

PhIAT Documentation -- Automatic Fitting

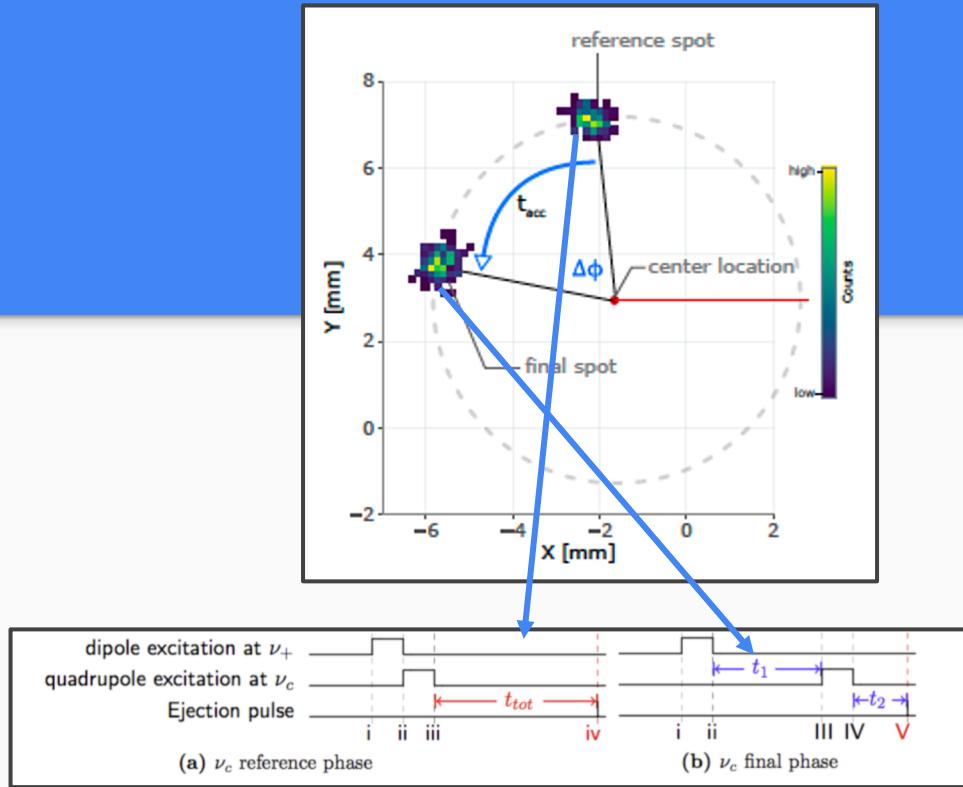
Sam Porter (wporter@triumf.ca)
University of British Columbia
TRIUMF, on behalf of the TITAN Collaboration

Overview

- **Language:** MATLAB (R2016a or newer)
- **Input:** A directory address (i.e. address to a folder) of MIDAS Files (ex: /Users/wsporter/Documents/Physics_Research/TITAN/PIICR_Analysis/Testing/Test_CAENOffset) OR a File List.csv (see midas_to_phiat Documentation for more)
- **Output:**
 - A .csv containing relevant info and potential cyclotron frequencies of spots in all files (if Create Freq ID checked)
 - A .xlsx containing relevant data fitting results (if Finish Analysis checked)
 - A .png of the sinusoidal fit of cyclotron frequency data (if Finish Analysis checked)
 - A .png of the sinusoidal fit of radius data (if Finish Analysis checked)

PI-ICR Basics

- The cyclotron frequency (ω_c) is determined via the phase difference (Φ_c) between two spots with different **accumulation times (Tacc)**
 - Reference Spot: Tacc = 0
 - Final Spot: Tacc = Nonzero Value
- PhiAT determines the X/Y Positions of these spots to find each of their phases



$$\omega_c = \frac{\phi_c + 2\pi N(t_{acc})}{2\pi t_{acc}}$$

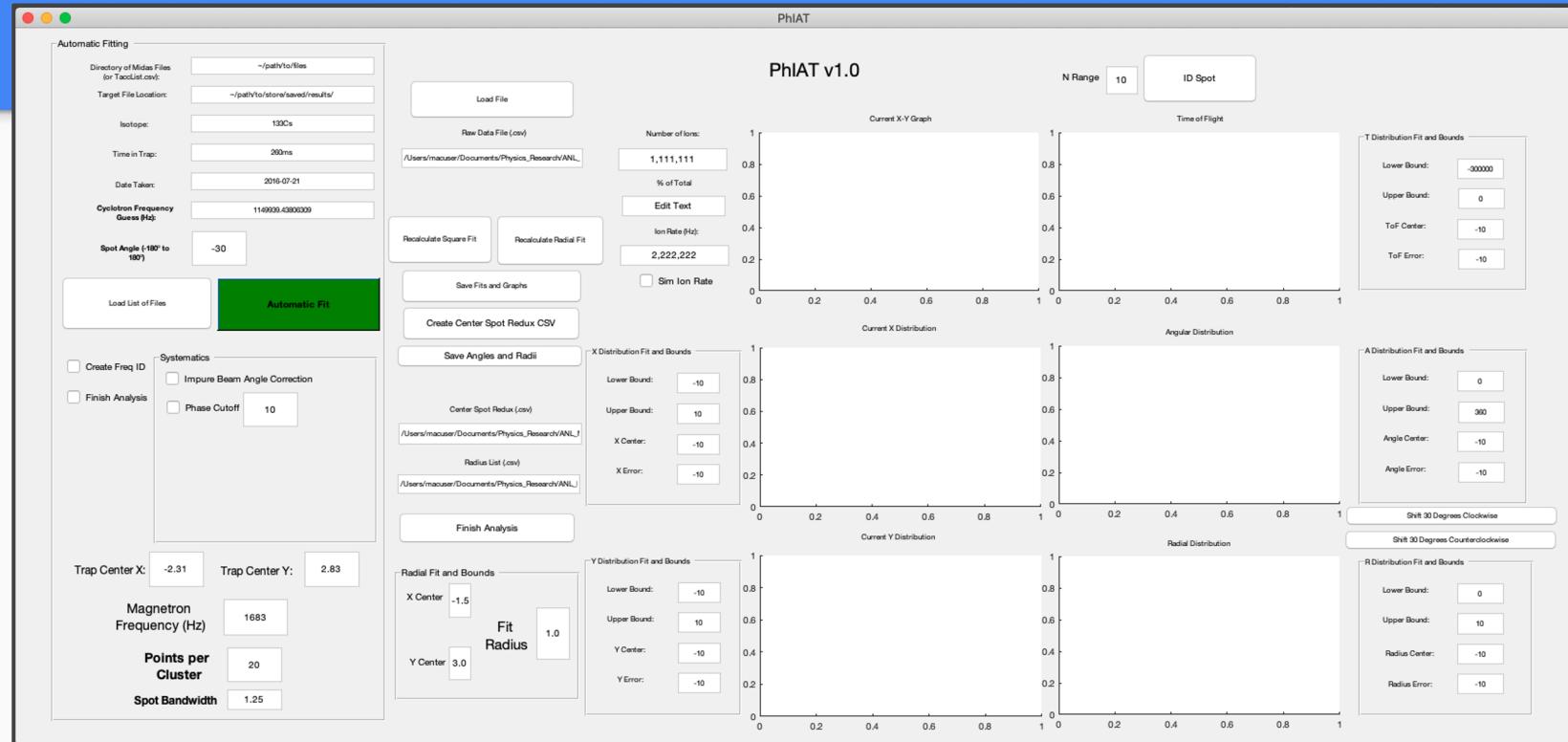
BEFORE YOU CONTINUE! -- titan_data

- PhIAT.m uses midas_to_phiat.py, which requires you download the **titan_data package**
 - This can be downloaded here: https://bitbucket.org/ttriumfdaq/titan_data/src/master/
- On Line 20 in midas_to_phiat.py: Change the address in sys.path.append from '`/Users/wsporter/Documents/Physics_Research/TITAN/PIICR_Analysis/titan_data`' to the local address of titan_data on your computer (i.e. '`/local/address/to/titan_data`')

