Coupling Correction in ATF2 EXT

7th ATF2 Project Meeting, 15-18 december 2008

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Coupling Correction in ATF2 EXT

One method for coupling measurement.
Simulation of Coupling Correction with the Flight simulator.
Study of the feasability of CC with 2 skew quad.
Next steps

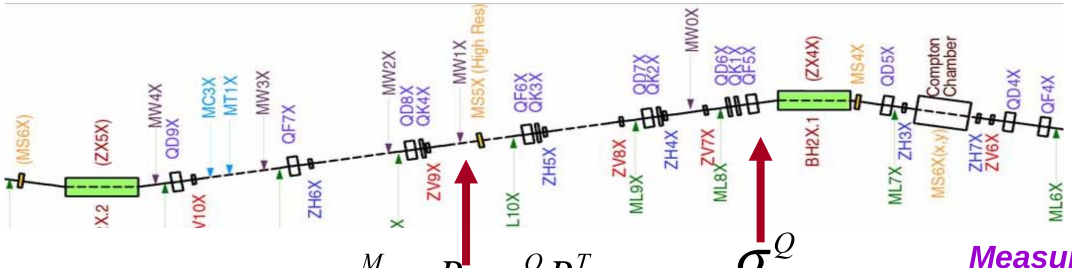
Coupling Correction

- Involved persons: CR, P. Bambade, S. Kuroda, G. White, M. Woodley...

- Goal: correct coupling upstream of the final focus line with available skew quads in EXT (2 then 4)

- Possible sources of coupling: DR, QM7 and other bending magnets (cf related talks of “Beam Diagnostics at Extraction Line (2) ” session 12/16), QS1X & QS2X used to correct the dispersion, roll quad errors...

Coupling Measurements: waist scan method - 1



$$\sigma^M = R_{tot}\sigma^Q R_{tot}^T \qquad \sigma^Q$$

Coupling terms

Measurable terms

$$\sigma = \begin{pmatrix} \sigma_{11} & \sigma_{12} & \sigma_{13} & \sigma_{14} \\ \sigma_{12} & \sigma_{22} & \sigma_{23} & \sigma_{24} \\ \sigma_{13} & \sigma_{23} & \sigma_{33} & \sigma_{34} \\ \sigma_{14} & \sigma_{24} & \sigma_{34} & \sigma_{44} \end{pmatrix}$$

Transfer Matrix:

normal quad: $R_{tot} = RQ$

skew quad: $R_{tot} = RQ_K$

$$R = \begin{pmatrix} R_{11} & R_{12} & 0 & 0 \\ R_{21} & R_{22} & 0 & 0 \\ 0 & 0 & R_{33} & R_{34} \\ 0 & 0 & R_{43} & R_{44} \end{pmatrix} \quad Q = \begin{pmatrix} 1 & 0 & 0 & 0 \\ k & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & -k & 1 \end{pmatrix} \quad Q_K = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & k & 0 \\ 0 & 0 & 1 & 0 \\ k & 0 & 0 & 1 \end{pmatrix}$$

•The squares of the measured beam sizes, σ_{11}^M, σ_{13}^M, σ_{33}^M, at a 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:

$$\sigma_{ij}=A_{ij}(k-B_{ij})^2+C_{ij}$$

• σ_{13}^M can be measured using a tilted wire scanner, u (10°), applying method described in *I. Agapov, G. Blair, M. Woodley, PRST-AB 10 112801 (2007) P. Emma, M. Woodley, ATF-99-04:*

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

where ϕ is the angle between x and tilted wires

Coupling Measurements: waist scan method - 2

With normal quad scan:

$$\sigma_{11}^{M} = (R_{11} + kR_{12})^2\sigma_{11}^{Q} + 2R_{12}(R_{11} + kR_{12})\sigma_{12}^{Q} + R_{12}^2\sigma_{22}^{Q}$$

$$\Rightarrow \sigma_{11}^{Q},\ \sigma_{12}^{Q},\ \sigma_{22}^{Q}$$

$$\sigma_{33}^{M} = (R_{33} - kR_{34})^2\sigma_{33}^{Q} + 2R_{34}(R_{33} - kR_{34})\sigma_{34}^{Q} + R_{34}^2\sigma_{44}^{Q}$$

$$\Rightarrow \sigma_{33}^{Q},\ \sigma_{34}^{Q},\ \sigma_{44}^{Q}$$

$$\sigma_{13}^{M} = (R_{11} + kR_{12})(R_{33} - kR_{34})\sigma_{13}^{Q} + R_{12}(R_{33} - kR_{34})\sigma_{23}^{Q} + (R_{11} + kR_{12})R_{34}\sigma_{14}^{Q} + R_{12}R_{34}\sigma_{24}^{Q}$$

$$\Rightarrow \sigma_{13}^{Q},\ [\sigma_{14}^{Q} - \sigma_{23}^{Q}],\ [R_{12}R_{33}\sigma_{23}^{Q} + R_{11}R_{34}\sigma_{14}^{Q} + R_{12}R_{34}\sigma_{24}^{Q}]$$

With skew quad scan:

$$\sigma_{11}^{M} = R_{11}^2\sigma_{11}^{QK} + 2R_{11}R_{12}\sigma_{12}^{QK} + R_{12}^2\sigma_{22}^{QK} + 2kR_{11}R_{12}\sigma_{13}^{QK} + 2kR_{12}^2\sigma_{23}^{QK} + k^2R_{12}^2\sigma_{33}^{QK}$$

$$\Rightarrow \sigma_{33}^{QK},\ [R_{11}\sigma_{13}^{QK} + R_{12}\sigma_{23}^{QK}],\ [R_{11}^2\sigma_{11}^{QK} + 2R_{11}R_{12}\sigma_{12}^{QK} + R_{12}^2\sigma_{22}^{QK}]$$

$$\sigma_{33}^{M} = R_{33}^2\sigma_{33}^{QK} + 2R_{33}R_{34}\sigma_{34}^{QK} + R_{34}^2\sigma_{44}^{QK} + 2kR_{33}R_{34}\sigma_{13}^{QK} + 2kR_{34}^2\sigma_{14}^{QK} + k^2R_{34}^2\sigma_{11}^{QK}$$

$$\Rightarrow \sigma_{11}^{QK},\ [R_{33}\sigma_{13}^{QK} + R_{34}\sigma_{14}^{QK}],\ [R_{33}^2\sigma_{33}^{QK} + 2R_{33}R_{34}\sigma_{34}^{QK} + R_{34}^2\sigma_{44}^{QK}]$$

$$\sigma_{13}^{M} = kR_{11}R_{34}\sigma_{11}^{QK} + kR_{12}R_{34}\sigma_{12}^{QK} + (k^2R_{12}R_{34} + R_{11}R_{33})\sigma_{13}^{QK} + R_{33}R_{12}\sigma_{23}^{QK} + kR_{12}R_{33}\sigma_{33}^{QK} + R_{11}R_{34}\sigma_{14}^{QK} + R_{12}R_{34}\sigma_{24}^{QK} + kR_{12}R_{34}\sigma_{34}^{QK}$$

$$\Rightarrow \sigma_{13}^{Q},\ [R_{12}R_{34}(\sigma_{12}^{QK} + \sigma_{34}^{QK}) + R_{11}R_{34}\sigma_{11}^{QK} + R_{12}R_{33}\sigma_{33}^{QK}],\ [R_{12}R_{33}\sigma_{23}^{QK} + R_{11}R_{34}\sigma_{14}^{QK} + R_{12}R_{34}\sigma_{24}^{KQ}]$$

Coupling Measurements: waist scan method – 3 comments

- Method ever suggested in *J. Rees and L. Rivkin, SLAC-PUB-3305, 1984.*

- To combine these Q and SQ scans would theoretically enable to reconstruct the 10 σ_{ij}

- Tilt angle measurement is necessary to get all coupling elements

BUT

- Would be “easy” if “skew-able” Quad, i.e. if $\sigma^{Q} \equiv \sigma^{QK}$

- Experimentally, σ^2_{11} SQ scan is not exploitable: flat “parabola”.

