MERIT Data Analysis

## (latest update : 07Oct08)

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1. Beam spot size using emittance measurements and optics

2. Alignment and beam direction

MERIT, VRVS Meeting
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September 25, 2008

Beam spot size analysis

MERIT Elements – Layout

QDE.430s (de-focusing) quads
3 elements in series

QFO.415s (focusing) quads
3 elements in series
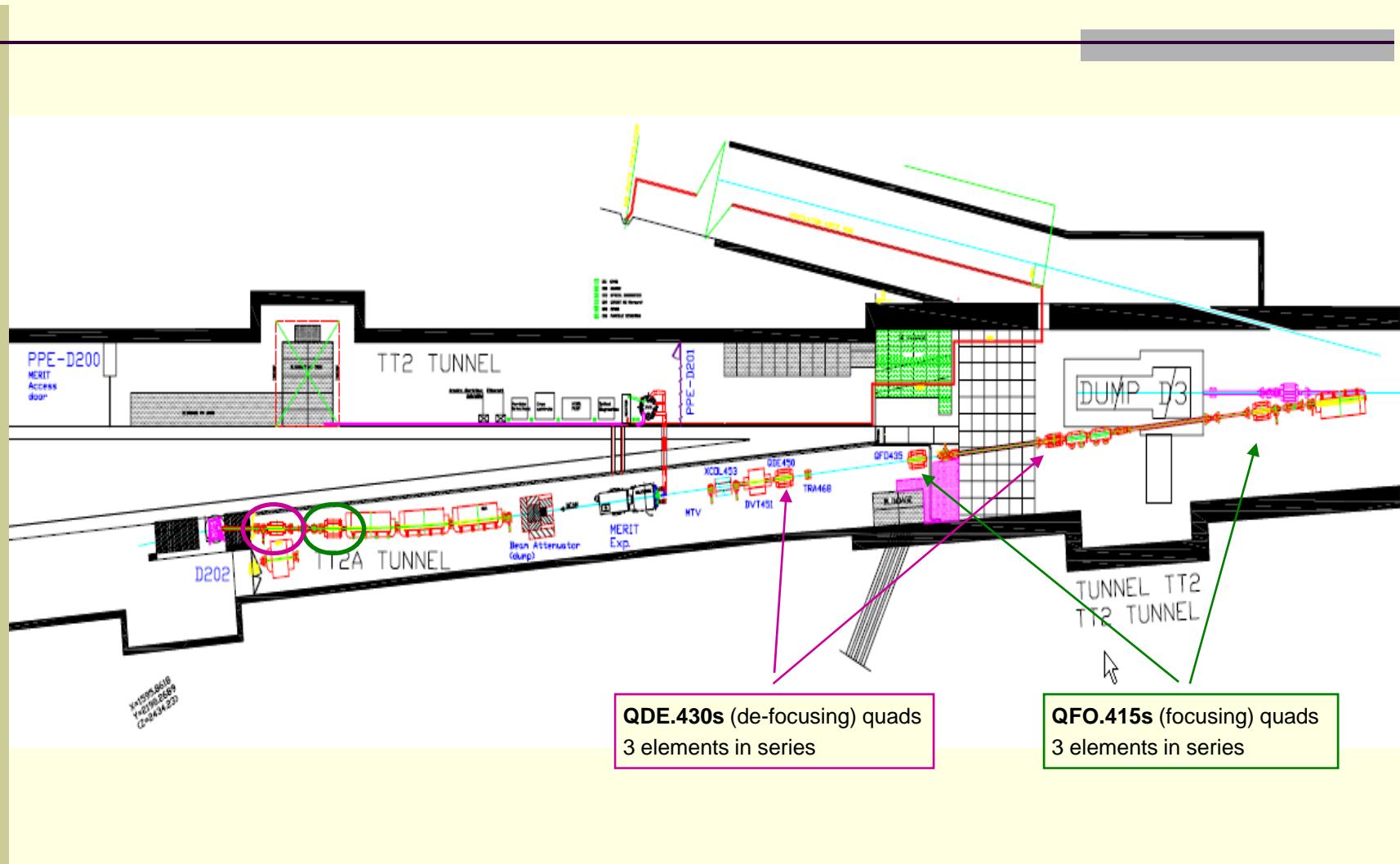
Survey data after the MERIT run – 18.12.2007

