Pion-LT Meeting

Mr. Muhammad Junaid
Ph.D. Student
Department of Physics,
University of Regina, Canada

LTSep Analysis

- Working on physics setting: **Q2 = 3.85, W = 2.62, t = 0.21 (2 epsilons)**
- Following studies need to be finalized before the LTSep analysis:
  - Missing mass offset and cut determination
  - Diamond cut determination
  - t-resolution check
  - t and phi-binning
  - Data and SIMC yields

LTSep Analysis

- **Cuts for pion physics data**

HMS Cuts (Electrons)
-8 < H_gtr_dp < 8
-0.08 < H_gtr_th < 0.08
-0.045 < H_gtr_ph < 0.045
H_hod_goodstarttime == 1.0
HMS_Cal_etottracknorm > 0.7
H_Cer_npeSum > 1.5

SHMS Cuts (Pions)
-10 < P_gtr_dp < 20
-0.06 < P_gtr_th < 0.06
-0.04 < P_gtr_ph < 0.04
P_hod_goodstarttime == 1.0
P_aero_npeSum > 1.5
1.2 < P_RF_DIST < 3.4

Analysis Cuts (Pions)
Ctime_epCoinTime_ROC1 Prompt Peak + Random Sub
0.90 < MMpi < 1.06
Diamond Cut Applied

- **Cuts for SIMC**

HMS Cuts (Electrons)
-8 < hsdelta< 8
-0.08 < hsxpfp< 0.08
-0.045 < hsypfp< 0.045

SHMS Cuts (Pions)
-10 < ssdelta< 20
-0.06 < ssxpfp< 0.06
-0.04 < ssypfp< 0.04

Analysis Cuts (Pions)
0.90 < MMpi < 1.06
Diamond Cut Applied

LTSep Analysis

- **Global Offsets:**

Global In-Plane Offsets – Momentum and Energy offsets in 0.1% unit, Angle offset in mrad unit			
BE	dBE	Global Offsets for 5.9 GeV to 9.9 GeV	
5984.8	-0.0500	HMS_dtheta	1.5000
6394.7	-0.1500	HMS_dp	0.0000
7937.6	-0.2222	SHMS_dtheta	1.4000
8478.6	-0.1333	SHMS_dp	4.5000
9171.3	-0.0444	Offsets for 10.5 GeV	
9876.9	-0.2222	HMS_dtheta	1.5000
		HMS_dp	-3.2000
10546.8	-1.0000	SHMS_dtheta	1.4000
		SHMS_dp	4.5000

- Implemented Out-of-plane offsets (**HMS = +0.001875rad and SHMS = -0.000155rad**)

MM Offset and Cut Study

- **Compared missing mass plots between data and SIMC for each setting**
- **Did peak fitting to calculate the difference between the data and the SIMC missing mass peaks**

