ILC BDS Emittance Diagnostics: Design and Requirements

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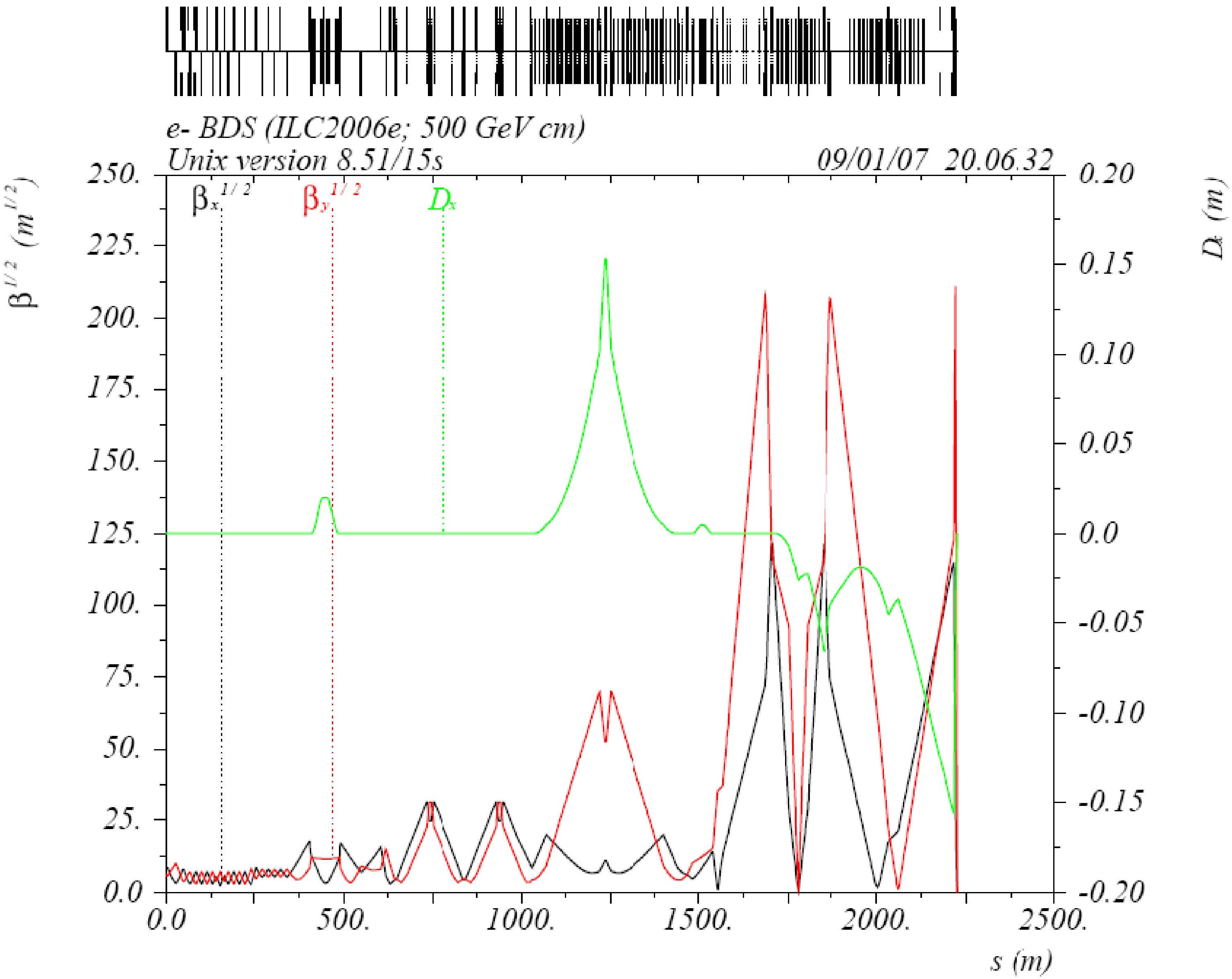
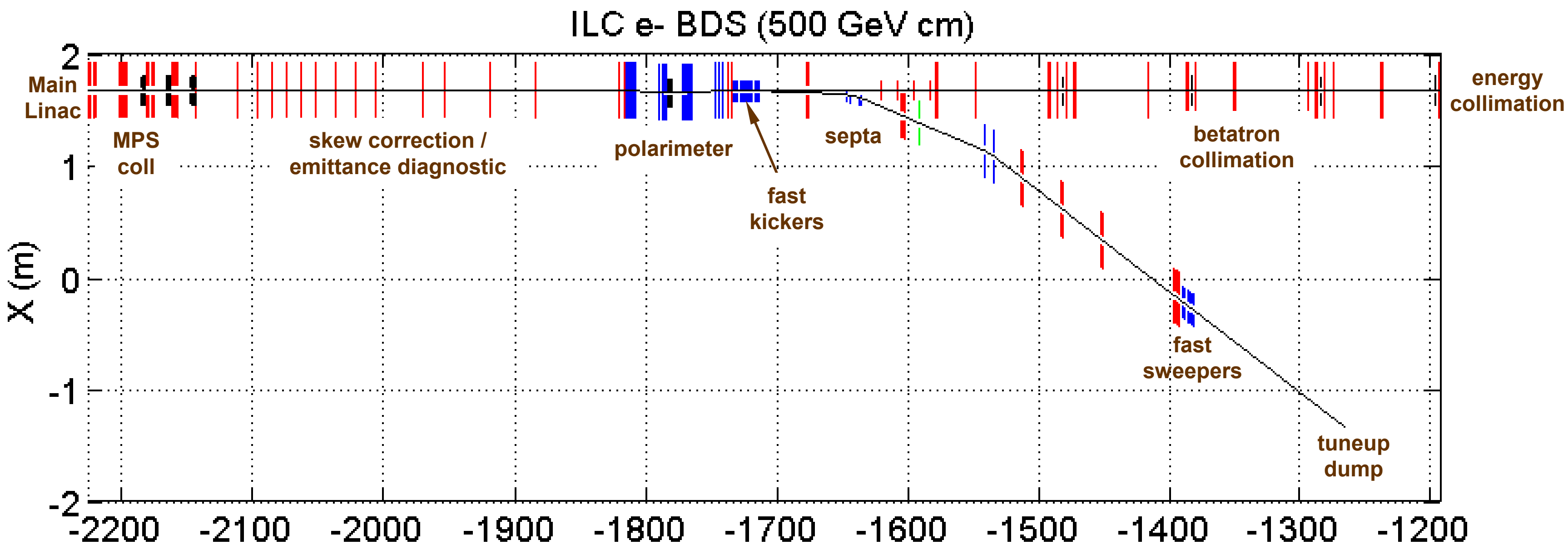
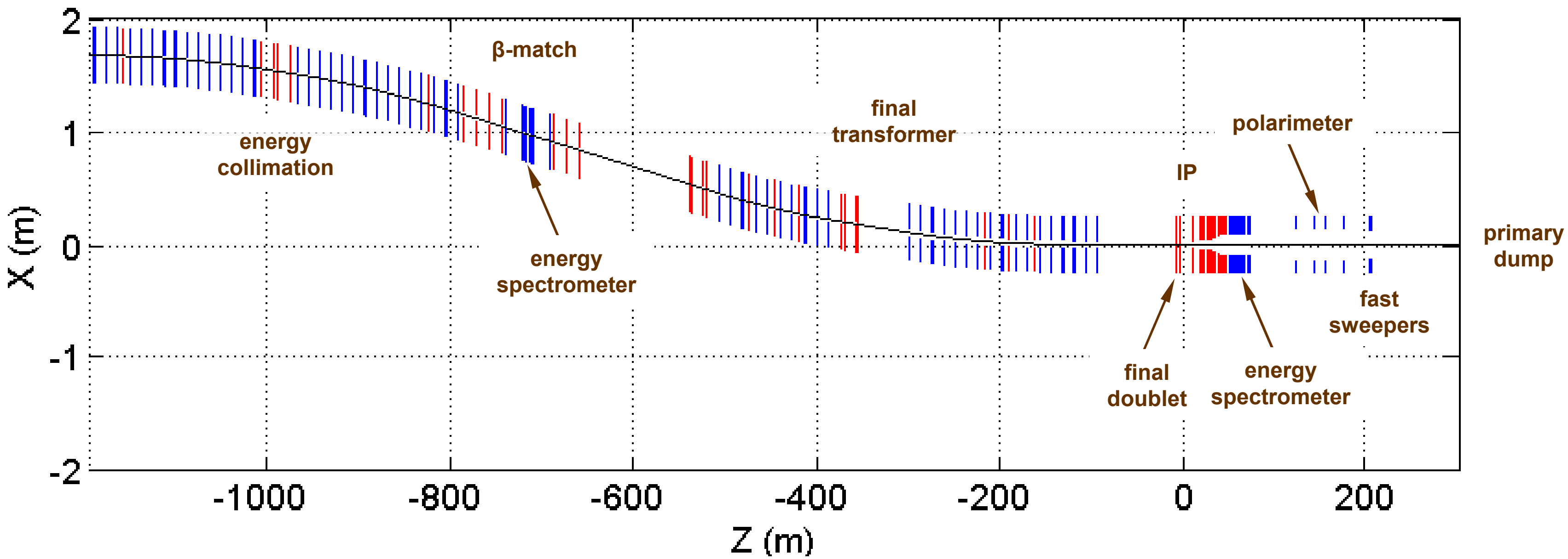


