MERIT beam spot from optics

(update of July 16,2008 talk)

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MERIT Elements – Layout

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

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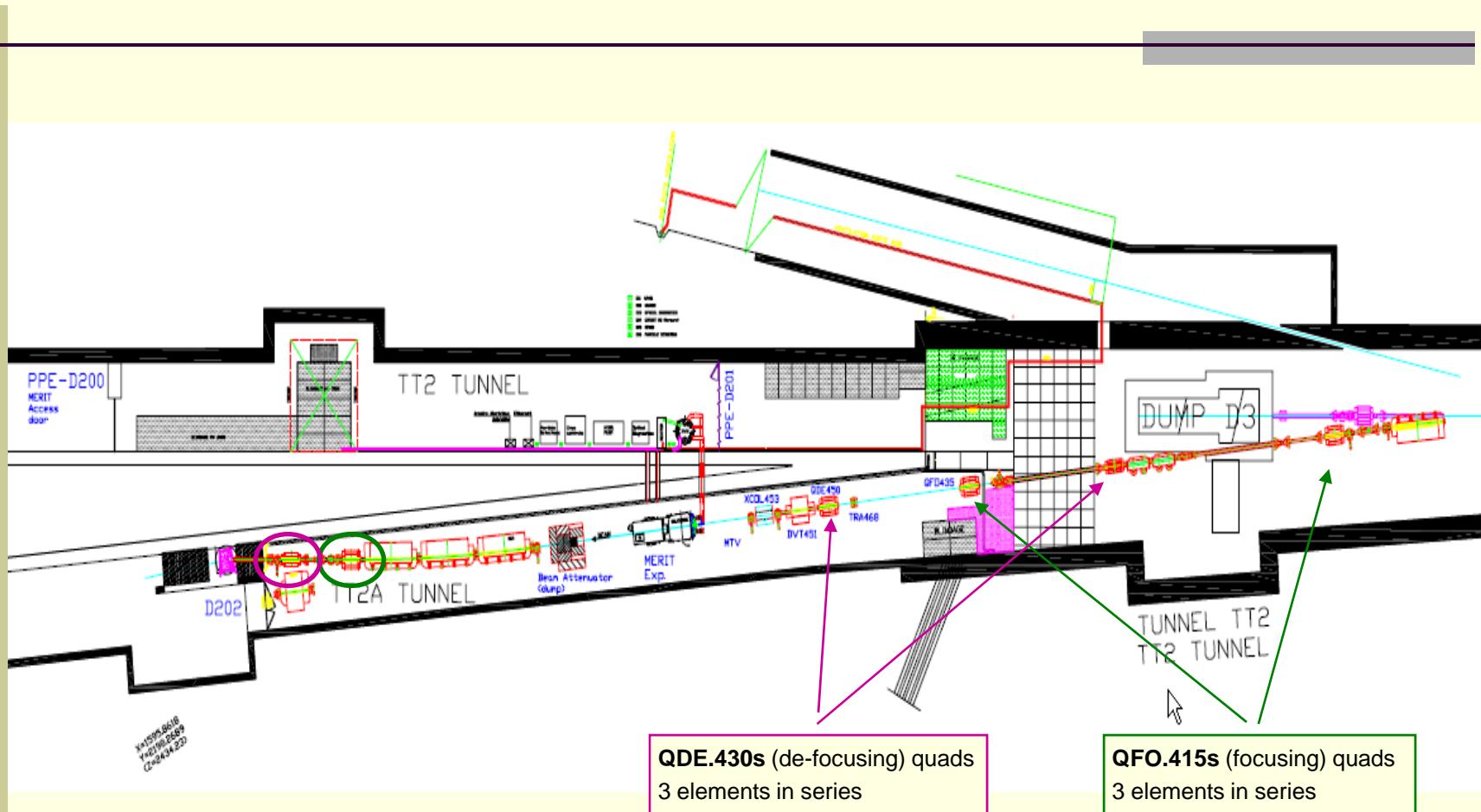
Survey data after the MERIT run – 18.12.2007

