

EMITTANCE PAPER

V. Blackmore

CM45

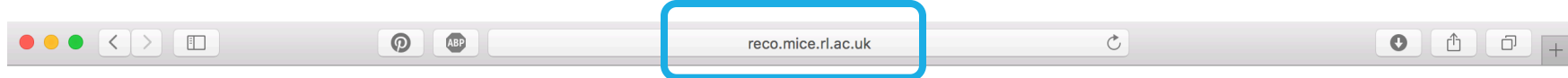
29th July 2016

CONTENTS

Goal: Everything you ever wanted to know about this analysis but were (never) afraid to ask.

1. Getting data.....	3
2. Extracting data	4—5
3. Applying cuts	7—36
4. 1D & 2D comparisons between data and MC	37—51
4. Covariance matrices & emittances	52—54
5. Error estimates	55—56
6. Ongoing analyses	57—62

GETTING DATA



MICE Reconstructed Data

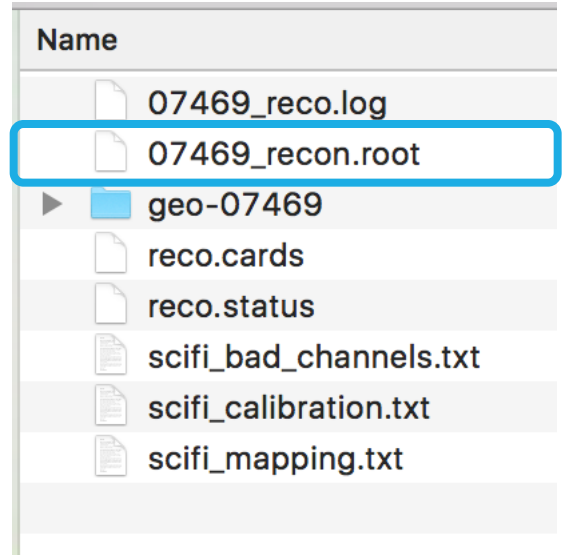
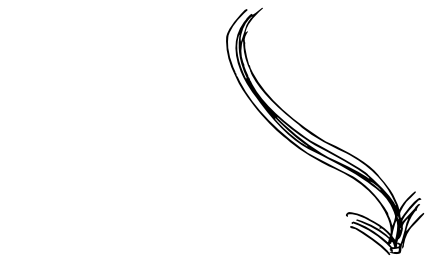
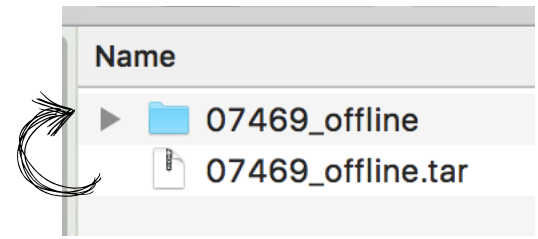
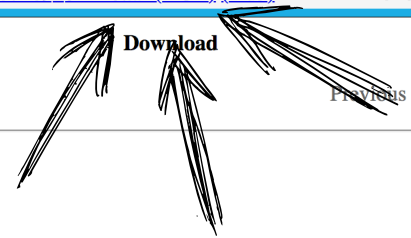
Show 25 entries

Search: 7469

Run Number	Run Date	Optics	Triggers	Reco Version	Download	Reco Date
7469	2015-10-07 15:38:57	3-200+M0	53469	MAUS-v2.0.0	07469_offline.tar (979.8 MB) (md5)	2016-03-04 12:54:01
7469	2015-10-07 15:38:57	3-200+M0	53469	MAUS-v2.1.0	07469_offline.tar (981.4 MB) (md5)	2016-03-17 10:50:27
7469	2015-10-07 15:38:57	3-200+M0	53469	MAUS-v1.3.3	07469_offline.tar (934.4 MB)	2016-01-08 16:23:55
7469	2015-10-07 15:38:57	3-200+M0	53469	MAUS-v2.3.1	07469_offline.tar (1 GB) (md5)	2016-05-06 14:40:55
7469	2015-10-07 15:38:57	3-200+M0	53469	MAUS-v2.4.0	07469_offline.tar (1 GB) (md5)	2016-06-14 10:15:14
7469	2015-10-07 15:38:57	3-200+M0	53469	MAUS-v2.5.0	07469_offline.tar (1 GB) (md5)	2016-06-23 11:19:32

Showing 1 to 6 of 6 entries (filtered from 1,925 total entries)

Previous 1 Next



EXTRACT-YOUR-OWN...

Not necessary for run 7469 (see later), but I'm including this here in case it's useful for other analyses...

The screenshot shows the GitHub repository page for 'victoriablackmore/Extract-MAUS-data'. The repository description is 'Extract data from a MAUS root file'. It has 30 commits, 1 branch, 0 releases, and 0 contributors. The 'Clone or download' button is highlighted with a blue box. Below the repository information, there is a commit history table.

Commit	Message	Time
Victoria Blackmore Merge branch 'working_branch'		Latest commit 924e8e1 2 minutes ago
.gitignore	Updating .gitignore	4 months ago
ExtractData.pro	Fixed pro file	4 months ago
ExtractData.pro.user	Initial commit	4 months ago
betterreadmaus.cpp	Change of mass cut to momentum loss cut	2 minutes ago
betterreadmaus.h	Change of mass cut to momentum loss cut	2 minutes ago

The screenshot shows the 'Clone or download' dropdown menu. The 'Clone with HTTPS' option is selected, showing the URL 'https://github.com/victoriablackmore/E'. The 'Download ZIP' button is highlighted with a blue box and has three arrows pointing to it. The 'Open in Desktop' button is also visible.

Clone with HTTPS ?
Use Git or checkout with SVN using the web URL.
`https://github.com/victoriablackmore/E`

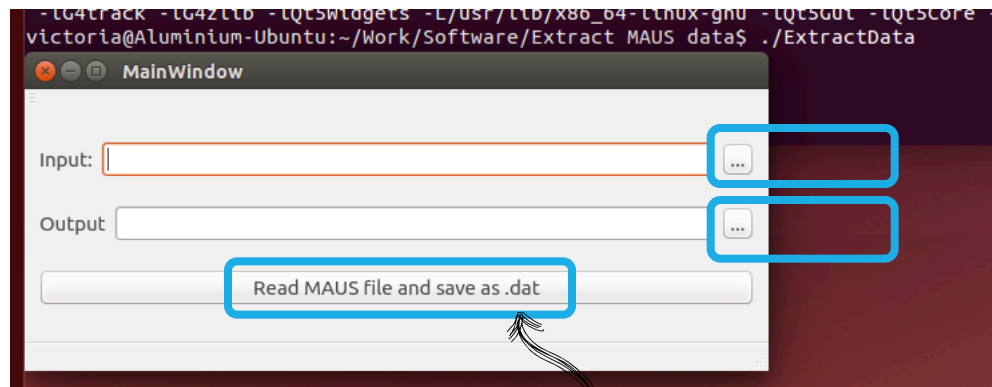
Open in Desktop Download ZIP

Not necessary for run 7469 (see later), but I'm including this here in case it's useful for other analyses...

EXTRACT-YOUR-OWN...

```
victoria@Aluminium-Ubuntu: ~
victoria@Aluminium-Ubuntu:~$ source WorkPrograms/maus/env.sh
INFO: Using third party libraries from /home/victoria/WorkPrograms/maus
MAUS web front-end directory: /home/victoria/WorkPrograms/maus/third_party/install/lib/maus-apps-0.2
Database directory: /home/victoria/WorkPrograms/maus/third_party/install/lib/maus-apps-0.2/db
Media directory: /home/victoria/WorkPrograms/maus/third_party/install/lib/maus-apps-0.2/media
Media directory (raw images): /home/victoria/WorkPrograms/maus/third_party/install/lib/maus-apps-0.2/media/raw
SUCCESS: MAUS setup
victoria@Aluminium-Ubuntu:~$
```

```
victoria@Aluminium-Ubuntu:~$ cd Work/Software/Extract\ MAUS\ data/
victoria@Aluminium-Ubuntu:~/Work/Software/Extract MAUS data$ qmake
victoria@Aluminium-Ubuntu:~/Work/Software/Extract MAUS data$ make
```



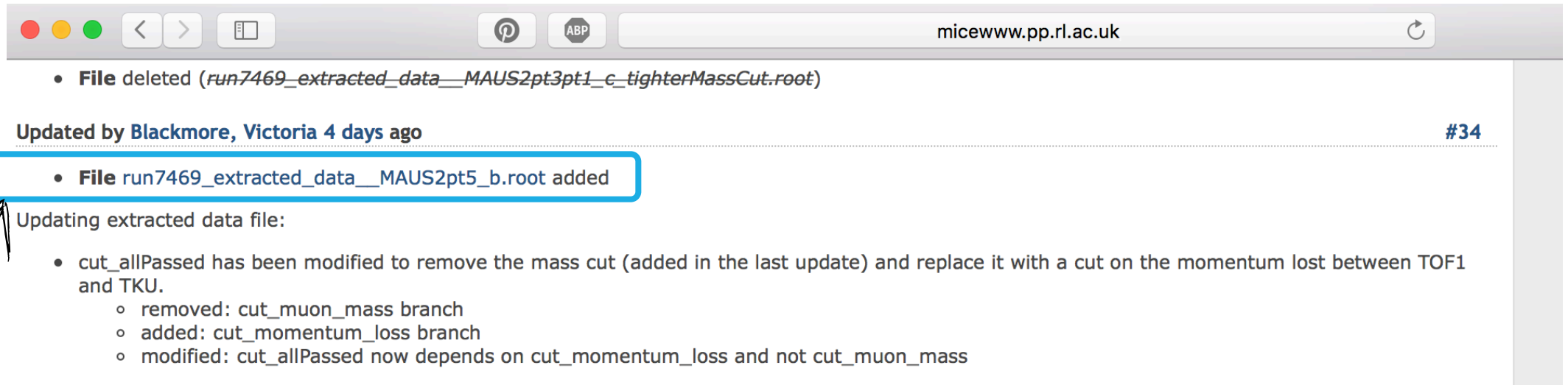
Oh look... a typo I just spotted.
It will save it as a .root file

1. Source your MAUS installation (NB: Your MAUS install must be of a version **at least** equal to what the data(MC) was reconstructed with)
2. Extract the downloaded source code from GitHub to your directory of choice. Here I put it in 'Extract MAUS data'. Then do:
 1. qmake
 2. make
3. Run the program with:
 1. ./ExtractData
4. Use the "highly intuitive" GUI to select your input reconstructed data or MC file, and pick a location and name for the output.
5. Click the button and wait.

The extraction code requires you have a recent(ish) install of Qt. It's often pre-installed on many linux distributions, but if 'qmake' does nothing for you, I can walk you through that extra hoop.

... OR BE LAZY.

<http://micewww.pp.rl.ac.uk/issues/1833>



- **File** deleted (*run7469_extracted_data__MAUS2pt3pt1_c_tighterMassCut.root*)

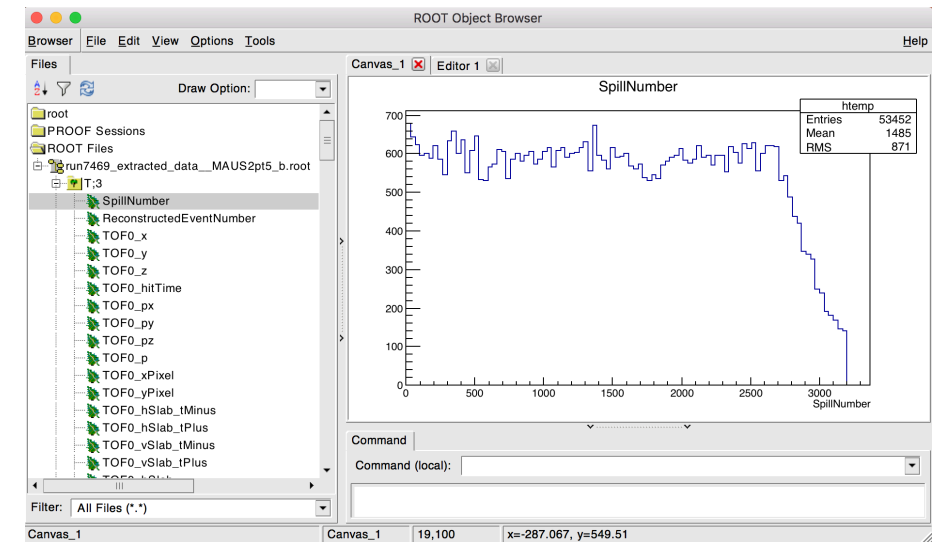
Updated by **Blackmore, Victoria** 4 days ago #34

- **File** *run7469_extracted_data__MAUS2pt5_b.root* added

Updating extracted data file:

- `cut_allPassed` has been modified to remove the mass cut (added in the last update) and replace it with a cut on the momentum lost between TOF1 and TKU.
 - removed: `cut_muon_mass` branch
 - added: `cut_momentum_loss` branch
 - modified: `cut_allPassed` now depends on `cut_momentum_loss` and not `cut_muon_mass`

```
[Aluminium:Data run 7469 Victoria$ root -l run7469_extracted_data__MAUS2pt5_b.root
root [0]
Attaching file run7469_extracted_data__MAUS2pt5_b.root as _file0...
root [1] TBrowser b;
```



BRANCHES IN EXTRACTED DATA FILE

Branch name	Type	Unit	Description
SpillNumber	Int	--	... as it sounds.
ReconstructedEventNumber	Int	--	... as it sounds. Particles can be ID'd by (spill, event)
TOF0_x, TOF0_y, TOF0_z	Double	mm	Position at TOF0 (x, y) according to PMT-based position measurement
TOF0_px, TOF0_py, TOF0_pz, TOF0_p	Double	MeV/c	Momentum at TOF0 according to M. Rayner reconstruction
TOF0_xPrime, TOF0_yPrime	Double	rad	Reconstructed angle at TOF0 according to M. Rayner reconstruction
TOF0_xPixel, TOF0_yPixel	Double	mm	Position of the TOF pixel crossed, i.e. crossing point of slabs
TOF0_hitTime	Double	ns	Time particle crossed TOF0
*TOF0_hSlab_tMinus, *TOF0_hSlab_tPlus	Double	ps	Time recorded at horizontal slab PMTs at positive (plus) and negative (minus) x
*TOF0_vSlab_tMinus, *TOF0_vSlab_tPlus	Double	ps	Time recorded at vertical slab PMTs at positive (plus) and negative (minus) y
TOF0_hSlab, TOF0_vSlab	Double	--	Horizontal (hSlab) and vertical (vSlab) numbers hit

* These are used to get the position of the particle at TOF0 according to the PMT times

BRANCHES IN EXTRACTED DATA FILE

Branch name	Type	Unit	Description
TOF1_x, TOF1_y, TOF1_z	Double	mm	Position at TOF1 (x, y) according to PMT-based position measurement
TOF1_px, TOF1_py, TOF1_pz, TOF1_p	Double	MeV/c	Momentum at TOF1 according to M. Rayner reconstruction
TOF1_xPrime, TOF1_yPrime	Double	rad	Reconstructed angle at TOF1 according to M. Rayner reconstruction
TOF1_xPixel, TOF1_yPixel	Double	mm	Position of the TOF pixel crossed, i.e. crossing point of slabs
TOF1_hitTime	Double	ns	Time particle crossed TOF1
*TOF1_hSlab_tMinus, *TOF1_hSlab_tPlus	Double	ps	Time recorded at horizontal slab PMTs at positive (plus) and negative (minus) x
*TOF1_vSlab_tMinus, *TOF1_vSlab_tPlus	Double	ps	Time recorded at vertical slab PMTs at positive (plus) and negative (minus) y
TOF1_hSlab, TOF1_vSlab	Double	--	Horizontal (hSlab) and vertical (vSlab) numbers hit

* These are used to get the position of the particle at TOF1 according to the PMT times

BRANCHES IN EXTRACTED DATA FILE

Branch name	Type	Unit	Description
TKU_s1_x, TKU_s1_y, TKU_s1_z	Double	mm	Position at tracker station 1 from MAUS::SciFiTrackPoint->pos().x()
TKU_s1_px, TKU_s1_py, TKU_s1_pz, TKU_s1_p	Double	MeV/c	Position at tracker station 1 from MAUS::SciFiTrackPoint->mom().x()
TKU_s1_pull	Double		Pull at tracker station 1 from MAUS::SciFiTrackPoint->pull()
TKU_s1_x_error, TKU_s1_y_error	Double	mm	Error on position from track fit (MAUS::SciFiTrackPoint->errors())
TKU_s1_px_error, TKU_s1_py_error	Double	MeV/c	Error on momentum from track fit (MAUS::SciFiTrackPoint->errors())
TKU_s1_kappa_error	Double	T/GeV*	kappa = qBz/Pz (in GeV), error from track fit (as above)
TKU_PValue	Double		P-value from MAUS::SciFiTrackPoint->P_value()
TKU_chiSquare	Double		Chi-squared from MAUS::SciFiTrackPoint->chi_2()
TKU_pattRec_r	Double	mm	Radius of patt. rec. circle from MAUS::SciFiHelicalPRTrack->get_R()
TKU_pattRec_dipAngle	Double	rad	Angle of helix from MAUS::SciFiHelicalPRTrack->get_dsdz()
TKU_pattRec_x0, TKU_pattRec_y0	Double	mm	Centre of patt. rec. circle from MAUS::SciFiHelicalPRTrack->get_circle_x0() and MAUS::SciFiHelicalPRTrack->get_circle_y0()

Replace 's1' with 's2' for station 2, 's3' for station 3, etc...

cut = 1, particle passed
cut = 0, particle failed

BRANCHES IN EXTRACTED DATA FILE

Branch name	Type	Unit	Description (or pass condition if branch begins with 'cut_')
TKU_mass	Double	MeV/c ²	Calculated particle mass using time-of-flight and TKU momentum
TKU_good	Int	--	If there were 5 station hits, this is 1. Otherwise, 0.
TKU_station_hits	Int	--	The number of station hits in the track
cut_TOF0_goodPMTPosition	Int	--	TOF0_xPixel - slabWidth <= TOF0_x <= TOF0_xPixel + slabWidth
cut_TOF1_goodPMTPosition	Int	--	TOF1_xPixel - slabWidth <= TOF1_x <= TOF1_xPixel + slabWidth
cut_goodRaynerReconstruction	Int	--	M. Rayner reconstruction converges
cut_TKU_hitAllStations	Int	--	TKU_station_hits == 5
cut_TimeOfFlight	Int	--	27 <= (TOF1_hitTime - TOF0_hitTime) <= 40
cut_hit_all_detectors	Int	--	cut_TOF0_goodPMTPosition && cut_TOF1_goodPMTPosition && cut_TKU_hitAllStations
cut_TOF0_singleHit	Int	--	MAUS::TOFEventSpacePoint->GetTOF0SpacePointArray()->size() == 1
cut_TOF1_singleHit			MAUS::TOFEventSpacePoint->GetTOF1SpacePointArray()->size() == 1

$cut = 1$, particle passed
 $cut = 0$, particle failed

BRANCHES IN EXTRACTED DATA FILE

Branch name	Type	Unit	Description
cut_TKU_singleTrack	Int	--	MAUS::SciFiTrack->size() == 1
cut_TKU_PValue	Int	--	TKU_PValue >= 0.01
cut_momentum_loss	Int	--	min_tracker(beta*gamma) <= tof(beta*gamma) <= max_tracker(beta*gamma)
cut_allPassed	Int	--	cut_TOF0_goodPMTPosition && cut_TOF1_goodPMTPosition && cut_goodRaynerReconstruction && cut_TKU_hitAllStations && cut_TimeOfFlight && cut_hit_all_detectors && cut_TOF0_singleHit && cut_TOF1_singleHit && cut_TKU_PValue && cut_momentum_loss

$$\min_tracker(\beta\gamma) = (p + p_{\min})/m_{\mu}$$

$$\max_tracker(\beta\gamma) = (p + p_{\max})/m_{\mu}$$

$$\text{tof}(\beta) = t_e/t_{\mu}$$

$$\text{tof}(\gamma) = 1/\sqrt{1 - \beta^2}$$

$$p_{\min} = 5 \text{ MeV}/c$$

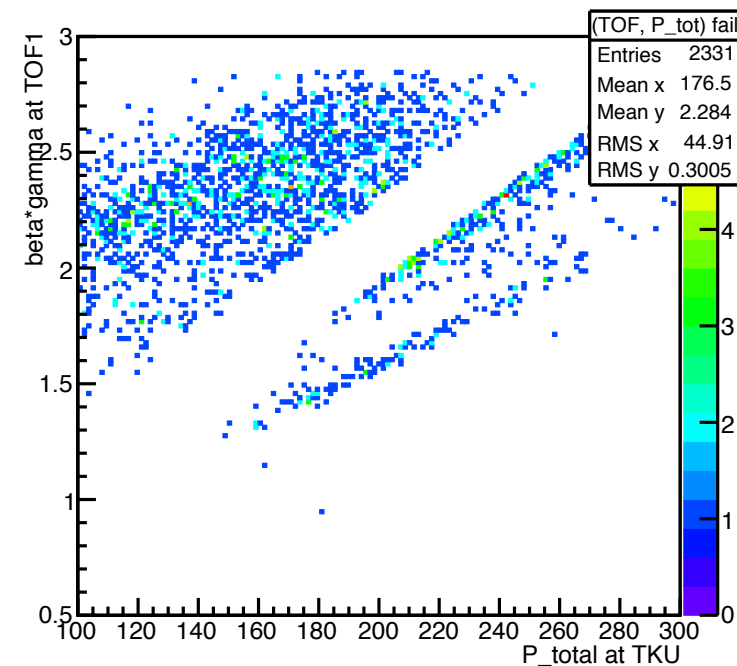
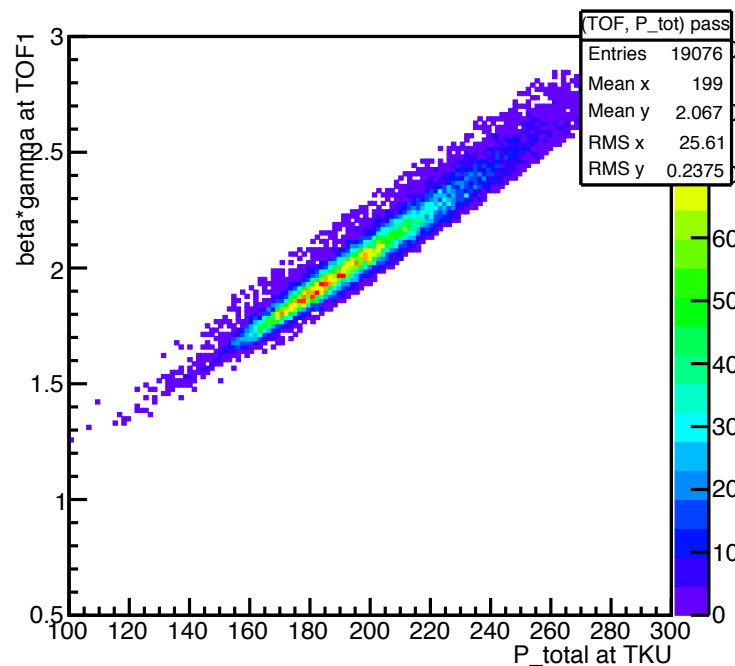
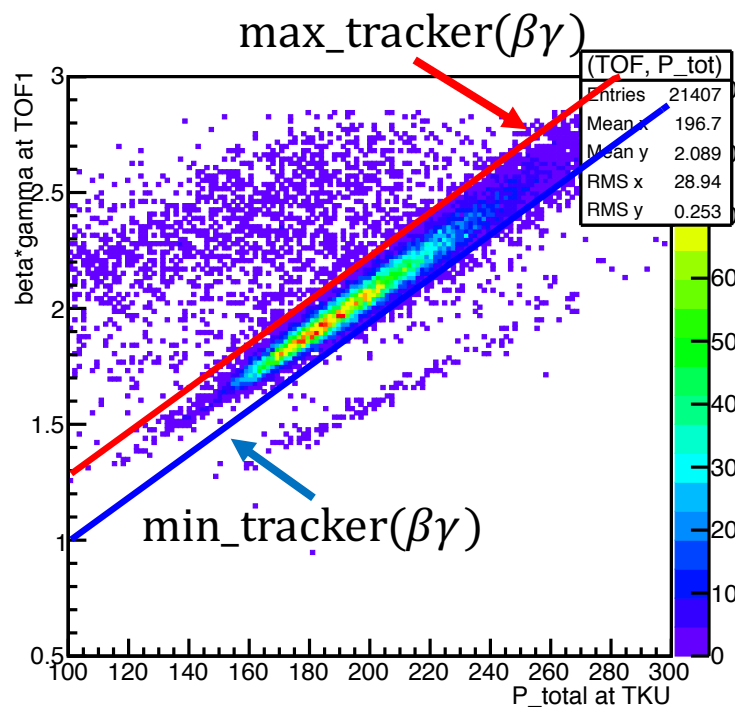
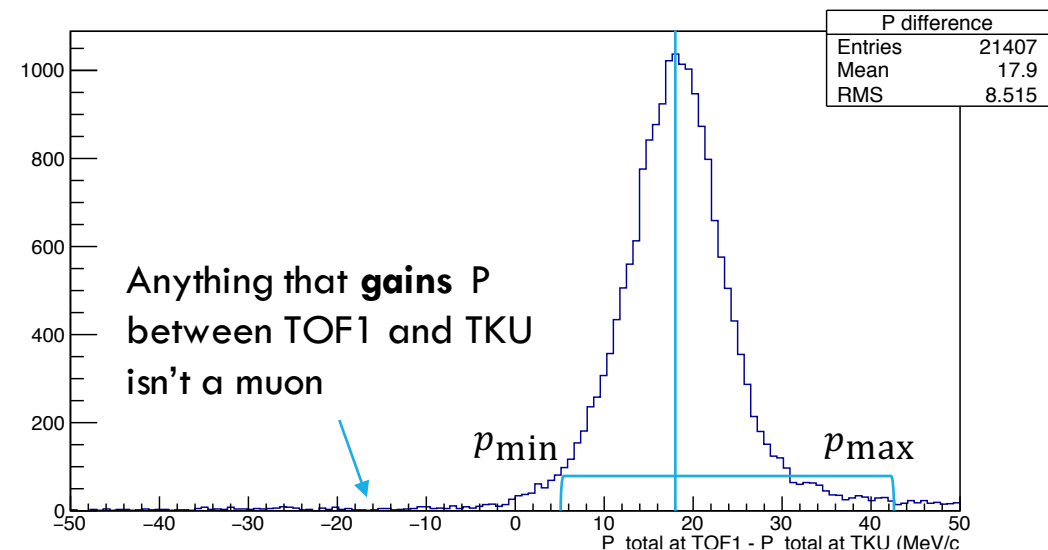
$$p_{\max} = 43.4 \text{ MeV}/c$$

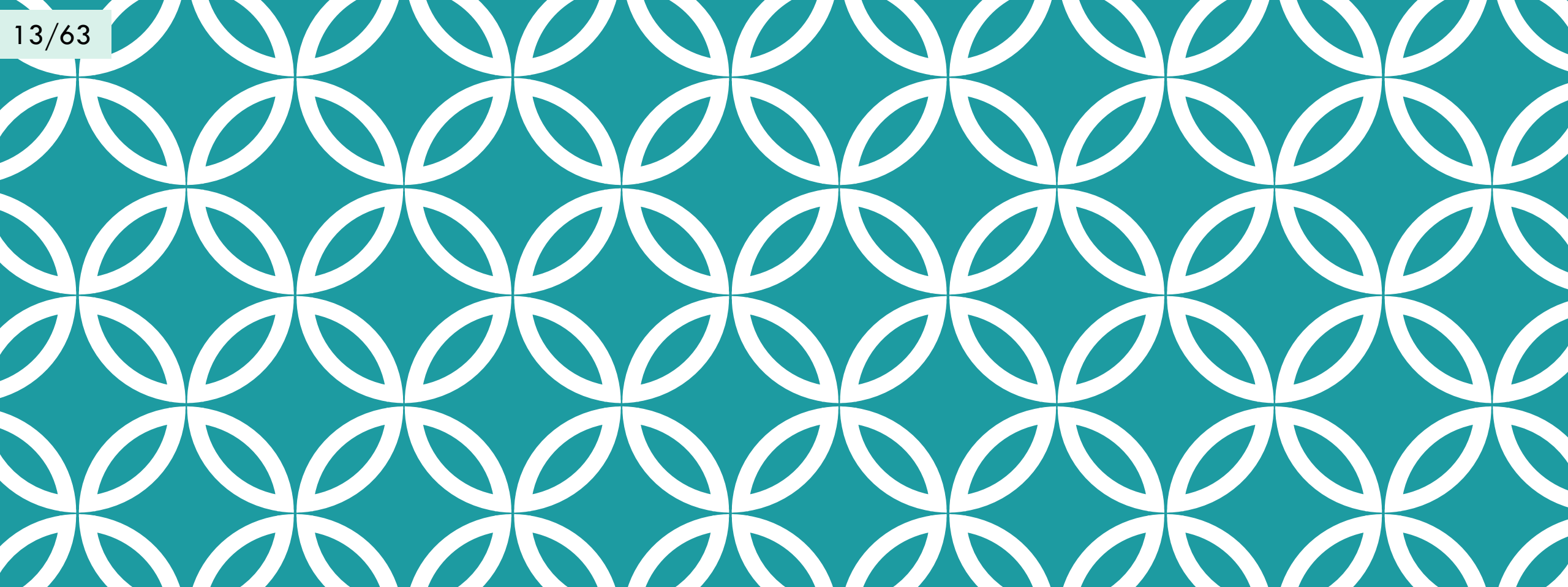
These are 3σ away from the mean total momentum difference between TOF1 and TKU

CUT_MOMENTUM_LOSS

$$\text{min_tracker}(\beta\gamma) = (p + p_{\text{min}})/m_{\mu}$$

$$\text{max_tracker}(\beta\gamma) = (p + p_{\text{max}})/m_{\mu}$$





WHAT'S WITH ALL THE CUTS?

Compare distributions:

- with all cuts applied
- with all but cut-of-interest applied

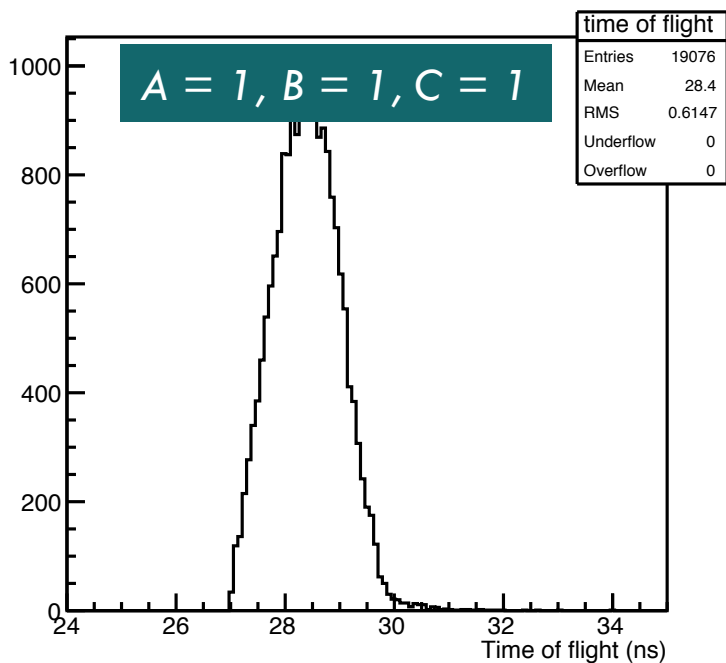
A THOUGHT EXPERIMENT ON CUTS

- Say we have 3 cuts: A, B & C
 - We want to accept particles that pass all 3 cuts, so we introduce a shorthand 'D'
 - $D = 1$ if $A = B = C = 1$
 - $D = 0$ otherwise
- We want to test the effectiveness of cut A:
 - Look at particles that have $D = 1$
 - Look at particles that have $A = 0, B = 1, C = 1$
 - Look at particles that have $A = 0$, regardless of what B & C do
 - If a particle fails A, see if it also fails B or C
- ... and now extend this to the 11 cuts we have

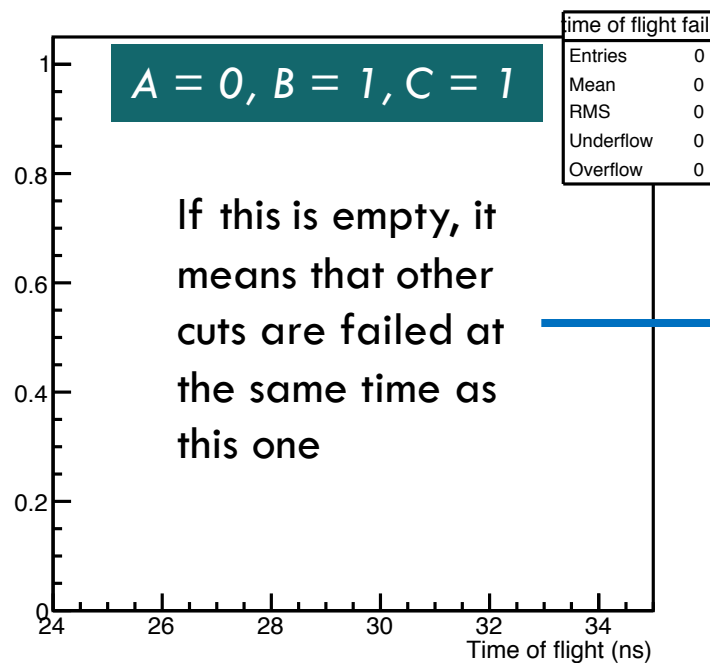
A THOUGHT EXPERIMENT ON CUTS

A pseudo-example of what's to come...

