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Evaluation of Total Loss Monitors for Cryomodule Radiation Measurement

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Total Loss Monitor at ASTA

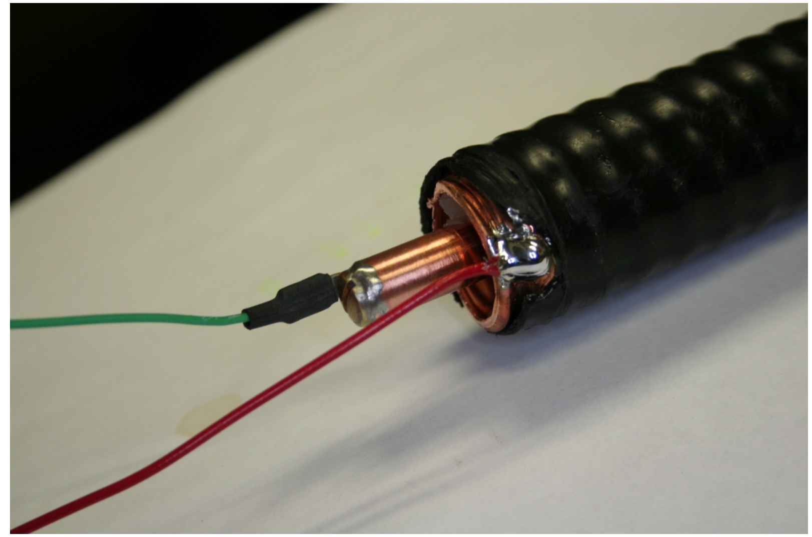
- ASTA
  - Field emission (> 20MV/m)
  - 31.5MV/m
  - X-rays and dark current generated

- Total Loss Monitor(TLM)
  - Radiation monitoring instrument
  - Beam diagnostics
    - Readings help identify the location of beam loss or radiation
  - Personnel protection

Structure

- Outside shield
- Center conductor
- Gas flow argon/CO_2

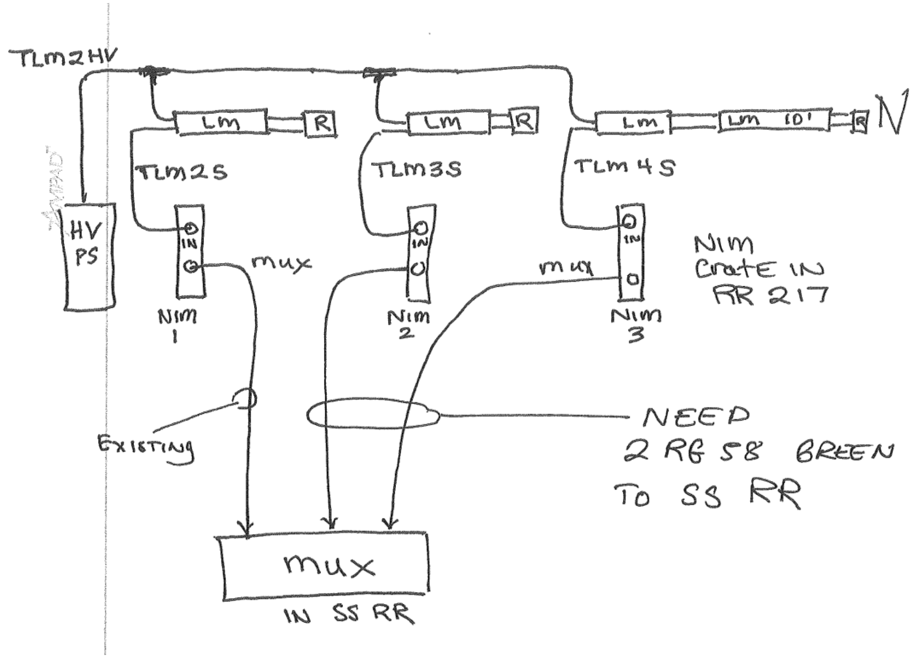
- An 800 volt bias applied to the outside shield
- Signal cable attached to the inner conductor



