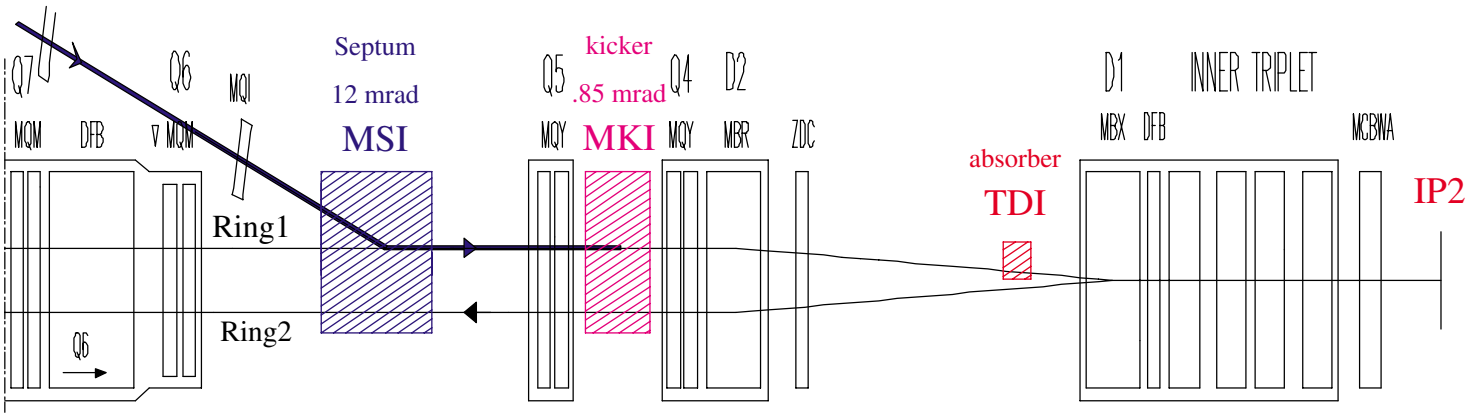
Collimation in the SPS-LHC transfer lines

- **Why passive protection in the transfer lines TI 2,8 ?**
  the inj. lines to the LHC are pulsed
  single batch (2.6e13 protons, 450 GeV) can do serious damage

- **protect LHC from bad injection**
  TDI only effective in the vertical plane for kicker failures
  passive protection in the transfer lines should also limit horizontal inj. oscillations
  depending on LHC collimator design, transfer line protection could also reduce risk of damage of collimation devices in the LHC