THEN

- Need to combined measurements at several wire scanner position.

- ... still under studies

Coupling corrections in the Flight Simulator

Available coupling correction method implemented in the FS by M. Woodley:

M. D. Woodley and P. E. Emma, physics/0008194 (August 2000)

- **Sequential minimizing of the projected vertical emittance with each of the skew quad.**
- **ε_y reconstructed using beam size measurement at multi wire scanner position and least mean square method.**

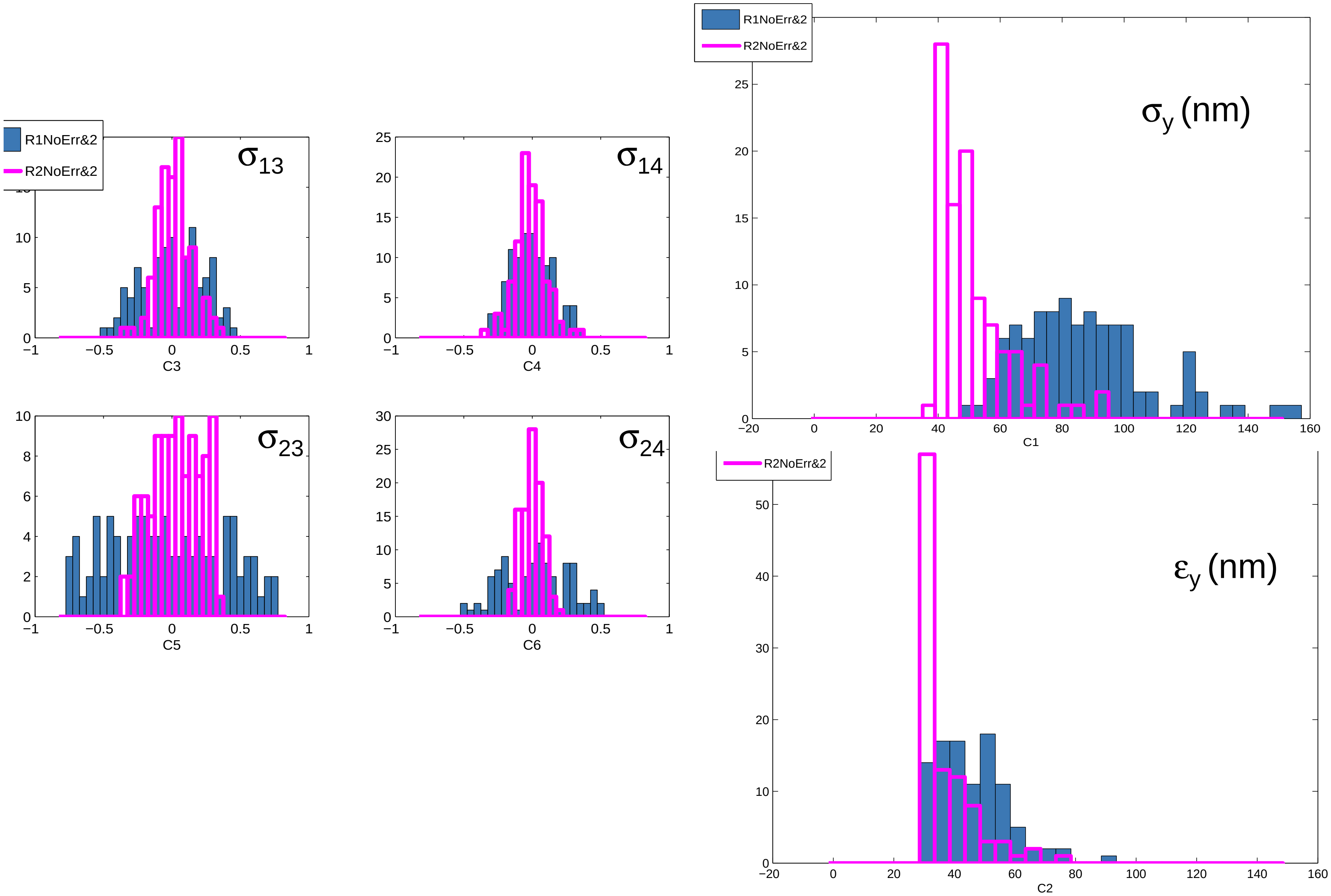
$$\begin{pmatrix} \sigma_{33}^{B} \\ \sigma_{33}^{C} \\ \cdots \\ \sigma_{33}^{N} \end{pmatrix} = \begin{pmatrix} R_{33}^{(AB)2} & R_{33}^{(AB)} R_{34}^{(AB)} & R_{34}^{(AB)2} \\ R_{33}^{(AC)2} & R_{33}^{(AC)} R_{34}^{(AC)} & R_{34}^{(AC)2} \\ \cdots & \cdots & \cdots \\ R_{33}^{(AN)2} & R_{33}^{(AN)} R_{34}^{(AN)} & R_{34}^{(AN)2} \end{pmatrix} \begin{pmatrix} \sigma_{33}^{A} \\ \sigma_{34}^{A} \\ \sigma_{44}^{A} \end{pmatrix}$$

Inputs of the simulations:

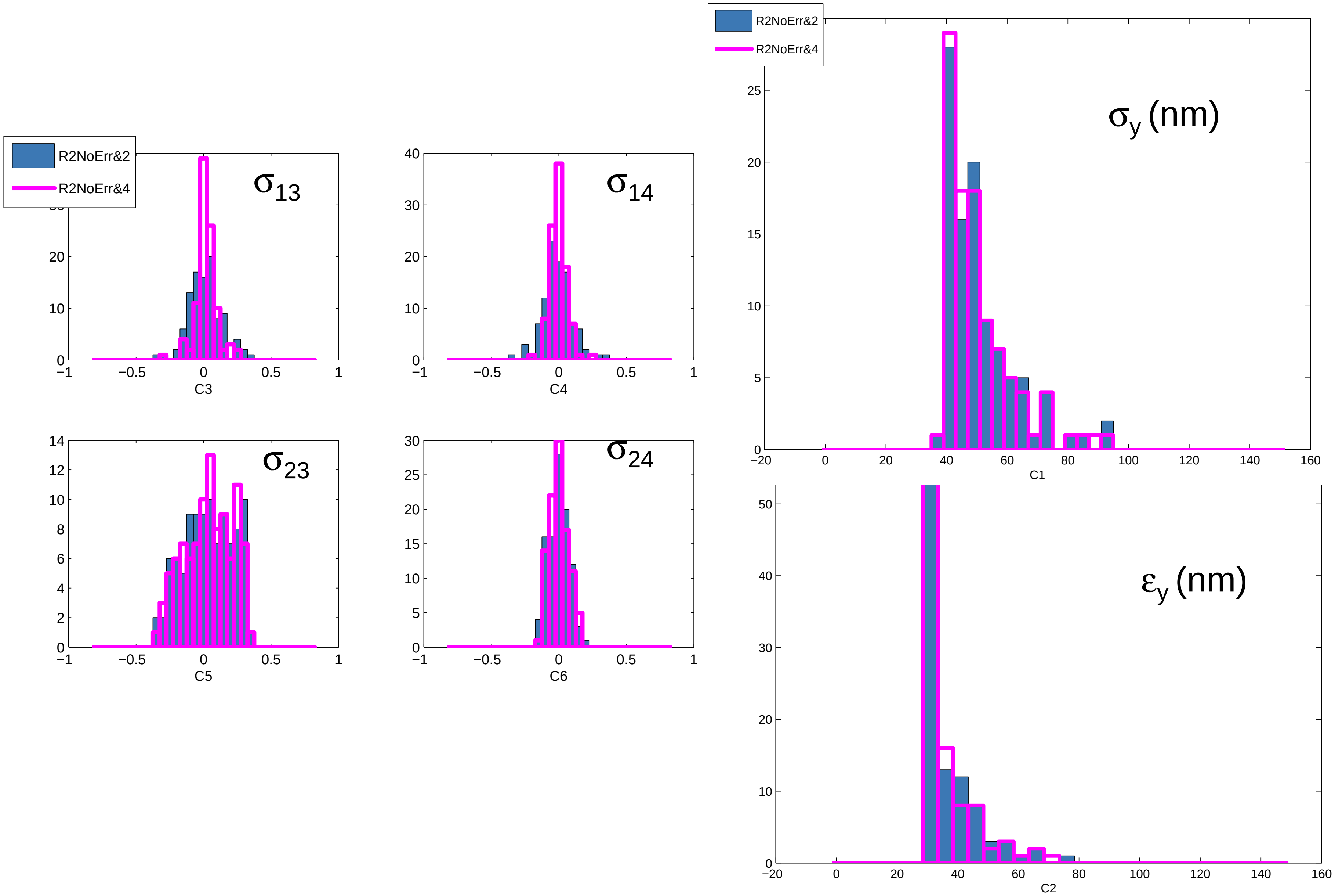
- **Standard Errors on magnet alignment, roll quad, B field...: SE**
- **DR errors: simulation of Kubo-san**
- **QM7 coupling: based on ATF-EXT emittance studies of 12March08, add a skew component in QM7: K1L=0.01547m^{-1}**
  see ATF Extraction line meeting, 30 April 2008
  http://ilcagenda.linearcollider.org/conferenceDisplay.py?confId=2715
- ***100 seeds***

