LARP

BNL - FNAL - LBNL - SLAC

LARP BEAM INSTRUMENTATION

A. Ratti (LBNL)

Presented at CM16 on behalf of all instrumentation presenters at CM16
R. Calaga, A. Fisher, H Matis, R. Pasquinelli, R. Miyamoto
and all participating colleagues worldwide

Montauk, NY
May 16-18, 2011

Outline

Experience from beam commissioning – Hardware updates

- Sync Light Monitor

Beam Operations

- AC Dipole – Optics measurements
- Schottky – Beam Beam
- Lumi – IP optimization

LTV/Toohig Impact

Sync Light Monitor - Progress Since CM15

November-December 2010: First run with lead ions

- Synchrotron light images from **lead**

November: Duplicate optical table set up in lab

- Detailed study of imaging

January 2011: Shutdown work in the tunnel

- New "slow" camera with a 25-ns gate, intensifier for "fast" camera
- Camera translation stage added for precise focus
- Thorough check and adjustment of component positions and alignment
- Longitudinal density monitors

March-May: Measurements with beam

- Bunch-by-bunch beam size
- Longitudinal structure

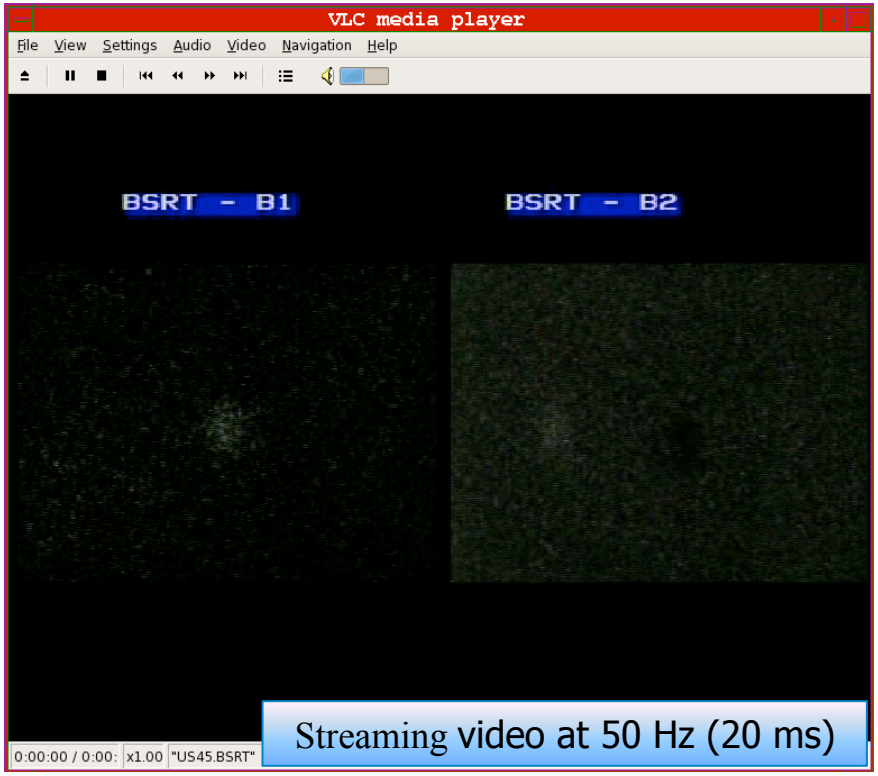
Summer: Testing upgrade ideas at SLAC (SPEAR3 ring)

- Halo monitor and rotating mask

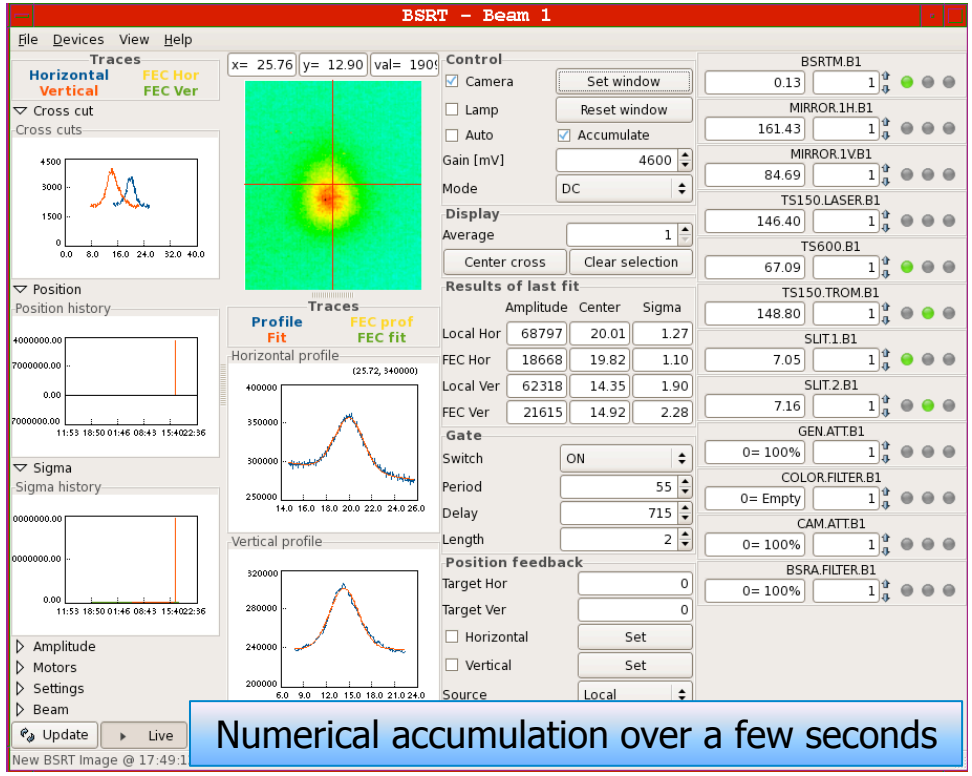
A. Fisher

First Images of Lead Ions at Injection

- 2010 Nov 10: Light from 17 bunches, integrated over 20 ms
  - Images are faint, since most emission is infrared at this energy
    - Original prediction: 1-s integration needed for a clear image of a single bunch
      - Equivalent to 20-ms integration of 50 bunches
      - 1-s integration directly on the CCD would require only an additional logic pulse



Streaming video at 50 Hz (20 ms)



Numerical accumulation over a few seconds

Simulated vs Measured Light Intensity

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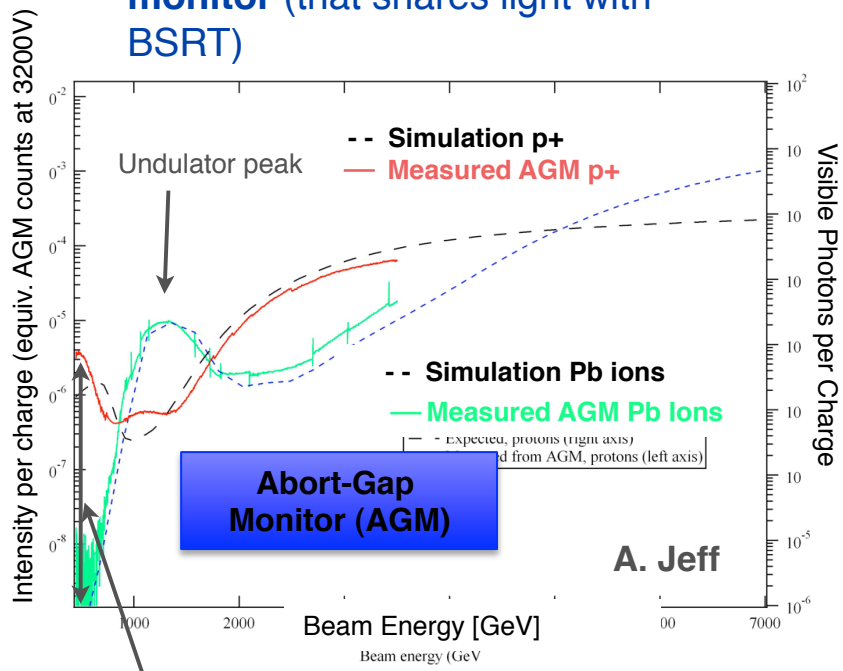
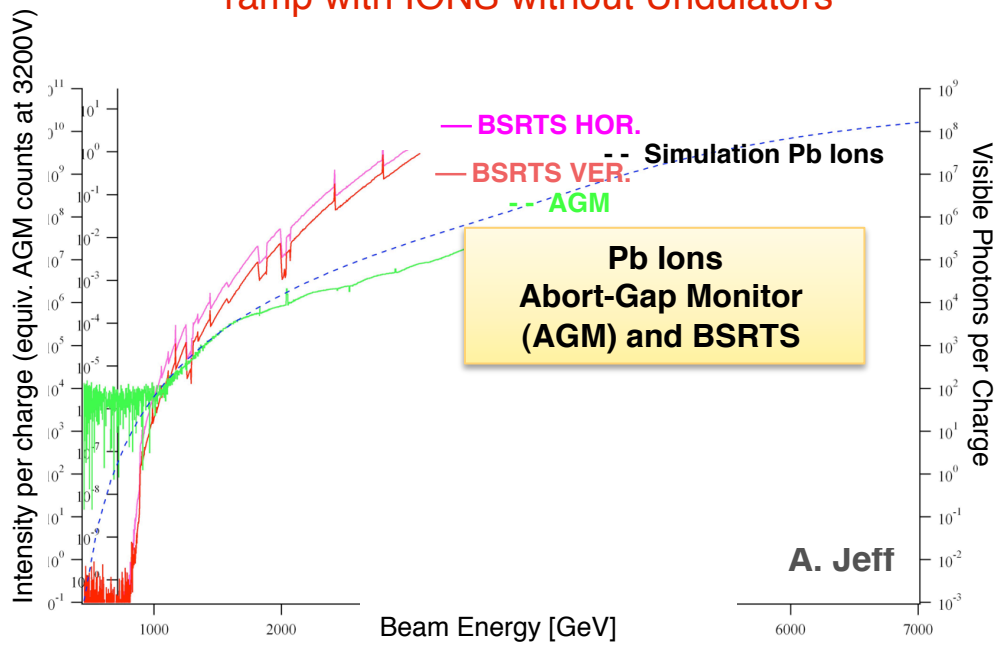
Photons per charge as simulated and measured by **Abort Gap monitor** (that shares light with BSRT)



Photons per charge as simulated and measured by **BSRT** during a ramp with IONS without Undulators



At least a factor of 10^4 between protons and ions at injection energy.

Nevertheless, it was possible to image the ions at injection.

