Preliminary Study of x-Ray Background

- Measurements at MTA, FNAL

D. Huang, Y. Torun, IIT
A. Bross, A. Moretti, FNAL
J. Norem, ANL

Outline

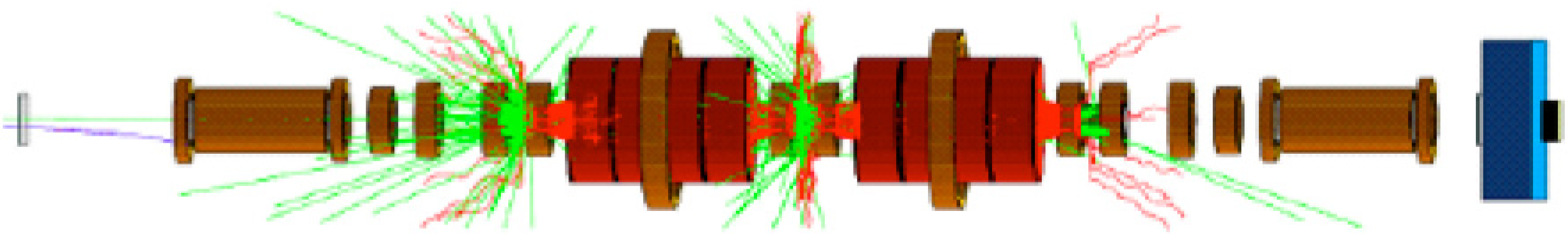
- **Motivations**
- **Experiment setup**
  - X-ray detectors and their positions
  - Electronics
  - Procedures
- **Measurements and data analysis**
  - 201-MHz cavity
  - 805-MHz cavity
- **Summary**

Where x-ray comes from?

- **High peak rf fields in cavity may induce**
  - Multipactoring
  - Field emission
  - Sparking
  - …
- **As a result:**
  - Electrons, ions, …, from cavity hit surface → x-rays

Motivations

- **Reducing background that is produced due to rf cavity at high field is important for MICE**
  - MICE detectors sitting next to rf cavities
- **Measuring x-ray flux and spectrum helps to understand**
  - MICE background at a given accelerating gradient
  - Cavity performance
- **G4MICE simulation**



Experiment setup

We installed 10 x-ray detectors at MTA

- **Nine of them are optimized for high rate measurement**
  - 9 scintillation counters: scintillator + lightguide + PMT, counting rate limit: ~ 10-million/s

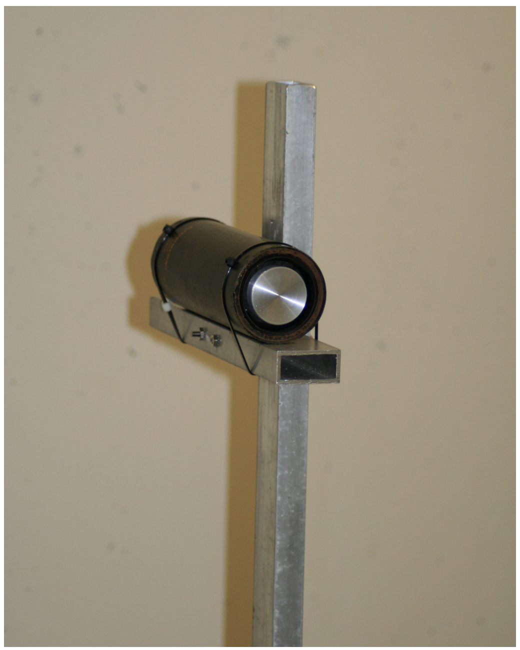
- **One for energy measurement**
  - 1 NaI crystal (#16) + PMT, counting rate limit: ~ 1-million/s

- **The most important detectors for us are #8 & #16, which are 4.7 meters downstream from the center of 201MHz cavity, the large paddle detector #8 can be viewed as a stand-in for Time-Of-Flight (TOF) in MICE.**

