# EXT Vertical Dispersion Correction

The Problem

- "sum knob" generates only η_y' at QS1X and QS2X, in-phase ($\Delta\psi_y = 180°$)
- good for correcting η_y generated in EXT … bad for correcting η_y coming from DR and extraction channel
- QS1X and QS2X can be used independently to correct arbitrary η_y/η_y', but large coupling is generated

Vertical Dispersion Correction: Twiss at Skew Quadrupoles
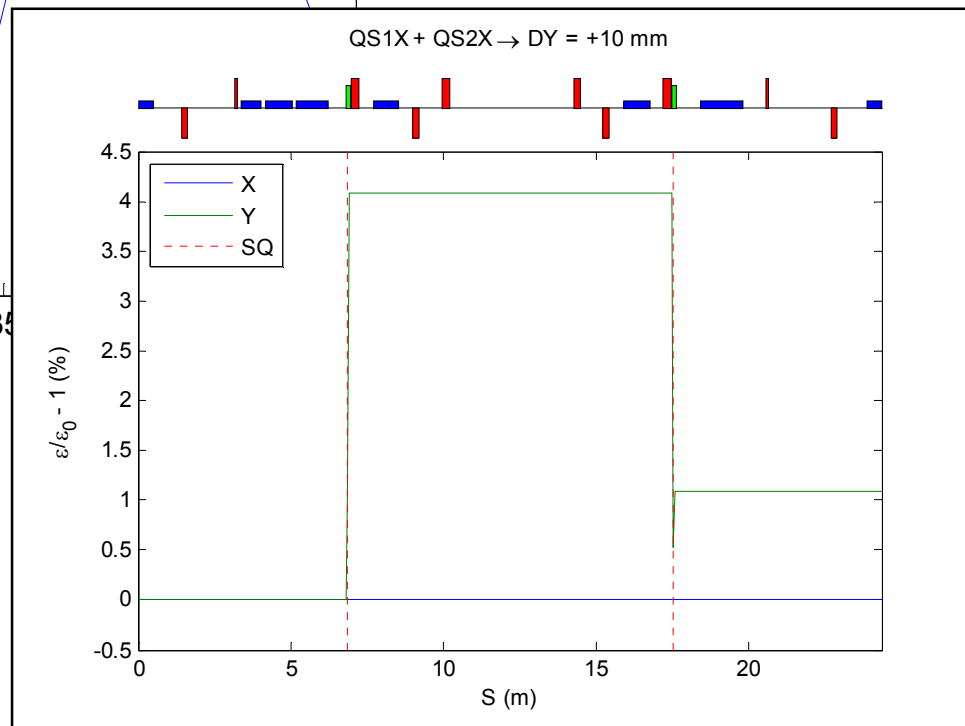
QS1X/QS2X Sum Knob Simulation

