THE GEORGE WASHINGTON UNIVERSITY
WASHINGTON, DC

Λ & Σ Analysis Update: Magnetic Field Studies

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K LONG FACILITY

Jefferson Lab

Λ AND Σ

- My primary channel of interest is the Λ baryon.
  - $K^0_L + p \rightarrow \pi^+ + \Lambda$
  - $\Lambda \rightarrow p + \pi^-$
- The other channel, which is a major background, is the Σ^0 baryon
  - $K^0_L + p \rightarrow \pi^+ + \Sigma^0$
  - $\Sigma^0 \rightarrow \Lambda + \gamma$
  - $\Lambda \rightarrow p + \pi^-$
- Based upon just reconstruction N_Λ / N_Σ is about
  - 2 for phase space MC
  - 6 for MC with cross section input
  - 5 ± 0.6 from experimental cross sections in R. J. Yamartino *et al*. in the beam momentum range 1.8 – 5 GeV.

Λ AND Σ^0 RESULTS

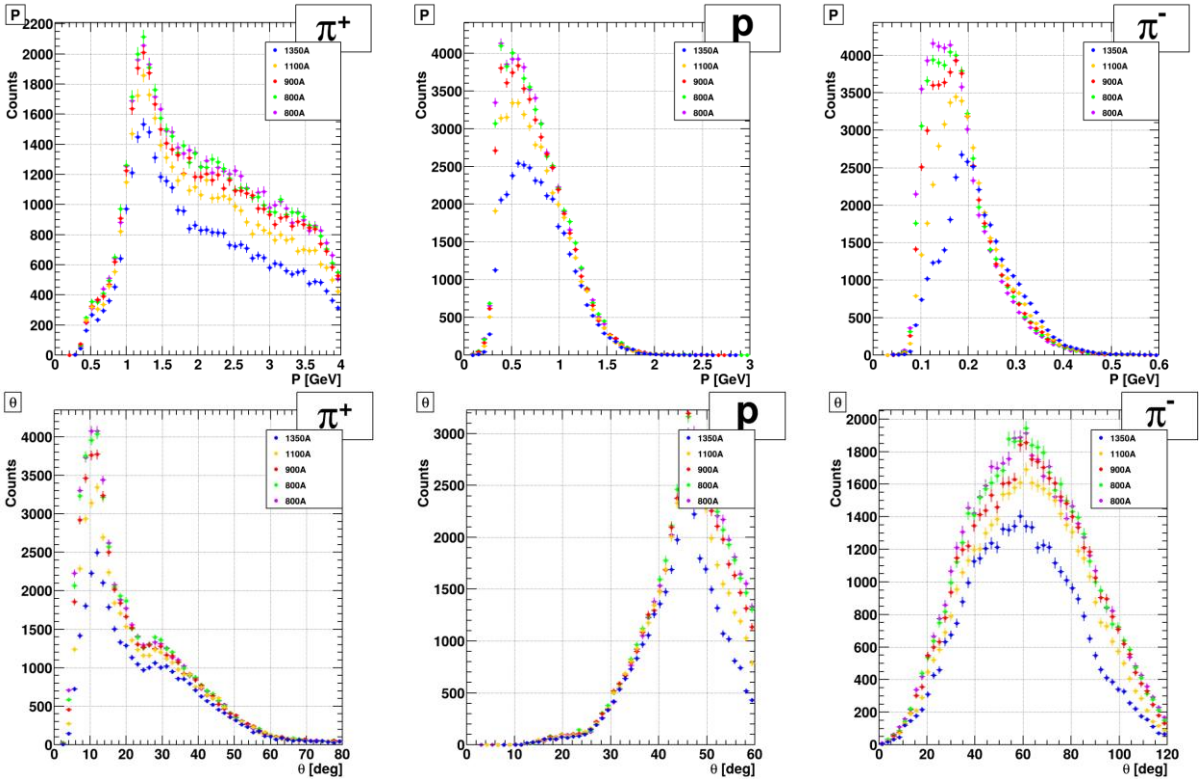
- This update deals with the affect of current on particle reconstruction.
- For each current, 1M events, from a beam energy range of 0.5 to 4.5 GeV, were generated using the physics-based generator.
- Five currents were studied: 1350A (the nominal current), 1100 A, 900A, 800A, and 700A.
- To the right is the table of the relative yield for the various currents, with Relative yield = $N_{current}$ / N_{1350}.
- The nominal current yield of the Λ and Σ^0 is 33698 and 4003 events, respectively.
- As a general trend, decreasing the current increases the yield.
- Λ and Σ^0 used Jana1 and Jana2 respectively.

Current (A)	Relative Yield (Σ^0)	Relative Yield (Λ)
1350	1.00	1.00
1100	1.44	1.27
900	1.73	1.43
800	1.51	1.50
700	1.53	1.51

- The above color scheme remains constant through out all plots.

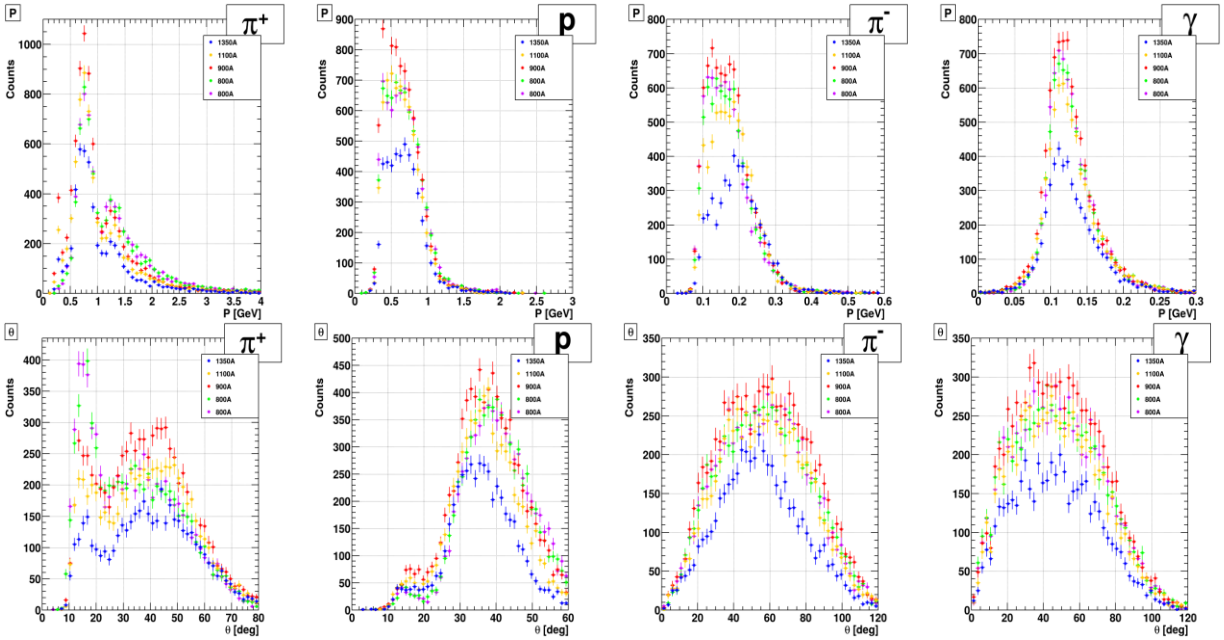
Λ: P AND Θ

- To the right are plots of the momenta and polar angle of the final state particles in the Λ decay for 5 different currents.
- The lion share of the increase in statistics happens at low momenta for the p and π^-, and higher polar angle for the p and π^-, while the opposite is seen in the π^+.



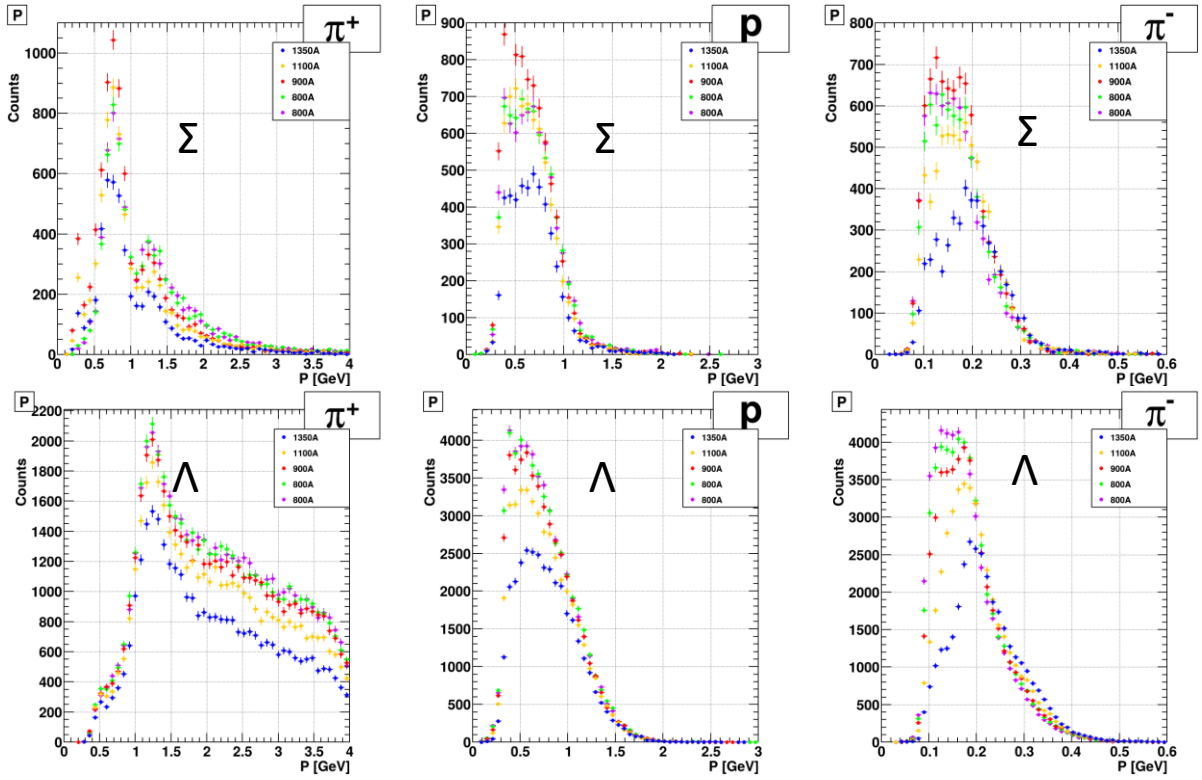
Σ^0: P AND Θ

- To the right are plots of the momenta and polar angle of the final state particles in the Σ^0 decay for 5 different currents.
- These results largely mirror those seen in the Λ channel, though the π^- and γ polar angle distributions increase symmetrically.



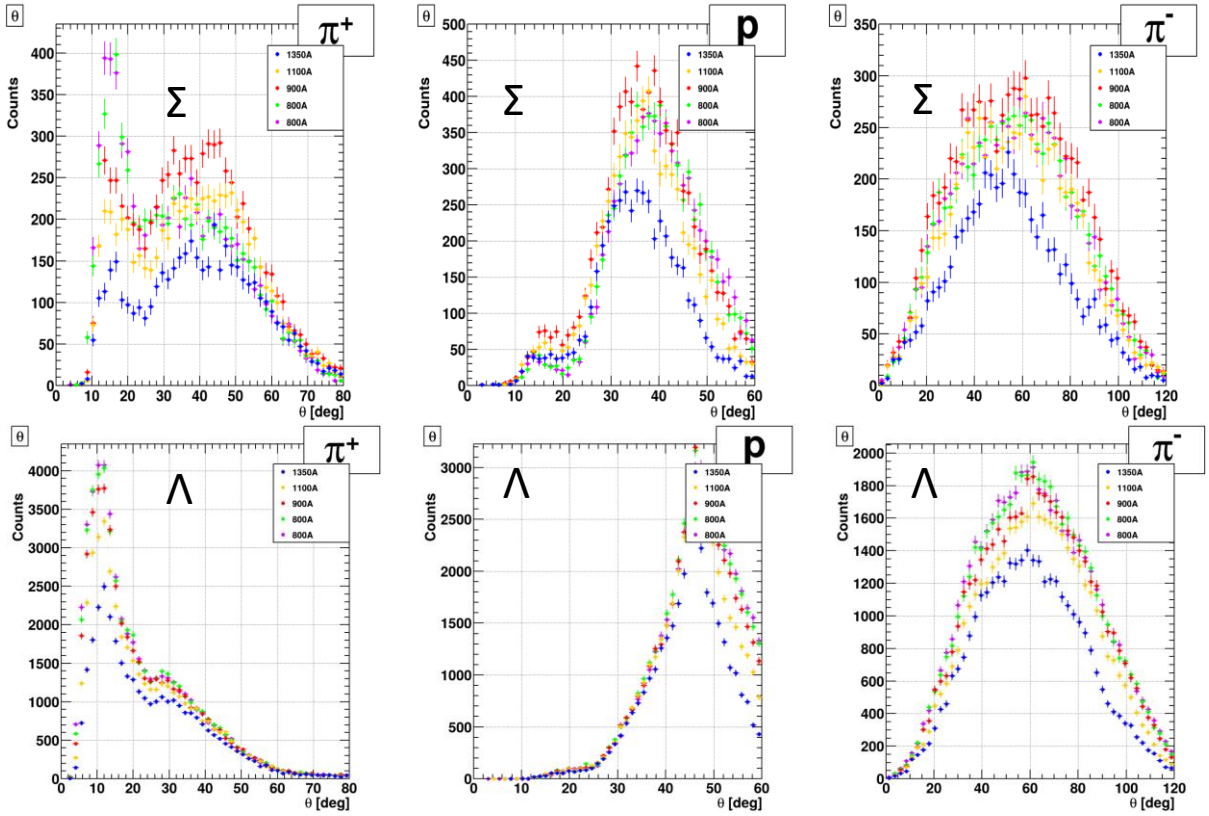
Λ and Σ Final State Particle Momenta

- The proton and π^- distributions look similar, albeit the Λ has a higher momentum tail.
- The π^+ shows a different structure.
- There is a dip round 1 GeV in the Σ's π^+ distribution that is absent in the Λ's π^+ distribution.
- This dip and the neighboring peak are in the same position as the π^+ from the Λ decay.



