



**High  
Luminosity  
LHC**

# Update on TAN aperture model and aperture margins for the HL-LHC upgrade

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Acknowledgments: R. Bruce, S. Chemli, R. De Maria,  
S. Fartoukh, M. Giovannozzi, S. Redaelli



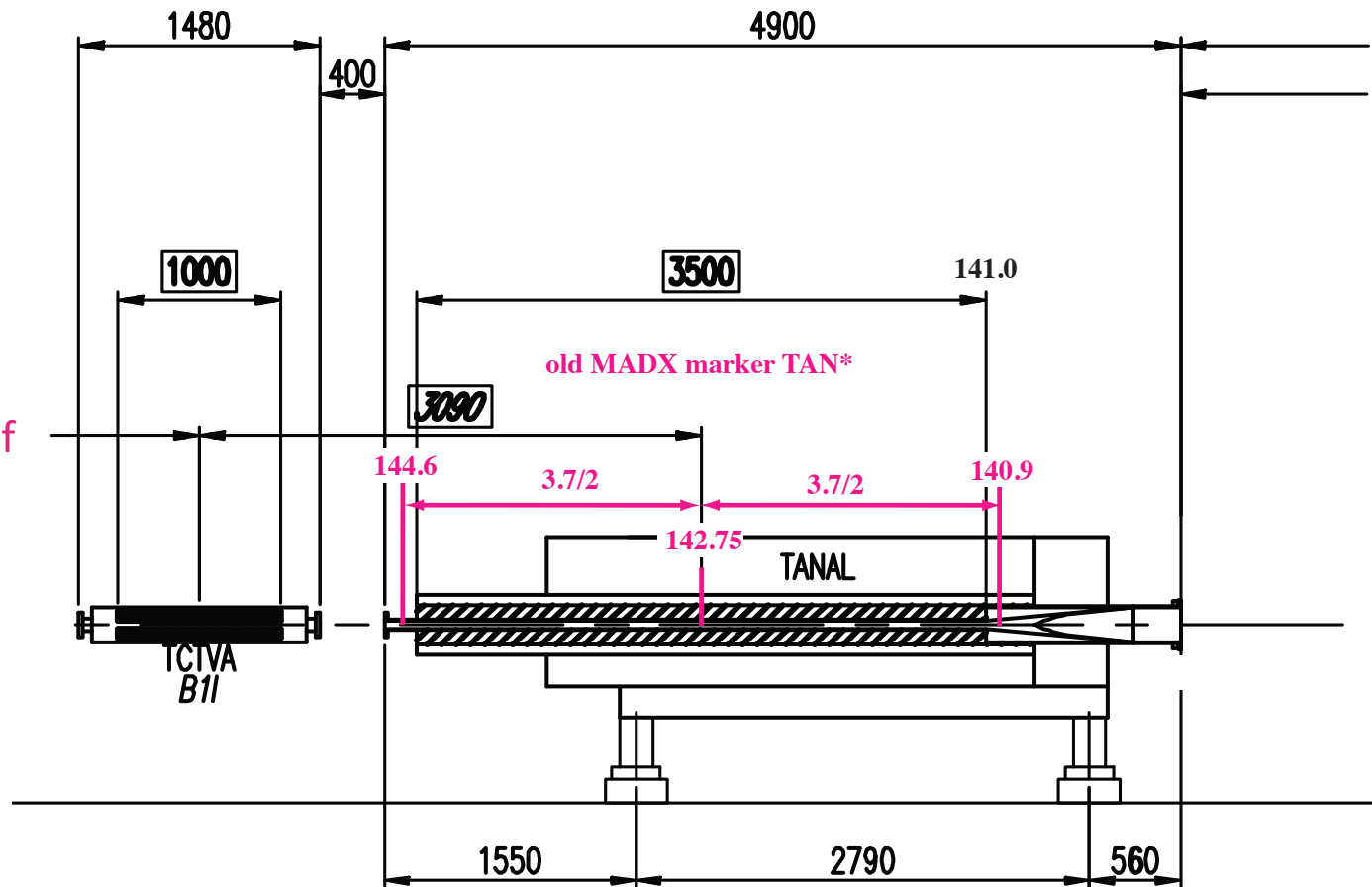
The HiLumi LHC Design Study is included in the High Luminosity LHC project and is partly funded by the European Commission within the Framework Programme 7 Capacities Specific Programme, Grant Agreement 284404.



