Instrumentation Highlights

M. Minty
on behalf of the Instrumentation Systems Group

Injectors	Linac LPM	
	(Booster BLM^{m}, BPM^{r})	m = modernization
	(AGS BLM^{r,m}, BPM^{r}, WCM^{m})	r = repair
	AGS e-IPM	

RHIC E-Lens
(BLM)
BPM
YAG / pinhole
eBSD
longitudinal profile
(transverse bunch-by-bunch dampers)

RHIC - absolute emittance measurements

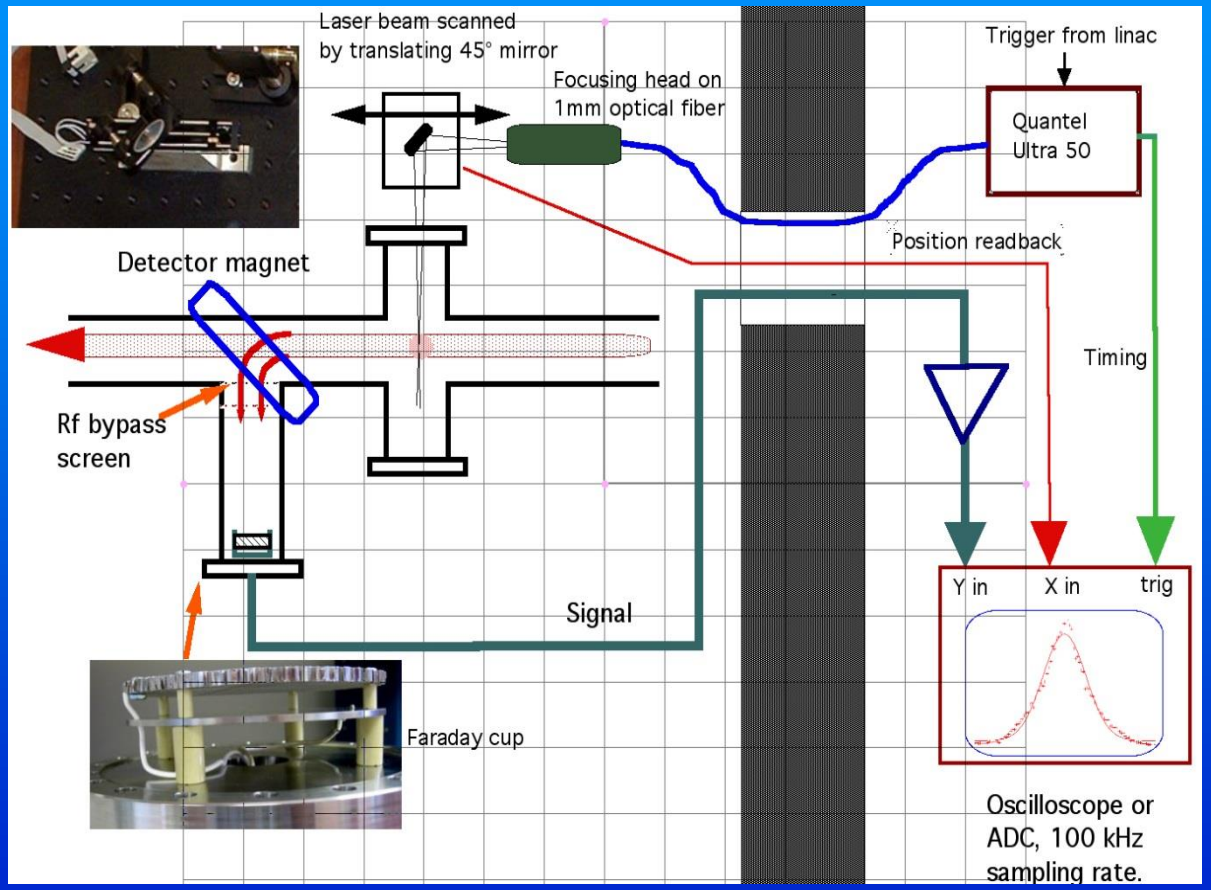
Not presented - but a major portion of group efforts: major installations and R&D for BPM upgrade, BLIP raster upgrade, ERL, CeC, LEReC, eRHIC

Linac Laser Profile Monitor (LPM)

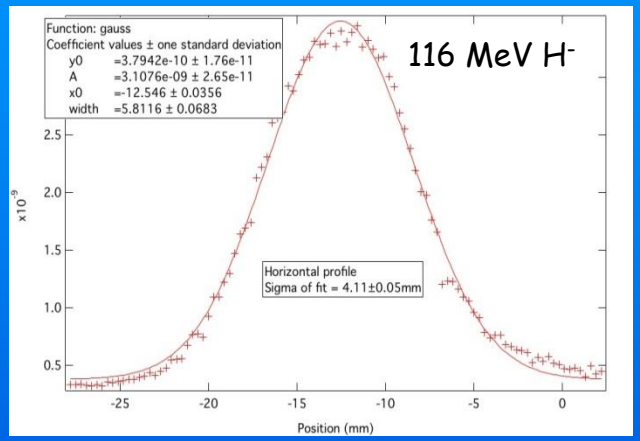
<2014: energy measurements by beam-gas scattering

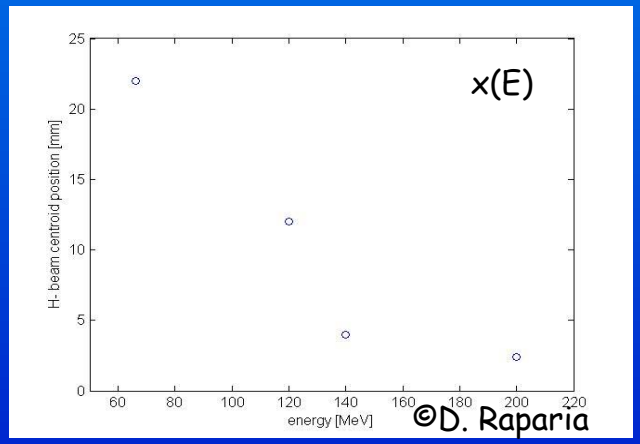
2014: Quantel laser (located outside of hi-rad tunnel) installed, laser light transported via optical fiber, laser PS interlocked to access controls to allow remote operation continuous energy and profile measurements (for last two months of run)

conceptual overview of LPM



horizontal profile





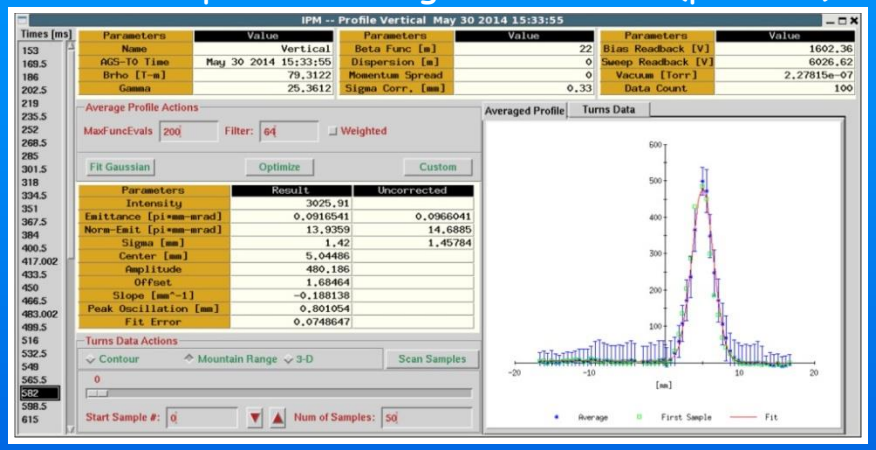
R. Connolly, S. Bellavia, C. Degen, H. Hartmann, C. Ho, R. Michnoff, L. DeSanto, D. Raparia

see also R. Connolly et al, "A detector to measure transverse profiles and energy of an H^- beam using gas stripping and photo neutralization", Journal of Instrumentation **7** P02001 (2012)