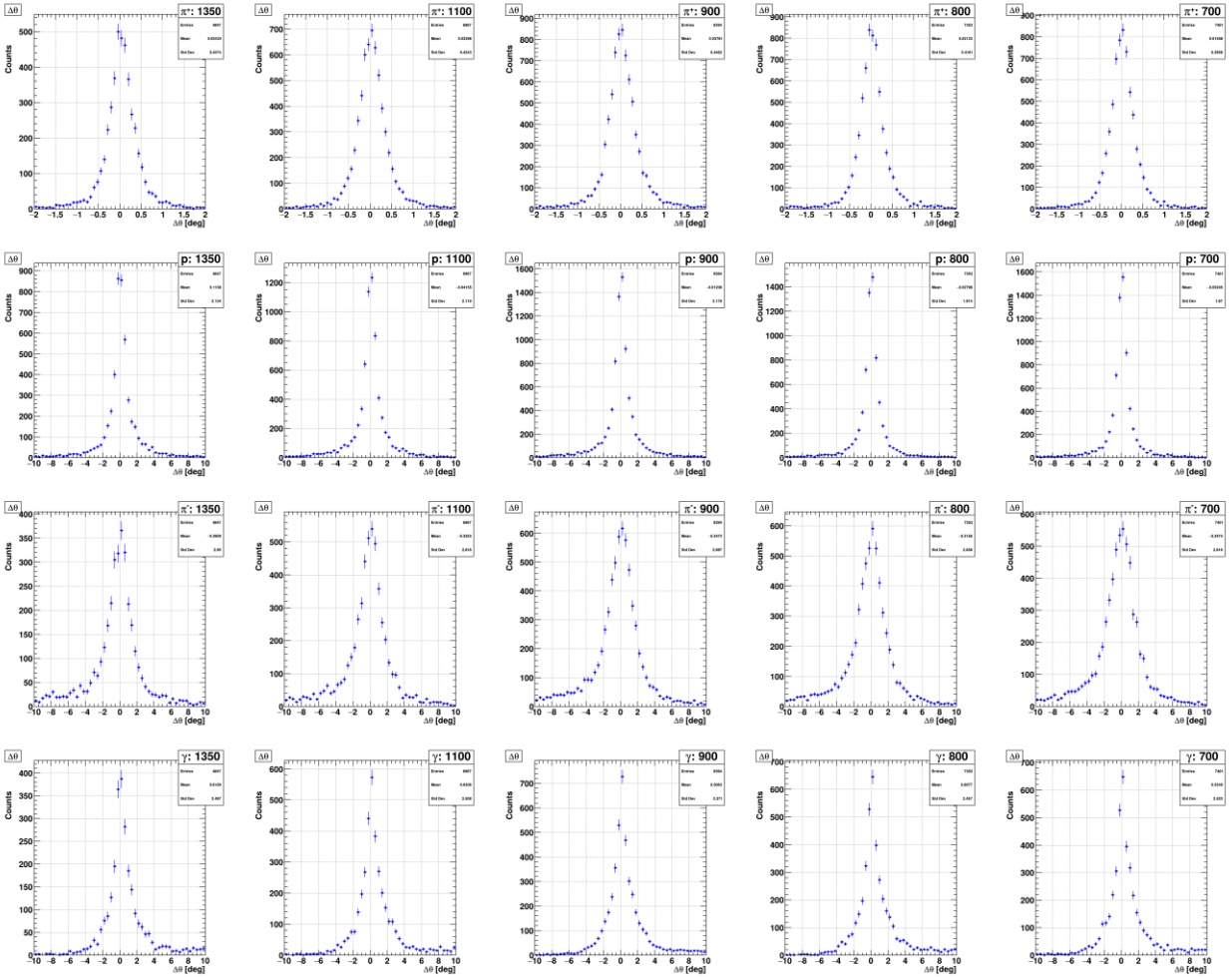
Λ and Σ Final State Particle Θ

- Similarly to the last slide, the Σ π^+ distribution looks like a distorted version of the Λ distribution.
- The hump seen in the Λ distribution after 25° seems to be reflected as a higher hump in the Σ distribution.



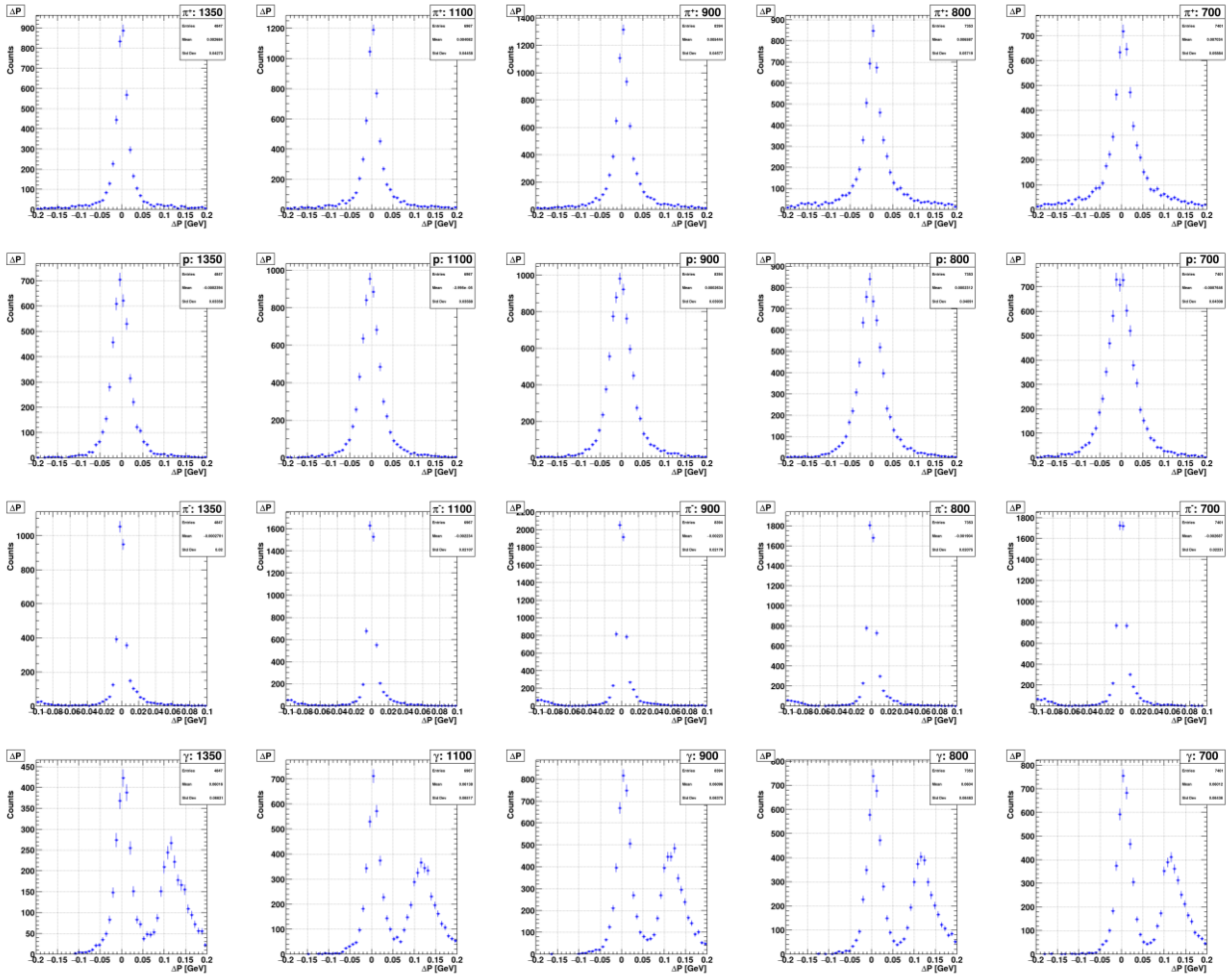
Σ: ΔΘ

- To the right are plots of the Δθ distributions for the π^+, π^-, proton, and γ as a function of current.
- The plots look fine across all currents with a general decrease in width with increasing current.



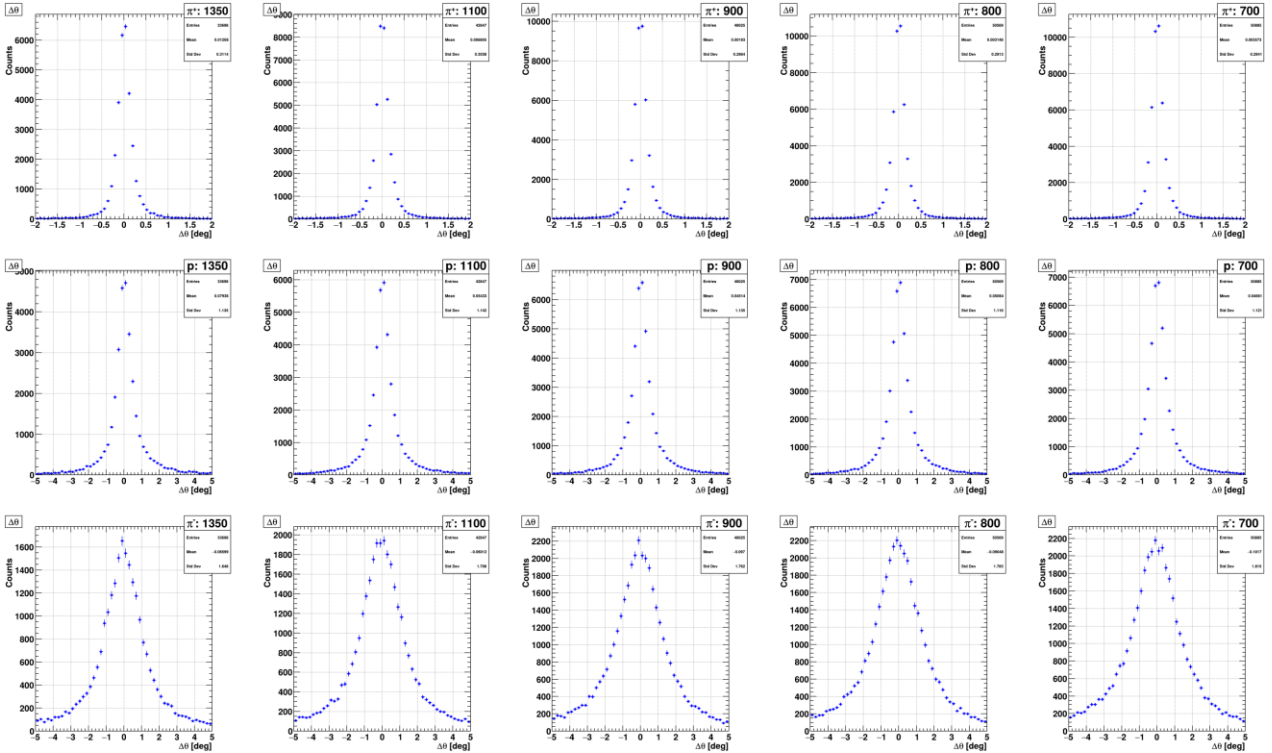
Σ: ΔP

- To the right are plots of the dP distributions for the π^+, π^-, proton, and γ as a function of current.
- Thes results mirror those of the Δθ, with a decrease in width with increasing current.
- The double peak structure in the γ distribution is being looked into.



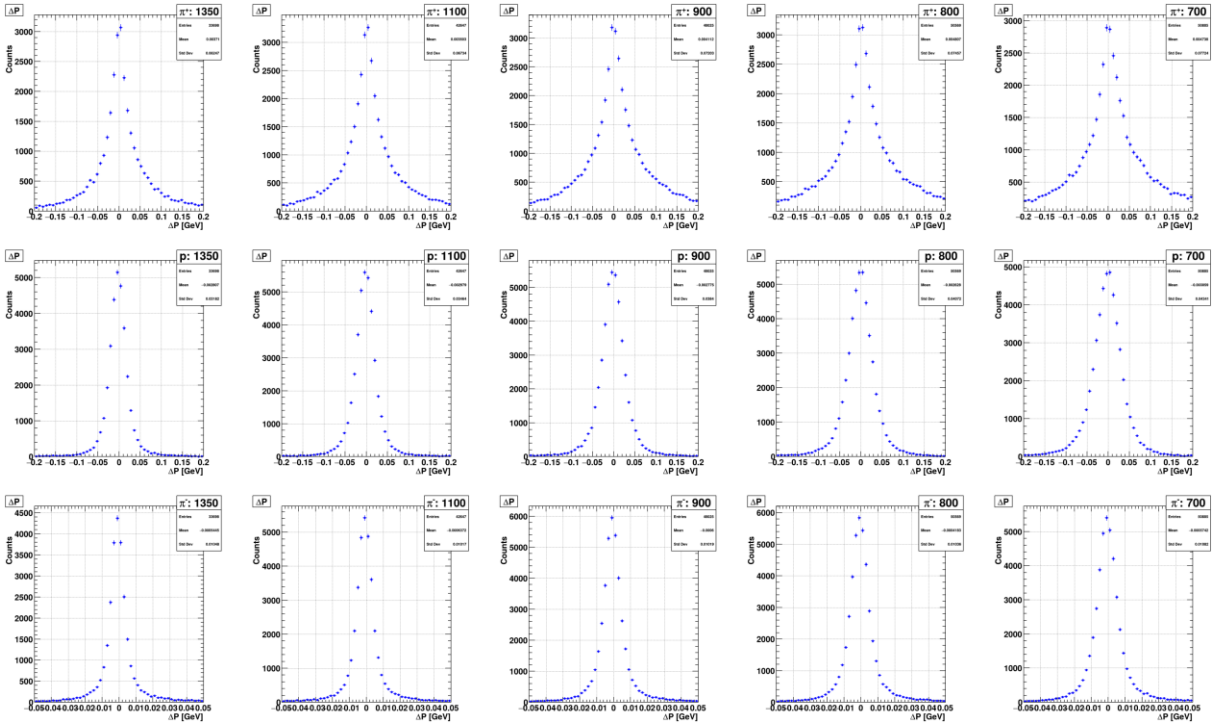
Λ: Δθ

- To the right are plots of the Δθ distributions for the π^+, proton, and the π^- as a function of current.
- These results mirror the distributions Σ Δθ distributions.



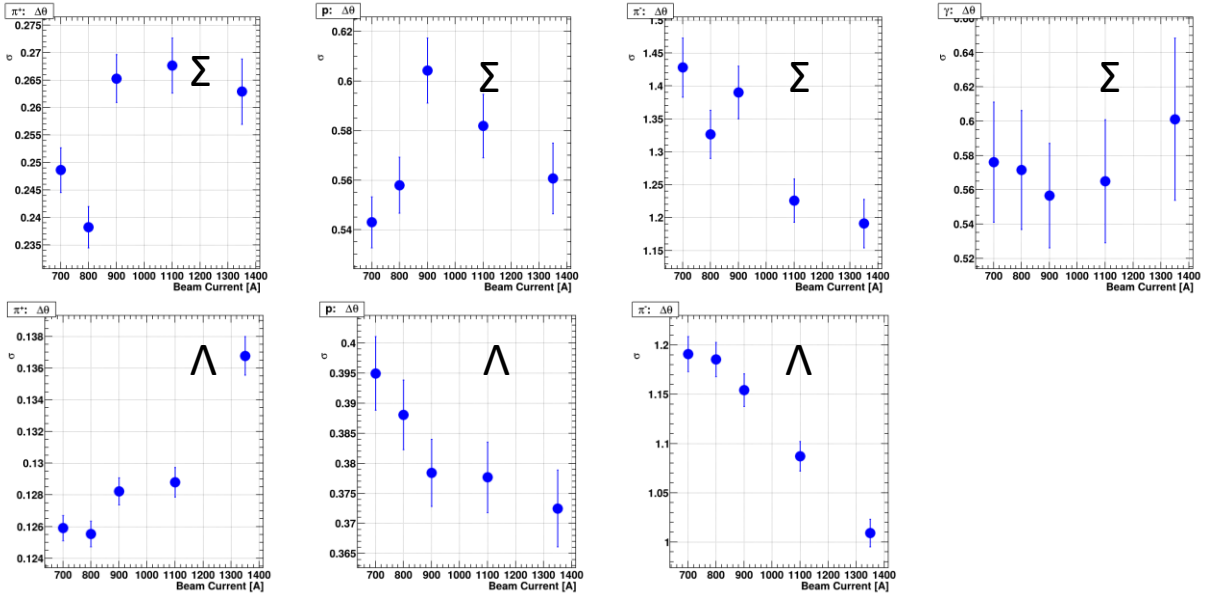
Λ: ΔP

- To the right are plots of the ΔP distributions for the π^+, proton, and the π^- as a function of current.



