 76.33 ± 1.87
Mean -0.09615 ± 0.00273
Sigma 0.1381 ± 0.0021
J1s
J4_75E
Entries 2700
Mean 0.1357
RMS 0.01104

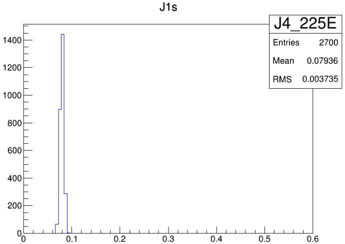

J4
J4_125
Entries 2700
Mean -0.09798
RMS 0.1074
χ² / ndf 57.49 / 68
Prob 0.8143
Constant 100 ± 2.4
Mean -0.09695 ± 0.00208
Sigma 0.1057 ± 0.0014

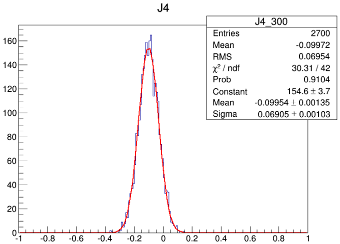

J1s
J4_125E
Entries 2700
Mean 0.1059
RMS 0.006729

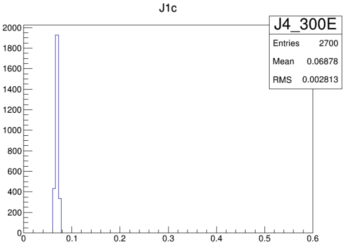

J4
J4_175
Entries 2700
Mean -0.09975
RMS 0.0915
χ² / ndf 50.56 / 57
Prob 0.7137
Constant 118.4 ± 2.8
Mean -0.1002 ± 0.0018
Sigma 0.0894 ± 0.0012


J1s
J4_175E
Entries 2700
Mean 0.08985
RMS 0.004787









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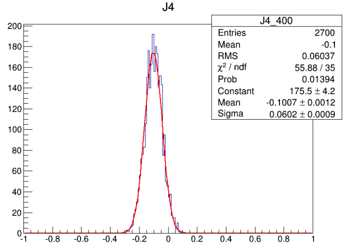
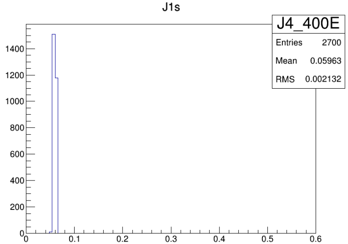
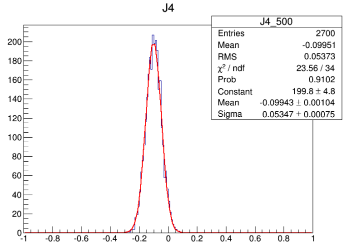
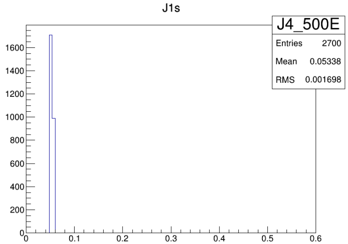
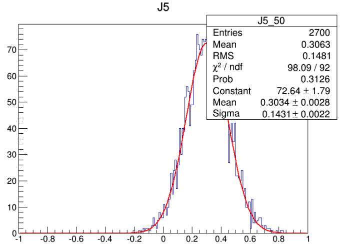
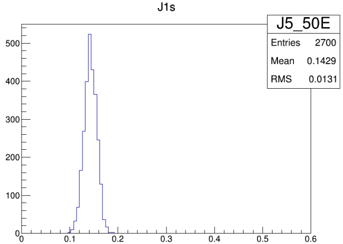

J4
J4_400
Entries 2700
Mean -0.1
RMS 0.06037
χ² / ndf 55.88 / 35
Prob 0.01394
Constant 175.5 ± 4.2
Mean -0.1007 ± 0.0012
Sigma 0.0602 ± 0.0009

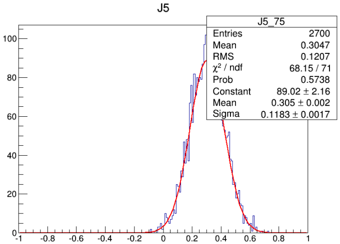

J1s
J4_400E
Entries 2700
Mean 0.05963
RMS 0.002132

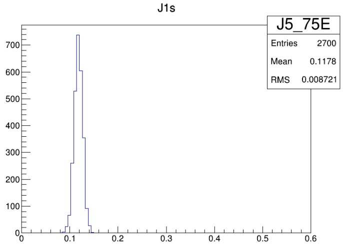

J4
J4_500
Entries 2700
Mean -0.09951
RMS 0.05373
χ² / ndf 23.56 / 34
Prob 0.9102
Constant 199.8 ± 4.8
Mean -0.09943 ± 0.00104
Sigma 0.05347 ± 0.00075

