# I-LHC TT2 LOW-β OPTICS: 1st BEAM PERFORMANCE

## Optics with QFO205 maximum current limited to 330 A

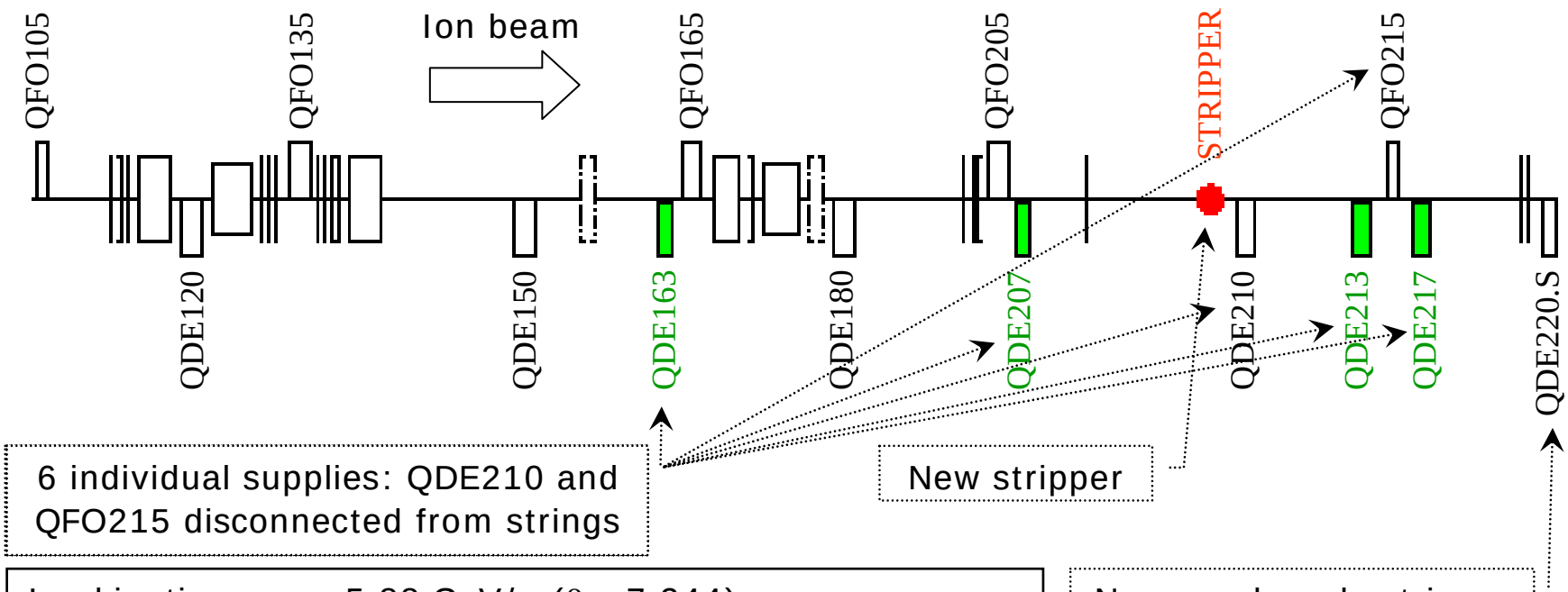
**C. Carli, D. Manglunki, M. Martini, S. Maury, R. Steerenberg**

### Contents

# I-LHC TT2 LOW-β OPTICS QUADRUPOLE LAYOUT

To suit with ion quadrupole gradients, QFO215 (0.8m) has been replaced by a 1.2 m long quadrupole (centred on previous one)

$IQFO205_{max}$=330 A




6 individual supplies: QDE210 and QFO215 disconnected from strings

New stripper

Ion kinetic energy 5.88 GeV/u ($\beta\gamma$=7.244)

- $B\rho^{54+}$ = 86.7 Tm (before stripping) 26 GeV/c eq. protons
- $B\rho^{82+}$ = 57.1 Tm (after stripping) 26 GeV/c eq. protons

New quadrupole strings:
QDE210.S → QDE220.S
QFO215.S → QFO225.S

TT2 low-β insertion

# I-LHC TT2 LOW-β OPTICS QUADRUPOLE LAYOUT

| Quadrupole | Type | Proton optics 25.1 GeV (26 GeV/c) | Ion optics 5.88 GeV/u (26 GeV/c eq. prot) | |
|---|---|---|---|---|
| QF0105 | Q101 (0.645 m) | 395.5 A | max 550 A | 507.4 A |
| QDE120 | Q120B(1.2 m) | (-)233.4 A | max 265 A | (-)264.8 A |
| QFO135 | Q120B(1.2 m) | 213.7 A | max 220 A | 173.0 A |
| QDE150 | Q120B(1.2 m) | (-)151.8 A | max 250 A | (-)111.5 A |
| QDE163 (1,2) | Q50A (0.5 m) | zero current for protons: 0 A | max 300 A | (-)277.6 A |
| QFO165 | Q120B(1.2 m) | 94.3 A | max 250 A | 235.6 A |
| QDE180 | Q120B(1.2 m) | (-)131.2 A | max 250 A | (-)187.0 A |
| QFO205 | Q120B(1.2 m) | 122.6 A | max 330 A | 329.8 A |
| QDE207 (1,2) | Q120B(1.2 m) | zero current for protons: 0 A | max 450 A | (-)261.5 A |
| QDE210 (2) | Q82 (0.82 m) | same as QDE220.S: (-)219.3 A | max 400 A | (-)144.3 A |
| QDE213 (1,2) | Q80 (0.8 m) | zero current for protons: 0 A | max 400 A | (-) 0.0 A |
| QFO215 (2) | Q120B(1.2 m) | same as QFO225.S: 241.2 A | max 500 A | 264.9 A |
| QDE217 (1,2) | Q80 (0.8 m) | zero current for protons: 0 A | max 300 A | (-)270.3 A |
| QDE220.S (3) | Q82 (0.82 m) | (-)219.3 A | max 250 A | (-)143.9 A |
| QFO225.S | Q80 (0.8 m) | 241.2 A | max 330 A | 164.4 A |
| QFO375 | Q80 (0.8 m) | 255.0 A | max 330 A | 130.9 A |