Calibration vs Wire Scanners

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Wire Scanners (WS)

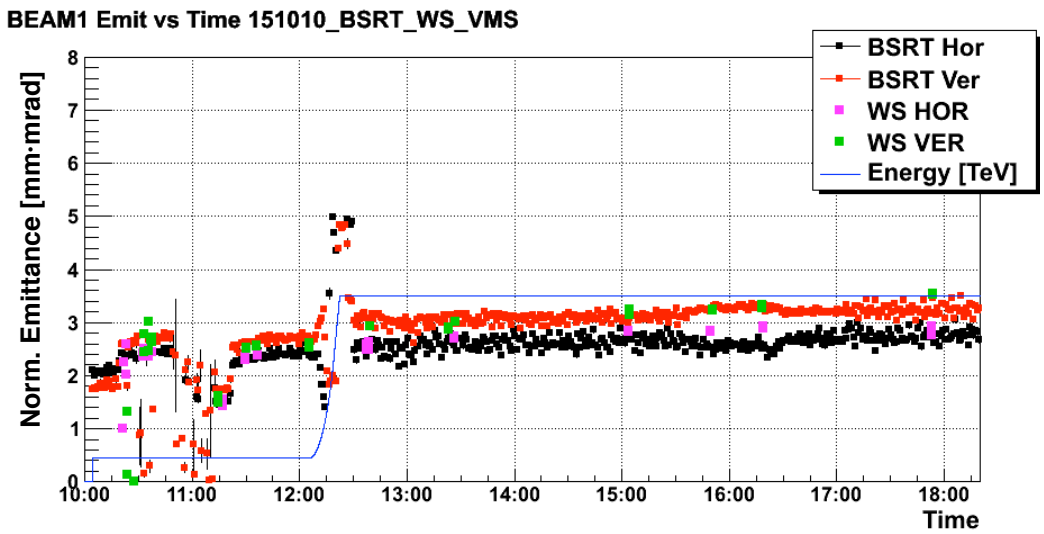
- Reference for LHC transverse profile measurements
- Can be used with just over 10^{13} protons without causing wire damage or a quench

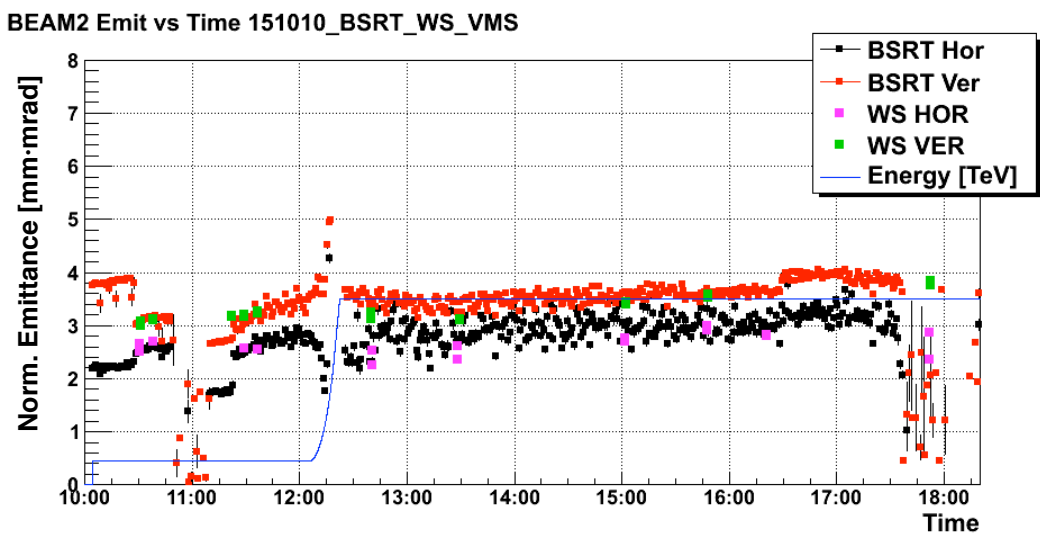
BSRTS calibration vs WS

- Measured for each beam and plane, as a function of energy
- Corrections applied in quadrature to BSRT beam-size data

Corrections of 400–500 μm

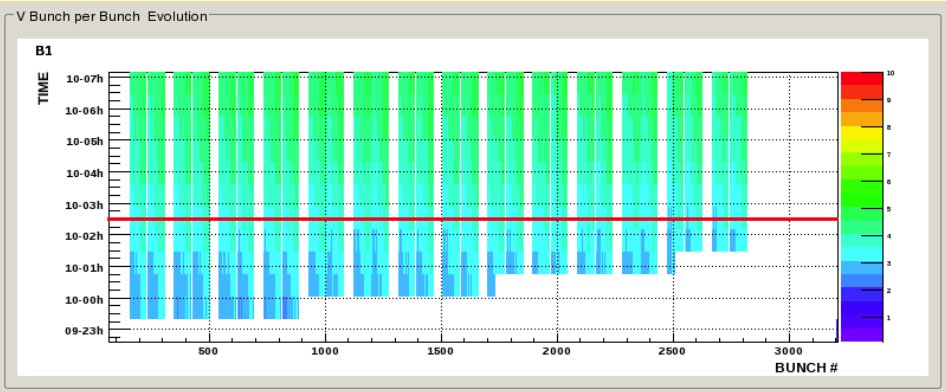
- Possible sources: camera, digitizer, slit adjustment, diffraction





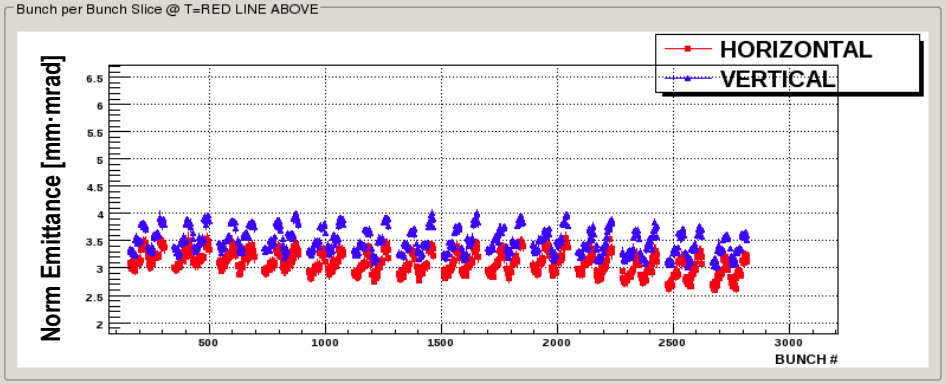
Monitoring LHC Emittance with BSRT

Transverse vertical emittance versus bunch number and time



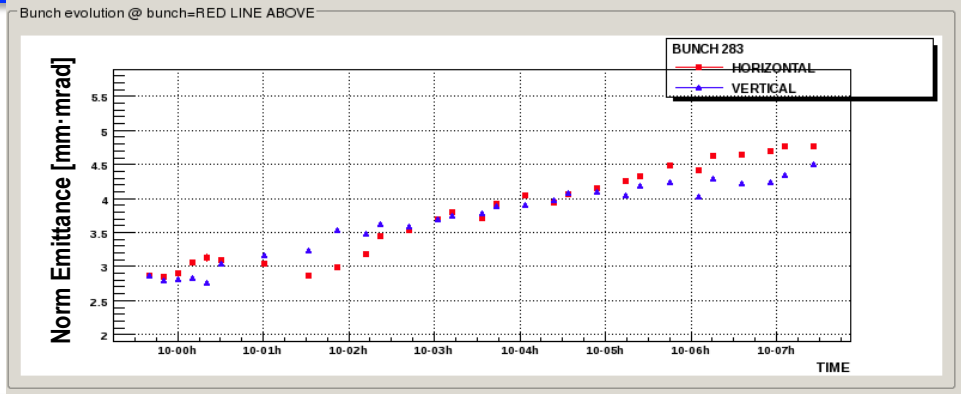
Bunch-by-bunch emittance at a fixed time

Structure comes from injectors. Sawtooth pattern here repeats with PS period.



Single-bunch emittance vs time

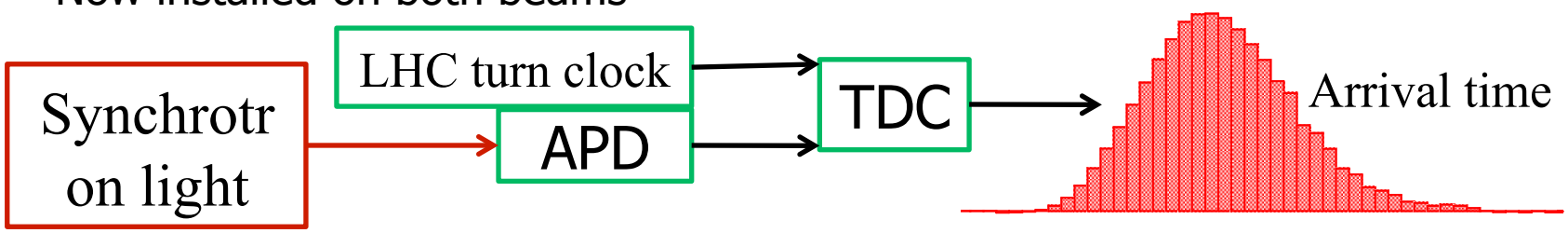
Emittance reduction between two measurements on the same bunch gives estimate of statistical error.



Longitudinal-Density Monitor

Monitor built by Adam Jeff

- Photon counting using an avalanche photodiode (APD)
- 1% of the BSRT's synchrotron light
- Histogram of time from turn clock to APD pulse, with 50-ps bins
- Now installed on both beams

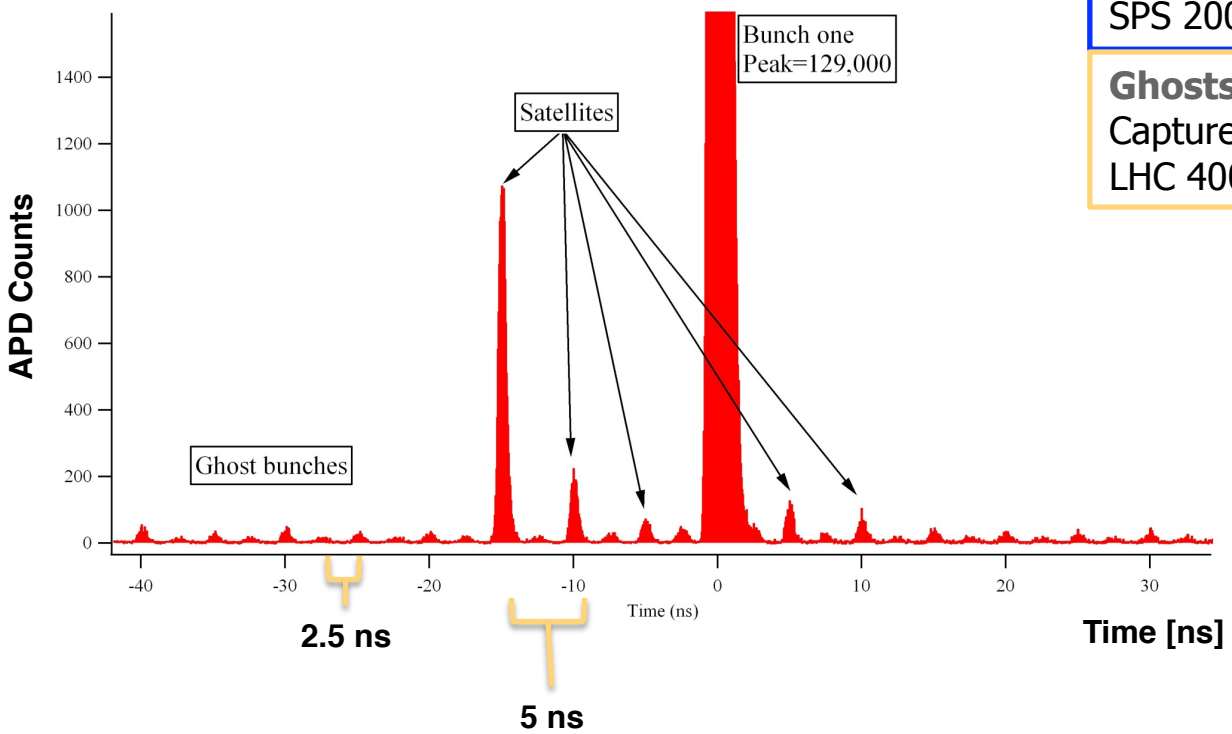


Modes:

- Fast mode: 1-ms accumulation, for bunch length, shape, and density
  - Requires corrections for photon pile-up, APD deadtime and afterpulsing
- Slow mode: 10-s accumulation, for tails and ghost bunches down to 5×10^5 protons (4×10^{-6} of a nominal full bunch)
  - Only 1 photon every 200 turns

LDM Measurement

Ions with 10-min integration



Satellites
Capture/splitting errors in the injectors
SPS 200 MHz → 5 ns

Ghosts
Capture/splitting errors in the LHC
LHC 400 MHz → 2.5 ns

LDM is the only LHC system able to see all structures from RF, with enough **dynamic range** and **time resolution** for monitoring satellites and ghosts

LARP

Beam-Halo Monitor

Halo monitoring was part of the original specification for the synchrotron-light monitor.

- LARP's involvement in both light monitors and collimation makes this a natural extension to the SLM project.

