Beamline EXP1 & EXP3

Experimental area 1 (EXP1)

Experimental area 3 (EXP3)
Orbit Independent Measurement

Momentum of bunch can be written in first order approximation

\[ p = p_0 + \Delta p \approx p_0 \cdot \left( 1 + \frac{\Delta x_3}{D_x(s_3)} \right) \]

Collective betatron motion occurs as small perturbation of the measured beam position:

\[ x_3 = \Delta x_3 + \delta x_{\beta} \]

To remove the betatron motion, two bpm’s in front of the spectrometer dipole can be used. One finds:

\[ \frac{\Delta p}{p_0} = a_1 x_1 + a_2 x_2 + a_3 x_3 \quad \text{with} \]

\[ a_1 = \frac{1}{D_x l_{12}} \cdot (M_{11} l_{2d} + M_{12}) = -0.958 \, m^{-1} \]

\[ a_2 = -\frac{1}{D_x l_{12}} \cdot (M_{11}(l_{12} + l_{2d}) + M_{12}) = 1.380 \, m^{-1} \]

\[ a_3 = \frac{1}{D_x} = -0.672 \, m^{-1} \]

If the bpm’s are calibrated and the resolution known, then the rms energy resolution yields:

\[ \frac{\delta p_{\text{res}}}{p_0} = \sqrt{\sum_i (a_i \delta x_{i,\text{res}})^2} = 1.2 \times 10^{-4} \]

(assumption: bpm noise is statistically independent)
Resolution of BPM’s in the experimental area

Experimental setup:

- Measurement (10/01) resolution bunch to bunch at 1 Hz:

  - BPM1:
    - mean: -1.35
    - rms: 0.07
    - Δ: 0.32
    - sum: 6000

  - BPM2:
    - mean: 2.41
    - rms: 0.07
    - Δ: 0.47
    - sum: 5935

  - BPM3:
    - mean: -2.0
    - rms: 0.06
    - Δ: 0.37
    - sum: 5937

- Jitter from electronic noise within a bunch train is expected to be smaller
- Measurements are planned this week (requires long pulse operation)
Calibration of BPM’s

Using well known steerers to induce kicks to the beam

Example BPM1EXP1:

Umrechnungsfunktion für BPM1

\[ x = -6.38 \cdot U^3 - 4.83 \cdot U^2 - 9.99 \cdot U - 1.56 \]

Results for the bpm electronic response functions:

\[ x_{\text{BPM}1} = -6.38 \cdot U^3 - 4.83 \cdot U^2 - 9.99 \cdot U - 1.56 \]
\[ x_{\text{BPM}2} = -17.93 \cdot U^3 - 6.37 \cdot U^2 - 17.30 \cdot U - 0.02 \]
\[ x_{\text{BPM}3} = -12.74 \cdot U^3 - 7.32 \cdot U^2 - 10.31 \cdot U - 0.13 \]
Energy of bunches in a macro pulse

Mean: 219.97 MeV  Number of Bunches: 176
1st Bunch: 219.20 MeV  Status: 8

Feedback: Nikolay.Sturm@desy.de
Dipole calibration:

wavelength calculated from bunch energy

Sase spectrum averaged over several bunches

\[ E_0 = \frac{2438.5 \pm 1}{\sqrt{\lambda_{\text{Photon}}}} \]
\[ E_0 = (8.09 \pm 0.1) \cdot J_{B1} \]

Induced artificial betatron oscillation:

Correction reduces the influence of betatron motion by more than a factor of 10 (in limited meas. range).
Measured Energy Stability

- Varies from time to time and depends on the machine parameters
- Intra-bunch energy spread during the measurements about 1%
- Energy jitter bunch to bunch at 1 Hz operation.

mean $E = 245.35$ MeV

rms $E = 0.09$ MeV

rms $dE/E = 4 \cdot 10^{-4}$

time $= 40$ min.

$\Rightarrow$ Energy stability is more than an order in magnitude smaller than the intra-bunch energy spread
Cross-Talk to trailing Bunch

BPM1
BPM2
BPM3

Large oscillations over a long time period (few 100 ns)

Sampling time of ADCs

2.25 MHz operation with present electronics not possible

Cross-talk to next bunch
Required Steps for High Precision Energy Measurement

• Adjustment of ADC timing

• Recalibration of BPMs with beam
  (inj & exp ⇒ 4 hours stable beam conditions)

• Measurement of the intra-macro pulse resolution
  (2 hours beam time/ parasitically possible)

• Implementation to the server
  (is a server also for the injector desired ?)

• Test of servers
  (2 hours stable beam conditions)

⇒ major hardware changes are not expected.