Estimates of beta-beating for 2015.

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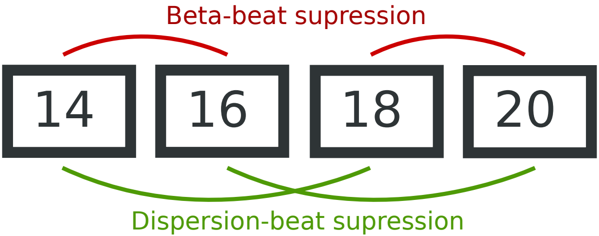
Outline.

- Beta-beat estimates at 7 TeV
  - Missing MQT magnets
  - Dipole b2 errors
  - Fringe fields
  - Hysteresis and saturation
  - MQX saturation
  - Extrapolation from 2012 local corrections
- Improvements in correction techniques
- Summary / Outlook

Beta-beat estimates.

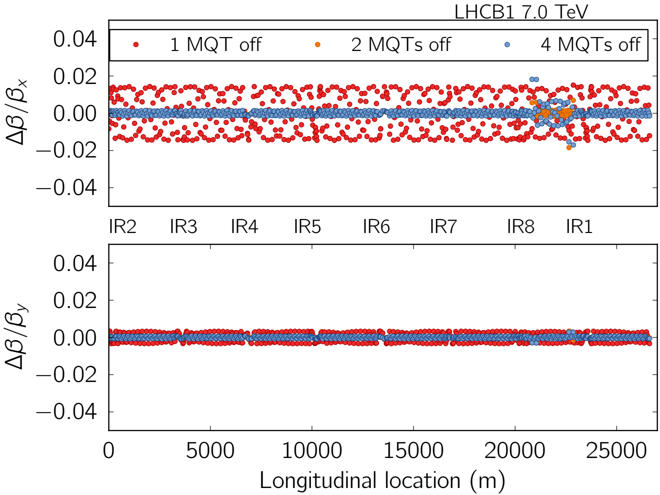
Missing MQT magnets.

- MQT 18.L1 is broken
- The disabled magnet can be compensated by increasing the strength of the other MQTs in this arc
- Switching off 4 MQTs is a favored solution for keeping low beta-beat and low dispersion-beat



Injection optics at 7 TeV - Missing MQT magnets.

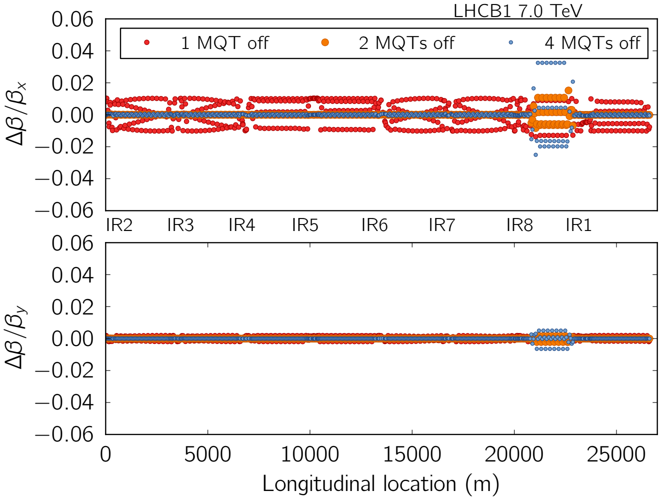
- Tune shift of 0.08 applied
- Global beta-beat is negligible if 4 MQTs are switched off
- Only around these MQT positions a larger beta-beat is observed



→ **2% peak beta-beat** (in arc81, negligible elsewhere)

ATS 20cm optics at 7 TeV - Missing MQT magnets.

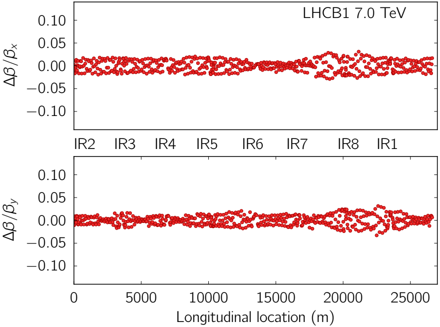
- Tune shift of 0.08 applied
- Global beta-beat is negligible if 4 MQTs are switched off
- Larger beta-beat in arc81



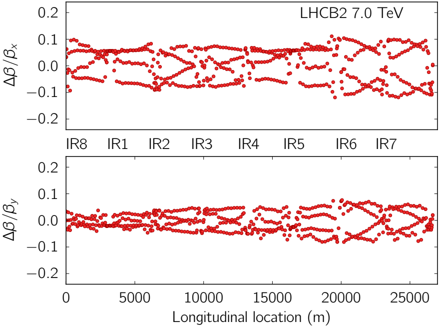
→ **4% peak beta-beat** (in arc81, negligible elsewhere)

Dipole b2 errors.

