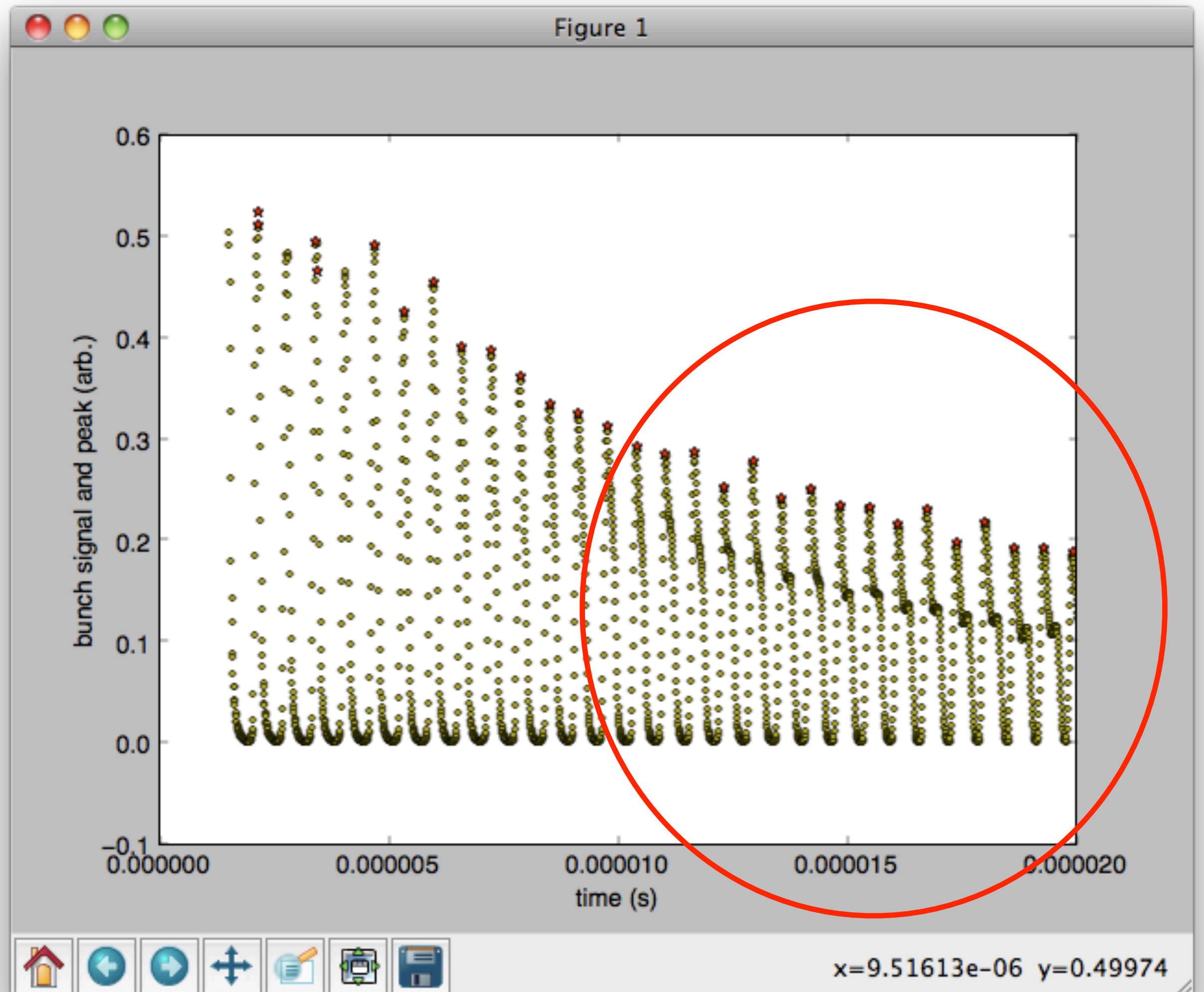
Science & Technology Facilities Council

2nd peak of bunch monitor

Shinji Machida
ASTeC/STFC Rutherford Appleton Laboratory
20 January 2014

Double peaks



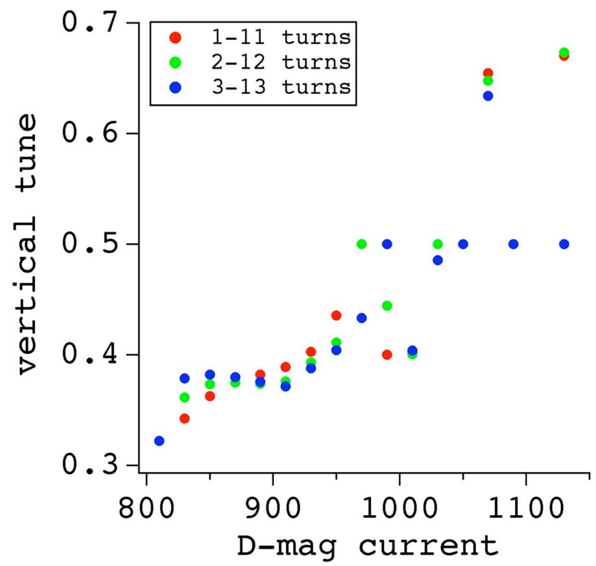
- Only developed around D-mag=1030 A.
- Second peak corresponds to lower momentum.
- If the tune measurement is correct, it occurs around a half integer tune.

