Interferometry Upgrade

UROP 2019

Alie Craplet - 09/10/19

Summary

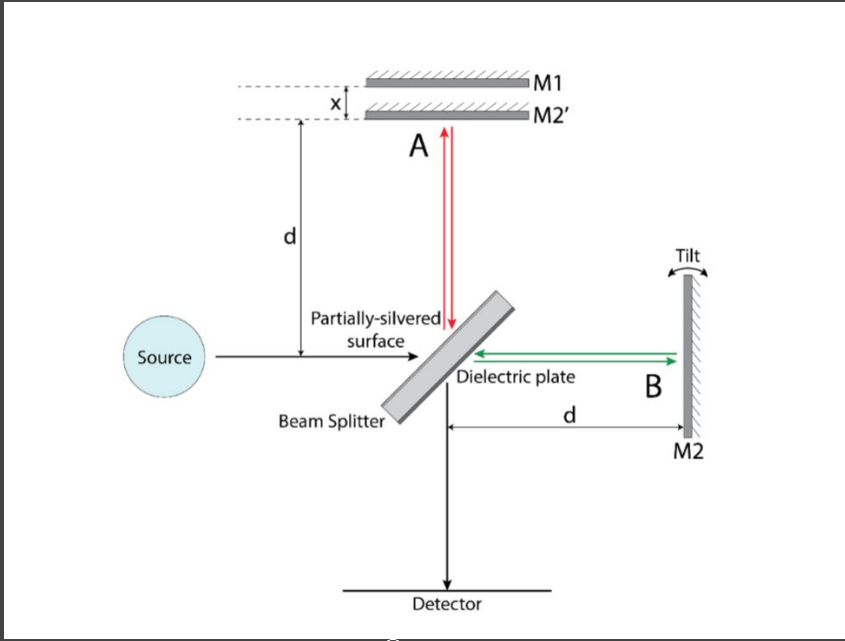
I/ The Experiment

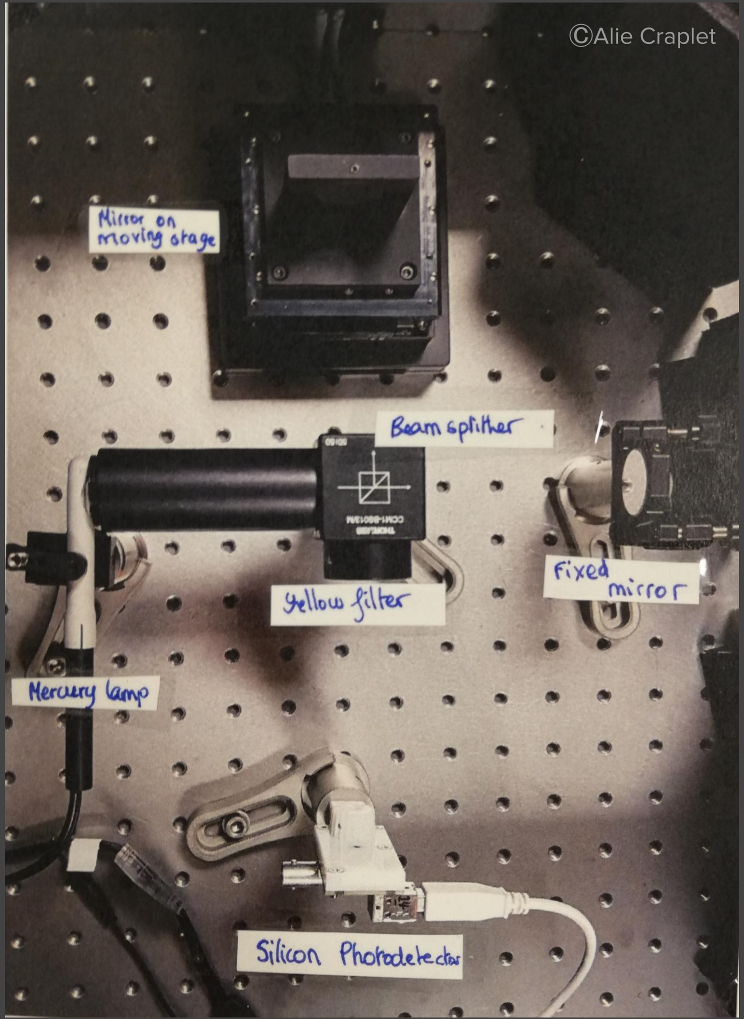
II/ Designing the correcting software

III/ Assembling a technical portfolio

VI/ Future prospects

I/The initial set-up



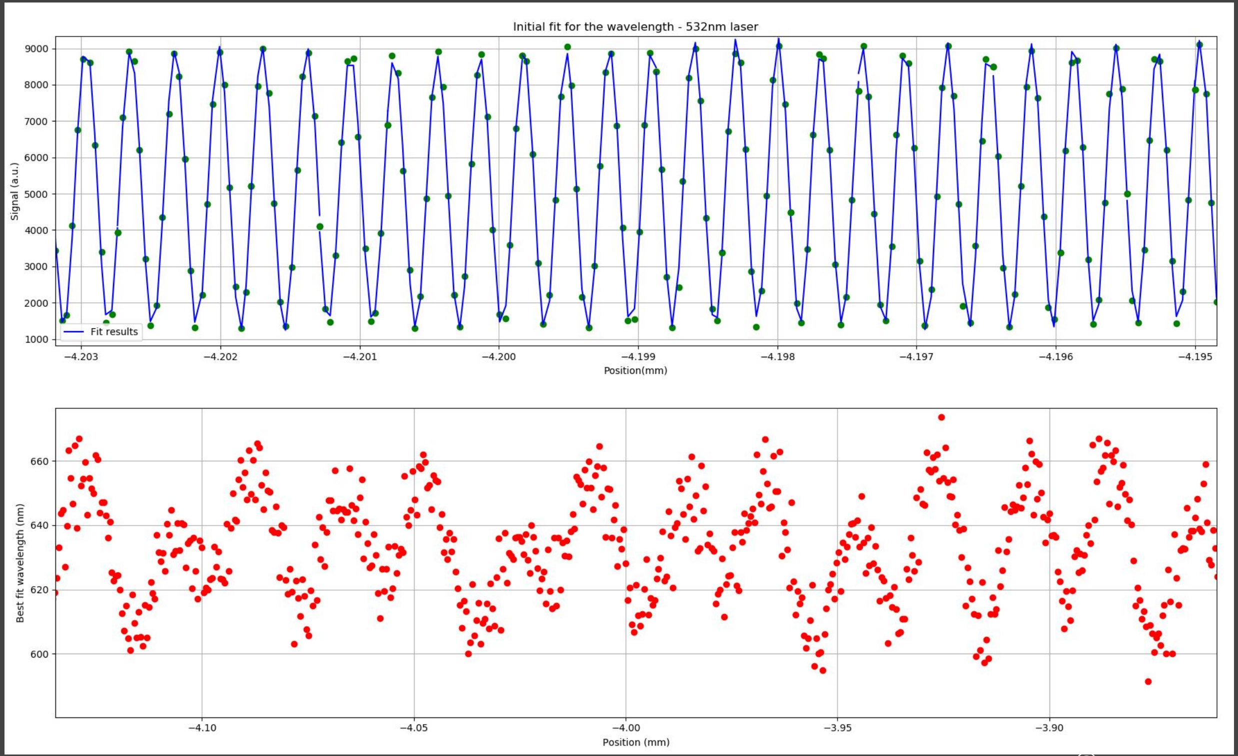


Set-up inspired by Michelson's Interferogram

A problem

Result of the sinusoidal fit for a monochromatic green laser, wavelength 532nm.

A typical pattern seems to occur, centered roughly on the right value with a spread of ~80nm.