- Nominal optics (0.4/10/0.4/3)



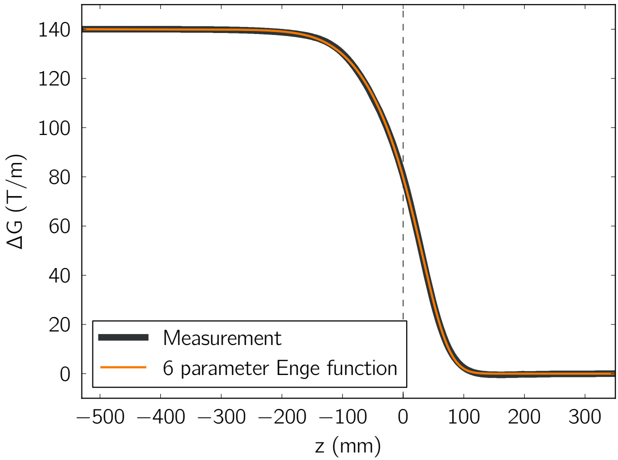
- ATS 0.2m optics



→ **3-10% peak beta-beat**

Fringe fields of triplet magnets.

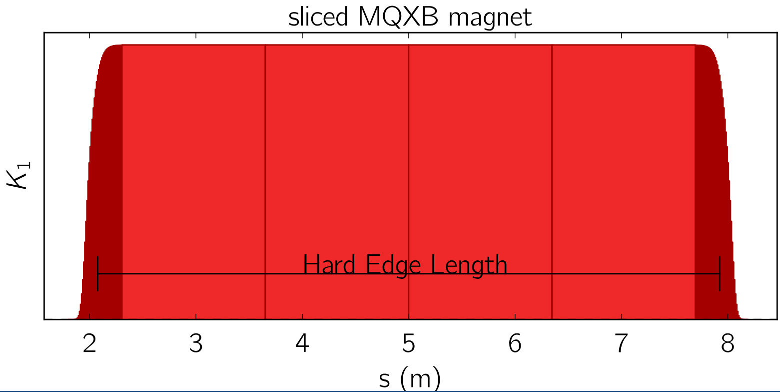
- Measured values of gradient versus longitudinal coordinate for MQXF magnets
- Applied on MQXA and MQXB by scaling with aperture (D)
- Fringe field fall off described by Enge function:



$$F(z) = \frac{1}{1+exp(a_1+a_2(z/D)+...+a_5(z/D)^6)}$$

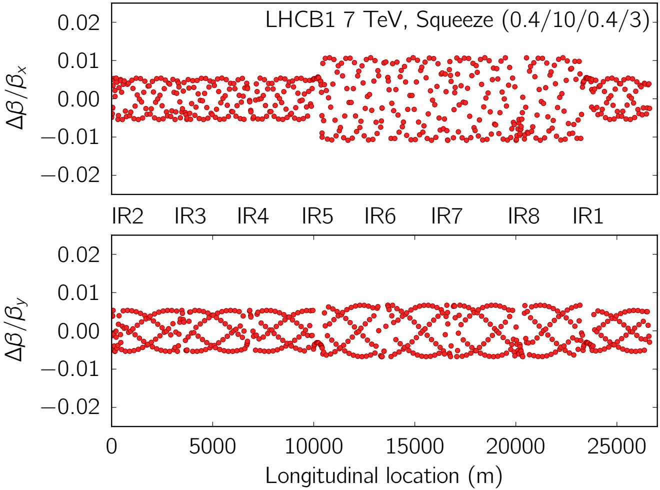
Fringe fields of triplet magnets.