But the coronagraph needs some changes:

- The Sun has a constant diameter and a sharp edge.
- The beam has a varying diameter and a profile that is roughly Gaussian

An adjustable mask is needed. Two approaches:

- A Digital Micro Mirror Array
- Rotating Mask

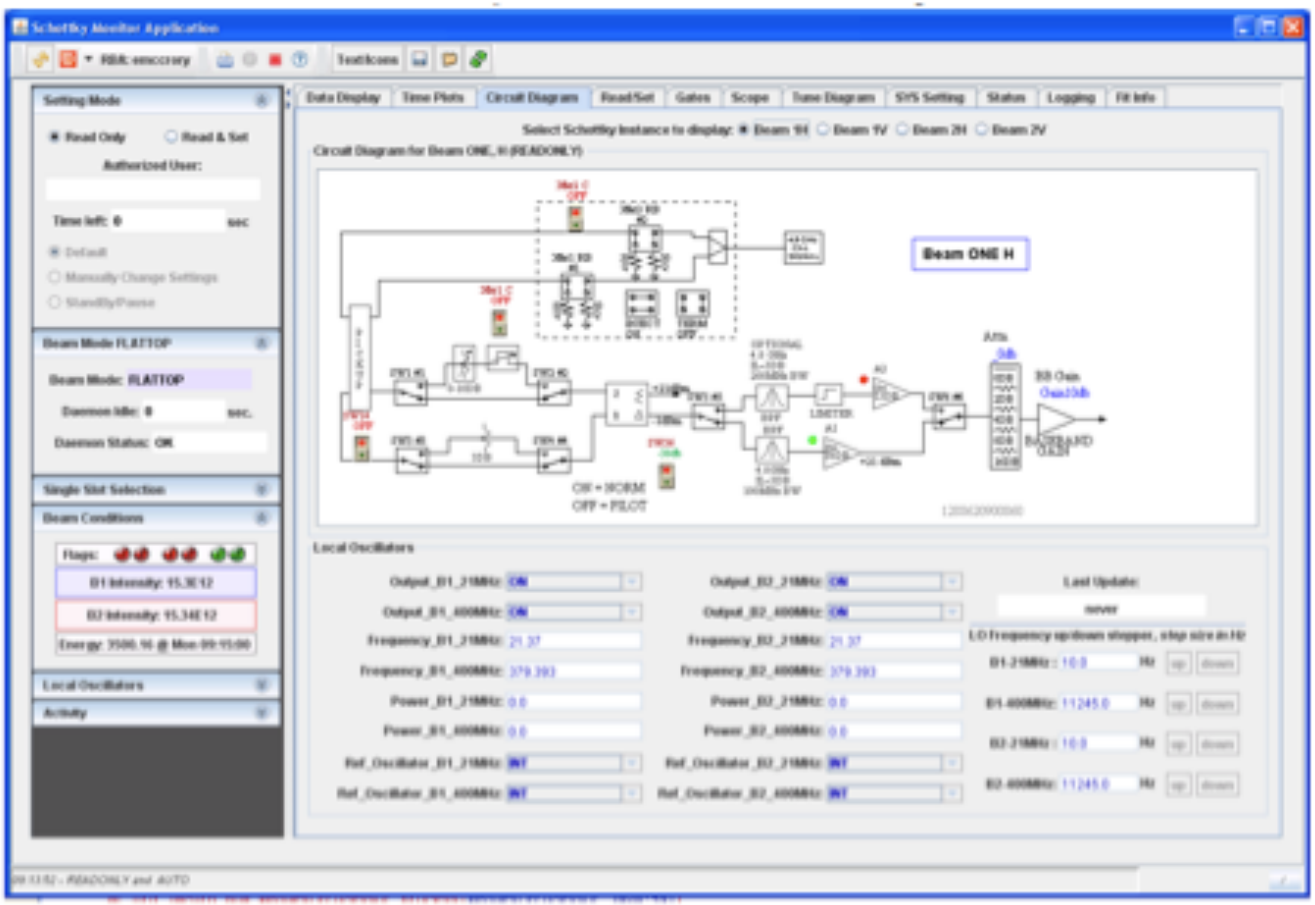
Tests of possible upgrades will begin this summer on SLAC's SPEAR-3 ring.

Schottky – Operation with Beam

- Capabilities and Commissioning
  - Non invasive measurements
  - Bunch by bunch transverse measurements
  - Measures single bunch with 10^{11} protons/bunch
  - Verified tunes track with other tune measurements
  - Chromaticities and Momentum spread measured
  - Signal tracking for ramped beam measurements

- Ideal task for Toohig fellow

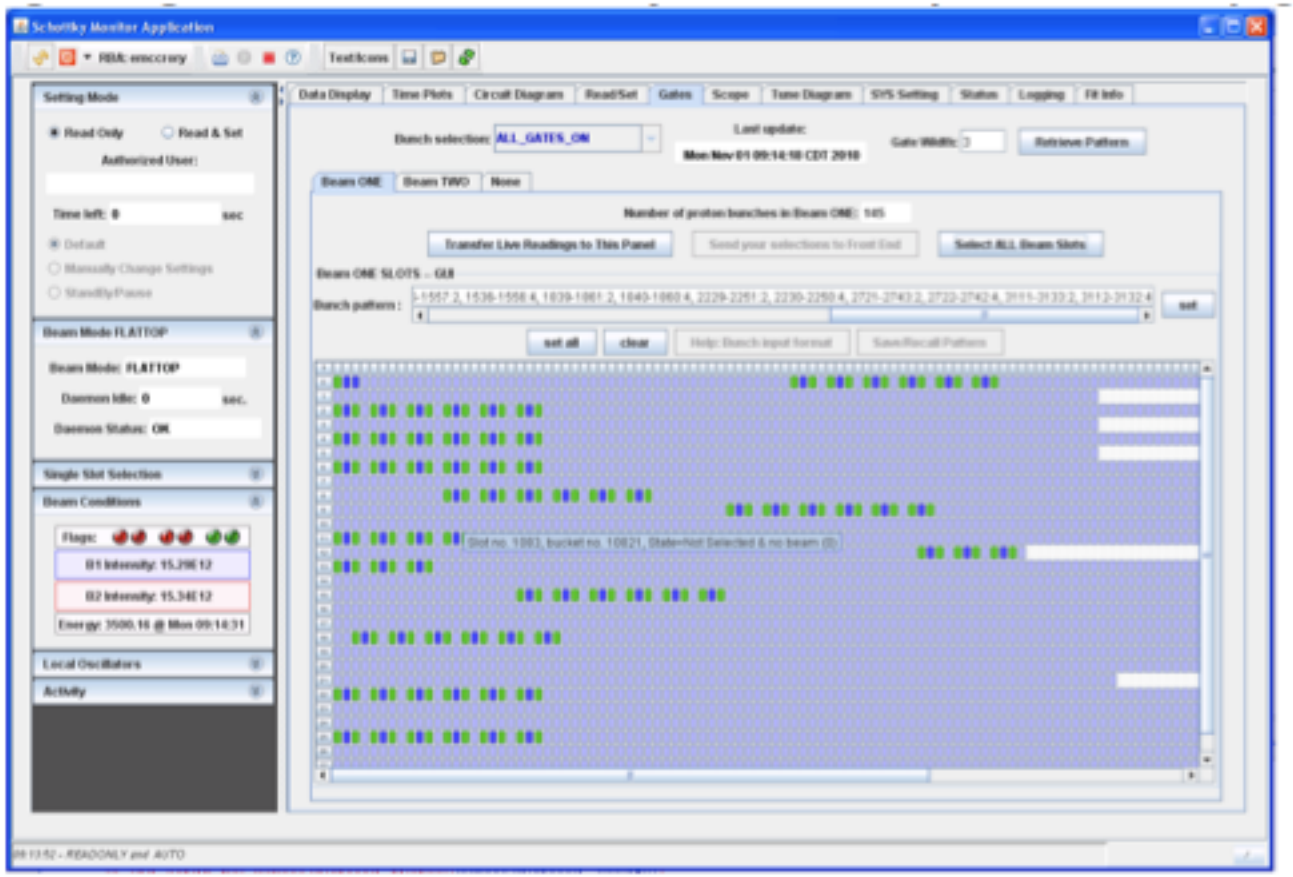
Schottky – Interactive Graphics Control



R. J. Pasquinelli

Automated Gating Control

Allows for any number of bunch configurations



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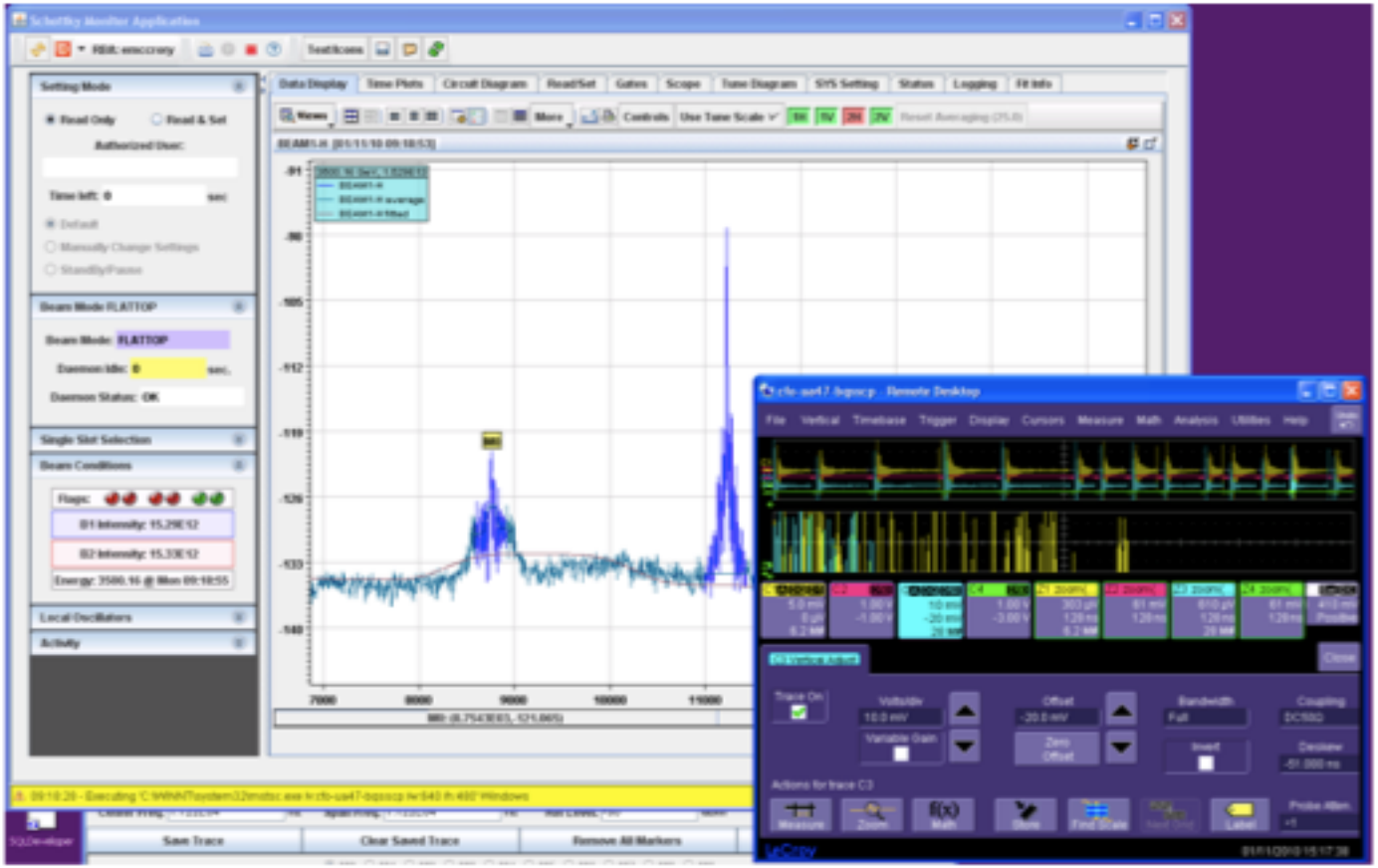
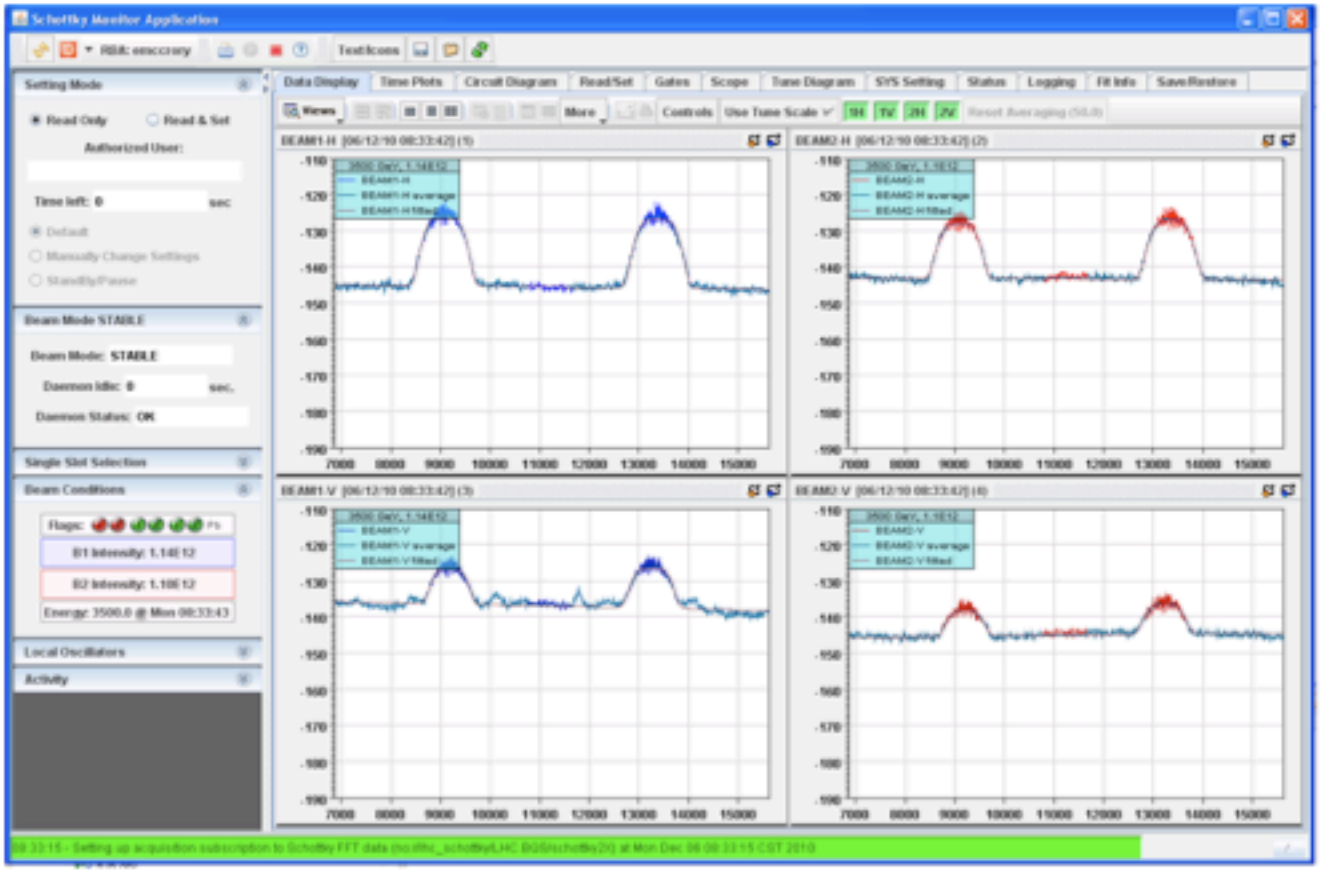
Remote Control of Gate Timing O-Scope