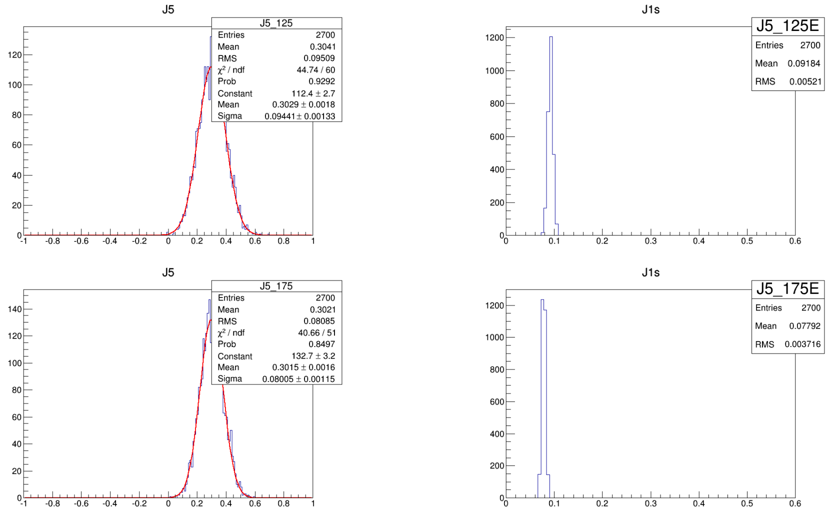

J1s
J4_500E
Entries 2700
Mean 0.05338
RMS 0.001698

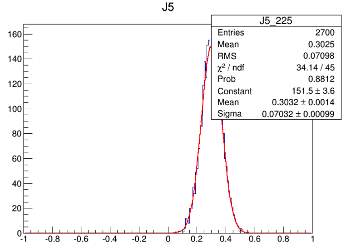

J5
J5_50
Entries 2700
Mean 0.3063
RMS 0.1481
χ² / ndf 98.09 / 92
Prob 0.3126
Constant 72.64 ± 1.79
Mean 0.3034 ± 0.0028
Sigma 0.1431 ± 0.0022

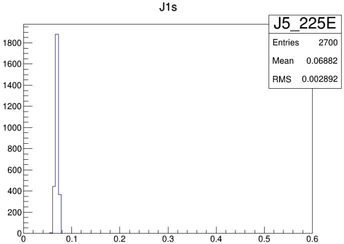

J1s
J5_50E
Entries 2700
Mean 0.1429
RMS 0.0131

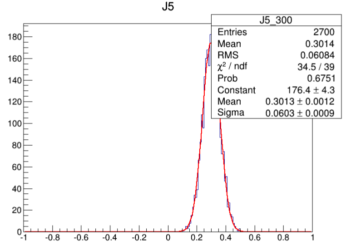

J5
J5_75
Entries 2700
Mean 0.3047
RMS 0.1207
χ² / ndf 68.15 / 71
Prob 0.5738
Constant 89.02 ± 2.16
Mean 0.305 ± 0.002
Sigma 0.1183 ± 0.0017

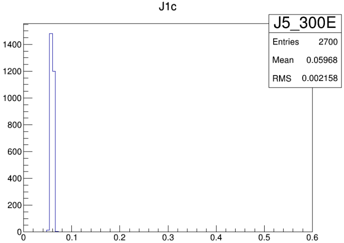

J1s
J5_75E
Entries 2700
Mean 0.1178
RMS 0.008721

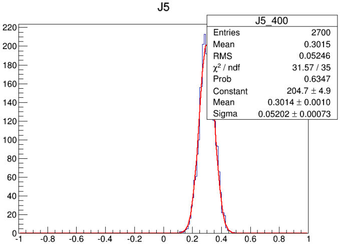

J5
J5_125
Entries 2700
Mean 0.3041
RMS 0.09509
χ2 / ndf 44.74 / 60
Prob 0.9292
Constant 112.4 ± 2.7
Mean 0.3029 ± 0.0018
Sigma 0.09441 ± 0.00133
J1s
J5_125E
Entries 2700
Mean 0.09184
RMS 0.00521
J5
J5_175
Entries 2700
Mean 0.3021
RMS 0.08085
χ2 / ndf 40.66 / 51
Prob 0.8497
Constant 132.7 ± 3.2
Mean 0.3015 ± 0.0016
Sigma 0.08005 ± 0.00115
J1s
J5_175E
Entries 2700
Mean 0.07792
RMS 0.003716