The TLM design is based on the HJ5-50, HELIAX® Standard Air Dielectric Coaxial Cable

Schematic diagram & working mechanism

- Radiation Detection
  - Measure the ionization charge by counting the number of electrons that are attracted to the inner conductor
  - Argon: electron attachment rate to form negative ion is small
  - CO_2: larger dynamic range, less sensitive to bias, economical
- Heartbeat resistors
  - 10 TOhm
  - 30% tolerance
- Background signal
  - 5 nC/minute
- MUX: send multiple signal in the form of a single, complex signal and recover the separate signals at the receiving end



Monte Carlo Simulation

- Accurately simulate electromagnetic showering
- Predict the TLM response with a given beam loss
- Example:
  - A 30 MeV electron beam is lost entirely in the cryomodule
  - 1.23E-13 GeV/cm^3 is lost in the TLM (Given by the simulation)

$$1.23 * 10^{-13} \frac{GeV}{cc - electron} * \frac{6.24E12electrons/sec}{\mu A} * 5203\ cc * \frac{1E9ev}{GeV} * \frac{ion\ pair}{30ev} * \frac{electron}{ion\ pair} * \frac{coulomb}{6.24E18\ electrons} * \frac{1E9nC}{coulomb} * \frac{60sec}{minute}$$

  - expected TLM response: =1282 nC/min-uA
- Verify in the future
  - Show the actual beam loss condition and the simulation are in agreement.

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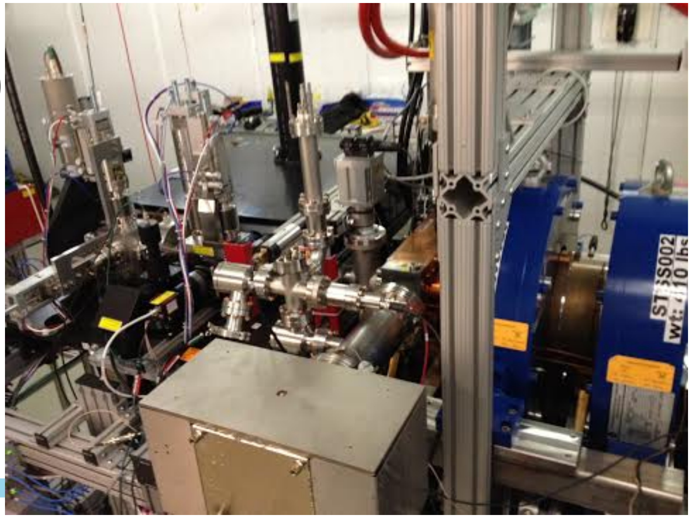
Measure X-ray radiation

- The X-rays due to field emission could not be easily simulated because it is difficult to estimate the number of electrons and their energy distribution.
- Though the TLM is mainly designed for beam loss measurement, it is worth to investigate and find out if the TLM is sensitive enough to detect the radiation created merely by field emission.