- 0.5m on each end of the magnet is modeled using the fringe field fit
- 50 slices of 10cm length on both ends
- the mid part of the magnet has the same k value as before but length is changed in order to achieve the same overall $k \cdot L$



Fringe fields of triplet magnets.

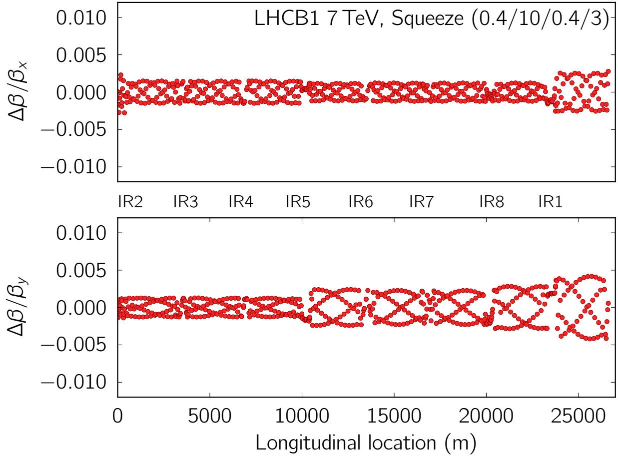
- Fringe field was applied to triplets in IR1 and IR5



→ **1% beta-beat**

Hysteresis at 7 TeV.

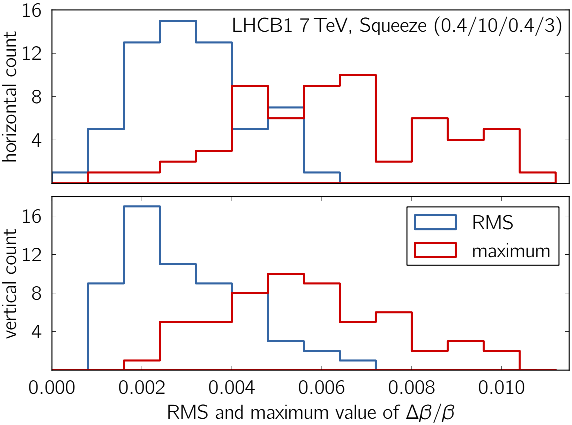
- FiDeL model describes ramp up branch
- This causes an error for magnets which are ramped down, e.g. during the squeeze
- 30 magnets from the MQY, MQM and MQML family



→ **0.5% peak beta-beat**

Saturation and hysteresis at 7 TeV (squeeze).

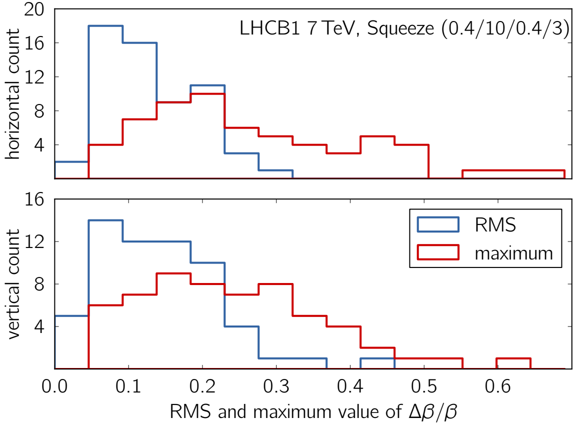
- Saturation uncertainties are treated statistically
- Simulation of 60 cases with random gradient errors following a Gaussian distribution within the saturation uncertainty
- Considered magnet types: MQ, MQY, MQM, MQML, MQMC and MQW



→ 1% peak beta-beat

Saturation and hysteresis at 7 TeV (squeeze).

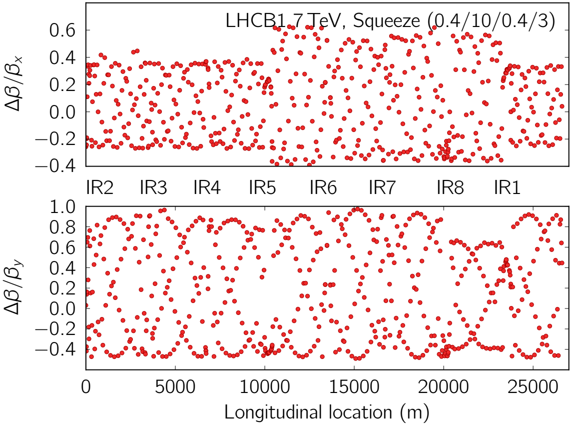
- Saturation uncertainty of triplet magnets MQXA and MQXB is now added to the simulation
- Strongest contribution to the beta-beat from these magnets



