

MERIT Data Analysis

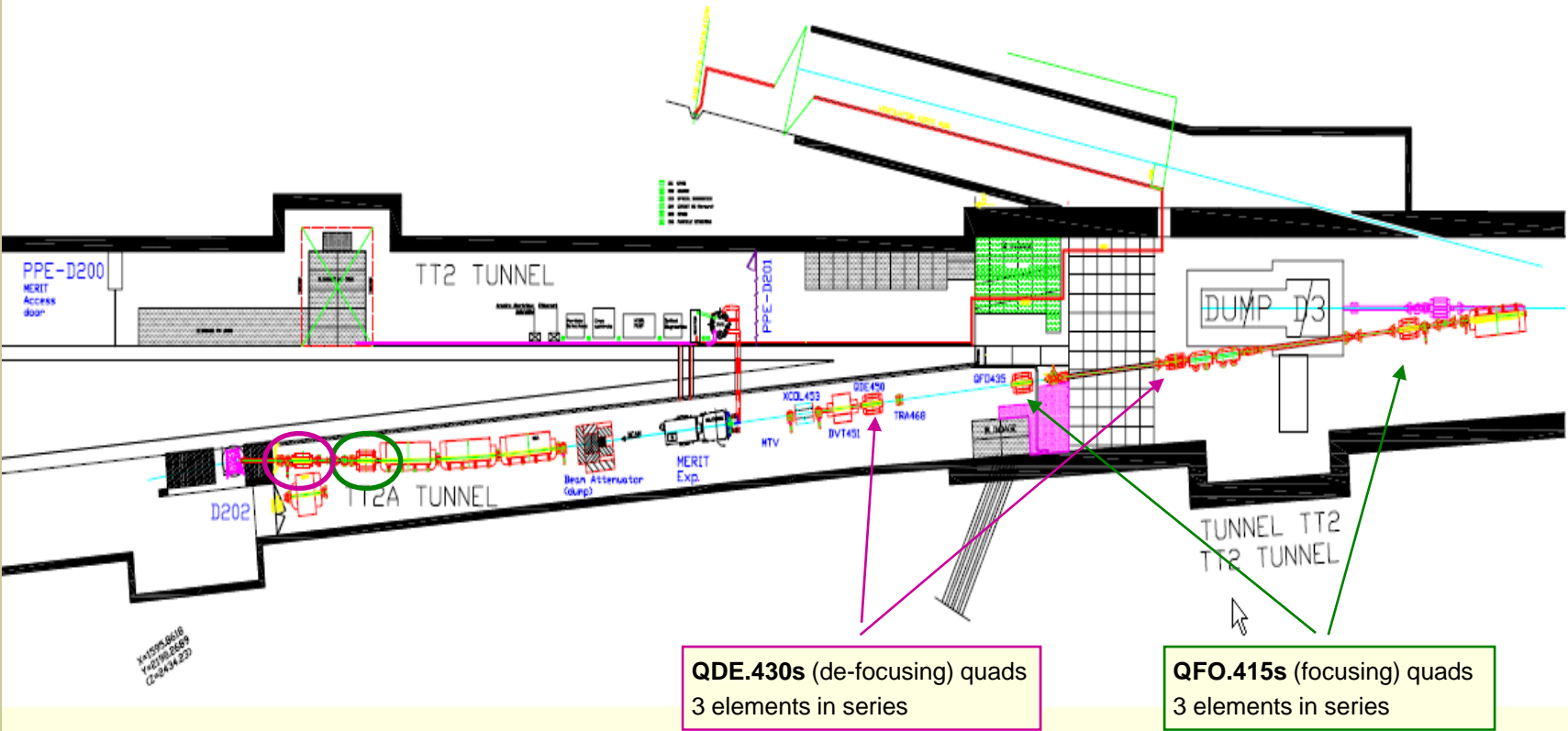
(latest update : 07Oct08)

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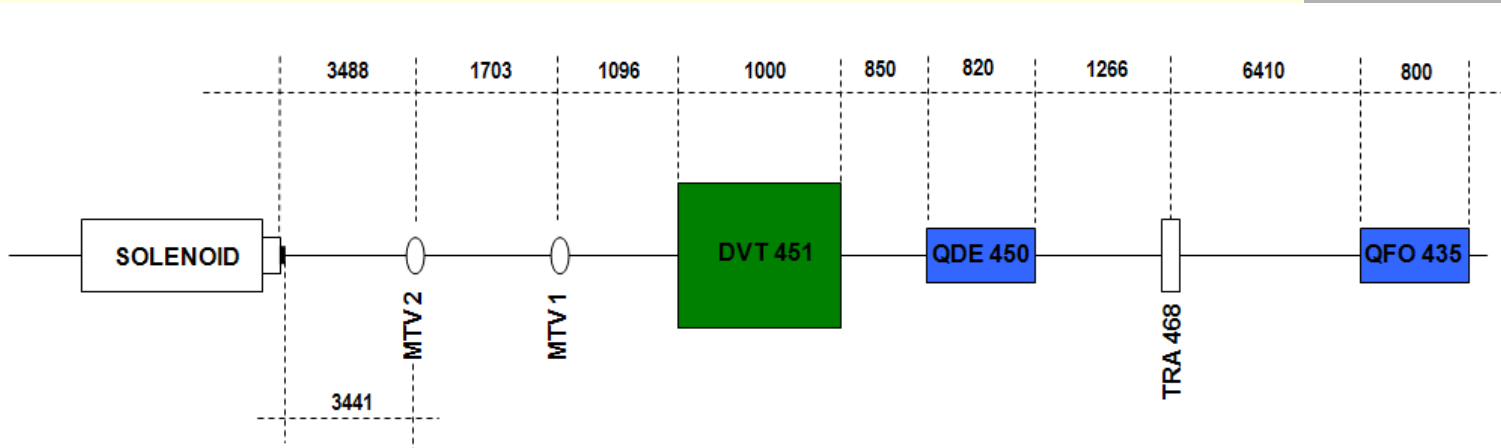
1. Beam spot size using emittance measurements and optics
2. Alignment and beam direction

