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TRT Barrel module QA and gain mapping

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Outline

- Motivation
- Purpose of gain mapping
- QA process related to gain mapping – MTS + Duke critical
- Method
- Development of QC criteria
- Results
- MGM-MTS comparison

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Motivation

- The motivation for this discussion is the finding that TRT barrel modules, particularly type 3, have significant numbers (~1.5%) of wire segments that fail current gain variation criteria
- These wires are currently recommended for removal
- Is the group ready to change criteria to avoid removing wires?

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Summary

- QC criteria are currently:
  - Flagging wires with *G*>8% and *S*>7.5%
  - Discussion of profiles and spectra
  - Removal of wire with *G*>8% and *S* positively correlated with *G*.
- Systematic effects on *G* are the order of 2%
- To ensure no offset >400 μm, the criterion is set at 8% (11% - 1% stat – 2% sys).

MTS or Duke scanner is the primary tool

- Rework at CERN (removal and replacement) is done on basis of **MTS or Duke** results
- **If a wire passes MTS or Duke criteria, it will be left in place (no re-rework)**
- MGM is useful only where a wire was replaced or MTS (or Duke data) is missing
- We can look at MTS, Duke must talk about their results.

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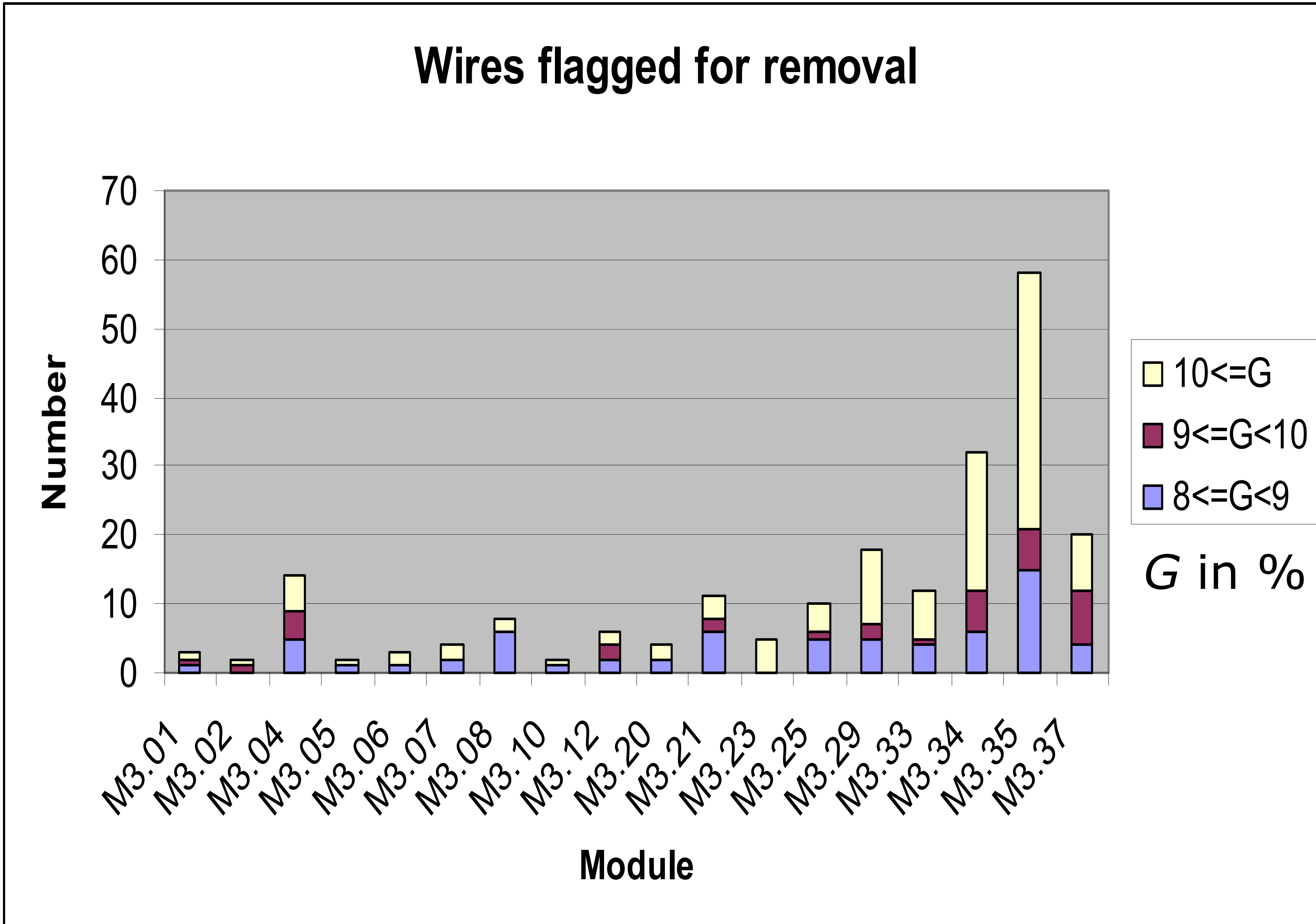
Size of problem

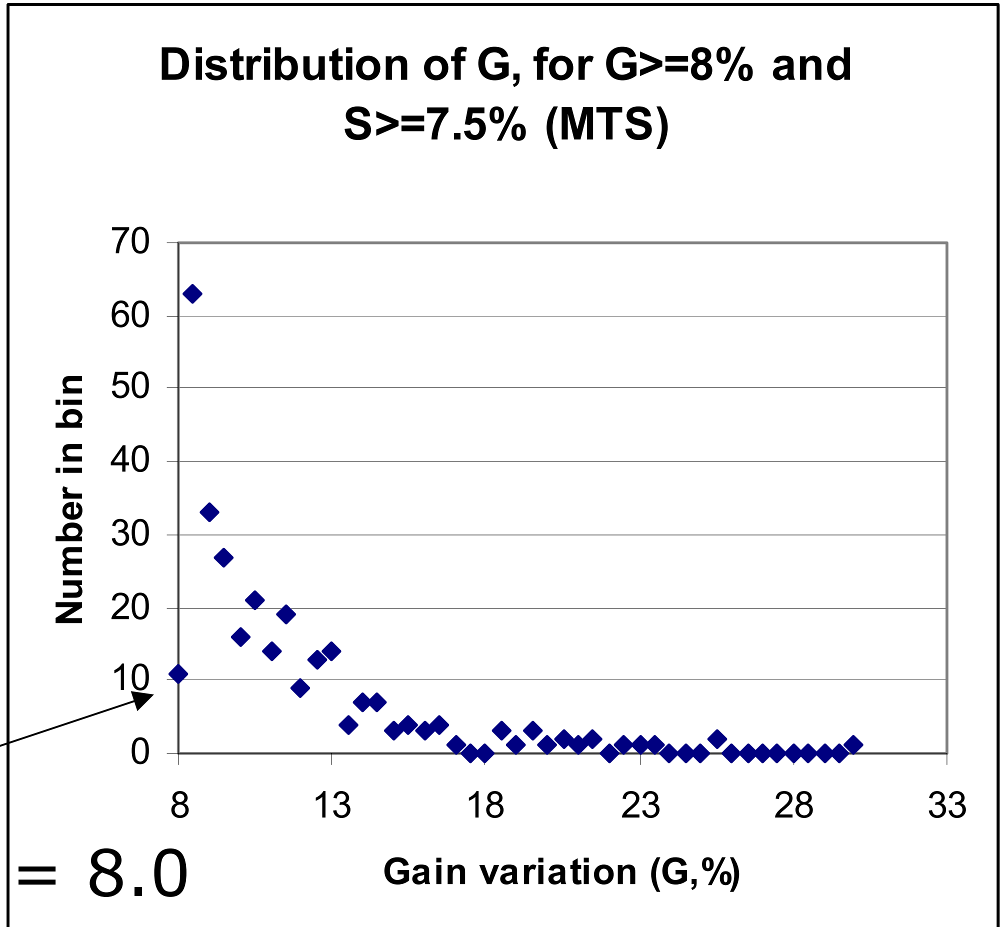
- Out of 18 type-3 modules mapped with MTS (~14,400 wires, 214 wires are flagged for removal (1.5%).
- Two modules (3.34 and 3.35) account for 90 flagged wires.

G range	8%<=G<9%	9%<=G<10%	G>=10%
18 modules	66	34	114
3.34, 3.35	21	12	57



Wires flagged for removal
Number
70
60
50
40
30
20
10
0
M3.01
M3.02
M3.04
M3.05
M3.06
M3.07
M3.08
M3.10
M3.12
M3.20
M3.21
M3.23
M3.25
M3.29
M3.33
M3.34
M3.35
M3.37
Module
10<=G
9<=G<10
8<=G<9
G in %

Histogram



G exactly = 8.0

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Conclusion

- If the *G* criterion is moved up, the worst modules will still have many wires with substantial offsets.
- Is this safe?
- Discussion of relation of gain variation to offset and choice of 8% for MTS follows.

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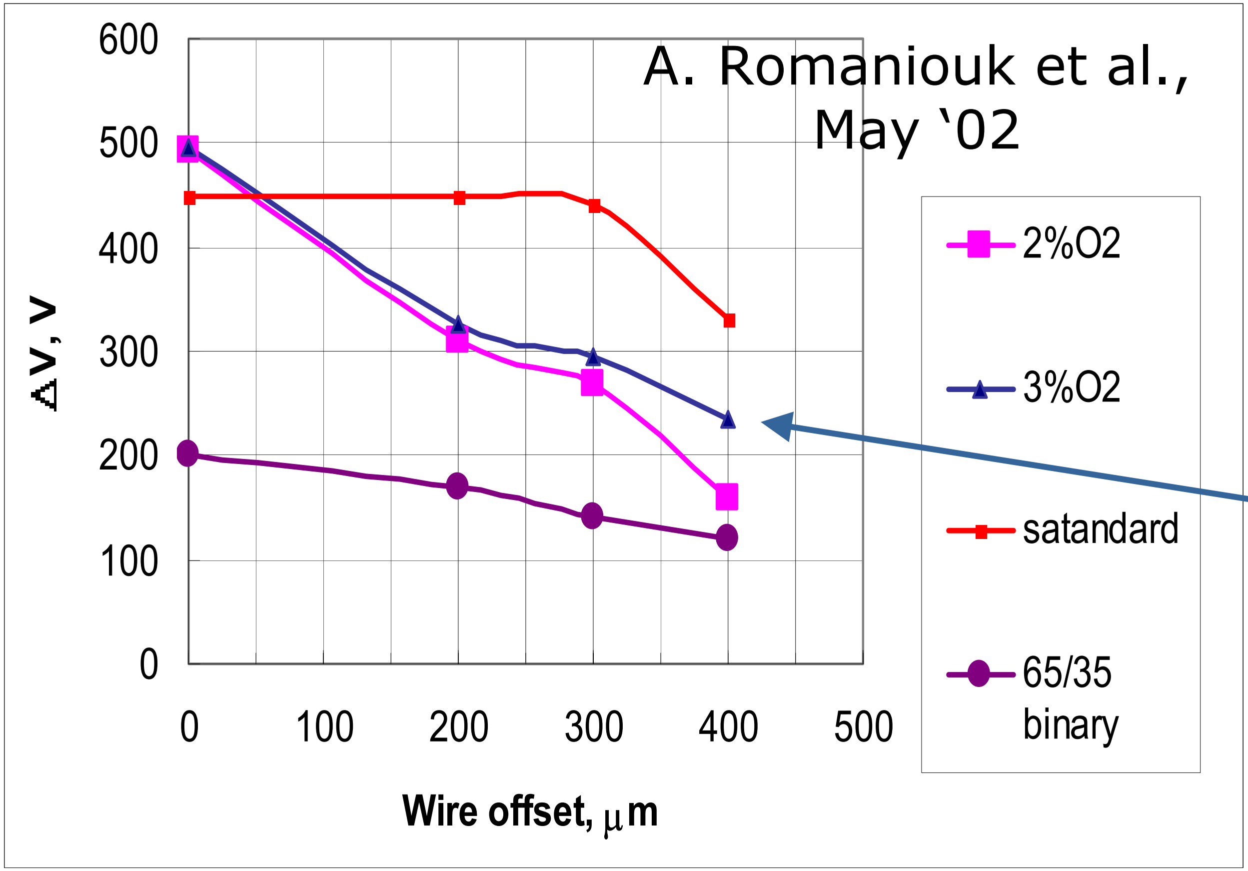
Primary purpose

- Create robust TRT by identifying wires for removal that might be subject to HV breakdown
- Current criterion: offset at any point on a wire must be $<400\ \mu m$ (see next slide)
- Perhaps **this** needs re-examination.

