Meeting of the LHC Collimation Working Group 14 Feb 2003, H. Burkhardt

Status of transfer line collimation and LHC protection at injection

- Reference numbers. Intensities, number of sigma

- Detailed look at transfer line Ti8

- Possible protection system and its expected performance reference numbers   collimation should be at least ok for nominal

SPS   (450 GeV)

- 1.1e11 protons per bunch, $\varepsilon = 7.82$ nm ($\varepsilon_N = 3.75$ μm), $\sigma_e = 4.68 \times 10^{-4}$
- 72 bunches per batch
- 3 or 4 batches,   max. intensity 4x72x1.1e11 = 3.2e13

  (and 4x72x1.7e11 = 4.9e13 or about 5e13 ultimate), 4 / 11 of an SPS turn or 7.2 μs

LHC, 450 GeV (injection)

- 1.1e11 per bunch
- 2808 bunches, in total 3.1e14 protons (2x12 SPS pulses)

Extraction done in single SPS turn at 450 GeV. For fast losses

- Damage level ~ 2e12 protons   and   Quench level ~ 1e9 protons

Attenuation factor for passive protection in the transfer lines:

> 20 to avoid damage   (better of order 100, Brennan)

From the SPS to the LHC

under standard running conditions, well adjusted, high intensity

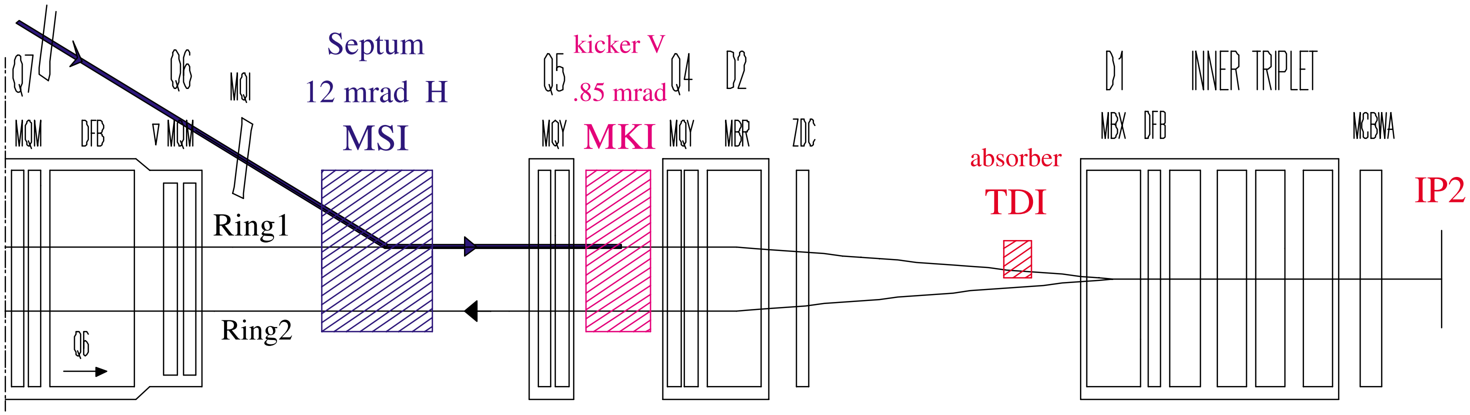
- SPS shave the beam before extraction to 4 σ in V and H
  injection tolerances:
  SPS c.o., SPS extraction, transfer line ripple and drifts, injection kicker ripple and drifts, all together 1.5 σ (LHC Report 208)
  or 5.5 σ filled with incoming beam in the LHC

- LHC: injected beam with tolerances and injection oscillations
  after about 1/2 turn:
  primary collimators at 6 – 7 σ, secondaries at 8.5 – 10 σ
  TDI, prim. and secondary collimators can survive full batch 3 – 5 e13

possible failures, and protection

SPS LSS4 fast 1.1 μs extraction kicker MKE, 0.5 mrad in H
followed by DC septum MSE, protected by TPSG (4m , C + Al + Cu)
Vertical Injection kicker MKI at end of Ti2/8
TDI protection against kicker failures 8 – 10 σ in V
wrong bending fields in pulsed transfer lines

Injection Region, here IP2 (IP 8 injected beam comes from the bottom)



- MSI thin, tight septum magnets with horizontal deflection
- MKI vertical kicker, brings beam in LHC plane
- TDI + secondary coll. downstream IP, to protect in V againts kicker failures

- the transfer line (warm magnets) is turned off when no injection is needed and pulsed horizontal extraction from SPS (MKE) and many horizontal + some vertical bends, wrong bending could result in local loss of full intensity
  most critical: end of line with tight septum

--> passive protection for septum needed. At the same time limit injection oscillations.