a slide from previous presentation

Science & Technology Facilities Council

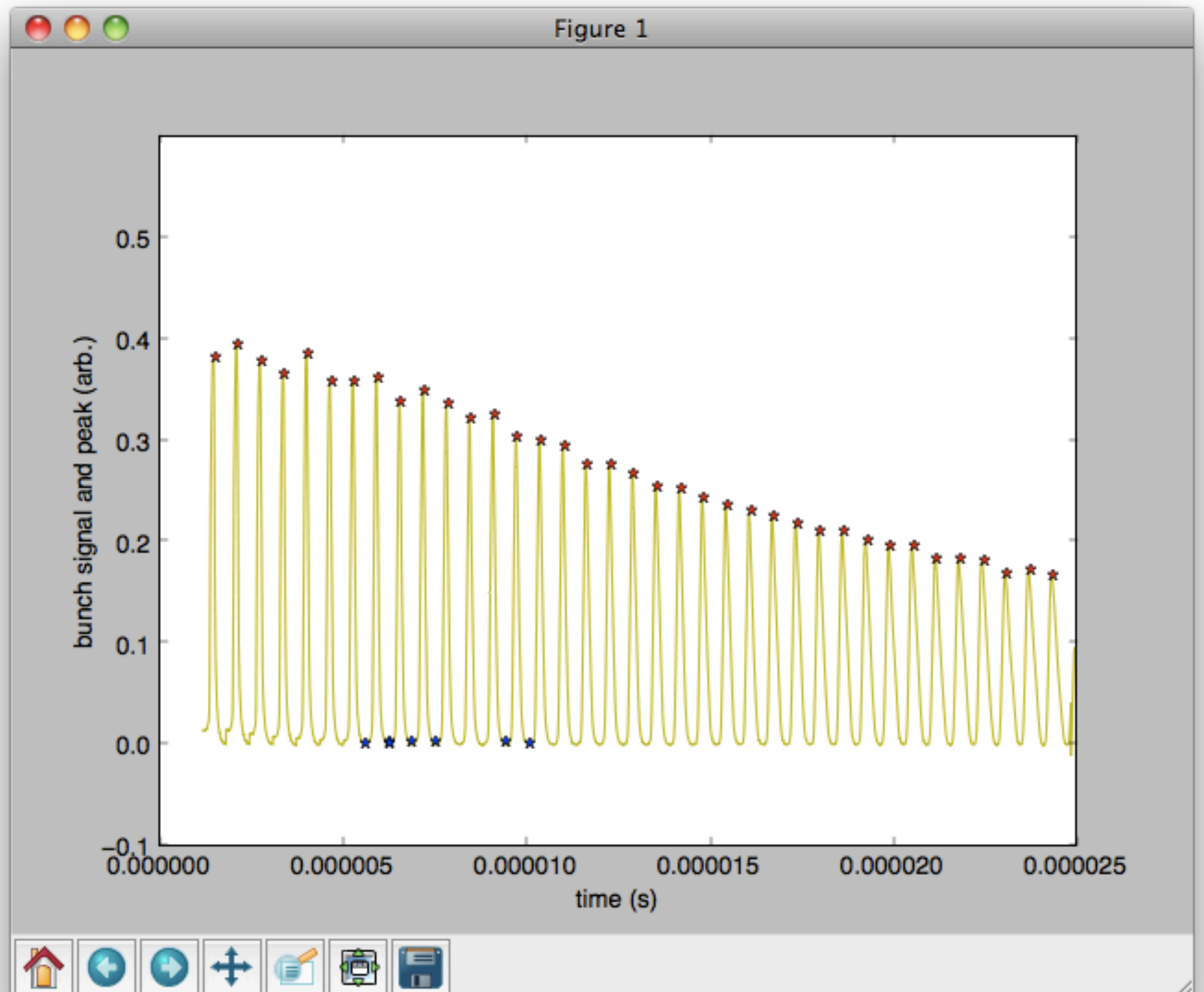
Goals

- How much energy loss is needed to have the second peak?
- Can we identify the source of energy loss?

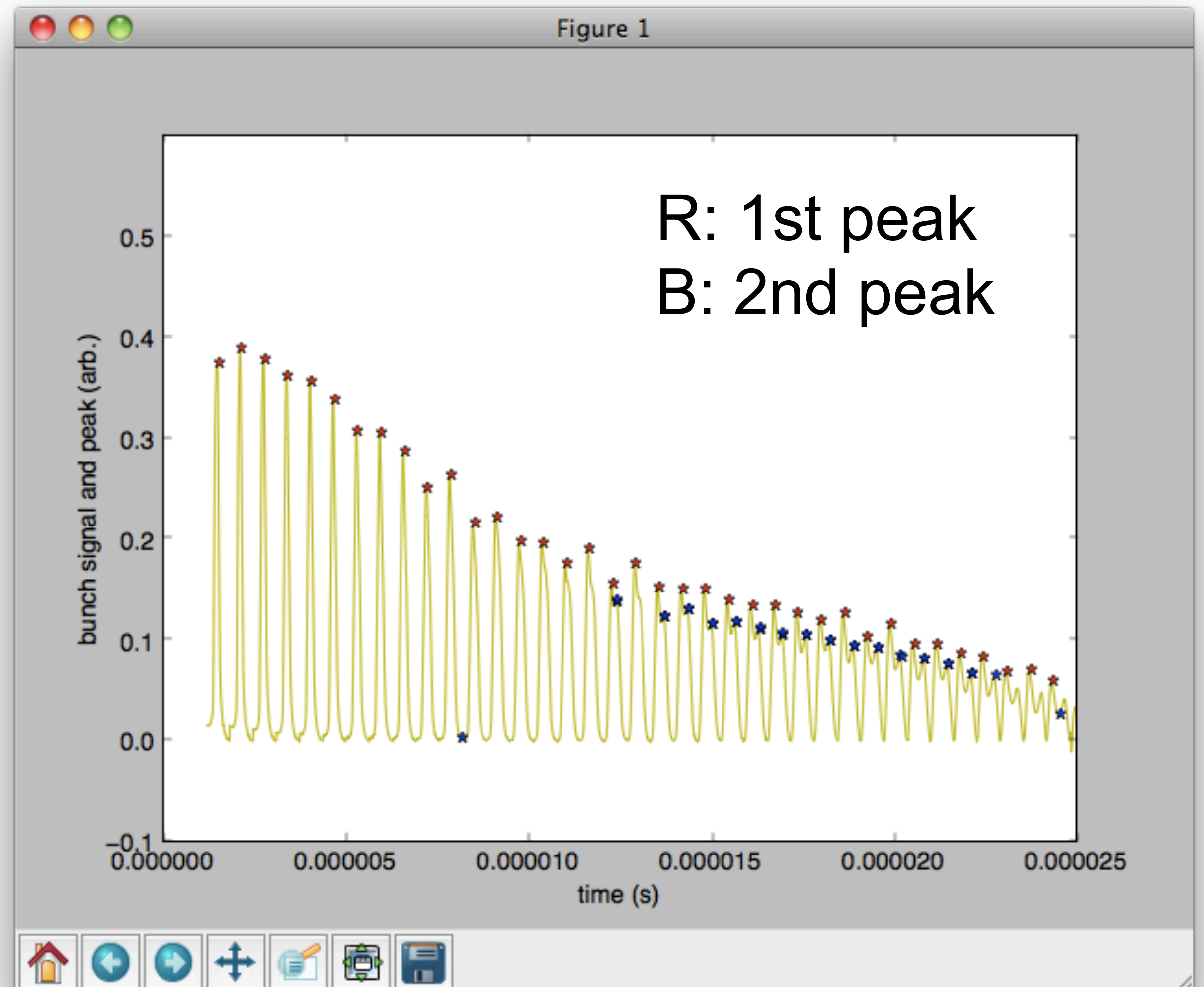


Bunch monitor signal

When tune approaches half integer, second peak in bunch monitor is developed.