3488 1703 1096 1000 850 820 1266 6410 800

SOLENOID MTV 2 MTV 1 DVT 451 QDE 450 TRA 468 QFO 435

3441
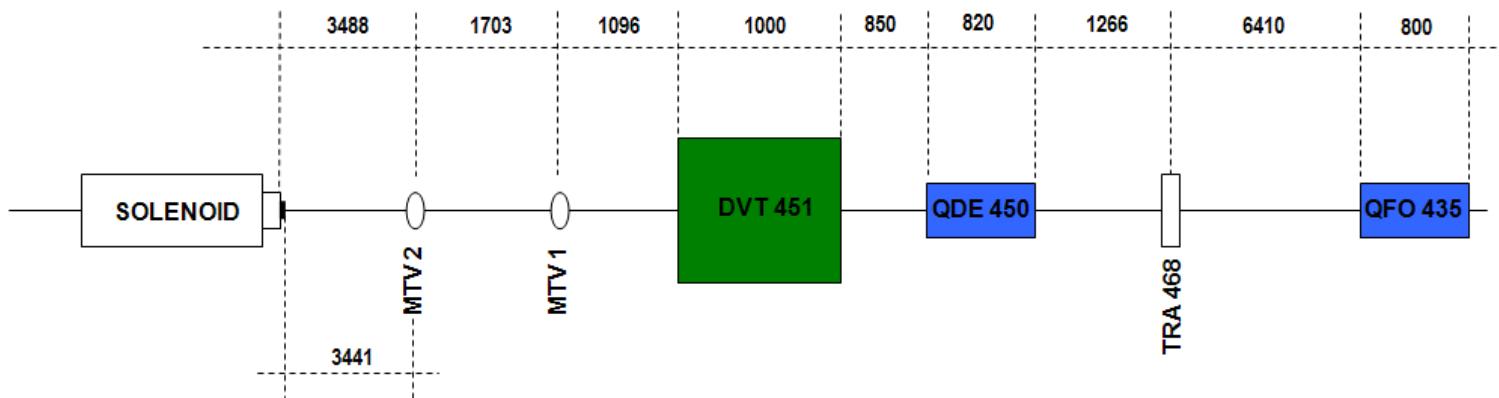
FTN start   304.69540

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	
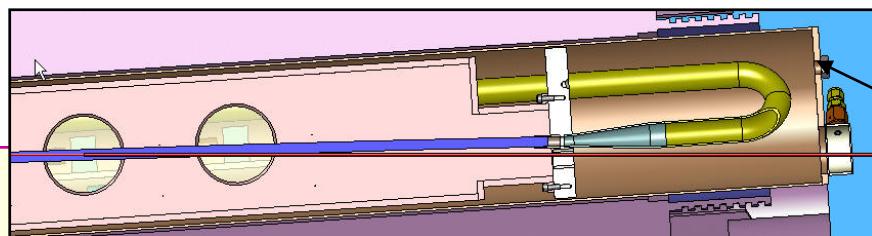
	Distance	TT2/FTN
MTV1	60.453	365.1484
MTV2	62.156	366.8514
HGTAU	65.644	370.3394
HGTAR	66.367	371.0624

Upstream face: -72.3cm

Beam optics

■ Fit parameters: QFO, QDO strengths and locations (within limits)
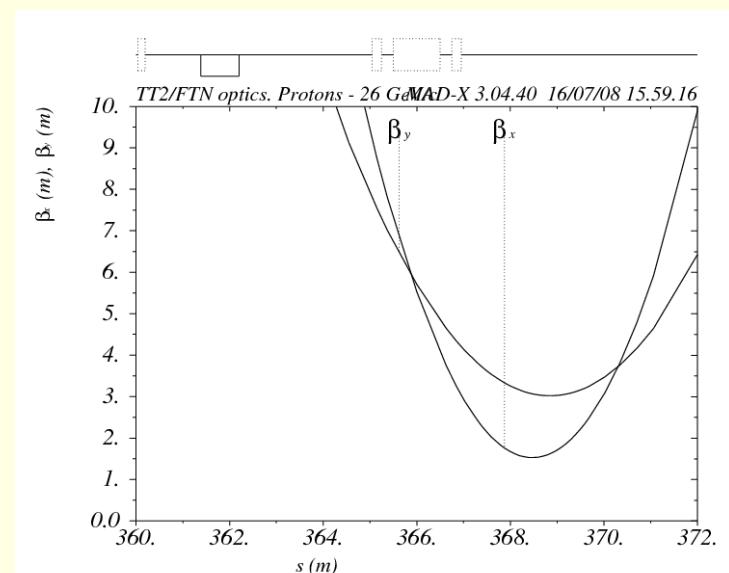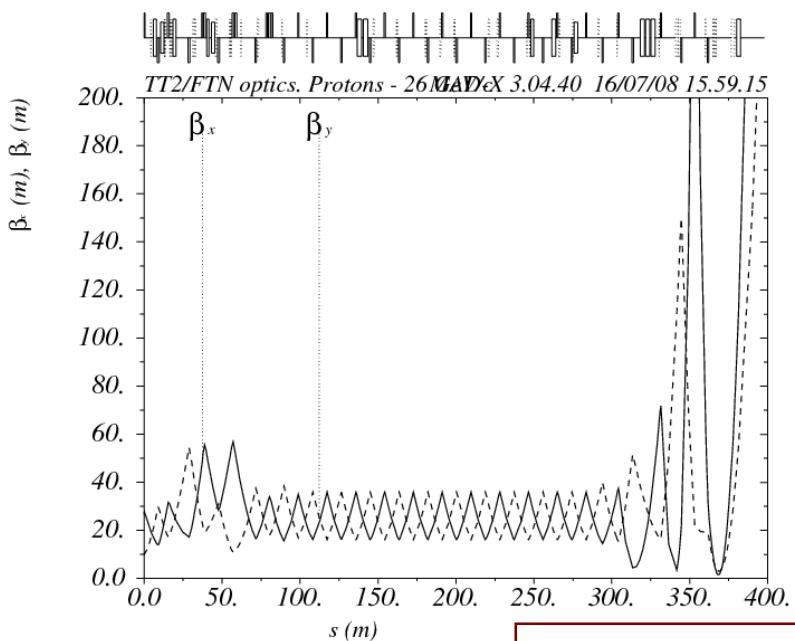
Element	S_line	Beta_x	Alfa_x	Delta_x	Beta_y	Alfa_y	Delta_y
	[m]	[m]	[]	[m]	[m]	[]	[m]
MTV.454	365.1484	8.7535	2.1732	1.5415	7.5513	1.2242	-0.0419
MTV.484	366.8514	3.2477	1.0598	1.6209	4.3414	0.6607	0.0294
HG-WUP	370.3394	3.8082	-1.2205	1.7834	3.7581	-0.4934	0.1756
HG-TARG	371.0624	5.9148	-1.6932	1.8171	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) - ε=0.25 (mm.mrad), Dp=0.1%

