

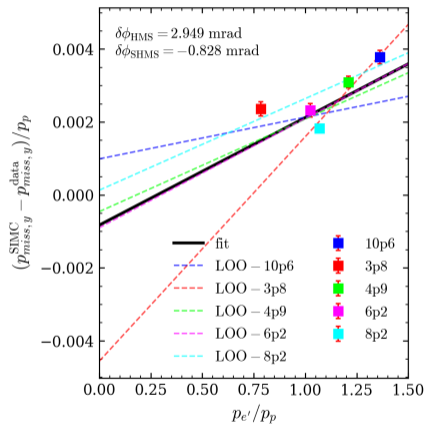
# **Kaon LT Meeting**

May 28, 2026

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# Out-of-plane angle offsets



- theoretical code for computing the derivative of  $E_m, P_m^{\text{per}}, P_{\text{miss}}^{\text{para}}, W$  w.r.t. the offsets
- $dE_{\text{beam}}, d\theta_{\text{HMS}}, dp_{\text{HMS}}, d\theta_{\text{SHMS}}, dp_{\text{SHMS}} \Rightarrow 4$  equations, 5 unknowns
- tune the offsets until the difference between data and SIMC peaks are minimized

$$\begin{bmatrix} \frac{\partial E_m}{\partial E_{\text{beam}}} & \frac{\partial E_m}{\partial \theta_{\text{HMS}}} & \frac{\partial E_m}{\partial p_{\text{HMS}}} & \frac{\partial E_m}{\partial \theta_{\text{SHMS}}} & \frac{\partial E_m}{\partial p_{\text{SHMS}}} \\ \frac{\partial P_m^{\text{per}}}{\partial E_{\text{beam}}} & \frac{\partial P_m^{\text{per}}}{\partial \theta_{\text{HMS}}} & \frac{\partial P_m^{\text{per}}}{\partial p_{\text{HMS}}} & \frac{\partial P_m^{\text{per}}}{\partial \theta_{\text{SHMS}}} & \frac{\partial P_m^{\text{per}}}{\partial p_{\text{SHMS}}} \\ \frac{\partial P_{\text{miss}}^{\text{para}}}{\partial E_{\text{beam}}} & \frac{\partial P_{\text{miss}}^{\text{para}}}{\partial \theta_{\text{HMS}}} & \frac{\partial P_{\text{miss}}^{\text{para}}}{\partial p_{\text{HMS}}} & \frac{\partial P_{\text{miss}}^{\text{para}}}{\partial \theta_{\text{SHMS}}} & \frac{\partial P_{\text{miss}}^{\text{para}}}{\partial p_{\text{SHMS}}} \\ \frac{\partial W}{\partial E_{\text{beam}}} & \frac{\partial W}{\partial \theta_{\text{HMS}}} & \frac{\partial W}{\partial p_{\text{HMS}}} & \frac{\partial W}{\partial \theta_{\text{SHMS}}} & \frac{\partial W}{\partial p_{\text{SHMS}}} \end{bmatrix} \begin{bmatrix} dE_{\text{beam}} \\ d\theta_{\text{HMS}} \\ dp_{\text{HMS}} \\ d\theta_{\text{SHMS}} \\ dp_{\text{SHMS}} \end{bmatrix} = \begin{bmatrix} E_m^{\text{data}} - E_m^{\text{SIMC}} \\ P_m^{\text{per,data}} - P_m^{\text{per,SIMC}} \\ P_{\text{miss}}^{\text{para,data}} - P_{\text{miss}}^{\text{para,SIMC}} \\ W^{\text{data}} - W^{\text{SIMC}} \end{bmatrix}$$

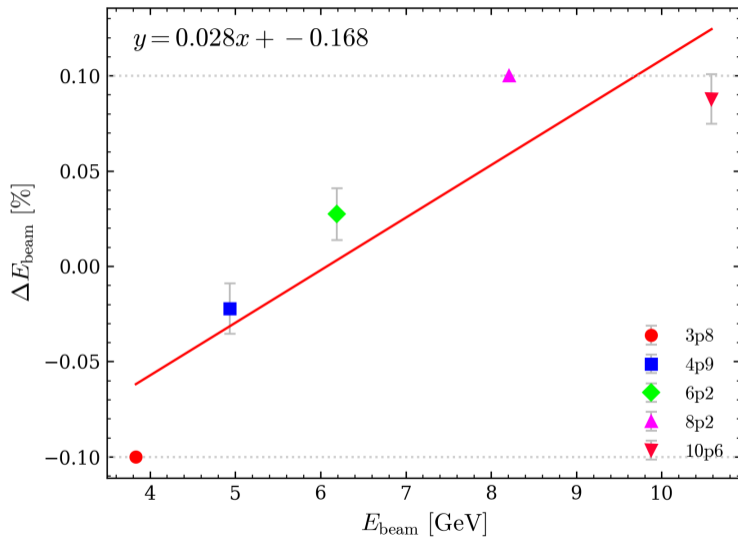
- have the option to stack the settings while fixing  $d\theta$  and  $dp$  to be the same for all kinematics
- 5 settings  $\Rightarrow$  20 equations, 9 unknowns