# TAN aperture model

# TAN aperture - old model

one circular aperture of +/- 26 mm and 3.7 m length



# TAN aperture - old model

previous aperture model:

1) absorber

```
l.TANAR=3.7  
TANAR : RCOLLIMATOR, L := l.TANAR;  
...  
TANAR.4R1: TANAR, at= 142.75+(0-IP10FS.B1)*DS, from= IP1;  
...
```

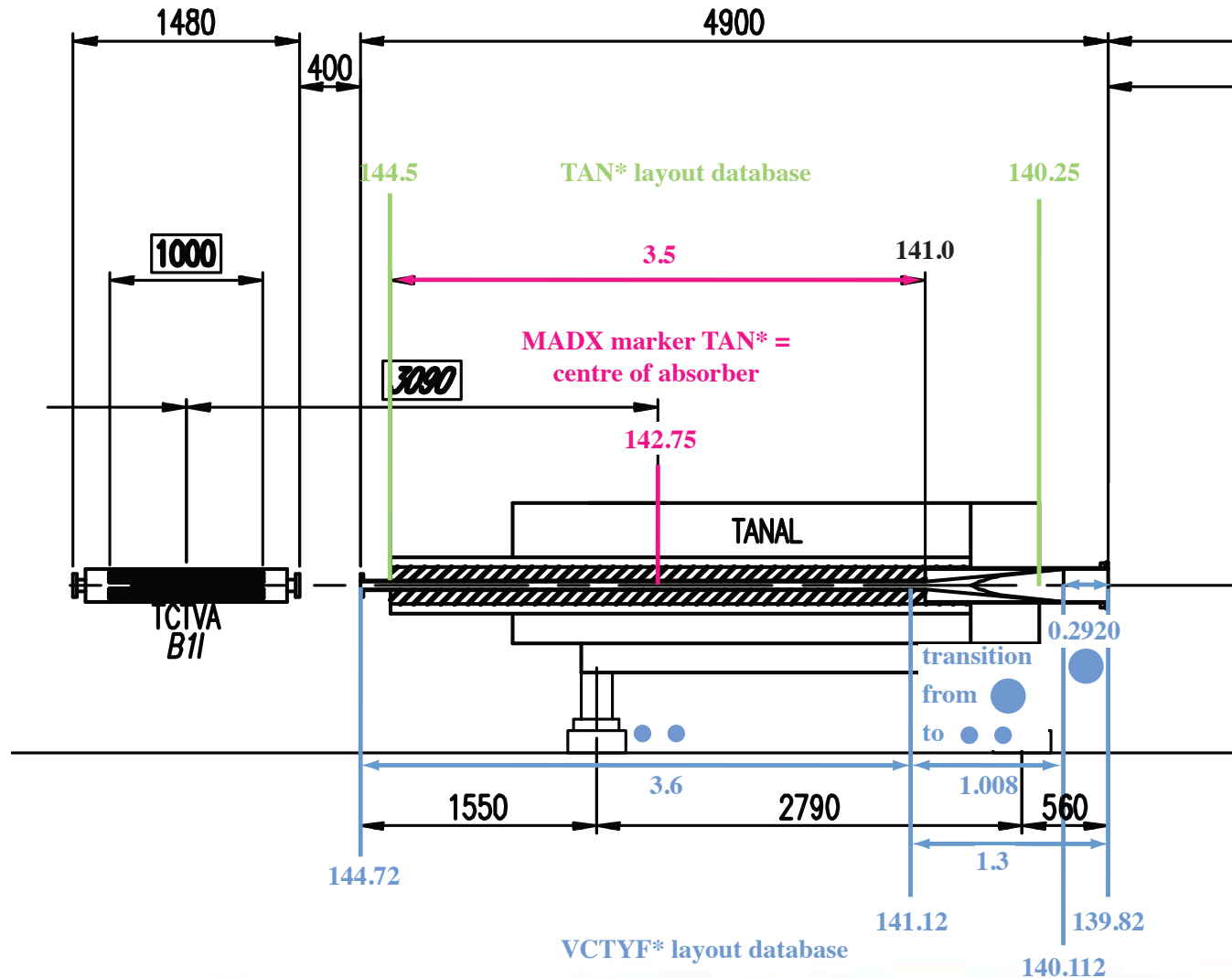
2) vacuum elements: only one marker at beginning of TAN (139.82 m - 144.72 m)

```
install, element = VCDW.4R1.P.B1, at= 139.4+(0-IP10FS.B1)*DS, from= IP1;  
install, element = VMEGB.4R1.A.B1, at= 139.4+(0-IP10FS.B1)*DS, from= IP1;  
install, element = VMEGB.4R1.B.B1, at= 139.825+(0-IP10FS.B1)*DS, from= IP1;  
install, element = VMZAW.4R1.A.B1, at= 144.52+(0-IP10FS.B1)*DS, from= IP1;  
install, element = VCTCJ.4R1.A.B1, at= 144.72+(0-IP10FS.B1)*DS, from= IP1;
```