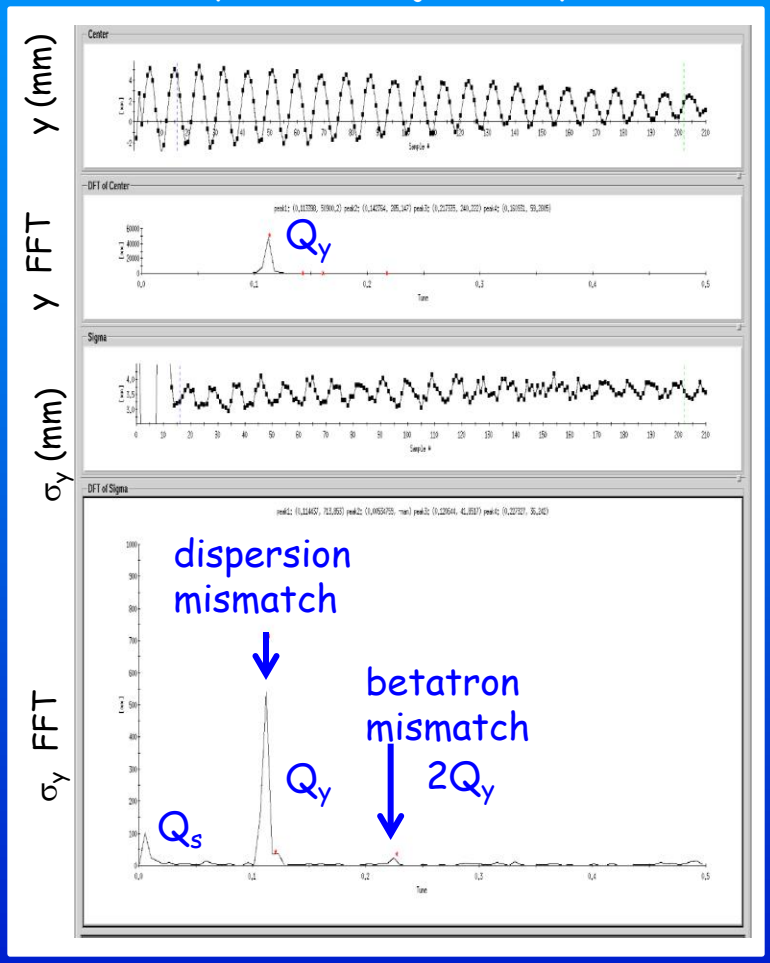
AGS electron-collecting ionization profile monitor (e-IPM)

2013: horizontal e-IPM installed
2014: vertical e-IPM installed; features larger (than RHIC) horizontal aperture
backleg windings added (both e-IPMs) for β-function measurements
gas leaks installed (both e-IPMs) for single-turn profiles at injection

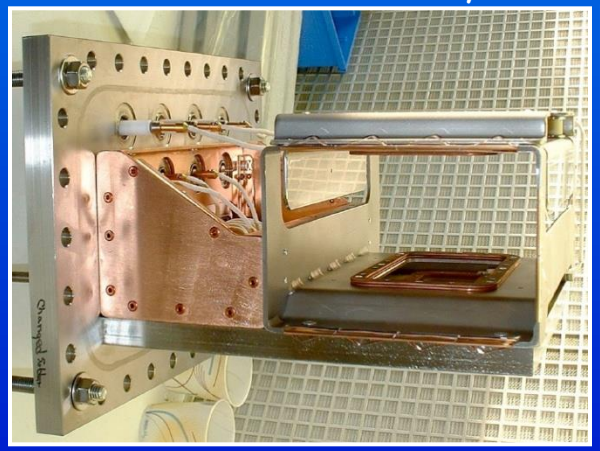
vertical profile during acceleration (protons)



turn-by-turn at injection (protons)



detector assembly

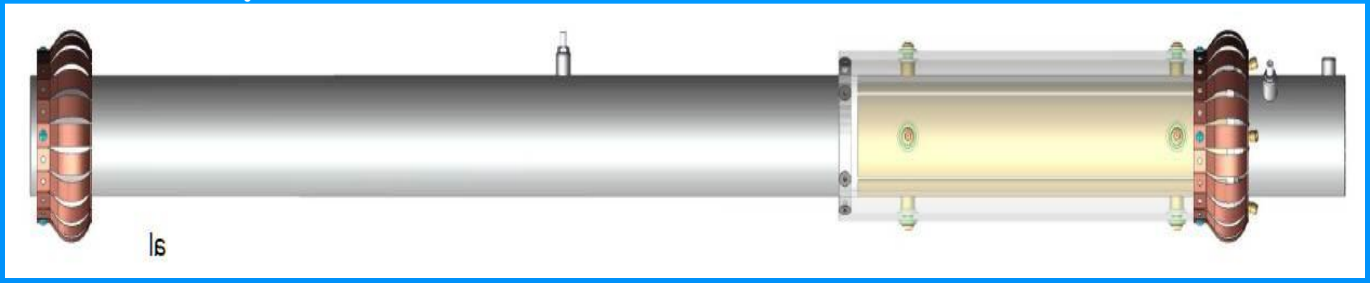


windings

R. Connolly, J. Fite, D. Gassner, H. Huang, S. Jao, R. Michnoff, J. Morris, P. Sampson, S. Tepikian

see also R. Connolly et al, "A RHIC-Style IPM in the Brookhaven AGS", C-A/AP/487 (Sept, 2013)

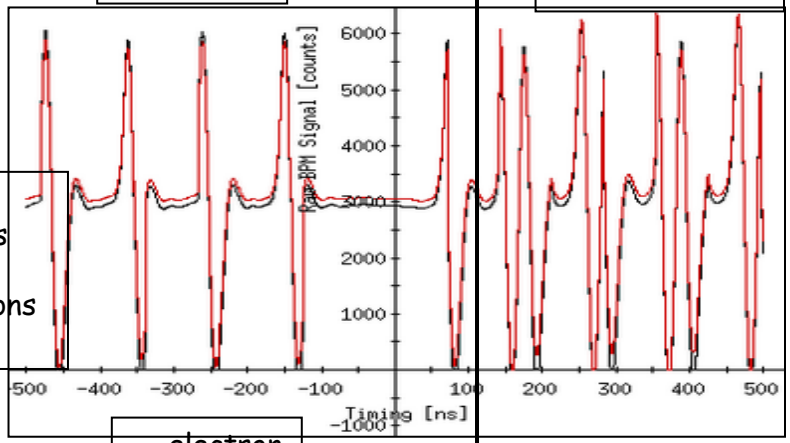
E-Lens beam position monitors (BPMs)



blue bunches

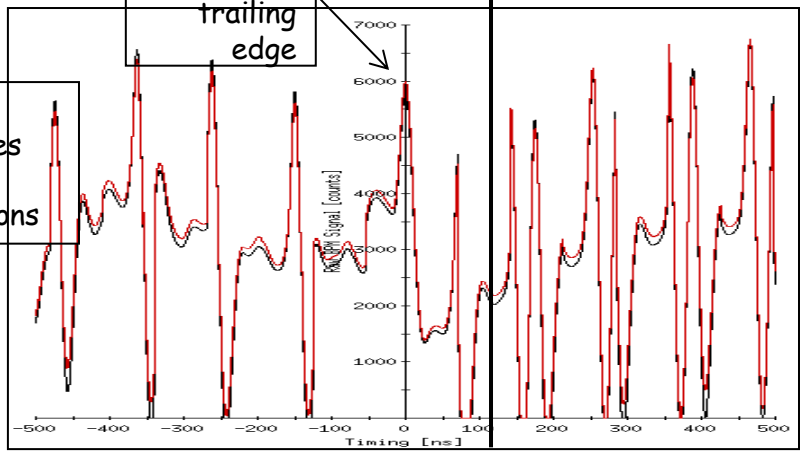
blue & yellow bunches

Ion bunches only (electrons off)