See *http://mice.iit.edu/mta/detectors/counters.html*

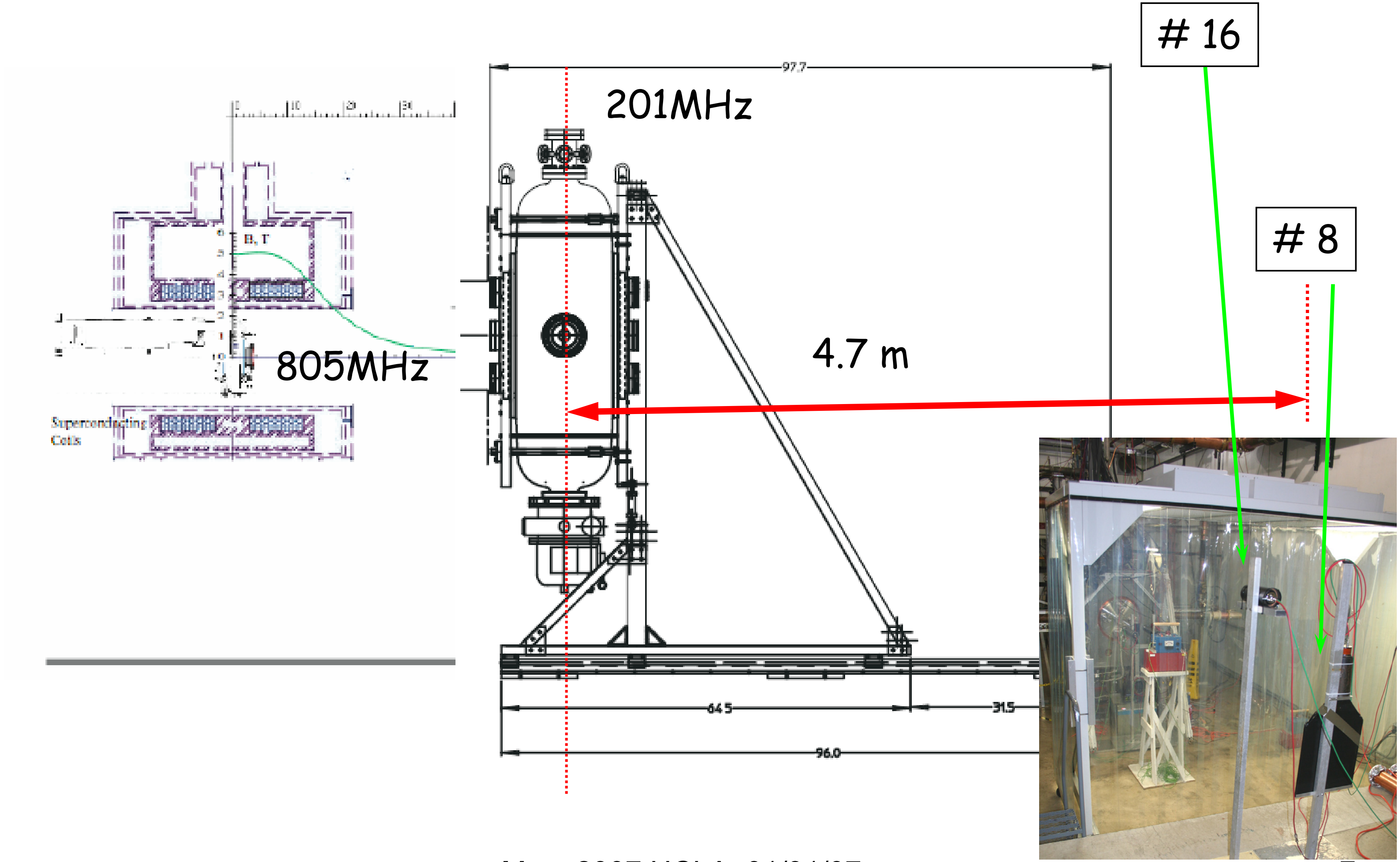
X-Ray Detectors

- **#16: NaI crystal (1.5″ diameter × 2″), upstream of 201 cavity**



- **#8: large thick scintillator paddle, upstream of 201 cavity similar to MICE TOF (14″ × 14.5″ × 0.5″)**