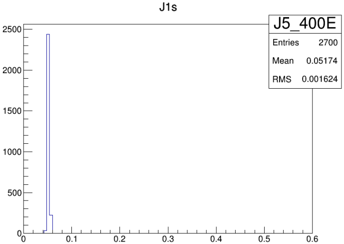

J5
J5_225
Entries 2700
Mean 0.3025
RMS 0.07098
χ² / ndf 34.14 / 45
Prob 0.8812
Constant 151.5 ± 3.6
Mean 0.3032 ± 0.0014
Sigma 0.07032 ± 0.00099

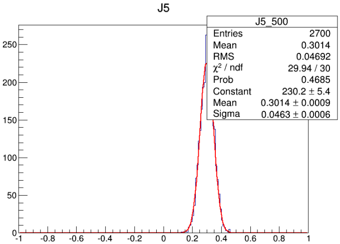

J1s
J5_225E
Entries 2700
Mean 0.06882
RMS 0.002892

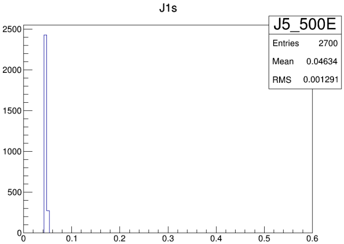

J5
J5_300
Entries 2700
Mean 0.3014
RMS 0.06084
χ² / ndf 34.5 / 39
Prob 0.6751
Constant 176.4 ± 4.3
Mean 0.3013 ± 0.0012
Sigma 0.0603 ± 0.0009

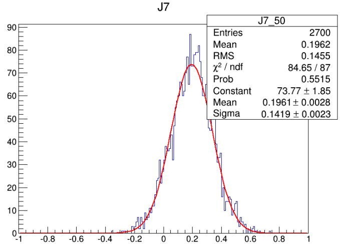

J1c
J5_300E
Entries 2700
Mean 0.05968
RMS 0.002158

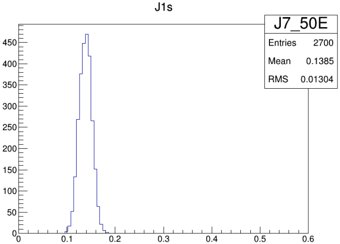

J5
J5_400
Entries 2700
Mean 0.3015
RMS 0.05246
χ² / ndf 31.57 / 35
Prob 0.6347
Constant 204.7 ± 4.9
Mean 0.3014 ± 0.0010
Sigma 0.05202 ± 0.00073

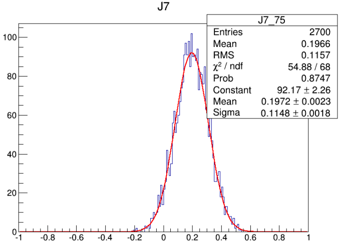

J1s
J5_400E
Entries 2700
Mean 0.05174
RMS 0.001624

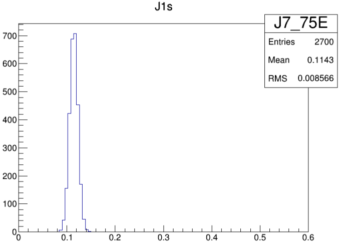

J5
J5_500
Entries 2700
Mean 0.3014
RMS 0.04692
χ² / ndf 29.94 / 30
Prob 0.4685
Constant 230.2 ± 5.4
Mean 0.3014 ± 0.0009
Sigma 0.0463 ± 0.0006

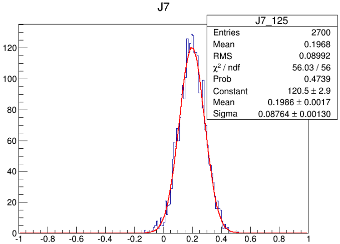

J1s
J5_500E
Entries 2700
Mean 0.04634
RMS 0.001291

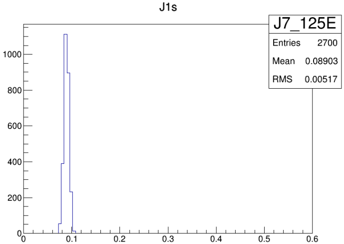

J7
J7_50
Entries 2700
Mean 0.1962
RMS 0.1455
χ^2 / ndf 84.65 / 87
Prob 0.5515
Constant 73.77 ± 1.85
Mean 0.1961 ± 0.0028
Sigma 0.1419 ± 0.0023