R. J. Pasquinelli

Schottky – Pb Ions Signals

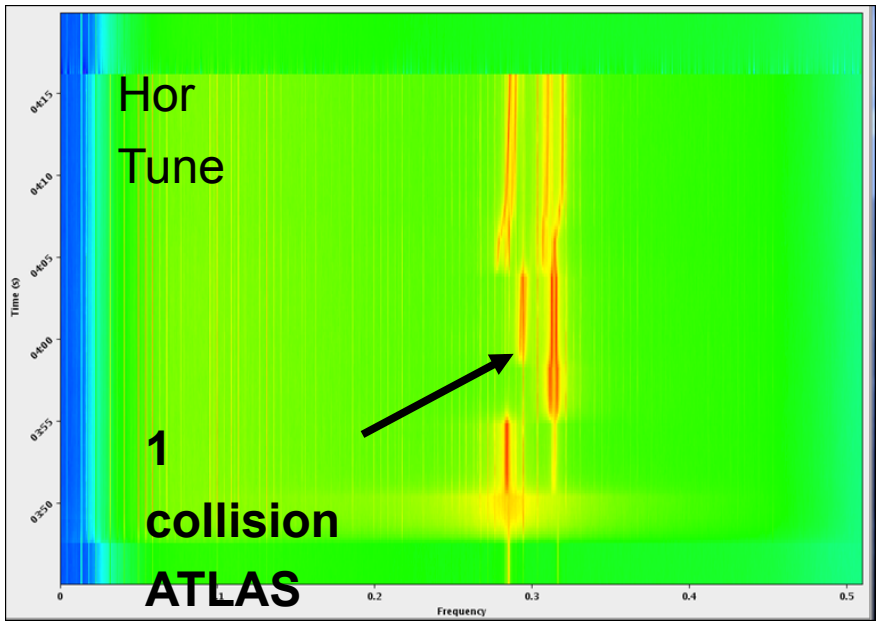
Lead Ions 1.1x10^{12} at 3.5 TeV

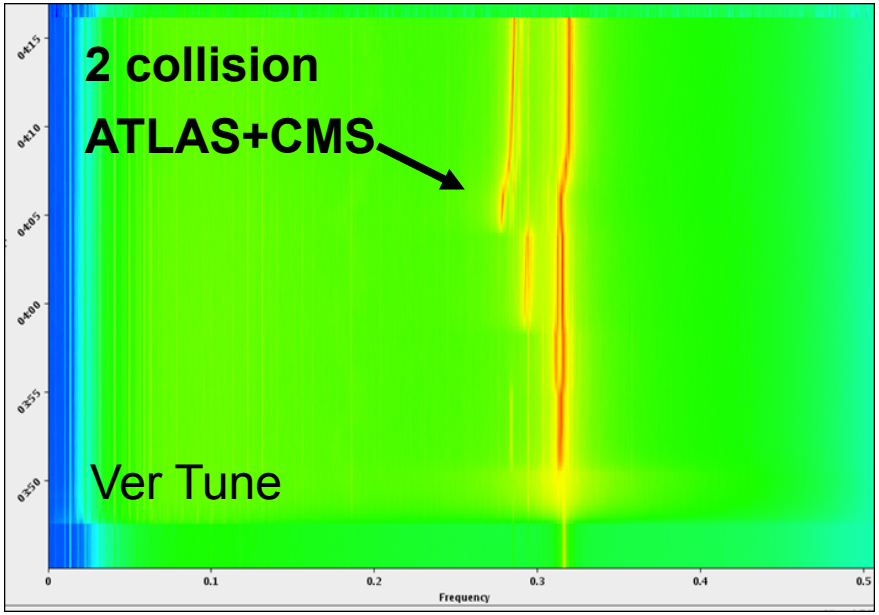


R. J. Pasquinelli

Beam-beam experiment - BBQ

BBQ Signals





Bunch intensities: ~1.9×10^{11}

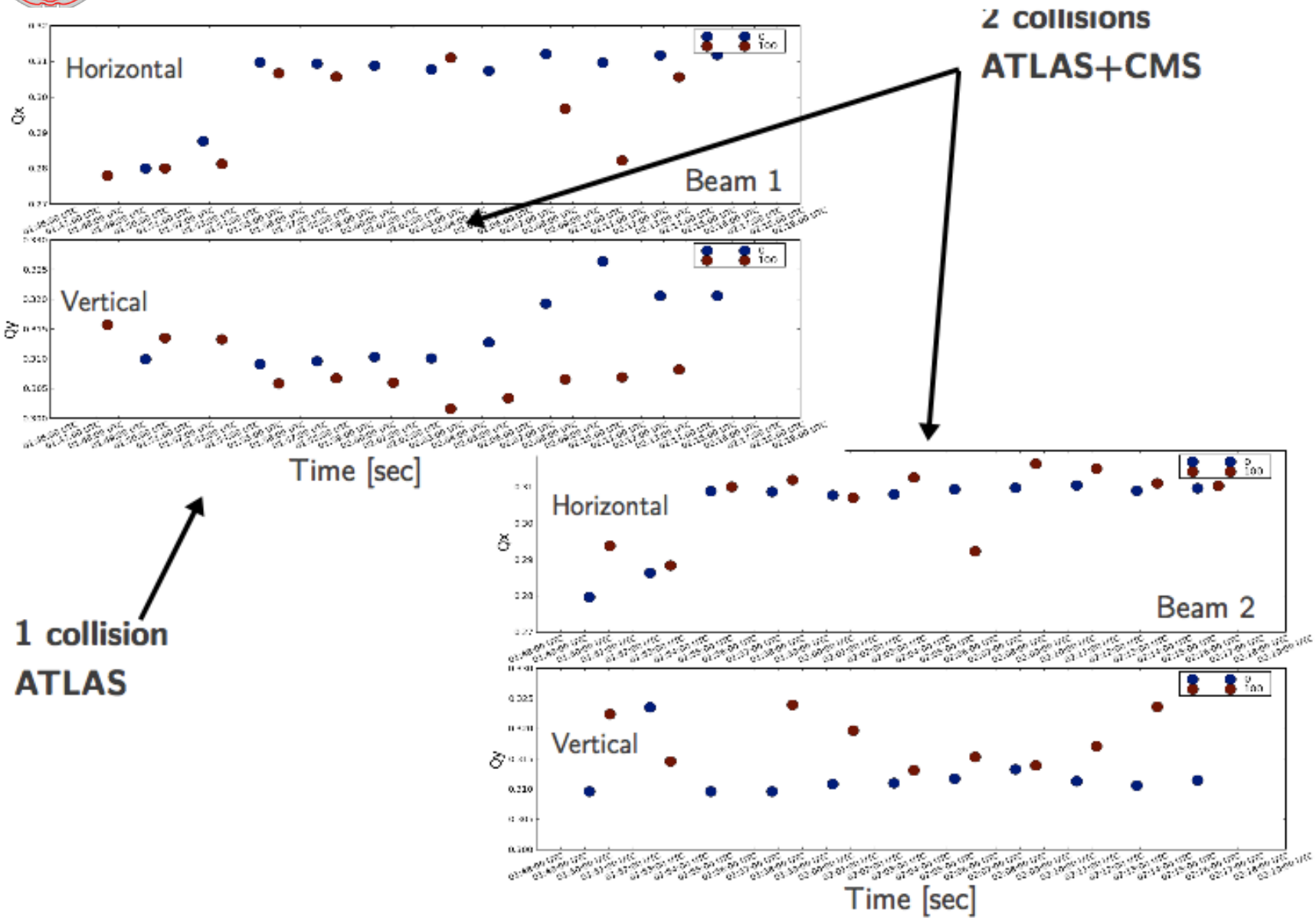
Emittances (x,y): ~1.3mm

Beam-beam tune shift > 0.015/IP

Schottky signal noisy

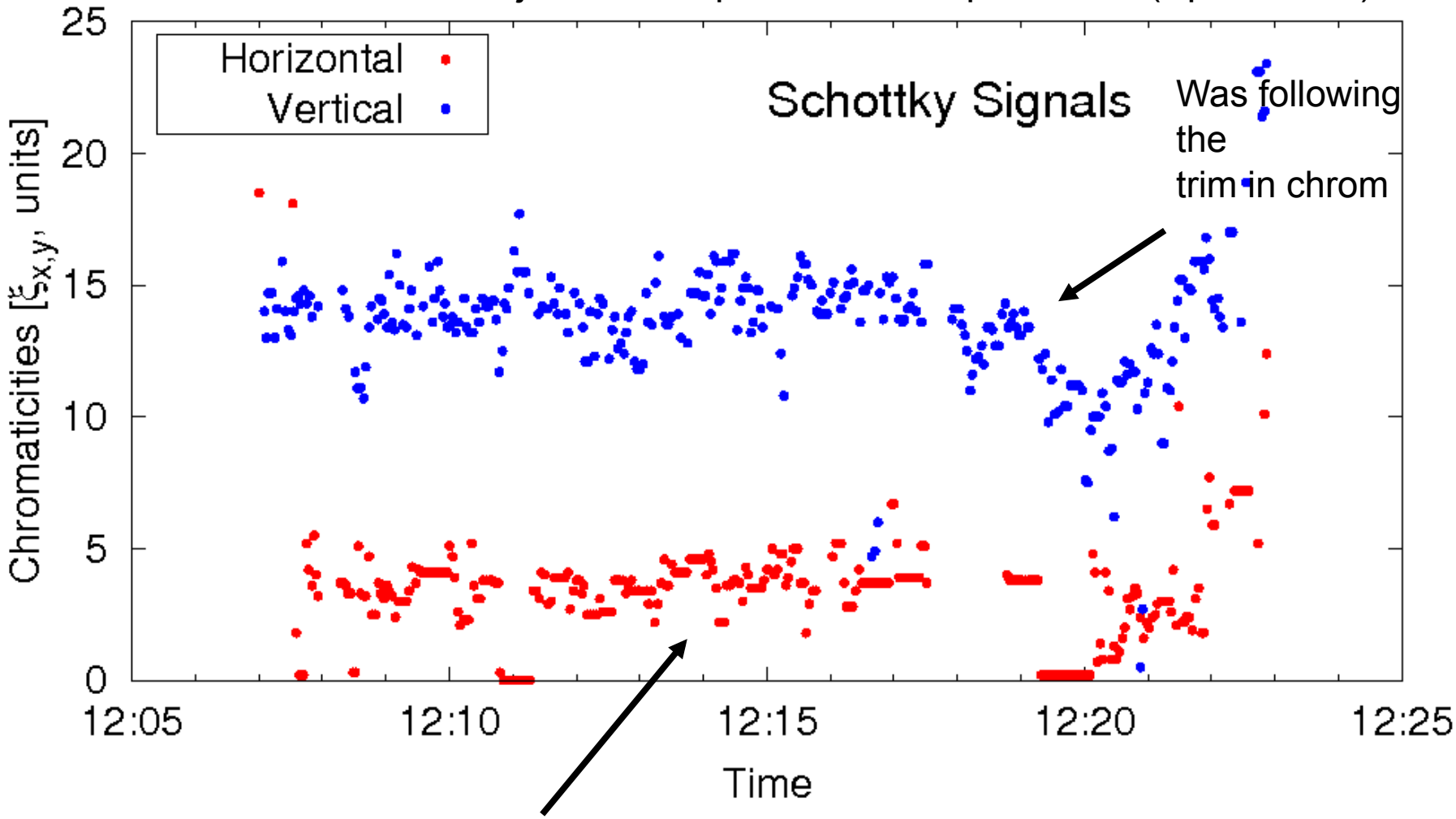
W. Herr et al.

Schottky Beam Beam Effects measurement



Chromaticity – Pilot Bunch

Injection setup for b-beat experiments (Apr 6, 2011)



Good chrom measurement for 20 min

Confirmed by classical radial modulation (horizontal, Beam 2)

Schottky - From the User Point of View

Powerful & non-invasive tool

- **System**: Decent signals (...sometimes, more reliability)
  - Excellent quality for ions (for protons → RF noise & coherent oscillations)
  - Never all signals (B1/B2, H/V, Intensities diff), needs manual input

- **Application**: Significant improvements/tools in 2011
  - Continuous monitoring of bunches & trains (Q, Q'...)

2010-11 Status

- Still in debugging mode....

Future

- Reliable signals (injection/top energy) → OP fixed display
