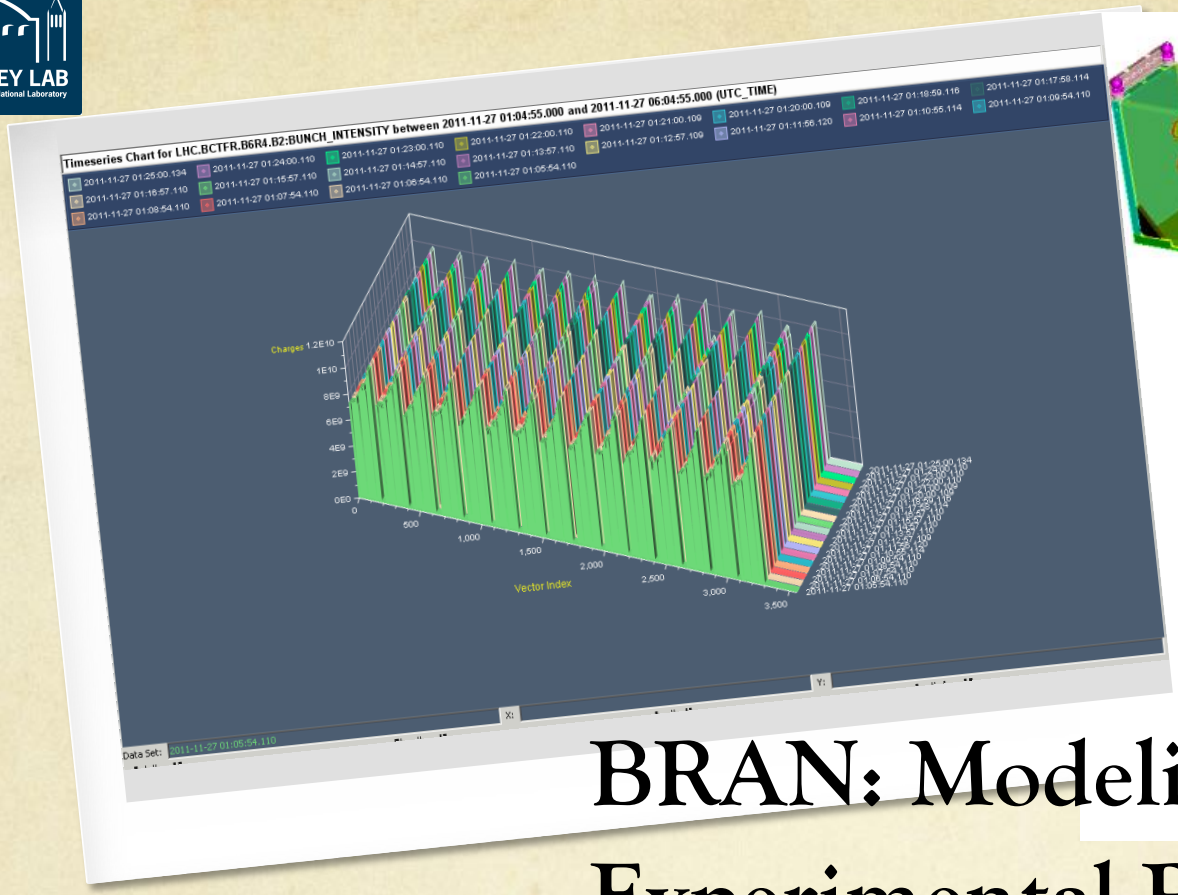
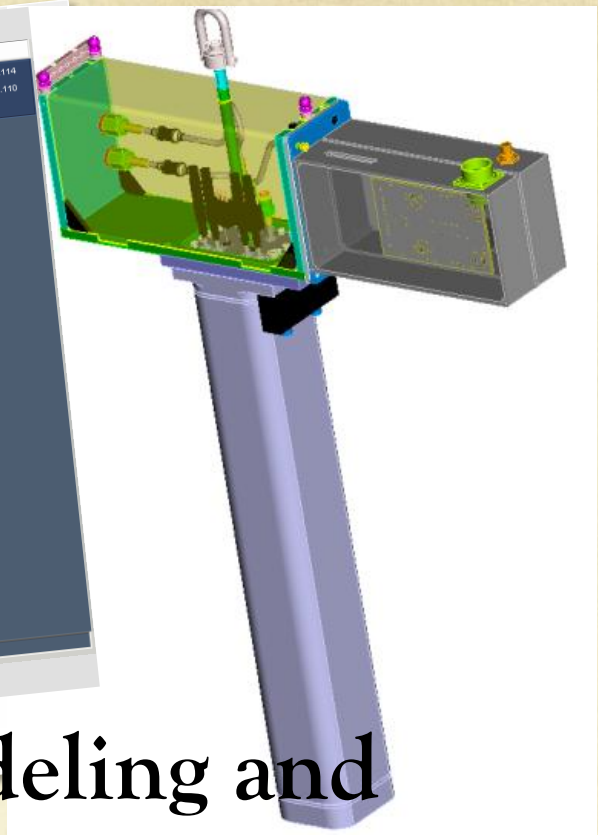
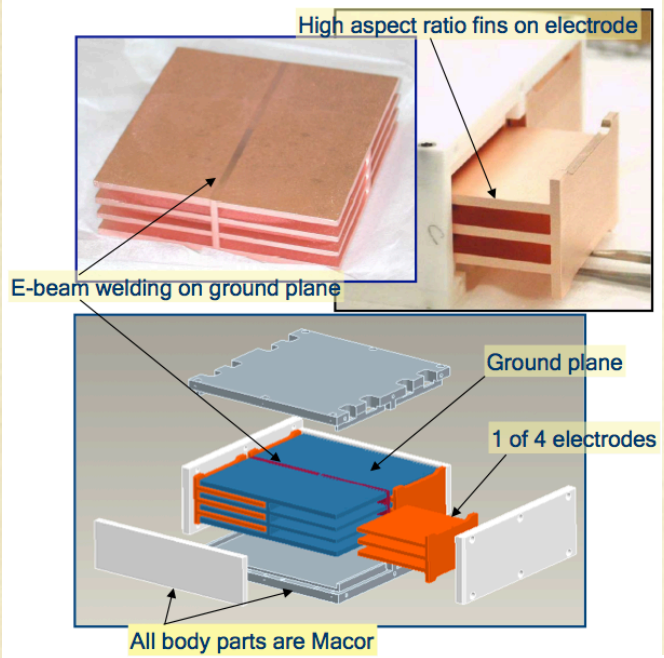


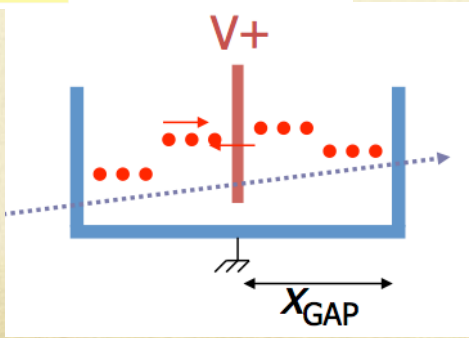


BRAN: Modeling and Experimental Results at ATLAS and CMS

H. Matis, M. Placidi, A. Ratti, W. Turner
[+ several students including S. Hedges] (LBNL)
E. Bravin (CERN), R. Miyamoto (BNL – now at ESSS)