Positions of Detectors

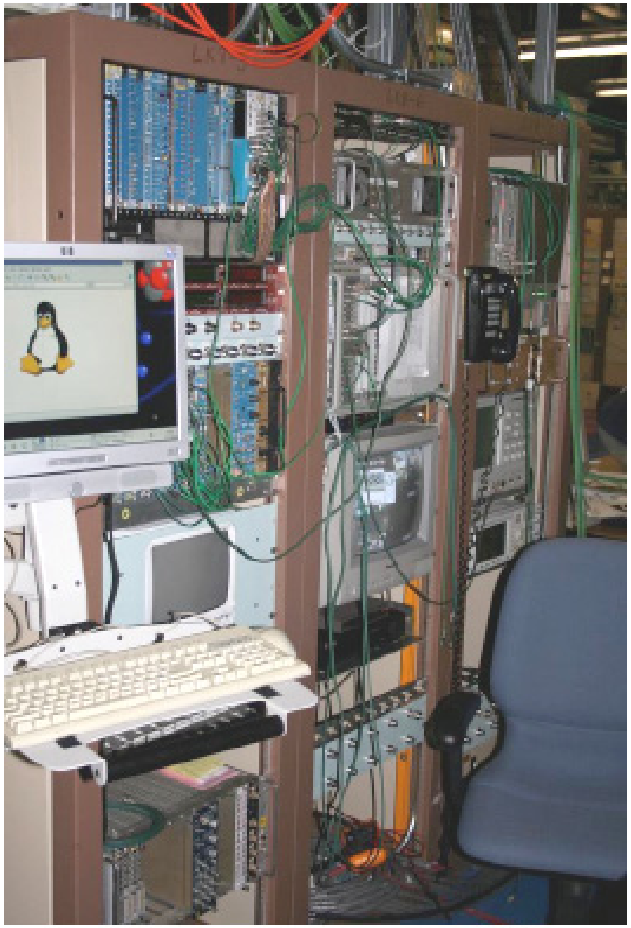


Electronics

- Spectrum measurements were carried out via the Computer Automated Measurement And Control (CAMAC) system on MTA data acquisition (DAQ) rack
  - The apparatus used:
    - ORTEC AD413A CAMAC Quad 8k ADC (Analog-to-Digital Converter)
    - ORTEC HM413 CAMAC FERAbus Histogram Memory
    - WIENER CC-USB CAMAC Crate controller

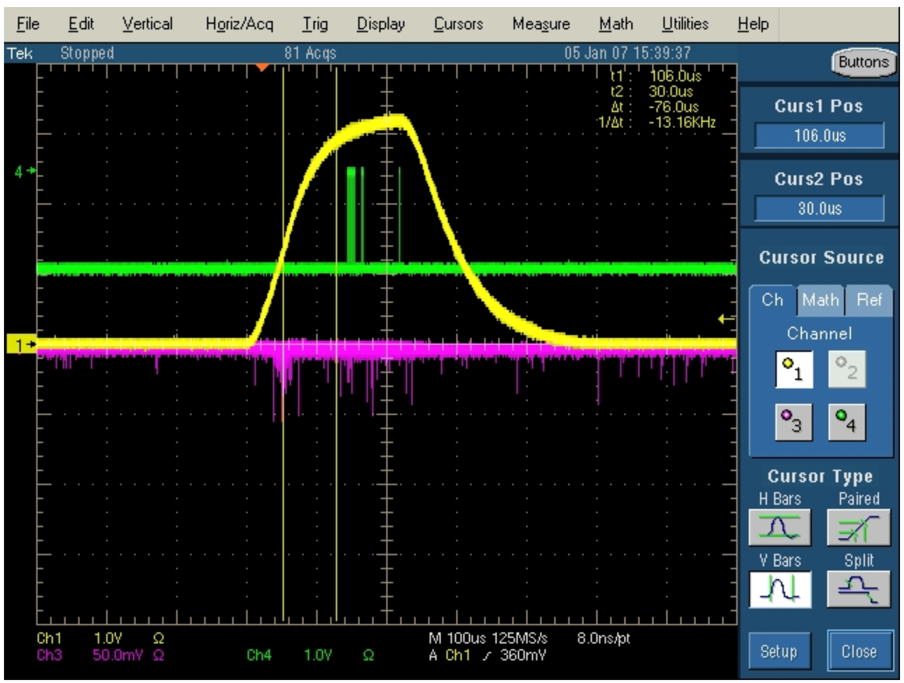
- LeCroy 623 Octal Discriminator and Fermi RFD-VS visual scalers were used to record x-ray events from detectors.

