ILC Beam Delivery System "Interim Working Assumption"

2006e Release

European LC Workshop, January 8-11 2007, Daresbury

IWA Design Criteria

- single interaction region, 14 mrad crossing angle (saves ~ 300 m of tunnel) … “push-pull” detectors
- start with design for 1 TeV cm (500 GeV beam)
- modify design for initial operation at (up to) 250 GeV; upgrade to 500 GeV to be accomplished by adding magnets only (no layout/geometry changes)
- decimate dipoles … reduce $\int Bdl$ for 250 GeV operation by reducing lengths (i.e. number of dipoles); reserve space for additional dipoles, keeping layout fixed
- quadrupoles & sextupoles unchanged …reduce $\int Gdl$ for 250 GeV operation by reducing strengths
- Final Doublet magnets will have to be replaced for upgrade to 500 GeV

Design Criteria (2)

- remove dedicated energy / emittance diagnostic chicane (saves ~ 100 m)
  - use polarimeter chicane (there are some issues here …)
- BSY kickers: length and strength of individual kicker modules unchanged
  - start with 9 kickers
  - space reserved for additional 16 kickers for 500 GeV
- BSY septa: lengths and strengths of individual magnets unchanged
  - start with three 2 m septa (2 @ 5 kG + 1 @ 10 kG)
  - space reserved for two additional septa for 500 GeV (1 @ 5 kG + 1 @ 10 kG)
- large bore BSY extraction magnets: unchanged
- rastering dipoles (BSY and post-IP): strength unchanged
  - start with 10 (5 horizontal and 5 vertical) for R_{sweep} = 3 cm
  - space reserved for additional 10 dipoles for 500 GeV
- spot size on BSY dump window unchanged (round; 1σ area = 2π mm^2)
- BSY length is ~644 m (~482 m in “minimal” 250 GeV system)
- BSY tuneup/extraction line length is ~467 m (~318 m in “minimal” 250 GeV system)
- Final Focus: 12 m “soft” bends divided into 5 × 2.4 m pieces
  - start with center piece only at each location
  - space reserved for remaining 4 pieces at each location for 500 GeV
- post-IP dump line: Yuri Nosochkov’s “push-pull” design (October 2006)
  - 5.5 m L*
  - break point between QF1 and SD0

Additional Design Data

Synchrotron Radiation Emittance Growth (DIMAD tracking; SYNC option 2)

- ILC2006c: @ 250 GeV, emit/emit0 = 1.0075 ; @ 500 GeV, emit/emit0 = 1.0137 (emit0 = 1e-5 m)
- ILC2006e: @ 250 GeV, emit/emit0 = 1.0036 ; @ 500 GeV, emit/emit0 = 1.0078 (emit0 = 1e-5 m)

Laserwire Spot Size

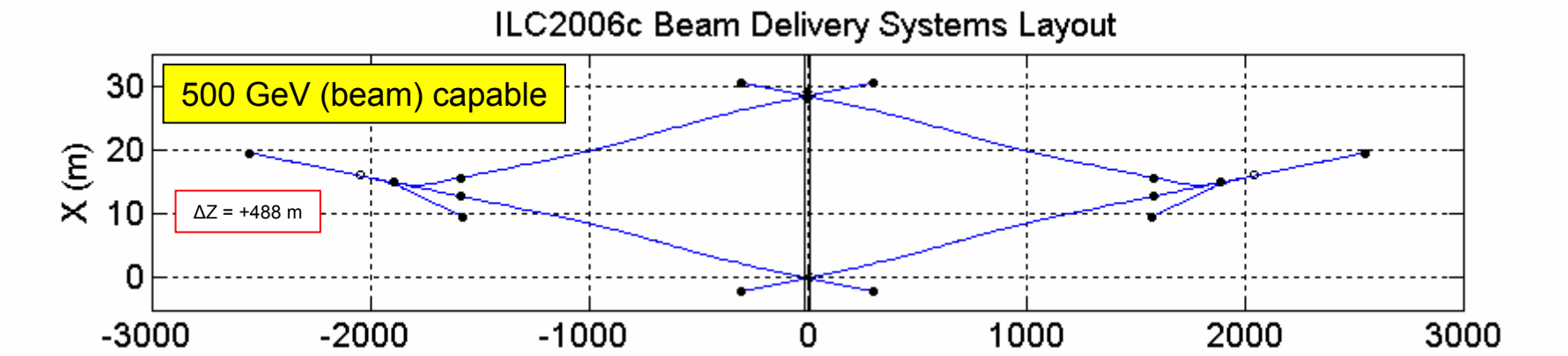
- "worst case" laserwire spot size: DR extracted emittance (2e-8 m), 500 GeV
- "nominal" laserwire spot size: BSY budgeted emittance (3.4e-8 m), 500 GeV
- emittance diagnostic FODO cell length: "worst case" spot > 1.0 um AND "nominal" spot > 1.5 um
  - L45 = 16.2 m (45° FODO cell drift length)
  - BETY(WS) = 64.752 m
  - "nominal" vertical spot size = 1.500 um
  - "worst case" vertical spot size = 1.150 um
  - skew/emit length = 247.102 m (1st skew quad to 4th wire scanner)

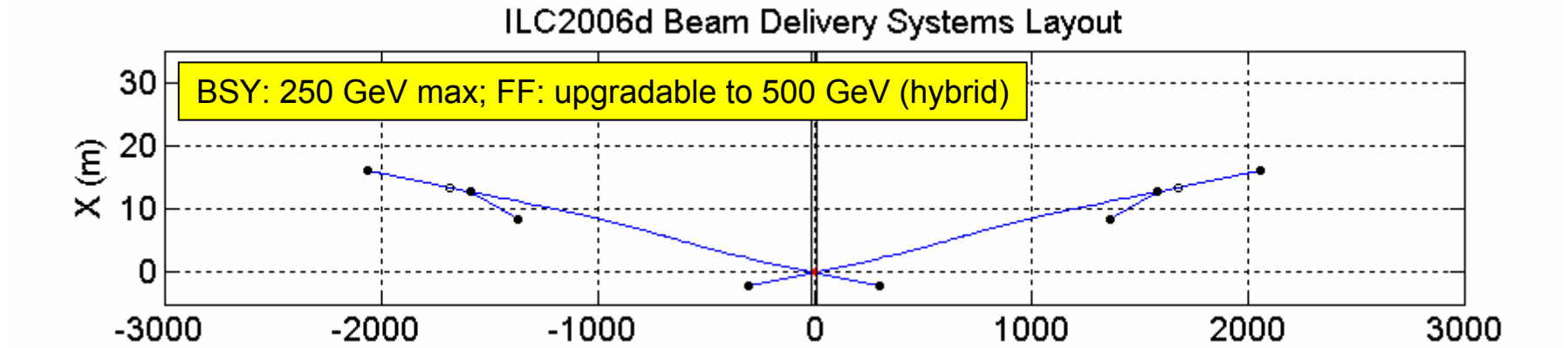
Polarimeter Chicane

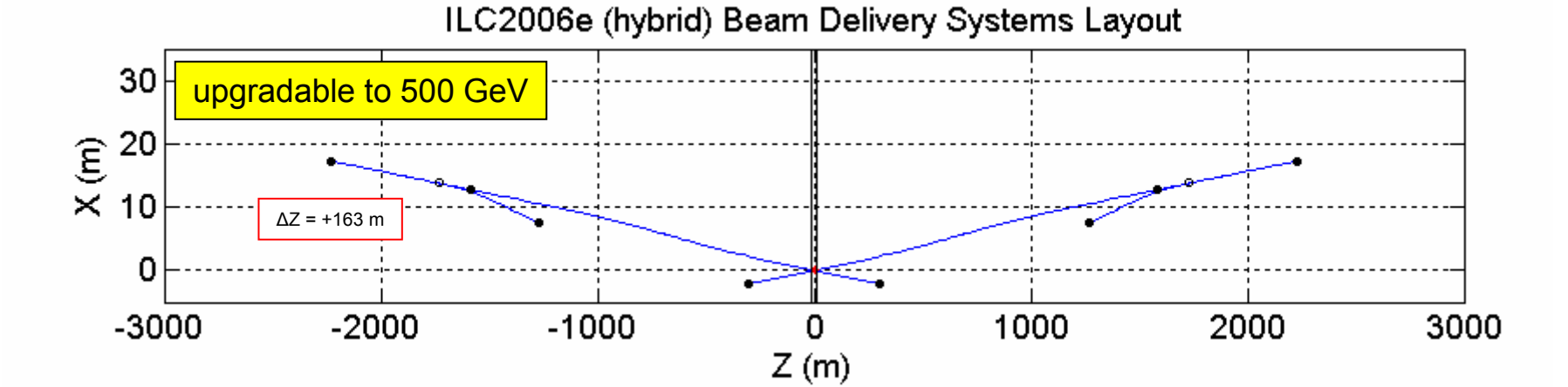
- peak dispersion = 20 mm @ 250 GeV, 10 mm @ 500 GeV ... constant B-field dipoles
- minimum center dipole separation = 8 m + 3.5 m (for MPS energy collimator)
- energy detection resolution: for dE/E = 1%, dX > 10*sigmaX (BSY budgeted emittance)

