Update on Lambda Simulation

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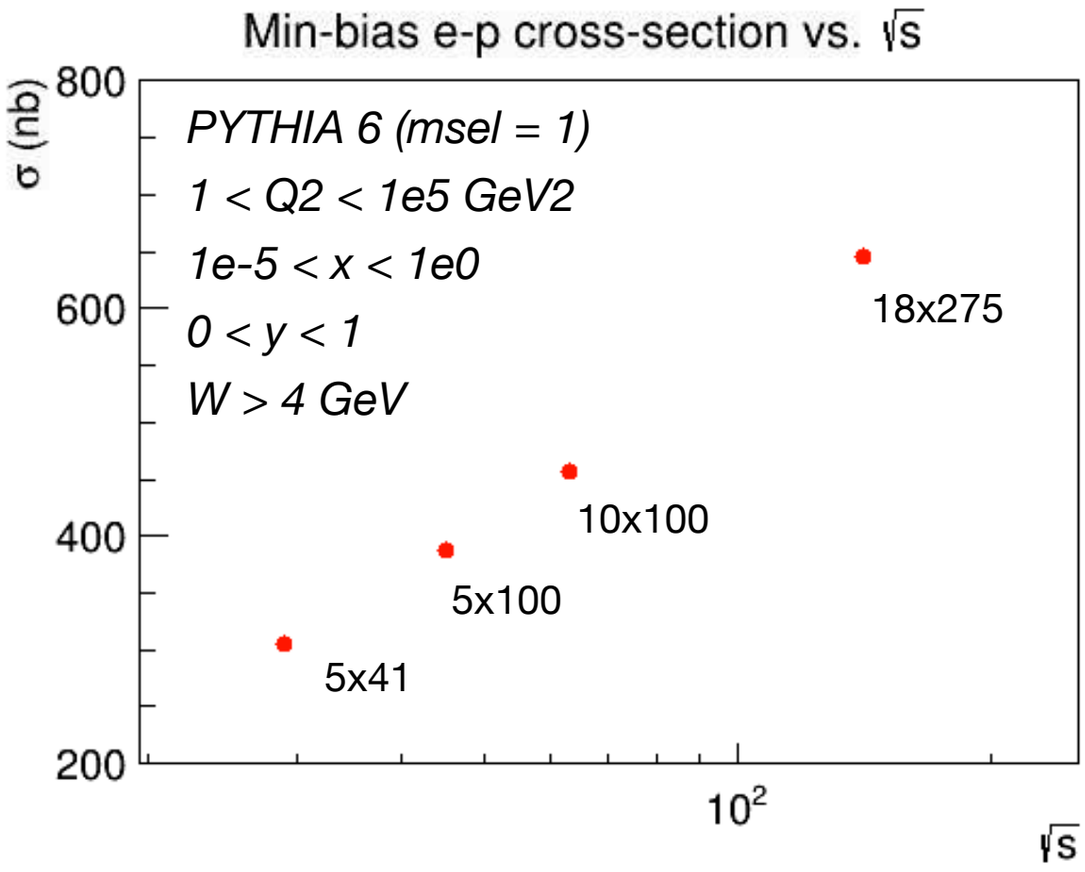
EIC YR SIDIS @ May 4, 2020

Lambda Simulation

PythiaeRHIC (pythia6) + eicsmear at eic nodes @RCF

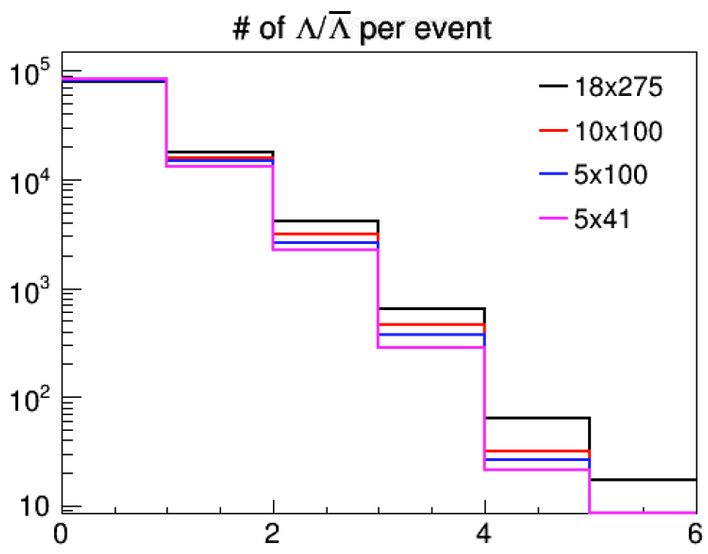


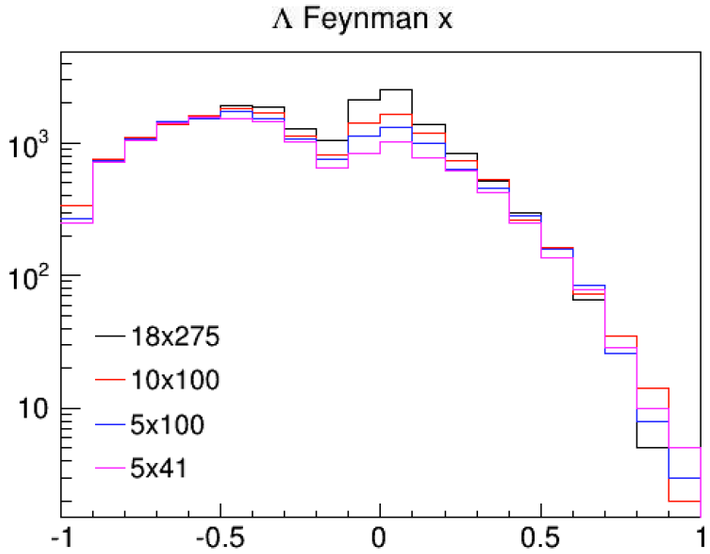
Lambda/Anti-Lambda selection

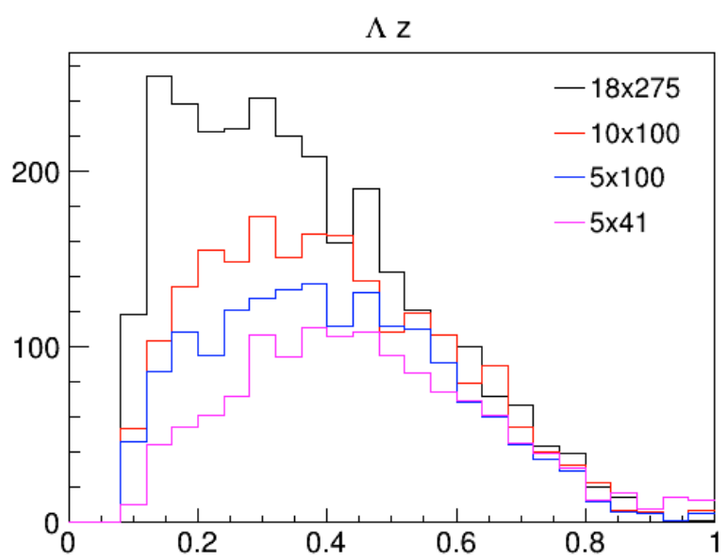
- Truth information based
- decay to proton and pion only (~63%)
- Eta of proton/pion: (-3.5, 3.5)
- p_T of proton/pion: >0.3 GeV
- Feynman-x: > 0 *xF = 2 * pz / W in the boson-hadron CM frame
- z_h : > 0.1 *z = (P.p_h)/(P.q)

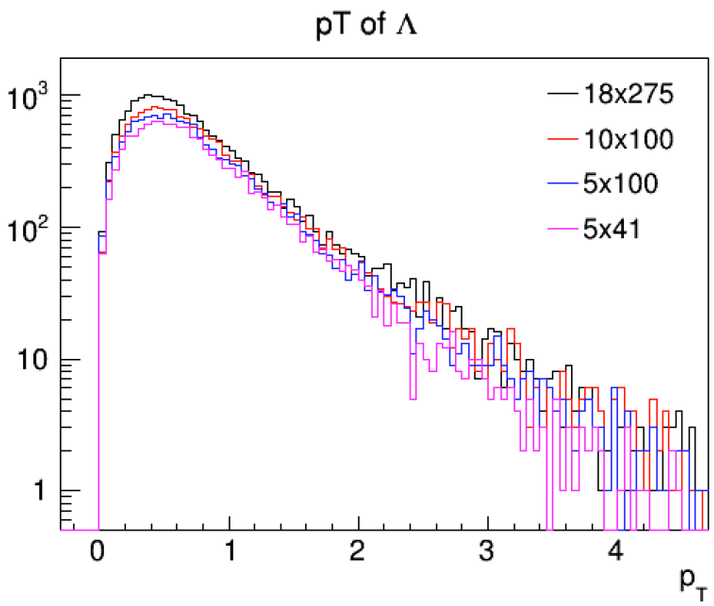
	# of generated	Luminosity of generated N_evt/x-section (fb-1)	Scale factor to 10 fb-1	# of lambda/Anti-Lambda generated (after all cuts)	# of lambda/Anti-Lambda scaled
5x41	1M	1.55E-03	6.45E+03	594/733	3.83M/4.73M
5x100	1M	2.19E-03	4.57E+03	***912/763***	4.18M/3.49M
10x100	1M	2.58E-03	3.88E+03	968/1088	3.76M/4.22M
18x275	1M	3.28E-03	3.05E+03	1382/1424	4.22M/4.34M

