RHIC pp Performance Run 15

V. Schoefer
for C-AD
RHIC Retreat
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Polarized proton operations

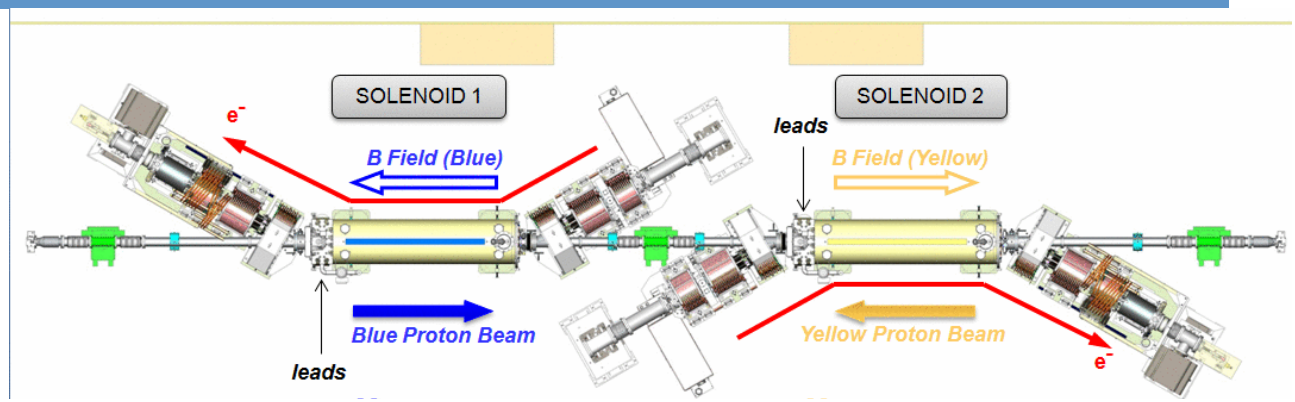
- E-lens
  - Device
  - Lattice
  - Operation (typical store)
- Emittance control
- Polarization

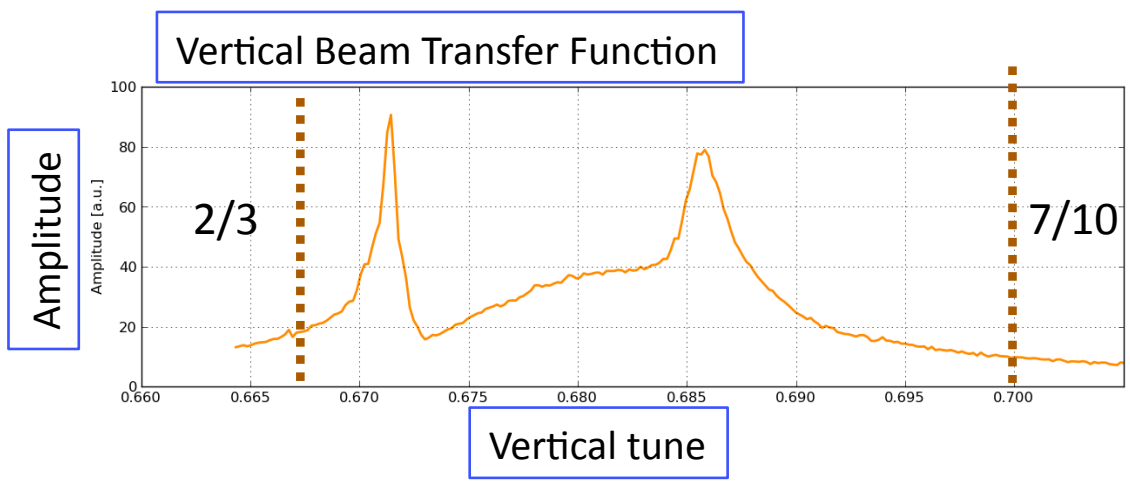
Beam-beam compensation

p-p lumi is limited by beam-beam.

Oncoming proton beam acts as a nonlinear defocusing force
Leads to beam decay, emittance increase

Carefully tailored electron beams provide equal but opposite focusing force





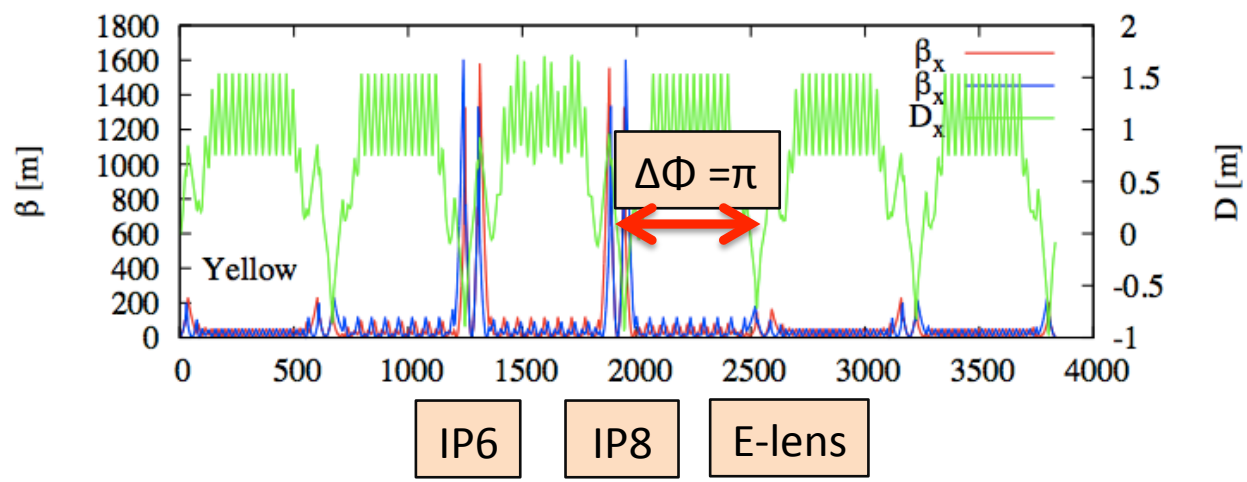
Beam-beam compensation

<u>Lattice improvements</u>

E-lens requires π phase advance from lens to one colliding IP

π/2 phase advance per cell and 'ATS' style beta squeeze allow passive compensation of sextupole driving terms

Increased off momentum DA



Complete retooling of the ramp/lattice creation software

Optics measured-to-model agreement quite good (10-15% beat beat) without need for additional correction.