New matching with $IQFO205_{max}$=330 A

Initially 437 A with $IQFO205_{max}$=500 A

(1) new quad, (2) new supply, (3) 2 quads out of 13 are of type QFS

# I-LHC TT2 LOW-β OPTICS QUADRUPOLE LAYOUT

| Quadrupole | Gradient | Integrated gradient | | Converter current | |
|---|---|---|---|---|---|
| QF0105 | 0.19499 $m^{-2}$ | max 13.920 T | 10.9003 T | max 550 A | 507.4 A |
| QDE120 | -0.13090 $m^{-2}$ | max 23.200 T | -13.6141 T | max 265 A | (-)264.8 A |
| QFO135 | 0.08565 $m^{-2}$ | max 23.200 T | 8.9078 T | max 220 A | 173.0 A |
| QDE150 | -0.05506 $m^{-2}$ | max 23.200 T | -5.7263 T | max 250 A | (-)111.5 A |
| QDE163 (1,2) | -0.12113 $m^{-2}$ | max 5.572 T | -5.2491 T | max 300 A | (-)277.6 A |
| QFO165 | 0.11666 $m^{-2}$ | max 23.200 T | 12.1334 T | max 250 A | 235.6 A |
| QDE180 | -0.09261 $m^{-2}$ | max 23.200 T | -9.6317 T | max 250 A | (-)187.0 A |
| QFO205 | 0.16150 $m^{-2}$ | max 23.200 T | 16.7966 T | max 330 A | 329.8 A |
| QDE207 (1,2) | -0.12931 $m^{-2}$ | max 23.200 T | -13.4482 T | max 450 A | (-)261.5 A |
| QDE210 (2) | -0.10995 $m^{-2}$ | max 16.662 T | -5.1453 T | max 400 A | (-)144.3 A |
| QDE213 (1,2) | 0.00000 $m^{-2}$ | max 15.640 T | 0.0000 T | max 400 A | (-) 0.0 A |
| QFO215 (2) | 0.19884 $m^{-2}$ | max 23.200 T | 13.6175 T | max 500 A | 264.9 A |
| QDE217 (1,2) | -0.20666 $m^{-2}$ | max 15.640 T | -9.4355 T | max 300 A | (-)270.3 A |
| QDE220.S (3) | -0.10958 $m^{-2}$ | max 16.662 T | -5.1284 T | max 250 A | (-)143.9 A |
| QFO225.S | 0.12599 $m^{-2}$ | max 15.640 T | 5.7525 T | max 330 A | 164.4 A |
| QFO375 | 0.10019 $m^{-2}$ | max 15.640 T | 4.5743 T | max 330 A | 130.9 A |

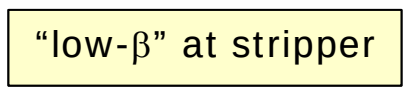
(1) new quad, (2) new supply, (3) 2 quads out of 13 are of type QFS

# I-LHC TT2 LOW-β OPTICS QUADRUPOLE OPTICS

1TT2 Pb optics - V5 2006 "MAD" Version: 8.51/15 Run: 27/10/06 14.46.31
Linear lattice functions. TWISS line: TT2 range: #S/#E
Delta(p)/p: 0.000000 symm: F super: 1 page 1