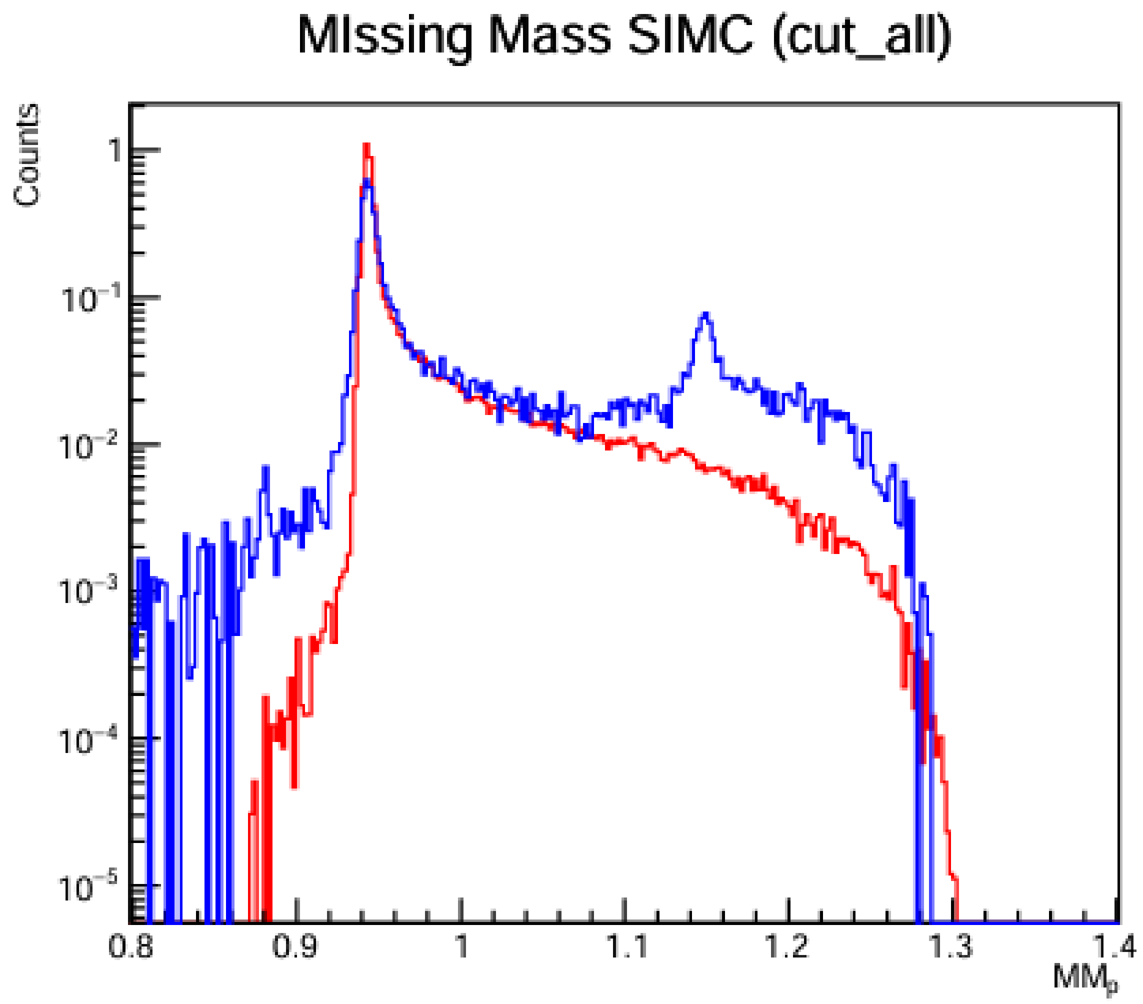
- **Found the following offsets:**

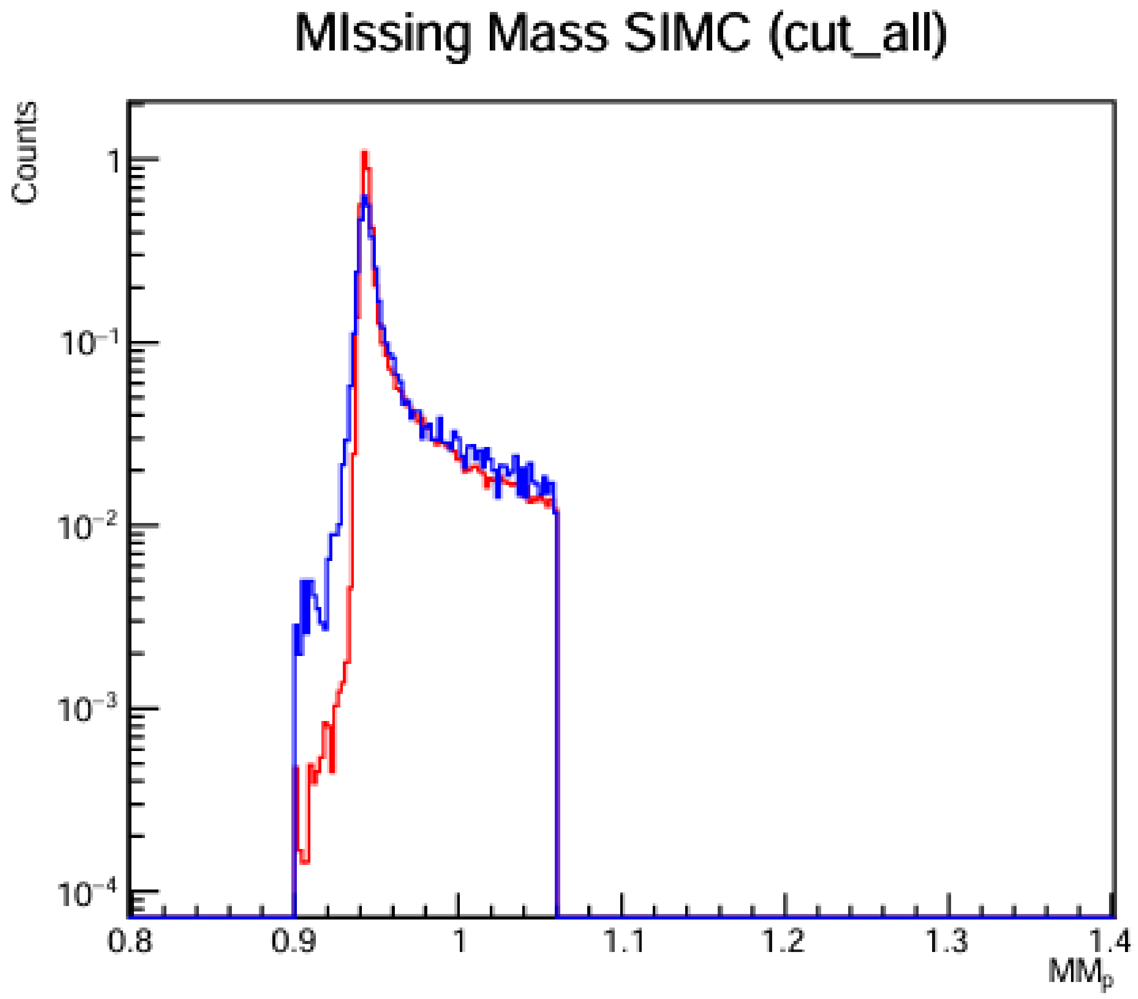
Settings	Offset Value
Q3p85_W2p62_t0p21_lowepsilon_center	-0.00649
Q3p85_W2p62_t0p21_lowepsilon_left	-0.005741
Q3p85_W2p62_t0p21_highepsilon_right	0.010645
Q3p85_W2p62_t0p21_highepsilon_center	0.010127
Q3p85_W2p62_t0p21_highepsilon_left	0.00917

- **Applied missing mass cut on both data and SIMC:**

0.90 < MMpi < 1.06

MM Offset and Cut Study





Diamond Cut Study

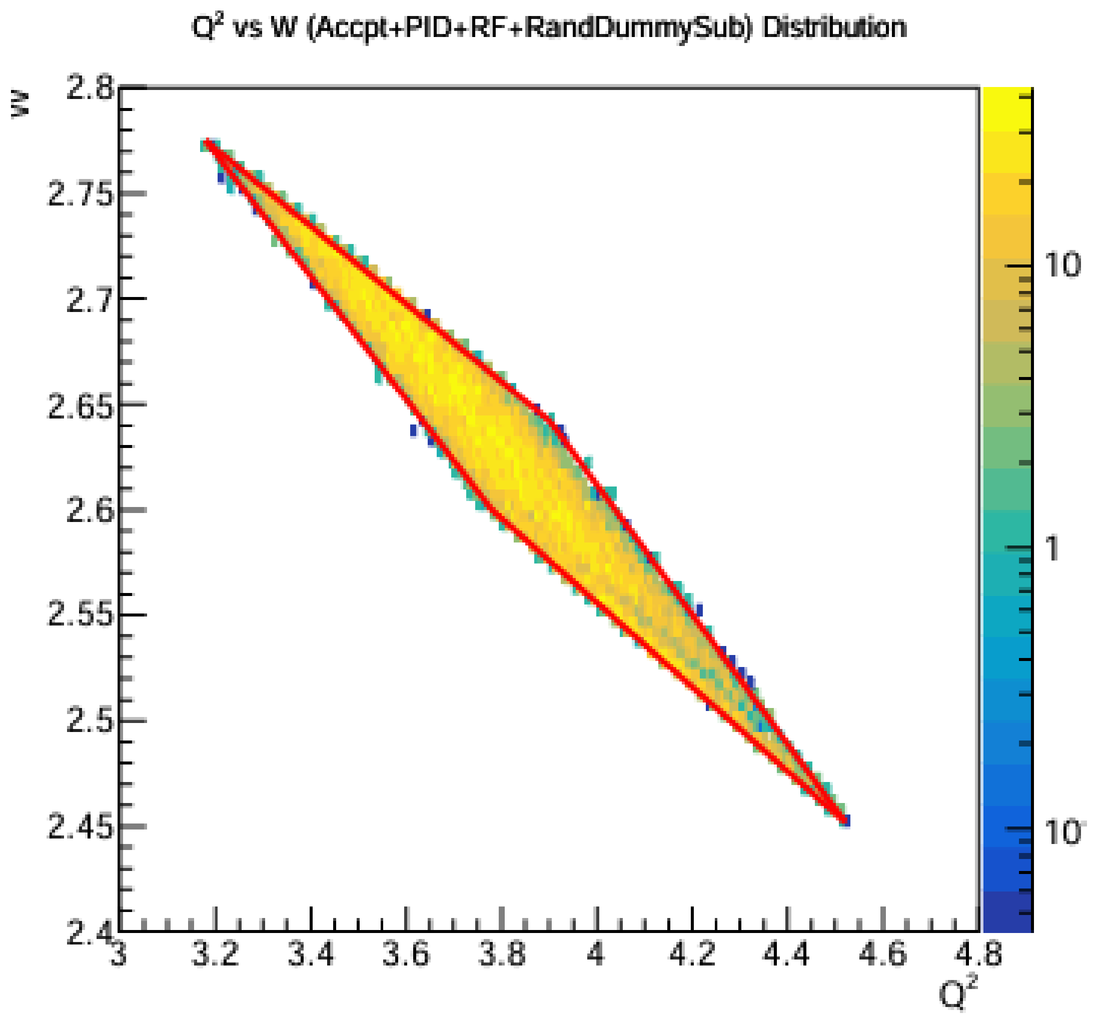
- **Determined diamond cut from "Q3p85_W2p62_t0p21_lowepsilon_center" setting by looking at Q2vsW plot.**

