Status of EXT coupling measurement analysis

9th ATF2 project meeting

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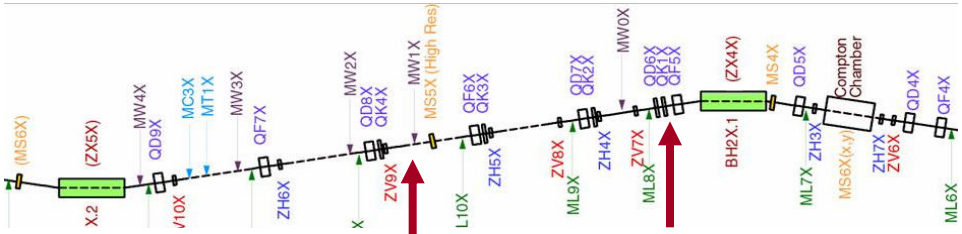
Measurement and correction of coupling in ATF2 EXT line

- **Goal: provide a non-couples beam to the Final Focus of ATF**
- **Coupling: $\sigma_{13}\ \sigma_{14}\ \sigma_{23}\ \sigma_{24} \neq 0$**
- **➔emittance growth**
- **4 skew quads to correct coupling.**
- **Classical iterativ method: Minimisation of vertical projected emittance by successive tuning of the skew quads**
- **Aim: direct correction**

➔ Need reconstruction of beam matrix at the first skew quad (QK1X).



$$\sigma^B = R\sigma^A R^T \qquad \sigma^A$$

Coupling terms

$$\sigma = \begin{pmatrix} <xx> & <xx'> & <xy> & <xy'> \\ <xx'> & <x'x'> & <x'y> & <x'y'> \\ <xy> & <x'y> & <yy> & <yy'> \\ <xy'> & <x'y'> & <yy'> & <y'y'> \end{pmatrix} = \begin{pmatrix} \sigma_{11} & \sigma_{12} & \sigma_{13} & \sigma_{14} \\ \sigma_{12} & \sigma_{22} & \sigma_{23} & \sigma_{24} \\ \sigma_{13} & \sigma_{23} & \sigma_{33} & \sigma_{34} \\ \sigma_{14} & \sigma_{24} & \sigma_{34} & \sigma_{44} \end{pmatrix}$$

Measurable terms

- σ_{11} et σ_{33} directly measured
- σ_{13} measured with at angle ϕ:

$$\sigma_{13} = \frac{\sigma_\phi^2}{2\cos\phi\sin\phi} - \frac{\sigma_{11}\cos\phi}{2\sin\phi} - \frac{\sigma_{33}\sin\phi}{2\cos\phi}$$

Projected emittances:

$$\varepsilon_x = \sqrt{\sigma_{11}\sigma_{22} - \sigma_{12}^2}$$

$$\varepsilon_y = \sqrt{\sigma_{33}\sigma_{44} - \sigma_{34}^2}$$

Measurement and correction of coupling in ATF2 EXT line

$$\sigma^M = R_{tot}\sigma^Q R_{tot}^T \qquad \sigma = \begin{pmatrix} \sigma_{11} & \sigma_{12} & \sigma_{13} & \sigma_{14} \\ \sigma_{12} & \sigma_{22} & \sigma_{23} & \sigma_{24} \\ \sigma_{13} & \sigma_{23} & \sigma_{33} & \sigma_{34} \\ \sigma_{14} & \sigma_{24} & \sigma_{34} & \sigma_{44} \end{pmatrix} \qquad R = \begin{pmatrix} R_{11} & R_{12} & 0 & 0 \\ R_{21} & R_{22} & 0 & 0 \\ 0 & 0 & R_{33} & R_{34} \\ 0 & 0 & R_{43} & R_{44} \end{pmatrix} \qquad Q_K = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & k & 0 \\ 0 & 0 & 1 & 0 \\ k & 0 & 0 & 1 \end{pmatrix}$$

