Beta* and beta-waist measurements and knobs

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β* and s* measurements

$$\Delta Q = \frac{\langle \beta \rangle \Delta K l}{4\pi}$$

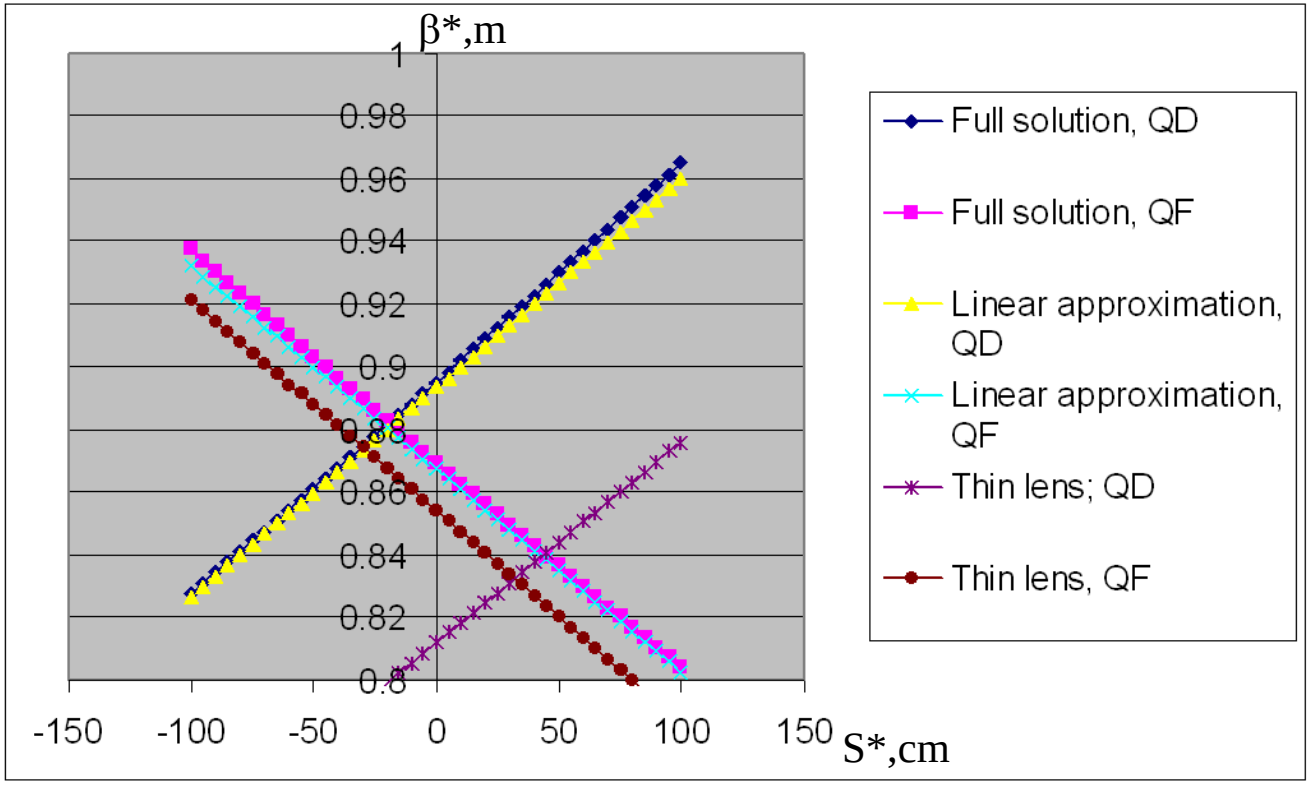
Change Q1 gradient -> measure betatron tune change -> extract quad beta function -> find β* and s* (using measurements both Q1 quads

$$\langle \beta \rangle = \langle m_{11}^2 \rangle \beta_0 - 2\langle m_{11} m_{12} \rangle \alpha_0 + \langle m_{12}^2 \rangle \gamma_0$$

$$\beta_0 = \beta^* + \frac{(L - s^*)^2}{\beta^*}; \quad \alpha_0 = -\frac{L - s^*}{\beta^*}; \quad \gamma_0 = \frac{1}{\beta^*}$$

$$\frac{L^2}{\beta^{*2}}; \quad \frac{L}{\beta^*}; \quad 1 \rightarrow$$ Terms hierarchy. Neglecting terms ~1 leads to linear equations (in β* and s*)