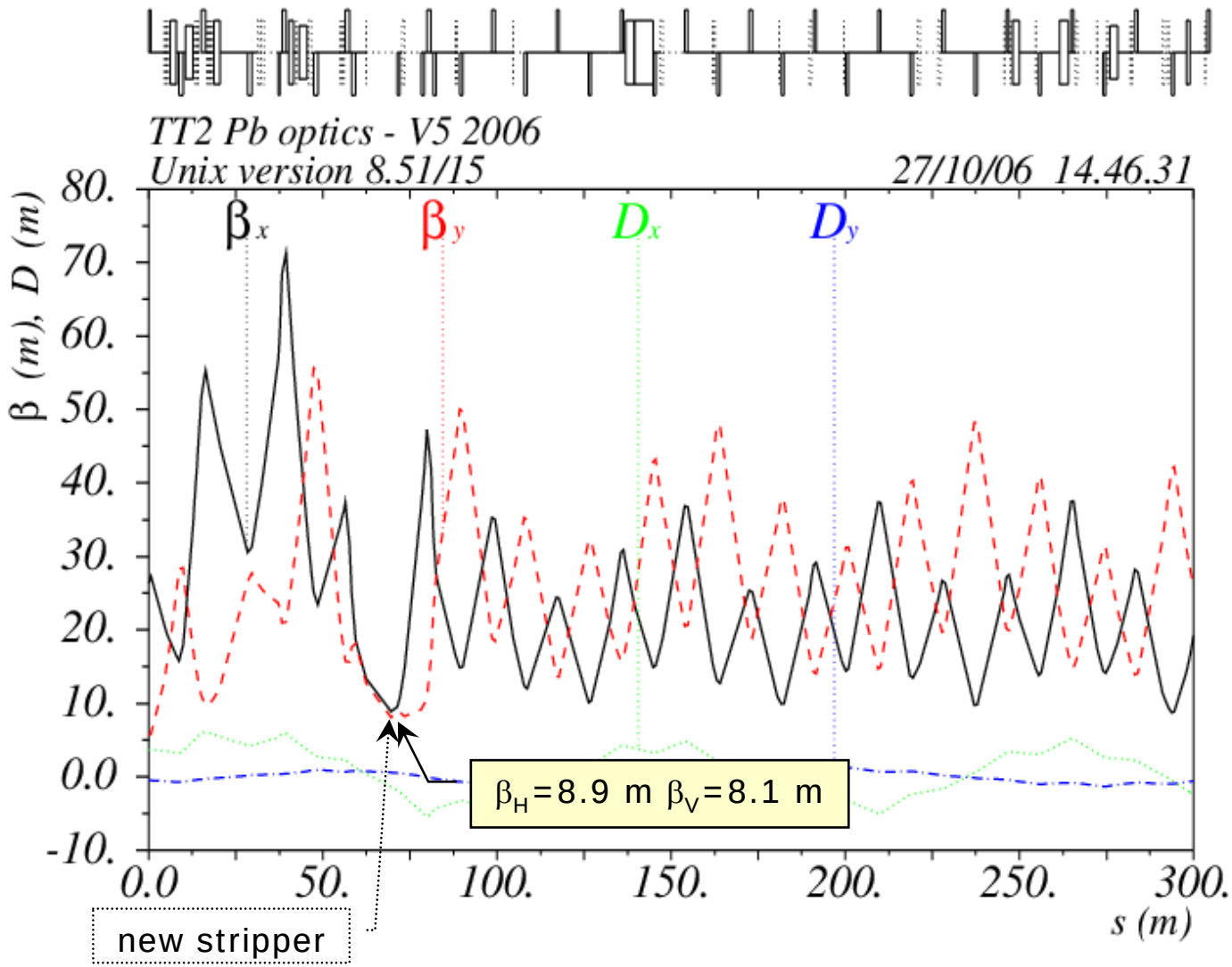
| ELEMENT SEQUENCE | | | I | HORIZONTAL | | | | | | | I | VERTICAL | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pos. no. | element name | occ. no. | dist [m] | I | betax [m] | alfax [1] | mux [2pi] | x(co) [mm] | px(co) [.001] | Dx [m] | Dpx [1] | I | betay [m] | alfay [1] | muy [2pi] | y(co) [mm] | py(co) [.001] | Dy [m] | Dpy [1] |
| begin | TT2 | 1 | 0.000 | | 26.420 | -2.350 | 0.000 | 0.0000 | 0.000 | 3.630 | 0.400 | | 5.720 | 0.310 | 0.000 | 0.0000 | 0.000 | -0.480 | 0.030 |
| 58 | MTV201 | 1 | 55.000 | | 34.169 | -1.022 | 0.272 | 0.0000 | 0.000 | 2.351 | -0.058 | | 20.958 | 1.911 | 0.476 | 0.0000 | 0.000 | 0.733 | -0.030 |
| 70 | STRN | 1 | 69.589 | | 8.855 | -0.097 | 0.441 | 0.0000 | 0.000 | -1.367 | -0.256 | | 8.061 | -0.130 | 0.674 | 0.0000 | 0.000 | 0.597 | -0.025 |
| 118 | MSG257 | 1 | 162.011 | | 15.306 | 1.004 | 1.212 | 0.0000 | 0.000 | 2.548 | -0.307 | | 43.115 | -1.957 | 1.389 | 0.0000 | 0.000 | 0.325 | 0.049 |
| 120 | MSG258 | 1 | 162.596 | | 14.176 | 0.927 | 1.218 | 0.0000 | 0.000 | 2.368 | -0.307 | | 45.443 | -2.022 | 1.391 | 0.0000 | 0.000 | 0.354 | 0.049 |
| 126 | MSG267 | 1 | 180.471 | | 11.003 | 0.548 | 1.389 | 0.0000 | 0.000 | -0.688 | -0.215 | | 34.577 | -1.390 | 1.493 | 0.0000 | 0.000 | 1.042 | 0.067 |
| 128 | MSG268 | 1 | 181.056 | | 10.402 | 0.479 | 1.398 | 0.0000 | 0.000 | -0.814 | -0.215 | | 36.232 | -1.440 | 1.496 | 0.0000 | 0.000 | 1.081 | 0.067 |
| 136 | MSG277 | 1 | 198.931 | | 15.755 | 0.610 | 1.563 | 0.0000 | 0.000 | -3.286 | 0.077 | | 27.962 | -1.312 | 1.630 | 0.0000 | 0.000 | 1.212 | 0.050 |
| 138 | MSG278 | 1 | 199.516 | | 15.070 | 0.559 | 1.569 | 0.0000 | 0.000 | -3.241 | 0.077 | | 29.531 | -1.369 | 1.633 | 0.0000 | 0.000 | 1.241 | 0.050 |
| end | TT2 | 1 | 304.695 | | 32.277 | 0.659 | 2.493 | 0.0000 | 0.000 | -3.777 | -0.017 | | 17.530 | -0.605 | 2.312 | 0.0000 | 0.000 | -0.257 | 0.045 |

| | | | | | |
|---|---|---|---|---|---|
| total length | = 304.695400 | mux | = 2.492803 | muy | = 2.312185 |
| delta(s) | = 0.000000 mm | dmux | = -3.243102 | dmuy | = -2.706828 |
| | | betax(max) | = 71.317244 | betay(max) | = 55.633769 |
| | | Dx(max) | = 6.096250 | Dy(max) | = 1.298974 |
| | | Dx(r.m.s.) | = 3.609330 | Dy(r.m.s.) | = 0.698078 |