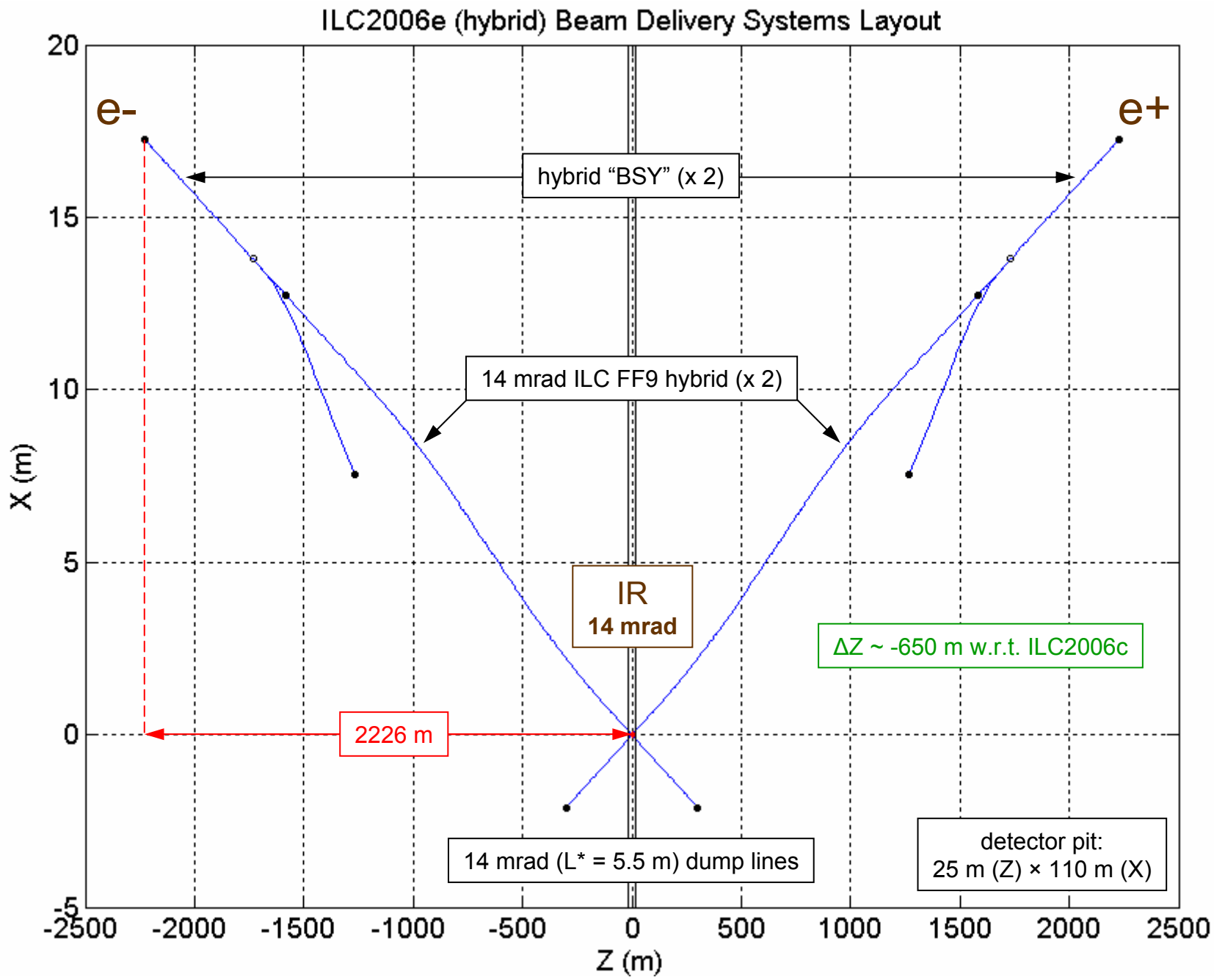
Extraction

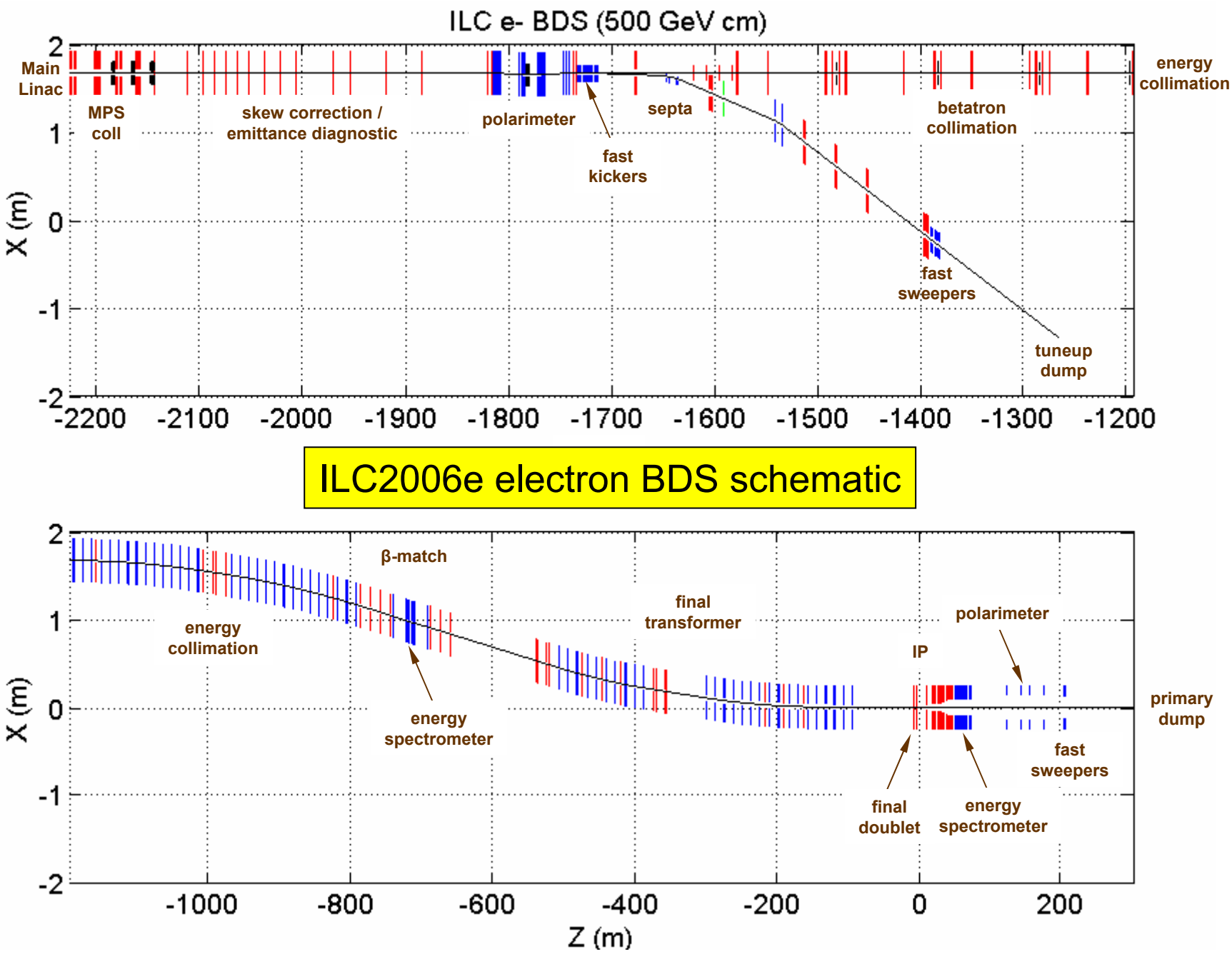
- septum aperture: R = 15 mm (+-10% dE/E acceptance)
- required offset at septum entrance: dX = 35 mm
- 9 kickers (9 × 2 m × 0.133 kG)
  - 1 TeV upgrade: 25 kickers (25 × 2 m × 0.133 kG ; Lkick/(Lkick+Ldrift) = 2/3)
- 3 septa (2 × 2 m × 5 kG + 1 × 2 m × 10 kG)
  - 1 TeV upgrade: 5 septa (3 × 2 m × 5 kG + 2 × 2 m × 10 kG)
- transverse clearance for IRT "Type B" quads: 135 mm
  - 0.5 * 171 mm (quad half-width) + 40 mm (extraction line beam pipe radius) + 10 mm (clearance)
- transverse clearance for extraction line 8 cm bore quad QFSM1: 220 mm
  - 0.5 * 16 inches (quad half-width) + 6 mm (IRT beam pipe radius) + 10 mm (clearance)
- 10 rastering kickers for 3 cm radius (10 × 0.8 m × 0.54 kG)
  - 1 TeV upgrade: 20 rastering kickers for 3 cm radius (20 × 0.8 m × 0.54 kG)
- required offset at dump: dX > 3 m

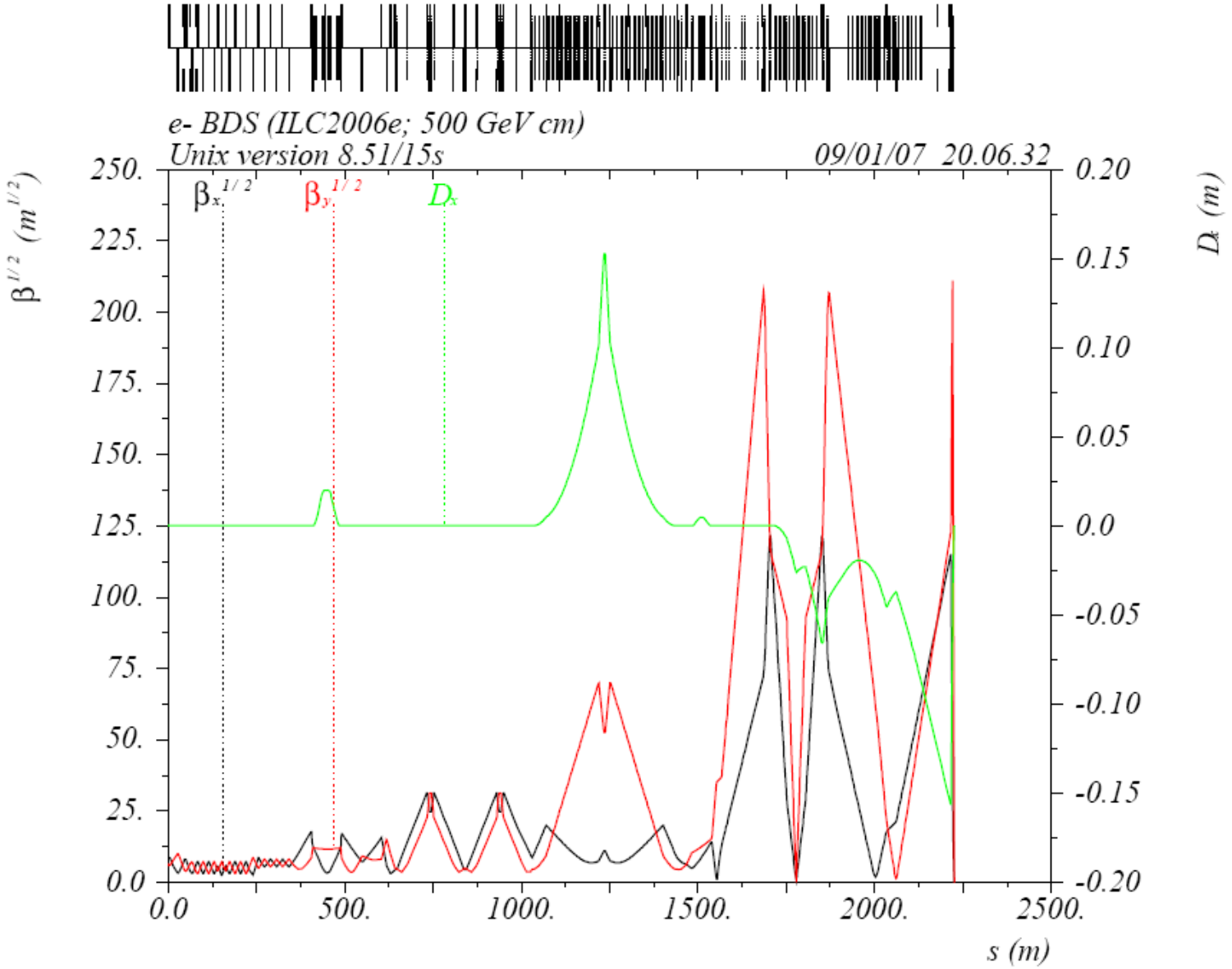

ILC2006c Beam Delivery Systems Layout
500 GeV (beam) capable
ΔZ = +488 m
X (m)
30
20
10
0
-3000
-2000
-1000
0
1000
2000
3000

