Chromaticity measurements at the FNAL booster

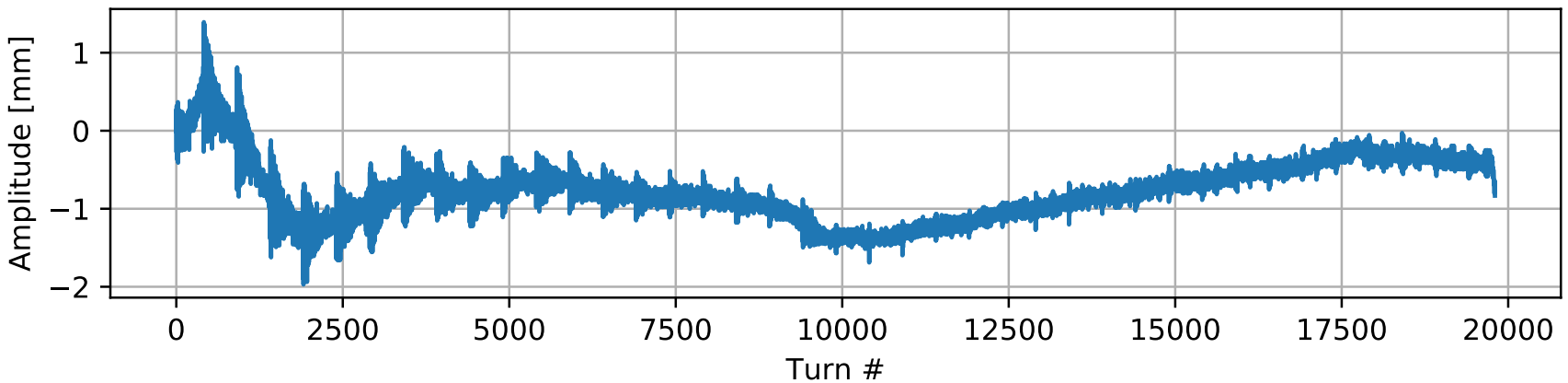
Michele Carlà et al.

02 Jul 2019

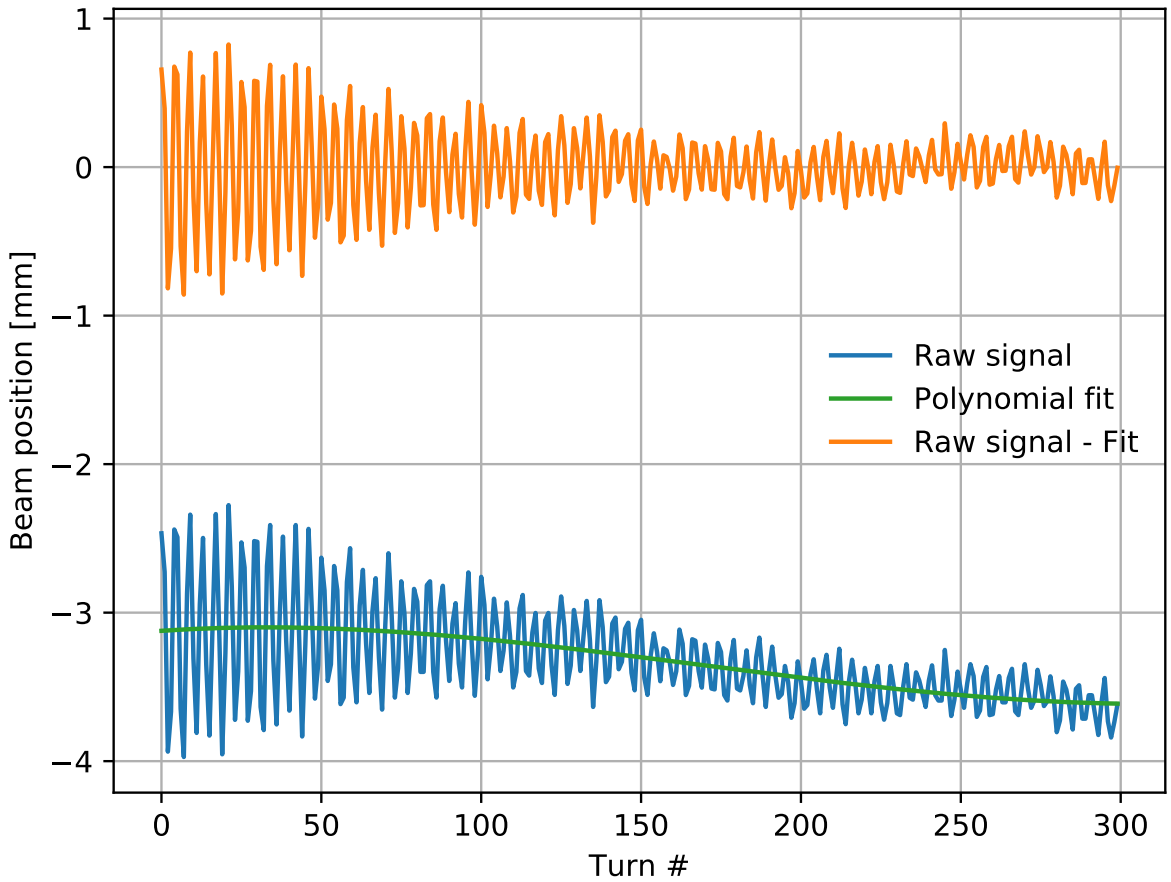
Chromaticity measurements at the FNAL booster