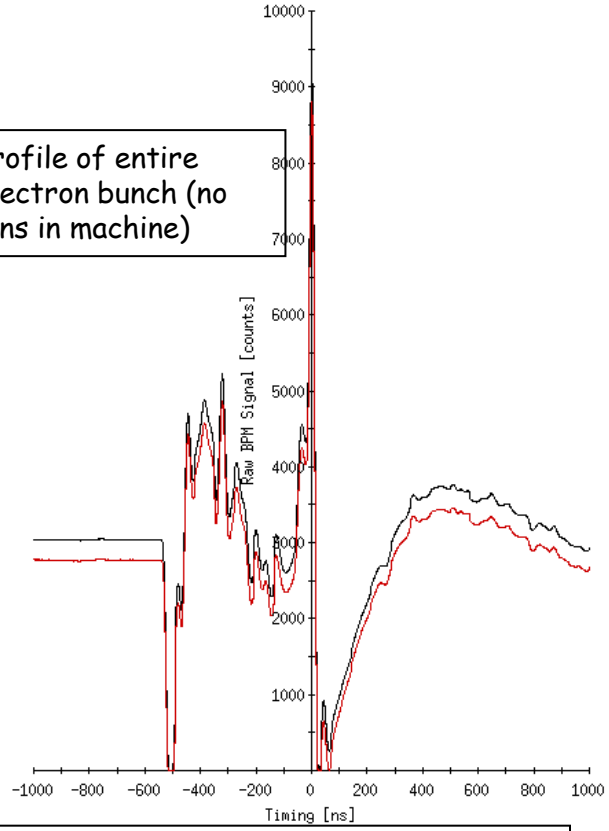


electron trailing edge

Ion bunches and electrons



Profile of entire electron bunch (no ions in machine)

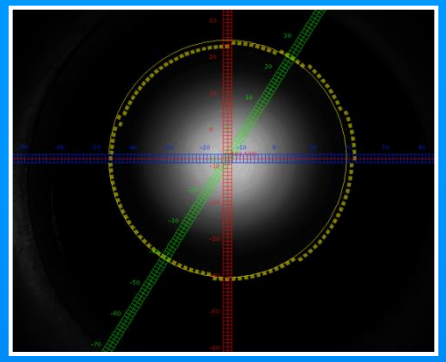


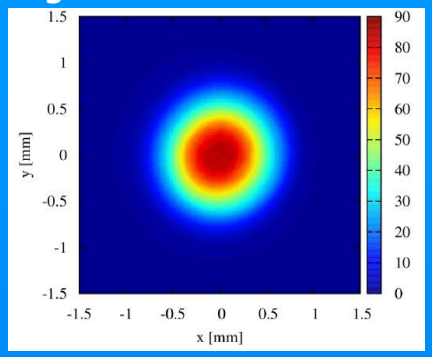
E-Lens BPMs profiles using standard RHIC IFE hardware

R. Michnoff, P. Cerniglia, C. Dawson, D. Gassner, J. Hock, R. Hulsart, P. Thieberger

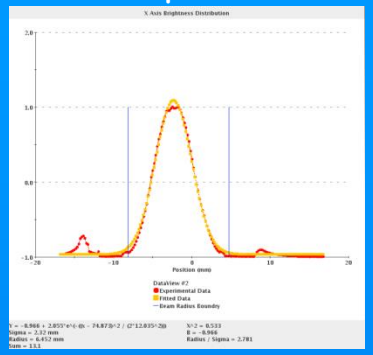
E-Lens Transverse Profiles

YAG images

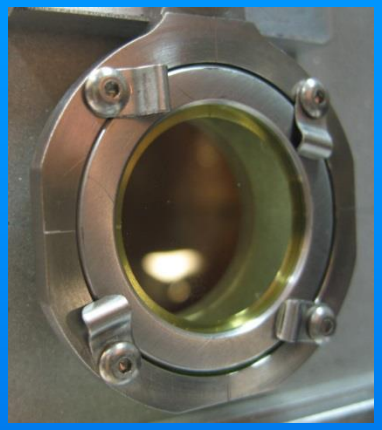




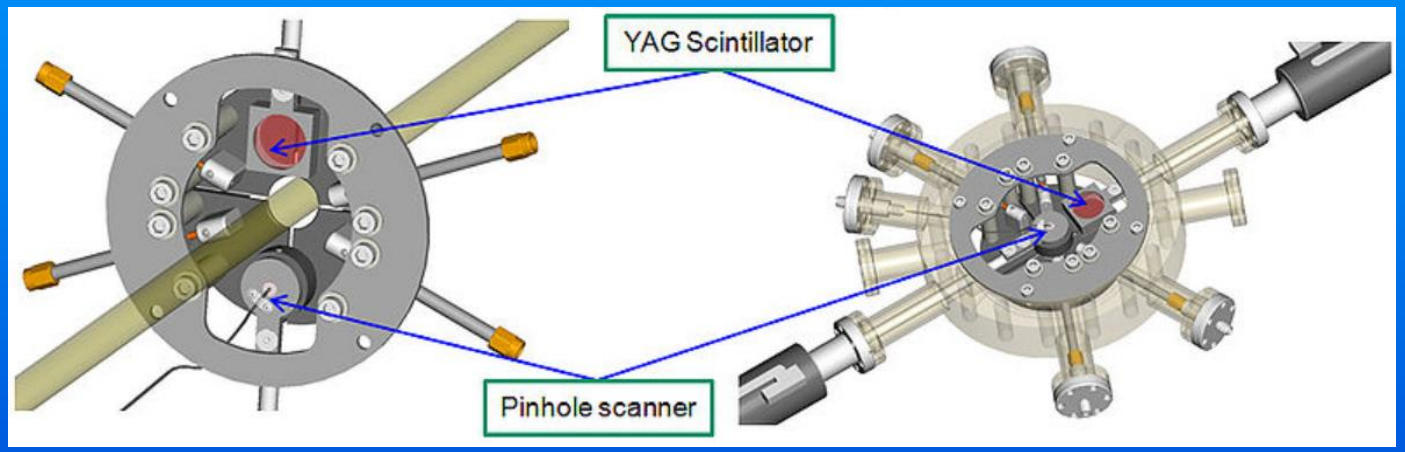
YAG profile



YAG crystal

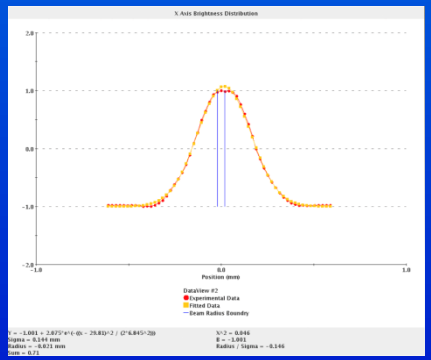


halo scrapers and profile detector supports



pinhole detector

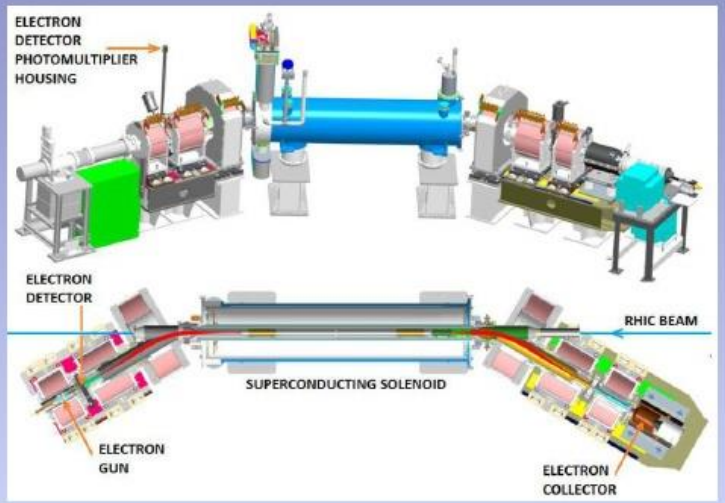
pinhole profile



Date: 5/13/2014
Electron energy: 4 kV
E- beam current: 0.120 A
Pulse length:
3 μs (YAG)
12 μs (pinhole)