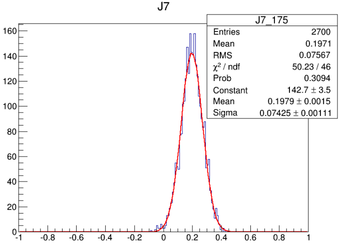

J1s
J7_50E
Entries 2700
Mean 0.1385
RMS 0.01304

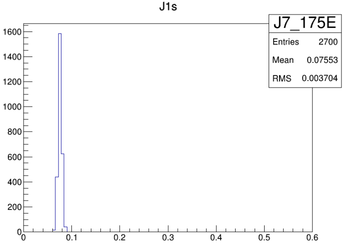

J7
J7_75
Entries 2700
Mean 0.1966
RMS 0.1157
χ^2 / ndf 54.88 / 68
Prob 0.8747
Constant 92.17 ± 2.26
Mean 0.1972 ± 0.0023
Sigma 0.1148 ± 0.0018

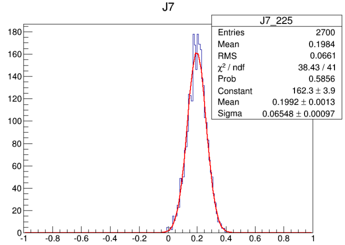

J1s
J7_75E
Entries 2700
Mean 0.1143
RMS 0.008566

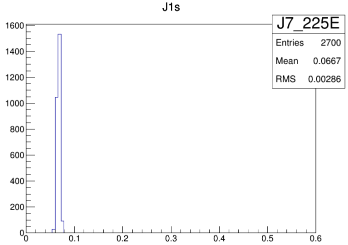

J7
J7_125
Entries 2700
Mean 0.1968
RMS 0.08992
χ² / ndf 56.03 / 56
Prob 0.4739
Constant 120.5 ± 2.9
Mean 0.1986 ± 0.0017
Sigma 0.08764 ± 0.00130

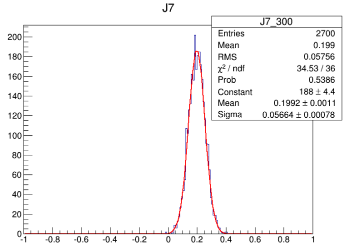

J1s
J7_125E
Entries 2700
Mean 0.08903
RMS 0.00517

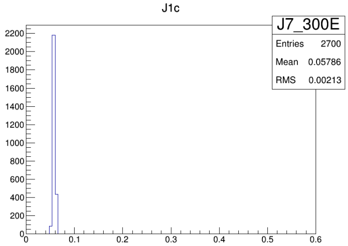

J7
J7_175
Entries 2700
Mean 0.1971
RMS 0.07567
χ² / ndf 50.23 / 46
Prob 0.3094
Constant 142.7 ± 3.5
Mean 0.1979 ± 0.0015
Sigma 0.07425 ± 0.00111

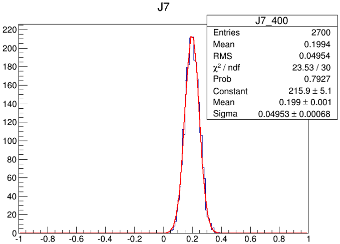

J1s
J7_175E
Entries 2700
Mean 0.07553
RMS 0.003704

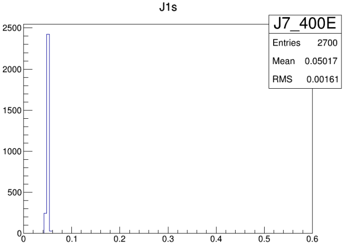

J7
J7_225
Entries 2700
Mean 0.1984
RMS 0.0661
χ² / ndf 38.43 / 41
Prob 0.5856
Constant 162.3 ± 3.9
Mean 0.1992 ± 0.0013
Sigma 0.06548 ± 0.00097

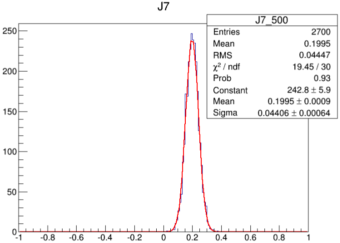

J1s
J7_225E
Entries 2700
Mean 0.0667
RMS 0.00286

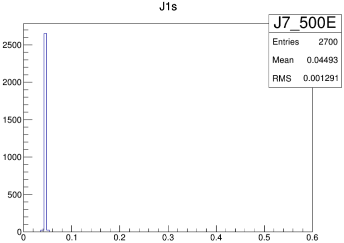

J7
J7_300
Entries 2700
Mean 0.199
RMS 0.05756
χ² / ndf 34.53 / 36
Prob 0.5386
Constant 188 ± 4.4
Mean 0.1992 ± 0.0011
Sigma 0.05664 ± 0.00078


