

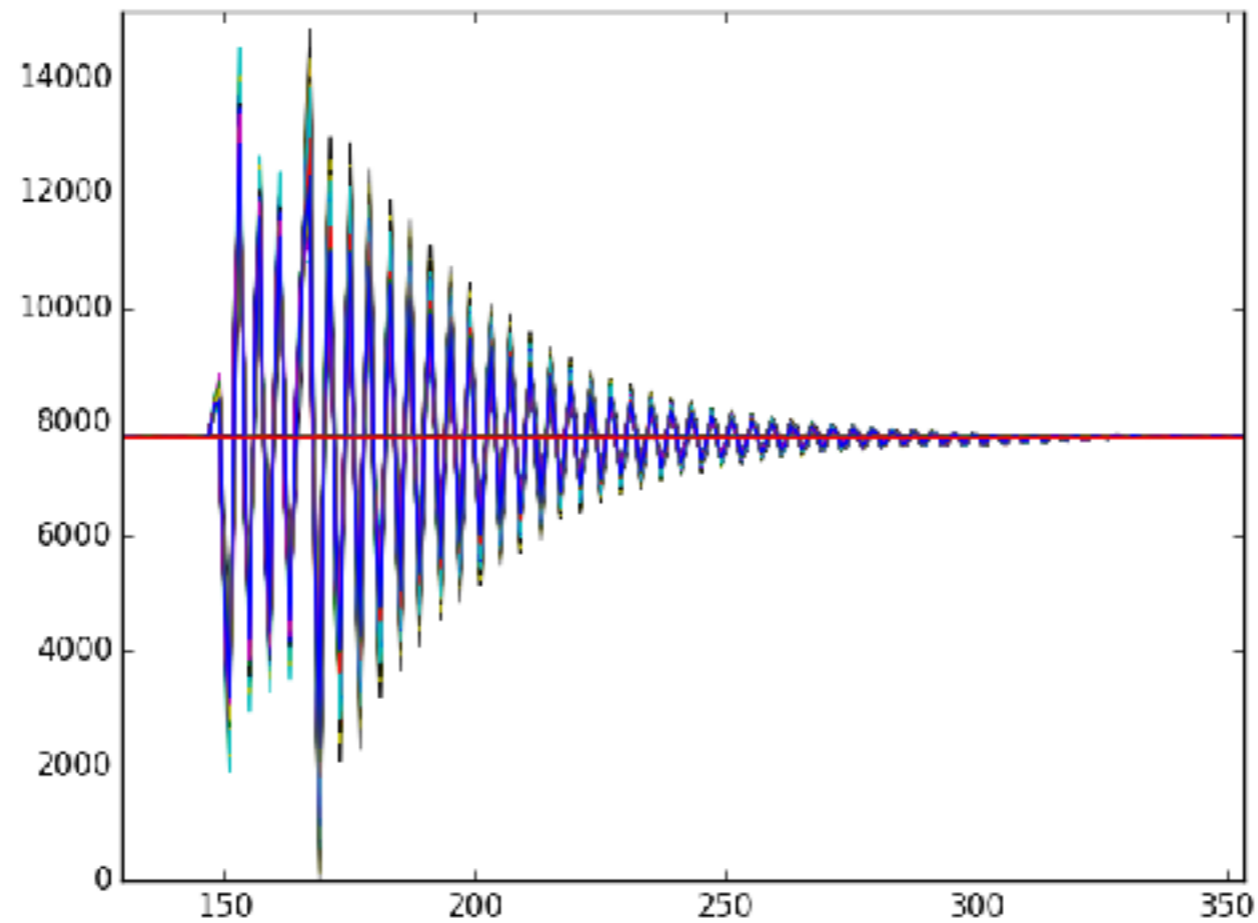
Multibunch cavity BPM processing

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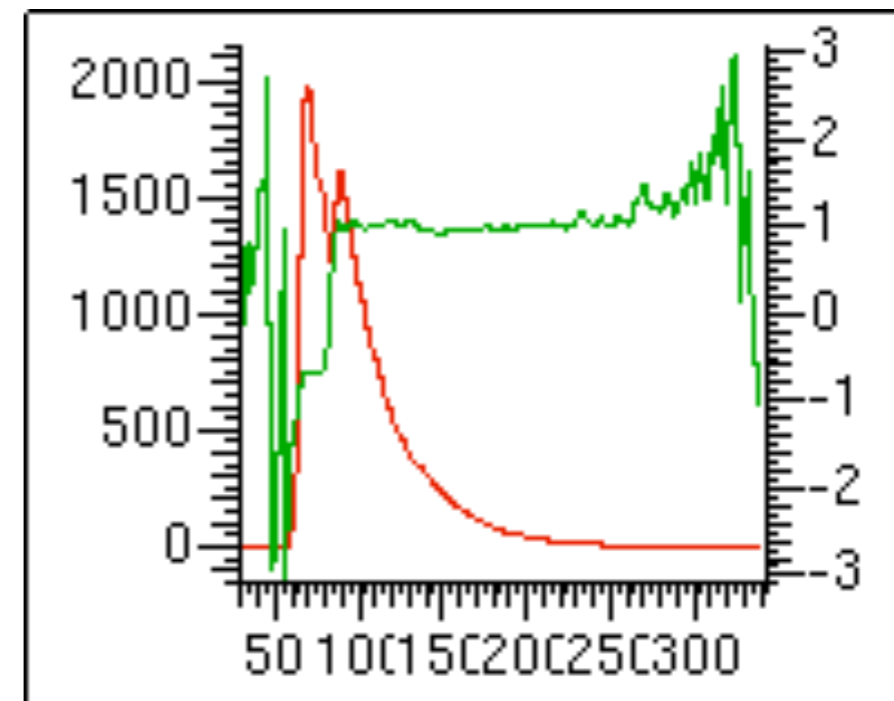
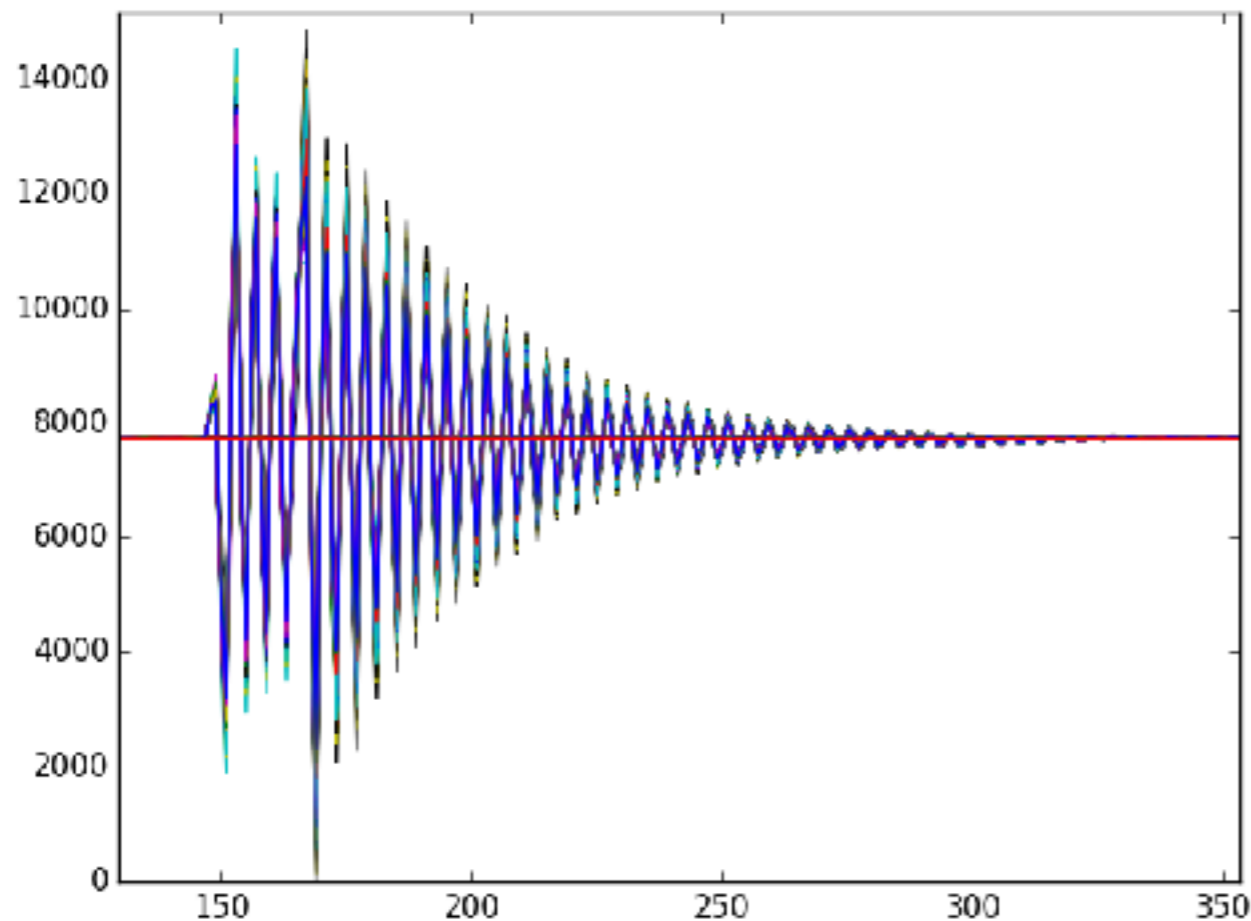
The problem