Beam spot size analysis

MERIT Elements – Layout



Survey data after the MERIT run – 18.12.2007



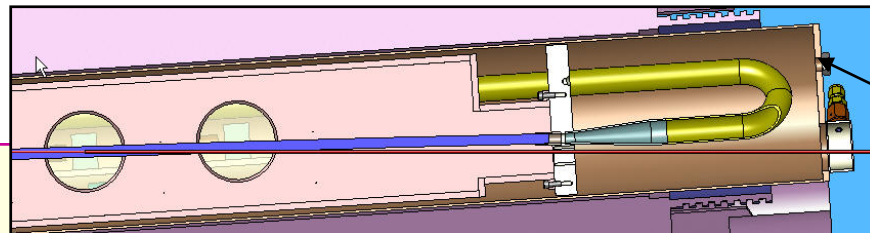
FTN start 304.69540

Data from GEODE database, registered on 15 June 2007

Element	Position	x	y	z	Distance	Rel. Distance	Center	TT2/FTN
FTNQFO.435	E	1636.84951	2179.54532	2434.22735	48.21100		48.61100	353.30640
	S	1636.11207	2179.85546	2434.22734	49.01100	0.80000		
FTNTRA.468	E/S	1634.82593	2180.39636	2434.22734	50.40625	1.39525		
FTNQDE.450	E	1629.01792	2182.83899	2434.22733	56.70700	6.30075	57.11700	361.81240
	S	1682.26050	2183.15688	2434.22733	57.52700	0.82000		
FTNDVT.451	E	1627.44810	2183.49920	2434.22732	58.41000	0.88300	58.91000	363.60540
	S	1626.52630	2183.88687	2434.22732	59.41000	1.00000		
FTNXCO.453	E	1625.49113	2184.32222	2434.22732	60.53300	1.12300	61.03300	365.72840
	S	1624.56933	2184.70990	2434.22732	61.53300	1.00000		

Measurements - 18.12.2007

Distance	TT2/FTN	Center
48.211	352.9064	48.611
49.011	353.7064	
55.421	360.1164	55.421
56.687	361.3824	57.097
57.507	362.2024	
58.357	363.0524	58.857
59.357	364.0524	

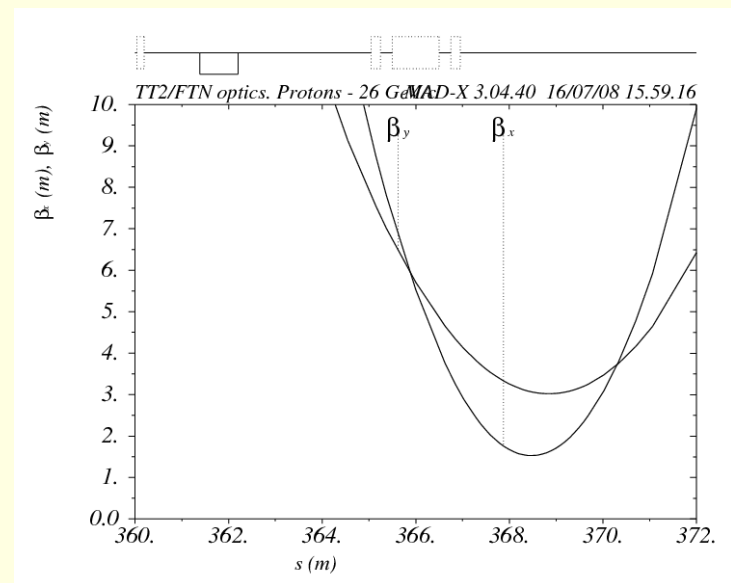
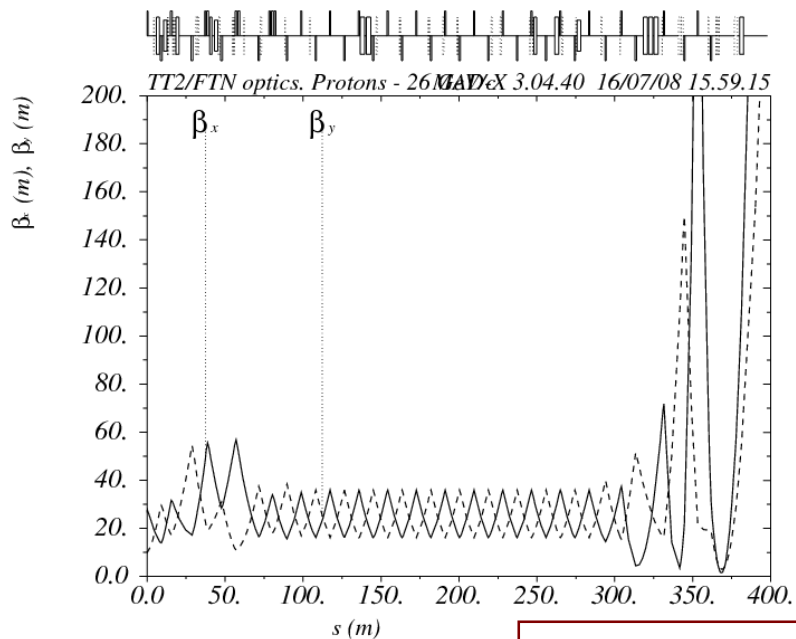


MTV1	60.453	365.1484
MTV2	62.156	366.8514
HGTAU	65.644	370.3394
HGTAR	66.367	371.0624

Upstream face: -72.3cm

Beam optics

- Fit parameters: QFO, QDO strengths and locations (within limits)



Element	S_line [m]	Beta_x [m]	Alfa_x []	Delta_x [m]	Beta_y [m]	Alfa_y []	Delta_y [m]
MTV.454	365.1484	8.7535	2.1732	1.5415	7.5513	1.2242	-0.0419
MTV.484	366.8514	3.2477	1.0598	1.6209	4.3414	0.6607	0.0294
HG-WUP	370.3394	3.8082	-1.2205	1.7834	3.7581	-0.4934	0.1756
HG-TARG	371.0624	5.9148	-1.6932	1.8171	4.6446	-0.7327	0.2058
HG-WDO	373.6914	19.3362	-3.4119	1.9397	10.7838	-1.6025	0.3160