$$\begin{bmatrix}
 \frac{\partial E_m^{(1)}}{\partial E_{\text{beam}}^{(1)}} & \frac{\partial E_m^{(1)}}{\partial E_{\text{beam}}^{(2)}} & \cdots & \frac{\partial E_m^{(1)}}{\partial E_{\text{beam}}^{(n)}} & \frac{\partial E_m^{(1)}}{\partial \theta_{\text{HMS}}} & \frac{\partial E_m^{(1)}}{\partial p_{\text{HMS}}} & \cdots \\
 \frac{\partial E_m^{(2)}}{\partial E_{\text{beam}}^{(1)}} & \frac{\partial E_m^{(2)}}{\partial E_{\text{beam}}^{(2)}} & \cdots & \frac{\partial E_m^{(2)}}{\partial E_{\text{beam}}^{(n)}} & \frac{\partial E_m^{(2)}}{\partial \theta_{\text{HMS}}} & \frac{\partial E_m^{(2)}}{\partial p_{\text{HMS}}} & \cdots \\
 \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \ddots \\
 \frac{\partial E_m^{(n)}}{\partial E_{\text{beam}}^{(1)}} & \frac{\partial E_m^{(n)}}{\partial E_{\text{beam}}^{(2)}} & \cdots & \frac{\partial E_m^{(n)}}{\partial E_{\text{beam}}^{(n)}} & \frac{\partial E_m^{(n)}}{\partial \theta_{\text{HMS}}} & \frac{\partial E_m^{(n)}}{\partial p_{\text{HMS}}} & \cdots \\
 \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \ddots
 \end{bmatrix}
 \begin{bmatrix}
 dE_{\text{beam}}^{(1)} \\
 dE_{\text{beam}}^{(2)} \\
 \vdots \\
 dE_{\text{beam}}^{(n)} \\
 d\theta_{\text{HMS}} \\
 dp_{\text{HMS}} \\
 \vdots
 \end{bmatrix}
 =
 \begin{bmatrix}
 \Delta E_m^{(1)} \\
 \Delta E_m^{(2)} \\
 \vdots \\
 \Delta P_m^{\text{per},(1)} \\
 \vdots
 \end{bmatrix}$$

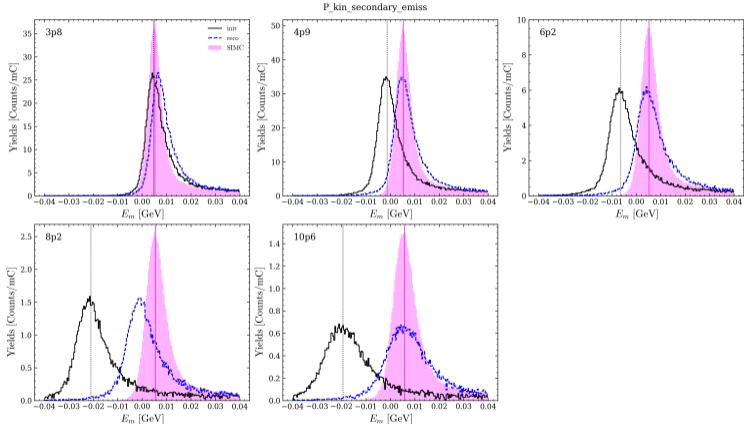
## Heepcheck using all settings

Setting	$E_{\text{beam}}$ (GeV)	$\theta_{\text{HMS}}$ (deg)	$\theta_{\text{SHMS}}$ (deg)	$p_{\text{HMS}}$ (GeV)	$p_{\text{SHMS}}$ (GeV)	$dE_{\text{beam}}$ (%)	$d\theta_{\text{HMS}}$ (mrad)	$dp_{\text{HMS}}$ (%)	$d\theta_{\text{SHMS}}$ (mrad)	$dp_{\text{SHMS}}$ (%)
3p8	3.835	-38.600	29.305	2.026	2.583	$-0.1000 \pm 0.0000$	$0.3396 \pm 0.2125$	$-0.1561 \pm 0.0100$	$0.5769 \pm 0.2192$	$-0.1192 \pm 0.0168$
4p9	4.933	-27.150	33.500	3.124	2.583	$-0.0222 \pm 0.0132$	$0.3396 \pm 0.2125$	$-0.1561 \pm 0.0100$	$0.5769 \pm 0.2192$	$-0.1192 \pm 0.0168$
6p2	6.190	-27.250	28.530	3.571	3.486	$0.0273 \pm 0.0137$	$0.3396 \pm 0.2125$	$-0.1561 \pm 0.0100$	$0.5769 \pm 0.2192$	$-0.1192 \pm 0.0168$
8p2	8.209	-24.000	25.775	4.672	4.371	$0.1000 \pm 0.0000$	$0.3396 \pm 0.2125$	$-0.1561 \pm 0.0100$	$0.5769 \pm 0.2192$	$-0.1192 \pm 0.0168$
10p6	10.585	-18.845	26.145	6.590	4.840	$0.0878 \pm 0.0130$	$0.3396 \pm 0.2125$	$-0.1561 \pm 0.0100$	$0.5769 \pm 0.2192$	$-0.1192 \pm 0.0168$