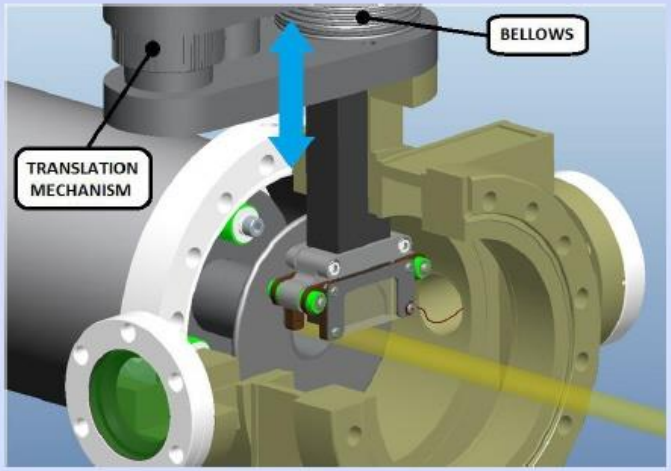
T. Miller et al, "Beam profile measurements in the RHIC electron lens using a pin-hole detector and YAG screens", to be presented at IBIC 2014 (Sept, 2014)

E-Lens Electron Back-Scattered Detector (eBSD), P. Thieberger et al

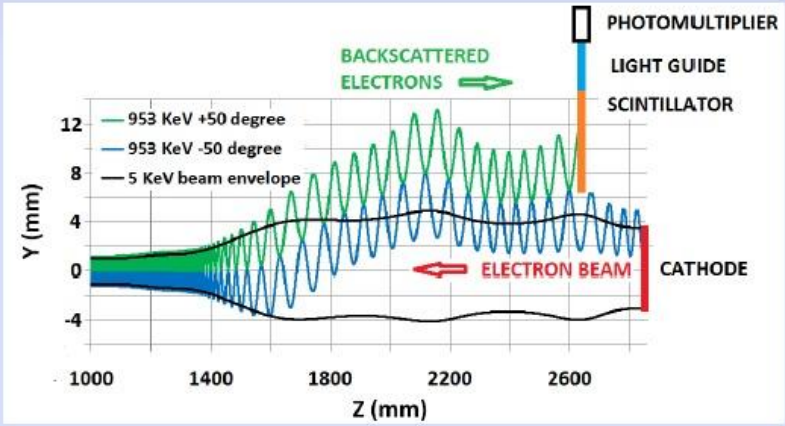


This system should provide a good "luminosity" signal to optimize the overlap of the electron and proton beams.

Achieving good position sensitivity along the interaction length will be much more difficult but would also be very useful for tuning.



Positioning mechanism and vacuum-side view of the detector well with the attached thin tungsten foil used for detecting low energy electrons returning from the collector. The backscattered high energy electrons will emerge from the vacuum through a thin window and will be detected by a plastic scintillation detector.

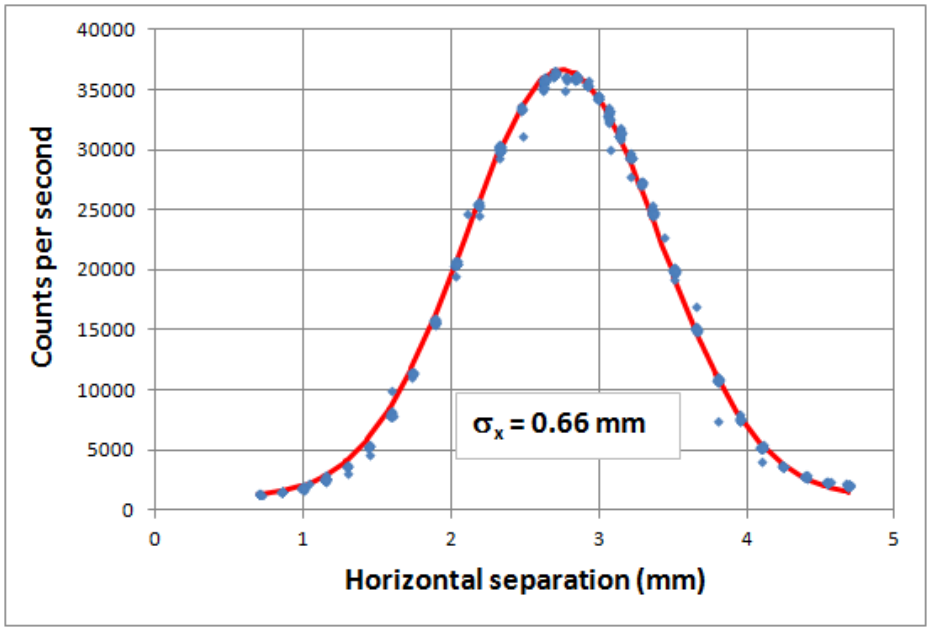


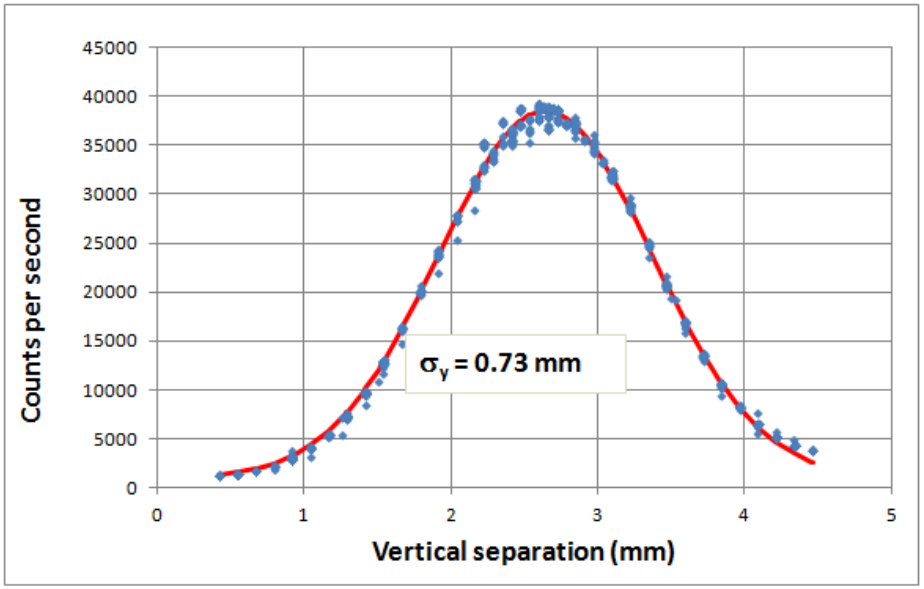
Schematic representation of the backscattered electron detector. Trajectories of two spiraling electrons were generated with an Opera simulation.

P. Thieberger, et al

Proof-of-principle electron-gold eBSD "luminosity" scans

Date:	4/15/2014
Ion Beam:	Gold
Beam energy:	100 GeV/u
Bunch intensity:	$7*10^8$
# of bunches:	2
Solenoid Field:	2T
Electron energy:	6 keV
e-beam current:	0.565 A