Solution for Yellow IR6 horizontal data



$$\beta_+ = \langle \beta(L) \rangle; \quad \beta_- = \langle \beta(-L) \rangle$$

$$a_\pm = \langle m_{11}^2 \rangle_\pm; \quad b_\pm = \langle m_{11} m_{12} \rangle_\pm; \quad c_\pm = \langle m_{12}^2 \rangle_\pm$$

$$s^* = -\frac{L^*(\beta_+ a_- - \beta_- a_+) + 2(\beta_+ b_- - \beta_- b_+)}{2(\beta_+ a_- + \beta_- a_+)}; \qquad \beta^* = \frac{1}{\beta_+}\left(a_+ L^2 + 2 b_+ L - 2 a_+ L s^*\right)$$

Another technique:
measurement using simultaneous Q1 gradient change on both side of the IR

$$\beta_+ - \beta_- = \frac{1}{\beta^*}\left((a_+ - a_-)L^2 + 2(b_+ - b_-)L - 2(a_+ + a_-)L\,s^*\right)$$

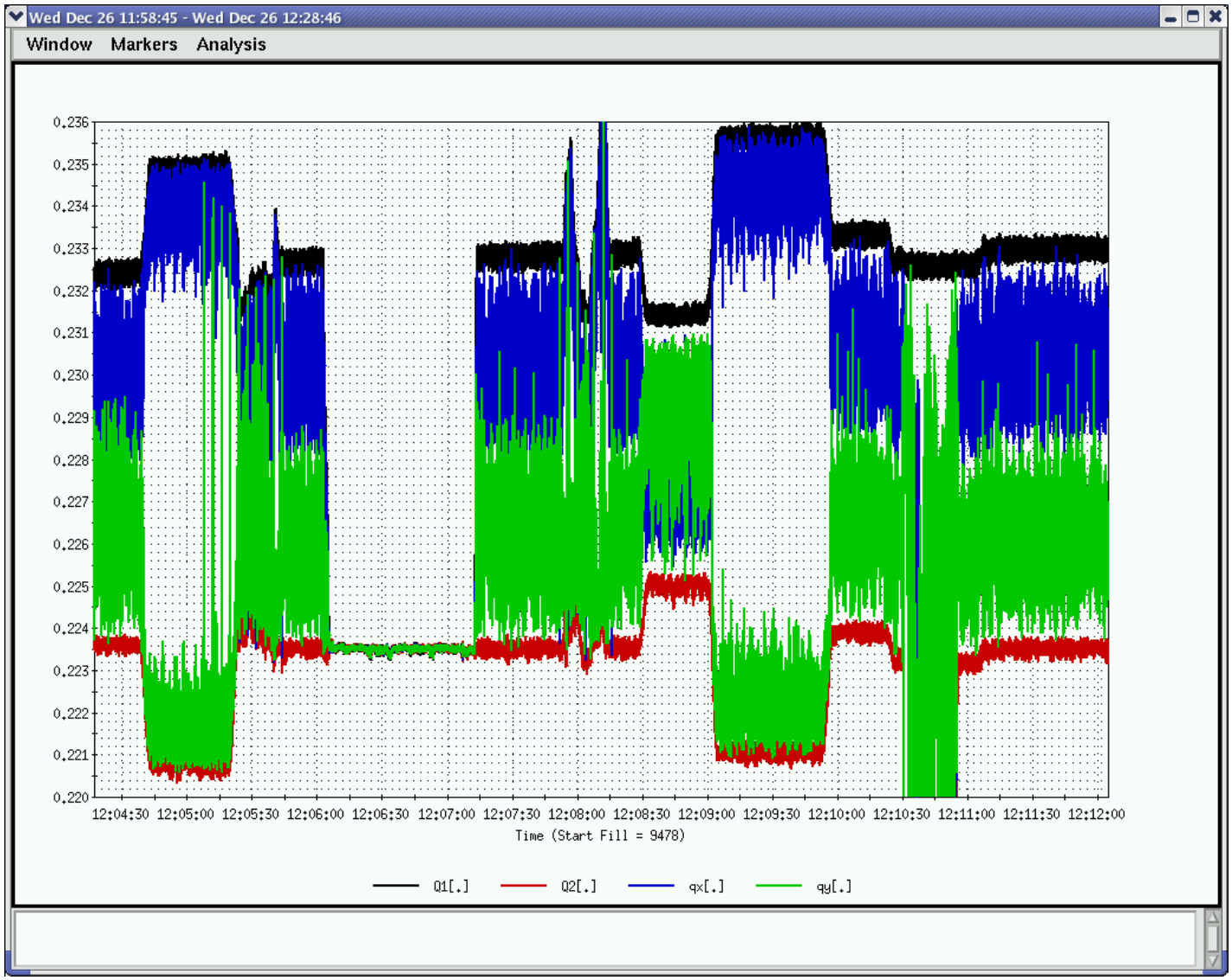
$$\beta_+ + \beta_- = \frac{L}{\beta^*}\left((a_+ + a_-)L + 2(b_+ + b_-)\right)$$