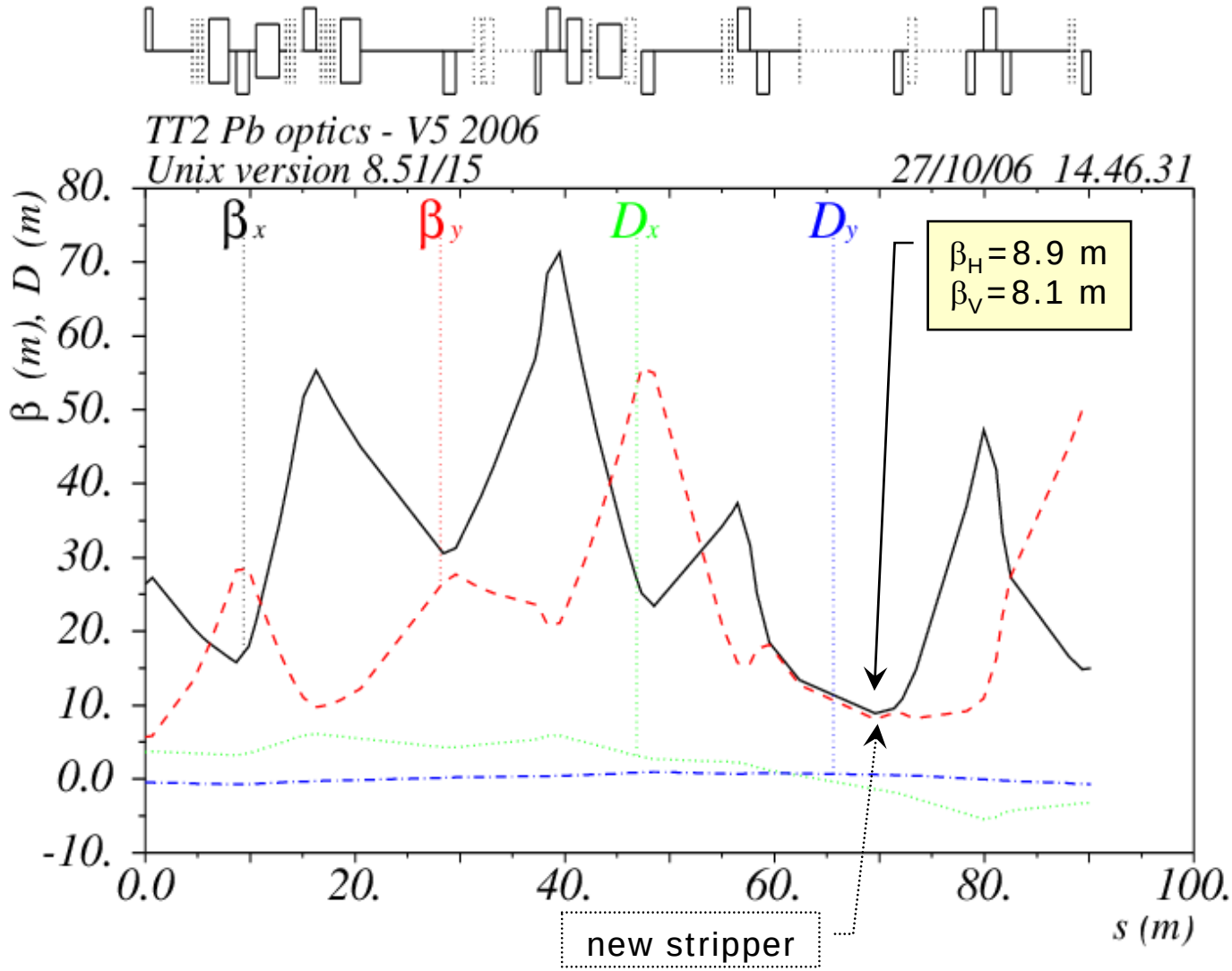

TT2 “low-β” optics with $IQFO205_{max}$=330 A instead of 437 A
(power converter limitation)

# I-LHC TT2 LOW-β OPTICS QUADRUPOLE OPTICS




TT2 “low-β” optics with $IQFO205_{max}$=330 A instead of 437 A

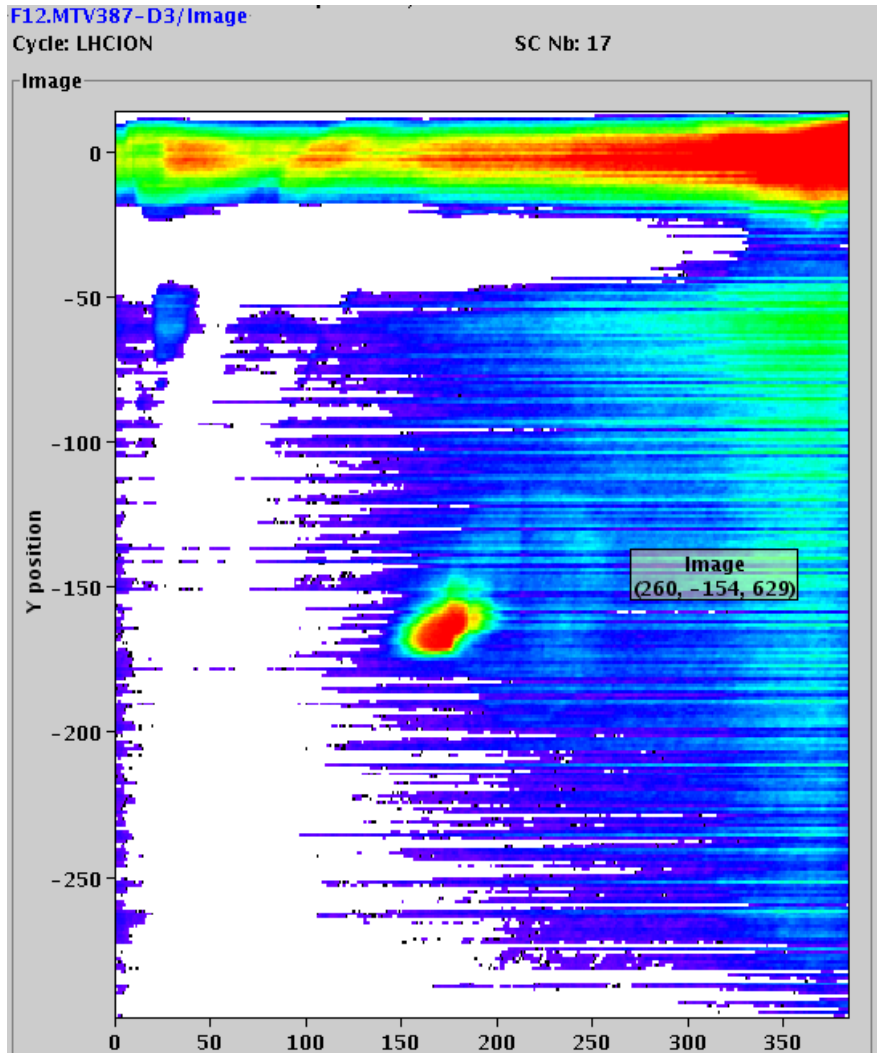
# I-LHC TT2 LOW-β OPTICS QUADRUPOLE OPTICS