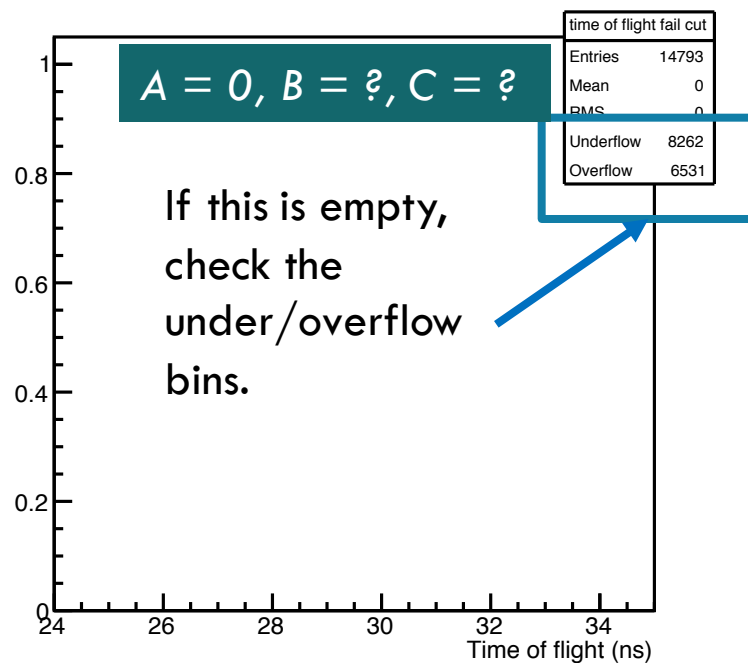
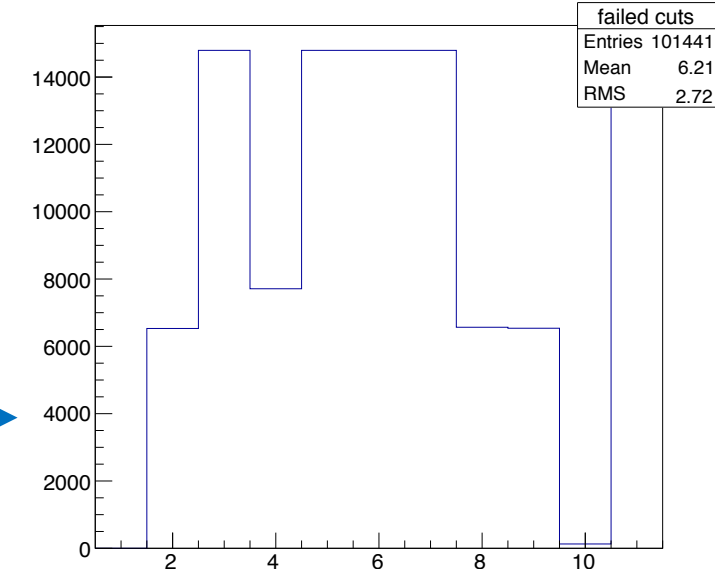
If this cut is failed, fill histogram with the other cuts that failed (so #entries ≠ #particles)



These particles pass all cuts



These particles pass all cuts except this one

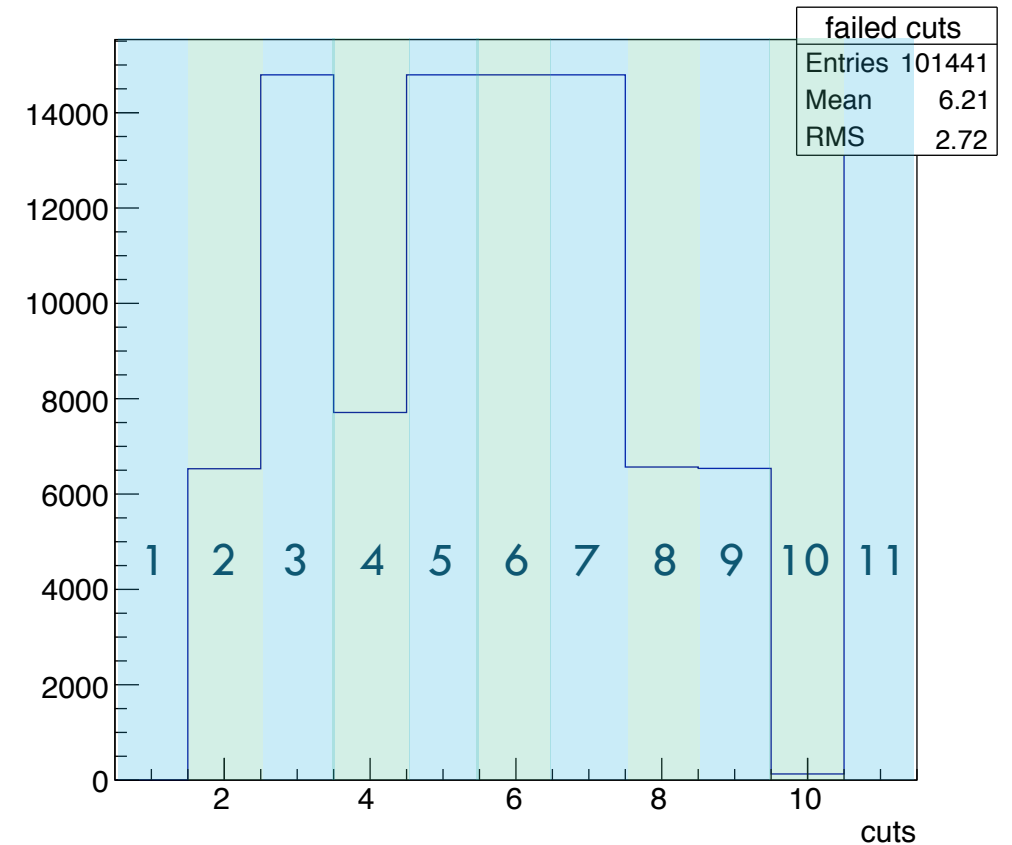


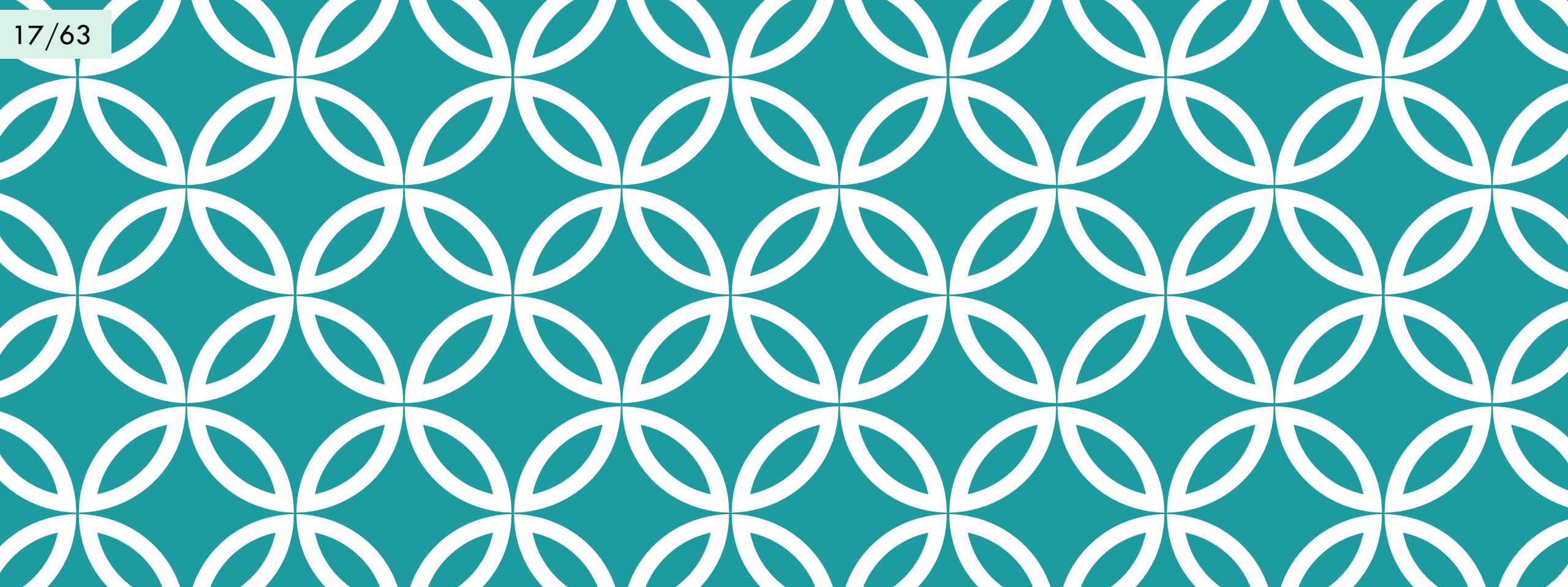
These particles fail this cut

A THOUGHT EXPERIMENT ON CUTS

A pseudo-example of what's to come...

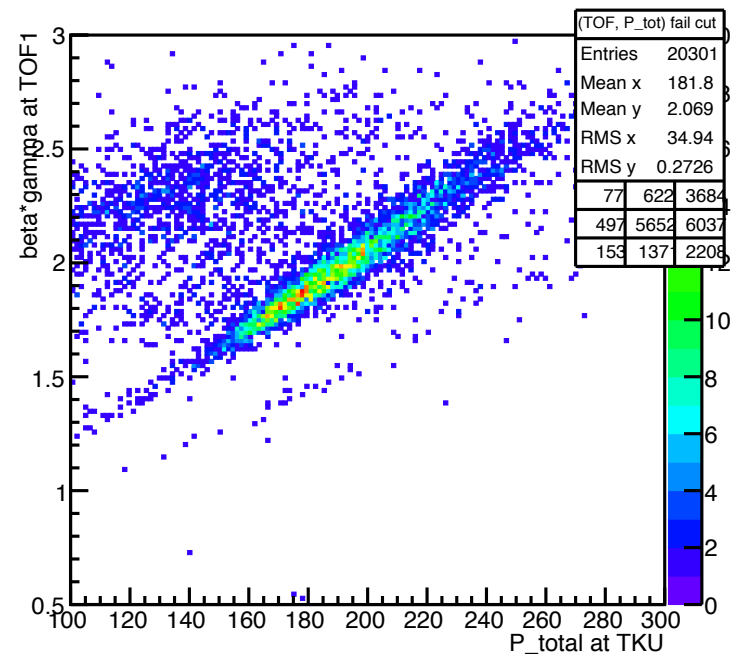
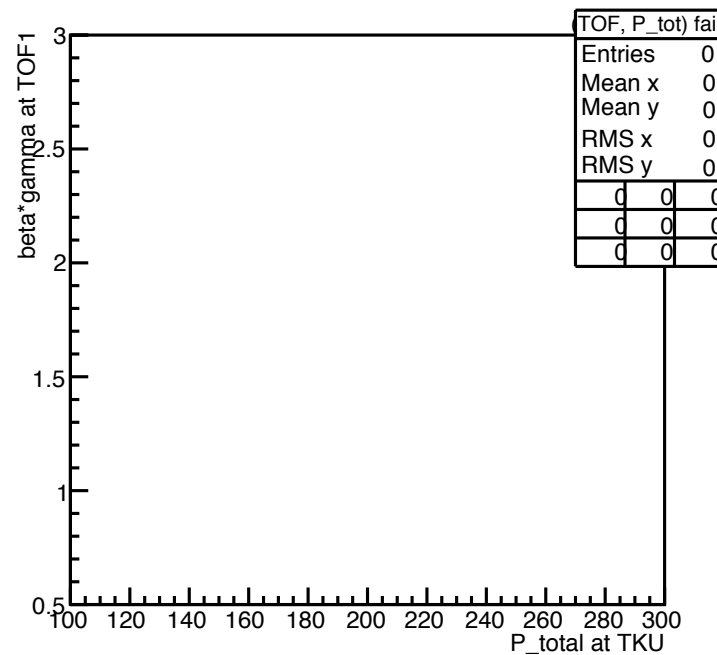
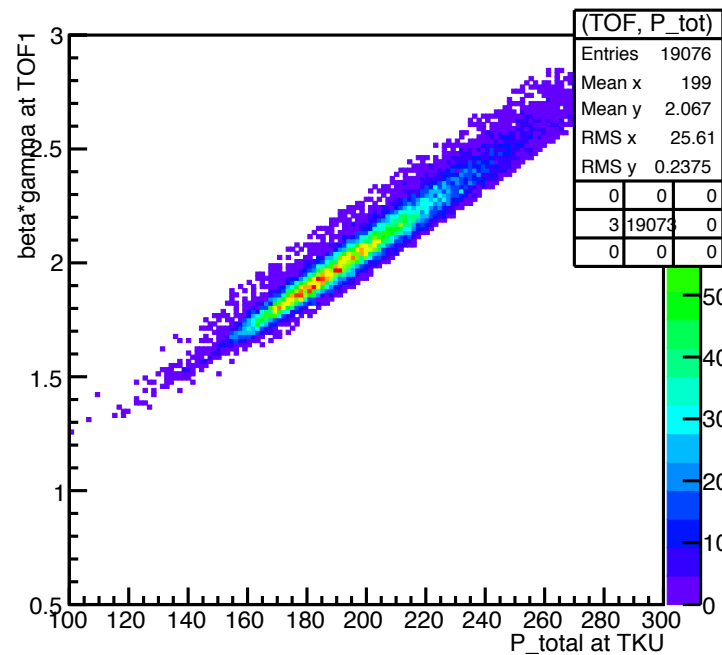
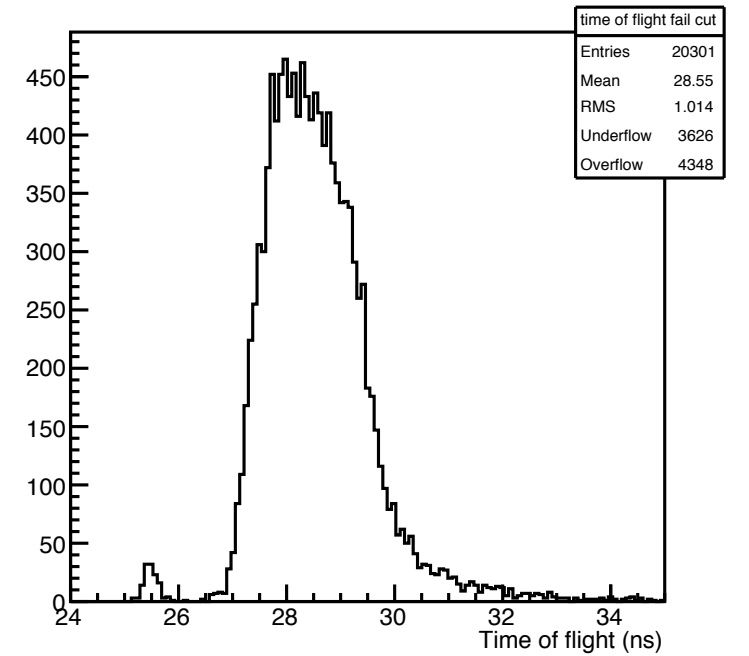
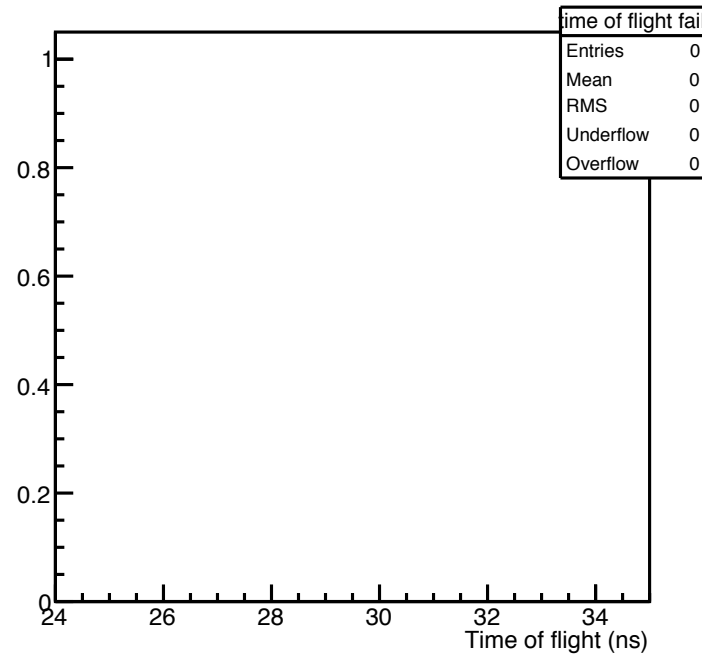
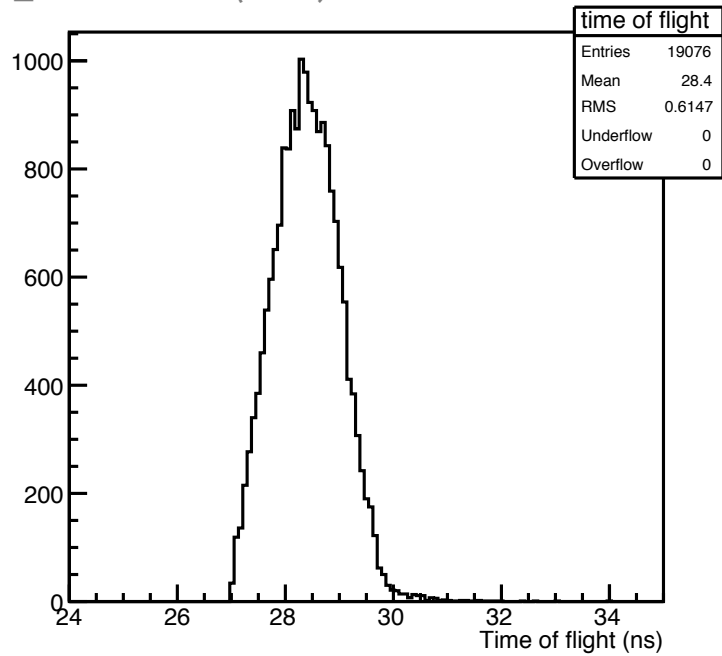
'Cut number'	Cut
1	cut_TOF0_goodPMTPosition
2	cut_TOF1_goodPMTPosition
3	cut_goodRaynerReconstruction
4	cut_TKU_hitAllStations
5	cut_TimeOfFlight
6	cut_hit_all_detectors
7	cut_TOF0_singleHit
8	cut_TOF1_singleHit
9	cut_TKU_singleTrack
10	cut_TKU_PValue
11	cut_momentum_loss

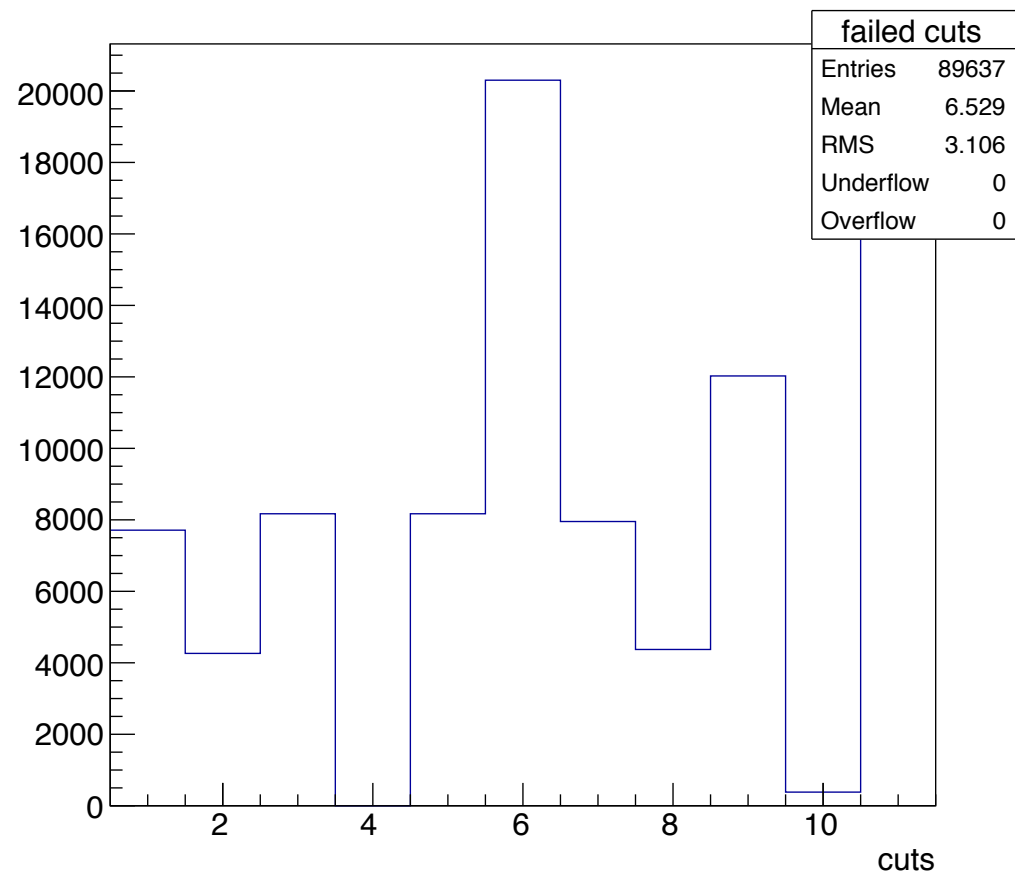




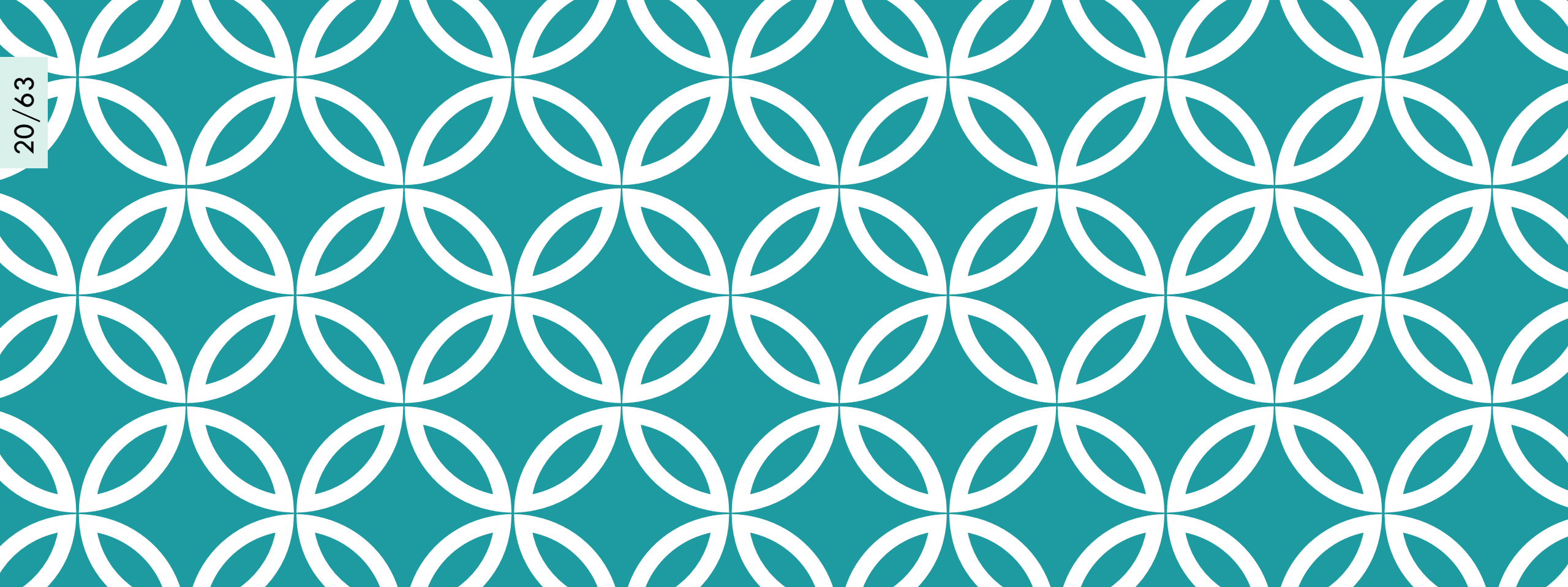
CUT_TKU_HITALLSTATIONS

AKA 'cut 4'



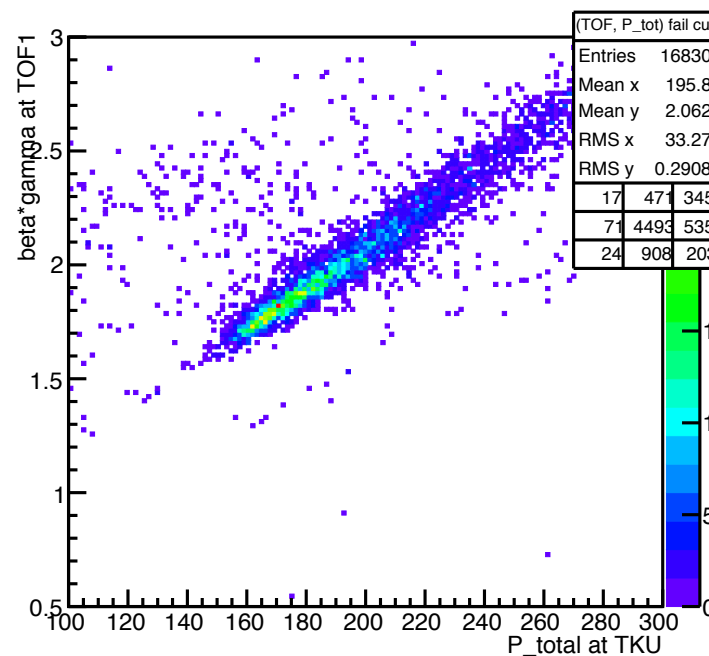
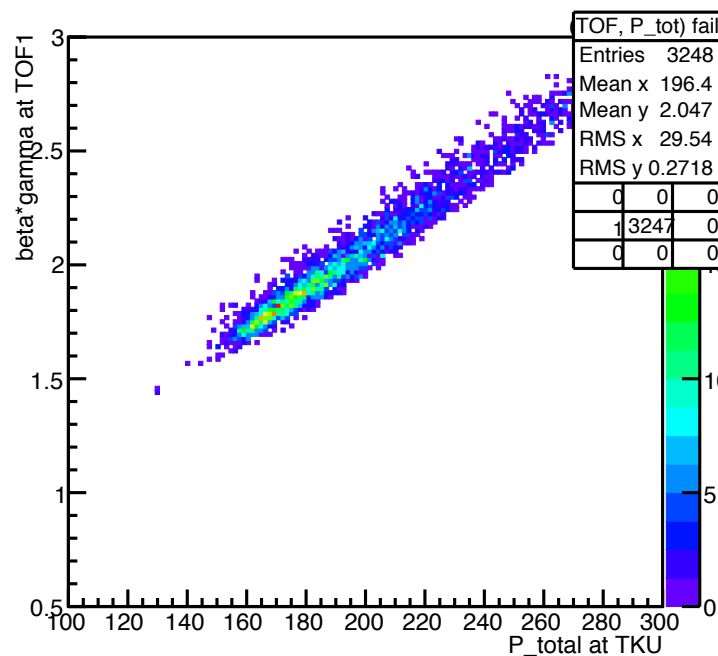
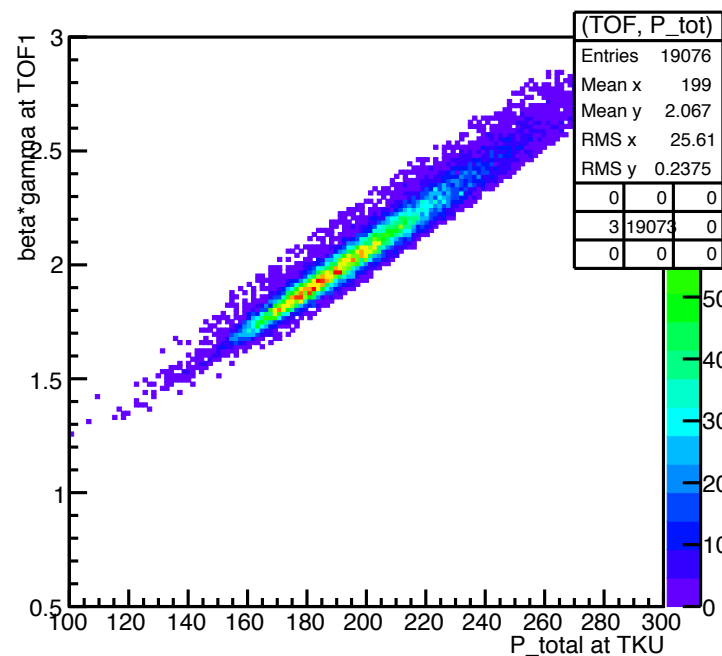
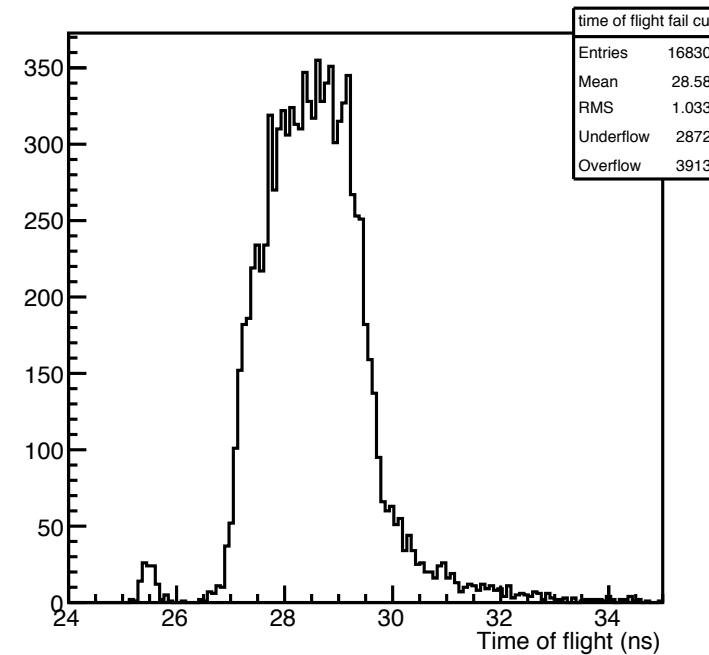
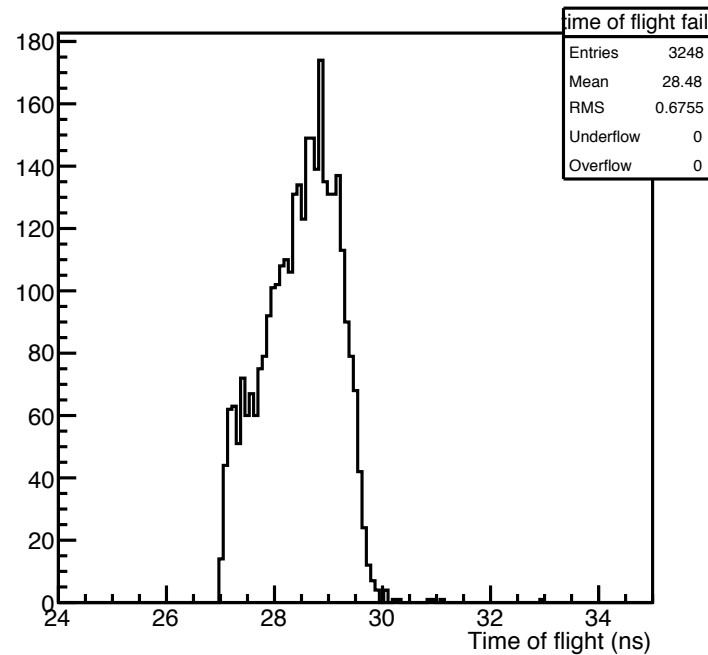
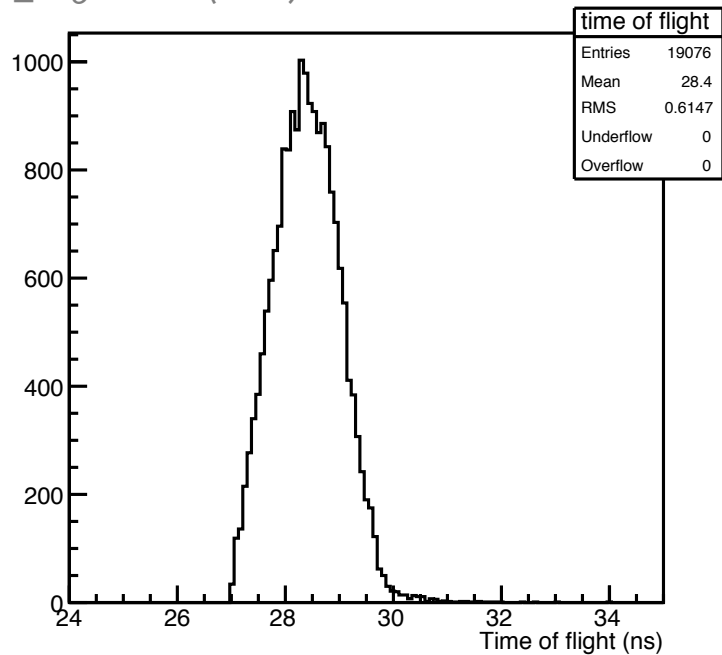