- *Signals generated by consequent bunches can overlap as cavities are microwave resonators.*



A solution

- In order to measure positions of multiple bunches with bunch spacing smaller or comparable with the decay time, the signals must be propagated in time and subtracted.
- Position measurement includes measuring both amplitude and phase, hence the subtraction ultimately needs to be done on phasors



What that technically means

- Need to detect the arrival of the bunches
- Every value and some parameters become arrays
- Every 1D array becomes a 2D array
- Speed and transparency important

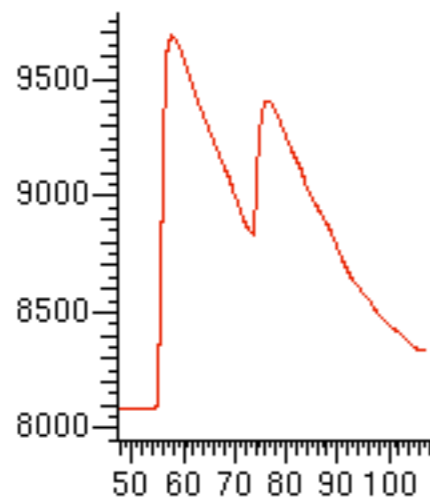
- Result: complete re-design of the low-level processing software
- Significant changes to the infrastructure (higher-level scripts)
- No dramatic change in interfaces, although previously used EDM is of limited functionality with arrays

Bunch search

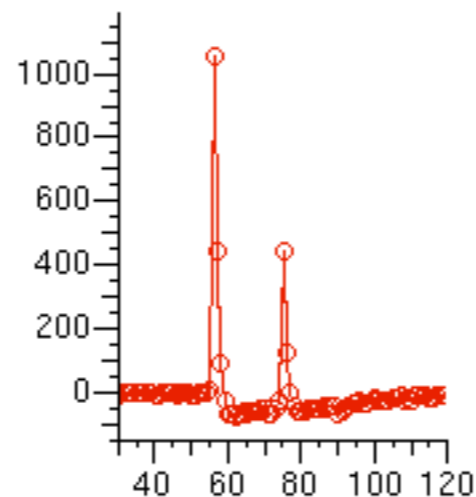
CDIODEnew
Isis9:waveform4

Start sample	Threshold	Pedestal	t0[0]	Number of bunches detected
<input type="text" value="10"/>	<input type="text" value="30"/>	8083.4	56.1358	0

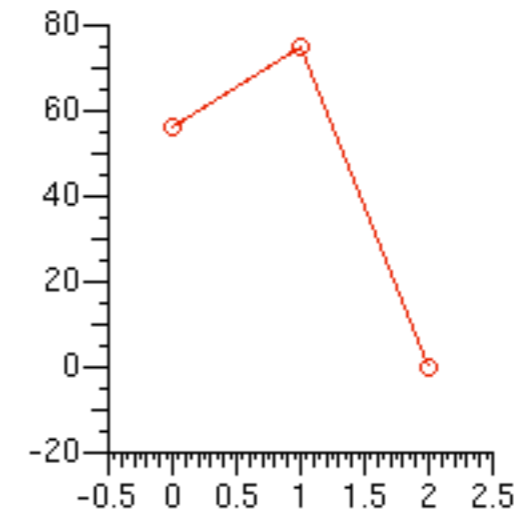
Diode waveform



Derivative



t0



- Number of bunches and timing between them may vary shot-to-shot (missing bunches, timing drifts)
- Use diode-rectified signal from the reference cavity
- Detect the bunches using the front of the signal
- Upper limits of resolution: bunch 1 ~20 ps bunch 2 ~60 ps
- At around 3 MHz frequency difference this means 0.02 and 0.06 degree respectively

EPICS IOC implementation

- Subroutines integrated in EPICS IOC
- Using aSub
- Advantage: easy synchronisation, no overhead in code

```
record(waveform, "$(name):i") {  
  field(NELM, "$(nb)")  
  field(FTVL, "DOUBLE")  
}
```