Beam-beam compensation

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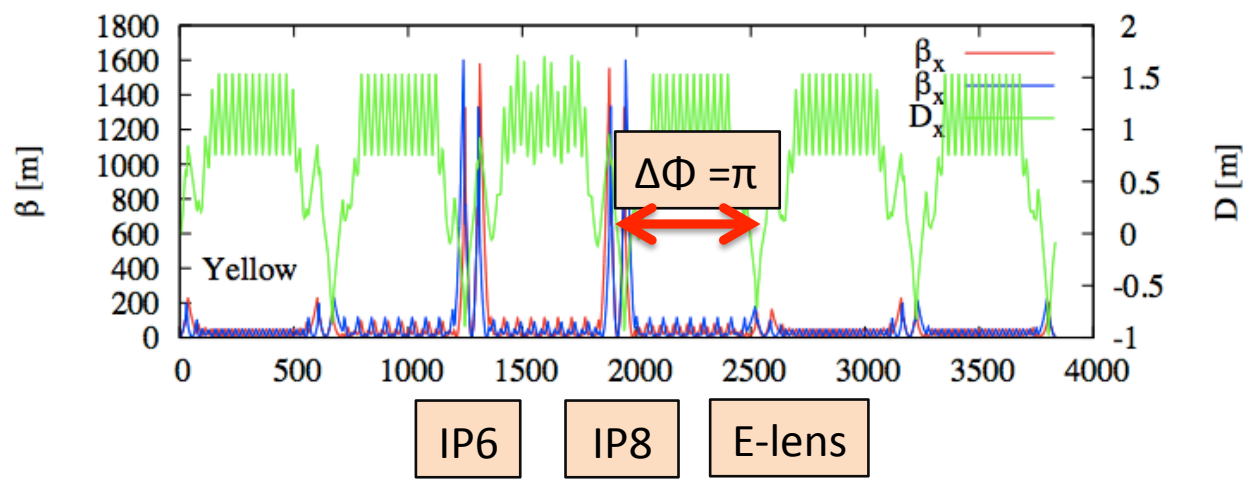
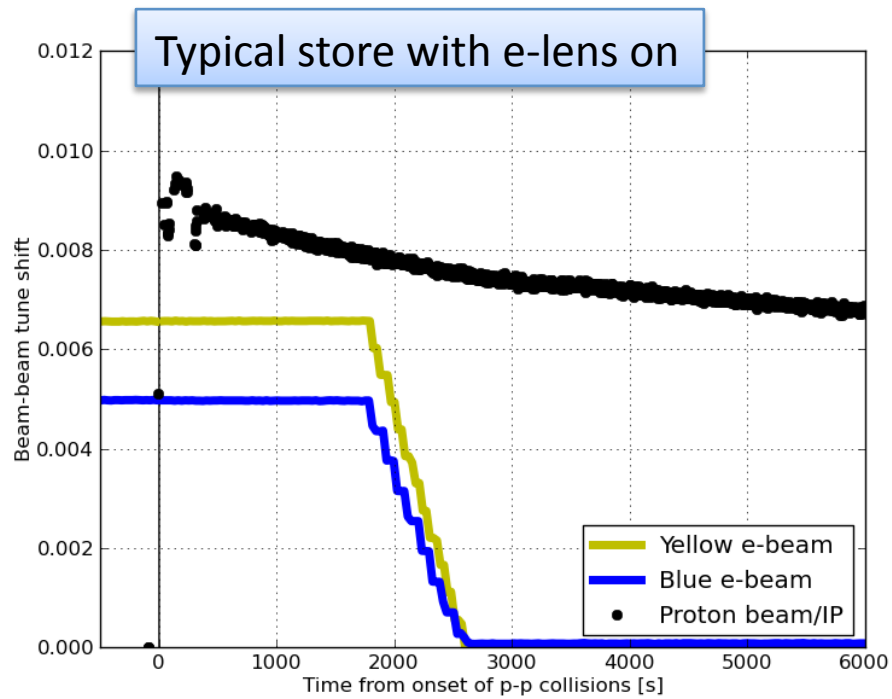


Momentum aperture improved, shown by increase in tolerable radial shift:

Run 12: +/- 0.7 mm radial shift
Run 15: +/- 1.25 mm radial shift

Beam-beam compensation

Run	Achieved BB tune shift/IP
Run12	0.006
Run 15 (no e-lens)	0.008
Run 15 (w/ e-lens)	0.010