Transfer Matrix of skew quad: $R_{tot} = RQ_K$

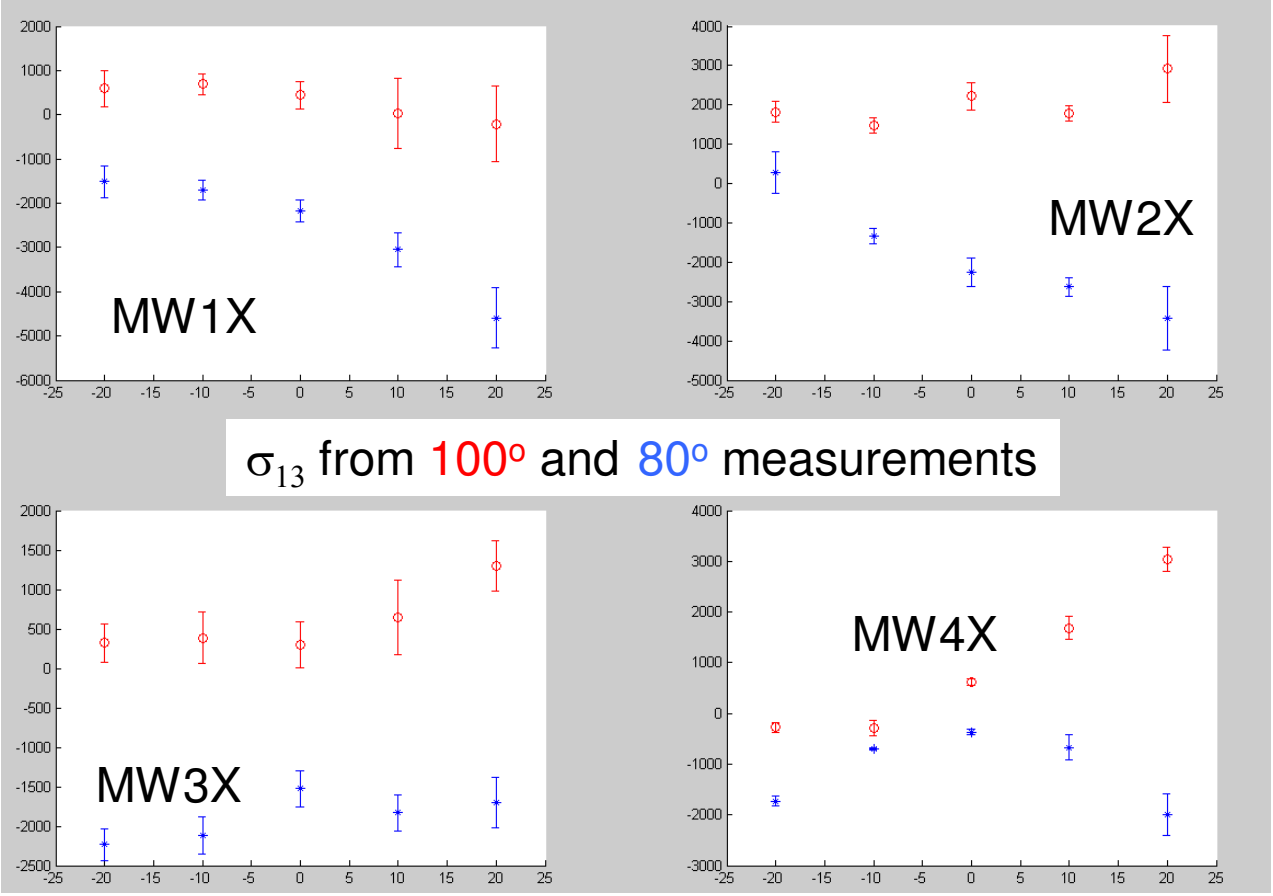
•The squares of the measured beam sizes, σ_{11}^M, σ_{13}^M, σ_{33}^M, at each wire scanner position can be expressed as a parabolic function of the strength of the scanned quad, described by 3 fit parameters A, B, C: $\sigma_{ij}=A_{ij}(k-B_{ij})^2+C_{ij}$

$$\begin{aligned}
\sigma_{11}^M &= R_{11}^2\sigma_{11}^{QK} + 2R_{11}R_{12}\sigma_{12}^{QK} + R_{12}^2\sigma_{22}^{QK} \Rightarrow AB^2 + C \\
&\quad + 2k(R_{11}R_{12}\sigma_{13}^{QK} + R_{12}^2\sigma_{23}^{QK}) \Rightarrow -2AB \\
&\quad + k^2R_{12}^2\sigma_{33}^{QK} \Rightarrow A \\
\sigma_{33}^M &= R_{33}^2\sigma_{33}^{QK} + 2R_{33}R_{34}\sigma_{34}^{QK} + R_{34}^2\sigma_{44}^{QK} \Rightarrow AB^2 + C \\
&\quad + 2k(R_{33}R_{34}\sigma_{13}^{QK} + R_{34}^2\sigma_{14}^{QK}) \Rightarrow -2AB \\
&\quad + k^2R_{34}^2\sigma_{11}^{QK} \Rightarrow A \\
\sigma_{13}^M &= R_{11}R_{33}\sigma_{13}^{QK} + R_{11}R_{34}\sigma_{14}^{QK} + R_{33}R_{12}\sigma_{23}^{QK} + R_{12}R_{34}\sigma_{24}^{QK} \Rightarrow AB^2 + C \\
&\quad + k(R_{11}R_{34}\sigma_{11}^{QK} + R_{12}R_{33}\sigma_{33}^{QK} + R_{12}R_{34}(\sigma_{12}^{QK} + \sigma_{34}^{QK})) \Rightarrow -2AB \\
&\quad + k^2R_{12}R_{34}\sigma_{13}^{QK} \Rightarrow A
\end{aligned}$$

Measurement of coupling in ATF2 EXT line

- Measurements of May 2009: σ_x, σ_y, $\sigma(80^o)$ et $\sigma(100^o)$ with QK1X scans (-20A,-10A,0A,10A,20A) at MW1X, MW2X, MW3X and MW4X.

