MERIT Data Analysis

(latest update : 07Oct08)

Contents

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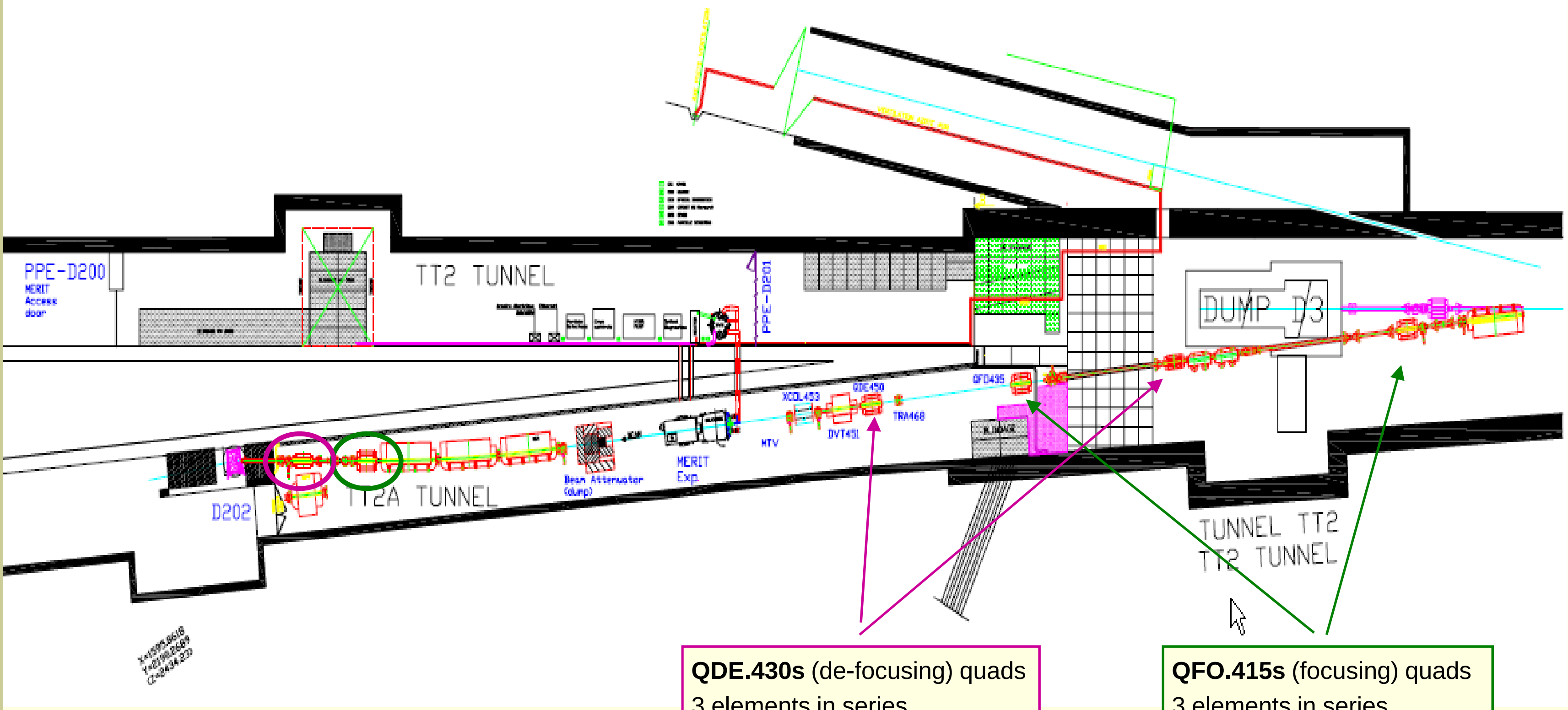
Beam spot size analysis

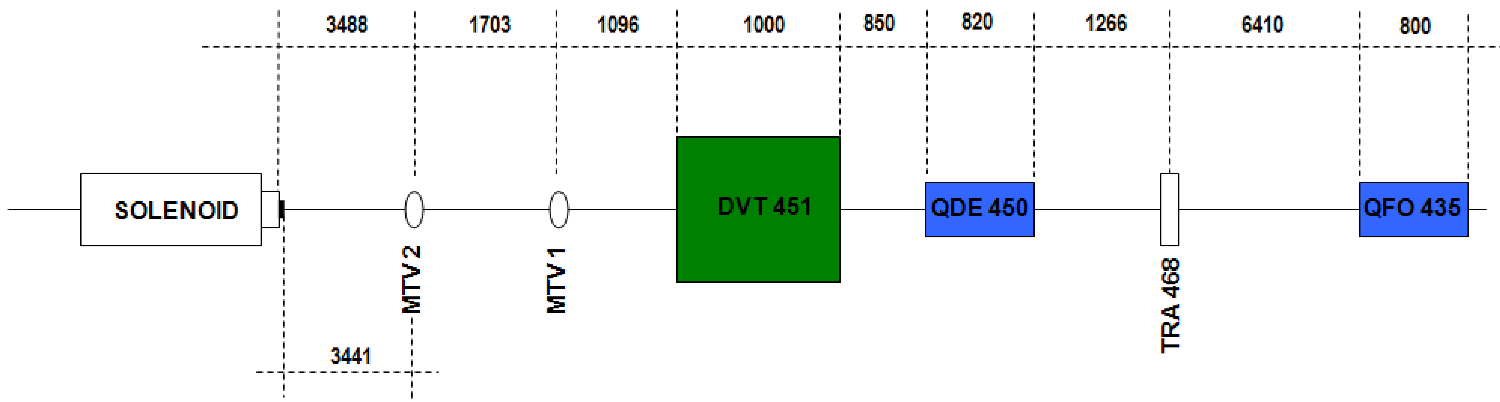
MERIT Elements – Layout



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



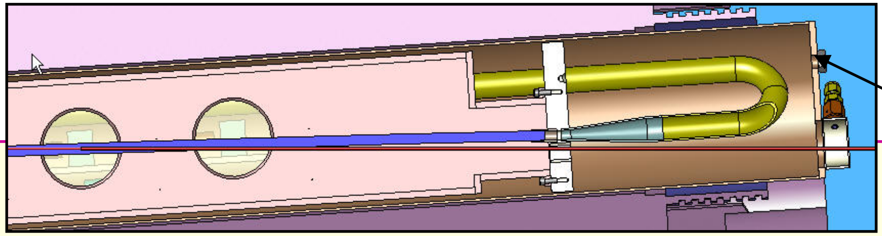
FTN start 304.69540

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	

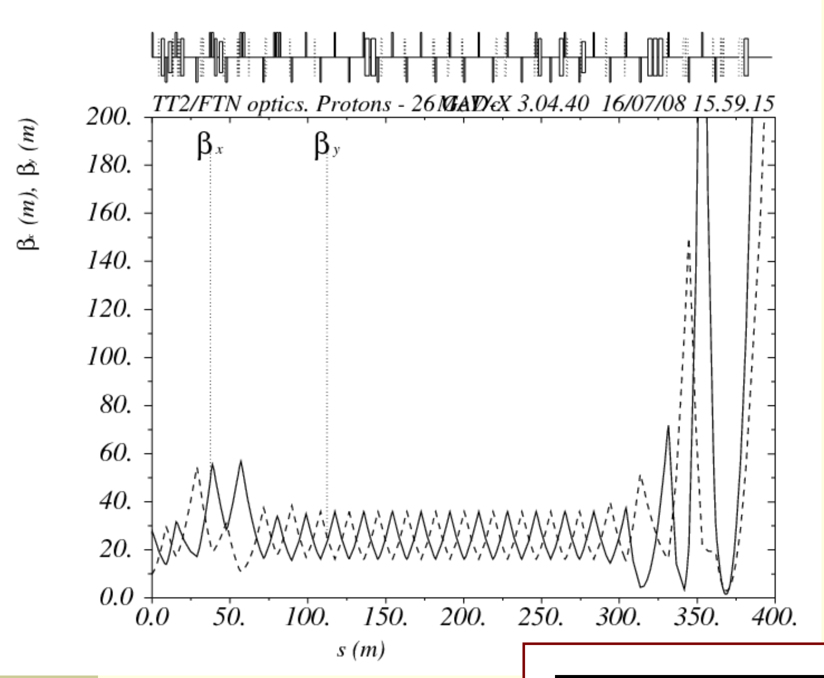


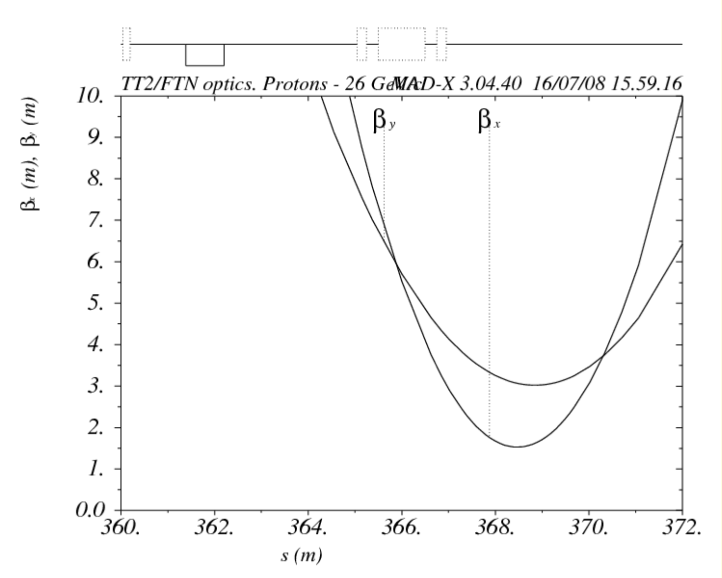
MTV1	60.453	365.1484
MTV2	62.156	366.8514
HGTAU	65.644	370.3394
HGTAR	66.367	371.0624

Upstream face: **-72.3cm**

Beam optics

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

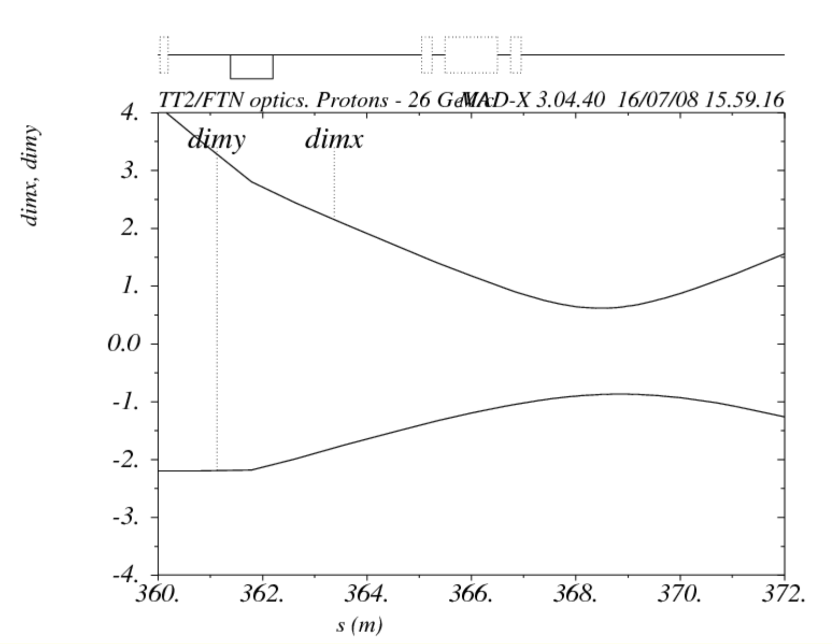




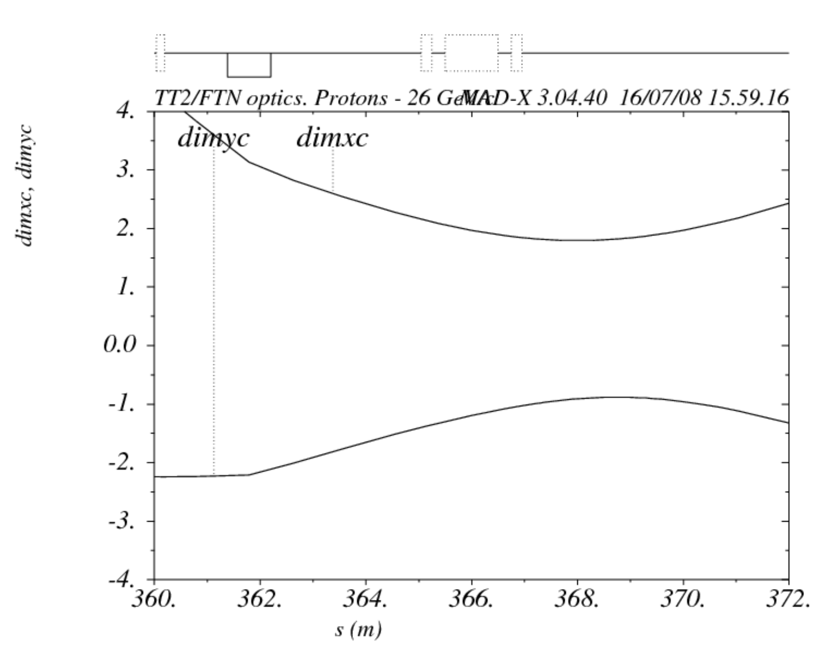
Element	S_line	Beta_x	Alfa_x	Delta_x	Beta_y	Alfa_y	Delta_y
	[m]	[m]	[]	[m]	[m]	[]	[m]
MTV.454	365.1484	8.7535	2.1732	1.5415	7.5513	1.2242	-0.0419
MTV.484	366.8514	3.2477	1.0598	1.6209	4.3414	0.6607	0.0294
HG-WUP	370.3394	3.8082	-1.2205	1.7834	3.7581	-0.4934	0.1756
HG-TARG	**371.0624**	**5.9148**	**-1.6932**	**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
  - σ(x) = 1.2mm , σ(y) = 1.1 mm
  - 238 J/gr @ 30TP

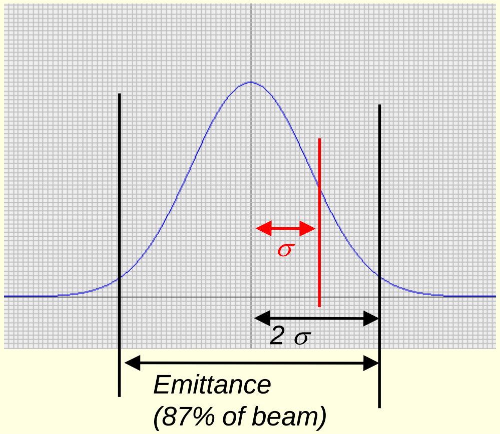


- With dispersion term
  - σ(x) = 2.2mm , σ(y) = 1.1 mm
  - 130 J/gr @ 30TP



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



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

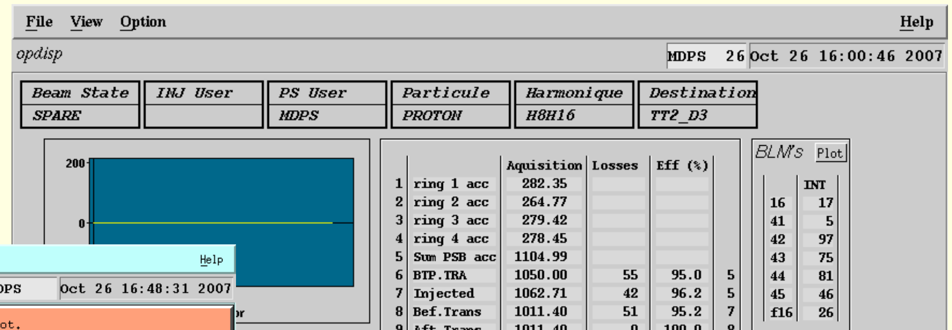
$$\varepsilon_{2\sigma} = f\left(w_{4\sigma}, \frac{\delta p}{p}_{2\sigma}\right) = \frac{\left(\frac{w_{4\sigma}}{2}\right)^2 - \left(\left|D_p\right| \frac{\delta p}{p}_{2\sigma}\right)^2}{\beta}$$