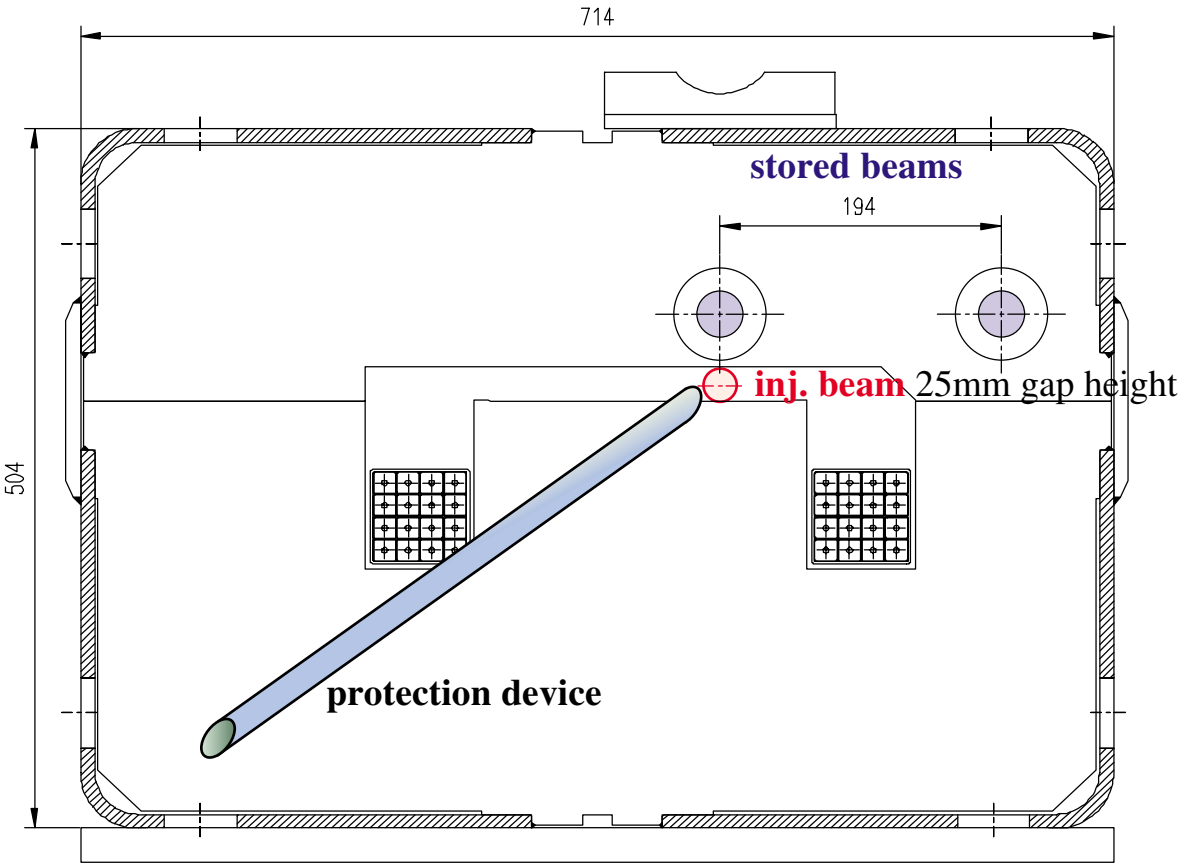


- **Main idea**
  passive protection in front of the septum (MSI)
  complemented by further device(s) at $\Delta = 90^{o}$ phase
  also consider momentum collimation at beginning of the lines

- **Look for best compromise between**
  simple, cheap, effective (narrow fixed pipe/collimators)
  easy operation/setup of injection (sufficient aperture for setup with pilots)

lhcinj/Title8.eps

1) passive protection of the septum



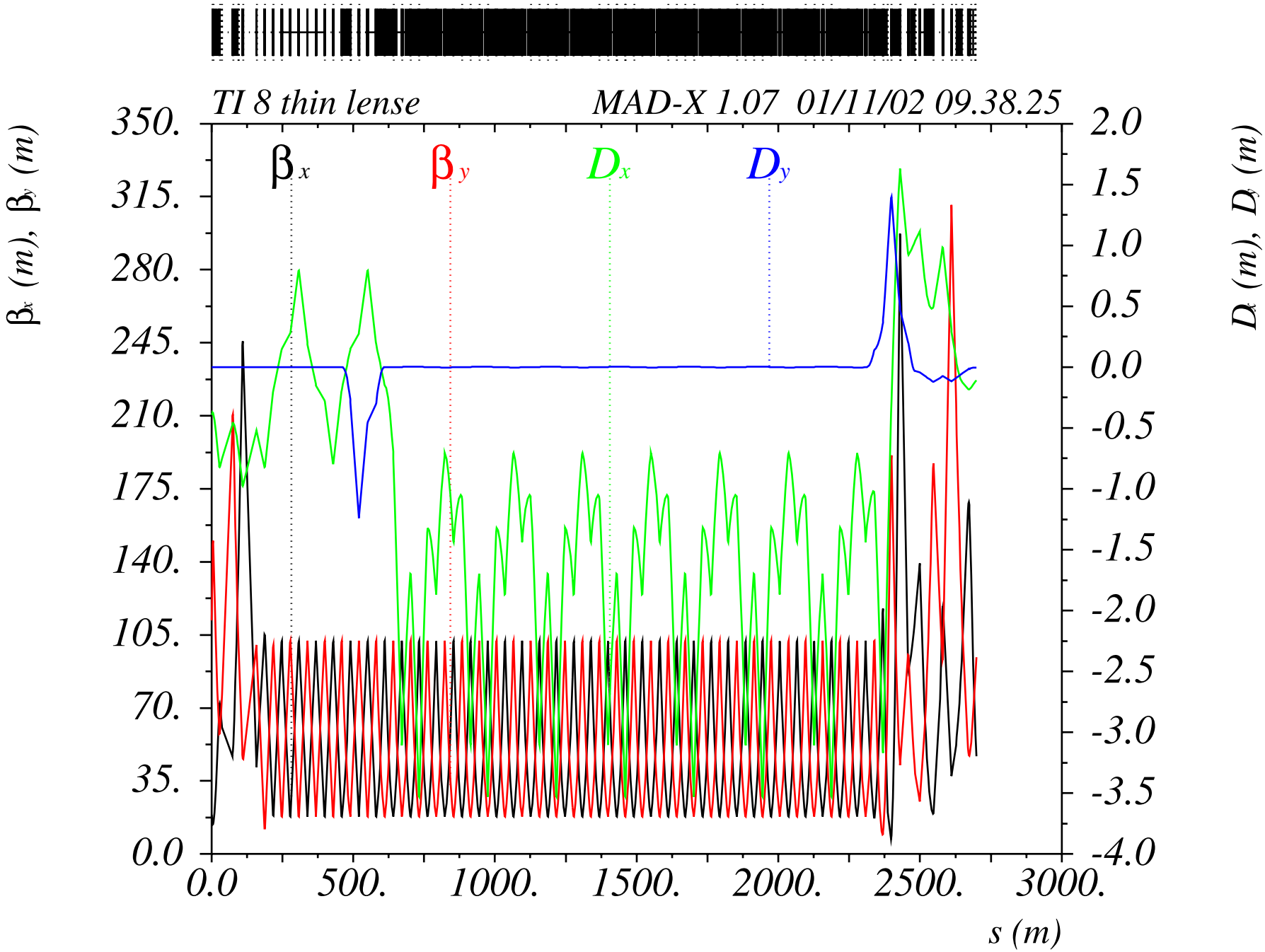
Septum (MSI) made of 5 magnets, 12 mrad total horizontal deflection
25 mm gap height, physical aperture for beam at best ~ 12 mm radius