e- BDS (ILC2006e; 500 GeV cm)
Unix version 8.51/15s
09/01/07 20.06.32
β^1/2 (m^1/2)
βx^1/2
βy^1/2
Dx
Dx (m)
s (m)
250.
225.
200.
175.
150.
125.
100.
75.
50.
25.
0.0
0.20
0.15
0.10
0.05
0.0
-0.05
-0.10
-0.15
-0.20
0.0
500.
1000.
1500.
2000.
2500.



ILC2006e electron BDS schematic



“Legacy” BDS Design Criteria

- minimal deviation from linac axis (no net bending) … for possible future multi-TeV operation
- emittance growth from incoherent synchrotron radiation (ISR) should be “small”
  - ILC total budgeted emittance growth from Damping Ring to IP: 20% horizontal, 100% vertical
  - BDS budget: 5% horizontal, 30% vertical
  - BDS design: emittance growth due to ISR < 1% @ 500 GeV (beam)
- bandwidth of fast abort / tuneup extraction line: ±10%

BCD → RDR: BDS 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 ∫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 ∫Gdl for 250 GeV operation by reducing strengths
- Final Doublet magnets will have to be replaced for upgrade to 500 GeV

Emittance Measurement & Correction

- MPS collimation
  - 90° FODO cells
  - sacrificial collimators; reserve 3 m space for each (no real design yet … tapered?)
- coupling correction and emittance diagnostics
  - after main linac
  - at entrance to BDS
  - upstream of fast abort / tuneup extraction (FATx) line
- coupling correction section
  - Paul Emma's 4 orthonormal skew quadrupole coupling correction lattice
  - as short as possible given quadrupole strength limits (9.6 kG @ 6 mm) and 500 GeV operation
- 4 station 2D emittance diagnostic section
  - 4 laserwires
  - 45° FODO lattice
  - as short as possible given minimum measurable spot size (~1 μm)
  - see http://www.slac.stanford.edu/cgi-wrap/getdoc/slac-pub-8581.pdf
- bending system to separate Compton-scattered laserwire photons from primary beam for detection
  - 4 dipole chicane … "share" upstream polarimeter chicane
  - since it's the only dispersive area upstream of the FATx system, include a sacrificial collimator to define the energy acceptance of the FATx system

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

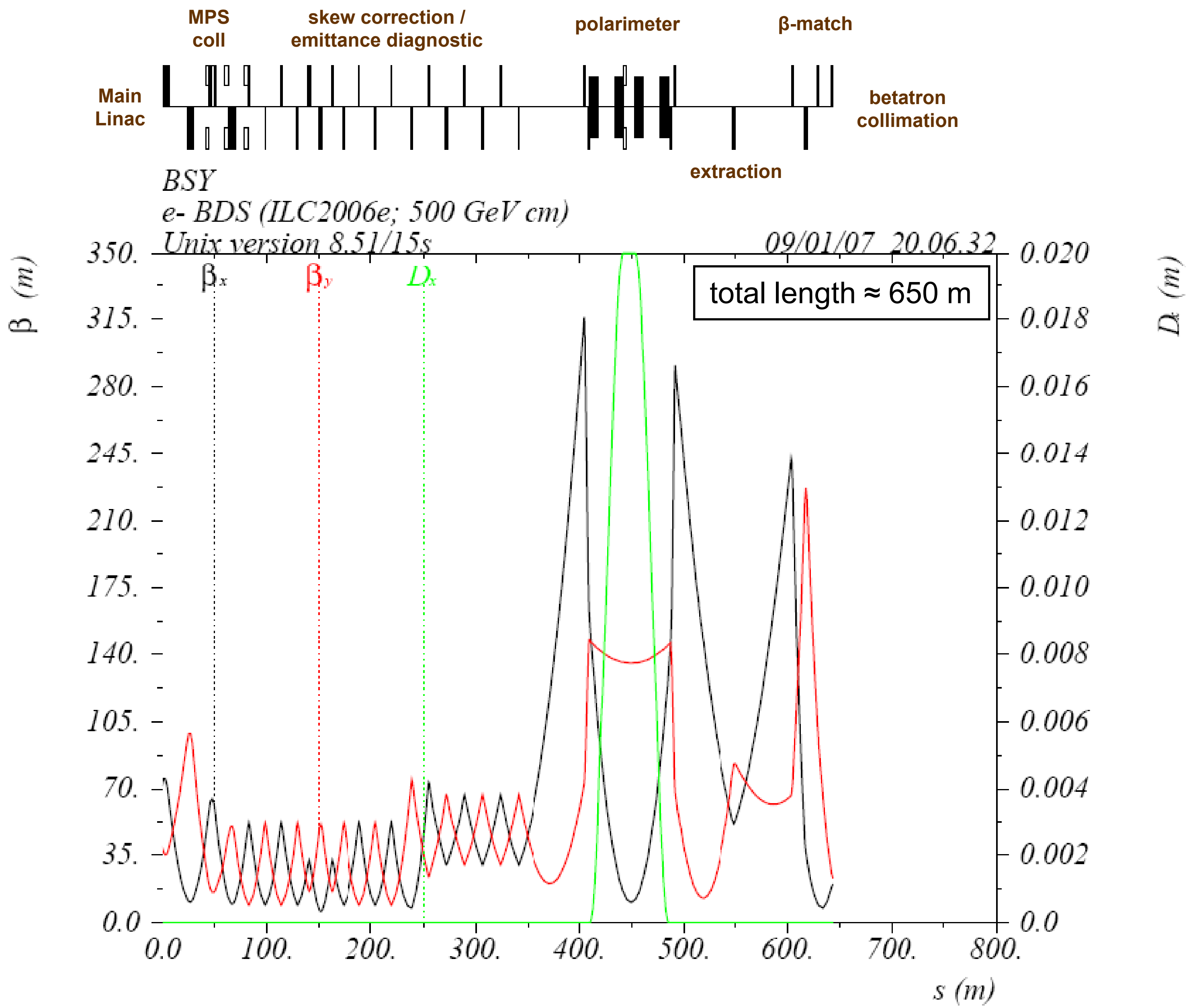
- "worst case" laserwire spot size: DR extracted emittance (2e-8 m), 500 GeV
- "nominal" laserwire spot size: BSY budgeted emittance (3.4e-8 m), 500 GeV
- emittance diagnostic FODO cell length: "worst case" spot > 1.0 um AND "nominal" spot > 1.5 um
  - L45 = 16.2 m (45° FODO cell drift length)
  - BETY(WS) = 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)