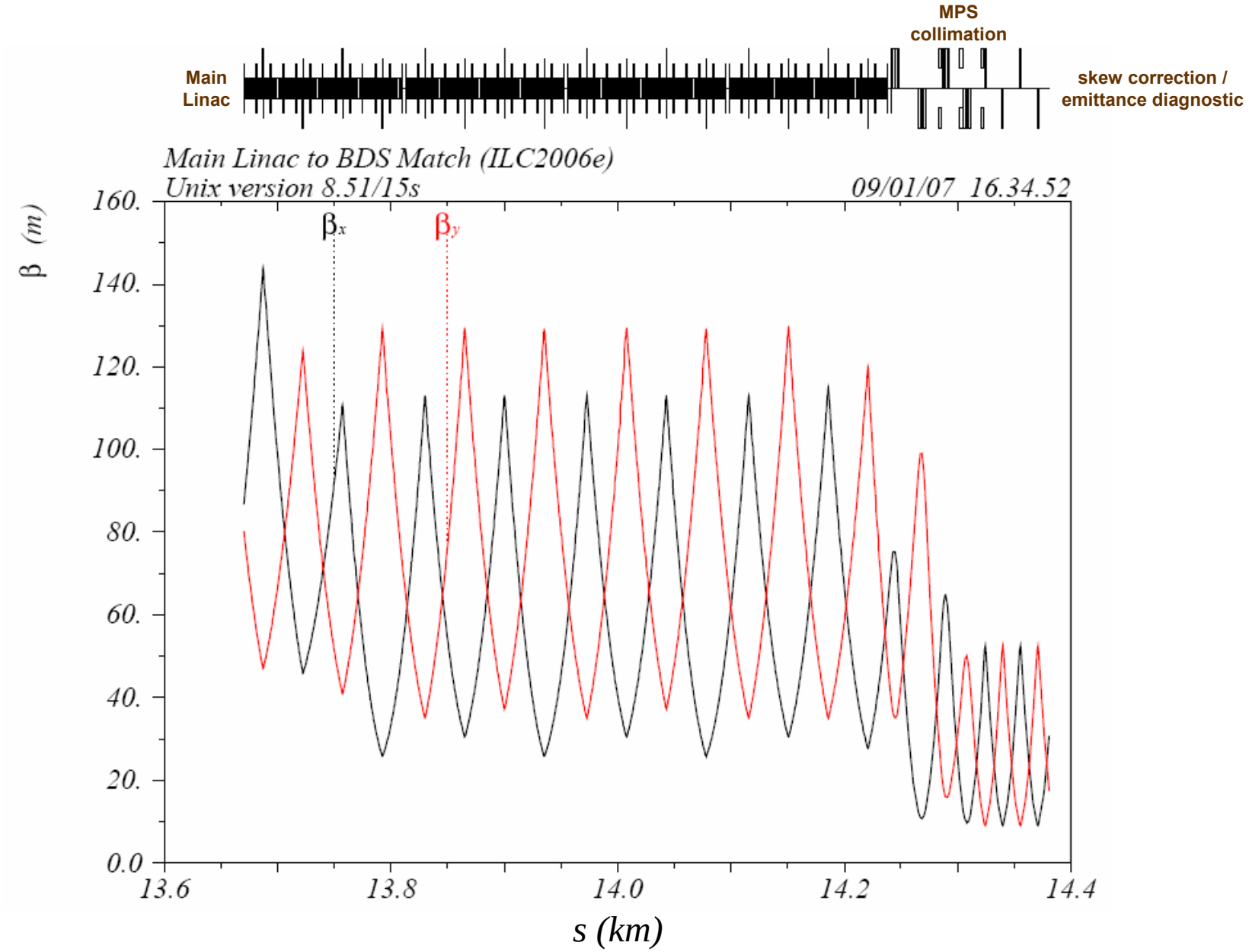

ILC2006d Beam Delivery Systems Layout
BSY: 250 GeV max; FF: upgradable to 500 GeV (hybrid)
X (m)
30
20
10
0
-3000
-2000
-1000
0
1000
2000
3000

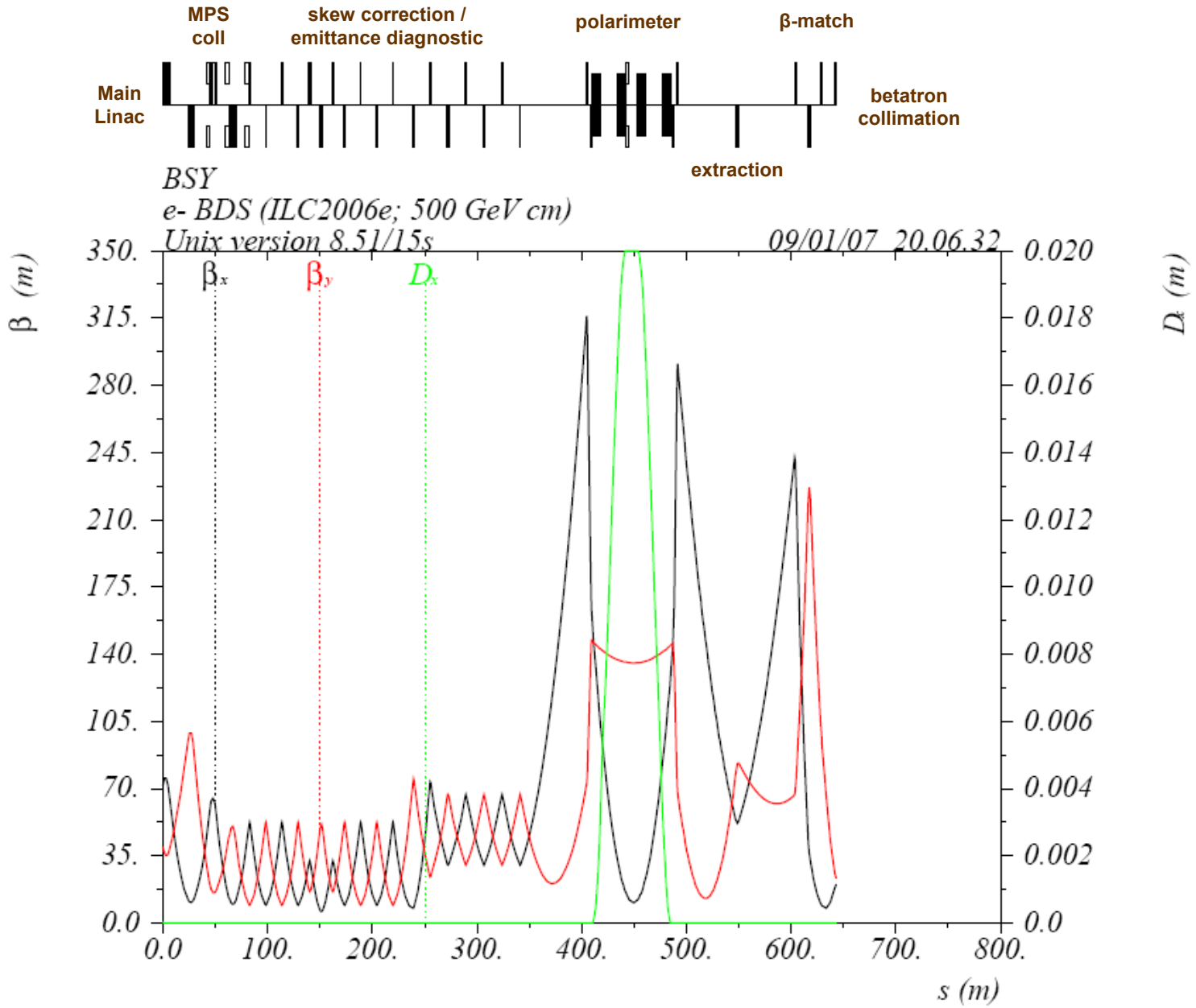

ILC2006e (hybrid) Beam Delivery Systems Layout
upgradable to 500 GeV
ΔZ = +163 m
X (m)
30
20
10
0
-3000
-2000
-1000
0
1000
2000
3000
Z (m)


ILC2006e (hybrid) Beam Delivery Systems Layout
e-
e+
hybrid “BSY” (x 2)
14 mrad ILC FF9 hybrid (x 2)
IR
14 mrad
ΔZ ~ -650 m w.r.t. ILC2006c
2226 m
14 mrad (L* = 5.5 m) dump lines
detector pit:
25 m (Z) × 110 m (X)
X (m)
Z (m)
20
15
10
5
0
-5
-2500
-2000
-1500
-1000
-500
0
500
1000
1500
2000
2500

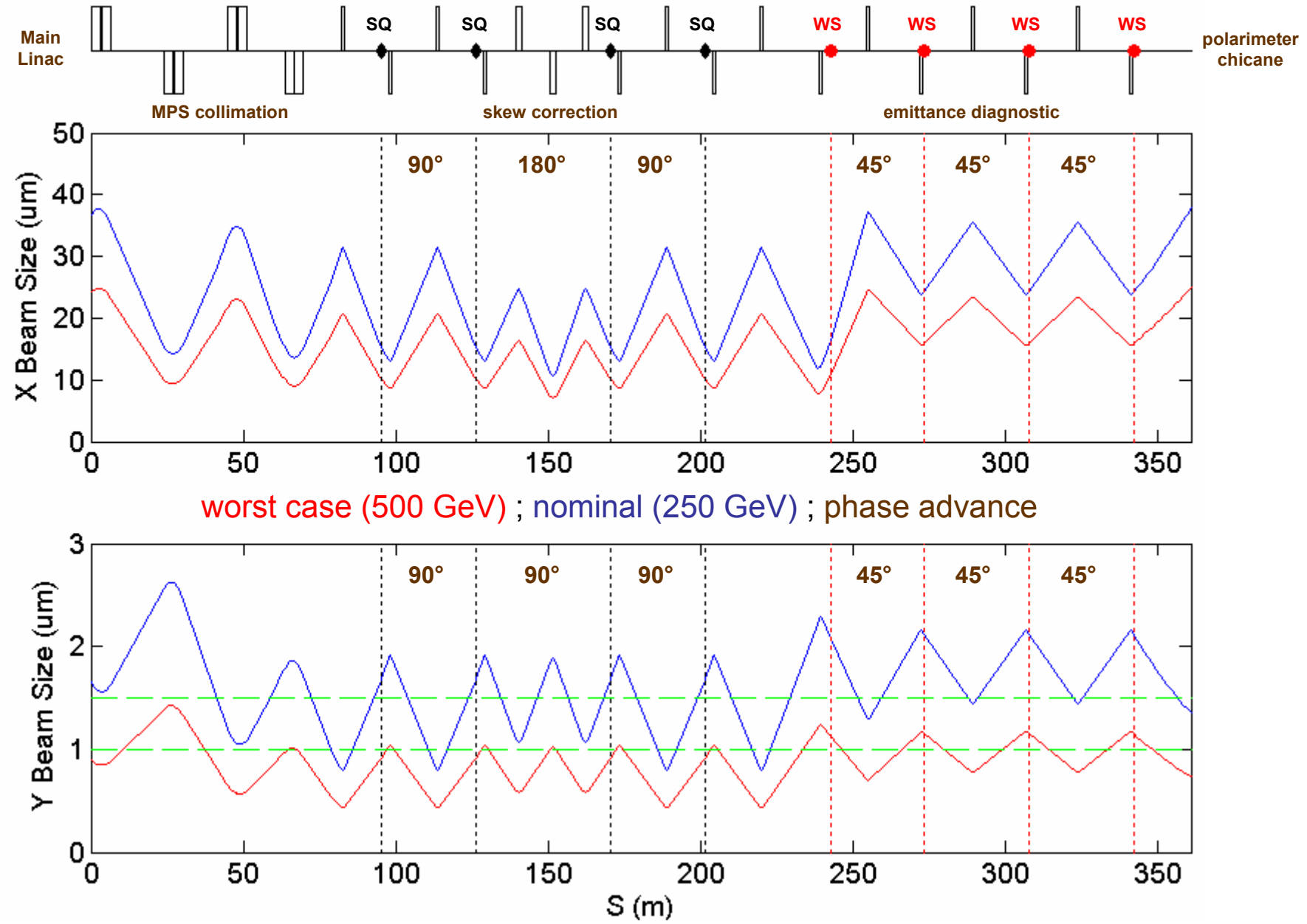

ILC e- BDS (500 GeV cm)
Main Linac
MPS coll
skew correction / emittance diagnostic
polarimeter
fast kickers
septa
betatron collimation
energy collimation
fast sweepers
tuneup dump
X (m)
ILC2006e electron BDS schematic
β-match
energy collimation
energy spectrometer
final transformer
IP
polarimeter
primary dump
fast sweepers
final doublet
energy spectrometer
Z (m)


e- BDS (ILC2006e; 500 GeV cm)
Unix version 8.51/15s
09/01/07 20.06.32
$\beta_x^{1/2}$
$\beta_y^{1/2}$
D_x
$\beta^{1/2}$ ($m^{1/2}$)
D_x (m)
250.
225.
200.
175.
150.
125.
100.
75.
50.
25.
0.0
0.20
0.15
0.10
0.05
0.0
-0.05
-0.10
-0.15
-0.20
0.0
500.
1000.
1500.
2000.
2500.
s (m)