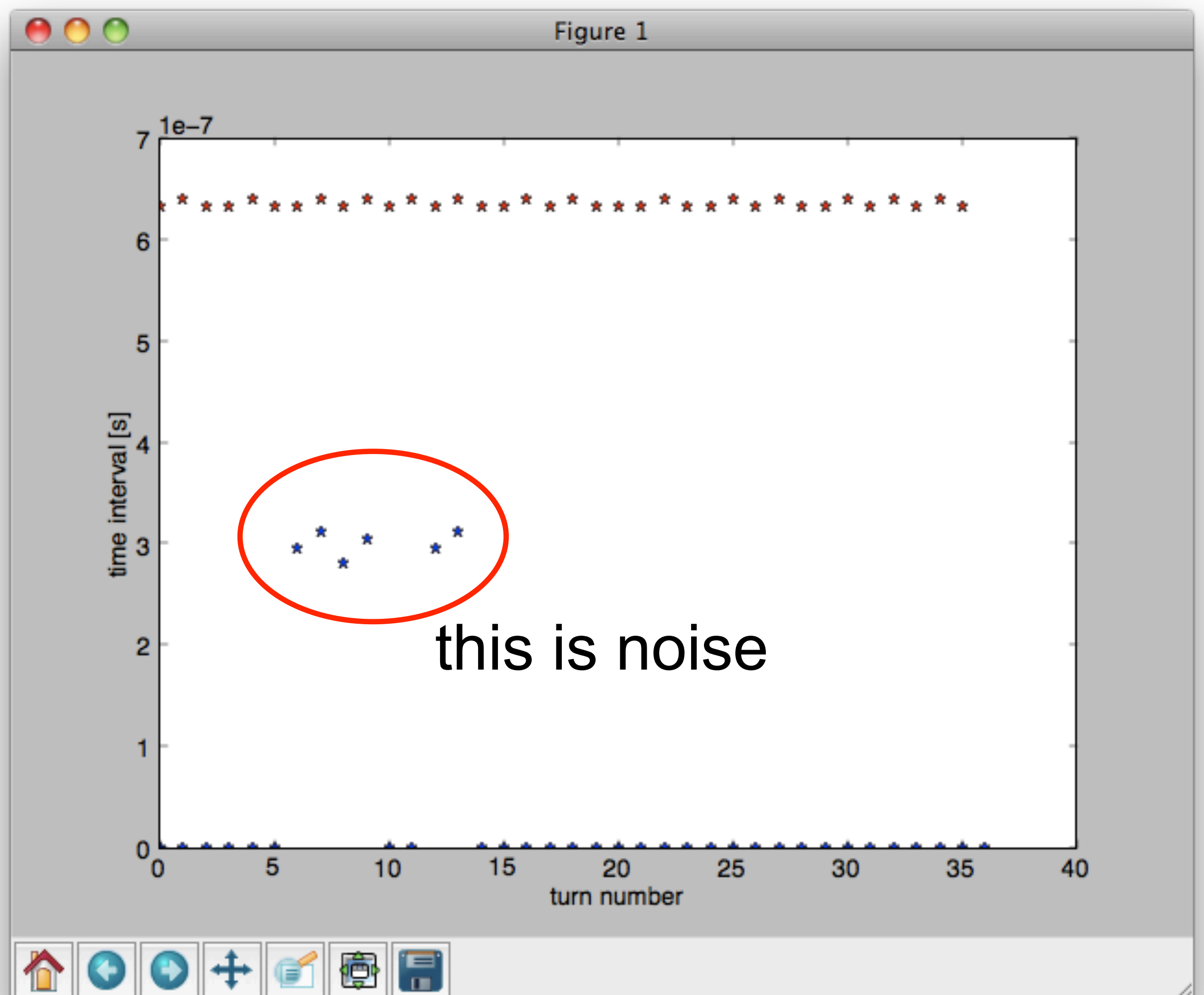
D-mag: 890 A



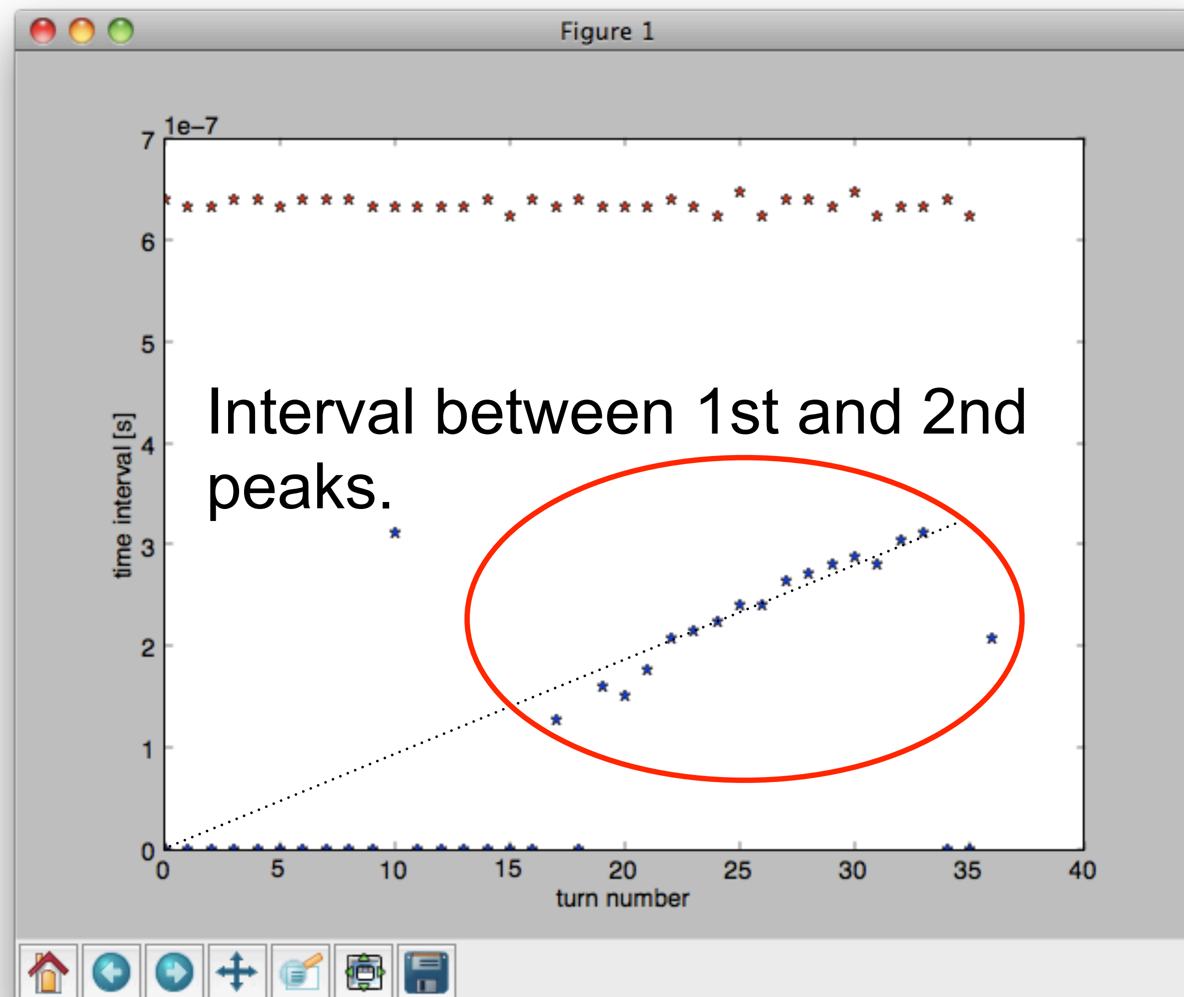
D-mag: 1070 A

Timing of peaks

Red: interval between consecutive 1st peaks (revolution time)
Blue: interval between 1st and 2nd peaks



D-mag: 890 A



D-mag: 1070 A

Two observations

1. Revolution time of 1st peak is more or less constant.

2. Interval between 1st and 2nd peaks linearly increases.

How the energy loss affects revolution time?

Model 1: Energy loss occurs once at the beginning.

$$\delta t_n/t = \eta\delta p/p$$

$$\Delta t(n) = \sum_n \delta t_n = \sum_n t\eta\delta p/p = nt\eta\delta p/p$$

Model 2: Energy loss occurs every turn continuously.

$$\delta t_n/t = n\eta\delta p/p$$

$$\Delta t(n) = \sum_n \delta t_n = \sum_n nt\eta\delta p/p = (n^2/2)t\eta\delta p/p$$

Almost constant rev. time means

Either Model 1: $\delta t_{n+1} - \delta t_n = 0$
or Model 2: $\delta t_{n+1} - \delta t_n = t\eta\delta p/p$ with small $t\eta\delta p/p$ compared with time resolution of 8 [ns] (125 MHz sampling).

Continuous energy loss with foil is an example of Model 2. However, it does not make observable change.

$$t\eta\delta p/p = \frac{t\eta}{2}\delta T/T = 0.019 \text{ [ns]}$$

where $\delta T = 760$ [eV]

Linear increase btw 1st and 2nd means

Model 1 is the right one

$$\Delta t(n) = \sum_n \delta t_n = \sum_n t\eta\delta p/p = nt\eta\delta p/p$$

From the data

$$\delta p/p = \frac{\Delta t(n)}{nt\eta} = 0.018$$

$\delta T = 0.4$ [MeV]

Why 2nd peak is developed?