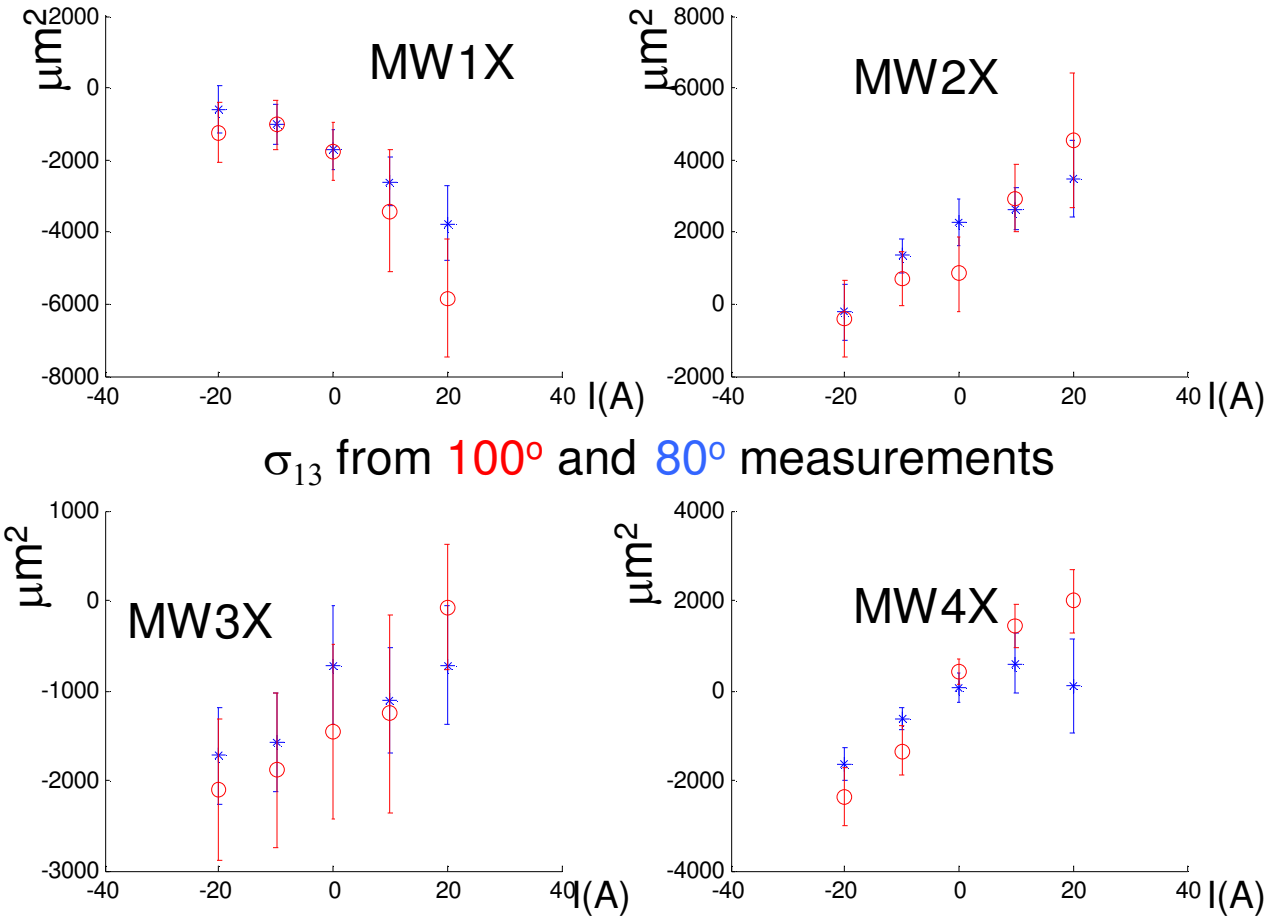
Problem: incoherences between measurements at 80^o and 100^o



➔ **Found 2 errors in ATF software control system (wrong correction of tilted sizes, and old configuration of MW2X)**

Measurement of coupling in ATF2 EXT line

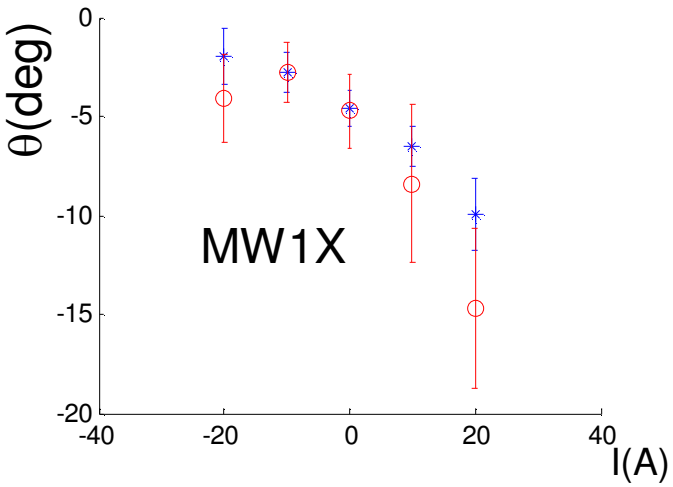
- After correction of those errors: coherence of coupling reconstruction from 80º and 100º