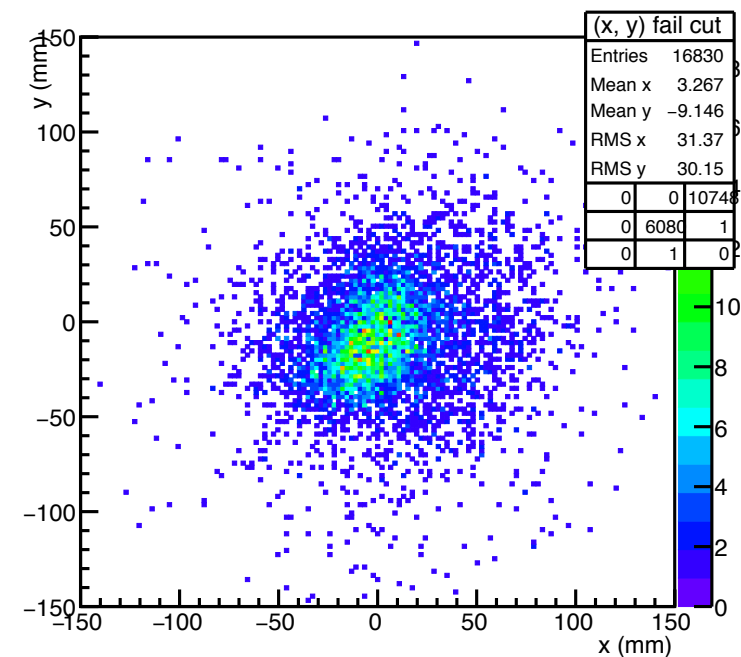
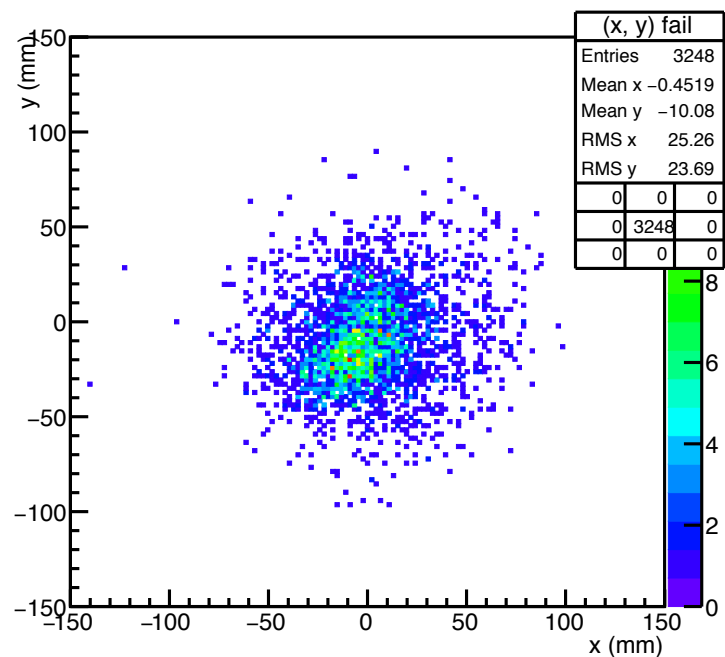
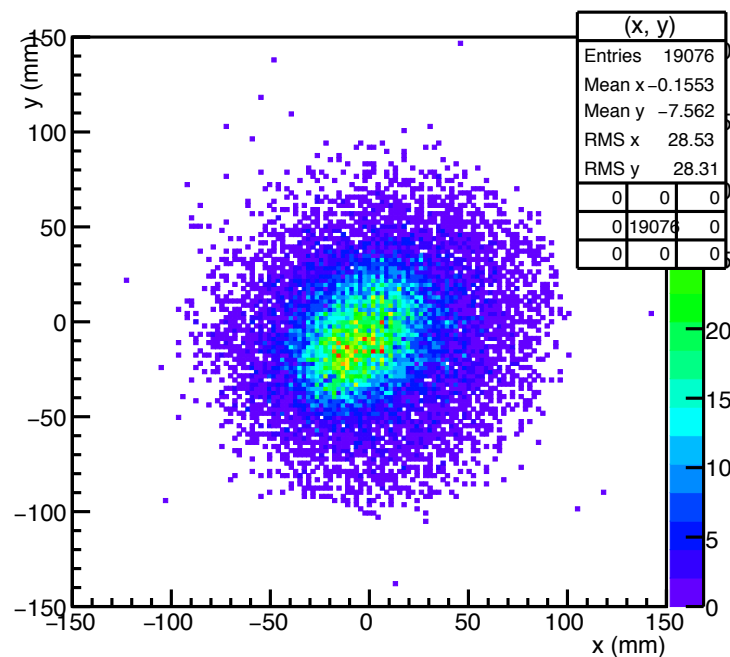
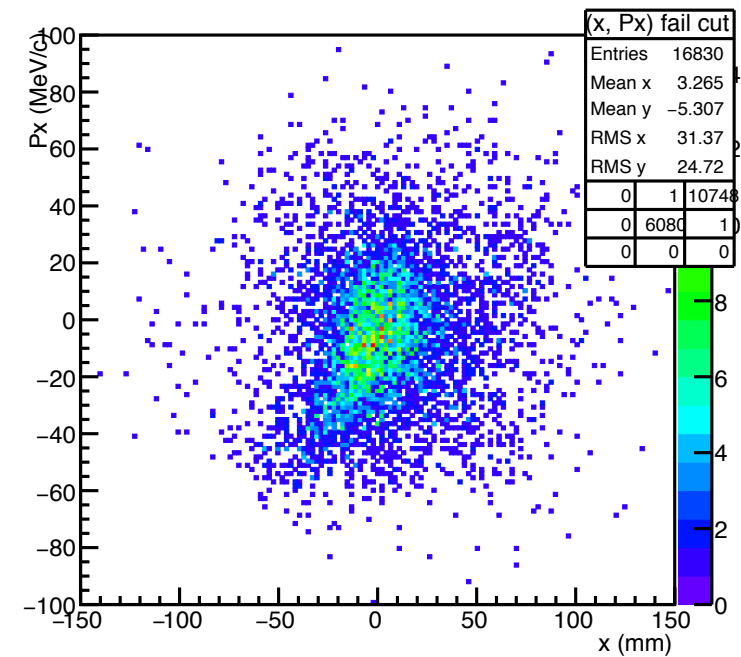
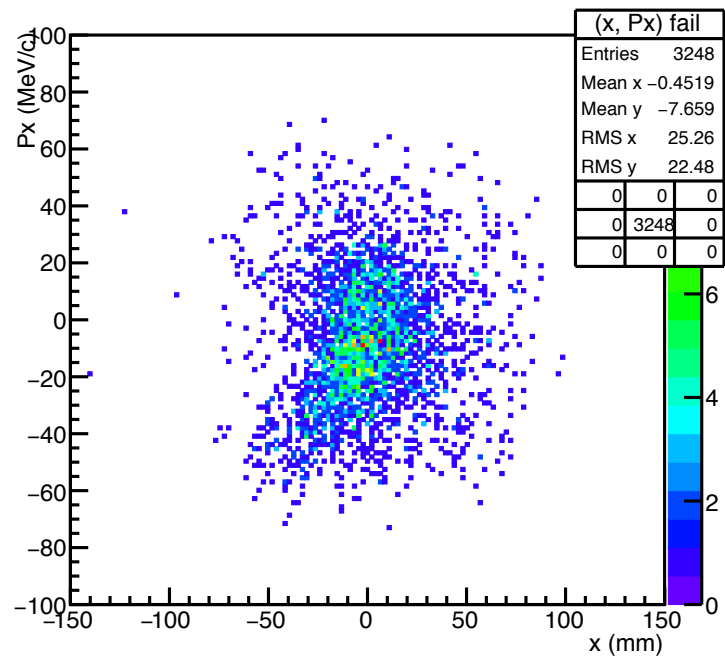
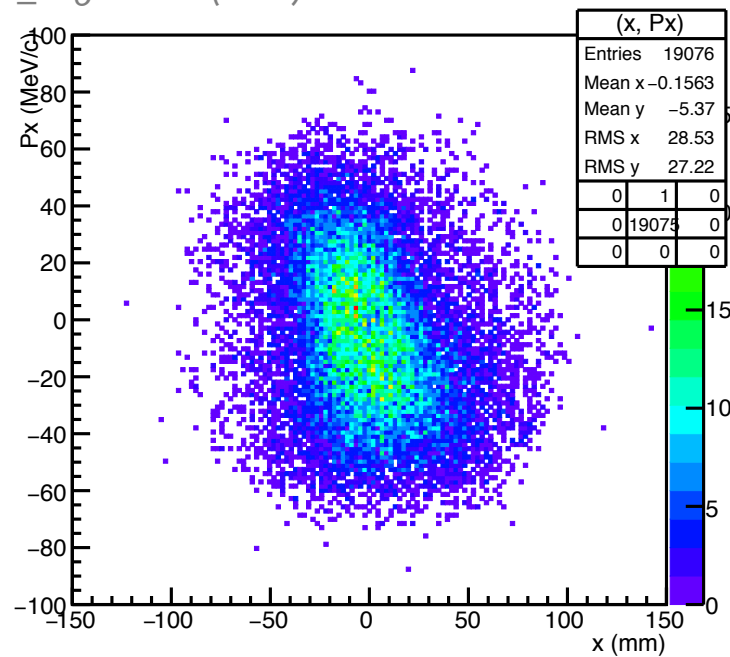
'Cut number'	Cut
1	cut_TOF0_goodPMTPosition
2	cut_TOF1_goodPMTPosition
3	cut_goodRaynerReconstruction
4	cut_TKU_hitAllStations
5	cut_TimeOfFlight
6	cut_hit_all_detectors
7	cut_TOF0_singleHit
8	cut_TOF1_singleHit
9	cut_TKU_singleTrack
10	cut_TKU_PValue
11	cut_momentum_loss

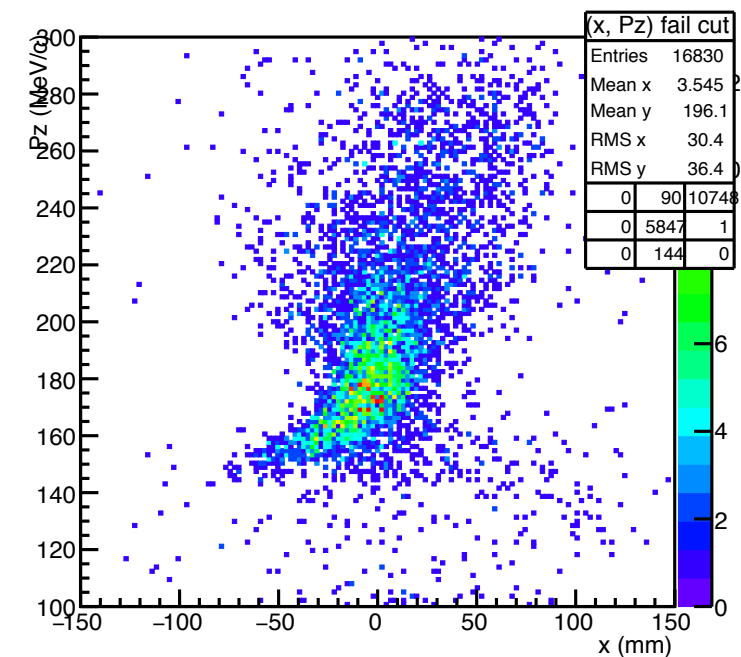
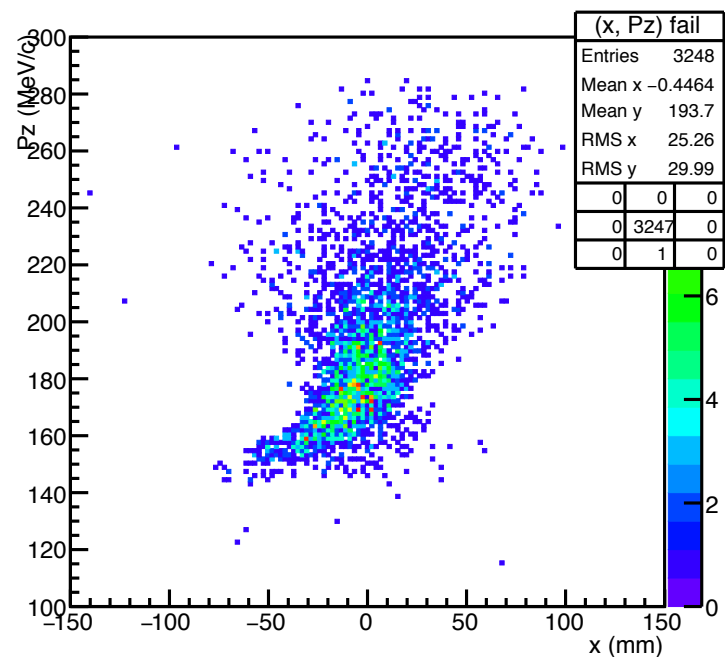
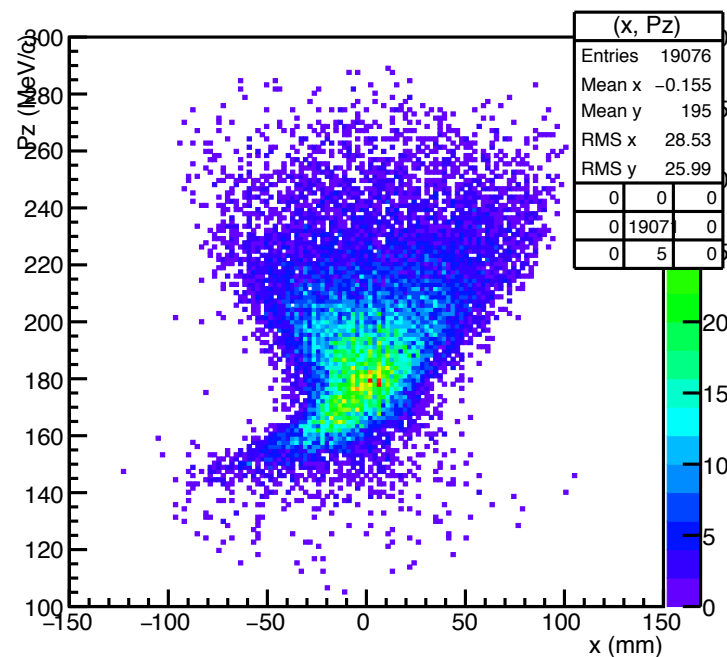
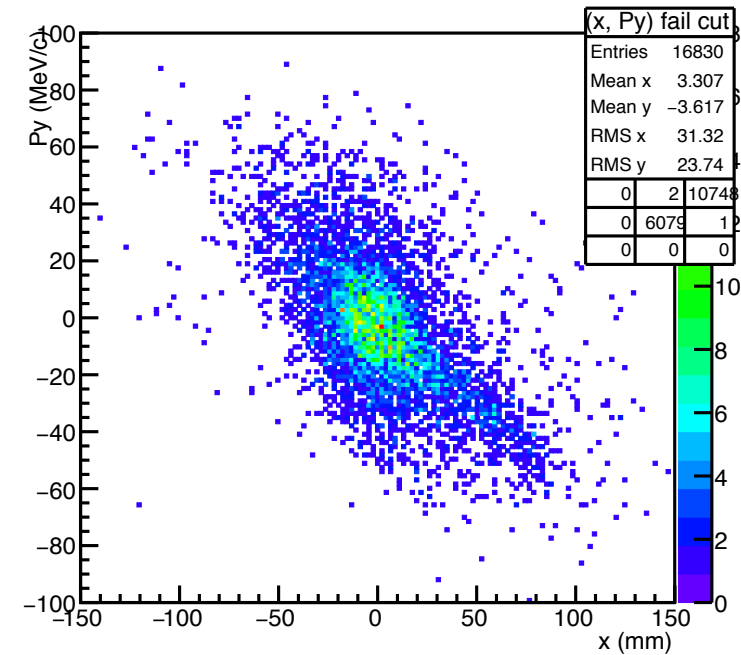
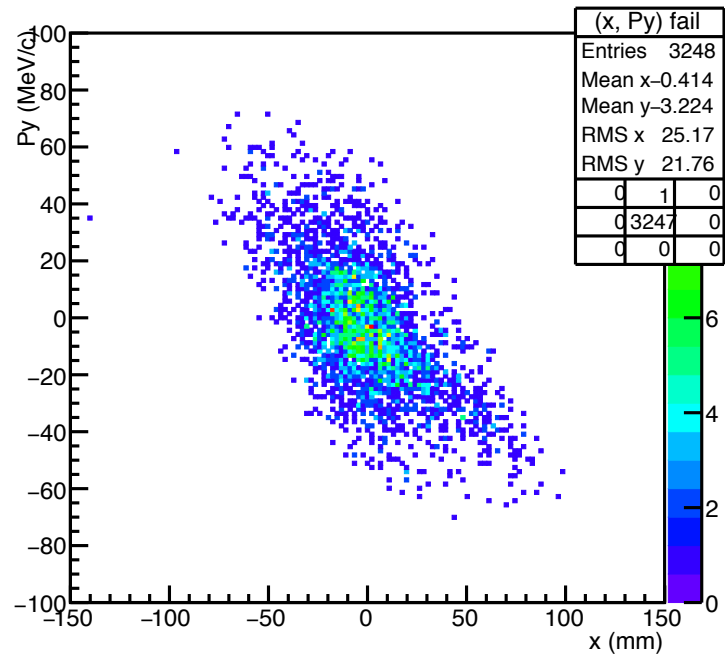
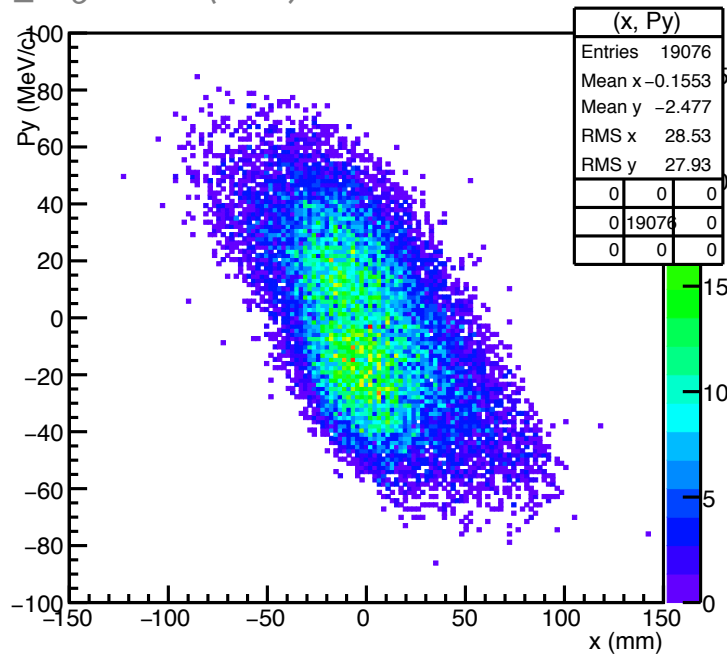


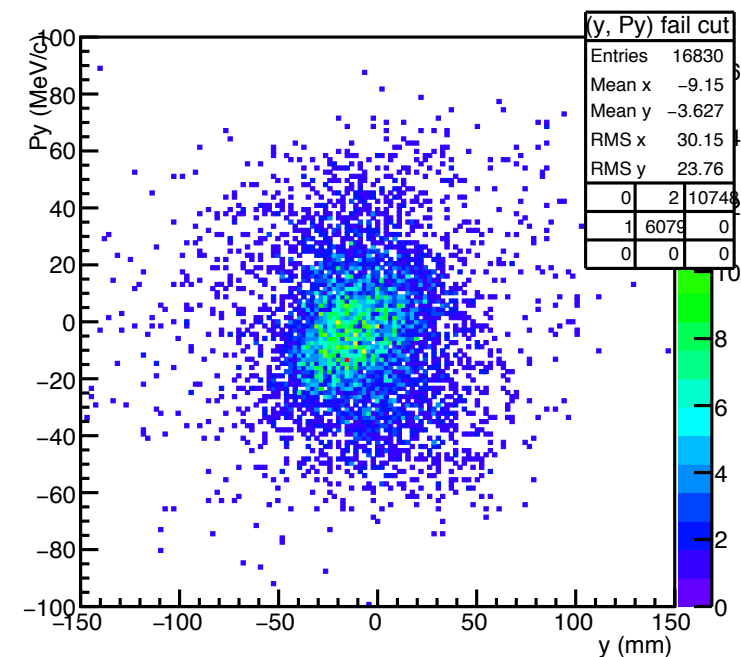
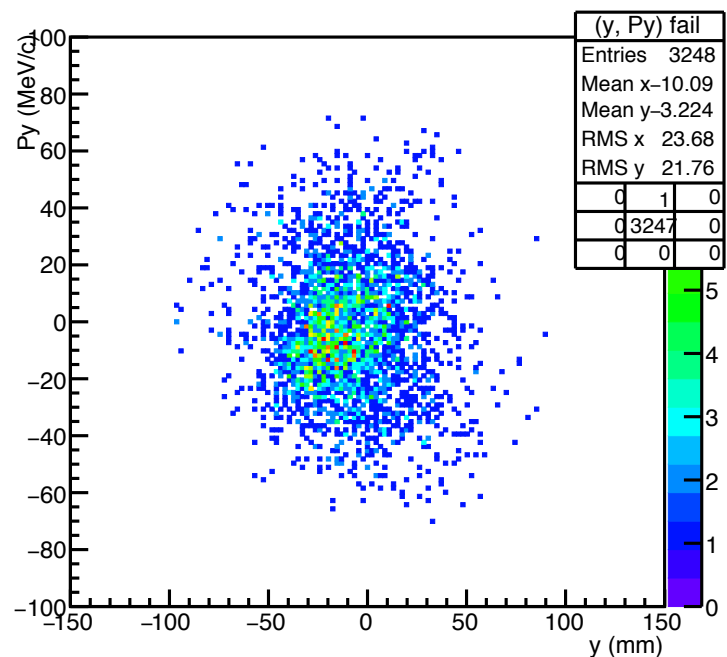
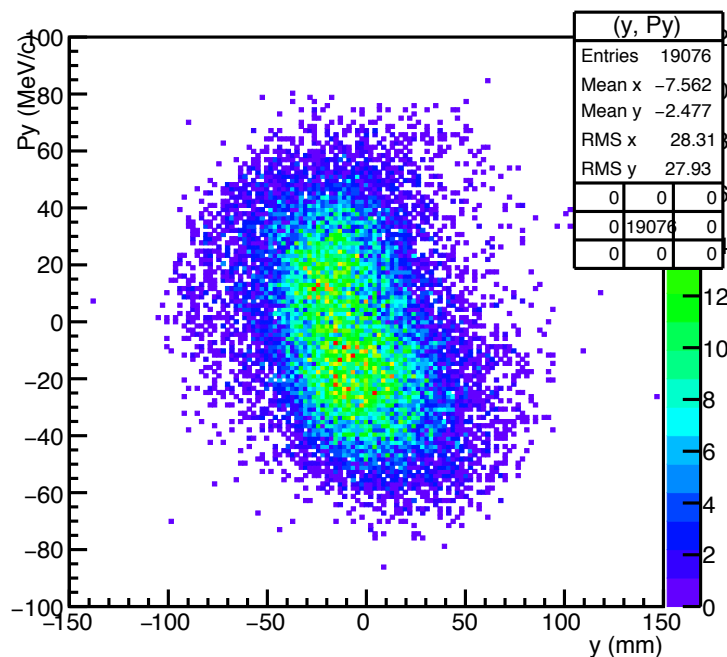
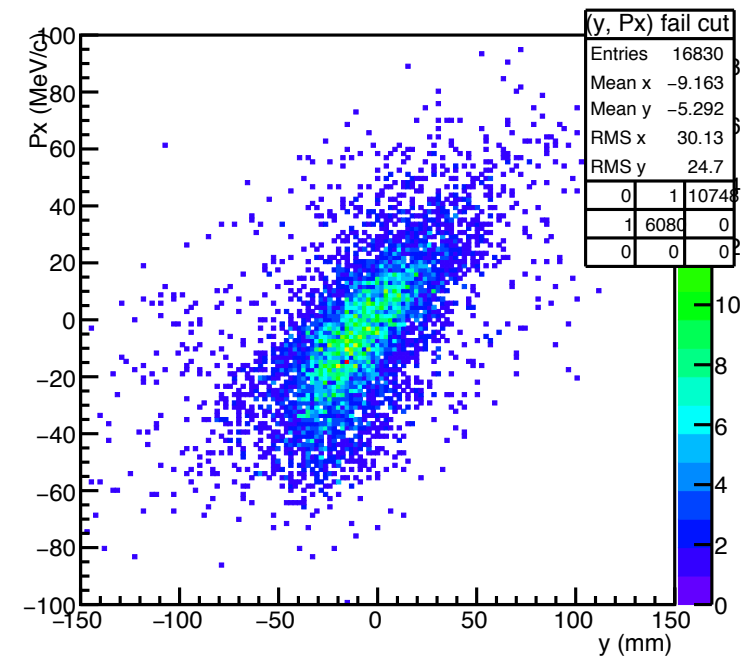
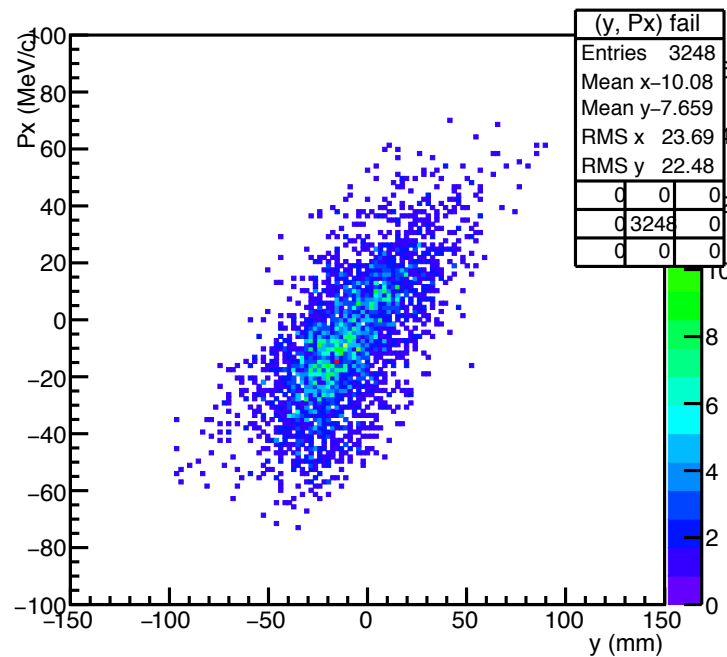
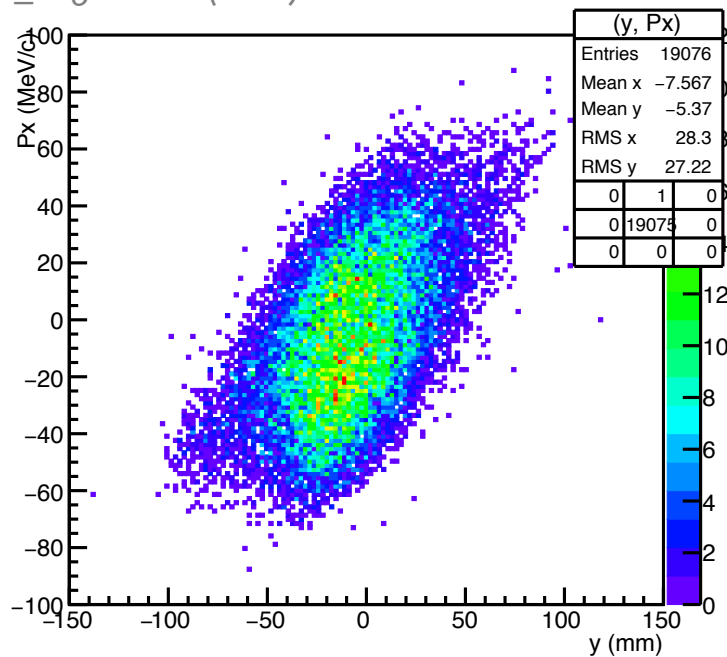
CUT_TKU_SINGLETRACK

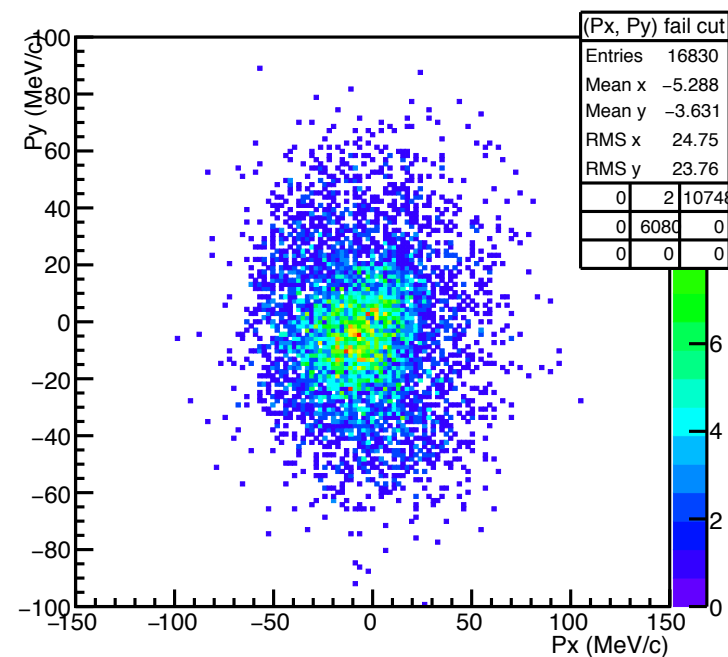
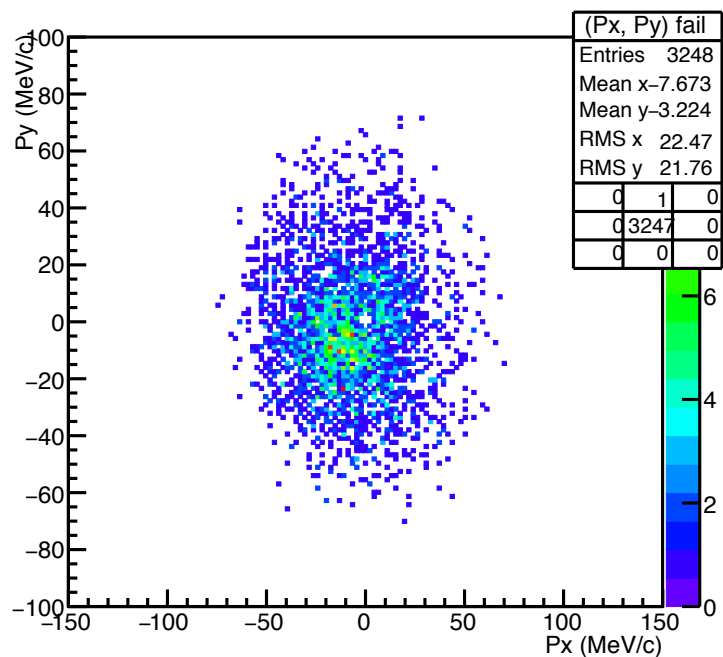
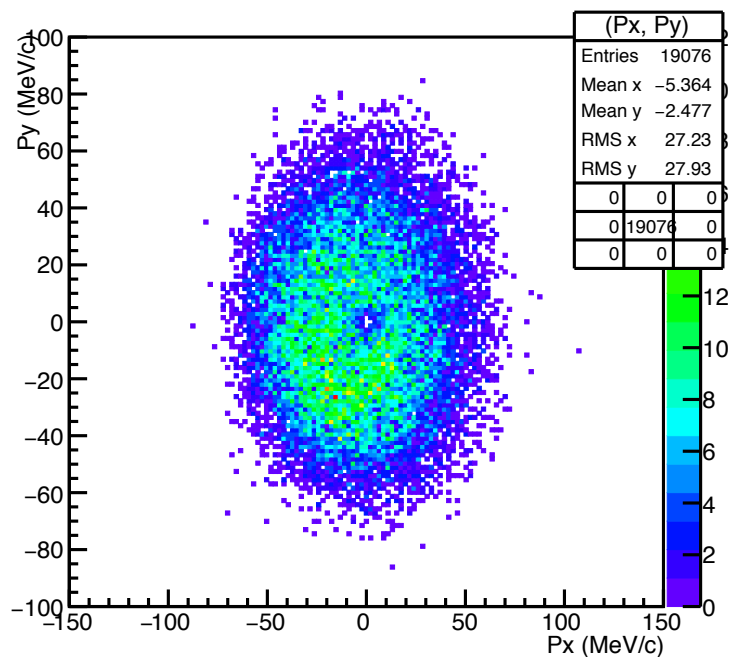
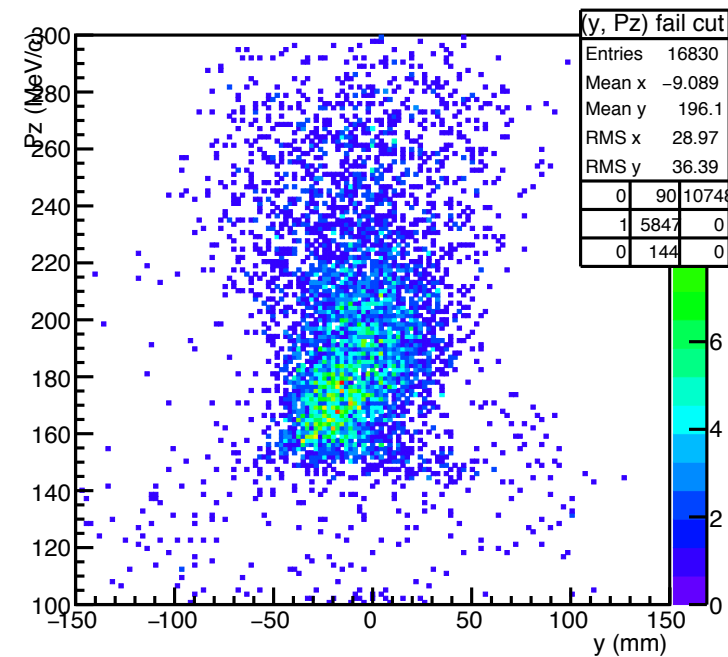
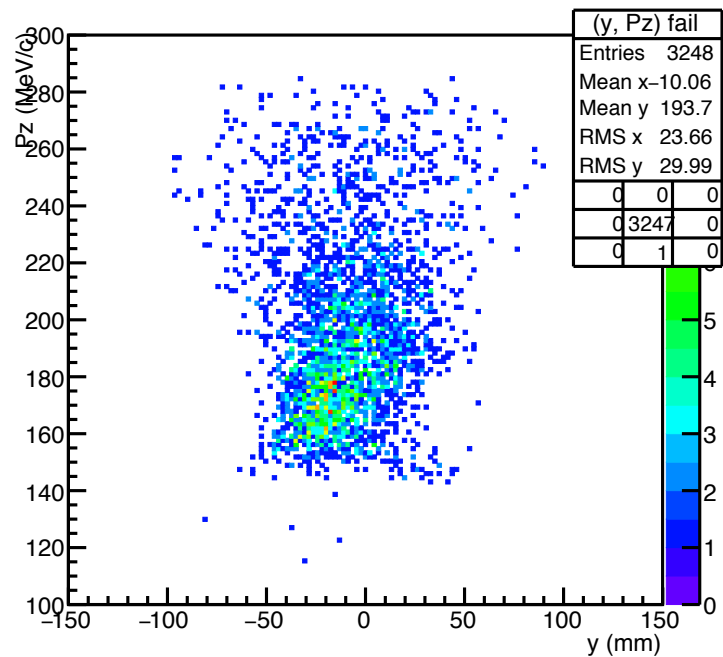
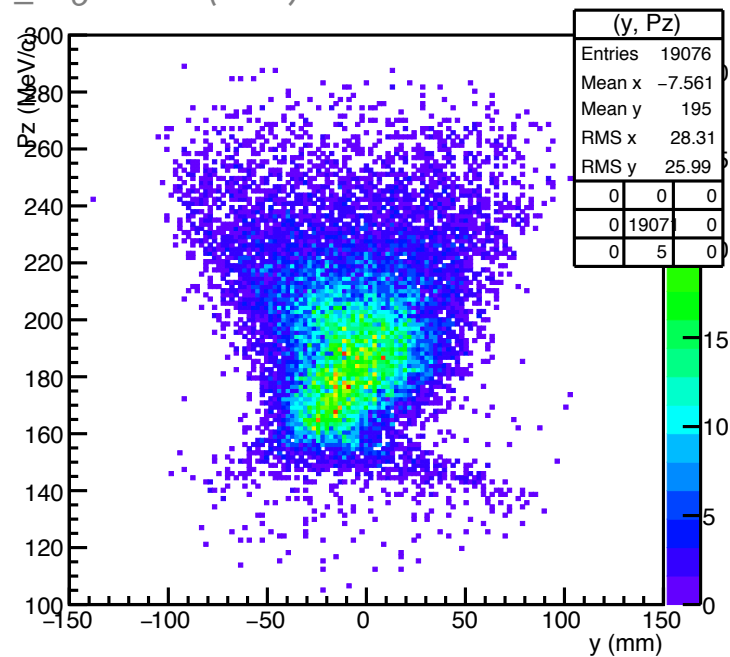
AKA 'cut 9'