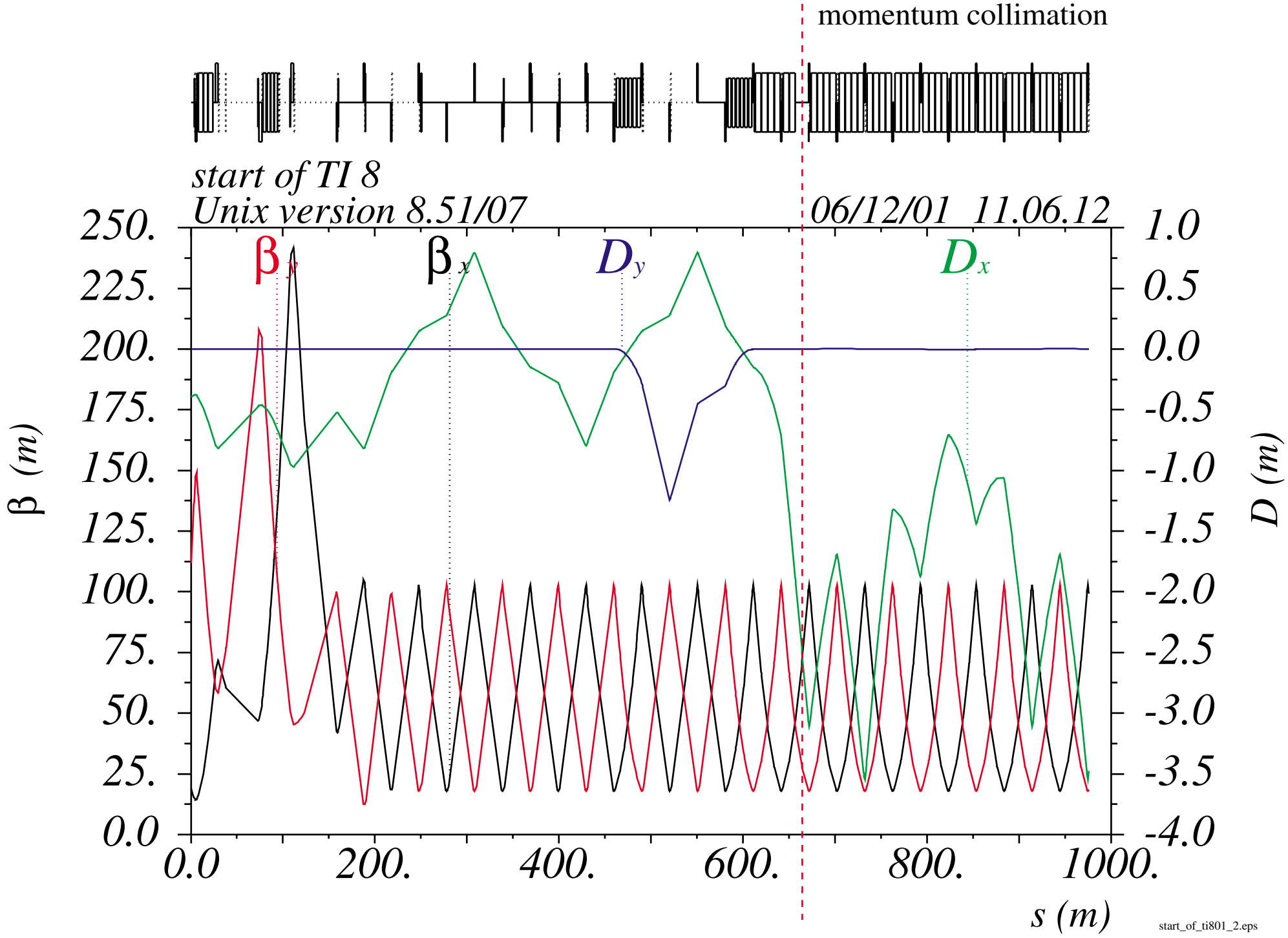
optics parameters, (nominal beam $\varepsilon = 7.8$ nm, $\Delta p/p = 0.47e\text{-}3$)
H $\beta =$ 52 m D = 0.07 m $1\sigma = 0.64$ mm
V $\beta = 216$ m D = 3.0 m $1\sigma = 1.9$ mm (1/3 from $\Delta p/p$)