Operational stability



For 3% O2 mix, ΔV* is 220V. With 50V safety factor, 170V.

Can we go past 400 μm? Past 170V?

Risk factors

- Protection of TRT in operation is by fuses (one for 8 straws) and HV modularity (one for 80 straws in type-3 barrel module)
  - If a wire segment is removed, two segments are lost.
  - If a wire segment draws enough current and blows a fuse, it will turn off 16 segments
  - **If the fuse does not blow, 160 segments may need to be turned off.**

Secondary purpose

- Assess overall quality of module by counting wires with an offset (at any point) $>300\mu m$
  - This is to be $<5\%$ of the total wire segments
- In practice this may only be used to select modules for installation, along with the number of dead wires.

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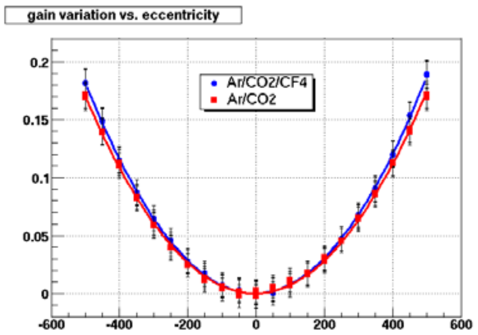
QA approach

- A quality circle meets to discuss data on each module. **All data, including gain profiles for each straw, are available at the meeting (usually a VC)**
- Additional criteria, quantitative and qualitative have been developed to reduce the evaluation task to manageable proportions
- The task is to evaluate 115k wire segments (~105 barrel modules)

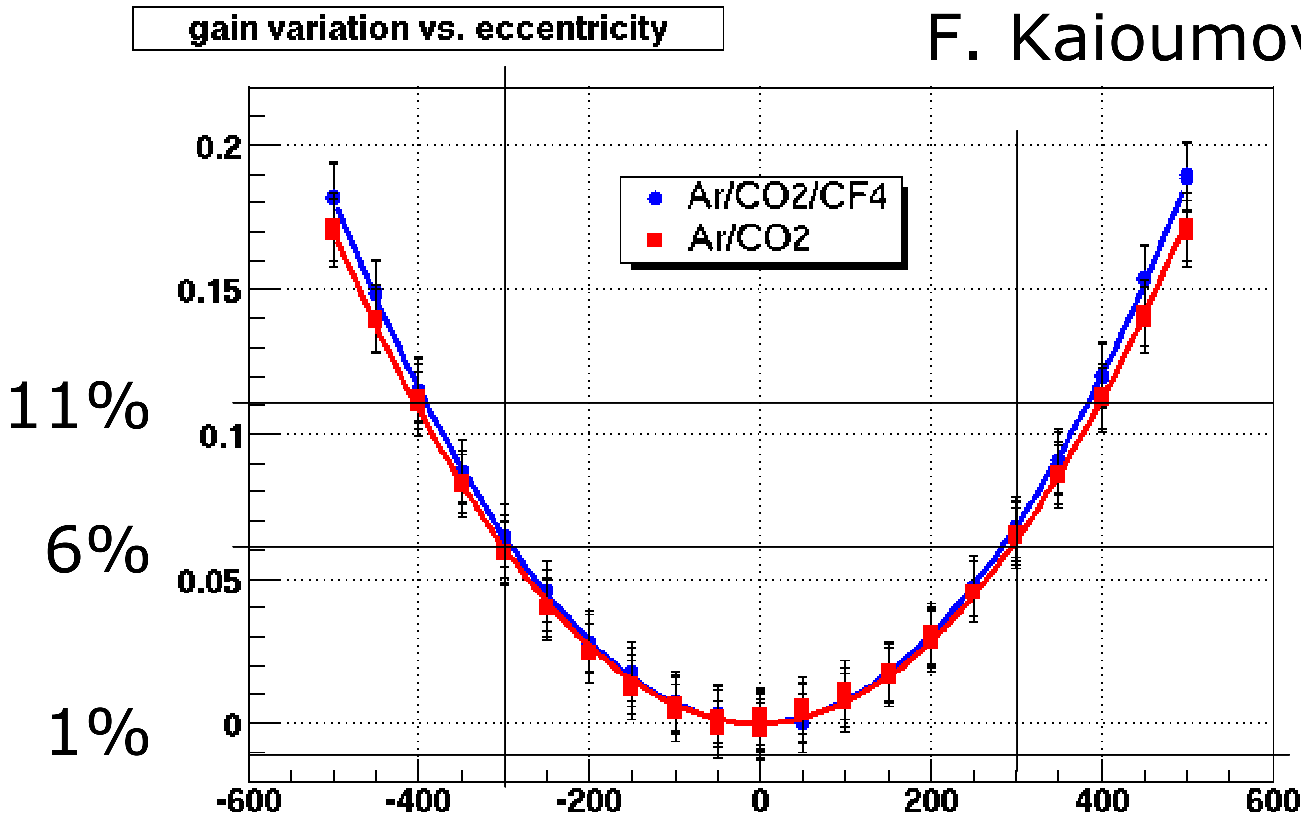
Method of estimating offset

- Measure gain at sample of points along wire segment and look for gain variation
- Gain criterion is based on measurements of Kaioumov *et al*.
- 400 μm -> 11% gain shift
- 300 μm -> 6% shift



Gain shift vs. offset

F. Kaioumov et al.



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Gain shift, sys + stat uncertainties

- Look at effective offset cut for 2% sys + 1% stat allowance, using quadratic fit to Kaioumov et al.:

Measured *G*	Sys+stat	Offset, μm
8	3	400
9	3	417
10	3	434
11	3	450

Confounding factors

- Offset is not the only parameter affecting gain variation; there are additional factors including:
  - Systematic effects in the mapping system (MGM and MTS)
  - Contamination
  - Wire diameter variation (Oh *et al.*)
  - Non-zero offset at every point
  - Statistics
- Additional criteria are needed to deal with these factors, as discussed below.

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Systematic effects

- Z-dependent global correction (‘slope correction’)
- Granularity of measurement
- Electronics non-proportionality
- Analysis
- Non-zero wire offsets.

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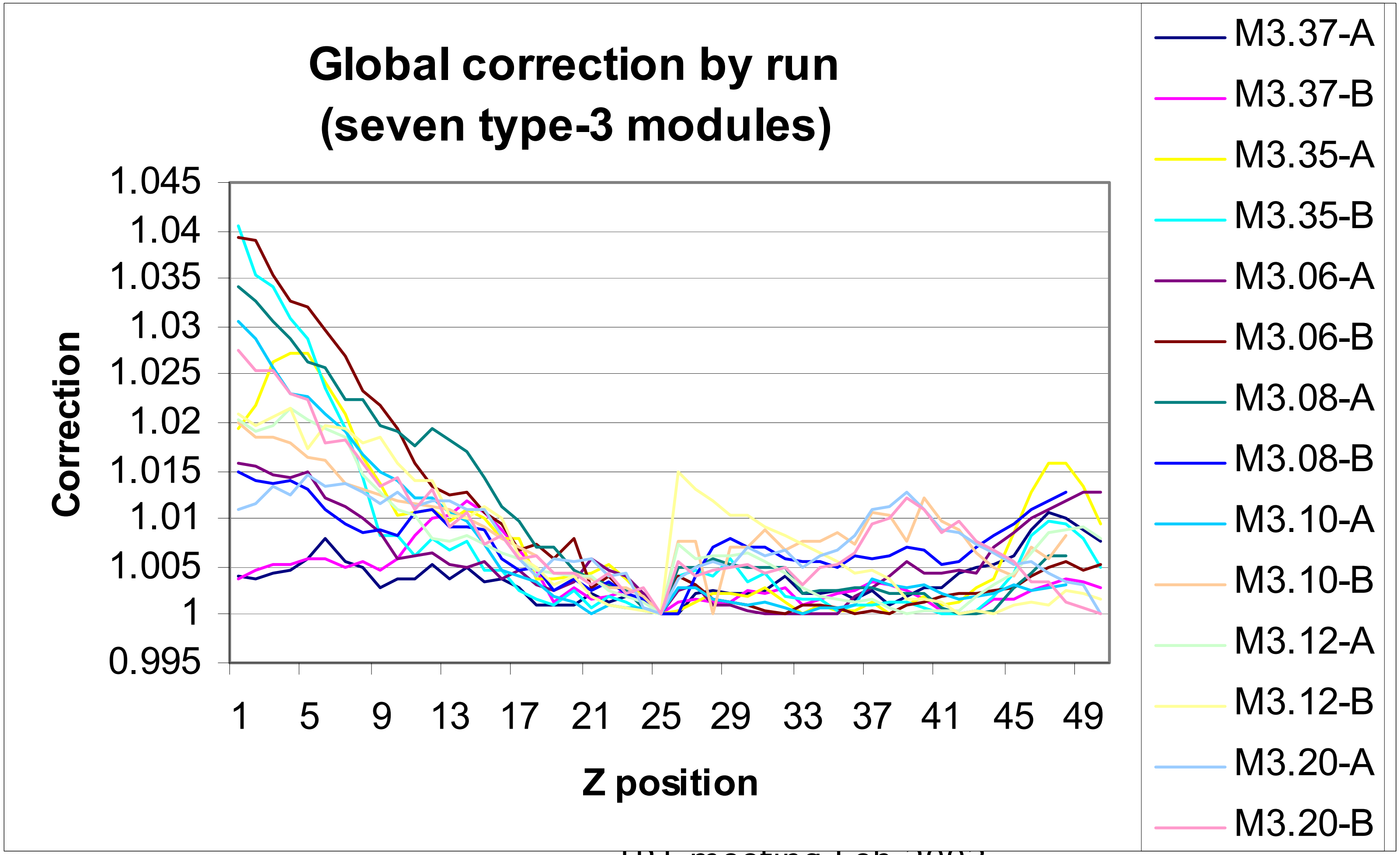
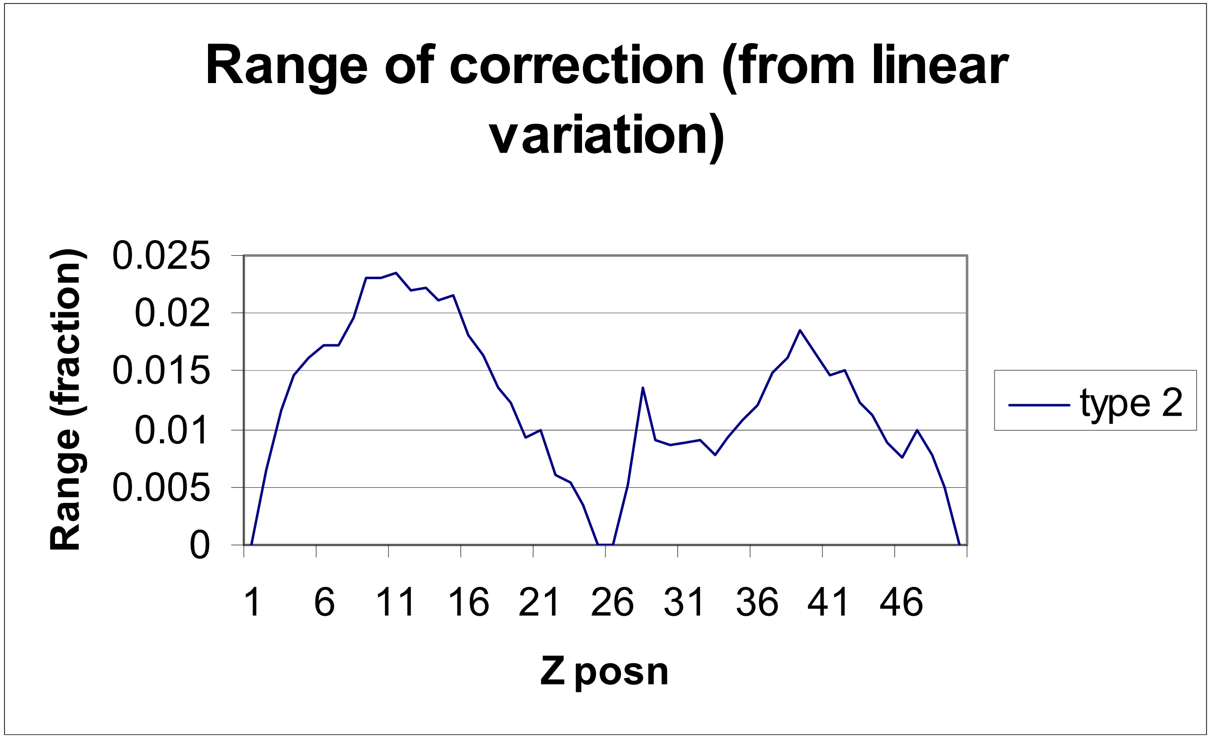
Z-dependent effects in MTS

- Since we scan in z, time, gas mix, temperature dependent effects contribute.
- Corrected by using a global average of ‘good’ wires (G<8% uncorrected).
- This introduces a ~1% systematic effect and will reduce corrected gain shift in module. See next slide.