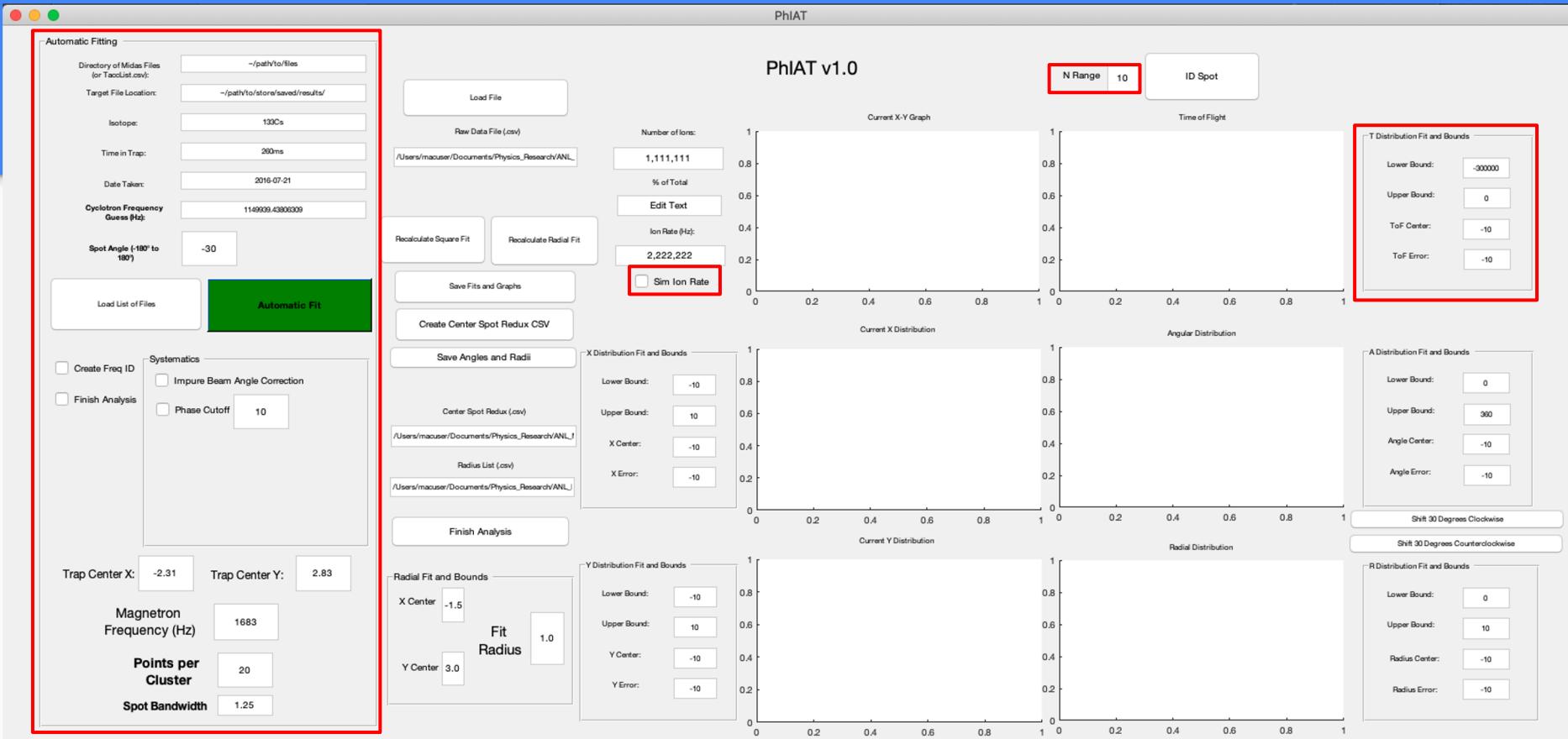
```
sys.path.append('/Users/wsporter/Documents/Physics_Research/TITAN/PIICR_Analysis/titan_data') # Address of titan_data module. NEW USERS NEED TO CHANGE  
THIS! #
```

Getting Started

- Press the Run Button to bring up the PhiAT GUI:



- Automatic fitting will only require the use of items in the red boxes, the rest is used for manual fitting (see Manual Fitting Documentation)



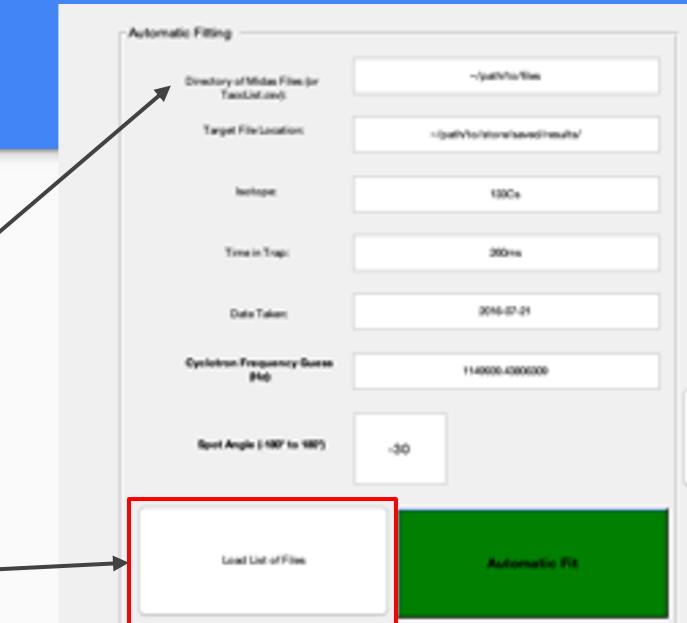
Loading a List of Files

- To start, input the address of the directory of MIDAS files (i.e.

/Users/wsporter/Documents/Physics_Research/TITAN/PIICR
_Analysis/Testing/Test_CAEONOffset)

- If you have already converted a directory of MIDAS files using midas_to_phiat.py, you can also input the address of the FileList.csv (see midas_to_phiat.py documentation)

- Click the Load List of Files button...



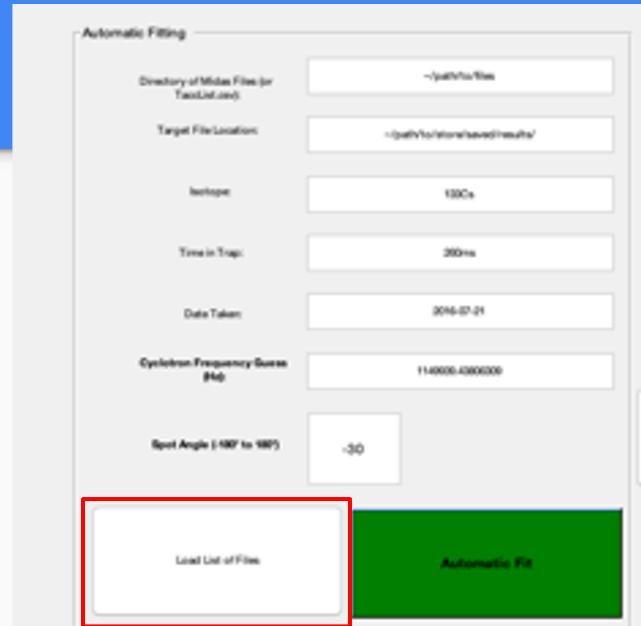
Loading a List of Files cont.

- Clicking Load List of Files runs `midas_to_phiat.py` and converts each MIDAS file into a readable .csv file containing (for each event):
 - X/Y Positions
 - Times of Flight from Ejection to MCP Contact
 - What trigger number of the TDC each event was recorded during
- `midas_to_phiat.py` also creates a `FileList.csv`, which contains a list of addresses of all data files



Loading a List of Files cont.