BRAN Chamber Design

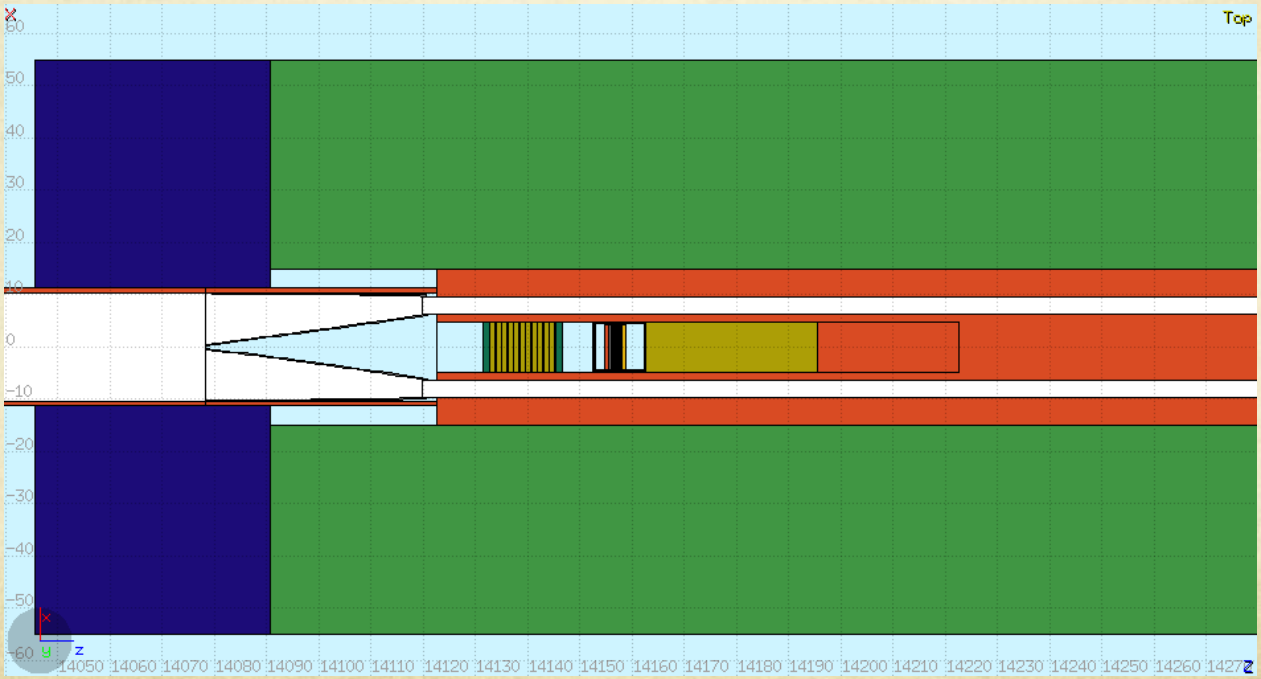




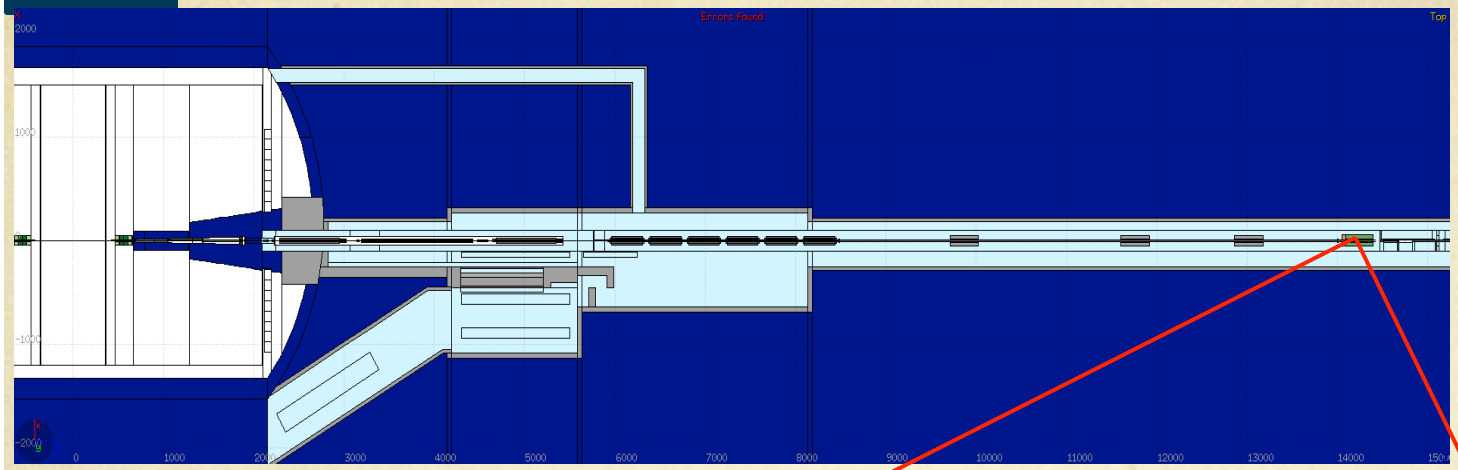
- 4 quadrant hi-pressure Ar-N_2 ionization chamber
- Located in the TAN on both sides of IP1 and IP5
- Designed to measure
  - the relative bunch × bunch luminosity
  - collisions at 25 ns bunch spacing
- Quadrant nature allows measurement of crossing angle

Overview of Simulations

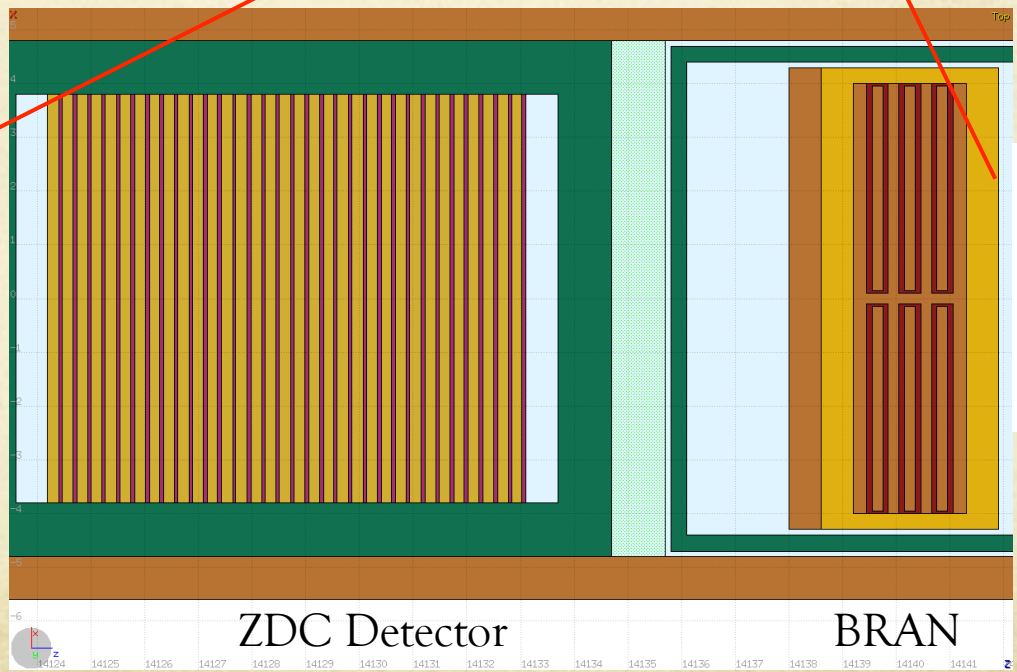
- Using FLUKA with IR1 and IR5 geometry done by CERN
- We have added a detailed model of the TAN including forward detectors and BRAN