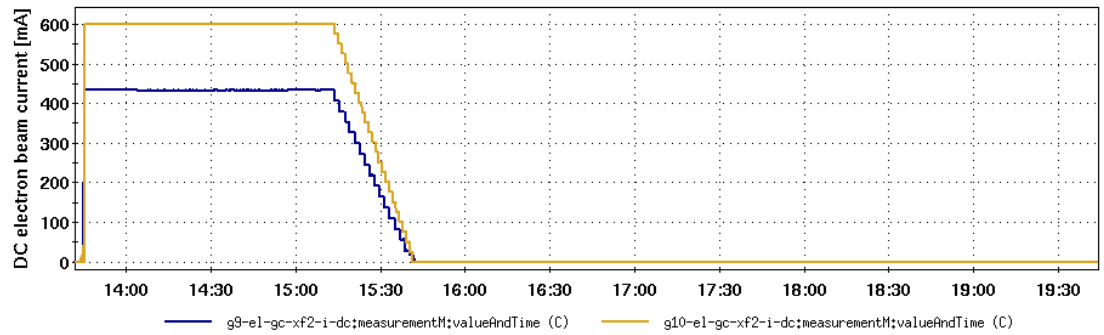


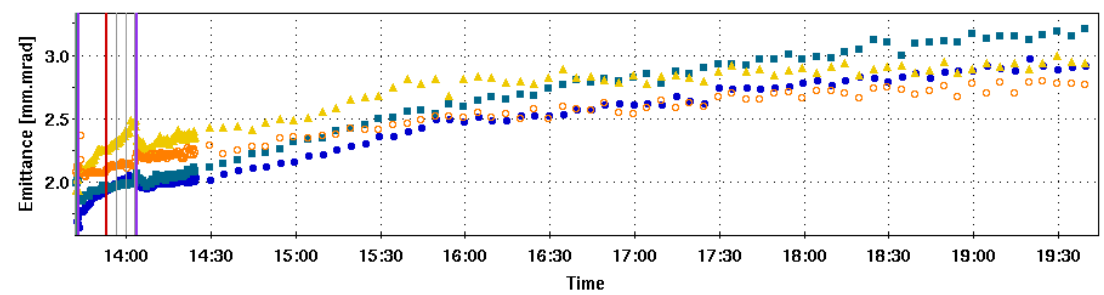
Blue e-lens limited to ~ 500 mA by onset of e-current instability
Yellow e-lens operating as expected at > 1 A

E-lens and emittance

E-lens does contribute a small amount of emittance growth while it is on

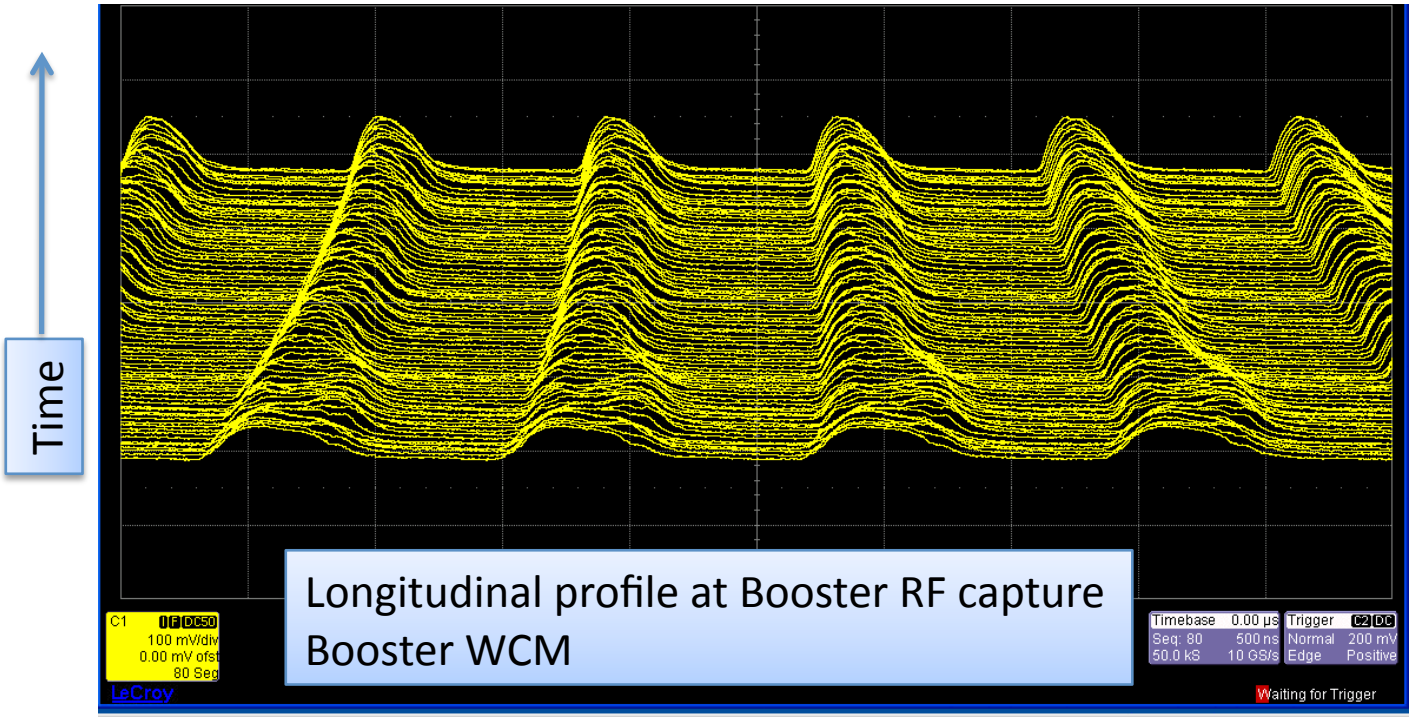
Growth minimized by careful tune control (>0.684, determined by careful attention from operators)





Blue emittance growth at store (even with e-lens off) consistently higher than yellow, perhaps due to difference in 2/3 resonance strength.