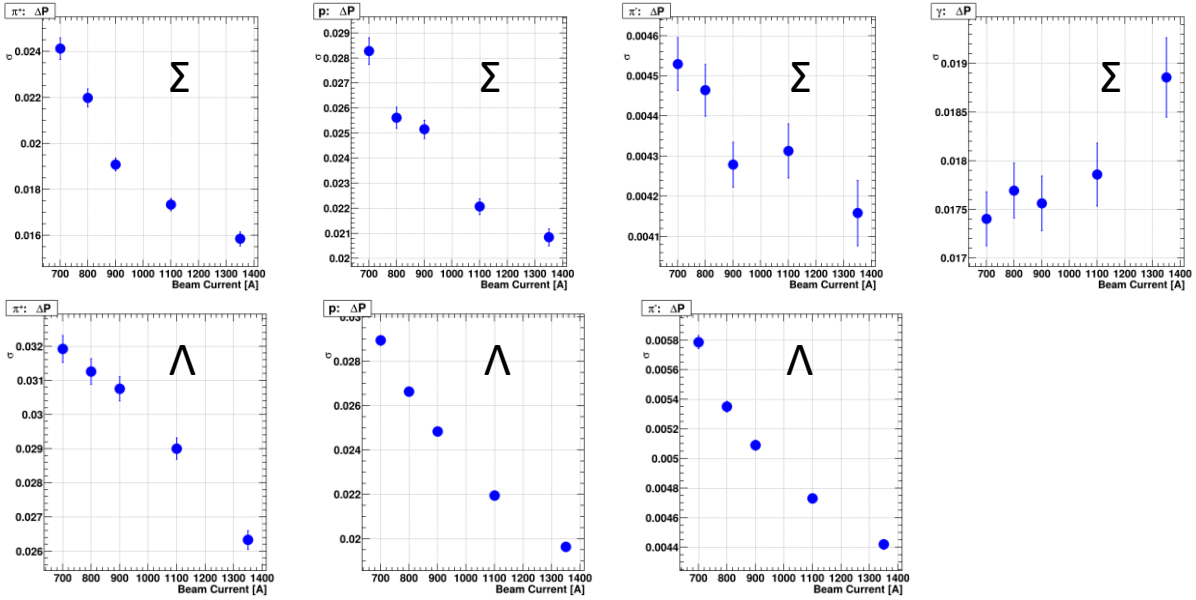
Θ Resolution

- To the right are plots of the Δθ distributions final state particles for the for Σ (top) and the Λ (bottom) as a function of beam current.
- The widths were extracted from a gaussian fit to the Δθ seen in the previous slides.
- Width seems to be proportional to the yield, with Λ yield decreasing as current increases and Σ yield increasing with current until 900A and then decreasing.



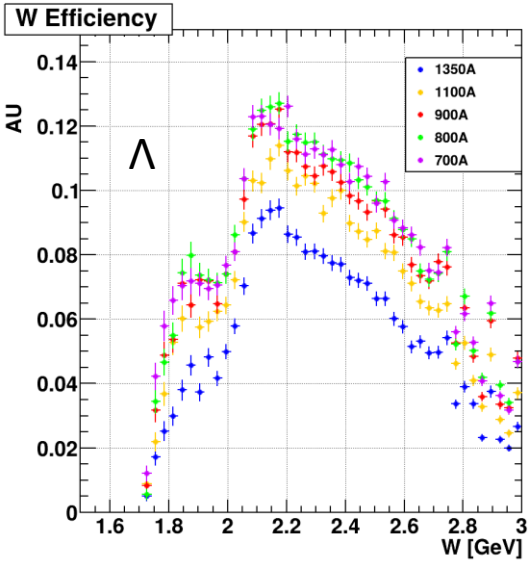
P Resolution

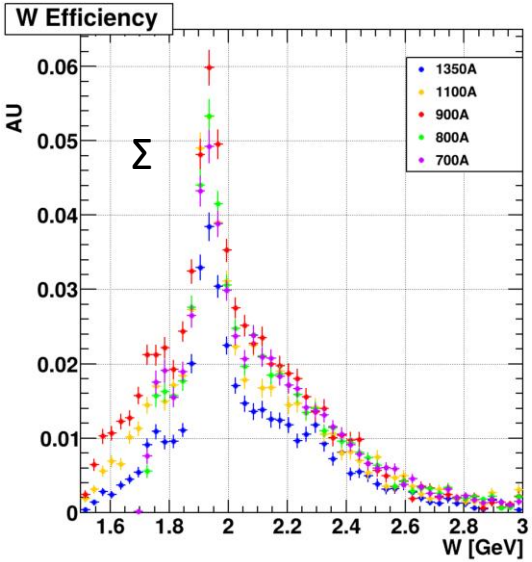
- To the right are plots of the ΔP distributions final state particles for the for Σ (top) and the Λ (bottom) as a function of beam current.
- Both sets of particles show the inverse relationship between beam current and width, save for the γ distribution.



W EFFICIENCY

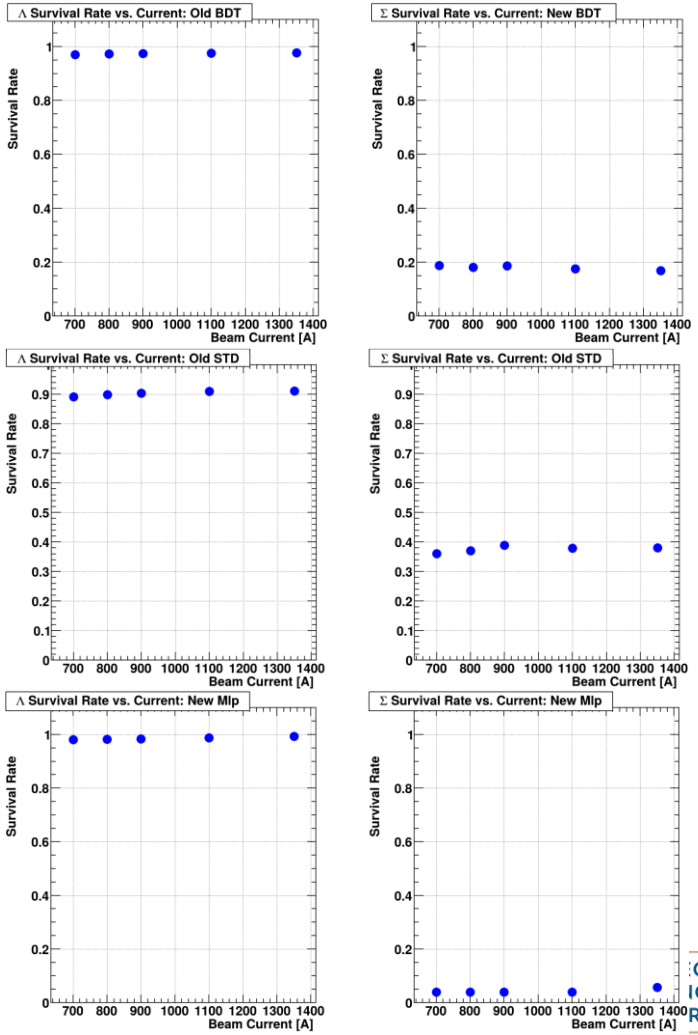
- The plot to the right is of the efficiency of W for the Λ (left) and the Σ (right) distributions as a function of current.
- The increase in efficiency mirror the increases in statistics.
- Decreasing the current yields more higher W Λs, with most of the increase coming from dropping from 1350 to 1100.
- The Λ is strongly peaked around W ~ 1.9 GeV and decreases in current increases this peak and the immediate neighboring events.





Current vs Λ/Σ Discrimination

- Selection cuts were developed to separate Λs proper and Λs coming from Σ decays.
- 3 different approaches were studied with the particle survival rates plotted to the right
  - Boosted Decision Trees (Top)
  - Handmade (Middle)
  - Neutral Net (Bottom)
- There is not much of a dependence on the current.
- Full description of the approaches is in the back up slides.



CONCLUSION

- In summation, the Λ and Σ kinematic distributions were studied as a function of magnetic field current.
- In general, the final state particles stemming from the decays show an increase in lower momenta and higher polar angle events as the current decreases.
- Polar angle resolution has been shown to be inversely proportional to the relative yield and momentum resolution increases as current increases.
- Discrimination between the Λ and Λs stemming from the decay of the Σ has been studied three ways: handmade cuts, BDTs, and NNs, and the results do not show any significant current decencies.

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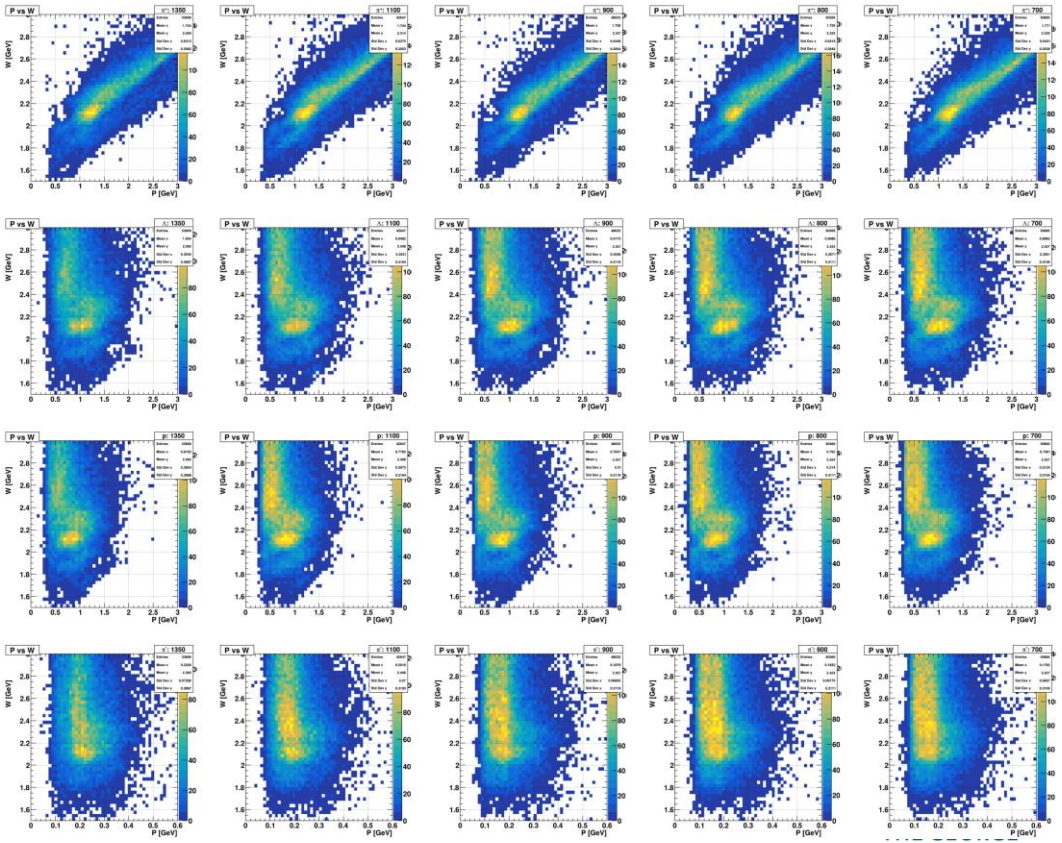
Backup Slides

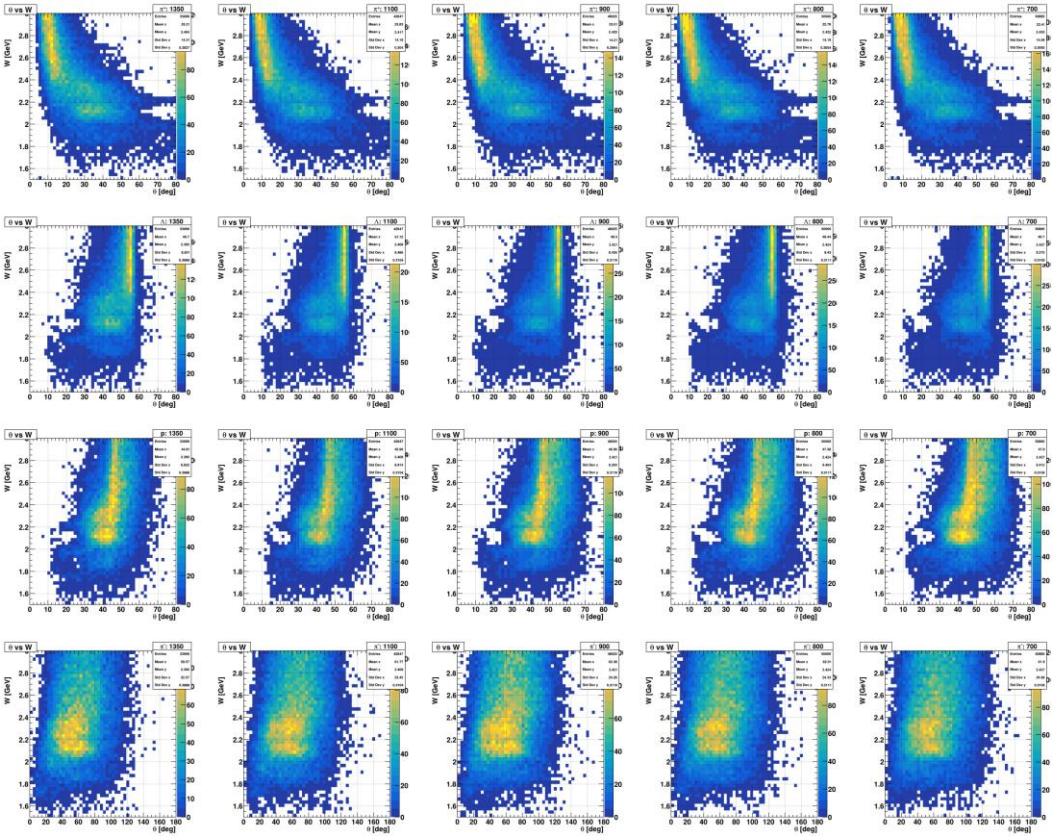
Λ: P vs. W

- To the right are plots of momentum vs W for the Λ, π^+, π^-, and p as function of current.
- The current decreases from left to right.
- There are not significant differences between the different currents.