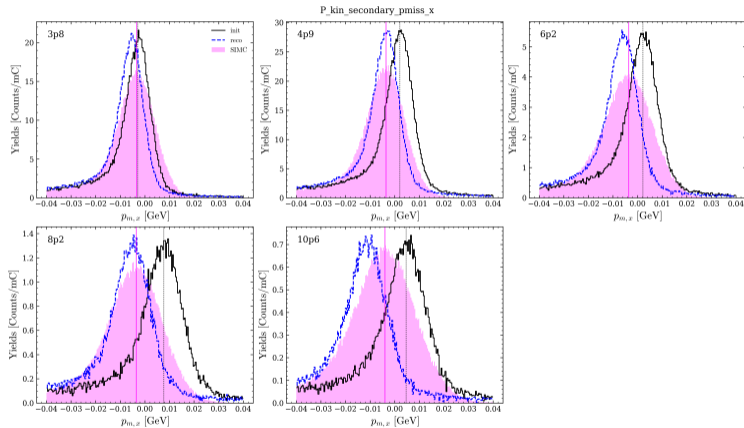
## Heepcheck using all settings



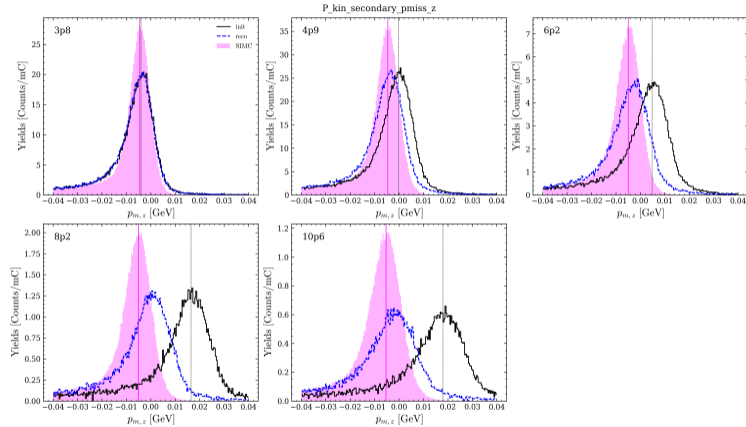
# Heepcheck using all settings P\_kin\_secondary\_emiss



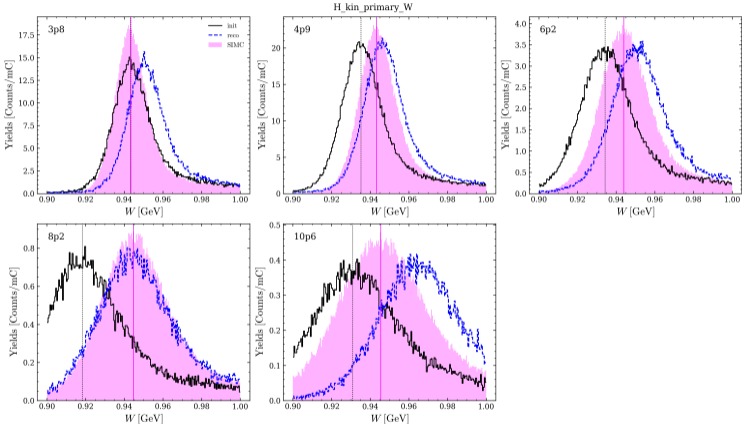
# Heepcheck using all settings P\_kin\_secondary\_pmiss\_x



# Heepcheck using all settings P\_kin\_secondary\_pmiss\_z



# Heepcheck using all settings H\_kin\_primary\_W

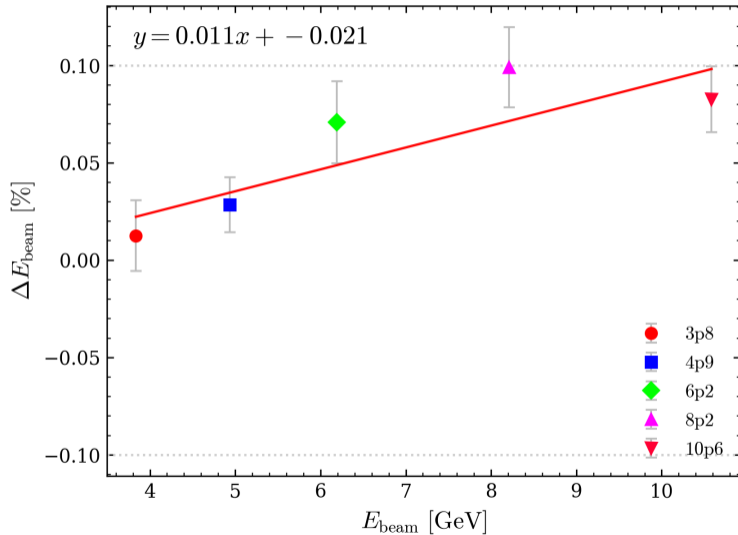


## Heapcheck on independent settings

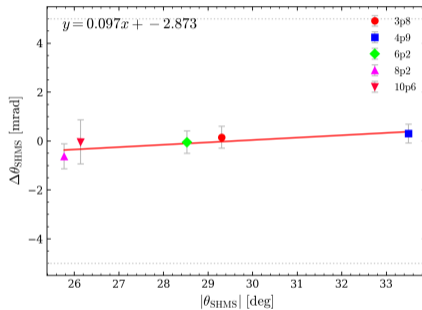
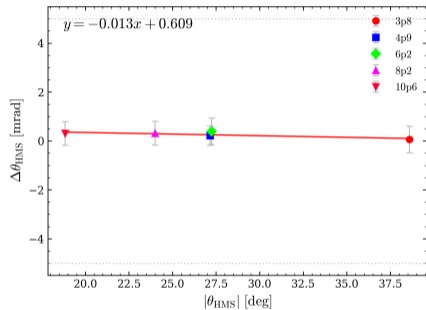
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Setting	$E_{\text{beam}}$ (GeV)	$\theta_{\text{HMS}}$ (deg)	$\theta_{\text{SHMS}}$ (deg)	$p_{\text{HMS}}$ (GeV)	$p_{\text{SHMS}}$ (GeV)	$dE_{\text{beam}}$ (%)	$d\theta_{\text{HMS}}$ (mrad)	$dp_{\text{HMS}}$ (%)	$d\theta_{\text{SHMS}}$ (mrad)	$dp_{\text{SHMS}}$ (%)
3p8	3.835	-38.600	29.305	2.026	2.583	$0.0125 \pm 0.0182$	$0.0585 \pm 0.5425$	$0.0064 \pm 0.0298$	$0.1501 \pm 0.4468$	$-0.0036 \pm 0.0124$
4p9	4.933	-27.150	33.500	3.124	2.583	$0.0283 \pm 0.0141$	$0.2152 \pm 0.4004$	$-0.1624 \pm 0.0149$	$0.3013 \pm 0.3842$	$-0.0064 \pm 0.0126$
6p2	6.190	-27.250	28.530	3.571	3.486	$0.0707 \pm 0.0210$	$0.3940 \pm 0.5391$	$-0.1566 \pm 0.0357$	$-0.0509 \pm 0.4592$	$-0.0466 \pm 0.0128$
8p2	8.209	-24.000	25.775	4.672	4.371	$0.0990 \pm 0.0206$	$0.3181 \pm 0.4863$	$-0.3203 \pm 0.0361$	$-0.6323 \pm 0.5113$	$-0.0767 \pm 0.0142$
10p6	10.585	-18.845	26.145	6.590	4.840	$0.0825 \pm 0.0169$	$0.3068 \pm 0.4835$	$-0.1365 \pm 0.0193$	$-0.0419 \pm 0.9006$	$-0.1581 \pm 0.0238$