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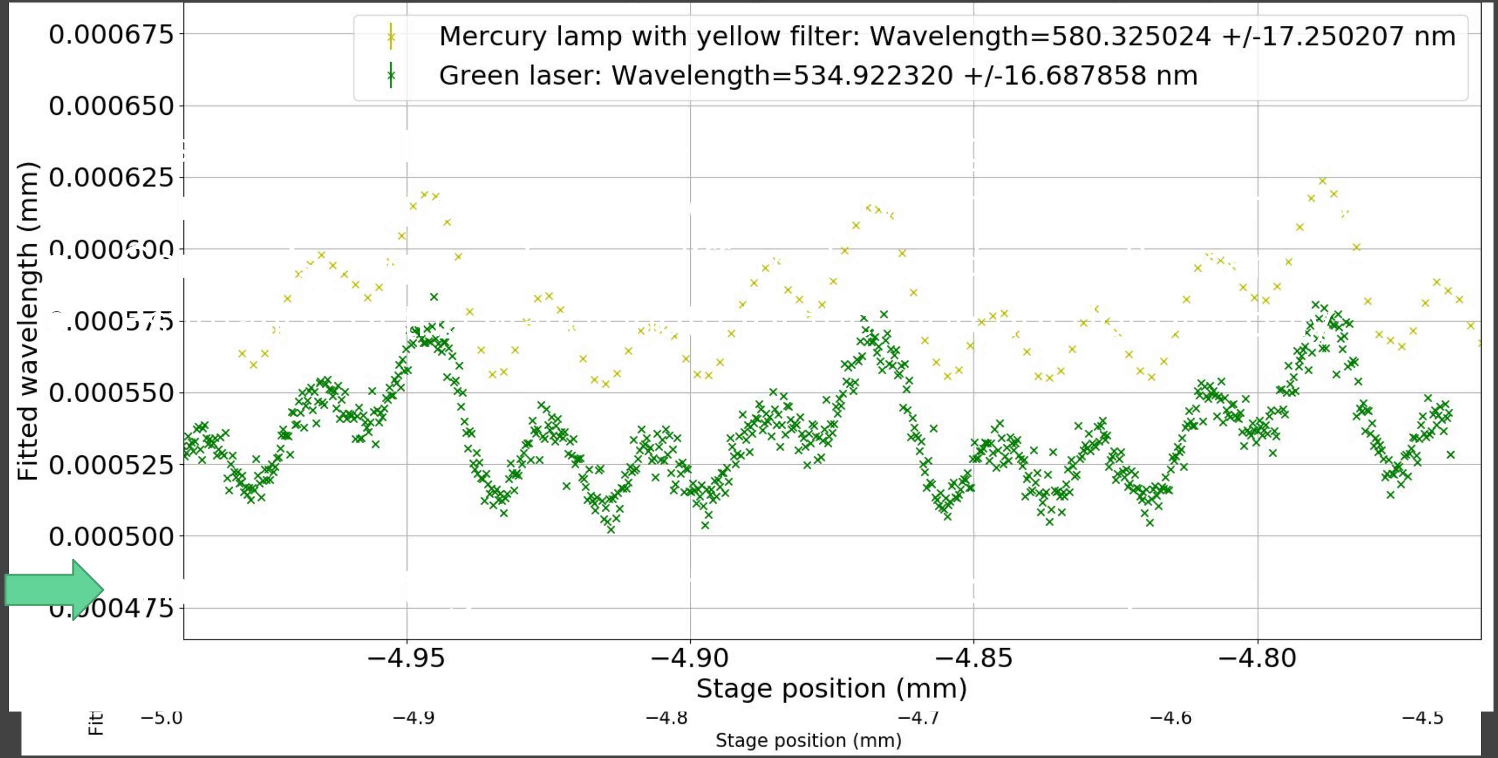
Further investigations

- Comparison of green laser and mercury light over the same range

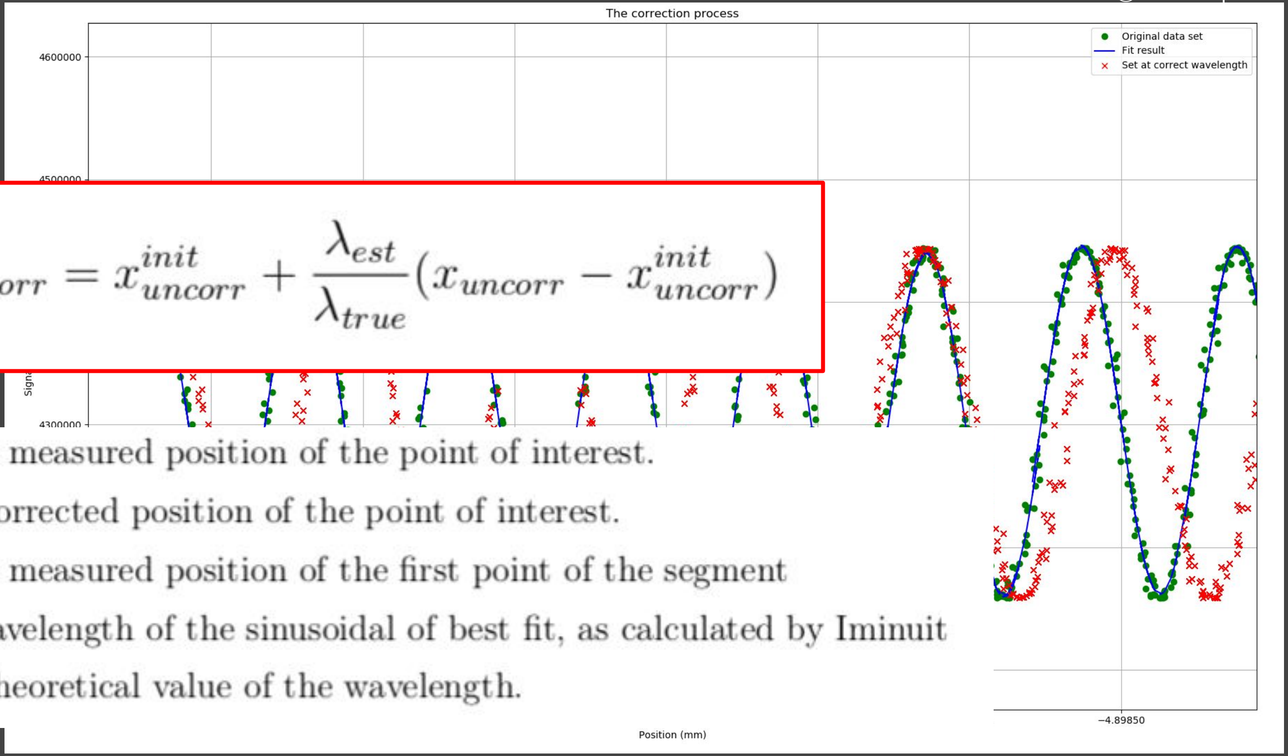


II/ Designing a correcting software

Monochromatic laser data (green) and its initial fit (blue).

The red corresponds t the sinusoidal with th fitted parameters and the correct wavelength

The position is lagging b true position stage.