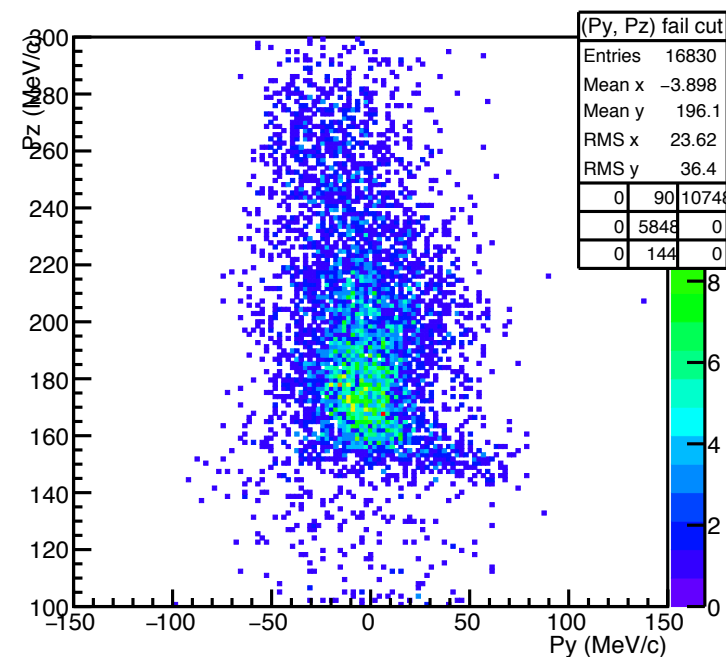
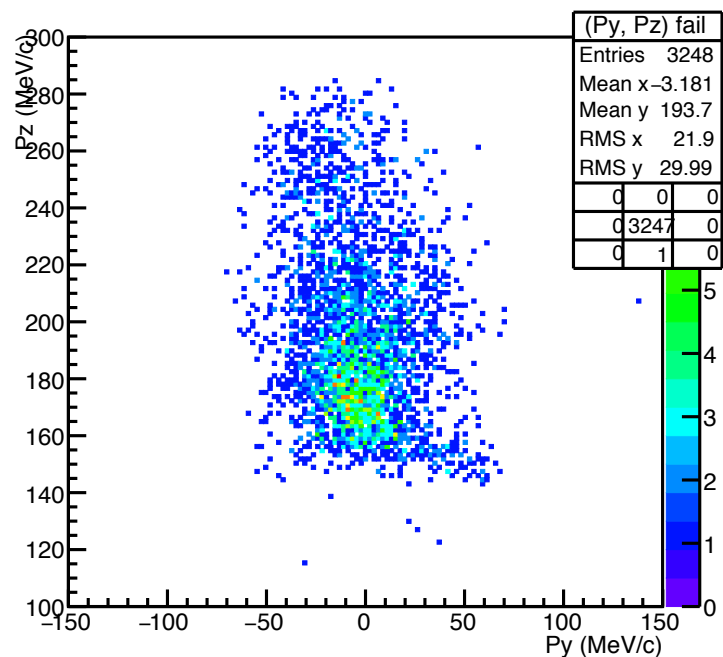
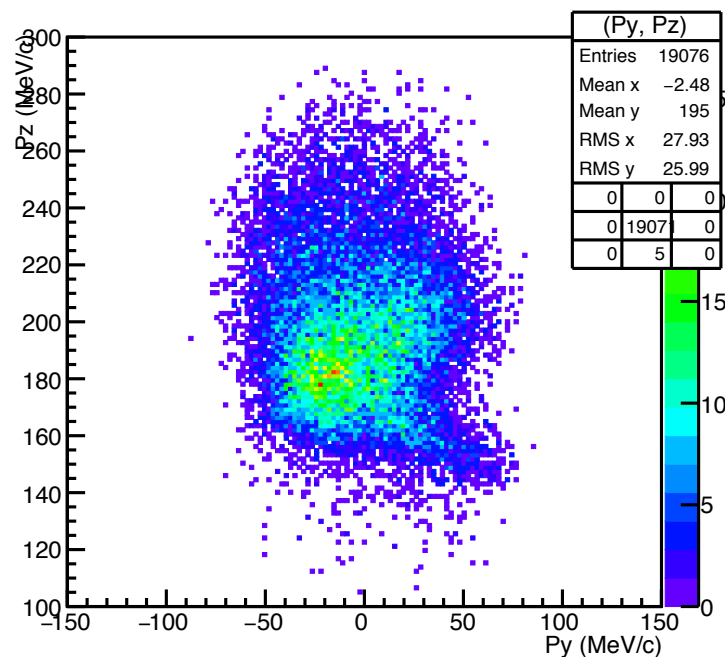
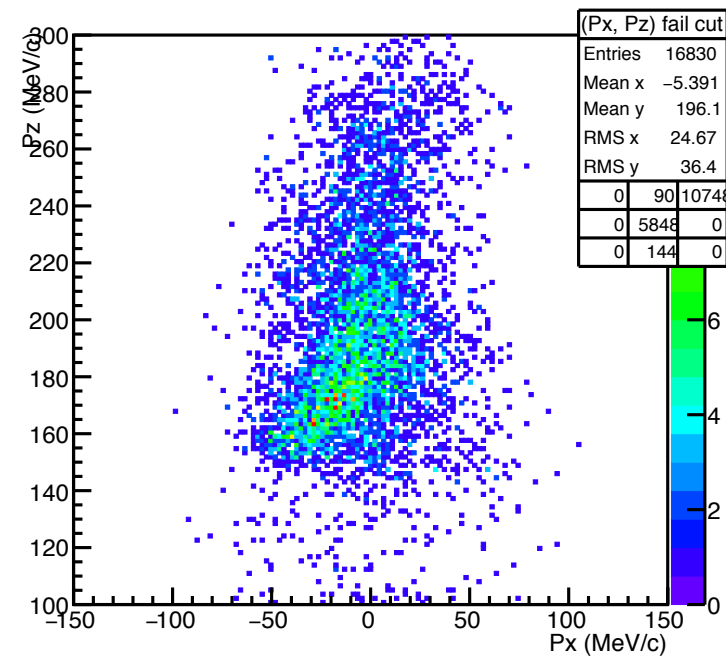
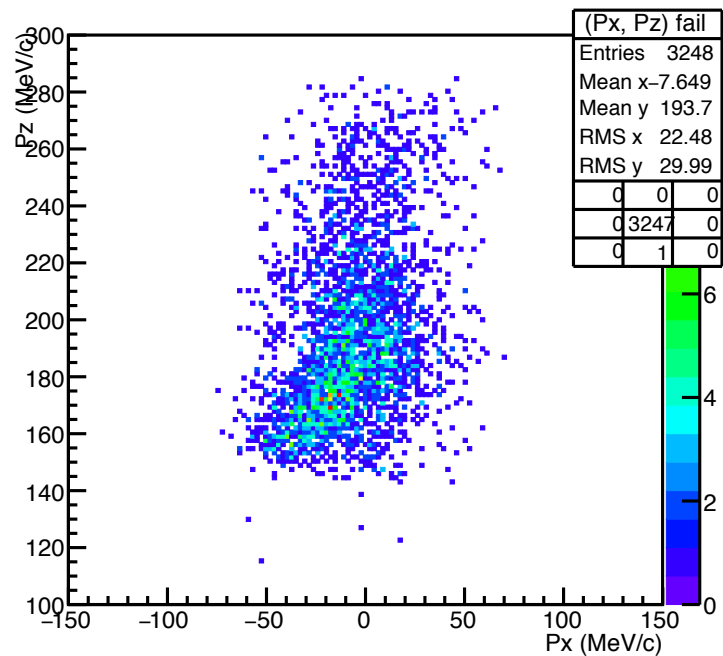
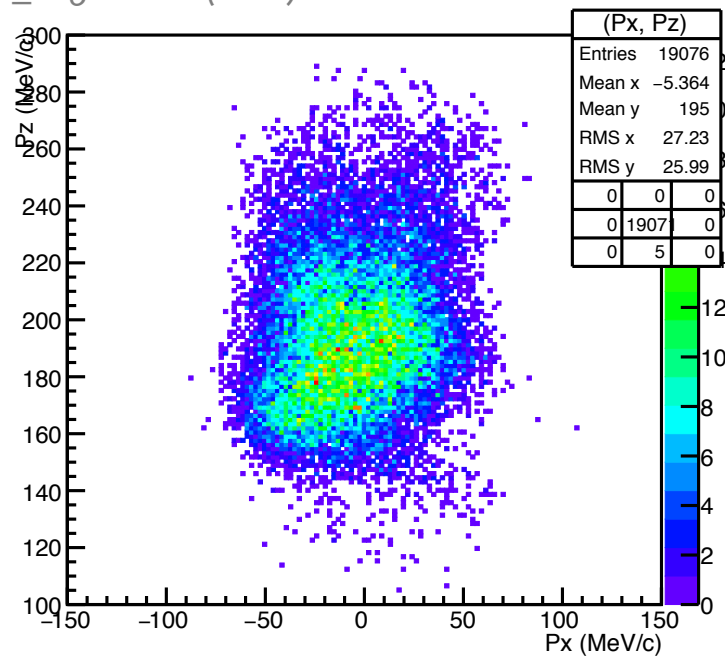


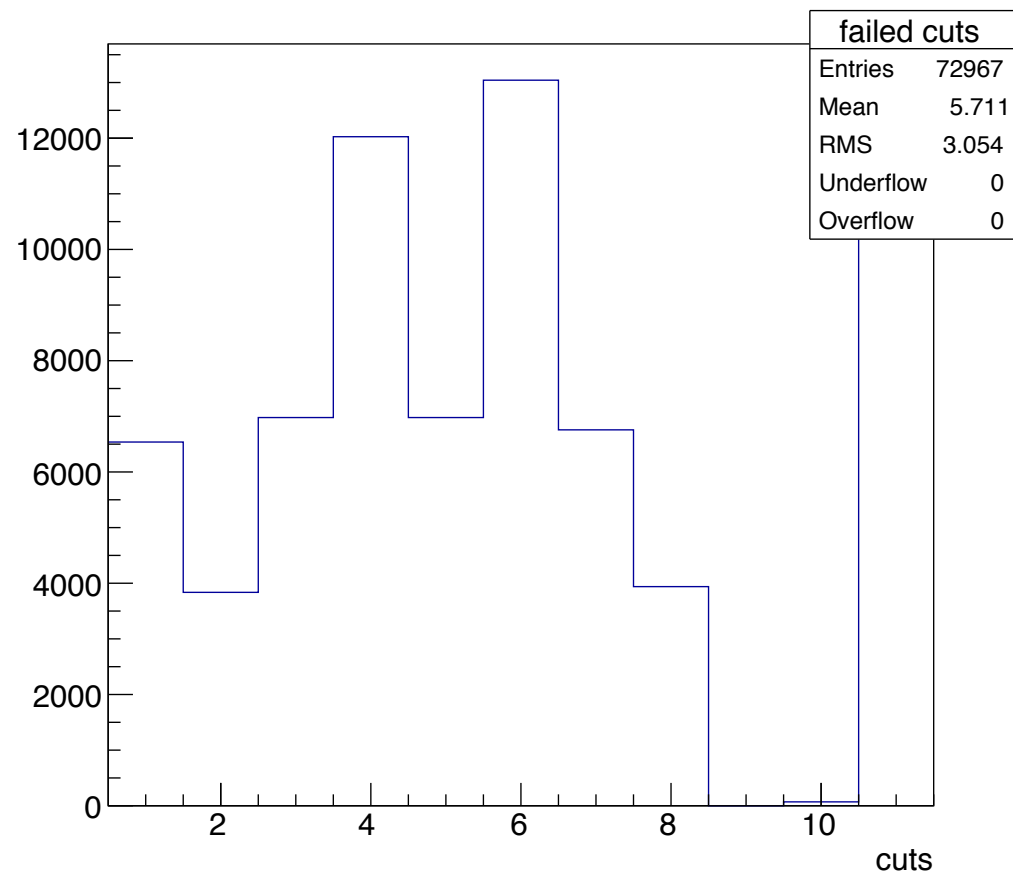




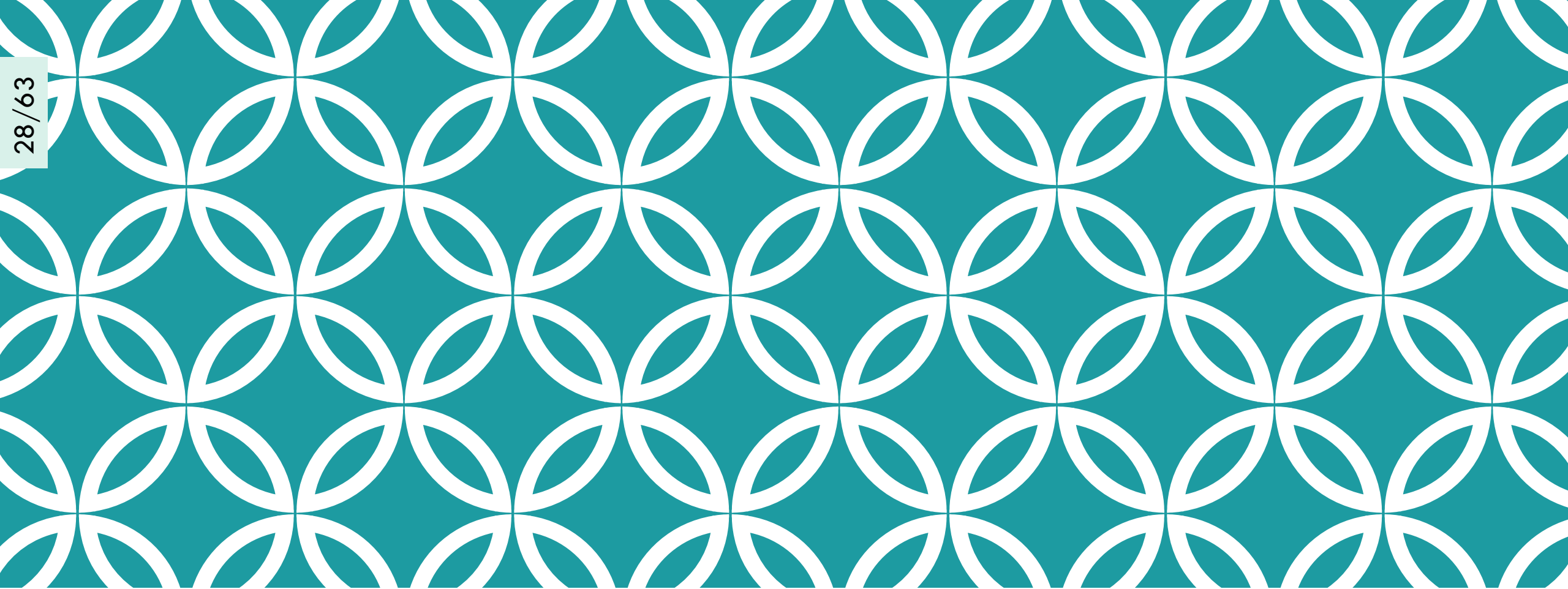






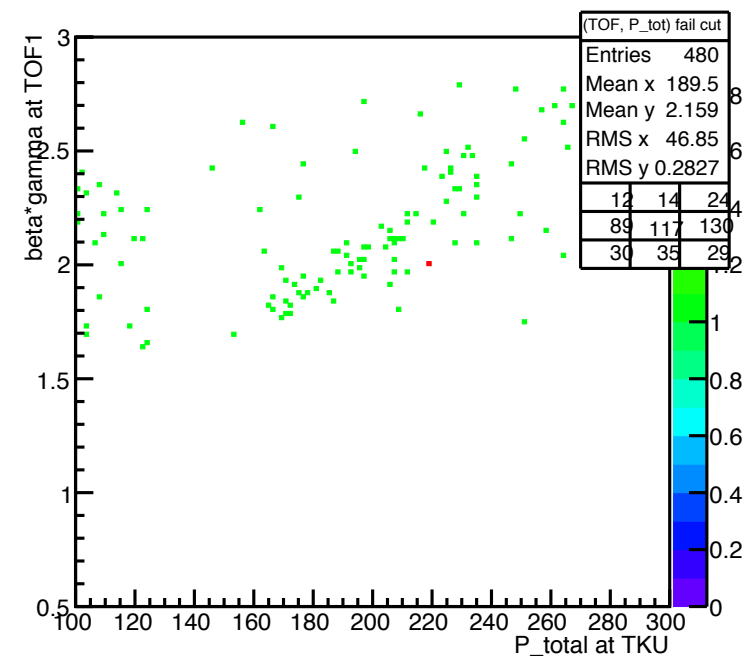
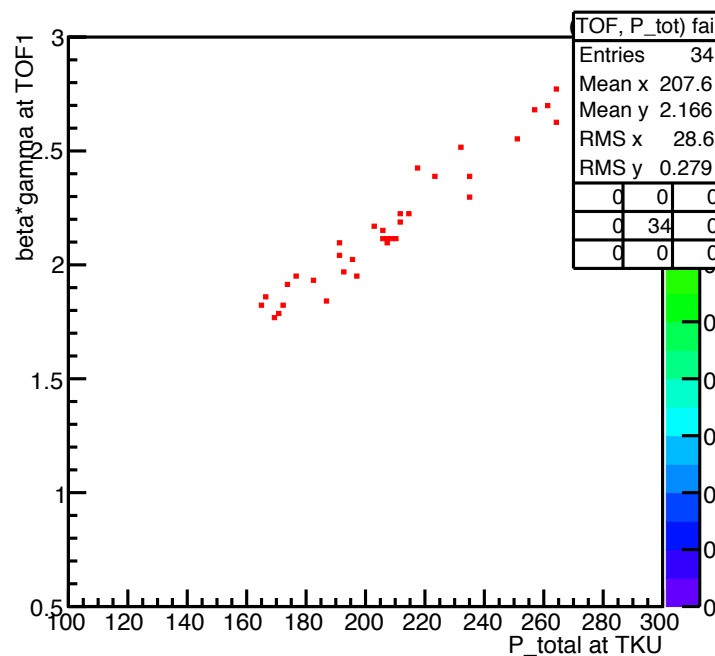
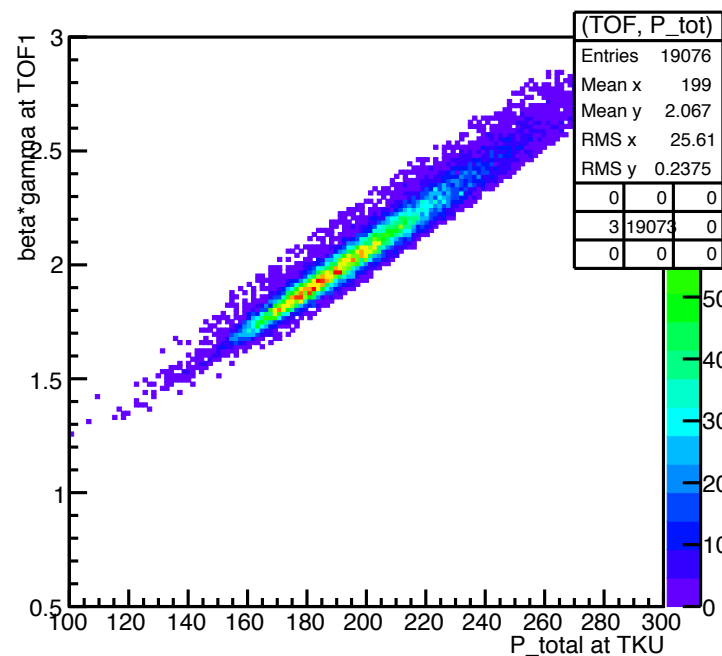
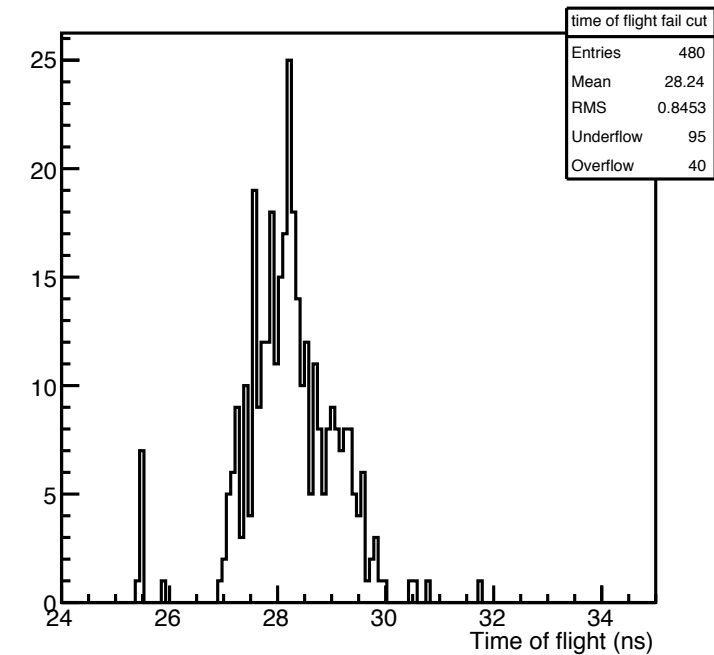
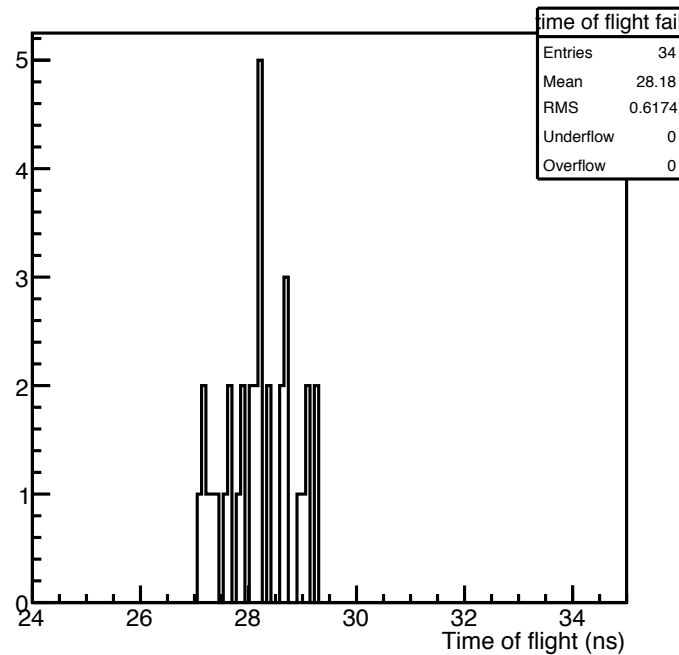
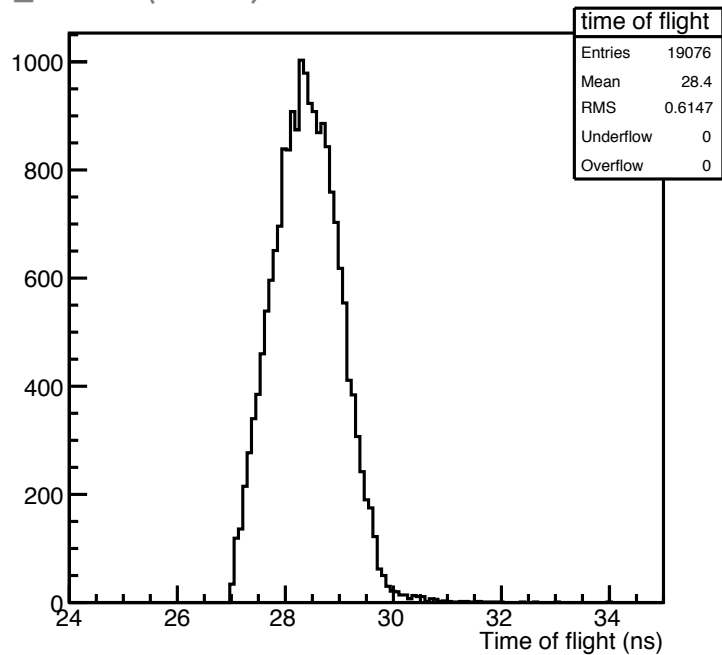


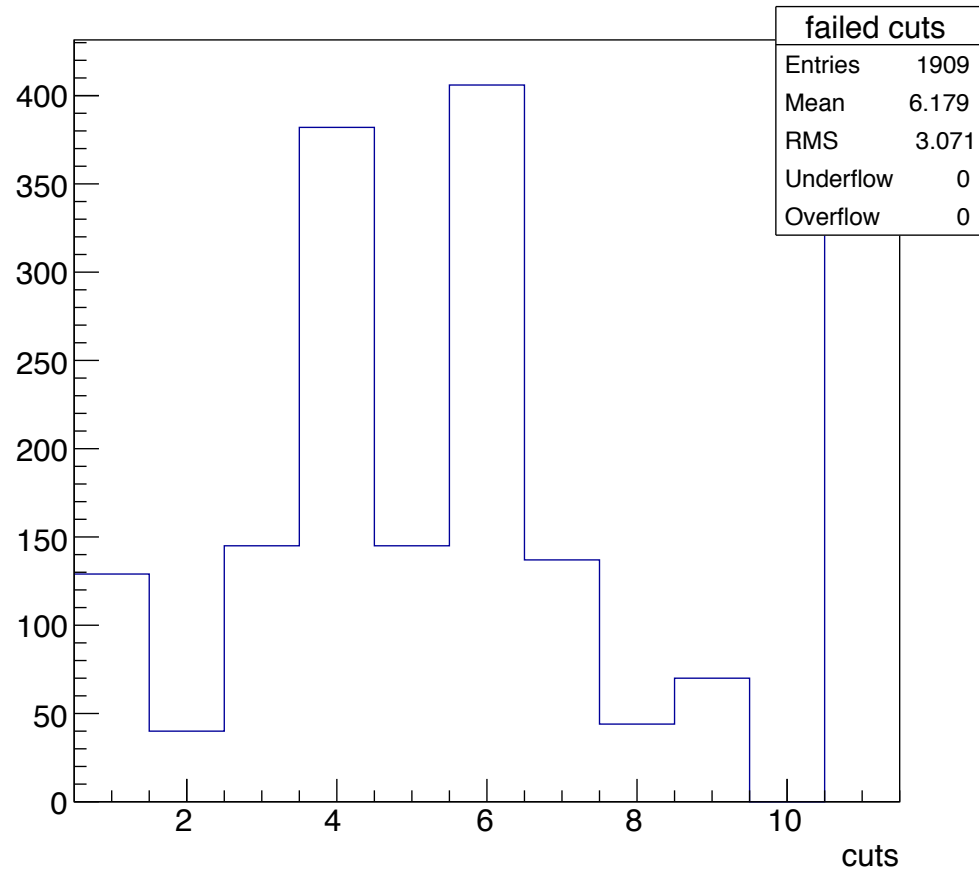
'Cut number'	Cut
1	cut_TOF0_goodPMTPosition
2	cut_TOF1_goodPMTPosition
3	cut_goodRaynerReconstruction
4	cut_TKU_hitAllStations
5	cut_TimeOfFlight
6	cut_hit_all_detectors
7	cut_TOF0_singleHit
8	cut_TOF1_singleHit
9	cut_TKU_singleTrack
10	cut_TKU_PValue
11	cut_momentum_loss



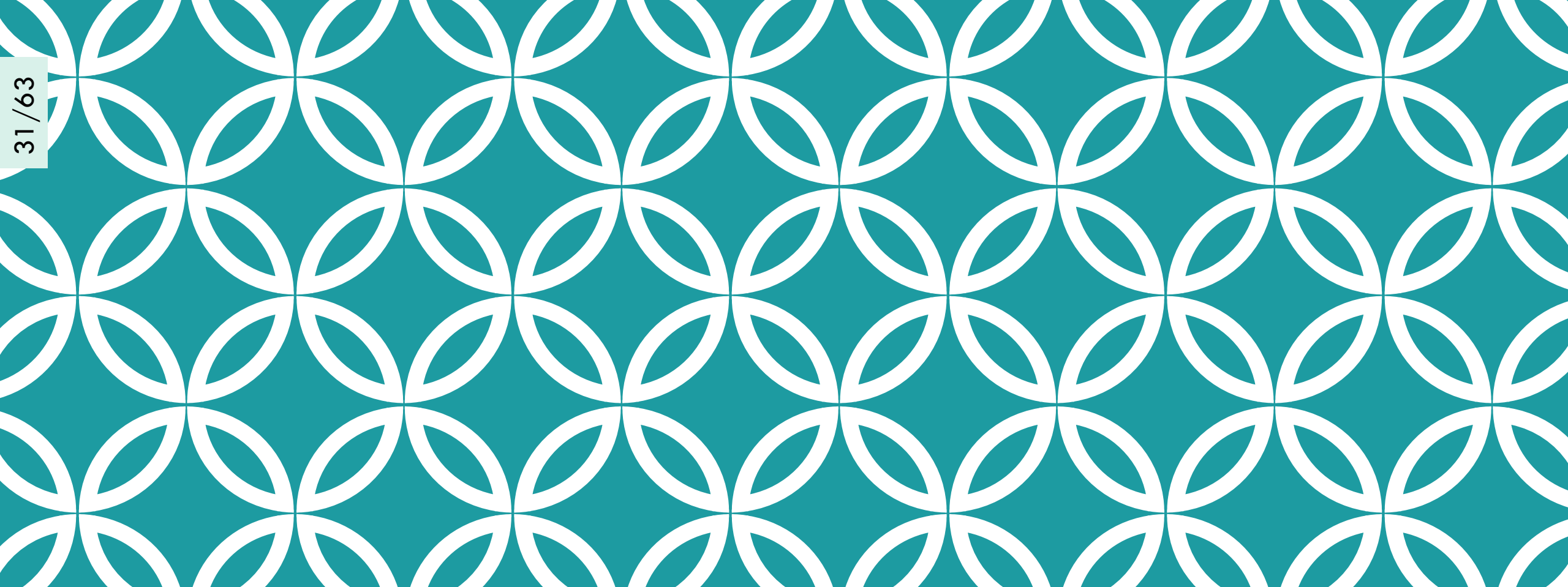
CUT_TKU_PVALUE

AKA 'cut 10'



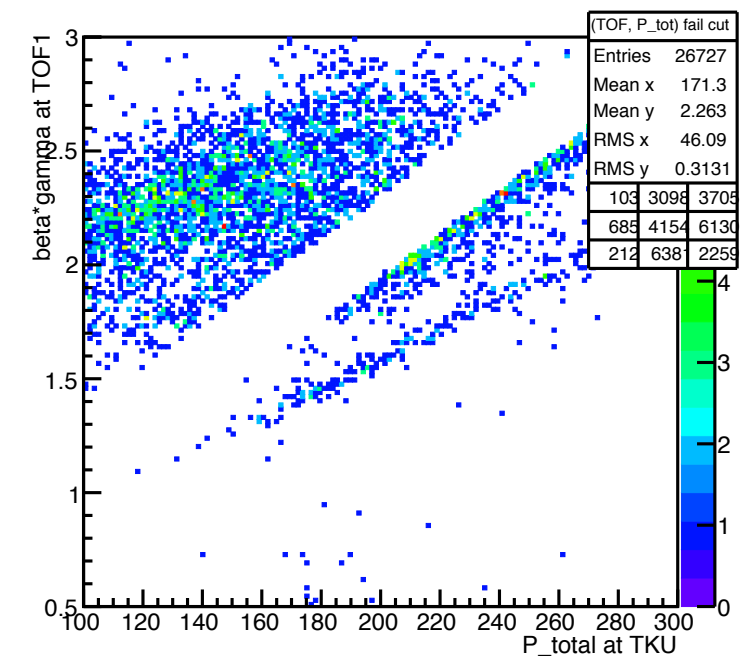
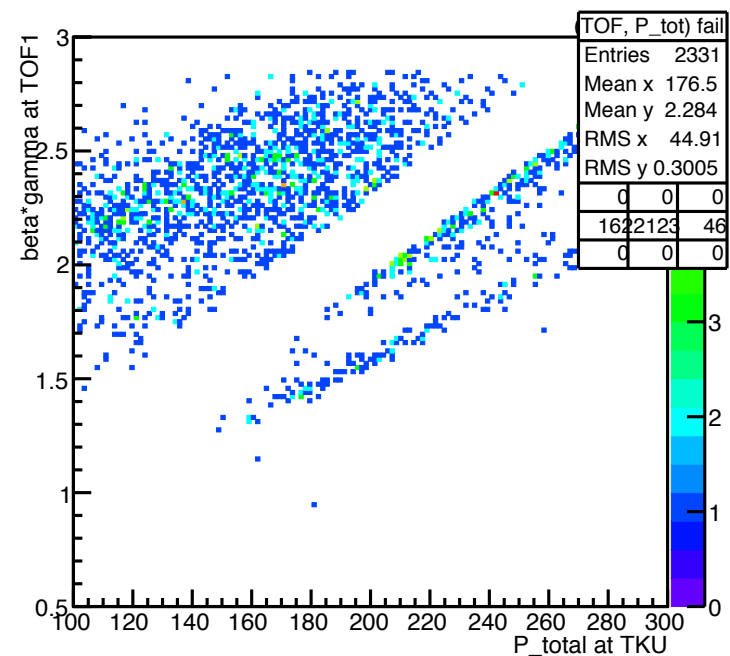
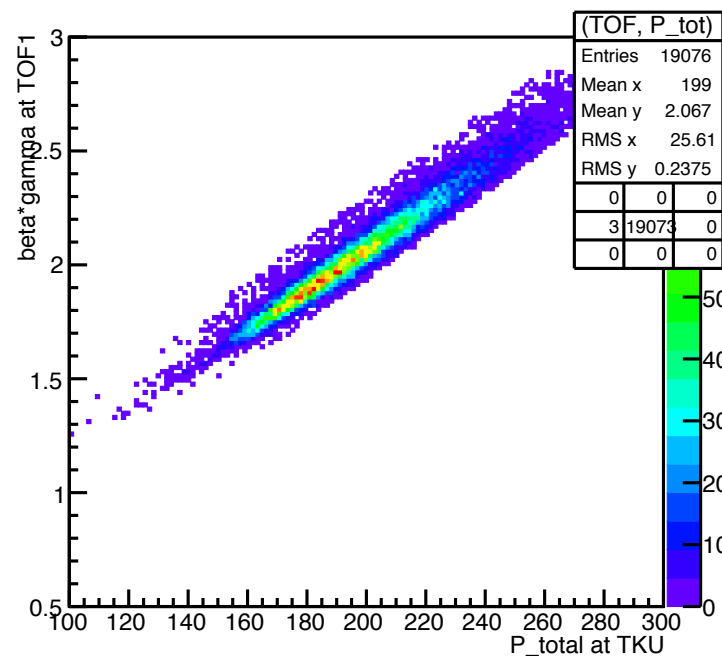
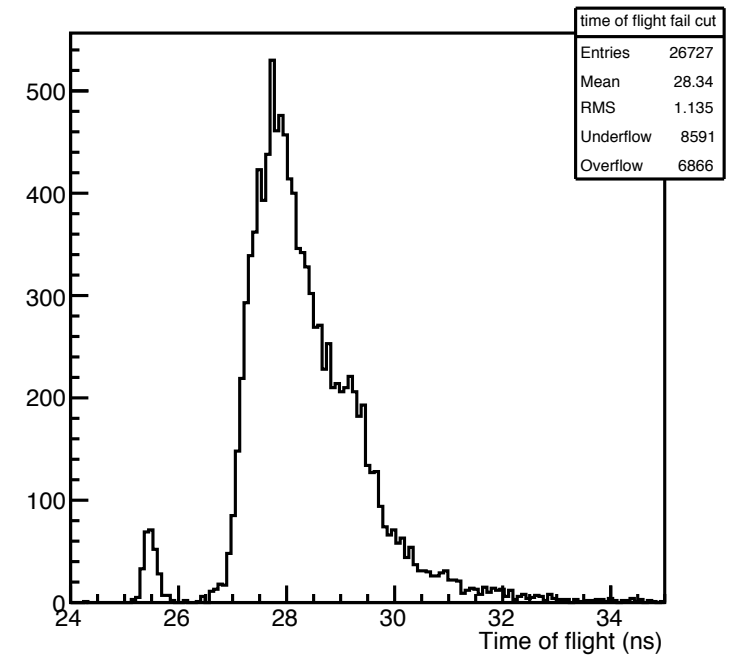
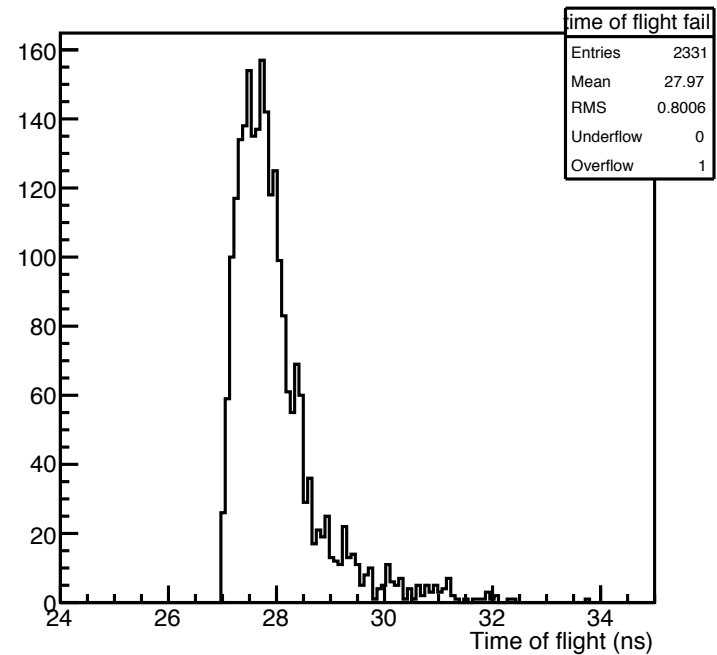
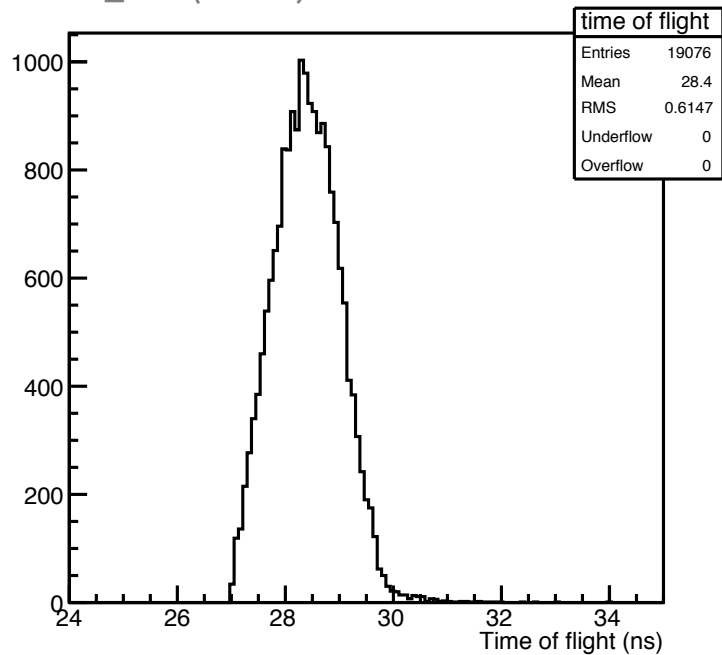