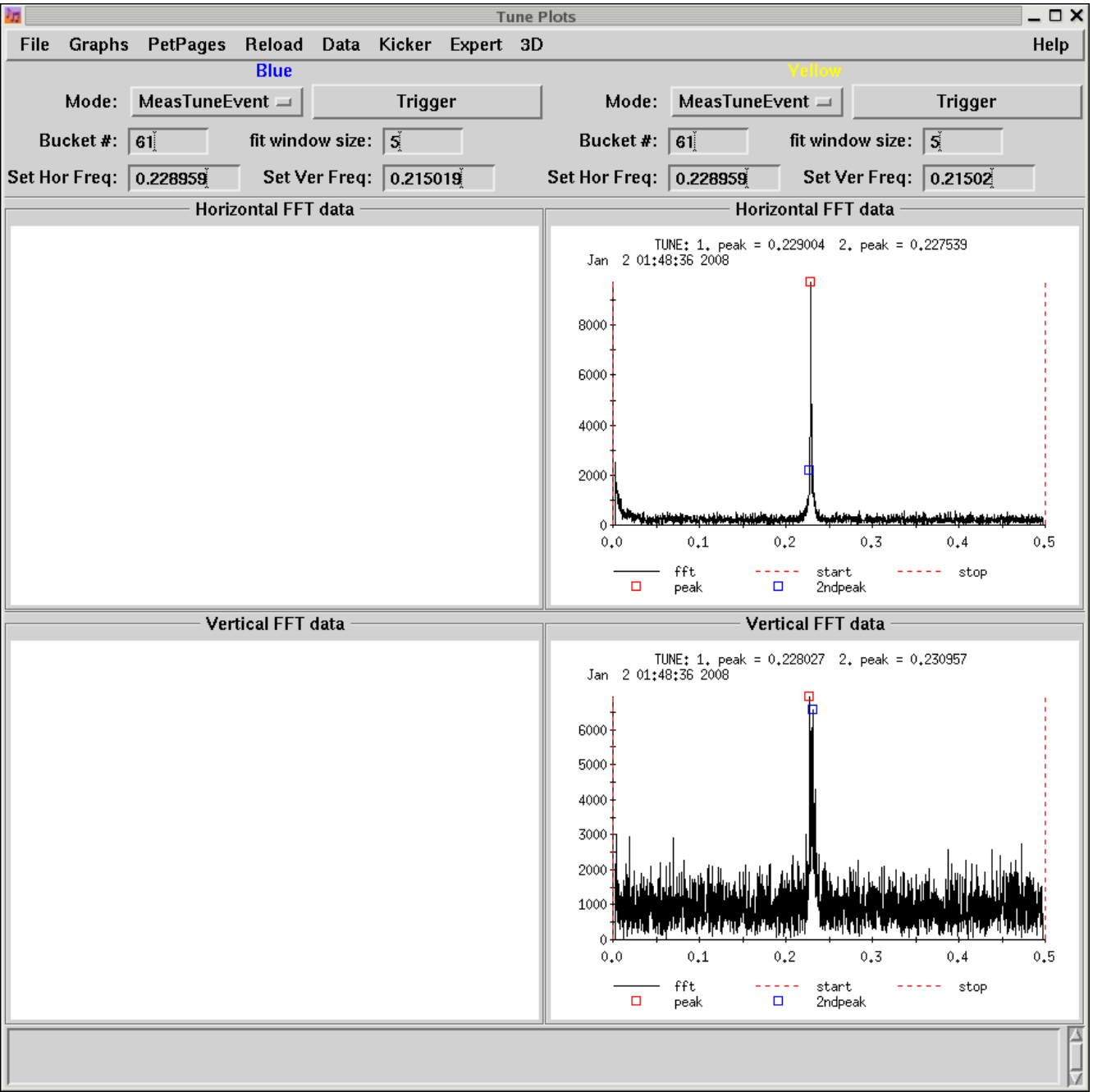
$$\Delta Q = \left(4.32 - 8.08\,s^*\right)\frac{\Delta Kl}{\beta^*}; \qquad \Delta Kl_+ = -\Delta Kl_- = \Delta Kl$$