- The FileList.csv is used so PhIAT can navigate to each individual file and then load in that respective data



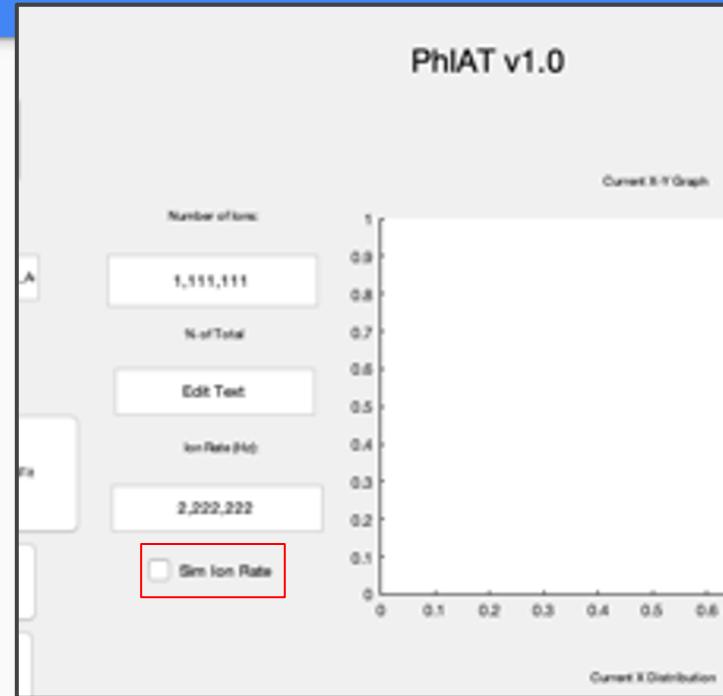
Automatic Fitting Overview

- After pressing the Load List of Files button, every other function (depending on what boxes are checked below) is completed simply by pressing the Automatic Fit button



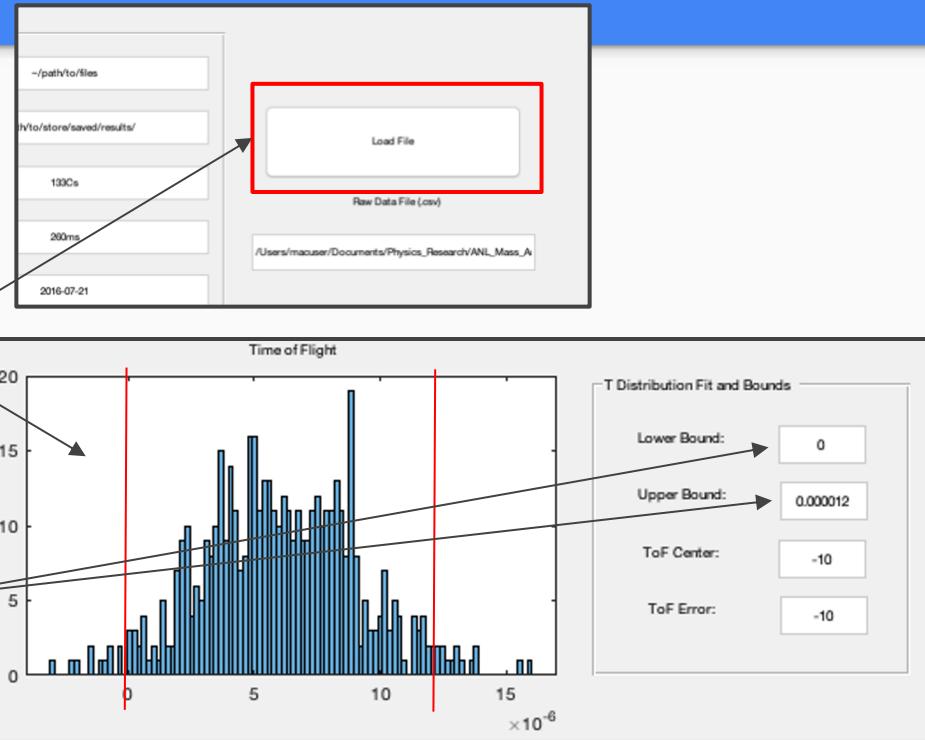
BEFORE YOU CONTINUE -- Simulated Data

- If you are fitting any simulated data (i.e. data produced from PI_ICR_simulated_data.m), **make sure the Sim Ion Rate checkbox is checked**
 - Since there is no count timing information from simulated data, leaving this unchecked will cause an error otherwise...



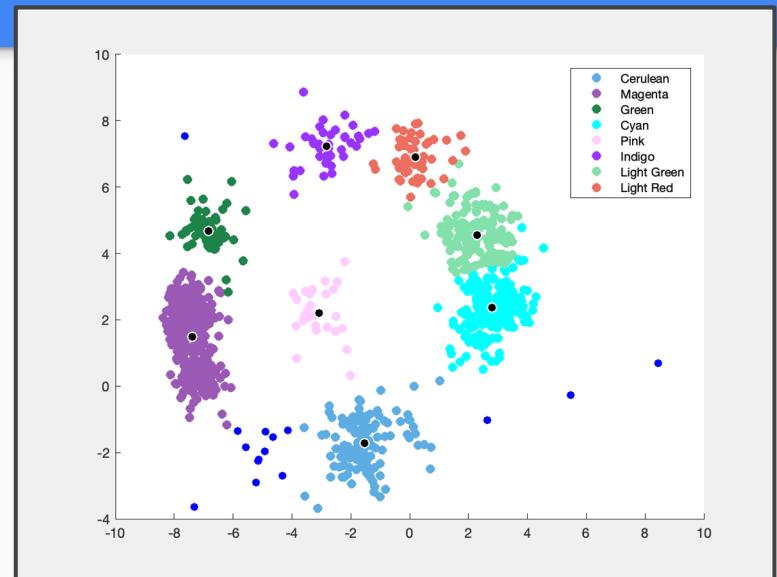
Before Automatic Fitting -- ToF Cuts

- Before automatic fitting, it's advised to apply a time of flight cut to throw away data outside of the expected times of flight (i.e. column 3 of each data .csv)
- Press Load File to load just the first file
 - Using the distribution seen in the ToF plot, determine bounds that cut out data outside of the counts majority
 - It's expected the distribution is pseudo-Gaussian
 - Put these bounds in the Lower Bound and Upper Bound boxes next to the ToF plot
- These will be taken into account when Automatic Fit is then pressed



Mean Shift Clustering

- Once Automatic Fit is pressed, the X/Y position data of each file is clustered into groups via a Mean Shift algorithm [1]:
 - Determines what cluster centers would have the highest density of nearest neighbors, and the groups those neighbors into a cluster



Mean Shift Clustering cont.

- The total number of cluster is NOT predetermined, depends on two user choices:
 - **Spot Bandwidth:** The effective “radius” of the cluster
 - A smaller value means smaller/finer clusters
 - **Points per Cluster:** Any resulting clusters that have less points than this value will instead belong to no cluster
- You will likely need to play around with these parameters to get clusters that represent what you would like/expect

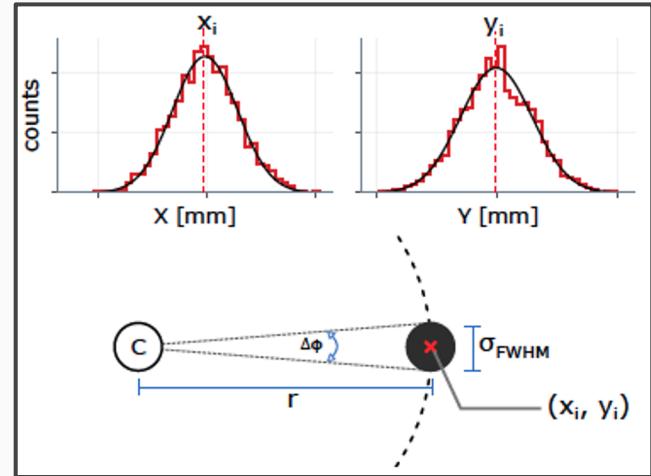
The screenshot shows a software interface for Mean Shift Clustering. Key parameters visible include:

- Cyclotron Frequency Guess (Hz): 114999.43806309
- Spot Angle (-180° to 180°): -30
- Load List of Files
- Automatic Fit
- Create Freq ID (unchecked)
- Finish Analysis (unchecked)
- Systematics
 - Impure Beam Angle Correction (unchecked)
 - Phase Cutoff (unchecked)
 - Value: 10
- Trap Center X: -2.31
- Trap Center Y: 2.83
- Magnetron Frequency (Hz): 1683
- Points per Cluster
 - Value: 20
 - Arrow pointing to the 'Points per Cluster' field
- Spot Bandwidth
 - Value: 1.25
 - Arrow pointing to the 'Spot Bandwidth' field

Fitting Clustered Data

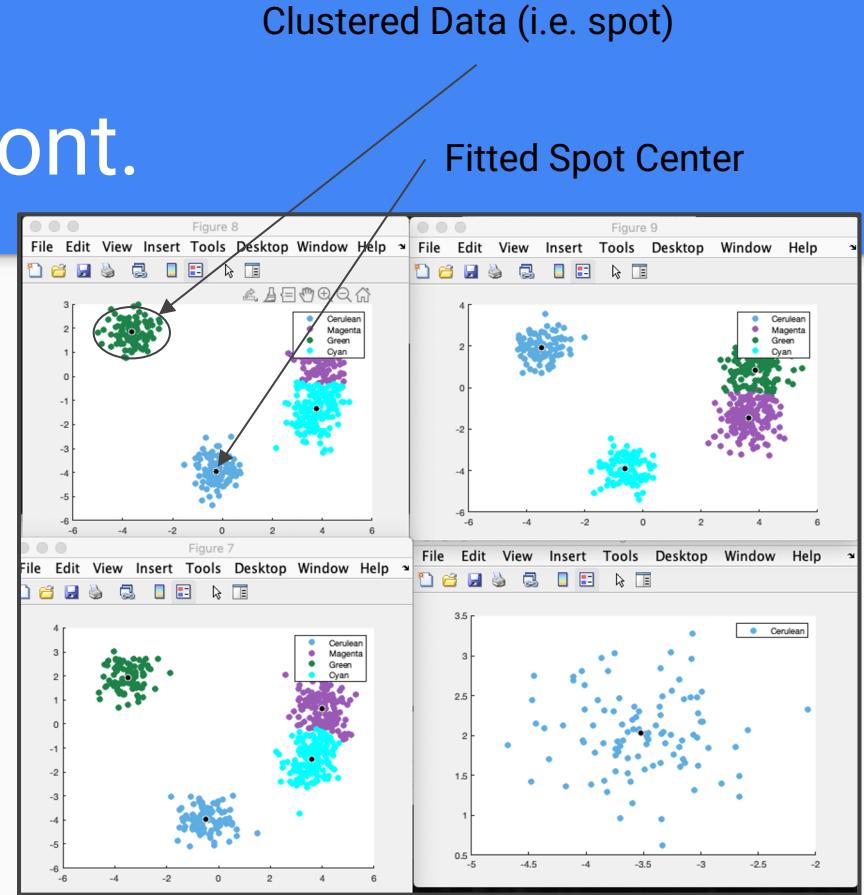
- The center of each cluster is determined by a 1D Gaussian fit in X/Y
 - via the Maximum Likelihood method
- The resulting fit parameters (mean and square root of the variance) are taken as the spot's center and standard deviation

```
[paramx,paramx_CI] = mle(data(myMembers,1),'distribution','norm','alpha',0.32);  
[paramy,paramy_CI] = mle(data(myMembers,2),'distribution','norm','alpha',0.32);
```



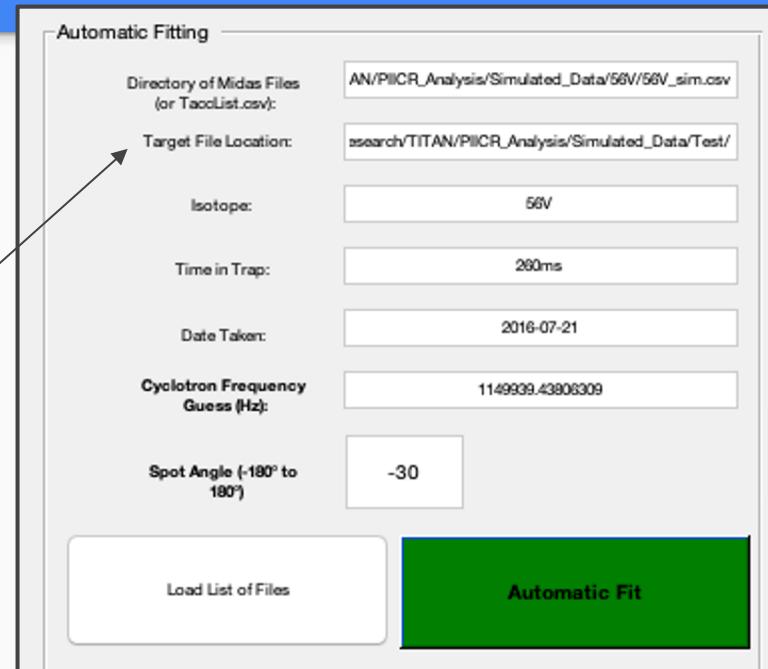
Fitting Clustered Data cont.

- Fits are done for every cluster in a file, and then resulting clusters (and unclustered points) and fit centers are plotted
 - PHIAT then cycles to the next file and does the same until all files have been fit
- If you have not checked any other boxes in the Automatic Fitting section, this is where the process stops



BEFORE YOU CONTINUE -- File Naming

- Checking other boxes in the Automatic Fitting section will result in files being saved and, thus, will need you to specify a file location (and some other parameters used in naming files):
- **Target File Location:** Folder in which resulting files will be saved (i.e.
`/Users/wsporter/Documents/Physics_Research/TITAN
/PIICR_Analysis/Simulated_Data/Test/`)



BEFORE YOU CONTINUE -- File Naming cont.

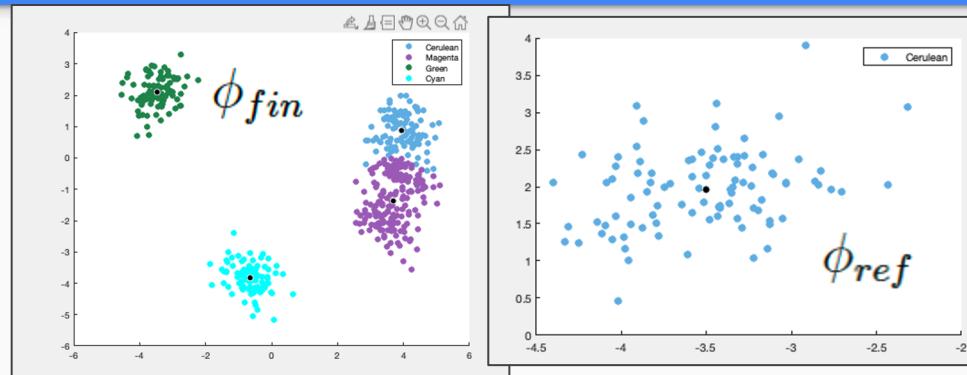
- **Isotope:** Primary mass of interest being analyzed
- **Time in Trap:** Total time ions spent inside the Penning trap
- **Date Taken:** Date file was taken
- These parameters are simply used in naming conventions, so their accuracy is only for user-benefit and has no effect on the analysis itself

Automatic Fitting

Directory of Midas Files (or TacList.csv):	AN/PIICR_Analysis/Simulated_Data/56V/56V_sim.csv
Target File Location:	research/TITAN/PIICR_Analysis/Simulated_Data/Test/
Isotope:	56V
Time in Trap:	280ms
Date Taken:	2016-07-21
Cyclotron Frequency Guess (Hz):	1149939.43806309
Spot Angle (-180° to 180°)	-30