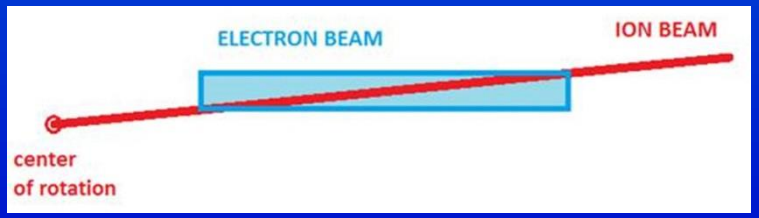


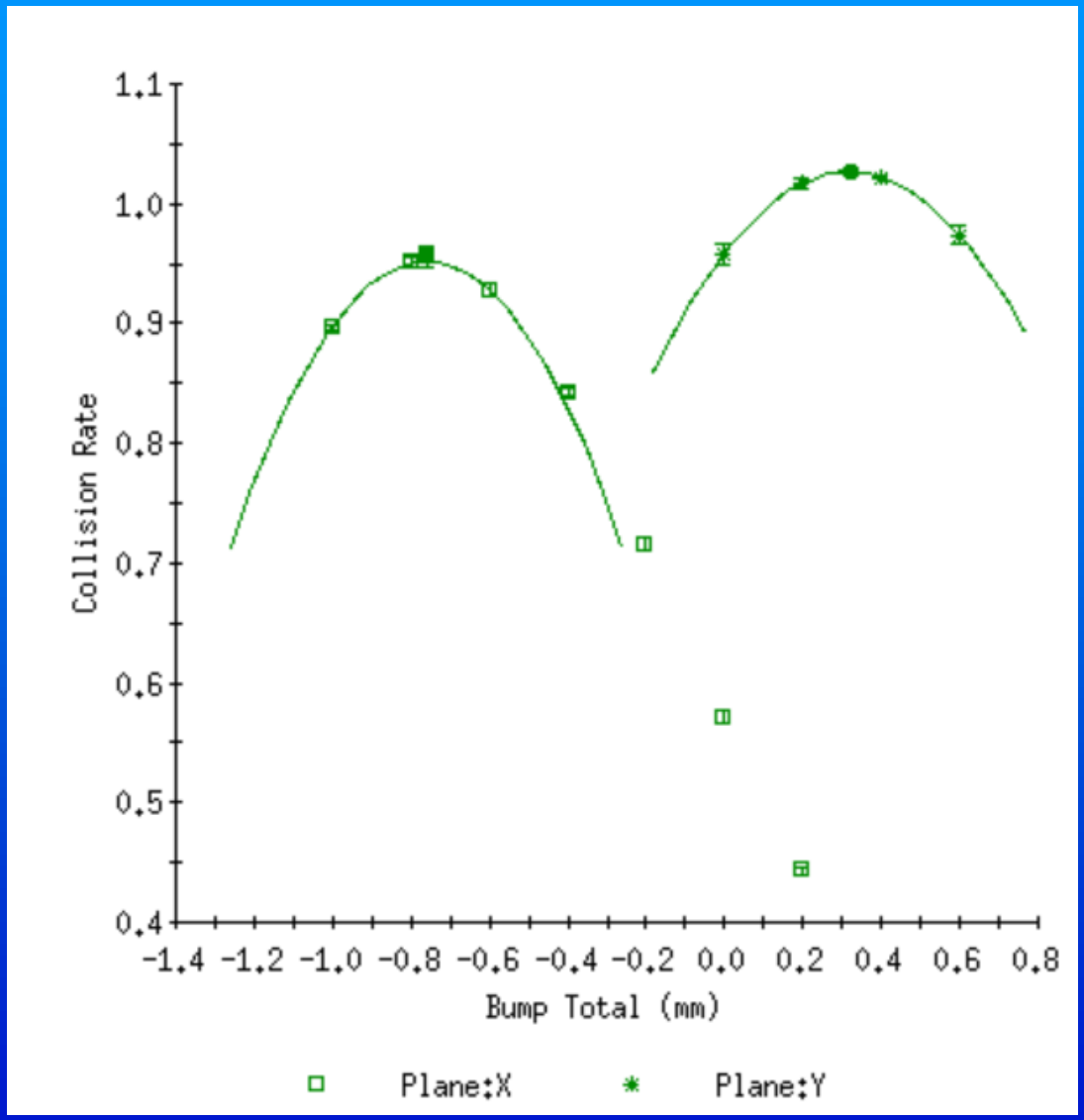
P. Thieberger et al, "The electron backscattering detector, a new tool for the precise mutual alignment of the electron and ion beams in electron lenses", to be presented at IBIC 2014 (Sept, 2014)

E-Lens eBSD:

LISA "luminosity" scans during horizontal and vertical automatic alignments

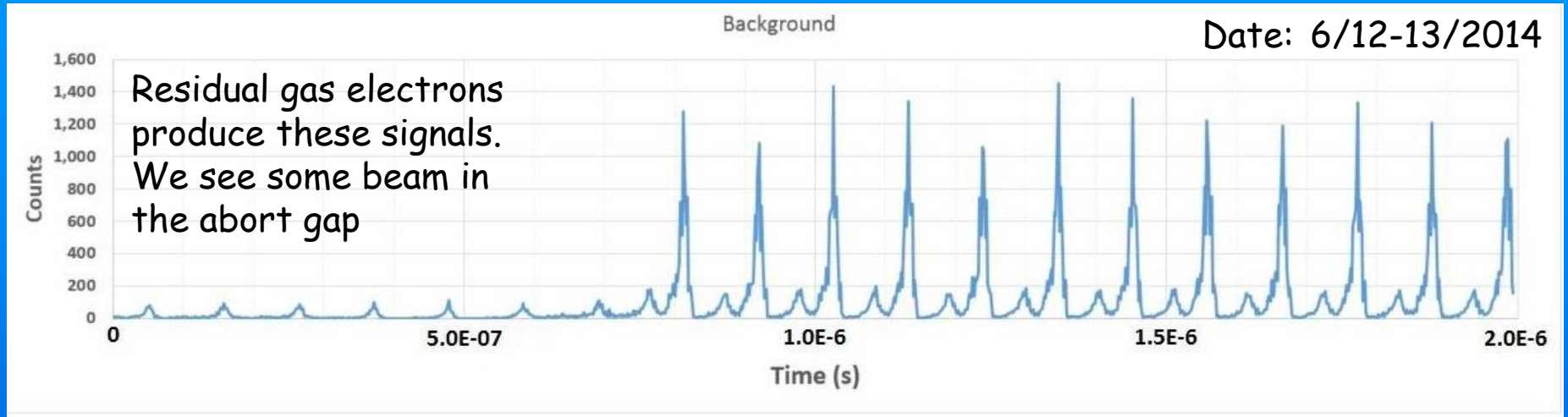
The program LISA (Luminosity and IR Steering Application) routinely used for optimizing luminosity for the experiments has been adapted to automatically optimize electron-ion alignment. The eBSD output pulses are used instead of the Zero Degree Calorimeter (ZDC) coincidence signals.

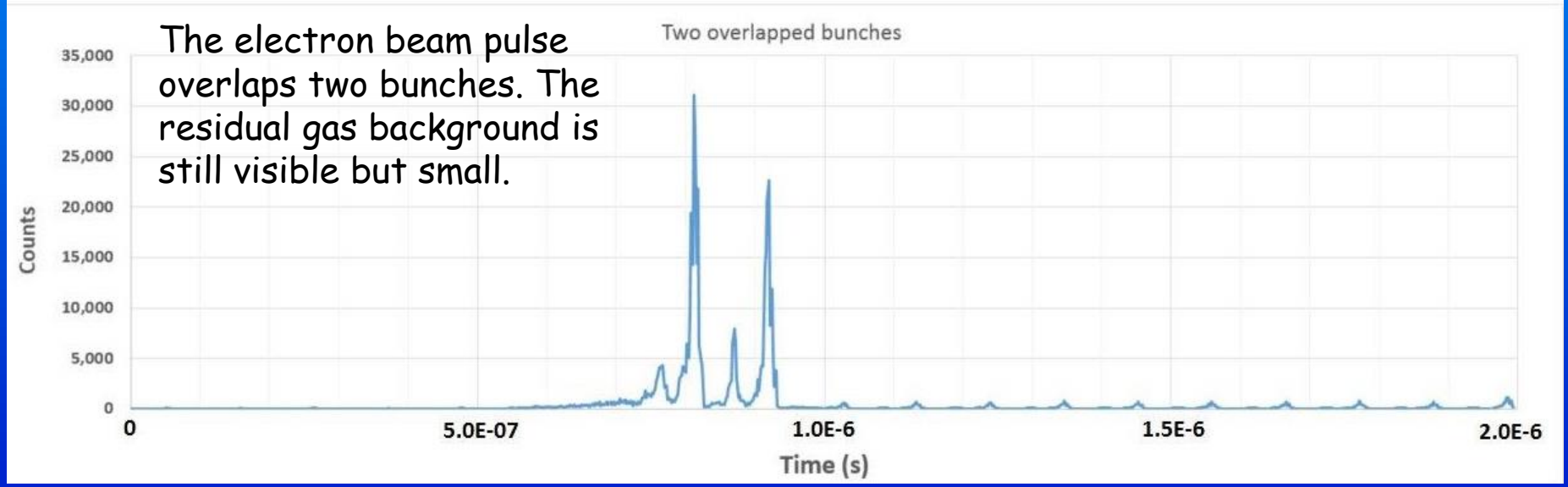




E-Lens eBSD: time-of-flight

eBSD time-resolved counting rates without (top) and with (bottom) electron beam. The small peaks to the left of the large ones may be due to misalignment.