- **Two** separated chromaticity **scan** acquired
- Repeated for the **vertical and horizontal** planes (**4 scans total**)
- The betatron motion was excited with a **pinger**
- The tune was measured several times at **different point in the cycle**

- Determine the **evolution** of the linear **chromaticity** along the cycle
- Investigate **non-linear chromaticity**

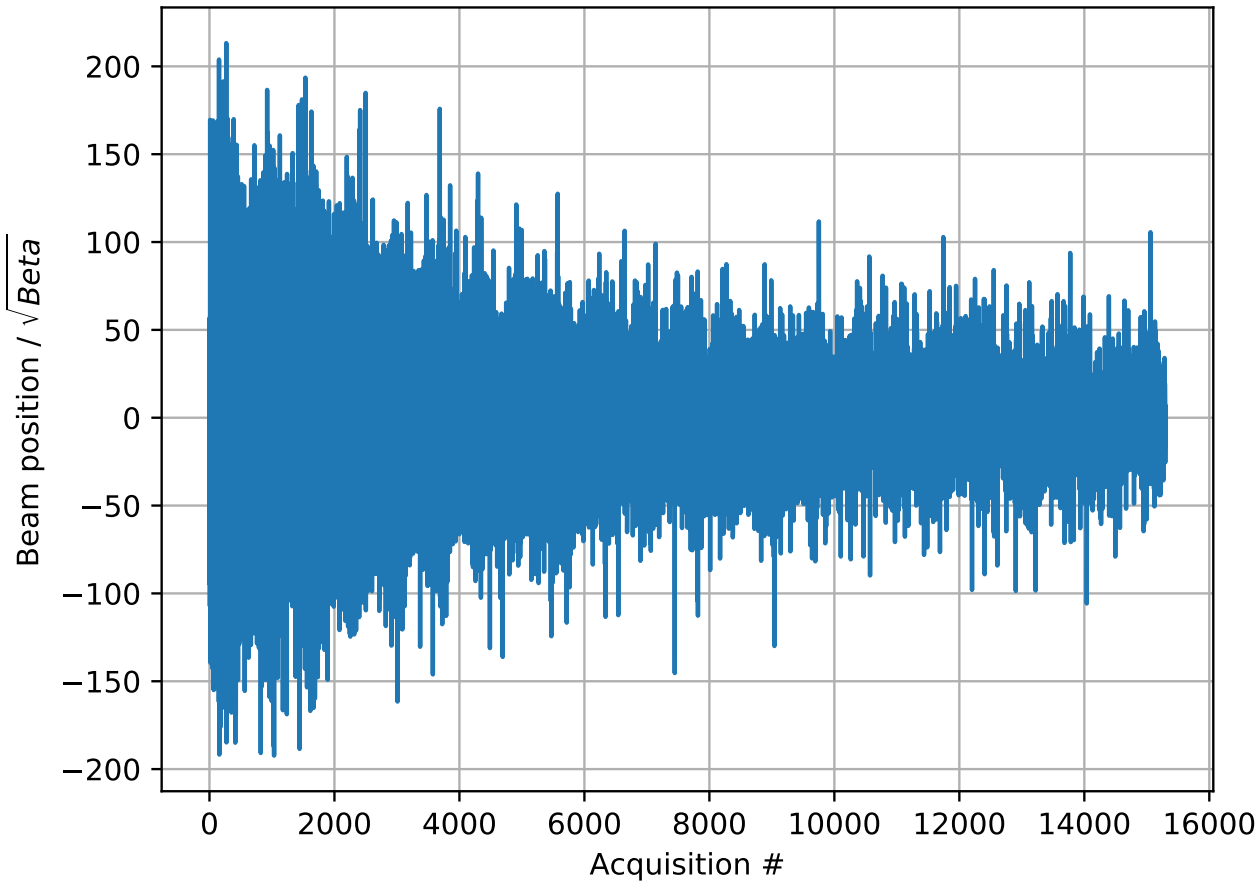