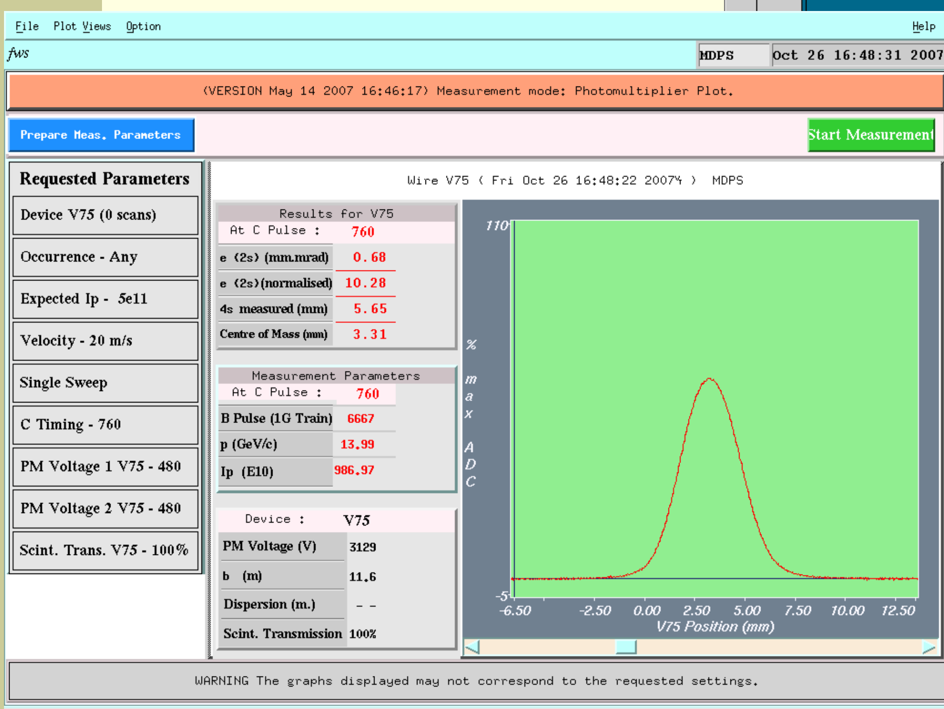
Beam Emittance measurement – 14 GeV/c

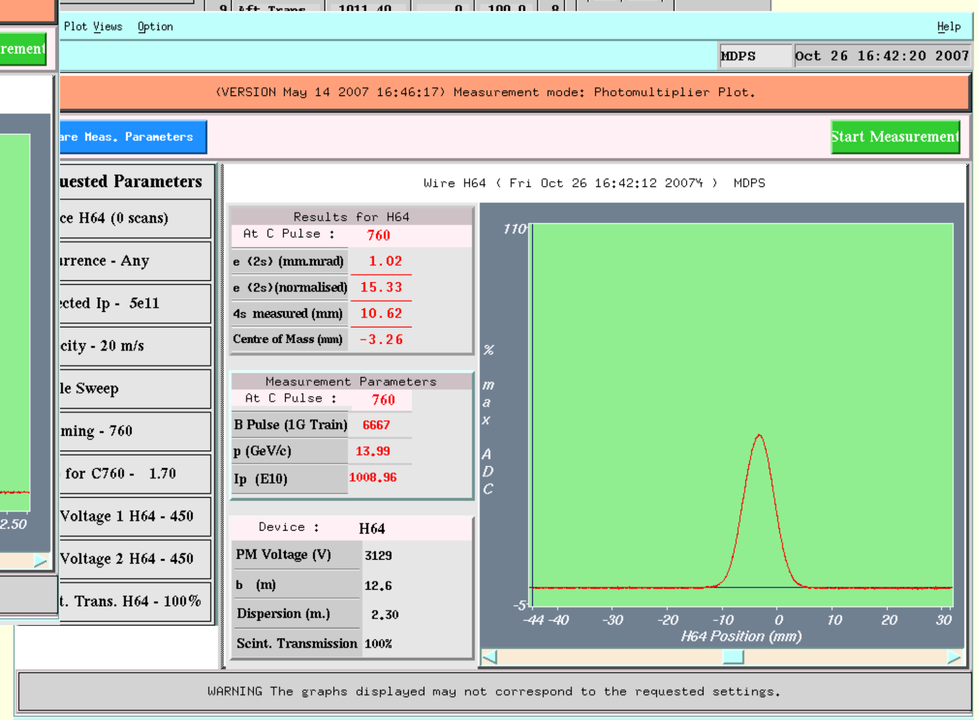
- Friday 26.10@15:55

Beam intensity:

- h16, 1E13





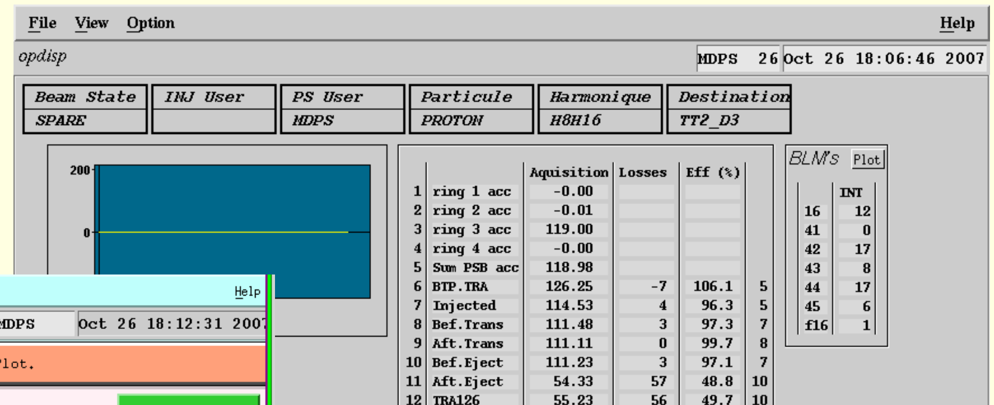


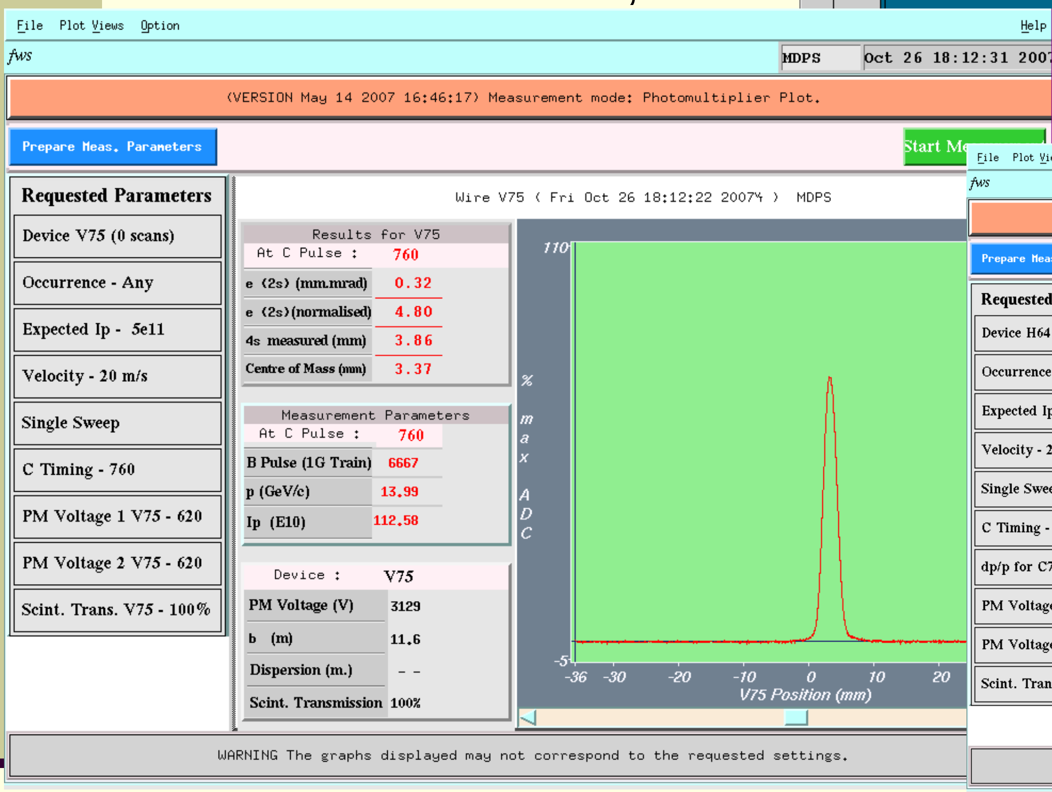
Beam Emittance measurement – 14 GeV/c

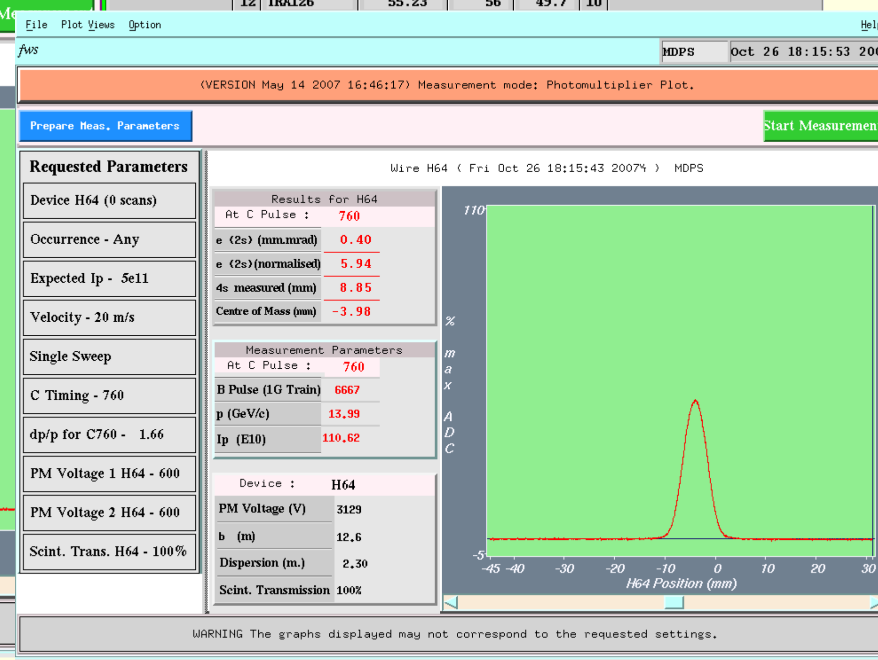
- Friday 26.10@17:37

Beam intensity:

- 2.5E11/bunch
- 2 extracted bunches,





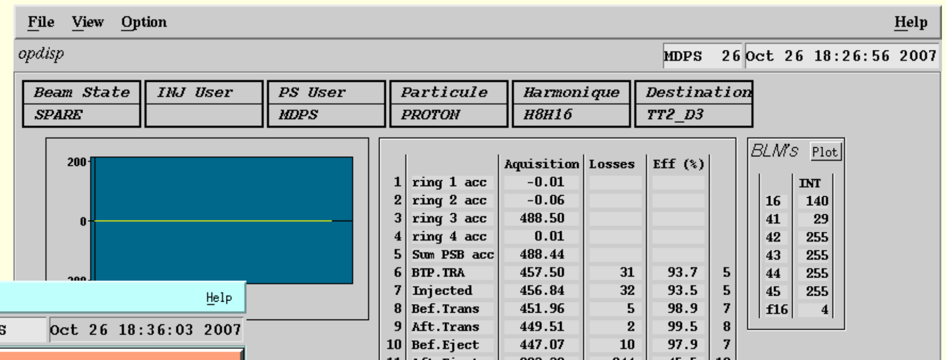


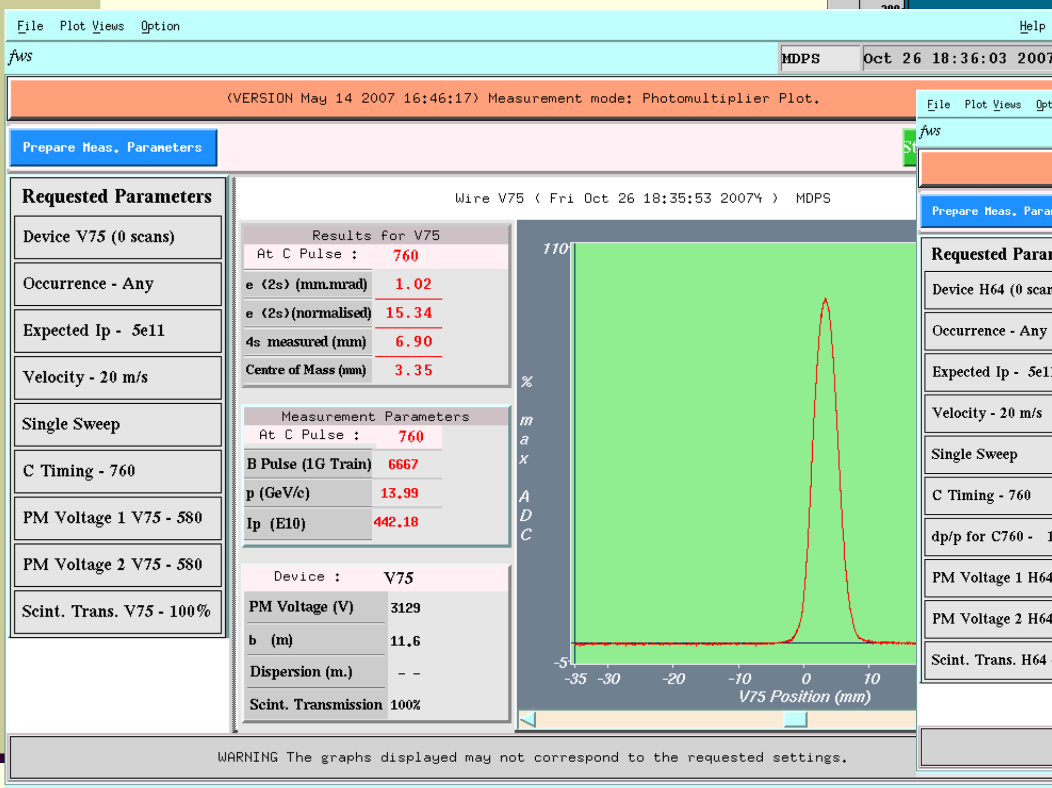
Beam Emittance measurement – 14 GeV/c

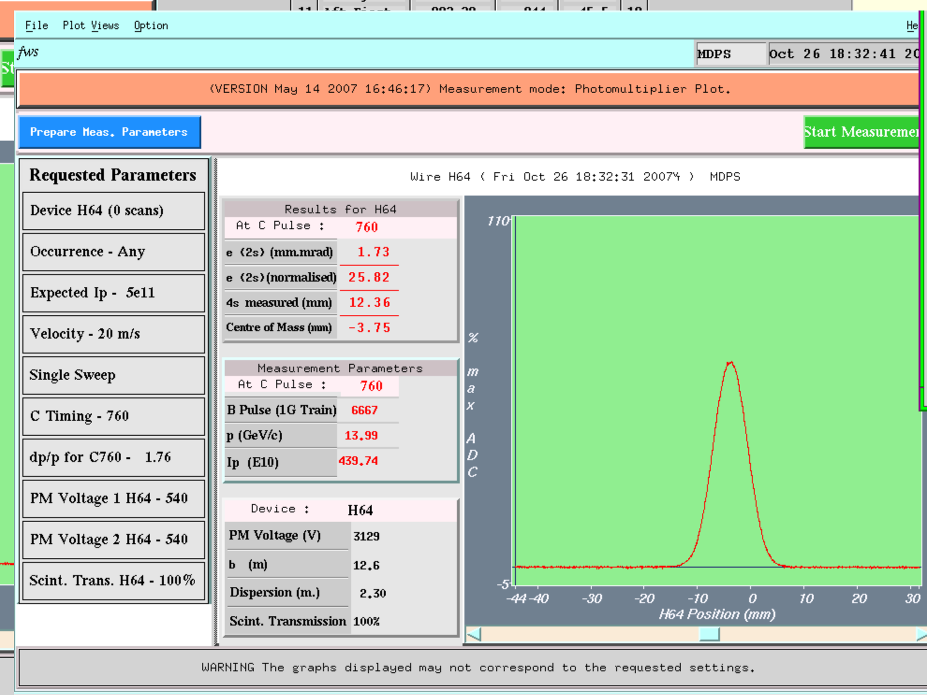
- Friday 26.10@18:24

Beam intensity:

- 1.3E12/bunch
- 2 extracted bunches,





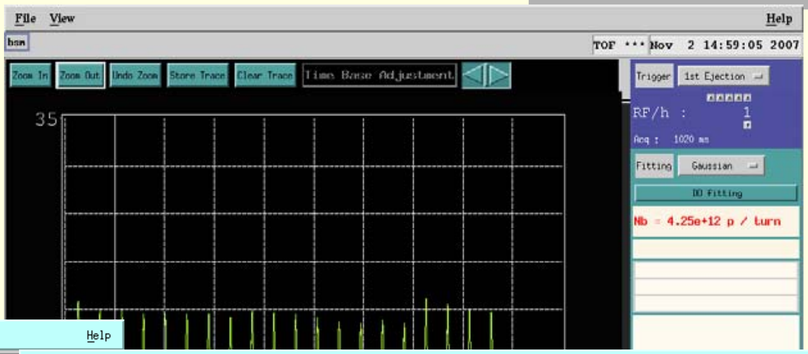


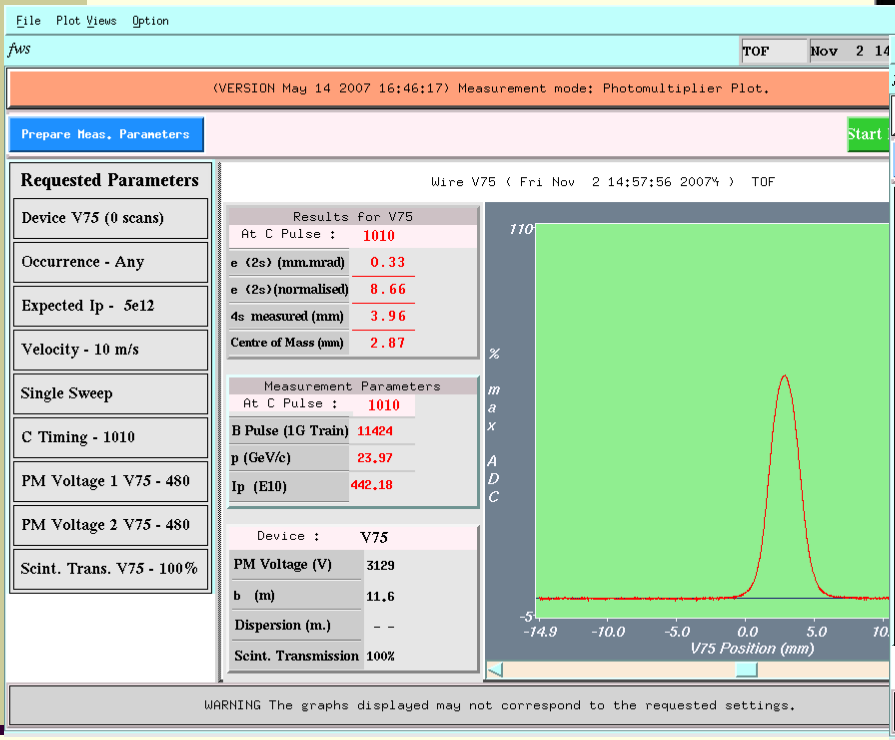
Beam Emittance measurement – 24 GeV/c

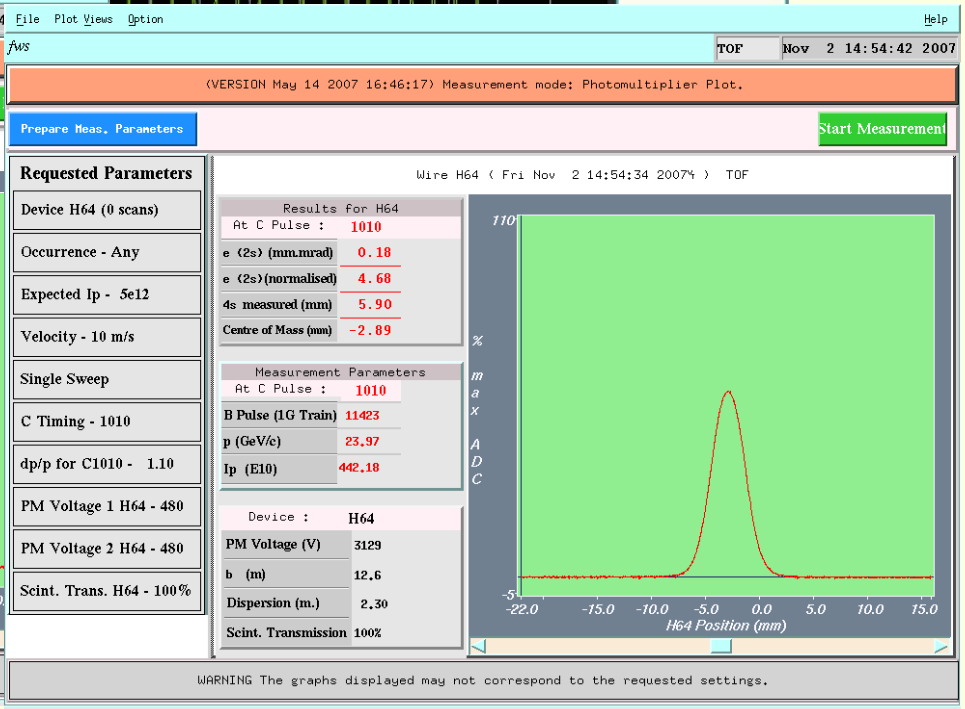
- Friday 02.11@14:55PM

Beam intensity:

- 2.5E11/bunch
- 16 bunches





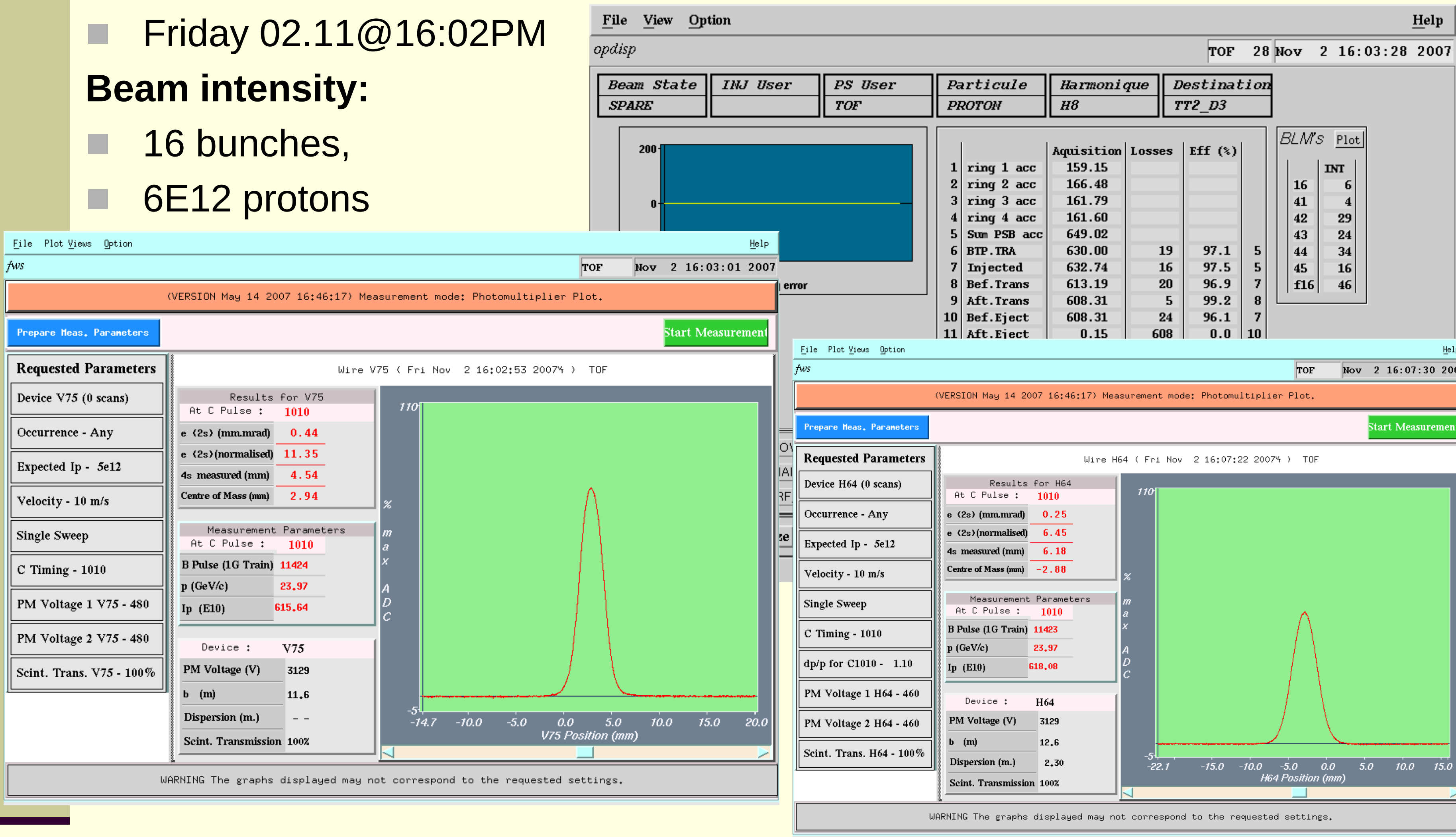


Beam Emittance measurement – 24 GeV/c

- 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)

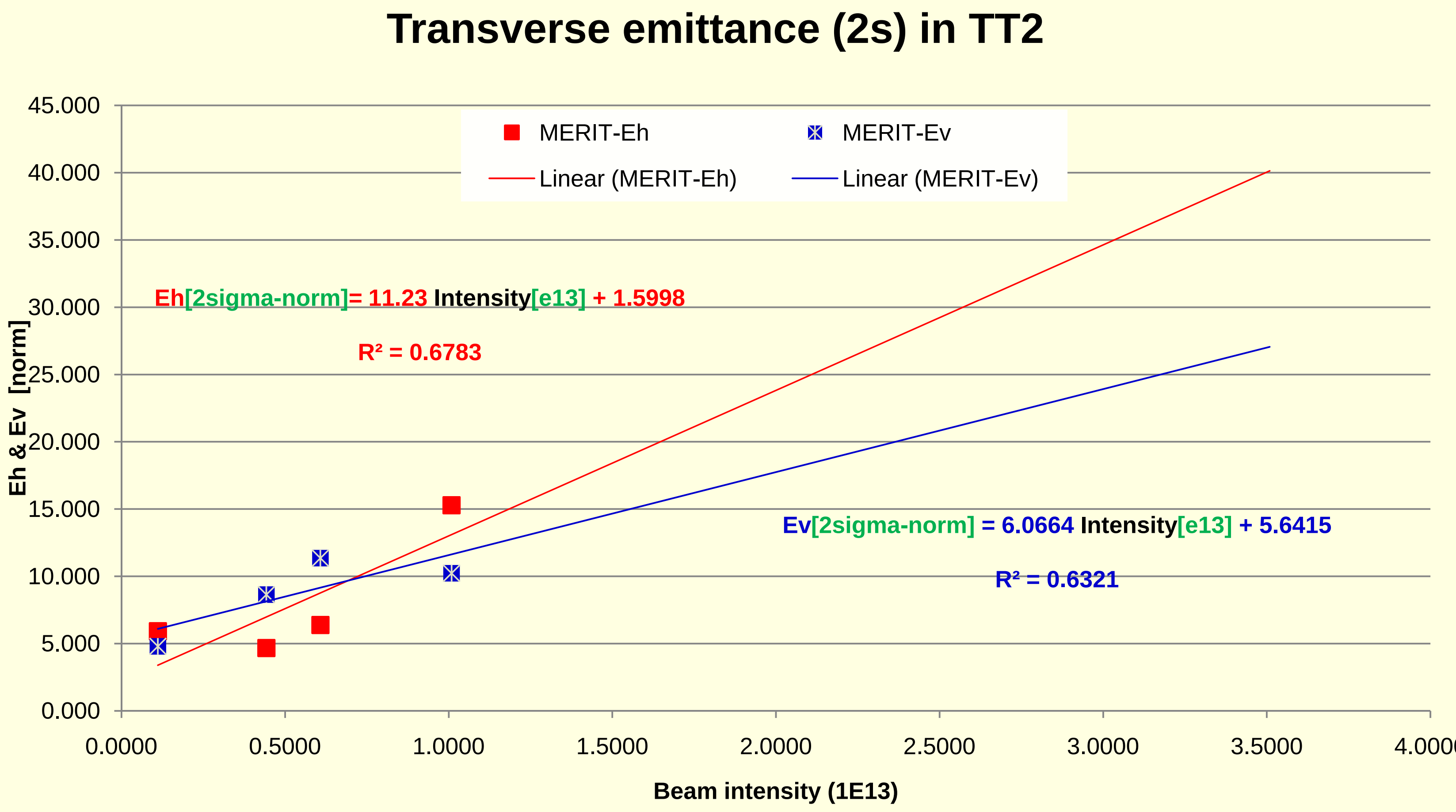
Date	Pbeam [GeV/c]	Beam Type	Intensity Bef.Eject [e10]	TRA126	TRA283	TRA386	Horizontal 4s meas [mm]	Vertical 4s meas [mm]	dp/p [2sigma, 0.1%]
26-Oct	13.99	h16	1008.96	695.71	996.75	1037.25	10.62	5.64	1.7
26-Oct	13.99	2x2.5e11, DT=1.7us	111.23	55.23	53.2	54.4	8.85	3.86	1.66
26-Oct	13.99	2x1.3e12, DT=1.7us	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

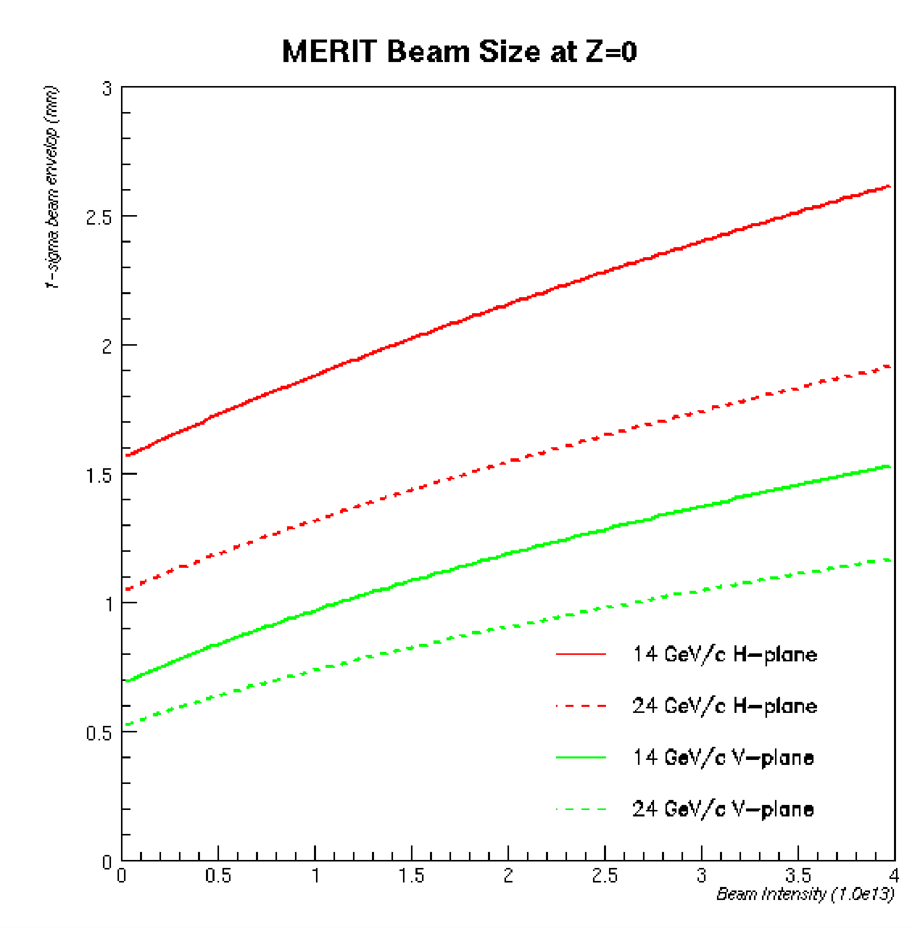
  - in good agreement with the online calculations

Emittance extrapolation



Estimated beam spot at the target (z=0)

- Using δp/p(2s) = 1.66(1.1)e-3 for 14(24) GeV/c



Estimated beam spot at the target (z=0)

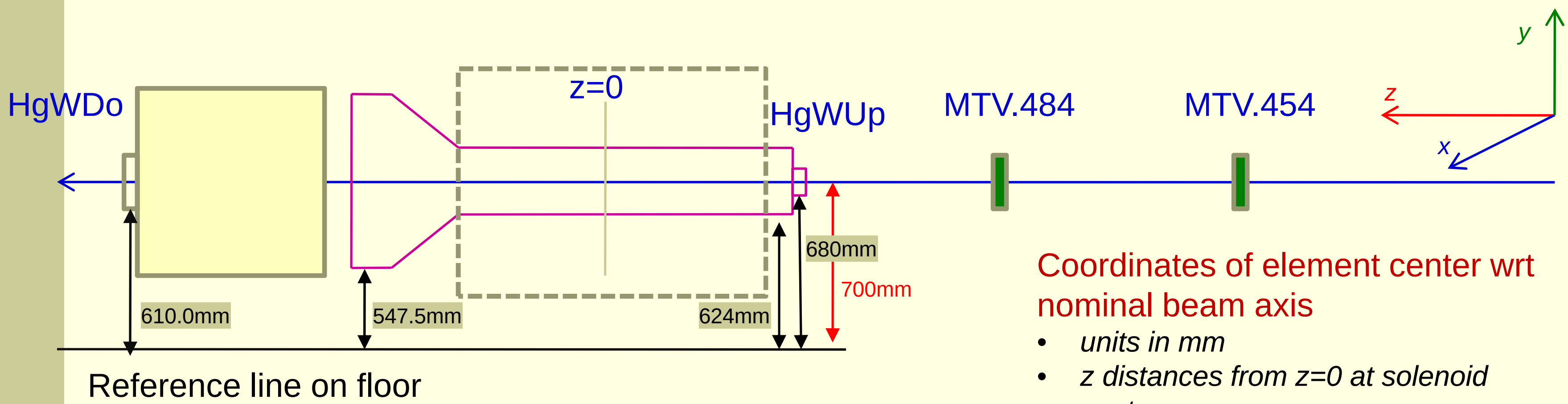
- Using $\delta p/p(2s)$ = 1.66(1.1)e-3 for 14(24) GeV/c