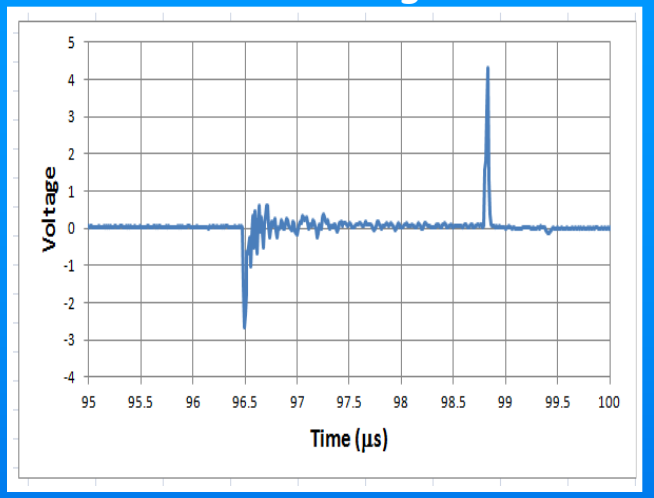
Electron time-of-flight spectra may help with the angular alignment

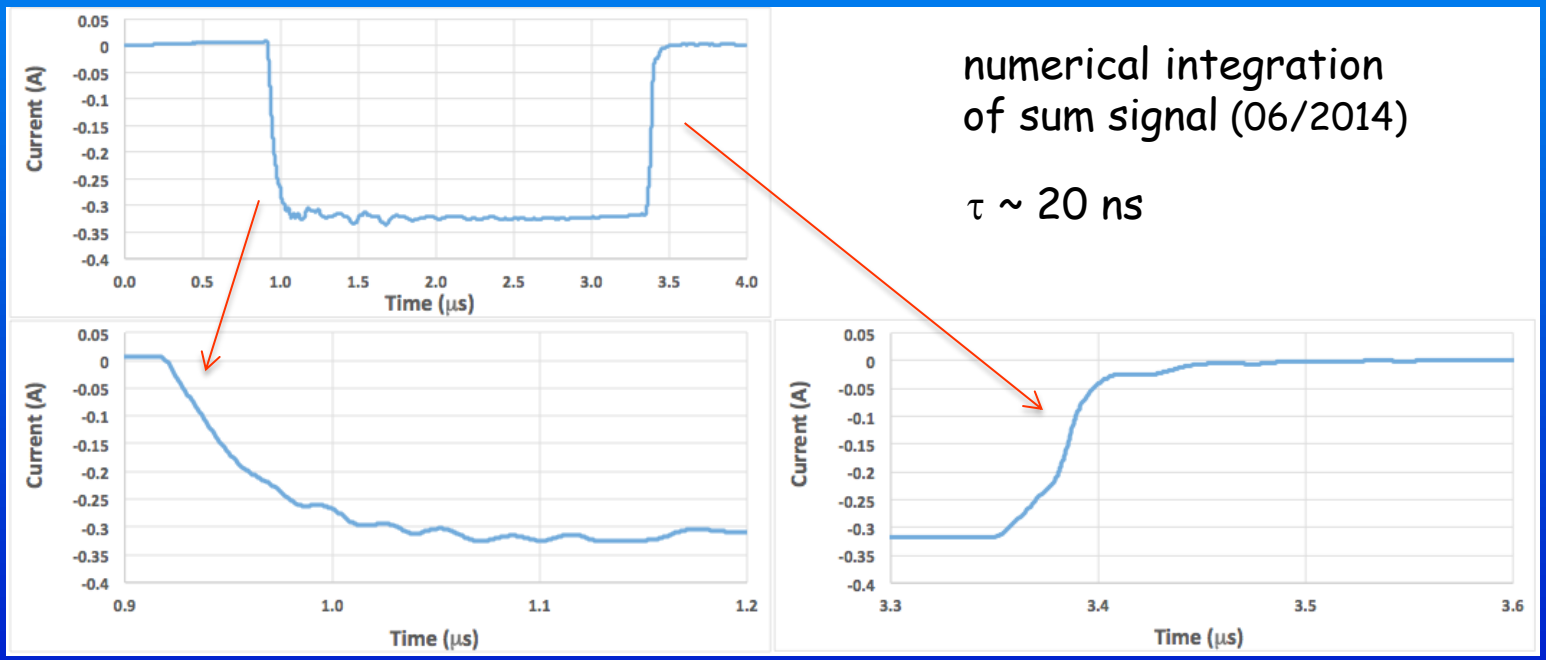
P. Thieberger, P. Adams, Z. Altinbas, M. Costanzo, C. Cullen, T. Miller

E-Lens: longitudinal profile measurement from BPM electrodes

diagnostic for working in parasitic mode (e- beam overlaps only a few bunches)

BPM sum signal





numerical integration of sum signal (06/2014)

$\tau \sim 20$ ns

In the future, will use unbiased cylindrical drift tube.

P. Thieberger, C. Dawson, T. Miller, S. Pikin

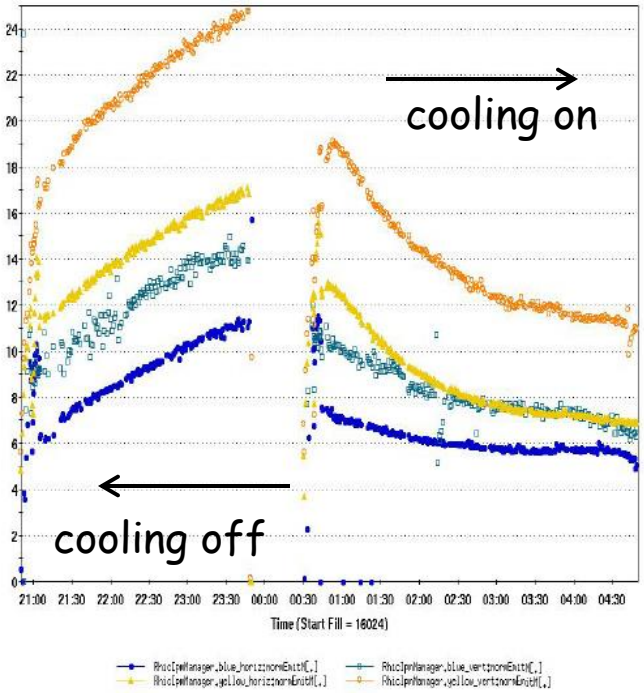
RHIC absolute emittance measurements

Motivation: three select outstanding puzzles

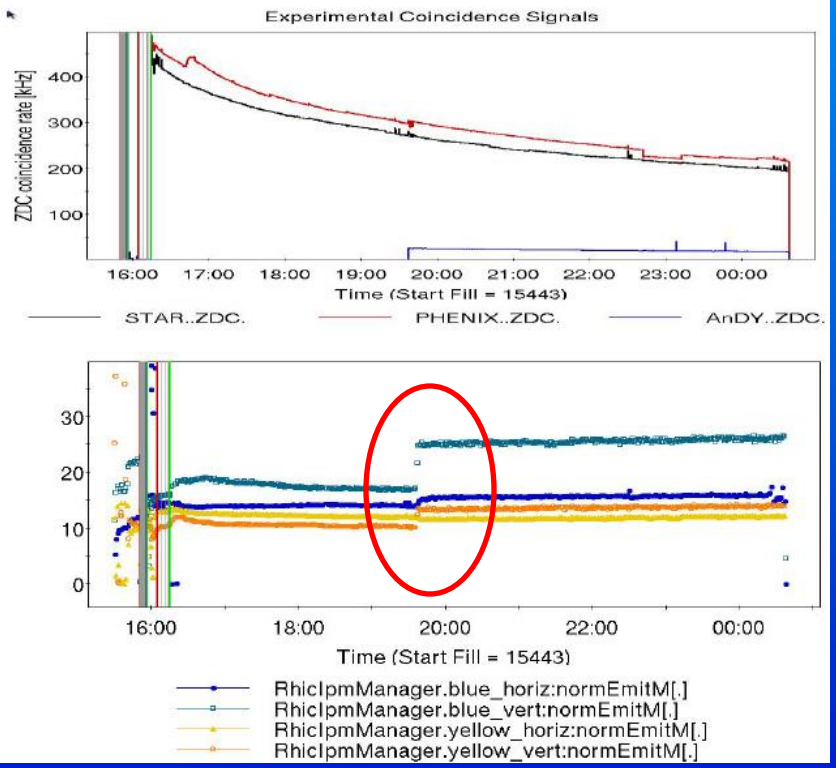
(from RHIC weekly 01/23/12)