Sample of global corrections

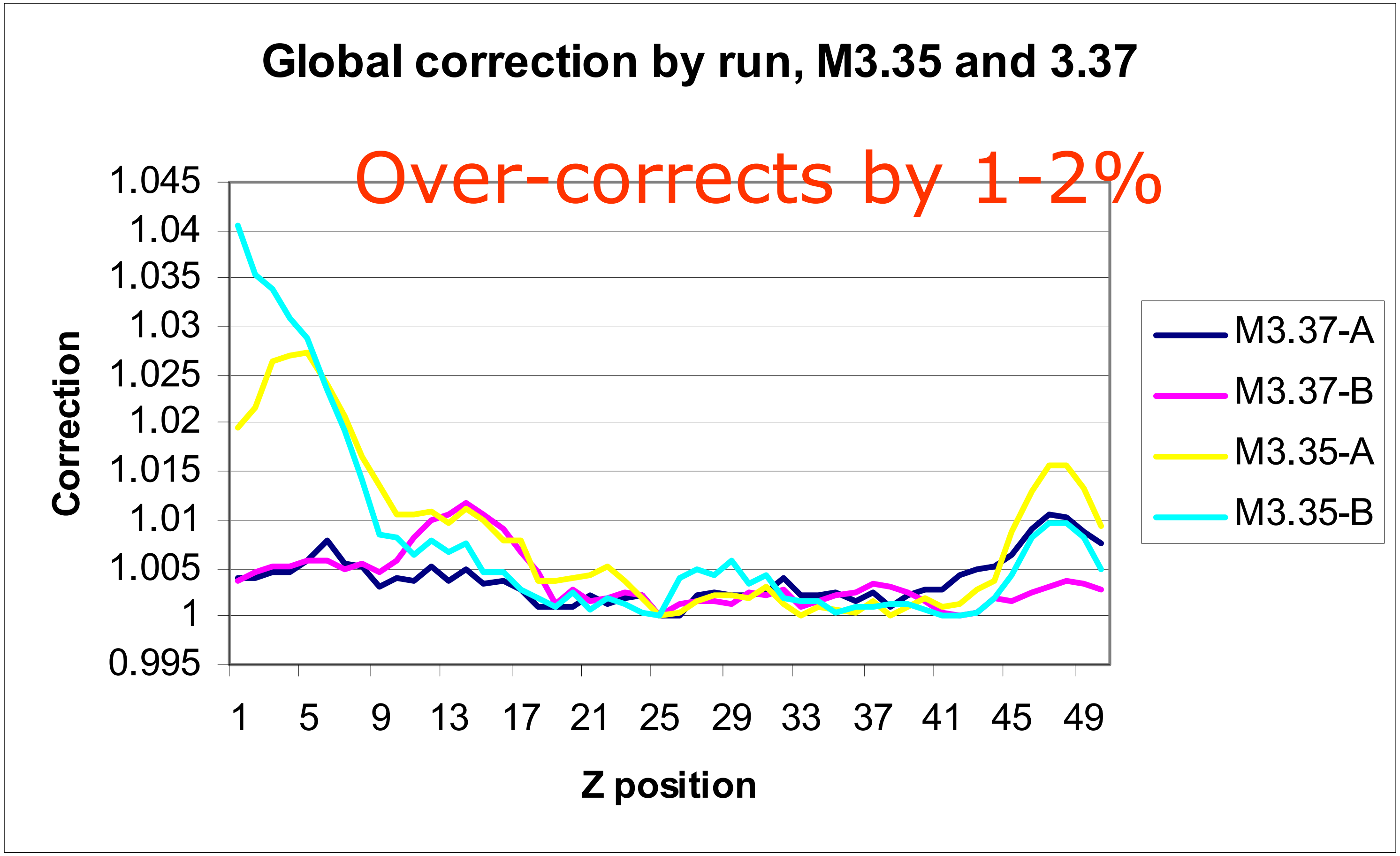


Range of global correction



From this sample, a 2% range is seen; a 1% systematic uncertainty results.

Special case



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Granularity

- Granularity : Measurements are made with ~2.8 cm spacing. For large gain variations, the maximum gain point can occur at the end of a wire segment or between two measured points. This effect depends on how quickly the gain varies.
  - For a bent straw, the maximum measured gain can be ~0.5-1% less than the actual maximum gain
  - A point distortion can be missed completely.

Electronics non-proportionality

- If the ADC channel is not proportional to the pulse height ($y \neq \alpha x$), then measured gain shifts can be different from actual shifts
- There are two effects: offset and non-linearity (discussed in previous presentations)
- For the MTS
  - Offset reduces the gain shift by ~8%
  - Non-linearity increases it by ~5%
  - Net effect is 3% x 8% reduction = 0.25% at cut.

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Analysis

- The peak-fitting is not the same as, although similar to that used in the paper by Kaioumov et al.
- In addition, the different photon energy changes the peak width and effect of offset
- An estimate of a 0.5% effect is reasonable.

Non-zero wire offset

- The method assumes that the wire is at least somewhere close to the center of the straw
- We know that 'hung wires' with offsets of >~350 μm are quite common (45 out of 14.4k), so offsets of ~100 μm must be frequent (~0.7% gain shift).
- The 16-channel tension test depends on wires being offset
- An allowance of 0.5% seems reasonable.

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Statistical effects

- The gain variation, G, is defined as: $G=(g_{n,max} - g_{n,min})/g_{n,min}$ where g_n is the normalized gain at a point
- For wires with significant variation, this statistic has a spread of 2-4 times the spread of a single point.
- This can be measured by comparing MTS with itself. Next slide.

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Statistics

- The reproducibility of the MTS, when there are no apparatus changes, is ~0.6% (see Peniscola talk)
- If the apparatus is changed (e.g. the wires do not use the same electronics channels, e.g., MTS vs. MGM), this becomes ~1%.
- We want at least a 1/8 chance or better of no wire being outside spec, so choose 1% (1σ at 1%, 1.7σ at 0.6%) as desirable allowance.

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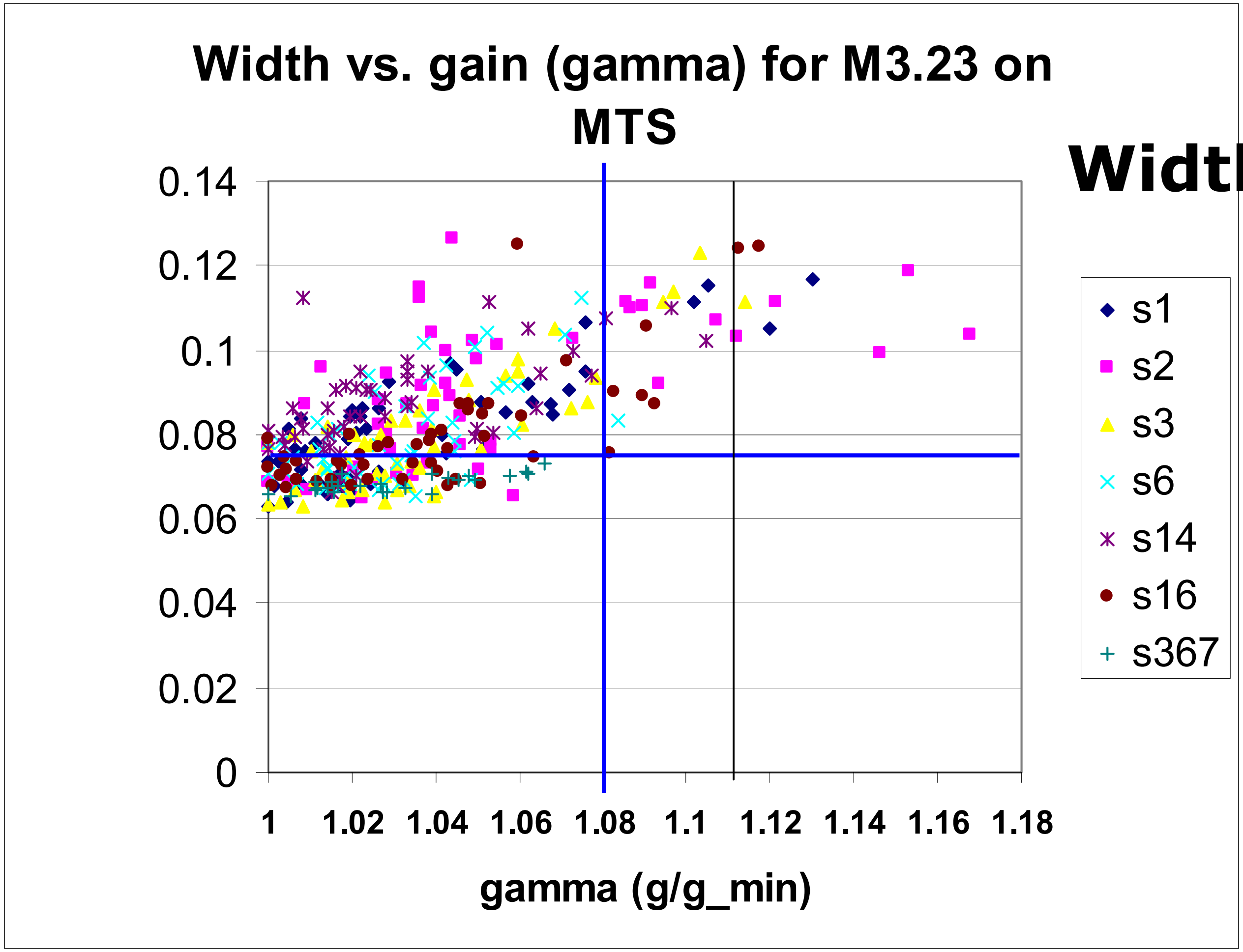
Summary of uncertainties

Description	Magnitude
Global correction	~1-2%
Granularity	~1%
Non-proportionality	~0.25%
Analysis	~0.5%
Non-zero wire offset	~0.5%
Statistics	~1%

Given the above, a 2% allowance for systematic effects is reasonable; with 1% for statistics, this gives 3% uncertainty.