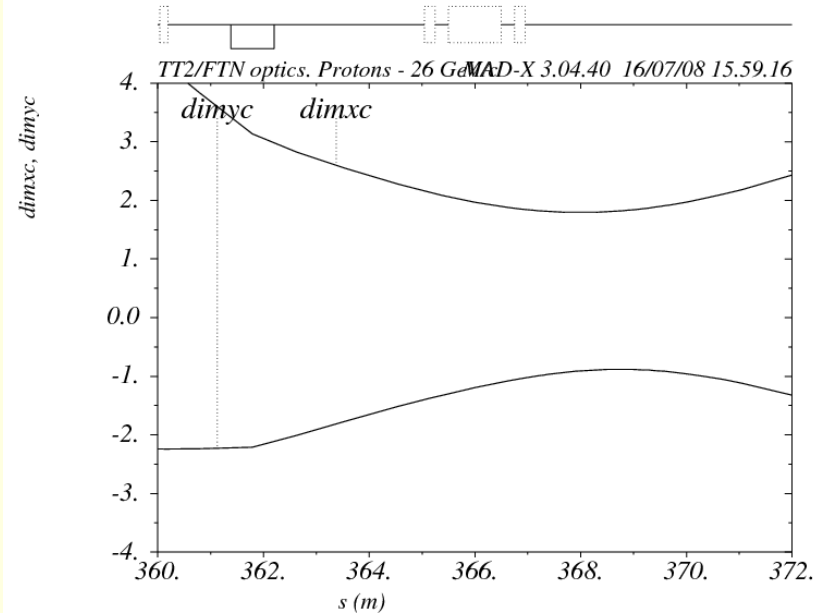
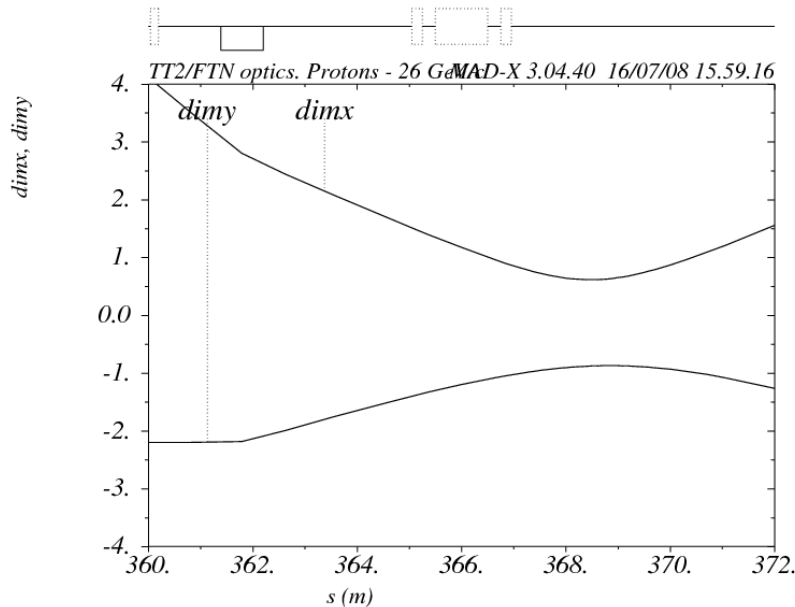
Beam envelope (1-sigma) - $\epsilon=0.25$ (mm.mrad), $Dp=0.1\%$

Without dispersion term

- $\sigma(x) = 1.2\text{mm}$, $\sigma(y) = 1.1\text{ mm}$
- 238 J/gr @ 30TP

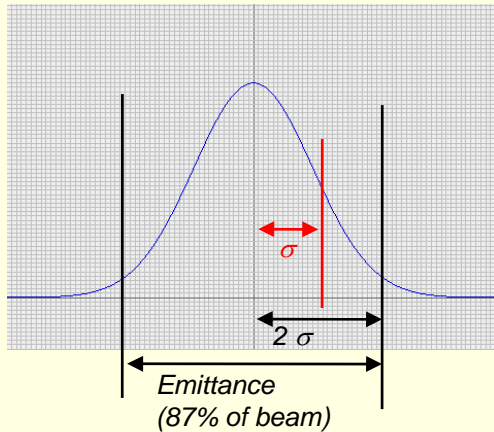
With dispersion term

- $\sigma(x) = 2.2\text{mm}$, $\sigma(y) = 1.1\text{ mm}$
- 130 J/gr @ 30TP



Reminder – Beam Emittance

- For **proton machines**, the emittance is measured by measuring the beam profile in a position of known beam parameters (optics)
 - The convention is to use **TWO sigma** value



Geometrical emittance:

$$\mathcal{E}_{\text{protons}} = \frac{(2\sigma)^2}{\beta}$$

Normalized emittance:

$$\mathcal{E}^* = (\beta\gamma) \mathcal{E}, \quad \beta\gamma = \frac{P_0}{M_0}$$

P [GeV/c]	($\beta\gamma$)
14.0	14.92
24.0	25.58

Including dispersion

$$\sigma = \sqrt{\mathcal{E} \cdot \beta + \left(|D_p| \frac{\delta p}{p} \right)^2}$$

What is measured in the machine

$$\mathcal{E}_{2\sigma} = f\left(w_{4\sigma}, \frac{\delta p}{p}_{2\sigma}\right) = \frac{\left(\frac{w_{4\sigma}}{2}\right)^2 - \left(|D_p| \frac{\delta p}{p}_{2\sigma}\right)^2}{\beta}$$

Beam Emittance measurement – 14 GeV/c

Friday 26.10@15:55

Beam intensity:

h16, 1E13

File View Option Help

opdisp MDPS 26 Oct 26 16:00:46 2007

Beam State	INJ User	PS User	Particule	Harmonique	Destination
SPARE		MDPS	PROTON	H8H16	TT2_D3

	Acquisition	Losses	Eff (%)
1 ring 1 acc	282.35		
2 ring 2 acc	264.77		
3 ring 3 acc	279.42		
4 ring 4 acc	278.45		
5 Sum PSB acc	1104.99		
6 BTP.TRA	1050.00	55	95.0
7 Injected	1062.71	42	96.2
8 Bef.Trans	1011.40	51	95.2
9 1st Trans	1011.40	0	100.0

BLMS	Plot
16	17
41	5
42	97
43	75
44	81
45	46
f16	26

File Plot Views Option Help

MDPS Oct 26 16:48:31 2007

(VERSION May 14 2007 16:46:17) Measurement mode: Photomultiplier Plot.