- **Without dispersion term**
  - $\sigma(x) = 1.2$mm , $\sigma(y) = 1.1$ mm
  - 238 J/gr @ 30TP
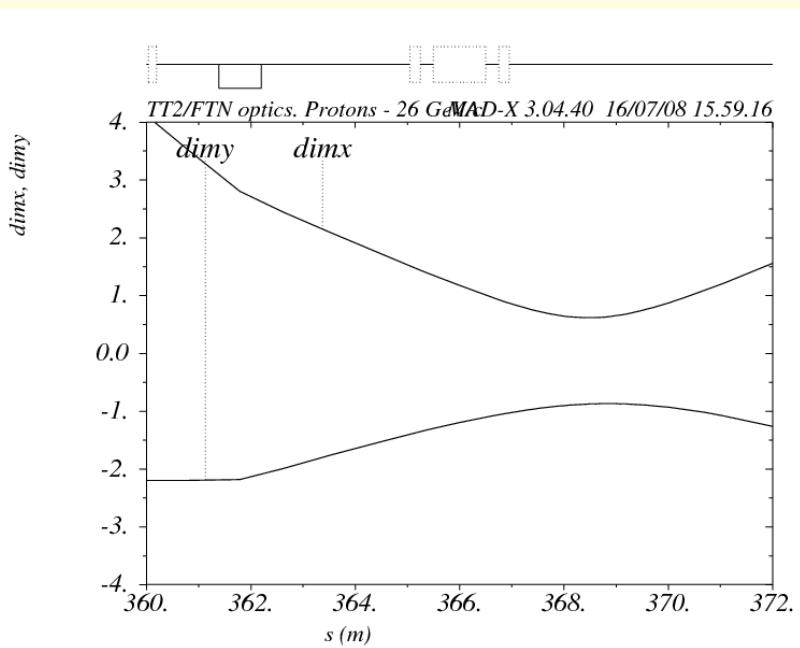
- **With dispersion term**
  - $\sigma(x) = 2.2$mm , $\sigma(y) = 1.1$ mm
  - 130 J/gr @ 30TP
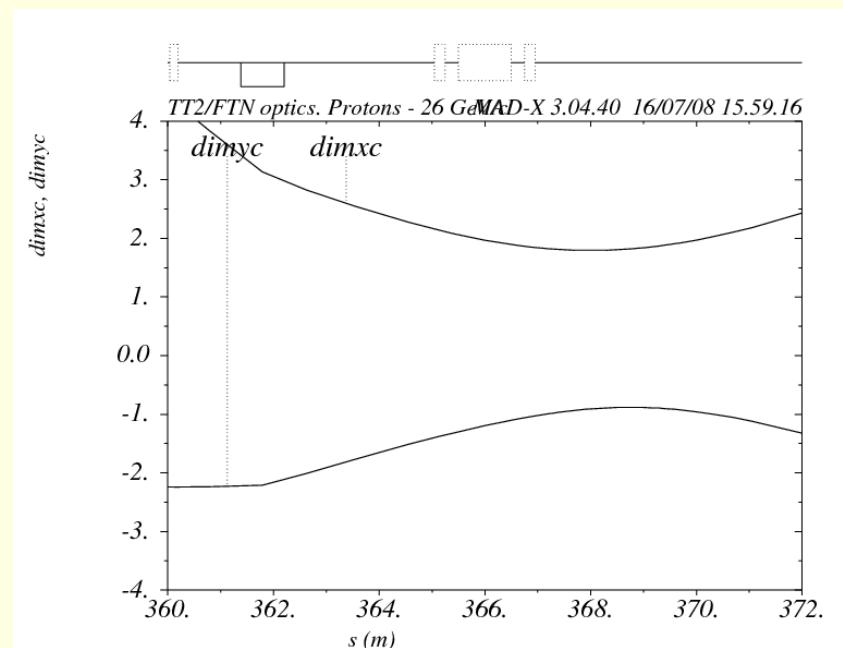
Reminder – Beam Emittance

- 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

σ

2 σ

*Emittance
(87% of beam)*
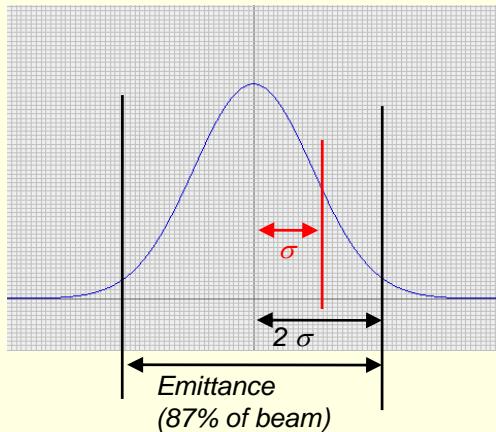
Geometrical emittance:

$$\varepsilon_{protons} = \frac{(2\sigma)^2}{\beta}$$

Normalized emittance:

$$\varepsilon^* = (\beta\gamma)\,\varepsilon\,,\ \beta\gamma = \frac{P_0}{M_0}$$

P [GeV/c]	(βγ)
14.0	14.92
24.0	25.58

Including dispersion

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

What is measured in the machine

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

Beam Emittance measurement – 14 GeV/c

- Friday 26.10@15:55

Beam intensity:

- h16, 1E13
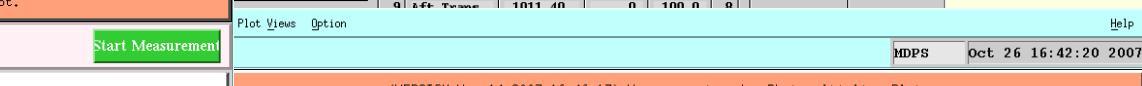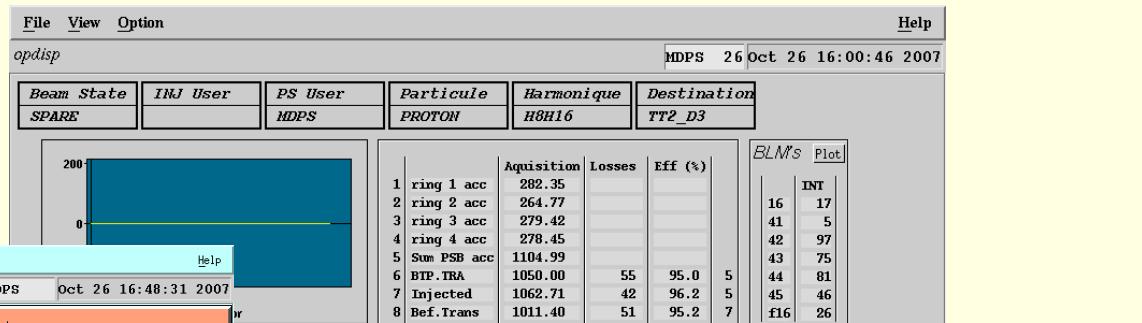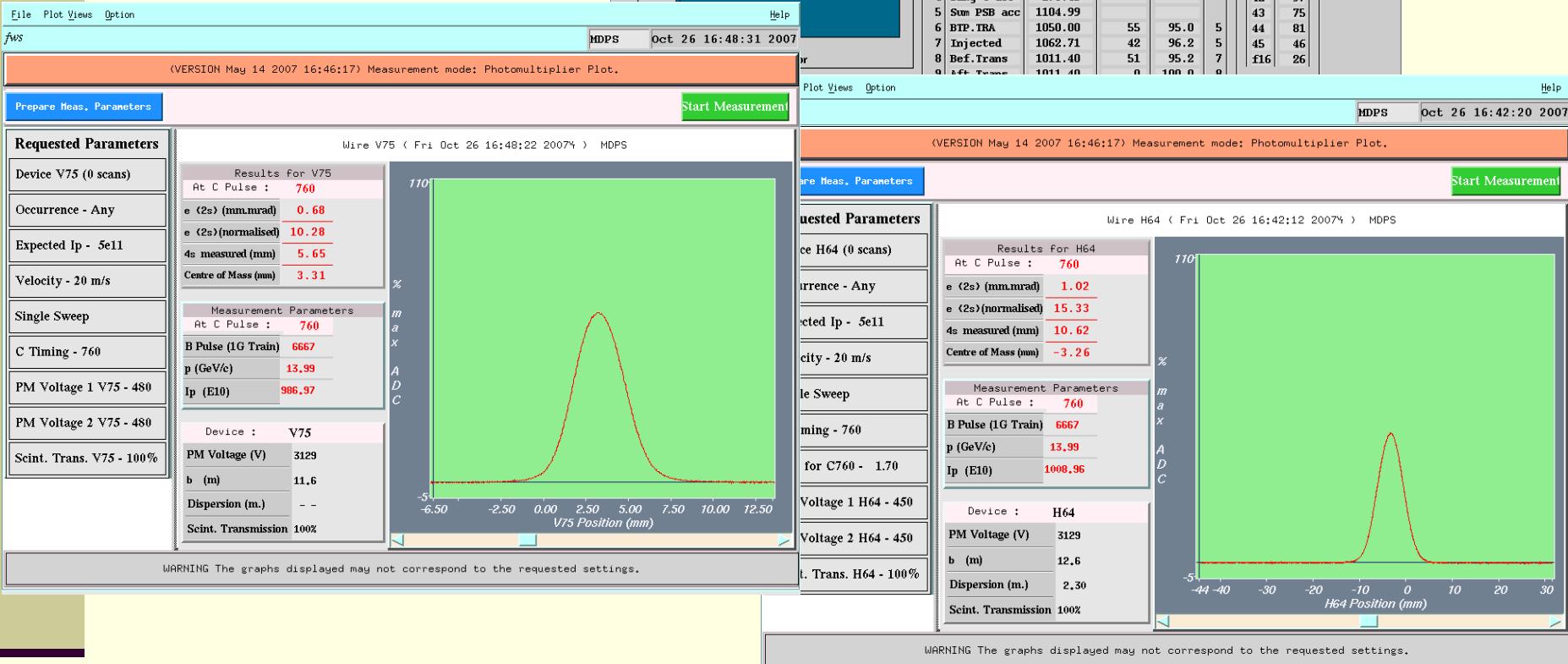
Beam Emittance measurement – 14 GeV/c

- Friday 26.10@17:37

Beam intensity:

- 2.5E11/bunch
- 2 extracted bunches,
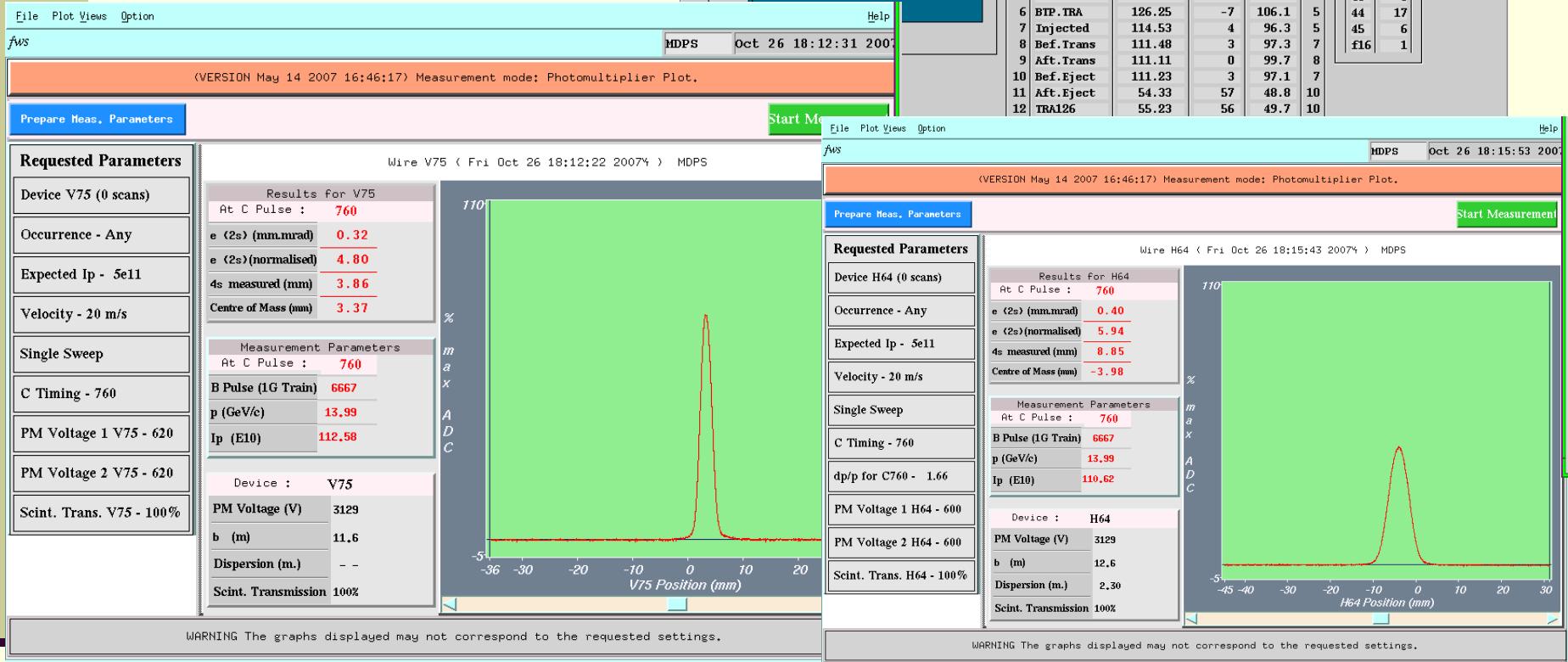
Beam Emittance measurement – 14 GeV/c

- 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
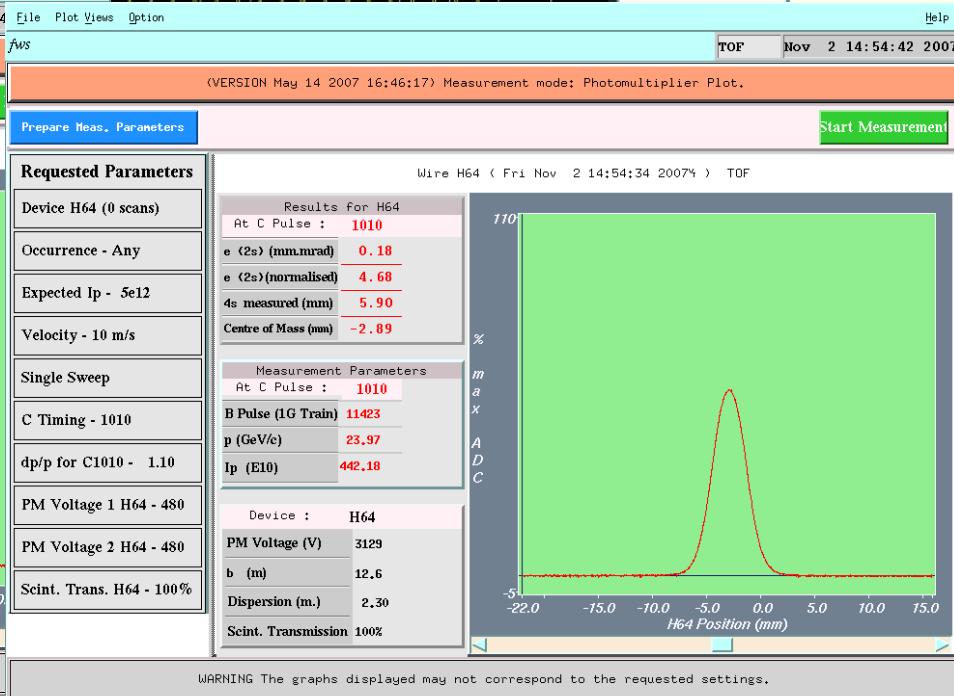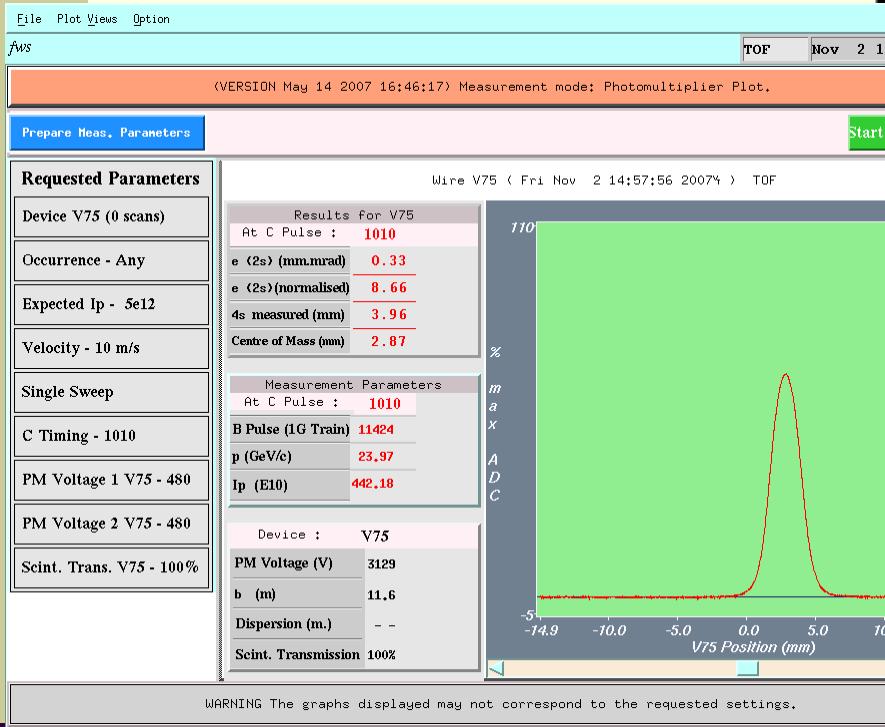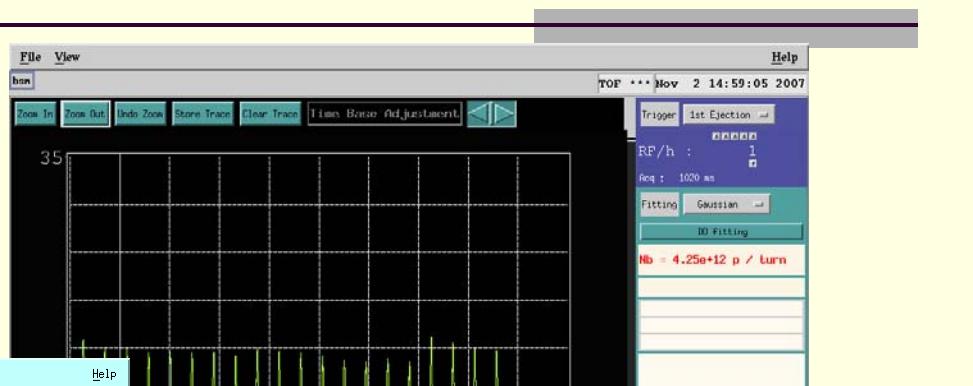
Beam Emittance measurement – 24 GeV/c