- Less user tweaking → leading to operational tool (like BBQ)

R. Calaga – T. Pieloni

Lumi Status

As LHC luminosity improves, so do the demands on the lumi monitor system

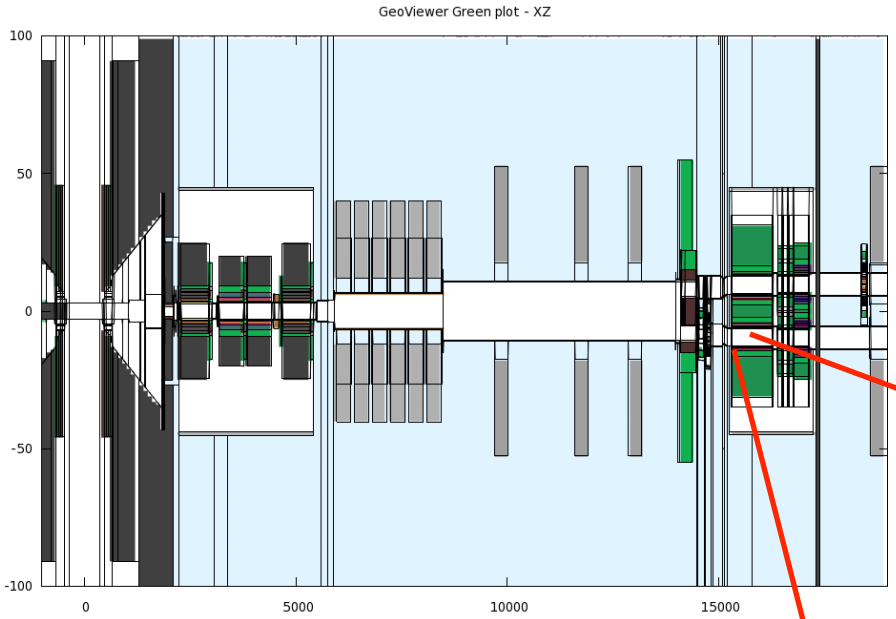
R. Miyamoto supporting LHC operations locally

- Numerous improvements and system tests
- Moving from counting to pulse height mode

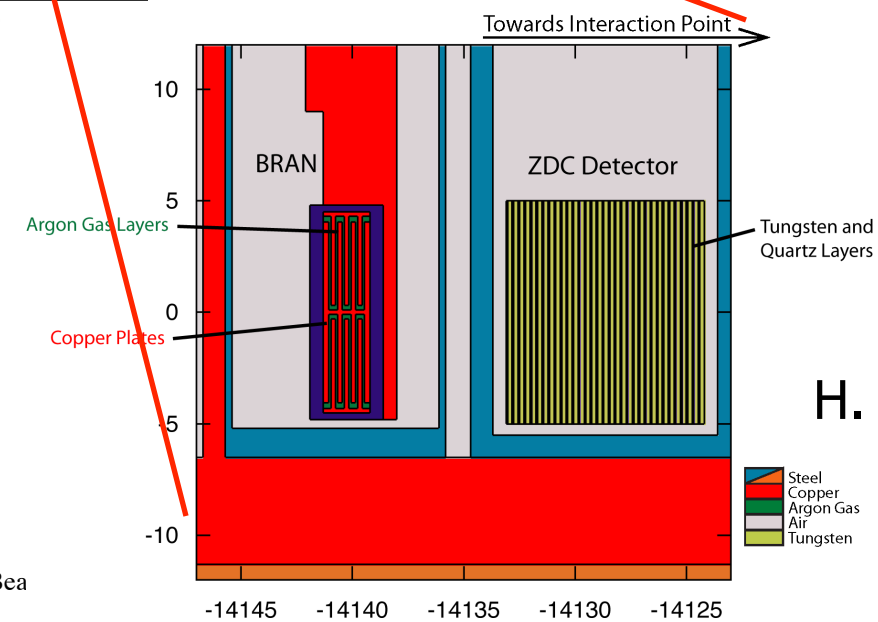
FLUKA model in support of data analysis

Developing operator panel for CCC

FLUKA model of IP



IP model developed at CERN



H. Matis

BRAN model previously developed at LBL

Recent Model Improvements

LARP

Imported the Fluka geometry of IP1

- Developed at CERN (ATS-note-2010-046)
- Models from IP to past the TAN

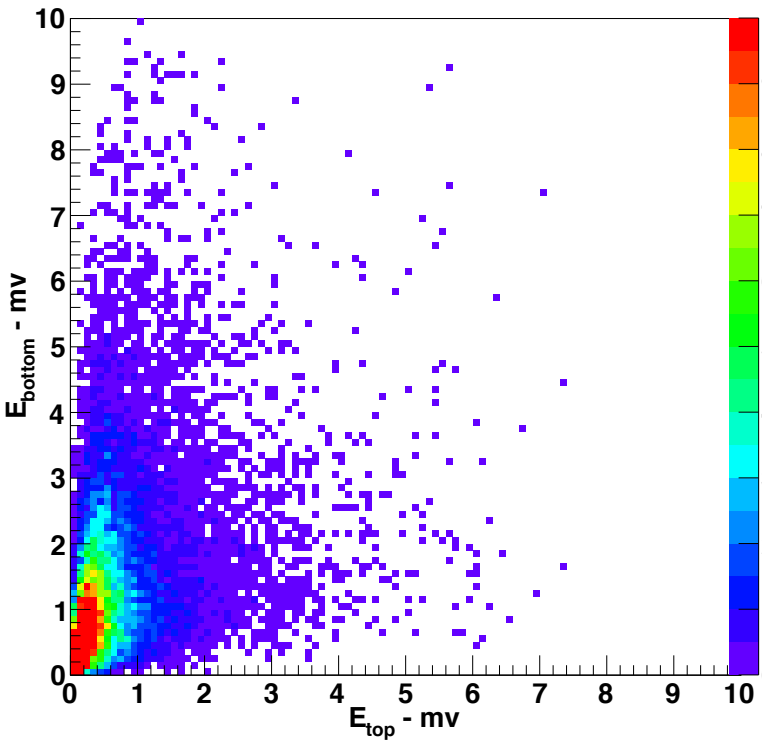
Fluka 2011 released

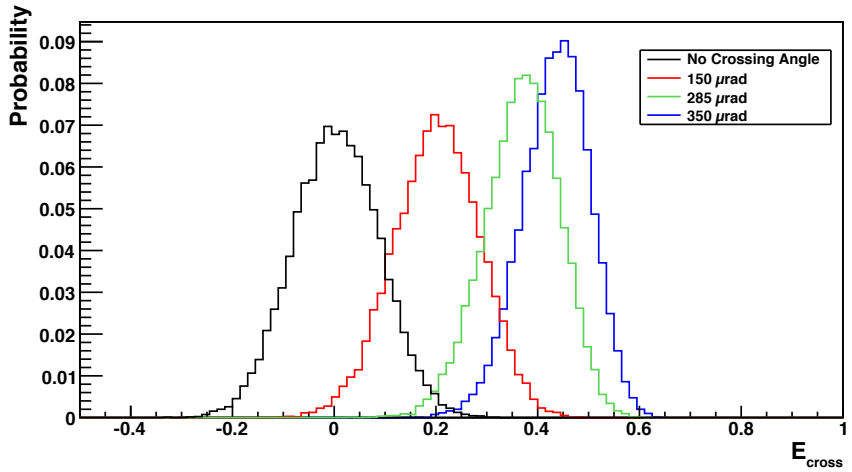
- Simulates collisions
- Specification of:
  - Ion species
  - Beam parameters (Crossing angle, momentum spread, beam size)
- Can do arbitrary energy
  - Easily match LHC operating energy
- Compare pp results with PbPb
  - Excellent tool for understand performance of BRAN and IP

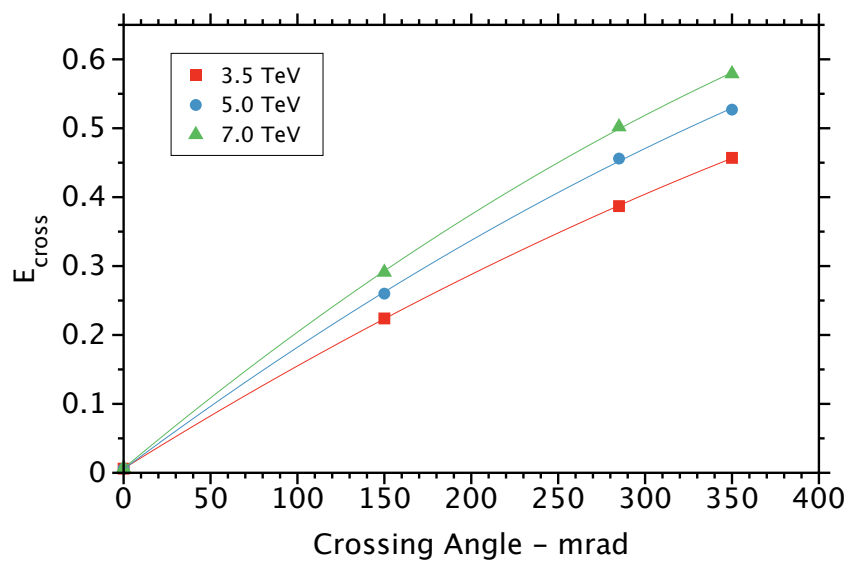
IP model and Fluka 2011 fully operational at LBNL