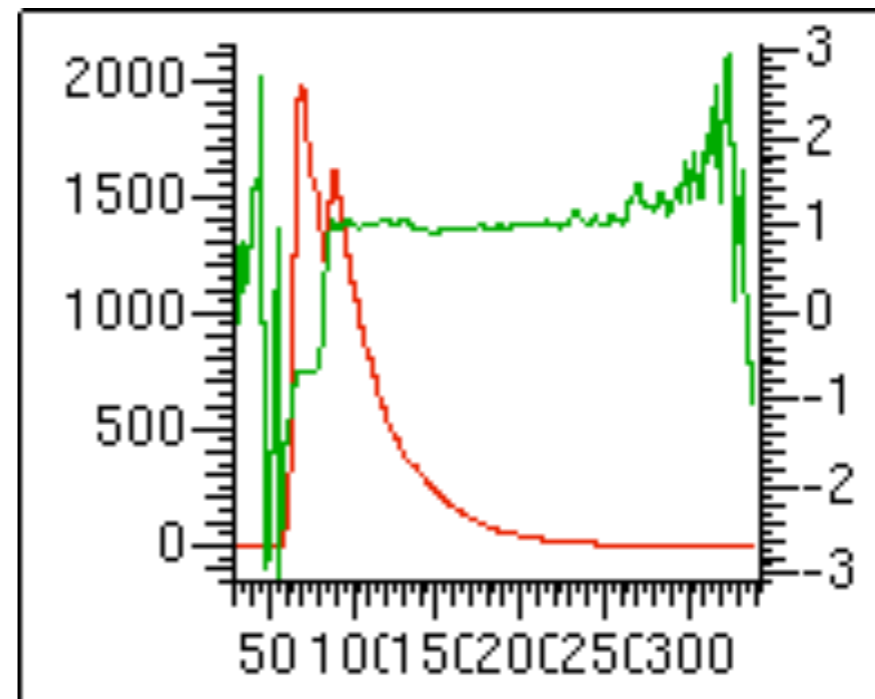
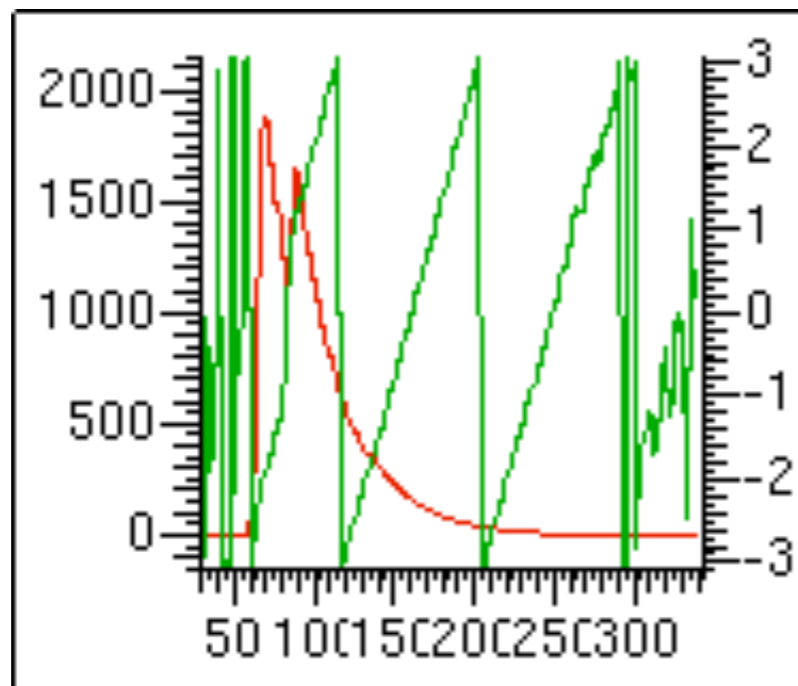
```
record(waveform, "$(name):q") {  
  field(NELM, "$(nb)")  
  field(FTVL, "DOUBLE")  
}
```

```
record(waveform, "$(name):posscale") {  
  field(NELM, "$(nb)")  
  field(FTVL, "DOUBLE")  
}
```

```
record(waveform, "$(name):tiltscale") {  
  field(NELM, "$(nb)")  
  field(FTVL, "DOUBLE")  
}
```

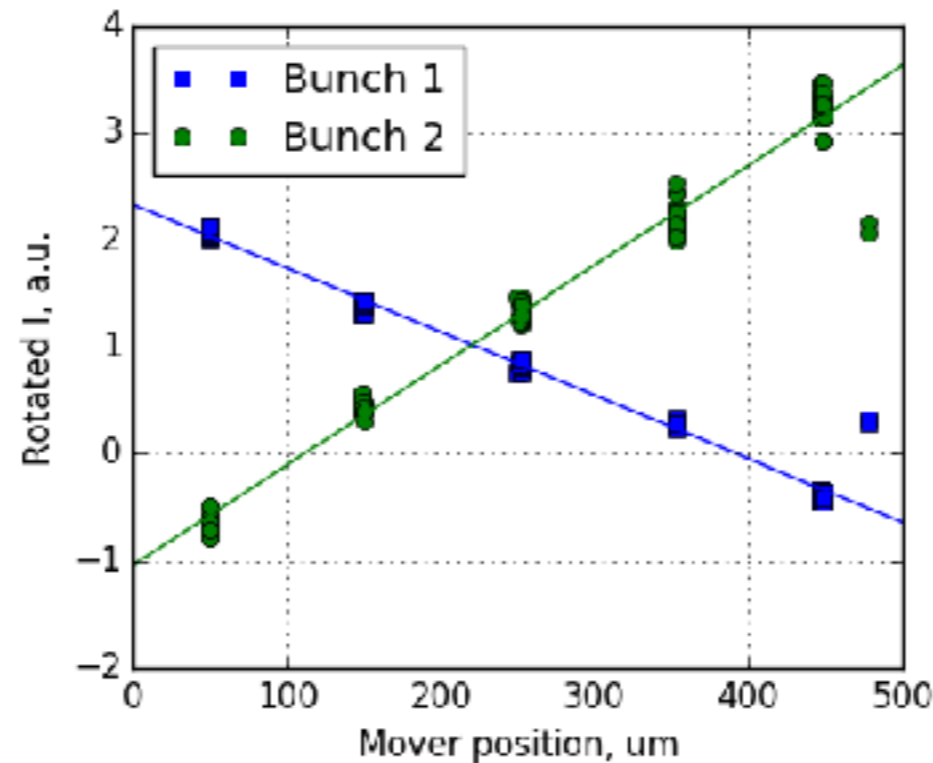
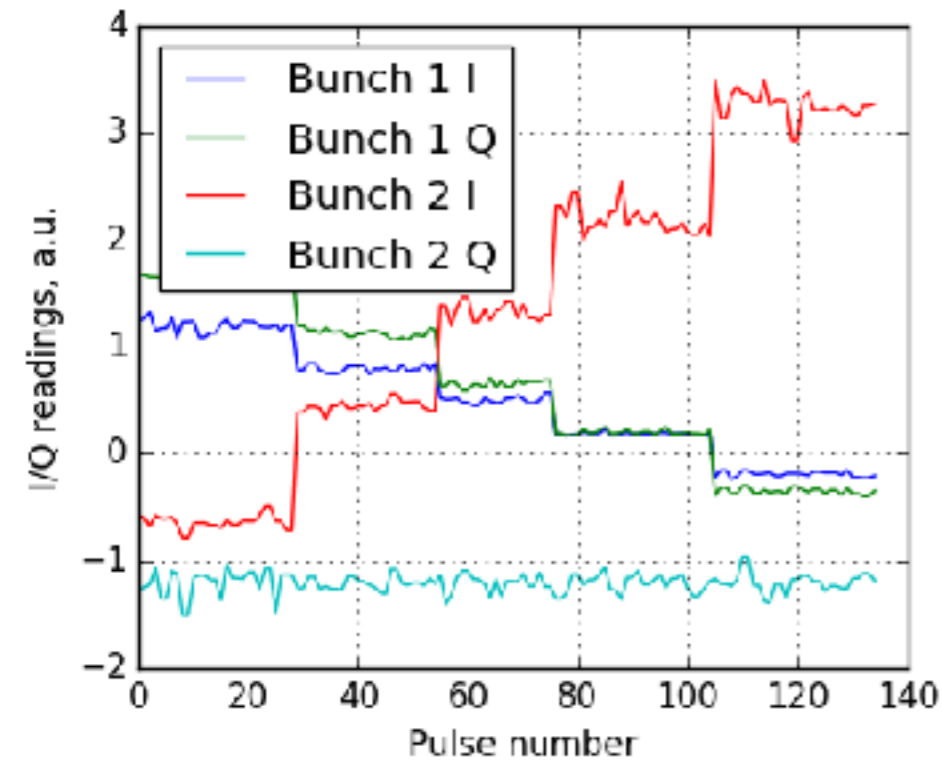
```
record(aSub, "$(name):CalcPos") {  
  field(INAM, "CalcPosTiltInit")  
  field(SNAM, "CalcPosTiltProc")  
  field(INPA, "$(name):sAmp CP")  
  field(NOA, "$(nb)")  
  field(INPB, "$(name):sPhi")  
  field(NOB, "$(nb)")  
  field(INPC, "$(name):sAmpCal")  
  field(INPD, "$(name):sPhiCal")  
  field(INPE, "$(rname):sAmp")  
  field(NOE, "$(nb)")  
  field(INPF, "$(rname):sPhi")  
  field(NOF, "$(nb)")  
  field(INPG, "$(rname):sAmpCal")  
  field(INPH, "$(rname):sPhiCal")  
  field(INPI, "CDIODEnew:nob")  
  field(FTI, "LONG")  
  field(INPJ, "$(name):usecal")  
  field(FTJ, "LONG")  
  field(INPK, "$(name):iqrot")  
  field(NOK, "$(nb)")  
  field(INPL, "$(name):posscale")  
  field(NOL, "$(nb)")  
  field(INPM, "$(name):tiltscale")  
  field(NOM, "$(nb)")  
  field(INPN, "$(name):posflip")  
  field(NON, "$(nb)")  
  field(INPO, "$(name):bbaoffset")  
  field(INPP, "$(name):bbaflip")  
  field(OUTA, "$(name):pos CA")  
  field(NOVA, "$(nb)")  
  field(OUTB, "$(name):tilt CA")  
  field(NOVB, "$(nb)")  
  field(OUTC, "$(name):i CA")  
  field(NOVC, "$(nb)")  
  field(OUTD, "$(name):q CA")  
  field(NOVD, "$(nb)")  
  field(OUTE, "$(name):ical CA")  
  field(OUTF, "$(name):qcal CA")  
}
```