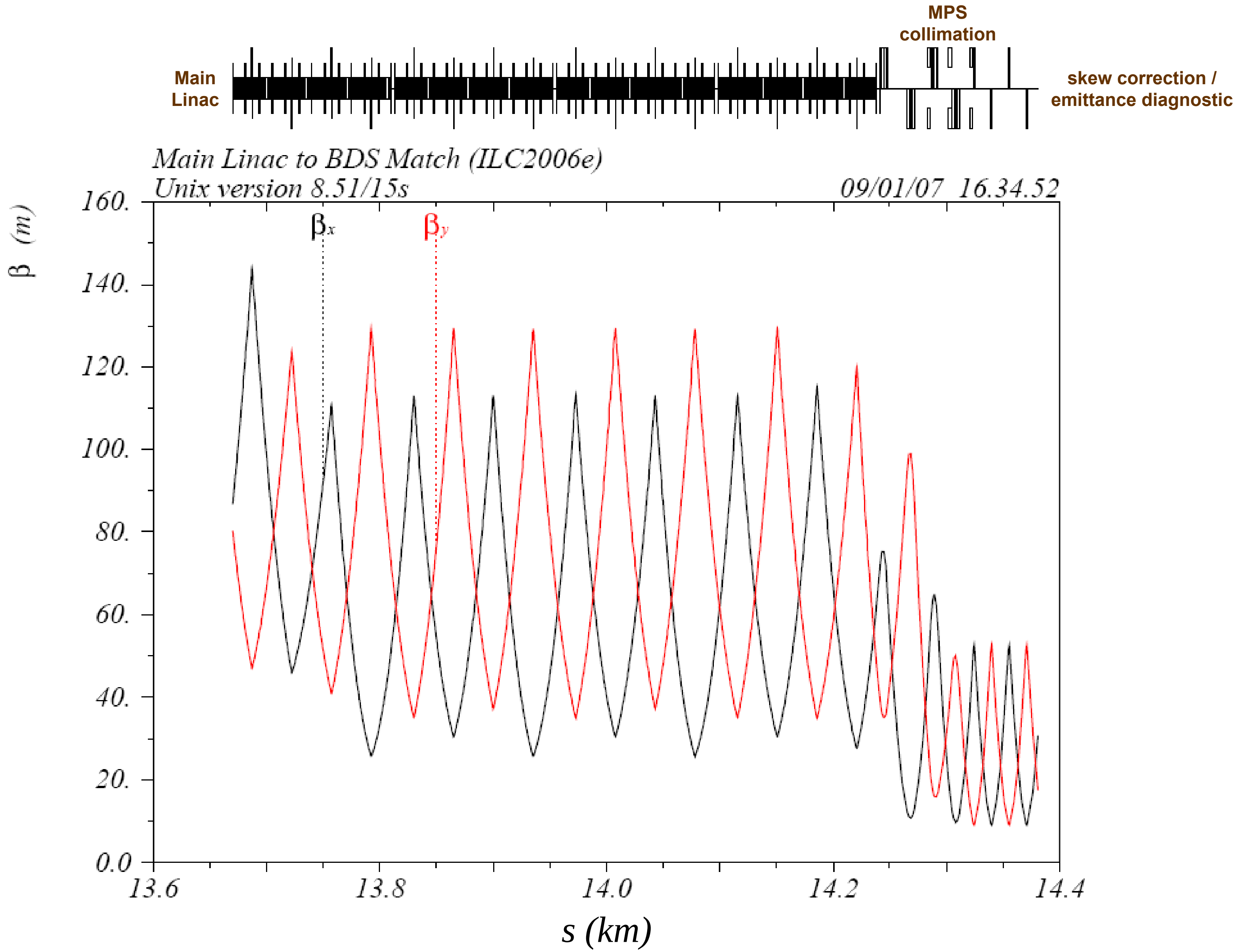
Polarimeter Chicane

- 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)