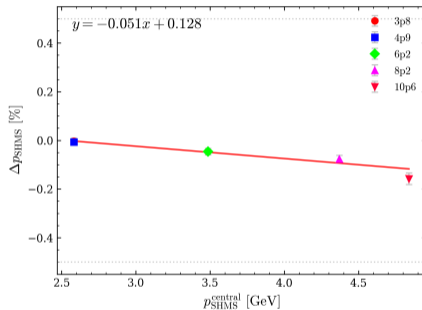
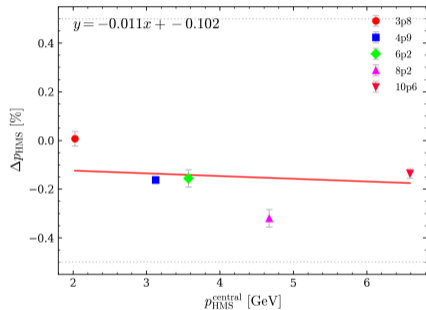
# Heepcheck on independent settings $dE_{\text{beam}}$



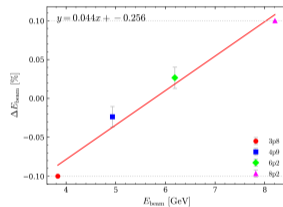
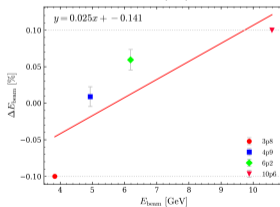
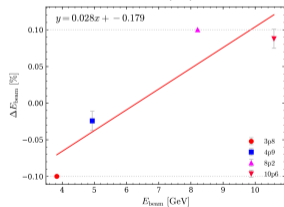
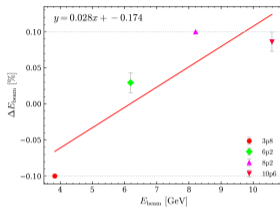
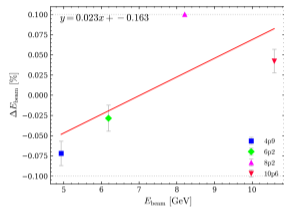
# Heepcheck on independent settings $d\theta$



# Heepcheck on independent settings $dp$



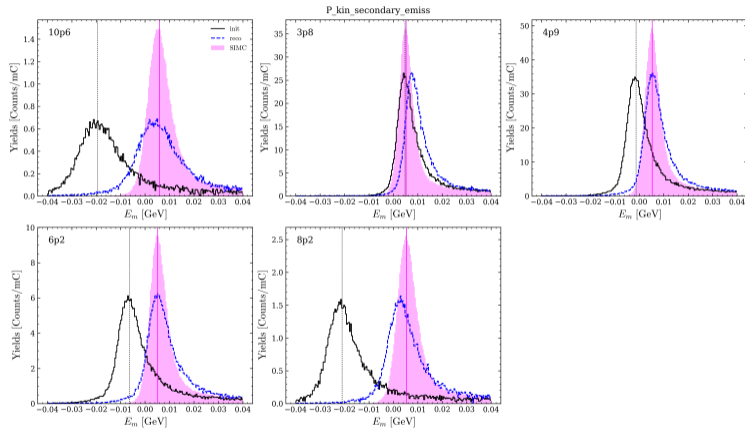
# Heepcheck loocv $dE_{\text{beam}}$



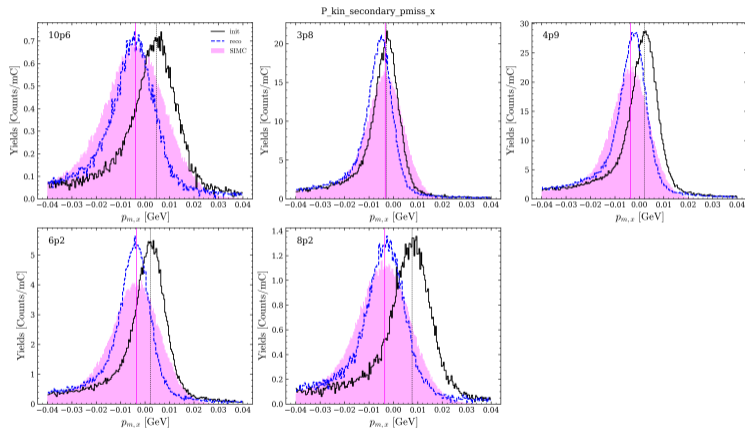
- Instead of using the theoretical derivatives, modify the cost function by directly reconstructing the kinematic variables with the offsets applied and take the  $\chi^2$  of the peaks.