Frequency, decay and sampling time tuning

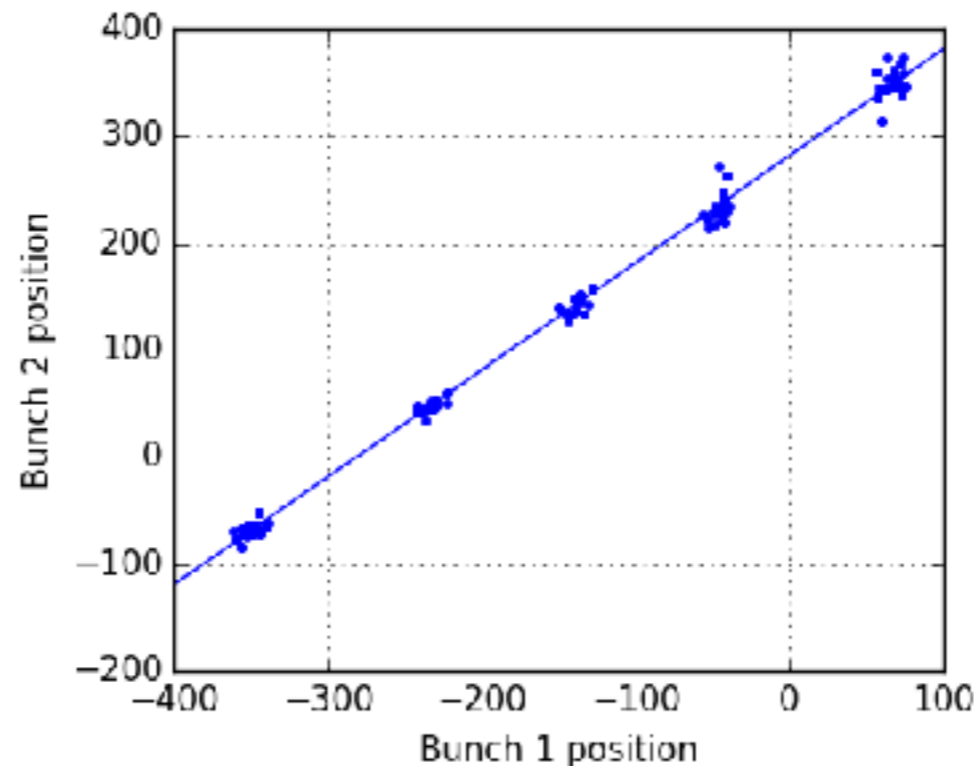
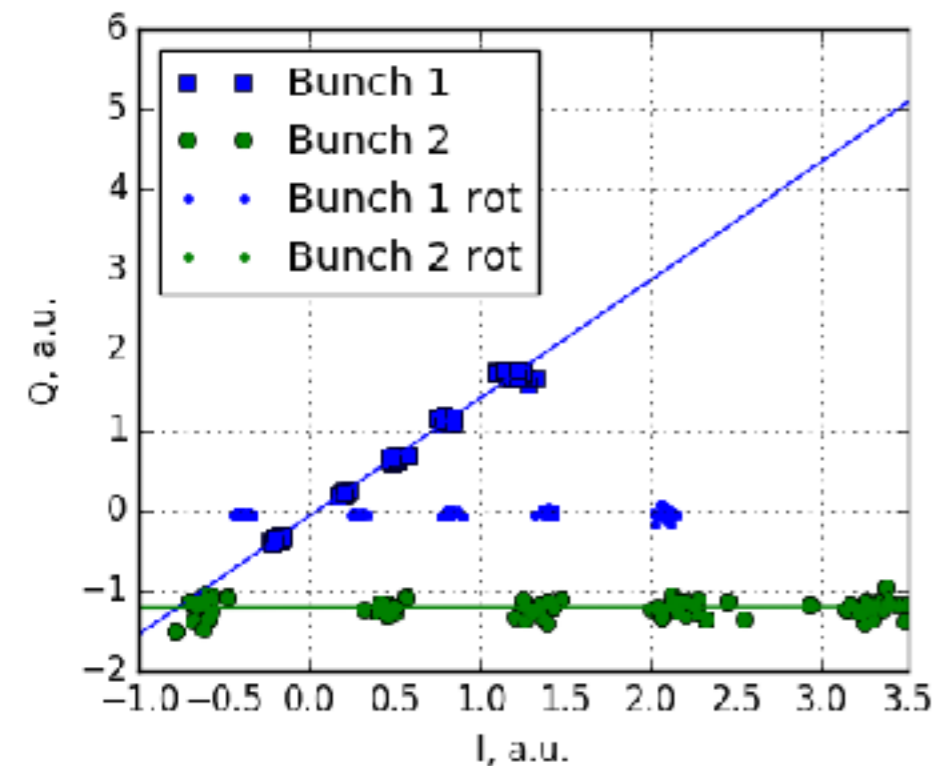


