## Technical Board Response Concerning the Proposal:

## Octupoles insertion at ATF2

Edu Marin ${ }^{1}$, Rogelio Tomás ${ }^{2}$
${ }^{1}$ SLAC, (USA)
${ }^{2}$ CERN, (SWITZERLAND)

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## Outline

(1) Proposal
(2) TB Concerns
(3) Answers
(4) Conclusions

## Octupole and QD0 Proposal

## ATF2 Ultra-low $\beta^{*}$ Iattice

Further minimisation of the impact of field errors of the ATF2 magnets is required to demonstrate the feasibility of higher chromaticity FFS based on local chromaticity correction

- Installing 2 octupole magnets OCT1FF and OCT2FF
- Replacing the existing QDOFF by a better field quality magnet


## Octupole Proposal

- Proposal made during the ATF2 Technical Board meeting held in February 2014 at KEK
- Positive response from the ATF2 board panel, but also a few questions were raised...


## Open Questions

(1) Correction capabilities of the octupoles magnets against different field errors (Polarity and strength of the measured multipole magnets was in doubt in the past )
(2) Alignment of the octupole magnets
(3) Relative jitter conditions between a new QD0 and IP
(4) Peripheral equipment
(5) Preferred option between installing 2 octupole magnets and/or QD0 replacement

## 1.- Field Errors

## Simulation Study

A Monte Carlo simulation study has been conducted to address the correction capabilities of the 2 octupole magnets (OCT1 and OCT2) against octupole field errors

- Simulation study based on 100 different machines
- Errors are randomly assigned to each ATF2 magnet
- Strength of multipoles $\left(\Delta K_{m}\right)$ increased by $25 \%, 50 \%$ and 75\%
- Angle of multipoles randomly varied

The initial average IP spot sizes are,

$$
<\sigma_{x}^{*}>=3.35 \pm 0.07 \mu \mathrm{~m} \quad<\sigma_{y}^{*}>=33 \pm 11 \mathrm{~nm}
$$

## Optimization

## Variables

For each machine the following variables are optimised against the IP spot size by means of a simplex algorithm:

- Strength of Sextupole (normal and skew) magnets
- Strength of Octupole magnets $\left(K_{\mathrm{OCT} 1}, K_{\mathrm{OCT} 2}\right)$
- Tilt of OCT1 magnet (Tiltoctı)


## Results

| $\Delta K_{m}$ <br> $[\%]$ | $\sigma_{x}^{*}$ <br> $[\mu \mathrm{~m}]$ | $\sigma_{y}^{*}$ <br> $[\mathrm{~nm}]$ | $K_{\text {OCT1 }}$ <br> $\left[m^{-4}\right]$ | $K_{\text {OCT2 }}$ <br> $\left[m^{-4}\right]$ | Tilt <br> ocT1 |
| :--- | :---: | :---: | :---: | :---: | :---: |
| 25 | $3.3 \pm 0.1$ | $22 \pm 1$ | $-194 \pm 33$ | $251 \pm 112$ | $-0.014 \pm 0.009$ |
| 50 | $3.3 \pm 0.1$ | $21.7 \pm 0.9$ | $-210 \pm 33$ | $241 \pm 103$ | $-0.016 \pm 0.01$ |
| 75 | $3.3 \pm 0.1$ | $21.9 \pm 0.8$ | $-212 \pm 33$ | $234 \pm 106$ | $-0.015 \pm 0.007$ |

## Simulation Results

Histograms of IP beam sizes obtained after optimization (Case $\Delta K_{m}=50 \%$ )



## 2.- Alignment of Octupole Magnets

## Tolerances

Transverse alignment tolerances of OCT1FF and OCT2FF

|  | Unit | OCT1FF | OCT2FF |
| :---: | :---: | :---: | :---: |
| X-offset | $[\mathrm{mm}]$ | $>0.1$ | $>0.1$ |
| Y-offset | $[\mathrm{mm}]$ | $\mathbf{0 . 0 2 5}$ | 0.09 |
| Z-Tilt | $[$ deg] | 0.1 | 1.4 |

The alignment requirements of OCT1FF cannot be satisfied by mechanical survey thus we foresee to mount OCT1FF on a high precision mover and practise beam based alignment

A BBA simulation study has been conducted to address this issue

## BBA

## Simulation

OCT1FF is scanned across a $\pm 2 \mathrm{~mm}$ range The beam position is recorded at the following downstream BPMs: MPREIP, IPBPMA, IPBPMB and MS1IP


## BBA

## Fitting

The octupole offset ( $x_{\text {offset }}$ ) sits at the inflexion point of the curve, which can be fitted by a $3^{\text {rd }}$ order polynomial $(\operatorname{cub}(x))$ as

$$
\operatorname{cub}(x)=c_{3} \cdot x^{3}+c_{2} \cdot x^{2}+c_{1} \cdot x+c_{0}
$$

The inflexion point satisfies the condition:

$$
\operatorname{cub}^{\prime \prime}\left(x_{\text {offset }}\right)=0 \quad \Longrightarrow \quad x_{\text {offset }}=\frac{-c_{2}}{c_{3}}
$$

$\delta x_{\text {offset }}$ depends on the fitted coefficients and ultimately on the BPM precision

## BBA

## Offset Error

A BPM reading error ( $\sigma_{\mathrm{BPM}}$ ) is assumed when fitting $\operatorname{cub}(x)$ Besides the error of $c_{i}$ provided by the fit, an additional contribution to $\delta c_{j}$ is obtained by fitting 2 additional curves $\mathrm{Cub}_{\mathrm{fit}}^{+}$and $\mathrm{Cub}_{\mathrm{fit}}^{-}$ $\mathrm{Cub}_{\mathrm{fit}}^{+}\left(\mathrm{Cub}_{\mathrm{fit}}^{+}\right)$are constructed by adding (subtracting) $\sigma_{\mathrm{BPM}}$ to the simulated data

$\delta x_{\text {offset }}$ is obtained as the weighted standard deviation of the 3 inflexion points using the inverse of the fitted errors as weight

## BBA

## Offset Error vs BPM error

The obtained relation between $\delta x_{\text {offset }}$ and $\sigma_{\text {BPM }}$ is


The average BPM resolution of the ATF2 monitors is $0.2 \mu \mathrm{~m}$

## 4.- Peripheral Equipment

## Agreements

It has been agreed that,

- KEK will provide
- supports for both octupole magnets
- mover for OCT1FF
- CERN will provide
- Power supplies


## 3.- \& 5.- Jitter and Preferred Solution

Installing the octupole magnets is our preferred solution because it allows to obtain similar IP spot sizes as obtained when replacing QD0
Additionally, it provides other benefits as

- Compensation of the effect of FD fringe fields
- Improves the tuning capabilities of the system


## Conclusions

- The pair of octupoles are able to correct for larger octupolar field errors of ATF2 magnets (75\%)
- The alignment tolerance of OCT1FF can be satisfied by means of BBA if the beam position is resolved within $0.2 \mu \mathrm{~m}$
- CERN will supply the octupoles + power supplies
- ATF2 will supply supports and 1 mover


## Final Remark

ATF2 offers a unique possibility to gain experience when operating high order magnets in a FFS. Which could be very useful for the future linear colliders