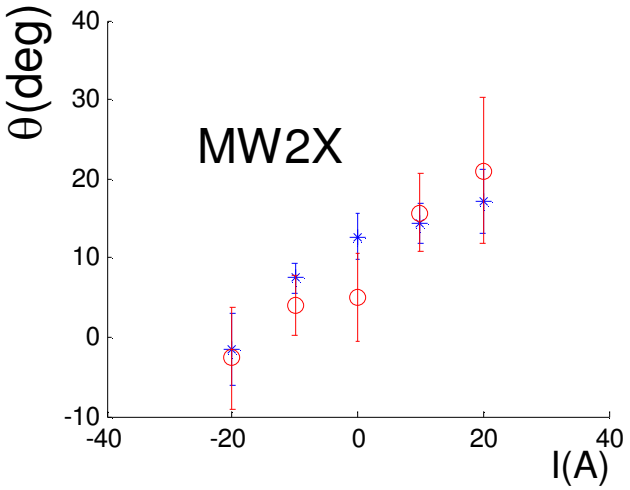


Measurement of coupling in ATF2 EXT line

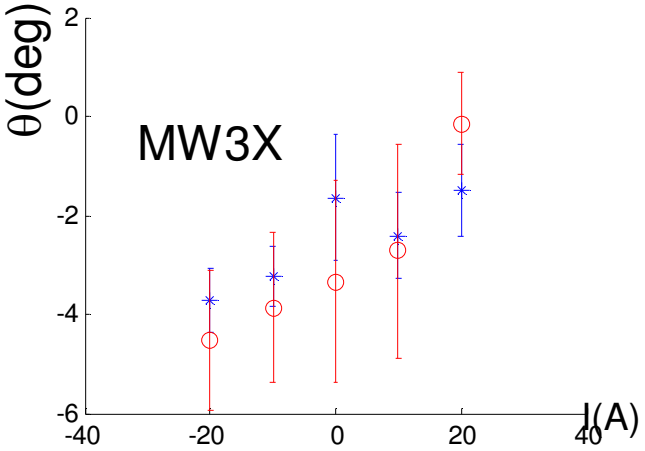
- which correspond to beam tilt angles:

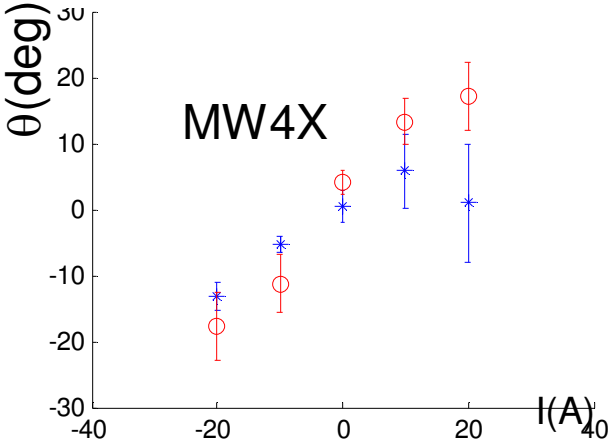
$$Tan[2\theta] = \frac{2\sigma_u^{\,2} - \sigma_x^{\,2} - \sigma_y^{\,2}}{\left(\sigma_x^{\,2} - \sigma_y^{\,2}\right) Sin[2\phi]} - \frac{Cos[2\phi]}{Sin[2\phi]}$$





θ from 100° and 80° measurements





Method for reconstruction of beam matrix parameters at QK1X -1

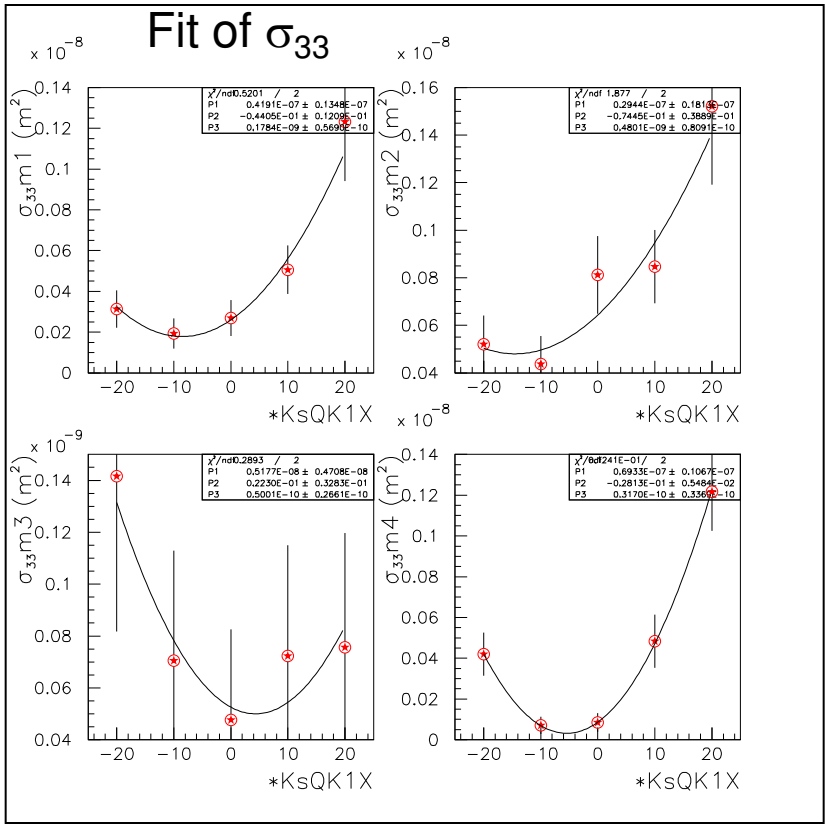
1. From measurements at 4 wires at k=0
2. From fit parameters of Skew scan & 4 wire3