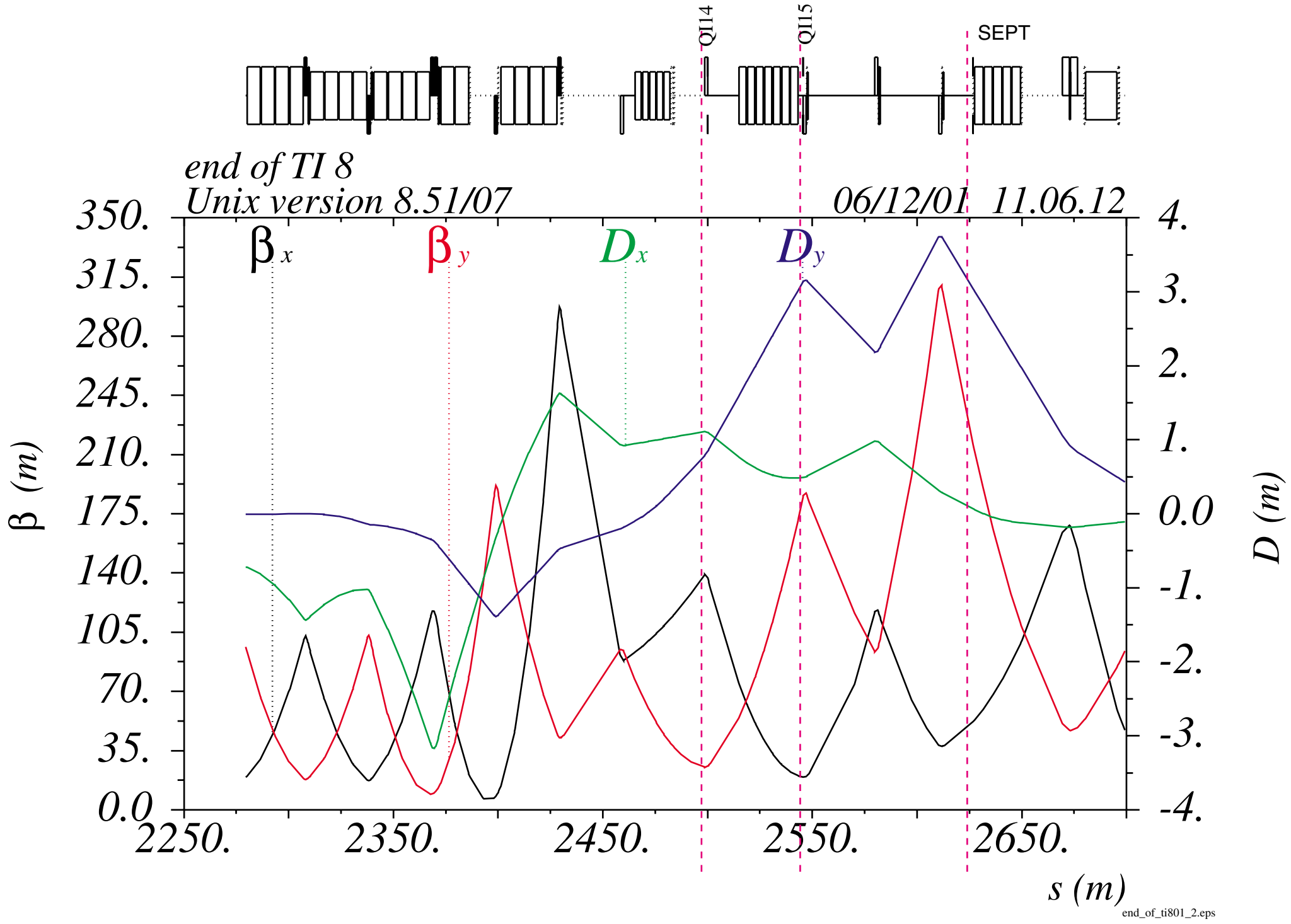
protection at 5σ would correspond to
$\pm$ 9.5 mm in V
$\pm$ 3.2 mm in H ($\pm$10 mm in H is 15.6σ or rather poor protection in LHC)