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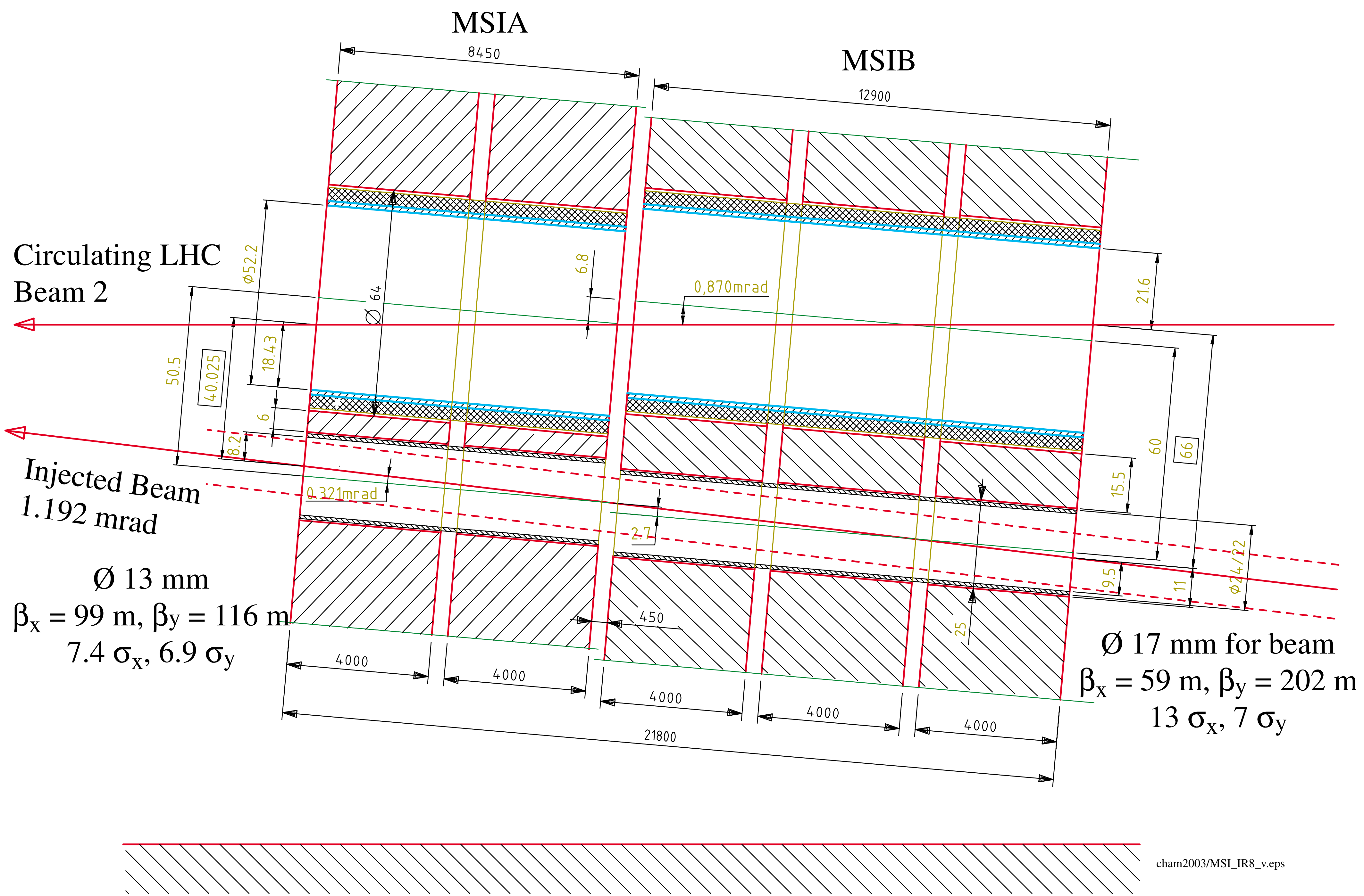
Septum MSI Ti8, seen from the side