Pbeam	Intensity	BetaGamma	Emittance-h(1s)	Dp*dp/p(1s)	Size-h(1s)	Emittance-v(1s)	Dp*dp/p(1s)	Size-v(1s)
[GeV/c]	*[Tp]*	*[]*	*[mm.mrad]*	*[mm]*	*[mm]*	*[mm.mrad]*	*[mm]*	*[mm]*
14	1.0	14.925	0.0456	1.508193	1.5951	0.1047	0.1708	0.7178
14	5.0	14.925	0.1208	1.508193	1.7290	0.1453	0.1708	0.8391
14	10.0	14.925	0.2149	1.508193	1.8830	0.1961	0.1708	0.9695
14	15.0	14.925	0.3090	1.508193	2.0253	0.2469	0.1708	1.0844
14	20.0	14.925	0.4030	1.508193	2.1583	0.2977	0.1708	1.1883
14	25.0	14.925	0.4971	1.508193	2.2836	0.3485	0.1708	1.2837
14	30.0	14.925	0.5911	1.508193	2.4023	0.3993	0.1708	1.3726
24	1.0	25.586	0.0266	0.999405	1.0753	0.0610	0.1132	0.5444
24	5.0	25.586	0.0705	0.999405	1.1899	0.0848	0.1132	0.6376
24	10.0	25.586	0.1254	0.999405	1.3192	0.1144	0.1132	0.7377
24	15.0	25.586	0.1802	0.999405	1.4369	0.1440	0.1132	0.8257
24	20.0	25.586	0.2351	0.999405	1.5457	0.1737	0.1132	0.9052
24	25.0	25.586	0.2899	0.999405	1.6474	0.2033	0.1132	0.9783
24	30.0	25.586	0.3448	0.999405	1.7431	0.2329	0.1132	1.0463

Alignment Information and Beam Direction

MERIT beam element survey

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



Coordinates of element center wrt nominal beam axis

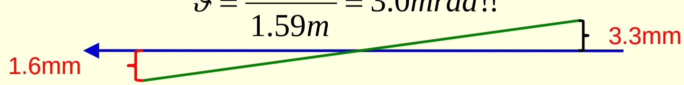
- *units in mm*
- *z distances from z=0 at solenoid center*

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}
Hgz=0	*{-1.0,??,0.0}*

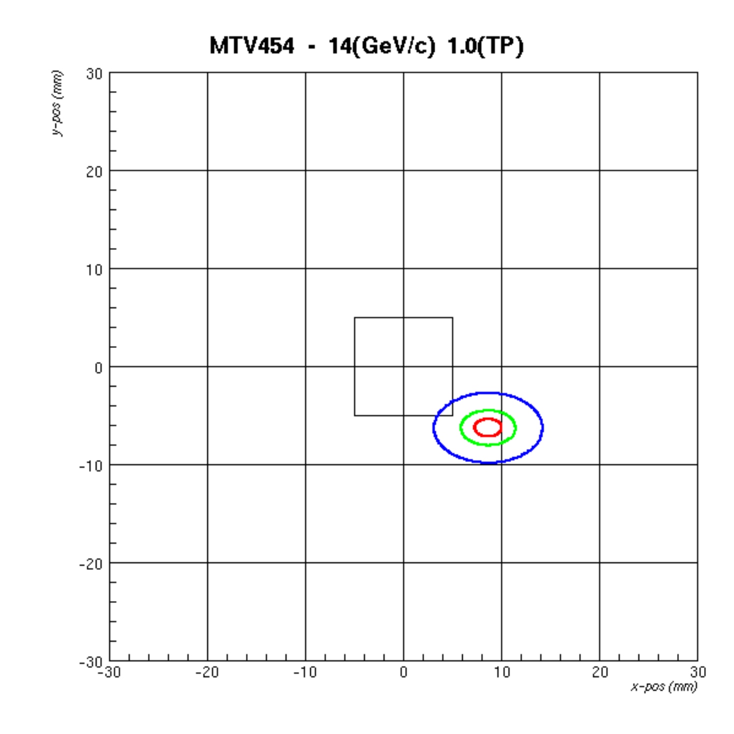
Solenoid tilt – (h-plane)

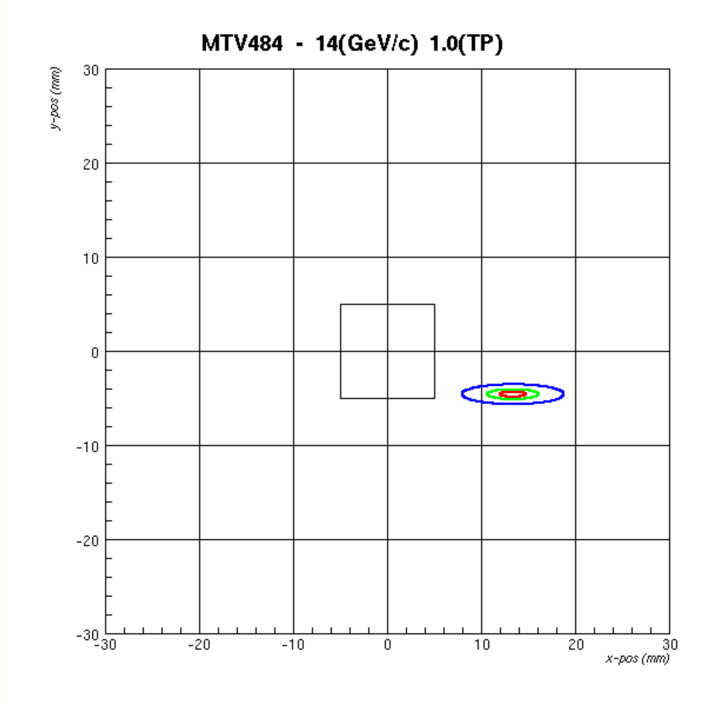
Position	**Distance**	**Radius**	**total**	**Difference**
HgWUp	680	23.495	703.495	-3.495
SecUp	624	79.375	703.375	-3.375
SecDo	547.5	150.876	698.376	+1.624
HgWDo	610.0	57.15	667.15	+32.85

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

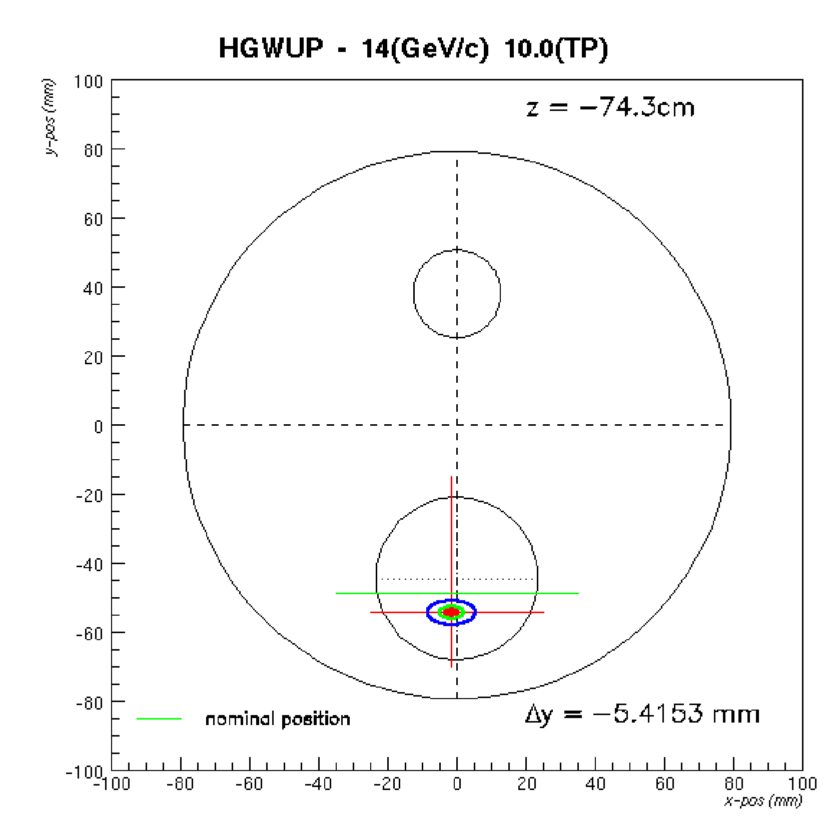


Nominal beam position in various elements





Beam at Hg container



Impact point calculation from the MTV data

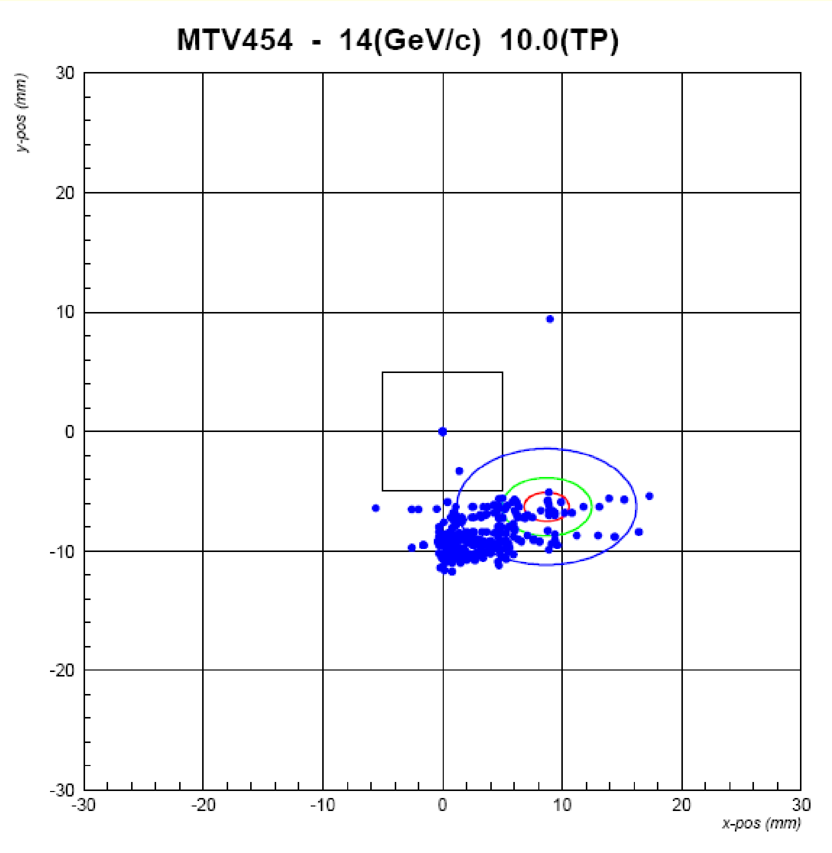
Projected beam impact point

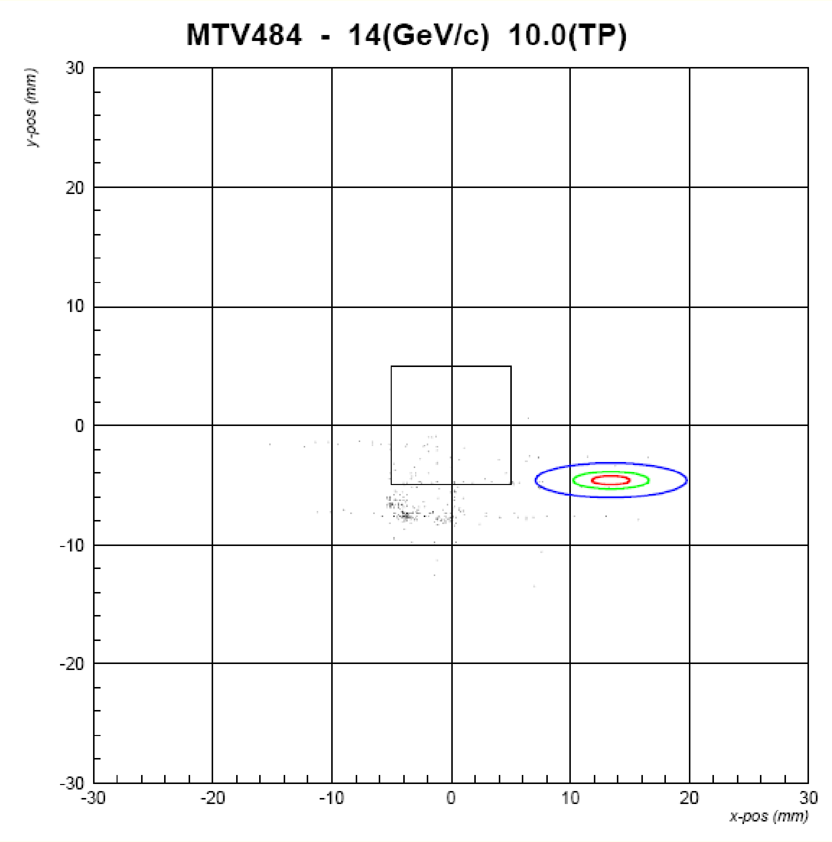
- Using the alignment information from the previous slides the beam impact point at the target can be calculated
  - For the H-plane there is no ambiguity
  - For the V-plane we must assume some tilt angle – or just the nominal?

- Two sets of MTV data were used:
  - The online measurements as recorded in the log files
  - The data from Goran who analyzed the flag information

Recorded beam position in the two flags

Online flag information from the logbook

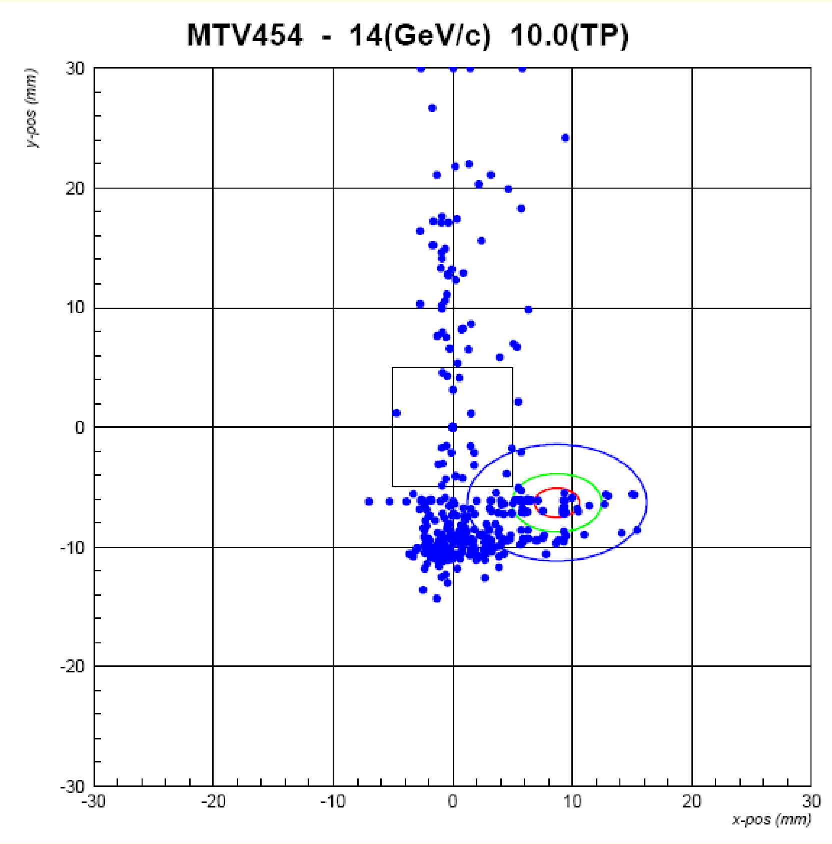


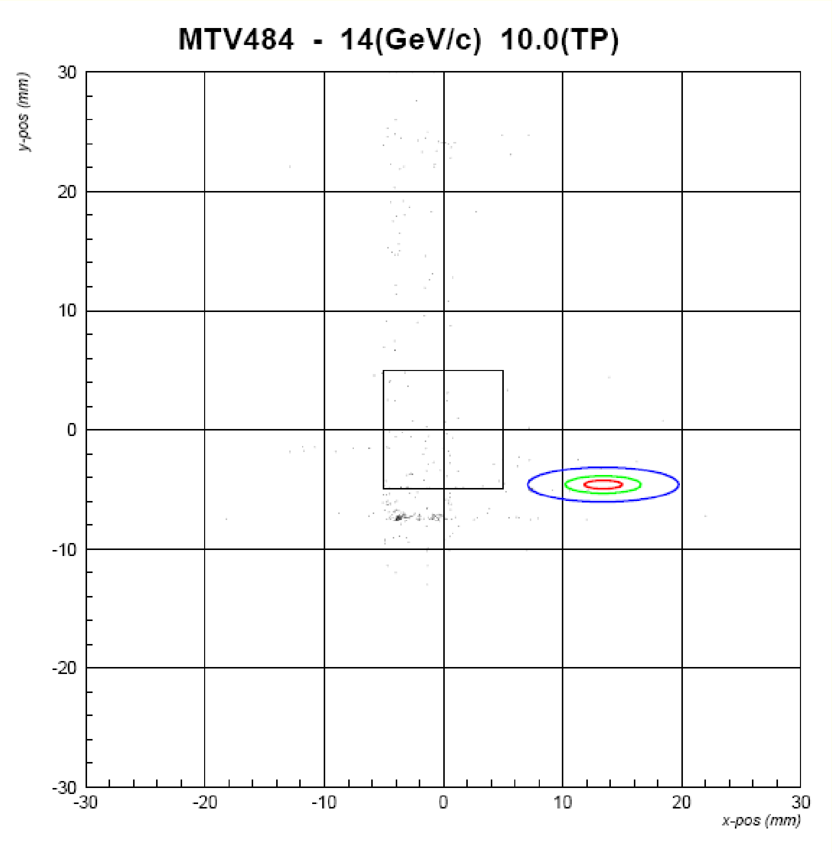


The ellipses indicate the nominal beam position at the flags according to the geometers