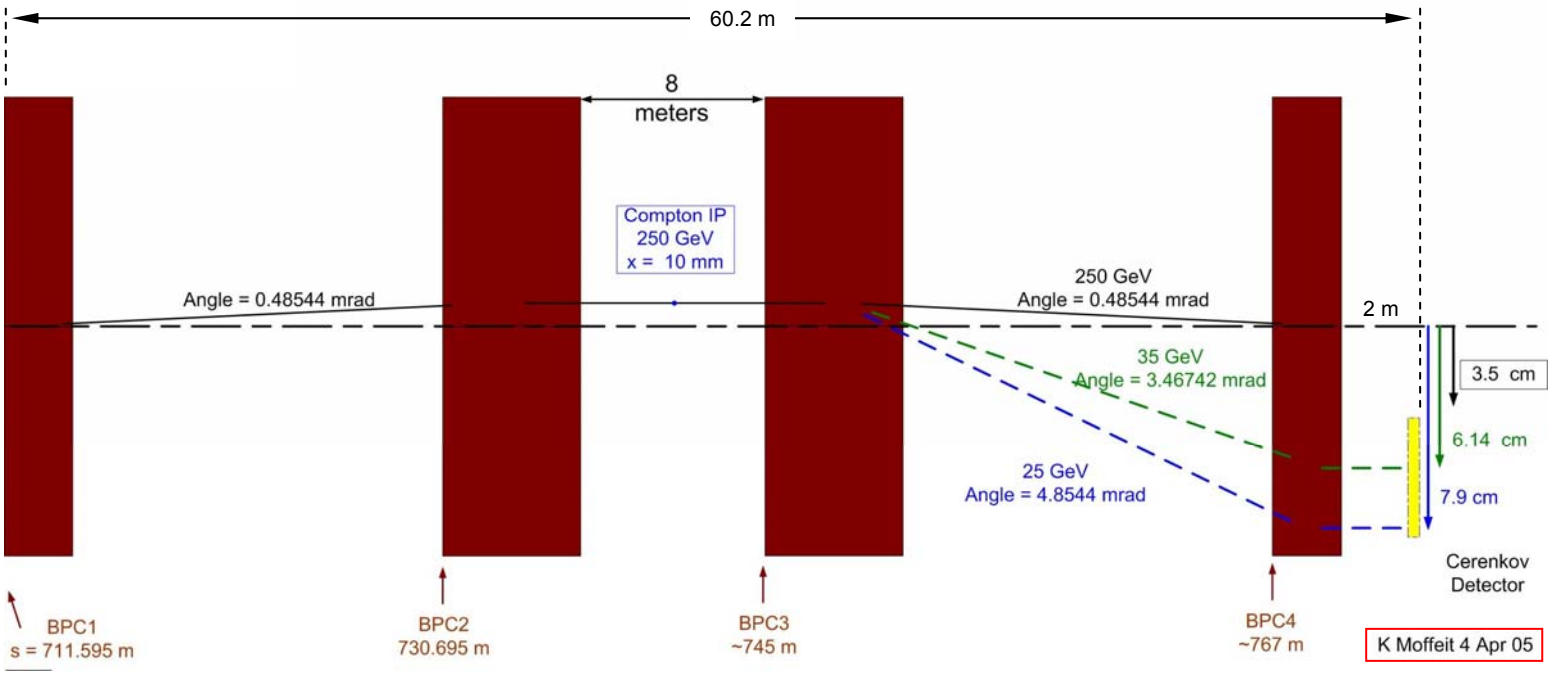

MPS
collimation
Main
Linac
skew correction /
emittance diagnostic
Main Linac to BDS Match (ILC2006e)
Unix version 8.51/15s
09/01/07 16.34.52
β (m)
βx
βy
160.
140.
120.
100.
80.
60.
40.
20.
0.0
13.6
13.8
14.0
14.2
14.4
s (km)


MPS coll
skew correction / emittance diagnostic
polarimeter
β-match
Main Linac
betatron collimation
extraction
BSY
e- BDS (ILC2006e; 500 GeV cm)
Unix version 8.51/15s
09/01/07 20.06.32
β (m)
Dx (m)
βx
βy
Dx
350.
315.
280.
245.
210.
175.
140.
105.
70.
35.
0.0
0.020
0.018
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.0
0.0
100.
200.
300.
400.
500.
600.
700.
800.
s (m)