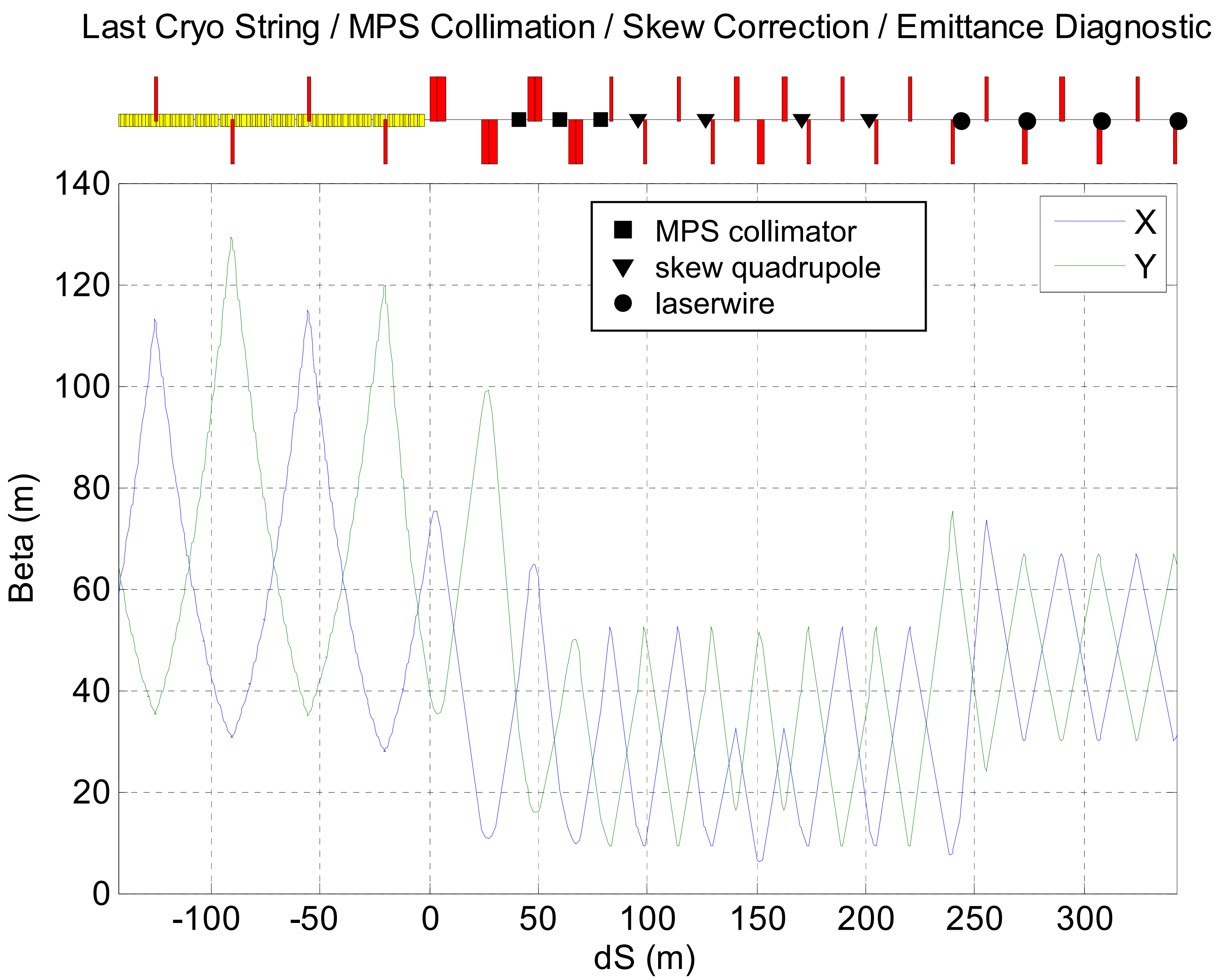
Extraction

- 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

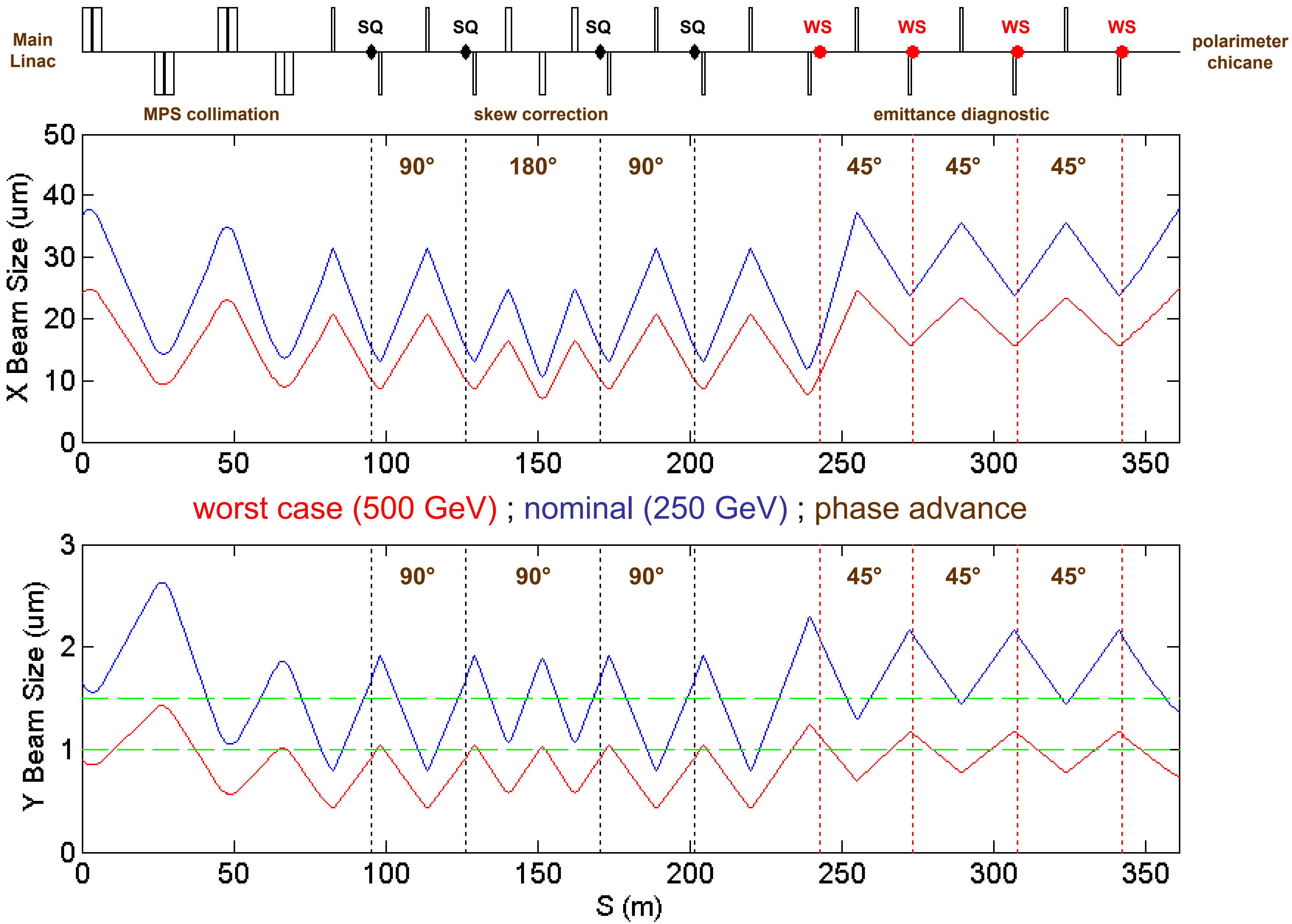

MPS
coll
skew correction /
emittance diagnostic
polarimeter
β-match
Main
Linac
betatron
collimation
extraction
BSY
e- BDS (ILC2006e; 500 GeV cm)
Unix version 8.51/15s
09/01/07 20.06.32
β (m)
D_x (m)
βx
βy
Dx
total length ≈ 650 m
350.
315.
280.
245.
210.
175.
140.
105.
70.
35.
0.0
0.020
0.018
0.016
0.014
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)