$$\Delta Q = \frac{108.2\,\Delta Kl}{\beta^*}; \qquad \Delta Kl_+ = \Delta Kl_- = \Delta Kl$$

Measurement with simultaneous gradient change showed the shift of the waist position. dKl = +-1e-4 shifts the waist, according to Todd's matrix, by ~8cm

Example of IR6 tune changes during Q1 gradient variations for mode and uncoupled tunes

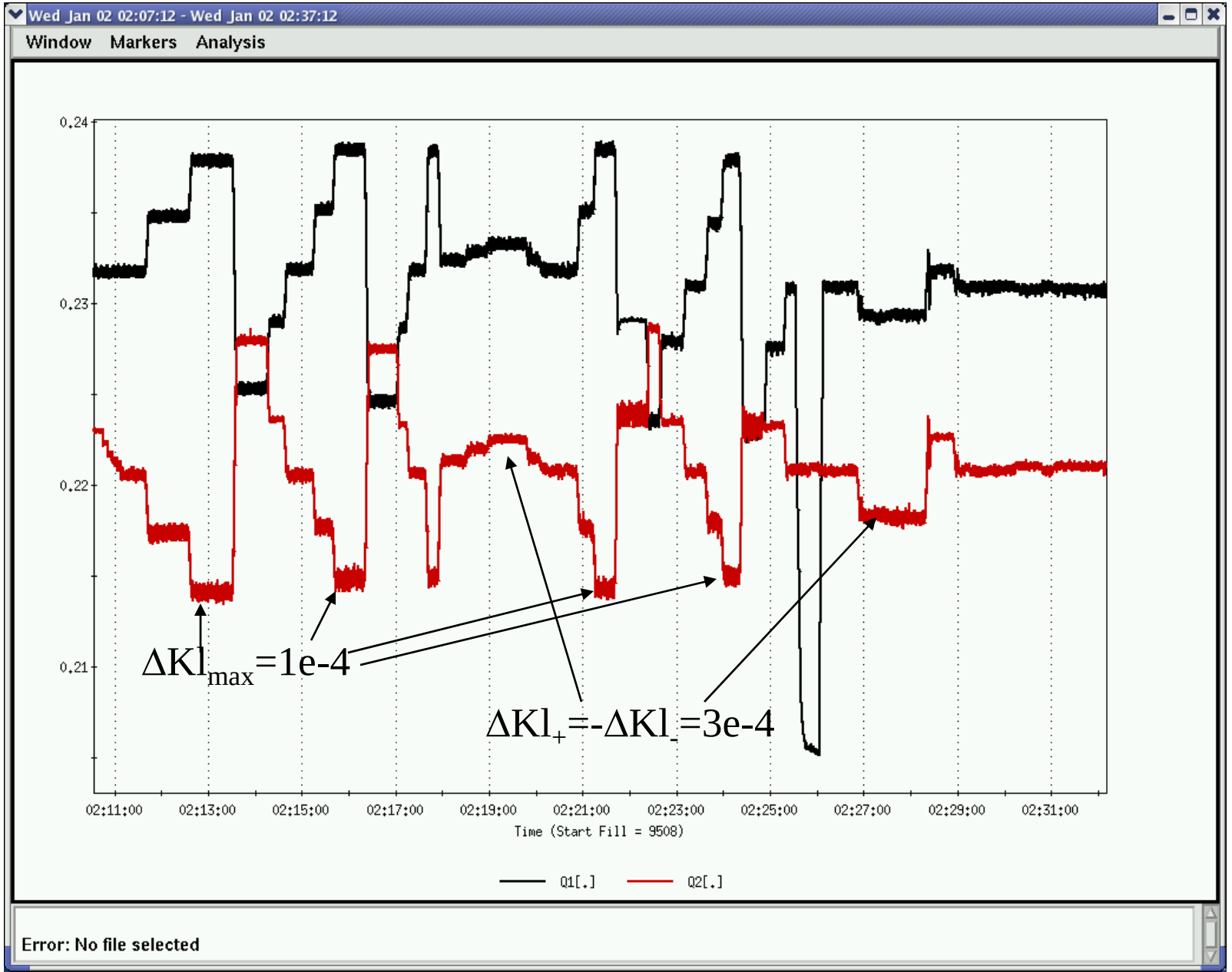




Careful preparation:

- decoupling to ~1e-3 level
- tune separation >0.01

Example of Yellow tune changes during Q1 gradient variations



Data for both rings from individual gradient changes. Blue lattice included non-zero tq4 at IR8 region.

	Yellow				Blue			
	IR6 H	IR6 V	IR8 H	IR8 V	IR6 H	IR6 V	IR8 H	IR8 V
β*,m	0.80	0.88	0.85	0.89	0.81	0.73	0.71	0.75
s*,cm	-34	-33	2	30	-5	-3	20	5

For BBQ accuracy of the tune measurements of 1e-4:
+-6cm error for s*, ~1.5% error for beta*

$$s^* = -\frac{L^*\left(\beta_+ a_- - \beta_- a_+\right) + 2\left(\beta_+ b_- - \beta_- b_+\right)}{2\left(\beta_+ a_- + \beta_- a_+\right)}; \qquad \beta^* = \frac{1}{\beta_+}\left(a_+ L^2 + 2b_+ L - 2a_+ L\, s^*\right)$$

Ramp Designer

File Help

OptiCalc | Design+Trim | Ramp: dAu82 | Config: dbconfig/1192023263 | Blue Species: d | Yellow Species: Au

Options	BetaStarSlopes	DR8toDRG	DipoleHarmonics	FamilyTF	WarmTF	polyField	specificTF
State	On	On	Off	On	On	On	On

Blue | Yellow | DxAngles | StoneEditor

DipoleRamp | BetaStar | TuneChrom | Lattice | Optics | MagCurr | Strengths | TransFunc | BDL | ShuntCurr | ShuntVolt