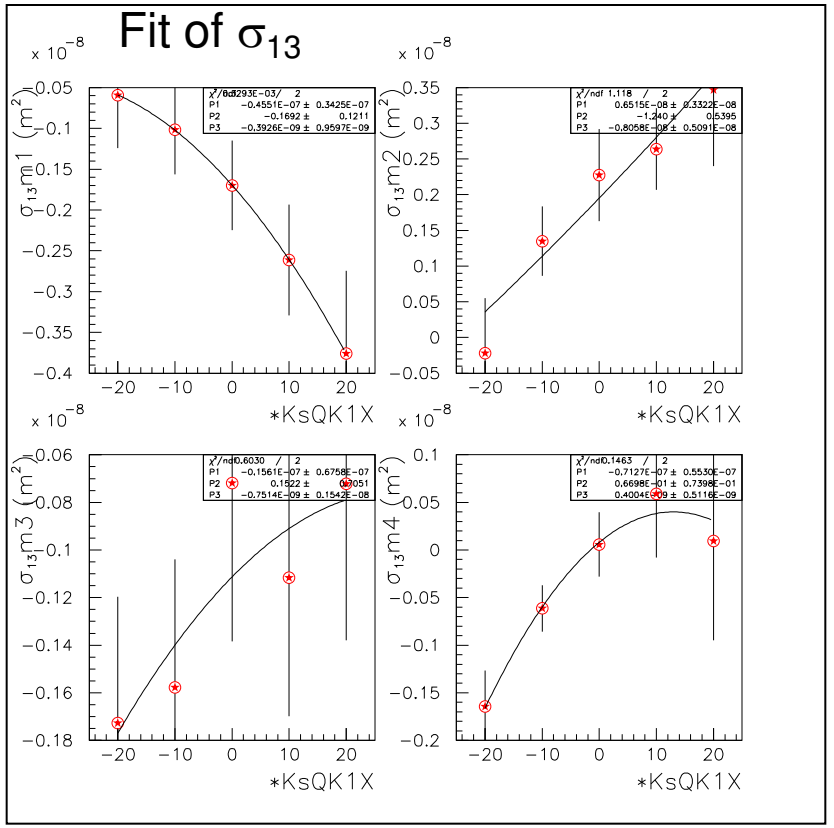
both use least square method

$$\sigma_{11}^{M} = R_{11}^{2}\sigma_{11}^{QK} + 2R_{11}R_{12}\sigma_{12}^{QK} + R_{12}^{2}\sigma_{22}^{QK} \Rightarrow AB^{2} + C$$
$$+ 2k(R_{11}R_{12}\sigma_{13}^{QK} + R_{12}^{2}\sigma_{23}^{QK}) \Rightarrow -2AB$$
$$+ k^{2}R_{12}^{2}\sigma_{33}^{QK} \Rightarrow A$$

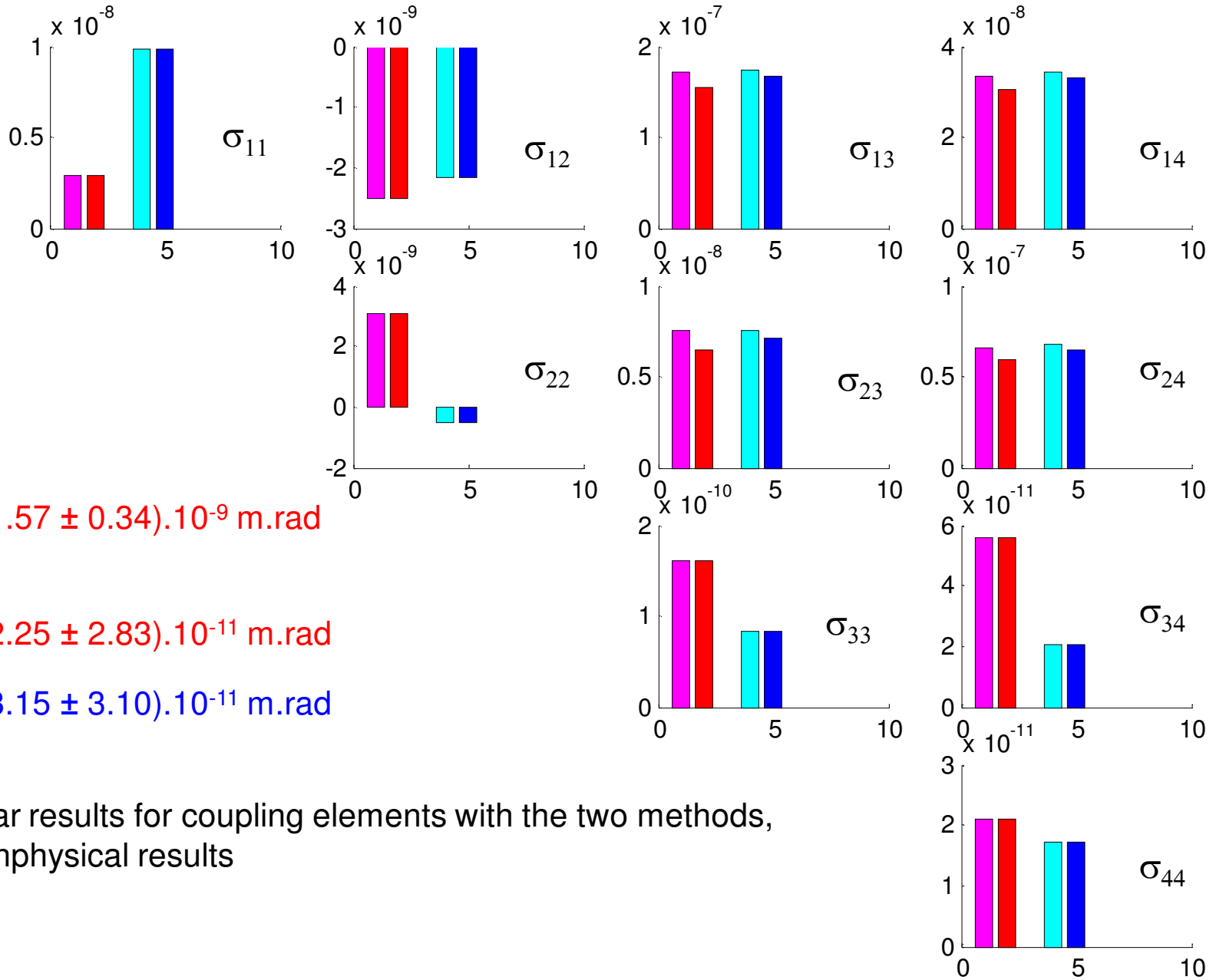
$$\sigma_{13}^{M} = R_{11}R_{33}\sigma_{13}^{QK} + R_{11}R_{34}\sigma_{14}^{QK} + R_{33}R_{12}\sigma_{23}^{QK} + R_{12}R_{34}\sigma_{24}^{QK} \Rightarrow AB^{2} + C$$
$$+ k(R_{11}R_{34}\sigma_{11}^{QK} + R_{12}R_{33}\sigma_{33}^{QK} + R_{12}R_{34}(\sigma_{12}^{QK} + \sigma_{34}^{QK})) \Rightarrow -2AB$$
$$+ k^{2}R_{12}R_{34}\sigma_{13}^{QK} \Rightarrow A$$