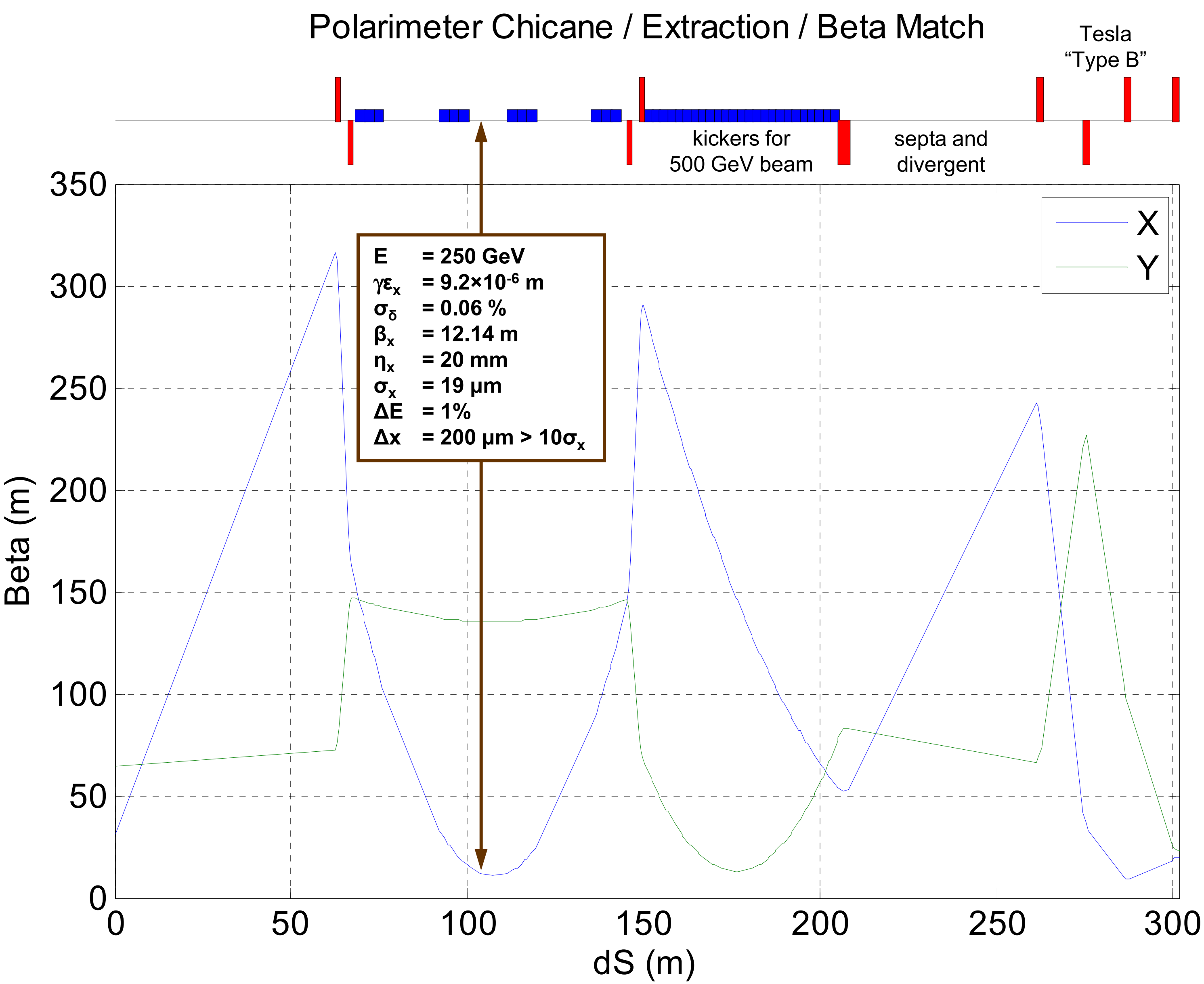


MPS
collimation
Main
Linac
skew correction /
emittance diagnostic
Main Linac to BDS Match (ILC2006e)
Unix version 8.51/15s
09/01/07 16.34.52
β (m)
βx
βy
160.
140.
120.
100.
80.
60.
40.
20.
0.0
13.6
13.8
14.0
14.2
14.4
s (km)


Last Cryo String / MPS Collimation / Skew Correction / Emittance Diagnostic
MPS collimator
skew quadrupole
laserwire
X
Y
Beta (m)
dS (m)
140
120
100
80
60
40
20
0
-100
-50
0
50
100
150
200
250
300

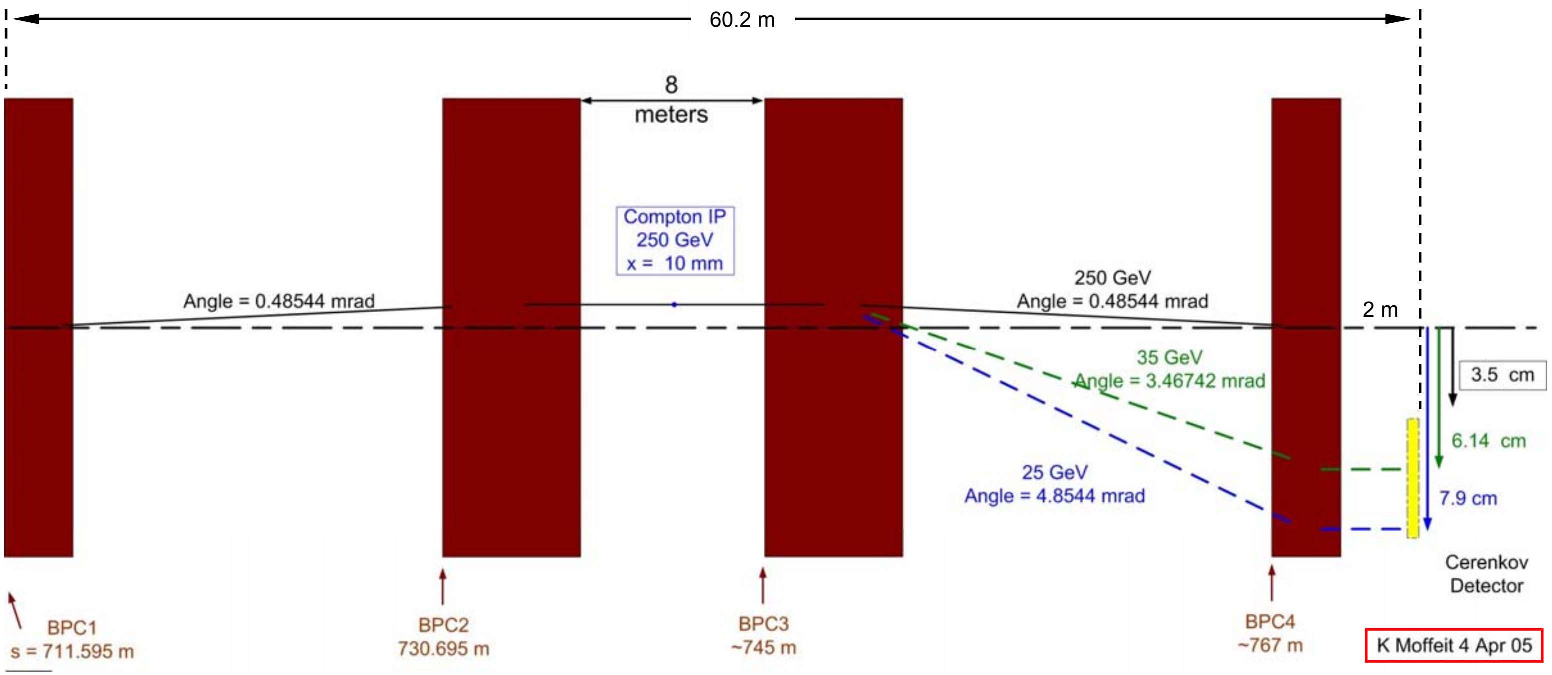
MPS / skew correction / emittance diagnostic