- (protons) large discrepancy between estimated and measured (ZDC) luminosity

- (ions) non-equal horizontal and vertical emittances with coupled beams and stochastic cooling

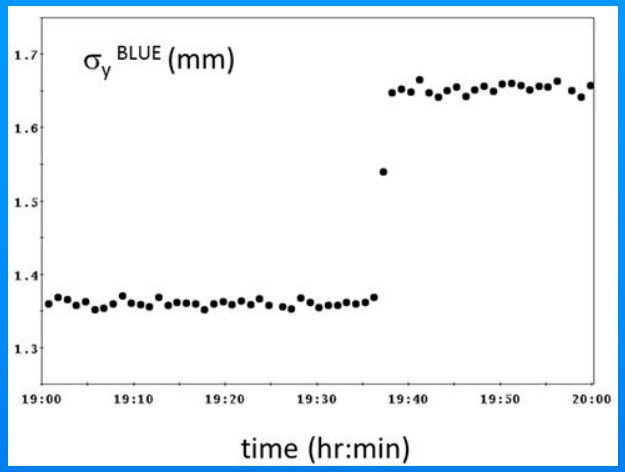


- (protons) reported emittance change with 3rd colliding beam experiment, AnDY



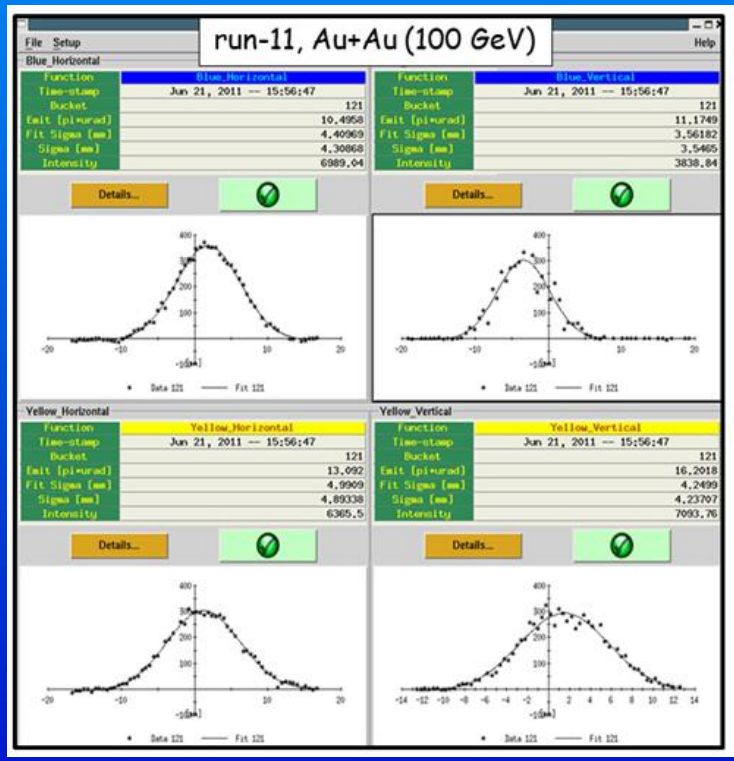
M. Minty et al, "Absolute emittance measurements at RHIC using ionization profile monitors", to be presented at IBIC 2014 (Sept, 2014)

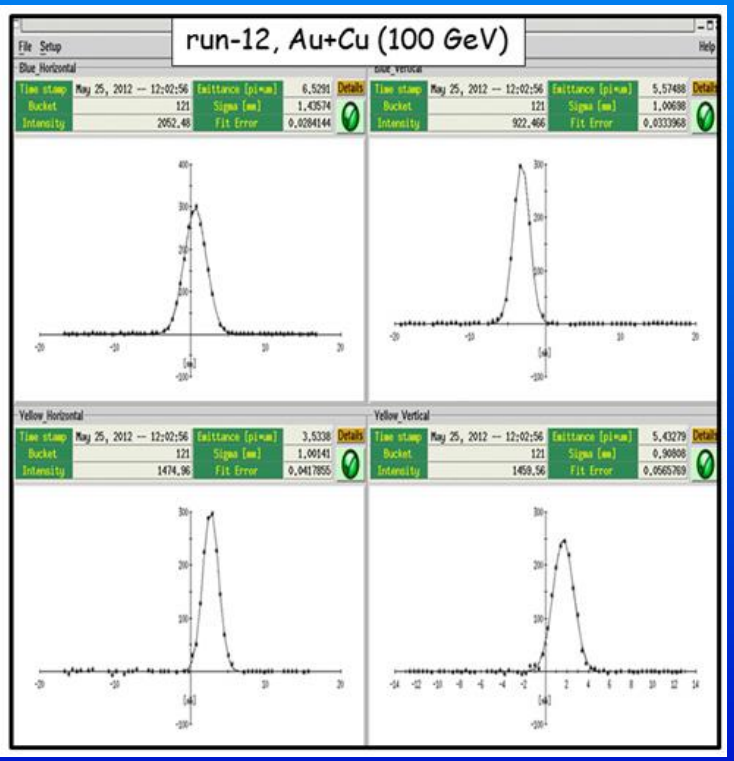
IPM channel-by-channel corrections (AnDY effect)



Number of Interaction Points	σ_y (mm) without corrections	σ_y (mm) with corrections
2	1.37	1.51
3	1.66	1.49
ratio	1.21	0.99

Number of Interaction Points	σ_y (mm) without corrections	σ_y (mm) with corrections
2	1.06	1.11
3	1.24	1.13
ratio	1.17	1.02