Prepare Meas. Parameters Start Measurement

Requested Parameters

Device V75 (0 scans)

Occurrence - Any

Expected Ip - 5e11

Velocity - 20 m/s

Single Sweep

C Timing - 760

PM Voltage 1 V75 - 480

PM Voltage 2 V75 - 480

Scint. Trans. V75 - 100%

Results for V75

At C Pulse : 760

e (2s) (mm.mrad) 0.68

e (2s)(normalised) 10.28

4s measured (mm) 5.65

Centre of Mass (mm) 3.31

Measurement Parameters

At C Pulse : 760

B Pulse (1G Train) 6667

p (GeV/c) 13.99

Ip (E10) 986.97

Device : V75

PM Voltage (V) 3129

b (m) 11.6

Dispersion (m.) --

Scint. Transmission 100%

WARNING The graphs displayed may not correspond to the requested settings.

Plot Views Option Help

MDPS Oct 26 16:42:20 2007

(VERSION May 14 2007 16:46:17) Measurement mode: Photomultiplier Plot.

Prepare Meas. Parameters Start Measurement

Requested Parameters

Device H64 (0 scans)

Occurrence - Any

Expected Ip - 5e11

Velocity - 20 m/s

Single Sweep

C Timing - 760

PM Voltage 1 H64 - 450

PM Voltage 2 H64 - 450

Scint. Trans. H64 - 100%

Results for H64

At C Pulse : 760

e (2s) (mm.mrad) 1.02

e (2s)(normalised) 15.33

4s measured (mm) 10.62

Centre of Mass (mm) -3.26

Measurement Parameters

At C Pulse : 760

B Pulse (1G Train) 6667

p (GeV/c) 13.99

Ip (E10) 1008.96

Device : H64

PM Voltage (V) 3129

b (m) 12.6

Dispersion (m.) 2.30

Scint. Transmission 100%

WARNING The graphs displayed may not correspond to the requested settings.

Beam Emittance measurement – 14 GeV/c

- Friday 26.10@17:37
- Beam intensity:**
- 2.5E11/bunch
- 2 extracted bunches,

opdisp MDPS 26 Oct 26 18:06:46 2007

Beam State	INJ User	PS User	Particule	Harmonique	Destination
SPARE		MDPS	PROTON	H8H16	TT2_D3

	Acquisition	Losses	Eff (%)
1 ring 1 acc	-0.00		
2 ring 2 acc	-0.01		
3 ring 3 acc	119.00		
4 ring 4 acc	-0.00		
5 Sum PSB acc	118.98		
6 BTP.TRA	126.25	-7	106.1
7 Injected	114.53	4	96.3
8 Bef.Trans	111.48	3	97.3
9 Aft.Trans	111.11	0	99.7
10 Bef.Eject	111.23	3	97.1
11 Aft.Eject	54.33	57	48.8
12 TRA126	55.23	56	49.7

BLM's Plot	
	INT
16	12
41	0
42	17
43	8
44	17
45	6
fl6	1

File Plot Views Option Help

MDPS Oct 26 18:12:31 2007

(VERSION May 14 2007 16:46:17) Measurement mode: Photomultiplier Plot.

Prepare Meas. Parameters Start Measurement

Requested Parameters

Device V75 (0 scans)

Occurrence - Any

Expected Ip - 5e11

Velocity - 20 m/s

Single Sweep

C Timing - 760

PM Voltage 1 V75 - 620

PM Voltage 2 V75 - 620

Scint. Trans. V75 - 100%

Results for V75

At C Pulse : 760

e (2s) (mm.mrad) 0.32

e (2s)(normalised) 4.80

4s measured (mm) 3.86

Centre of Mass (mm) 3.37

Measurement Parameters

At C Pulse : 760

B Pulse (1G Train) 6667

p (GeV/c) 13.99

Ip (E10) 112.58

Device : V75

PM Voltage (V) 3129

b (m) 11.6

Dispersion (m.) - -

Scint. Transmission 100%

WARNING The graphs displayed may not correspond to the requested settings.

File Plot Views Option Help

MDPS Oct 26 18:15:53 2007

(VERSION May 14 2007 16:46:17) Measurement mode: Photomultiplier Plot.

Prepare Meas. Parameters Start Measurement

Requested Parameters

Device H64 (0 scans)