DAQ at MTA

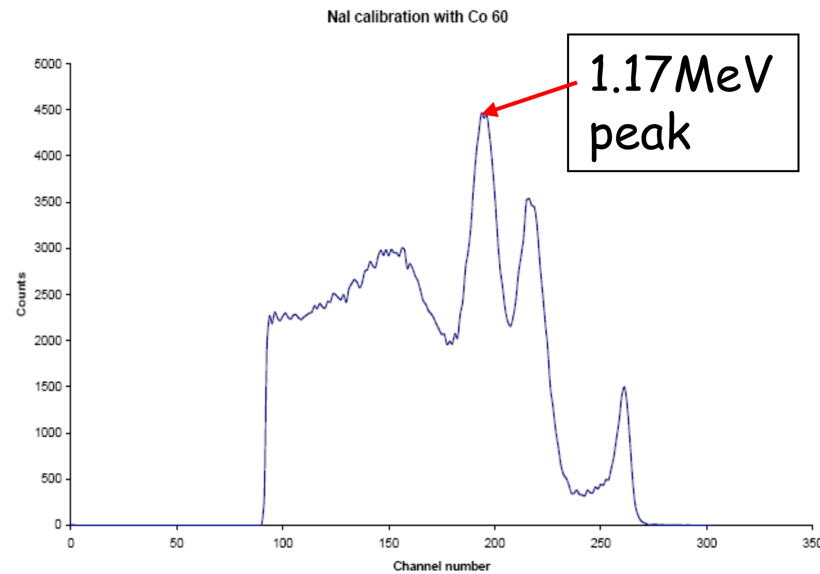


Procedures

- **X-ray background measurements**
  - Recording x-ray events for 1000 rf pulses
  - Creating electronic gates to record x-ray events at rf envelope during fill, flattop, decay and total range of rf pulse. RF pulse length ~ 100-μs