Crossing Angle Modeled in FLUKA

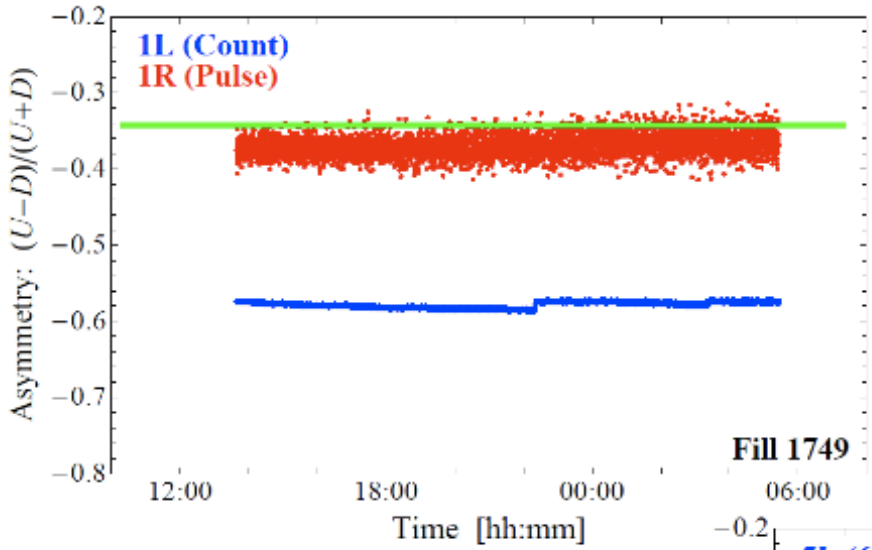
Can measure crossing angle by calculating differences between detector quadrants



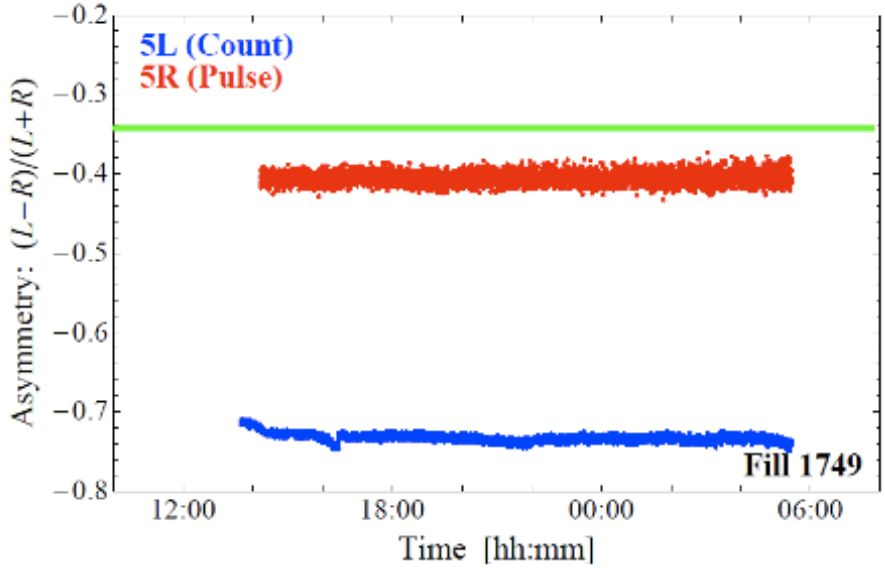




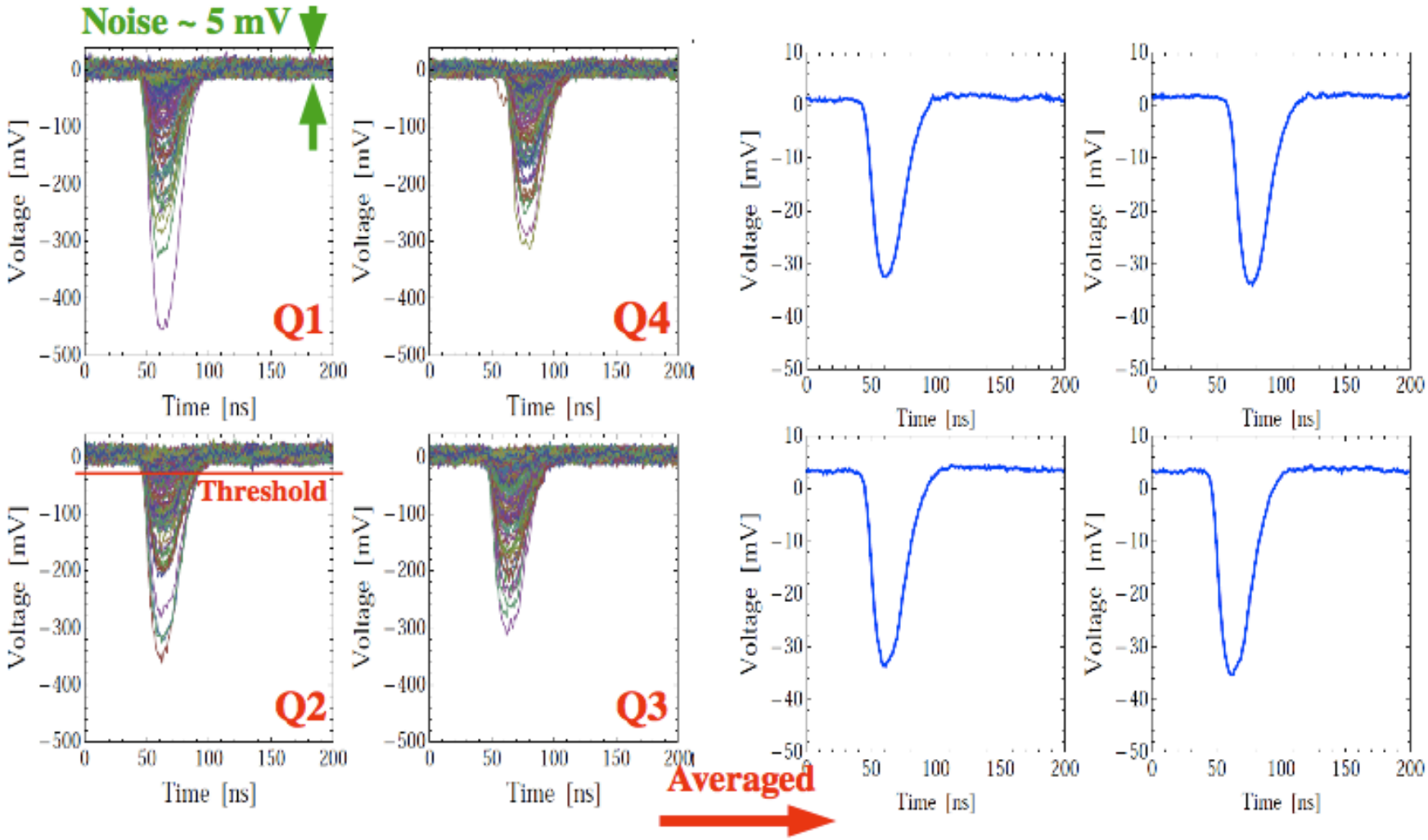
Crossing Angle Measured



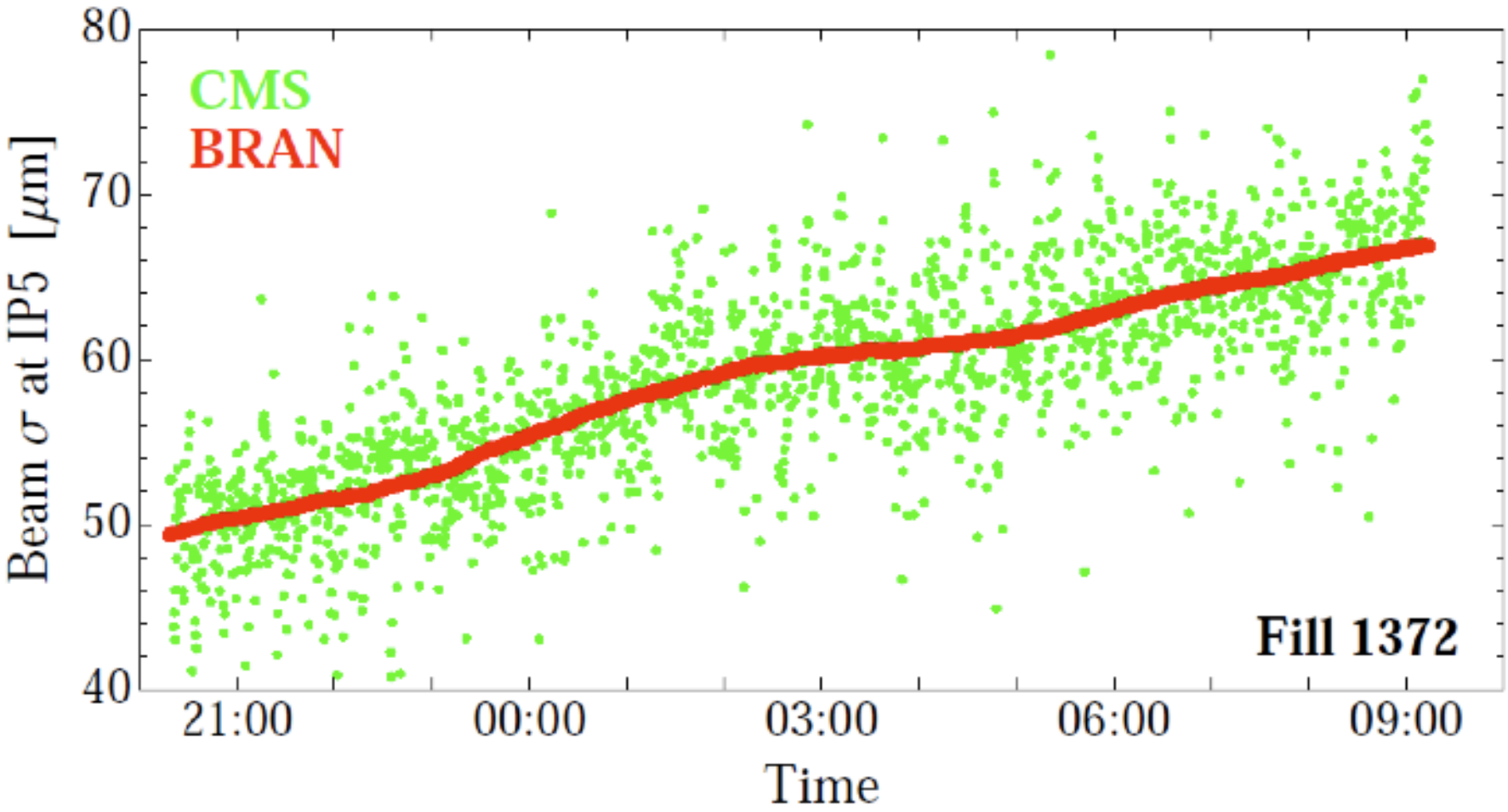
- We must use the pulse height for crossing angle measurements.
- Sensitive to the calibration. Calibration adjustment ongoing.