Reference and Final Spots -- How It Works

- Each “final” file (Nonzero Tacc) has been paired with a “reference” file (Zero Tacc) in the `FileList.csv`
- Based on ordering in `FileList.csv`, “final” files were fit first, and “reference” files second
- This pairing is used when determining the phase difference (ϕ_c)



"Final" File: multiple spots

"Reference" File: one spot

$$\phi_c = \phi_{fin} - \phi_{ref}$$

Determining Phase – How It Works

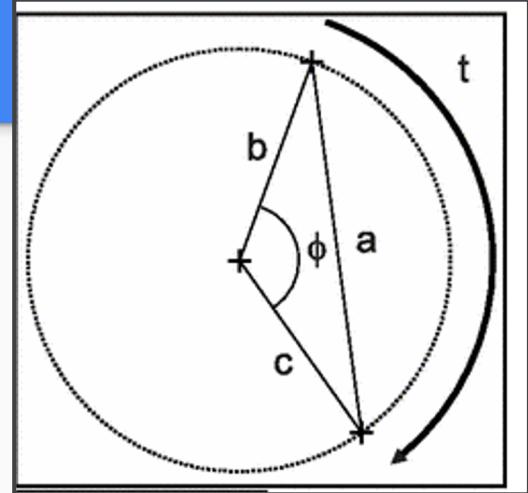
$$\phi_c = \arccos\left(\frac{b^2 + c^2 - a^2}{2bc}\right) \quad 0 \leq \phi \leq \pi$$

$$\phi_c = 2\pi - \arccos\left(\frac{b^2 + c^2 - a^2}{2bc}\right) \quad \pi < \phi < 2\pi$$

b: Distance from Trap Center to Reference Spot

c: Distance from Trap Center to Final Spot

a: Distance from Reference Spot to Final Spot



$$a = \sqrt{(x_{ref} - x_{fin})^2 + (y_{ref} - y_{fin})^2}$$

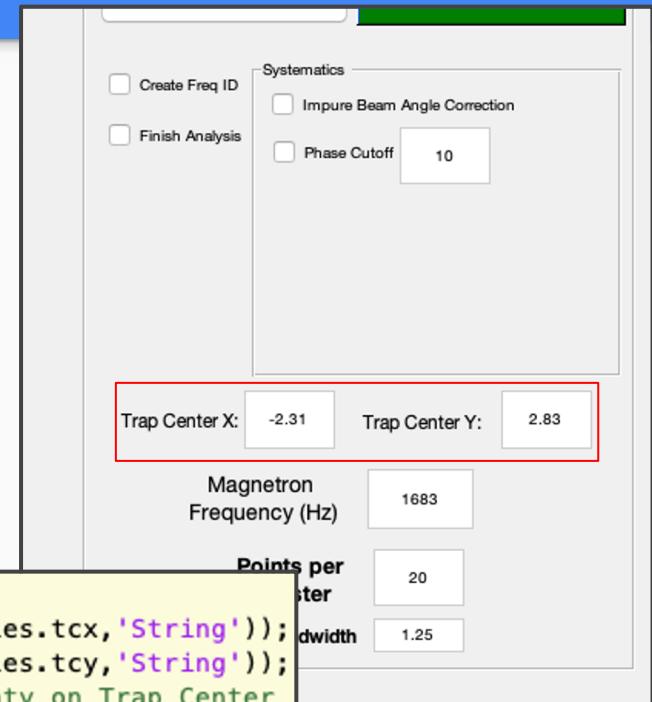
$$b = \sqrt{(x_{ref} - x_{CT})^2 + (y_{ref} - y_{CT})^2}$$

$$c = \sqrt{(x_{fin} - x_{CT})^2 + (y_{fin} - y_{CT})^2}$$

Determining Phase -- Trap Center

- The Trap Center [mm] is a user-defined input; make sure it reflects the most recent trap center determination to a given set of data
- The Trap Center uncertainty [mm] **must be changed in the script itself** (lines 556-557)
- **NOTE:** If using simulated data from PI_ICR_simulated_data.m, Trap Center is (0,0)

```
553 % Trap Center %%
554 - centerx = str2double(get(handles.tcx, 'String'));
555 - centery = str2double(get(handles.tcy, 'String'));
556 - centererrorx = 0.02; % Uncertainty on Trap Center
557 - centererrory = 0.02;
```



Finding Number of Turns -- How It Works

- To determine ω_c , we still need to know the number of turns (i.e. full revolutions) the ion made in the trap
 - $N(t_{acc})$
- We can't determine this experimentally, so we need to infer it
- This is done using the **guess cyclotron frequency (ω_c, guess)**

$$\omega_c = \frac{\phi_c + 2\pi N(t_{acc})}{2\pi t_{acc}}$$

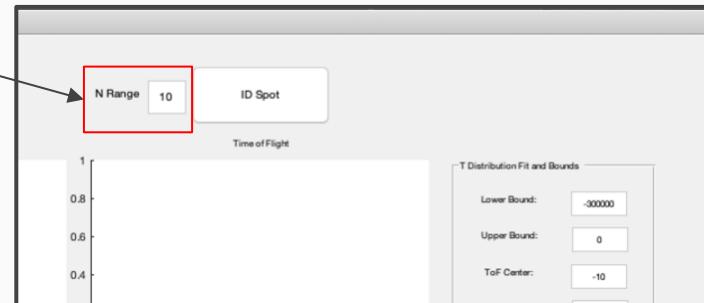
Isotope:	56V
Time in Trap:	280ms
Date Taken:	2016-07-21
Cyclotron Frequency Guess (Hz):	1149939.43806309
Spot Angle (-180° to 180°)	-30

Load List of Files Automatic Fit

Finding Number of Turns -- How It Works

- We determine the number of turns (N_{guess})
a spot would have given $\omega_c, guess$ and $\phi_c = 0$
- We then generate a range of N values, $N_{guess} - \lceil \frac{n_{range}}{2} \rceil$ to $N_{guess} + \lceil \frac{n_{range}}{2} \rceil$
where n_range is user-specified
- We then generate a cyclotron frequency
($\omega_{c,N}$) for every N value

$$\omega_c = \frac{\phi_c + 2\pi N(t_{acc})}{2\pi t_{acc}}$$



Create Freq ID Overview

- Checking Create Freq ID will create ID_Frequencies.csv, which contains the following data about **every spot in every 'final' file**:
 - Tacc [s]
 - Spot Color
 - Spot Angle [-180 to 180 deg] (w.r.t x-axis)
 - Ion Rate [counts/s]: Rate at which counts in a spot come in
 - Ion Percentage: Percentage of total counts (unnormalized)
 - Cyc Freq: Cyclotron frequencies $\omega_{c,N}$

A	B	C	D	E	F	G	H
Tacc	Spot_Color	Angle	Ion_Rate	Ion_Percentage	Cyc_Freq_6	Cyc_Freq_7	Cyc_Freq_8
0.6000002	Cerulean	-20.544541	0.0042485	0.4248497	1149930.19	1149931.85	1149932.51
0.6000002	Magenta	-136.61679	0.00186373	0.18637275	1149929.65	1149931.32	1149932.01
0.6000002	Green	-73.464039	0.00186373	0.18637275	1149929.94	1149931.61	1149932.29
0.6000002	Cyan	-37.091499	0.00146293	0.14629259	1149930.11	1149931.78	1149932.47
0.6000141	Cerulean	-22.764739	0.00372745	0.37274549	1149930.2	1149931.87	1149932.55

