★ Experimental measurement resolution of ATS optics
★ Global correction simulation
★ Local correction: Segment-by-segment simulation
★ K-modulation
Exp. ATS optics measurement resolution

Random

Average of $\frac{\sigma_{\text{phase}}}{\beta_{\text{model}}}$ (%)

- Neighboring BPM method
- N-BPM method

Systematic

Average of $\frac{\sigma_{\text{systematic}}}{\beta_{\text{model}}}$ (%)

Injection | Flattop | $\beta^* = 0.6\,\text{m}$ | ATS 0.2 m

- $\times 3$
- $\times 2$
From Ezio MQXF $b_2$ error is $10^{-3}$

Global corrections ($\vec{c} = R^{-1}\vec{b}$) are done after local corrections (segment-by-segment)

For global corrections we assume MQXF error has been effectively reduced by a factor 5 to $2 \times 10^{-4}$ thanks to local corrections
longitudinal quadrupole misalignment 1mm
transverse sextupole misalignment 1mm
dipole $b_2$ errors as tabulated

<table>
<thead>
<tr>
<th>Quadrupole</th>
<th>Error relative to their main field ($10^{-4}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MQ</td>
<td>$2 \times 18$</td>
</tr>
<tr>
<td>MQM</td>
<td>$2 \times 12$</td>
</tr>
<tr>
<td>MQY</td>
<td>$2 \times 7$</td>
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<tr>
<td>MQXA/B</td>
<td>$2$</td>
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<tr>
<td>MQW</td>
<td>$16$</td>
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<tr>
<td>MQT</td>
<td>$78$</td>
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<tr>
<td>MQXF</td>
<td>$2$</td>
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<tr>
<td>MQYY</td>
<td>$10$</td>
</tr>
<tr>
<td>MQYL</td>
<td>$2 \times 7$</td>
</tr>
</tbody>
</table>
**β-beating simulations before global corrs**

Before corrections

- HL-LHC $\beta^* = 15\text{cm}$
- LHC $\beta^* = 60\text{cm}$

Max $\Delta \beta/\beta$ vs. count

- HL-LHC $\beta^* = 15\text{cm}$
- LHC $\beta^* = 60\text{cm}$
Global correction simulations (1 iteration)

After global correction

HL-LHC $\beta^* = 15\text{cm}$
LHC $\beta^* = 60\text{cm}$

Max $\Delta \beta/\beta$

HL-LHC global corrections are harder than for LHC
HL-LHC local corrections are harder than for LHC (improved segment-by-segment needed)
Assume for HL-LHC
$\Delta Q_R$ and $\Delta Q_L$ tune measurement error of $10^{-5}$
tune measurement resolution of $10^{-4}$ after data filtering.
\( \beta^* \) resolution very sensitive to actual \( \beta^* \) and \( w \)
As usual, LHC is much easier.
** Between $\beta^*=0.7\text{m}$ and $0.15\text{m}$ there are about 30 steps changing $\beta^*$ by 5% 

** Doing optics commissioning as in 2012 might take about 7 shifts 

** à la carte $\beta^*$ is currently not conceivable but we will work on it 

** Other aspects to be tested are: larger $\beta^*$ at injection, ramp & squeeze, ATS optics corrections (never tested with success!)
Regarding optics commissioning HL-LHC is harder than LHC

Many improvements to come: algorithms, longer AC dipole, high resolution DOROS BPMs, etc.

Ezio’s tolerance of $b_2 = 10^{-3}$ for MQXF is rather high. Can we request a lower one, $2 \times 10^{-4}$?

K-modulation requirements: Tune measurement better than $10^{-5}$ and bipolar trims in the triplets

Experimental demonstration required
**β**\* before local correction (simulations)

**HL-LHC** \( β^* \) considerably more sensitive to MQXF errors than **LHC**

- LHC uncorrected
- HL-LHC uncorrected

only IR1 MQXF errors