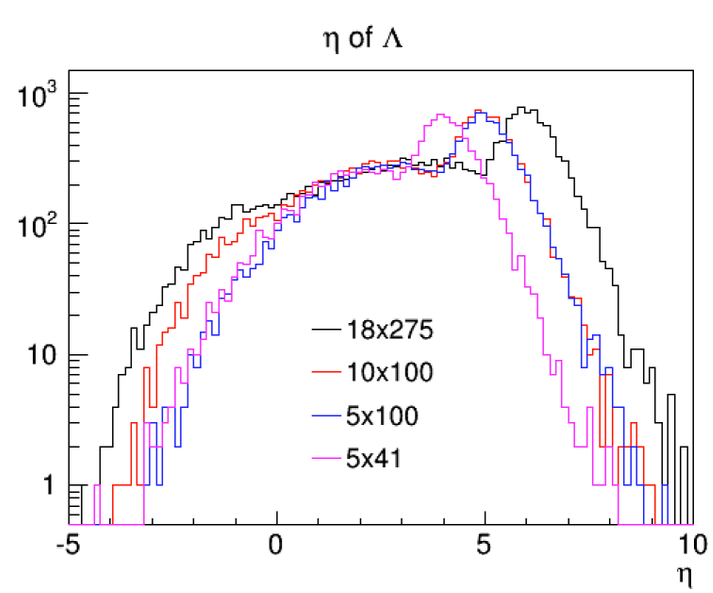
Lambda Kinematics



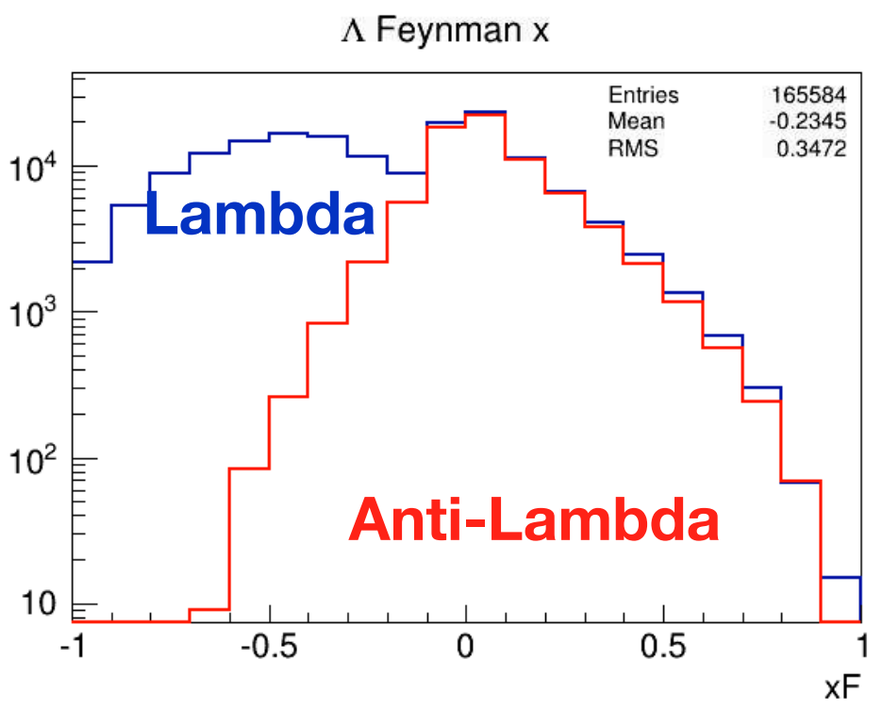


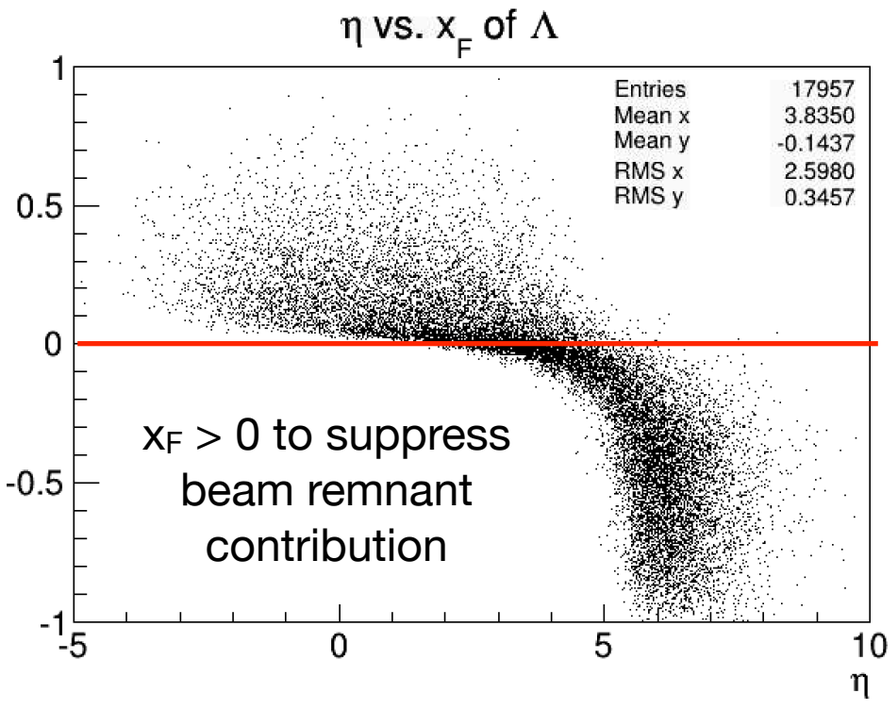


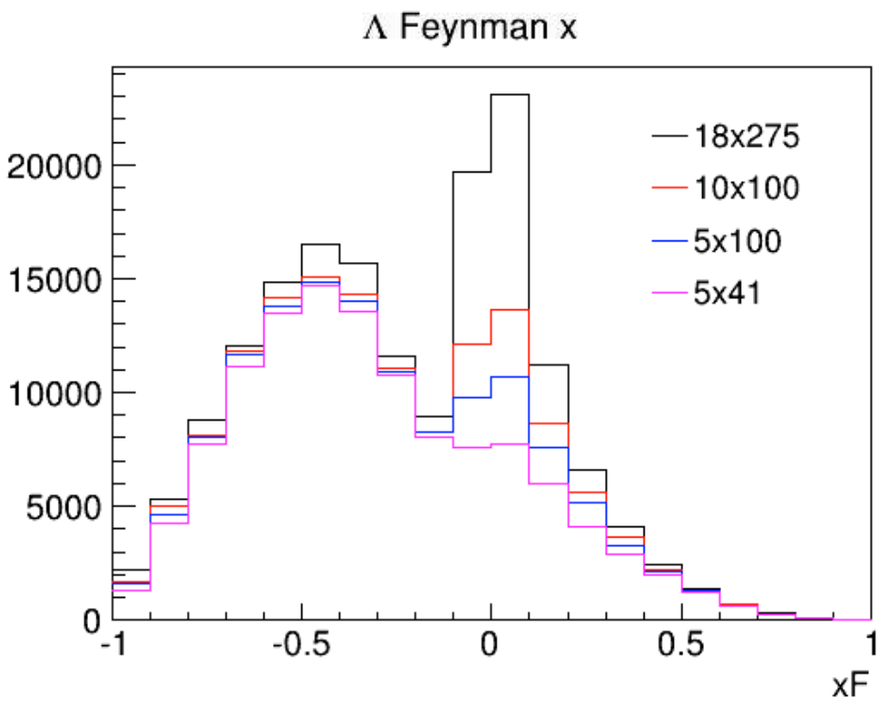


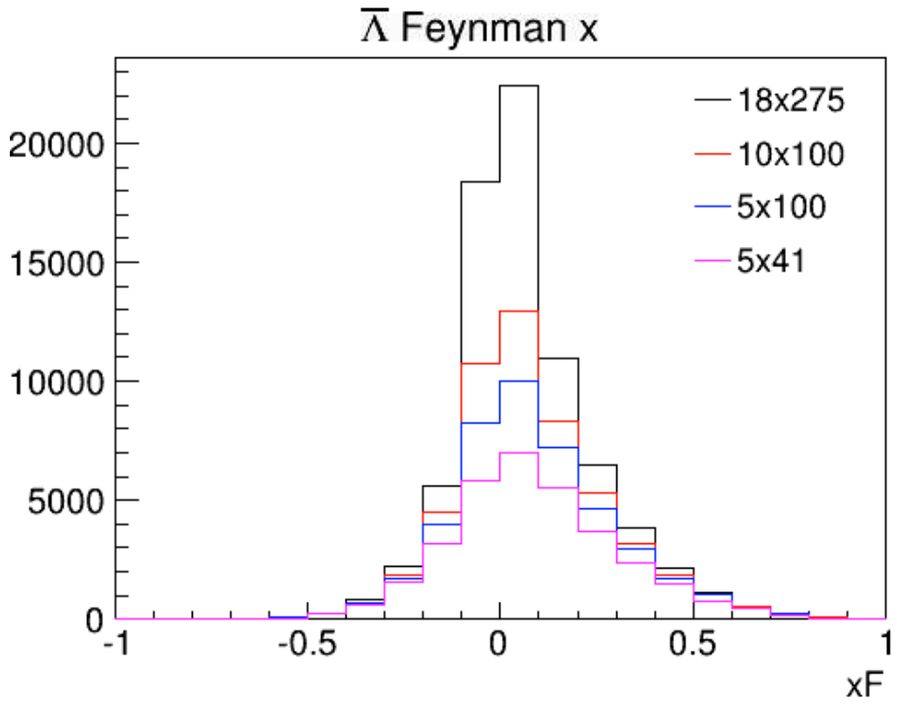


Feynman x


Λ Feynman x
Entries 165584
Mean -0.2345
RMS 0.3472
Lambda
Anti-Lambda
xF

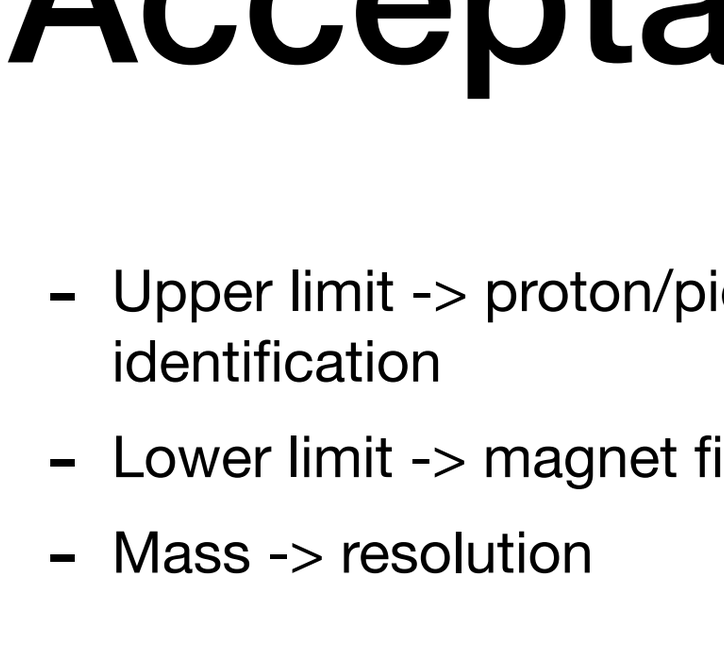

η vs. x_F of Λ
Entries 17957
Mean x 3.8350
Mean y -0.1437
RMS x 2.5980
RMS y 0.3457
x_F > 0 to suppress beam remnant contribution
η

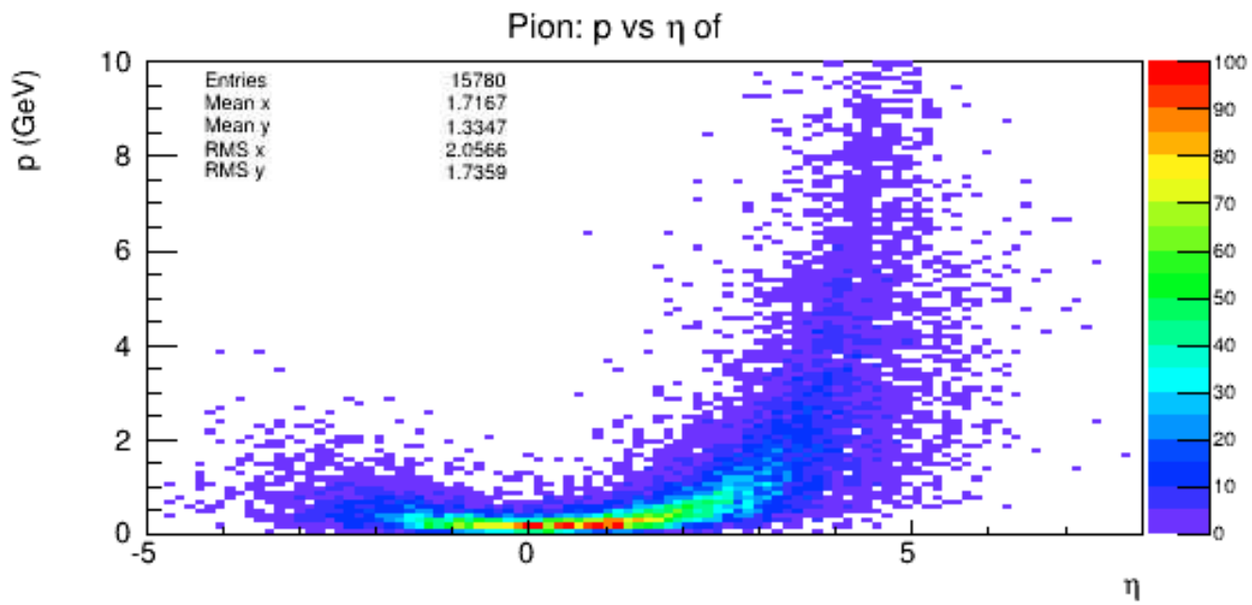

Λ Feynman x
18x275
10x100
5x100
5x41
xF

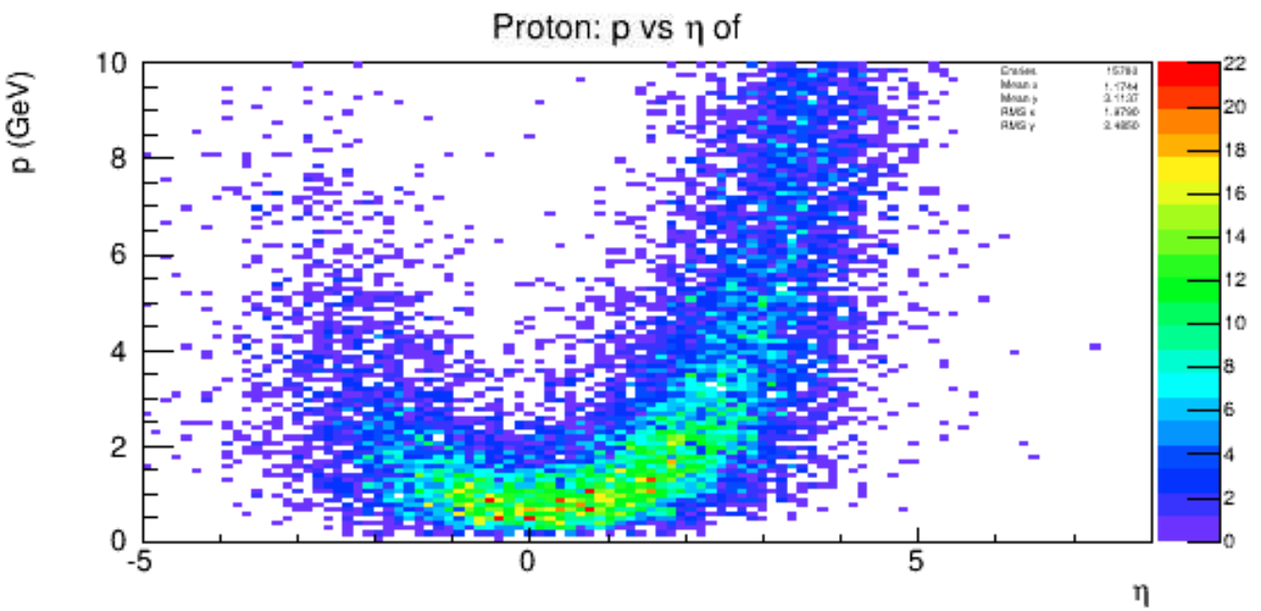

Λ̄ Feynman x
18x275
10x100
5x100
5x41
xF

Acceptance requirement

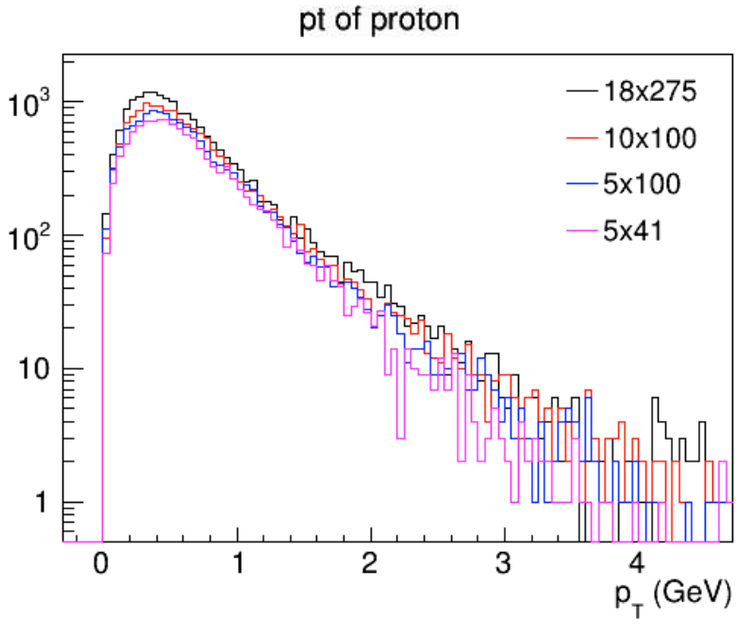
- Upper limit -> proton/pion identification
- Lower limit -> magnet filed
- Mass -> resolution

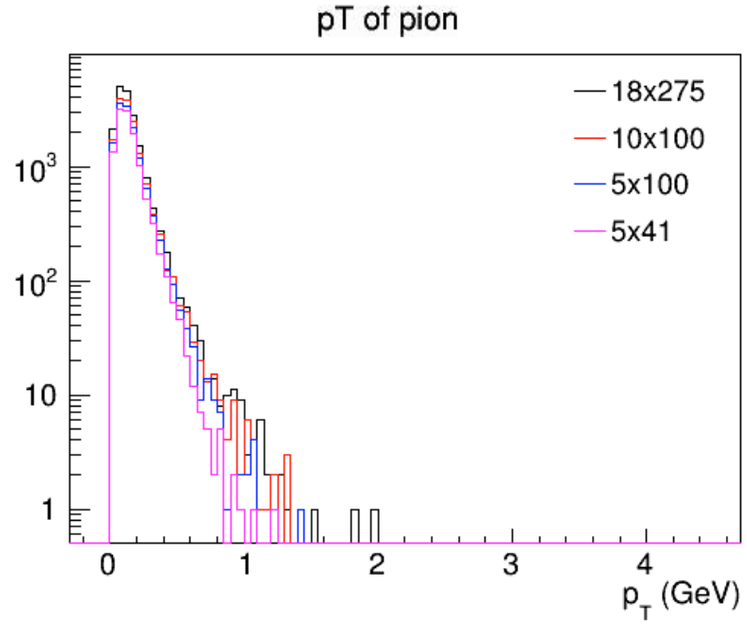


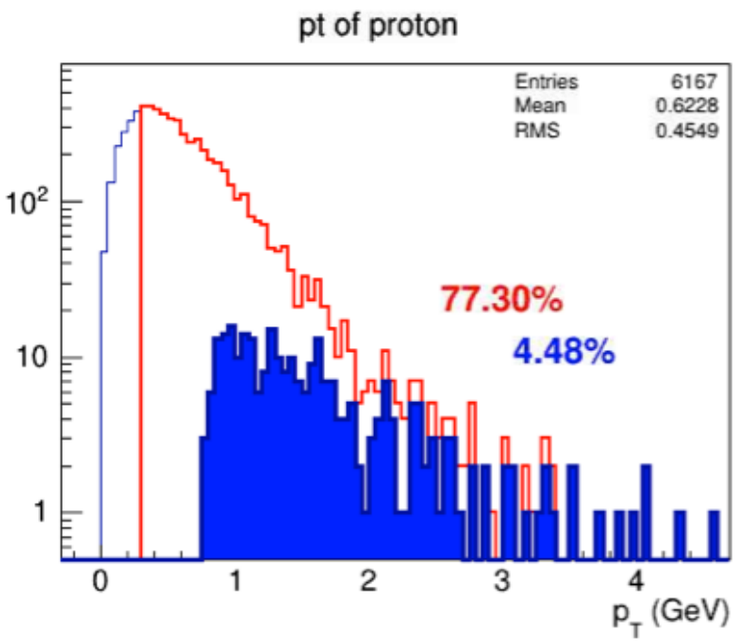


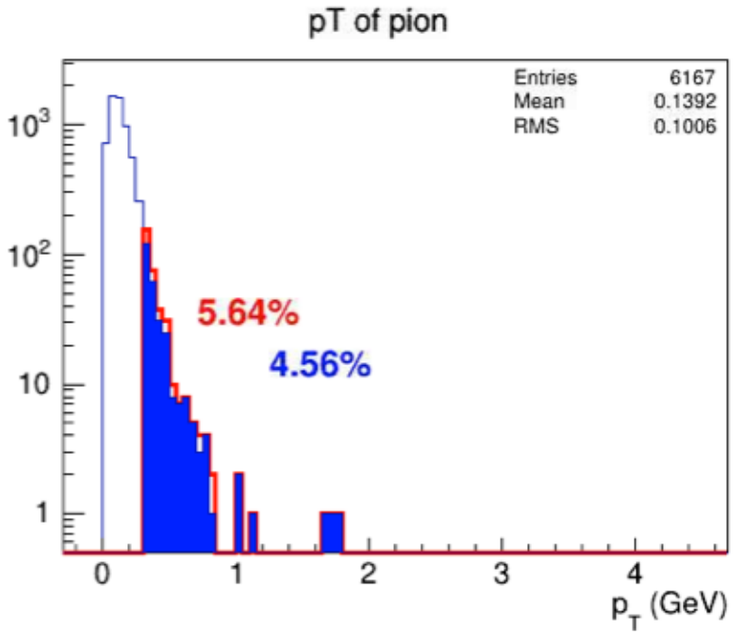


Final p_T limits









- p_T of pion and proton > 0.3 GeV
- Red is independent 0.3 GeV cut
- Blue filled is combined eta and pT cut

Lambda origin 18x275

This sample is from 1M min-bias DIS events, see earlier slides.