Orbit change is visible during some of the tune excitation



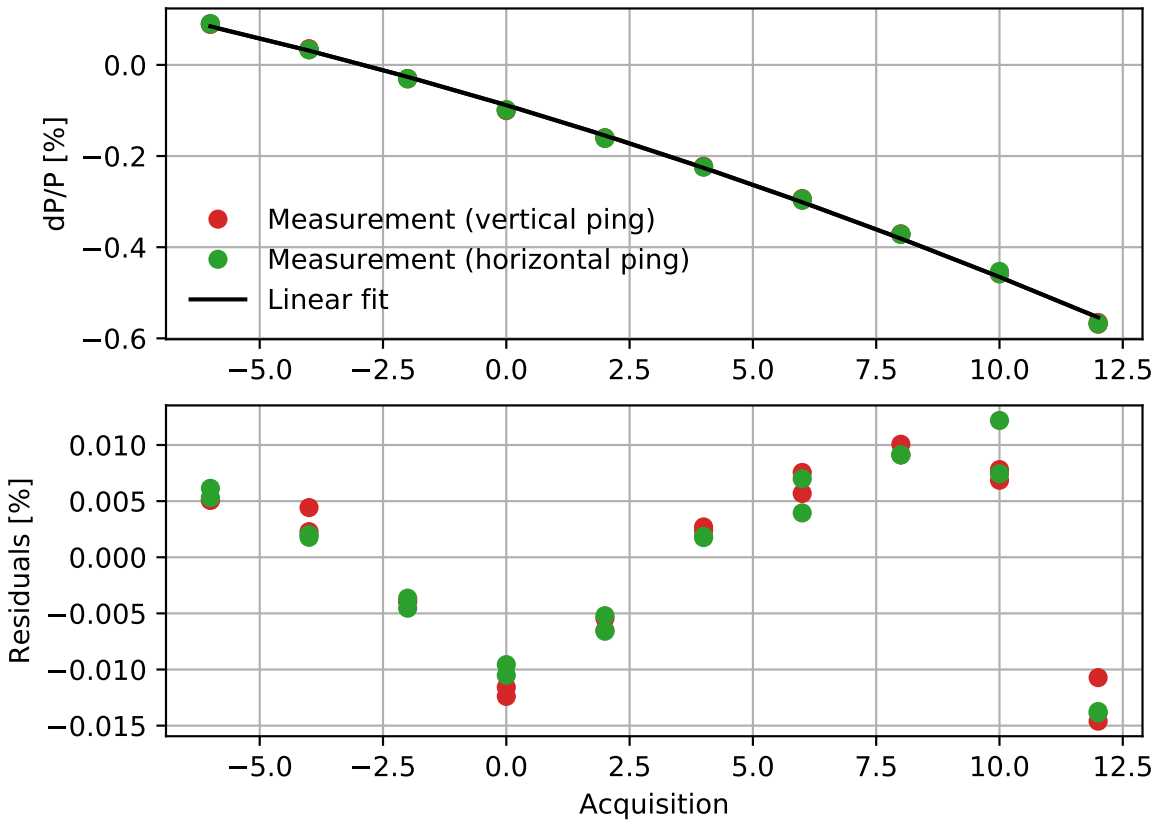
- The **orbit** is calculated with a **third order fit**
- The signal is **"straightened"** by removing the orbit

Signal from all the BPMs is combined in one single dataset



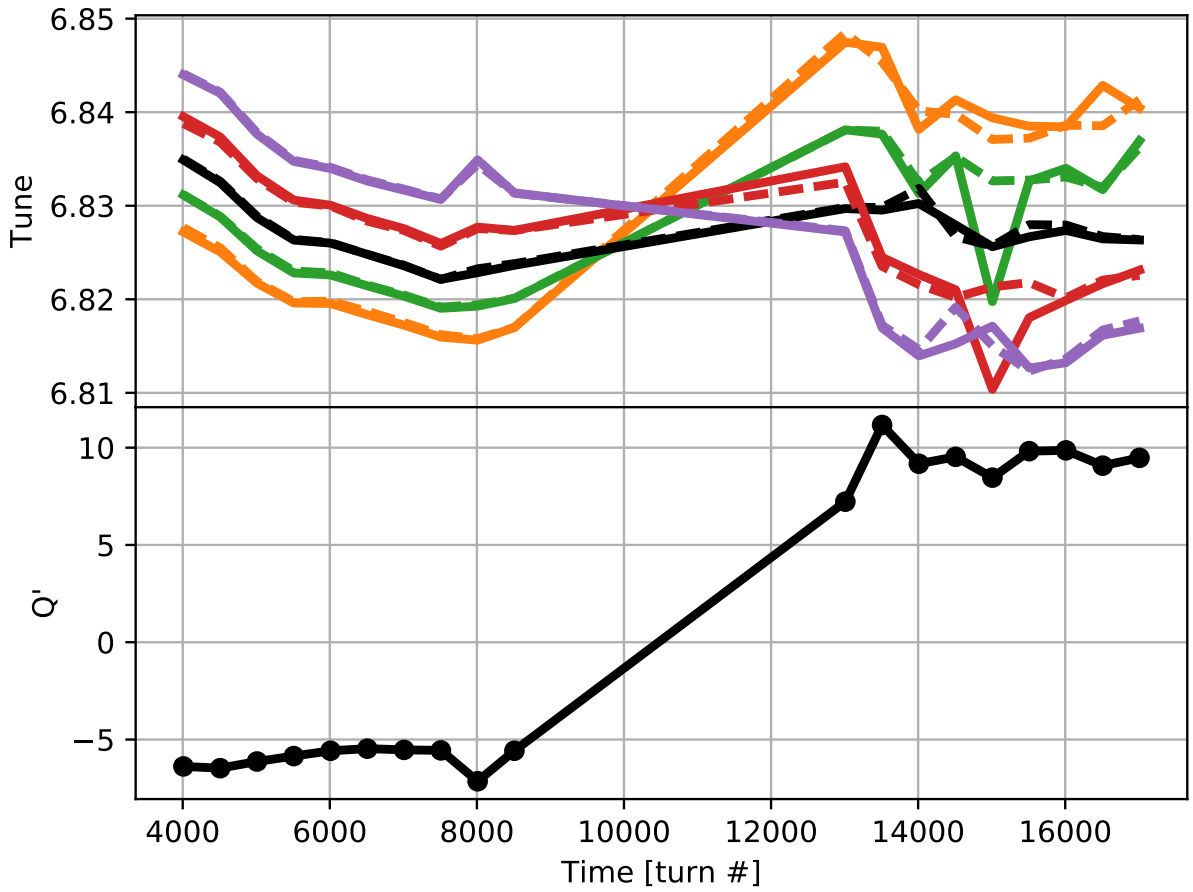
- Turn-by-turn Signal from **51 BPMs is combined** in one single dataset
- Tune is determined using the **Laskar method** (i.e. NAFF)