Lumi – Counting and Pulse Height Modes

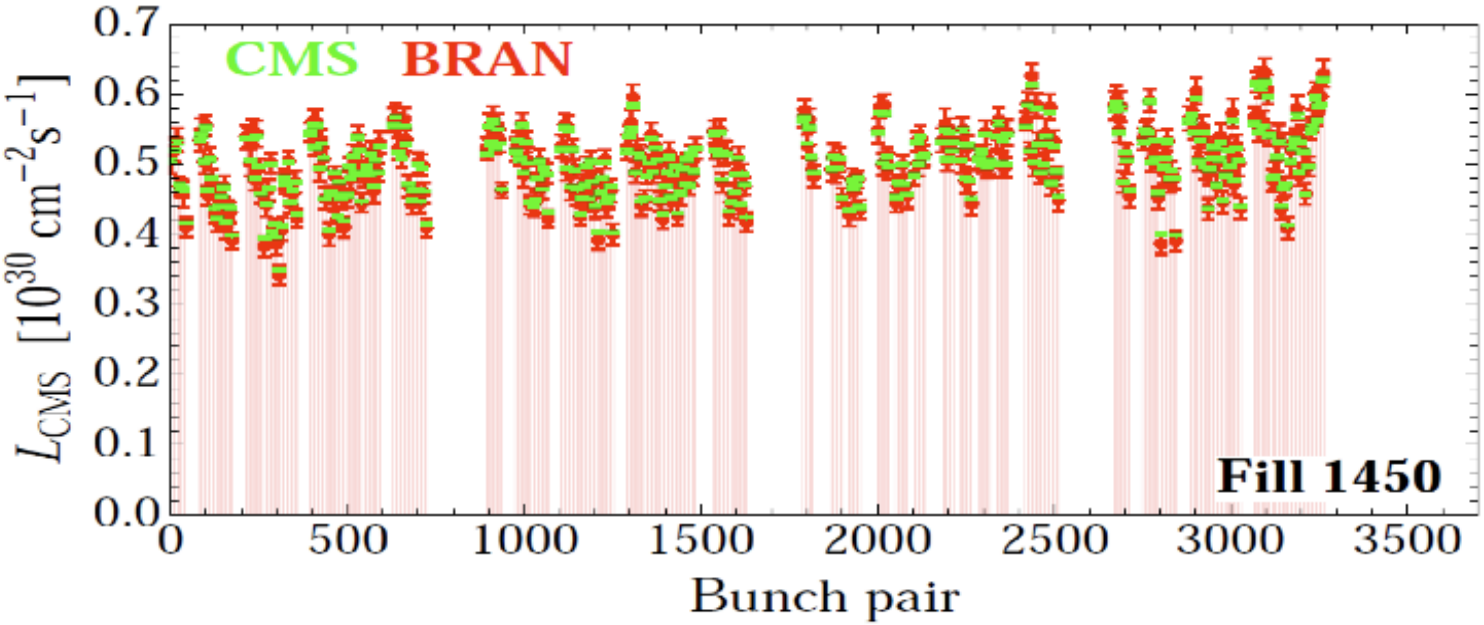


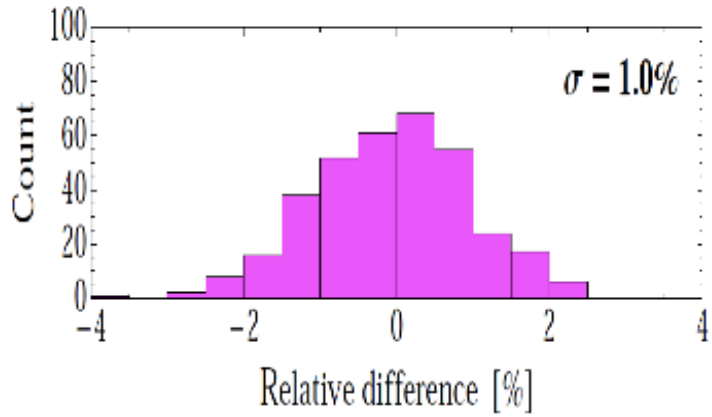
Interaction area evolution – IP5



Specific luminosity plot is part of the operator display under development

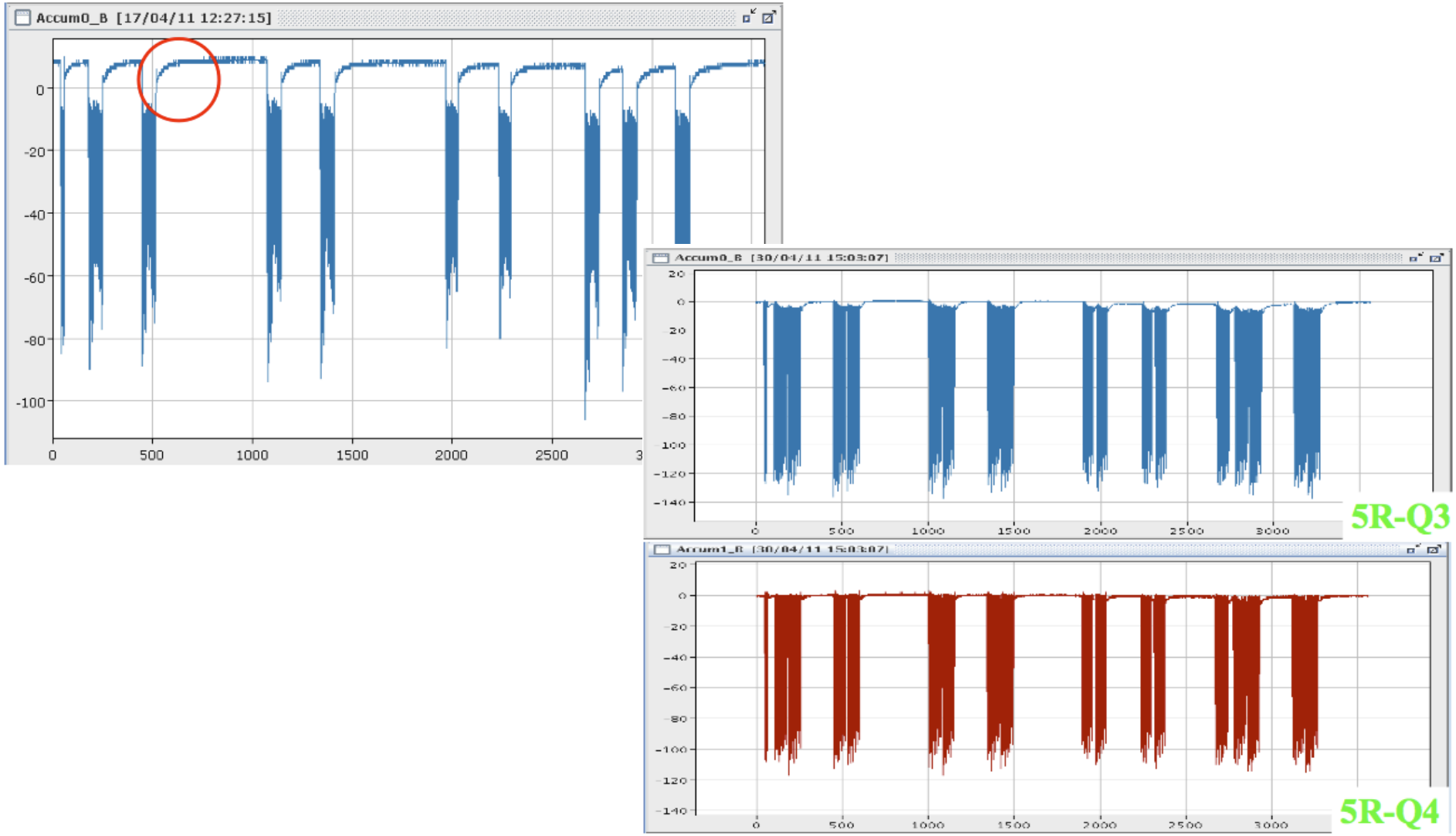
Bunch-by-Bunch Luminosity



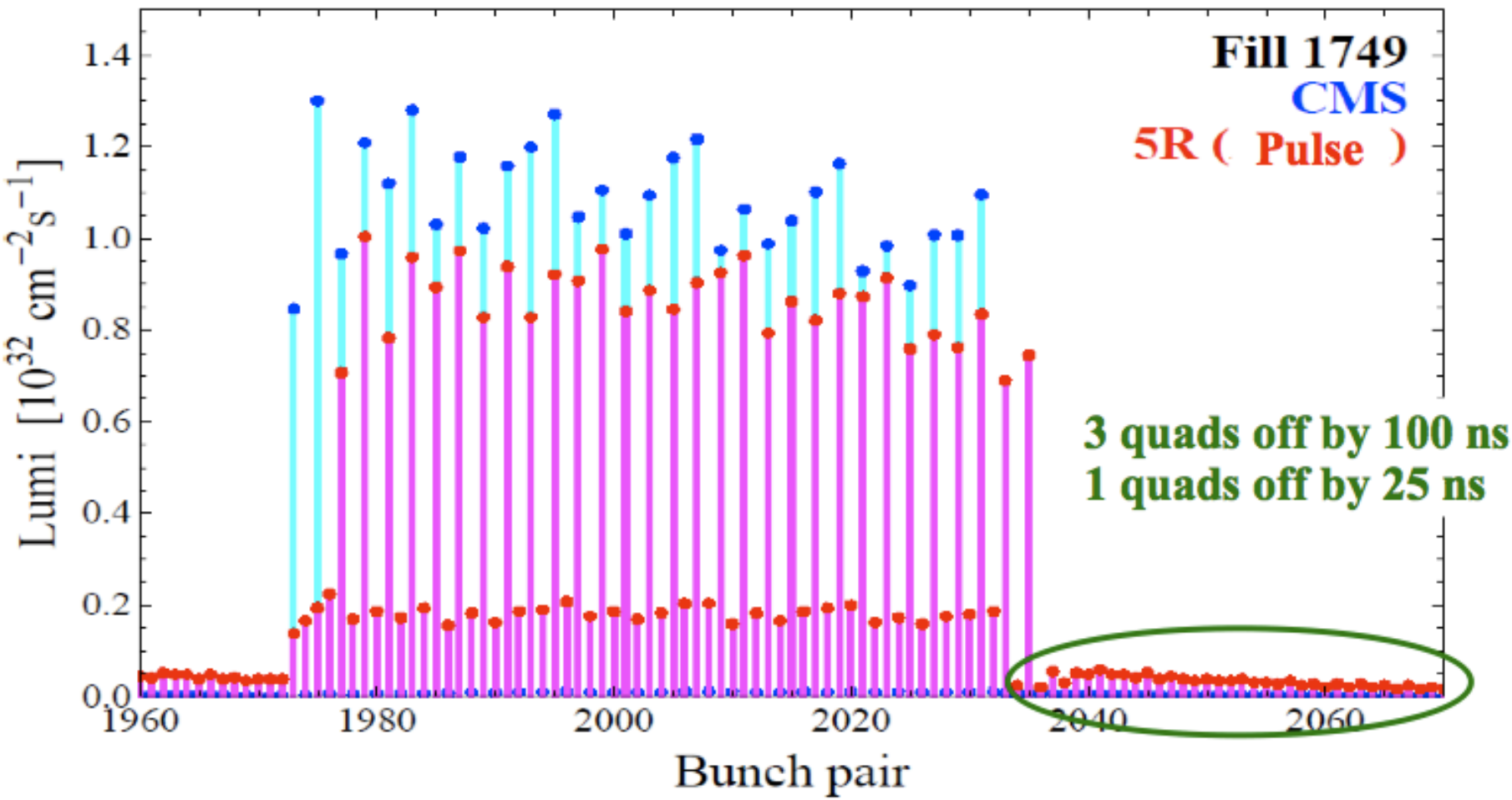


- ~1% discrepancy for bunch-by-bunch measurement.
- The discrepancy seems to come from the systematic.

Pulse Height Readout Adjustments



Readout Timing Adjustments



Operational at 50 ns

R. Miyamoto

AC Dipole Highlights

LARP

In the 2011 run, *β* changed from (3.5,3.5,3.5,3.5) m to (1.5,10,1.5,3) m at IPs (1,2,5,8). This is due to*

IP1 and IP5: further squeeze allowed after reviewing of aperture at tertiary collimators.

IP2 and IP8: luminosities could exceed design values.

During the recommissioning in 2011, optics measurements/corrections with **AC dipoles** performed:

Peak β-beating is reduced to ~10% at collision with local + global corrections. β-beating up to flattop is verified to be good enough.