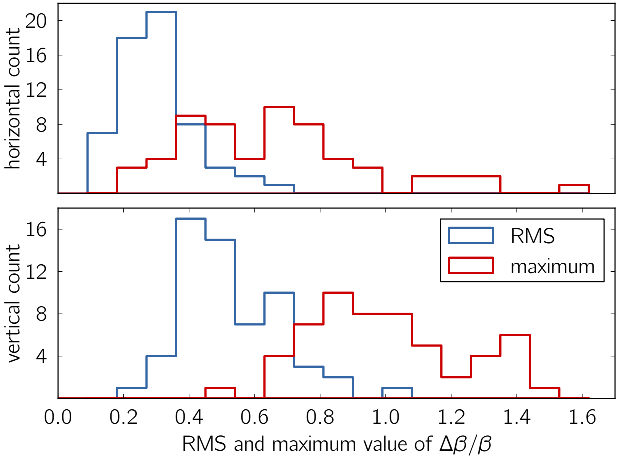
→ ≈ 60% peak beta-beat in worst case scenarios

Extrapolation from 2012 local corrections.

- Local corrections for $\beta^* = 0.6$ m (from 2012) $\rightarrow$ **80% peak beta-beat**
- Extrapolation to 0.4 m from known local corrections plus b2 errors $\rightarrow$ **100% peak beta-beat**



Estimated beta-beat from combining all aforementioned error sources.



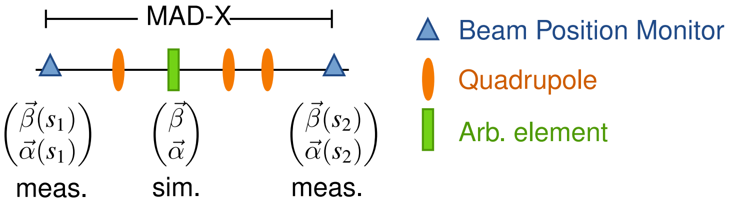
→ ≈ **160% peak beta-beat in worst case scenarios**

Summary from beta-beat estimates.

- Missing MQT magnets
  $\rightarrow$ **2-4% peak beta-beat** (in arc81, negligible elsewhere)
- Dipole b2 errors
  $\rightarrow$ **3-10% peak beta-beat**
- Fringe fields of triplets
  $\rightarrow$ **1% peak beta-beat**
- Hysteresis
  $\rightarrow$ **0.5% peak beta-beat**
- Saturation (w/o triplets)
  $\rightarrow$ **1% peak beta-beat**
- Saturation (with triplets)
  $\rightarrow \approx$ **60% peak beta-beat (worst case)**
- Extrapolation from measurement at 0.6 m
  $\rightarrow \approx$ **100% peak beta-beat**
- Approx. beta-beat from combining all error sources
  $\rightarrow \approx$ **160% peak beta-beat (worst case)**

Improvements of correction techniques.

Segment-by-Segment.



- Transport of optical functions from a BPM position
- Technique for investigating local corrections
- Calculation of optical functions at specific elements
- Uses measured optical function at starting point of simulation

Improvements in measured beta-function accuracy.

- New algorithm for beta-function measurement
- Accuracy has been increased especially in the IRs