# TAN aperture - new model

“3” models:

- (1) absorber
- (2) vacuum elements (“Y-chamber”)
- (3) layout database (beginning absorber - end of tank)



# TAN aperture - new model

MADX markers:

(1) absorber:

$\lambda$ .TANAR=3.5

TANAR : RCOLLIMATOR, L :=  $\lambda$ .TANAR;

...

TANAR.4R1: TANAR, at= 142.75+(0-IP10FS.B1)\*DS,  
from= IP1;

...

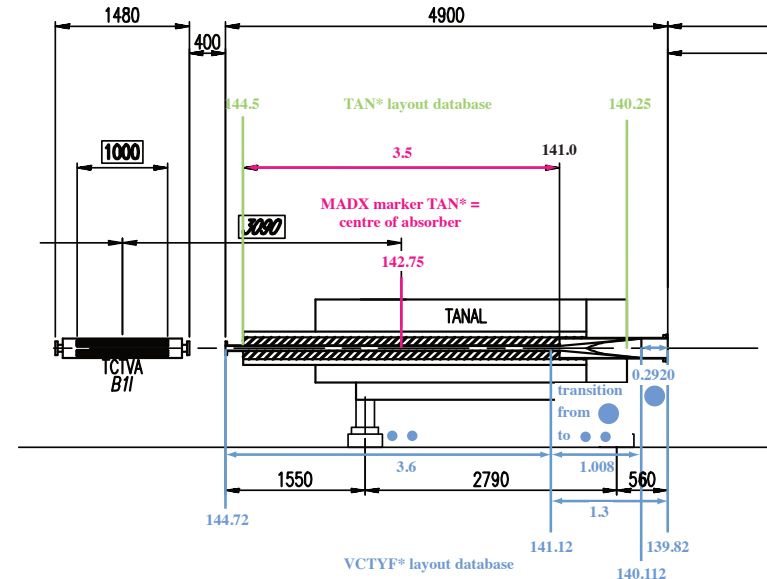
(2) vacuum elements (“Y-chamber”) - take Y-chamber markers from current file in the layout database (layoutapertures.madx)

install, element = VMEGB.4R1.A.B1, at= 139.4+(0-IP10FS.B1)\*DS, from= IP1;  
install, element = VCTYF.4R1.A.B1, at= 139.82+(0-IP10FS.B1)\*DS, from= IP1;  
install, element = VMEGB.4R1.B.B1, at= 139.825+(0-IP10FS.B1)\*DS, from= IP1;  
install, element = VCTYF.4R1.B.B1, at= 140.112+(0-IP10FS.B1)\*DS, from= IP1;

common  
circular  
aperture

install, element = VCTYF.4R1.C.B1, at= 141.12+(0-IP10FS.B1)\*DS, from= IP1;  
install, element = VCTYF.4R1.D.B1, at= 144.72+(0-IP10FS.B1)\*DS, from= IP1;

separate  
apertures



new Y-chamber TAN aperture defined in:

/afs/cern.ch/user/m/mfittere/public/HLLHCv1.0PIC10102013/aperture/aperture\_upgrade\_TAN.madx

# Update on aperture margins for the HL-LHC upgrade

# Optics

## 1. IT+D1 (upgrade only inner triplet and D1 area):



layout as in nominal sequence except area from IP to D1 (including D1)

## 2. HLLHC V1.0 (full upgrade):

- ▶ new IT, TAS, D1, D2, TAN + crab cavities
- ▶ change of MS section (new Q4, Q5 magnets and position, possible new TCT)
- ▶ additional sextupole at Q10
- ▶ ...



# Aperture margin evaluation strategy

as being discussed by Massimo, Roderik, Stefano, Stephane and Riccardo

nominal (design report):

```
bbeat=1.1, halo={6,halor=8.4,halox=7.3,haloy=7.3}, exn=3.75e-6, eyn=3.75e-6,  
cor=0.003, dp=0.00086, dparx=0.273, dpary=0.273
```

beam size (ideal model, but with mechanical tolerances):

```
bbeat=1.0, halo={6,halor=6,halox=6,haloy=6}, exn=3.50e-6, eyn=3.50e-6,  
cor=0.0, dp=0.0 (,dparx=0.273, dpary=0.273)
```

beam size+co (fit all measurements and co accounts for no measurement in MS magnets):

```
bbeat=1.0, halo={6,halor=6,halox=6,haloy=6}, exn=3.5e-6, eyn=3.5e-6,  
cor=0.003, dp=0.0 (,dparx=0.273, dpary=0.273)
```

**proposal 1** (add dispersion effects not measurable during last run, reduced co tolerances, add beta-beating tolerances)

```
bbeat=1.05, halo={6,halor=6,halox=6,haloy=6}, exn=3.50e-6, eyn=3.50e-6,  
cor=0.001, dp=2.0e-04, dparx=0.1, dpary=0.1
```

**proposal 2** (count on the correlation between  $\beta^*$  and triplet for on-momentum beta-beating, account for dispersion and off-momentum beta-beating)

```
twiss,...deltap={2e-4,0,-2e-4};  
bbeat=1.0, halo={6,halor=6,halox=6,haloy=6}, exn=3.50e-6, eyn=3.50e-6,  
cor=0.003, dp=0, dparx=0.1, dpary=0.1
```