Injector emittance



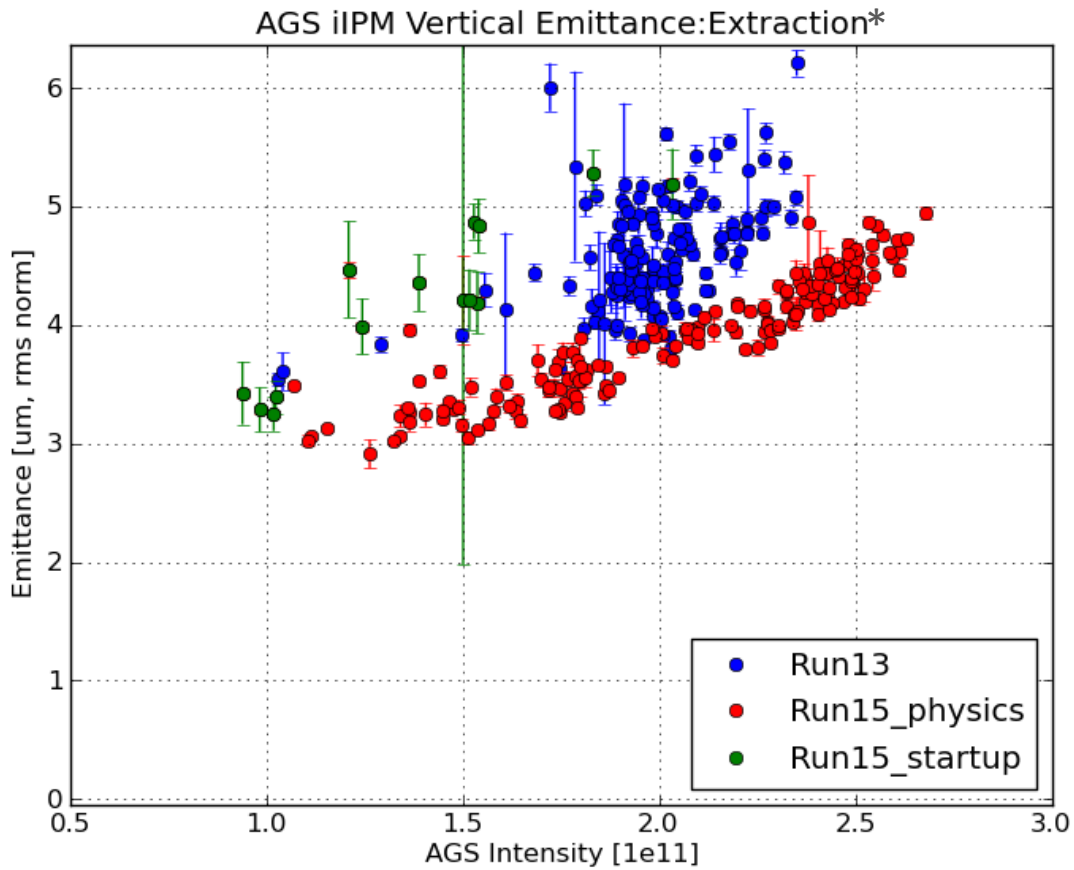
Booster space charge driven emittance growth indicated by Run 14 measurements

Additional RF frequencies added at capture to elongate bunches, reduce current density