FLUKA model of ATLAS IP1

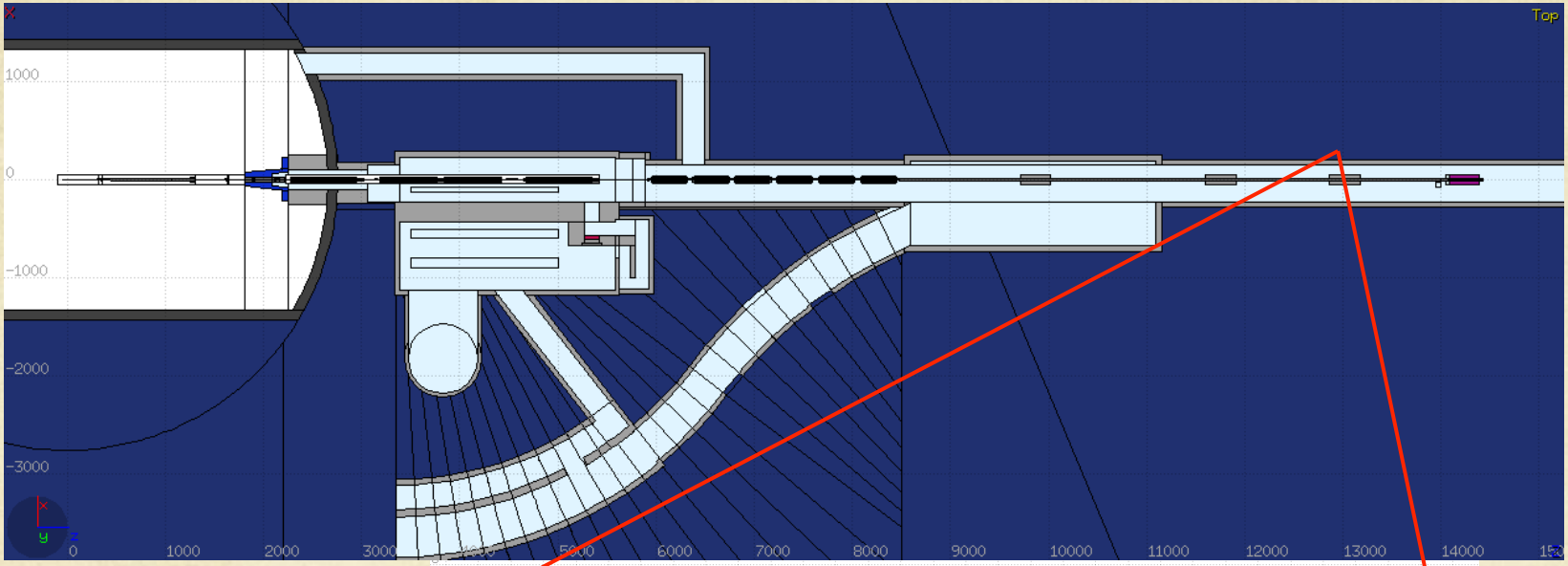


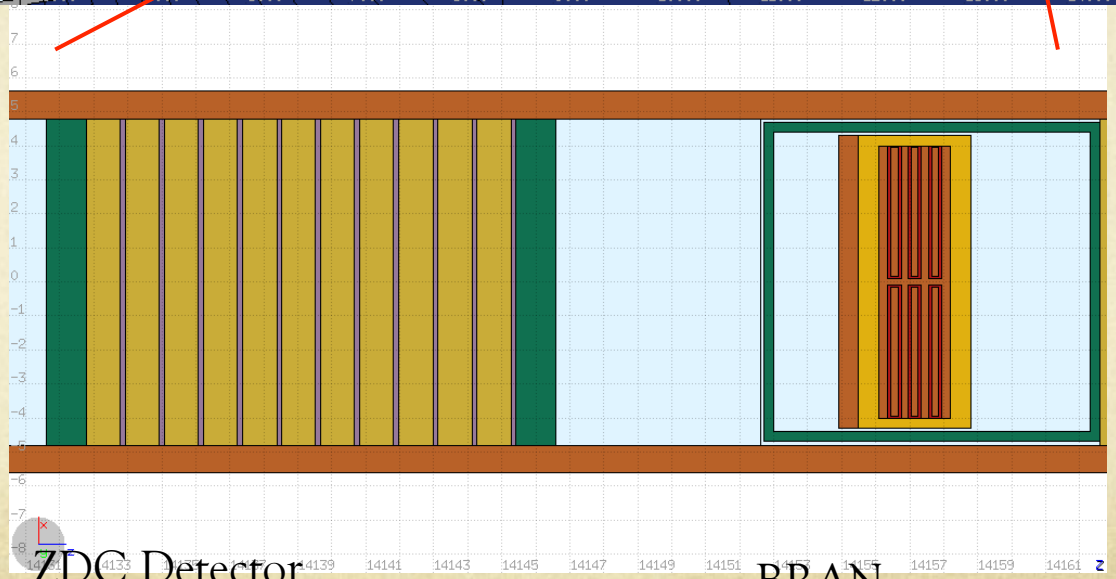
IP model developed at CERN



TAN Model developed by LBNL

FLUKA model of CMS IP5





Copper
Tungsten
Ceramic
Ar/N2
Steel
Quartz

ZDC Detector

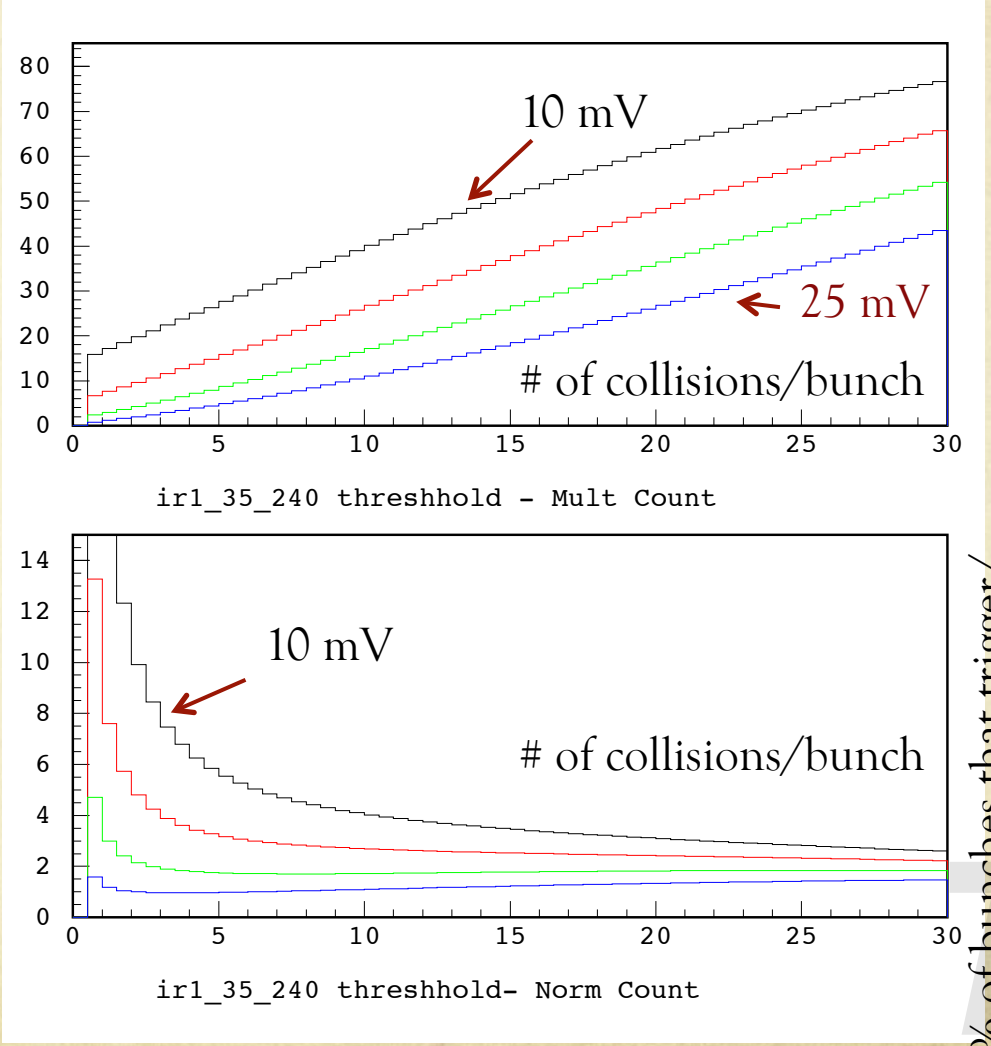
BRAN

Two methods of readout

- All four quadrants read out for each bunch and turn
- Data is processed in two ways
  - Counting Mode (currently recorded for left side of each IP)
    - Each bunch is counted as a "1" if exceeds a certain threshold
    - Software integrates over a specific number of turns
    - At lower luminosity this is linear as BRAN has a low acceptance
    - At higher luminosity can saturate
  - Pulse Height Mode (currently recorded for right side of each IP)
    - The signal voltage for each bunch is collected and summed for a number of turns
    - This higher statistical fluctuations but linear up to maximum digitization of the ADC (There are several ways to reduce the signal)

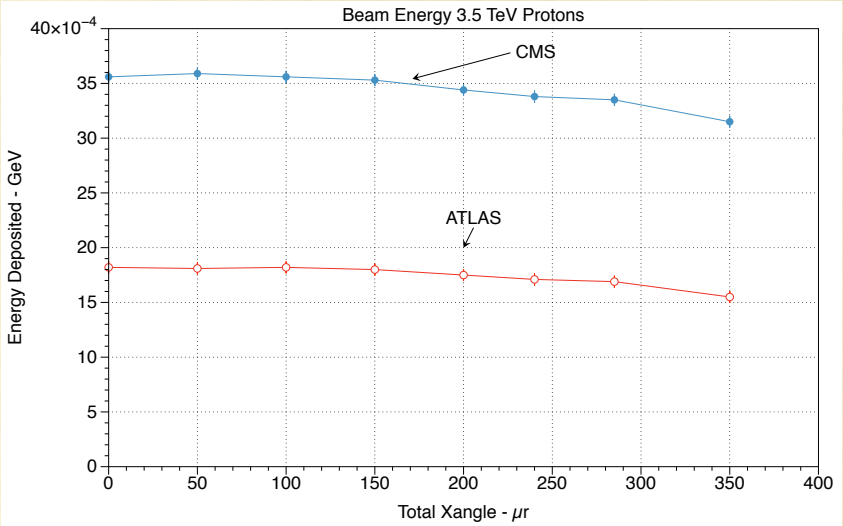
Simulated Counting Mode with Pileup

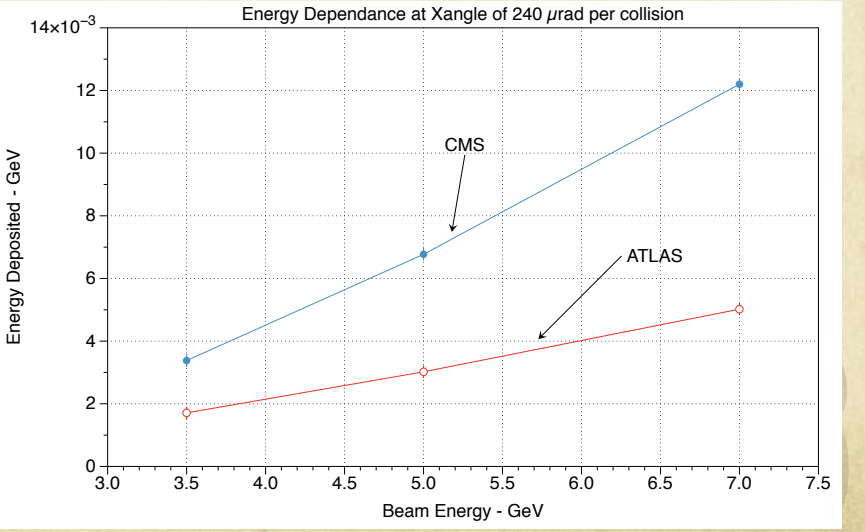
- Counting mode with thresholds of 10, 15, 20, 25 mV (number 2011 includes attenuators and cable lengths)
- Counting mode is linear but starts to saturate as rate increases
- One can reach a linear region by increasing threshold