$$\chi^2 = \sum_{i,x} \left( \frac{P_{x,i}^{\text{data}} - P_{x,i}^{\text{SIMC}}}{\sigma_i} \right)^2$$

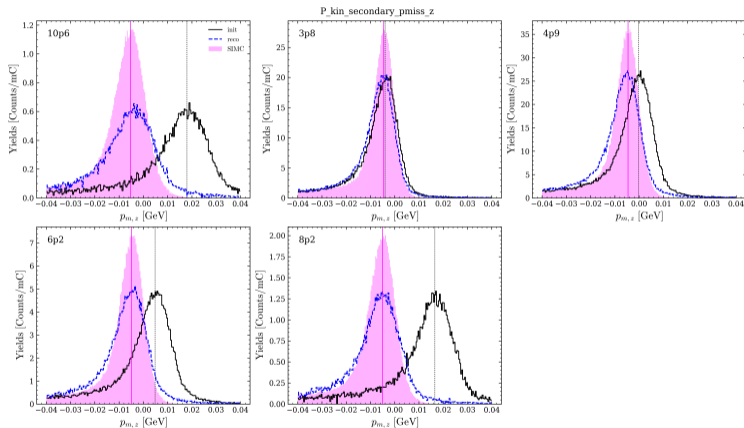
# HeepOptim using all settings P\_kin\_secondary\_emiss



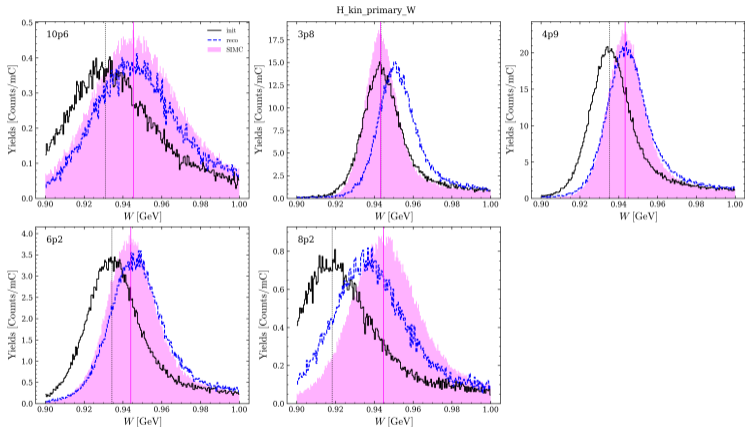
# HeepOptim using all settings P\_kin\_secondary\_pmiss\_x