- Precision measurement of the frequency of the signal, decay time of the processed amplitude and choice of the sampling time relative to the arrival time needed for processing and subtraction
- Synchronous detection allows to ignore phase propagation during subtraction (the phase is “flat”)
- Amplitude is propagated as decaying exponential

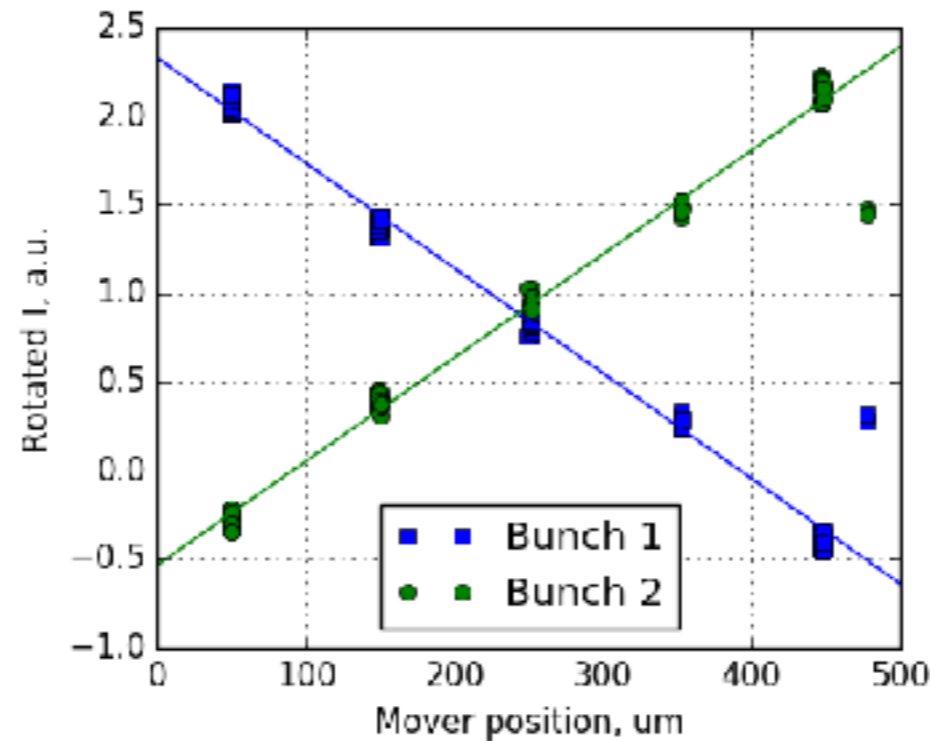
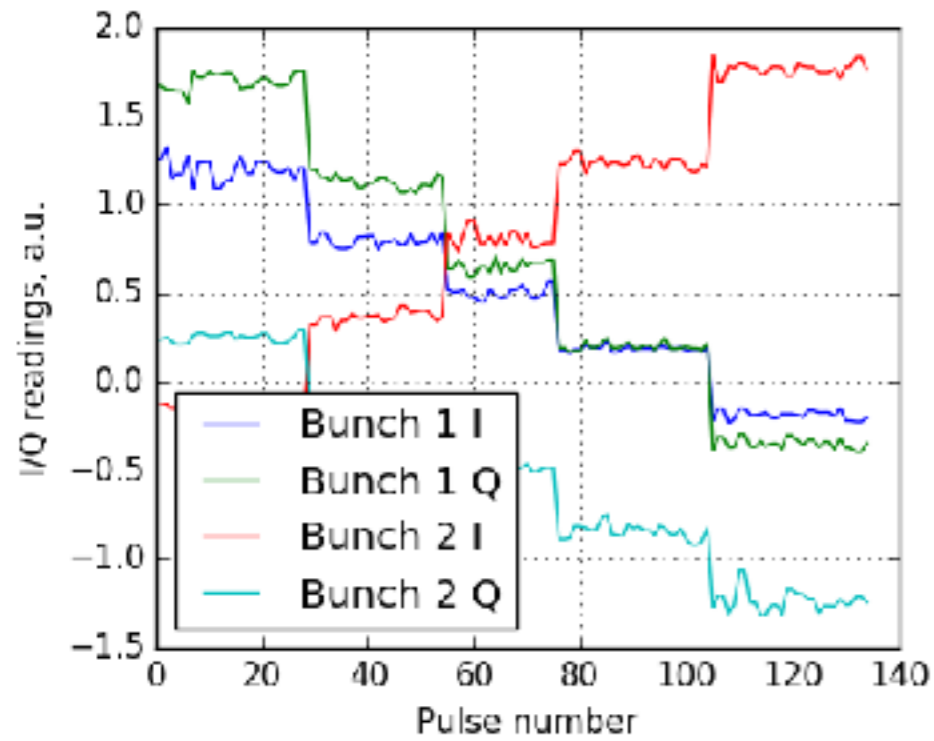
Calibration: Subtraction OFF