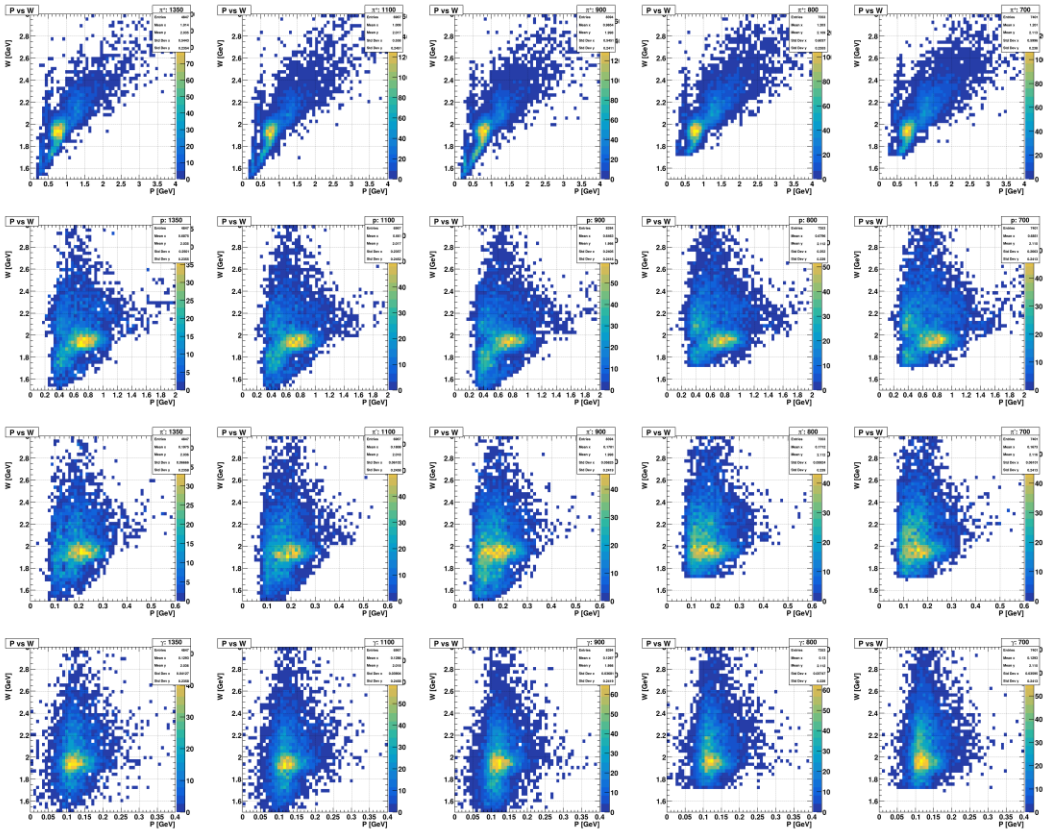
Λ: Θ vs. W

- To the right are plots of θ vs W for the Λ, π^+, π^-, and p as function of current.
- The current decreases from left to right.
- There are not significant differences between the different currents.



Σ: P vs. W

- To the right are plots of momentum vs W for the Λ, π^+, π^-, and p as function of current.
- The current decreases from left to right.
- There are not significant differences between the different currents.



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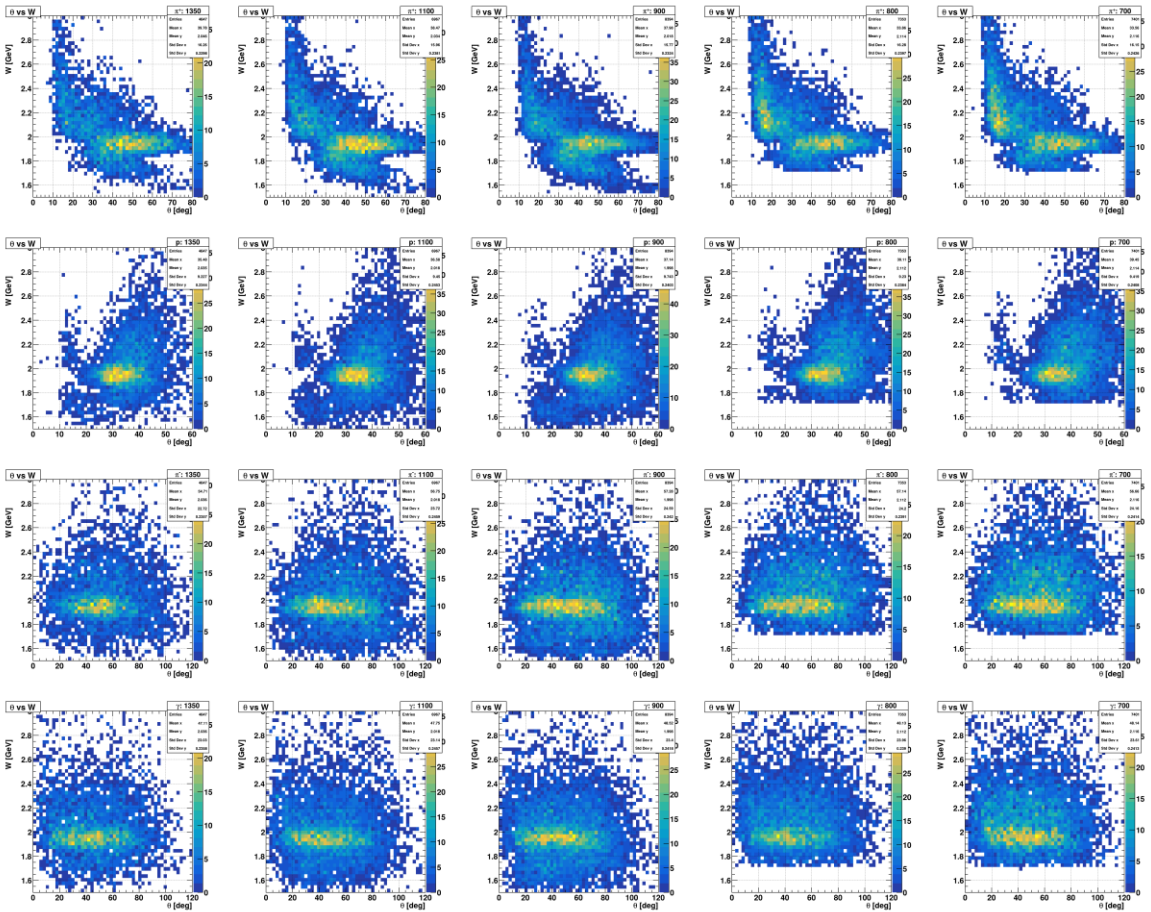
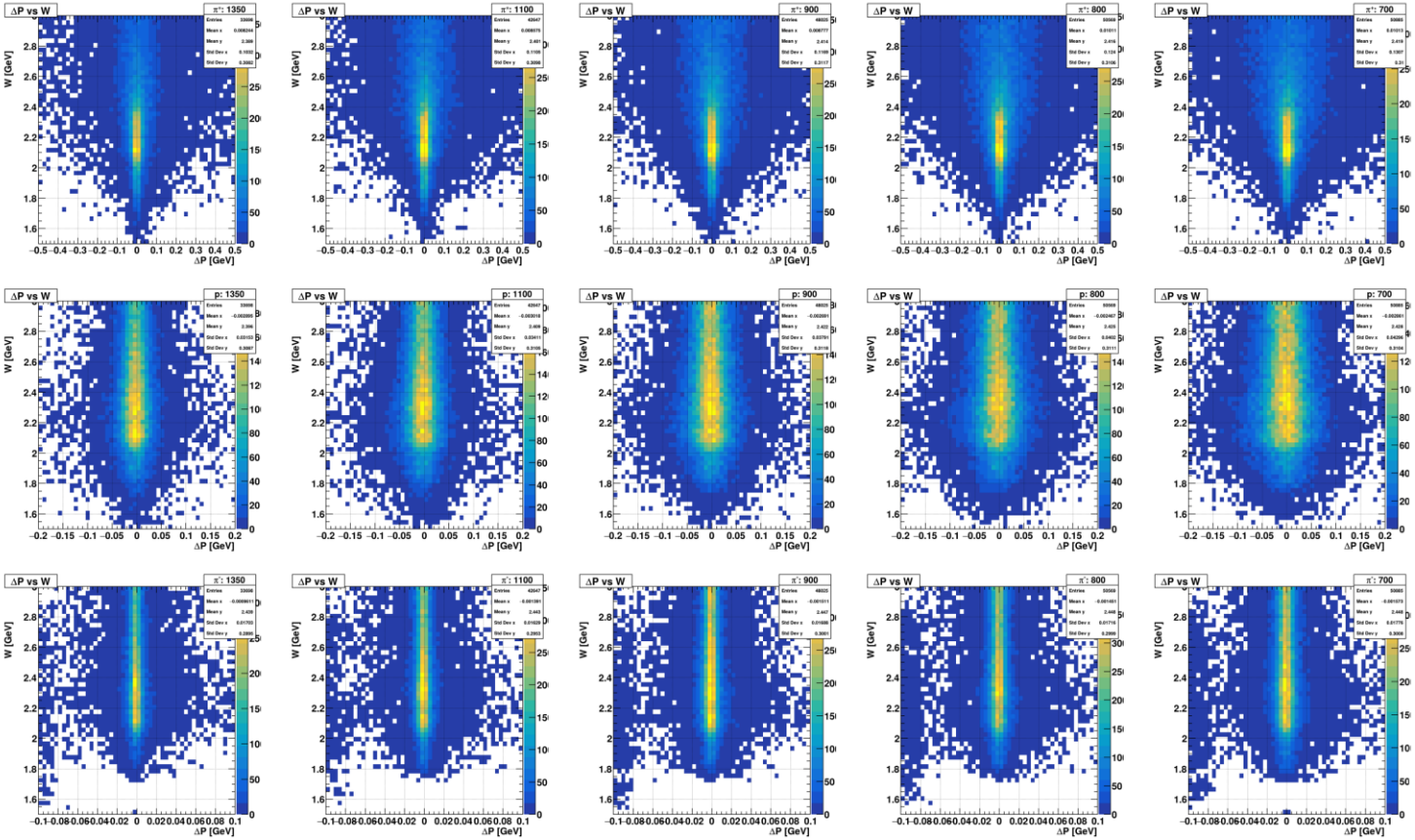
Σ: Θ vs. W

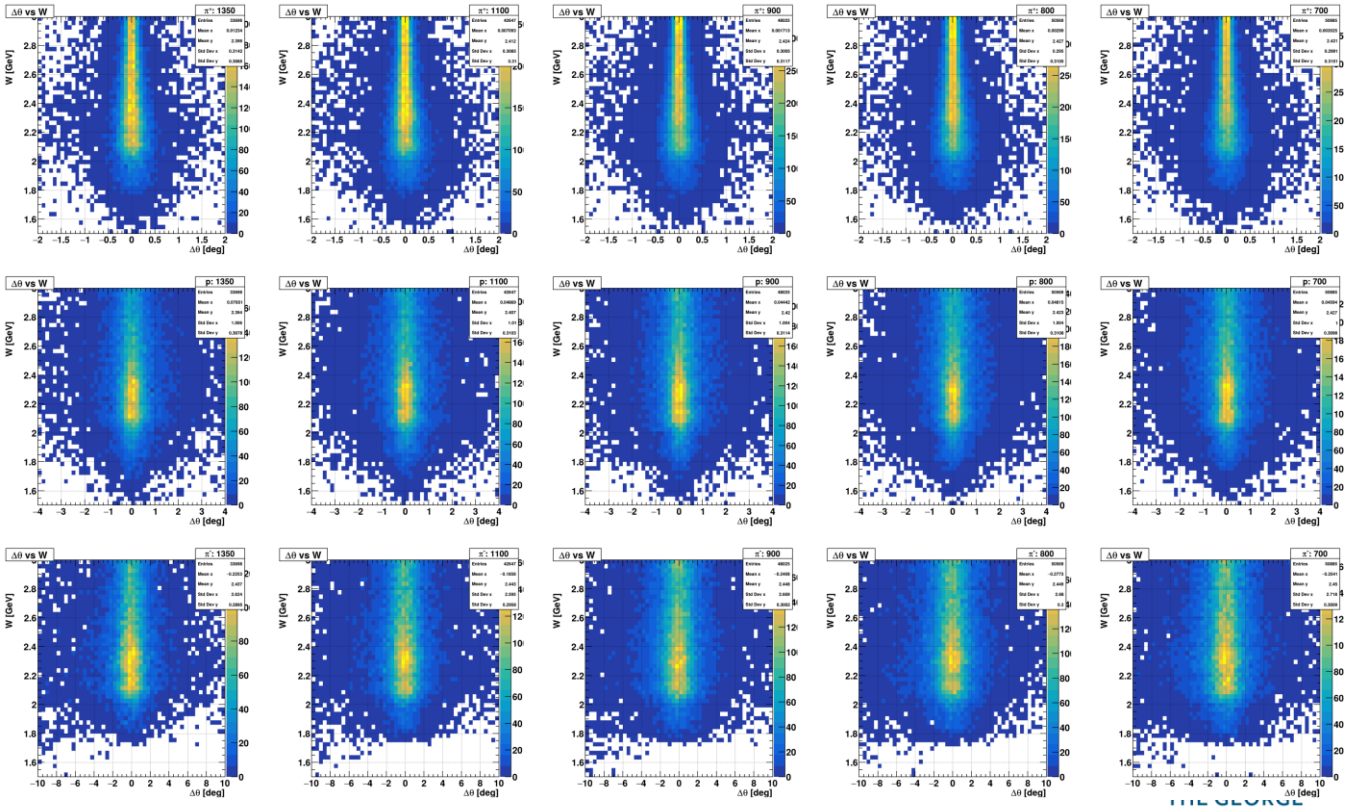
- To the right are plots of θ vs W for the Λ, π^+, π^-, and p as function of current.
- The current decreases from left to right.
- There are not significant differences between the different currents.