$\Delta\mu_y = 180°$

QS1X

QS2X

MDISP

$\Delta\eta_y = +10$ mm
$\Delta\eta'_y = -5.8$ mr
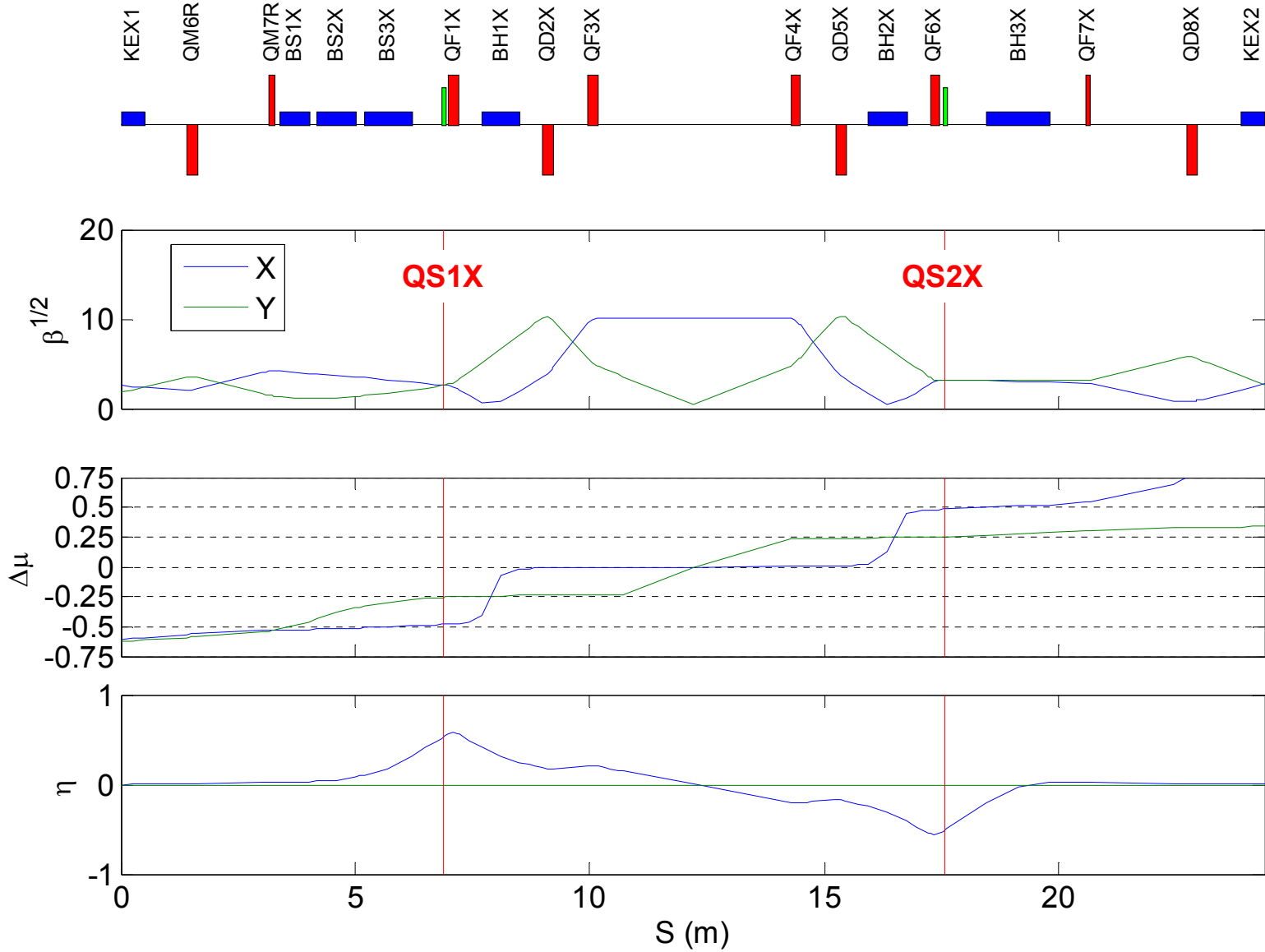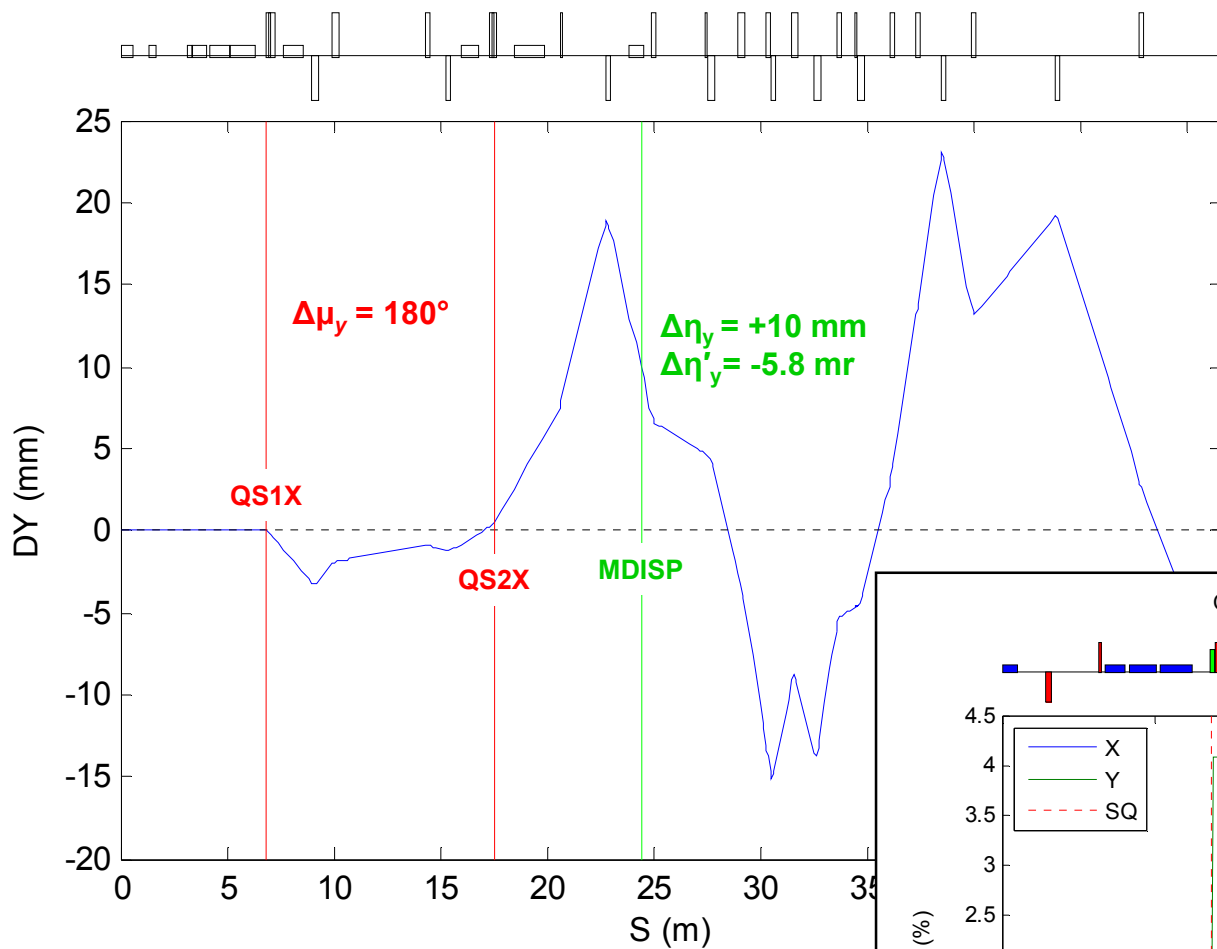
$$\frac{\Delta\eta_y}{\Delta\eta'_y} \approx -2$$

$I_{QS1X} = I_{QS2X} = 0.46$ amps

QS1X + QS2X → DY = +10 mm

Possible Solutions

1. "sum knob" correction of η_y at MDISP (ignore η_y') … propagate residual η_y' to wire scanners ... correct residual η_y/η_y' at IP
2. correct η_y/η_y' at MDISP with independent QS1X and QS2X; correct coupling with QKs
3. "sum knob" correction of η_y at MDISP; correct residual η_y' using ZVs (make a closed bump that generates η_y' at MDISP) … Kubo-san's idea
4. "sum knob" correction of η_y at MDISP; correct residual η_y' using a closed η_y bump across DR North straight section (generate pure η_y' at MDISP … DR skews or ZVs?)
5. correct η_y/η_y' at extraction point in Damping Ring as part of DR vertical dispersion correction
6. one or more additional EXT SQs?