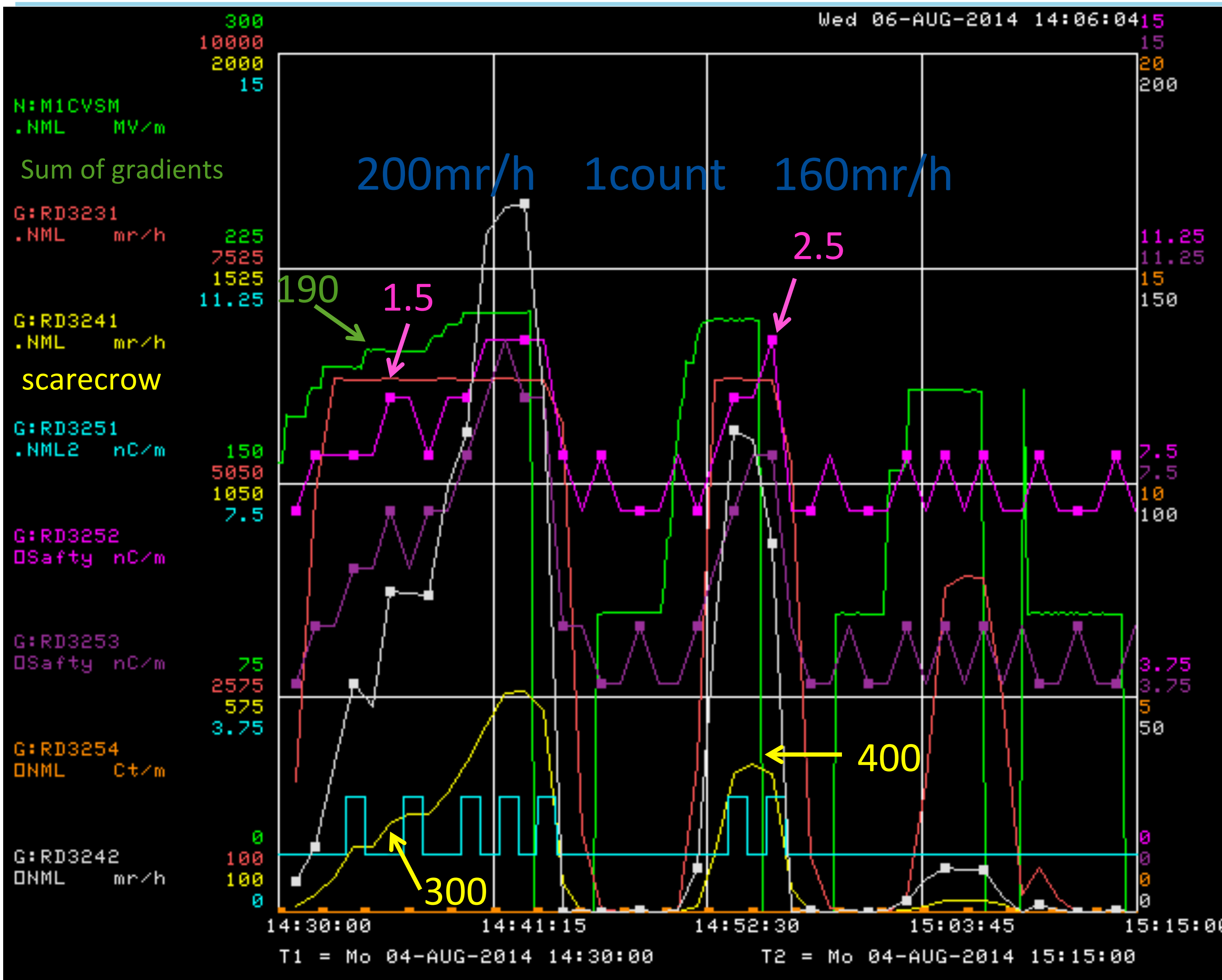
Calibration

- An estimation has been done to predict the response of the TLM with another calibrated scarecrow.
- Scarecrow: sensitive spot detector
- In the experiment, a beam is accelerated in the photoinjector gun and eventually absorbed by a Faraday cup, creating the radiation that two monitors are detecting.
- TLM response is linearly correlated with the scarecrow response
  - 12 cpm (TLM) ~ 2400 cpm (scarecrow)
  - A scarecrow count is 25 urem
  - subtract the background
  - Incorporate built-in quality factor

TLM: A count is about 160 mrem/hr.



TLMs' response to X-rays due to field emission



TLMs are functioning properly and could indeed see X-rays despite its low sensitivity.