# IT+D1 and HLLHCV1.0: min. n1 per element

SQUEEZE OPTICS (6.5 TeV)		APERTURE	minimum over IR1/5						
$\beta^*$ [m]	x-angle [ $\mu$ rad]		TAS	MQX*	D1	TAN	D2	Q4	Q5
IT+D1 0.15/0.15	$\pm 270$	nominal n1	7.97	7.14	7.7	<b>4.18</b>	7.31	<b>6.78</b>	7.27
		beam size + co	15.4	12.11	12.87	<b>9.41</b>	12.38	<b>11.64</b>	12.09
		beam size	17.85	13.03	13.91	<b>11.3</b>	14.49	13.9	15.26
		proposal 1	15.97	11.9	12.7	<b>9.92</b>	12.94	12.33	13.35
IT+D1 0.30/0.30	$\pm 190$	nominal n1	13.13	12.27	13.01	7.29	11.62	10.73	11.36
		beam size + co	23.71	19.1	20.12	14.4	18.56	17.33	17.8
		beam size	27.19	20.41	21.59	17.06	21.54	20.53	22.29
		proposal 1	24.56	18.83	19.9	15.18	19.29	18.31	19.62
IT+D1 0.20/0.40	$\pm 165$ ( $\pm 250$ )	nominal n1	12.33 (11.71)	12.09 (12.00)	13.04 (12.90)	<b>6.54 (6.20)</b>	10.63 (10.35)	10.54 (10.53)	9.92 (9.93)
		beam size + co	22.02 (21.40)	18.94 (18.93)	19.95 (19.96)	12.41 (12.11)	17.23 (17.23)	16.86 (16.85)	16.03 (16.05)
		beam size	24.94 (24.36)	20.01 (20.00)	21.14 (21.15)	14.58 (14.31)	19.67 (19.61)	19.4 (19.46)	19.7 (19.72)
		proposal 1	22.59 (22.02)	18.51 (18.53)	19.61 (19.62)	13.01 (12.74)	17.78 (17.78)	17.53 (17.53)	17.36 (17.38)
IT+D1 0.10/0.40	$\pm 165$	nominal n1	8.81	8.08	8.76	<b>4.42</b>	7.19	<b>7.02</b>	<b>6.56</b>
		beam size + co	15.73	13.39	14.11	<b>8.83</b>	12.19	11.92	<b>11.35</b>
		beam size	17.78	14.15	14.95	<b>10.35</b>	13.92	13.77	13.94
		proposal 1	16.05	13.03	13.8	<b>9.21</b>	12.52	12.35	12.22
HLLHCV1.0 0.15/0.15	$\pm 295$	nominal n1	7.72	<b>6.83</b>	7.36	7.37	10.36	13.72	17.65
		beam size + co	14.97	<b>11.68</b>	12.41	14.23	17.4	23.52	28.4
		beam size	17.42	12.61	13.45	15.85	19.22	25.72	31.96
		proposal 1	15.56	<b>11.49</b>	12.26	14.36	17.55	23.6	29.14
HLLHCV1.0 0.30/0.075	$\pm 275$	nominal n1	<b>6.95</b>	<b>6.82</b>	7.2	<b>6.14</b>	7.82	10.08	12.67
		beam size + co	13.24	<b>11.62</b>	12.09	<b>11.43</b>	13.34	16.71	20.2
		beam size	15.05	12.28	12.83	12.57	14.55	18.27	22.74
		proposal 1	13.52	<b>11.29</b>	11.81	<b>11.43</b>	13.19	16.7	20.62

6.5 TeV, mechanical tolerances included (see backup slides)  
aperture >11.7@6.5TeV sigma, R. Bruce



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# aperture tolerances IT+D1

names	aper_1	aper_2	aper_3	aper_4	rtol	xtol	ytol
MBRC.4L1.B1	31.300e-03	26.400e-03	31.300e-03	31.300e-03	840.000e-06	1.140e-03	1.200e-03
MBRC.4R1.B1	31.300e-03	26.400e-03	31.300e-03	31.300e-03	840.000e-06	850.000e-06	970.000e-06
TANA[LR].4[LR]1	26.000e-03	26.000e-03	26.000e-03	26.000e-03	2.000e-03	0.	0.
MBXA.4[LR]1	0.	0.	0.	0.	600.000e-06	1000.000e-06	1000.000e-06
MQXF*1	0.	0.	0.	0.	600.000e-06	1000.000e-06	1000.000e-06
TASC.1[LR]1	30.000e-03	30.000e-03	30.000e-03	30.000e-03	2.000e-03	500.000e-06	500.000e-06
MBRC.4[LR]1.B2	31.300e-03	26.400e-03	31.300e-03	31.300e-03	840.000e-06	1.140e-03	1.200e-03
TANA[LR].4[LR]1	26.000e-03	26.000e-03	26.000e-03	26.000e-03	2.000e-03	0.	0.
MBXA.4[LR]1	0.	0.	0.	0.	600.000e-06	1000.000e-06	1000.000e-06
MQXF*1	0.	0.	0.	0.	600.000e-06	1000.000e-06	1000.000e-06
TASC.1[LR]1	30.000e-03	30.000e-03	30.000e-03	30.000e-03	2.000e-03	500.000e-06	500.000e-06
MBRC.4[LR]5.B1	31.300e-03	26.400e-03	31.300e-03	31.300e-03	840.000e-06	1.140e-03	1.200e-03
TANC.4[LR]5	26.000e-03	26.000e-03	26.000e-03	26.000e-03	2.000e-03	0.	0.
MBXA.4[LR]5	0.	0.	0.	0.	600.000e-06	1000.000e-06	1000.000e-06
MQXF*5	0.	0.	0.	0.	600.000e-06	1000.000e-06	1000.000e-06
TASC.1[LR]5	30.000e-03	30.000e-03	30.000e-03	30.000e-03	2.000e-03	500.000e-06	500.000e-06
MBRC.4[LR]5.B2	31.300e-03	26.400e-03	31.300e-03	31.300e-03	840.000e-06	1.140e-03	1.200e-03
TANC.4[LR]5	26.000e-03	26.000e-03	26.000e-03	26.000e-03	2.000e-03	0.	0.
MBXA.4[LR]5	0.	0.	0.	0.	600.000e-06	1000.000e-06	1000.000e-06
MQXF*5	0.	0.	0.	0.	600.000e-06	1000.000e-06	1000.000e-06
TASC.1[LR]5	30.000e-03	30.000e-03	30.000e-03	30.000e-03	2.000e-03	500.000e-06	500.000e-06