Occurrence - Any

Expected Ip - 5e11

Velocity - 20 m/s

Single Sweep

C Timing - 760

dp/p for C760 - 1.66

PM Voltage 1 H64 - 600

PM Voltage 2 H64 - 600

Scint. Trans. H64 - 100%

Results for H64

At C Pulse : 760

e (2s) (mm.mrad) 0.40

e (2s)(normalised) 5.94

4s measured (mm) 8.85

Centre of Mass (mm) -3.98

Measurement Parameters

At C Pulse : 760

B Pulse (1G Train) 6667

p (GeV/c) 13.99

Ip (E10) 110.62

Device : H64

PM Voltage (V) 3129

b (m) 12.6

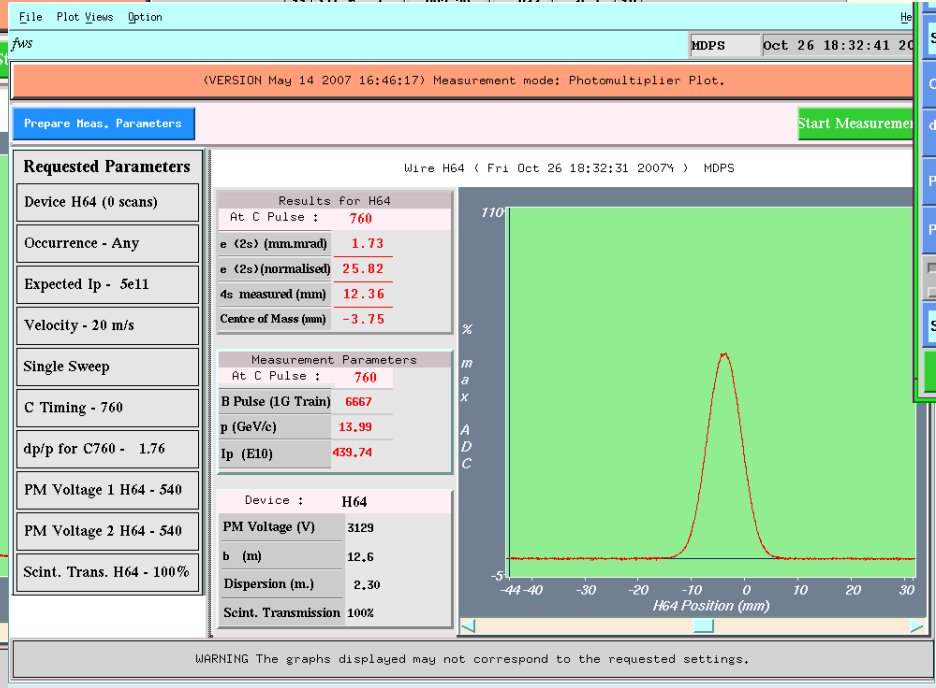
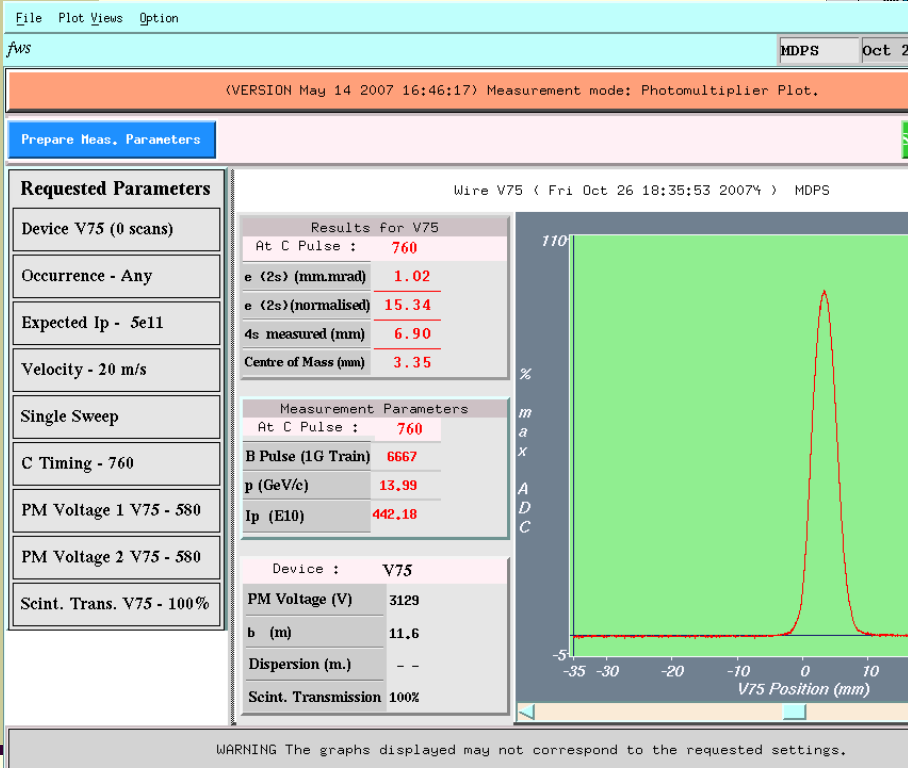
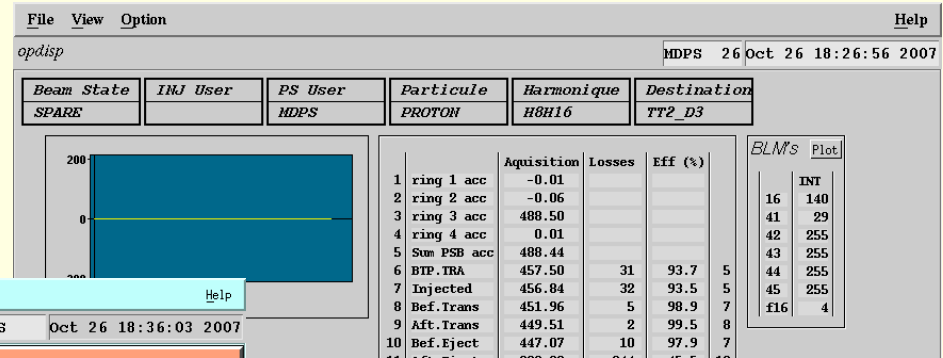
Dispersion (m.) 2.30

Scint. Transmission 100%

WARNING The graphs displayed may not correspond to the requested settings.

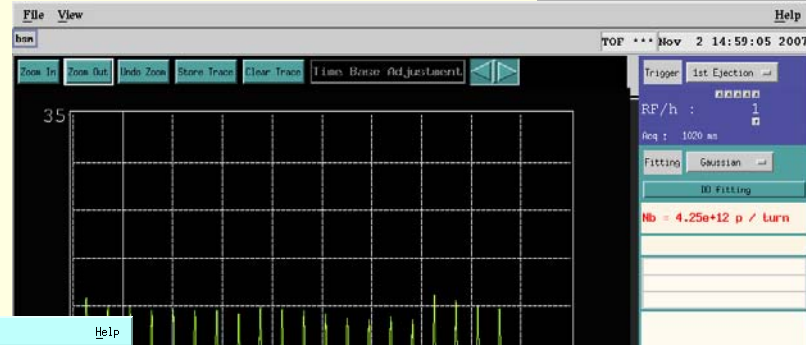
Beam Emittance measurement – 14 GeV/c

- Friday 26.10@18:24
- Beam intensity:**
- 1.3E12/bunch
- 2 extracted bunches,



Beam Emittance measurement – 24 GeV/c

- Friday 02.11 @ 14:55PM
- Beam intensity:**
- 2.5E11/bunch
- 16 bunches



File Plot Views Option

fwS TOF Nov 2 14

(VERSION May 14 2007 16:46:17) Measurement mode: Photomultiplier Plot.

Prepare Meas. Parameters Start

Requested Parameters

Device V75 (0 scans)

Occurrence - Any

Expected Ip - 5e12

Velocity - 10 m/s

Single Sweep

C Timing - 1010

PM Voltage 1 V75 - 480

PM Voltage 2 V75 - 480

Scint. Trans. V75 - 100%

Results for V75

At C Pulse :	1010
e (2s) (mm.mrad)	0.33
e (2s)(normalised)	8.66
4s measured (mm)	3.96
Centre of Mass (mm)	2.87

Measurement Parameters

At C Pulse :	1010
B Pulse (1G Train)	11424
p (GeV/c)	23.97
Ip (E10)	442.18

Device : V75

PM Voltage (V)	3129
b (m)	11.6
Dispersion (m.)	--
Scint. Transmission	100%

Wire V75 (Fri Nov 2 14:57:56 2007) TOF

WARNING The graphs displayed may not correspond to the requested settings.

File Plot Views Option

fwS TOF Nov 2 14:54:42 2007

(VERSION May 14 2007 16:46:17) Measurement mode: Photomultiplier Plot.