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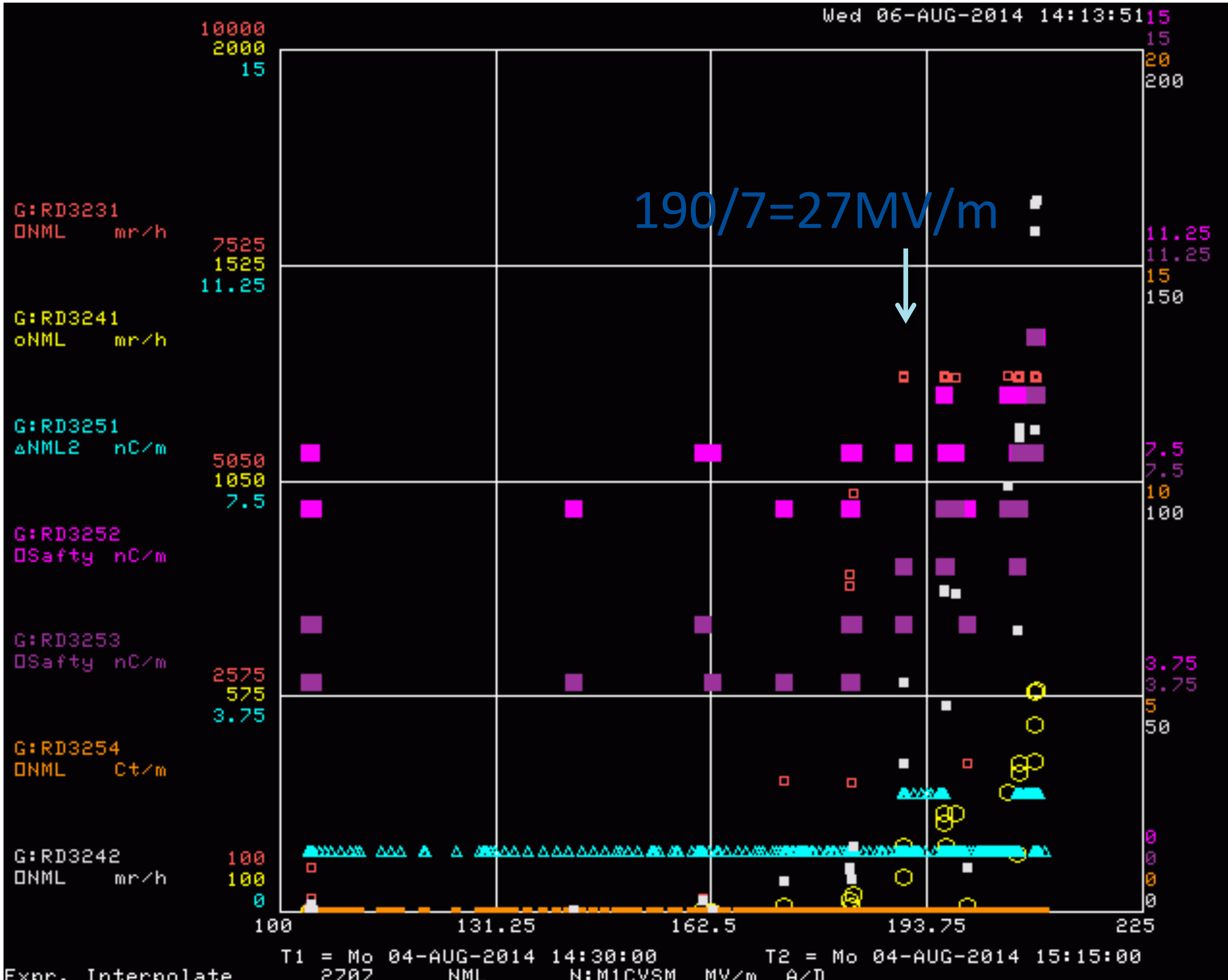
TLMs and scarecrow response vs. Gradient



TLM start to detect X-rays when the gradient is above 27 MV/m

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Conclusion

- The Total Loss Monitors have been successfully installed and proved to be working.
- It has been expected (with Monte Carlo simulation) and proved (by source check experiment) that a TLM is able to detect significant beam loss.
- In the future, when there is electron or proton beam going through the cavities, we could then fully take advantage of the TLM to perform beam diagnostics and radiation detection.
- Good agreement is shown between scarecrow and TLM in two situations (source check calibration and actual radiation.)
- However, TLM's sensitivity is relatively low in terms of detecting X-rays due to field emission. More studies are needed to fully understand its response and to improve its sensitivity.

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