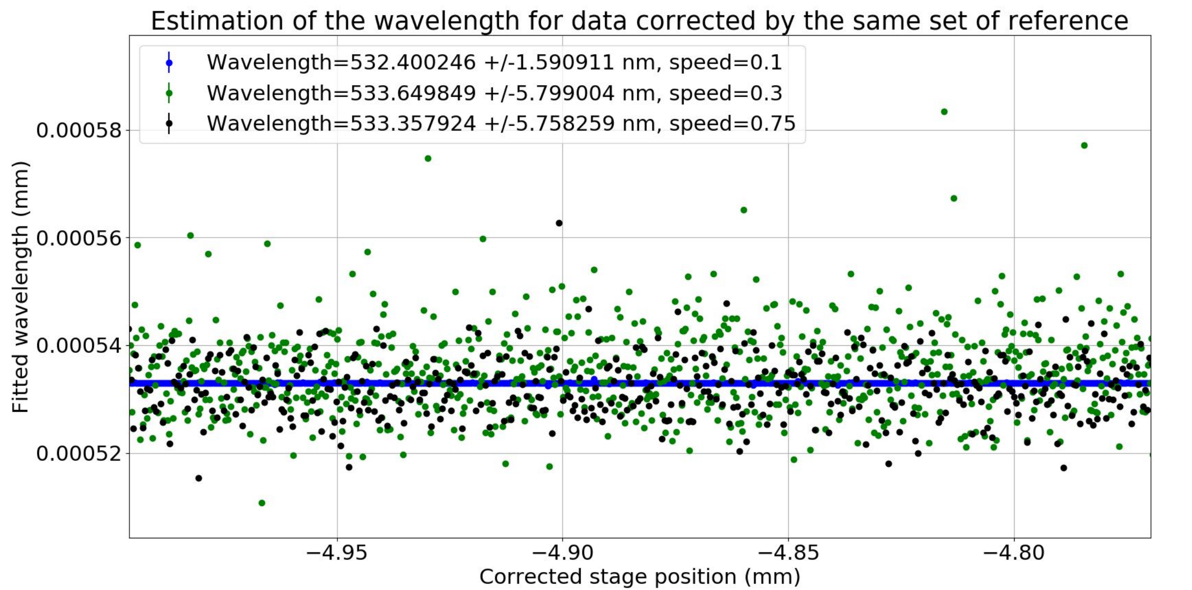


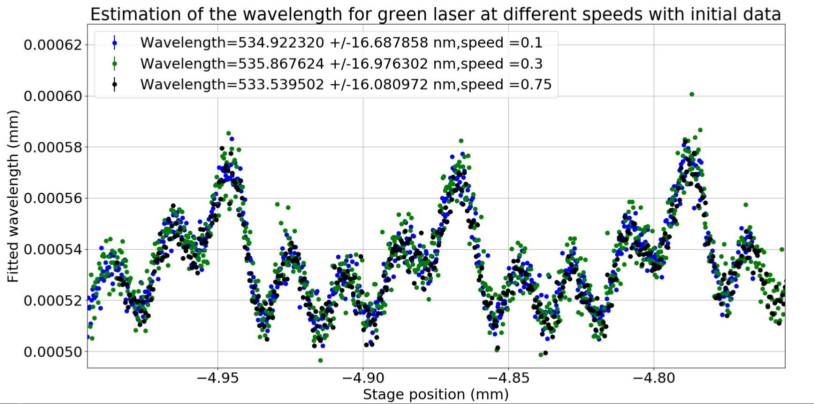
$$x_{corr} = x_{uncorr}^{init} + \frac{\lambda_{est}}{\lambda_{true}}(x_{uncorr} - x_{uncorr}^{init})$$

- x_{uncorr} is the measured position of the point of interest.
- x_{corr} is the corrected position of the point of interest.
- x_{uncorr}^{init} is the measured position of the first point of the segment
- λ_{est} is the wavelength of the sinusoidal of best fit, as calculated by Iminuit
- λ_{true} is the theoretical value of the wavelength.

Results - Green laser - A1

For all these runs with the green laser, the blue data is used as reference for the correction.



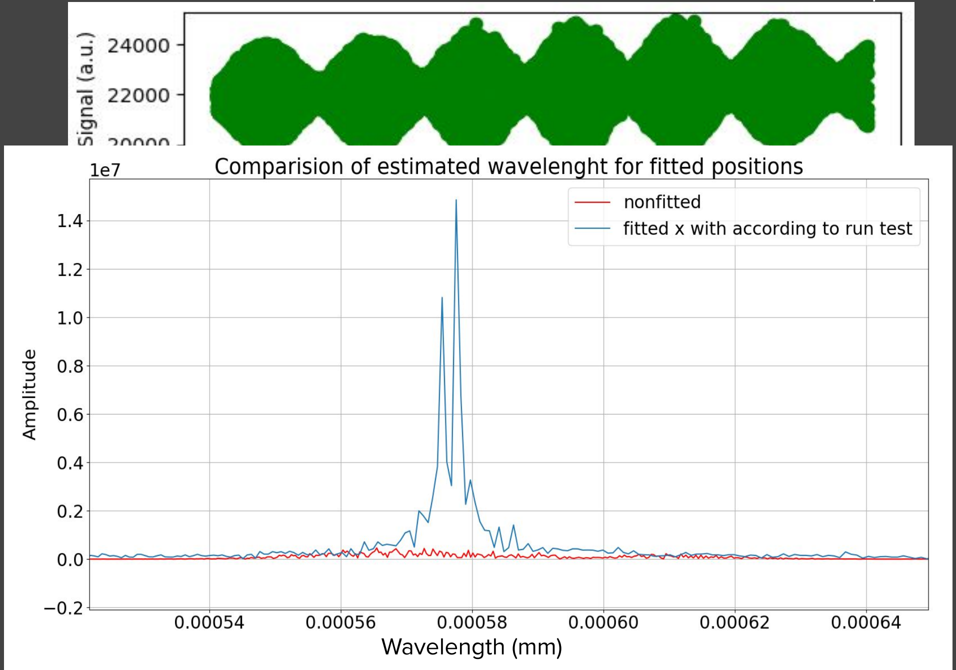


The theoretical value of the wavelength is 532.8nm. Error is given as 1 standard deviation.

Results - Mercury lamp with yellow filter - A1

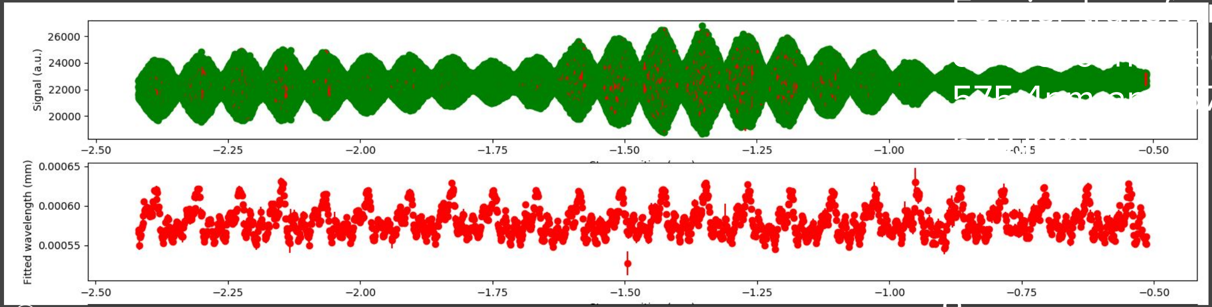
The correction largely reduced the spread in wavelength.

A set of uniformly spaced data points is required for a Fourier transform - regularly sampling along the line of best fit.



m of the initial mercury signal (red) and ed signal (blue). The two peaks are at 77.6nm (theoretical values 576.9nm and

The wavelength before any correction



Second approach (A2) - Simultaneous corrections

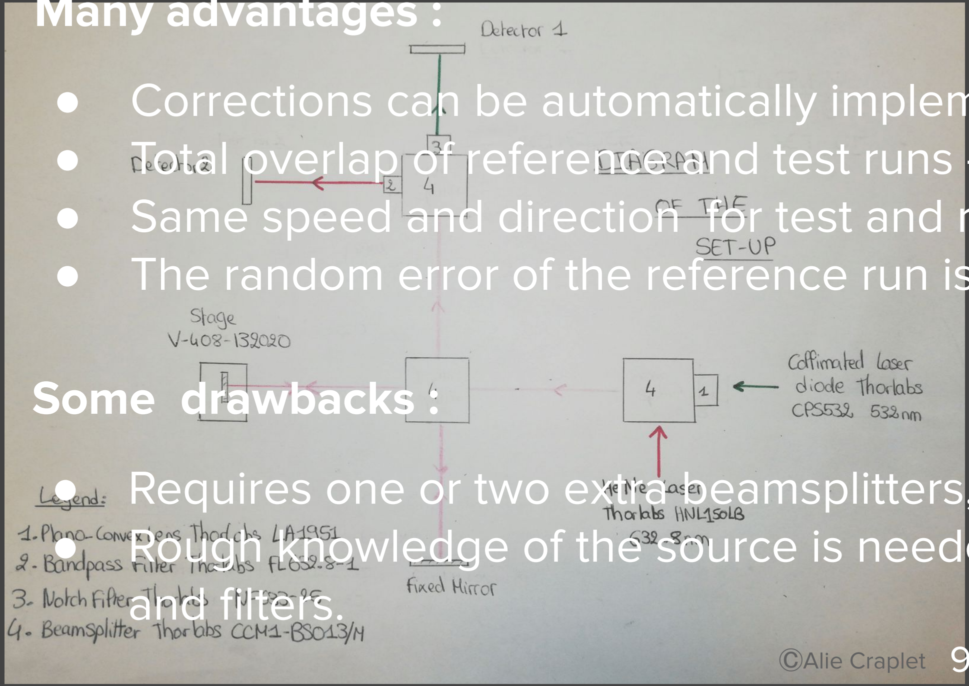
The updated set-up includes two light sources recorded and analysed simultaneously.