GOAL: test the efficiency of coupling correction (CC) with 2 skew Quad.

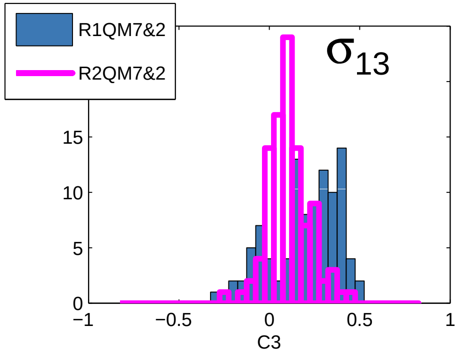
1.1-Test CC efficiency with 2 skew Quad at the IP
SE only, before Vs after CC

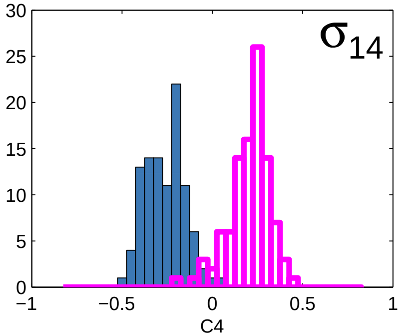


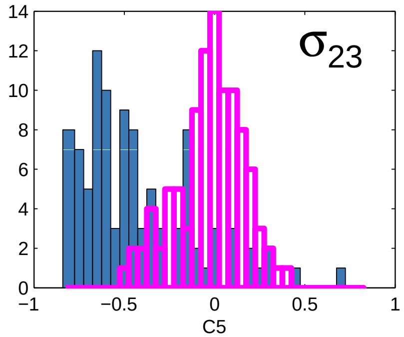
1.2-Test CC efficiency with 2 skew Quad at the IP
SE only, 2 skew Vs 4 skew, after CC

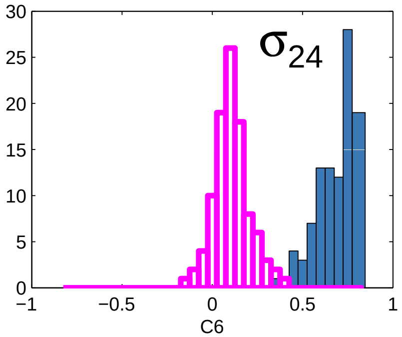


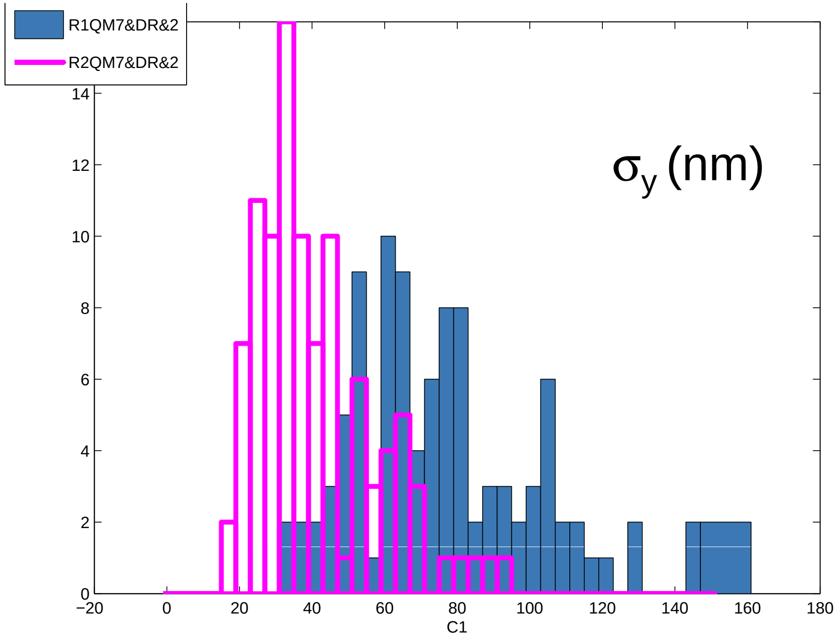
2.1-Test CC efficiency with 2 skew Quad at the IP SE+QM7, before Vs after CC