NOTE: "MDISP" is the start of the EXT diagnostics section (exit of 2nd extraction kicker)

Solution 1: Pros & Cons

- no new magnets or power supplies
- no perturbation in DR
- residual η_y' propagates to wire scanners and IP

name	η_y / mm	η'_y / mr	$\sigma_y(\beta)$ / μm	$\sigma_y(\eta)$ / μm
MW0X	33.5	-8.9	13.0	26.8
MW1X	27.0	7.3	8.7	21.6
MW2X	50.5	7.3	15.2	40.4
MW3X	18.6	-2.7	8.6	14.9
MW4X	9.8	-2.7	15.3	7.8
IP	-10.5	29.5	13.7	8.4
MW1IP	2.0	29.5	0.6	1.6

- "BX20BY100" optics; waists at MW1IP
- ε_x=1.5nm, ε_y=20pm, σ_δ=0.08%
- set η_y/η_y' at entrance to EXT to give η_y=10mm, η'_y=0 at MDISP
- correct η_y to zero at MDISP with "sum knob"
- propagate residual η'_y from MDISP

QS1X/QS2X Sum Knob Simulation
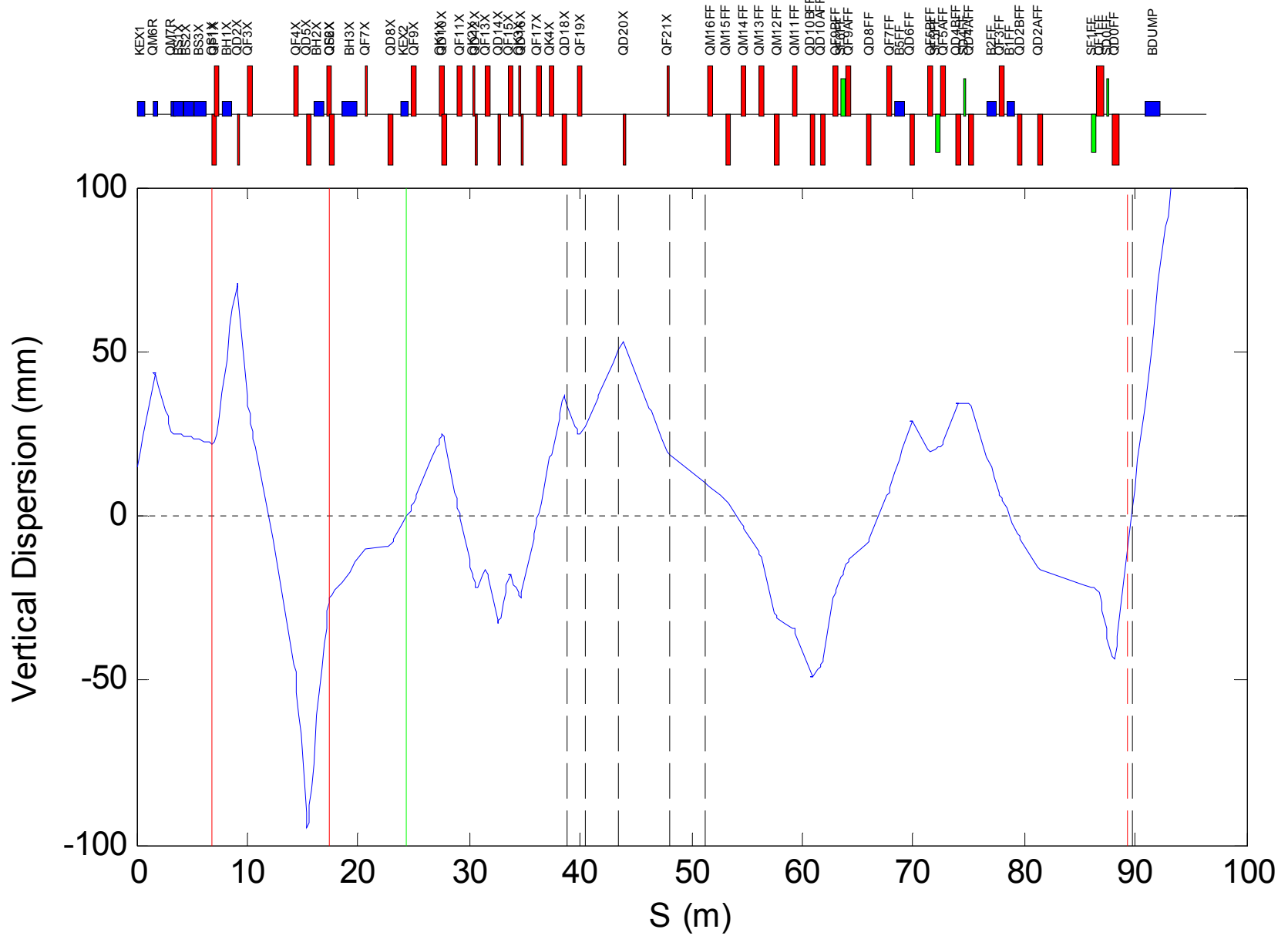
Solution 2: Pros & Cons