Energy is determined from the dispersive orbit



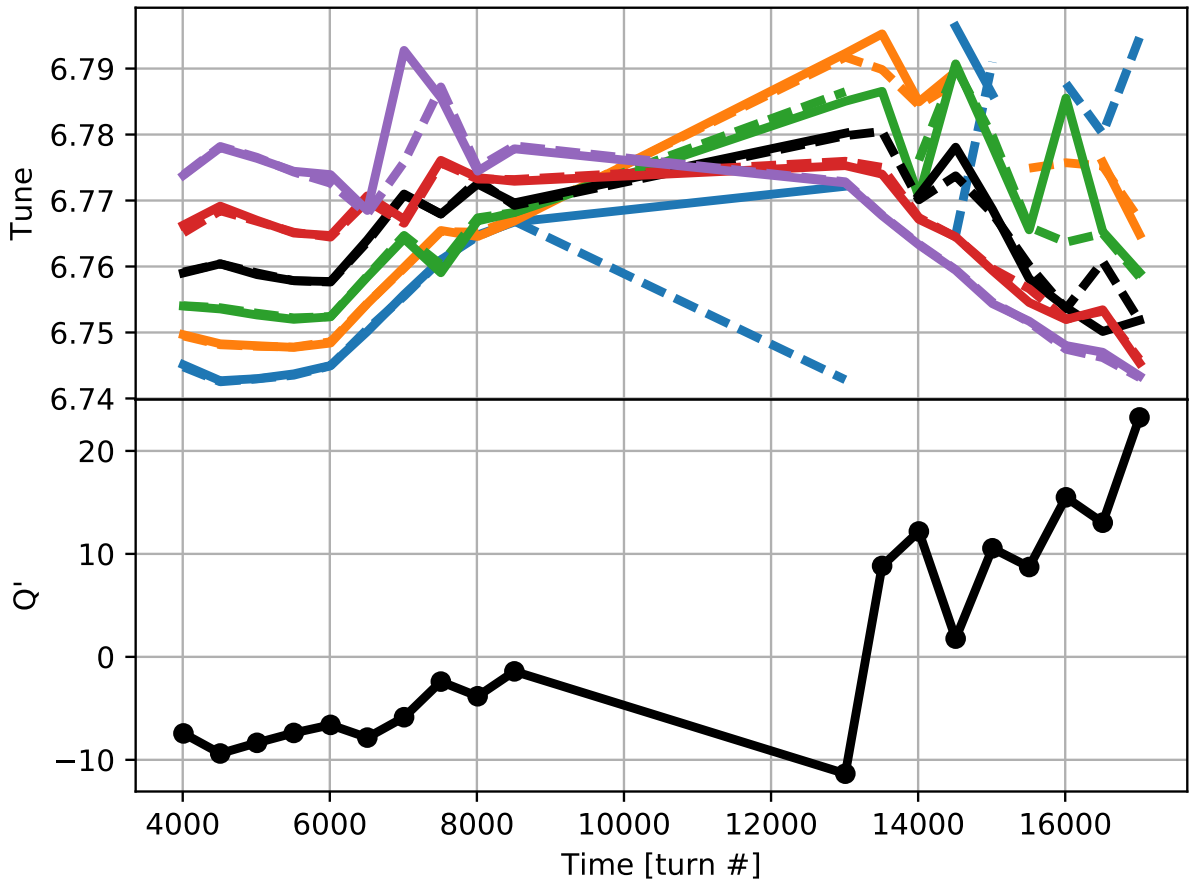
- The **2 datasets** (horizontal and vertical pings) are treated separately
  ...should provide **identical** results
- Plot shows **"radial-steering vs measured energy"**, a linear **fit** shows any mismatch
- Some higher order **pattern** is visible in the **residuals**