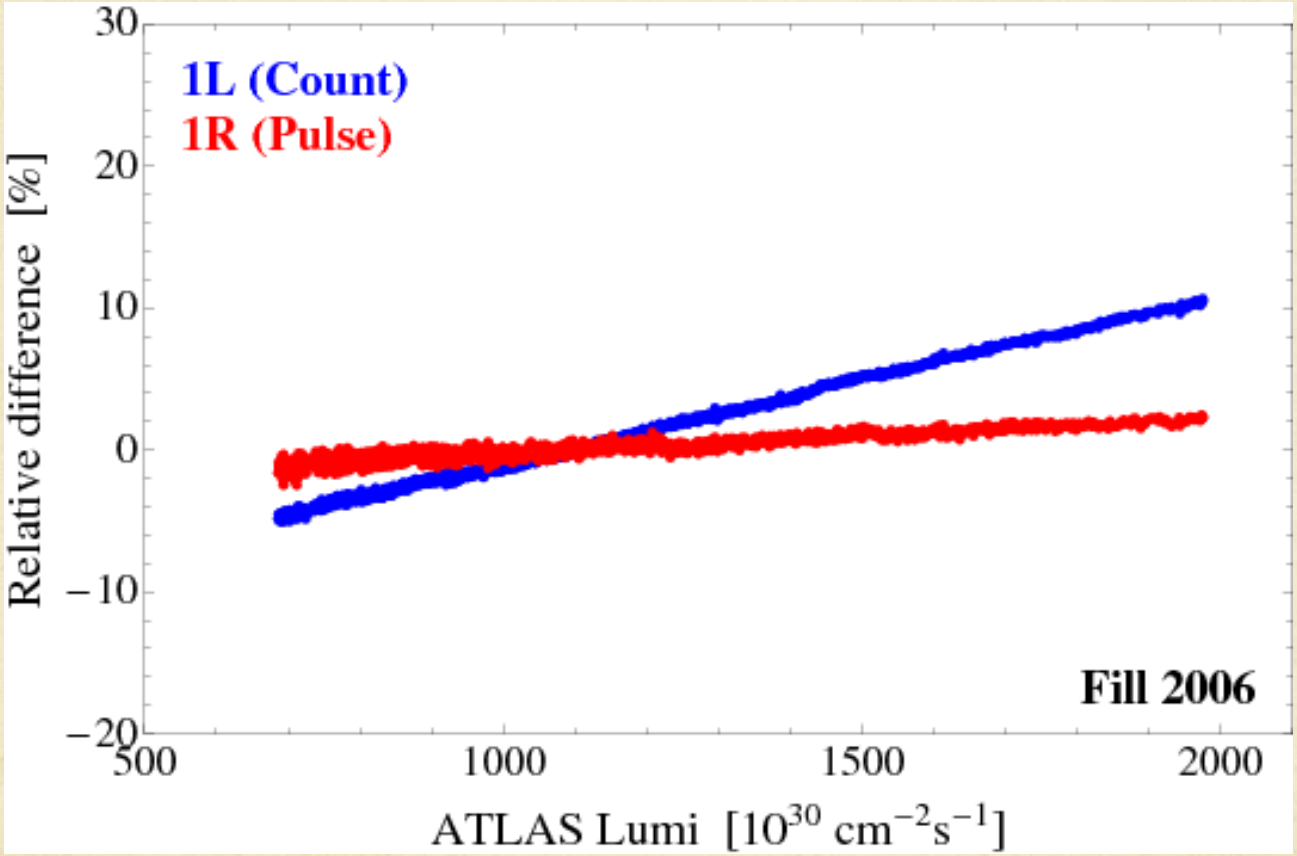
Average Energy Collected/pp interaction

- Difference of energy between ATLAS and CMS due to different absorbers
- Total energy deposited decreases with increasing crossing angle
- Mapped energy response from 3.5 to 7.0 TeV beam energy with varying crossing angle





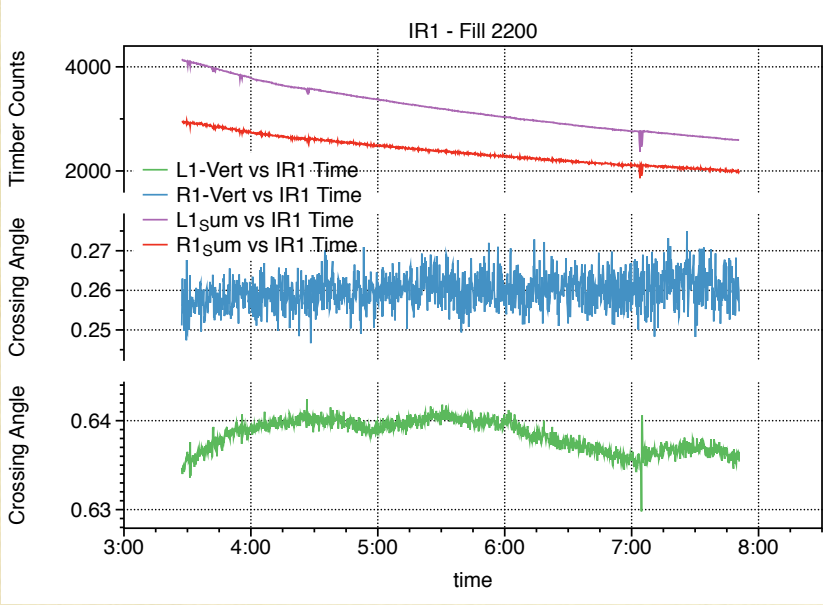
Correlation between BRAN and ATLAS



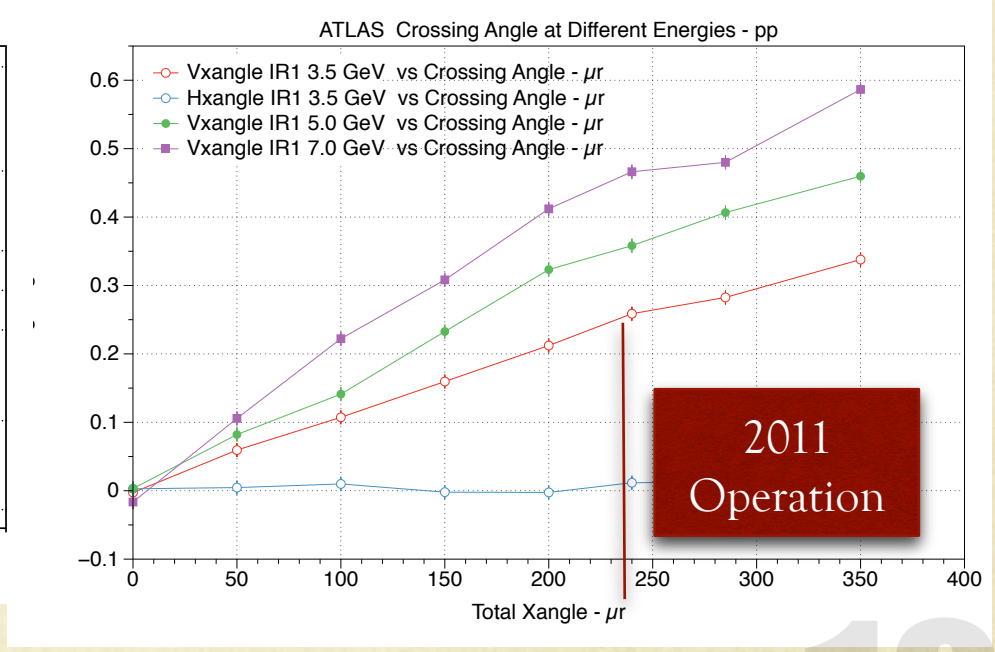
Crossing Angle: Data and Simulation

- Crossing Angle ratio defined as
  - $(Q_1+Q_2)-(Q_3+Q_4)/(Q_1+Q_2+Q_3+Q_4)$

- 0.259 ± 0.006 (vertical) for ATLAS at 240 μrad
- 0.261 ± 0.005 (horizontal) for CMS