- Friday 02.11@16:02PM

Beam intensity:

- 16 bunches,
- 6E12 protons
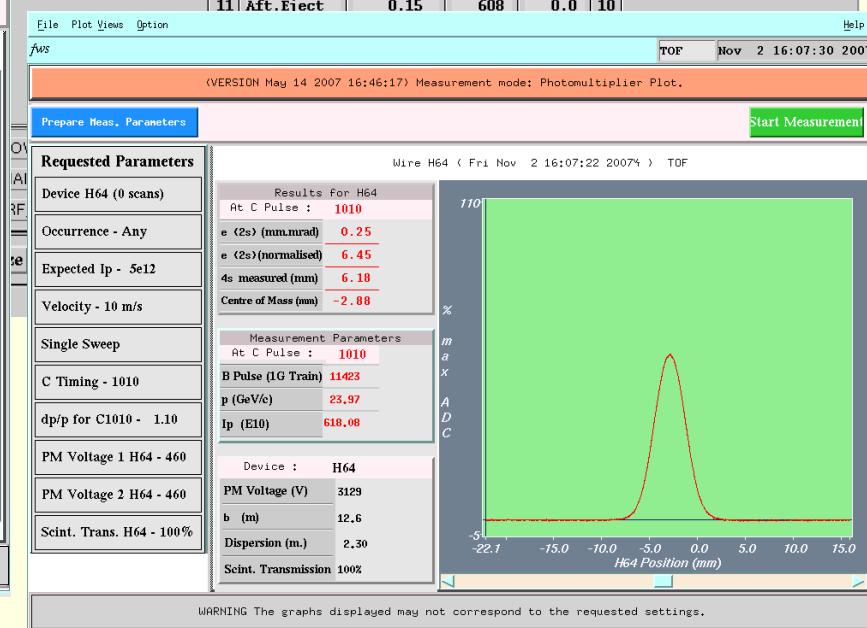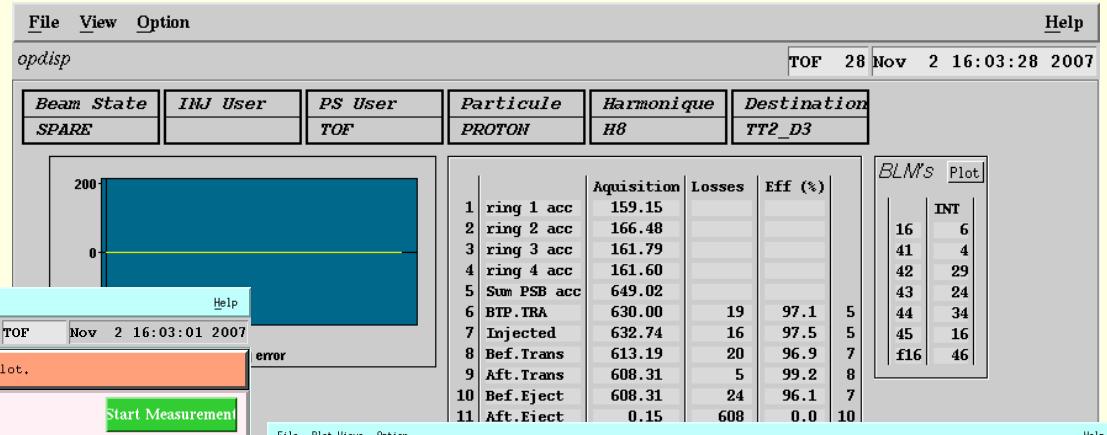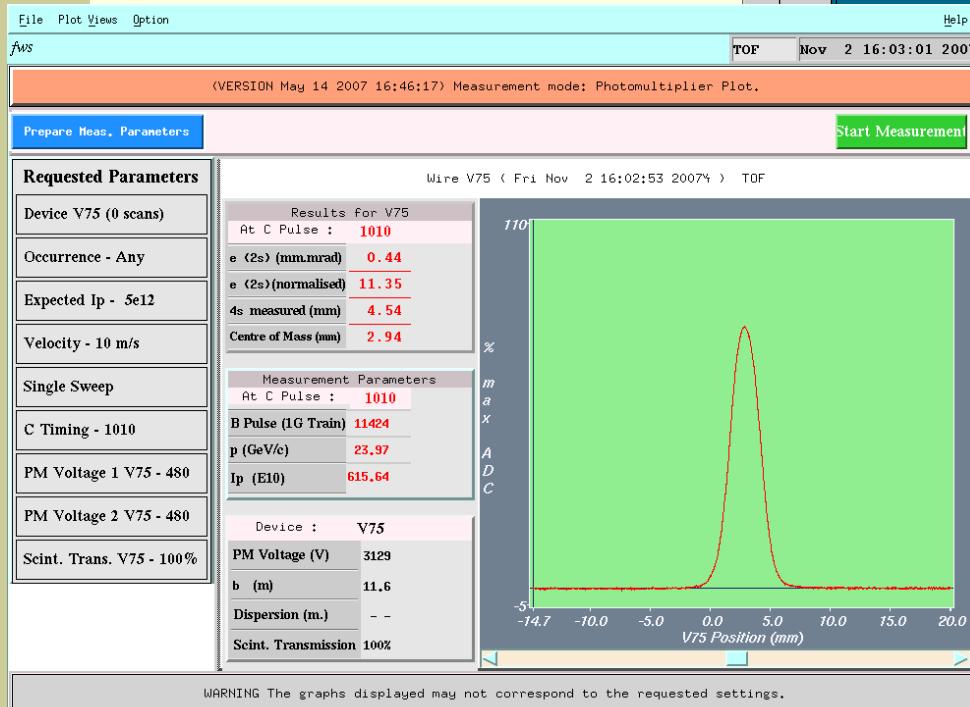
Beam Emittance measurement