Vertical linear chromaticity



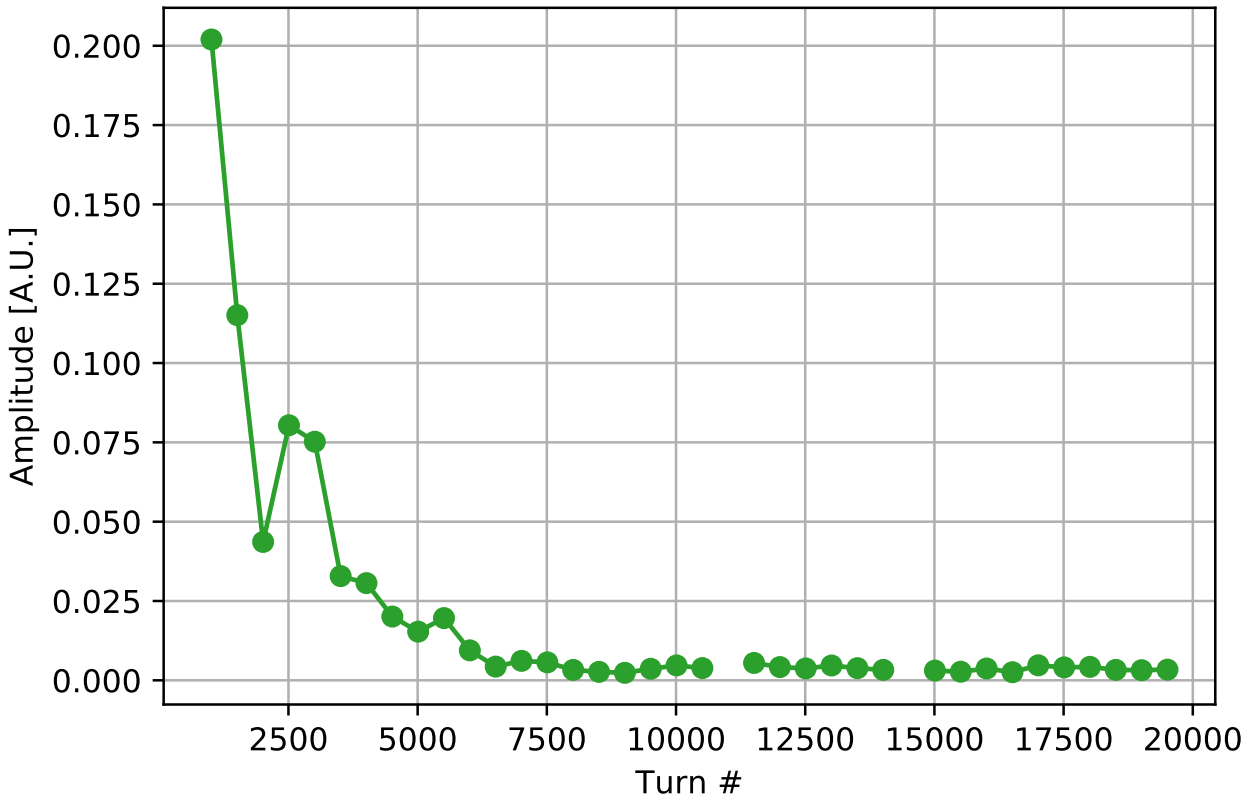
- Each **color** represents a different **energy** settings
- For each energy the tune is acquired 2 times (solid/dashed line)
- **At injection, transition crossing and extraction** the energy is set to nominal
  $\rightarrow$ **No measurement** available at these points

Horizontal linear chromaticity



- The **horizontal** measurement is **worst** respect to the vertical one
- Sometime a strong disagreement between the 2 datasets (solid/dashed) is visible ...maybe because of the higher chromaticity