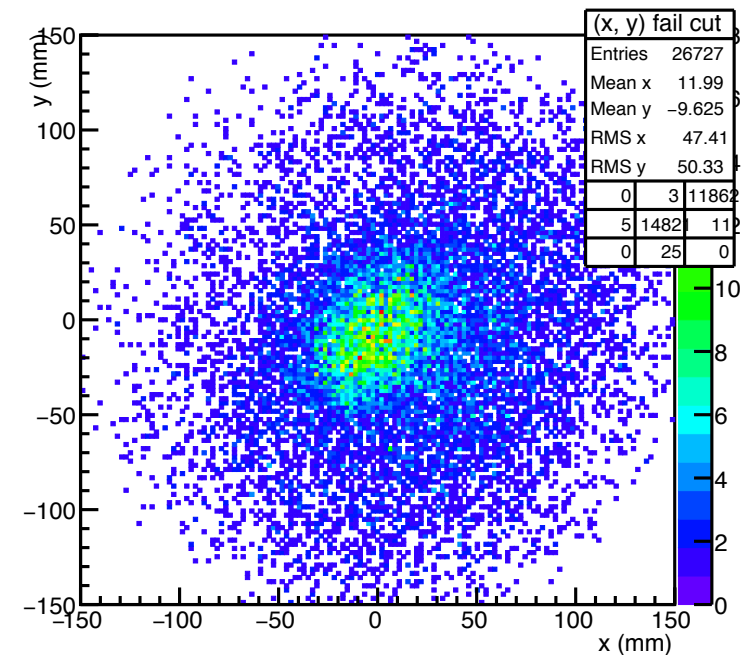
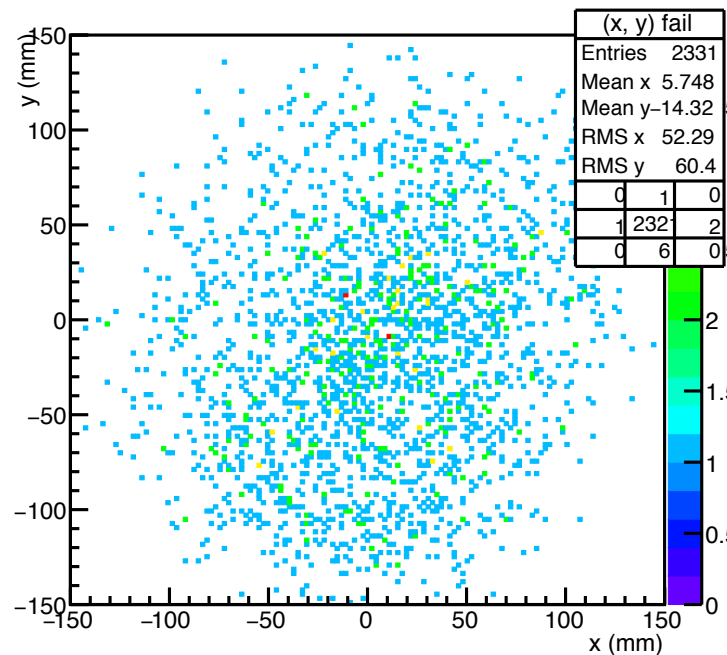
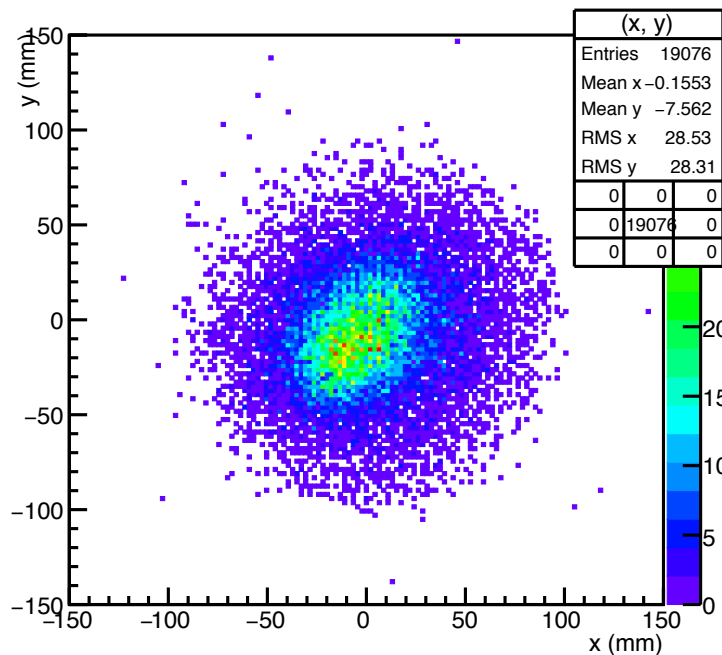
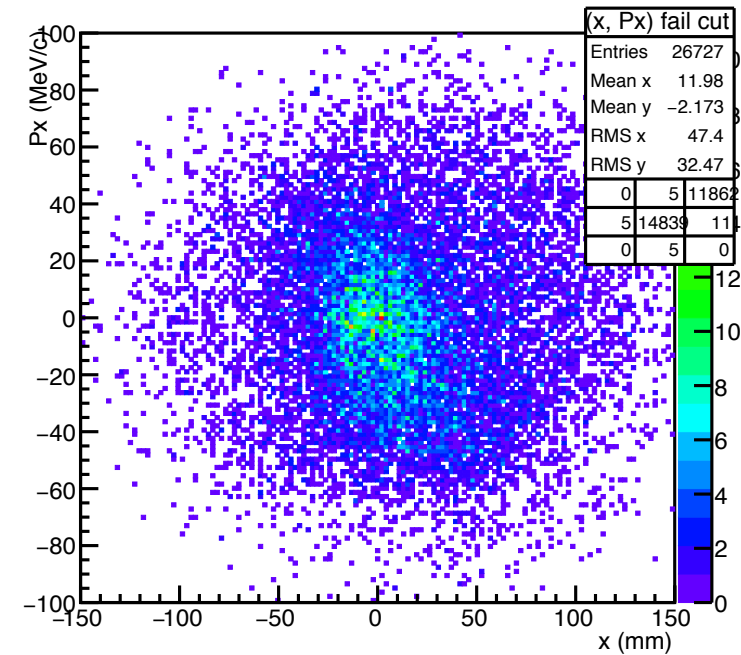
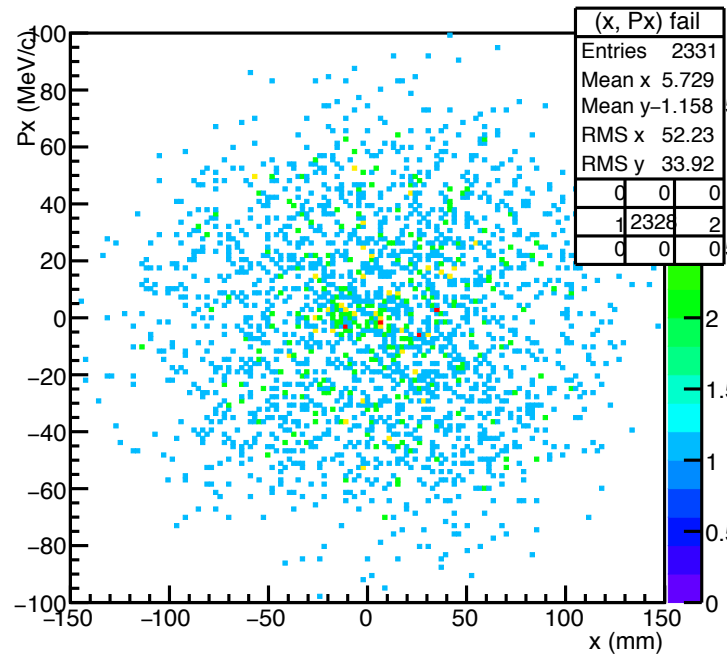
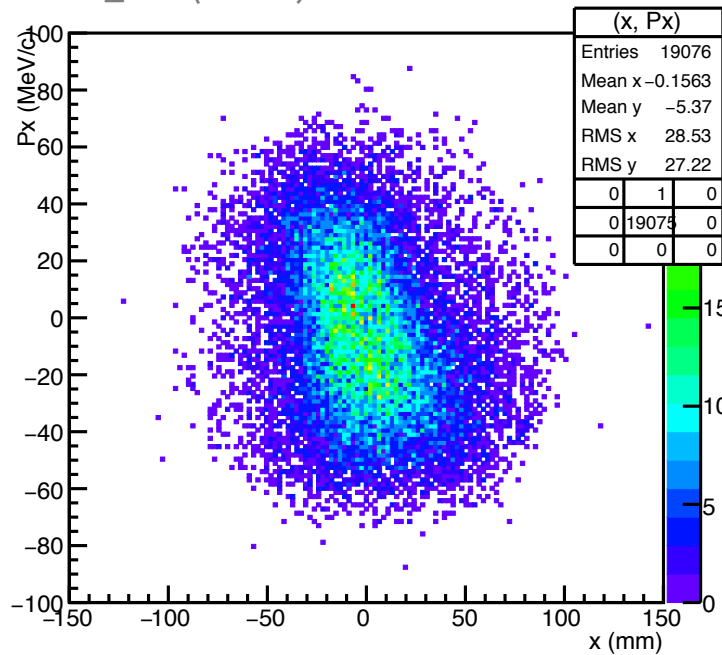
'Cut number'	Cut
1	cut_TOF0_goodPMTPosition
2	cut_TOF1_goodPMTPosition
3	cut_goodRaynerReconstruction
4	cut_TKU_hitAllStations
5	cut_TimeOfFlight
6	cut_hit_all_detectors
7	cut_TOF0_singleHit
8	cut_TOF1_singleHit
9	cut_TKU_singleTrack
10	cut_TKU_PValue
11	cut_momentum_loss

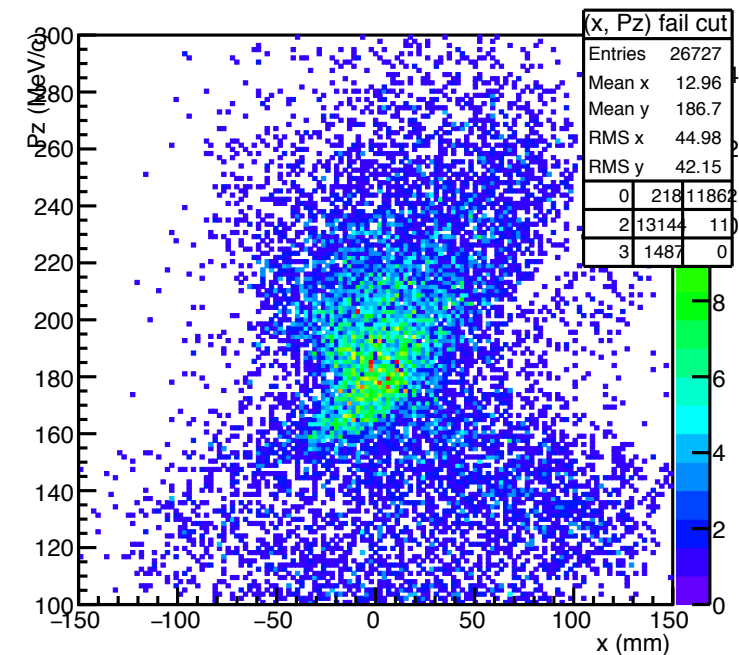
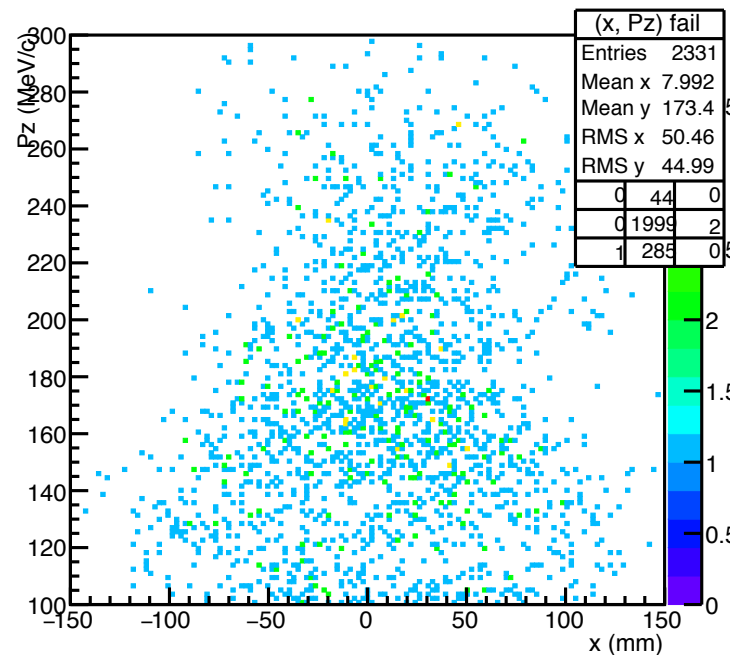
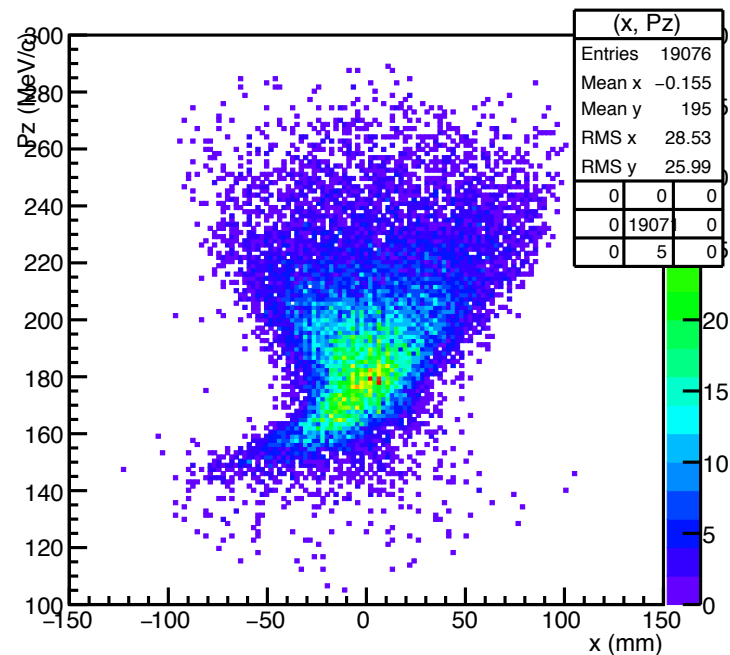
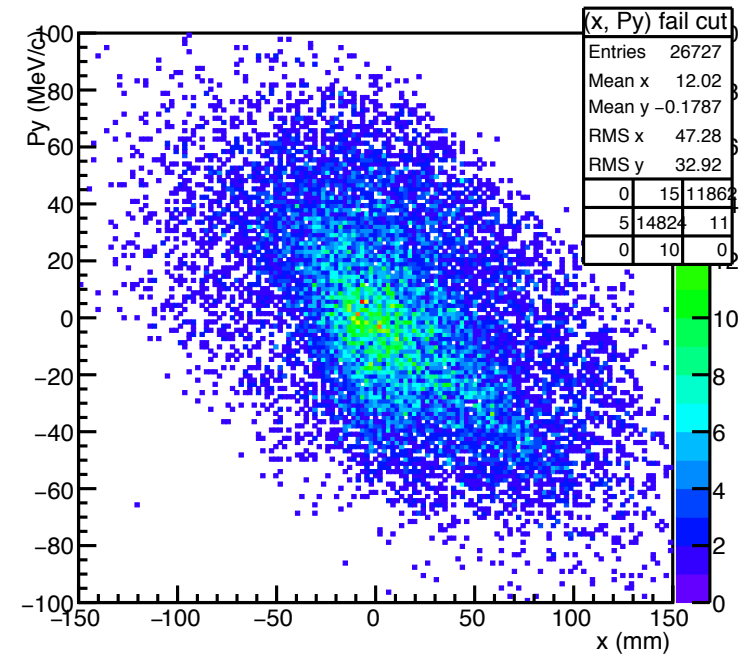
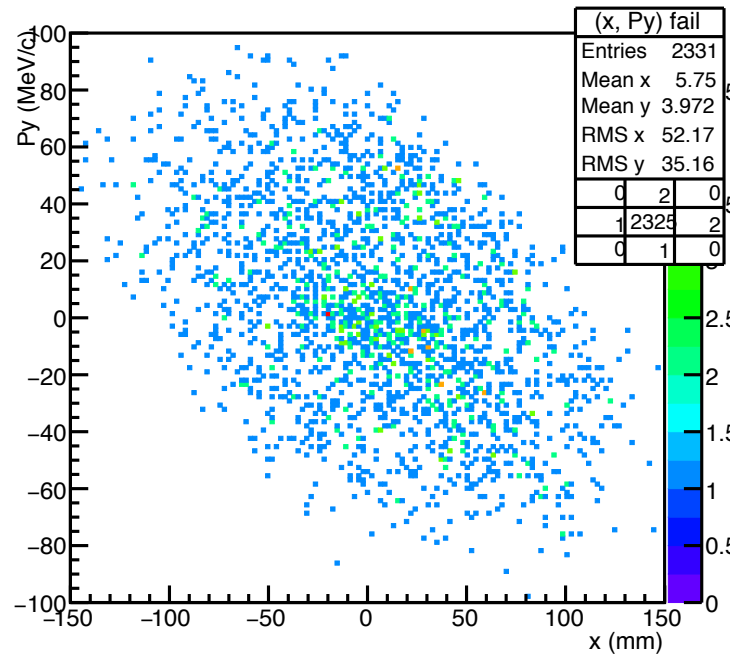
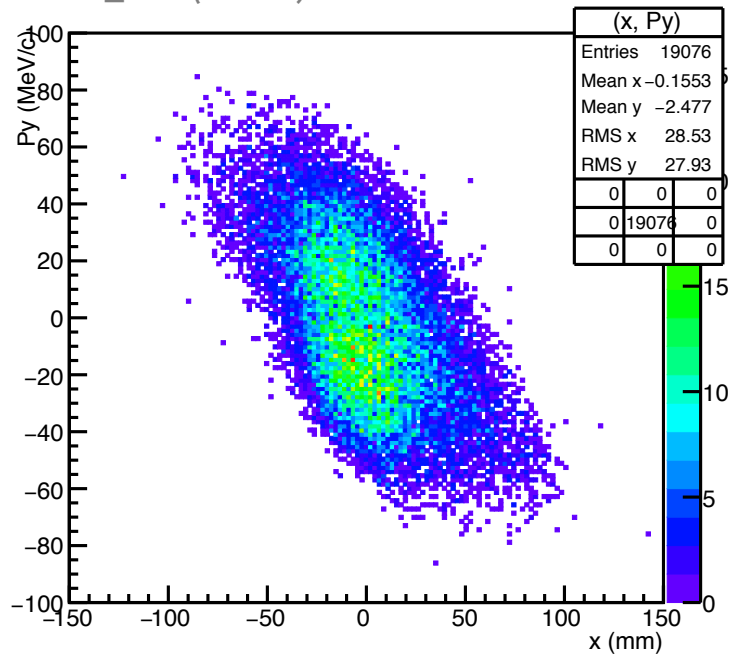


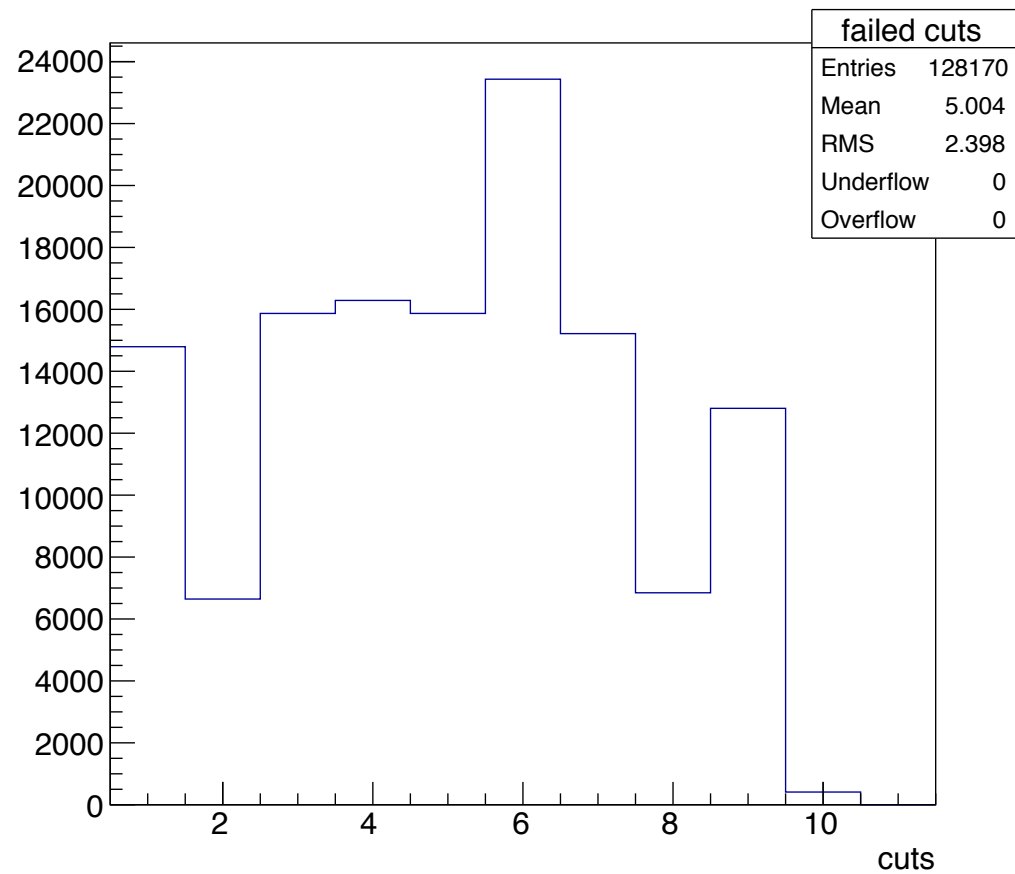
CUT_MOMENTUM_LOSS

AKA 'cut 11'







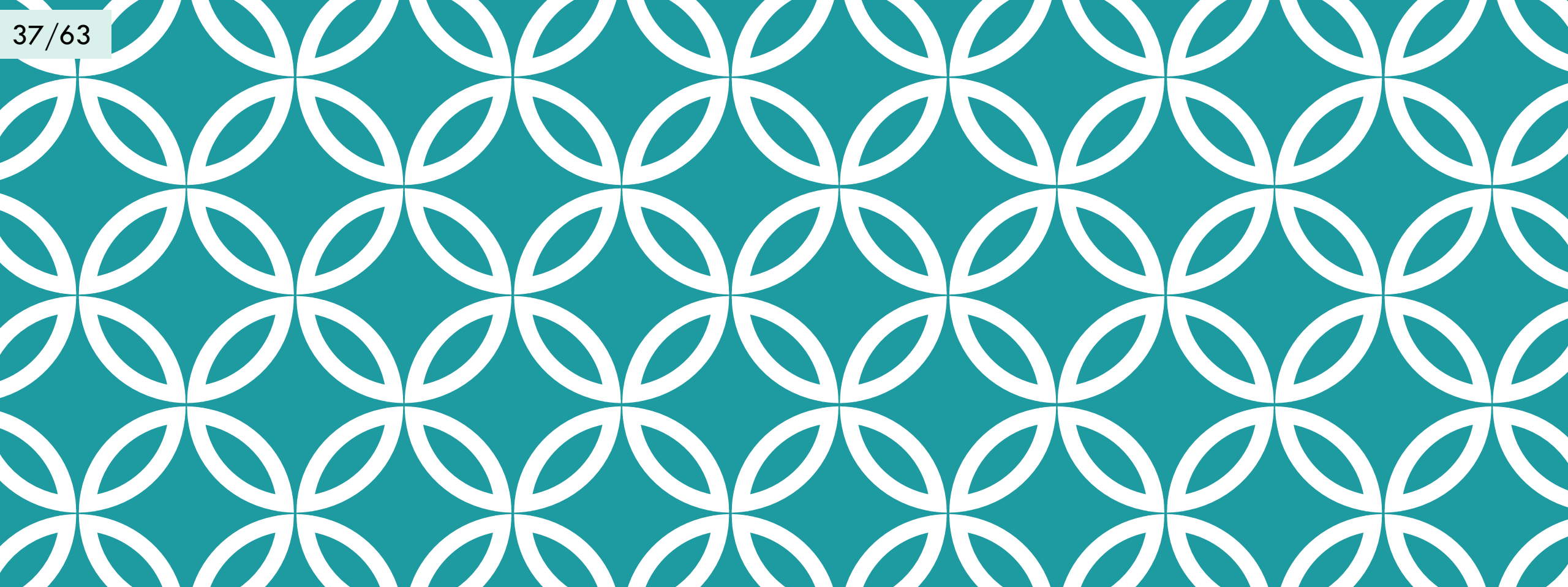


'Cut number'	Cut
1	cut_TOF0_goodPMTPosition
2	cut_TOF1_goodPMTPosition
3	cut_goodRaynerReconstruction
4	cut_TKU_hitAllStations
5	cut_TimeOfFlight
6	cut_hit_all_detectors
7	cut_TOF0_singleHit
8	cut_TOF1_singleHit
9	cut_TKU_singleTrack
10	cut_TKU_PValue
11	cut_momentum_loss

CUTS SUMMARY

- Data: 19076 surviving muons
- MC: 23398 surviving muons
- Extracted data file: http://micewww.pp.rl.ac.uk/attachments/6700/run7469_extracted_data_MAUS2pt5_b.root
- TOF PMT calibration for data: <http://micewww.pp.rl.ac.uk/attachments/5896/run7417.dat>
- Cut plots for data: http://micewww.pp.rl.ac.uk/attachments/6720/data_cut_comparisons.zip

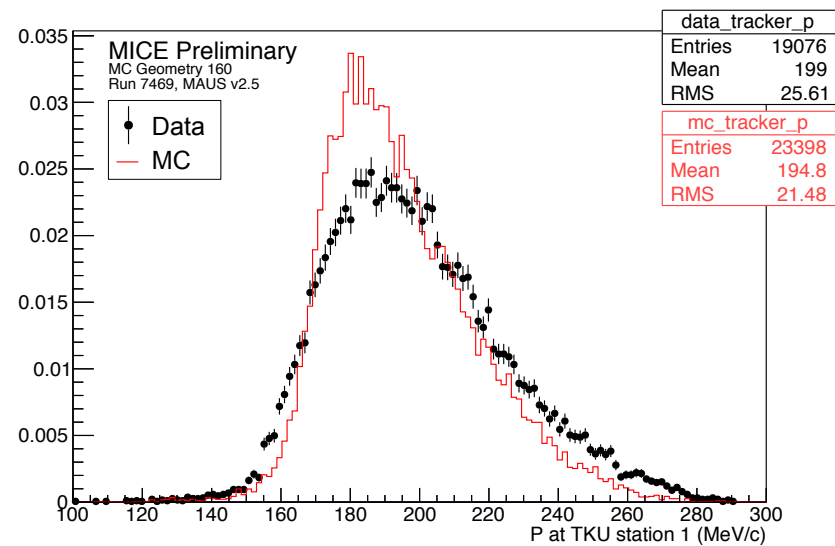
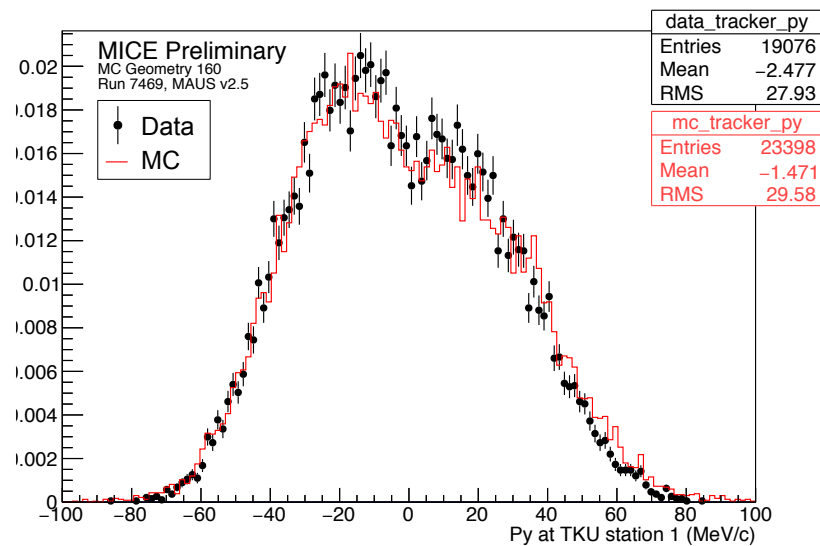
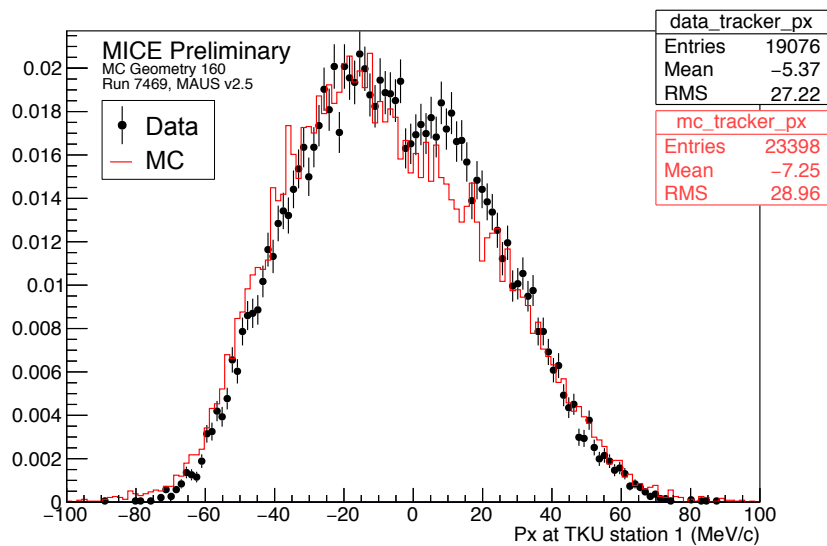
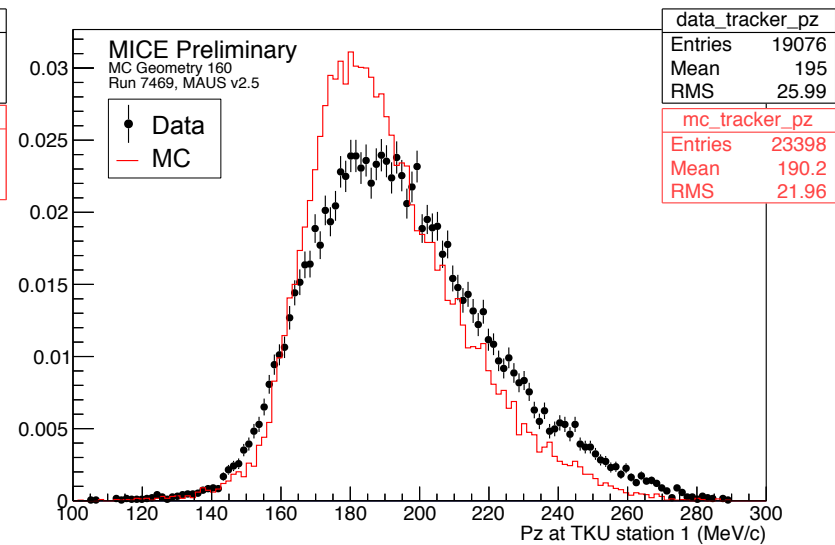
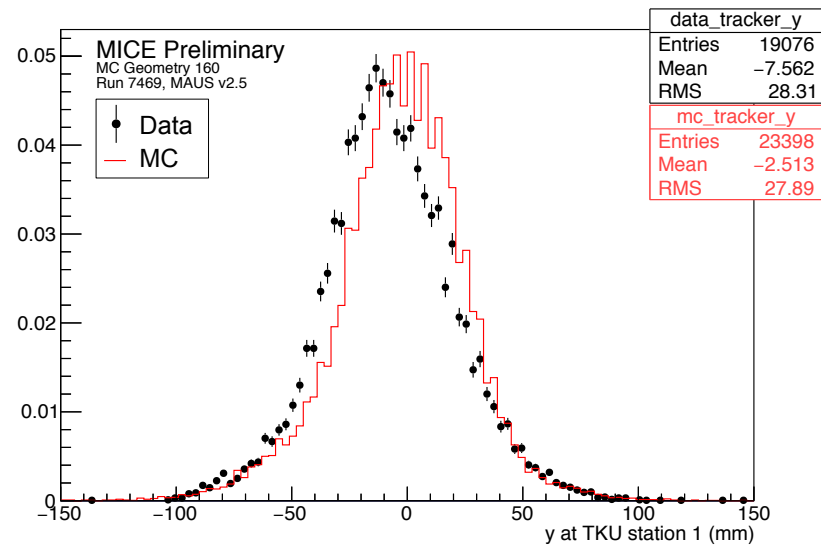
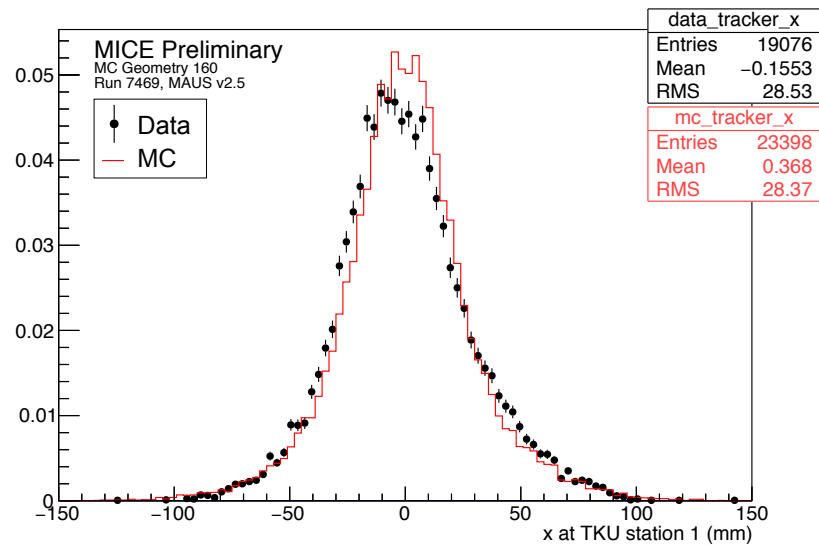
- Extracted MC file:
http://micewww.pp.rl.ac.uk/attachments/6724/mc_3mm200_07469_MAUS2pt5_extracted_data_c_withMCTOFCa_lib.root
- TOF PMT calibration for MC: http://micewww.pp.rl.ac.uk/attachments/6723/run7417_calibration_file_MC.txt
- Cut plots for MC: http://micewww.pp.rl.ac.uk/attachments/6722/mc_cut_comparisons.zip