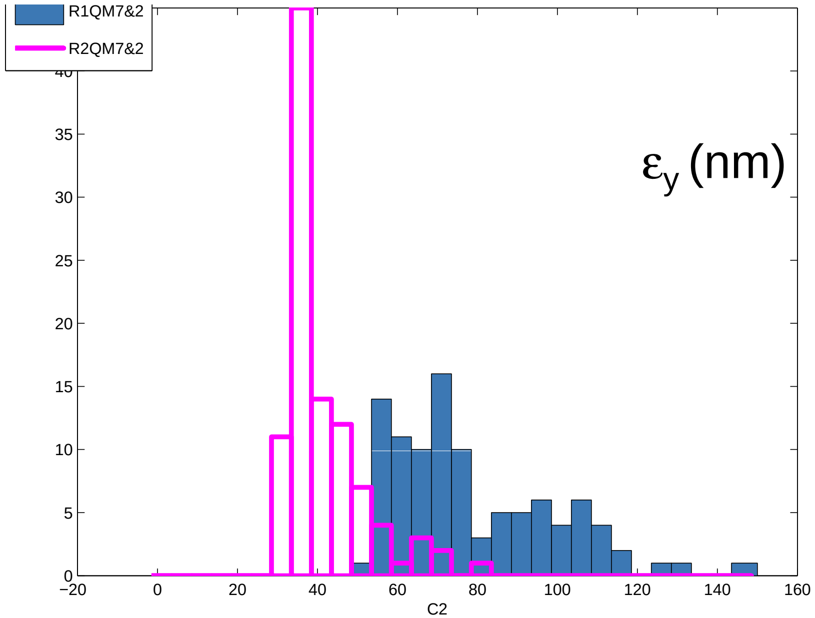




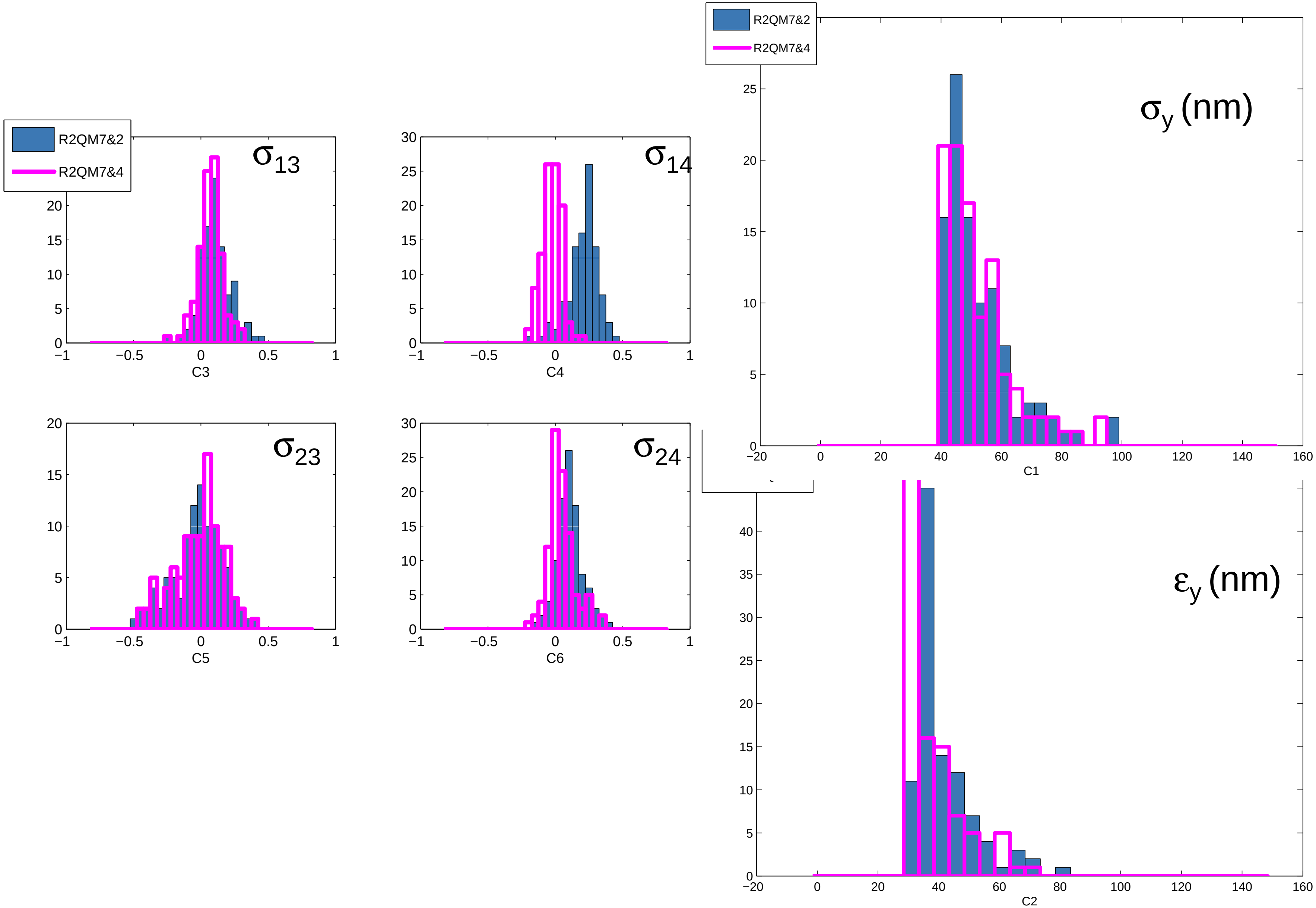




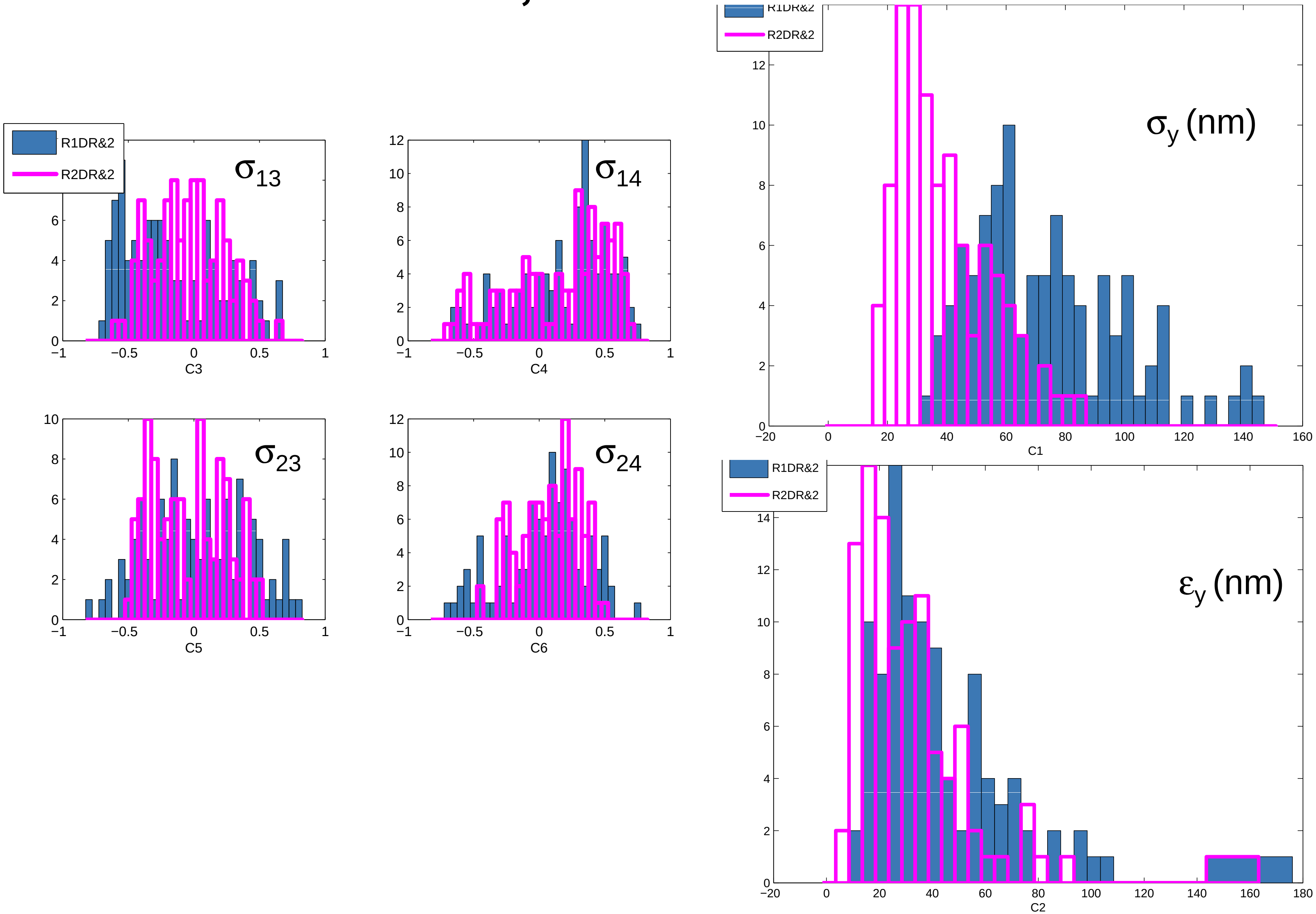




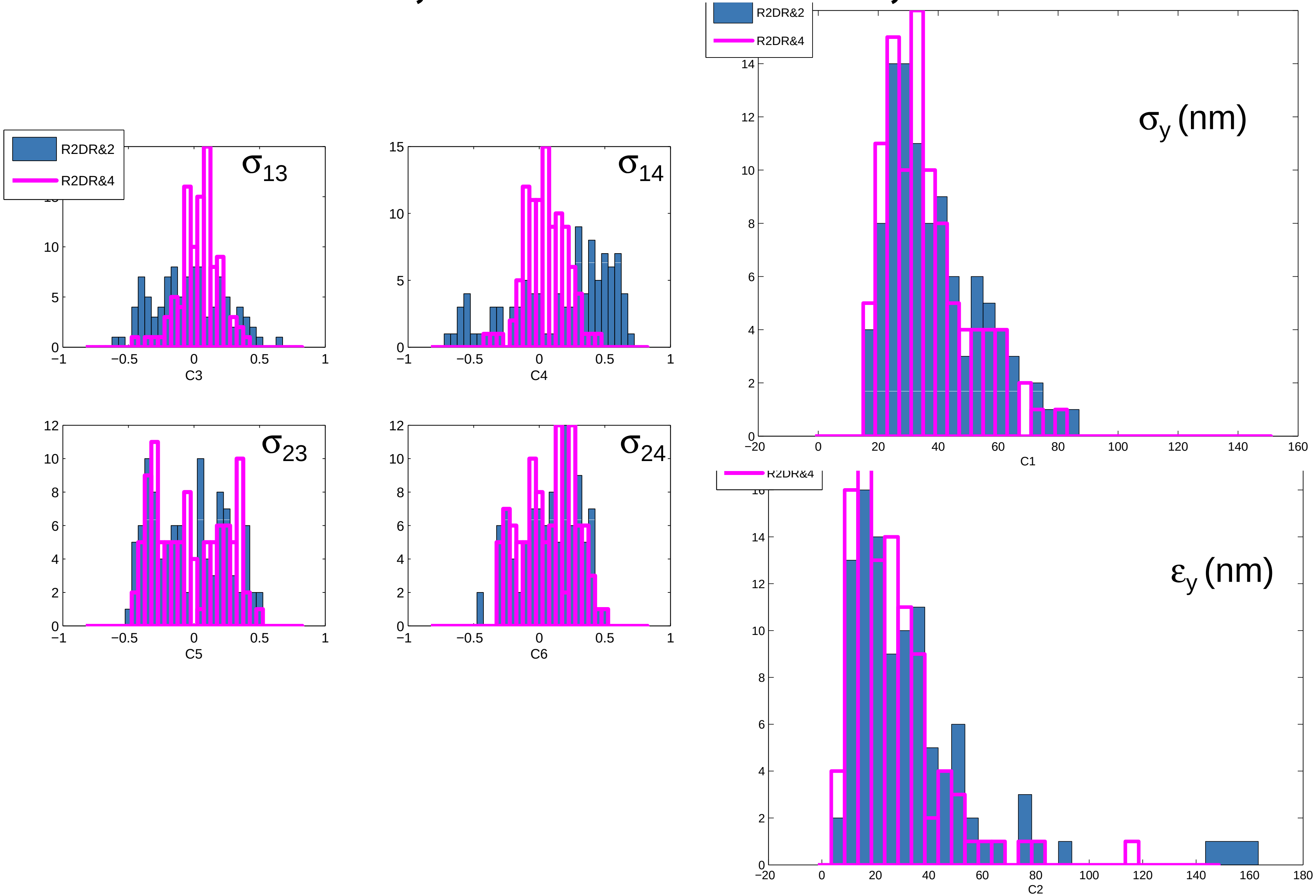