- no new magnets or power supplies
- no perturbation in DR
- limited correction range (see Kubo-san's presentation)
- generates maximum amount of coupling
  - drives QK1X to maximum current
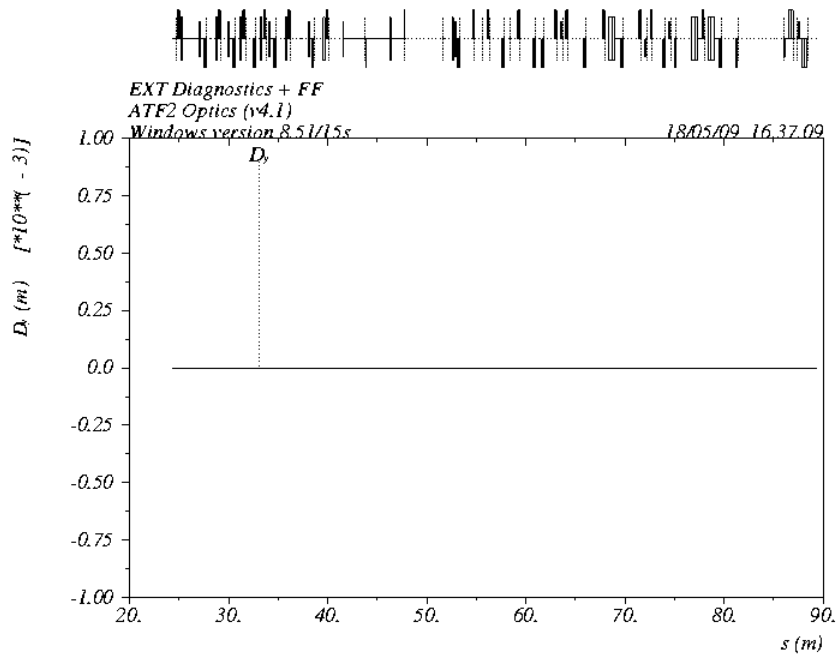 - residual vertical emittance growth

Energy = 1.2857 GeV
EmitX = 1.5 nm
EmitY = 25.0 pm
dP = 0.8 pm
"BX20BY100" FF optics

EXT Diagnostics + FF
ATF2 Optics (v4.1)
Windows version 8.51/15s   18/05/09 16.37.09

```
Vertical emittance parameters at MW0X
-----------------------------------------------------------

energy      =       1.2857                    GeV
emit        =      25.0000 +-      0.1611 pm
beta        =       8.4790 +-      0.0842 m     (    8.4790)
alpha       =       3.0756 +-      0.0348       (    3.0756)
Bmag        =       1.0000
chisq/N     =       0.0000


Propagated vertical spot sizes
----------------------------------------

MW0X =     14.6 um (   14.6 +-      0.1)
MW1X =      9.8 um (    9.8 +-      0.1)
MW2X =     17.0 um (   17.0 +-      0.1)
MW3X =      9.7 um (    9.7 +-      0.1)
MW4X =     17.1 um (   17.1 +-      0.1)


Vertical wire-to-wire phase advance
----------------------------------------

MW0X =      0.0 deg
MW1X =     17.4 deg
MW2X =     28.9 deg
MW3X =     43.2 deg
MW4X =     29.0 deg


EXT Skew Quadrupole Currents
-----------------------------

QS1X =    0.000 amp
QS2X =    0.000 amp
QK1X =    0.000 amp
QK2X =    0.000 amp
QK3X =    0.000 amp
QK4X =    0.000 amp


Other Beam Parameters
-----------------------------------------------------------

@MDISP : EtaY =       0.000 mm ; EtaPY =      -0.000 mr
@IP    : SigY =       0.500 um ; EtaY  =      -0.000 mm
@MW1IP : SigY =      21.106 um ; EtaY  =      -0.000 mm
```
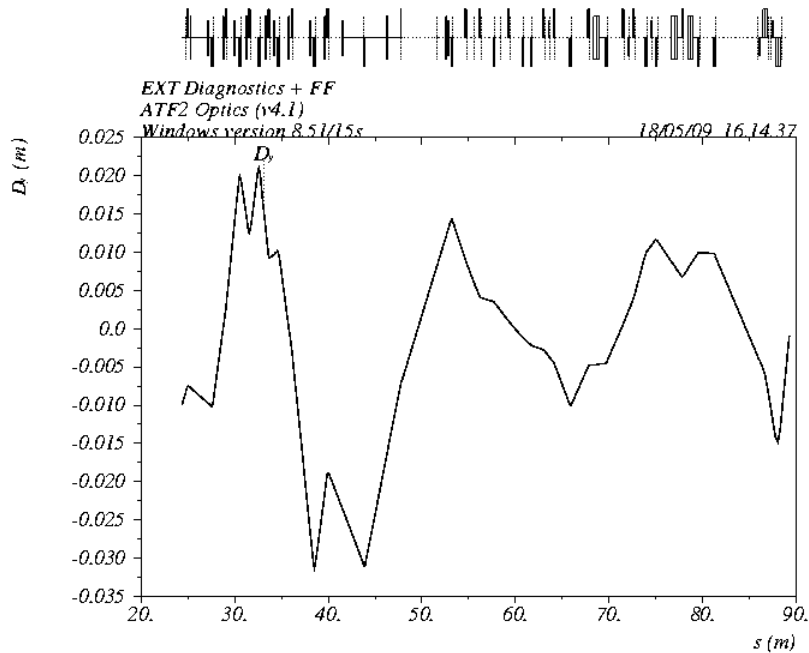
@ exit of KEX2:

EtaY = -10.0 mm
EtaPY = 4.5 mrad

EXT Diagnostics + FF
ATF2 Optics (v4.1)
Windows version 8.51/15s   18/05/09 16.14.37