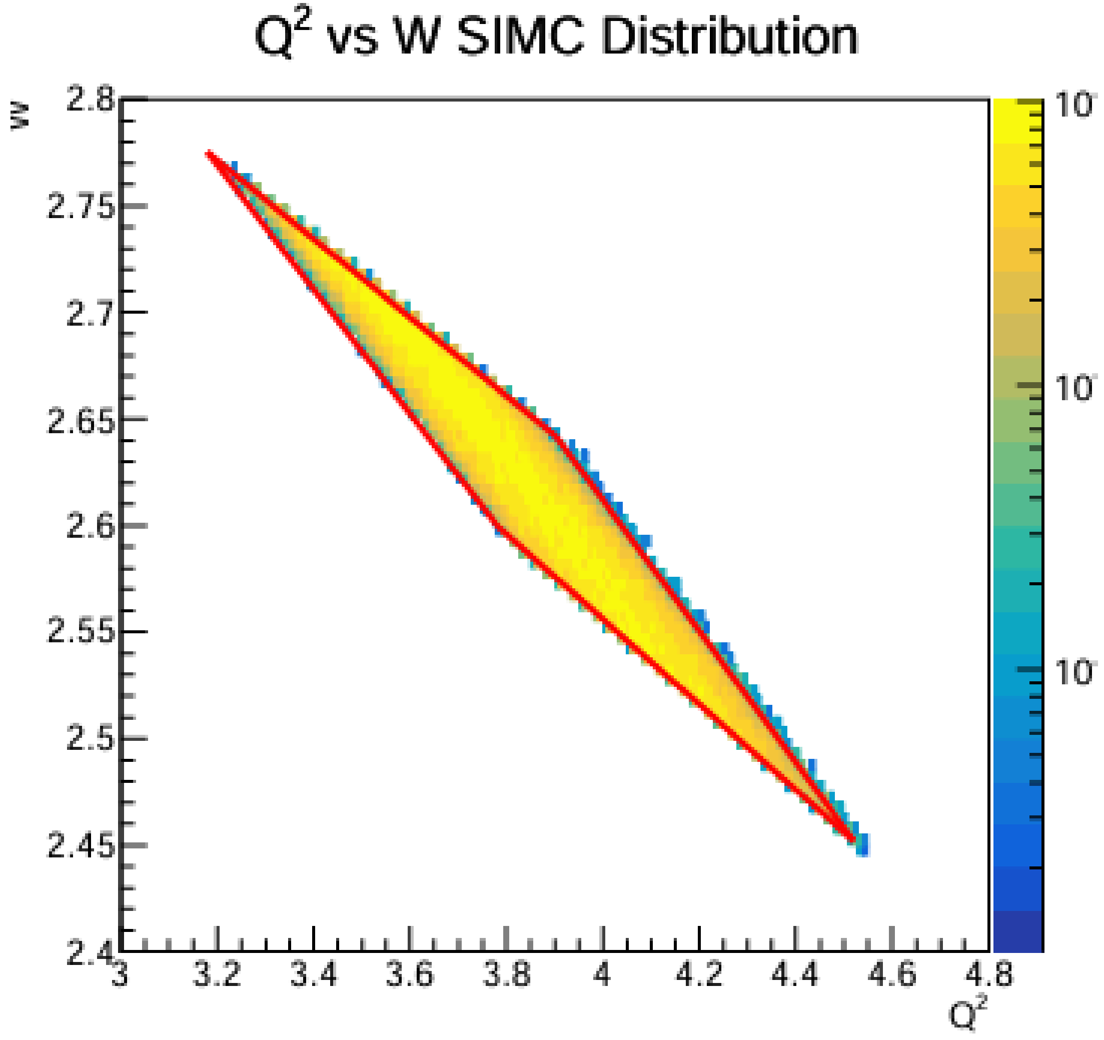
- **Found the following offsets:**

Vertex Points	Vertex Values (x, y)
Q3p85_W2p62_t0p21_top_left	(3.180, 2.775)
Q3p85_W2p62_t0p21_top_right	(3.902, 2.645)
Q3p85_W2p62_t0p21_bottom_left	(3.780, 2.600)
Q3p85_W2p62_t0p21_bottom right	(4.520, 2.452)

- **Tested diamond cut on all physics and SIMC settings.**
- **Diamond Cut looks good.**