Lambda

		all lambda		*after cuts*	
particle name	pdg id	# of lambda	fraction	# of lambda	fration
diquark (ud)0	2101	43615	26.34%	27	1.95%
sigma0	3212	25887	15.63%	325	23.52%
sigma*+	3224	19118	11.55%	61	4.41%
sigma*0	3214	15017	9.07%	45	3.26%
proton	2212	12678	7.66%	0	0.00%
u	2	10325	6.24%	197	14.25%
lambda_c+	4122	6308	3.81%	77	5.57%
cascade0	3322	5431	3.28%	95	6.87%
cascade+	3312	5210	3.15%	78	5.64%
s	3	4556	2.75%	207	14.98%
d	1	3872	2.34%	57	4.12%
ubar	-2	3066	1.85%	72	5.21%
sigma*-	3114	3029	1.83%	42	3.04%
diquark (uu)1	2203	1714	1.04%	2	0.14%
c	4	1361	0.82%	13	0.94%
diquark (ud)1	2103	1235	0.75%	13	0.94%
cbar	-4	1160	0.70%	24	1.74%
dbar	-1	1078	0.65%	26	1.88%
sbar	-3	749	0.45%	17	1.23%
cascade_c0	4132	72	0.04%	3	0.22%
omega-	3334	54	0.03%	1	0.07%
cascade_c+	4232	17	0.01%	0	0.00%
b	5	11	0.01%	0	0.00%
bbar	-5	11	0.01%	0	0.00%
B0	511	4	0.00%	0	0.00%
lmabda_b0	5122	2	0.00%	0	0.00%
B+	521	1	0.00%	0	0.00%
lambda_b0	-5122	1	0.00%	0	0.00%
j/psi(1s)	443	1	0.00%	0	0.00%
B-	-521	1	0.00%	0	0.00%
		165584		1382	

~1%

Anti-Lambda

		all lambda-bar		*after cuts*	
	pdg id	# of lambda	fraction	# of lambda	fration
anti-simga0	-3212	16966	22.56%	284	19.94%
u	2	7893	10.50%	178	12.50%
diquark (ud)0	2101	6517	8.67%	35	2.46%
anti-cascade0	-3322	5587	7.43%	91	6.39%
cascade-	-3312	5431	7.22%	94	6.60%
sbar	-3	4321	5.75%	241	16.92%
ubar	-2	4062	5.40%	107	7.51%
anti-sigma*0	-3214	3621	4.82%	68	4.78%
sigma*-	-3224	3607	4.80%	58	4.07%
sigma*+	-3114	3191	4.24%	43	3.02%
d	1	2985	3.97%	44	3.09%
diquark (uu)1	2203	2920	3.88%	18	1.26%
diquark (ud)1	2103	2210	2.94%	8	0.56%
cbar	-4	1419	1.89%	14	0.98%
dbar	-1	1375	1.83%	38	2.67%
c	4	1167	1.55%	12	0.84%
lambda_c-	-4122	1101	1.46%	63	4.42%
s	3	682	0.91%	23	1.62%
omega+	-3334	61	0.08%	1	0.07%
anti-cascade_c0	-4132	50	0.07%	4	0.28%
bbar	-5	14	0.02%	0	0.00%
cascade_c-	-4232	12	0.02%	0	0.00%
b	5	4	0.01%	0	0.00%
j/psi(1s)	443	2	0.00%	0	0.00%
lambda_b0	-5122	1	0.00%	0	0.00%
B+	521	1	0.00%	0	0.00%
		75200		1424	

~2%

Cuts:
p+pi decay only
p/pi eta (-3.5, 3.5) && p/pi pt >0.3 GeV
&& xF > 0 && z > 0.1

Lambda origin 5x41

This sample is from 1M min-bias DIS events, see earlier slides.

		all lambda		**after cut**				all lambdabar		**after cuts**	
particle name	pdg id	# of lambda	fraction	# of lambda	fration	particle name	pdg id	# of anti-lambda	fraction	# of anti-lambda	fration
diquark (ud)0	2101	46991	66.72%	65	8.63%	sigma*-	-3224	1379	4.20%	8	1.35%
simga0	3212	15305	21.73%	191	25.37%	anti-simga0	-3212	7501	22.83%	135	22.73%
sigma*+	3224	13933	19.78%	34	4.52%	diquark (ud)0	2101	4441	13.52%	66	11.11%
sigma*0	3214	12149	17.25%	40	5.31%	u	2	3551	10.81%	97	16.33%
proton	2212	8924	12.67%	0	0.00%	sbar	-3	2271	6.91%	103	17.34%
u	2	4911	6.97%	142	18.86%	anti-cascade0	-3322	2222	6.76%	25	4.21%
s	3	2934	4.17%	119	15.80%	cascade-	-3312	2114	6.43%	31	5.22%
lambda_c+	4122	2452	3.48%	17	2.26%	ubar	-2	1532	4.66%	38	6.40%
cascade0	3322	2002	2.84%	29	3.85%	diquark (uu)1	2203	1409	4.29%	13	2.19%
cascade+	3312	1794	2.55%	16	2.12%	diquark (ud)1	2103	1382	4.21%	15	2.53%
d	1	1626	2.31%	28	3.72%	sigma*-	-3214	1318	4.01%	9	1.52%
ubar	-2	1105	1.57%	30	3.98%	sigma*+	-3114	1209	3.68%	12	2.02%
sigma*-	3114	1008	1.43%	10	1.33%	d	1	1147	3.49%	18	3.03%
diquark (uu)1	2203	669	0.95%	9	1.20%	dbar	-1	564	1.72%	12	2.02%
diquark (ud)1	2103	654	0.93%	12	1.59%	lambda_c-	-4122	267	0.81%	4	0.67%
dbar	-1	433	0.61%	6	0.80%	s	3	178	0.54%	4	0.67%
sbar	-3	192	0.27%	3	0.40%	cbar	-4	170	0.52%	1	0.17%
c	4	163	0.23%	1	0.13%	c	4	159	0.48%	2	0.34%
cbar	-4	146	0.21%	0	0.00%	omega+	-3334	22	0.07%	0	0.00%
omega-	3334	18	0.03%	1	0.13%	anti-cascade_c0	-4132	18	0.05%	1	0.17%
cascade_c0	4132	9	0.01%	0	0.00%	cascade_c-	-4232	2	0.01%	0	0.00%
cascade_c+	4232	4	0.01%	0	0.00%						
lmabda_b0	5122	1	0.00%	0	0.00%						
Total #		70432		753		Total #		32856		594	

~1%

~2%

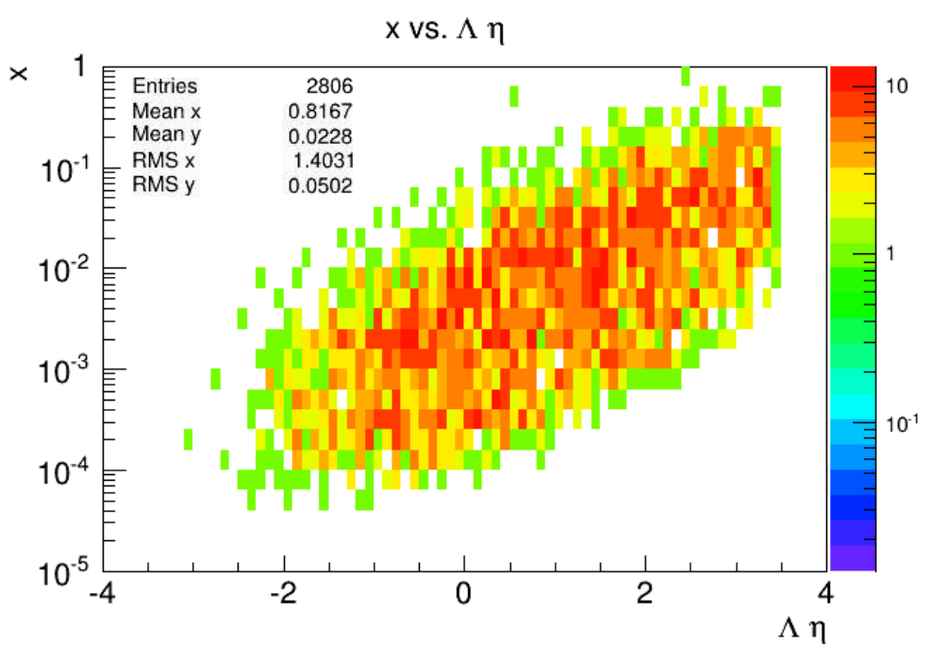
Cuts:

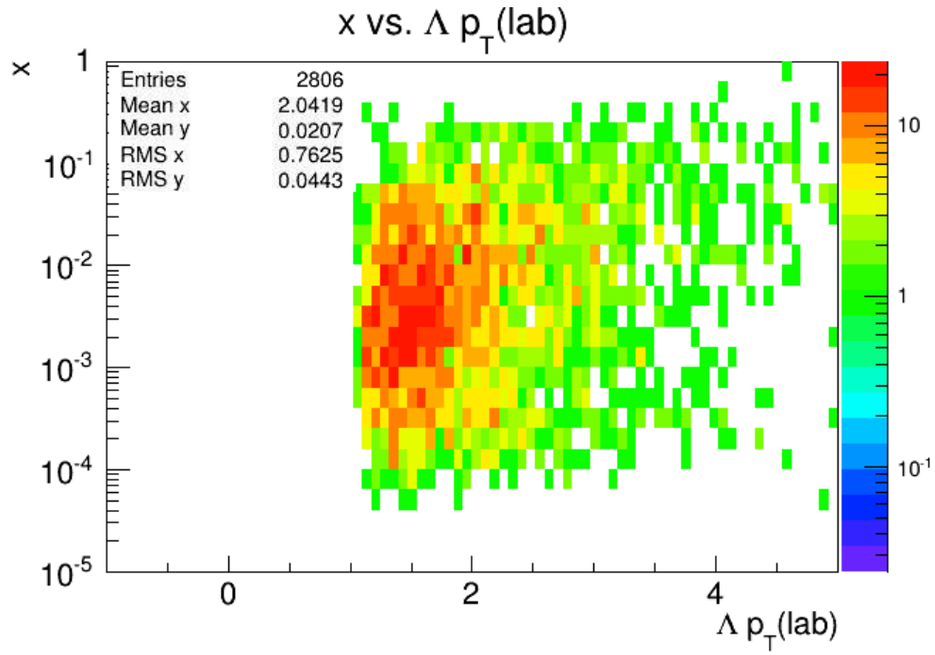
p+pi decay only

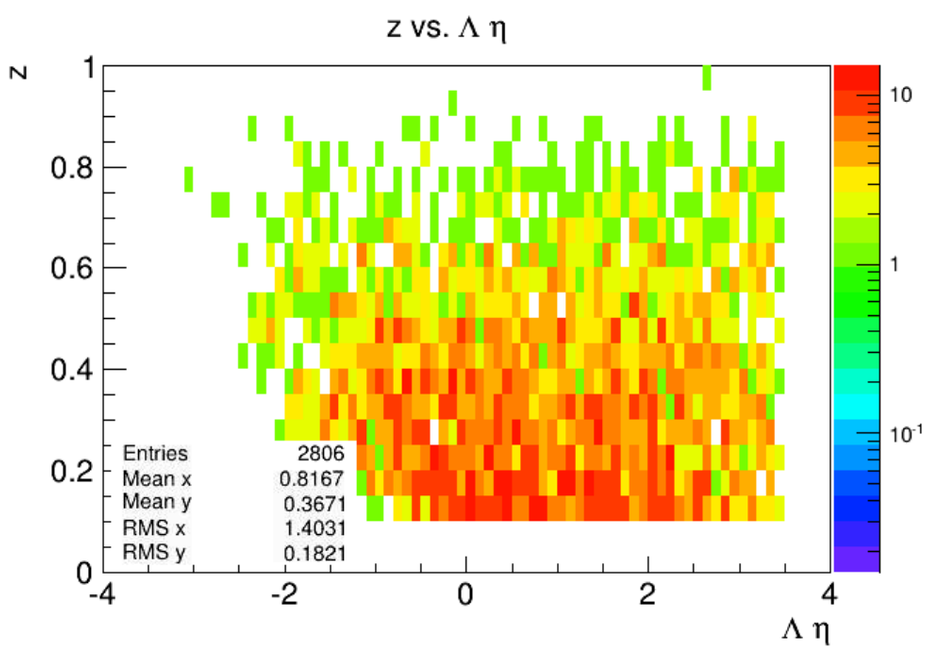
p/pi eta (-3.5, 3.5) && p/pi pt >0.3 GeV