TT2 “low-β” optics with $IQFO205_{max}$=330 A instead of 437 A

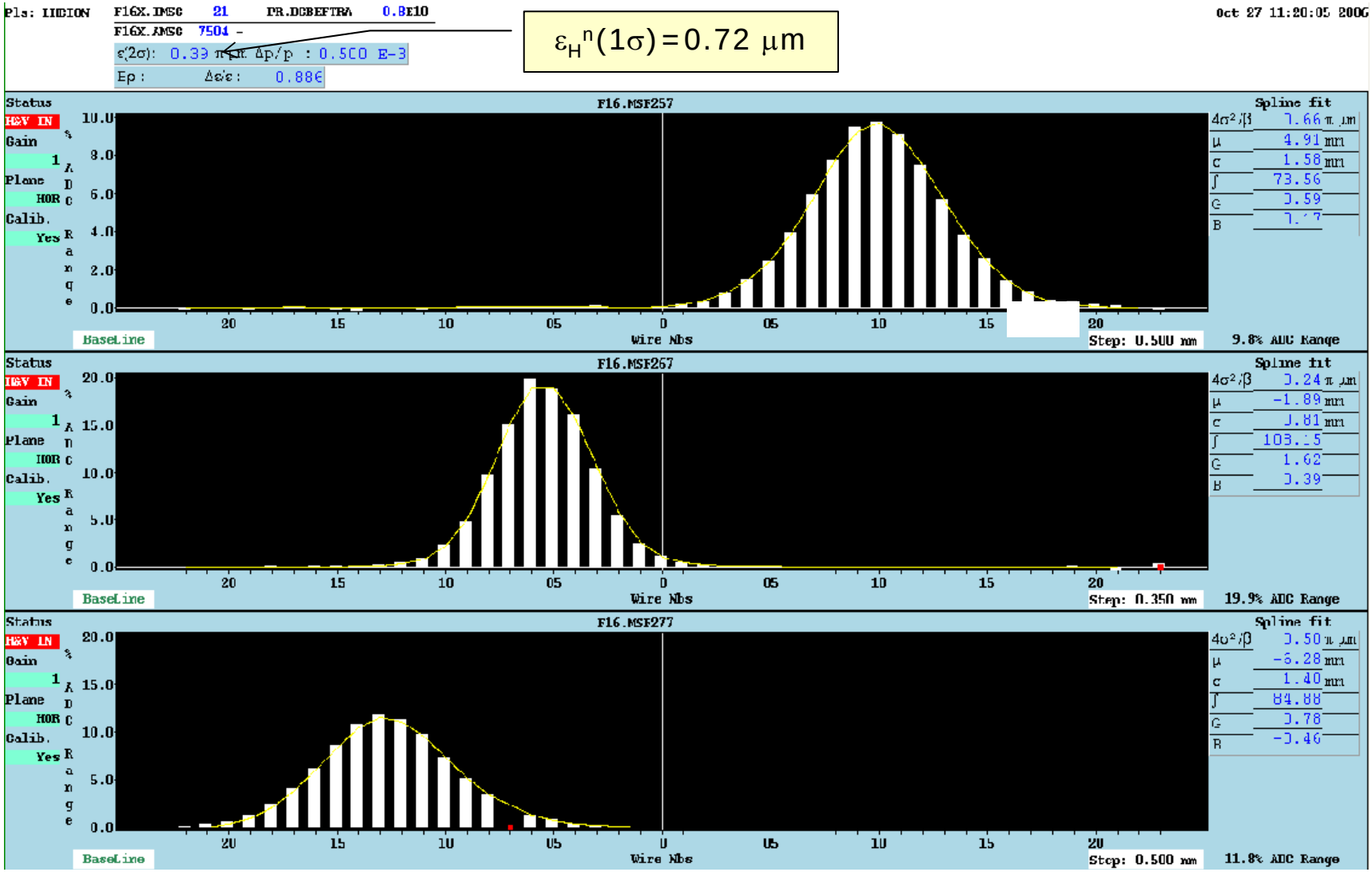
# I-LHC TT2 LOW-β OPTICS MEASUREMENT RESULTS

| Name | Status | CCV | AQN | Unit |
|---|---|---|---|---|
| F16.QFO105 | On | 507.40 | 507.44 | A |
| F16.BHZ117 | On | 211.30 | 211.39 | A |
| F16.QDE120 | On | 264.80 | 265.05 | A |
| F16.BVT123 | On | 275.95 | 276.09 | A |
| F16.QFO135 | On | 173.00 | 173.16 | A |
| F16.BHZ147 | On | 180.63 | 180.82 | A |
| F16.QDE150 | On | 111.50 | 111.53 | A |
| F16.QDE163 | On | 277.60 | 277.54 | A |
| F16.QFO165 | On | 235.60 | 235.86 | A |
| F16.BHZ167 | On | 155.05 | 155.18 | A |
| F16.BVT173 | On | 277.00 | 277.07 | A |
| F16.QDE180 | On | 187.00 | 187.19 | A |
| F16.QFO205 | On | 329.00 | 329.09 | A |
| F16.QDE207 | On | 261.50 | 261.46 | A |
| F16.QDE210 | On | 144.30 | 144.25 | A |
| F16.QDE213 | On | 0.00 | -0.03 | A |
| F16.QFO215 | On | 264.90 | 264.85 | A |
| F16.QDE217 | On | 270.30 | 270.26 | A |
| F16.QDE220S | On | 143.90 | 144.48 | A |
| F16.QFO225S | On | 164.40 | 164.79 | A |
| F16.BTI247 | On | 5.00 | 4.02 | A |
| F16.BTI247FTA | On | 0.00 | 4.02 | A |
| F16.BHZ327 | NOTCON | 0.00 | 0.00 | A |
| F16.BHZ327ATP | NOTCON | 0.00 | 0.00 | A |
| F16.DHZ337 | On | 10.50 | 10.49 | A |
| F16.DVT353 | On | 0.35 | 0.36 | A |
| F16.QFO375 | On | 130.90 | 133.39 | A |
| F16.BHZ377 | On | 0.00 | 0.00 | A |
| F16.BHZ377FTS | On | 317.54 | 0.00 | A |
| F16.SNP208 | On | 8.00 | 0.00 | A |