Recorded beam position in the two flags

Flag position from Goran

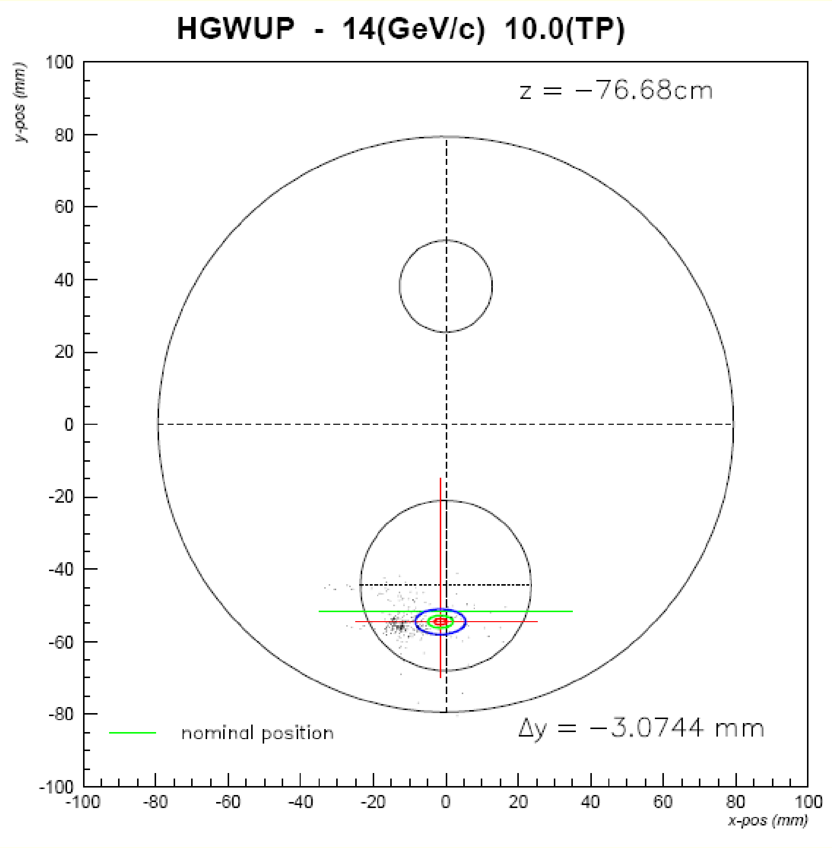


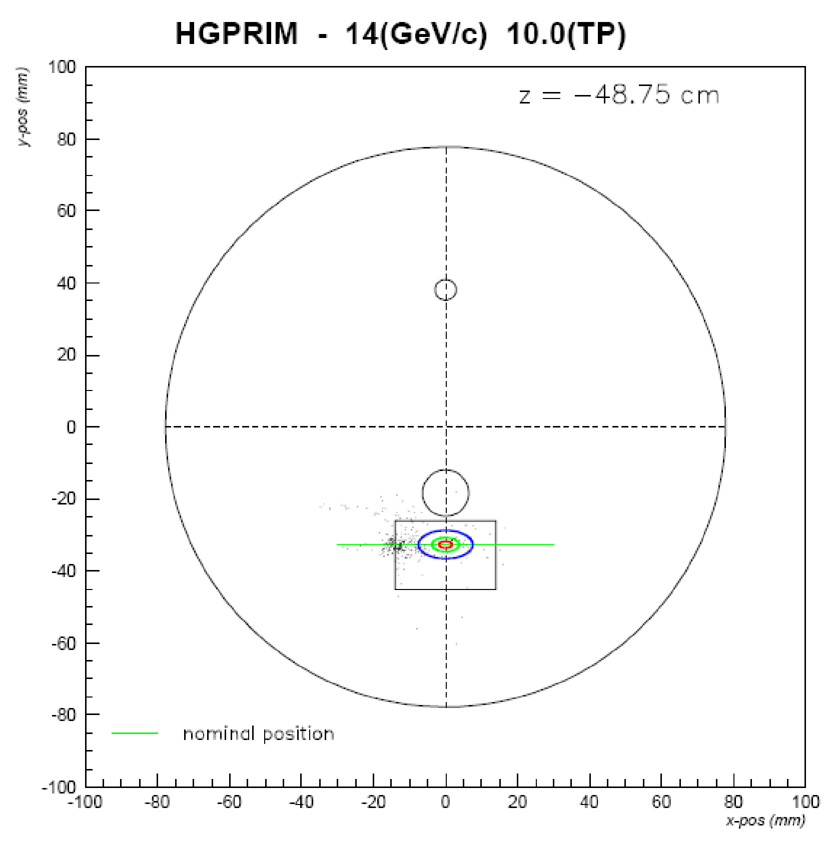


The ellipses indicate the nominal beam position at the flags according to the geometers

Projected beam position in the target

Online flag data from the logbook

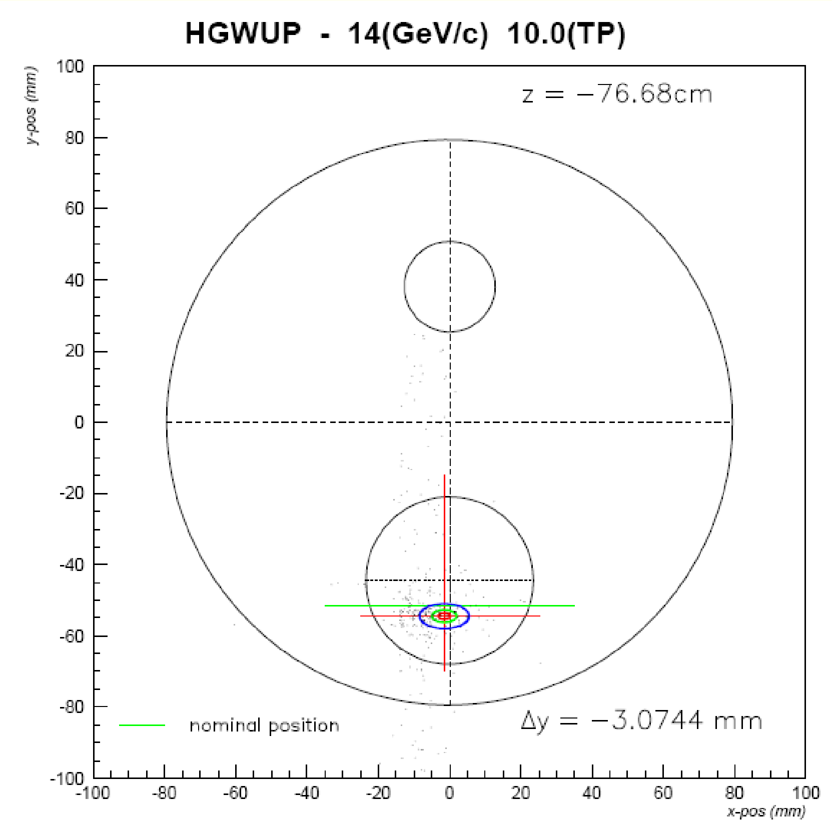


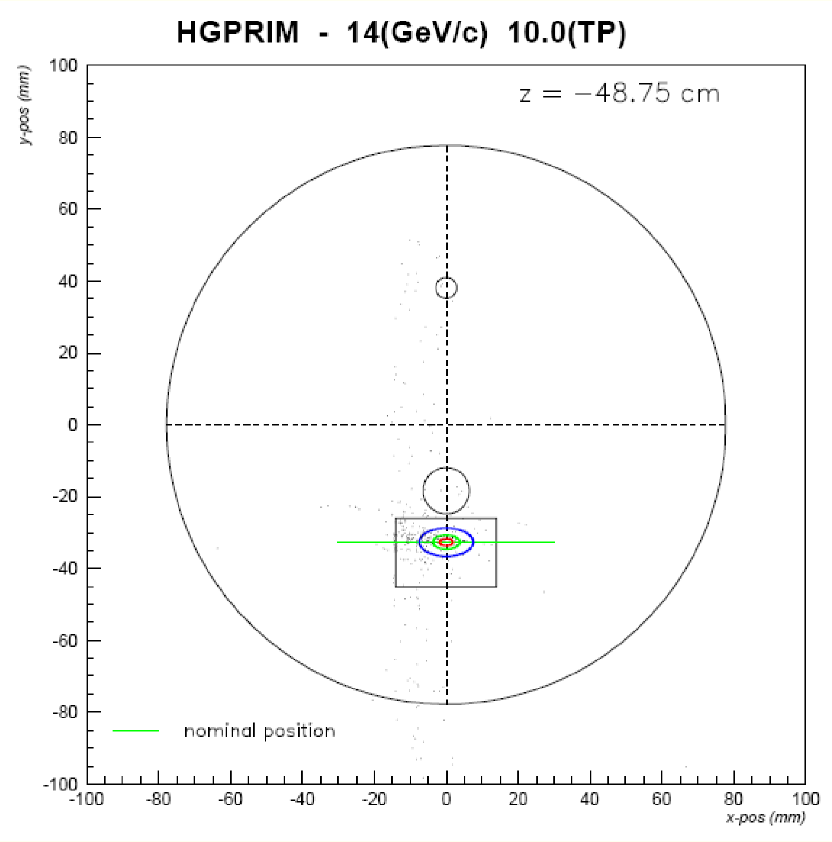


The ellipses indicate the nominal beam position at the flags according to the geometers

Projected beam position in the target

Using the data from Goran

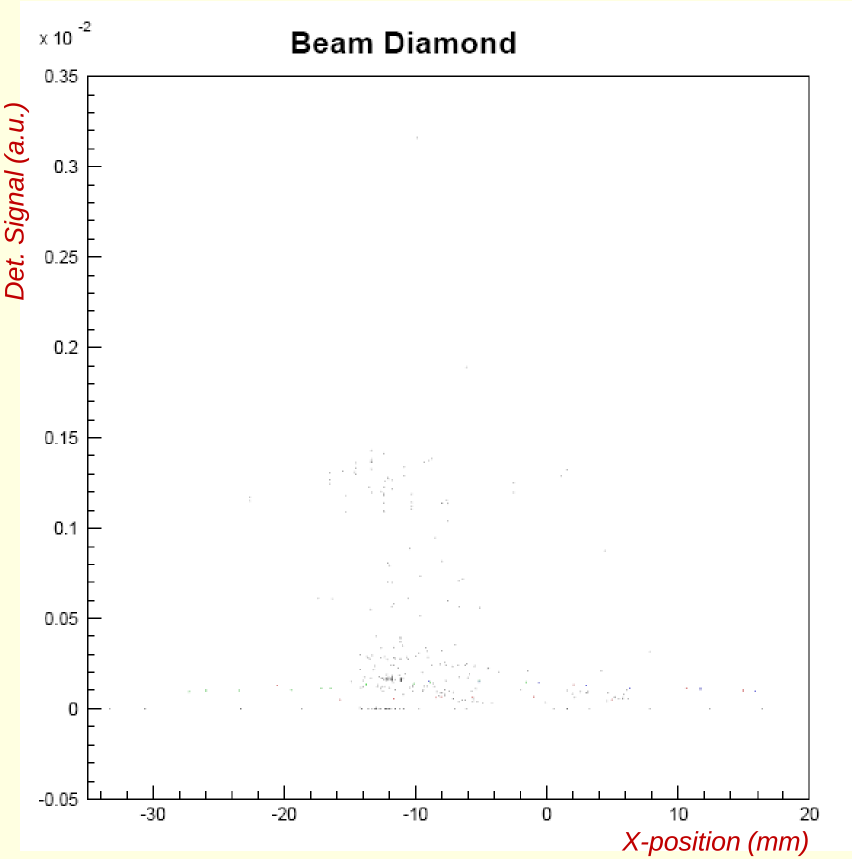




The ellipses indicate the nominal beam position at the flags according to the geometers

Information from the beam diamond

pCVD detector installed at the upstream window, well aligned with the target



According to this, the diamond position is around -12mm.

Projected beam impact point

Conclusions

- The recorder online (“eye”) and Goran’s analysis results for the flag info basically agree
  - Goran’s data show more spread,
    - remaining errors in the analysis that the eye is easier to correct
- The beam seems to be way off for flag-2 (MTV.484)
  - I don’t believe the alignment information from the geometers, but I don’t understand where the error comes
- Using the alignment information from the previous slides the beam impact point at the target can be estimated but it comes completely off that can’t be true
- The signal of the beam diamond (aligned within ±1.5mm to the target) peaks at ~-12mm in the horizontal direction
  - Re-calibrating using that offset, the beam impact point at the upstream window is within <2mm from the nominal
  - However we can’t say much on the angle of the beam!!!
- Vertically we seem to be ok

Pump – probe analysis using the diamond detectors

Pump – probe data analysis

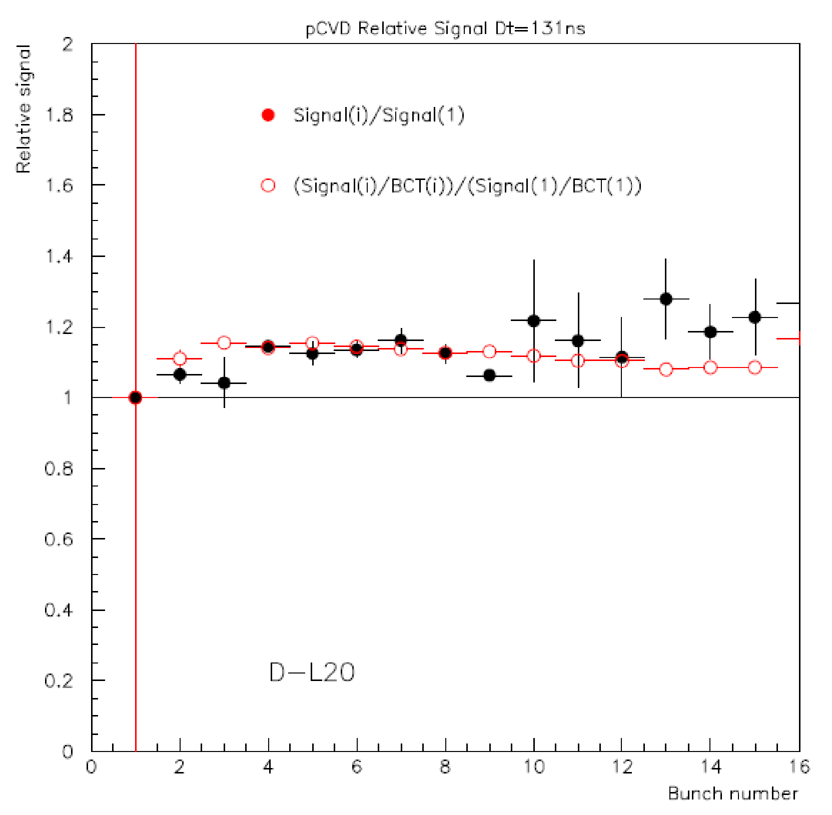
- The data used are from the Macrus's files
  - Reminder: the detector response for each bunch is calculated as the integral of the recorded signal over a time window
    - typically set to the interbunch spacing
  - i.e. no additional correction or more sophisticated algorithm for the signal extraction