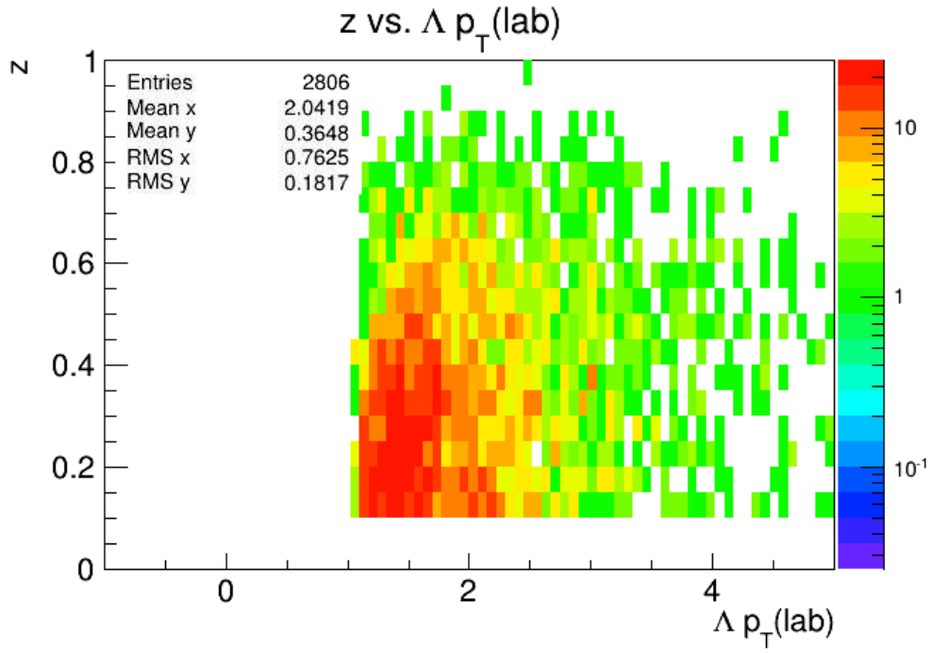
&& xF > 0 && z > 0.1

x_B and z_h vs eta and p_T

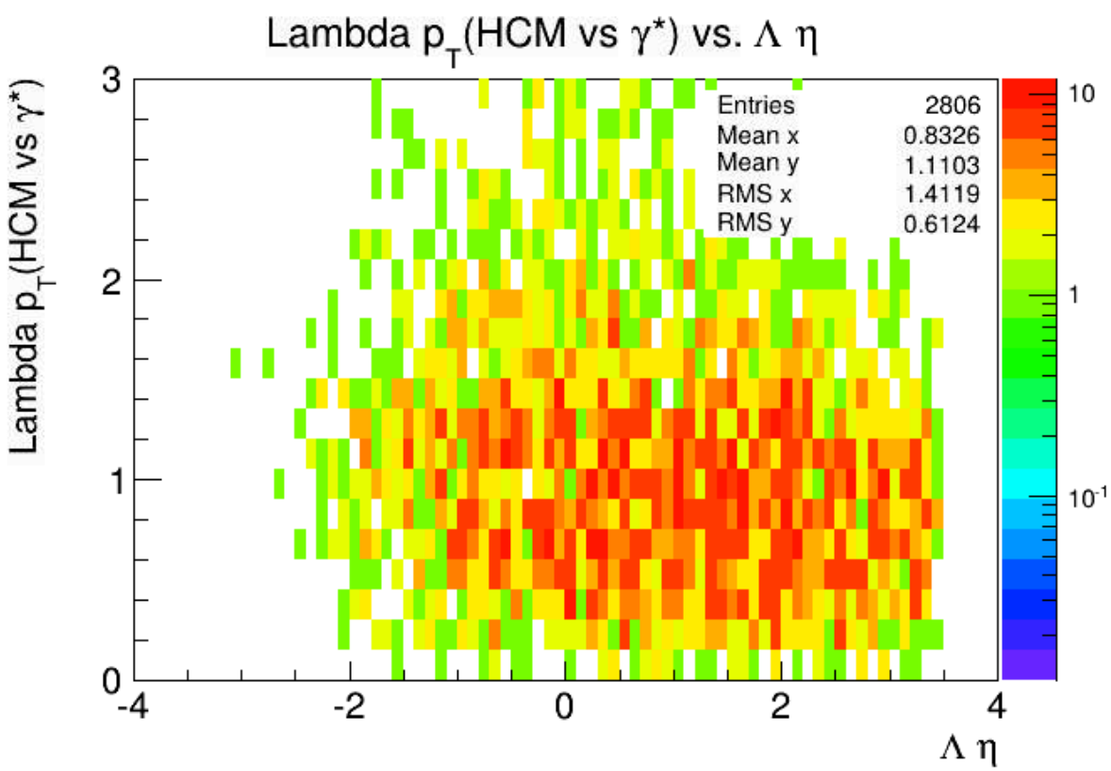


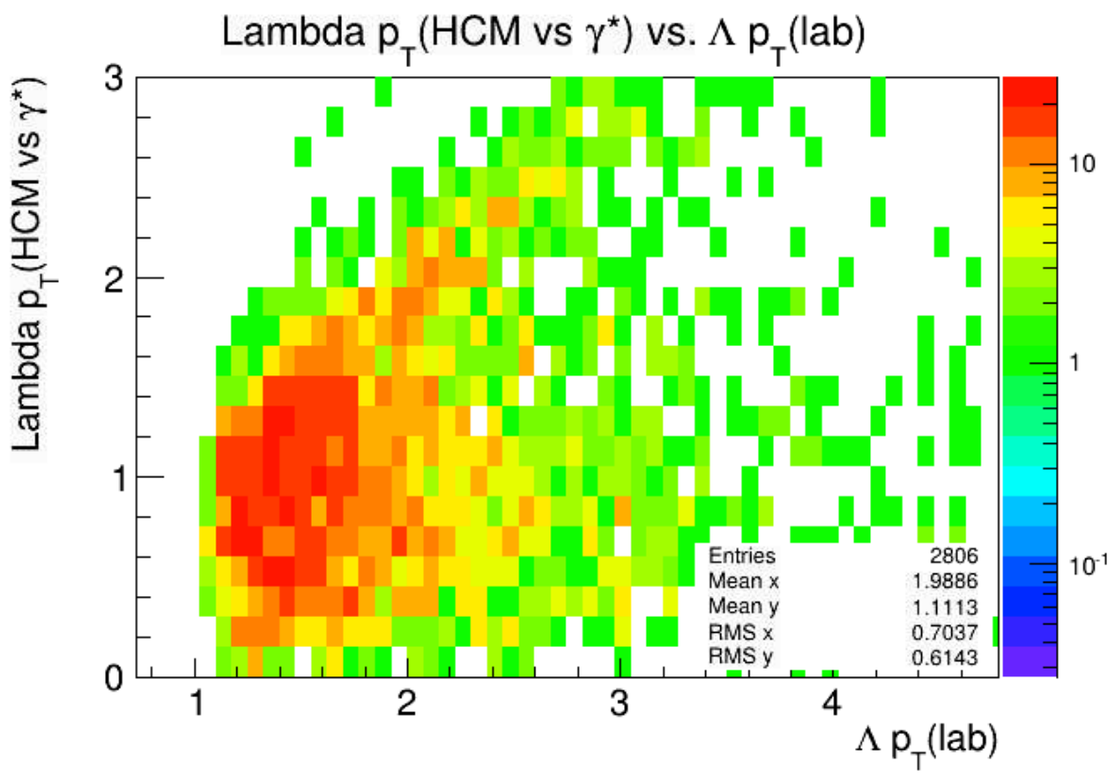






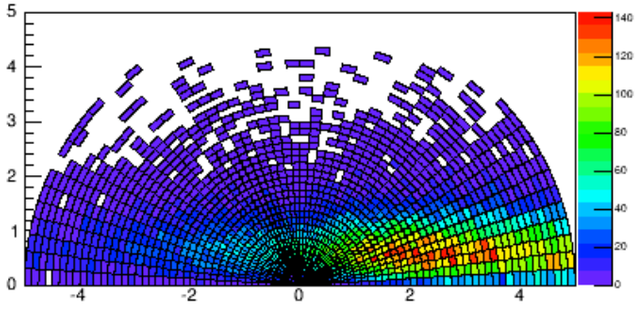
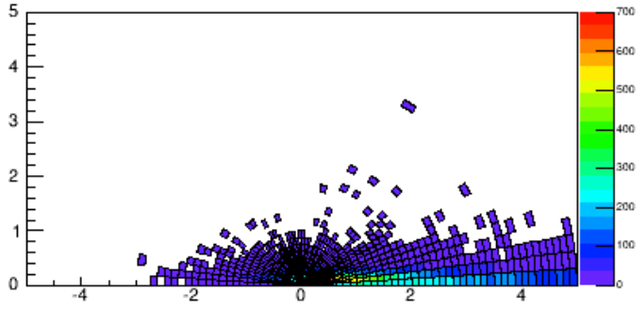
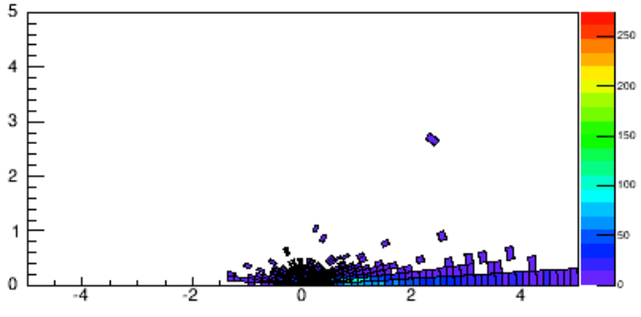
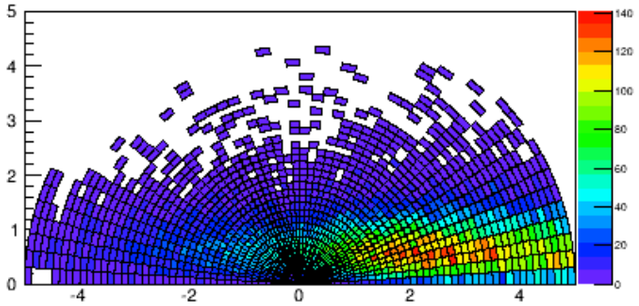
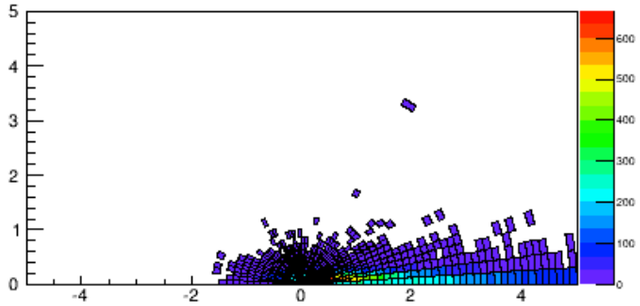
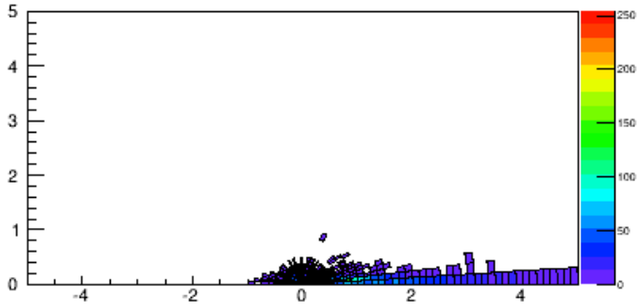
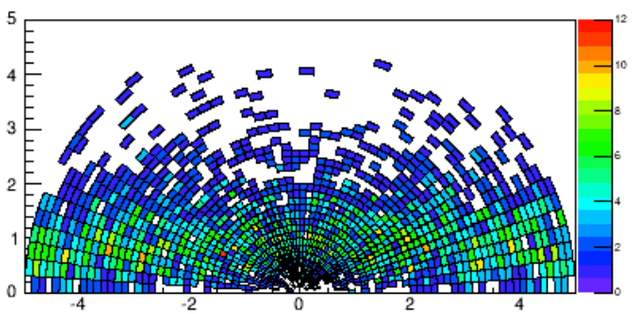
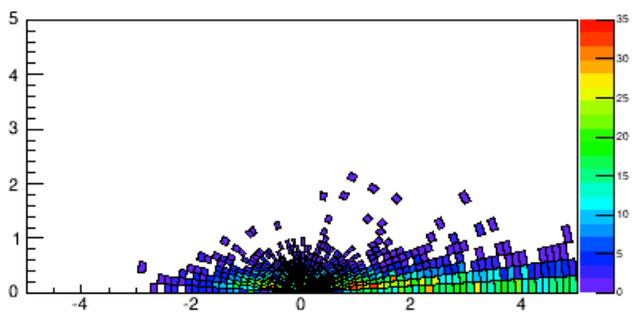
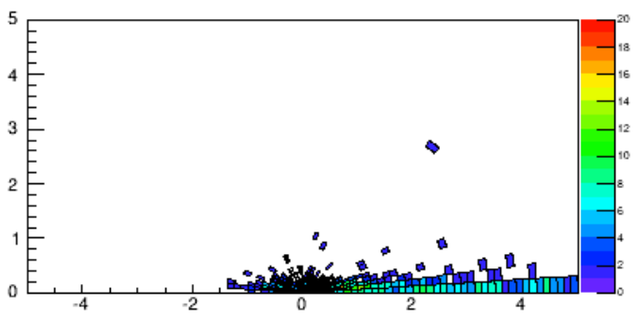
Transverse momentum in HCM and Lab frames





Momentum vs theta

275 GeV → ← 18 GeV

	Proton from Lambda	Pion from Lambda	Gamma from Sigma0
All			
z_h < 0.4			
z_h > 0.4			