- Two components exit from linac.
- Part of a beam went though material of ~500 (=400/0.76) times thicker than foil once.
  - Thickness of carbon foil is 20×10^{-6} [g/cm^2]/2 [g/cm^3]=0.1 um.
  - Thickness of material should be 0.05 mm (foil frame?).

Momentum spread of 1st peak

- When tune is not close to a half integer, 2nd peak does not appear.
- What is the momentum spread of 1st peak?
  - Two example of David's previous calculation are both close to a half integer tune.

Backup slides

Two observations

1. Revolution time of 1st peak is more or less constant.

What does that mean?

Model 1: Energy loss occurs once at the beginning and this is seen after 10 turns as a delay of revolution time.

$$dp/p = (1/\eta)dt/t$$

$$\eta = 1/(1+k) - 1/\gamma^2 = 0.86$$

$$dt = 8 \times 10^{-9}$$ [s] : time resolution

$$t = 10 \times 640 \times 10^{-9}$$ [s] : 10 turns rev. time

Energy loss at the beginning has to be more than

$dp/p = 1.45 \times 10^{-3}$ or $dT = 32$ [keV]

to be seen.

Model 2: Energy loss occurs every turn by the same amount.

When the shift of momentum is proportional to turn number, time delay per turn at n-th turn is

$$\delta t_n / t = \eta n \delta p / p$$

The total delay after n-th turn is

$$\sum \delta t_n / t = \sum \eta n \delta p / p = \eta (n^2/2) \delta p / p$$

$$\sum_{10t} \delta t_n = 8 \times 10^{-9}$$ [s] : time resolution

$$n = 10$$

Energy loss per turn has to be more than

$\delta p / p = 2.9 \times 10^{-4}$ or $\delta T = 6.4$ [keV]

One order lager than the energy loss by foil.

Model 2: Energy loss occurs continuously by the same amount.

When the shift of momentum is proportional to turn number, time delay per turn at n-th turn is

$$\delta t_n/t = \eta n \delta p/p$$

The total delay after n-th turn is

$$\sum \delta t_n/t = \sum \eta n \delta p/p = \eta(n^2/2)\delta p/p$$

Energy loss by foil for example,

$\delta T = 760$ [eV] or $\delta p/p = (1/2)\delta T/T = 3.45 \times 10^{-5}$

After 30 turns,

$$\sum_{30t} \delta t_n = t\eta(n^2/2)\delta p/p = 8.5 \times 10^{-9} \text{ [s]}$$

Hard to see with the present time resolution.

Two observations

Revolution time of 1st peak is more or less constant.

Main part of the bunch has constant momentum within the accuracy of measurement*.

*accuracy of measurement: no trend of consistent delay of revolution time within a few 10 turns.

$$dp/p = (1/\eta)dt/t$$

$$\eta = 1/(1+k) - 1/\gamma^2 = 0.86$$

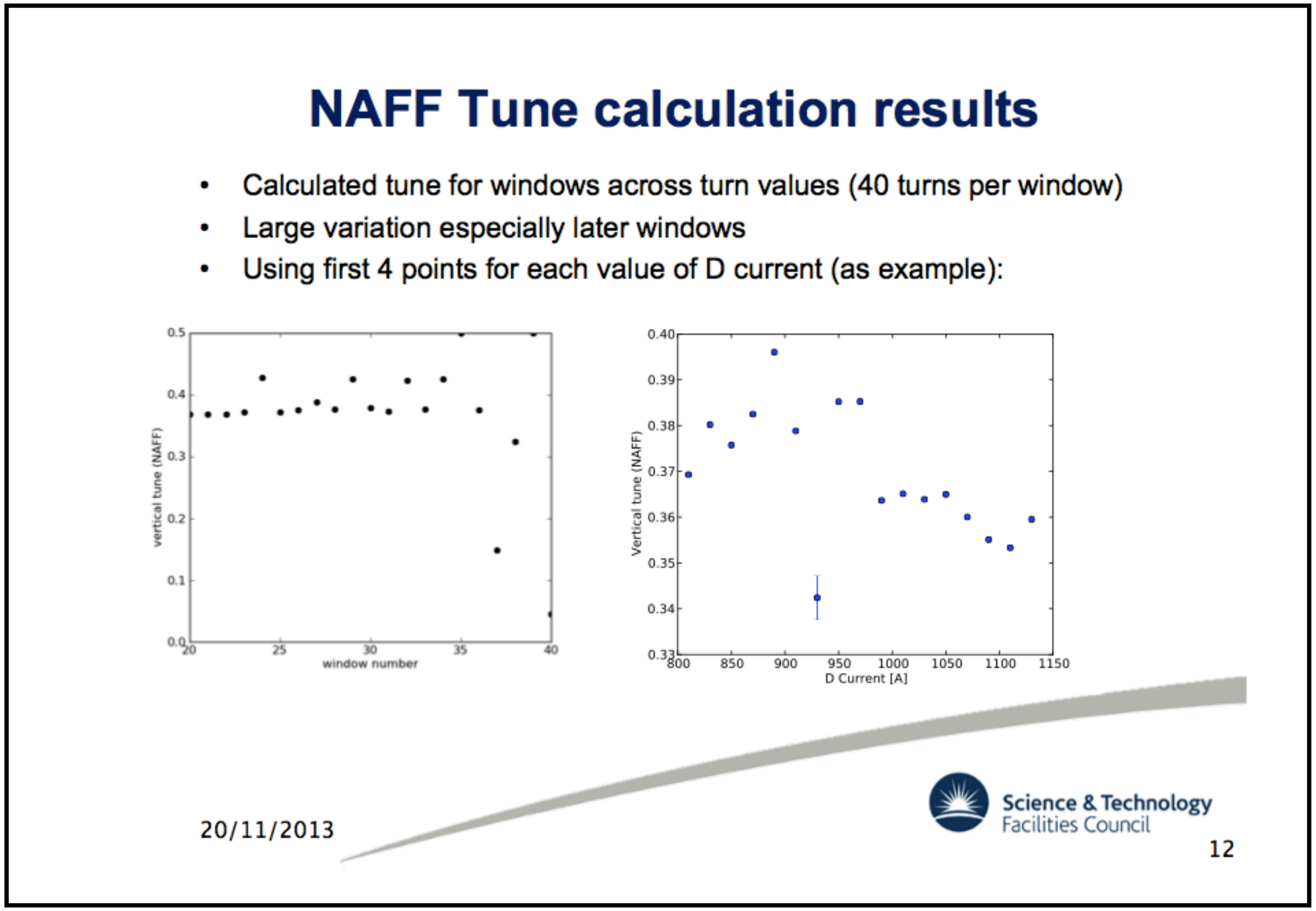
$$dt = 8 \times 10^{-9}$$: time resolution

$$t = 10 \times 640 \times 10^{-9}$$: 10 turns rev. time

$$dp/p = 1.45 \times 10^{-3}$$ or

$$dT = 32$$ [keV]

Preliminary analysis by Suzie



Vertical tune does not change much with D-mag current. Is it true?