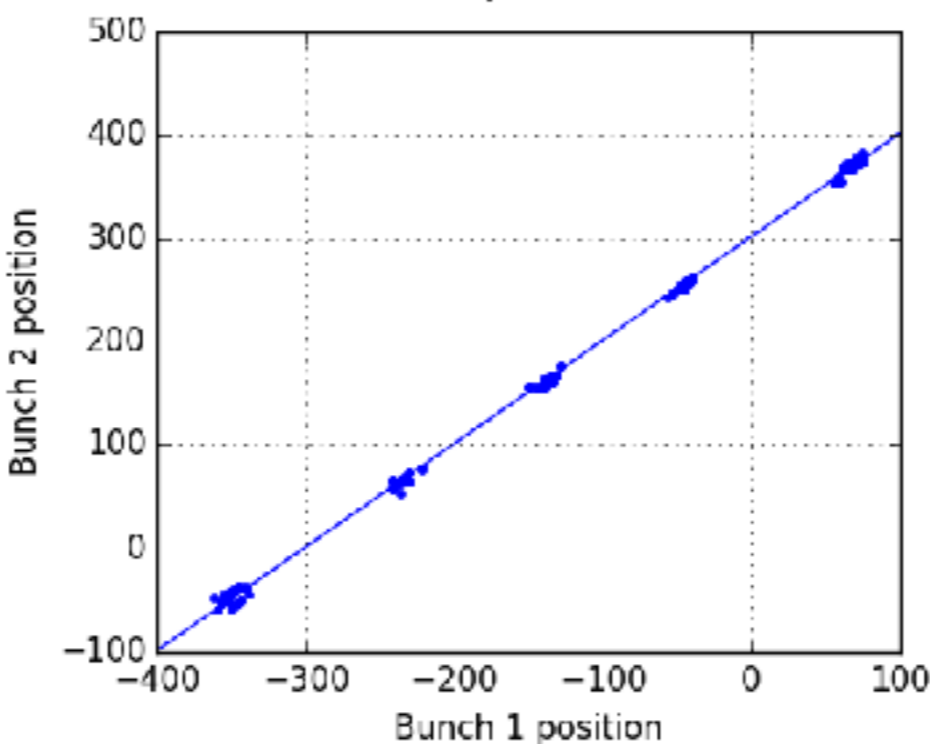
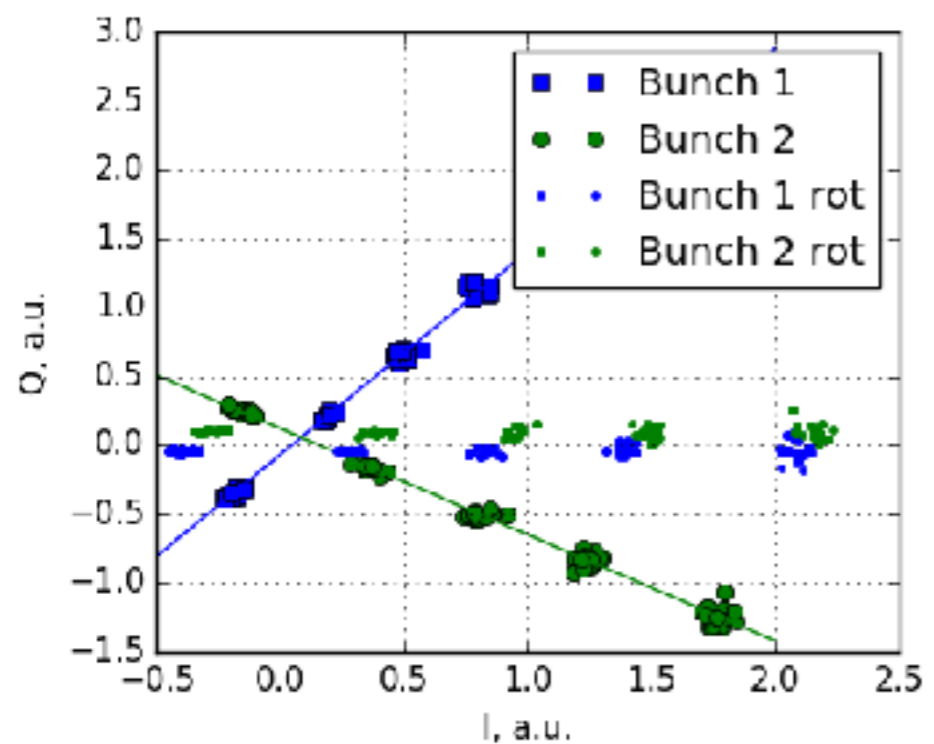
- Scales: 168 μm/a.u. and 107 μm/a.u.
- Residual within +/- 100 μm: 12.8 μm