Angle for theta, radius for momentum/energy

Momentum vs theta

275 GeV → ← 18 GeV

Proton from Lambda

Pion from Lambda

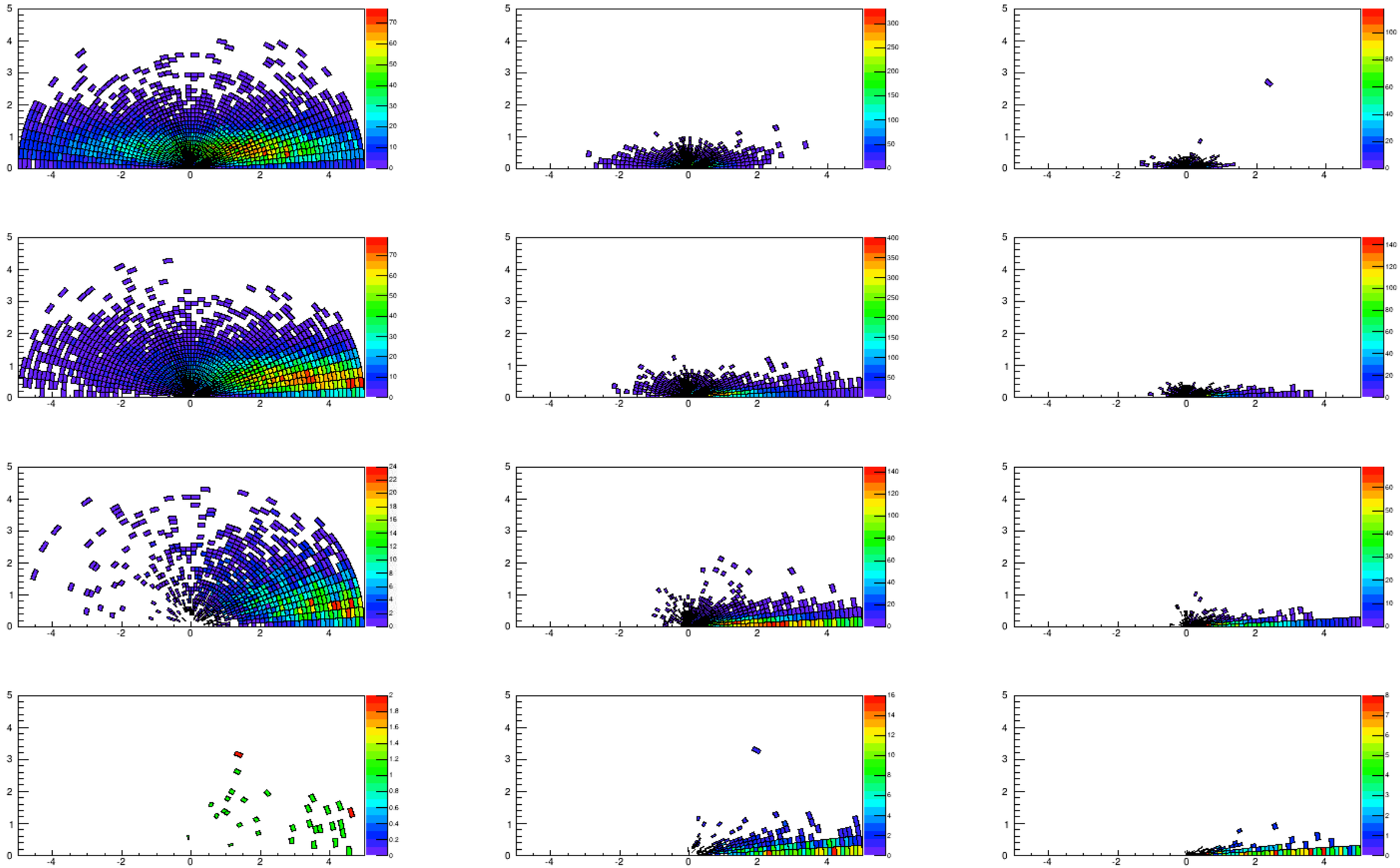
Gamma from Sigma0

1e-3

1e-2

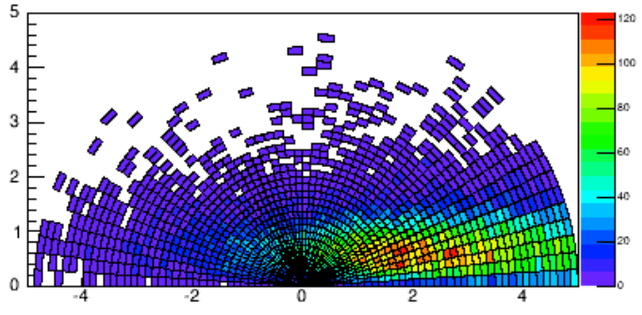
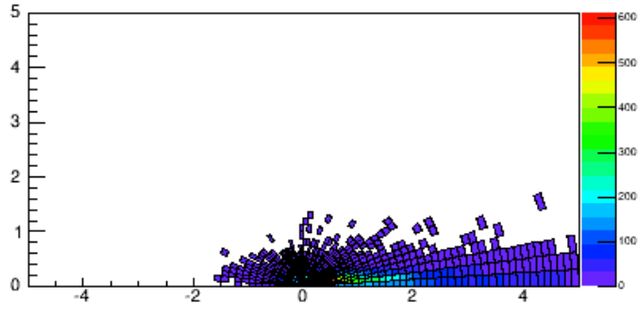
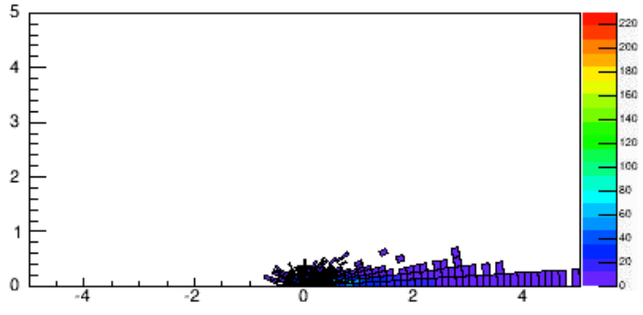
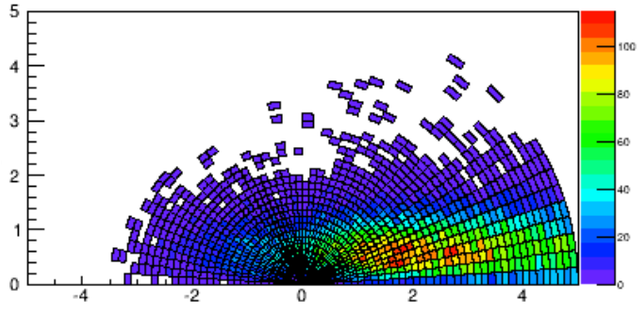
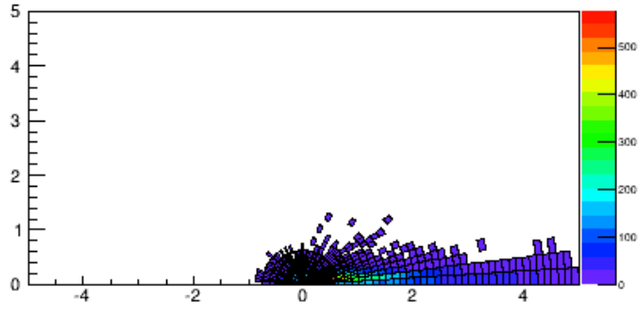
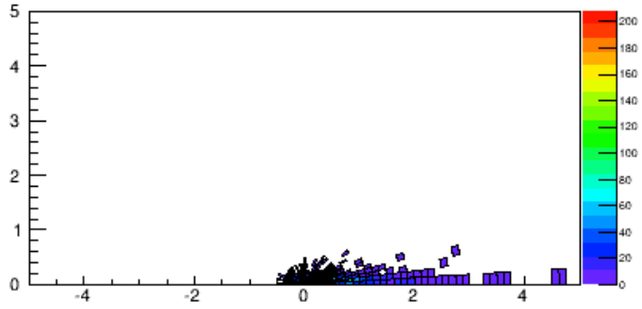
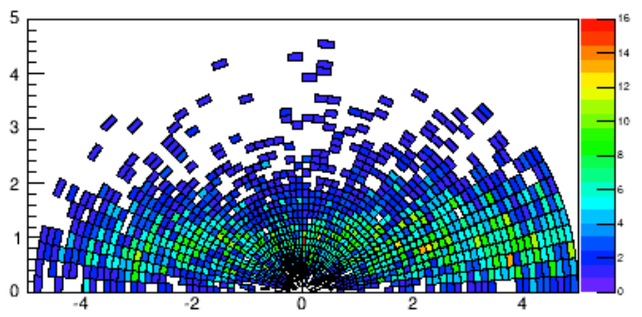
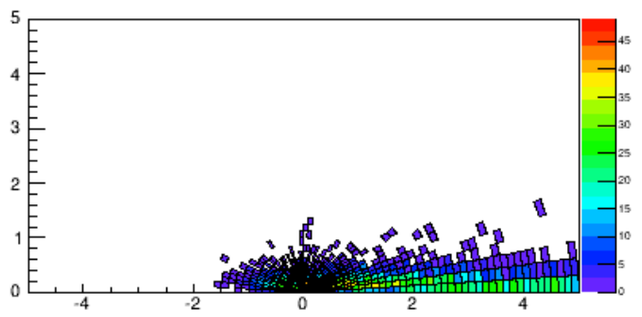
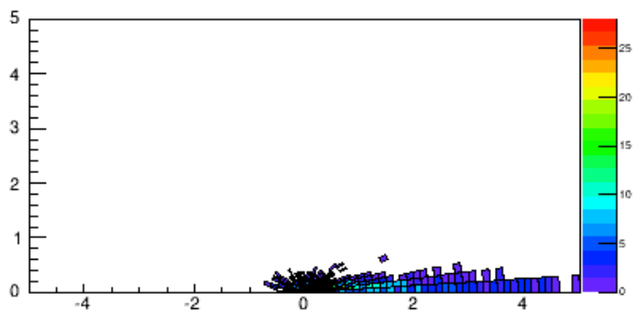
1e-1

X



Momentum vs theta

100 GeV ← 10 GeV

	Proton from Lambda	Pion from Lambda	Gamma from Sigma0
All			
z_h < 0.4			
z_h > 0.4			

Angle for theta, radius for momentum

Momentum vs theta

100 GeV ← 10 GeV

Proton from Lambda

Pion from Lambda

Gamma from Sigma0

1e-3

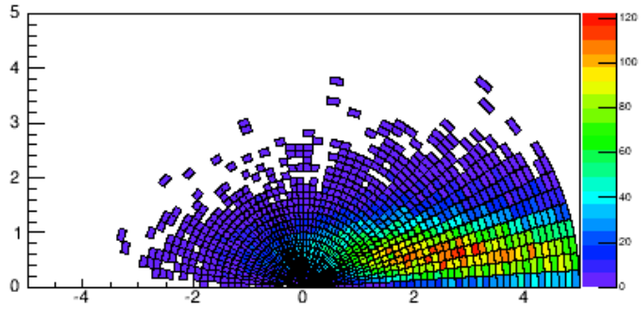
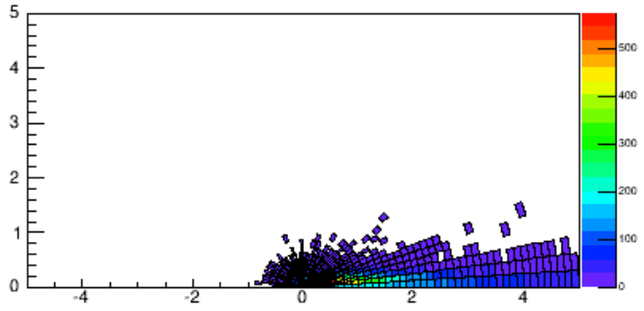
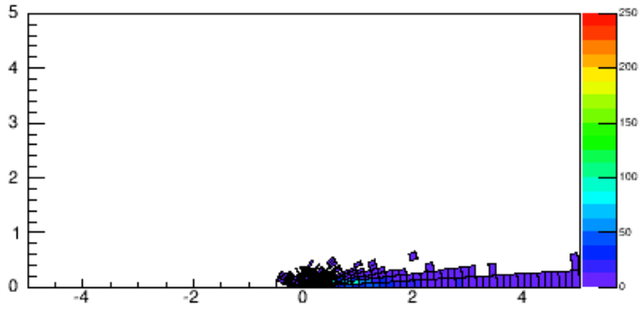
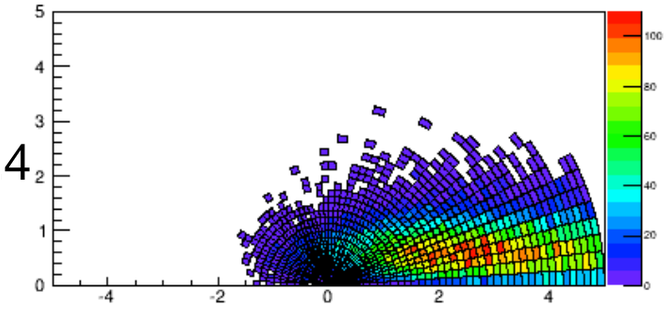
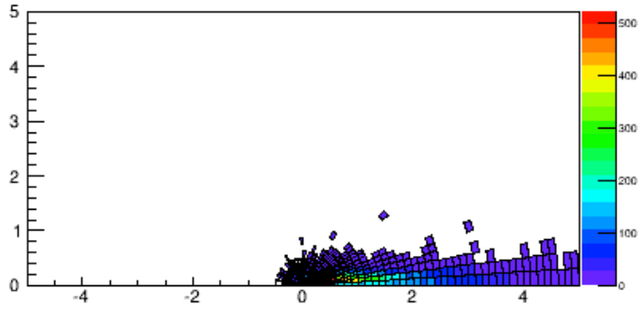
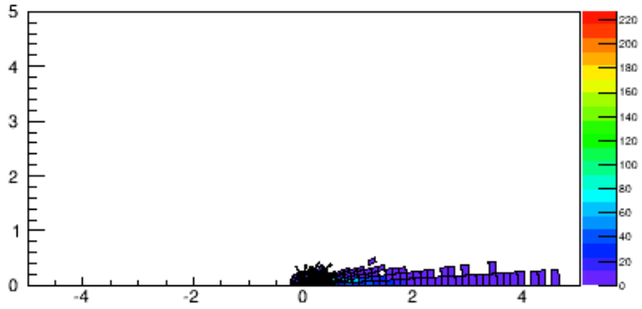
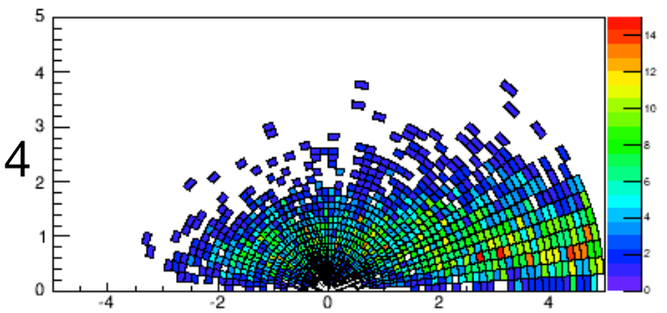
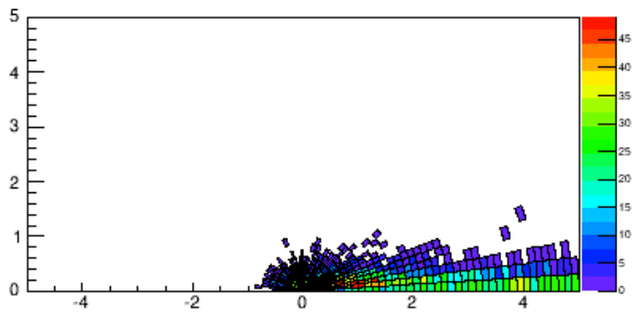
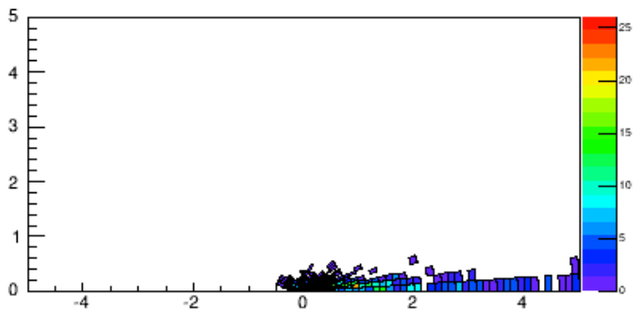
1e-2

1e-1

X

Momentum vs theta

100 GeV → ← 5 GeV

	Proton from Lambda	Pion from Lambda	Gamma from Sigma0
All			
z_h < 0.4			
z_h > 0.4			