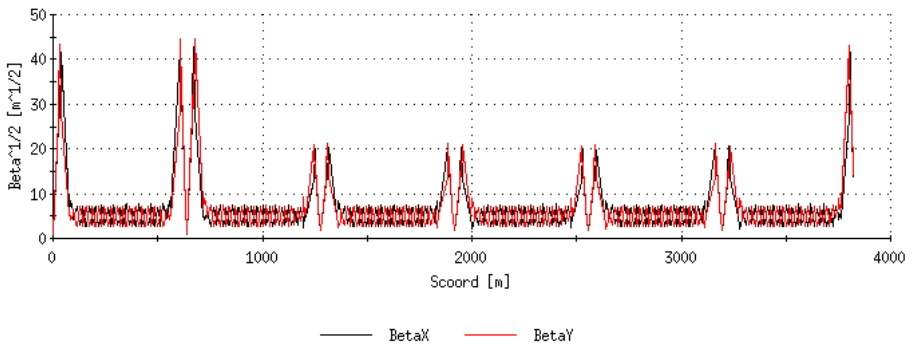
prompt dAu82::store

Twiss | Orbit

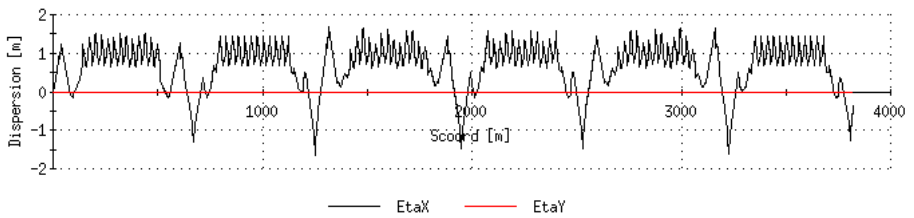
Tunes/Chroms

Stone #	21.000000000
Time [sec]	300.000000000
Gamma	107.396089446
BetaGamma	107.391433682
Brho [T-m]	831.763013200
Qx	31.245648375
Qy	32.360356501
ChromX	3.059479448
ChromY	-1.044115202
ChromX2	4205.523225201
ChromY2	5351.037301256
ChromX3	551051.148114927
ChromY3	28305.426927581
GammaT	26.612812913

Beta Function



Dispersion Function



IP Parameters

Value/IP	IP6	IP8	IP10	IP12	IP2	IP4
BetaX [m]	0.769747	0.721588	3.28418	3.21692	3.39989	3.12716
BetaY [m]	0.701473	0.719606	2.93896	2.95007	3.05246	3.01428
AlphaX	-0.141576	0.0307354	-0.0886547	0.108213	-0.0546039	0.14653
AlphaY	-0.0169573	-0.309331	-0.0292992	0.0032531	-0.0107152	0.0313425
EtaX [m]	-0.00220786	-0.0036729	0.0269735	-0.00991221	-0.0102478	0.0263547
EtaY [m]	0	0	0	0	0	0
EtaX'	0.0285481	-0.0296597	0.0403455	-0.0347008	0.0348656	-0.0397764
EtaY'	0	0	0	0	0	0

cdevRequestObject Error: Server failed to respond after 10.0 seconds with severity: 2 for device: dAu82nm1 -- get OpticsFunctions
Device Name: dAu82nm1 for the property: OpticsFunctions -- Failed to process message
Inform -- Getting the data...

IR8 knob:

$\Delta\alpha_y = -0.3$

$\alpha(0) = s^*/\beta^*$

Ramp Designer

File Help

OptiCalc | Design+Trim | Ramp: dAu82 | Config: dbconfig/1192023263 | Blue Species: d | Yellow Species: Au

Options	BetaStarSlopes	DR8toDRG	DipoleHarmonics	FamilyTF	WarmTF	polyField	specificTF
State	On	On	Off	On	On	On	On

Blue | Yellow | DxAngles | StoneEditor

DipoleRamp | BetaStar | TuneChrom | Lattice | Optics | MagCurr | Strengths | TransFunc | BDL | ShuntCurr | ShuntVolt