$$\sigma_{33}^{M} = R_{33}^{2}\sigma_{33}^{QK} + 2R_{33}R_{34}\sigma_{34}^{QK} + R_{34}^{2}\sigma_{44}^{QK} \Rightarrow AB^{2} + C$$
$$+ 2k(R_{33}R_{34}\sigma_{13}^{QK} + R_{34}^{2}\sigma_{14}^{QK}) \Rightarrow -2AB$$
$$+ k^{2}R_{34}^{2}\sigma_{11}^{QK} \Rightarrow A$$





Reconstruction of sigma matrix at QK1X from skew scan fits & multi-wires with 80º and 100º



$\varepsilon_x = (1.57 \pm 0.34).10^{-9}$ m.rad

ε_x= i

$\varepsilon_y = (2.25 \pm 2.83).10^{-11}$ m.rad

$\varepsilon_y = (3.15 \pm 3.10).10^{-11}$ m.rad

Similar results for coupling elements with the two methods, but unphysical results

Beam ellipse from 80^o tilted size measurements

from σ_x, σ_y and σ_ϕ ➔ beam ellipse parameters a, b and θ

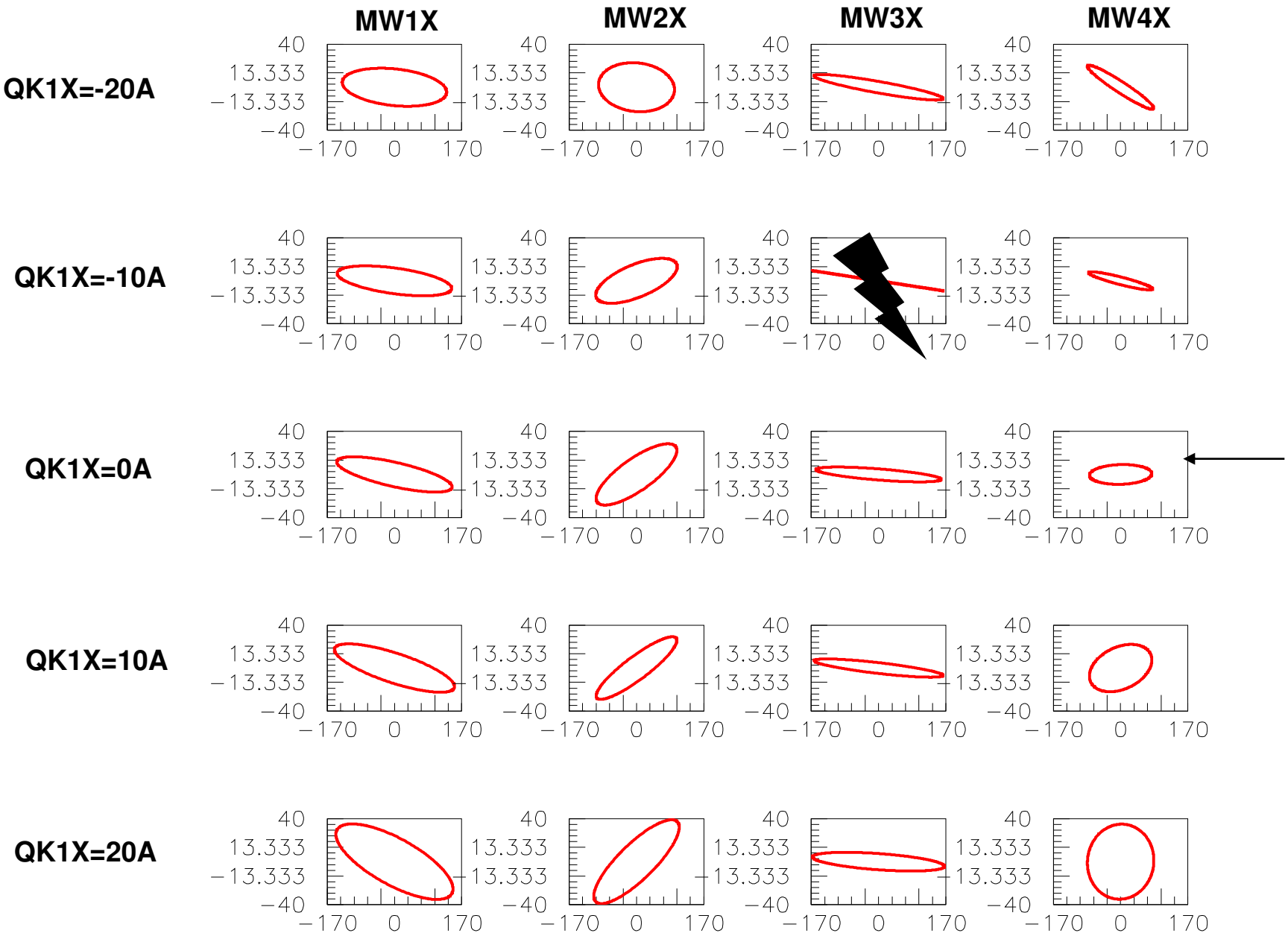