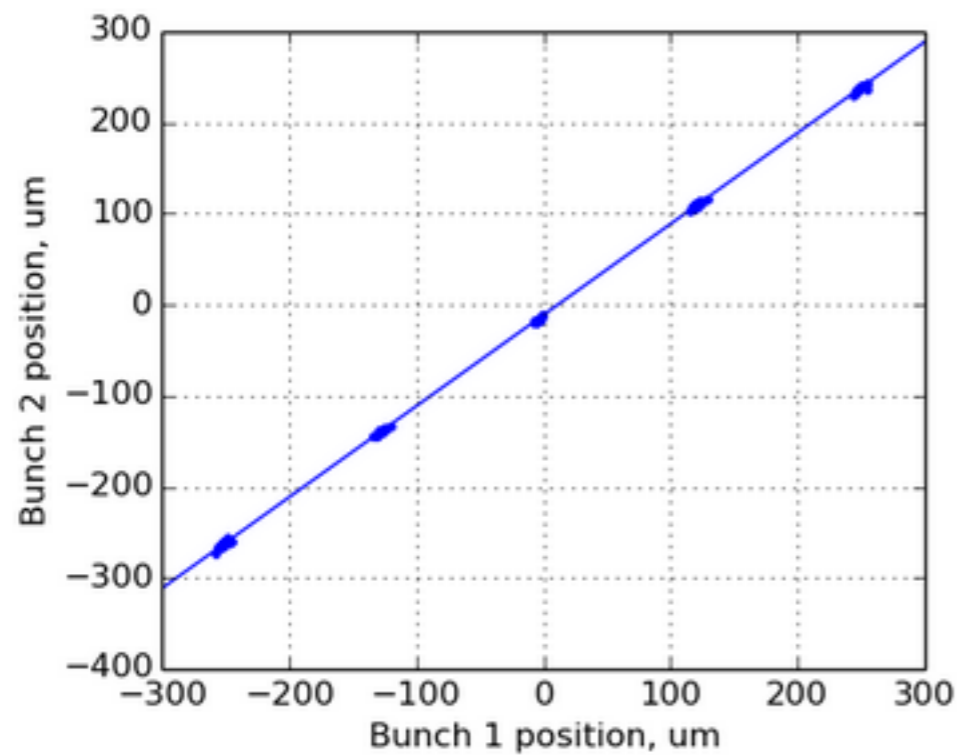
Calibration: Subtraction ON



- Scales: 168 μm/a.u. and 171 μm/a.u.
- Residual within +/- 100 μm: 2.9 μm

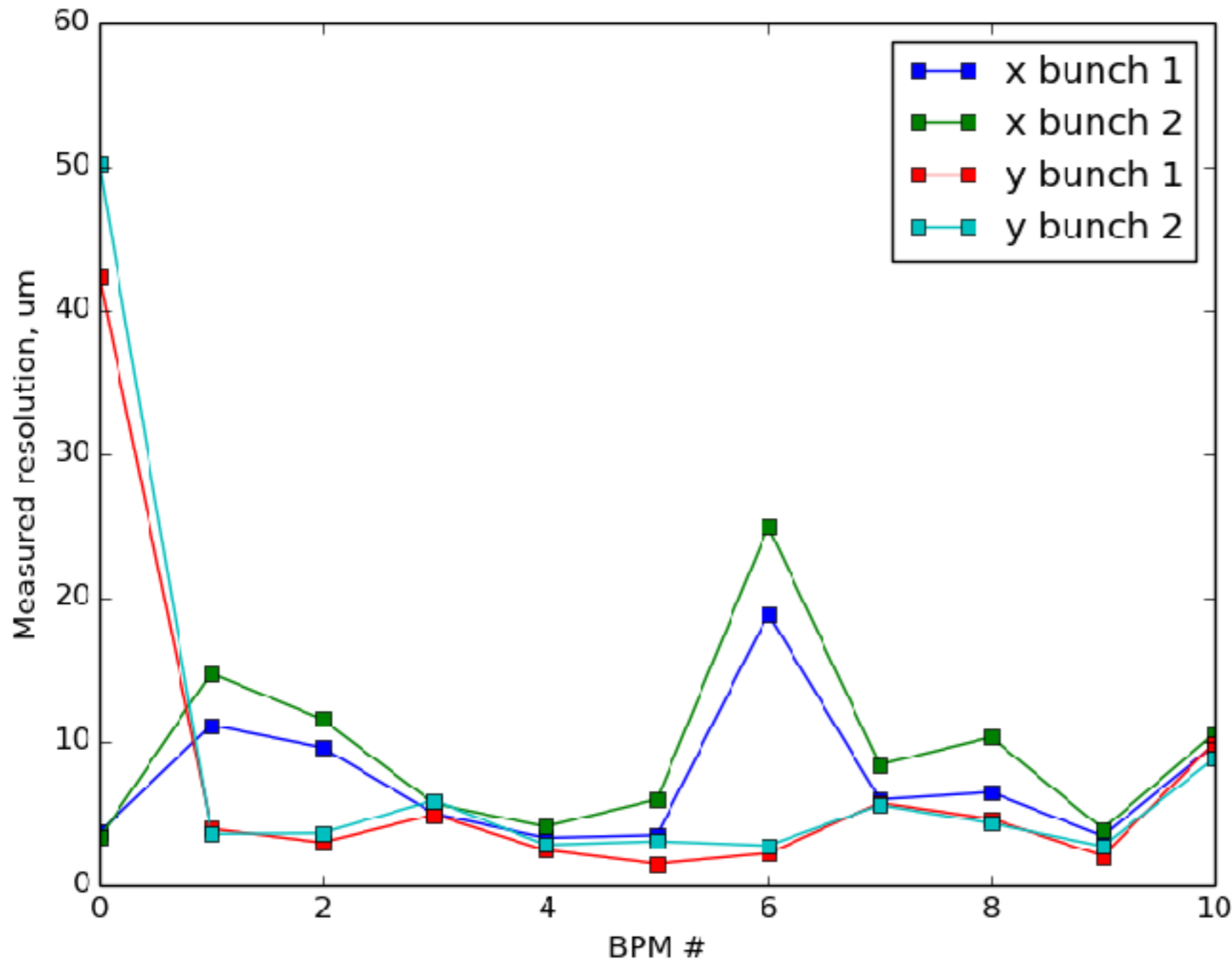


Resolution limit from calibrations



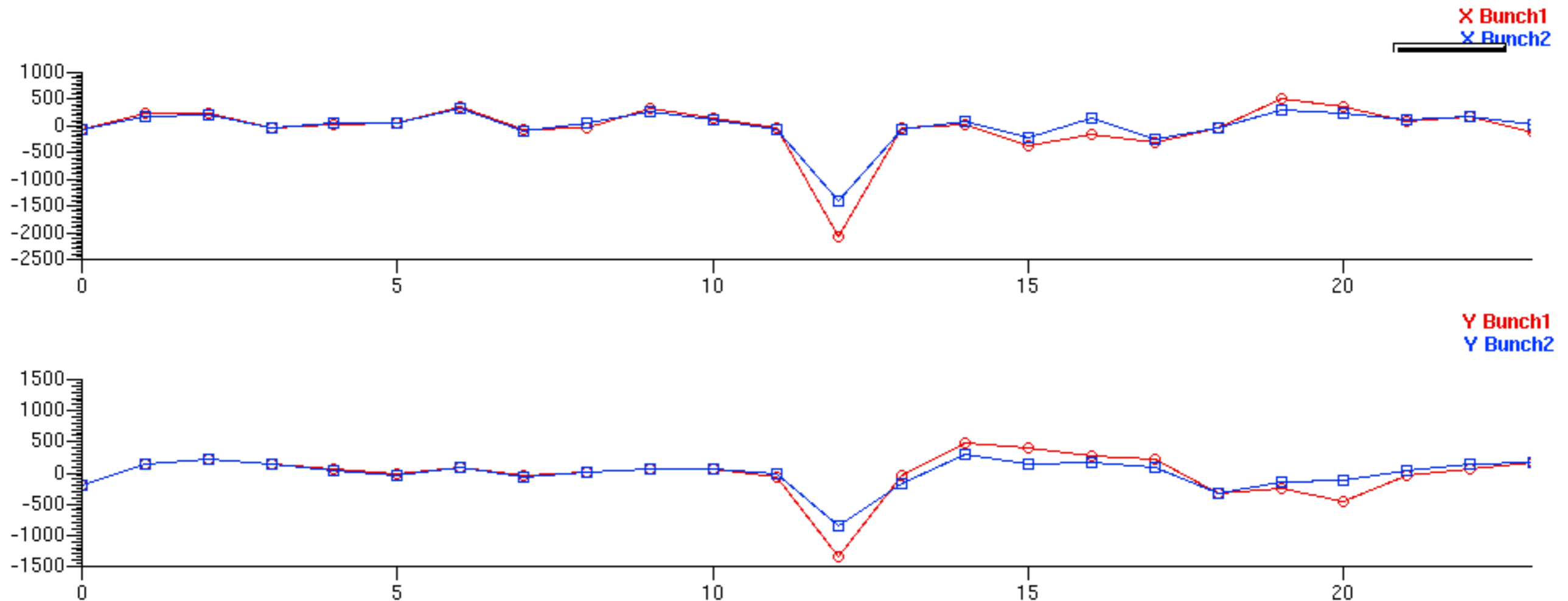
- Best bunch-bunch residuals observed are below 1 um, set the upper limit on resolution

Resolution study (preliminary)