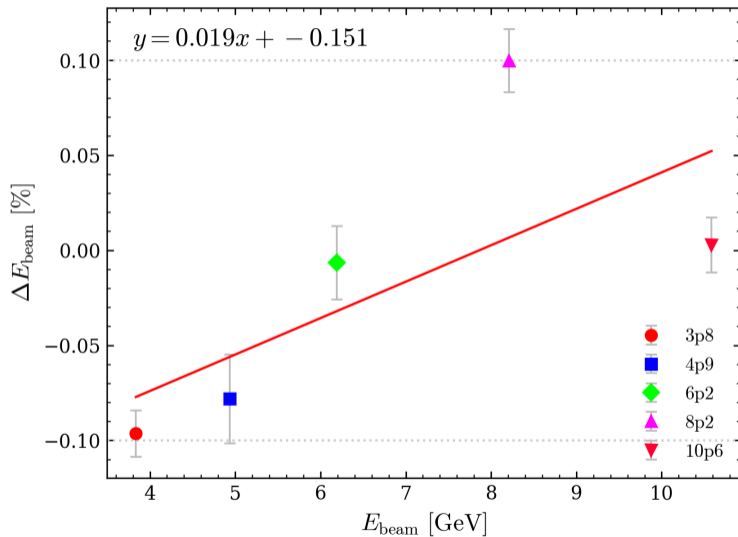


# HeepOptim using all settings P\_kin\_secondary\_pmiss\_z



# HeepOptim using all settings H\_kin\_primary\_W

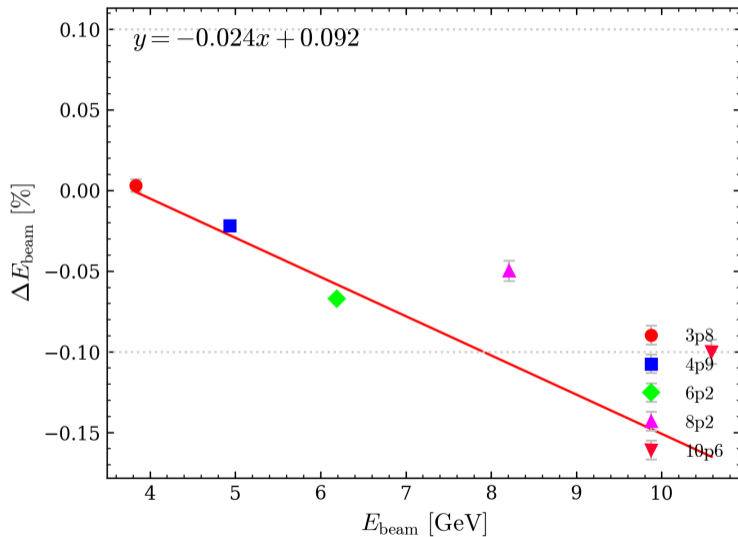




## HeepOptim using all settings

Setting	$E_{\text{beam}}$ (GeV)	$\theta_{\text{HMS}}$ (deg)	$\theta_{\text{SHMS}}$ (deg)	$p_{\text{HMS}}$ (GeV)	$p_{\text{SHMS}}$ (GeV)	$dE_{\text{beam}}$ (%)	$d\theta_{\text{HMS}}$ (mrad)	$dp_{\text{HMS}}$ (%)	$d\theta_{\text{SHMS}}$ (mrad)	$dp_{\text{SHMS}}$ (%)
3p8	3.835	-38.600	29.305	2.026	2.583	$-0.0964 \pm 0.0122$	$-1.2273 \pm 5.2276$	$-0.3725 \pm 0.0091$	$-0.6275 \pm 8.6398$	$0.0271 \pm 0.0116$
4p9	4.933	-27.150	33.500	3.124	2.583	$-0.0782 \pm 0.0234$	$-1.2273 \pm 5.2276$	$-0.3725 \pm 0.0091$	$-0.6275 \pm 8.6398$	$0.0271 \pm 0.0116$
6p2	6.190	-27.250	28.530	3.571	3.486	$-0.0066 \pm 0.0194$	$-1.2273 \pm 5.2276$	$-0.3725 \pm 0.0091$	$-0.6275 \pm 8.6398$	$0.0271 \pm 0.0116$
8p2	8.209	-24.000	25.775	4.672	4.371	$0.0997 \pm 0.0166$	$-1.2273 \pm 5.2276$	$-0.3725 \pm 0.0091$	$-0.6275 \pm 8.6398$	$0.0271 \pm 0.0116$
10p6	10.585	-18.845	26.145	6.590	4.840	$0.0027 \pm 0.0145$	$-1.2273 \pm 5.2276$	$-0.3725 \pm 0.0091$	$-0.6275 \pm 8.6398$	$0.0271 \pm 0.0116$

# HeepOptim using independent settings $dE_{\text{beam}}$



## HeepOptim using independent settings

Setting	$E_{\text{beam}}$ (GeV)	$\theta_{\text{HMS}}$ (deg)	$\theta_{\text{SHMS}}$ (deg)	$p_{\text{HMS}}$ (GeV)	$p_{\text{SHMS}}$ (GeV)	$dE_{\text{beam}}$ (%)	$d\theta_{\text{HMS}}$ (mrad)	$dp_{\text{HMS}}$ (%)	$d\theta_{\text{SHMS}}$ (mrad)	$dp_{\text{SHMS}}$ (%)
3p8	3.835	-38.600	29.305	2.026	2.583	$0.0030 \pm 0.0038$	$-0.4490 \pm 2.2342$	$-0.0191 \pm 0.0031$	$0.1691 \pm 3.1000$	$-0.0295 \pm 0.0031$
4p9	4.933	-27.150	33.500	3.124	2.583	$-0.0219 \pm 0.0010$	$-0.4123 \pm 0.8527$	$-0.2088 \pm 0.0016$	$0.8471 \pm 1.2452$	$-0.0657 \pm 0.0013$
6p2	6.190	-27.250	28.530	3.571	3.486	$-0.0672 \pm 0.0010$	$-0.9067 \pm 0.6261$	$-0.2842 \pm 0.0011$	$0.1641 \pm 1.1069$	$-0.1768 \pm 0.0011$
8p2	8.209	-24.000	25.775	4.672	4.371	$-0.0499 \pm 0.0063$	$-0.7625 \pm 0.8121$	$-0.4995 \pm 0.0047$	$-0.7373 \pm 3.8148$	$-0.1786 \pm 0.0046$
10p6	10.585	-18.845	26.145	6.590	4.840	$-0.1000 \pm 0.0076$	$-1.3435 \pm 0.8428$	$-0.4848 \pm 0.0080$	$-0.4120 \pm 3.4690$	$-0.0776 \pm 0.0029$

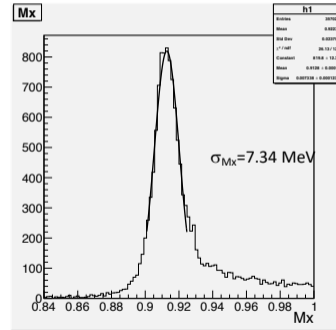
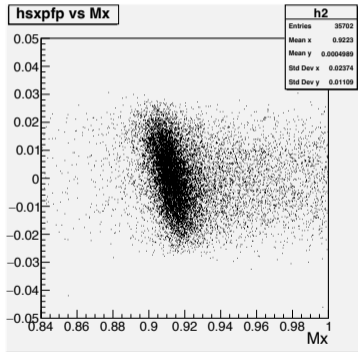
# hms saturation correction - From Dave

Run 4916,  $P_{\text{HMS}} = 5.292 \text{ GeV}$

Clearlest correlation observed with hsexpfp  $\rightarrow$  similar correlation observed during 6 GeV era

$\rightarrow$  Correction to  $\delta$  derived and implemented in 6 GeV analyzer  $\rightarrow$  exists in hcana (hsatcorr = 2000)

$\rightarrow$  Not turned on for analysis of this run



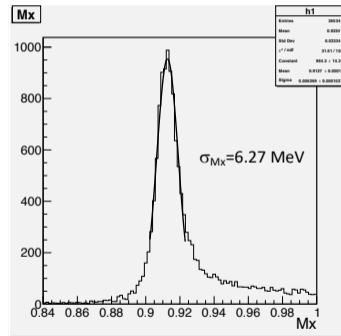
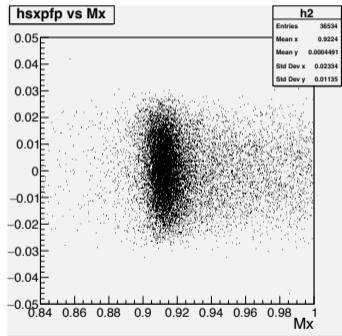
# hms saturation correction - From Dave