Consider: 3-4 m pipe with inside rings of low Z high temp. materials like Graphite or Boronnitrit

lhcinj/septum.eps


TI 8 thin lense
MAD-X 1.07 01/11/02 09.38.25
βx (m), βy (m)
Dx (m), Dy (m)
βx
βy
Dx
Dy
350.
315.
280.
245.
210.
175.
140.
105.
70.
35.
0.0
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
-3.5
-4.0
0.0
500.
1000.
1500.
2000.
2500.
3000.
s (m)


momentum collimation
start of TI 8
Unix version 8.51/07
06/12/01 11.06.12
β y
β x
D y
D x
β (m)
D (m)
250.
225.
200.
175.
150.
125.
100.
75.
50.
25.
0.0
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
-3.5
-4.0
0.0
200.
400.
600.
800.
1000.
s (m)
start_of_ti801_2.eps


QI14
QI15
SEPT
end of TI 8
Unix version 8.51/07
06/12/01 11.06.12
βx
βy
Dx
Dy
β (m)
D (m)
s (m)
350.
315.
280.
245.
210.
175.
140.
105.
70.
35.
0.0
4.
3.
2.
1.
0.0
-1.
-2.
-3.
-4.
2250.
2350.
2450.
2550.
2650.
end_of_ti801_2.eps

Currently considered and simulated tracking now with madx
passive devices, narrow pipes exchangeable or movable

1) H momentum cleaning at beginning of the line
2) V about 90^o from Septum
3) H about 90^o from Septum
4) Septum protection

with number for optics in Ti8:

Name	s, m	βx, m	Dx, m	σx, mm	frac disp	μx	Δμx	Δϕ, ^{0}
H								
COLLMOM	671.144	101.157	-3.078	1.693	2.62	2.518	0	
COLLQI14	2500.071	137.089	1.101	1.157	0.25	10.017	7.499	158^o
COLLQI15	2545.685	19.263	0.49	0.451	0.35	10.191	7.673	95^o
COLLMSI	2626.801	52.068	0.068	0.639	0.00	10.456	7.938	
V	s, m	βy, m	Dy, m	σy, mm	frac disp	μy	Δ μy	
COLLMOM	671.144	18.175	-0.001	0.377	0.00	2.485	0	
COLLQI14	2500.071	25.788	0.845	0.598	0.78	9.998	7.513	70^o
COLLQI15	2545.685	185.696	3.145	1.902	1.49	10.113	7.628	29^o
COLLMSI	2626.801	215.791	3.043	1.928	1.20	10.193	7.708	

5σ collimation would imply rather narrow apertures
H – 2.3 mm at QI15
V – 3.0 mm at QI14

Ti8, 2 and Madx

madx is new standard for LHC optics works; offers

- all optics and aperture information in one single file , for example

MQI5: QUADRUPOLE, L:=1.4, K1:=-.027873688578,apertype=ellipse,aperture={0.0135,0.02 }; // high