Angle for theta, radius for momentum

Momentum vs theta

100 GeV ← 5 GeV

Proton from Lambda

Pion from Lambda

Gamma from Sigma0

1e-3

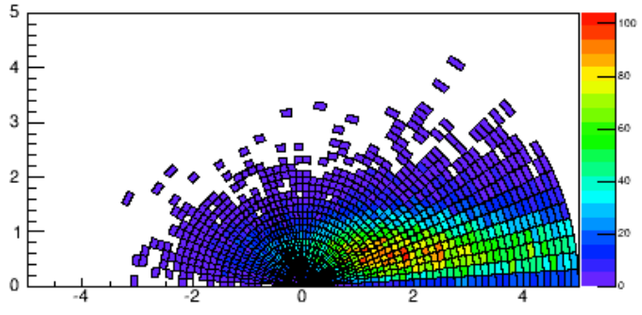
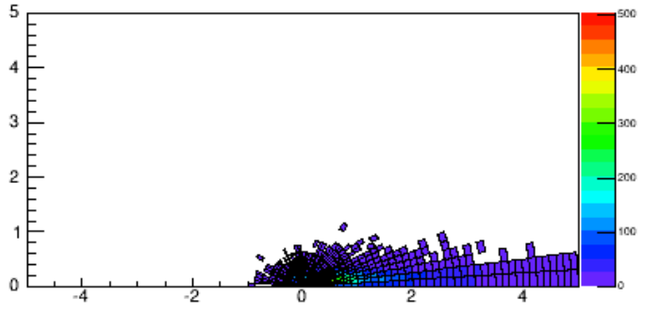
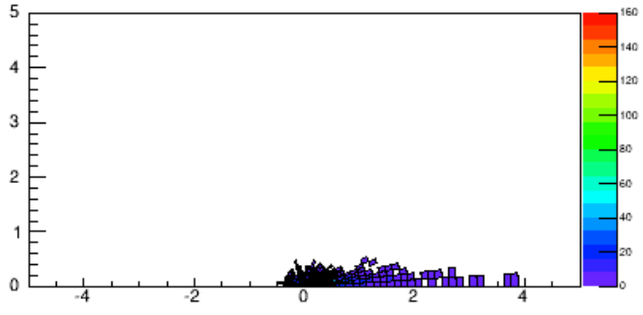
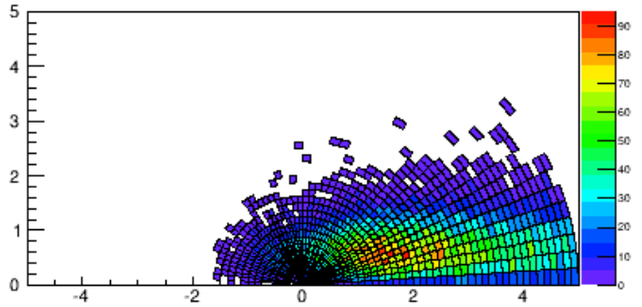
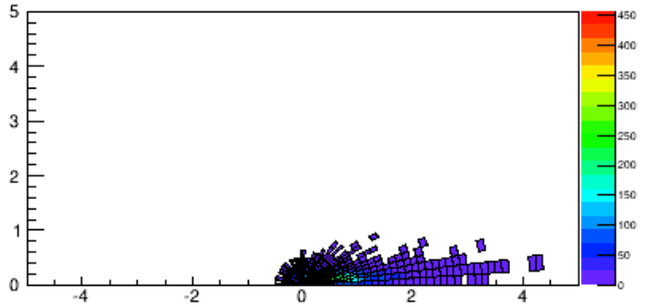
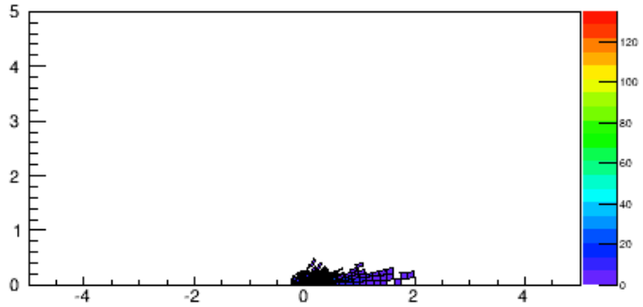
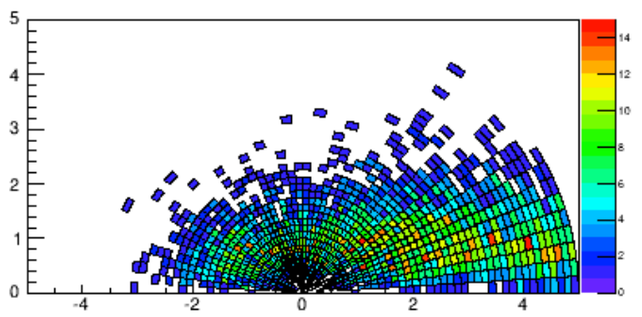
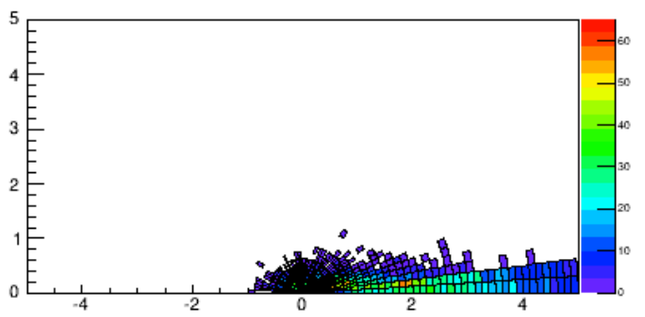
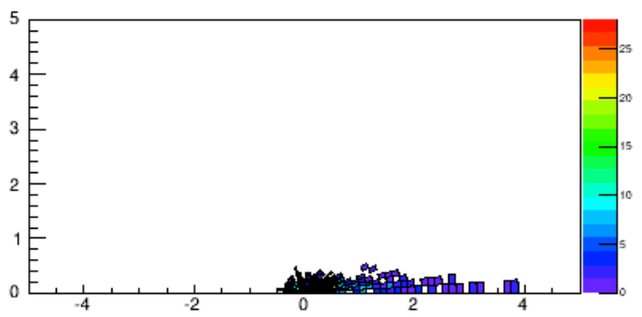
1e-2

1e-1

X

Momentum vs theta

41 GeV → ← 5 GeV

	Proton from Lambda	Pion from Lambda	Gamma from Sigma0
All			
z_h < 0.4			
z_h > 0.4			