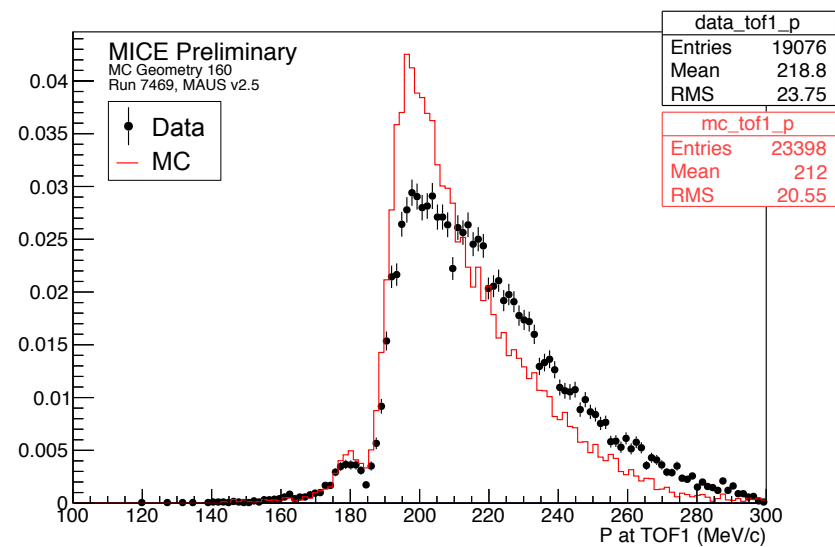
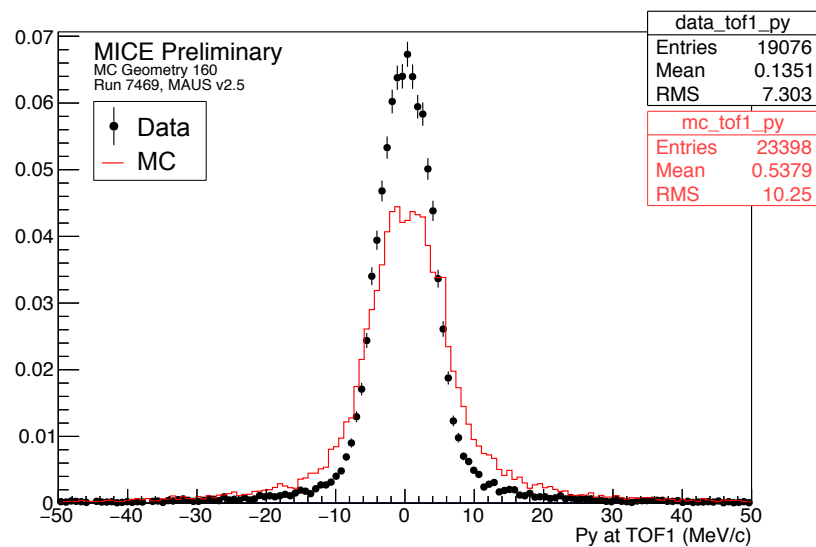
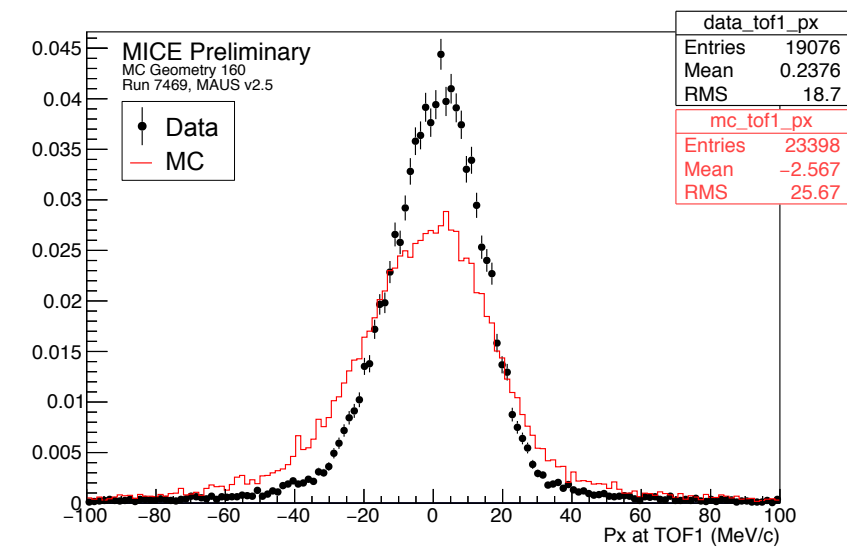
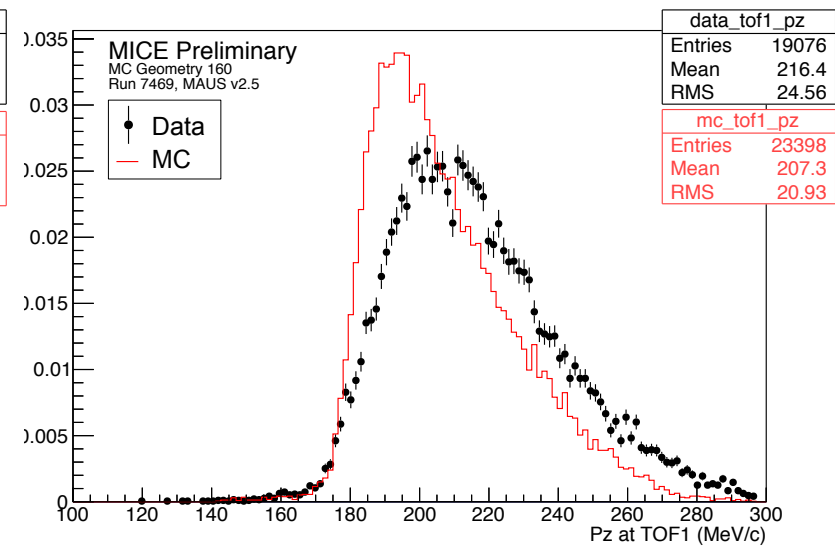
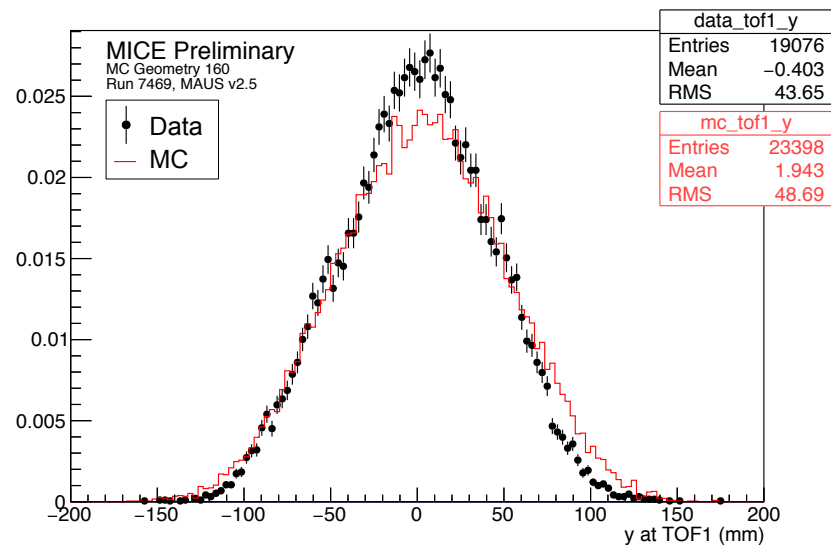
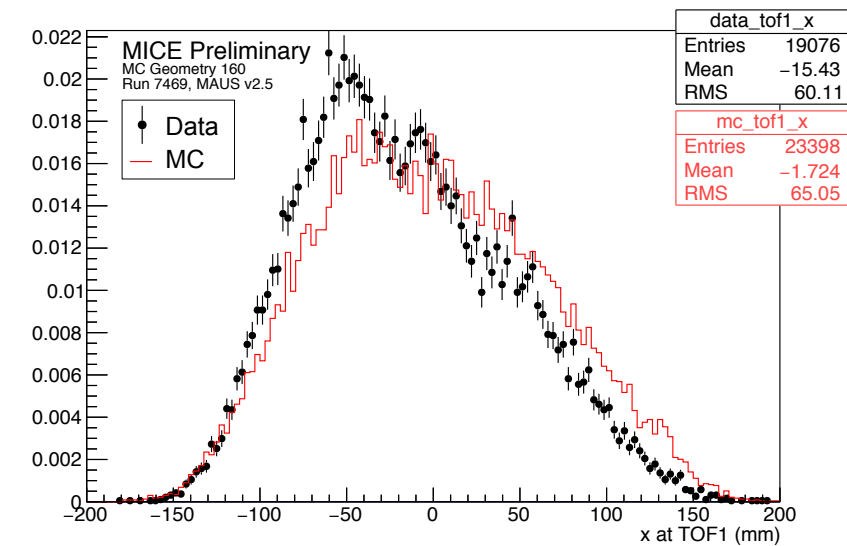
DATA-MC COMPARISON

Plots that follow are normalised to unit area

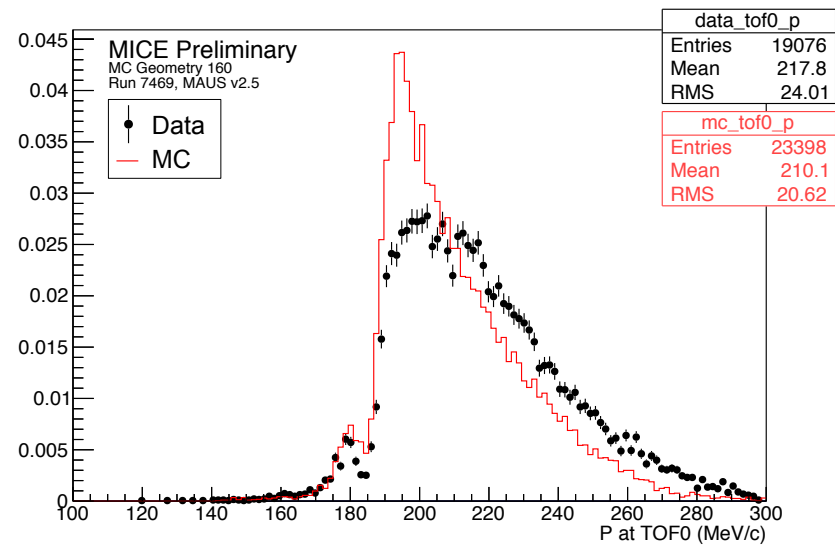
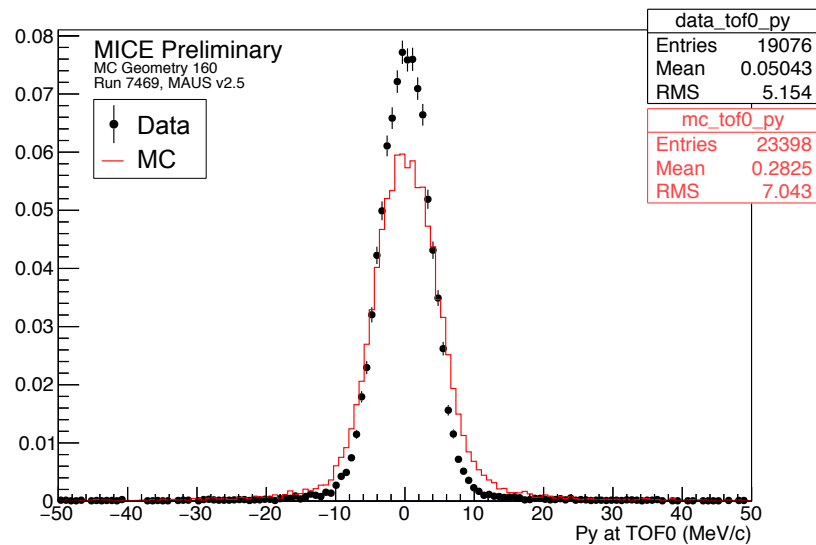
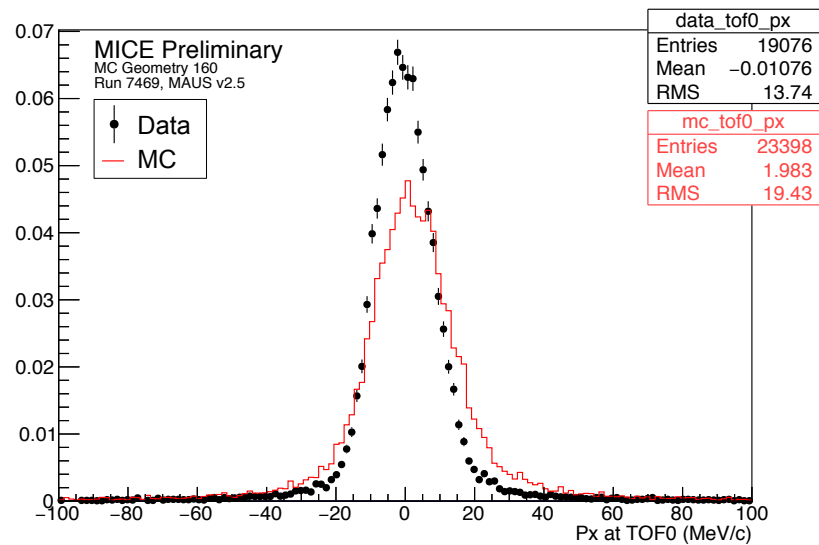
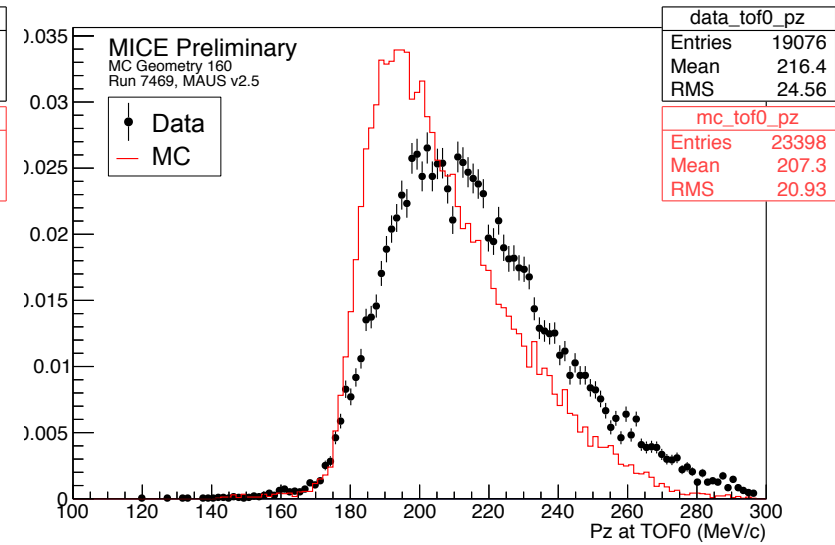
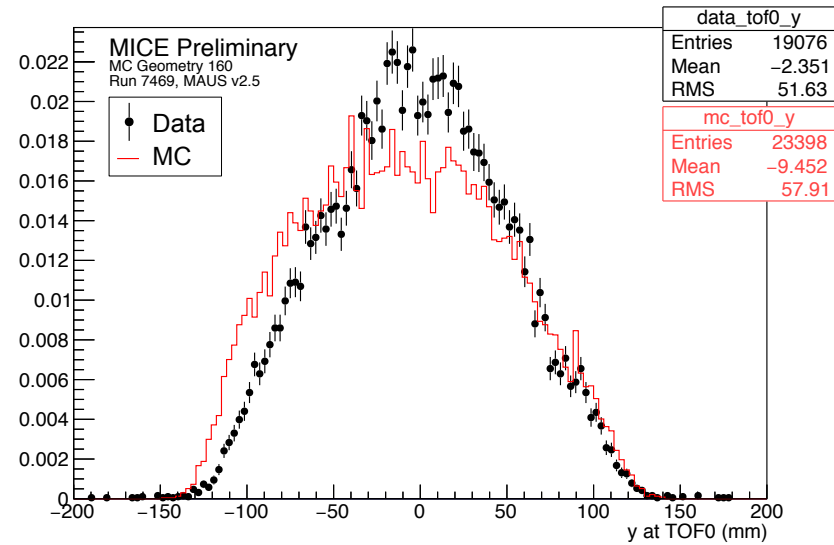
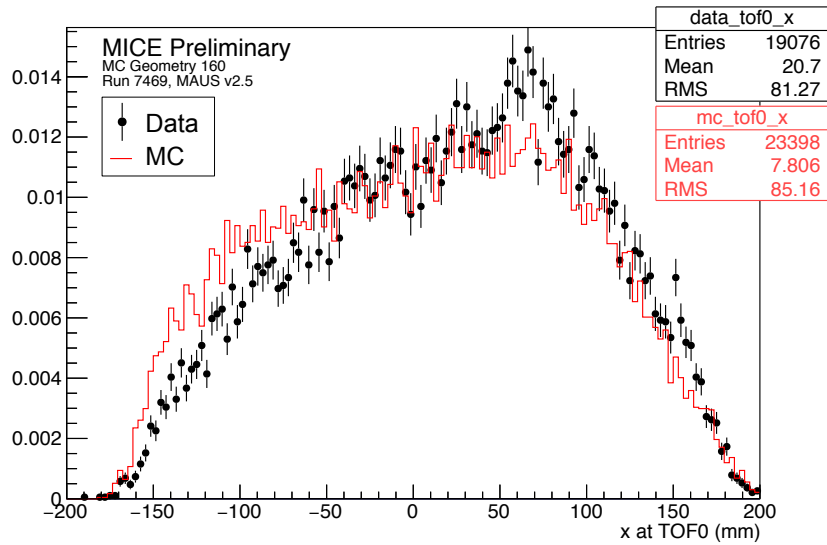
TKU STATION 1

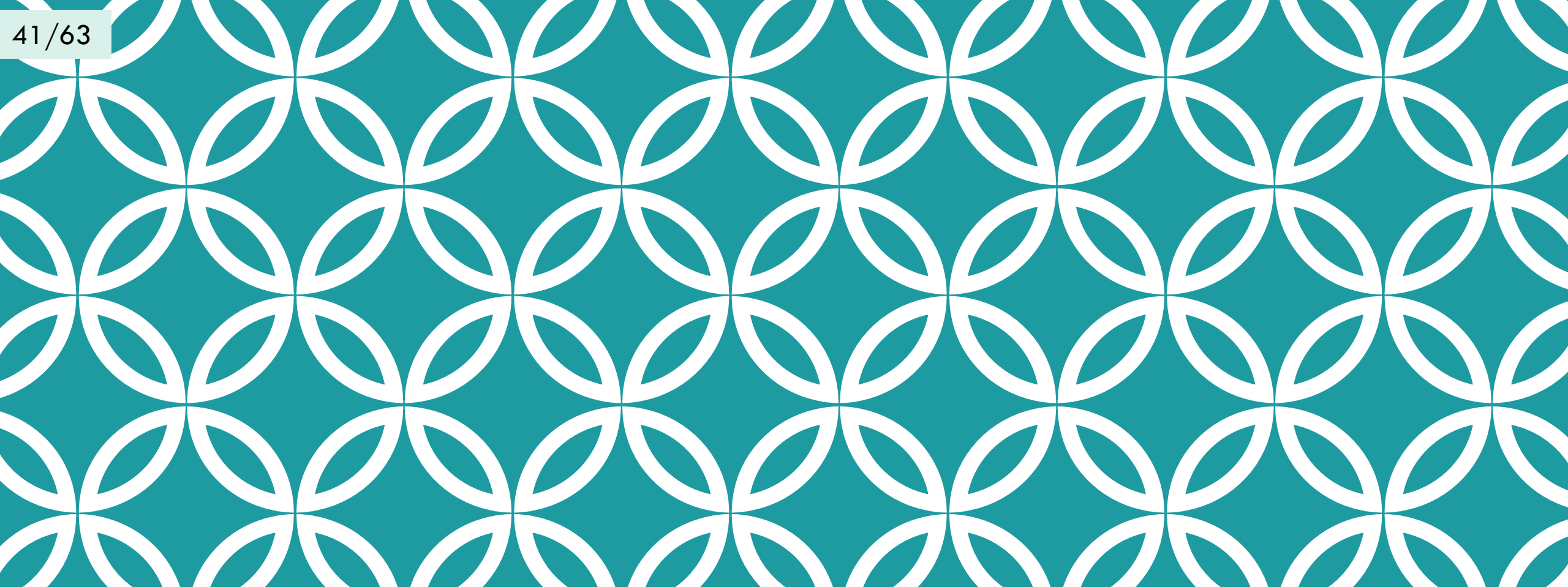


TOF1



TOF0



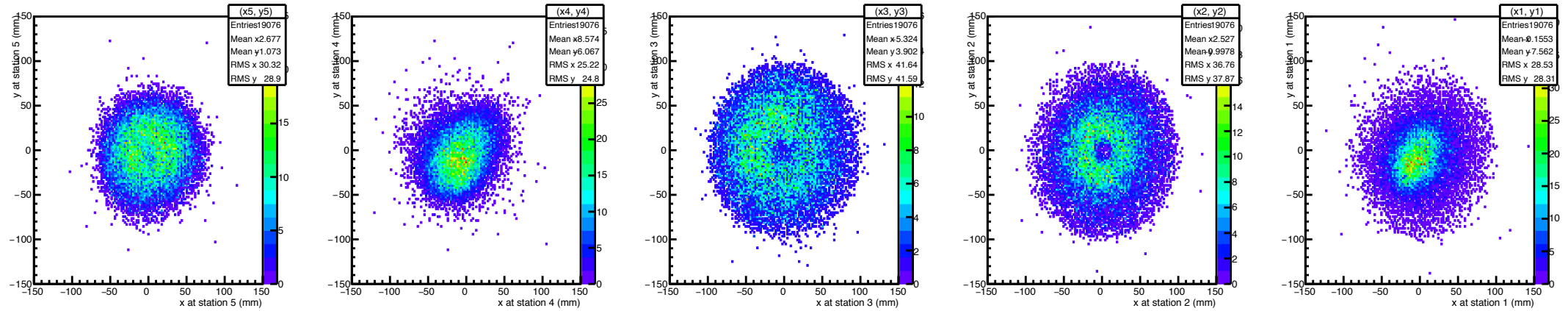


EVOLUTION OF PHASE SPACE ACROSS TRACKER

Top: Data
Bottom: MC

(X, Y)

Data



5

4

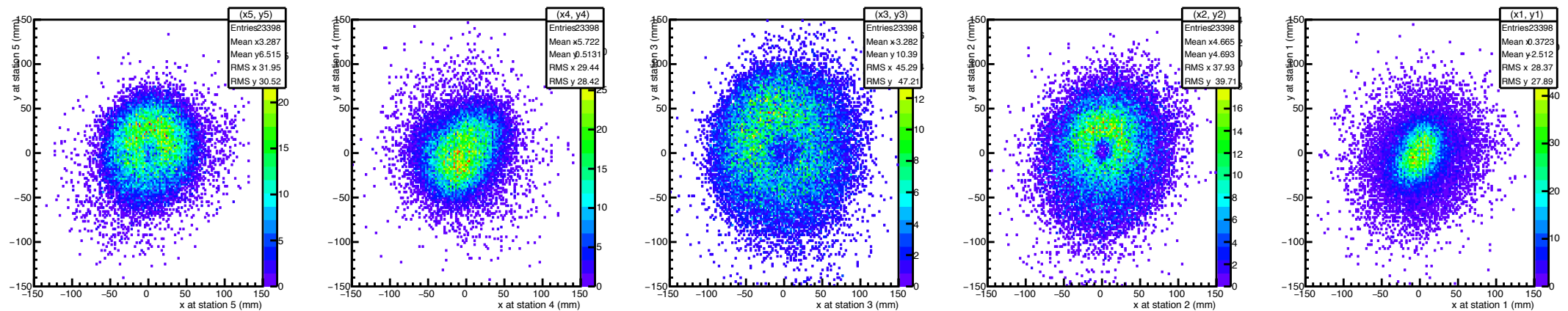
3

2

1

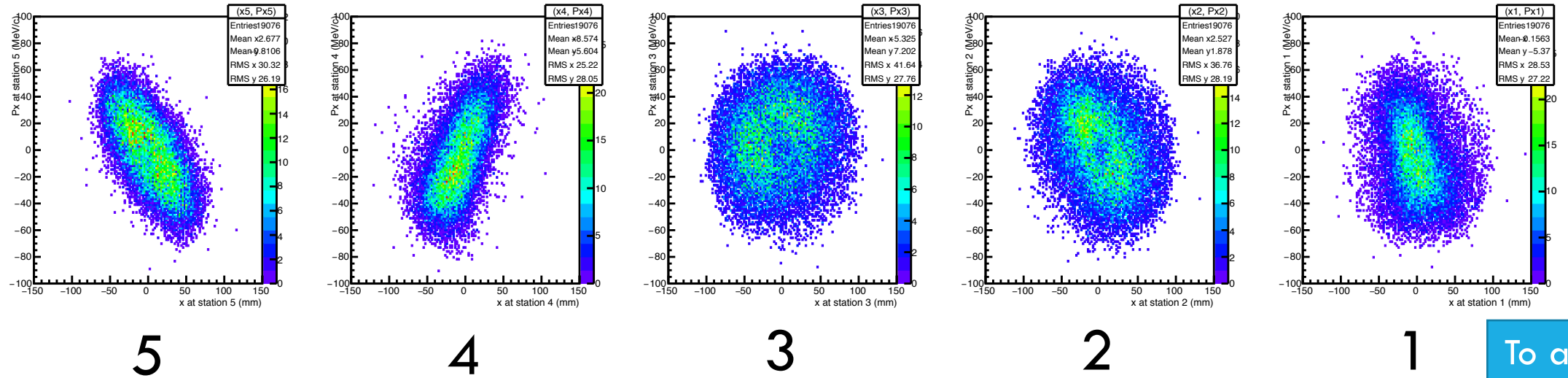
To absorber

MC



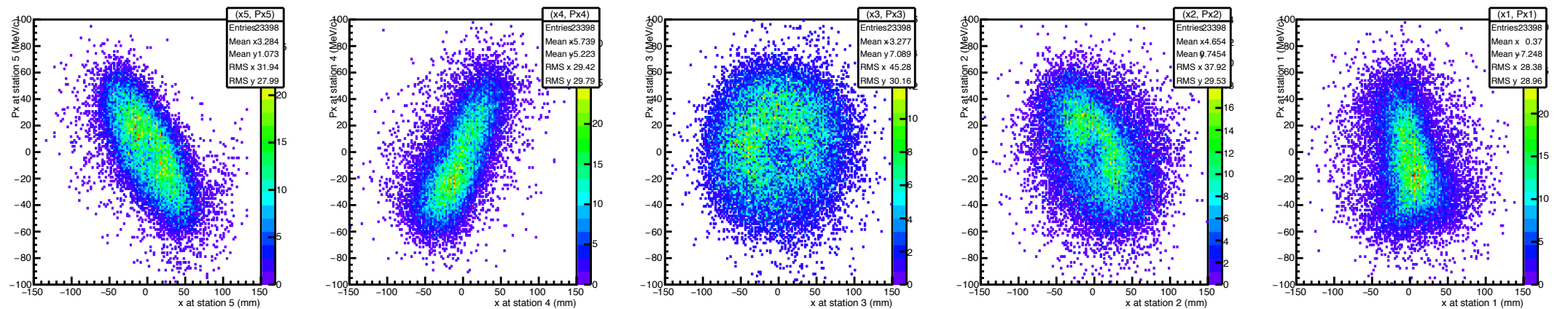
(X, PX)

Data



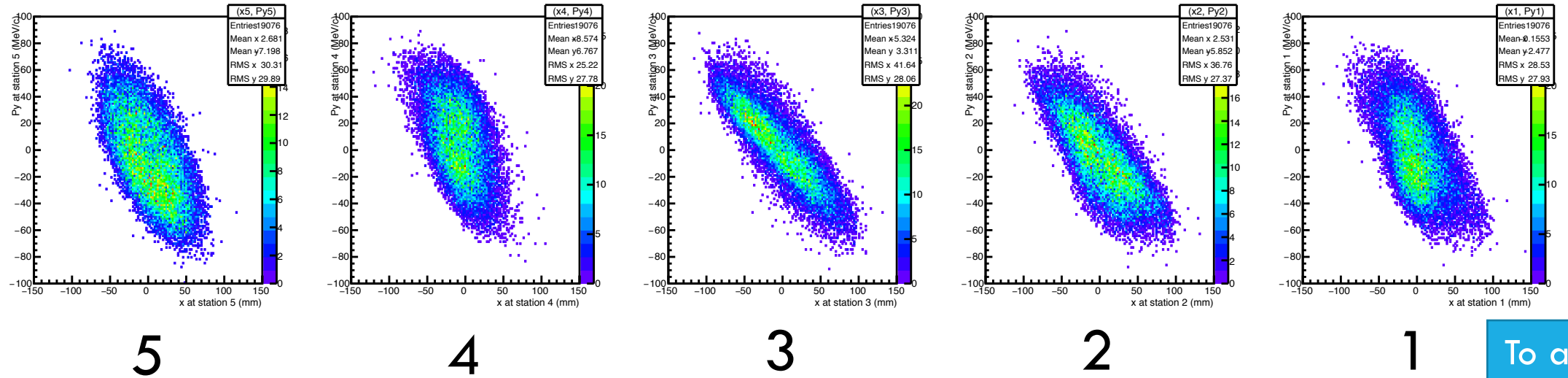
To absorber

MC



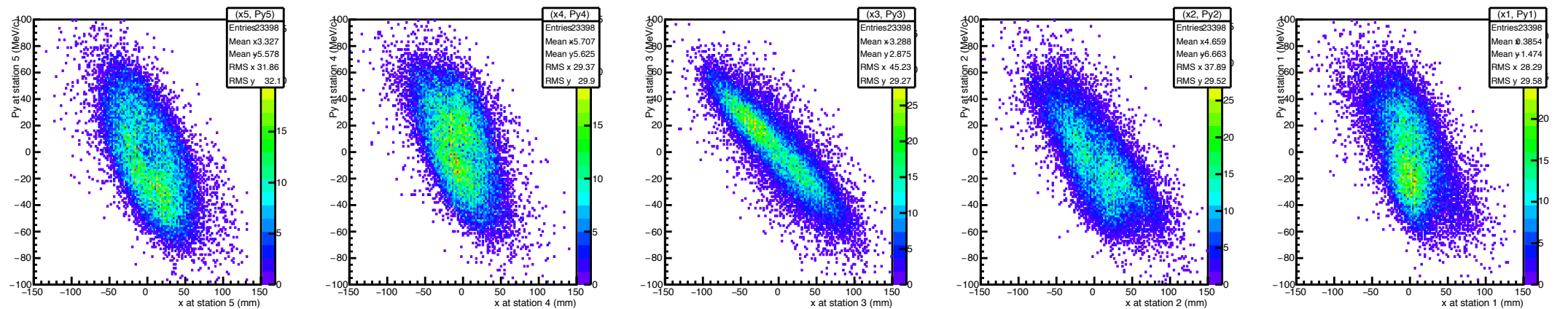
(X, PY)

Data



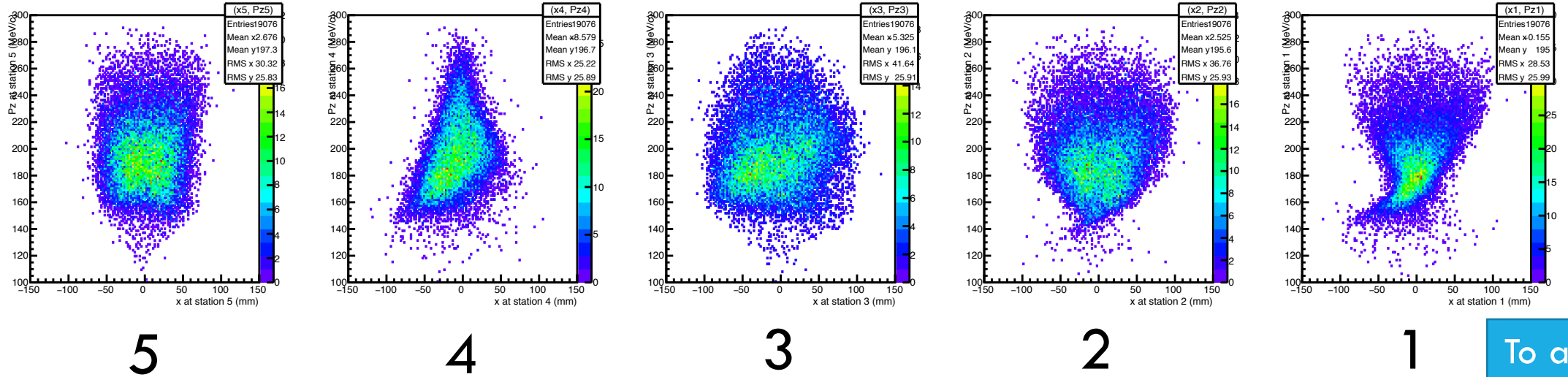
To absorber

MC



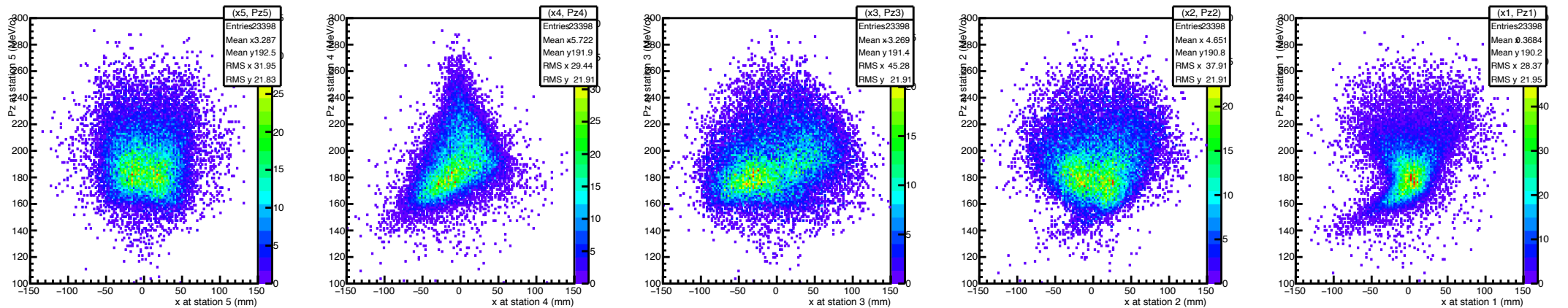
(X, P_Z)