→ Increased resolution for correction technique

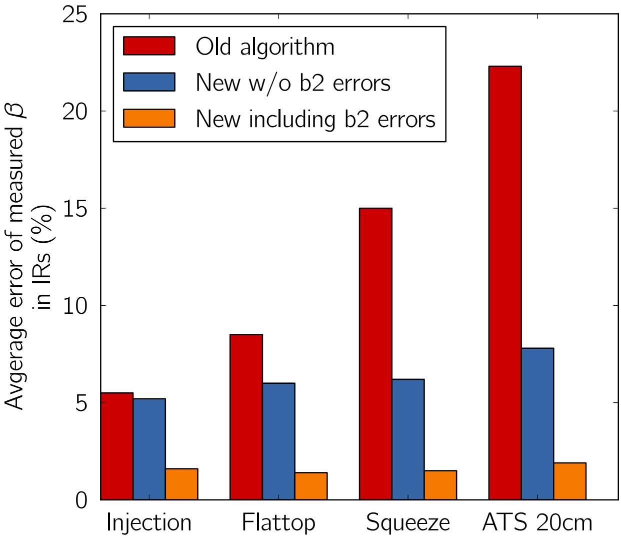
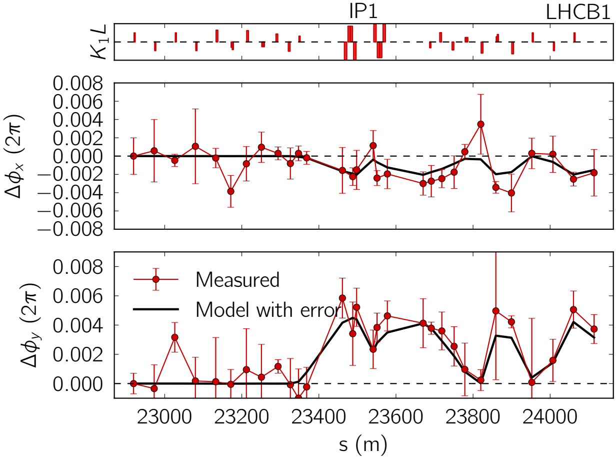


Illustration of Segment-by-Segment.

- Errors in the real machine cause deviation of the phase advance
- Searching for magnet errors that can reproduce the measured deviation

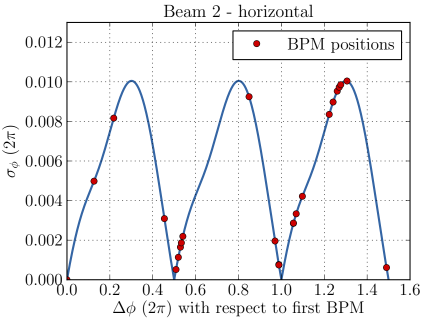
→ Correcting optics with this magnet errors

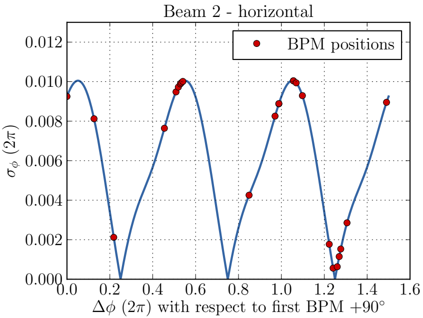


Systematic errors.

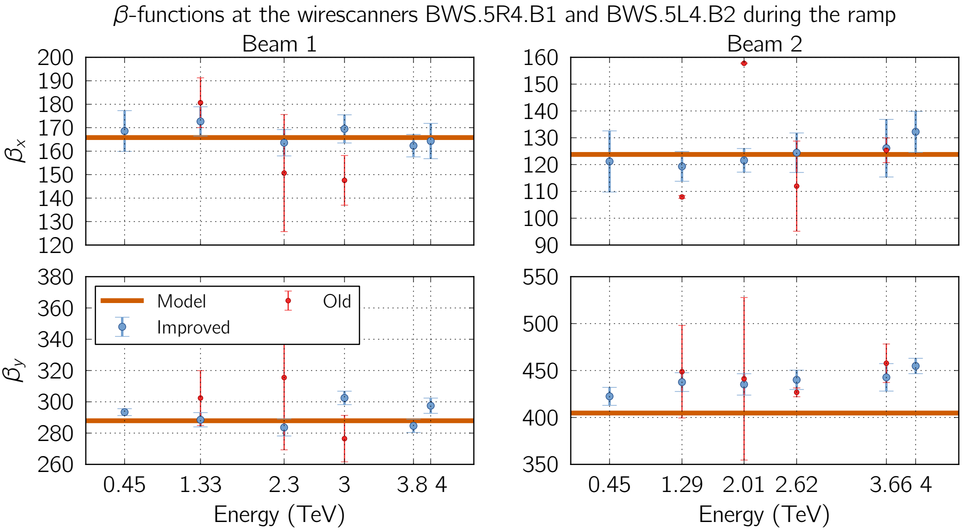
- Errors on the measured β- and α-functions propagate to an error of the phase advance $\rightarrow$ has not taken into account before
- Error on phase advance has minima which indicates higher sensitivity at specific locations