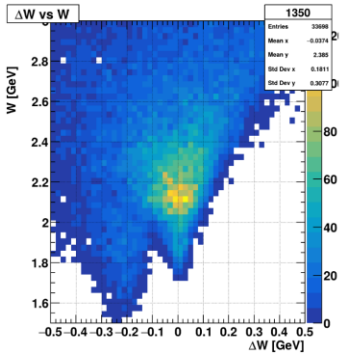
Λ: ΔP vs. W

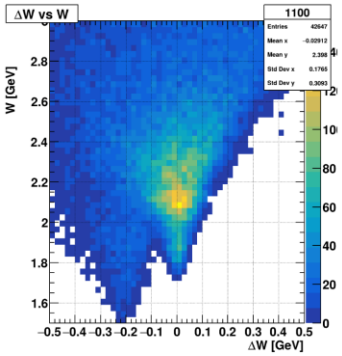

ΔP vs W
π⁺: 1350
π⁺: 1100
π⁺: 900
π⁺: 800
π⁺: 700
p: 1350
p: 1100
p: 900
p: 800
p: 700
W [GeV]
ΔP [GeV]

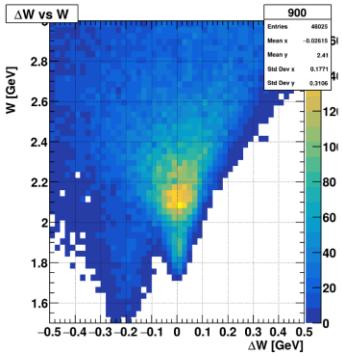
Λ: Δθ vs. W

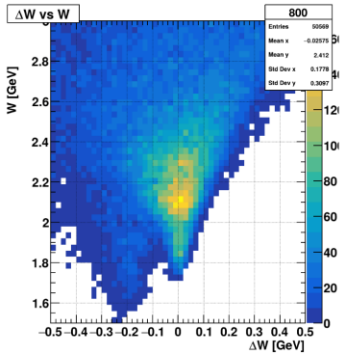

Δθ vs W
π⁺: 1350
π⁺: 1100
π⁺: 900
π⁺: 800
π⁺: 700
p: 1350
p: 1100
p: 900
p: 800
p: 700
W [GeV]
Δθ [deg]

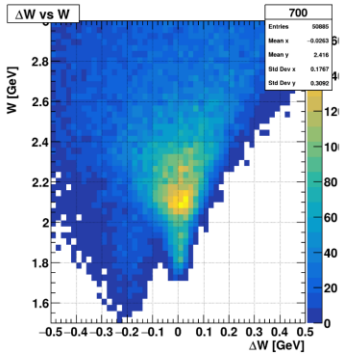
Lam ΔW v W


ΔW vs W
1350
W [GeV]
ΔW [GeV]

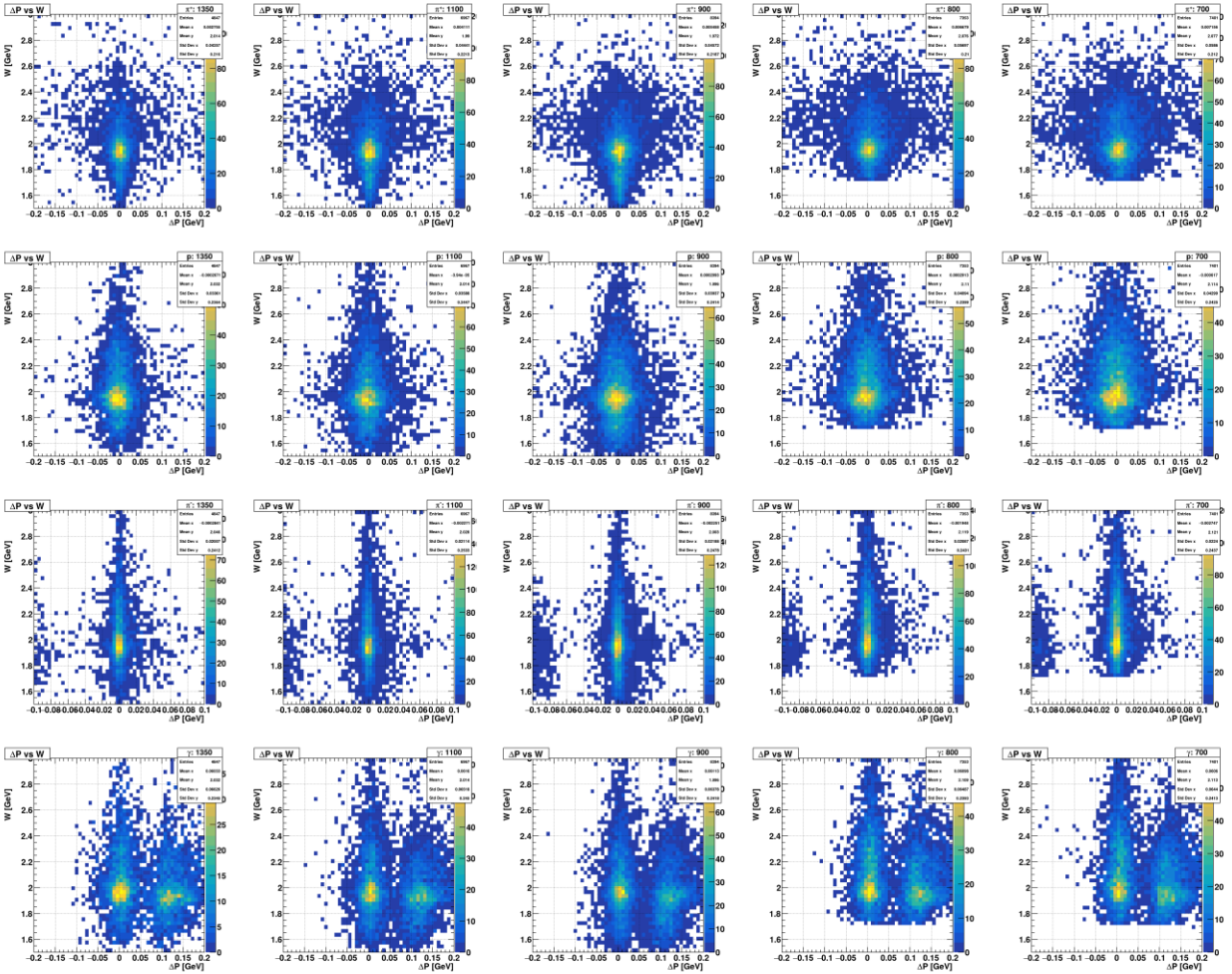

ΔW vs W
1100
W [GeV]
ΔW [GeV]


ΔW vs W
900
W [GeV]
ΔW [GeV]

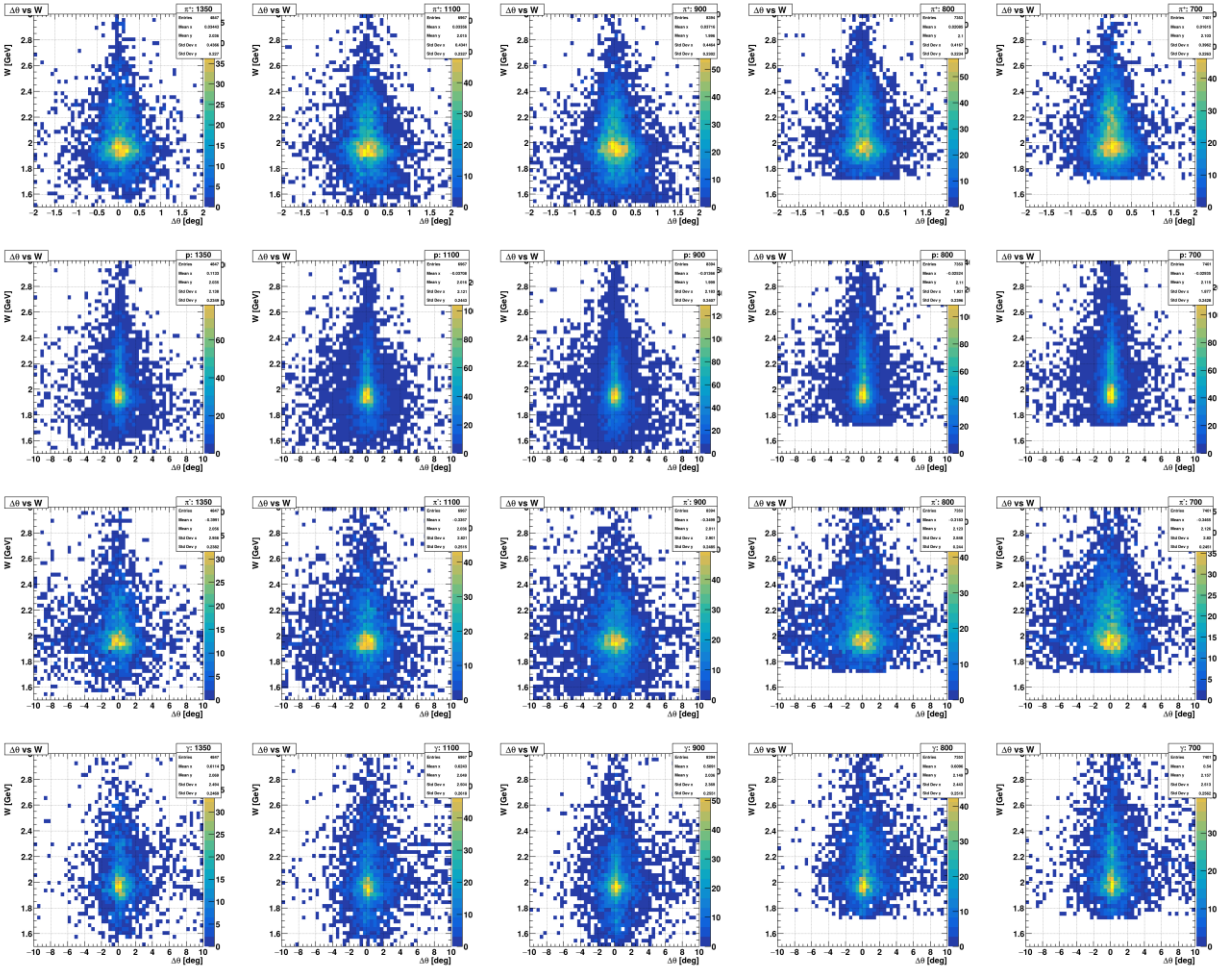

ΔW vs W
800
W [GeV]
ΔW [GeV]


ΔW vs W
700
W [GeV]
ΔW [GeV]

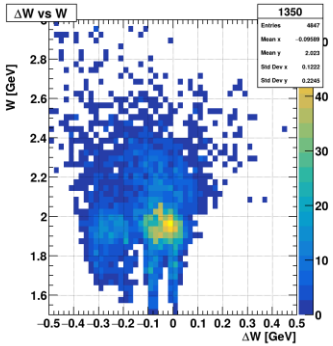
Σ: ΔP vs. W

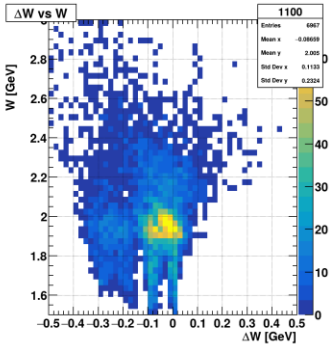

ΔP vs W
W [GeV]
ΔP [GeV]
π⁺: 1350
π⁺: 1100
π⁺: 900
π⁺: 800
π⁺: 700
p: 1350
p: 1100
p: 900
p: 800
p: 700
π⁻: 1350
π⁻: 1100
π⁻: 900
π⁻: 800
π⁻: 700
γ: 1350
γ: 1100
γ: 900
γ: 800
γ: 700

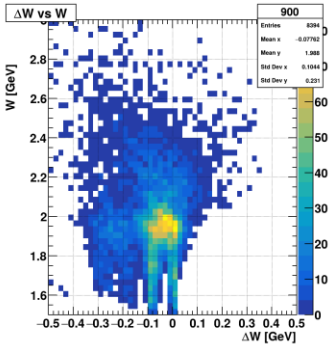
Σ: ΔΘ vs. W

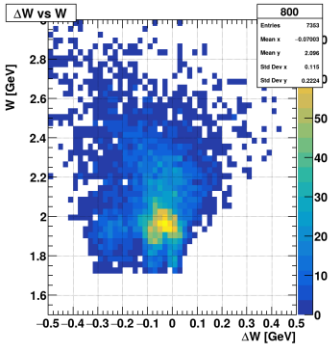

ΔΘ vs W
W [GeV]
ΔΘ [deg]
π⁺: 1350
π⁺: 1100
π⁺: 900
π⁺: 800
π⁺: 700
p: 1350
p: 1100
p: 900
p: 800
p: 700
π⁻: 1350
π⁻: 1100
π⁻: 900
π⁻: 800
π⁻: 700
γ: 1350
γ: 1100
γ: 900
γ: 800
γ: 700

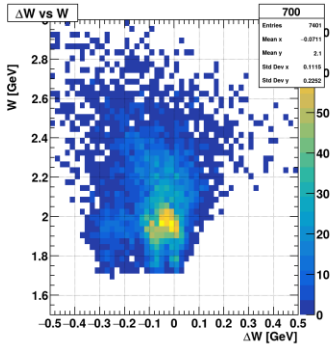
Σ: ΔW vs. W


ΔW vs W
1350
W [GeV]
ΔW [GeV]


ΔW vs W
1100
W [GeV]
ΔW [GeV]

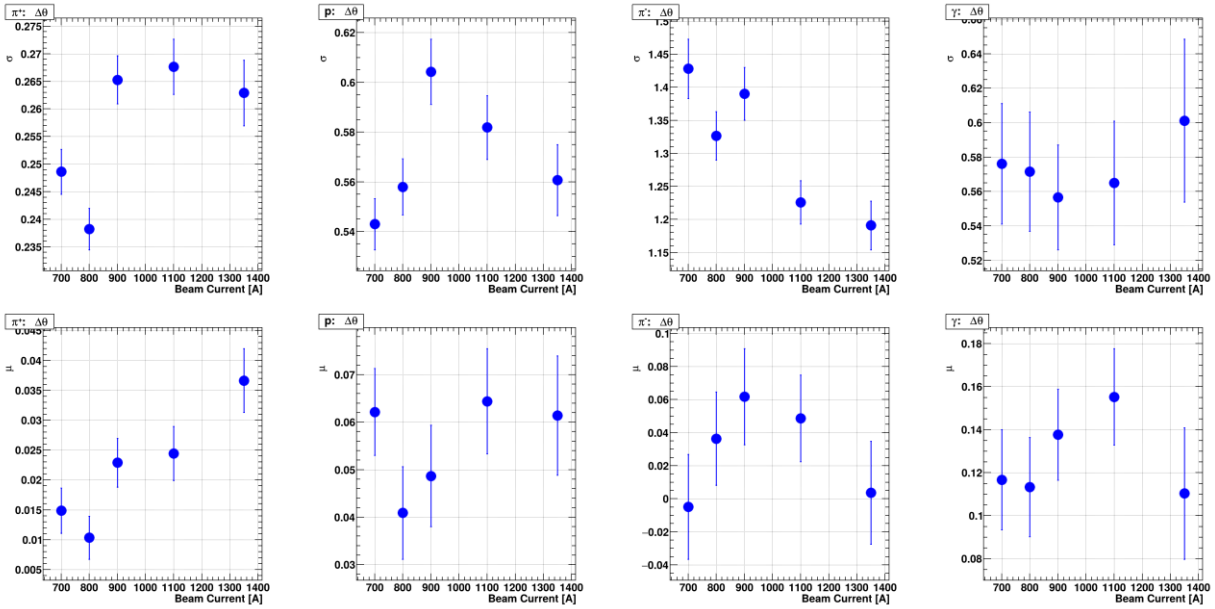

ΔW vs W
900
W [GeV]
ΔW [GeV]


ΔW vs W
800
W [GeV]
ΔW [GeV]


ΔW vs W
700
W [GeV]
ΔW [GeV]

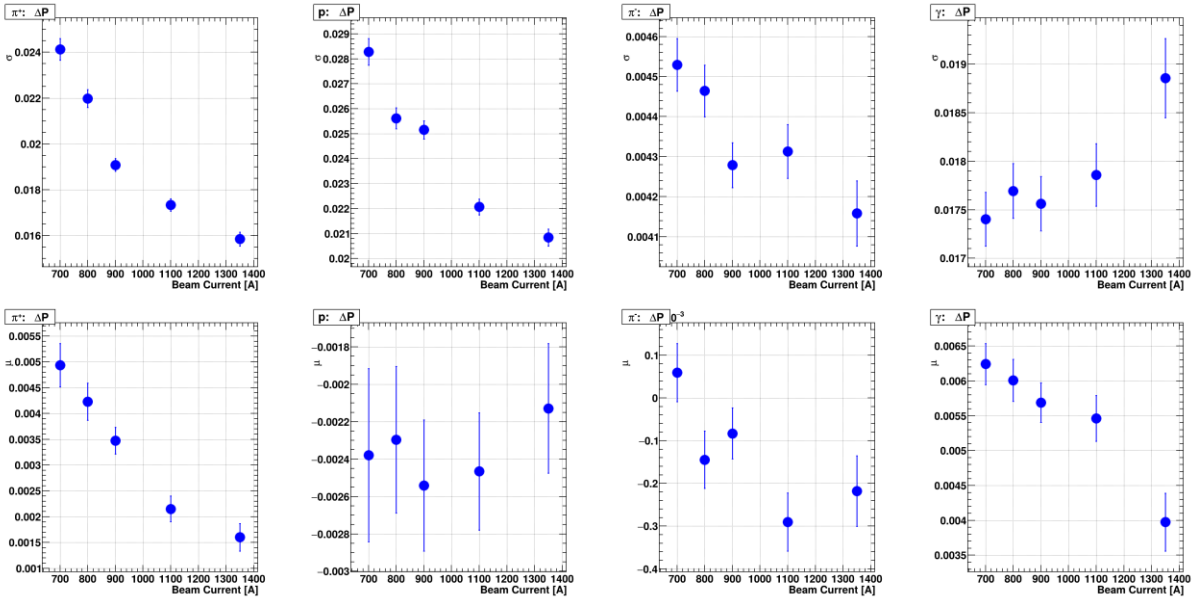
Σ: Δθ

- To the right are plots of the dθ distributions for the π^+, π^-, and the proton for the following currents: 1350, 1100, 900, 800, and 700 A.
- Thes results mirror those of the Δθ, with broad distributions and shifted means.