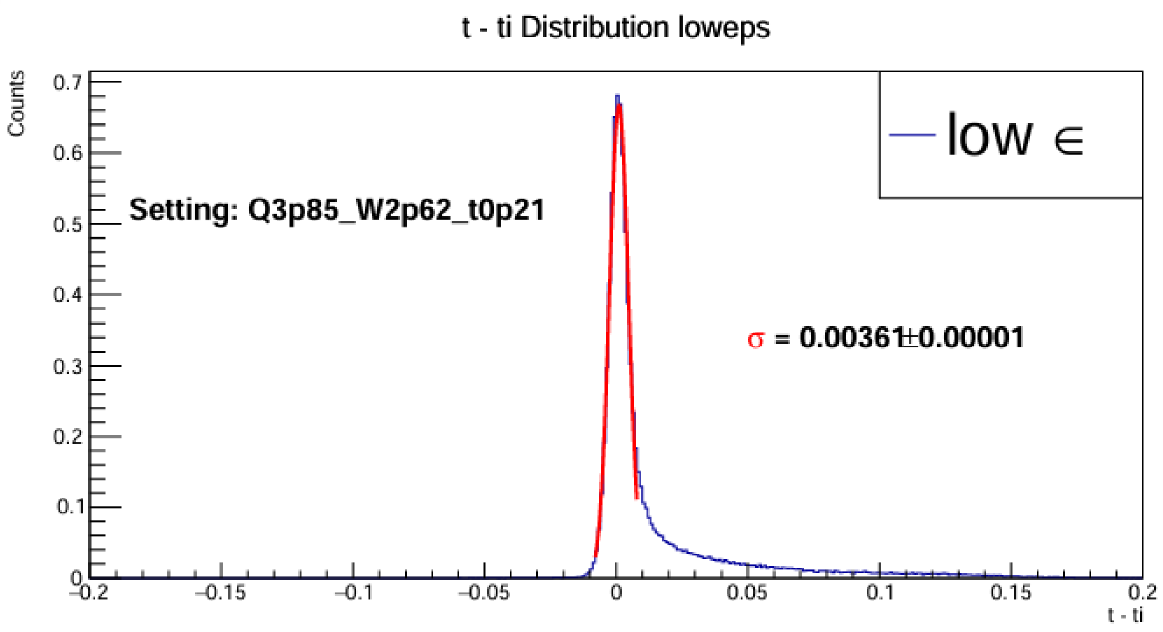
Diamond Cut Study

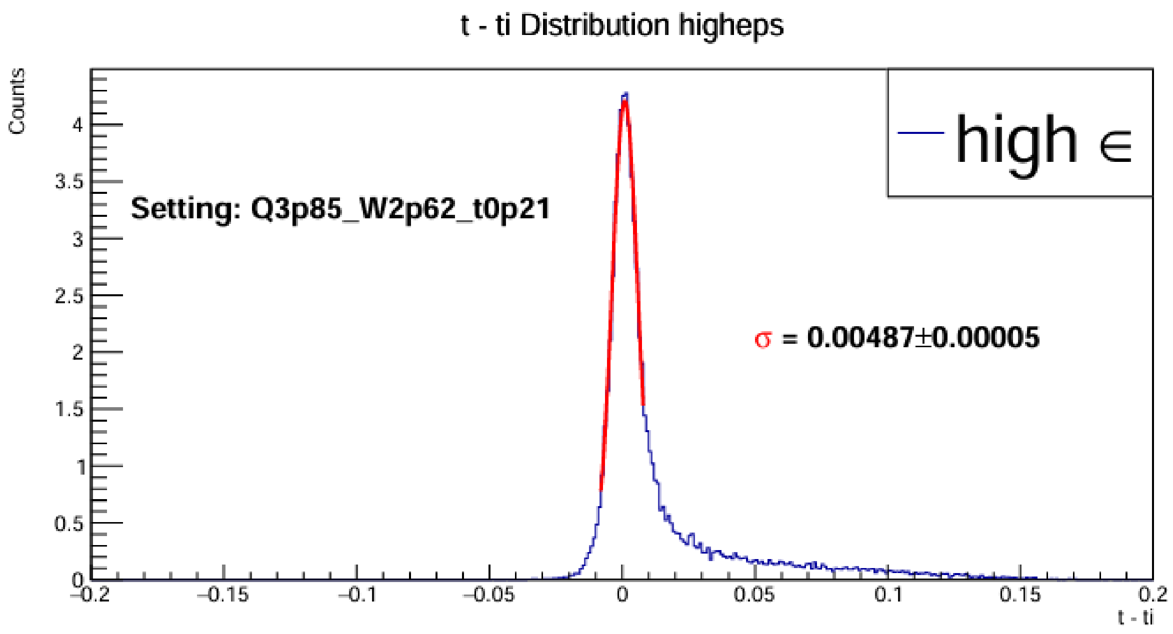




t-binning

- t-resolution plots for low and high epsilon data

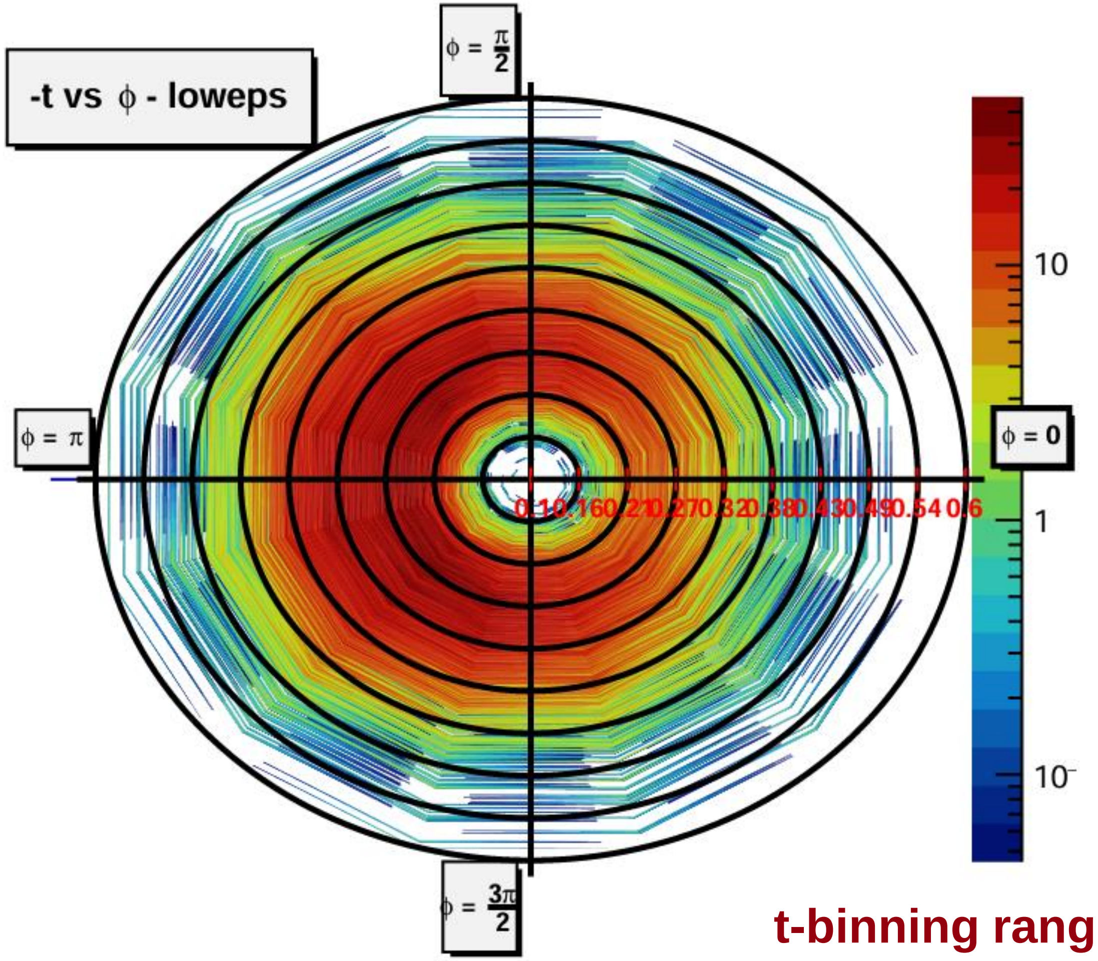