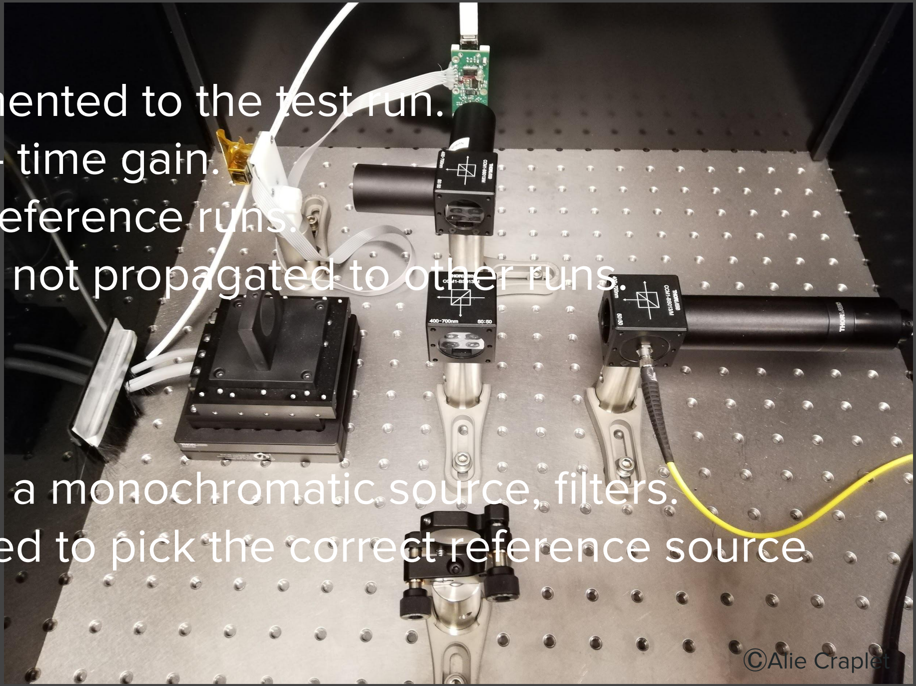
Many advantages :

- Corrections can be automatically implemented to the test run.
- Total overlap of reference and test runs - time gain.
- Same speed and direction for test and reference runs.
- The random error of the reference run is not propagated to other runs.

Some drawbacks :

- Requires one or two extra beamsplitters, a monochromatic source, filters.
- Rough knowledge of the source is needed to pick the correct reference source and filters.





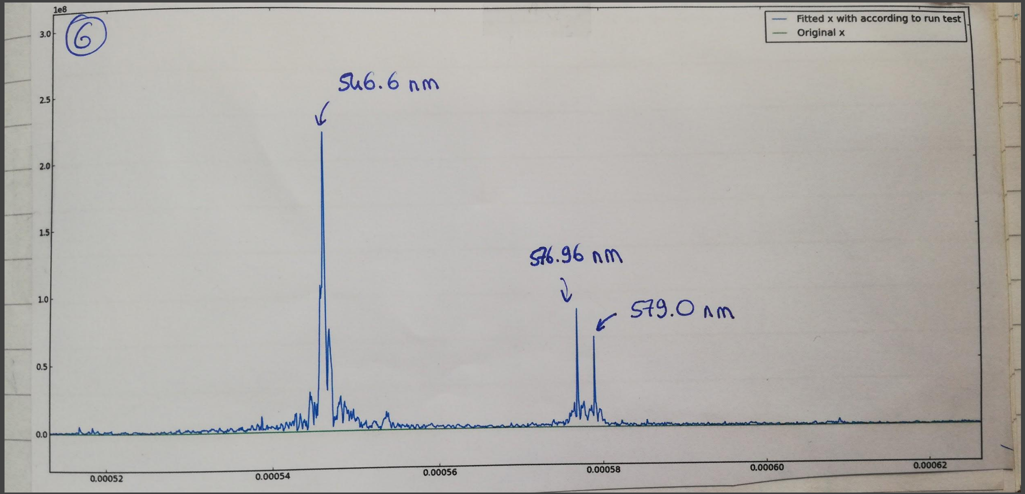
Results - Mercury lamp without filter - A2

Reference values for the emission lines of mercury :

546.08 nm - green line
576.96 nm - yellow doublet line 1
579.08 nm - yellow doublet line 2

Ref: J. Phys. Chem. Ref. Data 35, E. B. Saloman, 2006

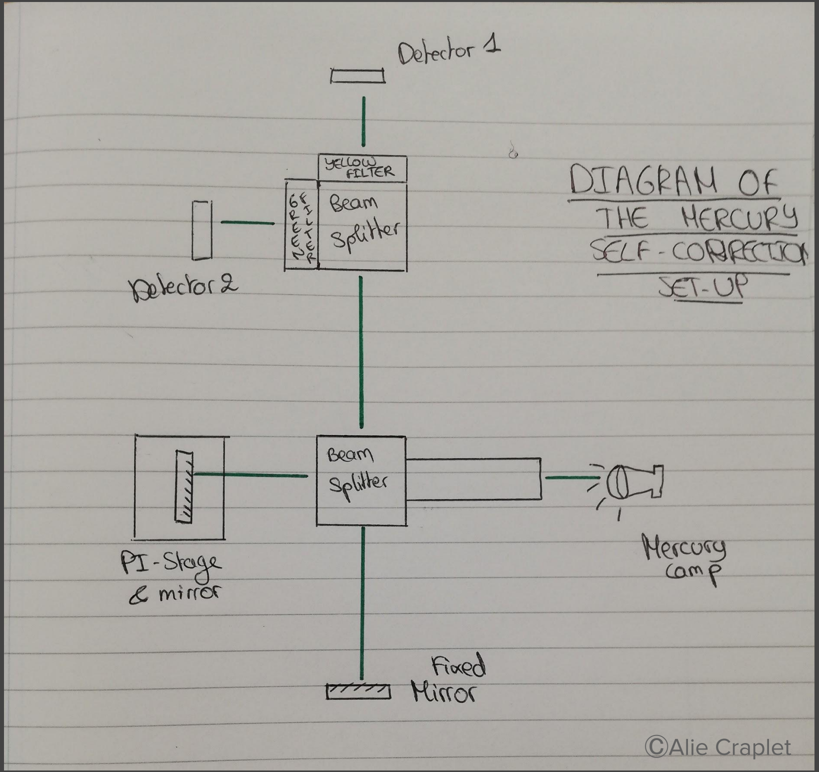
Fourier transform of the mercury light, corrected using the red laser data (simultaneous correction)



Alternative set-up (A3)- mercury ‘self correction’

Due to the lack of lasers, the students will not be working with the red lasers but will instead use the mercury single line as the monochromatic reference light.

We will encourage the students to devise themselves how to upgrade their set-up from the one detector version to the two detectors with mercury.

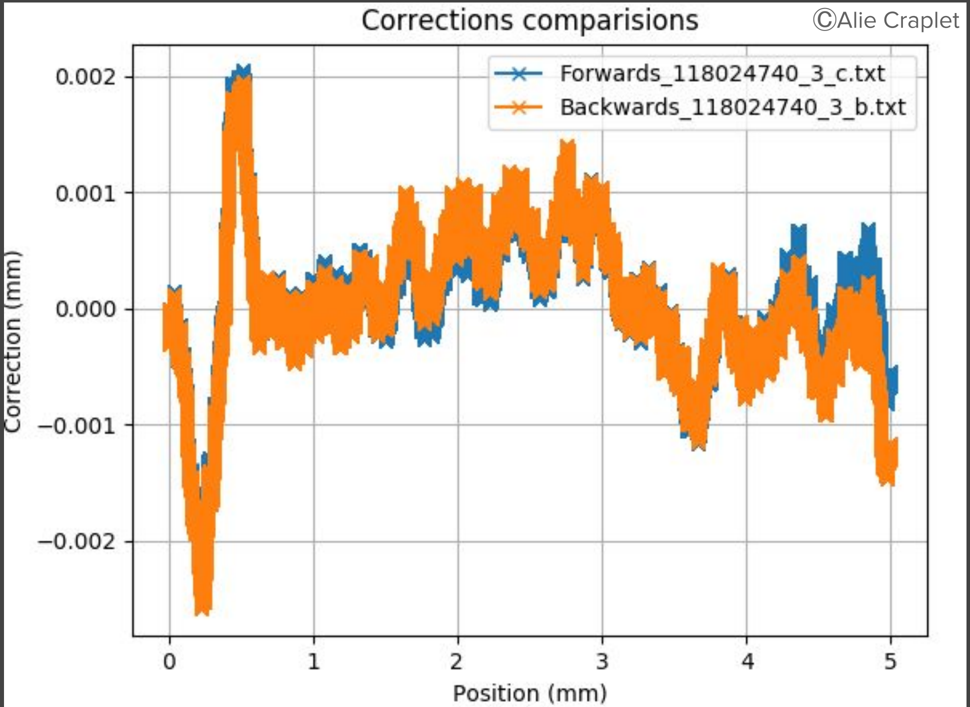


III/Building a technical case against PI

I had to build a technical case in order to get a refund from PI.