D_x (m) axis with D_y curve, s (m) horizontal axis

```
Vertical emittance parameters at MW0X
----------------------------------------------------------
energy      =      1.2857                   GeV
emit        =     47.5814 +-      0.2793 pm
beta        =     15.1278 +-      0.1201 m    (   8.4790)
alpha       =      5.1001 +-      0.0442      (   3.0756)
Bmag        =      1.2143
chisq/N     =     -0.0000


Propagated vertical spot sizes
------------------------------------------
MW0X =    26.8 um (   26.8 +-     0.1)
MW1X =    18.6 um (   18.6 +-     0.1)
MW2X =    29.5 um (   29.5 +-     0.1)
MW3X =    10.7 um (   10.7 +-     0.1)
MW4X =    18.0 um (   18.0 +-     0.1)


Vertical wire-to-wire phase advance
------------------------------------------
MW0X =     0.0 deg
MW1X =     9.3 deg
MW2X =    16.2 deg
MW3X =    42.6 deg
MW4X =    52.2 deg


EXT Skew Quadrupole Currents
-----------------------------
QS1X =   0.000 amp
QS2X =   0.000 amp
QK1X =   0.000 amp
QK2X =   0.000 amp
QK3X =   0.000 amp
QK4X =   0.000 amp


Other Beam Parameters
----------------------------------------------------------
@MDISP : EtaY =   -10.000 mm ; EtaPY =     4.500 mr
@IP    : SigY =     0.947 um ; EtaY  =    -1.005 mm
@MW1IP : SigY =    21.365 um ; EtaY  =     4.148 mm
```
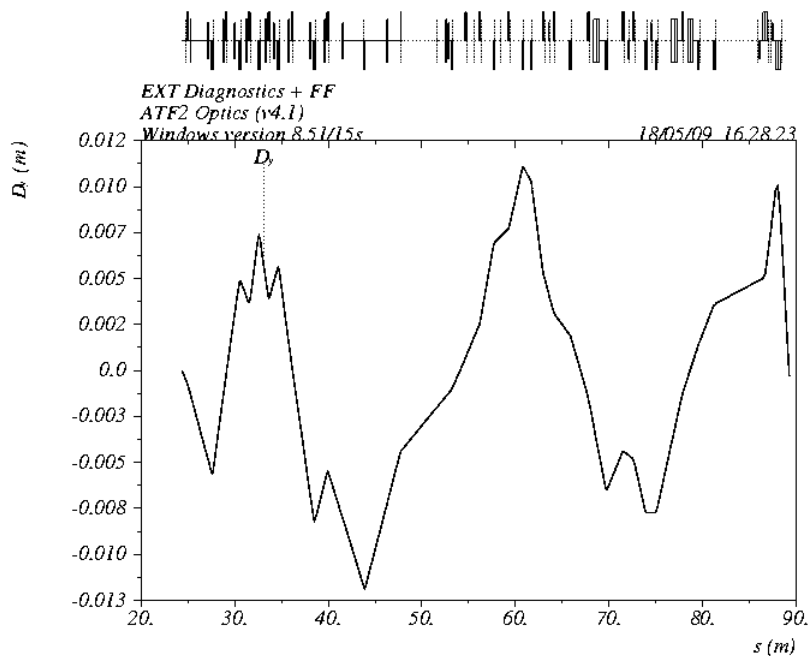
not corrected
for dispersion

correct using QS1-2X sum-knob

@ exit of KEX2:

EtaY = 0


```
Vertical emittance parameters at MW0X
----------------------------------------------------------
energy      =      1.2857              GeV
emit        =     28.4265 +-     0.1766 pm
beta        =      8.7610 +-     0.0791 m    (   8.4790)
alpha       =      3.0526 +-     0.0322      (   3.0756)
Bmag        =      1.0081
chisq/N     =      0.0000


Propagated vertical spot sizes
----------------------------------------------
MW0X =    15.8 um (  15.8 +-     0.1)
MW1X =    10.9 um (  10.9 +-     0.1)
MW2X =    19.3 um (  19.3 +-     0.1)
MW3X =    10.2 um (  10.2 +-     0.1)
MW4X =    17.2 um (  17.2 +-     0.1)


Vertical wire-to-wire phase advance
-------------------------------------------
MW0X =     0.0 deg
MW1X =    16.3 deg
MW2X =    25.7 deg
MW3X =    40.5 deg
MW4X =    31.2 deg


EXT Skew Quadrupole Currents
------------------------------
QS1X =   0.455 amp
QS2X =   0.455 amp
QK1X =   0.000 amp
QK2X =   0.000 amp
QK3X =   0.000 amp
QK4X =   0.000 amp


Other Beam Parameters
----------------------------------------------------------
@MDISP : EtaY =     -0.000 mm ; EtaPY =     -1.304 mr
@IP    : SigY =      0.564 um ; EtaY  =     -0.323 mm
@MW1IP : SigY =     21.367 um ; EtaY  =     -4.144 mm
```
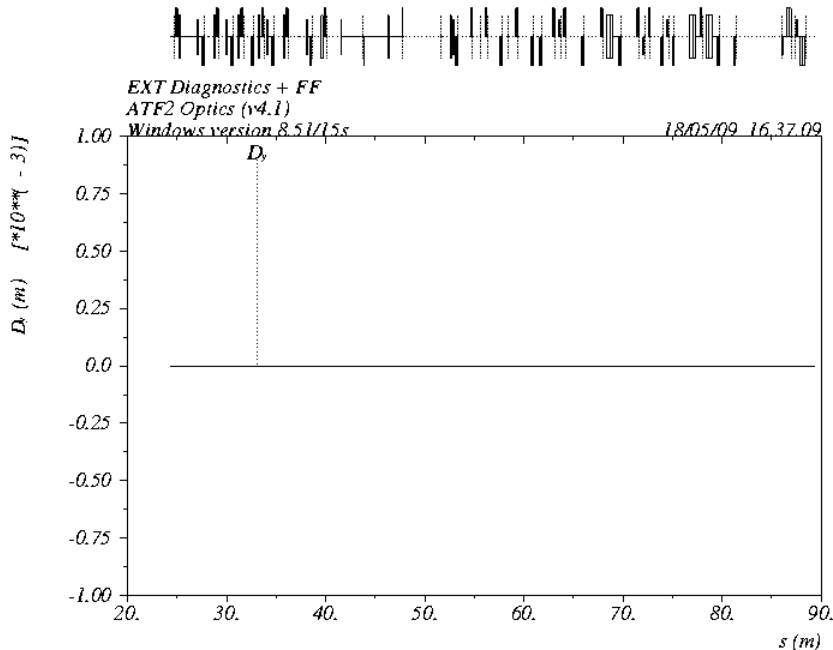
not corrected
for dispersion

correct using independent QS1-2X

@ exit of KEX2:

EtaY = 0
EtaPY = 0


```
Vertical emittance parameters at MW0X
----------------------------------------------------------
energy     =      1.2857                    GeV
emit       =    105.1845 +-      0.9319 pm
beta       =     35.1756 +-      0.3419 m     (    8.4791)
alpha      =     12.2896 +-      0.1210       (    3.0757)
Bmag       =      2.2214
chisq/N    =     -0.0000

Propagated vertical spot sizes
----------------------------------------------
MW0X  =    60.8 um (    60.8 +-      0.1)
MW1X  =    40.4 um (    40.4 +-      0.1)
MW2X  =    56.3 um (    56.3 +-      0.1)
MW3X  =    10.9 um (    10.9 +-      0.1)
MW4X  =    31.0 um (    31.0 +-      0.1)

Vertical wire-to-wire phase advance
----------------------------------------------
MW0X  =     0.0 deg
MW1X  =     4.2 deg
MW2X  =     8.6 deg
MW3X  =    50.7 deg
MW4X  =    87.4 deg

EXT Skew Quadrupole Currents
-----------------------------
QS1X  =   -6.295 amp
QS2X  =    6.359 amp
QK1X  =    0.000 amp
QK2X  =    0.000 amp
QK3X  =    0.000 amp
QK4X  =    0.000 amp

Other Beam Parameters
----------------------------------------------------------
@MDISP : EtaY =     -0.000 mm ; EtaPY =      0.000 mr
@IP    : SigY =      2.015 um ; EtaY  =     -0.000 mm
@MW1IP : SigY =     31.600 um ; EtaY  =      0.000 mm
```
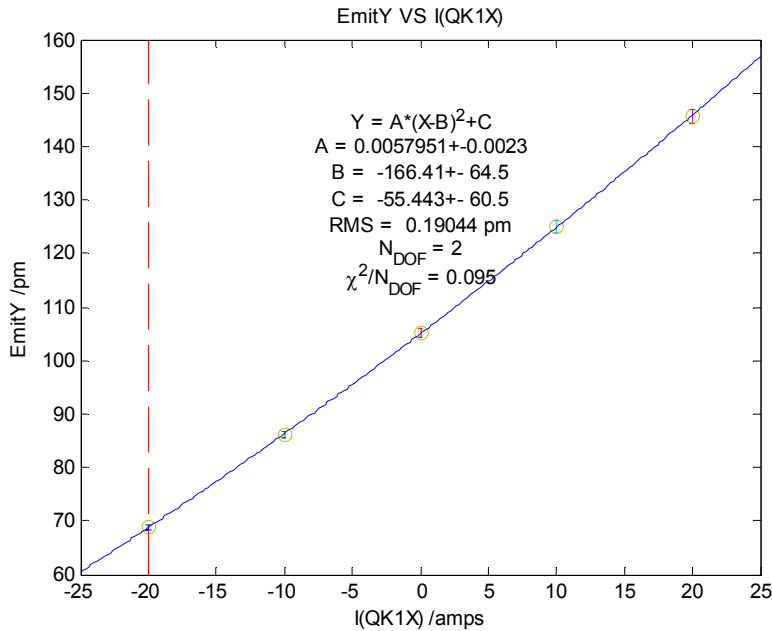
dispersion is zero

scan QK1X [-20,-10,0,+10,+20]

EmitY VS I(QK1X)

$Y = A*(X-B)^2+C$
A = 0.0057951+-0.0023
B = -166.41+- 64.5
C = -55.443+- 60.5
RMS = 0.19044 pm
N_{DOF} = 2
χ^2/N_{DOF} = 0.095

EmitY /pm

I(QK1X) /amps

set QK1X to -20 amps

@ exit of KEX2:

EmitY = 68.8034 pm

```
Vertical emittance parameters at MW0X
-----------------------------------------------------------
energy    =     1.2857                  GeV
emit      =    68.8034 +-      0.4293 pm
beta      =    21.3114 +-      0.1633 m    (   8.4786)
alpha     =     6.9767 +-      0.0567      (   3.0756)
Bmag      =     1.5688
chisq/N   =     0.0000


Propagated vertical spot sizes
-----------------------------------------------------------
MW0X =    38.3 um (   38.3 +-       0.1)
MW1X =    27.0 um (   27.0 +-       0.1)
MW2X =    42.6 um (   42.6 +-       0.1)
MW3X =    12.8 um (   12.8 +-       0.1)
MW4X =    18.5 um (   18.5 +-       0.1)


Vertical wire-to-wire phase advance
-----------------------------------------------------------
MW0X =     0.0 deg
MW1X =     6.5 deg
MW2X =    11.1 deg
MW3X =    34.7 deg
MW4X =    69.4 deg


EXT Skew Quadrupole Currents
------------------------------
QS1X =   -6.295 amp
QS2X =    6.359 amp
QK1X =  -20.007 amp
QK2X =    0.000 amp
QK3X =    0.000 amp
QK4X =    0.000 amp


Other Beam Parameters
-----------------------------------------------------------
@MDISP : EtaY =    -0.000 mm ; EtaPY =      0.000 mr
@IP    : SigY =     1.378 um ; EtaY  =     -0.000 mm
@MW1IP : SigY =    21.255 um ; EtaY  =      0.002 mm
```
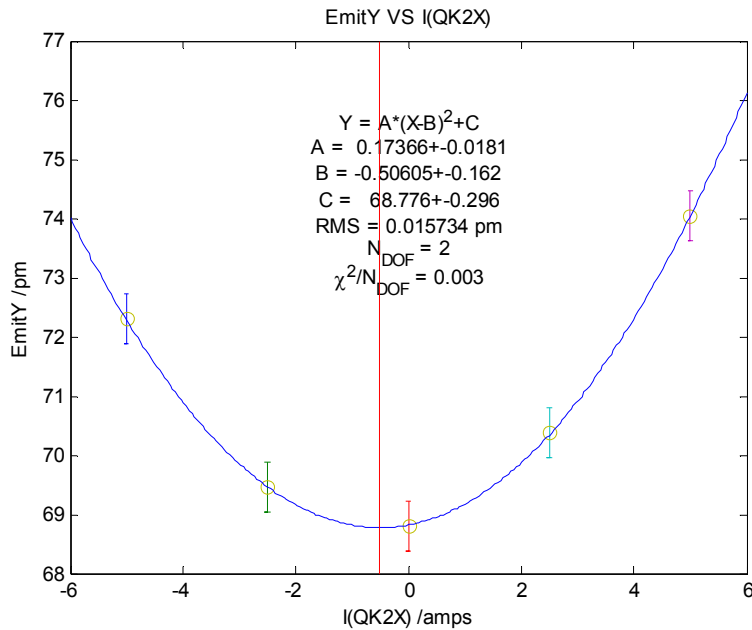
dispersion is zero