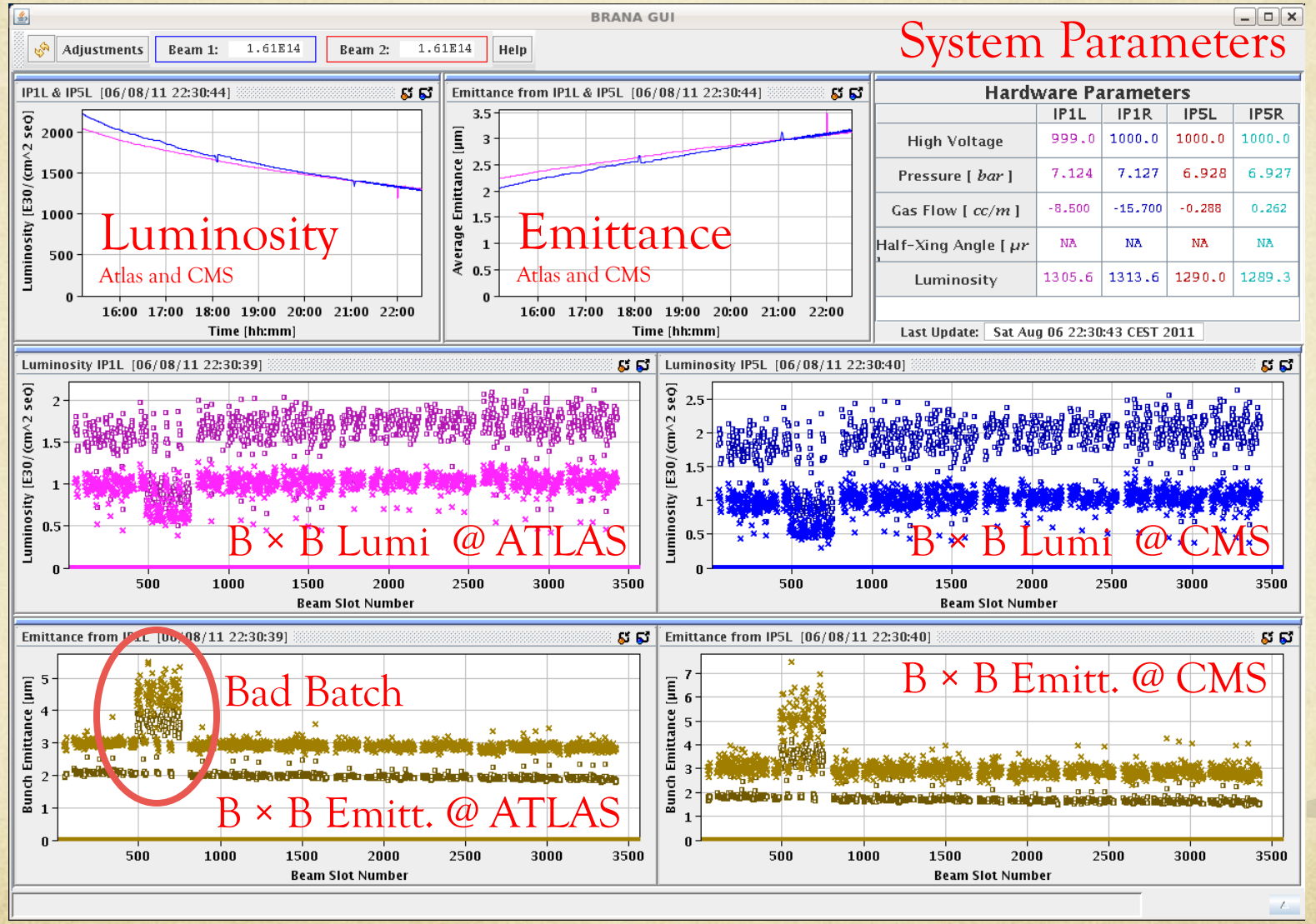


Data

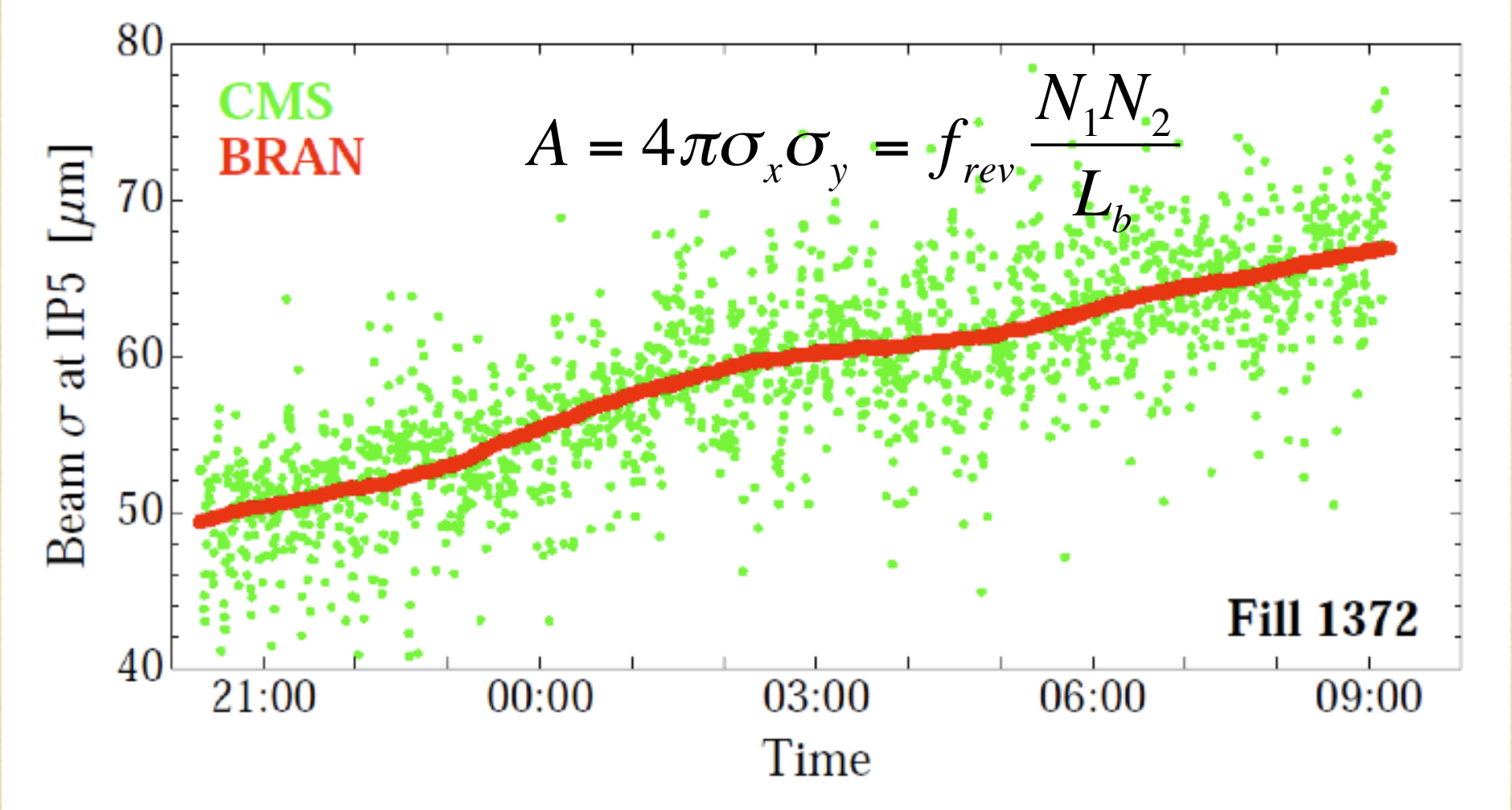


Simulation

New GUI for use in the CCC



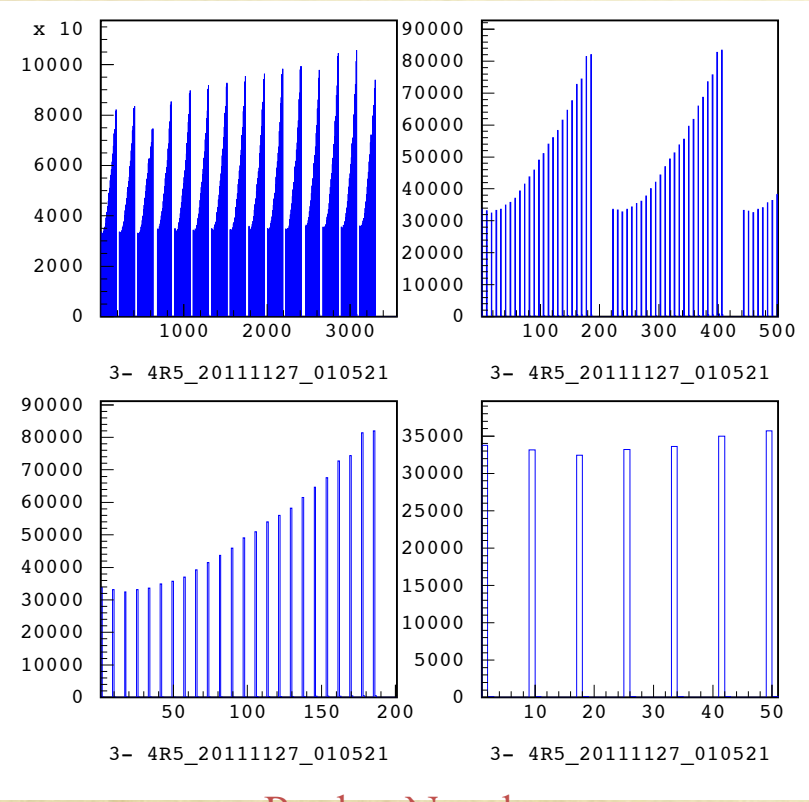
Beam Size Evolution– IP5



- The plot of the Specific Luminosity is part of the operator display

Tool providing data to experts

Counting Mode



Bucket Number

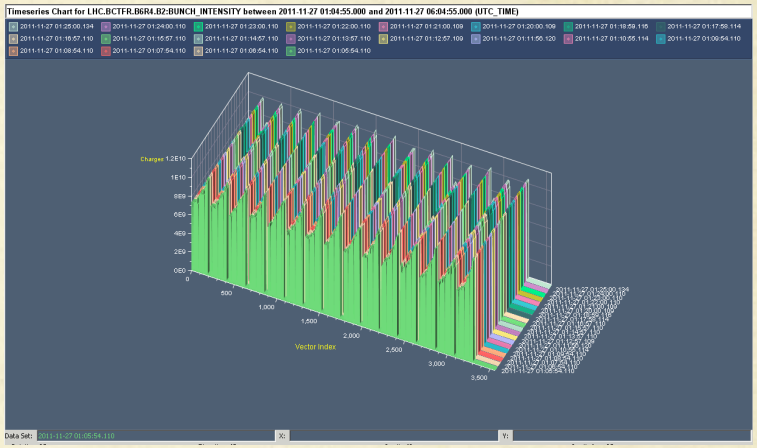
- Records both counting mode and pulse height mode at the same time for each quadrant of all detectors
- Useful tool to diagnose health and setup of detector

Provided by E. Bravin

Summary

- Timber Data is different in Left and Right for 2011 data
- BRAN is in LHC control system and being used to optimize collisions
- Fully integrated detailed FLUKA model of TAN with CERN's model of both IPs
- Detectors at the TAN are sensitive to crossing angle
  - As energy and or crossing angle increases, center of shower becomes more asymmetric
- BRAN is an excellent tool to cross check experiments