MPS / skew correction / emittance diagnostic

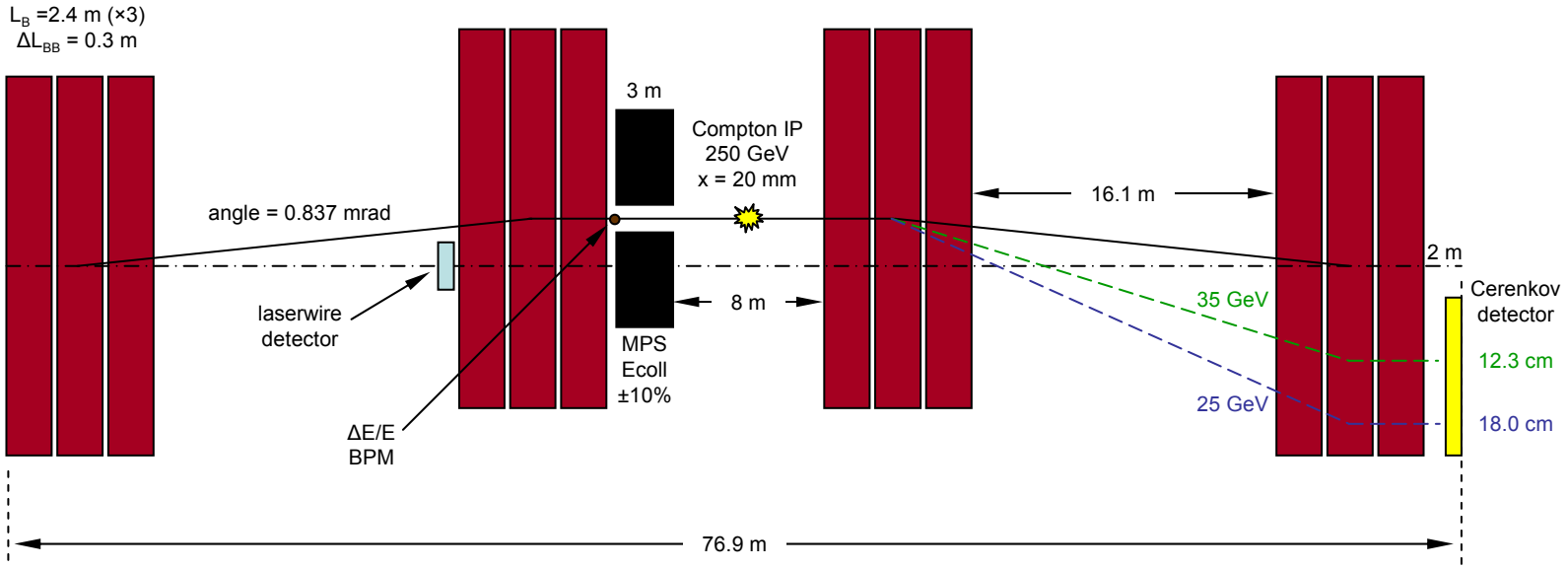


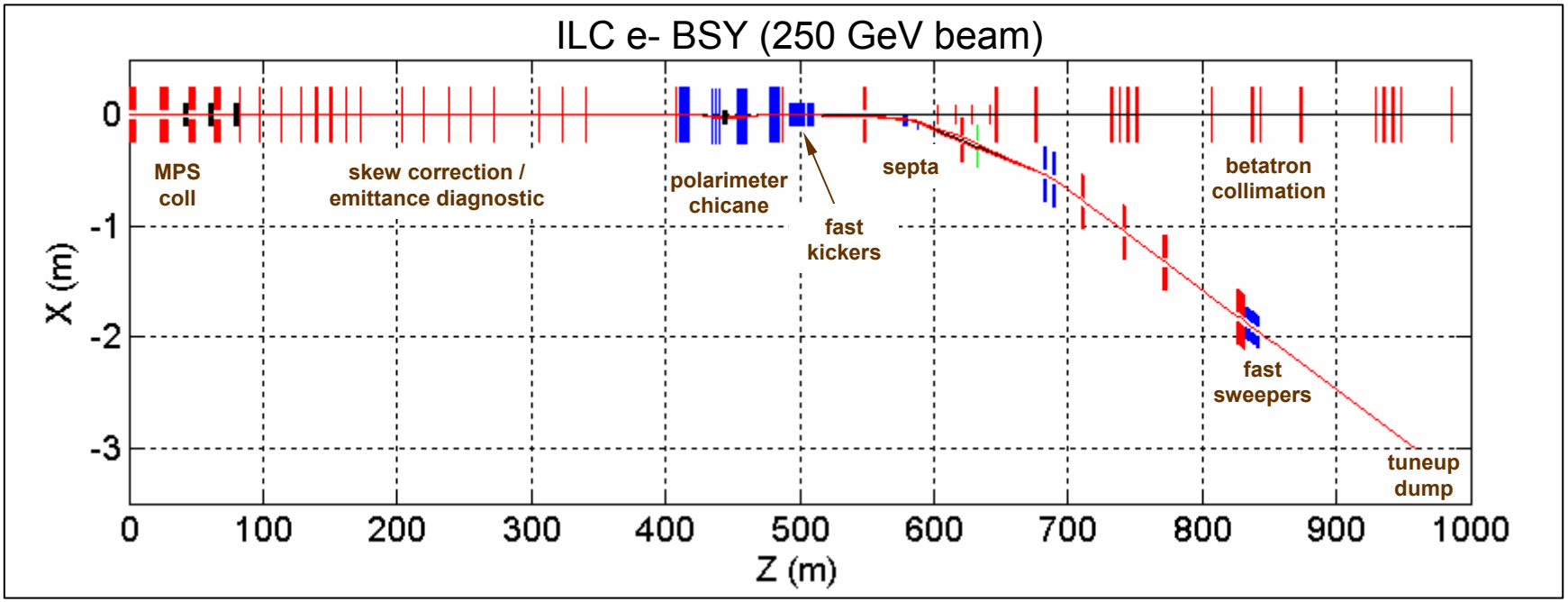
Original Upstream Polarimeter Chicane

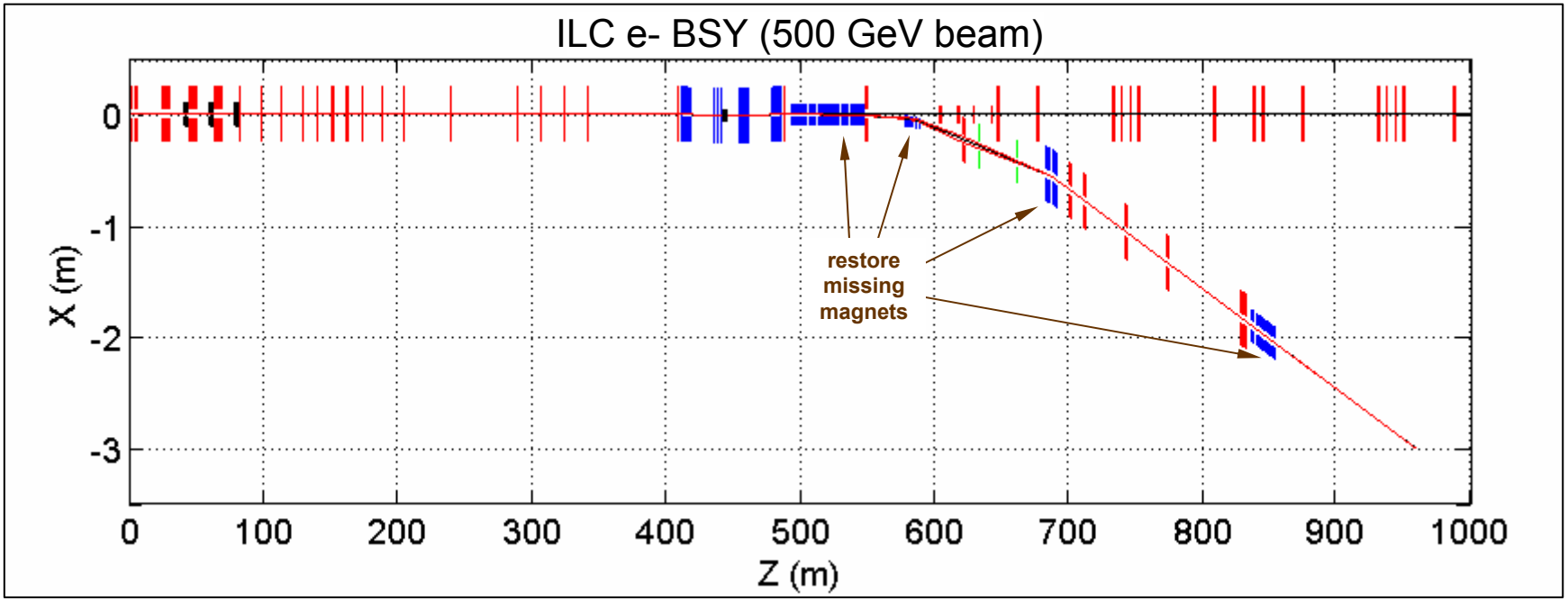


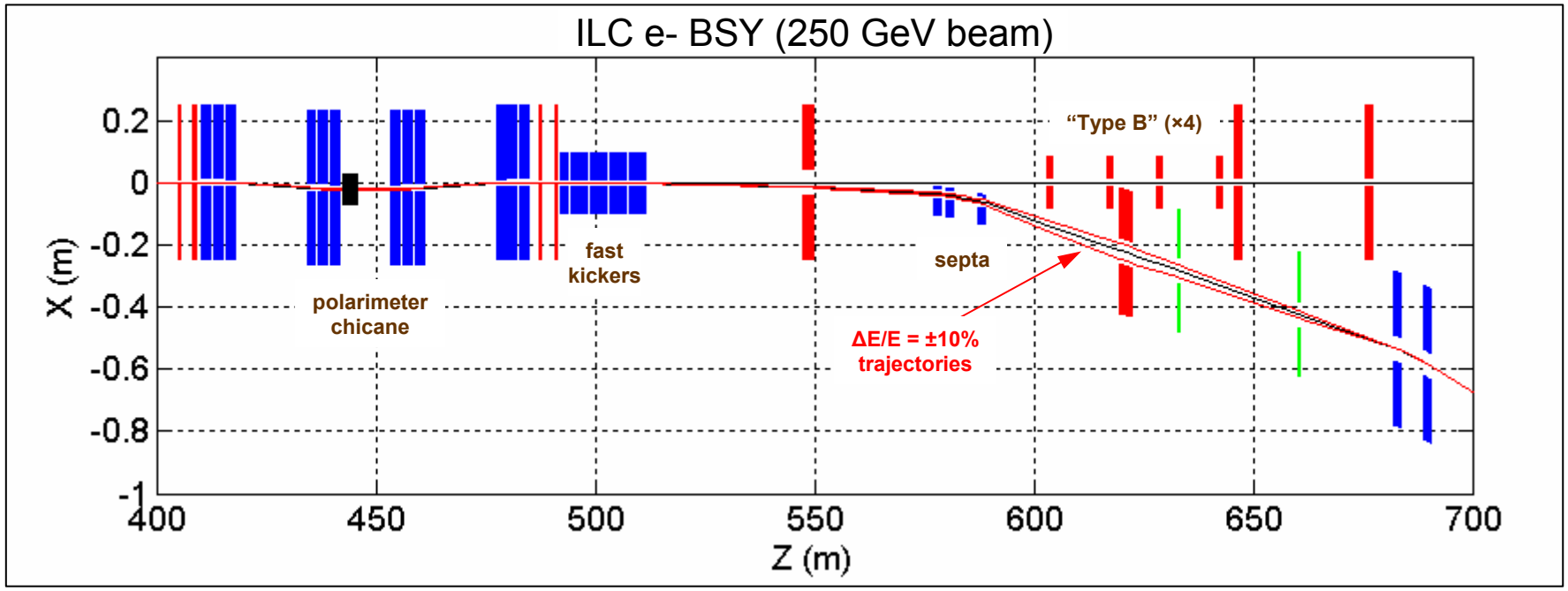
New Upstream Polarimeter Chicane

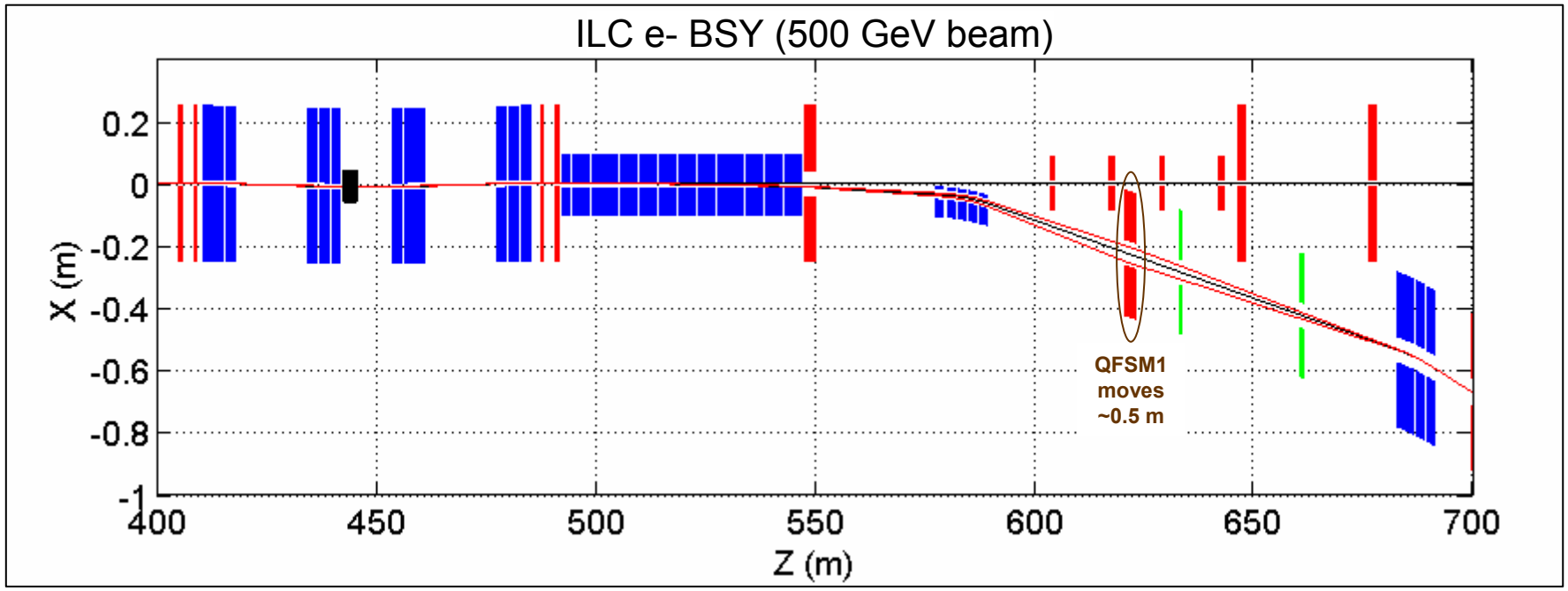
- constant integrated strength dipoles (B = 0.97 kG)
- dispersion = 20 mm @ 250 GeV, 10 mm @ 500 GeV
- dispersion scales inversely with energy (= 110 mm @ 45 GeV)
- transverse space for laserwire detector @ 500 GeV? (< 5 mm)
- magnet and vacuum chamber engineering issues?




ILC e- BSY (250 GeV beam)
MPS coll
skew correction / emittance diagnostic
polarimeter chicane
fast kickers
septa
betatron collimation
fast sweepers
tuneup dump
X (m)
Z (m)
0
-1
-2
-3
0
100
200
300
400
500
600
700
800
900
1000

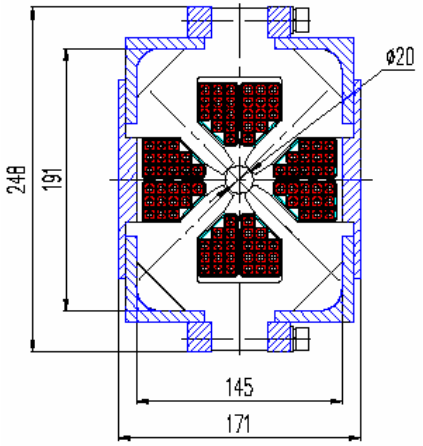

ILC e- BSY (500 GeV beam)
restore missing magnets
X (m)
Z (m)
0
-1
-2
-3
0
100
200
300
400
500
600
700
800
900
1000


ILC e- BSY (250 GeV beam)
X (m)
Z (m)
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
400
450
500
550
600
650
700
"Type B" (×4)
fast
kickers
septa
polarimeter
chicane
ΔE/E = ±10%
trajectories


ILC e- BSY (500 GeV beam)
X (m)
Z (m)
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
400
450
500
550
600
650
700
QFSM1
moves
~0.5 m