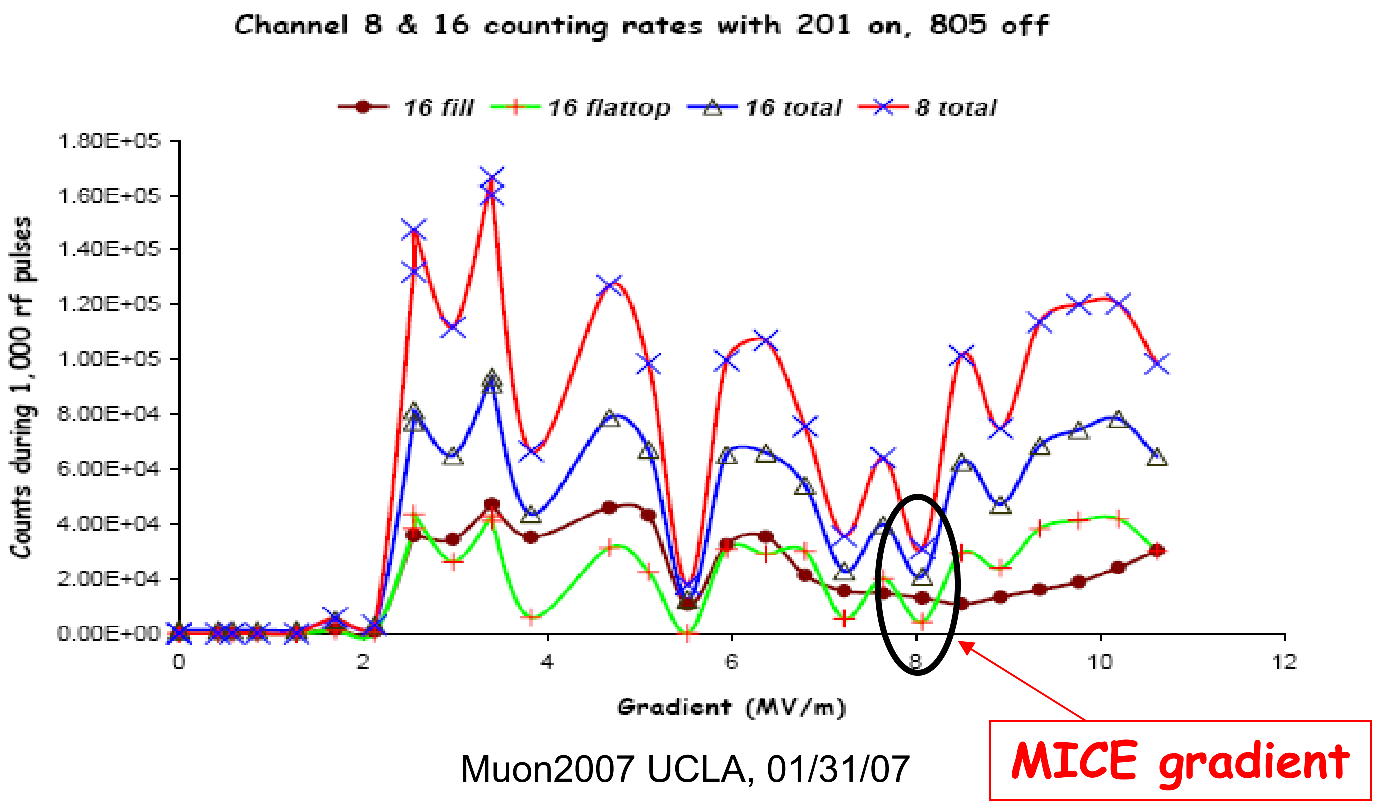
- **X-ray energy spectrum measurements**
  - The histogram memory HM413 was calibrated with Co60 source



  - HM413 histogram memory was used to histogram the signals from AD413A ADC
- **Note: there is cosmic-ray background for all the measurements**

X-Ray Background Measurement of the 201-MHz cavity

- Data taken in Dec. 2006 and Jan. 2007 with superconducting solenoid off
- The counting rates have been measured as a function of rf gradients. In comparison with the x-ray intensity, the cosmic background is negligible.
- For MICE, accelerating gradient is 8MV/m limited by rf source



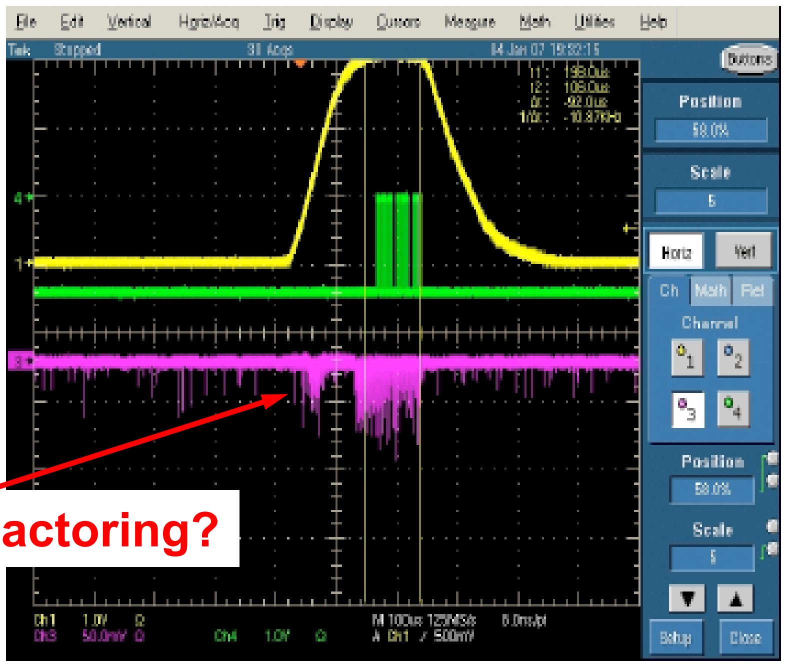
Multipactoring Study

Multipactoring is an effect that occurs when the electrons accelerated by RF fields are resonantly enhanced via an electron avalanche caused by secondary electron emission