For each stage the whole range was sampled four times going different directions.

A file explaining the code and describing the set-up used was also built.



Overlay of the corrections applied to the stage position showing very good agreement between backwards and forwards runs with the red laser

Outcome

PI recognises there is an error.

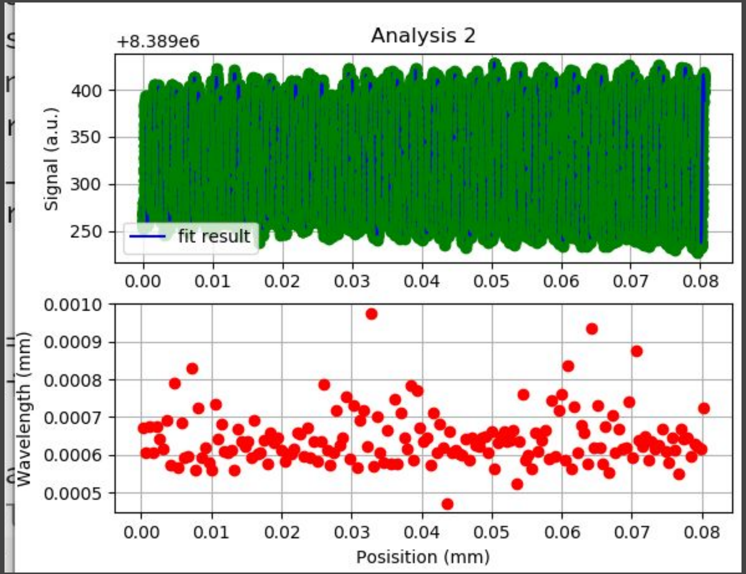
They propose to repair the hardware, causing a reduction in the range of movement.

More testing will be required as the ‘repaired’ stages come back to insure they are up to our standards.

IV/ Future prospects - Stages built in-house

Helping with the testing of the ‘repaired’ stages, as they arrive.

Continue the work on the in-house built prototype (mainly software design).



Fit of the green laser **after** the position correction with the new stage prototype.

The wavelength is : 642.4 +/- 69.7nm.

Not nearly precise enough to provide a good correction but we are optimistic it can be improved.

Conclusion

A cheap and efficient way of increasing the resolution of a simple set-up, up to research-level accuracy.

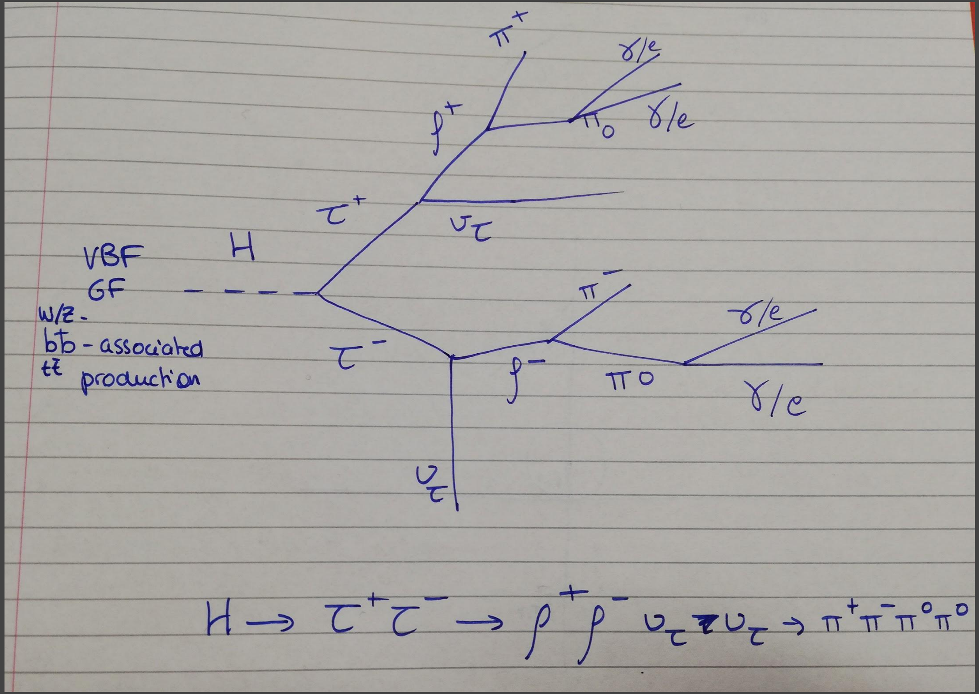
The students get to investigate a source of systematic error and understand the concept behind corrections from a known source.

The stages repairing process is under way and looks relatively promising.

Thank you for your attention

Any questions ?

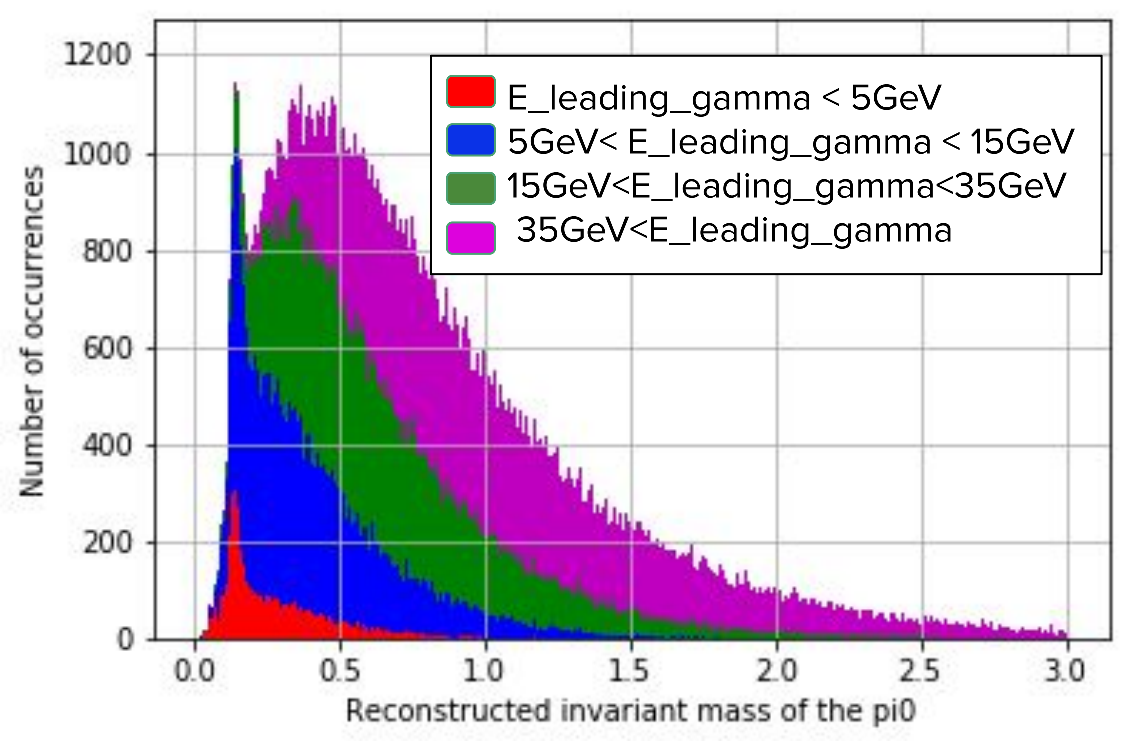
Additional Figures - CMS Higgs to tau experiment



The decay chain we were focussing on.