Timber Plot for PbPb

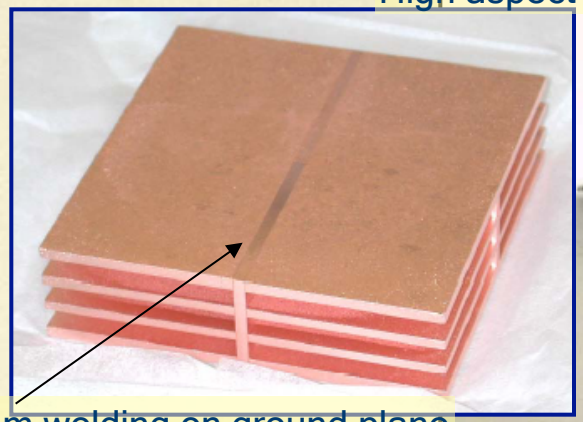


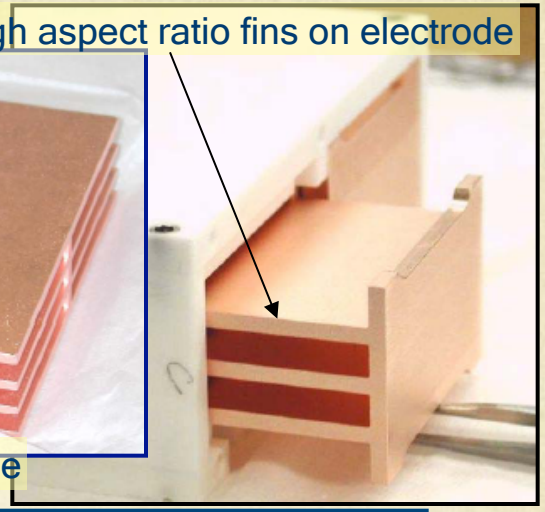
x axis: time
y axis: bunch #
z axis: Luminosity

Backup

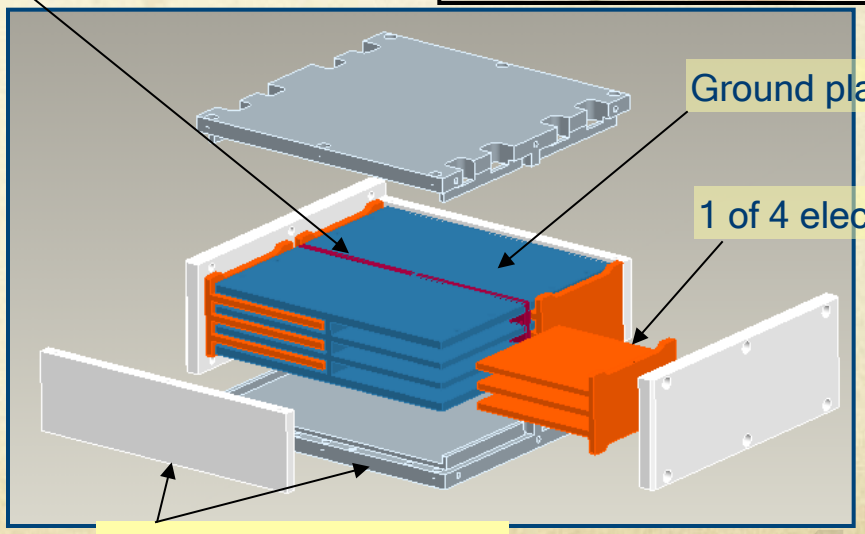
Ionization Chamber Fabrication

- Electrodes and ground plane
  - OFHC copper
  - Wire Electrical Discharge Machining (Wire-EDM)
  - High precision
  - Ground plane center element is e-beam welded
- Sensor body
  - Macor
  - Several fine features with high precision
  - Fasteners for assembly
  - Over-constrained assembly requires some craftsmanship for precise alignment

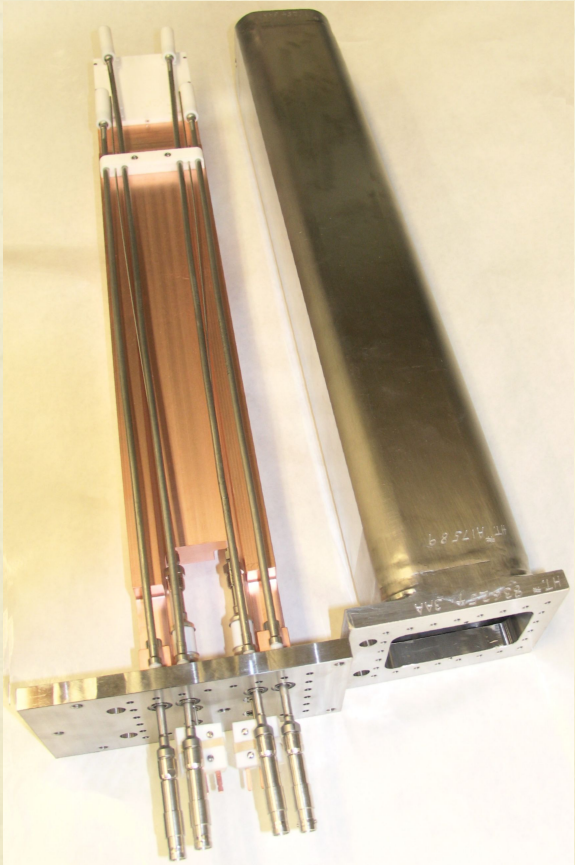


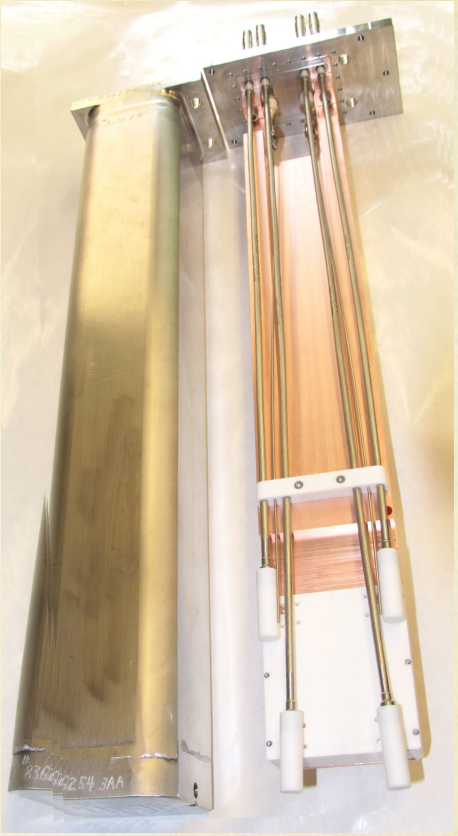


E-beam welding on ground plane



Case Hardware



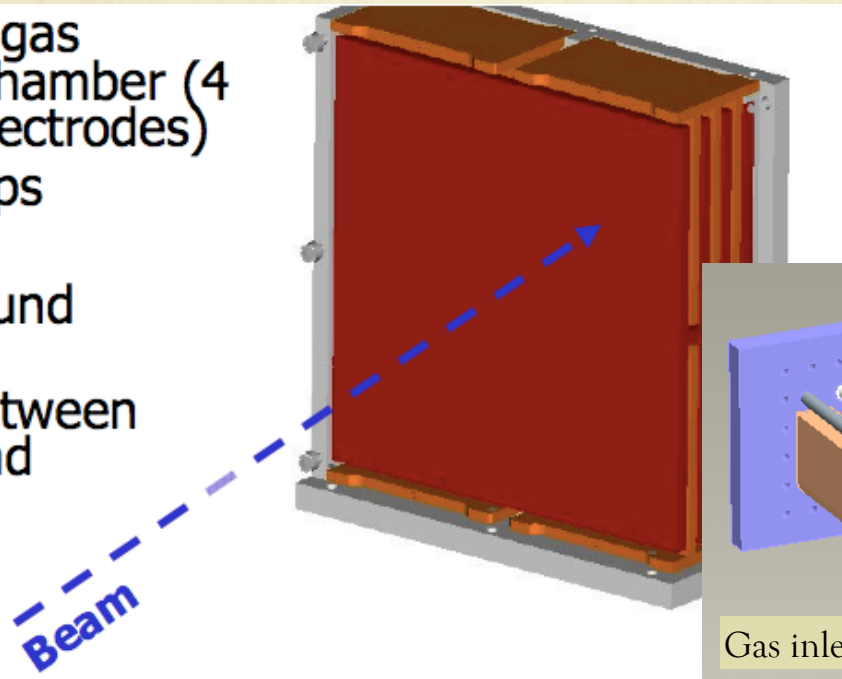


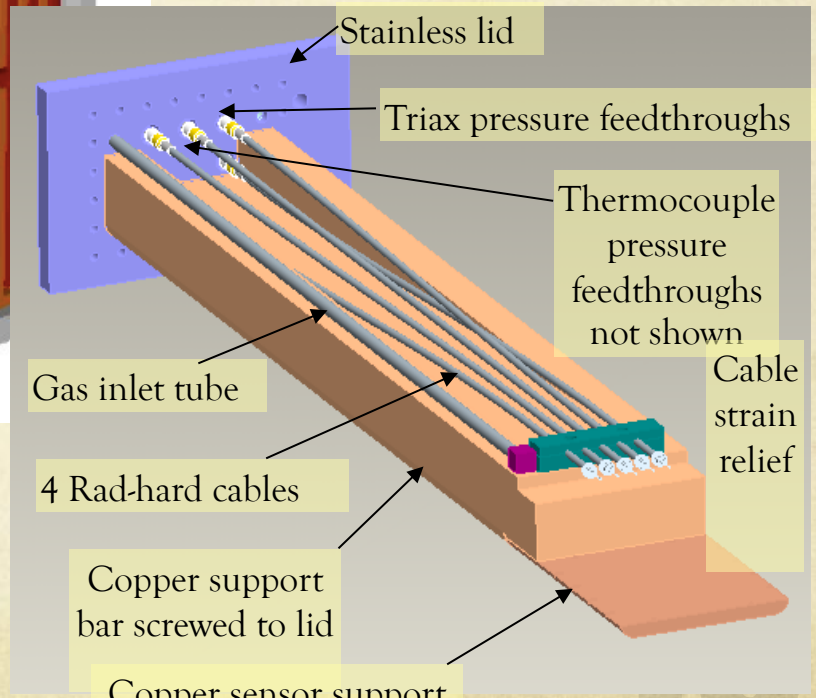
Ar-N2 Ionization Chamber Design

- 4 quadrant gas ionization chamber (4 quadrant electrodes)
- 6x1 mm gaps
- Ar + N_2
- Central ground structure
- 3m coax between chamber and electronics