# aperture tolerances HLLHCV1.0

names	aper_1	aper_2	aper_3	aper_4	rtol	xtol	ytol
MBRD.4 [LR] 1.B1	41.000e-03	36.000e-03	41.000e-03	41.000e-03	840.000e-06	1.360e-03	1000.000e-06
TANA [LR].4 [LR] 1	41.000e-03	37.000e-03	41.000e-03	37.000e-03	600.000e-06	1000.000e-06	1000.000e-06
MBXA.4 [LR] 1	0.	0.	0.	0.	600.000e-06	1000.000e-06	1000.000e-06
MQXF*1	0.	0.	0.	0.	600.000e-06	1000.000e-06	1000.000e-06
TASC.1 [LR] 1	30.000e-03	30.000e-03	30.000e-03	30.000e-03	2.000e-03	500.000e-06	500.000e-06
MBRD.4 [LR] 1.B2	41.000e-03	36.000e-03	41.000e-03	41.000e-03	840.000e-06	1.360e-03	1000.000e-06
TANA [LR].4 [LR] 1	41.000e-03	37.000e-03	41.000e-03	37.000e-03	600.000e-06	1000.000e-06	1000.000e-06
MBXA.4 [LR] 1	0.	0.	0.	0.	600.000e-06	1000.000e-06	1000.000e-06
MQXF*1	0.	0.	0.	0.	600.000e-06	1000.000e-06	1000.000e-06
TASC.1 [LR] 1	30.000e-03	30.000e-03	30.000e-03	30.000e-03	2.000e-03	500.000e-06	500.000e-06
names	aper_1	aper_2	aper_3	aper_4	rtol	xtol	ytol
MBRD.4 [LR] 5.B1	41.000e-03	36.000e-03	41.000e-03	41.000e-03	840.000e-06	1.360e-03	1000.000e-06
TANC.4 [LR] 5	41.000e-03	37.000e-03	41.000e-03	37.000e-03	600.000e-06	1000.000e-06	1000.000e-06
MBXA.4L5	0.	0.	0.	0.	600.000e-06	1000.000e-06	1000.000e-06
MQXF*5	0.	0.	0.	0.	600.000e-06	1000.000e-06	1000.000e-06
TASC.1 [LR] 5	30.000e-03	30.000e-03	30.000e-03	30.000e-03	2.000e-03	500.000e-06	500.000e-06
MBRD.4 [LR] 5.B2	41.000e-03	36.000e-03	41.000e-03	41.000e-03	840.000e-06	1.360e-03	1000.000e-06
TANC.4 [LR] 5	41.000e-03	37.000e-03	41.000e-03	37.000e-03	600.000e-06	1000.000e-06	1000.000e-06
MBXA.4 [LR] 5	0.	0.	0.	0.	600.000e-06	1000.000e-06	1000.000e-06
MQXF*5	0.	0.	0.	0.	600.000e-06	1000.000e-06	1000.000e-06
TASC.1 [LR] 5	30.000e-03	30.000e-03	30.000e-03	30.000e-03	2.000e-03	500.000e-06	500.000e-06