The determination of the photons' coordinates give informations about the pi0 and rho variables, important in further analysis of the Higgs CP properties.

Additional figure - HPS estimation of the pi0 mass



Estimation of the pi0 mass by the HPS algorithm (Two leading gammas).

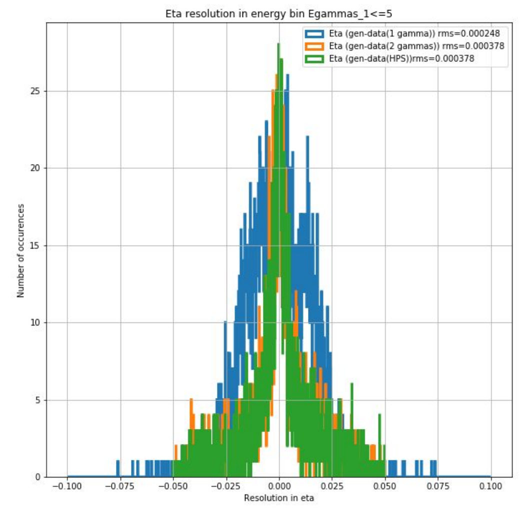
The peak is close to 139 MeV, the mass of the pi0. The tail should corresponds to pile-up events and other noises.

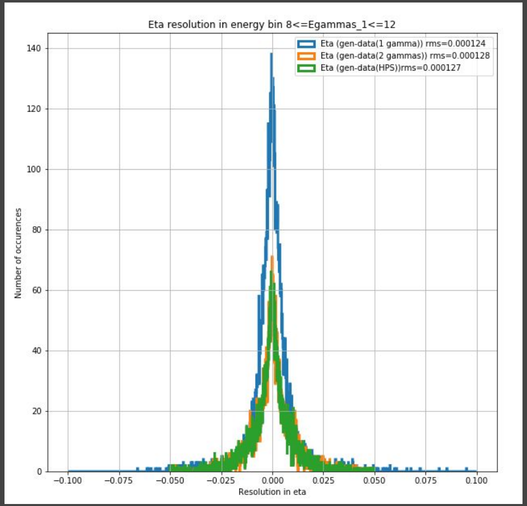
Note that at high energy for the pi0 the pi0 peak is better resolved.

Filters applied:
-tau_decay_mode_1==1
-tauFlag1==1

Additional figures - Eta resolution w.r.t energy of the leading gamma

Resolution in pi0's Eta for the different methods in the bin E_gamma1 < 5GeV.





Resolution in pi0's Eta for the different methods in the bin 8 < E_gamma1 < 12 GeV.

The resolution depends on the technique used. Three different eta estimations :

- 1 gamma (blue) : Taking the coordinate of the leading gamma as the coordinate of the pi0
- 2 gamma (orange) : Taking the coordinates of the 4 vector sum of the two leading gamma as pi0 coordinates
- HPS (green) : coordinates of the pi0 as calculated by the HPS algorithm (including all photons).

Additional Figures - Reconstruction of pi0 from CMS data

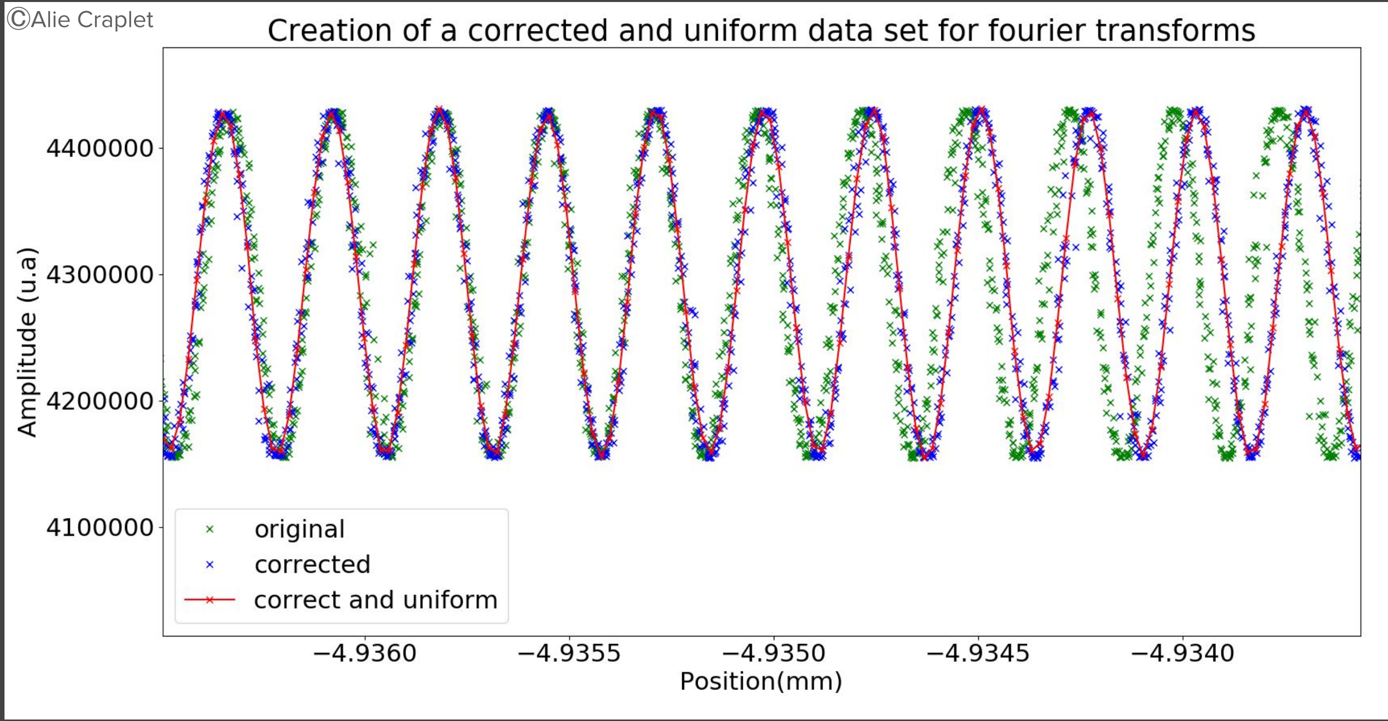
Second round of mva	Standard deviation (g-r)/(	Ngammas_1 (binary)	Etagammas_1	Etagammas_2	Etapi0_2	Etapi0_1	Ptgammas	Ptgammas_2	o8/u8
u8_s_N_Eta1_Eta2_Etapi02_EtaH_pt1_pt2	1.94122845969285	y	y	y	y	y	y	y	u8
u8_s_Eta1_Eta2_Etapi02_EtaH_pt1	2.07707956622161	n	y	y	y	y	y	n	u8
u8_s_N_Eta1_Eta2_Etapi02_EtaH_pt1	2.10420312326156	y	y	y	y	y	y	n	u8
u8_s_N_Eta1_Eta2_Etapi02	2.28557758623186	y	y	y	y	n	n	n	u8
u8_s_N_Eta1_Eta2_Etapi02_EtaH	2.28797031412217	y	y	y	y	y	n	n	u8
u8_s_Eta1_Eta2_Etapi02	2.40175873550143	n	y	y	y	n	n	n	u8
u8_s_Eta1_Eta2_Etapi02_EtaH	2.52635219309505	n	y	y	y	y	n	n	u8
u8_s_Eta1_Eta2_Etapi02_EtaH_pt1_pt2	2.6762214986928	n	y	y	y	y	y	y	u8
u8_s_N_Eta1_Eta2	2.69259171736872	y	y	y	n	n	n	n	u8
u8_s_Eta1_Eta2	3.06995858069426	n	y	y	n	n	n	n	u8
u8_s_N_Eta1	13.3675985758414	y	y	n	n	n	n	n	u8
u8_s_Eta1	42.6941709926467	n	y	n	n	n	n	n	u8

Resolution without mva (g-r)/g	M1	M2	MH
u8	3.1317139	16.367477	16.367477
o8	5.141333	5.813936	6.3398895