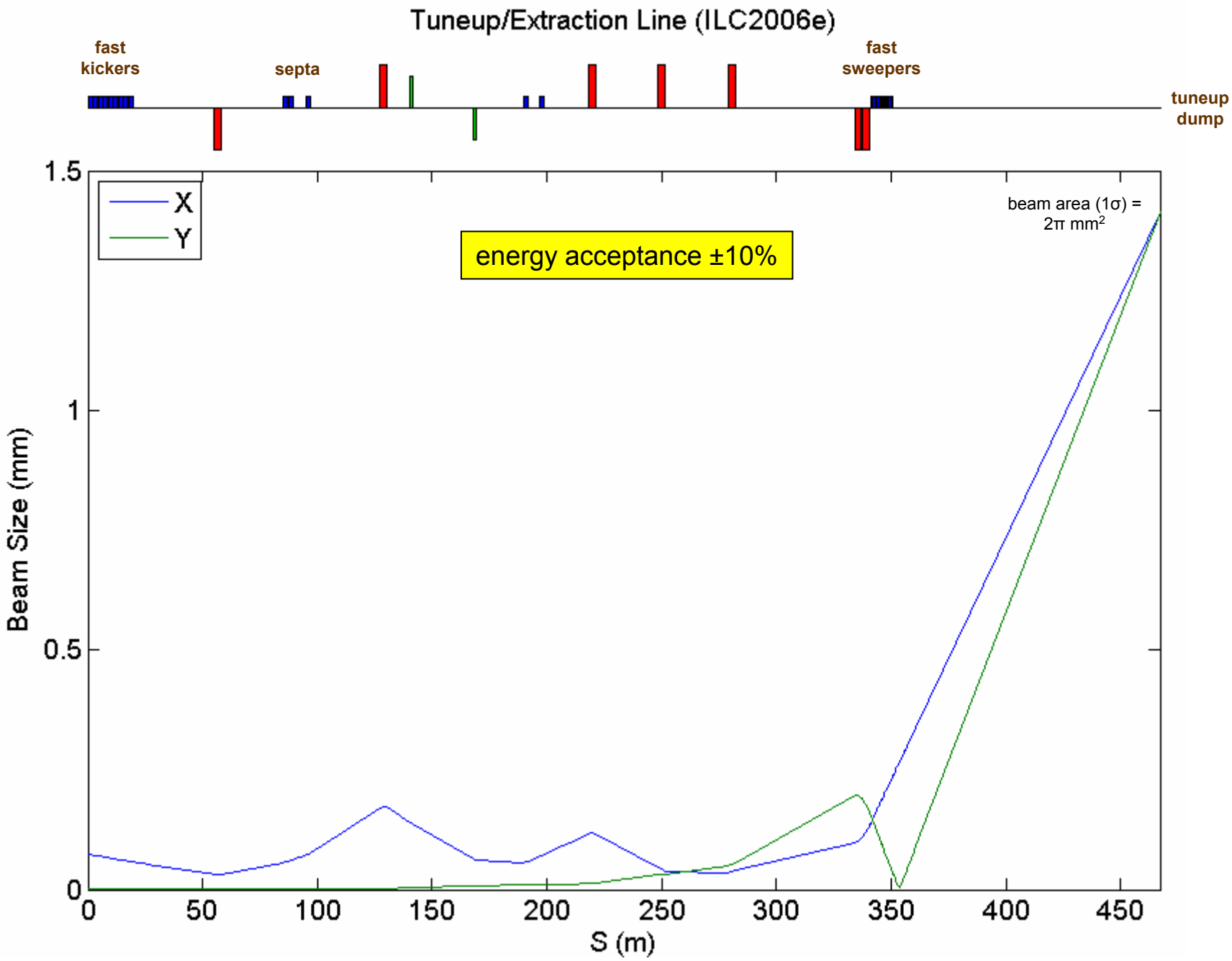
Some BSY Magnet Details

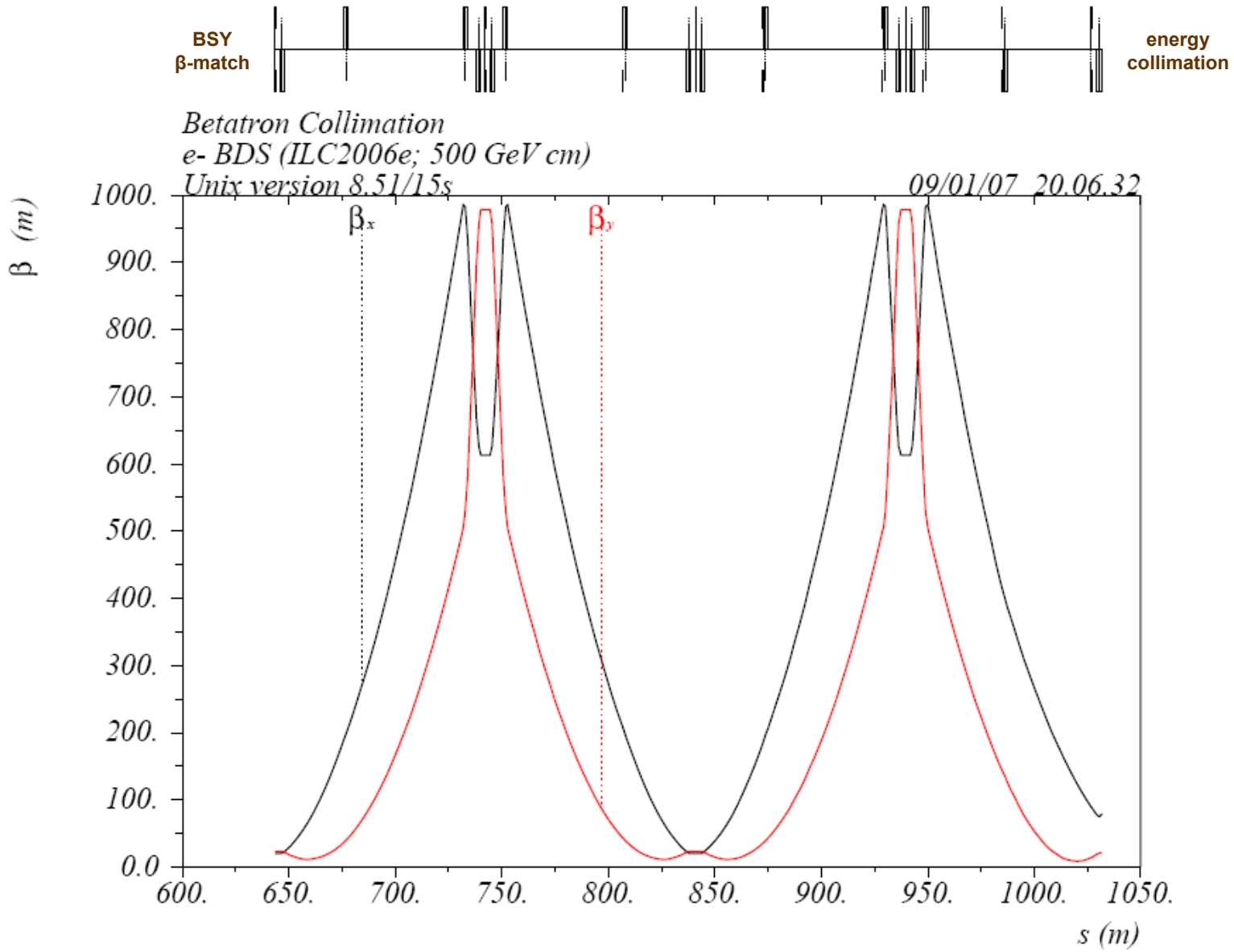
- polarimeter chicane dipoles (12)
  - L = 2.4 m, B = 0.97 kG
  - total chicane SR emittance growth < 0.3% @ 1 TeV cm (DIMAD)
- fast extraction kickers
  - 9 @ 500 GeV cm; 25 @ 1 TeV cm
  - in-vacuum stripline devices
  - L = 2 m, B = 0.0133 T @ 1 TeV cm
  - 100 ns rise-time
  - reference Tom Mattison