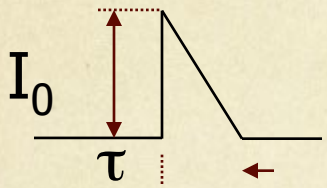
2 mm Cu

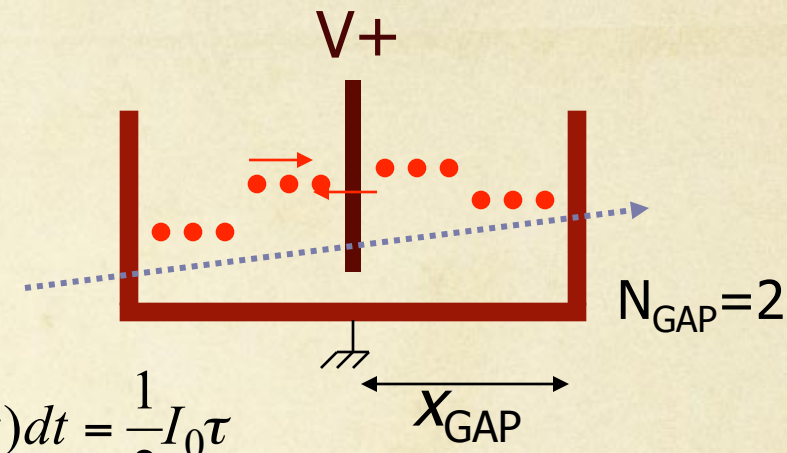
λ_R=14.4 mm





How to get Luminosity



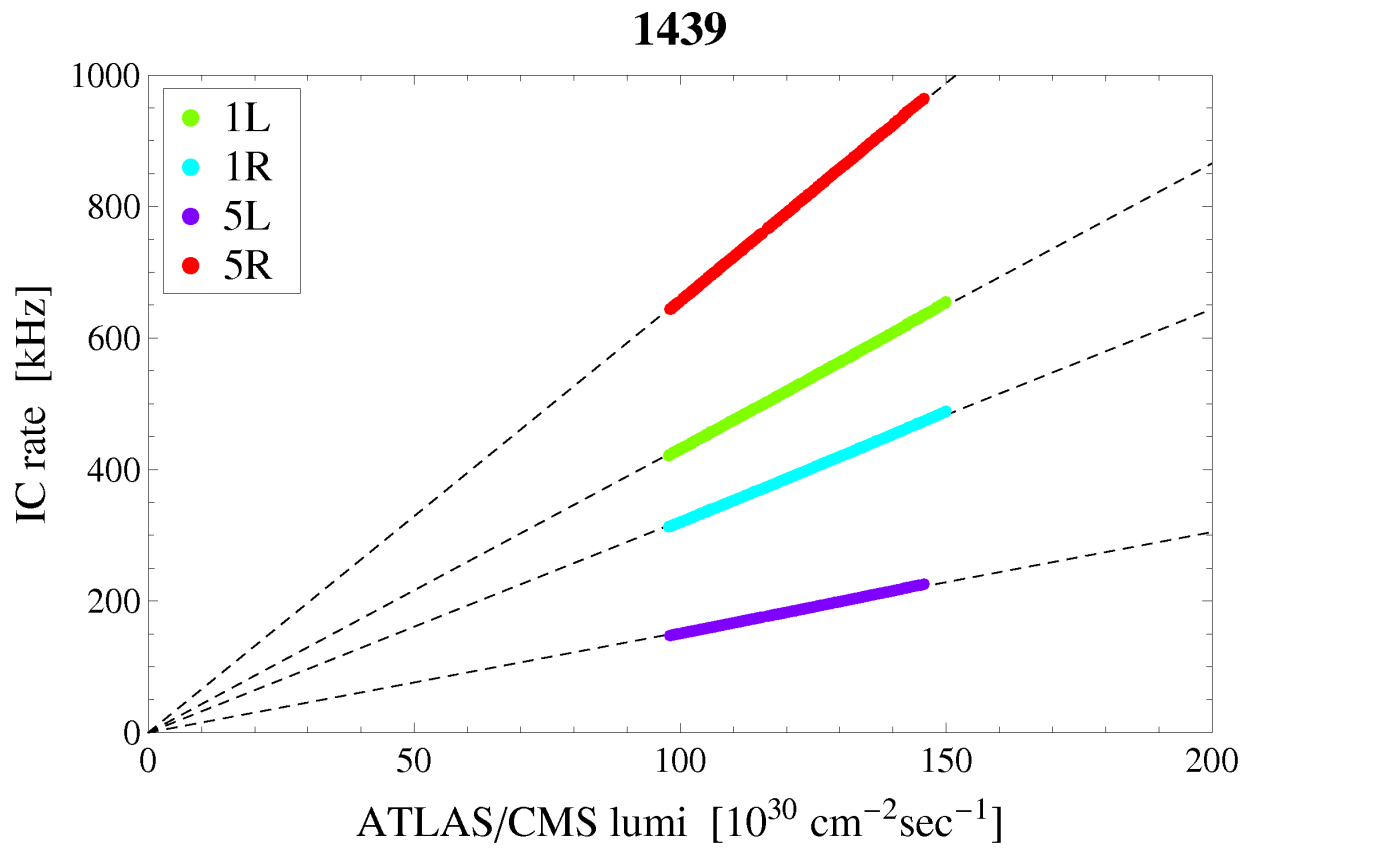


$\tau = x_{GAP}/v$

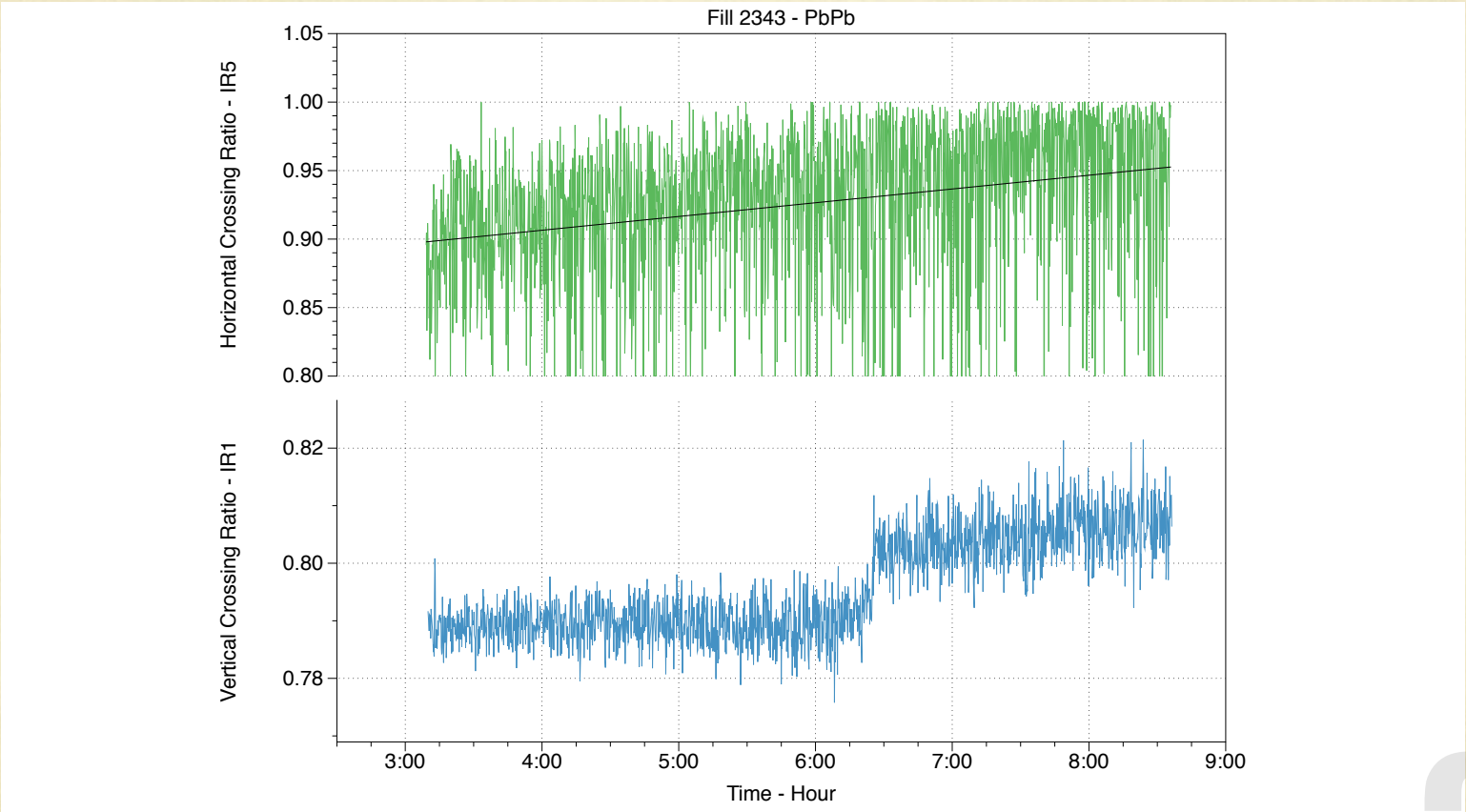
$$Q = \int_0^{\tau} I(t)dt = \frac{1}{2} I_0 \tau$$