J1c
J7_300E
Entries 2700
Mean 0.05786
RMS 0.00213









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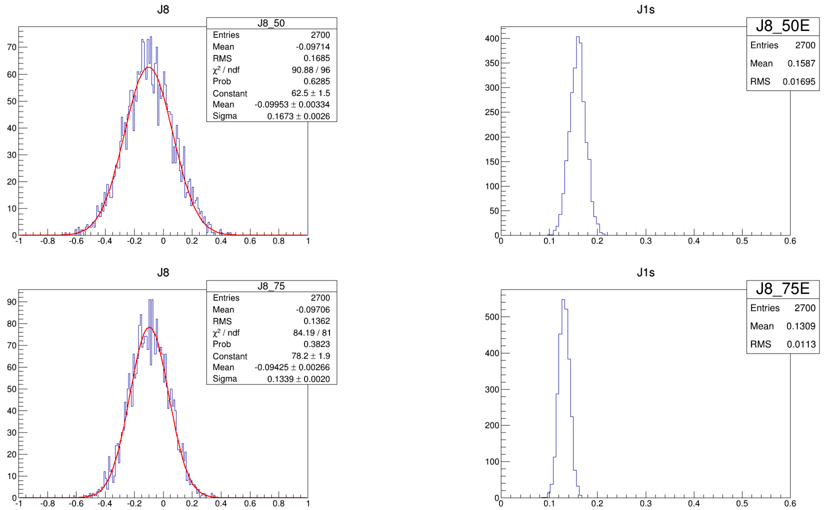

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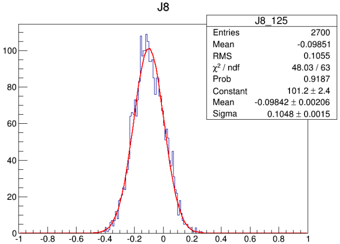
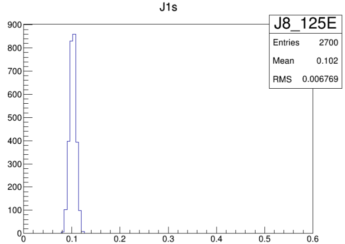
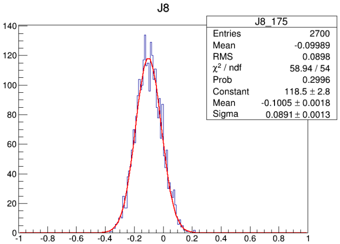
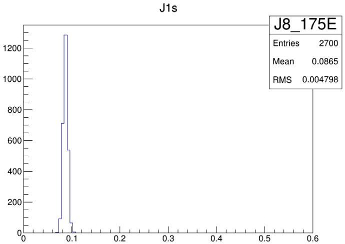
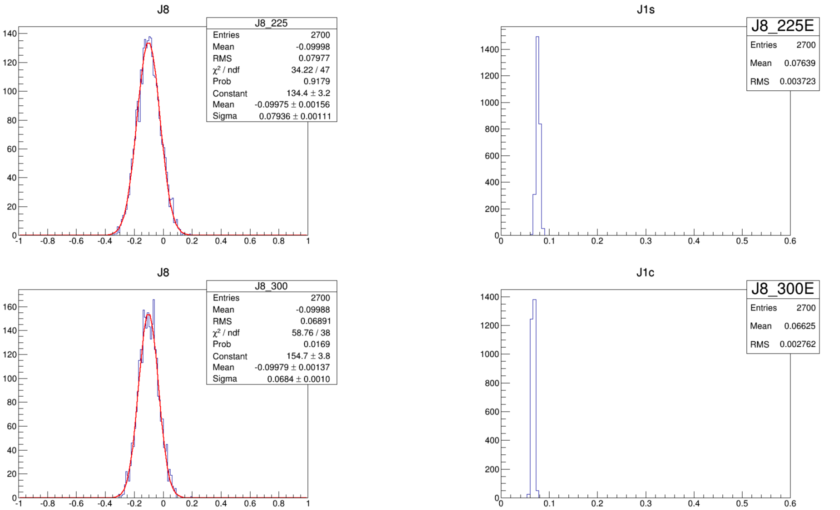
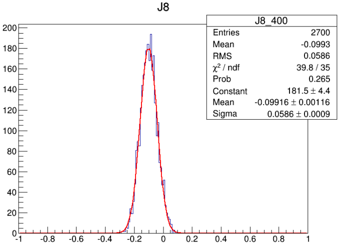