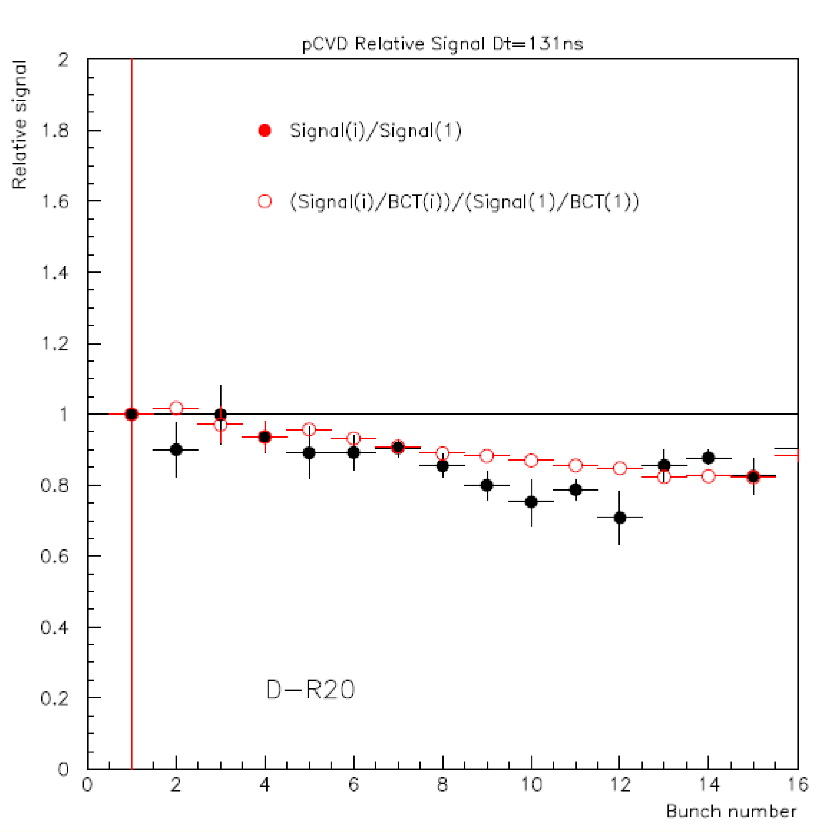
- Runs used
  - Use the information from Harold's run list to classify the runs
  - Use Adrian's data for BCT bunch information
  - Rungs are flagged as "bad" and rejected from the analysis if
    - Information is missing (e.g. BCT) or
    - Wrong readings for some bunches

- The observed response dependence vs bunch number was corrected

Diamond response vs bunch number

Data from all good runs with Dt(bunch)=131ns

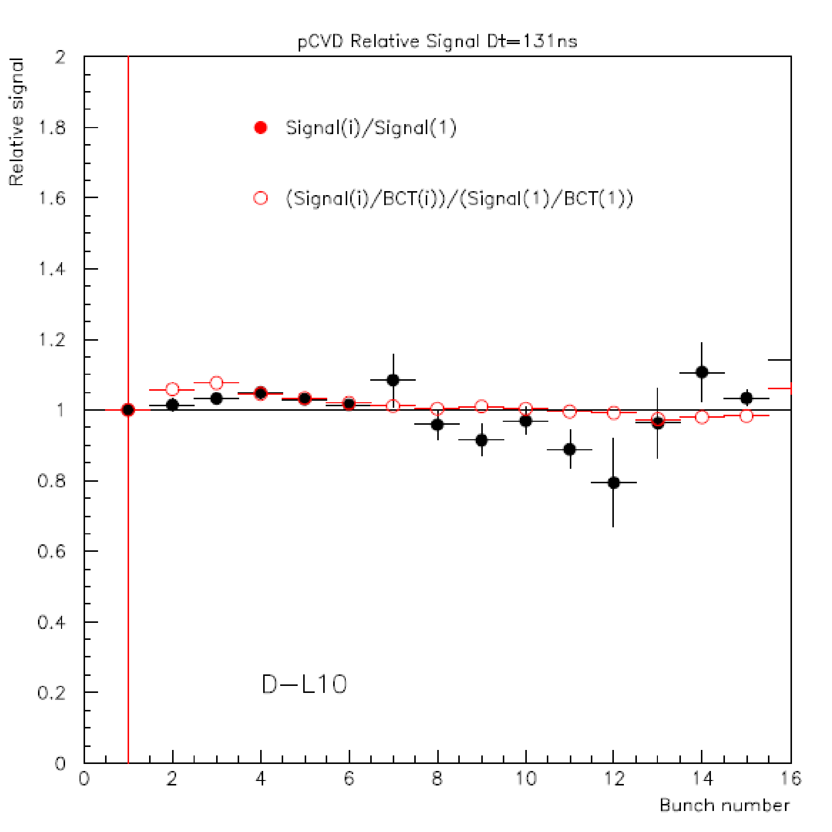


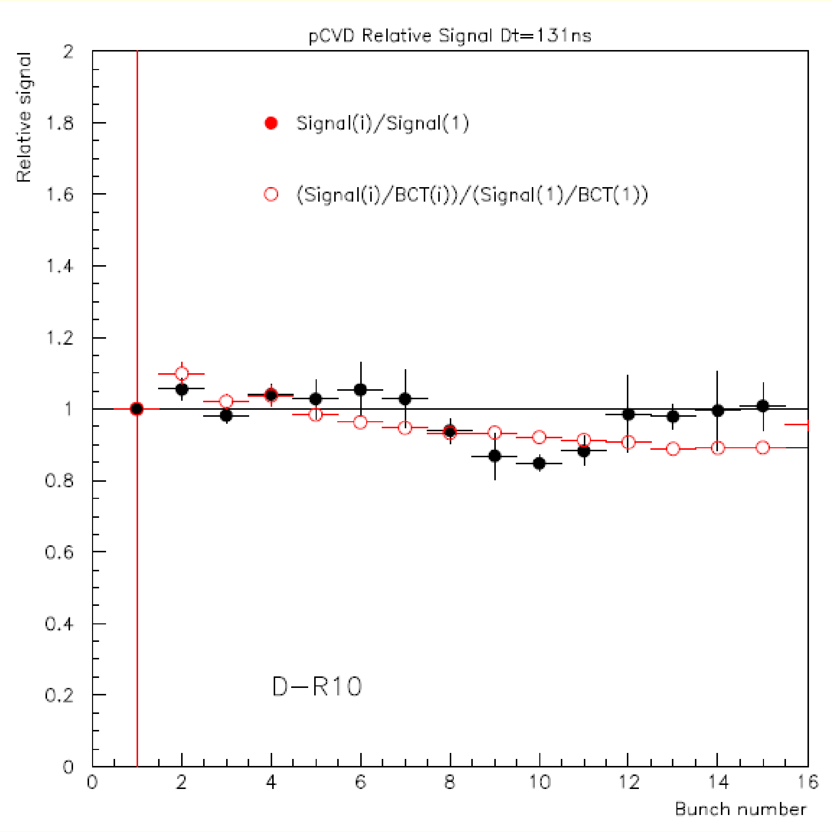


What is plotted is the response per bunch divided by # of protons, normalized to the first bunch

Diamond response vs bunch number

Data from all good runs with Dt(bunch)=131ns

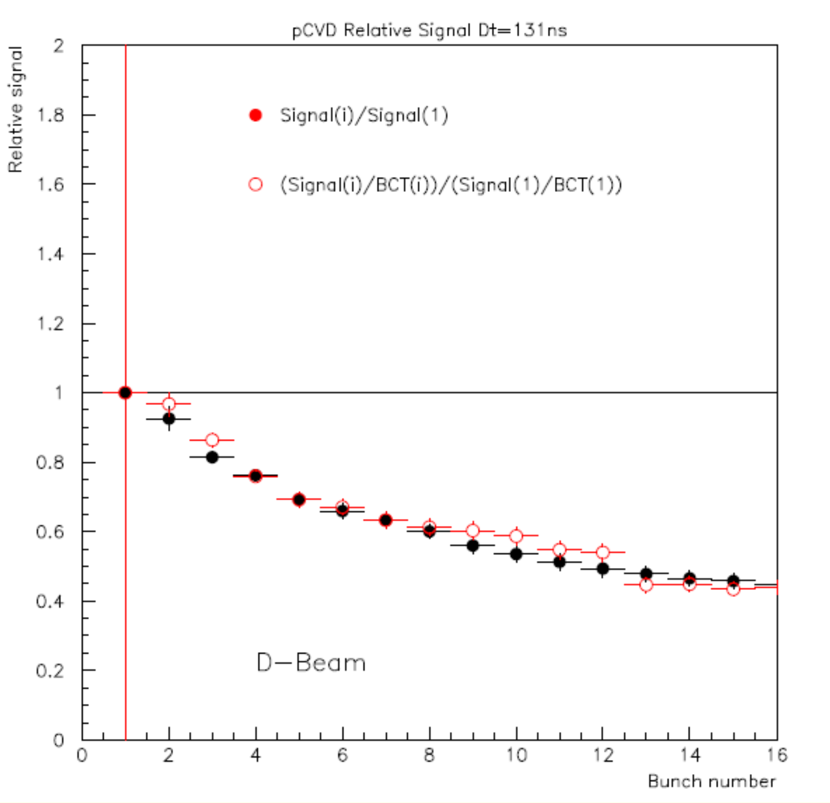


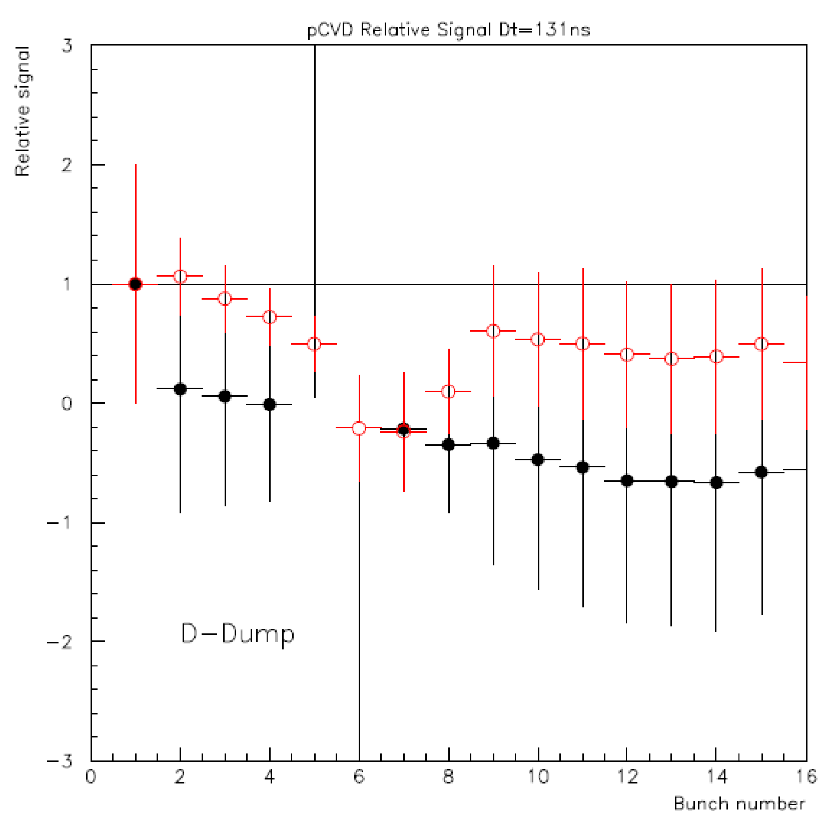


The correction with the BCT data smoothens the observed dependence

Diamond response vs bunch number

Data from all good runs with Dt(bunch)=131ns

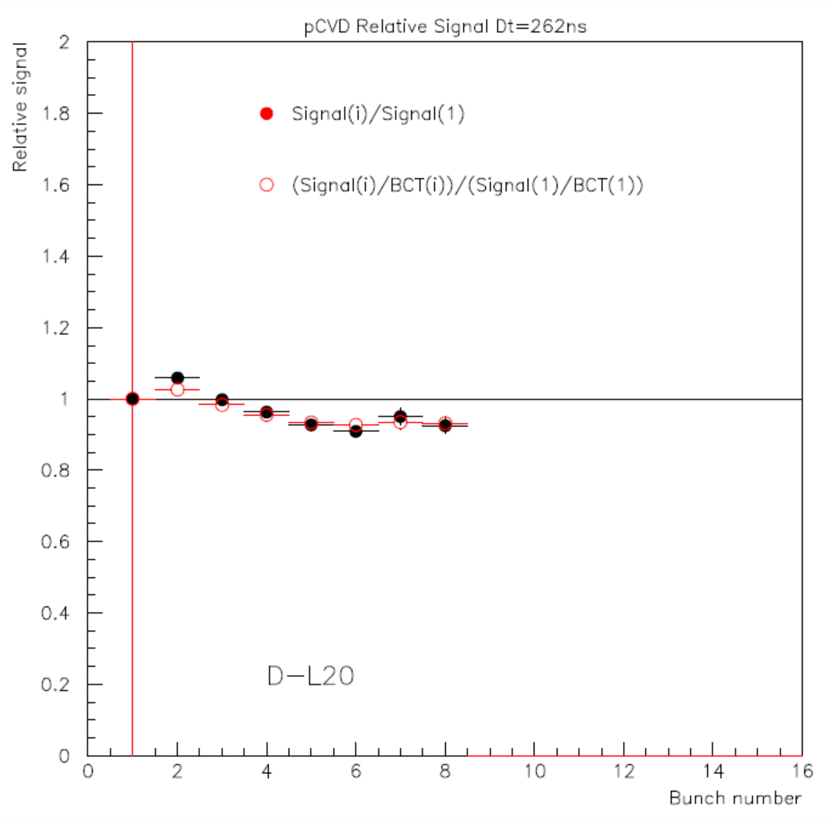


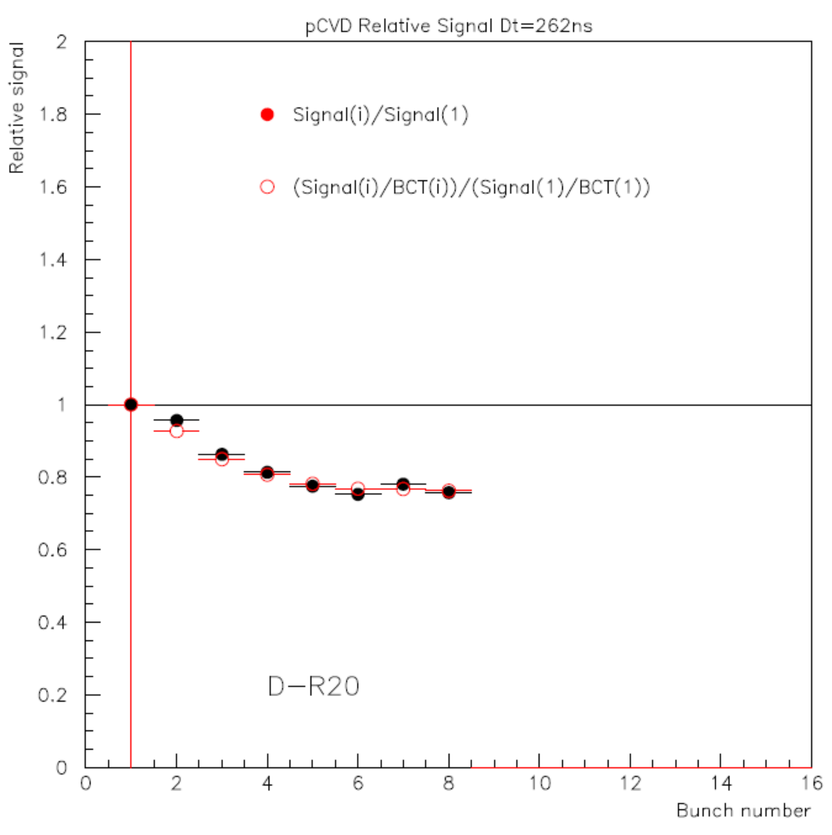


The strongest effect is for the beam diamond; the dump detector is rather strange at all cases…