2.2-Test CC efficiency with 2 skew Quad at the IP
SE+QM7, 2 skew Vs 4 skew, after CC



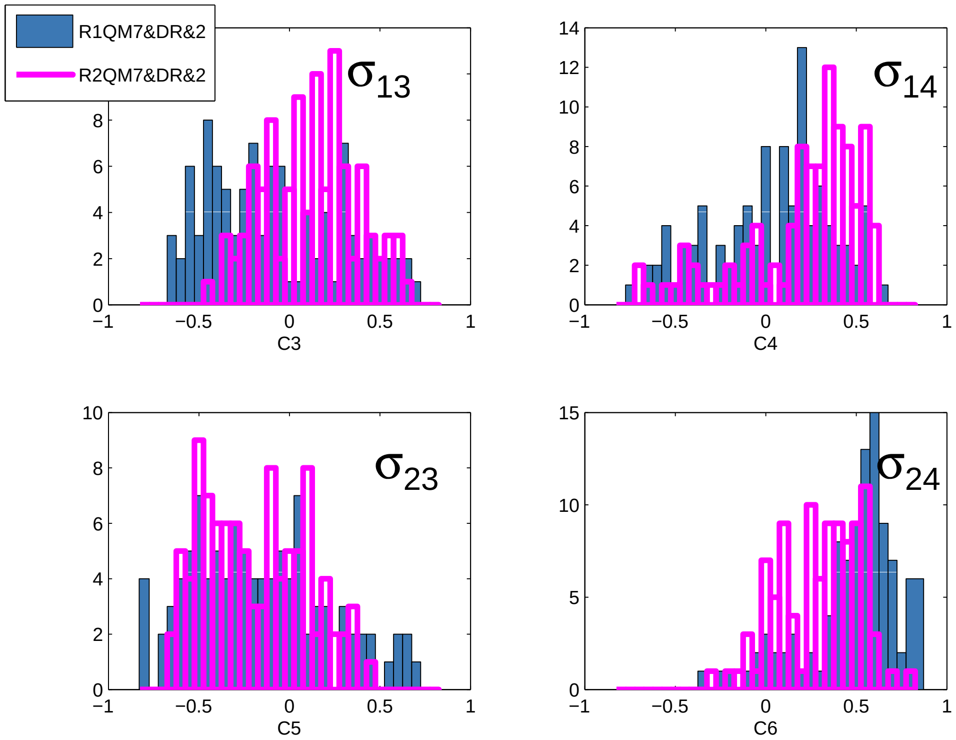
3.1-Test CC efficiency with 2 skew Quad at the IP SE+DR, before Vs after CC