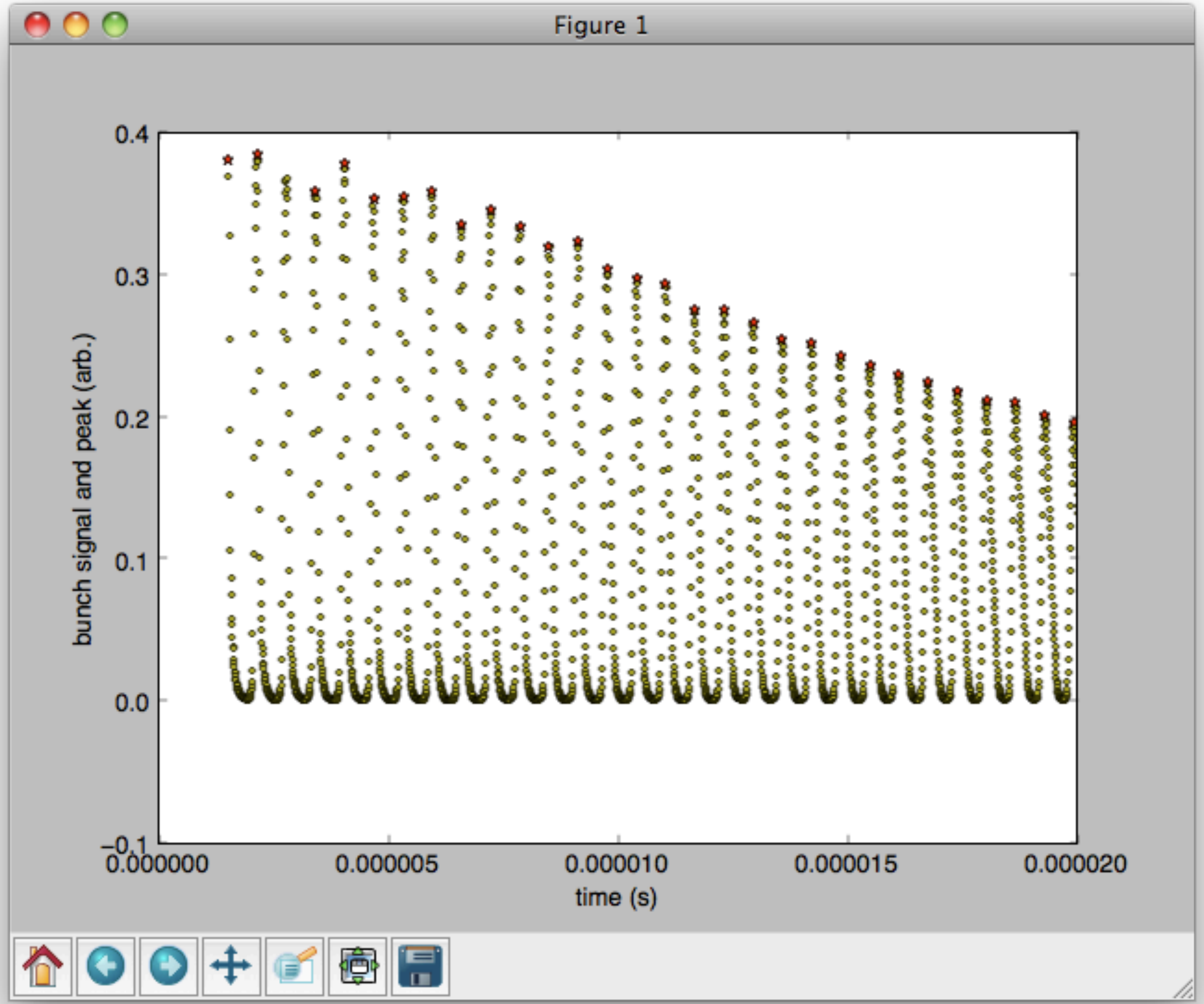
Conditions

- Data on 13 November 2013.
- No rf cavity.
- Small vertical offset at injection.
- F-mag current is fixed at 813.15 A. D-mag is varied from 810 to 1130 A.
- Use double (hebi,巳) and single (inu,戌) bunch monitors.

- More details can be found in a spread sheet by Suzie.

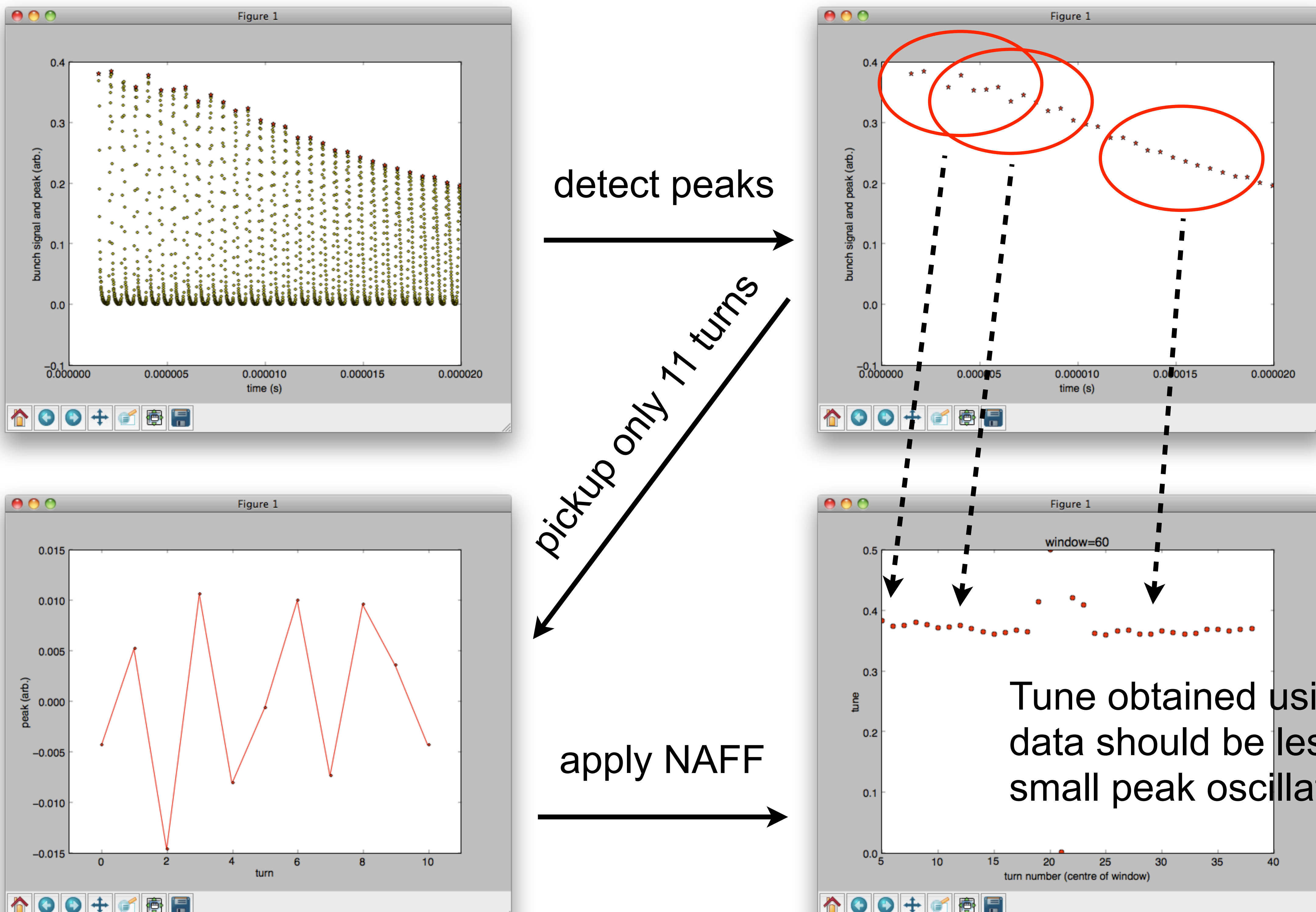
Bunch monitor single

- (Baseline is forced to be zero.)
- Peak height decays due to bunch broadening.
- Some oscillations of the peak height for the first 10~20 turns. Assume this s due to vertical betatron oscillations.



Science & Technology Facilities Council

Data analysis



Tune obtained using later 11 turns data should be less accurate due to small peak oscillations.