Second round of mva	Standard deviation (g-r)/(	Ngammas_1 (binary)	Etagammas_1	Etagammas_2	Etapi0_2	Etapi0_1	Ptgammas	Ptgammas_2	o8/u8
o8_s_N_Eta1_Eta2	0.807703999500236	y	y	y	n	n	n	n	o8
o8_s_Eta1_Eta2_Etapi02_EtaH_pt1	0.815077938668343	n	y	y	y	y	y	n	o8
o8_s_N_Eta1	0.893449791678482	y	y	n	n	n	n	n	o8
o8_s_Eta1_Eta2	0.898325855730188	n	y	y	n	n	n	n	o8
o8_s_N_Eta1_Eta2_Etapi02	1.04604531098863	n	y	y	y	n	n	n	o8
o8_s_Eta1_Eta2_Etapi02_EtaH	1.15754587177046	n	y	y	y	y	n	n	o8
o8_s_Eta1_Eta2_Etapi02_EtaH_pt1_pt2	1.39989546316907	n	y	y	y	y	y	y	o8
o8_s_N_Eta1_Eta2_Etapi02	1.42495554147149	y	y	y	y	n	n	n	o8
o8_s_Eta1	1.46002340388645	n	y	n	n	n	n	n	o8
o8_s_N_Eta1_Eta2_Etapi02_EtaH_pt1	2.05676636373049	y	y	y	y	y	y	n	o8
o8_s_N_Eta1_Eta2_Etapi02_EtaH	3.37344262470728	y	y	y	y	y	n	n	o8
o8_s_N_Eta1_Eta2_Etapi02_EtaH_pt1_pt2	4.93523039518115	y	y	y	y	y	y	y	o8

(GeV)

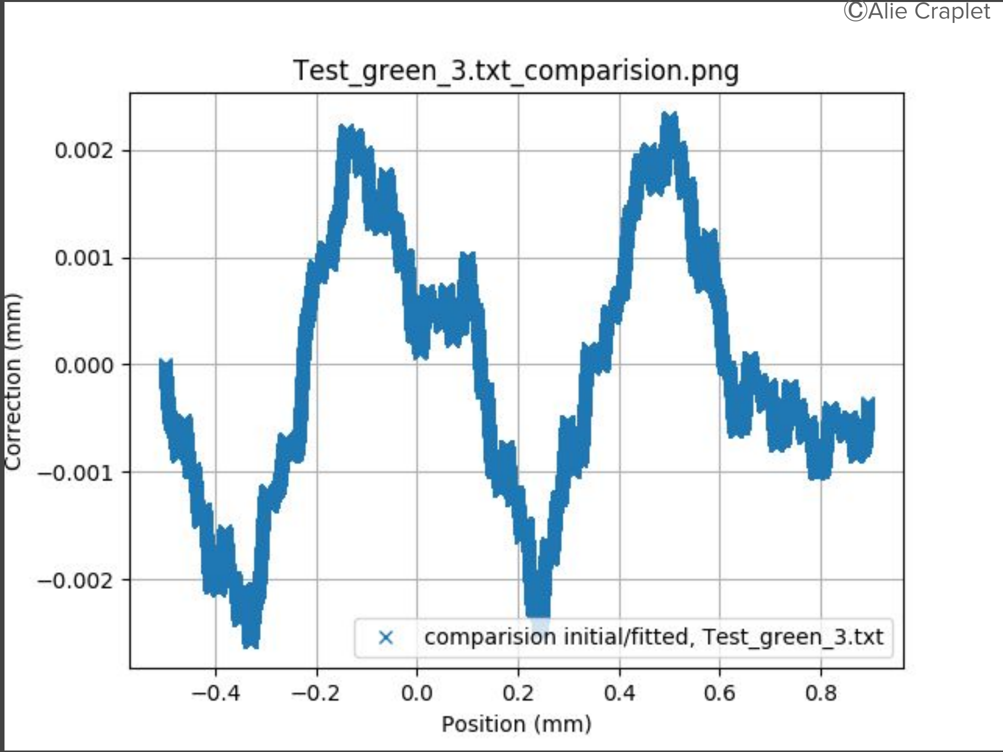
Additional Figures - Uniform set for Fourier Transforms



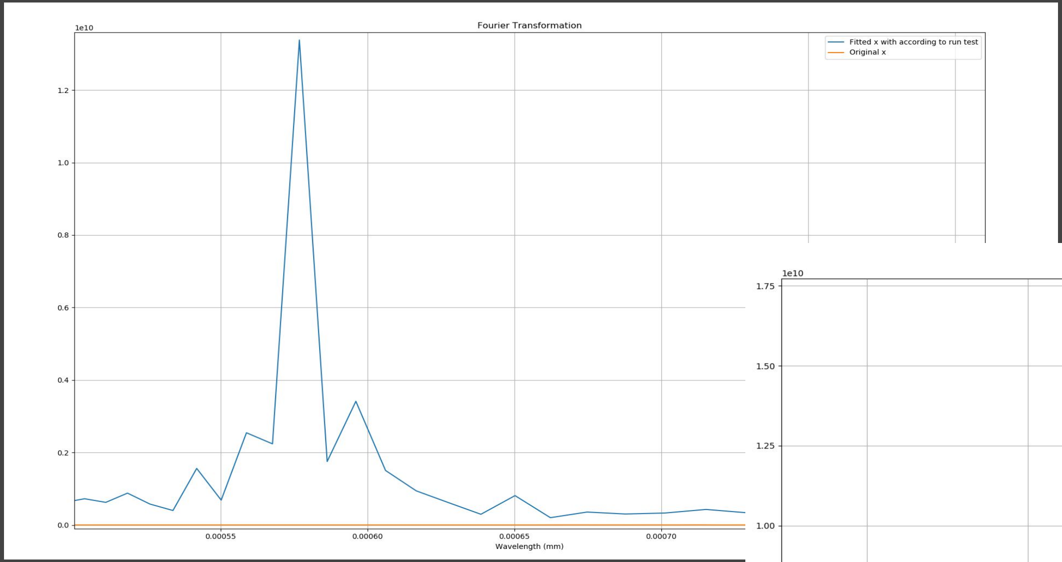
Additional Figures - Mercury reference

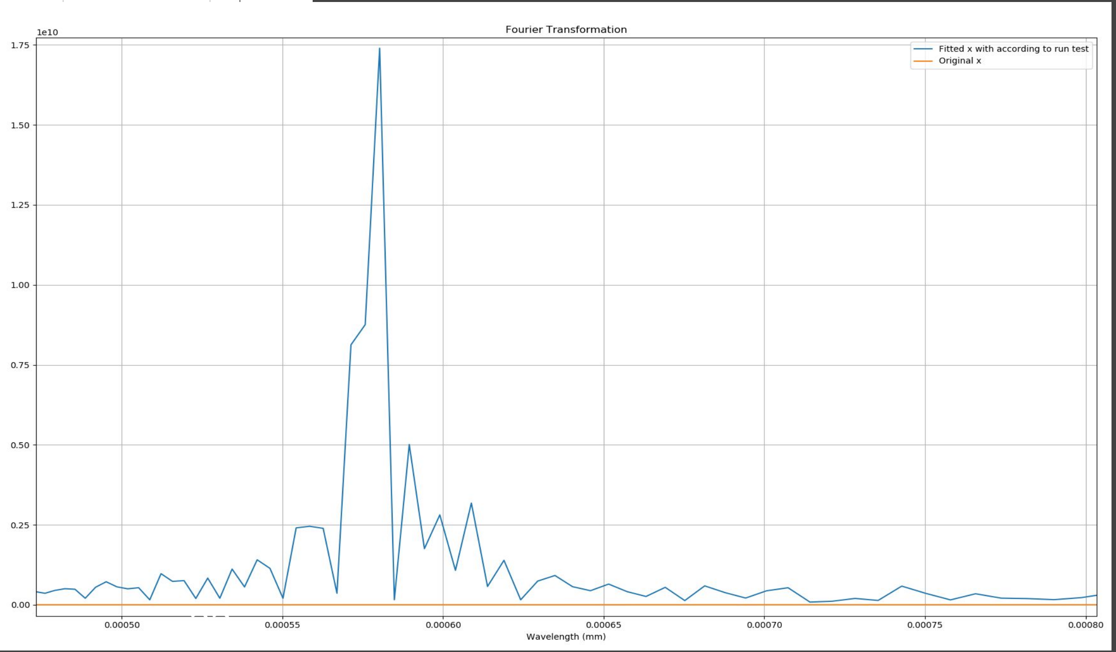
Observed air wavelength (Å)	Observed wave number (cm^{-1})	Intensity and comment	Classification				
			Configuration	Term	J		Configuration
5460.750	18307.415	*6000*	$5d^{10}6s(^2S)6p$	$^3P^o$	2	—	$5d^{10}6s(^2S)7s$
5549.634	18014.203	*50*	$5d^{10}6s(^2S)7s$	^1S	0	—	$5d^{10}6s(^2S)11p$
5675.811	17613.7	*600*	$5d^{10}6s(^2S)7s$	^3S	1	—	$5d^{10}6s(^2S)9p$
5769.610	17327.389	*1000*	$5d^{10}6s(^2S)6p$	$^1P^o$	1	—	$5d^{10}6s(^2S)6d$
5789.690	17267.29	*30*	$5d^{10}6s(^2S)6p$	$^1P^o$	1	—	$5d^{10}6s(^2S)6d$
5790.670	17264.372	*900*	$5d^{10}6s(^2S)6p$	$^1P^o$	1	—	$5d^{10}6s(^2S)6d$