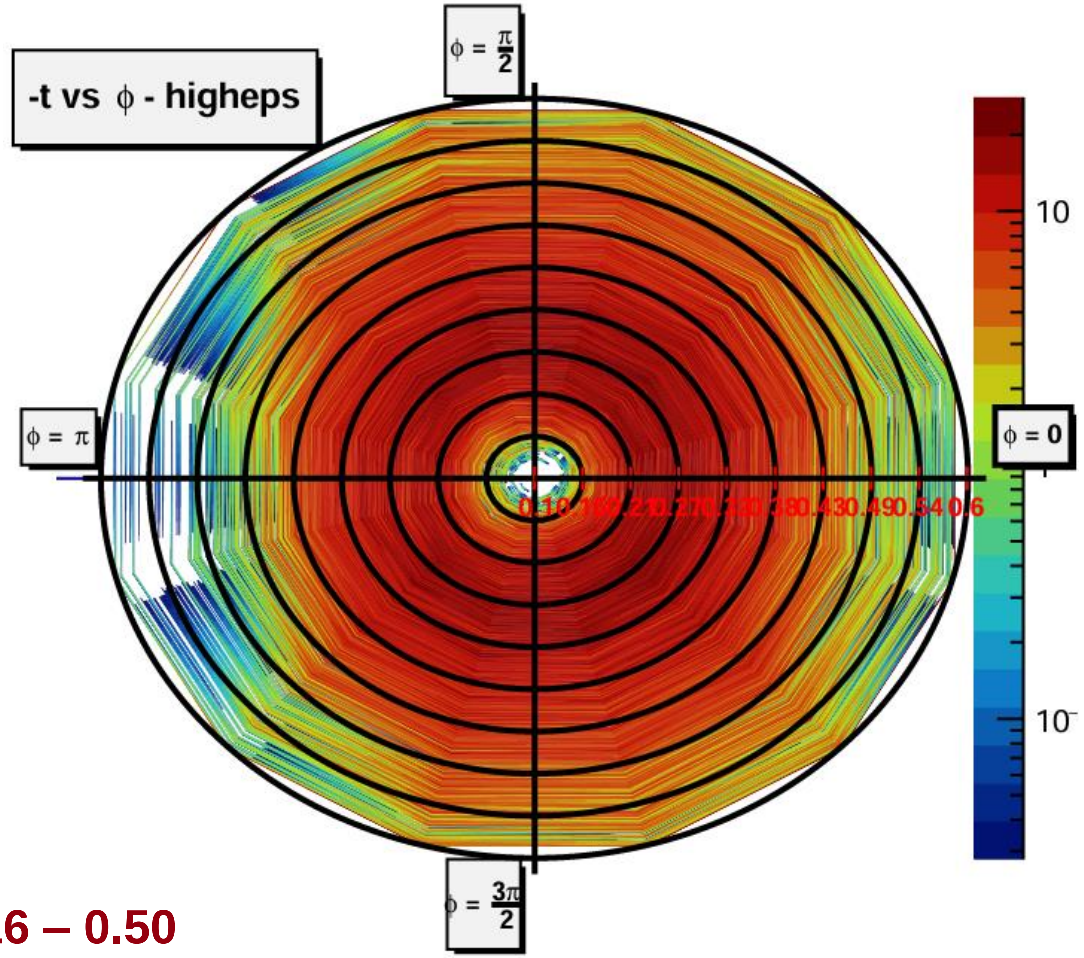


- NGC is included in SIMC.

t-binning

- **Phi distribution plots for high and low epsilon data.**
- **Determine range for t-binning by looking at tvsphi (high epsilon) plot.**