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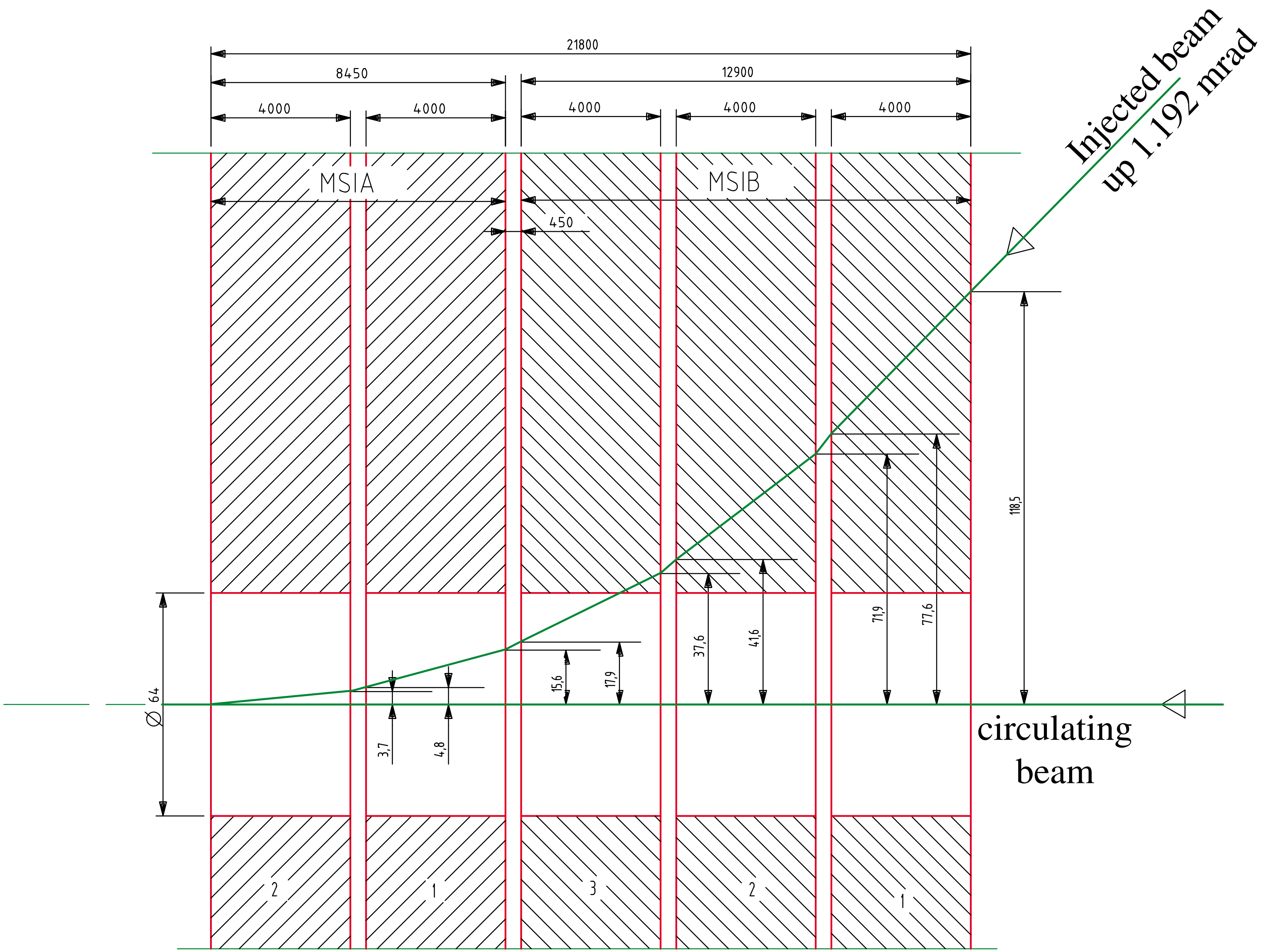
Septum MSI Ti8, seen from the top, in the plane of the circulating beam



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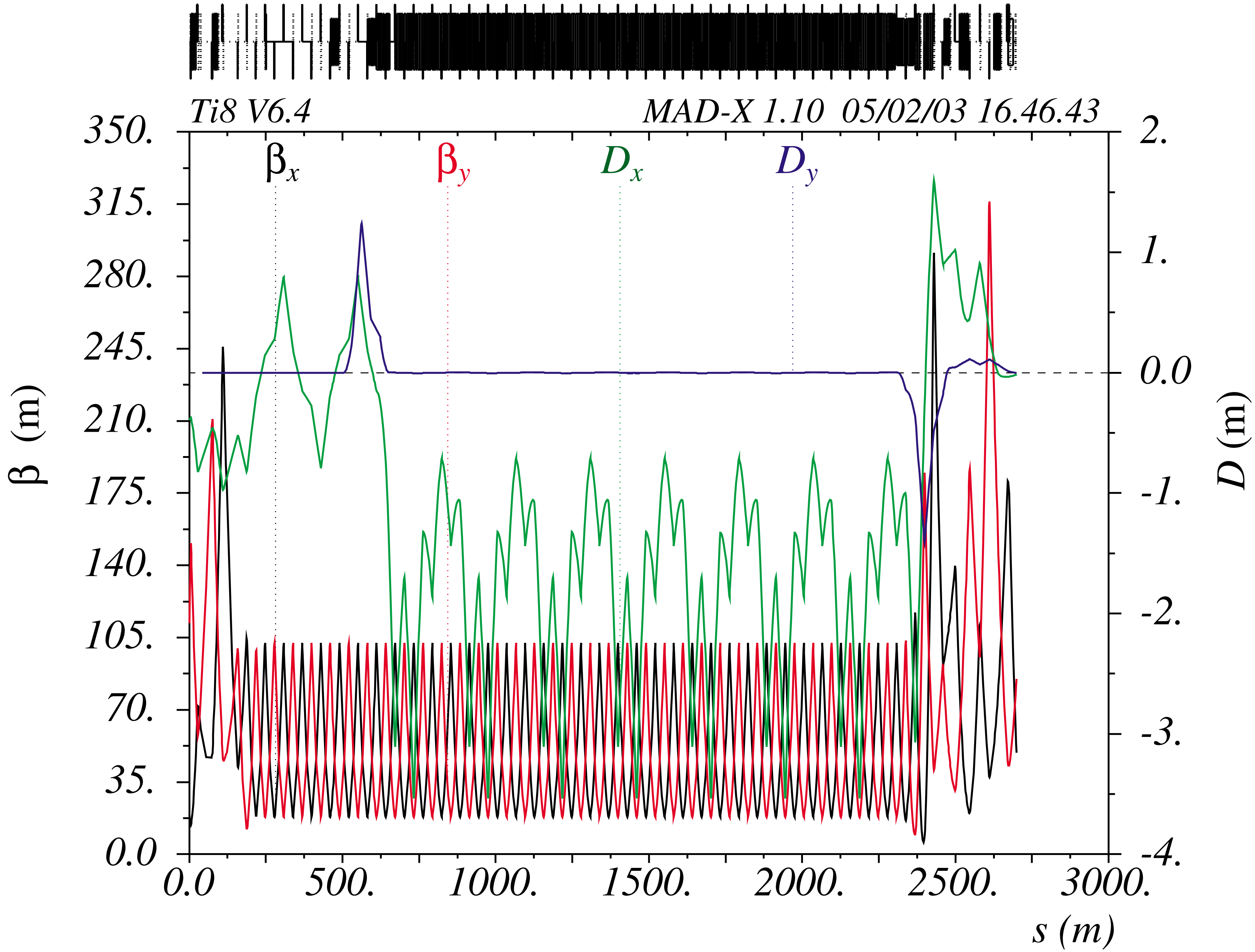