- **Summary of measured data**

Measured emittances during MERIT operation - (MERIT logbook)

Date	Pbeam	Beam Type	Bef.Eject	TRA126	TRA283	TRA386	Horizontal 4s meas	Vertical 4s meas	dp/p
	[GeV/c]				[e10]		[mm]	[mm]	[2sigma, 0.1%]
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

Legend: ■ MERIT-Eh   ⊠ MERIT-Ev
— Linear (MERIT-Eh)   — Linear (MERIT-Ev)

$Eh[2sigma-norm] = 11.23\ Intensity[e13] + 1.5998$

$R^2 = 0.6783$

$Ev[2sigma-norm] = 6.0664\ Intensity[e13] + 5.6415$

$R^2 = 0.6321$

Y-axis: Eh & Ev [norm]
X-axis: Beam intensity (1E13)
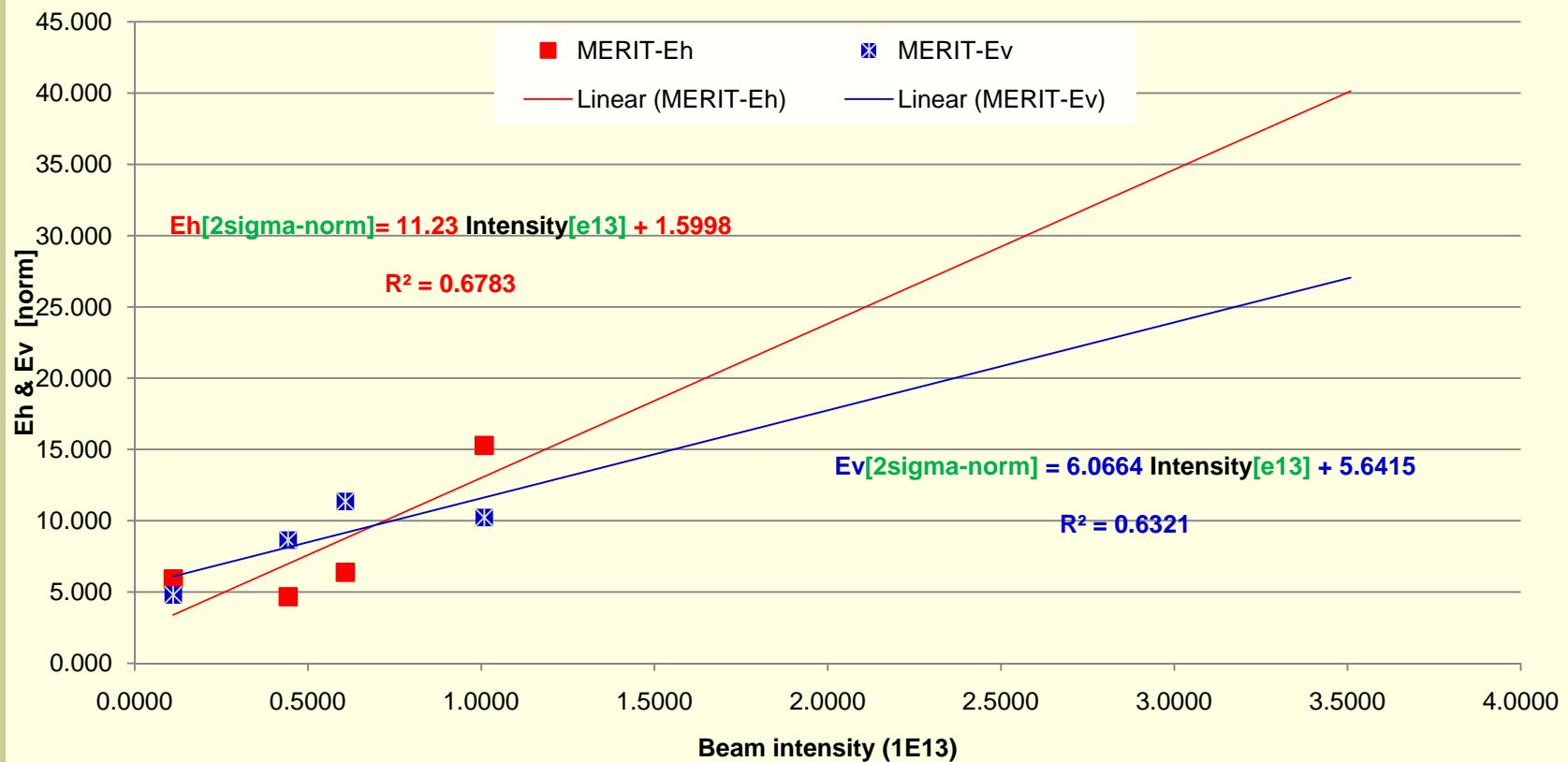
Estimated beam spot and density