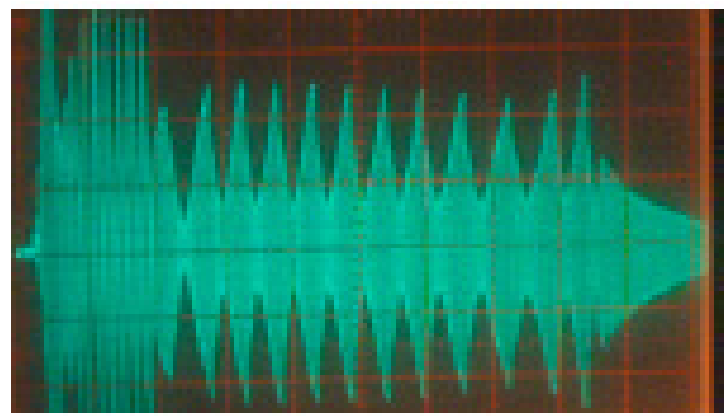
- The impact of an electron to a surface can, depending on its energy and angle, release one or more secondary electrons into the vacuum.
- These electrons can then be accelerated by the RF fields and impact with the same or another surface. Should the impact energies, number of electrons released and timing of the impacts be such that a sustained multiplication of the number of electrons occurs, the phenomenon can grow exponentially and may lead to operational problems of the RF system such as damage of RF components or loss/distortion of the RF signal.

Multipactoring?

- Possible multipactoring effects at some gradients, e.g., ~ 6.8MV/m in 201MHz cavity



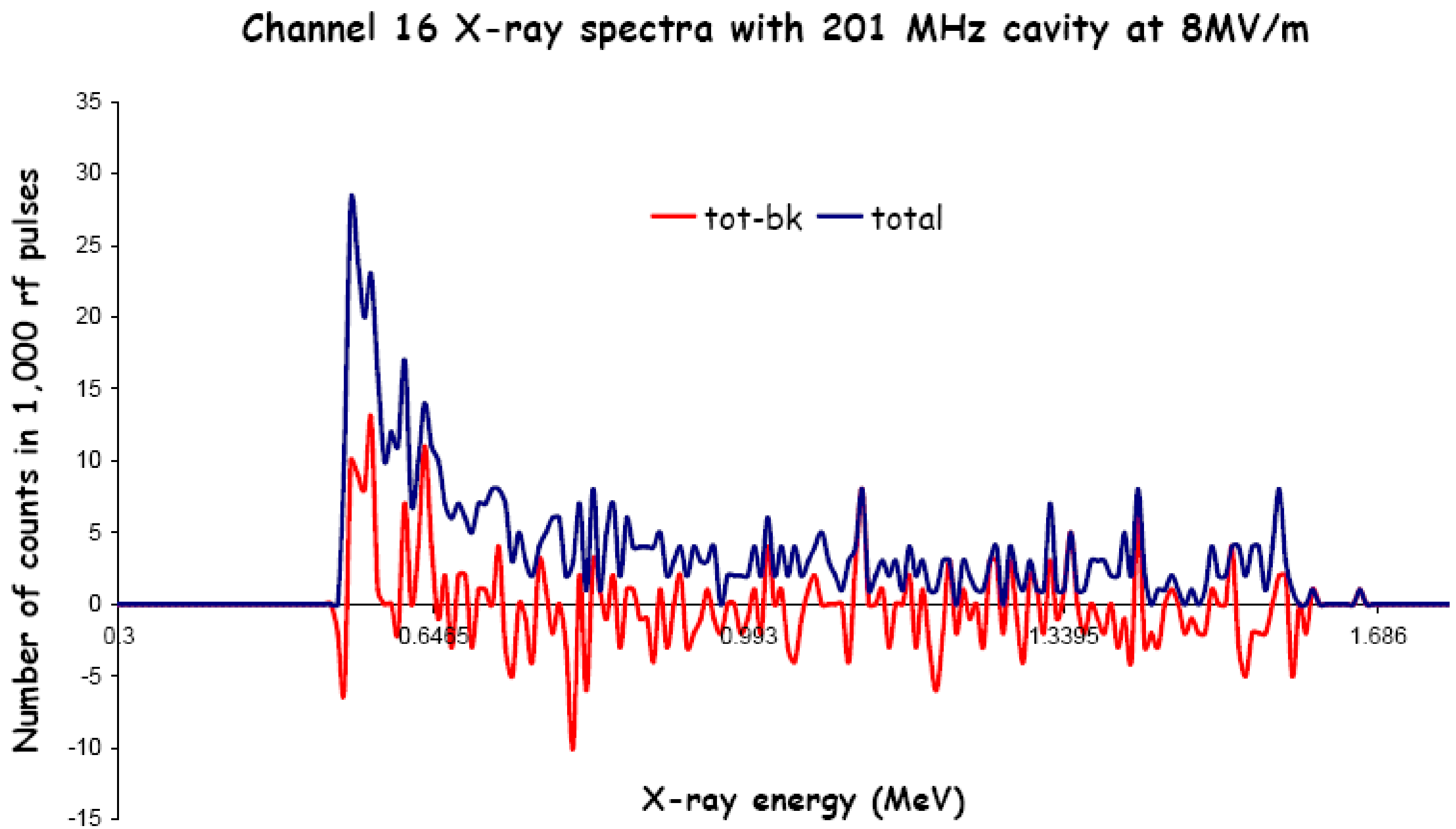
Typical multipactoring waveform pattern observed at the 805 MHz cavity at MTA