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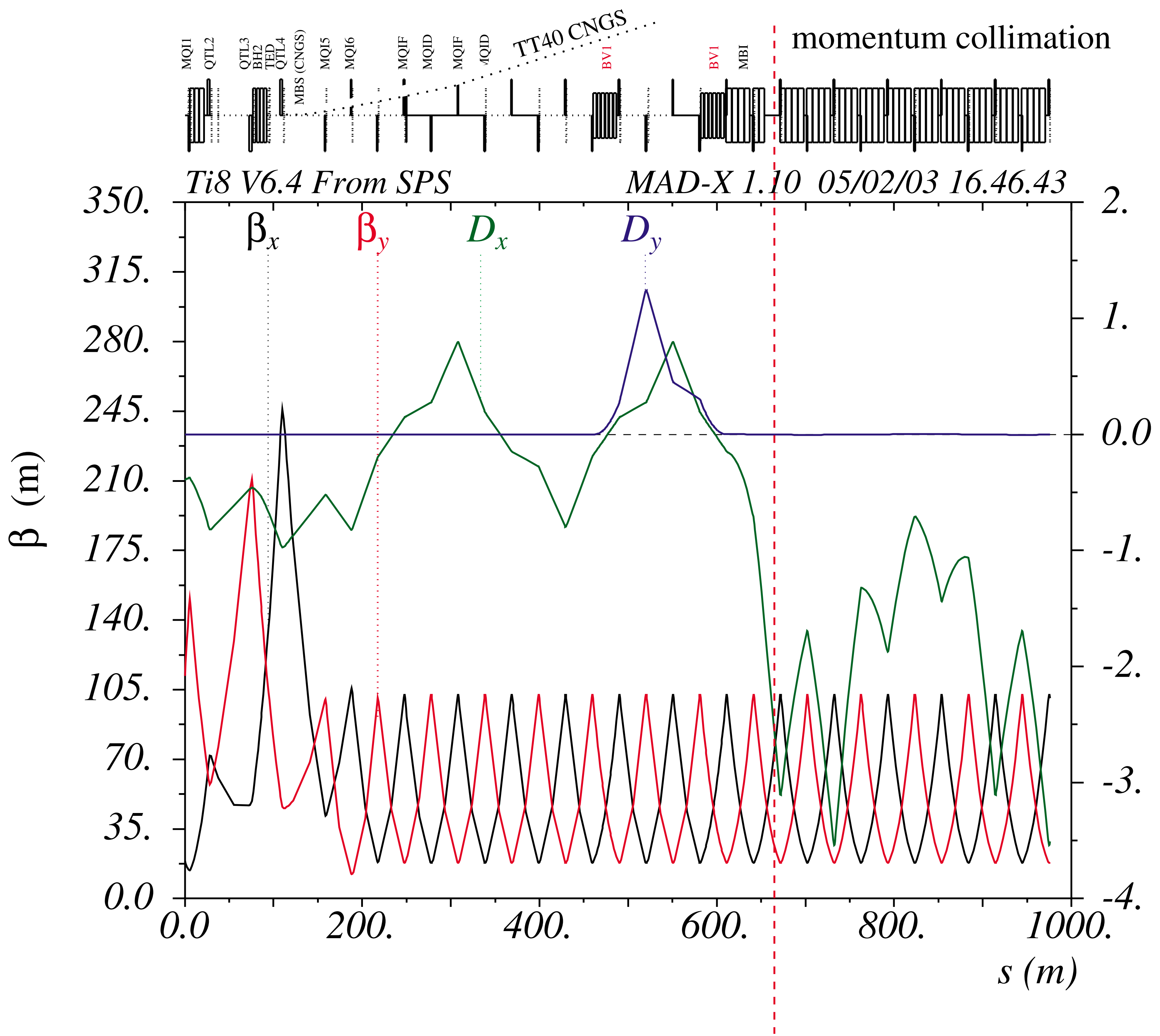