Width vs. gain for ‘bent’ straws



Width ~0.4%/%G

>11% gain shift correlates with width >9%

Gain & width profile of good wire (for comparison)

Module 2.14, straw 27

12%

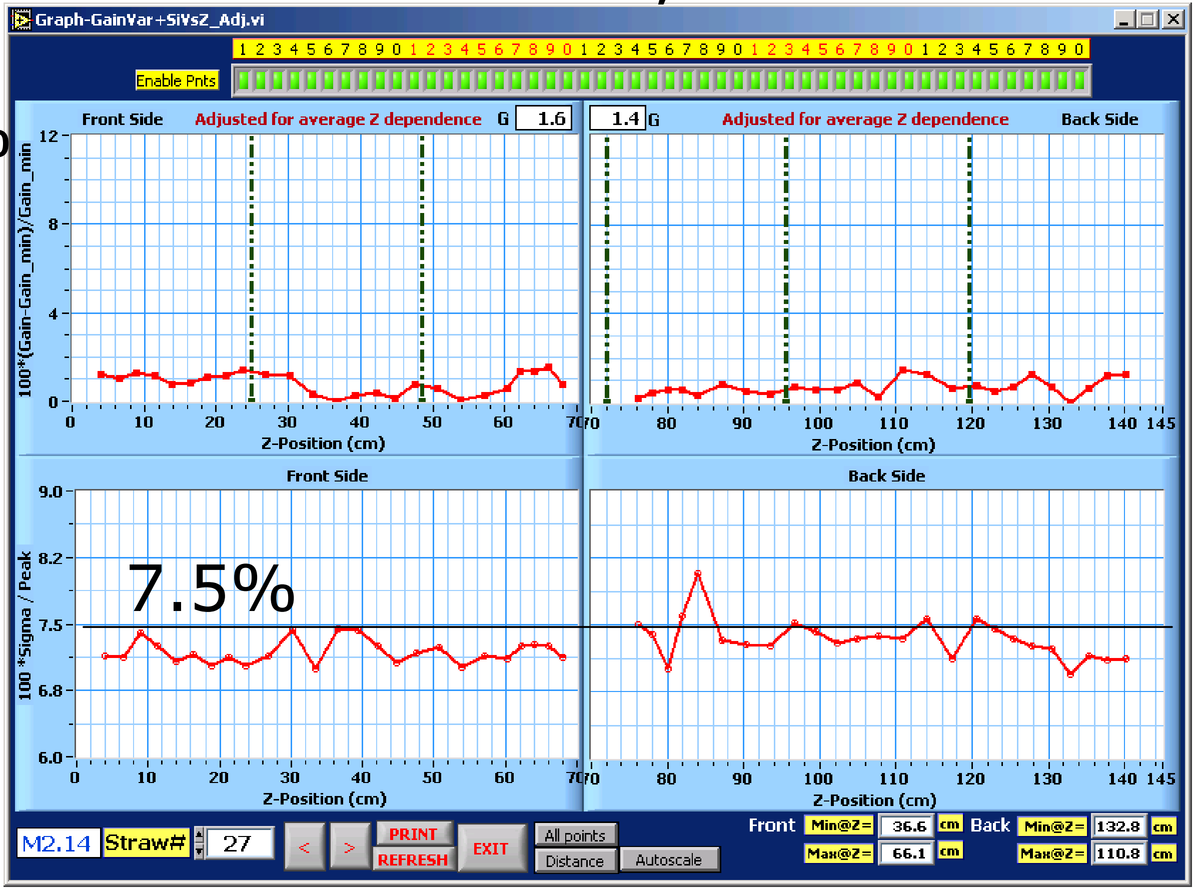
Gain shift

0%

9%

Width

6%



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‘Contaminated’ wire

Dropping the two lowest points results in G<8%; with this, the wire is acceptable

12%

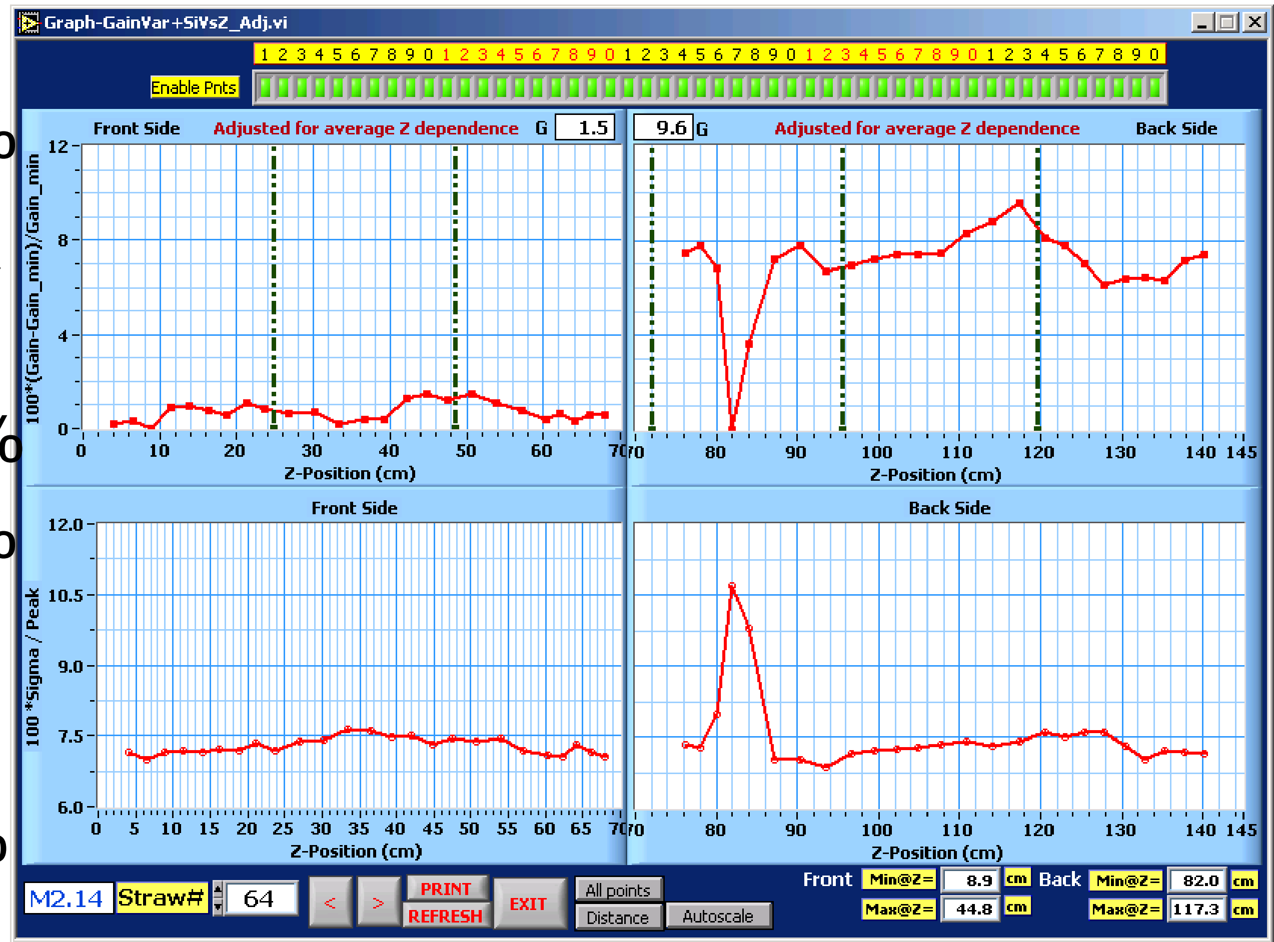
γ

0%

12%

σ/g

6%



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Contamination

- We attribute a gain-width profile like the previous slide to contamination in the straw, or on the wire, that will be etched away during operation in ATLAS
- Experience with module 1.03 supports this approach
- A characteristic is that the highest-gain point has a ‘normal’ width.

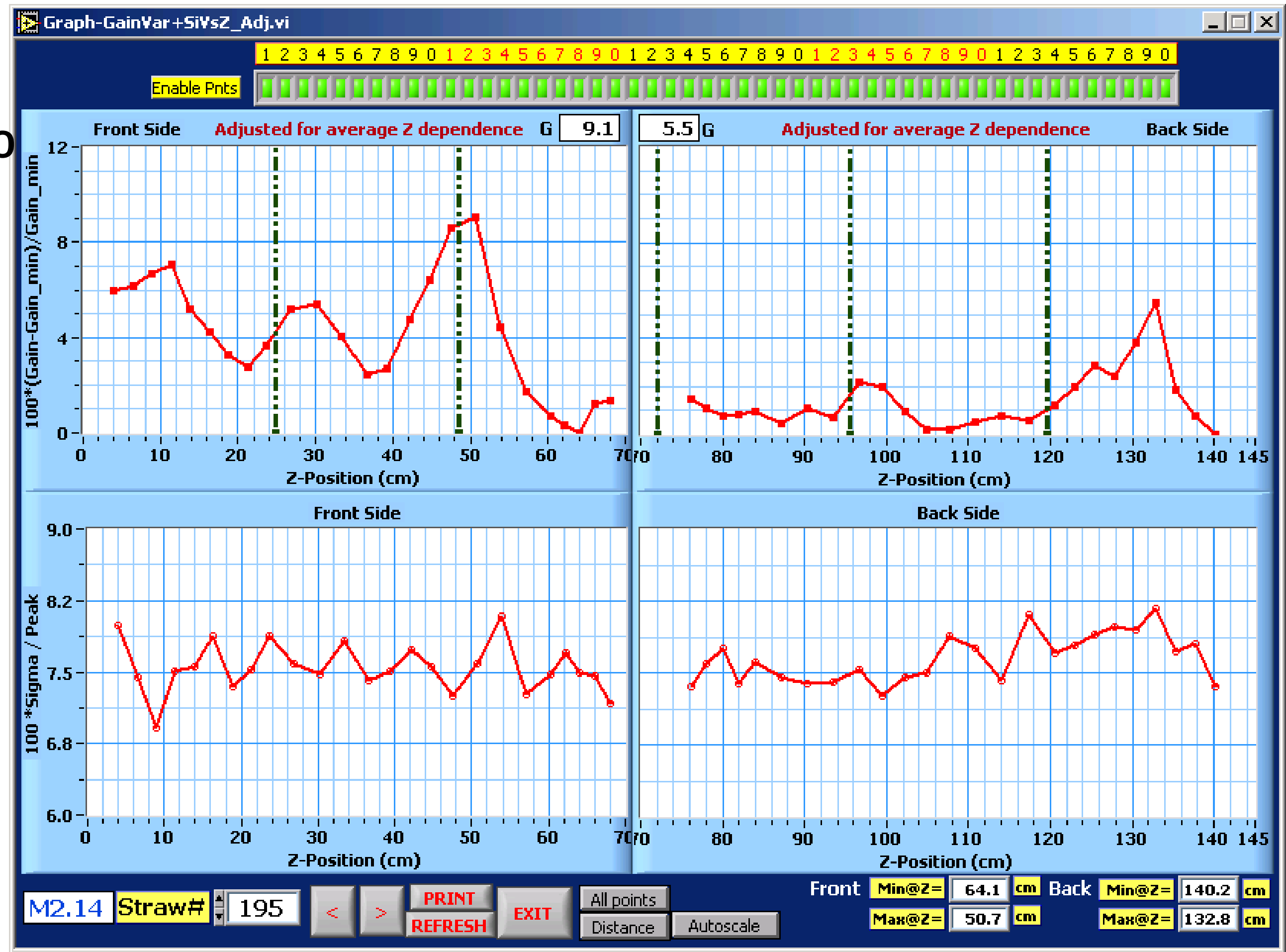
Wire diameter variation

Significant gain variations, with normal widths

12%

9%

6%



Bent straw (real offset)

Significant gain variation, with matching variations in width (this wire not flagged)