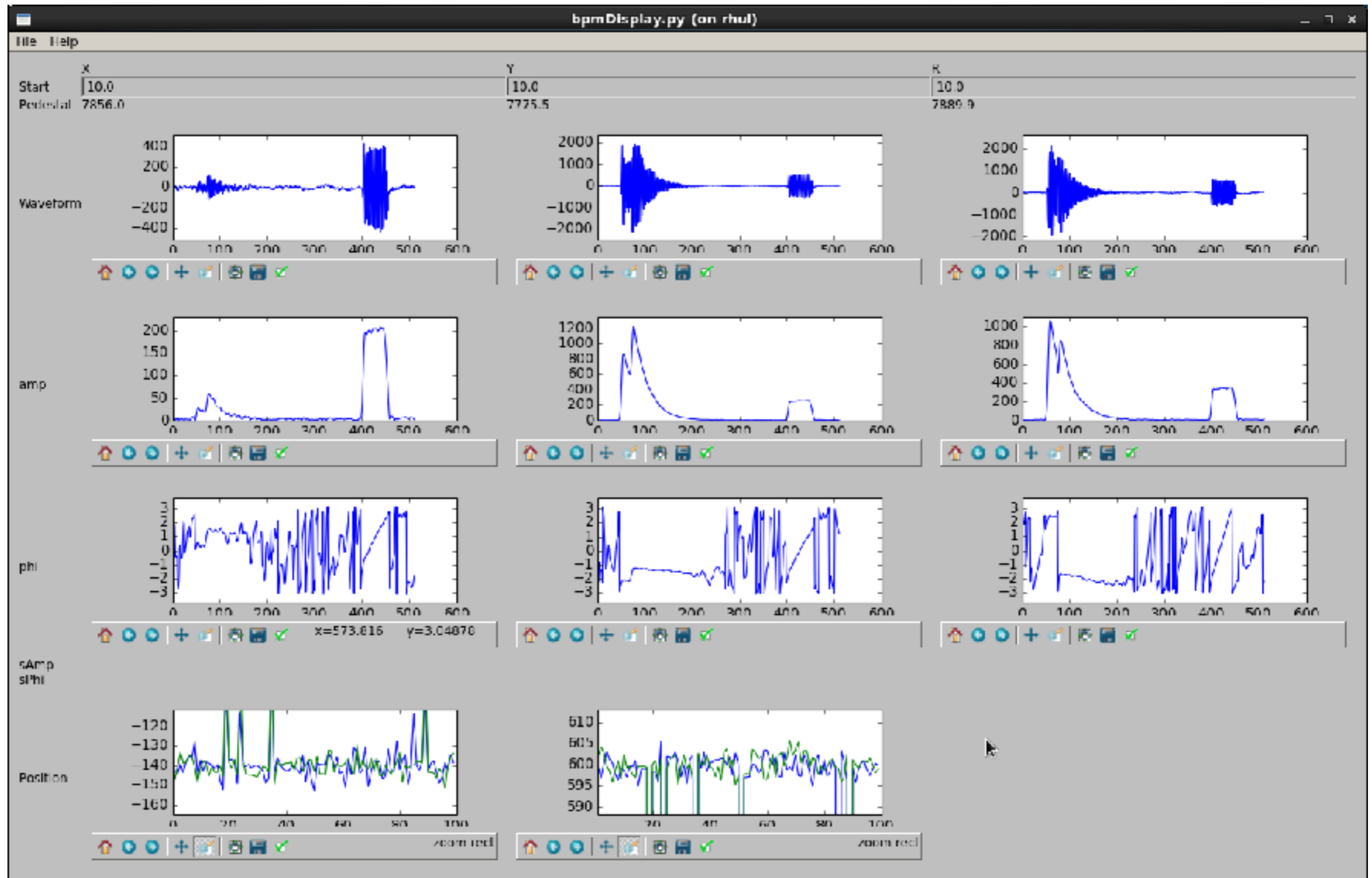
- Resolution measured on processed positions, “out of the box”, read directly from EPICS, no post-processing.
- SVD applied, so calibration scale errors are compensated, but not calibration phase rotation errors
- Not the best data, random selection, the first 11 (calibrated for this run) BPMs used
- Resolution consistent between 2 bunches, second bunch resolution 10-20% worse, as one would expect
- Most CBPMs below 5 um
- Problems can be identified, online monitor in works

Whole orbit measurement available online



- The orbit for both bunches is measured online
- Can see good correlation for the 2 bunches, offsets reach ~100-200 um @ high beta
- “Bumps” are usually caused by saturation

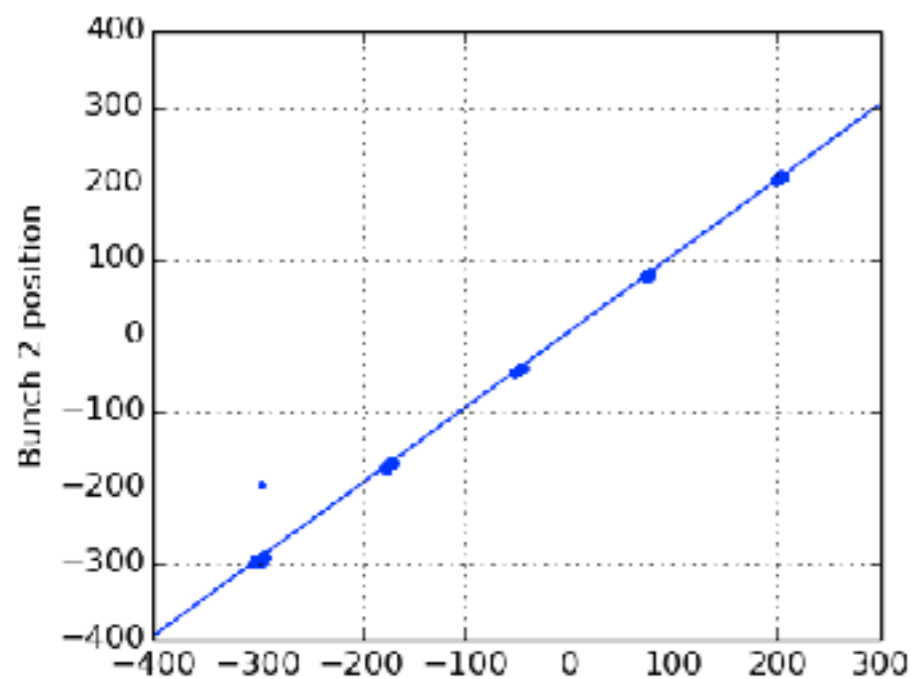
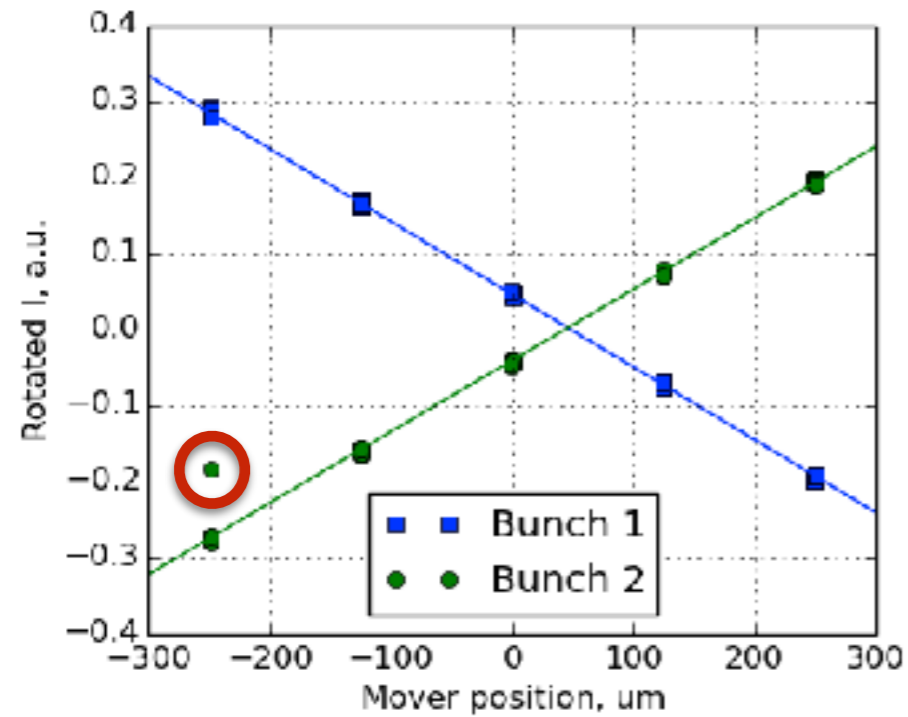
QT based interface started



Current status

- System is online and the processing is now stable
- Calibrations are automated
- Full orbit merge and monitor
- Resolution study is ongoing
- Can run offline data through online system
- Progress is there, but resources are limited
- Planning a publication

Ongoing work/ToDo list



- Occasional outliers
 - Possible racing condition between threads
 - Issues with data acquisition scripts
- Timing compensation
 - Bunch distance changes
 - Trigger timing changes
 - Considering using the downconverted reference signal instead of the diode due to better sensitivity and linearity
- Resolution testing, monitoring and improvements
- New QT interface may happen time allowing