Upstream face: **-72.3cm**

Beam optics

- Fit parameters: QFO, QDO strengths and locations (within limits)
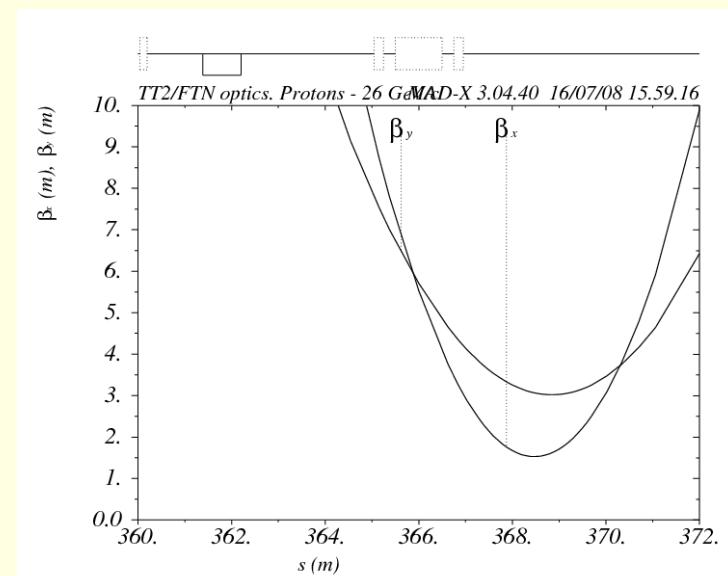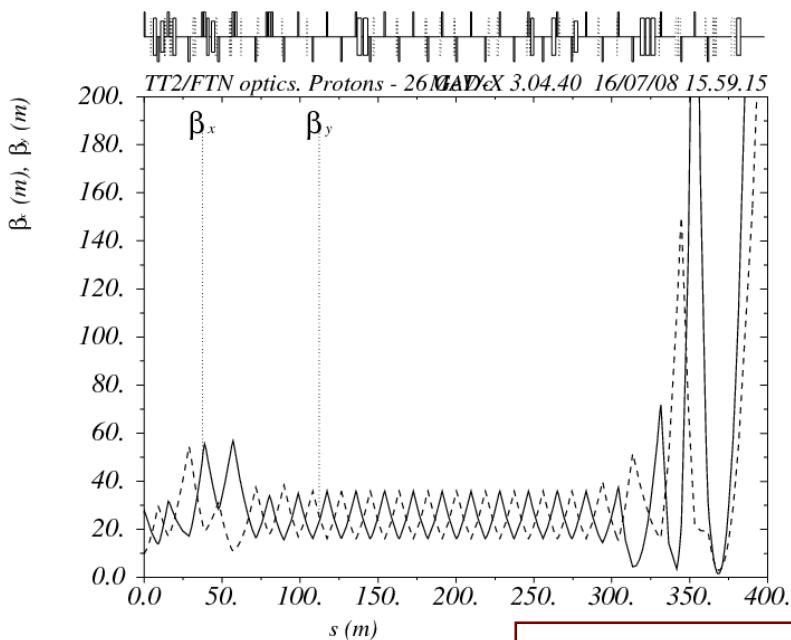
Element	S_line	Beta_x	Alfa_x	Delta_x	Beta_y	Alfa_y	Delta_y
	[m]	[m]	[]	[m]	[m]	[]	[m]
MTV.454	365.1484	8.7535	2.1732	1.5415	7.5513	1.2242	-0.0419
MTV.484	366.8514	3.2477	1.0598	1.6209	4.3414	0.6607	0.0294
HG-WUP	370.3394	3.8082	-1.2205	1.7834	3.7581	-0.4934	0.1756
HG-TARG	371.0624	5.9148	-1.6932	1.8171	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
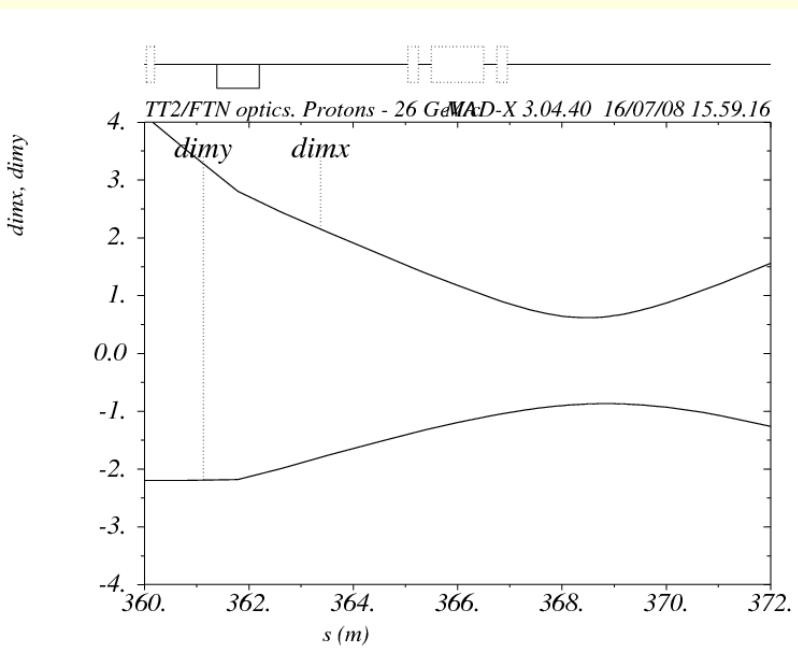
- **With dispersion term**
  - $\sigma(x) = 2.2$mm , $\sigma(y) = 1.1$ mm
  - 130 J/gr @ 30TP
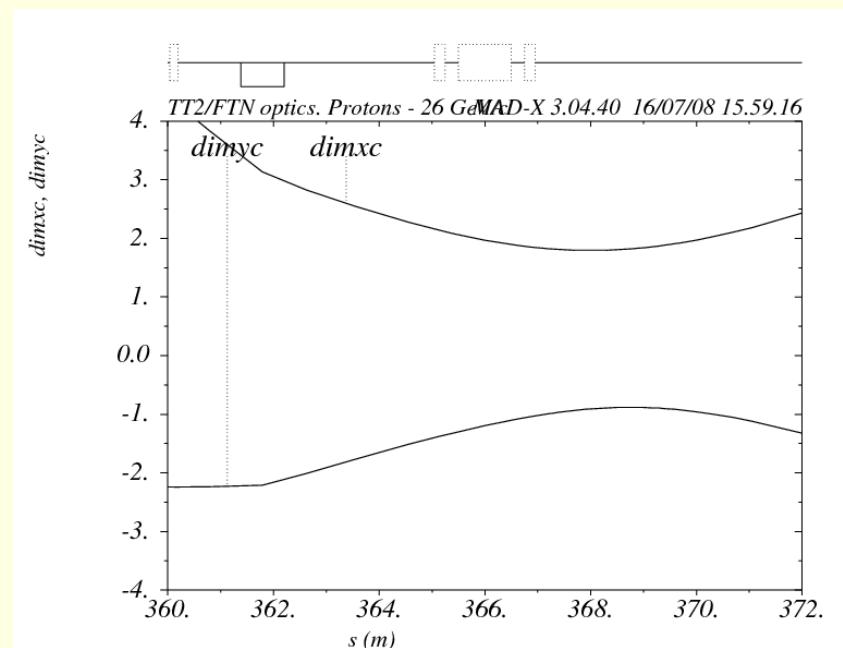
Reminder – Beam Emittance