Prepare Meas. Parameters Start Measurement

Requested Parameters

Device H64 (0 scans)

Occurrence - Any

Expected Ip - 5e12

Velocity - 10 m/s

Single Sweep

C Timing - 1010

dp/p for C1010 - 1.10

PM Voltage 1 H64 - 480

PM Voltage 2 H64 - 480

Scint. Trans. H64 - 100%

Results for H64

At C Pulse :	1010
e (2s) (mm.mrad)	0.18
e (2s)(normalised)	4.68
4s measured (mm)	5.90
Centre of Mass (mm)	-2.89

Measurement Parameters

At C Pulse :	1010
B Pulse (1G Train)	11423
p (GeV/c)	23.97
Ip (E10)	442.18

Device : H64

PM Voltage (V)	3129
b (m)	12.6
Dispersion (m.)	2.30
Scint. Transmission	100%

Wire H64 (Fri Nov 2 14:54:34 2007) TOF

WARNING The graphs displayed may not correspond to the requested settings.

Beam Emittance measurement – 24 GeV/c

Friday 02.11 @ 16:02PM

Beam intensity:

- 16 bunches,
- 6E12 protons

File View Option Help

opdisp TOF 28 Nov 2 16:03:28 2007

Beam State	INJ User	PS User	Particule	Harmonique	Destination
SPARE		TOF	PROTON	H8	TT2_D3

	Aquisition	Losses	Eff (%)
1 ring 1 acc	159.15		
2 ring 2 acc	166.48		
3 ring 3 acc	161.79		
4 ring 4 acc	161.60		
5 Sum PSB acc	649.02		
6 BTP. TRA	630.00	19	97.1
7 Injected	632.74	16	97.5
8 Bef. Trans	613.19	20	96.9
9 Aft. Trans	608.31	5	99.2
10 Bef. Eject	608.31	24	96.1
11 Aft. Eiect	0.15	608	0.0

BLM's Plot

	INT
16	6
41	4
42	29
43	24
44	34
45	16
f16	46

File Plot Views Option Help

fws TOF Nov 2 16:03:01 2007

(VERSION May 14 2007 16:46:17) Measurement mode: Photomultiplier Plot.

Prepare Meas. Parameters Start Measurement

Requested Parameters

Device V75 (0 scans)

Occurrence - Any

Expected Ip - 5e12

Velocity - 10 m/s

Single Sweep

C Timing - 1010

PM Voltage 1 V75 - 480

PM Voltage 2 V75 - 480

Scint. Trans. V75 - 100%

Results for V75

At C Pulse : 1010

e (2s) (mm.mrad) 0.44

e (2s) (normalised) 11.35

4s measured (mm) 4.54

Centre of Mass (mm) 2.94

Measurement Parameters

At C Pulse : 1010

B Pulse (1G Train) 11424

p (GeV/c) 23.97

Ip (E10) 615.64

Device : V75

PM Voltage (V) 3129

b (m) 11.6

Dispersion (m.) --

Scint. Transmission 100%

WARNING The graphs displayed may not correspond to the requested settings.

File Plot Views Option Help

fws TOF Nov 2 16:07:30 2007

(VERSION May 14 2007 16:46:17) Measurement mode: Photomultiplier Plot.

Prepare Meas. Parameters Start Measurement

Requested Parameters

Device H64 (0 scans)

Occurrence - Any

Expected Ip - 5e12

Velocity - 10 m/s

Single Sweep

C Timing - 1010

dp/p for C1010 - 1.10

PM Voltage 1 H64 - 460

PM Voltage 2 H64 - 460

Scint. Trans. H64 - 100%

Results for H64

At C Pulse : 1010

e (2s) (mm.mrad) 0.25

e (2s) (normalised) 6.45

4s measured (mm) 6.18

Centre of Mass (mm) -2.88

Measurement Parameters

At C Pulse : 1010

B Pulse (1G Train) 11423

p (GeV/c) 23.97

Ip (E10) 618.08

Device : H64

PM Voltage (V) 3129

b (m) 12.6

Dispersion (m.) 2.30

Scint. Transmission 100%

WARNING The graphs displayed may not correspond to the requested settings.

Beam Emittance measurement

- Summary of measured data

Measured emittances during MERIT operation - (MERIT logbook)

Date	Pbeam [GeV/c]	Beam Type	Intensity				Horizontal	Vertical	dp/p [2sigma, 0.1%]
			Bef.Eject	TRA126	TRA283	TRA386	4s meas	4s meas	
				[e10]				[mm]	
26-Oct	13.99	h16	1008.96	695.71	996.75	1037.25	10.62	5.64	1.7
26-Oct	13.99	2x2.5e11, DT=1.7us	111.23	55.23	53.2	54.4	8.85	3.86	1.66
26-Oct	13.99	2x1.3e12, DT=1.7us	447.07	168.98	222.75	281.25	12.36	6.9	1.76
2-Nov	23.97	16x2.5e11	442.8			425	5.9	3.96	1.1
2-Nov	23.97	16bunches	608.31	6.26	560.25	632.25	6.18	4.54	1.1