Σ: ΔP

- To the right are plots of the dp distributions for the π^+, π^-, and the proton for the following currents: 1350, 1100, 900, 800, and 700 A.
- Thes results mirror those of the Δθ, with broad distributions and shifted means.



Λ: Δθ

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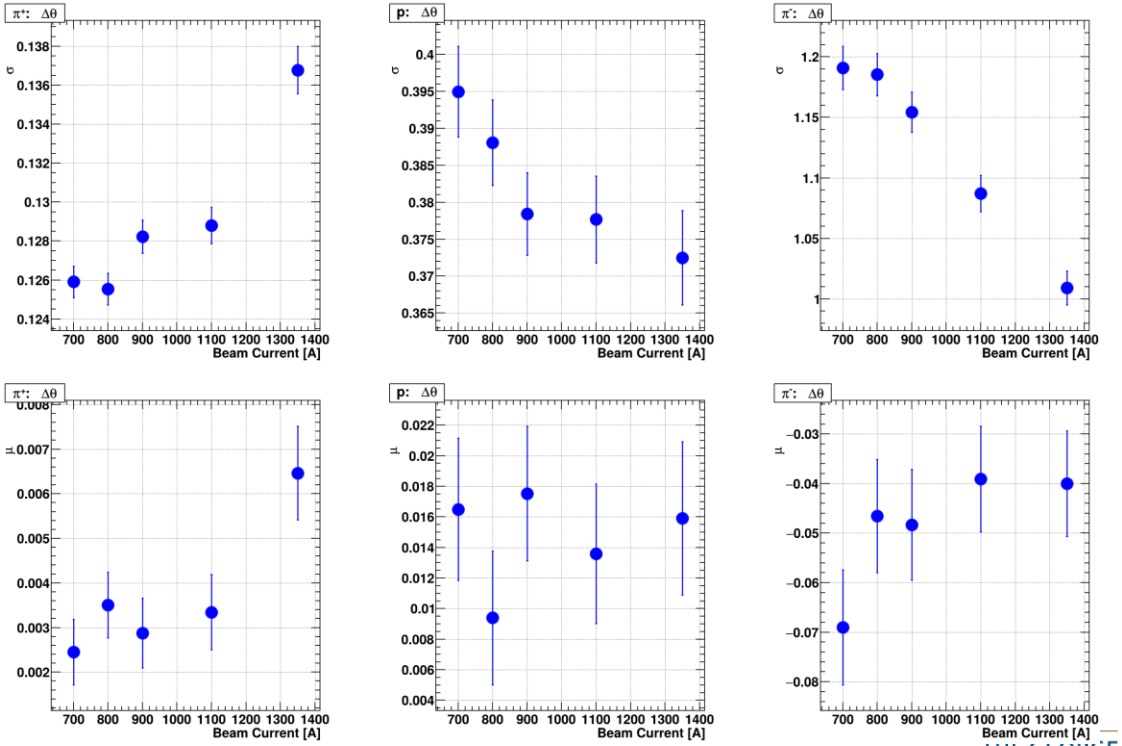

Λ: ΔP

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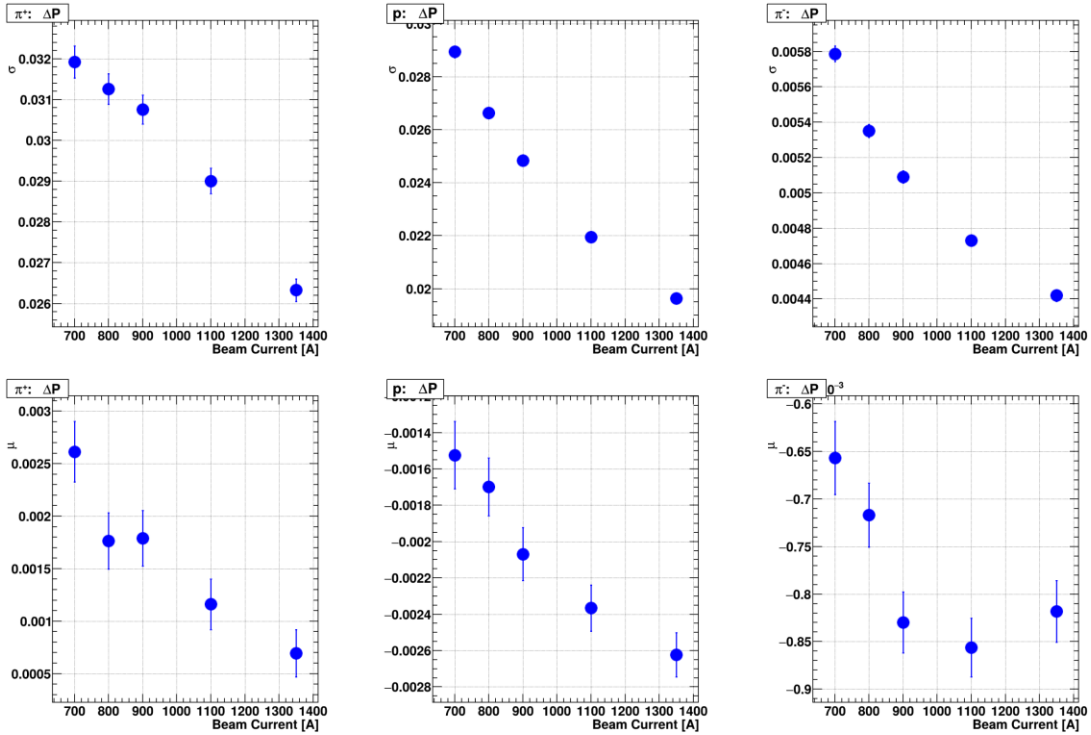
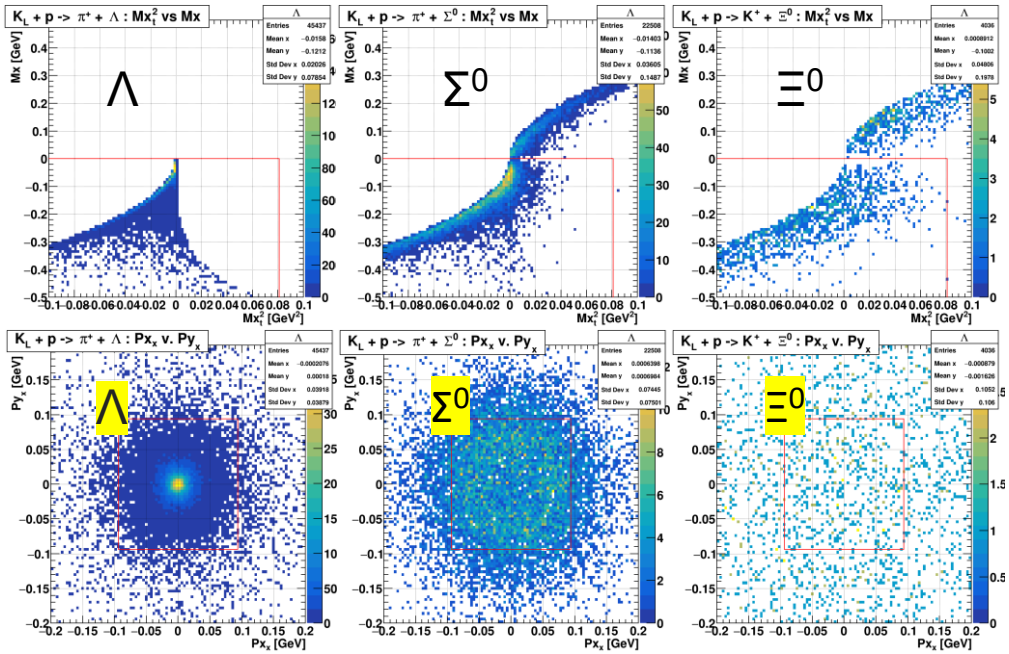
- Thes results mirror those of the Δθ, with broad distributions and shifted means.



Selection Cuts

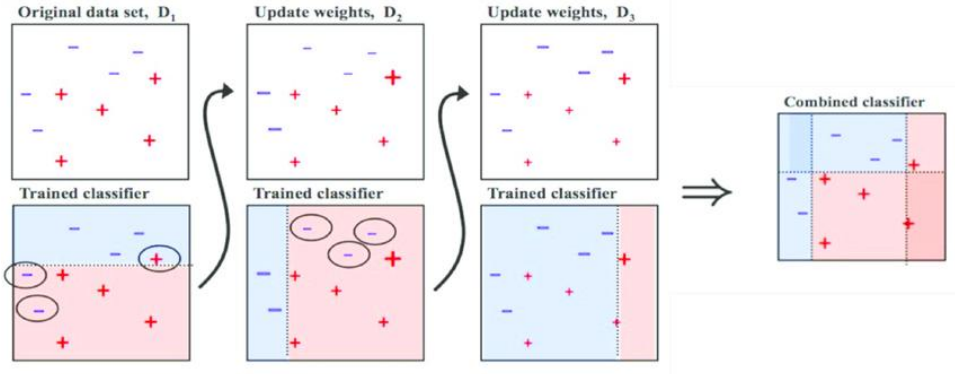
- I made some cuts initially:
  - $M_x < 0$ GeV : $[M_x = |K_L + p - \Lambda - \pi|]$
  - $M_{xt}^2 < 0.081$ GeV^2 : $[M_{xt}^2 = E_x^2 - p_{xz}^2]$
  - $P_{xx}, P_{xy} < 0.094$ GeV
- These removed ~10% of the Λ and 50% of the ∑.
- Then I did some machine learning within ROOT TMVA.



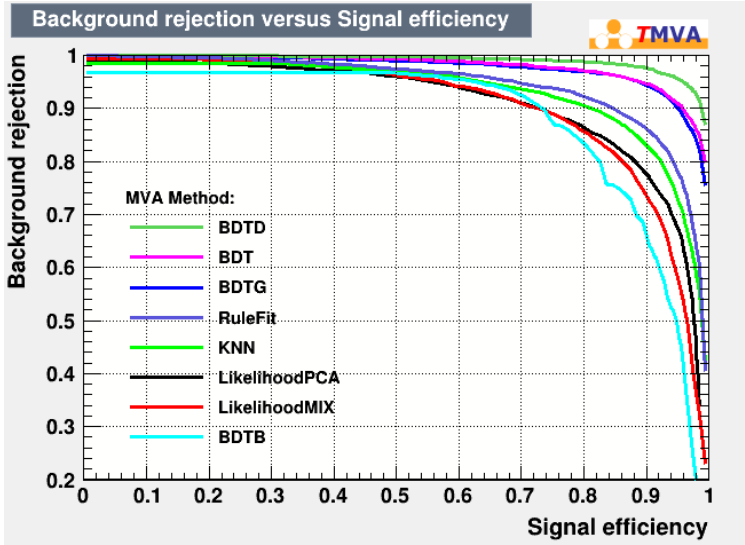
Below Are the results from that Initial ML trial

Boosted Decision Trees (BDTs)

- Multiple models were tried, but the BDTs showed the most promise in this preliminary ML trial.
- The best model, Adaptive BDT + Decorrelation, removed only removed 5% of the Λ and 90.7% of the Σ.



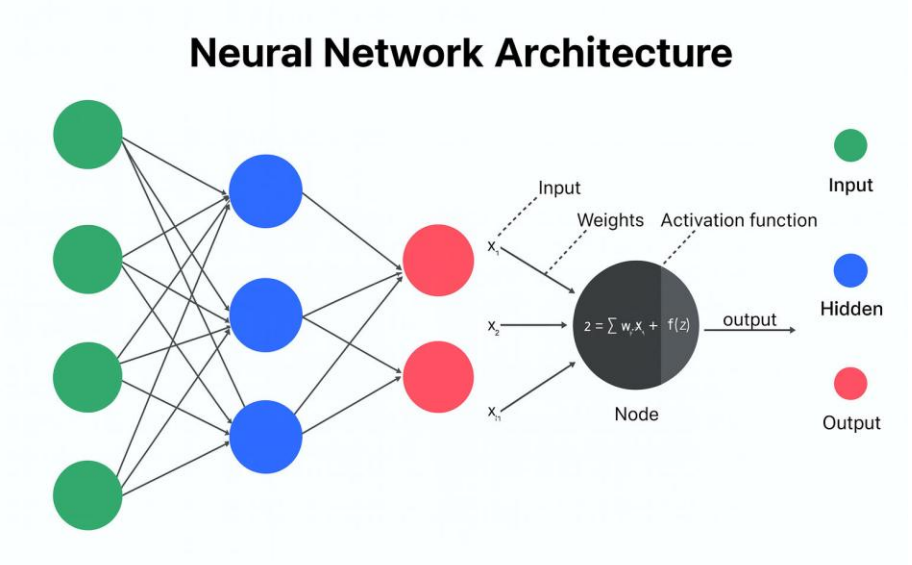
https://vagifaliyev.medium.com/adaptive-boosting-simply-explained-through-python-eebdb988de66



M. B. C. Scott

Neural Net

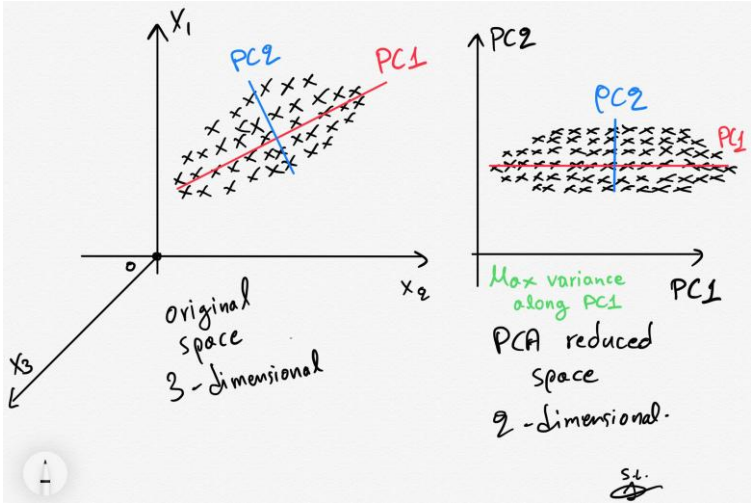
- I developed a new model using a neural net, or Multi-Layer Perceptron (MLP), with the sklearn package in python.
- I used ~33K Λ events and ~6K Σ events, using the physics-based generator with both coming from a run the nominal current.
- Procedure
  - I started off with 24 variables related to the Λ: the momenta and energy of the proton, Λ, π^-, and x, along with the masses, p_T, m_T^2, and E_T^2 of the Λ and the x.