NAFF algorithm

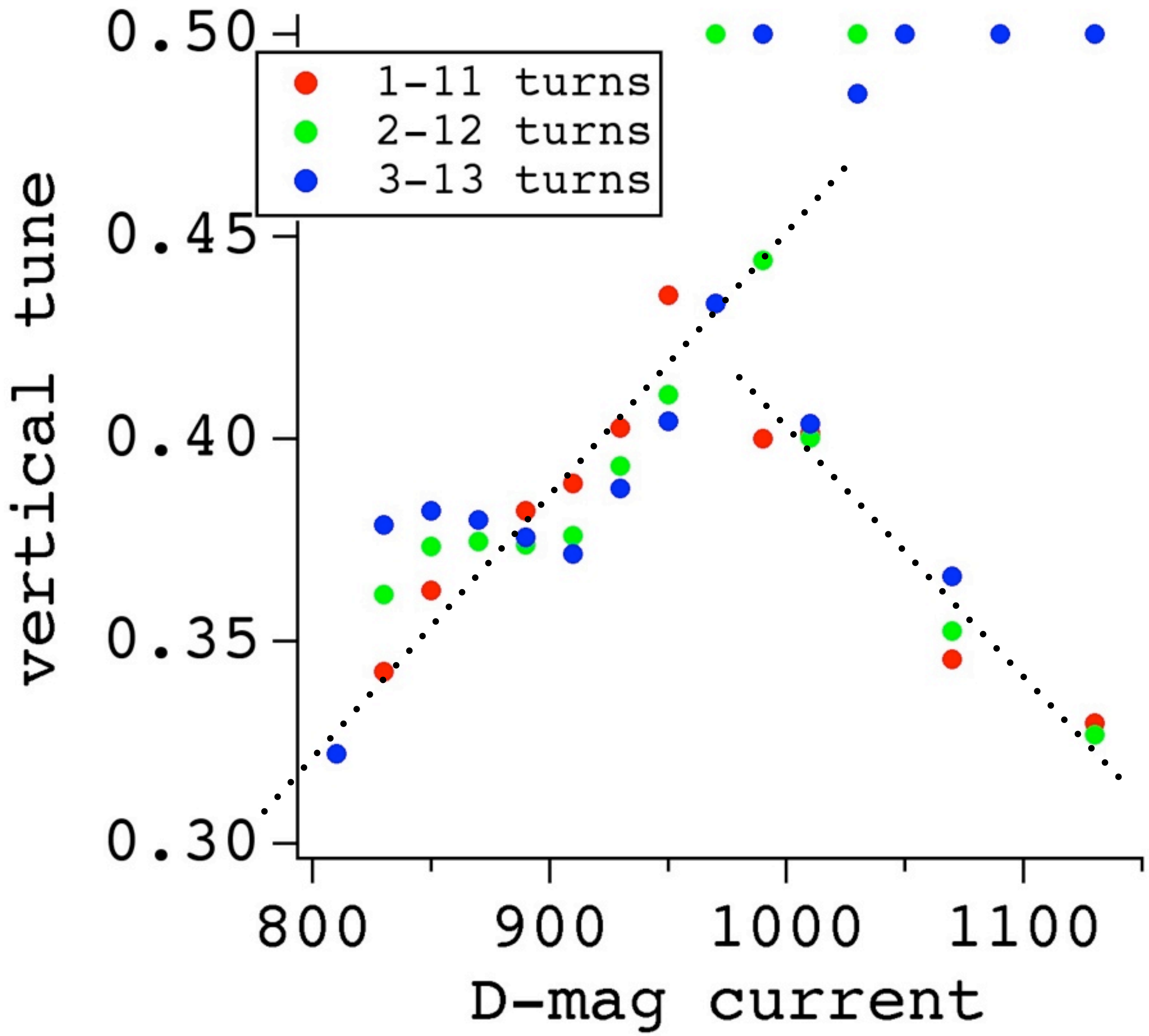
- Numerical Analysis of Fundamental Frequency.
- Find numerically the frequency ν which maximise $\phi(\nu)$

$$\phi(\nu) = \frac{1}{N}\sum_{n=0}^{N} z(n) exp(-2\pi i \nu n)$$

$z(n)$: data set to be analysed.

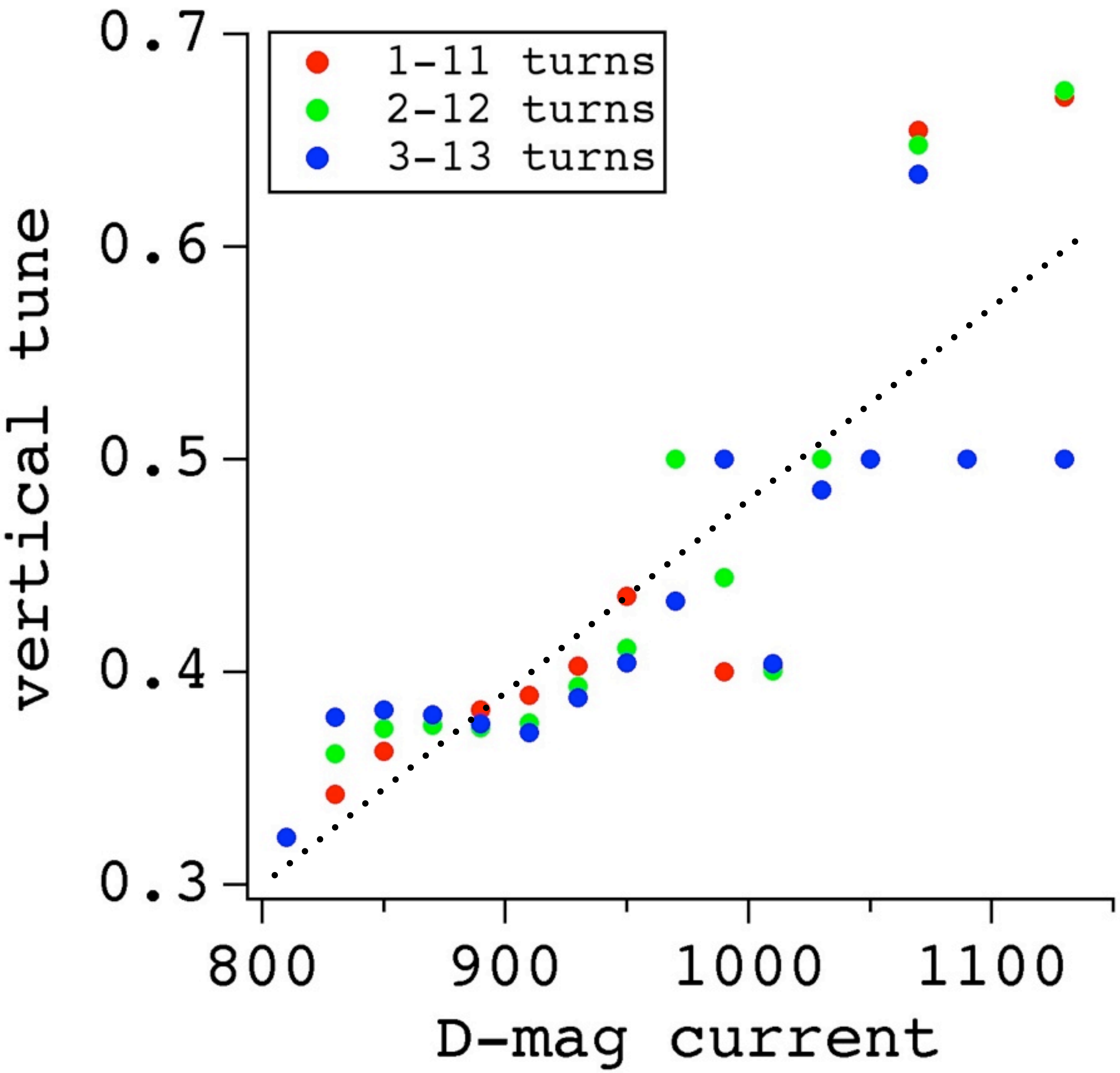
1. R. Bartolini, Particle Accelerators **52** 147 (1996).
2. J. Laskar, Physica D **67** 257 (1993).