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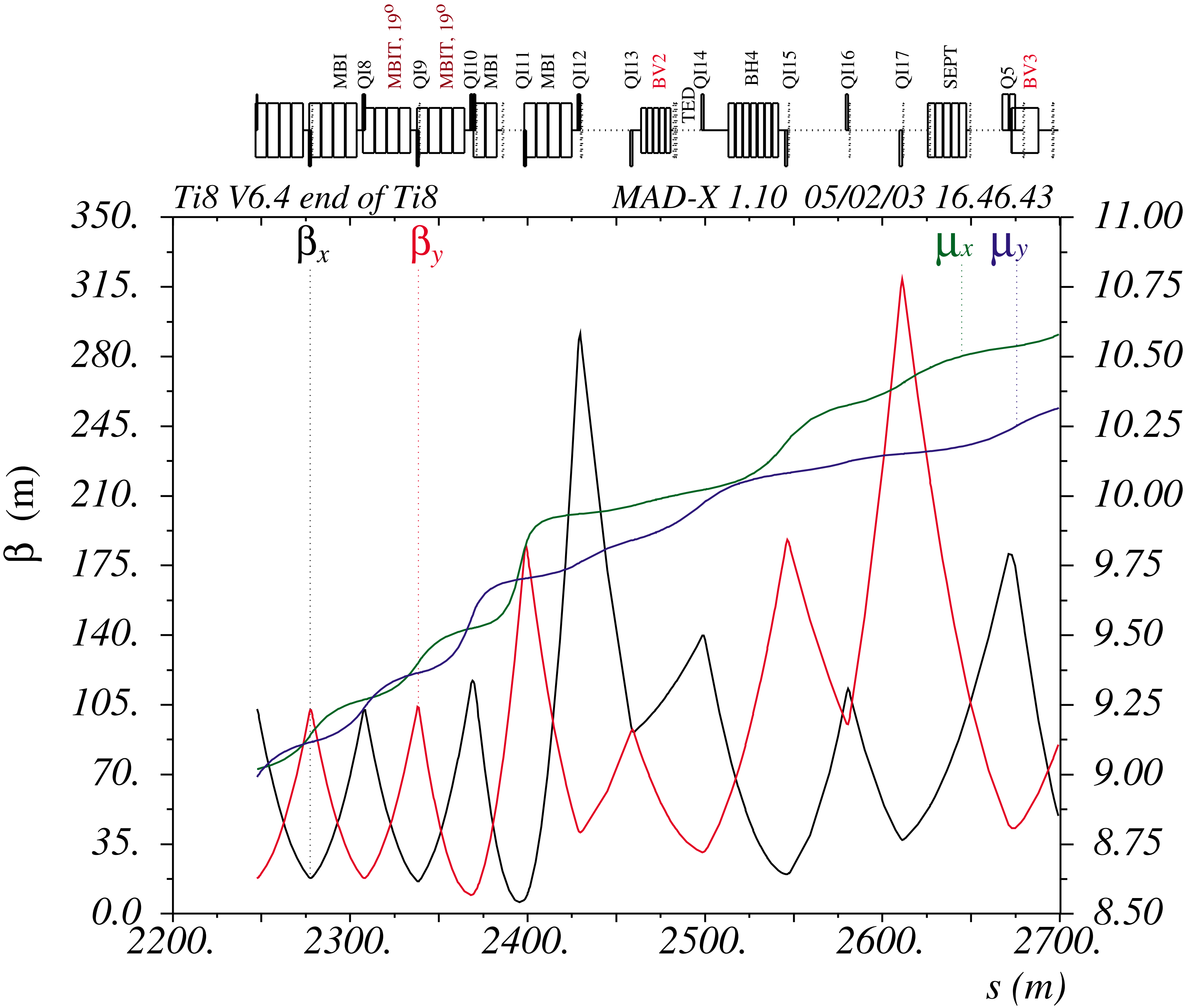