Applied corrected to  $\delta$ , determined "by eye"

→ Correction will be momentum dependent – need to look at the remaining data

→ Can't use old correction because we are using matrix elements fit at different momentum than 6 GeV era

$$\delta_{\text{corrected}} = \delta - 6.0 * \text{hsxpf}$$

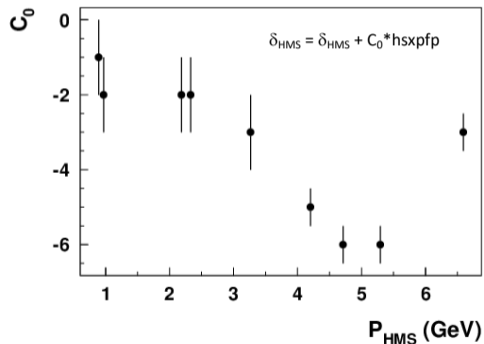


Effect comes from current offset in Q3 power supply. Got new power supplies in 2021 – not an issue anymore.

## hms saturation correction - From Dave

- Used Kaon-LT root trees to determine correction to  $\delta$
- Did not use all settings. Below  $\sim 2$  GeV, effect looks pretty constant
- Error bars smaller at larger momenta smaller since effect is larger – easier to see/correct

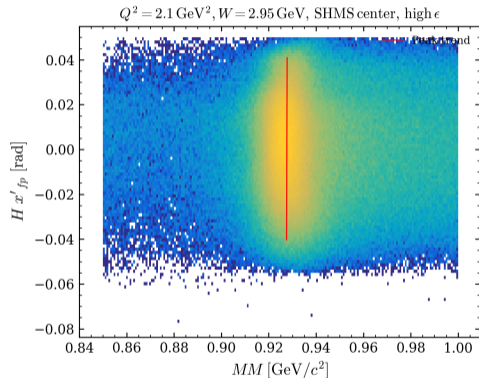
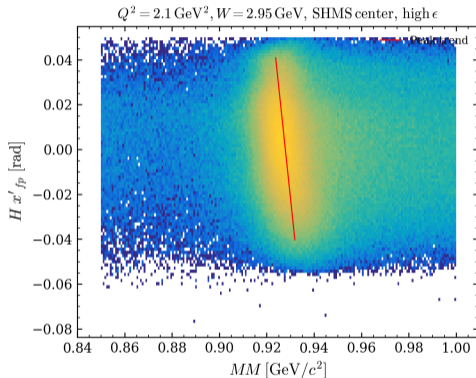
- At  $P=6.59$  GeV, effect is not totally linear
- Are high momentum matrix elements used here?



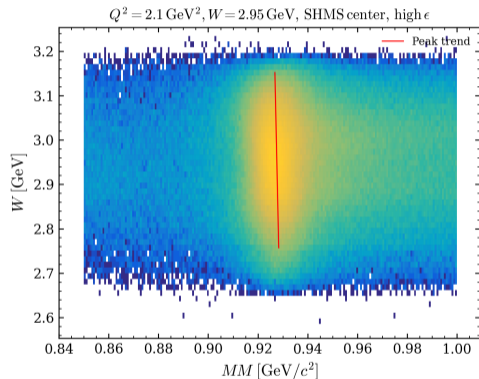
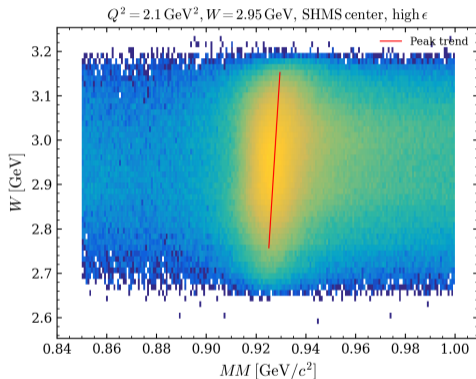
- [link to Dave's slides](#)

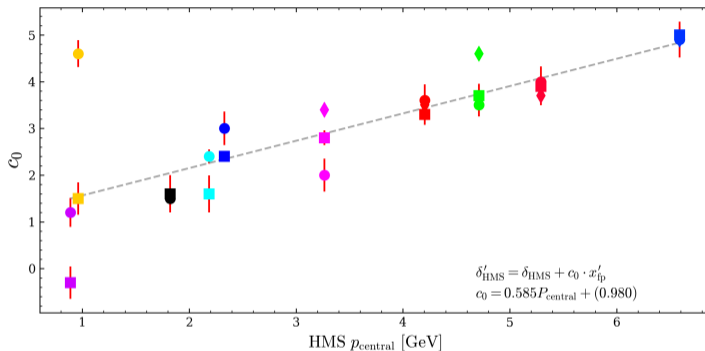
- use `Pass4a` replay  $\Rightarrow$  with the heap offset everyone has been using for kaon LT.
- not to compare with Dave's result as I have no idea what matrix / offsets was used back then.