J8
J8_125
Entries 2700
Mean -0.09851
RMS 0.1055
χ² / ndf 48.03 / 63
Prob 0.9187
Constant 101.2 ± 2.4
Mean -0.09842 ± 0.00206
Sigma 0.1048 ± 0.0015

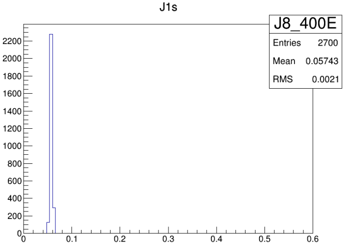

J1s
J8_125E
Entries 2700
Mean 0.102
RMS 0.006769

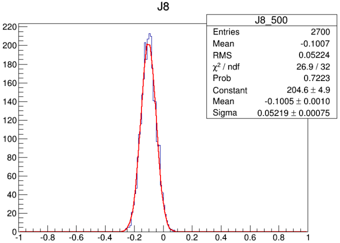

J8
J8_175
Entries 2700
Mean -0.09989
RMS 0.0898
χ² / ndf 58.94 / 54
Prob 0.2996
Constant 118.5 ± 2.8
Mean -0.1005 ± 0.0018
Sigma 0.0891 ± 0.0013

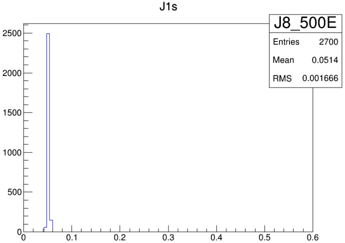

J1s
J8_175E
Entries 2700
Mean 0.0865
RMS 0.004798

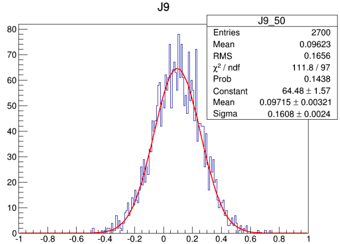

J8
J8_225
Entries 2700
Mean -0.09998
RMS 0.07977
χ² / ndf 34.22 / 47
Prob 0.9179
Constant 134.4 ± 3.2
Mean -0.09975 ± 0.00156
Sigma 0.07936 ± 0.00111
J1s
J8_225E
Entries 2700
Mean 0.07639
RMS 0.003723
J8
J8_300
Entries 2700
Mean -0.09988
RMS 0.06891
χ² / ndf 58.76 / 38
Prob 0.0169
Constant 154.7 ± 3.8
Mean -0.09979 ± 0.00137
Sigma 0.0684 ± 0.0010
J1c
J8_300E
Entries 2700
Mean 0.06625
RMS 0.002762

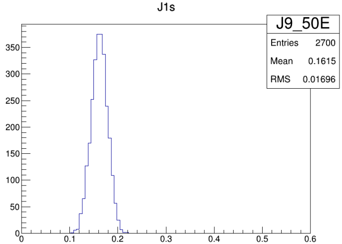

J8
J8_400
Entries 2700
Mean -0.0993
RMS 0.0586
χ² / ndf 39.8 / 35
Prob 0.265
Constant 181.5 ± 4.4
Mean -0.09916 ± 0.00116
Sigma 0.0586 ± 0.0009

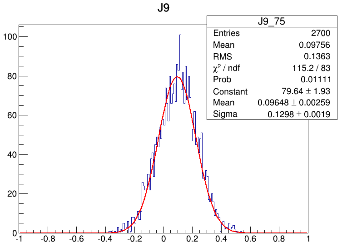

J1s
J8_400E
Entries 2700
Mean 0.05743
RMS 0.0021

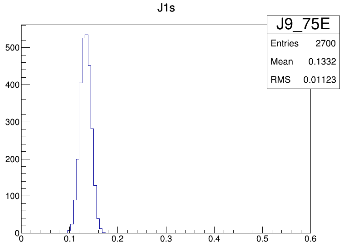

J8
J8_500
Entries 2700
Mean -0.1007
RMS 0.05224
χ² / ndf 26.9 / 32
Prob 0.7223
Constant 204.6 ± 4.9
Mean -0.1005 ± 0.0010
Sigma 0.05219 ± 0.00075

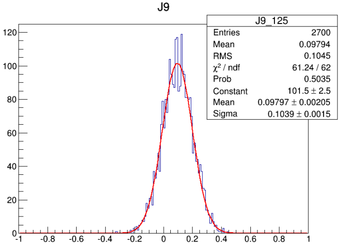

J1s
J8_500E
Entries 2700
Mean 0.0514
RMS 0.001666

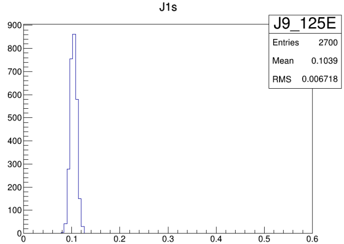

J9
J9_50
Entries 2700
Mean 0.09623
RMS 0.1656
χ² / ndf 111.8 / 97
Prob 0.1438
Constant 64.48 ± 1.57
Mean 0.09715 ± 0.00321
Sigma 0.1608 ± 0.0024