Injector emittance

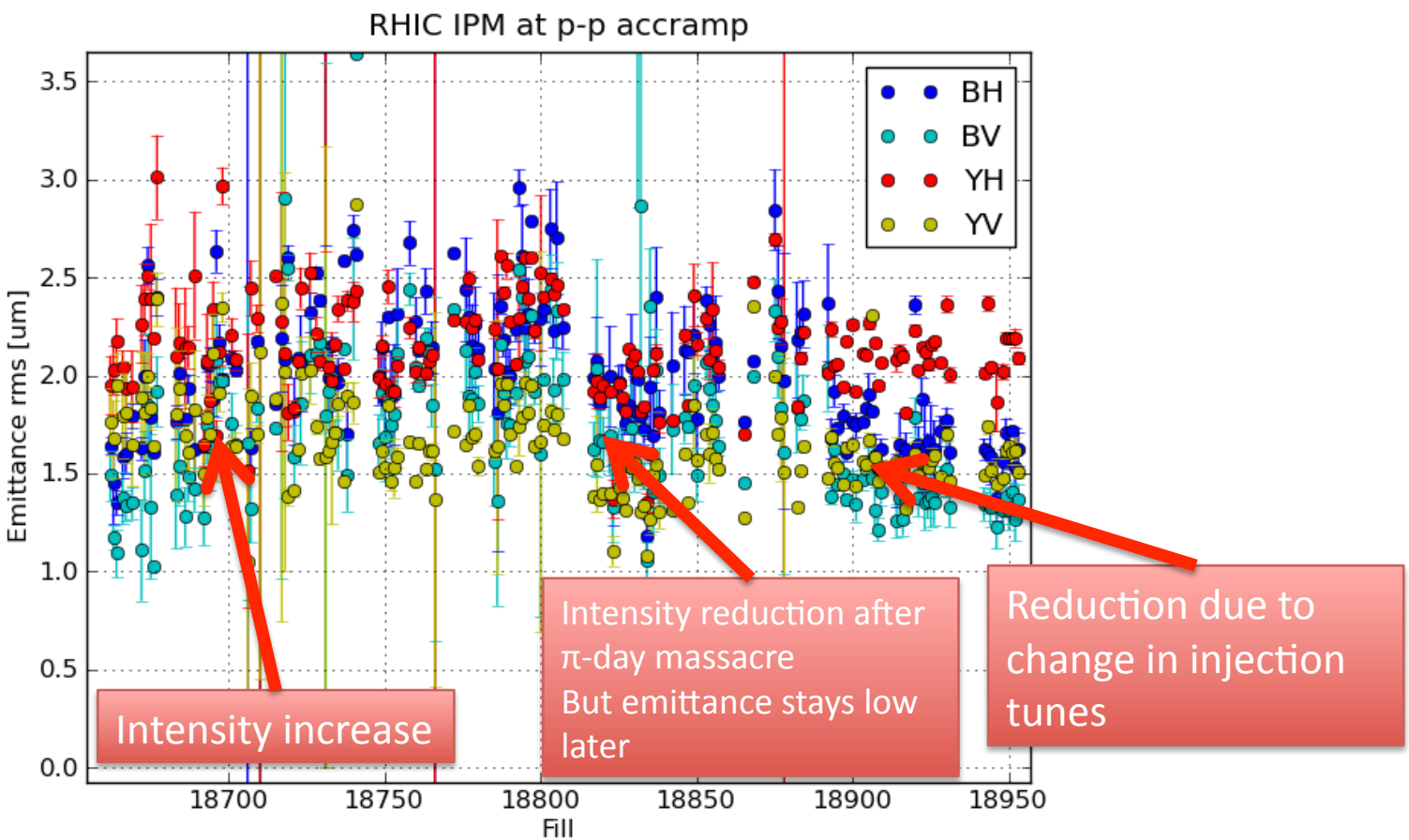
Injector emittance control improved by

- h=2 Booster capture
- Tuning with high intensity from source (10^{12}/pulse)



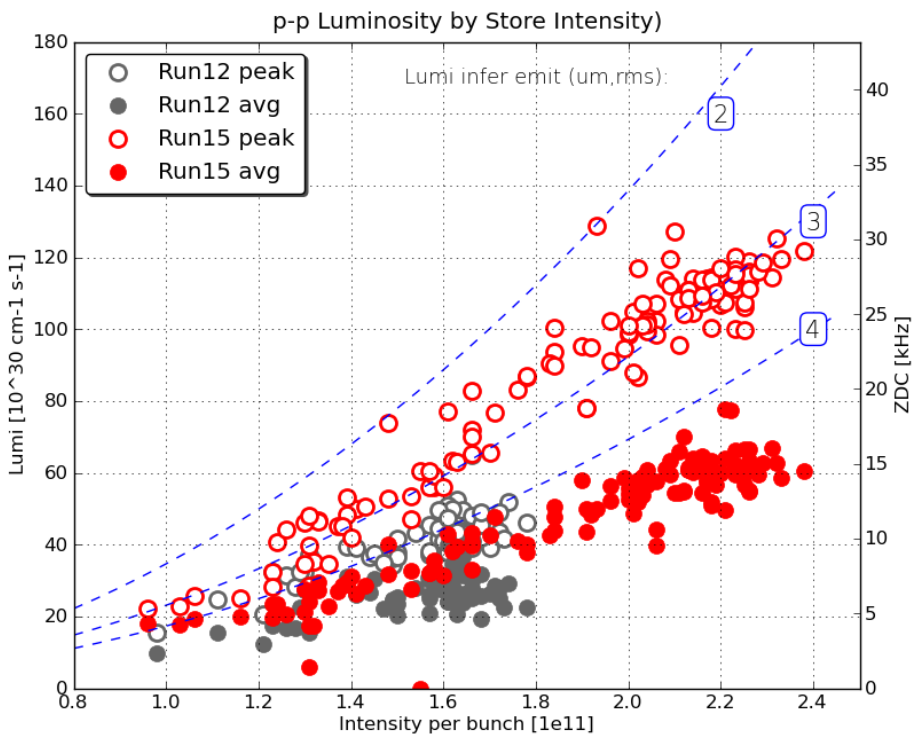
*This IPM has significant intensity-dependent systematics. Good for relative measurements, not absolute

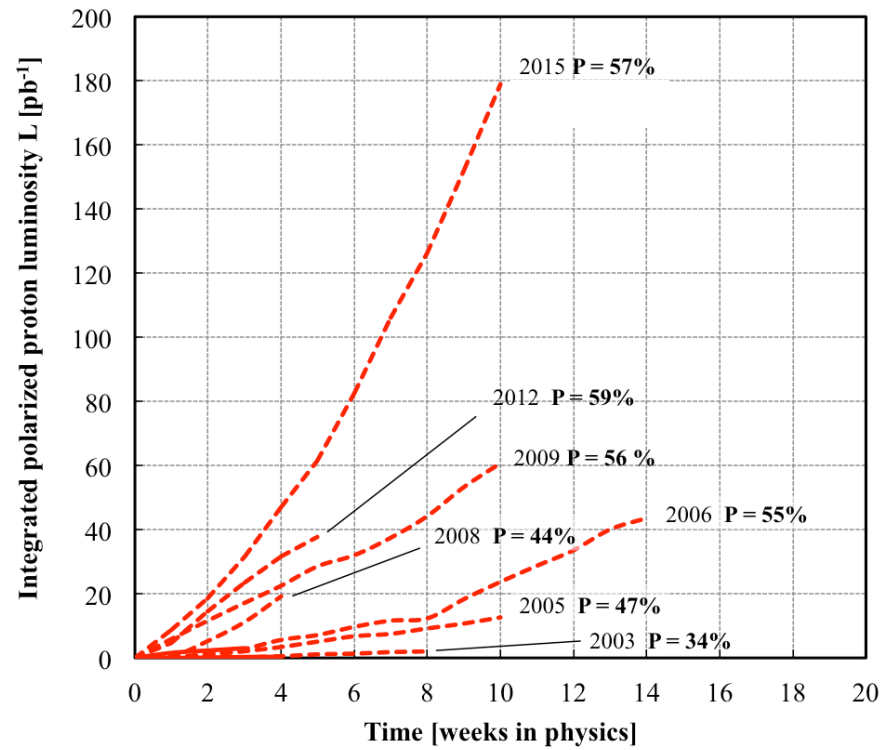
RHIC Emittance Control



Being able to take the IPM measurements seriously at injection, through ramp and store was totally crucial for operations to make and keep these improvements.