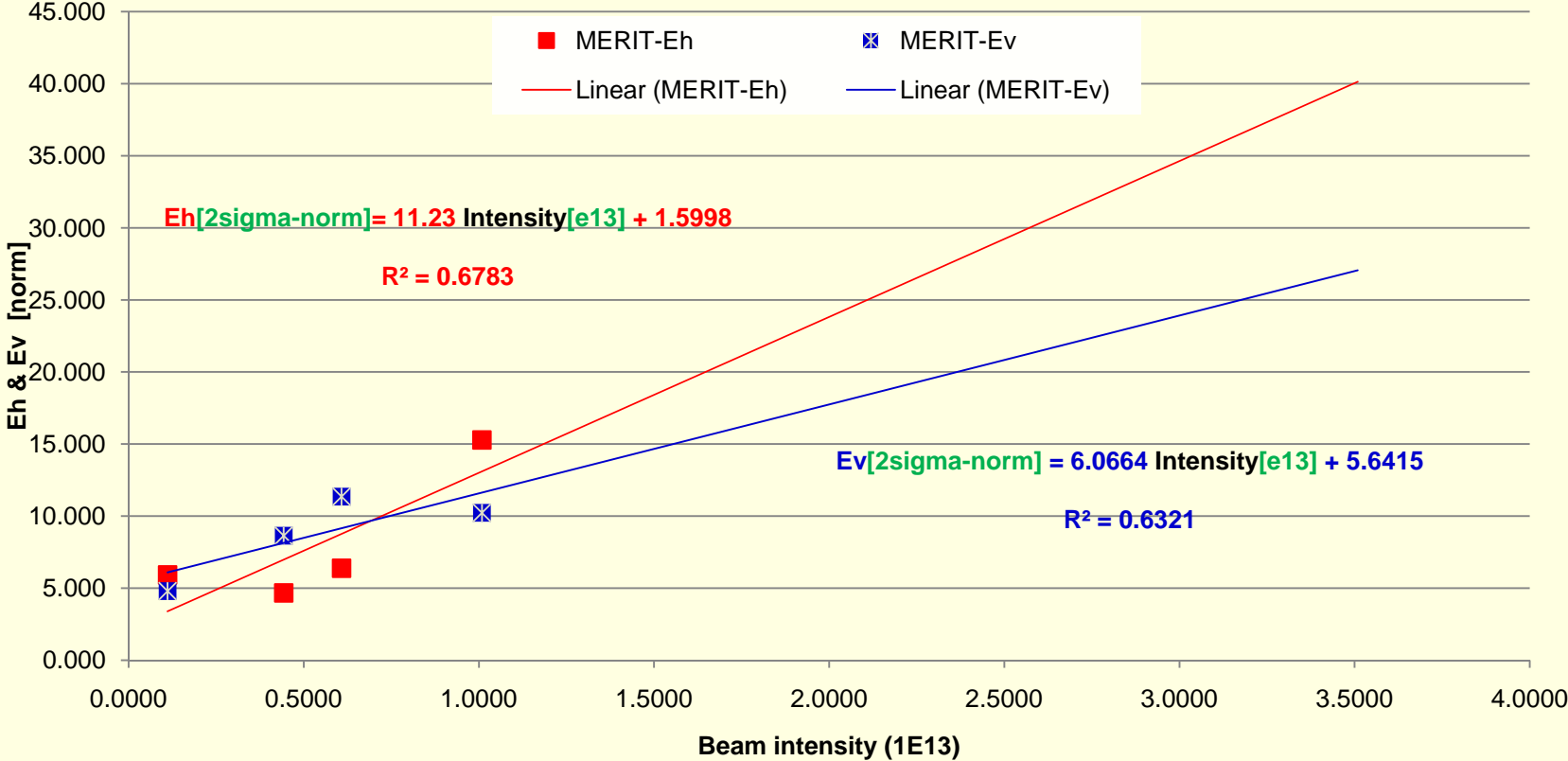
- Using the formulas of slide #6

Intensity [e13]	Pbeam [GeV/c]	Eh(2s) [mm.mrad]	Eh(2s) [norm]	Ev(2s) [mm.mrad]	Ev(2s) [norm]
1.0090	13.99	1.0244	15.279	0.6856	10.225
0.1112	13.99	0.3971	5.923	0.3211	4.789
0.4428	23.97	0.1827	4.668	0.3380	8.636
0.6080	23.97	0.2498	6.383	0.4442	11.352
0.4471	13.99	1.7306	25.812	1.0261	15.304