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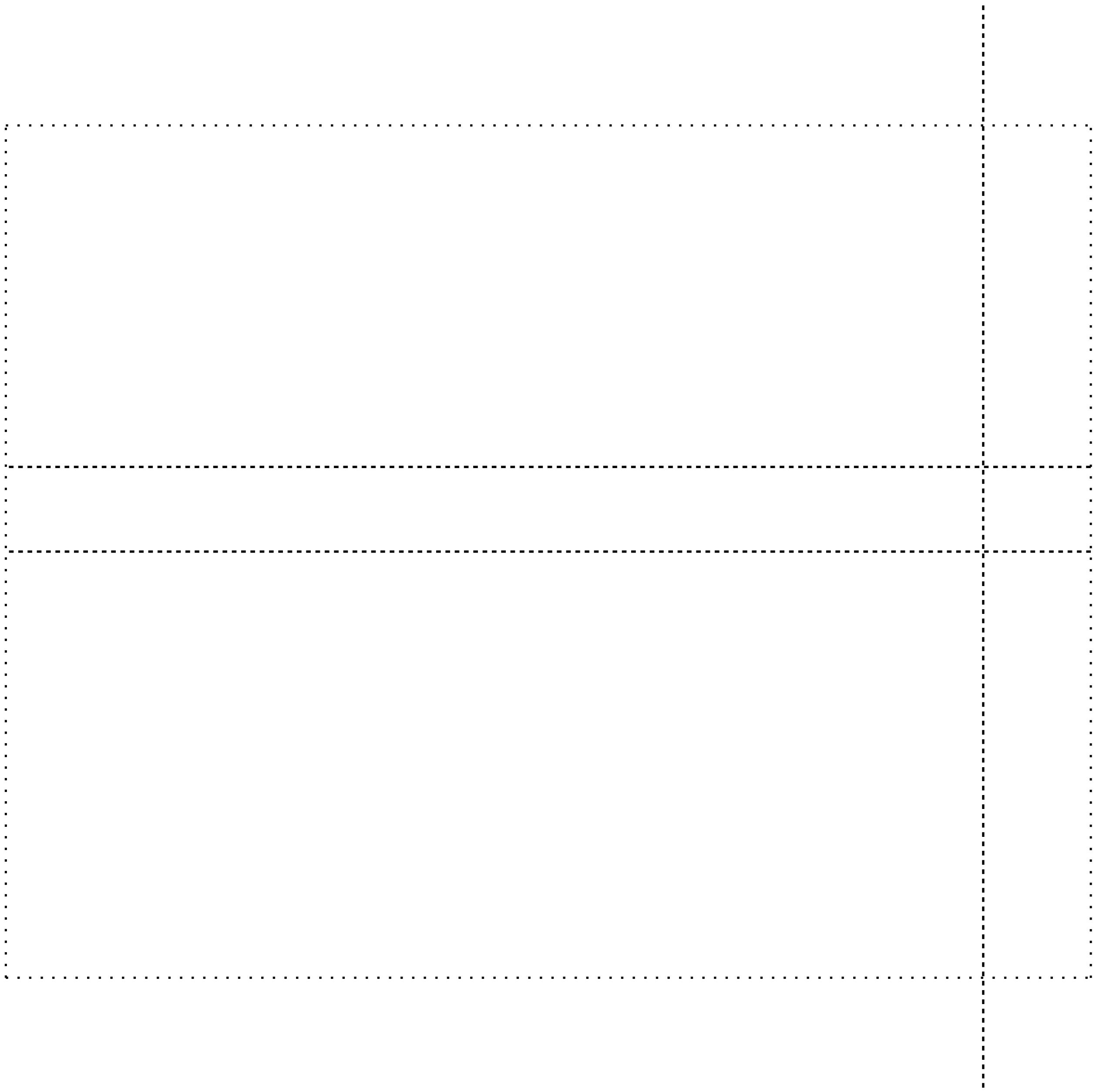