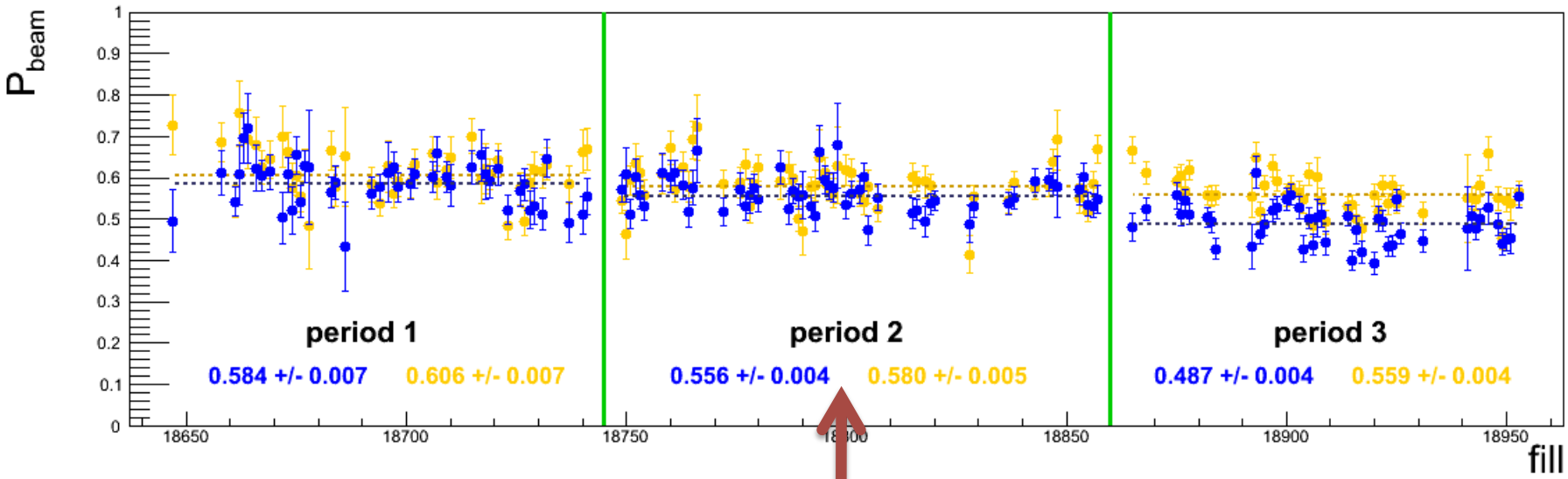
p-p Luminosity





Polarization

	Spin Direction		
PHENIX		Transverse	
STAR	Longitudinal	Transverse	Longitudinal



Successful transverse running

- Blue,yellow difference consistent with AtR transmission
- Polarization decay at store reliably <= 1%/hour
- Allowed revisiting the longitudinal running

Polarization

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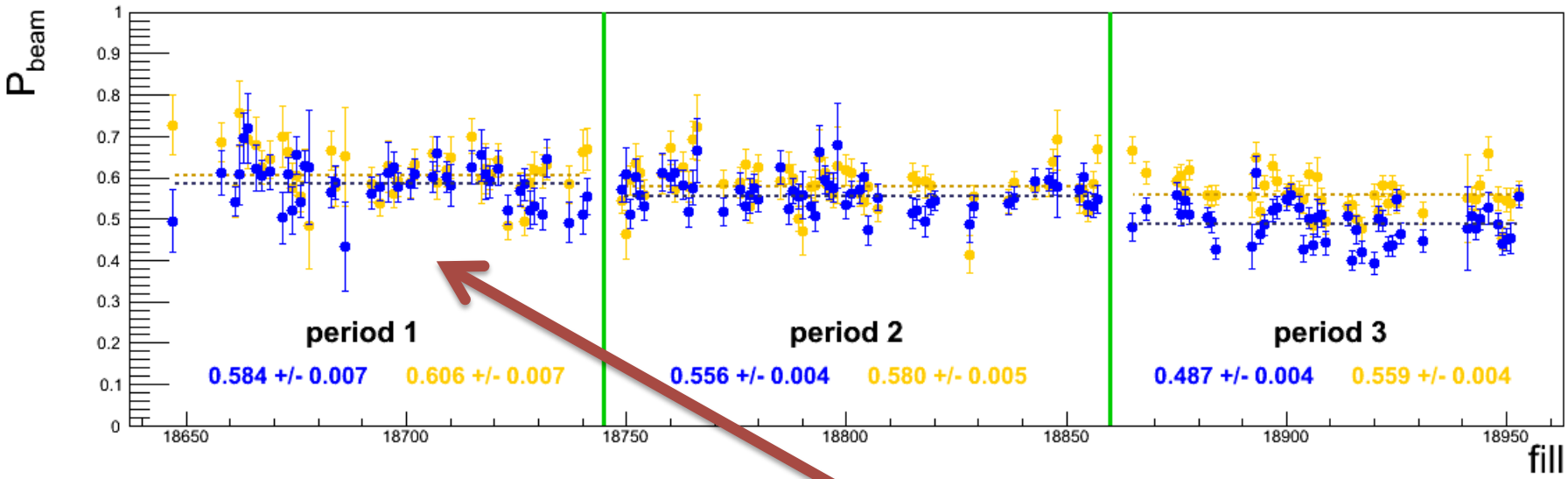
PHENIX		Transverse	
STAR	Longitudinal	Transverse	Longitudinal