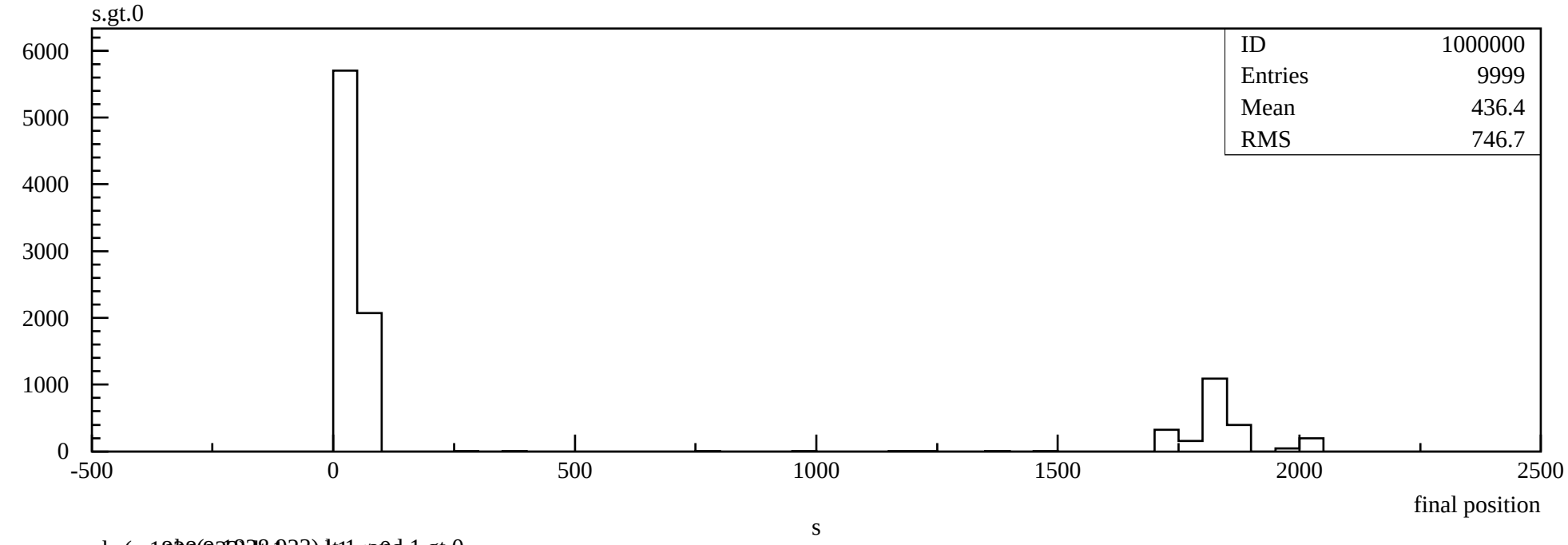
MQI6: QUADRUPOLE, L:=1.4, K1:=.027973832401 ,apertype=ellipse,aperture={0.02 ,0.0135}; // flat

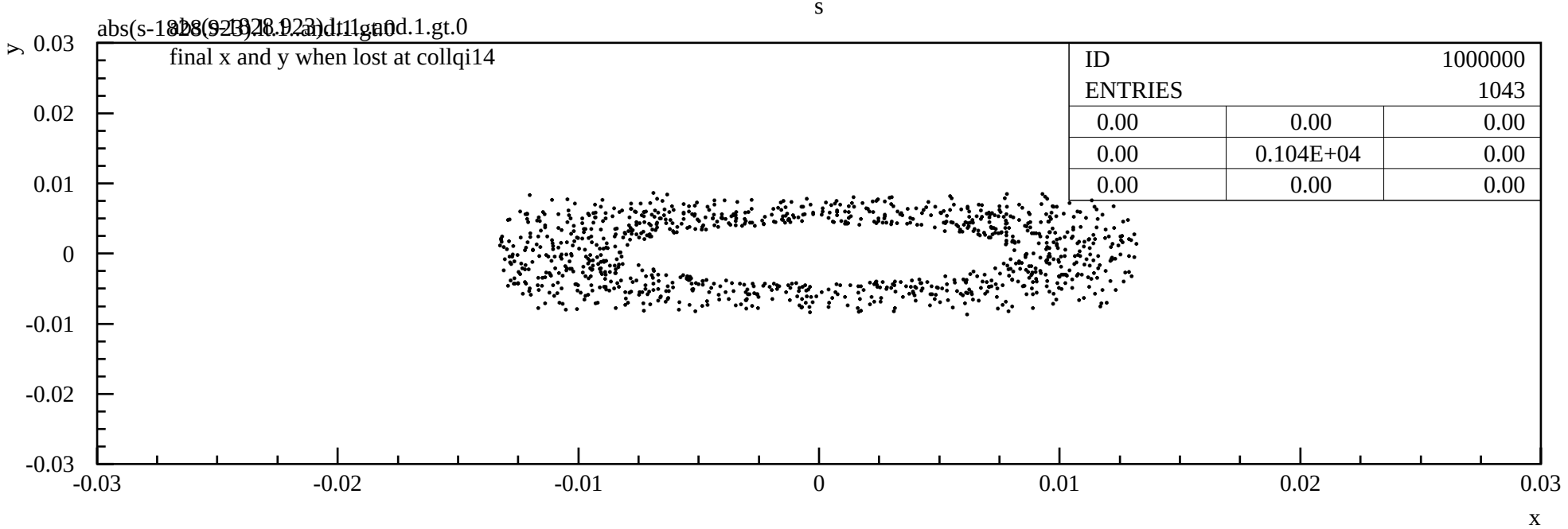
MBI: RBEND,L:= 6.30,ANGLE=-0.007611,apertype=ellipse,aperture={0.032,0.012}; // flat standard MBI chamber