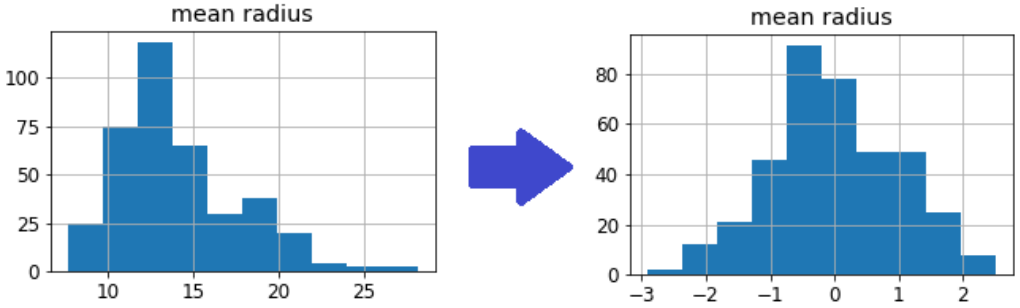
https://ik.imagekit.io/upgrad1/abroad-images/imageCompo/images/ChatGPT_Image_Nov_20_2025_03_47_56_PMTT18DE.png

Neural Net

- Procedure continued
  - Used PCA to reduce the number of variables to 20 while keeping basically all the variance of the data
  - Transformed the data with Power Transformer
- Principal component analysis (PCA) rotated the data to a space where each direction is a variance within the data as opposed to a variable.
- Power transformation transforms each variable so that it is Gaussian distributed.



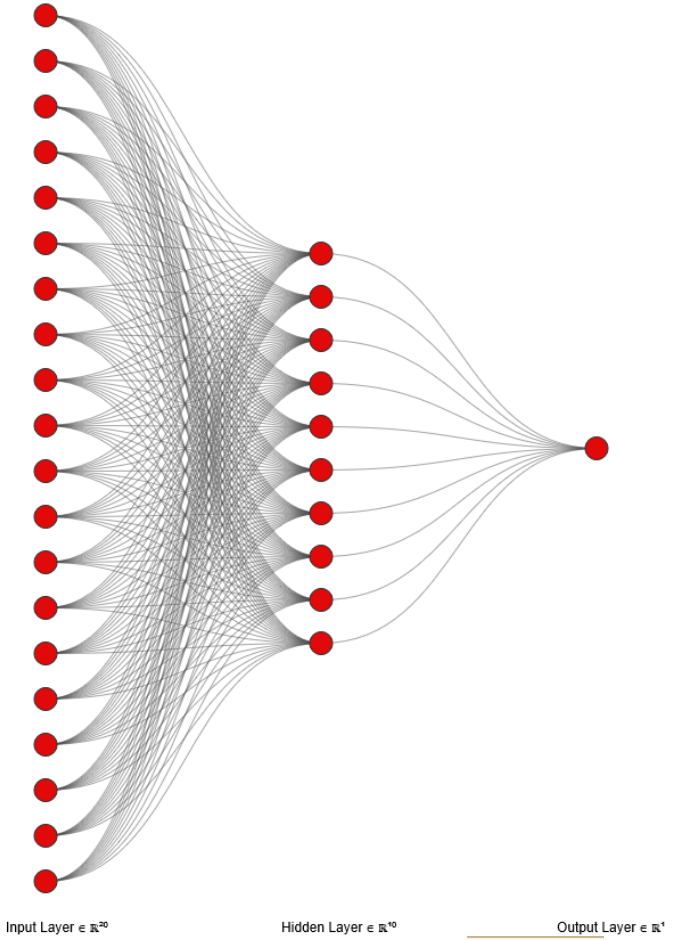
https://towardsdatascience.com/pca-clearly-explained-how-when-why-to-use-it-and-feature-importance-a-guide-in-python-7c274582c37e/



https://www.yourdatateacher.com/2021/04/21/when-and-how-to-use-power-transform-in-machine-learning/

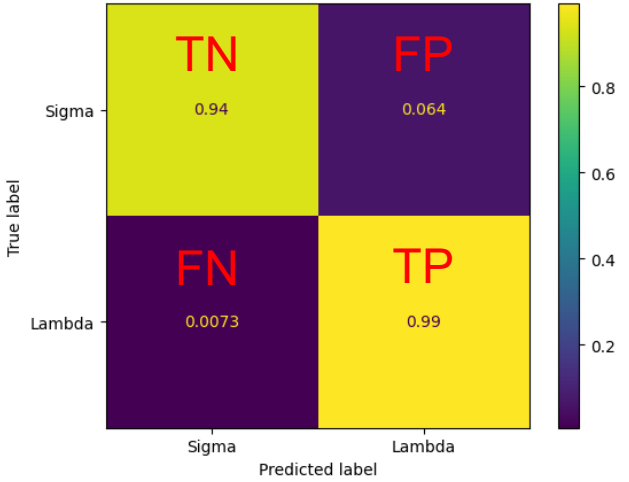
Neural Net

- Model
  - Max iterations = 400
  - 1 hidden layer of 10 nodes
  - The rest of the hyperparameters were at their default values
  - The Test and training scores were 0.988 and 0.985, respectively.
    - Scores closer to 1 signify better models and the closer the test and training scores are, the better the model is in terms of overfitting.
- The picture on the right is a graphical representation of the model.



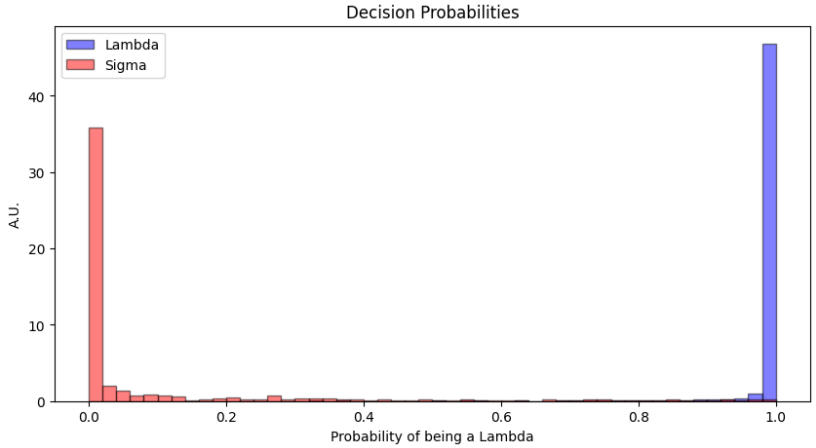
Neural Net

- The images on the right show that the model performs very well.
  - Only 6.4% of Σs would be misidentified as a Λ
  - Only 0.73% of Λs would be misidentified as a Σ
- The new model is significantly better than the old one



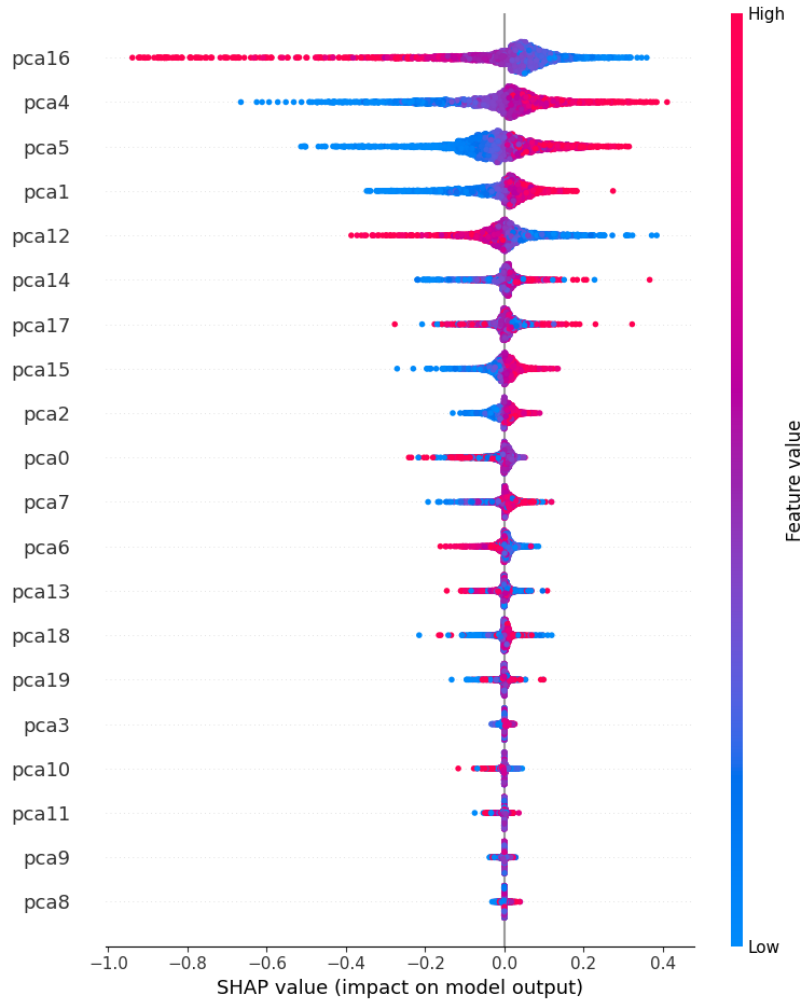
Model Characteristics	
Accuracy	0.985
Precision	0.990
Sensitivity	0.992
Specificity	0.935
F score	0.991

% Λ Retained	% Σ Retained BDT	NN
90	6.5	0.2
95	9.3	0.7
98	14.1	2.7
99	19.7	9.1



What is our NN actually doing?

- Using the SHAP package within python, the variables that are most important to the model can be found.
- The plot to the left ranks the 20 PCA variables from most to least important.
- From the PCA transform we can see which of our original variables are associated with each PCA variable. Full listing in back up slides.
- Top variables
  - pca16: Λ_m, x_E, x_{pz}
  - pca4: Λ_{ET2}, Λ_{mT2}, Λ_{pT}, Λ_{pz}, p_{pz}, x_m
  - pca5: x_m, x_{mT2}, x_{pT}
  - pca1: Λ_E, Λ_{ET}, Λ_{mT2}, Λ_{py}, Λ_{pz}
  - pca12: Λ_E, Λ_{ET2}, Λ_{mT2}, Λ_{pT}, p_E, x_m, x_{mT2}, x_{pT}, x_{px}, x_{py}



VARIABLE DEFINITIONS

- $x = K_0 + p - \Lambda - \pi^+$
- $E_T^2 = E^2 * p_T^2 / (p_T^2 + (p_x + p_y + p_z)^2)$
- $m_T^2 = E^2 - p_z^2$
- Decorrelation
  - Calculate the covariance matrix
  - Take its squareroot
  - The new variables are product of this inverse and the original variables
  - $X_{new} = (C')^{-1} X_{old}$
    - X is the column vector of the variables
    - C' = (Covariance Matrix)$^{0.5}$, which means that C'*C' = Covariance matrix

VARIABLE DEFINITIONS

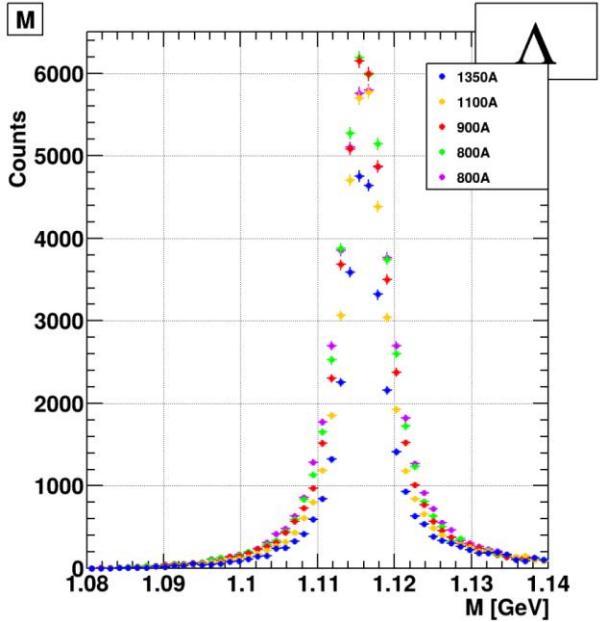
- T, F, N, P are True, False, Negative, and Positive, respectively.
- Accuracy: (TP + TN)/ALL , a measure of how accurate the model is in general
- Precision: TP/(TP + FP), a measure of how well the model is at discriminating against false positives
- Sensitivity/Recall: TP/(TP + FN), how well the model is at correctly predicting the positive cases
- Specificity: TN/(TN + FP), how well the model is at correctly predicting the negative case
- F score: 2*(Precision*Sensitivity)/(Precision + Sensitivity), the harmonic mean of the precision and the sensitivity. This is a measure of how well the model is at identifying positive cases and discriminating against false positives.