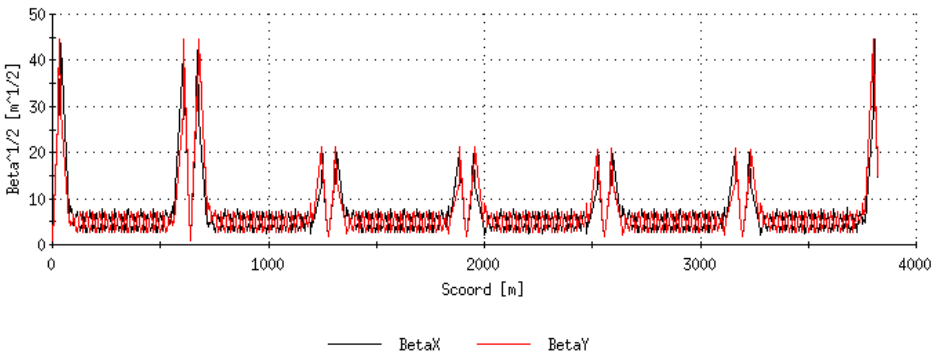
prompt dAu82::store

Twiss | Orbit

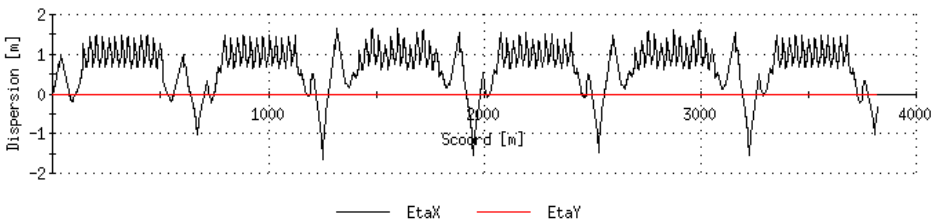
Tunes/Chroms

Stone #	21.000000000
Time [sec]	300.000000000
Gamma	107.396089446
BetaGamma	107.391433682
Brho [T-m]	831.763013200
Qx	31.244508129
Qy	32.364294345
ChromX	0.144256211
ChromY	-0.361146619
ChromX2	4502.883044414
ChromY2	5826.354915532
ChromX3	550305.511881219
ChromY3	13333.647927920
GammaT	26.623932369

Beta Function



Dispersion Function



IP Parameters

Value/IP	IP6	IP8	IP10	IP12	IP2	IP4
BetaX [m]	0.715412	0.744191	3.37709	3.43374	3.47738	3.32402
BetaY [m]	0.712343	0.725248	2.92591	2.92508	3.08408	3.03904
AlphaX	0.253775	0.0942925	-0.153284	0.124926	-0.115741	0.160833
AlphaY	0.286331	-0.318	-0.0206343	0.00855573	-0.0104879	0.0383305
EtaX [m]	-0.0132757	-0.00610169	0.0138025	-0.000120351	0.00219272	0.0153767
EtaY [m]	0	0	0	0	0	0
EtaX'	0.0221715	-0.0218078	0.0400543	-0.0374091	0.0355024	-0.0373244
EtaY'	0	0	0	0	0	0

cdevRequestObject Error: Server failed to respond after 10.0 seconds with severity: 2 for device: dAu82nm1 -- get OpticsFunctions
Device Name: dAu82nm1 for the property: OpticsFunctions -- Failed to process message
Inform -- Getting the data...

IR6 knob:

$\Delta\alpha_x = 0.3$

$\Delta\alpha_y = 0.3$

The results from the gradient variation measurements

	Yellow ring			
	IR6 H	IR6 V	IR8 H	IR8 V
β*,m 2 weeks before	0.80	0.88	0.85	0.89
before the knob	0.80	0.91	0.90	0.94
after the knob	0.76	0.96	0.86	0.88
s*,cm 2 weeks before	-34	-33	2	30
before the knob	-29	-53	-8	15
after the knob	13	-29	-9	-5
expected Δs*	24	27	0	-28
measured Δs*	42	24	-1	-20

For BBQ accuracy of the tune measurements of 1e-4:
+-6cm error for s*, ~1.5% error for beta*

AC Dipole Measurements for IR8 knob

Measurements by M.Bai

IR8 knob:

$\Delta\alpha_y = -0.3$

- Yellow beta* and waist at IP8 before Nikolay applied his knob
  - V beta*: 1.03+-0.02@-0.18
- Yellow beta* and waist at IP8 after Nikolay applied his knob
  - V beta*: 0.83+-0.02@0.04
- working point was also changed:
  - before: Qx=0.2297, Qy=0.2336
  - after: Qx=0.2312, Qy=0.2278

Plans

- Automate the measurement procedure and the output of results; make the method convenient for the use in the machine operation.

- Consider betatron coupling issues:
  - possibility of more accurate “uncoupled” tunes in BBQ
  - possibility of the algorithm modification in the presence of the coupling