Substantial radial component at STAR
- Incorrect rotator settings
- Difficulties with local direction measurement

Plot courtesy of K.O. Eyser

Polarization

	Spin Direction		
PHENIX		Transverse	
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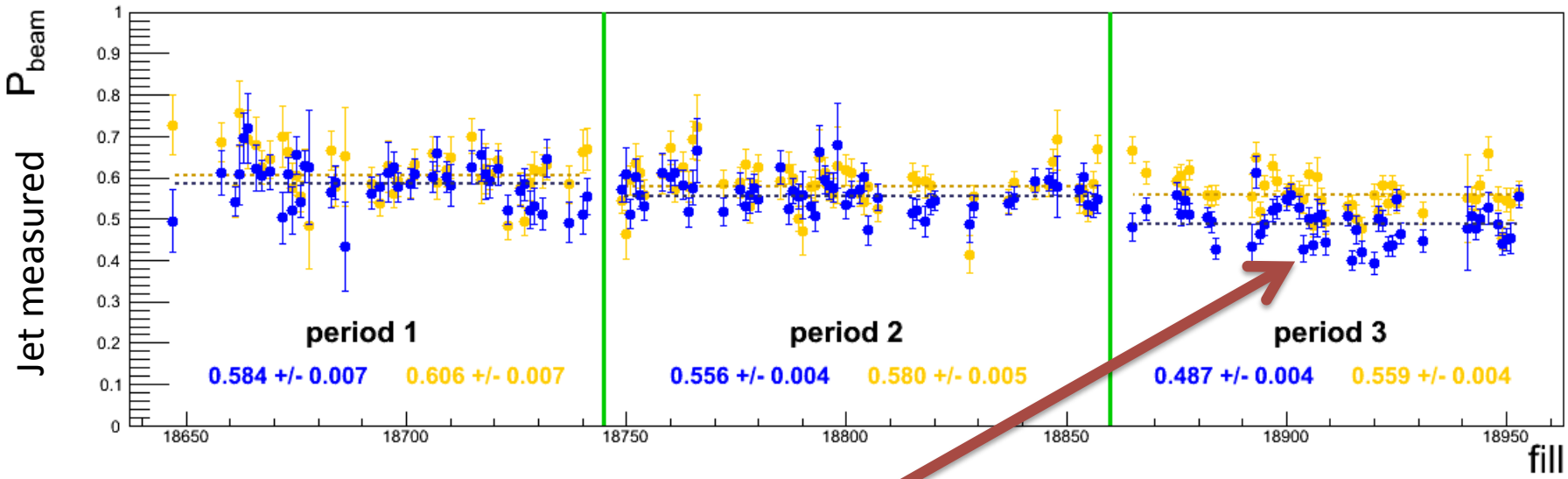


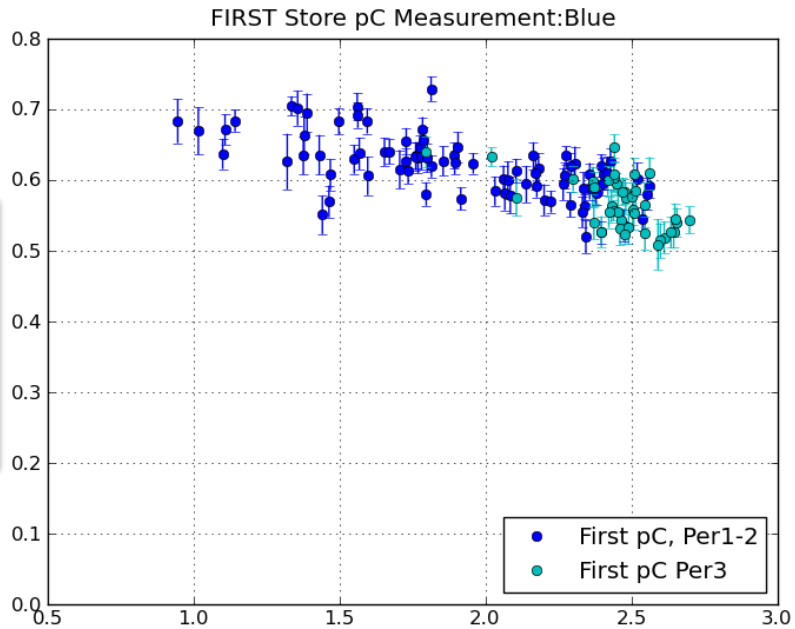
Revisiting longitudinal operation at STAR
- AGS polarization drops off
- Blue polarization lifetime at store nearly 2%/ hour

Plot courtesy of K.O. Eyser

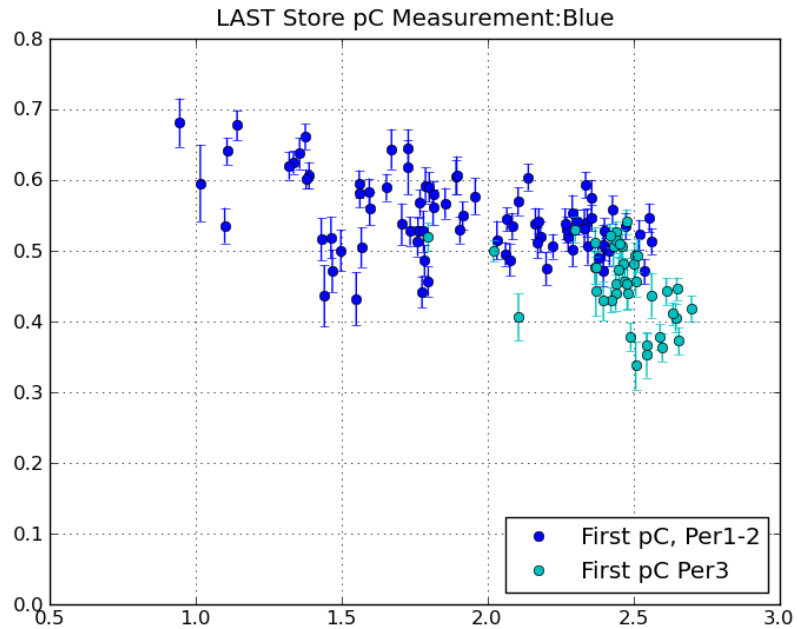
Polarization

Biggest RHIC polarization problem was lifetime during the last portion of the run