$$Tan[2\theta] = \frac{2\sigma_\varphi^{\,2} - \sigma_x^{\,2} - \sigma_y^{\,2}}{\left(\sigma_x^{\,2} - \sigma_y^{\,2}\right) Sin[2\varphi]} - \frac{Cos[2\varphi]}{Sin[2\varphi]}$$

$$a^2 = \frac{1}{2}\left(\sigma_x^{\,2} + \sigma_y^{\,2} + \frac{\sigma_x^{\,2} - \sigma_y^{\,2}}{Cos[2\theta]}\right)$$

$$b^2 = \frac{1}{2}\left(\sigma_x^{\,2} + \sigma_y^{\,2} - \frac{\sigma_x^{\,2} - \sigma_y^{\,2}}{Cos[2\theta]}\right)$$

Except for MW3X at QK1X=-10A (b<0), the measurements are physical

Beam ellipse from 80^{o} tilted size measurements



Method for reconstruction of beam matrix parameters at QK1X -2

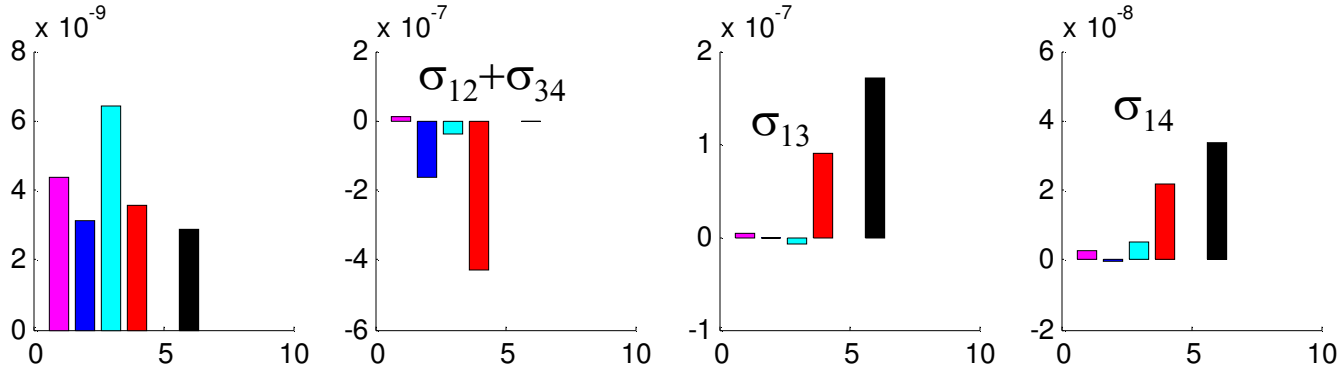
- From fit parameters of Skew scan separately for each wire
- Successive reconstruction of $\sigma_{11}\ \sigma_{33}\ \sigma_{13}$ ➔ $\sigma_{23}\ \sigma_{14}\ (\sigma_{12}+\sigma_{34})$ ➔ σ_{24}