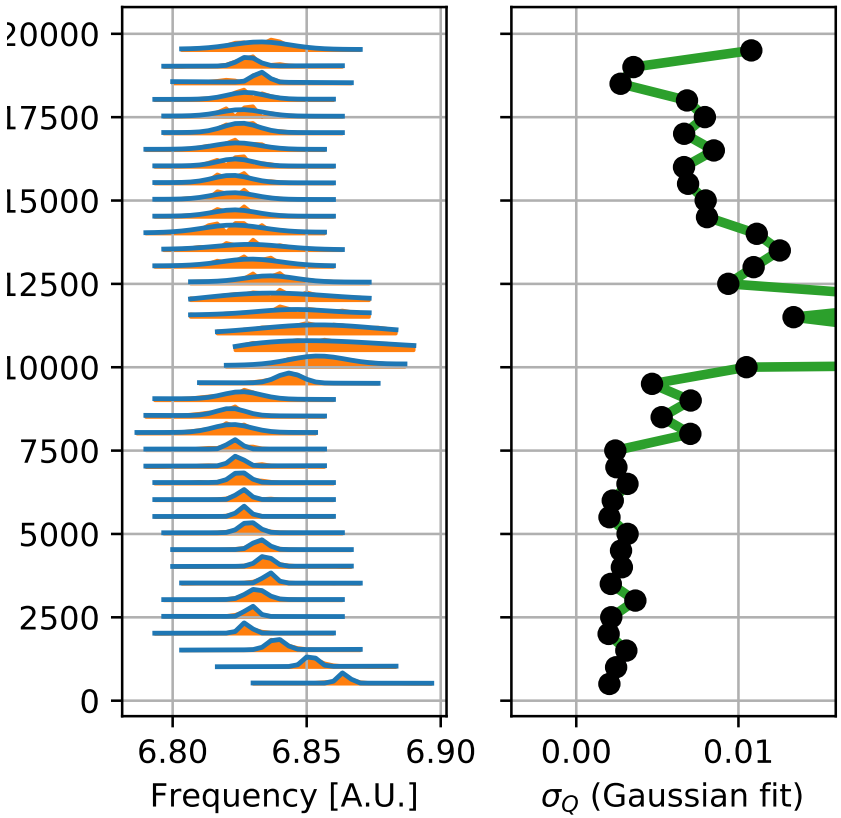
Betatron amplitude



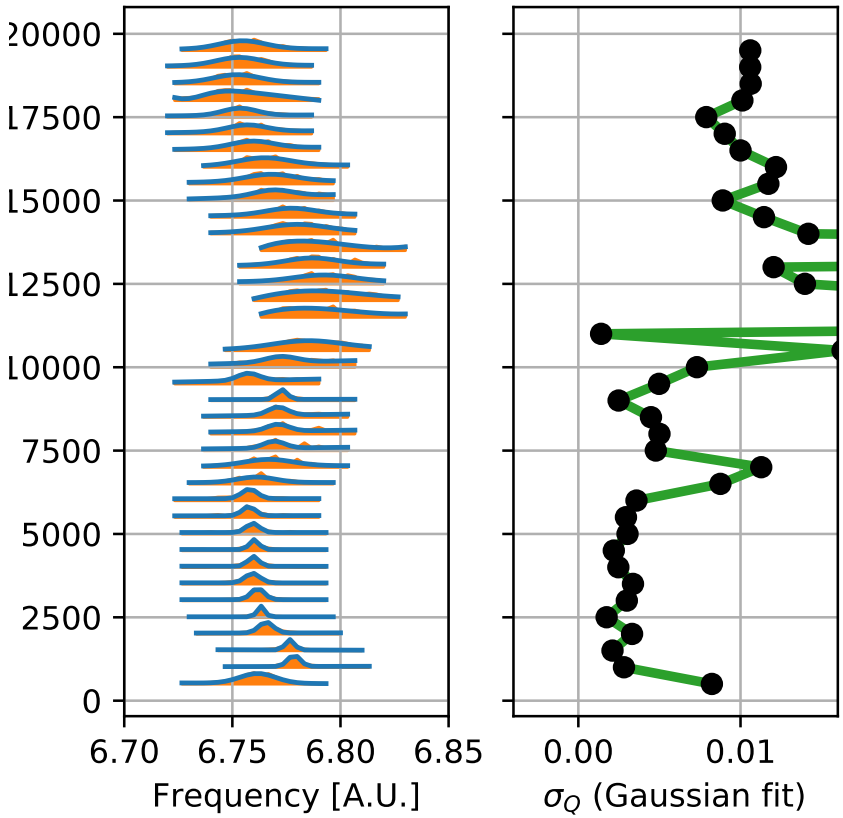
- The **horizontal** measurement is **worst** respect to the vertical one
- Sometime a strong disagreement between the 2 datasets (solid/dashed) is visible ...maybe because of the higher chromaticity