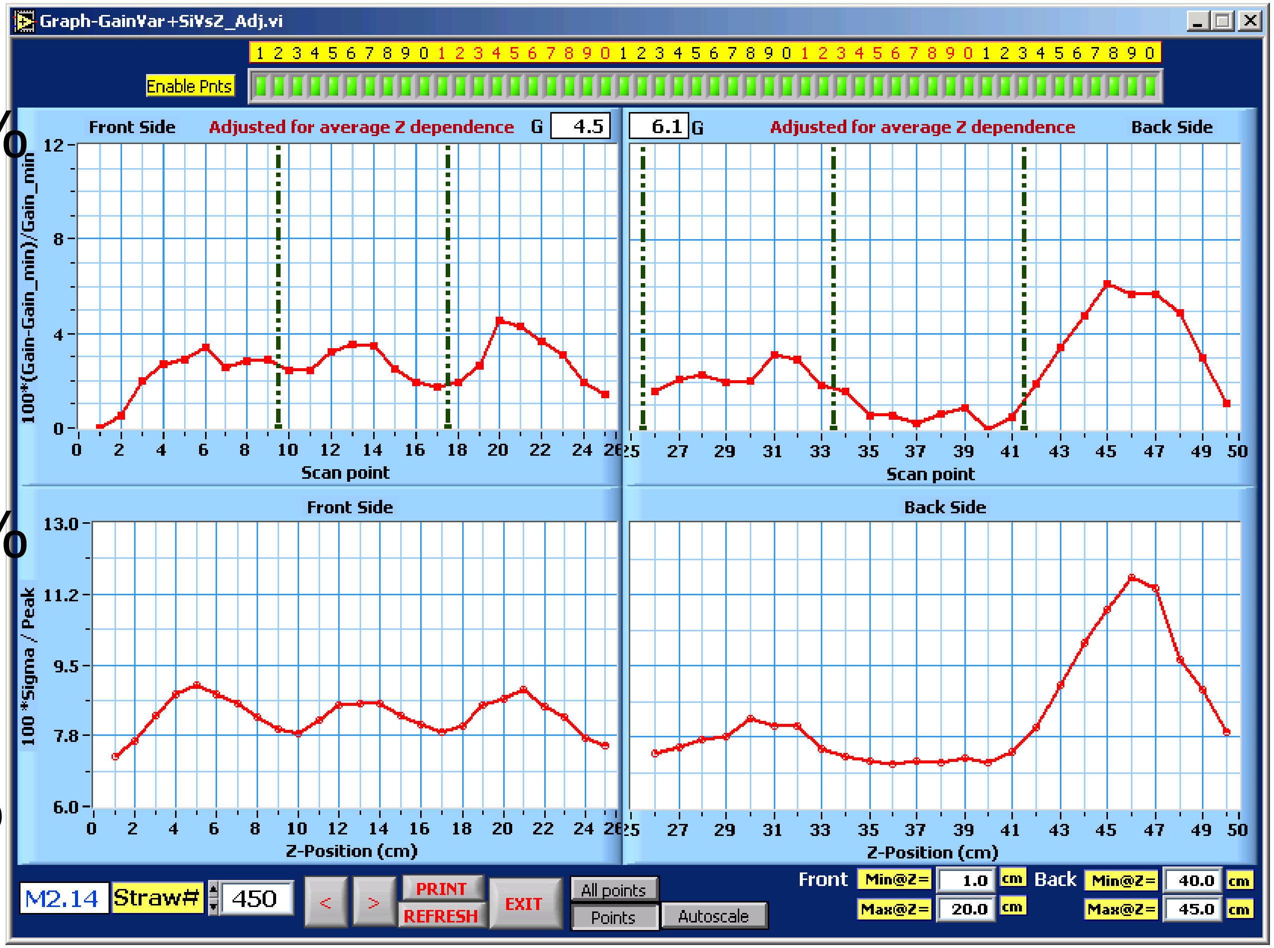
12%

γ

13%

σ

6%



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Wire categories

Category	Characteristic
Offset (bent, hung)	High-gain points have large width
Contaminated	High-gain points have normal width (low-gain points have large width)
Diameter variation	Gain variation present, but all widths normal

QA criteria

- Wires are selected for discussion based on:
  - Gain variation (G)>8%
  - Width of peak at **highest gain point** S >7.5%
- Decision on removal is based on study of gain profile and width profile

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Effect of QC criteria

- Offset wires; these are selected for further discussion
- Contaminated wires: since the large-width points have low gain, these are not often selected
- Wires with varying diameter: spectra have normal widths, so they are not often selected.

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MGM-MTS similarities

- X-rays are XRF from bromine (12 keV); beam is full width of module
- Ar-CO2 active (~1 vol/h) and purge gas
- Front-end and switching electronics (GPX, CSX, CCA, AIR)
- DAQ, database, and analysis software

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MGM-MTS differences

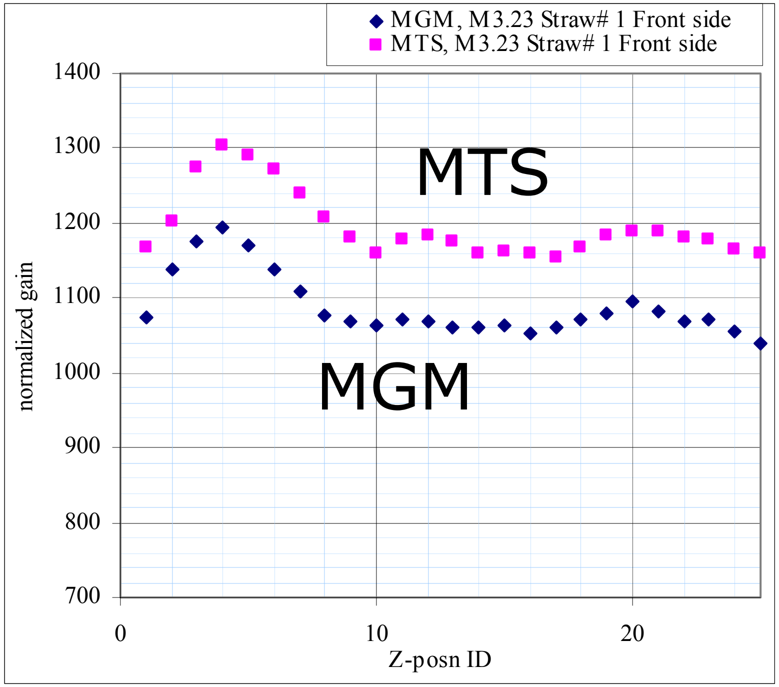
Item	MTS	MGM
X-ray beam size	~1 cm in z	~2 cm in z
Z position	May be different ~<2 cm	
HV	1255 V	1230 V*
*As a result, pulse height in GPX will be slightly smaller		
ADC	Amplifier+ FastComTech	PNPI
The different ADC setups mean different calibrations (offset, scale factor)		

Data reduction

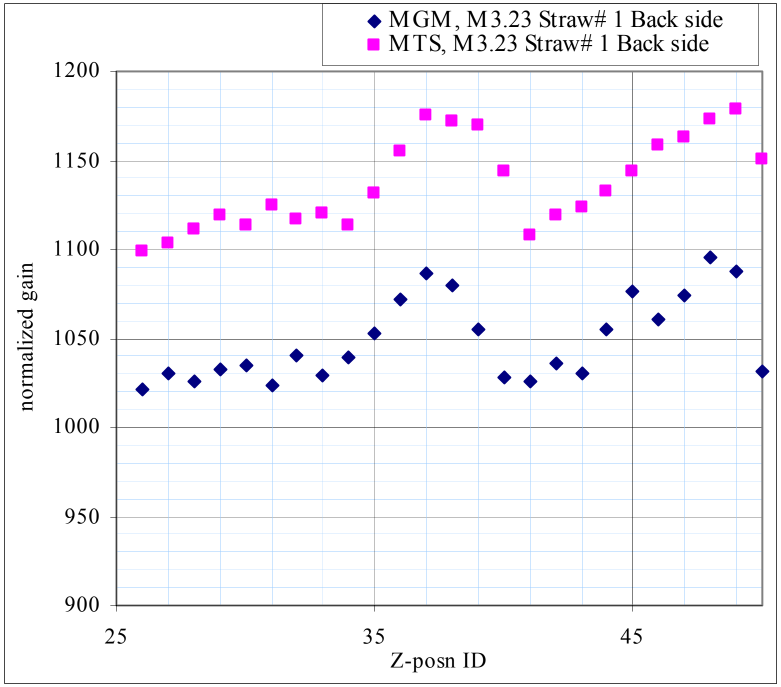
- The peak in each spectrum is fitted with a gaussian, finding the mean (g_p) and standard deviation (σ_p)
- The normalized gain at a point is the ratio of the straw mean to the the monitor mean: $g_n = g_{p,straw}/g_{p,mon}$ (multiplied by 500).
- The gain variation, G, is defined as: $G=(g_{n,max} - g_{n,min})/g_{n,min}$
- Gain shift at a point, $\gamma_n = g_n/g_{n,min}$

Sample gain profiles (1)

Front



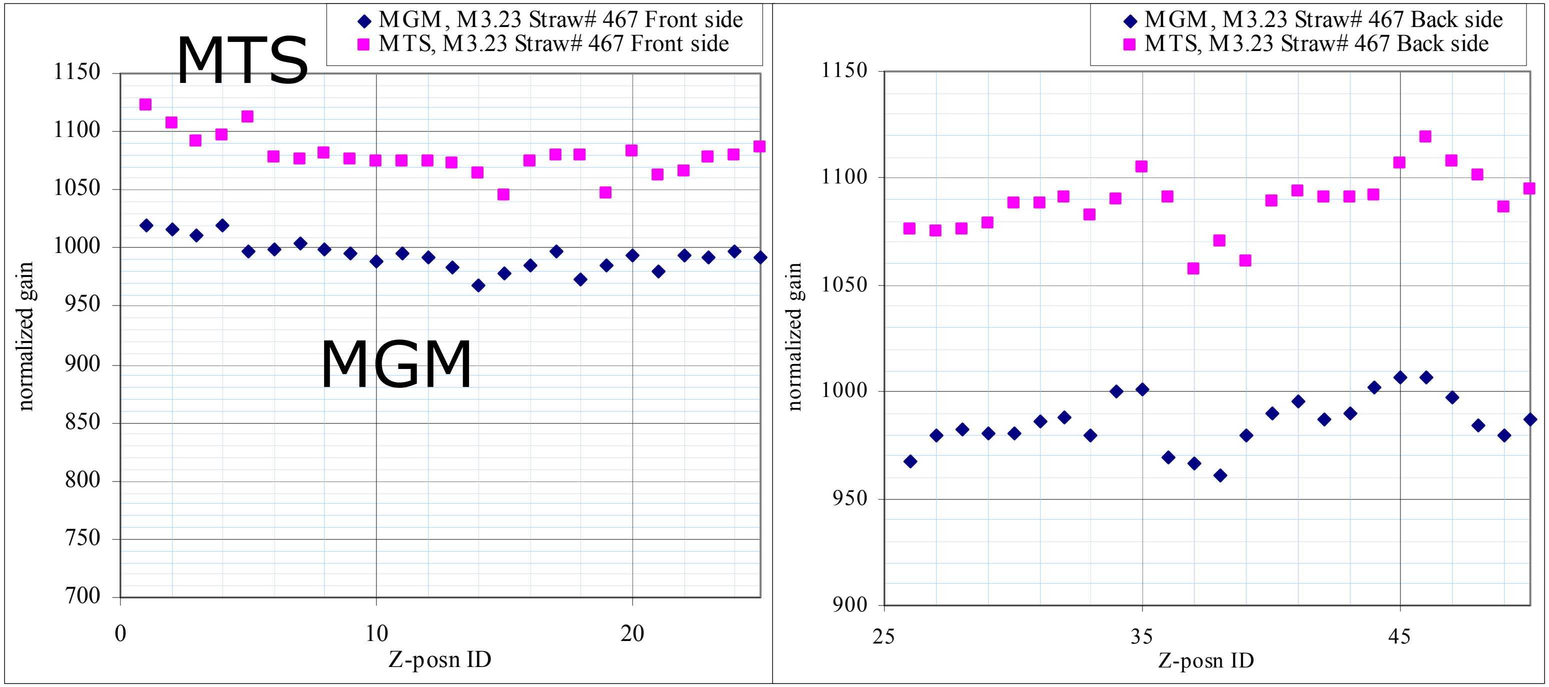
Back



M3.23, straw 1

Sample gain profiles (2)

Front Back

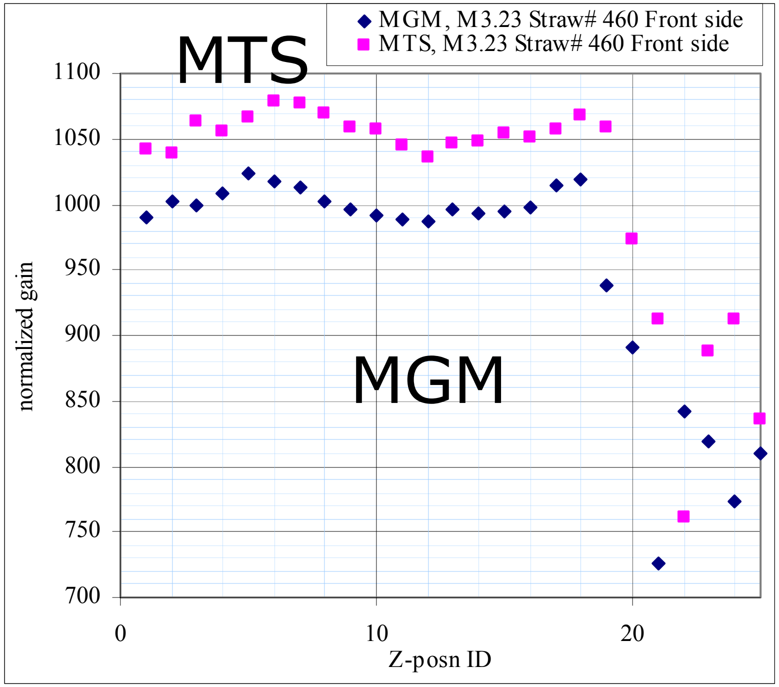


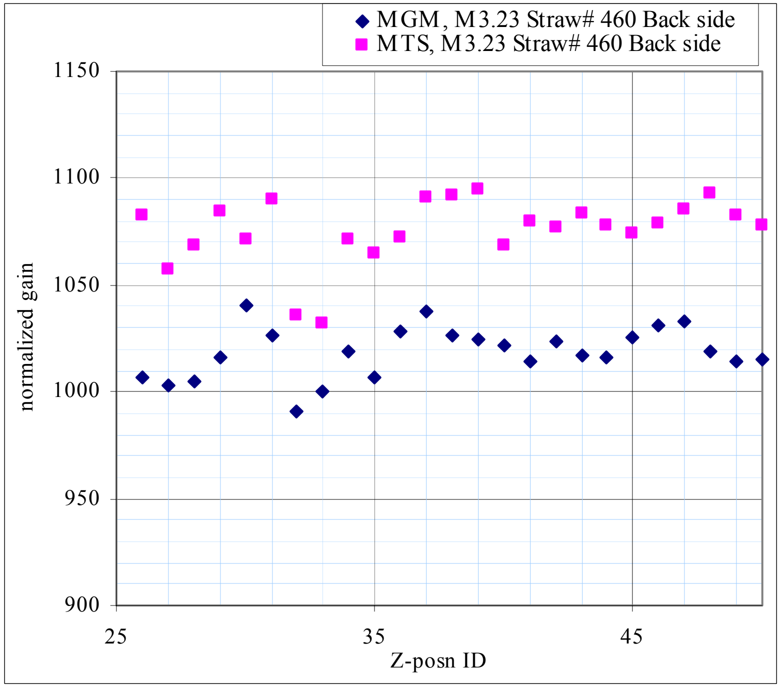
M3.23, straw 466

Sample gain profiles (3)