Data



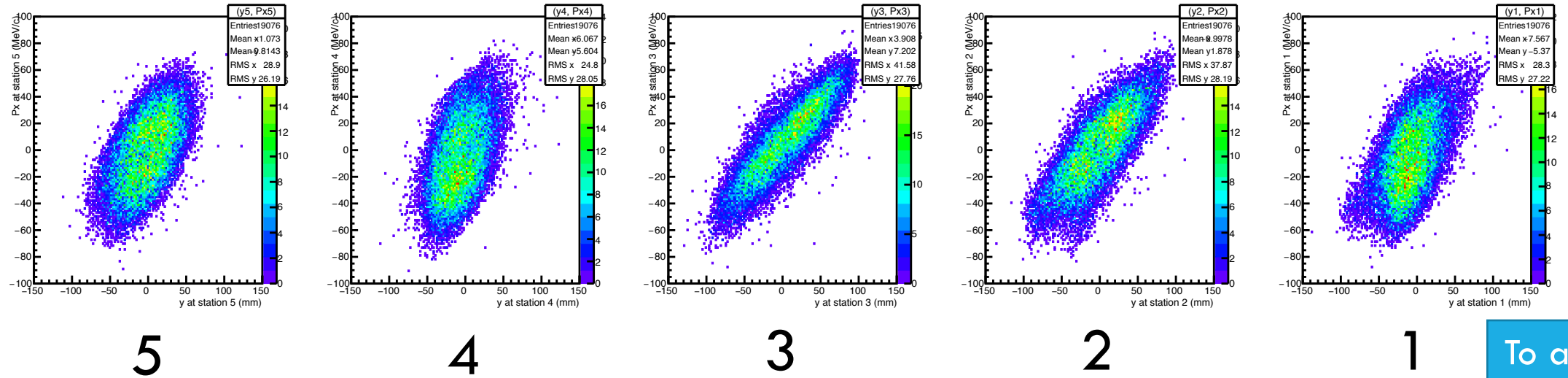
To absorber

MC



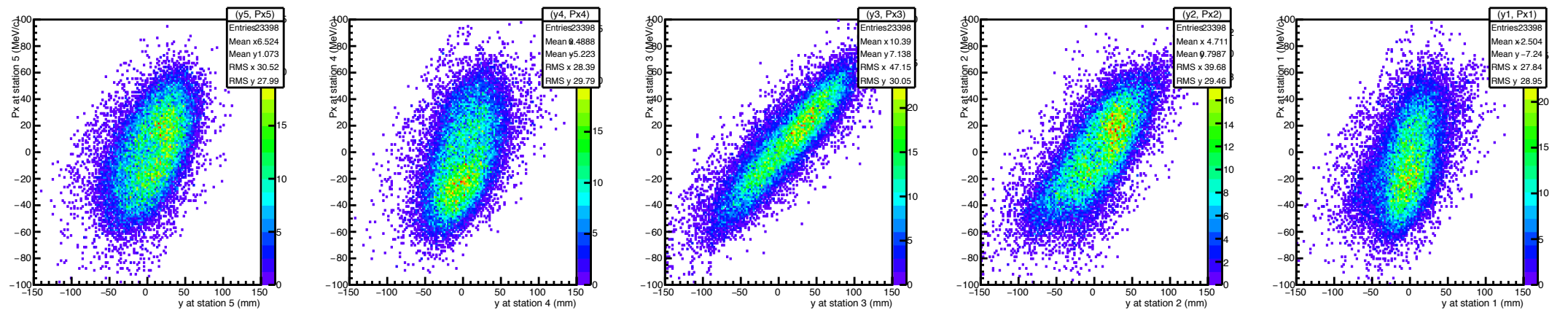
(Y, PX)

Data



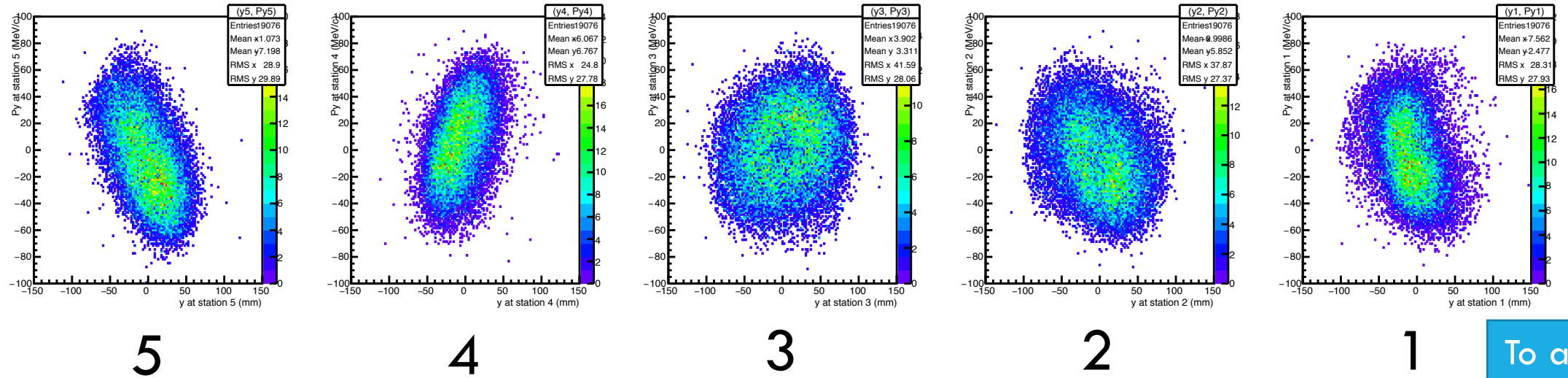
To absorber

MC



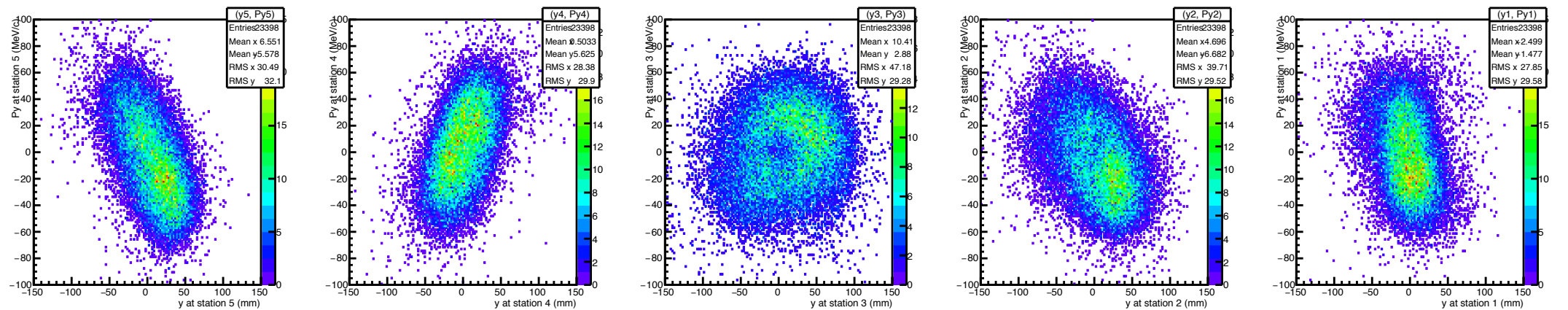
(Y, PY)

Data



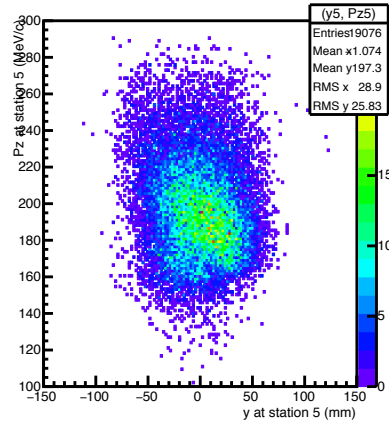
To absorber

MC

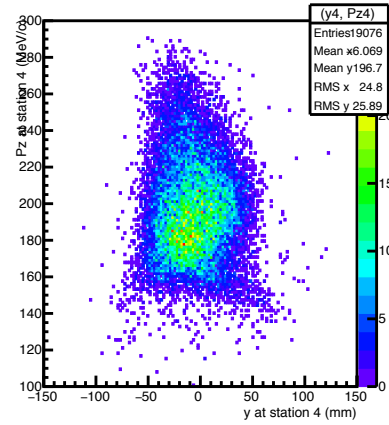


(Y, Pz)

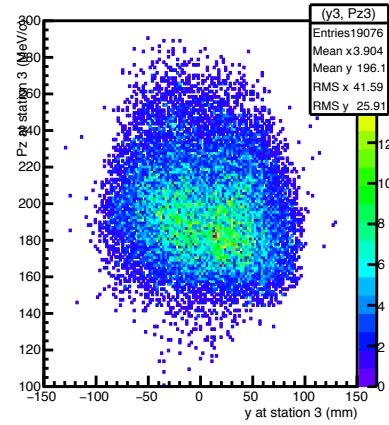
Data



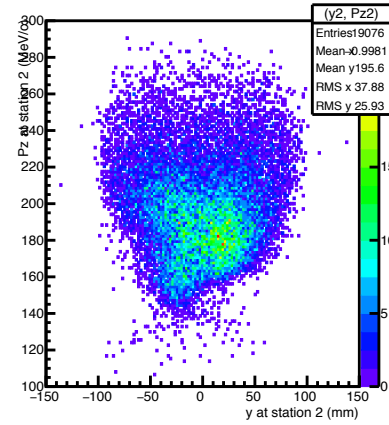
5



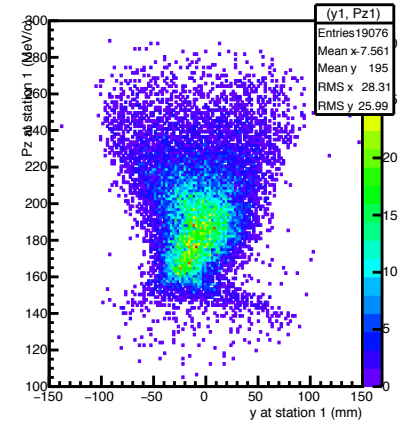
4



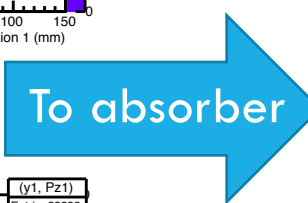
3



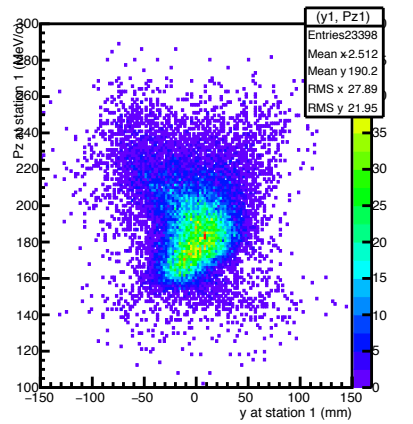
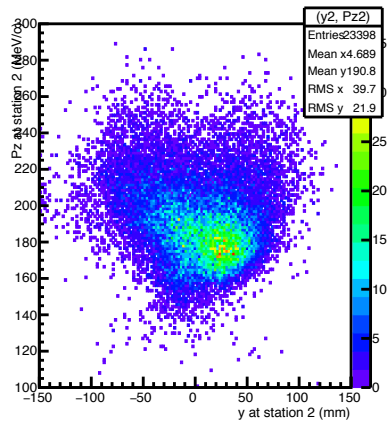
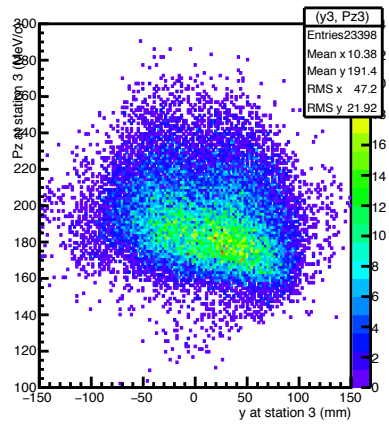
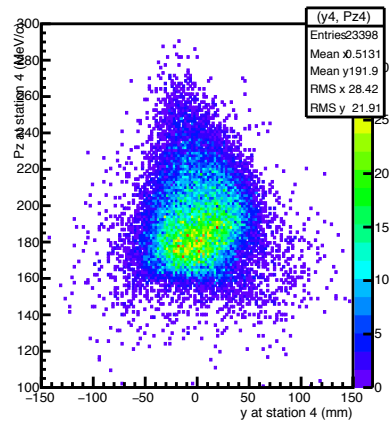
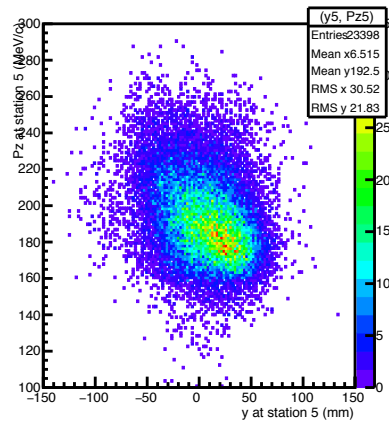
2



1

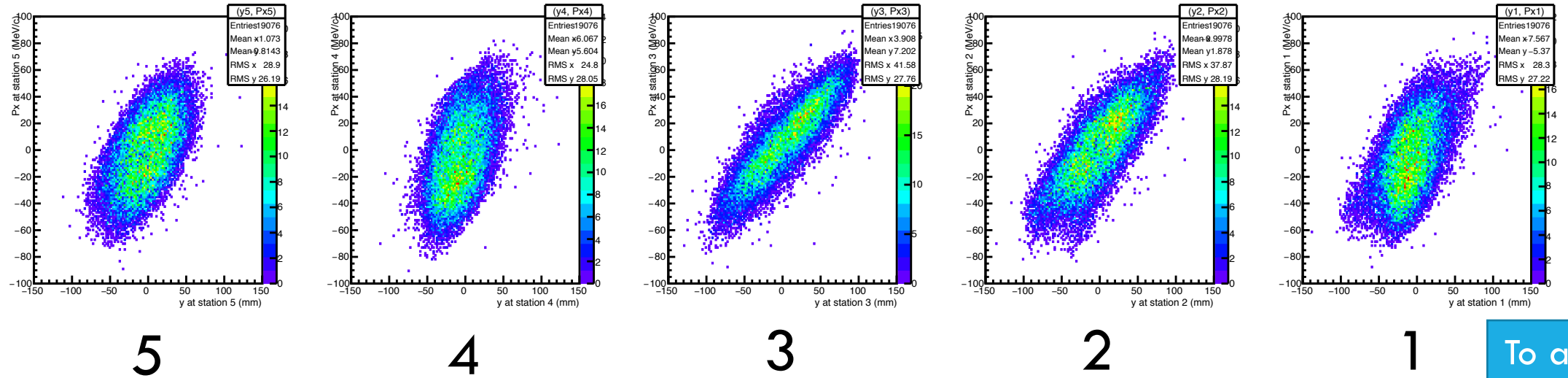


MC

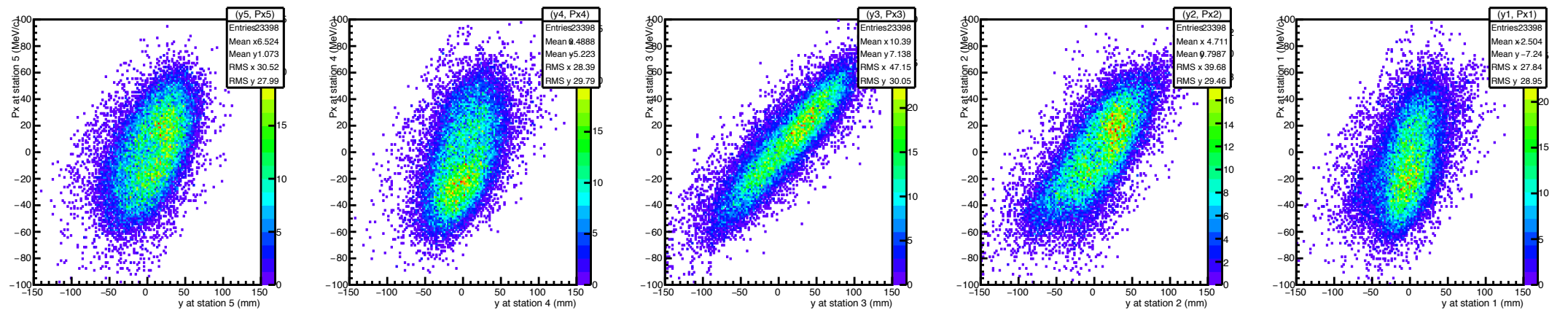


(PX, PY)

Data

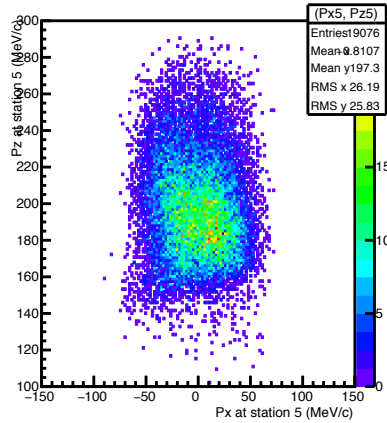


MC

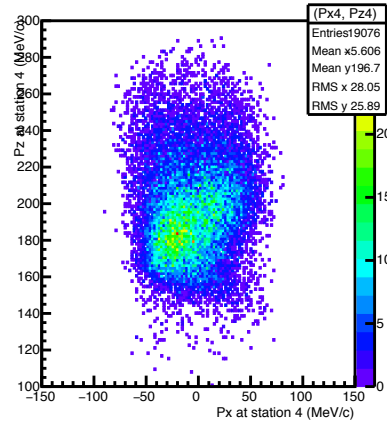


(PX, PZ)

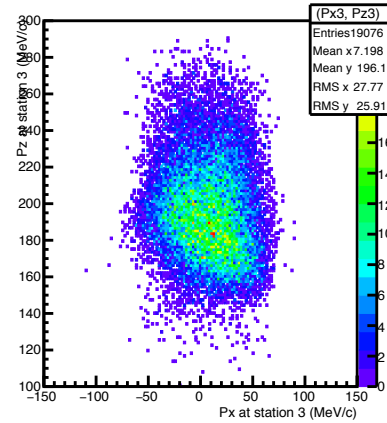
Data



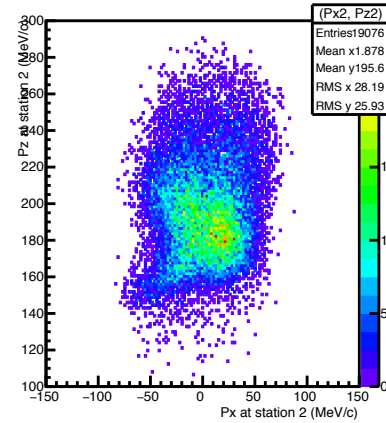
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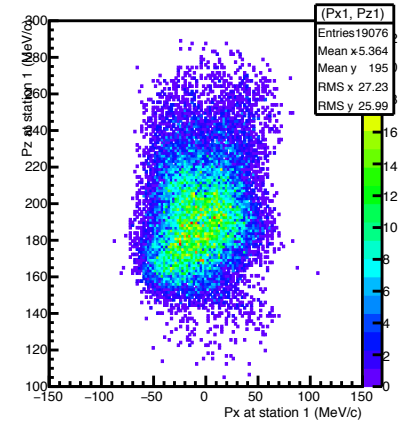
4



3



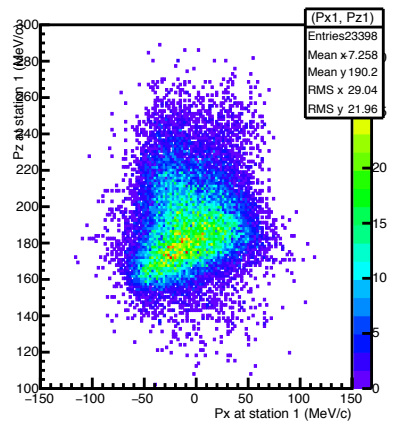
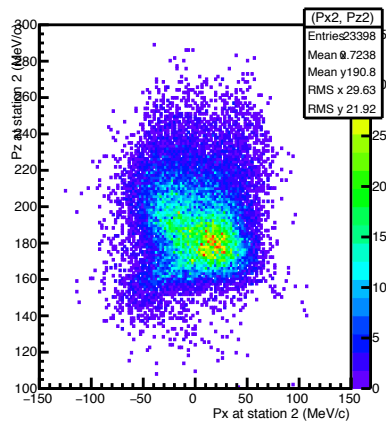
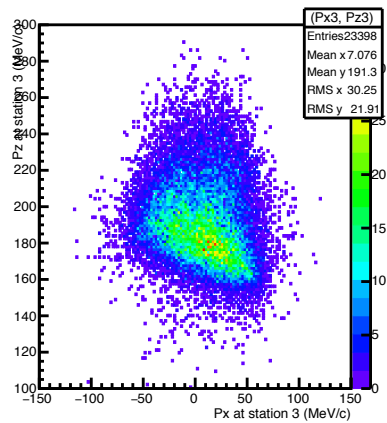
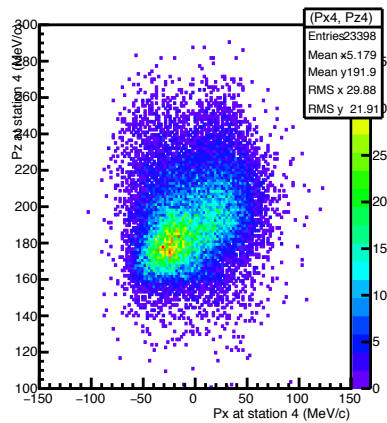
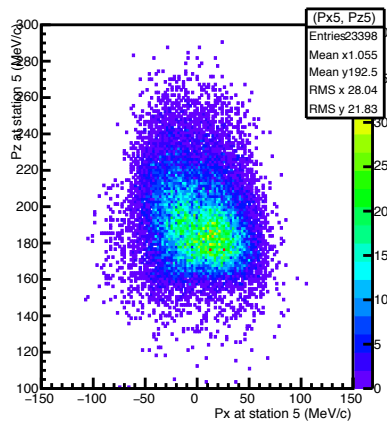
2



1

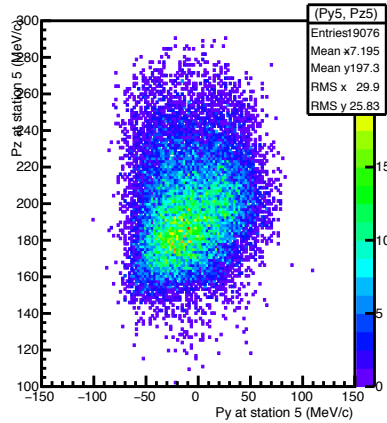
To absorber

MC

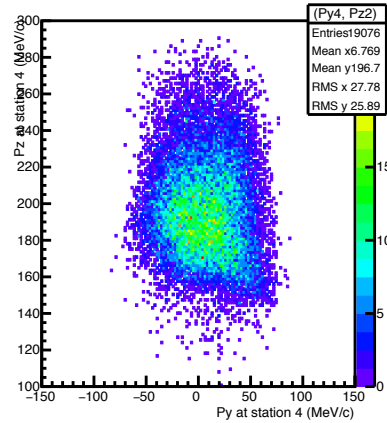


(PY, PZ)

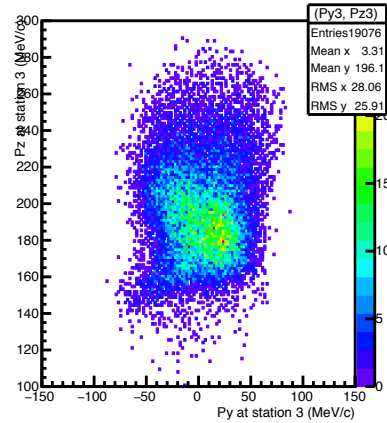
Data



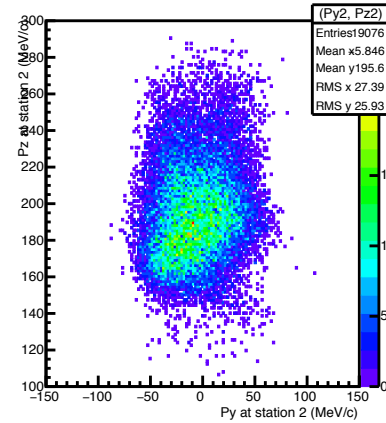
5



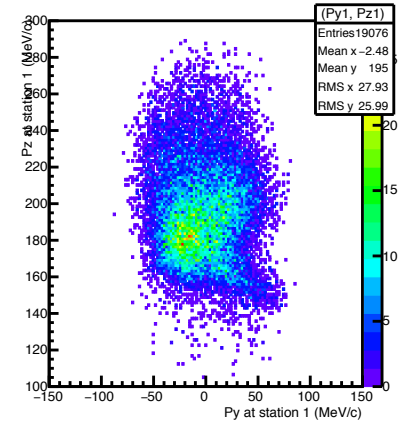
4



3



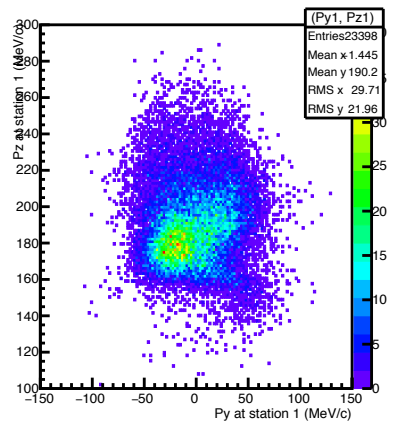
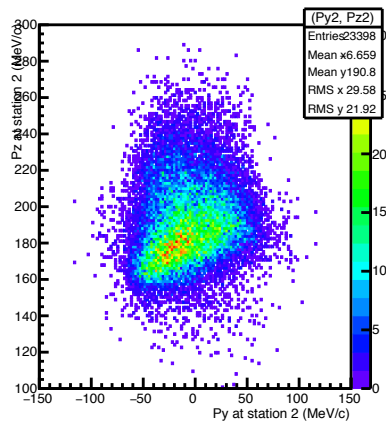
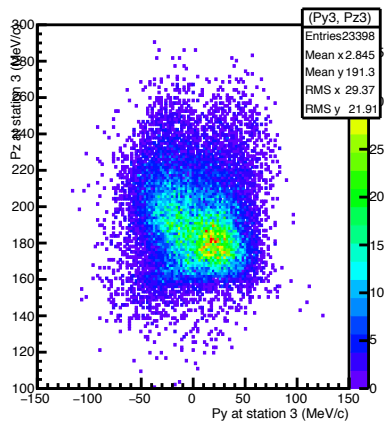
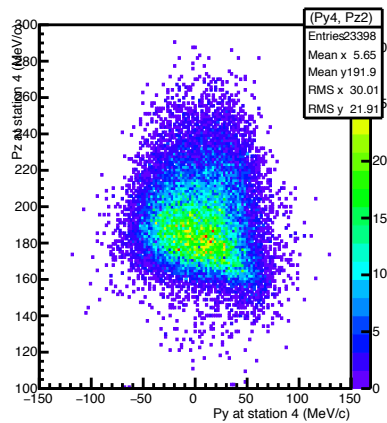
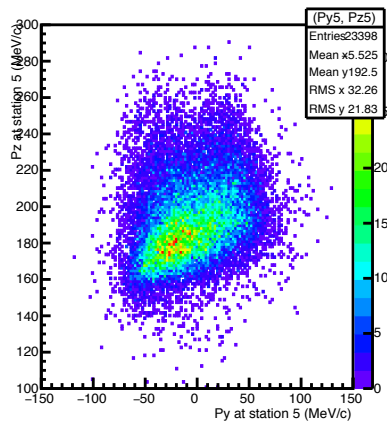
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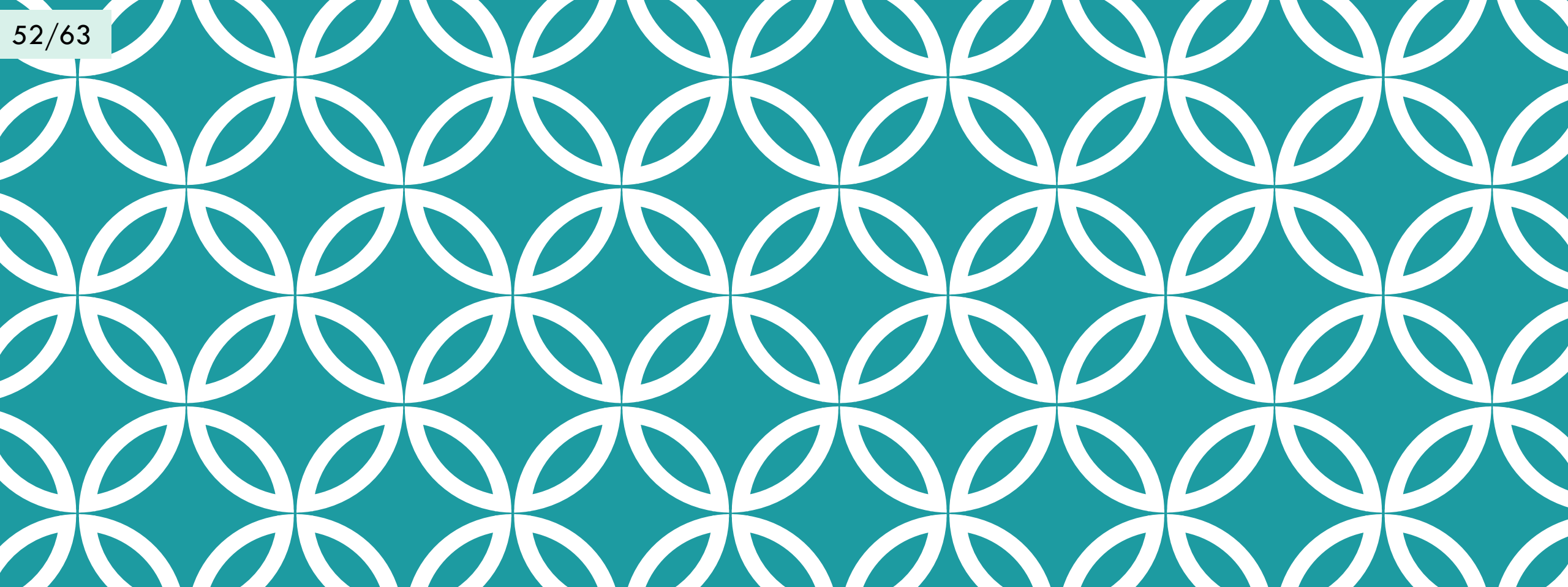


1

To absorber

MC





COVARIANCE MATRICES & EMITTANCES

... because we're not done yet!