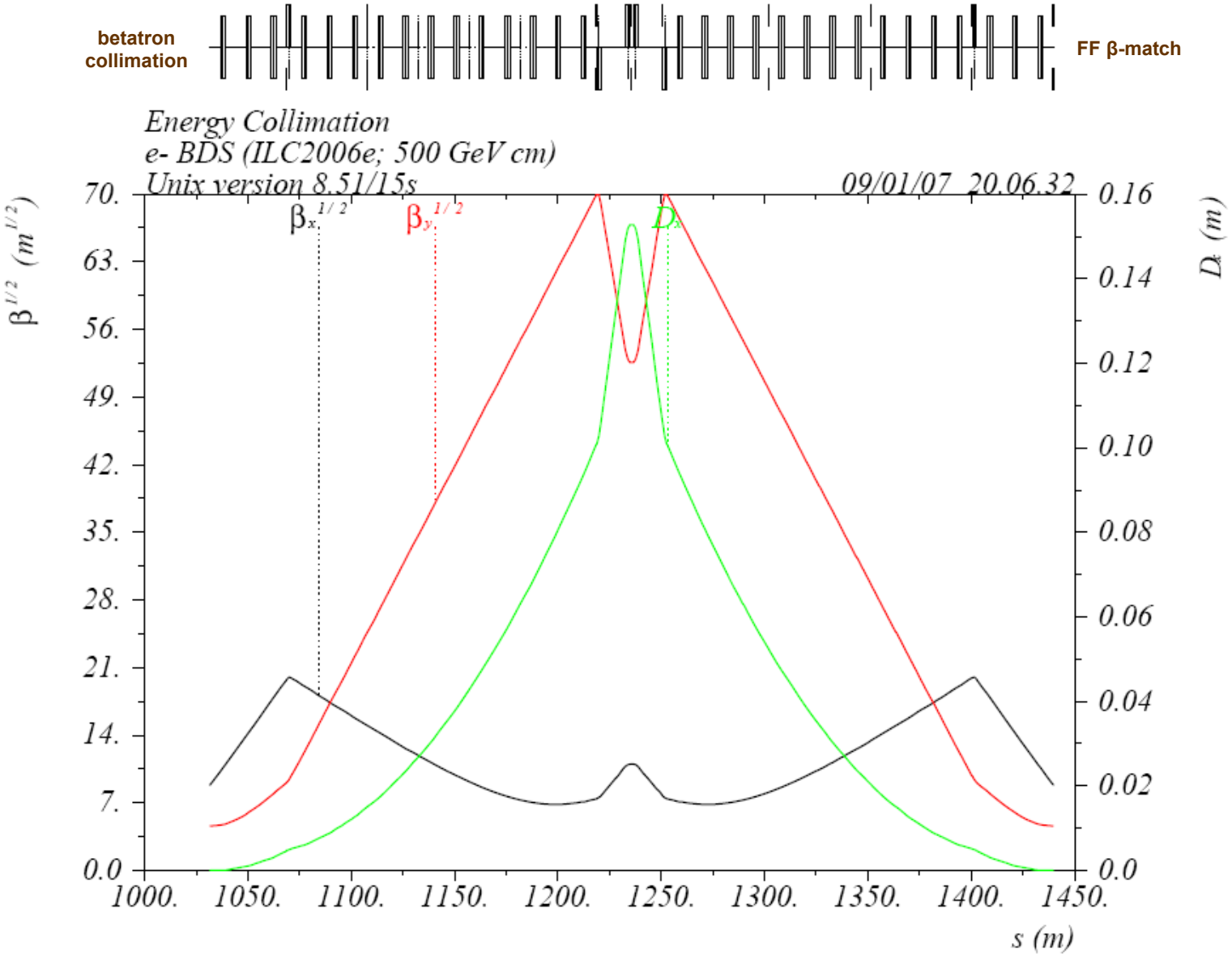
TESLA “Type B” quadrupole

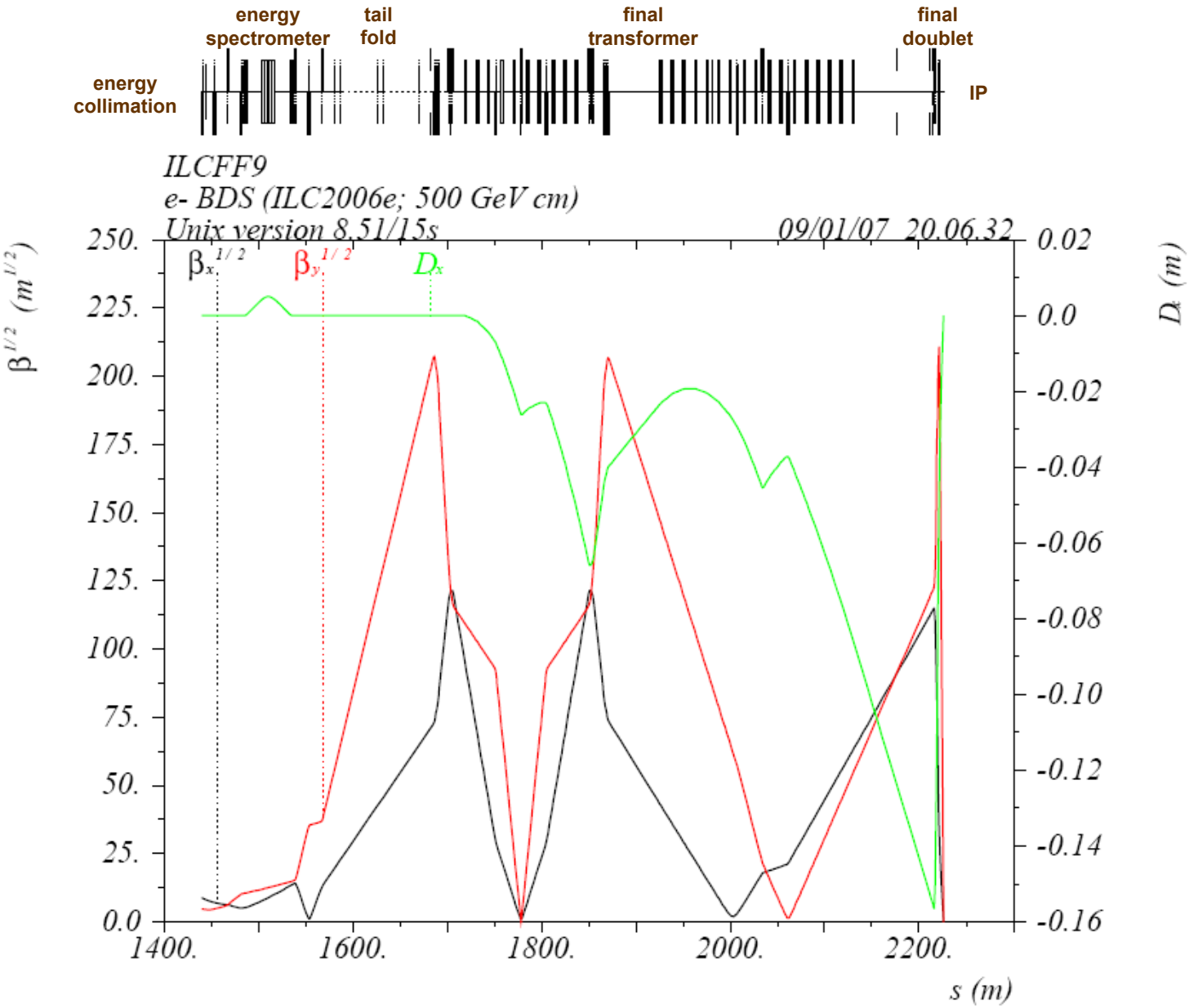
- for “tuneup” mode, assume large gap DC dipoles wrapped around (some of) the fast extraction kickers
- septa
  - 3 @ 500 GeV cm; 5 @ 1 TeV cm
  - current-sheet devices, 10 mm thick blade
  - L = 2 m, B = 0.5 T (3), 1.0 T (2) @ 1 TeV cm
  - reference Tom Mattison
- rastering kickers
  - 5 horizontal, 5 vertical @ 500 GeV cm; 10 horizontal, 10 vertical @ 1 TeV cm
  - L = 0.8 m, B = 0.054 T @ 1 TeV cm
  - 3 cm sweep radius (1.4 mm × 1.4 mm beam size at dump window) … factor of ≈ 25 reduction in energy deposition
  - reference TESLA Report 2001-05 (Maslov)

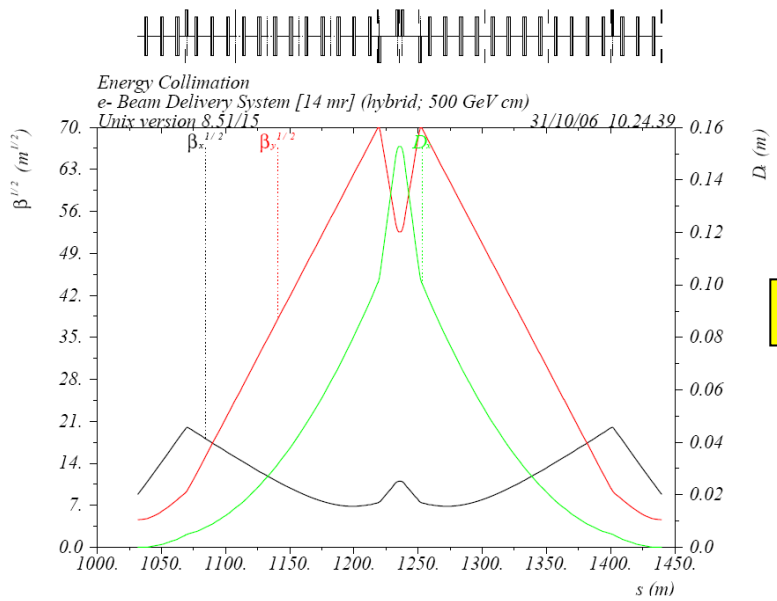

Tuneup/Extraction Line (ILC2006e)
fast kickers
septa
fast sweepers
tuneup dump
X
Y
energy acceptance ±10%
beam area (1σ) = 2π mm²
Beam Size (mm)
S (m)
0
0.5
1
1.5
0
50
100
150
200
250
300
350
400
450



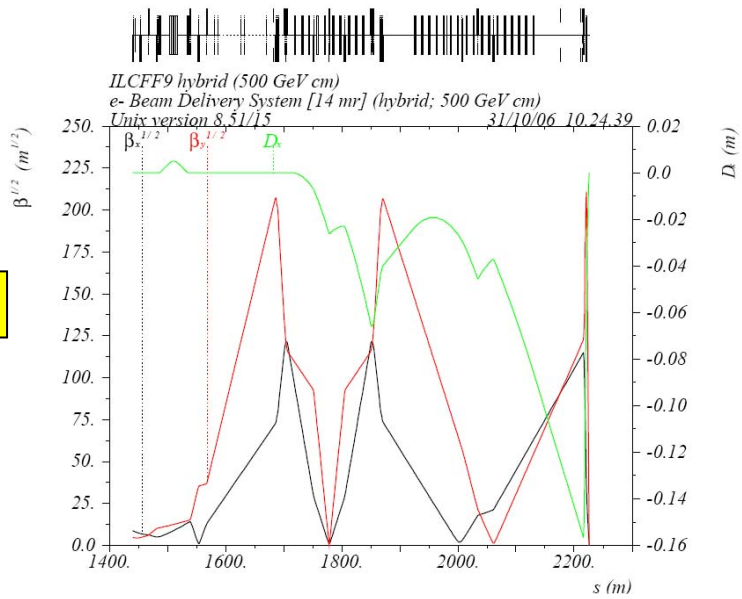
see Frank Jackson's talk (*Collimation Simulations and Optimisation*)

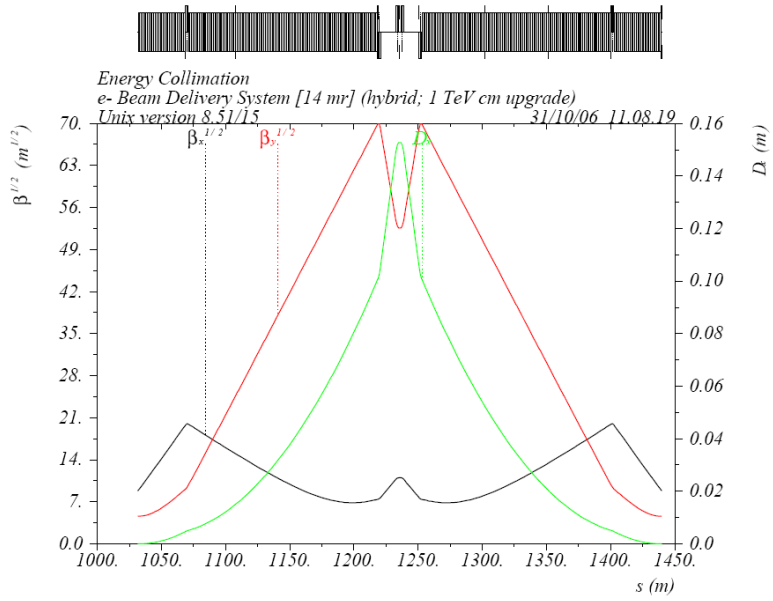

betatron collimation
FF β-match
Energy Collimation
e- BDS (ILC2006e; 500 GeV cm)
Unix version 8.51/15s
09/01/07 20.06.32
β^1/2 (m^1/2)
β_x^1/2
β_y^1/2
D_x
D_x (m)
70.
63.
56.
49.
42.
35.
28.
21.
14.
7.
0.0
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.0
1000.
1050.
1100.
1150.
1200.
1250.
1300.
1350.
1400.
1450.
s (m)


energy spectrometer
tail fold
final transformer
final doublet
energy collimation
IP
ILCFF9
e- BDS (ILC2006e; 500 GeV cm)
Unix version 8.51/15s
09/01/07 20.06.32
$\beta_x^{1/2}$
$\beta_y^{1/2}$
D_x
$\beta^{1/2}$ ($m^{1/2}$)
D_x (m)
250.
225.
200.
175.
150.
125.
100.
75.
50.
25.
0.0
0.02
0.0
-0.02
-0.04
-0.06
-0.08
-0.10
-0.12
-0.14
-0.16
1400.
1600.
1800.
2000.
2200.
s (m)