Results of single bunch monitor



Science & Technology Facilities Council

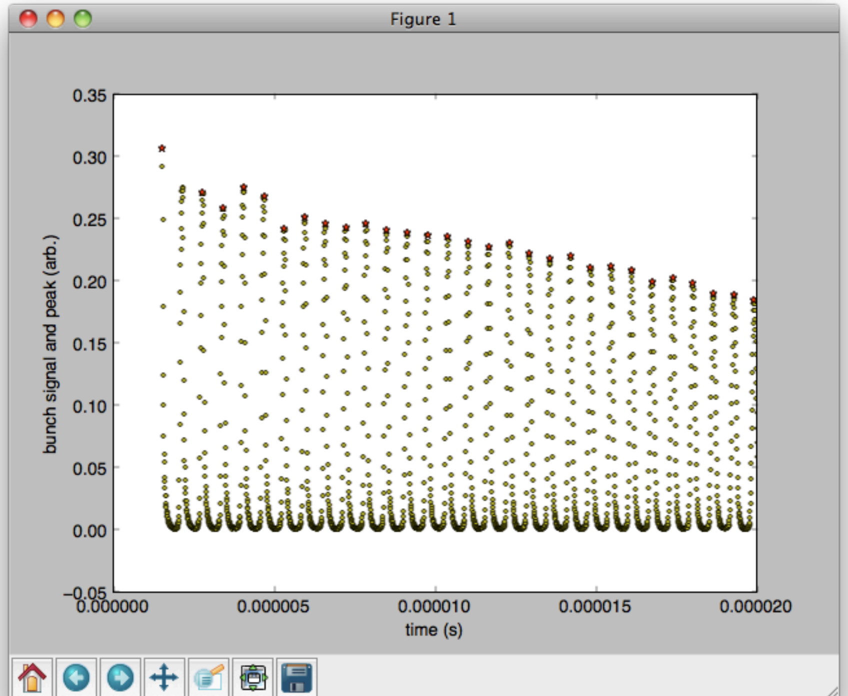
Results of single bunch monitor (some flipped)



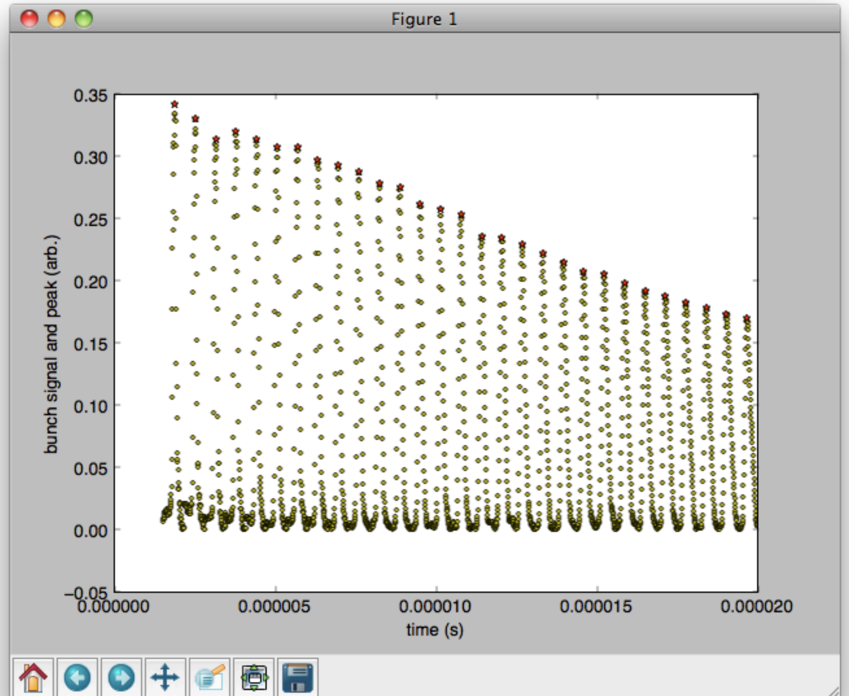
Should be checked by simulation if it is reasonable.