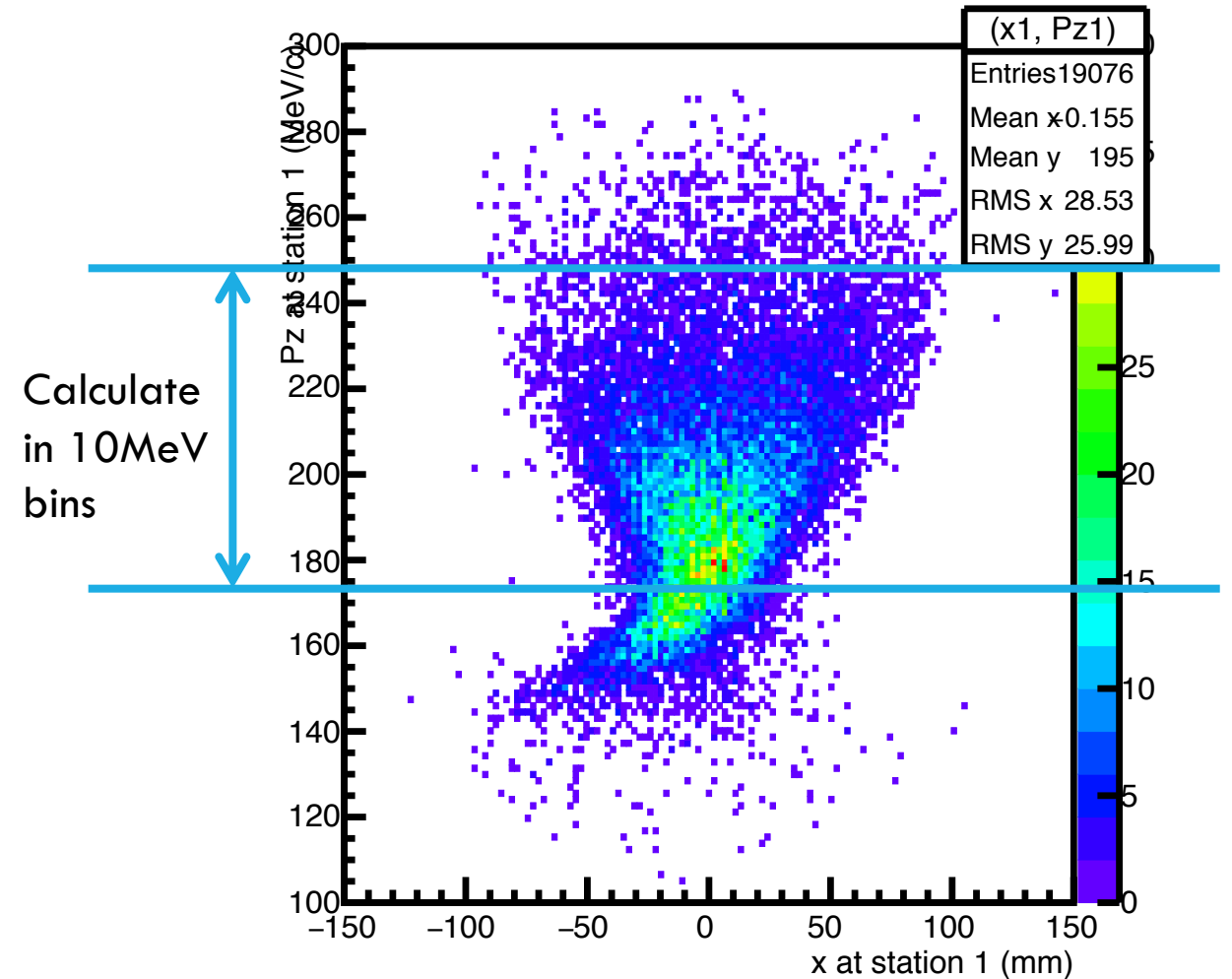
BUILDING A COVARIANCE MATRIX

- For each particle that passes all of the cuts, build a covariance matrix at TKU station 1 using (x, p_x, y, p_y)

- Covariance of $a, b = \text{cov}(a, b) = \sigma_{ab}$
- $\sigma_{ab} = \langle ab \rangle - \langle a \rangle \langle b \rangle$

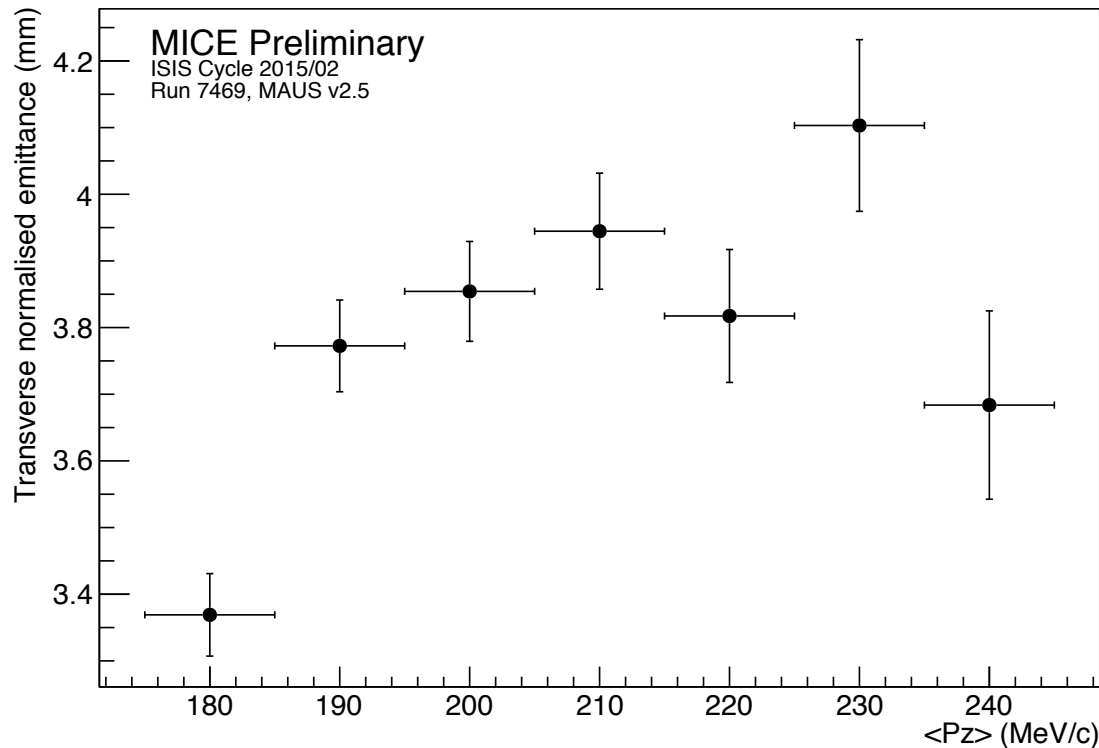
- $$\Sigma_{4D} = \begin{pmatrix} \sigma_{xx} & \sigma_{xPx} & \sigma_{xy} & \sigma_{xPy} \\ \sigma_{xPx} & \sigma_{xPx} & \sigma_{yPx} & \sigma_{PxPy} \\ \sigma_{xy} & \sigma_{yPx} & \sigma_{yy} & \sigma_{yPy} \\ \sigma_{xPy} & \sigma_{PxPy} & \sigma_{yPy} & \sigma_{PyPy} \end{pmatrix}$$

- $$\varepsilon_N = \frac{1}{m_\mu} \sqrt[4]{\det|\Sigma_{4D}|}$$

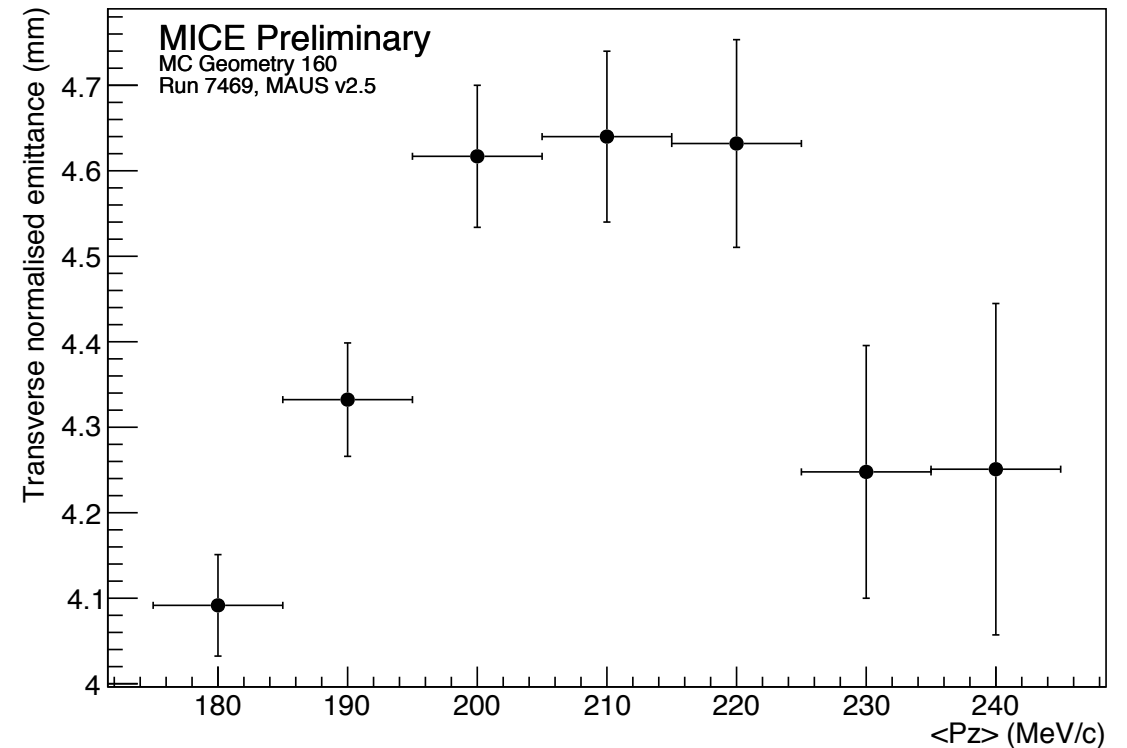


EMITTANCE

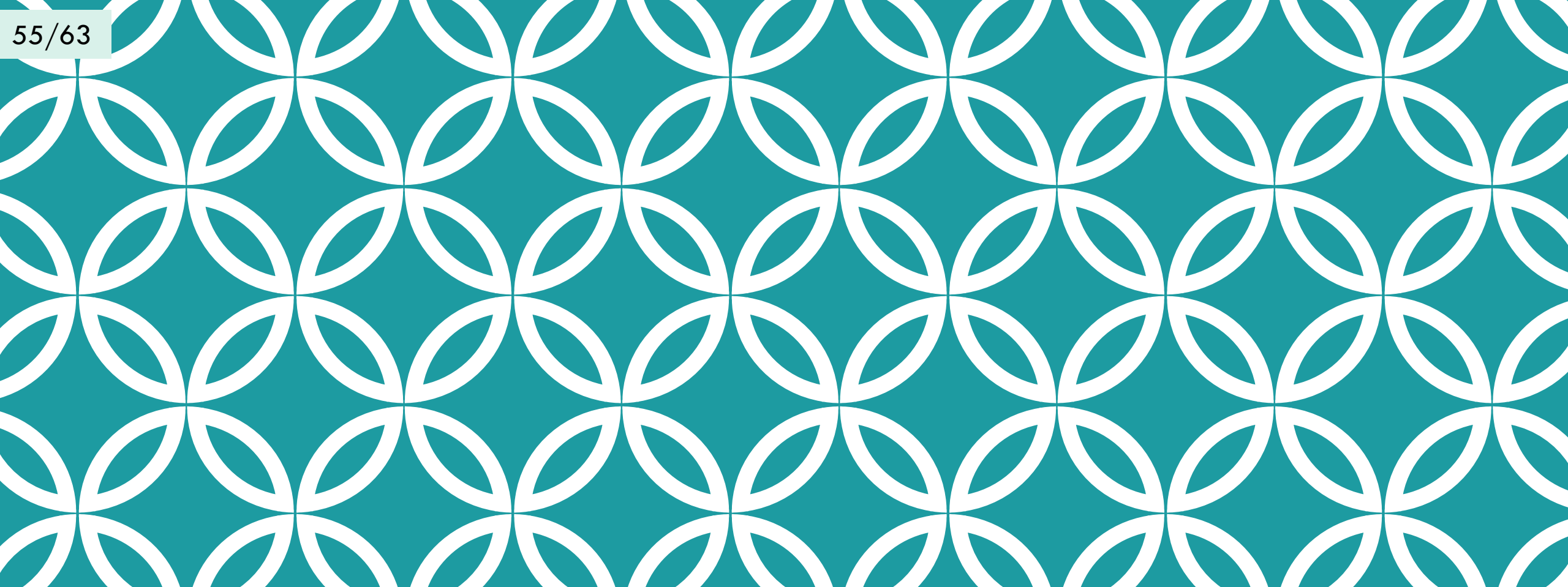
- There is a difference between data and MC
 - MC is consistently larger
 - MC also has more outliers (e.g. see ‘evolution of phase space across tracker’)
 - Outliers inflate emittance
 - Considering e.g. χ^2 cut, but first studying χ^2 distributions in data and MC



Data



MC



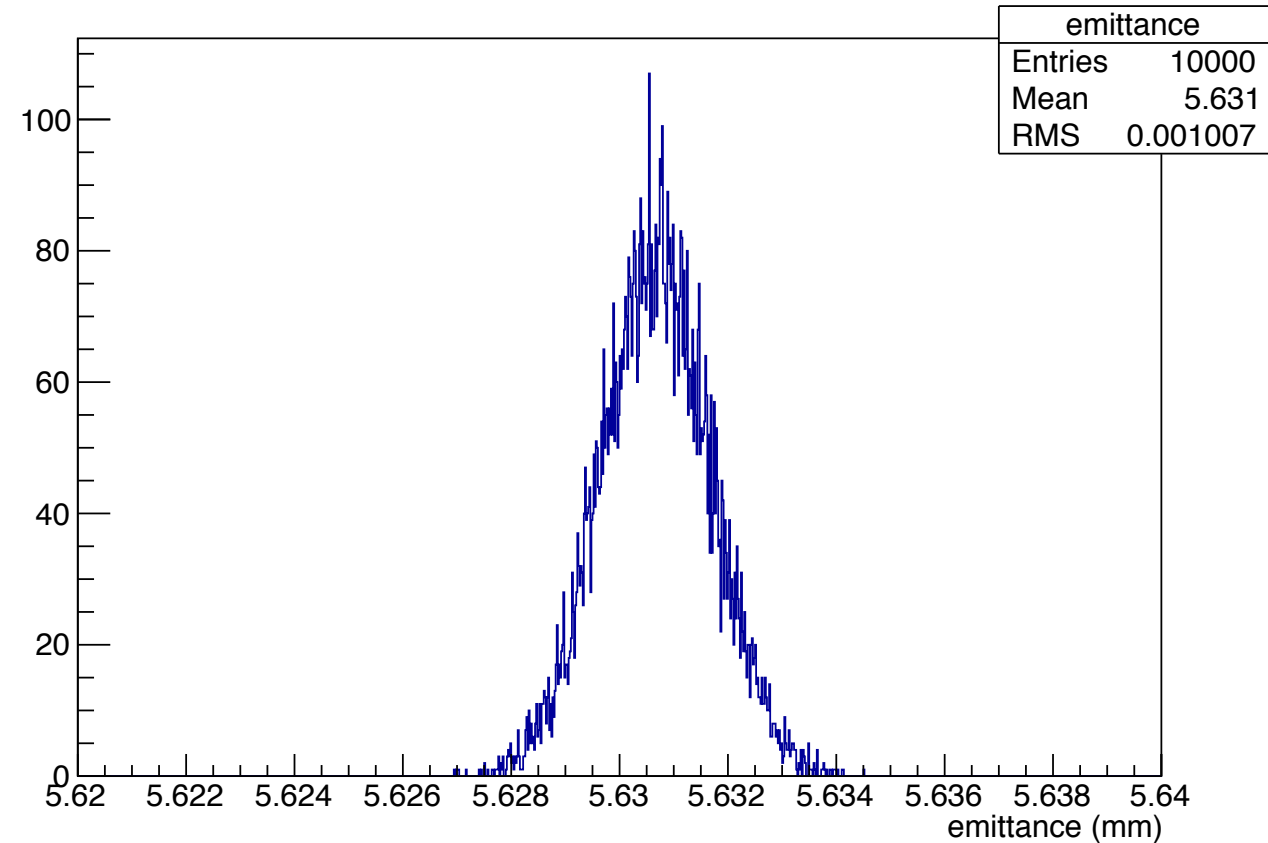
ERRORS/UNCERTAINTIES

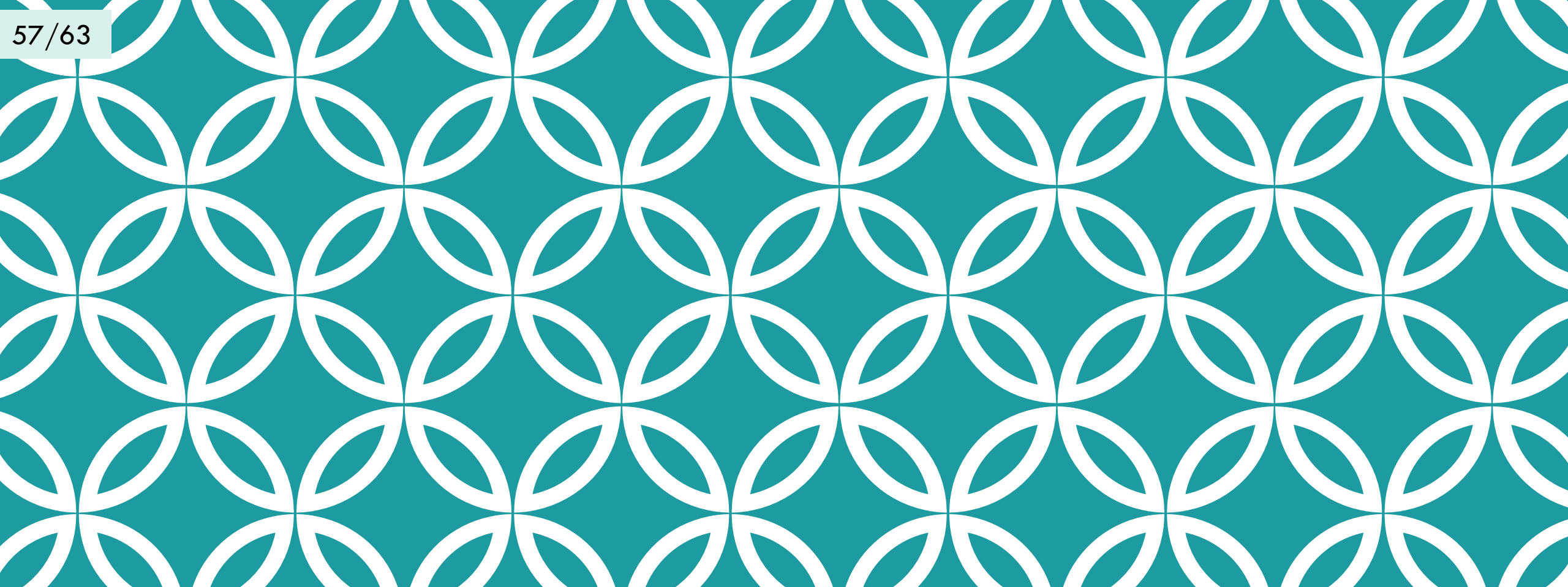


ERRORS/UNCERTAINTIES

Big!

- Statistical error: [MICE Note 341](#)
 - $\sigma_\varepsilon^2 = \varepsilon^2/N$
- Statistical error from track fit is negligible in comparison →
- Systematic error from misalignment of field to tracker estimated as negligible (see C. Rogers talk yesterday)
- Systematic error from misplaced/mispowered field map?
- Comparison with TOF1 emittance?





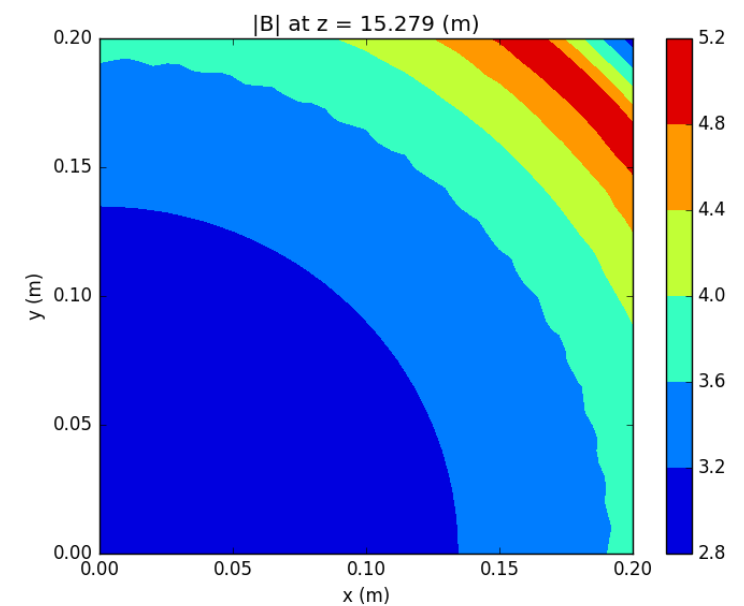
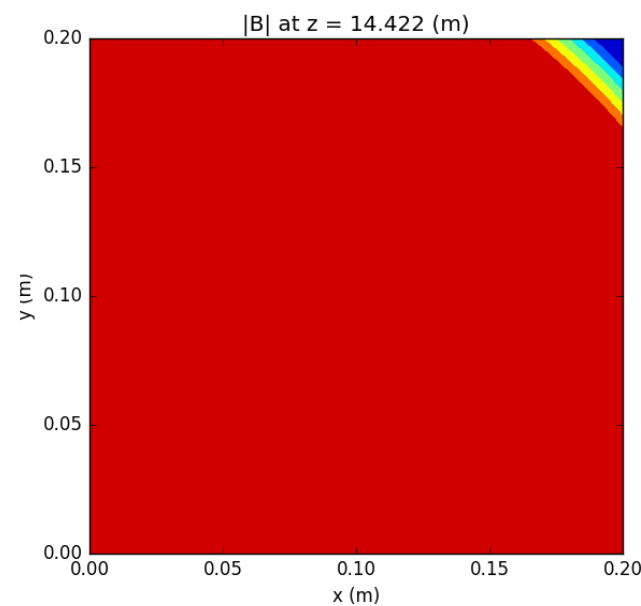
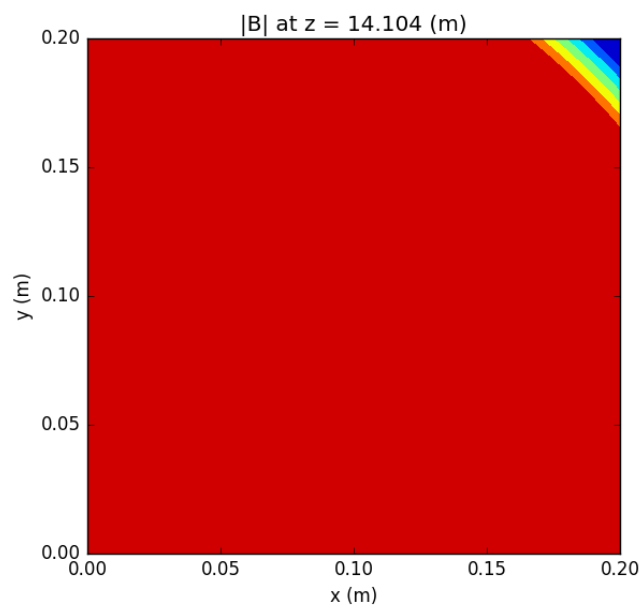
FIELDS

You may recognise the plots that follow from the VC!

* Looking at **non-rotated** OPERA field map. MAUS applies a rotation & translation ($dx = 0.00759$ mm, $dy = 0.1810$ mm, $\theta_x = -0.0458$ deg, $\theta_y = 0.0196$ deg)

HALL PROBE/OPERA COMPARISON (MAUS COORDS)

Probe #	z (mm) ± 5	x (mm)	y (mm)	Average B measured (T)	B from OPERA map (T)
65	14422	138.6	80.0	4.05	4.03
67	15279	-138.6	80.0	3.80	3.33
77	14104	138.6	80.0	4.08	4.06
79	14422	0.0	-160.0	4.05	4.03

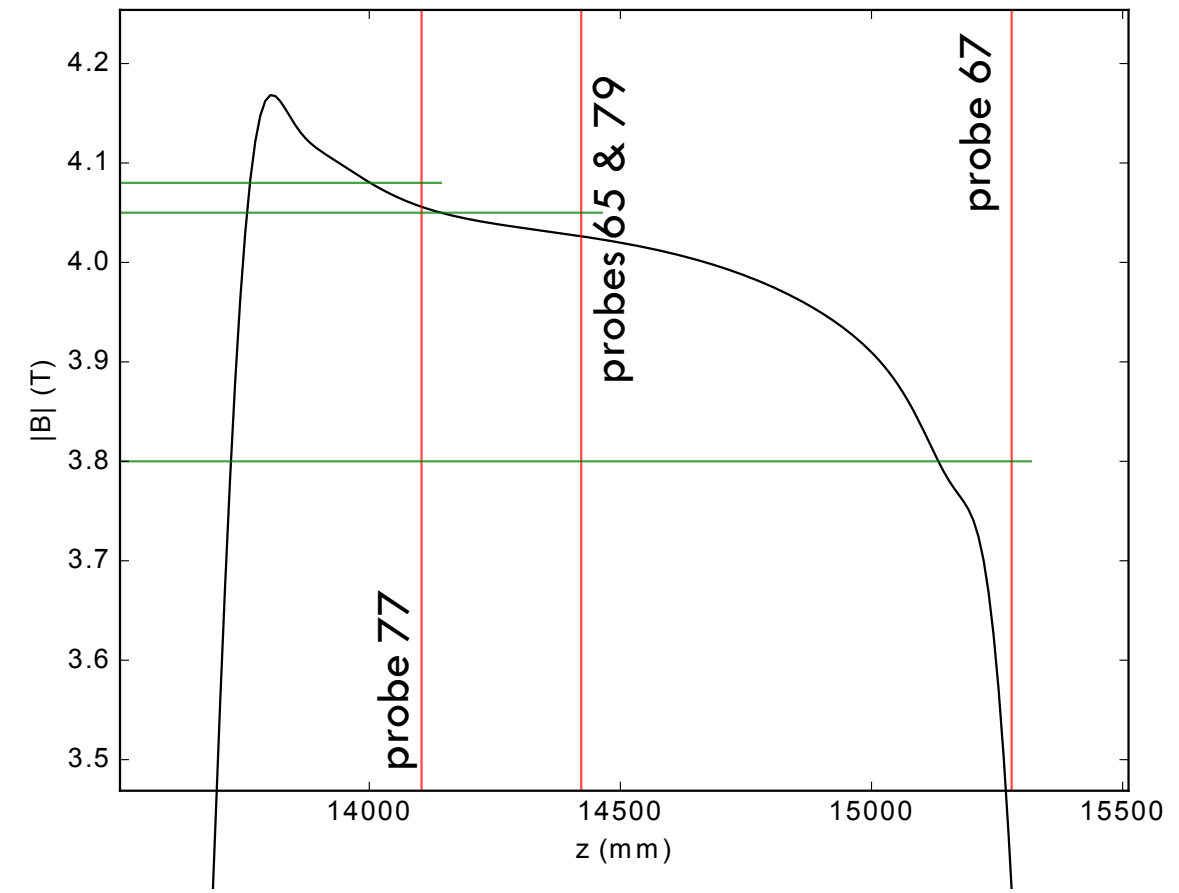
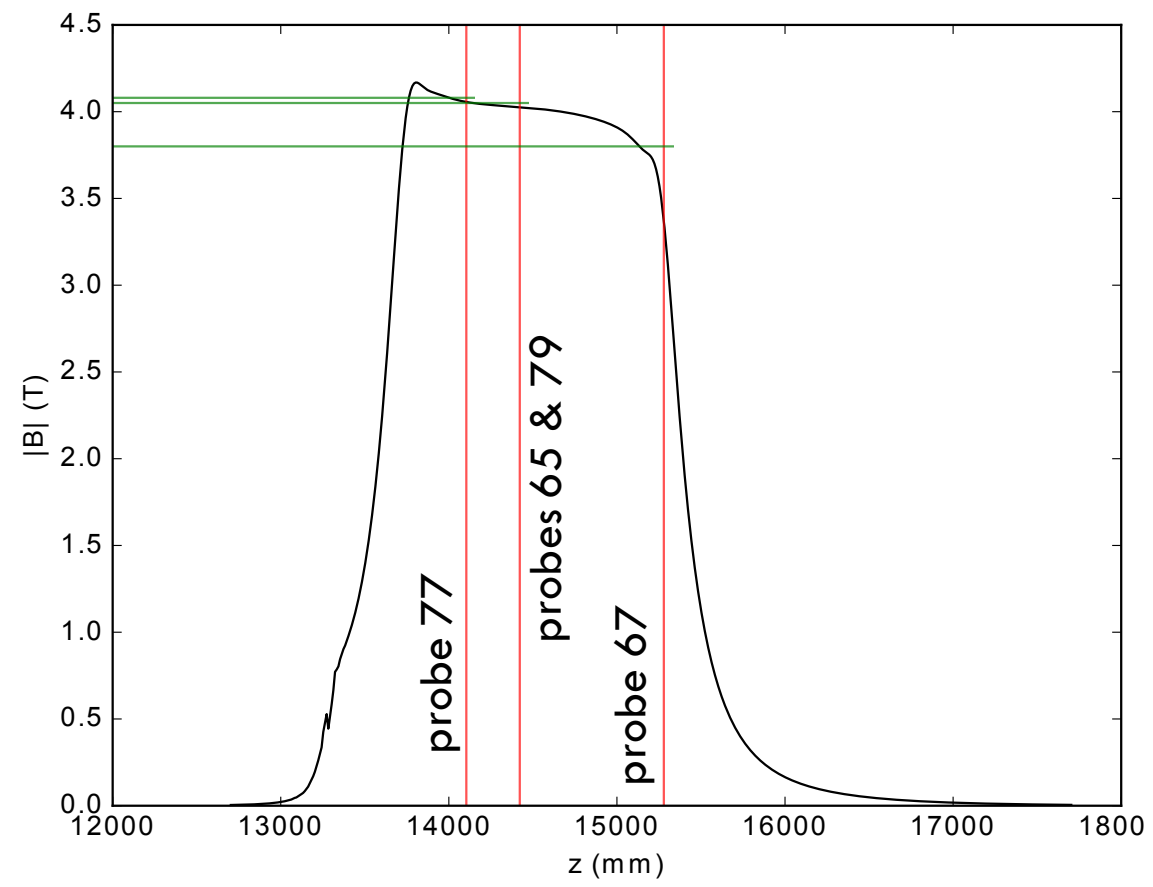


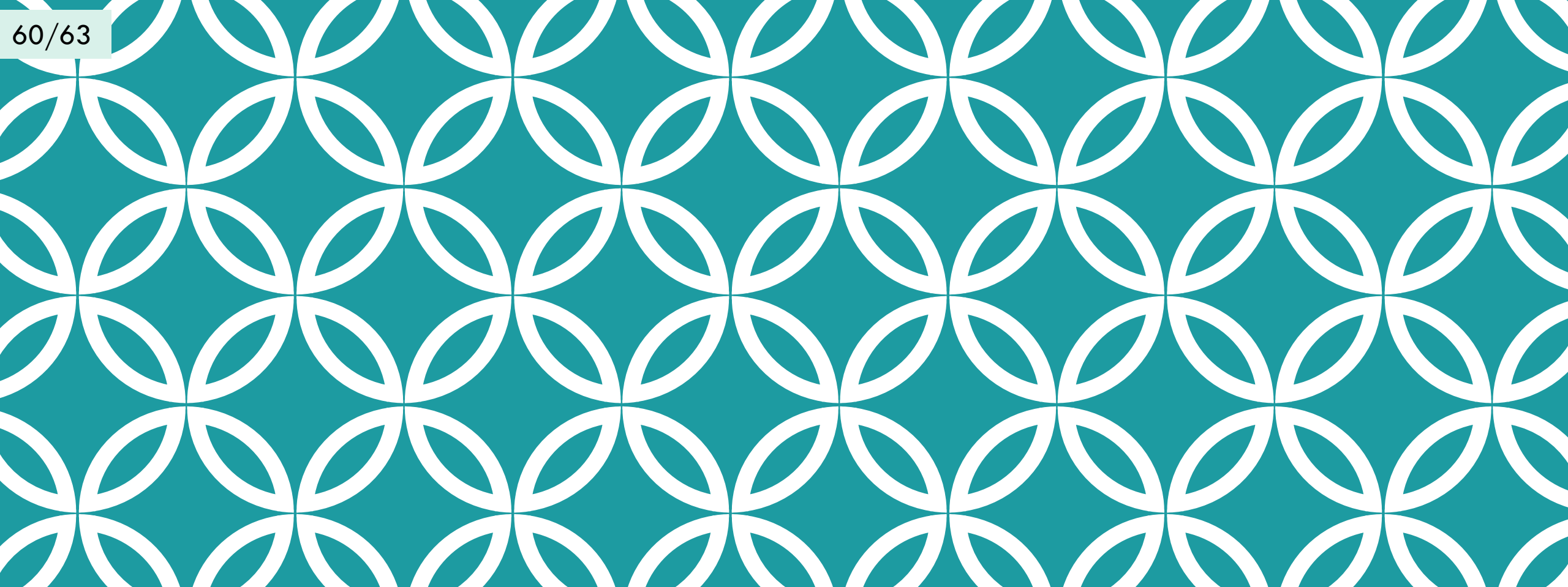
* Looking at **non-rotated** OPERA field map. MAUS applies a rotation & translation ($dx = 0.00759$ mm, $dy = 0.1810$ mm, $\theta_x = -0.0458$ deg, $\theta_y = 0.0196$ deg)

59/63

HALL PROBE/OPERA COMPARISON (MAUS COORDS)

At $r = 160$ mm, same radius as Hall probes





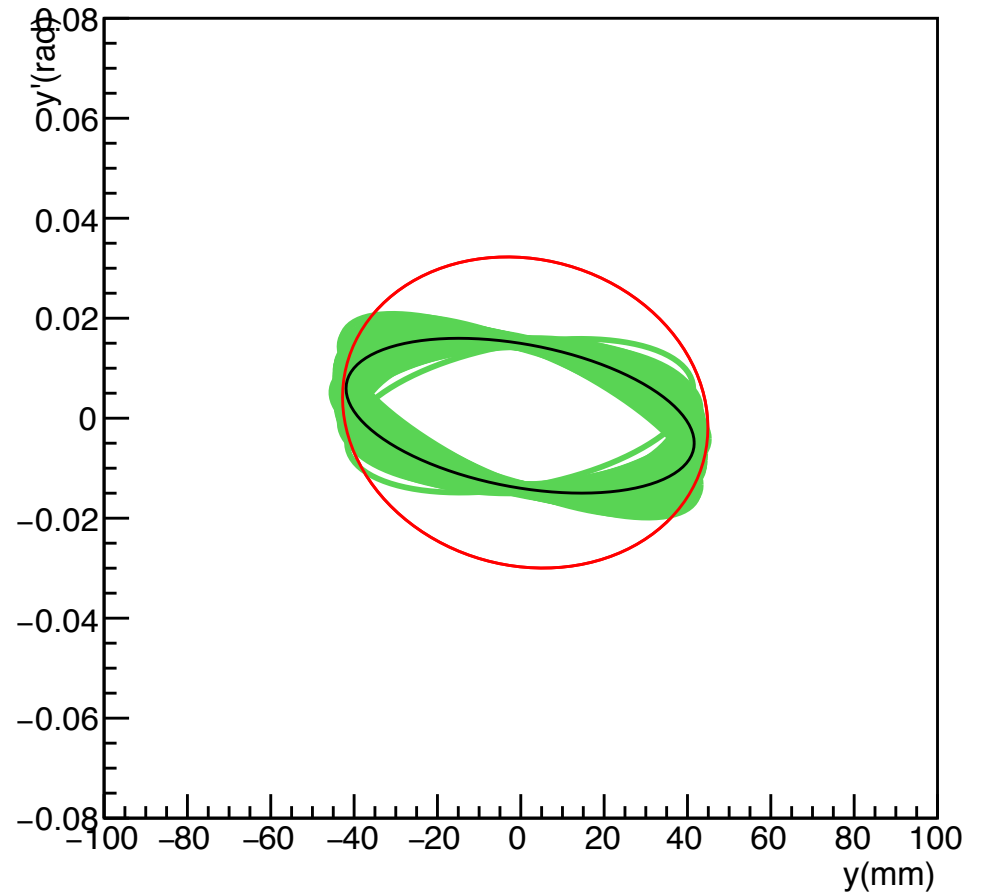
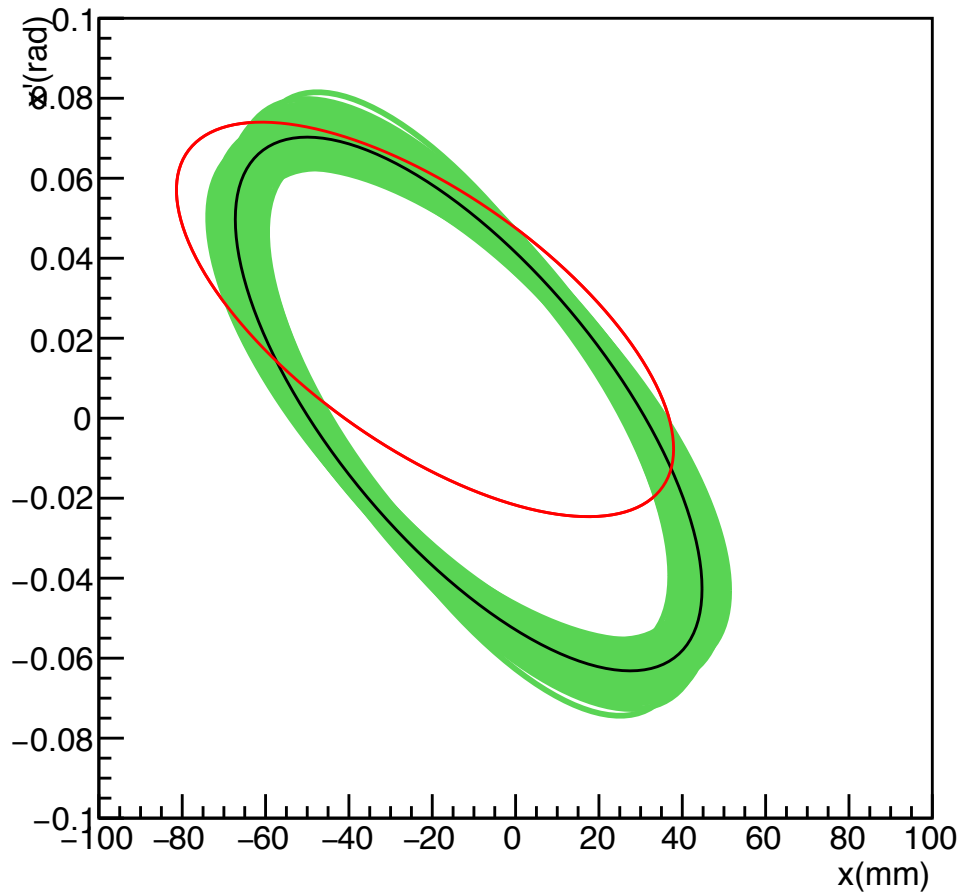
TOF—TRACKER COMPARISON



TRACKER → TOF1 EXTRAPOLATION

- Propagate tracker tracks back to TOF1
- Compare with Rayner reconstruction
- Offsets in means point to misalignment of field map when tracking?
- **Red**: Propagated tracks from Chris Rogers
- **Black**: TOF1 reconstruction using Mark Rayners method (i.e. Step 1 paper)
- **Green**: 1000 ellipses generated using errors on Rayner recon

TRACKER → TOF1 EXTRAPOLATION



SUMMARY

- Getting there...
 - Cuts about finalised – an improvement would be to track particles we suspect hit the diffuser aperture back and confirm they really did hit it (but depends on our knowledge of the field)
 - Emittance currently overestimated in MC – more outliers than data. Thinking about how to clean them up fairly
 - Optical parameters require canonical momenta – currently a (still) unsolved problem, have a go!
- Errors dominated by statistics
 - Not helped by binning along P_z , but best to avoid chromatic effects
 - Field-to-tracker tilt seems negligible, but we may not know the (longitudinal) position of the field well if we compare to Hall probe readings
- MC gets a lot of things right about the data, differences appear mostly with P_z -correlations