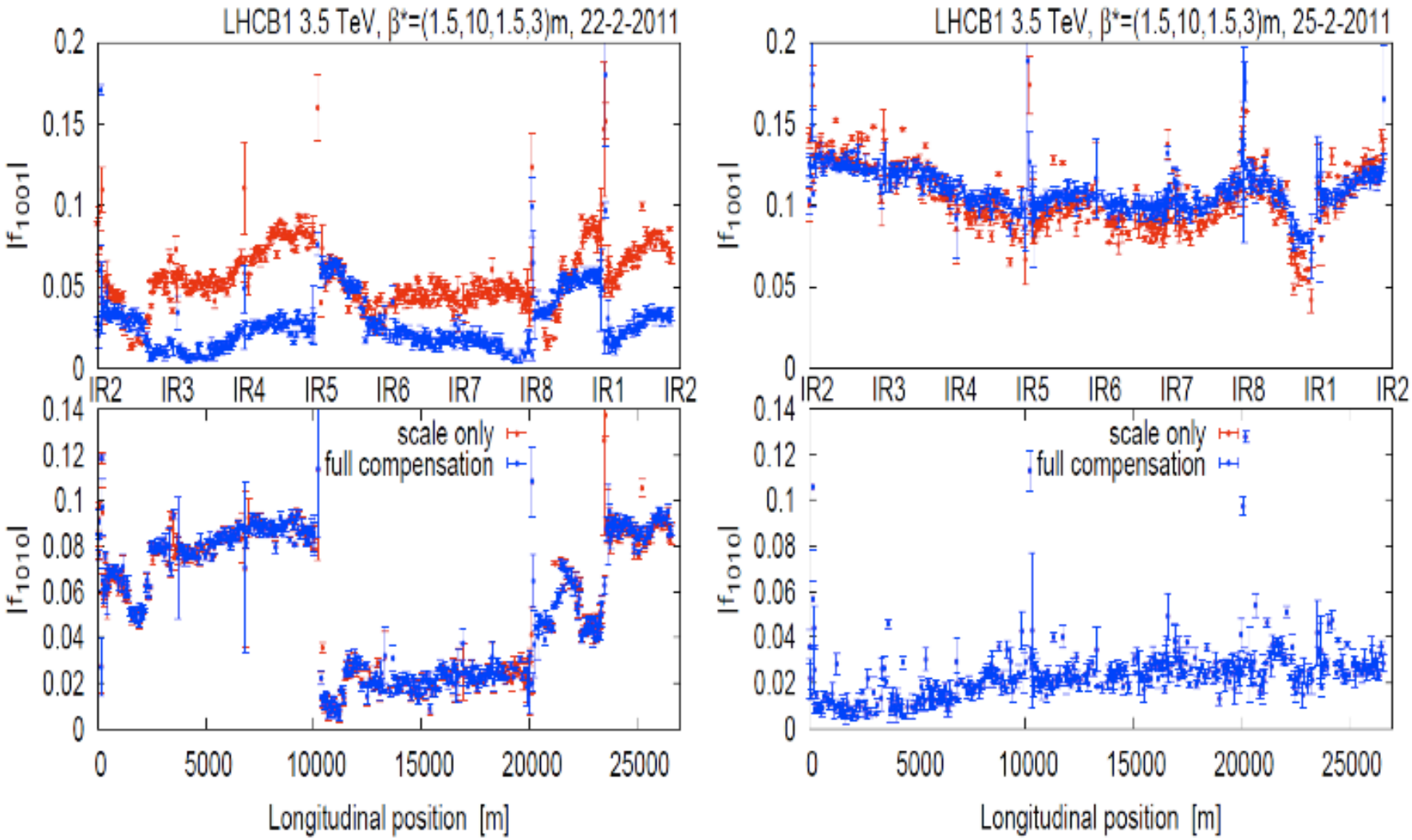
Coupling corrected at collision and later at injection and ramp for B2 during one MD.

Good machine stability verified. K-modulation performed to β^*.

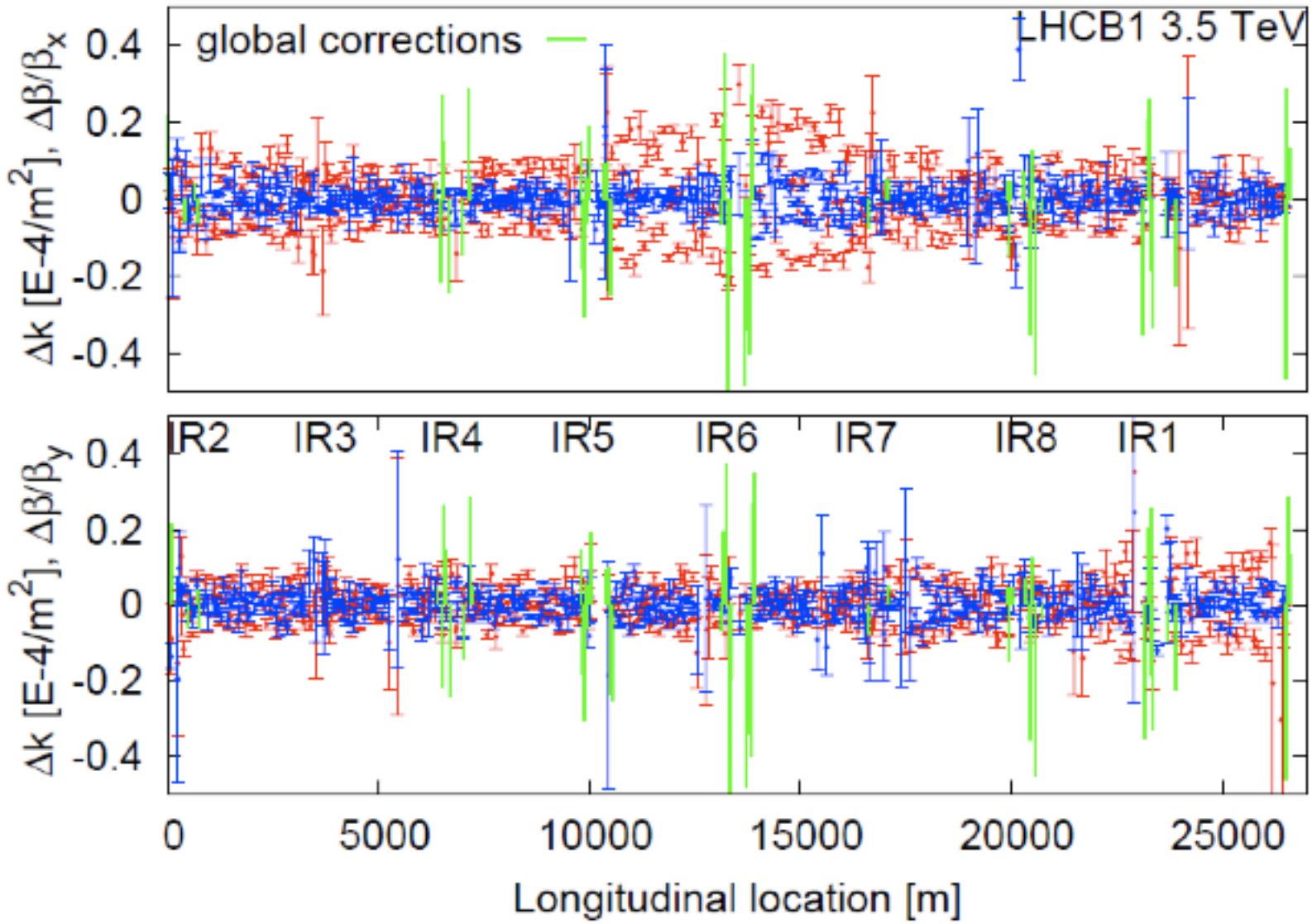
Improved diagnosis tools: GUI, codes, new analytics formula to measure coupling with AC dipoles.

Supported MDs: collision tunes from injection, 90 m β^*, ATS.

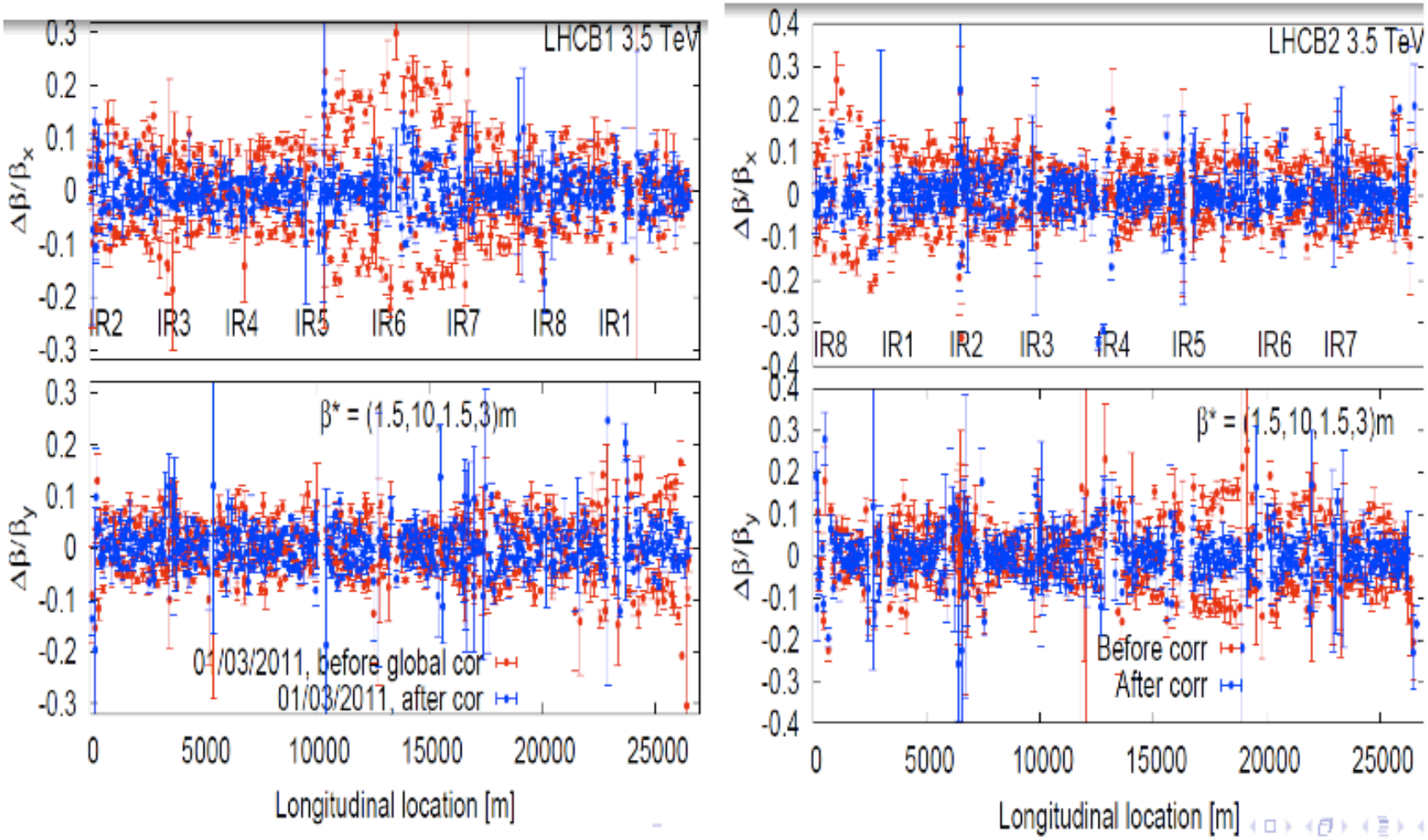
Improved Analysis



B1 Global Correction with SVD fit



Global ß-beating Correction at Collision



Achieved ~10% β-beating in both planes for both beams!

Handoff to CERN

All instruments are completed and fully operational

Last hardware issue resolved during 2010 winter break

Moving into operations requires two champions

- an instrument 'owner' in BE/BI to maintain and enhance the device
- an 'operator' in BE/OP to lead it into operations

LARP's experts continue to developthe performance of the instruments and collaborate with CERN staff

LARP

Conclusions

Developing instruments as the LHC performance increases

Toohig + LTVs essential to the process

- AC Dipole, Lumi – R. Miyamoto
- Sync Light – A. Fisher
- Schottky – R. Calaga

Hardware functioning well

- Possible improvements identified

Developing user applications to contribute to everyday operations

- Lumi, Schottky