Diamond response vs bunch number

Data from all good runs with Dt(bunch)=262ns

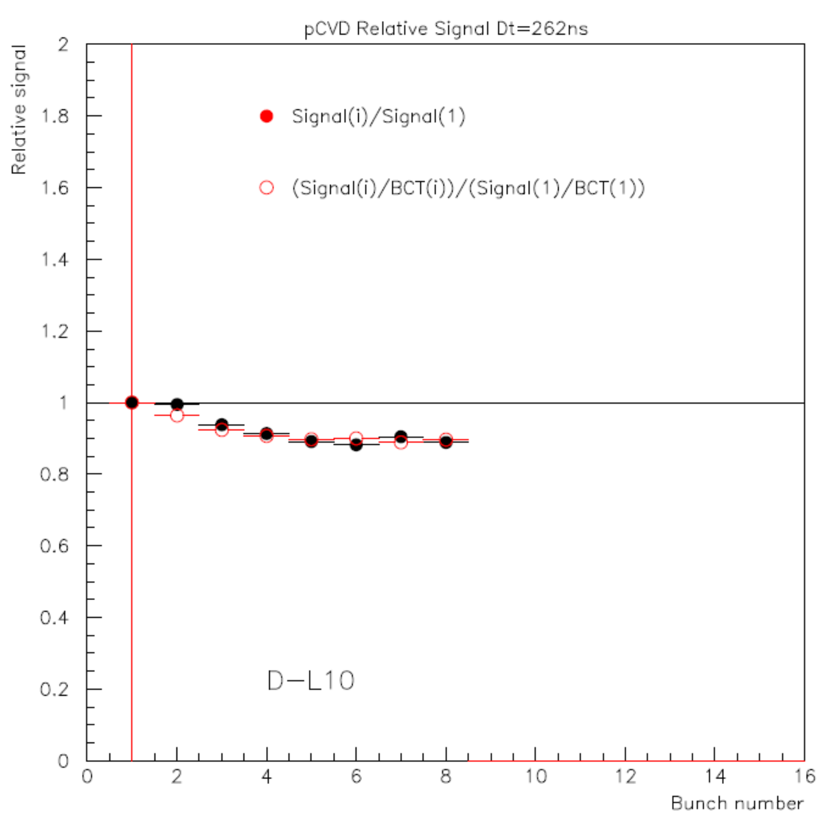


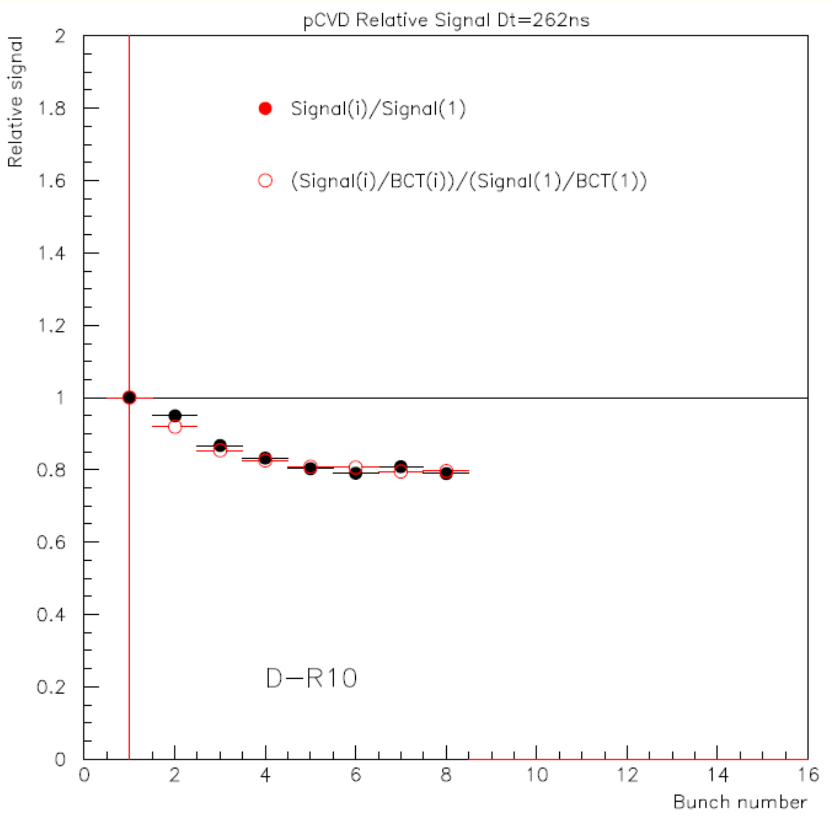


Normally the effect should be reduced with longer interbunch spacing, however the signal is larger…

Diamond response vs bunch number

Data from all good runs with Dt(bunch)=262ns

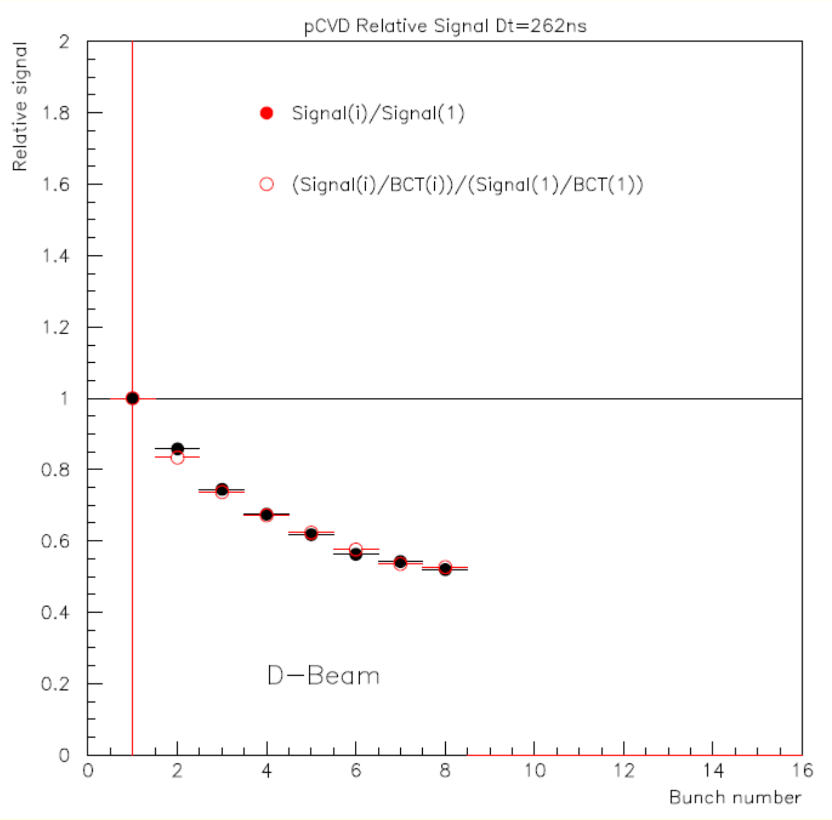


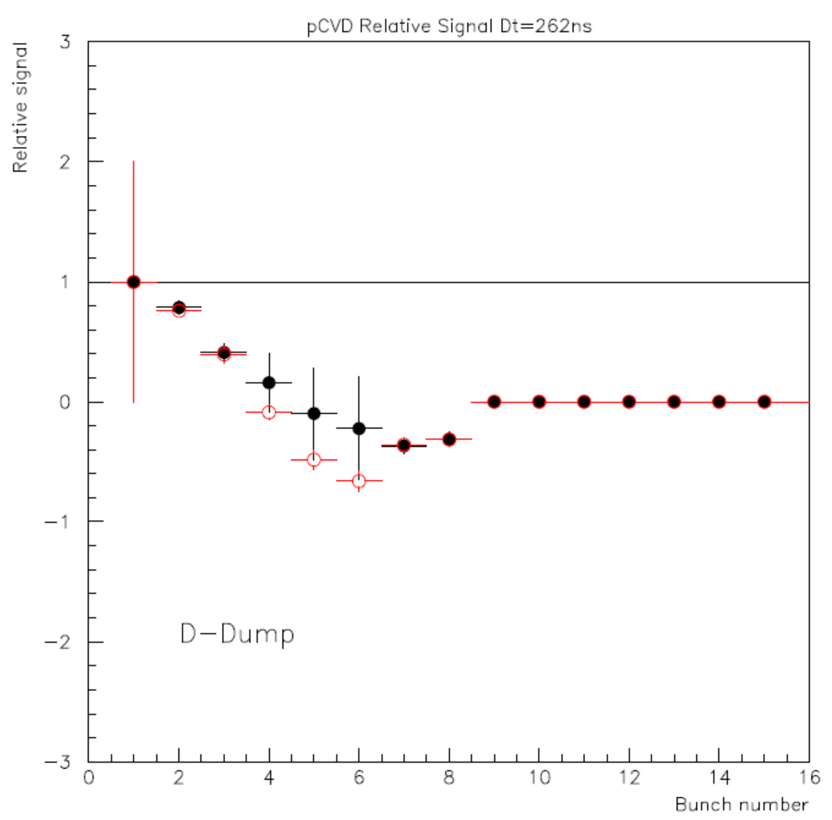


Normally the effect should be reduced with longer interbunch spacing, however the signal is larger…

Diamond response vs bunch number

Data from all good runs with Dt(bunch)=262ns

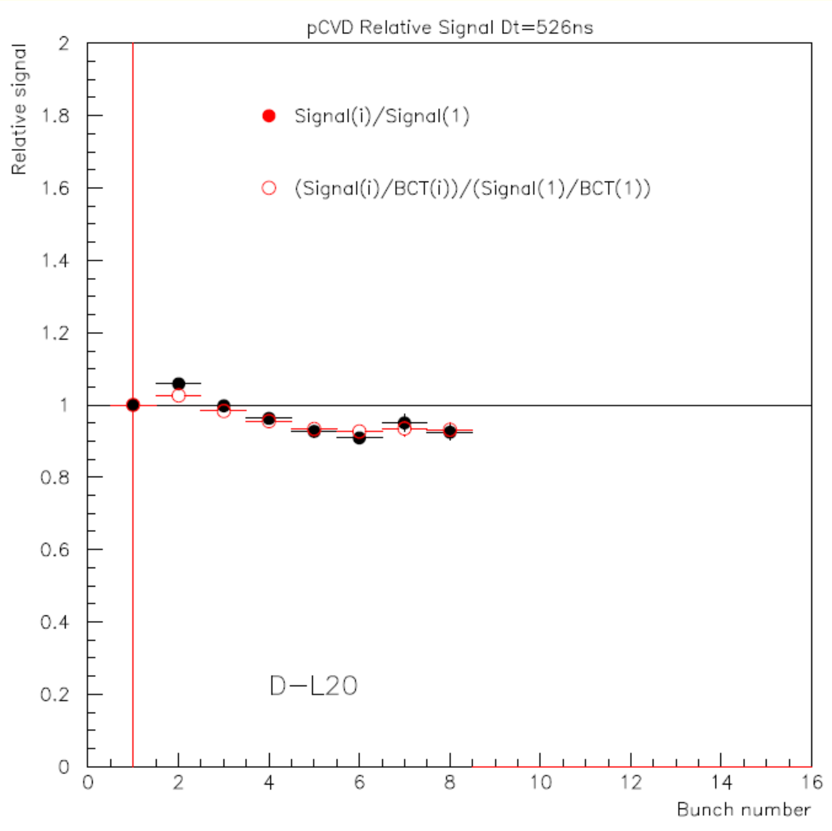


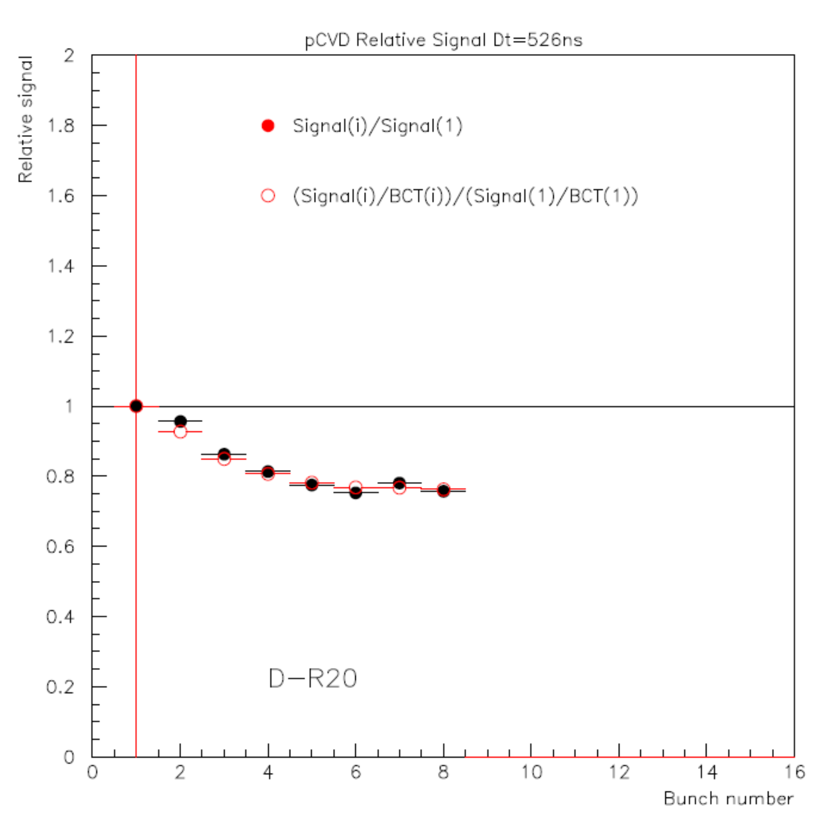


Normally the effect should be reduced with longer interbunch spacing, however the signal is larger…

Diamond response vs bunch number

Data from all good runs with Dt(bunch)=526ns

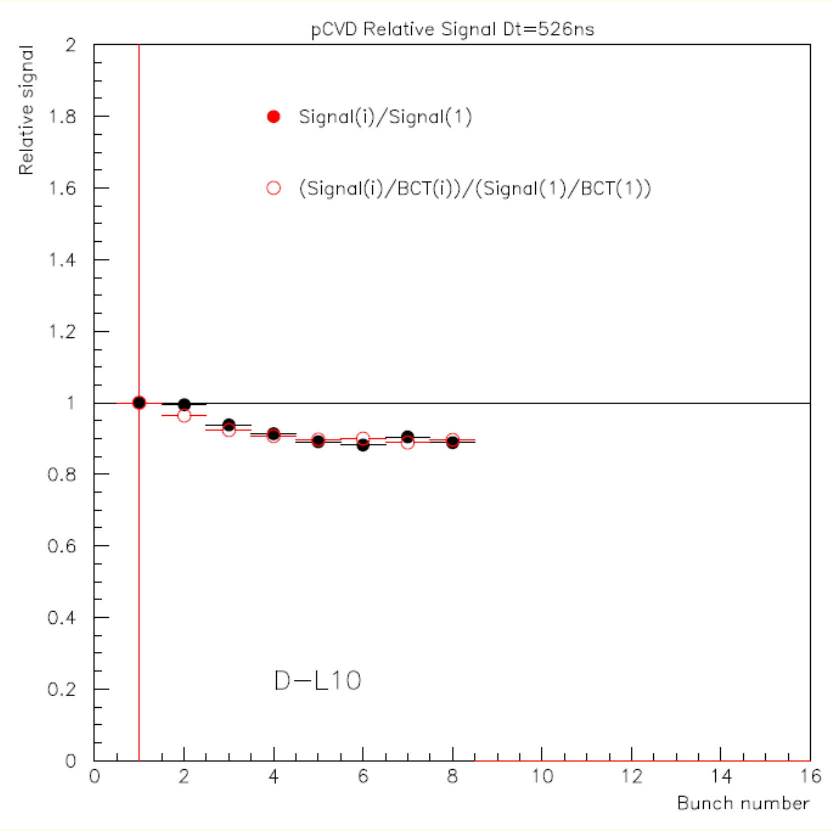


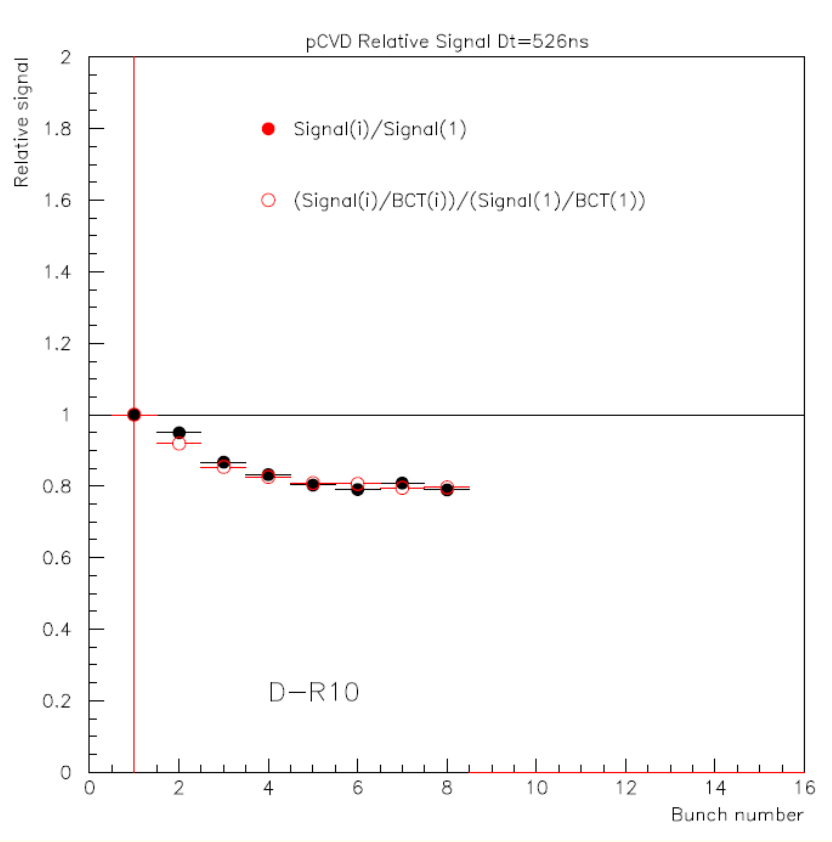


Normally the effect should be reduced with longer interbunch spacing, however the signal is larger…