$$R_{spot} = \frac{\eta_{spot}}{\eta_{total}} \sum_{i=1}^n \frac{R_i}{n}$$

R_i = Rates from 3rd Column of ion_rate.csv

η_{spot} = Number of counts in spot

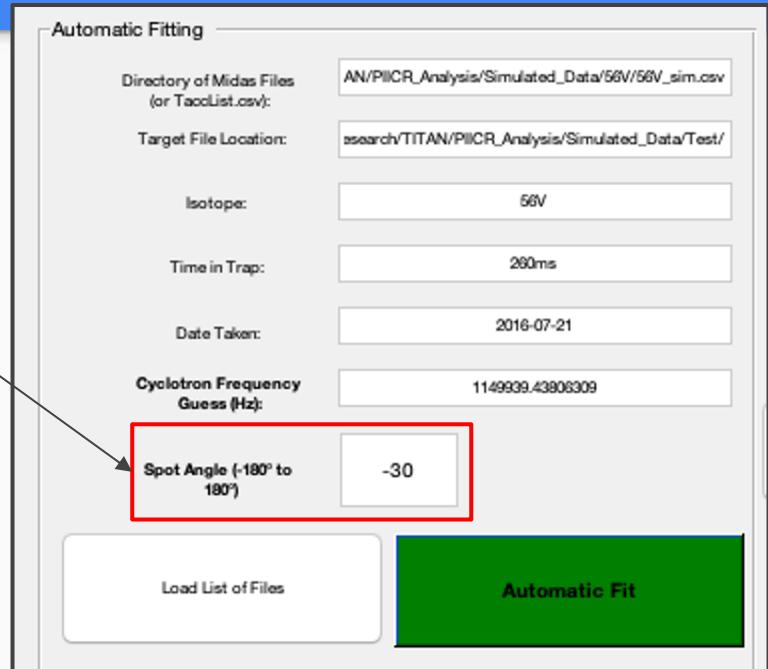
η_{total} = Total number of counts in file

Finish Analysis Overview

- Checking Finish Analysis will determine the final cyclotron frequency of one of the species present in the file by fitting a sinusoid to a spot's cyclotron frequency at each Tacc
- **Outputs:**
 - SineFit.png: An image of the ω_c vs. Tacc sinusoid fit
 - RadiusSineFit.png: An image of the Radius vs. Tacc sinusoid fit
 - Data.xlsx: Contains all relevant fitting information

Choosing a Spot/Species -- How It Works

- Select which species you'd like to finish analysis for by designating that spot's angle in **Spot Angle [deg]**
 - From -180 to 180 (w.r.t x-axis)
- For a set of files you want to 'finish analysis' on, all spots for a given species should be at a similar angle
 - This reasoning is discussed more in WHERE



Selecting ω_c from $\omega_{c,N}$ -- How It Works

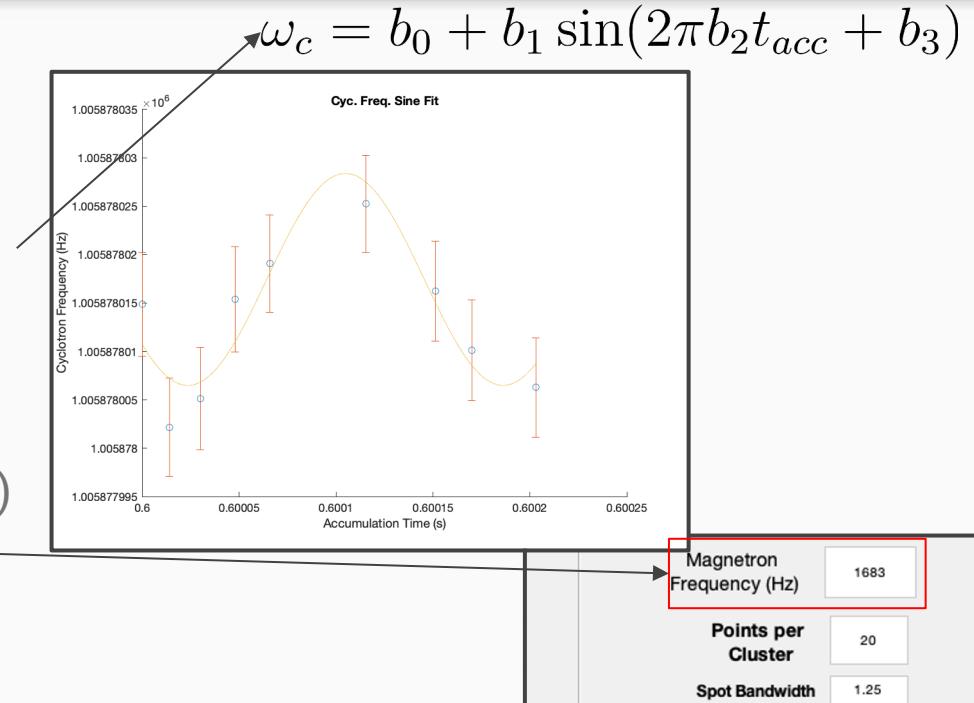
- We need to select one ω_c from the array of $\omega_{c,N}$ for each spot
- The ω_c **closest to $\omega_{c, \text{guess}}$** is selected, and thus is dependent on the user-input for Cyclotron Frequency Guess

Automatic Fitting

Directory of Midas Files (or TacList.csv):	AN/PIICR_Analysis/Simulated_Data/56V/56V_sim.csv
Target File Location:	research/TITAN/PIICR_Analysis/Simulated_Data/Test/
Isotope:	56V
Time in Trap:	260ms
Date Taken:	2016-07-21
Cyclotron Frequency Guess (Hz):	1149939.43806309
Spot Angle (-180° to 180°)	-30

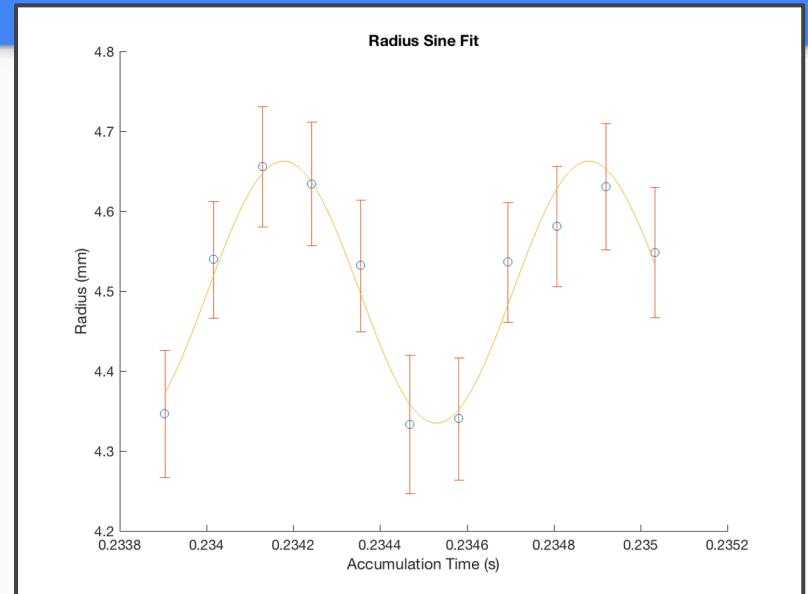
Sinusoid Fitting -- How It Works

- We now have a cyclotron frequency for our species at each Tacc
- We fit a 3-parameter sinusoid to ω_c , where **b₀** is our **true cyclotron frequency**
 - b₁ and b₃ are also fit, whereas b₂ is fixed at the **magnetron frequency** (ω_-)
 - ω_- is characteristic to the trap; make sure the user-input reflect the measurement most recent to the data



Radius Sinusoid Fitting -- How It Works

- The radii of the spots should also follow a similar sinusoid
- A 4-parameter sinusoid is fit to the radius data
 - This is only used to confirm the data is as expected
 - If the fit is poor, this can be a signal that something is wrong
- A .png image of both the w_c and Radius sinusoid fits is saved (SineFit.png and RadiusSineFit.png)

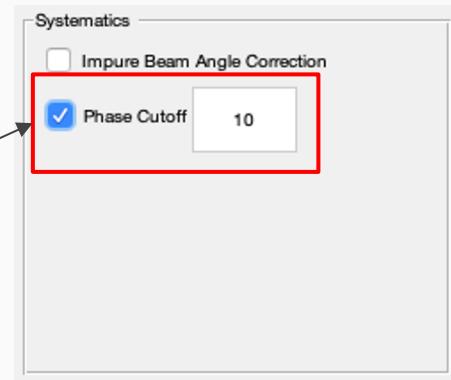


Data.csv

- Data.csv is saved, containing five tabs of relevant data:
 - Cyc. Freq. : The final cyclotron frequency, uncertainty and reduced Chi^2
 - Cyc. Freq. Data : The data input to sinusoid cyclotron frequency fit
 - Cyc. Freq. Fit Parameters: Resulting sinusoid fit parameters and uncertainties
 - Radius: The final radius, uncertainty and reduced Chi^2
 - Radius Fit Parameters: Resulting radius sinusoid fit parameters and uncertainties