- 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

Emittance (87% of beam)
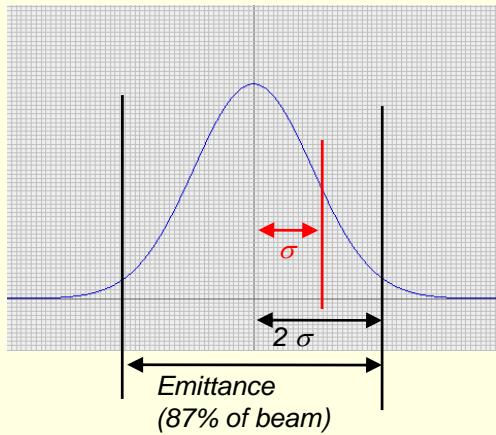
Geometrical emittance:

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

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

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

What is measured in the machine:

$$\varepsilon_{2\sigma} = f\left(4\sigma \text{ fitted width },\frac{\delta p}{p}\bigg|_{2\sigma}\right)$$

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

Beam Emittance measurement – 14 GeV/c

- Friday 26.10@15:55
Beam intensity:
- h16, 1E13
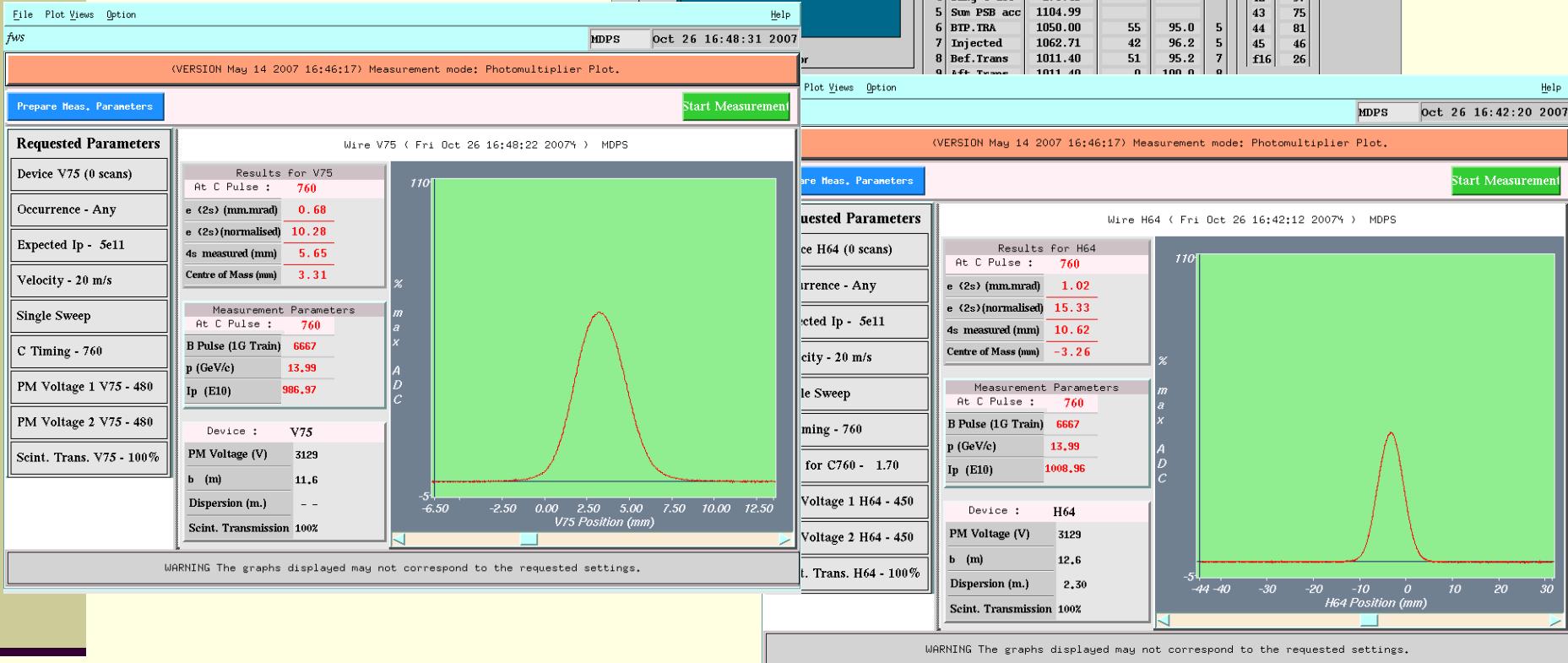
Beam Emittance measurement – 14 GeV/c