Diamond response vs bunch number

Data from all good runs with Dt(bunch)=526ns

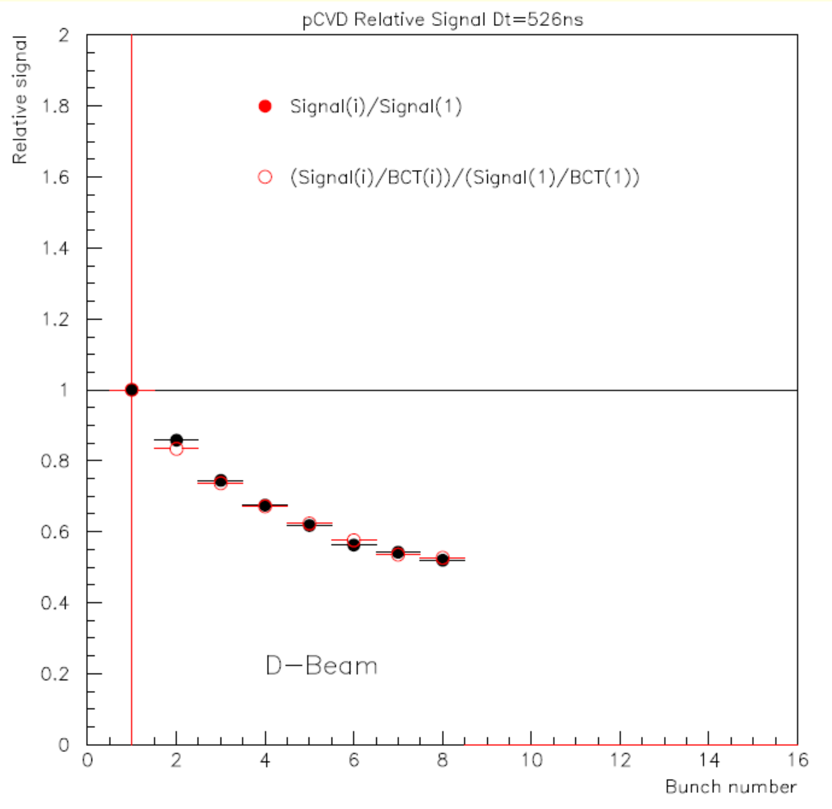


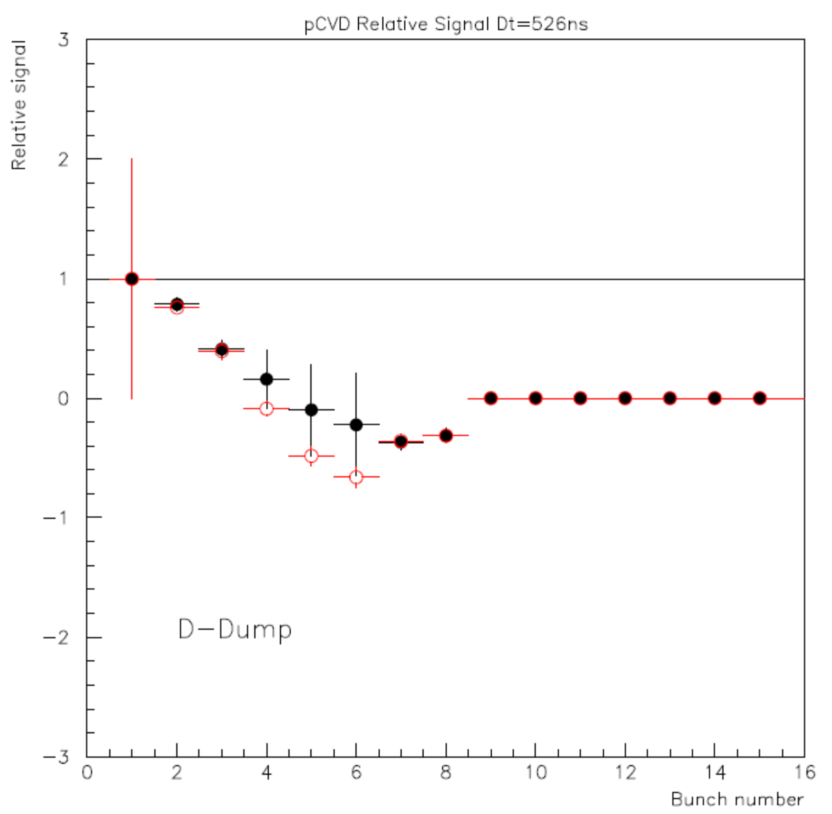


Normally the effect should be reduced with longer interbunch spacing, however the signal is larger…

Diamond response vs bunch number

Data from all good runs with Dt(bunch)=526ns

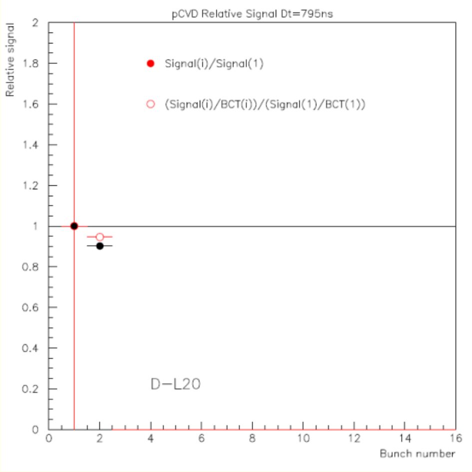


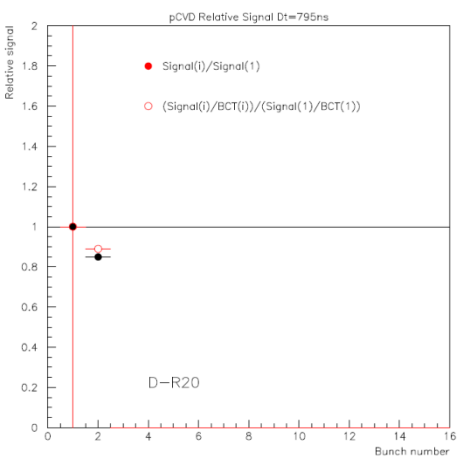


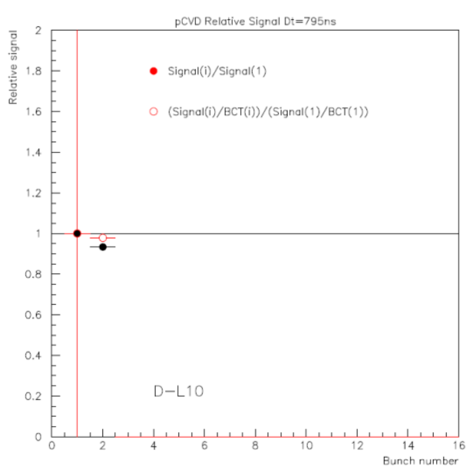
Normally the effect should be reduced with longer interbunch spacing, however the signal is larger…

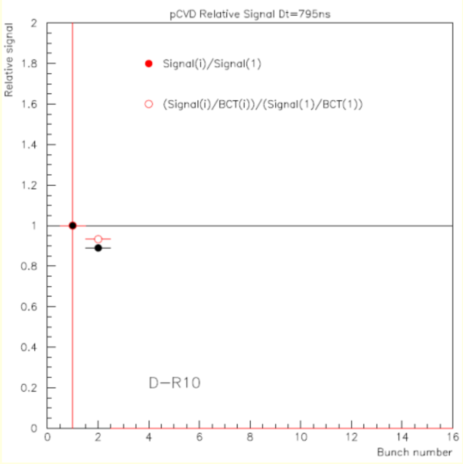
Diamond response vs bunch number

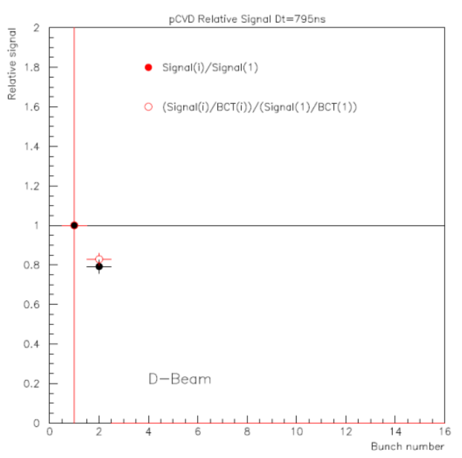
Data from all good runs with Dt(bunch)=795ns

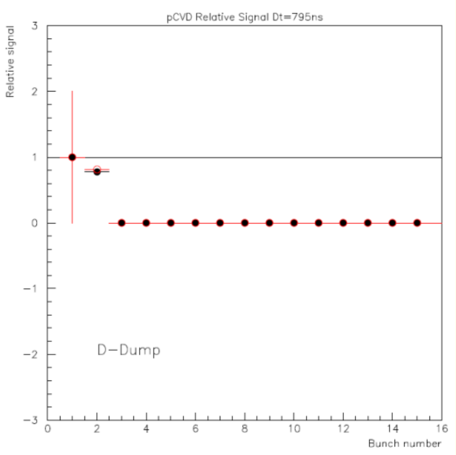






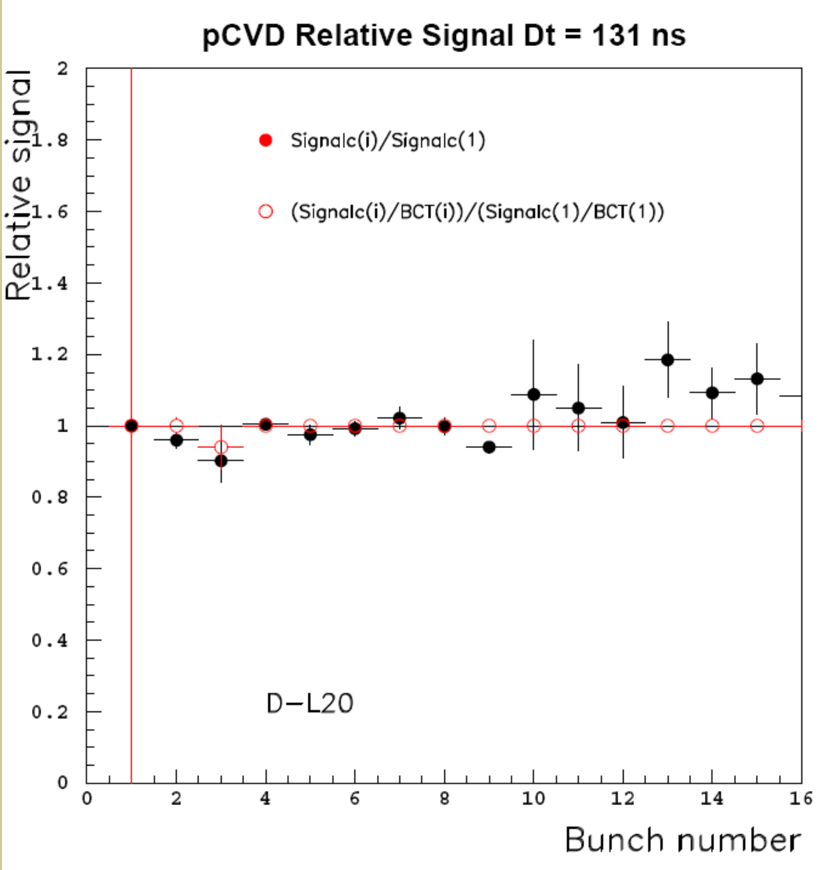


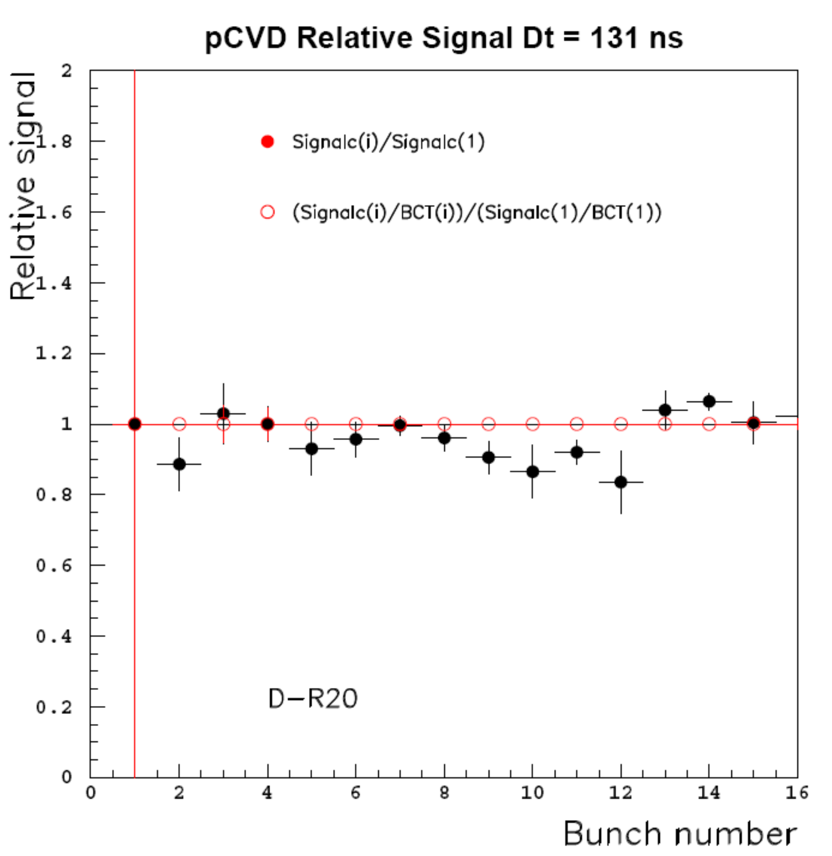




Diamond response vs bunch number

Data from all good runs with Dt(bunch)=131ns – after correction

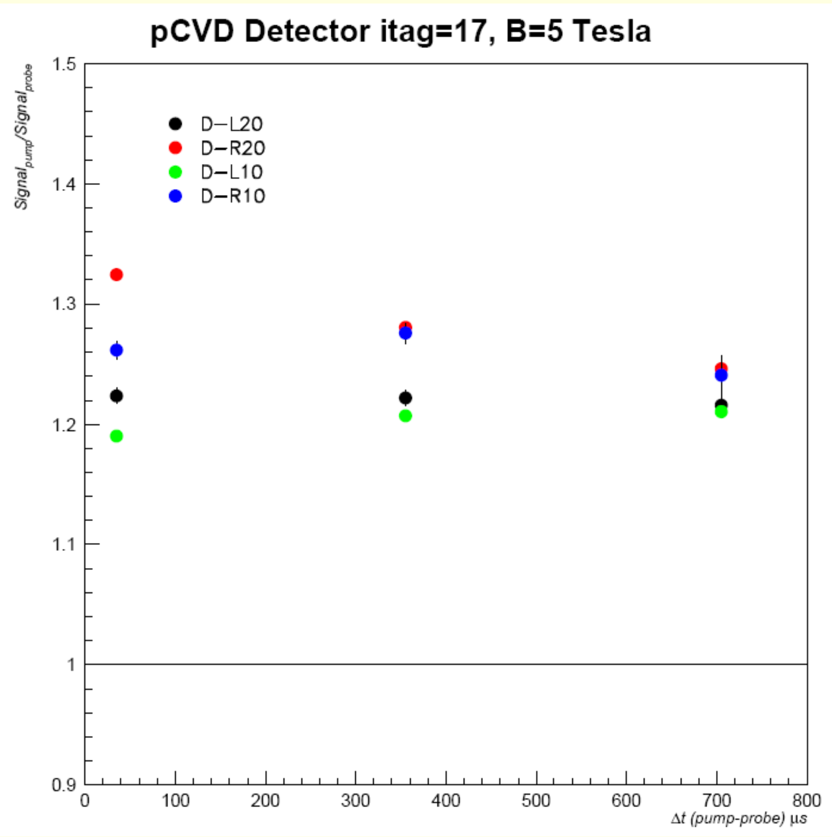




Similar plots for the other cases, not included here…

Pump – probe analysis result

Data from pump-probe runs – various Δt(bunch)



- What is plotted is:

$$R(\mathrm{det}) = \frac{\dfrac{\sum\limits_{i=1,N_{pump}} A(dt_{bunch},\mathrm{det})_i \cdot \dfrac{S_i}{BCT_i}}{N_{pump}}}{\dfrac{\sum\limits_{i=1,N_{probe}} B(dt_{bunch},\mathrm{det})_i \cdot \dfrac{S_i}{BCT_i}}{N_{probe}}}$$

  - where A, B are the correction coefficients evaluated as before for each bunch
  - In the present analysis A and B are the same coefficients, i.e. treat 1st bunch of probe as 1st bunch of pump – what would be the alternative???

- If cavitation is formed in the target, then the ratio should increase with the pump-probe distance (lower denominator)
- Is the difference L-R significant?

Pump – probe analysis

Comments – next steps

- Some runs are rejected because no BCT information is available → Adrian is checking that

- Additional correction vs beam position to apply

- Separate analysis vs beam(pump) intensity
  - what info from the beam impact can we get from the cameras?

- Do ratios (e.g. L/R) to improve errors?

- Is 5% "cavitation" something the MFH models predict?