- There may be a very weak multipactoring effect. But too weak to distort rf field and produce huge ripples like above.

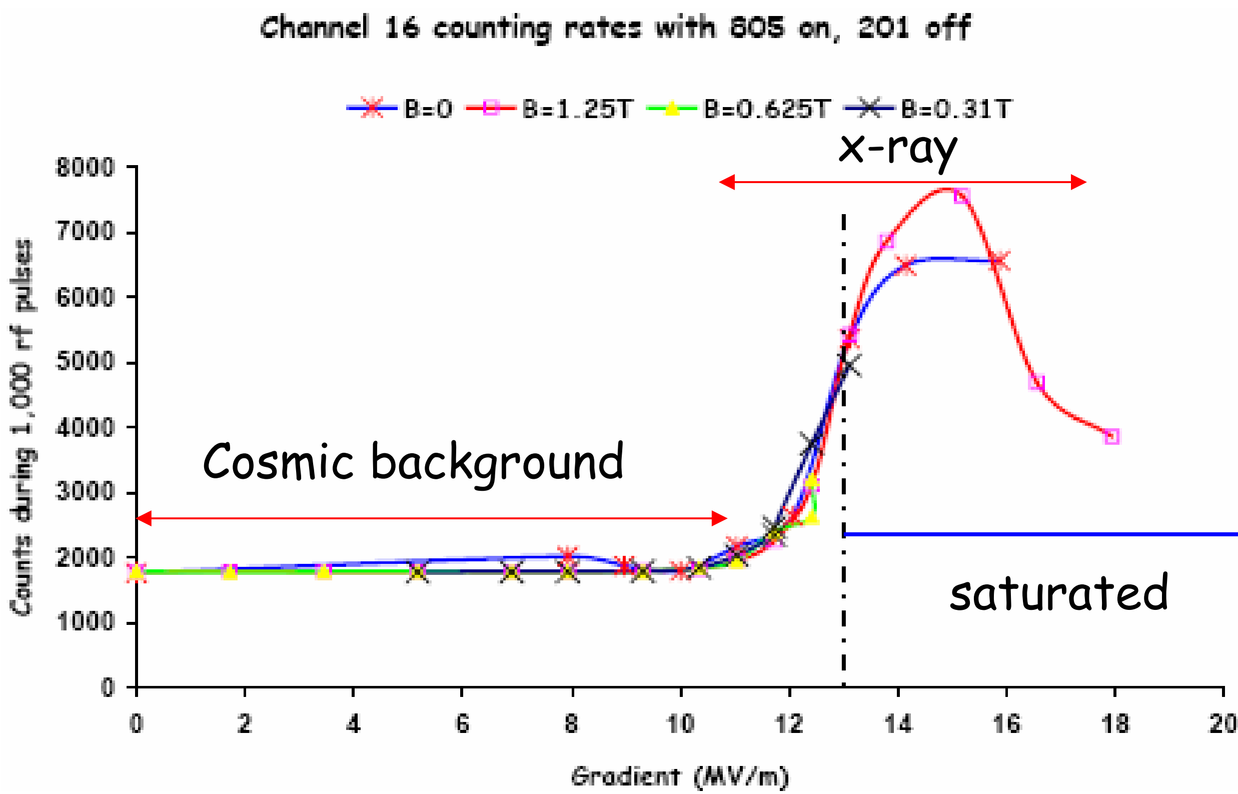
Energy Spectrum Measurement of the 201MHz cavity