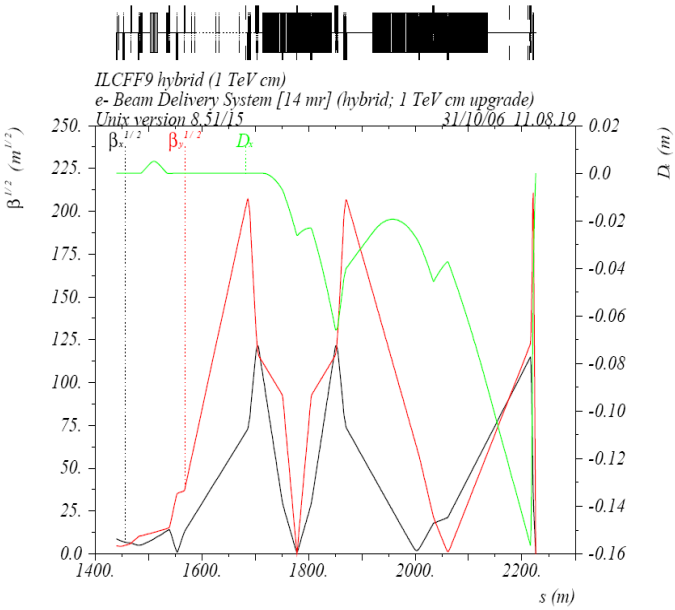


500 GeV cm





1 TeV cm



October 9, 2006 Y. Nosochkov, B. Parker

14 mrad Extraction Optics for Push-Pull Detector Option at 0.5 TeV CM

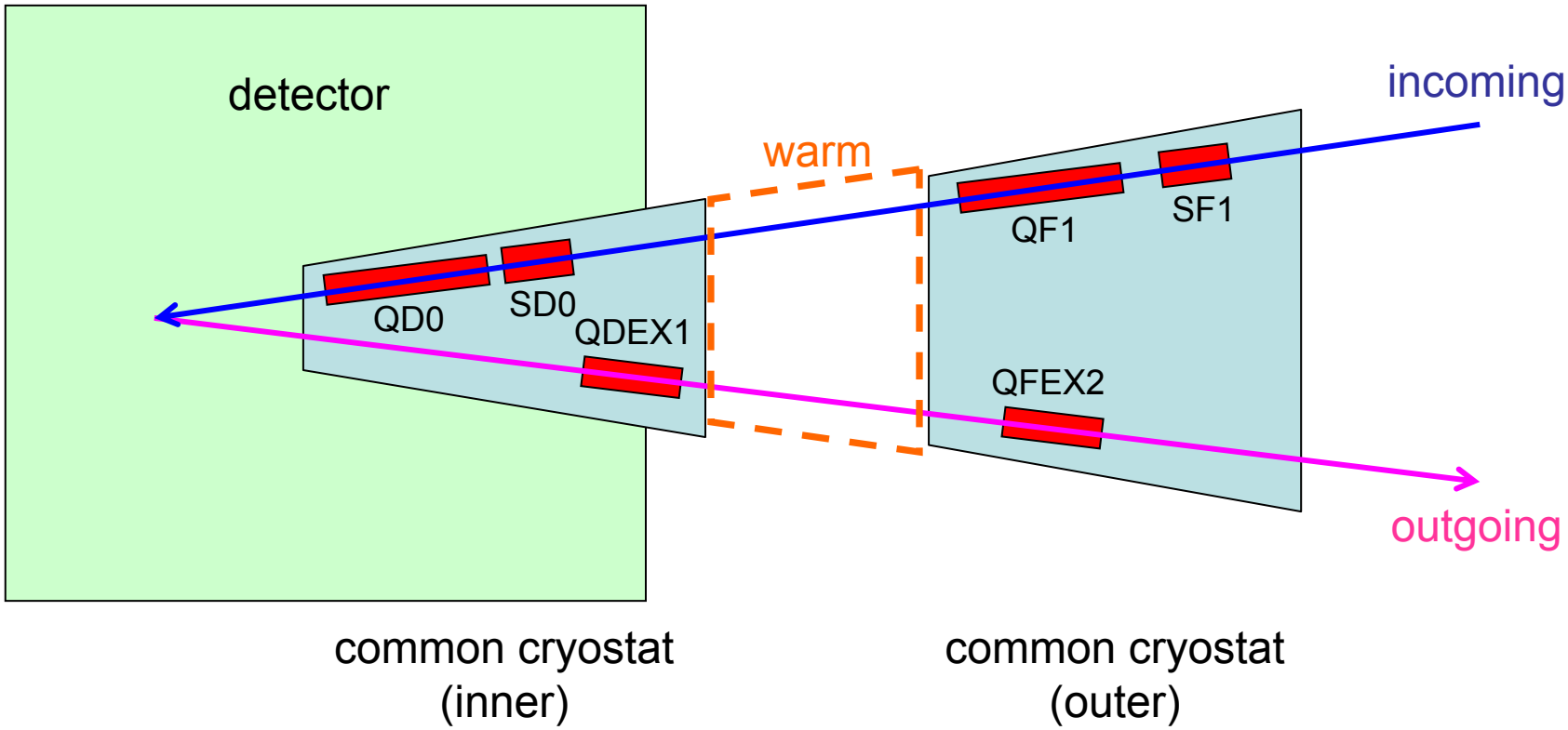
Push-pull modifications:

- Modify the SC extraction quads to provide a sufficient space between the SD0 and QF1 for a push-pull break point.
- Use shorter SC quads by maximizing the field for 0.5 TeV CM option only.
- Replace the two QDEX1A, QDEX1B quads with one 1.06 m long QDEX1 quad and move it upstream from 6 m to 5.5 m from IP.
- Reduce the QDEX1 aperture from 18 mm to 15 mm to fit into a smaller separation space.
- Reduce the length of QFEX2A to 1.2 m and move it upstream to overlap in z-position with QF1. The latter permits the QFEX2A to not having its own shielding since there is a magnetic shield from QF1.
- Reduce the QFEX2A aperture to 26 mm.
- The new QDEX1, QFEX2A integral B'L strengths are 106.0 T and 27.7 T.
- This modification provides 1.25 m free space (from 6.56 m to 7.81 m) for a break point between detector cryostat and the beamline cryostats.
- The 1.25 m space can include a short warm section for the feedback kicker.
- The new upstream position of QFEX2A increases the space for crab-cavity.

Other modifications:

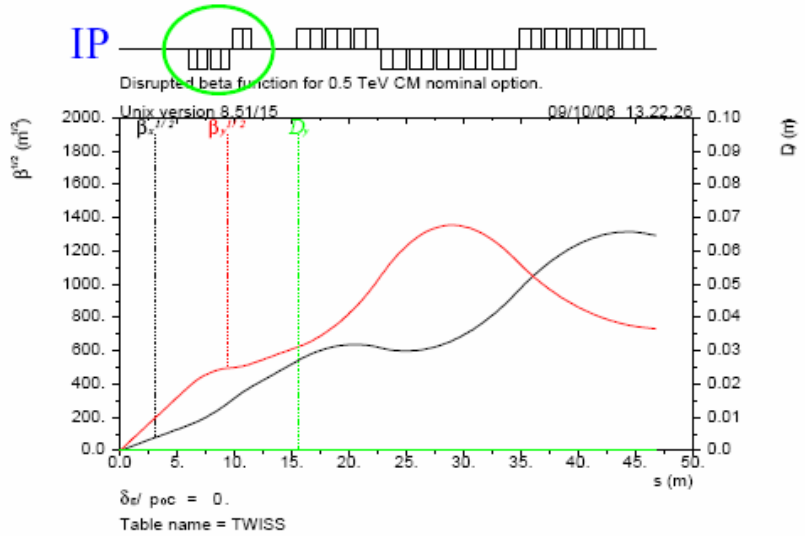
- Adjust the field in the warm quads without changing the positions, lengths and aperture.
- Update apertures in the diagnostic chicanes per K. Moffeit.

http://www-project.slac.stanford.edu/lc/bdir/Meetings/beamdelivery/2006-10-10/061009-dump-14mrad.pdf

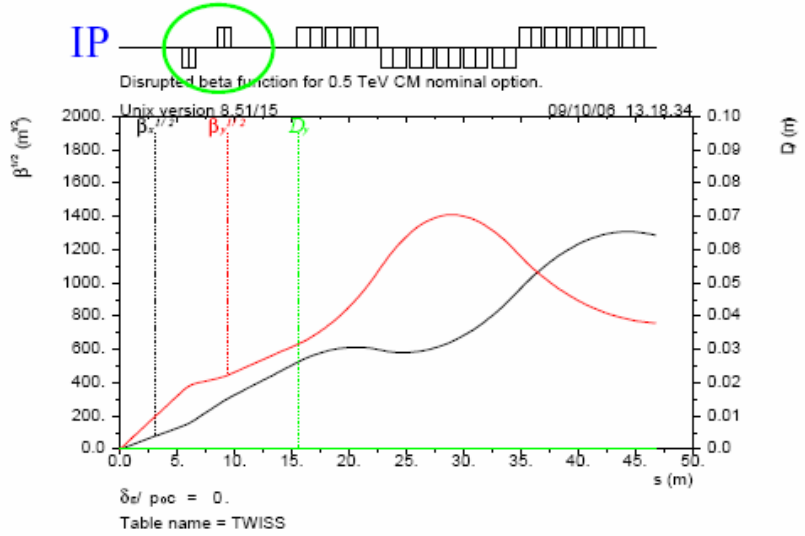

detector
incoming
warm
QF1
SF1
QD0
SD0
QDEX1
QFEX2
outgoing
common cryostat
(inner)
common cryostat
(outer)

Extraction quadrupoles near IP

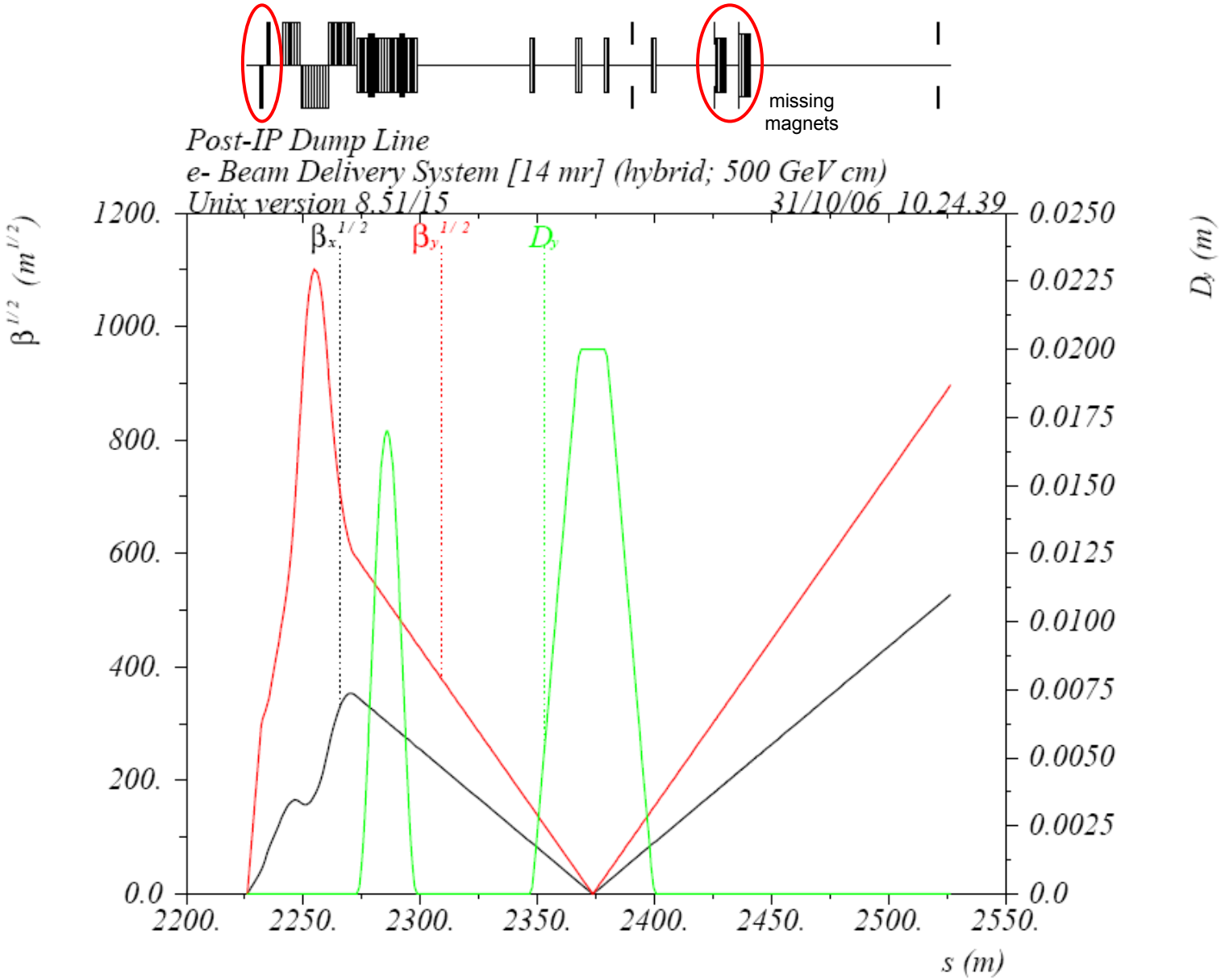
Nominal scheme



Push-pull scheme



Y. Nosochkov's 14 mrad L*= 5.5 m push-pull design



Summary

- ILC2006e system upgrade to 1 TeV cm involves adding magnets only … no geometry changes
  - no expansion into linac tunnel
  - dumps don't move
  - upstream polarimeters don't move
  - add 456 2.4 m "soft" bends, 32 extraction kicker modules, 4 septa, 4 tuneup/extraction bends, and 40 rastering kickers (and replace the Final Doublets) and you're there!
- total BDS Z-length is 4452 m
  - ILC2006c (2 IRs, 1 TeV cm capable) was 5100 m
  - ILC2006d (1 IR, hybrid FF, non-upgradable BSY) was 4125 m
  - ILC2006s (1 IR, non-upgradable, never released) was 3060 m
- can the polarimeter chicane be used by the laserwires and the ΔE/E detection system as envisioned over the full energy range?
  - transverse space for laserwire detector at high energy
  - maintaining ±10% energy acceptance at low energy
  - magnet, vacuum chamber, and diagnostics engineering issues
- bandwidth and collimation efficiency of Final Focus system can be further optimized (FJ)