TT2 magnet currents – Ion beam on dump D3

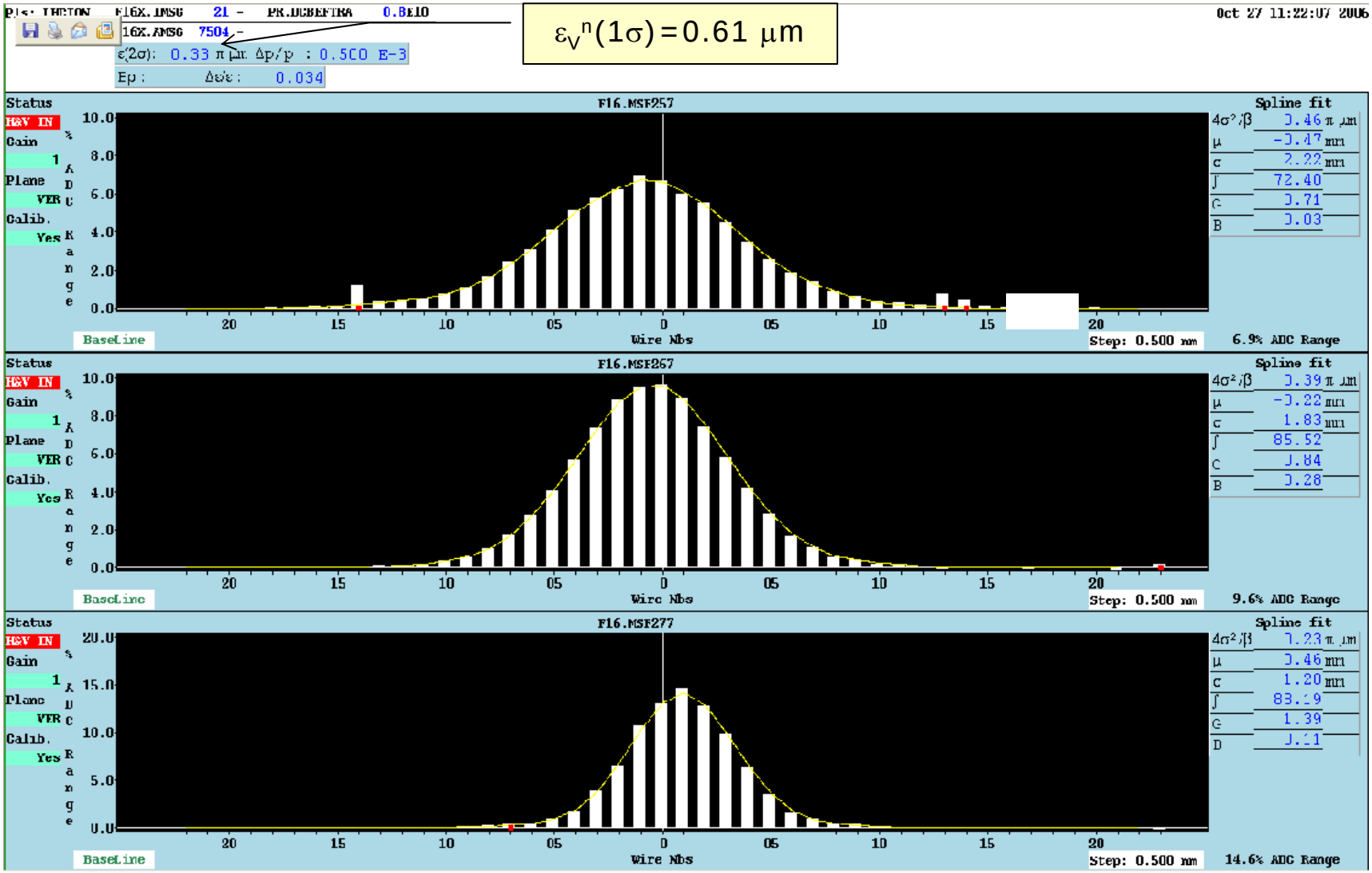
# I-LHC TT2 LOW-β OPTICS MEASUREMENT RESULTS




TT2 SEM-fil profiles with IQFO205=330 A

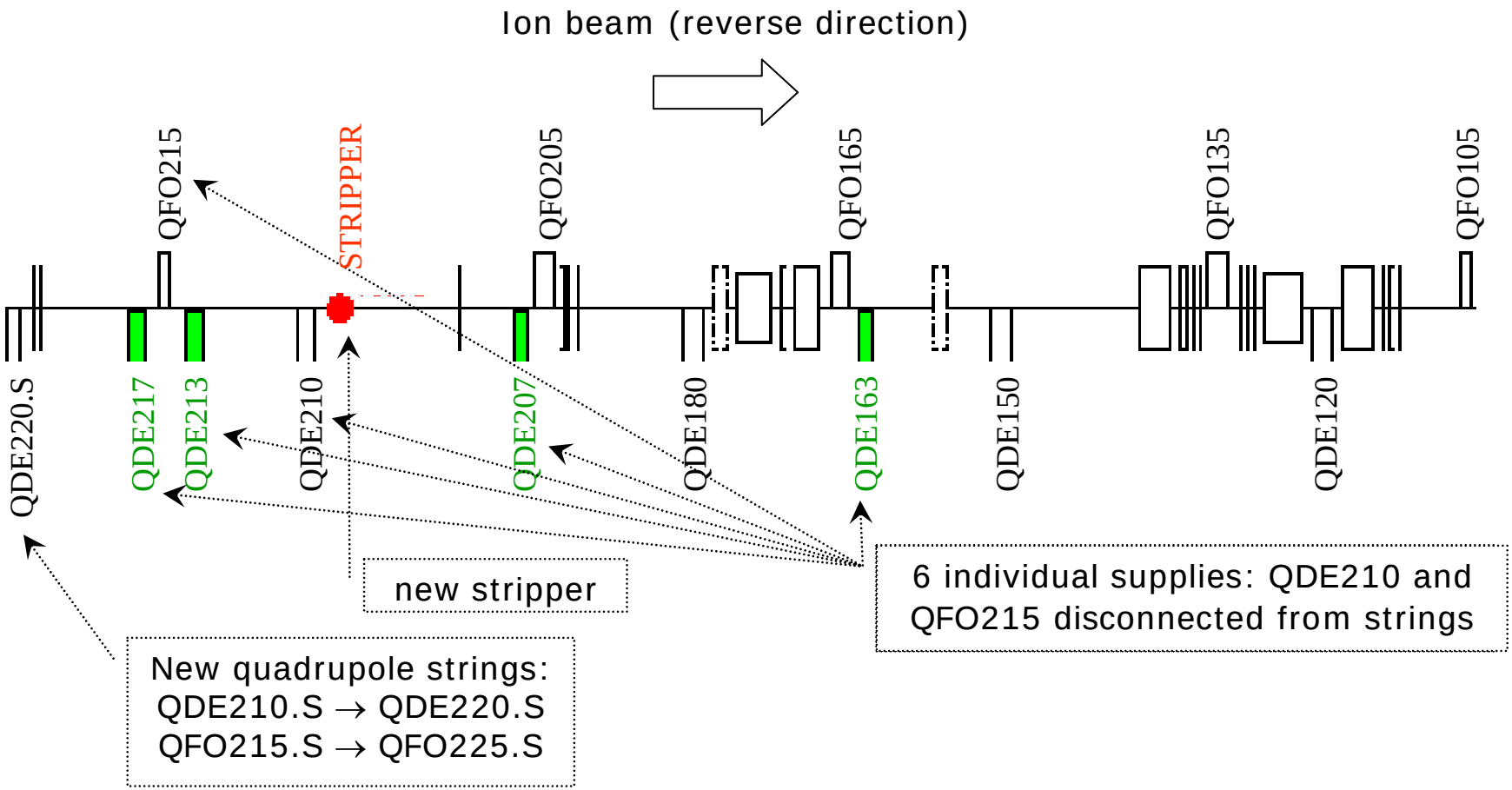
# I-LHC TT2 LOW-β OPTICS MEASUREMENT RESULTS