Additional Figure - Correction against position



Additional Figure - Fourier Transforms with new stage

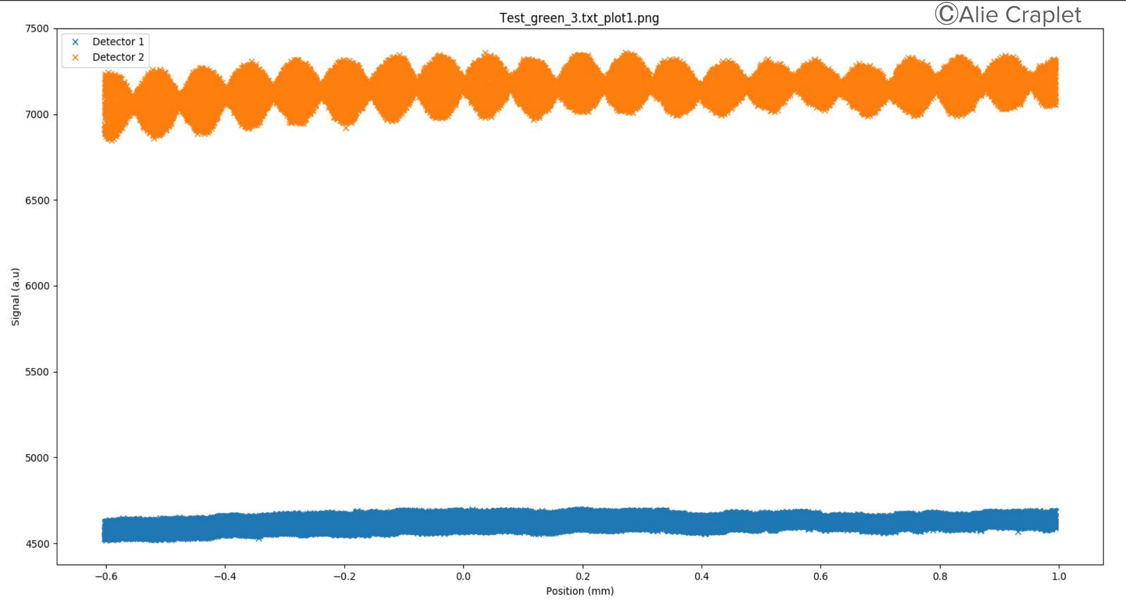




Additional Figures - mercury data for ‘self correction’

The code that the students can use for both plotting their data and correcting for the error is Code_correction.py.

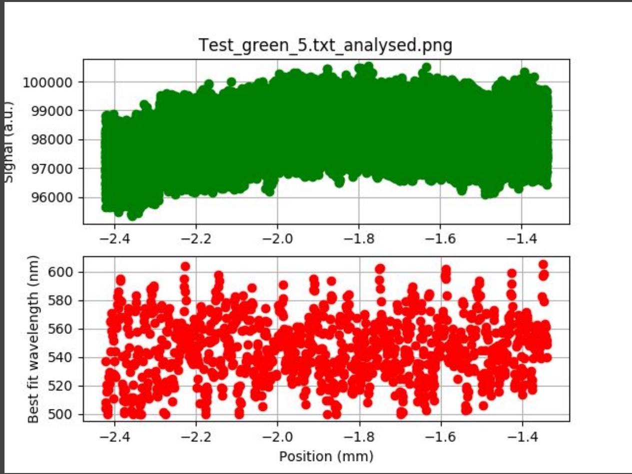
The students should modify it themselves to fit their particular needs.



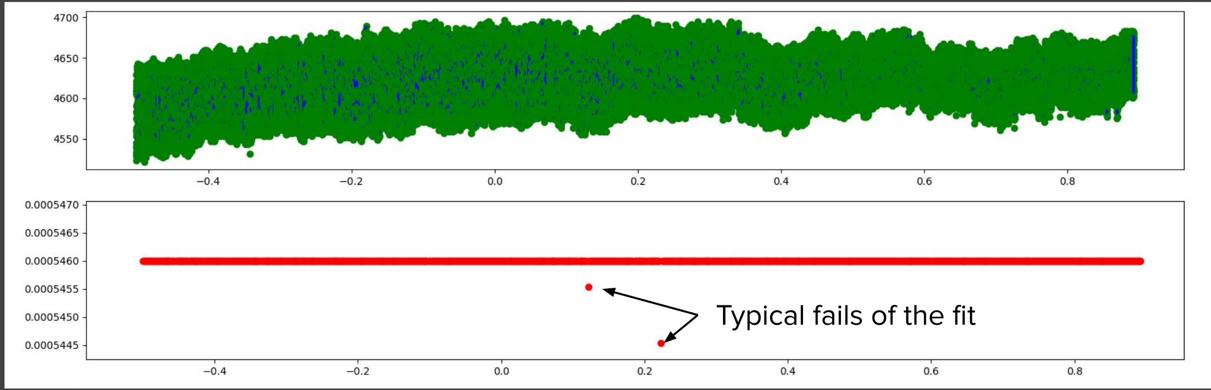
Plot of mercury’s green single line (blue) and yellow doublet (orange)

Additional Figures - green mercury data for ‘self correction’

The program first fits and correct the green signal and then applies the same corrections to the ‘test’ signal

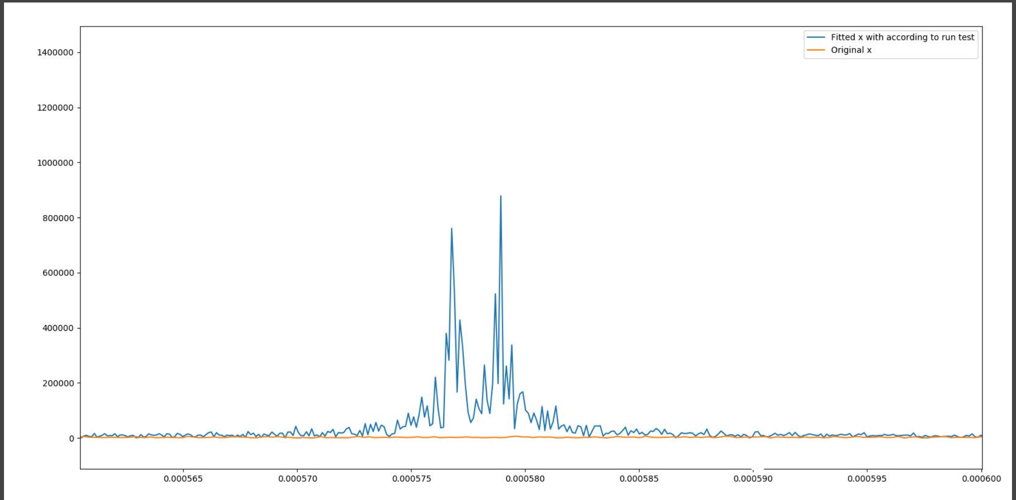


Estimation of the green wavelength **before** correction.



Estimation of the green wavelength **after** correction.

Additional Figures - mercury data for ‘self correction’



correction.

Fourier Transform of the doublet corrected signal (preliminary)

Fastest students can :

- Perform the correction with the red laser
- Compare quality of two approaches
- Reflect on sources of error associated with each technique