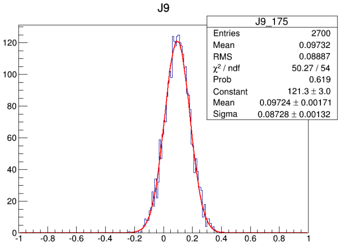

J1s
J9_50E
Entries 2700
Mean 0.1615
RMS 0.01696

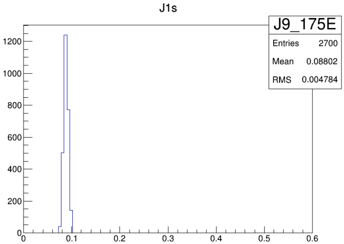

J9
J9_75
Entries 2700
Mean 0.09756
RMS 0.1363
χ² / ndf 115.2 / 83
Prob 0.01111
Constant 79.64 ± 1.93
Mean 0.09648 ± 0.00259
Sigma 0.1298 ± 0.0019

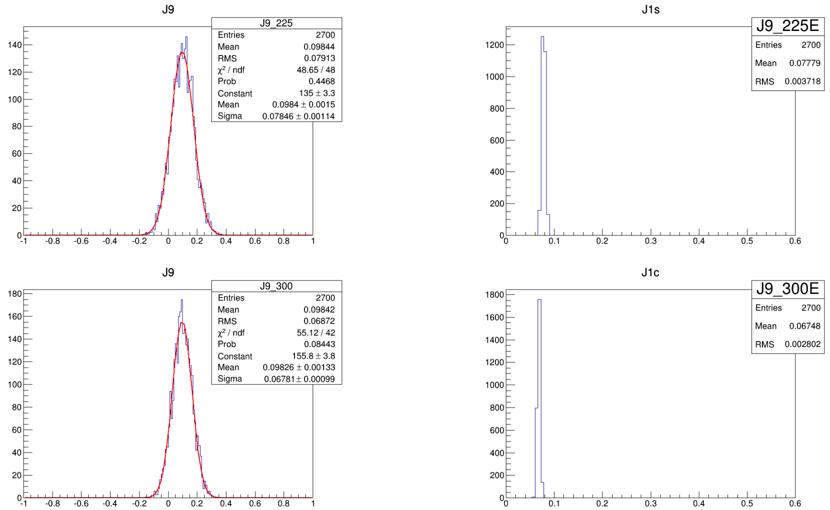

J1s
J9_75E
Entries 2700
Mean 0.1332
RMS 0.01123

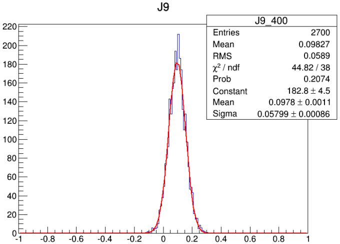

J9
J9_125
Entries 2700
Mean 0.09794
RMS 0.1045
χ² / ndf 61.24 / 62
Prob 0.5035
Constant 101.5 ± 2.5
Mean 0.09797 ± 0.00205
Sigma 0.1039 ± 0.0015

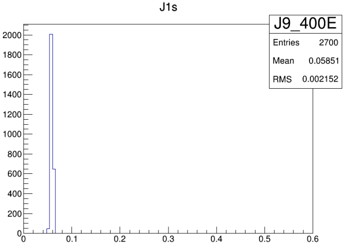

J1s
J9_125E
Entries 2700
Mean 0.1039
RMS 0.006718

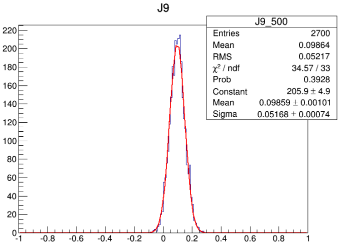

J9
J9_175
Entries 2700
Mean 0.09732
RMS 0.08887
χ² / ndf 50.27 / 54
Prob 0.619
Constant 121.3 ± 3.0
Mean 0.09724 ± 0.00171
Sigma 0.08728 ± 0.00132