- Friday 26.10@17:37

Beam intensity:

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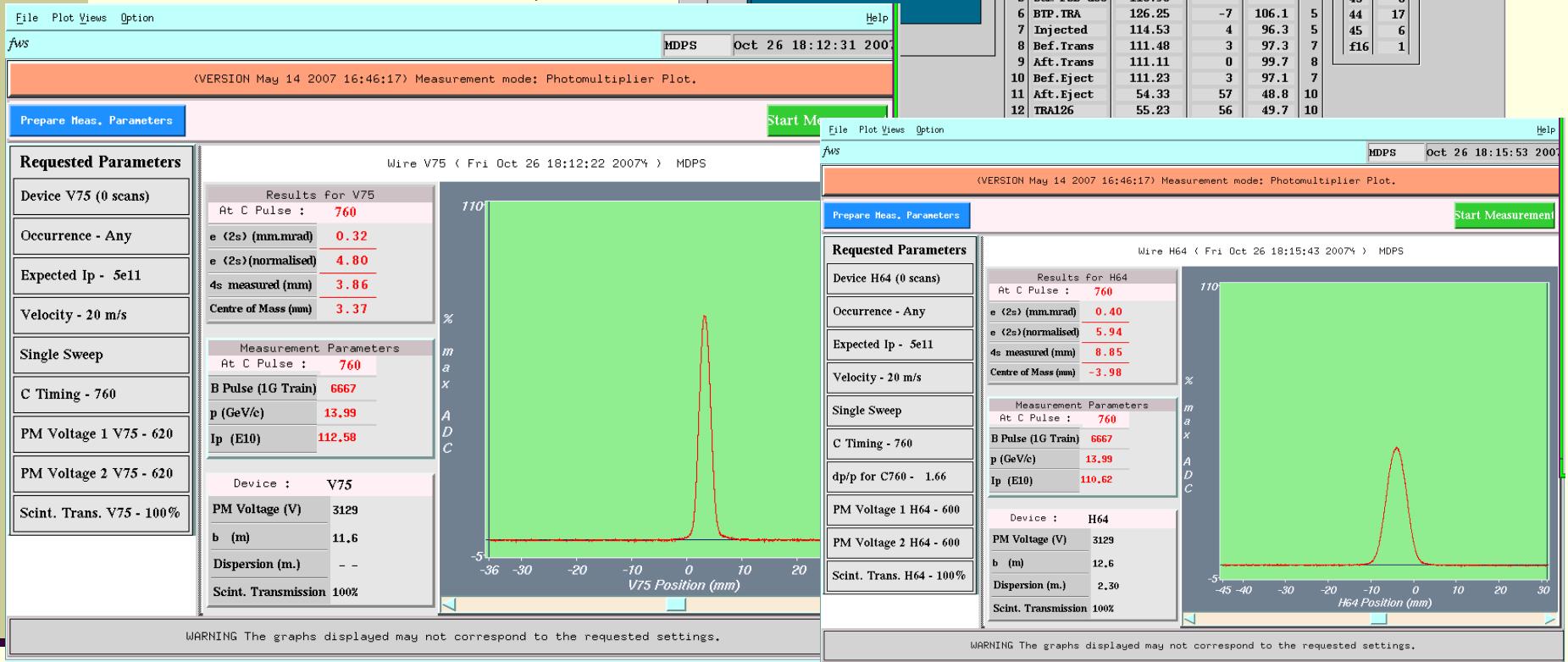
# Beam Emittance measurement – 14 GeV/c