Front

Back





M3.23, straw 466

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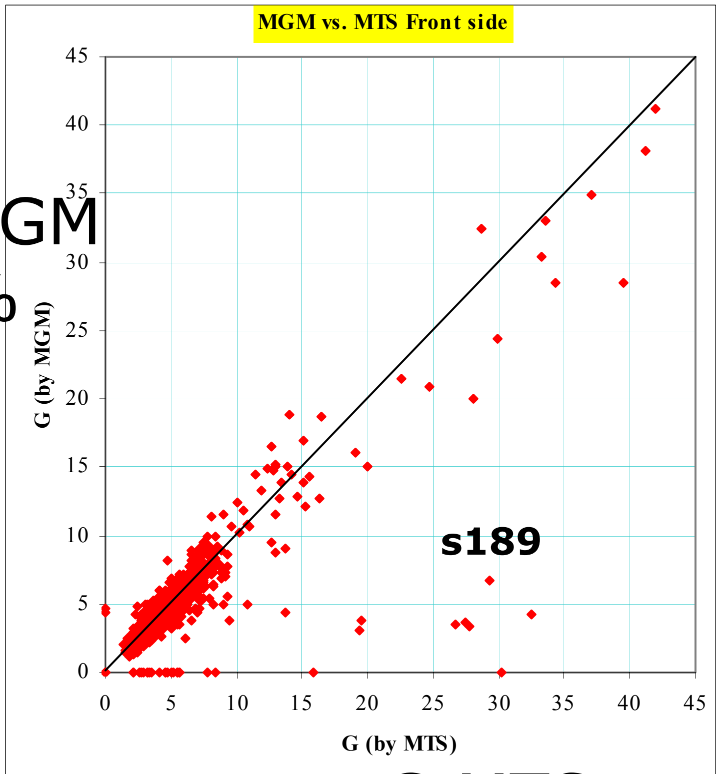
Comments

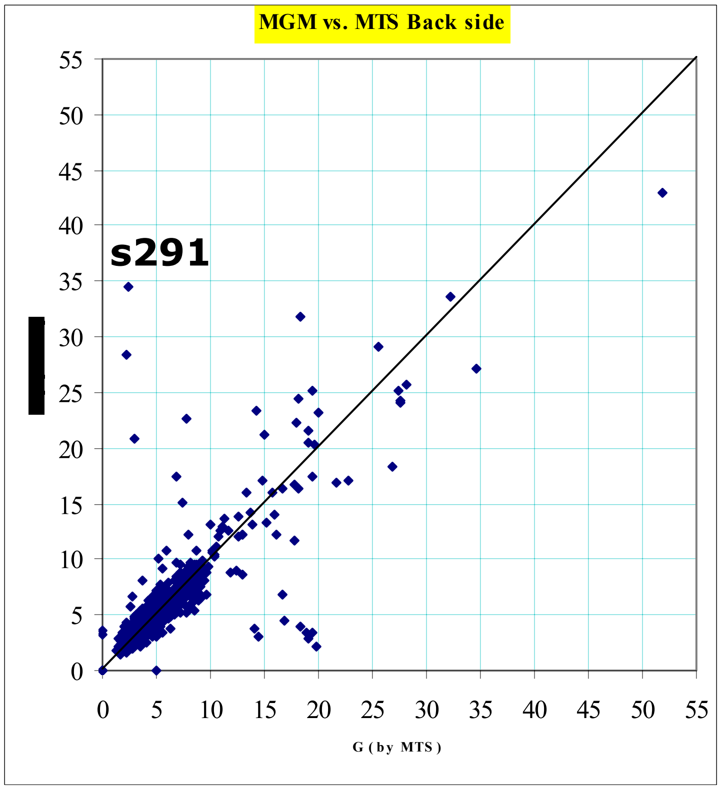
- Profiles match closely
- Slight shift in *z* between MGM and MTS; this will affect comparisons

Gain variation comparison

M3.23, front



M3.23, back

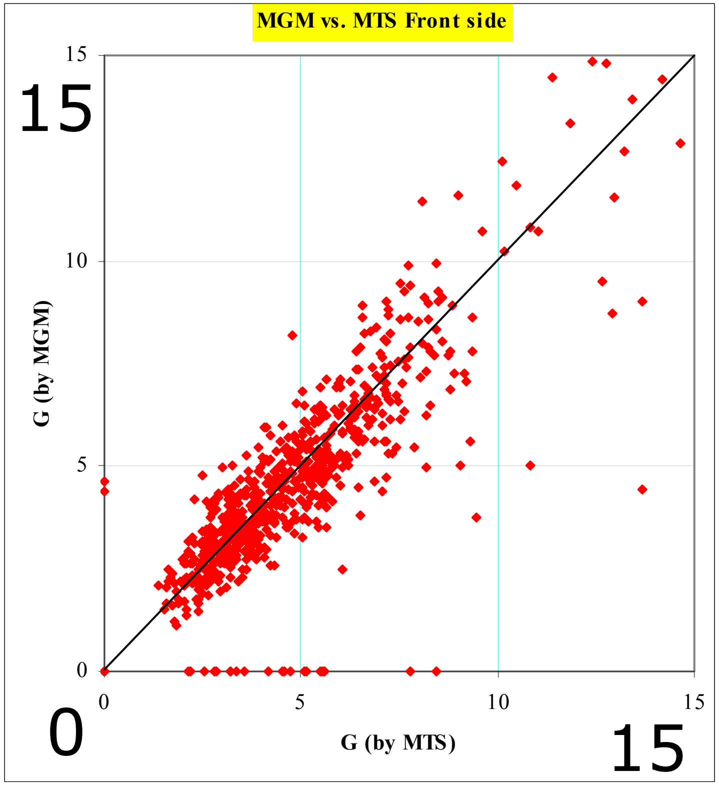


G,MGM %

G,MTS %

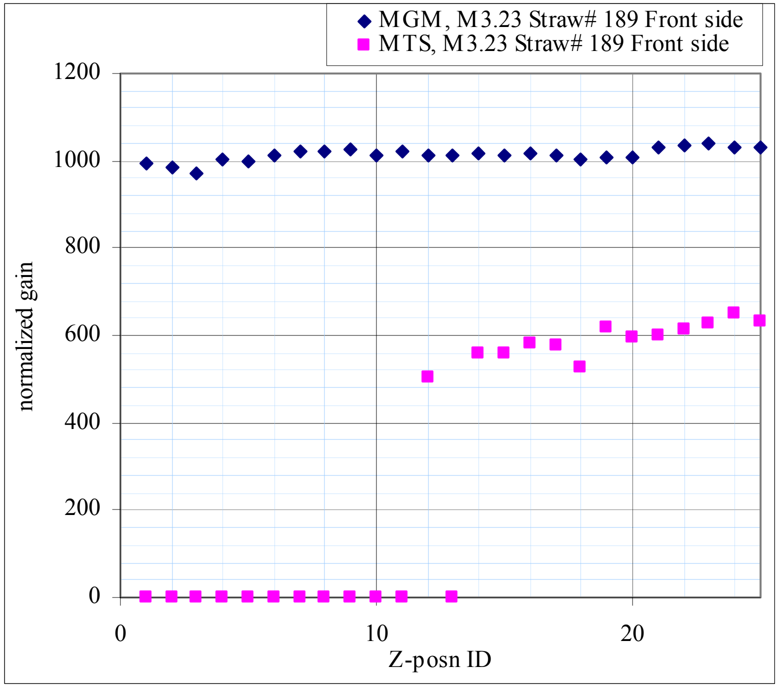
Gain variation (zoomed)

G, MGM (%)