Bunch shape

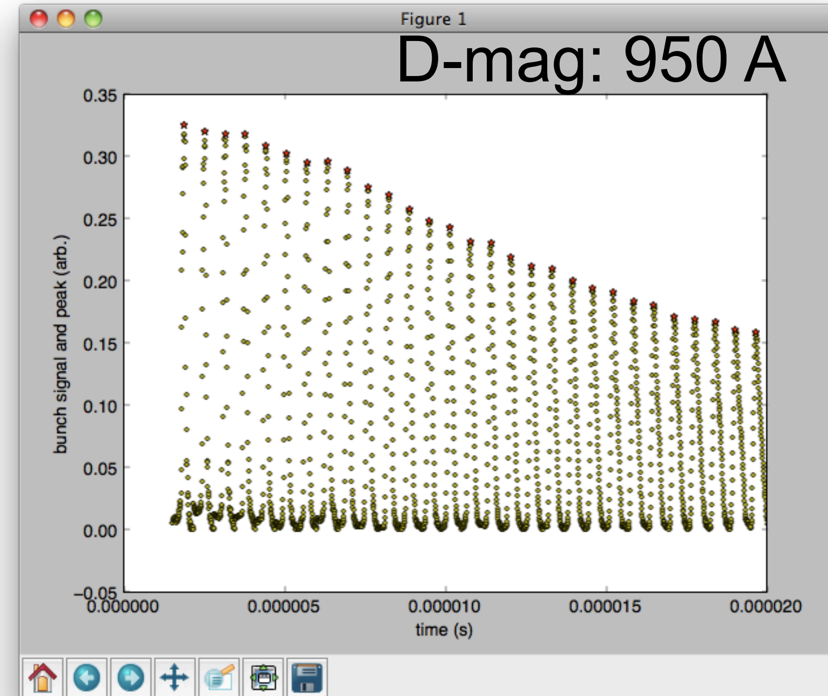
D-mag: 830 A



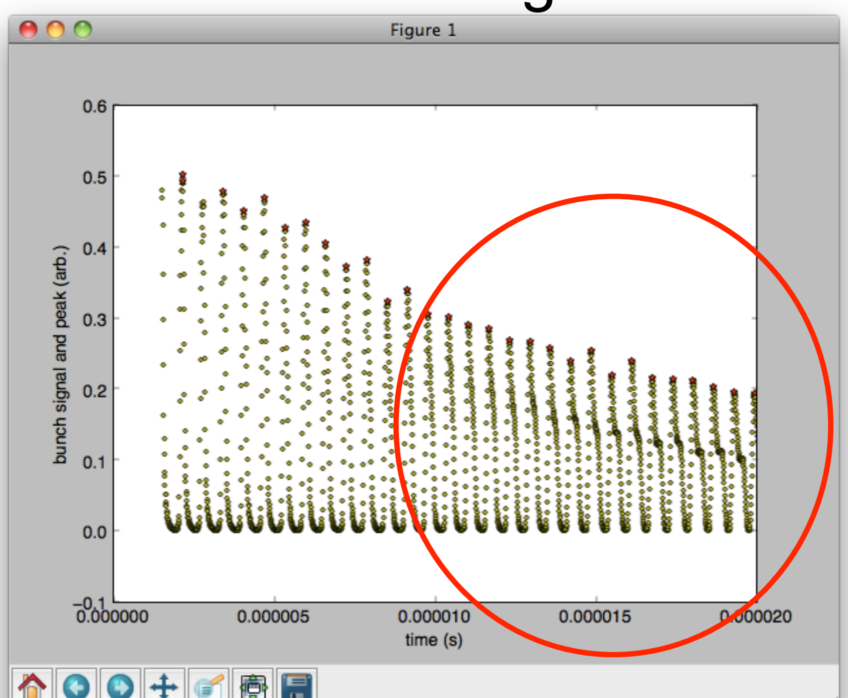
D-mag: 890 A



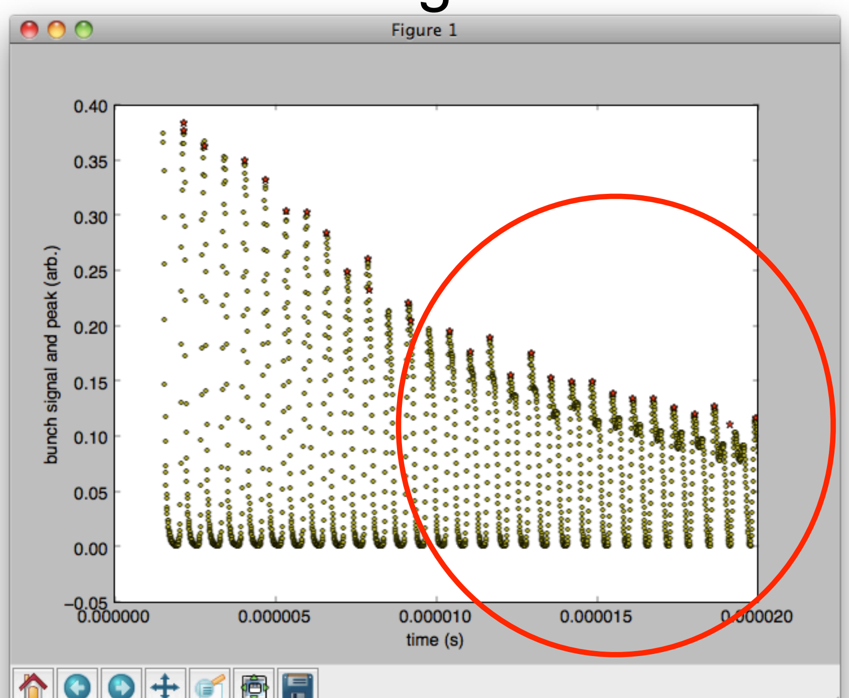
D-mag: 950 A



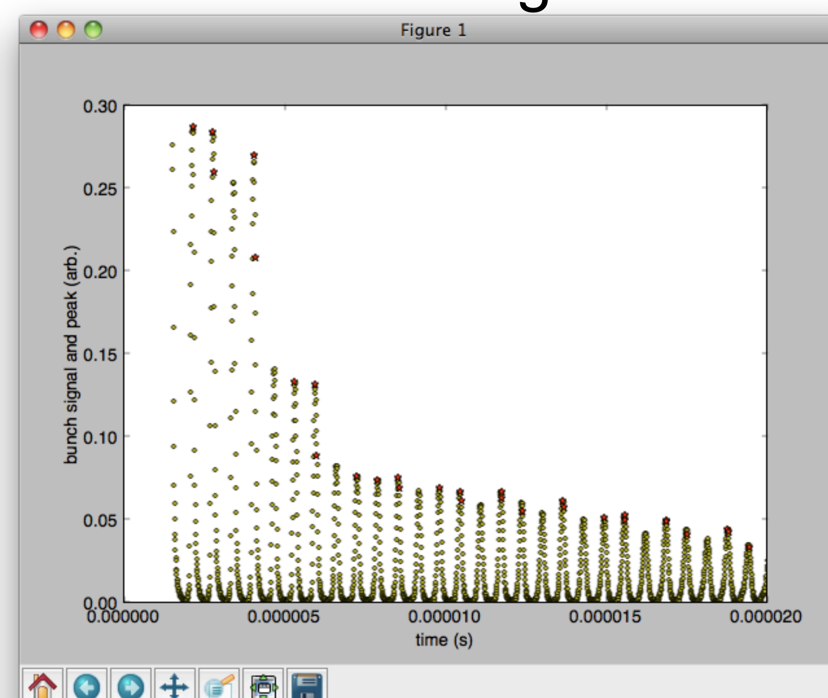
D-mag: 1010 A



D-mag: 1070 A



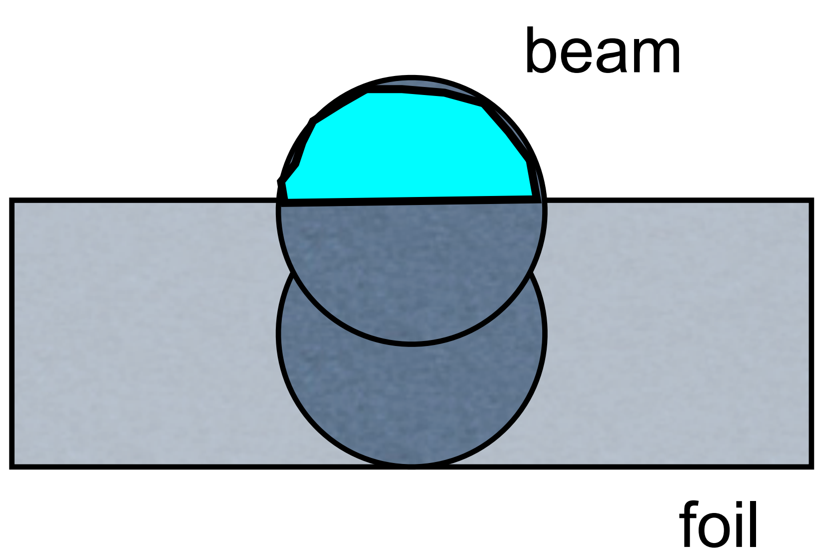
D-mag: 1130 A



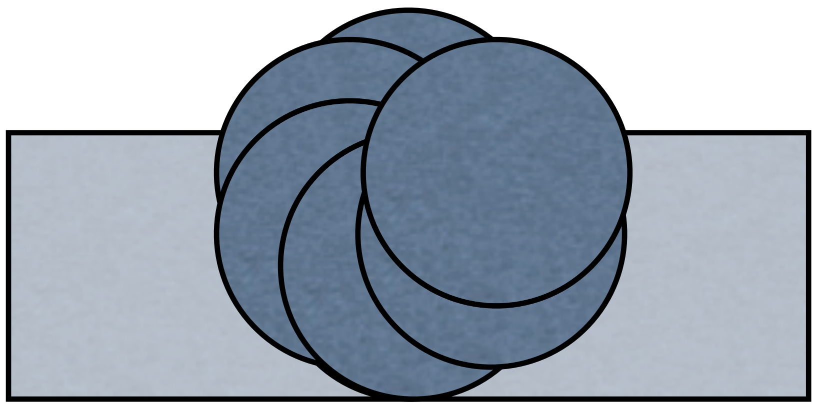
Science & Technology Facilities Council

Possible explanation

at half integer



at other tune



At half integer tune, some part of a beam can avoid foil hitting every other turn which makes two separate momentum evolution of a beam.

Science & Technology Facilities Council