Betatron motion decoherence

Vertical



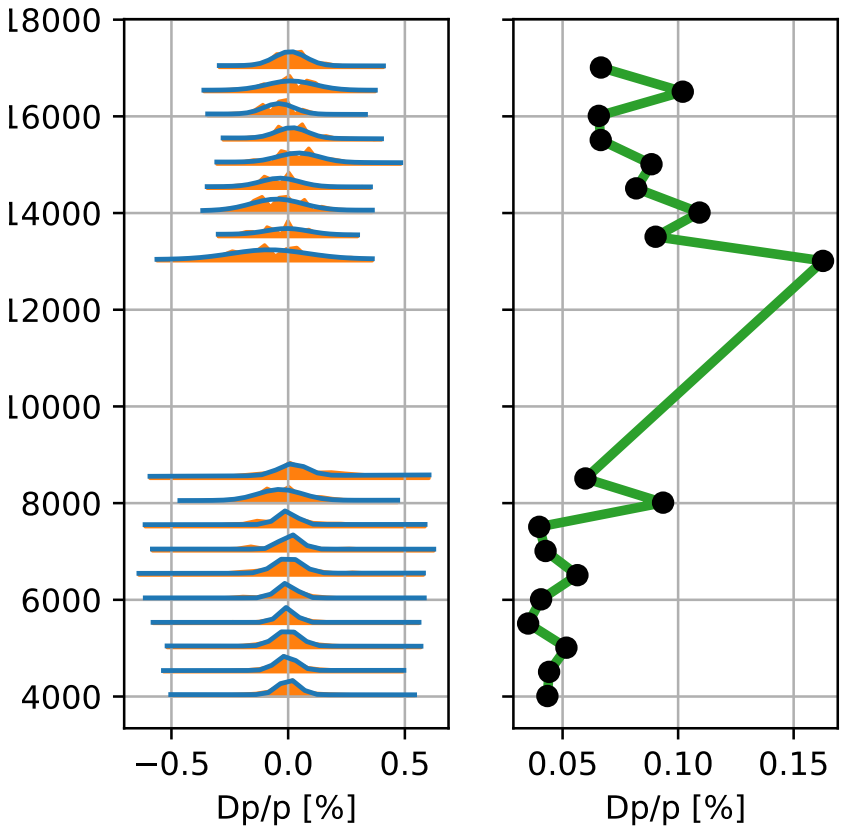
Horizontal



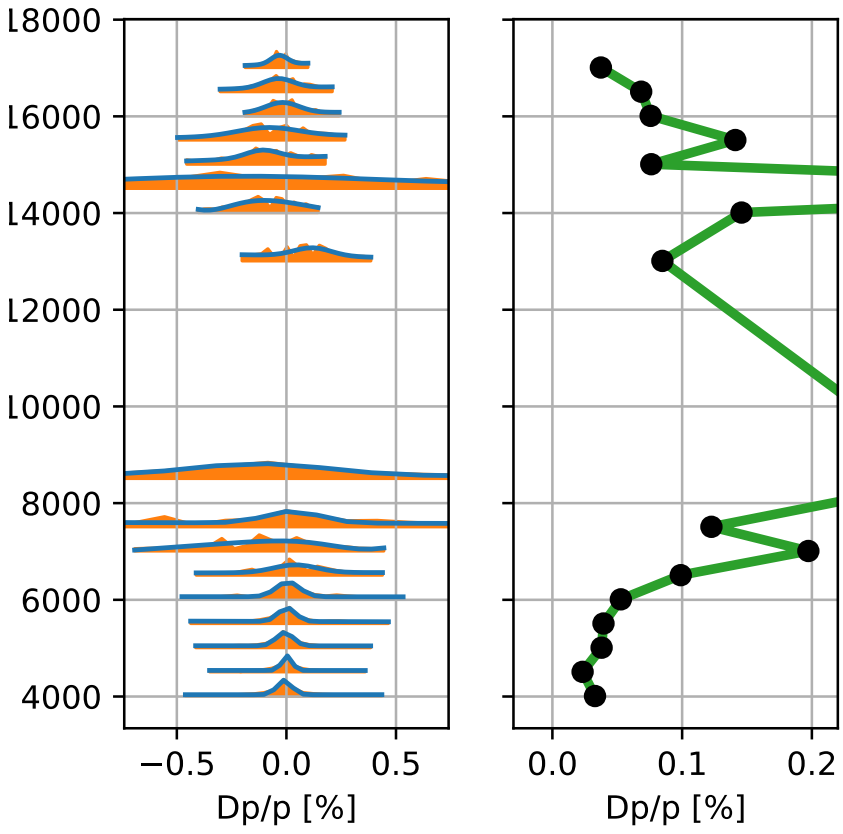
- The Fourier **spectrum** is calculated for **each excitation**
- The **width** (σ_Q) of the tune-peak is obtained from a **Gaussian fit**