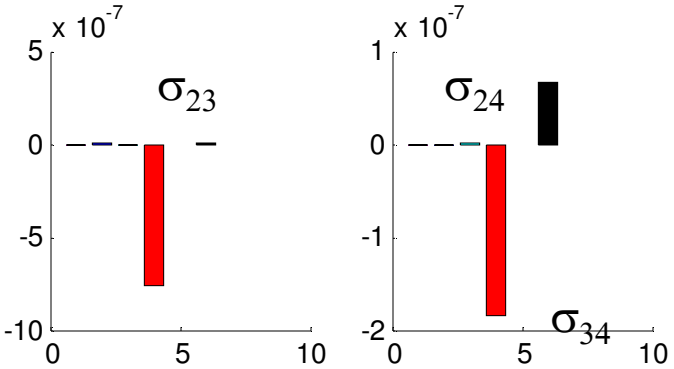
$$\sigma_{11}^{M} = R_{11}^{2}\sigma_{11}^{QK} + 2R_{11}R_{12}\sigma_{12}^{QK} + R_{12}^{2}\sigma_{22}^{QK} \Rightarrow AB^{2} + C$$
$$+ 2k(R_{11}R_{12}\sigma_{13}^{QK} + R_{12}^{2}\sigma_{23}^{QK}) \Rightarrow -2AB$$
$$+ k^{2}R_{12}^{2}\sigma_{33}^{QK} \Rightarrow A$$

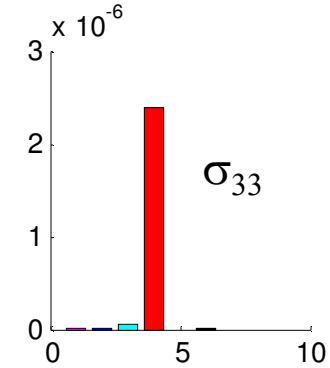
$$\sigma_{33}^{M} = R_{33}^{2}\sigma_{33}^{QK} + 2R_{33}R_{34}\sigma_{34}^{QK} + R_{34}^{2}\sigma_{44}^{QK} \Rightarrow AB^{2} + C$$
$$+ 2k(R_{33}R_{34}\sigma_{13}^{QK} + R_{34}^{2}\sigma_{14}^{QK}) \Rightarrow -2AB$$
$$+ k^{2}R_{34}^{2}\sigma_{11}^{QK} \Rightarrow A$$

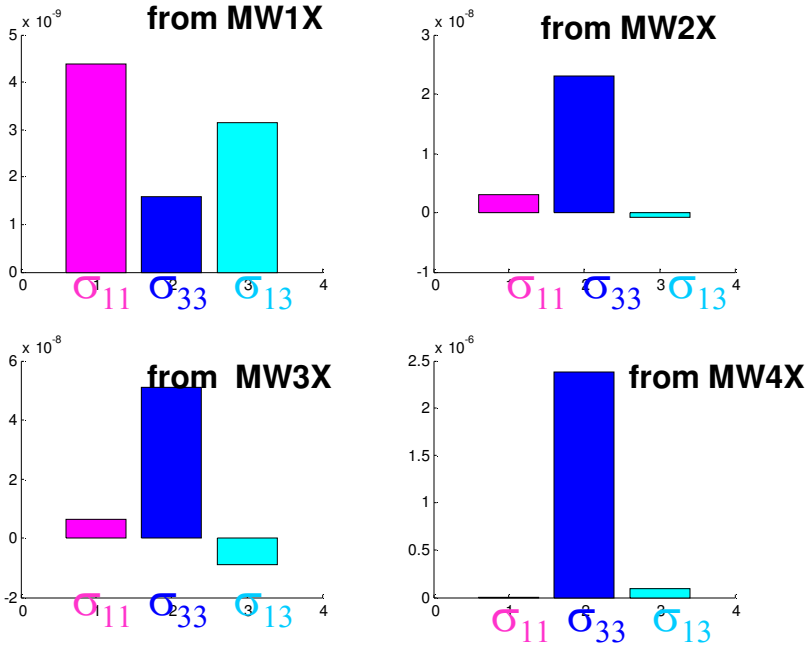
$$\sigma_{13}^{M} = R_{11}R_{33}\sigma_{13}^{QK} + R_{11}R_{34}\sigma_{14}^{QK} + R_{33}R_{12}\sigma_{23}^{QK} + R_{12}R_{34}\sigma_{24}^{QK} \Rightarrow AB^{2} + C$$
$$+ k(R_{11}R_{34}\sigma_{11}^{QK} + R_{12}R_{33}\sigma_{33}^{QK} + R_{12}R_{34}(\sigma_{12}^{QK} + \sigma_{34}^{QK})) \Rightarrow -2AB$$
$$+ k^{2}R_{12}R_{34}\sigma_{13}^{QK} \Rightarrow A$$

Methods of reconstruction of beam matrix parameters at QK1X from MW1X MW2X MW3X MW4X and from Multiwire method









➔ σ_{33} becomes larger than σ_{11}

MW4X ➔ large coupling

Summary

- Measurements at 80^o and 100^o ➔ correction of ATF softcontrol system
- Static coherence of those measurements.
- Multiwire method lead to unphysical results (correlations>>1) (Maybe phase advance problem)
- Skew quad can not provide reliable fit of σ_{11} (hard to fit σ_{33} parabola)
- Analysis is still on-going: Cholesky decomposition, ponderation of measurements according to their errors, MC simulation...