- in good agreement with the online calculations

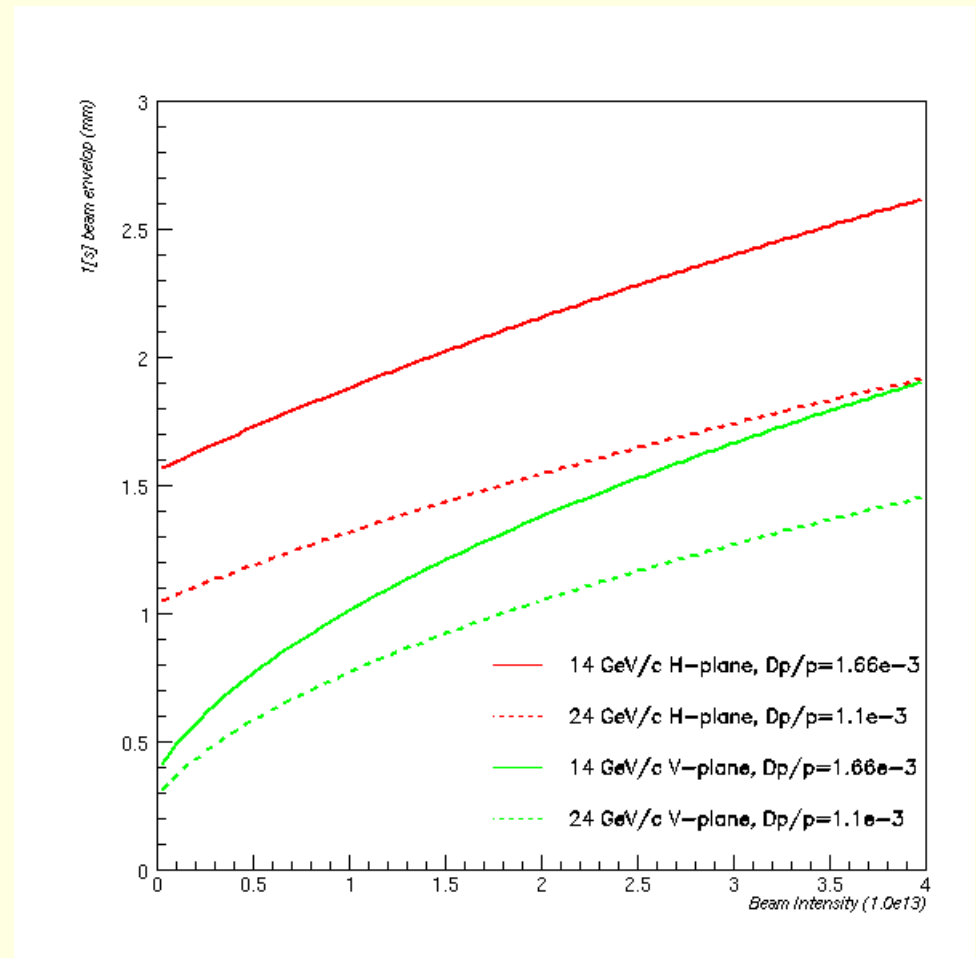
Emittance extrapolation

Transverse emittance (2s) in TT2



Estimated beam spot and density

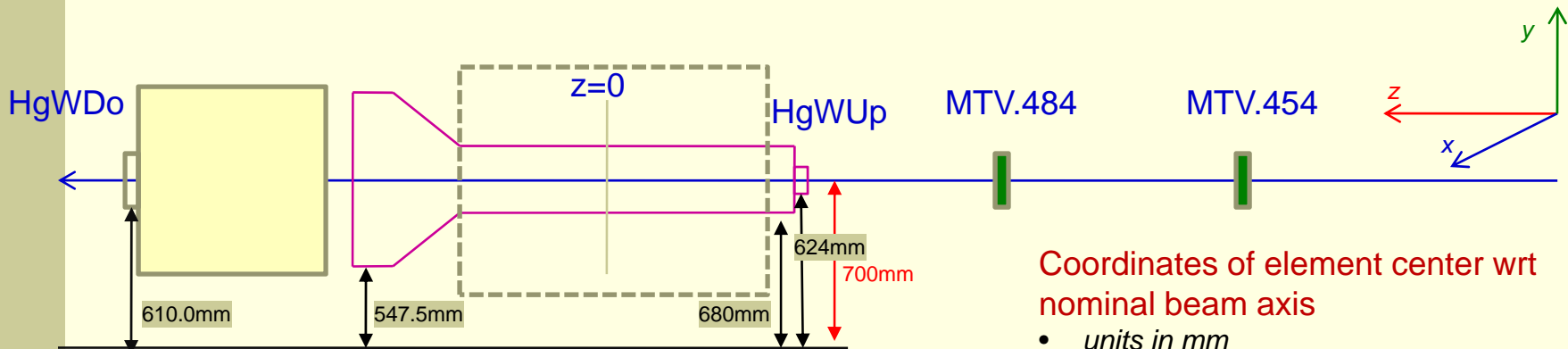
- Use the extrapolated emittances to estimate the beam spot and energy density at target



Alignment and Beam Direction

MERIT beam element survey

- Done by CERN geometers (TS/SU) after the run, 18.12.2007



Reference line on floor

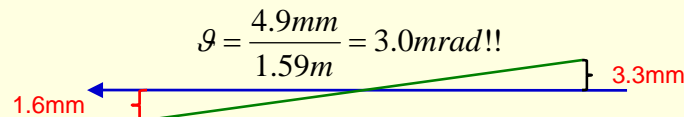
Solenoid tilt – (h-plane)

Position	Distance	Radius	total	Difference
HgWUp	680	23.495	703.495	-3.495
SecUp	624	79.375	703.375	-3.375
SecDo	547.5	150.876	698.376	+1.624
HgWDo	610.0	57.15	667.15	+32.85

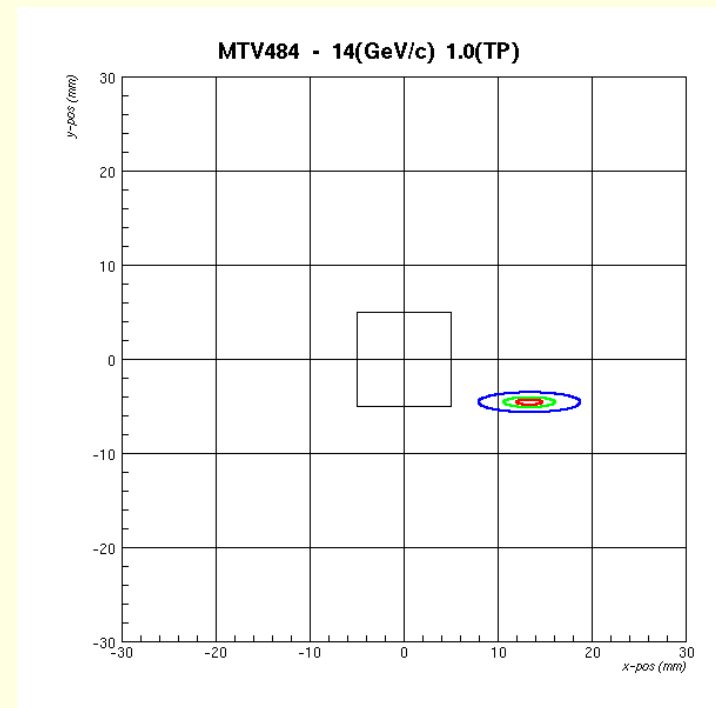
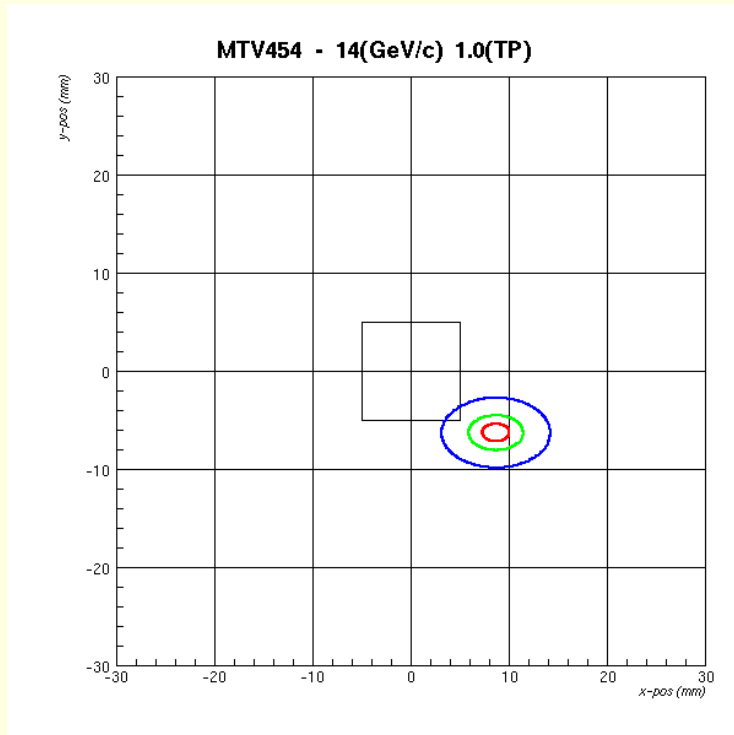
Coordinates of element center wrt nominal beam axis

- units in mm
- z distances from z=0 at solenoid center

Element	{x, y, z}
MTV.454	{+8.7,+6.3, -5893.95}
MTV484	{+13.4, +4.6, -4230.95}
HgWUp	{+1.5,-10.0,-742.95}
HgWDo	{+57.0, -26.0, +2950.2}



Nominal beam position in various elements



Beam at Hg container