Polarization



Intensity [1e11]

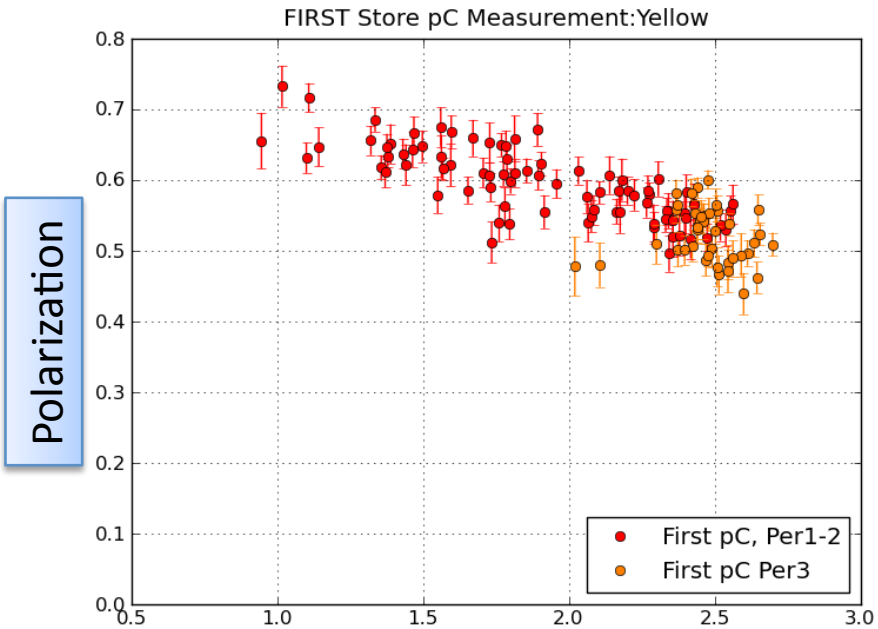


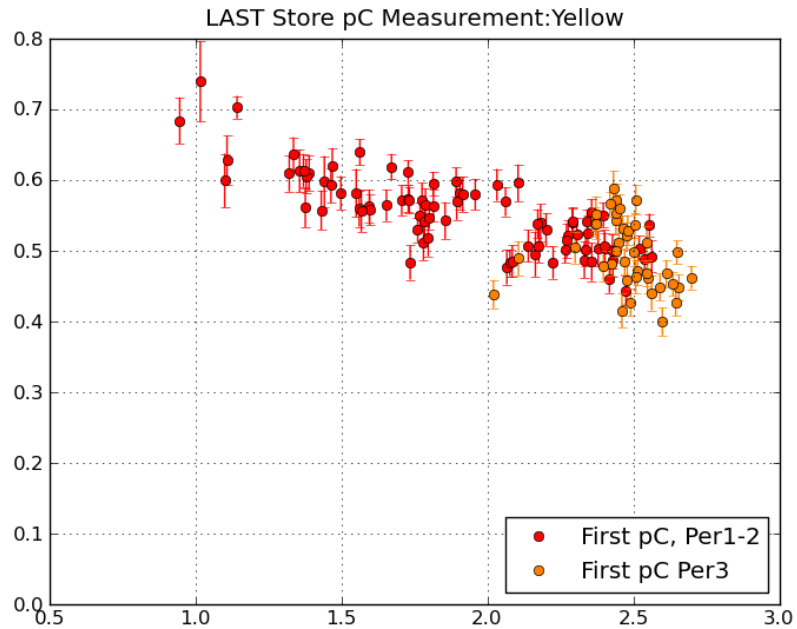
Intensity [1e11]

Period 3 (True longitudinal at STAR) has ~2%/hr polarization decay.

Polarization

Biggest RHIC polarization problem was lifetime during the last portion of the run





Intensity [1e11]

Intensity [1e11]

Period 3 (True longitudinal at STAR) Less of a decay problem in yellow

Polarization Problems: Possible cures

AGS Polarization

- Jump quad timing and field stability
- Extensive profile measurements at intermediate energies to localize polarization loss
- Probably something else also…
- *See Haixin's talk*

RHIC polarization lifetime and rotators

- Similar problems encountered in Run 9 100 GeV run
- Scans of rotator current in Run 15 need careful analysis (ongoing)
- Symptoms:
    - Associate with the rotators on
    - But NOT when there is a substantial radial component
    - Blue only
    - Points at local vertical orbit deflections (which would change a radial spin not at all)

Summary

- A challenging run, with many highlights, in particular:
  - Successful commissioning and first demonstration anywhere of electron lenses for beam-beam compensation and increased p-p luminosity
  - Significant progress in making the lattice design process
    - Allowed meeting many difficult constraints
  - Emittance control in the injectors was unprecedented.

- The challenges have produced 'homework:
  - Understanding polarization 'drift' in the AGS
  - Understanding polarization decay with rotators with 100 GeV beams