$\varepsilon_V^n(1\sigma) = 0.61\ \mu m$




TT2 SEM-fil profiles with IQFO205=330 A

# I-LHC TT2 LOW-β OPTICS QUADRUPOLE LAYOUT (REVERSED)




TT2 low-β insertion: Reverse direction for tracking back study

# I-LHC TT2 LOW-β OPTICS QUADRUPOLE OPTICS (REVERSED)

1TT2 Pb optics - V5 2006 "MAD" Version: 8.51/15 Run: 27/10/06 16.02.35
Linear lattice functions. TWISS line: TT2BACKT range: MSG257/ENDTT2A
Delta(p)/p: 0.000000 symm: F super: 1 page 1

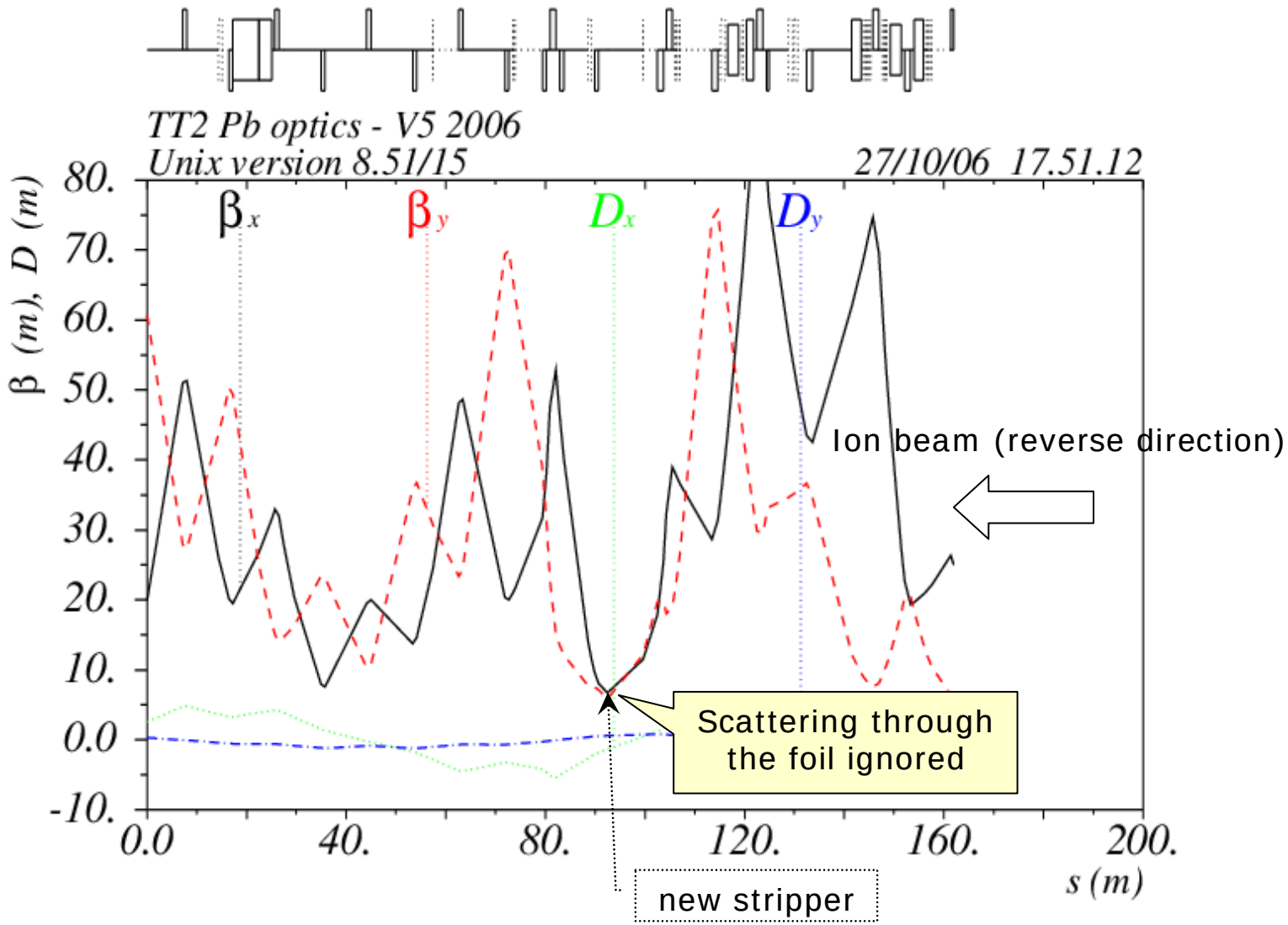
| ELEMENT SEQUENCE | | | | HORIZONTAL | | | | | | | VERTICAL | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pos. no. | element name | occ. no. | dist [m] | betax [m] | alfax [1] | mux [2pi] | x(co) [mm] | px(co) [.001] | Dx [m] | Dpx [1] | betay [m] | alfay [1] | muy [2pi] | y(co) [mm] | py(co) [.001] | Dy [m] | Dpy [1] |
| 44 | MSG257 | 1 | 0.000 | 19.900 | -1.540 | 0.000 | 0.0000 | 0.000 | 2.548 | 0.307 | 60.750 | 2.800 | 0.000 | 0.0000 | 0.000 | 0.325 | -0.049 |
| 92 | STRN | 1 | 92.423 | 6.723 | 0.237 | 0.740 | 0.0000 | 0.000 | -1.363 | 0.256 | 5.855 | 0.206 | 0.707 | 0.0000 | 0.000 | 0.592 | 0.025 |
| 158 | POINTR | 1 | 162.011 | 25.050 | 2.550 | 1.169 | 0.0000 | 0.000 | 3.623 | -0.399 | 6.656 | -0.697 | 1.416 | 0.0000 | 0.000 | -0.477 | -0.030 |
| 162 | ENDTT2A | 1 | 162.011 | 25.050 | 2.550 | 1.169 | 0.0000 | 0.000 | 3.623 | -0.399 | 6.656 | -0.697 | 1.416 | 0.0000 | 0.000 | -0.477 | -0.030 |