- Friday 26.10@18:24

Beam intensity:

- 1.3E12/bunch
- 2 extracted bunches,

File View Option   Help

opdisp   MDPS   26 Oct 26 18:26:56 2007

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

200

0

		Aquisition	Losses	Eff (%)
1	ring 1 acc	-0.01		
2	ring 2 acc	-0.06		
3	ring 3 acc	488.50		
4	ring 4 acc	0.01		
5	Sum PSB acc	488.44		
6	BTP.TRA	457.50	31	93.7	5
7	Injected	456.84	32	93.5	5
8	Bef.Trans	451.96	5	98.9	7
9	Aft.Trans	449.51	2	99.5	8
10	Bef.Eject	447.07	10	97.9	7

BLM's Plot

	INT
16	140
41	29
42	255
43	255
44	255
45	255
f16	4

File Plot Views Option   Help

fws   MDPS   Oct 26 18:36:03 2007

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

Prepare Meas. Parameters

Requested Parameters   Wire V75 (Fri Oct 26 18:35:53 2007⅘)   MDPS

Device V75 (0 scans)

Results for V75
At C Pulse :   760

e (2s) (mm.mrad)	1.02
e (2s)(normalised)	15.34
4s measured (mm)	6.90
Centre of Mass (mm)	3.35

Occurrence - Any

Expected Ip - 5e11

Velocity - 20 m/s

Single Sweep

Measurement Parameters
At C Pulse :   760

B Pulse (1G Train)	6667
p (GeV/c)	13.99
Ip (E10)	442.18

C Timing - 760

PM Voltage 1 V75 - 580

PM Voltage 2 V75 - 580

Device :   V75

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

Scint. Trans. V75 - 100%

V75 Position (mm)

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

File Plot Views Option   He

fws   MDPS   Oct 26 18:32:41 20

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

Prepare Meas. Parameters   Start Measurem

Requested Parameters   Wire H64 (Fri Oct 26 18:32:31 2007⅘)   MDPS

Device H64 (0 scans)

Results for H64
At C Pulse :   760

e (2s) (mm.mrad)	1.73
e (2s)(normalised)	25.82
4s measured (mm)	12.36
Centre of Mass (mm)	-3.75

Occurrence - Any

Expected Ip - 5e11

Velocity - 20 m/s

Single Sweep

Measurement Parameters
At C Pulse :   760

B Pulse (1G Train)	6667
p (GeV/c)	13.99
Ip (E10)	439.74

C Timing - 760

dp/p for C760 - 1.76

PM Voltage 1 H64 - 540

PM Voltage 2 H64 - 540

Device :   H64

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

Scint. Trans. H64 - 100%

H64 Position (mm)

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

Beam Emittance measurement – 24 GeV/c

- Friday 02.11@14:55PM

Beam intensity:

- 2.5E11/bunch
- 16 bunches
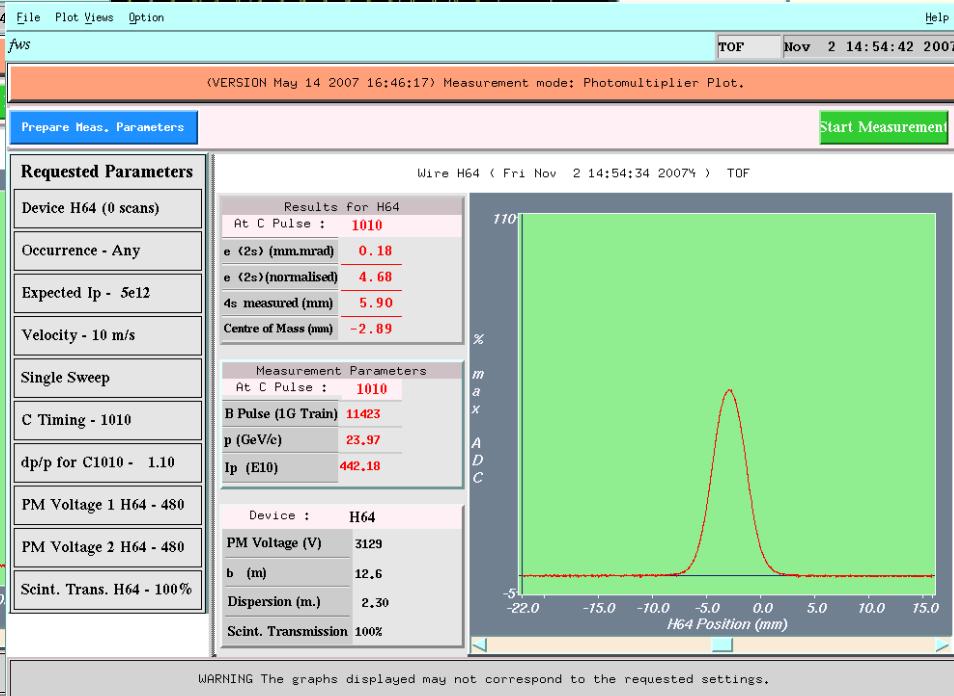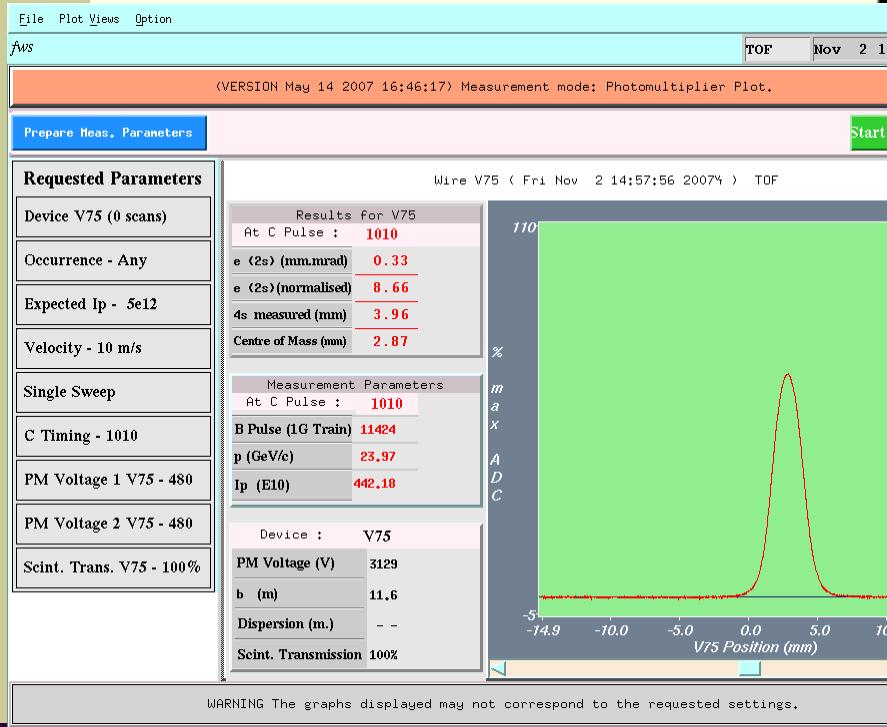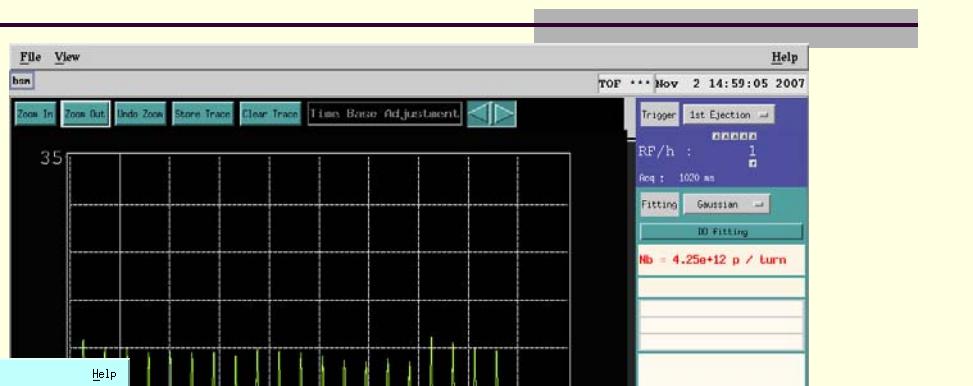
Beam Emittance measurement – 24 GeV/c

- Friday 02.11@16:02PM

Beam intensity:

- 16 bunches,
- 6E12 protons
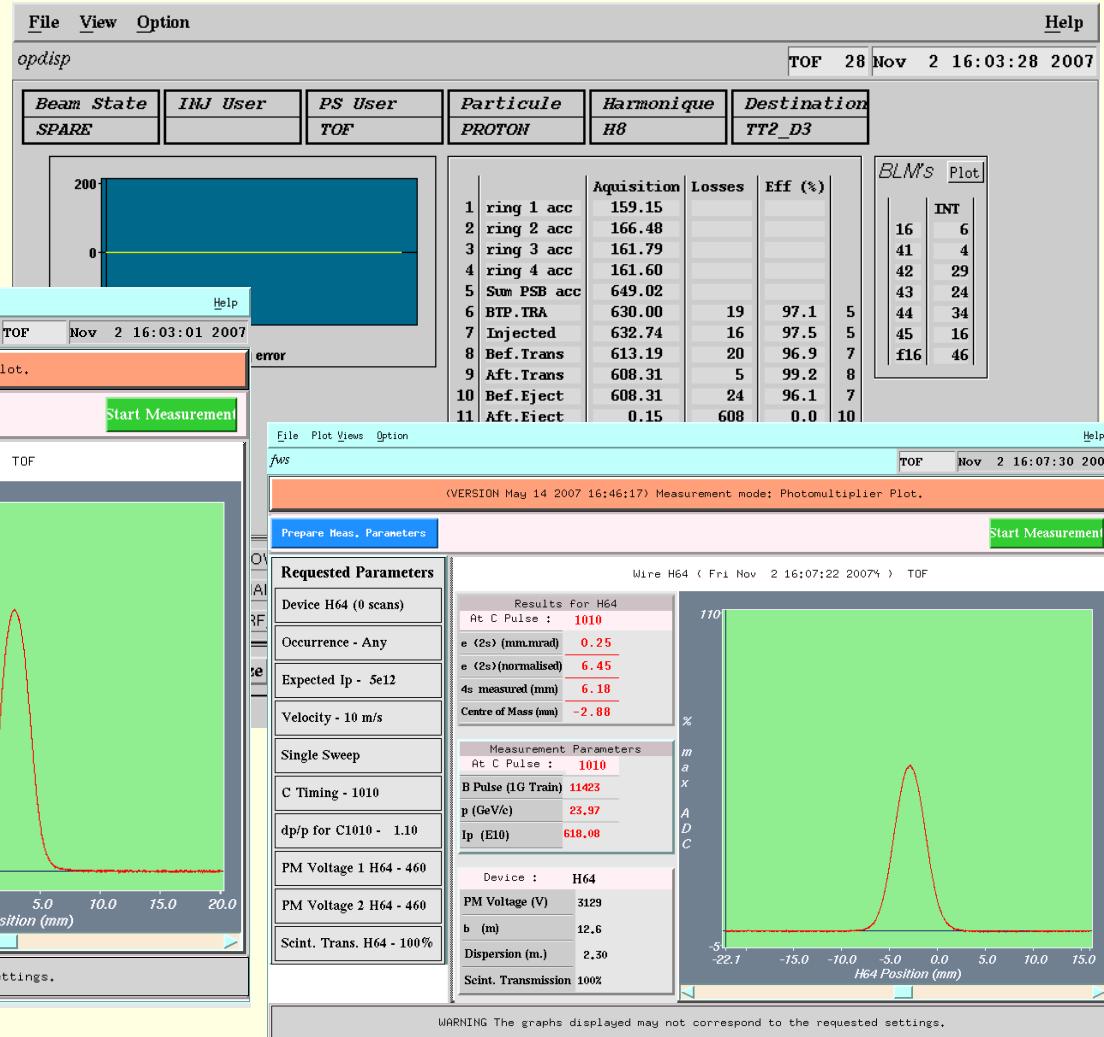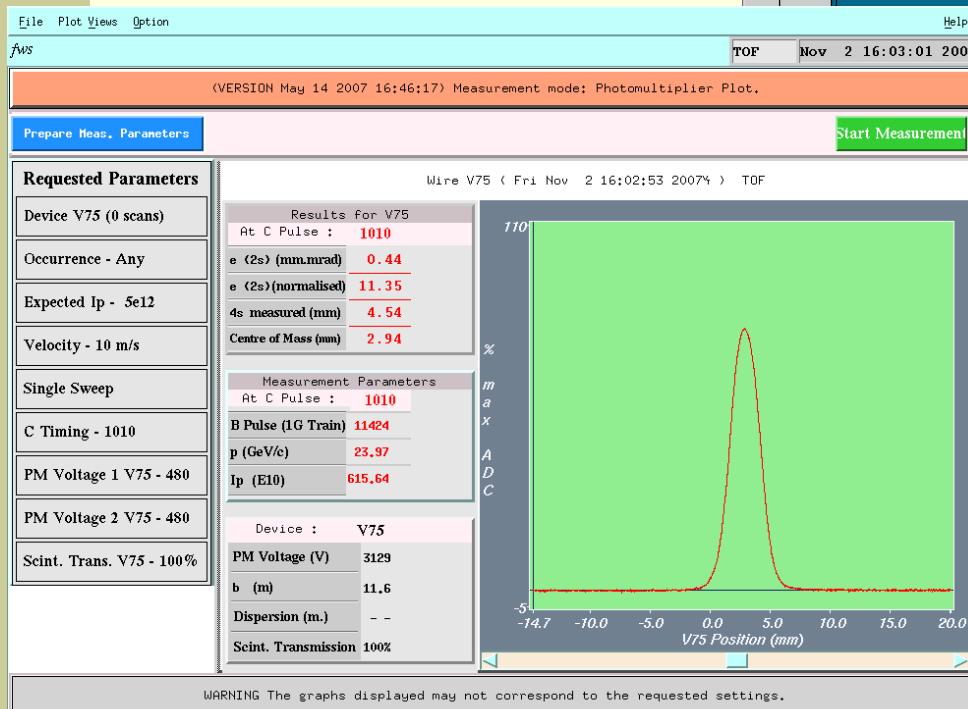
Beam Emittance measurement