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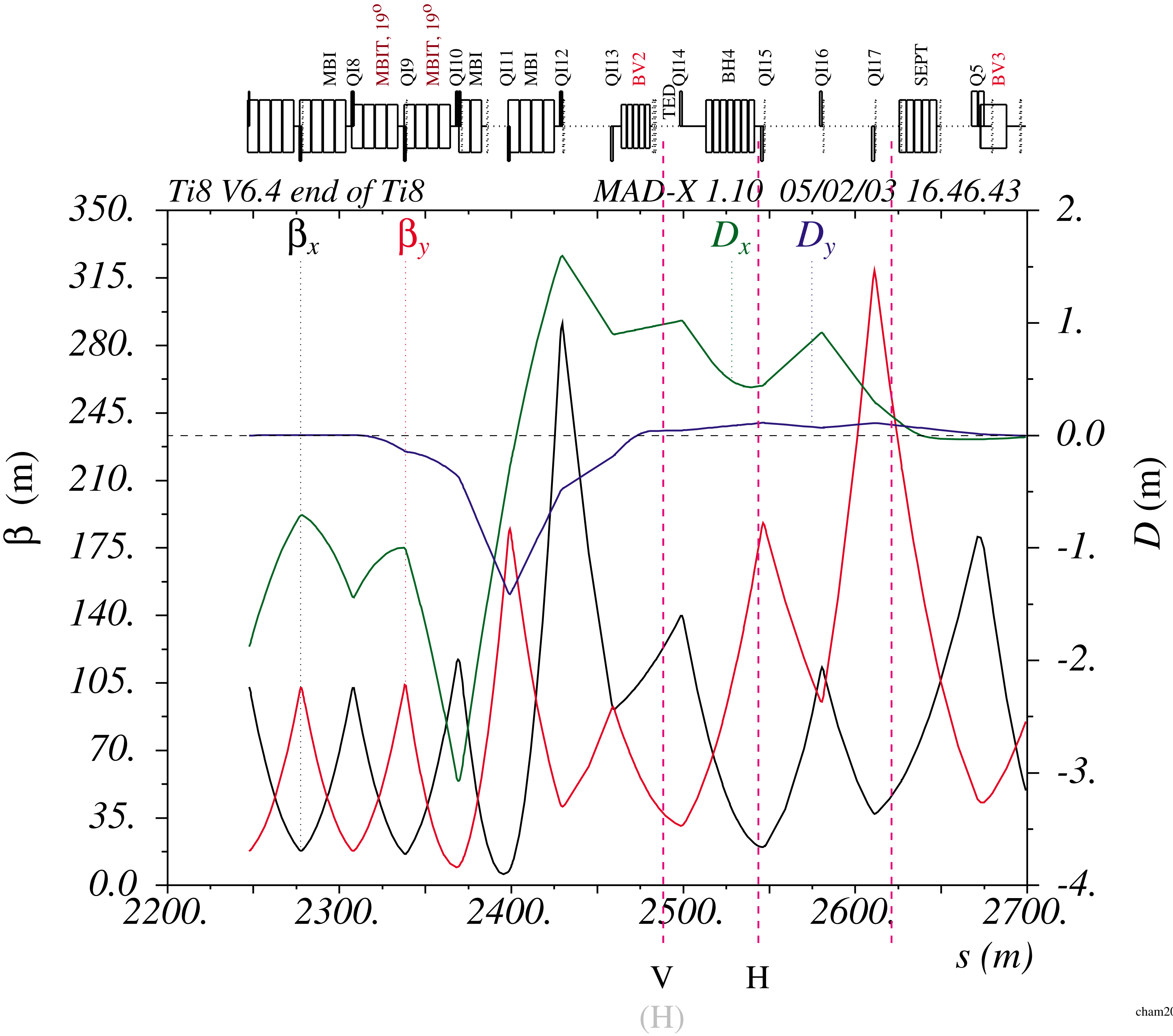

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Proposal

1) H momentum cleaning at beginning of the line
2) V about 90^{o} from Septum and 180^{o} in H, in front of TED
3) H about 90^{o} from Septum
4) Septum protection