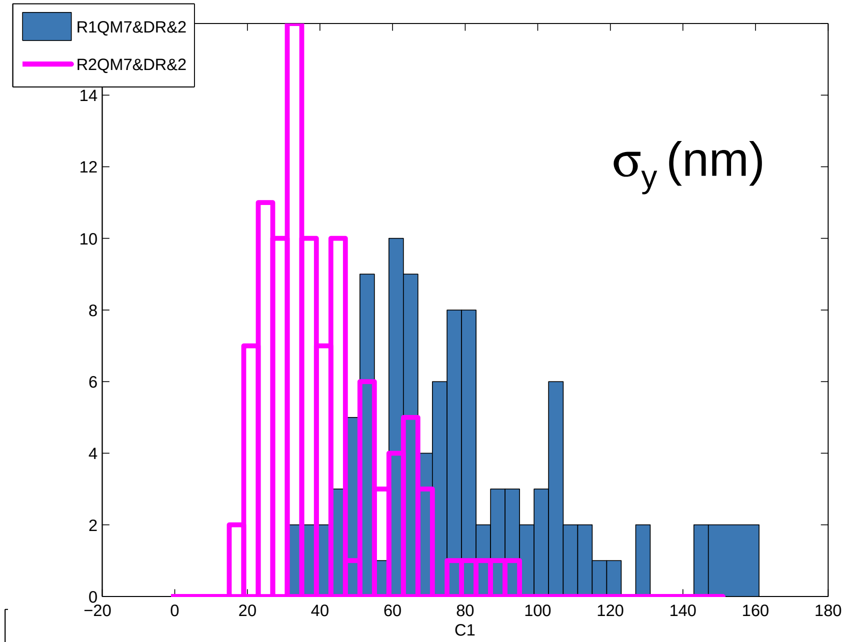


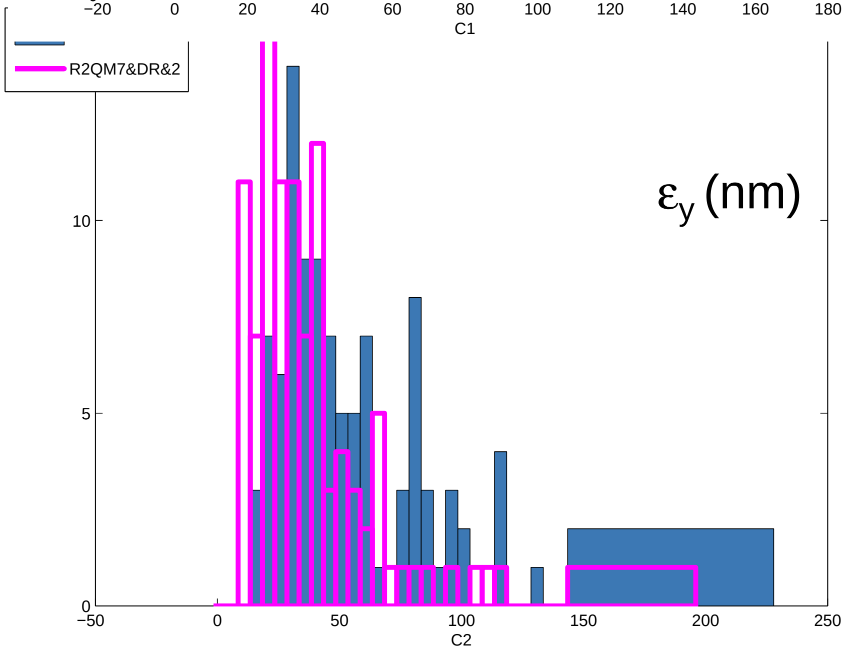
3.2-Test CC efficiency with 2 skew Quad at the IP
SE+DR, 2 skew Vs 4 skew, after CC



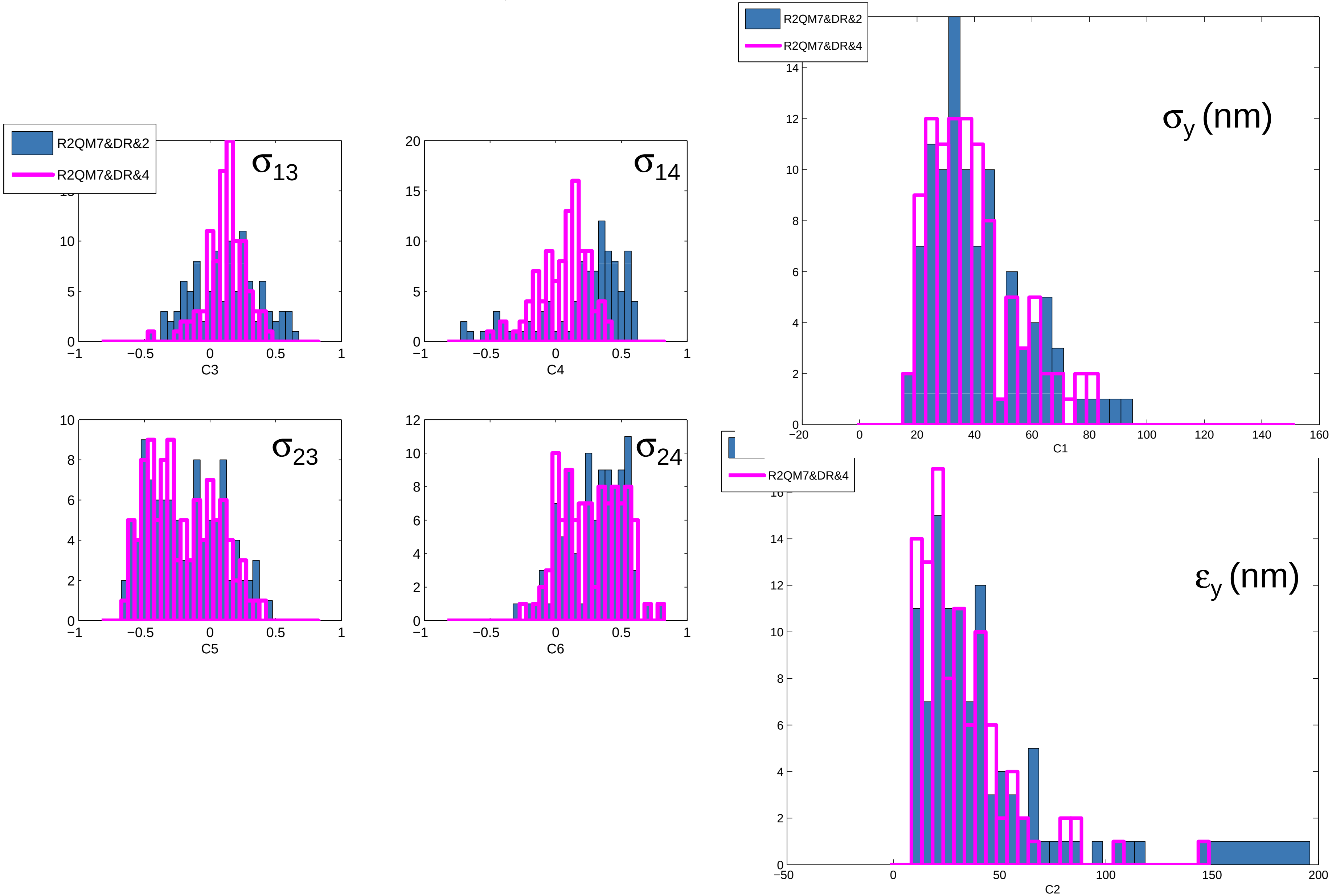
4.1-Test CC efficiency with 2 skew Quad at the IP SE+DR+QM7, before Vs after CC