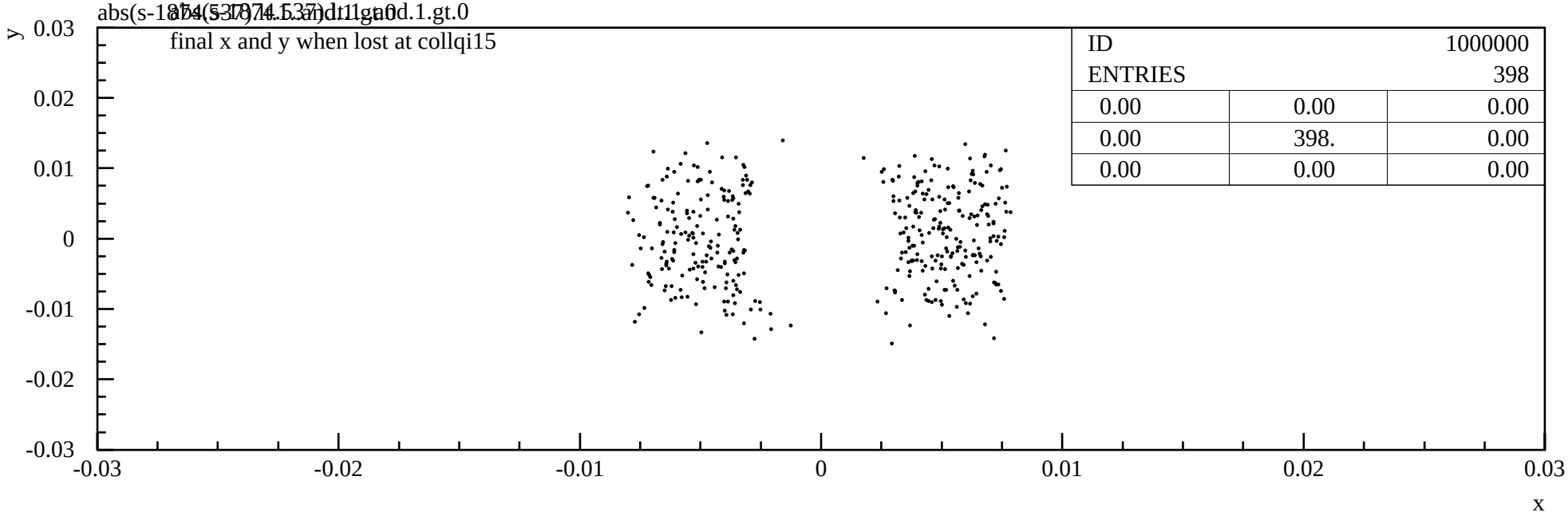
- access to tracking results with s-position; example of a track table:

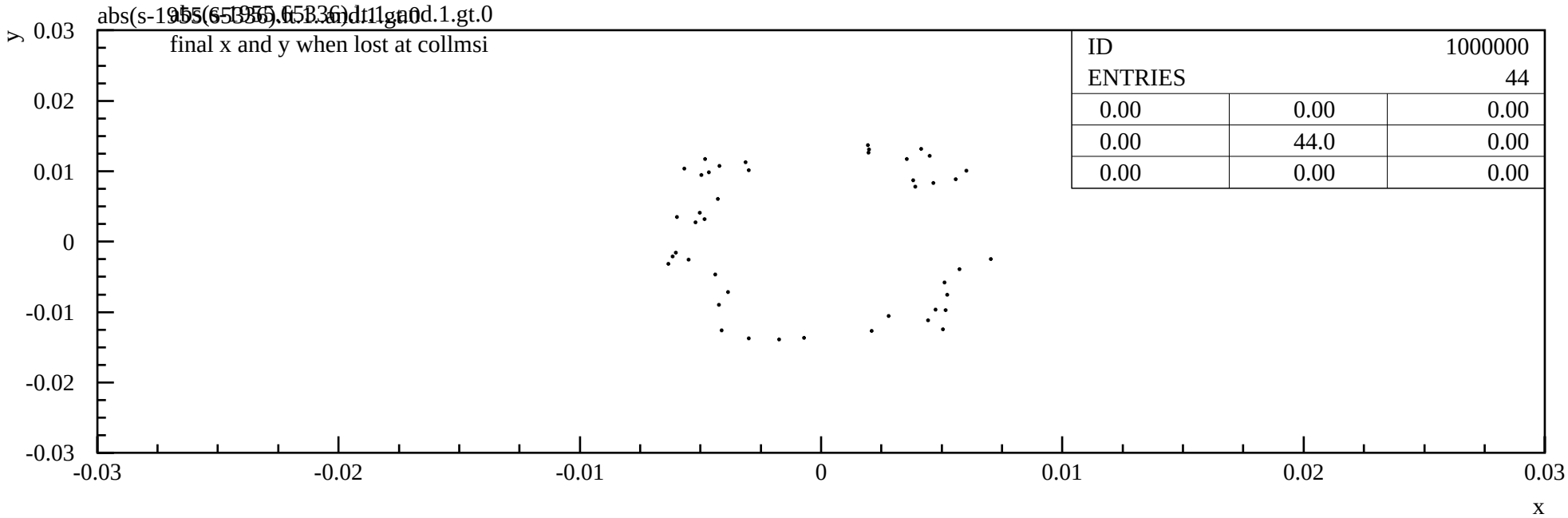
track,onepass,dump,aperture,onetable; generates tfs file :

```
@ TYPE          %08s "TRACKONE"
@ XC            %le                  0
@ PXC           %le                  0
...
* NUMBER          TURN            X              PX             Y              PY             T              PT             S
$ %hd         %hd          %le            %le            %le            %le            %le            %le
!segment       1       2   12150       0 start
 1              0              -0.012          -0.0003         0              0              0              -0.001         0
 2              0              -0.012          -0.0003         0              0              0              -0.0005        0
...
!segment       2       2    4509     892 m_collmom
 2240   1    0.01184669407     0.0002495981173   1.952980567e-06   1.443162573e-07   0.0002337388428   0.001   671.14411
 2245   1    0.01174313492     0.0002363807869   1.952985325e-06   1.443161797e-07   0.0002750067567   0.001   671.14411
 2250   1    0.01163957565     0.0002231634524   1.952989839e-06   1.443160468e-07   0.0003160286386   0.001   671.14411
 2330   1    0.01183650183     0.0003207196618   1.952949169e-06   1.443154279e-07   -5.467372026e-05  0.001   671.14411
```


s.gt.0
ID 1000000
Entries 9999
Mean 436.4
RMS 746.7
6000
5000
4000
3000
2000
1000
0
-500
0
500
1000
1500
2000
2500
final position
s


abs(s-1828(92828.923):d11gaod.1.gt.0
final x and y when lost at collqi14
ID 1000000
ENTRIES 1043
0.00 0.00 0.00
0.00 0.104E+04 0.00
0.00 0.00 0.00
y
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.03
-0.02
-0.01
0
0.01
0.02
0.03
x


abs(s-1874(53874.537)).and.11.gt.0
final x and y when lost at collqi15
ID 1000000
ENTRIES 398
0.00 0.00 0.00
0.00 398. 0.00
0.00 0.00 0.00
y
x
0.03
0.02
0.01
0
-0.01
-0.02
-0.03


abs(s-1955(65536).and.11.gt.0
final x and y when lost at collmsi
ID 1000000
ENTRIES 44
0.00 0.00 0.00
0.00 44.0 0.00
0.00 0.00 0.00
y
x
0.03
0.02
0.01
0
-0.01
-0.02
-0.03