- Signal is proportional to the # of parallel gaps
- Capacitance increases with # of gaps + slows down the signal
- Optimized for 6 gaps
- Must live in a radiation environment 10× worse than accelerator instruments have ever seen
  - ~**10 GGy/yr**, ~10^{18} N/cm^2 over lifetime (20 yrs), ~10^{16} p/cm^2 over lifetime

Correlations between BRAN and CMS and ATLAS

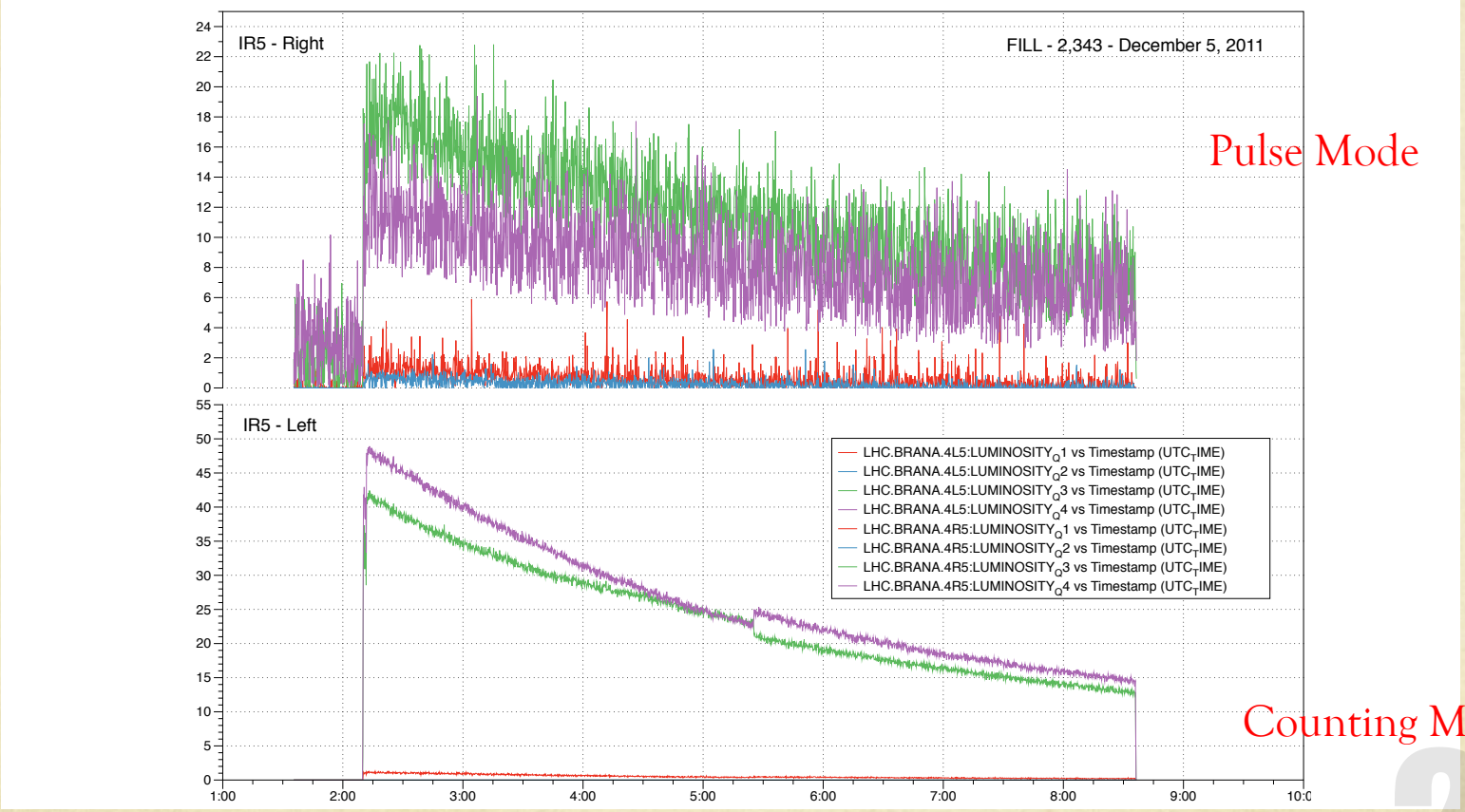


Can see subtle shift in Crossing Angle



PbPb Data in Timber

(Can average longer in Pulse Height Mode to lower error bars)

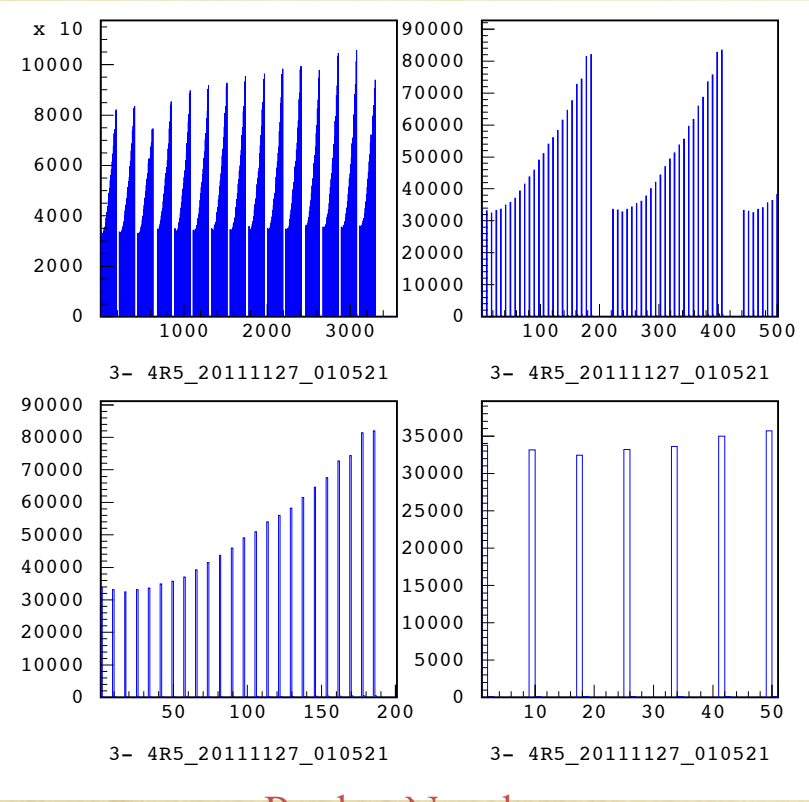


Pulse Mode

Counting Mode

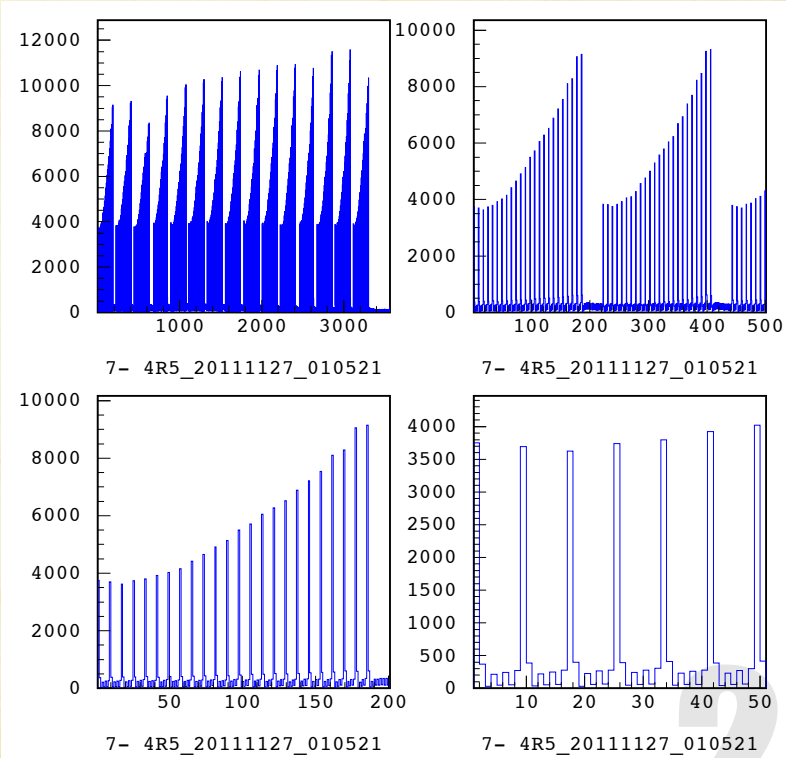
Program by Enrico Bravin

Counting Mode



Bucket Number

Pulse Height Mode



Bucket Number