| | | | | | |
|---|---|---|---|---|---|
| total length = | 162.011400 | mux = | 1.169478 | muy = | 1.416434 |
| delta(s) = | 0.000000 mm | dmux = | -2.021011 | dmuy = | -1.086701 |
| | | betax(max) = | 95.401279 | betay(max) = | 75.687713 |
| | | Dx(max) = | 6.090621 | Dy(max) = | 1.220557 |
| | | Dx(r.m.s.) = | 4.035069 | Dy(r.m.s.) = | 0.592776 |

"low-β" from track back
(foil scattering ignored)

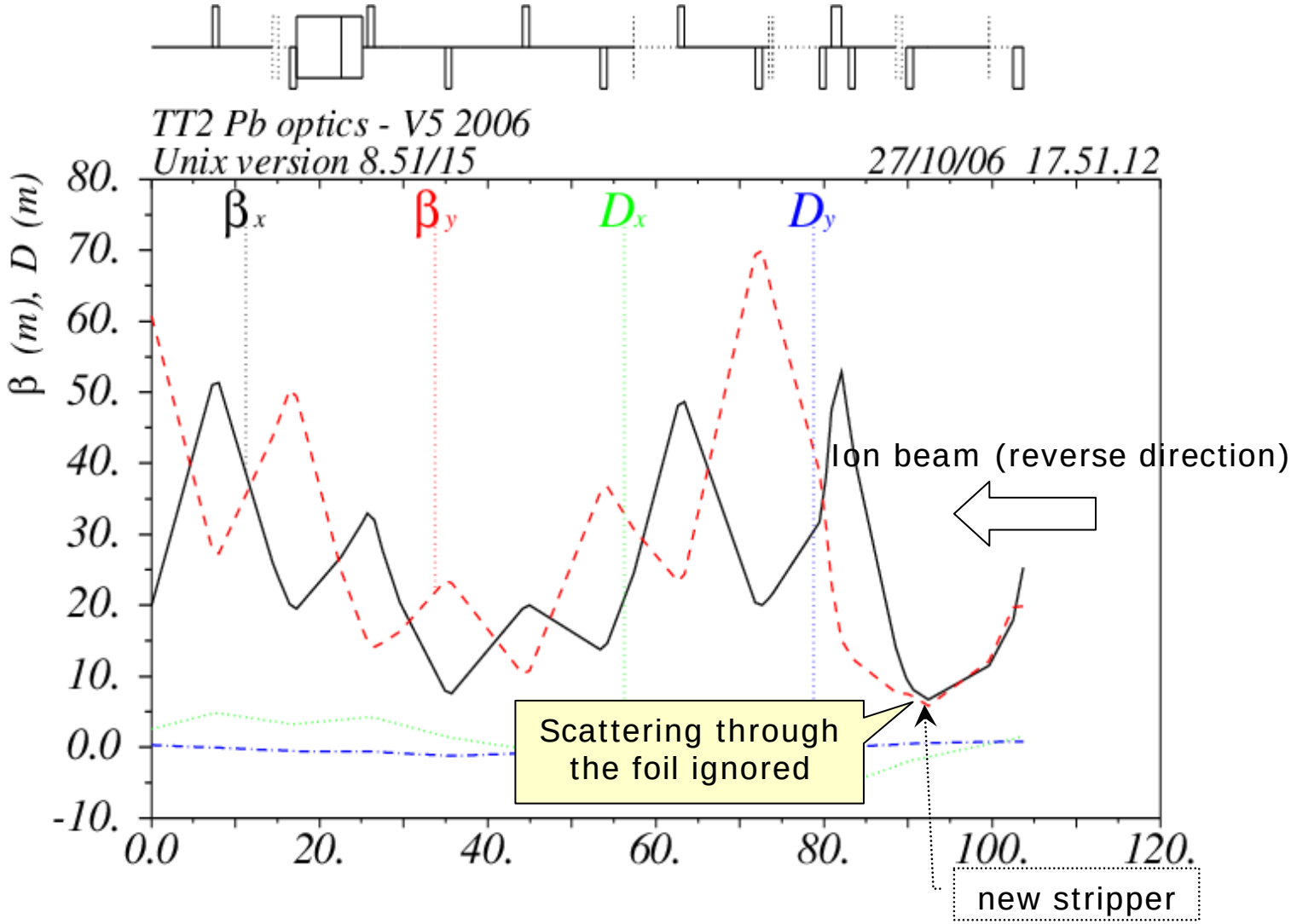
TT2 low-β optics with IQFO205=330 A: Tracking back using SEM-fil data

# I-LHC TT2 LOW-β OPTICS QUADRUPOLE OPTICS (REVERSED)




TT2 “low-β” optics with IQFO205=330 A: Tracking back using SEM-fil data

# I-LHC TT2 LOW-β OPTICS QUADRUPOLE OPTICS (REVERSED)




TT2 “low-β” optics with IQFO205=330 A: Tracking back using SEM-fil data