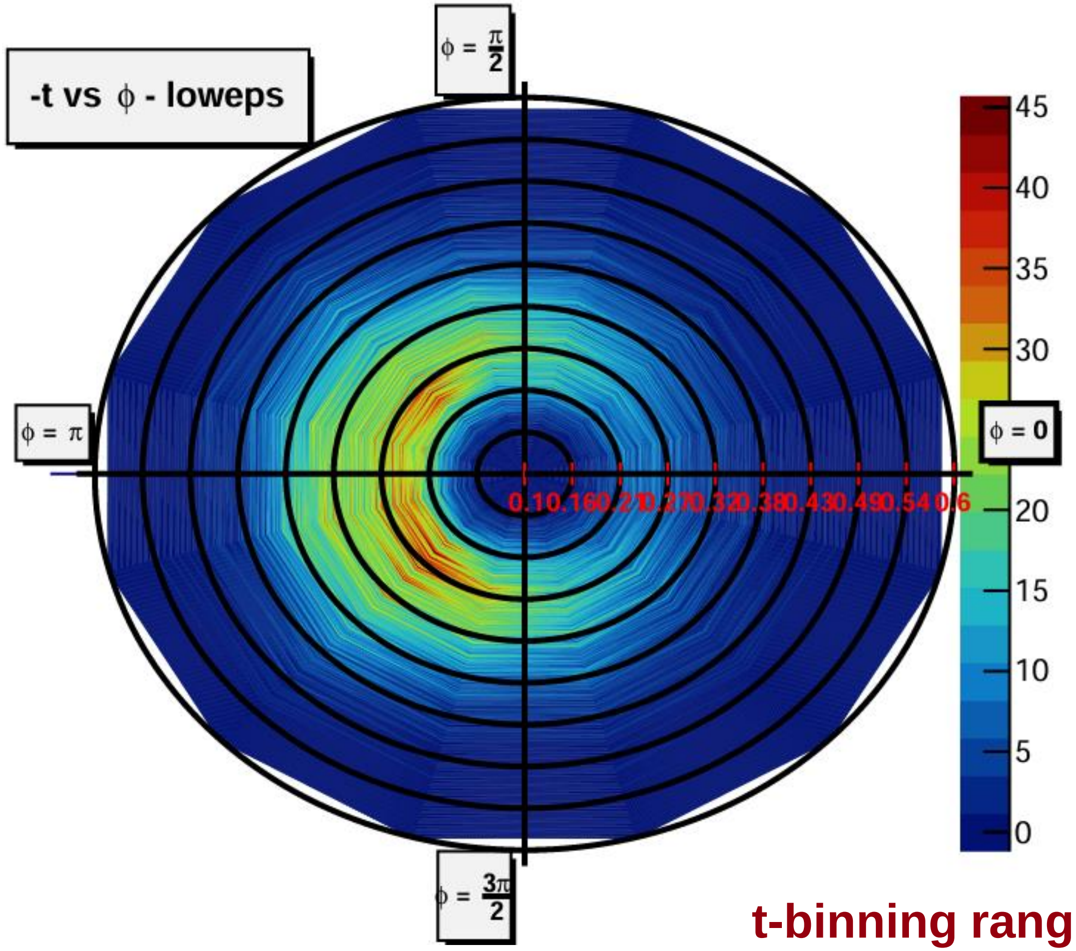


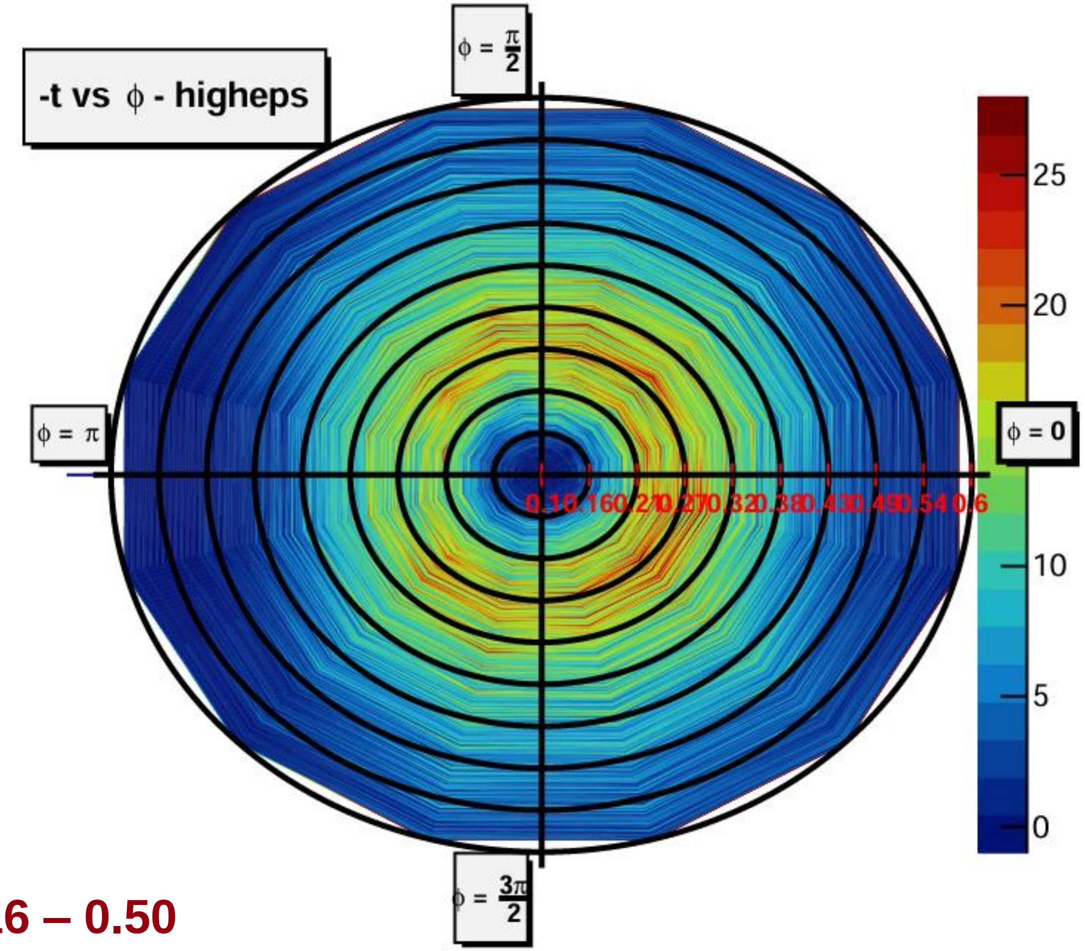


t-binning range 0.16 – 0.50

t-binning

- **Phi distribution plots for high and low epsilon data.**
- **Determine range for t-binning by looking at tvsphi (high epsilon) plot.**