Angle for theta, radius for momentum

Momentum vs theta

41 GeV → ← 5 GeV

Proton from Lambda

Pion from Lambda

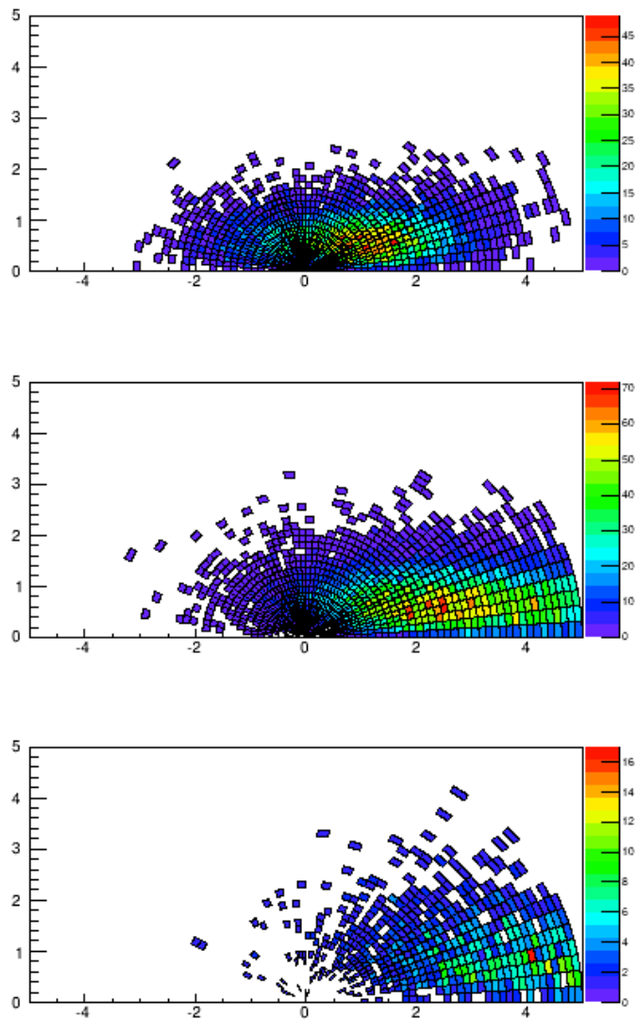
Gamma from Sigma0

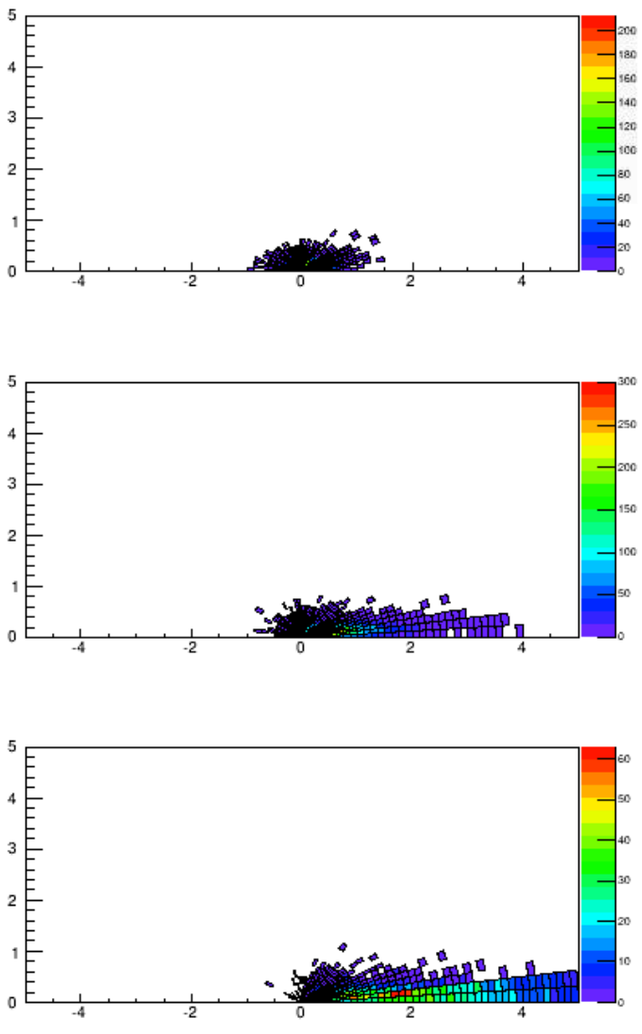
1e-3

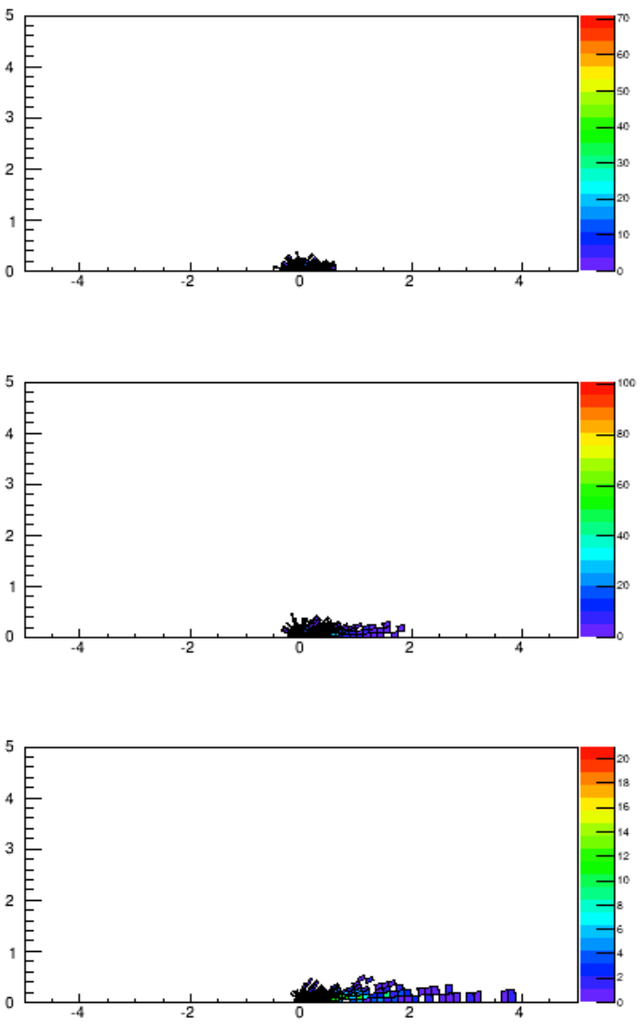
1e-2

1e-1

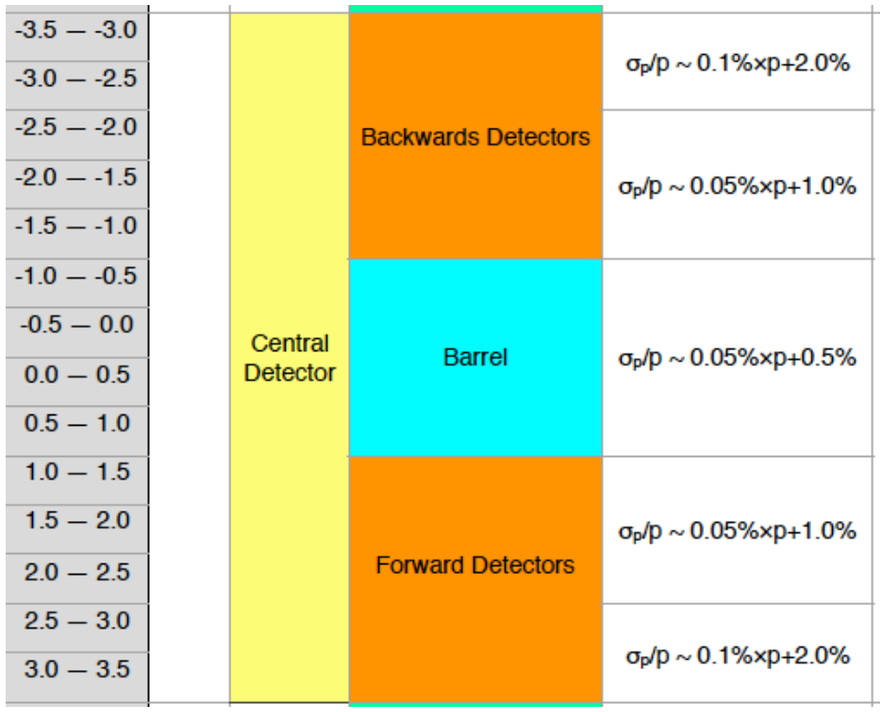
X







Smearing

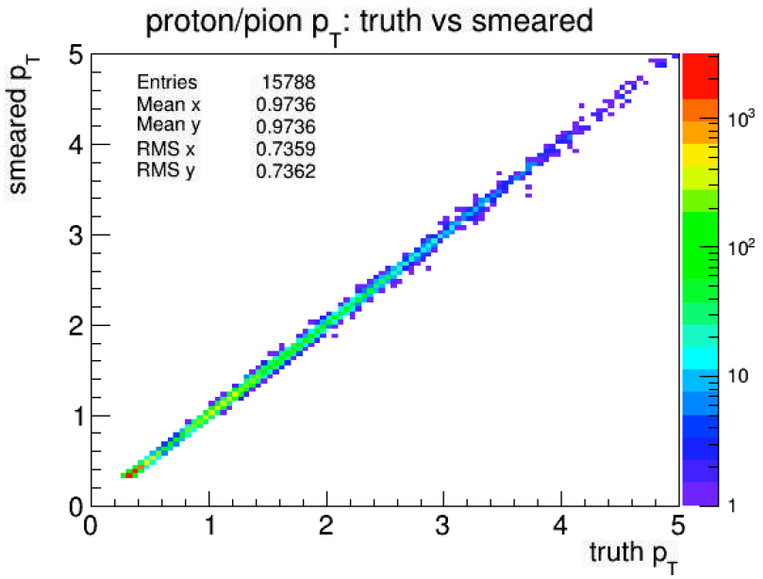


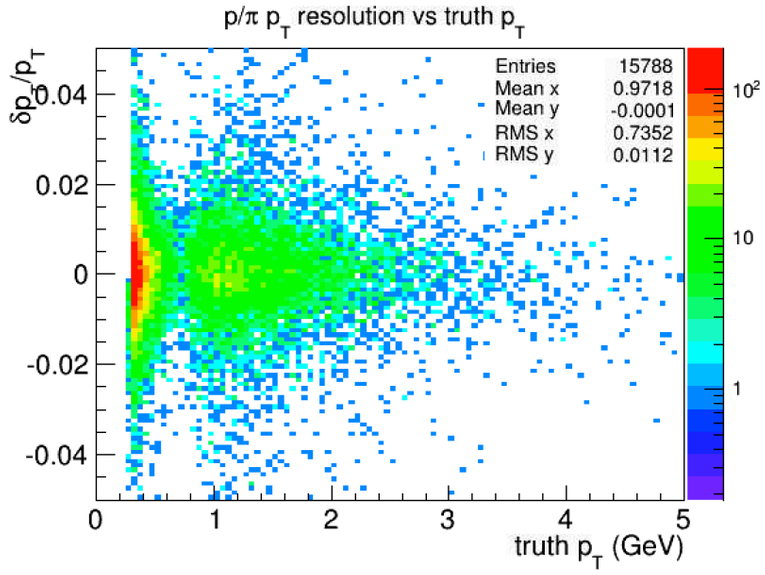
EIC_HANDBOOK_v1.2.pdf

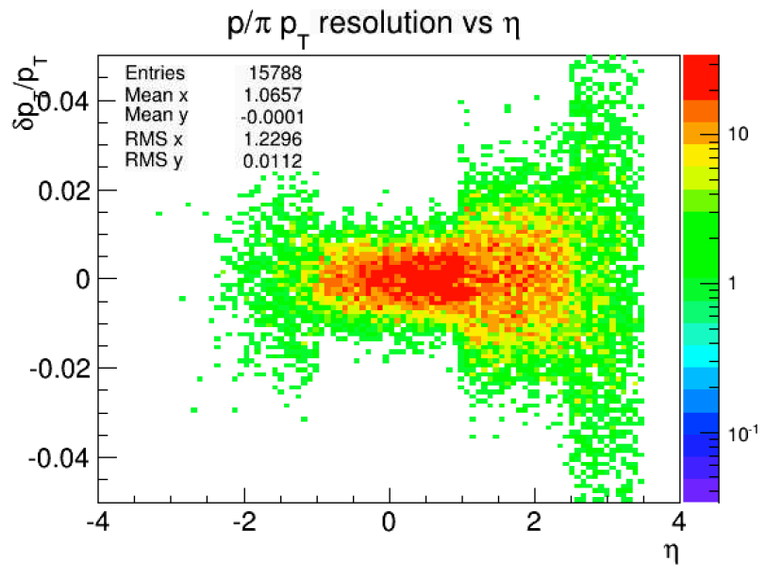
PID smearing matrix: temporarily using HERMES version

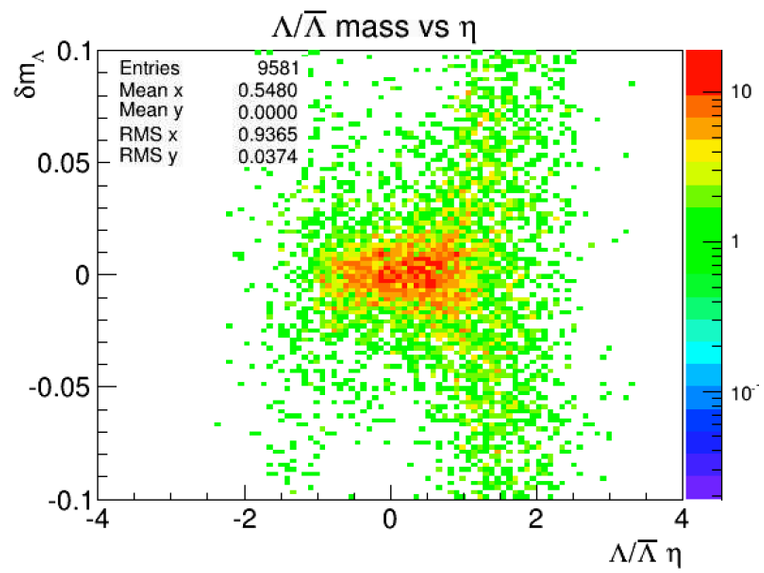
```
// Note: Smear::kCharged checks pdg charge, so includes muons (good)
// eta = -3.5 --  -2.5
// sigma_p/p ~ 0.1% p+2.0%
Smear::Acceptance::Zone TrackBack1Zone(ThetaFromEta ( -2.5 ),ThetaFromEta ( -3.5 ));
Smear::Device TrackBack1P(Smear::kP, "sqrt( pow ( 0.001*P*P, 2) + pow ( 0.02*P, 2) )");
TrackBack1P.Accept.AddZone(TrackBack1Zone);
TrackBack1P.Accept.SetCharge(Smear::kCharged);
// TrackBack1P.Accept.SetGenre(Smear::kHadronic);
det.AddDevice(TrackBack1P);

// eta = -2.5 --  -1
// sigma_p/p ~ 0.05% p+1.0%
Smear::Acceptance::Zone TrackBack2Zone(ThetaFromEta ( -1 ),ThetaFromEta ( -2.5 ));
Smear::Device TrackBack2P(Smear::kP, "sqrt( pow ( 0.0005*P*P, 2) + pow ( 0.01*P, 2) )");
TrackBack2P.Accept.AddZone(TrackBack2Zone);
TrackBack2P.Accept.SetCharge(Smear::kCharged);
// TrackBack2P.Accept.SetGenre(Smear::kHadronic);
det.AddDevice(TrackBack2P);

// eta = -1 -- +1
// sigma_p/p ~ 0.05% p+0.5%
Smear::Acceptance::Zone TrackBarrelZone(ThetaFromEta ( 1 ),ThetaFromEta ( -1 ));
Smear::Device TrackBarrelP(Smear::kP, "sqrt( pow ( 0.0005*P*P, 2) + pow ( 0.005*P, 2) )");
TrackBarrelP.Accept.AddZone(TrackBarrelZone);
TrackBarrelP.Accept.SetCharge(Smear::kCharged);
// TrackBarrelP.Accept.SetGenre(Smear::kHadronic);
det.AddDevice(TrackBarrelP);

// eta = 1 -- 2.5
// sigma_p/p ~ 0.05% p+1.0%
Smear::Acceptance::Zone TrackFwd2Zone(ThetaFromEta ( 2.5 ),ThetaFromEta ( 1 ));
Smear::Device TrackFwd2P(Smear::kP, "sqrt( pow ( 0.0005*P*P, 2) + pow ( 0.01*P, 2) )");
TrackFwd2P.Accept.AddZone(TrackFwd2Zone);
TrackFwd2P.Accept.SetCharge(Smear::kCharged);
// TrackFwd2P.Accept.SetGenre(Smear::kHadronic);
det.AddDevice(TrackFwd2P);

// eta = 2.5 -- 3.5
// sigma_p/p ~ 0.1% p+2.0%
Smear::Acceptance::Zone TrackFwd1Zone(ThetaFromEta ( 3.5 ),ThetaFromEta ( 2.5 ));
Smear::Device TrackFwd1P(Smear::kP, "sqrt( pow ( 0.001*P*P, 2) + pow ( 0.02*P, 2) )");
TrackFwd1P.Accept.AddZone(TrackFwd1Zone);
TrackFwd1P.Accept.SetCharge(Smear::kCharged);
// TrackFwd1P.Accept.SetGenre(Smear::kHadronic);
det.AddDevice(TrackFwd1P);
```

Smearing

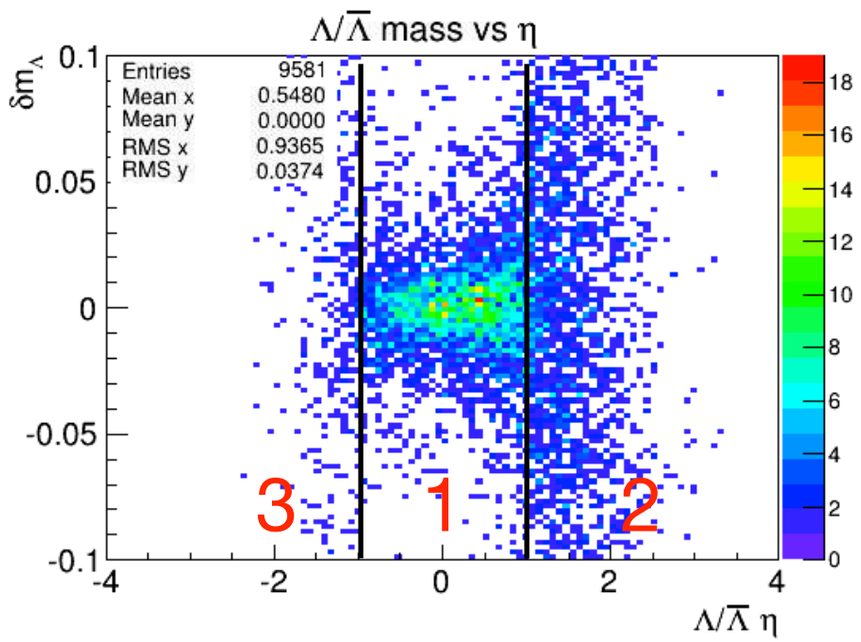

proton/pion p_T: truth vs smeared
Entries 15788
Mean x 0.9736
Mean y 0.9736
RMS x 0.7359
RMS y 0.7362
smeared p_T
truth p_T

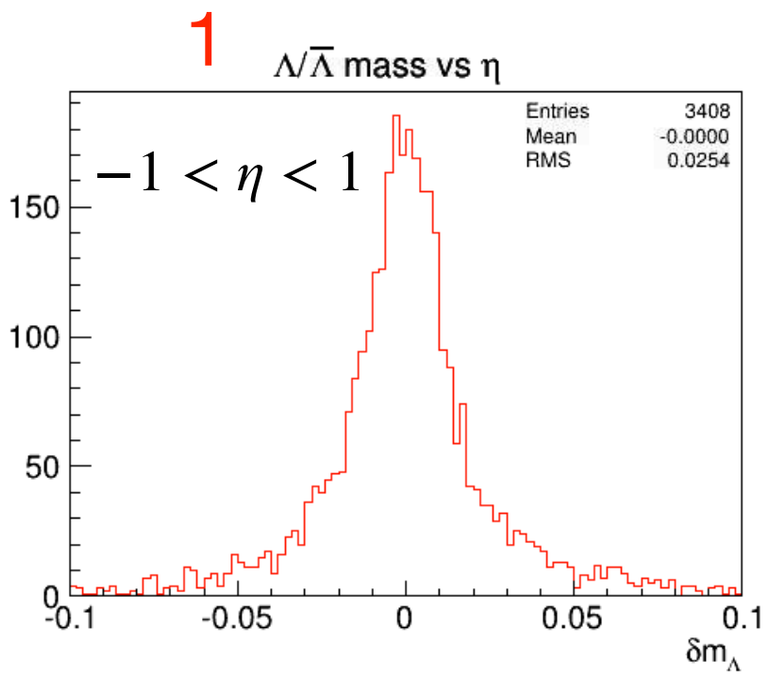

p/π p_T resolution vs truth p_T
Entries 15788
Mean x 0.9718
Mean y -0.0001
RMS x 0.7352
RMS y 0.0112
$\delta p_T/p_T$
truth p_T (GeV)

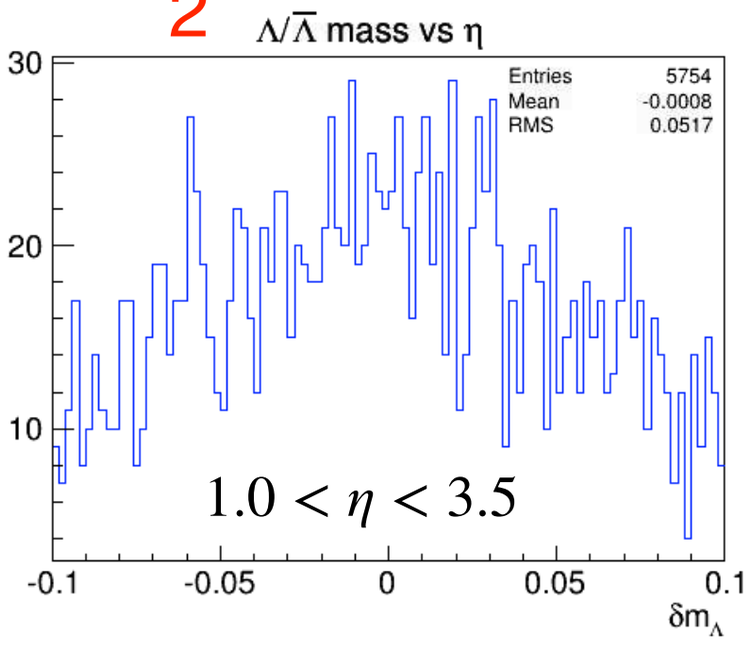

p/π p_T resolution vs η
Entries 15788
Mean x 1.0657
Mean y -0.0001
RMS x 1.2296
RMS y 0.0112
$\delta p_T/p_T$
η