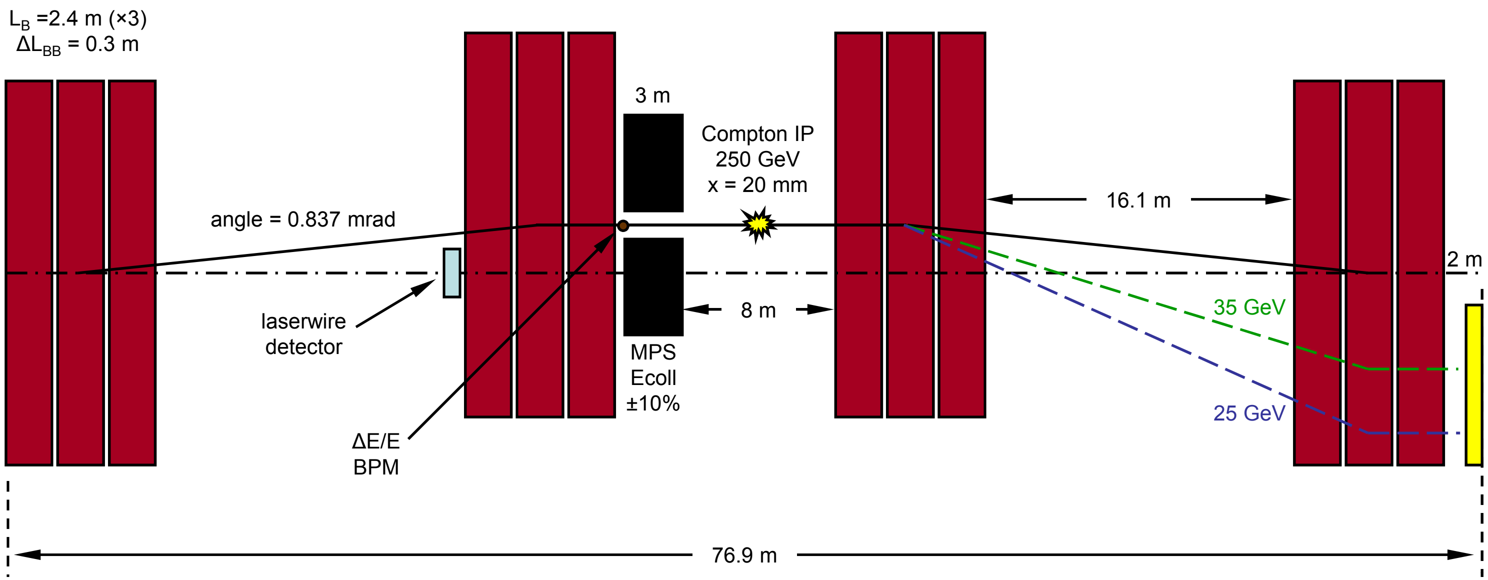
Polarimeter Chicane / Extraction / Beta Match
Tesla
"Type B"
kickers for
500 GeV beam
septa and
divergent
E = 250 GeV
γεx = 9.2×10-6 m
σδ = 0.06 %
βx = 12.14 m
ηx = 20 mm
σx = 19 μm
ΔE = 1%
Δx = 200 μm > 10σx
X
Y
Beta (m)
dS (m)
0
50
100
150
200
250
300
350

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?



Issues & Questions

Nick Walker @ BDS KOM: "Question everything … "

- do we really need coupling correction at the BDS entrance? can it be somehow incorporated into the Main Linac?
- do we really need emittance diagnostics at the BDS entrance? can it be somehow incorporated into the Main Linac? would a shorter, more invasive system (i.e. quadrupole scans) be acceptable?
- what is the minimum and maximum energy range required? capable of 1 TeV cm initially? or lengthened by moving back into the linac tunnel for the upgrade?
- do the laserwires really need a chicane for their detectors? can we just add a small bend to the beamline?
- what are the requirements for upstream polarimetry? is constant dipole field needed? does the sacrificial energy collimator compromise its performance? (see tomorrow's meeting:
  - https://www-mail.slac.stanford.edu/exchweb/bin/redir.asp?URL=https://fnal.webex.com/fnal/j.php?ED=99109907%26UID=0)
- is Giga-Z operation required? what effect does this have on the polarimeter design? cost?
- do we need a separate location for the laserwire detectors, energy collimator, and beam energy diagnostics? another chicane?
- can we use 4D emittance measurement? less invasive coupling correction, but longer system … beam matrix reconstruction technique?