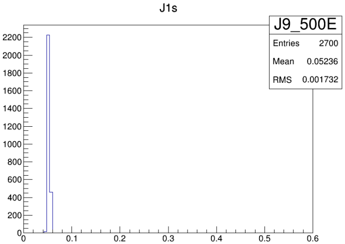

J1s
J9_175E
Entries 2700
Mean 0.08802
RMS 0.004784

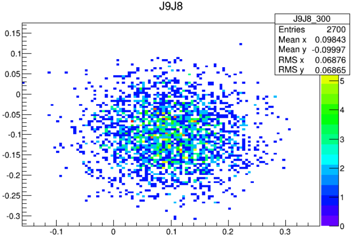

J9
J9_225
Entries 2700
Mean 0.09844
RMS 0.07913
χ² / ndf 48.65 / 48
Prob 0.4468
Constant 135 ± 3.3
Mean 0.0984 ± 0.0015
Sigma 0.07846 ± 0.00114
J1s
J9_225E
Entries 2700
Mean 0.07779
RMS 0.003718
J9
J9_300
Entries 2700
Mean 0.09842
RMS 0.06872
χ² / ndf 55.12 / 42
Prob 0.08443
Constant 155.8 ± 3.8
Mean 0.09826 ± 0.00133
Sigma 0.06781 ± 0.00099
J1c
J9_300E
Entries 2700
Mean 0.06748
RMS 0.002802

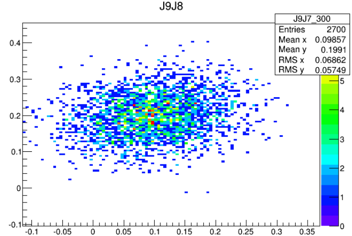

J9
J9_400
Entries 2700
Mean 0.09827
RMS 0.0589
χ² / ndf 44.82 / 38
Prob 0.2074
Constant 182.8 ± 4.5
Mean 0.0978 ± 0.0011
Sigma 0.05799 ± 0.00086

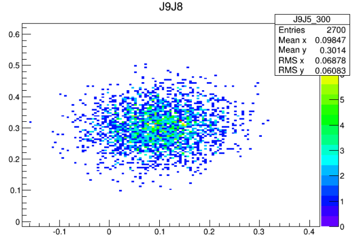

J1s
J9_400E
Entries 2700
Mean 0.05851
RMS 0.002152

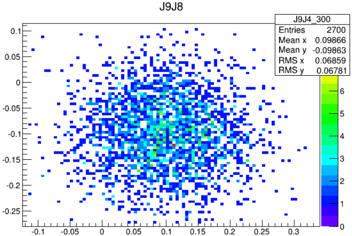

J9
J9_500
Entries 2700
Mean 0.09864
RMS 0.05217
χ² / ndf 34.57 / 33
Prob 0.3928
Constant 205.9 ± 4.9
Mean 0.09859 ± 0.00101
Sigma 0.05168 ± 0.00074


J1s
J9_500E
Entries 2700
Mean 0.05236
RMS 0.001732









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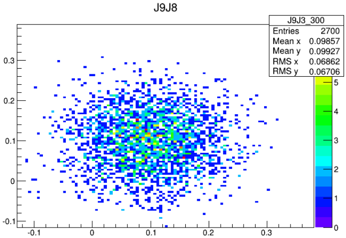
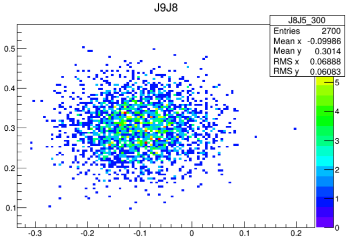
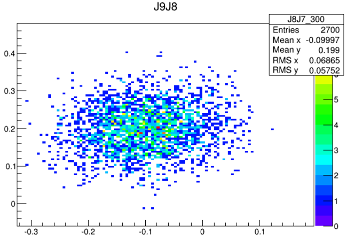
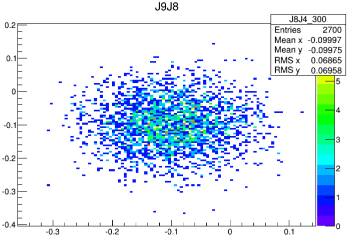

J9J8
J9J3_300
Entries 2700
Mean x 0.09857
Mean y 0.09927
RMS x 0.06862
RMS y 0.06706


J9J8
J8J5_300
Entries 2700
Mean x -0.09986
Mean y 0.3014
RMS x 0.06888
RMS y 0.06083


J9J8
J8J7_300
Entries 2700
Mean x -0.09997
Mean y 0.199
RMS x 0.06865
RMS y 0.05752


J9J8
J8J4_300
Entries 2700
Mean x -0.09997
Mean y -0.09975
RMS x 0.06865
RMS y 0.06958