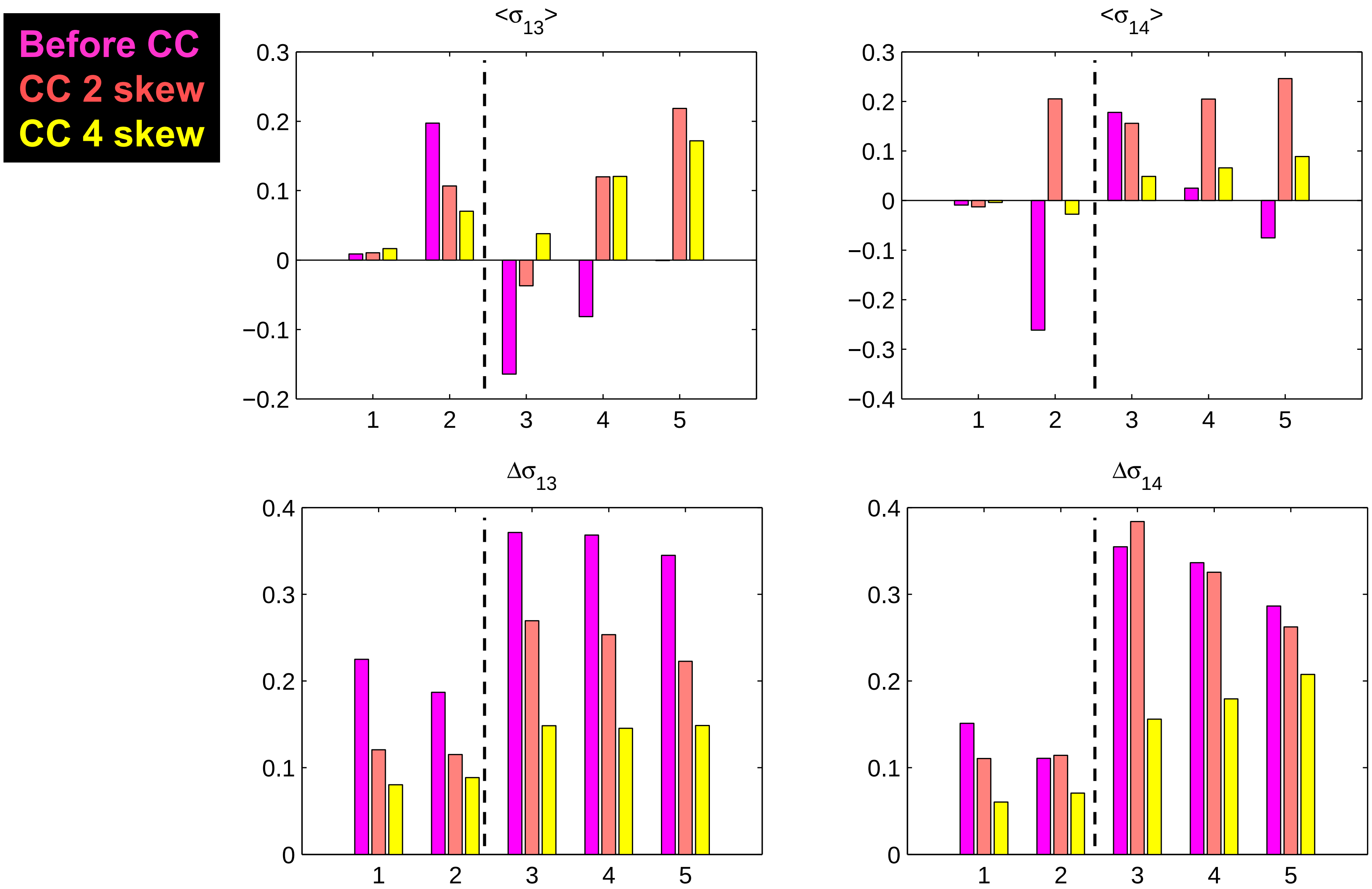


4.2-Test CC efficiency with 2 skew Quad at the IP
SE+DR+QM7, 2 skew Vs 4 skew, after CC



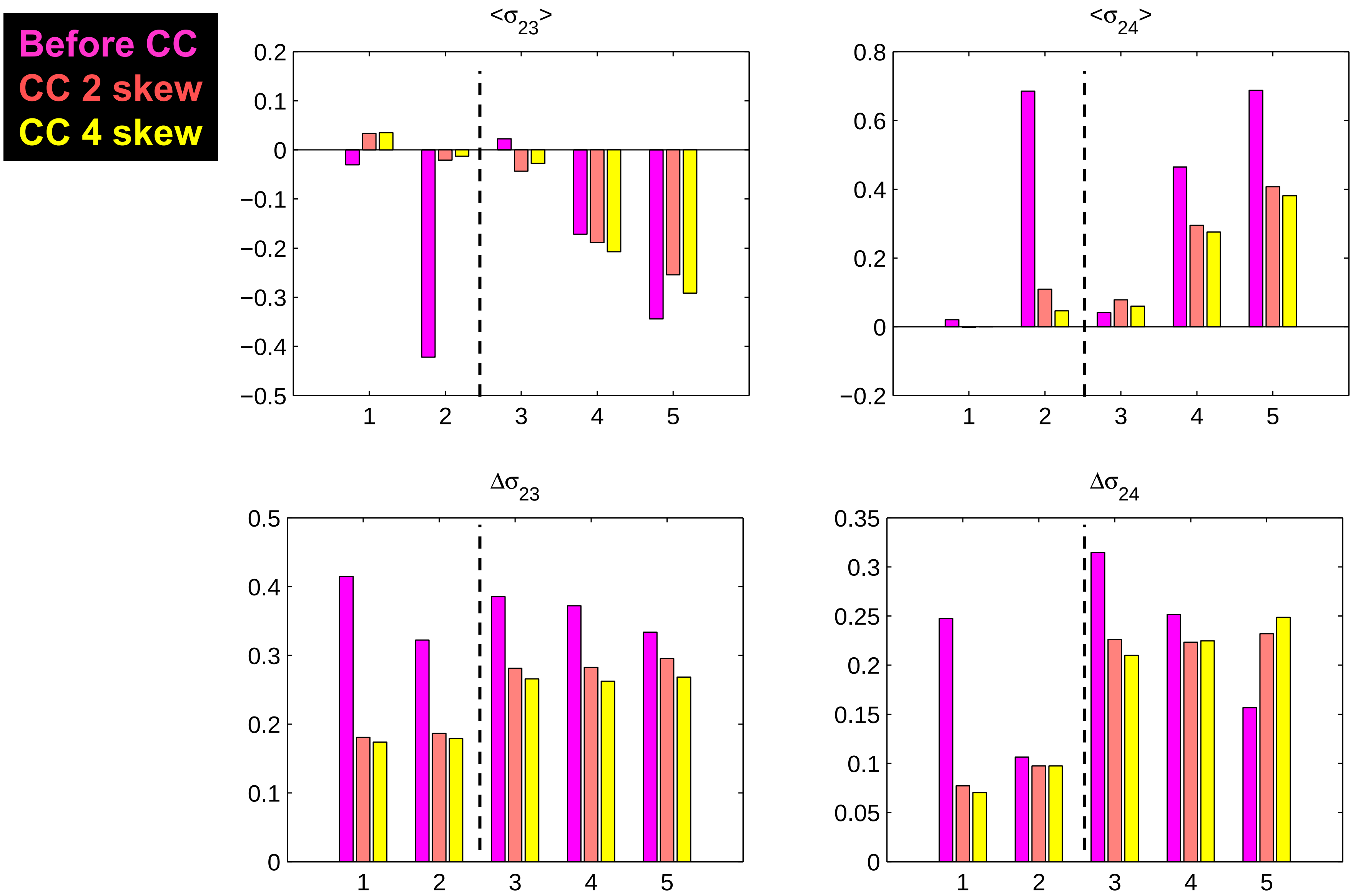
Full comparison mean value/ std for Coupling