- **Summary of measured data**

Measured emittances during MERIT operation - (MERIT logbook)

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

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

$R^2 = 0.6783$

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

$R^2 = 0.6321$
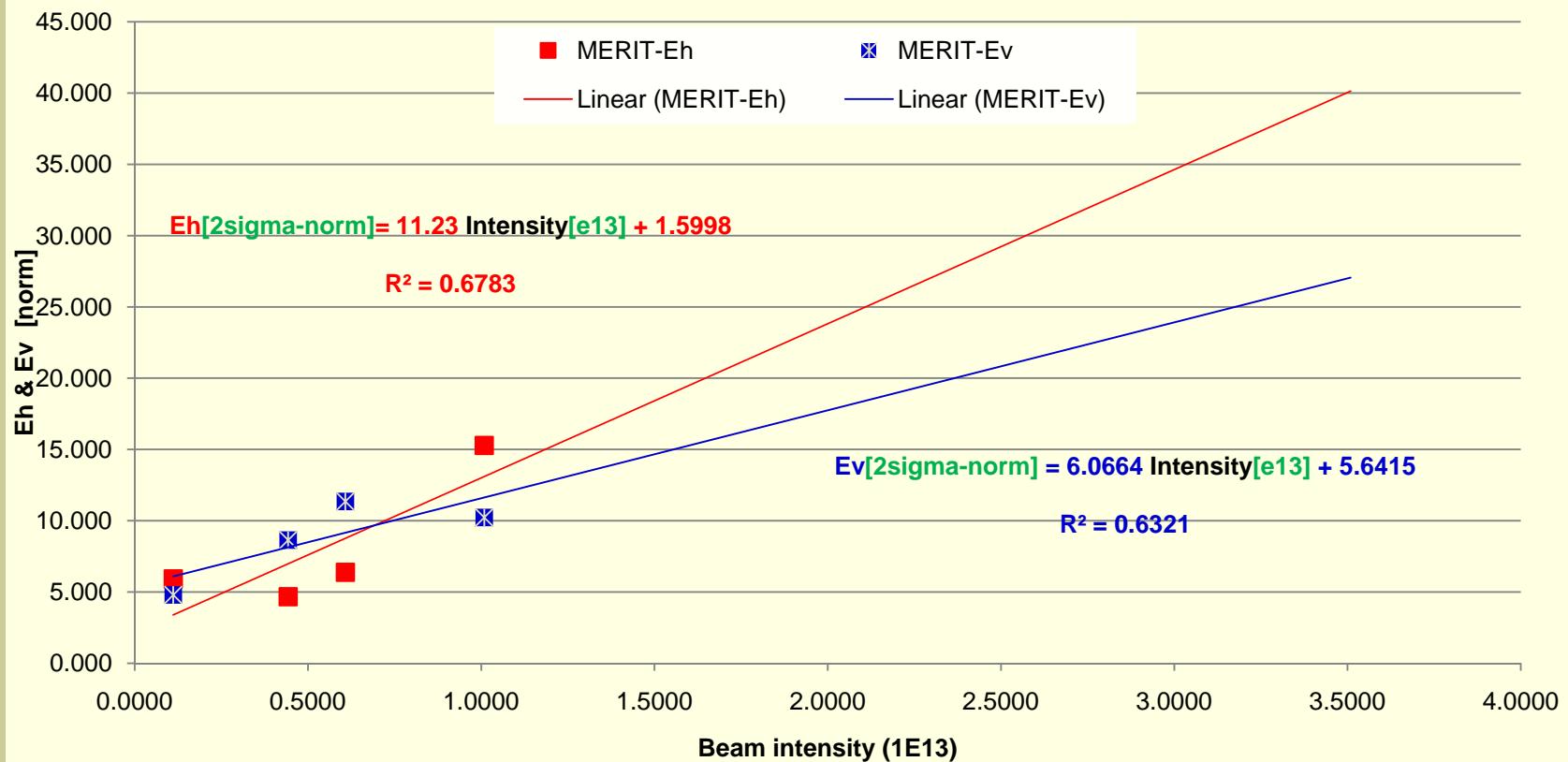
Estimated beam spot and density

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