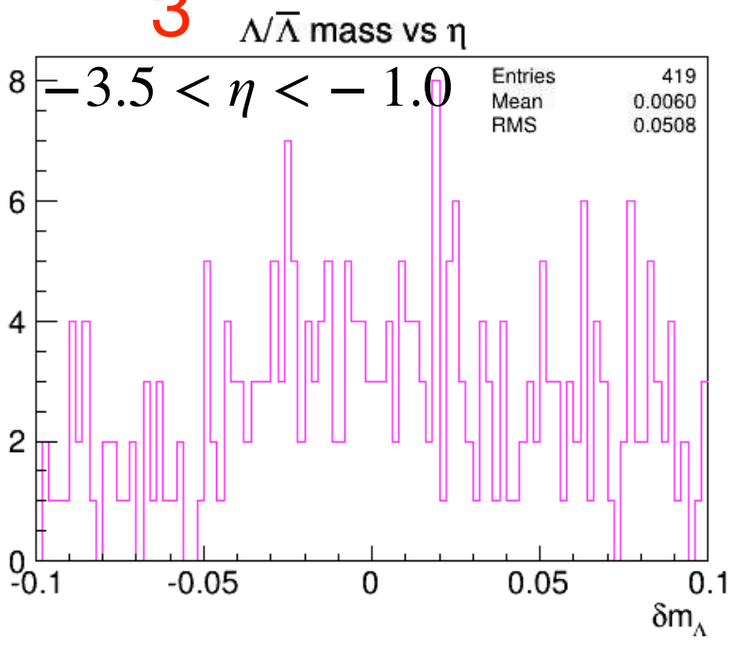

Λ/Λ̄ mass vs η
Entries 9581
Mean x 0.5480
Mean y 0.0000
RMS x 0.9365
RMS y 0.0374
δm_Λ
Λ/Λ̄ η

Lambda mass vs eta



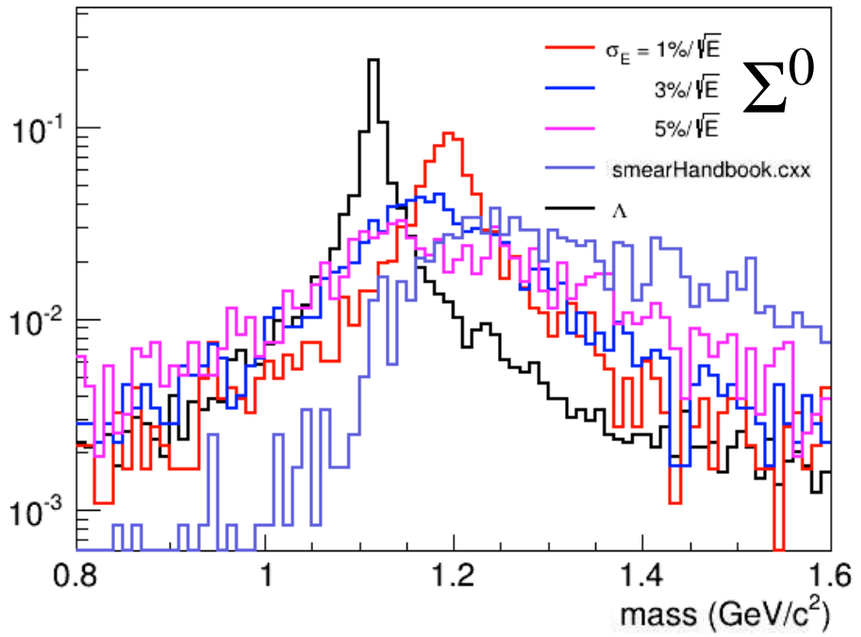




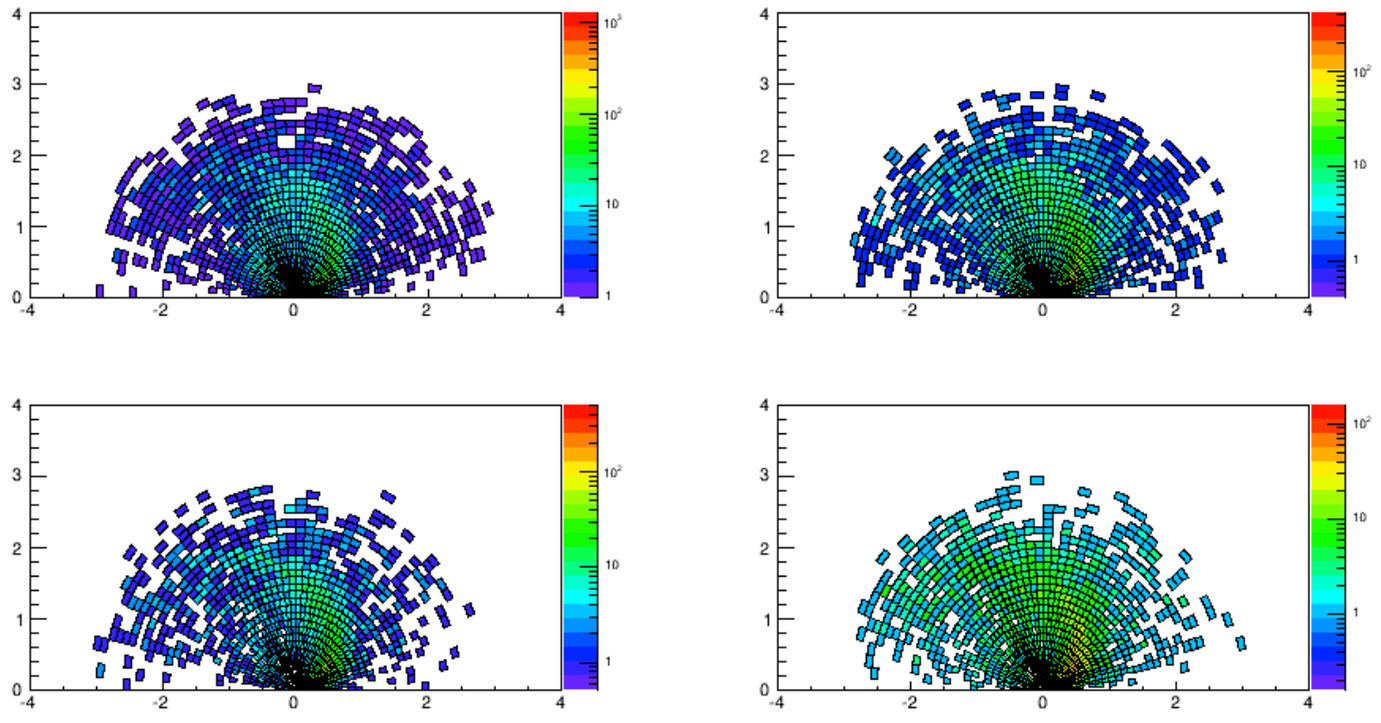


Smearing photon E for Sigma0

- In addition to the tracking smearing (handbook)
- Handbook setup push mass to larger side
- Lambda and sigma peak start merging at 3%/√E



Angle for theta, radius for open angle between lambda and photon



What we learned so far

- x-range sensitive to eta acceptance
- After eta and x_F cuts, beam remnant contribution is small
- Pion p_T lower limits determine the statistics
- Non-negligible feed-down contribution from sigma0, requiring both tracking and low energy (~1 GeV) photon energy resolutions.

Next Step

- Improve mass resolution studies
- Projection on FF and lambda spin transfer; model input needed

Backup

Lambda origin

index	status	pdg ID	Parent index	Children index	
1	21	11	0	3	4
2	21	2212	0	5	0
3	21	11	1	0	0
4	21	22	1	0	0
5	21	2212	2	0	0
6	21	22	4	0	0
7	21	2	5	0	0
8	21	22	6	0	0
9	21	2	7	0	0
10	21	2	9	0	0
11	1	11	3	0	0
12	12	2	10	15	16
13	11	2101	5	15	16
14	11	92	12	15	16
15	11	323	12	17	18
16	11	3122	13	19	20
17	1	321	15	0	0
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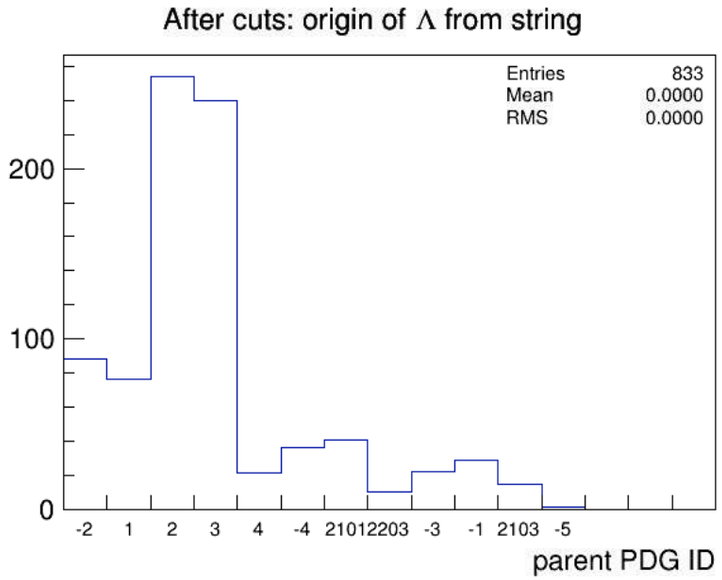
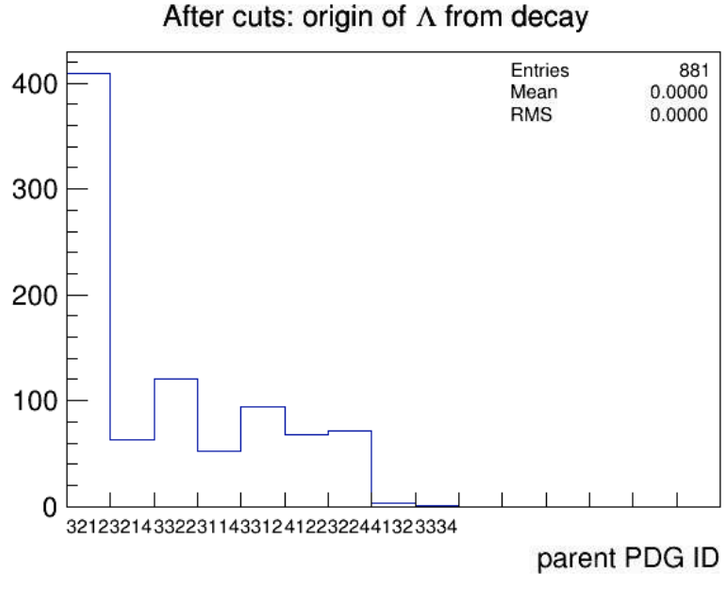
24	1	22	20	0	0

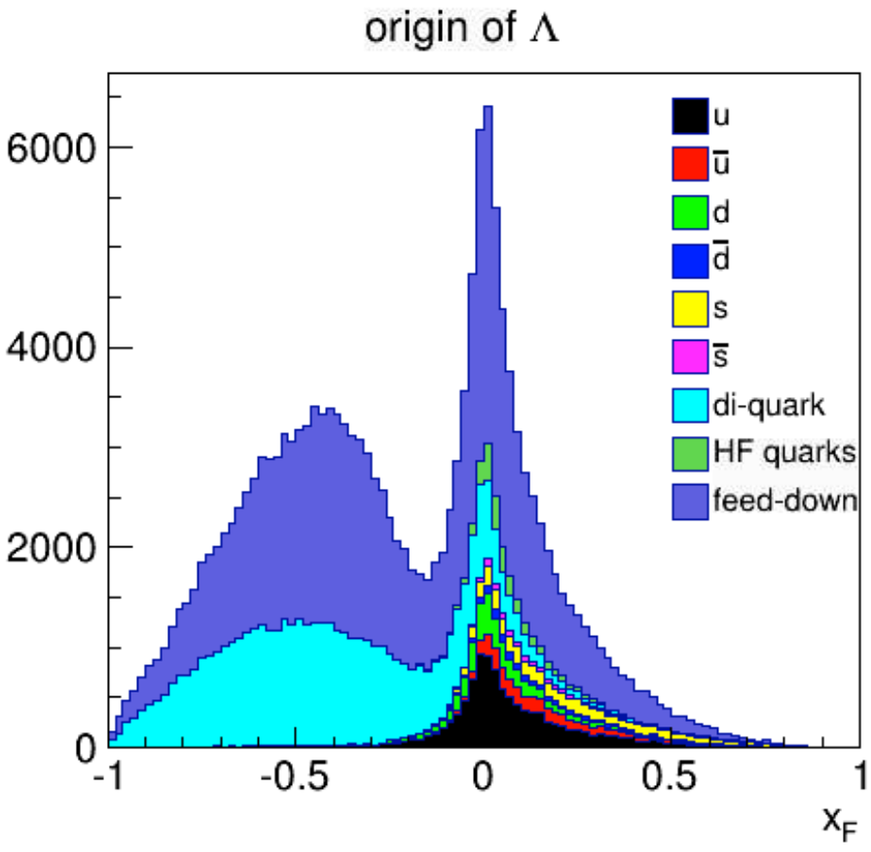
========== Event finished ==========



String and two ends share children particles

children particles have single parent




origin of Λ
6000
4000
2000
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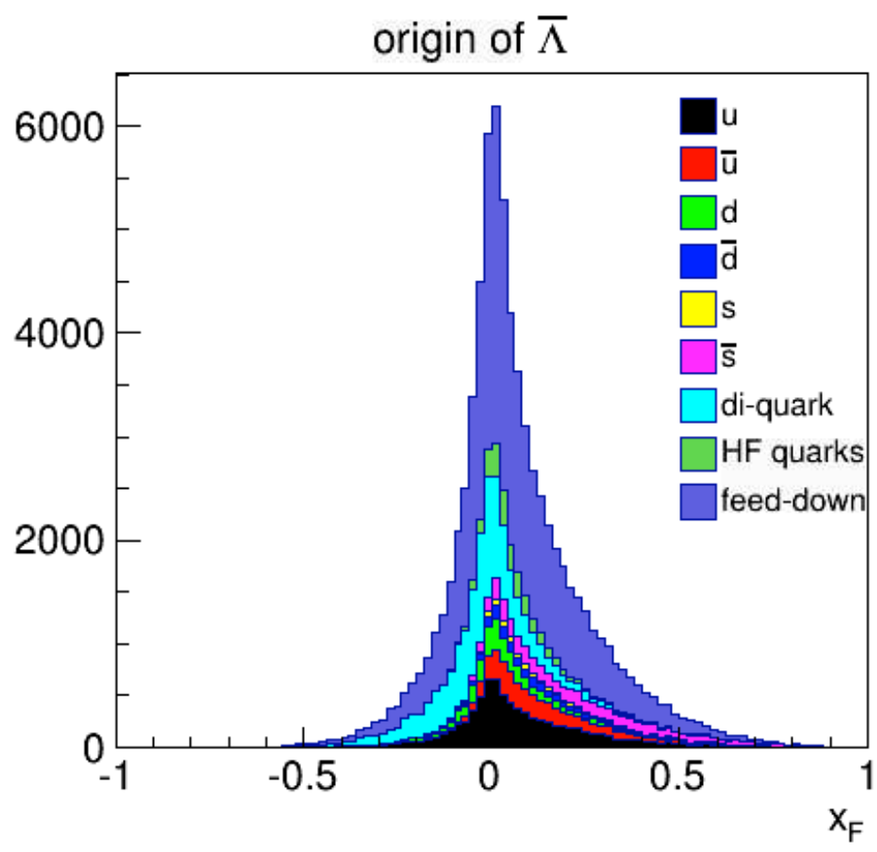
-1
-0.5
0
0.5
1
x_F
u
ū
d
d̄
s
s̄
di-quark
HF quarks
feed-down


origin of Λ̄
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4000
2000
0
-1
-0.5
0
0.5
1
x_F
u
ū
d
d̄
s
s̄
di-quark
HF quarks
feed-down