Systematics -- Phase Cutoff

- To minimize effects of magnetic field misalignment, a phase cutoff can be applied to cut away any data points with a reference/final phase difference greater than a user-set value (in deg)
 - i.e. any data points with final/reference phase > 10 deg here are not incorporated into sinusoid fit
 - Only implemented when box is checked



Systematics -- Impure Beam Correction

- The presence of multiple species in a beam will shift the reference phase, as ions acquire a small amount of mass-dependent phase during the ω_+ excitation
- This is corrected for by:

$$\phi_{corr} = 2\pi t_{ex} \sum_i \chi_i (\omega_c^i - \omega_c)$$

χ_i : fractional percentage of the ith contaminant species

ω_c^i : cyclotron frequency of ith contaminant species

Φ_{corr} : phase correction for species of interest

ω_c : cyclotron frequency of species of interest

Systematics -- Impure Beam Correction

$$t_{ex} = \frac{1}{\nu_+} T_+ + \frac{1}{\nu_c} T_c$$

$$\phi_{corr} = 2\pi t_{ex} \sum_i \chi_i (\omega_c^i - \omega_c)$$

$\nu_{+/c}$: frequency of $\omega_{+/c}$ excitation pulses

$T_{+/c}$: periods of $\omega_{+/c}$ excitation pulses

χ_i : fractional percentage of the i th contaminant species

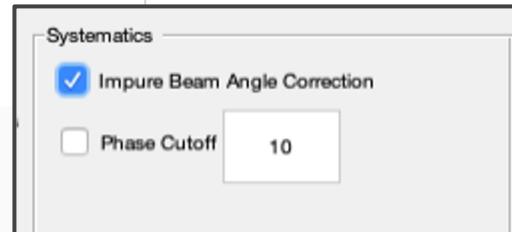
ω_c^i : cyclotron frequency of i th contaminant species

Φ_{corr} : phase correction for species of interest

ω_c : cyclotron frequency of species of interest

Systematics – Impure Beam Correction

```
if handles.angle_correction_impurebeam.Value  
  
    cyc_freq_list = [1081187.075,1081165.783,1081193.095]; % List of frequency of all species present in files  
    isotope_percentage_list = [0.071544715,0.144715447,0.699186992]; % Normalized percentage of counts in species spots in files (same order as above!)  
    cyc_freq_actual = 1081183.638; % Frequency of species of interest  
    correction_sum = 0;  
    i = 1;  
    size_cyc_list = size(cyc_freq_list);  
  
    while i <= size_cyc_list(2)  
        correction_sum = correction_sum + isotope_percentage_list(i)*(-cyc_freq_actual + cyc_freq_list(i));  
        i = i + 1;  
    end  
  
    t_exc = 0.0004904; % t_exc = Dipole Excitation Time + Quadrupole Excitation Time  
    angle_shift = 2*pi*t_exc*correction_sum  
  
    % Used if applying a global correction or global correction extreme  
    A1 = A1 + angle_shift;  
  
    % Used if applying a correction to each file  
    % A1(1) = A1(1) + 0.003914499  
    % A1(2) = A1(2) + -0.014409016  
    % A1(3) = A1(3) + 0.013170032  
end
```



- As of now, not automatically implemented, requires editing of code
- Only $cyc_freq_list (\omega_i^c)$, $isotope_percentage_list (\chi_i)$, $cyc_freq_actual (\omega_c)$ and $t_{exc} (t_{ex})$ will be changed
- Only implemented when box is checked

Systematics – Impure Beam Correction

```
if handles.angle_correction_impurebeam.Value

    cyc_freq_list = [1081187.075,1081165.783,1081193.095]; % List of frequency of all species present in files
    isotope_percentage_list = [0.071544715,0.144715447,0.699186992]; % Normalized percentage of counts in species spots in files (same order as above!)
    cyc_freq_actual = 1081183.638; % Frequency of species of interest
    correction_sum = 0;
    i = 1;
    size_cyc_list = size(cyc_freq_list);

    while i <= size_cyc_list(2)
        correction_sum = correction_sum + isotope_percentage_list(i)*(-cyc_freq_actual + cyc_freq_list(i));
        i = i + 1;
    end

    t_exc = 0.0004904; % t_exc = Dipole Excitation Time + Quadrupole Excitation Time
    angle_shift = 2*pi*t_exc*correction_sum

    % Used if applying a global correction or global correction extreme
    A1 = A1 + angle_shift;

    % Used if applying a correction to each file
    % A1(1) = A1(1) + 0.003914499
    % A1(2) = A1(2) + -0.014409016
    % A1(3) = A1(3) + 0.013170032
end
```

- If this is used,
percentages and
frequencies are global (i.e.
average over all files)

- If this is used,
percentages and
frequencies are for each
individual file and
manually applied in order
of fileList

Standard Analysis Procedure

- 1). Fit shorter Tacc files to determine potential cyclotron frequencies of unknown species
- 2). Once species identified, use higher Tacc files to find proper cyclotron frequency of species/ions of interest
- 3). Find cyclotron frequency of calibrant ion (separately taken data)
- 4). Determine mass excess from interest/calibrant ion frequencies using freq_to_mass_converter.m

Analysis Procedure Step 1

- Determine possible cyclotron frequencies of all spots in files with (relatively) shorter Tacc
- These Tacc are typically chosen arbitrarily, such that a certain species will NOT always end up at the same phase
 - This is critical, as it would be impossible to identify species via cyclotron frequencies if their spots were at the same phase across a set of files
- This is done via Create Freq ID and identifying common frequencies across files
 - NOTE: Here, use frequencies derived from AME as guess frequencies based on what is expected in the beam (TITAN-spreadsheet.xlsx will be helpful, see end for more details)

Analysis Procedure Step 2

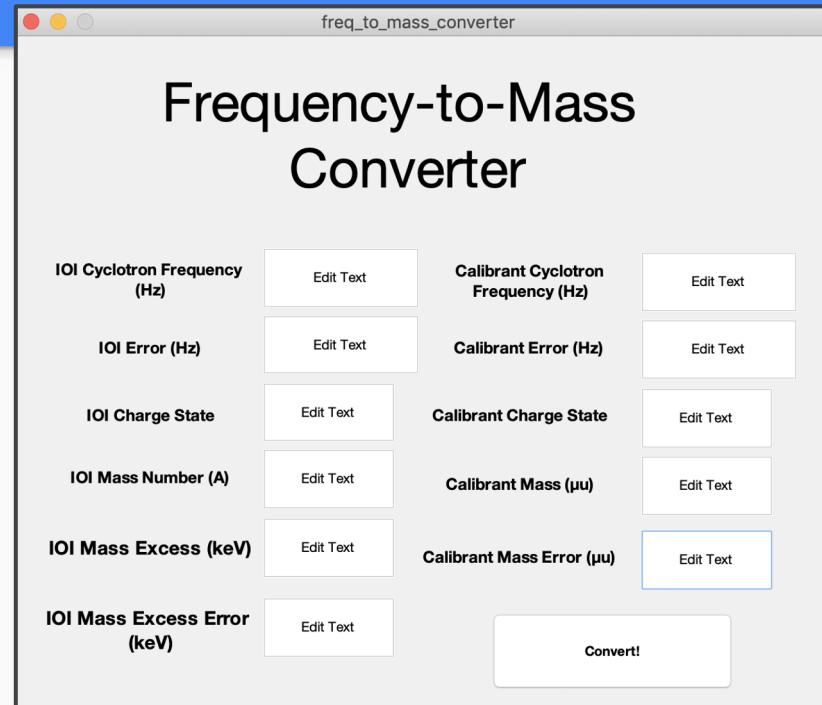
- Higher Tacc files are used to find the final cyclotron frequency (using sinusoid fitting)
 - These files will have Taccs chosen s.t. the ion of interest should be at similar angles close to the reference spot angle FOR ALL FILES
- The guess frequency here will be the frequency of the ion of interest species as determined in step 1
- The results of the sinusoid fit constitute the “final” cyclotron frequency for the ion of interest