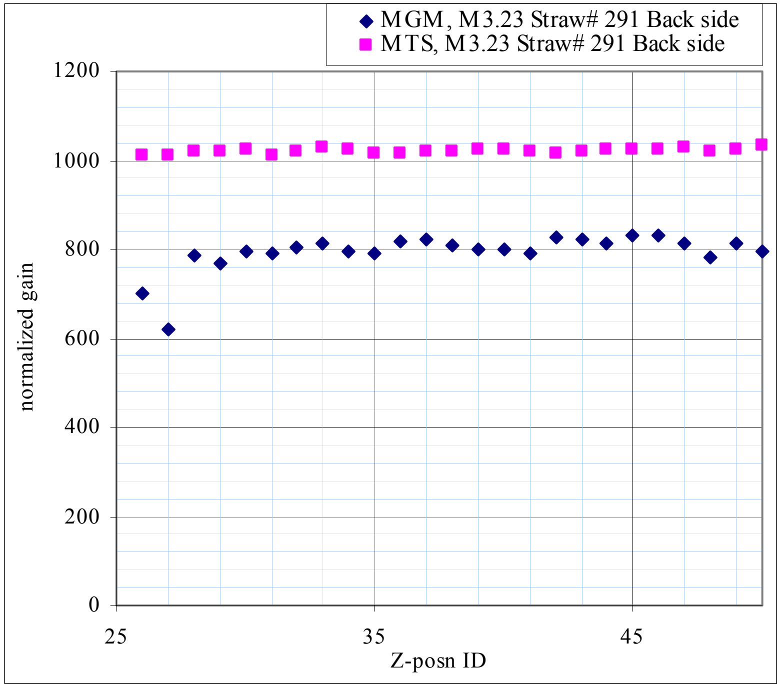


Oddities

s189



s291

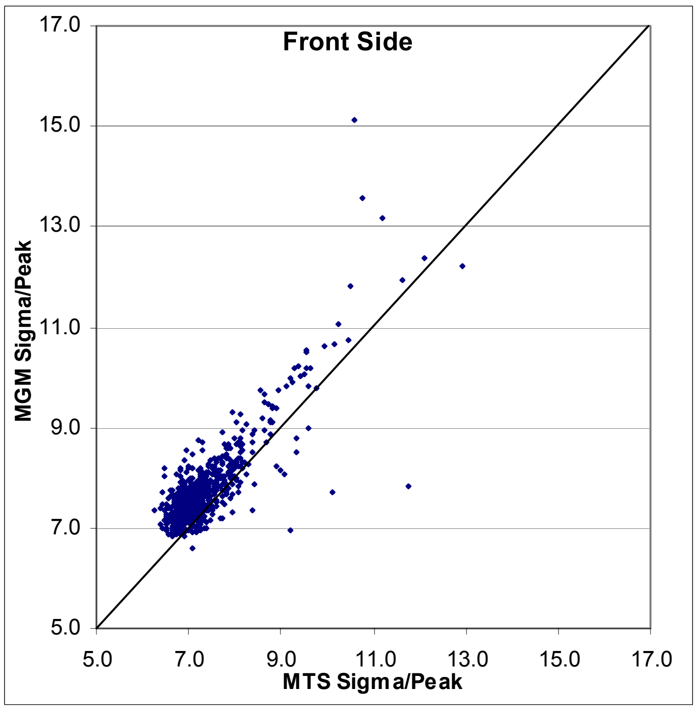


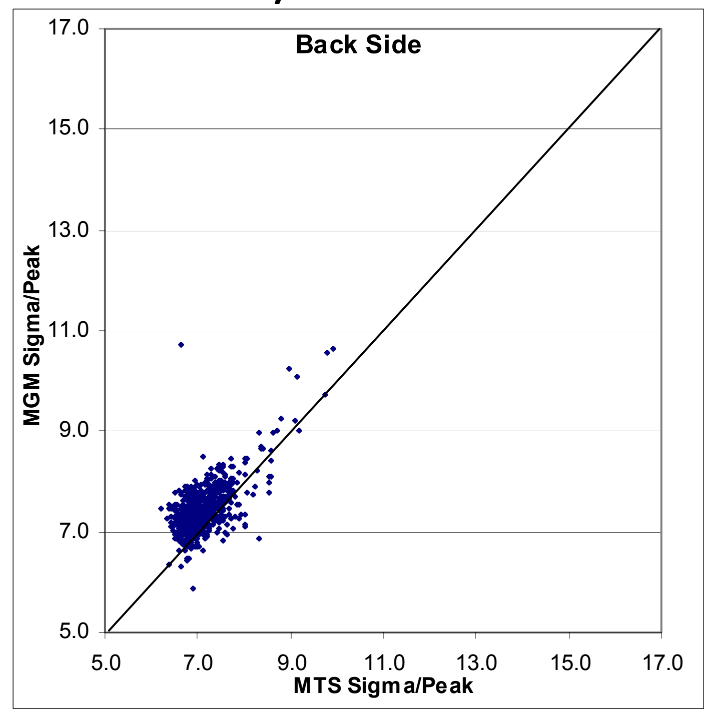
Width comparison

M3.23, front

M3.23, back

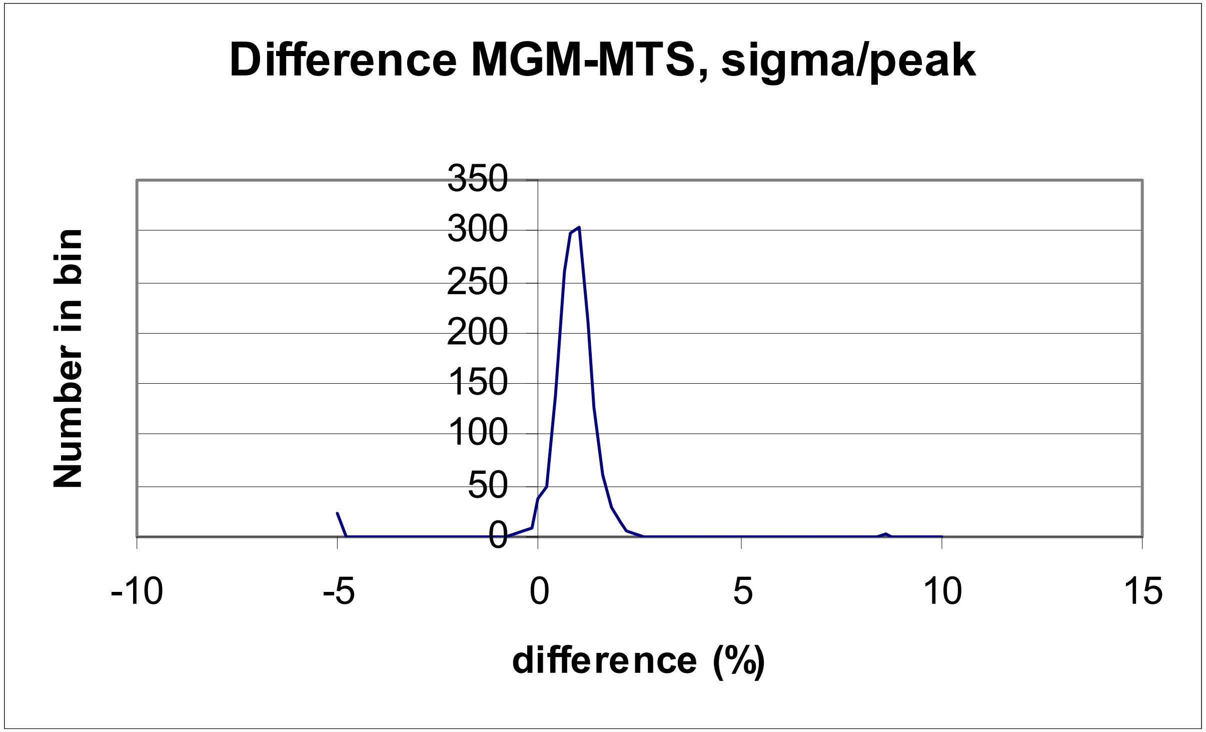
S,MGM %





S,MTS %

Width difference



Mean difference
0.8%

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Conclusions

- While gain variation agrees, width of peak is larger on average
- This can be due to a number of factors, e.g.:
  - Different offset (of ADC channel vs. pulse height)
  - Non-linearity in electronics
- Studies will be done, when time is available

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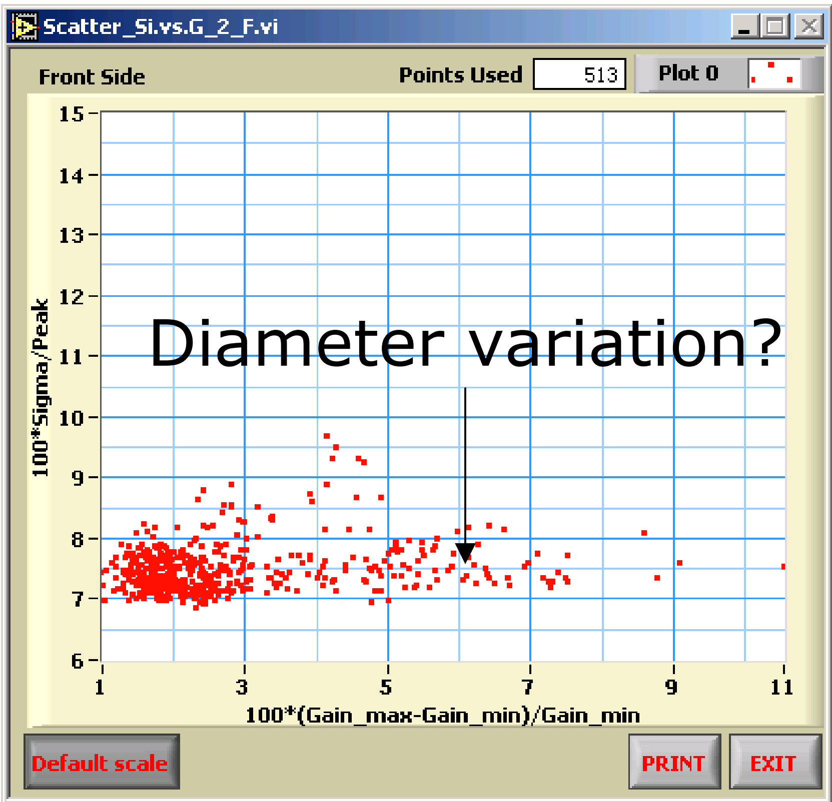
Comment on criteria

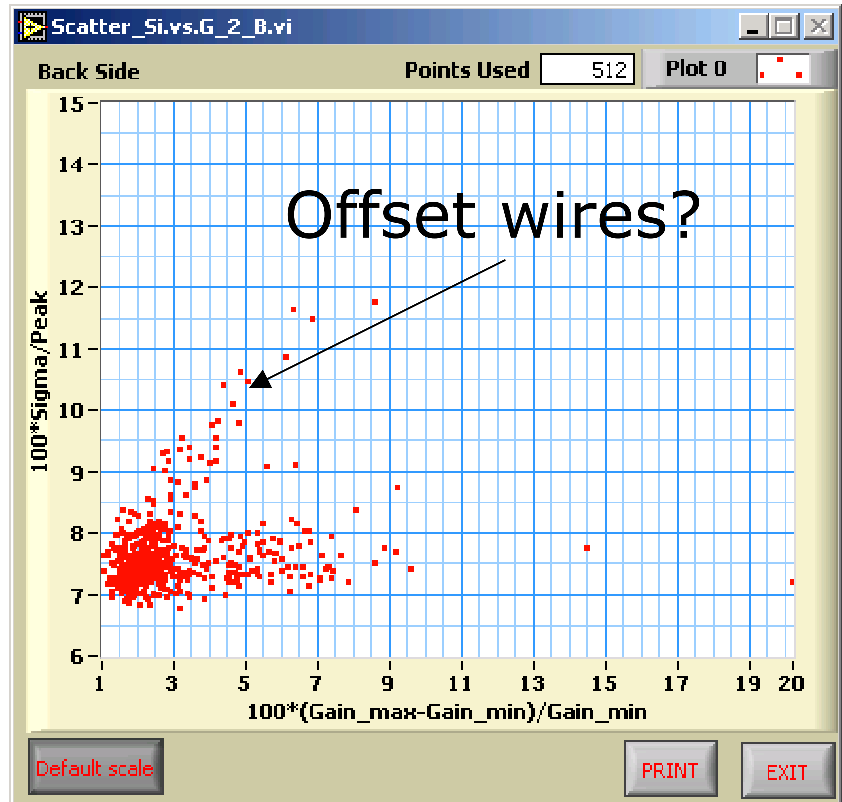
- Criteria to ‘flag’ wires are:
  - G > 8%
  - S (width/peak at maximum gain point) >7.5%
- Get better match of MGM to MTS for M3.23 if MGM criterion changed to S>7.9%
- However, width criterion results only in examination of the wire – overall pattern determines removal.

Conclusions

- *Z* shift between MTS and MGM
- Good agreement for G values
- Retain current criteria for wire 'flagging' and discussion.

Width vs gain M2.14





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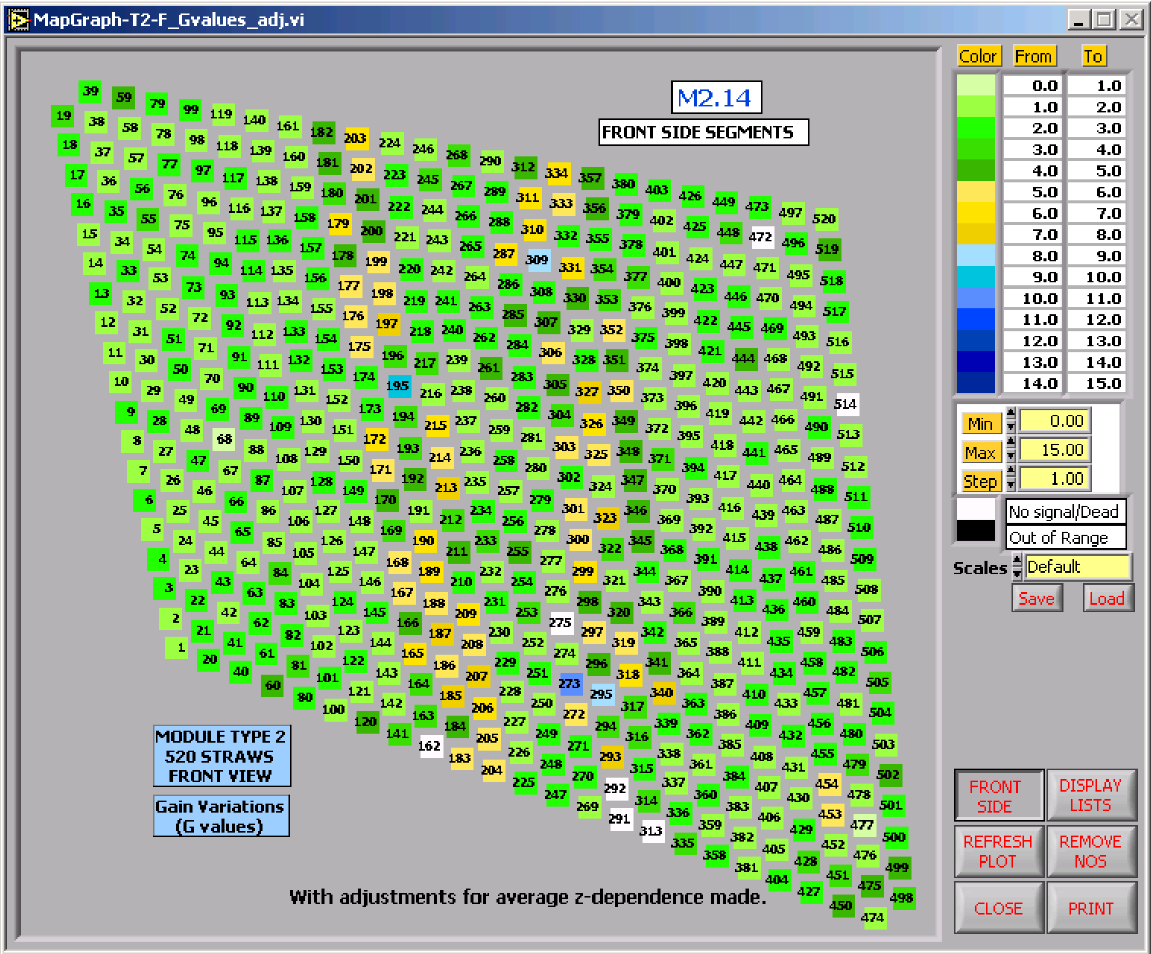
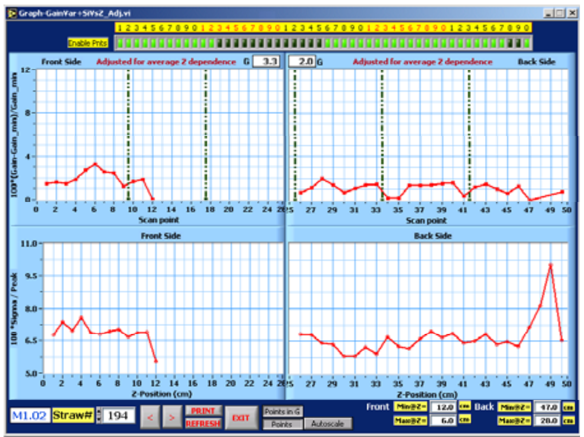
M2.14 map