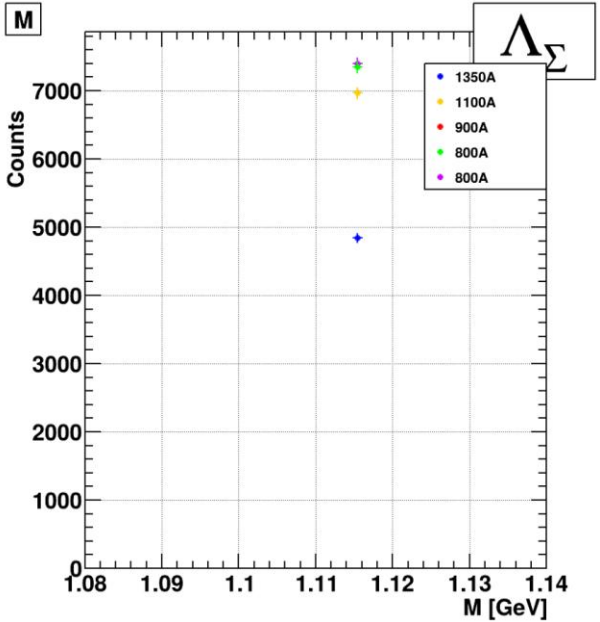
	pca0	pca1	pca2	pca3	pca4	pca5	pca6	\
lam_e	-0.000779	0.374191	0.126488	0.018439	-0.068226	0.028694	-0.116202	
lam_et2	0.003449	0.121152	0.040884	0.006898	0.759985	-0.069708	0.119322	
lam_m	-0.000573	0.001188	0.000327	0.000151	0.002643	0.006739	-0.022215	
lam_mt2	-0.001123	0.334583	0.111940	0.017404	0.406906	-0.051858	-0.094638	
lam_pt	0.000509	0.244967	0.081731	0.012685	0.302558	-0.068828	-0.071839	
lam_px	-0.004906	0.008429	0.087785	-0.770793	0.001163	0.001084	0.000703	
lam_py	-0.000808	0.249802	-0.729595	-0.080842	-0.001404	0.000101	0.001272	
lam_pz	-0.001858	0.524730	0.176880	0.025730	-0.282097	0.027629	-0.220237	
p_e	-0.001936	0.311083	0.105196	0.014608	-0.067874	0.031170	0.276367	
p_px	-0.004185	0.010142	0.058762	-0.605053	0.001740	0.001536	-0.004495	
p_py	-0.000314	0.196729	-0.574052	-0.051499	0.001781	0.003014	0.000640	
p_pz	-0.002495	0.428699	0.145785	0.020542	-0.239121	0.036162	0.461034	
pim_e	0.001158	0.063108	0.021293	0.003831	-0.000352	-0.002476	-0.392569	
pim_px	-0.000721	-0.001713	0.029023	-0.165740	-0.000577	-0.000452	0.005198	
pim_py	-0.000494	0.053073	-0.155543	-0.029343	-0.003186	-0.002913	0.000631	
pim_pz	0.000638	0.096031	0.031094	0.005188	-0.042976	-0.008534	-0.681271	
x_e	0.702024	0.000291	-0.000147	-0.004703	-0.018813	-0.077032	0.001216	
x_et2	0.000364	-0.000873	-0.000470	-0.000137	0.005026	0.038857	0.002158	
x_m	-0.011547	0.004900	0.000862	-0.000750	-0.114531	-0.541314	-0.013192	
x_mt2	-0.016739	0.004080	0.000409	-0.001306	-0.060757	-0.809181	0.040335	
x_pt	0.001350	-0.009169	-0.003608	-0.000661	0.010358	0.159835	0.009351	
x_px	0.000684	-0.000560	0.000124	0.005975	0.002949	0.023433	-0.003668	
x_py	0.000078	-0.002320	0.006153	-0.000435	-0.002649	0.004247	-0.003415	
x_pz	0.711810	0.004136	0.001221	-0.004407	0.010207	0.048469	0.001727	

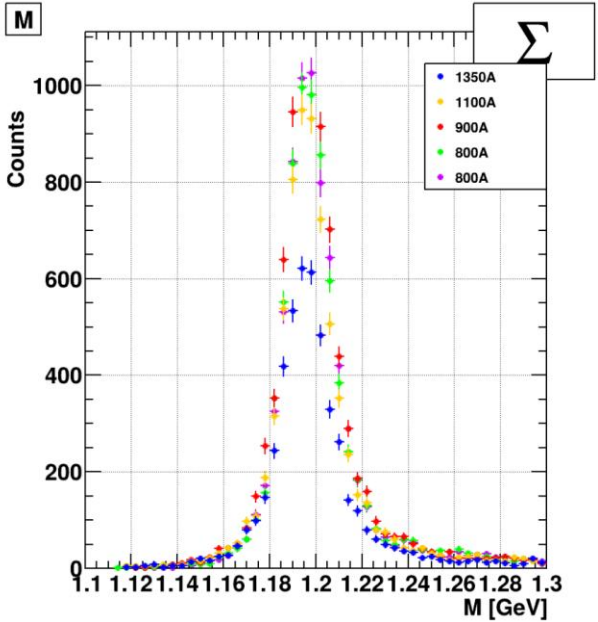
	pca7	pca8	pca9	pca10	pca11	pca12	pca13	\
lam_e	-0.067391	-0.001918	0.000365	-0.010550	0.006519	-0.180657	0.329293	
lam_et2	0.019755	-0.005161	0.000248	-0.021575	-0.002515	-0.300984	0.347053	
lam_m	-0.034947	0.000628	0.001249	0.008380	0.004789	0.062873	0.045775	
lam_mt2	-0.030093	0.001365	0.000154	0.030165	0.006959	0.399715	-0.130908	
lam_pt	0.140188	0.001114	-0.002302	0.005909	-0.012306	0.189535	-0.597405	
lam_px	0.002455	0.022087	-0.253244	0.007808	0.007130	0.000458	0.000772	
lam_py	0.002398	-0.254812	-0.020707	-0.004597	0.005459	0.001566	0.000242	
lam_pz	-0.002176	-0.000276	-0.002330	-0.004927	-0.003593	-0.058120	-0.037540	
p_e	-0.041565	-0.001037	0.002068	-0.003266	0.009347	-0.139869	0.316116	
p_px	-0.004483	-0.010925	0.544641	-0.002796	-0.013504	-0.002257	-0.002960	
p_py	-0.003194	0.543615	0.012038	0.007262	0.003696	-0.004896	0.000041	
p_pz	0.027446	0.000591	0.003265	-0.000001	-0.004397	0.035242	-0.147624	
pim_e	-0.025826	-0.000881	-0.001703	-0.007284	-0.002828	-0.040788	0.013176	
pim_px	0.006938	0.033012	-0.797885	0.010604	0.020634	0.002715	0.003732	
pim_py	0.005592	-0.798427	-0.032744	-0.011859	0.001763	0.006462	0.000201	
pim_pz	-0.029621	-0.000867	-0.005595	-0.004926	0.000804	-0.093362	0.110083	
x_e	-0.034564	-0.000870	0.001229	0.000433	0.004833	0.028458	-0.040849	
x_et2	-0.077049	0.000102	0.000212	0.005073	-0.005680	0.127501	0.077434	
x_m	0.673317	0.009176	0.008281	0.031288	-0.060943	0.340809	0.334520	
x_mt2	-0.549872	-0.001176	-0.003114	0.015385	0.057331	-0.115948	-0.098593	
x_pt	-0.445490	0.000994	0.001043	0.057692	0.012552	0.699545	0.358184	
x_px	0.037925	-0.014792	0.018850	0.946513	0.311768	-0.063714	-0.006676	
x_py	0.072982	0.005336	0.021660	-0.312159	0.945758	0.042040	0.013337	
x_pz	0.032624	0.000534	-0.000546	-0.000369	-0.004784	-0.025055	0.041734	

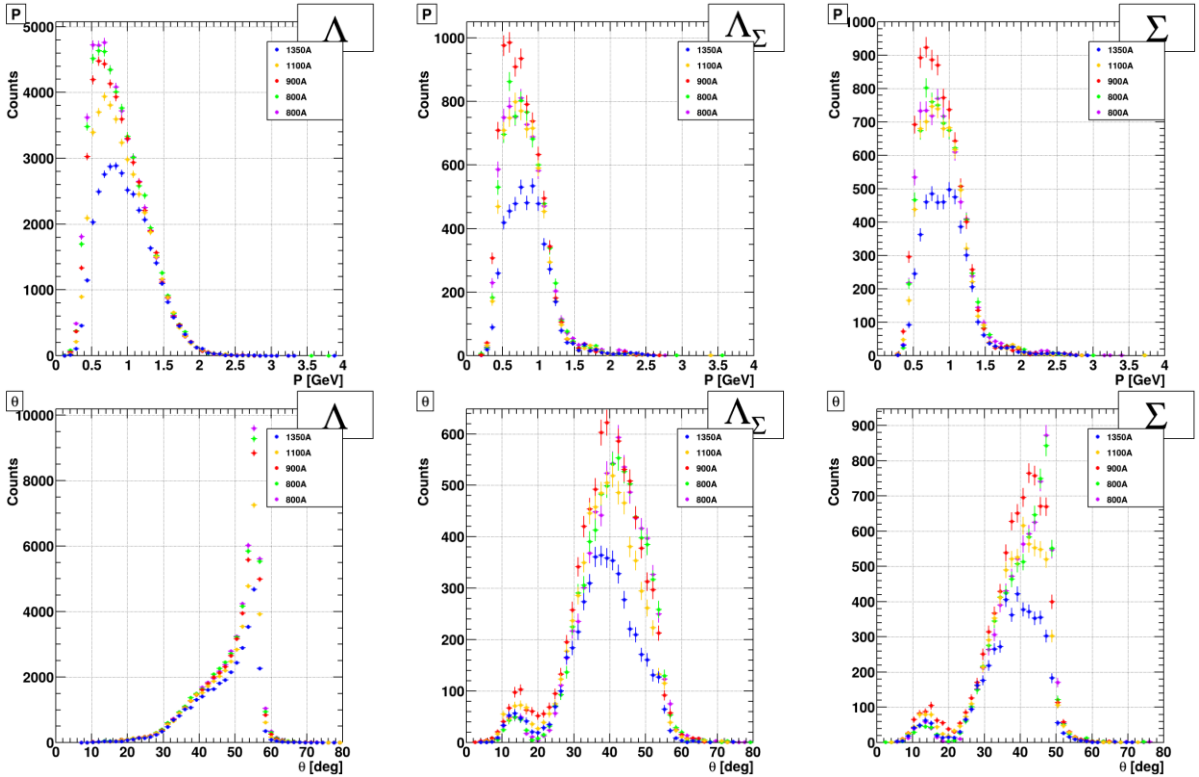
	pca14	pca15	pca16	pca17	pca18	pca19	\
lam_e	0.056899	0.129873	0.011293	-0.216883	0.074697	-0.522214	
lam_et2	-0.264384	0.151502	0.060436	0.047879	-0.023872	0.274999	
lam_m	0.239173	0.076479	-0.252219	-0.779264	0.284018	0.421309	
lam_mt2	0.685779	-0.036177	-0.006499	0.207357	-0.066049	-0.014930	
lam_pt	-0.471282	-0.193430	-0.071261	-0.272823	0.095686	-0.266197	
lam_px	0.000343	0.000791	0.000417	-0.000314	0.000185	-0.000070	
lam_py	0.000224	0.000625	-0.000252	-0.000067	-0.000068	-0.000095	
lam_pz	-0.161026	0.002309	0.016390	0.150588	-0.054577	0.416933	
p_e	0.064731	-0.518797	-0.022626	-0.137550	0.047010	-0.245656	
p_px	-0.000303	-0.000757	-0.000668	0.000680	-0.000432	0.000222	
p_py	-0.000404	0.000835	0.000913	0.000099	0.000050	0.000087	
p_pz	-0.077946	0.334121	0.018623	0.081521	-0.028894	0.202002	
pim_e	-0.007832	0.648670	0.033918	-0.079334	0.027687	-0.276557	
pim_px	0.000646	0.001548	0.001084	-0.000994	0.000616	-0.000292	
pim_py	0.000627	-0.000209	-0.001165	-0.000166	-0.000118	-0.000182	
pim_pz	-0.083080	-0.331812	-0.002233	0.069067	-0.025683	0.214931	
x_e	0.040281	-0.034831	0.678535	-0.146790	0.098625	0.051299	
x_et2	-0.078333	0.007730	-0.053837	0.344612	0.917789	-0.004878	
x_m	-0.079548	0.028654	-0.007462	-0.008080	-0.000455	-0.001819	
x_mt2	-0.007555	-0.000693	-0.098735	0.026000	-0.003192	-0.007576	
x_pt	-0.343908	0.025565	0.018141	-0.067665	-0.174941	0.010572	
x_px	-0.007865	0.007271	0.004271	0.004148	0.006252	-0.000452	
x_py	-0.013453	0.005270	-0.002415	0.003528	0.003933	0.002597	
x_pz	-0.037968	0.033303	-0.672110	0.144998	-0.097380	-0.050831	

	pca20	pca21	pca22	pca23
lam_e	5.773410e-01	3.182080e-03	-7.260953e-04	-2.040713e-04
lam_et2	-1.844570e-09	-2.683277e-09	-1.348296e-10	-5.858861e-10
lam_m	7.736337e-09	-1.020374e-08	-2.967798e-09	9.135539e-09
lam_mt2	-3.355998e-10	-3.164796e-10	-7.930971e-10	-2.427831e-10
lam_pt	1.457427e-09	5.689009e-09	-5.625065e-11	2.030177e-09
lam_px	-1.443065e-04	5.299555e-03	6.955658e-02	-5.731205e-01
lam_py	7.161679e-04	5.301235e-03	5.731142e-01	6.960466e-02
lam_pz	-3.187599e-03	5.772928e-01	-5.897393e-03	4.623205e-03
p_e	-5.773410e-01	-3.182080e-03	7.260994e-04	2.040681e-04
p_px	1.443049e-04	-5.299555e-03	-6.955658e-02	5.731205e-01
p_py	-7.161685e-04	-5.301234e-03	-5.731142e-01	-6.960466e-02
p_pz	3.187596e-03	-5.772928e-01	5.897391e-03	-4.623203e-03
pim_e	-5.773410e-01	-3.182078e-03	7.261005e-04	2.040681e-04
pim_px	1.443126e-04	-5.299555e-03	-6.955658e-02	5.731205e-01
pim_py	-7.161643e-04	-5.301235e-03	-5.731142e-01	-6.960466e-02
pim_pz	3.187596e-03	-5.772928e-01	5.897389e-03	-4.623204e-03
x_e	5.820592e-09	-3.151229e-09	4.005433e-10	-1.360673e-09
x_et2	-1.454394e-08	-1.014370e-08	-8.328744e-09	-8.630234e-09
x_m	-4.112701e-09	1.117421e-09	-5.498720e-10	-1.150568e-09
x_mt2	8.886467e-11	-1.532526e-10	4.228921e-10	2.025138e-10
x_pt	-1.755654e-10	3.671445e-09	1.715875e-09	1.106026e-09
x_px	3.165812e-09	2.424081e-11	-2.435620e-10	2.035802e-09
x_py	-3.414458e-09	-5.048098e-10	3.225688e-10	-8.283410e-10
x_pz	-6.029812e-09	3.177763e-09	-4.112858e-10	1.306722e-09


M
Λ
Counts
M [GeV]
1350A
1100A
900A
800A
800A


M
Λ_Σ
Counts
M [GeV]
1350A
1100A
900A
800A
800A


M
Σ
Counts
M [GeV]
1350A
1100A
900A
800A
800A


P
Λ
Λ_Σ
Σ
θ
Counts
P [GeV]
θ [deg]
1350A
1100A
900A
800A
800A