Analysis Procedure Step 3

- The cyclotron frequency of a calibrant ion is determined using the same prescription as step 2
- Since calibrants are precisely known, the guess frequency can be derived from AME as in step 1

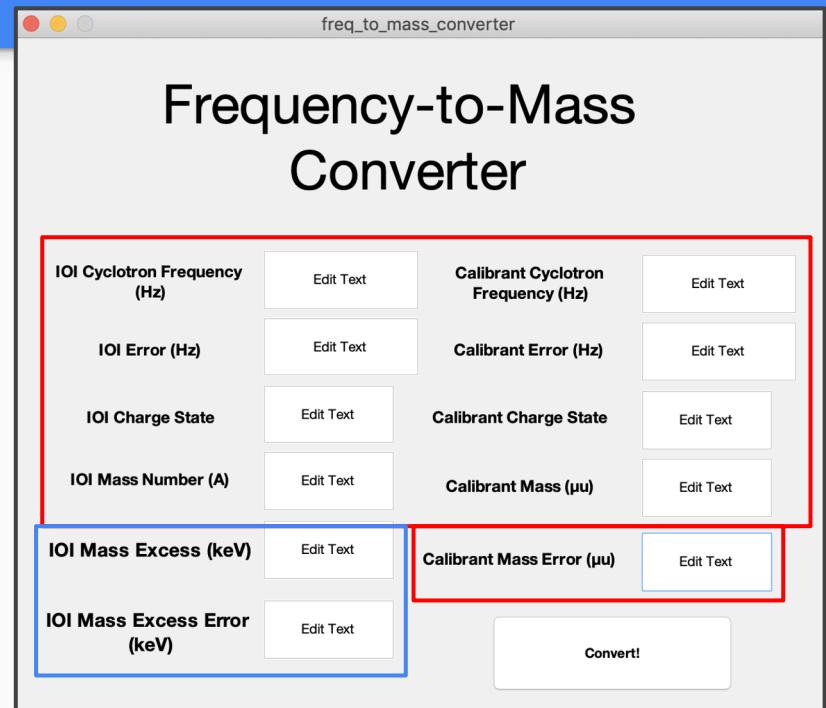
Analysis Procedure Step 4 - freq_to_mass_converter.m

- A separate GUI, freq_to_mass_converter, can be used to find the mass excess of the ion of interest from the frequencies of the ion of interest and calibrant



freq_to_mass_converter.m

- Blocks in red are user-input
- The output mass excess and error appear in the two boxes in blue when **Convert!** is pressed
- And there you go! We now have a final mass excess and error and have (in principle) completed the analysis process



TITAN_spreadsheet.xlsx

- A helpful, editable spreadsheet is included in the PhiAT package that includes masses, frequencies, phases, etc. -- TITAN_spreadsheet-YYYY.xlsx

TITAN_spreadsheet.xlsx -- Things that can be changed...

- Tacc (ms): Changing this changes the phases in columns T/U based on the corresponding frequency
- Ref Angle (deg): Set this as whatever angle the reference spot appears at for a given Tacc...this will shift all angles in column U appropriately given that reference spot

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
1	Species 1	# of Spec. 1	Species 2	# of Spec. 2	ICmt:	1.00E-03	Tacc (ms)	600.000	q	Mass (μu)	Omega-c (Hz)	Omega-minus (Hz)	Omega-plus (Hz)	Omega-z (Hz)	Tacc (ms)	n (minus)	n (plus)	n (s)	φ (c) (deg)	Ref Angle (deg)	MR-TOF separation (ns)	MR-TOF Time (ms)	e-mass (μu)
2	Species 1	# of Spec. 1	Species 2	# of Spec. 2	3	4	# of Spec. 3	4	# of Spec. 4											150	17.0	548.579	
3																							
4	85Rb	1							1	84911790	662795.000	6150.000	681224.0000	45589.3226	600.000	3690	396734	397677	48	-162	9/27/17		
5																							
6	11Li	1							1	11043724	5096246.874	6150.000	5094679.1158	#####	600.000	3690	3056808	3057749	52	-158	-9307860.432		
7																							
8	39K	1							1	38963706	1444409.260	6150.000	1442840.2795	67287.2710	600.000	3690	865704	866645	304	94	-1678301.977		
9																							
10	54Cr	1							1	53938877	1043390.616	6150.000	1041820.9784	57188.8345	600.000	3690	625092	626034	208	-2	0		
11	54Fe	1							1	53939608	1043376.479	6150.000	1041806.8413	57188.4471	600.000	3690	625084	626026	35	-175	115.169196		
12	54Mn	1							1	53940356	1043362.018	6150.000	1041792.3803	57188.0508	600.000	3690	625075	626017	151	-59	232.9787403		
13	54V	1							1	53946432	1043244.498	6150.000	1041674.8603	57184.8300	600.000	3690	625005	625946	327	117	1190.475829		
14	92Zr	1	160	1					2	107899950	1043175.986	6150.000	1041606.3480	57182.9522	600.000	3690	624964	625905	288	78	1748.755657		

TITAN_spreadsheet.xlsx -- Things that can be changed...

- Masses: Masses can be automatically input by putting an isotope in the Species 1 column (formatted AEI) and then designating the number of those isotopes in # of Spec. 1
 - Molecules are input by adding on appropriate isotopes and numbers in following columns
 - This automatically inputs the atomic mass in Column K

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
1				lcmt:		1.00E-03	Tacc (ms)	600.000	q	Mass (μu)	Omega-c (Hz)	Omega-minus (Hz)	Omega-plus (Hz)	Omega-z (Hz)	Tacc (ms)	n (minus)	n (plus)	n (c)	φ (c) (deg)	Ref Angle (deg) 150	MR-TOF separation (ns)	MR-TOF Time (ms)	e-mass (μu)
2	Species 1	# of Spec. 1	Species 2	# of Spec. 2	3	# of Spec. 3	4	# of Spec. 4													17.0	548.579	
3																							
4	85Rb	1							1	84911790	862735.000	6150.000	681224.0000	45380.3226	600.000	3690	396734	397677	48	-162		9/27/17	
5																							
6	11Li	1							1	11043724	5096246.874	6150.000	5094679.1158	#####	600.000	3690	3056808	3057749	52	-158		-9307860.432	
7																							
8	39K	1							1	38963706	1444409.260	6150.000	1442640.2795	67287.2710	600.000	3690	865704	866645	304	94		-1678301.977	
9																							
10	54Cr	1							1	53938877	1043390.616	6150.000	1041820.9784	57188.8345	600.000	3690	625092	626034	208	-2		0	
11	54Fe	1							1	53939608	1043376.479	6150.000	1041806.8413	57188.4471	600.000	3690	625084	626026	35	-175		115.169196	
12	54Mn	1							1	53940356	1043362.018	6150.000	1041792.3803	57188.0508	600.000	3690	625075	626017	151	-59		232.9787403	
13	54V	1							1	53946432	1043244.498	6150.000	1041674.8603	57184.8300	600.000	3690	625005	625946	327	117		1190.475829	
14	92Zr	1	16O	1					2	107899950	1043175.986	6150.000	1041606.3480	57182.9522	600.000	3690	624964	625905	288	78		1748.755657	

- Please contact Sam Porter (wporter@triumf.ca) if you have any questions
- Happy PI-ICRing!

References

[1]: D. Comaniciu and P. Meer, "Mean shift: a robust approach toward feature space analysis," in IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 24, no. 5, pp. 603-619, May 2002, doi: 10.1109/34.1000236.