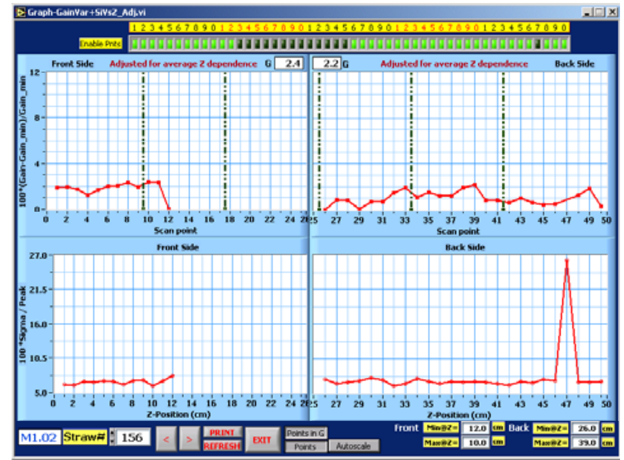


Stripes show wire diameter variation

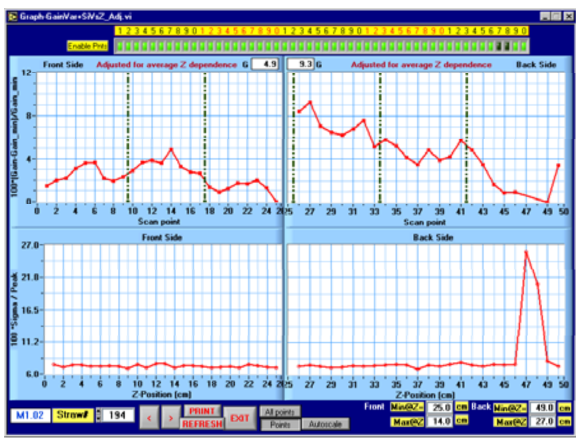
M1.02, wires replaced

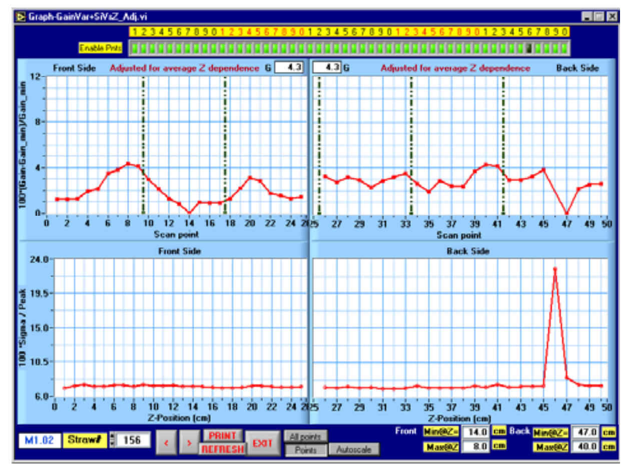
MTS





MGM





S194

s156

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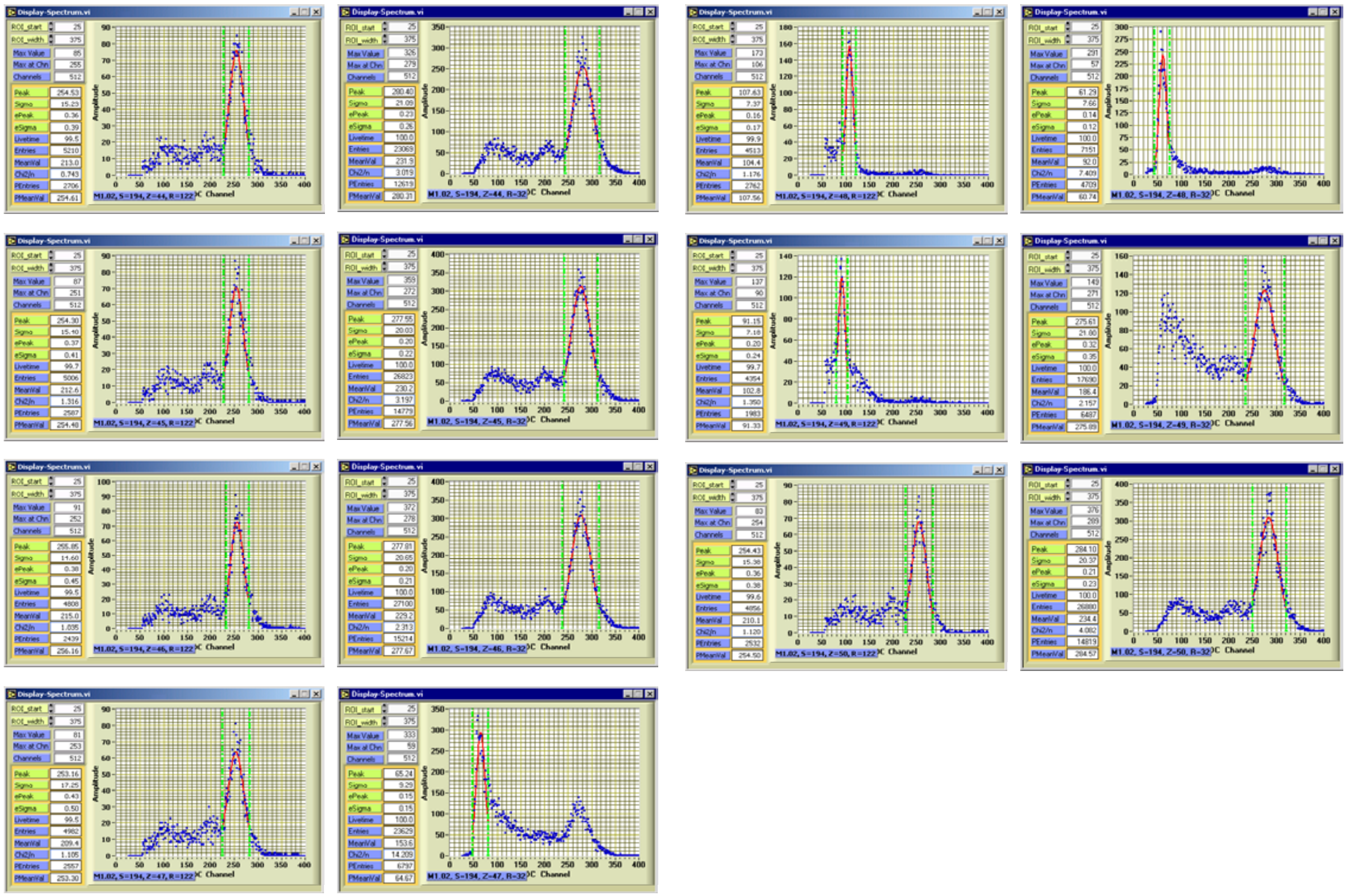
Spectra (s194) after wire replacement



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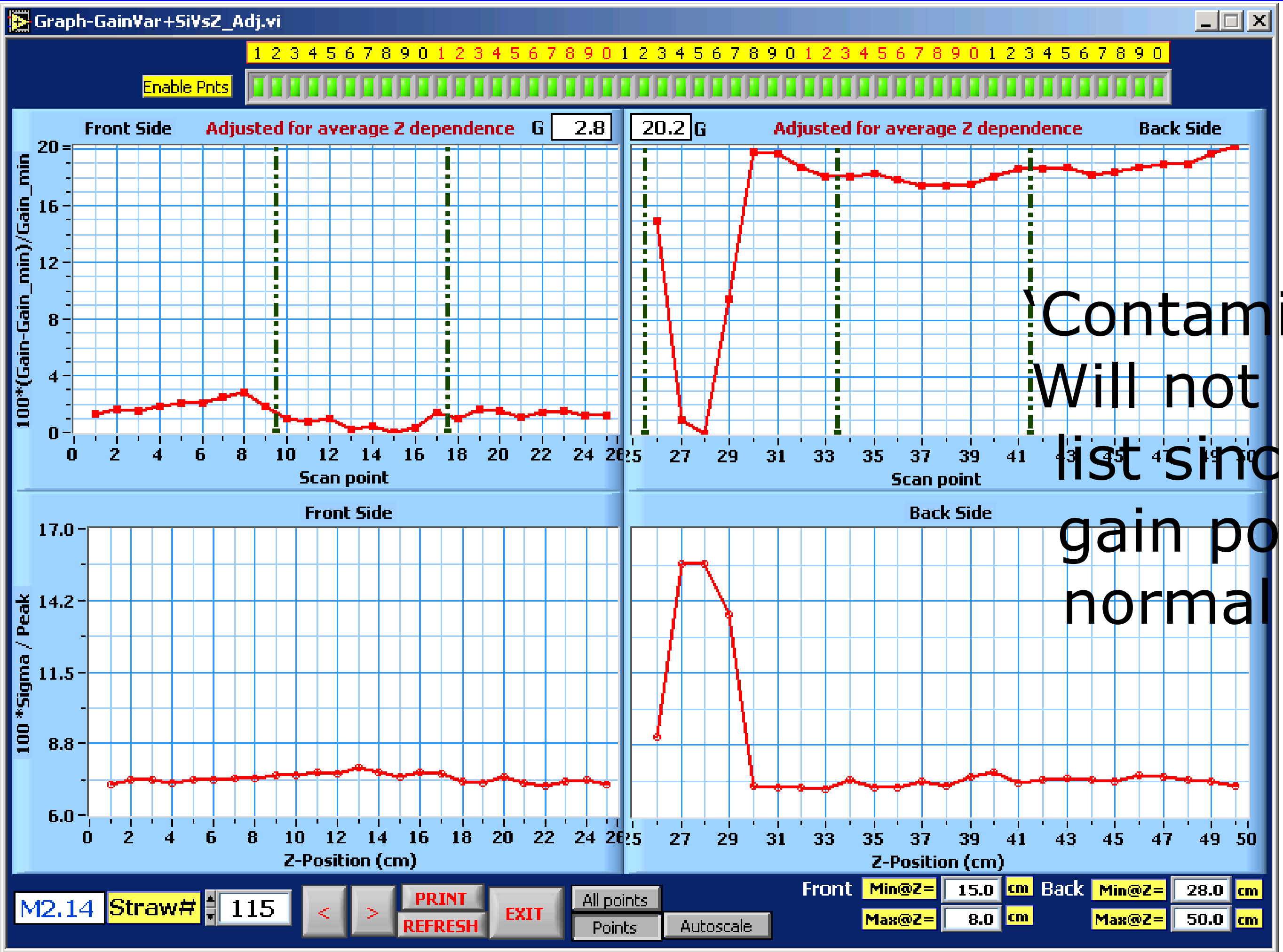
M2.14 s115



'Contamination.' Will not show in list since max. gain point has normal width.

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END