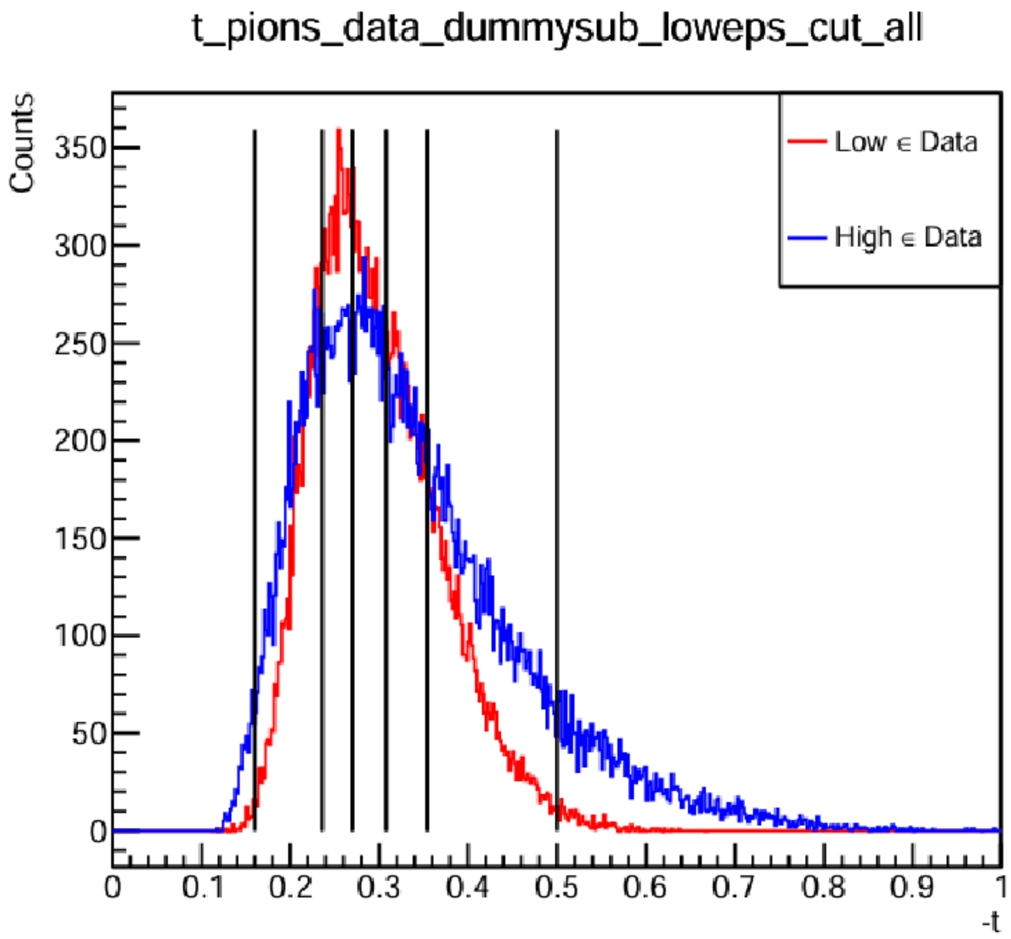


t-binning range 0.16 – 0.50

t-binning

- t-binning for "Q2 = 3.85, W = 2.62, t = 0.21 (2-epsilons) data"
- Divided "t" into 5-bins

t_min	t_max	Yield (loweps)	Error (loweps)	Yield (higheps)	Error (higheps)
0.160	0.236	5170.833	73.447	6505.667	81.246
0.236	0.270	5371.667	74.758	4316.333	66.242
0.270	0.308	5350.833	74.933	4937.667	70.942
0.308	0.354	5104.167	73.460	4955.167	71.335
0.354	0.500	5224.833	75.651	8588.167	94.167



t-binning range 0.16 – 0.50

- Divided "phi" into 15-bins.
- Calculated yield for each phi-bin of each t-bin for the data and SIMC.

LTSep Analysis

- SIMC and Data are normalized.
- Calculated Data/SIMC ratios for each setting.

Physics Setting	Physics Yield	SIMC Yield	Data/SIMC Ratio
Q3p85_W2p62_t0p21_loweps_center	4.506 +/- 0.086	4.802 +/- 0.007	0.938 +/- 0.018
Q3p85_W2p62_t0p21_loweps_left	3.684 +/- 0.073	3.817 +/- 0.006	0.965 +/- 0.019
Q3p85_W2p62_t0p21_higheps_right	24.481 +/- 0.741	25.116 +/- 0.108	0.975 +/- 0.030
Q3p85_W2p62_t0p21_higheps_center	25.612 +/- 0.798	28.391 +/- 0.120	0.902 +/- 0.028
Q3p85_W2p62_t0p21_higheps_left	18.307 +/- 0.481	20.177 +/- 0.087	0.907 +/- 0.024

LTSep Analysis

- Made Data and SIMC comparison plots
- SIMC and Data are normalized.

$$Effective\ charge = Charge\ \times Tracking\ Eff\ \times Detector\ Eff \times Hodo\frac{3}{4}Eff \times EDTM\ Live\ Time \times Boiling\ Corr$$

- In data normalization, Following quantities are included:
  - **Charge (run-by-run)**
  - **Tracking Efficiencies (HMS and SHMS run-by-run)**
  - **Detector Efficiencies (HMS Cer and HMS Cal run-by-run)**
  - **Hodo ¾ Efficiencies (HMS and SHMS run-by-run)**
  - **EDTM Live Time (run-by-run)**
  - **Dummy Target Thickness Correction Applied – (3.527 +/- 0.227 - PionLT)**
  - **Nathan’s Boiling Correction Applied (-0.00028)**

- Uncertainties Calculations (Absolute):
- Used raw histograms (after cuts) for error calculation.
- Took integral and error using ROOT (IntegralAndError())

- Effective charge is calculated as (calculated run-by-run);

$$Effective\_charge\_run\_i = Charge \times Tracking\ Eff \times Detector\ Eff \times Hodo\frac{3}{4}Eff \times EDTM\ Live\ Time \times Boiling\ Corr$$

$$Effective\_charge\_run\_i\_err = Effective\_charge\_run\_i \times \sqrt{\left(\frac{charge\_error}{charge}\right)^2 + \left(\frac{Tracking\_Eff\_error}{Tracking\_Eff}\right)^2 + \left(\frac{Detector\_Eff\_error}{Detector\ Eff}\right)^2 + \ldots\ldots}$$