1:SE 2:SE+QM7 3:SE+DR 4:SE+DR+QM7 5:SE+DR+2QM7



Full comparison mean value/ std for Coupling

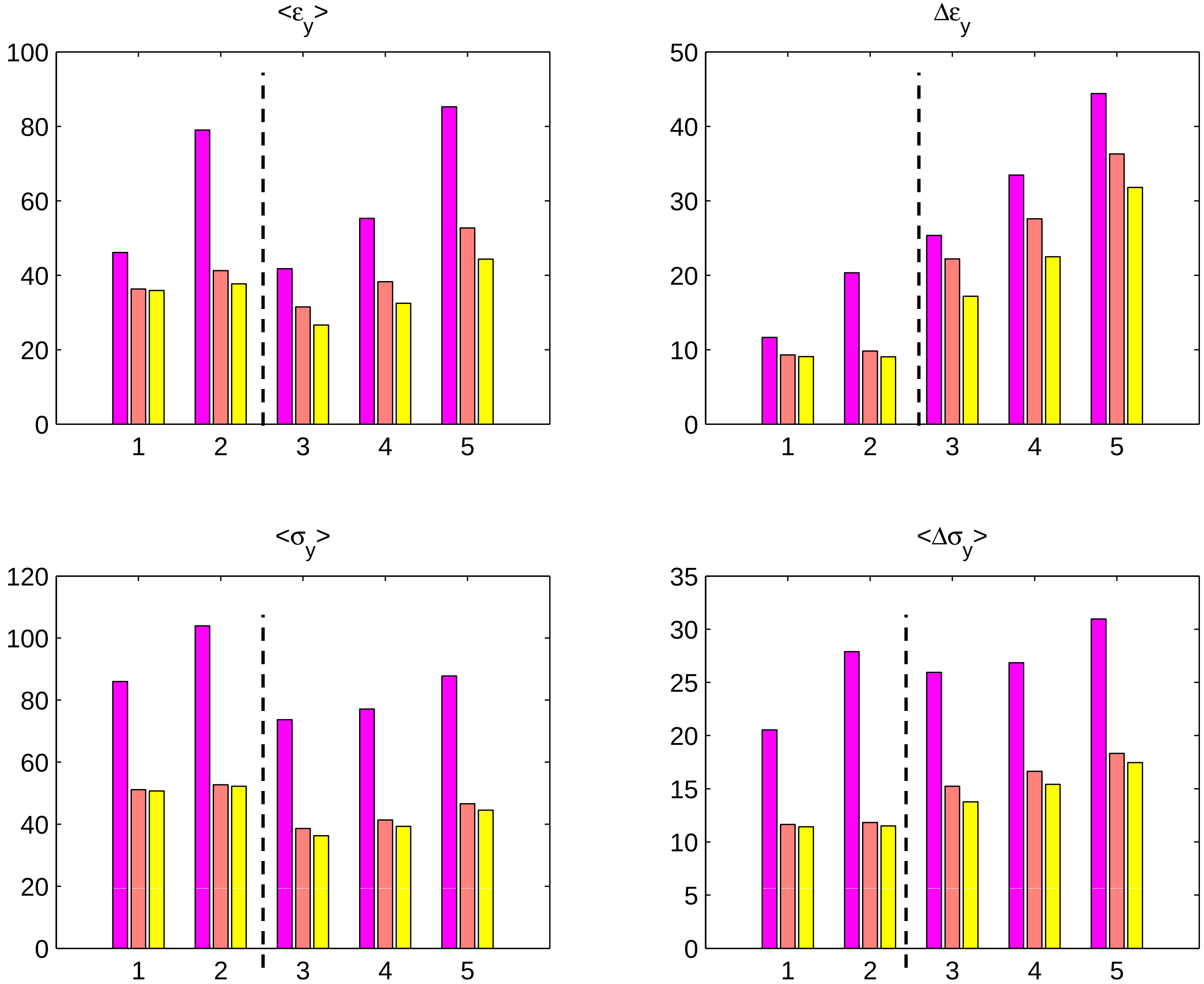
1:SE 2:SE+QM7 3:SE+DR 4:SE+DR+QM7 5:SE+DR+2QM7



Full comparison mean value/ std for ε_y & σ_y

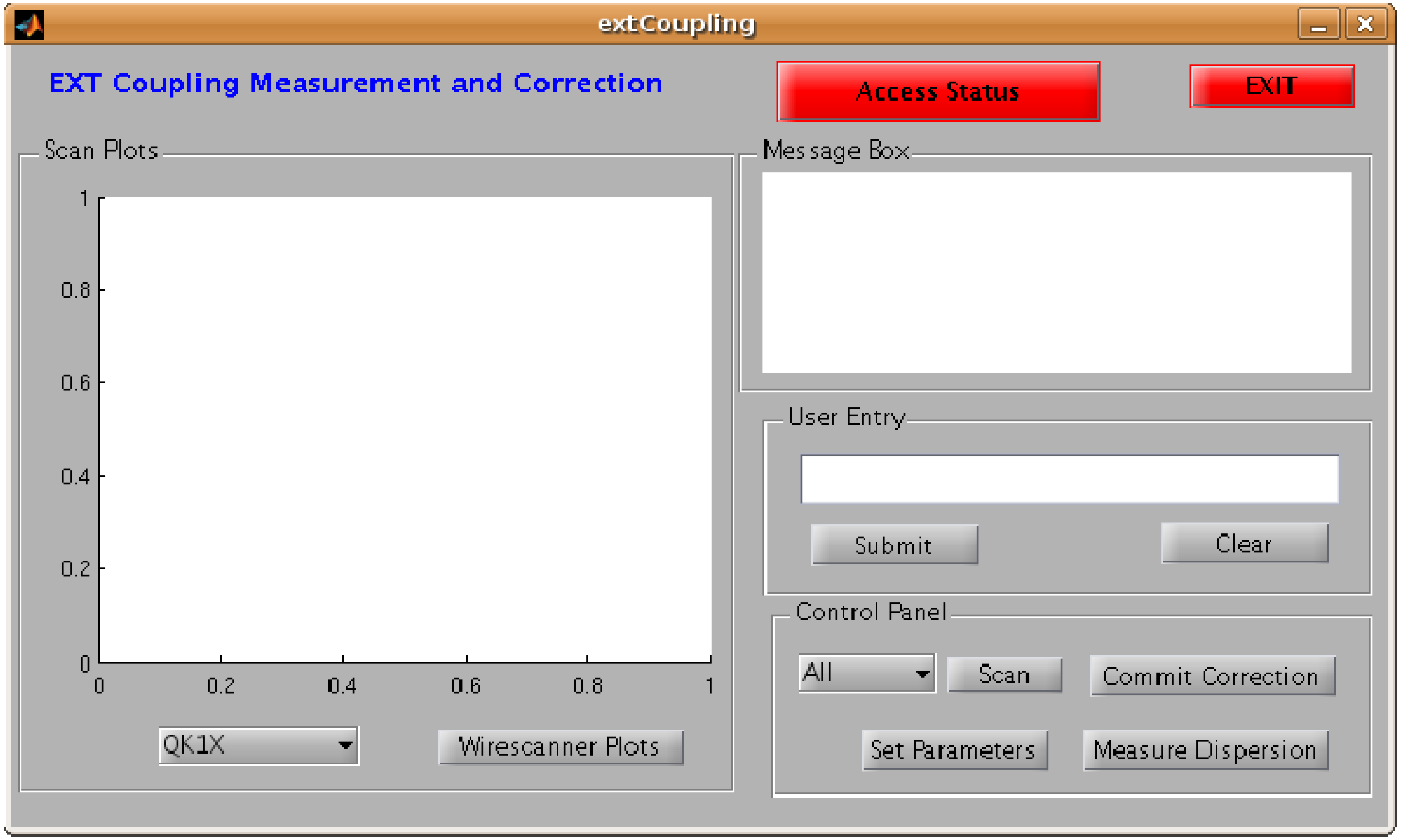
1:SE 2:SE+QM7 3:SE+DR 4:SE+DR+QM7 5:SE+DR+2QM7

Before CC
CC 2 skew
CC 4 skew



CC in Flight Simulator: next tools & features

- Implement waist scan method in FS to measure coupling
- A GUI for coupling correction & measurements is under development: visualization of parabola construction at each wire scanner during quad scan & automatic fits.



Summary & Next steps

- 4 beam matrix coupling elements are theoretically determinable using combined quad and skew quad scan with x, y and tilted measurements

➔ Should be implemented in FS and tested experimentally.

➔ Study of a direct method to calculate the appropriate skew strengths combination to correct the coupling .

- Using 4 skew to correct coupling reduce vertical emittance of ~ 15% to 20% compare to 2 skew when DR coupling.

➔ More tests are needed, maybe with another DR error generation.

- Implemented CC in FS should be tested experimentaly soon (12/17)
- A new GUI for CC is under development.