- **At 8-MV/m, the total counts recorded during 1000 rf pulses:**
  - #8: ~ 30,000; #16: ~ 21,000



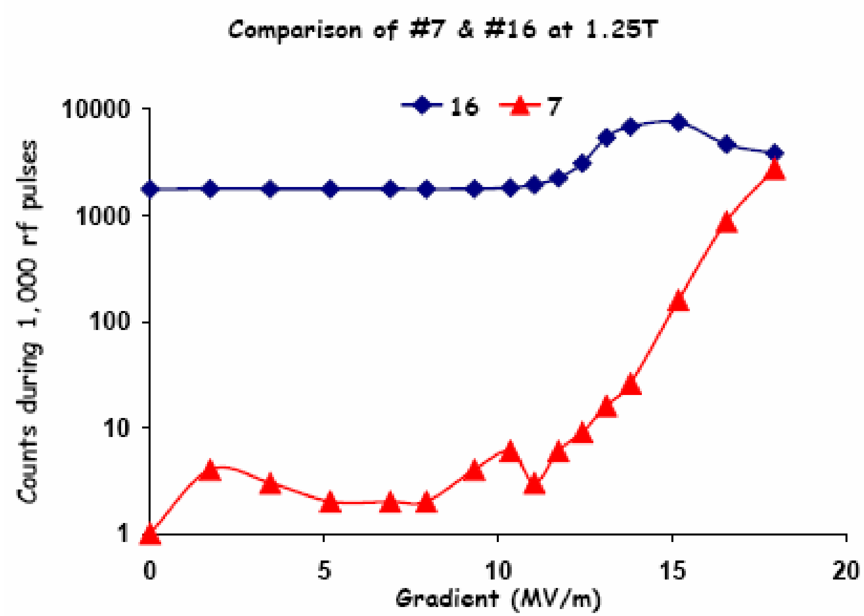
X-Ray Background Measurement of the 805-MHz Cavity

- **When the rf gradient is higher than ~ 13-MV/m, the counting rates increase significantly (over 1 million/s) → the NaI detector is not able to keep up and saturated. The counting rate is not accurate anymore, nor is the energy spectrum.**



X-Ray Background Measurement of the 805-MHz Cavity (cont'd)

- **Saturation: some adjacent pulses joint together, the counting rate is therefore decreased.**
- **However, # 7 scintillation detector (faster than NaI crystal), is not saturated.**



Summary and Plans

- **Preliminary experimental studies of x-ray background and energy spectra of 201-MHz and 805-MHz cavities were carried out at MTA.**
  - Experiment setup and diagnostics worked well, and ready for more extensive studies
- **Future improvement:**
  - More measurements of cosmic background with longer DAQ time
  - Faster detectors to overcome the saturation problem
  - Analytical study and numerical simulations of multipactoring and x-ray background
- **Coatings and different materials at high rf field region to suppress multipactoring effects**
  - TiN coatings
  - Button studies of 805-MHz cavity

Thank you