- Total effective charge is calculated as;

$$Total\_effective\_charge = Effective\_charge\_run1 + Effective\_charge\_run2 + Effective\_charge\_run3 + \ldots\ldots\ldots\ldots..$$

$$Total\_effective\_charge\_err = \sqrt{(Effective\_charge\_run1\_err)^2 + (Effective\_charge\_run2\_err)^2 + \cdots\ldots..}$$

- For dummy, also included thickness correction facto

LTSep Analysis

- Data/SIMC Ratio is calculated as (calculated run-by-run);

$$Normalized\_data = Data\_counts/Total\_data\_effective\_charge$$

$$Normalized\_data\_err = Normalized\_data \times \sqrt{\left(\frac{Data\_count\_error}{Data\_counts}\right)^2 + \left(\frac{Total\_data\_effective\_charge\_error}{Total\_data\_effective\_charge}\right)^2}$$

$$Normalized\_dummy = Dummy\_counts/Total\_dummy\_effective\_charge$$

$$Normalized\_dummy\_err = Normalized\_dummy \times \sqrt{\left(\frac{Dummy\_count\_error}{Dummy\_counts}\right)^2 + \left(\frac{Total\_dummy\_effective\_charge\_error}{Total\_dummy\_effective\_charge}\right)^2}$$

$$Normalized\_data\_dummy\_sub = Normalized\_data - Normalized\_dummy$$

$$Normalized\_data\_dummy\_sub\_err = \sqrt{(Normalized\_data\_err)^2 + (Normalized\_dummy\_err)^2}$$

$$Normalized\_simc = simc\_counts/(simc\_nevents/simc\_normfactor)$$

$$Normalized\_simc\_err = Normalized\_simc \times \left(\frac{simc\_count\_error}{simc\_counts}\right)$$

$$DataSimc\_Ratio = \frac{Normalized\_data\_dummy\_sub}{Normalized\_simc}$$

$$DataSimc\_Ratio\_error = DataSimc\_Ratio \times \sqrt{\left(\frac{Normalized\_data\_dummy\_sub\_err}{Normalized\_data\_dummy\_sub}\right)^2 + \left(\frac{Normalized\_simc\_err}{Normalized\_simc}\right)^2}$$

LTSep Analysis

- **Working on physics setting: "Q2 = 3.85, W = 2.62, t = 0.21 (2 epsilons)"**

- **The following studies have been finalized before the LTSep analysis:**
  - **Missing mass offset and cut determination**
  - **Diamond cut determination**
  - **t-resolution check**
  - **t-binning**
  - **phi-binning**
  - **Data yields**
  - **SIMC yields**
  - **Data/SIMC comparison and ratios**

In progress:

- Need to check HMS delta of low-epsilon data.
- The next step is iterations.

LTSep Analysis Framework

- The main shell script is located at the following path:

/u/group/c-pionlt/USERS/${USER}/hallc_replay_lt/UTIL_PION/scripts/yield/pion_prodYield_kinematic_analysis.sh

- All analysis Python scripts are located at the following path:

/u/group/c-pionlt/USERS/${USER}/hallc_replay_lt/UTIL_PION/scripts/yield/src/

- The input runlist files are located at the following path:

/u/group/c-pionlt/USERS/ /${USER}/hallc_replay_lt/UTIL_BATCH/InputRunLists/PionLT_2021_2022/

- **Each script produces ROOT, PDF, and CSV files.**
- The output ROOT and PDF files are saved to the following path:

/volatile/hallc/c-pionlt//${USER}//OUTPUT/Analysis/PionLT/

- The output CSV files are saved to the following path:

/u/group/c-pionlt/USERS/${USER}/hallc_replay_lt/UTIL_PION/LTSep_CSVs/

LTSep Analysis Framework

- To run this script, execute the following command (requires 3 arguments):

./pion_prodYield_kinematic_analysis.sh –{flags} {RUNTYPE - Prod} {RUNLIST}

Flags	Function	RUNLIST
-c	runs cut analyzer script to trim down the root file for further analysis	Setting by setting
-m	runs the missing mass check script to determine the cut for missing mass	Setting by setting
-d	runs the diamond cut script to determine the diamond cut for the data and SIMC	Setting by setting
-e	runs script to determine the t-resolution for the t-binning	Whole Setting
-t	runs t-binning script to determine the t-binning and t-range for the data and SIMC	Whole Setting
-p	runs phi-binning and physics yield script to determine the physics yields	Setting by setting
-s	runs simc yield script to determine SIMC yields	Setting by setting
-r	runs plotting script to compare Data/SIMC and determine ratios	Setting by setting

LTSep Analysis Framework


```
echo "----------------------------------------------------------------------"
echo "./pion_prodYield_kinematic_analysis.sh -{flags} {variable arguments, see help}"
echo "----------------------------------------------------------------------"
echo
echo "The following flags can be called for the physics analysis..."
echo "    -h, help"
echo "    -c, run cut analyser script to trim down the root file for further analysis"
echo "        cut -> Flag=-c RunType=arg1-(Prod) RunList=arg2 MaxEvents=arg3-(Optional)"
echo "    -m, run missing mass check script to determine the cut for missing mass"
echo "        mmcut -> Flag=-m RunType=arg1-(Prod) RunList=arg2 MaxEvents=arg3-(Optional)"
echo "    -d, run diamond cut check script to determine the diamond cut for data"
echo "        dcut -> Flag=-d RunType=arg1-(Prod) RunList=arg2 MaxEvents=arg3-(Optional)"
echo "    -e, run t-binning script to determine the t-resolution for data"
echo "        tresl -> Flag=-r RunType=arg1-(Prod) Setting=arg2 MaxEvents=arg3-(Optional)"
echo "    -t, run t-binning script to determine the t-binning for data"
echo "        tbin -> Flag=-t RunType=arg1-(Prod) Setting=arg2 MaxEvents=arg3-(Optional)"
echo "    -p, run phi-binning and physics yield script to determine the physcs yields"
echo "        phibin_pyield -> Flag=-y RunType=arg1-(Prod) RunList=arg2 MaxEvents=arg3-(Optional)"
echo "    -s, run simc yield script to determine simc yields"
echo "        simc -> Flag=-s RunType=arg1-(Prod) RunList=arg2 MaxEvents=arg3-(Optional)"
echo "    -r, run plotting script to compare Data/SIMC and determine ratios"
echo "        comp -> Flag=-p RunType=arg1-(Prod) RunList=arg2 MaxEvents=arg3-(Optional)"
exit 0
```