$\rightarrow$ Local corrections might be better constrained by using 2 segments with starting location separated by $\approx 90^\circ$



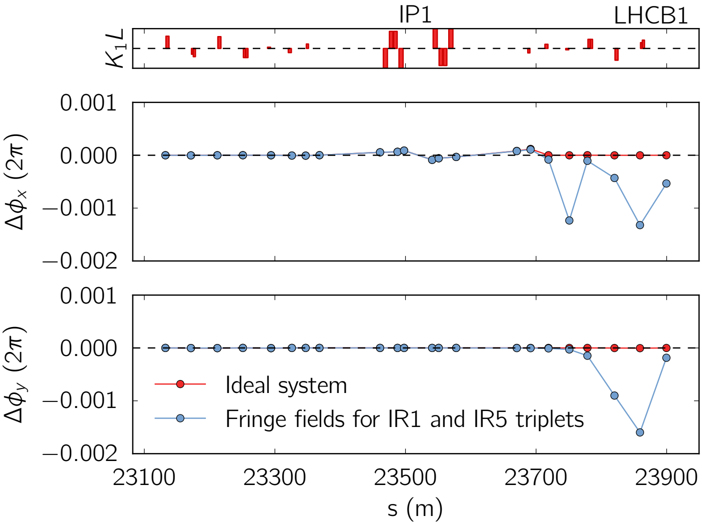


Example for error bar improvement.

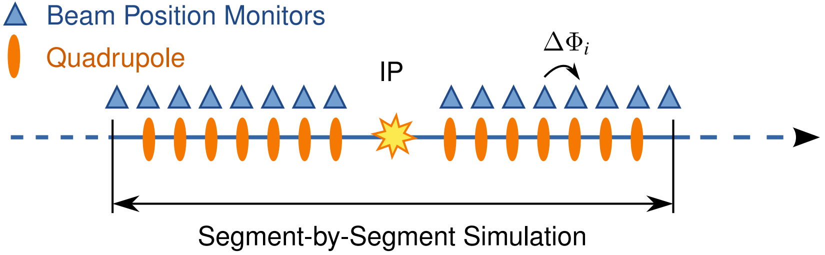


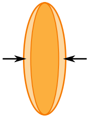
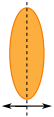
Impact of fringe fields on Segment-by-Segment.

- Fringe fields in the triplet cause also a phase advance
- Should be implemented in Segment-by-Segment for higher precision



Offline correction technique.



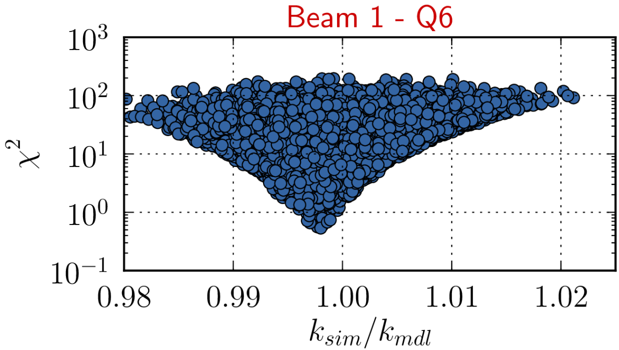
- Monte-Carlo Approach to fit optics to measured constraints
- Vary quadrupole strengths Δk  and long. positions Δs 

→ Variation of simulated phase advances $\Delta\Phi_{i,Sim}$

- Minimize $\chi^2 = \sum_i \left(\frac{\Delta\Phi_{i,Meas} - \Delta\Phi_{i,Sim}}{\sigma(\Delta\Phi_i)} \right)^2$

Offline correction technique.

- Flexible technique $\rightarrow$ can be combined with other measurements (k-modulation)
- This method was tested in IR1 in combination with constraints from ALFA detector measurements



Summary of improvements in correction techniques.

- beta-function measured with higher accuracy
  $\rightarrow$ Higher precision of Segment-by-Segment
- Code will be extended to use combine start location for the simulation
  $\rightarrow$ Sensitivity for different error sources
- Impact of known model uncertainties will be considered (Fringe fields, MQT, b2...)
- Monte-Carlo approach for offline corrections