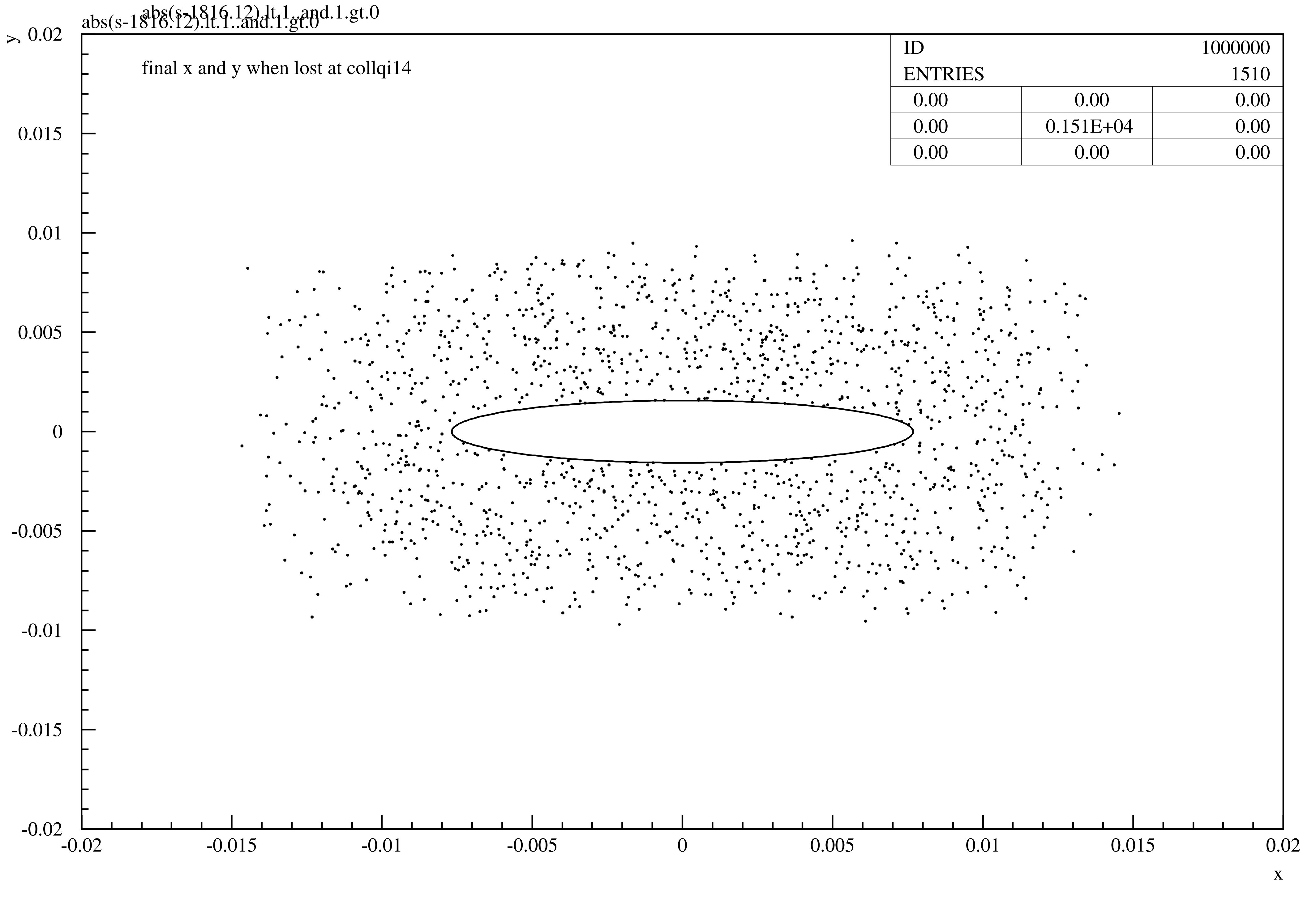
with number for optics in Ti8:

Name	s, m	β_x, m	D_x, m	σ_x, mm	frac disp	μ_x	$\Delta\mu_x$ to MSI
H							
COLLMOM	671	102	-3.08	1.69	2.62	2.52	20^{o}
COLLQI14	2487	122	0.99	1.08	0.22	9.92	163^{o}
COLLQI15	2546	19.8	0.44	0.45	0.28	10.19	97^{o}
COLLMSI	2627	54.3	0.11	0.65	0.006	10.46	0^{o}
V	s, m	β_y, m	D_y, m	σ_y, mm	frac disp	μ_y	$\Delta\ \mu_y$
COLLMOM	671	18.2	-0.001	0.38	0.00	2.49	117^{o}
COLLQI14	2487	38.4	0.042	0.55	0.001	9.92	87^{o}
COLLQI15	2546	186	0.11	1.2	0.002	10.1	29^{o}
COLLMSI	2627	218	0.09	1.31	0.001	10.16	0^{o}

5σ collimation would imply rather narrow apertures

H $\pm$ 2.3 mm at QI15

V $\pm$ 2.8 mm at QI14


abs(s-1816.12).lt.1..and.1.gt.0
abs(s-1816.12).lt.1..and.1.gt.0
final x and y when lost at collqi14
ID 1000000
ENTRIES 1510
0.00 0.00 0.00
0.00 0.151E+04 0.00
0.00 0.00 0.00
y
0.02
0.015
0.01
0.005
0
-0.005
-0.01
-0.015
-0.02
-0.02
-0.015
-0.01
-0.005
0
0.005
0.01
0.015
0.02
x

Transfer Line Collimation Performance Estimate

- momentum collimation $D_X = 3.5$ m, $r_X = +/- 3.2$ cm, $\sigma_X = 2$ mm.
  max. momentum acceptance arc $\Delta E/E = +/- 2.8$ cm/3.5 m = +/- 0.8 %
  mom. collimation at $D_X = 3$ m, $\beta_X = 100$ m, $1\sigma = 1.7$ mm, set to 5σ or +/- 8.5 mm
  limits $\Delta E/E = +/- 8.5$ mm / 3.5 m = +/- 0.24 %

- betatron collimation estimate,
  critical thickness in carbon at 450 GeV $b_c = 12\ \mu$m
  for flat losses over 5 mm collimation by 5 mm / 12 μm = 420
  worst full impact of small beam s = 0.5 mm, still collimation by about 40

multiple scattering $$\theta_0 = \frac{13.6\,\mathrm{MeV}}{\beta c p}\sqrt{x/X_0}\,[1 + 0.038\log(x/X_0)] \approx 53\,\mu\mathrm{rad}$$

Graphite $\rho = 2.3$ g/cm^3 ; nuclear interaction length $\lambda = 26.6$ cm, 2λ as distance x, $X_0 = 18.8$ cm