scan QK2X [-5,-2.5,0,+2.5,+5]

EmitY VS I(QK2X)

$Y = A*(X-B)^2+C$
$A = 0.17366+-0.0181$
$B = -0.50605+-0.162$
$C = 68.776+-0.296$
$RMS = 0.015734$ pm
$N_{DOF} = 2$
$\chi^2/N_{DOF} = 0.003$

EmitY /pm

I(QK2X) /amps

set QK2X to -0.506 amps

@ exit of KEX2:

EmitY = 68.7557 pm

```
Vertical emittance parameters at MW0X
---------------------------------------------------------
energy    =      1.2857                  GeV
emit      =     68.7557 +-     0.4293 pm
beta      =     21.3528 +-     0.1636 m    (    8.4786)
alpha     =      6.9837 +-     0.0567      (    3.0756)
Bmag      =      1.5730
chisq/N   =      0.0000


Propagated vertical spot sizes
------------------------------------
MW0X =     38.3 um (    38.3 +-      0.1)
MW1X =     27.0 um (    27.0 +-      0.1)
MW2X =     42.7 um (    42.7 +-      0.1)
MW3X =     12.8 um (    12.8 +-      0.1)
MW4X =     18.4 um (    18.4 +-      0.1)


Vertical wire-to-wire phase advance
------------------------------------
MW0X =      0.0 deg
MW1X =      6.5 deg
MW2X =     11.0 deg
MW3X =     34.5 deg
MW4X =     69.4 deg


EXT Skew Quadrupole Currents
------------------------------
QS1X =   -6.295 amp
QS2X =    6.359 amp
QK1X =  -20.007 amp
QK2X =   -0.506 amp
QK3X =    0.000 amp
QK4X =    0.000 amp


Other Beam Parameters
---------------------------------------------------------
@MDISP : EtaY =     -0.000 mm ; EtaPY =      0.000 mr
@IP    : SigY =      1.380 um ; EtaY  =     -0.000 mm
@MW1IP : SigY =     21.193 um ; EtaY  =     -0.007 mm
```
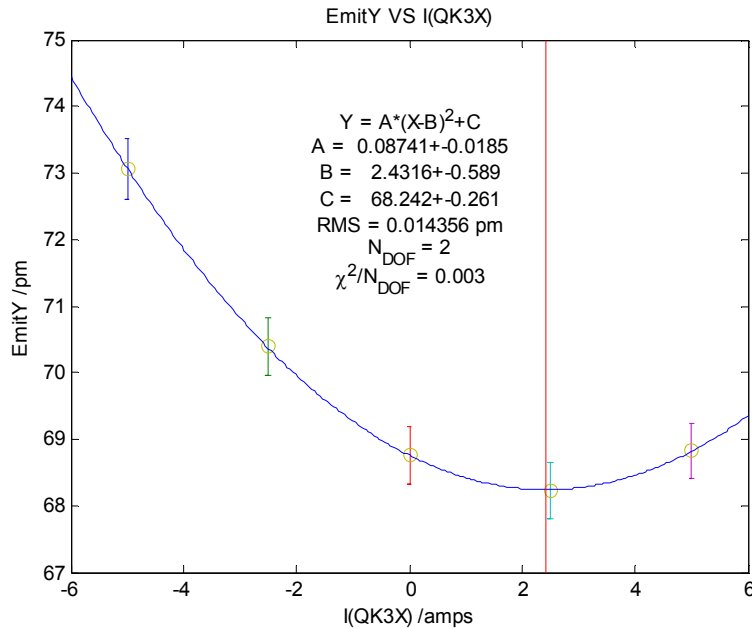
dispersion is zero

scan QK3X [-5,-2.5,0,+2.5,+5]

EmitY VS I(QK3X)

$$Y = A*(X-B)^2+C$$
A = 0.08741+-0.0185
B = 2.4316+-0.589
C = 68.242+-0.261
RMS = 0.014356 pm
N_{DOF} = 2
χ^2/N_{DOF} = 0.003

EmitY /pm

I(QK3X) /amps

set QK3X to +2.432 amps

@ exit of KEX2:

EmitY = 68.2255 pm

```
Vertical emittance parameters at MW0X
---------------------------------------------------------
energy    =      1.2857                GeV
emit      =     68.2255 +-     0.4214 pm
beta      =     21.0538 +-     0.1597 m    (   8.4786)
alpha     =      6.8740 +-     0.0554      (   3.0756)
Bmag      =      1.5602
chisq/N   =      0.0000


Propagated vertical spot sizes
-----------------------------------------------
MW0X =    37.9 um (   37.9 +-      0.1)
MW1X =    26.8 um (   26.8 +-      0.1)
MW2X =    42.4 um (   42.4 +-      0.1)
MW3X =    12.8 um (   12.8 +-      0.1)
MW4X =    18.3 um (   18.3 +-      0.1)


Vertical wire-to-wire phase advance
-----------------------------------------------
MW0X =     0.0 deg
MW1X =     6.6 deg
MW2X =    11.2 deg
MW3X =    34.3 deg
MW4X =    68.3 deg


EXT Skew Quadrupole Currents
-----------------------------
QS1X =  -6.295 amp
QS2X =   6.359 amp
QK1X = -20.007 amp
QK2X =  -0.506 amp
QK3X =   2.432 amp
QK4X =   0.000 amp


Other Beam Parameters
---------------------------------------------------------
@MDISP : EtaY =    -0.000 mm ; EtaPY =      0.000 mr
@IP    : SigY =     1.368 um ; EtaY  =      0.001 mm
@MW1IP : SigY =    21.172 um ; EtaY  =     -0.036 mm
```
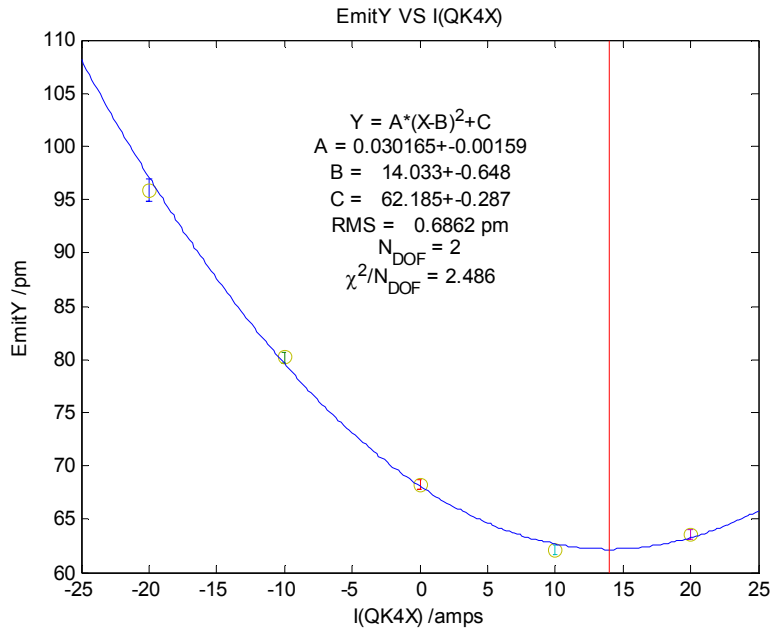
dispersion is zero

scan QK4X [-20,-10,0,+10,+20]

EmitY VS I(QK4X)

$$Y = A*(X-B)^2+C$$
A = 0.030165+-0.00159
B = 14.033+-0.648
C = 62.185+-0.287
RMS = 0.6862 pm
N_{DOF} = 2
χ^2/N_{DOF} = 2.486

EmitY /pm

I(QK4X) /amps

set QK4X to +14.033 amps

@ exit of KEX2:

EmitY = 61.7352 pm

```
Vertical emittance parameters at MW0X
---------------------------------------------------------
energy     =      1.2857                 GeV
emit       =     61.7352 +-     0.4537 pm
beta       =     19.2828 +-     0.1817 m    (    8.4789)
alpha      =      7.2366 +-     0.0704      (    3.0756)
Bmag       =      1.3698
chisq/N    =     -0.0000


Propagated vertical spot sizes
---------------------------------------------------------
MW0X =     34.5 um (    34.5 +-      0.1)
MW1X =     21.5 um (    21.5 +-      0.1)
MW2X =     27.9 um (    27.9 +-      0.1)
MW3X =     10.3 um (    10.3 +-      0.1)
MW4X =     28.0 um (    28.0 +-      0.1)


Vertical wire-to-wire phase advance
---------------------------------------------------------
MW0X =      0.0 deg
MW1X =      8.1 deg
MW2X =     19.4 deg
MW3X =     75.3 deg
MW4X =     43.1 deg


EXT Skew Quadrupole Currents
-----------------------------
QS1X =   -6.295 amp
QS2X =    6.359 amp
QK1X =  -20.007 amp
QK2X =   -0.506 amp
QK3X =    2.432 amp
QK4X =   14.033 amp


Other Beam Parameters
---------------------------------------------------------
@MDISP : EtaY =    -0.000 mm ; EtaPY =     0.000 mr
@IP    : SigY =     1.052 um ; EtaY  =     0.001 mm
@MW1IP : SigY =    31.578 um ; EtaY  =    -0.037 mm
```

dispersion is zero

Solution 3: Pros & Cons

- no new magnets or power supplies
- no perturbation in DR
- reasonable correction range (see Kubo-san's presentation)
- effects of orbit bump
  - Shintake monitor backgrounds?
  - emittance growth and/or coupling from sampling kicker field vertically off-axis?

Solution 4: Pros & Cons

- no new magnets or power supplies
- perturbation in DR
- limited correction range (only DR skews tried so far)
- effects of dispersion bump
    - DR vertical emittance?
    - DR laserwire operation?

Future

- measure dispersion (skew quads OFF) at least once per shift ... is η_y/η_y' predominantly from EXT sources, or from DR? (document conditions; save workspaces)
- study roll errors in septa (effects and correction)
- η_y/η_y' bump in DR using ZVs?
- and …
- and …
- and …