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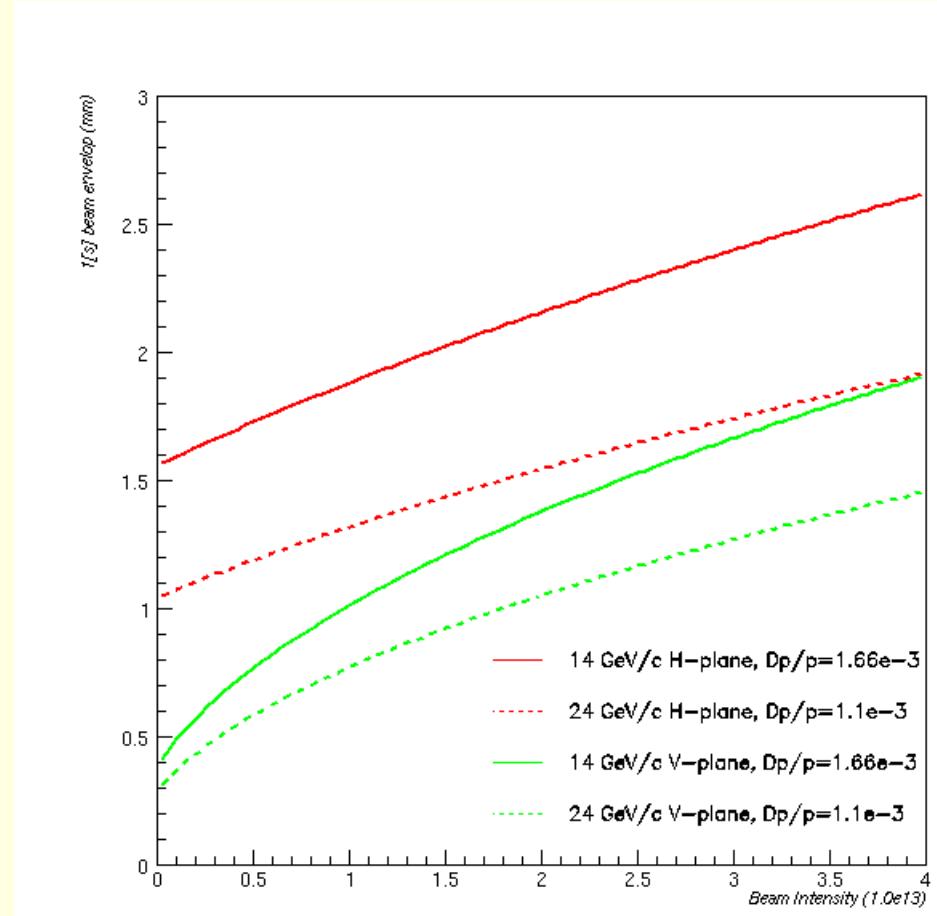
Alignment and Beam Direction

MERIT beam element survey

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

HgWDo   z=0   HgWUp   MTV.484   MTV.454

624mm
700mm
610.0mm   547.5mm   680mm

Reference line on floor

Coordinates of element center wrt nominal beam axis
- *units in mm*
- *z distances from z=0 at solenoid center*
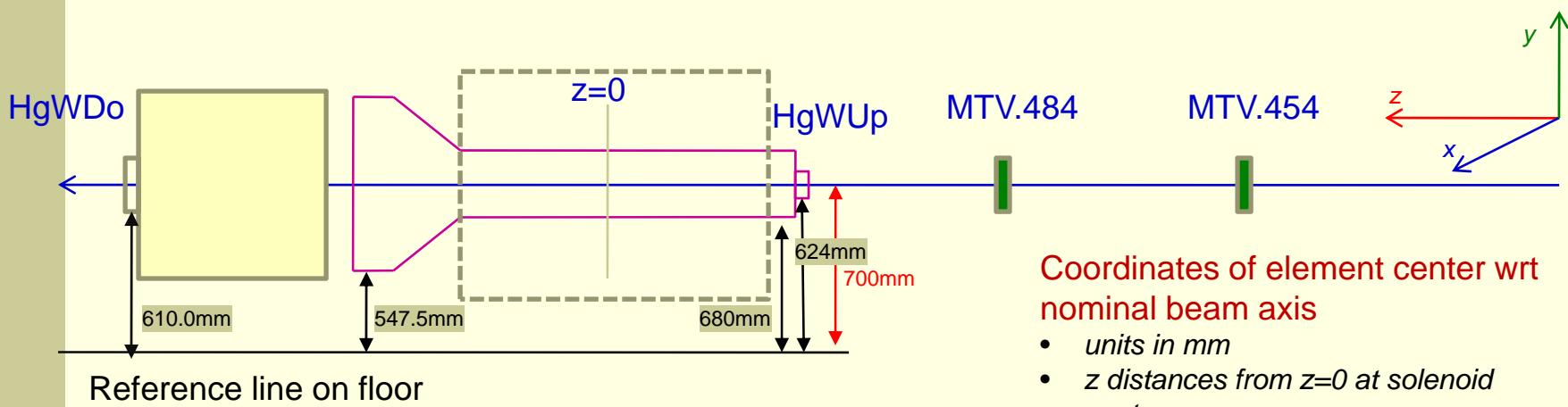
Solenoid tilt – (h-plane)

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

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}

$$\vartheta = \frac{4.9mm}{1.59m} = 3.0mrad!!$$

3.3mm

1.6mm

Nominal beam position in various elements

Beam at Hg container