Energy spread from turn-by-turn spectra

Vertical

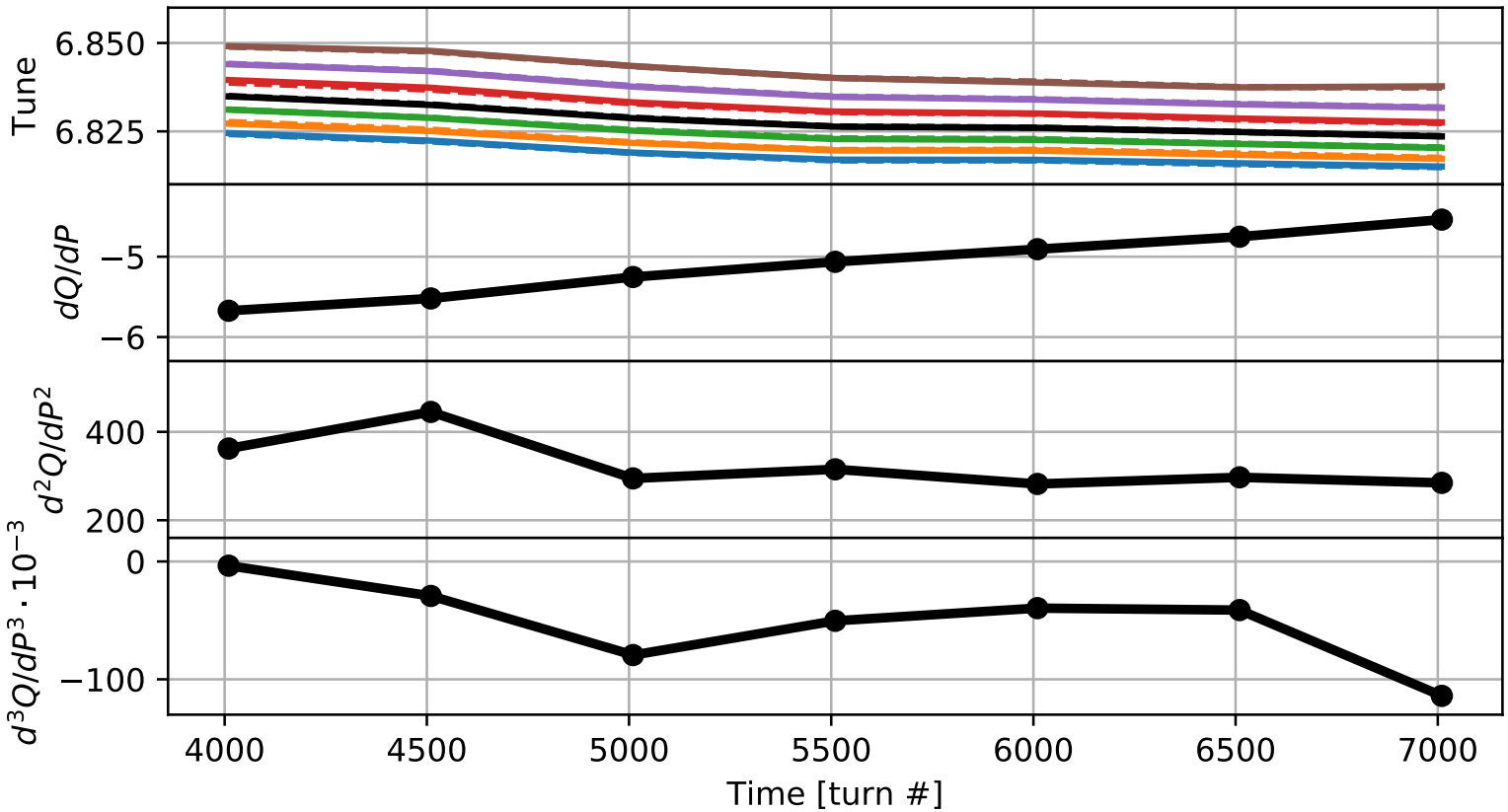


Horizontal



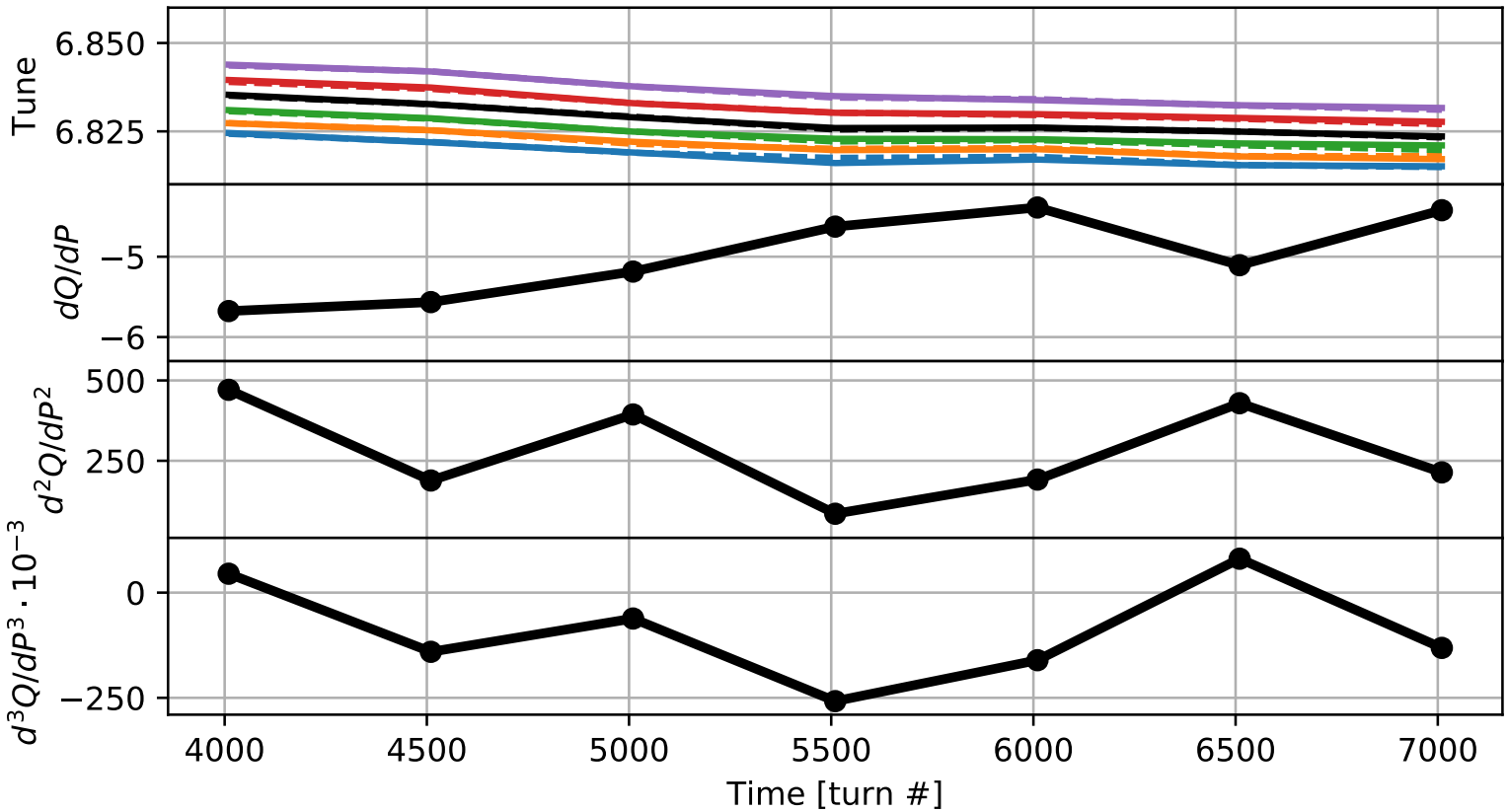
- The Fourier **spectrum amplitude** is proportional to the **energy distribution**
- The **width** of the betatron **peak** provides information on the **energy spread**

Vertical non-linear chromaticity before transition



- Energy scan ranges from -6mm to +6mm
- **Only** measurements **before transition** are good enough
- The **second order** chromaticity (octupole-like) looks quite **constant**
- The third order chromaticity (decapole-like) is a bit more "noisy"

Horizontal non-linear chromaticity before transition



- Energy scan ranges from -6mm to +4mm
- **Only** measurements **before transition** are good enough
- The **second order** chromaticity (octupole-like) looks **similar** to the **horizontal**
- The third order chromaticity (decapole-like) is ...mostly noise

What we learnt?

- Radial steering **wider than 6mm** did not provided clean tune measurements
- **Lowering** the linear **chromaticity** could help with decoherence and allowing to resolve better higher order terms
- **Reducing number of injections** (lower energy spread?) could help
  This would also help with beam stability in case of lower chromaticity
- **Energy** has been determined by fitting the dispersive orbit
  While the result looks robust the method **suffers from non-linearities in the optics and BPMs**
- Measurement of the **RF frequency** would allow for a simple and robust determination of the **energy**