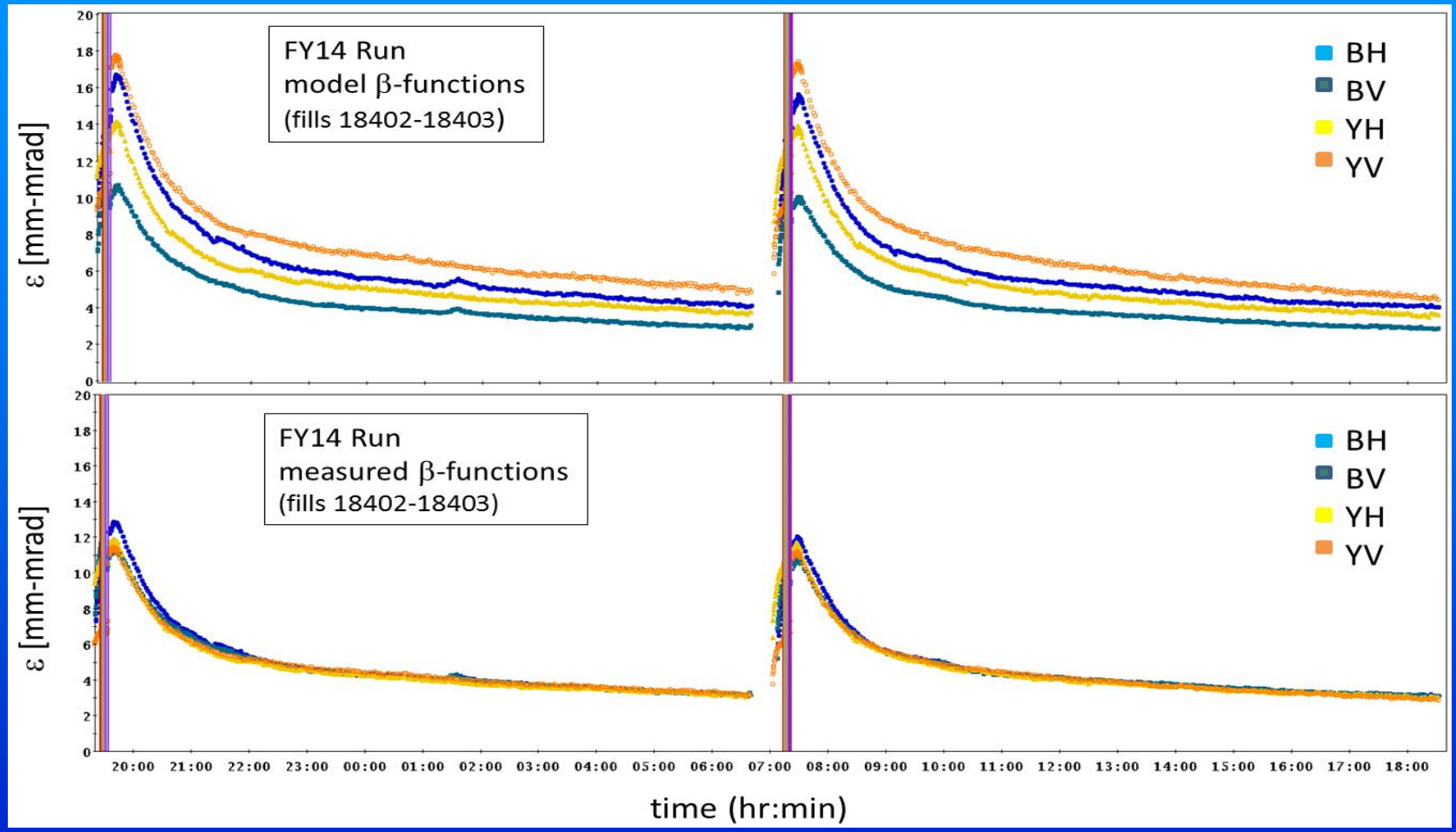




M. Minty, R. Connolly, T. Summers, S. Tepikian

RHIC IPM emittances with model (top) and measured (bottom) β-fctns

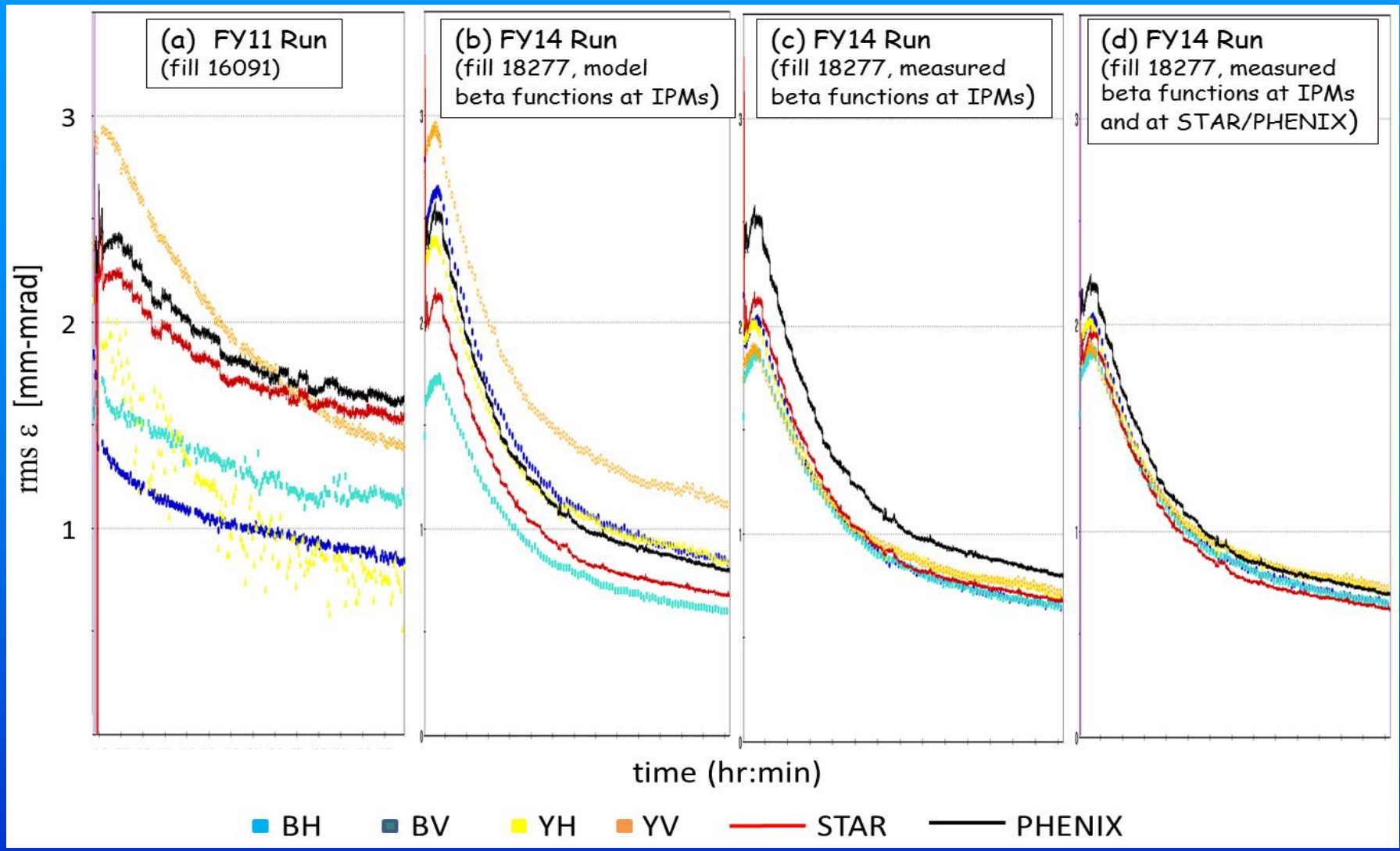
	Blue Horizontal	Blue Vertical	Yellow Horizontal	Yellow Vertical
β_{model} (m)	202	118	206	112
β_{meas} (m)	262	109	245	174
$\beta_{model}/\beta_{meas}$	0.77	1.08	0.84	0.64



Evolution of the transverse beam emittances with 3D stochastic cooling during the FY14 RHIC Run. IPM emittances shown using model beta functions (top) and measured beta functions (bottom).

M. Minty, C. Liu

RHIC IPM and Zero Degree Counter (ZDC) emittances



Comparison of rms emittance measurements from the IPMs and ZDCs during Au+Au 100 GeV operations.

(a) FY11 - no channel-by-channel corrections, remaining plots with
(b) IPM - model beta functions, ZDC – model beta functions
(c) IPM – measured beta functions, ZDC – model beta functions
(d) Measured beta functions at IPMs and ZDCs

Instrumentation Highlights Summary

Upgrades and modernization efforts in the Injectors continue. Linac LPM and AGS e-IPMs will provide valuable data in FY15 Run.

Key E-Lens diagnostics have been developed including

beam positions, both electron and ion
transverse e- beam profiling using YAG screens and pinhole detectors
the new and novel electron back-scattered detector

- the counting rates with protons will be more than adequate
- the system will provide the sensitivity and precision necessary to achieve the very stringent E-Lens beam alignment requirements

Absolute emittance measurements in RHIC were demonstrated using the IPMs. These are consistent with those derived from ZDCs. Together with measurements from the injectors, a better understanding of sources of emittance dilution between the AGS and RHIC and during acceleration in the AGS and RHIC will be better measured, localized and, eventually, corrected.