# hms saturation correction $Q^2 = 2.1 \text{ GeV}^2$ , $W = 2.95 \text{ GeV}$ , center, high $\epsilon$



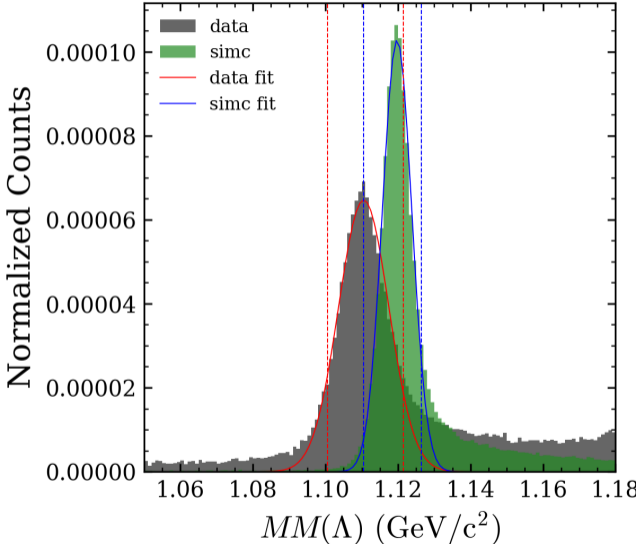
# hms saturation correction $Q^2 = 2.1 \text{ GeV}^2$ , $W = 2.95 \text{ GeV}$ , center, high $\epsilon$





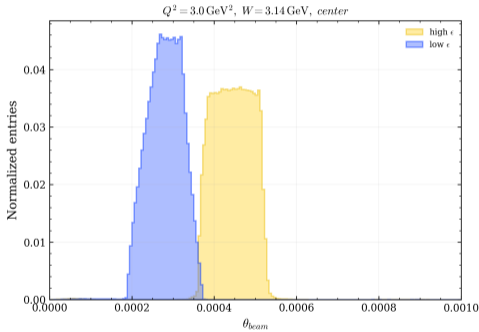
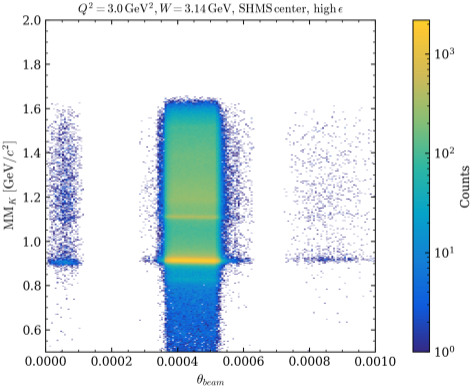
- $Q^2 = 3.0 \text{ GeV}^2, W = 3.14 \text{ GeV}, \text{ left, low } \epsilon$
- $Q^2 = 4.4 \text{ GeV}^2, W = 2.74 \text{ GeV}, \text{ left, low } \epsilon$
- $Q^2 = 5.5 \text{ GeV}^2, W = 3.02 \text{ GeV}, \text{ left, low } \epsilon$
- $Q^2 = 3.0 \text{ GeV}^2, W = 2.32 \text{ GeV}, \text{ left, low } \epsilon$
- $Q^2 = 2.1 \text{ GeV}^2, W = 2.95 \text{ GeV}, \text{ left, low } \epsilon$
- $Q^2 = 3.0 \text{ GeV}^2, W = 3.14 \text{ GeV}, \text{ center, low } \epsilon$
- $Q^2 = 4.4 \text{ GeV}^2, W = 2.74 \text{ GeV}, \text{ center, low } \epsilon$
- $Q^2 = 5.5 \text{ GeV}^2, W = 3.02 \text{ GeV}, \text{ center, low } \epsilon$
- $Q^2 = 3.0 \text{ GeV}^2, W = 2.32 \text{ GeV}, \text{ center, low } \epsilon$
- $Q^2 = 2.1 \text{ GeV}^2, W = 2.95 \text{ GeV}, \text{ center, low } \epsilon$
- $Q^2 = 3.0 \text{ GeV}^2, W = 3.14 \text{ GeV}, \text{ left, high } \epsilon$
- $Q^2 = 4.4 \text{ GeV}^2, W = 2.74 \text{ GeV}, \text{ left, high } \epsilon$
- $Q^2 = 5.5 \text{ GeV}^2, W = 3.02 \text{ GeV}, \text{ left, high } \epsilon$
- $Q^2 = 3.0 \text{ GeV}^2, W = 2.32 \text{ GeV}, \text{ left, high } \epsilon$
- $Q^2 = 2.1 \text{ GeV}^2, W = 2.95 \text{ GeV}, \text{ left, high } \epsilon$
- $Q^2 = 3.0 \text{ GeV}^2, W = 3.14 \text{ GeV}, \text{ center, high } \epsilon$
- $Q^2 = 4.4 \text{ GeV}^2, W = 2.74 \text{ GeV}, \text{ center, high } \epsilon$
- $Q^2 = 5.5 \text{ GeV}^2, W = 3.02 \text{ GeV}, \text{ center, high } \epsilon$
- $Q^2 = 3.0 \text{ GeV}^2, W = 2.32 \text{ GeV}, \text{ center, high } \epsilon$
- $Q^2 = 2.1 \text{ GeV}^2, W = 2.95 \text{ GeV}, \text{ center, high } \epsilon$
- ◆  $Q^2 = 3.0 \text{ GeV}^2, W = 3.14 \text{ GeV}, \text{ right, high } \epsilon$
- ◆  $Q^2 = 4.4 \text{ GeV}^2, W = 2.74 \text{ GeV}, \text{ right, high } \epsilon$
- ◆  $Q^2 = 5.5 \text{ GeV}^2, W = 3.02 \text{ GeV}, \text{ right, high } \epsilon$
- ◆  $Q^2 = 3.0 \text{ GeV}^2, W = 2.32 \text{ GeV}, \text{ right, high } \epsilon$
- ◆  $Q^2 = 2.1 \text{ GeV}^2, W = 2.95 \text{ GeV}, \text{ right, high } \epsilon$

- do not see huge improvement in resolution, need to check my results.



# beam angle ?

- beam angle seems not to be the issue



- check the hms saturation using kaon peak
- use the updated offsets to check production data